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Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40 – 2600 MeV protons

Prepared by

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Institute for Theoretical and Experimental Physics (ITEP)

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V.P. Lunev, N.N. Titarenko, Yu.N. Shubin, V.S. Barashenkov
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October 2009

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Abstract

The Project is aimed at experimental determining and computer-aided theoretical simulating the independent and cumulative yields of residual radioactive product nuclei in high-energy proton-irradiated thin targets made of high-isotopic and natural lead (^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb) and bismuth (^{209}Bi) that are the most probable choice to be the target materials in the accelerator-driven (hybrid) systems (ADS) coupled to a high-current proton accelerator. The yields of residual product nuclei are of great importance when estimating such basic radiation-technology characteristics of the hybrid facility targets as the total target activity, the target “poisoning”, the buildup of long-lived nuclides, the α -activity, the content of low-pressure evaporated nuclides (Hg), the content of the chemically-active nuclides that drastically spoil the corrosion resistance of the facility structure materials, etc.

In view of the above, the radioactive product nuclide yields from targets materials were experimentally determined using the ITEP U-10 proton accelerator in 55 measurement runs using the monoisotopic and natural lead (^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb) and bismuth (^{209}Bi) targets within the proton energy range fractionated minutely, namely at 0.04, 0.07, 0.10, 0.8, 1.2, 1.4, 1.6, and 2.6 GeV to cover the entire range of the internuclear hadron cascading.

As a result, 5972 cumulative and independent yields of residual radioactive product nuclei, whose lifetimes range from 8 minutes to 32 years, have been measured. Besides, the cross sections for the $^{27}\text{Al}(p,x)^{24}\text{Na}$ and $^{27}\text{Al}(p,x)^7\text{Be}$ monitor reactions have been measured at the same proton energies together with the $^{27}\text{Al}(n,p)^{27}\text{Mg}$ reaction rate that characterizes the neutron background contributions in each experiment. The experimental nuclide yields are determined by the direct γ -spectrometry method. The γ -spectrometer resolution is 1.8 keV in the 1332 keV ^{60}Co γ -line. The experimental γ -spectra are processed by the GENIE2000 code. The γ -lines are identified, and the cross sections calculated, by the ITEP-developed SIGMA code using the PCNUDAT database. The proton fluence is monitored by the $^{27}\text{Al}(p,x)^{22}\text{Na}$ reaction.

Measurement data have been compared with the calculation results of the LAHET, CEM03, LAQGSM+GEM2, and INCL4+ABLA codes, as well as of the CASCADE, CASCADO, and LAHETO codes, whose associate INC models were being further specified under the Project. The predictive power of the tested codes has been found to be different, but still satisfactory throughout the mass and energy ranges of most of the reaction products obtained in the shallow spallation region by all the above-mentioned codes. On the other hand, the predictive power of the codes has proven to be very unsatisfactory for the reaction products within the deep spallation, fission, and fragmentation regions. Therefore, all the codes have to be improved, with their associate models for generation of the fission and fragmentation products being most desirable.

Keywords: nuclear reaction, spallation, deep spallation, fission, fragmentation, yields, residual nuclides, cross sections, simulation, Monte-Carlo codes, comparison.

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1 Introduction

The present work is the Final Technical Report on the ISTC Project #2002 "Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40-2600 MeV protons"[1], which continues and expands the ISTC Project #839 "Experimental and theoretical study of the yields of residual product nuclei produced in thin targets irradiated by 100-2600 MeV protons"[2]. Despite the close similarity in the subjects of Projects #839 and #2002, they are somewhat different. Project #839 was aimed at measuring the residual product nuclide yields in many high-enriched and natural isotopic composition targets irradiated selectively by 100-2600 MeV protons ($^{182,183,184,186}\text{W}$ by 0.2, 0.8, and 1.6 GeV protons; ^{nat}W , ^{56}Fe , ^{58}Ni , and ^{93}Nb by 2.6 GeV protons; ^{232}Th , ^{nat}U , and ^{99}Tc by 0.1, 0.2, 0.8, 1.2, and 1.6 GeV protons; ^{59}Co and $^{63,65}\text{Cu}$ by 0.2, 1.2, 1.6, and 2.6 GeV protons; ^{nat}Hg by 0.1, 0.2, 0.8, and 2.6 GeV protons; ^{208}Pb by 1.0 GeV protons) and at estimating the predictive power of different simulation codes, given the above set of proton-nucleus interactions.

Project #2002 is aimed at measuring the residual product nuclide yields in much less numerous high-enriched and natural-composition targets ($^{206,207,208,nat}\text{Pb}$, ^{209}Bi), but with a more detailed division of the entire proton energy range throughout the intranuclear hadron cascading region (0.04, 0.07, 0.1, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.6, and 2.6 GeV), i.e., at deriving the excitation functions of the residual product nuclei within the 40-2600 MeV energy range and at estimating the accuracy of predicting the excitation functions calculated via different codes (LAHET, CEM03, LAQGSM+GEM2, INCL4+ABLA, CASCADE, CASCADO, and LAHETO). Most of the codes are under development at different laboratories worldwide. Besides, when implementing the Project, the INC models of some codes (CASCADE, CASCADO, and LAHETO) were modified and verified using, among others, the experimental data obtained.

The spallation reactions have had an ever-increasing interest in recent years because, first of all, they can be used to design the intensive neutron sources to be used in the accelerator-driven subcritical reactor systems or in physical and technological researches [3]. Designing the accelerator-driven subcritical systems (ADS facilities) necessitates that the yields of various reaction-produced nuclei should be known to within a sufficient accuracy that would make it possible to predict the number of radioactive isotopes produced in a target. In fact, the short-lived isotopes can hamper operations of the ADS facilities, while the long-lived isotopes lead to a persistent increase in the ADS facility radioactivity. The Pb and Bi nuclear data are of particular importance because the two elements are regarded as the best-choice target materials in most of the latest conceptual designs of ADS facilities. Therefore, the excitation functions of the residual product nuclide yields in ($^{206,207,208,nat}\text{Pb}$ and ^{209}Bi) are extremely desirable to measure in detail.

Table 1 is a detailed list of the energies and target materials used in the researches under the reported Project.

Table 1: Target materials and irradiation energies.

Target	Proton energy (GeV)										
	0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
^{209}Bi	+	+	+	+	+	+	+	+	+	+	+
^{208}Pb	+	+	+	+	+	+	+	+	+	+	+
^{207}Pb	+	+	+	+	+	+	+	+	+	+	+
^{206}Pb	+	+	+	+	+	+	+	+	+	+	+
<i>nat.</i> Pb	+	+	+	+	+	+	+	+	+	+	+

2 The techniques for experimental determining the cross sections for residual nuclide production

Like Project #839, the yields or cross sections of radioactive nuclei produced in proton (p) interactions with the ($^{A_{Tag}}_{Z_{Tag}}\text{Tag}$) target nuclei were determined under Project #2002 by the direct kinematics method $p \rightarrow ^{A_{Tag}}_{Z_{Tag}}\text{Tag}$ using the semiconductor γ -spectrometry. The methodological support of the Project #2002 experiments was actually the same as in Project #839, the only difference being that the two-link structure of the decay chain relationships was replaced with its three-link counterpart to determine the cross sections for the identified radioactive residual product nuclei. The replacement makes it possible to apply the mathematical model of nuclear transformations to calculating any complicated nuclear decay chain.

2.1 Mathematical representation of three-link chain of reaction product yields

Under inelastic proton-target interactions, the residual product-nuclei are generated in different intranuclear processes, such as spallation, fission, fragmentation, emission of light nuclei and nucleons, and decays of their precursors in a transformation chain.

The general form of the proton-target interactions is

$$^{A_{Tag}}_{Z_{Tag}}\text{Tag}(p, x)^A_ZN ,$$

where (p, x) denotes the type of nuclear reaction; Tag and N are the chemical symbols of elements (i.e., of target-nuclei and of products); A_{Tag} and Z_{Tag} are, respectively, the mass number and the charge of a target nucleus; A и Z are, respectively, the mass number and the charge of a nuclide produced in a respective nuclear reaction.

As a rule, the parentage chains of radioactive product decays include over 6-8 nuclides. In practice, however, the chains are always implied to permit a simplification. In particular the chains can be reduced to the three-link (and even two-link) patterns.

The following possible cases are meant (see Fig. 1):

- The characteristic decay time of an irradiated target sample before the measurements

start is much longer than the halflife of the most long-lived precursor of nuclide N_1 . In this case, conforming to Fig. 1, σ_1 is the cumulative yield of nuclide $N_1 - \sigma_1^{cum}$;

- The halflife of the precursor of nuclide N_1 is much longer than both the nuclide halflife (the screening case) and the experiment time. In this case, nuclide N_1 may be treated to be the first in a transformation chain, i.e. σ_1 is the independent yield of nuclide $N_1 - \sigma_1^{ind}$; generic

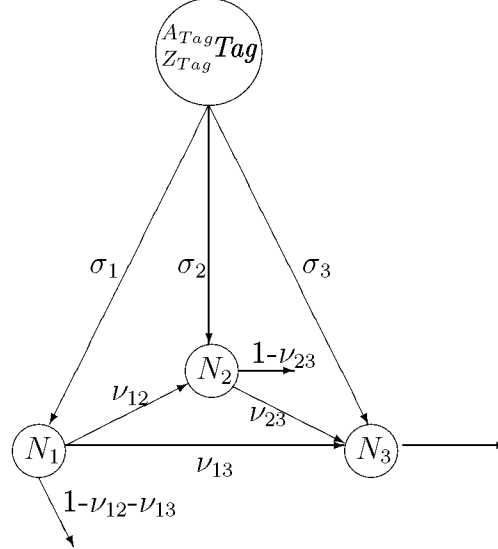


Fig. 1: A schematic of production and radioactive transformations of three nuclides in a chain.

The present work uses mainly the three-link transformation chain version that permits reduction to the two-link version. In the case of mono-energy proton beam, the production reaction rate of each residual product nucleus R_i ($i = 1, 2, 3, st$) [c^{-1}] can be presented as

$$R_i^{cum/ind} = \sigma_i^{cum/ind} \cdot \Phi \quad i = 1, 2, 3, st \quad (1)$$

where $\sigma_1^{cum/ind}$, σ_2^{ind} , and σ_3^{ind} are the cumulative or independent cross sections for production of nuclides N_1 , N_2 , and N_3 , respectively; $\sigma_{st}^{cum/ind}$ are the cumulative or independent cross sections of the monitor reactions used in calculating the mean density of proton flux (see formulas 89 – 115); Φ is the mean proton flux density [proton $\cdot$ (cm $^2 \cdot$ s) $^{-1}$].

In terms of the above definition of reaction rates, the three-link transformation chain can be mathematically described by the following set of differential equations:

$$\begin{cases} \frac{dN_1(t)}{dt} = N_{Tag} R_1^{cum/ind} - \lambda_1 N_1(t) , \\ \frac{dN_2(t)}{dt} = N_{Tag} R_2^{ind} + \nu_{12} \lambda_1 N_1(t) - \lambda_2 N_2(t) , \\ \frac{dN_3(t)}{dt} = N_{Tag} R_3^{ind} + \nu_{13} \lambda_1 N_1(t) + \nu_{23} \lambda_2 N_2(t) - \lambda_3 N_3(t) , \end{cases} \quad (2)$$

with initial conditions $N_1(0) = N_2(0) = N_3(0) = 0$. Here, $N_1(t)$, $N_2(t)$, $N_3(t)$ are numbers of product nuclei; $R_1^{cum/ind}$, R_2^{ind} , R_3^{ind} are, respectively, their cumulative or independent production rates; λ_1 , λ_2 , λ_3 are decay constants; ν_{ij} are probabilities for the i -th nuclide to decay into the j -th nuclide; N_{Tag} is the number of nuclei of element $\frac{A_{Tag}}{Z_{Tag}} Tag$ in an experimental sample; t is current time measured from start moment of irradiation till its end.

The pulsed irradiation mode was used in the reported experiments, i.e. use was made of recurrent irradiation runs consisting each of K pulses of duration τ and repetition rate T (see Fig. 2).

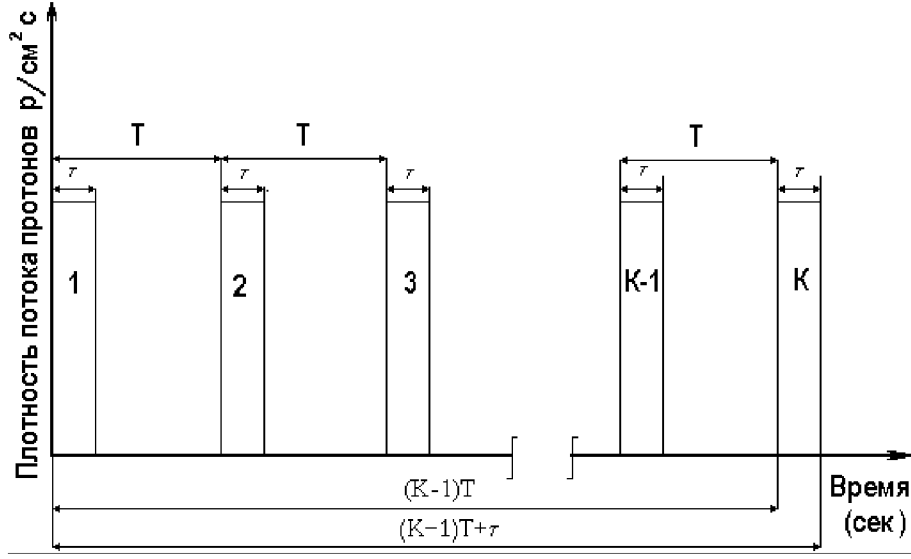


Fig. 2: Characteristics of pulsed irradiation mode

Given the pulsed irradiation mode, the solution for the set of differential equations (89) by the moment of irradiation end $t_{irr} = (K - 1)T + \tau$ is described by the following formulas:

$$N_1(t_{irr}) = N_{Tag} R_1^{cum/ind} \frac{F_1}{\lambda_1}, \quad (3)$$

$$N_2(t_{irr}) = N_{Tag} \nu_{12} R_1^{cum/ind} \frac{\lambda_2}{\lambda_2 - \lambda_1} \cdot \frac{F_1}{\lambda_2} + N_{Tag} \left[R_2^{ind} - \nu_{12} R_1^{cum/ind} \frac{\lambda_1}{\lambda_2 - \lambda_1} \right] \cdot \frac{F_2}{\lambda_2}, \quad (4)$$

$$\begin{aligned} N_3(t_{irr}) = & N_{Tag} R_1^{cum/ind} \left[\nu_{13} + \nu_{12} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_1} \right] \frac{\lambda_3}{\lambda_3 - \lambda_1} \cdot \frac{F_1}{\lambda_3} + \\ & + N_{Tag} \nu_{23} \left[R_2^{ind} - \nu_{12} R_1^{cum/ind} \frac{\lambda_1}{\lambda_2 - \lambda_1} \right] \frac{\lambda_3}{\lambda_3 - \lambda_2} \cdot \frac{F_2}{\lambda_3} + \\ & + N_{Tag} \left[R_3^{ind} + \nu_{23} R_2^{ind} \frac{\lambda_2}{\lambda_2 - \lambda_3} + R_1^{cum/ind} \frac{\lambda_1}{\lambda_1 - \lambda_3} \left(\nu_{13} + \nu_{12} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_3} \right) \right] \frac{F_3}{\lambda_3} \end{aligned} \quad (5)$$

where F_i is a function determined as

$$F_i(t_{irr}) = (1 - e^{-\lambda_i \tau}) \frac{1 - e^{-\lambda_i t_{irr}}}{1 - e^{-\lambda_i T}}, \quad i = 1, 2, 3. \quad (6)$$

The detailed transformations that lead to the above form of function F_i are presented below when calculating the mean proton flux density Φ (see formulas 89–96).

The irradiation having stopped, the decays of the product nucleons N_1 , N_2 , and N_3 are

described by the following set of equations:

$$\begin{cases} \frac{dN_1(t)}{dt} = -\lambda_1 N_1(t) , \\ \frac{dN_2(t)}{dt} = \nu_{12} \lambda_1 N_1(t) - \lambda_2 N_2(t) , \\ \frac{dN_3(t)}{dt} = \nu_{13} \lambda_1 N_1(t) + \nu_{23} \lambda_2 N_2(t) - \lambda_3 N_3(t), \end{cases} \quad (7)$$

with initial conditions $N_i(0)=N_{i_0}$, $i = 1, 2, 3$ where N_{i_0} is the number of nuclei in the first nuclide produced by the decay start moment (the irradiation stop moment); t is the current time measured from the irradiation stop moment. The solution for the set (7) at any moment t of "decay" is

$$N_1(t) = N_{1_0} e^{-\lambda_1 t}, \quad (8)$$

$$N_2(t) = \frac{\lambda_1}{\lambda_2 - \lambda_1} N_{1_0} \nu_{12} e^{-\lambda_1 t} + \left(N_{2_0} + \frac{\lambda_1}{\lambda_1 - \lambda_2} \nu_{12} N_{1_0} \right) e^{-\lambda_2 t}, \quad (9)$$

$$\begin{aligned} N_3(t) = & N_{1_0} \frac{\lambda_1}{\lambda_3 - \lambda_1} \left[\nu_{13} + \nu_{12} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_1} \right] e^{-\lambda_1 t} + \\ & + \nu_{23} \frac{\lambda_2}{\lambda_3 - \lambda_2} \left(N_{2_0} - N_{1_0} \frac{\lambda_1}{\lambda_2 - \lambda_1} \right) e^{-\lambda_2 t} + \\ & + \left[N_{3_0} + N_{2_0} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_3} + N_{1_0} \frac{\lambda_1}{\lambda_1 - \lambda_3} \left(\nu_{13} + \nu_{12} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_3} \right) \right] e^{-\lambda_3 t}. \end{aligned} \quad (10)$$

The number of product nuclei at the irradiation stop moment corresponds to that at the decaying start moment. In this case, the following condition is satisfied:

$$N_{i_0} = N_i(t_{irr}), \quad i = 1, 2, 3. \quad (11)$$

The γ -spectrometric experiment is actually to measure the areas of the total absorption peaks $\check{S}_{1_l}, \check{S}_{2_l}, \check{S}_{3_l}$ (at γ -line energies E_1, E_2, E_3) in each l -th γ -spectrum. The areas can be expressed via count rates $\check{S}_{1_l} = \check{S}_{1_l}/t_{live_l}$, $\check{S}_{2_l} = \check{S}_{2_l}/t_{live_l}$, $\check{S}_{3_l} = \check{S}_{3_l}/t_{live_l}$. This representation is used because the spectrometer performance has to be allowed for by introducing time corrections.

To gain the desired statistics, the spectrometer "live" time, t_{live_l} , is always set for measuring the l -th γ -spectrum, while the l -th γ -spectrum buildup time is defined by the "true" measurement time $t_{true_l} = (t_{e_l} - t_{b_l})$, where t_{b_l} and t_{e_l} are the start and stop times of the l -th γ -spectrum buildup. The spectrometer allows always for the "dead" time Δt_{dead_l} spent by the spectrometer for analyzing the input pulses. Therefore, the simple relation $t_{true_l} = t_{live_l} + \Delta t_{dead_l}$ holds between the "true" and "live" spectrometer operation times t_{true_l} and t_{live_l} .

During the stage of calculating the experimental count rates $\check{S}_{i_l}$, the measured γ -spectra are processed using the "live" measurement time t_{live_l} , thereby allowing for the spectrometer load. When simulating the experimental S_{i_l} values, however, the corrections for the nuclide decays that occur within the l -th γ -spectrum measurement time must be calculated by integration over "true" measurement time t_{true_l} .

At the same time, the S_{1l} , S_{2l} , and S_{3l} values can be expressed via the $N_1(t)$, $N_2(t)$, and $N_3(t)$ values, which solve the set (7):

$$S_{il} = \frac{1}{t_{true_l}} \int_{t_{c_l}}^{t_{c_l} + t_{true_l}} N_{i0} \lambda_i \eta_i \varepsilon_i e^{-\lambda_i t} dt, \quad (12)$$

where η_i are the quantum yields of γ -lines; ε_i are the detection effectiveness of the spectrometer at γ -line energies E_i ; t_{c_l} is the time elapsed from the irradiation stop moment to the start moment of the l -the measurement start moment (i.e., the "decaying" or "cooling" time of a sample t_{cool}); t_{true_l} is the "true" time of the l -the measurement.

By the start moment of the l -th measurement and allowing for the condition (11), then, the calculated count rates S_{1l} , S_{2l} , and S_{3l} can be presented as

$$S_{1l} = A_1 \frac{1 - e^{-\lambda_1 t_{true_l}}}{\lambda_1 t_{true_l}} e^{-\lambda_1 t_{c_l}}, \quad (13)$$

$$S_{2l} = B_1 \frac{1 - e^{-\lambda_1 t_{true_l}}}{\lambda_1 t_{true_l}} e^{-\lambda_1 t_{c_l}} + B_2 \frac{1 - e^{-\lambda_2 t_{true_l}}}{\lambda_2 t_{true_l}} e^{-\lambda_2 t_{c_l}}, \quad (14)$$

$$S_{3l} = C_1 \frac{1 - e^{-\lambda_1 t_{true_l}}}{\lambda_1 t_{true_l}} e^{-\lambda_1 t_{c_l}} + C_2 \frac{1 - e^{-\lambda_2 t_{true_l}}}{\lambda_2 t_{true_l}} e^{-\lambda_2 t_{c_l}} + C_3 \frac{1 - e^{-\lambda_3 t_{true_l}}}{\lambda_3 t_{true_l}} e^{-\lambda_3 t_{c_l}}, \quad (15)$$

where

$$A_1 = N_{Tag} R_1^{cum/ind} \eta_1 \varepsilon_1 F_1, \quad (16)$$

$$B_1 = N_{Tag} R_1^{cum/ind} \eta_2 \varepsilon_2 \frac{\lambda_2}{\lambda_2 - \lambda_1} \nu_{12} F_1, \quad (17)$$

$$B_2 = N_{Tag} \eta_2 \varepsilon_2 \left(R_2^{ind} - R_1^{cum/ind} \nu_{12} \frac{\lambda_1}{\lambda_2 - \lambda_1} \right) F_2, \quad (18)$$

$$C_1 = N_{Tag} R_1^{cum/ind} \eta_3 \varepsilon_3 \frac{\lambda_3}{\lambda_3 - \lambda_1} \left[\nu_{13} + \nu_{12} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_1} \right] F_1, \quad (19)$$

$$C_2 = N_{Tag} \nu_{23} \eta_3 \varepsilon_3 \frac{\lambda_3}{\lambda_3 - \lambda_2} \left(R_2^{ind} - R_1^{cum/ind} \nu_{12} \frac{\lambda_1}{\lambda_2 - \lambda_1} \right) F_2, \quad (20)$$

$$C_3 = N_{Tag} \eta_3 \varepsilon_3 \left[R_3^{ind} + R_2^{ind} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_3} + R_1^{cum/ind} \frac{\lambda_1}{\lambda_1 - \lambda_3} \left(\nu_{13} + \nu_{12} \nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_3} \right) \right] F_3 \quad (21)$$

The tree-link chain (Fig. 1) may be transformed into its two-link counterpart in case a chain is deprived of a nucleus, namely, N_3 (the first case), N_2 (the second case), and N_1 (the third case).

In the first case, when nucleus N_3 is absent ($\nu_{13} = 0$ и $\nu_{23} = 0$), each third equation is excluded from the sets (2) and (7). As a result, the factors A_1 , B_1 , and B_2 represented by formulas (16)-(18) for a given chain are only sought for. The detailed solution for this type of two-link chains is described in [4].

The second case occurs in the absence of nuclide N_2 when nuclide N_1 transmutes fully

into N_3 ($\nu_{12} = 0$ and $\nu_{23} = 0$). The expressions (19)-(21), then, take the form

$$C_1 = N_{Tag} R_1^{cum/ind} \eta_3 \varepsilon_3 \frac{\lambda_3}{\lambda_3 - \lambda_2} \nu_{13} F_1 , \quad (22)$$

$$C_2 = 0 , \quad (23)$$

$$C_3 = N_{Tag} \eta_3 \varepsilon_3 \left[R_3^{ind} - R_1^{cum/ind} \nu_{13} \frac{\lambda_1}{\lambda_3 - \lambda_1} \right] F_3 . \quad (24)$$

The parameters C_1 and C_3 of the resulting two-link chain are completely in correspondence with the parameters B_1 and B_2 in the expressions (17) and (18) if subscript 2 in (17) and (18) is replaced with 3 subject that $\nu_{12} = 0$ and $\nu_{23} = 0$.

In the third case (nuclide N_1 is absent), the same occurs at $\nu_{12} = 0$ and $\nu_{13} = 0$, resulting in the chain that consists only of transmutation of N_2 into N_3 . Given this version, the expressions (19)-(21) for parameters C_1 , C_2 , and C_3 take the form

$$C_1 = 0 , \quad (25)$$

$$C_2 = N_{Tag} \nu_{23} \eta_3 \varepsilon_3 \frac{\lambda_3}{\lambda_3 - \lambda_2} R_2^{ind} F_2 , \quad (26)$$

$$C_3 = N_{Tag} \eta_3 \varepsilon_3 \left[R_3^{ind} - R_2^{ind} \nu_{23} \frac{\lambda_2}{\lambda_3 - \lambda_2} \right] F_3 . \quad (27)$$

These formulas are the same as the expressions (17) and (18) for the parameters B_1 and B_2 of the two-link chain when subscript 2 in (27) and (27) is replaced with 1, and 3 with 2, subject that $\nu_{12} = 0$ and $\nu_{13} = 0$.

In case $\nu_{13} = \nu_{23} = 0$, the chain turns into the single-link chain, while the parameters C_1 , C_2 , and C_3 take the form

$$C_1 = 0 , \quad (28)$$

$$C_2 = 0 , \quad (29)$$

$$C_3 = N_{Tag} R_3^{ind} \eta_3 \varepsilon_3 F_3 . \quad (30)$$

The factors A_1 , B_1 , B_2 , C_1 , C_2 , and C_3 , which carry information on the reaction rates $R_1^{cum/ind}$, R_2^{ind} , and R_3^{ind} , are determined using the least squares method by fitting the experimental dots $\tilde{S}_{1l}$, $\tilde{S}_{2l}$, and $\tilde{S}_{3l}$ that correspond to count rates for a definite peak in the next measurement run. The sets of the dots form so called decay curves. Fig. 3 show examples of the decay curves for some product nuclei of $^{208}\text{Pb}(\text{p},\text{x})$ -reactions.

The following functions are used in fitting:

$$g_1(t_{c_l}) = A_1 \frac{1 - e^{-\lambda_1 t_{true_l}}}{\lambda_1 t_{true_l}} e^{-\lambda_1 t_{c_l}} , \quad (31)$$

$$g_2(t_{c_l}) = B_1 \frac{1 - e^{-\lambda_1 t_{true_l}}}{\lambda_1 t_{true_l}} e^{-\lambda_1 t_{c_l}} + B_2 \frac{1 - e^{-\lambda_2 t_{true_l}}}{\lambda_2 t_{true_l}} e^{-\lambda_2 t_{c_l}} , \quad (32)$$

$$g_3(t_{c_l}) = C_1 \frac{1 - e^{-\lambda_1 t_{true_l}}}{\lambda_1 t_{true_l}} e^{-\lambda_1 t_{c_l}} + C_2 \frac{1 - e^{-\lambda_2 t_{true_l}}}{\lambda_2 t_{true_l}} e^{-\lambda_2 t_{c_l}} + C_3 \frac{1 - e^{-\lambda_3 t_{true_l}}}{\lambda_3 t_{true_l}} e^{-\lambda_3 t_{c_l}} . \quad (33)$$

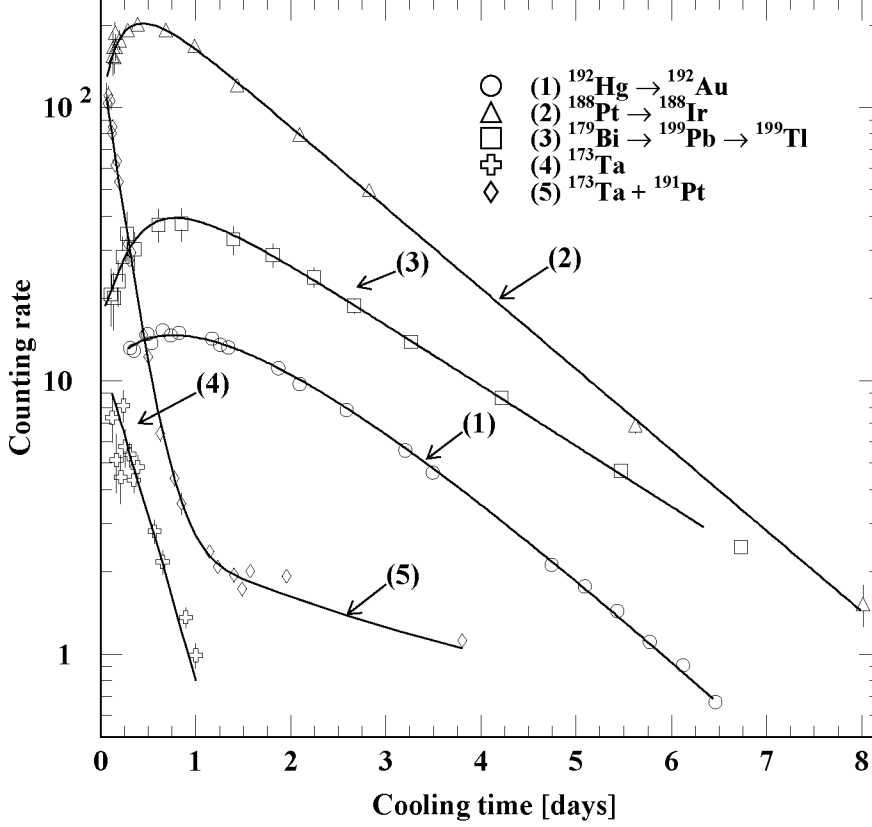


Fig. 3: Typical examples of the measured counting rates and fitted decay curves. Curve (1) is the generically related decay of two nuclides of sufficiently close halfives $^{192}\text{Hg}(4.85\text{h}) \rightarrow ^{192}\text{Au}(4.94\text{h})$, $E_\gamma(^{192}\text{Pt}) = 316.5 \text{ keV}$. Curve 2 is the same for substantially different halfives $^{188}\text{Pt}(10.2\text{d}) \rightarrow ^{188}\text{Ir}(41.5\text{h})$, $E_\gamma(^{188}\text{Os}) = 2214.6 \text{ keV}$. Curve (3) is the generically related decay of three nuclides $^{199}\text{Bi}(27\text{m}) \rightarrow ^{199}\text{Pb}(90\text{m}) \rightarrow ^{199}\text{Tl}(7.42\text{h})$, $E_\gamma(^{199}\text{Tl}) = 208.2 \text{ keV}$. Curve (4) is the decay $^{173}\text{Ta}(3.14\text{h})$, $E_\gamma(^{173}\text{Hf}) = 160.4 \text{ keV}$. Curve (5) describes the decay of two generically non-related nuclides [$^{173}\text{Ta}(3.14\text{h}) + ^{191}\text{Pt}(2.802\text{d})$], with close $E_\gamma = 172.2 \text{ keV}$ of their daughters. To clarify the picture, the scaling factors have been introduced for some of the curves.

Conforming to least squares fitting, the quadratic functionals are introduced:

$$\Omega_i = \sum_{l=1}^{L_i} \left(\tilde{S}_{i_l} - g_i(t_{c_l}) \right)^2 \cdot W_{i_l} , \quad (34)$$

$$W_{i_l} = \frac{1}{\left(\Delta \tilde{S}_{i_l} \right)^2} , \quad i = 1, 2, 3 \quad (35)$$

where $\Delta\tilde{S}_{il}$ are absolute errors in $\tilde{S}_{il}$; L_i is the number of experimental dots to support the i -th nuclide.

The condition of minimizing the functionals Ω_i may be used to obtain the expressions to determine the factors $\hat{A}_1, \hat{B}_1, \hat{B}_2, \hat{C}_1, \hat{C}_2, \hat{C}_3$ and their errors:

$$\hat{A}_1 = \frac{\sum_{l=1}^{L_1} \left(\tilde{S}_{1l} e^{-\lambda_1 t_{cl}} \cdot h_{1l} \cdot W_{1l} \right)}{\sum_{l=1}^{L_1} \left(e^{-2\lambda_1 t_{cl}} \cdot h_{1l}^2 \cdot W_{1l} \right)}, \quad \Delta\hat{A}_1 = \sqrt{\frac{1}{\sum_{l=1}^{L_1} \left(e^{-2\lambda_1 t_{cl}} \cdot h_{1l}^2 \cdot W_{1l} \right)}} \cdot \sqrt{\frac{\hat{\Omega}_1}{L_1 - 1}}, \quad (36)$$

$$\hat{\vec{B}} = M_B^{-1} \cdot \vec{Z}_B, \quad \Delta\hat{B}_i = \sqrt{(M_B^{-1})_{ii}} \cdot \sqrt{\frac{\hat{\Omega}_2}{L_2 - 2}}, \quad (i = 1, 2), \quad (37)$$

$$\hat{\vec{C}} = M_C^{-1} \cdot \vec{Z}_C, \quad \Delta\hat{C}_i = \sqrt{(M_C^{-1})_{ii}} \cdot \sqrt{\frac{\hat{\Omega}_3}{L_3 - 3}}, \quad (i = 1, 2, 3), \quad (38)$$

$$\begin{aligned} \hat{\vec{B}} &= \begin{Bmatrix} \hat{B}_1 \\ \hat{B}_2 \end{Bmatrix}, & \vec{Z}_B &= \begin{Bmatrix} Z_{B1} \\ Z_{B2} \end{Bmatrix}, \\ \hat{\vec{C}} &= \begin{Bmatrix} \hat{C}_1 \\ \hat{C}_2 \\ \hat{C}_3 \end{Bmatrix}, & \vec{Z}_C &= \begin{Bmatrix} Z_{C1} \\ Z_{C2} \\ Z_{C3} \end{Bmatrix}. \end{aligned}$$

where $\hat{\Omega}_1, \hat{\Omega}_2, \hat{\Omega}_3$ are the values of the functionals $\Omega_1, \Omega_2, \Omega_3$ at $A_1 = \hat{A}_1, \vec{B} = \hat{\vec{B}}, \vec{C} = \hat{\vec{C}}$.

The matrices M_B, M_C and the vectors of the right-hand part $\vec{Z}_B, \vec{Z}_C$ of the input sets of linear equations are

$$\begin{cases} (M_B)_{ij} = \sum_{l=1}^{L_2} \left(e^{-(\lambda_i + \lambda_j) t_{cl}} h_{il} h_{jl} \cdot W_{2l} \right), \\ (Z_B)_i = \sum_{l=1}^{L_2} \left(\tilde{S}_{2l} e^{-\lambda_i t_{cl}} h_{il} \cdot W_{2l} \right), \end{cases} \quad i, j = 1, 2, \quad (39)$$

$$\begin{cases} (M_C)_{ij} = \sum_{l=1}^{L_3} \left(e^{-(\lambda_i + \lambda_j) t_{cl}} h_{il} h_{jl} \cdot W_{3l} \right), \\ (Z_C)_i = \sum_{l=1}^{L_3} \left(\tilde{S}_{3l} e^{-\lambda_i t_{cl}} h_{il} \cdot W_{3l} \right), \end{cases} \quad i, j = 1, 2, 3, \quad (40)$$

$$h_{il} = \frac{1 - e^{-\lambda_i t_{true\ l}}}{\lambda_i t_{true\ l}},$$

where h_{il}, h_{jl} is the set of the factors that allows for the decay of the i -th or j -th nuclide in the l -th measurement.

It should also be noted that a correction must be introduced to allow for absorption of γ -quanta in the materials of monitor and of experimental sample. The correction value and its error were calculated for γ -quanta of energy E_j in the experimental sample material as

$$k_{\mu_j} = \frac{k \cdot \sigma_{tot_j} \cdot H}{1 - e^{-k \cdot \sigma_{tot_j} \cdot H}}, \quad (41)$$

$$\frac{\Delta k_{\mu_j}}{k_{\mu_j}} = (1 - k_{\mu_j} e^{-k \cdot \sigma_{tot_j} \cdot H}) \frac{\Delta \sigma_{tot_j}}{\sigma_{tot_j}}, \quad (42)$$

where H is the experimental sample depth (g/cm²); σ_{tot_j} is the cross section for interaction of γ -quanta of the j -th energy with matter (barn/atom; $k = \frac{N_{Av}}{M} \cdot 10^{-24}$ is the conversion factor from dimension [barn/atom] to dimension [cm²/g], where N_{Av} is Avogadro number, M is molecular weight. The values of the cross sections for interaction of γ -quanta of the i -th energy with matter have been taken from [5]. Conforming to the recommendations of [5], the relative errors in the cross sections for interaction of the γ -quanta in the 100-2600 keV range were broken into two groups. The error was taken to be 10% in the first group (below 200 keV) and 5% in the second group (above 200 keV). In this case, the relative error of factor k_{μ} was 0.05% – 0.1% within a selected depth interval of experimental samples, the fact that failed actually to affect the error in the final results.

Formulas (16) and (36) can be used to obtain the expression for calculating the (cumulative or independent) reaction rate of the first nuclide:

$$R_1^{cum/ind} = \frac{1}{N_{Tag} \eta_1 \varepsilon_1} \cdot \frac{A_1^*}{F_1}. \quad (43)$$

In measuring the activity of the second nuclide in the chain, the formulas (17), (18), and (37) can be used to obtain expressions for simultaneous calculating the reaction rate of the first nuclide and for calculating the independent and cumulative reaction rates of the second nuclide:

$$R_1^{cum/ind} = \frac{1}{N_{Tag} \eta_2 \varepsilon_2} \cdot \frac{B_1^*}{F_1} \cdot \frac{1}{\nu_{12}} \left(1 - \frac{\lambda_1}{\lambda_2} \right), \quad (44)$$

$$R_2^{ind} = \frac{1}{N_{Tag} \eta_2 \varepsilon_2} \left[\frac{B_2^*}{F_2} + \frac{B_1^* \lambda_1}{F_1 \lambda_2} \right], \quad (45)$$

$$R_2^{cum} = R_2^{ind} + \nu_{12} R_1^{cum/ind} = \frac{1}{N_{Tag} \eta_2 \varepsilon_2} \left[\frac{B_1^*}{F_1} + \frac{B_2^*}{F_2} \right]. \quad (46)$$

In measuring the activity of the third nuclide in the chain, the formulas (19) – (21), and (38) can be used to obtain the expressions for simultaneous calculating the reaction rate of the first nuclide, for calculating the independent and cumulative reaction rates of the second

nuclide, and for calculating the independent and cumulative reaction rates of the third nuclide:

$$R_1^{cum/ind} = \frac{1}{N_{Tag}\eta_3\varepsilon_3} \cdot \frac{C_1^*}{F_1} \cdot r, \quad (47)$$

$$R_2^{ind} = \frac{1}{N_{Tag}\eta_3\varepsilon_3} \left[\frac{C_1^*}{F_1} \nu_{12} \frac{\lambda_1}{\lambda_2 - \lambda_1} \frac{1}{r} + \frac{C_2^*}{F_2} \frac{1}{\nu_{23}} \left(1 - \frac{\lambda_2}{\lambda_3} \right) \right], \quad (48)$$

$$R_2^{cum} = R_2^{ind} + \nu_{12} R_1^{cum/ind} = \frac{1}{N_{Tag}\eta_3\varepsilon_3} \left[\frac{C_1^*}{F_1} \nu_{12} \frac{\lambda_2}{\lambda_2 - \lambda_1} \frac{1}{r} + \frac{C_2^*}{F_2} \frac{1}{\nu_{23}} \left(1 - \frac{\lambda_2}{\lambda_3} \right) \right], \quad (49)$$

$$R_3^{ind} = \frac{1}{N_{Tag}\eta_3\varepsilon_3} \left[\frac{C_1^*}{F_1} \frac{\lambda_1}{\lambda_3} + \frac{C_2^*}{F_2} \frac{\lambda_2}{\lambda_3} + \frac{C_3^*}{F_3} \right], \quad (50)$$

$$R_3^{cum} = R_3^{ind} + \nu_{13} R_1^{cum/ind} + \nu_{23} R_2^{ind} + \nu_{12}\nu_{23} R_1^{cum/ind} = \frac{1}{N_{Tag}\eta_3\varepsilon_3} \left[\frac{C_1^*}{F_1} + \frac{C_2^*}{F_2} + \frac{C_3^*}{F_3} \right] \quad (51)$$

$$\text{where } r = \frac{1}{\nu_{13} + \nu_{12}\nu_{23} \frac{\lambda_2}{\lambda_2 - \lambda_1}} \left(1 - \frac{\lambda_1}{\lambda_3} \right), \quad (52)$$

$$A_1^* = \hat{A}_1 \cdot k_{\mu_1}, \quad \vec{B}^* = \hat{\vec{B}} \cdot k_{\mu_2}, \quad \vec{C}^* = \hat{\vec{C}} \cdot k_{\mu_3}.$$

The yields of reaction products may be calculated later via their mean production rates obtained by averaging a few $(R_{ij}^{ind/cum} \pm \Delta R_{ij}^{ind/cum})$ values calculated for k different γ -lines. It is expedient, therefore, to use the definitions of the relative quantum yield and of the relative spectrometer detection effectiveness, between which the following relations hold:

$$\eta_{ij} = k_{\gamma_i} \cdot \eta_{ij}^{rel}; \quad \varepsilon_{ij} = k_{\varepsilon} \cdot \varepsilon_{ij}^{rel} \quad (53)$$

In this case the values of $k_{\gamma_i} \pm \Delta k_{\gamma_i}$ were taken to conform to [34], while the value of factor $k_{\varepsilon} \pm \Delta k_{\varepsilon}$ was determined using the procedure described in 2.6.1. The relative reaction rate can, then, be determined via the above factors k_{γ_i} and k_{ε} , while the absolute reaction rates calculated by formulas (43), (44)-(46), and (47)-(52) can be presented as

$${}^{rel}R_{ij}^{cum/ind} = R_{ij}^{cum/ind} \cdot k_{\gamma_i} \cdot k_{\varepsilon} \cdot N_{tag} \quad (54)$$

The errors in the relative count rates $\Delta R_1^{cum/ind}$, ΔR_2^{ind} , ΔR_2^{cum} , ΔR_3^{ind} , and ΔR_3^{cum} can be calculated using the error transfer formulas allowing for the errors in all values that enter expressions (43), (44) – (46), (47) – (52), and (54):

$$\Delta {}^{rel}R_1^{cum/ind} = {}^{rel}R_1^{cum/ind} \cdot \sqrt{\left(\frac{\Delta \hat{A}_1}{\hat{A}_1} \right)^2 + \left(\frac{\Delta k_{\mu_1}}{k_{\mu_1}} \right)^2 + \left(\frac{\Delta \eta_1^{rel}}{\eta_1^{rel}} \right)^2 + \left(\frac{\Delta \varepsilon_1^{rel}}{\varepsilon_1^{rel}} \right)^2} \quad (55)$$

$$\Delta {}^{rel}R_1^{cum/ind} = {}^{rel}R_1^{cum/ind} \cdot \sqrt{\left(\frac{\Delta \hat{B}_1}{\hat{B}_1} \right)^2 + \left(\frac{\Delta k_{\mu_2}}{k_{\mu_2}} \right)^2 + \left(\frac{\Delta \eta_2^{rel}}{\eta_2^{rel}} \right)^2 + \left(\frac{\Delta \varepsilon_2^{rel}}{\varepsilon_2^{rel}} \right)^2} \quad (56)$$

for single-link chain;

$$\Delta^{rel} R_2^{ind} = {}^{rel} R_2^{ind} \cdot \sqrt{\left(\frac{\Delta \hat{G}_{B_1}}{\hat{G}_{B_1}}\right)^2 + \left(\frac{\Delta k_{\mu_2}}{k_{\mu_2}}\right)^2 + \left(\frac{\Delta \eta_2^{rel}}{\eta_2^{rel}}\right)^2 + \left(\frac{\Delta \varepsilon_2^{rel}}{\varepsilon_2^{rel}}\right)^2} \quad (57)$$

$$\Delta^{rel} R_2^{cum} = {}^{rel} R_2^{cum} \cdot \sqrt{\left(\frac{\Delta \hat{G}_{B_2}}{\hat{G}_{B_2}}\right)^2 + \left(\frac{\Delta k_{\mu_2}}{k_{\mu_2}}\right)^2 + \left(\frac{\Delta \eta_2^{rel}}{\eta_2^{rel}}\right)^2 + \left(\frac{\Delta \varepsilon_2^{rel}}{\varepsilon_2^{rel}}\right)^2} \quad (58)$$

for two-link chain;

$$\Delta^{rel} R_1^{cum/ind} = {}^{rel} R_1^{cum/ind} \cdot \sqrt{\left(\frac{\Delta \hat{C}_1}{\hat{C}_1}\right)^2 + \left(\frac{\Delta k_{\mu_3}}{k_{\mu_3}}\right)^2 + \left(\frac{\Delta \eta_3^{rel}}{\eta_3^{rel}}\right)^2 + \left(\frac{\Delta \varepsilon_3^{rel}}{\varepsilon_3^{rel}}\right)^2} \quad (59)$$

$$\Delta^{rel} R_2^{ind} = {}^{rel} R_2^{ind} \cdot \sqrt{\left(\frac{\Delta \hat{G}_{C_1}}{\hat{G}_{C_1}}\right)^2 + \left(\frac{\Delta k_{\mu_3}}{k_{\mu_3}}\right)^2 + \left(\frac{\Delta \eta_3^{rel}}{\eta_3^{rel}}\right)^2 + \left(\frac{\Delta \varepsilon_3^{rel}}{\varepsilon_3^{rel}}\right)^2} \quad (60)$$

$$\Delta^{rel} R_2^{cum} = {}^{rel} R_2^{cum} \cdot \sqrt{\left(\frac{\Delta \hat{G}_{C_2}}{\hat{G}_{C_2}}\right)^2 + \left(\frac{\Delta k_{\mu_3}}{k_{\mu_3}}\right)^2 + \left(\frac{\Delta \eta_3^{rel}}{\eta_3^{rel}}\right)^2 + \left(\frac{\Delta \varepsilon_3^{rel}}{\varepsilon_3^{rel}}\right)^2} \quad (61)$$

$$\Delta^{rel} R_3^{ind} = {}^{rel} R_3^{ind} \cdot \sqrt{\left(\frac{\Delta \hat{G}_{C_3}}{\hat{G}_{C_3}}\right)^2 + \left(\frac{\Delta k_{\mu_3}}{k_{\mu_3}}\right)^2 + \left(\frac{\Delta \eta_3^{rel}}{\eta_3^{rel}}\right)^2 + \left(\frac{\Delta \varepsilon_3^{rel}}{\varepsilon_3^{rel}}\right)^2} \quad (62)$$

$$\Delta^{rel} R_3^{cum} = {}^{rel} R_3^{cum} \cdot \sqrt{\left(\frac{\Delta \hat{G}_{C_4}}{\hat{G}_{C_4}}\right)^2 + \left(\frac{\Delta k_{\mu_3}}{k_{\mu_3}}\right)^2 + \left(\frac{\Delta \eta_3^{rel}}{\eta_3^{rel}}\right)^2 + \left(\frac{\Delta \varepsilon_3^{rel}}{\varepsilon_3^{rel}}\right)^2} \quad (63)$$

for three-link chain.

Considering formulas (36), (37), and (38), the errors in the functions

$$G_{B_1}(\vec{B}) = \frac{B_1}{F_1} \frac{\lambda_1}{\lambda_2} + \frac{B_2}{F_2} \quad , \quad (64)$$

$$G_{B_2}(\vec{B}) = \frac{B_1}{F_1} + \frac{B_2}{F_2} \quad , \quad (65)$$

$$G_{C_1}(\vec{C}) = \frac{C_1}{F_1} \nu_{12} \frac{\lambda_1}{\lambda_2 - \lambda_1} \frac{1}{r} + \frac{C_2}{F_2} \frac{1}{\nu_{23}} \left(1 - \frac{\lambda_2}{\lambda_3}\right) \quad , \quad (66)$$

$$G_{C_2}(\vec{C}) = \frac{C_1}{F_1} \nu_{12} \frac{\lambda_2}{\lambda_2 - \lambda_1} \frac{1}{r} + \frac{C_2}{F_2} \frac{1}{\nu_{23}} \left(1 - \frac{\lambda_2}{\lambda_3}\right) \quad , \quad (67)$$

$$G_{C_3}(\vec{C}) = \frac{C_1}{F_1} \frac{\lambda_1}{\lambda_3} + \frac{C_2}{F_2} \frac{\lambda_2}{\lambda_3} + \frac{C_3}{F_3} \quad , \quad (68)$$

$$G_{C_4}(\vec{C}) = \frac{C_1}{F_1} + \frac{C_2}{F_2} + \frac{C_3}{F_3} \quad , \quad (69)$$

of the parameters B_1 , B_2 , C_1 , C_2 , and C_3 that enter the expressions (64) – (69) were determined as

$$\Delta G_{B_i}^2 = \text{grad } G_{B_i} \cdot M_B^{-1} \cdot (\text{grad } G_{B_i})^T, \quad i = 1, 2 \quad (70)$$

where

$$\text{grad } G_{B_1} = \left\{ \frac{1}{F_1} \cdot \frac{\lambda_1}{\lambda_2}, \frac{1}{F_2} \right\}, \quad \text{grad } G_{B_2} = \left\{ \frac{1}{F_1}, \frac{1}{F_2} \right\}, \quad (71)$$

$$\Delta G_{C_i}^2 = \text{grad } G_{C_i} \cdot M_C^{-1} \cdot (\text{grad } G_{C_i})^T, \quad i = 1, 2, 3, 4 \quad (72)$$

where

$$\text{grad } G_{C_1} = \left\{ \frac{1}{F_1} \nu_{12} \frac{\lambda_1}{\lambda_2 - \lambda_1} \frac{1}{r}, \frac{1}{F_2} \frac{1}{\nu_{23}} \left(1 - \frac{\lambda_2}{\lambda_3} \right), 0 \right\}, \quad (73)$$

$$\text{grad } G_{C_2} = \left\{ \frac{1}{F_1} \nu_{12} \frac{\lambda_2}{\lambda_2 - \lambda_1} \frac{1}{r}, \frac{1}{F_2} \frac{1}{\nu_{23}} \left(1 - \frac{\lambda_2}{\lambda_3} \right), 0 \right\}, \quad (74)$$

$$\text{grad } G_{C_3} = \left\{ \frac{\lambda_1}{\lambda_3} \frac{1}{F_1}, \frac{\lambda_2}{\lambda_3} \frac{1}{F_2}, \frac{1}{F_3} \right\}. \quad (75)$$

$$\text{grad } G_{C_4} = \left\{ \frac{1}{F_1}, \frac{1}{F_3}, \frac{1}{F_3} \right\}. \quad (76)$$

The mean relative independent or cumulative production rates of the i -th nuclide derived from j γ -lines were calculated to be

$$\overline{R}_i^{\text{cum/ind}} = \frac{\sum_{j=1}^k \overline{R}_{ij}^{\text{cum/ind}} \cdot \overline{W}_{ij}}{\sum_{j=1}^k \overline{W}_{ij}}, \quad \text{где } \overline{W}_{ij} = \frac{1}{\left(\Delta \overline{R}_{ij}^{\text{cum/ind}} \right)^2}. \quad (77)$$

$$\Delta \overline{R}_i^{\text{cum/ind}} = \max \left\{ \left(\Delta \overline{R}_i^{\text{cum/ind}} \right)', \left(\Delta \overline{R}_i^{\text{cum/ind}} \right)'' \right\}, \quad \text{где} \quad (78)$$

$$\left(\Delta \overline{R}_i^{\text{cum/ind}} \right)' = \sqrt{\frac{\sum_{j=1}^k \overline{W}_{ij} \left(\overline{R}_i^{\text{cum/ind}} - \overline{R}_{ij} \right)^2}{(k-1) \sum_{j=1}^k \overline{W}_{ij}}}, \quad \left(\Delta \overline{R}_i^{\text{cum/ind}} \right)'' = \sqrt{\frac{1}{\sum_{j=1}^k \overline{W}_{ij}}}, \quad (79)$$

The mean absolute independent or cumulative production rates of the i -th nuclides were calculated together with their errors from the relative production rates:

$$\overline{R}_i^{cum/ind} = \frac{rel \overline{R}_i^{cum/ind}}{k_{\gamma_i} \cdot k_{\varepsilon} \cdot N_{tag}} \quad (80)$$

$$\Delta \overline{R}_i^{cum/ind} = \overline{R}_i^{cum/ind} \cdot \sqrt{\left(\frac{\Delta rel \overline{R}_i^{cum/ind}}{rel \overline{R}_i^{cum/ind}}\right)^2 + \left(\frac{\Delta k_{\gamma_i}}{k_{\gamma_i}}\right)^2 + \left(\frac{\Delta k_{\varepsilon}}{k_{\varepsilon}}\right)^2 + \left(\frac{\Delta N_{Tag}}{N_{Tag}}\right)^2} \quad (81)$$

In case but a single γ -line is involved in the reaction rate calculations (this is possible when but one of j γ -lines is selected, or when a nuclide shows a single γ -line, $j=1$), the absolute quantum yield of that sole γ -line ($\eta_i \pm \Delta\eta_i$) and the absolute detection effectiveness ($\varepsilon_i \pm \Delta\varepsilon_i$) are used in formulas (43), (44)-(46), and (47)-(52).

Since

$$\left(\frac{\Delta\eta_{ij}}{\eta_{ij}}\right)^2 = \left(\frac{\Delta k_{\gamma_i}}{k_{\gamma_i}}\right)^2 + \left(\frac{\Delta\eta_{ij}^{rel}}{\eta_{ij}^{rel}}\right)^2 \quad \left(\frac{\Delta\varepsilon_{ij}}{\varepsilon_{ij}}\right)^2 = \left(\frac{\Delta k_{\varepsilon}}{k_{\varepsilon}}\right)^2 + \left(\frac{\Delta\varepsilon_{ij}^{rel}}{\varepsilon_{ij}^{rel}}\right)^2, \quad (82)$$

formula (81) is transformed, making allowance for formulas (56) - (63), to calculate the error in the reaction rate calculated for a single γ -line (formulas (88) and (120), for example).

In case a few nuclides of different halflives are of identical γ -quantum energy (within the spectrometer resolution), while the precursors of the nuclides are absent (or their halflives are much shorter (or much longer in the case of "screening") compared with any of the nuclides in question, the total count rate in total absorption peak S_{sum_l} at moment t_{cl} equals the sum of count rates recorded when measuring γ -quanta from each of the nuclides and can be calculated as

$$S_{sum_l} = \sum_{k=1}^n \frac{1}{t_{true_l}} \int_{t_{cl}}^{t_{cl}+t_{true_l}} A_{1k} e^{-\lambda_k t} dt = \sum_{k=1}^n A_{1k} \frac{1 - e^{-\lambda_k t_{true_l}}}{\lambda_k t_{true_l}} e^{-\lambda_k t_{cl}}, \quad (83)$$

$$A_{1k} = N_T R_k^{ind/cum} \eta_k \varepsilon F_k. \quad (84)$$

where n is the number of the nuclides; ε is the detection effectiveness corresponding to their common γ -line.

The factors A_{1k} can be determined from the approximation curve using the least squares fitting via minimization of the functional

$$\begin{aligned} \Omega_4 &= \sum_{l=1}^{L_4} \left(\tilde{S}_{sum_l} - S_{sum_l} \right)^2 \cdot W_{sum_l} = \\ &= \sum_{l=1}^{L_4} \left(\tilde{S}_{sum_l} - \sum_{k=1}^n A_{1k} h_{kl} e^{-\lambda_k t_{cl}} \right)^2 \cdot W_{sum_l}, \end{aligned} \quad (85)$$

$$W_{sum_l} = \frac{1}{\left(\Delta \tilde{S}_{sum_l} \right)^2} \quad (86)$$

for the parameters A_{1_k} , where $\tilde{S}_{sum_l}$ and $\Delta\tilde{S}_{sum_l}$ are the experimental values of the recorded total count rate in the total absorption peak at moment t_{c_l} and of their error; L_4 is the number of experimental dots.

As a result, we get the following set of linear equations:

$$\vec{Z} = M \times \vec{A_1} ,$$

где

$$\vec{A_1} = \begin{Bmatrix} A_{1_1} \\ A_{1_2} \\ \vdots \\ A_{1_n} \end{Bmatrix} , \quad \vec{Z} = \begin{Bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_n \end{Bmatrix}$$

$$Z_i = \sum_{k=1}^L \tilde{S}_{sum_k} h_{ik} e^{-\lambda_i t_{c_k}} \cdot W_{sum_k} ,$$

$$M_{ij} = \sum_{k=1}^L e^{-(\lambda_i + \lambda_j) t_{c_k}} h_{ik} h_{jk} \cdot W_{sum_k} .$$

The solution for the set is

$$\hat{\vec{A_1}} = M^{-1} \times \vec{Z} ,$$

$$\Delta\hat{A}_{1_k} = \sqrt{(M^{-1})_{kk}} \cdot \sqrt{\frac{\hat{\Omega}_4}{L_4 - n}} , \quad (k = 1, 2, ..n) ,$$

where $\hat{\Omega}_4$ is the value of functional Ω_4 at $A_{1_k} = \hat{A}_{1_k}$ ($k = 1, 2, ..n$) calculated by formula (85).

The production rate for the k -th of n nuclides can, then, be written as

$$R_k^{ind/cum} = \frac{A_{1_k}^*}{\eta_k \varepsilon F_k N_{Tag}} , \quad A_{1_k}^* = \hat{A}_{1_k} \cdot k_{\mu_1} . \quad (87)$$

The error in expression (87) is determined as

$$\Delta R_k^{ind/cum} = R_k^{ind/cum} \cdot \sqrt{\left(\frac{\Delta\hat{A}_{1_k}}{\hat{A}_{1_k}}\right)^2 + \left(\frac{\Delta k_{\mu_1}}{k_{\mu_1}}\right)^2 + \left(\frac{\Delta\eta_k}{\eta_k}\right)^2 + \left(\frac{\Delta\varepsilon}{\varepsilon}\right)^2 + \left(\frac{\Delta N_{Tag}}{N_{Tag}}\right)^2} \quad (88)$$

2.2 Mean proton flux determining

The production rates of the identified residual nuclei having been determined, the cross sections for their production will be determined if the mean proton flux density is known. The latter is determined here by the monitor techniques based on simultaneous irradiation of an experimental sample and an Al standard foil of identical dimensions. Aluminum has been selected to be the

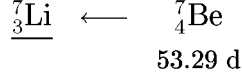


Fig. 4: Isobaric chain $A = 7$.

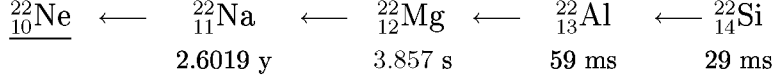


Fig. 5: Isobaric chain $A = 22$.

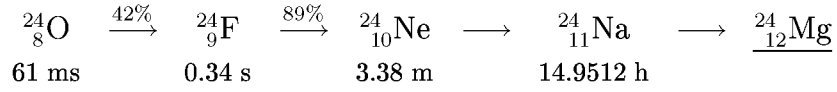


Fig. 6: Isobaric chain $A = 24$.

standard foil material because the reactions ${}^{27}\text{Al}(\text{p},\text{x}){}^7\text{Be}$, ${}^{27}\text{Al}(\text{p},\text{x}){}^{22}\text{Na}$, and ${}^{27}\text{Al}(\text{p},\text{x}){}^{24}\text{Na}$ are mostly used as monitor reaction to determine the proton flux density.

Figs. 4, 5, and 6 show the isobaric chains that include ${}^7\text{Be}$, ${}^{22}\text{Na}$, and ${}^{24}\text{Na}$ [126].

The ${}^7\text{Be}$, ${}^{22}\text{Na}$, and ${}^{24}\text{Na}$ production chains indicates that ${}^7\text{Be}$ alone is produced directly by nuclear reaction, while ${}^{22}\text{Na}$ and ${}^{24}\text{Na}$ are produced by both nuclear reaction and decay transmutations. Therefore, the independent cross section of the ${}^{27}\text{Al}(\text{p},\text{x}){}^7\text{Be}$ reaction and the cumulative cross sections of the ${}^{27}\text{Al}(\text{p},\text{x}){}^{22}\text{Na}$ and ${}^{27}\text{Al}(\text{p},\text{x}){}^{24}\text{Na}$ reactions are used as monitor cross sections. This is why the procedure of ${}^{22}\text{Na}$ and ${}^{24}\text{Na}$ measurements in the irradiated standard foils has to meet certain conditions because their precursors ${}^{22}\text{Mg}$ and ${}^{24}\text{Ne}$ need definite time to decay. In measuring ${}^{22}\text{Na}$, the decay time must be above ~ 30 s, i.e. ~ 40 min for ${}^{24}\text{Na}$. If these conditions are satisfied, the ${}^{22}\text{Na}$ and ${}^{24}\text{Na}$ production chains can be much simplified:

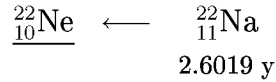


Fig. 7: Simplified isobaric chain $A = 22$.

Let the function $\ddot{R}_{st}^{ind/cum}(x, y, t)$, which is numerically equal to the ${}^7\text{Be}$, ${}^{22}\text{Na}$, and ${}^{24}\text{Na}$ production rates at a point with coordinates (x, y) at moment t , be introduced with a view to describing the production rates of ${}^7\text{Be}$, ${}^{22}\text{Na}$, and ${}^{24}\text{Na}$ at each point of the monitor foil

As noted above, the described experiments have been made in the pulsed irradiation mode, i.e. use was made of recurrent irradiation that included K pulses of duration τ each and

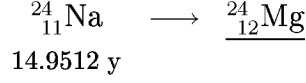


Fig. 8: Simplified isobaric chain $A = 24$.

repetition rate T (see Fig. 2).

The single-link radioactive transformation chains shown in Figs. 4, 7, and 8 can be described mathematically as

$$\frac{dN_{st}(x, y, t)}{dt} = N_{Al} \cdot \ddot{R}_{st}^{ind/cum}(x, y, t) - \lambda_{st} \cdot N_{st}(x, y, t), \quad (89)$$

with initial conditions $N_{st}(x, y, 0) = 0$, $st = {}^7\text{Be}, {}^{22}\text{Na}, {}^{24}\text{Na}$.

Here, $N_{st}(x, y, t)$ is the number of either ${}^7\text{Be}$ or ${}^{22}\text{Na}$ or ${}^{24}\text{Na}$ product nuclei in the vicinity of point (x, y) ; $\ddot{R}_{st}^{ind/cum}(x, y, t)$ are their independent (${}^7\text{Be}$) or cumulative (${}^{22}\text{Na}$ and ${}^{24}\text{Na}$) production rates in the vicinity of point (x, y) at time t measured from the start to stop moment of irradiation; λ_{st} are the ${}^7\text{Be}$, ${}^{22}\text{Na}$, and ${}^{24}\text{Na}$ decay constants; N_{Al} is the number of Al nuclei in the standard foil.

Conforming to the irradiation conditions, the function $\ddot{R}_{st}^{ind/cum}(x, y, t)$ for the j -th pulse can be presented as

$$\ddot{R}_{st}^{ind/cum}(x, y, t) = \begin{cases} R_{st}^{ind/cum}(x, y), & \text{for } (j-1)T \leq t < (j-1)T + \tau, \\ 0, & \text{for } (j-1)T + \tau \leq t \leq jT, \end{cases} \quad (90)$$

Given the first pulse, the solution for the first equation (89) is

$$N_{st1}(x, y, t) = N_{Al} \cdot R_{st}^{ind/cum}(x, y) \cdot \frac{1 - e^{-\lambda_{st} \cdot t}}{\lambda_{st}} \quad (91)$$

where t runs through $0 < t < \tau$.

Considering the decays of the product nuclides (${}^7\text{Be}$, ${}^{22}\text{Na}$, and ${}^{24}\text{Na}$) within time from τ to $(K-1) \cdot T + \tau$ (i.e. by the irradiation stop moment), the number of the nuclides produced in the first pulse is

$$N_{st1}(x, y, [(K-1) \cdot T + \tau]) = N_{Al} \cdot R_{st}^{ind/cum}(x, y) \cdot \frac{1 - e^{-\lambda_{st} \cdot \tau}}{\lambda_{st}} \cdot e^{-\lambda_{st} \cdot (K-1) \cdot T} \quad (92)$$

The number of nuclides produced from the j -th pulse at the irradiation stop moment is

$$N_{stj}(x, y, [(K-1) \cdot T + \tau]) = N_{Al} \cdot R_{st}^{ind/cum}(x, y) \cdot \frac{1 - e^{-\lambda_{st} \cdot \tau}}{\lambda_{st}} \cdot e^{-\lambda_{st} \cdot (K-j) \cdot T} \quad (93)$$

The total target nuclide number at the irradiation stop moment must be determined by summing up the partial contributions from all pulses:

$$\begin{aligned}
N_{st}(x, y, [(K-1) \cdot T + \tau]) &= \sum_{j=1}^K N_{stj} = \\
&= \sum_{j=1}^K N_{Al} \cdot R_{st}^{ind/cum}(x, y) \cdot \frac{1 - e^{-\lambda_{st} \cdot \tau}}{\lambda_{st}} \cdot e^{-\lambda_{st} \cdot (K-j) \cdot T} = \\
&= N_{Al} \cdot R_{st}^{ind/cum}(x, y) \cdot \frac{1 - e^{-\lambda_{st} \cdot \tau}}{\lambda_{st}} \cdot [1 + e^{-\lambda_{st} \cdot T} + e^{-\lambda_{st} \cdot 2T} + \dots + e^{-\lambda_{st} \cdot (K-1) \cdot T}]
\end{aligned} \tag{94}$$

It should be noted that the square brackets in (94) contain a sum of geometric series members with geometric ratio $q = e^{-\lambda_{st} \cdot T}$. In this case, the eventual number of radioactive products from K pulses can be expressed as

$$\begin{aligned}
N_{st}(x, y, [(K-1) \cdot T + \tau]) &= N_{Al} \cdot R_{st}^{ind/cum}(x, y) \cdot \frac{1 - e^{-\lambda_{st} \cdot \tau}}{\lambda_{st}} \cdot \frac{1 - q^K}{1 - q} = \\
&= N_{Al} \cdot R_{st}^{ind/cum}(x, y) \cdot \frac{1 - e^{-\lambda_{st} \cdot \tau}}{\lambda_{st}} \cdot \frac{1 - e^{-\lambda_{st} \cdot KT}}{1 - e^{-\lambda_{st} \cdot T}} = \frac{N_{Al} \cdot R_{st}^{ind/cum}(x, y)}{\lambda_{st}} \cdot F_{st}
\end{aligned} \tag{95}$$

The introduced definition of the function F_{st} reflects saturation of any nuclide irradiated at characteristic times τ , T , KT (see Fig.2):

$$F_{st} = (1 - e^{-\lambda_{st} \cdot \tau}) \frac{1 - e^{-\lambda_{st} \cdot KT}}{1 - e^{-\lambda_{st} \cdot T}} \cong \frac{\tau}{T} \cdot (1 - e^{-\lambda_{st} \cdot [(K-1) \cdot T + \tau]}) , \tag{96}$$

because $\tau, T \ll \frac{1}{\lambda_{st}}$.

In this case, the expression

$$\bar{R}_{st}^{ind/cum}(x, y) \cong \frac{\tau}{T} \cdot R_{st}^{ind/cum}(x, y) \tag{97}$$

holds to within sufficient accuracy τ , where, $\bar{R}_{st}^{ind/cum}(x, y)$ is the T -averaged ${}^7\text{Be}$, ${}^{22}\text{Na}$, and ${}^{24}\text{Na}$ production rate in a single proton pulse at monitor point with coordinates (x, y) .

The designation $t_{irr} = (K-1)T + \tau$ can, then, be used to present the expression (95) as

$$N_{st}(x, y, T_{irr}) = \frac{N_{Al} \cdot \bar{R}_{st}^{ind/cum}(x, y)}{\lambda_{st}} \cdot (1 - e^{-\lambda_{st} \cdot t_{irr}}) \tag{98}$$

The number of ${}^7\text{Be}$, ${}^{22}\text{Na}$ or ${}^{24}\text{Na}$ nuclei produced within time t_{irr} in the mass element dm located at point with coordinates (x, y) can be presented as

$$dN_{st}(x, y, t_{irr}) = \frac{dm}{M} \cdot N_{Av} \cdot \frac{\bar{R}_{st}^{ind/cum}(x, y)}{\lambda_{st}} \cdot (1 - e^{-\lambda_{st} \cdot t_{irr}}) \tag{99}$$

The number of ^7Be , ^{22}Na or ^{24}Na nuclei produced within time t_{irr} in the mass element dm located at point with coordinates (x, y) can be presented as

$$dm = \rho \cdot dV = \rho \cdot H \cdot dS, \quad (100)$$

where ρ is the monitor density; H is the monitor depth; dS is the monitor spot area with coordinates (x, y) .

If the thickness H is constant, then

$$\rho = \frac{m}{V} = \frac{m}{S \cdot H} \quad (101)$$

where m is monitor mass; S is monitor area.

Substituting (101) in (100), we get $dm = \frac{m}{S \cdot H} \cdot H \cdot dS = \frac{m}{S} \cdot dS$.

The expression (99) can, then, be presented as

$$dN_{st}(x, y, t_{irr}) = \frac{1}{S} \cdot \frac{m}{M} \cdot N_{Av} \cdot \frac{\bar{R}_{st}^{ind/cum}(x, y)}{\lambda_{st}} \cdot (1 - e^{-\lambda_{st} \cdot t_{irr}}) \cdot dS \quad (102)$$

where m is monitor mass; S is monitor area.

Substituting (101) in (100), we get $dm = \frac{m}{S \cdot H} \cdot H \cdot dS = \frac{m}{S} \cdot dS$.

The expression (99) can, then, be presented as

$$N_{st}(T_{irr}) = \frac{m}{M} \cdot N_{Av} \cdot \frac{1}{\lambda_{st}} \cdot (1 - e^{-\lambda_{st} \cdot T_{irr}}) \cdot \frac{1}{S} \iint_S \bar{R}_{st}^{ind/cum}(x, y) dS \cdot (1 - e^{-\lambda_{st} \cdot T_{irr}}) \quad (103)$$

Here, $\hat{R}_{st}^{ind/cum} = \frac{1}{S} \iint_S \bar{R}_{st}^{ind/cum}(x, y) dS$ is the mean ^7Be , ^{22}Na , ^{24}Na production rate over the standard foil area.

We can write:

$$N_{st}(t_{irr}) = \frac{m}{M} \cdot N_{Av} \cdot \frac{\hat{R}_{st}^{ind/cum}}{\lambda_{st}} \cdot (1 - e^{-\lambda_{st} \cdot t_{irr}}) = \frac{N_{Al} \cdot \hat{R}_{st}^{ind/cum} \cdot F'_{st}}{\lambda_{st}} \quad (104)$$

where $F'_{st} = (1 - e^{-\lambda_{st} \cdot t_{irr}})$.

The irradiation having stopped, the decays of the ^7Be , ^{22}Na or ^{24}Na product nuclides can be described as

$$\frac{dN_{st}(t)}{dt} = -\lambda_{st} \cdot N_{st}(t), \quad (105)$$

where $F'_{st} = (1 - e^{-\lambda_{st} \cdot t_{irr}})$.

The irradiation having stopped, the decays of the ^7Be , ^{22}Na or ^{24}Na product nuclides can be described as

$$N_{st}(t) = N_{st0} \cdot e^{-\lambda_{st} \cdot t} \quad (106)$$

As noted above, the ^7Be , ^{22}Na or ^{24}Na total absorption peaks $\check{S}_{i_l}$ are actually measured in the experiment at γ -line energies $E_1=477.6$ keV, (10.5%), $E_2=1274.5$ keV (99.9%), and $E_3=1369.0$ keV (100%) that can be expressed via count rates $\check{S}_{i_l} = \check{S}_{i_l}/t_{live_l}$.

Considering the above and using expressions (104) and (106), the calculated S_{st_l} values can be expressed via the $N_{st}(t_{irr})$ values as

$$\begin{aligned} S_{st_l} &= \frac{1}{t_{true_l}} \int_{t_{c_l}}^{t_{c_l}+t_{true_l}} N_{st0} \cdot \lambda_{st} \cdot \eta_{st} \cdot \varepsilon_{st} \cdot e^{-\lambda_{st} \cdot t} \cdot dt = \\ &= N_{st0} \cdot \lambda_{st} \cdot \eta_{st} \cdot \varepsilon_{st} \cdot e^{-\lambda_{st} \cdot t_{c_l}} \cdot \frac{1 - e^{-\lambda_{st} \cdot t_{true_l}}}{\lambda_{st} \cdot t_{true_l}} = D_{1st} \cdot h_{st_l} \cdot e^{-\lambda_{st} \cdot t_{c_l}} \end{aligned} \quad (107)$$

$$D_{1st} = N_{Al} \cdot \hat{R}_{st} \cdot F'_{st} \cdot \eta_{st} \cdot \varepsilon_{st}, \quad h_{st_l} = \frac{1 - e^{-\lambda_{st} \cdot t_{true_l}}}{\lambda_{st} \cdot t_{true_l}} \quad (108)$$

After introducing, by analogy of (106), the approximation function

$$g_{st}(t_{c_l}) = D_{1st} \cdot \frac{1 - e^{-\lambda_{st} \cdot t_{true_l}}}{\lambda_{st} \cdot t_{true_l}} \cdot e^{-\lambda_{st} \cdot t_{c_l}} \quad (109)$$

to describe the calculated S_{st_l} values, the least squares fitting can be used to construct the quadratic functional

$$\Omega_{st} = \sum_{l=1}^{L_{st}} \left(\tilde{S}_{st_l} - g_{st}(t_{c_l}) \right)^2 \cdot W_{st_l}(t_{c_l}), \quad (110)$$

где $W_{st_l} = \left(\frac{1}{\Delta \tilde{S}_{st_l}} \right)^2$.

By minimizing this functional, we can calculate the $\hat{D}_{1st}$ and $\Delta \hat{D}_{1st}$ values as

$$\hat{D}_{1st} = \frac{\sum_{l=1}^{L_{st}} \left(\tilde{S}_{st_l} \cdot e^{-\lambda_{st} \cdot t_{true_l}} \cdot h_{st_l} \cdot W_{st_l} \right)}{\sum_{l=1}^{L_{st}} \left(e^{-2\lambda_{st} \cdot t_{true_l}} \cdot h_{st_l}^2 \cdot W_{st_l} \right)}, \quad \Delta \hat{D}_{1st} = \sqrt{\frac{1}{\sum_{l=1}^{L_{st}} \left(e^{-2\lambda_{st} \cdot t_{true_l}} \cdot h_{st_l}^2 \cdot W_{st_l} \right)}}, \quad (111)$$

The production rate of a respective nuclide $\hat{R}_{st}^{ind/cum}$ and its error $\Delta \hat{R}_{st}^{ind/cum}$ are

$$\hat{R}_{st}^{ind/cum} = \frac{D_{1st}^*}{N_{Al} \cdot F'_{st} \cdot \eta_{st} \cdot \varepsilon_{st}}, \quad (112)$$

where $D_{1st}^* = \hat{D}_{1st} \cdot k_{\mu st}$.

$$\frac{\Delta \hat{R}_{st}^{ind/cum}}{\hat{R}_{st}^{ind/cum}} = \sqrt{\left(\frac{\Delta \hat{D}_{1st}}{\hat{D}_{1st}}\right)^2 + \left(\frac{\Delta k_{\mu st}}{k_{\mu st}}\right)^2 + \left(\frac{\Delta \eta_{st}}{\eta_{st}}\right)^2 + \left(\frac{\Delta \varepsilon_{st}}{\varepsilon_{st}}\right)^2 + \left(\frac{\Delta N_{Al}}{N_{Al}}\right)^2} \quad (113)$$

If a reaction cross section is known, we can calculate the mean charged particle flux density $\hat{\Phi}$, as averaged over time and sample area, together with its error $\Delta \hat{\Phi}$:

$$\hat{\Phi} = \frac{\hat{R}_{st}^{ind/cum}}{\sigma_{st}^{ind/cum}} \quad (114)$$

$$\frac{\Delta \hat{\Phi}}{\hat{\Phi}} = \sqrt{\left(\frac{\Delta \hat{R}_{st}^{ind/cum}}{\hat{R}_{st}^{ind/cum}}\right)^2 + \left(\frac{\Delta \sigma_{st}^{ind/cum}}{\sigma_{st}^{ind/cum}}\right)^2} \quad (115)$$

2.3 Nuclide production cross section determining

Conforming to (1) and using (43), (44)-(46), (47)-(52), (80), (87) and (114) the independent and cumulative cross sections of the respective nuclides can be presented as

$$\sigma_i^{ind/cum} = \frac{R_i^{ind/cum}}{\Phi} \quad \sigma_i^{ind/cum} = \frac{\bar{R}_i^{ind/cum}}{\Phi}, \quad i = 1, 2, 3 \quad (116)$$

$$\Delta \sigma_i^{ind/cum} = \sigma_i^{ind/cum} \cdot \sqrt{\left(\frac{\Delta R_i^{ind/cum}}{R_i^{ind/cum}}\right)^2 + \left(\frac{\Delta \Phi}{\Phi}\right)^2}, \quad (117)$$

$$\Delta \sigma_i^{ind/cum} = \sigma_i^{ind/cum} \cdot \sqrt{\left(\frac{\Delta \bar{R}_i^{ind/cum}}{\bar{R}_i^{ind/cum}}\right)^2 + \left(\frac{\Delta \Phi}{\Phi}\right)^2} \quad (118)$$

It should be noted that formulas (47) – (49) were obtained on assumption that the γ -ray intensities of the two nuclides produced by irradiation are recorded up to the desired accuracy within the period from the irradiation start moment to the ultimate moment when the intensity can still be recorded. In practice, however, this requirement either can or cannot be met, thus creating either more or less favorite conditions of taking measurements and analyzing the results.

In some cases, where the fitting of experimental dots precludes determination of factor B_1^* , it is expedient to introduce the concept of supracumulative yield [6, 7]:

$$R_2^{cum*} = R_2^{ind} + \frac{\lambda_1}{\lambda_1 - \lambda_2} \nu_1 R_1^{cum} = \frac{B_2^*}{N_{Tag} \eta_2 \varepsilon_2 F_2} \quad (119)$$

$$\Delta R_2^{cum*} = R_2^{cum*} \cdot \sqrt{\left(\frac{\Delta \hat{B}_2}{\hat{B}_2}\right)^2 + \left(\frac{\Delta k_{\mu_2}}{k_{\mu_2}}\right)^2 + \left(\frac{\Delta \eta_2}{\eta_2}\right)^2 + \left(\frac{\Delta \varepsilon_2}{\varepsilon_2}\right)^2 + \left(\frac{\Delta N_{Tag}}{N_{Tag}}\right)^2} \quad (120)$$

$$\sigma_2^{cum*} = \frac{R_2^{cum*}}{\Phi} \quad (121)$$

$$\Delta \sigma_2^{cum*} = \sigma_2^{cum*} \cdot \sqrt{\left(\frac{\Delta R_2^{cum*}}{R_2^{cum*}}\right)^2 + \left(\frac{\Delta \Phi}{\Phi}\right)^2} \quad (122)$$

From formula (119) it follows that the σ_2^{cum*} value can be taken to be the upper boundary when comparing between experiment and calculations.

2.4 Preparing, certifying, and irradiating the experimental samples

The experimental samples and the monitors were prepared by cutting them off (^{27}Al) metal foil, by pressing (^{209}Bi) metal powder, and by pressing separate tiny (^{nat}Pb , ^{208}Pb , ^{207}Pb , and ^{206}Pb) pellets. All the prepared experimental samples and monitors were of the same 10.5-mm diameter.

Table 2 presents the isotopic composition of the samples used.

Table 2: Isotopic composition of targets.

Isotope	Certificate No.	Isotopic composition, %
^{209}Bi	ALDRICH – – Nr 26,400-8	^{209}Bi - 99.99 %
^{208}Pb	334-12	^{204}Pb - -; ^{206}Pb - 0.87 %; ^{207}Pb - 1.93 %; ^{208}Pb - 97.20 %.
^{207}Pb	65-1.6	^{204}Pb - 0.03 %; ^{206}Pb - 2.61 %; ^{207}Pb - 88.3 ± 0.2 %; ^{208}Pb - 9.06 %.
^{206}Pb	332-8	^{204}Pb - - %; ^{206}Pb - 94.00 %; ^{207}Pb - 4.04 %; ^{208}Pb - 1.96 %.
^{nat}Pb	[15]*	^{204}Pb - 1.4 %; ^{206}Pb - 24.1 %; ^{207}Pb - 22.1 %; ^{208}Pb - 52.4 %.

* isotopic composition was not determined, the data are from [15].

From Table 2 it follows that the researches are characterized by using mostly the experimental samples that are high-enriched with appropriate isotopes. Undoubtedly, the research results could have been much affected by any chemical impurity in the samples. Therefore, the contents of the impurities were analyzed thoroughly. In case the respective certificates failed to indicate appropriate data, the samples were analyzed (^{nat}Pb , ^{209}Bi) at the mass-spectrometry and chromatography laboratories (MS & GS Lab) of the State Metrology Center (GIREDMET). The analysis was made by spark mass-spectrometry using the Japanese (JEOL Co)-made JMS-01-BM2 double-focusing mass spectrometer. Table 3 presents the total content of chemical impurities in the samples according to [9] – [13].

Having been prepared, the samples and the monitors were weighed by the BP-61 analytical balance (SARTORIUS Co-made [8], a $\leq 1 \cdot 10^{-4}$ g weighing accuracy), whereupon each sample and a monitor were placed, preserving their geometry, in a polyethylene envelope that was welded tight to be irradiated later.

Table 3: The content of chemical impurities in high-enriched samples.

Chemical impurities, % at	Target				
	^{209}Bi	^{208}Pb	^{207}PbW	^{206}Pb	^{nat}Pb
Na	<0.01% for all impurities	0.0005	0.0002	0.001	<0.000006
Mg		0.0004	0.0003	0.0007	0.000005
Al		<0.001	<0.001	0.001	0.00002
Si		0.002	0.003	0.003	0.00001
Ca		<0.0009	0.0009	0.001	0.0001
Cr		<0.0003		<0.0003	0.00002
Mn					<0.000003
Fe		0.002	<0.001	0.0003	0.0002
Ni		<0.0003		<0.0003	0.000009
Cu		<0.0003	<0.0003	0.0003	<0.00002
Zn		<0.001		<0.001	<0.000006
Ag		<0.0002		<0.0002	<0.00001
Sn		<0.0003	<0.0003	<0.0003	<0.00002
Sb		<0.001	<0.001	<0.001	<0.00002
Bi		<0.0003	<0.0003	<0.0003	<0.0001
					the rest impurities have an even lower content
	Certificate No.				
	ALDRICH – Nr 26,400-8	334-12	65-1.6	332-8	7336.99

2.5 Irradiation of experimental samples

2.5.1 The general irradiation pattern

The samples were actually irradiated by the monoenergetic proton beam extracted from the ITEP U-10 proton synchrotron, which is a ring-shaped facility capable of accelerating protons up to 9.3 GeV at 25 MeV injection into the ring.

Fig.9 is a schematic of the sample-irradiating facility. The proton beam fast extraction units are also shown.

The proton beam goes from an accelerating ring to the transport channel, wherefrom protons of any energy within the 40-2600 MeV range can be extracted by the fast extraction system that includes a kicker-magnet of 15 mrad bending angle, a correcting magnet of 20-30 mrad bending angle, and two magnetic lenses that focus the beam into an ellipsis of 10-15 mm axes. The focusing has actually made all protons hit a sample, except for energies below 150 MeV and 2600 MeV (see Fig. 10).



Fig. 9: The facility schematic and the fast extraction units: 1. Table to place the samples to be irradiated. 2. Current transformer. 3. Outlet flange of vacuumized proton guide. 4. Bending magnet. 5, 6. Doublet of quadrupole lenses. 7. Septum magnet. 8, 9. Magnetic units of accelerating ring. 10. Kicker-magnet.

Pending the irradiation runs, a sample-Al interlayer-Al monitor sandwich was scotch-fastened to a 50x50-mm, 0.1-mm thick Al plate placed normally to proton beam. The experimental samples and the monitors were manufactured to within the accuracy that provided for their identical geometric dimensions.

The geometry selected has prevented ^{24}Na , ^{22}Na , and ^7Be from making an additional contribution to the experimental samples by being ejected from Al monitors. The Al plate was used to monitor the total proton beam intensity (see Subsection 2.5.2.2).

The basic irradiation parameters are given in Table 4. The proton beam parameters are presented in detail in Subsection 2.5.2. Within 10-15 min after an irradiation run end, the "sandwich" was taken off from the irradiated polyethylene envelope, whereupon the experimental sample and the monitor were placed inside non-irradiated polyethylene envelopes welded tight to prevent any possible loss during later measurements. After that, the envelopes were γ -spectrometered. To estimate the possible loss of radioactive recoil nuclei that can have escaped from an experimental sample, the unsealed irradiated envelopes were monitored using a γ -spectrometer. The loss has been found to be below the detection threshold of the spectrometer.

2.5.2 The proton beam parameters

2.5.2.1 Proton beam energies

The energy of the extracted proton beam has to be known because the reported project was eventually aimed at deriving the energy dependence (i.e. the excitation function) of the yields (cross sections) of residual product nuclei.

In accelerating protons, their energy is measured making allowance for one of the main synchrotron characteristics, namely, the invariable length of the closed proton orbit inside a ring. This means that the proton energy can be calculated by measuring the proton orbiting

frequency f_r :

$$E_0 = \frac{m_p c^2}{\sqrt{c^2 - L^2 f_r^2}} - m_p, \quad (123)$$

where E_0 is the kinetic energy of a ring-orbiting proton; $m_p=938.26$ MeV is proton mass; $L=251.21$ m is the closed-orbit length; $c = 2.99776 \times 10^8$ m/s is speed of light.

Значение The f_r value is multiple to the accelerating radio frequency:

$$f_a = h f_r \quad (124)$$

where $h=4$ is number of harmonics; f_a is the accelerating radio frequency that varies from 1.07 to 4.85 MHz. The f_a signal gets shaped safely, thus precluding any problem in measuring the f_a values up to 10^{-4} and even better. The energy measurement error is energy-dependent and can be calculated as

$$\frac{\Delta E_f}{E_0} = \beta^2 \frac{\gamma^3}{\gamma - 1} \sqrt{\left(\frac{\Delta f_a}{f_a}\right)^2 + \left(\frac{\Delta L}{L}\right)^2}, \quad (125)$$

where β is the proton velocity that equals $L f_a / h c$; γ is a relativistic factor that equals $1/\sqrt{1 - \beta^2}$. The L value is known up to relativistic error of 10^{-4} .

On the way of transporting the beam to the samples, a minor beam energy fraction is lost for proton interactions with the transport channel structure materials, with air that fills the transport channel-target spacing, and in the targets proper. The loss is allowed for via the expression

$$E_{sample} = E_0 - E_{loss} \quad (126)$$

where E_{sample} is the proton beam energy at half-depth of experimental sample (target); E_{loss} is the energy loss along proton path from transport channel to mid-target determined as $E_{loss} = \delta E_{mem} - \delta E_{air} - 0.5 \cdot \delta E_{sample}$, where δE_{mem} , δE_{air} , and δE_{sample} are, respectively, energy losses in the metal membrane at the transport channel outlet, in the channel-target air spacing, and in the target proper. The losses were calculated by the formula $\delta E = (dE/dx)X$, which is valid because the material depth (X) traversed by the beam is insignificant, so the specific loss for ionization dE/dx can well be regarded as constant. At proton energies of 70 MeV and 40 MeV, however, the energy loss for ionization is sufficiently high, so its variations over the proton paths via samples and monitors have to be allowed for. The dE/dx values were taken from [39].

The energies and their loss in the membrane (0.1-mm steel), in the outlet flange-sample spacing, in the samples proper, and in the monitors are presented in Table 4 for each of the irradiation runs. The Table 4 presents also the $^{27}\text{Al}(p,x)^{22}\text{Na}$ monitor reaction cross sections used in the Project at the proton energies calculated for the sample and monitor half-depths.

Besides, the Table 4 lists the energy uncertainties calculated as

$$\Delta E_{sample} = \sqrt{\Delta E_0^2 + \Delta E_{spread}^2/4 + \sum (\delta E_{loss})^2} \quad (127)$$

where ΔE_0 is the energy uncertainty of the transport channel protons determined as

$$\Delta E_0 = \sqrt{\Delta E_f^2 + \Delta E_p^2}, \quad (128)$$

where ΔE_f is the energy measurement error determined by formula (125); ΔE_p is the proton energy dissipation in an accelerator ring determined as

$$\Delta E_p = \frac{0.005 \cdot p}{m_p + E_0} \cdot \sqrt{220 \text{ MeV}/c \cdot p}; \quad (129)$$

ΔE_{spread} is the energy difference between the target inlet and outlet; $\sum \delta E_{loss}$ is root of the sum of dispersions of the Landau fluctuation of energy loss [38]; p is a pulse corresponding to energy E_0 .

Additionally, Table 4 presents the energies and their uncertainties calculated at the monitor half-depths using formulas similar to (126) and (127).

From Table 4 it follows that the proton and monitor proton energy uncertainties are ranging from 0.3% (at 2.6 GeV) to 4% (at 0.04 GeV).

Table 4: The energies of the proton beams that irradiate the sample-monitor sandwich including the loss for ionization in the transport channel structure material; the $^{27}\text{Al}(\text{p},\text{x})^{22}\text{Na}$ monitor reaction cross sections at the calculated energies.

Sample	Date	Freq. MHz	E_0 , MeV	weight samp. (g)	weight monit. (g)	Length air (mm)	E_{loss} in membrane (MeV)	E_{loss} in sample (MeV)	E_{loss} in monitor (MeV)	E_{loss} in air (MeV)	$\sum E_{loss}$ in sample	$\sum E_{loss}$ in monitor	E_{sample} in sample	$E_{monitor}$ in monitor	σ_{mon} (mb)
^{nat}Pb	23-окт-2001	4.6033	2608.9±7.9	0.2045	0.1100	2500	0.11±0.02	0.26±0.05	0.20±0.03	0.59±0.47	0.84±0.47	1.07±0.47	2608±8	2608±8	11.4±0.9
$^{nat}\text{Pb-2}$	23-окт-2003	4.602	2595.6±7.8	0.2034	0.1200	185	0.11±0.02	0.26±0.05	0.22±0.03	0.04±0.04	0.29±0.05	0.53±0.07	2595±8	2595±8	11.4±0.9
^{209}Bi	29-окт-2001	4.6034	2609.9±7.9	0.2913	0.1104	2500	0.11±0.02	0.38±0.07	0.21±0.03	0.59±0.47	0.89±0.47	1.19±0.48	2609±8	2609±8	11.4±0.9
^{208}Pb	5-ноя-2001	4.6031	2606.8±7.9	0.1261	0.1203	2500	0.11±0.02	0.16±0.03	0.22±0.03	0.59±0.47	0.79±0.47	0.98±0.47	2606±8	2606±8	11.4±0.9
^{207}Pb	30-окт-2001	4.6035	2610.9±7.9	0.1368	0.1095	2500	0.11±0.02	0.18±0.03	0.20±0.03	0.59±0.47	0.79±0.47	0.98±0.47	2610±8	2610±8	11.4±0.9
^{206}Pb	6-ноя-2001	4.6034	2609.9±7.9	0.1230	0.1112	2500	0.11±0.02	0.16±0.03	0.21±0.03	0.59±0.47	0.79±0.47	0.97±0.47	2609±8	2609±8	11.4±0.9
^{nat}Pb	8-апр-2002	4.435	1599.2±4.0	0.2054	0.1111	1770	0.12±0.02	0.27±0.05	0.21±0.03	0.43±0.35	0.68±0.35	0.92±0.35	1598±4	1598±4	13.2±1.0
^{209}Bi	8-апр-2002	4.435	1599.2±4.0	0.3429	0.1111	1770	0.12±0.02	0.45±0.08	0.21±0.03	0.43±0.35	0.77±0.35	1.09±0.36	1598±4	1598±4	13.2±1.0
^{208}Pb	11-апр-2002	4.4357	1601.7±4.0	0.1438	0.1104	1770	0.12±0.02	0.19±0.03	0.21±0.03	0.43±0.35	0.64±0.35	0.83±0.35	1601±4	1601±4	13.2±1.0
^{207}Pb	11-апр-2002	4.435	1599.2±4.0	0.1434	0.1106	1770	0.12±0.02	0.19±0.03	0.21±0.03	0.43±0.35	0.64±0.35	0.83±0.35	1599±4	1598±4	13.2±1.0
^{206}Pb	15-апр-2002	4.435	1599.2±4.0	0.1358	0.1101	1770	0.12±0.02	0.18±0.03	0.21±0.03	0.43±0.35	0.63±0.35	0.82±0.35	1599±4	1598±4	13.2±1.0
^{nat}Pb	22-фев-2002	4.287	1195.3±3.2	0.1378	0.1106	1770	0.12±0.02	0.19±0.04	0.22±0.04	0.44±0.37	0.66±0.37	0.86±0.37	1195±3	1194±3	14.4±1.0
^{209}Bi	26-фев-2002	4.285	1191.2±3.2	0.2905	0.1115	1770	0.12±0.02	0.40±0.08	0.22±0.04	0.44±0.37	0.76±0.37	1.07±0.38	1190±3	1190±3	14.4±1.0
^{208}Pb	4-мар-2002	4.29	1201.6±3.2	0.1368	0.1096	1770	0.12±0.02	0.19±0.04	0.22±0.04	0.44±0.37	0.66±0.37	0.86±0.37	1201±3	1201±3	14.4±1.0
^{207}Pb	11-мар-2002	4.289	1199.5±3.2	0.1450	0.1102	1770	0.12±0.02	0.20±0.04	0.22±0.04	0.44±0.37	0.66±0.37	0.87±0.37	1199±3	1199±3	14.4±1.0
^{206}Pb	15-мар-2002	4.284	1189.1±3.2	0.1380	0.1105	1770	0.12±0.02	0.19±0.04	0.22±0.04	0.44±0.37	0.66±0.37	0.86±0.37	1188±3	1188±3	14.4±1.0
^{nat}Pb	18-апр-2002	4.018	799.8±2.5	0.1913	0.1227	1770	0.13±0.02	0.27±0.06	0.26±0.05	0.48±0.41	0.74±0.41	1.01±0.41	799±2	799±2	15.5±1.1
^{209}Bi	18-апр-2002	4.018	799.8±2.5	0.2865	0.1228	1770	0.13±0.02	0.41±0.09	0.26±0.05	0.48±0.41	0.81±0.41	1.15±0.42	799±2	799±2	15.5±1.1
^{208}Pb	6-июн-2002	4.018	799.8±2.5	0.1389	0.1224	1770	0.13±0.02	0.20±0.04	0.26±0.05	0.48±0.41	0.71±0.41	0.94±0.41	799±2	799±2	15.5±1.1
^{207}Pb	6-июн-2002	4.018	799.8±2.5	0.1393	0.1226	1770	0.13±0.02	0.20±0.04	0.26±0.05	0.48±0.41	0.71±0.41	0.94±0.41	799±2	799±2	15.5±1.1
^{206}Pb	10-июн-2002	4.018	799.8±2.5	0.1420	0.1220	1770	0.13±0.02	0.20±0.04	0.26±0.04	0.48±0.41	0.71±0.41	0.94±0.41	799±2	799±2	15.5±1.1
^{nat}Pb	13-июн-2002	3.783	600.3±2.1	0.1537	0.1187	1770	0.14±0.03	0.24±0.05	0.28±0.05	0.52±0.45	0.78±0.45	1.04±0.46	600±2	599±2	16.0±1.0
^{209}Bi	17-июн-2002	3.783	600.3±2.1	0.3016	0.2243	1770	0.14±0.03	0.47±0.10	0.52±0.09	0.52±0.45	0.90±0.46	1.40±0.47	599±2	599±2	16.0±1.0
^{208}Pb	17-июн-2002	3.783	600.3±2.1	0.1401	0.1227	1770	0.14±0.03	0.22±0.05	0.29±0.05	0.52±0.45	0.77±0.45	1.03±0.46	600±2	599±2	16.0±1.0
^{207}Pb	24-июн-2002	3.783	600.3±2.1	0.1478	0.1227	1770	0.14±0.03	0.23±0.05	0.29±0.05	0.52±0.45	0.78±0.45	1.04±0.46	600±2	599±2	16.0±1.0
^{206}Pb	24-июн-2002	3.783	600.3±2.1	0.1403	0.1224	1770	0.14±0.03	0.22±0.05	0.29±0.05	0.52±0.45	0.77±0.45	1.03±0.46	600±2	599±2	16.0±1.0
^{nat}Pb	14-окт-2002	3.404	400.1±1.6	0.2435	0.1209	185	0.17±0.03	0.44±0.10	0.33±0.06	0.06±0.06	0.46±0.08	0.84±0.12	400±2	399±2	15.8±1.0
^{209}Bi	14-окт-2002	3.404	400.1±1.6	0.2936	0.1233	185	0.17±0.03	0.53±0.12	0.34±0.06	0.06±0.06	0.50±0.09	0.94±0.14	400±2	399±2	15.8±1.0
^{208}Pb	21-окт-2002	3.404	400.1±1.6	0.1424	0.1230	185	0.17±0.03	0.26±0.06	0.34±0.06	0.06±0.06	0.36±0.07	0.66±0.09	400±2	399±2	15.8±1.0
^{207}Pb	17-окт-2002	3.402	399.3±1.6	0.1452	0.1230	185	0.17±0.03	0.26±0.06	0.34±0.06	0.06±0.06	0.37±0.07	0.67±0.10	399±2	399±2	15.8±1.0
^{206}Pb	21-окт-2002	3.404	400.1±1.6	0.1383	0.1208	185	0.17±0.03	0.25±0.06	0.33±0.06	0.06±0.06	0.36±0.07	0.65±0.09	400±2	399±2	15.8±1.0
^{nat}Pb	28-окт-2002	2.929	250.0±1.2	0.1123	0.1231	185	0.22±0.04	0.26±0.06	0.44±0.08	0.08±0.08	0.43±0.09	0.78±0.12	250±1	249±1	15.0±0.9
^{209}Bi	24-окт-2002	2.929	250.0±1.2	0.2860	0.1225	185	0.22±0.04	0.66±0.16	0.44±0.08	0.08±0.08	0.63±0.12	1.18±0.18	249±1	249±1	15.0±0.9
^{208}Pb	31-окт-2002	2.929	250.0±1.2	0.1386	0.1234	185	0.22±0.04	0.32±0.08	0.44±0.08	0.08±0.08	0.46±0.10	0.84±0.12	250±1	249±1	15.0±0.9
^{207}Pb	28-окт-2002	2.929	250.0±1.2	0.1298	0.1235	185	0.22±0.04	0.30±0.07	0.44±0.08	0.08±0.08	0.45±0.10	0.82±0.12	250±1	249±1	15.0±0.9
^{206}Pb	31-окт-2002	2.929	250.0±1.2	0.1374	0.1231	185	0.22±0.04	0.32±0.07	0.44±0.08	0.08±0.08	0.46±0.10	0.84±0.12	250±1	249±1	15.0±0.9
^{nat}Pb	2-дек-2002	2.418	150.0±0.9	0.1049	0.1466	185	0.30±0.07	0.33±0.08	0.72±0.15	0.12±0.11	0.58±0.13	1.10±0.17	149±1	149±1	17.1±1.1
^{209}Bi	5-дек-2002	2.418	150.0±0.9	0.2944	0.1471	185	0.30±0.07	0.92±0.23	0.72±0.15	0.12±0.11	0.88±0.17	1.70±0.28	149±1	148±1	17.1±1.1
^{208}Pb	9-дек-2002	2.418	150.0±0.9	0.1390	0.1442	185	0.30±0.07	0.44±0.11	0.71±0.14	0.12±0.11	0.63±0.14	1.21±0.18	149±1	149±1	17.1±1.1
^{207}Pb	5-дек-2002	2.418	150.0±0.9	0.1393	0.1220	185	0.30±0.07	0.44±0.11	0.60±0.12	0.12±0.11	0.63±0.14	1.15±0.18	149±1	149±1	17.1±1.1

Prolongation of Table 4.

Sample	Date	Freq. MHz	E_0 , MeV	weight samp. (g)	weight monit. (g)	Length air (mm)	E_{loss} in membrane (MeV)	E_{loss} in sample (MeV)	E_{loss} in monitor (MeV)	E_{loss} in air (MeV)	$\sum E_{loss}$ in sample	$\sum E_{loss}$ in monitor	E_{sample} in sample	$E_{monitor}$ in monitor	σ_{mon} (mb)
²⁰⁶ Pb	9-дек-2002	2.418	150.0±0.9	0.1413	0.1432	185	0.30±0.07	0.44±0.11	0.70±0.14	0.12±0.11	0.64±0.14	1.21±0.18	149±1	149±1	17.1±1.1
^{nat} Pb	24-фев-2003	2.046	100.2±0.7	0.2010	0.1231	185	0.40±0.09	0.82±0.22	0.81±0.17	0.15±0.15	0.96±0.21	1.78±0.29	99.3±0.8	98.5±0.8	19.8±1.2
²⁰⁹ Bi	27-фев-2003	2.048	100.5±0.7	0.2986	0.1216	185	0.40±0.09	1.22±0.33	0.80±0.17	0.15±0.15	1.16±0.24	2.18±0.38	99.3±0.9	98.3±0.9	19.8±1.2
²⁰⁸ Pb	3-мар-2003	2.047	100.4±0.7	0.1387	0.1212	185	0.40±0.09	0.57±0.15	0.79±0.17	0.15±0.15	0.84±0.19	1.52±0.25	99.5±0.8	98.8±0.8	19.8±1.2
²⁰⁷ Pb	27-фев-2003	2.048	100.5±0.7	0.1481	0.1203	185	0.40±0.09	0.61±0.16	0.79±0.17	0.15±0.15	0.86±0.19	1.55±0.25	99.6±0.8	98.9±0.8	19.8±1.2
²⁰⁶ Pb	3-мар-2003	2.047	100.4±0.7	0.1420	0.1208	185	0.40±0.09	0.58±0.16	0.79±0.17	0.15±0.15	0.84±0.19	1.53±0.25	99.5±0.8	98.8±0.8	19.8±1.2
^{nat} Pb	14-апр-2003	1.749	70.13±0.52	0.1941	0.1213	185	0.52±0.12	1.03±0.29	1.06±0.24	0.20±0.20	1.23±0.27	2.28±0.39	68.9±0.8	67.8±0.8	22.4±1.4
²⁰⁹ Bi	17-апр-2003	1.747	69.95±0.52	0.3036	0.1216	185	0.52±0.12	1.61±0.46	1.07±0.24	0.20±0.20	1.52±0.33	2.86±0.53	68.4±1.0	67.1±0.9	22.7±1.4
²⁰⁸ Pb	21-апр-2003	1.749	70.13±0.52	0.1358	0.1211	185	0.52±0.12	0.72±0.20	1.06±0.23	0.20±0.20	1.08±0.25	1.97±0.33	69.1±0.7	68.2±0.8	22.3±1.4
²⁰⁷ Pb	17-апр-2003	1.747	69.95±0.52	0.1552	0.1202	185	0.52±0.12	0.82±0.23	1.05±0.23	0.20±0.20	1.13±0.26	2.07±0.35	68.8±0.7	67.9±0.8	22.4±1.4
²⁰⁶ Pb	21-апр-2003	1.749	70.13±0.52	0.1405	0.1204	185	0.52±0.12	0.75±0.21	1.06±0.23	0.20±0.20	1.09±0.25	1.99±0.33	69.0±0.7	68.1±0.8	22.3±1.4
^{nat} Pb	19-июн-2003	1.351	40.00±0.35	0.2076	0.1211	185	0.79±0.21	1.70±0.53	1.73±0.41	0.32±0.32	1.96±0.46	3.68±0.68	38.0±1.0	36.3±1.2	25.9±2.0
²⁰⁹ Bi	23-июн-2003	1.351	40.00±0.35	0.3083	0.1215	185	0.79±0.21	2.55±0.79	1.76±0.42	0.32±0.32	2.38±0.55	4.54±0.90	37.6±1.4	35.5±1.3	22.1±2.0
²⁰⁸ Pb	30-июн-2003	1.351	40.00±0.35	0.1378	0.1213	185	0.79±0.21	1.12±0.35	1.71±0.41	0.32±0.32	1.68±0.42	3.09±0.55	38.3±0.8	36.9±1.1	28.4±2.0
²⁰⁸ Pb-2	3-июл-2003	1.353	40.13±0.35	0.1396	0.1201	185	0.79±0.20	1.13±0.35	1.69±0.40	0.32±0.32	1.68±0.42	3.09±0.55	38.4±0.8	37.0±1.1	28.9±2.0
²⁰⁷ Pb	23-июн-2003	1.351	40.00±0.35	0.1276	0.1210	185	0.79±0.21	1.04±0.32	1.70±0.40	0.32±0.32	1.63±0.41	3.00±0.54	38.4±0.7	37.0±1.1	28.7±2.0
²⁰⁶ Pb	30-июн-2003	1.351	40.00±0.35	0.1419	0.1208	185	0.79±0.21	1.16±0.36	1.70±0.41	0.32±0.32	1.69±0.42	3.12±0.56	38.3±0.8	36.9±1.1	28.2±2.0

2.5.2.2 Geometric parameters of proton beams

As mentioned in 2.5.1, two Al foils were used in each measurement run to monitor the proton beam, namely, (1) a $\varnothing 10.5$ mm foil to determine the number of protons that passed through an irradiated sample and (2) a 50x50 mm foil to determine the total number of the extracted beam protons. Having been multiplied by the foil-to-foil area ratio, the ^{24}Na production rate ratio of the two foils makes it possible to determine the proton beam fraction that traversed an experimental sample.

Fig. 10 shows the resulting dependence on proton energy and demonstrates that the system provides stable parameters of proton beam extraction in the 150–2600 MeV range. Given the energy range below 150 MeV and 2600 MeV energy, the proton beam gets broadened somewhat, thus decreasing the percentage of protons across a sample, so the desired proton fluence was attained by increasing the irradiation time.

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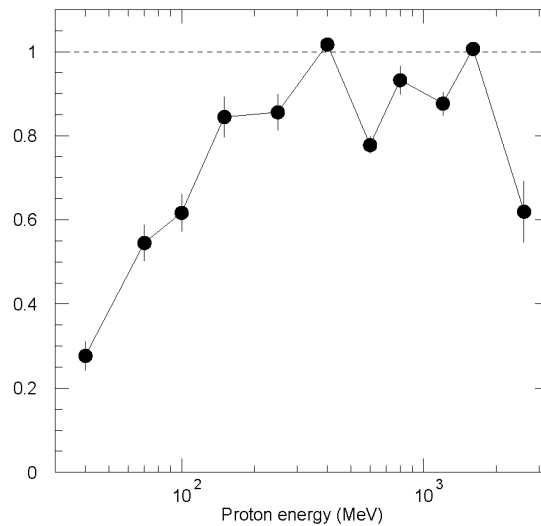


Fig. 10: The proton beam fraction across an experimental sample versus proton energy.

The results of detailed calculating the ^{24}Na production rates in the $\varnothing 10.5$ standard foil and in the 50x50 mm large square foil at $E_p = \sim 40$ MeV, ~ 70 MeV, 100 MeV, 150 MeV, 250 MeV, 400 MeV, 600 MeV, 800 MeV, 1200 MeV, 1600 MeV, and 2600 MeV are listed in Tables 7, 13, 19, 25, 31, 37, 43, 49, 55, 61, and 67 in Section 2 of Appendix to the present Report. The weights of the foils are presented in Tables 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, and 34 of this Report.

2.5.2.3 The fine structure oscillograms of proton beam The oscillograms were recorded using the current transformer developed and manufactured by ITEP (Fig. 9, unit 2). The LeCroy LT-344 oscilloscope of 2-ns resolution was used as a meter. The digitized oscilloscope readings were written to a file at a $2\mu\text{s}$ full sweep (~ 1000 values). Fig.11 shows the fine structure oscillograms of proton beams ($E_p = 40$ MeV and $E_p = 800$ MeV) recorded with the LeCroy

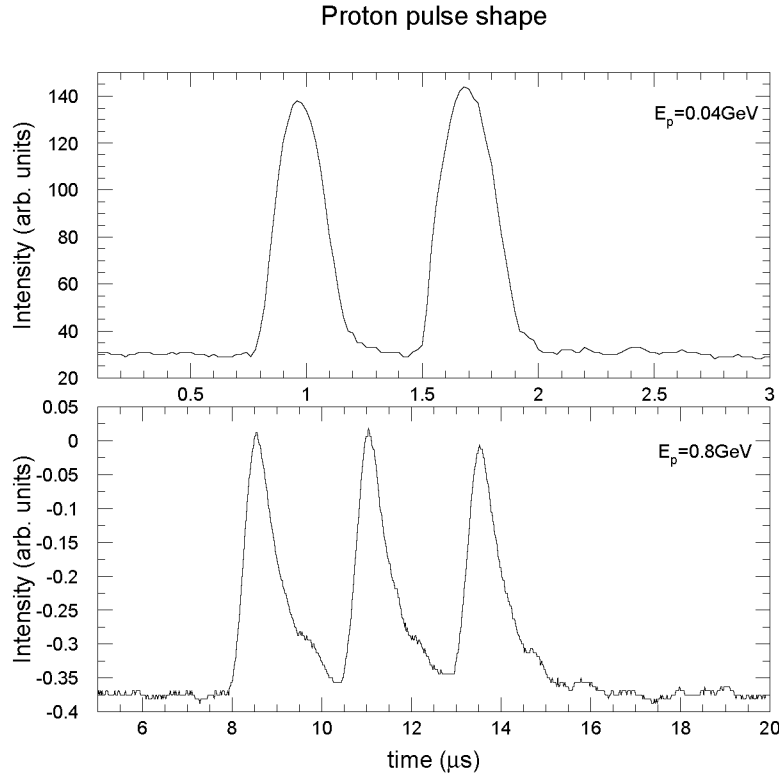


Fig. 11: The fine structure oscillograms of proton beams ($E_p = 40 \text{ MeV}$ and $E_p = 800 \text{ MeV}$).

2.5.3 Time stability of proton beam

In some experiments (^{nat}Pb , $E_p = 40 \text{ MeV}$ and $E_p = 800 \text{ MeV}$), the proton beam stability was estimated not only in space, but also in time. With that purpose, the current transformer was used throughout the measurement cycle to measure the intensity of each extracted proton bunch. Fig.12 shows the time distribution of proton beam intensity throughout the irradiation period. From the figure it follows that the proton beam instability is sufficiently weak and can be disregarded when determining the cross sections of the measured products.

2.5.4 Neutron background

When irradiated, the experimental samples are induced not only by primary beam protons, but also by secondaries that are mainly neutrons produced in the primary proton interactions with transport channel structure materials, shielding, as well as with a sample proper, with Al monitor, with interlayer, and with polyethylene envelope. To estimate the contribution of the background particles, whose interactions account for production of identical reaction products in experimental samples, the Al monitors were measured to determine the number of ^{27}Mg nuclei and the numbers of ^7Be , ^{22}Na , and ^{24}Na nuclei produced in the $^{27}\text{Al}(n,p)^{27}\text{Mg}$, $^{27}\text{Al}(p,x)^7\text{Be}$,

Proton beam stability

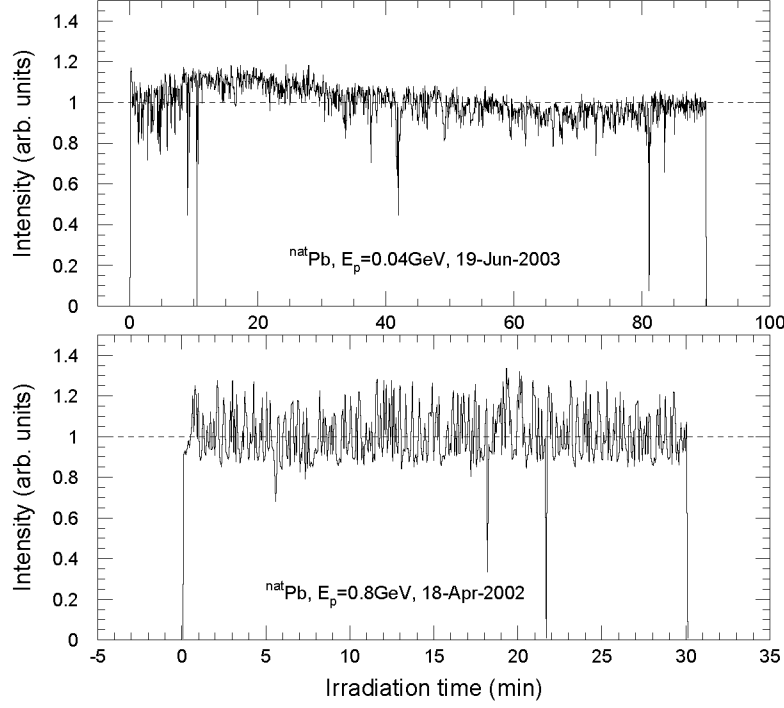


Fig. 12: Time distribution of the 40 MeV and 800 MeV proton beam intensities.

$^{27}\text{Al}(p,x)^{22}\text{Na}$, and $^{27}\text{Al}(p,x)^{24}\text{Na}$ reactions, respectively. The relevant ratio of mean secondary neutron flux to mean primary proton flux $\bar{\Phi}_n/\bar{\Phi}_p$ can be found from the expression [2]

$$\frac{\bar{\Phi}_n}{\bar{\Phi}_p} = \frac{\sigma_{p,x}^{7\text{Be}, 22\text{Na}, 24\text{Na}} / \bar{\sigma}_{n,p}^{27\text{Mg}}}{N^{7\text{Be}, 22\text{Na}, 24\text{Na}} / N^{27\text{Mg}} - \bar{\sigma}_{n,x}^{7\text{Be}, 22\text{Na}, 24\text{Na}} / \bar{\sigma}_{n,p}^{27\text{Mg}}} \quad (130)$$

where $\bar{\sigma}_{n,p}^{27\text{Mg}}$, $\bar{\sigma}_{n,x}^{7\text{Be}}$, $\bar{\sigma}_{n,x}^{22\text{Na}}$, and $\bar{\sigma}_{n,\alpha}^{24\text{Na}}$ are the respective reaction cross sections mean-weighted over neutron spectrum and calculated by formula (131); $\sigma_{p,x}^{22\text{Na}}$, $\sigma_{p,x}^{24\text{Na}}$ and $\sigma_{p,x}^{7\text{Be}}$ are the $^{27}\text{Al}(p,x)^{24}\text{Na}$, $^{27}\text{Al}(p,x)^{22}\text{Na}$, and $^{27}\text{Al}(p,x)^{7\text{Be}}$ reaction cross sections; $N^{24\text{Na}}$, $N^{22\text{Na}}$, $N^{27\text{Mg}}$, and $N^{7\text{Be}}$ are numbers of ^{24}Na , ^{22}Na , ^{27}Mg , and $^{7\text{Be}}$ nuclei produced in Al monitors, with their decay under irradiation being allowed for.

The expression for calculating the reaction cross sections mean-weighted over neutron spectrum is

$$\bar{\sigma}_x = \frac{\int \sigma_x(E) \Phi(E) dE}{\int \Phi(E) dE} \quad (131)$$

where x designates $^{27}\text{Al}(n,p)^{27}\text{Mg}$, $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$, $^{27}\text{Al}(n,x)^{22}\text{Na}$, and $^{27}\text{Al}(n,x)^{7\text{Be}}$.

The neutron spectrum $\Phi(E)$ used to calculate the weighted mean cross sections of $^{27}\text{Al}(n,p)^{27}\text{Mg}$, $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$, $^{27}\text{Al}(n,x)^{22}\text{Na}$, and $^{27}\text{Al}(n,x)^{7\text{Be}}$ reactions was estimated by LAHET code. The excitation functions of the above reactions were taken from the MENDL2 database [14]. The mean weighted cross section $\bar{\sigma}_{n,p}^{27\text{Mg}}$ was taken to be 25 mbarn.

Note that the values of the $^{27}\text{Al}(p,x)^{24}\text{Na}$ and $^{27}\text{Al}(p,x)^{7\text{Be}}$ reaction cross sections used

here have been determined in this work (see 2.7).

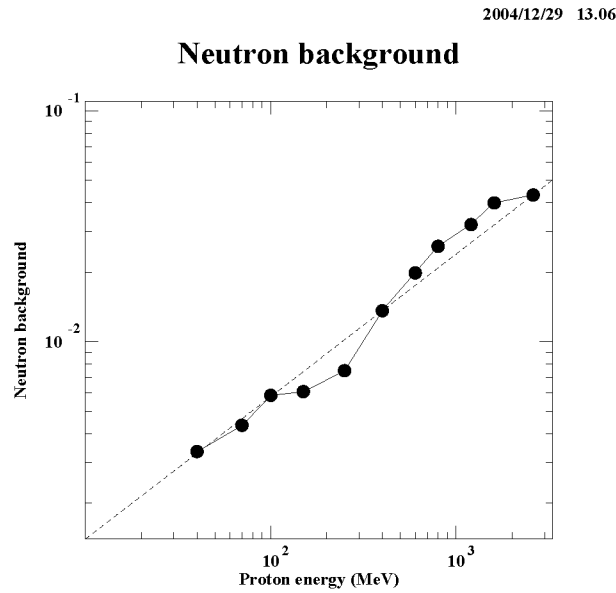


Fig. 13: The mean neutron flux-to-mean proton flux density ratio in the proton flux versus proton beam energy.

Fig. 13 shows the measurement results. Presented on double logarithmic scale, the nearly-linear rise of the $\overline{\Phi}_n/\overline{\Phi}_p$ ratio with increasing proton energy indicates a correlation between the increases in neutron yield and in neutron background. The appropriate estimates have shown that, given the highest $\overline{\Phi}_n/\overline{\Phi}_p$ value, the contribution of the neutron component at 2.6 GeV proton energy (the (n,Xn) reaction) is insignificant (to the (p,p(X-1)n)reaction, respectively).

2.6 γ -spectrum measurements

The facility used to measure the irradiated samples and monitors is the spectrometer manufactured by CANBERRA PACKARD Trading Corp. (a 1.8 keV resolution in the 1332 keV ^{60}Co (γ -line) based on GC-2518 coaxial Ge crystal, a 1510 integrated signal processor (a 6000 V power supply, a 100 MHz 8192-channel ADC, and a spectrometric amplifier), a SYSTEM-100 master card (near the end of the Project implementation, a major forced us to replace that card with a AccuSpec-B master card) that emulates a multichannel analyzer (a complete card of the PC standard for 8K memory channels with DMA-interface and NIM unit) as an integral part of IBM PC.

2.6.1 Characteristics of the spectrometer

The very numerous radioactive reaction products involved in the measurements, the γ -spectra are extremely complicated, especially during the initial decay period. Besides, the γ -spectrum intensity varies by a few orders throughout the γ -spectrum measurement time. Therefore, the possible instability of the spectrometer performance may not only hamper in acquiring and

processing experimental data, but also distort the results obtained. That is why the performance characteristics were constantly monitored during the experiments.

2.6.1.1 Determination of admissible measurement modes The spectrometer parameters that define the admissible measurement modes include

- temperature and time stability,
- cascade summation effects,
- ultimate spectrometer load,
- absolute height-energy effectiveness of the spectrometer.

2.6.1.1.1 Temperature stability The temperature stability was supported by a conditioner for producing the appropriate microclimate in the Laboratory measurement room.

2.6.1.1.2 Time stability The time stability is estimated by recurrent measuring γ -emission from ^{152}Eu . The long-term observations (see Fig. 14) made at the Laboratory have shown that the fluctuations of the channel positions of the 121.78 keV, 778.90 keV, and 1408.01 keV γ -line photopeak detection maxima from their means in the channels are mostly within 0.10 %. The observed temperature drift of instrumental line in the measured γ -spectra is allowed for by permanent calibrating the spectrometer, thus providing a 0.1-0.3 keV error in measuring the energy of γ -emission from the irradiated samples. In such a way, we can substantially reduce the number of the nuclide γ -lines that are to be considered as additional contributions to the determined cross section of a respective reaction.

Fig.15 shows the total statistics of the spectrometer time stability.

2.6.1.1.3 Quantitative estimation of count loss The count loss at high spectrometer loads was estimated by the method of two sources. One of the sources (^{137}Cs) was fixed at H that defines the Ge detector - γ -source spacing, while the height of the second source (^{152}Eu) was decreased during measurements. The position of the first source provided a moderate load of the spectrometer, while the position of the second source imitated the increased load inherent to the measurements. Fig.16 shows the variations of the ^{137}Cs γ -line resolution and peak area versus spectrometer load.

The results obtained were used to determine the ultimate spectrometer load that failed to exceed 5% in all measurement runs. To maintain these conditions, the experimental samples began being monitored at height ~ 1240 mm and higher, which decreased then down to the ultimate height of 40 mm to reduce the influence of the cascade summation effects. The experimental estimation of the cascade summation effects that distort the measured γ -spectra, which was made using ^{24}Na and ^{60}Co placed at a 40-mm height, together with the computational estimation of the same effects by the method described in [36], showed that $\Delta k_{\gamma,\gamma} \leq 3.0$ %.

Time fluctuation of ^{152}Eu peaks locations for GC-2518

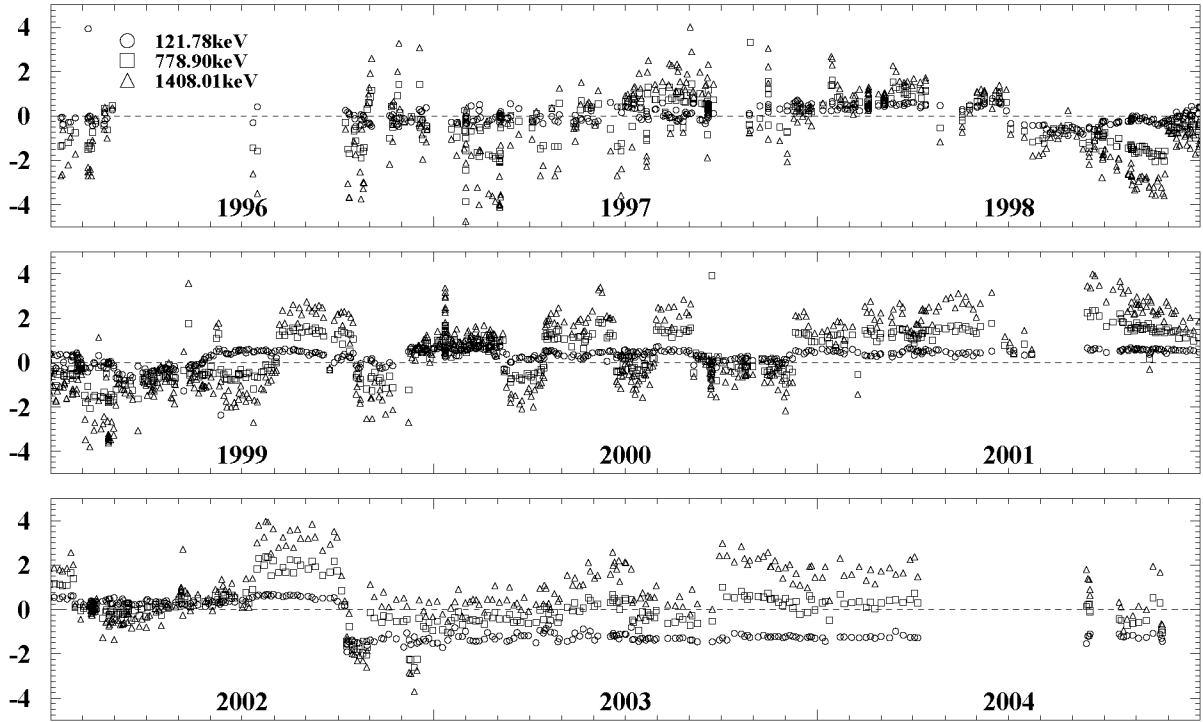


Fig. 14: Positions of the 121.78 keV, 778.90 keV, and 1408.01 keV γ -line photopeak detection maxima.

Statistics of time fluctuation of ^{152}Eu peaks

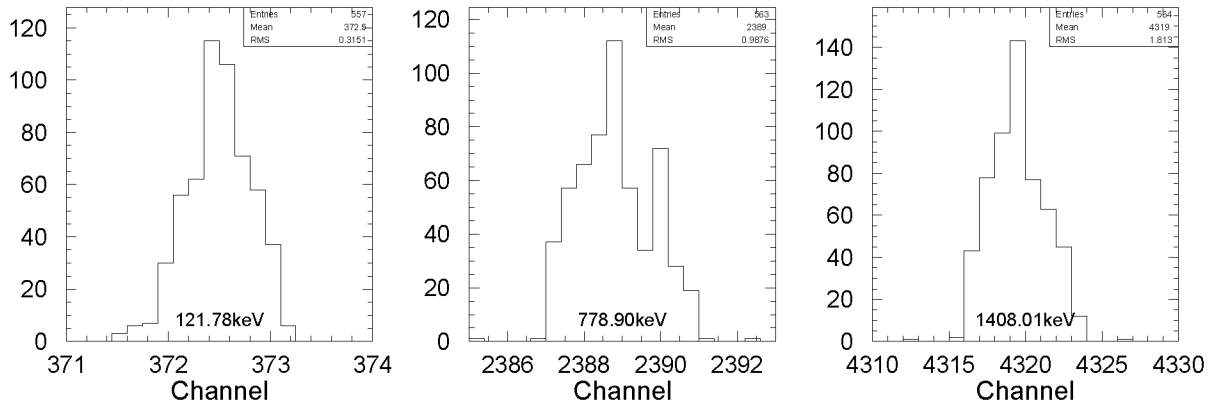


Fig. 15: General statistics of the spectrometer time stability.

2.6.1.1.4 The detection effectiveness of the spectrometer The absolute height-energy effectiveness of the spectrometer detection effectiveness is an important characteristic of the spectrometer because its value is used directly to calculate the independent and cumulative yields in formulas (43-49 and 87). Therefore, the measurements were made under preselected standard conditions that included the effects that distort the form of the instrumental spectrum. Like the routine measurements, the standard measures were taken to reduce the contribution

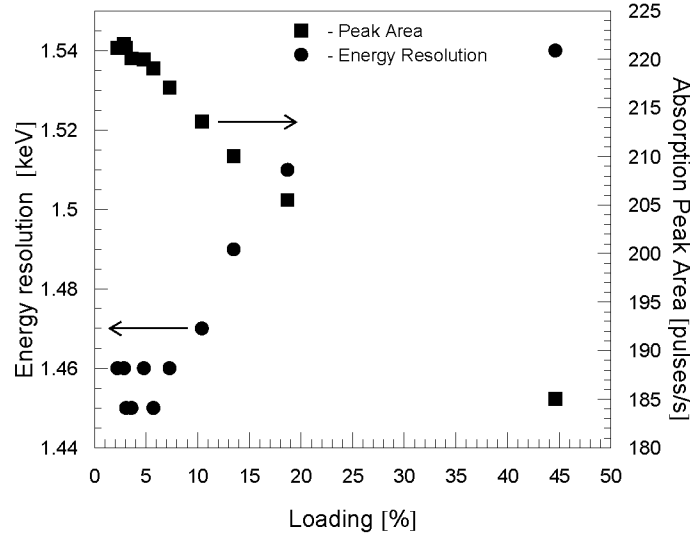


Fig. 16: Load characteristics of the spectrometer

from the errors associated with the geometric reproducibility (provided by a job-oriented support), with the system deadtime (determined by t_{live} and t_{true} of the spectrometer), with the measurement time (determined by the accuracy of the PC quartz generator), and with the source half-lives (determined by selecting a set of γ -sources, whose certification date is close the date of measurements).

The absolute height-energy effectiveness $\varepsilon(E_0)$ for energy E_0 , that corresponds to the γ -line energy of a monitored source, as well as its error, can be presented as

$$\varepsilon(E_0) = \frac{S}{A \cdot e^{-\lambda \cdot t_d} \cdot \eta} \quad (132)$$

where S is count rate in total absorption peak (pulse/s) at energy E_0 ; η is the absolute γ -line quantum yield; A is the certified γ -source activity reduced to the measurement moment; t_d is time span between the γ -source certification date and measurement time; $\lambda = 0.693/T_{1/2}$ is the γ -source decay constant.

$$\Delta\varepsilon(E_0) = \varepsilon(E_0) \cdot \sqrt{\left(\frac{\Delta S}{S}\right)^2 + \left(\frac{\Delta A}{A}\right)^2 + \left(\frac{0.693 \cdot t_d \cdot \Delta T_{1/2}}{T_{1/2}^2}\right)^2 + \left(\frac{\Delta \eta}{\eta}\right)^2} \quad (133)$$

Use was made of the certified independent γ -sources from the OSGI-3#9402 set of sources tested and approved by D.I. Mendelev VNIIM. The set includes ^{54}Mn , ^{57}Co , ^{60}Co , ^{88}Y , ^{109}Cd , ^{113}Sn , ^{133}Ba , ^{137}Cs , ^{139}Ce , ^{152}Eu , ^{228}Th , ^{241}Am .

Additionally, use was made of the ^{22}Na source from the OSGI#237 set tested and approved by the VNIIFTRI.

The source certification date, the activity, and the nuclear data used to calculate the absolute effectiveness were taken to conform to the Certificate ratings [37].

The techniques for determining the absolute height-energy effectiveness of the spectrometer detection are described in detail in the Final Report on ISTC Project#839 [2]. In the present Project, the detection effectiveness was also determined for 900 mm and 1240 mm heights.

Fig. 17 shows the results of experimental determining and computational simulating the absolute spectrometer detection effectiveness at different heights.

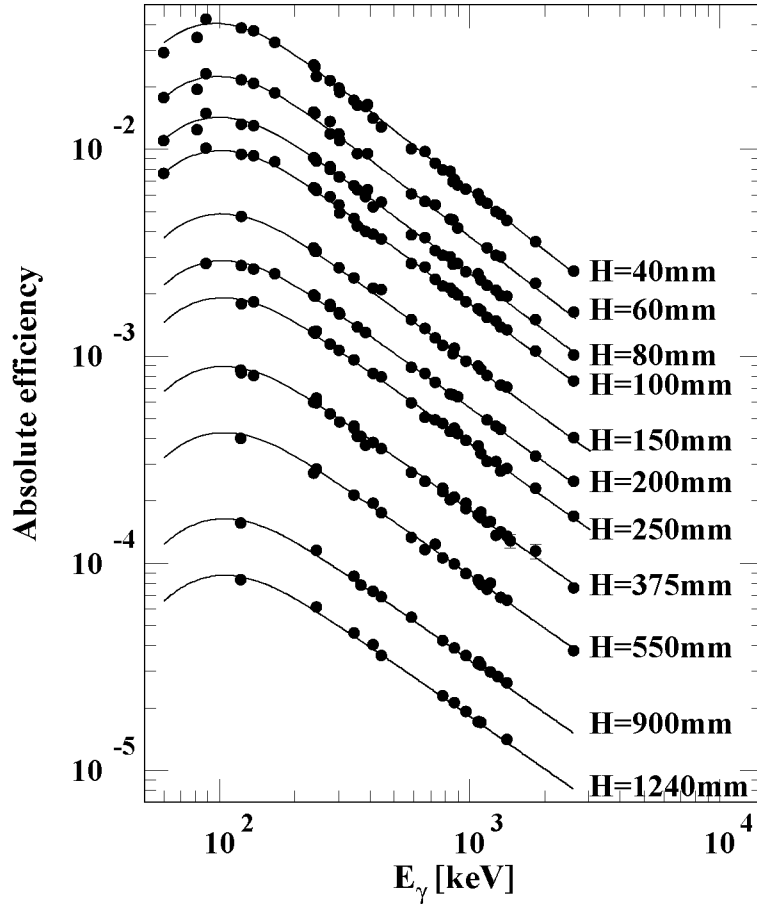


Fig. 17: The computational height-energy simulation of the absolute spectrometer detection effectiveness

From Fig. 17 it follows that the techniques developed makes it possible to adequately describe the experimental values of the absolute spectrometer detection effectiveness at any height and to correctly reproduce the variations of the slope of the energy dependence curve of the spectrometer detection effectiveness on double-logarithmic scale with varying height H .

The proposed techniques make it possible to calculate the absolute spectrometer detection effectiveness at 100 keV $\div$ 2600 keV energies and 40 mm $\div$ 1240 mm heights. The calculated values of the absolute height-energy detection effectiveness of the spectrometer were used to calculate the height factors when plotting the decay time dependences of the nuclide γ -line count rates.

Absolute and Relative Efficiencies at H=40mm

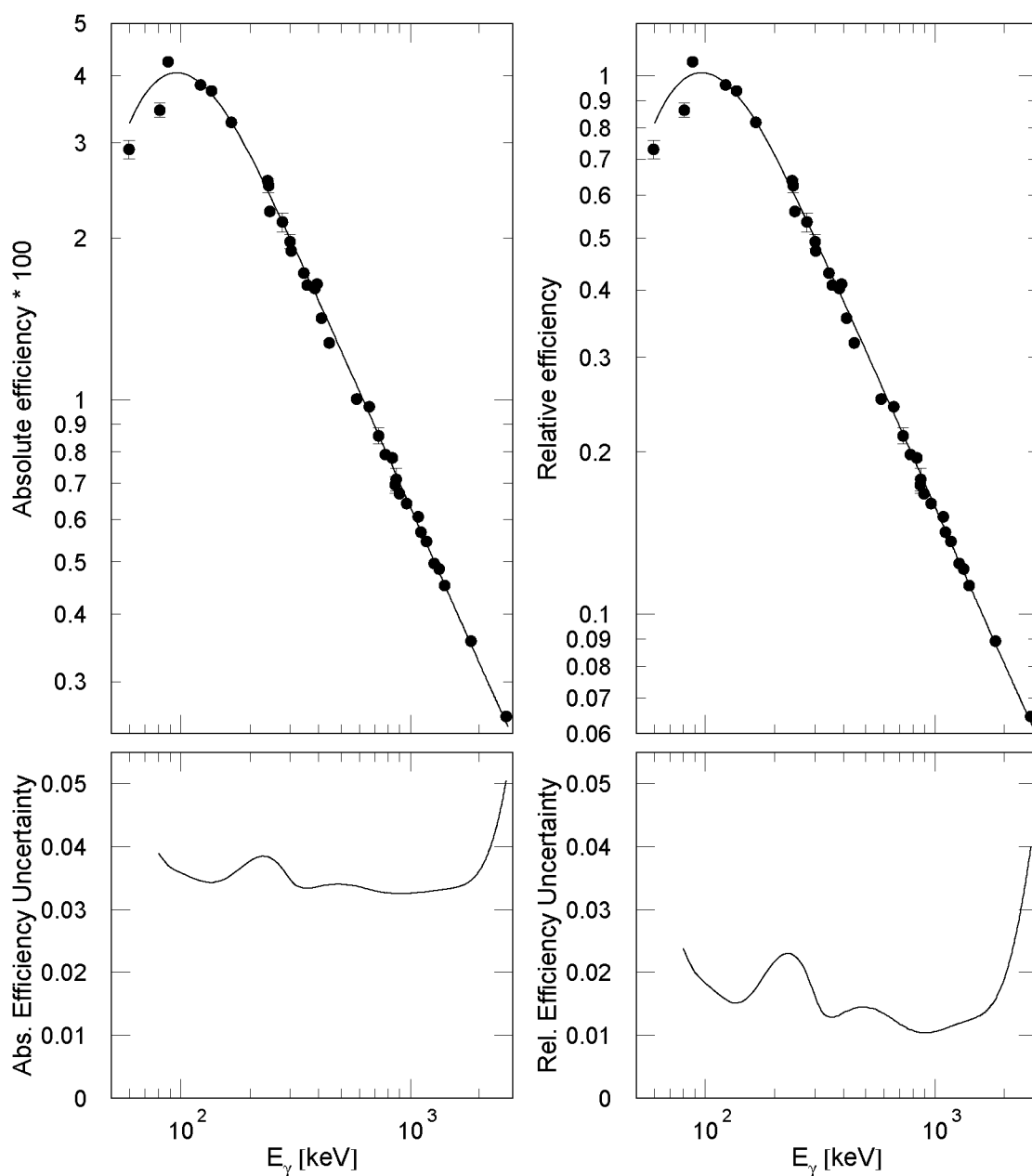


Fig. 18: The absolute and relative detection effectivenesses at 40 mm height and their respective relative errors.

Since all the measured count rates of the nuclide γ -lines were reduced to the 40 mm height, the relative spectrometer detection effectiveness was also calculated for that height by renormalizing the reference points of the measured absolute effectiveness. As noted in 2.1, the absolute detection effectiveness of the spectrometer can also be presented via relative effectiveness to be a product of two co-factors:

$$\varepsilon(E) = k_\varepsilon \cdot \varepsilon^{rel}(E), \quad (134)$$

where k_ε is a fixed factor with a 0.7% error defined by the certified γ -source activity accuracy; $\varepsilon^{rel}(E)$ is the relative effectiveness with an error defined by the error in relative quantum yields and by the measurement statistics.

Given the above representation, the error in the absolute detection effectiveness is calculated as

$$\frac{\Delta\varepsilon(E)}{\varepsilon(E)} = \sqrt{\left(\frac{\Delta\varepsilon^{rel}(E)}{\varepsilon^{rel}(E)}\right)^2 + \left(\frac{\Delta k_\varepsilon}{k_\varepsilon}\right)^2 + \left(\frac{\Delta k_{\gamma\gamma}}{k_{\gamma\gamma}}\right)^2} \quad (135)$$

The formula for calculating the relative detection effectiveness is of the same form as used to calculate the absolute detection effectiveness:

$$\varepsilon^{rel}(E) = \exp \left[\sum_{i=k}^{k+3} P_i \cdot (\ln E)^{i-k} \right] \quad (136)$$

where

$$k = \begin{cases} 1, & \text{для } \ln E < \ln E_0 \\ 5, & \text{для } \ln E \geq \ln E_0 \end{cases}$$

The error in the relative detection effectiveness of the spectrometer is determined as

$$\Delta\varepsilon^{rel} = \varepsilon^{rel} \cdot \sqrt{\frac{\chi^2}{F}} \cdot \sqrt{\sum_{i=k}^{k+3} \sum_{j=k}^{k+3} M_{ij}^{-1} \cdot (\ln E)^{i-k} \cdot (\ln E)^{j-k}} \quad (137)$$

where

$$\chi^2 = \sum_{i=1}^{N_1+N_2} [\varepsilon^{exp}(E_i) - \varepsilon^{calc}(E_i)]^2 \cdot \frac{1}{\Delta_i^2}, \quad (138)$$

The $\varepsilon^{calc}(E_i)$ is calculated by formula (136); Δ_i is absolute error in the relative detection effectiveness of the spectrometer at energy E_i .

$$F = N_1 + N_2 - m_1 - m_2 + k - 3, \quad (139)$$

Table 5 lists the coefficients for calculating the relative detection effectiveness.

Fig.18 shows the absolute and relative detection effectivenesses of spectrometer at $H = 40$ mm together with their errors. The fixed factor for $H=40$ mm corresponds to $k_\varepsilon = 25.24 \pm 0.17$. The error in the relative detection effectiveness of spectrometer is within (1–4)% (see Fig.18).

In the ranges of relatively low and high energies ($E_\gamma < 100$ кэВ, $E_\gamma > 1840$ кэВ), the mean error is ≈ 2.5 %; in the $400 \text{ keV} < E_\gamma < 600 \text{ keV}$ energy range that is supported by scanty reference points, the mean error is ≈ 2.0 %; in the remaining ranges, the error is within ≈ 1.5 %. The error in the absolute detection effectiveness of spectrometer is within (4.2–5.5)% (see Fig.18).

Table 5: The values of the parameters of the relative detection effectiveness curve for $H = 40$ mm.

$E \leq 300 \text{ keV}$	P_1	P_2	P_3	P_4
	-68.656518692	40.107437134	-7.6702423096	0.47793984413
$E > 300 \text{ keV}$	P_5	P_6	P_7	P_8
	-18.926873917	9.6137084961	-1.5634212494	0.076607346535

2.6.1.2 The laboratory room background The occurrences of the background γ -lines produced in a sample by the natural radioactive background and by possible radioactive impurities are allowed for by analyzing the γ -spectra of the non-irradiated samples, whose measurement conditions are the same as those of irradiated samples. Fig. 19 shows the laboratory room radioactive background (buildup time ~ 4 days) that is characteristic of γ -spectrometry. The background implies occurrences of the natural radionuclides that enter the ^{238}U , ^{235}U , and ^{232}Th decay chains, except for γ -line energies 661 keV (^{137}Cs) and 344.9, 722.9 keV (^{108}Ag). The presence of ^{137}Cs and ^{108}Ag is a probable result of the long-term heavy-water reactor operation in the ITEP area.

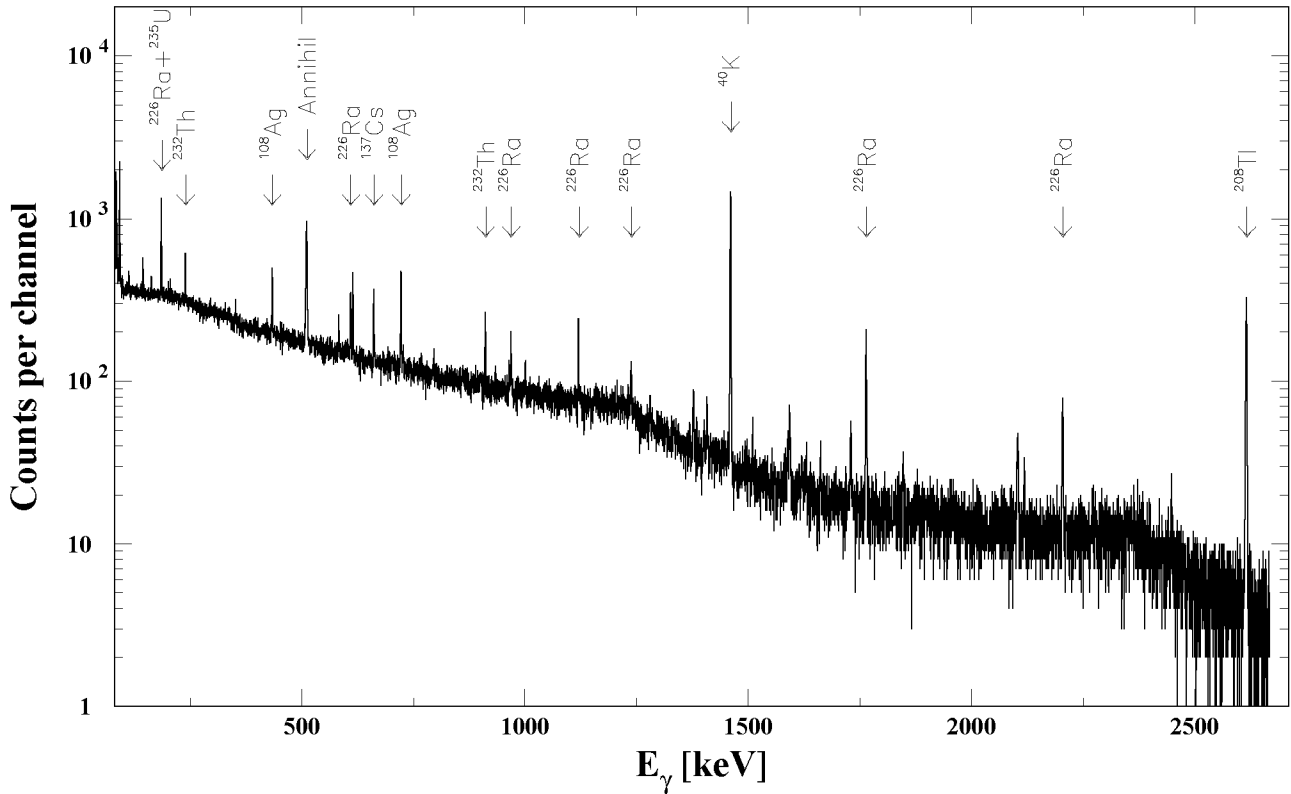


Fig. 19: Radioactive background spectrum of laboratory room.

2.6.2 Processing of γ -spectra

It was as early as the Project #839 implementation period that the potentialities of the codes with automatic γ -spectra processing mode were found to be restricted by the extremely complicated nature of the measured γ -spectra, resulting from the very numerous γ -lines and from the fact that they are essentially variable.

Despite the fact that we have reached the ultimate resolution inherent to our Ge detector, the transient multiplets were rather numerous in the spectra.

Considering the above, the GENIE-2000 code [16] was used to process the γ -spectra. The code is advantageous in that it permits the automatic packet-mode processing of the measured γ -spectra by interactive fitting the peaks in each of the spectra to be followed by additional monitoring of the tentative processing result outside the packet. Namely, an effort is made to find out whether the domains of the peaks are multiplets, real peaks that fail to satisfy the search criterion, spurious peaks, or else. The fitting quality is displayed to be dots of normalized differences between the input data and the fitting results.

The said techniques for spectrum processing have made it possible to substantially raise the quality of processing the measured γ -spectra. The GENIE-2000 code uses the generalized second derivative method to seek for the peaks. The areas of the peaks are determined using the summation algorithm or by least squares fitting in terms of the modified Gauss function. The highest number of iterations is 30. Convergence is improved by damping.

The algorithm includes calculations of the peak domain boundaries and of the areas of peaks together with their errors for both singlets and multiplets. The underpeak background is approximated by either linear or stepwise form. Up to sixteen peaks may occur in a multiplet. A single ROI may contain up to 512 channels. Any range, wherein more than 16 peaks or 512 channels are expected, must be broken in the deepest depression region to provide formation of two domains with less than 16 peaks or 512 channels. The errors are calculated by the techniques that are typical of the γ -spectrometry method on assumption that the channels are devoid of any correlation of counts. The comprehensive description of the algorithms used in the GENIE-2000 can be found in the Manual on Designer's Software [16] and in [17]-[32].

Figs. 20 and 21 exemplify the extra-packet usage of the GENIE-2000 code. The figures present the operation window of the code, showing an analyzed spectrum fraction of the 600 GeV proton-irradiated ^{nat}Pb spectrum in ~ 12 hours after irradiation. The processing reports are also shown. The energies within the γ -spectrum fragment are ranging from 562.7 keV to 590.4 keV.

The upper panels show the results of primary processing the spectrum by the automatic packet mode of GENIE2000 code. Separation of multiplets does not prove to be satisfactory, as confirmed by the report. The lower panels show the result of the additional manual processing by the interactive fitting mode. Table 6 presents the nuclear physics characteristics of the identified nuclides from [33] together with the positions of maxima calculated using the energy calibration of the spectrometer for all GENIE2000-determined 10 peaks.

Obviously, the multiplet separation quality got improved, thus permitting the code to separate the peaks by energy differences of ~ 1 keV. In turn, this has made it possible to additionally identify ~ 10 nuclides. In such a way, the number of the identified nuclides increased

substantially, with the quality of determining their yields being improved

Table 6: Nuclear-physics parameters of the nuclides identified.

	Nuclide	$T_{1/2}$	Energy, keV (PCNUDAT)	Energy, keV (GENIE)	γ -yield, %
1	^{165}Tm	30.06 h	564.18	564.52	2.31
	^{191}Au	3.18 h	565.13		0.49
2	^{189}Pt	10.87 h	568.85	568.94	7.1
	^{96}Nb	23.54 h	568.87		58.0
3	^{170}Hf	16.01 h	572.90	573.21	15
	^{193}Hg	11.8 h	573.25		26
4	^{187}Ir	10.5 h	576.60	576.62	0.85
5	^{202}Bi	1.72 h	578.56	579.15	7.3
	^{200}Tl	26.1 h	579.28		13.8
6	^{198}Au	4.94 h	582.63	582.57	2.7
7	^{186}Ir	16.64 h	584.42	584.70	5.4
	^{200}Tl	26.1 h	584.55		3.56
	^{195}Hg	9.9 h	585.13		1.99
8	^{191}Au	3.18 h	586.44	586.54	17.00
9	^{198}Tl	1.87 h	587.20	587.95	52.5
	^{181}Re	19.9 h	587.40		0.69
	^{192}Au	4.94 h	588.58		0.30
10	^{187}Ir	10.5 h	589.47	589.47	0.277

The processed γ -spectra were united to form a single input file for SIGMA code, which plots the temporal intensity variations of a selected γ -line and, then, uses the γ -line energy and the nuclide lifetimes estimated by the code proper, together with the PCNUDAT database [33, 34, 35], to identify the product nuclei and to calculate their yields by formulas 43-49), and (87).

The contribution of pair production in the Ge detector was analyzed for all peaks with $E_\gamma > 1022$ keV by calculating the energies of the peaks of single and double ejections. For that purpose, the peaks with $E_i - 511$ keV and $E_i - 1022$ keV were set to correspondence with the peaks at $E_i - 511$ keV and $E_i - 1022$ keV. Any peak, whose energy was found to coincide with the said difference to within the energy measurement error (~ 0.15 keV), was excluded from further analysis.

It should be noted that all the data (the irradiation parameters, the experimental sample characteristics, the spectrometer calibration data, the measured γ -spectra, and the experimental results obtained), which must be used to determine the yields, can be found in the "ExpData" experimental database of the Laboratory. The database is being replenished with fresh data and is stored on the Laboratory server to provide prompt access.

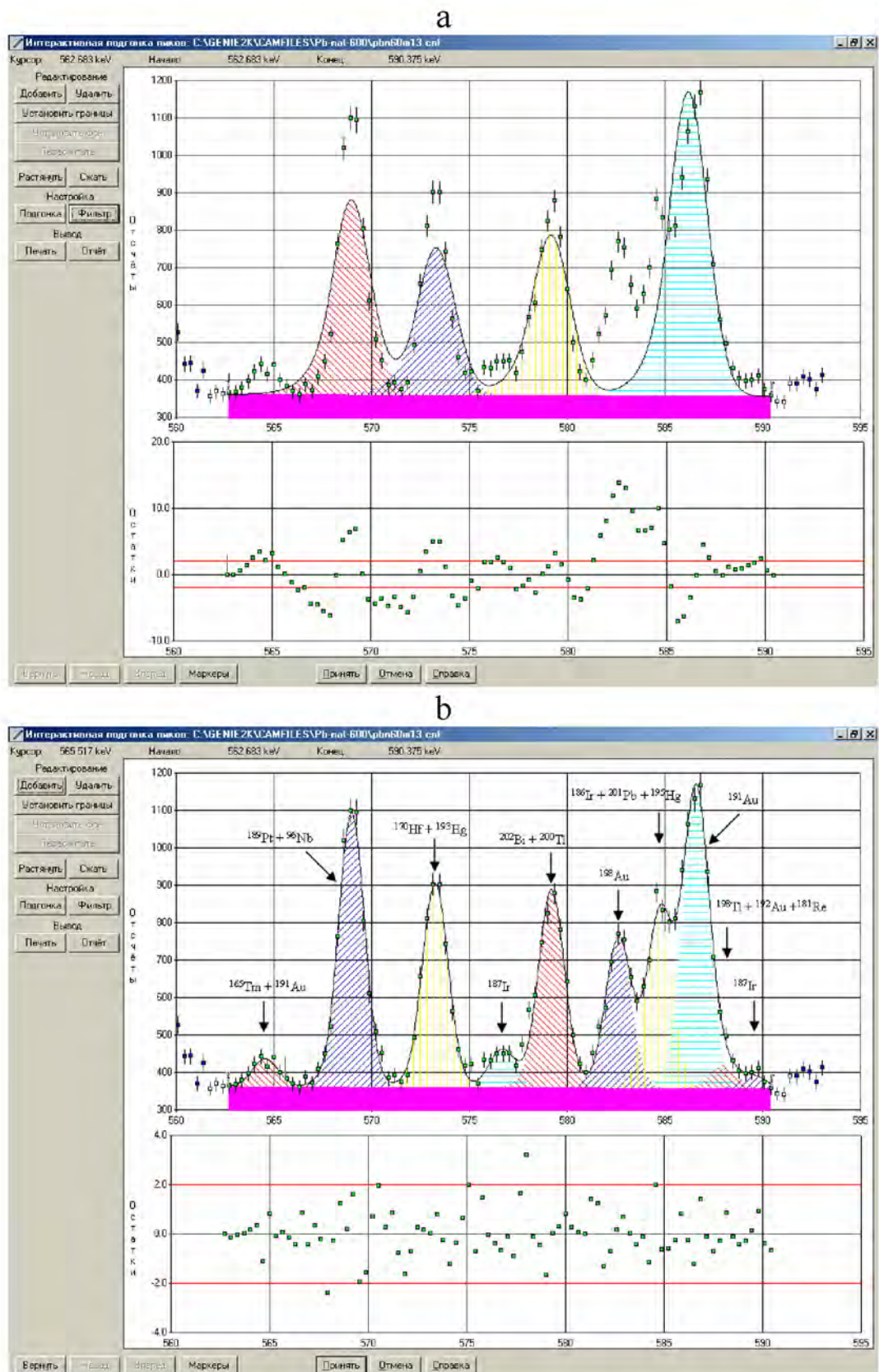


Fig. 20: The results of primary processing a γ -spectrum by the automatic (a) and manual interactive fitting(b) modes of the GENIE-2000 code.

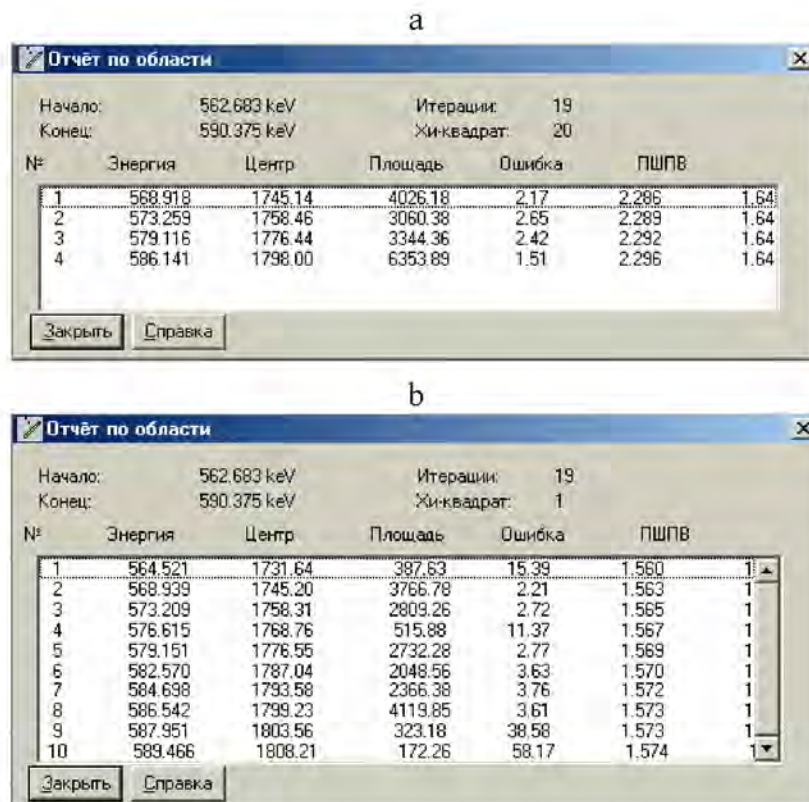


Fig. 21: The GENIE-2000 report on the parameters of the found peaks. The legend (a) and (b) is the same as in Fig. 20.

2.7 The monitoring reactions

The $^{27}\text{Al}(\text{p},\text{x})^{22}\text{Na}$ reaction was used to monitor the proton beam. Fig. 22 shows all the data from the EXFOR database (29 publications in total) [40], together with the data by J. Tobailem from [42] and [43]. Similarly to [44], the data by G.F. Steyn et al. [41] were used at energies below 200 MeV, while the data by J. Tobailem [43] were used above 200 MeV.

The "Eye guide" method was used to plot a smooth curve that evaluates the $^{27}\text{Al}(\text{p},\text{x})^{22}\text{Na}$ reaction excitation function within a 30-3000 MeV range. The desired monitoring reaction cross sections were derived from the curve at the real proton beam energies at the monitor half-depths (see Table 4).

The sufficiently low contribution from the neutron component (as seen in Fig. 13 $\Phi_n/\Phi_p < \sim 4-5\%$) has made it possible to attain the desired accuracy of calculating not only the production rate $R_{^{22}\text{Na}}$, but also the production rates $R_{^{24}\text{Na}}$ and $R_{^7\text{Be}}$ by formula (112). Tables 7, 13, 19, 25, 31, 37, 43, 49, 55, 61, and 67 in Section 2 of Appendix to this Report present the detailed results of the ^7Be , ^{24}Na , and ^{22}Na production rate measurements in the standard foils. The production cross sections $\sigma_{^{24}\text{Na}}$ and $\sigma_{^7\text{Be}}$ can, then, be presented as

$$\frac{\sigma_{^{24}\text{Na},^7\text{Be}}}{\sigma_{^{22}\text{Na}}} = \frac{D_{^{24}\text{Na},^7\text{Be}}^*}{D_{^{22}\text{Na}}^*} \cdot \frac{(\eta \cdot \varepsilon)_{^{22}\text{Na}}}{(\eta \cdot \varepsilon)_{^{24}\text{Na},^7\text{Be}}} \cdot \frac{F_{^{22}\text{Na}}}{F_{^{24}\text{Na},^7\text{Be}}} . \quad (140)$$

Figs. 23 and 24 show the excitation functions of the $^{27}\text{Al}(\text{p},\text{x})^{24}\text{Na}$ and $^{27}\text{Al}(\text{p},\text{x})^7\text{Be}$ reactions together with the data obtained elsewhere. Table 7 presents numerically the nuclide production cross sections $\sigma_{^{24}\text{Na}}$ and $\sigma_{^7\text{Be}}$ at the respective energies. The absolute errors $\Delta\sigma_{^{24}\text{Na}}$ and $\Delta\sigma_{^7\text{Be}}$ are presented in Table 7 disregarding/including the error in the monitoring cross section, i.e. $\Delta\sigma_{^{22}\text{Na}}$.

Table 7: The monitoring cross sections (mbarn) for $^{27}\text{Al}(\text{p},\text{x})^{22}\text{Na}$ production and the cross sections (mbarn) obtained for $^{27}\text{Al}(\text{p},\text{x})^{24}\text{Na}$ and $^{27}\text{Al}(\text{p},\text{x})^7\text{Be}$ production.

Proton energy (MeV)	$^{27}\text{Al}(\text{p},\text{x})^{22}\text{Na}$	$^{27}\text{Al}(\text{p},\text{x})^7\text{Be}$	$^{27}\text{Al}(\text{p},\text{x})^{24}\text{Na}$
2606 ± 8	11.4 ± 0.9	$9.18 \pm (0.29/0.78)$	$10.87 \pm (0.34/0.92)$
1599 ± 4	13.2 ± 1.0	$9.06 \pm (0.29/0.75)$	$12.59 \pm (0.40/1.03)$
1194 ± 3	14.4 ± 1.0	$8.23 \pm (0.26/0.63)$	$13.26 \pm (0.42/1.01)$
799 ± 2	15.5 ± 1.1	$6.33 \pm (0.21/0.49)$	$13.40 \pm (0.42/1.04)$
599 ± 2	16.0 ± 1.0	$4.89 \pm (0.16/0.34)$	$13.09 \pm (0.41/0.92)$
399 ± 2	15.8 ± 1.0	$3.11 \pm (0.10/0.22)$	$12.01 \pm (0.38/0.85)$
249 ± 1	15.0 ± 0.9	$1.79 \pm (0.06/0.12)$	$10.65 \pm (0.33/0.72)$
149 ± 1	17.1 ± 1.1	$1.26 \pm (0.04/0.09)$	$11.02 \pm (0.35/0.79)$
98.7 ± 0.8	19.8 ± 1.2	$0.957 \pm (0.033/0.067)$	$11.73 \pm (0.37/0.80)$
68.2 ± 0.8	22.3 ± 1.4	$0.672 \pm (0.028/0.051)$	$11.74 \pm (0.43/0.85)$
68.1 ± 0.8	22.3 ± 1.4	$0.854 \pm (0.039/0.067)$	$11.74 \pm (0.43/0.85)$
67.9 ± 0.8	22.4 ± 1.4	$0.646 \pm (0.026/0.048)$	$11.70 \pm (0.43/0.85)$
67.8 ± 0.8	22.4 ± 1.4	$0.590 \pm (0.027/0.046)$	$11.09 \pm (0.40/0.80)$
67.1 ± 0.9	22.7 ± 1.4	$0.658 \pm (0.030/0.051)$	$11.69 \pm (0.43/0.84)$
37.0 ± 1.1	28.7 ± 2.0	$0.209 \pm (0.033/0.036)$	$0.824 \pm (0.031/0.065)$
36.9 ± 1.1	28.4 ± 2.0	$0.198 \pm (0.069/0.071)$	$0.804 \pm (0.030/0.064)$
36.9 ± 1.1	28.2 ± 2.0	$0.172 \pm (0.033/0.036)$	$0.796 \pm (0.029/0.064)$
35.5 ± 1.3	22.1 ± 2.0	$0.328 \pm (0.028/0.041)$	$0.564 \pm (0.021/0.055)$
36.3 ± 1.2	25.9 ± 2.0	$0.166 \pm (0.024/0.027)$	$0.703 \pm (0.026/0.060)$

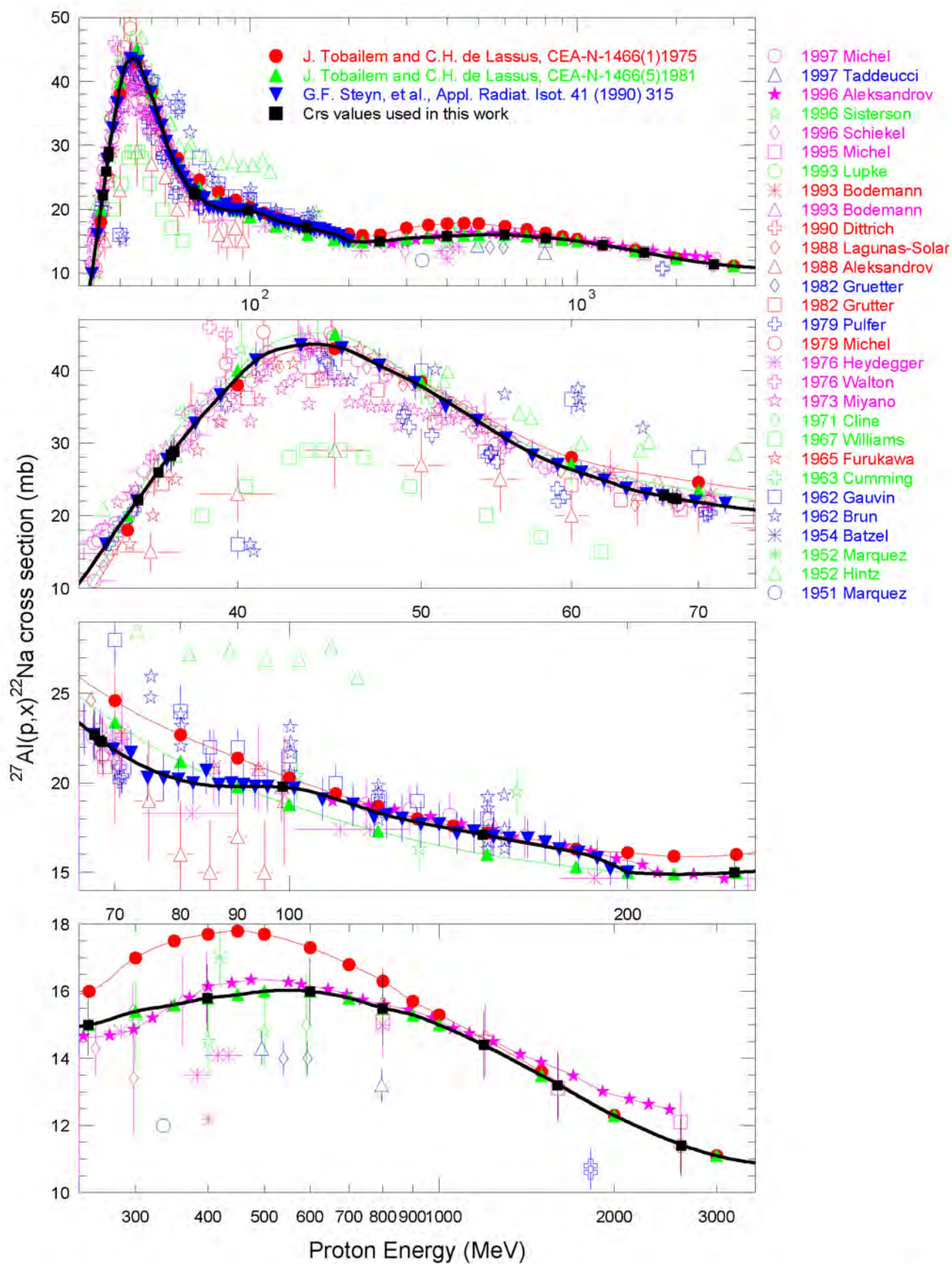


Fig. 22: The $^{27}\text{Al}(p,x)^{22}\text{Na}$ reaction cross sections. The black line is the applied evaluation. The values used in the experiments are labeled with black squares.

$^{27}\text{Al}(p,x)^{24}\text{Na}$ cross section measured at ITEP and other labs

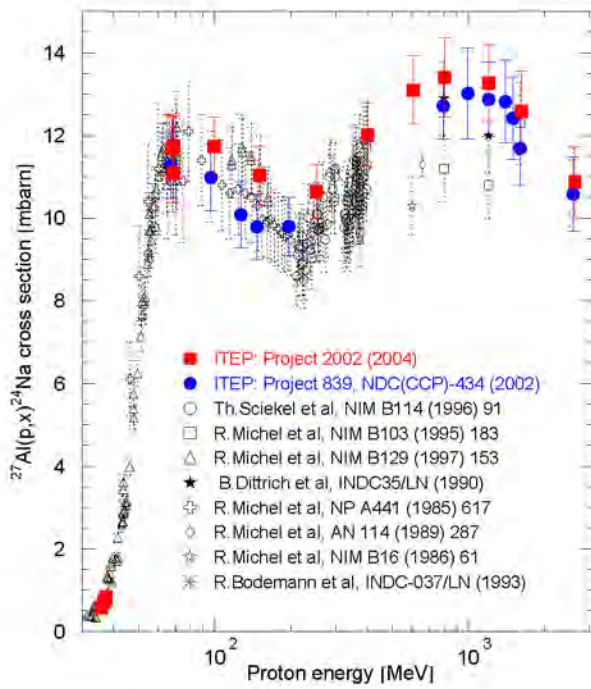


Fig. 23: The results obtained here for $^{27}\text{Al}(p,x)^{24}\text{Na}$ reaction (red squares) together with the data obtained elsewhere.

$^{27}\text{Al}(p,x)^7\text{Be}$ cross section measured at ITEP and other labs

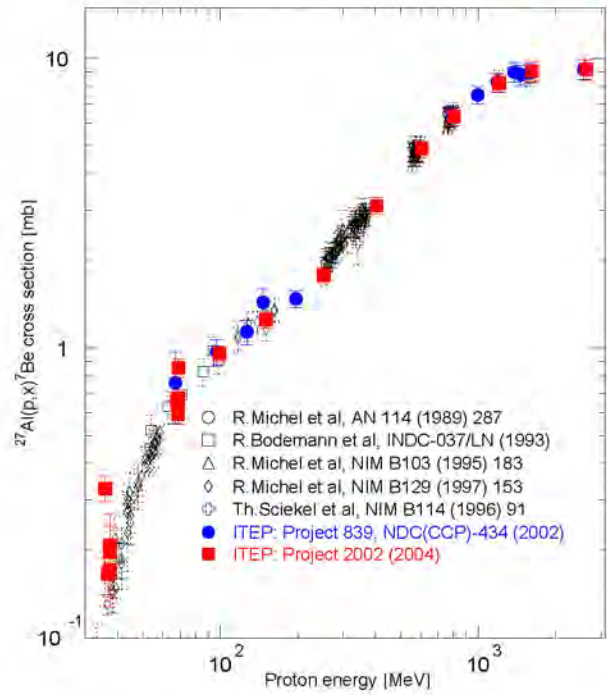


Fig. 24: The results obtained here for $^{27}\text{Al}(p,x)^7\text{Be}$ reaction (red squares) together with the data obtained elsewhere.

2.8 Conclusion

Conforming to the tasks outlined in the ISTC # 2002 Workplan (see Section 4 "Scope of activities"):

- Task 1: Manufacture of samples,
- Task 2: Calibration of spectrometer; stability tests,
- Task 3: Adjustment of the 600 MeV proton beam extraction,
- Task 4: Irradiation of experimental samples,
- Task 5: γ -spectrometry of experimental samples,
- Task 6: Processing of γ -spectra,
- Task 7: Identification of γ -lines and determination of residual radioactive nuclide yields,

the preparatory and current works that support implementation of the researches under the Project are described at length in Chapter 2, namely,

1. manufacture and certification of 55 experimental samples (targets) of high-enriched and natural lead (^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb) and bismuth (^{209}Bi) of 9.85 g total weight, as well as 55 aluminum monitors (^{27}Al) of 6.75 g total weight (Subsection 2.4);
2. description of spectrometer and of its admissible operation modes (the temperature and time stability, the cascade summation effects, the ultimate load, the absolute height-energy detection effectiveness (Subsection 2.6.1);
3. description of the external proton beam designed to suit the Project tasks and to provide extraction of 40-2600 MeV protons; detailed description of the techniques for determining the proton energies, the neutrino background, and the geometric parameters of the beam (Subsections 2.5.2.1, 2.5.4, 2.5.2.2);
4. techniques for irradiating 55 experimental samples (Subsection 2.4);
5. techniques for γ -spectrometry 55 irradiated experimental samples/targets and monitors (Subsection 2.6 and for processing 1548 measured γ -spectra of samples/targets and 604 γ -spectra of monitors (Subsection 2.6);
6. modification of SIGMA code that is used to identify γ -lines and to determine yields/cross sections of radioactive residual product nuclei. The modification was to go over from the mathematical two-link model of nuclear chains to the three-link model
7. evaluation of the excitation function of the $^{27}\text{Al}(p,x)^{22}\text{Na}$ monitoring reaction in the 0.04 - 2.6 GeV energy range (Subsection 2.7);

3 Experimental results and their errors

In total (see Table 9), 5972 yields (cross section for production) of radioactive residual products have been determined, of which 702 independent yields (labeled (i)), 712 independent yields of metastable state ($i(\Sigma m_j)$), 546 sums of independent yields of metastable and ground states ($i(\Sigma m_j + g)$), and 4012 cumulative and supracumulative yields ($c + c^*$). To visualize the presentation, the list of measurements of each reaction product has been compiled and presented in Table 8 for all 55 experiments carried out. The values of the yields or cross sections for production of residual nuclei were calculated by formulas (116), and their errors by formulas (117) and (118). Formulas (116) show that each of the production rates of a residual product can be obtained via both a single γ -line and a few different γ -lines. The detailed information on calculating each of the production rates of a residual product in experimental samples and in monitors, as well as their errors, can be found in Section 2 of Appendix to the present Report. All the experimental values of the yields (cross sections for production) of residual nuclides are presented in Tables 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, and 33 for ^{206}Pb , ^{207}Pb , ^{208}Pb , and ^{nat}Pb , and in Table 35 for ^{209}Bi . The proton energies and their errors, as well as the proton flux densities and their errors that must be used to calculate the yields (cross sections for production) of radioactive residual nuclei by formulas (114) and (115), are presented together with some other irradiation parameters in Tables 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, and 34.

In some cases, the presented values of the yields have been obtained from experimental data via simple calculations. For convenience, Table 8 and the Tables of results 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, and 34 make use of a particular marker (* in front of the reaction product name). Such cases are discussed in detail below.

1. Only supracumulative production rate of a measured nuclide R_n^{cum*} and the cumulative production rate of its precursor R_{n-1}^{cum} are often determined experimentally. In this case, the modified formula (119) can be used to calculate the cumulative production rate R_n^{cum} of a measured nuclide and its error ΔR_n^{cum} as

$$R_n^{cum*} = R_n^{ind} + \frac{\lambda_{n-1}}{\lambda_{n-1} - \lambda_n} \cdot \nu_{n-1,n} \cdot R_{n-1}^{cum} = R_n^{cum} + \frac{\lambda_n}{\lambda_{n-1} - \lambda_n} \cdot \nu_{n-1,n} \cdot R_{n-1}^{cum} \quad (141)$$

$$\Delta R_n^{cum*} = \sqrt{\Delta(R_n^{cum})^2 + \left(\frac{\lambda_n}{\lambda_{n-1} - \lambda_n} \cdot \nu_{n-1,n} \right)^2 \cdot \Delta(R_{n-1}^{cum})^2} \quad (142)$$

$$R_n^{cum} = R_n^{cum*} - \frac{\lambda_n}{\lambda_{n-1} - \lambda_n} \cdot \nu_{n-1,n} \cdot R_{n-1}^{cum} \quad (143)$$

$$\Delta R_n^{cum} = \sqrt{\Delta(R_n^{cum*})^2 + \left(\frac{\lambda_n}{\lambda_{n-1} - \lambda_n} \cdot \nu_{n-1,n} \right)^2 \cdot \Delta(R_{n-1}^{cum})^2} \quad (144)$$

Formulas (143) and (144) were used together with formulas (149) and (150) to calculate the cumulative yields and their errors for the following 13 products: $^{*204}\text{Bi}$, $^{*203}\text{Pb}$, $^{*201}\text{Pb}$, $^{*201}\text{Tl}$, $^{*197}\text{Tl}$, $^{*181}\text{Re}$, $^{*177}\text{Ta}$, $^{*173}\text{Hf}$, $^{*170}\text{Lu}$, $^{*169}\text{Yb}$, $^{*152}\text{Tb}$, $^{*149}\text{Eu}$, and $^{*147}\text{Eu}$.

2. The situation occurs sometimes where cumulative reaction rate is determined for a reaction product at certain energies, while supracumulative rate is determined at some other energies for the same reaction product. To facilitate plotting, the respective values of supracumulative yields and their errors have been additionally either calculated ($^{*204}\text{Bi}$, $^{*202}\text{Bi}$, and $^{*201}\text{Pb}$ using the modified formula (141) and (142) and formulas (149) and (151)) or determined via decay curves (^{199}Tl , ^{201}Tl , ^{171}Lu , formula (121)).
3. In the case of $^{*202}\text{Tl}$, the reaction product experimental data were corrected to calculate the independent yield of the nuclide and its error using formulas (145), (149), (152), and (146):

$$R_{202\text{Tl}}^{\text{ind}} = R_{202\text{Tl}}^{\text{cum}} - 0.095 \cdot R_{202m\text{Pb}}^{\text{ind}} \quad (145)$$

$$\Delta R_{202\text{Tl}}^{\text{ind}} = \sqrt{\Delta(R_{202\text{Tl}}^{\text{cum}})^2 + 0.095^2 \cdot \Delta(R_{202m\text{Pb}}^{\text{ind}})^2} \quad (146)$$

4. The total cumulative rate and its error have been calculated for $^{*195}\text{Hg}$ making allowance for the contribution of independent reaction rate of long-lived metastable state of ^{195m}Hg . Considering formulas(147), (149), (148), and (153), the total cumulative yield of ^{195}Hg is presented in the Tables of results.

$$R_{195\text{Hg}}^{\text{cum}_t} = R_{195\text{Hg}}^{\text{cum}} + R_{195m\text{Hg}}^{\text{ind}} \quad (147)$$

$$\Delta R_{195\text{Hg}}^{\text{cum}_t} = \sqrt{\Delta(R_{195\text{Hg}}^{\text{cum}})^2 + \Delta(R_{195m\text{Hg}}^{\text{ind}})^2} \quad (148)$$

The resulting reaction rates were used to calculate the values of σ_n^{cum} , $\sigma_n^{\text{cum}*}$, $\sigma_{202\text{Tl}}^{\text{ind}}$ и $\sigma_{195\text{Hg}}^{\text{cum}_t}$ and their errors:

$$\sigma_n^{\text{cum}} = \frac{R_n^{\text{cum}}}{\Phi}, \quad \sigma_n^{\text{cum}*} = \frac{R_n^{\text{cum}*}}{\Phi}, \quad \sigma_{202\text{Tl}}^{\text{ind}} = \frac{R_{202\text{Tl}}^{\text{ind}}}{\Phi}, \quad \sigma_{195\text{Hg}}^{\text{cum}_t} = \frac{R_{195\text{Hg}}^{\text{cum}_t}}{\Phi} \quad (149)$$

$$\Delta\sigma_n^{\text{cum}} = \sigma_n^{\text{cum}} \cdot \sqrt{\left(\frac{\Delta R_n^{\text{cum}}}{R_n^{\text{cum}}}\right)^2 + \left(\frac{\Delta\Phi}{\Phi}\right)^2}, \quad (150)$$

$$\Delta\sigma_n^{\text{cum}*} = \sigma_n^{\text{cum}*} \cdot \sqrt{\left(\frac{\Delta R_n^{\text{cum}*}}{R_n^{\text{cum}*}}\right)^2 + \left(\frac{\Delta\Phi}{\Phi}\right)^2}, \quad (151)$$

$$\Delta\sigma_{202Tl}^{ind} = \sigma_{202Tl}^{ind} \cdot \sqrt{\left(\frac{\Delta R_{202Tl}^{ind}}{R_{202Tl}^{ind}}\right)^2 + \left(\frac{\Delta\Phi}{\Phi}\right)^2} \quad (152)$$

$$\Delta\sigma_{195Hg}^{cum_t} = \sigma_{195Hg}^{cum_t} \cdot \sqrt{\left(\frac{\Delta R_{195Hg}^{cum_t}}{R_{195Hg}^{cum_t}}\right)^2 + \left(\frac{\Delta\Phi}{\Phi}\right)^2} \quad (153)$$

The aggregate Table 9 has special columns (Yield type (calc)) showing the total number of the yields calculated. Table 8 presens the energies, at which the yields were calculated. The total number of the yields calculated is 311 that include 51 independent yields and 260 cumulative and supracumulative yields. All the calculated values are presented in the Tables of results. The results obtained have made it possible to plot 1024 excitation functions for 215 residual nuclides in the 0.04 - 2.6 GeV proton energy range, which are shown in Figs. 53 - 83.

Table 8: List of product measurements in each experiment.

Нуклид	Тип	$T_{1/2}$	Total	Энергия (ГэВ)											
				0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6	
²⁰⁷ Po	i(m+g)	5.80H	11	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁶ Po	i	8.8D	11	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁵ Po	i	1.66H	7	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁴ Po	i	3.53H	6	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰³ Po	i(m+g)	36.7M	4	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰² Po	i	44.7M	4	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰¹ Po	i(m+g)	15.3M	2	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁷ Bi	i	31.55Y	28	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰⁷ Bi	c	31.55Y	11	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁶ Bi	i	6.243D	55	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰⁶ Bi	c	6.243D	11	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁵ Bi	i	15.31D	44	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰⁵ Bi	c	15.31D	11	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁴ Bi	i	11.22H	48	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰⁴ Bi	c	11.22H	4	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
* ²⁰⁴ Bi	c	11.22H	2	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰⁴ Bi	c*	11.22H	6	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
* ²⁰⁴ Bi	c*	11.22H	4	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰³ Bi	i(m+g)	11.76H	44	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰³ Bi	c	11.76H	10	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰² Bi	i	1.72H	46	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰² Bi	c	1.72H	4	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰² Bi	c*	1.72H	6	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
* ²⁰² Bi	c*	1.72H	4	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
²⁰¹ Bi	i	108M	17	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰¹ Bi	c*	108M	3	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
¹⁹⁹ Bi	i	27M	8	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
¹⁹⁹ Bi	c*	27M	2	-----	+	-----	+	-----	+	-----	+	-----	+	-----	+
^{204m} Pb	i(m)	67.2M	51	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{204m} Pb	c	67.2M	48	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰³ Pb	i(m1+m2+g)	51.873H	21	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰³ Pb	c	51.873H	21	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
* ²⁰³ Pb	c	51.873H	33	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰³ Pb	c*	51.873H	34	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{202m} Pb	i(m)	3.53H	51	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰¹ Pb	i(m+g)	9.33H	9	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰¹ Pb	c	9.33H	9	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
* ²⁰¹ Pb	c	9.33H	8	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰¹ Pb	c*	9.33H	42	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
* ²⁰¹ Pb	c*	9.33H	9	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰⁰ Pb	c	21.5H	50	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁹ Pb	c*	90M	45	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁸ Pb	c	2.4H	44	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{197m} Pb	c*	43M	44	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁶ Pb	c*	37M	20	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{195m} Pb	i(m)	15.0M	35	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
* ²⁰² Tl	i	12.23D	51	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰² Tl	c	12.23D	54	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰¹ Tl	c	72.912H	4	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
* ²⁰¹ Tl	c	72.912H	13	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰¹ Tl	c*	72.912H	52	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰⁰ Tl	i	26.1H	49	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰⁰ Tl	c	26.1H	50	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁹ Tl	c	7.42H	19	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁹ Tl	c*	7.42H	49	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{198m} Tl	i(m)	1.87H	45	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
* ¹⁹⁷ Tl	c	2.84H	27	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁷ Tl	c*	2.84H	28	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{196m} Tl	i(m)	1.41H	43	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁵ Tl	c*	1.16H	19	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
²⁰³ Hg	c	46.612D	45	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{197m} Hg	i(m)	23.8H	40	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁷ Hg	c*	64.14H	18	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{195m} Hg	i(m)	41.6H	37	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
* ¹⁹⁵ Hg	ct	9.9H	19	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁵ Hg	c	9.9H	19	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{193m} Hg	i(m)	11.8H	39	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹² Hg	c	4.85H	39	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁰ Hg	c*	20.0M	35	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
^{198m} Au	i(m)	2.27D	30	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁸ Au	i(m+g)	2.69517D	34	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁸ Au	i	2.69517D	31	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁶ Au	i(m1+m2+g)	6.183D	43	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁵ Au	c	186.098D	43	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁴ Au	i(m1+m2+g)	38.02H	39	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹² Au	i(m+g)	4.94H	38	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹² Au	c	4.94H	39	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹¹ Au	c*	3.18H	31	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹⁰ Au	c	42.8M	34	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁹¹ Pt	c	2.802D	35	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁸⁹ Pt	c	10.87H	35	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+
¹⁸⁸ Pt	c	10.2D	35	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+	+++++	+

Continuation of Table 8.

Нуклид	Тип	$T_{1/2}$	Total	Энергия (ГэВ)										
				0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
¹⁸⁷ Pt	c	2.35H	14	-----	-----	-----	-----	-----	+++++	+++++	+++++	-----	-----	-----
¹⁸⁶ Pt	c	2.08H	34	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸⁴ Pt	c	17.3M	24	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	-----
¹⁹² Ir	i(m1+g)	73.827D	19	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	-----
¹⁹⁰ Ir	i(m1+g)	11.78D	21	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	-----
¹⁸⁹ Ir	c	13.2D	35	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸⁸ Ir	i	41.5H	22	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	-----
¹⁸⁸ Ir	c	41.5H	34	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸⁷ Ir	c*	10.5H	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸⁶ Ir	c	16.64H	34	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸⁵ Ir	c	14.4H	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸⁴ Ir	c*	3.09H	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸³ Ir	c	57M	14	-----	-----	-----	-----	-----	+++++	+++++	+++++	-----	-----	-----
¹⁸⁵ Os	c	93.6D	35	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
^{183m} Os	c*	9.9H	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸² Os	c	22.10H	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸¹ Os	c	105M	14	-----	-----	-----	-----	-----	+++++	+++++	+++++	-----	-----	-----
¹⁸⁰ Os	c	21.5M	29	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁸³ Re	c	70.0D	35	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
^{182m} Re	c	12.7H	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
* ¹⁸¹ Re	c	19.9H	14	-----	-----	-----	-----	-----	+++++	+++++	+++++	-----	-----	-----
¹⁸¹ Re	c*	19.9H	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁹ Re	c*	19.5M	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁸ Re	c*	13.2M	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁸ W	c	21.6D	22	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	-----
¹⁷⁷ W	c	135M	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁶ W	c	2.5H	12	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	-----
* ¹⁷⁷ Ta	c	56.56H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁷ Ta	c*	56.56H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁶ Ta	c	8.09H	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁶ Ta	c*	8.09H	5	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁵ Ta	c	10.5H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁴ Ta	c	1.14H	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷³ Ta	c	3.14H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷² Ta	c*	36.8M	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁵ Hf	c	70D	31	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
* ¹⁷³ Hf	c	23.6H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷³ Hf	c*	23.6H	26	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷² Hf	c	1.87Y	27	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷¹ Hf	c	12.1H	12	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁰ Hf	c	16.01H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁸ Hf	c	25.95M	2	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷³ Lu	c	1.37Y	30	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷² Lu	i(m+g)	6.70D	14	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷² Lu	c	6.70D	27	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷¹ Lu	c*	8.24D	29	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷¹ Lu	c	8.24D	12	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁰ Lu	c	2.012D	13	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
* ¹⁷⁰ Lu	c	2.012D	12	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁷⁰ Lu	c*	2.012D	13	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁹ Lu	c	34.06H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁷ Lu	c	51.5M	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
* ¹⁶⁹ Yb	c	32.026D	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁹ Yb	c*	32.026D	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁶ Yb	c	56.7H	24	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶² Yb	c	18.87M	3	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁷ Tm	c	9.25D	24	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁵ Tm	c	30.06H	25	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶³ Tm	c	1.810H	3	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶¹ Er	c*	3.21H	19	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁶⁰ Er	c	28.58H	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵⁹ Er	c*	36M	15	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
^{160m} Ho	c	5.02H	19	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵⁶ Ho	c*	56M	15	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵⁷ Dy	c	8.14H	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵⁵ Dy	c*	9.9H	19	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵² Dy	c	2.38H	14	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵⁵ Tb	c*	5.32D	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵³ Tb	c*	2.34D	19	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵² Tb	c	17.5H	4	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
* ¹⁵² Tb	c	17.5H	10	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵² Tb	c*	17.5H	10	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵¹ Tb	c	17.609H	14	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵⁰ Tb	c	3.48H	3	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁴⁹ Tb	c	4.118H	10	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁴⁸ Tb	c	60M	10	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵³ Gd	c	240.4D	19	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁵¹ Gd	c	124D	15	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁴⁹ Gd	c	9.28D	24	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁴⁷ Gd	c	38.06H	15	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁴⁶ Gd	c	48.27D	20	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
* ¹⁴⁹ Eu	c	93.1D	15	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++
¹⁴⁹ Eu	c*	93.1D	15	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++

Continuation of Table 8.

Нуклид	Тип	$T_{1/2}$	Total	Энергия (ГэВ)											
				0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6	
* ¹⁴⁷ Bu	c	24.1D	15	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	
¹⁴⁷ Bu	c*	24.1D	15	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	
¹⁴⁶ Bu	i	4.61D	20	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	
¹⁴⁶ Bu	c	4.61D	20	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	
¹⁴⁵ Bu	c	5.93D	15	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	
¹⁴³ Pm	c	265D	15	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	
¹³⁶ Nd	c	50.65M	5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	
¹³⁴ Pr	c*	17M	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----+	
¹³⁹ Ce	c	137.640D	36	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
¹³⁵ Ce	c	17.7H	10	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	
¹³⁴ Ce	c	3.16D	5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	
¹³² Ce	c	3.51H	10	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	
¹³⁰ Ce	c	25M	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----+	
¹³² La	c	4.8H	11	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	
¹³³ Ba	c	3848.9D	11	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	
¹³¹ Ba	c	11.50D	21	-----	-----	-----	-----	-----	-----	++++	-----	+++++	+++++	+++++	
¹²⁸ Ba	c	2.43D	15	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	
¹²⁹ Cs	c	32.06H	14	-----	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	
¹²⁷ Xe	c	36.4D	40	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
¹²⁵ Xe	c	16.9H	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----+	
¹²³ Xe	c	2.08H	11	-----	-----	-----	-----	-----	-----	-----	-----	-----	++++	+++++	
¹²⁶ I	i	13.11D	7	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	-----	
¹²⁴ I	i	4.1760D	3	-----	-----	-----	-----	-----	-----	++++	++++	++++	++++	-----	
¹²¹ I	c*	2.12H	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----+	
^{123m} Te	i(m)	119.7D	42	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
^{121m} Te	i(m)	154D	36	-----	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	
¹²¹ Te	c	19.16D	35	-----	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	
^{119m} Te	i(m)	4.70D	26	-----	-----	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	
¹¹⁹ Te	c	16.05H	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----+	
¹¹⁶ Te	c	2.49H	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	++++	+++++	
¹²⁴ Sb	i(m1+m2+g)	60.20D	29	-----	++++	++++	+++++	+++++	+++++	++++	++++	++++	-----	-----	
¹²² Sb	i(m+g)	2.7238D	3	-----	-----	-----	++++	++++	++++	++++	++++	++++	-----	-----	
^{120m} Sb	i(m)	5.76D	43	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
^{118m} Sb	i(m)	5.00H	4	-----	-----	-----	-----	-----	++++	-----	++++	++++	++++	++++	
¹¹⁵ Sb	c*	32.1M	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	++++	++++	
^{117m} Sn	i(m)	13.60D	8	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	
¹¹³ Sn	c	115.09D	29	-----	-----	-----	-----	++++	++++	+++++	+++++	+++++	+++++	+++++	
^{114m} In	i(m)	49.51D	36	-----	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	
¹¹¹ In	c	2.8047D	23	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	
¹¹⁰ In	i	4.9H	4	-----	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	
¹⁰⁹ In	c	4.2H	5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	
¹¹⁵ Cd	c	53.46H	5	-----	-----	++++	-----	++++	++++	++++	++++	-----	-----	-----	
^{110m} Ag	i(m)	249.76D	43	-----	-----	++++	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
^{106m} Ag	i(m)	8.28D	31	-----	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	
¹⁰⁵ Ag	c	41.29D	18	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	
¹⁰⁰ Pd	c	3.63D	17	-----	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	
¹⁰⁷ Rh	c	21.7M	3	-----	-----	++++	++++	++++	++++	++++	++++	++++	++++	++++	
¹⁰⁵ Rh	c	35.36H	29	-----	-----	++++	++++	+++++	+++++	+++++	+++++	+++++	-----	-----	
^{102m} Rh	i(m)	2.9Y	5	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	-----	
¹⁰² Rh	i	207D	27	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	
^{101m} Rh	c	4.34D	35	-----	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	
¹⁰¹ Rh	c	3.3Y	1	-----	-----	-----	-----	-----	++++	-----	-----	-----	-----	-----	
¹⁰⁰ Rh	i(m+g)	20.8H	17	-----	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	
¹⁰⁰ Rh	c	20.8H	17	-----	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	
^{99m} Rh	c	4.7H	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	++++	
¹⁰⁶ Ru	c	373.59D	4	-----	-----	++++	++++	++++	++++	++++	++++	-----	-----	-----	
¹⁰³ Ru	c	39.26D	51	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
⁹⁶ Tc	i(m+g)	4.28D	31	-----	-----	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	
⁹⁹ Mo	c	65.94H	42	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
^{93m} Mo	i(m)	6.85H	12	-----	-----	-----	-----	-----	-----	-----	++++	-----	++++	++++	
⁹⁶ Nb	i	23.35H	42	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
⁹⁵ Nb	i(m+g)	34.975D	43	-----	++++	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	-----	
⁹⁵ Nb	c	34.975D	51	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
^{92m} Nb	i(m)	10.15D	16	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	-----	
⁹⁰ Nb	c*	14.60H	17	-----	-----	-----	-----	-----	-----	++++	-----	++++	++++	++++	
⁹⁷ Zr	c	16.744H	34	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	++++	-----	-----	
⁹⁵ Zr	c	64.02D	51	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
⁸⁹ Zr	c	78.41H	35	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	
⁸⁸ Zr	c	83.4D	36	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	++++	
^{90m} Y	i(m)	3.19H	19	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	-----	
⁸⁸ Y	i	106.65D	37	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	++++	
⁸⁸ Y	c	106.65D	38	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	++++	
⁸⁷ Y	c*	79.8H	35	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	
⁸⁶ Y	c	14.74H	12	-----	-----	-----	-----	-----	-----	-----	-----	++++	++++	++++	
⁸⁵ Sr	c	64.84D	35	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	
⁸⁶ Rb	i(m+g)	18.631D	22	-----	-----	-----	++++	++++	++++	++++	++++	-----	-----	-----	
⁸⁴ Rb	i(m+g)	32.77D	25	-----	-----	-----	++++	++++	++++	-----	-----	-----	++++	++++	
⁸³ Rb	c	86.2D	36	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	++++	
^{82m} Rb	i(m)	6.472H	20	-----	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	
⁸² Br	i(m+g)	35.30H	41	-----	-----	++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	
⁷⁵ Se	c	119.779D	34	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	
⁷⁶ As	i	1.0778D	6	-----	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	
⁷⁴ As	i	17.77D	35	-----	-----	-----	-----	++++	++++	++++	++++	++++	++++	++++	

Continuation of Table 8.

Нуклид	Тип	$T_{1/2}$	Total	Энергия (ГэВ)										
				0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
⁷¹ As	c	65.28H	15	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++
⁷² Ga	i	14.10H	31	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	-----+
⁷² Ga	c	14.10H	31	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	-----+
⁷² Zn	c	46.5H	31	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	-----+
⁶⁵ Zn	c	244.26D	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
⁵⁸ Co	i(m+g)	70.86D	10	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++
⁵⁶ Co	c	77.233D	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----+
⁵⁹ Fe	c	44.472D	34	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++	+++++	+++++
⁵⁴ Mn	i	312.11D	20	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++
⁵² Mn	c	5.591D	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----+
⁴⁸ V	c	15.9735D	15	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++
⁴⁸ Sc	i	43.67H	16	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++
⁴⁶ Sc	i(m+g)	83.79D	26	-----	-----	-----	-----	-----	-----	+++++	+++++	+++++	+++++	+++++
²⁸ Mg	c	20.915H	9	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++
²⁴ Na	c	14.9590H	11	-----	-----	-----	-----	-----	-----	-----	-----	-----	+++++	+++++
⁷ Be	i	53.29D	27	-----	-----	-----	-----	-----+	-----+	+++++	+++++	+++++	+++++	+++++

Table 9: Number of measured reaction product yields of different types in each experiment.

Experiment	Yield type (measured)							Yield type (calc)				Total
	c*	c	i	i(m+g)	i(m)	i(m1+m2+g)	i(m1+g)	c*	c	i	c _t	
²⁰⁶ Pb, E _p =0.04GeV	1	3	4	1	2	1	—	—	—	1	—	13
²⁰⁷ Pb, E _p =0.04GeV	—	3	4	1	—	1	—	—	—	—	—	9
²⁰⁸ Pb, E _p =0.04GeV	—	2	4	1	—	1	—	—	—	—	—	8
^{nat} Pb, E _p =0.04GeV	1	5	6	2	1	1	—	1	1	—	—	18
²⁰⁹ Bi, E _p =0.04GeV	1	6	3	2	1	—	—	—	—	—	—	13
²⁰⁶ Pb, E _p =0.07GeV	2	10	6	2	3	2	—	1	1	1	—	28
²⁰⁷ Pb, E _p =0.07GeV	2	11	7	2	2	2	—	1	1	1	—	29
²⁰⁸ Pb, E _p =0.07GeV	2	11	7	2	2	1	—	1	1	1	—	28
^{nat} Pb, E _p =0.07GeV	2	11	7	2	2	1	—	1	1	1	—	28
²⁰⁹ Bi, E _p =0.07GeV	3	16	7	3	1	1	—	2	1	1	—	35
²⁰⁶ Pb, E _p =0.1GeV	6	14	9	3	7	3	—	1	2	1	—	46
²⁰⁷ Pb, E _p =0.1GeV	5	14	8	3	5	3	—	1	2	1	—	42
²⁰⁸ Pb, E _p =0.1GeV	4	12	8	3	3	3	—	1	1	1	—	36
^{nat} Pb, E _p =0.1GeV	6	14	8	3	5	3	—	1	2	1	—	43
²⁰⁹ Bi, E _p =0.1GeV	6	20	9	6	4	2	—	2	—	1	—	50
²⁰⁶ Pb, E _p =0.15GeV	10	19	10	6	12	3	—	—	3	1	1	65
²⁰⁷ Pb, E _p =0.15GeV	10	19	11	5	12	3	—	—	3	1	1	65
²⁰⁸ Pb, E _p =0.15GeV	10	17	10	6	12	3	—	—	3	1	1	63
^{nat} Pb, E _p =0.15GeV	10	17	10	6	12	3	—	—	3	1	1	63
²⁰⁹ Bi, E _p =0.15GeV	10	26	10	8	11	2	—	2	1	1	—	71
²⁰⁶ Pb, E _p =0.25GeV	13	39	12	7	14	3	—	—	4	1	1	94
²⁰⁷ Pb, E _p =0.25GeV	13	38	13	7	14	3	—	—	4	1	1	94
²⁰⁸ Pb, E _p =0.25GeV	13	38	13	7	14	3	—	—	4	1	1	94
^{nat} Pb, E _p =0.25GeV	13	39	13	7	14	3	—	—	4	1	1	95
²⁰⁹ Bi, E _p =0.25GeV	14	44	13	9	17	4	—	2	1	1	1	106
²⁰⁶ Pb, E _p =0.4GeV	18	49	12	8	17	3	1	—	2	1	1	112
²⁰⁷ Pb, E _p =0.4GeV	18	49	13	8	17	2	1	—	2	1	1	112
²⁰⁸ Pb, E _p =0.4GeV	18	48	13	8	17	3	2	—	2	1	1	113
^{nat} Pb, E _p =0.4GeV	18	51	13	8	17	3	2	—	2	1	1	116
²⁰⁹ Bi, E _p =0.4GeV	20	58	14	7	20	4	—	—	3	1	1	128
²⁰⁶ Pb, E _p =0.6GeV	23	64	13	8	18	2	2	—	7	1	1	139
²⁰⁷ Pb, E _p =0.6GeV	23	64	13	8	18	3	2	—	7	1	1	140
²⁰⁸ Pb, E _p =0.6GeV	23	64	14	8	18	3	2	—	7	1	1	141
^{nat} Pb, E _p =0.6GeV	23	64	14	8	18	3	2	—	7	1	1	141
²⁰⁹ Bi, E _p =0.6GeV	26	66	14	8	20	4	—	—	7	1	1	147

Continuation of Table 9.

Experiment	Yield type (measured)							Yield type (calc)				Total
	c*	c	i	i(m+g)	i(m)	i(m1+m2+g)	i(m1+g)	c*	c	i	c _t	
²⁰⁶ Pb, E _p =0.8GeV	25	76	15	9	19	3	2	–	6	1	–	156
²⁰⁷ Pb, E _p =0.8GeV	25	74	15	8	19	2	2	–	6	1	–	152
²⁰⁸ Pb, E _p =0.8GeV	25	74	16	8	19	3	2	–	6	1	–	154
^{nat} Pb, E _p =0.8GeV	25	74	16	8	19	3	2	–	6	1	–	154
²⁰⁹ Bi, E _p =0.8GeV	27	77	16	9	23	3	–	–	6	1	–	162
²⁰⁶ Pb, E _p =1.2GeV	30	86	16	9	17	2	2	–	7	1	–	170
²⁰⁷ Pb, E _p =1.2GeV	30	86	16	9	17	2	2	–	7	1	–	170
²⁰⁸ Pb, E _p =1.2GeV	30	86	16	9	17	2	2	–	7	1	–	170
^{nat} Pb, E _p =1.2GeV	30	86	17	9	17	2	2	–	7	1	–	171
²⁰⁹ Bi, E _p =1.2GeV	33	94	13	9	22	3	–	–	8	1	–	183
²⁰⁶ Pb, E _p =1.6GeV	30	94	15	11	18	2	2	–	7	1	–	180
²⁰⁷ Pb, E _p =1.6GeV	30	94	15	11	18	2	2	–	7	1	–	180
²⁰⁸ Pb, E _p =1.6GeV	30	94	17	11	18	2	2	–	7	1	–	182
^{nat} Pb, E _p =1.6GeV	30	93	17	11	18	2	2	–	7	1	–	181
²⁰⁹ Bi, E _p =1.6GeV	36	101	14	10	18	3	–	–	9	1	–	192
²⁰⁶ Pb, E _p =2.6GeV	28	94	14	10	16	2	–	–	6	1	–	171
²⁰⁷ Pb, E _p =2.6GeV	28	94	14	10	16	2	–	–	6	1	–	171
²⁰⁸ Pb, E _p =2.6GeV	28	94	15	10	16	2	–	–	6	1	–	172
^{nat} Pb, E _p =2.6GeV	28	97	16	10	16	2	2	–	6	1	–	178
²⁰⁹ Bi, E _p =2.6GeV	37	107	13	10	19	3	–	–	8	1	–	198
Total	952	2800	651	374	712	132	40	17	224	51	19	5972

3.1 Errors in experimental results

Determination of errors in the residual nuclide cross sections and in the energies at which they are produced forms an important part of any experimental work. This issue is particularly topical in this work because not only the the cross sections for production of residual products from $^{208,207,206,nat}\text{Pb}$ and ^{209}Bi are experimentally determined in the 40 - 2600 MeV range, but also the predictive power of certain theoretical codes to describe the respective excitation functions is estimated. Therefore, the uncertainties in both energies and cross sections have been analyzed carefully.

The proton energy uncertainty is produced by the U-10 synchrotron operation and by the geometric parameters of transport channel that provides the 40 MeV < E < 3000 MeV proton beam extraction. The proton energy uncertainties are listed in Table 4.

The uncertainty in the cross sections for production of residual nuclei is due to the following two factors. The first arises from the technical performances of the materials and equipment used, namely, γ -spectrometer operation [16], the certification accuracy of the γ -sources used for calibrating, the accuracy of the analytical BP-61 balance, and by the certification accuracy of the compositions of materials used in irradiations. The second factor arises from the nuclear data uncertainty in different databases and reference sources used:

- ENSDF [35],
- PCNUDAT [33],
- Tables of Isotopes (8th Edition) [34],
- Photon cross section from 1 keV to 100 MeV for elements Z=1 to Z=100, [5],
- Original works (cross sections of the $^{27}\text{Al}(\text{p},\text{x})^{22}\text{Na}$ monitor reaction [43]).

The errors in the presented cross sections for production of residuals consist of the errors in their production rates and the errors in determining the proton flux densities.

Systematization of the uncertainties in the cofactors that enter the rates of residual nuclide production in experimental samples and in monitor, as well as their relative contribution to the total error, are presented in Tables 10 and 11. The comparative analysis of separate sources of the uncertainties (see Tables 10 and 11) demonstrates that the significance of the sources varies largely.

In the case of experimental samples, the major uncertainties of reaction rates are represented by statistical error, by absolute spectrometer effectiveness, and by uncertainty in absolute abundance, but the absolute spectrometer effectiveness alone counts in uncertainties of the monitoring reaction rates.

The uncertainty in proton flux density is determined solely by the monitoring reaction cross section uncertainty.

The uncertainties were disregarded if they arose from sample composition uncertainties, from uncertainty in the correction that allows for production of measured nuclides by secondaries (see 2.5.4, 2.5.2.2), from uncertainty in the decay constant, from uncertainties in irradiation

time, decay time, and measurement time (t_{irr}, t_d, t), and from uncertainty in proton flux constancy throughout irradiation time.

As a result, the uncertainty of experimental determining the presented yields (cross sections for production) of radioactive residuals is ranging from 7.5 to 72.3% with average value 11.5%. The distributions of uncertainties of reaction rates and of cross sections are shown in Fig. 25.

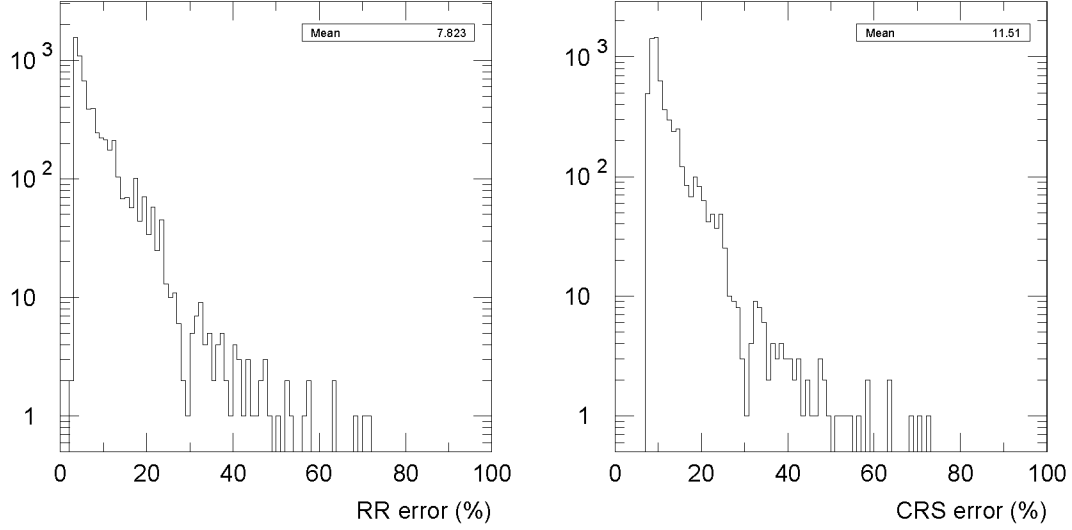


Fig. 25: Distributions of uncertainties of reaction rates (left panel) and of cross sections (right panel).

Table 10: The uncertainties in the values used to calculate the reaction rates in the samples together with their relative contribution to the total uncertainty.

Uncertainty source	Absolute uncertainty (%)	Percentage in the total uncertainty
PROTON ENERGY UNCERTAINTIES		
Uncertainty of proton energy determination allowing for geometric dimensions of transport channel and of samples (see 2.5.2.1, табл. 4), (E)		
$E_p > 70$ MeV	0.25 – 0.91	100
$E_p \leq 70$ MeV	0.87 – 3.72	100
UNCERTAINTIES IN MEASURED REACTION RATES IN SAMPLES		
Statistical error of count rate in total absorption peak with due allowance for correction of unresolved γ -lines (see 2.1), background under the peak, and γ -spectrum transients (see 2.6), and allowing for the dead time and count loss of the spectrometer (see 2.6.1), (A, B, C)	0.05 – 71.82	0.02 – 99.75
Uncertainty of correction for γ -quantum absorption in a sample (see 2.1), k_μ	0.00 – 5.07	0.00 – 52.42
Uncertainty of absolute detection effectiveness of spectrometer (see 2.6.1), (ε^E)	3.25 – 4.32	0.23 – 100.00
Uncertainty of relative detection effectiveness of spectrometer (ε_{rel}^E) and of relative-to-absolute effectiveness scaling factor ($k_{\varepsilon_{rel}^E}$) (see 2.6.1)	1.04 – 3.03 0.71	0.03 – 42.10 0.01 – 4.69
Uncertainty of absolute quantum yield of γ -lines, (η)	0.00 – 16.67	0.00 – 94.48
Uncertainty of absolute-to-relative γ -line quantum yield scaling factor, (k_γ)		
Uncertainty of the number of experimental sample nuclei	0.03 – 0.10	0.00 – 0.08
Total uncertainty	3.28 – 71.95	100

Table 11: The uncertainties in the values used to calculate the reaction rates in the monitors together with their relative contribution to the total uncertainty. Uncertainty of proton flux.

Uncertainty source	Absolute uncertainty (%)	Percentage in the total uncertainty
PROTON ENERGY UNCERTAINTIES		
Uncertainty of proton energy determination allowing for geometric dimensions of transport channel and of samples and monitors (see 2.5.2.1, табл. 4), (E)		
$E_p > 70$ MeV	0.25 – 0.92	100
$E_p \leq 70$ MeV	1.18 – 3.66	100
UNCERTAINTIES IN MEASURED REACTION RATES IN MONITORS		
Statistical error of count rate in total absorption peak with due allowance for correction of unresolved γ -lines (see 2.1), background under the peak, and γ -spectrum transients (see 2.6), and allowing for the dead time and count loss of the spectrometer (see 2.6.1), (A, B, C)	0.57 – 1.39	2.90 – 14.99
Uncertainty of correction for γ -quantum absorption in a sample (see 2.1), k_μ	0.01 – 0.04	0.00 – 0.01
Uncertainty of absolute detection effectiveness of spectrometer (see 2.6.1), (ε^E)	3.31	85.01 – 97.63
Uncertainty of absolute quantum yield of γ -lines, (η)	0.01	0.00
Uncertainty of the number of experimental sample nuclei	0.03 – 0.10	0.01 – 0.08
Total uncertainty	3.35 – 3.59	100
UNCERTAINTIES IN PROTON FLUX		
Uncertainty of monitoring reaction cross section σ^{22Na}	6.00 – 9.05	74.83 – 87.76
Total uncertainty	6.87 – 9.66	100

3.2 Experimental results for 0.04 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 12 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.04GeV protons. Table 13 presents values of the measured residual nuclide yields.

Table 12: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ -specra sample/monitor/plate	ExpData index
^{nat} Pb	38.0±1.0	207.6	121.1	714.5	90	1.39±0.12	24/11/1	pbn040
²⁰⁸ Pb	38.3±0.8	137.8	121.3	708.8	75	1.95±0.15	20/12/1	pb8040
²⁰⁷ Pb	38.4±0.7	127.6	121.0	706.0	90	2.11±0.16	23/08/1	pb7040
²⁰⁶ Pb	38.3±0.8	141.9	120.8	702.4	75	2.08±0.16	23/09/1	pb6040

Table 13: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 0.04$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	–	30.2±3.9	89.4±7.3	51.2±4.5
²⁰⁶ Bi	i	6.243D	26.9±2.3	82.6±7.0	197±17	130±12
²⁰⁵ Bi	i	15.31D	119±10	328±28	1059±91	659±60
²⁰⁴ Bi	i	11.22H	285±24	961±84	46.6±4.2	286±26
²⁰³ Bi	i(m+g)	11.76H	933±79	44.2±3.7	9.34±0.78	253±23
²⁰² Bi	i	1.72H	0.854±0.124	–	–	6.76±0.63
²⁰¹ Bi	i	108M	–	–	–	10.7±1.0
^{204m} Pb	i(m)	67.2M	34.3±3.0	–	–	11.3±1.2
^{204m} Pb	c	67.2M	76.8±6.6	–	–	54.0±4.9
²⁰³ Pb	i(m1+m2+g)	51.873H	34.1±4.0	4.52±1.10	0.333±0.075	11.4±1.5
²⁰³ Pb	c	51.873H	965±78	47.9±3.9	9.72±0.79	267±23
^{202m} Pb	i(m)	3.53H	0.755±0.292	–	–	–
²⁰¹ Pb	i(m+g)	9.33H	–	–	–	1.16±0.55
²⁰¹ Pb	c	9.33H	–	–	–	11.9±1.3
* ²⁰¹ Pb	c*	9.33H	–	–	–	14.4±1.5
* ²⁰² Tl	i	12.23D	5.04±0.44	–	–	–
²⁰² Tl	c	12.23D	5.11±0.42	4.65±0.37	0.474±0.056	2.56±0.22
* ²⁰¹ Tl	c	72.912H	–	–	–	12.7±1.2
²⁰¹ Tl	c*	72.912H	6.46±0.59	–	–	14.4±1.3
²⁰³ Hg	c	46.612D	–	0.091±0.063	–	0.047±0.025

3.3 Experimental results for 0.07 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 14 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.07GeV protons. Table 15 presents values of the measured residual nuclide yields.

Table 14: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-spectra sample/monitor/plate	ExpData index
^{nat} Pb	68.9 ± 0.8	194.1	121.3	707.5	75	0.840 ± 0.060	22/13/1	pbn070
²⁰⁸ Pb	69.1 ± 0.7	135.8	121.1	708.5	60	2.31 ± 0.16	20/11/1	pb8070
²⁰⁷ Pb	68.8 ± 0.7	155.2	120.2	718.2	75	2.41 ± 0.17	21/11/1	pb7070
²⁰⁶ Pb	69.0 ± 0.7	140.5	120.4	711.2	60	2.07 ± 0.15	22/10/1	pb6070

Table 15: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 0.07$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	–	14.6±1.3	36.5±3.0	30.5±5.0
²⁰⁶ Bi	i	6.243D	13.4±1.1	37.1±2.9	57.8±4.6	46.3±3.6
²⁰⁵ Bi	i	15.31D	45.1±3.6	83.9±6.7	103±8	93.9±7.4
²⁰⁴ Bi	i	11.22H	71.8±5.6	106±8	122±9	121±9
²⁰³ Bi	i(m+g)	11.76H	124±10	179±14	255±20	269±21
²⁰² Bi	i	1.72H	175±14	327±26	370±29	305±24
²⁰¹ Bi	i	108M	410±32	370±29	27.8±2.2	187±14
^{204m} Pb	i(m)	67.2M	41.3±3.3	57.0±4.5	54.0±4.4	54.8±4.3
^{204m} Pb	c	67.2M	51.9±4.1	72.8±5.7	72.2±5.8	72.9±5.7
²⁰³ Pb	i(m1+m2+g)	51.873H	138±10	136±10	98.6±7.8	110±13
²⁰³ Pb	c	51.873H	264±20	317±23	355±26	388±29
^{202m} Pb	i(m)	3.53H	47.5±3.9	43.3±3.6	19.9±2.4	28.7±2.5
²⁰¹ Pb	i(m+g)	9.33H	80.8±8.8	31.4±4.1	5.08±1.41	32.3±4.3
²⁰¹ Pb	c	9.33H	497±48	406±39	33.2±3.2	222±21
* ²⁰¹ Pb	c*	9.33H	595±56	494±46	39.8±3.7	267±25
²⁰⁰ Pb	c	21.5H	253±20	15.0±1.2	2.41±0.19	49.6±3.8
* ²⁰² Tl	i	12.23D	4.74±0.51	4.35±0.47	4.50±0.44	4.97±0.47
²⁰² Tl	c	12.23D	9.26±0.69	8.46±0.63	6.40±0.48	7.70±0.57
* ²⁰¹ Tl	c	72.912H	529±44	434±36	43.6±3.7	238±20
²⁰¹ Tl	c*	72.912H	602±45	493±37	48.4±3.7	271±20
²⁰⁰ Tl	i	26.1H	10.1±1.8	11.3±1.0	10.1±0.8	12.4±1.4
²⁰⁰ Tl	c	26.1H	255±20	26.1±2.1	12.4±1.0	60.7±4.8
¹⁹⁹ Tl	c*	7.42H	12.9±1.4	11.6±1.1	4.92±0.86	16.4±1.5
^{198m} Tl	i(m)	1.87H	8.56±0.73	–	–	–
²⁰³ Hg	c	46.612D	0.050±0.013	0.297±0.024	0.518±0.041	0.354±0.056
¹²⁴ Sb	i(m1+m2+g)	60.20D	0.106±0.018	0.077±0.017	–	–
¹⁰³ Ru	c	39.26D	1.68±0.13	1.33±0.10	0.848±0.067	1.18±0.09
⁹⁵ Nb	c	34.975D	1.62±0.12	1.29±0.09	0.847±0.080	1.06±0.10
⁹⁷ Zr	c	16.744H	–	1.35±0.11	1.02±0.09	1.10±0.10

Continuation of Table 15.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{95}Zr	c	64.02D	1.59 ± 0.12	1.22 ± 0.09	0.749 ± 0.058	1.01 ± 0.08

3.4 Experimental results for 0.1 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 16 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.1GeV protons. Table 17 presents values of the measured residual nuclide yields.

Table 16: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-specra sample/monitor/plate	ExpData index
^{nat} Pb	99.3 ± 0.8	201.0	123.1	702.8	40	1.43 ± 0.10	32/11/1	pbn100
²⁰⁸ Pb	99.5 ± 0.8	138.7	121.2	701.3	45	2.38 ± 0.17	26/11/1	pb8100
²⁰⁷ Pb	99.6 ± 0.8	148.1	120.3	709.0	35	2.03 ± 0.14	25/11/1	pb7100
²⁰⁶ Pb	99.5 ± 0.8	142.0	120.8	712.3	45	2.74 ± 0.19	27/11/1	pb6100

Table 17: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for E_p = 0.1 GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	2.27±1.12	11.0±1.5	26.7±3.2	14.8±1.9
²⁰⁶ Bi	i	6.243D	8.93±0.69	24.8±1.9	42.6±3.3	29.4±2.3
²⁰⁵ Bi	i	15.31D	29.8±2.3	52.8±4.1	67.1±5.2	53.0±4.1
²⁰⁴ Bi	i	11.22H	43.2±3.3	56.6±4.3	67.2±5.1	58.0±4.4
²⁰³ Bi	i(m+g)	11.76H	62.2±4.7	81.6±6.2	90.6±6.9	82.0±6.2
²⁰² Bi	i	1.72H	73.8±5.8	90.5±7.1	105±8	95.0±7.4
²⁰¹ Bi	i	108M	97.5±7.4	125±9	139±11	129±10
¹⁹⁹ Bi	i	27M	106±9	130±11	68.4±7.6	113±11
^{204m} Pb	i(m)	67.2M	33.3±2.6	44.5±3.5	53.1±4.1	47.6±3.7
^{204m} Pb	c	67.2M	39.7±3.1	52.9±4.1	63.1±4.9	56.2±4.4
²⁰³ Pb	i(m1+m2+g)	51.873H	121±9	121±10	129±10	124±10
²⁰³ Pb	c	51.873H	181±13	204±15	219±16	205±15
^{202m} Pb	i(m)	3.53H	38.6±3.7	46.0±4.4	51.6±4.5	46.5±4.2
²⁰¹ Pb	i(m+g)	9.33H	120±12	109±11	106±10	109±11
²⁰¹ Pb	c	9.33H	218±21	237±23	247±23	239±23
* ²⁰¹ Pb	c*	9.33H	242±23	267±25	280±26	270±25
²⁰⁰ Pb	c	21.5H	243±19	266±21	275±21	268±21
¹⁹⁹ Pb	c*	90M	489±47	455±39	212±18	334±29
¹⁹⁸ Pb	c	2.4H	292±23	99.8±8.2	—	106±8
^{197m} Pb	c*	43M	31.8±4.7	2.68±0.63	—	12.6±1.2
* ²⁰² Tl	i	12.23D	13.0±1.1	13.5±1.2	12.0±1.1	12.4±1.1
²⁰² Tl	c	12.23D	16.7±1.2	17.8±1.3	16.9±1.2	16.8±1.2
* ²⁰¹ Tl	c	72.912H	247±24	271±26	281±25	270±24
²⁰¹ Tl	c*	72.912H	279±25	305±27	317±27	305±26
²⁰⁰ Tl	i	26.1H	31.5±3.5	25.7±3.5	21.4±3.2	21.5±2.3
²⁰⁰ Tl	c	26.1H	224±17	245±19	249±19	237±18
¹⁹⁹ Tl	c*	7.42H	320±25	308±24	146±12	225±18
^{198m} Tl	i(m)	1.87H	8.02±0.71	8.74±1.19	11.8±1.6	10.7±0.9
* ¹⁹⁷ Tl	c	2.84H	63.9±24.3	23.5±8.0	—	36.4±13.2

Continuation of Table 17.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{197}Tl	c*	2.84H	74.6±24.3	24.4±8.0	18.1±6.0	40.6±13.2
^{196m}Tl	i(m)	1.41H	27.0±5.0	22.5±4.2	—	14.6±2.7
^{203}Hg	c	46.612D	0.141±0.020	0.514±0.051	0.921±0.070	0.703±0.063
^{197}Hg	c*	64.14H	55.8±4.9	—	—	30.2±5.5
^{196}Au	i(m1+m2+g)	6.183D	0.079±0.010	0.095±0.024	0.118±0.022	0.095±0.032
^{195}Au	c	186.098D	12.3±1.4	3.19±0.47	—	5.76±0.76
^{123m}Te	i(m)	119.7D	0.146±0.014	—	—	—
^{124}Sb	i(m1+m2+g)	60.20D	0.178±0.018	0.191±0.024	0.206±0.026	0.223±0.033
^{120m}Sb	i(m)	5.76D	0.111±0.010	—	—	0.704±0.130
^{110m}Ag	i(m)	249.76D	0.287±0.030	0.236±0.041	—	—
^{103}Ru	c	39.26D	3.51±0.26	2.97±0.22	2.28±0.18	2.73±0.21
^{99}Mo	c	65.94H	4.12±0.32	3.55±0.28	2.98±0.23	3.19±0.25
^{96}Nb	i	23.35H	1.09±0.12	—	—	—
^{95}Nb	i(m+g)	34.975D	0.493±0.037	0.327±0.031	0.068±0.043	0.206±0.043
^{95}Nb	c	34.975D	3.52±0.25	2.93±0.21	2.32±0.18	2.75±0.20
^{97}Zr	c	16.744H	1.59±0.12	1.55±0.13	1.59±0.14	1.63±0.12
^{95}Zr	c	64.02D	3.04±0.23	2.53±0.19	2.15±0.16	2.42±0.18

3.5 Experimental results for 0.15 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 18 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.15GeV protons. Table 19 presents values of the measured residual nuclide yields.

Table 18: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-specra sample/monitor/plate	ExpData index
^{nat} Pb	149 ± 1	104.9	146.6	704.8	60	1.58 ± 0.12	36/13/1	pbn150
²⁰⁸ Pb	149 ± 1	139.0	144.2	702.3	45	4.23 ± 0.31	26/08/1	pb8150
²⁰⁷ Pb	149 ± 1	139.3	122.0	701.5	40	3.54 ± 0.26	26/10 /1	pb7150
²⁰⁶ Pb	149 ± 1	141.3	143.2	721.8	45	4.25 ± 0.31	24/08/1	pb6150

Table 19: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for E_p = 0.15 GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	–	7.78±1.23	18.6±1.7	10.9±1.3
²⁰⁶ Bi	i	6.243D	6.02±0.49	15.3±1.2	25.9±2.1	17.6±1.4
²⁰⁵ Bi	i	15.31D	19.8±1.6	31.0±2.5	37.6±3.0	30.6±2.5
²⁰⁴ Bi	i	11.22H	26.7±2.1	31.6±2.5	35.2±2.8	30.4±2.4
²⁰³ Bi	i(m+g)	11.76H	38.1±3.1	40.7±3.3	42.8±3.4	39.7±3.2
²⁰² Bi	i	1.72H	38.4±3.2	40.4±3.3	42.7±3.5	39.8±3.2
²⁰¹ Bi	i	108M	41.7±4.3	38.8±4.3	49.3±5.2	41.1±4.2
¹⁹⁹ Bi	i	27M	31.8±3.0	29.1±3.4	37.6±4.7	33.3±3.6
^{204m} Pb	i(m)	67.2M	23.9±2.1	29.9±2.5	36.5±3.0	30.4±2.5
^{204m} Pb	c	67.2M	27.9±2.3	34.6±2.8	41.8±3.4	35.0±2.8
* ²⁰³ Pb	c	51.873H	125±10	126±10	131±11	126±10
²⁰³ Pb	c*	51.873H	136±11	138±11	143±12	137±11
^{202m} Pb	i(m)	3.53H	30.5±2.6	34.1±3.0	39.1±3.3	35.2±2.9
* ²⁰¹ Pb	c	9.33H	127±10	136±11	134±11	129±10
²⁰¹ Pb	c*	9.33H	137±11	145±11	146±12	139±11
²⁰⁰ Pb	c	21.5H	122±10	119±9	120±10	116±9
¹⁹⁹ Pb	c*	90M	216±22	217±20	224±19	210±19
¹⁹⁸ Pb	c	2.4H	182±17	172±16	158±13	164±14
^{197m} Pb	c*	43M	108±12	92.2±10.5	78.0±8.0	85.7±10.4
¹⁹⁶ Pb	c*	37M	97.0±10.5	69.6±8.4	42.5±6.4	62.1±6.7
^{195m} Pb	i(m)	15.0M	40.1±3.4	22.2±2.0	6.74±1.01	19.1±2.7
* ²⁰² Tl	i	12.23D	18.7±1.6	20.0±1.7	20.3±1.7	19.3±1.6
²⁰² Tl	c	12.23D	21.6±1.8	23.2±1.9	24.0±2.0	22.7±1.9
²⁰¹ Tl	c	72.912H	168±16	168±15	172±17	167±15
²⁰¹ Tl	c*	72.912H	194±19	192±16	196±19	191±18
²⁰⁰ Tl	i	26.1H	37.0±4.0	38.7±3.9	35.4±3.8	33.9±3.5
²⁰⁰ Tl	c	26.1H	158±13	157±13	152±12	150±12
¹⁹⁹ Tl	c*	7.42H	194±17	185±16	175±15	178±16
^{198m} Tl	i(m)	1.87H	20.6±1.7	17.4±1.4	16.3±1.4	18.3±1.5

Continuation of Table 19.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
$^{*197}\text{Tl}$	c	2.84H	155±29	138±25	113±19	123±25
^{197}Tl	c*	2.84H	191±30	169±26	139±20	152±25
^{196m}Tl	i(m)	1.41H	34.5±6.6	28.7±5.5	22.5±4.4	26.7±5.1
^{195}Tl	c*	1.16H	63.5±8.9	36.4±5.3	19.3±2.9	36.3±5.1
^{203}Hg	c	46.612D	0.376±0.035	0.866±0.081	1.44±0.12	1.05±0.12
^{197m}Hg	i(m)	23.8H	4.83±0.42	4.72±0.42	5.46±0.48	4.52±0.39
^{197}Hg	c*	64.14H	157±14	132±12	109±10	120±11
^{195m}Hg	i(m)	41.6H	6.04±0.48	5.28±0.42	4.76±0.38	5.63±0.45
$^{*195}\text{Hg}$	ct	9.9H	89.2±11.2	54.7±6.9	30.3±3.6	51.3±6.2
^{195}Hg	c	9.9H	83.1±10.9	49.4±6.7	25.6±3.4	45.7±6.0
^{193m}Hg	i(m)	11.8H	3.64±0.88	2.63±0.50	1.23±0.41	2.49±0.37
^{192}Hg	c	4.85H	13.6±1.1	6.62±0.53	1.39±0.11	6.13±0.49
^{198m}Au	i(m)	2.27D	0.100±0.022	0.102±0.035	0.115±0.023	0.071±0.013
^{198}Au	i(m+g)	2.69517D	0.208±0.031	0.307±0.042	0.414±0.040	0.355±0.030
^{198}Au	i	2.69517D	0.108±0.046	0.206±0.069	0.299±0.047	0.283±0.029
^{196}Au	i(m1+m2+g)	6.183D	0.514±0.043	0.527±0.052	0.547±0.045	0.501±0.042
^{195}Au	c	186.098D	88.1±8.3	53.4±4.9	28.9±3.2	48.6±5.3
^{194}Au	i(m1+m2+g)	38.02H	0.761±0.092	0.701±0.093	0.544±0.068	0.721±0.087
^{192}Au	i(m+g)	4.94H	0.646±0.309	—	1.42±0.41	0.783±0.177
^{192}Au	c	4.94H	18.0±2.6	8.28±1.22	3.39±0.53	8.38±1.22
^{127}Xe	c	36.4D	0.178±0.016	0.113±0.014	0.071±0.016	0.090±0.015
^{123m}Te	i(m)	119.7D	0.330±0.030	0.303±0.035	0.222±0.030	0.337±0.033
^{124}Sb	i(m1+m2+g)	60.20D	0.149±0.016	0.189±0.020	0.197±0.019	0.166±0.024
^{120m}Sb	i(m)	5.76D	0.328±0.029	0.250±0.022	0.146±0.013	0.207±0.024
^{110m}Ag	i(m)	249.76D	0.961±0.089	0.580±0.100	0.354±0.036	0.552±0.077
^{103}Ru	c	39.26D	4.81±0.40	4.11±0.34	3.42±0.29	3.82±0.32
^{99}Mo	c	65.94H	4.69±0.39	4.23±0.35	3.80±0.32	4.09±0.34
^{96}Nb	i	23.35H	2.30±0.19	1.61±0.13	1.13±0.10	1.56±0.13
^{95}Nb	i(m+g)	34.975D	1.86±0.16	1.17±0.09	0.749±0.062	1.07±0.09
^{95}Nb	c	34.975D	5.15±0.42	4.26±0.34	3.47±0.28	4.07±0.33
^{97}Zr	c	16.744H	1.12±0.10	1.33±0.11	1.29±0.14	1.23±0.11
^{95}Zr	c	64.02D	3.27±0.26	3.05±0.24	2.74±0.22	2.92±0.23
^{88}Zr	c	83.4D	0.071±0.029	0.041±0.024	—	—
^{88}Y	i	106.65D	0.289±0.026	0.146±0.021	—	—
^{88}Y	c	106.65D	0.360±0.036	0.187±0.019	—	—
^{84}Rb	i(m+g)	32.77D	0.421±0.046	0.160±0.050	0.136±0.042	0.161±0.072
^{82}Br	i(m+g)	35.30H	1.39±0.11	0.990±0.094	0.776±0.065	1.00±0.08

3.6 Experimental results for 0.25 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 20 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.25GeV protons. Table 21 presents values of the measured residual nuclide yields.

Table 20: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-spectra sample/monitor/plate	ExpData index
^{nat} Pb	250 ± 1	112.3	123.1	714.9	30	6.92 ± 0.48	27/10/1	pbn250
²⁰⁸ Pb	250 ± 1	138.6	123.4	706.4	20	5.12 ± 0.35	25/09/1	pb8250
²⁰⁷ Pb	250 ± 1	129.8	123.5	711.2	30	6.99 ± 0.48	26/11/1	pb7250
²⁰⁶ Pb	250 ± 1	137.4	123.1	715.6	25	5.23 ± 0.36	25/10/1	pb6250

Table 21: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 0.25$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	–	3.50±0.43	10.3±1.2	5.48±0.61
²⁰⁶ Bi	i	6.243D	3.30±0.26	8.39±0.65	13.8±1.1	10.3±0.8
²⁰⁵ Bi	i	15.31D	10.9±0.8	17.1±1.3	20.0±1.6	17.7±1.4
²⁰⁴ Bi	i	11.22H	15.1±1.1	17.2±1.3	17.8±1.3	17.6±1.3
²⁰³ Bi	i(m+g)	11.76H	20.9±1.6	21.8±1.7	20.6±1.6	21.6±1.7
²⁰² Bi	i	1.72H	19.5±1.6	19.6±1.5	18.2±1.6	19.7±1.6
²⁰¹ Bi	i	108M	24.9±6.8	18.7±4.9	19.8±5.2	20.3±5.3
^{204m} Pb	i(m)	67.2M	16.7±1.4	19.6±1.6	21.2±1.7	20.1±1.6
^{204m} Pb	c	67.2M	18.9±1.5	22.1±1.7	23.9±1.9	22.8±1.8
* ²⁰³ Pb	c	51.873H	77.0±6.1	75.3±6.0	74.1±5.8	78.8±6.2
²⁰³ Pb	c*	51.873H	83.2±6.5	81.7±6.3	80.1±6.2	85.1±6.6
^{202m} Pb	i(m)	3.53H	20.4±2.0	22.4±2.0	23.6±2.1	23.5±2.3
* ²⁰¹ Pb	c	9.33H	75.6±6.3	73.1±6.0	70.9±5.8	71.9±6.3
²⁰¹ Pb	c*	9.33H	81.6±6.5	77.6±6.2	75.6±6.0	76.7±6.5
²⁰⁰ Pb	c	21.5H	67.7±5.1	63.6±4.8	62.8±4.8	66.6±5.0
¹⁹⁹ Pb	c*	90M	127±13	121±10	122±11	122±11
¹⁹⁸ Pb	c	2.4H	105±9	97.9±8.7	90.6±7.8	95.8±7.9
^{197m} Pb	c*	43M	67.2±6.3	61.7±5.8	56.6±5.8	63.9±5.9
¹⁹⁶ Pb	c*	37M	69.3±9.8	59.5±8.3	50.3±7.4	61.2±8.7
^{195m} Pb	i(m)	15.0M	39.9±3.5	33.4±2.8	28.3±2.5	35.0±2.8
* ²⁰² Tl	i	12.23D	20.5±1.6	21.7±1.7	22.6±1.8	22.8±1.8
²⁰² Tl	c	12.23D	22.4±1.7	23.8±1.9	24.9±1.9	25.1±2.0
* ²⁰¹ Tl	c	72.912H	111±9	109±9	107±9	113±9
²⁰¹ Tl	c*	72.912H	122±10	120±9	117±9	123±10
²⁰⁰ Tl	i	26.1H	35.7±3.4	38.7±3.4	36.8±3.5	38.0±3.2
²⁰⁰ Tl	c	26.1H	103±8	102±8	96.1±7.4	104±8
¹⁹⁹ Tl	c*	7.42H	125±10	125±10	117±10	127±11
^{198m} Tl	i(m)	1.87H	28.3±2.9	26.9±2.3	27.2±2.5	24.1±3.0
* ¹⁹⁷ Tl	c	2.84H	122±22	106±21	109±18	106±18

Continuation of Table 21.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{197}Tl	c*	2.84H	145±23	127±21	128±18	128±19
^{196m}Tl	i(m)	1.41H	61.1±11.5	57.9±10.9	55.7±10.5	56.1±10.6
^{195}Tl	c*	1.16H	76.6±10.4	59.1±8.2	55.7±7.8	60.6±8.3
^{203}Hg	c	46.612D	0.805±0.083	1.58±0.13	2.44±0.20	1.92±0.15
^{197m}Hg	i(m)	23.8H	7.75±0.63	9.41±0.79	9.55±0.80	9.14±0.76
^{197}Hg	c*	64.14H	120±11	112±10	103±9	117±10
^{195m}Hg	i(m)	41.6H	10.7±0.8	10.8±0.8	11.4±0.9	11.2±0.9
* ^{195}Hg	ct	9.9H	104±12	101±12	87.0±10.2	94.5±11.2
^{195}Hg	c	9.9H	93.5±12.0	89.8±11.6	75.6±9.7	83.3±10.8
^{193m}Hg	i(m)	11.8H	10.1±1.8	9.65±1.59	8.09±1.52	9.17±1.90
^{192}Hg	c	4.85H	51.0±3.8	41.4±3.1	32.1±2.4	41.5±3.1
^{190}Hg	c*	20.0M	25.1±1.9	18.3±1.4	13.5±1.0	19.4±1.5
^{198m}Au	i(m)	2.27D	0.198±0.016	0.237±0.021	0.398±0.030	0.264±0.044
^{198}Au	i(m+g)	2.69517D	0.561±0.043	0.780±0.061	1.02±0.08	0.882±0.077
^{198}Au	i	2.69517D	0.363±0.030	0.543±0.046	0.686±0.076	0.619±0.086
^{196}Au	i(m1+m2+g)	6.183D	1.28±0.10	1.52±0.12	1.78±0.14	1.69±0.13
^{195}Au	c	186.098D	115±10	107±9	86.0±8.3	104±9
^{194}Au	i(m1+m2+g)	38.02H	2.32±0.27	3.01±0.28	2.93±0.26	2.97±0.27
^{192}Au	i(m+g)	4.94H	3.99±1.09	2.74±0.39	4.20±0.63	2.90±0.41
^{192}Au	c	4.94H	66.1±5.3	54.3±4.3	44.3±3.5	54.5±4.3
^{191}Au	c*	3.18H	37.2±5.5	29.5±3.4	22.4±3.8	34.5±5.1
^{190}Au	c	42.8M	29.2±2.6	22.3±2.0	16.3±1.8	21.1±2.3
^{191}Pt	c	2.802D	37.2±3.0	29.9±2.4	23.4±1.9	30.0±2.4
^{189}Pt	c	10.87H	26.1±2.2	20.4±1.7	16.3±1.5	20.2±1.7
^{188}Pt	c	10.2D	17.9±1.4	13.0±1.0	9.22±0.70	13.2±1.0
^{186}Pt	c	2.08H	7.73±1.77	4.77±1.10	3.09±0.73	4.66±1.07
^{189}Ir	c	13.2D	23.3±3.0	16.2±2.1	12.4±1.6	16.4±2.1
^{188}Ir	i	41.5H	1.19±0.34	0.913±0.184	1.34±0.33	0.839±0.180
^{188}Ir	c	41.5H	19.3±1.9	14.4±1.4	10.7±1.0	13.6±1.3
^{186}Ir	c	16.64H	3.65±0.34	2.69±0.25	1.71±0.16	2.78±0.24
^{185}Os	c	93.6D	5.33±0.41	3.46±0.27	2.22±0.19	3.52±0.29
^{183}Re	c	70.0D	2.34±0.25	1.34±0.12	0.674±0.079	1.36±0.13
^{175}Hf	c	70D	0.240±0.029	—	—	—
^{139}Ce	c	137.640D	0.143±0.015	0.128±0.014	0.099±0.021	0.135±0.013
^{127}Xe	c	36.4D	0.392±0.033	0.270±0.027	0.201±0.025	0.272±0.025
^{123m}Te	i(m)	119.7D	0.382±0.044	0.332±0.029	0.265±0.029	0.341±0.028
^{121m}Te	i(m)	154D	0.343±0.026	0.256±0.019	0.171±0.013	0.250±0.019
^{121}Te	c	19.16D	0.432±0.046	0.340±0.036	0.221±0.047	0.270±0.027
^{124}Sb	i(m1+m2+g)	60.20D	0.159±0.022	0.119±0.016	0.131±0.025	0.133±0.017
^{120m}Sb	i(m)	5.76D	0.465±0.037	0.378±0.032	0.313±0.026	0.375±0.031
^{114m}In	i(m)	49.51D	1.13±0.11	0.827±0.118	0.632±0.078	0.838±0.091
^{110m}Ag	i(m)	249.76D	1.30±0.11	1.04±0.08	0.895±0.080	1.08±0.09
^{105}Rh	c	35.36H	5.34±0.45	4.84±0.41	4.25±0.36	4.71±0.40
^{101m}Rh	c	4.34D	0.298±0.034	0.224±0.029	0.185±0.029	0.171±0.019
^{103}Ru	c	39.26D	4.94±0.39	4.46±0.35	3.87±0.31	4.57±0.36
^{99}Mo	c	65.94H	4.40±0.42	4.20±0.56	4.05±0.38	4.40±0.40
^{96}Nb	i	23.35H	2.77±0.23	2.35±0.19	1.81±0.14	2.35±0.18
^{95}Nb	i(m+g)	34.975D	2.80±0.22	2.25±0.17	1.75±0.14	2.27±0.18
^{95}Nb	c	34.975D	5.94±0.46	5.26±0.40	4.56±0.35	5.35±0.41
^{97}Zr	c	16.744H	0.933±0.080	1.04±0.09	1.19±0.10	1.01±0.08

Continuation of Table 21.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	<i>nat</i> Pb
^{95}Zr	c	64.02D	3.19 ± 0.24	3.06 ± 0.23	2.76 ± 0.21	3.12 ± 0.24
^{89}Zr	c	78.41H	0.411 ± 0.046	0.235 ± 0.021	0.204 ± 0.024	0.236 ± 0.021
^{88}Zr	c	83.4D	0.141 ± 0.053	–	0.064 ± 0.016	0.049 ± 0.026
^{88}Y	i	106.65D	1.05 ± 0.09	0.792 ± 0.065	0.547 ± 0.044	0.820 ± 0.067
^{88}Y	c	106.65D	1.19 ± 0.10	0.833 ± 0.065	0.612 ± 0.048	0.869 ± 0.068
^{87}Y	c*	79.8H	0.507 ± 0.040	0.321 ± 0.027	0.211 ± 0.019	0.321 ± 0.027
^{85}Sr	c	64.84D	0.684 ± 0.064	0.404 ± 0.037	0.295 ± 0.039	0.429 ± 0.041
^{86}Rb	i(m+g)	18.631D	4.23 ± 0.40	2.84 ± 0.25	2.56 ± 0.27	2.82 ± 0.24
^{84}Rb	i(m+g)	32.77D	1.64 ± 0.14	1.15 ± 0.10	0.699 ± 0.119	1.13 ± 0.10
^{83}Rb	c	86.2D	0.675 ± 0.069	0.504 ± 0.053	0.429 ± 0.079	0.532 ± 0.054
^{82}Br	i(m+g)	35.30H	1.82 ± 0.15	1.57 ± 0.13	1.32 ± 0.11	1.56 ± 0.13
^{75}Se	c	119.779D	0.138 ± 0.033	0.097 ± 0.014	–	0.082 ± 0.017
^{74}As	i	17.77D	0.393 ± 0.045	0.261 ± 0.029	0.172 ± 0.025	0.282 ± 0.031
^{72}Ga	i	14.10H	0.439 ± 0.230	0.553 ± 0.097	0.523 ± 0.103	0.616 ± 0.131
^{72}Ga	c	14.10H	0.832 ± 0.213	0.856 ± 0.104	0.752 ± 0.102	0.876 ± 0.132
^{72}Zn	c	46.5H	0.393 ± 0.048	0.303 ± 0.034	0.230 ± 0.027	0.260 ± 0.039
^{59}Fe	c	44.472D	–	0.209 ± 0.028	0.185 ± 0.108	0.214 ± 0.044

3.7 Experimental results for 0.4 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 22 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.4GeV protons. Table 23 presents values of the measured residual nuclide yields.

Table 22: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-specra sample/monitor/plate	ExpData index
^{nat} Pb	400 ± 2	243.5	120.9	710.2	25	6.78 ± 0.50	32/13 /1	pbn400
²⁰⁸ Pb	400 ± 2	142.4	123.0	702.7	25	6.24 ± 0.45	29/10/1	pb8400
²⁰⁷ Pb	399 ± 2	145.2	123.0	716.6	20	4.45 ± 0.32	34/10/1	pb7400
²⁰⁶ Pb	400 ± 2	138.3	120.8	716.7	25	6.70 ± 0.48	28/10/1	pb6400

Table 23: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 0.4$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	–	5.66±1.06	6.06±0.72	4.18±0.46
²⁰⁶ Bi	i	6.243D	2.10±0.17	5.32±0.44	8.31±0.68	6.42±0.53
²⁰⁵ Bi	i	15.31D	6.77±0.55	10.9±0.9	12.0±1.0	10.5±0.9
²⁰⁴ Bi	i	11.22H	9.34±0.73	10.7±0.8	10.8±0.8	10.5±0.8
²⁰³ Bi	i(m+g)	11.76H	12.8±1.0	13.2±1.1	12.6±1.0	12.8±1.0
²⁰² Bi	i	1.72H	10.8±1.0	11.0±1.0	9.40±0.84	9.77±0.91
^{204m} Pb	i(m)	67.2M	14.2±1.2	17.1±1.4	17.1±1.4	16.7±1.4
^{204m} Pb	c	67.2M	15.6±1.3	18.7±1.5	18.7±1.5	18.3±1.5
* ²⁰³ Pb	c	51.873H	58.1±4.7	57.5±5.0	51.8±4.3	57.0±4.7
²⁰³ Pb	c*	51.873H	61.9±5.0	61.4±5.2	55.6±4.6	60.8±5.0
^{202m} Pb	i(m)	3.53H	15.5±1.6	18.1±1.7	19.0±1.7	17.7±1.6
²⁰¹ Pb	c*	9.33H	54.9±4.8	53.2±4.4	49.9±4.1	55.0±4.7
²⁰⁰ Pb	c	21.5H	43.9±3.5	44.7±3.5	39.5±3.1	43.4±3.5
¹⁹⁹ Pb	c*	90M	79.6±7.7	81.4±7.9	69.3±6.4	75.5±7.0
¹⁹⁸ Pb	c	2.4H	66.1±6.6	64.4±6.0	58.5±5.9	65.2±6.0
^{197m} Pb	c*	43M	47.0±4.1	46.8±4.1	39.8±3.4	43.9±3.9
¹⁹⁶ Pb	c*	37M	48.8±6.9	47.5±6.6	42.1±5.9	44.0±6.3
^{195m} Pb	i(m)	15.0M	25.9±2.2	25.0±2.1	21.7±1.8	23.3±2.3
* ²⁰² Tl	i	12.23D	20.9±1.7	22.2±1.8	22.2±1.8	21.9±1.8
²⁰² Tl	c	12.23D	22.4±1.7	23.9±1.8	24.0±1.8	23.5±1.8
²⁰¹ Tl	c*	72.912H	91.6±6.9	94.1±7.1	86.3±6.5	92.6±7.2
²⁰⁰ Tl	i	26.1H	36.8±3.7	36.8±3.5	36.3±3.4	36.4±3.3
²⁰⁰ Tl	c	26.1H	79.8±6.5	80.3±6.4	75.2±6.1	79.2±6.5
¹⁹⁹ Tl	c*	7.42H	98.6±11.2	98.3±11.1	90.3±9.6	97.8±10.2
^{198m} Tl	i(m)	1.87H	31.0±2.8	29.8±3.1	30.4±2.9	25.6±5.0
* ¹⁹⁷ Tl	c	2.84H	95.0±17.3	87.5±16.1	87.2±15.3	92.9±15.5
¹⁹⁷ Tl	c*	2.84H	111±18	103±17	101±16	108±16
^{196m} Tl	i(m)	1.41H	58.8±11.0	62.4±11.6	58.4±10.9	60.3±11.3
¹⁹⁵ Tl	c*	1.16H	63.8±9.0	57.7±7.9	57.1±8.2	56.3±7.9

Continuation of Table 23.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{203}Hg	c	46.612D	1.24 $\pm$ 0.10	2.39 $\pm$ 0.18	3.44 $\pm$ 0.26	2.64 $\pm$ 0.20
^{197m}Hg	i(m)	23.8H	11.2 $\pm$ 0.9	13.3 $\pm$ 1.1	14.0 $\pm$ 1.1	13.4 $\pm$ 1.2
^{197}Hg	c*	64.14H	101 $\pm$ 9	109 $\pm$ 9	105 $\pm$ 9	107 $\pm$ 9
^{195m}Hg	i(m)	41.6H	15.0 $\pm$ 1.2	16.8 $\pm$ 1.3	16.3 $\pm$ 1.3	17.0 $\pm$ 1.4
$^{*195}\text{Hg}$	ct	9.9H	99.9 $\pm$ 11.8	102 $\pm$ 12	91.8 $\pm$ 10.7	95.4 $\pm$ 11.2
^{195}Hg	c	9.9H	84.9 $\pm$ 10.9	85.5 $\pm$ 10.9	75.5 $\pm$ 9.7	78.4 $\pm$ 10.2
^{193m}Hg	i(m)	11.8H	14.5 $\pm$ 2.5	15.1 $\pm$ 2.7	14.5 $\pm$ 2.5	16.9 $\pm$ 3.9
^{192}Hg	c	4.85H	65.4 $\pm$ 5.1	62.5 $\pm$ 4.9	53.7 $\pm$ 4.2	59.0 $\pm$ 4.8
^{190}Hg	c*	20.0M	44.6 $\pm$ 3.5	40.6 $\pm$ 3.2	35.2 $\pm$ 2.8	40.2 $\pm$ 3.2
^{198m}Au	i(m)	2.27D	0.293 $\pm$ 0.023	0.431 $\pm$ 0.034	0.651 $\pm$ 0.051	0.485 $\pm$ 0.039
^{198}Au	i(m+g)	2.69517D	1.07 $\pm$ 0.08	1.53 $\pm$ 0.12	1.80 $\pm$ 0.14	1.61 $\pm$ 0.12
^{198}Au	i	2.69517D	0.793 $\pm$ 0.083	1.11 $\pm$ 0.10	1.14 $\pm$ 0.10	1.14 $\pm$ 0.09
^{196}Au	i(m1+m2+g)	6.183D	2.24 $\pm$ 0.18	2.94 $\pm$ 0.24	3.38 $\pm$ 0.27	3.06 $\pm$ 0.25
^{195}Au	c	186.098D	92.0 $\pm$ 10.1	92.9 $\pm$ 10.5	96.1 $\pm$ 10.0	113 $\pm$ 10
^{194}Au	i(m1+m2+g)	38.02H	4.56 $\pm$ 0.42	5.25 $\pm$ 0.55	5.93 $\pm$ 0.55	5.83 $\pm$ 0.54
^{192}Au	i(m+g)	4.94H	6.59 $\pm$ 0.99	9.55 $\pm$ 0.91	9.63 $\pm$ 1.39	9.05 $\pm$ 1.13
^{192}Au	c	4.94H	86.3 $\pm$ 7.1	83.7 $\pm$ 6.8	76.2 $\pm$ 6.5	81.0 $\pm$ 7.0
^{191}Au	c*	3.18H	61.6 $\pm$ 6.5	65.0 $\pm$ 6.4	53.8 $\pm$ 7.1	63.9 $\pm$ 6.4
^{190}Au	c	42.8M	53.1 $\pm$ 4.7	49.2 $\pm$ 4.3	43.6 $\pm$ 3.8	46.6 $\pm$ 4.3
^{191}Pt	c	2.802D	58.8 $\pm$ 4.9	58.3 $\pm$ 5.3	50.1 $\pm$ 4.3	57.1 $\pm$ 4.9
^{189}Pt	c	10.87H	56.6 $\pm$ 4.7	53.4 $\pm$ 4.5	47.0 $\pm$ 4.1	53.6 $\pm$ 4.5
^{188}Pt	c	10.2D	46.8 $\pm$ 3.7	42.7 $\pm$ 3.4	37.3 $\pm$ 2.9	42.0 $\pm$ 3.4
^{187}Pt	c	2.35H	33.5 $\pm$ 3.8	29.6 $\pm$ 2.9	26.1 $\pm$ 2.7	28.2 $\pm$ 3.3
^{186}Pt	c	2.08H	31.2 $\pm$ 7.1	28.6 $\pm$ 6.5	23.8 $\pm$ 5.4	26.7 $\pm$ 6.1
^{184}Pt	c	17.3M	24.6 $\pm$ 5.2	19.8 $\pm$ 4.3	16.6 $\pm$ 3.3	19.0 $\pm$ 3.9
^{192}Ir	i(m1+g)	73.827D	–	–	0.069 $\pm$ 0.019	0.076 $\pm$ 0.009
^{190}Ir	i(m1+g)	11.78D	0.166 $\pm$ 0.075	0.210 $\pm$ 0.056	0.348 $\pm$ 0.049	0.243 $\pm$ 0.026
^{189}Ir	c	13.2D	47.0 $\pm$ 3.9	44.8 $\pm$ 3.7	38.7 $\pm$ 3.2	46.5 $\pm$ 4.1
^{188}Ir	i	41.5H	1.38 $\pm$ 0.26	2.41 $\pm$ 0.30	1.48 $\pm$ 0.41	3.57 $\pm$ 0.70
^{188}Ir	c	41.5H	48.3 $\pm$ 3.9	44.8 $\pm$ 3.6	38.4 $\pm$ 3.1	45.7 $\pm$ 3.7
^{187}Ir	c*	10.5H	47.3 $\pm$ 4.3	43.1 $\pm$ 3.9	38.8 $\pm$ 3.4	46.2 $\pm$ 4.3
^{186}Ir	c	16.64H	16.9 $\pm$ 1.5	15.3 $\pm$ 1.3	13.2 $\pm$ 1.2	15.1 $\pm$ 1.5
^{185}Ir	c	14.4H	24.0 $\pm$ 2.5	21.2 $\pm$ 1.9	17.2 $\pm$ 1.5	20.2 $\pm$ 2.2
^{184}Ir	c*	3.09H	27.2 $\pm$ 2.3	23.2 $\pm$ 2.0	18.5 $\pm$ 1.6	23.2 $\pm$ 2.0
^{183}Ir	c	57M	20.1 $\pm$ 5.4	18.0 $\pm$ 4.6	18.7 $\pm$ 4.9	17.7 $\pm$ 4.6
^{185}Os	c	93.6D	30.8 $\pm$ 2.5	27.3 $\pm$ 2.2	22.3 $\pm$ 1.8	25.9 $\pm$ 2.1
^{183m}Os	c*	9.9H	12.5 $\pm$ 1.0	10.9 $\pm$ 0.9	8.82 $\pm$ 0.71	10.4 $\pm$ 0.9
^{182}Os	c	22.10H	20.3 $\pm$ 1.6	16.7 $\pm$ 1.3	13.3 $\pm$ 1.0	16.8 $\pm$ 1.4
^{180}Os	c	21.5M	10.6 $\pm$ 1.0	7.96 $\pm$ 0.83	6.62 $\pm$ 0.59	8.15 $\pm$ 0.78
^{183}Re	c	70.0D	22.2 $\pm$ 1.8	19.2 $\pm$ 1.6	15.1 $\pm$ 1.3	18.1 $\pm$ 1.6
^{182m}Re	c	12.7H	21.3 $\pm$ 1.9	18.0 $\pm$ 1.8	14.4 $\pm$ 1.3	16.0 $\pm$ 1.5
^{181}Re	c*	19.9H	14.5 $\pm$ 1.9	11.4 $\pm$ 1.5	8.94 $\pm$ 1.17	10.8 $\pm$ 1.4
^{175}Hf	c	70D	2.68 $\pm$ 0.22	2.11 $\pm$ 0.18	1.37 $\pm$ 0.12	1.90 $\pm$ 0.16
^{172}Hf	c	1.87Y	–	–	–	0.726 $\pm$ 0.077
^{173}Lu	c	1.37Y	1.38 $\pm$ 0.15	1.37 $\pm$ 0.16	0.767 $\pm$ 0.132	0.910 $\pm$ 0.097
^{172}Lu	c	6.70D	–	–	–	0.808 $\pm$ 0.084
^{171}Lu	c*	8.24D	0.587 $\pm$ 0.053	0.482 $\pm$ 0.059	0.347 $\pm$ 0.052	0.433 $\pm$ 0.042
^{139}Ce	c	137.640D	0.169 $\pm$ 0.019	0.158 $\pm$ 0.017	0.160 $\pm$ 0.016	0.187 $\pm$ 0.019
^{127}Xe	c	36.4D	0.595 $\pm$ 0.052	0.512 $\pm$ 0.057	0.424 $\pm$ 0.036	0.471 $\pm$ 0.042
^{123m}Te	i(m)	119.7D	0.431 $\pm$ 0.035	0.379 $\pm$ 0.031	0.356 $\pm$ 0.029	0.392 $\pm$ 0.032

Continuation of Table 23.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{121m}Te	i(m)	154D	0.507 ± 0.040	0.421 ± 0.036	0.309 ± 0.024	0.421 ± 0.034
^{121}Te	c	19.16D	0.807 ± 0.069	0.597 ± 0.053	0.482 ± 0.052	0.513 ± 0.044
^{124}Sb	i(m1+m2+g)	60.20D	0.122 ± 0.014	—	0.125 ± 0.015	0.112 ± 0.018
^{120m}Sb	i(m)	5.76D	0.543 ± 0.049	0.505 ± 0.063	0.436 ± 0.054	0.546 ± 0.055
^{113}Sn	c	115.09D	0.324 ± 0.038	0.323 ± 0.043	—	0.222 ± 0.023
^{114m}In	i(m)	49.51D	1.64 ± 0.14	1.33 ± 0.13	1.05 ± 0.09	1.26 ± 0.12
^{110m}Ag	i(m)	249.76D	1.57 ± 0.13	1.50 ± 0.12	1.20 ± 0.10	1.39 ± 0.11
^{106m}Ag	i(m)	8.28D	0.536 ± 0.073	0.386 ± 0.059	0.279 ± 0.042	0.361 ± 0.048
^{105}Rh	c	35.36H	5.51 ± 0.45	5.53 ± 0.48	4.82 ± 0.40	5.15 ± 0.44
^{102}Rh	i	207D	0.712 ± 0.112	0.554 ± 0.124	0.410 ± 0.065	0.406 ± 0.078
^{101m}Rh	c	4.34D	0.823 ± 0.082	0.663 ± 0.078	0.465 ± 0.048	0.556 ± 0.056
^{103}Ru	c	39.26D	5.47 ± 0.41	5.30 ± 0.40	4.81 ± 0.37	5.14 ± 0.40
^{96}Tc	i(m+g)	4.28D	0.630 ± 0.055	0.502 ± 0.046	0.290 ± 0.059	0.495 ± 0.044
^{99}Mo	c	65.94H	5.31 ± 0.41	5.45 ± 0.42	4.72 ± 0.37	4.94 ± 0.41
^{96}Nb	i	23.35H	3.36 ± 0.27	3.00 ± 0.25	2.59 ± 0.22	3.19 ± 0.27
^{95}Nb	i(m+g)	34.975D	3.84 ± 0.28	3.46 ± 0.26	2.88 ± 0.22	3.29 ± 0.25
^{95}Nb	c	34.975D	7.07 ± 0.52	6.83 ± 0.50	5.84 ± 0.43	6.39 ± 0.48
^{92m}Nb	i(m)	10.15D	0.315 ± 0.029	0.302 ± 0.026	0.315 ± 0.031	0.270 ± 0.022
^{97}Zr	c	16.744H	0.842 ± 0.074	0.816 ± 0.087	0.980 ± 0.079	0.986 ± 0.091
^{95}Zr	c	64.02D	3.23 ± 0.25	3.37 ± 0.26	2.99 ± 0.24	3.13 ± 0.25
^{89}Zr	c	78.41H	1.11 ± 0.09	0.916 ± 0.069	0.630 ± 0.054	0.850 ± 0.067
^{88}Zr	c	83.4D	0.374 ± 0.029	0.275 ± 0.022	0.182 ± 0.014	0.288 ± 0.023
^{90m}Y	i(m)	3.19H	3.99 ± 0.35	3.43 ± 0.27	3.10 ± 0.26	3.86 ± 0.35
^{88}Y	i	106.65D	2.36 ± 0.21	2.04 ± 0.18	1.62 ± 0.15	1.85 ± 0.15
^{88}Y	c	106.65D	2.72 ± 0.23	2.27 ± 0.19	1.66 ± 0.14	2.06 ± 0.17
^{87}Y	c*	79.8H	1.44 ± 0.11	1.16 ± 0.09	0.768 ± 0.059	1.06 ± 0.08
^{85}Sr	c	64.84D	1.64 ± 0.14	1.31 ± 0.12	1.00 ± 0.09	1.15 ± 0.10
^{86}Rb	i(m+g)	18.631D	4.95 ± 0.42	4.56 ± 0.39	3.88 ± 0.32	3.83 ± 0.32
^{84}Rb	i(m+g)	32.77D	2.59 ± 0.28	3.45 ± 0.32	2.51 ± 0.25	2.14 ± 0.18
^{83}Rb	c	86.2D	1.93 ± 0.17	1.49 ± 0.14	1.18 ± 0.11	1.35 ± 0.12
^{82}Br	i(m+g)	35.30H	2.40 ± 0.20	2.22 ± 0.18	1.86 ± 0.15	2.26 ± 0.18
^{75}Se	c	119.779D	0.436 ± 0.037	0.345 ± 0.031	0.262 ± 0.028	0.349 ± 0.040
^{74}As	i	17.77D	0.988 ± 0.103	0.787 ± 0.083	0.622 ± 0.075	0.784 ± 0.081
^{72}Ga	i	14.10H	0.990 ± 0.170	0.841 ± 0.173	1.03 ± 0.21	0.989 ± 0.120
^{72}Ga	c	14.10H	1.36 ± 0.17	1.34 ± 0.17	1.37 ± 0.20	1.37 ± 0.14
^{72}Zn	c	46.5H	0.368 ± 0.050	0.496 ± 0.068	0.344 ± 0.064	0.382 ± 0.037
^{59}Fe	c	44.472D	0.380 ± 0.039	0.357 ± 0.076	0.287 ± 0.043	0.352 ± 0.064

3.8 Experimental results for 0.6 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 24 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.6GeV protons. Table 25 presents values of the measured residual nuclide yields.

Table 24: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-specra sample/monitor/plate	ExpData index
^{nat} Pb	600 ± 2	153.7	118.7	729.2	25	5.15 ± 0.37	32/10/1	pbn600
²⁰⁸ Pb	600 ± 2	140.1	122.7	720.1	29	4.27 ± 0.30	27/10/1	pb8600
²⁰⁷ Pb	600 ± 2	147.8	122.7	707.0	30	4.70 ± 0.34	31/10/1	pb7600
²⁰⁶ Pb	600 ± 2	140.3	122.4	713.2	30	5.14 ± 0.37	29/09/1	pb6600

Table 25: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 0.6$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	—	—	4.83±0.90	3.68±0.74
²⁰⁶ Bi	i	6.243D	1.51±0.12	3.66±0.29	5.40±0.43	4.04±0.32
²⁰⁵ Bi	i	15.31D	4.85±0.38	7.19±0.56	7.99±0.63	6.95±0.55
²⁰⁴ Bi	i	11.22H	6.14±0.48	7.03±0.55	6.97±0.54	6.83±0.53
²⁰³ Bi	i(m+g)	11.76H	7.80±0.64	7.65±0.74	7.35±0.72	7.68±0.70
²⁰² Bi	i	1.72H	6.93±2.01	6.28±1.41	6.09±0.76	7.33±1.20
^{204m} Pb	i(m)	67.2M	13.5±1.1	14.4±1.1	14.4±1.1	14.7±1.2
^{204m} Pb	c	67.2M	14.4±1.2	15.5±1.2	15.4±1.2	15.7±1.3
* ²⁰³ Pb	c	51.873H	48.0±3.9	45.1±3.7	40.7±3.3	44.8±3.6
²⁰³ Pb	c*	51.873H	50.3±3.7	47.4±3.5	42.9±3.2	47.1±3.5
^{202m} Pb	i(m)	3.53H	12.6±1.1	14.0±1.2	14.3±1.3	13.3±1.1
²⁰¹ Pb	c*	9.33H	43.6±3.8	40.5±3.5	35.2±3.6	40.2±3.5
²⁰⁰ Pb	c	21.5H	31.9±2.5	30.4±2.4	27.7±2.2	30.1±2.3
¹⁹⁹ Pb	c*	90M	64.0±11.4	60.4±10.9	54.8±9.9	55.2±9.8
¹⁹⁸ Pb	c	2.4H	44.6±8.2	42.0±7.7	38.0±7.0	40.2±7.4
^{197m} Pb	c*	43M	31.1±2.7	29.3±2.5	27.0±2.3	29.7±2.6
¹⁹⁶ Pb	c*	37M	30.3±4.2	28.4±4.0	25.5±3.6	32.6±4.6
^{195m} Pb	i(m)	15.0M	17.4±3.6	14.9±3.0	14.7±3.0	16.9±3.7
* ²⁰² Tl	i	12.23D	20.1±1.6	20.5±1.7	20.3±1.7	20.6±1.7
²⁰² Tl	c	12.23D	21.2±1.6	21.9±1.6	21.7±1.6	21.9±1.6
²⁰¹ Tl	c*	72.912H	72.6±5.4	70.4±5.2	66.2±4.9	69.8±5.2
²⁰⁰ Tl	i	26.1H	28.4±2.3	28.5±2.5	29.1±2.5	28.2±2.3
²⁰⁰ Tl	c	26.1H	59.9±4.7	59.0±4.6	56.6±4.5	58.0±4.6
¹⁹⁹ Tl	c	7.42H	58.0±6.9	55.4±6.4	55.9±5.5	58.0±5.6
¹⁹⁹ Tl	c*	7.42H	69.2±6.3	66.7±6.0	65.4±5.9	67.4±6.1
^{198m} Tl	i(m)	1.87H	25.2±3.7	26.9±3.7	25.3±3.5	24.5±3.4
* ¹⁹⁷ Tl	c	2.84H	44.4±19.0	48.0±20.1	46.2±19.1	61.6±24.7
¹⁹⁷ Tl	c*	2.84H	54.9±19.0	57.9±20.1	55.3±19.1	71.7±24.7
^{196m} Tl	i(m)	1.41H	49.2±9.2	49.4±9.2	48.8±9.1	50.6±9.4

Continuation of Table 25.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{195}Tl	c*	1.16H	50.5 $\pm$ 7.3	41.3 $\pm$ 5.7	36.6 $\pm$ 5.1	43.7 $\pm$ 6.3
^{203}Hg	c	46.612D	1.64 $\pm$ 0.12	2.95 $\pm$ 0.23	4.14 $\pm$ 0.31	3.17 $\pm$ 0.24
^{197m}Hg	i(m)	23.8H	9.83 $\pm$ 0.78	11.8 $\pm$ 0.9	13.1 $\pm$ 1.0	12.0 $\pm$ 1.0
^{195m}Hg	i(m)	41.6H	14.6 $\pm$ 1.4	16.6 $\pm$ 1.5	17.0 $\pm$ 1.5	16.3 $\pm$ 1.5
* ^{195}Hg	ct	9.9H	78.5 $\pm$ 9.0	78.3 $\pm$ 8.8	73.4 $\pm$ 8.1	76.8 $\pm$ 8.6
^{195}Hg	c	9.9H	63.9 $\pm$ 8.1	61.7 $\pm$ 7.8	56.4 $\pm$ 7.2	60.4 $\pm$ 7.7
^{193m}Hg	i(m)	11.8H	22.1 $\pm$ 3.7	22.8 $\pm$ 3.7	22.2 $\pm$ 3.7	22.5 $\pm$ 3.5
^{192}Hg	c	4.85H	56.1 $\pm$ 4.4	54.3 $\pm$ 4.2	51.1 $\pm$ 4.0	53.5 $\pm$ 4.2
^{190}Hg	c*	20.0M	43.5 $\pm$ 7.2	40.8 $\pm$ 6.8	38.8 $\pm$ 6.4	41.8 $\pm$ 7.0
^{198m}Au	i(m)	2.27D	0.407 $\pm$ 0.032	0.561 $\pm$ 0.044	0.769 $\pm$ 0.060	0.629 $\pm$ 0.049
^{198}Au	i(m+g)	2.69517D	1.38 $\pm$ 0.11	1.94 $\pm$ 0.14	2.40 $\pm$ 0.18	2.04 $\pm$ 0.15
^{198}Au	i	2.69517D	1.00 $\pm$ 0.11	1.40 $\pm$ 0.12	1.62 $\pm$ 0.13	1.45 $\pm$ 0.13
^{196}Au	i(m1+m2+g)	6.183D	2.84 $\pm$ 0.23	3.66 $\pm$ 0.30	4.35 $\pm$ 0.36	3.80 $\pm$ 0.30
^{195}Au	c	186.098D	58.2 $\pm$ 6.8	72.6 $\pm$ 8.5	68.9 $\pm$ 8.1	75.0 $\pm$ 8.9
^{194}Au	i(m1+m2+g)	38.02H	5.63 $\pm$ 0.51	7.00 $\pm$ 0.63	7.76 $\pm$ 0.70	7.03 $\pm$ 0.64
^{192}Au	i(m+g)	4.94H	8.24 $\pm$ 1.34	11.2 $\pm$ 1.7	10.5 $\pm$ 1.6	11.5 $\pm$ 1.7
^{192}Au	c	4.94H	77.3 $\pm$ 10.9	78.9 $\pm$ 11.2	74.6 $\pm$ 10.5	77.6 $\pm$ 11.0
^{191}Au	c*	3.18H	74.2 $\pm$ 7.0	73.2 $\pm$ 6.1	68.5 $\pm$ 5.8	73.0 $\pm$ 5.9
^{190}Au	c	42.8M	55.8 $\pm$ 6.2	57.3 $\pm$ 5.9	53.2 $\pm$ 5.3	52.8 $\pm$ 4.7
^{191}Pt	c	2.802D	56.0 $\pm$ 4.7	56.6 $\pm$ 4.8	54.7 $\pm$ 4.6	55.5 $\pm$ 4.7
^{189}Pt	c	10.87H	61.4 $\pm$ 5.0	60.4 $\pm$ 4.9	57.8 $\pm$ 4.7	59.2 $\pm$ 4.9
^{188}Pt	c	10.2D	55.3 $\pm$ 4.3	54.9 $\pm$ 4.3	51.4 $\pm$ 4.0	53.1 $\pm$ 4.1
^{187}Pt	c	2.35H	49.7 $\pm$ 11.1	45.9 $\pm$ 10.4	40.3 $\pm$ 9.0	42.5 $\pm$ 9.5
^{186}Pt	c	2.08H	44.4 $\pm$ 10.1	42.5 $\pm$ 9.6	39.2 $\pm$ 8.9	37.0 $\pm$ 2.9
^{184}Pt	c	17.3M	37.6 $\pm$ 7.2	34.1 $\pm$ 6.5	30.6 $\pm$ 6.0	34.8 $\pm$ 6.8
^{192}Ir	i(m1+g)	73.827D	0.100 $\pm$ 0.018	0.114 $\pm$ 0.020	0.163 $\pm$ 0.018	0.124 $\pm$ 0.016
^{190}Ir	i(m1+g)	11.78D	0.357 $\pm$ 0.045	0.457 $\pm$ 0.041	0.478 $\pm$ 0.075	0.450 $\pm$ 0.052
^{189}Ir	c	13.2D	53.5 $\pm$ 4.3	53.1 $\pm$ 4.3	51.9 $\pm$ 4.2	52.5 $\pm$ 4.3
^{188}Ir	i	41.5H	1.99 $\pm$ 0.26	2.63 $\pm$ 0.32	2.95 $\pm$ 0.31	2.48 $\pm$ 0.32
^{188}Ir	c	41.5H	57.3 $\pm$ 4.5	57.4 $\pm$ 4.5	54.0 $\pm$ 4.3	55.4 $\pm$ 4.4
^{187}Ir	c*	10.5H	59.6 $\pm$ 5.1	56.3 $\pm$ 5.0	49.9 $\pm$ 4.3	53.6 $\pm$ 4.5
^{186}Ir	c	16.64H	23.8 $\pm$ 2.0	23.9 $\pm$ 2.0	22.3 $\pm$ 1.9	23.8 $\pm$ 1.9
^{185}Ir	c	14.4H	37.0 $\pm$ 3.3	35.8 $\pm$ 3.2	32.7 $\pm$ 2.9	35.1 $\pm$ 3.1
^{184}Ir	c*	3.09H	44.3 $\pm$ 3.6	42.5 $\pm$ 3.5	39.1 $\pm$ 3.3	40.5 $\pm$ 3.5
^{183}Ir	c	57M	39.7 $\pm$ 9.8	38.9 $\pm$ 9.6	33.3 $\pm$ 8.2	35.2 $\pm$ 8.9
^{185}Os	c	93.6D	48.8 $\pm$ 3.8	48.3 $\pm$ 3.9	44.4 $\pm$ 3.5	46.5 $\pm$ 3.7
^{183m}Os	c*	9.9H	25.6 $\pm$ 2.2	24.0 $\pm$ 2.2	20.3 $\pm$ 2.2	23.1 $\pm$ 1.8
^{182}Os	c	22.10H	43.3 $\pm$ 3.4	41.6 $\pm$ 3.2	38.7 $\pm$ 3.0	40.0 $\pm$ 3.1
^{181}Os	c	105M	14.3 $\pm$ 2.0	12.3 $\pm$ 1.7	11.2 $\pm$ 1.6	12.8 $\pm$ 1.8
^{180}Os	c	21.5M	32.4 $\pm$ 2.7	27.9 $\pm$ 2.3	24.5 $\pm$ 2.1	25.9 $\pm$ 2.2
^{183}Re	c	70.0D	44.1 $\pm$ 3.9	42.8 $\pm$ 3.5	38.5 $\pm$ 3.3	41.2 $\pm$ 3.4
^{182m}Re	c	12.7H	45.1 $\pm$ 3.8	42.6 $\pm$ 3.7	37.2 $\pm$ 3.3	40.3 $\pm$ 3.5
* ^{181}Re	c	19.9H	30.9 $\pm$ 4.1	28.9 $\pm$ 3.9	27.0 $\pm$ 3.6	29.9 $\pm$ 4.1
^{181}Re	c*	19.9H	32.2 $\pm$ 4.2	30.1 $\pm$ 3.9	28.0 $\pm$ 3.7	31.2 $\pm$ 4.1
^{179}Re	c*	19.5M	39.7 $\pm$ 3.7	35.1 $\pm$ 4.9	29.8 $\pm$ 2.7	35.7 $\pm$ 3.5
^{178}Re	c*	13.2M	35.3 $\pm$ 4.9	29.8 $\pm$ 4.2	27.4 $\pm$ 3.9	30.9 $\pm$ 4.5
^{178}W	c	21.6D	20.8 $\pm$ 2.9	18.9 $\pm$ 2.8	19.2 $\pm$ 3.1	17.4 $\pm$ 1.8
^{177}W	c	135M	20.3 $\pm$ 2.6	18.1 $\pm$ 2.3	15.5 $\pm$ 2.0	18.6 $\pm$ 2.4
^{176}W	c	2.5H	7.40 $\pm$ 2.92	8.89 $\pm$ 3.26	8.80 $\pm$ 2.17	15.0 $\pm$ 2.8
* ^{177}Ta	c	56.56H	20.9 $\pm$ 5.2	20.9 $\pm$ 5.2	18.0 $\pm$ 4.6	21.2 $\pm$ 5.2

Continuation of Table 25.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{177}Ta	c*	56.56H	21.7±5.1	21.7±5.1	18.7±4.6	21.9±5.2
^{176}Ta	c	8.09H	23.0±2.6	19.5±2.4	16.0±1.8	17.4±2.0
^{175}Ta	c	10.5H	18.0±1.5	15.9±1.3	13.3±1.2	15.5±1.3
^{173}Ta	c	3.14H	13.5±1.8	12.1±1.6	11.1±1.6	11.0±1.5
^{175}Hf	c	70D	17.1±1.4	15.1±1.2	12.7±1.0	14.7±1.2
* ^{173}Hf	c	23.6H	12.5±1.3	10.5±1.1	8.06±0.87	10.7±1.1
^{173}Hf	c*	23.6H	14.6±1.3	12.3±1.1	9.76±0.88	12.4±1.1
^{172}Hf	c	1.87Y	9.46±0.73	8.07±0.63	6.42±0.50	7.83±0.61
^{170}Hf	c	16.01H	7.38±1.18	6.11±1.19	5.26±0.78	5.96±1.22
^{173}Lu	c	1.37Y	12.1±1.0	10.5±0.9	8.68±0.74	10.1±0.9
^{172}Lu	c	6.70D	9.55±0.77	8.23±0.67	6.62±0.57	7.54±0.70
^{171}Lu	c*	8.24D	9.45±0.73	7.93±0.61	6.34±0.49	7.63±0.59
* ^{170}Lu	c	2.012D	5.66±0.81	5.01±0.94	3.45±0.71	5.42±0.94
^{170}Lu	c*	2.012D	9.32±0.81	8.04±0.89	6.06±0.72	8.38±0.88
^{169}Lu	c	34.06H	5.22±0.42	4.26±0.37	3.74±0.32	4.30±0.41
* ^{169}Yb	c	32.026D	5.51±0.47	4.72±0.41	3.72±0.34	4.50±0.38
^{169}Yb	c*	32.026D	5.75±0.48	4.92±0.42	3.90±0.35	4.70±0.39
^{166}Yb	c	56.7H	2.87±0.28	2.33±0.24	1.77±0.18	2.43±0.25
^{167}Tm	c	9.25D	3.99±0.82	3.32±0.68	2.55±0.52	3.23±0.67
^{165}Tm	c	30.06H	2.12±0.21	1.71±0.16	1.15±0.12	1.61±0.16
^{149}Gd	c	9.28D	0.246±0.030	0.245±0.029	0.141±0.023	0.167±0.023
^{139}Ce	c	137.640D	0.255±0.025	0.225±0.021	0.254±0.029	0.265±0.030
^{127}Xe	c	36.4D	0.806±0.066	0.742±0.061	0.626±0.055	0.694±0.057
^{123m}Te	i(m)	119.7D	0.416±0.034	0.420±0.037	0.429±0.045	0.374±0.038
^{121m}Te	i(m)	154D	0.586±0.045	0.553±0.043	0.465±0.036	0.500±0.039
^{121}Te	c	19.16D	1.12±0.09	0.946±0.079	0.820±0.069	0.953±0.079
^{119m}Te	i(m)	4.70D	0.454±0.036	0.364±0.040	0.260±0.025	0.396±0.034
^{124}Sb	i(m1+m2+g)	60.20D	—	0.107±0.015	0.125±0.018	0.150±0.021
^{120m}Sb	i(m)	5.76D	0.531±0.040	0.527±0.039	0.471±0.038	0.500±0.042
^{113}Sn	c	115.09D	0.578±0.058	0.540±0.066	0.377±0.044	0.404±0.045
^{114m}In	i(m)	49.51D	1.76±0.14	1.91±0.16	1.52±0.15	1.66±0.19
^{110m}Ag	i(m)	249.76D	1.66±0.14	1.57±0.14	1.44±0.13	1.52±0.13
^{106m}Ag	i(m)	8.28D	0.883±0.073	0.738±0.066	0.507±0.048	0.667±0.058
^{105}Rh	c	35.36H	5.89±0.48	5.62±0.47	5.33±0.43	5.58±0.47
^{102}Rh	i	207D	0.898±0.130	0.758±0.121	0.682±0.108	0.679±0.111
^{101m}Rh	c	4.34D	1.24±0.12	1.01±0.10	0.801±0.084	1.00±0.10
^{103}Ru	c	39.26D	5.32±0.40	5.10±0.38	4.93±0.37	5.07±0.38
^{96}Tc	i(m+g)	4.28D	1.19±0.10	0.953±0.081	0.760±0.065	0.935±0.080
^{96}Nb	i	23.35H	3.31±0.27	3.07±0.27	3.08±0.32	2.99±0.26
^{95}Nb	i(m+g)	34.975D	4.17±0.30	3.92±0.29	3.42±0.25	3.82±0.28
^{95}Nb	c	34.975D	7.14±0.52	6.94±0.51	6.38±0.47	6.79±0.49
^{92m}Nb	i(m)	10.15D	0.385±0.036	0.355±0.030	0.335±0.029	0.334±0.028
^{97}Zr	c	16.744H	0.723±0.065	0.835±0.077	0.880±0.070	0.880±0.070
^{95}Zr	c	64.02D	2.97±0.23	2.99±0.23	2.95±0.23	2.93±0.23
^{89}Zr	c	78.41H	1.93±0.14	1.60±0.12	1.18±0.09	1.57±0.12
^{88}Zr	c	83.4D	0.749±0.058	0.610±0.047	0.478±0.037	0.550±0.043
^{90m}Y	i(m)	3.19H	3.76±0.29	3.42±0.28	3.36±0.26	3.51±0.27
^{88}Y	i	106.65D	3.63±0.29	3.07±0.25	2.53±0.20	3.11±0.24
^{88}Y	c	106.65D	4.32±0.36	3.70±0.31	2.94±0.24	3.51±0.28
^{87}Y	c*	79.8H	2.81±0.25	2.32±0.23	1.87±0.22	2.17±0.17

Continuation of Table 25.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{85}Sr	c	64.84D	2.82 ± 0.24	2.40 ± 0.20	1.86 ± 0.16	2.29 ± 0.20
^{86}Rb	i(m+g)	18.631D	5.13 ± 0.39	4.51 ± 0.39	4.20 ± 0.38	3.88 ± 0.36
^{83}Rb	c	86.2D	3.23 ± 0.27	2.58 ± 0.23	2.18 ± 0.19	2.66 ± 0.23
^{82}Br	i(m+g)	35.30H	2.66 ± 0.22	2.52 ± 0.21	2.30 ± 0.19	2.51 ± 0.21
^{75}Se	c	119.779D	0.986 ± 0.082	0.884 ± 0.074	0.610 ± 0.052	0.818 ± 0.067
^{74}As	i	17.77D	1.73 ± 0.17	1.49 ± 0.15	1.15 ± 0.12	1.40 ± 0.14
^{72}Ga	i	14.10H	1.44 ± 0.15	1.19 ± 0.23	1.10 ± 0.21	1.17 ± 0.12
^{72}Ga	c	14.10H	1.86 ± 0.17	1.64 ± 0.23	1.47 ± 0.21	1.51 ± 0.14
^{72}Zn	c	46.5H	0.419 ± 0.048	0.448 ± 0.063	0.378 ± 0.047	0.348 ± 0.035
^{59}Fe	c	44.472D	0.751 ± 0.064	0.681 ± 0.071	0.528 ± 0.050	0.638 ± 0.056
^{46}Sc	i(m+g)	83.79D	0.116 ± 0.016	0.108 ± 0.015	0.112 ± 0.016	0.142 ± 0.022
^7Be	i	53.29D	1.15 ± 0.20	0.918 ± 0.204	1.14 ± 0.22	1.15 ± 0.22

3.9 Experimental results for 0.8 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 26 presents parameters of ^{nat,208,207,206}Pb irradiation by 0.8GeV protons. Table 27 presents values of the measured residual nuclide yields.

Table 26: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ -spectra sample/monitor/plate	ExpData index
^{nat} Pb	799 ± 2	191.3	122.7	703.9	30	4.58 ± 0.36	27/11/1	pbn800
²⁰⁸ Pb	799 ± 2	138.9	122.4	720.3	30	4.73 ± 0.37	31/10/1	pb8800
²⁰⁷ Pb	799 ± 2	139.3	122.6	713.9	30	4.68 ± 0.37	29/10/1	pb7800
²⁰⁶ Pb	799 ± 2	142.0	122.0	708.6	30	5.15 ± 0.41	33/10/1	pb6800

Table 27: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 0.8$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	–	–	5.78±0.90	3.39±0.64
²⁰⁶ Bi	i	6.243D	1.27±0.11	3.06±0.27	4.52±0.40	3.41±0.29
²⁰⁵ Bi	i	15.31D	3.83±0.33	5.83±0.50	6.46±0.56	5.67±0.49
²⁰⁴ Bi	i	11.22H	4.75±0.40	5.68±0.48	5.59±0.47	5.64±0.48
²⁰³ Bi	i(m+g)	11.76H	5.31±0.54	6.11±0.61	5.38±0.56	5.75±0.57
²⁰² Bi	i	1.72H	6.56±0.73	5.60±0.71	5.29±0.71	6.06±0.66
^{204m} Pb	i(m)	67.2M	12.2±1.1	13.8±1.2	13.9±1.2	12.6±1.1
^{204m} Pb	c	67.2M	12.9±1.1	14.6±1.3	14.8±1.3	13.5±1.2
* ²⁰³ Pb	c	51.873H	41.9±3.7	39.0±3.4	35.2±3.1	39.2±3.4
²⁰³ Pb	c*	51.873H	43.5±3.5	40.8±3.3	36.8±3.0	40.9±3.3
^{202m} Pb	i(m)	3.53H	10.5±1.1	12.2±1.3	12.1±1.2	11.5±1.2
²⁰¹ Pb	c*	9.33H	35.4±3.6	34.9±3.6	31.8±3.3	33.8±3.5
²⁰⁰ Pb	c	21.5H	25.1±2.1	24.0±2.0	21.6±1.8	24.0±2.0
¹⁹⁹ Pb	c*	90M	45.1±8.1	46.0±8.3	45.7±8.3	44.5±8.0
¹⁹⁸ Pb	c	2.4H	32.9±6.1	30.7±5.8	28.6±5.3	29.9±5.6
^{197m} Pb	c*	43M	24.4±2.3	23.9±2.3	21.5±2.0	23.6±5.2
^{195m} Pb	i(m)	15.0M	13.0±2.7	11.6±2.4	9.99±2.08	11.8±2.4
* ²⁰² Tl	i	12.23D	18.6±1.6	19.0±1.7	18.9±1.7	18.9±1.7
²⁰² Tl	c	12.23D	19.6±1.6	20.2±1.6	20.1±1.6	20.0±1.6
²⁰¹ Tl	c*	72.912H	59.7±4.9	59.2±4.8	55.9±4.6	58.5±4.8
²⁰⁰ Tl	i	26.1H	23.6±2.1	25.8±2.3	26.0±2.3	24.9±2.3
²⁰⁰ Tl	c	26.1H	48.7±4.2	49.7±4.3	47.6±4.1	48.6±4.2
¹⁹⁹ Tl	c	7.42H	43.6±6.2	44.8±6.3	43.6±6.1	42.4±5.9
¹⁹⁹ Tl	c*	7.42H	55.5±7.7	52.6±7.3	52.4±7.3	53.1±7.5
^{198m} Tl	i(m)	1.87H	22.8±3.2	24.5±3.6	24.0±3.3	23.8±3.5
^{196m} Tl	i(m)	1.41H	38.2±7.2	38.2±7.3	39.7±7.5	40.1±7.6
²⁰³ Hg	c	46.612D	1.75±0.15	3.21±0.26	4.46±0.37	3.39±0.28
^{197m} Hg	i(m)	23.8H	8.93±0.78	10.8±0.9	11.9±1.0	11.1±1.0
^{195m} Hg	i(m)	41.6H	12.5±1.2	14.4±1.4	16.2±1.6	14.7±1.4

Continuation of Table 27.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{193m}Hg	i(m)	11.8H	18.1 $\pm$ 4.0	19.9 $\pm$ 3.9	20.0 $\pm$ 4.1	19.2 $\pm$ 4.1
^{192}Hg	c	4.85H	42.8 $\pm$ 3.6	43.6 $\pm$ 3.7	41.3 $\pm$ 3.5	42.4 $\pm$ 3.6
^{190}Hg	c*	20.0M	33.0 $\pm$ 5.6	32.0 $\pm$ 5.5	29.7 $\pm$ 5.1	33.9 $\pm$ 5.8
^{198m}Au	i(m)	2.27D	0.339 $\pm$ 0.029	0.636 $\pm$ 0.054	0.878 $\pm$ 0.074	0.593 $\pm$ 0.050
^{198}Au	i(m+g)	2.69517D	1.45 $\pm$ 0.12	1.96 $\pm$ 0.16	2.47 $\pm$ 0.20	2.10 $\pm$ 0.17
^{198}Au	i	2.69517D	1.12 $\pm$ 0.10	1.31 $\pm$ 0.11	1.57 $\pm$ 0.14	1.51 $\pm$ 0.15
^{196}Au	i(m1+m2+g)	6.183D	2.78 $\pm$ 0.25	3.68 $\pm$ 0.32	4.43 $\pm$ 0.38	3.80 $\pm$ 0.33
^{195}Au	c	186.098D	49.6 $\pm$ 6.2	68.7 $\pm$ 8.5	64.6 $\pm$ 7.9	61.0 $\pm$ 7.7
^{194}Au	i(m1+m2+g)	38.02H	5.23 $\pm$ 0.51	6.75 $\pm$ 0.65	7.86 $\pm$ 0.76	7.02 $\pm$ 0.69
^{192}Au	i(m+g)	4.94H	8.54 $\pm$ 1.26	10.3 $\pm$ 1.6	12.8 $\pm$ 1.9	10.1 $\pm$ 1.5
^{192}Au	c	4.94H	61.0 $\pm$ 8.8	64.4 $\pm$ 9.3	64.0 $\pm$ 9.3	63.1 $\pm$ 9.2
^{191}Au	c*	3.18H	60.3 $\pm$ 5.4	59.1 $\pm$ 5.4	61.8 $\pm$ 5.6	61.4 $\pm$ 5.5
^{190}Au	c	42.8M	45.1 $\pm$ 4.4	46.9 $\pm$ 4.4	45.4 $\pm$ 4.4	45.1 $\pm$ 4.1
^{191}Pt	c	2.802D	45.6 $\pm$ 4.2	47.8 $\pm$ 4.5	47.7 $\pm$ 4.5	47.2 $\pm$ 4.4
^{189}Pt	c	10.87H	50.3 $\pm$ 4.4	53.9 $\pm$ 4.7	52.6 $\pm$ 4.6	51.4 $\pm$ 4.5
^{188}Pt	c	10.2D	46.9 $\pm$ 4.0	49.6 $\pm$ 4.2	49.0 $\pm$ 4.2	48.2 $\pm$ 4.1
^{187}Pt	c	2.35H	37.2 $\pm$ 8.6	33.9 $\pm$ 7.9	38.2 $\pm$ 8.8	37.0 $\pm$ 8.4
^{186}Pt	c	2.08H	39.4 $\pm$ 9.0	40.2 $\pm$ 9.2	39.5 $\pm$ 9.0	40.6 $\pm$ 9.3
^{184}Pt	c	17.3M	36.9 $\pm$ 7.6	33.9 $\pm$ 6.7	33.3 $\pm$ 6.6	34.4 $\pm$ 6.7
^{192}Ir	i(m1+g)	73.827D	0.118 $\pm$ 0.014	0.193 $\pm$ 0.028	0.165 $\pm$ 0.022	0.152 $\pm$ 0.017
^{190}Ir	i(m1+g)	11.78D	0.311 $\pm$ 0.044	0.483 $\pm$ 0.049	0.559 $\pm$ 0.055	0.448 $\pm$ 0.044
^{189}Ir	c	13.2D	44.2 $\pm$ 3.9	47.0 $\pm$ 4.1	47.6 $\pm$ 4.2	46.1 $\pm$ 4.1
^{188}Ir	i	41.5H	2.64 $\pm$ 0.49	3.21 $\pm$ 0.31	3.80 $\pm$ 0.49	3.26 $\pm$ 0.38
^{188}Ir	c	41.5H	49.4 $\pm$ 4.2	52.3 $\pm$ 4.5	52.6 $\pm$ 4.5	51.2 $\pm$ 4.4
^{187}Ir	c*	10.5H	52.9 $\pm$ 5.1	54.0 $\pm$ 5.4	49.7 $\pm$ 4.7	52.5 $\pm$ 5.3
^{186}Ir	c	16.64H	21.6 $\pm$ 2.0	22.3 $\pm$ 2.0	23.6 $\pm$ 2.1	23.1 $\pm$ 2.1
^{185}Ir	c	14.4H	34.6 $\pm$ 3.3	35.8 $\pm$ 3.4	36.2 $\pm$ 3.4	34.3 $\pm$ 3.3
^{184}Ir	c*	3.09H	43.6 $\pm$ 4.0	45.2 $\pm$ 4.0	43.1 $\pm$ 3.9	45.2 $\pm$ 4.1
^{183}Ir	c	57M	42.9 $\pm$ 10.8	48.3 $\pm$ 11.9	42.4 $\pm$ 10.5	44.4 $\pm$ 10.9
^{185}Os	c	93.6D	46.3 $\pm$ 4.0	49.3 $\pm$ 4.2	48.5 $\pm$ 4.2	47.6 $\pm$ 4.1
^{183m}Os	c*	9.9H	26.3 $\pm$ 2.3	26.8 $\pm$ 2.4	25.7 $\pm$ 2.2	26.2 $\pm$ 2.2
^{182}Os	c	22.10H	42.0 $\pm$ 4.0	44.5 $\pm$ 4.0	43.5 $\pm$ 4.0	43.8 $\pm$ 4.0
^{181}Os	c	105M	16.1 $\pm$ 2.3	16.7 $\pm$ 2.6	16.3 $\pm$ 2.4	15.3 $\pm$ 2.3
^{180}Os	c	21.5M	37.1 $\pm$ 3.4	36.2 $\pm$ 3.2	35.0 $\pm$ 3.1	35.0 $\pm$ 3.1
^{183}Re	c	70.0D	45.9 $\pm$ 4.1	48.3 $\pm$ 4.3	45.5 $\pm$ 4.8	45.7 $\pm$ 4.3
^{182m}Re	c	12.7H	49.2 $\pm$ 4.5	49.6 $\pm$ 4.4	47.1 $\pm$ 4.2	45.9 $\pm$ 4.1
* ^{181}Re	c	19.9H	41.0 $\pm$ 5.6	42.2 $\pm$ 5.8	40.5 $\pm$ 5.5	40.8 $\pm$ 5.6
^{181}Re	c*	19.9H	42.5 $\pm$ 5.7	43.8 $\pm$ 5.8	42.1 $\pm$ 5.6	42.3 $\pm$ 5.7
^{179}Re	c*	19.5M	49.0 $\pm$ 5.2	48.6 $\pm$ 5.0	46.3 $\pm$ 5.9	45.5 $\pm$ 5.7
^{178}Re	c*	13.2M	54.1 $\pm$ 8.0	50.1 $\pm$ 7.1	45.7 $\pm$ 6.6	53.9 $\pm$ 7.6
^{178}W	c	21.6D	27.1 $\pm$ 3.6	29.1 $\pm$ 4.3	29.1 $\pm$ 3.8	27.8 $\pm$ 3.4
^{177}W	c	135M	30.5 $\pm$ 4.0	30.9 $\pm$ 4.1	28.4 $\pm$ 3.7	29.3 $\pm$ 3.9
^{176}W	c	2.5H	24.4 $\pm$ 3.2	20.1 $\pm$ 4.6	18.2 $\pm$ 3.2	24.2 $\pm$ 2.8
* ^{177}Ta	c	56.56H	32.2 $\pm$ 8.1	32.2 $\pm$ 8.1	30.6 $\pm$ 7.6	33.4 $\pm$ 8.6
^{177}Ta	c*	56.56H	33.4 $\pm$ 8.0	33.4 $\pm$ 8.0	31.8 $\pm$ 7.6	34.7 $\pm$ 8.5
^{176}Ta	c	8.09H	31.4 $\pm$ 2.8	31.7 $\pm$ 3.1	30.7 $\pm$ 2.9	30.1 $\pm$ 2.7
^{175}Ta	c	10.5H	30.3 $\pm$ 2.8	29.3 $\pm$ 2.7	27.2 $\pm$ 2.6	28.4 $\pm$ 2.8
^{174}Ta	c	1.14H	24.4 $\pm$ 2.9	24.2 $\pm$ 2.9	22.1 $\pm$ 2.6	22.1 $\pm$ 2.6
^{173}Ta	c	3.14H	27.1 $\pm$ 3.6	26.1 $\pm$ 3.5	23.7 $\pm$ 3.2	26.3 $\pm$ 3.5
^{172}Ta	c*	36.8M	13.3 $\pm$ 1.7	12.0 $\pm$ 1.5	10.3 $\pm$ 1.4	11.2 $\pm$ 1.4

Continuation of Table 27.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{175}Hf	c	70D	28.7±2.5	28.9±2.5	26.7±2.3	27.5±2.4
* ^{173}Hf	c	23.6H	27.1±2.5	26.0±2.5	24.0±2.4	25.5±2.5
^{173}Hf	c*	23.6H	31.2±2.8	30.0±2.7	27.6±2.6	29.5±2.7
^{172}Hf	c	1.87Y	19.9±1.7	19.5±1.6	17.7±1.5	18.9±1.6
^{170}Hf	c	16.01H	22.5±2.4	21.8±2.3	18.8±2.0	21.2±2.3
^{173}Lu	c	1.37Y	23.8±2.2	23.5±2.1	21.7±2.0	23.2±2.1
^{172}Lu	c	6.70D	20.3±1.8	19.6±1.7	17.9±1.6	19.0±1.6
^{171}Lu	c*	8.24D	22.6±2.0	21.8±1.9	19.9±1.8	21.4±1.8
* ^{170}Lu	c	2.012D	13.3±2.0	13.1±2.0	11.6±1.7	12.2±1.9
^{170}Lu	c*	2.012D	24.5±2.3	23.9±2.4	20.9±2.0	22.7±2.2
^{169}Lu	c	34.06H	13.5±1.2	12.9±1.1	11.2±1.0	12.4±1.1
^{167}Lu	c	51.5M	8.93±0.98	8.62±0.86	10.3±1.4	10.2±1.1
* ^{169}Yb	c	32.026D	15.6±1.4	14.6±1.3	13.1±1.2	14.4±1.3
^{169}Yb	c*	32.026D	16.2±1.4	15.2±1.3	13.6±1.2	15.0±1.3
^{166}Yb	c	56.7H	10.3±0.9	9.59±0.81	8.24±0.70	9.11±0.77
^{167}Tm	c	9.25D	13.0±2.7	12.1±2.5	10.7±2.2	11.7±2.4
^{165}Tm	c	30.06H	9.24±0.86	8.36±0.75	7.20±0.71	8.45±0.76
^{161}Er	c*	3.21H	9.09±0.97	8.24±0.89	7.21±0.84	7.84±0.85
^{160}Er	c	28.58H	4.91±0.42	4.50±0.38	3.68±0.31	4.23±0.36
^{160m}Ho	c	5.02H	5.59±1.17	4.36±1.42	3.89±1.11	5.56±1.19
^{157}Dy	c	8.14H	2.62±0.25	2.20±0.22	1.85±0.17	2.36±0.22
^{155}Dy	c*	9.9H	1.68±0.16	1.51±0.15	1.28±0.14	1.59±0.16
^{155}Tb	c*	5.32D	1.84±0.19	1.58±0.17	1.26±0.13	1.44±0.16
^{153}Tb	c*	2.34D	1.21±0.13	1.12±0.13	0.929±0.113	0.828±0.103
^{153}Gd	c	240.4D	1.12±0.12	0.995±0.124	0.765±0.095	0.953±0.099
^{149}Gd	c	9.28D	0.788±0.080	0.669±0.074	0.557±0.067	0.703±0.082
^{146}Gd	c	48.27D	0.482±0.044	0.411±0.037	0.309±0.032	0.384±0.034
^{146}Eu	i	4.61D	0.090±0.028	0.051±0.016	0.105±0.024	0.118±0.015
^{146}Eu	c	4.61D	0.572±0.055	0.462±0.042	0.414±0.042	0.501±0.045
^{139}Ce	c	137.640D	0.472±0.043	0.423±0.042	0.396±0.035	0.465±0.041
^{131}Ba	c	11.50D	0.571±0.093	0.586±0.079	0.521±0.059	0.543±0.060
^{127}Xe	c	36.4D	0.892±0.080	0.875±0.098	0.793±0.071	0.850±0.076
^{123m}Te	i(m)	119.7D	0.388±0.034	0.392±0.041	0.322±0.035	0.380±0.043
^{121m}Te	i(m)	154D	0.533±0.045	0.508±0.043	0.475±0.040	0.524±0.044
^{121}Te	c	19.16D	1.16±0.10	1.06±0.09	0.948±0.084	1.10±0.12
^{119m}Te	i(m)	4.70D	0.502±0.045	0.392±0.048	0.400±0.038	0.427±0.051
^{124}Sb	i(m1+m2+g)	60.20D	0.096±0.015	—	0.077±0.014	0.118±0.015
^{120m}Sb	i(m)	5.76D	0.434±0.037	0.471±0.040	0.476±0.042	0.471±0.040
^{113}Sn	c	115.09D	0.736±0.067	0.583±0.068	0.559±0.053	0.642±0.061
^{114m}In	i(m)	49.51D	1.59±0.14	1.78±0.17	1.60±0.16	1.80±0.16
^{111}In	c	2.8047D	1.10±0.10	0.972±0.086	0.814±0.095	0.943±0.085
^{110m}Ag	i(m)	249.76D	1.35±0.12	1.42±0.13	1.35±0.12	1.36±0.12
^{106m}Ag	i(m)	8.28D	1.03±0.09	0.926±0.084	0.755±0.068	0.836±0.076
^{100}Pd	c	3.63D	0.080±0.009	—	—	—
^{105}Rh	c	35.36H	5.46±0.49	5.37±0.48	5.28±0.48	5.31±0.48
^{102}Rh	i	207D	1.31±0.19	1.07±0.16	1.09±0.16	1.37±0.19
^{101m}Rh	c	4.34D	1.47±0.15	1.26±0.13	1.10±0.11	1.29±0.14
^{100}Rh	i(m+g)	20.8H	0.711±0.062	—	—	—
^{100}Rh	c	20.8H	0.791±0.069	—	—	—
^{103}Ru	c	39.26D	4.37±0.36	4.63±0.38	4.47±0.37	4.47±0.37

Continuation of Table 27.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{96}Tc	i(m+g)	4.28D	1.43 ± 0.13	1.30 ± 0.12	1.04 ± 0.09	1.20 ± 0.11
^{99}Mo	c	65.94H	3.69 ± 0.31	3.78 ± 0.32	3.85 ± 0.33	3.85 ± 0.33
^{96}Nb	i	23.35H	2.88 ± 0.25	2.78 ± 0.26	2.74 ± 0.26	2.76 ± 0.30
^{95}Nb	i(m+g)	34.975D	3.79 ± 0.30	3.75 ± 0.30	3.46 ± 0.28	3.60 ± 0.29
^{95}Nb	c	34.975D	6.31 ± 0.51	6.50 ± 0.52	6.13 ± 0.49	6.22 ± 0.50
^{92m}Nb	i(m)	10.15D	0.393 ± 0.033	0.395 ± 0.033	0.318 ± 0.027	0.358 ± 0.034
^{97}Zr	c	16.744H	0.683 ± 0.070	0.731 ± 0.073	0.651 ± 0.059	0.686 ± 0.065
^{95}Zr	c	64.02D	2.50 ± 0.21	2.63 ± 0.22	2.65 ± 0.22	2.59 ± 0.22
^{89}Zr	c	78.41H	2.44 ± 0.20	2.19 ± 0.18	1.80 ± 0.14	2.06 ± 0.17
^{88}Zr	c	83.4D	1.07 ± 0.09	0.925 ± 0.078	0.763 ± 0.065	0.866 ± 0.073
^{90m}Y	i(m)	3.19H	3.56 ± 0.30	3.55 ± 0.31	3.23 ± 0.30	3.26 ± 0.29
^{88}Y	i	106.65D	4.03 ± 0.38	3.64 ± 0.31	3.29 ± 0.28	3.49 ± 0.33
^{88}Y	c	106.65D	5.01 ± 0.44	4.58 ± 0.39	3.86 ± 0.36	4.30 ± 0.38
^{87}Y	c*	79.8H	3.49 ± 0.34	3.12 ± 0.31	2.62 ± 0.26	2.98 ± 0.27
^{85}Sr	c	64.84D	3.44 ± 0.31	3.14 ± 0.29	2.58 ± 0.24	2.98 ± 0.27
^{86}Rb	i(m+g)	18.631D	4.84 ± 0.41	4.78 ± 0.41	4.56 ± 0.40	5.23 ± 0.45
^{83}Rb	c	86.2D	4.03 ± 0.37	3.50 ± 0.32	3.06 ± 0.28	3.45 ± 0.31
^{82m}Rb	i(m)	6.472H	1.43 ± 0.15	1.38 ± 0.15	1.06 ± 0.13	1.21 ± 0.14
^{82}Br	i(m+g)	35.30H	2.39 ± 0.21	2.46 ± 0.21	2.38 ± 0.20	2.49 ± 0.22
^{75}Se	c	119.779D	1.49 ± 0.13	1.38 ± 0.12	1.06 ± 0.09	1.23 ± 0.11
^{74}As	i	17.77D	2.13 ± 0.22	1.97 ± 0.21	1.72 ± 0.18	1.86 ± 0.20
^{72}Ga	i	14.10H	1.25 ± 0.18	1.44 ± 0.18	1.53 ± 0.18	1.62 ± 0.19
^{72}Ga	c	14.10H	1.65 ± 0.19	1.90 ± 0.20	1.88 ± 0.20	1.92 ± 0.20
^{72}Zn	c	46.5H	0.399 ± 0.049	0.463 ± 0.053	0.349 ± 0.045	0.301 ± 0.041
^{59}Fe	c	44.472D	0.772 ± 0.072	0.851 ± 0.095	0.844 ± 0.085	0.903 ± 0.084
^{54}Mn	i	312.11D	0.357 ± 0.043	0.395 ± 0.055	0.332 ± 0.037	0.358 ± 0.037
^{46}Sc	i(m+g)	83.79D	0.180 ± 0.022	0.237 ± 0.066	0.206 ± 0.042	0.238 ± 0.023
^7Be	i	53.29D	1.40 ± 0.25	1.42 ± 0.52	1.53 ± 0.23	1.34 ± 0.20

3.10 Experimental results for 1.2 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 28 presents parameters of ^{nat,208,207,206}Pb irradiation by 1.2GeV protons. Table 29 presents values of the measured residual nuclide yields.

Table 28: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-specra sample/monitor/plate	ExpData index
^{nat} Pb	1195 ± 3	139.0	110.6	704.8	30	7.76 ± 0.60	33/13/1	pbn12g
²⁰⁸ Pb	1201 ± 3	136.8	109.6	712.7	20	5.01 ± 0.39	31/12/1	pb812g
²⁰⁷ Pb	1199 ± 3	145.0	110.2	700.3	20	5.90 ± 0.46	28/12/1	pb712g
²⁰⁶ Pb	1188 ± 3	138.0	110.5	692.1	20	6.84 ± 0.53	31/12/1	pb612g

Table 29: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 1.2$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	—	—	—	3.46±0.63
²⁰⁶ Bi	i	6.243D	1.27±0.11	2.65±0.23	3.75±0.33	2.92±0.25
²⁰⁵ Bi	i	15.31D	3.42±0.36	4.43±0.40	4.93±0.44	4.71±0.41
²⁰⁴ Bi	i	11.22H	3.99±0.33	4.33±0.36	4.48±0.37	4.46±0.37
²⁰³ Bi	i(m+g)	11.76H	4.78±0.48	3.98±0.53	3.93±0.42	4.13±0.41
²⁰² Bi	i	1.72H	6.21±0.66	4.34±0.66	4.47±0.71	3.86±0.53
^{204m} Pb	i(m)	67.2M	11.8±1.1	11.0±1.0	10.3±1.1	11.6±1.1
^{204m} Pb	c	67.2M	12.4±1.2	11.6±1.0	10.9±1.1	12.3±1.1
* ²⁰³ Pb	c	51.873H	38.8±3.3	32.5±2.8	29.3±2.5	32.5±2.8
²⁰³ Pb	c*	51.873H	40.2±3.2	33.7±2.7	30.4±2.4	33.7±2.7
^{202m} Pb	i(m)	3.53H	8.60±0.90	9.79±1.07	9.67±1.06	9.50±0.97
²⁰¹ Pb	c*	9.33H	30.6±3.1	26.3±2.7	24.0±2.4	26.0±2.6
²⁰⁰ Pb	c	21.5H	21.0±1.7	18.3±1.5	17.0±1.4	17.6±1.5
¹⁹⁹ Pb	c*	90M	42.3±7.6	35.5±6.4	33.6±6.0	32.4±5.9
¹⁹⁸ Pb	c	2.4H	30.2±5.6	25.0±4.7	23.6±4.4	23.7±4.4
^{197m} Pb	c*	43M	18.8±4.1	15.9±3.5	15.0±3.3	15.6±3.4
^{195m} Pb	i(m)	15.0M	8.90±1.83	7.57±1.56	6.88±1.45	7.87±1.66
* ²⁰² Tl	i	12.23D	18.0±1.5	16.6±1.4	16.6±1.4	16.5±1.4
²⁰² Tl	c	12.23D	18.8±1.5	17.5±1.4	17.5±1.4	17.4±1.4
²⁰¹ Tl	c*	72.912H	52.5±4.2	48.0±3.8	44.4±3.6	46.0±3.7
²⁰⁰ Tl	i	26.1H	22.3±2.0	21.3±2.1	21.0±2.2	22.0±2.0
²⁰⁰ Tl	c	26.1H	42.8±3.6	38.8±3.3	37.1±3.2	38.6±3.3
¹⁹⁹ Tl	c	7.42H	38.5±5.4	39.0±5.5	33.6±4.8	33.3±4.8
¹⁹⁹ Tl	c*	7.42H	44.6±6.2	40.8±5.7	38.0±5.3	40.2±5.6
^{198m} Tl	i(m)	1.87H	18.9±2.6	23.0±3.2	19.0±2.7	19.5±3.1
^{196m} Tl	i(m)	1.41H	32.0±6.0	31.2±5.9	30.8±5.8	29.5±5.6
²⁰³ Hg	c	46.612D	1.90±0.16	3.07±0.25	4.24±0.34	3.23±0.26
^{197m} Hg	i(m)	23.8H	8.49±0.73	8.76±0.77	10.1±0.9	8.87±0.76
^{195m} Hg	i(m)	41.6H	13.2±2.0	13.4±2.1	12.7±2.0	12.8±2.0

Continuation of Table 29.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{193m}Hg	i(m)	11.8H	14.0 $\pm$ 3.4	13.7 $\pm$ 2.7	14.8 $\pm$ 3.4	13.2 $\pm$ 2.7
^{192}Hg	c	4.85H	33.2 $\pm$ 2.8	31.5 $\pm$ 2.6	30.5 $\pm$ 2.5	29.9 $\pm$ 2.5
^{190}Hg	c*	20.0M	24.1 $\pm$ 4.1	22.5 $\pm$ 3.8	22.6 $\pm$ 3.8	21.7 $\pm$ 3.7
^{198m}Au	i(m)	2.27D	0.361 $\pm$ 0.030	0.461 $\pm$ 0.038	0.722 $\pm$ 0.060	0.583 $\pm$ 0.048
^{198}Au	i(m+g)	2.69517D	1.51 $\pm$ 0.12	1.97 $\pm$ 0.15	2.50 $\pm$ 0.21	1.88 $\pm$ 0.16
^{198}Au	i	2.69517D	1.19 $\pm$ 0.11	1.51 $\pm$ 0.12	1.84 $\pm$ 0.20	1.27 $\pm$ 0.15
^{196}Au	i(m1+m2+g)	6.183D	2.69 $\pm$ 0.23	3.19 $\pm$ 0.27	3.91 $\pm$ 0.33	3.26 $\pm$ 0.28
^{195}Au	c	186.098D	34.2 $\pm$ 4.2	44.0 $\pm$ 5.4	47.3 $\pm$ 5.7	41.9 $\pm$ 5.1
^{194}Au	i(m1+m2+g)	38.02H	5.02 $\pm$ 0.57	5.67 $\pm$ 0.64	6.60 $\pm$ 0.75	5.75 $\pm$ 0.65
^{192}Au	i(m+g)	4.94H	8.95 $\pm$ 1.41	8.39 $\pm$ 1.41	9.82 $\pm$ 1.48	8.71 $\pm$ 1.33
^{192}Au	c	4.94H	47.4 $\pm$ 6.8	44.5 $\pm$ 6.4	45.2 $\pm$ 6.5	43.9 $\pm$ 6.3
^{191}Au	c*	3.18H	47.3 $\pm$ 5.7	44.5 $\pm$ 5.3	45.4 $\pm$ 5.2	41.7 $\pm$ 4.7
^{190}Au	c	42.8M	33.3 $\pm$ 3.7	34.8 $\pm$ 3.5	36.5 $\pm$ 3.3	31.4 $\pm$ 3.9
^{191}Pt	c	2.802D	34.5 $\pm$ 3.8	33.2 $\pm$ 3.9	34.7 $\pm$ 3.5	32.3 $\pm$ 3.4
^{189}Pt	c	10.87H	40.5 $\pm$ 3.6	38.9 $\pm$ 3.4	40.0 $\pm$ 3.5	37.9 $\pm$ 3.3
^{188}Pt	c	10.2D	37.8 $\pm$ 3.1	36.7 $\pm$ 3.0	36.9 $\pm$ 3.1	35.2 $\pm$ 2.9
^{186}Pt	c	2.08H	30.2 $\pm$ 6.9	29.3 $\pm$ 6.7	28.6 $\pm$ 6.5	29.1 $\pm$ 6.7
^{184}Pt	c	17.3M	29.7 $\pm$ 5.8	23.8 $\pm$ 5.0	25.4 $\pm$ 5.0	30.1 $\pm$ 6.2
^{192}Ir	i(m1+g)	73.827D	0.109 $\pm$ 0.017	0.144 $\pm$ 0.018	0.210 $\pm$ 0.022	0.164 $\pm$ 0.015
^{190}Ir	i(m1+g)	11.78D	0.395 $\pm$ 0.040	0.414 $\pm$ 0.059	0.569 $\pm$ 0.056	0.383 $\pm$ 0.041
^{189}Ir	c	13.2D	32.4 $\pm$ 4.2	33.8 $\pm$ 4.4	35.0 $\pm$ 4.6	32.7 $\pm$ 4.3
^{188}Ir	i	41.5H	3.06 $\pm$ 0.68	2.79 $\pm$ 0.34	4.47 $\pm$ 0.57	3.77 $\pm$ 0.54
^{188}Ir	c	41.5H	42.3 $\pm$ 3.6	40.9 $\pm$ 3.4	42.6 $\pm$ 3.6	40.4 $\pm$ 3.4
^{187}Ir	c*	10.5H	36.2 $\pm$ 4.1	37.8 $\pm$ 4.0	36.2 $\pm$ 3.8	35.3 $\pm$ 3.2
^{186}Ir	c	16.64H	17.8 $\pm$ 1.7	17.4 $\pm$ 1.6	18.0 $\pm$ 1.6	18.1 $\pm$ 1.6
^{185}Ir	c	14.4H	28.3 $\pm$ 2.7	26.5 $\pm$ 2.5	28.3 $\pm$ 2.7	26.2 $\pm$ 2.5
^{184}Ir	c*	3.09H	34.4 $\pm$ 3.0	34.3 $\pm$ 3.0	36.2 $\pm$ 3.2	34.8 $\pm$ 3.0
^{185}Os	c	93.6D	37.6 $\pm$ 3.2	36.6 $\pm$ 3.1	37.8 $\pm$ 3.2	35.8 $\pm$ 3.0
^{183m}Os	c*	9.9H	21.9 $\pm$ 1.9	21.5 $\pm$ 1.9	21.0 $\pm$ 1.8	21.0 $\pm$ 1.9
^{182}Os	c	22.10H	36.9 $\pm$ 3.4	35.3 $\pm$ 3.2	34.5 $\pm$ 3.2	34.1 $\pm$ 3.1
^{180}Os	c	21.5M	31.9 $\pm$ 2.8	30.9 $\pm$ 2.9	32.2 $\pm$ 3.0	28.1 $\pm$ 2.7
^{183}Re	c	70.0D	38.9 $\pm$ 3.5	38.0 $\pm$ 3.3	39.7 $\pm$ 3.5	36.9 $\pm$ 3.3
^{182m}Re	c	12.7H	40.4 $\pm$ 3.8	38.4 $\pm$ 3.6	39.3 $\pm$ 3.8	37.6 $\pm$ 3.5
^{181}Re	c*	19.9H	33.2 $\pm$ 4.4	32.9 $\pm$ 4.4	33.9 $\pm$ 4.5	31.4 $\pm$ 4.2
^{179}Re	c*	19.5M	47.4 $\pm$ 5.1	46.6 $\pm$ 4.3	45.0 $\pm$ 4.1	42.7 $\pm$ 5.1
^{178}Re	c*	13.2M	50.1 $\pm$ 7.0	46.8 $\pm$ 6.5	47.3 $\pm$ 7.0	49.0 $\pm$ 7.0
^{178}W	c	21.6D	29.3 $\pm$ 3.9	29.3 $\pm$ 2.9	24.1 $\pm$ 5.5	25.5 $\pm$ 3.2
^{177}W	c	135M	32.7 $\pm$ 4.3	32.6 $\pm$ 4.3	33.7 $\pm$ 4.4	33.1 $\pm$ 4.3
^{176}W	c	2.5H	27.9 $\pm$ 5.3	30.7 $\pm$ 3.9	30.4 $\pm$ 5.7	23.8 $\pm$ 3.4
$^{*177}\text{Ta}$	c	56.56H	33.9 $\pm$ 8.4	34.5 $\pm$ 8.6	33.6 $\pm$ 8.4	32.2 $\pm$ 8.0
^{177}Ta	c*	56.56H	35.2 $\pm$ 8.4	35.9 $\pm$ 8.6	35.0 $\pm$ 8.4	33.6 $\pm$ 8.0
^{176}Ta	c	8.09H	35.5 $\pm$ 3.5	34.3 $\pm$ 3.3	33.9 $\pm$ 3.4	34.7 $\pm$ 3.1
^{175}Ta	c	10.5H	34.4 $\pm$ 3.2	33.2 $\pm$ 3.0	33.3 $\pm$ 3.2	32.8 $\pm$ 3.2
^{174}Ta	c	1.14H	34.1 $\pm$ 4.0	32.2 $\pm$ 3.7	32.7 $\pm$ 3.8	31.5 $\pm$ 3.7
^{173}Ta	c	3.14H	35.1 $\pm$ 4.6	35.1 $\pm$ 4.6	34.5 $\pm$ 4.5	34.1 $\pm$ 4.5
^{172}Ta	c*	36.8M	17.4 $\pm$ 2.2	17.1 $\pm$ 2.1	17.1 $\pm$ 2.2	17.9 $\pm$ 2.3
^{175}Hf	c	70D	34.0 $\pm$ 2.9	32.8 $\pm$ 2.8	33.6 $\pm$ 2.9	31.9 $\pm$ 2.8
$^{*173}\text{Hf}$	c	23.6H	35.2 $\pm$ 3.2	33.2 $\pm$ 3.0	33.4 $\pm$ 3.1	32.1 $\pm$ 2.9
^{173}Hf	c*	23.6H	40.6 $\pm$ 3.5	38.6 $\pm$ 3.3	38.7 $\pm$ 3.4	37.3 $\pm$ 3.2
^{172}Hf	c	1.87Y	28.6 $\pm$ 2.4	28.0 $\pm$ 2.3	27.6 $\pm$ 2.3	27.3 $\pm$ 2.3

Continuation of Table 29.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{171}Hf	c	12.1H	31.3 ± 3.2	27.9 ± 3.1	27.9 ± 3.6	27.8 ± 3.5
^{170}Hf	c	16.01H	37.9 ± 4.0	36.6 ± 3.8	35.2 ± 3.7	35.0 ± 3.7
^{173}Lu	c	1.37Y	33.0 ± 2.9	30.8 ± 2.7	31.9 ± 2.8	30.3 ± 2.7
^{172}Lu	i(m+g)	6.70D	0.147 ± 0.049	0.161 ± 0.054	0.212 ± 0.031	0.181 ± 0.021
^{172}Lu	c	6.70D	29.2 ± 2.5	28.5 ± 2.5	28.1 ± 2.4	27.2 ± 2.3
^{171}Lu	c*	8.24D	35.2 ± 3.0	33.9 ± 2.9	33.3 ± 3.2	32.6 ± 2.9
^{171}Lu	c	8.24D	32.2 ± 2.7	30.7 ± 2.5	30.8 ± 2.5	29.6 ± 2.4
^{170}Lu	c	2.012D	26.8 ± 2.5	26.5 ± 2.3	25.5 ± 2.3	24.6 ± 2.1
^{169}Lu	c	34.06H	24.7 ± 2.2	23.6 ± 2.0	22.7 ± 2.0	22.4 ± 1.9
^{167}Lu	c	51.5M	23.5 ± 2.8	22.5 ± 3.3	20.6 ± 3.2	20.8 ± 3.8
* ^{169}Yb	c	32.026D	27.6 ± 2.4	25.7 ± 2.2	26.3 ± 2.2	25.2 ± 2.1
^{169}Yb	c*	32.026D	28.7 ± 2.4	26.8 ± 2.3	27.3 ± 2.3	26.2 ± 2.2
^{166}Yb	c	56.7H	24.2 ± 2.0	22.3 ± 1.9	21.7 ± 1.8	21.1 ± 1.8
^{167}Tm	c	9.25D	27.8 ± 5.8	26.0 ± 5.4	25.7 ± 5.3	25.1 ± 5.2
^{165}Tm	c	30.06H	23.6 ± 2.1	22.0 ± 1.9	21.3 ± 1.9	21.1 ± 1.9
^{161}Er	c*	3.21H	23.6 ± 2.4	23.6 ± 2.4	22.7 ± 2.3	23.0 ± 2.3
^{160}Er	c	28.58H	17.9 ± 1.5	16.5 ± 1.4	15.2 ± 1.3	15.7 ± 1.3
^{159}Er	c*	36M	21.4 ± 1.8	18.8 ± 1.6	17.1 ± 1.4	20.2 ± 1.7
^{160m}Ho	c	5.02H	18.9 ± 2.4	17.8 ± 2.2	17.4 ± 3.1	17.4 ± 2.2
^{156}Ho	c*	56M	14.2 ± 1.2	13.0 ± 1.2	11.5 ± 1.1	11.9 ± 1.1
^{157}Dy	c	8.14H	13.5 ± 1.2	12.5 ± 1.1	11.2 ± 1.0	11.9 ± 1.1
^{155}Dy	c*	9.9H	10.7 ± 0.9	9.55 ± 0.81	8.94 ± 0.77	9.38 ± 0.80
^{152}Dy	c	2.38H	4.97 ± 0.45	4.67 ± 0.40	4.19 ± 0.38	4.57 ± 0.41
^{155}Tb	c*	5.32D	10.4 ± 1.2	9.41 ± 1.22	9.22 ± 0.92	8.60 ± 1.35
^{153}Tb	c*	2.34D	7.84 ± 0.80	7.41 ± 0.75	6.89 ± 0.70	6.87 ± 0.70
* ^{152}Tb	c	17.5H	6.72 ± 0.75	5.58 ± 0.65	5.58 ± 0.68	5.89 ± 0.66
^{152}Tb	c*	17.5H	7.50 ± 0.76	6.32 ± 0.67	6.24 ± 0.68	6.61 ± 0.67
^{151}Tb	c	17.609H	5.18 ± 0.53	4.04 ± 0.56	4.26 ± 0.47	4.99 ± 0.50
^{153}Gd	c	240.4D	7.39 ± 0.67	6.68 ± 0.67	6.35 ± 0.58	6.57 ± 0.59
^{151}Gd	c	124D	5.60 ± 0.66	5.01 ± 0.63	5.48 ± 0.67	5.42 ± 0.62
^{149}Gd	c	9.28D	6.63 ± 0.64	5.80 ± 0.55	5.18 ± 0.52	5.69 ± 0.56
^{147}Gd	c	38.06H	5.04 ± 0.46	4.39 ± 0.41	3.64 ± 0.34	4.04 ± 0.55
^{146}Gd	c	48.27D	4.81 ± 0.41	4.06 ± 0.34	3.54 ± 0.30	3.90 ± 0.33
* ^{149}Eu	c	93.1D	8.16 ± 0.81	6.52 ± 0.91	7.26 ± 1.14	5.78 ± 0.63
^{149}Eu	c*	93.1D	8.89 ± 0.81	7.16 ± 0.91	7.84 ± 1.14	6.41 ± 0.64
* ^{147}Eu	c	24.1D	5.54 ± 0.50	4.90 ± 0.49	4.21 ± 0.39	4.49 ± 0.42
^{147}Eu	c*	24.1D	5.90 ± 0.52	5.21 ± 0.51	4.47 ± 0.41	4.78 ± 0.44
^{146}Eu	i	4.61D	0.632 ± 0.057	0.666 ± 0.061	0.679 ± 0.059	0.650 ± 0.058
^{146}Eu	c	4.61D	5.44 ± 0.46	4.72 ± 0.40	4.22 ± 0.36	4.55 ± 0.38
^{145}Eu	c	5.93D	3.40 ± 0.34	2.93 ± 0.28	2.41 ± 0.23	2.76 ± 0.26
^{143}Pm	c	265D	3.07 ± 0.32	2.47 ± 0.26	2.21 ± 0.25	2.42 ± 0.25
^{139}Ce	c	137.640D	2.21 ± 0.18	1.99 ± 0.16	1.86 ± 0.15	1.91 ± 0.15
^{131}Ba	c	11.50D	1.21 ± 0.12	1.13 ± 0.11	1.15 ± 0.13	1.19 ± 0.12
^{128}Ba	c	2.43D	0.705 ± 0.104	0.797 ± 0.098	0.675 ± 0.111	0.650 ± 0.078
^{127}Xe	c	36.4D	1.33 ± 0.11	1.13 ± 0.13	1.11 ± 0.10	1.07 ± 0.10
^{123m}Te	i(m)	119.7D	0.261 ± 0.032	0.318 ± 0.049	0.356 ± 0.044	0.280 ± 0.035
^{121m}Te	i(m)	154D	0.494 ± 0.041	0.446 ± 0.037	0.392 ± 0.033	0.443 ± 0.037
^{121}Te	c	19.16D	1.52 ± 0.13	1.41 ± 0.12	1.24 ± 0.11	1.29 ± 0.11
^{119m}Te	i(m)	4.70D	0.586 ± 0.051	0.638 ± 0.060	0.501 ± 0.053	0.490 ± 0.043
^{120m}Sb	i(m)	5.76D	0.377 ± 0.041	0.388 ± 0.046	0.395 ± 0.041	0.367 ± 0.032

Continuation of Table 29.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{113}Sn	c	115.09D	1.11 ± 0.10	0.874 ± 0.091	0.817 ± 0.076	0.854 ± 0.075
^{114m}In	i(m)	49.51D	1.64 ± 0.16	1.44 ± 0.17	1.34 ± 0.12	1.27 ± 0.11
^{111}In	c	2.8047D	1.45 ± 0.12	1.22 ± 0.10	1.08 ± 0.09	1.18 ± 0.10
^{110m}Ag	i(m)	249.76D	1.10 ± 0.09	1.06 ± 0.11	1.02 ± 0.09	1.03 ± 0.09
^{106m}Ag	i(m)	8.28D	1.20 ± 0.11	1.02 ± 0.10	0.972 ± 0.089	0.953 ± 0.093
^{105}Ag	c	41.29D	1.34 ± 0.14	1.11 ± 0.12	0.914 ± 0.167	1.20 ± 0.24
^{100}Pd	c	3.63D	0.190 ± 0.026	0.106 ± 0.038	0.136 ± 0.025	0.099 ± 0.028
^{105}Rh	c	35.36H	4.88 ± 0.44	3.96 ± 0.37	4.36 ± 0.41	4.03 ± 0.39
^{102}Rh	i	207D	1.04 ± 0.15	0.887 ± 0.138	0.867 ± 0.147	0.992 ± 0.140
^{101m}Rh	c	4.34D	1.86 ± 0.19	1.57 ± 0.16	1.38 ± 0.15	1.49 ± 0.15
^{100}Rh	i(m+g)	20.8H	1.05 ± 0.10	0.819 ± 0.101	0.797 ± 0.079	1.01 ± 0.12
^{100}Rh	c	20.8H	1.24 ± 0.11	0.925 ± 0.097	0.932 ± 0.084	1.11 ± 0.12
^{103}Ru	c	39.26D	3.48 ± 0.28	3.35 ± 0.27	3.46 ± 0.28	3.33 ± 0.27
^{96}Tc	i(m+g)	4.28D	1.71 ± 0.15	1.42 ± 0.13	1.30 ± 0.12	1.39 ± 0.12
^{99}Mo	c	65.94H	3.07 ± 0.26	2.86 ± 0.24	3.12 ± 0.26	2.87 ± 0.24
^{96}Nb	i	23.35H	2.25 ± 0.25	2.15 ± 0.19	1.93 ± 0.17	2.09 ± 0.19
^{95}Nb	i(m+g)	34.975D	3.40 ± 0.27	3.14 ± 0.26	2.98 ± 0.24	2.94 ± 0.23
^{95}Nb	c	34.975D	5.20 ± 0.41	4.96 ± 0.39	4.99 ± 0.39	4.81 ± 0.38
^{90}Nb	c*	14.60H	1.07 ± 0.11	0.973 ± 0.130	0.847 ± 0.108	0.964 ± 0.111
^{95}Zr	c	64.02D	1.78 ± 0.15	1.84 ± 0.15	1.96 ± 0.16	1.89 ± 0.16
^{89}Zr	c	78.41H	3.07 ± 0.24	2.61 ± 0.20	2.37 ± 0.19	2.59 ± 0.21
^{88}Zr	c	83.4D	1.47 ± 0.12	1.19 ± 0.10	1.11 ± 0.09	1.22 ± 0.10
^{88}Y	i	106.65D	4.02 ± 0.34	3.73 ± 0.32	3.35 ± 0.28	3.52 ± 0.30
^{88}Y	c	106.65D	5.47 ± 0.48	4.78 ± 0.40	4.47 ± 0.38	4.73 ± 0.41
^{87}Y	c*	79.8H	4.21 ± 0.33	3.56 ± 0.28	3.18 ± 0.25	3.42 ± 0.27
^{86}Y	c	14.74H	1.76 ± 0.16	1.39 ± 0.15	1.30 ± 0.21	1.41 ± 0.13
^{85}Sr	c	64.84D	4.17 ± 0.39	3.57 ± 0.32	3.22 ± 0.29	3.41 ± 0.31
^{83}Rb	c	86.2D	4.74 ± 0.43	4.13 ± 0.37	3.87 ± 0.35	4.00 ± 0.39
^{82m}Rb	i(m)	6.472H	2.12 ± 0.26	1.66 ± 0.17	1.54 ± 0.20	1.70 ± 0.16
^{82}Br	i(m+g)	35.30H	1.90 ± 0.16	1.85 ± 0.16	1.90 ± 0.16	1.94 ± 0.16
^{75}Se	c	119.779D	2.03 ± 0.18	1.73 ± 0.16	1.58 ± 0.16	1.68 ± 0.16
^{74}As	i	17.77D	2.57 ± 0.27	2.17 ± 0.23	2.09 ± 0.22	2.18 ± 0.23
^{71}As	c	65.28H	0.351 ± 0.033	0.184 ± 0.038	0.143 ± 0.025	0.199 ± 0.019
^{72}Ga	i	14.10H	1.04 ± 0.16	1.52 ± 0.17	1.36 ± 0.16	1.30 ± 0.18
^{72}Ga	c	14.10H	1.47 ± 0.18	1.82 ± 0.18	1.70 ± 0.17	1.68 ± 0.19
^{72}Zn	c	46.5H	0.428 ± 0.047	0.297 ± 0.051	0.339 ± 0.051	0.381 ± 0.047
^{59}Fe	c	44.472D	1.15 ± 0.11	1.07 ± 0.10	1.01 ± 0.09	1.09 ± 0.10
^{54}Mn	i	312.11D	0.741 ± 0.092	0.638 ± 0.086	0.581 ± 0.059	0.590 ± 0.066
^{48}V	c	15.9735D	0.092 ± 0.012	0.074 ± 0.013	0.094 ± 0.015	0.079 ± 0.013
^{48}Sc	i	43.67H	0.430 ± 0.043	0.423 ± 0.049	0.434 ± 0.040	0.395 ± 0.036
^{46}Sc	i(m+g)	83.79D	0.584 ± 0.053	0.513 ± 0.071	0.452 ± 0.060	0.539 ± 0.051
^7Be	i	53.29D	2.56 ± 0.32	1.94 ± 0.18	2.88 ± 0.42	2.19 ± 0.26

3.11 Experimental results for 1.6 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 30 presents parameters of ^{nat,208,207,206}Pb irradiation by 1.6GeV protons. Table 31 presents values of the measured residual nuclide yields.

Table 30: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-specra sample/monitor/plate	ExpData index
^{nat} Pb	1598 ± 4	205.4	111.1	696.6	20	5.42 ± 0.45	28/10/1	pbn16g
²⁰⁸ Pb	1601 ± 4	143.8	110.4	700.8	30	3.40 ± 0.28	26/10/1	pb816g
²⁰⁷ Pb	1599 ± 4	143.4	110.6	691.3	30	2.27 ± 0.19	26/10/1	pb716g
²⁰⁶ Pb	1599 ± 4	135.8	110.1	721.9	30	4.07 ± 0.34	29/11/1	pb616g

Table 31: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for $E_p = 1.6$ GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	—	—	4.96±0.98	3.66±0.84
²⁰⁶ Bi	i	6.243D	1.35±0.13	3.23±0.29	3.92±0.35	3.14±0.29
²⁰⁵ Bi	i	15.31D	3.37±0.39	4.63±0.48	5.20±0.50	4.54±0.46
²⁰⁴ Bi	i	11.22H	3.91±0.35	4.92±0.44	4.41±0.39	4.66±0.41
²⁰³ Bi	i(m+g)	11.76H	4.29±0.47	5.22±0.55	4.08±0.44	5.08±0.54
²⁰² Bi	i	1.72H	3.18±0.45	3.84±0.54	2.95±0.46	2.69±0.45
^{204m} Pb	i(m)	67.2M	10.8±1.0	12.1±1.2	13.1±1.2	11.2±1.1
^{204m} Pb	c	67.2M	11.4±1.0	12.9±1.3	13.7±1.3	11.9±1.2
* ²⁰³ Pb	c	51.873H	36.3±3.3	33.8±3.1	27.8±2.6	31.5±2.9
²⁰³ Pb	c*	51.873H	37.6±3.2	35.4±3.1	29.0±2.5	33.0±2.8
^{202m} Pb	i(m)	3.53H	8.97±1.11	10.3±1.0	9.09±0.88	9.19±1.11
²⁰¹ Pb	c*	9.33H	27.1±2.9	26.4±2.8	22.4±2.4	24.1±2.6
²⁰⁰ Pb	c	21.5H	18.8±1.7	18.0±1.6	16.9±1.5	16.5±1.5
¹⁹⁹ Pb	c*	90M	33.0±6.0	34.8±6.4	27.5±5.0	34.6±6.3
¹⁹⁸ Pb	c	2.4H	24.5±4.6	25.9±4.9	21.5±4.1	21.6±4.2
^{197m} Pb	c*	43M	15.8±3.5	15.6±3.5	13.4±3.0	14.1±3.1
^{195m} Pb	i(m)	15.0M	6.86±1.45	6.81±1.48	5.78±1.23	5.74±1.21
* ²⁰² Tl	i	12.23D	16.7±1.5	17.8±1.6	15.9±1.5	16.0±1.5
²⁰² Tl	c	12.23D	17.6±1.5	18.7±1.6	16.7±1.4	16.9±1.5
²⁰¹ Tl	c*	72.912H	47.0±4.0	48.9±4.2	40.8±3.6	43.2±3.7
²⁰⁰ Tl	i	26.1H	19.5±1.8	21.0±2.0	18.5±2.0	18.2±1.7
²⁰⁰ Tl	c	26.1H	38.0±3.4	38.9±3.5	34.7±3.1	34.6±3.1
¹⁹⁹ Tl	c	7.42H	33.0±4.7	29.5±4.6	23.5±3.7	29.6±4.5
¹⁹⁹ Tl	c*	7.42H	38.6±5.5	38.4±5.6	34.1±4.9	35.9±5.2
^{198m} Tl	i(m)	1.87H	16.2±2.3	19.6±2.8	15.6±2.4	15.1±2.2
^{196m} Tl	i(m)	1.41H	28.4±5.4	30.9±5.9	27.1±5.2	27.2±5.2
²⁰³ Hg	c	46.612D	1.81±0.16	3.29±0.29	4.21±0.37	3.24±0.28
^{197m} Hg	i(m)	23.8H	7.32±0.68	9.58±0.88	9.17±0.84	8.71±0.82
^{195m} Hg	i(m)	41.6H	11.5±2.0	13.4±2.2	13.0±2.1	12.3±1.9

Continuation of Table 31.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{193m}Hg	i(m)	11.8H	14.6 $\pm$ 2.5	18.1 $\pm$ 3.1	15.3 $\pm$ 2.6	16.4 $\pm$ 2.8
^{192}Hg	c	4.85H	27.4 $\pm$ 2.4	28.7 $\pm$ 2.6	25.1 $\pm$ 2.2	25.4 $\pm$ 2.3
^{190}Hg	c*	20.0M	18.4 $\pm$ 3.2	20.4 $\pm$ 3.6	15.9 $\pm$ 2.8	16.1 $\pm$ 2.8
^{198m}Au	i(m)	2.27D	0.381 $\pm$ 0.043	0.542 $\pm$ 0.092	0.790 $\pm$ 0.079	0.655 $\pm$ 0.089
^{198}Au	i(m+g)	2.69517D	1.25 $\pm$ 0.11	1.91 $\pm$ 0.18	2.17 $\pm$ 0.19	1.76 $\pm$ 0.16
^{198}Au	i	2.69517D	0.874 $\pm$ 0.093	1.36 $\pm$ 0.19	1.38 $\pm$ 0.15	1.11 $\pm$ 0.16
^{196}Au	i(m1+m2+g)	6.183D	2.43 $\pm$ 0.23	3.32 $\pm$ 0.31	3.62 $\pm$ 0.33	3.14 $\pm$ 0.30
^{195}Au	c	186.098D	44.2 $\pm$ 5.5	37.8 $\pm$ 4.8	40.0 $\pm$ 5.0	38.7 $\pm$ 5.0
^{194}Au	i(m1+m2+g)	38.02H	4.52 $\pm$ 0.54	5.65 $\pm$ 0.67	5.85 $\pm$ 0.69	5.19 $\pm$ 0.61
^{192}Au	i(m+g)	4.94H	6.24 $\pm$ 1.07	8.12 $\pm$ 1.41	8.55 $\pm$ 1.46	8.02 $\pm$ 1.29
^{192}Au	c	4.94H	37.5 $\pm$ 5.6	40.7 $\pm$ 6.0	37.3 $\pm$ 5.5	36.7 $\pm$ 5.4
^{191}Au	c*	3.18H	40.4 $\pm$ 4.7	43.9 $\pm$ 5.5	37.4 $\pm$ 4.7	34.3 $\pm$ 4.2
^{190}Au	c	42.8M	28.8 $\pm$ 3.3	30.2 $\pm$ 3.4	27.2 $\pm$ 2.8	30.1 $\pm$ 3.1
^{191}Pt	c	2.802D	28.8 $\pm$ 3.2	31.3 $\pm$ 3.8	29.1 $\pm$ 3.4	28.7 $\pm$ 3.4
^{189}Pt	c	10.87H	34.4 $\pm$ 3.2	36.8 $\pm$ 3.5	33.3 $\pm$ 3.1	34.9 $\pm$ 3.4
^{188}Pt	c	10.2D	28.8 $\pm$ 2.6	31.1 $\pm$ 2.8	28.7 $\pm$ 2.6	28.0 $\pm$ 2.5
^{186}Pt	c	2.08H	24.4 $\pm$ 5.6	26.3 $\pm$ 6.1	23.5 $\pm$ 5.4	22.9 $\pm$ 5.3
^{184}Pt	c	17.3M	22.7 $\pm$ 4.6	24.8 $\pm$ 5.8	21.7 $\pm$ 4.4	19.6 $\pm$ 4.4
^{192}Ir	i(m1+g)	73.827D	0.120 $\pm$ 0.022	0.203 $\pm$ 0.047	0.204 $\pm$ 0.030	0.123 $\pm$ 0.017
^{190}Ir	i(m1+g)	11.78D	0.371 $\pm$ 0.073	0.478 $\pm$ 0.092	0.513 $\pm$ 0.070	0.332 $\pm$ 0.092
^{189}Ir	c	13.2D	25.4 $\pm$ 3.4	31.4 $\pm$ 4.3	26.1 $\pm$ 3.7	30.4 $\pm$ 4.0
^{188}Ir	i	41.5H	—	—	2.78 $\pm$ 0.53	1.51 $\pm$ 0.56
^{188}Ir	c	41.5H	28.4 $\pm$ 3.8	33.0 $\pm$ 4.4	32.1 $\pm$ 4.3	30.1 $\pm$ 4.0
^{187}Ir	c*	10.5H	30.1 $\pm$ 3.0	32.4 $\pm$ 3.4	30.2 $\pm$ 3.3	26.2 $\pm$ 3.9
^{186}Ir	c	16.64H	13.3 $\pm$ 1.3	15.6 $\pm$ 1.5	14.9 $\pm$ 1.4	14.1 $\pm$ 1.3
^{185}Ir	c	14.4H	21.6 $\pm$ 2.4	23.7 $\pm$ 2.5	21.2 $\pm$ 3.5	21.3 $\pm$ 2.3
^{184}Ir	c*	3.09H	27.3 $\pm$ 2.5	30.6 $\pm$ 2.8	27.5 $\pm$ 2.5	27.8 $\pm$ 2.6
^{185}Os	c	93.6D	29.6 $\pm$ 2.8	32.7 $\pm$ 2.9	30.6 $\pm$ 2.8	29.7 $\pm$ 2.7
^{183m}Os	c*	9.9H	17.2 $\pm$ 1.9	18.8 $\pm$ 1.7	17.4 $\pm$ 1.6	16.4 $\pm$ 1.7
^{182}Os	c	22.10H	30.3 $\pm$ 2.9	33.9 $\pm$ 3.3	28.7 $\pm$ 3.0	28.8 $\pm$ 2.8
^{180}Os	c	21.5M	24.0 $\pm$ 2.3	27.0 $\pm$ 2.5	26.2 $\pm$ 2.5	26.2 $\pm$ 2.4
^{183}Re	c	70.0D	30.7 $\pm$ 2.8	33.5 $\pm$ 3.2	31.6 $\pm$ 3.4	30.6 $\pm$ 2.9
^{182m}Re	c	12.7H	30.8 $\pm$ 3.0	32.2 $\pm$ 4.7	31.9 $\pm$ 3.2	28.6 $\pm$ 3.0
^{181}Re	c*	19.9H	27.9 $\pm$ 3.8	30.5 $\pm$ 4.2	28.3 $\pm$ 3.9	26.6 $\pm$ 3.6
^{179}Re	c*	19.5M	38.8 $\pm$ 5.9	41.1 $\pm$ 4.7	37.8 $\pm$ 4.0	38.3 $\pm$ 3.7
^{178}Re	c*	13.2M	41.6 $\pm$ 6.0	45.2 $\pm$ 6.6	43.7 $\pm$ 6.3	40.6 $\pm$ 6.0
^{178}W	c	21.6D	21.8 $\pm$ 2.5	26.1 $\pm$ 4.7	22.2 $\pm$ 4.1	22.5 $\pm$ 2.9
^{177}W	c	135M	25.0 $\pm$ 3.4	30.9 $\pm$ 4.2	26.4 $\pm$ 3.6	26.9 $\pm$ 3.8
* ^{177}Ta	c	56.56H	27.0 $\pm$ 6.8	33.0 $\pm$ 8.3	29.3 $\pm$ 7.4	31.0 $\pm$ 7.8
^{177}Ta	c*	56.56H	28.0 $\pm$ 6.7	34.2 $\pm$ 8.3	30.3 $\pm$ 7.3	32.1 $\pm$ 7.8
^{176}Ta	c	8.09H	27.5 $\pm$ 3.9	31.4 $\pm$ 2.9	29.5 $\pm$ 2.8	28.1 $\pm$ 4.0
^{175}Ta	c	10.5H	28.5 $\pm$ 2.8	32.3 $\pm$ 3.2	29.4 $\pm$ 3.2	27.9 $\pm$ 2.7
^{174}Ta	c	1.14H	29.1 $\pm$ 3.5	32.7 $\pm$ 4.0	29.5 $\pm$ 3.6	29.6 $\pm$ 3.6
^{173}Ta	c	3.14H	30.8 $\pm$ 4.2	36.4 $\pm$ 5.0	30.5 $\pm$ 4.2	34.2 $\pm$ 4.7
^{172}Ta	c*	36.8M	17.9 $\pm$ 2.3	22.0 $\pm$ 2.9	18.8 $\pm$ 2.4	17.3 $\pm$ 2.4
^{175}Hf	c	70D	28.2 $\pm$ 2.6	31.6 $\pm$ 2.9	29.2 $\pm$ 2.7	28.9 $\pm$ 2.7
* ^{173}Hf	c	23.6H	29.0 $\pm$ 2.8	32.9 $\pm$ 3.2	30.8 $\pm$ 3.0	29.4 $\pm$ 2.9
^{173}Hf	c*	23.6H	33.8 $\pm$ 3.1	38.4 $\pm$ 3.6	35.5 $\pm$ 3.3	34.7 $\pm$ 3.2
^{172}Hf	c	1.87Y	24.9 $\pm$ 2.2	27.2 $\pm$ 2.4	25.6 $\pm$ 2.3	25.3 $\pm$ 2.2
^{171}Hf	c	12.1H	24.6 $\pm$ 3.6	28.2 $\pm$ 3.5	24.4 $\pm$ 2.8	22.6 $\pm$ 3.9

Continuation of Table 31.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{170}Hf	c	16.01H	34.4±3.8	38.1±4.3	34.5±3.8	34.4±3.8
^{173}Lu	c	1.37Y	28.3±2.7	31.1±3.0	28.8±2.7	28.5±2.7
^{172}Lu	i(m+g)	6.70D	0.095±0.024	0.245±0.044	0.281±0.031	0.218±0.030
^{172}Lu	c	6.70D	24.7±2.4	27.2±2.7	25.9±2.5	24.8±2.4
^{171}Lu	c*	8.24D	31.4±3.1	34.8±3.2	32.7±3.1	31.0±3.0
^{171}Lu	c	8.24D	28.7±2.5	31.9±2.8	29.4±2.6	28.5±2.5
^{170}Lu	c	2.012D	23.8±2.3	27.5±2.6	25.5±2.4	23.8±2.8
^{169}Lu	c	34.06H	23.4±2.4	25.5±2.5	23.5±2.2	22.8±2.2
^{167}Lu	c	51.5M	22.6±3.0	26.8±2.9	21.5±3.2	23.7±2.9
* ^{169}Yb	c	32.026D	26.1±2.4	28.0±2.6	26.1±2.4	26.0±2.4
^{169}Yb	c*	32.026D	27.2±2.5	29.2±2.6	27.2±2.5	27.1±2.4
^{166}Yb	c	56.7H	24.7±2.2	27.8±2.5	25.9±2.3	24.3±2.2
^{167}Tm	c	9.25D	27.6±5.8	30.1±6.3	27.9±5.8	26.6±5.6
^{165}Tm	c	30.06H	25.6±2.4	28.3±2.7	25.3±2.4	24.9±2.3
^{161}Er	c*	3.21H	27.3±2.9	30.2±3.2	26.0±2.8	26.8±2.9
^{160}Er	c	28.58H	24.3±2.2	26.3±2.3	23.0±2.0	22.6±2.0
^{159}Er	c*	36M	30.2±2.7	30.1±2.7	27.0±2.4	26.8±2.4
^{160m}Ho	c	5.02H	23.6±3.0	24.4±3.2	22.8±2.9	22.3±2.9
^{156}Ho	c*	56M	25.2±2.3	26.5±2.5	24.2±2.2	24.7±2.2
^{157}Dy	c	8.14H	20.8±2.0	22.7±2.2	20.2±1.9	19.7±1.9
^{155}Dy	c*	9.9H	18.1±1.6	18.8±1.7	17.3±1.6	16.3±1.5
^{152}Dy	c	2.38H	10.3±0.9	11.0±1.0	9.12±0.86	9.82±0.90
^{155}Tb	c*	5.32D	17.3±2.0	18.7±1.9	17.1±1.6	17.0±1.6
^{153}Tb	c*	2.34D	14.2±1.5	15.8±1.7	14.0±1.5	12.8±1.4
* ^{152}Tb	c	17.5H	11.1±1.3	12.6±1.5	10.8±1.3	10.5±1.2
^{152}Tb	c*	17.5H	12.7±1.3	14.4±1.5	12.3±1.3	12.1±1.3
^{151}Tb	c	17.609H	10.6±1.1	11.3±1.1	9.64±0.97	9.96±1.18
^{149}Tb	c	4.118H	4.42±0.57	4.44±0.88	2.90±0.82	4.32±0.75
^{148}Tb	c	60M	6.81±0.62	6.17±0.59	5.28±0.57	5.77±0.69
^{153}Gd	c	240.4D	13.1±1.2	13.8±1.3	12.7±1.2	12.4±1.2
^{151}Gd	c	124D	11.6±1.3	11.8±1.5	10.7±1.3	10.2±1.2
^{149}Gd	c	9.28D	14.0±1.3	14.7±1.4	12.6±1.2	12.9±1.2
^{147}Gd	c	38.06H	11.2±1.0	11.5±1.1	9.89±0.95	9.58±0.89
^{146}Gd	c	48.27D	11.7±1.0	11.8±1.0	9.95±0.89	10.5±0.9
* ^{149}Eu	c	93.1D	15.0±1.5	15.2±1.7	14.5±1.5	15.0±1.6
^{149}Eu	c*	93.1D	16.5±1.6	16.8±1.7	15.9±1.5	16.4±1.6
* ^{147}Eu	c	24.1D	13.1±1.2	13.5±1.3	11.8±1.1	11.8±1.1
^{147}Eu	c*	24.1D	13.9±1.3	14.3±1.4	12.5±1.2	12.5±1.2
^{146}Eu	i	4.61D	1.54±0.14	1.73±0.16	1.65±0.15	1.47±0.13
^{146}Eu	c	4.61D	13.0±1.2	13.5±1.2	11.4±1.0	11.8±1.1
^{145}Eu	c	5.93D	8.85±0.83	8.98±0.85	7.81±0.74	8.17±0.77
^{143}Pm	c	265D	7.75±0.82	8.56±0.91	7.11±0.76	7.00±0.76
^{139}Ce	c	137.640D	6.81±0.58	6.91±0.60	5.99±0.52	6.24±0.54
^{135}Ce	c	17.7H	4.20±0.42	4.60±0.44	3.69±0.37	3.93±0.38
^{132}Ce	c	3.51H	2.95±0.29	3.67±0.35	2.59±0.26	3.48±0.35
^{132}La	c	4.8H	3.06±0.36	3.27±0.42	2.90±0.35	2.93±0.45
^{133}Ba	c	3848.9D	4.24±0.55	4.81±0.69	3.63±0.51	3.47±0.43
^{131}Ba	c	11.50D	3.67±0.35	3.78±0.35	3.25±0.30	3.39±0.31
^{128}Ba	c	2.43D	2.43±0.24	2.59±0.30	2.09±0.34	2.16±0.20
^{129}Cs	c	32.06H	4.19±0.44	4.31±0.46	3.54±0.38	3.85±0.40

Continuation of Table 31.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{127}Xe	c	36.4D	3.06 ± 0.30	3.05 ± 0.28	2.61 ± 0.24	2.72 ± 0.26
^{123}Xe	c	2.08H	3.29 ± 0.40	3.19 ± 0.38	2.94 ± 0.34	3.38 ± 0.52
^{123m}Te	i(m)	119.7D	0.270 ± 0.028	0.247 ± 0.047	0.288 ± 0.030	0.249 ± 0.030
^{121m}Te	i(m)	154D	0.459 ± 0.041	0.506 ± 0.045	0.466 ± 0.042	0.468 ± 0.042
^{121}Te	c	19.16D	2.41 ± 0.22	2.52 ± 0.23	2.20 ± 0.20	2.24 ± 0.20
^{119m}Te	i(m)	4.70D	0.695 ± 0.071	0.883 ± 0.082	0.701 ± 0.069	0.695 ± 0.064
^{120m}Sb	i(m)	5.76D	0.349 ± 0.037	0.382 ± 0.049	0.358 ± 0.034	0.354 ± 0.048
^{113}Sn	c	115.09D	1.40 ± 0.13	1.11 ± 0.13	1.24 ± 0.11	1.27 ± 0.11
^{114m}In	i(m)	49.51D	1.17 ± 0.25	1.06 ± 0.18	1.30 ± 0.16	1.50 ± 0.66
^{111}In	c	2.8047D	1.81 ± 0.21	1.82 ± 0.17	1.55 ± 0.14	1.61 ± 0.16
^{110m}Ag	i(m)	249.76D	0.875 ± 0.083	0.967 ± 0.111	0.901 ± 0.084	0.891 ± 0.086
^{106m}Ag	i(m)	8.28D	1.15 ± 0.11	1.21 ± 0.12	1.12 ± 0.11	1.10 ± 0.12
^{105}Ag	c	41.29D	1.66 ± 0.22	1.47 ± 0.17	1.26 ± 0.16	1.36 ± 0.15
^{100}Pd	c	3.63D	0.288 ± 0.049	0.283 ± 0.038	0.130 ± 0.094	0.264 ± 0.063
^{102}Rh	i	207D	0.888 ± 0.134	0.924 ± 0.153	0.913 ± 0.136	0.899 ± 0.131
^{101m}Rh	c	4.34D	2.00 ± 0.24	2.02 ± 0.23	1.69 ± 0.18	1.72 ± 0.18
^{100}Rh	i(m+g)	20.8H	1.30 ± 0.16	1.34 ± 0.16	1.08 ± 0.15	1.10 ± 0.22
^{100}Rh	c	20.8H	1.58 ± 0.17	1.63 ± 0.17	1.21 ± 0.13	1.36 ± 0.20
^{103}Ru	c	39.26D	2.74 ± 0.24	2.88 ± 0.26	2.69 ± 0.24	2.63 ± 0.23
^{96}Tc	i(m+g)	4.28D	1.69 ± 0.16	1.76 ± 0.17	1.47 ± 0.14	1.48 ± 0.14
^{99}Mo	c	65.94H	2.35 ± 0.21	2.57 ± 0.24	2.40 ± 0.22	2.33 ± 0.22
^{93m}Mo	i(m)	6.85H	1.09 ± 0.11	1.15 ± 0.12	0.906 ± 0.093	1.23 ± 0.15
^{96}Nb	i	23.35H	1.79 ± 0.18	1.95 ± 0.20	1.77 ± 0.24	1.64 ± 0.16
^{95}Nb	i(m+g)	34.975D	2.58 ± 0.22	2.85 ± 0.25	2.59 ± 0.23	2.59 ± 0.22
^{95}Nb	c	34.975D	4.14 ± 0.35	4.58 ± 0.39	4.16 ± 0.36	4.10 ± 0.35
^{90}Nb	c*	14.60H	1.43 ± 0.14	1.39 ± 0.17	1.15 ± 0.13	1.12 ± 0.11
^{95}Zr	c	64.02D	1.45 ± 0.13	1.71 ± 0.15	1.59 ± 0.14	1.50 ± 0.13
^{89}Zr	c	78.41H	3.20 ± 0.27	3.21 ± 0.28	2.60 ± 0.22	2.70 ± 0.23
^{88}Zr	c	83.4D	1.77 ± 0.16	1.61 ± 0.14	1.36 ± 0.12	1.40 ± 0.12
^{88}Y	i	106.65D	3.69 ± 0.33	3.65 ± 0.34	3.20 ± 0.29	3.47 ± 0.37
^{88}Y	c	106.65D	5.48 ± 0.49	5.46 ± 0.51	4.56 ± 0.41	4.75 ± 0.45
^{87}Y	c*	79.8H	4.33 ± 0.37	4.27 ± 0.37	3.46 ± 0.30	3.60 ± 0.31
^{86}Y	c	14.74H	1.91 ± 0.17	1.74 ± 0.23	1.42 ± 0.14	1.84 ± 0.18
^{85}Sr	c	64.84D	4.21 ± 0.40	4.28 ± 0.41	3.50 ± 0.33	3.70 ± 0.35
^{84}Rb	i(m+g)	32.77D	3.80 ± 0.35	4.39 ± 0.41	3.48 ± 0.33	3.42 ± 0.31
^{83}Rb	c	86.2D	4.94 ± 0.47	5.36 ± 0.58	4.32 ± 0.47	4.32 ± 0.41
^{82m}Rb	i(m)	6.472H	1.94 ± 0.24	1.98 ± 0.26	1.73 ± 0.25	2.16 ± 0.24
^{82}Br	i(m+g)	35.30H	1.65 ± 0.15	1.83 ± 0.17	1.67 ± 0.15	1.53 ± 0.14
^{75}Se	c	119.779D	2.26 ± 0.22	2.22 ± 0.21	1.87 ± 0.18	1.98 ± 0.19
^{74}As	i	17.77D	2.60 ± 0.28	2.59 ± 0.28	2.21 ± 0.24	2.34 ± 0.26
^{71}As	c	65.28H	0.487 ± 0.054	0.497 ± 0.053	0.394 ± 0.042	0.521 ± 0.048
^{72}Ga	i	14.10H	1.13 ± 0.25	1.38 ± 0.18	1.45 ± 0.20	0.883 ± 0.079
^{72}Ga	c	14.10H	1.49 ± 0.24	1.76 ± 0.19	1.85 ± 0.21	1.10 ± 0.10
^{72}Zn	c	46.5H	0.364 ± 0.099	0.382 ± 0.063	0.394 ± 0.062	0.216 ± 0.019
^{58}Co	i(m+g)	70.86D	0.859 ± 0.099	0.801 ± 0.092	0.828 ± 0.103	0.750 ± 0.080
^{59}Fe	c	44.472D	1.16 ± 0.11	1.29 ± 0.16	1.23 ± 0.12	1.22 ± 0.11
^{54}Mn	i	312.11D	1.06 ± 0.10	1.21 ± 0.12	0.944 ± 0.101	0.970 ± 0.091
^{48}V	c	15.9735D	0.177 ± 0.019	0.179 ± 0.021	0.154 ± 0.017	0.167 ± 0.018
^{48}Sc	i	43.67H	0.543 ± 0.054	0.629 ± 0.063	0.609 ± 0.058	0.489 ± 0.070
^{46}Sc	i(m+g)	83.79D	1.02 ± 0.11	0.993 ± 0.094	0.878 ± 0.084	0.814 ± 0.094

Continuation of Table 31.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	<i>nat</i> Pb
^{28}Mg	c	20.915H	0.460 ± 0.061	0.366 ± 0.041	0.408 ± 0.043	—
^{24}Na	c	14.9590H	1.53 ± 0.14	2.01 ± 0.21	1.88 ± 0.18	1.88 ± 0.17
^7Be	i	53.29D	4.27 ± 0.45	3.62 ± 0.44	5.76 ± 0.69	3.53 ± 0.34

3.12 Experimental results for 2.6 GeV proton-irradiated ^{nat,208,207,206}Pb targets.

Table 32 presents parameters of ^{nat,208,207,206}Pb irradiation by 2.6GeV protons. Table 33 presents values of the measured residual nuclide yields.

Table 32: Parameters of irradiation of ^{nat,208,207,206}Pb.

Target	Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor-plate (mg)	Time of irradiation (min)	Average proton flux p/(cm ² · s) × 10 ⁻¹⁰	Number of γ-spectra sample/monitor/plate	ExpData index
^{nat} Pb	2595 ± 8	203.4	120.0	722.9	33	6.98 ± 0.60	29/12/1	pbn26g
²⁰⁸ Pb	2606 ± 8	126.1	120.3	415.0	60	1.00 ± 0.09	36/13/1	pb826g
²⁰⁷ Pb	2610 ± 8	136.8	109.5	431.9	81	0.396 ± 0.034	31/13/1	pb726g
²⁰⁶ Pb	2609 ± 8	123.0	111.2	396.0	45	1.20 ± 0.10	33/12/1	pb626g

Table 33: Experimental values of measured yields of ^{206,207,208,nat}Pb(p,x) reaction products for E_p = 2.6 GeV.

Product	Type	T _{1/2}	Yields [mbarn] for			
			²⁰⁶ Pb	²⁰⁷ Pb	²⁰⁸ Pb	^{nat} Pb
²⁰⁷ Bi	i	31.55Y	–	–	6.08±1.37	7.94±0.98
²⁰⁶ Bi	i	6.243D	1.54±0.15	2.59±0.25	3.10±0.29	3.29±0.31
²⁰⁵ Bi	i	15.31D	4.00±0.81	4.16±0.48	4.48±0.64	4.87±0.47
²⁰⁴ Bi	i	11.22H	3.62±0.33	3.17±0.29	3.36±0.31	4.11±0.38
²⁰³ Bi	i(m+g)	11.76H	3.66±0.41	3.02±0.32	3.14±0.33	4.23±0.44
²⁰² Bi	i	1.72H	2.73±0.48	2.72±0.76	2.02±0.41	3.48±0.50
^{204m} Pb	i(m)	67.2M	12.0±1.1	10.5±1.0	10.3±1.0	11.9±1.1
^{204m} Pb	c	67.2M	12.6±1.2	11.1±1.1	10.8±1.0	12.5±1.2
* ²⁰³ Pb	c	51.873H	33.8±3.2	25.1±2.4	22.2±2.1	30.0±2.8
²⁰³ Pb	c*	51.873H	34.9±3.1	26.0±2.3	23.1±2.0	31.3±2.8
^{202m} Pb	i(m)	3.53H	8.61±0.91	7.93±1.38	7.68±0.79	8.17±0.82
²⁰¹ Pb	c*	9.33H	24.1±2.6	18.7±2.0	16.7±1.8	20.9±2.3
²⁰⁰ Pb	c	21.5H	15.6±1.4	12.8±1.2	11.5±1.1	14.1±1.3
¹⁹⁹ Pb	c*	90M	31.4±5.7	25.7±4.7	21.0±3.9	25.2±2.3
¹⁹⁸ Pb	c	2.4H	23.5±4.5	19.2±3.7	14.9±2.8	18.8±3.6
^{197m} Pb	c*	43M	13.1±2.9	11.0±2.5	9.93±2.21	10.1±2.3
* ²⁰² Tl	i	12.23D	15.3±1.4	12.7±1.2	12.9±1.2	14.7±1.4
²⁰² Tl	c	12.23D	16.1±1.4	13.4±1.2	13.7±1.2	15.5±1.4
²⁰¹ Tl	c*	72.912H	41.6±3.8	32.7±3.0	31.2±2.8	38.4±3.4
²⁰⁰ Tl	i	26.1H	17.7±1.7	13.5±1.3	13.9±1.3	16.9±1.6
²⁰⁰ Tl	c	26.1H	33.0±3.1	26.2±2.4	25.2±2.3	31.3±2.9
¹⁹⁹ Tl	c	7.42H	27.3±4.1	21.7±3.4	22.5±3.8	–
¹⁹⁹ Tl	c*	7.42H	35.7±5.2	26.7±3.9	25.4±3.7	27.3±2.5
^{198m} Tl	i(m)	1.87H	15.3±2.3	11.0±1.7	12.0±1.7	11.5±1.6
^{196m} Tl	i(m)	1.41H	24.9±4.8	22.8±4.4	20.6±4.0	23.7±4.6
²⁰³ Hg	c	46.612D	1.55±0.17	2.12±0.20	3.39±0.30	3.01±0.27
^{197m} Hg	i(m)	23.8H	6.31±0.59	6.51±0.61	6.68±0.64	7.03±0.67
^{195m} Hg	i(m)	41.6H	11.0±1.7	9.57±1.52	10.6±1.7	11.7±1.9
^{193m} Hg	i(m)	11.8H	13.0±2.2	11.3±1.9	11.2±1.9	13.5±2.3

Continuation of Table 33.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{192}Hg	c	4.85H	21.1±1.9	18.3±1.7	17.3±1.6	19.3±1.8
^{190}Hg	c*	20.0M	13.2±2.4	16.1±3.1	14.9±2.8	12.1±2.2
^{198}Au	i(m+g)	2.69517D	1.17±0.16	1.87±0.41	1.36±0.25	1.44±0.16
^{196}Au	i(m1+m2+g)	6.183D	2.18±0.19	2.33±0.22	2.87±0.27	2.70±0.25
^{195}Au	c	186.098D	27.4±3.5	26.4±3.5	28.8±3.6	33.5±4.4
^{194}Au	i(m1+m2+g)	38.02H	3.74±0.45	3.91±0.47	4.46±0.54	4.62±0.56
^{192}Au	i(m+g)	4.94H	6.61±1.05	5.74±0.94	7.60±1.17	7.00±1.10
^{192}Au	c	4.94H	30.2±4.5	25.3±3.8	26.6±4.0	28.6±4.3
^{190}Au	c	42.8M	27.9±3.7	25.8±3.2	24.6±3.0	27.0±3.2
^{191}Pt	c	2.802D	20.4±2.9	18.1±2.6	18.6±2.7	21.2±2.2
^{189}Pt	c	10.87H	25.7±2.7	22.6±2.5	22.8±2.4	24.2±3.0
^{188}Pt	c	10.2D	20.4±2.1	19.1±1.9	19.9±1.9	20.6±1.9
^{186}Pt	c	2.08H	18.8±4.4	16.7±3.9	16.2±3.8	17.4±4.0
^{192}Ir	i(m1+g)	73.827D	—	—	—	0.159±0.015
^{190}Ir	i(m1+g)	11.78D	—	—	—	0.389±0.046
^{189}Ir	c	13.2D	22.2±3.1	16.2±2.3	20.3±2.8	21.7±2.9
^{188}Ir	c	41.5H	22.6±3.1	20.5±2.8	20.8±2.8	22.8±2.1
^{187}Ir	c*	10.5H	23.4±2.7	23.2±2.4	20.4±2.3	18.1±2.1
^{186}Ir	c	16.64H	9.77±0.93	9.11±0.88	9.36±0.96	10.9±1.0
^{185}Ir	c	14.4H	15.9±2.1	13.4±1.9	14.3±1.9	14.4±2.8
^{184}Ir	c*	3.09H	20.8±2.0	19.8±1.9	18.8±1.8	19.5±1.9
^{185}Os	c	93.6D	21.5±2.0	19.4±1.8	20.2±1.9	22.0±2.0
^{183m}Os	c*	9.9H	11.6±1.1	10.7±1.0	11.0±1.0	12.1±1.1
^{182}Os	c	22.10H	20.4±2.1	19.1±2.0	19.2±2.0	24.6±2.3
^{180}Os	c	21.5M	19.2±2.0	20.1±2.0	17.9±1.8	16.0±1.5
^{183}Re	c	70.0D	21.8±2.0	21.0±2.0	21.6±2.0	22.1±2.2
^{182m}Re	c	12.7H	24.1±2.4	21.3±2.2	21.6±2.2	22.9±2.5
^{181}Re	c*	19.9H	20.1±2.8	18.2±2.5	18.7±2.6	21.0±2.9
^{179}Re	c*	19.5M	32.3±3.4	36.1±4.2	28.3±4.3	22.2±4.5
^{178}Re	c*	13.2M	31.7±4.9	36.4±5.6	30.7±4.6	24.8±3.8
^{178}W	c	21.6D	—	—	—	15.7±2.1
^{177}W	c	135M	18.9±2.6	18.0±2.5	17.6±2.4	19.1±2.7
$^{*177}\text{Ta}$	c	56.56H	21.2±5.4	19.6±5.0	19.0±4.8	20.9±5.3
^{177}Ta	c*	56.56H	22.0±5.4	20.4±5.0	19.7±4.8	21.7±5.3
^{176}Ta	c	8.09H	20.4±2.0	18.1±2.0	20.5±2.7	21.7±2.5
^{175}Ta	c	10.5H	20.5±2.1	17.8±1.9	18.1±1.9	18.9±2.2
^{174}Ta	c	1.14H	21.2±2.6	18.9±2.4	19.6±2.4	20.8±2.7
^{173}Ta	c	3.14H	23.5±3.4	22.1±3.1	22.4±3.1	22.9±3.2
^{172}Ta	c*	36.8M	14.3±1.9	16.0±2.4	14.4±1.9	13.4±1.8
^{175}Hf	c	70D	19.6±1.9	17.8±1.7	18.5±1.7	19.8±1.9
$^{*173}\text{Hf}$	c	23.6H	19.9±2.0	17.1±1.9	18.6±1.9	20.9±2.2
^{173}Hf	c*	23.6H	23.5±2.3	20.5±2.1	22.0±2.1	24.4±2.4
^{172}Hf	c	1.87Y	17.3±1.6	16.1±1.5	16.8±1.5	17.7±1.6
^{171}Hf	c	12.1H	14.5±2.5	11.3±1.4	16.0±2.2	18.0±2.4
^{170}Hf	c	16.01H	23.5±2.6	21.3±2.4	21.6±2.4	24.2±2.7
^{173}Lu	c	1.37Y	18.7±1.8	17.2±1.7	18.0±1.8	18.5±1.8
^{172}Lu	i(m+g)	6.70D	0.172±0.031	0.163±0.054	0.196±0.056	0.217±0.023
^{172}Lu	c	6.70D	17.3±1.8	15.9±1.7	16.9±1.8	17.9±1.7
^{171}Lu	c*	8.24D	21.4±1.9	19.0±1.7	20.1±1.8	21.5±1.9
^{171}Lu	c	8.24D	20.5±1.9	18.3±1.7	19.2±1.7	20.3±1.8

Continuation of Table 33.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{170}Lu	c	2.012D	18.1±1.8	16.0±1.9	16.6±1.7	17.4±1.8
^{169}Lu	c	34.06H	16.3±1.5	14.8±1.4	15.4±1.4	16.7±1.9
^{167}Lu	c	51.5M	17.9±1.8	18.2±1.9	16.7±1.7	15.2±1.9
$^{*169}\text{Yb}$	c	32.026D	18.5±1.7	16.9±1.6	17.6±1.6	18.8±1.8
^{169}Yb	c*	32.026D	19.3±1.8	17.6±1.6	18.3±1.7	19.6±1.8
^{166}Yb	c	56.7H	18.1±1.7	16.0±1.5	16.4±1.5	18.4±1.7
^{167}Tm	c	9.25D	20.2±4.3	17.9±3.8	19.1±4.0	19.7±4.1
^{165}Tm	c	30.06H	19.8±1.9	17.9±1.9	18.7±2.0	18.8±1.8
^{161}Er	c*	3.21H	24.8±2.7	21.4±2.4	22.3±2.4	23.8±2.6
^{160}Er	c	28.58H	20.3±1.9	18.4±1.7	18.9±1.7	19.9±1.8
^{159}Er	c*	36M	23.5±2.2	26.4±2.4	20.2±1.8	25.7±2.4
^{160m}Ho	c	5.02H	21.6±2.8	18.5±2.4	18.8±2.5	19.5±2.3
^{156}Ho	c*	56M	23.2±2.2	23.2±2.3	20.7±1.9	22.3±2.1
^{157}Dy	c	8.14H	18.7±1.8	17.2±1.7	17.5±1.7	18.6±1.8
^{155}Dy	c*	9.9H	17.1±1.6	15.3±1.4	16.1±1.5	16.4±1.5
^{152}Dy	c	2.38H	11.6±1.1	10.6±1.0	10.3±0.9	11.2±1.0
^{155}Tb	c*	5.32D	16.9±1.6	15.9±1.7	16.8±1.6	17.0±1.7
^{153}Tb	c*	2.34D	14.8±1.6	13.0±1.4	13.7±1.5	14.4±1.6
^{152}Tb	c	17.5H	11.9±1.3	10.8±1.2	11.5±1.4	12.3±1.3
^{151}Tb	c	17.609H	13.1±1.3	11.5±1.1	11.1±1.1	12.2±1.5
^{149}Tb	c	4.118H	7.25±0.84	6.25±0.64	5.39±0.64	5.19±0.64
^{148}Tb	c	60M	8.63±0.80	7.36±0.76	7.15±0.69	7.49±0.70
^{153}Gd	c	240.4D	12.6±1.2	12.4±1.2	12.9±1.3	13.3±1.5
^{151}Gd	c	124D	12.4±1.5	11.7±1.9	11.7±1.4	12.6±1.5
^{149}Gd	c	9.28D	16.4±1.6	14.0±1.4	14.4±1.4	15.8±1.5
^{147}Gd	c	38.06H	13.5±1.3	12.2±1.2	12.1±1.2	13.4±1.3
^{146}Gd	c	48.27D	14.8±1.4	12.6±1.2	12.6±1.1	14.8±1.4
$^{*149}\text{Eu}$	c	93.1D	18.7±2.0	16.0±2.7	16.4±2.2	19.2±1.9
^{149}Eu	c*	93.1D	20.5±2.0	17.5±2.8	17.9±2.2	21.0±1.9
$^{*147}\text{Eu}$	c	24.1D	17.9±1.7	14.5±1.4	14.9±1.4	16.6±1.6
^{147}Eu	c*	24.1D	18.8±1.8	15.3±1.5	15.8±1.5	17.6±1.7
^{146}Eu	i	4.61D	2.07±0.20	1.95±0.19	2.27±0.21	2.28±0.21
^{146}Eu	c	4.61D	17.2±1.6	14.9±1.4	15.2±1.4	16.6±1.5
^{145}Eu	c	5.93D	12.9±1.2	10.9±1.1	11.1±1.1	12.0±1.2
^{143}Pm	c	265D	12.5±1.4	11.2±1.3	11.1±1.2	12.4±1.3
^{136}Nd	c	50.65M	8.88±1.05	7.81±1.02	5.54±0.67	6.80±0.82
^{139}Ce	c	137.640D	13.0±1.2	11.7±1.0	11.7±1.0	12.7±1.1
^{135}Ce	c	17.7H	11.4±1.2	9.45±0.91	9.77±1.02	11.3±1.1
^{134}Ce	c	3.16D	9.81±1.08	9.26±1.17	10.2±1.1	10.8±1.2
^{132}Ce	c	3.51H	8.54±0.78	8.36±0.77	8.01±0.73	9.10±0.83
^{132}La	c	4.8H	8.94±1.07	7.48±0.89	7.40±0.88	8.31±0.99
^{133}Ba	c	3848.9D	9.09±1.13	7.92±1.93	10.9±1.2	10.4±0.9
^{131}Ba	c	11.50D	9.74±0.91	8.48±0.83	8.74±0.89	9.20±0.90
^{128}Ba	c	2.43D	7.77±1.01	6.93±0.68	6.73±0.84	7.16±0.70
^{129}Cs	c	32.06H	10.8±1.1	9.36±0.99	9.51±1.00	10.3±1.1
^{127}Xe	c	36.4D	8.61±0.81	7.32±0.69	7.60±0.71	8.23±0.78
^{123}Xe	c	2.08H	8.28±0.78	7.62±0.75	7.29±0.68	7.64±0.74
^{123m}Te	i(m)	119.7D	0.214±0.070	0.210±0.041	0.219±0.037	0.218±0.023
^{121m}Te	i(m)	154D	0.548±0.050	0.549±0.051	0.709±0.065	0.641±0.059
^{121}Te	c	19.16D	6.71±0.63	5.60±0.53	5.79±0.55	6.45±0.60

Continuation of Table 33.

Product	Type	$T_{1/2}$	Yields [mbarn] for			
			^{206}Pb	^{207}Pb	^{208}Pb	^{nat}Pb
^{119m}Te	i(m)	4.70D	1.41 ± 0.13	1.41 ± 0.14	1.33 ± 0.12	1.42 ± 0.12
^{120m}Sb	i(m)	5.76D	0.344 ± 0.049	0.302 ± 0.049	0.333 ± 0.033	0.334 ± 0.033
^{113}Sn	c	115.09D	4.08 ± 0.37	3.27 ± 0.31	3.30 ± 0.31	3.75 ± 0.33
^{114m}In	i(m)	49.51D	1.32 ± 0.14	0.907 ± 0.211	1.15 ± 0.19	1.29 ± 0.14
^{111}In	c	2.8047D	4.23 ± 0.39	3.64 ± 0.34	3.51 ± 0.33	4.05 ± 0.38
^{110}In	i	4.9H	2.75 ± 0.28	1.97 ± 0.38	2.15 ± 0.27	2.44 ± 0.35
^{109}In	c	4.2H	3.91 ± 0.42	2.91 ± 0.28	2.99 ± 0.28	3.40 ± 0.32
^{110m}Ag	i(m)	249.76D	0.660 ± 0.073	0.668 ± 0.107	0.651 ± 0.098	0.723 ± 0.068
^{106m}Ag	i(m)	8.28D	1.64 ± 0.16	1.49 ± 0.19	1.35 ± 0.13	1.59 ± 0.15
^{105}Ag	c	41.29D	3.20 ± 0.31	2.46 ± 0.26	2.35 ± 0.24	2.94 ± 0.28
^{100}Pd	c	3.63D	0.723 ± 0.079	0.530 ± 0.101	0.571 ± 0.059	0.756 ± 0.072
^{102}Rh	i	207D	0.905 ± 0.153	0.922 ± 0.180	0.645 ± 0.116	0.757 ± 0.115
^{101m}Rh	c	4.34D	3.33 ± 0.37	3.06 ± 0.34	2.71 ± 0.30	3.22 ± 0.35
^{100}Rh	i(m+g)	20.8H	1.81 ± 0.20	1.29 ± 0.17	1.56 ± 0.16	1.94 ± 0.21
^{100}Rh	c	20.8H	2.53 ± 0.25	1.82 ± 0.19	2.13 ± 0.21	2.70 ± 0.27
^{103}Ru	c	39.26D	2.20 ± 0.21	2.02 ± 0.20	1.93 ± 0.18	2.01 ± 0.18
^{96}Tc	i(m+g)	4.28D	2.04 ± 0.20	1.66 ± 0.16	1.62 ± 0.16	1.87 ± 0.18
^{99}Mo	c	65.94H	2.07 ± 0.19	1.60 ± 0.16	1.76 ± 0.16	1.86 ± 0.18
^{93m}Mo	i(m)	6.85H	1.45 ± 0.14	1.36 ± 0.14	1.31 ± 0.13	1.42 ± 0.15
^{96}Nb	i	23.35H	1.31 ± 0.13	1.23 ± 0.16	1.34 ± 0.18	1.14 ± 0.21
^{95}Nb	c	34.975D	3.16 ± 0.28	2.70 ± 0.24	2.81 ± 0.25	3.04 ± 0.27
^{90}Nb	c*	14.60H	2.53 ± 0.24	1.89 ± 0.18	1.63 ± 0.15	1.95 ± 0.19
^{95}Zr	c	64.02D	1.15 ± 0.11	1.14 ± 0.12	1.19 ± 0.12	1.14 ± 0.10
^{89}Zr	c	78.41H	3.96 ± 0.35	3.18 ± 0.28	2.99 ± 0.26	3.60 ± 0.32
^{88}Zr	c	83.4D	2.56 ± 0.23	2.21 ± 0.20	1.90 ± 0.17	2.22 ± 0.20
^{88}Y	i	106.65D	3.03 ± 0.30	2.86 ± 0.29	2.95 ± 0.28	3.05 ± 0.29
^{88}Y	c	106.65D	6.03 ± 0.59	4.81 ± 0.47	4.42 ± 0.41	5.41 ± 0.51
^{87}Y	c*	79.8H	5.05 ± 0.45	4.03 ± 0.36	4.07 ± 0.36	4.44 ± 0.42
^{86}Y	c	14.74H	2.64 ± 0.24	2.05 ± 0.19	1.96 ± 0.18	2.63 ± 0.25
^{85}Sr	c	64.84D	4.79 ± 0.47	4.05 ± 0.40	3.81 ± 0.37	4.28 ± 0.42
^{84}Rb	i(m+g)	32.77D	3.23 ± 0.31	3.09 ± 0.39	2.63 ± 0.26	3.09 ± 0.28
^{83}Rb	c	86.2D	5.30 ± 0.55	4.46 ± 0.47	4.23 ± 0.50	5.15 ± 0.62
^{82m}Rb	i(m)	6.472H	2.28 ± 0.23	1.95 ± 0.20	2.06 ± 0.21	2.42 ± 0.25
^{82}Br	i(m+g)	35.30H	1.28 ± 0.12	1.02 ± 0.10	1.02 ± 0.10	1.24 ± 0.12
^{75}Se	c	119.779D	2.77 ± 0.25	2.29 ± 0.21	2.19 ± 0.20	2.52 ± 0.23
^{74}As	i	17.77D	2.49 ± 0.28	2.13 ± 0.25	2.05 ± 0.23	2.40 ± 0.27
^{71}As	c	65.28H	0.800 ± 0.084	0.684 ± 0.079	0.582 ± 0.058	0.867 ± 0.081
^{72}Ga	i	14.10H	—	—	—	1.19 ± 0.22
^{72}Ga	c	14.10H	—	—	—	1.42 ± 0.23
^{72}Zn	c	46.5H	—	—	—	0.227 ± 0.041
^{58}Co	i(m+g)	70.86D	1.45 ± 0.18	1.51 ± 0.28	1.15 ± 0.23	1.26 ± 0.12
^{56}Co	c	77.233D	—	—	—	0.106 ± 0.011
^{59}Fe	c	44.472D	1.43 ± 0.15	1.26 ± 0.14	1.31 ± 0.15	1.46 ± 0.14
^{54}Mn	i	312.11D	1.85 ± 0.18	1.60 ± 0.24	1.66 ± 0.16	1.68 ± 0.15
^{48}V	c	15.9735D	0.434 ± 0.043	0.332 ± 0.036	0.303 ± 0.031	0.382 ± 0.037
^{48}Sc	i	43.67H	0.884 ± 0.101	0.746 ± 0.072	0.760 ± 0.072	0.910 ± 0.087
^{46}Sc	i(m+g)	83.79D	1.89 ± 0.17	1.68 ± 0.16	1.58 ± 0.14	1.86 ± 0.17
^{28}Mg	c	20.915H	1.05 ± 0.10	0.923 ± 0.091	0.983 ± 0.091	1.04 ± 0.10
^{24}Na	c	14.9590H	4.56 ± 0.40	3.88 ± 0.35	3.93 ± 0.35	4.51 ± 0.40
^7Be	i	53.29D	7.01 ± 0.86	8.35 ± 0.87	5.45 ± 0.55	7.06 ± 0.63

3.13 Experimental results for ^{209}Bi targets irradiated with 0.04, 0.07, 0.1, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.6, 2.6 GeV protons.

Table 34 presents parameters of ^{209}Bi irradiation by 0.04, 0.07, 0.1, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.6, 2.6 GeV protons. Table 35 presents values of the measured residual nuclide yields.

Table 34: Parameters of ^{209}Bi irradiation.

Proton energy (MeV)	Weight of sample (mg)	Weight of monitor (mg)	Weight of monitor- plate (mg)	Time of irradiation (min)	Average proton flux $p/(\text{cm}^2 \cdot \text{s})$ $\times 10^{-10}$	Number of γ -spectra sample/ monitor/ plate	ExpData index
37.6 ± 1.4	308.3	121.5	707.6	60	1.78 ± 0.17	25/11/1	bi9040
68.4 ± 1.0	303.6	121.6	713.0	45	2.32 ± 0.16	25/13/1	bi9070
99.3 ± 0.9	298.6	121.6	711.6	20	2.63 ± 0.18	24/13/1	bi9100
149 ± 1	294.4	147.1	713.0	30	3.67 ± 0.27	29/13/1	bi9150
249 ± 1	286.0	122.5	707.6	20	8.26 ± 0.57	36/13/1	bi9250
400 ± 2	293.6	123.3	700.6	30	6.64 ± 0.48	34/12/1	bi9400
599 ± 2	301.6	224.3	719.0	15	3.84 ± 0.27	28/10/1	bi9600
799 ± 2	286.5	122.8	688.4	20	4.34 ± 0.34	26/11/1	bi9800
1190 ± 3	290.5	111.5	692.6	20	5.06 ± 0.39	39/13/1	bi912g
1598 ± 4	342.9	111.1	701.9	20	3.38 ± 0.28	28/11/1	bi916g
2609 ± 8	291.4	110.4	427.6	70	0.978 ± 0.084	31/13/1	bi926g

Table 35: Experimental values of measured yields of $^{209}\text{Bi}(\text{p},\text{x})$ reaction products for $E_p = 0.04, 0.07, 0.1, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.6, 2.6$ GeV.

Product	Type	$T_{1/2}$	Yields [mbarn] for										
			0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
^{207}Po	i(m+g)	5.80H	303±31	75.9±6.0	47.4±4.3	29.4±2.4	15.3±1.3	9.67±0.73	6.54±0.50	5.77±0.49	4.86±0.42	4.54±0.41	4.32±0.39
^{206}Po	i	8.8D	1178±120	108±8	61.2±4.6	34.6±2.7	18.9±1.4	10.8±0.8	7.36±0.57	6.17±0.52	4.83±0.40	4.66±0.41	4.15±0.38
^{205}Po	i	1.66H	10.3±1.1	162±13	77.0±6.0	39.8±3.2	22.2±2.0	14.0±1.4	8.29±1.13	—	—	—	—
^{204}Po	i	3.53H	—	351±27	91.9±7.0	42.4±3.3	21.2±1.6	12.9±1.5	9.23±0.86	—	—	—	—
^{203}Po	i(m+g)	36.7M	—	301±24	89.1±7.3	34.6±3.4	16.9±1.7	—	—	—	—	—	—
^{202}Po	i	44.7M	—	3.63±0.28	112±8	27.4±2.2	18.5±2.6	—	—	—	—	—	—
^{201}Po	i(m+g)	15.3M	—	—	29.0±2.5	7.14±1.19	—	—	—	—	—	—	—
^{207}Bi	c	31.55Y	446±45	219±17	169±13	116±10	81.9±6.4	66.4±5.4	61.0±6.1	59.6±5.1	58.7±5.0	60.0±5.4	57.3±5.4
^{206}Bi	i	6.243D	30.4±3.2	124±10	101±8	70.9±5.7	48.9±3.8	40.6±3.3	35.9±2.9	34.2±3.0	32.9±2.8	32.1±2.9	28.7±2.7
^{206}Bi	c	6.243D	1146±117	224±18	159±12	104±8	67.0±5.2	51.1±4.1	42.9±3.4	40.5±3.5	37.1±3.2	36.6±3.3	32.7±3.1
^{205}Bi	c	15.31D	12.8±1.4	295±23	203±16	128±10	78.9±6.0	55.8±4.4	44.7±3.5	40.2±3.5	36.1±3.0	33.9±3.1	29.4±2.7
^{204}Bi	i	11.22H	—	98.0±8.9	119±11	86.0±7.5	51.7±5.2	—	—	—	—	—	—
^{204}Bi	c	11.22H	—	450±37	209±19	125±11	73.6±6.0	—	—	—	—	—	—
$^{*204}\text{Bi}$	c	11.22H	—	—	—	—	—	44.0±3.6	33.0±2.6	—	—	—	—
^{204}Bi	c*	11.22H	—	—	—	—	—	49.9±3.9	37.2±2.9	32.7±2.8	27.6±2.3	25.7±2.3	21.7±2.0
$^{*204}\text{Bi}$	c*	11.22H	—	611±47	251±21	144±12	83.4±6.6	—	—	—	—	—	—
^{203}Bi	c	11.76H	—	413±32	227±17	133±10	77.0±5.8	54.7±4.3	34.6±2.7	30.0±2.5	24.7±2.1	23.3±2.1	18.1±1.7
^{202}Bi	i	1.72H	—	2.56±0.95	110±9	99.8±8.3	67.6±5.8	—	—	—	—	—	—
^{202}Bi	c	1.72H	—	6.87±0.55	220±17	125±10	71.7±5.5	—	—	—	—	—	—
^{202}Bi	c*	1.72H	—	—	—	—	—	47.0±3.9	30.8±2.9	26.7±2.3	21.1±1.9	20.1±1.9	15.0±1.4
$^{*202}\text{Bi}$	c*	1.72H	—	9.64±0.76	305±23	146±11	85.9±6.6	—	—	—	—	—	—
^{201}Bi	c*	108M	—	—	168±14	105±9	68.7±5.2	—	—	—	—	—	—
^{199}Bi	c*	27M	—	—	—	49.8±4.9	29.2±2.9	—	—	—	—	—	—
^{204m}Pb	i(m)	67.2M	3.37±0.35	—	—	9.55±1.75	11.3±1.3	9.69±1.12	10.6±1.0	11.3±1.1	10.4±1.0	10.4±1.1	9.08±0.93
^{204m}Pb	c	67.2M	—	—	—	—	—	16.9±1.5	16.1±1.3	16.2±1.4	14.5±1.3	14.2±1.4	12.3±1.2
^{203}Pb	i(m1+m2+g)	51.873H	—	—	13.9±2.8	27.7±3.6	28.4±2.6	25.2±1.9	30.1±2.9	27.7±2.6	24.3±2.2	19.9±3.1	19.5±2.2
^{203}Pb	c	51.873H	—	—	244±18	161±13	106±8	80.6±6.0	63.3±4.7	57.0±4.6	48.4±3.9	43.5±3.8	36.7±3.3
$^{*203}\text{Pb}$	c	51.873H	—	409±34	—	—	—	—	—	—	—	—	—
^{203}Pb	c*	51.873H	1.39±0.14	530±41	—	—	—	—	—	—	—	—	—
^{202m}Pb	i(m)	3.53H	—	5.34±0.70	8.78±1.28	14.0±1.3	16.7±1.5	14.8±1.3	14.1±1.2	14.4±1.6	11.7±1.3	10.6±1.1	9.60±0.95
^{201}Pb	c*	9.33H	—	12.6±1.2	260±21	171±14	116±9	85.5±7.1	64.9±5.4	58.3±6.1	48.3±4.8	39.7±4.2	32.4±3.4
^{200}Pb	c	21.5H	—	5.28±0.41	67.3±5.3	140±11	86.6±6.5	68.9±5.4	48.6±3.8	39.8±3.4	32.0±2.7	27.7±2.5	21.7±2.0
^{199}Pb	c*	90M	—	—	23.1±2.6	195±20	171±14	143±14	90.9±12.2	56.2±4.8	56.1±5.7	42.2±5.6	38.9±6.2
^{198}Pb	c	2.4H	—	—	27.0±2.5	93.7±7.9	112±9	72.8±5.7	51.8±4.0	55.5±10.3	44.0±8.2	37.9±7.2	30.2±5.8
^{197m}Pb	c*	43M	—	—	6.96±0.64	34.8±3.1	69.0±5.7	62.2±5.7	46.5±4.0	38.0±3.7	28.2±2.6	23.8±2.3	17.6±1.8
^{196}Pb	c*	37M	—	—	—	20.2±2.9	58.1±7.9	60.5±8.4	50.6±7.0	—	—	—	—
^{195m}Pb	i(m)	15.0M	—	—	—	—	30.0±6.0	35.1±7.2	26.1±5.3	20.5±4.2	13.7±2.8	12.2±2.6	9.02±1.92
$^{*202}\text{Tl}$	i	12.23D	—	0.737±0.094	1.82±0.20	2.81±0.27	4.46±0.39	5.97±0.51	6.32±0.54	6.34±0.58	5.95±0.53	5.66±0.53	4.80±0.46
^{202}Tl	c	12.23D	—	1.24±0.09	2.66±0.19	4.14±0.31	6.05±0.43	7.37±0.55	7.66±0.57	7.71±0.63	7.06±0.56	6.67±0.57	5.71±0.50
^{201}Tl	c*	72.912H	—	14.7±1.2	273±20	185±14	129±9	101±8	78.2±5.9	68.1±5.6	55.2±4.5	46.9±4.1	38.5±3.4
^{200}Tl	i	26.1H	—	—	7.51±1.02	16.4±5.1	17.5±2.0	12.6±1.2	14.6±1.4	15.5±1.5	12.5±1.1	11.3±1.4	9.28±0.97
^{200}Tl	c	26.1H	—	5.50±0.45	62.4±4.9	133±11	99.9±7.7	82.2±6.5	62.3±4.9	54.6±4.7	43.8±3.7	38.1±3.4	30.6±2.8
^{199}Tl	c*	7.42H	—	—	23.6±3.1	133±11	121±10	96.1±8.4	79.2±7.5	65.4±6.3	55.5±5.4	45.4±4.6	36.2±3.7
^{198m}Tl	i(m)	1.87H	—	—	—	5.27±0.53	8.91±0.92	15.6±2.2	15.5±3.2	18.9±2.8	12.3±1.8	9.73±1.65	9.51±1.42
$^{*197}\text{Tl}$	c	2.84H	—	—	—	60.7±23.5	88.8±25.1	84.6±27.8	78.3±19.4	57.2±18.1	40.3±16.4	44.6±17.2	18.0±8.4
^{197}Tl	c*	2.84H	—	—	—	72.4±23.5	112±25	106±28	94.0±19.7	70.0±18.4	49.8±16.6	52.7±17.3	24.0±8.5
^{196m}Tl	i(m)	1.41H	—	—	—	12.8±2.5	27.7±5.2	36.4±6.8	34.2±6.5	37.8±7.2	29.2±5.5	24.1±4.6	18.8±3.6
^{195}Tl	c*	1.16H	—	—	—	—	—	48.9±6.7	60.9±8.7	46.7±6.6	—	—	—
^{203}Hg	c	46.612D	—	—	—	0.075±0.022	0.109±0.016	0.229±0.024	—	—	—	—	—

Continuation of Table 35.

Product	Type	T _{1/2}	Yields [mbarn] for										
			0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
^{197m} Hg	i(m)	23.8H	—	—	—	2.21±0.24	3.55±0.51	5.32±0.57	5.73±0.55	5.65±0.56	4.68±0.44	4.21±0.46	3.57±0.40
¹⁹⁷ Hg	c*	64.14H	—	—	—	45.5±4.3	80.7±8.1	86.8±7.6	56.0±7.9	—	—	—	—
^{195m} Hg	i(m)	41.6H	—	—	—	—	5.46±1.28	8.05±0.63	9.51±1.42	10.2±1.6	7.24±1.11	—	—
* ¹⁹⁵ Hg	ct	9.9H	—	—	—	—	63.0±7.7	76.4±9.3	69.1±8.3	—	—	—	—
¹⁹⁵ Hg	c	9.9H	—	—	—	—	57.5±7.2	68.3±8.7	59.6±7.6	—	—	—	—
^{193m} Hg	i(m)	11.8H	—	—	—	—	5.08±1.03	9.54±2.35	11.8±1.7	14.2±2.8	11.1±2.5	7.62±1.58	5.48±1.14
¹⁹² Hg	c	4.85H	—	—	—	—	23.1±1.7	46.1±3.6	51.7±4.0	46.5±3.9	34.7±2.9	27.2±2.4	19.7±1.8
¹⁹⁰ Hg	c*	20.0M	—	—	—	—	13.6±2.7	32.0±2.5	43.1±3.3	37.4±3.2	25.0±2.1	19.3±1.7	15.4±2.8
^{198m} Au	i(m)	2.27D	—	—	—	—	—	—	0.057±0.041	0.034±0.016	—	—	—
¹⁹⁸ Au	i(m+g)	2.69517D	—	—	—	—	—	—	0.514±0.048	0.665±0.055	—	—	—
¹⁹⁸ Au	i	2.69517D	—	—	—	—	—	0.378±0.031	0.457±0.074	0.631±0.058	—	—	—
¹⁹⁶ Au	i(m1+m2+g)	6.183D	—	—	—	—	0.327±0.031	0.720±0.055	0.985±0.074	1.11±0.09	1.16±0.10	1.09±0.11	0.860±0.085
¹⁹⁵ Au	c	186.098D	—	—	—	24.5±2.7	61.7±7.1	70.0±9.1	63.9±8.3	53.0±7.1	39.7±5.3	31.0±4.4	24.4±3.4
¹⁹⁴ Au	i(m1+m2+g)	38.02H	—	—	—	—	0.641±0.075	1.67±0.19	2.55±0.28	2.74±0.32	2.60±0.30	2.27±0.28	1.92±0.23
¹⁹² Au	i(m+g)	4.94H	—	—	—	—	0.920±0.471	4.25±0.84	5.83±1.33	6.25±1.03	4.79±0.79	4.60±0.77	4.06±0.67
¹⁹² Au	c	4.94H	—	—	—	—	29.8±2.4	62.5±5.1	67.0±9.5	61.2±8.9	44.6±6.4	35.5±5.2	26.0±3.9
¹⁹¹ Au	c*	3.18H	—	—	—	—	16.3±1.7	45.0±4.2	55.3±4.9	58.9±5.8	32.1±3.7	24.9±3.6	20.5±2.6
¹⁹⁰ Au	c	42.8M	—	—	—	—	12.0±1.9	—	46.3±4.3	42.7±3.9	36.2±3.3	26.2±3.4	25.2±3.1
¹⁹¹ Pt	c	2.802D	—	—	—	—	16.1±1.3	38.8±3.2	45.8±3.7	42.9±3.8	32.3±2.9	25.7±2.5	18.5±2.1
¹⁸⁹ Pt	c	10.87H	—	—	—	—	9.60±1.87	38.2±3.2	51.1±4.9	49.6±4.4	37.6±3.3	31.6±3.1	25.5±2.7
¹⁸⁸ Pt	c	10.2D	—	—	—	—	5.10±0.38	27.7±2.2	43.1±3.4	44.9±3.8	33.9±2.8	26.4±2.3	18.4±1.8
¹⁸⁷ Pt	c	2.35H	—	—	—	—	—	—	29.3±7.2	33.9±8.0	—	—	—
¹⁸⁶ Pt	c	2.08H	—	—	—	—	—	19.5±4.4	26.9±2.1	28.9±2.4	30.6±7.0	24.4±5.6	16.8±3.9
¹⁸⁴ Pt	c	17.3M	—	—	—	—	—	—	31.6±6.2	33.2±6.7	28.1±5.6	24.8±5.3	—
¹⁸⁹ Ir	c	13.2D	—	—	—	—	7.96±1.00	30.4±2.5	40.5±3.5	46.8±7.4	31.5±2.7	26.4±3.5	18.6±2.5
¹⁸⁸ Ir	c	41.5H	—	—	—	—	4.02±0.39	31.4±2.5	42.0±3.3	46.6±4.0	36.0±3.1	27.5±2.7	—
¹⁸⁷ Ir	c*	10.5H	—	—	—	—	—	24.4±2.4	38.0±3.4	46.4±4.8	35.2±3.5	24.6±2.9	17.0±1.9
¹⁸⁶ Ir	c	16.64H	—	—	—	—	—	9.55±0.87	18.4±1.7	20.4±1.9	15.5±1.4	12.5±1.2	8.43±0.83
¹⁸⁵ Ir	c	14.4H	—	—	—	—	—	13.2±1.3	26.6±2.4	31.0±2.9	24.8±2.3	18.6±1.9	12.3±1.5
¹⁸⁴ Ir	c*	3.09H	—	—	—	—	—	13.2±1.3	33.6±2.9	39.5±3.7	34.9±3.1	26.4±2.5	18.0±1.7
¹⁸³ Ir	c	57M	—	—	—	—	—	—	—	38.0±9.5	33.7±8.3	—	—
¹⁸⁵ Os	c	93.6D	—	—	—	—	1.27±0.10	16.2±1.3	35.8±2.9	42.7±3.7	35.2±3.0	27.6±2.5	18.8±1.8
^{183m} Os	c*	9.9H	—	—	—	—	—	6.15±0.50	17.3±1.4	23.9±2.1	21.1±1.8	16.7±1.5	10.7±1.0
¹⁸² Os	c	22.10H	—	—	—	—	—	9.15±0.72	30.3±2.4	42.3±3.6	40.4±3.4	30.6±2.7	20.6±1.9
¹⁸¹ Os	c	105M	—	—	—	—	—	3.71±0.57	10.5±1.6	13.1±1.9	12.6±1.9	8.01±1.30	7.36±1.17
¹⁸⁰ Os	c	21.5M	—	—	—	—	—	—	21.5±1.9	33.3±3.4	32.1±2.9	27.4±2.6	18.8±2.2
¹⁸³ Re	c	70.0D	—	—	—	—	0.442±0.042	10.6±0.9	30.8±2.5	40.7±3.5	35.0±3.2	27.9±2.6	19.5±1.9
^{182m} Re	c	12.7H	—	—	—	—	—	10.7±1.0	32.9±2.7	44.4±4.1	38.9±3.4	30.5±2.9	21.1±2.1
* ¹⁸¹ Re	c	19.9H	—	—	—	—	—	6.13±1.05	24.4±3.2	35.9±4.7	34.2±4.4	27.5±3.9	16.5±2.4
¹⁸¹ Re	c*	19.9H	—	—	—	—	—	6.48±1.04	25.4±3.3	37.2±4.8	35.4±4.5	28.3±3.9	17.2±2.4
¹⁷⁹ Re	c*	19.5M	—	—	—	—	—	—	23.4±2.6	42.0±5.3	45.9±4.3	39.9±3.8	25.1±3.4
¹⁷⁸ Re	c*	13.2M	—	—	—	—	—	—	23.7±3.3	43.8±6.2	49.0±6.9	38.9±5.7	28.6±4.4
¹⁷⁸ W	c	21.6D	—	—	—	—	—	—	23.9±4.3	33.5±4.3	28.2±2.9	25.4±2.6	18.5±3.3
¹⁷⁷ W	c	135M	—	—	—	—	—	—	15.0±2.1	26.5±3.7	32.7±4.6	28.1±4.2	18.4±2.7
* ¹⁷⁷ Ta	c	56.56H	—	—	—	—	—	—	15.7±4.0	27.9±7.2	34.6±8.8	27.8±7.2	18.8±4.8
¹⁷⁷ Ta	c*	56.56H	—	—	—	—	—	—	16.3±4.0	29.0±7.2	36.0±8.8	29.0±7.2	19.5±4.8
¹⁷⁶ Ta	c*	8.09H	—	—	—	—	—	—	16.2±1.8	31.6±3.3	42.2±3.7	35.2±3.5	22.7±2.3
¹⁷⁵ Ta	c	10.5H	—	—	—	—	—	—	11.2±1.0	25.0±2.6	31.7±3.0	26.2±4.8	17.0±2.9
¹⁷⁴ Ta	c	1.14H	—	—	—	—	—	—	—	19.6±2.3	30.5±3.6	28.6±3.5	18.6±2.3
¹⁷³ Ta	c	3.14H	—	—	—	—	—	—	10.0±1.4	22.6±3.0	35.3±4.7	32.8±4.5	24.1±3.3
¹⁷² Ta	c*	36.8M	—	—	—	—	—	—	—	10.7±1.4	18.7±2.3	17.9±2.3	14.3±1.9
¹⁷⁵ Hf	c	70D	—	—	—	—	—	0.967±0.083	10.2±0.8	23.1±2.0	31.9±2.8	27.6±2.5	17.8±1.7

Continuation of Table 35.

Product	Type	T _{1/2}	Yields [mbarn] for										
			0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
* ¹⁷³ Hf	c	23.6H	—	—	—	—	—	—	4.81±1.04	19.6±1.9	33.6±3.8	31.4±4.0	23.7±2.9
¹⁷³ Hf	c*	23.6H	—	—	—	—	—	0.628±0.086	6.34±1.07	23.0±2.1	39.0±4.1	36.5±4.2	27.3±3.1
¹⁷² Hf	c	1.87Y	—	—	—	—	—	0.265±0.060	5.32±0.41	16.1±1.4	26.2±2.2	25.4±2.3	15.9±1.5
¹⁷⁰ Hf	c	16.01H	—	—	—	—	—	—	4.70±0.55	12.2±1.0	32.6±3.0	32.1±3.5	22.0±2.5
¹⁶⁸ Hf	c	25.95M	—	—	—	—	—	—	—	—	—	25.2±6.9	18.8±5.1
¹⁷³ Lu	c	1.37Y	—	—	—	—	—	0.414±0.068	6.90±0.60	19.2±1.8	29.7±2.6	27.1±2.6	16.9±1.7
¹⁷² Lu	i(m+g)	6.70D	—	—	—	—	—	—	—	—	—	0.149±0.026	0.158±0.023
¹⁷² Lu	c	6.70D	—	—	—	—	—	0.351±0.083	5.33±0.43	16.3±1.4	26.3±2.3	25.1±2.3	16.5±1.6
¹⁷¹ Lu	c*	8.24D	—	—	—	—	—	—	5.28±0.41	17.5±1.5	32.0±2.7	30.0±2.7	20.3±1.9
¹⁷⁰ Lu	c	2.012D	—	—	—	—	—	—	—	—	—	—	15.2±1.6
* ¹⁷⁰ Lu	c	2.012D	—	—	—	—	—	—	3.10±0.48	11.9±1.3	19.6±2.2	19.8±2.6	—
¹⁷⁰ Lu	c*	2.012D	—	—	—	—	—	—	5.44±0.53	17.9±1.6	35.7±3.1	35.7±3.4	24.5±2.3
¹⁶⁹ Lu	c	34.06H	—	—	—	—	—	—	2.89±0.31	9.37±0.85	21.6±1.9	21.5±2.0	15.4±1.4
¹⁶⁷ Lu	c	51.5M	—	—	—	—	—	—	—	8.48±1.84	22.9±1.9	24.1±3.4	17.8±2.0
* ¹⁶⁹ Yb	c	32.026D	—	—	—	—	—	—	2.94±0.24	12.3±1.1	26.0±2.2	26.2±2.4	18.0±1.7
¹⁶⁹ Yb	c*	32.026D	—	—	—	—	—	—	3.07±0.25	12.7±1.1	27.0±2.3	27.2±2.5	18.7±1.8
¹⁶⁶ Yb	c	56.7H	—	—	—	—	—	—	—	7.36±0.62	21.2±1.8	23.1±2.2	16.4±1.6
¹⁶² Yb	c	18.87M	—	—	—	—	—	—	—	—	16.3±2.5	22.8±3.5	18.8±3.1
¹⁶⁷ Tm	c	9.25D	—	—	—	—	—	—	—	9.21±1.91	23.9±2.2	25.7±2.7	18.1±1.9
¹⁶⁵ Tm	c	30.06H	—	—	—	—	—	—	0.830±0.108	6.61±0.65	21.2±1.9	24.9±2.4	18.2±2.0
¹⁶³ Tm	c	1.810H	—	—	—	—	—	—	—	—	15.6±1.9	20.2±2.7	16.3±2.0
¹⁶¹ Er	c*	3.21H	—	—	—	—	—	—	—	—	16.6±1.7	23.4±2.6	20.0±2.2
¹⁶⁰ Er	c	28.58H	—	—	—	—	—	—	—	3.50±0.60	15.3±1.3	22.1±2.0	18.4±1.7
¹⁵⁹ Er	c*	36M	—	—	—	—	—	—	—	—	15.5±1.3	23.7±2.1	22.4±2.0
^{160m} Ho	c	5.02H	—	—	—	—	—	—	—	—	18.4±2.8	22.3±2.9	17.6±2.3
¹⁵⁶ Ho	c*	56M	—	—	—	—	—	—	—	—	11.5±1.0	21.2±1.9	22.6±2.1
¹⁵⁷ Dy	c	8.14H	—	—	—	—	—	—	—	1.68±0.17	11.1±1.0	18.2±1.8	17.2±1.7
¹⁵⁵ Dy	c*	9.9H	—	—	—	—	—	—	—	—	8.53±0.75	15.0±1.4	15.8±1.5
¹⁵² Dy	c	2.38H	—	—	—	—	—	—	—	—	—	8.96±0.81	10.8±1.0
¹⁵⁵ Tb	c*	5.32D	—	—	—	—	—	—	—	1.19±0.15	8.59±0.85	15.6±1.5	14.9±1.4
¹⁵³ Tb	c*	2.34D	—	—	—	—	—	—	—	—	5.75±1.04	11.6±1.7	13.0±1.5
* ¹⁵² Tb	c	17.5H	—	—	—	—	—	—	—	—	—	10.2±1.2	11.0±1.4
¹⁵² Tb	c*	17.5H	—	—	—	—	—	—	—	—	—	11.6±1.3	12.7±1.4
¹⁵¹ Tb	c	17.609H	—	—	—	—	—	—	—	—	—	9.90±0.95	11.2±1.1
¹⁵⁰ Tb	c	3.48H	—	—	—	—	—	—	—	—	2.54±0.47	5.32±0.91	6.05±1.01
¹⁴⁹ Tb	c	4.118H	—	—	—	—	—	—	—	—	—	5.07±0.54	5.92±0.62
¹⁴⁸ Tb	c	60M	—	—	—	—	—	—	—	—	—	7.07±0.71	6.97±0.73
¹⁵³ Gd	c	240.4D	—	—	—	—	—	—	—	—	5.73±0.57	10.9±1.2	11.7±1.2
¹⁵¹ Gd	c	124D	—	—	—	—	—	—	—	—	4.78±0.45	10.1±1.0	11.4±1.1
¹⁴⁹ Gd	c	9.28D	—	—	—	—	—	—	—	0.646±0.132	5.06±0.47	12.5±1.2	15.1±1.5
¹⁴⁷ Gd	c	38.06H	—	—	—	—	—	—	—	3.82±0.36	9.47±0.90	9.47±0.90	12.7±1.2
¹⁴⁶ Gd	c	48.27D	—	—	—	—	—	—	—	0.360±0.036	3.76±0.31	9.86±0.88	14.0±1.3
* ¹⁴⁹ Eu	c	93.1D	—	—	—	—	—	—	—	—	6.41±0.62	13.9±1.4	17.1±1.6
¹⁴⁹ Eu	c*	93.1D	—	—	—	—	—	—	—	—	6.97±0.66	15.2±1.5	18.7±1.8
* ¹⁴⁷ Eu	c	24.1D	—	—	—	—	—	—	—	—	4.41±0.40	11.4±1.1	15.5±1.5
¹⁴⁷ Eu	c*	24.1D	—	—	—	—	—	—	—	—	—	4.68±0.41	12.1±1.1
¹⁴⁶ Eu	i	4.61D	—	—	—	—	—	—	—	0.227±0.090	0.585±0.051	1.35±0.12	1.86±0.19
¹⁴⁶ Eu	c	4.61D	—	—	—	—	—	—	—	0.587±0.096	4.25±0.36	11.1±1.0	15.8±1.6
¹⁴⁵ Eu	c	5.93D	—	—	—	—	—	—	—	—	2.50±0.23	7.71±0.73	10.9±1.0
¹⁴³ Pm	c	265D	—	—	—	—	—	—	—	—	2.27±0.30	6.76±0.72	11.5±1.2
¹³⁶ Nd	c	50.65M	—	—	—	—	—	—	—	—	—	—	7.80±0.97
¹³⁴ Pr	c*	17M	—	—	—	—	—	—	—	—	—	—	6.92±0.79

Continuation of Table 35.

Product	Type	T _{1/2}	Yields [mbarn] for											
			0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6	
¹³⁹ Ce	c	137.640D	—	—	—	0.100±0.012	0.171±0.015	0.267±0.021	0.326±0.029	0.541±0.047	1.94±0.16	5.86±0.51	11.7±1.0	
¹³⁵ Ce	c	17.7H	—	—	—	—	—	—	—	—	—	3.72±0.37	10.3±1.1	
¹³⁴ Ce	c	3.16D	—	—	—	—	—	—	—	—	—	—	9.63±0.98	
¹³² Ce	c	3.51H	—	—	—	—	—	—	—	—	—	3.05±0.27	8.70±0.79	
¹³⁰ Ce	c	25M	—	—	—	—	—	—	—	—	—	—	5.07±0.62	
¹³² La	c	4.8H	—	—	—	—	—	—	—	—	0.692±0.163	2.66±0.32	7.19±0.86	
¹³³ Ba	c	3848.9D	—	—	—	—	—	—	—	—	1.50±0.72	3.63±0.40	9.19±1.06	
¹³¹ Ba	c	11.50D	—	—	—	—	—	0.435±0.061	—	0.820±0.108	1.43±0.13	3.33±0.31	8.81±0.83	
¹²⁸ Ba	c	2.43D	—	—	—	—	—	—	—	—	0.829±0.104	2.14±0.22	6.97±0.78	
¹²⁹ Cs	c	32.06H	—	—	—	—	—	1.11±0.11	1.25±0.16	1.70±0.18	2.25±0.23	4.27±0.47	9.78±1.02	
¹²⁷ Xe	c	36.4D	—	—	—	0.271±0.025	0.532±0.043	0.830±0.068	1.12±0.09	1.36±0.12	1.75±0.15	3.10±0.28	7.71±0.72	
¹²⁵ Xe	c	16.9H	—	—	—	—	—	—	—	—	—	3.80±0.38	8.01±0.74	
¹²³ Xe	c	2.08H	—	—	—	—	—	—	—	—	2.37±0.31	3.79±0.45	7.34±0.72	
¹²⁶ I	i	13.11D	—	—	—	0.650±0.144	0.617±0.076	0.501±0.077	0.390±0.063	0.389±0.061	0.256±0.050	0.245±0.045	—	
¹²⁴ I	i	4.1760D	—	—	—	—	—	0.696±0.058	0.962±0.083	0.975±0.086	—	—	—	
¹²¹ I	c*	2.12H	—	—	—	—	—	—	—	2.32±0.24	—	2.92±0.32	7.05±0.68	
^{123m} Te	i(m)	119.7D	—	—	0.254±0.023	0.584±0.047	0.659±0.052	0.723±0.056	0.687±0.064	0.641±0.062	0.560±0.054	0.411±0.038	0.316±0.039	
^{121m} Te	i(m)	154D	—	—	—	0.272±0.027	0.527±0.040	0.755±0.059	0.876±0.068	0.899±0.076	0.726±0.060	0.691±0.062	0.680±0.062	
¹²¹ Te	c	19.16D	—	—	—	—	0.382±0.037	0.981±0.079	1.42±0.13	1.65±0.14	1.91±0.16	2.58±0.24	6.11±0.61	
^{119m} Te	i(m)	4.70D	—	—	—	—	—	0.345±0.031	0.508±0.042	0.772±0.069	0.806±0.067	0.866±0.088	1.36±0.12	
¹¹⁹ Te	c	16.05H	—	—	—	—	—	—	—	—	—	—	3.61±0.34	
¹¹⁶ Te	c	2.49H	—	—	—	—	—	—	—	—	1.38±0.24	1.30±0.25	3.71±0.49	
¹²⁴ Sb	i(m1+m2+g)	60.20D	—	0.283±0.025	0.415±0.037	0.347±0.030	0.254±0.031	0.212±0.020	0.159±0.019	—	—	—	—	
¹²² Sb	i(m+g)	2.7238D	—	—	0.630±0.055	0.773±0.065	0.717±0.057	—	—	—	—	—	—	
^{120m} Sb	i(m)	5.76D	—	—	0.201±0.028	0.683±0.056	0.815±0.065	1.04±0.08	1.10±0.13	0.884±0.102	0.625±0.053	0.555±0.052	0.410±0.039	
^{118m} Sb	i(m)	5.00H	—	—	—	—	—	1.11±0.12	—	1.16±0.16	0.896±0.116	—	1.04±0.12	
¹¹⁵ Sb	c*	32.1M	—	—	—	—	—	—	—	—	—	2.30±0.28	5.58±0.56	
^{117m} Sn	i(m)	13.60D	—	—	—	0.924±0.075	1.24±0.10	1.58±0.12	1.71±0.14	1.60±0.13	1.22±0.10	1.11±0.10	0.833±0.080	
¹¹³ Sn	c	115.09D	—	—	—	—	—	0.408±0.037	0.622±0.058	1.05±0.09	1.32±0.11	1.61±0.14	3.55±0.31	
^{114m} In	i(m)	49.51D	—	—	—	0.757±0.117	1.45±0.12	2.00±0.17	2.24±0.20	2.55±0.22	2.27±0.20	1.62±0.21	1.54±0.15	
¹¹¹ In	c	2.8047D	—	—	—	—	0.217±0.029	0.646±0.065	1.20±0.11	1.61±0.14	1.92±0.17	2.13±0.20	4.10±0.38	
¹⁰⁹ In	c	4.2H	—	—	—	—	—	—	—	—	—	—	3.39±0.35	
¹¹⁵ Cd	c	53.46H	—	—	1.59±0.20	1.19±0.10	0.868±0.076	0.695±0.064	0.598±0.053	—	—	—	—	
^{110m} Ag	i(m)	249.76D	—	—	0.466±0.048	1.43±0.12	1.99±0.15	2.43±0.19	2.62±0.21	2.39±0.20	1.83±0.15	1.45±0.13	1.03±0.10	
^{106m} Ag	i(m)	8.28D	—	—	—	—	0.222±0.037	0.505±0.070	1.03±0.20	1.33±0.12	1.43±0.13	1.44±0.13	1.69±0.16	
¹⁰⁵ Ag	c	41.29D	—	—	—	—	—	0.348±0.152	0.905±0.111	1.10±0.13	1.72±0.17	1.90±0.20	2.79±0.30	
¹⁰⁰ Pd	c	3.63D	—	—	—	—	—	—	—	0.066±0.037	0.168±0.034	0.261±0.036	0.656±0.067	
¹⁰⁷ Rh	c	21.7M	—	3.55±0.46	8.12±1.01	9.86±1.32	—	—	—	—	—	—	—	
¹⁰⁵ Rh	c	35.36H	—	4.17±0.51	6.47±0.54	8.77±0.83	8.27±0.78	9.23±0.75	8.28±0.68	9.05±0.79	6.58±0.58	5.00±0.51	—	
^{102m} Rh	i(m)	2.9Y	—	—	—	—	0.720±0.077	1.04±0.11	1.90±0.80	1.93±0.23	1.90±0.26	—	—	
¹⁰² Rh	i	207D	—	—	—	—	—	—	—	0.440±0.213	—	1.36±0.19	1.04±0.15	
^{101m} Rh	c	4.34D	—	—	—	—	0.268±0.030	0.840±0.089	1.61±0.16	1.96±0.21	2.33±0.24	2.46±0.26	3.45±0.37	
¹⁰¹ Rh	c	3.3Y	—	—	—	—	—	0.343±0.059	—	—	—	—	—	
¹⁰⁰ Rh	i(m+g)	20.8H	—	—	—	—	—	—	—	1.08±0.12	1.27±0.14	1.50±0.18	1.67±0.19	
¹⁰⁰ Rh	c	20.8H	—	—	—	—	—	—	—	1.15±0.11	1.44±0.14	1.76±0.19	2.33±0.24	
^{99m} Rh	c	4.7H	—	—	—	—	—	—	—	—	—	—	1.61±0.20	
¹⁰⁶ Ru	c	373.59D	—	2.49±0.27	4.08±0.44	2.62±0.54	2.97±0.27	—	—	—	—	—	—	
¹⁰³ Ru	c	39.26D	0.464±0.064	3.53±0.27	6.50±0.48	8.10±0.62	8.21±0.60	8.66±0.70	8.33±0.67	7.69±0.63	5.69±0.46	4.49±0.39	3.34±0.30	
⁹⁶ Tc	i(m+g)	4.28D	—	—	—	—	0.227±0.028	0.714±0.081	1.38±0.12	1.93±0.18	2.13±0.19	2.11±0.20	2.15±0.21	
⁹⁹ Mo	c	65.94H	—	3.47±0.34	6.91±0.59	7.56±0.68	7.99±0.68	7.98±0.68	7.76±0.66	6.50±0.60	5.15±0.46	3.89±0.38	2.98±0.29	
^{93m} Mo	i(m)	6.85H	—	—	—	—	—	—	—	1.10±0.14	0.986±0.115	1.07±0.17	1.41±0.14	
⁹⁶ Nb	i	23.35H	—	—	1.62±0.17	3.20±0.26	4.10±0.31	5.15±0.41	5.13±0.43	4.77±0.42	3.72±0.32	3.00±0.29	1.71±0.18	

Continuation of Table 35.

Product	Type	$T_{1/2}$	Yields [mbarn] for										
			0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
^{95}Nb	i(m+g)	34.975D	0.069±0.007	0.118±0.048	0.882±0.073	2.43±0.18	4.07±0.29	5.44±0.40	5.91±0.43	5.98±0.48	4.86±0.38	3.96±0.35	2.79±0.25
^{95}Nb	c	34.975D	0.388±0.038	3.15±0.23	6.22±0.44	8.04±0.59	9.22±0.65	10.6±0.8	10.9±0.8	10.2±0.8	7.90±0.62	6.54±0.56	4.50±0.39
^{92m}Nb	i(m)	10.15D	—	—	—	—	—	0.311±0.030	0.441±0.035	0.419±0.040	0.422±0.048	—	—
^{90}Nb	c*	14.60H	—	—	—	—	—	0.260±0.054	—	0.898±0.105	1.26±0.11	1.47±0.15	2.09±0.21
^{97}Zr	c	16.744H	—	—	2.83±0.23	2.26±0.20	2.25±0.17	1.43±0.12	1.12±0.10	1.17±0.11	1.01±0.09	—	—
^{95}Zr	c	64.02D	0.322±0.033	3.02±0.23	5.28±0.40	5.63±0.44	5.21±0.39	5.17±0.40	5.05±0.39	4.16±0.35	3.10±0.26	2.57±0.23	1.72±0.16
^{89}Zr	c	78.41H	—	—	—	—	0.400±0.041	1.21±0.09	2.35±0.18	3.10±0.25	3.82±0.30	3.75±0.32	4.10±0.36
^{88}Zr	c	83.4D	—	—	—	—	0.071±0.045	0.293±0.023	0.809±0.063	1.24±0.11	1.81±0.15	2.00±0.18	2.49±0.23
^{90m}Y	i(m)	3.19H	—	—	—	—	3.89±0.29	5.68±0.50	6.37±0.82	5.49±0.46	4.27±0.36	3.35±0.33	2.23±0.22
^{88}Y	i	106.65D	—	—	—	—	1.33±0.10	3.02±0.28	4.42±0.33	5.40±0.47	5.17±0.41	4.75±0.43	3.60±0.33
^{88}Y	c	106.65D	—	—	—	0.333±0.030	1.40±0.10	3.24±0.28	5.16±0.38	6.55±0.58	7.07±0.56	6.82±0.62	6.18±0.59
^{87}Y	c*	79.8H	—	—	—	—	0.578±0.047	1.62±0.15	3.14±0.25	4.47±0.36	5.29±0.42	5.26±0.45	5.57±0.49
^{85}Sr	c	64.84D	—	—	—	—	0.622±0.060	1.70±0.15	3.33±0.28	4.36±0.40	5.08±0.45	5.12±0.49	4.91±0.48
^{86}Rb	i(m+g)	18.631D	—	—	—	2.41±0.21	4.17±0.31	6.46±0.49	6.74±0.53	6.96±0.58	5.33±0.46	—	—
^{84}Rb	i(m+g)	32.77D	—	—	—	0.510±0.109	1.59±0.14	—	—	—	5.30±0.47	4.75±0.43	3.62±0.38
^{83}Rb	c	86.2D	—	—	—	0.218±0.082	0.756±0.073	2.01±0.17	3.77±0.32	5.04±0.46	5.88±0.52	5.79±0.55	5.57±0.54
^{82m}Rb	i(m)	6.472H	—	—	—	—	—	—	—	1.77±0.30	2.28±0.31	2.76±0.36	2.99±0.34
^{82}Br	i(m+g)	35.30H	—	—	1.00±0.09	1.81±0.19	2.49±0.19	3.26±0.26	3.65±0.31	3.56±0.31	3.17±0.33	2.20±0.20	1.66±0.16
^{75}Se	c	119.779D	—	—	—	—	0.125±0.019	0.513±0.056	1.12±0.12	1.82±0.18	2.37±0.23	2.84±0.27	3.15±0.38
^{76}As	i	1.0778D	—	—	—	—	—	2.45±0.24	2.68±0.26	3.21±0.33	4.48±0.43	4.88±0.64	3.06±0.39
^{74}As	i	17.77D	—	—	—	—	0.452±0.063	1.09±0.11	2.02±0.21	2.75±0.29	3.18±0.33	3.08±0.34	2.75±0.31
^{71}As	c	65.28H	—	—	—	—	—	—	—	—	0.368±0.034	0.490±0.049	0.845±0.080
^{72}Ga	i	14.10H	—	—	—	—	—	1.40±0.21	1.99±0.22	2.12±0.20	2.03±0.21	1.23±0.16	1.41±0.14
^{72}Ga	c	14.10H	—	—	—	—	—	1.91±0.24	2.42±0.24	2.58±0.23	2.41±0.23	1.81±0.19	1.60±0.16
^{72}Zn	c	46.5H	—	—	—	—	—	0.511±0.046	0.440±0.049	0.457±0.047	0.379±0.050	0.583±0.063	0.186±0.030
^{65}Zn	c	244.26D	—	—	—	—	—	—	—	—	1.08±0.11	1.31±0.13	2.01±0.18
^{58}Co	i(m+g)	70.86D	—	—	—	—	—	—	—	—	—	0.967±0.102	1.33±0.19
^{56}Co	c	77.233D	—	—	—	—	—	—	—	—	—	—	0.075±0.017
^{59}Fe	c	44.472D	—	—	—	—	0.253±0.033	0.501±0.071	0.915±0.109	1.13±0.11	1.43±0.12	1.51±0.14	1.59±0.15
^{54}Mn	i	312.11D	—	—	—	—	—	—	—	0.410±0.056	0.789±0.066	1.17±0.13	1.79±0.16
^{52}Mn	c	5.591D	—	—	—	—	—	—	—	—	—	—	0.198±0.025
^{48}V	c	15.9735D	—	—	—	—	—	—	—	—	0.129±0.014	0.154±0.018	0.385±0.054
^{48}Sc	i	43.67H	—	—	—	—	—	—	—	0.317±0.039	0.566±0.048	0.576±0.055	0.797±0.087
^{46}Sc	i(m+g)	83.79D	—	—	—	—	—	0.046±0.008	0.094±0.020	0.321±0.036	0.578±0.053	0.998±0.091	1.88±0.16
^{28}Mg	c	20.915H	—	—	—	—	—	—	—	—	—	0.367±0.044	1.04±0.10
^{24}Na	c	14.9590H	—	—	—	—	—	—	—	—	0.865±0.080	1.81±0.18	4.38±0.39
^7Be	i	53.29D	—	—	—	—	1.07±0.13	1.23±0.13	1.72±0.26	2.01±0.24	3.77±0.36	5.33±0.48	8.18±0.73

3.14 Inconsistence of PCNUDAT database

The nuclear decay data from PCNUDAT database [33] were used to obtain the nuclear reaction cross sections. Analysis of obtained experimental data together with the observed behavior of the decay curves of the reaction products have exposed some drawbacks of the database, namely,

1. PCNUDAT is devoid of some nuclide γ -lines that occur in the γ -spectra of measured samples:
 - γ -lines of two ^{158m}Ho metastable states ($T_{1/2} = 28$ min. and 21.3 min) and ground state ($T_{1/2} = 11.3$ min.) with energy above 67.2 keV are absent, while the 846.7 and 847.4 keV γ -lines of ^{158m}Ho ($T_{1/2} = 28$ min) make it difficult to determine the ^{56}Mn ($T_{1/2} = 2.5789$ h) by the 845.75 keV γ -line;
 - data on ^{171}Hf ($T_{1/2} = 12.1$ h) γ -lines are absent, except for 20.0 keV γ -line. Therefore, the ^{171}Hf cross section was inferred from the $^{171}\text{Hf} \rightarrow ^{171}\text{Lu}$ decay curve;
 - information on the ^{188}Au ($T_{1/2} = 8.84$ min.) γ -lines is absent outright, whereas the peaks of the nuclide are observed in the measured γ -spectra and are present in the REUS database [127].
2. PCNUDAT presents discrepant quantum yields for some nuclides. Therefore, the cross sections inferred from quantum yields of a given nuclide prove to be very different. From Table 36 it follows that the ^{188}Pt cross sections inferred from the ^{188}Ir γ -line energies of up to 1210 keV are 1.44 times the cross sections inferred from the γ -line energies above 1210 keV.

Table 36: The ^{188}Pt cross sections inferred from the ^{188}Ir γ -line energies of up to 1210 keV.

E_γ	Q. yield	Error	Cr. sect.	Error
2214.59	18.7	1.6	38.4	3.4
2059.65	7.1	0.6	36.4	3.2
2049.78	5.0	0.4	35.9	3.0
1715.67	6.2	0.5	35.1	2.9
1574.48	2.63	0.24	34.6	3.3
mean			36.0	1.4
1209.77	6.9	0.7	53.8	5.5
633.02	18	3	58.1	9.7
477.99	14.7	0.6	51.0	2.3
322.91	1.62	0.15	50.4	4.8
155.05	30	3	54.6	5.6
mean			51.8	1.8

Table 37 lists the ^{188}Pt cross sections inferred from the ^{188}Pt lines.

The mean cross section from Table 37 is seen to be the same, within the errors, as the mean cross section in Table 36 at energies of up to 1210 keV. In all the experimental runs,

Table 37: The ^{188}Pt cross sections inferred from ^{188}Pt eigenlines.

E_γ	Q. yield	Error	Cr. sect.	Error
187.59	19.4	1.2	52.8	3.5
195.05	18.6	1.2	51.6	3.5
423.34	4.4	0.3	51.9	3.7
381.43	7.5	0.5	50.5	3.5
mean			51.7	1.8

therefore, the ^{188}Ir and ^{188}Pt cross sections were inferred from γ -line energies of up to 1210 keV.

A twofold difference is observed in the ^{198}Pb ($T_{1/2} = 2.4$ h) cross sections inferred from the, 173.4 and 290.3 keV γ -lines. In the experiments with 100 - 600 MeV protons, the nuclide cross section can be inferred from other γ -lines. Within the errors, the cross sections coincide with those inferred from the 173.4 keV γ -line. Therefore, the 173.4 keV γ -line was selected in all experiments to determine the cross sections.

The ^{177}W cross section inferred from the 115.65 keV γ -line is about two times as small as the cross sections inferred from other γ -lines of the nuclide. In all the experiments, the cross sections were inferred from the 115.65 keV γ -line because it has the highest quantum yield.

3. The determined cross sections were sometimes found to be unbalanced within the same isobaric chain. In a few chains, the cumulative cross sections of nuclides exceeded the cross sections of their isobaric chain daughters, which may be accounted for by occurrences of unknown transitions in the radionuclide decay chains.

- The ^{199}Pb ($T_{1/2}=90\text{min}$) cross sections are significantly in excess of the ^{199}Tl ($T_{1/2} = 7.42\text{h}$) cross sections for Pb at $E_p = 100$ and 150 MeV and for Bi at $E_p = 150, 250$, and 400 MeV. The differences for the rest targets and proton energies are within experimental errors;
- the cross section of ^{189}Pt ($T_{1/2} = 10.87$ h) exceeds that of ^{189}Ir ($T_{1/2} = 13.2$ h). Normally, the difference fails to extend to beyond the error in experimental determining the cross sections, but is always observed experimentally;
- the cross sections of ^{173}Lu ($T_{1/2} = 1.37$ years) are significantly below those of its precursors ^{173}Hf ($T_{1/2} = 23.6$ h) and ^{173}Ta ($T_{1/2} = 3.14$ h);
- the cross sections of ^{170}Lu ($T_{1/2} = 2.012$ days) are significantly below those of its precursor ^{170}Hf ($T_{1/2} = 16.01$ hours).

3.15 Comparison with the data obtained elsewhere

To compare the reported Project results with the data obtained elsewhere, we have analyzed 326 works from the EXFOR international database that determined the cross sections

and yields of secondary nuclear reaction products. Of 326 works, 82 publications ([45] – [123]) used the Pb and Bi as target nuclei, just as in this Project. The data from 68 publications were compared with the reported results. The rest 14 works were excluded from the comparison because:

- work [78] studied the reaction cross sections of the ^{204}Pb isotope, which we did not use;
- works [47], [48], [49], [50], [111], and [112] experimented with thick targets;
- works [72], [84], [96], [99], [104], [107], and [110] measured the ratios of secondary nuclide reaction rates rather than the absolute values of the reaction rates;

Figs. 53 - 83 present the reported data together with the results obtained elsewhere. Most (>90%) of the displayed data of other laboratories are from [56, 82, 83, 90, 93, 94, 102, 105, 106, 108, 117, 123]. It should be noted that nearly all works make use of the same method as in the reported Project, namely the direct kinematics together with γ -spectrometry, thus permitting a straightforward comparison among the results. The works [102] and [123] use the inverse kinematics method, so their data were recalculated using formulas (160) and (161) with the branching factors from the ENSDF database (see Section 5 for more details).

The comparison of most (above $\sim 80\%$) of the data reported here with the results obtained elsewhere has demonstrated a satisfactory agreement. To exemplify the agreement, Fig. 26 shows the $^{203}\text{Bi}(i(m+g))$, $^{203}\text{Pb}(c)$, and $^{200}\text{Pb}(c)$ excitation functions.

In some cases, however, the agreement with the inverse kinematics results are explicitly unsatisfactory. Presented as an example in Fig. 27 are the data for $^{186}\text{Ir}(c)$, $^{105}\text{Rh}(c)$, and $^{59}\text{Fe}(c)$, which, on the other hand, demonstrate a satisfactory agreement with most of the direct kinematics results.

A satisfactory agreement with the inverse kinematics results is also observed sometimes (the examples are presented in Fig. 28 for $^{173}\text{Lu}(c)$), while the agreement with the direct kinematics results is not satisfactory. Finally, there exist the cases of unsatisfactory agreement with both direct and inverse kinematics results ($^{121}\text{Te}(c)$ in Fig. 28 is a relevant example).

The observed disagreement with the direct kinematics results is accounted for by the differences in the methods used to process γ -spectra, by the errors in identifying γ -spectra, and by discrepancies in the decay databases and in the monitor reaction cross sections. Importance of using different decay data bases and of different γ -spectra processing methods is well demonstrated via the data comparison with the data obtained in our previous works, for example in [4], which was made using GDISP database [124] and ASPRO [125] γ -processing code with just automatic mode.

The observed disagreement with the inverse kinematics results can also be accounted for by uncertainties in the decay chain branching factors (see Subsection 5.1 for details). The detailed comparison between the direct and inverse kinematics data can be found in [2].

It should be noted that the discrepancy in the experimental data makes it very difficult to modify the theoretical models (see Subsection 4). Therefore, the causes of the disagreement between the ITEP and GSI data must be examined in more detail using simpler target nuclei.

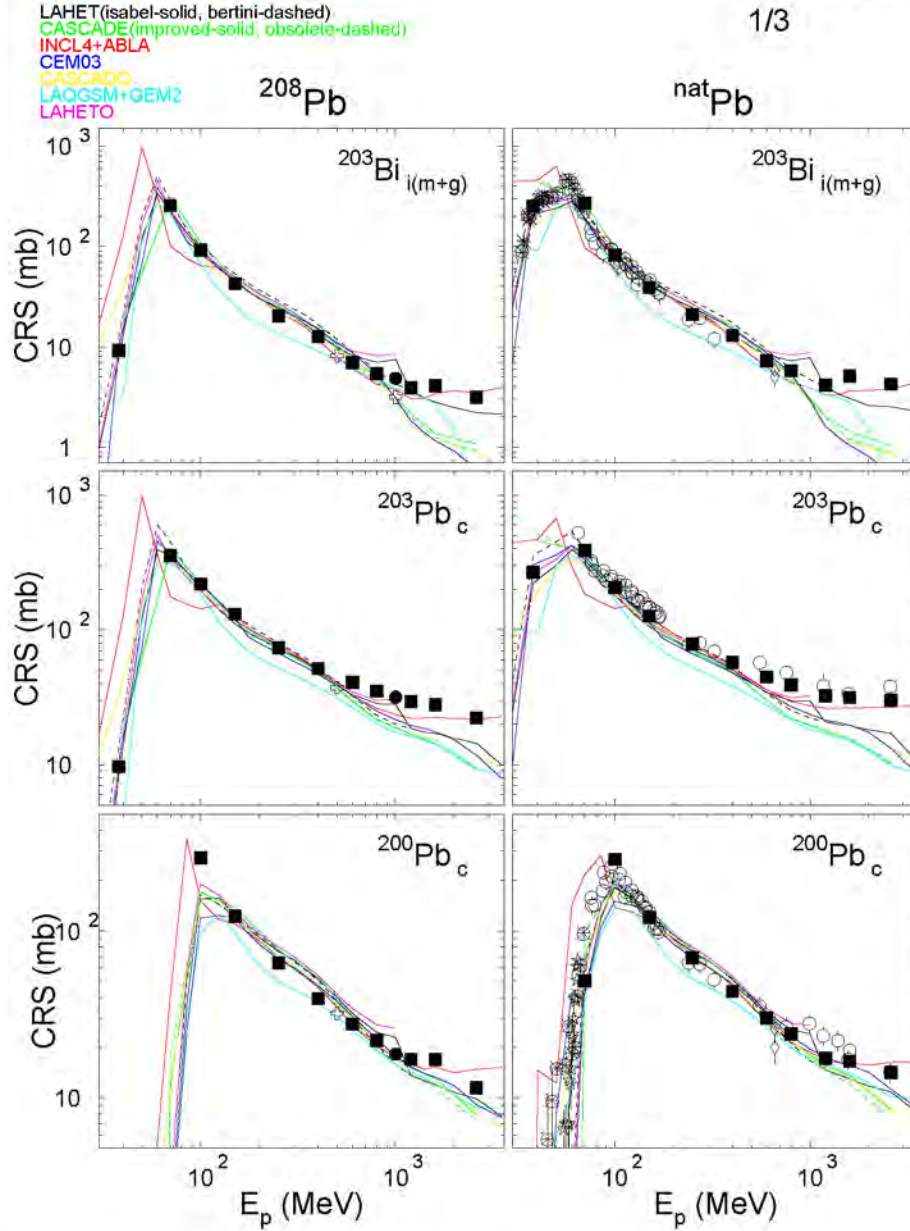


Fig. 26: Comparison with the results obtained elsewhere: ^{203}Bi , ^{203}Pb , and ^{200}Pb . ■ - This Report, ○ - [117, 105, 82, 108], ◇ - [83, 93], open star - [56, 90], + - [123, 102], star - [106], • - [6], □ - [94]

Say, ^{56}Fe may be irradiated with 300-1500 MeV protons at ITEP because the respective data have been obtained at GSI.

Note also that, despite some differences between the ITEP and ZSR [117] data, the two datasets can well be used to obtain the commonly estimated excitation functions. The data that suffer great differences must be reprocessed and, if necessary, repeated measurements must be made.

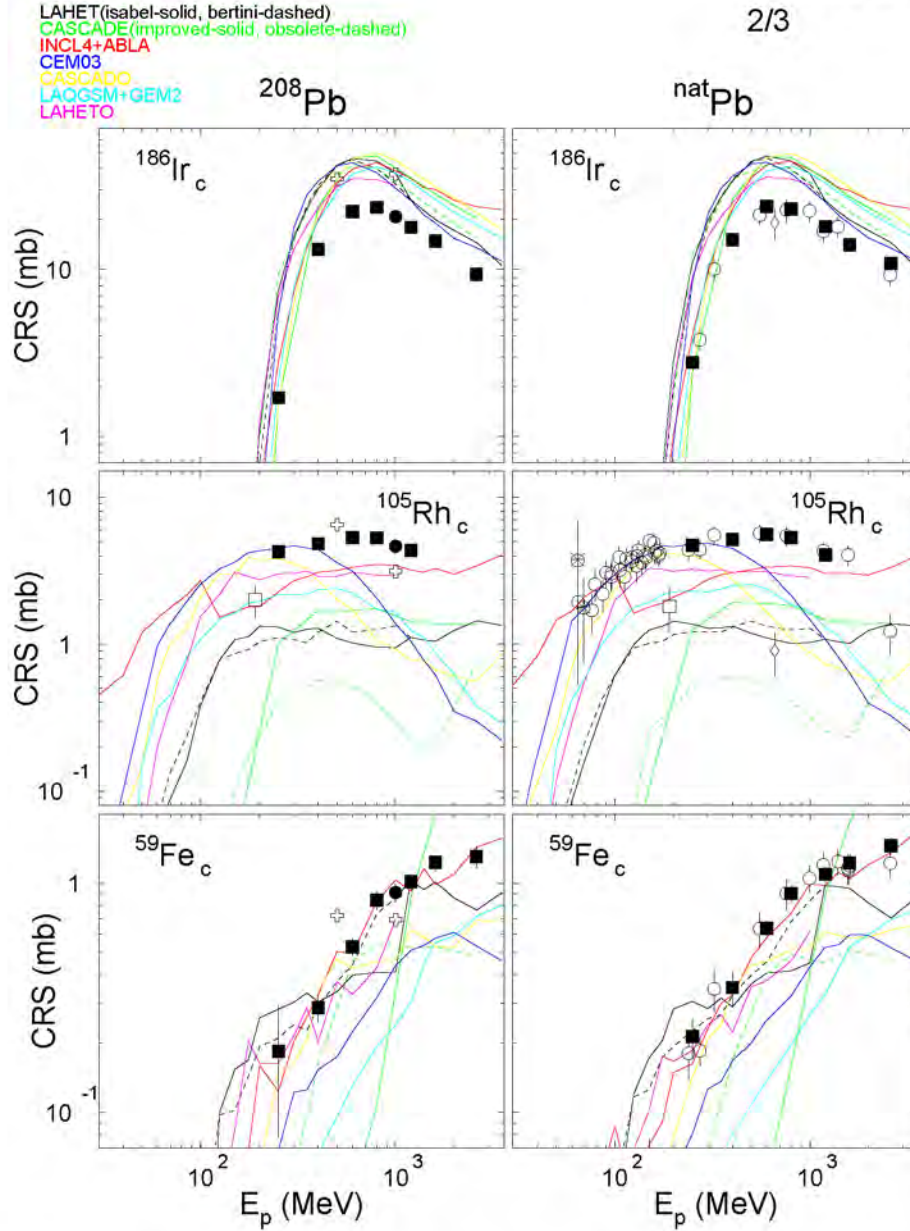


Fig. 27: Comparison with the results obtained elsewhere: ^{186}Ir , ^{105}Rh , and ^{59}Fe . ■ - This Report, ○ - [117, 105, 82, 108], ◇ - [83, 93], open star - [56, 90], + - [123, 102], star - [106], • - [6], □ - [94]

Analysis of different groups of measured excitation functions has shown that the data obtained by the same method are more consistent than the data obtained by different methods. The causes of the discrepancies found are to be studied later.

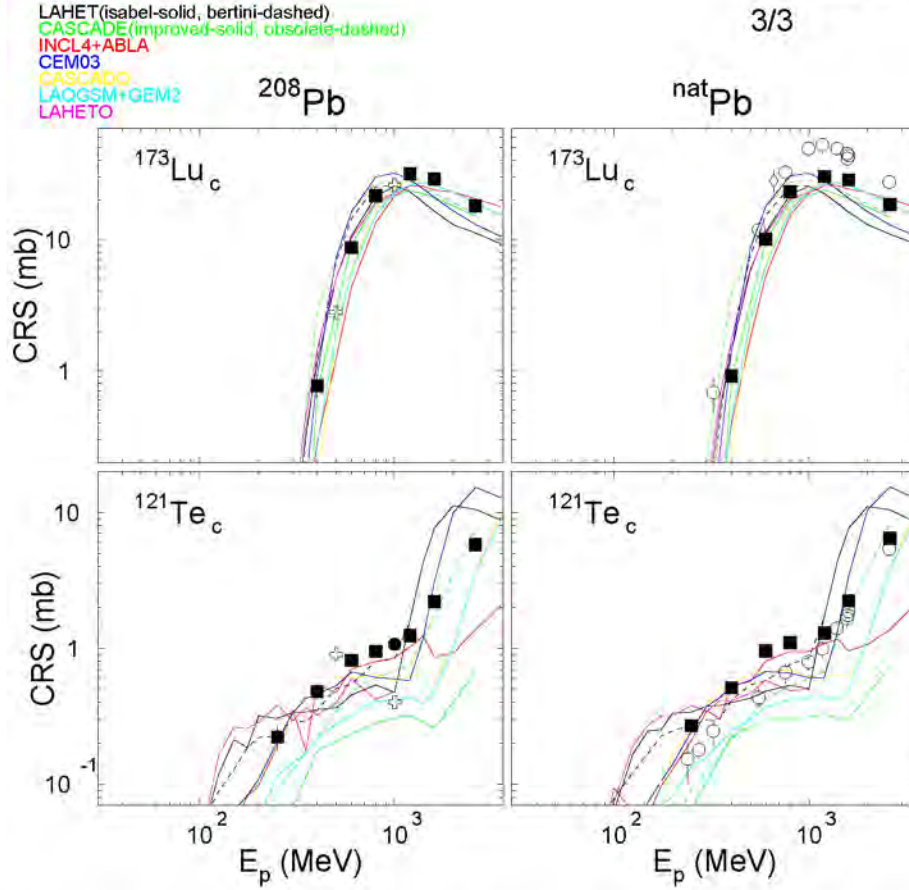


Fig. 28: Comparison with the results obtained elsewhere: ^{173}Lu and ^{121}Te . ■ - This Report, ○ - [117, 105, 82, 108], ◇ - [83, 93], open star - [56, 90], + - [123, 102], star - [106], • - [6], □ - [94]

3.16 Conclusions

In pursuance of the ISTC Project #2002 Workplan item (see Section 4 **Scope of activities**):

- Task 7: Identification of γ -lines and determination of residual radioactive nuclide yields,

Chapter 3 presents the following results obtained for five target types (^{nat}Pb , ^{206}Pb , ^{207}Pb , ^{208}Pb , and ^{209}Bi) and eleven proton energies ($E_p = 0.04, 0.07, 0.1, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.6$, and 2.6 GeV):

1. 5972 numerical values of measured yields of radioactive residual product nuclei, of which 702 independent yields, 712 independent yields of metastable state, 546 sums of independent yields of metastable and ground states, 4012 cumulative and supracumulative yields.
2. The results obtained have made it possible to obtain 1024 excitation functions for 215 different reaction products.

3. The main sources of errors in the experimental data obtained have been analyzed.
4. The obtained data have been compared with the available experimental data obtained elsewhere. The comparison results have been analyzed.

4 Analysis of Spallation and Fission Residual Yields with the Intranuclear Cascade Model

The analysis of the recent experimental data on spallation reaction yields [123, 144, 145] demonstrated that calculations with many widely used simulation codes do not guarantee accuracies required for technical applications related to accelerator-driven power systems. In this connection, a task of improvement of simulation codes based on the Intranuclear Cascade Model (INCM) was taken up as essential part of the present Project beside the main task of new measurements of reaction product yields induced by incident protons on separated isotopes of lead and bismuth, which are considered as advanced materials of ADS targets.

Along with the data obtained under the Project we include into consideration also data of other experiments. Above all it relates to the recent GSI data measured with the inverse kinematics method [123, 143, 144]. In this experiment, practically all nuclides produced in spallation, fission and fragmentation processes were identified, and a high accuracy of obtained data permits considering them as a crucial benchmark for models included in different simulation codes. The GSI data can be directly compared with residual yields calculated by the INCM codes in contrast to the data of activation measurements, which require a transformation of independent yields into the cumulative ones and include the corresponding uncertainties of branching for analyzed decay chains.

Below we consider all sets of recent experimental data that can be used to test and improve the modern versions of the INCM codes.

4.1 Main ingredients of INCM

Spallation reactions are generally modeled as a two-stage process. In the first stage, the nucleon-nucleon collisions inside the nucleus induce the loss of a few high-energy nucleons and lead to the formation of excited prefragments [128, 129, 130]. This process can be continued by a preequilibrium emission of nucleons in some versions of the INCM [131, 133]. In the second stage, the prefragments get deexcited by evaporation of neutrons and light charged particles or by fission.

As an example the mass and excitation energy distributions of prefragments, which arise in the reaction $^{208}\text{Pb}+p(1\text{GeV})$ after a cascade of nucleon-nucleon collisions inside the nucleus, are shown in Fig. 29. Calculations are performed with three versions of the INCM, which we want to discuss in this Report:

- the LAHET [131] with default parameters including the pre-equilibrium emission of particles;

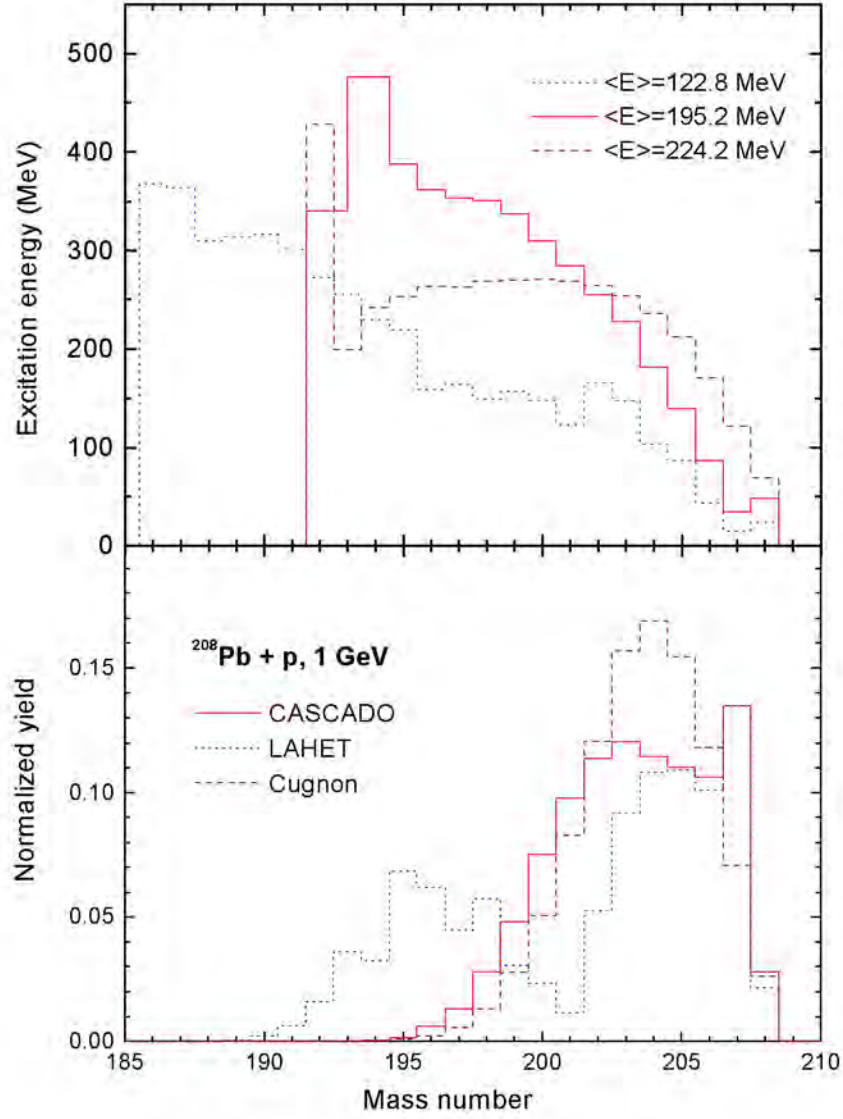


Fig. 29: Distribution of the prefragment masses and excitation energies after the first stage of the INC.

- the INCL-3 code based on the Cugnon model [146], [147] combined with the ABLA evaporation model developed at GSI [16] [148];
- the CASCADO code related historically to the CASCADE code [130], but with an essentially modified evaporation approach that takes into account the IPPE experience on the level-density and nuclear-fission analysis [149].

All codes give rather low excitation energies 25-50 MeV for the prefragments close to lead and the increase of excitation energies up to the averaged values of $\langle U \rangle = 150\text{-}200$ MeV for the most probable prefragments with $A \sim 200\text{-}206$. Prefragments with higher excitation energies arise in the mass region $A < 200$ with a relatively low probability. The distributions shown in Fig. 29 can be considered as the input data for the second (evaporation) stage of the INC.

All evaporation models are based on the well-known Weisskopf-Ewing formula [150] for

the emission widths

$$\Gamma_i(U) = \frac{(2s+1)m_i \int_0^{U-B_i} \varepsilon \sigma_i(\varepsilon) \rho_i(U-B_i-\varepsilon) d\varepsilon}{\pi^2 \hbar^3 \rho_c(U)}, \quad (154)$$

where s_i and m_i are the spin and mass of the emitted particle, B_i is its binding energy in the compound nucleus with the excitation energy U , σ_i is the absorption cross section for the inverse reaction, ρ_i and ρ_c are the level densities for the residual and compound nucleus, respectively.

The absorption cross section is usually approximated by the relation

$$\sigma(\varepsilon) = \begin{cases} 0, & \text{for } \varepsilon < C_{Coul} \\ \pi R_i^2, & \text{for } \varepsilon \geq C_{Coul} \end{cases} \quad (155)$$

where C_{Coul} is the Coulomb barrier height and $R_i = r_i A^{1/3}$ is the radius of a nucleus with mass A and kinetic energy e . In accordance with such an approach the relation (154) can be approximated by a rather simple formula

$$\Gamma_i(U) = \frac{(2s+1)m_i r_i^2 A_i^{2/3} T_i^2 \rho_i(U-B_i-C_i)}{\pi^2 \hbar^3 \rho_c(U)}, \quad (156)$$

where T_i is the nuclear temperature for the appropriate residual nucleus.

More complex formula for the emission width were considered by Dresner [151], who used the Fermi-gas-model relations for the level density to calculate the integral of Eq. (154) in an explicit form taking into account some small corrections related to pre-exponential factors in the level density expressions. For excitation energies above the neutron binding energy, which are important for most of the practical applications, the difference between the Dresner's approximation and calculations based on Eq. (156) can be neglected as a rule.

An important question concerning the simple approximation (155) relates to the estimation of the radius parameters r_i and the Coulomb barrier. For the original Weisskopf-Ewing formula (154), all calculations can be made on the basis of optical models without any reference to the geometrical cross-section and the effective Coulomb barrier that are required for Eq. (156). The best choice of the parameters r_i , which could differ for different emitted particles, corresponds to the agreement of the results obtained from Eq.(156) with more accurate statistical calculations based on Eq. (154). It is obvious that an exact equality of the two results can be achieved at a certain energy only. Nevertheless, we could require an agreement between calculations based on Eqs. (154) and (156) for the crucial energies, which correspond to the average energies of the Maxwell spectra of evaporated particles. In the practical versions of the INCM the parameters of the effective Coulomb barriers and the geometrical cross-sections are usually estimated by fitting some experimental data and we should note that the values of r_i differ essentially in the widely used codes.

Another important component of evaporation models relates to the description of the fission widths. Usually, the following simplified form of the well-known Bohr-Wheeler formula [152] is applied for this purpose and can be written as :

$$\Gamma_f^{BW}(U) = \frac{T_f \rho_f(U-B_f)}{2\pi \rho_c(U)} \quad (157)$$

where B_f is the fission barrier height and ρ_f is the density of nuclear levels in fission channel.

In the last decades it was recognized that the description of the fission probability for high excitation energies requires some essential modifications of the Bohr-Wheeler approach relevant to the collective motion dynamics. To create a collective mode similar to the fission process, some transient time is required [153]. The dependence of such a time on nuclear properties can be derived by solving the time-dependent Fokker-Planck equation for the collective degree of freedom. For an oscillator form of collective potential, the transient time for overdamped regime can be approximated by a rather simple relation [153]

$$\tau_f = \frac{\beta}{2\omega^2} \ln \frac{10B_f}{T_f} \quad (158)$$

where β is the reduced damping coefficient and ω is the frequency of the corresponding collective oscillations. Taking into consideration the transient time, the relation for the fission width can be written as

$$\Gamma_f(U) = \Gamma_f^{BW}(U) f_K(\beta) \cdot e^{\{-\tau_f \sum_\nu \Gamma_\nu(U)/\hbar\}} \quad (159)$$

where $f_K = [1 + (\beta/2\omega)^2 - \beta/2\omega]^{1/2}$ is the Kramer's coefficient [154], that estimates a reduction of the fission probability induced by dissipation of collective motion, and the sum in Eq. (159) includes all decay channels that compete with fission.

The main effect of factors that are additional to the Bohr-Wheeler formula is a hindrance of fission for times smaller than the transient time, and this hindrance reduces the fission widths strongly at excitation energies 100-150 MeV over the fission barrier. As shown by the analysis of heavy U-ion-induced reactions, the hindrance of fission plays a crucial role in the consistent description of the total amount of neutrons and light charged particles emitted by the fissile nuclei [155], as well as of the residual product yields observed in the fragmentation of relativistic heavy ions [156].

The fission barriers used by different INCM codes are compared in Fig. 30 with the experimental fission-barrier values available for pre-actinide nuclei [149]. All codes try to include shell corrections to fission barriers that are very important for near-magic pre-actinides at excitation energies below 50 MeV, but a transition to the liquid-drop values is realized in a different way. A simple liquid-drop model is used in the LAHET and the earlier CASCADE [130], the Sierk's barriers [157] in the GSI model, and the droplet model fitted to experimental barriers [149] in CASCADO. It is obvious that the barrier variation affects essentially the calculated fission-fragment yields. The barriers used in LAHET seem too high for near-magic nuclei, which [underestimates?, see file 2002-RU6] strongly the fissility of such nuclei and always requires some adjustment of barriers to obtain correct values of fission cross sections.

In addition to the above mentioned differences in the particle emission conditions and in the various systematics for fission barriers, there are some discrepancies in the hadrons interaction cross-sections used by the codes. The experimental data on the cross sections of $p-p$ and $n-p$ interactions compiled in [160], are compared in Fig. codes. The similar data for the $\pi^\pm p$ interactions are shown in Fig. 32 .

The differences in the parameterizations of the total cross-sections in various codes are negligible, whereas the elastic and inelastic cross-sections disagree more essentially. In particular, the CASCADE parameterization for the elastic cross-section was based on relatively old experimental

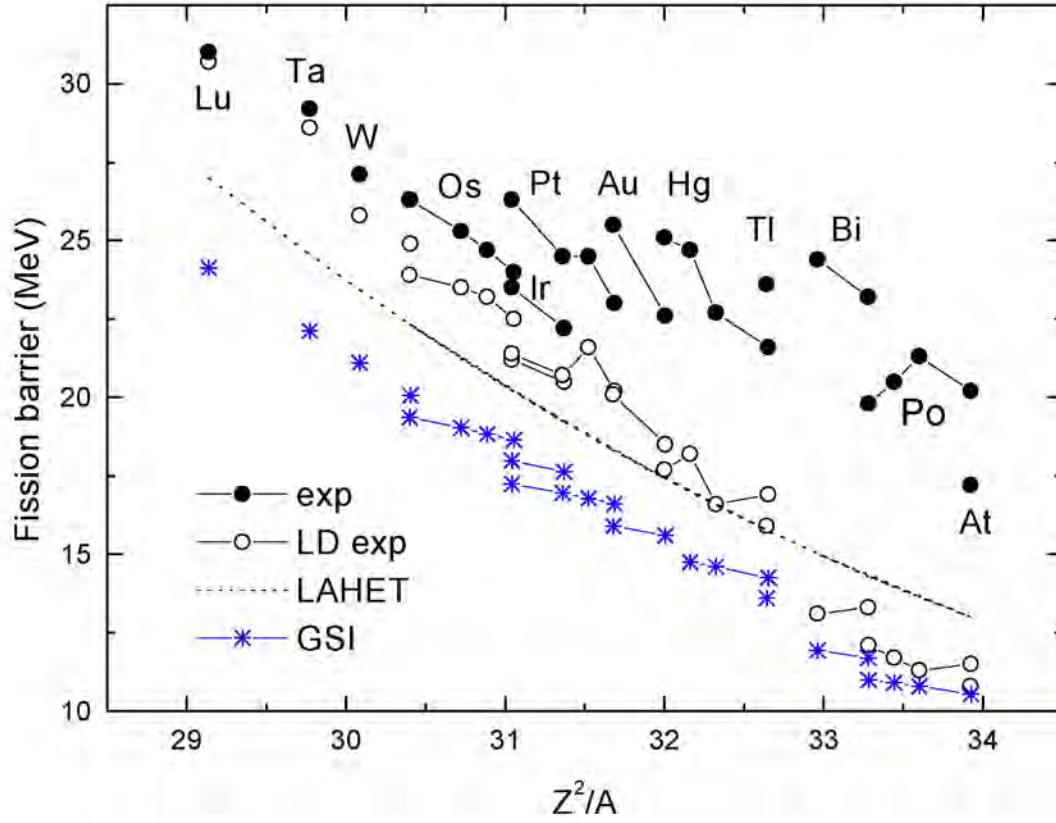


Fig. 30: Fission barriers (solid circles) and their liquid-drop components (open circles) estimated from the experimental data analysis as compared with the liquid-drop barriers used in the LAHET (dotted curve) and GSI (asterisks) codes.

data, which differ essentially in the energy range 400 - 4000 MeV from new experimental data, as well as from the parameterization used by the INCL-3 code [141]. Deviations in the elastic cross section affect the inelastic cross-sections directly due to restrictions connected with the total cross sections. In the CASCADO, The hadron interaction cross-sections corrected in accordance with the recent experimental data [160]. Similar corrections seem to be used also in the last version of the INCL-4 code [141], as well as in the updated versions of the CEM code [134]. Note that, in the case of LAHET code, the updated hadrons-interaction cross-sections are used only in the LAHET (Isabel) version that operates at the incident particle energies below 1 GeV. At higher particle energies, the LAHET (Bertini) version alone, which includes old parameterizations of hadron interactions, is available. The direct consequence of that is a rather bad description of the reaction product yields in the LAHET calculations at the proton energies above 1 GeV, examples of which will be demonstrated below.

4.2 Experimental data analysis with the previous versions of codes

Calculations performed with different INC plus evaporation-fission models are compared in Fig. 33 with the experimental data on the isotopic distributions of residual yields measured at GSI for the $^{208}\text{Pb}+p$ (1 GeV) reaction [123]. To avoid too complex plots, only a part of available

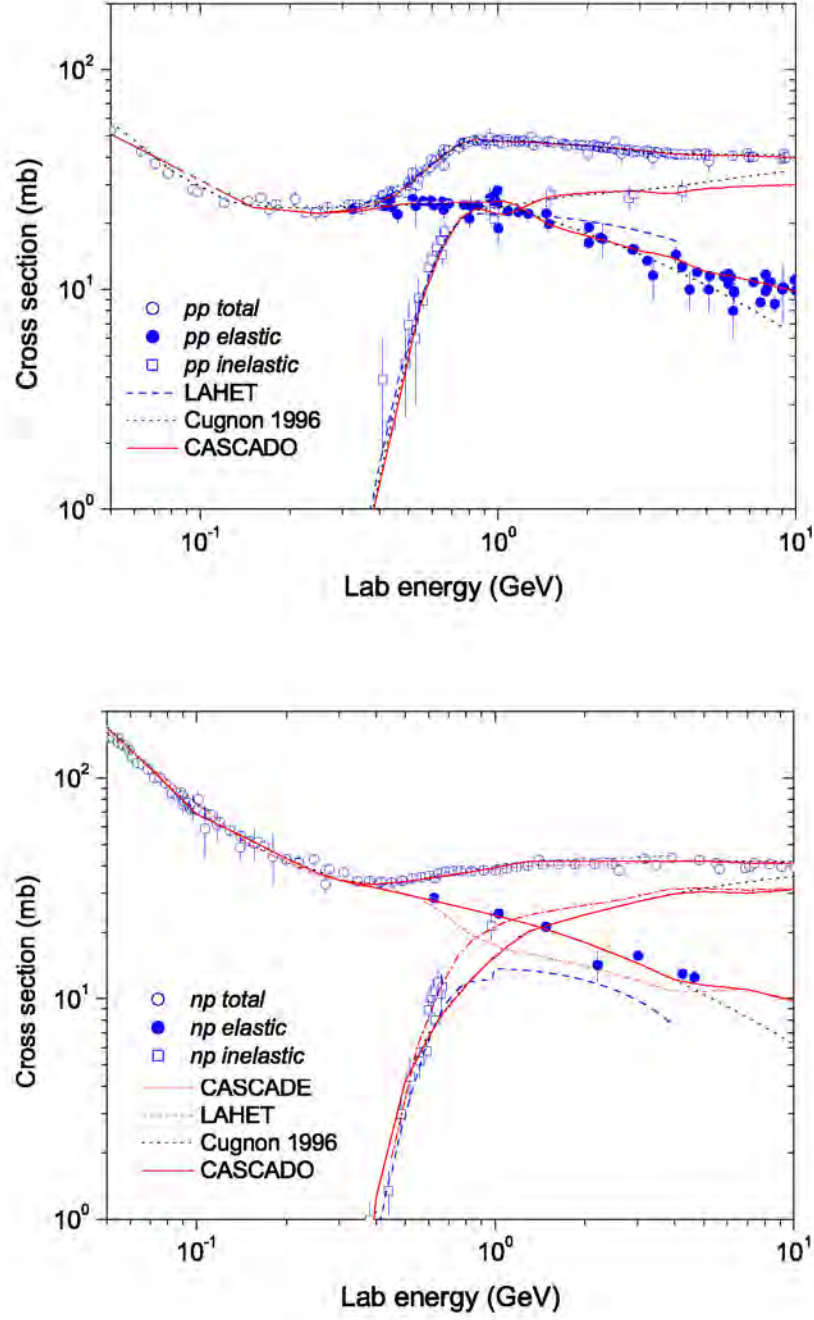


Fig. 31: Total, elastic, and inelastic cross sections for $p-p$ and $n-p$ collisions used by various INCM codes in comparison with experimental data.

data is shown. Most of the observed isotopic distributions have a shape close to the Gaussian, the position of whose maximum is determined by a competing evaporation of neutrons and charged-particles. Essential deviations from the Gaussian are observed for fragments with masses close to the target mass (the projectile for inverse kinematics reactions). For such fragments the emission of a small number of neutrons is possible only without a competition with proton

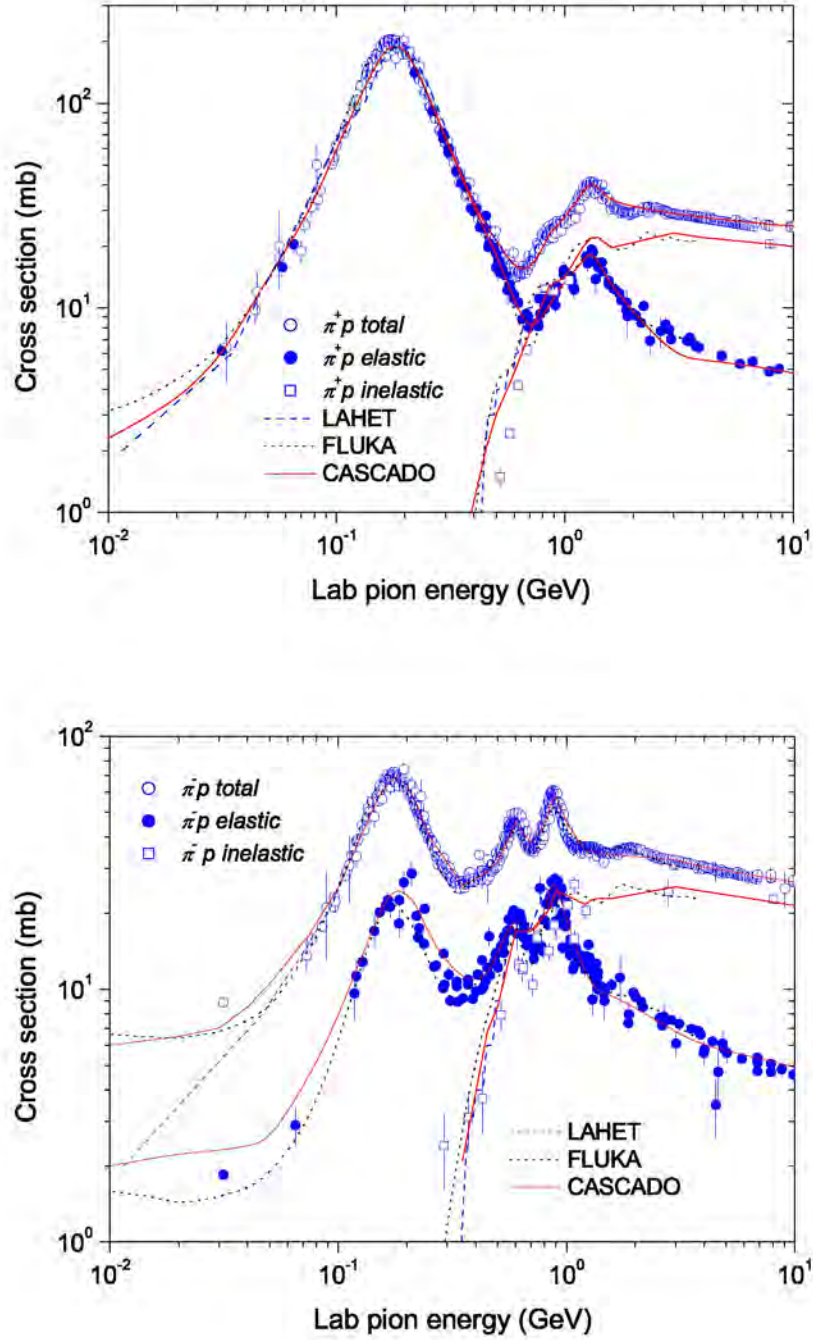


Fig. 32: Total, elastic, and inelastic cross sections for $\pi^+ - p$ and $\pi^- - p$ collisions used by various INCM codes in comparison with experimental data .

evaporation.

The calculations made with the commonly used LAHET code system (Isabel version) [131] give the isotopic distributions shifted with respect to the experimental ones towards the neutron-rich side (Fig. 33). This can be related to the fact that the prediction of the neutron-

proton evaporation competition is not satisfactory enough. On the other hand, in a mass region very close to the target mass, LAHET calculations are in good agreement with the experimental data and this result is the direct consequence of a reasonable estimation of the excitation-energy distribution at the end of the INC stage.

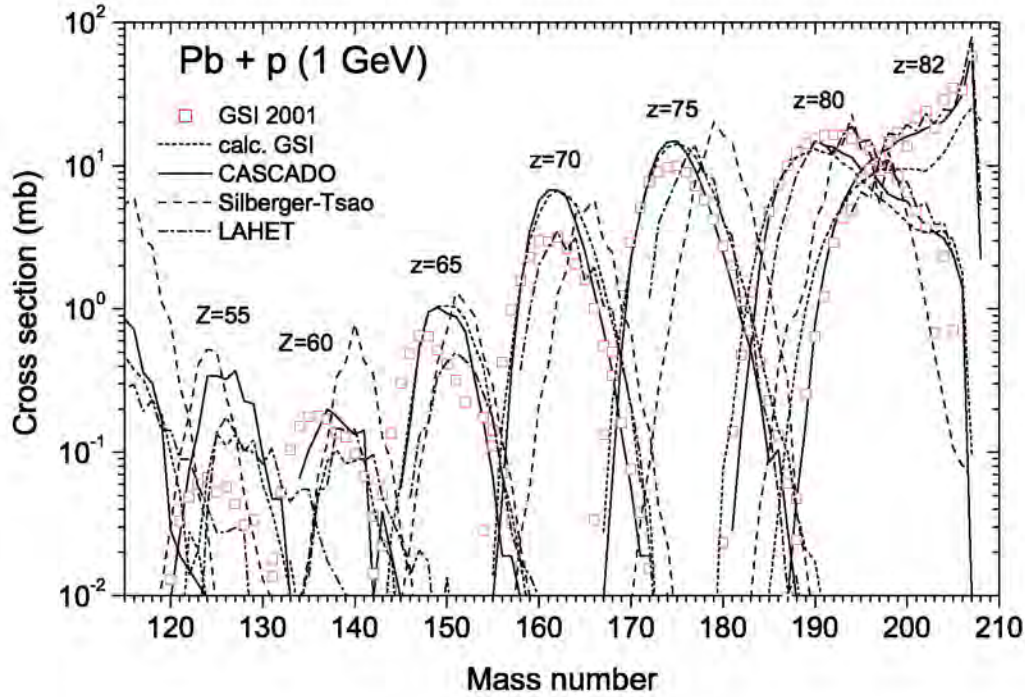


Fig. 33: Experimental data on isotopic distribution of spallation residues in the reaction $1A$ $\Gamma\alpha B$ ^{208}Pb on hydrogen in comparison with the results calculated by different versions of INCM and with the empirical systematics [159].

The calculations with the INCL-3 code [147], combined with the GSI evaporation-fission model, reproduce experimental data much better than the LAHET code. This comes mainly from a better description of the neutron-proton competition as compared with LAHET [131]. The main defect of the INCL-3 calculations is the underestimation of production of residuals that are very close to the target nuclei, which represents an important part of the total cross section. This is ascribed to the sharp-surface approximation in the INCL-3 model [147], which leads to a bad description of the most peripheral reactions. These defects are eliminated in the new INCL-4 code [141], on the basis of which a much better description of product yields is achieved for the mass region $A > 180$, but an essential underestimation of product yields still remains for masses $150 < A < 180$.

Calculations by CASCADO, which uses practically the same approximations for the evaporation-fission model as in the GSI model, differ from the GSI calculations in a mass region close to the projectile. The CASCADO results are close to the LAHET ones for $Z=82$, which can be explained by the similarity of the excitation-energy distributions of the two codes

at the end of the INC stage. Differences between the GSI and CASCADO results in the low mass region for $Z=55$ are attributed to the fission-fragment contribution, which is probably overestimated in the CASCADO calculations. This problem requires an additional analysis of the fission-product distribution simulation.

Fig. 33 shows also the results of the empirical parameterization by Silberger et al. [159] for the production cross sections of individual isotopes in high-energy proton interaction, which is widely used in astrophysical applications. It can be seen that the parameterization fails clearly to predict the center-position of isotopic distributions. As shown in Ref. [123], the differences between the empirical predictions and the experimental data increase even more for the fission-fragment region.

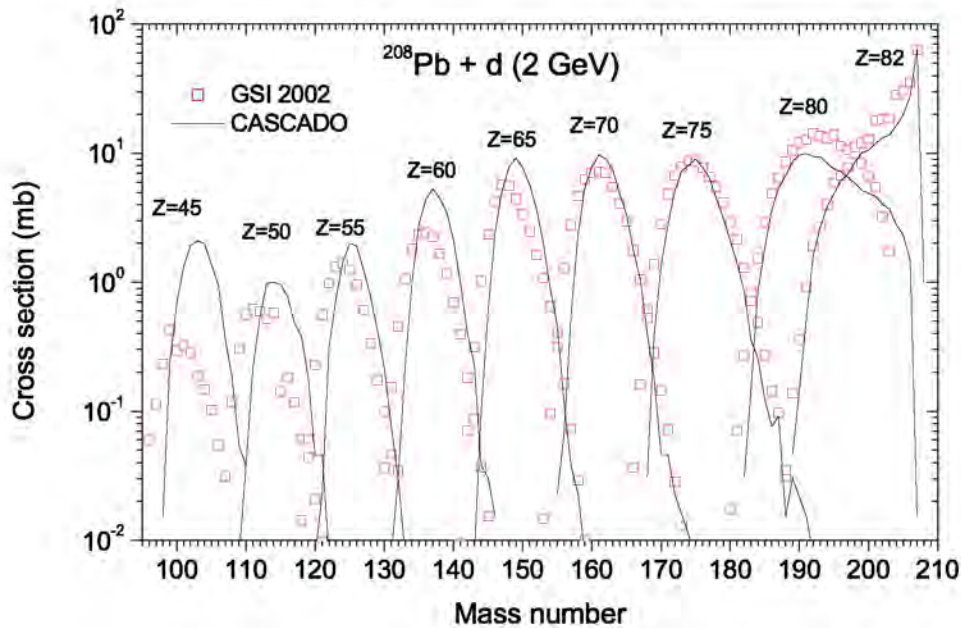


Fig. 34: Experimental data on isotopic distribution of spallation residues in the reaction of 1A GeV ^{208}Pb on deuterium in comparison with CASCADO calculations.

The calculations with CASCADO for other initial conditions, namely for the reaction $^{208}\text{Pb} + d$ (2 GeV), are shown in Fig. 34 together with experimental data from [144]. The entry energy in this case is two times higher than for the hydrogen target, and the corresponding difference arises in the distribution of excitation energies at the end of the INC stage. So, the production cross-sections remain approximately the same for $Z > 70$, but increase by several times for lighter spallation and fission products. The general quality of the theoretical simulation of the experimental data is the same as in the case of proton interactions (see Fig. 33). Some overestimation of calculated yields for $Z < 46$ can again be related to the defects of the fission-product yield description.

4.3 The model modifications and the calculations with updated codes

The above disagreements between calculations and experimental data require a more accurate estimation of the respective model parameters and some modifications of available codes. For example, to improve the description of fission-fragment yields with LAHET, it is necessary to use a better parameterization of the fission-fragment mass distribution, on the one hand, and to achieve a consistent description of observed fission cross sections, on the other hand. Needs for improvements of the fission-product distribution are seen distinctly from Fig. 35 that presents the comparison of LAHET calculations with experimental data for two incident proton energies: 1 GeV and 160 MeV. In the case of the lead target for default parameters, the calculated fission cross sections are underestimated at all energies and the widths of mass distributions are always overestimated.

The available experimental data on fission cross sections for pre-actinides are compiled in Ref. [161], where they were used to develop a phenomenological systematics of the proton-induced fission cross section for energies up to 10 GeV. So, in the following calculations we always adjusted the fission barriers to get an agreement with experimental data, where they were available, and with the systematics predictions [161] in other cases.

In addition to residual-product yields, the spectra of emitted particles are used to verify the INCM codes. As an example, the experimental data on double-differential neutron spectra are compared in Fig. 36 with calculations for the incident proton energies 800 and 113 MeV. High-energy parts of spectra are reproduced reasonably by all the codes, but some essential discrepancies are seen in the case of low energy parts of the spectra. In particular, the CASCADO results simulate better the low energy part of neutron spectra for the proton energy 113 MeV, but they underestimate the high energy part at backward directions. The latter is a direct consequence of a low contribution of preequilibrium processes in the early CASCADO versions.

The causes of the above discrepancies are:

1. different break-off conditions for the cascade stage of nucleons collisions, which are introduced by imposing some restrictions on energies of colliding nucleons [130], or some stopping-time to the cascade evolution consideration [146], or more complex additional conditions to the optical potential formation [133] ;
2. different Coulomb barrier parameterizations, which determine charge particle evaporation widths as competed with the dominant neutron evaporation channel;
3. different preequilibrium process contributions, which are neglected in INCL-3 and earlier CASCADE and are, probably, overestimated in CEM-95.

To get a consistent description of neutron and light charged-particle yields, a contribution of preequilibrium processes should be taken into account rather accurately. The available experimental data on neutron and charged-particle spectra were carefully analyzed to estimate an optimal parameterization of matrix elements that determine a preequilibrium process contribution at different excitation energies. As an example, a description of the inclusive neutron and proton spectra at the incident proton energy of 62 MeV is shown in Fig. 37 for both default

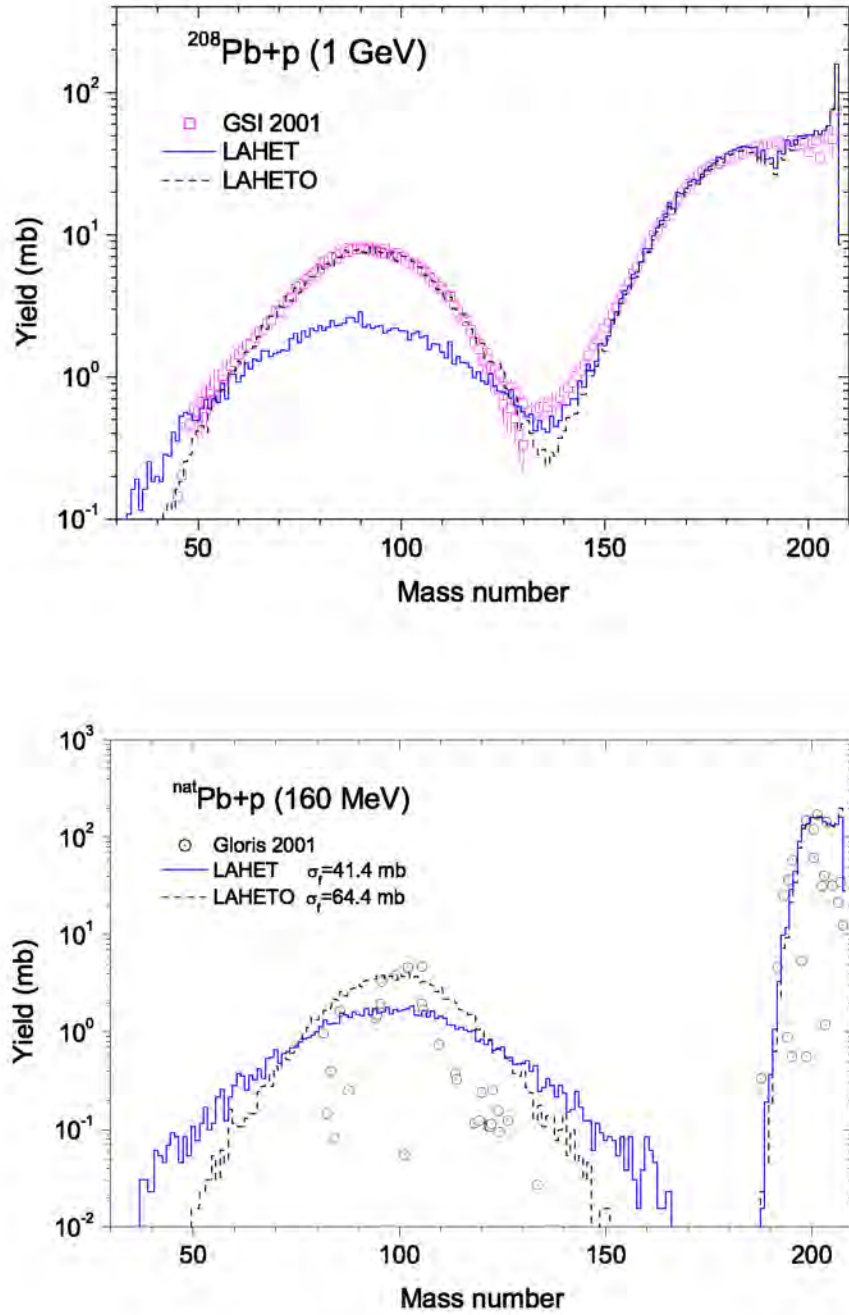


Fig. 35: Experimental data on the residual-product mass distributions for the reaction $^{208}\text{Pb}+p$ at the incident proton energies of 1 GeV (upper plot) and 160 MeV (lower plot) compared with the default LAHET calculations and the modified LAHETO calculations.

and modified LAHET calculations. The Coulomb radius parameters required for calculations of charged particle widths or similar widths of preequilibrium emission were taken in accordance with recommendations of the GSI group. These modifications of the preequilibrium evaporation model are rather similar to modifications used in the latest versions of the INC model, which

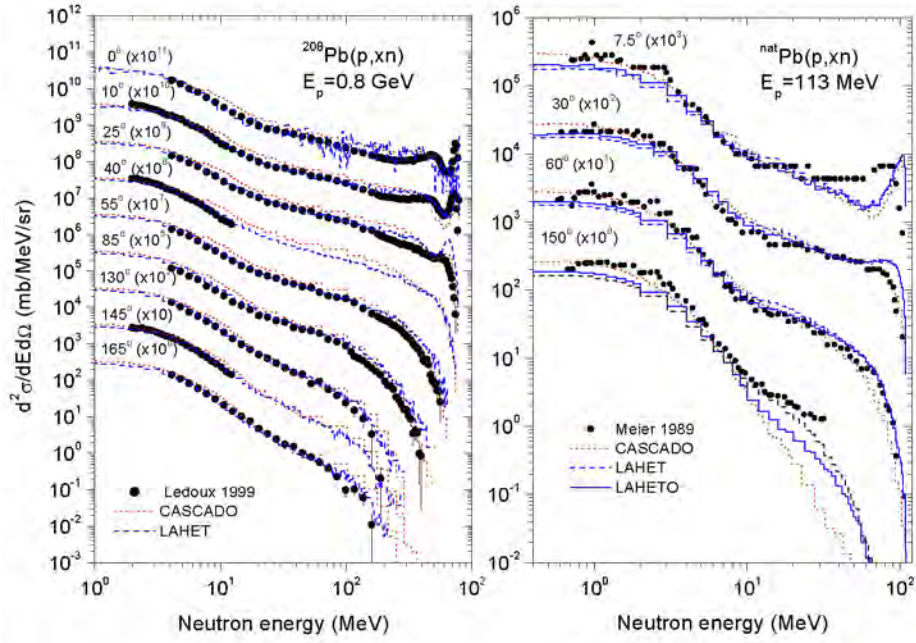


Fig. 36: Experimental data on spectra of the $^{208}\text{Pb}(p,xn)$ reaction for the incident proton energies of 800 and 113 MeV compared with the default LAHET calculations including I

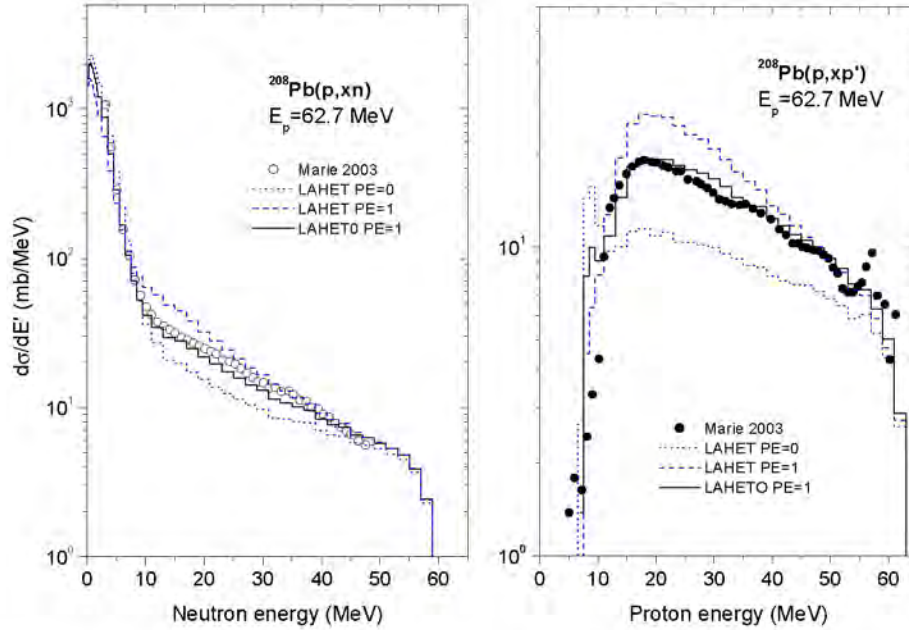


Fig. 37: Experimental data on spectra of the $^{208}\text{Pb}(p,xn)$ and $^{208}\text{Pb}(p,xp')$ reactions for the incident proton energy of 62,7 MeV [28] compared with the default LAHET calculations including (PE=1) and without (PE=0) preequilibrium processes and with the modified LAHETO calculations.

is under development at LANL [134, 137].

The main part of the fission barriers systematics from CEM-95 was inserted by us into the CASCADO code. At the same time, we added the blocks to CEM-95 for calculating fission product yields and neutron evaporation from the excited fission fragments. In all codes, we adjusted the liquid drop model parameters and the corresponding shell corrections for level densities and fission barriers to achieve an optimal agreement of calculated fission cross-sections with the available experimental data. By means of a phenomenological parameterization of the fission-fragment mass and charge distributions, we adjusted the description of the experimental data for the fission product yields. The details of the improvements for the LAHET code are presented in the Appendix.

As a result of the above modifications, the CASCADO code was modified essentially, the CEM-95 code was transformed into the CAMO code, and the LAHET code was transformed into the LAHETO code.

The spallation and fission-fragment mass distributions calculated with the modified codes for the incident proton energy of 1 GeV are compared in Fig. 38 with the GSI data [123] and with the recent activation measurements of cumulative product yields [117, 6]. Since the GSI data are obtained by means of integration over the complete isobaric-product distribution, while the cumulative yields correspond to but a part of the product distribution, the activation measurement results should coincide within errors, or be lower than the integrated isobaric yields. Such disposition of data is really observed in most cases, but some results of activation measurements run above the GSI data. This contradiction in the data indicates some latent systematic errors, which should be understood with a view to eventual exhaustive test of all INCM codes.

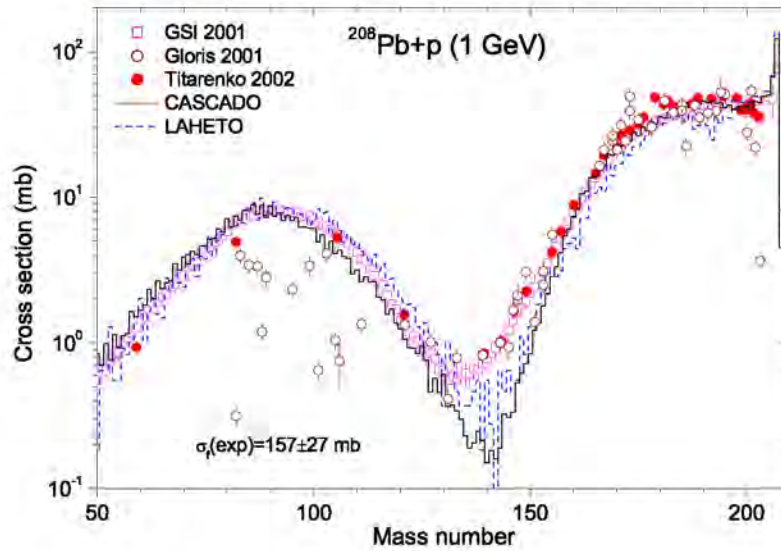


Fig. 38: Experimental data on the residual-mass distribution (open squares) and residual cumulative yields (solid circles) for the $^{208}\text{Pb}+p(1 \text{ GeV})$ reaction in comparison with cascade-model calculations.

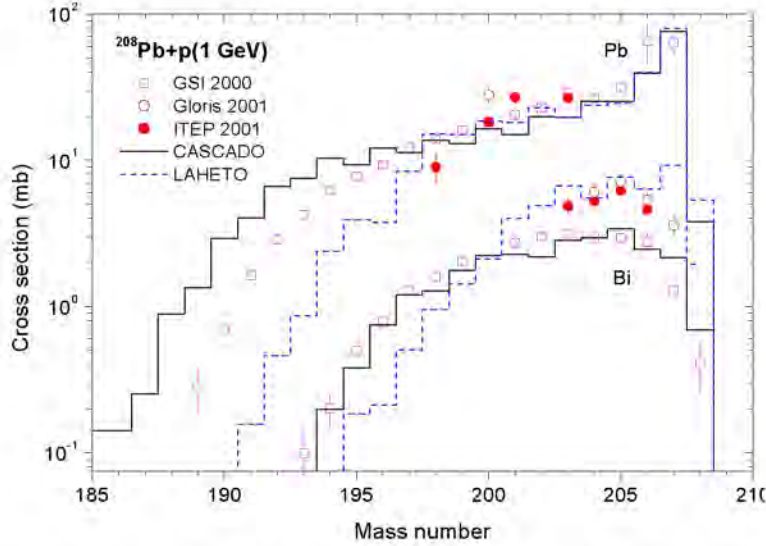


Fig. 39: Experimental data on Pb and Bi isotopic yields for the $^{208}Pb+p(1 \text{ GeV})$ reaction in comparison with cascade-model calculations.

The calculations of the isotopic lead and bismuth yields for the above mentioned reaction are compared with experimental data in Fig. 39. In the case of lead isotopes, we observe a good agreement between the experimental data, but the experimental data are rather discrepant in the case of bismuth isotopes, so a choice of preferable model parameters is difficult on the basis of them.

Cumulative yields of spallation and fission products were measured under the Project for the targets of ^{206}Pb , ^{207}Pb , and ^{208}Pb irradiated by 2.6 GeV protons. The data obtained for ^{208}Pb are compared with the CASCADO and LAHETO calculations in Figs. 40 and 41. The CASCADO results reproduce the experimental data approximately to the same degree as the above calculations at 1 GeV. At the same time, the LAHETO (Bertini) results look too low for the spallation-product yields and too high for fission products. This is a consequence of the improper parameterization of the hadron interactions in the LAHET (Bertini) code at energies above 1 GeV, and essential improvements of the code must be carried out to reach a consistent simulation of spallation and fission product yields at high energies.

To understand better the main regularities of the spallation and fission product distributions at various Energies, we performed calculations of residual-product yields for several intermediate energies between 70 MeV and 1 GeV. The calculations with the LAHETO, CASCADO, and CAMO at the incident proton energy 750 MeV are compared in Fig. 42 with the experimental data obtained by Gloris et al. [117] and Blanchard et al. [163] for proton energies of 754 and 759 MeV, respectively, and with the data obtained under the present Project at 799 MeV. Similar calculations at the incident proton energy 550 MeV are compared in the lower panel of Fig. 42 with the experimental data by Blanchard et al. [163] and Gloris et al. [117] available for energies 548 and 553 MeV and with the data of this Project for 600 MeV.

The new experimental data obtained recently at GSI by the inverse kinematics method for $^{208}Pb + p$ reaction at the energy 500 MeV per nucleon [162] are shown in Fig. 43 together with data by Gloris et al. [117] for the proton energy 550 MeV. The GSI data are reproduced

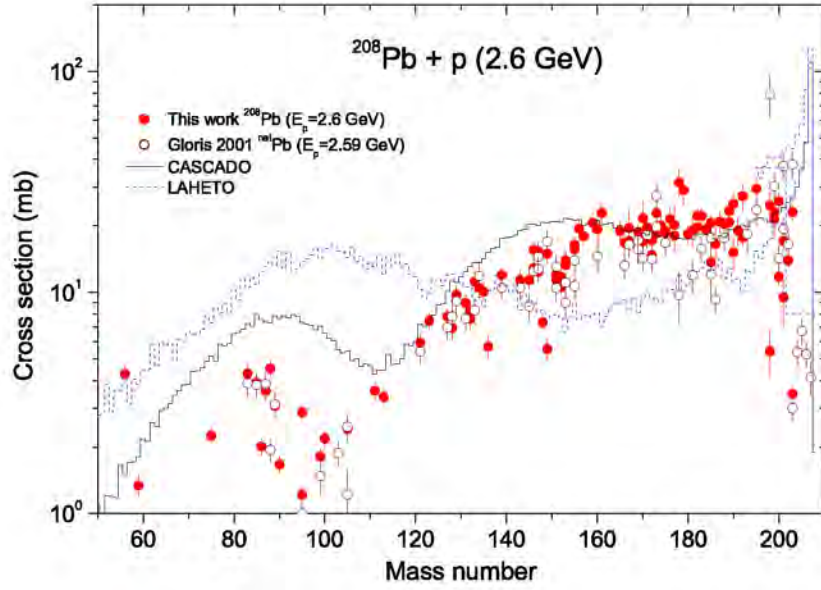


Fig. 40: Experimental data on residual cumulative yields for the $^{208}\text{Pb} + p$ (2.6 GeV) reaction compared with cascade-model calculations.

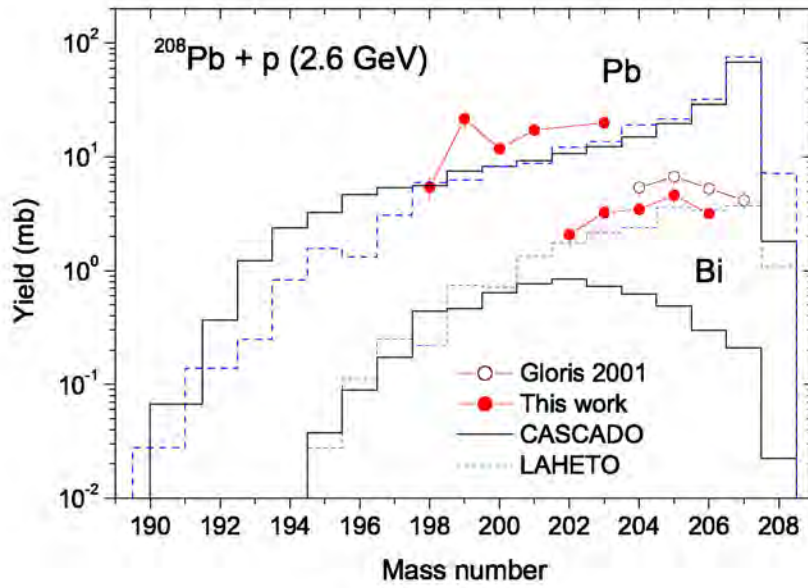


Fig. 41: Experimental data on Pb and Bi isotopic yields for the $^{208}\text{Pb} + p$ (2.6 GeV) reaction compared with cascade-model calculations.

well by the CASCADO calculations and a little worse by the CAMO and LAHETO ones.

Unfortunately, the GSI data for the fission product yields are available as but tentative and they should be reanalyzed because they contradict the estimations of the integral fission cross section. Calculations of the isotopic lead and bismuth yields are compared with the experimental data in Fig. 44. The calculations agree reasonably with the GSI data at mass region of maximal yields, but show some discrepancies on the left-hand slope of isotopic yields and overestimate essentially the yields of for bismuth isotopes close to the target nucleus ($A > 205$).

The calculations at the incident proton energy 300 MeV are compared in Fig. 45 with the data by Gloris et al. [117] and by Blanchard et al. [163] for the proton energies 312 and 322 MeV, respectively. The experimental data for the proton energies 230 and 239 MeV, as well as the data of the present Project at the energy 250 MeV are compared in Fig. 46 with calculations at the proton energy of 230 MeV. All codes describe reasonably the available data, but the deep spallation product yields look better if reproduced by the LAHETO code. It should be noted that we a good agreement of the fission cross sections calculated by all the codes with evaluations based on the experimental data systematics [161], and such an agreement seems important enough to get a consistent description of all the available experimental data.

The calculations with all three codes at the proton energy 150 MeV are compared with the data by Gloris et al. [117] and with the data of the present Project in Fig. 47. The upper panel shows the data for the $^{208}\text{Pb}+p$ reaction, while the lower panel includes similar results for the ^{206}Pb target . The yields of bismuth isotopes in both reactions are compared with calculations in Fig. 48. All calculations reproduce reasonably the experimental data except for the heaviest bismuth isotopes, for which the calculated yields are 20-30% above the experimental ones. The data for ^{207}Pb target obtained under the Project are intermediate between the data for ^{206}Pb and ^{208}Pb targets, as their agreement with calculations looks similar to the results shown in Figs. 47 and 48.

The experimental data obtained under the Project for the bismuth target are compared with the calculations in Fig. 49 for the residual mass yields (upper panel) and the yields of Po isotopes (lower panel). Data for bismuth are of particular interest for the current ADS designs that consider a lead-bismuth eutectic as an advanced promising heavy-metal coolant. The general conclusion concerning the agreement between experiment and calculations for bismuth is the same as for lead isotopes.

We have performed calculations and analysis of the mass and isotopic yields of the spallation and fission products at proton energies below 100 MeV. The calculations for ^{208}Pb target at the incident proton energy 70 MeV are compared with the available experimental data in Fig. 50. The agreement between the experimental data and calculations remains approximately the same as in the case of higher proton energies.

The analysis of all the above calculations allows us to conclude that the INCM codes with parameters tuned to the reliable experimental data simulate consistently the mass and charge distributions of spallation and fissions products for a broad range of incident proton energies, from 40-50 MeV up to 2-4 GeV. For lower energies, the nuclear structure effects, which are disregarded under semi-classical consideration of intranuclear collisions in the INCM, increase essentially, and many approximations of the INCM become justified poorly.

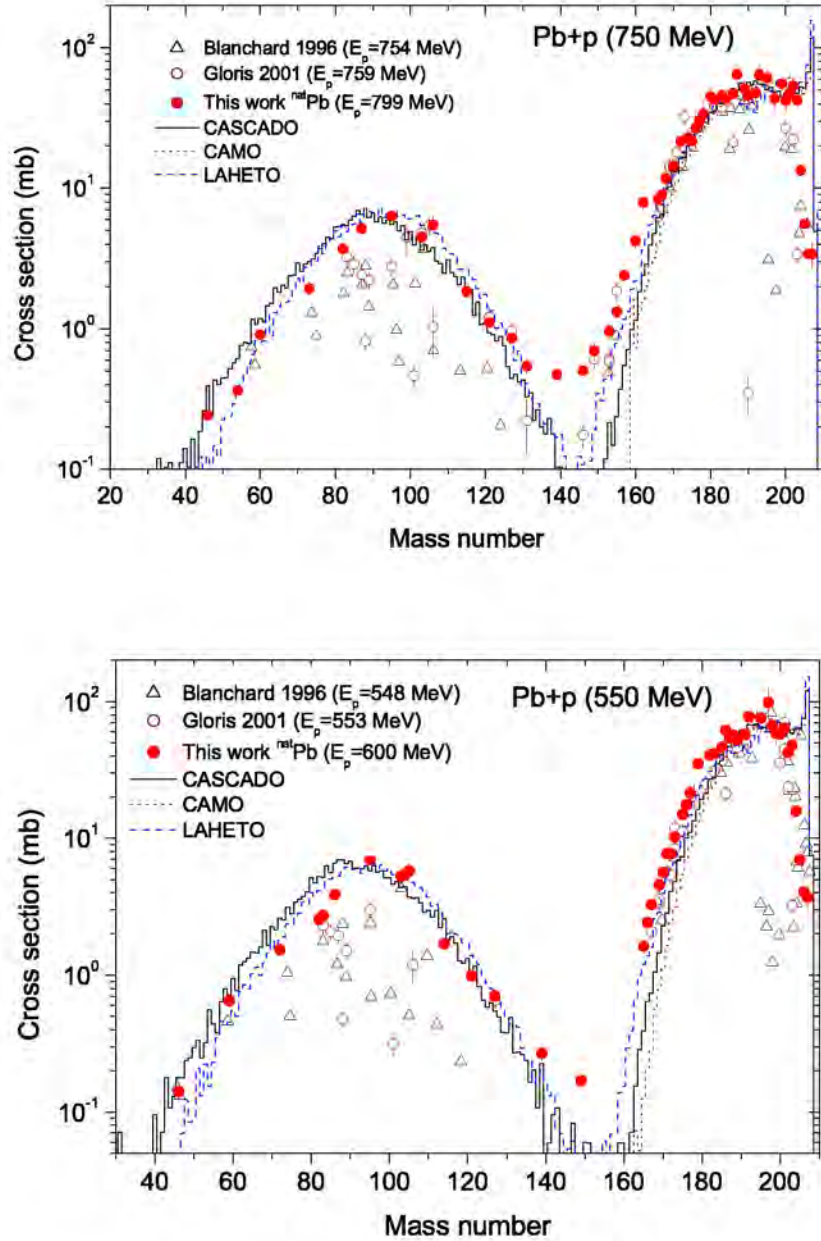


Fig. 42: Experimental data on residual cumulative yields for the $^{208}\text{Pb}+p$ reaction at the incident proton energies around 750 MeV (upper part) and about 550 MeV (lower part) compared with cascade-model calculations.

4.4 Conclusions

In pursuance of the ISTC Project #2002 Workplan item (see Section 4 **Scope of activities**):

- Task 9: Updating the models and codes on the basis of comparison of the simulation results with new experimental data obtained under the Project,

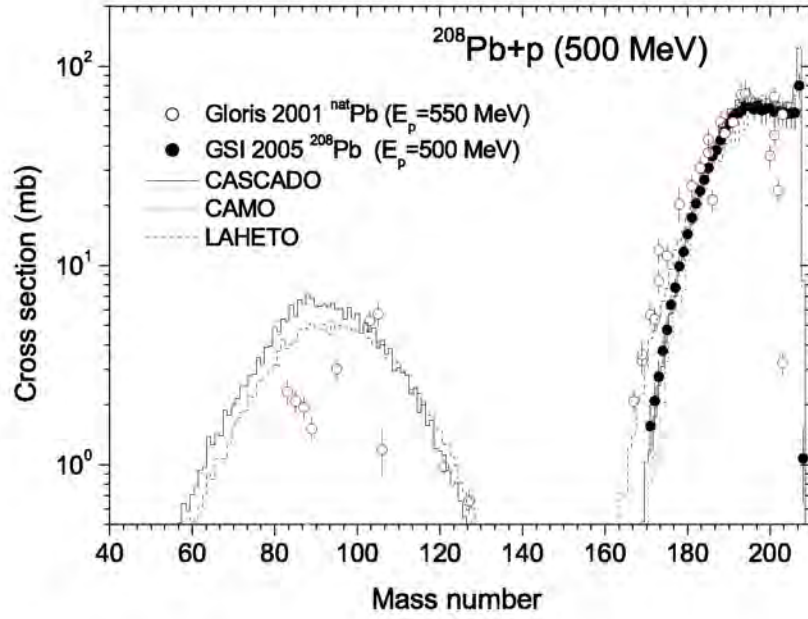


Fig. 43: The new experimental data on residues mass yields for the $^{208}\text{Pb}+p$ reaction at the incident proton energies 500 MeV compared with cascade-model calculations .

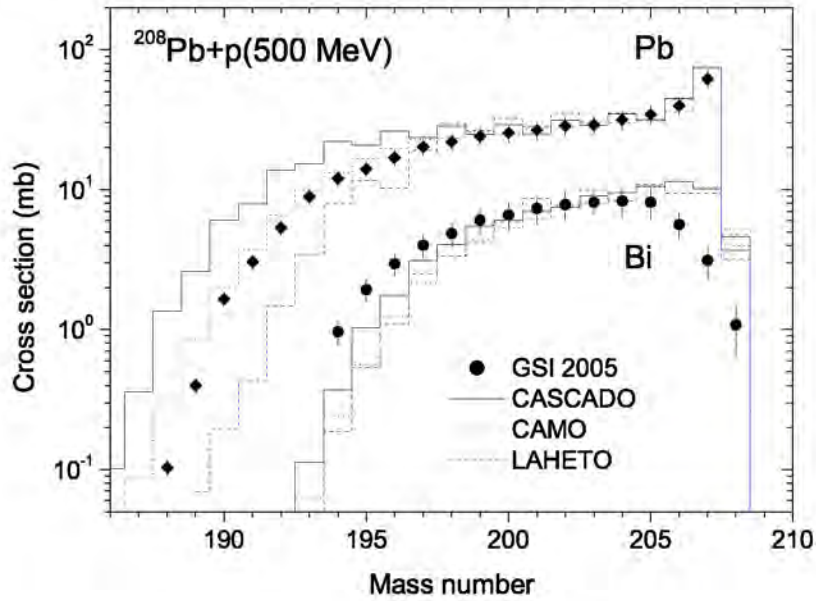


Fig. 44: Experimental data on the bismuth and lead isotopic yields for ^{208}Pb irradiated by 500 MeV protons compared with cascade-model calculations.

the following results have been obtained:

1. The yields of spallation and fission products for the proton-induced reactions on lead and bismuth targets have been calculated with some widely used codes that correspond to various versions of the INC model.
2. Differences between calculation results were analyzed, and the effect of both main approximations and model parameters on the obtained results studied, for the recent versions of the most popular codes.
3. In addition to the reaction product yields, the spectra of emitted neutrons and charged particles were analyzed, and contributions of the fast cascade, preequilibrium and equilibrium evaporation reaction mechanisms to the observed spectra investigated in details.
4. Some modifications of codes connected with a more correct simulation of nuclear processes and with a more accurate selection of model parameters have allowed us to improve the description of the available experimental data essentially. The recent GSI data together with the experimental data of the present Project have made it possible to achieve an optimal estimation of the model parameters for the proton-induced reactions on separated isotopes of lead and bismuth targets at energies close to 1 GeV.
5. Updated versions of the CASCADO, LAHETO, and CAMO codes describe consistently the total experimental dataset of spallation and fission product yields at the proton interaction with $^{206,207,208}\text{Pb}$ and ^{209}Bi targets in the wide energy range from 40 MeV up to 2.6 GeV.

With a view to future improving the theoretical models and increasing their prediction power, it seems quite important to reduce the above discussed disagreement between the experimental data obtained in the activation measurements and by the inverse kinematics method.

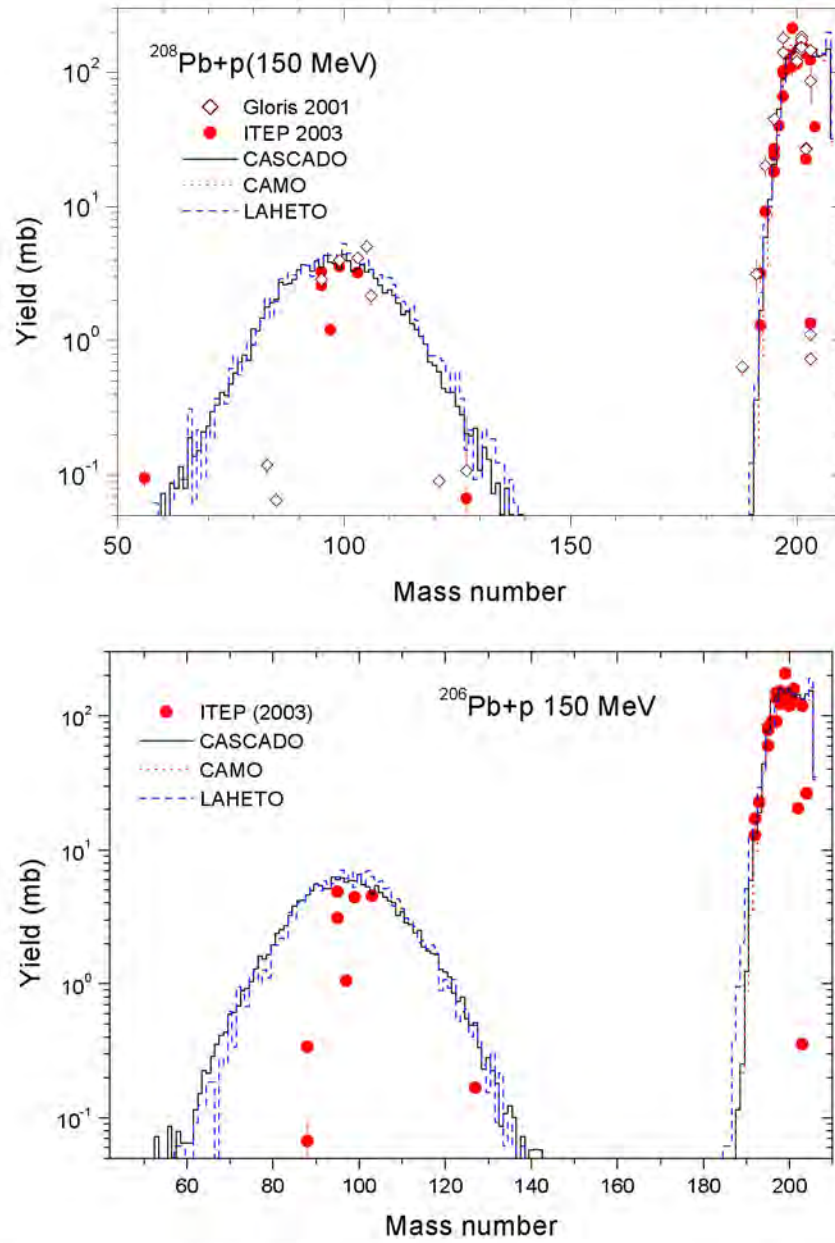


Fig. 45: The same as in Fig. 14 for the incident proton energies about 300 MeV .

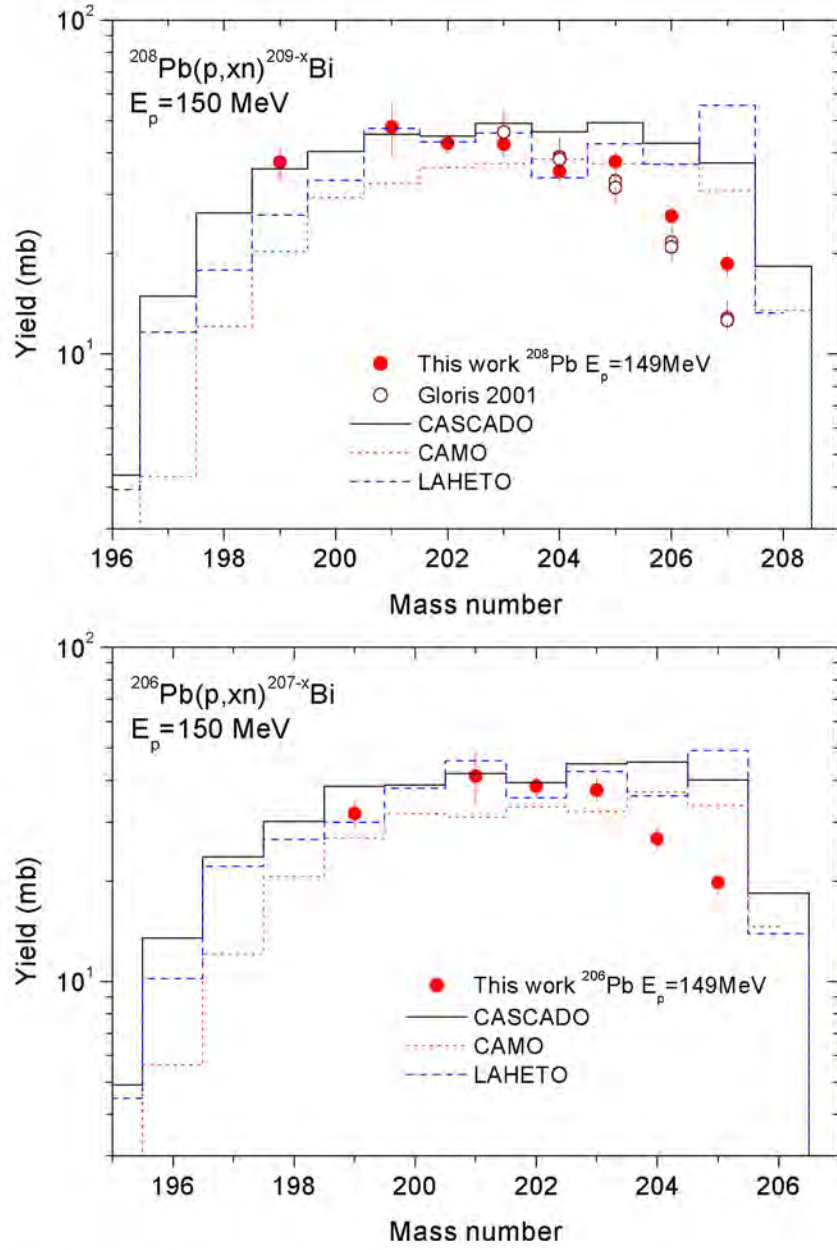


Fig. 46: The same as in Fig. 14 for the incident proton energies about 230 MeV

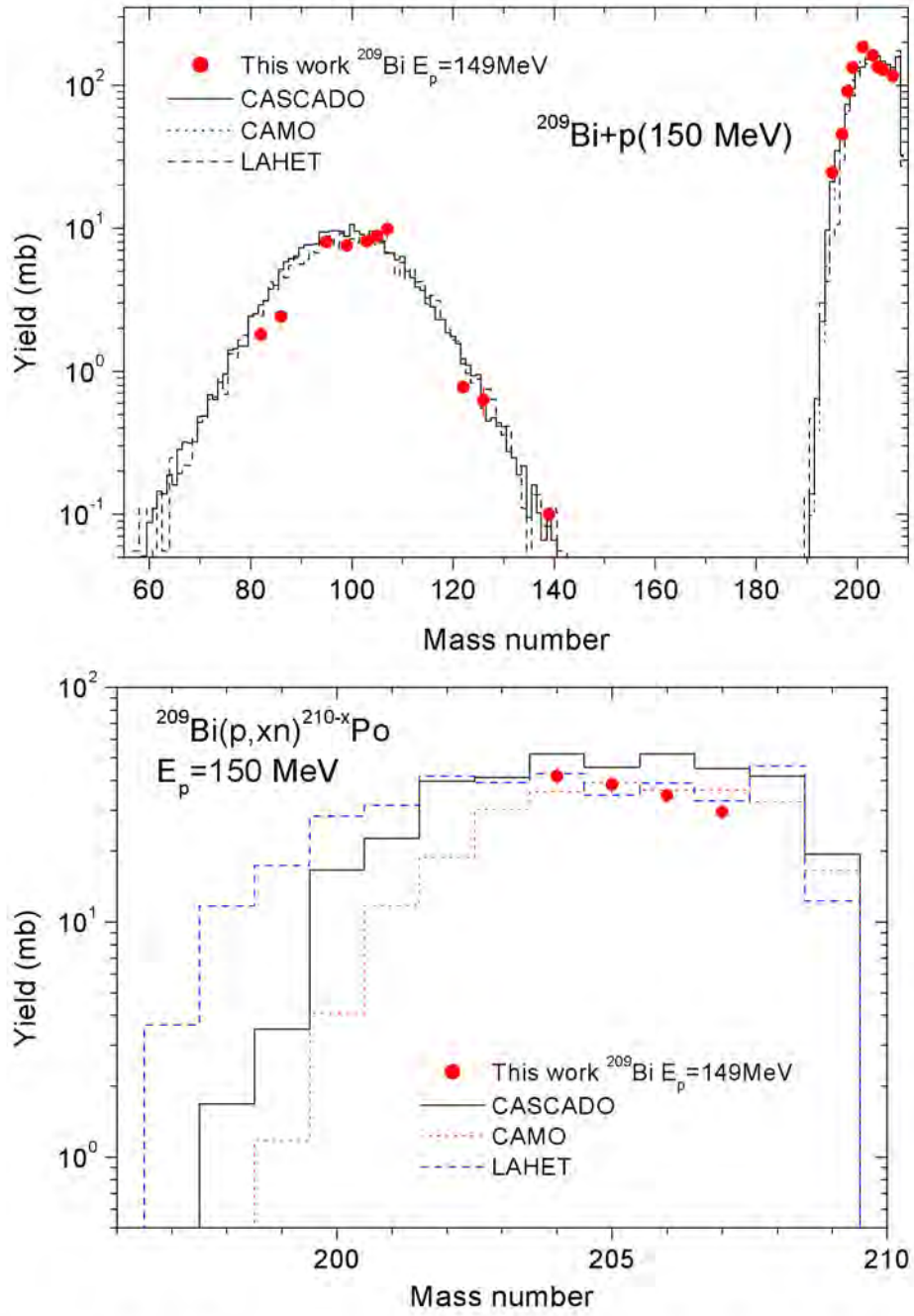


Fig. 47: Experimental data on cumulative yields of spallation and fission products for ^{208}Pb and ^{206}Pb targets irradiated by 150 MeV protons compared with cascade-model calculations.

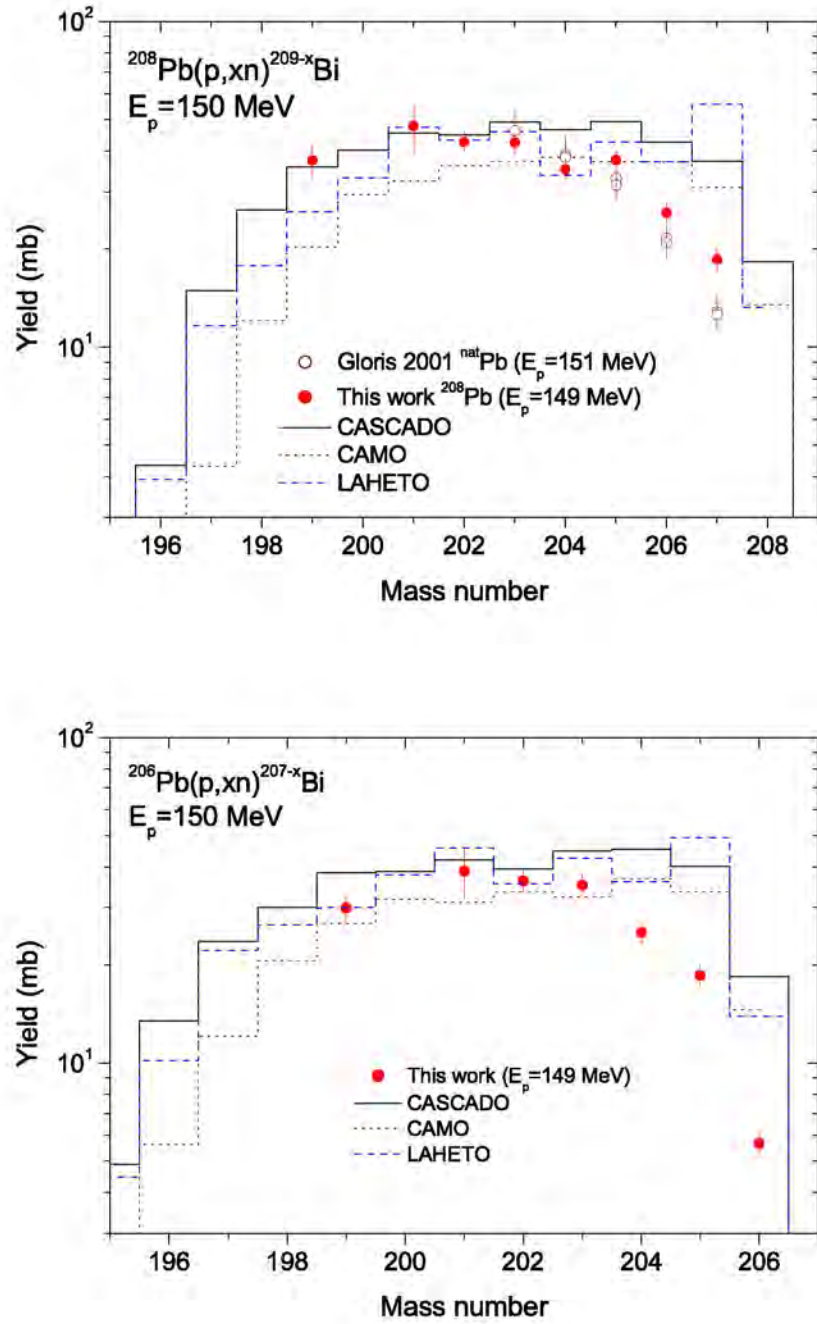


Fig. 48: Experimental data on the bismuth isotopic yields for ^{208}Pb and ^{206}Pb targets irradiated by 150 MeV protons compared with cascade-model calculations.

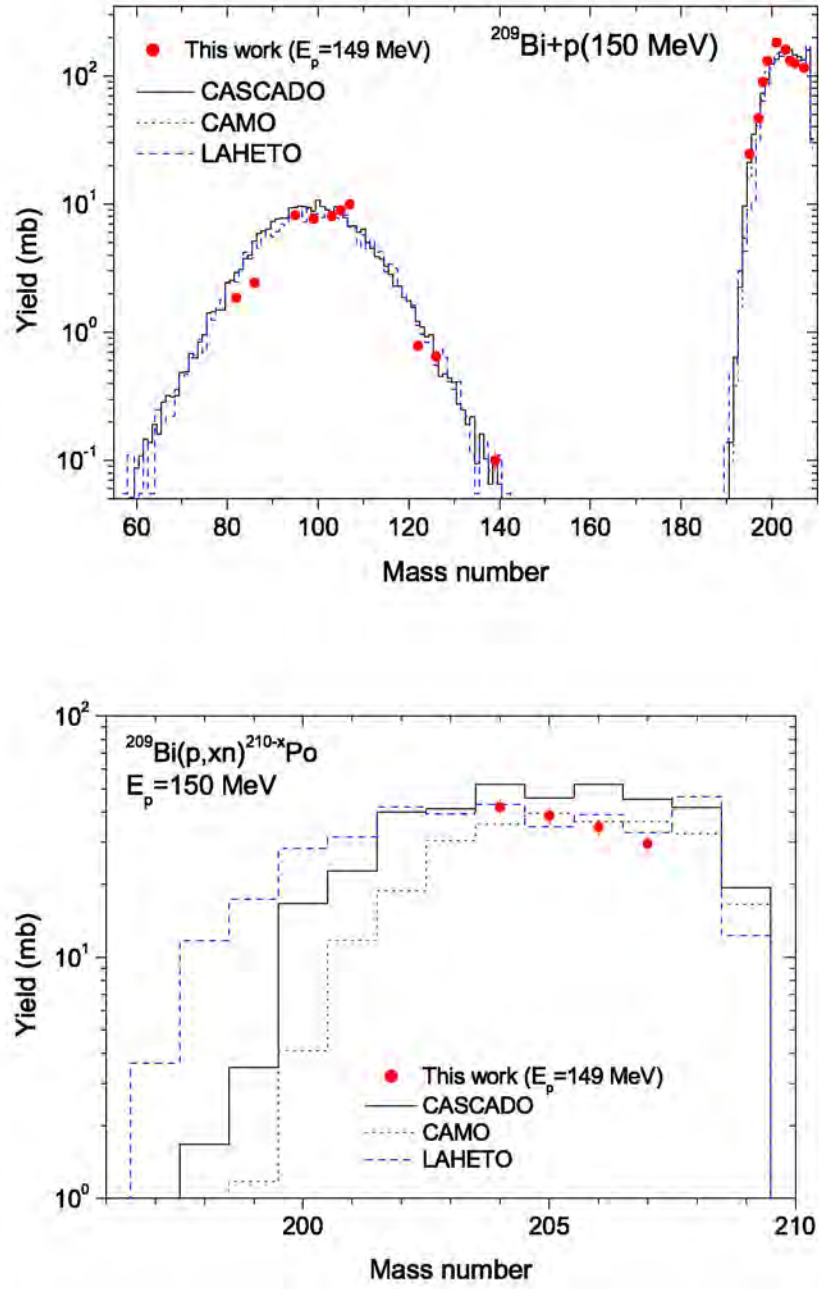


Fig. 49: Experimental data on cumulative yields of spallation and fission products and on the polonium isotopic yields for ^{209}Bi target irradiated by 150 MeV protons compared with cascade-model calculations.

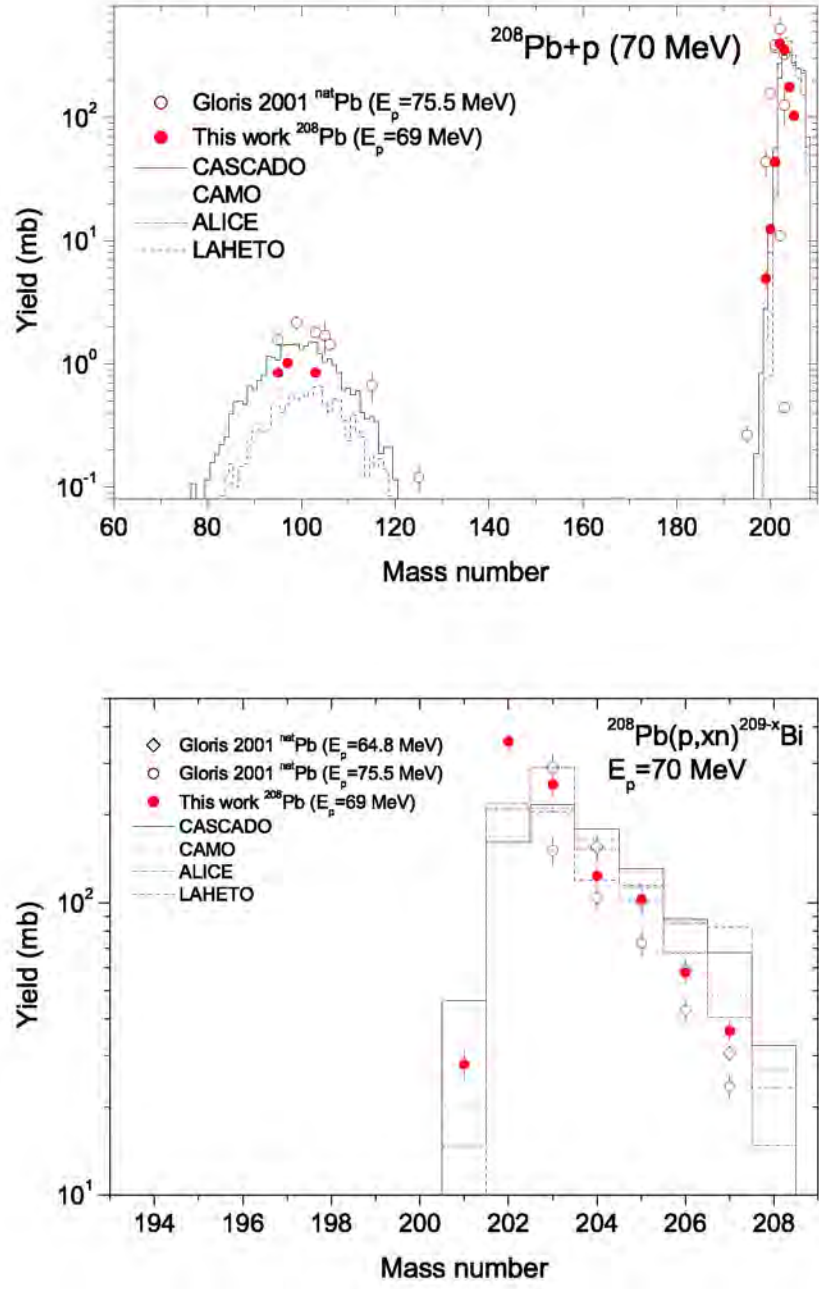


Fig. 50: Experimental data on cumulative yields of spallation and fission products and on the bismuth isotopic yields for ^{208}Pb target irradiated by 70 MeV protons compared with cascade-model calculations.

5 Theoretical simulation of experimental data by different codes

As noted above, any computational simulation implies calculations of independent product yields only, whereas most of the experimental results (except for the GSI inverse kinematics data) are the cumulative and supracumulative yields. In case the experimental and simulated independent yields are involved directly in the comparison or representation of excitation functions, any correct comparison or representation of the excitation functions of the values of cumulative and supracumulative yields necessitates the procedure of their calculations from independent simulated or experimental values of their precursor yields.

5.1 Radioactive decay chains used in simulations

In general, the radioactive nuclide production chain can be presented as

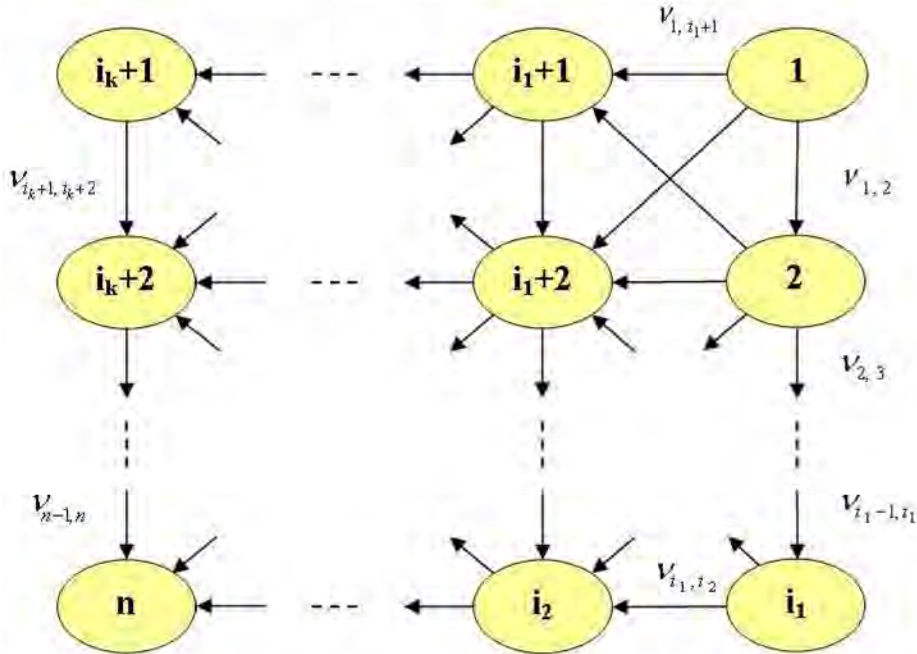


Fig. 51: Radioactive transformation pattern.

Examine a chain of n nuclides connected to each other by β^- , ε , n , p , and α transitions. Let all the chain nuclides be so numbered that a lower-number nuclide gets always transformed into a higher-number nuclide. Having known, then, the independent cross sections for production of all the chain nuclides, we can calculate the respective cumulative cross sections as

$$\sigma_k^{cum} = \sum_{j=1}^k m_{kj} \cdot \sigma_j^{ind}, k = 1, 2, \dots, n \quad (160)$$

where m_{kj} is a matrix, whose elements are calculated as

$$m_{kj} = \begin{cases} \sum_{i=j}^{k-1} \nu_{ik} \cdot m_{ij}, & \text{for } k > j, \\ 1, & \text{for } k = j, \\ 0, & \text{for } k < j, \end{cases} \quad (161)$$

where ν_{ik} are the branching factors, i.e. denote the probability for the i -th nuclide to be transformed into the k -th nuclide. The vector form of the expression for calculating the cumulative yields is

$$\vec{\sigma}^{cum} = M \cdot \vec{\sigma}^{ind}, \quad (162)$$

where M is a matrix with elements m_{kj} ; $\vec{\sigma}^{cum}$ and $\vec{\sigma}^{ind}$ are the vectors, whose elements are, respectively, the cumulative and independent cross sections of the chain elements.

$$\vec{\sigma}^{cum} = \begin{pmatrix} \sigma_1^{cum} \\ \sigma_2^{cum} \\ \vdots \\ \sigma_n^{cum} \end{pmatrix}, \quad \vec{\sigma}^{ind} = \begin{pmatrix} \sigma_1^{ind} \\ \sigma_2^{ind} \\ \vdots \\ \sigma_n^{ind} \end{pmatrix} \quad (163)$$

The cumulative cross section errors can be calculated as

$$\Delta\sigma_k^{cum} = \sqrt{\sum_{i=1}^n m_{ki}^2 \cdot (\Delta\sigma_i^{ind})^2} \quad (164)$$

where $\Delta\sigma_j^{ind}$ is absolute error of cross section σ_j^{ind} .

The values of branching factors ν_{ik} were retrieved from the ENSDF database taken from <http://ie.lbl.gov/databases/ENSDFdata.exe> (Database: Self-extracting ENSDF archive (23 MB). Last updated March, 2005) [35]. Note that the ENSDF database turns out to use 18 modes ² of radioactive nuclide decays: β^- , β^-n , IT , ε , $\varepsilon+\beta^+$, p , α , β^+p , $\beta^+\alpha$, β^+2p , εp , $\varepsilon\alpha$, 2ε , n , β^+ , $2\beta^-$, $2\beta^+$, $2e$.

All modes that lead to identical changes in nuclear charge and mass were combined to form twelve groups of decays, as tabulated below.

Table 38: Modes of decays and variations in nuclear charges and masses

Nos.	Mode		Modes from	
			ENSDF	$\Delta A \Delta Z$
1	β^-	β^-	0	+1
2	β^+	$\beta^+, \varepsilon, \varepsilon+\beta^+$	0	-1
3	β^-n	β^-n	-1	+1
4	β^+p	$\beta^+p, \varepsilon p$	-1	-2
5	$\beta^+\alpha$	$\beta^+\alpha, \varepsilon\alpha$	-4	-3
6	β^+2p	β^+2p	-2	-3

²There exists also the SF-mode, which is irrelevant to our researches.

7	p	p	-1	-1
8	α	α	-4	-2
9	$2\beta^+$	$2\beta^+, 2\varepsilon, 2 e$	0	-2
10	n	n	-1	0
11	$2\beta^-$	$2\beta^-$	0	+2
12	IT	IT	0	0

Use was made of branching factors for ground states or, in case the latter are absent, for the first metastable state. If an accurate branching factor value is unknown and presented as ($<$) or ($>$) that a certain limit, the branching factor is taken to equal the value of the limit, i.e. ($<$) or ($>$) was replaced with ($=$).

If a branching factor value is indicated to be unknown (marked ?), it was taken to be 0 in case numerical values of other branching factors are presented (considering the above remark), or else 1 in case other decay modes are not indicated. If other decay modes are presented, but the sum of their values is below 100%, the unknown branching factor was taken to equal 100% less the sum of the rest presented decay modes. If a few decay modes with unknown branching factors are presented, their values are taken to equal the ratio of 100% to the number of the presented modes. If but a single decay mode with its branching factor below 100% is presented (for example, $\alpha=4.5\%$ is only presented for ^{161}Ta), the missing difference was ascribed to the β^+ mode (in the case of neutron-deficient nuclides) or to the β^- mode (in the case of neutron-excessive nuclides).

If a delayed-decay mode ($\beta^+\alpha$, for instance) is indicated, the value of the delayed mode (α) was subtracted from the value of the principal mode (β^+). The branching factors for ^{181}Ta and ^{151}La were taken from Nuclear Wallet Cards (January 2000) because their values were not found in the ENSDFdata.exe file [126]. In total, 2470 nuclides with their branching factors have been selected from the ENSDFdata.exe file. Of them, 610 precursors were used to build the respective decay chains.

It should be noted that branching factor values derived in the above manner from the ENSDFdata.exe file are sometimes very different from the data of other sources. In the case of ^{177}Au , for example, ENSDF gives $\alpha \leq 100\%$, $\varepsilon+\beta^+-?$, whereas the Nuclear Wallet Cards indicates $\varepsilon \geq 60$.

On account of all the above reasons and considering the great importance of the given information in verifying the relevant codes, all chains are presented together with their branching factors in Chapter 4 of Appendix to this Report. Plotted as an example in Fig. 52 is the ^{143}Pm chain that includes 43 precursors.

For convenience, the analyzed decay chains were broken into groups of $^{208,207,206,\text{nat}}\text{Pb}$ and ^{209}Bi decay chains. The $^{208,207,206,\text{nat}}\text{Pb}$ decay chain members were restricted to the Bi isotopes, and the ^{209}Bi decay chain members to the Po isotopes. The chains, wherein Po was not found, are identical. Note that some codes simulate the yields of the Po isotopes from $^{208,207,206,\text{nat}}\text{Pb}$, and of the At isotopes from ^{209}Bi . The yields of the products are, however, so small ($<< 1$ mb) that they can well be disregarded to avoid any excessive complication of the chains. The presented radioactive chains permit them to be grouped into independent yields (**i**, **i**($\Sigma m_j + g$)), cumulative yields **c**, and supracumulative yields **c***.

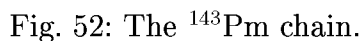


Table 39: List of nuclides together with their supracumulative yields, halfives, branching factors, and supracumulativity coefficients.

145

1	2	3	4	5	6	7	8	9	10
40	¹⁹⁹ ₈₁ Tl	7.42h	¹⁹⁹ ₈₂ Pb	90m	c*		1	1.2534	1.2534
44	¹⁹⁵ ₈₁ Tl	1.16h	¹⁹⁵ ₈₂ Pb	≈15m	c*	c*	1	1.2747	1.2747
46	¹⁹⁷ ₈₀ Hg	64.14h	¹⁹⁷ ₈₁ Tl	2.84h	c*	c*	1	1.0463	1.0463
53	¹⁹⁰ ₈₀ Hg	20.0m	¹⁹⁰ ₈₁ Tl	3.7m	c*	c*	1	1.2270	1.2270
62	¹⁹¹ ₇₉ Au	3.18h	¹⁹¹ ₈₀ Hg	49m	c*	c*	1	1.3456	1.3456
75	¹⁸⁷ ₇₇ Ir	10.5h	¹⁸⁷ ₇₈ Pt	2.35h	c*	c*	1	1.2883	1.2883
78	¹⁸⁴ ₇₇ Ir	3.09h	¹⁸⁴ ₇₈ Pt	17.3m	c*	c*	1	1.1029	1.1029
81	^{183m} ₇₆ Os	9.9h	¹⁸³ ₇₇ Ir	57m	c*	c*	1	1.1061	1.1061
88	¹⁷⁹ ₇₅ Re	19.5m	¹⁷⁹ ₇₆ Os	6.5m	c*	c*	1	1.5000	1.5000
89	¹⁷⁸ ₇₅ Re	13.2m	¹⁷⁸ ₇₆ Os	5.0m	c*	c*	1	1.6098	1.6098
94	¹⁷⁶ ₇₃ Ta	8.09h	¹⁷⁶ ₇₄ W	2.5h		c*	1	1.4472	1.4472
98	¹⁷² ₇₃ Ta	36.8m	¹⁷² ₇₄ W	6.6m	c*	c*	1	1.2185	1.2185
118	¹⁶¹ ₆₈ Er	3.21h	¹⁶¹ ₆₉ Tm	33m	c*	c*	1	1.2068	1.2068
120	¹⁵⁹ ₆₈ Er	36m	¹⁵⁹ ₆₉ Tm	9.13m	c*	c*	1	1.3398	1.3398
122	¹⁵⁶ ₆₇ Ho	56m	¹⁵⁶ ₆₈ Er	19.5m	c*	c*	1	1.5342	1.5342
124	¹⁵⁵ ₆₆ Dy	9.9h	¹⁵⁵ ₆₇ Ho	48m	c*	c*	1	1.0879	1.0879
127	¹⁵⁵ ₆₅ Tb	5.32d	¹⁵⁵ ₆₆ Dy	9.9h		c*	1	1.0841	1.0841
128	¹⁵³ ₆₅ Tb	2.34d	¹⁵³ ₆₆ Dy	6.4h	c*	c*	0.9999	1.0478	1.0477
146	¹³⁴ ₅₉ Pr	17m	¹³⁴ ₆₀ Nd	8.5m		c*	1	2.0000	2.0000
162	¹²¹ ₅₃ I	2.12h	¹²¹ ₅₄ Xe	40.1m		c*	1	1.4604	1.4604
173	¹¹⁵ ₅₁ Sb	32.1m	¹¹⁵ ₅₂ Te	5.8m		c*	1	1.2205	1.2205
203	⁹⁰ ₄₁ Nb	14.60h	⁹⁰ ₄₂ Mo	5.56h	c*	c*	1	1.6150	1.6150
211	⁸⁷ ₃₉ Y	79.8h	^{87m} ₃₉ Y	13.37h	c*	c*	0.9843	1.2013	1.1824

Analyzing the radioactive transformation chains presented in Chapter 4 of Appendix to this Report permits the following general comments:

- 29 of the measured metastable states are excluded from the comparison: ^{204m}₈₂Pb, ^{202m}₈₂Pb, ^{197m}₈₂Pb, ^{195m}₈₂Pb, ^{198m}₈₁Tl, ^{196m}₈₁Tl, ^{197m}₈₀Hg, ^{195m}₈₀Hg, ^{193m}₈₀Hg, ^{198m}₇₉Au, ^{183m}₇₆Os, ^{182m}₇₅Re, ^{160m}₆₇Ho, ^{123m}₅₂Te, ^{121m}₅₂Te, ^{119m}₅₂Te, ^{120m}₅₁Sb, ^{118m}₅₁Sb, ^{117m}₅₀Sn, ^{114m}₄₉In, ^{110m}₄₇Ag, ^{106m}₄₇Ag, ^{102m}₄₅Rh, ^{101m}₄₅Rh, ^{99m}₄₅Rh, ^{93m}₄₂Mo, ^{92m}₄₁Nb, ^{90m}₃₉Y, ^{82m}₃₇Rb.
- The nuclides, whose branching factors of metastable states (except for IT-mode) differ from those of ground states, may also be radioactive chain members. In such a case, the total branching factor of a given nuclide differs from the ground state branching factor presented here, thereby introducing a systematic error.

This is of particular importance in case the decay modes of the nuclides extend to other chains. Of 44 nuclides belonging to the chain presented in Fig. 52, ¹⁶⁷Re is such a nuclide. According to the ENDSFdat.exe file, ¹⁶⁷Re has $\beta^+ \sim 99\%$, $\alpha \sim 1\%$, while ^{167m}Re has $\alpha \sim 100\%$. Table 40 presents other examples of different branching factors of metastable and ground states. This problem is also urgent in the cases where a measured nuclide (it makes no difference if the nuclide yield is independent or cumulative) has its metastable states with their internal conversion factor *IT* below 100% (the nuclides are exemplified in Table 41).

Table 40: Examples of the $^{208,207,206,nat}\text{Pb}$ and ^{209}Bi decay chain nuclides with different α -decay fractions of their ground and metastable states.

Nuc- lide	$T_{2_{1/2}}$	Decay mode		Iso- mer	$T_{1_{1/2}}$	Decay mode		
		ε %	α %			IT %	ε %	α %
$^{203}_{84}\text{Po}$	36.7m	99.89	0.11	$^{203m}_{84}\text{Po}$	45s	≈ 100		0.04
$^{201}_{84}\text{Po}$	15.3m	98.4	1.6	$^{201m}_{84}\text{Po}$	8.9m	56	41	2.9
$^{199}_{84}\text{Po}$	4.58m	92.5	7.5	$^{199m}_{84}\text{Po}$	4.13m	2.5	73.5	24
$^{197}_{84}\text{Po}$	1.4m	56	44	$^{197m}_{84}\text{Po}$	31s	0.01	16	84
$^{201}_{83}\text{Bi}$	108m	100	$<1.0 \cdot 10^{-4}$	$^{201m}_{83}\text{Bi}$	59.1m	≤ 6.8	>93	≈ 0.3
$^{197}_{83}\text{Bi}$	9.33m	100	$1.0 \cdot 10^{-4}$	$^{197m}_{83}\text{Bi}$	5.04m	<0.3	45	55

Table 41: Examples of measured nuclides and their metastable state decay fractions.

Nuc- lide (2)	Isomer $T_{2_{1/2}}$ (1)	$T_{1_{1/2}}$	Decay type				
			IT %	ε %	α %	β^- %	
$^{203}_{84}\text{Po}$	36.7m	$^{201m}_{84}\text{Po}$	45s	≈ 100	-	0.04	-
$^{201}_{84}\text{Po}$	15.3m	$^{201m}_{84}\text{Po}$	8.9m	56	41	2.9	-
$^{201}_{83}\text{Bi}$	108m	$^{201m}_{83}\text{Bi}$	59.1m	≤ 6.8	> 93	≈ 0.3	-
$^{199}_{83}\text{Bi}$	27m	$^{199m}_{83}\text{Bi}$	24.70m	≤ 2	98	≈ 0.01	-
$^{199}_{82}\text{Pb}$	90m	$^{199m}_{82}\text{Pb}$	12.2 m	93	7	-	-

The above features of the chains have an undoubted effect on the values of the squared deviation factor $< F >$ that determine the predictive power of the tested codes.

5.2 The codes used to simulate the experimental results

Apart of CASCADO and LAHETO, other five codes were used to calculate our measured cross sections:

- LAHET [131] is a well known and one of the most widely used in different nuclear applications code. It involves Monte-Carlo modeling of transport of nucleons, pions, muons, light ions, and antinucleons in extended objects or thin targets (interactions with nuclei). LAHET was developed at Los Alamos National Laboratory and includes several options of models to choose from to simulate the intranuclear cascade (INC), preequilibrium, evaporation, and fission of nuclei. The Bertini and ISABEL INC, Multistage Preequilibrium Model (MPM), Dresner's evaporation, and Atchison's (RAL) fission models (see details and references in [131]) are used in the work.
- CEM03 is the last, 2003, version of the improved Cascade-Exciton Model (CEM) [132] proposed initially at JINR, Dubna [133]. It has a longer cascade stage, less preequilibrium emission, and a longer evaporation stage with a higher initial excitation energy compared

to its precursors CEM97 and CEM95. It is based on an improved [134] Dubna INC, extended Fermi break up and coalescence models from [135], and includes an improved version of the Generalized Evaporation-fission Model (GEM2) by Furihata [136]. CEM03 and/or its precursors are incorporated into the MARS, MCNPX, and LAHET transport codes and are used in many applications. The above modifications of CEM03 and the simulations were carried out at LANL by S.G.Mashnik.

- LAQGSM+GEM2 is a further development [137] of the Los Alamos version of the Quark-Gluon String Model [138] based of the Quark-Gluon String Model (QGSM) realized initially at JINR, Dubna [139]. It includes an improved version [134] of a time-dependent Dubna intranuclear cascade model, often referred in the literature simply as the Dubna intranuclear Cascade Model (DCM) [135] that makes use of experimental elementary cross sections (or those calculated with the Quark-Gluon String Model[139] for energies above 4.5 GeV/A), the improved pre-equilibrium model from CEM03 described above, refined versions of the Fermi break-up and coalescence models from [135], and an improved version of the Furihata's Generalized Evaporation-fission Model (GEM2) [136] as realized in CEM03. Here, we use the last, 2003, version of the code LAQGSM+GEM2, named LAQGSM03 [140], that was incorporated recently into the MARS and LAHET transport codes and is currently being incorporated into MCNPX. The above modifications of LAQGSM+GEM2 and the simulations were carried out at LANL by S.G.Mashnik, K. Gudima, and A. Sierk.
- INCL4+ABLA [141], [142] code is based on a recent version of the Liege INC by Cugnon et al. [141] merged with the GSI evaporation/fission model ABLA by Schmidt et al. [142]. This code system was developed in the framework of the HINDAS project, it was incorporated into LAHET3 and MCNPX transport codes, and is widely used at present in Europe. The above modifications of INCL4+ABLA were carried out at CEA-Saclay by A. Boudard.
- CASCADE is a transport code system developed at JINR, Dubna [130]. It allows to calculate nuclear reactions both on thin and thick targets and includes a time-dependent INC (different from [135]), the preequilibrium and evaporation models of CEM [133], and the Fong statistical fission model. It is under further development at JINR; its different modifications are used at present in many nuclear applications, mainly in the Former USSR.

To get a correct comparison for the results obtained by different codes, the calculated yields values were renormalized to the same cross sections for inelastic proton-nucleus interactions. We calculated the cross sections via the semi-empirical formula [168]:

$$\begin{aligned}
 \sigma_{inel} &= 45A^{0.7}f(A)g(E), \text{ (in mb)} \\
 f(A) &= 1 + 0.016 \sin(5.3 - 2.63 \log A), \\
 g(E) &= 1 - 0.62 \exp(-E/200) \sin(10.9E^{-0.28}),
 \end{aligned}
 \tag{165}$$

where A is the mass number of the target, E is the energy (in MeV) of the projectile proton.

The calculated proton-nucleus inelastic cross sections of the targets are presented in Table 42.

Table 42: Inelastic proton-nucleus interaction cross sections [mbarn] calculated by formulae [168].

Target	Proton energy (GeV)										
	0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
²⁰⁶ Pb	2487	1995	1757	1612	1613	1714	1798	1833	1851	1853	1853
²⁰⁷ Pb	2495	2002	1762	1617	1618	1720	1804	1839	1857	1859	1860
²⁰⁸ Pb	2503	2008	1768	1622	1624	1726	1810	1845	1863	1865	1866
²⁰⁹ Bi	2512	2015	1774	1628	1629	1732	1816	1851	1869	1872	1872

5.3 Simualtion-to-Experimental Comparison

The modeling was carried out at 25 energies from 0.03 to 3.5 GeV to produce smooth excitation functions (EF). The **default options** were used in all the simulation codes without modifying the latter to get the optimal agreement with experimental data. All the calculations were made prio to obtaining any experimental results. With such an approach, our comparisons demonstrate the real predictive, rather than the descriptive power of the codes. To make the comparison to experimental data (ED) correct, the required cumulative yields were calculated on the base of simulated independent yields with the use of formulas 160 and 162. The metastable products were not simulated. We compared simulated and experimental EF both qualitatively (by plots) and quantitatively (by the mean simulated-to-experiment squared deviation factor $\langle F \rangle$, $\langle F \rangle = 10\sqrt{\langle \log(\sigma_{cal,i}/\sigma_{exp,i})^2 \rangle}$). Three set of figures were drawn for the qualitative comparison:

1. 884 figures with EF simulated by the codes and ED measured (Figs. 53 – 83).
2. 55 figures with mass production cross sections measured and simulated (Figs 84 – 138, plotted both in logarithmic and linear scale). The measured data shown at these figures are the measured cumulative and supra cumulative yields of the nuclides that are in immediate proximity to the stable isotope of a given mass (or the sum of such yields from either side in the cases where both left- and right-hand branches of the chain are present). Obviously, the simulation results do not contradict the experimental data if the simulated values run above the experimental data and follow the general trend of the latter. This is because the direct γ -spectrometry identifies only the radioactive products, which generally form a significant fraction of the total mass yield, but are never equal to the total mass yield when a stable isobar is produced.
3. 10 figures with simulation-to-experimental ration statistics (Figs 139 – 148) to be used for the quantitative comparison.

To understand how different codes agree with the data in different nuclide production regions, we divided conventionally all products into four groups: shallow spallation products ($A > 170$), deep spallation products ($140 < A < 170$), fission products ($30 < A < 140$), and fragmentation products ($A < 30$).

Besides, the energy ranges are conditionally broken into groups of low ($E_p < 0.1 \text{ GeV}$), medium ($0.1 \text{ GeV} < E_p < 1.0 \text{ GeV}$), and high ($E_p > 1.0 \text{ GeV}$) energies. The mean deviation factors $\langle F \rangle$ are presented in Table 43 for each combination of product and energy groups, and in Table 44 for each group separately together with the $\langle F \rangle$ values for all the comparison events. To facilitate the analysis, three least $\langle F \rangle$ values are shown to be red, and three highest $\langle F \rangle$ values to be blue, in each of the comparison event groups.

Table 43: Mean squared deviation factors $\langle F \rangle$ for different ranges of products in three energy groups: < 0.1 / $0.1-1.0$ / > 1.0 GeV.

Code	Product mass (A), Proton energy group (E_p , GeV)											
	A > 170			140 < A < 170			30 < A < 140			A < 30		
	<0.1	0.1-1.0	>1.0	<0.1	0.1-1.0	>1.0	<0.1	0.1-1.0	>1.0	<0.1	0.1-1.0	>1.0
ISABEL	4.29	1.62	—	—	1.77	—	7.98	3.13	—	—	334.	—
BERTINI	3.97	1.54	1.69	—	2.30	1.82	5.73	2.95	2.41	—	418.	25.2
INCL4+ABLA	5.19	1.84	1.40	—	7.76	2.80	2.12	1.92	2.53	—	—	49.9
CASCADE	2.99	1.58	1.85	—	2.53	1.86	80.7	10.8	3.61	—	—	162.
CASCADE-2004	3.84	1.87	1.71	—	1.66	1.41	105	6.72	3.96	—	—	61.0
LAQGSM+GEM2	3.19	1.88	1.94	—	4.88	1.59	2.23	2.83	2.61	—	42.1	15.1
CEM03	2.21	1.61	2.46	—	2.75	1.87	1.32	1.89	2.64	—	14.4	7.69
CASCADO	2.93	2.01	1.79	—	4.98	1.38	1.39	2.47	3.26	—	177.	58.5
LAHETO	5.30	1.65	—	—	1.96	—	2.93	1.94	—	—	—	—

Table 44: Mean squared deviation factors $\langle F \rangle$ separately for different energy groups and ranges of products ($A > 30$) and for all comparisons as well.

Code	Product mass (A)			Proton energy (E_p , GeV)			Total
	A > 170	140 < A < 170	30 < A < 140	$E_p < 0.1$	$0.1 < E_p < 1.0$	$E_p > 1.0$	
ISABEL	1.81	1.81	2.87	4.88	2.13	—	2.16
BERTINI	1.75	1.93	2.75	4.26	2.06	1.97	2.10
INCL4+ABLA	1.90	3.74	2.22	4.63	2.18	2.13	2.25
CASCADE	1.77	2.01	6.93	4.93	3.93	2.44	3.25
CASCADE-2004	1.93	1.47	5.54	6.54	3.23	2.42	2.94
LAQGSM+GEM2	1.98	2.32	2.71	3.03	2.35	2.09	2.26
CEM03	1.98	2.07	2.25	2.08	1.77	2.39	2.07
CASCADO	1.99	2.22	2.83	2.69	2.33	2.22	2.29
LAHETO	1.99	1.96	1.98	4.85	1.76	—	1.98

5.4 Conclusions

In pursuance of the ISTC Project #2002 Workplan item (see Section 4 **Scope of activities**):

- Task 8: Theoretical simulations and calculations by different codes,

Chapter 5 presents the tables and figures that permit the following conclusions:

1. $A > 170$ (shallow spallation products): most of the products from this region are predicted satisfactorily, with a mean deviation factor below 2. Deviations above factor 2 are observed, as a rule, for independent yields (e.g., for ^{192}Ir), for (p,xn) reactions, and for near-threshold energies, the fact that markedly affects $\langle F \rangle$ below 0.1 GeV. Also, the deviations between ED and simulated EF's as well as between results by different codes increase at energies above 1 GeV. The near-target products (A above 200) are predicted variously at different proton energies: For instance, CEM03 predicts such products with $\langle F \rangle \sim 1.5$ at energies below 1 GeV, but underestimates them significantly ($\langle F \rangle \sim 6$) at energies above 1 GeV. On the contrary, LAHET and LAQGSM+GEM2 predict these products with $\langle F \rangle \sim 1.5 - 2$ at energies above 1 GeV, but fail to do so well at lower energies ($\langle F \rangle \sim 4 - 5$). The similar is true for INCL4+ABLA: $\langle F \rangle \sim 1.3 - 1.5$ at $E_p > 0.1$ GeV, $\langle F \rangle \sim 6$ at $E_p < 0.1$ GeV. Note also that all codes gave similar $\langle F \rangle$ values averaged over all energies, which makes it difficult to choose the best among them.
2. $140 < A < 170$ (deep spallation products). With decreasing mass of the products (excitation energy after the intranuclear cascade stage of a reaction increasing), the predictive power of almost all the codes also decreases. The degradation of the predictive power of different codes varies. For example, for BERTINI, $\langle F \rangle$ increases up to only 1.9; for LAQGSM+GEM2, $\langle F \rangle$ increases up to 2.3; and in the case of INCL4+ABLA, $\langle F \rangle$ increases up to 3.7. The INCL4+ABLA underestimates significantly the deep spallation products, thus overestimating their threshold energies. Note also that the thresholds of some reactions predicted by different codes may vary by up to hundreds of MeV. For example, the threshold for the production of ^{146}Eu predicted by different codes varies from 600 to 1200 MeV. Judging from the $\langle F \rangle$ values, CASCADE-2004 is much ahead of the rest codes ($\langle F \rangle = 1.47$ against $\langle F \rangle = 1.81$ for BERTINI).
3. Fission products (FP) are about a third of all measured and analyzed nuclides, and are described by the codes worse than the spallation products. The deviation between ED and simulated EF's as well as between different calculations themselves are much bigger than for the spallation products. INCL4+ABLA and CEM03, as well as LAHETO, show the best predictive power for fission products, whose $\langle F \rangle$ is ranging from 2.0 to 2.3. It should be noted, however, that LAHETO was not used to make calculations in the highest-energy group ($E_p > 1.0$ GeV), for which the INCL4+ABLA and CEM03 predictive powers get decreased, so the best resulting $\langle F \rangle$ value (1.98) cannot be a credible argument for considering LAHETO the best fission code. A peculiar agreement is demonstrated by the code INCL4+ABLA: $\langle F \rangle$ is too high (up to 6) in the $120 < A < 140$ region where FP's overlap with deep spallation products, however, its agreement becomes the best ($\langle F \rangle$ from 1.5 to 2.0) in comparison with other codes for fission products with $A < 120$. LAQGSM+GEM2 shows somewhat bigger deviation from ED ($\langle F \rangle$ up to 4), however, the agreement is better in the $80 < A < 110$ region, with $\langle F \rangle$ around 2. CASCADE shows a much worse agreement on FP's ($\langle F \rangle$ up to ~ 20) compared with all the rest codes. Note

that most of the simulated EF's are below ED in the fission region, i.e. the fission mode seems to be underestimated by the codes. The agreement of calculations with the fission data varies with the proton energy. For example, INCL4+ABLA underestimates FP's at energies from ~ 0.1 to ~ 1 GeV, shows a good agreement at ~ 1 GeV, and overestimates them at higher energies. CEM03 predicts most of FP at relatively low energies ($< \sim 0.5$ GeV) much better than at higher energies.

4. Despite the fact that but few fragmentation products have been measured and, then, compared with simulations under the reported Project, it can be concluded definitely that the fragmentation products are much underestimated by all the codes tested. The simulations underestimate the measured fragmentation yields by an order and more. As a whole, the CEM03 and LAQGSM+GEM2 results for these fragments are closest to ED.

The comparison among the mean deviation factors obtained for different energy groups has demonstrated an explicit decrease in the predictive power in the low-energy range ($E_p < 0.1$ GeV), for which CEM03 alone gives $\langle F \rangle = 2.1$, thus permitting it to be regarded as the stablest "universal"(as regards predictive power) code. As for the mean deviation factor, CEM03 also gives high results (2.1), like ISABEL and LAHETO, which, however, were not used to make calculations in the upper range of energies.

Finally, we would like to mention that, as the gamma-spectrometry method used to obtain all experimental data analyzed here allows measuring only part of the products from any nuclear reaction, our comparison does not pretend to be comprehensive and to choose the best from the tested codes. Rather, it points to some distinct problems each code still has, helping the authors of the codes to further improve them.

Nuclide formation CRS's from Pb's and Bi

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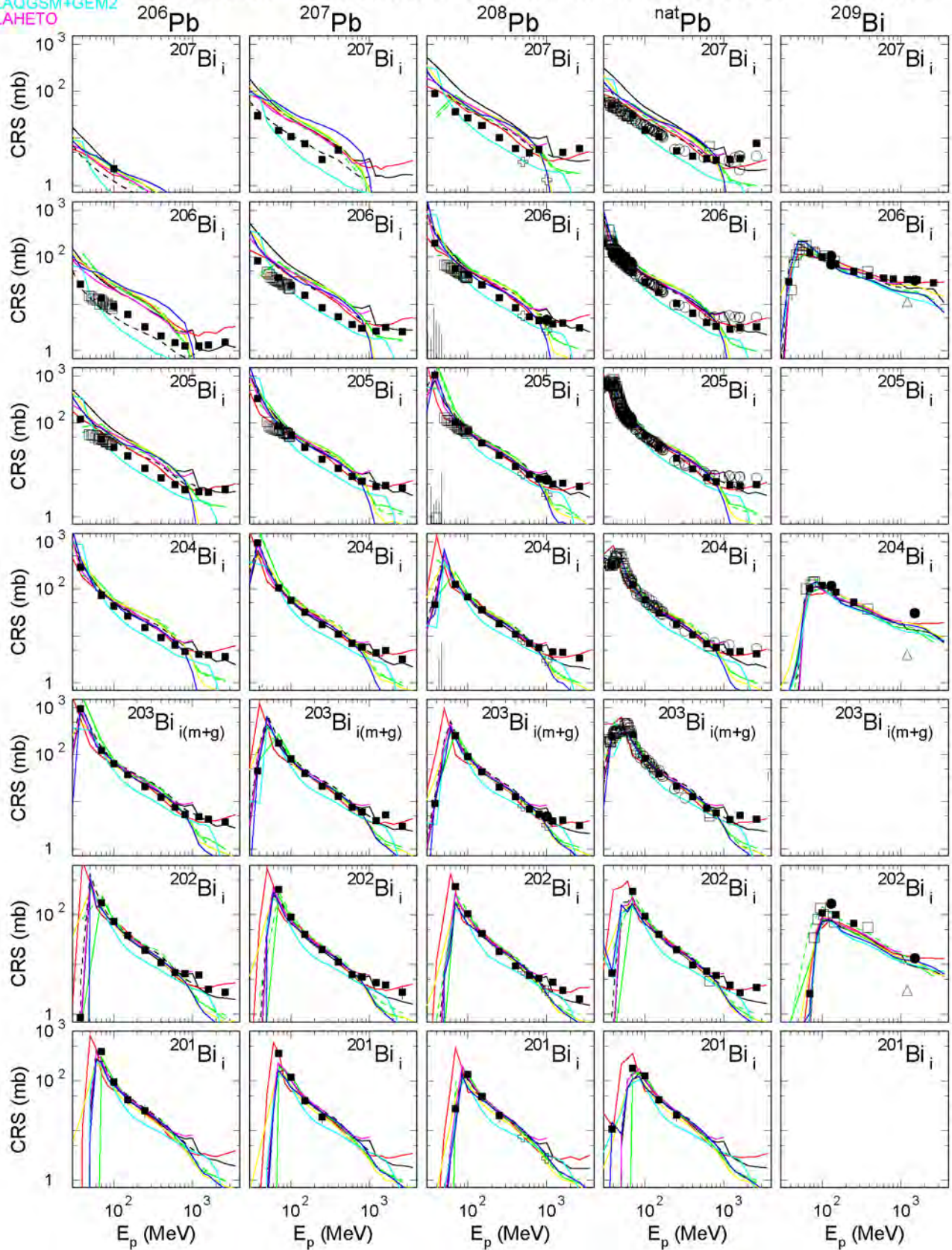


Fig. 53: The simulated and experimental cross sections of the measured reactions (■ - this work, + - [123], ○ - [117], ● - [6, 4], △ - [101], ▮ - other works; LAHET - black (ISABEL - solid, BERTINI - dashed), CEM03 - blue, INCL4+ABLA - red, CASCADE - green, LAQGSM03 - cyan, LEHETO - magenta, CASCADO - yellow.

Nuclide formation CRS's from Pb's and Bi

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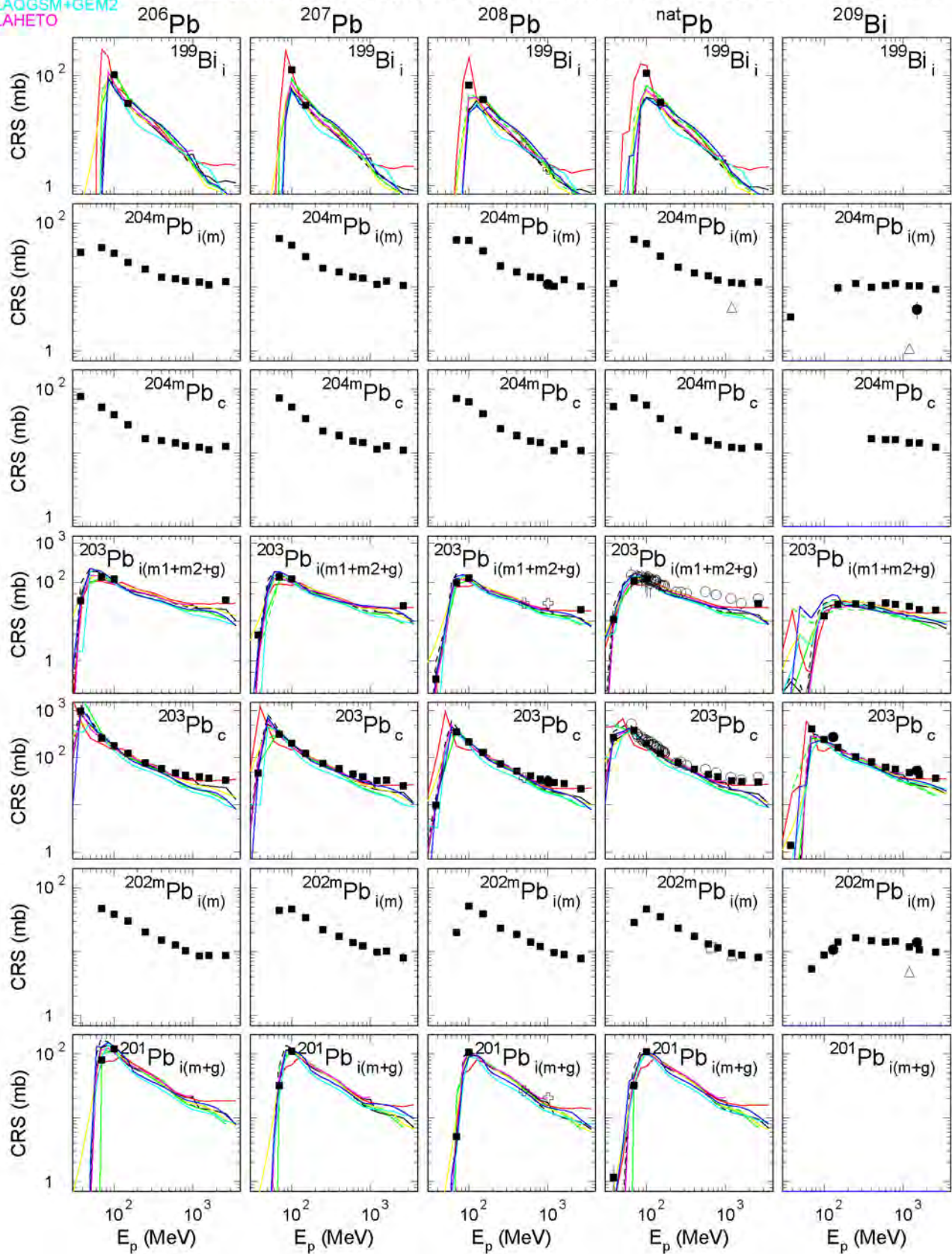


Fig. 54: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

LAHET(isabel-solid, bertini-dashed)
 CASCADe(improved-solid, obsolete-dashed)
 INCL4+ABLA
 CEM03
 CASCADO
 LAQGSM+GEM2
 LAHETO

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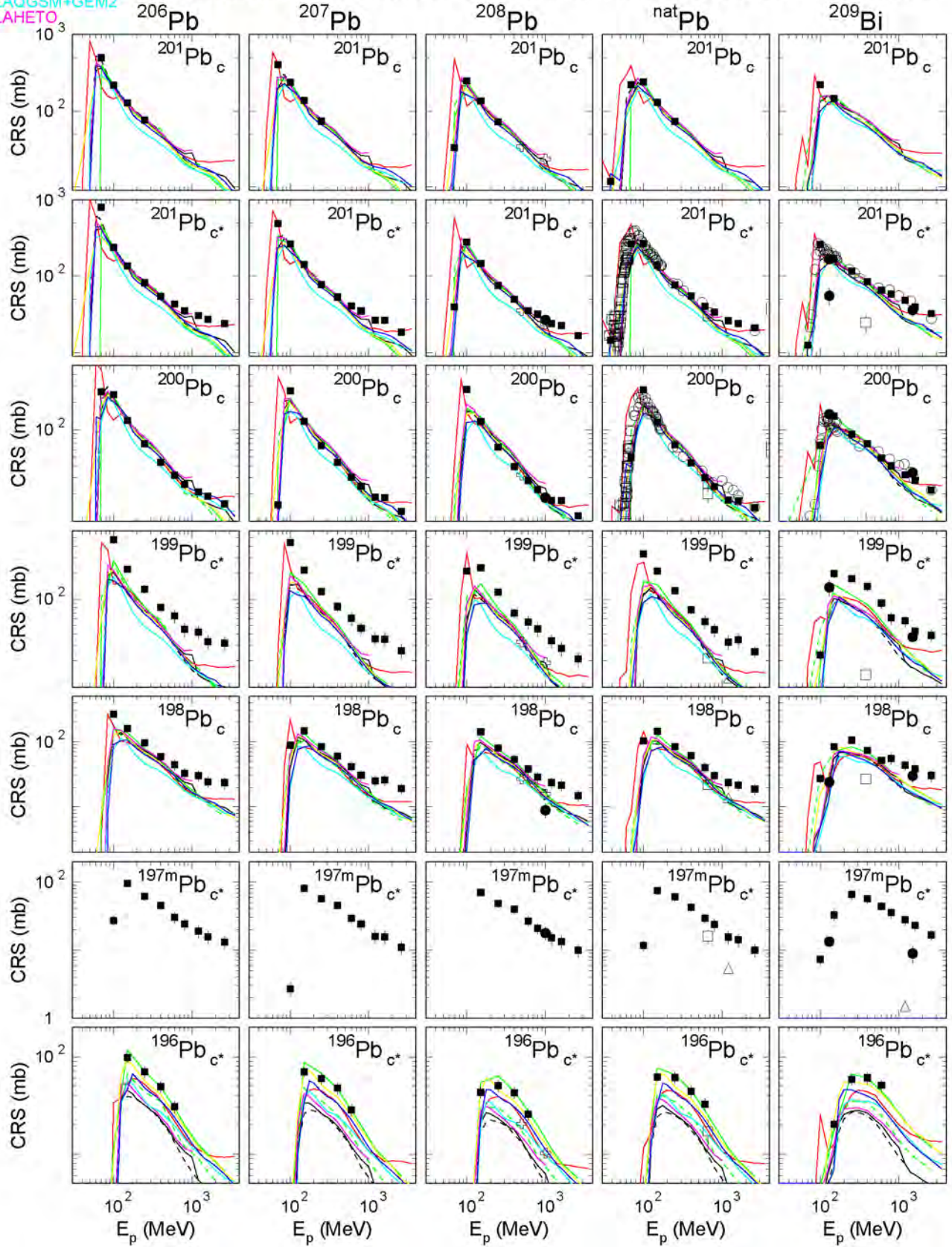


Fig. 55: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

Nuclide formation CRS's from Pb's and Bi

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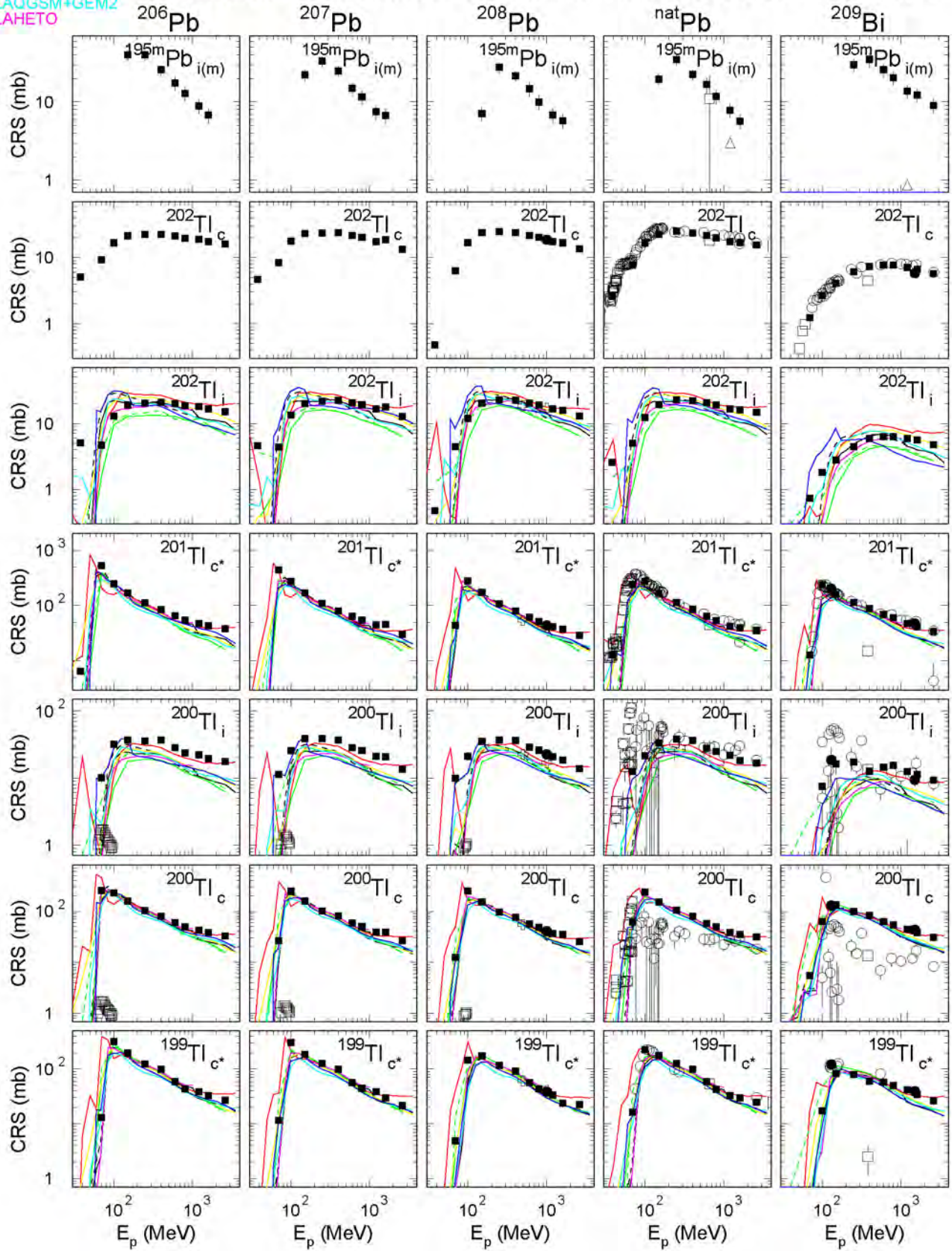


Fig. 56: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

Nuclide formation CRS's from Pb's and Bi

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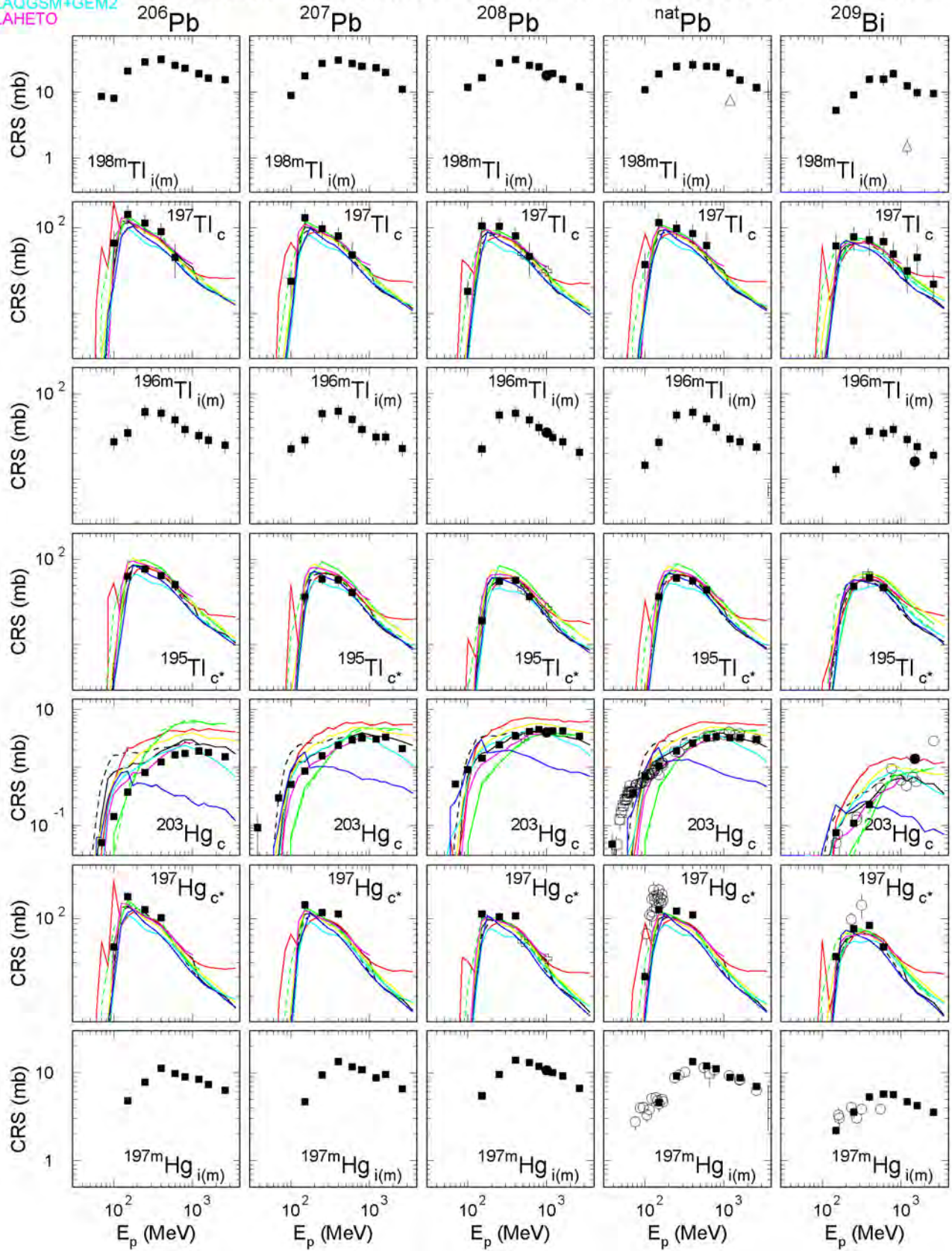


Fig. 57: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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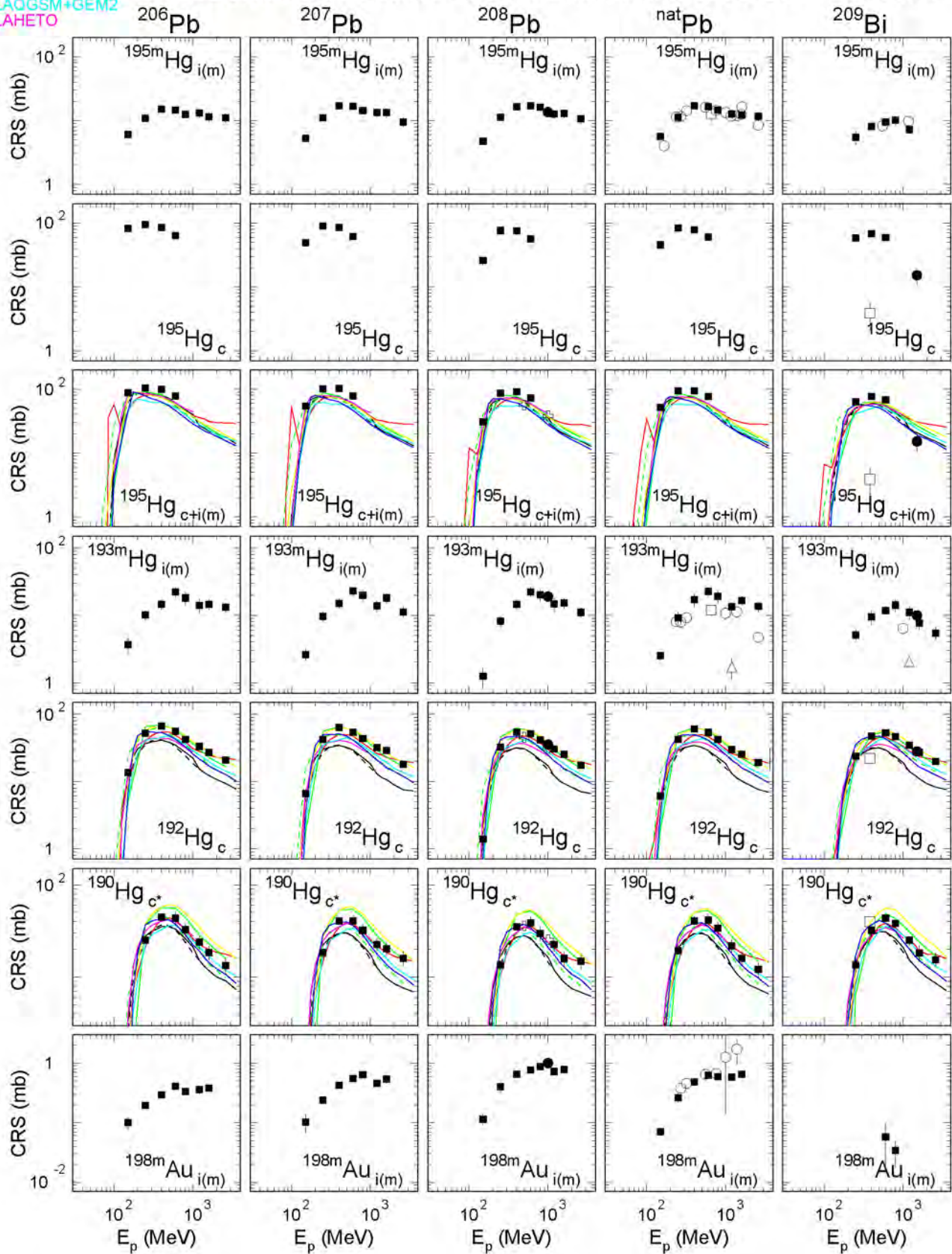


Fig. 58: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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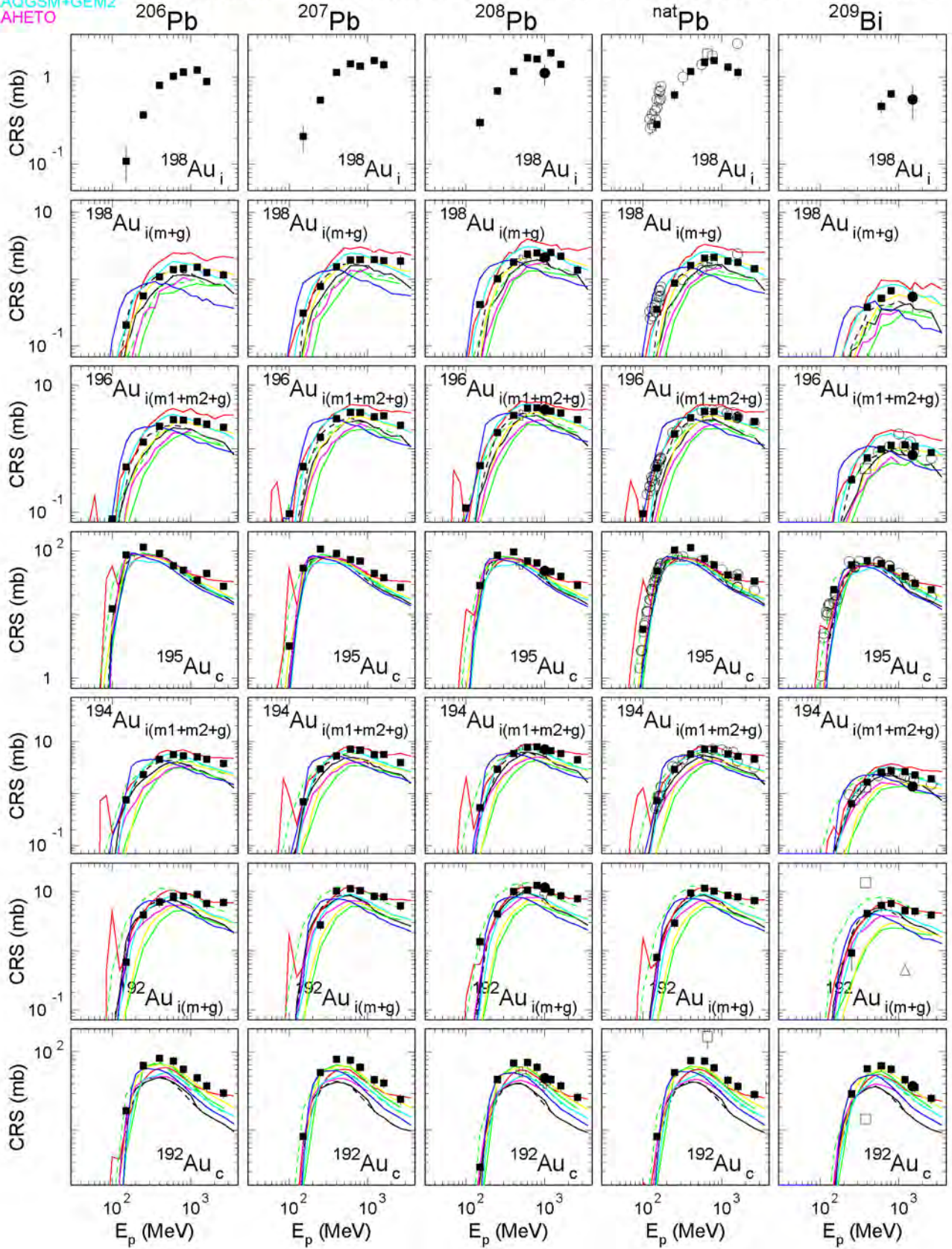


Fig. 59: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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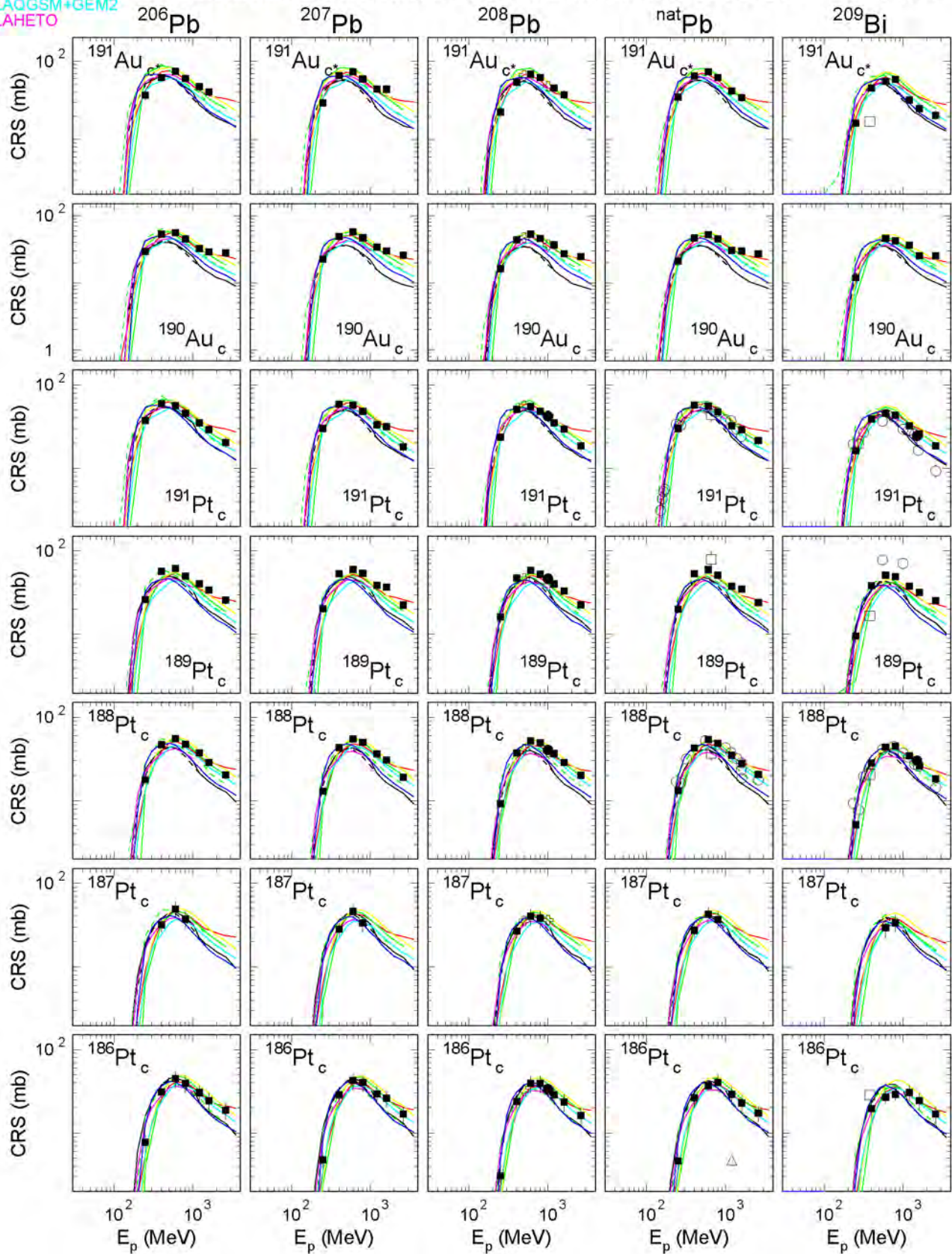


Fig. 60: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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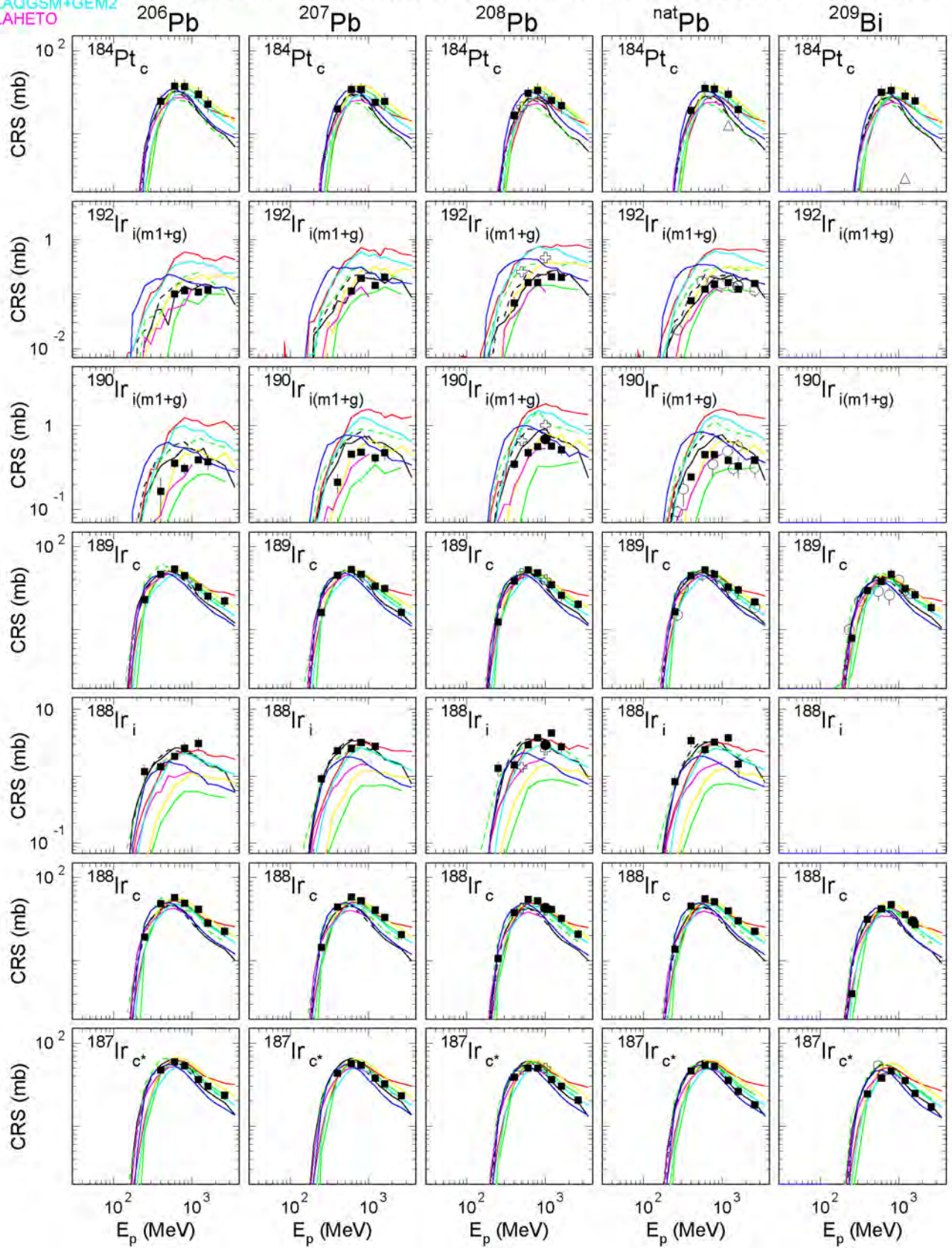


Fig. 61: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

Nuclide formation CRS's from Pb's and Bi

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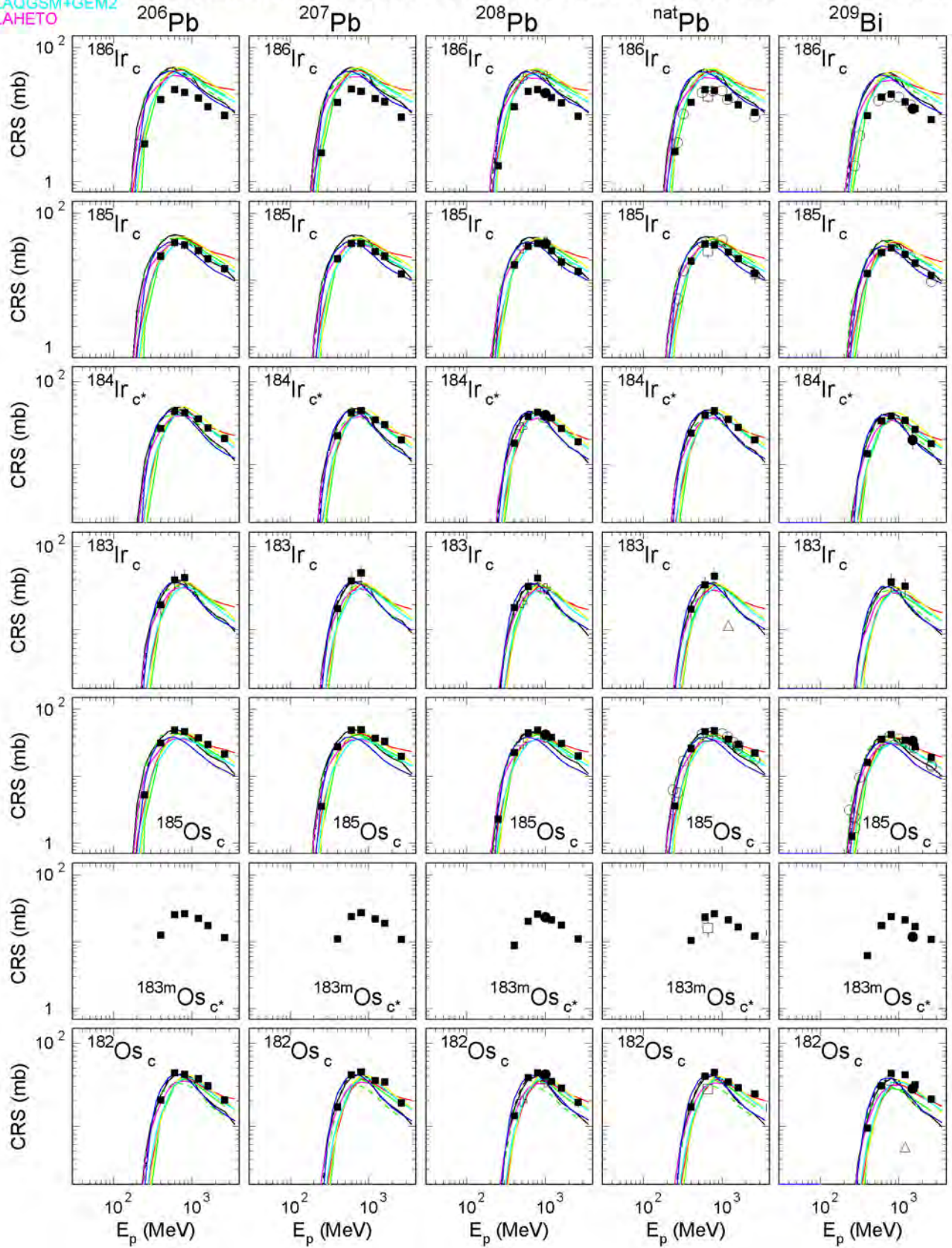


Fig. 62: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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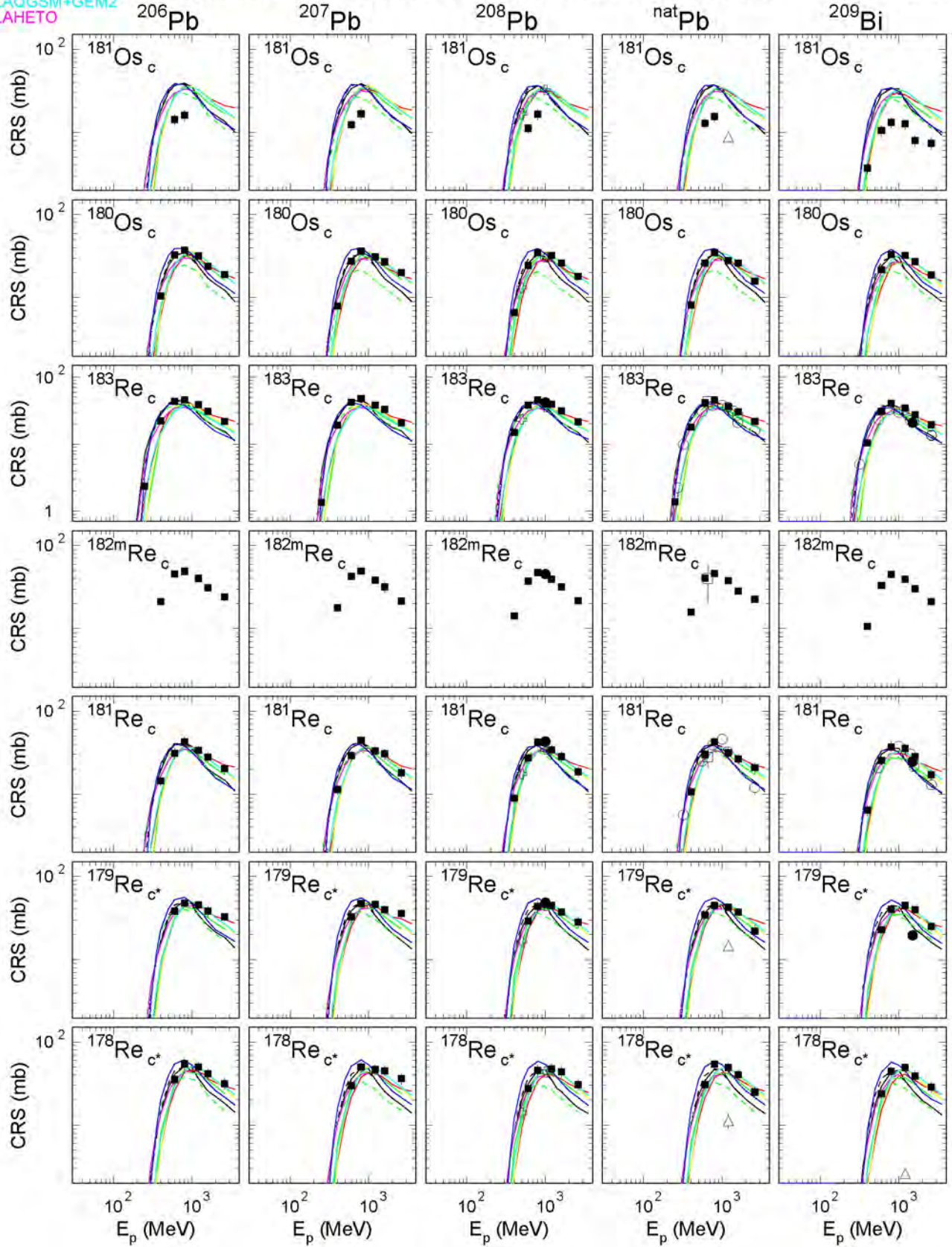


Fig. 63: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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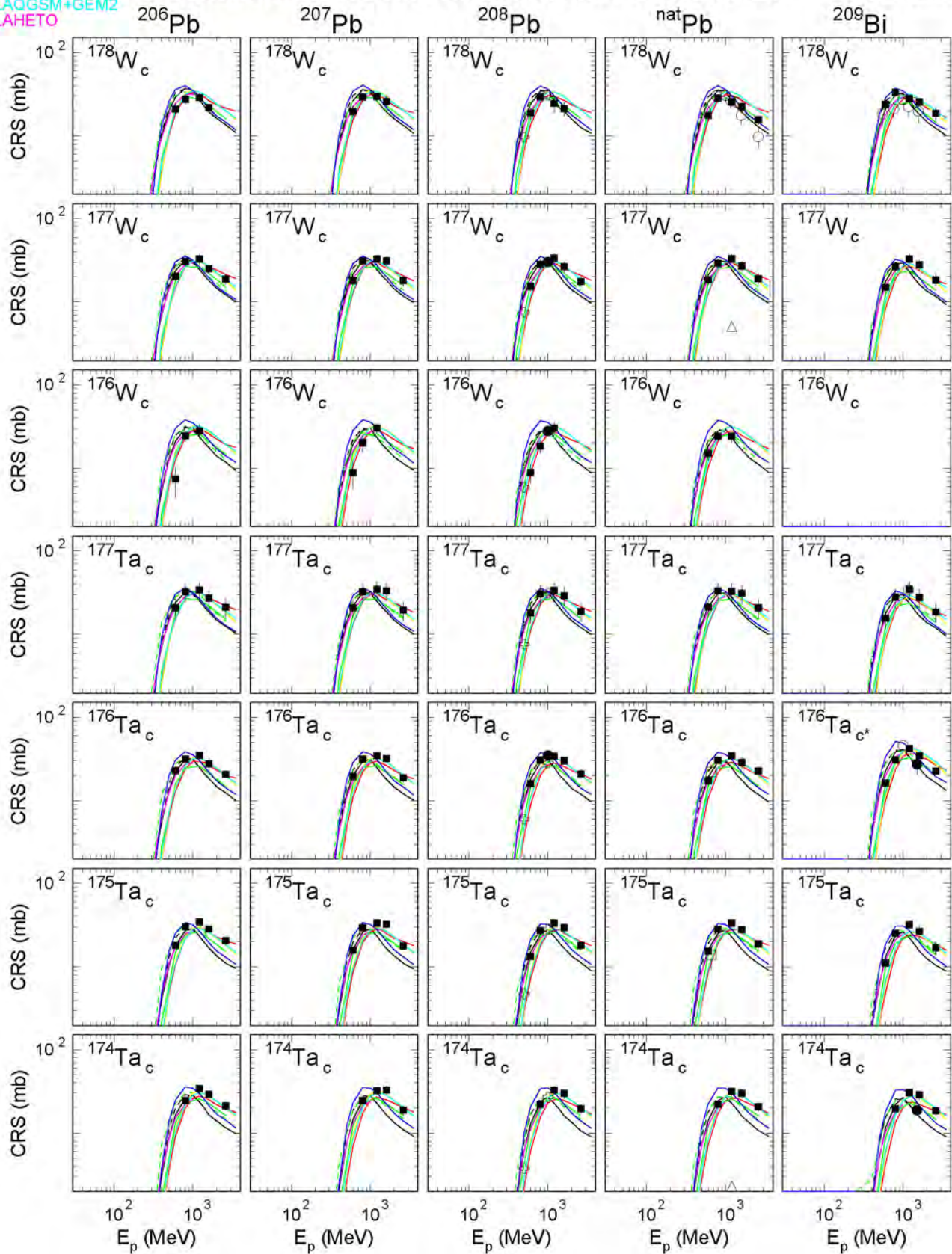


Fig. 64: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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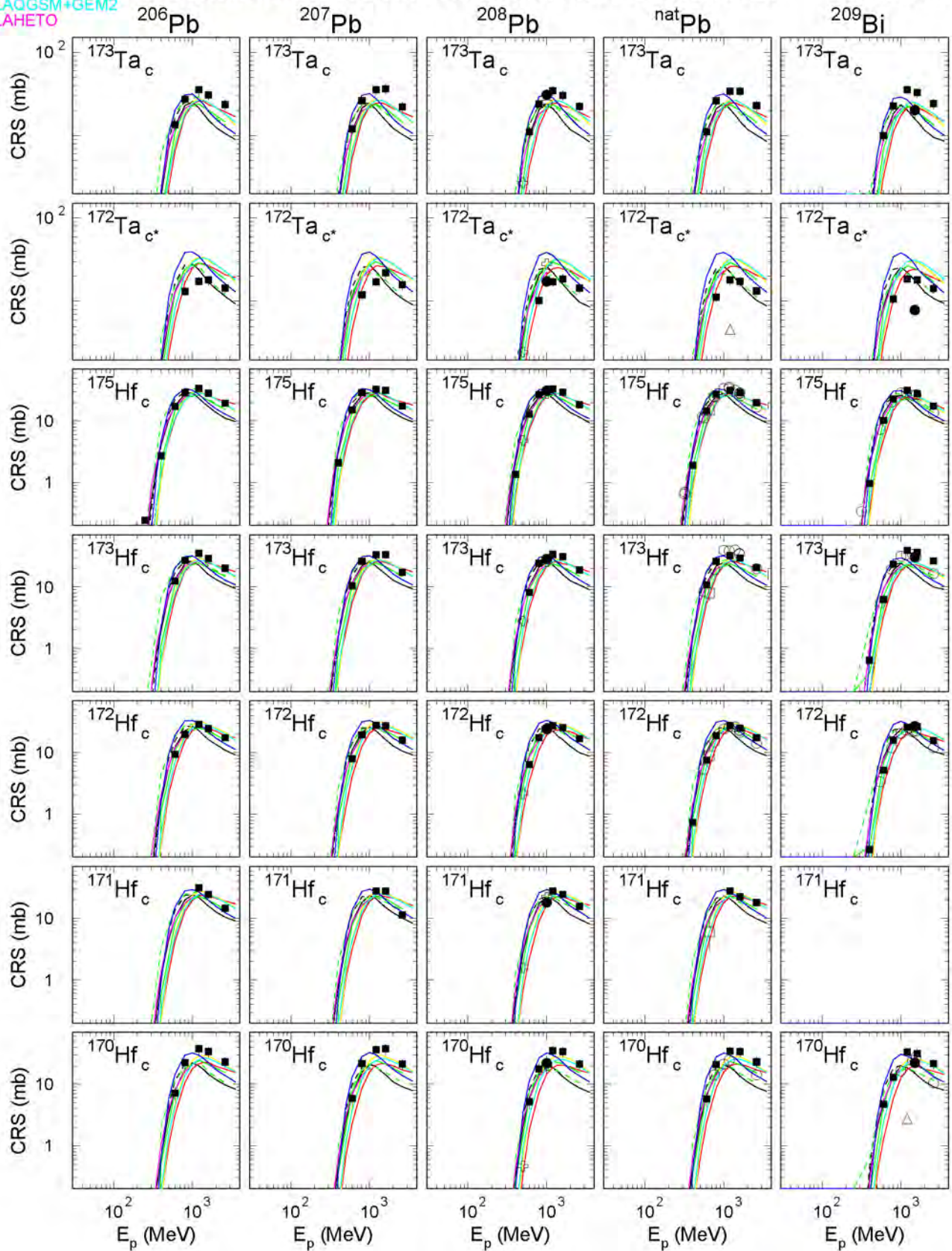


Fig. 65: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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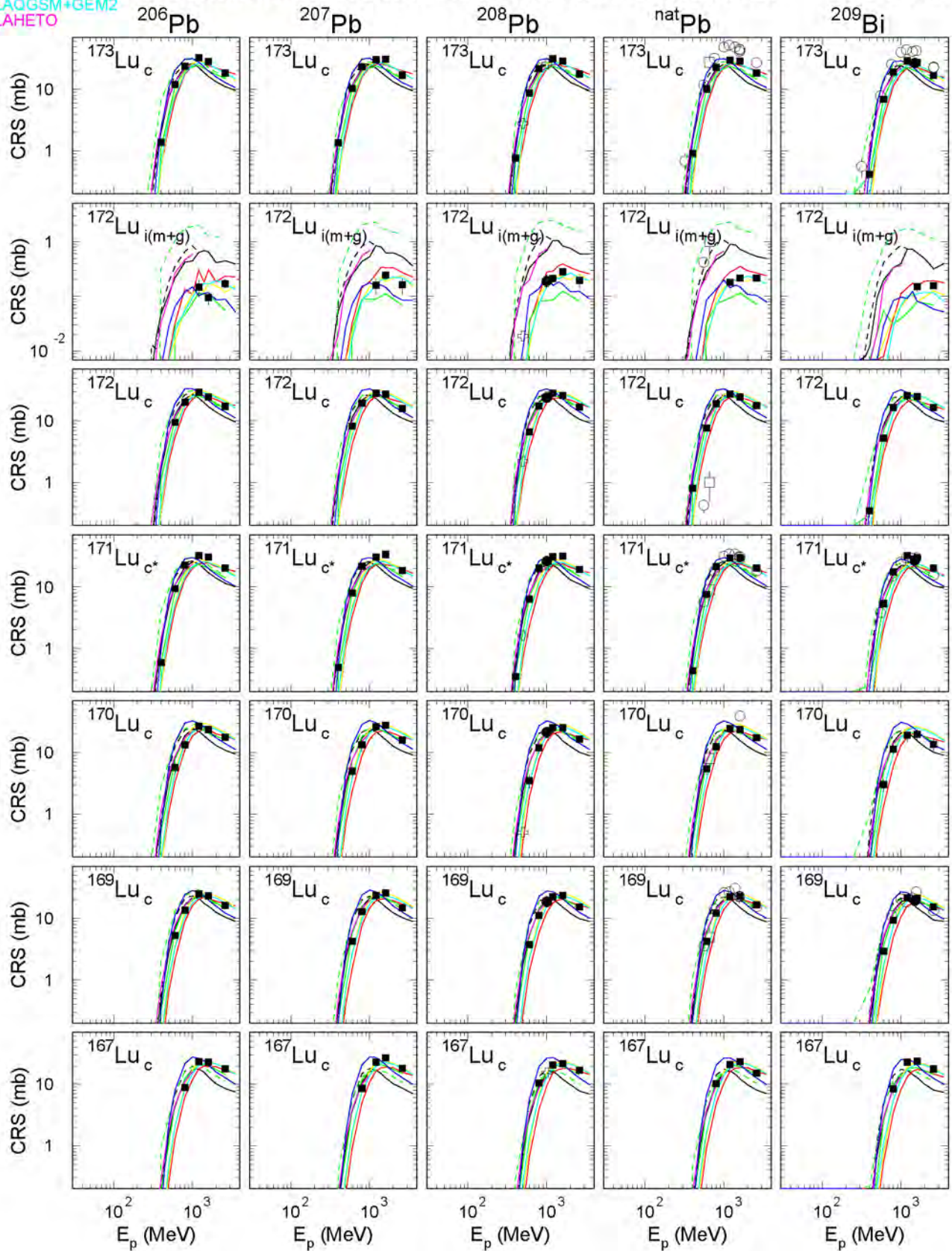


Fig. 66: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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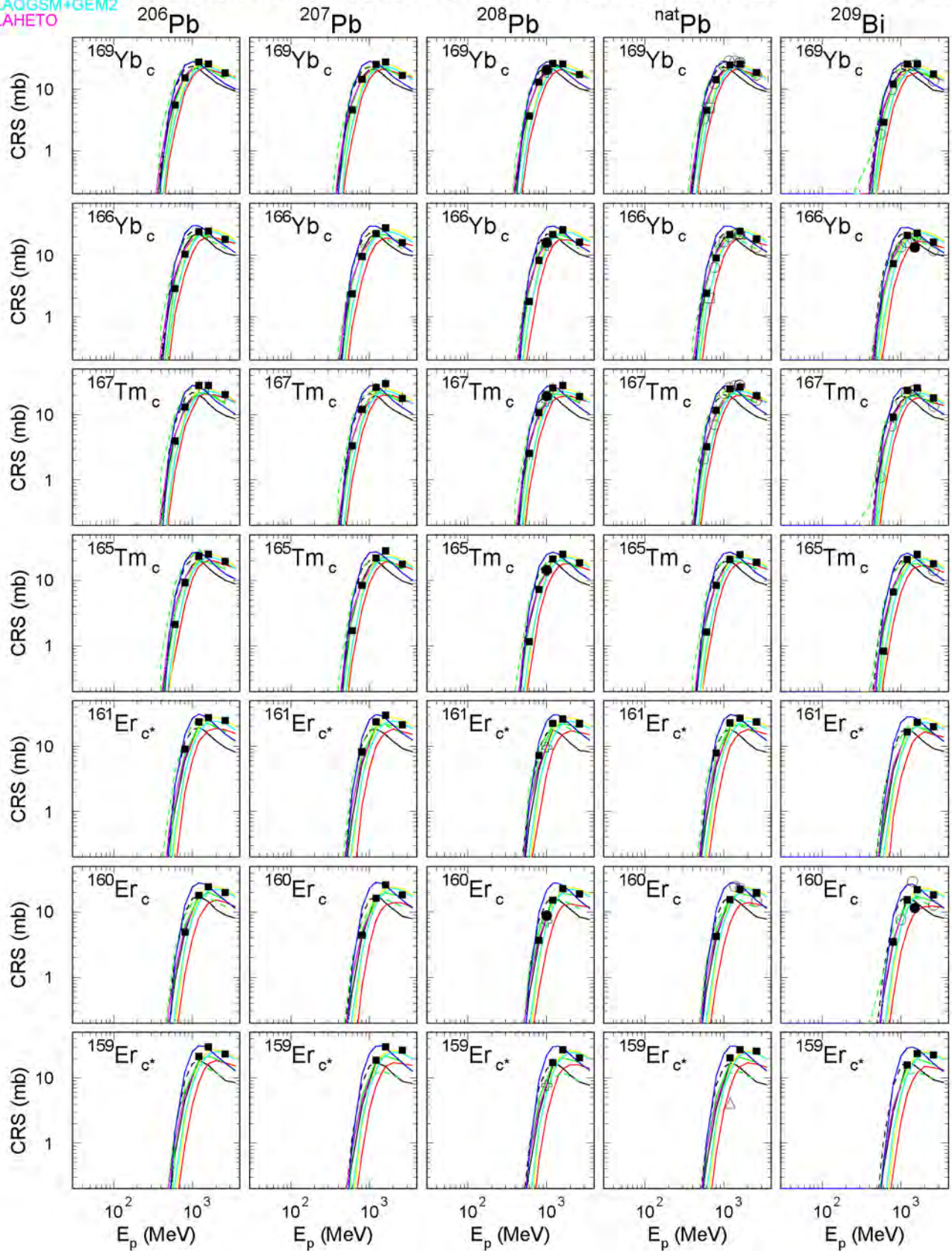


Fig. 67: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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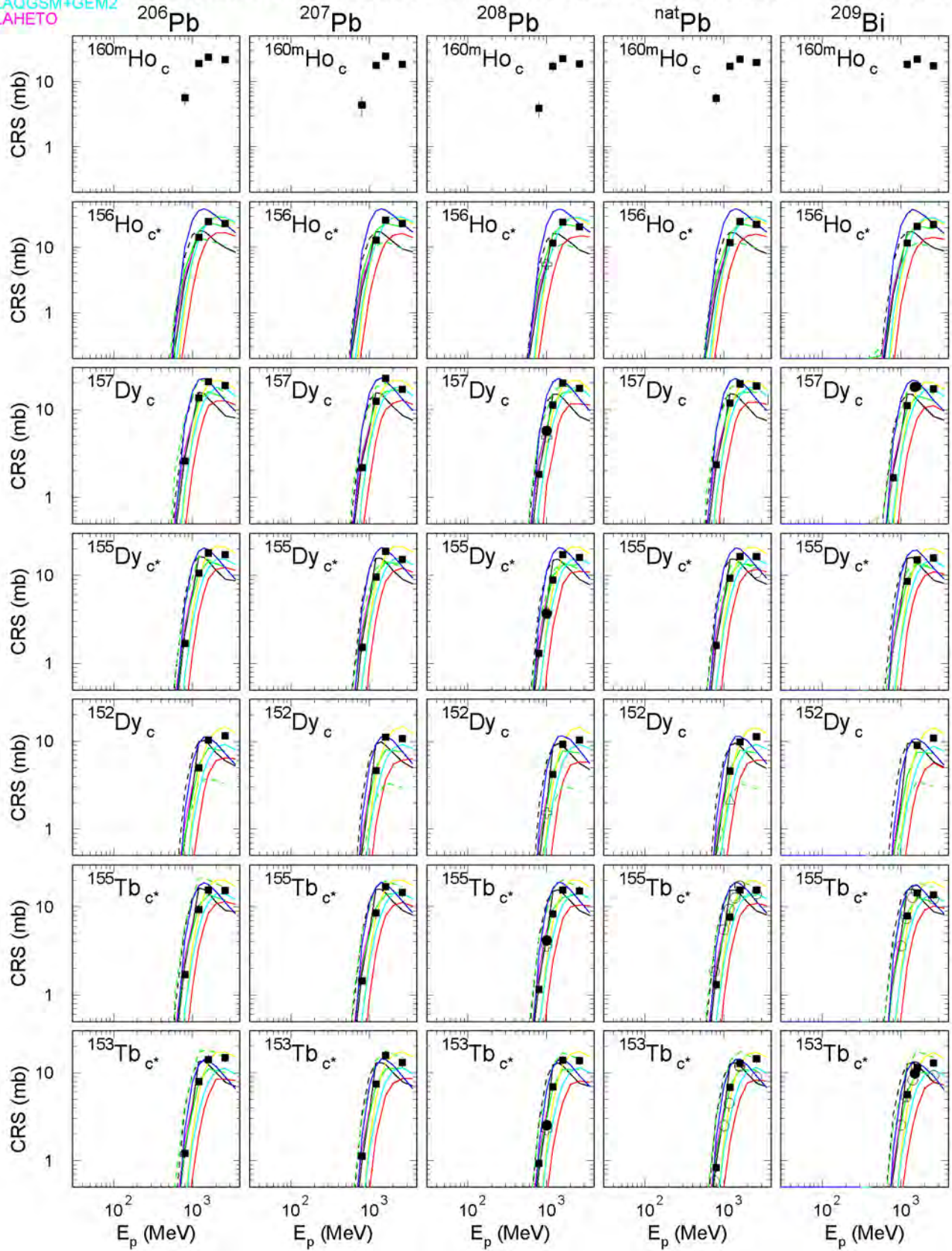


Fig. 68: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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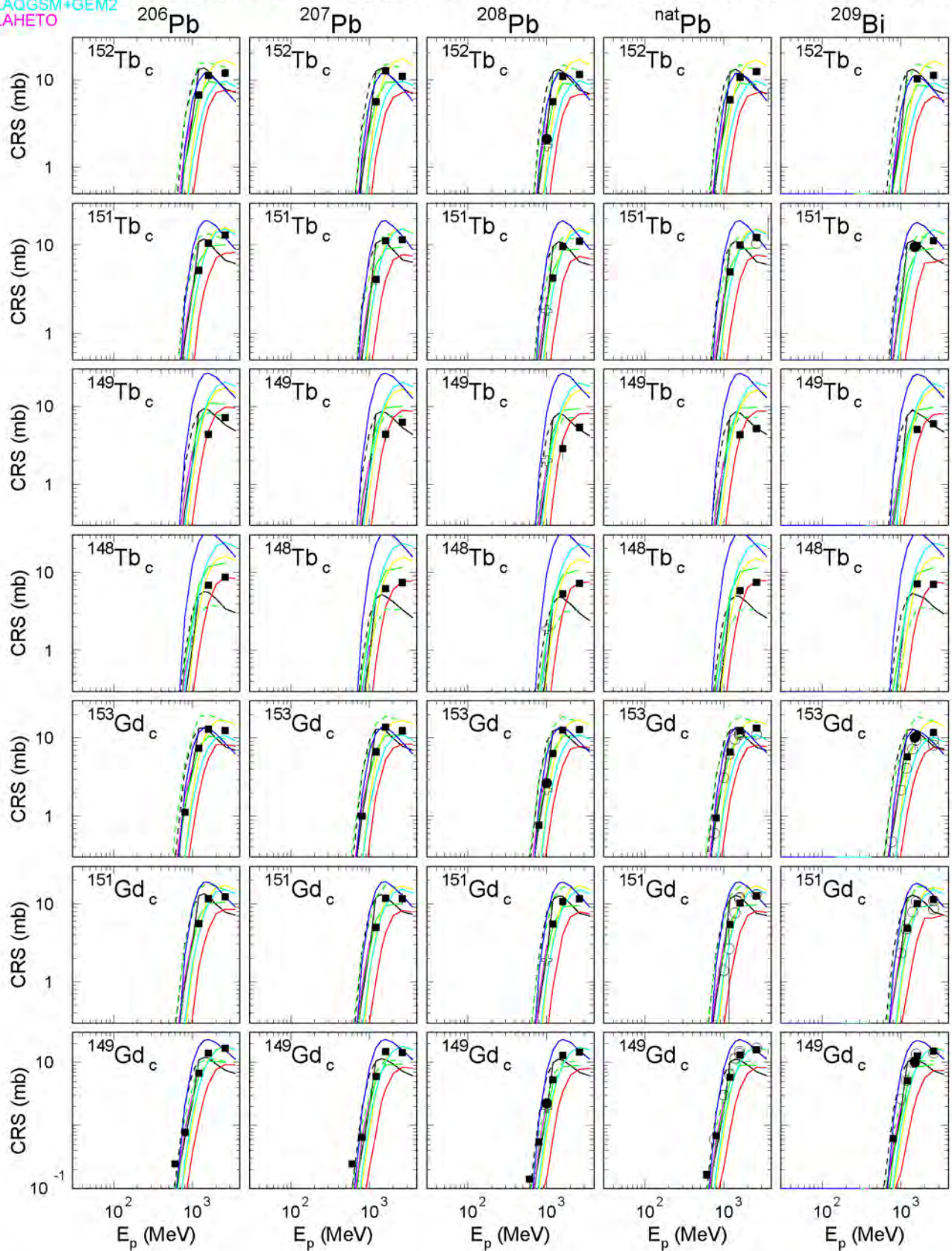


Fig. 69: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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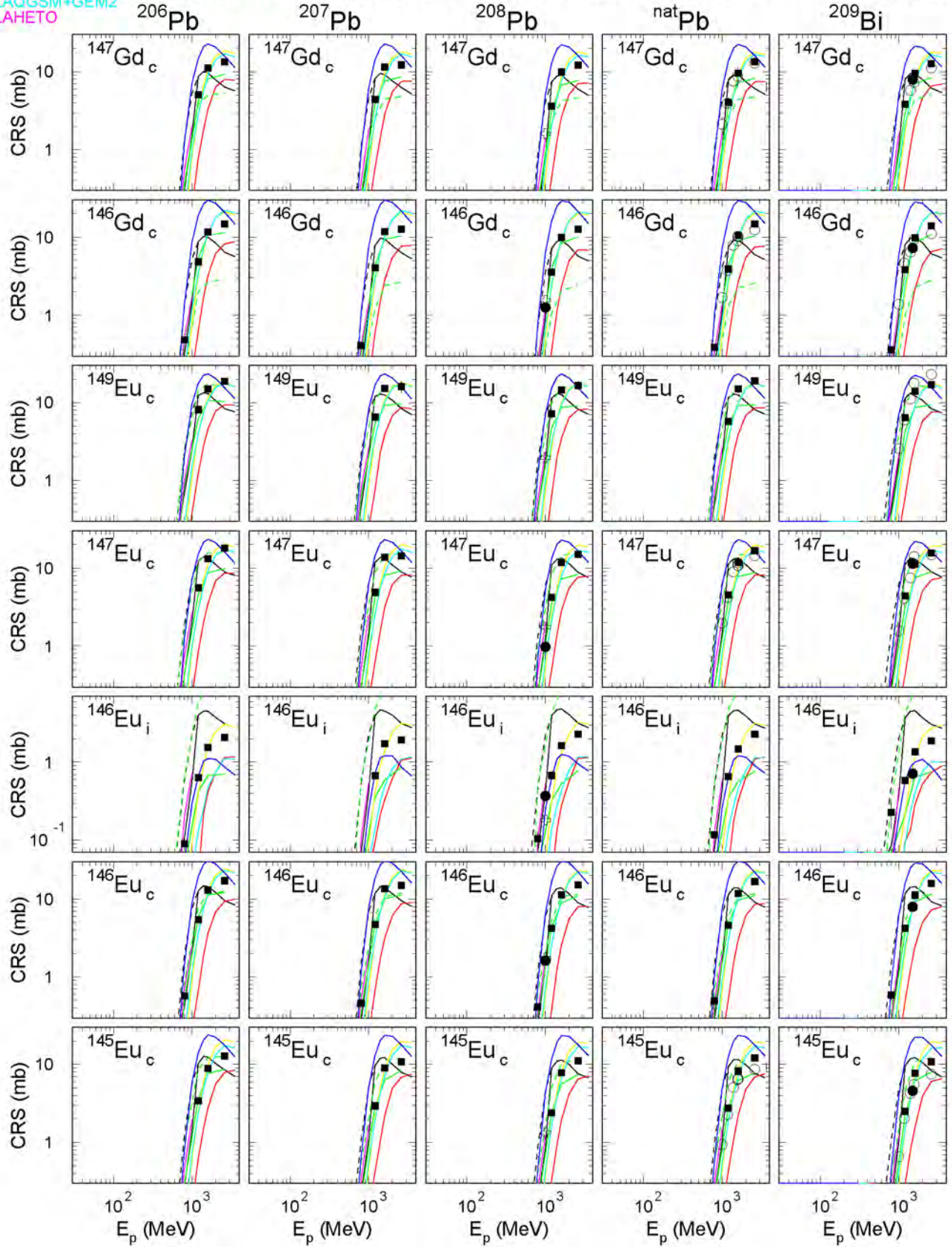


Fig. 70: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

Nuclide formation CRS's from Pb's and Bi

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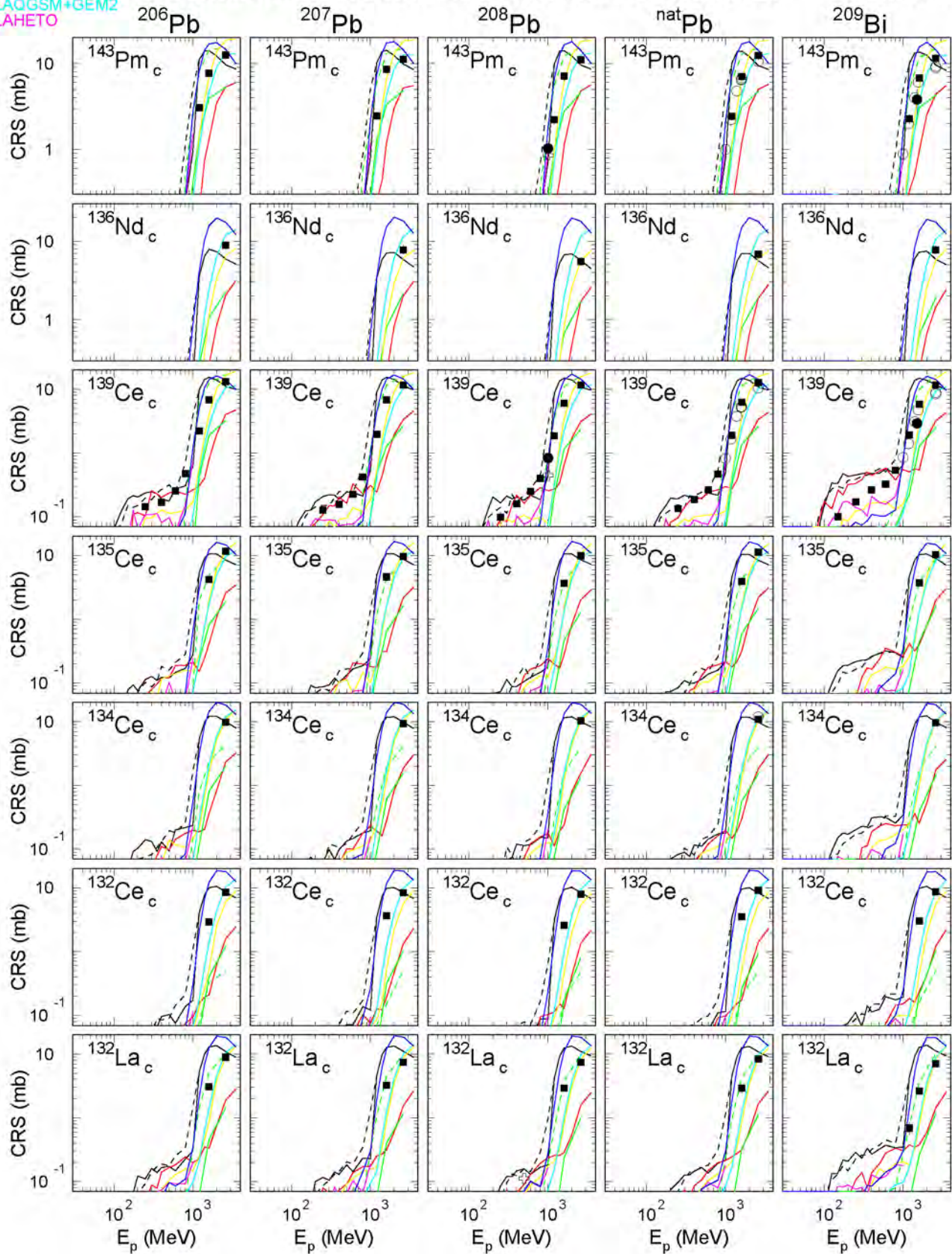


Fig. 71: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

LAHET(isabel-solid, bertini-dashed)
 CASCADE(improved-solid, obsolete-dashed)
 INCL4+ABLA
 CEM03
 CASCADO
 LAQGS+GEM2
 LAHETO

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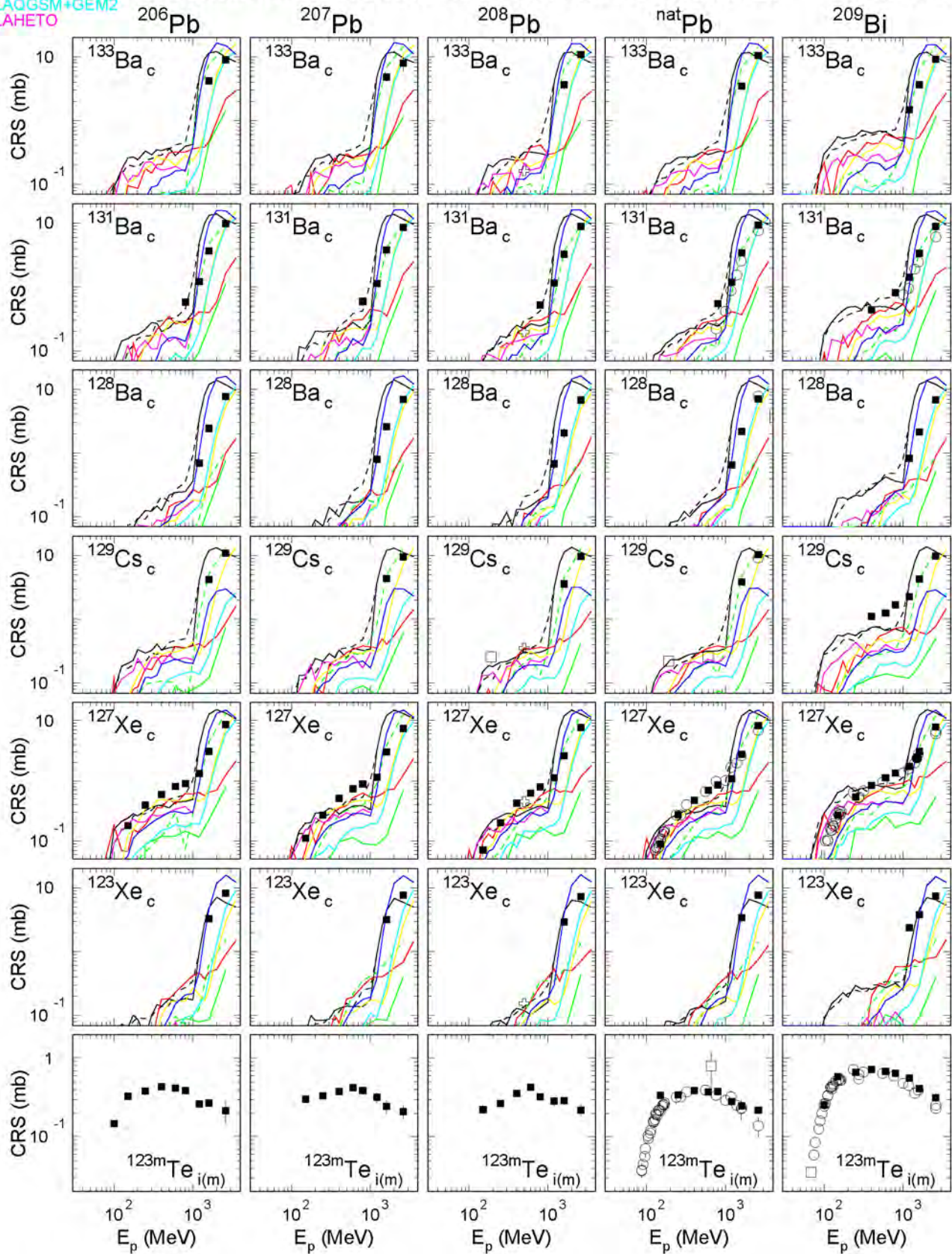


Fig. 72: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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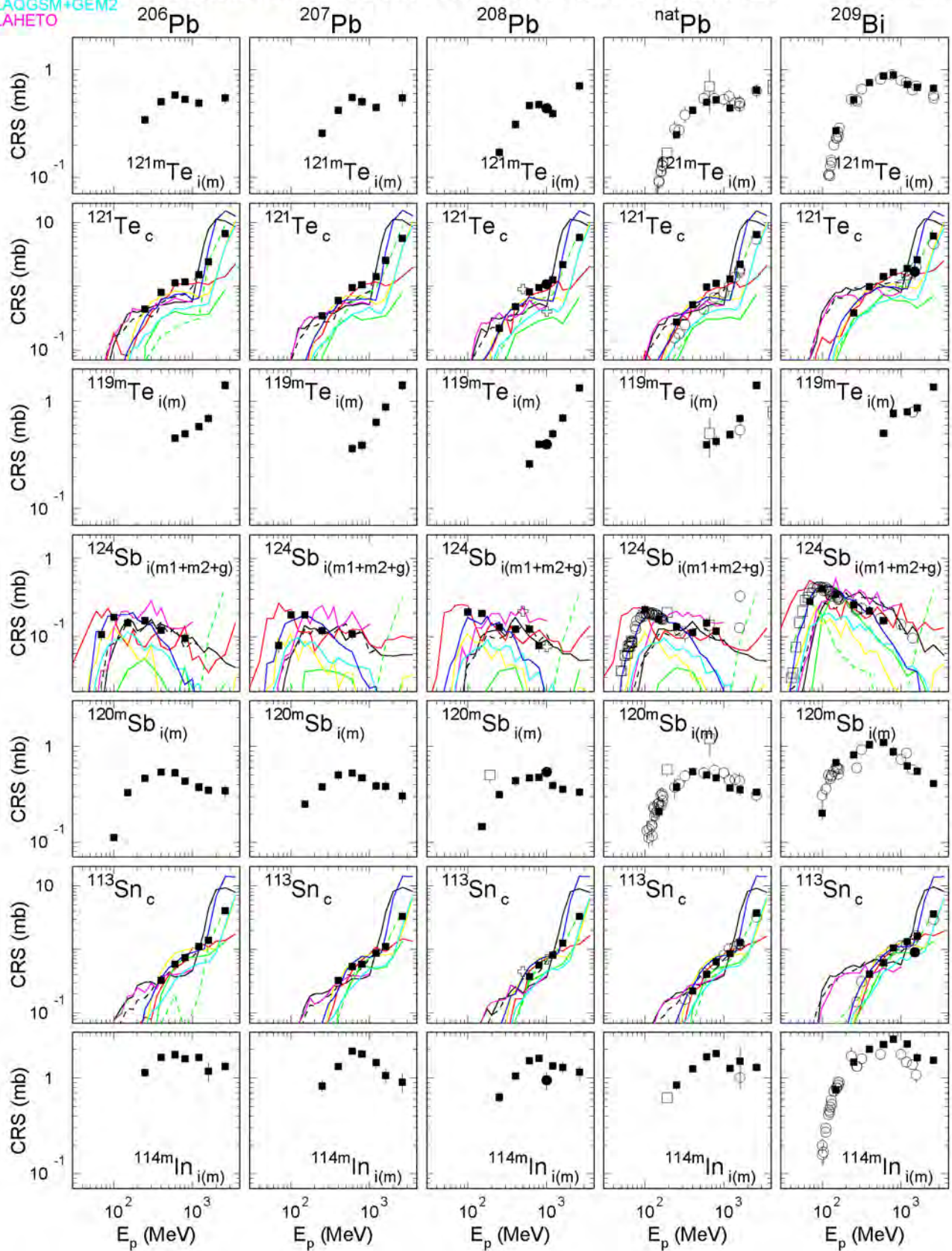


Fig. 73: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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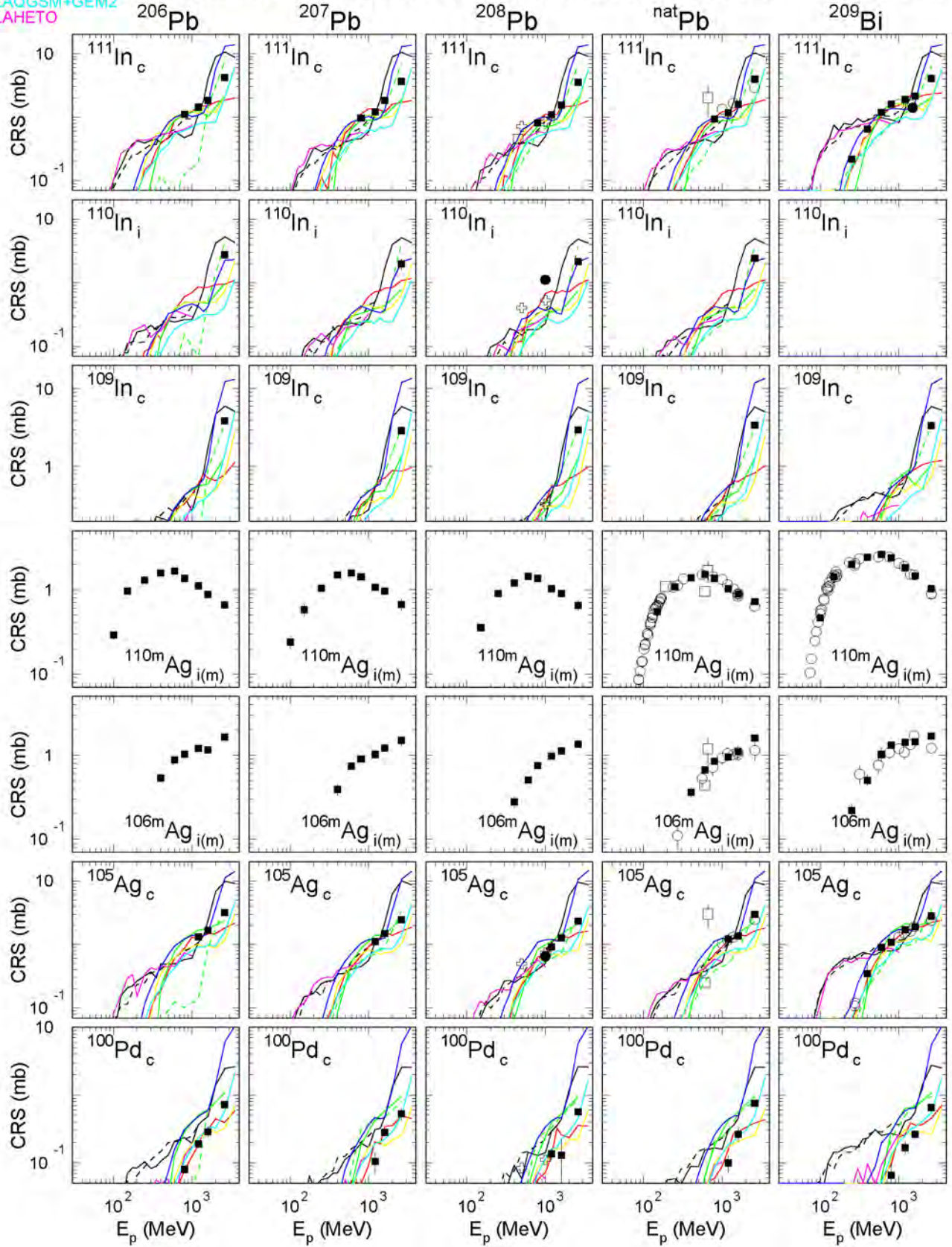


Fig. 74: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

LAHET(isabel-solid, bertini-dashed)
 CASCADE(improved-solid, obsolete-dashed)
 INCL4+ABLA
 CEM03
 CASCADE
 LAQGSM+GEM2
 LAHETO

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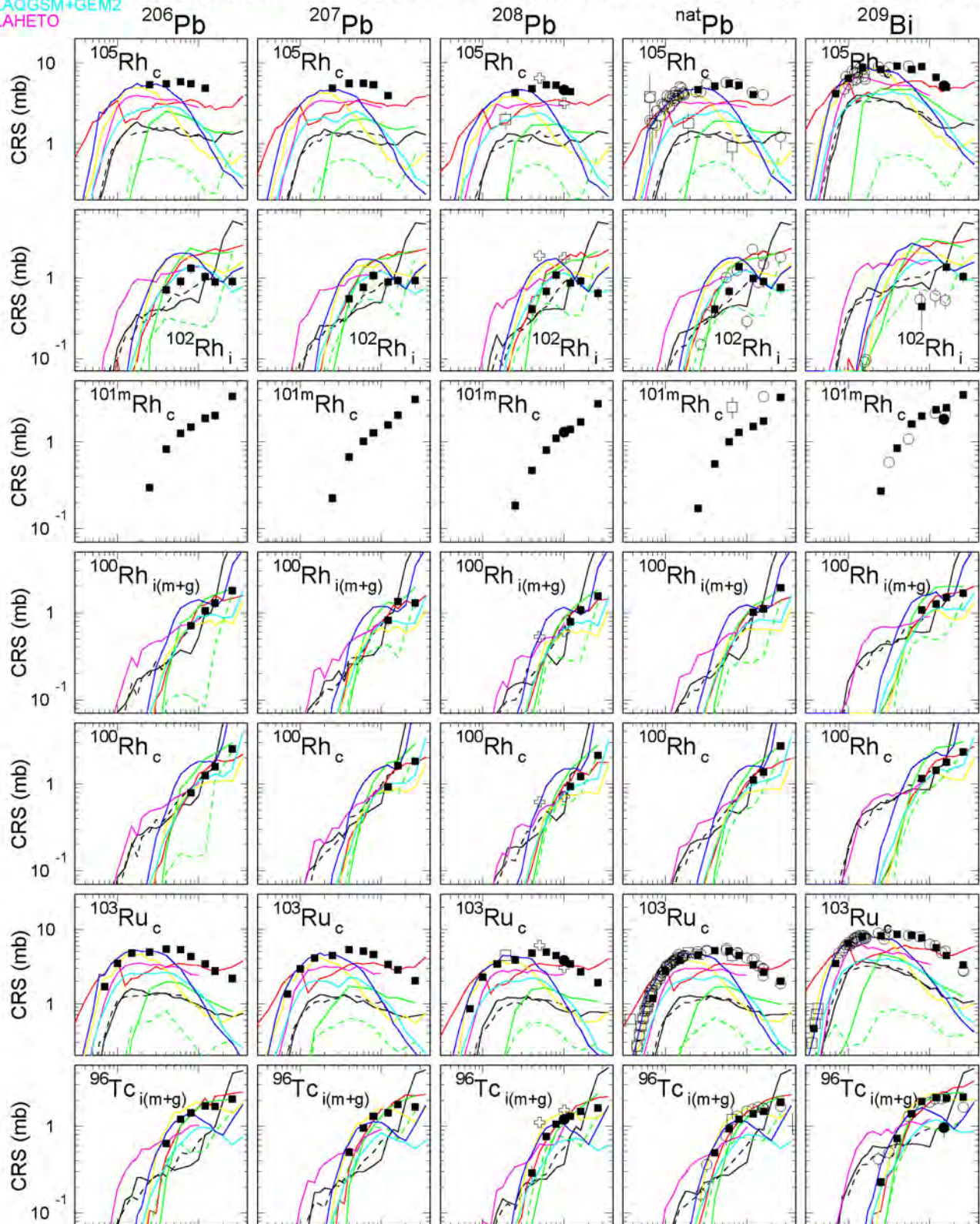


Fig. 75: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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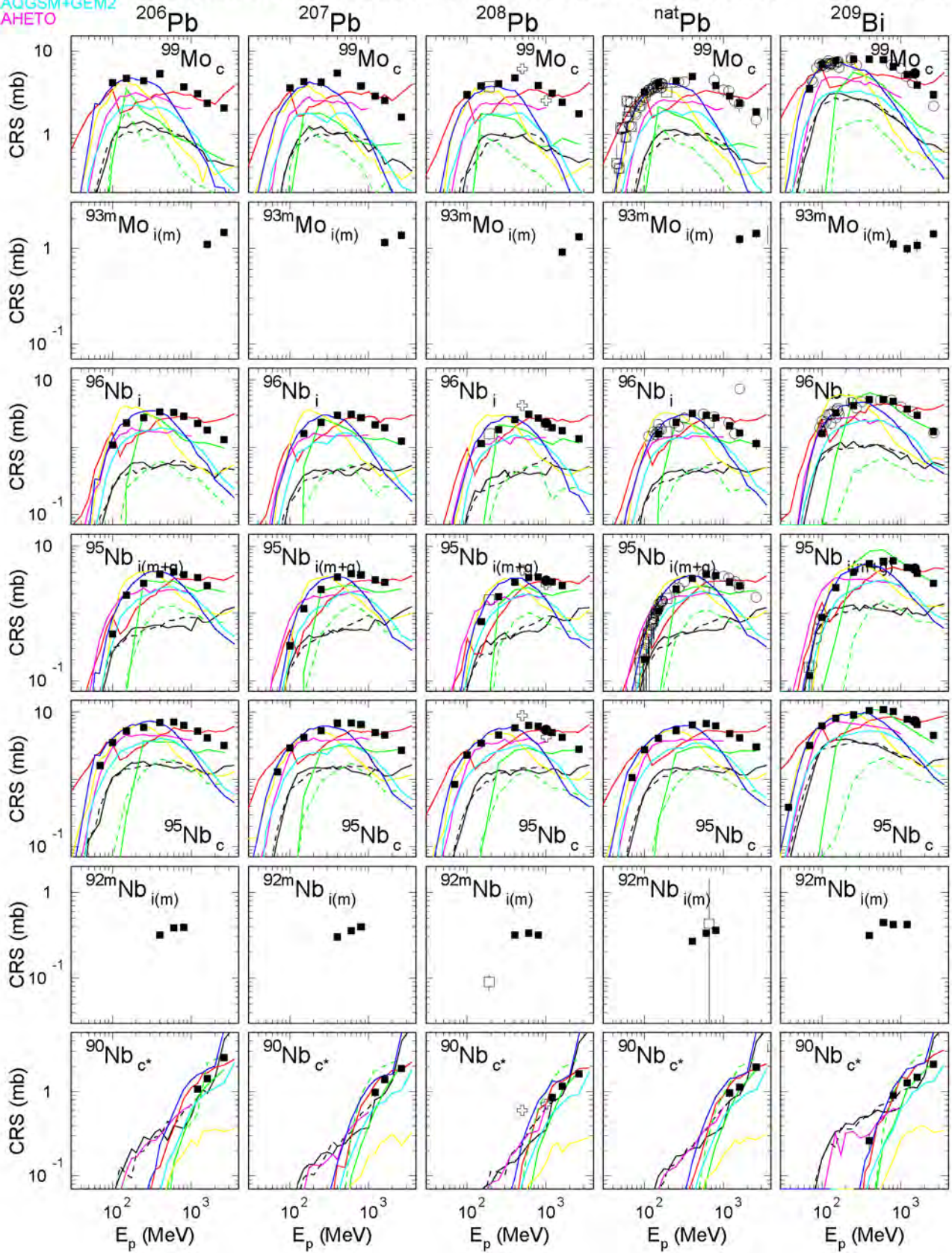


Fig. 76: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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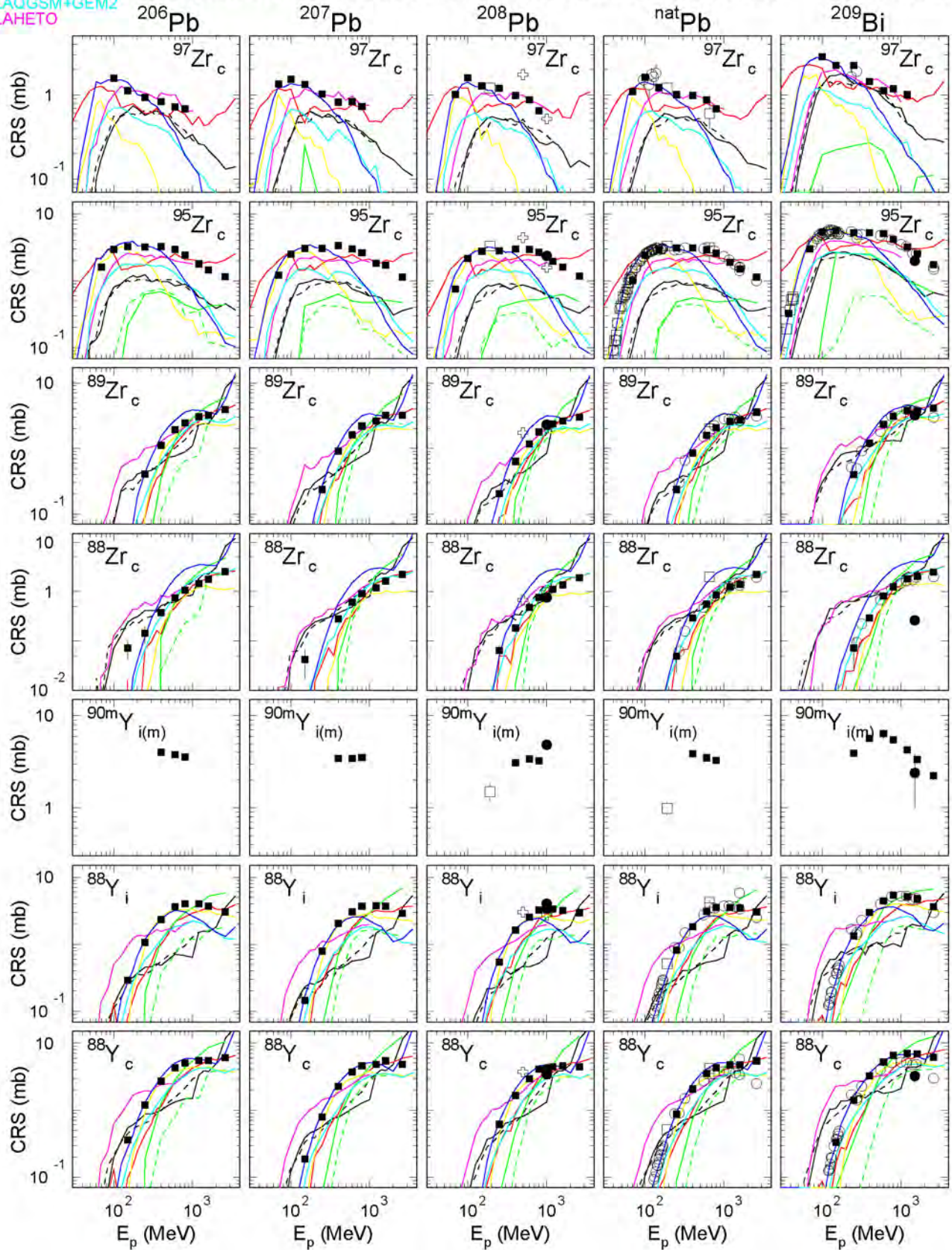


Fig. 77: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

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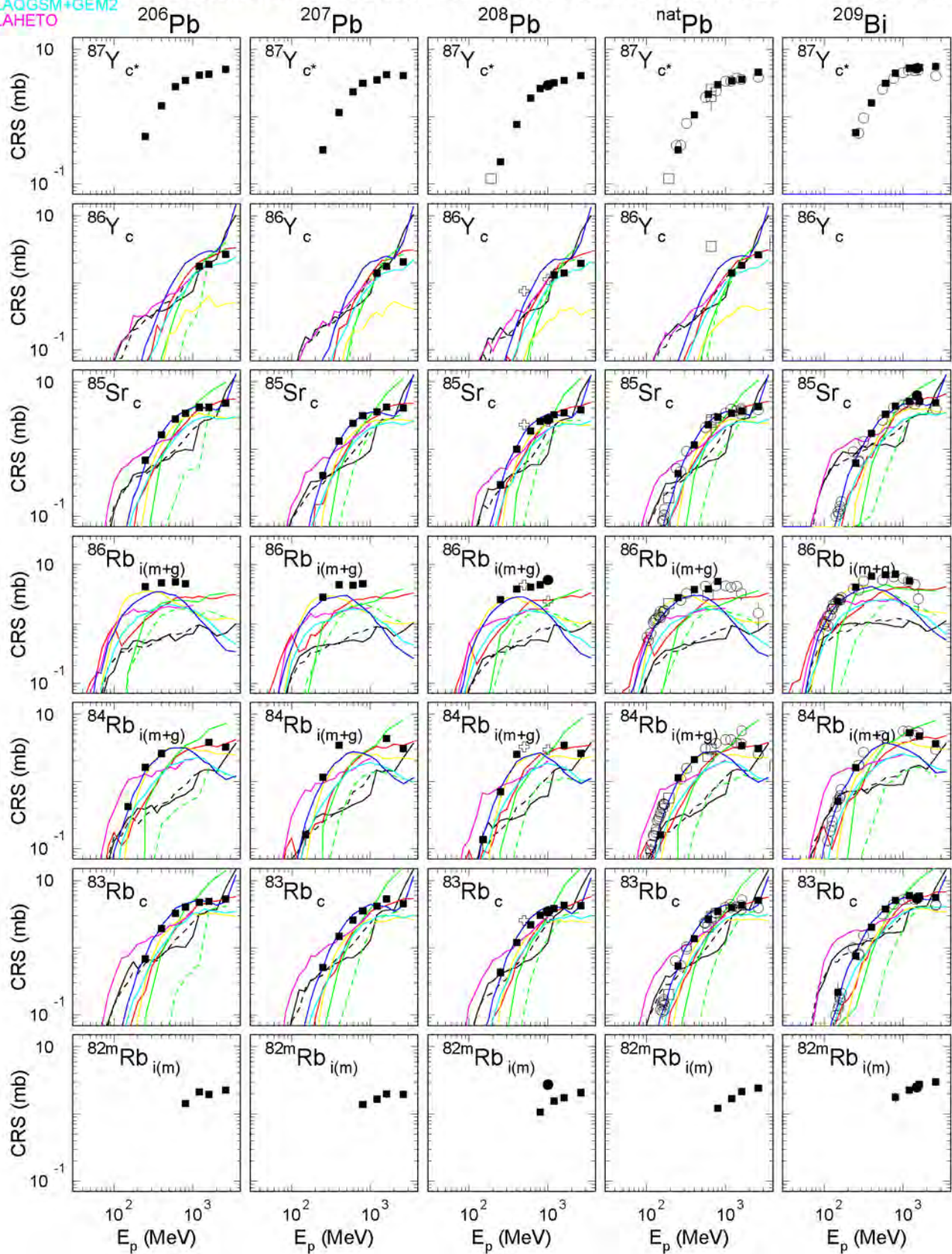


Fig. 78: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

LAHET(isabel-solid, bertini-dashed)
 CASCADE(improved-solid, obsolete-dashed)
 INCL4+ABLA
 CEM03
 CASCADO
 LAQGS+GEM2
 LAHETO

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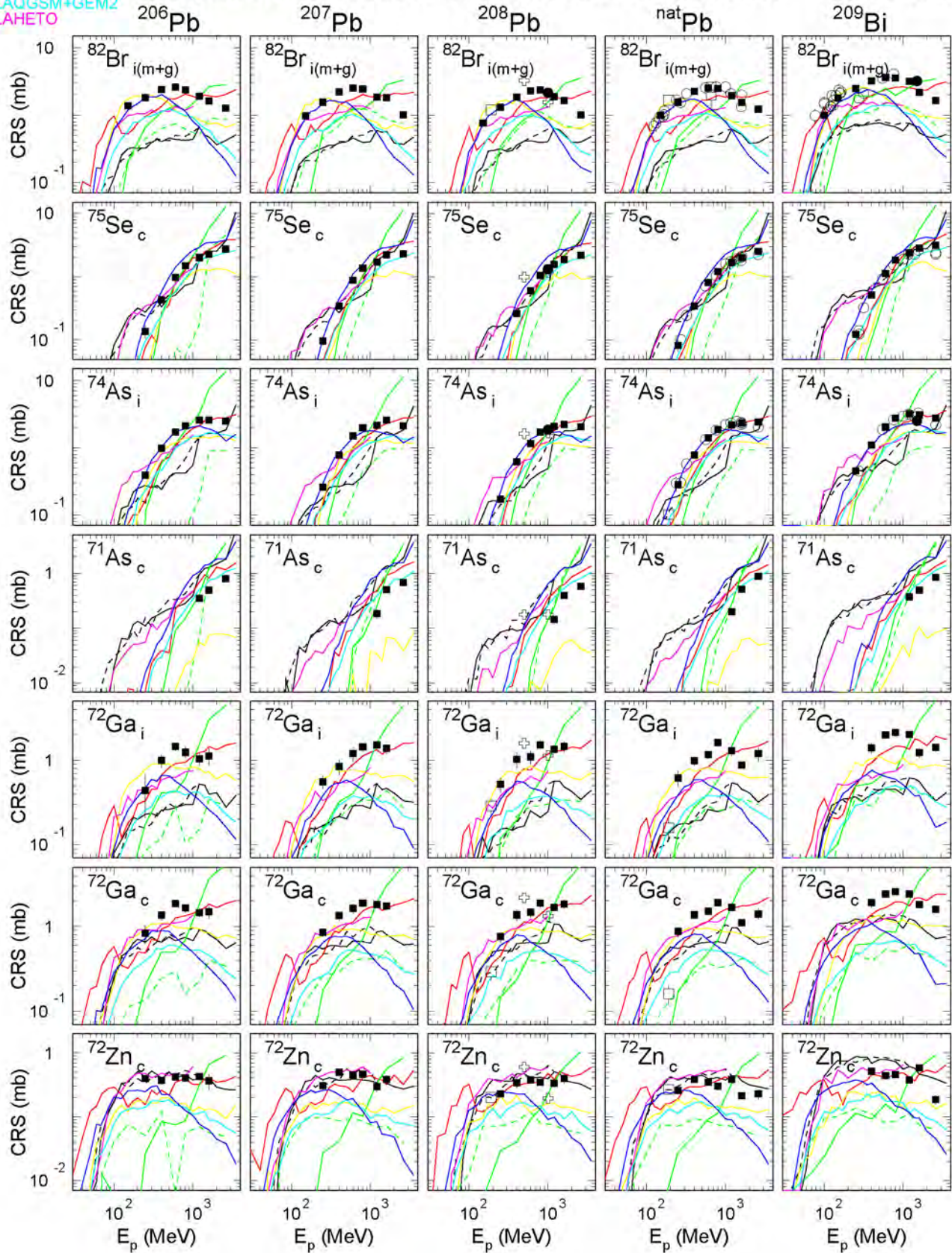


Fig. 79: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

LAHET(isabel-solid, bertini-dashed)
 CASCADE(improved-solid, obsolete-dashed)
 INCL4+ABLA
 CEM03
 CASCADO
 LAQGS+GEM2
 LAHETO

2005/06/25 19.27

Nuclide formation CRS's from Pb's and Bi

28 /31

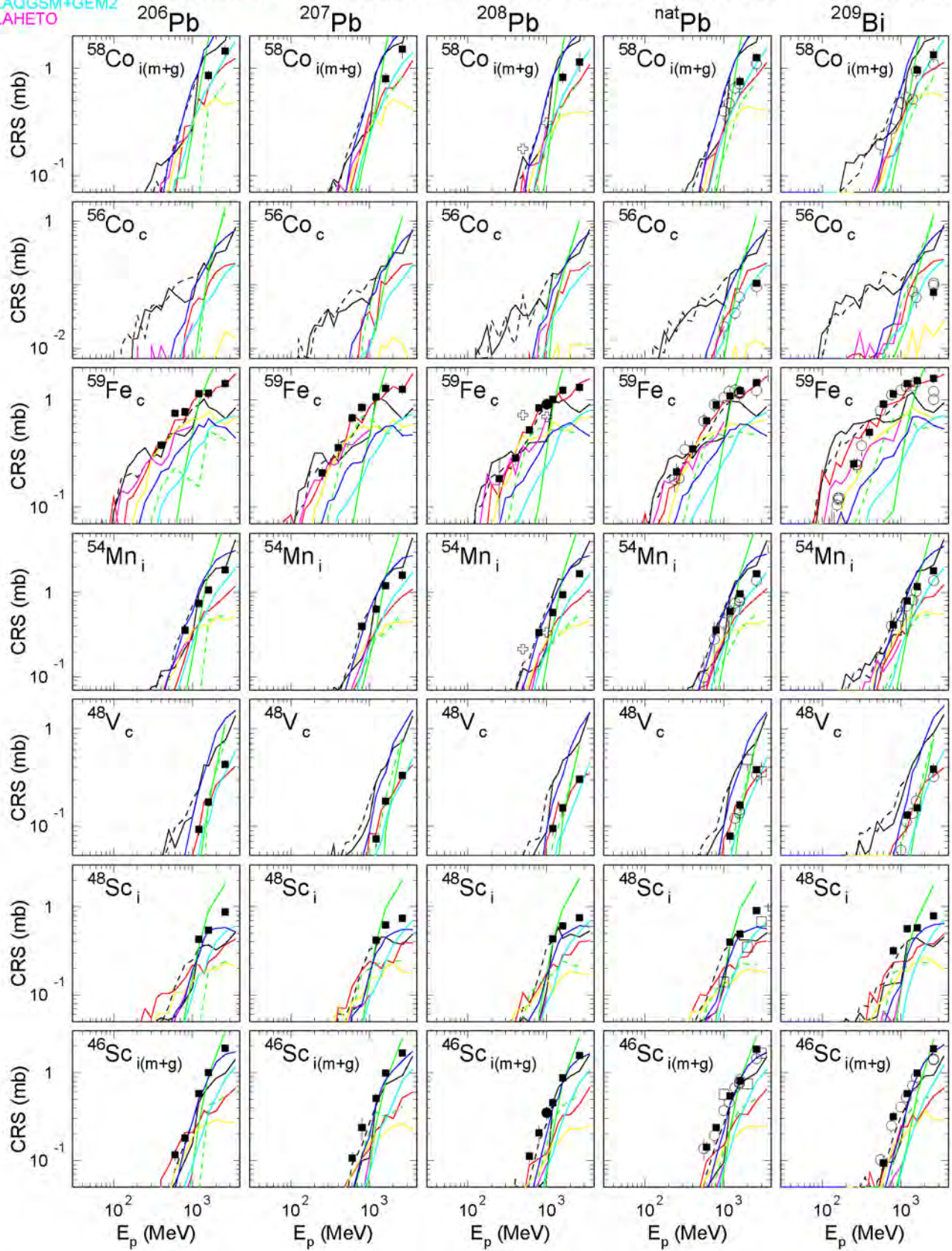


Fig. 80: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

LAHET(isabel-solid, bertini-dashed)
 CASCADE(improved-solid, obsolete-dashed)
 INCL4+ABLA
 CEM03
 CASCADO
 LAQGSM+GEM2
 LAHETO

2005/06/25 19.28

Nuclide formation CRS's from Pb's and Bi

29 /31

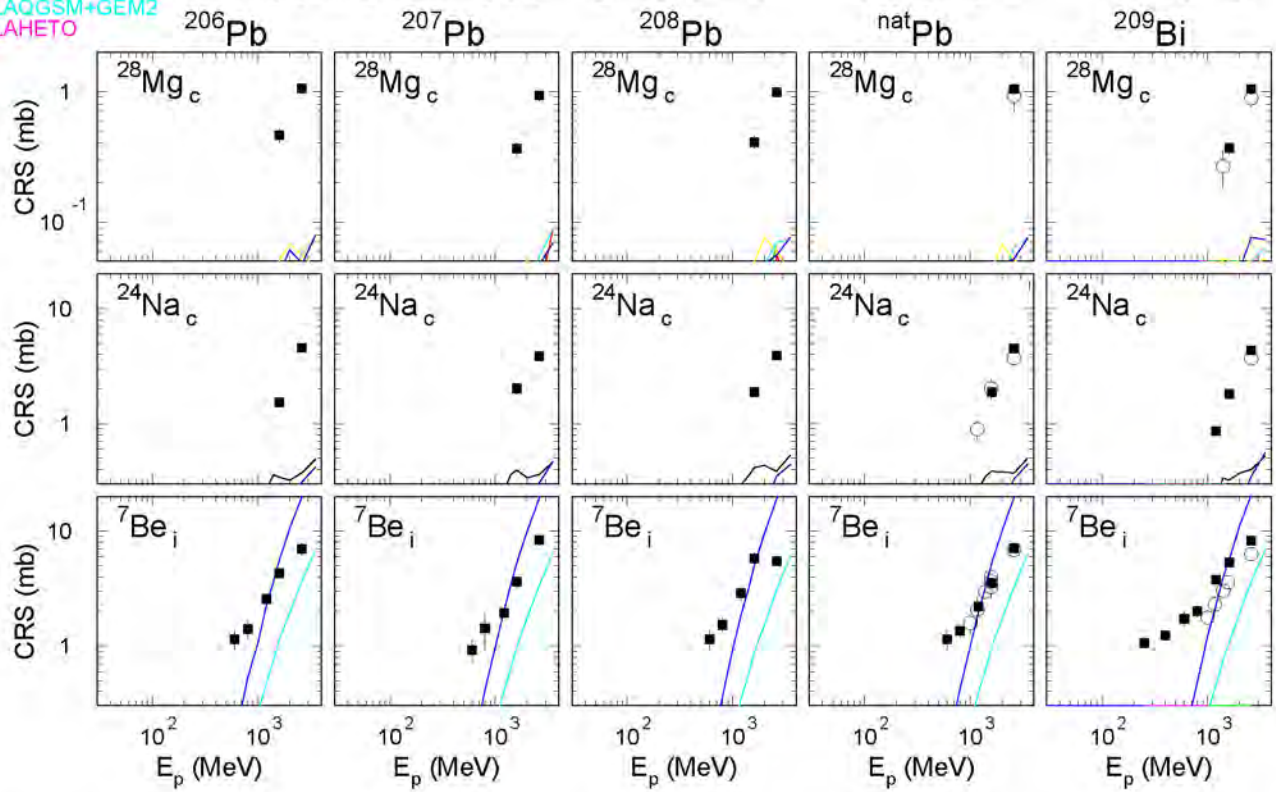


Fig. 81: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

Nuclide formation CRS's from Bi

30 /31

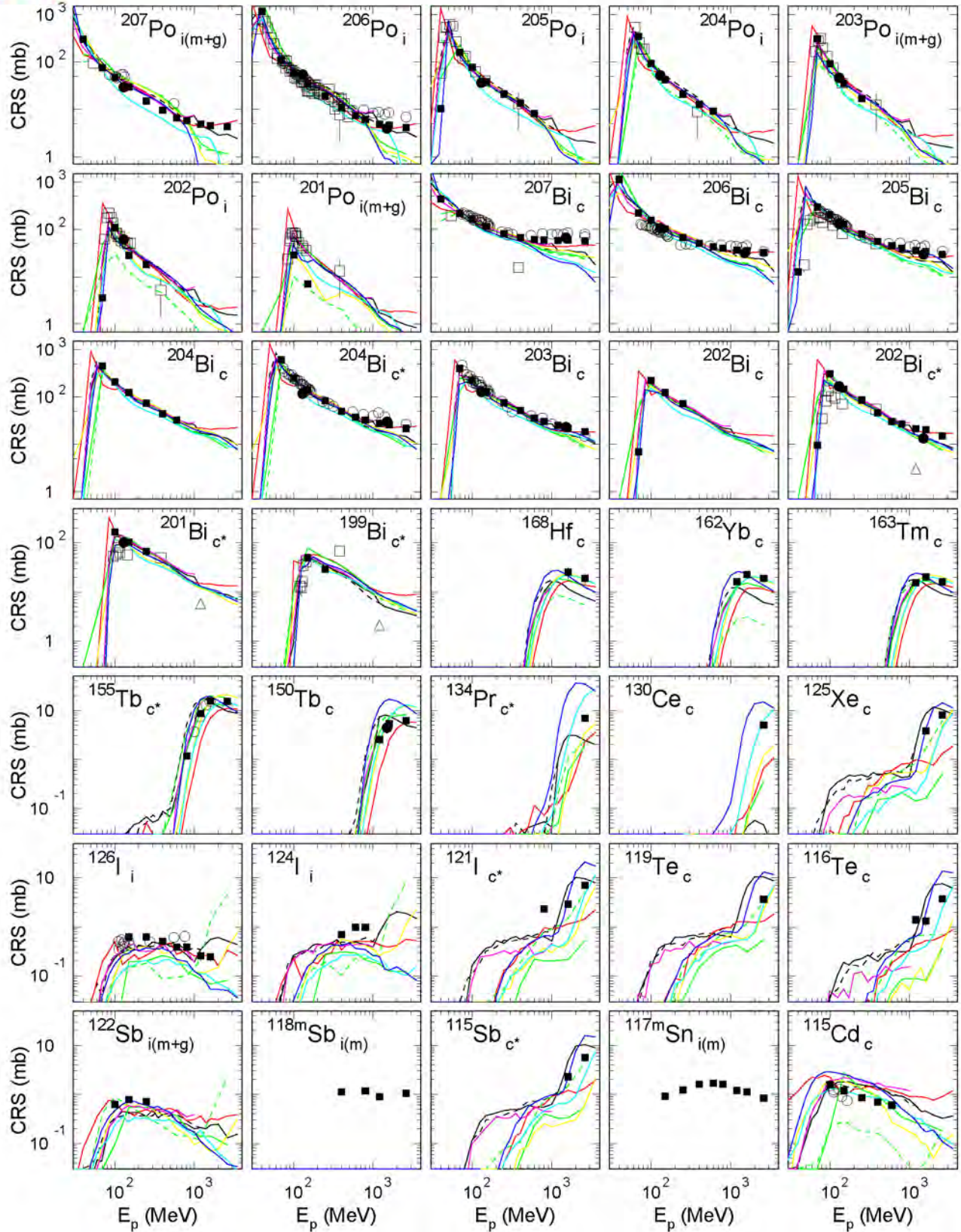


Fig. 82: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

LAHET(isabel-solid, bertini-dashed)
 CASCADE(improved-solid, obsolete-dashed)
 INCL4+ABLA
 CEM03
 CASCADO
 LAQGSM+GEM2
 LAHETO

2005/06/25 18.59

Nuclide formation CRS's from Bi

31 /31

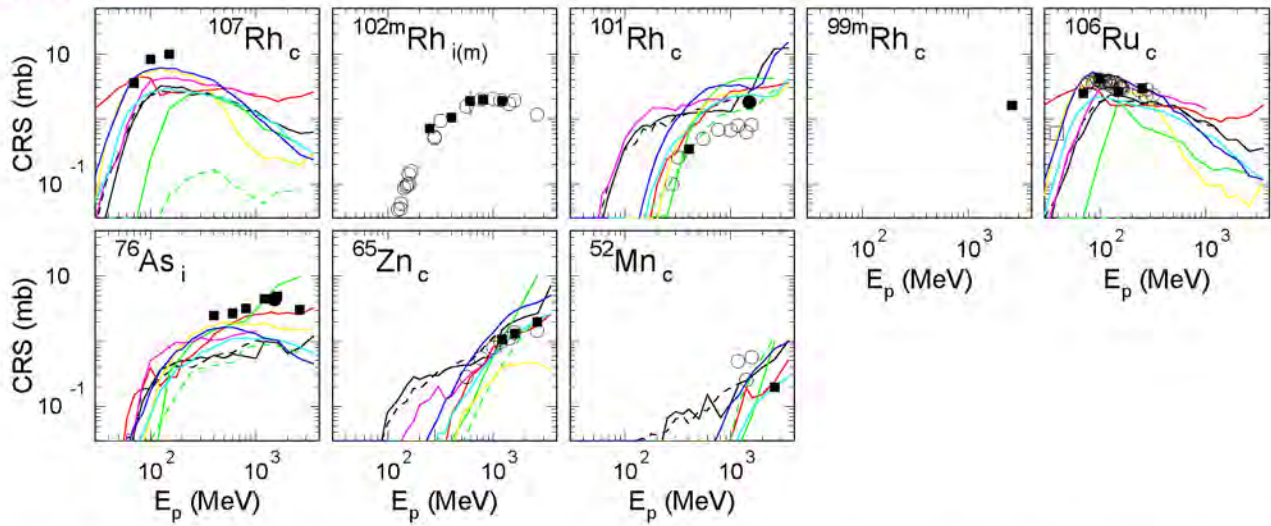


Fig. 83: The simulated and experimental cross sections of the measured reactions (Continuation of Fig. 53).

Mass production in ^{206}Pb induced by 40 MeV protons

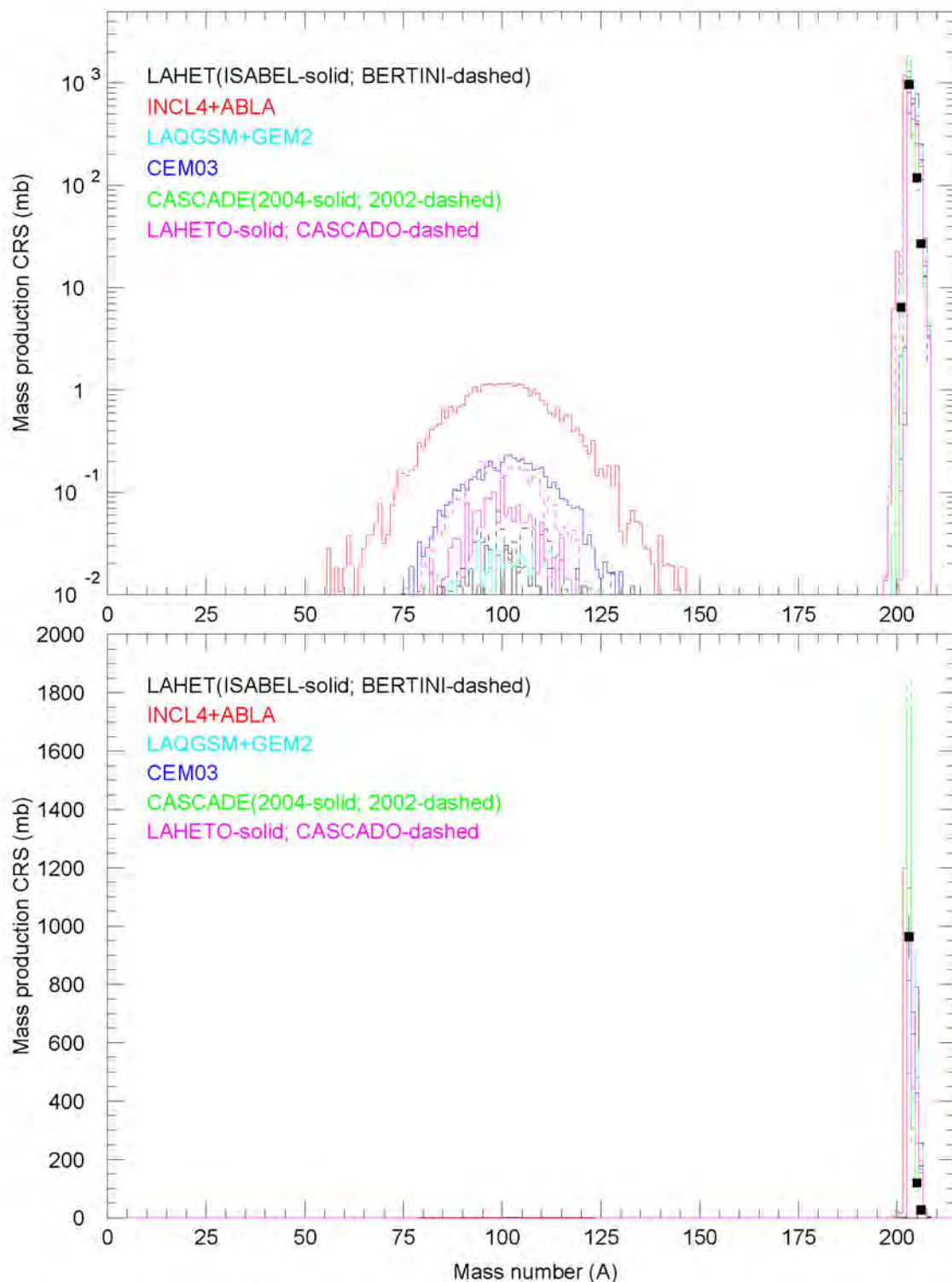


Fig. 84: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.04 GeV protons.

Mass production in ^{207}Pb induced by 40 MeV protons

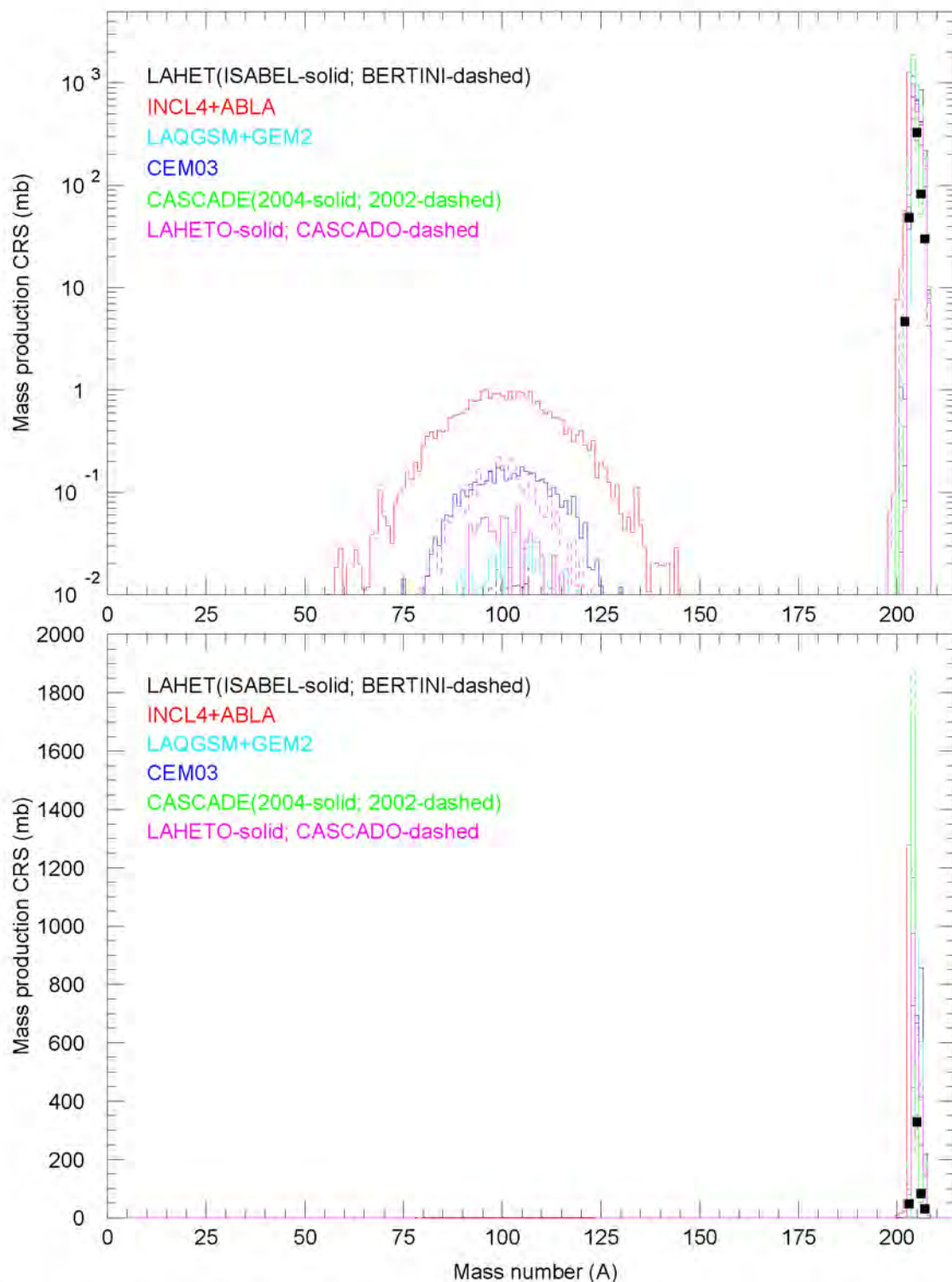


Fig. 85: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.04 GeV protons.

Mass production in ^{208}Pb induced by 40 MeV protons

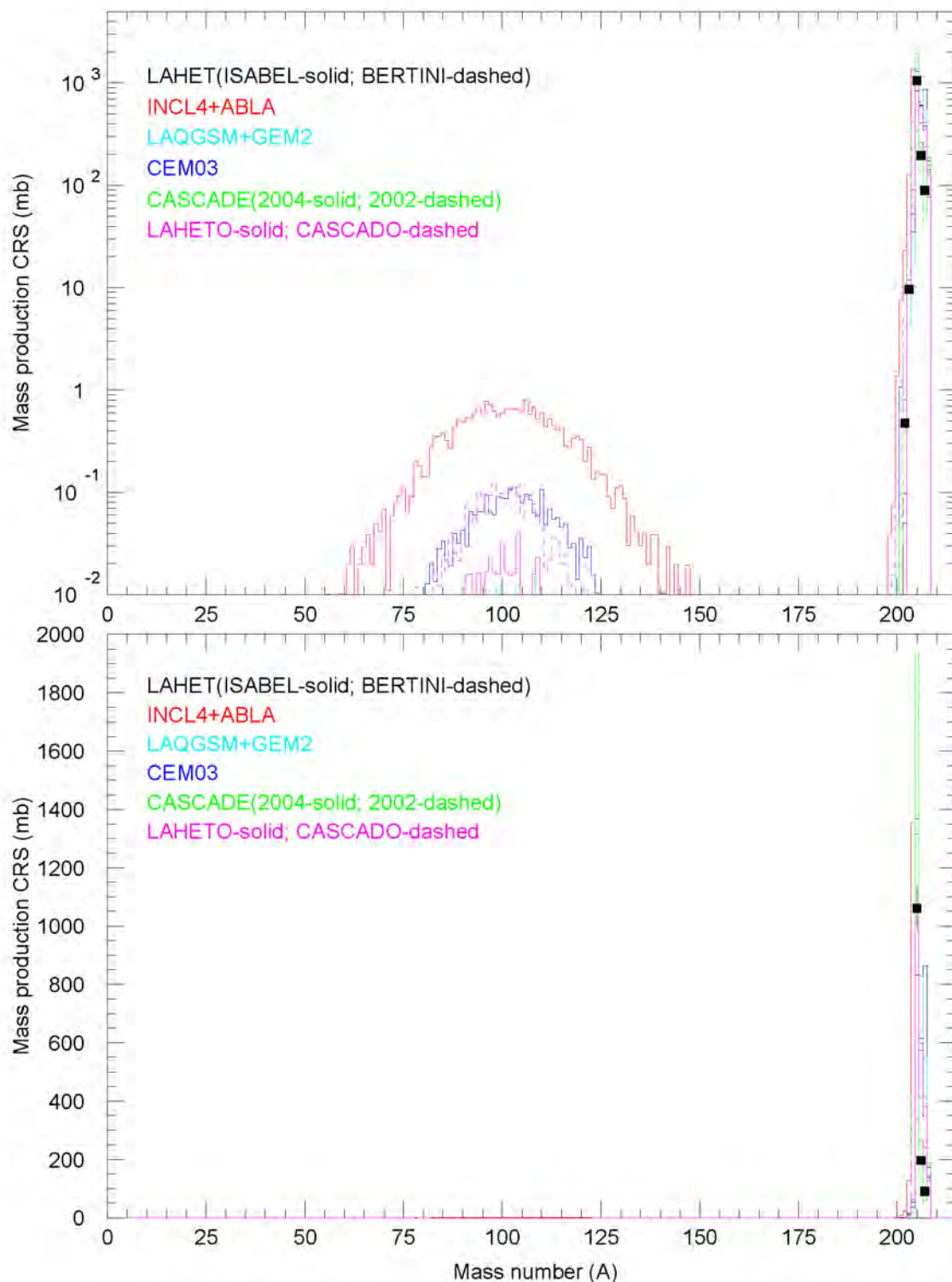


Fig. 86: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.04 GeV protons.

Mass production in ^{nat}Pb induced by 40 MeV protons

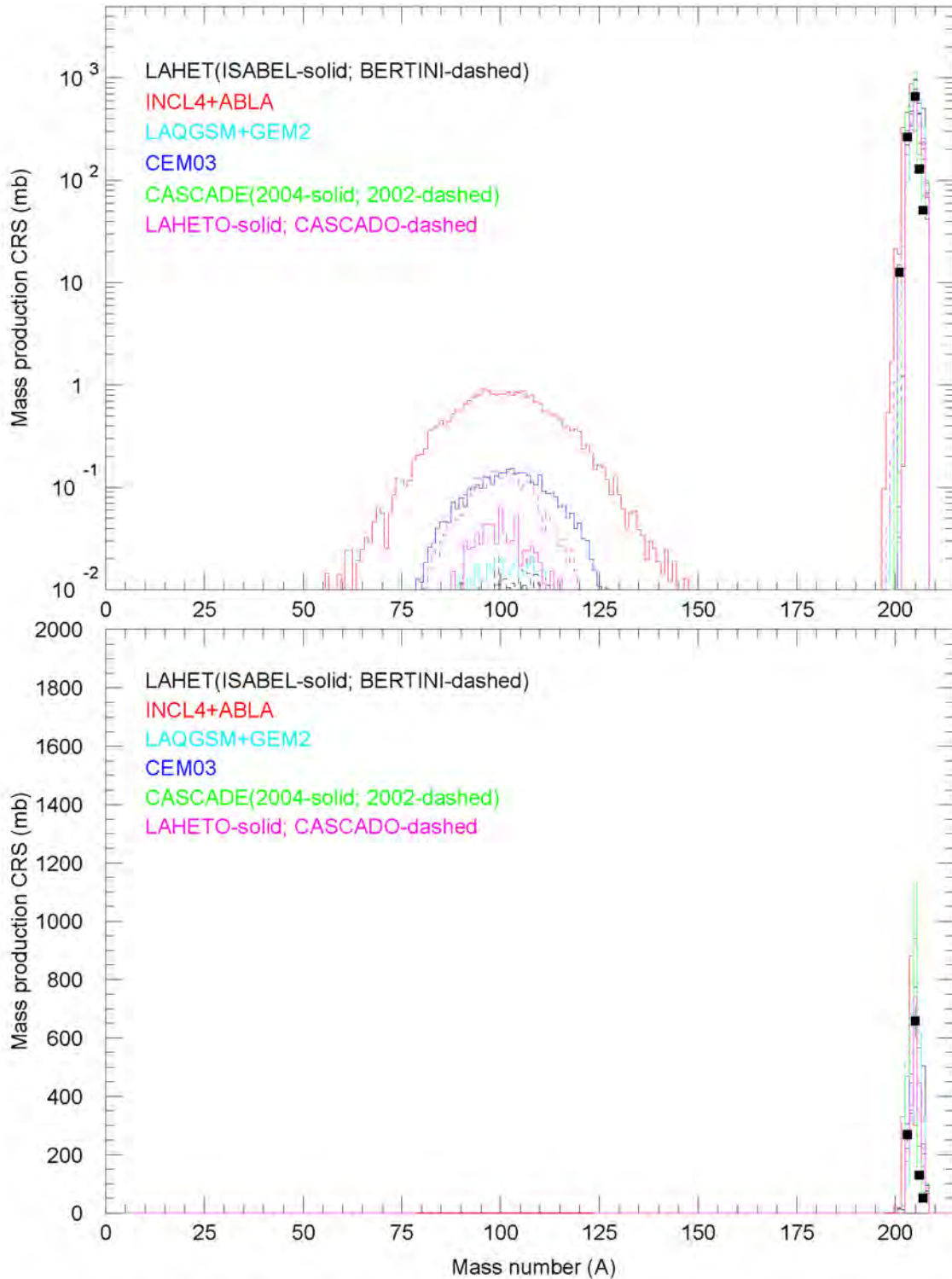


Fig. 87: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.04 GeV protons.

Mass production in ^{209}Bi induced by 40 MeV protons

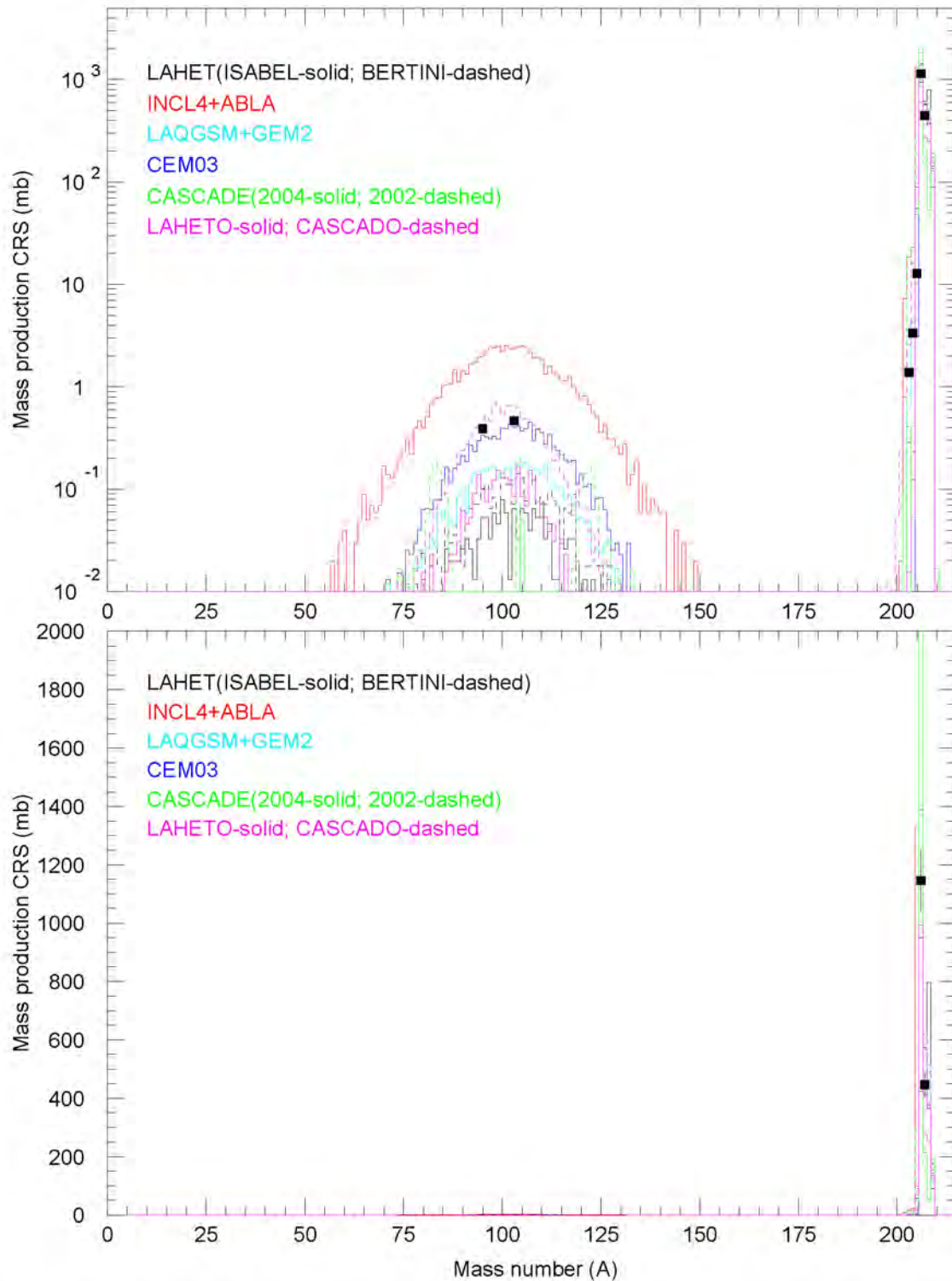


Fig. 88: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.04 GeV protons.

Mass production in ^{206}Pb induced by 70 MeV protons

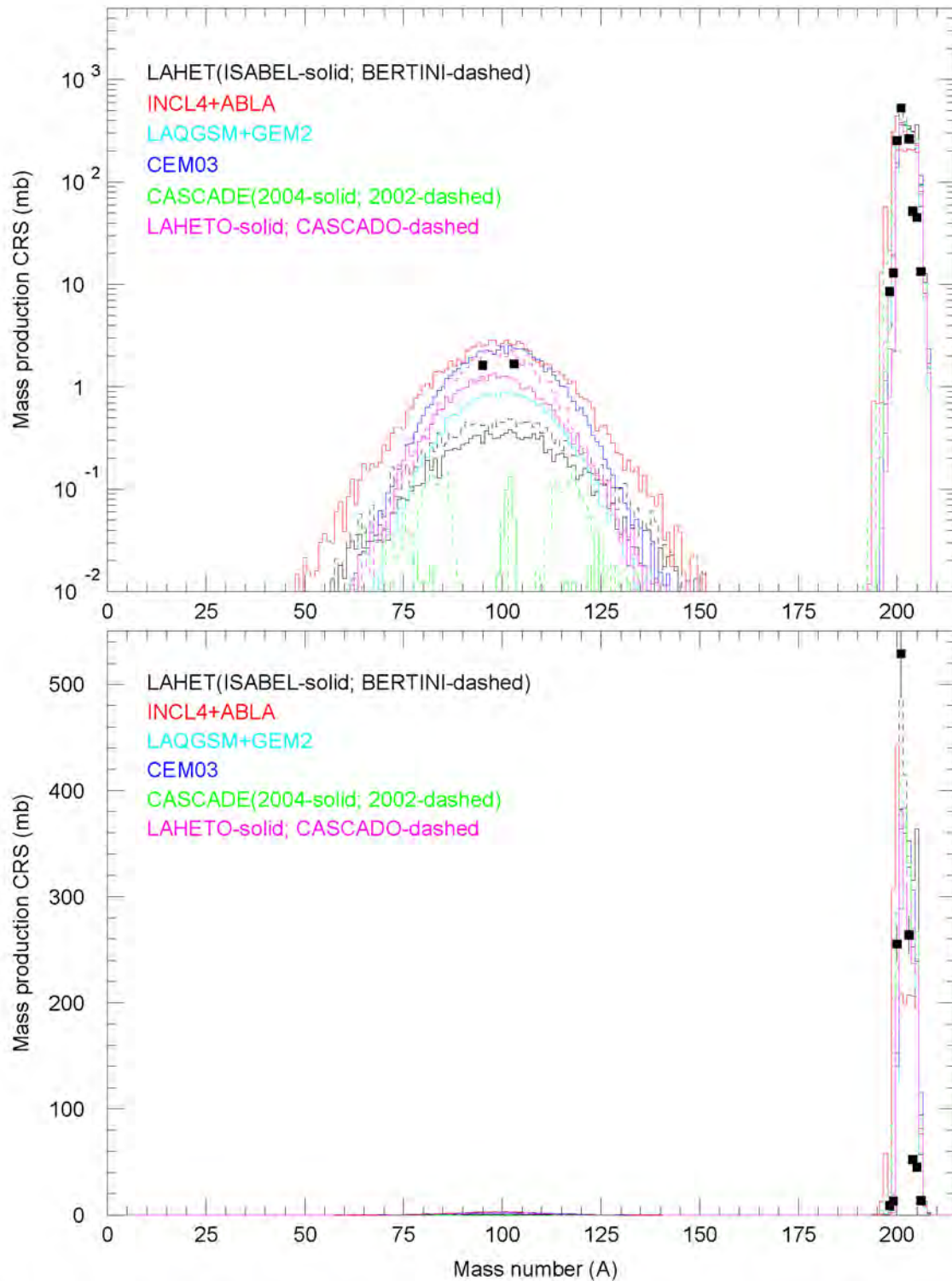


Fig. 89: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.07 GeV protons.

Mass production in ^{207}Pb induced by 70 MeV protons

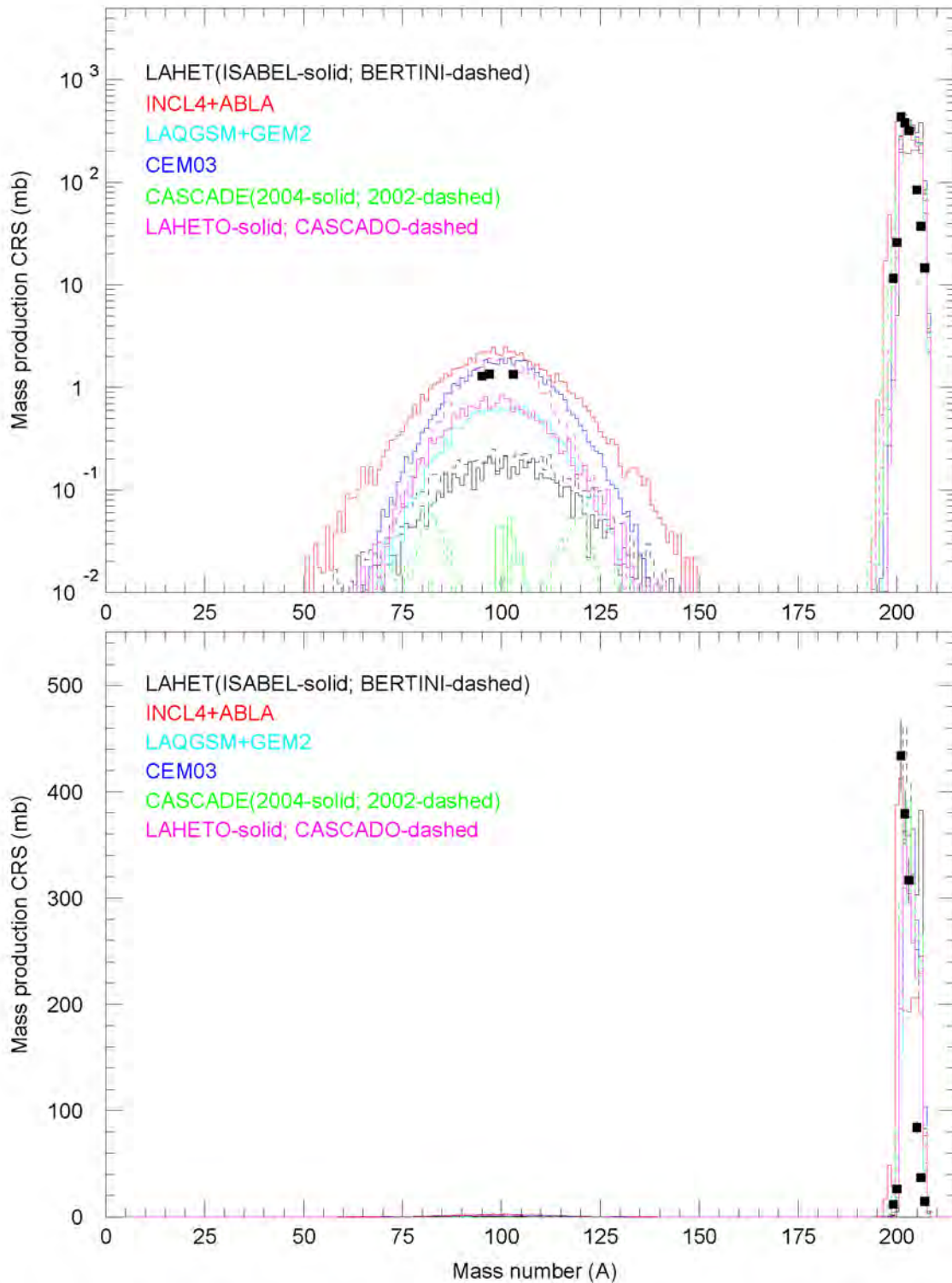


Fig. 90: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.07 GeV protons.

Mass production in ^{208}Pb induced by 70 MeV protons

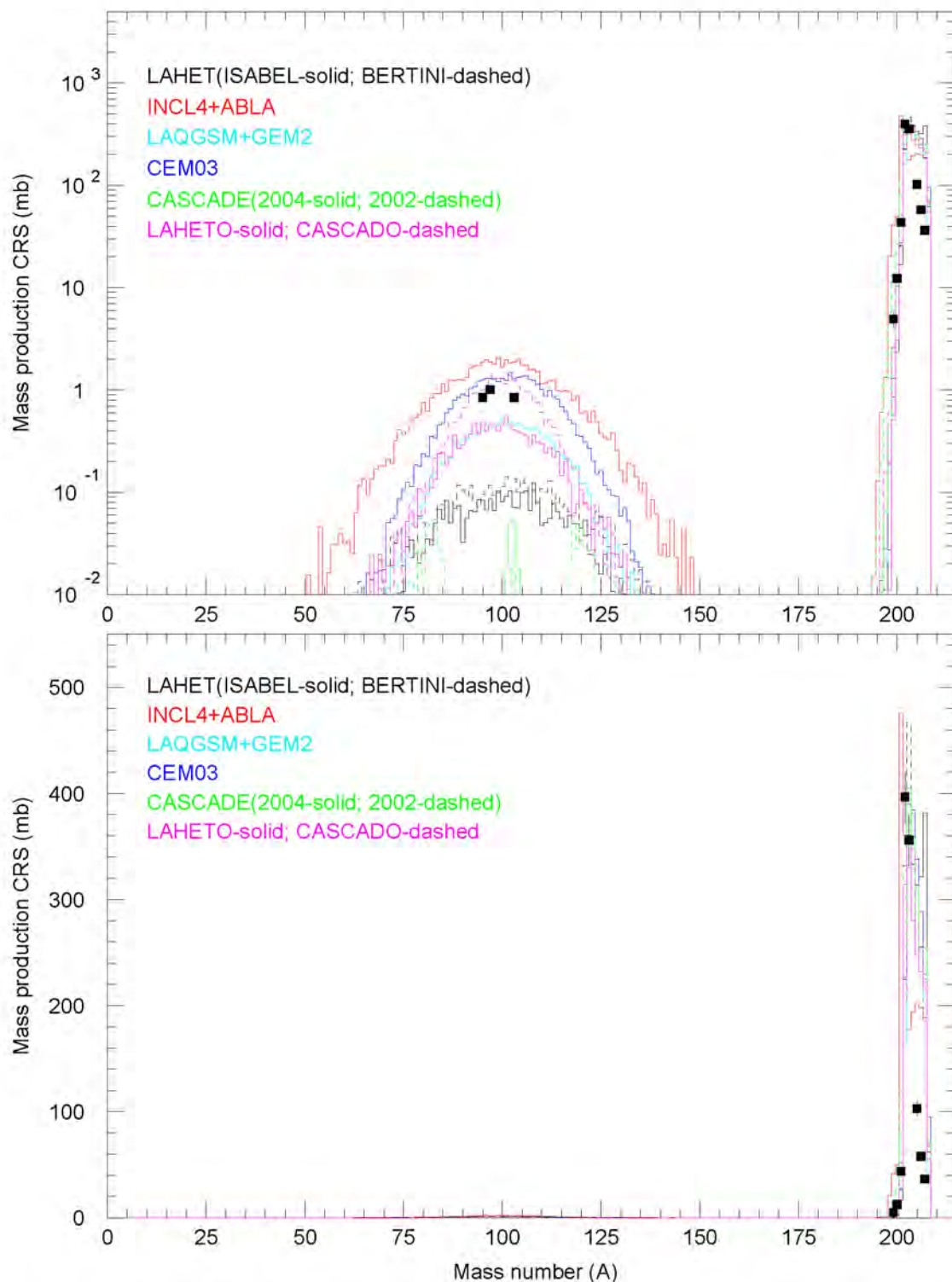


Fig. 91: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.07 GeV protons.

Mass production in ^{nat}Pb induced by 70 MeV protons

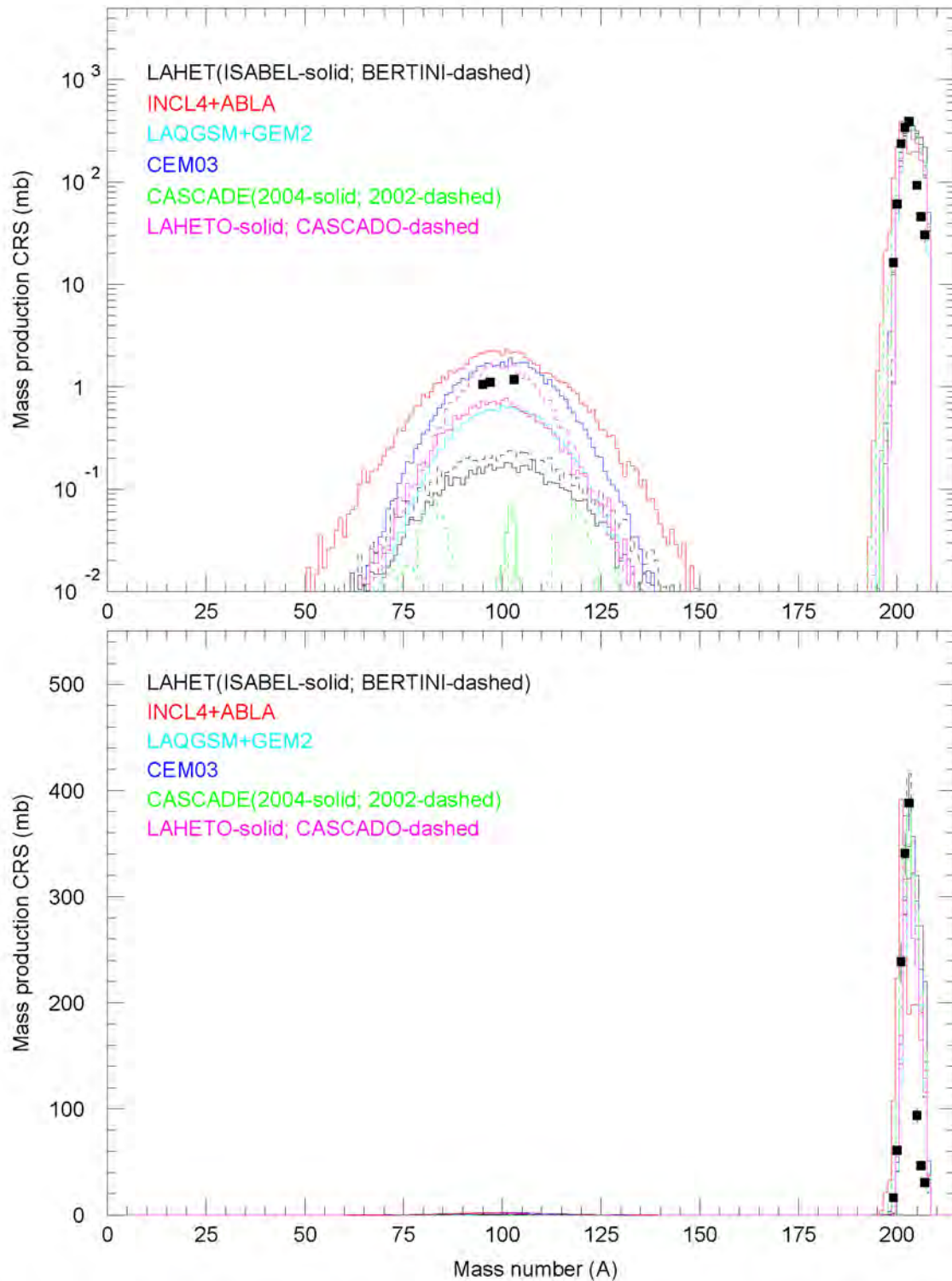


Fig. 92: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.07 GeV protons.

Mass production in ^{209}Bi induced by 70 MeV protons

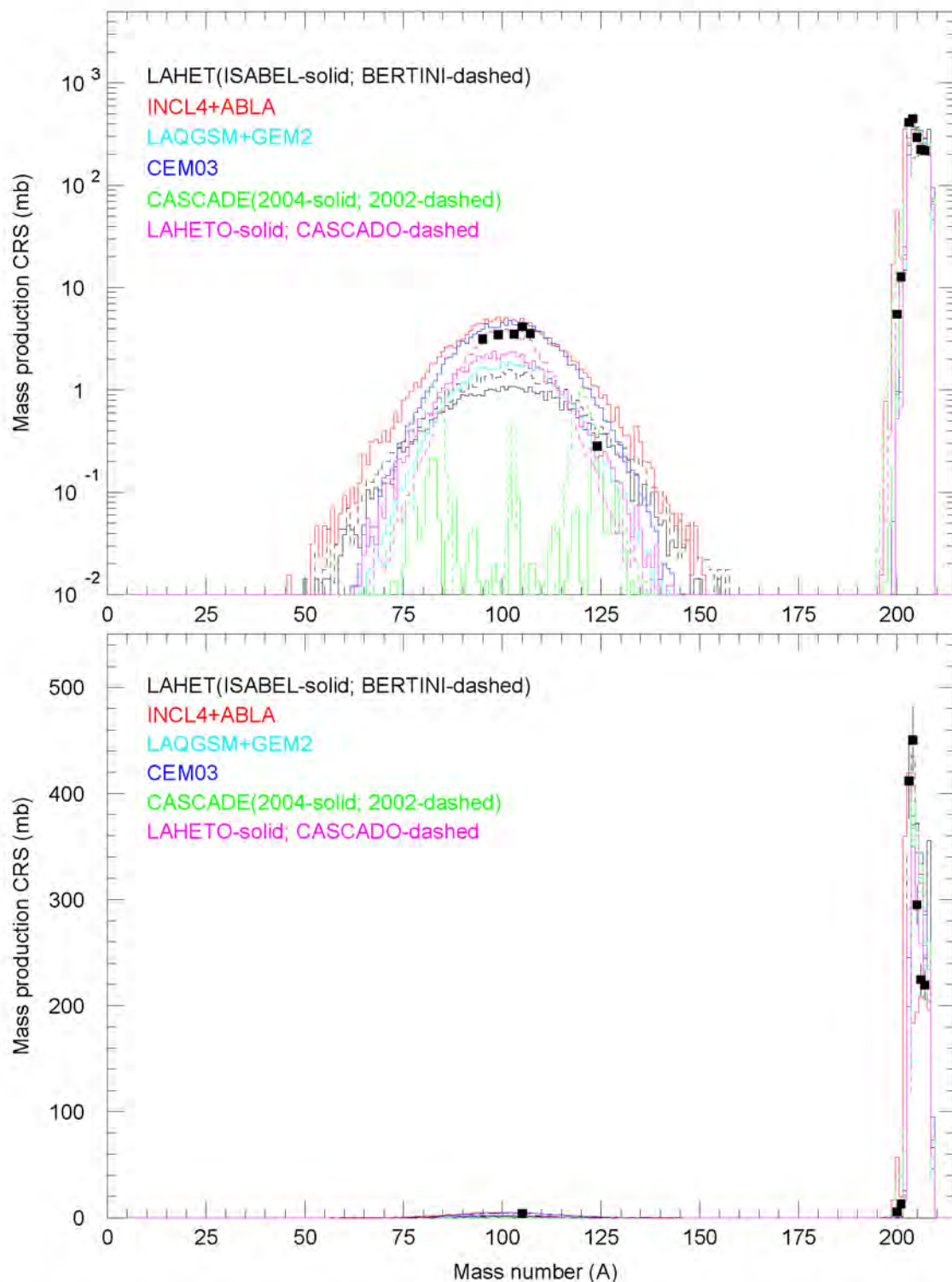


Fig. 93: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.07 GeV protons.

Mass production in ^{206}Pb induced by 100 MeV protons

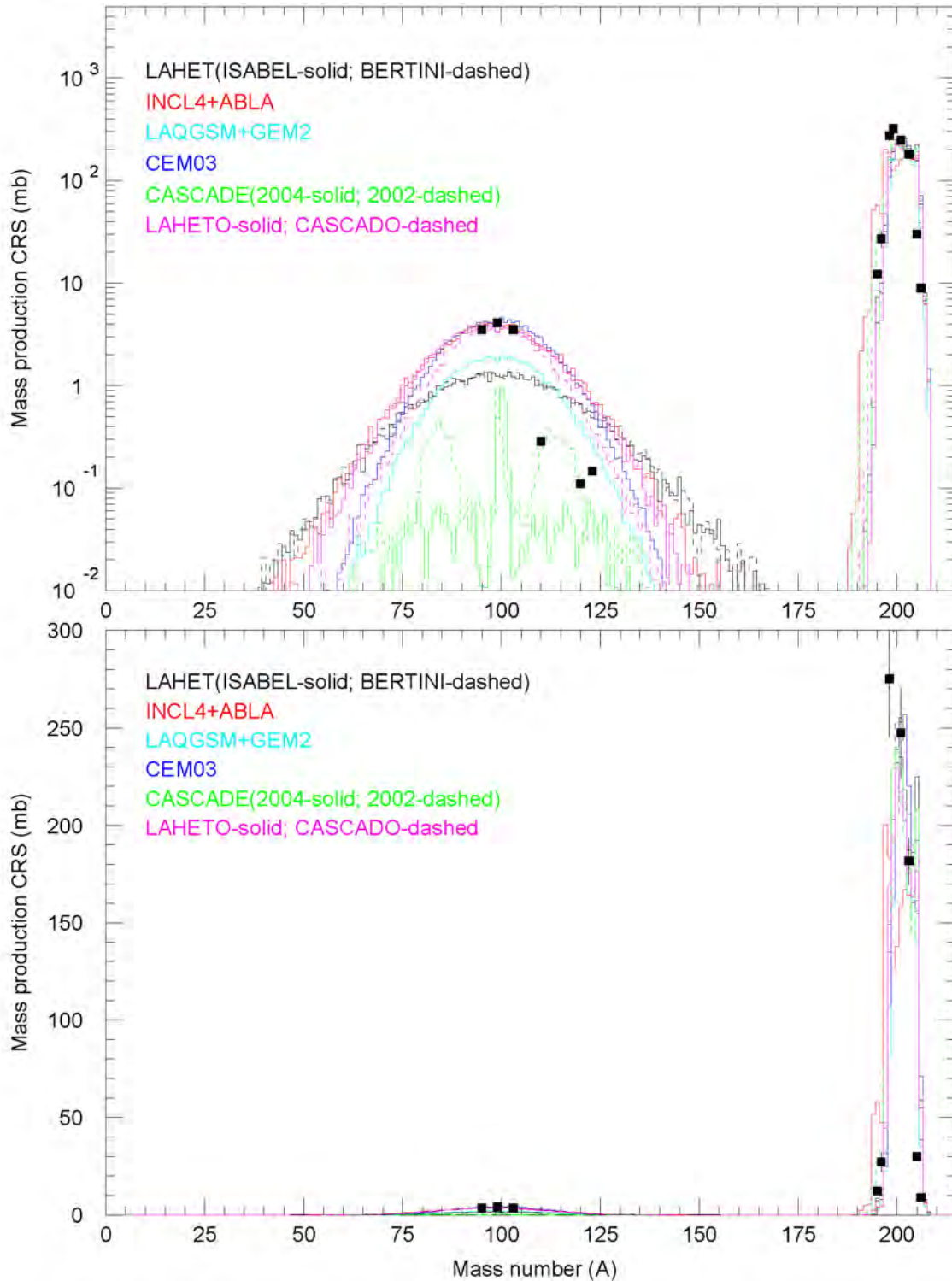


Fig. 94: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.1 GeV protons.

Mass production in ^{207}Pb induced by 100 MeV protons

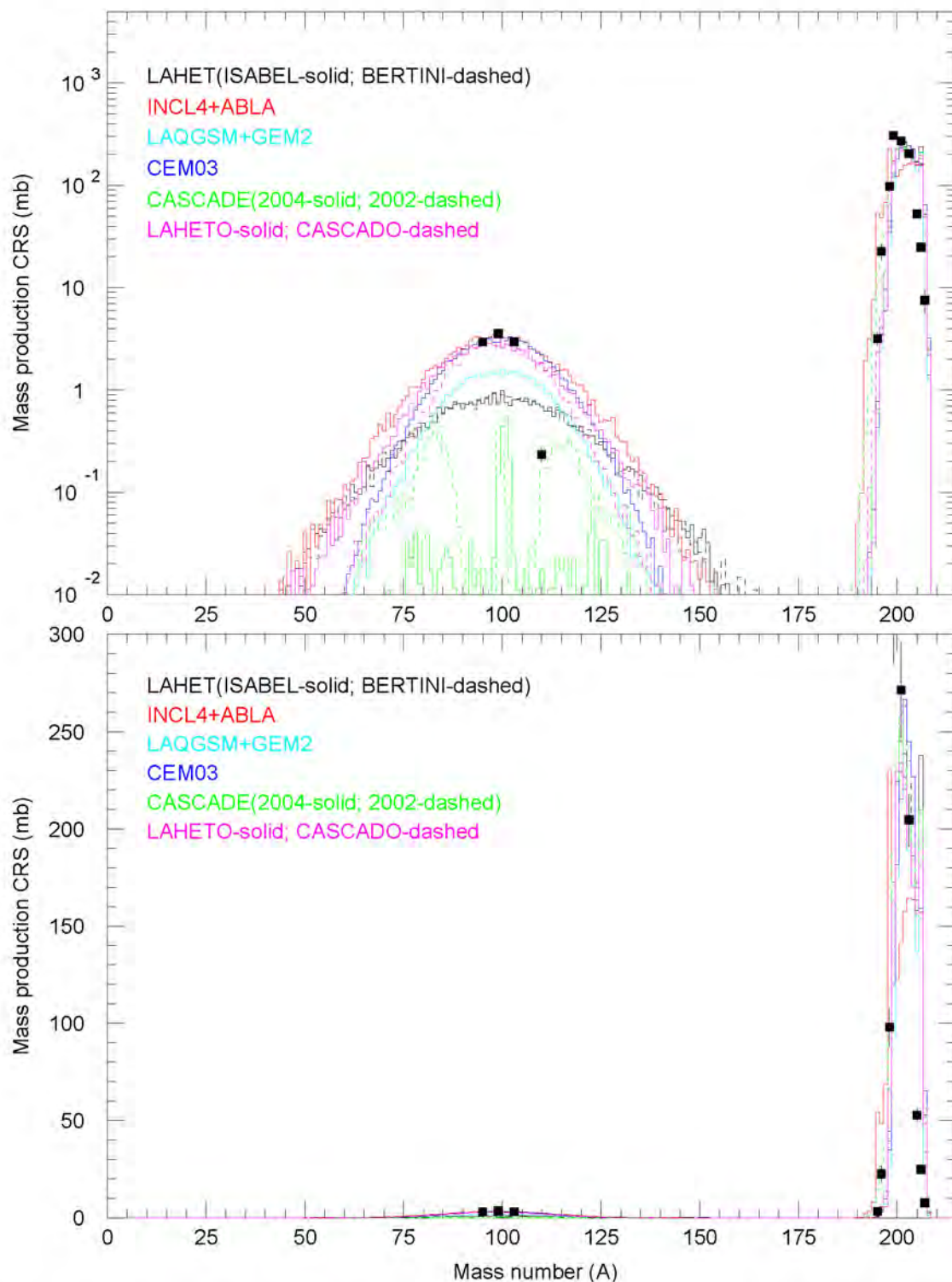


Fig. 95: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.1 GeV protons.

Mass production in ^{208}Pb induced by 100 MeV protons

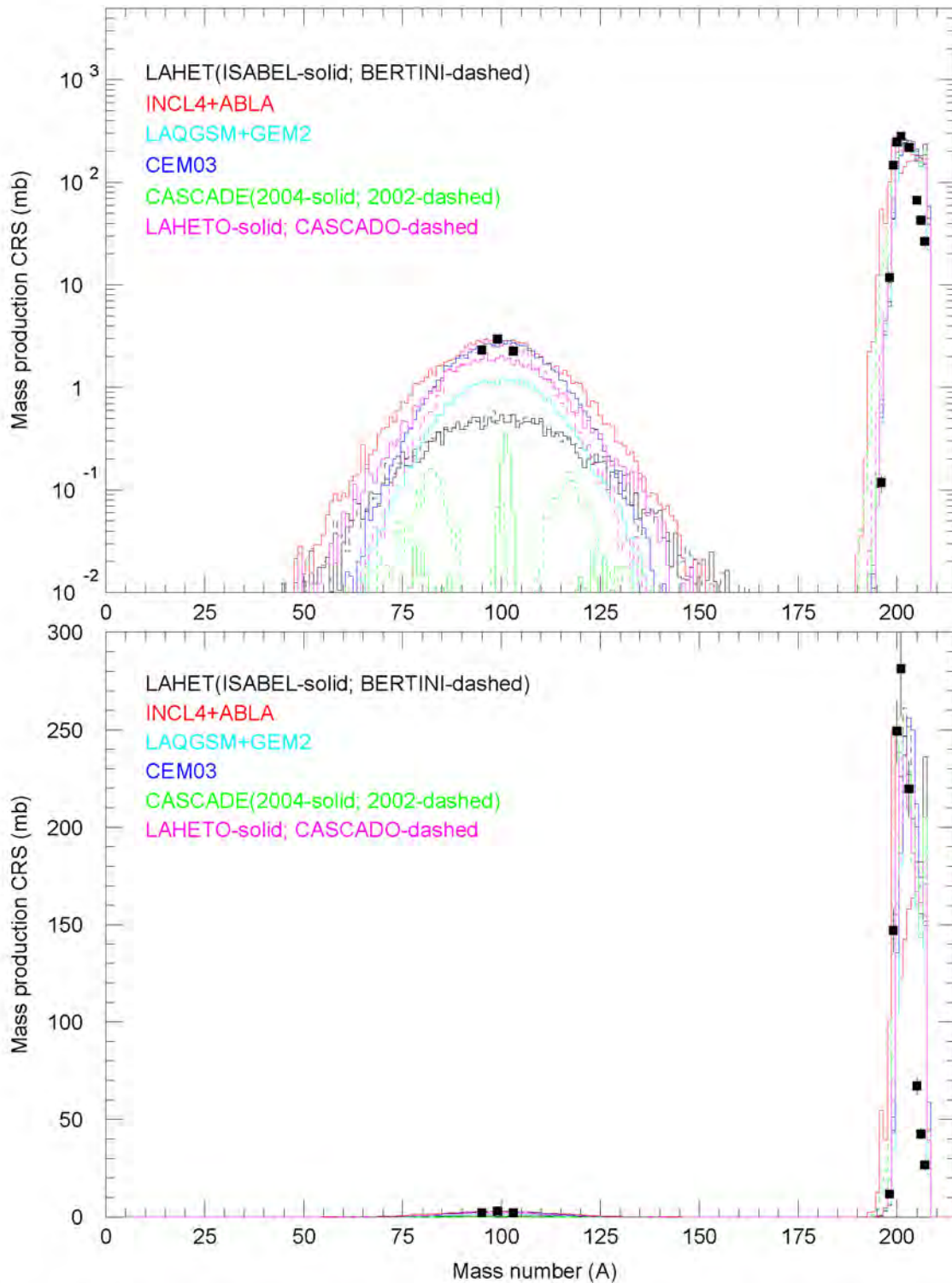


Fig. 96: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.1 GeV protons.

Mass production in ^{nat}Pb induced by 100 MeV protons

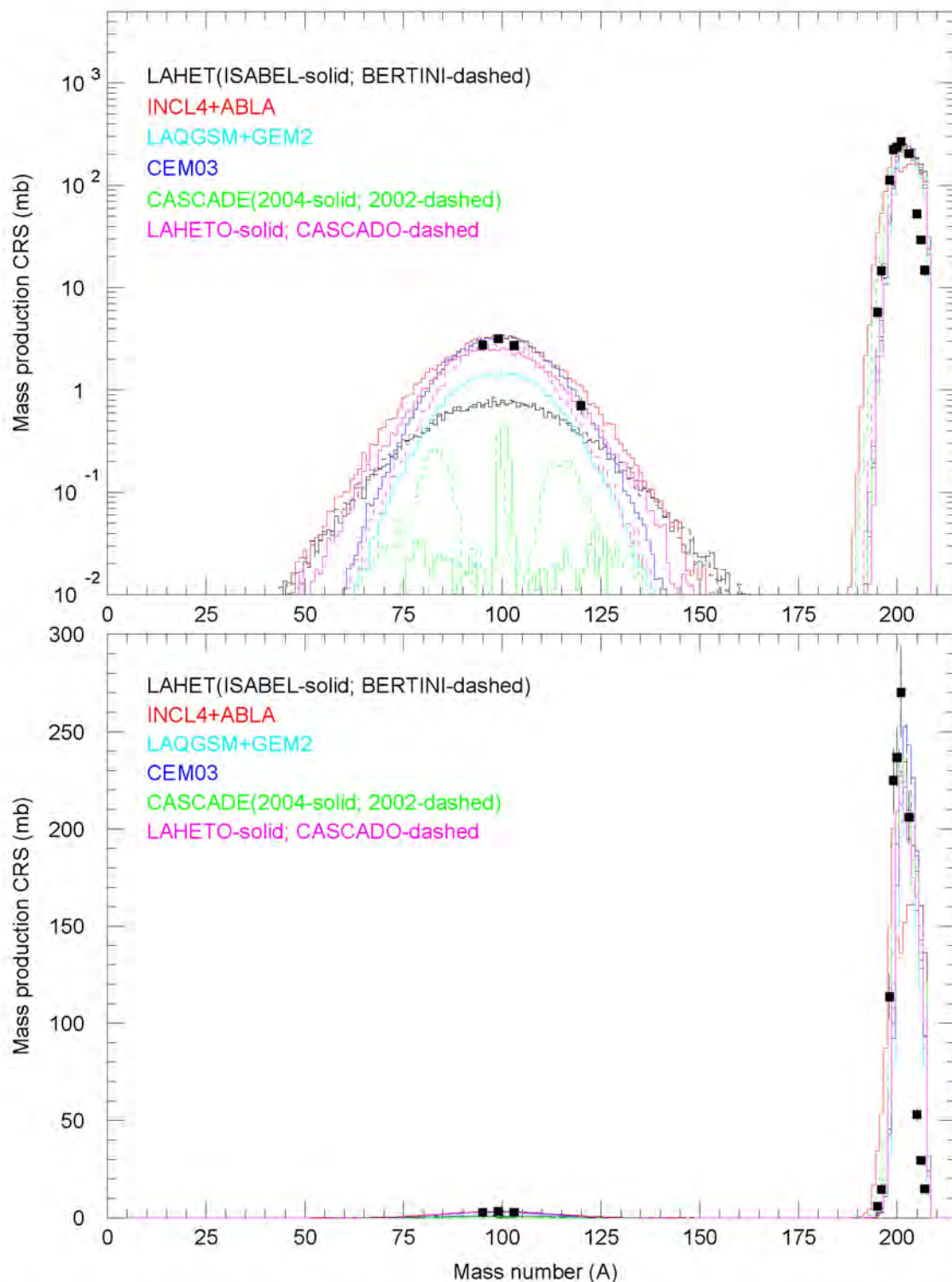


Fig. 97: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.1 GeV protons.

Mass production in ^{209}Bi induced by 100 MeV protons

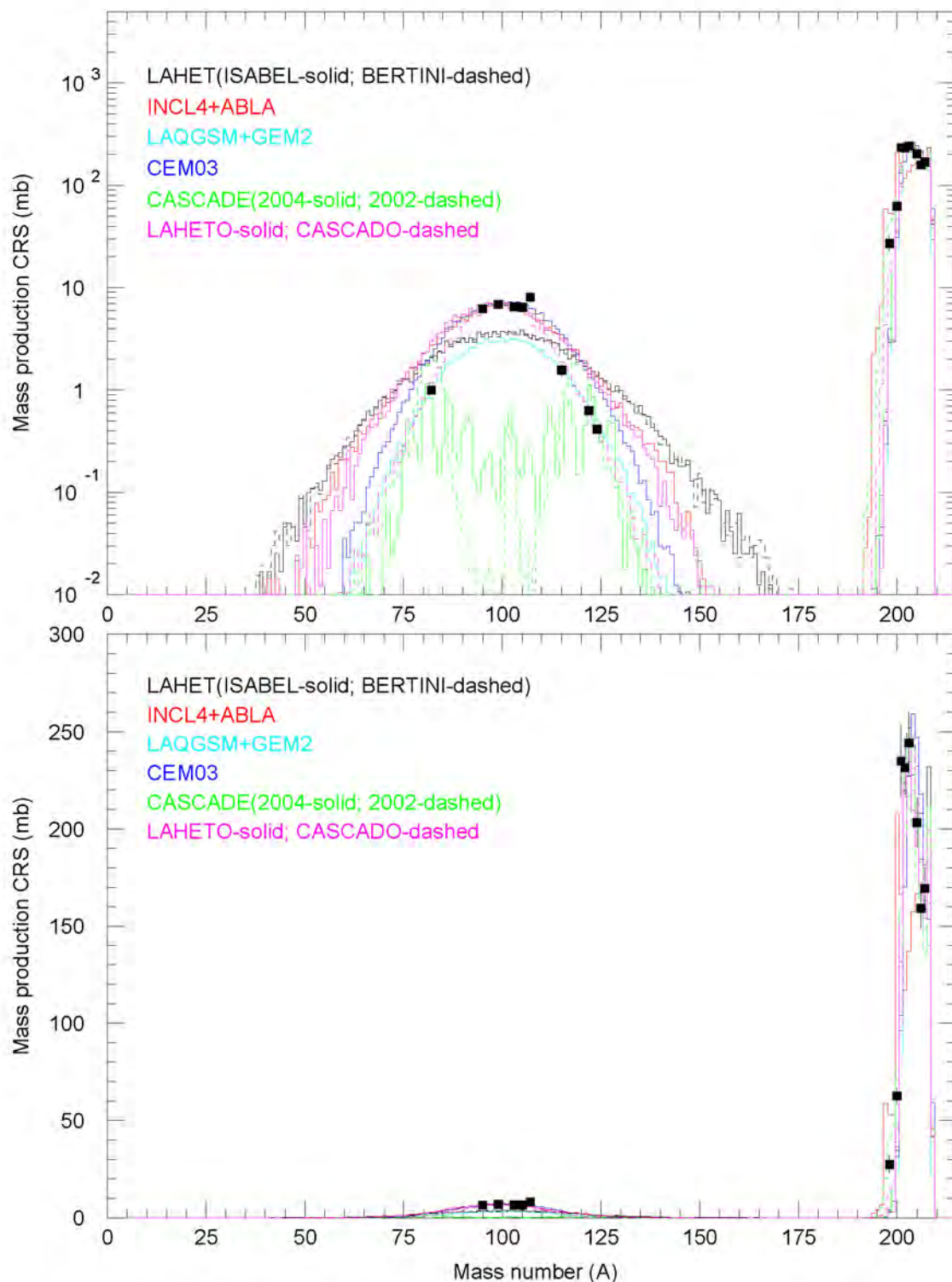


Fig. 98: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.1 GeV protons.

Mass production in ^{206}Pb induced by 150 MeV protons

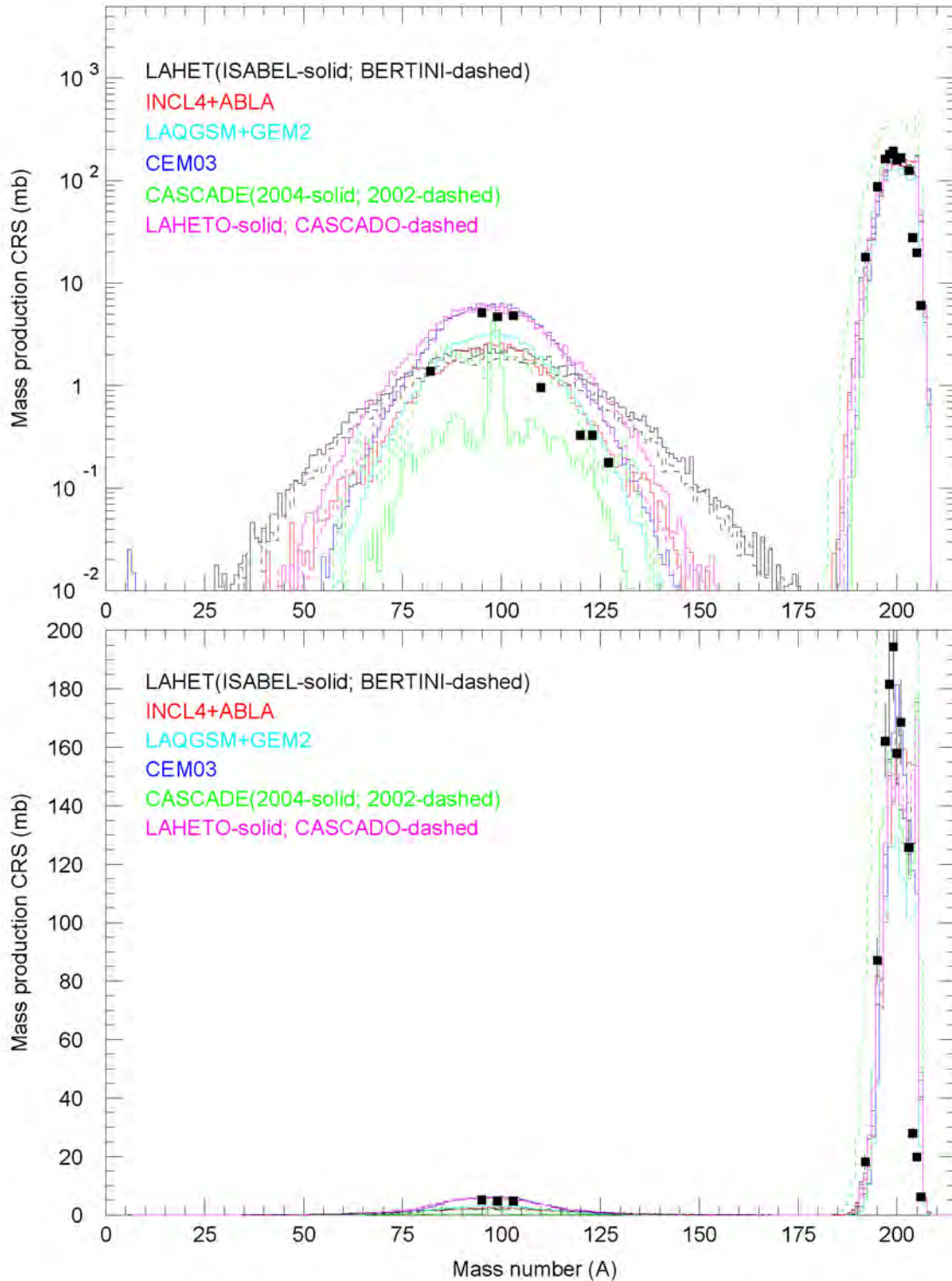


Fig. 99: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.15 GeV protons.

Mass production in ^{207}Pb induced by 150 MeV protons

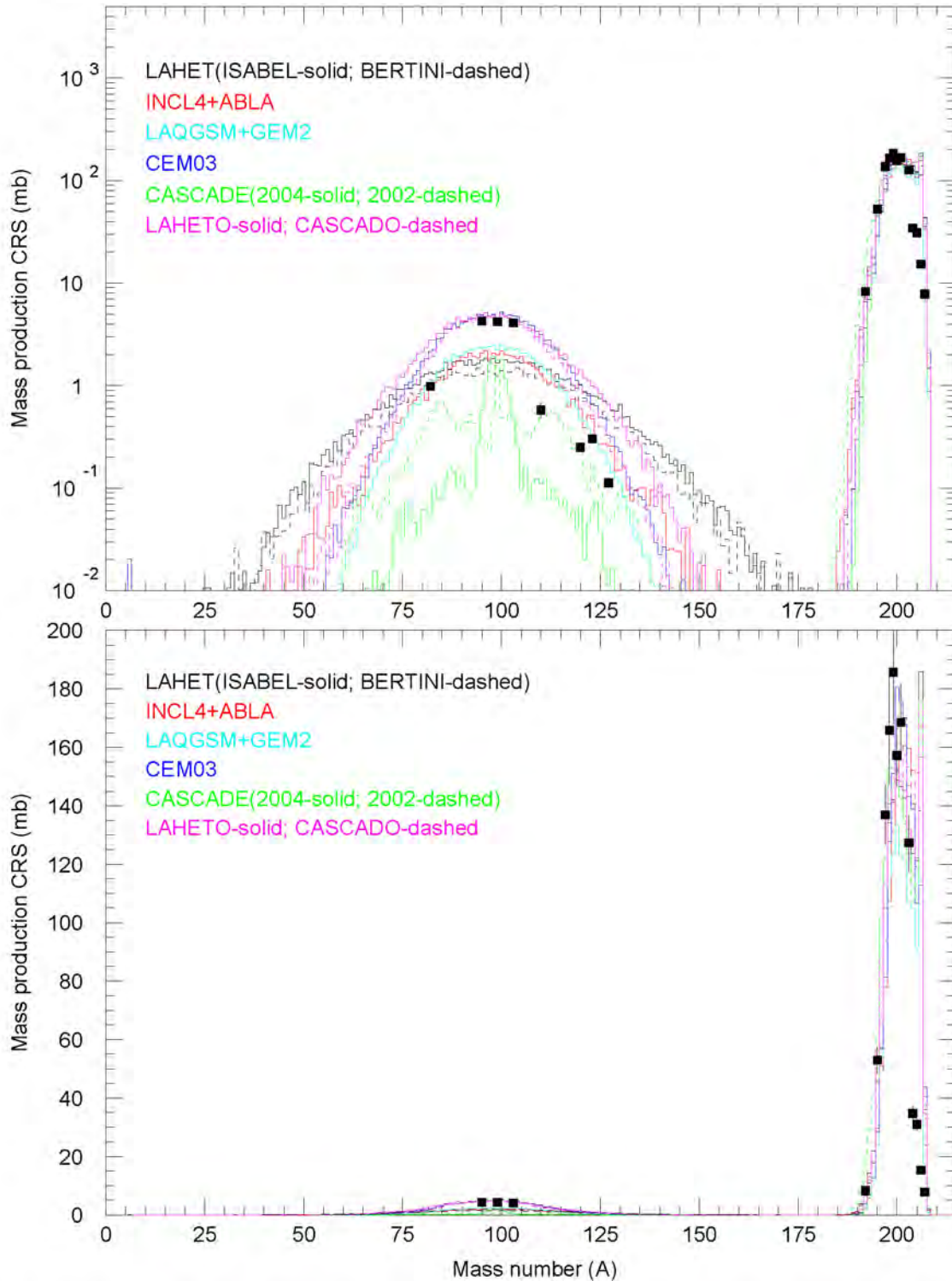


Fig. 100: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.15 GeV protons.

Mass production in ^{208}Pb induced by 150 MeV protons

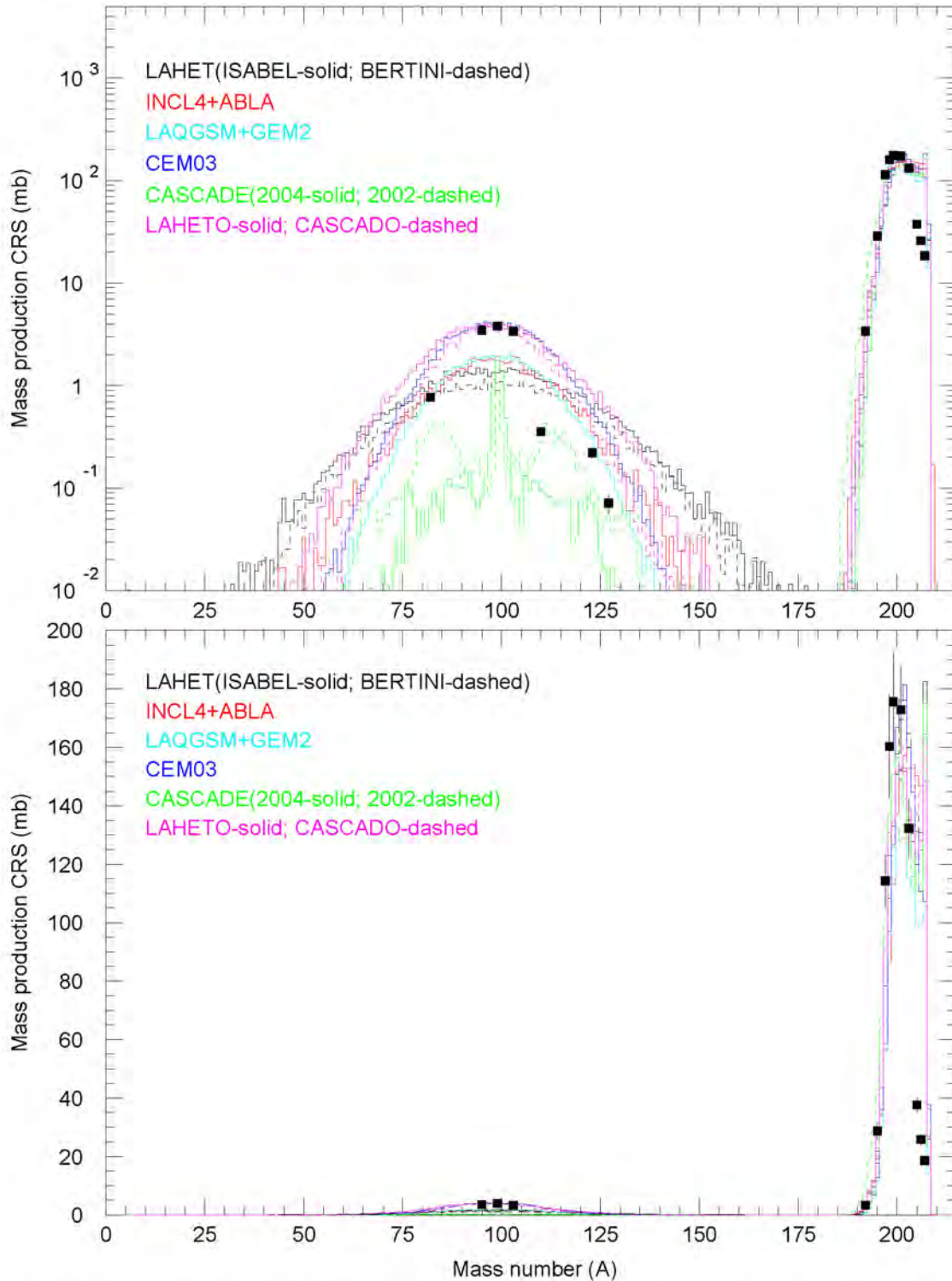


Fig. 101: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.15 GeV protons.

Mass production in ^{nat}Pb induced by 150 MeV protons

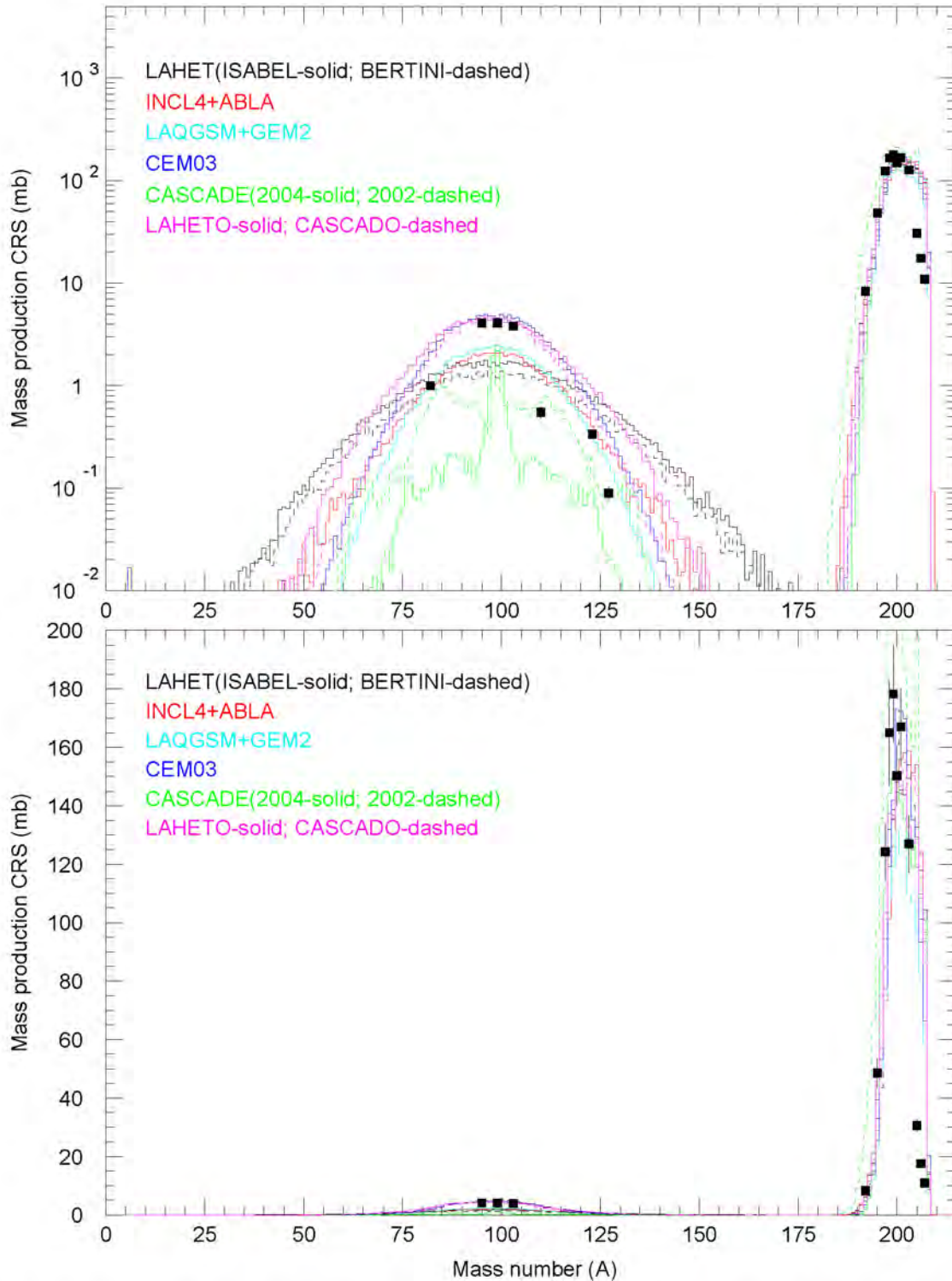


Fig. 102: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.15 GeV protons.

Mass production in ^{209}Bi induced by 150 MeV protons

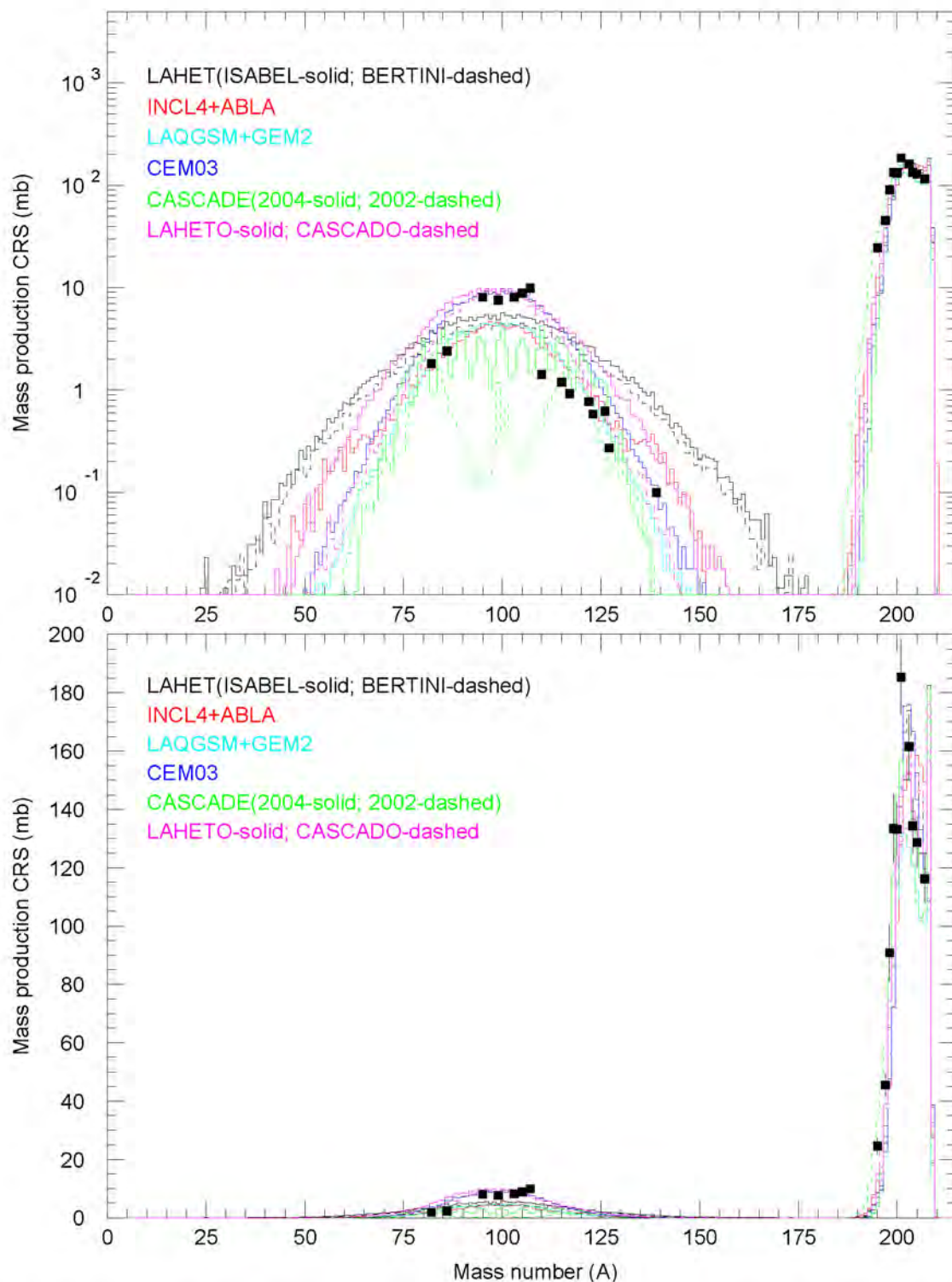


Fig. 103: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.15 GeV protons.

Mass production in ^{206}Pb induced by 250 MeV protons

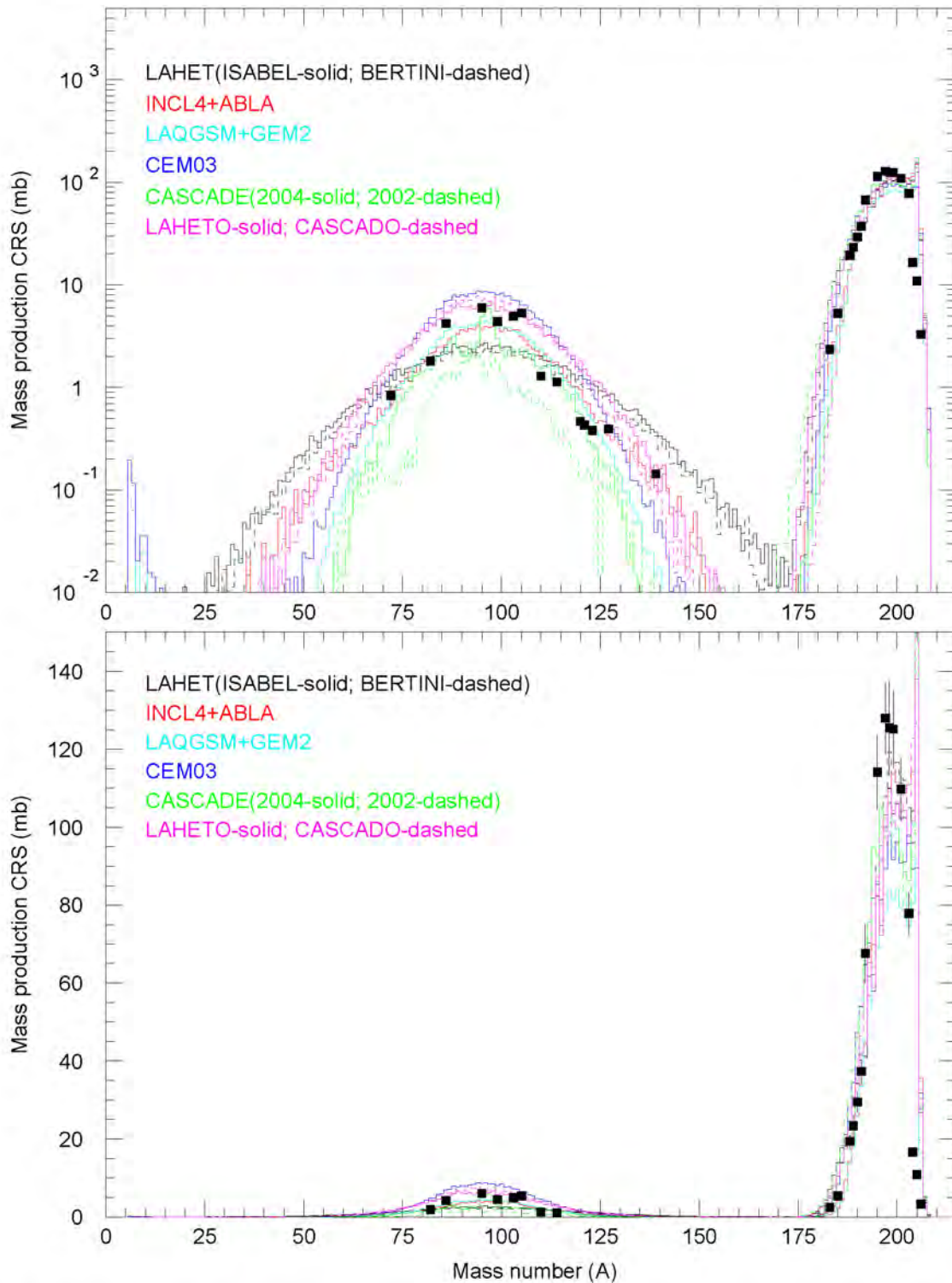


Fig. 104: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.25 GeV protons.

Mass production in ^{207}Pb induced by 250 MeV protons

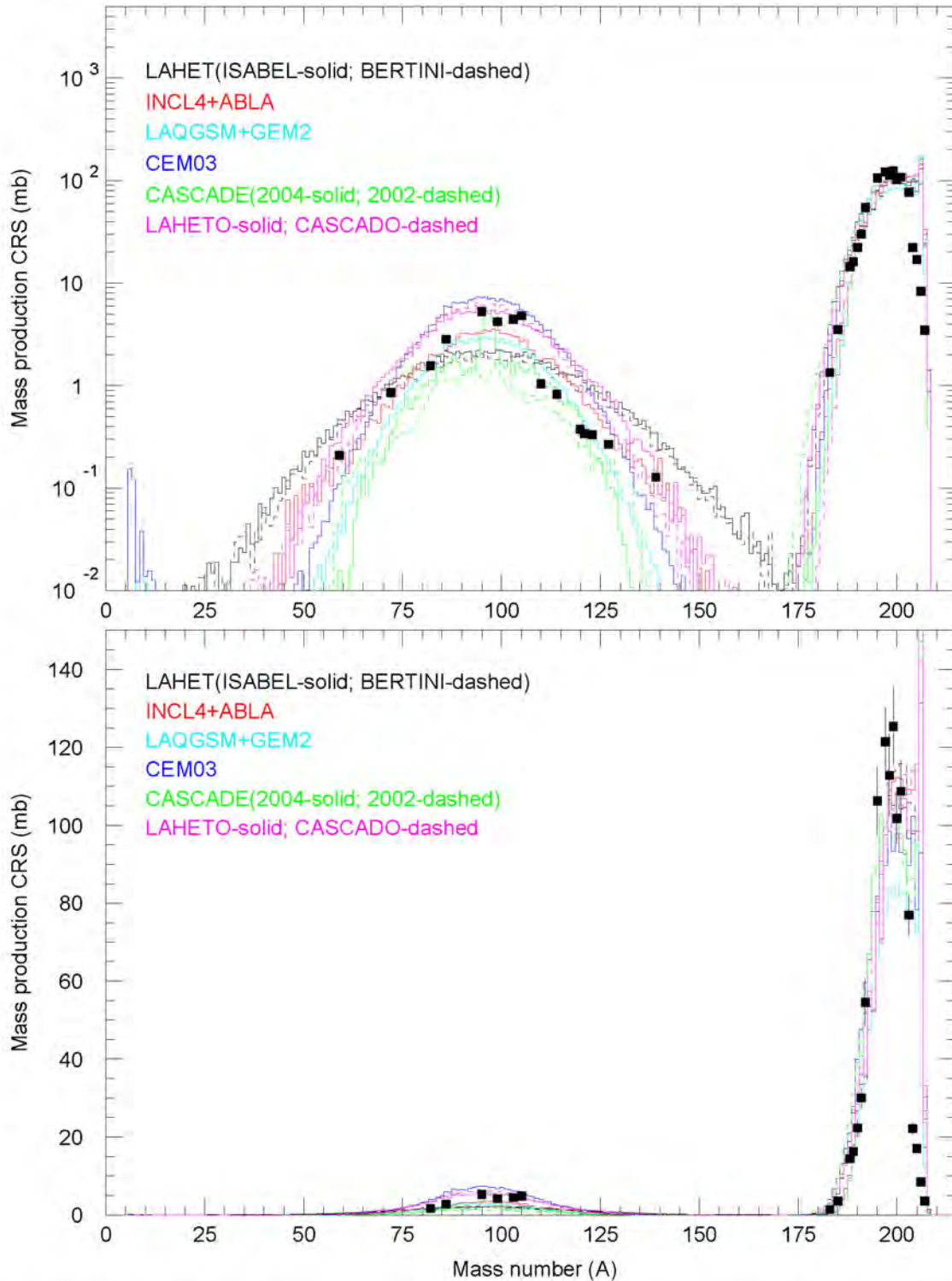


Fig. 105: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.25 GeV protons.

Mass production in ^{208}Pb induced by 250 MeV protons

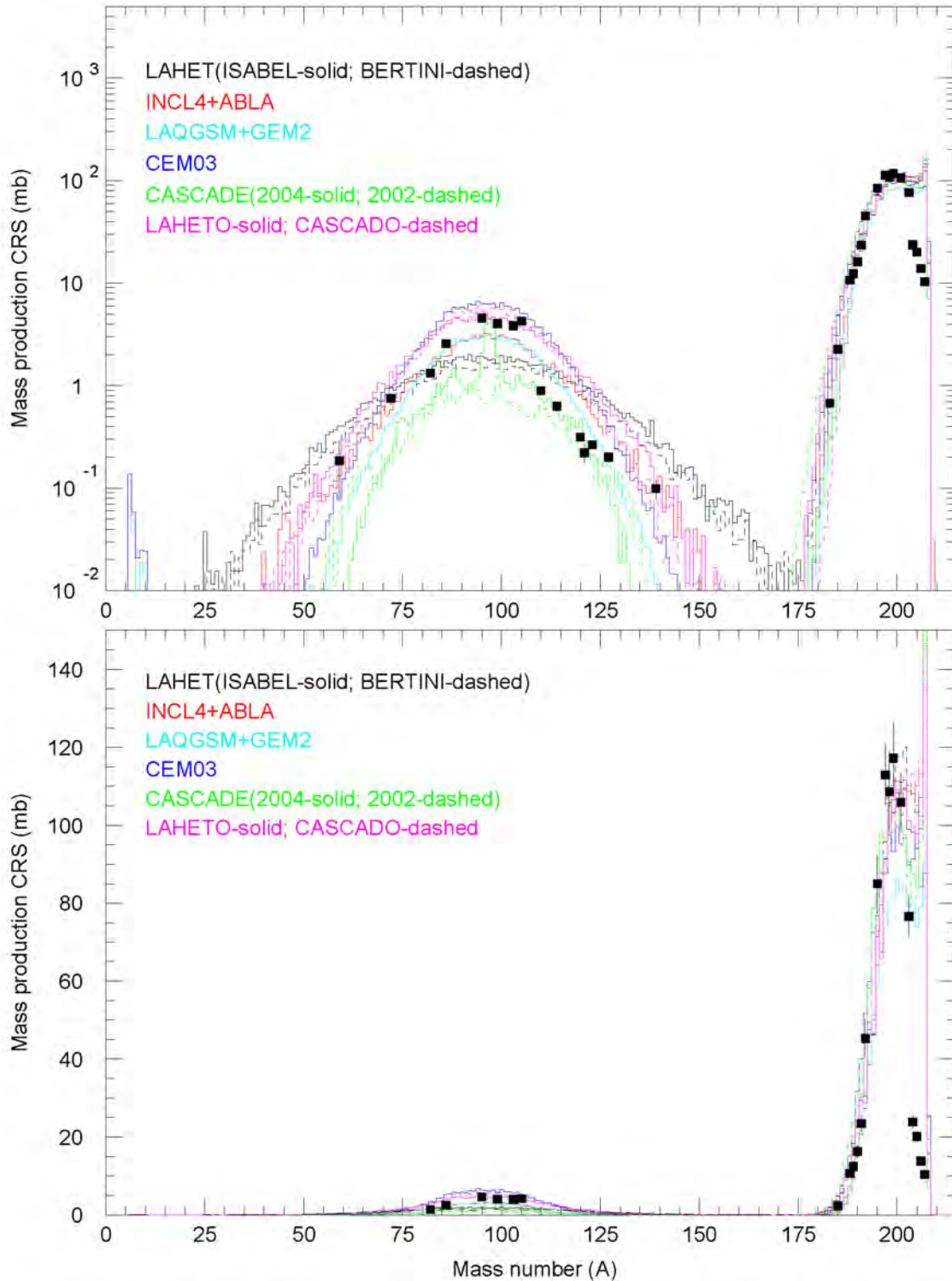


Fig. 106: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.25 GeV protons.

Mass production in ^{nat}Pb induced by 250 MeV protons

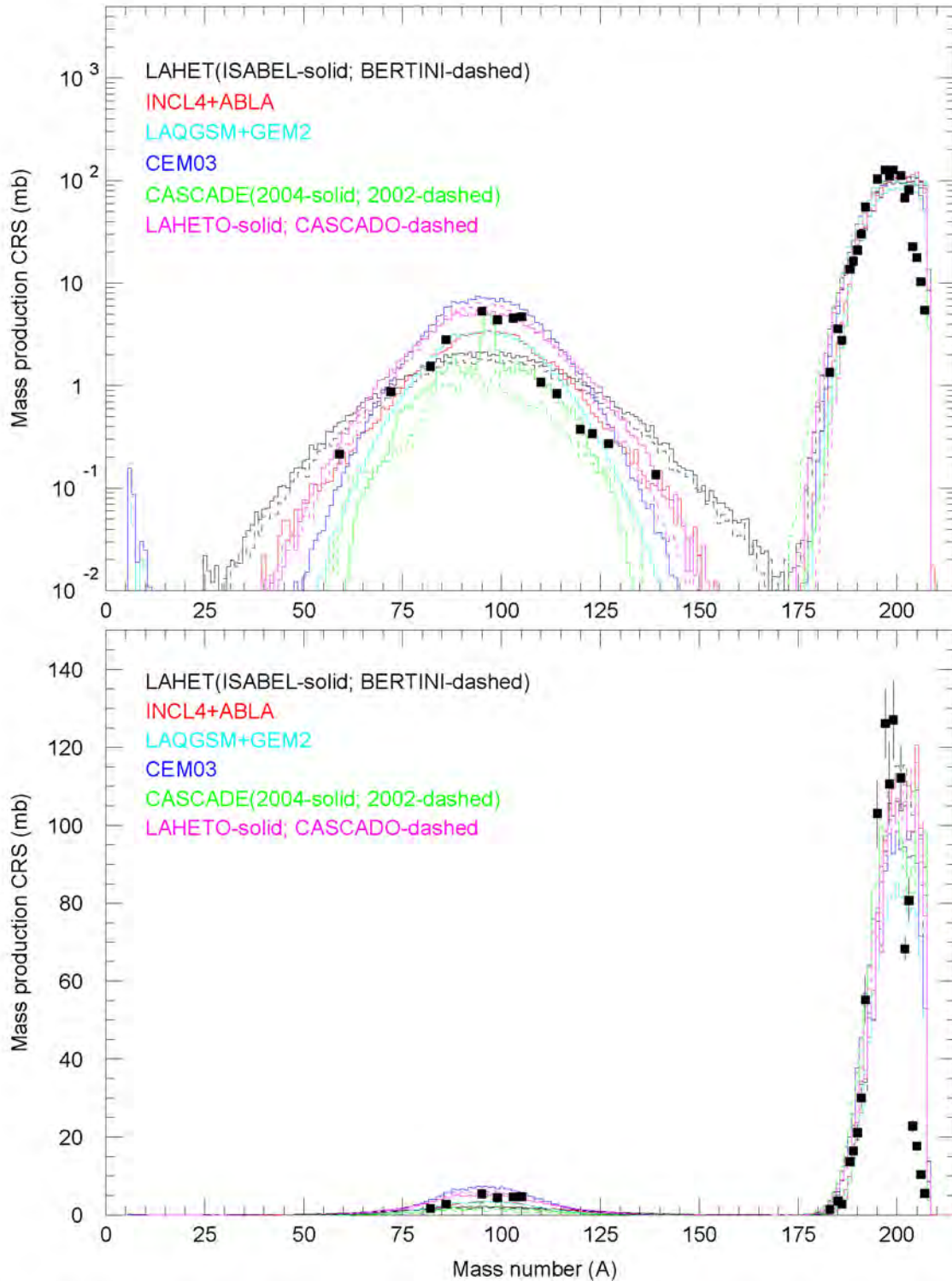


Fig. 107: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.25 GeV protons.

Mass production in ^{209}Bi induced by 250 MeV protons

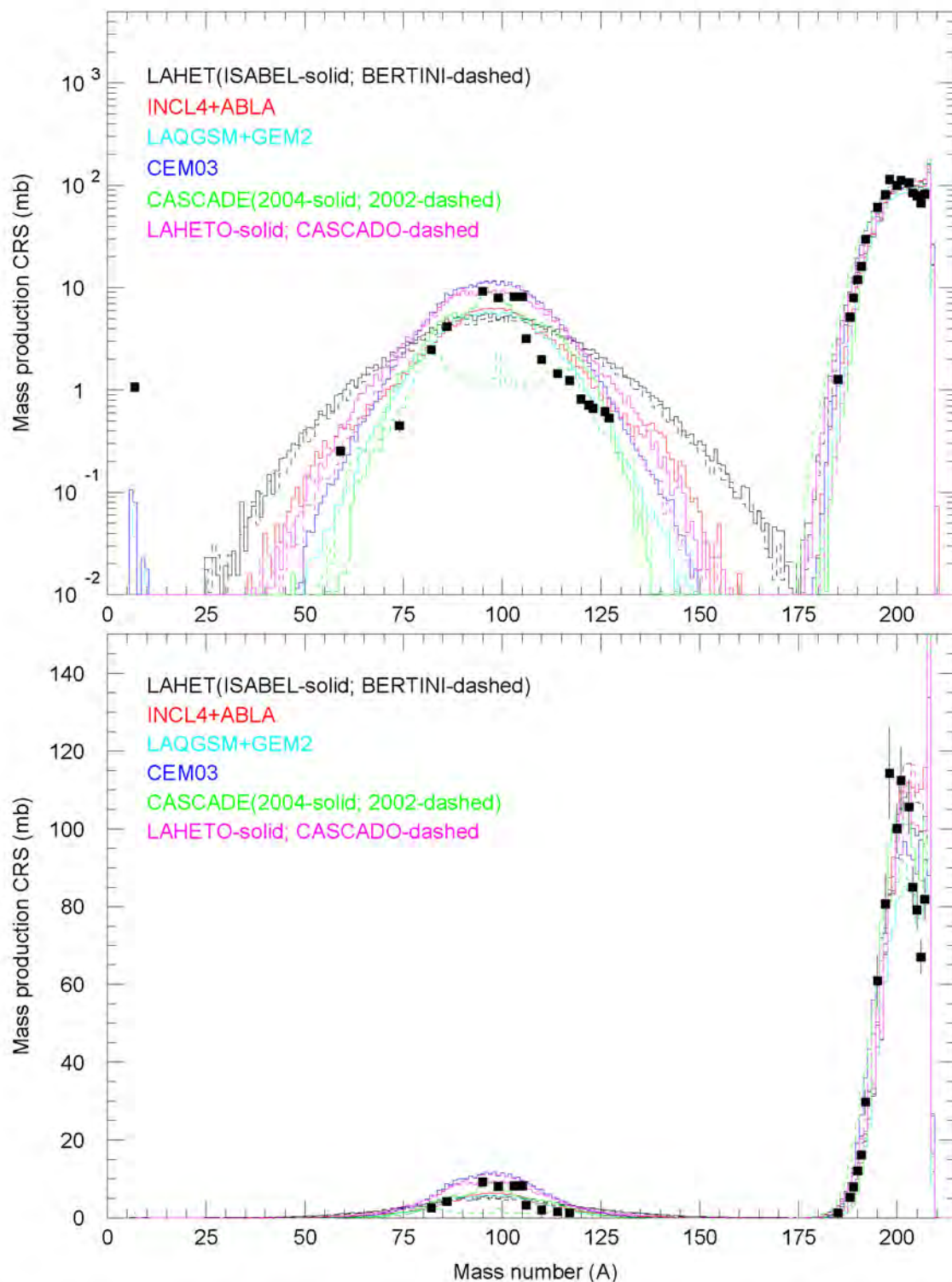


Fig. 108: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.25 GeV protons.

Mass production in ^{206}Pb induced by 400 MeV protons

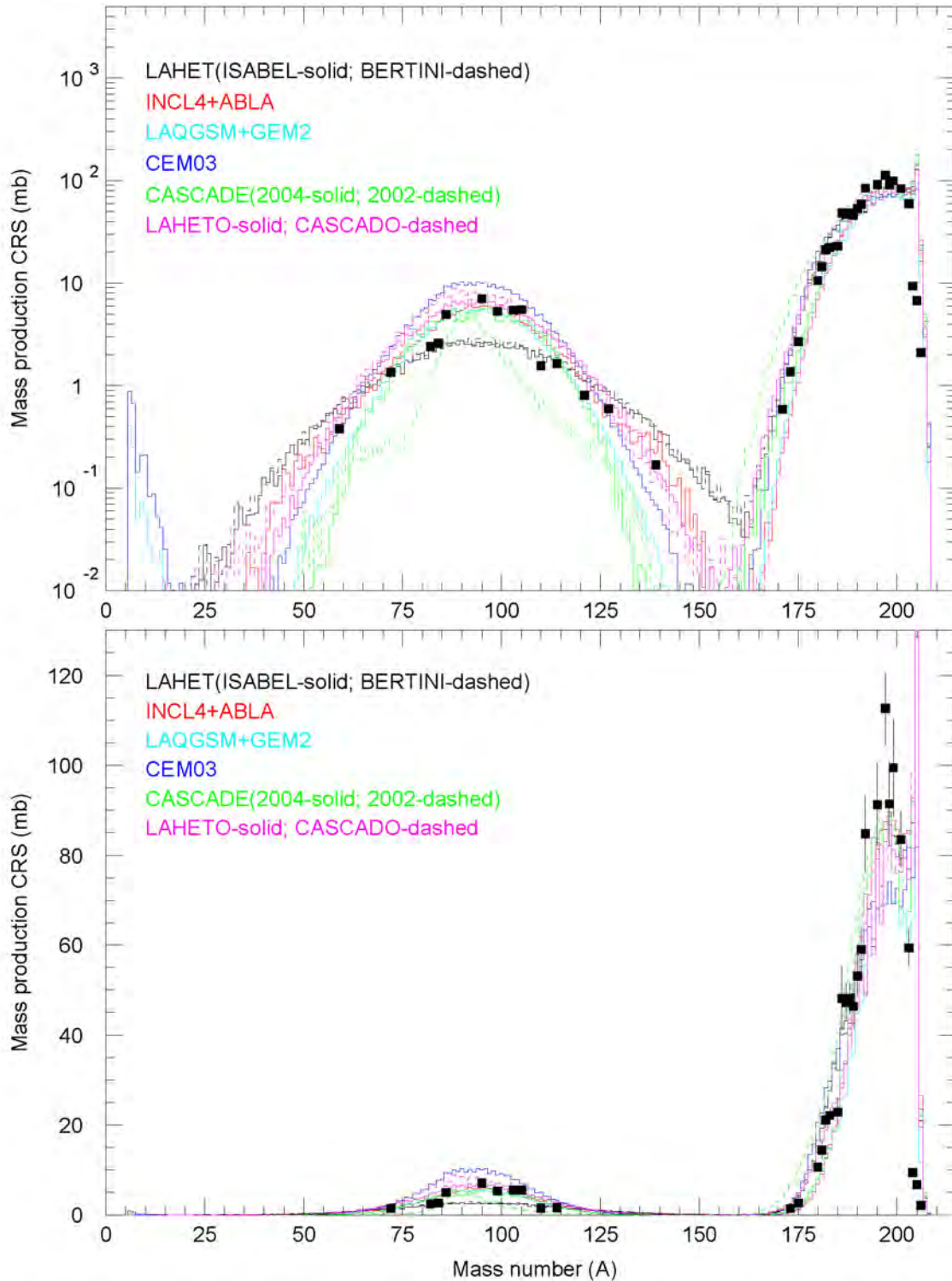


Fig. 109: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.4 GeV protons.

Mass production in ^{207}Pb induced by 400 MeV protons

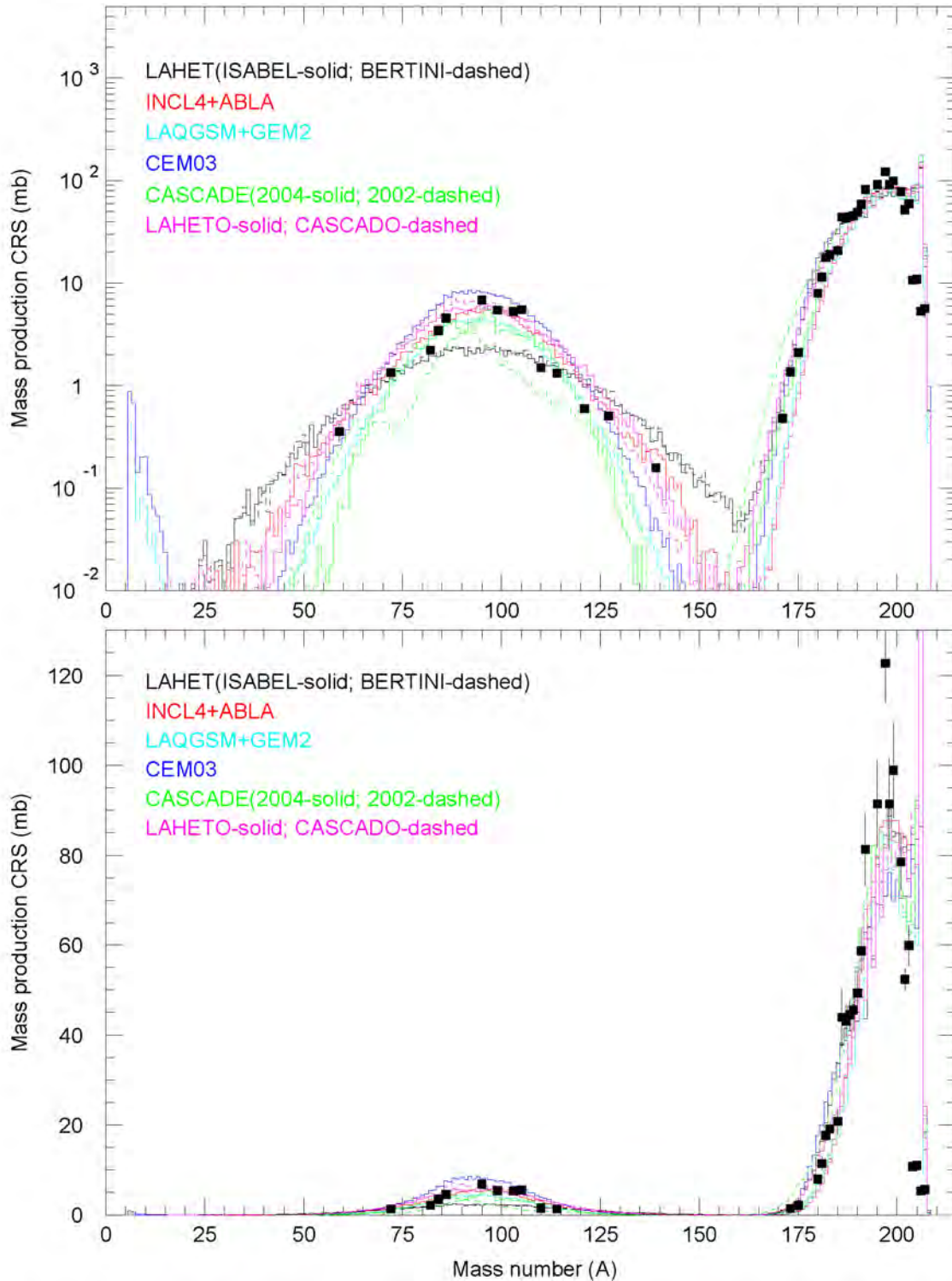


Fig. 110: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.4 GeV protons.

Mass production in ^{208}Pb induced by 400 MeV protons

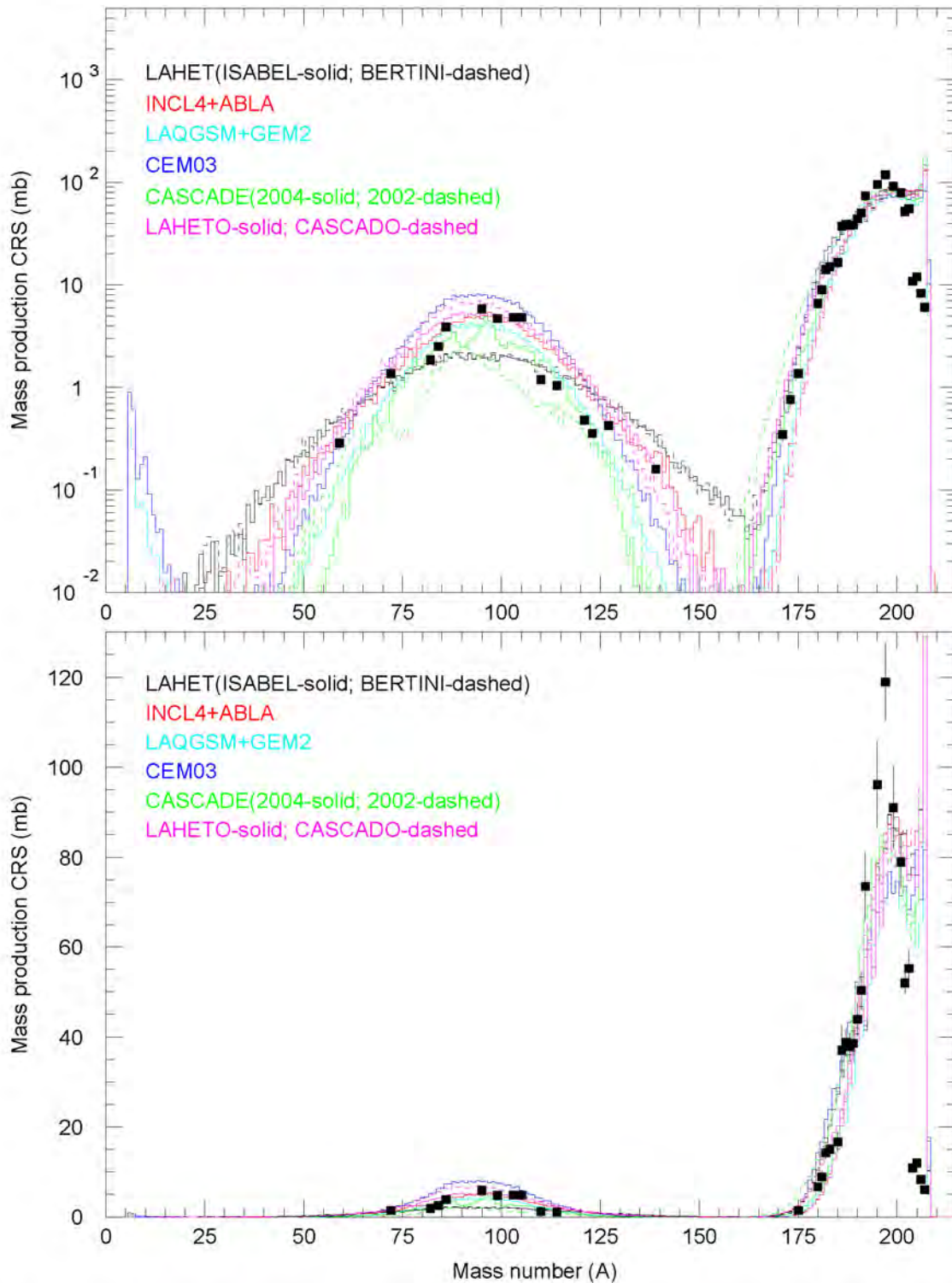


Fig. 111: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.4 GeV protons.

Mass production in ^{nat}Pb induced by 400 MeV protons

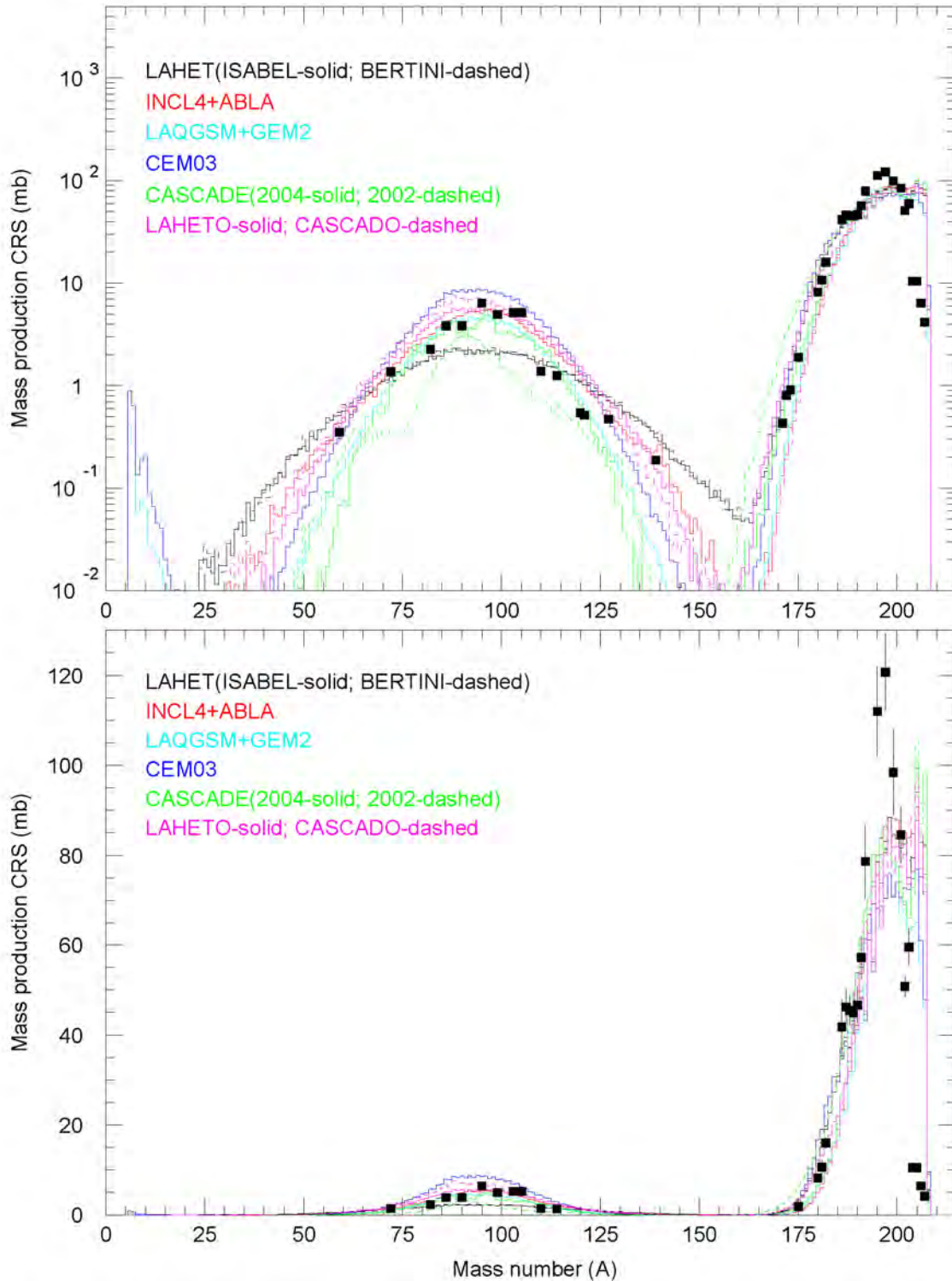


Fig. 112: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.4 GeV protons.

Mass production in ^{209}Bi induced by 400 MeV protons

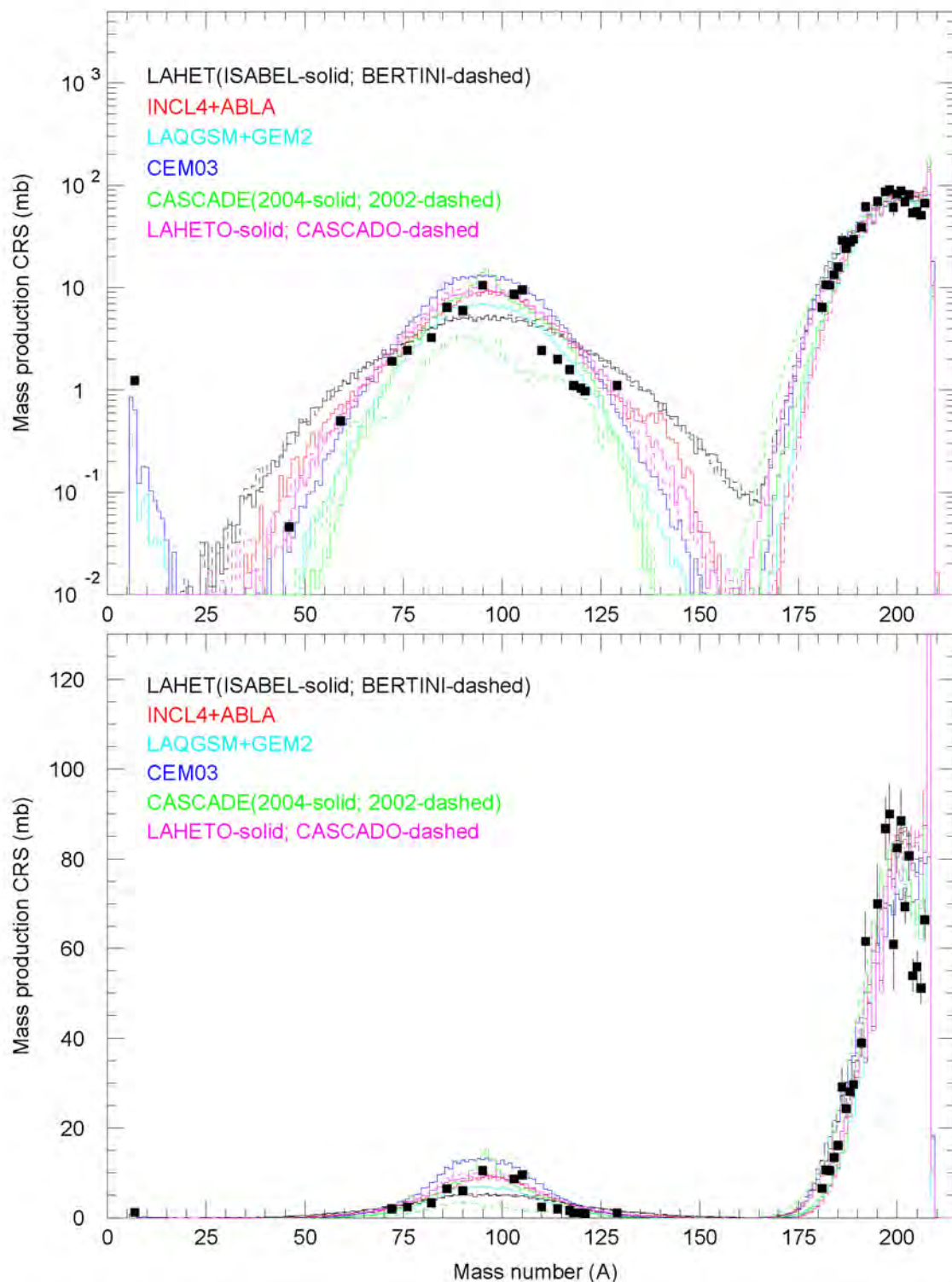


Fig. 113: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.4 GeV protons.

Mass production in ^{206}Pb induced by 600 MeV protons

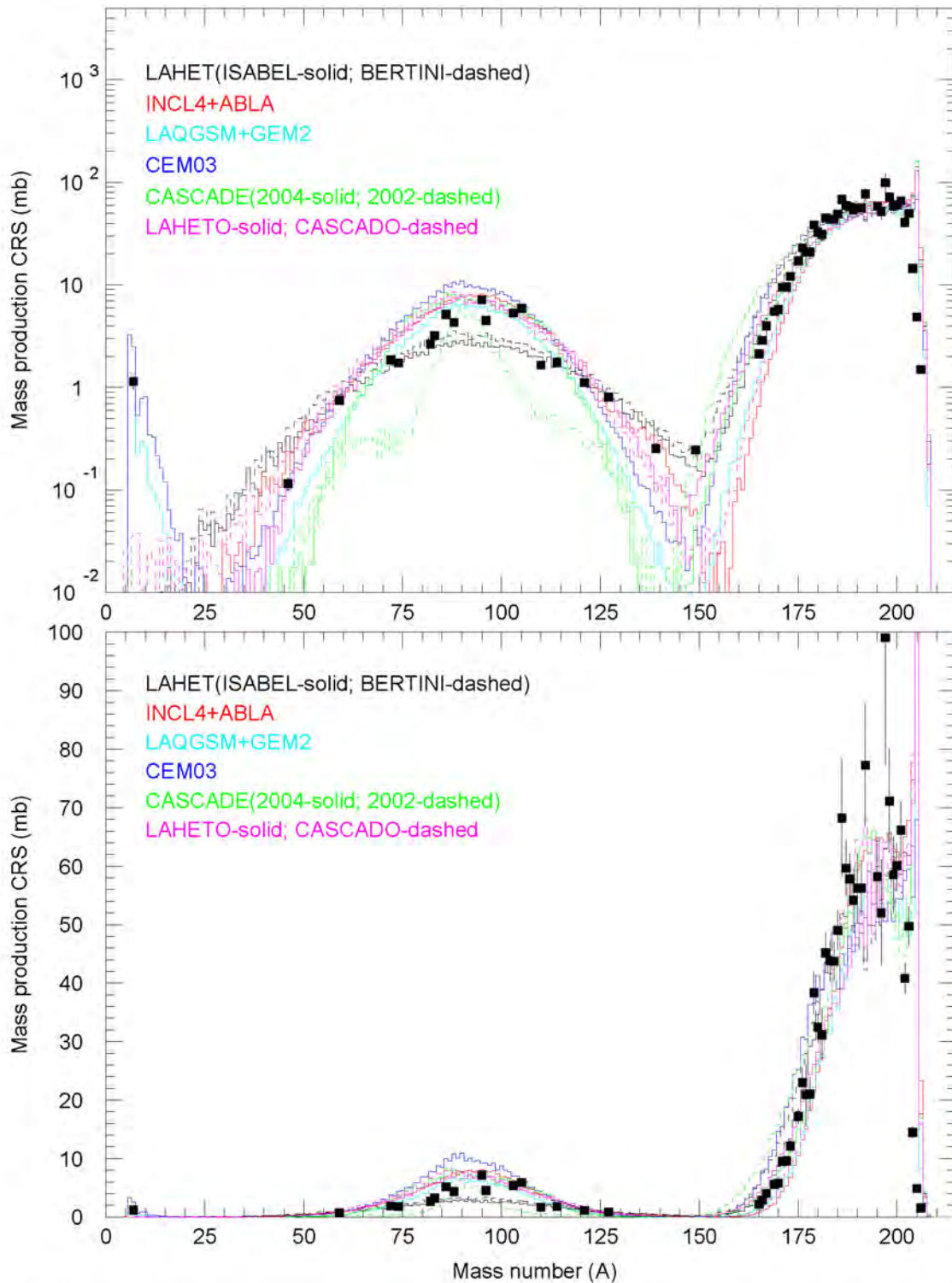


Fig. 114: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.6 GeV protons.

Mass production in ^{207}Pb induced by 600 MeV protons

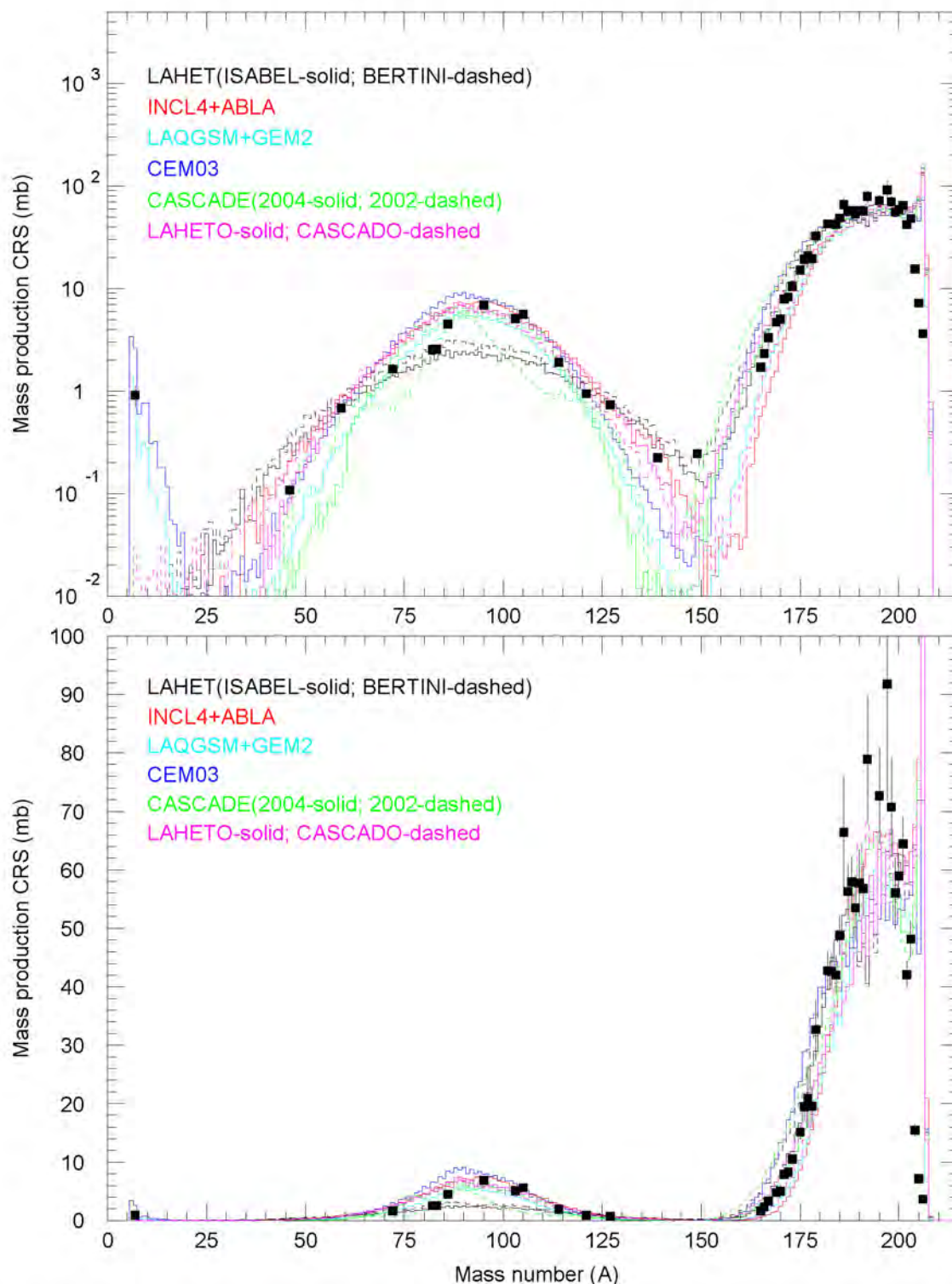


Fig. 115: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.06 GeV protons.

Mass production in ^{208}Pb induced by 600 MeV protons

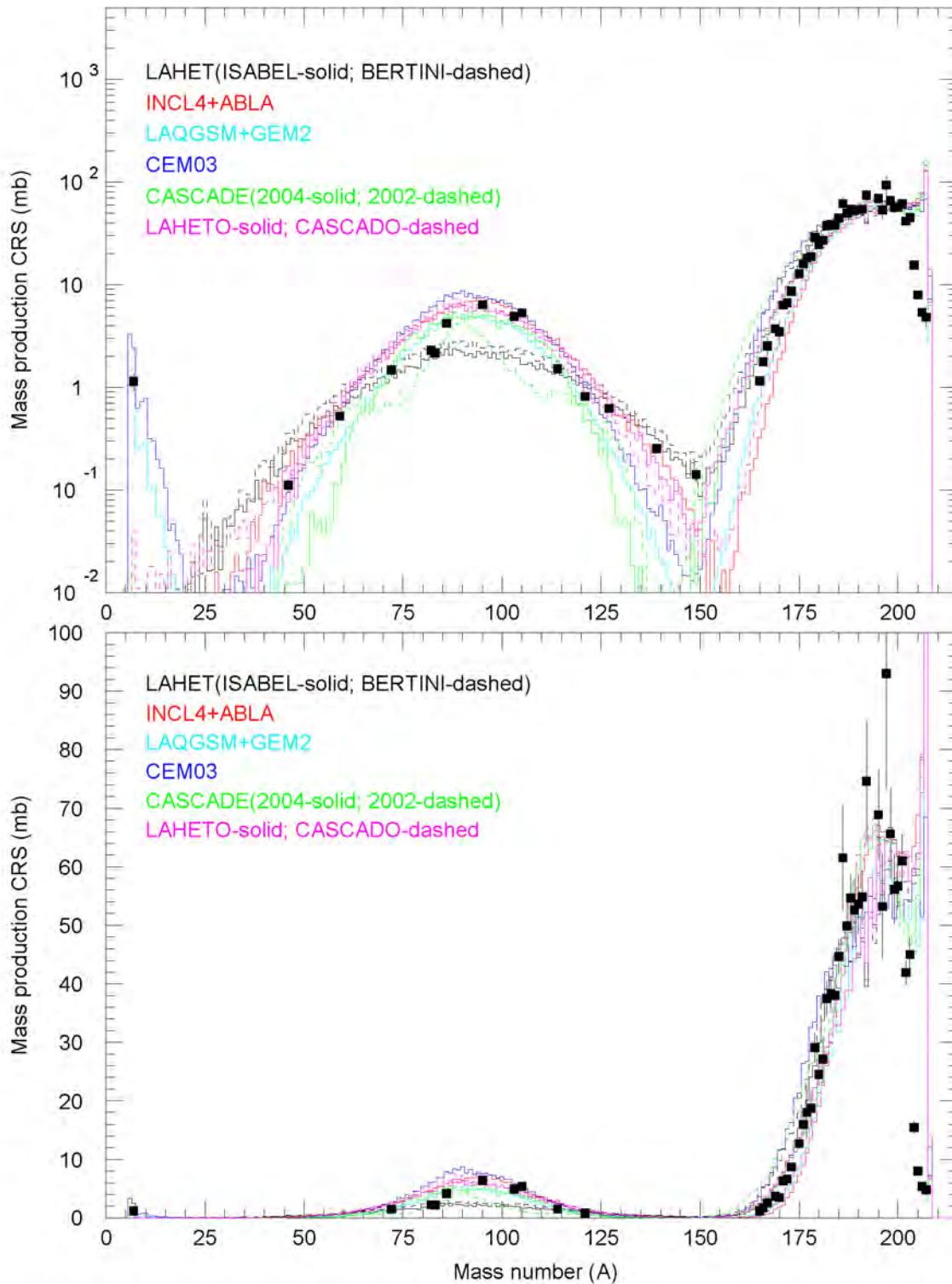


Fig. 116: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.6 GeV protons.

Mass production in ^{nat}Pb induced by 600 MeV protons

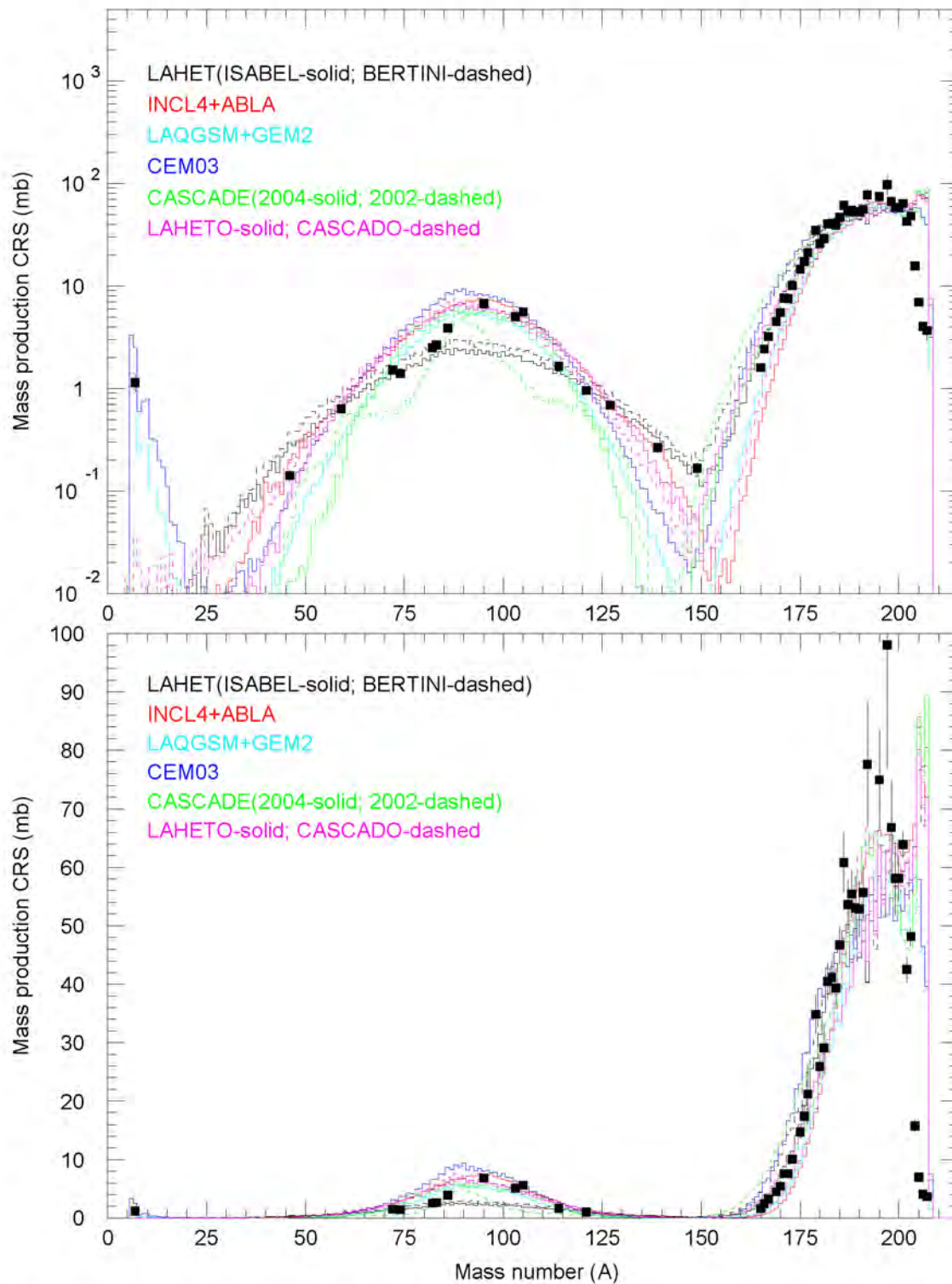


Fig. 117: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.6 GeV protons.

Mass production in ^{209}Bi induced by 600 MeV protons

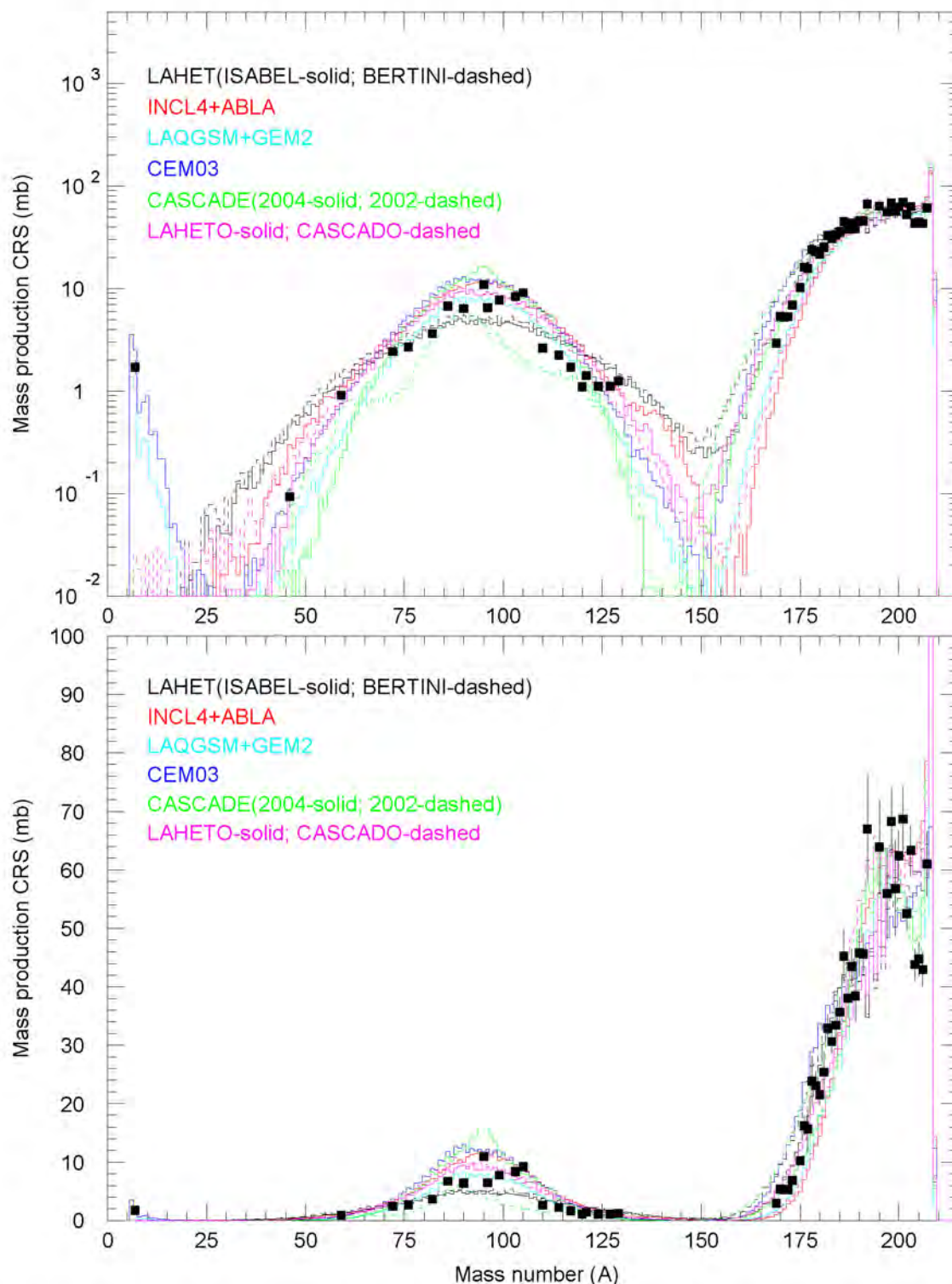


Fig. 118: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.6 GeV protons.

Mass production in ^{206}Pb induced by 800 MeV protons

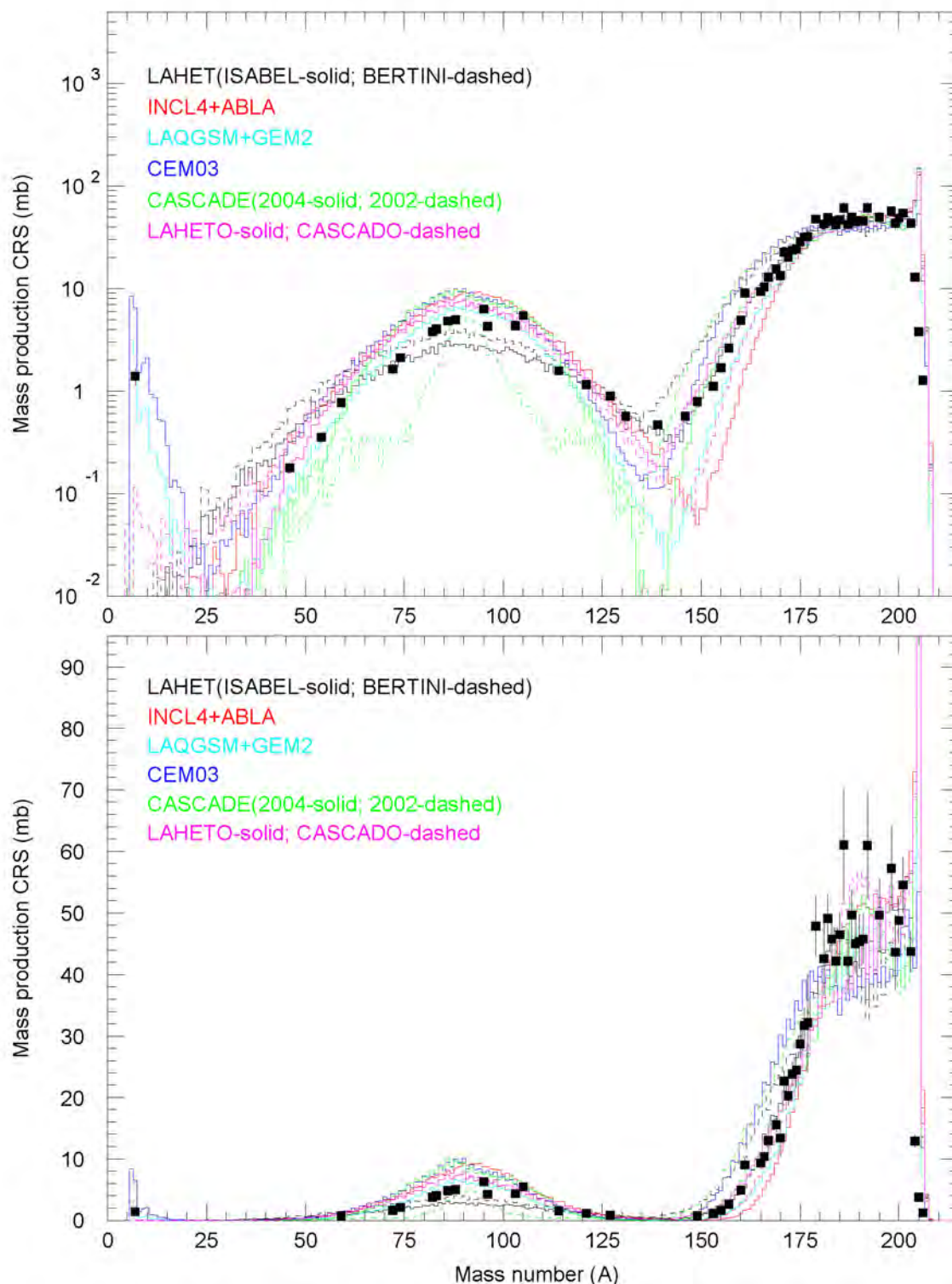


Fig. 119: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 0.8 GeV protons.

Mass production in ^{207}Pb induced by 800 MeV protons

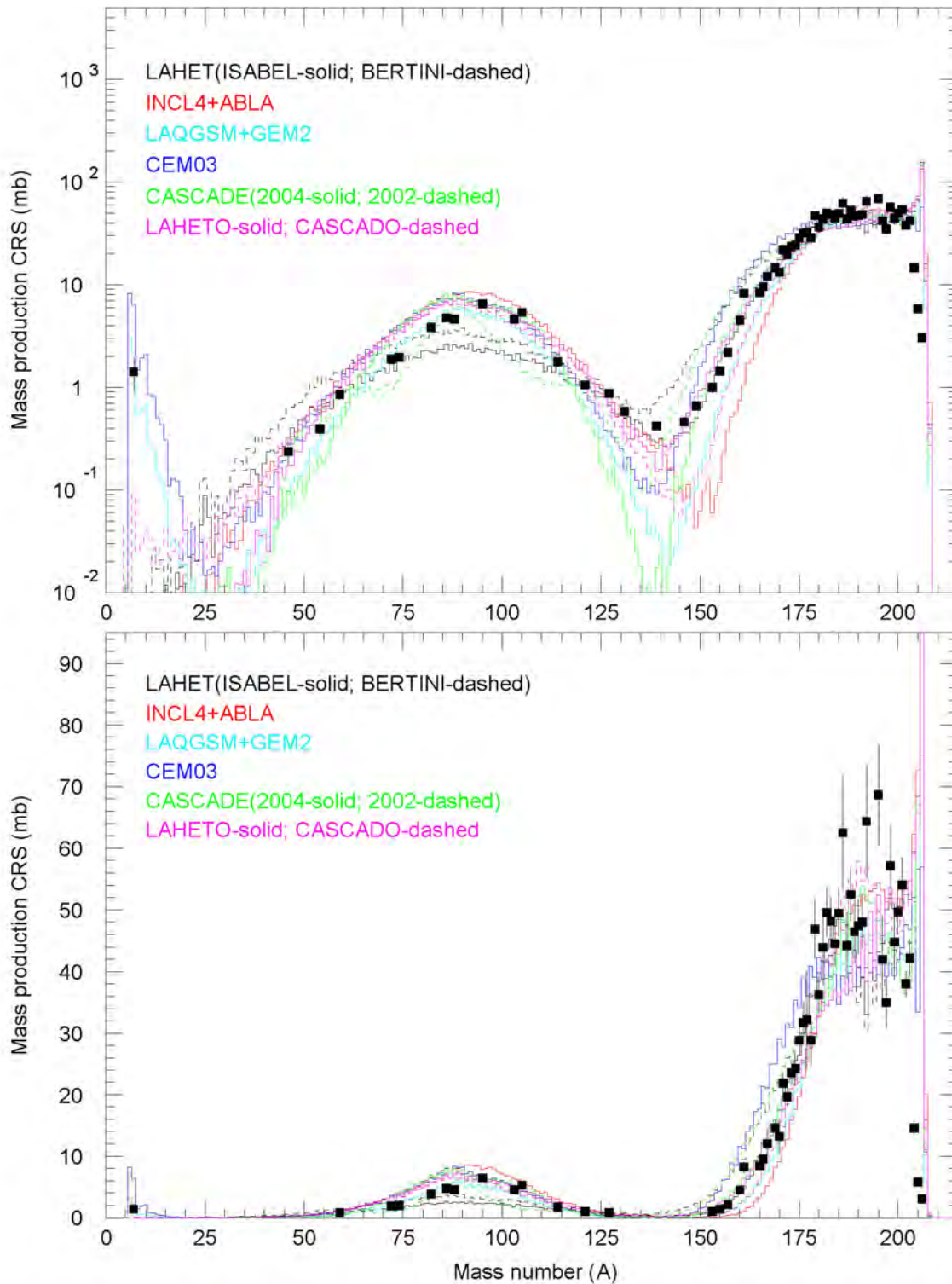


Fig. 120: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 0.8 GeV protons.

Mass production in ^{208}Pb induced by 800 MeV protons

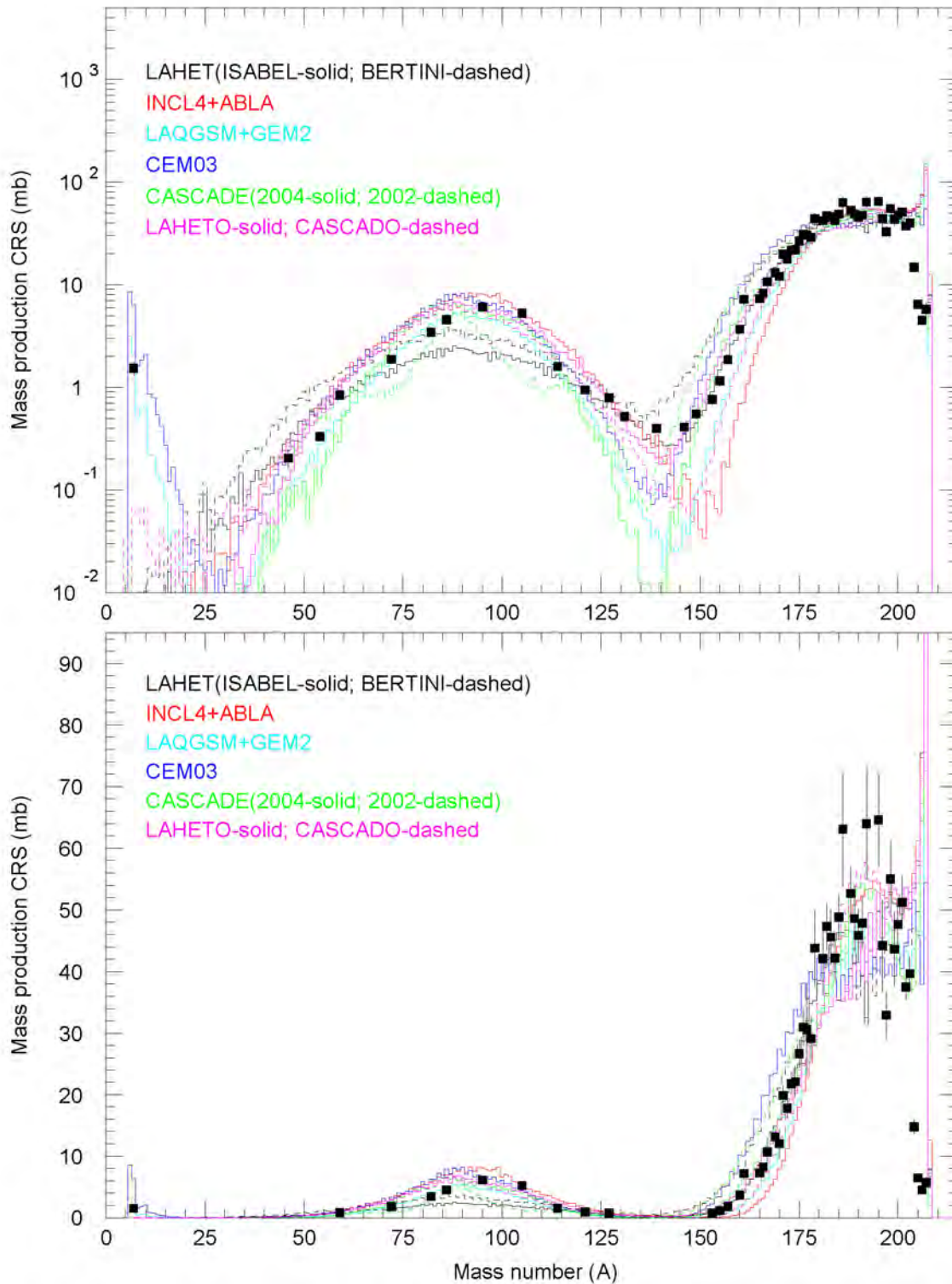


Fig. 121: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 0.8 GeV protons.

Mass production in ^{nat}Pb induced by 800 MeV protons

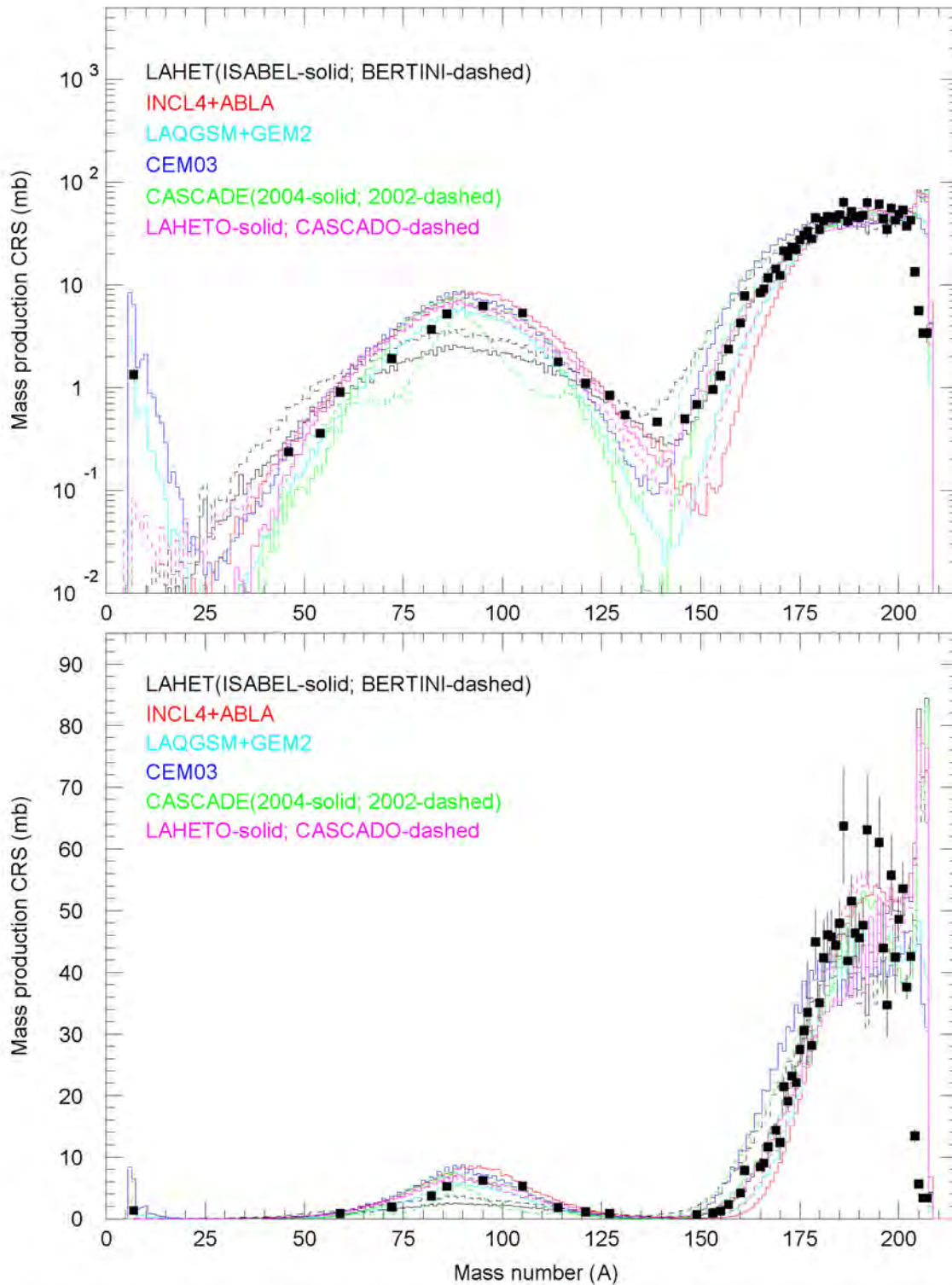


Fig. 122: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 0.8 GeV protons.

Mass production in ^{209}Bi induced by 800 MeV protons

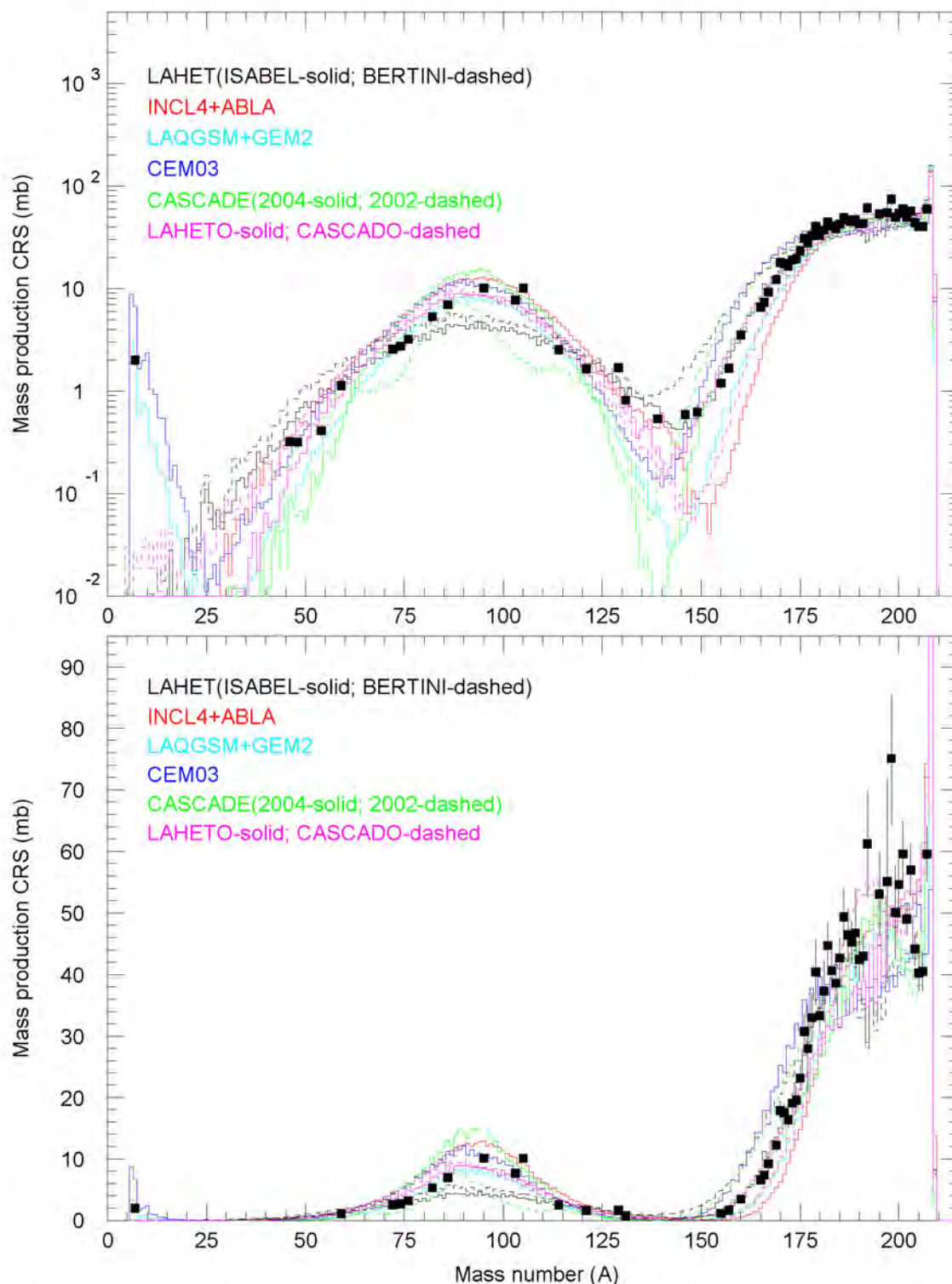


Fig. 123: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 0.8 GeV protons.

Mass production in ^{206}Pb induced by 1200 MeV protons

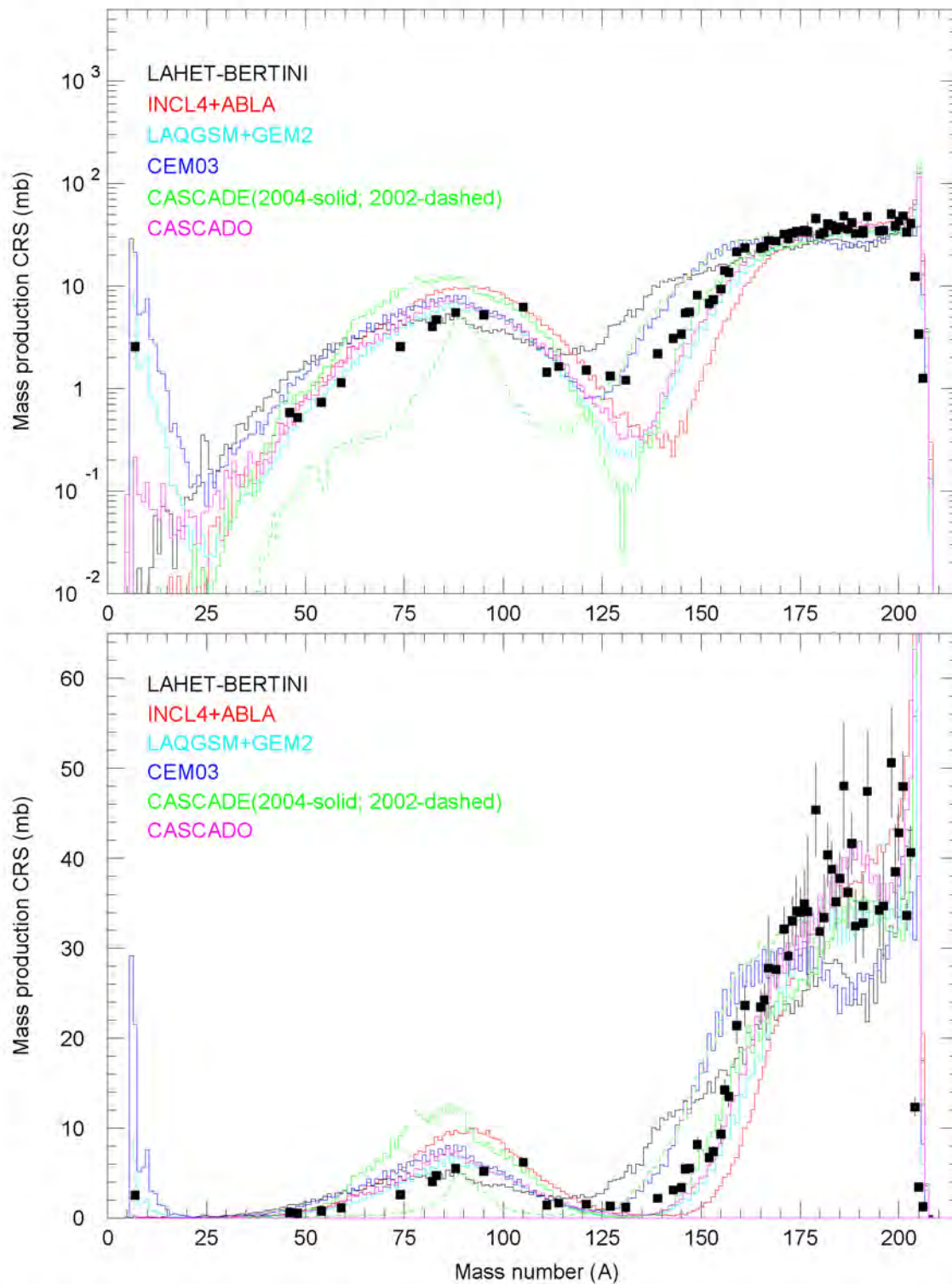


Fig. 124: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 1.2 GeV protons.

Mass production in ^{207}Pb induced by 1200 MeV protons

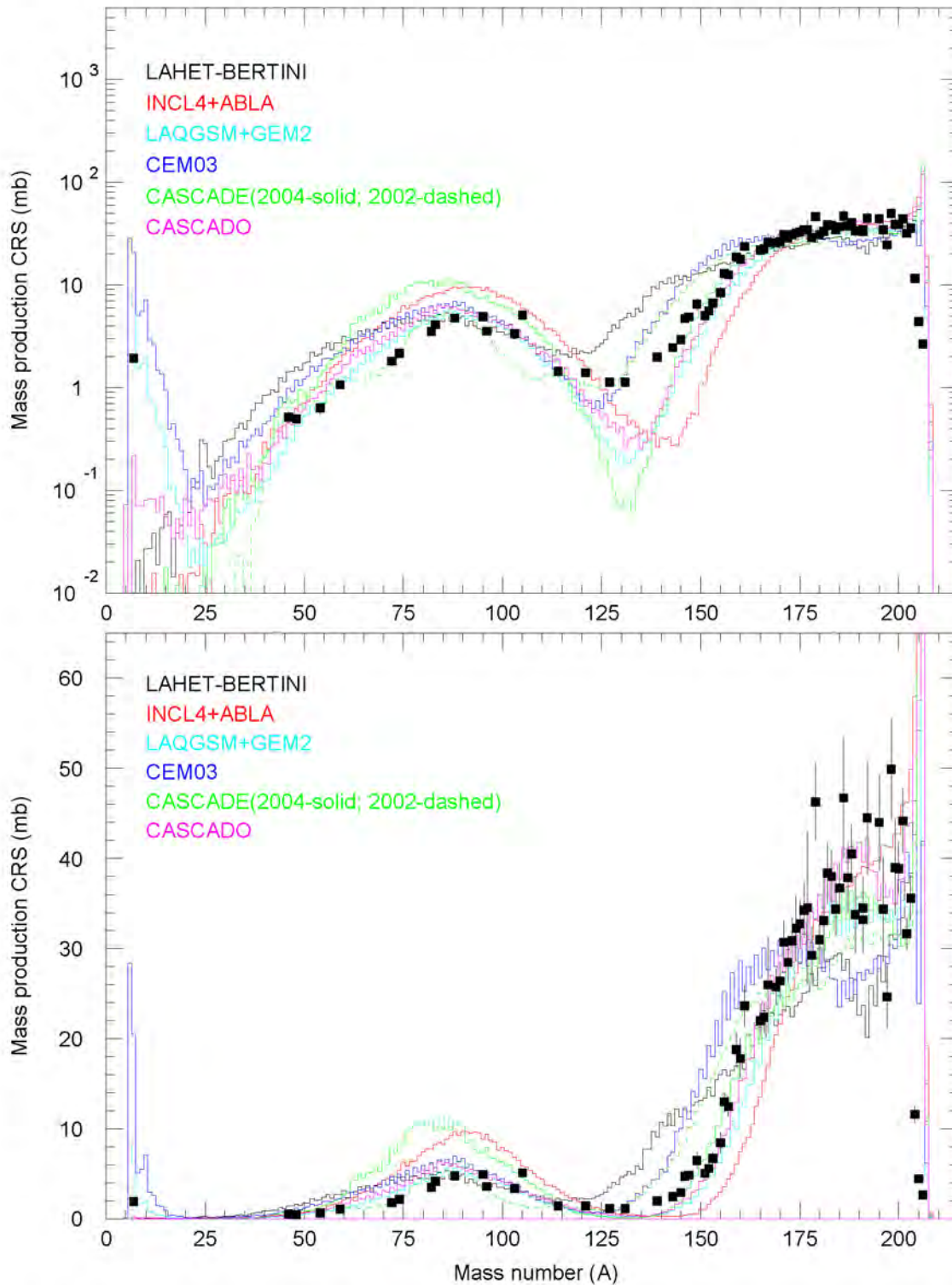


Fig. 125: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 1.2 GeV protons.

Mass production in ^{208}Pb induced by 1200 MeV protons

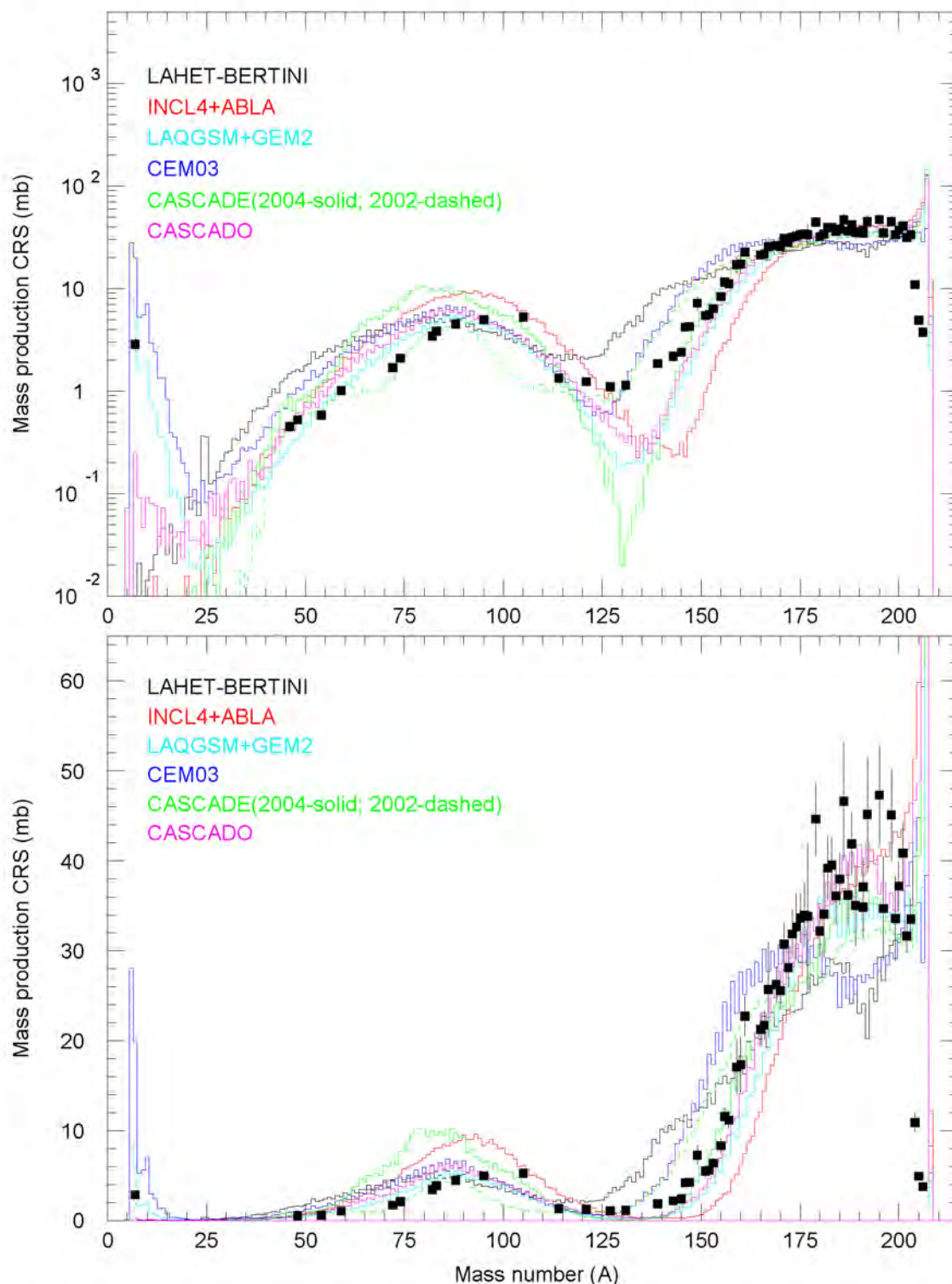


Fig. 126: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 1.2 GeV protons.

Mass production in ^{nat}Pb induced by 1200 MeV protons

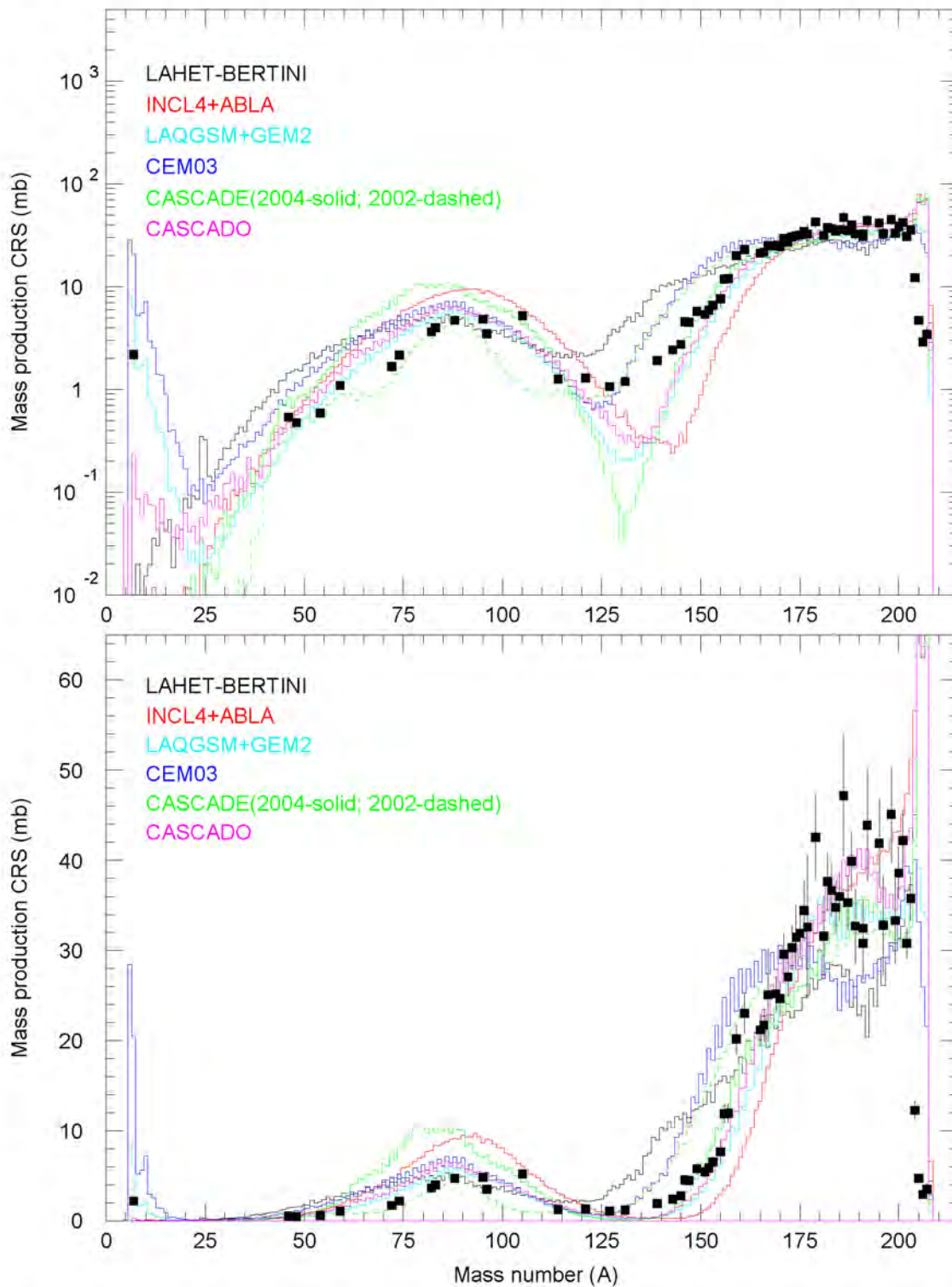


Fig. 127: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 1.2 GeV protons.

Mass production in ^{209}Bi induced by 1200 MeV protons

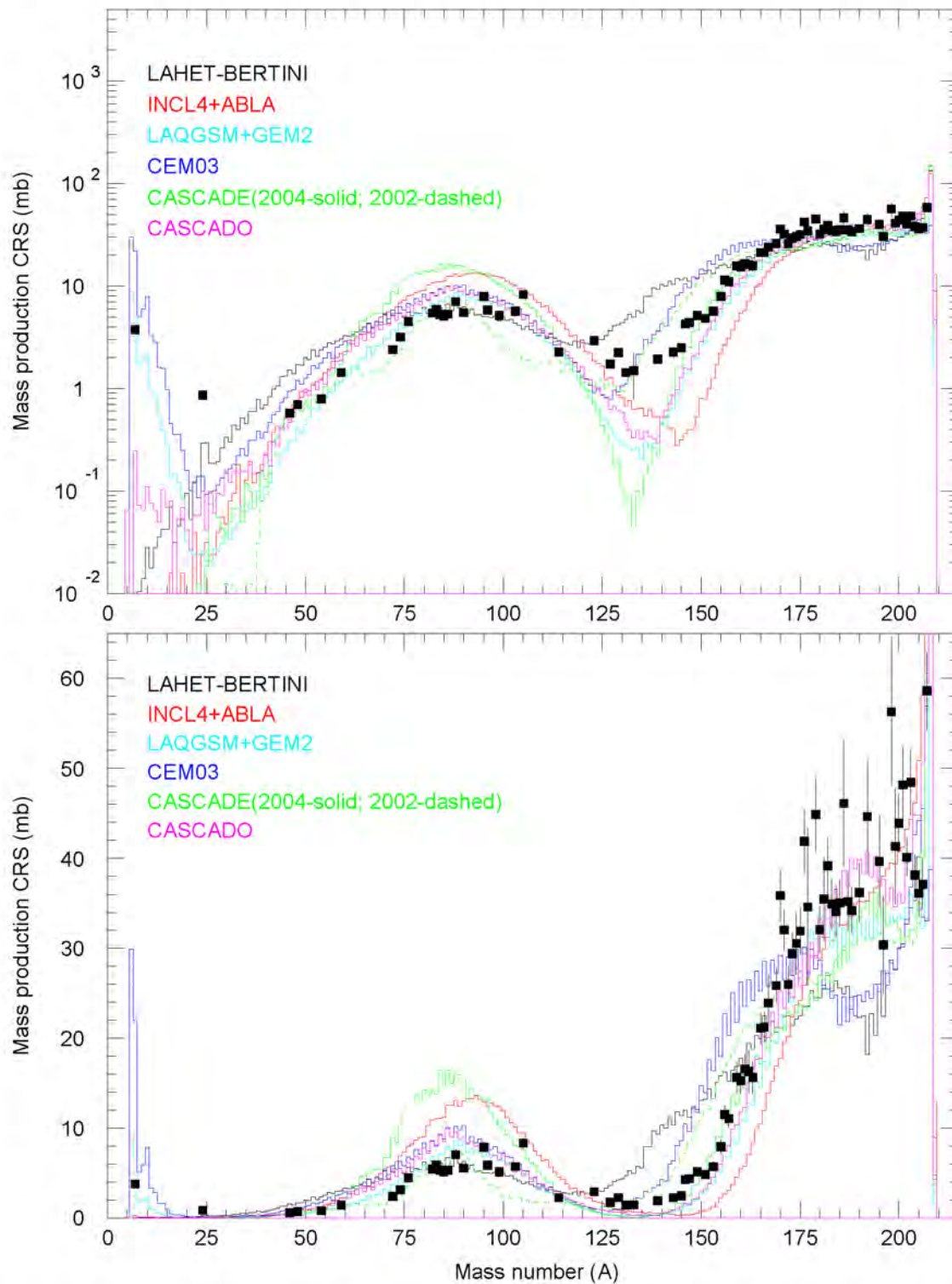


Fig. 128: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 1.2 GeV protons.

Mass production in ^{206}Pb induced by 1600 MeV protons

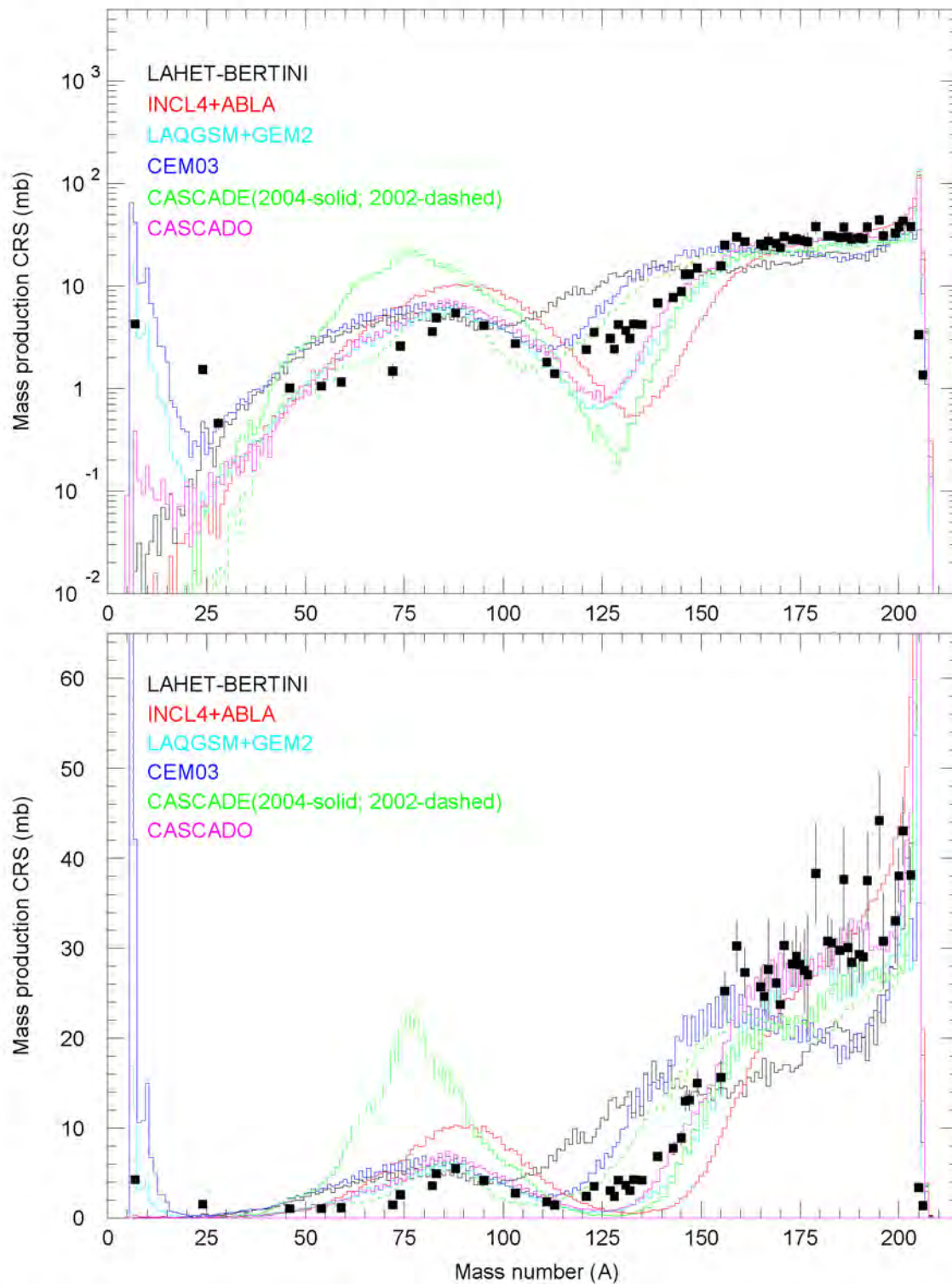


Fig. 129: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 1.6 GeV protons.

Mass production in ^{207}Pb induced by 1600 MeV protons

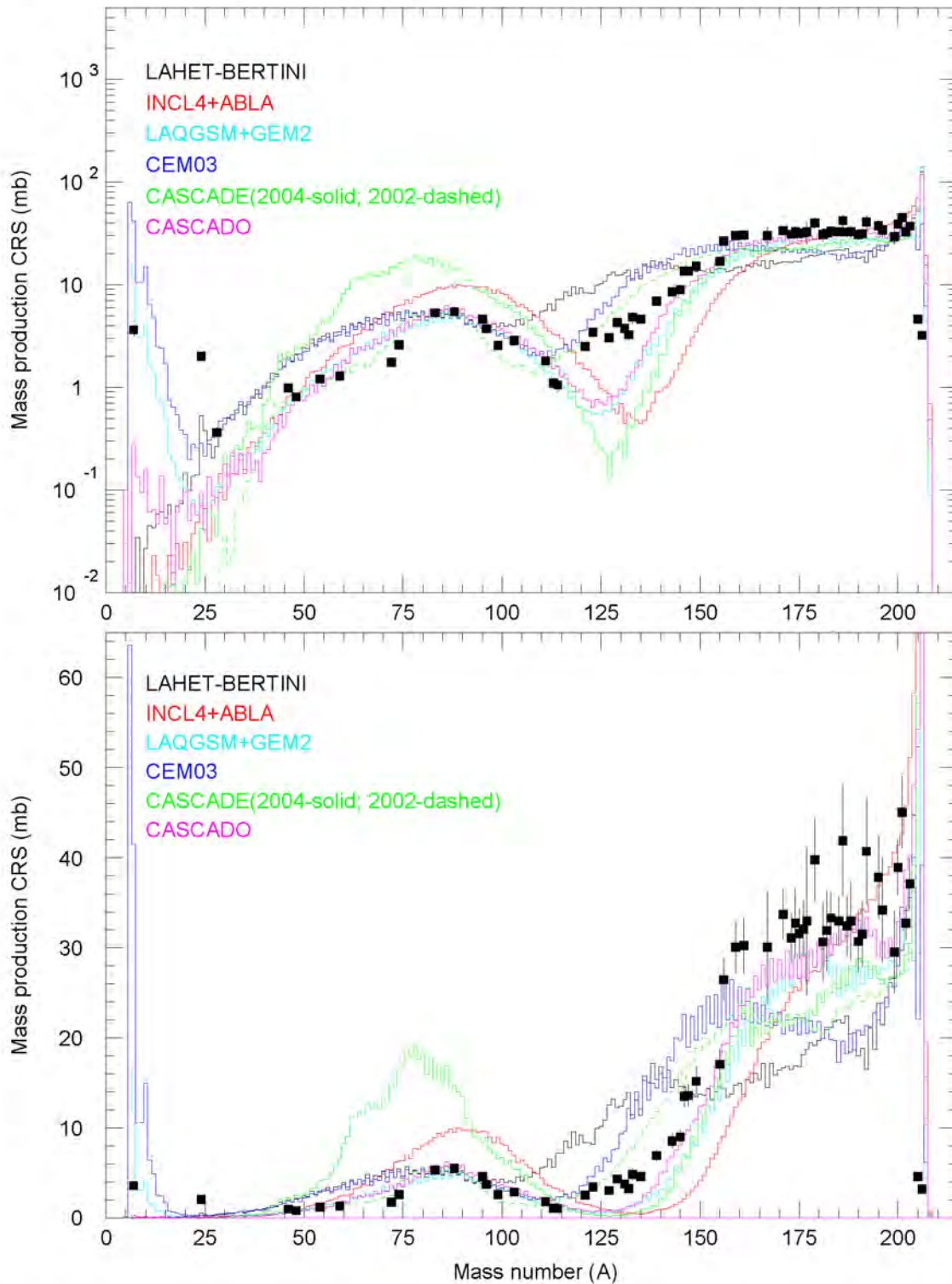


Fig. 130: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 1.6 GeV protons.

Mass production in ^{208}Pb induced by 1600 MeV protons

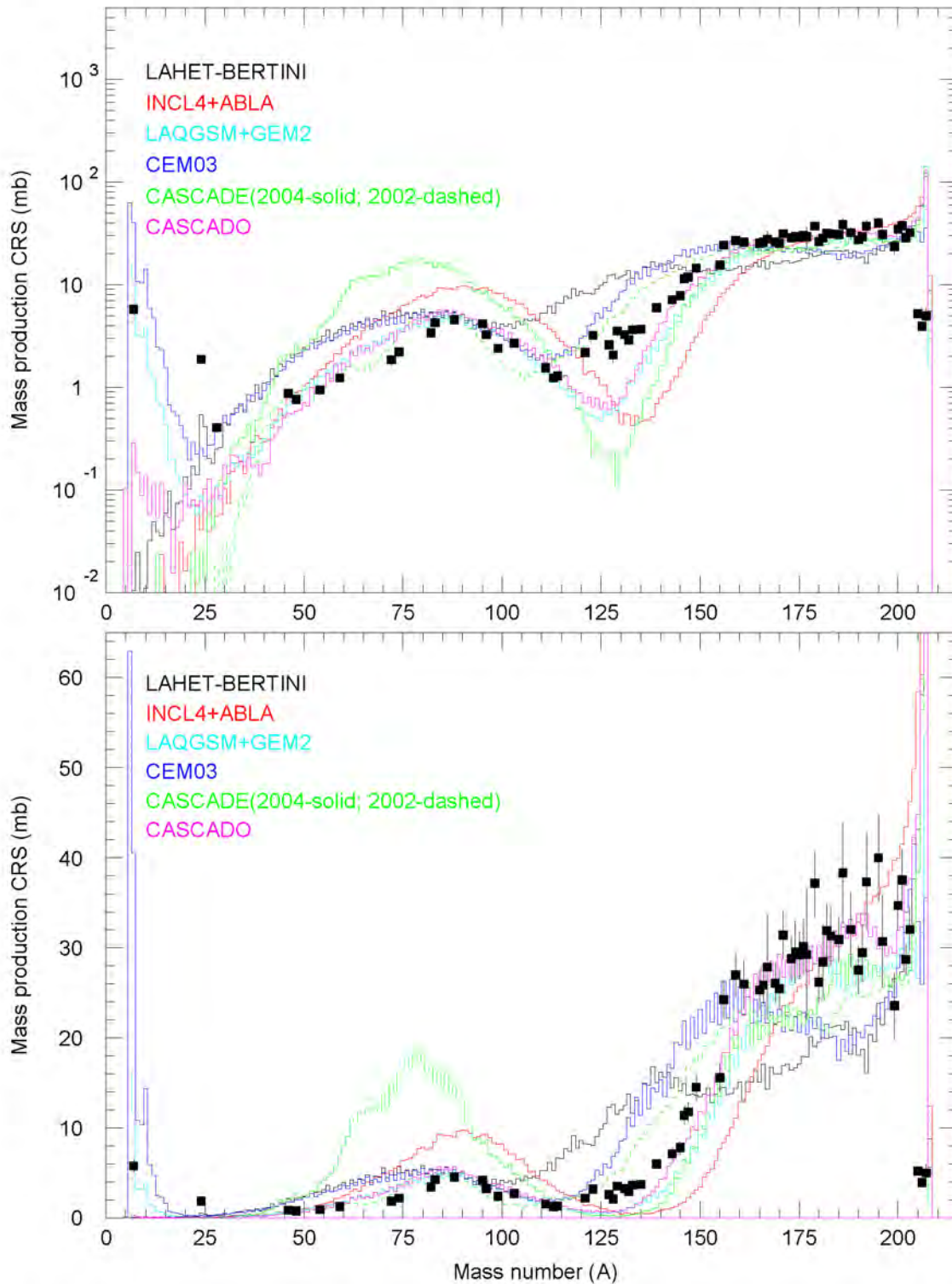


Fig. 131: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 1.6 GeV protons.

Mass production in ^{nat}Pb induced by 1600 MeV protons

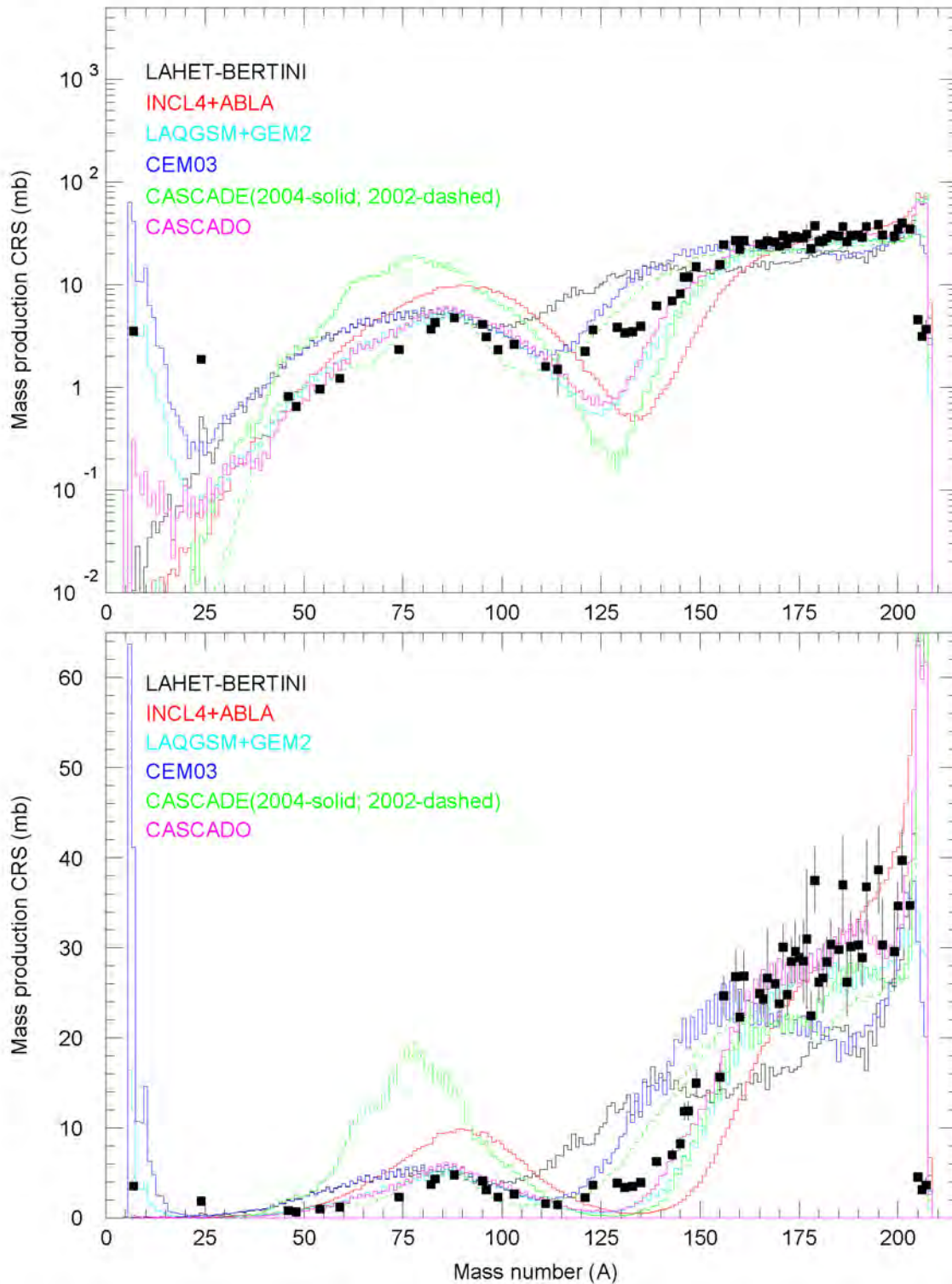


Fig. 132: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 1.6 GeV protons.

Mass production in ^{209}Bi induced by 1600 MeV protons

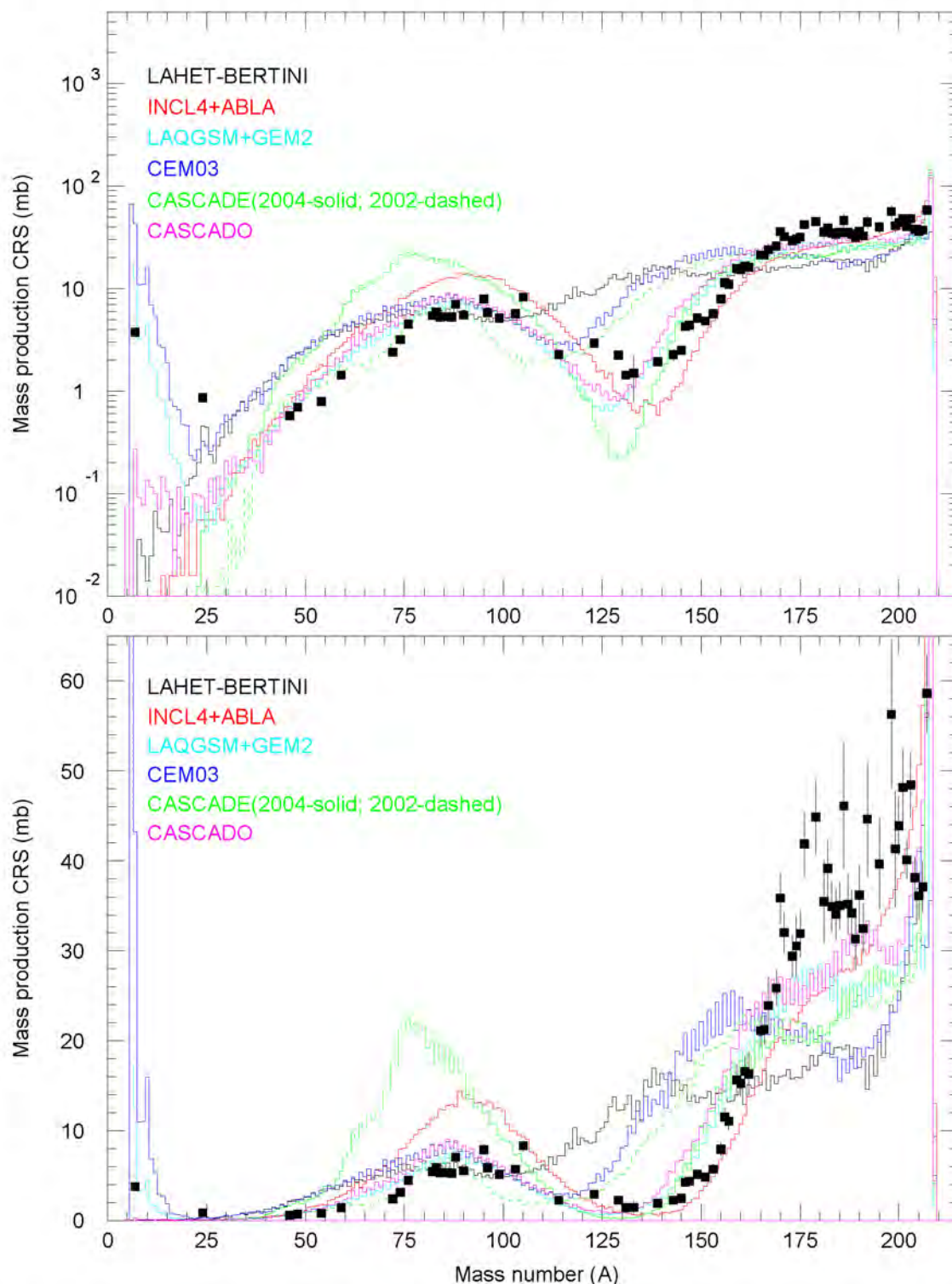


Fig. 133: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 1.6 GeV protons.

Mass production in ^{206}Pb induced by 2600 MeV protons

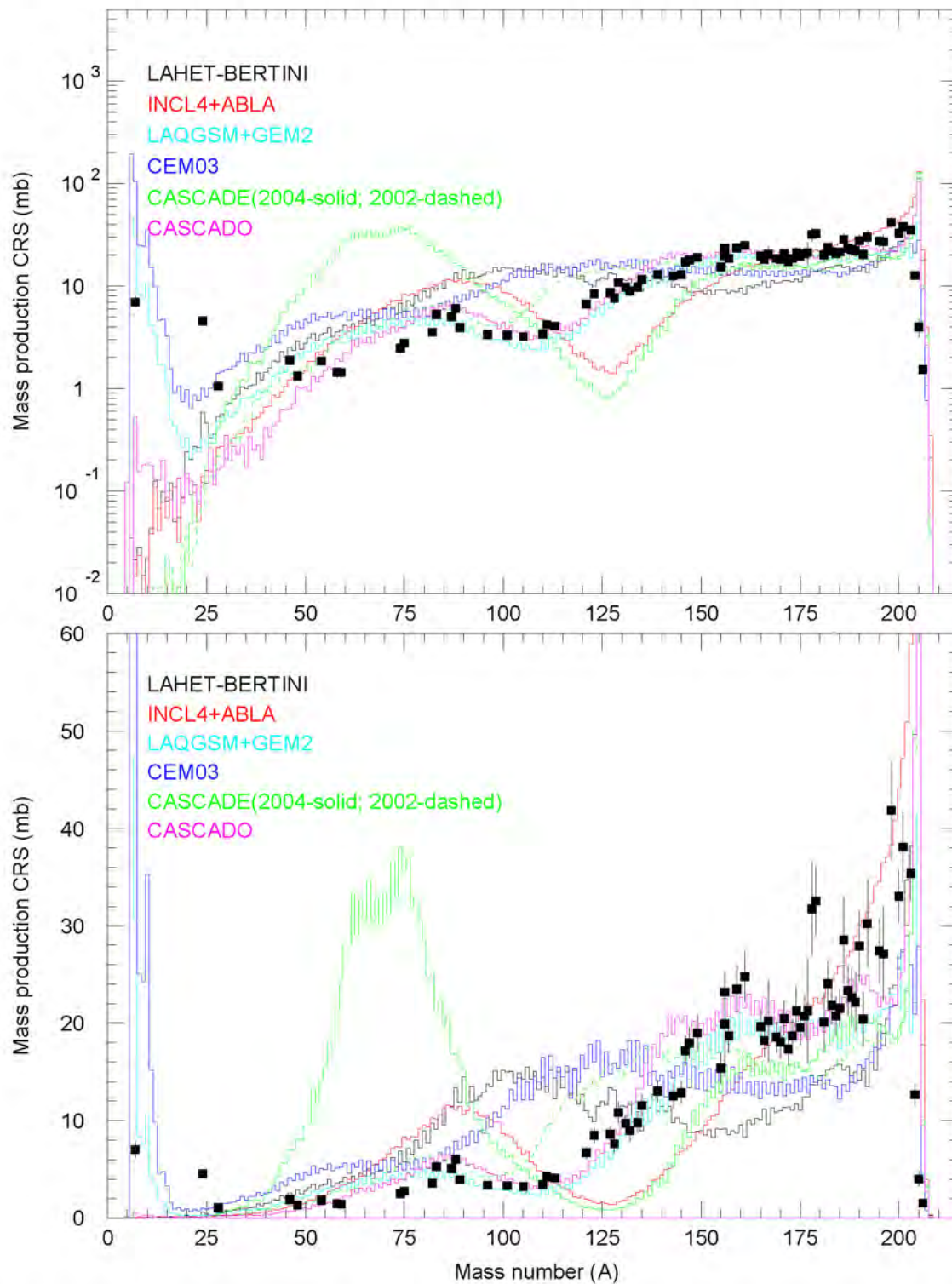


Fig. 134: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{206}Pb irradiated with 2.6 GeV protons.

Mass production in ^{207}Pb induced by 2600 MeV protons

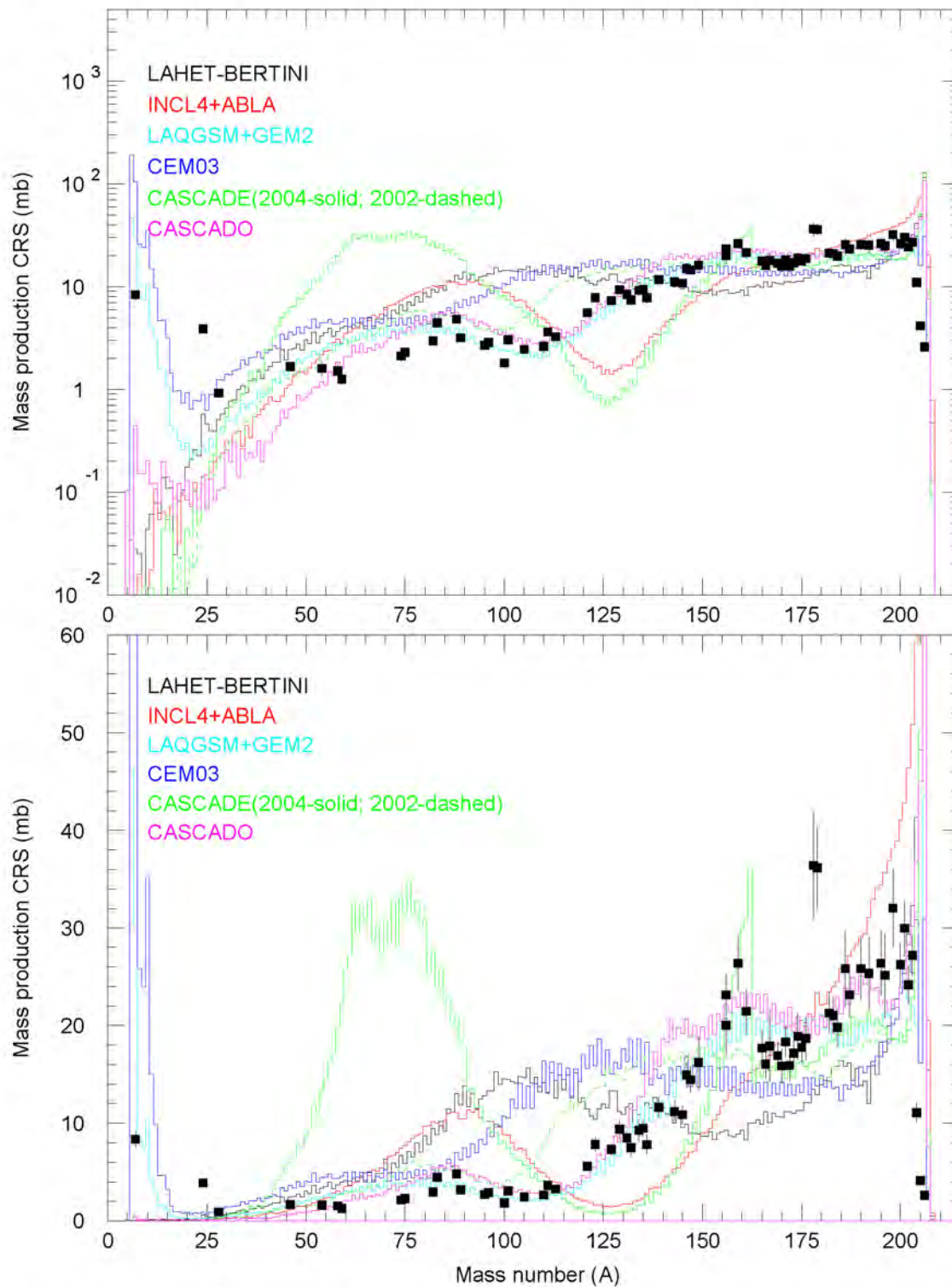


Fig. 135: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{207}Pb irradiated with 2.6 GeV protons.

Mass production in ^{208}Pb induced by 2600 MeV protons

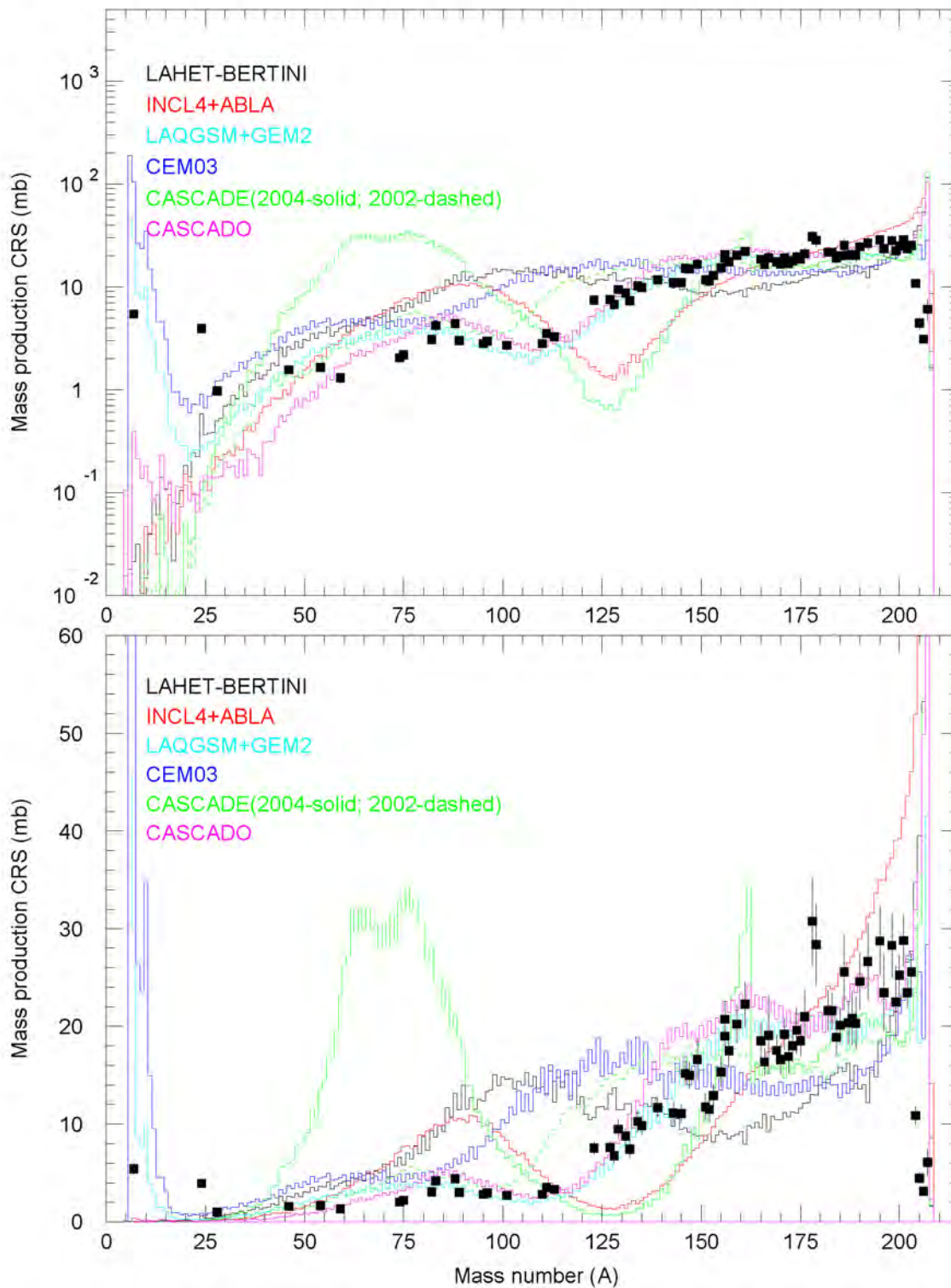


Fig. 136: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{208}Pb irradiated with 2.6 GeV protons.

Mass production in ^{nat}Pb induced by 2600 MeV protons

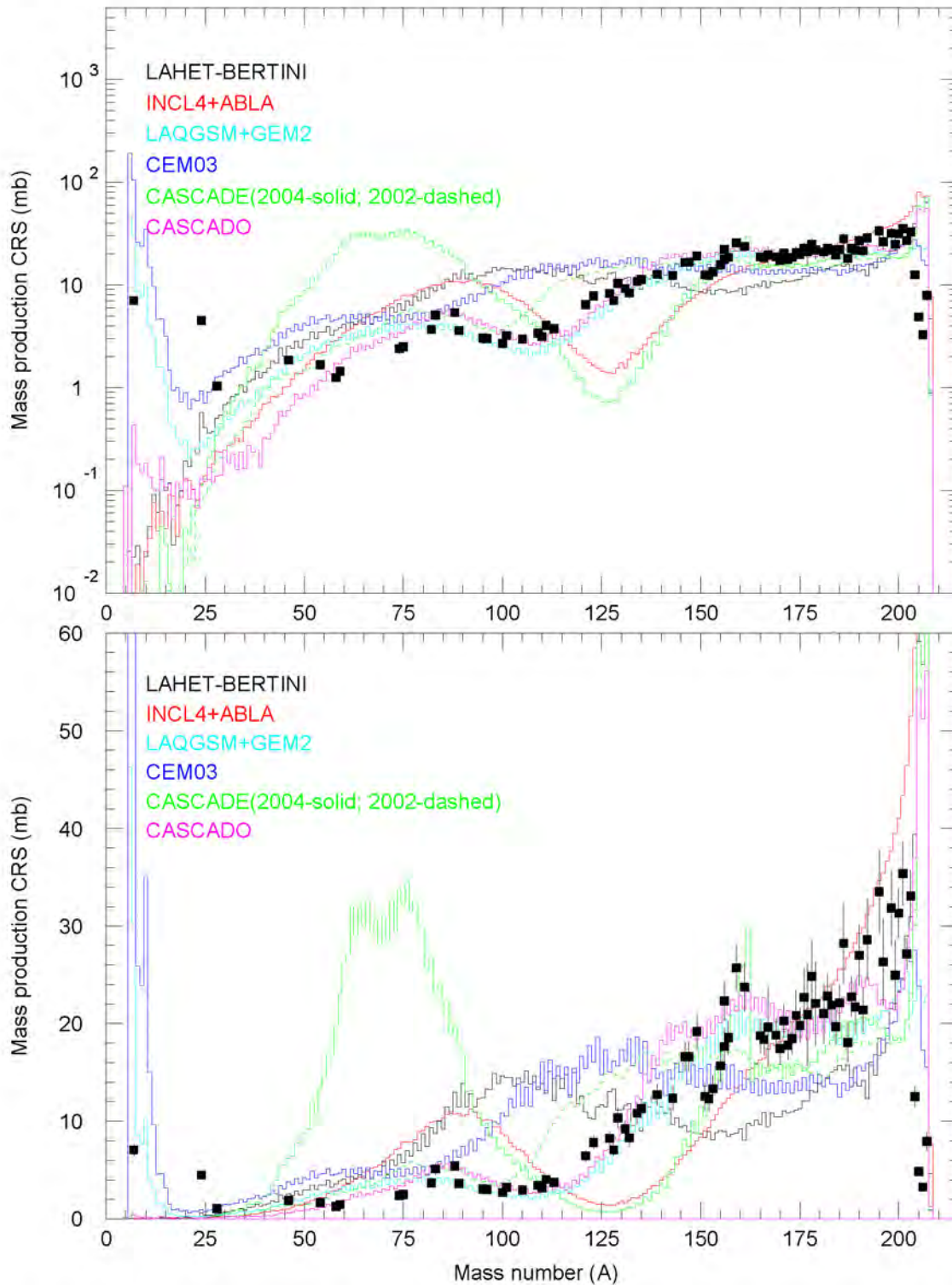


Fig. 137: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{nat}Pb irradiated with 2.6 GeV protons.

Mass production in ^{209}Bi induced by 2600 MeV protons

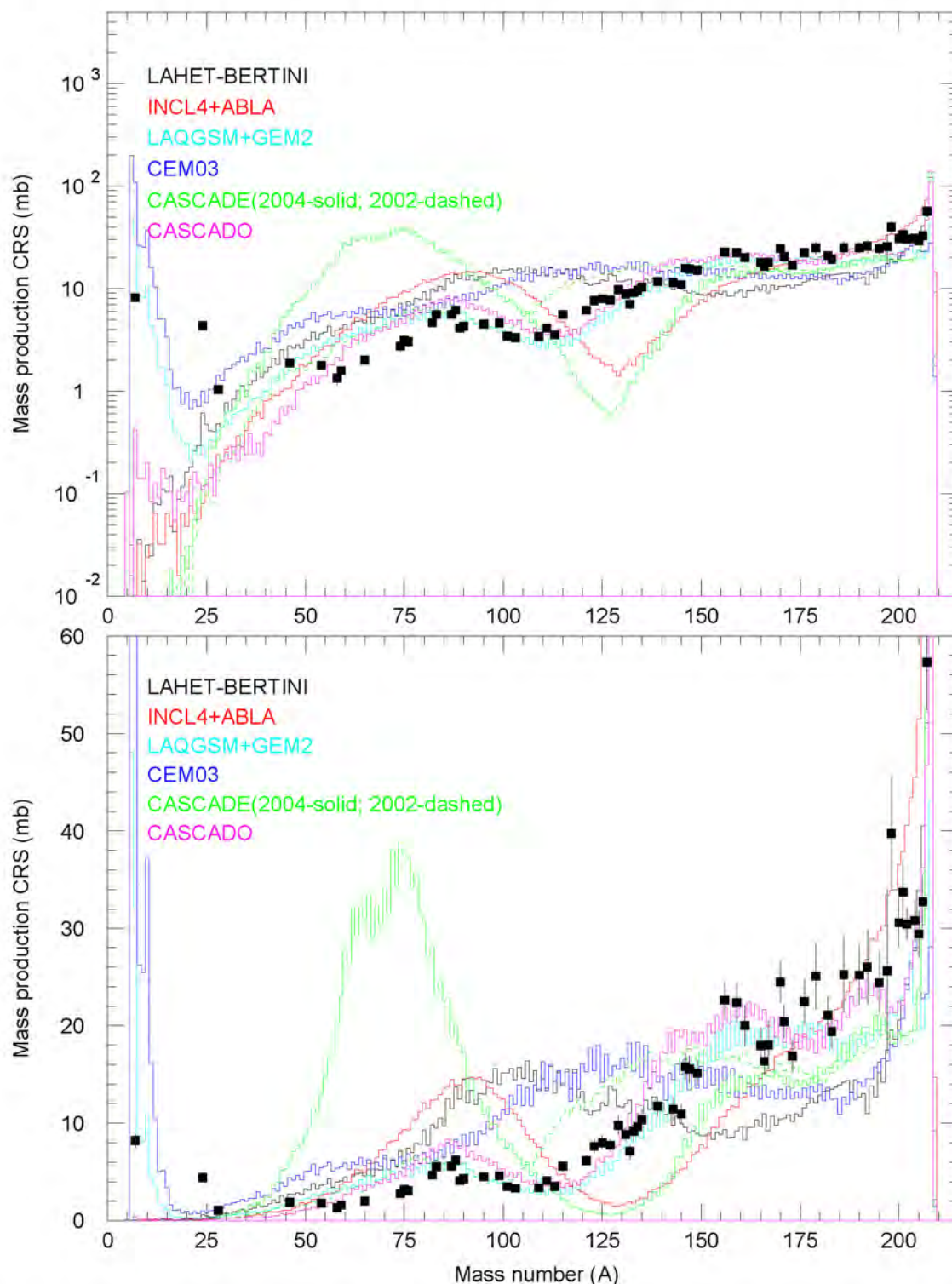


Fig. 138: The simulated mass distributions of reaction products together with the measured cumulative and supra-cumulative yields in ^{209}Bi irradiated with 2.6 GeV protons.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $E_p < 0.1 \text{ GeV}$; $A_{\text{product}} > 170$

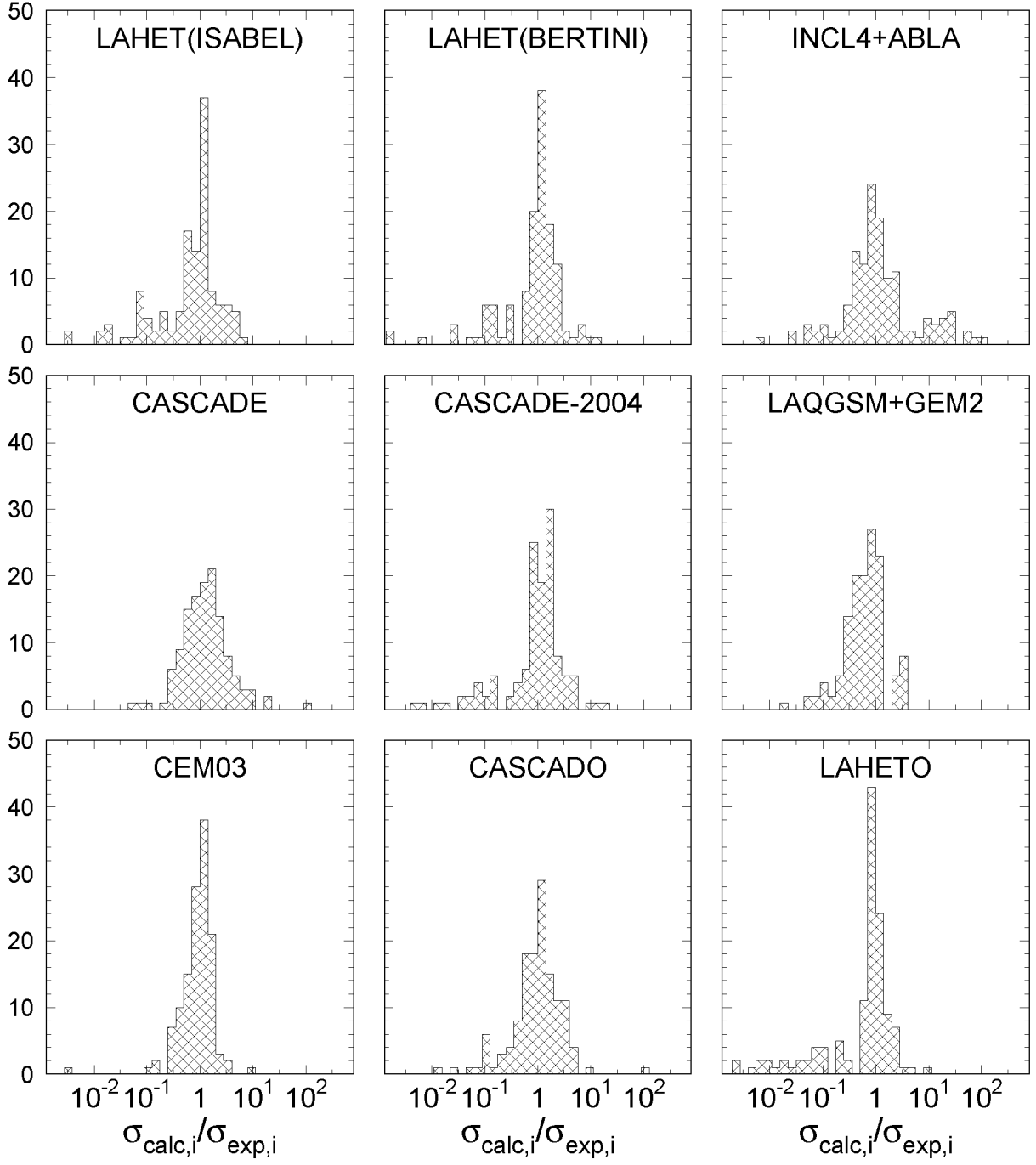


Fig. 139: Statistics of the simulation-to-experiment ratios for shallow spallation products ($A > 170$) at $E_p < 0.1 \text{ GeV}$.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $E_p < 0.1 \text{ GeV}$; $30 < A_{\text{product}} < 140$

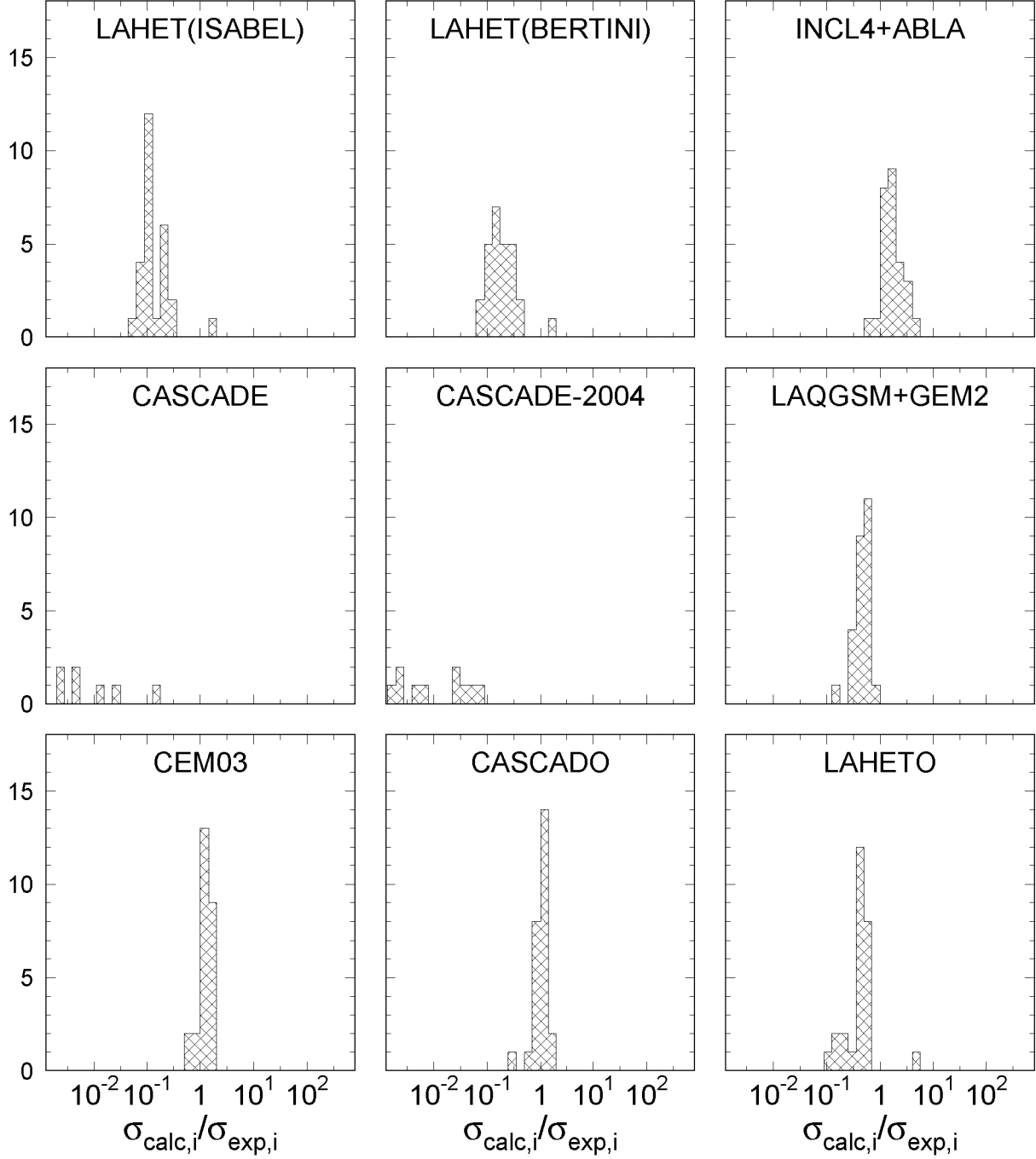


Fig. 140: Statistics of the simulation-to-experiment ratios for fission products ($30 < A < 140$) at $E_p < 0.1 \text{ GeV}$.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $0.1 \leq E_p < 1 \text{ GeV}$; $A_{\text{product}} > 170$

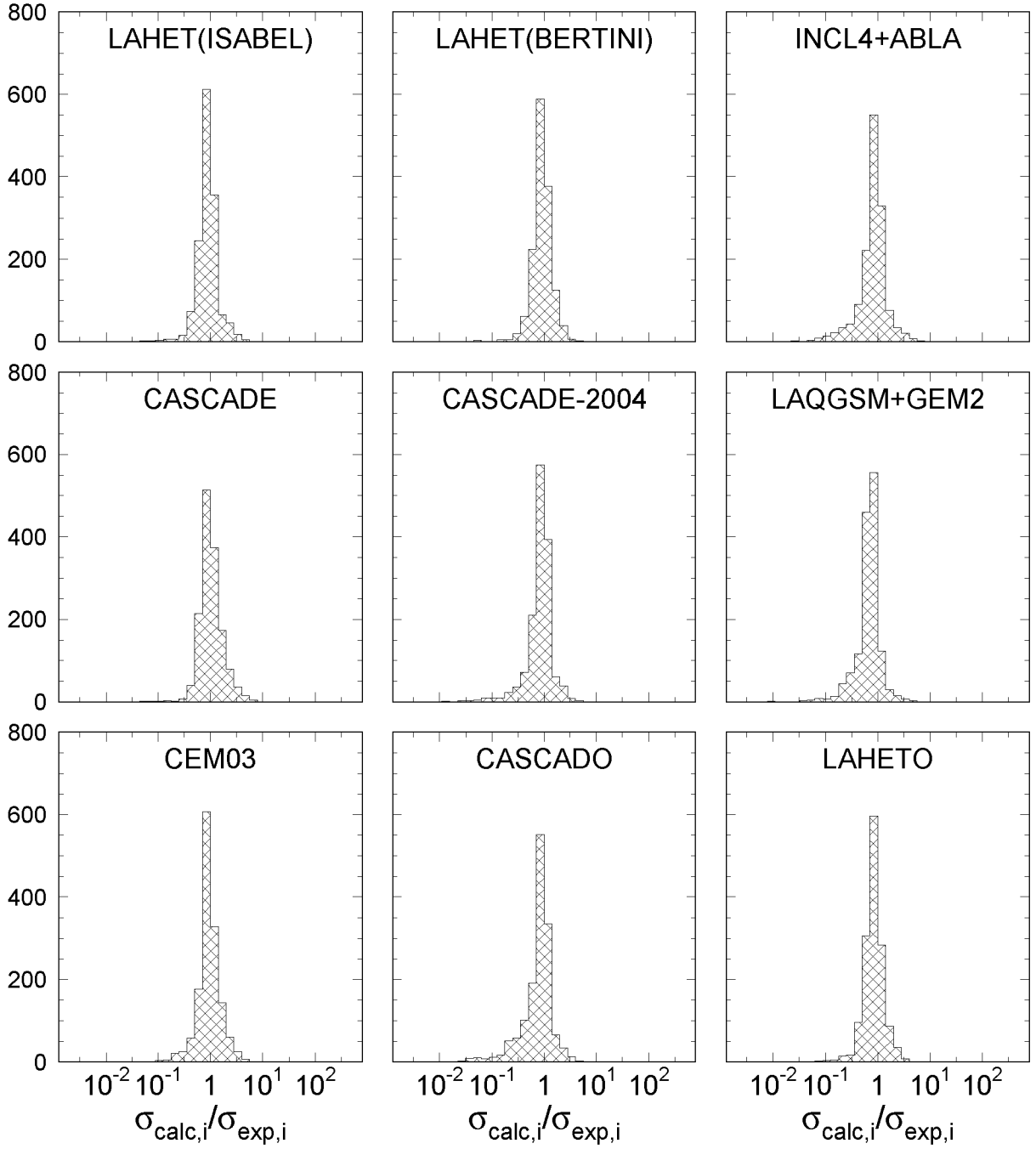


Fig. 141: Statistics of the simulation-to-experiment ratios for shallow spallation products ($A > 170$) at $0.1 \text{ GeV} \leq E_p < 1.0 \text{ GeV}$.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $0.1 \leq E_p < 1 \text{ GeV}$; $140 < A_{\text{product}} < 170$

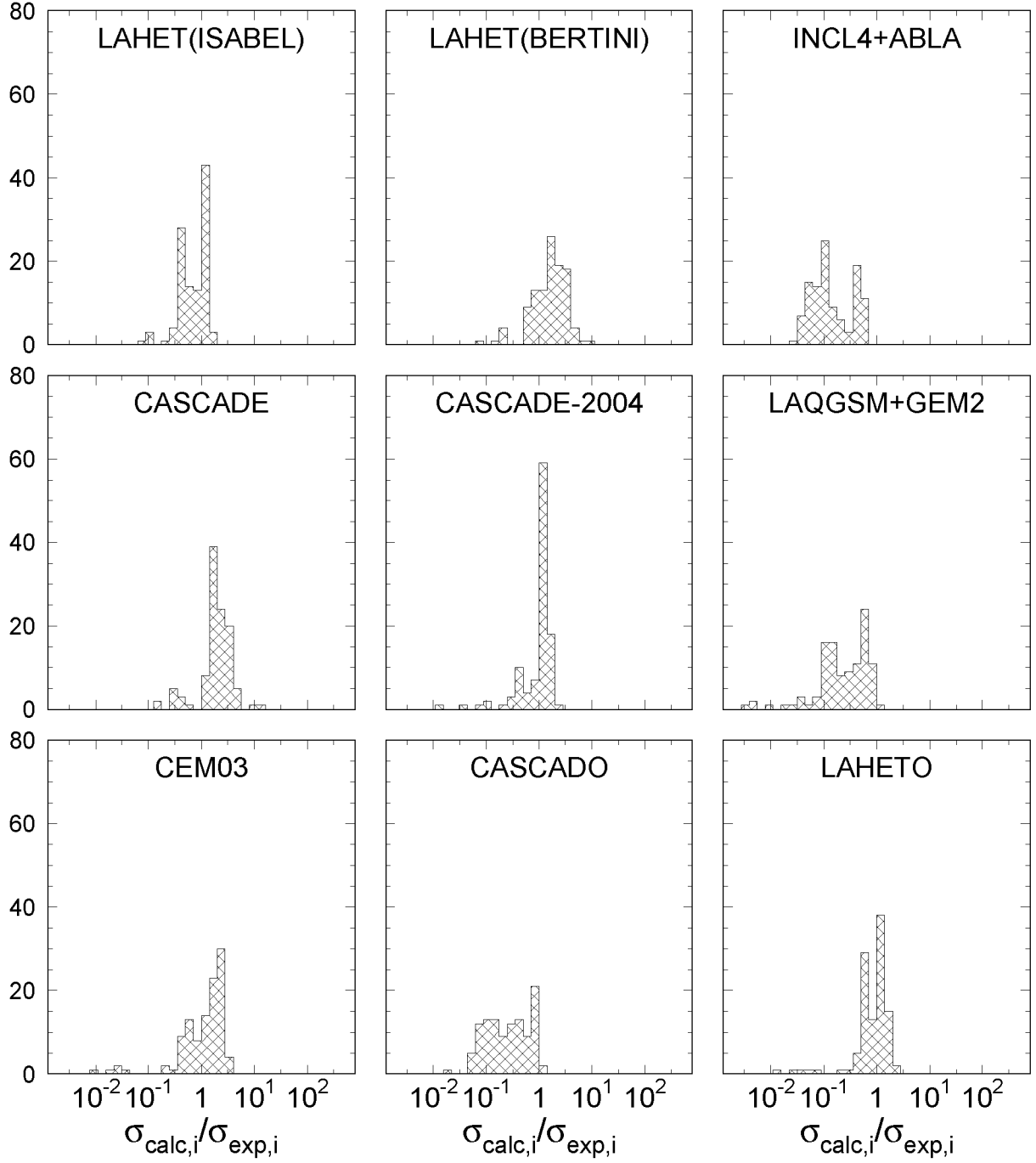


Fig. 142: Statistics of the simulation-to-experiment ratios for deep spallation products ($140 < A < 170$) at $0.1 \text{ GeV} \leq E_p < 1.0 \text{ GeV}$.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $0.1 \leq E_p < 1 \text{ GeV}$; $30 < A_{\text{product}} < 140$

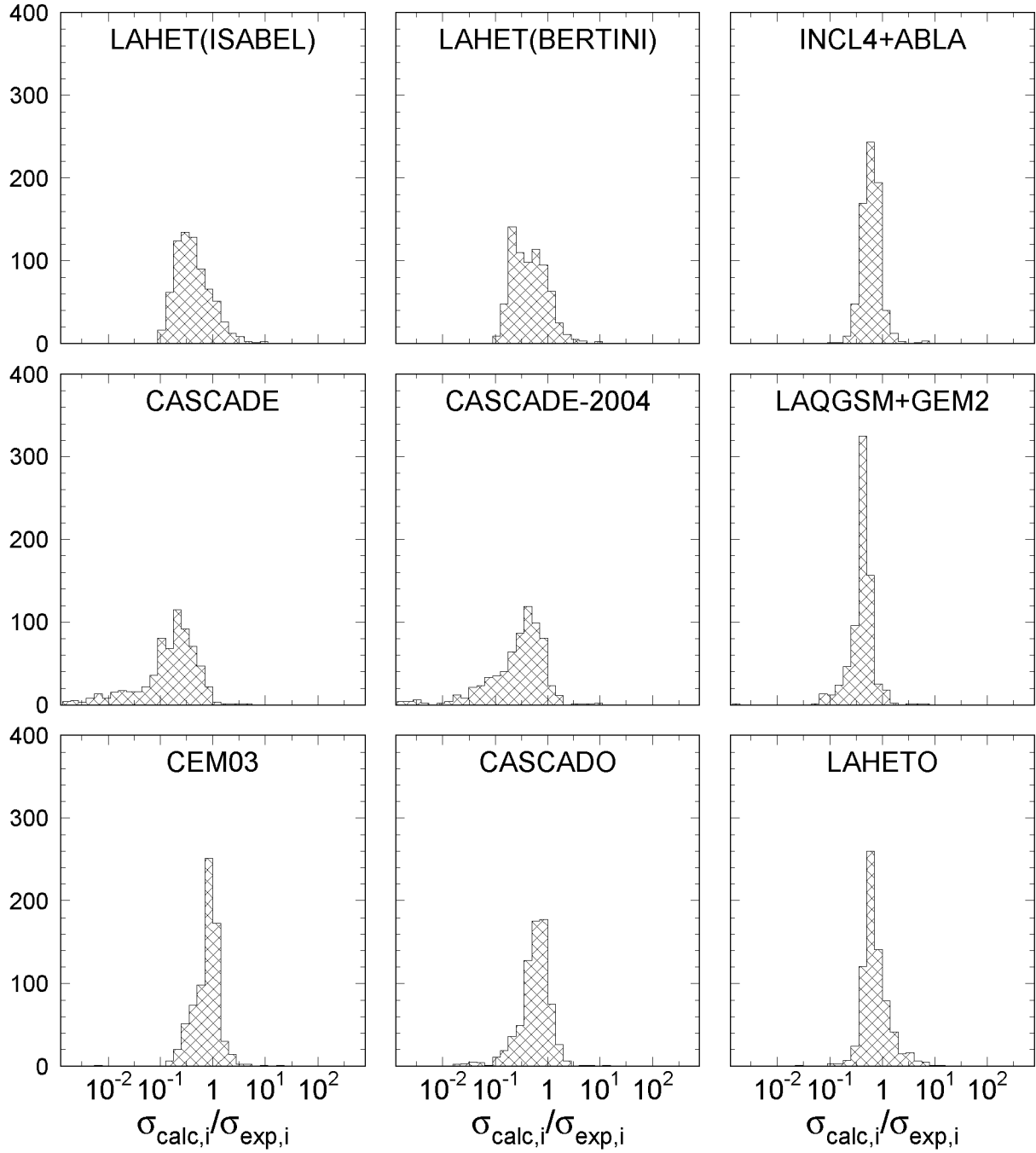


Fig. 143: Statistics of the simulation-to-experiment ratios for fission products ($30 < A < 140$) at $0.1 \text{ GeV} \leq E_p < 1.0 \text{ GeV}$.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $0.1 \leq E_p < 1 \text{ GeV}$; $A_{\text{product}} < 30$

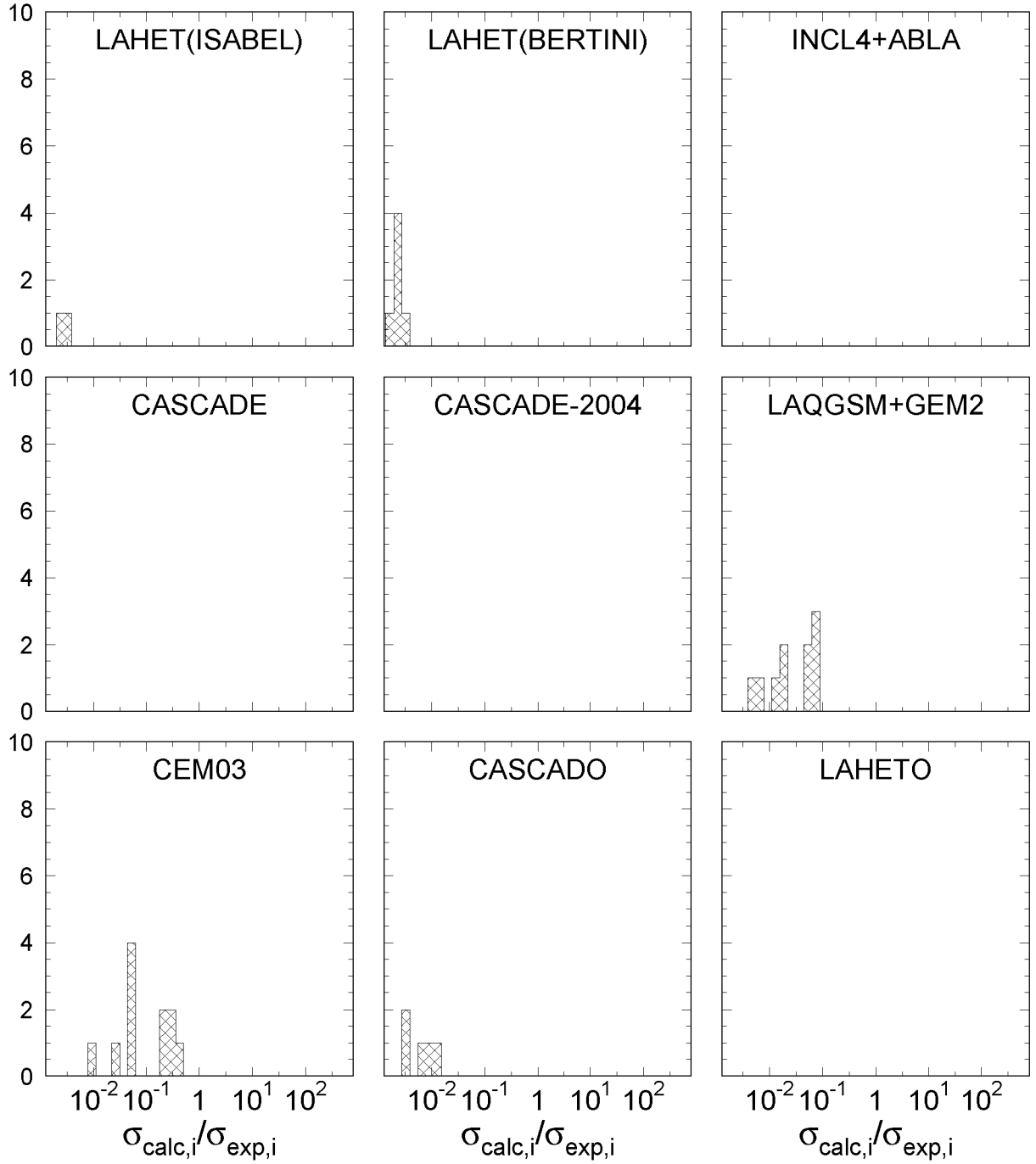


Fig. 144: Statistics of the simulation-to-experiment ratios for fragmentation products ($A < 30$) at $0.1 \text{ GeV} \leq E_p < 1.0 \text{ GeV}$.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $E_p > 1\text{GeV}$; $A_{\text{product}} > 170$

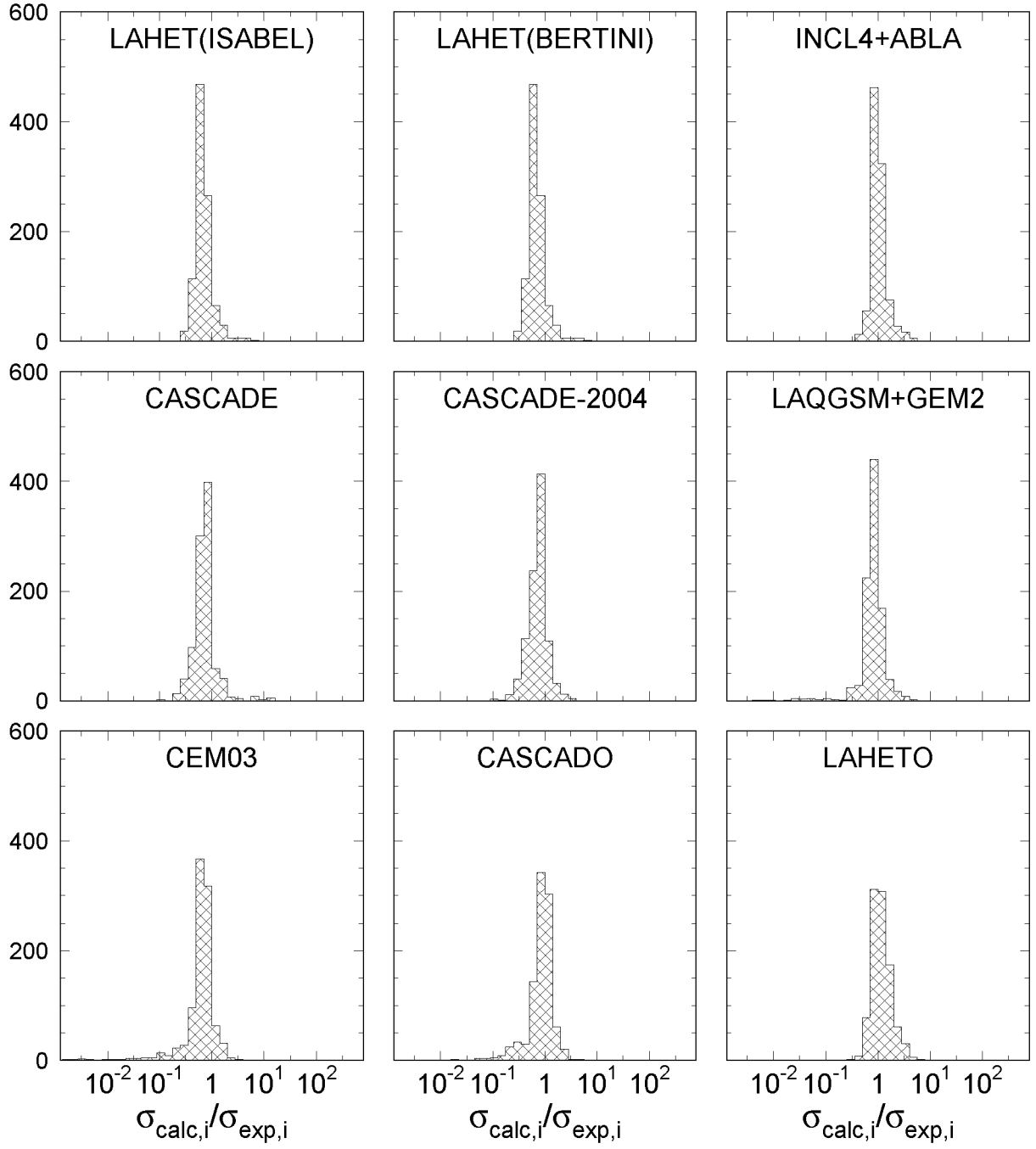


Fig. 145: Statistics of the simulation-to-experiment ratios for shallow spallation products ($A > 170$) at $E_p > 1.0$ GeV.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $E_p > 1\text{GeV}$; $140 < A_{\text{product}} < 170$

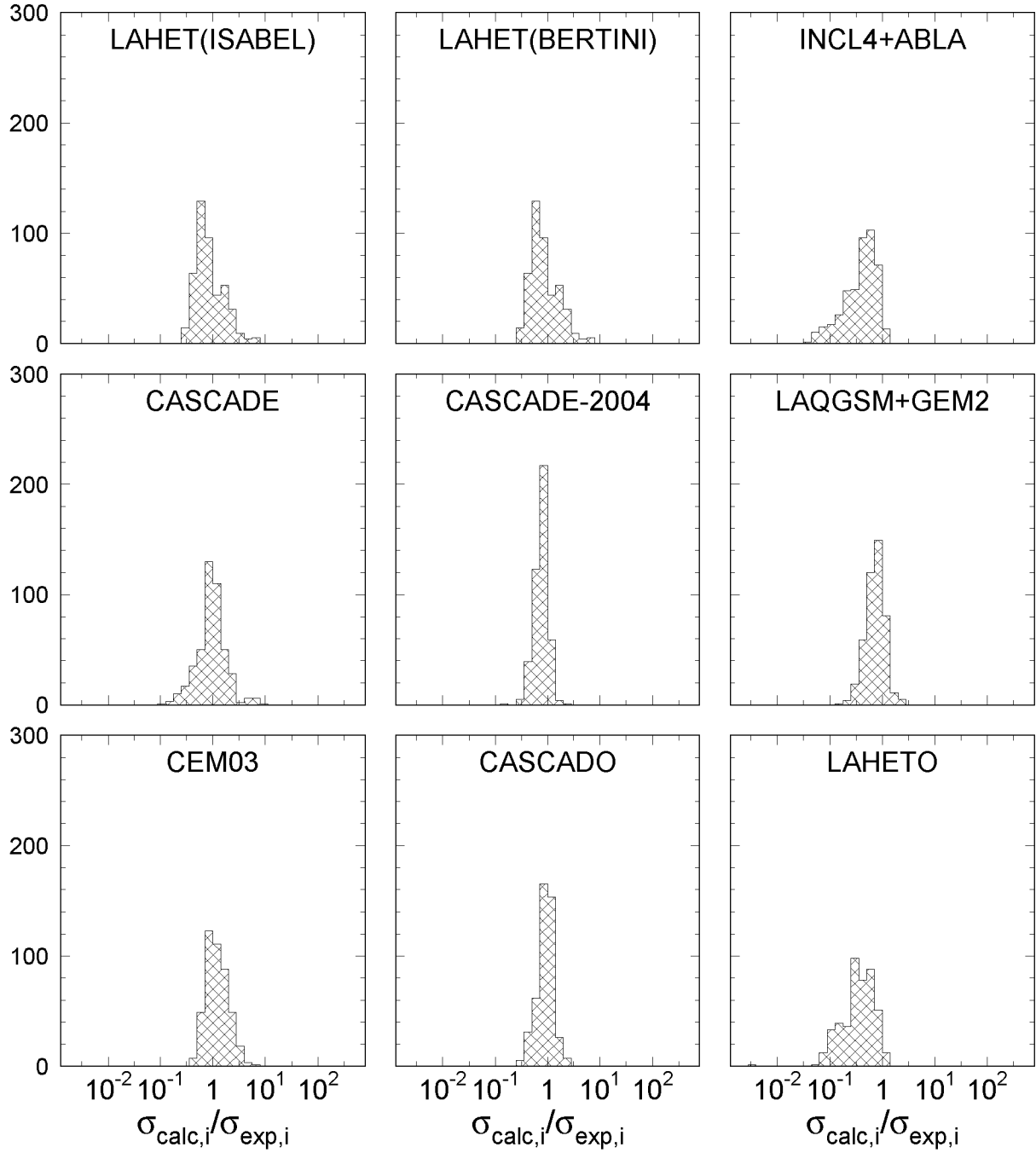


Fig. 146: Statistics of the simulation-to-experiment ratios for deep spallation products ($140 < A < 170$) at $E_p > 1.0$ GeV.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $E_p > 1\text{GeV}$; $30 < A_{\text{product}} < 140$

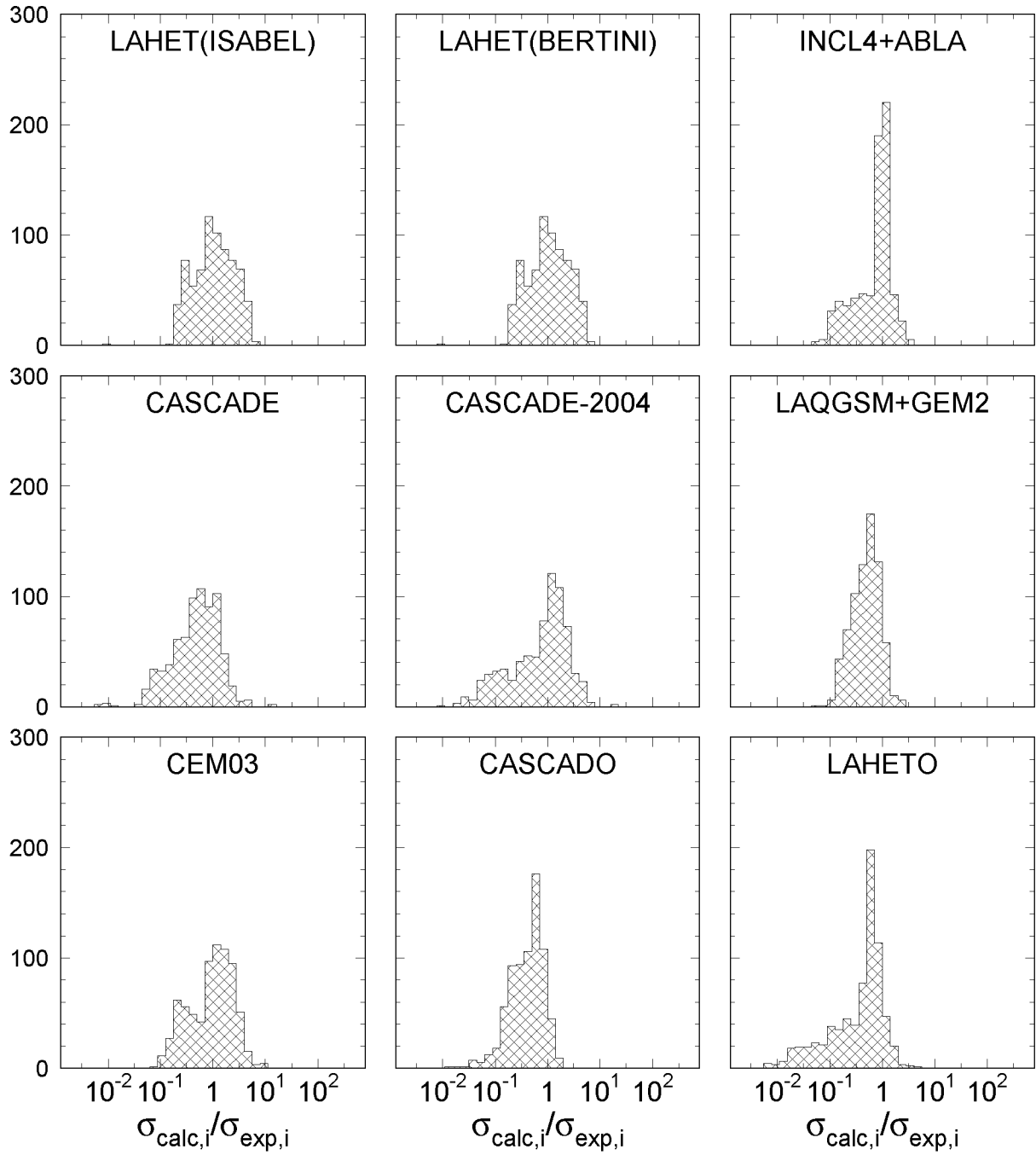


Fig. 147: Statistics of the simulation-to-experiment ratios for fission products ($30 < A < 140$) at $E_p > 1.0$ GeV.

Statistics of $\sigma_{\text{calc},i}/\sigma_{\text{exp},i}$: $E_p > 1\text{GeV}$; $A_{\text{product}} < 30$

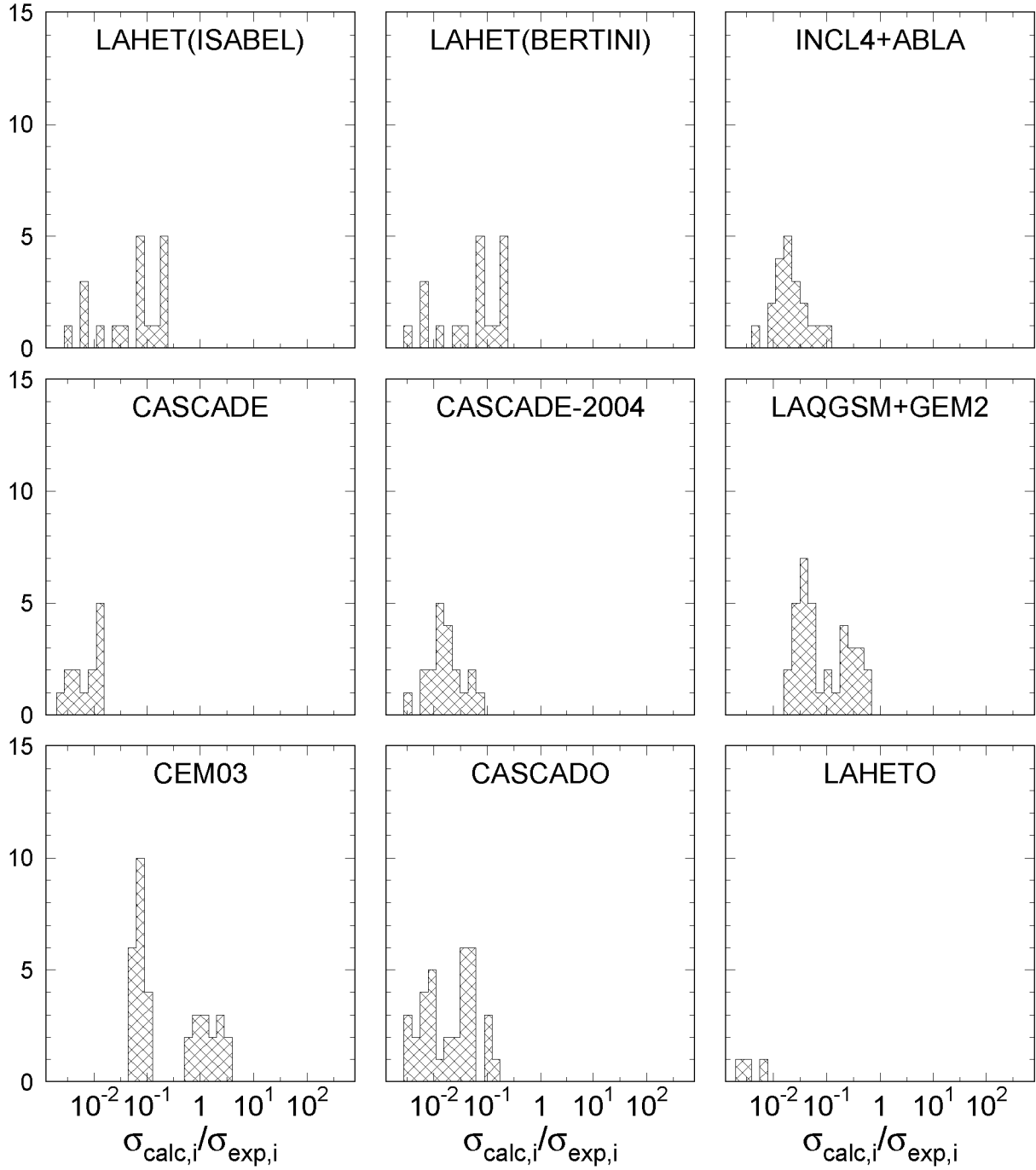


Fig. 148: Statistics of the simulation-to-experiment ratios for fragmentation products ($A < 30$) at $E_p > 1.0$ GeV.

6 CONCLUSION

The *experimental* researches realized using the job-oriented ITEP U-10 proton accelerator external beam, which has been purportedly created under the reported Project, have resulted in 5972 independent and cumulative yields of radioactive product nuclides half-lives ranging from 8 min to 32 years for the most promising ADS target materials.

In total, 55 experiments have been carried out to irradiate monoisotopic and high-enriched (^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb), and (^{209}Bi) targets within a broad range of projectile proton energies (0.04, 0.07, 0.10, 0.15, 0.25, 0.6, 0.8, 1.2, 1.4, 1.6, and 2.6 GeV), which covers the entire region of intranuclear hadron cascading. Besides, the $^{27}\text{Al}(\text{p},\text{x})^{24}\text{Na}$ and $^{27}\text{Al}(\text{p},\text{x})^7\text{Be}$ monitor reaction cross sections have been measured at the same proton beam energies.

In pursuance of the Project Workplan, 2152 γ -spectra of the irradiated targets have been measured and processed.

The following conclusions are drawn from the results of *theoretical* studies under the reported Project:

- The cross sections of spallation product yields have been calculated using different codes based on the INC models and the preequilibrium and evaporation models. The discrepancies have been studied in the results of predicting the cross sections for proton interactions with Pb and Bi isotopes by different computational codes. The approximations and parameters used in different INC codes were studied. Not only the data on the product yield cross sections, but also the spectra of emitted neutrons and charged particles have been analyzed. The contributions of the various reaction mechanisms and their impact on different reaction characteristics were examined.
- It has been shown that, to improve the description of the total experimental dataset, the parameters of the models that underlie the codes have to be specified further, and the codes properly modified to a certain degree. With the view to optimally describing the experimental 1 GeV data, the GSI experimental data were used to consistently determine the parameters of the models that underlie different codes.
- The mass and isotope distributions of the products of spallation reactions on Pb and Bi isotopes have been calculated using the updated CASCADO, LAHETO, CAMO, and ALICE-IPPE codes; the calculation results have been compared with the experimental 70 MeV - 2.6 GeV data.
- The above analyses and the comparison results demonstrate a reasonable agreement of the calculations by our updated codes with the available experimental data on the mass and isotope distributions of the products of spallation reactions on the Pb and Bi isotopes in a broad energy range. The agreement has proved to be much better than that observed prior to implementing the Project.
- The predictive power of the codes tested here varies, but was found to be satisfactory for most of the nuclides in the spallation region, though none of the benchmarked codes agrees well with the data in the entire mass region of product nuclides, which necessitates further

updating of the codes. On the whole, the predictive power of all codes in the fission region is worse than in the spallation region; the agreement is even worse in the fragmentation region and at the boundary between spallation and fission. Therefore, development of better evaporation/fission/fragmentation models is now of high priority.

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9 List of publications

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7. Yury E. Titarenko, Vyacheslav F. Batyaev, Valery M. Zhivun, Evgeny I. Karpikhin, Alexander B. Koldobsky, Ruslan D. Mulambetov, Svetlana V. Mulambetova, Yury V. Trebukhovsky, Sergey L. Zaitsev, Konstantin A. Lipatov, Stepan G. Mashnik, Richard E. Prael. Excitation Functions of Products from $^{208,207,206,nat}\text{Pb}$ and $^{209}\text{Bi}(p,x)$ Reactions Measured in the 40–2600 Energy Range and Predicted Theoretically. // International Conference on Nuclear Data for Science and Technology (ND2004), September 26-October 1, 2004, Santa Fe, NM, USA, pp. 1070–1073; Book of abstracts (LA-UR-04-5900) p. 147; LA-UR-04-8090; LA-UR-04-0403
8. A.V. Ignatyuk, N.T. Kulagin, V.P. Lunev, N.N. Titarenko, Yu.N. Shubin, V.F. Batyaev, Yu.E. Titarenko, V.M. Zhivun. Analysis of Spallation and Fission Fragment Residues for Lead Isotopes Irradiated by Protons at Energies 0.15, 1.0 and 2.6 GeV. // International Conference on Nuclear Data for Science and Technology (ND2004), September 26-October 1, 2004, Santa Fe, NM, USA, pp. 1307–1312; Book of abstracts LA-UR-04-5900 p. 258.
9. Yu.E. Titarenko, V.F. Batyaev, V.M. Zhivun, A.B. Koldobsky, Yu.V. Trebukhovsky, E.I. Karpikhin, R.D. Mulambetov, S.V. Mulambetova, Yu.V. Nekrasov, A.Yu Titarenko, K.A. Lipatov, S.G. Mashnik, R.E. Prael, K. Gudima, M. Baznat. Cross Sections for Nuclide Production in 1 GeV Proton-Irradiated ^{208}Pb and 0.8 GeV Proton-Irradiated ^{197}Au . // Imbedded topical AccApp'03 (Nuclear Applications of Accelerator Technology) 2003 Annual Meeting of the American Nuclear Society (ANS) in San Diego, 1-5 June 2003, California, USA, pp.839–846; LANL Report LA-UR-03-3401; nucl-ex/0305024.

10 List of contributions at conferences and workshops

10.1 List of conferences

1. Workshop on Nuclear Data for the Transmutation of Nuclear Waste, September 1-5, 2003 at GSI-Darmstadt, Germany.
2. Tenth International Conference on Radiation Shielding (ICRS-10) and Thirteenth Topical Meeting on Radiation Protection and Shielding (RPS-2004) 9-14 May 2004 Funchal (Portugal).
3. Shielding Aspects at accelerators, Targets and Irradiation Facilities Seventh Meetings, 17-18 May 2004, Sacavem (Portugal);
4. International Conference on Nuclear Data for Science and Technology (ND2004), September 26-October 1, 2004, Santa Fe, NM, USA

10.2 List of presentations

1. Yu.E. Titarenko, V.F. Batyaev, E.I.Karpikhin, V.M.Zhivun, A.B.Koldobsky, R.D. Mulambetov, S.V. Mulambetova, S.G.Mashnik, R.E.Prael. Nuclide Production in ^{197}Au , ^{208}Pb and natU Irradiated with 0.8-1 GeV Protons: Comparison with other Experiments and with Theoretical Predictions. // Workshop on Nuclear Data for the Transmutation of Nuclear Waste, September 1-5, 2003 at GSI-Darmstadt, Germany.
2. A.V.Ignatyuk, N.T.Kulagin, V.P.Lunev, Yu.N.Shubin, N.N.Titarenko, V.F.Batyaev, Yu.E.Titarenko, V.M.Zhivun. Analysis of Spallation Residues for Separated Lead Isotopes Irradiated by Protons at Energies 0.15, 1.0 and 2.6 GeV. // Workshop on Nuclear Data for the Transmutation of Nuclear Waste, September 1-5, 2003 at GSI-Darmstadt, Germany.
3. Yu. E. Titarenko, V. F. Batyaev, V. M. Zhivun, E. I. Karpikhin, A. B. Koldobsky, R. D. Mulambetov, S. V. Mulambetova, Yu. V. Trebukhovsky, S. L. Zaitsev, K. A. Lipatov, S. G. Mashnik, and R. E. Prael. Theoretical simulation of residual nuclide products in $^{208,207,206}\text{Pb}$, ^{nat}Pb and $^{209}\text{Bi}(p,x)$ reactions at inter-medium and high energies. Tenth International Conference on Radiation Shielding (ICRS-10) and Thirteenth Topical Meeting on Radiation Protection and Shielding (RPS-2004) 9-14 May 2004 Funchal (Portugal). Book of abstracts p. 465; LA-UR-04-3274.
4. Yu. E. Titarenko, V. F. Batyaev, V. M. Zhivun, E. I. Karpikhin, A. V. Koldobsky, R. D. Mulambetov, S. V. Mulambetova, Yu. V. Trebukhovsky, S. L. Zaitsev, K. A. Lipatov, and S.G. Mashnik. Experimental study of independent and cumulative product yields in $^{208,207,206,nat}\text{Pb}$ and ^{209}Bi targets irradiated with 0.04-2.6 GeV protons. Proc. of Seventh Meeting Workshop Shielding Aspects at accelerators, Targets and Irradiation Facilities, 17-18 May 2004, Sacavem (Portugal), pp. 103–114, OECD 2005; LA-UR-04-3046, LA-UR-04-3708.

5. Yury E. Titarenko, Vyacheslav F. Batyaev, Valery M. Zhivun, Evgeny I. Karpikhin, Alexander B. Koldobsky, Ruslan D. Mulambetov, Svetlana V. Mulambetova, Yury V. Trebukhovskiy, Sergey L. Zaitsev, Konstantin A. Lipatov, Stepan G. Mashnik, Richard E. Prael. Excitation Functions of Products from $^{208,207,206,nat}\text{Pb}$ and $^{209}\text{Bi}(p,x)$ Reactions Measured in the 40–2600 Energy Range and Predicted Theoretically. // International Conference on Nuclear Data for Science and Technology (ND2004), September 26–October 1, 2004, Santa Fe, NM, USA, pp. 1070–1073; Book of abstracts (LA-UR-04-5900) p. 147; LA-UR-04-8090; LA-UR-04-0403

6. A.V. Ignatyuk, N.T. Kulagin, V.P. Lunev, N.N. Titarenko, Yu.N. Shubin, V.F. Batyaev, Yu.E. Titarenko, V.M. Zhivun. Analysis of Spallation and Fission Fragment Residues for Lead Isotopes Irradiated by Protons at Energies 0.15, 1.0 and 2.6 GeV. // International Conference on Nuclear Data for Science and Technology (ND2004), September 26–October 1, 2004, Santa Fe, NM, USA, pp. 1307–1312; Book of abstracts LA-UR-04-5900 p. 258.

7. Yu.E. Titarenko, V.F. Batyaev, V.M. Zhivun, A.B. Koldobsky, Yu.V. Trebukhovskiy, E.I. Karpikhin, R.D. Mulambetov, S.V. Mulambetova, Yu.V. Nekrasov, A.Yu Titarenko, K.A. Lipatov, S.G. Mashnik, R.E. Prael, K. Gudima, M. Baznat. Cross Sections for Nuclide Production in 1 GeV Proton-Irradiated ^{208}Pb and 0.8 GeV Proton-Irradiated ^{197}Au . // Imbedded topical AccApp'03 (Nuclear Applications of Accelerator Technology) 2003 Annual Meeting of the American Nuclear Society (ANS) in San Diego, 1-5 June 2003, California, USA, pp.839–846; LANL Report LA-UR-03-3401; nucl-ex/0305024.

10.3 List of workshops

Workshop	Presentation title
1 BASTRA Cluster Meeting of EC funded FP5 projects, CERN, Geneva, Switzerland, December 5, 2001	ISTC Project #2002: Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40-2600 MeV protons
2 Second BASTRA Cluster Meeting at Uppsala University, Uppsala, 12 September 2002	The ISTC Projects #2002 and 2405 differential and integral nuclear data experiments relevant for waste transmutation
3 ADS R&D Workshop, Minsk, Belarus, 27 May 2003	The ADS-related experimental activity at ITEP
4 IAEA Training workshop Technology and Applications of ADS, Trieste, Italy, 13-17 October 2003	The ADS-related experimental activity at ITEP
5 ENEA Centre in Casaccia, Rome, Italy, Oct 21, 2003	Prolongation of the ISTC project #2002. Support for data measurements for the TRADE Project by Russian ISTC groups
6 ADS-related ISTC Projects Meeting at Moscow, 24 January 2004	ISTC Project #2002: current status and results
7 ADS-related ISTC Projects Meeting at Moscow, 24 January 2004	Prolongation of #2002 IJ collaborative effort with TRADE
8 IAEA Technical Meeting on ADS XS libraries, Vienna, Austria, 15-17 December 2004.	ITEP potential for ADS XS library creation

11 Co-operation with Foreign Collaborators

1. S. Mashnik carried out the nuclide production yield simulation via the CEM03 and LAQGSM+GEM2 codes.
2. A. Boudard delivered the INCL4+ABLA to be used in the Project simulations (October 2003) and gave useful remarks on the code results (April 2004).
3. The preliminary results of the project were sent to:
 - C.H.M. Broeders ^{nat}Pb 600MeV (February 2003) who used them under the MEGAPIE and PDS-XADS projects;
 - E. Gonzales (March 2004);

- K.H. Schmidt (technical report draft was sent in December 2004);
 - W. Gudowski (technical report draft was given in December 2004);
4. S.Leray, R.Michel, C.H.M. Broeders, S. Mashnik, H. Ait-Abderhamid, T.Fukahory, E.Pitcher, W. Gudowski, P. Ferguson, N. Hertel: the working plan of the project proposal ISTC#3266 was coordinated (January - March 2005)

12 Appendix 1. Detailed calculation of nuclide production rates.

12.1 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.04$ GeV

12.1.1 Nuclide production rates for ^{206}Pb

Table 45: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.04$ GeV, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	56.55 ± 2.83
			1718.7	31.8 ± 0.6	58.60 ± 2.33
			1595.3	5.01 ± 0.08	67.13 ± 3.48
			1098.3	13.50 ± 0.21	54.10 ± 2.07
			1018.6	7.60 ± 0.11	59.37 ± 2.21
			881.0	66.2 ± 1.0	60.83 ± 2.23
			803.1	98.9 ± 1.4	56.77 ± 2.06
			657.2	1.91 ± 0.04	57.63 ± 2.93
			632.2	4.47 ± 0.07	53.17 ± 2.39
			537.5	30.5 ± 0.5	50.31 ± 2.23
			516.2	40.7 ± 0.6	54.17 ± 2.18
			497.1	15.31 ± 0.22	52.74 ± 2.36
			398.0	10.74 ± 0.15	51.66 ± 1.96
			343.5	23.4 ± 0.4	54.15 ± 2.11
			262.7	3.02 ± 0.06	52.77 ± 4.86
			184.0	15.8 ± 0.4	61.85 ± 2.87
			$RR_{mean} =$		55.91 ± 1.96
^{205}Bi	i	15.31D	1903.4	2.47 ± 0.04	260.7 ± 11.5
			1861.7	6.17 ± 0.10	260.9 ± 10.4
			1775.8	3.99 ± 0.08	267.1 ± 11.1
			1764.3	32.5 ± 0.7	267.2 ± 11.0
			1614.3	2.28 ± 0.04	276.2 ± 11.2
			1190.0	2.26 ± 0.07	265.3 ± 12.5
			1043.8	7.51 ± 0.10	242.0 ± 8.6
			987.7	16.13 ± 0.17	260.8 ± 9.1
			703.5	31.1 ± 0.1	243.9 ± 8.4
			579.8	5.44 ± 0.07	237.4 ± 8.9
			570.6	4.34 ± 0.07	228.2 ± 8.6
			549.8	2.95 ± 0.04	219.8 ± 8.2
			284.1	1.69 ± 0.02	245.5 ± 10.6
			260.5	1.09 ± 0.04	237.1 ± 15.0
			$RR_{mean} =$		246.5 ± 8.8
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	643.5 ± 70.0
			1211.7	3.0 ± 0.4	563.6 ± 78.4
			984.0	59 ± 4	617.1 ± 46.5
			918.3	10.8 ± 0.9	694.0 ± 62.2
			899.2	98 ± 9	590.0 ± 19.4
			791.2	3.3 ± 0.3	776.7 ± 75.5

Continuation of Table 45.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			670.7	11.4 ± 0.9	646.4 ± 55.5
			374.8	82 ± 5	695.9 ± 145.1
			176.1	1.12 ± 0.09	799.9 ± 71.7
			$RR_{mean} =$		593.2 ± 18.3
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	1901 ± 121
			1983.0	0.88 ± 0.05	1997 ± 137
			1893.0	8.2 ± 0.6	1963 ± 160
			1888.0	1.94 ± 0.10	1977 ± 125
			1847.3	11.4 ± 0.8	1882 ± 148
			1719.6	3.40 ± 0.23	1836 ± 142
			1679.6	8.8 ± 0.7	1889 ± 164
			1536.5	7.5 ± 0.6	1920 ± 167
			1506.7	3.7 ± 0.3	1854 ± 163
			1034.0	8.8 ± 0.5	1922 ± 126
			896.8	13.1 ± 0.7	1935 ± 121
			820.2	29.6 ± 1.5	1974 ± 119
			816.3	4.03 ± 0.21	1991 ± 123
			722.4	4.8 ± 0.4	1985 ± 178
			569.3	1.22 ± 0.07	2100 ± 142
			279.2	*	1936 ± 71
			264.2	5.2 ± 0.4	1944 ± 167
			186.6	3.11 ± 0.22	2200 ± 177
			$RR_{mean} =$		$1939 \pm 60.$
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	1.486 ± 0.439
			657.5	60.6 ± 1.8	1.491 ± 0.366
			422.1	83.7 ± 2.5	2.084 ± 0.297
			$RR_{mean} =$		1.775 ± 0.217
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	71.17 ± 2.75
			374.7	89 ± 15	76.16 ± 13.18
			$RR_{mean} =$		71.25 ± 2.75
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	159.6 ± 5.4
			374.7	89 ± 15	163.5 ± 28.1
			$RR_{mean} =$		159.7 ± 5.4
$^{203}\text{Pb}_i$	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	70.88 ± 6.48
$^{203}\text{Pb}_c$	c	51.873H	279.2	80.8 ± 0.2	$2007 \pm 73.$
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	1.569 ± 0.596
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	10.63 ± 0.39
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	13.44 ± 0.74

12.1.2 Nuclide production rates for ^{207}Pb

Table 46: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 0.04 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	1063.7	74.5 ± 0.2	63.71 ± 6.87
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	189.7 ± 8.6
			1718.7	31.8 ± 0.6	185.9 ± 7.3
			1595.3	5.01 ± 0.08	199.1 ± 7.7

Continuation of Table 46.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1098.3	13.50 ± 0.21	172.6 ± 6.5
			1018.6	7.60 ± 0.11	187.8 ± 6.9
			881.0	66.2 ± 1.0	183.4 ± 6.6
			803.1	98.9 ± 1.4	176.2 ± 6.3
			657.2	1.91 ± 0.04	177.3 ± 7.5
			632.2	4.47 ± 0.07	168.0 ± 6.3
			620.5	5.76 ± 0.09	164.8 ± 6.7
			537.5	30.5 ± 0.5	159.9 ± 6.2
			516.2	40.7 ± 0.6	170.9 ± 6.4
			497.1	15.31 ± 0.22	162.3 ± 6.1
			398.0	10.74 ± 0.15	164.4 ± 6.1
			343.5	23.4 ± 0.4	167.0 ± 6.3
			262.7	3.02 ± 0.06	173.6 ± 8.1
			184.0	15.8 ± 0.4	193.4 ± 8.7
			$RR_{mean} =$		174.2 ± 6.0
^{205}Bi	i	15.31D	1903.4	2.47 ± 0.04	717.6 ± 28.2
			1861.7	6.17 ± 0.10	725.5 ± 28.4
			1775.8	3.99 ± 0.08	735.0 ± 29.4
			1764.3	32.5 ± 0.7	741.6 ± 30.0
			1614.3	2.28 ± 0.04	776.0 ± 31.0
			1190.0	2.26 ± 0.07	718.2 ± 32.8
			1043.8	7.51 ± 0.10	667.6 ± 23.7
			987.7	16.13 ± 0.17	722.1 ± 24.8
			703.5	31.1 ± 0.1	675.0 ± 22.6
			579.8	5.44 ± 0.07	649.7 ± 23.7
			570.6	4.34 ± 0.07	629.0 ± 23.8
			$RR_{mean} =$		691.4 ± 24.6
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	2047 ± 214
			1652.1	0.56 ± 0.08	2081 ± 308
			1211.7	3.0 ± 0.4	1769 ± 243
			1043.6	1.27 ± 0.17	1814 ± 256
			984.0	59 ± 4	1847 ± 139
			918.3	10.8 ± 0.9	2101 ± 188
			899.2	98 ± 9	2051 ± 200
			791.2	3.3 ± 0.3	2176 ± 211
			670.7	11.4 ± 0.9	1946 ± 167
			374.8	82 ± 5	2070 ± 144
			176.1	1.12 ± 0.09	2541 ± 226
			$RR_{mean} =$		2025 ± 84
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	131.3 ± 11.7
			1983.0	0.88 ± 0.05	124.8 ± 13.2
			1893.0	8.2 ± 0.6	105.4 ± 8.9
			1888.0	1.94 ± 0.10	113.0 ± 8.2
			1847.3	11.4 ± 0.8	88.91 ± 7.12
			1679.6	8.8 ± 0.7	86.13 ± 7.66
			1536.5	7.5 ± 0.6	207.2 ± 18.4
			1506.7	3.7 ± 0.3	81.35 ± 8.78
			1034.0	8.8 ± 0.5	91.24 ± 6.32
			896.8	13.1 ± 0.7	79.42 ± 6.15
			820.2	29.6 ± 1.5	124.5 ± 7.6
			816.3	4.03 ± 0.21	103.4 ± 10.3

Continuation of Table 46.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			722.4	4.8 ± 0.4	97.58 ± 10.11
			279.2	*	91.47 ± 3.77
			264.2	5.2 ± 0.4	101.7 ± 9.4
			186.6	3.11 ± 0.22	109.8 ± 10.4
$RR_{mean} =$					93.14 ± 2.87
$^{203}\text{Pb}_i$	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	9.536 ± 2.213
$^{203}\text{Pb}_c$	c	51.873H	279.2	80.8 ± 0.2	101.0 ± 3.7
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	9.797 ± 0.355
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	0.1918 ± 0.1310

12.1.3 Nuclide production rates for ^{208}Pb

Table 47: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.04 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	1063.7	74.5 ± 0.2	174.2 ± 6.5
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	414.2 ± 18.3
			1718.7	31.8 ± 0.6	408.0 ± 16.0
			1595.3	5.01 ± 0.08	414.4 ± 16.0
			1098.3	13.50 ± 0.21	377.9 ± 14.8
			1018.6	7.60 ± 0.11	414.9 ± 15.0
			881.0	66.2 ± 1.0	398.6 ± 14.4
			803.1	98.9 ± 1.4	382.5 ± 13.7
			657.2	1.91 ± 0.04	373.1 ± 15.7
			632.2	4.47 ± 0.07	384.6 ± 16.3
			620.5	5.76 ± 0.09	364.7 ± 15.4
			537.5	30.5 ± 0.5	353.6 ± 13.7
			516.2	40.7 ± 0.6	375.4 ± 14.1
			497.1	15.31 ± 0.22	355.1 ± 13.7
			398.0	10.74 ± 0.15	359.8 ± 13.9
			343.5	23.4 ± 0.4	367.4 ± 14.2
			262.7	3.02 ± 0.06	408.4 ± 19.9
			184.0	15.8 ± 0.4	424.5 ± 19.2
$RR_{mean} =$					383.4 ± 13.0
^{205}Bi	i	15.31D	1903.4	2.47 ± 0.04	2170 ± 85
			1861.7	6.17 ± 0.10	2201 ± 85
			1775.8	3.99 ± 0.08	2218 ± 91
			1764.3	32.5 ± 0.7	2256 ± 91
			1614.3	2.28 ± 0.04	2312 ± 88
			1190.0	2.26 ± 0.07	2141 ± 99
			1043.8	7.51 ± 0.10	2013 ± 72
			987.7	16.13 ± 0.17	2136 ± 74
			703.5	31.1 ± 0.1	2040 ± 68
			579.8	5.44 ± 0.07	1970 ± 72
			570.6	4.34 ± 0.07	1941 ± 74
			549.8	2.95 ± 0.04	1850 ± 70
			284.1	1.69 ± 0.02	2033 ± 80
			260.5	1.09 ± 0.04	1974 ± 106

Continuation of Table 47.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	2063 ± 72.
²⁰⁴ Bi	i	11.22H	1755.3	1.22 ± 0.12	74.67 ± 8.21
			1652.1	0.56 ± 0.08	83.46 ± 13.53
			1211.7	3.0 ± 0.4	75.52 ± 10.60
			1043.6	1.27 ± 0.17	122.7 ± 26.1
			984.0	59 ± 4	85.98 ± 6.49
			918.3	10.8 ± 0.9	96.62 ± 8.70
			899.2	98 ± 9	96.83 ± 9.46
			791.2	3.3 ± 0.3	87.15 ± 8.75
			670.7	11.4 ± 0.9	90.92 ± 7.84
			374.8	82 ± 5	97.30 ± 6.80
			176.1	1.12 ± 0.09	111.8 ± 10.2
				<i>RR_{mean}</i> =	90.82 ± 4.19
²⁰³ Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	17.16 ± 1.52
			1893.0	8.2 ± 0.6	17.62 ± 1.48
			1888.0	1.94 ± 0.10	16.55 ± 1.44
			1847.3	11.4 ± 0.8	16.85 ± 1.37
			1679.6	8.8 ± 0.7	15.25 ± 1.40
			1536.5	7.5 ± 0.6	25.10 ± 2.29
			1506.7	3.7 ± 0.3	16.74 ± 1.81
			1034.0	8.8 ± 0.5	16.12 ± 1.11
			896.8	13.1 ± 0.7	17.99 ± 1.25
			820.2	29.6 ± 1.5	18.43 ± 1.14
			816.3	4.03 ± 0.21	16.03 ± 1.18
			722.4	4.8 ± 0.4	19.84 ± 2.01
			279.2	*	18.28 ± 0.69
			264.2	5.2 ± 0.4	17.73 ± 1.61
			186.6	3.11 ± 0.22	19.75 ± 1.73
				<i>RR_{mean}</i> =	18.19 ± 0.56
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	0.6482 ± 0.1393
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	18.93 ± 0.70
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	0.9223 ± 0.0869

12.1.4 Nuclide production rates for ^{nat}Pb

Table 48: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.04 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	1063.7	74.5 ± 0.2	71.24 $\pm$ 2.93
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	194.6 ± 8.7
			1718.7	31.8 ± 0.6	194.7 ± 7.6
			1595.3	5.01 ± 0.08	204.5 ± 7.9
			1018.6	7.60 ± 0.11	193.9 ± 7.0
			881.0	66.2 ± 1.0	189.6 ± 6.8
			803.1	98.9 ± 1.4	182.4 ± 6.5
			657.2	1.91 ± 0.04	189.4 ± 7.9
			632.2	4.47 ± 0.07	177.1 ± 7.0
			620.5	5.76 ± 0.09	168.2 ± 6.3

Continuation of Table 48.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{205}Bi	i	15.31D	537.5	30.5 ± 0.5	166.9 ± 6.3
			516.2	40.7 ± 0.6	177.5 ± 6.6
			497.1	15.31 ± 0.22	168.2 ± 6.3
			398.0	10.74 ± 0.15	169.8 ± 6.2
			343.5	23.4 ± 0.4	173.7 ± 6.5
			262.7	3.02 ± 0.06	182.2 ± 8.3
			184.0	15.8 ± 0.4	201.6 ± 9.2
			$RR_{mean} =$		180.5 ± 6.3
			1861.7	6.17 ± 0.10	980.0 ± 37.9
			1775.8	3.99 ± 0.08	998.2 ± 39.8
			1764.3	32.5 ± 0.7	993.8 ± 40.2
			1614.3	2.28 ± 0.04	1038 ± 40
			1190.0	2.26 ± 0.07	967.2 ± 44.2
			1043.8	7.51 ± 0.10	899.0 ± 31.8
			987.7	16.13 ± 0.17	971.3 ± 33.3
^{204}Bi	i	11.22H	703.5	31.1 ± 0.1	908.6 ± 30.2
			579.8	5.44 ± 0.07	879.0 ± 32.0
			570.6	4.34 ± 0.07	849.6 ± 32.0
			549.8	2.95 ± 0.04	823.2 ± 30.3
			284.1	1.69 ± 0.02	905.8 ± 35.3
			260.5	1.09 ± 0.04	882.7 ± 46.8
			$RR_{mean} =$		917.5 ± 32.7
			1755.3	1.22 ± 0.12	398.1 ± 42.4
			1652.1	0.56 ± 0.08	502.9 ± 76.2
			1211.7	3.0 ± 0.4	396.2 ± 54.7
			1043.6	1.27 ± 0.17	478.0 ± 68.4
			984.0	59 ± 4	407.6 ± 30.7
			918.3	10.8 ± 0.9	459.3 ± 41.2
			899.2	98 ± 9	396.0 ± 13.0
			791.2	3.3 ± 0.3	475.9 ± 46.5
^{203}Bi	i(m+g)	11.76H	670.7	11.4 ± 0.9	431.0 ± 37.0
			374.8	82 ± 5	476.1 ± 99.3
			176.1	1.12 ± 0.09	538.9 ± 48.2
			$RR_{mean} =$		398.5 ± 12.3
			2011.0	1.76 ± 0.09	354.3 ± 22.8
			1983.0	0.88 ± 0.05	354.8 ± 24.8
			1893.0	8.2 ± 0.6	355.0 ± 29.0
			1888.0	1.94 ± 0.10	351.6 ± 22.4
			1847.3	11.4 ± 0.8	338.2 ± 26.6
			1679.6	8.8 ± 0.7	335.9 ± 29.2
			1536.5	7.5 ± 0.6	368.2 ± 32.1
			1506.7	3.7 ± 0.3	336.6 ± 29.7
			1034.0	8.8 ± 0.5	341.1 ± 22.5
			896.8	13.1 ± 0.7	339.8 ± 21.4
			820.2	29.6 ± 1.5	361.4 ± 21.9
^{203}Bi	i(m+g)	11.76H	816.3	4.03 ± 0.21	355.4 ± 22.1
			722.4	4.8 ± 0.4	355.6 ± 32.1
			401.3	*	327.7 ± 18.2
			279.2	*	356.0 ± 13.1
			264.2	5.2 ± 0.4	358.4 ± 30.9
			186.6	3.11 ± 0.22	391.4 ± 31.6

Continuation of Table 48.					
Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{202}Bi	i	1.72H	$RR_{mean} =$		351.7 ± 10.8
			960.7	99.28 ± 0.02	9.510 ± 0.354
			657.5	60.6 ± 1.8	8.925 ± 0.514
^{201}Bi	i	108M	$RR_{mean} =$		9.408 ± 0.365
			1650.9	5.8 ± 1.3	15.89 ± 4.33
			629.1	24 ± 6	14.60 ± 3.71
			331.2	*	14.88 ± 1.28
$^{204m}\text{Pb}_i$	i(m)	67.2M	$RR_{mean} =$		14.90 ± 0.46
			899.2	99.17 ± 0.02	15.82 ± 1.15
			374.7	89 ± 15	15.30 ± 2.75
$^{204m}\text{Pb}_c$	c	67.2M	$RR_{mean} =$		15.75 ± 1.09
			899.2	99.17 ± 0.02	75.19 ± 2.62
			374.7	89 ± 15	75.03 ± 12.92
			$RR_{mean} =$		75.19 ± 2.62
$^{203}\text{Pb}_i$	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	15.81 ± 1.63
$^{203}\text{Pb}_c$	c	51.873H	279.2	80.8 ± 0.2	371.8 ± 13.6
$^{201}\text{Pb}_i$	i(m+g)	9.33H	331.2	79 ± 5	1.614 ± 0.749
$^{201}\text{Pb}_c$	c	9.33H	331.2	79 ± 5	16.50 ± 1.20
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	3.560 ± 0.132
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	20.03 ± 0.84
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	0.06505 ± 0.03477

12.1.5 Nuclide production rates for ^{209}Bi

Table 49: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.04 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	2060.2	1.32 ± 0.09	488.6 ± 38.5
			1662.7	0.32 ± 0.04	549.5 ± 72.4
			1372.4	1.22 ± 0.03	592.1 ± 25.4
			1360.4	0.57 ± 0.07	515.9 ± 66.3
			1148.3	5.72 ± 0.12	544.8 ± 21.9
			992.3	59.3 ± 0.9	517.4 ± 18.8
			947.9	1.17 ± 0.06	583.3 ± 36.2
			911.8	17.0 ± 0.3	535.4 ± 20.1
			892.3	0.37 ± 0.02	536.5 ± 37.3
			742.6	28.2 ± 0.5	545.6 ± 20.6
			687.6	1.82 ± 0.06	526.3 ± 25.2
			629.8	1.34 ± 0.04	515.4 ± 23.9
			405.8	9.7 ± 0.6	552.2 ± 39.1
			369.5	1.73 ± 0.06	550.4 ± 27.0
			345.3	2.01 ± 0.06	559.2 ± 25.5
			307.6	0.56 ± 0.04	596.3 ± 48.5
			297.4	0.95 ± 0.02	537.2 ± 23.7
			249.6	1.60 ± 0.09	544.7 ± 37.8
			$RR_{mean} =$		538.6 ± 17.4
^{206}Po	i	8.8D	1878.7	*	2246 ± 101
			1718.7	*	2238 ± 89

Continuation of Table 49.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1595.3	*	2231 ± 87
			1405.0	*	2210 ± 93
			1190.9	0.47 ± 0.07	2264 ± 347
			1114.5	0.29 ± 0.05	2228 ± 393
			1098.3	*	2100 ± 79
			1032.3	33 ± 5	2142 ± 332
			1007.2	3.1 ± 0.4	2010 ± 268
			980.2	7.1 ± 0.9	2096 ± 275
			902.5	0.25 ± 0.04	2280 ± 376
			895.1	*	2208 ± 81
			881.0	*	2154 ± 79
			860.9	3.5 ± 0.5	2054 ± 301
			818.2	1.04 ± 0.14	2203 ± 306
			807.4	23 ± 3	2066 ± 278
			803.1	*	2090 ± 76
			784.6	*	2119 ± 99
			677.7	1.47 ± 0.20	2060 ± 289
			668.8	0.86 ± 0.12	2095 ± 301
			632.2	*	2109 ± 81
			620.5	*	2006 ± 81
			579.8	1.06 ± 0.14	1942 ± 265
			554.6	1.56 ± 0.21	1988 ± 276
			537.5	*	1923 ± 76
			522.5	15.7 ± 2.0	2021 ± 267
			516.2	*	1990 ± 76
			497.1	*	1988 ± 76
			469.0	0.26 ± 0.04	1974 ± 315
			463.4	1.79 ± 0.24	2042 ± 283
			457.8	0.15 ± 0.02	1733 ± 265
			398.0	*	1971 ± 76
			381.2	0.18 ± 0.03	2232 ± 328
			369.1	0.17 ± 0.03	2211 ± 334
			354.9	0.39 ± 0.06	1922 ± 304
			343.5	*	2019 ± 80
			338.4	19.2 ± 2.5	2181 ± 293
			311.6	4.2 ± 0.6	2245 ± 330
			286.4	24 ± 3	2217 ± 289
			281.9	0.84 ± 0.11	1948 ± 265
			262.7	*	2192 ± 99
			184.0	*	2328 ± 111
$RR_{mean} =$					$2094 \pm 65.$
^{205}Po	i	1.66H	1239.1	4.6 ± 0.4	17.63 ± 1.75
			1001.2	28.8 ± 2.2	17.95 ± 1.51
			872.4	37 ± 2	18.43 ± 1.19
			849.8	25.5 ± 2.1	18.86 ± 1.71
			836.8	19.2 ± 1.6	19.02 ± 1.74
			261.0	4.0 ± 0.4	15.40 ± 1.83
$RR_{mean} =$					18.33 ± 0.62
^{207}Bi	c	31.55Y	1770.2	6.87 ± 0.04	800.4 ± 34.8
			1063.7	74.5 ± 0.2	789.6 ± 26.5
			569.7	97.74 ± 0.03	793.0 ± 27.2

Continuation of Table 49.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	792.0 ± 25.5
²⁰⁶ Bi _i	i	6.243D	1718.7	31.8 ± 0.6	50.98 ± 2.31
			1595.3	5.01 ± 0.08	59.20 ± 4.86
			1405.0	1.43 ± 0.03	59.86 ± 8.10
			1098.3	13.50 ± 0.21	57.87 ± 3.81
			895.1	15.66 ± 0.23	47.51 ± 2.36
			881.0	66.2 ± 1.0	53.01 ± 2.23
			803.1	98.9 ± 1.4	54.19 ± 2.73
			784.6	0.54 ± 0.01	69.30 ± 31.57
			632.2	4.47 ± 0.07	45.35 ± 4.60
			620.5	5.76 ± 0.09	49.12 ± 7.38
			537.5	30.5 ± 0.5	61.85 ± 5.14
			516.2	40.7 ± 0.6	66.51 ± 5.73
			497.1	15.31 ± 0.22	61.56 ± 4.10
			398.0	10.74 ± 0.15	61.60 ± 5.58
			343.5	23.4 ± 0.4	68.27 ± 5.79
			262.7	3.02 ± 0.06	67.40 ± 7.07
			184.0	15.8 ± 0.4	61.62 ± 3.84
²⁰⁶ Bi _c	c	6.243D	1878.7	2.01 ± 0.05	2166 ± 94
			1718.7	31.8 ± 0.6	2166 ± 84
			1595.3	5.01 ± 0.08	2167 ± 82
			1405.0	1.43 ± 0.03	2149 ± 87
			1098.3	13.50 ± 0.21	2042 ± 75
			895.1	15.66 ± 0.23	2134 ± 76
			881.0	66.2 ± 1.0	2089 ± 75
			803.1	98.9 ± 1.4	2029 ± 73
			784.6	0.54 ± 0.01	2072 ± 90
			632.2	4.47 ± 0.07	2038 ± 76
			620.5	5.76 ± 0.09	1945 ± 75
			537.5	30.5 ± 0.5	1879 ± 72
			516.2	40.7 ± 0.6	1947 ± 73
			497.1	15.31 ± 0.22	1941 ± 73
			398.0	10.74 ± 0.15	1924 ± 72
			343.5	23.4 ± 0.4	1976 ± 76
			262.7	3.02 ± 0.06	2138 ± 93
			184.0	15.8 ± 0.4	2261 ± 104
				RR _{mean} =	2037 ± 67.
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	22.88 ± 1.06
			1764.3	32.5 ± 0.7	25.58 ± 1.15
			987.7	16.13 ± 0.17	23.77 ± 1.08
			703.5	31.1 ± 0.1	20.73 ± 0.89
				RR _{mean} =	22.82 ± 1.26
^{204m} Pb	i(m)	67.2M	899.2	99.17 ± 0.02	5.980 ± 0.212
			374.7	89 ± 15	6.933 ± 1.194
				RR _{mean} =	5.987 ± 0.212
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	2.474 ± 0.107
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	0.8249 ± 0.0853
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	0.1227 ± 0.0040
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	0.6901 ± 0.0226
⁹⁵ Zr	c	64.02D	765.8	*	0.5726 ± 0.0188

Continuation of Table 49.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			756.7	54.46 ± 0.10	0.5808 ± 0.0514
$RR_{mean} =$					0.5727 ± 0.0177

12.1.6 Nuclide production rates for ^{27}Al

Table 50: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.04 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	0.3581 ± 0.0685
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.1669 ± 0.0084
			1014.4	28.0 ± 0.4	0.1677 ± 0.0145
$RR_{mean} =$				0.1670 ± 0.0079	
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	58.62 ± 1.98
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.654 ± 0.056
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.1691 ± 0.0059
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	0.4402 ± 0.0674
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.1733 ± 0.0069
			1014.4	28.0 ± 0.4	0.1774 ± 0.0101
$RR_{mean} =$				0.1741 ± 0.0066	
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	60.49 ± 2.04
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.737 ± 0.058
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.1693 ± 0.0058
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	0.3851 ± 0.1341
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.1613 ± 0.0074
			1014.4	28.0 ± 0.4	0.1663 ± 0.0090
$RR_{mean} =$				0.1631 ± 0.0067	
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	55.31 ± 1.87
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.565 ± 0.053
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.1782 ± 0.0062
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	0.2313 ± 0.0320
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.1129 ± 0.0044
			1014.4	28.0 ± 0.4	0.1196 ± 0.0069
$RR_{mean} =$				0.1141 ± 0.0043	
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	36.03 ± 1.21
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.9787 ± 0.0329
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.1056 ± 0.0036
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	0.5836 ± 0.0485

Continuation of Table 50.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.1576 ± 0.0062
			1014.4	28.0 ± 0.4	0.1635 ± 0.0088
			$RR_{mean} =$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	39.28 ± 1.33
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.003 ± 0.034
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.1842 ± 0.0066

12.2 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.07$ GeV

12.2.1 Nuclide production rates for ^{206}Pb

Table 51: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.07$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁶ Bi	i	6.243D	1878.7	2.01 ± 0.05	30.50 ± 1.82
			1718.7	31.8 ± 0.6	30.33 ± 1.23
			1595.3	5.01 ± 0.08	29.72 ± 1.63
			1098.3	13.50 ± 0.21	27.71 ± 1.26
			1018.6	7.60 ± 0.11	29.40 ± 1.19
			895.1	15.66 ± 0.23	30.07 ± 1.21
			881.0	66.2 ± 1.0	28.99 ± 1.06
			803.1	98.9 ± 1.4	27.98 ± 1.01
			657.2	1.91 ± 0.04	26.67 ± 1.97
			632.2	4.47 ± 0.07	27.10 ± 1.55
			620.5	5.76 ± 0.09	26.57 ± 1.29
			537.5	30.5 ± 0.5	23.84 ± 0.96
			516.2	40.7 ± 0.6	27.02 ± 1.05
			497.1	15.31 ± 0.22	25.28 ± 1.11
			398.0	10.74 ± 0.15	26.14 ± 1.02
			343.5	23.4 ± 0.4	27.23 ± 1.06
			262.7	3.02 ± 0.06	27.38 ± 2.06
			184.0	15.8 ± 0.4	30.57 ± 1.42
RR _{mean} =					27.64 ± 0.97
²⁰⁵ Bi	i	15.31D	1903.4	2.47 ± 0.04	95.37 ± 5.20
			1861.7	6.17 ± 0.10	98.14 ± 4.09
			1775.8	3.99 ± 0.08	102.9 ± 4.3
			1764.3	32.5 ± 0.7	101.9 ± 4.2
			1614.3	2.28 ± 0.04	105.5 ± 4.5
			1190.0	2.26 ± 0.07	104.0 ± 6.7
			1043.8	7.51 ± 0.10	92.87 ± 3.44
			987.7	16.13 ± 0.17	93.03 ± 3.36
			894.6	0.62 ± 0.01	77.19 ± 10.37
			703.5	31.1 ± 0.1	92.59 ± 3.15
			579.8	5.44 ± 0.07	89.18 ± 3.52
			570.6	4.34 ± 0.07	89.37 ± 3.53
			549.8	2.95 ± 0.04	84.99 ± 3.30
			284.1	1.69 ± 0.02	93.97 ± 3.89
			260.5	1.09 ± 0.04	87.41 ± 5.78
RR _{mean} =					93.29 ± 3.20
²⁰⁴ Bi	i	11.22H	1755.3	1.22 ± 0.12	174.8 ± 19.5
			1211.7	3.0 ± 0.4	139.5 ± 19.5
			1043.6	1.27 ± 0.17	214.9 ± 31.9
			984.0	59 ± 4	153.5 ± 11.6
			918.3	10.8 ± 0.9	172.6 ± 15.6
			899.2	98 ± 9	147.6 ± 4.9
			791.2	3.3 ± 0.3	178.9 ± 17.8
			670.7	11.4 ± 0.9	157.5 ± 13.6

Continuation of Table 51.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			374.8	82 ± 5	173.3 ± 36.2
			176.1	1.12 ± 0.09	199.7 ± 20.1
			$RR_{mean} =$		148.5 ± 4.6
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	241.8 ± 16.2
			1983.0	0.88 ± 0.05	232.0 ± 17.4
			1893.0	8.2 ± 0.6	259.5 ± 21.3
			1888.0	1.94 ± 0.10	256.7 ± 18.2
			1847.3	11.4 ± 0.8	253.3 ± 20.0
			1719.6	3.40 ± 0.23	252.5 ± 20.1
			1679.6	8.8 ± 0.7	256.2 ± 22.4
			1536.5	7.5 ± 0.6	252.5 ± 22.5
			1506.7	3.7 ± 0.3	245.3 ± 22.3
			1034.0	8.8 ± 0.5	257.8 ± 17.2
			896.8	13.1 ± 0.7	256.7 ± 16.3
			847.2	8.5 ± 0.5	260.1 ± 17.8
			820.2	29.6 ± 1.5	262.1 ± 15.9
			816.3	4.03 ± 0.21	260.6 ± 16.5
			722.4	4.8 ± 0.4	258.4 ± 23.5
			569.3	1.22 ± 0.07	291.2 ± 22.8
			401.3	*	195.8 ± 20.0
			279.2	*	260.2 ± 10.0
			264.2	5.2 ± 0.4	254.4 ± 22.1
			186.6	3.11 ± 0.22	323.3 ± 26.4
			$RR_{mean} =$		257.0 ± 7.9
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	366.4 ± 12.5
			954.5	7.8 ± 0.5	338.0 ± 25.3
			927.3	7.1 ± 0.4	314.4 ± 22.9
			657.5	60.6 ± 1.8	361.9 ± 16.9
			578.6	7.3 ± 0.4	358.7 ± 25.8
			569.3	4.8 ± 0.3	344.1 ± 26.9
			422.1	83.7 ± 2.5	368.5 ± 17.6
			346.5	4.6 ± 0.3	349.8 ± 27.6
			168.1	4.8 ± 0.3	385.2 ± 29.1
			$RR_{mean} =$		362.2 ± 12.0
^{201}Bi	i	108M	1650.9	5.8 ± 1.3	728.1 ± 166.0
			1570.8	2.4 ± 0.6	801.7 ± 204.3
			1325.2	6.1 ± 1.3	737.8 ± 161.0
			1108.1	3.9 ± 0.9	760.2 ± 180.1
			936.2	11.3 ± 2.5	763.5 ± 171.4
			847.7	1.8 ± 0.4	715.0 ± 162.9
			629.1	24 ± 6	714.6 ± 180.5
			331.2	*	861.7 ± 62.6
			$RR_{mean} =$		847.7 ± 26.1
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	85.32 ± 2.89
			374.7	89 ± 15	89.05 ± 15.34
			$RR_{mean} =$		85.34 ± 2.89
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	107.5 ± 3.6
			374.7	89 ± 15	110.8 ± 19.1
			$RR_{mean} =$		107.5 ± 3.6
$^{203}\text{Pb}_i$	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	285.9 ± 11.1

Continuation of Table 51.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{203}\text{Pb}_c$	c	51.873H	279.2	80.8 ± 0.2	546.1 ± 19.9
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	93.62 ± 8.87
			490.5	9.1 ± 0.7	105.8 ± 9.4
			459.7	8.6 ± 0.7	105.2 ± 9.9
			422.1	86 ± 5	96.31 ± 6.98
			389.9	6.2 ± 0.6	93.19 ± 12.74
			$RR_{mean} =$		98.36 ± 4.07
$^{201}\text{Pb}_i$	i(m+g)	9.33H	331.2	79 ± 5	167.2 ± 14.7
$^{201}\text{Pb}_c$	c	9.33H	331.2	79 ± 5	$1029 \pm 74.$
^{200}Pb	c	21.5H	1604.5	*	486.9 ± 50.2
			1514.9	*	506.0 ± 42.2
			1362.9	*	536.5 ± 67.4
			1205.7	*	522.9 ± 36.8
			605.4	0.56 ± 0.05	632.7 ± 62.8
			579.3	*	537.9 ± 35.2
			525.5	0.42 ± 0.04	503.9 ± 57.4
			367.9	*	506.3 ± 19.4
			268.4	3.96 ± 0.20	587.0 ± 38.9
			257.2	4.46 ± 0.17	598.6 ± 34.8
			235.6	4.30 ± 0.17	606.2 ± 35.0
			147.6	37.7 ± 1.4	543.5 ± 29.5
			$RR_{mean} =$		523.1 ± 16.1
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	19.15 ± 0.70
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	$1245 \pm 46.$
$^{200}\text{Tl}_i$	i	26.1H	1604.5	1.17 ± 0.10	48.64 ± 28.69
			1362.9	3.4 ± 0.4	28.34 ± 16.75
			1205.7	29.9 ± 1.8	23.62 ± 5.75
			886.2	2.02 ± 0.13	36.24 ± 20.67
			367.9	87.2 ± 0.4	17.62 ± 4.35
			$RR_{mean} =$		20.94 ± 3.36
$^{200}\text{Tl}_c$	c	26.1H	1604.5	1.17 ± 0.10	535.6 ± 51.4
			1362.9	3.4 ± 0.4	564.8 ± 69.7
			1205.7	29.9 ± 1.8	546.5 ± 37.9
			886.2	2.02 ± 0.13	546.3 ± 40.9
			367.9	87.2 ± 0.4	523.9 ± 19.2
^{199}Tl	c*	7.42H	$RR_{mean} =$		528.0 ± 18.6
			455.5	12.4 ± 1.4	24.55 ± 3.06
			247.3	9.3 ± 1.1	26.05 ± 3.52
			208.2	12.3 ± 1.4	31.01 ± 3.92
^{198m}Tl	i(m)	1.87H	$RR_{mean} =$		26.68 ± 2.07
			636.7	57 ± 6	17.78 ± 2.07
			587.2	52.5 ± 2.0	17.71 ± 1.10
			282.8	28 ± 3	17.51 ± 2.32
^{203}Hg	c	46.612D	$RR_{mean} =$		17.70 ± 0.83
			279.2	81.46 ± 0.13	0.1044 ± 0.0265
^{124}Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.2190 ± 0.0334
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	3.484 ± 0.146
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	3.348 ± 0.115
^{95}Zr	c	64.02D	765.8	*	3.314 ± 0.117
			756.7	54.46 ± 0.10	3.188 ± 0.184

Continuation of Table 51.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$RR_{mean} =$					3.299 ± 0.102

12.2.2 Nuclide production rates for ^{207}Pb

Table 52: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 0.07 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	1063.7	74.5 ± 0.2	36.53 ± 2.37
			569.7	97.74 ± 0.03	34.33 ± 2.07
			$RR_{mean} =$		35.26 ± 1.74
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	100.0 ± 4.6
			1718.7	31.8 ± 0.6	95.12 ± 3.75
			1595.3	5.01 ± 0.08	101.0 ± 3.9
			1098.3	13.50 ± 0.21	88.80 ± 3.34
			1018.6	7.60 ± 0.11	95.75 ± 3.52
			895.1	15.66 ± 0.23	95.67 ± 3.49
			881.0	66.2 ± 1.0	92.70 ± 3.34
			803.1	98.9 ± 1.4	90.34 ± 3.22
			657.2	1.91 ± 0.04	87.35 ± 3.93
			632.2	4.47 ± 0.07	87.01 ± 3.41
			620.5	5.76 ± 0.09	83.06 ± 3.18
			537.5	30.5 ± 0.5	82.37 ± 3.12
			516.2	40.7 ± 0.6	86.98 ± 3.25
			497.1	15.31 ± 0.22	83.00 ± 3.10
			398.0	10.74 ± 0.15	83.99 ± 3.13
			343.5	23.4 ± 0.4	86.43 ± 3.29
			262.7	3.02 ± 0.06	92.74 ± 4.29
			184.0	15.8 ± 0.4	98.47 ± 4.44
			$RR_{mean} =$		89.38 ± 3.06
^{205}Bi	i	15.31D	1903.4	2.47 ± 0.04	216.7 ± 8.8
			1861.7	6.17 ± 0.10	211.3 ± 8.3
			1775.8	3.99 ± 0.08	215.5 ± 8.8
			1764.3	32.5 ± 0.7	214.5 ± 8.7
			1614.3	2.28 ± 0.04	228.9 ± 9.2
			1190.0	2.26 ± 0.07	211.2 ± 9.7
			1043.8	7.51 ± 0.10	195.3 ± 7.0
			987.7	16.13 ± 0.17	210.3 ± 7.4
			894.6	0.62 ± 0.01	176.4 ± 13.6
			703.5	31.1 ± 0.1	197.5 ± 6.6
			579.8	5.44 ± 0.07	191.5 ± 7.0
			570.6	4.34 ± 0.07	184.8 ± 7.1
			$RR_{mean} =$		202.2 ± 7.1
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	278.3 ± 31.7
			1211.7	3.0 ± 0.4	250.6 ± 35.2
			1043.6	1.27 ± 0.17	335.9 ± 48.8
			984.0	59 ± 4	264.6 ± 20.0
			918.3	10.8 ± 0.9	291.7 ± 26.2
			899.2	98 ± 9	254.1 ± 8.3

Continuation of Table 52.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			791.2	3.3 ± 0.3	308.1 ± 30.4
			670.7	11.4 ± 0.9	280.0 ± 24.1
			374.8	82 ± 5	299.5 ± 62.5
			176.1	1.12 ± 0.09	337.3 ± 33.9
			$RR_{mean} =$		255.9 ± 7.9
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	412.9 ± 27.2
			1983.0	0.88 ± 0.05	453.2 ± 32.6
			1893.0	8.2 ± 0.6	435.4 ± 35.8
			1888.0	1.94 ± 0.10	441.2 ± 29.1
			1847.3	11.4 ± 0.8	422.6 ± 33.4
			1719.6	3.40 ± 0.23	416.3 ± 34.3
			1679.6	8.8 ± 0.7	424.1 ± 36.9
			1536.5	7.5 ± 0.6	449.2 ± 39.6
			1506.7	3.7 ± 0.3	429.4 ± 38.8
			1034.0	8.8 ± 0.5	421.6 ± 27.9
			936.0	0.74 ± 0.04	424.6 ± 42.7
			896.8	13.1 ± 0.7	418.1 ± 26.4
			847.2	8.5 ± 0.5	436.6 ± 29.7
			820.2	29.6 ± 1.5	443.4 ± 26.9
			816.3	4.03 ± 0.21	442.1 ± 27.6
			722.4	4.8 ± 0.4	444.3 ± 40.1
			569.3	1.22 ± 0.07	470.8 ± 37.5
			401.3	*	353.0 ± 26.5
			279.2	*	435.0 ± 16.4
			264.2	5.2 ± 0.4	440.9 ± 38.4
			186.6	3.11 ± 0.22	520.2 ± 42.2
			$RR_{mean} =$		431.5 ± 13.3
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	791.4 ± 28.2
			954.5	7.8 ± 0.5	763.2 ± 57.5
			927.3	7.1 ± 0.4	783.0 ± 53.1
			657.5	60.6 ± 1.8	790.4 ± 36.5
			578.6	7.3 ± 0.4	774.6 ± 51.8
			569.3	4.8 ± 0.3	808.7 ± 60.3
			422.1	83.7 ± 2.5	783.1 ± 36.5
			346.5	4.6 ± 0.3	752.5 ± 56.7
			168.1	4.8 ± 0.3	836.3 ± 61.8
			$RR_{mean} =$		788.5 ± 26.3
^{201}Bi	i	108M	1650.9	5.8 ± 1.3	780.2 ± 177.5
			1570.8	2.4 ± 0.6	876.9 ± 222.3
			1325.2	6.1 ± 1.3	795.8 ± 173.3
			1108.1	3.9 ± 0.9	848.0 ± 199.0
			936.2	11.3 ± 2.5	758.4 ± 170.5
			847.7	1.8 ± 0.4	820.3 ± 187.1
			629.1	24 ± 6	773.8 ± 196.0
			331.2	*	902.3 ± 65.1
			$RR_{mean} =$		890.7 ± 27.5
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	137.3 ± 4.6
			374.7	89 ± 15	141.2 ± 24.3
			$RR_{mean} =$		137.3 ± 4.6
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	175.4 ± 5.8
			374.7	89 ± 15	178.8 ± 30.7

Continuation of Table 52.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	175.4 ± 5.8
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	327.3 ± 13.0
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	762.3 ± 27.8
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	102.7 ± 10.2
			490.5	9.1 ± 0.7	108.5 ± 9.7
			459.7	8.6 ± 0.7	120.6 ± 11.7
			422.1	86 ± 5	100.3 ± 7.4
			389.9	6.2 ± 0.6	102.0 ± 12.1
			RR _{mean} =		
²⁰¹ Pb _i	i(m+g)	9.33H	331.2	79 ± 5	75.56 ± 8.66
²⁰¹ Pb _c	c	9.33H	331.2	79 ± 5	977.8 ± 70.1
²⁰⁰ Pb	c	21.5H	1514.9	*	33.17 ± 3.51
			1205.7	*	37.71 ± 2.83
			367.9	*	35.73 ± 1.34
			235.6	4.30 ± 0.17	46.65 ± 4.59
			147.6	37.7 ± 1.4	39.66 ± 2.22
			RR _{mean} =		
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	20.39 ± 0.75
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	1188 ± 44.
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	34.58 ± 4.44
			1205.7	29.9 ± 1.8	28.89 ± 2.55
			367.9	87.2 ± 0.4	26.77 ± 1.13
RR _{mean} =				27.19 ± 1.29	
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	67.74 ± 5.80
			1205.7	29.9 ± 1.8	66.60 ± 4.64
			367.9	87.2 ± 0.4	62.50 ± 2.16
RR _{mean} =				62.84 ± 2.14	
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	26.51 ± 3.39
			247.3	9.3 ± 1.1	26.60 ± 4.05
			208.2	12.3 ± 1.4	31.09 ± 4.09
RR _{mean} =				27.90 ± 1.71	
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	0.7156 ± 0.0337
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.1848 ± 0.0380
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	3.215 ± 0.126
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	3.112 ± 0.103
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	3.253 ± 0.164
⁹⁵ Zr	c	64.02D	765.8	*	2.953 ± 0.099
			756.7	54.46 ± 0.10	2.847 ± 0.117
RR _{mean} =				2.932 ± 0.090	

12.2.3 Nuclide production rates for ^{208}Pb

Table 53: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.07 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	1063.7	74.5 ± 0.2	84.38 $\pm$ 4.19
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	143.8 ± 6.6
			1718.7	31.8 ± 0.6	142.9 ± 5.7

Continuation of Table 53.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1595.3	5.01 ± 0.08	151.1 ± 5.9
			1098.3	13.50 ± 0.21	133.8 ± 5.0
			1018.6	7.60 ± 0.11	145.6 ± 5.3
			895.1	15.66 ± 0.23	141.8 ± 5.2
			881.0	66.2 ± 1.0	139.5 ± 5.0
			803.1	98.9 ± 1.4	135.3 ± 4.8
			657.2	1.91 ± 0.04	129.6 ± 6.2
			632.2	4.47 ± 0.07	129.7 ± 5.0
			620.5	5.76 ± 0.09	124.3 ± 4.7
			537.5	30.5 ± 0.5	123.1 ± 4.7
			516.2	40.7 ± 0.6	130.8 ± 4.9
			497.1	15.31 ± 0.22	124.8 ± 4.6
			398.0	10.74 ± 0.15	124.1 ± 4.6
			343.5	23.4 ± 0.4	130.2 ± 4.9
			262.7	3.02 ± 0.06	132.8 ± 6.0
			184.0	15.8 ± 0.4	148.8 ± 6.7
			$RR_{mean} =$		133.6 ± 4.6
^{205}Bi	i	15.31D	1903.4	2.47 ± 0.04	248.2 ± 10.7
			1861.7	6.17 ± 0.10	245.8 ± 9.7
			1775.8	3.99 ± 0.08	251.0 ± 10.3
			1764.3	32.5 ± 0.7	253.7 ± 10.4
			1614.3	2.28 ± 0.04	253.5 ± 10.5
			1190.0	2.26 ± 0.07	248.5 ± 11.6
			1043.8	7.51 ± 0.10	229.6 ± 8.3
			987.7	16.13 ± 0.17	245.3 ± 8.5
			894.6	0.62 ± 0.01	246.2 ± 26.9
			703.5	31.1 ± 0.1	232.0 ± 7.9
			579.8	5.44 ± 0.07	223.8 ± 8.2
			570.6	4.34 ± 0.07	221.8 ± 9.1
			$RR_{mean} =$		237.6 ± 8.0
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	297.1 ± 33.0
			1211.7	3.0 ± 0.4	276.1 ± 38.5
			1043.6	1.27 ± 0.17	386.6 ± 55.6
			984.0	59 ± 4	293.8 ± 22.3
			918.3	10.8 ± 0.9	326.5 ± 29.3
			899.2	98 ± 9	280.2 ± 9.4
			791.2	3.3 ± 0.3	337.0 ± 33.4
			670.7	11.4 ± 0.9	309.3 ± 26.7
			374.8	82 ± 5	333.0 ± 69.5
			176.1	1.12 ± 0.09	387.1 ± 35.2
			$RR_{mean} =$		282.6 ± 8.7
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	579.8 ± 37.6
			1983.0	0.88 ± 0.05	628.3 ± 44.0
			1893.0	8.2 ± 0.6	596.5 ± 48.8
			1888.0	1.94 ± 0.10	592.6 ± 38.6
			1847.3	11.4 ± 0.8	578.6 ± 45.7
			1719.6	3.40 ± 0.23	552.4 ± 47.0
			1679.6	8.8 ± 0.7	575.4 ± 50.0
			1536.5	7.5 ± 0.6	596.0 ± 52.0
			1506.7	3.7 ± 0.3	552.5 ± 49.0
			1034.0	8.8 ± 0.5	589.0 ± 38.9

Continuation of Table 53.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹			
			936.0	0.74 ± 0.04	646.2 ± 43.7			
			896.8	13.1 ± 0.7	573.9 ± 36.3			
			847.2	8.5 ± 0.5	601.4 ± 40.7			
			820.2	29.6 ± 1.5	603.4 ± 36.5			
			816.3	4.03 ± 0.21	600.2 ± 37.3			
			722.4	4.8 ± 0.4	606.3 ± 54.8			
			569.3	1.22 ± 0.07	663.9 ± 55.7			
			401.3	*	551.3 ± 35.3			
			279.2	*	594.3 ± 22.2			
			264.2	5.2 ± 0.4	606.7 ± 52.4			
			186.6	3.11 ± 0.22	680.6 ± 55.0			
			RR _{mean} =				590.2 ± 18.2	
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	859.2 ± 30.3			
			954.5	7.8 ± 0.5	867.5 ± 64.1			
			927.3	7.1 ± 0.4	859.3 ± 58.3			
			657.5	60.6 ± 1.8	846.4 ± 39.6			
			578.6	7.3 ± 0.4	872.9 ± 57.5			
			569.3	4.8 ± 0.3	857.0 ± 67.9			
			422.1	83.7 ± 2.5	854.4 ± 40.2			
			346.5	4.6 ± 0.3	809.2 ± 60.9			
			168.1	4.8 ± 0.3	889.8 ± 65.5			
			RR _{mean} =				856.9 ± 28.5	
			²⁰¹ Bi	i	108M	1650.9	5.8 ± 1.3	45.71 ± 15.15
						1325.2	6.1 ± 1.3	72.11 ± 16.60
1108.1	3.9 ± 0.9	84.18 ± 21.71						
936.2	11.3 ± 2.5	53.91 ± 12.63						
629.1	24 ± 6	54.83 ± 14.01						
331.2	*	64.94 ± 5.39						
RR _{mean} =						64.41 ± 1.99		
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	124.8 ± 4.8			
			374.7	89 ± 15	131.4 ± 22.7			
			RR _{mean} =				125.0 ± 4.8	
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	166.9 ± 6.0			
			374.7	89 ± 15	173.1 ± 29.9			
			RR _{mean} =				166.9 ± 6.0	
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	228.0 ± 10.3			
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	822.3 ± 30.0			
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	43.95 ± 4.95			
			490.5	9.1 ± 0.7	47.99 ± 4.69			
			459.7	8.6 ± 0.7	66.75 ± 7.00			
			422.1	86 ± 5	36.99 ± 4.17			
			389.9	6.2 ± 0.6	48.61 ± 5.89			
			RR _{mean} =				46.13 ± 4.50	
²⁰¹ Pb _i	i(m+g)	9.33H	331.2	79 ± 5	11.75 ± 3.17			
²⁰¹ Pb _c	c	9.33H	331.2	79 ± 5	76.69 ± 5.53			
²⁰⁰ Pb	c	21.5H	1205.7	*	6.852 ± 0.971			
			579.3	*	6.076 ± 1.518			
			367.9	*	5.269 ± 0.245			
			147.6	37.7 ± 1.4	8.170 ± 0.745			
			RR _{mean} =				5.580 ± 0.172	

Continuation of Table 53.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	14.80 ± 0.55
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	112.0 ± 4.4
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	24.09 ± 2.30
			579.3	13.8 ± 0.7	22.76 ± 2.54
			367.9	87.2 ± 0.4	23.24 ± 0.87
			RR _{mean} =		23.26 ± 0.85
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	30.94 ± 2.31
			579.3	13.8 ± 0.7	28.84 ± 2.07
			367.9	87.2 ± 0.4	28.51 ± 1.00
			RR _{mean} =		28.63 ± 0.98
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	11.39 ± 1.85
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	1.198 ± 0.054
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	1.961 ± 0.091
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	1.959 ± 0.135
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	2.351 ± 0.141
⁹⁵ Zr	c	64.02D	765.8	*	1.795 ± 0.146
			756.7	54.46 ± 0.10	1.694 ± 0.117
			RR _{mean} =		1.732 ± 0.053

12.2.4 Nuclide production rates for ^{nat}Pb

Table 54: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.07 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	1063.7	74.5 ± 0.2	28.37 ± 2.71
			569.7	97.74 ± 0.03	20.58 ± 3.52
			RR _{mean} =		
²⁰⁶ Bi	i	6.243D	1878.7	2.01 ± 0.05	42.15 ± 2.18
			1718.7	31.8 ± 0.6	41.50 ± 1.63
			1595.3	5.01 ± 0.08	42.49 ± 1.68
			1098.3	13.50 ± 0.21	38.84 ± 1.46
			1018.6	7.60 ± 0.11	41.28 ± 1.54
			895.1	15.66 ± 0.23	41.62 ± 1.58
			881.0	66.2 ± 1.0	40.54 ± 1.46
			803.1	98.9 ± 1.4	39.28 ± 1.40
			657.2	1.91 ± 0.04	36.72 ± 1.95
			632.2	4.47 ± 0.07	37.80 ± 1.52
			620.5	5.76 ± 0.09	37.67 ± 1.52
			537.5	30.5 ± 0.5	36.15 ± 1.37
			516.2	40.7 ± 0.6	38.07 ± 1.43
			497.1	15.31 ± 0.22	35.79 ± 1.34
			398.0	10.74 ± 0.15	36.62 ± 1.35
			343.5	23.4 ± 0.4	38.07 ± 1.46
			262.7	3.02 ± 0.06	40.01 ± 1.86
			184.0	15.8 ± 0.4	43.22 ± 1.99
			RR _{mean} =		
²⁰⁵ Bi	i	15.31D	1903.4	2.47 ± 0.04	81.68 ± 3.41
			1861.7	6.17 ± 0.10	81.64 ± 3.19

Continuation of Table 54.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1775.8	3.99 ± 0.08	84.74 ± 3.50
			1764.3	32.5 ± 0.7	83.04 ± 3.38
			1614.3	2.28 ± 0.04	87.51 ± 3.63
			1190.0	2.26 ± 0.07	81.35 ± 3.79
			1043.8	7.51 ± 0.10	75.68 ± 2.71
			987.7	16.13 ± 0.17	81.63 ± 2.83
			894.6	0.62 ± 0.01	68.81 ± 10.71
			703.5	31.1 ± 0.1	76.88 ± 2.62
			579.8	5.44 ± 0.07	74.07 ± 2.90
			570.6	4.34 ± 0.07	72.54 ± 3.01
			$RR_{mean} =$		78.91 ± 2.71
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	106.1 ± 12.2
			1211.7	3.0 ± 0.4	86.12 ± 12.09
			1043.6	1.27 ± 0.17	145.6 ± 20.5
			984.0	59 ± 4	104.0 ± 7.9
			918.3	10.8 ± 0.9	118.0 ± 10.6
			899.2	98 ± 9	101.5 ± 3.3
			791.2	3.3 ± 0.3	125.2 ± 12.2
			670.7	11.4 ± 0.9	109.4 ± 9.4
			374.8	82 ± 5	119.0 ± 24.8
			176.1	1.12 ± 0.09	137.9 ± 12.9
			$RR_{mean} =$		101.9 ± 3.1
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	222.9 ± 14.4
			1983.0	0.88 ± 0.05	239.4 ± 16.8
			1893.0	8.2 ± 0.6	228.5 ± 18.7
			1888.0	1.94 ± 0.10	206.8 ± 13.4
			1847.3	11.4 ± 0.8	223.7 ± 17.6
			1719.6	3.40 ± 0.23	230.6 ± 18.1
			1679.6	8.8 ± 0.7	216.4 ± 18.8
			1536.5	7.5 ± 0.6	230.1 ± 20.1
			1506.7	3.7 ± 0.3	212.7 ± 18.8
			1034.0	8.8 ± 0.5	227.4 ± 15.0
			936.0	0.74 ± 0.04	239.1 ± 16.5
			896.8	13.1 ± 0.7	224.4 ± 14.1
			847.2	8.5 ± 0.5	231.2 ± 15.7
			820.2	29.6 ± 1.5	232.4 ± 14.1
			816.3	4.03 ± 0.21	224.4 ± 13.9
			722.4	4.8 ± 0.4	234.6 ± 21.1
			569.3	1.22 ± 0.07	248.4 ± 18.0
			401.3	*	176.6 ± 14.3
			279.2	*	233.5 ± 10.6
			264.2	5.2 ± 0.4	228.0 ± 19.7
			186.6	3.11 ± 0.22	268.5 ± 21.7
			$RR_{mean} =$		226.2 ± 7.0
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	259.3 ± 9.4
			954.5	7.8 ± 0.5	254.5 ± 18.8
			927.3	7.1 ± 0.4	241.4 ± 17.1
			657.5	60.6 ± 1.8	259.5 ± 12.4
			578.6	7.3 ± 0.4	239.4 ± 17.4
			569.3	4.8 ± 0.3	254.3 ± 19.6
			422.1	83.7 ± 2.5	253.6 ± 12.2

Continuation of Table 54.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			346.5	4.6 ± 0.3	240.0 ± 18.4
			168.1	4.8 ± 0.3	266.1 ± 20.1
			<i>RR_{mean}</i> =		255.8 ± 8.6
²⁰¹ Bi	i	108M	1650.9	5.8 ± 1.3	130.2 ± 30.0
			1570.8	2.4 ± 0.6	161.0 ± 41.5
			1325.2	6.1 ± 1.3	145.8 ± 31.6
			1108.1	3.9 ± 0.9	140.9 ± 33.1
			936.2	11.3 ± 2.5	130.6 ± 29.4
			847.7	1.8 ± 0.4	131.6 ± 33.5
			629.1	24 ± 6	139.9 ± 35.5
			331.2	*	159.3 ± 11.7
			<i>RR_{mean}</i> =		157.0 ± 4.8
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	46.03 ± 1.58
			374.7	89 ± 15	46.76 ± 8.08
			<i>RR_{mean}</i> =		46.04 ± 1.58
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	61.26 ± 2.05
			374.7	89 ± 15	61.69 ± 10.63
			<i>RR_{mean}</i> =		61.26 ± 2.05
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	92.26 ± 8.75
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	325.8 ± 12.0
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	22.88 ± 2.32
			490.5	9.1 ± 0.7	26.13 ± 2.78
			459.7	8.6 ± 0.7	26.24 ± 2.83
			422.1	86 ± 5	23.42 ± 2.02
			389.9	6.2 ± 0.6	23.70 ± 2.84
			<i>RR_{mean}</i> =		24.12 ± 1.15
²⁰¹ Pb _i	i(m+g)	9.33H	331.2	79 ± 5	27.11 ± 3.16
²⁰¹ Pb _c	c	9.33H	331.2	79 ± 5	186.4 ± 13.4
²⁰⁰ Pb	c	21.5H	1604.5	*	42.03 ± 6.85
			1514.9	*	44.97 ± 4.31
			1362.9	*	43.13 ± 5.53
			1205.7	*	42.62 ± 2.99
			579.3	*	40.68 ± 2.91
			367.9	*	40.51 ± 1.42
			268.4	3.96 ± 0.20	45.93 ± 3.00
			257.2	4.46 ± 0.17	48.21 ± 2.78
			147.6	37.7 ± 1.4	48.63 ± 2.72
			<i>RR_{mean}</i> =		41.64 ± 1.28
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	6.468 ± 0.240
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	227.6 ± 8.5
²⁰⁰ Tl _i	i	26.1H	1604.5	1.17 ± 0.10	15.51 ± 8.78
			1514.9	4.0 ± 0.3	7.405 ± 2.925
			1362.9	3.4 ± 0.4	10.29 ± 2.70
			1205.7	29.9 ± 1.8	11.05 ± 1.21
			886.2	2.02 ± 0.13	22.98 ± 3.91
			579.3	13.8 ± 0.7	10.59 ± 2.11
			367.9	87.2 ± 0.4	9.684 ± 0.915
			<i>RR_{mean}</i> =		10.45 ± 0.96
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	57.54 ± 6.93
			1514.9	4.0 ± 0.3	52.38 ± 4.49

Continuation of Table 54.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1362.9	3.4 ± 0.4	53.42 ± 6.65
			1205.7	29.9 ± 1.8	53.67 ± 3.73
			886.2	2.02 ± 0.13	59.44 ± 4.71
			579.3	13.8 ± 0.7	51.27 ± 3.35
			367.9	87.2 ± 0.4	50.19 ± 1.80
			$RR_{mean} =$		50.99 ± 1.77
^{199}Tl	c*	7.42H	455.5	12.4 ± 1.4	13.32 ± 1.63
			247.3	9.3 ± 1.1	13.04 ± 1.72
			208.2	12.3 ± 1.4	15.22 ± 1.90
			$RR_{mean} =$		13.78 ± 0.78
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	0.2978 ± 0.0428
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	0.9909 ± 0.0446
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	0.8904 ± 0.0566
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	0.9259 ± 0.0597
^{95}Zr	c	64.02D	765.8	*	0.9093 ± 0.0698
			756.7	54.46 ± 0.10	0.7648 ± 0.0788
			$RR_{mean} =$		0.8486 ± 0.0262

12.2.5 Nuclide production rates for ^{209}Bi

Table 55: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.07 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	1148.3	5.72 ± 0.12	190.4 ± 9.1
			992.3	59.3 ± 0.9	173.0 ± 6.4
			742.6	28.2 ± 0.5	176.2 ± 7.8
			405.8	9.7 ± 0.6	174.9 ± 14.2
			$RR_{mean} =$		176.2 ± 6.4
^{206}Po	i	8.8D	1878.7	*	263.9 ± 11.8
			1844.5	*	253.7 ± 18.7
			1595.3	*	272.9 ± 10.8
			1405.0	*	266.2 ± 11.3
			1098.3	*	243.1 ± 9.6
			1032.3	33 ± 5	262.9 ± 40.8
			1032.3	33 ± 5	262.7 ± 40.7
			1018.6	*	269.3 ± 9.8
			1007.2	3.1 ± 0.4	246.3 ± 32.9
			980.2	7.1 ± 0.9	258.1 ± 33.8
			895.1	*	264.1 ± 9.7
			881.0	*	260.2 ± 9.6
			818.2	1.04 ± 0.14	300.4 ± 42.3
			807.4	23 ± 3	247.8 ± 33.4
			803.1	*	249.0 ± 9.1
			677.7	1.47 ± 0.20	267.9 ± 38.9
			657.2	*	264.1 ± 20.7
			632.2	*	238.7 ± 10.0
			620.5	*	241.8 ± 11.2
			554.6	1.56 ± 0.21	219.1 ± 31.3

Continuation of Table 55.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			537.5	*	230.7 ± 9.1
			522.5	15.7 ± 2.0	244.2 ± 32.2
			516.2	*	244.5 ± 9.4
			497.1	*	230.9 ± 9.4
			463.4	1.79 ± 0.24	240.7 ± 33.5
			398.0	*	235.4 ± 9.6
			386.2	*	216.2 ± 10.9
			343.5	*	242.8 ± 9.6
			338.4	19.2 ± 2.5	260.5 ± 35.1
			311.6	4.2 ± 0.6	268.3 ± 39.5
			286.4	24 ± 3	262.3 ± 34.1
			184.0	*	279.2 ± 13.5
			$RR_{mean} =$		249.9 ± 7.7
^{205}Po	i	1.66H	1513.7	2.11 ± 0.22	394.7 ± 45.0
			1239.1	4.6 ± 0.4	362.6 ± 34.7
			1001.2	28.8 ± 2.2	355.9 ± 29.8
			872.4	37 ± 2	376.9 ± 24.5
			849.8	25.5 ± 2.1	381.0 ± 33.9
			836.8	19.2 ± 1.6	375.5 ± 34.2
			261.0	4.0 ± 0.4	377.9 ± 42.3
			$RR_{mean} =$		375.0 ± 13.0
^{204}Po	i	3.53H	1964.8	*	691.9 ± 237.7
			1703.3	*	820.1 ± 111.6
			1524.1	*	671.7 ± 107.2
			1414.7	*	653.2 ± 153.1
			1274.8	*	717.2 ± 131.7
			1211.7	*	612.6 ± 94.9
			1040.0	9.6 ± 0.5	863.6 ± 53.6
			1016.3	24.1 ± 1.0	824.8 ± 44.1
			984.0	*	727.0 ± 55.4
			918.3	*	862.7 ± 83.2
			899.2	*	831.4 ± 84.9
			884.0	29.9 ± 1.2	836.5 ± 43.5
			762.5	11.5 ± 0.5	809.1 ± 44.8
			680.4	7.6 ± 0.4	786.7 ± 51.3
			670.7	*	772.8 ± 67.5
			539.5	1.35 ± 0.10	880.0 ± 74.8
			534.9	13.2 ± 0.8	774.4 ± 54.4
			451.9	1.91 ± 0.10	887.4 ± 58.7
			440.5	*	928.0 ± 159.4
			426.8	1.88 ± 0.14	804.1 ± 68.6
			374.8	*	829.4 ± 58.4
			317.0	4.3 ± 0.5	840.4 ± 102.4
			305.0	3.26 ± 0.17	785.0 ± 50.0
			289.3	*	883.0 ± 86.3
			270.1	27.8 ± 1.3	814.0 ± 49.3
			219.4	*	961.7 ± 88.0
			203.6	2.81 ± 0.13	937.7 ± 59.4
			176.1	*	921.4 ± 120.4
			137.0	9.7 ± 0.4	907.2 ± 63.4
			$RR_{mean} =$		815.4 ± 25.1

Continuation of Table 55.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰³ Po	i(m+g)	36.7M	1264.0	0.93 ± 0.13	719.5 ± 108.6
			1242.4	4.6 ± 0.4	675.3 ± 64.6
			1123.9	1.59 ± 0.19	753.0 ± 95.5
			1090.9	19.2 ± 1.6	666.5 ± 64.6
			908.6	55 ± 3	676.7 ± 47.8
			893.5	18.7 ± 1.5	666.7 ± 60.9
			822.9	2.36 ± 0.21	762.6 ± 74.8
			647.7	2.03 ± 0.20	798.5 ± 86.3
			419.3	2.4 ± 0.3	974.6 ± 133.1
			389.9	1.10 ± 0.13	858.5 ± 108.5
			214.8	14.3 ± 1.4	788.0 ± 85.1
			189.5	3.8 ± 0.4	608.0 ± 70.8
			175.2	3.0 ± 0.4	705.8 ± 99.6
²⁰² Po	i	44.7M	960.7	*	10.20 ± 2.12
			688.6	51 ± 6	7.768 ± 1.292
			RR _{mean} =	8.420 ± 0.260	
²⁰⁷ Bi	c	31.55Y	1770.2	6.87 ± 0.04	541.0 ± 55.1
			1063.7	74.5 ± 0.2	507.6 ± 17.1
			569.7	97.74 ± 0.03	511.7 ± 21.2
			RR _{mean} =	508.8 ± 16.9	
²⁰⁶ Bi _i	i	6.243D	1878.7	2.01 ± 0.05	316.5 ± 13.9
			1844.5	0.57 ± 0.03	331.4 ± 24.3
			1595.3	5.01 ± 0.08	321.6 ± 13.1
			1405.0	1.43 ± 0.03	285.4 ± 12.2
			1098.3	13.50 ± 0.21	288.2 ± 13.2
			1018.6	7.60 ± 0.11	300.0 ± 10.8
			895.1	15.66 ± 0.23	305.4 ± 11.2
			881.0	66.2 ± 1.0	294.6 ± 11.1
			803.1	98.9 ± 1.4	303.8 ± 11.6
			657.2	1.91 ± 0.04	258.8 ± 38.2
			632.2	4.47 ± 0.07	290.8 ± 14.5
			620.5	5.76 ± 0.09	254.7 ± 17.7
			537.5	30.5 ± 0.5	252.4 ± 10.4
			516.2	40.7 ± 0.6	254.8 ± 10.1
			497.1	15.31 ± 0.22	258.1 ± 12.3
			398.0	10.74 ± 0.15	262.3 ± 13.0
			386.2	0.52 ± 0.01	317.1 ± 15.0
			343.5	23.4 ± 0.4	265.7 ± 11.5
			184.0	15.8 ± 0.4	322.6 ± 16.0
			RR _{mean} =	287.9 ± 10.4	
²⁰⁶ Bi _c	c	6.243D	1878.7	2.01 ± 0.05	565.9 ± 24.4
			1844.5	0.57 ± 0.03	571.2 ± 36.9
			1595.3	5.01 ± 0.08	579.6 ± 21.8
			1405.0	1.43 ± 0.03	536.9 ± 21.4
			1098.3	13.50 ± 0.21	517.9 ± 19.6
			1018.6	7.60 ± 0.11	554.5 ± 19.8
			895.1	15.66 ± 0.23	554.9 ± 19.9
			881.0	66.2 ± 1.0	540.5 ± 19.5
			803.1	98.9 ± 1.4	539.0 ± 19.5
			657.2	1.91 ± 0.04	508.3 ± 31.3

Continuation of Table 55.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{205}Bi	c	15.31D	632.2	4.47 ± 0.07	516.4 ± 20.2
			620.5	5.76 ± 0.09	483.2 ± 20.5
			537.5	30.5 ± 0.5	470.4 ± 18.0
			516.2	40.7 ± 0.6	485.8 ± 18.2
			497.1	15.31 ± 0.22	476.4 ± 18.3
			398.0	10.74 ± 0.15	484.8 ± 18.6
			386.2	0.52 ± 0.01	521.4 ± 21.8
			343.5	23.4 ± 0.4	495.1 ± 19.1
			184.0	15.8 ± 0.4	586.4 ± 27.3
			$RR_{mean} =$		
			520.5 $\pm$ 18.0		
			1903.4	2.47 ± 0.04	735.2 ± 28.9
			1861.7	6.17 ± 0.10	712.4 ± 27.8
			1775.8	3.99 ± 0.08	747.7 ± 30.5
			1764.3	32.5 ± 0.7	725.6 ± 29.7
			1619.1	0.37 ± 0.02	768.4 ± 45.0
			1614.3	2.28 ± 0.04	769.4 ± 29.5
			1551.0	0.97 ± 0.03	687.0 ± 32.6
			1351.5	1.06 ± 0.04	744.1 ± 38.1
			1190.0	2.26 ± 0.07	714.6 ± 33.0
			1072.4	0.30 ± 0.01	669.5 ± 30.6
			1043.8	7.51 ± 0.10	665.5 ± 24.3
$^{204}\text{Bi}_i$	i	11.22H	992.7	0.09 ± 0.04	786.3 ± 353.1
			987.7	16.13 ± 0.17	710.0 ± 24.7
			910.9	1.64 ± 0.04	661.6 ± 27.3
			872.0	0.42 ± 0.01	691.2 ± 30.3
			828.2	0.29 ± 0.01	722.9 ± 44.9
			813.8	0.47 ± 0.01	668.7 ± 31.4
			761.3	0.68 ± 0.04	662.9 ± 45.9
			761.3	0.68 ± 0.04	660.2 ± 45.6
			759.1	1.04 ± 0.05	756.0 ± 44.9
			744.7	0.70 ± 0.02	673.9 ± 28.6
			703.5	31.1 ± 0.1	678.5 ± 22.6
			579.8	5.44 ± 0.07	640.1 ± 23.5
			573.8	0.62 ± 0.01	609.6 ± 27.4
			570.6	4.34 ± 0.07	660.4 ± 33.2
			549.8	2.95 ± 0.04	610.0 ± 24.0
			493.6	0.37 ± 0.01	653.2 ± 29.8
			349.5	0.56 ± 0.01	676.0 ± 33.7
			$RR_{mean} =$		
			684.1 $\pm$ 22.5		
			1964.8	0.37 ± 0.04	278.6 ± 290.2
			1703.3	1.99 ± 0.17	249.3 ± 107.1
			1524.1	0.96 ± 0.09	298.9 ± 107.1
			1414.7	0.97 ± 0.12	390.7 ± 169.5
			1274.8	2.14 ± 0.25	189.3 ± 126.3
			1211.7	3.0 ± 0.4	302.6 ± 67.5
			984.0	59 ± 4	210.5 ± 16.6
			918.3	10.8 ± 0.9	184.5 ± 40.5
			899.2	98 ± 9	204.7 ± 33.8
			670.7	11.4 ± 0.9	220.3 ± 22.3
			440.5	2.5 ± 0.4	236.1 ± 68.7
			374.8	82 ± 5	221.7 ± 16.0

Continuation of Table 55.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁴ Bi _c	c	11.22H	289.3	2.86 ± 0.25	284.7 ± 34.6
			219.4	2.30 ± 0.17	430.3 ± 50.3
			176.1	1.12 ± 0.09	295.1 ± 112.7
			<i>RR_{mean}</i> =		227.4 ± 13.0
			1964.8	0.37 ± 0.04	965.9 ± 133.5
			1703.3	1.99 ± 0.17	1064 ± 101
			1524.1	0.96 ± 0.09	966.1 ± 100.3
			1414.7	0.97 ± 0.12	1040 ± 140
			1274.8	2.14 ± 0.25	901.8 ± 113.9
			1211.7	3.0 ± 0.4	911.2 ± 126.0
			984.0	59 ± 4	932.7 ± 70.3
			918.3	10.8 ± 0.9	1042 ± 94
			899.2	98 ± 9	1031 ± 101
			791.2	3.3 ± 0.3	1227 ± 130
			670.7	11.4 ± 0.9	988.0 ± 84.7
			440.5	2.5 ± 0.4	1158 ± 190
			374.8	82 ± 5	1046 ± 73
			289.3	2.86 ± 0.25	1162 ± 110
			219.4	2.30 ± 0.17	1386 ± 117
			176.1	1.12 ± 0.09	1210 ± 111
²⁰³ Bi	c	11.76H	<i>RR_{mean}</i> =		1044 ± 44.
			2011.0	1.76 ± 0.09	906.2 ± 58.7
			2001.0	0.83 ± 0.05	915.7 ± 67.3
			1983.0	0.88 ± 0.05	959.8 ± 67.2
			1893.0	8.2 ± 0.6	939.1 ± 76.7
			1888.0	1.94 ± 0.10	938.7 ± 60.0
			1847.3	11.4 ± 0.8	900.9 ± 71.0
			1719.6	3.40 ± 0.23	789.4 ± 74.1
			1679.6	8.8 ± 0.7	889.6 ± 77.3
			1536.5	7.5 ± 0.6	953.2 ± 83.2
			1506.7	3.7 ± 0.3	882.2 ± 78.1
			1224.0	0.73 ± 0.04	860.3 ± 60.5
			1199.0	2.02 ± 0.11	1032 ± 68
			1034.0	8.8 ± 0.5	910.4 ± 60.6
			1000.3	0.98 ± 0.05	972.9 ± 67.3
			936.0	0.74 ± 0.04	1008 ± 70
			896.8	13.1 ± 0.7	868.6 ± 54.7
			866.5	1.49 ± 0.08	825.7 ± 57.8
			847.2	8.5 ± 0.5	950.6 ± 64.3
			825.2	14.6 ± 1.1	937.3 ± 77.3
			820.2	29.6 ± 1.5	934.6 ± 56.6
			816.3	4.03 ± 0.21	934.9 ± 58.5
			722.4	4.8 ± 0.4	957.0 ± 86.4
			401.3	*	936.4 ± 43.5
			381.7	1.28 ± 0.07	971.4 ± 65.0
			279.2	*	973.6 ± 36.1
			264.2	5.2 ± 0.4	948.2 ± 82.2
			186.6	3.11 ± 0.22	1054 ± 86
			<i>RR_{mean}</i> =		959.3 ± 29.6
²⁰² Bi _i	i	1.72H	960.7	99.28 ± 0.02	5.946 ± 2.175

Continuation of Table 55.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰² Bi _c	c	1.72H	960.7	99.28 ± 0.02	15.94 ± 0.79
²⁰³ Pb	c*	51.873H	680.5	0.75 ± 0.02	1231 ± 58
			401.3	3.35 ± 0.07	1225 ± 51
			279.2	80.8 ± 0.2	1232 ± 46
			RR _{mean} =		1230 ± 42.
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	12.40 ± 1.42
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	29.24 ± 2.20
²⁰⁰ Pb	c	21.5H	367.9	*	12.50 ± 0.61
			147.6	37.7 ± 1.4	10.84 ± 1.14
			RR _{mean} =		12.25 ± 0.38
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	2.887 ± 0.120
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	34.08 ± 1.67
²⁰⁰ Tl _c	c	26.1H	367.9	87.2 ± 0.4	12.75 ± 0.66
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.6574 ± 0.0403
¹⁰⁷ Rh	c	21.7M	302.8	66 ± 6	8.236 ± 0.941
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	9.676 ± 1.000
¹⁰⁶ Ru	c	373.59D	621.9(D)	9.93 ± 0.23	5.785 ± 0.516
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	8.185 ± 0.336
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	8.055 ± 0.608
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	0.2728 ± 0.1094
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	7.317 ± 0.254
⁹⁵ Zr	c	64.02D	765.8	*	7.109 ± 0.253
			756.7	54.46 ± 0.10	6.945 ± 0.249
			724.2	44.17 ± 0.16	6.597 ± 0.344
			RR _{mean} =		7.003 ± 0.216

12.2.6 Nuclide production rates for ^{27}Al

Table 56: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.07 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	24.20 ± 0.81
^7Be	i	53.29D	477.6	10.52 ± 0.06	1.761 ± 0.077
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.1827 ± 0.0179
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	45.98 ± 1.55
^{24}Na	c	14.9590H	1369.0	100 ± 0	24.20 ± 0.81
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.681 ± 0.056
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	1.555 ± 0.059
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.3004 ± 0.0236
			1014.4	28.0 ± 0.4	0.2354 ± 0.0836
$RR_{mean} =$					0.2963 ± 0.0229
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	53.94 ± 1.81
^{24}Na	c	14.9590H	1369.0	100 ± 0	28.17 ± 0.94

Continuation of Table 56.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.426 ± 0.048
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	1.555 ± 0.062
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.2241 ± 0.0217
			1014.4	28.0 ± 0.4	0.2088 ± 0.0558
				$RR_{mean} =$	0.2222 ± 0.0205
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	51.58 ± 1.73
^{24}Na	c	14.9590H	1369.0	100 ± 0	27.16 ± 0.91
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.672 ± 0.056
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	0.4960 ± 0.0216
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.09431 ± 0.01289
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	18.82 ± 0.63
^{24}Na	c	14.9590H	1369.0	100 ± 0	9.316 ± 0.310
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.6985 ± 0.0234
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	1.527 ± 0.066
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.3509 ± 0.0277
			1014.4	28.0 ± 0.4	0.2876 ± 0.1070
				$RR_{mean} =$	0.3475 ± 0.0270
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	52.67 ± 1.79
^{24}Na	c	14.9590H	1369.0	100 ± 0	27.11 ± 0.90
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.418 ± 0.048

12.3 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.1$ GeV

12.3.1 Nuclide production rates for ^{206}Pb

Table 57: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.1$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	569.7	97.74 ± 0.03	6.229 ± 3.049
²⁰⁶ Bi	i	6.243D	1878.7	2.01 ± 0.05	27.28 ± 1.48
			1718.7	31.8 ± 0.6	26.48 ± 1.05
			1595.3	5.01 ± 0.08	28.59 ± 1.24
			1098.3	13.50 ± 0.21	23.93 ± 0.94
			1018.6	7.60 ± 0.11	25.04 ± 1.03
			895.1	15.66 ± 0.23	25.65 ± 0.95
			881.0	66.2 ± 1.0	25.43 ± 0.93
			803.1	98.9 ± 1.4	24.48 ± 0.88
			657.2	1.91 ± 0.04	25.75 ± 1.71
			632.2	4.47 ± 0.07	24.03 ± 1.56
			620.5	5.76 ± 0.09	22.01 ± 1.01
			537.5	30.5 ± 0.5	22.46 ± 0.86
			516.2	40.7 ± 0.6	23.49 ± 0.88
			497.1	15.31 ± 0.22	23.50 ± 1.01
			398.0	10.74 ± 0.15	22.91 ± 0.86
			343.5	23.4 ± 0.4	24.35 ± 0.96
			262.7	3.02 ± 0.06	27.65 ± 3.15
			184.0	15.8 ± 0.4	27.82 ± 1.28
RR _{mean} =					24.45 ± 0.84
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	86.90 ± 3.45
			1775.8	3.99 ± 0.08	87.69 ± 3.88
			1764.3	32.5 ± 0.7	87.92 ± 3.57
			1614.3	2.28 ± 0.04	94.90 ± 4.06
			1190.0	2.26 ± 0.07	86.19 ± 4.11
			1043.8	7.51 ± 0.10	78.32 ± 2.89
			987.7	16.13 ± 0.17	84.77 ± 2.96
			703.5	31.1 ± 0.1	80.43 ± 2.70
			579.8	5.44 ± 0.07	76.23 ± 3.08
			570.6	4.34 ± 0.07	74.56 ± 2.94
			284.1	1.69 ± 0.02	78.74 ± 3.41
			260.5	1.09 ± 0.04	78.08 ± 4.38
RR _{mean} =					81.70 ± 2.90
²⁰⁴ Bi	i	11.22H	1755.3	1.22 ± 0.12	129.6 ± 17.1
			1211.7	3.0 ± 0.4	133.9 ± 19.2
			984.0	59 ± 4	121.6 ± 9.2
			918.3	10.8 ± 0.9	138.8 ± 12.6
			899.2	98 ± 9	117.8 ± 3.9
			791.2	3.3 ± 0.3	170.2 ± 17.6
			670.7	11.4 ± 0.9	124.3 ± 10.8
			374.8	82 ± 5	138.9 ± 29.0
RR _{mean} =					118.4 ± 3.7
²⁰³ Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	169.1 ± 11.7

Continuation of Table 57.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1893.0	8.2 ± 0.6	178.8 ± 14.8
			1888.0	1.94 ± 0.10	170.9 ± 12.6
			1847.3	11.4 ± 0.8	169.4 ± 13.4
			1679.6	8.8 ± 0.7	181.8 ± 15.9
			1536.5	7.5 ± 0.6	177.3 ± 15.8
			1506.7	3.7 ± 0.3	165.2 ± 15.0
			1034.0	8.8 ± 0.5	174.8 ± 11.7
			896.8	13.1 ± 0.7	167.4 ± 10.7
			847.2	8.5 ± 0.5	179.4 ± 12.5
			820.2	29.6 ± 1.5	184.1 ± 11.2
			816.3	4.03 ± 0.21	199.7 ± 12.8
			722.4	4.8 ± 0.4	185.9 ± 17.0
			279.2	*	165.9 ± 8.4
			264.2	5.2 ± 0.4	172.3 ± 15.1
			186.6	3.11 ± 0.22	213.6 ± 20.0
			<i>RR_{mean}</i> =		170.4 ± 5.3
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	199.5 ± 7.0
			954.5	7.8 ± 0.5	191.0 ± 15.8
			927.3	7.1 ± 0.4	204.9 ± 15.6
			657.5	60.6 ± 1.8	223.0 ± 10.6
			569.3	4.8 ± 0.3	190.6 ± 19.4
			422.1	83.7 ± 2.5	208.5 ± 10.2
			346.5	4.6 ± 0.3	171.0 ± 17.8
			<i>RR_{mean}</i> =		202.2 ± 7.4
²⁰¹ Bi	i	108M	1650.9	5.8 ± 1.3	204.9 ± 47.4
			1570.8	2.4 ± 0.6	240.6 ± 62.3
			1325.2	6.1 ± 1.3	270.2 ± 58.8
			1108.1	3.9 ± 0.9	265.3 ± 63.0
			936.2	11.3 ± 2.5	247.9 ± 55.8
			629.1	24 ± 6	230.2 ± 58.3
			331.2	*	269.6 ± 20.2
			<i>RR_{mean}</i> =		267.1 ± 8.2
¹⁹⁹ Bi	i	27M	1034.0	5.8 ± 0.4	294.5 ± 26.1
			946.0	10.8 ± 0.6	252.1 ± 18.8
			841.7	11 ± 0	300.5 ± 14.6
			837.4	9.5 ± 0.6	311.0 ± 27.8
			<i>RR_{mean}</i> =		289.5 ± 15.1
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	91.07 ± 3.21
			374.7	89 ± 15	99.46 ± 17.13
			<i>RR_{mean}</i> =		91.15 ± 3.21
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	108.7 ± 3.7
			374.7	89 ± 15	116.9 ± 20.1
			<i>RR_{mean}</i> =		108.8 ± 3.7
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	331.0 ± 14.2
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	496.9 ± 18.2
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	112.6 ± 10.6
			657.5	32.4 ± 1.7	86.68 ± 6.95
			490.5	9.1 ± 0.7	125.1 ± 11.4
			459.7	8.6 ± 0.7	124.2 ± 11.8
			422.1	86 ± 5	110.1 ± 7.7
			389.9	6.2 ± 0.6	112.4 ± 14.9

Continuation of Table 57.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹			
				<i>RR_{mean}</i> =	105.7 ± 6.9			
²⁰¹ Pb _i	i(m+g)	9.33H	331.2	79 ± 5	328.6 ± 24.2			
²⁰¹ Pb _c	c	9.33H	331.2	79 ± 5	598.1 ± 42.9			
²⁰⁰ Pb	c	21.5H	605.4	0.56 ± 0.05	687.8 ± 69.7			
			525.5	0.42 ± 0.04	616.2 ± 66.2			
			450.5	3.33 ± 0.08	675.8 ± 29.2			
			268.4	3.96 ± 0.20	663.2 ± 43.1			
			257.2	4.46 ± 0.17	690.4 ± 38.3			
			235.6	4.30 ± 0.17	657.4 ± 37.5			
			147.6	37.7 ± 1.4	624.4 ± 33.7			
			142.3	3.16 ± 0.19	662.1 ± 48.8			
							<i>RR_{mean}</i> =	665.6 ± 22.3
			¹⁹⁹ Pb	c*	90M	1749.7	2.3 ± 0.4	1037 ± 194
1382.7	2.9 ± 0.5	1448 ± 295						
1135.0	7.8 ± 1.2	1561 ± 250						
937.9	2.1 ± 0.4	1332 ± 276						
781.5	1.9 ± 0.3	1106 ± 180						
762.0	2.2 ± 0.4	1125 ± 210						
720.2	6.5 ± 1.0	1483 ± 238						
366.9	44 ± 7	1572 ± 260						
353.4	9.5 ± 1.5	1596 ± 269						
						<i>RR_{mean}</i> =	1338 ± 88.	
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	654.1 ± 135.1			
			575.0	3.1 ± 0.7	685.9 ± 157.2			
			365.4	19 ± 5	816.9 ± 217.0			
			259.5	5.8 ± 1.2	732.2 ± 154.3			
			173.4	18 ± 3	812.6 ± 138.8			
				<i>RR_{mean}</i> =	800.6 ± 31.3			
^{197m} Pb	c*	43M	774.3	14 ± 3	61.65 ± 13.98			
			387.7	25 ± 6	76.50 ± 18.66			
			385.9	74 ± 15	97.51 ± 20.08			
				<i>RR_{mean}</i> =	87.17 ± 11.21			
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	45.66 ± 1.64			
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	739.9 ± 27.4			
			135.3	2.56 ± 0.02	826.2 ± 35.2			
				<i>RR_{mean}</i> =	763.2 ± 44.9			
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	654.0 ± 61.9			
			1514.9	4.0 ± 0.3	651.0 ± 53.8			
			1366.3	0.9 ± 0.3	609.8 ± 204.6			
			1362.9	3.4 ± 0.4	682.4 ± 83.7			
			1291.1	0.60 ± 0.06	700.8 ± 77.7			
			1205.7	29.9 ± 1.8	632.3 ± 43.5			
			886.2	2.02 ± 0.13	615.2 ± 45.8			
			828.3	10.8 ± 0.7	645.3 ± 47.5			
			783.6	0.57 ± 0.18	548.5 ± 176.4			
			628.6	1.00 ± 0.08	561.8 ± 54.1			
			579.3	13.8 ± 0.7	632.8 ± 39.9			
			367.9	87.2 ± 0.4	605.8 ± 21.6			
							<i>RR_{mean}</i> =	614.0 ± 20.8
²⁰⁰ Tl _i	i	26.1H	828.3	10.8 ± 0.7	86.37 ± 7.78			
¹⁹⁹ Tl	c*	7.42H	750.4	1.04 ± 0.12	932.7 ± 114.7			

Continuation of Table 57.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			492.3	1.53 ± 0.17	884.7 ± 107.0
			455.5	12.4 ± 1.4	831.0 ± 98.2
			403.5	1.72 ± 0.19	850.0 ± 100.1
			333.9	1.76 ± 0.20	982.0 ± 118.1
			284.1	2.21 ± 0.24	918.4 ± 106.3
			247.3	9.3 ± 1.1	868.6 ± 108.5
			208.2	12.3 ± 1.4	844.8 ± 101.9
			158.4	5.0 ± 0.6	804.0 ± 101.0
			$RR_{mean} =$		875.4 $\pm$ 32.9
^{198m}Tl	i(m)	1.87H	587.2	52.5 ± 2.0	21.84 ± 1.50
			282.8	28 ± 3	22.66 ± 2.89
			$RR_{mean} =$		21.96 $\pm$ 1.21
^{197}Tl	c*	2.84H	152.2	7.3 ± 2.3	204.4 $\pm$ 65.3
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	73.93 $\pm$ 13.02
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	0.3863 $\pm$ 0.0484
^{197}Hg	c*	64.14H	191.4	0.63 ± 0.02	152.7 $\pm$ 9.6
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	0.2158 $\pm$ 0.0244
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	33.68 $\pm$ 3.32
^{124}Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.4885 $\pm$ 0.0395
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.4009 $\pm$ 0.0298
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	0.2820 ± 0.0221
			1023.3	99.4 ± 0.3	0.2903 ± 0.0302
			197.3	87.0 ± 1.1	0.3291 ± 0.0224
			$RR_{mean} =$		0.3029 $\pm$ 0.0181
^{110m}Ag	i(m)	249.76D	657.8	94.3 ± 0.3	0.7862 $\pm$ 0.0650
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	9.610 $\pm$ 0.379
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	11.29 $\pm$ 0.53
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	2.979 $\pm$ 0.280
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	1.349 $\pm$ 0.056
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	9.636 $\pm$ 0.321
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	4.347 $\pm$ 0.198
^{95}Zr	c	64.02D	765.8	*	8.362 ± 0.284
			756.7	54.46 ± 0.10	7.551 ± 0.281
			724.2	44.17 ± 0.16	8.730 ± 0.397
			$RR_{mean} =$		8.332 $\pm$ 0.257

12.3.2 Nuclide production rates for ^{207}Pb

Table 58: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 0.1 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	22.43 $\pm$ 2.67
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	51.94 ± 2.53
			1718.7	31.8 ± 0.6	53.74 ± 2.17
			1595.3	5.01 ± 0.08	59.89 ± 2.58
			1098.3	13.50 ± 0.21	49.10 ± 1.82
			1018.6	7.60 ± 0.11	54.50 ± 2.12
			895.1	15.66 ± 0.23	53.53 ± 1.97

Continuation of Table 58.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			881.0	66.2 ± 1.0	53.24 ± 1.92
			803.1	98.9 ± 1.4	50.65 ± 1.84
			657.2	1.91 ± 0.04	55.19 ± 2.71
			632.2	4.47 ± 0.07	50.86 ± 2.39
			620.5	5.76 ± 0.09	46.84 ± 2.10
			537.5	30.5 ± 0.5	46.00 ± 1.76
			516.2	40.7 ± 0.6	49.17 ± 1.83
			497.1	15.31 ± 0.22	46.53 ± 1.80
			398.0	10.74 ± 0.15	47.06 ± 1.84
			343.5	23.4 ± 0.4	48.49 ± 1.83
			262.7	3.02 ± 0.06	45.66 ± 3.14
			184.0	15.8 ± 0.4	56.52 ± 2.55
			$RR_{mean} =$		50.42 ± 1.76
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	112.9 ± 4.4
			1775.8	3.99 ± 0.08	121.1 ± 5.2
			1764.3	32.5 ± 0.7	114.9 ± 4.7
			1614.3	2.28 ± 0.04	121.6 ± 5.4
			1190.0	2.26 ± 0.07	110.6 ± 5.3
			1043.8	7.51 ± 0.10	103.6 ± 3.8
			987.7	16.13 ± 0.17	111.6 ± 3.9
			703.5	31.1 ± 0.1	104.1 ± 3.5
			579.8	5.44 ± 0.07	100.8 ± 4.0
			570.6	4.34 ± 0.07	98.59 ± 4.23
			284.1	1.69 ± 0.02	106.1 ± 4.5
			260.5	1.09 ± 0.04	100.7 ± 5.7
			$RR_{mean} =$		107.4 ± 3.8
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	123.4 ± 14.2
			1211.7	3.0 ± 0.4	111.7 ± 15.8
			984.0	59 ± 4	118.1 ± 9.0
			918.3	10.8 ± 0.9	132.0 ± 11.9
			899.2	98 ± 9	114.4 ± 3.8
			791.2	3.3 ± 0.3	129.1 ± 14.4
			670.7	11.4 ± 0.9	124.1 ± 10.7
			374.8	82 ± 5	136.5 ± 28.5
			176.1	1.12 ± 0.09	164.9 ± 17.5
			$RR_{mean} =$		115.1 ± 3.6
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	156.9 ± 10.8
			1893.0	8.2 ± 0.6	159.8 ± 13.3
			1888.0	1.94 ± 0.10	162.4 ± 11.5
			1847.3	11.4 ± 0.8	159.4 ± 12.6
			1679.6	8.8 ± 0.7	158.3 ± 13.8
			1536.5	7.5 ± 0.6	162.9 ± 14.3
			1506.7	3.7 ± 0.3	143.9 ± 13.1
			1034.0	8.8 ± 0.5	153.6 ± 10.3
			896.8	13.1 ± 0.7	162.1 ± 10.3
			847.2	8.5 ± 0.5	165.3 ± 11.4
			820.2	29.6 ± 1.5	166.0 ± 10.1
			816.3	4.03 ± 0.21	172.1 ± 11.2
			722.4	4.8 ± 0.4	170.1 ± 15.5
			279.2	*	167.9 ± 9.5
			264.2	5.2 ± 0.4	152.8 ± 13.4

Continuation of Table 58.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			186.6	3.11 ± 0.22	204.8 ± 17.0
			<i>RR_{mean}</i> =		165.9 ± 5.1
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	183.5 ± 6.5
			954.5	7.8 ± 0.5	177.2 ± 18.2
			927.3	7.1 ± 0.4	153.8 ± 12.2
			657.5	60.6 ± 1.8	194.4 ± 9.3
			569.3	4.8 ± 0.3	182.7 ± 15.9
			422.1	83.7 ± 2.5	190.4 ± 9.1
			346.5	4.6 ± 0.3	178.5 ± 15.0
			<i>RR_{mean}</i> =		184.0 ± 6.6
²⁰¹ Bi	i	108M	1650.9	5.8 ± 1.3	206.2 ± 47.5
			1570.8	2.4 ± 0.6	245.5 ± 63.5
			1325.2	6.1 ± 1.3	218.6 ± 48.3
			1108.1	3.9 ± 0.9	198.2 ± 46.8
			936.2	11.3 ± 2.5	217.4 ± 49.3
			629.1	24 ± 6	200.6 ± 50.9
			331.2	*	260.3 ± 19.4
			<i>RR_{mean}</i> =		254.0 ± 7.8
¹⁹⁹ Bi	i	27M	1034.0	5.8 ± 0.4	294.3 ± 27.5
			946.0	10.8 ± 0.6	243.2 ± 19.0
			841.7	11 ± 0	267.3 ± 16.3
			837.4	9.5 ± 0.6	265.2 ± 22.9
			<i>RR_{mean}</i> =		263.7 ± 12.2
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	90.40 ± 3.27
			374.7	89 ± 15	97.86 ± 16.85
			<i>RR_{mean}</i> =		90.48 ± 3.26
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	107.5 ± 3.8
			374.7	89 ± 15	115.0 ± 19.8
			<i>RR_{mean}</i> =		107.6 ± 3.8
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	246.9 ± 12.9
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	414.9 ± 15.3
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	99.41 ± 9.38
			657.5	32.4 ± 1.7	77.50 ± 5.95
			490.5	9.1 ± 0.7	105.8 ± 9.3
			459.7	8.6 ± 0.7	113.9 ± 10.9
			422.1	86 ± 5	97.93 ± 6.83
			389.9	6.2 ± 0.6	106.7 ± 11.7
			<i>RR_{mean}</i> =		93.50 ± 6.08
²⁰¹ Pb _i	i(m+g)	9.33H	331.2	79 ± 5	221.6 ± 16.6
²⁰¹ Pb _c	c	9.33H	331.2	79 ± 5	481.9 ± 34.6
²⁰⁰ Pb	c	21.5H	605.4	0.56 ± 0.05	575.6 ± 56.6
			525.5	0.42 ± 0.04	518.2 ± 54.6
			450.5	3.33 ± 0.08	548.7 ± 23.2
			268.4	3.96 ± 0.20	531.6 ± 34.6
			257.2	4.46 ± 0.17	572.3 ± 32.1
			235.6	4.30 ± 0.17	513.6 ± 29.3
			147.6	37.7 ± 1.4	505.4 ± 27.5
			142.3	3.16 ± 0.19	554.7 ± 42.0
			<i>RR_{mean}</i> =		541.1 ± 18.3
¹⁹⁹ Pb	c*	90M	1749.7	2.3 ± 0.4	760.8 ± 137.5
			1382.7	2.9 ± 0.5	1030 ± 192

Continuation of Table 58.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1135.0	7.8 ± 1.2	952.5 ± 152.1
			937.9	2.1 ± 0.4	842.7 ± 171.7
			781.5	1.9 ± 0.3	872.0 ± 144.3
			762.0	2.2 ± 0.4	796.7 ± 154.0
			720.2	6.5 ± 1.0	934.9 ± 166.4
			366.9	44 ± 7	1020 ± 172
			353.4	9.5 ± 1.5	1124 ± 185
			<i>RR_{mean}</i> =		925.4 ± 47.4
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	172.1 ± 36.3
			575.0	3.1 ± 0.7	146.5 ± 34.5
			365.4	19 ± 5	201.5 ± 53.6
			259.5	5.8 ± 1.2	194.5 ± 41.3
			173.4	18 ± 3	207.1 ± 35.4
			<i>RR_{mean}</i> =		203.0 ± 9.1
^{197m} Pb	c*	43M	385.9	74 ± 15	5.455 ± 1.235
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	36.28 ± 1.30
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	603.5 ± 22.2
			135.3	2.56 ± 0.02	670.9 ± 28.9
			<i>RR_{mean}</i> =		620.8 ± 35.1
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	500.3 ± 48.5
			1514.9	4.0 ± 0.3	522.3 ± 43.5
			1366.3	0.9 ± 0.3	529.3 ± 177.7
			1362.9	3.4 ± 0.4	539.5 ± 66.3
			1291.1	0.60 ± 0.06	494.5 ± 53.9
			1205.7	29.9 ± 1.8	507.6 ± 35.0
			886.2	2.02 ± 0.13	522.2 ± 38.8
			828.3	10.8 ± 0.7	514.8 ± 37.7
			783.6	0.57 ± 0.18	393.0 ± 126.8
			628.6	1.00 ± 0.08	462.0 ± 44.6
			579.3	13.8 ± 0.7	503.8 ± 31.4
			367.9	87.2 ± 0.4	495.7 ± 17.6
			<i>RR_{mean}</i> =		498.9 ± 16.9
²⁰⁰ Tl _i	i	26.1H	828.3	10.8 ± 0.7	52.34 ± 6.31
¹⁹⁹ Tl	c*	7.42H	750.4	1.04 ± 0.12	643.8 ± 80.9
			492.3	1.53 ± 0.17	602.0 ± 71.1
			455.5	12.4 ± 1.4	600.8 ± 71.1
			403.5	1.72 ± 0.19	626.8 ± 73.4
			333.9	1.76 ± 0.20	701.8 ± 85.0
			284.1	2.21 ± 0.24	695.5 ± 81.8
			247.3	9.3 ± 1.1	615.9 ± 77.1
			208.2	12.3 ± 1.4	590.9 ± 71.4
			158.4	5.0 ± 0.6	589.1 ± 74.2
			<i>RR_{mean}</i> =		626.0 ± 23.7
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	16.90 ± 1.35
			282.8	28 ± 3	22.46 ± 2.73
			<i>RR_{mean}</i> =		17.77 ± 2.09
¹⁹⁷ Tl	c*	2.84H	152.2	7.3 ± 2.3	49.68 ± 15.96
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	45.79 ± 8.05
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	1.045 ± 0.081
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.3885 ± 0.0429

Continuation of Table 58.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	0.1931 ± 0.0463
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	6.479 ± 0.872
^{110m}Ag	i(m)	249.76D	657.8	94.3 ± 0.3	0.4806 ± 0.0767
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	6.039 ± 0.247
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	7.224 ± 0.341
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	0.6641 ± 0.0468
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	5.955 ± 0.205
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	3.159 ± 0.169
^{95}Zr	c	64.02D	765.8	*	5.339 ± 0.191
			756.7	54.46 ± 0.10	4.782 ± 0.193
			724.2	44.17 ± 0.16	5.047 ± 0.244
			$RR_{mean} =$		5.154 ± 0.159

12.3.3 Nuclide production rates for ^{208}Pb

Table 59: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.1 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	569.7	97.74 ± 0.03	63.40 ± 6.41
²⁰⁶ Bi	i	6.243D	1878.7	2.01 ± 0.05	111.1 ± 5.5
			1718.7	31.8 ± 0.6	109.1 ± 4.3
			1595.3	5.01 ± 0.08	115.1 ± 4.8
			1098.3	13.50 ± 0.21	101.0 ± 3.7
			1018.6	7.60 ± 0.11	109.4 ± 4.0
			895.1	15.66 ± 0.23	106.8 ± 3.8
			881.0	66.2 ± 1.0	106.2 ± 3.8
			803.1	98.9 ± 1.4	101.9 ± 3.6
			657.2	1.91 ± 0.04	95.33 ± 4.38
			632.2	4.47 ± 0.07	99.45 ± 3.92
			620.5	5.76 ± 0.09	96.33 ± 3.63
			537.5	30.5 ± 0.5	93.67 ± 3.54
			516.2	40.7 ± 0.6	98.90 ± 3.67
			497.1	15.31 ± 0.22	94.42 ± 3.57
			398.0	10.74 ± 0.15	94.43 ± 3.46
			343.5	23.4 ± 0.4	98.34 ± 3.70
			262.7	3.02 ± 0.06	100.7 ± 4.7
			184.0	15.8 ± 0.4	113.3 ± 5.1
RR _{mean} =					101.3 ± 3.4
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	165.7 ± 6.5
			1775.8	3.99 ± 0.08	168.7 ± 7.0
			1764.3	32.5 ± 0.7	169.8 ± 6.9
			1614.3	2.28 ± 0.04	179.9 ± 7.4
			1190.0	2.26 ± 0.07	157.9 ± 7.8
			1043.8	7.51 ± 0.10	153.4 ± 5.7
			987.7	16.13 ± 0.17	166.8 ± 5.8
			703.5	31.1 ± 0.1	156.2 ± 5.3
			579.8	5.44 ± 0.07	151.1 ± 5.7
570.6	4.34 ± 0.07	146.7 ± 6.3			

Continuation of Table 59.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			284.1	1.69 ± 0.02	152.0 ± 6.7
			260.5	1.09 ± 0.04	149.2 ± 8.1
			$RR_{mean} =$		159.4 ± 5.5
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	158.4 ± 20.1
			1211.7	3.0 ± 0.4	147.5 ± 20.8
			984.0	59 ± 4	166.7 ± 12.6
			918.3	10.8 ± 0.9	187.0 ± 16.9
			899.2	98 ± 9	158.7 ± 5.3
			791.2	3.3 ± 0.3	179.2 ± 18.8
			670.7	11.4 ± 0.9	175.7 ± 15.2
			374.8	82 ± 5	188.4 ± 39.3
			$RR_{mean} =$		159.6 ± 4.9
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	229.3 ± 15.9
			1893.0	8.2 ± 0.6	212.1 ± 17.6
			1888.0	1.94 ± 0.10	193.9 ± 13.9
			1847.3	11.4 ± 0.8	211.8 ± 16.8
			1679.6	8.8 ± 0.7	209.7 ± 18.4
			1536.5	7.5 ± 0.6	232.1 ± 20.8
			1506.7	3.7 ± 0.3	203.6 ± 18.8
			1034.0	8.8 ± 0.5	213.6 ± 14.5
			896.8	13.1 ± 0.7	207.2 ± 13.2
			847.2	8.5 ± 0.5	230.4 ± 16.1
			820.2	29.6 ± 1.5	225.8 ± 13.7
			816.3	4.03 ± 0.21	228.6 ± 14.7
			722.4	4.8 ± 0.4	239.6 ± 22.0
			279.2	*	213.9 ± 9.1
			264.2	5.2 ± 0.4	218.6 ± 19.1
			186.6	3.11 ± 0.22	265.8 ± 21.8
			$RR_{mean} =$		215.3 ± 6.6
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	249.2 ± 8.8
			954.5	7.8 ± 0.5	247.4 ± 20.1
			927.3	7.1 ± 0.4	227.3 ± 16.7
			657.5	60.6 ± 1.8	259.7 ± 12.6
			569.3	4.8 ± 0.3	249.2 ± 22.3
			422.1	83.7 ± 2.5	257.7 ± 12.3
			346.5	4.6 ± 0.3	215.9 ± 18.0
			$RR_{mean} =$		249.0 ± 8.6
^{201}Bi	i	108M	1650.9	5.8 ± 1.3	278.0 ± 64.7
			1570.8	2.4 ± 0.6	348.9 ± 90.8
			1325.2	6.1 ± 1.3	320.7 ± 71.7
			936.2	11.3 ± 2.5	304.7 ± 68.5
			629.1	24 ± 6	283.2 ± 71.9
			331.2	*	333.9 ± 24.2
			$RR_{mean} =$		330.8 ± 10.2
^{199}Bi	i	27M	1034.0	5.8 ± 0.4	194.5 ± 28.8
			841.7	11 ± 0	148.8 ± 17.6
			837.4	9.5 ± 0.6	169.1 ± 30.4
			$RR_{mean} =$		162.5 ± 14.0
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	126.0 ± 4.5
			374.7	89 ± 15	132.8 ± 22.9

Continuation of Table 59.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	126.1 ± 4.5
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	149.8 ± 5.2
			374.7	89 ± 15	156.4 ± 27.0
				<i>RR_{mean}</i> =	149.9 ± 5.2
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	305.8 ± 12.7
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	519.6 ± 19.0
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	125.2 ± 11.8
			657.5	32.4 ± 1.7	106.1 ± 8.3
			490.5	9.1 ± 0.7	143.2 ± 12.5
			459.7	8.6 ± 0.7	132.0 ± 12.2
			422.1	86 ± 5	125.3 ± 8.8
			389.9	6.2 ± 0.6	132.8 ± 14.3
			<i>RR_{mean}</i> =		122.6 ± 6.4
²⁰¹ Pb _i	i(m+g)	9.33H	331.2	79 ± 5	252.0 ± 18.5
²⁰¹ Pb _c	c	9.33H	331.2	79 ± 5	585.9 ± 42.0
²⁰⁰ Pb	c	21.5H	605.4	0.56 ± 0.05	824.9 ± 86.2
			525.5	0.42 ± 0.04	593.1 ± 66.6
			450.5	3.33 ± 0.08	656.6 ± 27.9
			268.4	3.96 ± 0.20	646.3 ± 41.7
			257.2	4.46 ± 0.17	680.7 ± 38.1
			235.6	4.30 ± 0.17	664.6 ± 38.5
			147.6	37.7 ± 1.4	611.6 ± 32.9
			142.3	3.16 ± 0.19	630.9 ± 46.9
			<i>RR_{mean}</i> =		652.4 ± 22.5
¹⁹⁹ Pb	c*	90M	1749.7	2.3 ± 0.4	411.2 ± 84.8
			1382.7	2.9 ± 0.5	576.0 ± 127.2
			1135.0	7.8 ± 1.2	491.2 ± 81.8
			781.5	1.9 ± 0.3	565.5 ± 97.3
			762.0	2.2 ± 0.4	483.4 ± 92.8
			720.2	6.5 ± 1.0	455.6 ± 78.7
			366.9	44 ± 7	534.2 ± 88.0
			353.4	9.5 ± 1.5	534.2 ± 89.5
<i>RR_{mean}</i> =		503.4 ± 23.2			
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	40.12 ± 1.45
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	734.1 ± 26.9
			135.3	2.56 ± 0.02	802.2 ± 33.9
				<i>RR_{mean}</i> =	752.6 ± 38.1
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	626.5 ± 59.0
			1514.9	4.0 ± 0.3	607.3 ± 50.1
			1366.3	0.9 ± 0.3	600.8 ± 202.3
			1362.9	3.4 ± 0.4	635.7 ± 78.2
			1291.1	0.60 ± 0.06	632.1 ± 68.3
			1205.7	29.9 ± 1.8	602.4 ± 41.6
			886.2	2.02 ± 0.13	617.0 ± 46.7
			828.3	10.8 ± 0.7	609.6 ± 44.8
			783.6	0.57 ± 0.18	499.5 ± 164.0
			628.6	1.00 ± 0.08	563.4 ± 56.1
			579.3	13.8 ± 0.7	610.4 ± 38.2
			367.9	87.2 ± 0.4	583.5 ± 20.8
			<i>RR_{mean}</i> =		591.0 ± 20.0

Continuation of Table 59.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{200}\text{Tl}_i$	i	26.1H	367.9	87.2 ± 0.4	50.85 ± 6.90
^{199}Tl	c*	7.42H	750.4	1.04 ± 0.12	404.3 ± 56.9
			492.3	1.53 ± 0.17	378.6 ± 47.5
			455.5	12.4 ± 1.4	318.9 ± 37.8
			403.5	1.72 ± 0.19	363.9 ± 43.0
			284.1	2.21 ± 0.24	398.6 ± 50.0
			247.3	9.3 ± 1.1	338.1 ± 42.3
			208.2	12.3 ± 1.4	321.3 ± 38.9
			158.4	5.0 ± 0.6	332.0 ± 41.8
$RR_{mean} =$					347.2 ± 15.3
^{198m}Tl	i(m)	1.87H	282.8	28 ± 3	28.00 ± 3.46
^{197}Tl	c*	2.84H	152.2	7.3 ± 2.3	42.92 ± 14.11
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	2.188 ± 0.096
^{124}Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.4905 ± 0.0534
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	0.2807 ± 0.0480
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	5.413 ± 0.257
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	7.072 ± 0.313
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	0.1606 ± 0.1018
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	5.502 ± 0.240
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	3.784 ± 0.237
^{95}Zr	c	64.02D	765.8	*	5.390 ± 0.264
			756.7	54.46 ± 0.10	4.780 ± 0.257
			724.2	44.17 ± 0.16	5.347 ± 0.540
$RR_{mean} =$					5.118 ± 0.158

12.3.4 Nuclide production rates for ^{nat}Pb

Table 60: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.1 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	21.15 ± 2.36
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	45.14 ± 2.27
			1718.7	31.8 ± 0.6	45.54 ± 1.80
			1595.3	5.01 ± 0.08	48.72 ± 2.07
			1098.3	13.50 ± 0.21	41.78 ± 1.58
			1018.6	7.60 ± 0.11	45.13 ± 1.66
			895.1	15.66 ± 0.23	43.70 ± 1.58
			881.0	66.2 ± 1.0	43.88 ± 1.58
			803.1	98.9 ± 1.4	42.20 ± 1.51
			657.2	1.91 ± 0.04	40.70 ± 2.29
			632.2	4.47 ± 0.07	40.21 ± 1.67
			620.5	5.76 ± 0.09	39.99 ± 1.75
			537.5	30.5 ± 0.5	38.79 ± 1.47
			516.2	40.7 ± 0.6	40.90 ± 1.54
			497.1	15.31 ± 0.22	39.52 ± 1.52
			398.0	10.74 ± 0.15	39.84 ± 1.48
			343.5	23.4 ± 0.4	41.26 ± 1.57
			262.7	3.02 ± 0.06	40.31 ± 2.83

Continuation of Table 60.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			184.0	15.8 ± 0.4	46.56 ± 2.11
			$RR_{mean} =$		42.11 ± 1.42
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	79.29 ± 3.15
			1775.8	3.99 ± 0.08	82.89 ± 3.46
			1764.3	32.5 ± 0.7	81.82 ± 3.32
			1190.0	2.26 ± 0.07	78.30 ± 3.94
			1043.8	7.51 ± 0.10	73.50 ± 2.70
			987.7	16.13 ± 0.17	79.05 ± 2.74
			703.5	31.1 ± 0.1	74.56 ± 2.50
			579.8	5.44 ± 0.07	73.35 ± 2.82
			570.6	4.34 ± 0.07	71.89 ± 2.88
			549.8	2.95 ± 0.04	72.82 ± 2.91
			284.1	1.69 ± 0.02	74.59 ± 3.42
			260.5	1.09 ± 0.04	72.51 ± 4.42
			$RR_{mean} =$		75.83 ± 2.53
^{204}Bi	i	11.22H	1755.3	1.22 ± 0.12	89.38 ± 10.39
			1703.3	1.99 ± 0.17	99.64 ± 9.46
			1211.7	3.0 ± 0.4	74.60 ± 10.43
			984.0	59 ± 4	85.51 ± 6.45
			918.3	10.8 ± 0.9	98.33 ± 8.83
			899.2	98 ± 9	82.46 ± 2.73
			791.2	3.3 ± 0.3	98.25 ± 9.80
			670.7	11.4 ± 0.9	90.24 ± 7.80
			374.8	82 ± 5	97.75 ± 20.39
			176.1	1.12 ± 0.09	105.7 ± 10.1
			$RR_{mean} =$		83.06 ± 2.56
^{203}Bi	i(m+g)	11.76H	2011.0	1.76 ± 0.09	120.6 ± 8.0
			1893.0	8.2 ± 0.6	117.1 ± 9.6
			1888.0	1.94 ± 0.10	112.7 ± 7.7
			1847.3	11.4 ± 0.8	112.9 ± 8.9
			1679.6	8.8 ± 0.7	115.7 ± 10.1
			1536.5	7.5 ± 0.6	120.9 ± 10.6
			1506.7	3.7 ± 0.3	105.2 ± 9.4
			1034.0	8.8 ± 0.5	114.0 ± 7.6
			896.8	13.1 ± 0.7	118.5 ± 7.5
			847.2	8.5 ± 0.5	119.7 ± 8.2
			820.2	29.6 ± 1.5	120.6 ± 7.3
			816.3	4.03 ± 0.21	117.4 ± 7.3
			722.4	4.8 ± 0.4	121.8 ± 11.0
			279.2	*	116.8 ± 5.8
			264.2	5.2 ± 0.4	116.5 ± 10.1
			186.6	3.11 ± 0.22	141.8 ± 11.5
			$RR_{mean} =$		117.4 ± 3.6
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	135.7 ± 4.7
			954.5	7.8 ± 0.5	138.4 ± 10.6
			927.3	7.1 ± 0.4	116.7 ± 8.9
			657.5	60.6 ± 1.8	143.9 ± 6.8
			569.3	4.8 ± 0.3	138.9 ± 10.7
			422.1	83.7 ± 2.5	140.2 ± 6.7
			346.5	4.6 ± 0.3	123.5 ± 10.5

Continuation of Table 60.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	136.1 ± 4.7
²⁰¹ Bi	i	108M	1650.9	5.8 ± 1.3	150.8 ± 34.7
			1570.8	2.4 ± 0.6	205.2 ± 52.4
			1325.2	6.1 ± 1.3	165.4 ± 36.1
			1108.1	3.9 ± 0.9	180.0 ± 42.9
			936.2	11.3 ± 2.5	164.7 ± 37.2
			629.1	24 ± 6	162.1 ± 41.1
			331.2	*	186.6 ± 13.7
				<i>RR_{mean}</i> =	184.2 ± 5.7
¹⁹⁹ Bi	i	27M	1034.0	5.8 ± 0.4	166.8 ± 17.0
			837.4	9.5 ± 0.6	157.8 ± 15.3
				<i>RR_{mean}</i> =	161.8 ± 11.9
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	68.08 ± 2.37
			374.7	89 ± 15	72.22 ± 12.44
				<i>RR_{mean}</i> =	68.11 ± 2.37
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	80.44 ± 2.75
			374.7	89 ± 15	84.48 ± 14.54
				<i>RR_{mean}</i> =	80.47 ± 2.75
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	176.8 ± 8.2
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	293.6 ± 10.8
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	70.18 ± 6.56
			657.5	32.4 ± 1.7	57.23 ± 4.19
			490.5	9.1 ± 0.7	75.08 ± 6.49
			459.7	8.6 ± 0.7	74.03 ± 6.73
			422.1	86 ± 5	70.76 ± 4.88
			389.9	6.2 ± 0.6	68.56 ± 7.72
				<i>RR_{mean}</i> =	66.51 ± 3.74
²⁰¹ Pb _i	i(m+g)	9.33H	331.2	79 ± 5	155.6 ± 11.6
²⁰¹ Pb _c	c	9.33H	331.2	79 ± 5	342.2 ± 24.5
²⁰⁰ Pb	c	21.5H	605.4	0.56 ± 0.05	433.1 ± 43.0
			525.5	0.42 ± 0.04	396.7 ± 42.3
			450.5	3.33 ± 0.08	385.4 ± 16.4
			268.4	3.96 ± 0.20	386.8 ± 24.7
			257.2	4.46 ± 0.17	395.5 ± 21.7
			235.6	4.30 ± 0.17	384.0 ± 21.7
			147.6	37.7 ± 1.4	365.9 ± 20.5
			142.3	3.16 ± 0.19	369.0 ± 27.6
				<i>RR_{mean}</i> =	384.4 ± 12.8
¹⁹⁹ Pb	c*	90M	1749.7	2.3 ± 0.4	386.3 ± 70.1
			1382.7	2.9 ± 0.5	477.2 ± 88.4
			1135.0	7.8 ± 1.2	507.0 ± 81.8
			937.9	2.1 ± 0.4	440.5 ± 87.7
			781.5	1.9 ± 0.3	460.0 ± 75.6
			762.0	2.2 ± 0.4	411.8 ± 79.9
			720.2	6.5 ± 1.0	464.8 ± 78.1
			366.9	44 ± 7	546.0 ± 90.9
353.4	9.5 ± 1.5	584.2 ± 95.8			
				<i>RR_{mean}</i> =	478.9 ± 25.1
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	143.7 ± 30.1
			575.0	3.1 ± 0.7	141.9 ± 32.9
			365.4	19 ± 5	157.1 ± 41.7

Continuation of Table 60.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			259.5	5.8 ± 1.2	144.8 ± 30.6
			173.4	18 ± 3	151.9 ± 26.0
			<i>RR_{mean}</i> =		151.2 ± 5.8
^{197m} Pb	c*	43M	387.7	25 ± 6	14.74 ± 3.72
			385.9	74 ± 15	18.39 ± 3.80
			<i>RR_{mean}</i> =		17.99 ± 1.26
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	24.03 ± 0.87
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	427.1 ± 16.2
			135.3	2.56 ± 0.02	467.1 ± 22.2
			<i>RR_{mean}</i> =		436.2 ± 21.5
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	331.9 ± 30.9
			1514.9	4.0 ± 0.3	359.1 ± 29.6
			1366.3	0.9 ± 0.3	333.0 ± 111.6
			1362.9	3.4 ± 0.4	365.1 ± 44.7
			1291.1	0.60 ± 0.06	354.1 ± 38.1
			1205.7	29.9 ± 1.8	347.4 ± 23.9
			886.2	2.02 ± 0.13	345.7 ± 25.1
			828.3	10.8 ± 0.7	349.7 ± 25.5
			783.6	0.57 ± 0.18	318.1 ± 101.4
			628.6	1.00 ± 0.08	296.2 ± 28.9
			579.3	13.8 ± 0.7	348.8 ± 21.4
			367.9	87.2 ± 0.4	336.9 ± 11.7
			<i>RR_{mean}</i> =		338.7 ± 11.3
²⁰⁰ Tl _i	i	26.1H	367.9	87.2 ± 0.4	30.74 ± 2.61
¹⁹⁹ Tl	c*	7.42H	750.4	1.04 ± 0.12	361.0 ± 44.5
			492.3	1.53 ± 0.17	320.7 ± 37.7
			455.5	12.4 ± 1.4	304.8 ± 36.0
			403.5	1.72 ± 0.19	352.0 ± 41.7
			284.1	2.21 ± 0.24	328.9 ± 38.4
			247.3	9.3 ± 1.1	318.1 ± 39.7
			208.2	12.3 ± 1.4	307.5 ± 37.1
			158.4	5.0 ± 0.6	299.9 ± 37.7
			<i>RR_{mean}</i> =		322.2 ± 12.3
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	15.33 ± 0.89
			282.8	28 ± 3	15.13 ± 1.80
			<i>RR_{mean}</i> =		15.32 ± 0.68
¹⁹⁷ Tl	c*	2.84H	152.2	7.3 ± 2.3	58.17 ± 18.51
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	20.85 ± 3.67
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	1.007 ± 0.065
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	43.18 ± 7.38
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	0.1365 ± 0.0453
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	8.250 ± 0.958
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.3193 ± 0.0434
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	1.008 ± 0.175
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	3.911 ± 0.171
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	4.571 ± 0.225
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	0.2956 ± 0.0582
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	3.935 ± 0.158
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	2.328 ± 0.090
⁹⁵ Zr	c	64.02D	765.8	*	3.672 ± 0.165

Continuation of Table 60.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			756.7	54.46 ± 0.10	3.218 ± 0.172
			724.2	44.17 ± 0.16	3.368 ± 0.230
			$RR_{mean} =$		3.464 ± 0.107

12.3.5 Nuclide production rates for ^{209}Bi

Table 61: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.1 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	121.0 ± 4.5
			742.6	28.2 ± 0.5	135.4 ± 6.0
			$RR_{mean} =$		124.5 ± 7.2
^{206}Po	i	8.8D	1878.7	*	167.2 ± 9.0
			1718.7	*	173.4 ± 7.1
			1595.3	*	178.4 ± 8.2
			1405.0	*	146.2 ± 8.5
			1098.3	*	162.6 ± 6.0
			1032.3	33 ± 5	165.2 ± 25.6
			1018.6	*	173.1 ± 6.7
			1007.2	3.1 ± 0.4	149.1 ± 20.1
			895.1	*	171.9 ± 6.5
			881.0	*	172.1 ± 6.4
			818.2	1.04 ± 0.14	193.4 ± 29.7
			807.4	23 ± 3	156.9 ± 21.1
			803.1	*	161.9 ± 5.9
			677.7	1.47 ± 0.20	161.7 ± 23.2
			657.2	*	154.3 ± 9.9
			632.2	*	156.1 ± 6.3
			620.5	*	151.5 ± 6.4
			537.5	*	147.5 ± 5.7
			522.5	15.7 ± 2.0	151.0 ± 19.9
			516.2	*	155.1 ± 6.0
			497.1	*	151.9 ± 5.7
			463.4	1.79 ± 0.24	143.2 ± 21.3
			398.0	*	155.3 ± 6.4
			343.5	*	155.1 ± 6.0
			338.4	19.2 ± 2.5	162.3 ± 21.8
			311.6	4.2 ± 0.6	168.2 ± 24.8
			286.4	24 ± 3	165.5 ± 21.5
			184.0	*	178.2 ± 8.5
			$RR_{mean} =$		160.8 ± 5.0
^{205}Po	i	1.66H	1001.2	28.8 ± 2.2	193.3 ± 16.9
			872.4	37 ± 2	202.8 ± 13.3
			849.8	25.5 ± 2.1	208.4 ± 18.8
			836.8	19.2 ± 1.6	203.3 ± 18.7
			$RR_{mean} =$		202.3 ± 7.2
^{204}Po	i	3.53H	1211.7	*	288.9 ± 66.4
			1040.0	9.6 ± 0.5	266.4 ± 17.6

Continuation of Table 61.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1016.3	24.1 ± 1.0	242.7 ± 13.2
			984.0	*	220.3 ± 19.9
			918.3	*	269.7 ± 36.0
			899.2	*	213.2 ± 22.8
			884.0	29.9 ± 1.2	257.2 ± 13.6
			762.5	11.5 ± 0.5	253.6 ± 15.1
			680.4	7.6 ± 0.4	245.8 ± 18.6
			670.7	*	214.7 ± 25.8
			534.9	13.2 ± 0.8	241.4 ± 21.6
			374.8	*	229.3 ± 19.6
			317.0	4.3 ± 0.5	277.3 ± 35.7
			305.0	3.26 ± 0.17	241.8 ± 23.2
			270.1	27.8 ± 1.3	246.9 ± 15.1
			219.4	*	320.8 ± 86.7
			137.0	9.7 ± 0.4	254.6 ± 18.6
			$RR_{mean} =$		241.2 ± 7.4
^{203}Po	i(m+g)	36.7M	1090.9	19.2 ± 1.6	248.2 ± 24.3
			908.6	55 ± 3	231.9 ± 15.3
			893.5	18.7 ± 1.5	218.5 ± 20.3
			214.8	14.3 ± 1.4	332.6 ± 40.3
			175.2	3.0 ± 0.4	271.9 ± 42.1
			$RR_{mean} =$		233.9 ± 10.3
^{202}Po	i	44.7M	960.7	*	281.0 ± 16.1
			688.6	51 ± 6	313.8 ± 38.5
			657.5	*	231.7 ± 25.1
			422.1	*	307.7 ± 14.9
			316.0	14.3 ± 1.8	300.0 ± 39.8
			$RR_{mean} =$		293.1 ± 9.0
^{201}Po	i(m+g)	15.3M	890.1	91 ± 4	76.05 ± 4.61
^{207}Bi	c	31.55Y	1770.2	6.87 ± 0.04	478.6 ± 45.2
			1063.7	74.5 ± 0.2	437.2 ± 16.7
			569.7	97.74 ± 0.03	449.1 ± 16.3
			$RR_{mean} =$		444.8 ± 15.2
$^{206}\text{Bi}_i$	i	6.243D	1878.7	2.01 ± 0.05	291.9 ± 13.8
			1718.7	31.8 ± 0.6	282.7 ± 11.2
			1595.3	5.01 ± 0.08	300.1 ± 12.5
			1405.0	1.43 ± 0.03	299.6 ± 13.5
			1098.3	13.50 ± 0.21	258.0 ± 9.4
			1018.6	7.60 ± 0.11	279.8 ± 10.3
			895.1	15.66 ± 0.23	286.5 ± 10.5
			881.0	66.2 ± 1.0	274.1 ± 9.9
			803.1	98.9 ± 1.4	267.0 ± 9.6
			657.2	1.91 ± 0.04	273.6 ± 14.6
			632.2	4.47 ± 0.07	261.0 ± 10.0
			620.5	5.76 ± 0.09	253.5 ± 10.1
			537.5	30.5 ± 0.5	245.5 ± 9.3
			516.2	40.7 ± 0.6	253.5 ± 9.5
			497.1	15.31 ± 0.22	243.6 ± 9.0
			398.0	10.74 ± 0.15	245.0 ± 9.4
			343.5	23.4 ± 0.4	257.3 ± 9.7
			184.0	15.8 ± 0.4	300.5 ± 13.8

Continuation of Table 61.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹			
			RR _{mean} =		264.9 ± 9.1			
²⁰⁶ Bi _c	c	6.243D	1878.7	2.01 ± 0.05	449.8 ± 19.7			
			1718.7	31.8 ± 0.6	446.5 ± 17.4			
			1595.3	5.01 ± 0.08	468.8 ± 17.7			
			1405.0	1.43 ± 0.03	437.7 ± 17.7			
			1098.3	13.50 ± 0.21	411.6 ± 14.9			
			1018.6	7.60 ± 0.11	443.3 ± 15.9			
			895.1	15.66 ± 0.23	448.9 ± 16.1			
			881.0	66.2 ± 1.0	436.7 ± 15.7			
			803.1	98.9 ± 1.4	420.1 ± 15.0			
			657.2	1.91 ± 0.04	419.4 ± 17.5			
			632.2	4.47 ± 0.07	408.5 ± 15.2			
			620.5	5.76 ± 0.09	396.7 ± 14.8			
			537.5	30.5 ± 0.5	384.9 ± 14.5			
			516.2	40.7 ± 0.6	400.1 ± 14.9			
			497.1	15.31 ± 0.22	387.1 ± 14.3			
			398.0	10.74 ± 0.15	391.7 ± 14.4			
			343.5	23.4 ± 0.4	403.8 ± 15.2			
			184.0	15.8 ± 0.4	468.9 ± 21.5			
			RR _{mean} =		418.2 ± 14.2			
²⁰⁵ Bi	c	15.31D	1903.4	2.47 ± 0.04	570.5 ± 22.6			
			1861.7	6.17 ± 0.10	556.6 ± 21.6			
			1775.8	3.99 ± 0.08	564.8 ± 22.9			
			1764.3	32.5 ± 0.7	568.8 ± 23.0			
			1614.3	2.28 ± 0.04	587.3 ± 22.7			
			1551.0	0.97 ± 0.03	558.7 ± 30.3			
			1351.5	1.06 ± 0.04	579.0 ± 30.0			
			1190.0	2.26 ± 0.07	569.9 ± 26.2			
			1043.8	7.51 ± 0.10	511.0 ± 18.1			
			987.7	16.13 ± 0.17	549.0 ± 18.9			
			910.9	1.64 ± 0.04	503.1 ± 21.4			
			759.1	1.04 ± 0.05	561.1 ± 34.2			
			744.7	0.70 ± 0.02	519.0 ± 22.9			
			703.5	31.1 ± 0.1	517.7 ± 17.3			
			579.8	5.44 ± 0.07	483.5 ± 18.3			
			570.6	4.34 ± 0.07	511.3 ± 19.9			
						RR _{mean} =		532.7 ± 18.1
			²⁰⁴ Bi _i	i	11.22H	1211.7	3.0 ± 0.4	159.5 ± 73.9
984.0	59 ± 4	283.1 ± 24.6						
918.3	10.8 ± 0.9	283.8 ± 42.6						
899.2	98 ± 9	357.4 ± 36.2						
670.7	11.4 ± 0.9	320.5 ± 35.8						
374.8	82 ± 5	344.4 ± 27.3						
219.4	2.30 ± 0.17	420.1 ± 113.1						
			RR _{mean} =		313.5 ± 19.5			
²⁰⁴ Bi _c	c	11.22H	1211.7	3.0 ± 0.4	446.5 ± 64.5			
			984.0	59 ± 4	502.0 ± 38.0			
			918.3	10.8 ± 0.9	551.8 ± 50.3			
			899.2	98 ± 9	569.1 ± 55.6			
			670.7	11.4 ± 0.9	533.8 ± 46.2			
			374.8	82 ± 5	572.2 ± 40.0			

Continuation of Table 61.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			219.4	2.30 ± 0.17	738.8 ± 68.7
			<i>RR_{mean}</i> =		548.8 ± 30.5
²⁰³ Bi	c	11.76H	2011.0	1.76 ± 0.09	568.6 ± 37.4
			2001.0	0.83 ± 0.05	555.8 ± 41.2
			1983.0	0.88 ± 0.05	557.7 ± 40.0
			1893.0	8.2 ± 0.6	604.6 ± 49.4
			1888.0	1.94 ± 0.10	573.6 ± 37.8
			1719.6	3.40 ± 0.23	645.7 ± 55.6
			1679.6	8.8 ± 0.7	574.1 ± 49.9
			1536.5	7.5 ± 0.6	610.8 ± 53.5
			1506.7	3.7 ± 0.3	545.2 ± 48.4
			1199.0	2.02 ± 0.11	629.1 ± 41.7
			1034.0	8.8 ± 0.5	558.2 ± 40.2
			936.0	0.74 ± 0.04	608.3 ± 46.4
			896.8	13.1 ± 0.7	575.9 ± 36.3
			866.5	1.49 ± 0.08	566.8 ± 37.5
			847.2	8.5 ± 0.5	599.9 ± 40.8
			825.2	14.6 ± 1.1	643.0 ± 53.8
			820.2	29.6 ± 1.5	599.6 ± 36.6
			816.3	4.03 ± 0.21	571.5 ± 35.7
			722.4	4.8 ± 0.4	623.1 ± 56.5
			401.3	*	438.4 ± 74.2
			381.7	1.28 ± 0.07	706.5 ± 47.6
			279.2	*	604.8 ± 22.8
			264.2	5.2 ± 0.4	585.6 ± 50.8
			186.6	3.11 ± 0.22	707.2 ± 57.8
			<i>RR_{mean}</i> =		595.2 ± 18.4
²⁰² Bi _i	i	1.72H	960.7	99.28 ± 0.02	300.9 ± 17.2
			422.1	83.7 ± 2.5	282.9 ± 13.4
			<i>RR_{mean}</i> =		288.9 ± 12.3
²⁰² Bi _c	c	1.72H	960.7	99.28 ± 0.02	576.3 ± 19.6
			657.5	60.6 ± 1.8	580.8 ± 27.8
			422.1	83.7 ± 2.5	584.4 ± 26.5
			<i>RR_{mean}</i> =		577.9 ± 19.2
²⁰¹ Bi	c*	108M	1650.9	5.8 ± 1.3	431.0 ± 99.1
			1325.2	6.1 ± 1.3	463.1 ± 100.5
			1014.1	10.7 ± 2.3	457.6 ± 99.8
			936.2	11.3 ± 2.5	445.8 ± 100.2
			902.0	8.4 ± 1.8	414.8 ± 90.3
			629.1	24 ± 6	443.5 ± 112.1
			<i>RR_{mean}</i> =		442.5 ± 18.2
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	36.54 ± 7.03
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	641.3 ± 23.6
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	23.06 ± 3.04
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	618.3 ± 52.0
			1238.8	1.18 ± 0.08	672.0 ± 57.5
			692.4	4.27 ± 0.16	676.2 ± 37.9
			584.5	3.56 ± 0.16	662.8 ± 38.4
			361.3	9.9 ± 0.5	725.1 ± 44.6
			331.2	79 ± 5	749.6 ± 54.5

Continuation of Table 61.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	682.5 ± 26.8
²⁰⁰ Pb	c	21.5H	450.5	3.33 ± 0.08	186.6 ± 9.7
			268.4	3.96 ± 0.20	169.8 ± 11.2
			257.2	4.46 ± 0.17	178.9 ± 10.4
			235.6	4.30 ± 0.17	173.8 ± 11.1
			147.6	37.7 ± 1.4	170.4 ± 10.5
			142.3	3.16 ± 0.19	166.3 ± 13.8
				<i>RR_{mean}</i> =	176.6 ± 6.4
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	65.36 ± 12.36
			353.4	9.5 ± 1.5	57.16 ± 10.67
				<i>RR_{mean}</i> =	60.58 ± 5.40
¹⁹⁸ Pb	c	2.4H	365.4	19 ± 5	74.82 ± 20.02
			173.4	18 ± 3	70.58 ± 12.53
				<i>RR_{mean}</i> =	70.81 ± 4.23
^{197m} Pb	c*	43M	387.7	25 ± 6	21.02 ± 5.44
			385.9	74 ± 15	18.05 ± 3.78
				<i>RR_{mean}</i> =	18.28 ± 1.09
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	6.984 ± 0.262
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	717.1 ± 27.6
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	23.48 ± 9.06
			1205.7	29.9 ± 1.8	18.70 ± 3.72
			579.3	13.8 ± 0.7	18.07 ± 4.47
			367.9	87.2 ± 0.4	21.51 ± 4.00
				<i>RR_{mean}</i> =	19.73 ± 2.31
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	172.1 ± 22.0
			1514.9	4.0 ± 0.3	168.3 ± 14.5
			1362.9	3.4 ± 0.4	172.3 ± 21.1
			1225.5	3.36 ± 0.21	166.4 ± 19.1
			1205.7	29.9 ± 1.8	170.8 ± 11.9
			579.3	13.8 ± 0.7	166.5 ± 10.3
			367.9	87.2 ± 0.4	162.1 ± 6.1
				<i>RR_{mean}</i> =	163.9 ± 5.8
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	71.93 ± 9.03
			247.3	9.3 ± 1.1	49.74 ± 6.91
			208.2	12.3 ± 1.4	66.32 ± 8.26
				<i>RR_{mean}</i> =	61.93 ± 6.94
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.6677 ± 0.0444
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	1.090 ± 0.068
¹²² Sb	i(m+g)	2.7238D	564.2	70.67 ± 0.18	1.655 ± 0.102
^{120m} Sb	i(m)	5.76D	197.3	87.0 ± 1.1	0.5273 ± 0.0643
¹¹⁵ Cd	c	53.46H	527.9	27.4 ± 0.6	2.878 ± 0.525
			336.2	45.9 ± 1.0	4.300 ± 0.226
				<i>RR_{mean}</i> =	4.172 ± 0.428
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	1.372 ± 0.211
			657.8	94.3 ± 0.3	1.194 ± 0.100
				<i>RR_{mean}</i> =	1.224 ± 0.092
¹⁰⁷ Rh	c	21.7M	302.8	66 ± 6	21.32 ± 2.30
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	17.15 ± 0.88
			306.1	5.1 ± 0.4	15.40 ± 2.06
				<i>RR_{mean}</i> =	17.00 ± 0.78

Continuation of Table 61.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{106}Ru	c	373.59D	621.9(D)	9.93 ± 0.23	10.71 ± 0.95
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	17.07 ± 0.66
^{99}Mo	c	65.94H	181.1	5.99 ± 0.12	17.11 ± 1.41
			140.5	90.27 ± 0.33	18.54 ± 1.00
			$RR_{mean} =$		18.14 ± 0.89
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	3.986 ± 0.520
			778.2	96.45 ± 0.22	4.390 ± 0.401
			$RR_{mean} =$		4.245 ± 0.329
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	2.316 ± 0.124
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	16.33 ± 0.55
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	7.443 ± 0.394
^{95}Zr	c	64.02D	765.8	*	14.14 ± 0.48
			756.7	54.46 ± 0.10	13.52 ± 0.49
			724.2	44.17 ± 0.16	13.35 ± 0.75
			$RR_{mean} =$		13.87 ± 0.43
^{82}Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	2.636 ± 0.166

12.3.6 Nuclide production rates for ^{27}Al

Table 62: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.1 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	2.572 ± 0.101
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.3452 ± 0.0278
			1014.4	28.0 ± 0.4	0.3581 ± 0.0834
$RR_{mean} =$					0.3463 ± 0.0268
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	54.22 ± 1.84
^{24}Na	c	14.9590H	1369.0	100 ± 0	31.97 ± 1.06
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.463 ± 0.050
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	1.910 ± 0.124
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.2359 ± 0.0174
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	40.26 ± 1.37
^{24}Na	c	14.9590H	1369.0	100 ± 0	23.82 ± 0.79
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.318 ± 0.044
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	2.270 ± 0.114
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.3282 ± 0.0661
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	47.05 ± 1.59
^{24}Na	c	14.9590H	1369.0	100 ± 0	27.59 ± 0.92
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.617 ± 0.054
^{27}Al -monitor for ^{nat}Pb					

Continuation of Table 62.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^7Be	i	53.29D	477.6	10.52 ± 0.06	1.397 ± 0.060
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.3203 ± 0.0254
			1014.4	28.0 ± 0.4	0.3521 ± 0.1013
$RR_{mean} =$					0.3219 ± 0.0249
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	28.35 ± 0.97
^{24}Na	c	14.9590H	1369.0	100 ± 0	16.89 ± 0.56
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.120 ± 0.037
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	2.553 ± 0.109
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.4970 ± 0.0256
			1014.4	28.0 ± 0.4	0.4669 ± 0.0445
$RR_{mean} =$					0.4912 ± 0.0239
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	52.00 ± 1.75
^{24}Na	c	14.9590H	1369.0	100 ± 0	31.09 ± 1.04
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.452 ± 0.049

12.4 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.15$ GeV

12.4.1 Nuclide production rates for ^{206}Pb

Table 63: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.15$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹			
²⁰⁶ Bi	i	6.243D	1878.7	2.01 ± 0.05	24.29 ± 1.46			
			1718.7	31.8 ± 0.6	27.32 ± 1.21			
			1595.3	5.01 ± 0.08	29.19 ± 1.27			
			1098.3	13.50 ± 0.21	25.22 ± 0.96			
			1018.6	7.60 ± 0.11	26.13 ± 1.02			
			895.1	15.66 ± 0.23	26.58 ± 1.00			
			881.0	66.2 ± 1.0	26.14 ± 0.95			
			803.1	98.9 ± 1.4	25.01 ± 0.90			
			632.2	4.47 ± 0.07	31.63 ± 1.33			
			620.5	5.76 ± 0.09	26.51 ± 1.09			
			537.5	30.5 ± 0.5	23.42 ± 0.92			
			516.2	40.7 ± 0.6	24.57 ± 0.94			
			497.1	15.31 ± 0.22	24.37 ± 1.04			
			398.0	10.74 ± 0.15	23.99 ± 0.91			
			343.5	23.4 ± 0.4	24.56 ± 0.96			
			262.7	3.02 ± 0.06	27.42 ± 2.68			
			184.0	15.8 ± 0.4	29.26 ± 1.35			
RR _{mean} =				25.60 ± 0.90				
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	88.20 ± 3.58			
			1775.8	3.99 ± 0.08	89.60 ± 3.74			
			1764.3	32.5 ± 0.7	89.47 ± 3.68			
			1614.3	2.28 ± 0.04	95.64 ± 3.96			
			1190.0	2.26 ± 0.07	84.07 ± 4.05			
			1043.8	7.51 ± 0.10	81.56 ± 3.04			
			987.7	16.13 ± 0.17	88.24 ± 3.05			
			759.1	1.04 ± 0.05	87.82 ± 5.63			
			703.5	31.1 ± 0.1	82.87 ± 2.79			
			579.8	5.44 ± 0.07	79.04 ± 3.24			
			573.8	0.62 ± 0.01	90.42 ± 7.10			
			570.6	4.34 ± 0.07	79.37 ± 3.21			
			549.8	2.95 ± 0.04	76.91 ± 3.13			
			284.1	1.69 ± 0.02	76.43 ± 3.65			
			RR _{mean} =				84.08 ± 2.91	
			²⁰⁴ Bi	i	11.22H	1211.7	3.0 ± 0.4	105.7 ± 15.4
						984.0	59 ± 4	117.0 ± 9.0
918.3	10.8 ± 0.9	133.8 ± 12.2						
899.2	98 ± 9	112.8 ± 3.9						
670.7	11.4 ± 0.9	119.2 ± 10.4						
374.8	82 ± 5	134.5 ± 28.1						
RR _{mean} =				113.5 ± 3.5				
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	156.8 ± 13.0			
			1847.3	11.4 ± 0.8	152.5 ± 12.2			
			1679.6	8.8 ± 0.7	156.4 ± 13.8			

Continuation of Table 63.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1536.5	7.5 ± 0.6	164.3 ± 14.6
			1506.7	3.7 ± 0.3	140.1 ± 13.0
			1034.0	8.8 ± 0.5	150.3 ± 10.1
			896.8	13.1 ± 0.7	171.3 ± 11.2
			847.2	8.5 ± 0.5	161.4 ± 11.3
			820.2	29.6 ± 1.5	164.6 ± 10.1
			816.3	4.03 ± 0.21	162.1 ± 10.9
			722.4	4.8 ± 0.4	174.2 ± 16.1
			264.2	5.2 ± 0.4	160.1 ± 14.2
			186.6	3.11 ± 0.22	33.88 ± 52.83
			$RR_{mean} =$		161.8 ± 5.5
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	162.3 ± 6.1
			422.1	83.7 ± 2.5	170.5 ± 10.3
			$RR_{mean} =$		163.4 ± 6.0
^{201}Bi	i	108M	1325.2	6.1 ± 1.3	179.0 ± 39.9
			629.1	24 ± 6	170.6 ± 43.2
			$RR_{mean} =$		177.1 ± 12.6
^{199}Bi	i	27M	946.0	10.8 ± 0.6	115.4 ± 24.3
			841.7	11 ± 0	134.1 ± 9.0
			837.4	9.5 ± 0.6	152.6 ± 19.1
			$RR_{mean} =$		135.2 ± 8.2
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	101.4 ± 4.0
			374.7	89 ± 15	131.5 ± 23.1
			$RR_{mean} =$		101.8 ± 4.5
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	118.3 ± 4.4
			374.7	89 ± 15	148.3 ± 25.9
			$RR_{mean} =$		118.6 ± 4.7
^{203}Pb	c*	51.873H	680.5	0.75 ± 0.02	603.1 ± 28.9
			401.3	3.35 ± 0.07	565.2 ± 22.7
			279.2	80.8 ± 0.2	582.0 ± 21.2
			$RR_{mean} =$		579.5 ± 19.8
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	123.5 ± 11.6
			490.5	9.1 ± 0.7	138.7 ± 12.4
			459.7	8.6 ± 0.7	124.2 ± 11.9
			422.1	86 ± 5	130.8 ± 9.9
			$RR_{mean} =$		129.6 ± 5.6
^{201}Pb	c*	9.33H	1277.1	1.63 ± 0.12	558.3 ± 49.3
			1238.8	1.18 ± 0.08	516.4 ± 44.0
			1098.5	1.83 ± 0.12	515.3 ± 39.7
			1069.9	1.14 ± 0.11	658.0 ± 82.0
			946.0	7.4 ± 0.6	536.5 ± 47.8
			907.6	5.7 ± 0.4	571.5 ± 45.1
			767.3	3.16 ± 0.16	602.7 ± 38.6
			692.4	4.27 ± 0.16	580.1 ± 30.3
			361.3	9.9 ± 0.5	624.7 ± 38.4
			331.2	79 ± 5	639.7 ± 46.1
			167.4	*	676.5 ± 59.2
			135.3	*	383.6 ± 293.4
			$RR_{mean} =$		583.4 ± 18.0
^{200}Pb	c	21.5H	1514.9	*	534.2 ± 44.7
			1407.6	*	571.7 ± 55.8

Continuation of Table 63.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1362.9	*	544.2 ± 67.2
			1225.5	*	516.6 ± 37.4
			1205.7	*	541.9 ± 37.4
			886.2	*	470.0 ± 38.7
			828.3	*	522.2 ± 38.7
			701.6	*	509.3 ± 44.4
			579.3	*	481.3 ± 30.5
			525.5	0.42 ± 0.04	565.4 ± 63.9
			450.5	3.33 ± 0.08	626.3 ± 27.6
			367.9	*	504.5 ± 17.5
			268.4	3.96 ± 0.20	629.4 ± 41.0
			257.2	4.46 ± 0.17	635.6 ± 36.4
			235.6	4.30 ± 0.17	606.5 ± 37.0
			147.6	37.7 ± 1.4	573.4 ± 31.5
			142.3	3.16 ± 0.19	554.4 ± 41.1
			<i>RR_{mean}</i> =		519.9 ± 16.0
¹⁹⁹ Pb	c*	90M	1502.0	2.1 ± 0.4	912.9 ± 183.6
			1382.7	2.9 ± 0.5	965.8 ± 186.0
			1135.0	7.8 ± 1.2	933.7 ± 152.2
			1029.2	1.62 ± 0.25	711.7 ± 116.6
			781.5	1.9 ± 0.3	856.9 ± 141.8
			762.0	2.2 ± 0.4	1139 ± 222
			720.2	6.5 ± 1.0	1006 ± 160
			366.9	44 ± 7	1099 ± 183
			353.4	9.5 ± 1.5	1297 ± 224
			<i>RR_{mean}</i> =		918.1 ± 62.0
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	586.4 ± 121.5
			575.0	3.1 ± 0.7	629.8 ± 144.9
			365.4	19 ± 5	840.6 ± 223.2
			173.4	18 ± 3	792.3 ± 135.8
			<i>RR_{mean}</i> =		771.9 ± 42.3
^{197m} Pb	c*	43M	774.3	14 ± 3	381.3 ± 83.8
			695.6	9.5 ± 2.0	369.8 ± 82.4
			387.7	25 ± 6	471.6 ± 114.7
			385.9	74 ± 15	521.5 ± 107.2
			222.8	25 ± 6	367.9 ± 90.0
			<i>RR_{mean}</i> =		457.5 ± 38.4
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	420.8 ± 51.0
			253.1	27 ± 3	404.4 ± 49.0
			<i>RR_{mean}</i> =		412.3 ± 32.7
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	167.6 ± 31.6
			383.6	107 ± 20	174.7 ± 33.4
			<i>RR_{mean}</i> =		170.2 ± 7.4
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	91.80 ± 3.32
²⁰¹ Tl _c	c	72.912H	167.4	10.00 ± 0.06	703.3 ± 27.0
			135.3	2.57 ± 0.02	831.5 ± 55.4
			<i>RR_{mean}</i> =		715.0 ± 43.0
²⁰¹ Tl	c*	72.912H	135.3	2.56 ± 0.02	908.0 ± 39.1
			167.4	10.00 ± 0.06	800.5 ± 29.4
			<i>RR_{mean}</i> =		826.5 ± 52.7
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	150.6 ± 18.5

Continuation of Table 63.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1407.6	1.45 ± 0.13	207.1 ± 27.3
			1362.9	3.4 ± 0.4	188.6 ± 27.9
			1225.5	3.36 ± 0.21	166.7 ± 18.4
			1205.7	29.9 ± 1.8	118.5 ± 10.9
			886.2	2.02 ± 0.13	232.7 ± 40.0
			828.3	10.8 ± 0.7	173.6 ± 19.3
			701.6	1.29 ± 0.10	230.0 ± 28.5
			579.3	13.8 ± 0.7	216.6 ± 25.3
			367.9	87.2 ± 0.4	150.3 ± 13.2
			<i>RR_{mean}</i> =		157.3 ± 12.4
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	684.8 ± 56.8
			1407.6	1.45 ± 0.13	778.8 ± 75.2
			1362.9	3.4 ± 0.4	732.8 ± 90.1
			1225.5	3.36 ± 0.21	683.3 ± 49.0
			1205.7	29.9 ± 1.8	660.4 ± 45.6
			886.2	2.02 ± 0.13	702.8 ± 54.7
			828.3	10.8 ± 0.7	695.8 ± 51.5
			701.6	1.29 ± 0.10	739.3 ± 63.3
			579.3	13.8 ± 0.7	697.9 ± 45.0
			367.9	87.2 ± 0.4	654.8 ± 23.8
			<i>RR_{mean}</i> =		669.6 ± 22.9
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	840.5 ± 99.7
			247.3	9.3 ± 1.1	831.2 ± 104.0
			208.2	12.3 ± 1.4	808.2 ± 97.8
			<i>RR_{mean}</i> =		826.6 ± 40.6
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	87.52 ± 4.65
			282.8	28 ± 3	87.62 ± 10.14
			<i>RR_{mean}</i> =		87.53 ± 3.38
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	619.8 ± 208.4
			152.2	7.3 ± 2.3	956.5 ± 304.2
			134.0	2.0 ± 0.7	803.5 ± 284.5
			<i>RR_{mean}</i> =		811.3 ± 112.7
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	146.6 ± 25.8
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	270.0 ± 32.2
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	1.600 ± 0.089
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	668.2 ± 35.2
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	20.55 ± 0.99
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	25.79 ± 2.47
			261.8	31 ± 4	26.29 ± 3.59
			779.8	54.2 ± 0.1	24.58 ± 5.05
			<i>RR_{mean}</i> =		25.67 ± 0.79
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	353.3 ± 38.3
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	13.59 ± 2.30
			407.6	32 ± 6	22.05 ± 4.26
			<i>RR_{mean}</i> =		15.49 ± 3.57
¹⁹² Hg	c	4.85H	316.5	*	73.73 ± 9.31
			274.8	50.2 ± 2.5	55.56 ± 3.83
			<i>RR_{mean}</i> =		57.85 ± 1.78
^{198m} Au	i(m)	2.27D	411.8	*	0.4250 ± 0.0874
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	0.4596 ± 0.1926

Continuation of Table 63.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{198}\text{Au}_c$	i(m+g)	2.69517D	411.8	95.58 ± 0.12	0.8846 ± 0.1136
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	2.209 ± 0.088
			333.0	22.9 ± 0.6	2.079 ± 0.127
			$RR_{mean} =$		2.184 ± 0.085
^{195}Au	c	186.098D	129.8	0.82 ± 0.05	387.3 ± 30.3
			98.9	10.9 ± 0.9	347.6 ± 33.9
			$RR_{mean} =$		374.5 ± 21.9
^{194}Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	3.235 ± 0.309
$^{192}\text{Au}_i$	i(m+g)	4.94H	316.5	58 ± 7	2.748 ± 1.297
$^{192}\text{Au}_c$	c	4.94H	316.5	58 ± 7	76.48 ± 9.62
^{127}Xe	c	36.4D	202.9	68.3 ± 0.5	0.7553 ± 0.0416
^{124}Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.6329 ± 0.0522
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.403 ± 0.074
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	1.400 ± 0.057
			1023.3	99.4 ± 0.3	1.322 ± 0.054
			197.3	87.0 ± 1.1	1.512 ± 0.065
			$RR_{mean} =$		1.396 ± 0.067
^{110m}Ag	i(m)	249.76D	657.8	94.3 ± 0.3	4.084 ± 0.232
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	20.45 ± 0.77
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	19.93 ± 0.81
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	9.712 ± 0.555
			849.9	20.45 ± 0.20	10.19 ± 0.63
			778.2	96.45 ± 0.22	9.813 ± 0.361
			460.0	26.62 ± 0.20	9.573 ± 0.444
			$RR_{mean} =$		9.782 ± 0.338
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	7.890 ± 0.312
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	21.88 ± 0.76
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	4.756 ± 0.211
^{95}Zr	c	64.02D	765.8	*	14.11 ± 0.56
			756.7	54.46 ± 0.10	13.79 ± 0.49
			$RR_{mean} =$		13.89 ± 0.43
^{88}Zr	c	83.4D	898.0	*	0.3009 ± 0.1213
$^{88}\text{Y}_i$	i	106.65D	898.0	93.7 ± 0.3	1.228 ± 0.063
$^{88}\text{Y}_c$	c	106.65D	898.0	93.7 ± 0.3	1.529 ± 0.101
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	1.790 ± 0.145
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	6.201 ± 0.390
			776.5	83.5 ± 1.2	6.002 ± 0.244
			554.3	70.8 ± 1.0	5.745 ± 0.230
			$RR_{mean} =$		5.889 ± 0.212

12.4.2 Nuclide production rates for ^{207}Pb

Table 64: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 0.15 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	27.55 ± 3.86
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	57.09 ± 3.18

Continuation of Table 64.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1718.7	31.8 ± 0.6	58.17 ± 2.30
			1595.3	5.01 ± 0.08	63.22 ± 2.80
			1098.3	13.50 ± 0.21	54.05 ± 2.03
			1018.6	7.60 ± 0.11	56.57 ± 2.08
			895.1	15.66 ± 0.23	56.66 ± 2.08
			881.0	66.2 ± 1.0	56.80 ± 2.06
			803.1	98.9 ± 1.4	54.23 ± 1.93
			632.2	4.47 ± 0.07	51.72 ± 2.40
			620.5	5.76 ± 0.09	52.97 ± 2.22
			537.5	30.5 ± 0.5	50.72 ± 1.95
			516.2	40.7 ± 0.6	52.78 ± 1.96
			497.1	15.31 ± 0.22	50.29 ± 1.94
			398.0	10.74 ± 0.15	51.41 ± 1.92
			343.5	23.4 ± 0.4	52.40 ± 2.08
			262.7	3.02 ± 0.06	54.22 ± 3.49
			184.0	15.8 ± 0.4	60.26 ± 2.71
			<i>RR_{mean}</i> =		54.26 ± 1.83
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	116.7 ± 4.6
			1775.8	3.99 ± 0.08	119.9 ± 4.9
			1764.3	32.5 ± 0.7	119.1 ± 4.9
			1614.3	2.28 ± 0.04	124.4 ± 5.0
			1190.0	2.26 ± 0.07	115.1 ± 5.6
			1043.8	7.51 ± 0.10	108.2 ± 4.0
			987.7	16.13 ± 0.17	115.5 ± 4.0
			759.1	1.04 ± 0.05	112.5 ± 8.2
			703.5	31.1 ± 0.1	107.9 ± 3.6
			579.8	5.44 ± 0.07	104.4 ± 4.1
			573.8	0.62 ± 0.01	98.43 ± 5.62
			570.6	4.34 ± 0.07	107.6 ± 4.2
			549.8	2.95 ± 0.04	96.15 ± 3.79
			284.1	1.69 ± 0.02	103.4 ± 4.5
			<i>RR_{mean}</i> =		109.7 ± 3.9
²⁰⁴ Bi	i	11.22H	1211.7	3.0 ± 0.4	102.6 ± 15.9
			984.0	59 ± 4	118.2 ± 9.0
			918.3	10.8 ± 0.9	130.5 ± 11.9
			899.2	98 ± 9	111.1 ± 3.8
			670.7	11.4 ± 0.9	116.6 ± 10.2
			374.8	82 ± 5	130.4 ± 27.2
			<i>RR_{mean}</i> =		111.8 ± 3.4
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	142.5 ± 11.8
			1847.3	11.4 ± 0.8	137.8 ± 11.0
			1679.6	8.8 ± 0.7	132.9 ± 11.7
			1536.5	7.5 ± 0.6	141.8 ± 12.6
			1506.7	3.7 ± 0.3	113.8 ± 11.1
			1034.0	8.8 ± 0.5	134.6 ± 9.2
			896.8	13.1 ± 0.7	145.7 ± 9.3
			847.2	8.5 ± 0.5	141.3 ± 9.8
			820.2	29.6 ± 1.5	148.2 ± 9.0
			816.3	4.03 ± 0.21	155.7 ± 11.7
			722.4	4.8 ± 0.4	156.9 ± 14.7
			264.2	5.2 ± 0.4	144.7 ± 14.2

Continuation of Table 64.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			186.6	3.11 ± 0.22	105.1 ± 23.5
			<i>RR_{mean}</i> =		144.2 ± 5.0
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	142.1 ± 5.4
			422.1	83.7 ± 2.5	147.5 ± 7.9
			<i>RR_{mean}</i> =		143.1 ± 5.2
²⁰¹ Bi	i	108M	1325.2	6.1 ± 1.3	134.1 ± 30.7
			629.1	24 ± 6	147.4 ± 37.4
			<i>RR_{mean}</i> =		137.4 ± 11.3
¹⁹⁹ Bi	i	27M	946.0	10.8 ± 0.6	90.14 ± 20.32
			841.7	11 ± 0	97.44 ± 8.10
			837.4	9.5 ± 0.6	124.8 ± 13.3
			<i>RR_{mean}</i> =		103.2 ± 9.2
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	105.6 ± 4.1
			374.7	89 ± 15	131.7 ± 22.7
			<i>RR_{mean}</i> =		106.0 ± 4.4
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	122.3 ± 4.6
			374.7	89 ± 15	148.0 ± 25.5
			<i>RR_{mean}</i> =		122.6 ± 4.6
²⁰³ Pb	c*	51.873H	680.5	0.75 ± 0.02	494.3 ± 26.3
			401.3	3.35 ± 0.07	478.9 ± 19.2
			279.2	80.8 ± 0.2	494.3 ± 18.0
			<i>RR_{mean}</i> =		489.0 ± 16.7
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	119.4 ± 11.3
			490.5	9.1 ± 0.7	131.2 ± 13.0
			459.7	8.6 ± 0.7	105.6 ± 10.0
			422.1	86 ± 5	124.8 ± 8.9
			<i>RR_{mean}</i> =		120.8 ± 6.0
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	472.2 ± 43.8
			1238.8	1.18 ± 0.08	435.3 ± 39.4
			1098.5	1.83 ± 0.12	442.9 ± 35.1
			1069.9	1.14 ± 0.11	580.6 ± 63.3
			946.0	7.4 ± 0.6	462.4 ± 41.5
			907.6	5.7 ± 0.4	478.7 ± 37.6
			767.3	3.16 ± 0.16	511.8 ± 33.0
			692.4	4.27 ± 0.16	487.2 ± 27.9
			584.5	3.56 ± 0.16	599.2 ± 35.2
			361.3	9.9 ± 0.5	523.7 ± 32.4
			331.2	79 ± 5	535.4 ± 38.6
			167.4	*	571.4 ± 38.8
			135.3	*	516.0 ± 104.9
			<i>RR_{mean}</i> =		513.5 ± 15.8
²⁰⁰ Pb	c	21.5H	886.2	*	390.5 ± 29.6
			701.6	*	386.4 ± 35.8
			579.3	*	384.8 ± 24.2
			1514.9	*	446.7 ± 36.9
			1407.6	*	484.6 ± 49.2
			1362.9	*	446.2 ± 55.3
			1225.5	*	425.4 ± 30.9
			1205.7	*	431.9 ± 29.8
			525.5	0.42 ± 0.04	483.4 ± 52.2
			450.5	3.33 ± 0.08	507.6 ± 21.7

Continuation of Table 64.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁹ Pb	c*	90M	367.9	*	407.9 ± 14.3
			268.4	3.96 ± 0.20	490.2 ± 32.2
			257.2	4.46 ± 0.17	505.3 ± 30.1
			235.6	4.30 ± 0.17	504.6 ± 29.6
			147.6	37.7 ± 1.4	478.0 ± 26.2
			142.3	3.16 ± 0.19	470.8 ± 38.3
			<i>RR_{mean}</i> =		423.2 ± 13.1
			1502.0	2.1 ± 0.4	685.7 ± 138.4
			1382.7	2.9 ± 0.5	749.2 ± 138.1
			1135.0	7.8 ± 1.2	800.2 ± 131.6
¹⁹⁸ Pb	c	2.4H	1029.2	1.62 ± 0.25	637.8 ± 105.4
			781.5	1.9 ± 0.3	656.0 ± 117.2
			762.0	2.2 ± 0.4	820.6 ± 174.1
			720.2	6.5 ± 1.0	892.3 ± 143.3
			366.9	44 ± 7	854.4 ± 141.4
			353.4	9.5 ± 1.5	907.4 ± 151.9
			<i>RR_{mean}</i> =		769.0 ± 43.7
			865.3	5.9 ± 1.2	442.5 ± 91.9
			575.0	3.1 ± 0.7	486.6 ± 112.1
			365.4	19 ± 5	629.9 ± 167.3
^{197m} Pb	c*	43M	173.4	18 ± 3	623.2 ± 106.6
			<i>RR_{mean}</i> =		608.0 ± 33.7
			774.3	14 ± 3	265.2 ± 58.6
			695.6	9.5 ± 2.0	254.9 ± 59.0
			387.7	25 ± 6	346.9 ± 84.2
			385.9	74 ± 15	371.6 ± 76.5
			222.8	25 ± 6	265.1 ± 64.8
			<i>RR_{mean}</i> =		326.7 ± 28.4
			502.1	26 ± 3	274.8 ± 33.9
			253.1	27 ± 3	229.0 ± 27.2
¹⁹⁶ Pb	c*	37M	<i>RR_{mean}</i> =		246.7 ± 23.5
			394.2	44 ± 8	79.92 ± 16.79
			383.6	107 ± 20	78.21 ± 14.98
			<i>RR_{mean}</i> =		78.56 ± 4.36
			202Tl	91.4 ± 1.0	82.28 ± 3.00
²⁰¹ Tl _c	c	72.912H	167.4	10.00 ± 0.06	584.2 ± 21.9
			135.3	2.57 ± 0.02	641.4 ± 30.9
			<i>RR_{mean}</i> =		596.1 ± 29.6
			135.3	2.56 ± 0.02	717.6 ± 30.7
			167.4	10.00 ± 0.06	667.9 ± 24.5
			<i>RR_{mean}</i> =		681.3 ± 30.5
			1514.9	4.0 ± 0.3	116.3 ± 12.1
			1407.6	1.45 ± 0.13	148.0 ± 33.4
			1362.9	3.4 ± 0.4	148.2 ± 24.6
			1225.5	3.36 ± 0.21	129.2 ± 14.9
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	116.4 ± 10.2
			886.2	2.02 ± 0.13	171.1 ± 22.0
			828.3	10.8 ± 0.7	155.7 ± 16.9
			701.6	1.29 ± 0.10	230.3 ± 33.7
			579.3	13.8 ± 0.7	185.8 ± 19.5
			367.9	87.2 ± 0.4	139.7 ± 12.7

Continuation of Table 64.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			<i>RR_{mean}</i> =		137.1 ± 9.4
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	563.1 ± 46.5
			1407.6	1.45 ± 0.13	632.7 ± 62.8
			1362.9	3.4 ± 0.4	594.5 ± 73.4
			1225.5	3.36 ± 0.21	554.6 ± 39.8
			1205.7	29.9 ± 1.8	548.4 ± 37.9
			886.2	2.02 ± 0.13	561.6 ± 41.8
			828.3	10.8 ± 0.7	565.4 ± 41.9
			701.6	1.29 ± 0.10	616.6 ± 54.2
			579.3	13.8 ± 0.7	570.6 ± 36.3
			367.9	87.2 ± 0.4	547.6 ± 20.2
			<i>RR_{mean}</i> =		556.2 ± 19.1
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	638.8 ± 75.6
			247.3	9.3 ± 1.1	671.1 ± 84.8
			208.2	12.3 ± 1.4	668.4 ± 80.9
			<i>RR_{mean}</i> =		656.6 ± 32.3
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	61.33 ± 3.30
			282.8	28 ± 3	68.63 ± 7.93
			<i>RR_{mean}</i> =		61.65 ± 2.43
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	452.9 ± 152.6
			152.2	7.3 ± 2.3	689.0 ± 218.8
			134.0	2.0 ± 0.7	646.9 ± 230.5
			<i>RR_{mean}</i> =		599.4 ± 80.6
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	101.5 ± 18.1
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	129.0 ± 16.2
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	3.066 ± 0.178
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	468.4 ± 25.0
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	16.73 ± 0.84
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	18.02 ± 1.86
			261.8	31 ± 4	20.30 ± 2.79
			779.8	54.2 ± 0.1	20.57 ± 5.79
			<i>RR_{mean}</i> =		18.69 ± 0.58
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	175.1 ± 20.1
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	8.322 ± 1.425
			407.6	32 ± 6	11.92 ± 2.31
			<i>RR_{mean}</i> =		9.308 ± 1.630
¹⁹² Hg	c	4.85H	316.5	*	31.87 ± 4.10
			274.8	50.2 ± 2.5	22.39 ± 1.58
			<i>RR_{mean}</i> =		23.46 ± 0.72
^{198m} Au	i(m)	2.27D	411.8	*	0.3598 ± 0.1203
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	0.7282 ± 0.2374
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	1.088 ± 0.127
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	1.935 ± 0.092
			333.0	22.9 ± 0.6	1.688 ± 0.121
			<i>RR_{mean}</i> =		1.866 ± 0.125
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	195.7 ± 15.7
			98.9	10.9 ± 0.9	177.4 ± 17.3
			<i>RR_{mean}</i> =		189.3 ± 10.5
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	2.485 ± 0.275
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	29.33 ± 3.77

Continuation of Table 64.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	0.3995 ± 0.0384
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.6709 ± 0.0523
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.073 ± 0.094
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	0.8687 ± 0.0601
			197.3	87.0 ± 1.1	0.8952 ± 0.0449
			<i>RR_{mean}</i> =		0.8872 ± 0.0403
^{110m} Ag	i(m)	249.76D	657.8	94.3 ± 0.3	2.055 ± 0.322
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	14.57 ± 0.55
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	14.99 ± 0.61
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	6.096 ± 0.389
			849.9	20.45 ± 0.20	6.019 ± 0.669
			778.2	96.45 ± 0.22	5.613 ± 0.270
			460.0	26.62 ± 0.20	5.613 ± 0.315
			<i>RR_{mean}</i> =		5.719 ± 0.227
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	4.146 ± 0.137
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	15.08 ± 0.49
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	4.722 ± 0.212
⁹⁵ Zr	c	64.02D	765.8	*	11.03 ± 0.36
			756.7	54.46 ± 0.10	9.990 ± 0.397
			<i>RR_{mean}</i> =		10.82 ± 0.33
⁸⁸ Zr	c	83.4D	898.0	*	0.1440 ± 0.0832
⁸⁸ Y _i	i	106.65D	898.0	93.7 ± 0.3	0.5187 ± 0.0622
⁸⁸ Y _c	c	106.65D	898.0	93.7 ± 0.3	0.6627 ± 0.0491
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	0.5683 ± 0.1720
⁸² Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	4.633 ± 0.818
			776.5	83.5 ± 1.2	3.756 ± 0.195
			554.3	70.8 ± 1.0	3.300 ± 0.168
			<i>RR_{mean}</i> =		3.508 ± 0.215

12.4.3 Nuclide production rates for ^{208}Pb

Table 65: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.15 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	78.79 ± 4.63
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	114.6 ± 6.1
			1718.7	31.8 ± 0.6	117.2 ± 4.6
			1595.3	5.01 ± 0.08	127.9 ± 5.5
			1098.3	13.50 ± 0.21	108.4 ± 4.0
			1018.6	7.60 ± 0.11	117.5 ± 4.3
			895.1	15.66 ± 0.23	113.1 ± 4.2
			881.0	66.2 ± 1.0	114.3 ± 4.1
			803.1	98.9 ± 1.4	110.1 ± 3.9
			632.2	4.47 ± 0.07	105.5 ± 4.1
			620.5	5.76 ± 0.09	107.3 ± 4.1
			537.5	30.5 ± 0.5	101.1 ± 3.8
			516.2	40.7 ± 0.6	106.7 ± 4.0
			497.1	15.31 ± 0.22	101.8 ± 3.9

Continuation of Table 65.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			398.0	10.74 ± 0.15	102.7 ± 3.8
			343.5	23.4 ± 0.4	107.0 ± 4.1
			262.7	3.02 ± 0.06	111.2 ± 5.7
			184.0	15.8 ± 0.4	122.7 ± 5.5
			$RR_{mean} =$		109.5 ± 3.7
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	167.4 ± 6.6
			1775.8	3.99 ± 0.08	173.6 ± 7.2
			1764.3	32.5 ± 0.7	170.7 ± 7.0
			1614.3	2.28 ± 0.04	177.1 ± 7.0
			1190.0	2.26 ± 0.07	162.6 ± 7.6
			1043.8	7.51 ± 0.10	154.5 ± 5.8
			987.7	16.13 ± 0.17	167.2 ± 5.9
			759.1	1.04 ± 0.05	165.4 ± 11.4
			703.5	31.1 ± 0.1	157.1 ± 5.3
			579.8	5.44 ± 0.07	151.0 ± 5.7
			573.8	0.62 ± 0.01	138.2 ± 9.8
			570.6	4.34 ± 0.07	155.1 ± 6.2
			549.8	2.95 ± 0.04	144.8 ± 5.7
			284.1	1.69 ± 0.02	153.5 ± 6.4
			$RR_{mean} =$		159.3 ± 5.5
^{204}Bi	i	11.22H	1211.7	3.0 ± 0.4	136.5 ± 19.4
			984.0	59 ± 4	155.7 ± 11.8
			918.3	10.8 ± 0.9	172.5 ± 15.7
			899.2	98 ± 9	148.1 ± 5.0
			670.7	11.4 ± 0.9	158.0 ± 13.8
			374.8	82 ± 5	171.9 ± 35.9
			$RR_{mean} =$		148.8 ± 4.6
^{203}Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	189.0 ± 15.6
			1847.3	11.4 ± 0.8	176.3 ± 14.0
			1679.6	8.8 ± 0.7	179.2 ± 15.9
			1536.5	7.5 ± 0.6	189.3 ± 16.7
			1506.7	3.7 ± 0.3	165.1 ± 15.3
			1034.0	8.8 ± 0.5	173.6 ± 11.9
			896.8	13.1 ± 0.7	183.4 ± 11.7
			847.2	8.5 ± 0.5	175.8 ± 12.7
			820.2	29.6 ± 1.5	182.6 ± 11.2
			816.3	4.03 ± 0.21	195.3 ± 13.9
			722.4	4.8 ± 0.4	175.5 ± 16.5
			264.2	5.2 ± 0.4	184.0 ± 16.5
			186.6	3.11 ± 0.22	135.2 ± 26.6
			$RR_{mean} =$		181.4 ± 5.9
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	180.3 ± 6.6
			422.1	83.7 ± 2.5	183.9 ± 9.7
			$RR_{mean} =$		180.9 ± 6.5
^{201}Bi	i	108M	1325.2	6.1 ± 1.3	217.9 ± 49.0
			629.1	24 ± 6	187.9 ± 47.6
			$RR_{mean} =$		209.0 ± 15.9
^{199}Bi	i	27M	946.0	10.8 ± 0.6	121.9 ± 13.9
			841.7	11 ± 0	165.2 ± 9.2
			837.4	9.5 ± 0.6	193.1 ± 19.3

Continuation of Table 65.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	159.0 ± 16.0
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	154.4 ± 5.5
			374.7	89 ± 15	182.6 ± 31.5
				$RR_{mean} =$	154.6 ± 5.5
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	176.6 ± 6.2
			374.7	89 ± 15	204.2 ± 35.2
				$RR_{mean} =$	176.8 ± 6.2
²⁰³ Pb	c*	51.873H	680.5	0.75 ± 0.02	622.2 ± 46.6
			401.3	3.35 ± 0.07	597.3 ± 24.0
			279.2	80.8 ± 0.2	611.4 ± 22.3
				$RR_{mean} =$	606.9 ± 20.8
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	159.9 ± 15.0
			490.5	9.1 ± 0.7	171.3 ± 15.9
			459.7	8.6 ± 0.7	160.0 ± 14.6
			422.1	86 ± 5	167.6 ± 11.8
				$RR_{mean} =$	165.7 ± 6.8
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	571.2 ± 49.0
			1238.8	1.18 ± 0.08	565.4 ± 49.4
			1098.5	1.83 ± 0.12	547.9 ± 46.8
			1069.9	1.14 ± 0.11	717.2 ± 84.0
			946.0	7.4 ± 0.6	543.2 ± 48.3
			907.6	5.7 ± 0.4	572.3 ± 45.0
			767.3	3.16 ± 0.16	633.1 ± 40.2
			692.4	4.27 ± 0.16	619.9 ± 31.9
			584.5	3.56 ± 0.16	659.0 ± 39.4
			361.3	9.9 ± 0.5	623.8 ± 38.2
			331.2	79 ± 5	640.6 ± 46.2
			167.4	*	641.2 ± 30.8
			135.3	*	620.1 ± 121.7
				$RR_{mean} =$	617.2 ± 19.0
²⁰⁰ Pb	c	21.5H	1514.9	*	514.9 ± 42.5
			1407.6	*	564.8 ± 54.8
			1362.9	*	537.5 ± 66.3
			1225.5	*	510.1 ± 37.7
			1205.7	*	521.0 ± 35.9
			886.2	*	471.6 ± 38.1
			828.3	*	490.9 ± 36.4
			701.6	*	442.7 ± 45.9
			579.3	*	461.5 ± 29.1
			525.5	0.42 ± 0.04	533.5 ± 58.2
			450.5	3.33 ± 0.08	578.0 ± 26.0
			367.9	*	492.3 ± 17.4
			268.4	3.96 ± 0.20	584.5 ± 37.4
			257.2	4.46 ± 0.17	609.4 ± 34.6
			235.6	4.30 ± 0.17	610.1 ± 36.2
			147.6	37.7 ± 1.4	565.9 ± 31.0
			142.3	3.16 ± 0.19	539.0 ± 39.3
				$RR_{mean} =$	506.4 ± 15.6
¹⁹⁹ Pb	c*	90M	1502.0	2.1 ± 0.4	1077 ± 221
			1382.7	2.9 ± 0.5	1063 ± 192
			1135.0	7.8 ± 1.2	858.3 ± 139.4

Continuation of Table 65.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1029.2	1.62 ± 0.25	901.5 ± 145.9
			781.5	1.9 ± 0.3	921.7 ± 152.4
			762.0	2.2 ± 0.4	955.3 ± 182.8
			720.2	6.5 ± 1.0	953.7 ± 156.4
			366.9	44 ± 7	1015 ± 169
			353.4	9.5 ± 1.5	1078 ± 179
			<i>RR_{mean}</i> =		949.9 ± 39.7
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	545.0 ± 112.8
			575.0	3.1 ± 0.7	561.8 ± 129.3
			365.4	19 ± 5	691.9 ± 183.7
			173.4	18 ± 3	676.8 ± 115.6
^{197m} Pb	c*	43M	<i>RR_{mean}</i> =		668.2 ± 27.7
			774.3	14 ± 3	277.9 ± 60.5
			695.6	9.5 ± 2.0	291.8 ± 68.4
			387.7	25 ± 6	327.9 ± 79.6
			385.9	74 ± 15	366.0 ± 75.3
			222.8	25 ± 6	255.9 ± 62.6
			<i>RR_{mean}</i> =		330.1 ± 24.0
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	211.0 ± 26.0
			253.1	27 ± 3	163.2 ± 19.4
			<i>RR_{mean}</i> =		180.1 ± 23.5
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	40.80 ± 10.33
			383.6	107 ± 20	27.48 ± 5.49
			<i>RR_{mean}</i> =		28.56 ± 3.74
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	101.7 ± 3.7
²⁰¹ Tl _c	c	72.912H	167.4	10.00 ± 0.06	710.6 ± 26.2
			135.3	2.57 ± 0.02	812.2 ± 38.3
			<i>RR_{mean}</i> =		729.6 ± 45.6
²⁰¹ Tl	c*	72.912H	135.3	2.56 ± 0.02	905.5 ± 38.4
			167.4	10.00 ± 0.06	804.7 ± 29.5
			<i>RR_{mean}</i> =		830.7 ± 51.0
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	167.9 ± 15.5
			1407.6	1.45 ± 0.13	199.0 ± 24.8
			1362.9	3.4 ± 0.4	148.9 ± 23.9
			1225.5	3.36 ± 0.21	140.9 ± 19.0
			1205.7	29.9 ± 1.8	119.8 ± 9.8
			886.2	2.02 ± 0.13	163.1 ± 29.9
			828.3	10.8 ± 0.7	178.2 ± 17.7
			701.6	1.29 ± 0.10	282.2 ± 53.2
			579.3	13.8 ± 0.7	210.0 ± 21.8
			367.9	87.2 ± 0.4	130.6 ± 15.9
			<i>RR_{mean}</i> =		149.7 ± 11.7
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	682.8 ± 56.2
			1407.6	1.45 ± 0.13	763.8 ± 73.6
			1362.9	3.4 ± 0.4	686.4 ± 84.4
			1225.5	3.36 ± 0.21	650.9 ± 47.0
			1205.7	29.9 ± 1.8	640.9 ± 44.1
			886.2	2.02 ± 0.13	634.8 ± 48.1
			828.3	10.8 ± 0.7	669.2 ± 49.2
			701.6	1.29 ± 0.10	724.9 ± 66.5
			579.3	13.8 ± 0.7	671.6 ± 42.5

Continuation of Table 65.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			367.9	87.2 ± 0.4	622.9 ± 23.6
			<i>RR_{mean}</i> =		641.6 ± 22.3
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	726.1 ± 85.9
			247.3	9.3 ± 1.1	747.1 ± 93.4
			208.2	12.3 ± 1.4	760.2 ± 92.0
			<i>RR_{mean}</i> =		742.6 ± 36.4
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	68.87 ± 3.75
			282.8	28 ± 3	73.66 ± 8.47
			<i>RR_{mean}</i> =		69.12 ± 2.77
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	459.9 ± 154.4
			152.2	7.3 ± 2.3	674.0 ± 214.0
			134.0	2.0 ± 0.7	580.2 ± 207.7
			<i>RR_{mean}</i> =		589.0 ± 71.9
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	95.39 ± 17.26
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	81.84 ± 10.71
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	6.085 ± 0.230
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	461.2 ± 26.1
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	23.12 ± 1.15
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	18.21 ± 2.14
			261.8	31 ± 4	22.60 ± 3.07
			779.8	54.2 ± 0.1	22.71 ± 4.84
			<i>RR_{mean}</i> =		20.14 ± 0.62
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	108.3 ± 12.1
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	4.235 ± 0.936
			407.6	32 ± 6	8.184 ± 1.636
			<i>RR_{mean}</i> =		5.213 ± 1.713
¹⁹² Hg	c	4.85H	316.5	*	8.320 ± 1.350
			274.8	50.2 ± 2.5	4.762 ± 0.910
			<i>RR_{mean}</i> =		5.881 ± 0.181
^{198m} Au	i(m)	2.27D	411.8	*	0.4887 ± 0.0887
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	1.266 ± 0.174
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	1.755 ± 0.108
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	2.320 ± 0.091
			333.0	22.9 ± 0.6	2.190 ± 0.281
			<i>RR_{mean}</i> =		2.315 ± 0.088
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	130.8 ± 11.1
			98.9	10.9 ± 0.9	111.8 ± 10.9
			<i>RR_{mean}</i> =		122.5 ± 10.2
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	2.303 ± 0.231
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	6.026 ± 1.694
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	14.35 ± 1.98
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	0.3013 ± 0.0624
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.8355 ± 0.0528
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.9407 ± 0.1084
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	0.6005 ± 0.0344
			197.3	87.0 ± 1.1	0.6629 ± 0.0497
			<i>RR_{mean}</i> =		0.6186 ± 0.0342
^{110m} Ag	i(m)	249.76D	657.8	94.3 ± 0.3	1.498 ± 0.105
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	14.49 ± 0.59
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	16.10 ± 0.66

Continuation of Table 65.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	4.901 ± 0.359
			849.9	20.45 ± 0.20	4.682 ± 0.604
			778.2	96.45 ± 0.22	4.860 ± 0.249
			460.0	26.62 ± 0.20	4.513 ± 0.362
			RR _{mean} =		
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	3.173 ± 0.123
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	14.71 ± 0.49
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	5.443 ± 0.448
⁹⁵ Zr	c	64.02D	765.8	*	11.64 ± 0.40
			756.7	54.46 ± 0.10	11.55 ± 0.44
			RR _{mean} =		
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	0.5742 ± 0.1726
⁸² Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	3.850 ± 0.476
			776.5	83.5 ± 1.2	3.342 ± 0.169
			554.3	70.8 ± 1.0	3.208 ± 0.152
			RR _{mean} =		

12.4.4 Nuclide production rates for ^{nat}Pb

Table 66: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.15 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	1063.7	74.5 ± 0.2	19.60 ± 5.05
			569.7	97.74 ± 0.03	16.97 ± 1.75
			RR _{mean} =		17.23 ± 1.67
²⁰⁶ Bi	i	6.243D	1878.7	2.01 ± 0.05	30.02 ± 1.69
			1718.7	31.8 ± 0.6	29.74 ± 1.21
			1595.3	5.01 ± 0.08	30.99 ± 1.50
			1098.3	13.50 ± 0.21	27.24 ± 1.04
			1018.6	7.60 ± 0.11	29.37 ± 1.10
			895.1	15.66 ± 0.23	29.14 ± 1.09
			881.0	66.2 ± 1.0	29.09 ± 1.05
			803.1	98.9 ± 1.4	28.15 ± 1.01
			632.2	4.47 ± 0.07	27.34 ± 1.18
			620.5	5.76 ± 0.09	26.57 ± 1.11
			537.5	30.5 ± 0.5	26.21 ± 1.00
			516.2	40.7 ± 0.6	27.26 ± 1.03
			497.1	15.31 ± 0.22	26.26 ± 1.09
			398.0	10.74 ± 0.15	26.76 ± 1.00
			343.5	23.4 ± 0.4	26.90 ± 1.02
262.7	3.02 ± 0.06	28.62 ± 1.92			
184.0	15.8 ± 0.4	31.14 ± 1.40			
RR _{mean} =		27.91 ± 0.92			
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	51.13 ± 2.04
			1775.8	3.99 ± 0.08	52.03 ± 2.26
			1764.3	32.5 ± 0.7	51.56 ± 2.12
			1614.3	2.28 ± 0.04	51.93 ± 2.19
			1190.0	2.26 ± 0.07	50.77 ± 2.54

Continuation of Table 66.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1043.8	7.51 ± 0.10	46.12 ± 1.74
			987.7	16.13 ± 0.17	50.53 ± 1.80
			759.1	1.04 ± 0.05	50.82 ± 3.63
			703.5	31.1 ± 0.1	47.44 ± 1.60
			579.8	5.44 ± 0.07	45.47 ± 1.83
			573.8	0.62 ± 0.01	50.75 ± 3.81
			570.6	4.34 ± 0.07	46.01 ± 1.79
			284.1	1.69 ± 0.02	47.65 ± 2.01
			<i>RR_{mean}</i> =		48.47 ± 1.63
²⁰⁴ Bi	i	11.22H	1211.7	3.0 ± 0.4	43.34 ± 6.17
			984.0	59 ± 4	49.46 ± 3.75
			918.3	10.8 ± 0.9	56.95 ± 5.24
			899.2	98 ± 9	47.97 ± 1.61
			670.7	11.4 ± 0.9	52.03 ± 4.50
			374.8	82 ± 5	56.23 ± 11.74
			<i>RR_{mean}</i> =		48.16 ± 1.49
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	60.53 ± 5.00
			1847.3	11.4 ± 0.8	59.83 ± 4.76
			1679.6	8.8 ± 0.7	60.86 ± 5.34
			1536.5	7.5 ± 0.6	64.44 ± 5.69
			1506.7	3.7 ± 0.3	52.82 ± 4.98
			1034.0	8.8 ± 0.5	60.04 ± 4.02
			896.8	13.1 ± 0.7	63.30 ± 4.01
			847.2	8.5 ± 0.5	63.91 ± 4.44
			820.2	29.6 ± 1.5	64.08 ± 3.90
			816.3	4.03 ± 0.21	63.10 ± 4.09
			722.4	4.8 ± 0.4	65.00 ± 6.02
			264.2	5.2 ± 0.4	64.76 ± 5.62
			186.6	3.11 ± 0.22	58.50 ± 8.84
			<i>RR_{mean}</i> =		62.92 ± 2.03
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	63.22 ± 2.32
			422.1	83.7 ± 2.5	62.50 ± 3.13
			<i>RR_{mean}</i> =		63.07 ± 2.25
²⁰¹ Bi	i	108M	629.1	24 ± 6	66.39 ± 16.83
			1325.2	6.1 ± 1.3	64.81 ± 14.42
			<i>RR_{mean}</i> =		65.13 ± 4.63
¹⁹⁹ Bi	i	27M	946.0	10.8 ± 0.6	44.09 ± 9.73
			841.7	11 ± 0	50.60 ± 3.85
			837.4	9.5 ± 0.6	61.53 ± 6.09
			<i>RR_{mean}</i> =		52.71 ± 4.12
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	48.05 ± 1.75
			374.7	89 ± 15	59.57 ± 10.29
			<i>RR_{mean}</i> =		48.15 ± 1.82
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	55.24 ± 1.96
			374.7	89 ± 15	66.63 ± 11.50
			<i>RR_{mean}</i> =		55.32 ± 1.96
²⁰³ Pb	c*	51.873H	680.5	0.75 ± 0.02	230.8 ± 10.5
			279.2	80.8 ± 0.2	216.6 ± 7.9
			401.3	3.35 ± 0.07	212.4 ± 8.6
			<i>RR_{mean}</i> =		217.5 ± 8.0
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	52.66 ± 4.95

Continuation of Table 66.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			490.5	9.1 ± 0.7	57.78 ± 5.08
			459.7	8.6 ± 0.7	51.88 ± 4.85
			422.1	86 ± 5	56.91 ± 3.94
			<i>RR_{mean}</i> =		55.68 ± 2.23
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	230.8 ± 19.9
			1238.8	1.18 ± 0.08	195.4 ± 15.7
			1098.5	1.83 ± 0.12	191.3 ± 15.2
			1069.9	1.14 ± 0.11	239.3 ± 25.5
			946.0	7.4 ± 0.6	201.1 ± 17.7
			907.6	5.7 ± 0.4	206.7 ± 16.1
			767.3	3.16 ± 0.16	214.9 ± 13.5
			692.4	4.27 ± 0.16	213.0 ± 10.9
			584.5	3.56 ± 0.16	261.7 ± 15.0
			361.3	9.9 ± 0.5	227.7 ± 13.9
			331.2	79 ± 5	231.2 ± 16.6
			167.4	*	231.3 ± 21.1
			135.3	*	283.9 ± 41.9
			<i>RR_{mean}</i> =		220.3 ± 6.8
²⁰⁰ Pb	c	21.5H	886.2	*	173.0 ± 12.9
			701.6	*	169.9 ± 16.7
			268.4	3.96 ± 0.20	215.9 ± 13.8
			1514.9	*	193.9 ± 16.1
			1407.6	*	199.7 ± 20.3
			1362.9	*	195.5 ± 24.0
			1225.5	*	186.5 ± 13.6
			1205.7	*	192.6 ± 13.3
			828.3	*	178.6 ± 13.1
			579.3	*	171.2 ± 10.6
			525.5	0.42 ± 0.04	211.0 ± 28.0
			450.5	3.33 ± 0.08	233.1 ± 10.0
			367.9	*	179.3 ± 6.3
			235.6	4.30 ± 0.17	202.9 ± 11.6
			147.6	37.7 ± 1.4	211.4 ± 11.1
			142.3	3.16 ± 0.19	210.9 ± 15.3
			<i>RR_{mean}</i> =		184.4 ± 5.7
¹⁹⁹ Pb	c*	90M	1502.0	2.1 ± 0.4	293.3 ± 59.2
			1382.7	2.9 ± 0.5	344.5 ± 62.7
			1135.0	7.8 ± 1.2	326.9 ± 52.3
			1029.2	1.62 ± 0.25	312.9 ± 51.3
			781.5	1.9 ± 0.3	278.9 ± 47.9
			762.0	2.2 ± 0.4	388.8 ± 73.7
			720.2	6.5 ± 1.0	318.9 ± 52.0
			366.9	44 ± 7	374.2 ± 61.2
			353.4	9.5 ± 1.5	424.4 ± 70.1
			<i>RR_{mean}</i> =		331.9 ± 17.4
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	263.7 ± 45.0
			865.3	5.9 ± 1.2	203.9 ± 42.3
			575.0	3.1 ± 0.7	211.7 ± 48.5
			365.4	19 ± 5	267.9 ± 71.1
			<i>RR_{mean}</i> =		259.7 ± 11.7
^{197m} Pb	c*	43M	385.9	74 ± 15	158.0 ± 32.5

Continuation of Table 66.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			774.3	14 ± 3	104.3 ± 23.3
			695.6	9.5 ± 2.0	110.7 ± 25.1
			387.7	25 ± 6	138.8 ± 33.7
			222.8	25 ± 6	105.9 ± 25.8
			<i>RR_{mean}</i> =		135.7 ± 13.1
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	106.1 ± 12.9
			253.1	27 ± 3	92.68 ± 11.00
			<i>RR_{mean}</i> =		98.27 ± 7.72
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	28.37 ± 5.52
			394.2	44 ± 8	36.65 ± 7.48
			<i>RR_{mean}</i> =		30.30 ± 3.62
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	35.87 ± 1.32
²⁰¹ Tl _c	c	72.912H	167.4	10.00 ± 0.06	256.8 ± 9.8
			135.3	2.57 ± 0.02	282.1 ± 12.6
			<i>RR_{mean}</i> =		263.8 ± 13.9
²⁰¹ Tl	c*	72.912H	135.3	2.56 ± 0.02	326.6 ± 13.2
			167.4	10.00 ± 0.06	291.9 ± 10.7
			<i>RR_{mean}</i> =		302.2 ± 18.4
²⁰⁰ Tl _i	i	26.1H	701.6	1.29 ± 0.10	78.57 ± 15.10
			1407.6	1.45 ± 0.13	78.81 ± 13.25
			1205.7	29.9 ± 1.8	39.83 ± 3.91
			1514.9	4.0 ± 0.3	45.23 ± 5.32
			1362.9	3.4 ± 0.4	56.57 ± 7.70
			1225.5	3.36 ± 0.21	49.80 ± 6.02
			886.2	2.02 ± 0.13	57.05 ± 6.47
			828.3	10.8 ± 0.7	64.71 ± 5.66
			579.3	13.8 ± 0.7	68.36 ± 5.78
			367.9	87.2 ± 0.4	56.81 ± 5.29
			<i>RR_{mean}</i> =		53.63 ± 4.00
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	232.5 ± 16.1
			1514.9	4.0 ± 0.3	239.2 ± 19.8
			1407.6	1.45 ± 0.13	278.5 ± 27.3
			1362.9	3.4 ± 0.4	252.1 ± 30.9
			1225.5	3.36 ± 0.21	236.3 ± 16.9
			886.2	2.02 ± 0.13	230.1 ± 16.8
			828.3	10.8 ± 0.7	243.3 ± 17.8
			701.6	1.29 ± 0.10	248.5 ± 22.1
			579.3	13.8 ± 0.7	239.6 ± 14.8
			367.9	87.2 ± 0.4	236.1 ± 8.6
			<i>RR_{mean}</i> =		237.6 ± 8.1
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	279.6 ± 33.1
			247.3	9.3 ± 1.1	286.0 ± 35.7
			208.2	12.3 ± 1.4	282.0 ± 34.0
			<i>RR_{mean}</i> =		282.1 ± 13.8
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	28.87 ± 1.57
			282.8	28 ± 3	29.30 ± 3.36
			<i>RR_{mean}</i> =		28.90 ± 1.16
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	177.0 ± 59.6
			134.0	2.0 ± 0.7	259.9 ± 92.1
			152.2	7.3 ± 2.3	283.3 ± 89.9

Continuation of Table 66.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	241.0 $\pm$ 36.2
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	42.20 $\pm$ 7.42
^{195}Tl	c*	1.16H	884.5	10.0 ± 1.1	57.43 $\pm$ 6.91
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	1.662 $\pm$ 0.151
^{197}Hg	c*	64.14H	191.4	0.63 ± 0.02	189.5 $\pm$ 10.7
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	7.153 $\pm$ 0.325
^{195m}Hg	i(m)	41.6H	261.8	31 ± 4	9.156 ± 1.245
			560.3	7.0 ± 0.6	8.827 ± 0.856
			779.8	54.2 ± 0.1	9.032 ± 2.040
				$RR_{mean} =$	8.911 $\pm$ 0.275
$^{195}\text{Hg}_c$	c	9.9H	779.8	6.8 ± 0.7	72.33 $\pm$ 7.88
^{193m}Hg	i(m)	11.8H	573.2	26 ± 4	3.616 ± 0.589
			407.6	32 ± 6	4.715 ± 0.915
				$RR_{mean} =$	3.935 $\pm$ 0.513
^{192}Hg	c	4.85H	316.5	*	12.02 ± 1.51
			274.8	50.2 ± 2.5	9.359 ± 0.640
				$RR_{mean} =$	9.709 $\pm$ 0.300
^{198m}Au	i(m)	2.27D	411.8	*	0.1131 $\pm$ 0.0180
$^{198}\text{Au}_i$	i	2.69517D	411.8	95.58 ± 0.12	0.4485 $\pm$ 0.0331
$^{198}\text{Au}_c$	i(m+g)	2.69517D	411.8	95.58 ± 0.12	0.5616 $\pm$ 0.0235
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	0.7995 ± 0.0320
			333.0	22.9 ± 0.6	0.7227 ± 0.0632
				$RR_{mean} =$	0.7923 $\pm$ 0.0332
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	71.63 ± 6.81
			129.8	0.82 ± 0.05	83.14 ± 7.65
				$RR_{mean} =$	76.87 $\pm$ 6.20
^{194}Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	1.142 $\pm$ 0.109
$^{192}\text{Au}_i$	i(m+g)	4.94H	316.5	58 ± 7	1.239 $\pm$ 0.266
$^{192}\text{Au}_c$	c	4.94H	316.5	58 ± 7	13.26 $\pm$ 1.67
^{127}Xe	c	36.4D	202.9	68.3 ± 0.5	0.1421 $\pm$ 0.0207
^{124}Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.2634 $\pm$ 0.0326
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.5332 $\pm$ 0.0354
^{120m}Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	0.2800 ± 0.0259
			1171.7	100 ± 0	0.3409 ± 0.0490
			197.3	87.0 ± 1.1	0.3641 ± 0.0249
				$RR_{mean} =$	0.3275 $\pm$ 0.0299
^{110m}Ag	i(m)	249.76D	657.8	94.3 ± 0.3	0.8732 $\pm$ 0.1035
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	6.050 $\pm$ 0.258
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	6.473 $\pm$ 0.256
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	2.656 ± 0.155
			849.9	20.45 ± 0.20	2.631 ± 0.196
			778.2	96.45 ± 0.22	2.417 ± 0.096
			460.0	26.62 ± 0.20	2.483 ± 0.151
				$RR_{mean} =$	2.476 $\pm$ 0.093
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	1.698 $\pm$ 0.083
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	6.441 $\pm$ 0.232
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	1.943 $\pm$ 0.089
^{95}Zr	c	64.02D	765.8	*	4.786 ± 0.202
			756.7	54.46 ± 0.10	4.460 ± 0.195
				$RR_{mean} =$	4.624 $\pm$ 0.143

Continuation of Table 66.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	0.2552 ± 0.1119
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	1.764 ± 0.120
			776.5	83.5 ± 1.2	1.581 ± 0.071
			554.3	70.8 ± 1.0	1.535 ± 0.076
			$RR_{mean} =$		1.584 ± 0.068

12.4.5 Nuclide production rates for ^{209}Bi

Table 67: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.15 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	107.3 ± 4.1
			742.6	28.2 ± 0.5	111.4 ± 5.7
			$RR_{mean} =$		108.1 ± 3.9
^{206}Po	i	8.8D	1878.7	*	140.3 ± 10.1
			1718.7	*	136.9 ± 5.6
			1595.3	*	147.0 ± 7.3
			1098.3	*	126.2 ± 5.4
			1032.3	33 ± 5	128.5 ± 19.9
			1018.6	*	133.9 ± 5.7
			1007.2	3.1 ± 0.4	119.7 ± 16.2
			980.2	7.1 ± 0.9	130.8 ± 17.1
			895.1	*	133.9 ± 5.4
			881.0	*	130.7 ± 4.9
			807.4	23 ± 3	111.8 ± 15.1
			803.1	*	129.0 ± 4.7
			677.7	1.47 ± 0.20	149.0 ± 21.1
			632.2	*	123.5 ± 7.0
			620.5	*	116.5 ± 5.0
			554.6	1.56 ± 0.21	115.6 ± 16.6
			537.5	*	118.3 ± 5.1
			522.5	15.7 ± 2.0	120.6 ± 15.9
			516.2	*	123.6 ± 5.5
			497.1	*	117.8 ± 4.7
			463.4	1.79 ± 0.24	125.4 ± 17.8
			398.0	*	121.9 ± 6.1
			343.5	*	122.8 ± 5.2
			338.4	19.2 ± 2.5	128.1 ± 17.2
			311.6	4.2 ± 0.6	120.7 ± 18.1
			286.4	24 ± 3	130.2 ± 16.9
			184.0	*	143.1 ± 7.1
			$RR_{mean} =$		127.1 ± 3.9
^{205}Po	i	1.66H	1001.2	28.8 ± 2.2	135.9 ± 11.9
			872.4	37 ± 2	147.8 ± 9.5
			849.8	25.5 ± 2.1	135.5 ± 12.6
			$RR_{mean} =$		146.3 ± 5.3
^{204}Po	i	3.53H	1211.7	*	89.82 ± 86.42
			1040.0	9.6 ± 0.5	154.6 ± 11.8

Continuation of Table 67.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1016.3	24.1 ± 1.0	156.9 ± 8.6
			984.0	*	112.6 ± 9.3
			918.3	*	173.3 ± 23.2
			899.2	*	146.1 ± 17.1
			884.0	29.9 ± 1.2	166.9 ± 8.9
			670.7	*	123.3 ± 20.8
			534.9	13.2 ± 0.8	148.7 ± 11.9
			374.8	*	174.0 ± 15.9
			270.1	27.8 ± 1.3	163.8 ± 10.1
			137.0	9.7 ± 0.4	169.1 ± 12.5
			<i>RR_{mean}</i> =		155.6 ± 4.8
²⁰³ Po	i(m+g)	36.7M	908.6	55 ± 3	127.2 ± 9.2
²⁰² Po	i	44.7M	960.7	*	97.69 ± 10.34
			688.6	51 ± 6	145.1 ± 17.9
			422.1	*	95.05 ± 7.99
			316.0	14.3 ± 1.8	127.3 ± 17.3
			<i>RR_{mean}</i> =		100.8 ± 3.1
²⁰¹ Po	i(m+g)	15.3M	890.1	91 ± 4	26.22 ± 4.01
²⁰⁷ Bi	c	31.55Y	1770.2	6.87 ± 0.04	469.1 ± 29.4
			1063.7	74.5 ± 0.2	437.4 ± 17.5
			569.7	97.74 ± 0.03	415.0 ± 15.4
			<i>RR_{mean}</i> =		426.3 ± 17.1
²⁰⁶ Bi _i	i	6.243D	1878.7	2.01 ± 0.05	280.2 ± 14.5
			1718.7	31.8 ± 0.6	276.7 ± 10.9
			1595.3	5.01 ± 0.08	291.7 ± 11.9
			1098.3	13.50 ± 0.21	256.7 ± 9.9
			1018.6	7.60 ± 0.11	280.1 ± 10.7
			895.1	15.66 ± 0.23	275.8 ± 10.2
			881.0	66.2 ± 1.0	273.8 ± 9.9
			803.1	98.9 ± 1.4	256.7 ± 9.2
			632.2	4.47 ± 0.07	258.9 ± 10.8
			620.5	5.76 ± 0.09	255.4 ± 9.8
			537.5	30.5 ± 0.5	238.5 ± 9.4
			516.2	40.7 ± 0.6	249.1 ± 9.9
			497.1	15.31 ± 0.22	242.8 ± 9.1
			398.0	10.74 ± 0.15	241.2 ± 9.9
			343.5	23.4 ± 0.4	249.1 ± 9.7
			184.0	15.8 ± 0.4	295.2 ± 13.9
			<i>RR_{mean}</i> =		260.4 ± 9.0
²⁰⁶ Bi _c	c	6.243D	1878.7	2.01 ± 0.05	412.8 ± 18.4
			1718.7	31.8 ± 0.6	406.1 ± 15.8
			1595.3	5.01 ± 0.08	430.6 ± 16.2
			1098.3	13.50 ± 0.21	375.9 ± 13.8
			1018.6	7.60 ± 0.11	406.6 ± 14.7
			895.1	15.66 ± 0.23	402.4 ± 14.4
			881.0	66.2 ± 1.0	397.4 ± 14.3
			803.1	98.9 ± 1.4	378.6 ± 13.5
			632.2	4.47 ± 0.07	375.6 ± 14.1
			620.5	5.76 ± 0.09	365.5 ± 13.6
			537.5	30.5 ± 0.5	350.4 ± 13.3
			516.2	40.7 ± 0.6	365.9 ± 13.7

Continuation of Table 67.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			497.1	15.31 ± 0.22	354.1 ± 13.1
			398.0	10.74 ± 0.15	356.4 ± 13.2
			343.5	23.4 ± 0.4	365.1 ± 13.8
			184.0	15.8 ± 0.4	430.4 ± 19.8
			<i>RR_{mean}</i> =		380.6 ± 13.2
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	481.1 ± 18.6
			1775.8	3.99 ± 0.08	491.0 ± 19.7
			1764.3	32.5 ± 0.7	492.6 ± 19.9
			1619.1	0.37 ± 0.02	506.1 ± 33.1
			1614.3	2.28 ± 0.04	516.0 ± 19.8
			1551.0	0.97 ± 0.03	492.5 ± 25.2
			1351.5	1.06 ± 0.04	489.7 ± 25.7
			1190.0	2.26 ± 0.07	505.3 ± 23.3
			1043.8	7.51 ± 0.10	447.6 ± 16.1
			987.7	16.13 ± 0.17	480.1 ± 16.5
			890.2	0.68 ± 0.01	510.8 ± 21.2
			759.1	1.04 ± 0.05	494.4 ± 29.1
			744.7	0.70 ± 0.02	443.2 ± 18.8
			703.5	31.1 ± 0.1	448.6 ± 15.0
			260.5	1.09 ± 0.04	450.3 ± 24.3
			<i>RR_{mean}</i> =		471.2 ± 15.9
²⁰⁴ Bi _i	i	11.22H	1211.7	3.0 ± 0.4	326.4 ± 124.2
			984.0	59 ± 4	322.9 ± 24.7
			918.3	10.8 ± 0.9	309.6 ± 35.7
			899.2	98 ± 9	328.9 ± 34.1
			670.7	11.4 ± 0.9	337.2 ± 36.8
			374.8	82 ± 5	296.6 ± 24.2
			<i>RR_{mean}</i> =		315.7 ± 15.2
²⁰⁴ Bi _c	c	11.22H	1211.7	3.0 ± 0.4	415.7 ± 65.7
			984.0	59 ± 4	434.7 ± 32.7
			918.3	10.8 ± 0.9	481.8 ± 43.5
			899.2	98 ± 9	474.0 ± 46.3
			670.7	11.4 ± 0.9	459.7 ± 39.9
			374.8	82 ± 5	469.5 ± 32.9
			<i>RR_{mean}</i> =		458.2 ± 20.1
²⁰³ Bi	c	11.76H	2011.0	1.76 ± 0.09	486.3 ± 32.4
			1983.0	0.88 ± 0.05	486.0 ± 39.4
			1893.0	8.2 ± 0.6	478.6 ± 39.2
			1888.0	1.94 ± 0.10	465.7 ± 31.3
			1847.3	11.4 ± 0.8	466.5 ± 36.8
			1679.6	8.8 ± 0.7	458.2 ± 39.9
			1536.5	7.5 ± 0.6	500.6 ± 43.8
			1506.7	3.7 ± 0.3	456.1 ± 40.6
			1034.0	8.8 ± 0.5	450.7 ± 30.8
			896.8	13.1 ± 0.7	461.6 ± 29.4
			847.2	8.5 ± 0.5	504.3 ± 34.2
			825.2	14.6 ± 1.1	520.0 ± 43.2
			820.2	29.6 ± 1.5	501.8 ± 30.4
			816.3	4.03 ± 0.21	492.0 ± 31.1
			722.4	4.8 ± 0.4	518.3 ± 47.1
			401.3	*	428.9 ± 80.9

Continuation of Table 67.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			279.2	*	490.5 ± 19.8
			264.2	5.2 ± 0.4	508.2 ± 44.1
			<i>RR_{mean}</i> =		488.6 ± 15.1
²⁰² Bi _i	i	1.72H	960.7	99.28 ± 0.02	363.0 ± 16.9
			422.1	83.7 ± 2.5	370.6 ± 18.2
			<i>RR_{mean}</i> =		366.4 ± 14.7
²⁰² Bi _c	c	1.72H	960.7	99.28 ± 0.02	458.7 ± 15.4
			657.5	60.6 ± 1.8	472.1 ± 22.7
			422.1	83.7 ± 2.5	463.8 ± 21.1
			<i>RR_{mean}</i> =		460.6 ± 15.2
²⁰¹ Bi	c*	108M	1650.9	5.8 ± 1.3	345.6 ± 79.0
			1325.2	6.1 ± 1.3	396.0 ± 86.7
			1014.1	10.7 ± 2.3	396.2 ± 86.4
			936.2	11.3 ± 2.5	424.9 ± 95.9
			902.0	8.4 ± 1.8	373.4 ± 82.3
			629.1	24 ± 6	395.0 ± 99.7
			<i>RR_{mean}</i> =		387.3 ± 16.5
¹⁹⁹ Bi	c*	27M	841.7	11 ± 0	182.7 ± 13.5
^{204m} Pb	i(m)	67.2M	899.2	99.17 ± 0.02	33.25 ± 3.17
			374.7	89 ± 15	53.48 ± 9.69
			<i>RR_{mean}</i> =		35.06 ± 5.88
²⁰³ Pb _i	i(m1+m2+g)	51.873H	401.3	3.35 ± 0.07	170.4 ± 99.6
			279.2	80.8 ± 0.2	101.0 ± 11.2
			<i>RR_{mean}</i> =		101.8 ± 11.1
²⁰³ Pb _c	c	51.873H	401.3	3.35 ± 0.07	599.3 ± 31.7
			279.2	80.8 ± 0.2	591.5 ± 21.8
			<i>RR_{mean}</i> =		592.9 ± 21.2
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	52.31 ± 5.43
			422.1	86 ± 5	51.07 ± 4.80
			<i>RR_{mean}</i> =		51.58 ± 3.24
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	608.0 ± 55.2
			1238.8	1.18 ± 0.08	640.7 ± 53.9
			767.3	3.16 ± 0.16	657.5 ± 42.4
			692.4	4.27 ± 0.16	586.5 ± 30.9
			361.3	9.9 ± 0.5	652.8 ± 40.0
			331.2	79 ± 5	677.6 ± 49.1
			<i>RR_{mean}</i> =		627.5 ± 24.8
²⁰⁰ Pb	c	21.5H	450.5	3.33 ± 0.08	510.8 ± 22.6
			268.4	3.96 ± 0.20	527.8 ± 34.5
			257.2	4.46 ± 0.17	526.3 ± 30.4
			235.6	4.30 ± 0.17	551.6 ± 31.4
			147.6	37.7 ± 1.4	486.0 ± 30.0
			142.3	3.16 ± 0.19	494.3 ± 39.8
			<i>RR_{mean}</i> =		515.1 ± 17.7
¹⁹⁹ Pb	c*	90M	1382.7	2.9 ± 0.5	804.4 ± 155.6
			1135.0	7.8 ± 1.2	722.6 ± 118.0
			720.2	6.5 ± 1.0	582.4 ± 99.8
			366.9	44 ± 7	775.3 ± 133.0
			353.4	9.5 ± 1.5	829.4 ± 138.7
			<i>RR_{mean}</i> =		715.1 ± 51.6
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	275.7 ± 58.2

Continuation of Table 67.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			575.0	3.1 ± 0.7	288.8 ± 67.4
			365.4	19 ± 5	358.3 ± 95.3
			259.5	5.8 ± 1.2	321.4 ± 68.2
			173.4	18 ± 3	351.8 ± 60.3
			$RR_{mean} =$		344.0 ± 15.0
^{197m}Pb	c*	43M	387.7	25 ± 6	111.8 ± 27.2
			385.9	74 ± 15	129.3 ± 26.6
			$RR_{mean} =$		127.6 ± 6.4
^{196}Pb	c*	37M	253.1	27 ± 3	74.12 ± 9.27
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	15.20 ± 0.56
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	680.5 ± 26.2
$^{200}\text{Tl}_i$	i	26.1H	579.3	13.8 ± 0.7	99.82 ± 24.46
			367.9	87.2 ± 0.4	91.44 ± 18.79
			1205.7	29.9 ± 1.8	41.12 ± 11.00
			$RR_{mean} =$		60.04 ± 18.24
$^{200}\text{Tl}_c$	c	26.1H	1604.5	1.17 ± 0.10	447.8 ± 41.9
			1514.9	4.0 ± 0.3	483.5 ± 40.0
			1366.3	0.9 ± 0.3	468.5 ± 158.0
			1362.9	3.4 ± 0.4	499.3 ± 61.8
			1225.5	3.36 ± 0.21	559.4 ± 43.3
			1205.7	29.9 ± 1.8	479.1 ± 33.7
			886.2	2.02 ± 0.13	481.8 ± 40.2
			579.3	13.8 ± 0.7	504.8 ± 33.5
			367.9	87.2 ± 0.4	484.4 ± 21.2
			$RR_{mean} =$		488.8 ± 18.1
^{199}Tl	c*	7.42H	455.5	12.4 ± 1.4	475.6 ± 56.6
			247.3	9.3 ± 1.1	491.1 ± 61.6
			208.2	12.3 ± 1.4	491.7 ± 59.5
			158.4	5.0 ± 0.6	506.7 ± 64.6
			$RR_{mean} =$		489.1 ± 22.6
^{198m}Tl	i(m)	1.87H	587.2	52.5 ± 2.0	19.34 ± 1.49
^{197}Tl	c*	2.84H	152.2	7.3 ± 2.3	266.0 ± 84.6
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	47.18 ± 8.75
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	0.2762 ± 0.0802
^{197}Hg	c*	64.14H	191.4	0.63 ± 0.02	167.1 ± 11.4
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	8.110 ± 0.696
^{195}Au	c	186.098D	129.8	0.82 ± 0.05	91.79 ± 13.33
			98.9	10.9 ± 0.9	89.27 ± 9.99
			$RR_{mean} =$		90.08 ± 7.35
^{139}Ce	c	137.640D	165.9	79.89 ± 0.01	0.3654 ± 0.0358
^{127}Xe	c	36.4D	202.9	68.3 ± 0.5	0.9949 ± 0.0639
^{126}I	i	13.11D	666.3	33.1 ± 2.5	2.852 ± 0.314
			388.6	34 ± 3	1.865 ± 0.274
			$RR_{mean} =$		2.386 ± 0.498
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.143 ± 0.098
^{121m}Te	i(m)	154D	212.2	81.4 ± 1.1	0.9990 ± 0.0718
^{124}Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	1.274 ± 0.069
^{122}Sb	i(m+g)	2.7238D	564.2	70.67 ± 0.18	2.838 ± 0.149
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	2.545 ± 0.110
			197.3	87.0 ± 1.1	2.441 ± 0.126

Continuation of Table 67.					
Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	2.507 $\pm$ 0.099
^{117m}Sn	i(m)	13.60D	158.6	86.4 ± 0.4	3.394 $\pm$ 0.163
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	2.780 $\pm$ 0.389
^{115}Cd	c	53.46H	527.9	27.4 ± 0.6	4.324 ± 0.287
			336.2	45.9 ± 1.0	4.425 ± 0.296
				$RR_{mean} =$	4.373 $\pm$ 0.218
^{110m}Ag	i(m)	249.76D	1384.3	24.9 ± 0.8	6.144 ± 0.823
			937.5	34.2 ± 0.6	4.695 ± 0.388
			884.7	72.7 ± 0.4	5.110 ± 0.201
			657.8	94.3 ± 0.3	5.374 ± 0.202
				$RR_{mean} =$	5.233 $\pm$ 0.198
^{107}Rh	c	21.7M	302.8	66 ± 6	36.22 $\pm$ 4.22
^{105}Rh	c	35.36H	318.9	19.1 ± 0.6	31.55 ± 1.68
			306.1	5.1 ± 0.4	36.58 ± 3.42
				$RR_{mean} =$	32.19 $\pm$ 1.95
^{106}Ru	c	373.59D	621.9(D)	9.93 ± 0.23	9.604 $\pm$ 1.885
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	29.74 $\pm$ 1.12
^{99}Mo	c	65.94H	739.5	12.13 ± 0.22	26.25 ± 1.14
			181.1	5.99 ± 0.12	29.05 ± 1.49
			140.5	90.27 ± 0.33	30.18 ± 1.59
				$RR_{mean} =$	27.77 $\pm$ 1.47
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	11.01 ± 0.65
			778.2	96.45 ± 0.22	11.92 ± 0.49
			460.0	26.62 ± 0.20	11.96 ± 0.63
				$RR_{mean} =$	11.75 $\pm$ 0.45
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	8.908 $\pm$ 0.325
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	29.54 $\pm$ 0.98
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	8.295 $\pm$ 0.515
^{95}Zr	c	64.02D	765.8	*	20.82 ± 0.71
			756.7	54.46 ± 0.10	19.60 ± 0.71
			724.2	44.17 ± 0.16	20.80 ± 0.75
				$RR_{mean} =$	20.69 $\pm$ 0.64
$^{88}\text{Y}_c$	c	106.65D	898.0	93.7 ± 0.3	1.222 $\pm$ 0.073
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	8.862 $\pm$ 0.503
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	1.873 $\pm$ 0.382
^{83}Rb	c	86.2D	520.4	45 ± 4	0.7999 $\pm$ 0.2966
^{82}Br	i(m+g)	35.30H	776.5	83.5 ± 1.2	6.965 ± 0.317
			554.3	70.8 ± 1.0	5.980 ± 0.383
				$RR_{mean} =$	6.657 $\pm$ 0.501

12.4.6 Nuclide production rates for ^{27}Al

Table 68: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.15$ GeV, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					

Continuation of Table 68.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^7Be	i	53.29D	477.6	10.52 ± 0.06	5.520 ± 0.239
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.5949 ± 0.0381
			1014.4	28.0 ± 0.4	0.7315 ± 0.1020
$RR_{mean} =$			0.6087 ± 0.0453		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	72.67 ± 2.59
^{24}Na	c	14.9590H	1369.0	100 ± 0	47.19 ± 1.57
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.708 ± 0.058
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	4.444 ± 0.173
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.5137 ± 0.0423
			1014.4	28.0 ± 0.4	0.6629 ± 0.1040
$RR_{mean} =$			0.5329 ± 0.0526		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	60.58 ± 2.10
^{24}Na	c	14.9590H	1369.0	100 ± 0	38.95 ± 1.30
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.779 ± 0.061
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	5.238 ± 0.202
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.6326 ± 0.0382
			1014.4	28.0 ± 0.4	0.6038 ± 0.0808
$RR_{mean} =$			0.6283 ± 0.0360		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	72.41 ± 2.54
^{24}Na	c	14.9590H	1369.0	100 ± 0	46.73 ± 1.55
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.607 ± 0.055
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	1.991 ± 0.077
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.2113 ± 0.0196
			1014.4	28.0 ± 0.4	0.2058 ± 0.0816
$RR_{mean} =$			0.2110 ± 0.0192		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	27.07 ± 0.94
^{24}Na	c	14.9590H	1369.0	100 ± 0	17.47 ± 0.58
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.8073 ± 0.0270
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	4.573 ± 0.173
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.7536 ± 0.0450
			1014.4	28.0 ± 0.4	0.7470 ± 0.1172
$RR_{mean} =$			0.7529 ± 0.0433		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	62.79 ± 2.11
^{24}Na	c	14.9590H	1369.0	100 ± 0	40.25 ± 1.35
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.507 ± 0.052

12.5 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.25$ GeV

12.5.1 Nuclide production rates for ^{206}Pb

Table 69: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.25$ GeV, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	19.27 ± 0.81
			1098.3	13.50 ± 0.21	16.81 ± 1.86
			895.1	15.66 ± 0.23	20.47 ± 0.87
			881.0	66.2 ± 1.0	17.43 ± 0.67
			803.1	98.9 ± 1.4	16.99 ± 0.62
			620.5	5.76 ± 0.09	18.03 ± 1.07
			537.5	30.5 ± 0.5	15.74 ± 0.66
			516.2	40.7 ± 0.6	16.46 ± 0.62
			497.1	15.31 ± 0.22	18.87 ± 0.90
			398.0	10.74 ± 0.15	15.89 ± 0.68
			343.5	23.4 ± 0.4	16.26 ± 0.67
			184.0	15.8 ± 0.4	21.71 ± 1.04
			$RR_{mean} =$		17.27 ± 0.70
^{205}Bi	i	15.31D	579.8	5.44 ± 0.07	54.78 ± 3.41
			1861.7	6.17 ± 0.10	64.67 ± 3.38
			1775.8	3.99 ± 0.08	63.40 ± 4.09
			1764.3	32.5 ± 0.7	59.87 ± 2.48
			1614.3	2.28 ± 0.04	58.66 ± 3.19
			1190.0	2.26 ± 0.07	64.76 ± 4.35
			1043.8	7.51 ± 0.10	56.62 ± 2.29
			987.7	16.13 ± 0.17	64.52 ± 2.93
			759.1	1.04 ± 0.05	60.17 ± 4.84
			703.5	31.1 ± 0.1	55.88 ± 1.90
			570.6	4.34 ± 0.07	50.80 ± 2.85
			549.8	2.95 ± 0.04	51.28 ± 2.48
			284.1	1.69 ± 0.02	58.82 ± 6.02
			$RR_{mean} =$		57.06 ± 2.05
^{204}Bi	i	11.22H	984.0	59 ± 4	83.15 ± 6.31
			918.3	10.8 ± 0.9	90.26 ± 8.56
			899.2	98 ± 9	78.54 ± 2.72
			670.7	11.4 ± 0.9	81.64 ± 7.44
			374.8	82 ± 5	86.51 ± 18.17
			$RR_{mean} =$		79.03 ± 2.44
^{203}Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	103.8 ± 9.1
			1847.3	11.4 ± 0.8	105.4 ± 8.8
			1679.6	8.8 ± 0.7	101.6 ± 9.1
			1034.0	8.8 ± 0.5	102.9 ± 7.8
			896.8	13.1 ± 0.7	107.3 ± 7.1
			847.2	8.5 ± 0.5	115.2 ± 8.3
			820.2	29.6 ± 1.5	111.7 ± 6.9
			$RR_{mean} =$		109.6 ± 3.7
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	103.0 ± 4.8
			422.1	83.7 ± 2.5	98.66 ± 7.97

Continuation of Table 69.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	102.1 ± 4.5
²⁰¹ Bi	i	108M	629.1	24 ± 6	130.2 ± 34.3
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	98.60 ± 3.92
			374.7	89 ± 15	124.0 ± 21.6
				$RR_{mean} =$	98.94 ± 4.22
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	86.82 ± 3.62
			374.7	89 ± 15	113.2 ± 19.8
				$RR_{mean} =$	87.23 ± 4.22
²⁰³ Pb	c*	51.873H	401.3	3.35 ± 0.07	424.9 ± 17.3
			279.2	80.8 ± 0.2	441.0 ± 16.1
				$RR_{mean} =$	435.1 ± 15.5
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	98.29 ± 9.49
			490.5	9.1 ± 0.7	140.4 ± 15.5
			459.7	8.6 ± 0.7	92.46 ± 10.39
			422.1	86 ± 5	109.4 ± 8.1
				$RR_{mean} =$	106.5 ± 7.4
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	460.2 ± 39.7
			1238.8	1.18 ± 0.08	378.2 ± 38.1
			1098.5	1.83 ± 0.12	371.5 ± 35.7
			1069.9	1.14 ± 0.11	474.6 ± 56.0
			946.0	7.4 ± 0.6	391.8 ± 34.7
			907.6	5.7 ± 0.4	433.6 ± 34.1
			692.4	4.27 ± 0.16	425.9 ± 23.1
			361.3	9.9 ± 0.5	456.1 ± 28.0
			331.2	79 ± 5	447.4 ± 32.2
				$RR_{mean} =$	426.9 ± 16.9
²⁰⁰ Pb	c	21.5H	1514.9	*	367.8 ± 31.5
			1407.6	*	432.7 ± 42.3
			1362.9	*	359.7 ± 44.5
			1225.5	*	346.0 ± 26.7
			1205.7	*	377.5 ± 26.0
			886.2	*	330.3 ± 29.9
			828.3	*	333.3 ± 26.1
			701.6	*	296.8 ± 29.0
			579.3	*	334.4 ± 22.2
			450.5	3.33 ± 0.08	463.9 ± 20.6
			367.9	*	350.9 ± 12.3
			268.4	3.96 ± 0.20	490.2 ± 44.1
			235.6	4.30 ± 0.17	409.2 ± 23.4
			147.6	37.7 ± 1.4	370.2 ± 20.0
			142.3	3.16 ± 0.19	388.4 ± 29.8
				$RR_{mean} =$	354.0 ± 10.9
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	685.0 ± 109.5
			762.0	2.2 ± 0.4	941.9 ± 189.3
			720.2	6.5 ± 1.0	564.2 ± 92.0
			366.9	44 ± 7	697.7 ± 114.7
			353.4	9.5 ± 1.5	742.2 ± 122.8
¹⁹⁸ Pb	c	2.4H		$RR_{mean} =$	665.4 ± 46.9
			865.3	5.9 ± 1.2	452.5 ± 93.9
			575.0	3.1 ± 0.7	462.8 ± 111.1
			365.4	19 ± 5	605.2 ± 161.0

Continuation of Table 69.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			173.4	18 ± 3	555.6 ± 95.3
			<i>RR_{mean}</i> =		546.9 ± 24.1
^{197m} Pb	c*	43M	774.3	14 ± 3	307.5 ± 67.5
			695.6	9.5 ± 2.0	263.6 ± 67.1
			387.7	25 ± 6	377.7 ± 91.7
			385.9	74 ± 15	378.1 ± 77.9
			222.8	25 ± 6	321.8 ± 78.9
			<i>RR_{mean}</i> =		351.6 ± 22.3
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	362.6 ± 44.8
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	214.6 ± 42.1
			383.6	107 ± 20	205.1 ± 39.6
			<i>RR_{mean}</i> =		208.8 ± 11.2
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	117.3 ± 4.3
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	636.6 ± 23.4
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	190.6 ± 23.8
			1407.6	1.45 ± 0.13	158.5 ± 22.4
			1362.9	3.4 ± 0.4	239.9 ± 32.2
			1225.5	3.36 ± 0.21	191.2 ± 25.0
			1205.7	29.9 ± 1.8	162.1 ± 11.8
			886.2	2.02 ± 0.13	232.5 ± 39.8
			828.3	10.8 ± 0.7	269.2 ± 26.6
			701.6	1.29 ± 0.10	317.3 ± 39.5
			579.3	13.8 ± 0.7	198.1 ± 22.8
			367.9	87.2 ± 0.4	181.8 ± 10.8
			<i>RR_{mean}</i> =		186.9 ± 12.3
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	558.4 ± 47.0
			1407.6	1.45 ± 0.13	591.2 ± 57.2
			1362.9	3.4 ± 0.4	599.6 ± 73.7
			1225.5	3.36 ± 0.21	537.2 ± 39.7
			1205.7	29.9 ± 1.8	539.6 ± 37.1
			886.2	2.02 ± 0.13	562.8 ± 45.2
			828.3	10.8 ± 0.7	602.5 ± 44.7
			701.6	1.29 ± 0.10	614.2 ± 54.2
			579.3	13.8 ± 0.7	532.4 ± 34.2
			367.9	87.2 ± 0.4	532.7 ± 18.8
			<i>RR_{mean}</i> =		540.7 ± 18.2
¹⁹⁹ Tl	c*	7.42H	750.4	1.04 ± 0.12	689.2 ± 90.7
			455.5	12.4 ± 1.4	642.9 ± 76.7
			333.9	1.76 ± 0.20	649.2 ± 80.5
			247.3	9.3 ± 1.1	633.7 ± 80.5
			208.2	12.3 ± 1.4	648.9 ± 78.6
			158.4	5.0 ± 0.6	676.9 ± 87.1
			<i>RR_{mean}</i> =		653.3 ± 27.8
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	144.1 ± 14.2
			282.8	28 ± 3	155.3 ± 18.2
			<i>RR_{mean}</i> =		148.1 ± 10.9
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	560.6 ± 189.6
			152.2	7.3 ± 2.3	871.3 ± 276.5
			134.0	2.0 ± 0.7	845.3 ± 299.7
			<i>RR_{mean}</i> =		757.7 ± 106.7

Continuation of Table 69.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	319.6 ± 56.0
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	400.6 ± 46.9
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	4.212 ± 0.326
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	628.8 ± 34.3
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	40.53 ± 1.79
^{195m} Hg	i(m)	41.6H	779.8	54.2 ± 0.1	52.47 ± 10.73
			560.3	7.0 ± 0.6	55.69 ± 5.44
			261.8	31 ± 4	59.76 ± 8.04
			<i>RR_{mean}</i> =		55.78 ± 1.72
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	489.0 ± 53.3
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	47.58 ± 7.59
			407.6	32 ± 6	67.01 ± 12.80
			<i>RR_{mean}</i> =		52.59 ± 8.65
¹⁹² Hg	c	4.85H	2335.7	*	313.7 ± 68.1
			316.5	*	323.5 ± 40.8
			296.0	*	324.0 ± 46.5
			274.8	50.2 ± 2.5	258.8 ± 16.6
			<i>RR_{mean}</i> =		266.6 ± 8.2
¹⁹⁰ Hg	c*	20.0M	295.8	*	126.4 ± 13.6
			142.6	68 ± 10	145.5 ± 22.9
			<i>RR_{mean}</i> =		131.2 ± 4.0
^{198m} Au	i(m)	2.27D	411.8	*	1.035 ± 0.047
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	1.901 ± 0.085
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	2.936 ± 0.103
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	7.865 ± 1.312
			355.7	87.0 ± 0.8	6.576 ± 0.252
			333.0	22.9 ± 0.6	6.953 ± 0.335
			<i>RR_{mean}</i> =		6.673 ± 0.247
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	620.9 ± 48.6
			98.9	10.9 ± 0.9	565.0 ± 55.1
			<i>RR_{mean}</i> =		603.0 ± 32.0
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	13.32 ± 1.18
			293.6	10.4 ± 0.8	11.11 ± 1.04
			<i>RR_{mean}</i> =		12.11 ± 1.17
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	19.65 ± 4.36
			296.0	22 ± 3	45.58 ± 17.32
			<i>RR_{mean}</i> =		20.87 ± 5.52
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	343.1 ± 43.1
			296.0	22 ± 3	369.6 ± 52.9
			<i>RR_{mean}</i> =		345.8 ± 13.7
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	194.5 ± 25.7
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	162.5 ± 16.8
			295.8	71 ± 5	149.7 ± 12.4
			<i>RR_{mean}</i> =		153.0 ± 8.2
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	205.1 ± 25.0
			456.5	3.4 ± 0.4	197.8 ± 24.5
			409.4	8.0 ± 0.9	186.9 ± 22.0
			172.2	3.5 ± 0.4	193.5 ± 23.3
			<i>RR_{mean}</i> =		194.5 ± 8.4
¹⁸⁹ Pt	c	10.87H	607.6	8.10 ± 0.16	133.2 ± 7.0

Continuation of Table 69.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			568.8	7.1 ± 0.6	144.1 ± 14.5
			544.9	5.8 ± 0.5	153.4 ± 15.4
			243.5	7.0 ± 1.2	130.7 ± 23.2
			$RR_{mean} =$		136.6 ± 6.4
¹⁸⁸ Pt	c	10.2D	1209.8	*	99.03 ± 10.73
			634.9	*	98.56 ± 16.12
			423.3	4.4 ± 0.3	95.89 ± 7.50
			381.4	7.5 ± 0.5	89.72 ± 6.81
			195.1	18.6 ± 1.2	90.22 ± 6.76
			187.6	19.4 ± 1.2	92.96 ± 6.84
			155.1	*	95.01 ± 10.10
			140.4	2.33 ± 0.15	103.3 ± 12.5
			$RR_{mean} =$		93.77 ± 2.89
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	40.43 ± 8.82
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	121.8 ± 13.3
¹⁸⁸ Ir _i	i	41.5H	634.9	5.0 ± 0.8	4.149 ± 1.317
			155.1	30 ± 3	7.655 ± 1.157
			$RR_{mean} =$		6.209 ± 1.737
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	98.75 ± 10.68
			634.9	5.0 ± 0.8	102.7 ± 16.8
			155.1	30 ± 3	102.7 ± 10.9
			$RR_{mean} =$		101.0 ± 6.9
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	19.09 ± 1.22
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	28.68 ± 2.38
			717.4	3.94 ± 0.16	23.29 ± 3.39
			646.1	78 ± 3	27.94 ± 1.46
			$RR_{mean} =$		27.88 ± 0.99
¹⁸³ Re	c	70.0D	208.8	2.95 ± 0.09	15.01 ± 1.51
			162.3	23.3 ± 0.7	11.95 ± 0.64
			$RR_{mean} =$		12.24 ± 0.97
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	1.258 ± 0.122
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	0.7498 ± 0.0607
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	2.051 ± 0.108
			172.1	25.5 ± 0.8	2.050 ± 0.266
			$RR_{mean} =$		2.051 ± 0.103
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.8296 ± 0.0988
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.999 ± 0.182
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	2.102 ± 0.229
			212.2	81.4 ± 1.1	1.740 ± 0.106
			$RR_{mean} =$		1.794 ± 0.055
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	2.259 ± 0.183
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.427 ± 0.105
			197.3	87.0 ± 1.1	2.435 ± 0.113
			$RR_{mean} =$		2.431 ± 0.093
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	5.933 ± 0.434
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	7.618 ± 0.576
			884.7	72.7 ± 0.4	6.797 ± 0.362
			657.8	94.3 ± 0.3	6.451 ± 0.377
			$RR_{mean} =$		6.780 ± 0.341
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	27.92 ± 1.33

Continuation of Table 69.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{101m} Rh	c	4.34D	306.9	81 ± 5	1.560 ± 0.143
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	25.85 ± 0.98
⁹⁹ Mo	c	65.94H	739.5	12.13 ± 0.22	21.90 ± 0.92
			140.5	90.27 ± 0.33	24.58 ± 1.06
			<i>RR_{mean}</i> =		23.04 ± 1.50
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	15.19 ± 0.88
			849.9	20.45 ± 0.20	16.85 ± 0.79
			778.2	96.45 ± 0.22	13.76 ± 0.57
			568.9	58.0 ± 0.3	13.68 ± 0.55
			460.0	26.62 ± 0.20	15.07 ± 0.64
			<i>RR_{mean}</i> =		14.47 ± 0.69
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	14.63 ± 0.50
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	31.07 ± 1.04
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	4.882 ± 0.249
⁹⁵ Zr	c	64.02D	765.8	*	16.59 ± 0.61
			756.7	54.46 ± 0.10	16.61 ± 0.60
			724.2	44.17 ± 0.16	17.46 ± 0.95
			<i>RR_{mean}</i> =		16.67 ± 0.51
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	2.150 ± 0.187
⁸⁸ Zr	c	83.4D	898.0	*	0.7393 ± 0.2715
⁸⁸ Y _i	i	106.65D	898.0	93.7 ± 0.3	5.513 ± 0.300
⁸⁸ Y _c	c	106.65D	898.0	93.7 ± 0.3	6.252 ± 0.254
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	2.651 ± 0.105
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	3.579 ± 0.223
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	22.13 ± 1.43
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	8.580 ± 0.471
⁸³ Rb	c	86.2D	529.6	29.3 ± 2.1	3.353 ± 0.391
			520.4	45 ± 4	3.742 ± 0.432
			<i>RR_{mean}</i> =		3.529 ± 0.268
⁸² Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	10.59 ± 0.56
			776.5	83.5 ± 1.2	9.721 ± 0.398
			698.4	28.5 ± 0.4	9.177 ± 0.415
			554.3	70.8 ± 1.0	9.260 ± 0.387
			<i>RR_{mean}</i> =		9.526 ± 0.381
⁷⁵ Se	c	119.779D	136.0	58.3 ± 0.8	0.7204 ± 0.1678
⁷⁴ As	i	17.77D	595.8	59 ± 4	2.057 ± 0.188
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	2.295 ± 1.195
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	4.352 ± 1.073
⁷² Zn	c	46.5H	2201.7	*	2.057 ± 0.205

12.5.2 Nuclide production rates for ²⁰⁷Pb

Table 70: Detailed calculation of nuclide production rates for ²⁰⁷Pb for $E_p = 0.25$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	569.7	97.74 ± 0.03	24.45 ± 2.47
²⁰⁶ Bi	i	6.243D	1878.7	2.01 ± 0.05	63.04 ± 4.12

Continuation of Table 70.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1718.7	31.8 ± 0.6	62.77 ± 2.53
			1595.3	5.01 ± 0.08	68.60 ± 3.01
			1098.3	13.50 ± 0.21	63.95 ± 3.22
			1018.6	7.60 ± 0.11	72.68 ± 3.65
			895.1	15.66 ± 0.23	63.16 ± 2.35
			881.0	66.2 ± 1.0	59.92 ± 2.16
			803.1	98.9 ± 1.4	58.02 ± 2.08
			620.5	5.76 ± 0.09	57.62 ± 2.35
			537.5	30.5 ± 0.5	53.65 ± 2.05
			516.2	40.7 ± 0.6	56.85 ± 2.12
			497.1	15.31 ± 0.22	55.14 ± 2.18
			398.0	10.74 ± 0.15	54.63 ± 2.04
			343.5	23.4 ± 0.4	56.73 ± 2.17
			184.0	15.8 ± 0.4	68.39 ± 3.22
			<i>RR_{mean}</i> =		58.65 ± 2.14
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	125.2 ± 5.0
			1775.8	3.99 ± 0.08	126.1 ± 5.4
			1764.3	32.5 ± 0.7	127.4 ± 5.2
			1614.3	2.28 ± 0.04	132.6 ± 6.1
			1190.0	2.26 ± 0.07	128.8 ± 6.4
			1043.8	7.51 ± 0.10	116.8 ± 4.3
			987.7	16.13 ± 0.17	132.0 ± 4.7
			759.1	1.04 ± 0.05	128.1 ± 8.5
			703.5	31.1 ± 0.1	116.1 ± 3.9
			579.8	5.44 ± 0.07	113.3 ± 4.6
			570.6	4.34 ± 0.07	112.8 ± 4.5
			549.8	2.95 ± 0.04	108.8 ± 4.2
			284.1	1.69 ± 0.02	122.7 ± 5.2
			<i>RR_{mean}</i> =		119.7 ± 4.3
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	125.4 ± 9.6
			918.3	10.8 ± 0.9	133.5 ± 12.7
			899.2	98 ± 9	119.4 ± 4.2
			670.7	11.4 ± 0.9	121.9 ± 10.8
			374.8	82 ± 5	139.4 ± 29.1
			<i>RR_{mean}</i> =		120.0 ± 3.7
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	137.9 ± 11.9
			1847.3	11.4 ± 0.8	140.4 ± 11.3
			1679.6	8.8 ± 0.7	141.1 ± 12.8
			1034.0	8.8 ± 0.5	149.6 ± 10.4
			896.8	13.1 ± 0.7	150.2 ± 10.1
			847.2	8.5 ± 0.5	153.4 ± 11.0
			820.2	29.6 ± 1.5	155.8 ± 9.5
			<i>RR_{mean}</i> =		152.4 ± 5.2
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	136.6 ± 5.5
			422.1	83.7 ± 2.5	139.5 ± 7.7
			<i>RR_{mean}</i> =		137.3 ± 5.2
²⁰¹ Bi	i	108M	629.1	24 ± 6	131.0 ± 33.3
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	136.6 ± 5.3
			374.7	89 ± 15	170.7 ± 29.5
			<i>RR_{mean}</i> =		137.0 ± 5.7
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	154.5 ± 5.8

Continuation of Table 70.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰³ Pb	c*	51.873H	374.7	89 ± 15	188.2 ± 32.5
			<i>RR_{mean}</i> =		154.9 ± 5.9
			401.3	3.35 ± 0.07	557.8 ± 22.7
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	579.3 ± 21.2
			<i>RR_{mean}</i> =		571.3 ± 20.5
			960.7	92 ± 8	146.5 ± 13.8
^{202m} Pb	i(m)	3.53H	490.5	9.1 ± 0.7	195.0 ± 18.1
			459.7	8.6 ± 0.7	144.6 ± 14.0
			422.1	86 ± 5	156.1 ± 10.9
			<i>RR_{mean}</i> =		156.5 ± 9.0
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	562.1 ± 48.9
			1238.8	1.18 ± 0.08	473.9 ± 42.5
			1098.5	1.83 ± 0.12	464.8 ± 63.8
			1069.9	1.14 ± 0.11	515.5 ± 59.3
			946.0	7.4 ± 0.6	485.8 ± 42.9
			907.6	5.7 ± 0.4	528.0 ± 42.0
			692.4	4.27 ± 0.16	562.7 ± 29.4
			361.3	9.9 ± 0.5	581.1 ± 35.8
			331.2	79 ± 5	585.1 ± 42.1
			<i>RR_{mean}</i> =		542.5 ± 22.0
²⁰⁰ Pb	c	21.5H	1514.9	*	462.6 ± 38.9
			1407.6	*	509.7 ± 51.1
			1362.9	*	499.9 ± 61.7
			1225.5	*	442.3 ± 35.0
			1205.7	*	471.2 ± 32.6
			886.2	*	442.3 ± 33.9
			828.3	*	458.3 ± 33.8
			701.6	*	388.3 ± 35.3
			579.3	*	419.9 ± 26.9
			450.5	3.33 ± 0.08	570.6 ± 26.1
			367.9	*	438.5 ± 15.3
			268.4	3.96 ± 0.20	582.0 ± 50.7
			235.6	4.30 ± 0.17	566.8 ± 32.9
			147.6	37.7 ± 1.4	460.9 ± 25.8
			142.3	3.16 ± 0.19	602.7 ± 43.9
			<i>RR_{mean}</i> =		445.0 ± 13.7
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	851.9 ± 140.1
			762.0	2.2 ± 0.4	1114 ± 216
			720.2	6.5 ± 1.0	805.4 ± 129.7
			366.9	44 ± 7	823.9 ± 134.9
			353.4	9.5 ± 1.5	864.6 ± 144.1
			<i>RR_{mean}</i> =		844.9 ± 40.6
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	498.9 ± 103.7
			575.0	3.1 ± 0.7	553.5 ± 128.4
			365.4	19 ± 5	741.2 ± 198.2
			173.4	18 ± 3	702.4 ± 120.2
			<i>RR_{mean}</i> =		684.9 ± 38.5
^{197m} Pb	c*	43M	774.3	14 ± 3	358.4 ± 78.5
			695.6	9.5 ± 2.0	384.5 ± 93.7
			387.7	25 ± 6	456.9 ± 111.1
			385.9	74 ± 15	467.2 ± 96.2

Continuation of Table 70.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			222.8	25 ± 6	375.5 ± 91.7
			<i>RR_{mean}</i> =		431.6 ± 27.4
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	416.2 ± 50.6
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	232.7 ± 44.9
			383.6	107 ± 20	233.8 ± 44.6
			<i>RR_{mean}</i> =		233.3 ± 11.3
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	166.4 ± 6.0
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	839.7 ± 30.9
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	256.2 ± 25.7
			1407.6	1.45 ± 0.13	279.4 ± 39.3
			1362.9	3.4 ± 0.4	254.3 ± 34.7
			1225.5	3.36 ± 0.21	267.9 ± 33.7
			1205.7	29.9 ± 1.8	231.6 ± 18.1
			886.2	2.02 ± 0.13	274.6 ± 28.3
			828.3	10.8 ± 0.7	331.2 ± 25.6
			701.6	1.29 ± 0.10	414.3 ± 42.1
			579.3	13.8 ± 0.7	296.2 ± 27.7
			367.9	87.2 ± 0.4	260.6 ± 14.5
			<i>RR_{mean}</i> =		270.4 ± 14.9
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	718.8 ± 59.7
			1407.6	1.45 ± 0.13	789.2 ± 77.3
			1362.9	3.4 ± 0.4	754.2 ± 92.7
			1225.5	3.36 ± 0.21	710.1 ± 52.9
			1205.7	29.9 ± 1.8	702.8 ± 48.6
			886.2	2.02 ± 0.13	716.9 ± 53.0
			828.3	10.8 ± 0.7	789.5 ± 57.5
			701.6	1.29 ± 0.10	802.6 ± 68.9
			579.3	13.8 ± 0.7	716.1 ± 45.8
			367.9	87.2 ± 0.4	699.2 ± 24.9
			<i>RR_{mean}</i> =		710.4 ± 24.1
¹⁹⁹ Tl	c*	7.42H	750.4	1.04 ± 0.12	965.3 ± 130.3
			455.5	12.4 ± 1.4	831.4 ± 99.0
			333.9	1.76 ± 0.20	946.5 ± 118.7
			247.3	9.3 ± 1.1	849.4 ± 106.1
			208.2	12.3 ± 1.4	841.9 ± 102.0
			158.4	5.0 ± 0.6	882.4 ± 113.3
			<i>RR_{mean}</i> =		871.5 ± 37.2
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	185.5 ± 11.9
			282.8	28 ± 3	206.9 ± 23.9
			<i>RR_{mean}</i> =		188.0 ± 9.4
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	649.1 ± 219.4
			152.2	7.3 ± 2.3	1056 ± 335
			134.0	2.0 ± 0.7	919.1 ± 327.5
			<i>RR_{mean}</i> =		889.5 ± 137.0
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	404.9 ± 70.8
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	413.2 ± 49.9
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	11.06 ± 0.50
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	783.0 ± 44.6
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	65.82 ± 3.14
^{195m} Hg	i(m)	41.6H	779.8	54.2 ± 0.1	65.59 ± 13.75

Continuation of Table 70.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			560.3	7.0 ± 0.6	77.40 ± 7.29
			261.8	31 ± 4	82.77 ± 11.23
			$RR_{mean} =$		75.79 ± 2.34
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	627.8 ± 68.6
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	61.38 ± 9.89
			407.6	32 ± 6	83.55 ± 15.99
			$RR_{mean} =$		67.46 ± 10.10
¹⁹² Hg	c	4.85H	2335.7	*	328.7 ± 66.6
			316.5	*	359.7 ± 45.2
			296.0	*	371.0 ± 53.2
			274.8	50.2 ± 2.5	280.6 ± 17.7
			$RR_{mean} =$		289.4 ± 8.9
¹⁹⁰ Hg	c*	20.0M	295.8	*	123.3 ± 15.4
			142.6	68 ± 10	137.3 ± 21.1
			$RR_{mean} =$		128.1 ± 4.0
^{198m} Au	i(m)	2.27D	411.8	*	1.659 ± 0.092
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	3.796 ± 0.190
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	5.456 ± 0.198
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	10.52 ± 1.72
			355.7	87.0 ± 0.8	10.49 ± 0.38
			333.0	22.9 ± 0.6	11.40 ± 0.52
			$RR_{mean} =$		10.65 ± 0.41
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	768.7 ± 58.2
			98.9	10.9 ± 0.9	705.8 ± 68.2
			$RR_{mean} =$		751.1 ± 36.5
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	20.31 ± 1.81
			293.6	10.4 ± 0.8	22.53 ± 2.36
			$RR_{mean} =$		21.04 ± 1.30
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	19.25 ± 3.35
			296.0	22 ± 3	14.01 ± 19.14
			$RR_{mean} =$		19.17 ± 2.42
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	378.9 ± 47.5
			296.0	22 ± 3	385.0 ± 55.4
			$RR_{mean} =$		379.5 ± 14.8
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	206.1 ± 18.9
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	155.1 ± 18.8
			295.8	71 ± 5	156.6 ± 13.5
			$RR_{mean} =$		156.3 ± 9.2
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	223.9 ± 27.3
			456.5	3.4 ± 0.4	201.9 ± 24.9
			409.4	8.0 ± 0.9	201.2 ± 23.7
			172.2	3.5 ± 0.4	213.9 ± 25.8
			$RR_{mean} =$		209.0 ± 9.0
¹⁸⁹ Pt	c	10.87H	607.6	8.10 ± 0.16	143.5 ± 7.8
			568.8	7.1 ± 0.6	137.4 ± 16.3
			544.9	5.8 ± 0.5	147.4 ± 15.5
			243.5	7.0 ± 1.2	135.5 ± 24.2
			$RR_{mean} =$		142.9 ± 6.9
¹⁸⁸ Pt	c	10.2D	1209.8	*	100.8 ± 10.8
			634.9	*	98.64 ± 16.21

Continuation of Table 70.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			423.3	4.4 ± 0.3	90.21 ± 7.06
			381.4	7.5 ± 0.5	85.73 ± 6.49
			195.1	18.6 ± 1.2	88.25 ± 6.63
			187.6	19.4 ± 1.2	90.80 ± 6.59
			155.1	*	93.82 ± 9.96
			140.4	2.33 ± 0.15	94.61 ± 9.05
			<i>RR_{mean}</i> =		91.22 ± 2.81
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	33.38 ± 7.31
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	113.5 ± 12.2
¹⁸⁸ Ir _i	i	41.5H	634.9	5.0 ± 0.8	2.990 ± 4.546
			155.1	30 ± 3	6.641 ± 1.284
			<i>RR_{mean}</i> =		6.388 ± 1.210
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	101.5 ± 11.0
			634.9	5.0 ± 0.8	101.6 ± 17.1
			155.1	30 ± 3	100.4 ± 10.7
			<i>RR_{mean}</i> =		101.0 ± 7.0
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	18.83 ± 1.15
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	24.59 ± 1.86
			717.4	3.94 ± 0.16	27.81 ± 2.76
			646.1	78 ± 3	24.02 ± 1.27
			<i>RR_{mean}</i> =		24.20 ± 0.89
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	9.363 ± 0.538
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	0.8971 ± 0.0742
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	1.889 ± 0.185
			172.1	25.5 ± 0.8	1.890 ± 0.190
			<i>RR_{mean}</i> =		1.890 ± 0.138
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.8324 ± 0.0986
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.323 ± 0.120
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	2.080 ± 0.241
			212.2	81.4 ± 1.1	1.756 ± 0.099
			<i>RR_{mean}</i> =		1.792 ± 0.055
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	2.376 ± 0.196
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.561 ± 0.126
			197.3	87.0 ± 1.1	2.784 ± 0.152
			<i>RR_{mean}</i> =		2.646 ± 0.136
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	5.786 ± 0.721
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	6.916 ± 0.423
			884.7	72.7 ± 0.4	7.627 ± 0.336
			657.8	94.3 ± 0.3	7.136 ± 0.317
			<i>RR_{mean}</i> =		7.292 ± 0.300
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	33.88 ± 1.65
^{101m} Rh	c	4.34D	306.9	81 ± 5	1.564 ± 0.170
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	31.21 ± 1.17
⁹⁹ Mo	c	65.94H	739.5	12.13 ± 0.22	26.64 ± 1.13
			140.5	90.27 ± 0.33	33.17 ± 1.36
			<i>RR_{mean}</i> =		29.40 ± 3.35
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	16.48 ± 0.99
			849.9	20.45 ± 0.20	18.47 ± 0.97
			778.2	96.45 ± 0.22	16.02 ± 0.76
			568.9	58.0 ± 0.3	16.15 ± 0.96

Continuation of Table 70.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			460.0	26.62 ± 0.20	15.87 ± 0.72
			$RR_{mean} =$		16.40 ± 0.67
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	15.75 ± 0.55
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	36.78 ± 1.23
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	7.263 ± 0.325
^{95}Zr	c	64.02D	765.8	*	21.22 ± 0.77
			756.7	54.46 ± 0.10	21.29 ± 0.74
			724.2	44.17 ± 0.16	22.19 ± 0.91
			$RR_{mean} =$		21.37 ± 0.66
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	1.644 ± 0.091
$^{88}\text{Y}_i$	i	106.65D	898.0	93.7 ± 0.3	5.541 ± 0.247
$^{88}\text{Y}_c$	c	106.65D	898.0	93.7 ± 0.3	5.825 ± 0.220
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	2.242 ± 0.114
^{85}Sr	c	64.84D	514.0	96 ± 4	2.824 ± 0.174
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	19.85 ± 1.09
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	8.074 ± 0.388
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	4.647 ± 0.837
			529.6	29.3 ± 2.1	3.517 ± 0.459
			520.4	45 ± 4	3.340 ± 0.384
			$RR_{mean} =$		3.525 ± 0.283
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	12.12 ± 0.64
			776.5	83.5 ± 1.2	11.44 ± 0.49
			698.4	28.5 ± 0.4	10.16 ± 0.55
			554.3	70.8 ± 1.0	10.65 ± 0.45
			$RR_{mean} =$		11.00 ± 0.49
^{75}Se	c	119.779D	136.0	58.3 ± 0.8	0.6814 ± 0.0879
^{74}As	i	17.77D	595.8	59 ± 4	1.823 ± 0.155
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	3.868 ± 0.620
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	5.990 ± 0.597
^{72}Zn	c	46.5H	2201.7	*	2.122 ± 0.190
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	1.447 ± 0.174
			1099.2	56.5 ± 1.9	1.648 ± 0.562
			$RR_{mean} =$		1.463 ± 0.165

12.5.3 Nuclide production rates for ^{208}Pb

Table 71: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.25 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	52.91 ± 4.94
^{206}Bi	i	6.243D	1878.7	2.01 ± 0.05	75.81 ± 5.39
			1718.7	31.8 ± 0.6	75.17 ± 3.01
			1595.3	5.01 ± 0.08	88.83 ± 4.89
			1098.3	13.50 ± 0.21	72.08 ± 2.97
			1018.6	7.60 ± 0.11	79.50 ± 3.35
			895.1	15.66 ± 0.23	74.60 ± 2.86
			881.0	66.2 ± 1.0	71.70 ± 2.63
			803.1	98.9 ± 1.4	69.78 ± 2.49

Continuation of Table 71.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			620.5	5.76 ± 0.09	72.58 ± 3.03
			537.5	30.5 ± 0.5	64.92 ± 2.49
			516.2	40.7 ± 0.6	67.35 ± 2.56
			497.1	15.31 ± 0.22	67.29 ± 2.68
			398.0	10.74 ± 0.15	66.57 ± 2.50
			343.5	23.4 ± 0.4	68.04 ± 2.58
			184.0	15.8 ± 0.4	81.85 ± 3.73
			<i>RR_{mean}</i> =		70.55 ± 2.49
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	111.7 ± 4.7
			1775.8	3.99 ± 0.08	111.9 ± 5.1
			1764.3	32.5 ± 0.7	107.1 ± 4.4
			1614.3	2.28 ± 0.04	108.6 ± 4.9
			1190.0	2.26 ± 0.07	115.7 ± 6.1
			1043.8	7.51 ± 0.10	102.1 ± 4.4
			987.7	16.13 ± 0.17	109.9 ± 4.1
			759.1	1.04 ± 0.05	109.6 ± 7.9
			703.5	31.1 ± 0.1	98.21 ± 3.31
			579.8	5.44 ± 0.07	98.69 ± 4.08
			570.6	4.34 ± 0.07	101.3 ± 4.4
			549.8	2.95 ± 0.04	89.01 ± 4.93
			284.1	1.69 ± 0.02	90.68 ± 4.40
			<i>RR_{mean}</i> =		102.3 ± 3.7
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	92.07 ± 7.10
			918.3	10.8 ± 0.9	106.7 ± 9.9
			899.2	98 ± 9	90.55 ± 3.07
			670.7	11.4 ± 0.9	98.95 ± 9.62
			374.8	82 ± 5	103.8 ± 21.7
			<i>RR_{mean}</i> =		91.00 ± 2.81
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	93.96 ± 8.12
			1847.3	11.4 ± 0.8	108.8 ± 9.0
			1679.6	8.8 ± 0.7	104.8 ± 9.7
			1034.0	8.8 ± 0.5	97.72 ± 7.10
			896.8	13.1 ± 0.7	102.2 ± 6.8
			847.2	8.5 ± 0.5	106.4 ± 7.7
			820.2	29.6 ± 1.5	110.6 ± 6.9
			<i>RR_{mean}</i> =		105.5 ± 3.9
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	94.87 ± 4.16
			422.1	83.7 ± 2.5	85.07 ± 7.14
			<i>RR_{mean}</i> =		93.25 ± 4.64
²⁰¹ Bi	i	108M	629.1	24 ± 6	101.4 ± 25.8
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	108.3 ± 4.0
			374.7	89 ± 15	137.8 ± 23.8
			<i>RR_{mean}</i> =		108.6 ± 4.3
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	121.9 ± 4.4
			374.7	89 ± 15	150.8 ± 26.0
			<i>RR_{mean}</i> =		122.1 ± 4.5
²⁰³ Pb	c*	51.873H	401.3	3.35 ± 0.07	404.1 ± 16.1
			279.2	80.8 ± 0.2	413.2 ± 15.1
			<i>RR_{mean}</i> =		409.8 ± 14.1
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	115.0 ± 10.8
			490.5	9.1 ± 0.7	138.3 ± 15.9

Continuation of Table 71.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			459.7	8.6 ± 0.7	103.0 ± 10.1
			422.1	86 ± 5	126.4 ± 8.9
			<i>RR_{mean}</i> =		120.8 ± 7.0
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	386.8 ± 34.5
			1238.8	1.18 ± 0.08	369.8 ± 33.7
			1098.5	1.83 ± 0.12	335.6 ± 31.7
			1069.9	1.14 ± 0.11	386.3 ± 63.0
			946.0	7.4 ± 0.6	346.9 ± 31.1
			907.6	5.7 ± 0.4	386.5 ± 30.5
			692.4	4.27 ± 0.16	403.7 ± 23.4
			361.3	9.9 ± 0.5	412.9 ± 25.4
			331.2	79 ± 5	403.4 ± 29.0
			<i>RR_{mean}</i> =		386.9 ± 15.0
²⁰⁰ Pb	c	21.5H	1514.9	*	307.3 ± 26.8
			1407.6	*	396.7 ± 41.2
			1362.9	*	334.2 ± 41.7
			1225.5	*	304.5 ± 23.9
			1205.7	*	329.1 ± 23.0
			886.2	*	278.0 ± 23.4
			828.3	*	291.8 ± 21.6
			701.6	*	250.5 ± 26.7
			579.3	*	286.5 ± 18.3
			450.5	3.33 ± 0.08	398.2 ± 17.0
			367.9	*	317.0 ± 11.1
			268.4	3.96 ± 0.20	410.4 ± 31.8
			235.6	4.30 ± 0.17	374.1 ± 21.2
			147.6	37.7 ± 1.4	334.6 ± 18.1
			142.3	3.16 ± 0.19	425.3 ± 31.2
			<i>RR_{mean}</i> =		321.2 ± 9.9
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	694.0 ± 112.4
			762.0	2.2 ± 0.4	677.4 ± 155.4
			720.2	6.5 ± 1.0	541.5 ± 93.6
			366.9	44 ± 7	574.8 ± 95.2
			353.4	9.5 ± 1.5	703.3 ± 118.3
			<i>RR_{mean}</i> =		623.4 ± 39.5
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	353.9 ± 74.5
			575.0	3.1 ± 0.7	380.4 ± 88.7
			365.4	19 ± 5	477.6 ± 126.9
			173.4	18 ± 3	474.7 ± 81.3
			<i>RR_{mean}</i> =		463.7 ± 24.1
^{197m} Pb	c*	43M	774.3	14 ± 3	269.3 ± 60.3
			695.6	9.5 ± 2.0	167.0 ± 49.4
			387.7	25 ± 6	316.3 ± 76.8
			385.9	74 ± 15	310.9 ± 64.0
			222.8	25 ± 6	245.8 ± 60.0
			<i>RR_{mean}</i> =		289.7 ± 22.0
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	257.5 ± 33.2
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	138.4 ± 28.1
			383.6	107 ± 20	147.6 ± 28.3
			<i>RR_{mean}</i> =		144.8 ± 7.9

Continuation of Table 71.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	127.1 ± 4.6
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	598.1 ± 22.0
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	230.8 ± 25.2
			1407.6	1.45 ± 0.13	196.6 ± 33.9
			1362.9	3.4 ± 0.4	200.4 ± 29.8
			1225.5	3.36 ± 0.21	200.4 ± 23.1
			1205.7	29.9 ± 1.8	173.4 ± 14.9
			886.2	2.02 ± 0.13	221.0 ± 28.1
			828.3	10.8 ± 0.7	253.7 ± 20.2
			701.6	1.29 ± 0.10	302.1 ± 40.7
			579.3	13.8 ± 0.7	221.6 ± 18.1
			367.9	87.2 ± 0.4	164.0 ± 8.9
			<i>RR_{mean}</i> =		
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	538.0 ± 45.1
			1407.6	1.45 ± 0.13	593.3 ± 58.6
			1362.9	3.4 ± 0.4	534.6 ± 66.0
			1225.5	3.36 ± 0.21	504.9 ± 36.9
			1205.7	29.9 ± 1.8	502.6 ± 34.9
			886.2	2.02 ± 0.13	499.0 ± 38.2
			828.3	10.8 ± 0.7	545.4 ± 39.8
			701.6	1.29 ± 0.10	552.6 ± 49.6
			579.3	13.8 ± 0.7	508.0 ± 31.7
			367.9	87.2 ± 0.4	481.0 ± 16.7
			<i>RR_{mean}</i> =		
¹⁹⁹ Tl	c*	7.42H	750.4	1.04 ± 0.12	746.4 ± 93.2
			455.5	12.4 ± 1.4	595.3 ± 70.8
			333.9	1.76 ± 0.20	553.5 ± 67.4
			247.3	9.3 ± 1.1	571.5 ± 71.5
			208.2	12.3 ± 1.4	574.8 ± 69.5
			158.4	5.0 ± 0.6	628.9 ± 79.8
<i>RR_{mean}</i> =				597.4 ± 30.3	
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	136.9 ± 10.6
			282.8	28 ± 3	147.8 ± 17.2
<i>RR_{mean}</i> =				139.3 ± 8.6	
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	504.6 ± 169.9
			152.2	7.3 ± 2.3	742.2 ± 235.6
			134.0	2.0 ± 0.7	716.3 ± 257.9
<i>RR_{mean}</i> =				656.8 ± 81.6	
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	285.1 ± 50.0
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	284.8 ± 34.7
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	12.46 ± 0.55
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	529.1 ± 28.2
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	48.84 ± 2.30
^{195m} Hg	i(m)	41.6H	779.8	54.2 ± 0.1	53.13 ± 10.41
			560.3	7.0 ± 0.6	59.47 ± 5.82
			261.8	31 ± 4	59.03 ± 7.99
<i>RR_{mean}</i> =				58.08 ± 1.79	
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	386.8 ± 41.9
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	37.20 ± 6.05
			407.6	32 ± 6	53.49 ± 10.28

Continuation of Table 71.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	41.36 ± 7.22
¹⁹² Hg	c	4.85H	2335.7	*	127.7 ± 32.7
			316.5	*	203.7 ± 25.6
			296.0	*	215.5 ± 31.5
			274.8	50.2 ± 2.5	159.8 ± 10.1
				$RR_{mean} =$	164.2 ± 5.1
¹⁹⁰ Hg	c*	20.0M	295.8	*	66.21 ± 8.42
			142.6	68 ± 10	74.46 ± 11.65
				$RR_{mean} =$	69.00 ± 2.13
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.407 ± 0.201
			411.8	*	1.690 ± 0.188
				$RR_{mean} =$	2.038 ± 0.063
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	3.507 ± 0.303
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	5.197 ± 0.215
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	8.266 ± 1.278
			355.7	87.0 ± 0.8	9.046 ± 0.327
			333.0	22.9 ± 0.6	9.435 ± 0.444
				$RR_{mean} =$	9.105 ± 0.312
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	458.7 ± 36.0
			98.9	10.9 ± 0.9	403.5 ± 39.3
				$RR_{mean} =$	440.0 ± 29.4
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	15.39 ± 1.37
			293.6	10.4 ± 0.8	14.63 ± 1.32
				$RR_{mean} =$	15.00 ± 0.86
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	21.36 ± 3.86
			296.0	22 ± 3	25.87 ± 17.62
				$RR_{mean} =$	21.48 ± 2.87
¹⁹² Au _c	c	4.94H	2335.7	1.7 ± 0.3	234.2 ± 52.5
			316.5	58 ± 7	225.1 ± 28.3
			296.0	22 ± 3	241.4 ± 35.4
				$RR_{mean} =$	226.6 ± 9.0
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	114.8 ± 17.9
¹⁹⁰ Au _c	c	42.8M	295.8	71 ± 5	83.29 ± 7.12
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	127.2 ± 15.5
			456.5	3.4 ± 0.4	121.7 ± 15.0
			409.4	8.0 ± 0.9	116.4 ± 13.7
			172.2	3.5 ± 0.4	115.7 ± 14.0
				$RR_{mean} =$	119.5 ± 5.1
¹⁸⁹ Pt	c	10.87H	607.6	8.10 ± 0.16	82.40 ± 5.29
			568.8	7.1 ± 0.6	98.58 ± 10.03
			544.9	5.8 ± 0.5	86.06 ± 10.01
			243.5	7.0 ± 1.2	65.23 ± 11.91
				$RR_{mean} =$	83.61 ± 5.36
¹⁸⁸ Pt	c	10.2D	1209.8	*	53.96 ± 5.95
			634.9	*	50.42 ± 8.36
			423.3	4.4 ± 0.3	46.50 ± 4.36
			381.4	7.5 ± 0.5	47.63 ± 3.64
			195.1	18.6 ± 1.2	44.13 ± 3.35
			187.6	19.4 ± 1.2	46.22 ± 3.38
			155.1	*	47.10 ± 5.02

Continuation of Table 71.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			140.4	2.33 ± 0.15	48.51 ± 4.81
			$RR_{mean} =$		47.18 ± 1.46
^{186}Pt	c	2.08H	689.4	70 ± 15	15.82 ± 3.54
^{189}Ir	c	13.2D	245.1	6.0 ± 0.6	63.22 ± 6.89
$^{188}\text{Ir}_i$	i	41.5H	634.9	5.0 ± 0.8	2.814 ± 2.289
			155.1	30 ± 3	7.503 ± 0.992
			$RR_{mean} =$		6.854 ± 1.632
$^{188}\text{Ir}_c$	c	41.5H	1209.8	6.9 ± 0.7	55.08 ± 6.08
			634.9	5.0 ± 0.8	53.23 ± 8.90
			155.1	30 ± 3	54.61 ± 5.82
			$RR_{mean} =$		54.58 ± 3.79
^{186}Ir	c	16.64H	434.8	33.9 ± 1.1	8.755 ± 0.536
^{185}Os	c	93.6D	874.8	6.29 ± 0.25	14.65 ± 1.85
			717.4	3.94 ± 0.16	17.59 ± 4.02
			646.1	78 ± 3	11.26 ± 0.61
			$RR_{mean} =$		11.37 ± 0.58
^{183}Re	c	70.0D	162.3	23.3 ± 0.7	3.449 ± 0.325
^{139}Ce	c	137.640D	165.9	79.89 ± 0.01	0.5053 ± 0.1030
^{127}Xe	c	36.4D	202.9	68.3 ± 0.5	0.9805 ± 0.0765
			172.1	25.5 ± 0.8	1.248 ± 0.159
			$RR_{mean} =$		1.026 ± 0.106
^{124}Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.6708 ± 0.1184
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.356 ± 0.113
^{121m}Te	i(m)	154D	573.1	88.6 ± 0.1	1.059 ± 0.294
			212.2	81.4 ± 1.1	0.8601 ± 0.0930
			$RR_{mean} =$		0.8771 ± 0.0271
$^{121}\text{Te}_c$	c	19.16D	573.1	80.3 ± 2.5	1.129 ± 0.225
^{120m}Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	1.586 ± 0.101
			197.3	87.0 ± 1.1	1.615 ± 0.093
			$RR_{mean} =$		1.602 ± 0.076
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	3.234 ± 0.329
^{110m}Ag	i(m)	249.76D	937.5	34.2 ± 0.6	4.960 ± 0.480
			884.7	72.7 ± 0.4	4.914 ± 0.270
			657.8	94.3 ± 0.3	4.317 ± 0.221
			$RR_{mean} =$		4.581 ± 0.255
^{105}Rh	c	35.36H	318.9	19.1 ± 0.6	21.74 ± 1.08
^{101m}Rh	c	4.34D	306.9	81 ± 5	0.9487 ± 0.1353
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	19.81 ± 0.79
^{99}Mo	c	65.94H	739.5	12.13 ± 0.22	18.90 ± 1.05
			140.5	90.27 ± 0.33	21.43 ± 0.86
			$RR_{mean} =$		20.69 ± 1.31
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	10.03 ± 0.53
			849.9	20.45 ± 0.20	8.399 ± 0.916
			778.2	96.45 ± 0.22	9.224 ± 0.356
			568.9	58.0 ± 0.3	8.934 ± 0.396
			460.0	26.62 ± 0.20	9.433 ± 0.425
			$RR_{mean} =$		9.263 ± 0.332
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	8.937 ± 0.364
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	23.31 ± 0.81
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	6.084 ± 0.299

Continuation of Table 71.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{95}Zr	c	64.02D	765.8	*	14.51 ± 0.58
			756.7	54.46 ± 0.10	14.12 ± 0.59
			724.2	44.17 ± 0.16	13.47 ± 0.67
			$RR_{mean} =$		14.14 ± 0.44
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	1.042 ± 0.102
^{88}Zr	c	83.4D	1836.1	*	0.4513 ± 0.6167
			898.0	*	0.3241 ± 0.0779
			$RR_{mean} =$		0.3261 ± 0.0773
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	2.839 ± 0.608
			898.0	93.7 ± 0.3	2.800 ± 0.112
			$RR_{mean} =$		2.800 ± 0.112
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	3.290 ± 0.375
			898.0	93.7 ± 0.3	3.124 ± 0.114
			$RR_{mean} =$		3.128 ± 0.114
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	1.081 ± 0.063
^{85}Sr	c	64.84D	514.0	96 ± 4	1.509 ± 0.169
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	13.09 ± 1.03
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	3.578 ± 0.555
^{83}Rb	c	86.2D	529.6	29.3 ± 2.1	2.530 ± 0.431
			520.4	45 ± 4	1.795 ± 0.452
			$RR_{mean} =$		2.195 ± 0.372
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	7.739 ± 0.408
			776.5	83.5 ± 1.2	6.585 ± 0.293
			698.4	28.5 ± 0.4	6.566 ± 0.400
			554.3	70.8 ± 1.0	6.525 ± 0.304
			$RR_{mean} =$		6.737 ± 0.321
^{74}As	i	17.77D	595.8	59 ± 4	0.8811 ± 0.1122
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	2.674 ± 0.492
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	3.848 ± 0.450
^{72}Zn	c	46.5H	2201.7	*	1.175 ± 0.109
^{59}Fe	c	44.472D	1099.2	56.5 ± 1.9	0.9448 ± 0.5468

12.5.4 Nuclide production rates for ^{nat}Pb

Table 72: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.25 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	37.91 ± 3.34
^{206}Bi	i	6.243D	1595.3	5.01 ± 0.08	82.92 ± 3.85
			1018.6	7.60 ± 0.11	86.43 ± 3.93
			184.0	15.8 ± 0.4	80.71 ± 3.76
			1878.7	2.01 ± 0.05	73.78 ± 3.93
			1718.7	31.8 ± 0.6	77.03 ± 3.13
			1098.3	13.50 ± 0.21	76.85 ± 3.05
			895.1	15.66 ± 0.23	76.62 ± 2.86
			881.0	66.2 ± 1.0	73.60 ± 2.67
			803.1	98.9 ± 1.4	71.17 ± 2.54
			620.5	5.76 ± 0.09	69.24 ± 2.81

Continuation of Table 72.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			537.5	30.5 ± 0.5	64.62 ± 2.56
			516.2	40.7 ± 0.6	69.07 ± 2.57
			497.1	15.31 ± 0.22	67.63 ± 2.62
			398.0	10.74 ± 0.15	65.80 ± 2.48
			343.5	23.4 ± 0.4	68.37 ± 2.61
			<i>RR_{mean}</i> =		71.50 ± 2.60
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	133.6 ± 5.4
			1775.8	3.99 ± 0.08	133.8 ± 6.4
			1764.3	32.5 ± 0.7	130.2 ± 5.4
			1614.3	2.28 ± 0.04	135.8 ± 5.9
			1190.0	2.26 ± 0.07	130.0 ± 8.5
			1043.8	7.51 ± 0.10	117.8 ± 4.7
			987.7	16.13 ± 0.17	131.3 ± 4.7
			759.1	1.04 ± 0.05	120.4 ± 8.4
			703.5	31.1 ± 0.1	119.2 ± 4.0
			579.8	5.44 ± 0.07	114.1 ± 4.7
			570.6	4.34 ± 0.07	111.1 ± 4.4
			284.1	1.69 ± 0.02	123.4 ± 5.5
			<i>RR_{mean}</i> =		122.4 ± 4.4
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	122.4 ± 9.3
			918.3	10.8 ± 0.9	134.6 ± 12.4
			899.2	98 ± 9	121.8 ± 4.1
			670.7	11.4 ± 0.9	129.7 ± 11.7
			374.8	82 ± 5	140.6 ± 29.4
			<i>RR_{mean}</i> =		122.2 ± 3.8
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	142.1 ± 12.1
			1847.3	11.4 ± 0.8	142.7 ± 11.8
			1679.6	8.8 ± 0.7	147.2 ± 13.3
			1034.0	8.8 ± 0.5	140.7 ± 10.1
			896.8	13.1 ± 0.7	147.1 ± 9.6
			847.2	8.5 ± 0.5	145.7 ± 10.4
			820.2	29.6 ± 1.5	152.8 ± 9.3
			<i>RR_{mean}</i> =		149.3 ± 4.9
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	134.8 ± 5.4
			422.1	83.7 ± 2.5	146.3 ± 9.0
			<i>RR_{mean}</i> =		136.7 ± 6.0
²⁰¹ Bi	i	108M	629.1	24 ± 6	140.6 ± 35.7
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	139.2 ± 4.8
			374.7	89 ± 15	176.6 ± 30.5
			<i>RR_{mean}</i> =		139.4 ± 5.1
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	157.5 ± 5.4
			374.7	89 ± 15	194.3 ± 33.5
			<i>RR_{mean}</i> =		157.7 ± 5.5
²⁰³ Pb	c*	51.873H	401.3	3.35 ± 0.07	575.0 ± 23.5
			279.2	80.8 ± 0.2	596.9 ± 21.8
			<i>RR_{mean}</i> =		589.0 ± 21.0
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	153.8 ± 14.5
			490.5	9.1 ± 0.7	208.6 ± 19.0
			459.7	8.6 ± 0.7	147.6 ± 14.6
			422.1	86 ± 5	160.4 ± 11.5

Continuation of Table 72.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	162.4 ± 10.9
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	538.1 ± 53.9
			1238.8	1.18 ± 0.08	463.1 ± 42.6
			1098.5	1.83 ± 0.12	453.7 ± 42.7
			1069.9	1.14 ± 0.11	443.1 ± 50.8
			946.0	7.4 ± 0.6	485.9 ± 43.7
			907.6	5.7 ± 0.4	529.0 ± 42.9
			692.4	4.27 ± 0.16	559.5 ± 31.0
			361.3	9.9 ± 0.5	598.9 ± 37.3
			331.2	79 ± 5	597.3 ± 43.0
				<i>RR_{mean}</i> =	531.1 ± 25.5
²⁰⁰ Pb	c	21.5H	1514.9	*	484.4 ± 40.4
			1407.6	*	539.2 ± 57.4
			1362.9	*	508.3 ± 62.8
			1225.5	*	451.7 ± 33.7
			1205.7	*	492.7 ± 34.3
			886.2	*	456.4 ± 36.0
			828.3	*	472.3 ± 35.6
			701.6	*	423.0 ± 44.9
			579.3	*	427.8 ± 27.0
			450.5	3.33 ± 0.08	569.9 ± 25.4
			367.9	*	454.8 ± 15.7
			268.4	3.96 ± 0.20	607.3 ± 48.1
			235.6	4.30 ± 0.17	595.5 ± 34.5
			147.6	37.7 ± 1.4	473.6 ± 25.3
			142.3	3.16 ± 0.19	538.3 ± 39.5
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	834.5 ± 136.8
			762.0	2.2 ± 0.4	1106 ± 220
			720.2	6.5 ± 1.0	771.6 ± 122.6
			366.9	44 ± 7	919.2 ± 153.4
			353.4	9.5 ± 1.5	899.2 ± 147.0
				<i>RR_{mean}</i> =	847.9 ± 47.2
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	536.9 ± 111.1
			575.0	3.1 ± 0.7	515.4 ± 119.1
			365.4	19 ± 5	734.9 ± 195.4
			173.4	18 ± 3	673.8 ± 115.1
				<i>RR_{mean}</i> =	663.5 ± 30.3
^{197m} Pb	c*	43M	774.3	14 ± 3	366.5 ± 80.0
			695.6	9.5 ± 2.0	461.2 ± 109.1
			387.7	25 ± 6	482.6 ± 117.1
			385.9	74 ± 15	470.7 ± 96.8
			222.8	25 ± 6	373.4 ± 91.0
				<i>RR_{mean}</i> =	442.2 ± 26.8
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	424.0 ± 52.7
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	244.2 ± 45.6
			383.6	107 ± 20	237.1 ± 45.2
				<i>RR_{mean}</i> =	242.2 ± 9.6
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	173.4 ± 6.3
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	854.1 ± 31.3
²⁰⁰ Tl _{<i>i</i>}	i	26.1H	1514.9	4.0 ± 0.3	245.2 ± 23.1

Continuation of Table 72.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1407.6	1.45 ± 0.13	265.2 ± 54.3
			1362.9	3.4 ± 0.4	262.2 ± 36.3
			1225.5	3.36 ± 0.21	283.8 ± 28.5
			1205.7	29.9 ± 1.8	223.8 ± 19.1
			886.2	2.02 ± 0.13	285.2 ± 33.3
			828.3	10.8 ± 0.7	306.7 ± 26.1
			701.6	1.29 ± 0.10	390.2 ± 59.8
			579.3	13.8 ± 0.7	324.6 ± 25.7
			367.9	87.2 ± 0.4	253.0 ± 12.3
			$RR_{mean} =$		262.9 ± 13.1
$^{200}\text{Tl}_c$	c	26.1H	1514.9	4.0 ± 0.3	729.6 ± 60.3
			1407.6	1.45 ± 0.13	804.4 ± 81.9
			1362.9	3.4 ± 0.4	770.5 ± 94.7
			1225.5	3.36 ± 0.21	735.5 ± 53.3
			1205.7	29.9 ± 1.8	716.6 ± 49.8
			886.2	2.02 ± 0.13	741.6 ± 55.6
			828.3	10.8 ± 0.7	779.0 ± 57.1
			701.6	1.29 ± 0.10	813.2 ± 74.0
			579.3	13.8 ± 0.7	752.4 ± 47.1
			367.9	87.2 ± 0.4	707.7 ± 24.7
			$RR_{mean} =$		719.8 ± 24.1
^{199}Tl	c*	7.42H	750.4	1.04 ± 0.12	955.1 ± 132.1
			455.5	12.4 ± 1.4	915.5 ± 109.5
			333.9	1.76 ± 0.20	1031 ± 126
			247.3	9.3 ± 1.1	822.4 ± 102.8
			208.2	12.3 ± 1.4	816.1 ± 98.6
			158.4	5.0 ± 0.6	823.6 ± 105.3
			$RR_{mean} =$		879.3 ± 43.8
^{198m}Tl	i(m)	1.87H	587.2	52.5 ± 2.0	158.3 ± 13.0
			282.8	28 ± 3	197.9 ± 22.6
			$RR_{mean} =$		166.6 ± 17.0
^{197}Tl	c*	2.84H	1411.3	4.5 ± 1.5	687.3 ± 230.8
			152.2	7.3 ± 2.3	1023 ± 325
			134.0	2.0 ± 0.7	859.5 ± 306.3
			$RR_{mean} =$		885.9 ± 112.5
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	388.7 ± 68.1
^{195}Tl	c*	1.16H	884.5	10.0 ± 1.1	419.7 ± 49.4
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	13.27 ± 0.51
^{197}Hg	c*	64.14H	191.4	0.63 ± 0.02	810.2 ± 42.7
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	63.28 ± 2.88
^{195m}Hg	i(m)	41.6H	779.8	54.2 ± 0.1	74.33 ± 15.70
			560.3	7.0 ± 0.6	77.30 ± 7.27
			261.8	31 ± 4	84.42 ± 11.40
			$RR_{mean} =$		77.79 ± 2.40
$^{195}\text{Hg}_c$	c	9.9H	779.8	6.8 ± 0.7	576.6 ± 63.3
^{193m}Hg	i(m)	11.8H	573.2	26 ± 4	56.86 ± 9.02
			407.6	32 ± 6	86.02 ± 16.47
			$RR_{mean} =$		63.52 ± 12.39
^{192}Hg	c	4.85H	2335.7	*	302.8 ± 66.3
			316.5	*	356.0 ± 44.7

Continuation of Table 72.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁰ Hg	c*	20.0M	296.0	*	345.4 ± 49.9
			274.8	50.2 ± 2.5	278.7 ± 17.5
			<i>RR_{mean}</i> =		287.1 ± 8.9
			295.8	*	137.4 ± 13.8
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	128.0 ± 19.7
			<i>RR_{mean}</i> =		134.4 ± 4.1
			411.8	*	1.825 ± 0.274
^{198m} Au	i(m)	2.27D	411.8	*	1.825 ± 0.274
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	4.283 ± 0.518
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	6.108 ± 0.328
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	12.05 ± 1.62
			355.7	87.0 ± 0.8	11.53 ± 0.42
			333.0	22.9 ± 0.6	12.47 ± 0.59
			<i>RR_{mean}</i> =		11.69 ± 0.44
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	745.4 ± 57.9
			98.9	10.9 ± 0.9	671.5 ± 64.0
			<i>RR_{mean}</i> =		720.9 ± 41.3
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	20.89 ± 1.88
			293.6	10.4 ± 0.8	20.21 ± 2.01
			<i>RR_{mean}</i> =		20.59 ± 1.25
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	19.85 ± 3.16
			296.0	22 ± 3	45.39 ± 21.77
			<i>RR_{mean}</i> =		20.08 ± 2.49
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	375.8 ± 47.1
			296.0	22 ± 3	390.8 ± 56.2
			<i>RR_{mean}</i> =		377.2 ± 14.7
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	238.8 ± 31.0
¹⁹⁰ Au _c	c	42.8M	295.8	71 ± 5	146.1 ± 12.1
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	222.7 ± 27.1
			456.5	3.4 ± 0.4	201.1 ± 24.8
			409.4	8.0 ± 0.9	198.5 ± 23.4
			172.2	3.5 ± 0.4	212.9 ± 25.7
			<i>RR_{mean}</i> =		207.4 ± 8.9
¹⁸⁹ Pt	c	10.87H	607.6	8.10 ± 0.16	139.5 ± 6.9
			568.8	7.1 ± 0.6	143.5 ± 15.1
			544.9	5.8 ± 0.5	140.9 ± 14.1
			243.5	7.0 ± 1.2	126.2 ± 22.6
			<i>RR_{mean}</i> =		139.5 ± 6.3
¹⁸⁸ Pt	c	10.2D	1209.8	*	101.2 ± 10.8
			634.9	*	95.26 ± 15.58
			423.3	4.4 ± 0.3	93.05 ± 7.52
			381.4	7.5 ± 0.5	86.87 ± 6.55
			195.1	18.6 ± 1.2	86.76 ± 6.49
			187.6	19.4 ± 1.2	88.88 ± 6.42
			155.1	*	91.99 ± 9.78
			140.4	2.33 ± 0.15	96.85 ± 8.73
			<i>RR_{mean}</i> =		91.09 ± 2.81
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	32.27 ± 7.07
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	113.8 ± 12.5
¹⁸⁸ Ir _i	i	41.5H	634.9	5.0 ± 0.8	6.672 ± 1.724
			155.1	30 ± 3	5.021 ± 1.631

Continuation of Table 72.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	5.807 ± 1.179
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	89.61 ± 9.81
			634.9	5.0 ± 0.8	101.9 ± 16.7
			155.1	30 ± 3	97.01 ± 10.37
RR _{mean} =				94.32 ± 6.52	
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	19.26 ± 1.04
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	27.91 ± 1.93
			717.4	3.94 ± 0.16	22.99 ± 2.41
			646.1	78 ± 3	24.05 ± 1.27
RR _{mean} =				24.39 ± 1.13	
¹⁸³ Re	c	70.0D	208.8	2.95 ± 0.09	12.19 ± 2.18
			162.3	23.3 ± 0.7	9.316 ± 0.517
RR _{mean} =				9.405 ± 0.575	
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	0.9361 ± 0.0603
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	1.845 ± 0.094
			172.1	25.5 ± 0.8	2.130 ± 0.190
RR _{mean} =				1.886 ± 0.116	
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.9226 ± 0.0959
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.363 ± 0.110
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	1.577 ± 0.153
			212.2	81.4 ± 1.1	1.774 ± 0.095
RR _{mean} =				1.730 ± 0.053	
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	1.866 ± 0.133
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.624 ± 0.155
			197.3	87.0 ± 1.1	2.576 ± 0.128
RR _{mean} =				2.594 ± 0.113	
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	5.798 ± 0.484
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	8.051 ± 0.511
			884.7	72.7 ± 0.4	7.570 ± 0.317
			657.8	94.3 ± 0.3	7.195 ± 0.313
RR _{mean} =				7.459 ± 0.299	
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	32.59 ± 1.62
^{101m} Rh	c	4.34D	306.9	81 ± 5	1.185 ± 0.106
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	31.65 ± 1.19
⁹⁹ Mo	c	65.94H	739.5	12.13 ± 0.22	28.78 ± 1.70
			140.5	90.27 ± 0.33	31.76 ± 1.62
RR _{mean} =				30.45 ± 1.75	
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	16.40 ± 1.03
			849.9	20.45 ± 0.20	15.56 ± 1.26
			778.2	96.45 ± 0.22	16.59 ± 0.64
			568.9	58.0 ± 0.3	15.44 ± 0.80
			460.0	26.62 ± 0.20	16.18 ± 0.83
RR _{mean} =				16.24 ± 0.57	
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	15.70 ± 0.55
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	37.06 ± 1.24
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	6.980 ± 0.320
⁹⁵ Zr	c	64.02D	765.8	*	21.56 ± 0.76
			756.7	54.46 ± 0.10	20.92 ± 0.79
			724.2	44.17 ± 0.16	23.10 ± 0.95
RR _{mean} =				21.57 ± 0.67	

Continuation of Table 72.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	1.636 ± 0.094
^{88}Zr	c	83.4D	898.0	*	0.3411 ± 0.1806
$^{88}\text{Y}_i$	i	106.65D	898.0	93.7 ± 0.3	5.678 ± 0.247
$^{88}\text{Y}_c$	c	106.65D	898.0	93.7 ± 0.3	6.019 ± 0.224
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	2.222 ± 0.104
^{85}Sr	c	64.84D	514.0	96 ± 4	2.967 ± 0.192
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	19.54 ± 0.93
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	7.837 ± 0.455
^{83}Rb	c	86.2D	529.6	29.3 ± 2.1	3.876 ± 0.375
			520.4	45 ± 4	3.368 ± 0.423
			$RR_{mean} =$		3.683 ± 0.271
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	12.33 ± 0.67
			776.5	83.5 ± 1.2	10.87 ± 0.45
			698.4	28.5 ± 0.4	9.784 ± 0.641
			554.3	70.8 ± 1.0	10.33 ± 0.52
			$RR_{mean} =$		10.79 ± 0.52
^{75}Se	c	119.779D	136.0	58.3 ± 0.8	0.5644 ± 0.1081
^{74}As	i	17.77D	595.8	59 ± 4	1.952 ± 0.168
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	4.265 ± 0.861
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	6.067 ± 0.809
^{72}Zn	c	46.5H	2201.7	*	1.802 ± 0.239
^{59}Fe	c	44.472D	1099.2	56.5 ± 1.9	1.479 ± 0.285

12.5.5 Nuclide production rates for ^{209}Bi

Table 73: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.25 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	128.9 ± 4.8
			742.6	28.2 ± 0.5	113.3 ± 6.6
			$RR_{mean} =$		126.4 ± 6.9
^{206}Po	i	8.8D	1878.7	*	170.0 ± 11.8
			1718.7	*	166.6 ± 7.8
			1098.3	*	156.7 ± 6.6
			1032.3	33 ± 5	160.1 ± 24.8
			1018.6	*	172.1 ± 7.1
			1007.2	3.1 ± 0.4	160.3 ± 21.6
			980.2	7.1 ± 0.9	158.2 ± 20.8
			895.1	*	162.2 ± 6.0
			881.0	*	162.9 ± 6.1
			807.4	23 ± 3	150.0 ± 20.2
			803.1	*	155.1 ± 5.8
			620.5	*	169.7 ± 6.4
			537.5	*	140.6 ± 5.6
			522.5	15.7 ± 2.0	148.1 ± 19.6
			516.2	*	148.2 ± 5.7
			497.1	*	148.8 ± 7.3
			463.4	1.79 ± 0.24	159.5 ± 22.6

Continuation of Table 73.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			398.0	*	149.0 ± 5.9
			343.5	*	146.6 ± 6.0
			338.4	19.2 ± 2.5	155.3 ± 20.9
			311.6	4.2 ± 0.6	164.5 ± 24.3
			286.4	24 ± 3	158.6 ± 20.6
			184.0	*	163.6 ± 7.9
			<i>RR_{mean}</i> =		156.1 ± 4.8
²⁰⁵ Po	i	1.66H	1001.2	28.8 ± 2.2	154.2 ± 13.6
			872.4	37 ± 2	189.7 ± 12.6
			849.8	25.5 ± 2.1	175.3 ± 16.1
²⁰⁴ Po	i	3.53H	<i>RR_{mean}</i> =		183.1 ± 10.6
			1040.0	9.6 ± 0.5	177.7 ± 12.1
			1016.3	24.1 ± 1.0	168.8 ± 9.3
			899.2	*	166.3 ± 18.7
			884.0	29.9 ± 1.2	179.1 ± 9.8
			670.7	*	156.6 ± 27.4
			534.9	13.2 ± 0.8	160.7 ± 12.5
			374.8	*	188.6 ± 19.2
			270.1	27.8 ± 1.3	192.8 ± 11.9
			<i>RR_{mean}</i> =		175.2 ± 5.4
²⁰³ Po	i(m+g)	36.7M	908.6	55 ± 3	139.3 ± 10.6
²⁰² Po	i	44.7M	688.6	51 ± 6	152.8 ± 19.2
²⁰⁷ Bi	c	31.55Y	1770.2	6.87 ± 0.04	670.2 ± 44.9
			1063.7	74.5 ± 0.2	699.1 ± 24.9
			569.7	97.74 ± 0.03	659.1 ± 23.0
²⁰⁶ Bi _i	i	6.243D	<i>RR_{mean}</i> =		676.1 ± 25.0
			1878.7	2.01 ± 0.05	433.2 ± 21.7
			1718.7	31.8 ± 0.6	430.9 ± 18.0
			1595.3	5.01 ± 0.08	431.0 ± 17.5
			1098.3	13.50 ± 0.21	403.0 ± 15.2
			1018.6	7.60 ± 0.11	433.3 ± 16.2
			895.1	15.66 ± 0.23	433.4 ± 15.6
			881.0	66.2 ± 1.0	417.3 ± 15.1
			803.1	98.9 ± 1.4	405.6 ± 14.6
			537.5	30.5 ± 0.5	370.2 ± 14.1
			516.2	40.7 ± 0.6	386.0 ± 14.4
			497.1	15.31 ± 0.22	372.0 ± 14.6
			398.0	10.74 ± 0.15	376.1 ± 14.0
			343.5	23.4 ± 0.4	390.0 ± 14.9
			184.0	15.8 ± 0.4	471.7 ± 21.7
			<i>RR_{mean}</i> =		404.0 ± 14.3
²⁰⁶ Bi _c	c	6.243D	1878.7	2.01 ± 0.05	593.9 ± 26.5
			1718.7	31.8 ± 0.6	588.4 ± 23.2
			1595.3	5.01 ± 0.08	613.8 ± 23.2
			1098.3	13.50 ± 0.21	551.1 ± 20.1
			1018.6	7.60 ± 0.11	595.9 ± 21.5
			895.1	15.66 ± 0.23	586.7 ± 21.0
			881.0	66.2 ± 1.0	571.2 ± 20.5
			803.1	98.9 ± 1.4	552.2 ± 19.7
			537.5	30.5 ± 0.5	503.1 ± 19.0
			516.2	40.7 ± 0.6	526.0 ± 19.5

Continuation of Table 73.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			497.1	15.31 ± 0.22	512.7 ± 19.2
			398.0	10.74 ± 0.15	516.9 ± 18.9
			343.5	23.4 ± 0.4	528.6 ± 19.9
			184.0	15.8 ± 0.4	626.3 ± 28.7
			<i>RR_{mean}</i> =		553.5 ± 19.7
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	663.8 ± 25.9
			1775.8	3.99 ± 0.08	673.5 ± 27.6
			1764.3	32.5 ± 0.7	685.1 ± 27.7
			1614.3	2.28 ± 0.04	721.1 ± 28.0
			1551.0	0.97 ± 0.03	684.1 ± 33.6
			1351.5	1.06 ± 0.04	714.4 ± 38.1
			1190.0	2.26 ± 0.07	645.4 ± 29.8
			1043.8	7.51 ± 0.10	607.9 ± 21.6
			987.7	16.13 ± 0.17	662.1 ± 23.0
			890.2	0.68 ± 0.01	673.0 ± 41.9
			872.0	0.42 ± 0.01	665.6 ± 32.8
			759.1	1.04 ± 0.05	689.8 ± 41.3
			703.5	31.1 ± 0.1	629.1 ± 21.1
			<i>RR_{mean}</i> =		651.4 ± 22.1
²⁰⁴ Bi _i	i	11.22H	984.0	59 ± 4	457.3 ± 36.2
			918.3	10.8 ± 0.9	300.1 ± 42.0
			899.2	98 ± 9	466.3 ± 46.7
			670.7	11.4 ± 0.9	447.4 ± 47.9
			374.8	82 ± 5	439.4 ± 34.9
			<i>RR_{mean}</i> =		426.5 ± 31.2
²⁰⁴ Bi _c	c	11.22H	984.0	59 ± 4	580.7 ± 43.8
			918.3	10.8 ± 0.9	609.5 ± 55.2
			899.2	98 ± 9	631.5 ± 61.6
			670.7	11.4 ± 0.9	602.9 ± 52.1
			374.8	82 ± 5	626.8 ± 43.8
			<i>RR_{mean}</i> =		608.1 ± 26.9
²⁰³ Bi	c	11.76H	2011.0	1.76 ± 0.09	634.3 ± 44.6
			1893.0	8.2 ± 0.6	606.7 ± 49.8
			1888.0	1.94 ± 0.10	564.6 ± 38.2
			1847.3	11.4 ± 0.8	602.1 ± 47.5
			1679.6	8.8 ± 0.7	596.6 ± 52.1
			1536.5	7.5 ± 0.6	639.5 ± 56.6
			1506.7	3.7 ± 0.3	571.5 ± 51.5
			1034.0	8.8 ± 0.5	626.7 ± 41.8
			896.8	13.1 ± 0.7	603.5 ± 38.5
			847.2	8.5 ± 0.5	623.2 ± 42.3
			825.2	14.6 ± 1.1	700.4 ± 57.8
			820.2	29.6 ± 1.5	647.0 ± 39.2
			816.3	4.03 ± 0.21	626.2 ± 40.9
			722.4	4.8 ± 0.4	829.1 ± 75.3
			279.2	*	637.4 ± 25.8
			264.2	5.2 ± 0.4	702.0 ± 61.0
			<i>RR_{mean}</i> =		635.7 ± 19.6
²⁰² Bi _i	i	1.72H	960.7	99.28 ± 0.02	517.1 ± 29.5
			657.5	60.6 ± 1.8	610.2 ± 46.0
			422.1	83.7 ± 2.5	575.4 ± 27.8

Continuation of Table 73.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			<i>RR_{mean}</i> =		558.2 ± 29.3
²⁰² Bi _c	c	1.72H	960.7	99.28 ± 0.02	589.8 ± 20.7
			657.5	60.6 ± 1.8	599.1 ± 29.7
			422.1	83.7 ± 2.5	596.9 ± 27.2
			<i>RR_{mean}</i> =		592.2 ± 20.0
²⁰¹ Bi	c*	108M	1325.2	6.1 ± 1.3	491.8 ± 107.6
			936.2	11.3 ± 2.5	497.1 ± 112.1
			902.0	8.4 ± 1.8	566.4 ± 124.4
			629.1	24 ± 6	503.1 ± 127.2
			361.3	*	583.3 ± 53.5
			331.2	*	565.0 ± 42.7
			<i>RR_{mean}</i> =		567.6 ± 17.5
¹⁹⁹ Bi	c*	27M	841.7	11 ± 0	240.9 ± 19.2
^{204m} Pb	i(m)	67.2M	899.2	99.17 ± 0.02	91.83 ± 5.33
			374.7	89 ± 15	136.8 ± 24.0
			<i>RR_{mean}</i> =		93.42 ± 8.77
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	234.8 ± 16.3
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	872.1 ± 32.1
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	126.9 ± 12.2
			422.1	86 ± 5	141.3 ± 10.1
			<i>RR_{mean}</i> =		137.7 ± 7.5
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	894.4 ± 79.0
			946.0	7.4 ± 0.6	858.5 ± 75.6
			767.3	3.16 ± 0.16	978.8 ± 64.5
			692.4	4.27 ± 0.16	994.4 ± 54.4
			361.3	9.9 ± 0.5	968.2 ± 60.1
			<i>RR_{mean}</i> =		956.1 ± 38.8
²⁰⁰ Pb	c	21.5H	1604.5	*	665.2 ± 67.0
			1514.9	*	769.7 ± 65.7
			1366.3	*	743.7 ± 250.8
			1362.9	*	850.2 ± 105.0
			1225.5	*	742.7 ± 54.9
			1205.7	*	753.1 ± 52.2
			886.2	*	765.0 ± 62.0
			579.3	*	717.7 ± 48.0
			450.5	3.33 ± 0.08	844.5 ± 36.9
			257.2	4.46 ± 0.17	943.0 ± 62.1
			235.6	4.30 ± 0.17	898.7 ± 52.3
			147.6	37.7 ± 1.4	811.2 ± 49.3
			367.9	*	676.2 ± 23.8
			<i>RR_{mean}</i> =		715.3 ± 22.1
¹⁹⁹ Pb	c*	90M	1502.0	2.1 ± 0.4	1226 ± 244
			1382.7	2.9 ± 0.5	1466 ± 262
			1135.0	7.8 ± 1.2	1351 ± 217
			720.2	6.5 ± 1.0	1363 ± 220
			366.9	44 ± 7	1419 ± 234
			353.4	9.5 ± 1.5	1667 ± 274
			<i>RR_{mean}</i> =		1410 ± 67.
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	783.9 ± 163.1
			575.0	3.1 ± 0.7	788.9 ± 182.4
			365.4	19 ± 5	940.4 ± 249.7

Continuation of Table 73.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			259.5	5.8 ± 1.2	939.6 ± 198.5
			173.4	18 ± 3	940.2 ± 160.9
			<i>RR_{mean}</i> =		928.5 ± 35.4
^{197m} Pb	c*	43M	387.7	25 ± 6	514.2 ± 124.8
			385.9	74 ± 15	575.0 ± 118.3
			<i>RR_{mean}</i> =		569.8 ± 26.8
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	479.9 ± 58.4
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	247.7 ± 47.5
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	49.94 ± 1.83
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	1068 ± 41.
²⁰⁰ Tl _i	i	26.1H	579.3	13.8 ± 0.7	158.0 ± 27.4
			367.9	87.2 ± 0.4	140.6 ± 14.9
			<i>RR_{mean}</i> =		144.4 ± 13.4
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	780.1 ± 73.7
			1514.9	4.0 ± 0.3	868.8 ± 72.4
			1366.3	0.9 ± 0.3	748.1 ± 251.5
			1362.9	3.4 ± 0.4	845.1 ± 104.0
			1225.5	3.36 ± 0.21	845.4 ± 61.1
			1205.7	29.9 ± 1.8	836.0 ± 57.7
			886.2	2.02 ± 0.13	834.1 ± 63.3
			579.3	13.8 ± 0.7	875.7 ± 54.9
			367.9	87.2 ± 0.4	816.8 ± 29.5
			<i>RR_{mean}</i> =		825.1 ± 28.3
¹⁹⁹ Tl	c*	7.42H	247.3	9.3 ± 1.1	986.5 ± 123.2
			208.2	12.3 ± 1.4	1014 ± 124
			158.4	5.0 ± 0.6	1098 ± 139
			455.5	12.4 ± 1.4	957.9 ± 113.4
			<i>RR_{mean}</i> =		1003 ± 46.
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	73.56 ± 6.05
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	699.3 ± 235.0
			152.2	7.3 ± 2.3	1100 ± 349
			<i>RR_{mean}</i> =		925.9 ± 200.4
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	229.0 ± 40.5
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	403.4 ± 49.5
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	0.8965 ± 0.1222
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	666.2 ± 52.5
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	29.30 ± 3.82
^{195m} Hg	i(m)	41.6H	779.8	54.2 ± 0.1	45.08 ± 10.21
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	474.7 ± 51.5
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	41.93 ± 8.14
¹⁹² Hg	c	4.85H	316.5	*	238.2 ± 30.0
			296.0	*	248.4 ± 36.2
			274.8	50.2 ± 2.5	184.6 ± 11.6
			<i>RR_{mean}</i> =		190.5 ± 5.9
¹⁹⁰ Hg	c*	20.0M	301.8	*	120.0 ± 101.4
			295.8	*	111.6 ± 22.5
			<i>RR_{mean}</i> =		111.9 ± 21.2
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	2.704 ± 0.196
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	544.1 ± 47.3
			98.9	10.9 ± 0.9	453.8 ± 50.4

Continuation of Table 73.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	509.7 ± 46.6
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	5.294 ± 0.529
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	7.601 ± 3.863
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	245.8 ± 30.9
			296.0	22 ± 3	244.5 ± 35.1
			RR _{mean} =		245.7 ± 9.7
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	134.6 ± 11.2
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	172.2 ± 64.8
			295.8	71 ± 5	96.26 ± 13.30
			RR _{mean} =		98.75 ± 13.88
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	136.6 ± 16.9
			456.5	3.4 ± 0.4	134.1 ± 17.1
			409.4	8.0 ± 0.9	126.1 ± 15.0
			359.9	6.0 ± 0.7	125.4 ± 16.1
			351.2	3.4 ± 0.4	151.2 ± 19.5
			172.2	3.5 ± 0.4	135.1 ± 18.0
			RR _{mean} =		132.9 ± 5.6
¹⁸⁹ Pt	c	10.87H	243.5	7.0 ± 1.2	79.29 ± 14.68
¹⁸⁸ Pt	c	10.2D	478.0	*	40.77 ± 2.38
			381.4	7.5 ± 0.5	47.32 ± 3.84
			195.1	18.6 ± 1.2	43.09 ± 3.27
			187.6	19.4 ± 1.2	41.55 ± 3.05
			155.1	*	45.37 ± 4.87
RR _{mean} =		42.15 ± 1.30			
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	65.77 ± 7.23
¹⁸⁸ Ir _c	c	41.5H	2214.6	18.7 ± 1.6	31.17 ± 3.02
			2059.6	7.1 ± 0.6	35.39 ± 4.50
			478.0	14.7 ± 0.6	39.34 ± 6.07
RR _{mean} =		33.23 ± 2.30			
¹⁸⁵ Os	c	93.6D	646.1	78 ± 3	10.45 ± 0.56
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	3.653 ± 0.261
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.416 ± 0.084
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	4.378 ± 0.191
			172.1	25.5 ± 0.8	4.473 ± 0.358
RR _{mean} =		4.391 ± 0.182			
¹²⁶ I	i	13.11D	388.6	34 ± 3	5.091 ± 0.545
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	5.438 ± 0.264
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	4.289 ± 0.214
			212.2	81.4 ± 1.1	4.435 ± 0.232
RR _{mean} =		4.354 ± 0.134			
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	3.154 ± 0.230
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	2.095 ± 0.219
¹²² Sb	i(m+g)	2.7238D	564.2	70.67 ± 0.18	5.918 ± 0.302
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	6.976 ± 0.513
			197.3	87.0 ± 1.1	6.686 ± 0.282
RR _{mean} =		6.728 ± 0.273			
^{117m} Sn	i(m)	13.60D	158.6	86.4 ± 0.4	10.20 ± 0.55
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	12.01 ± 0.69
¹¹¹ In	c	2.8047D	245.4	94 ± 1	1.790 ± 0.208
¹¹⁵ Cd	c	53.46H	336.2	45.9 ± 1.0	7.164 ± 0.440

Continuation of Table 73.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{110m} Ag	i(m)	249.76D	1505.0	13.60 ± 0.19	16.66 ± 1.04
			1384.3	24.9 ± 0.8	18.31 ± 1.01
			937.5	34.2 ± 0.6	16.98 ± 0.92
			884.7	72.7 ± 0.4	16.35 ± 0.58
			763.9	22.62 ± 0.21	16.22 ± 0.99
			657.8	94.3 ± 0.3	16.19 ± 0.56
<i>RR_{mean}</i> =				16.40 ± 0.54	
^{106m} Ag	i(m)	8.28D	451.0	28.2 ± 0.8	1.829 ± 0.281
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	69.77 ± 3.41
			306.1	5.1 ± 0.4	57.82 ± 6.33
<i>RR_{mean}</i> =				68.32 ± 4.44	
^{102m} Rh	i(m)	2.9Y	631.3	56 ± 2	6.361 ± 1.563
			475.1	95 ± 4	5.905 ± 0.506
<i>RR_{mean}</i> =				5.944 ± 0.488	
^{101m} Rh	c	4.34D	306.9	81 ± 5	2.209 ± 0.205
¹⁰⁶ Ru	c	373.59D	621.9(D)	9.93 ± 0.23	24.57 ± 1.58
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	67.77 ± 2.57
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	1.874 ± 0.197
⁹⁹ Mo	c	65.94H	181.1	5.99 ± 0.12	63.63 ± 3.39
			140.5	90.27 ± 0.33	68.71 ± 3.63
<i>RR_{mean}</i> =				66.00 ± 3.25	
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	36.14 ± 1.96
			849.9	20.45 ± 0.20	32.32 ± 1.89
			778.2	96.45 ± 0.22	34.31 ± 1.25
			568.9	58.0 ± 0.3	32.95 ± 1.41
			460.0	26.62 ± 0.20	33.23 ± 1.51
<i>RR_{mean}</i> =				33.82 ± 1.15	
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	33.61 ± 1.12
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	76.16 ± 2.50
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	18.62 ± 0.85
⁹⁵ Zr	c	64.02D	765.8	*	42.94 ± 1.43
			756.7	54.46 ± 0.10	41.85 ± 1.50
			724.2	44.17 ± 0.16	44.66 ± 1.55
<i>RR_{mean}</i> =				42.99 ± 1.33	
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	3.302 ± 0.266
⁸⁸ Zr	c	83.4D	898.0	*	0.5869 ± 0.3732
^{90m} Y	i(m)	3.19H	202.5	97.3 ± 0.4	32.09 ± 1.39
⁸⁸ Y _i	i	106.65D	898.0	93.7 ± 0.3	10.96 ± 0.48
⁸⁸ Y _c	c	106.65D	898.0	93.7 ± 0.3	11.55 ± 0.44
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	4.767 ± 0.263
			388.5	82.1 ± 0.5	4.776 ± 0.267
<i>RR_{mean}</i> =				4.771 ± 0.213	
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	5.134 ± 0.376
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	34.41 ± 1.41
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	13.15 ± 0.86
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	5.447 ± 0.707
			529.6	29.3 ± 2.1	6.675 ± 0.683
			520.4	45 ± 4	6.460 ± 0.726
<i>RR_{mean}</i> =				6.242 ± 0.418	
⁸² Br	i(m+g)	35.30H	776.5	83.5 ± 1.2	20.78 ± 0.83

Continuation of Table 73.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			698.4	28.5 ± 0.4	19.80 ± 1.14
			554.3	70.8 ± 1.0	20.45 ± 0.91
			$RR_{mean} =$		20.54 ± 0.73
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	1.484 ± 0.308
			136.0	58.3 ± 0.8	0.9914 ± 0.0952
			$RR_{mean} =$		1.031 ± 0.138
^{74}As	i	17.77D	595.8	59 ± 4	3.735 ± 0.470
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	2.093 ± 0.240
^7Be	i	53.29D	477.6	10.52 ± 0.06	8.818 ± 0.959

12.5.6 Nuclide production rates for ^{27}Al

Table 74: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.25 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	9.362 ± 0.356
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.9740 ± 0.0550
			1014.4	28.0 ± 0.4	1.007 ± 0.095
			$RR_{mean} =$		0.9810 ± 0.0509
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	78.48 ± 2.66
^{24}Na	c	14.9590H	1369.0	100 ± 0	56.10 ± 1.88
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.491 ± 0.083
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	12.58 ± 0.48
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	1.186 ± 0.069
			1014.4	28.0 ± 0.4	1.046 ± 0.120
			$RR_{mean} =$		1.158 ± 0.067
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	104.9 ± 3.6
^{24}Na	c	14.9590H	1369.0	100 ± 0	74.42 ± 2.47
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.829 ± 0.095
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	9.009 ± 0.365
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.9677 ± 0.0546
			1014.4	28.0 ± 0.4	0.8547 ± 0.0883
			$RR_{mean} =$		0.9420 ± 0.0556
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	76.73 ± 2.63
^{24}Na	c	14.9590H	1369.0	100 ± 0	54.04 ± 1.80
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.356 ± 0.080
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	12.47 ± 0.46
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	1.179 ± 0.100
			1014.4	28.0 ± 0.4	1.082 ± 0.261

Continuation of Table 74.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$RR_{mean} =$					1.168 $\pm$ 0.095
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	103.8 $\pm$ 3.6
^{24}Na	c	14.9590H	1369.0	100 ± 0	73.36 $\pm$ 2.44
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.755 $\pm$ 0.092
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	14.94 $\pm$ 0.58
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.255 ± 0.117
			1014.4	28.0 ± 0.4	2.216 ± 0.223
$RR_{mean} =$					2.249 $\pm$ 0.111
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	123.9 $\pm$ 4.2
^{24}Na	c	14.9590H	1369.0	100 ± 0	88.37 $\pm$ 2.94
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	3.117 $\pm$ 0.105

12.6 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.4$ GeV

12.6.1 Nuclide production rates for ^{206}Pb

Table 75: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.4$ GeV, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	13.95 ± 0.76
			1098.3	13.50 ± 0.21	10.92 ± 0.93
			895.1	15.66 ± 0.23	16.30 ± 1.33
			881.0	66.2 ± 1.0	16.44 ± 0.96
			803.1	98.9 ± 1.4	14.09 ± 0.52
			620.5	5.76 ± 0.09	17.01 ± 1.67
			537.5	30.5 ± 0.5	13.06 ± 1.07
			516.2	40.7 ± 0.6	13.63 ± 0.65
			497.1	15.31 ± 0.22	14.77 ± 1.03
			398.0	10.74 ± 0.15	14.19 ± 0.84
			343.5	23.4 ± 0.4	14.00 ± 0.76
			$RR_{mean} =$		14.07 ± 0.54
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	46.49 ± 3.46
			1861.7	6.17 ± 0.10	46.01 ± 3.91
			1775.8	3.99 ± 0.08	56.58 ± 4.04
			1764.3	32.5 ± 0.7	47.17 ± 2.35
			1614.3	2.28 ± 0.04	55.91 ± 6.19
			1190.0	2.26 ± 0.07	51.66 ± 4.12
			1043.8	7.51 ± 0.10	41.22 ± 1.85
			703.5	31.1 ± 0.1	45.25 ± 1.56
			570.6	4.34 ± 0.07	44.92 ± 2.14
			284.1	1.69 ± 0.02	51.64 ± 4.47
			$RR_{mean} =$		45.35 ± 1.67
^{204}Bi	i	11.22H	984.0	59 ± 4	66.68 ± 5.17
			918.3	10.8 ± 0.9	77.95 ± 7.73
			899.2	98 ± 9	62.13 ± 2.14
			670.7	11.4 ± 0.9	65.73 ± 6.43
			374.8	82 ± 5	68.73 ± 14.38
			$RR_{mean} =$		62.55 ± 1.93
^{203}Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	92.16 ± 8.12
			1847.3	11.4 ± 0.8	82.36 ± 7.35
			1679.6	8.8 ± 0.7	74.88 ± 7.43
			896.8	13.1 ± 0.7	81.76 ± 5.93
			820.2	29.6 ± 1.5	87.65 ± 5.55
			$RR_{mean} =$		85.59 ± 3.32
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	70.88 ± 3.70
			422.1	83.7 ± 2.5	79.22 ± 6.91
			$RR_{mean} =$		72.35 ± 3.88
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	95.03 ± 3.55
			374.7	89 ± 15	111.2 ± 19.3
			$RR_{mean} =$		95.20 ± 3.55
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	104.3 ± 3.8
			374.7	89 ± 15	119.8 ± 20.7

Continuation of Table 75.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			<i>RR_{mean}</i> =		104.5 ± 3.8
²⁰³ Pb	c*	51.873H	401.3	3.35 ± 0.07	408.2 ± 16.5
			279.2	80.8 ± 0.2	418.2 ± 15.3
			<i>RR_{mean}</i> =		414.6 ± 14.3
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	98.77 ± 9.49
			459.7	8.6 ± 0.7	82.69 ± 12.05
			422.1	86 ± 5	110.8 ± 8.3
			<i>RR_{mean}</i> =		104.1 ± 7.5
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	396.4 ± 37.8
			1238.8	1.18 ± 0.08	351.6 ± 44.3
			1098.5	1.83 ± 0.12	300.5 ± 27.6
			946.0	7.4 ± 0.6	380.9 ± 34.0
			907.6	5.7 ± 0.4	414.3 ± 34.7
			692.4	4.27 ± 0.16	359.4 ± 20.8
			331.2	79 ± 5	406.2 ± 29.2
			<i>RR_{mean}</i> =		367.7 ± 18.5
²⁰⁰ Pb	c	21.5H	1514.9	*	278.2 ± 23.9
			1407.6	*	311.7 ± 36.7
			1362.9	*	276.3 ± 35.0
			1225.5	*	269.0 ± 21.4
			1205.7	*	317.6 ± 21.9
			828.3	*	289.0 ± 22.8
			701.6	*	279.4 ± 32.4
			579.3	*	269.7 ± 18.2
			367.9	*	293.7 ± 10.3
			147.6	37.7 ± 1.4	325.3 ± 17.4
			<i>RR_{mean}</i> =		294.0 ± 9.1
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	486.6 ± 79.9
			366.9	44 ± 7	564.7 ± 92.5
			353.4	9.5 ± 1.5	579.2 ± 99.7
			<i>RR_{mean}</i> =		533.1 ± 33.9
¹⁹⁸ Pb	c	2.4H	365.4	19 ± 5	525.1 ± 140.6
			865.3	5.9 ± 1.2	322.8 ± 68.5
			173.4	18 ± 3	453.6 ± 78.0
			<i>RR_{mean}</i> =		442.9 ± 30.4
^{197m} Pb	c*	43M	387.7	25 ± 6	323.6 ± 78.6
			385.9	74 ± 15	318.9 ± 65.7
			222.8	25 ± 6	273.3 ± 66.8
			<i>RR_{mean}</i> =		315.1 ± 14.8
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	327.1 ± 40.7
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	175.6 ± 33.2
			383.6	107 ± 20	170.8 ± 32.6
			<i>RR_{mean}</i> =		173.5 ± 7.7
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	149.8 ± 5.4
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	613.5 ± 22.6
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	295.2 ± 26.9
			1407.6	1.45 ± 0.13	418.9 ± 51.3
			1362.9	3.4 ± 0.4	354.5 ± 46.5
			1225.5	3.36 ± 0.21	318.9 ± 29.2
			1205.7	29.9 ± 1.8	208.5 ± 15.1
			828.3	10.8 ± 0.7	345.0 ± 27.5

Continuation of Table 75.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			701.6	1.29 ± 0.10	306.8 ± 50.3
			579.3	13.8 ± 0.7	270.4 ± 25.0
			367.9	87.2 ± 0.4	228.4 ± 10.4
			$RR_{mean} =$		246.5 ± 17.5
$^{200}\text{Tl}_c$	c	26.1H	1514.9	4.0 ± 0.3	573.4 ± 47.5
			1407.6	1.45 ± 0.13	730.6 ± 71.6
			1362.9	3.4 ± 0.4	630.9 ± 77.7
			1225.5	3.36 ± 0.21	587.9 ± 42.9
			1205.7	29.9 ± 1.8	526.1 ± 36.2
			828.3	10.8 ± 0.7	634.0 ± 46.4
			701.6	1.29 ± 0.10	586.2 ± 54.9
			579.3	13.8 ± 0.7	540.0 ± 34.9
			367.9	87.2 ± 0.4	522.1 ± 18.2
			$RR_{mean} =$		534.5 ± 20.2
^{199}Tl	c*	7.42H	247.3	9.3 ± 1.1	624.1 ± 78.4
			208.2	12.3 ± 1.4	626.3 ± 76.5
			158.4	5.0 ± 0.6	830.4 ± 108.8
			$RR_{mean} =$		660.4 ± 58.3
^{198m}Tl	i(m)	1.87H	587.2	52.5 ± 2.0	204.8 ± 14.3
			282.8	28 ± 3	222.0 ± 25.8
			$RR_{mean} =$		207.6 ± 11.5
^{197}Tl	c*	2.84H	1411.3	4.5 ± 1.5	569.6 ± 191.7
			152.2	7.3 ± 2.3	877.4 ± 280.3
			134.0	2.0 ± 0.7	812.8 ± 291.4
			$RR_{mean} =$		742.6 ± 106.4
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	393.9 ± 69.0
^{195}Tl	c*	1.16H	884.5	10.0 ± 1.1	427.4 ± 53.1
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	8.281 ± 0.359
^{197}Hg	c*	64.14H	191.4	0.63 ± 0.02	679.7 ± 36.4
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	74.78 ± 3.37
^{195m}Hg	i(m)	41.6H	779.8	54.2 ± 0.1	89.22 ± 18.39
			560.3	7.0 ± 0.6	103.2 ± 9.7
			261.8	31 ± 4	104.9 ± 14.1
			$RR_{mean} =$		100.8 ± 3.1
$^{195}\text{Hg}_c$	c	9.9H	779.8	6.8 ± 0.7	568.5 ± 62.7
^{193m}Hg	i(m)	11.8H	573.2	26 ± 4	88.49 ± 14.07
			407.6	32 ± 6	122.6 ± 23.4
			$RR_{mean} =$		97.44 ± 15.30
^{192}Hg	c	4.85H	2335.7	*	424.0 ± 83.8
			2236.9	*	477.2 ± 80.8
			316.5	*	536.0 ± 67.4
			296.0	*	525.7 ± 74.6
			274.8	50.2 ± 2.5	425.9 ± 26.8
			$RR_{mean} =$		437.8 ± 13.5
^{190}Hg	c*	20.0M	301.8	*	288.7 ± 47.1
			295.8	*	297.2 ± 26.9
			142.6	68 ± 10	309.1 ± 47.7
			$RR_{mean} =$		298.6 ± 9.2
^{198m}Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.085 ± 0.239
			411.8	*	1.826 ± 0.247

Continuation of Table 75.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	1.962 ± 0.061
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	5.314 ± 0.435
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	7.139 ± 0.304
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	14.67 ± 2.17
			355.7	87.0 ± 0.8	14.95 ± 0.55
			333.0	22.9 ± 0.6	15.44 ± 0.75
			RR _{mean} =		15.04 ± 0.52
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	658.6 ± 56.3
			98.9	10.9 ± 0.9	563.4 ± 55.4
			RR _{mean} =		616.4 ± 51.0
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	31.57 ± 2.81
			293.6	10.4 ± 0.8	29.70 ± 2.62
			RR _{mean} =		30.56 ± 1.73
¹⁹² Au _i	i(m+g)	4.94H	2335.7	1.7 ± 0.3	175.2 ± 94.9
			2236.9	5.6 ± 0.9	20.10 ± 26.42
			316.5	58 ± 7	43.13 ± 6.64
			296.0	22 ± 3	85.26 ± 24.57
			RR _{mean} =		44.15 ± 5.80
¹⁹² Au _c	c	4.94H	2335.7	1.7 ± 0.3	599.2 ± 125.3
			2236.9	5.6 ± 0.9	497.3 ± 84.0
			316.5	58 ± 7	579.1 ± 72.7
			296.0	22 ± 3	611.0 ± 87.1
			RR _{mean} =		578.0 ± 22.4
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	419.7 ± 22.9
			293.5	2.84 ± 0.19	354.8 ± 32.0
			166.5	3.32 ± 0.24	494.0 ± 46.0
			RR _{mean} =		412.5 ± 31.5
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	348.8 ± 33.0
			295.8	71 ± 5	359.8 ± 28.9
			RR _{mean} =		356.0 ± 17.9
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	418.3 ± 51.0
			456.5	3.4 ± 0.4	379.2 ± 46.6
			409.4	8.0 ± 0.9	373.6 ± 44.0
			351.2	3.4 ± 0.4	399.9 ± 50.7
			172.2	3.5 ± 0.4	418.6 ± 51.9
			RR _{mean} =		394.1 ± 16.5
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	460.1 ± 43.7
			607.6	8.10 ± 0.16	372.1 ± 15.6
			568.8	7.1 ± 0.6	379.0 ± 35.7
			544.9	5.8 ± 0.5	403.9 ± 38.6
			243.5	7.0 ± 1.2	385.9 ± 68.1
			RR _{mean} =		379.1 ± 15.3
¹⁸⁸ Pt	c	10.2D	1209.8	*	327.1 ± 35.1
			634.9	*	341.1 ± 56.0
			633.0	*	345.8 ± 58.8
			478.0	*	311.4 ± 17.0
			423.3	4.4 ± 0.3	321.3 ± 24.8
			381.4	7.5 ± 0.5	305.3 ± 22.8
			322.9	*	297.8 ± 29.8
			195.1	18.6 ± 1.2	309.9 ± 23.2
			187.6	19.4 ± 1.2	317.4 ± 22.9

Continuation of Table 75.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			155.1	*	326.9 ± 34.7
			140.4	2.33 ± 0.15	322.0 ± 25.1
			<i>RR_{mean}</i> =		313.5 ± 9.7
¹⁸⁷ Pt	c	2.35H	304.8	4.3 ± 1.0	191.2 ± 47.3
			106.4	8.8 ± 1.8	234.7 ± 50.4
			<i>RR_{mean}</i> =		224.4 ± 19.7
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	209.0 ± 45.4
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	164.6 ± 33.2
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	1.110 ± 0.498
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	301.7 ± 41.9
			245.1	6.0 ± 0.6	315.8 ± 34.0
			<i>RR_{mean}</i> =		314.7 ± 12.4
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	8.474 ± 2.810
			478.0	14.7 ± 0.6	13.00 ± 5.68
			155.1	30 ± 3	9.178 ± 2.033
			<i>RR_{mean}</i> =		9.247 ± 1.575
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	322.0 ± 34.7
			634.9	5.0 ± 0.8	344.1 ± 56.5
			633.0	18 ± 3	354.3 ± 60.3
			478.0	14.7 ± 0.6	324.4 ± 18.0
			322.9	1.62 ± 0.15	294.2 ± 29.6
			155.1	30 ± 3	336.1 ± 35.7
			<i>RR_{mean}</i> =		323.5 ± 11.8
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	316.8 ± 20.3
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	101.7 ± 7.9
			434.8	33.9 ± 1.1	109.3 ± 5.7
			137.2	41.4 ± 0.7	120.7 ± 5.6
			<i>RR_{mean}</i> =		113.5 ± 6.2
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	166.3 ± 25.7
			254.2	13.3 ± 2.4	139.7 ± 26.2
			<i>RR_{mean}</i> =		161.0 ± 11.8
¹⁸⁴ Ir	c*	3.09H	841.3	8.0 ± 0.8	192.9 ± 22.7
			264.0	68 ± 4	182.5 ± 13.1
			119.8	31 ± 3	175.4 ± 19.0
			<i>RR_{mean}</i> =		182.5 ± 7.5
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	134.7 ± 35.0
¹⁸⁵ Os	c	93.6D	880.5	5.17 ± 0.21	215.7 ± 15.4
			874.8	6.29 ± 0.25	212.4 ± 11.4
			717.4	3.94 ± 0.16	211.5 ± 11.9
			646.1	78 ± 3	202.2 ± 10.3
			<i>RR_{mean}</i> =		206.1 ± 7.0
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	84.86 ± 4.34
			1101.9	49.0 ± 1.3	83.34 ± 3.87
			<i>RR_{mean}</i> =		83.88 ± 3.07
¹⁸² Os	c	22.10H	1221.5	*	141.5 ± 10.4
			1189.2	*	139.7 ± 10.6
			1121.4	*	137.4 ± 8.5
			180.2	33.5 ± 1.7	132.5 ± 9.0
			<i>RR_{mean}</i> =		136.2 ± 4.2
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	71.00 ± 4.50

Continuation of Table 75.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	144.5 ± 10.7
			208.8	2.95 ± 0.09	148.4 ± 7.7
			162.3	23.3 ± 0.7	149.2 ± 7.1
			<i>RR_{mean}</i> =		148.4 ± 5.6
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	128.5 ± 9.7
			1189.2	15 ± 1	149.0 ± 11.6
			1121.4	31.8 ± 1.6	148.8 ± 9.5
			<i>RR_{mean}</i> =		142.6 ± 8.0
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	91.97 ± 20.78
			365.5	56 ± 8	98.81 ± 14.60
			<i>RR_{mean}</i> =		96.93 ± 10.50
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	17.97 ± 0.90
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	9.216 ± 0.770
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	3.934 ± 0.239
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.132 ± 0.100
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	4.033 ± 0.198
			172.1	25.5 ± 0.8	3.496 ± 0.487
			<i>RR_{mean}</i> =		3.983 ± 0.199
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.8145 ± 0.0793
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.888 ± 0.140
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	3.463 ± 0.162
			573.1	88.6 ± 0.1	3.144 ± 0.251
			<i>RR_{mean}</i> =		3.394 ± 0.105
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	5.404 ± 0.293
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	3.566 ± 0.145
			197.3	87.0 ± 1.1	4.033 ± 0.259
			<i>RR_{mean}</i> =		3.635 ± 0.200
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.169 ± 0.212
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	11.00 ± 0.55
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	11.30 ± 0.61
			884.7	72.7 ± 0.4	10.52 ± 0.41
			657.8	94.3 ± 0.3	10.03 ± 0.47
			<i>RR_{mean}</i> =		10.49 ± 0.43
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	3.803 ± 0.422
			717.3	28.9 ± 0.8	2.453 ± 0.453
			451.0	28.2 ± 0.8	3.891 ± 0.289
			<i>RR_{mean}</i> =		3.590 ± 0.412
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	36.89 ± 1.82
¹⁰² Rh	i	207D	475.1	46 ± 5	4.767 ± 0.685
^{101m} Rh	c	4.34D	306.9	81 ± 5	5.514 ± 0.413
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	36.62 ± 1.37
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	4.137 ± 0.275
			812.5	82 ± 4	4.290 ± 0.266
			<i>RR_{mean}</i> =		4.218 ± 0.212
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	35.60 ± 1.46
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	23.23 ± 1.18
			778.2	96.45 ± 0.22	22.76 ± 0.93
			568.9	58.0 ± 0.3	21.64 ± 0.88
			460.0	26.62 ± 0.20	23.11 ± 1.05
			<i>RR_{mean}</i> =		22.49 ± 0.79

Continuation of Table 75.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	25.70 ± 0.87
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	47.38 ± 1.57
^{92m}Nb	i(m)	10.15D	934.4	99.07 ± 0.04	2.113 ± 0.134
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	5.637 ± 0.333
^{95}Zr	c	64.02D	765.8	*	21.88 ± 0.76
			756.7	54.46 ± 0.10	21.17 ± 0.76
			724.2	44.17 ± 0.16	21.97 ± 1.03
			$RR_{\text{mean}} =$		21.61 ± 0.67
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	7.465 ± 0.298
^{88}Zr	c	83.4D	392.9	97.24 ± 0.00	2.467 ± 0.213
			1836.1	*	2.504 ± 0.089
			898.0	*	2.779 ± 0.354
			$RR_{\text{mean}} =$		2.507 ± 0.077
^{90m}Y	i(m)	3.19H	479.5	90.74 ± 0.05	26.73 ± 1.57
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	16.26 ± 0.57
			898.0	93.7 ± 0.3	14.98 ± 0.58
			$RR_{\text{mean}} =$		15.80 ± 0.78
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	18.77 ± 0.65
			898.0	93.7 ± 0.3	17.76 ± 0.61
			$RR_{\text{mean}} =$		18.22 ± 0.75
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	9.655 ± 0.348
^{85}Sr	c	64.84D	514.0	96 ± 4	10.96 ± 0.60
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	33.17 ± 1.78
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	17.33 ± 1.45
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	13.19 ± 1.42
			529.6	29.3 ± 2.1	13.66 ± 1.21
			520.4	45 ± 4	11.92 ± 1.18
			$RR_{\text{mean}} =$		12.93 ± 0.68
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	18.24 ± 1.20
			776.5	83.5 ± 1.2	16.02 ± 0.66
			698.4	28.5 ± 0.4	16.34 ± 0.83
			554.3	70.8 ± 1.0	15.52 ± 0.68
			$RR_{\text{mean}} =$		16.05 ± 0.62
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	2.913 ± 0.157
			136.0	58.3 ± 0.8	2.927 ± 0.159
			$RR_{\text{mean}} =$		2.920 ± 0.129
^{74}As	i	17.77D	595.8	59 ± 4	6.622 ± 0.533
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	6.633 ± 1.050
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	9.097 ± 0.976
^{72}Zn	c	46.5H	2201.7	*	2.465 ± 0.292
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	2.863 ± 0.399
			1099.2	56.5 ± 1.9	2.471 ± 0.209
			$RR_{\text{mean}} =$		2.547 ± 0.187

12.6.2 Nuclide production rates for ^{207}Pb

Table 76: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 0.4$ GeV, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	25.18 ± 4.41
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	26.10 ± 1.14
			1098.3	13.50 ± 0.21	24.03 ± 1.72
			895.1	15.66 ± 0.23	27.85 ± 1.18
			881.0	66.2 ± 1.0	23.57 ± 1.08
			803.1	98.9 ± 1.4	23.96 ± 0.87
			620.5	5.76 ± 0.09	22.57 ± 1.16
			537.5	30.5 ± 0.5	22.21 ± 0.95
			516.2	40.7 ± 0.6	23.46 ± 1.01
			497.1	15.31 ± 0.22	23.63 ± 1.27
			398.0	10.74 ± 0.15	20.89 ± 0.91
			343.5	23.4 ± 0.4	23.03 ± 0.96
			184.0	15.8 ± 0.4	28.23 ± 1.61
			$RR_{mean} =$		23.69 ± 0.92
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	54.32 ± 2.77
			1775.8	3.99 ± 0.08	52.61 ± 3.04
			1764.3	32.5 ± 0.7	50.29 ± 2.15
			1614.3	2.28 ± 0.04	54.45 ± 4.28
			1190.0	2.26 ± 0.07	47.95 ± 4.28
			1043.8	7.51 ± 0.10	46.84 ± 2.32
			703.5	31.1 ± 0.1	47.69 ± 1.61
			570.6	4.34 ± 0.07	47.34 ± 2.37
			284.1	1.69 ± 0.02	48.46 ± 3.75
			$RR_{mean} =$		48.53 ± 1.65
^{204}Bi	i	11.22H	984.0	59 ± 4	50.12 ± 3.83
			918.3	10.8 ± 0.9	54.46 ± 5.43
			899.2	98 ± 9	47.36 ± 1.62
			670.7	11.4 ± 0.9	48.78 ± 4.37
			374.8	82 ± 5	53.98 ± 11.27
			$RR_{mean} =$		47.61 ± 1.47
^{203}Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	52.77 ± 4.79
			1847.3	11.4 ± 0.8	58.45 ± 4.89
			1679.6	8.8 ± 0.7	56.64 ± 5.31
			896.8	13.1 ± 0.7	58.35 ± 4.06
			820.2	29.6 ± 1.5	59.54 ± 3.77
			$RR_{mean} =$		58.53 ± 2.06
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	50.49 ± 2.53
			422.1	83.7 ± 2.5	46.41 ± 2.93
			$RR_{mean} =$		48.95 ± 2.49
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	76.03 ± 2.78
			374.7	89 ± 15	86.18 ± 14.87
			$RR_{mean} =$		76.13 ± 2.78
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	83.13 ± 2.98
			374.7	89 ± 15	92.95 ± 16.02
			$RR_{mean} =$		83.22 ± 2.98
^{203}Pb	c*	51.873H	401.3	3.35 ± 0.07	259.2 ± 11.8
			279.2	80.8 ± 0.2	278.8 ± 10.2
			$RR_{mean} =$		273.2 ± 12.2

Continuation of Table 76.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	72.25 ± 6.89
			459.7	8.6 ± 0.7	71.76 ± 7.01
			422.1	86 ± 5	84.87 ± 5.86
			<i>RR_{mean}</i> =		80.34 ± 5.00
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	243.2 ± 22.2
			1238.8	1.18 ± 0.08	224.0 ± 25.5
			1098.5	1.83 ± 0.12	210.4 ± 25.7
			946.0	7.4 ± 0.6	238.6 ± 21.2
			907.6	5.7 ± 0.4	253.2 ± 20.1
			692.4	4.27 ± 0.16	226.0 ± 13.3
			331.2	79 ± 5	260.4 ± 18.7
			<i>RR_{mean}</i> =		236.8 ± 9.9
²⁰⁰ Pb	c	21.5H	1514.9	*	209.7 ± 18.0
			1407.6	*	279.5 ± 34.0
			1362.9	*	214.3 ± 26.9
			1225.5	*	176.7 ± 13.1
			1205.7	*	207.9 ± 14.4
			828.3	*	192.6 ± 16.2
			701.6	*	138.3 ± 15.2
			579.3	*	184.9 ± 12.0
			367.9	*	195.7 ± 6.9
			147.6	37.7 ± 1.4	217.2 ± 11.7
			<i>RR_{mean}</i> =		198.8 ± 6.1
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	334.4 ± 53.9
			366.9	44 ± 7	371.1 ± 61.2
			353.4	9.5 ± 1.5	409.3 ± 68.4
¹⁹⁸ Pb	c	2.4H	<i>RR_{mean}</i> =		362.2 ± 23.8
			365.4	19 ± 5	412.9 ± 110.5
			865.3	5.9 ± 1.2	219.3 ± 46.3
			173.4	18 ± 3	290.7 ± 49.8
^{197m} Pb	c*	43M	<i>RR_{mean}</i> =		286.7 ± 17.2
			387.7	25 ± 6	217.1 ± 52.9
			385.9	74 ± 15	210.1 ± 43.4
			222.8	25 ± 6	184.9 ± 45.3
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	211.6 ± 26.1
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	112.2 ± 21.2
			383.6	107 ± 20	110.4 ± 21.1
²⁰² Tl	c	12.23D	<i>RR_{mean}</i> =		111.4 ± 5.0
			439.6	91.4 ± 1.0	106.4 ± 3.8
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	418.8 ± 15.4
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	151.3 ± 14.8
			1407.6	1.45 ± 0.13	130.5 ± 38.3
			1362.9	3.4 ± 0.4	178.7 ± 24.2
			1225.5	3.36 ± 0.21	207.8 ± 16.0
			1205.7	29.9 ± 1.8	144.4 ± 10.3
			828.3	10.8 ± 0.7	224.5 ± 18.8
			701.6	1.29 ± 0.10	268.4 ± 28.4
			579.3	13.8 ± 0.7	167.9 ± 13.3
			367.9	87.2 ± 0.4	155.6 ± 7.2

Continuation of Table 76.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁰ Tl _c	c	26.1H		$RR_{mean} =$	163.7 ± 10.2
			1514.9	4.0 ± 0.3	361.0 ± 29.9
			1407.6	1.45 ± 0.13	410.0 ± 43.0
			1362.9	3.4 ± 0.4	393.0 ± 48.3
			1225.5	3.36 ± 0.21	384.6 ± 27.4
			1205.7	29.9 ± 1.8	352.3 ± 24.2
			828.3	10.8 ± 0.7	417.0 ± 30.6
			701.6	1.29 ± 0.10	406.6 ± 35.3
			579.3	13.8 ± 0.7	352.7 ± 22.0
			367.9	87.2 ± 0.4	351.3 ± 12.2
¹⁹⁹ Tl	c*	7.42H		$RR_{mean} =$	357.2 ± 12.4
			247.3	9.3 ± 1.1	407.5 ± 51.1
			208.2	12.3 ± 1.4	417.8 ± 50.4
			158.4	5.0 ± 0.6	540.0 ± 68.7
^{198m} Tl	i(m)	1.87H		$RR_{mean} =$	437.6 ± 38.0
			587.2	52.5 ± 2.0	128.7 ± 9.4
			282.8	28 ± 3	153.2 ± 17.5
¹⁹⁷ Tl	c*	2.84H		$RR_{mean} =$	132.8 ± 10.0
			1411.3	4.5 ± 1.5	342.3 ± 115.2
			152.2	7.3 ± 2.3	534.1 ± 169.5
			134.0	2.0 ± 0.7	501.1 ± 179.2
^{196m} Tl	i(m)	1.41H		$RR_{mean} =$	459.6 ± 65.8
			695.4	41 ± 7	277.5 ± 48.4
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	257.0 ± 30.8
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	10.64 ± 0.42
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	486.6 ± 26.6
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	59.30 ± 2.70
^{195m} Hg	i(m)	41.6H	779.8	54.2 ± 0.1	65.82 ± 13.88
			560.3	7.0 ± 0.6	75.36 ± 7.47
			261.8	31 ± 4	82.02 ± 11.04
				$RR_{mean} =$	74.57 ± 2.30
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	380.3 ± 41.5
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	60.73 ± 9.68
			407.6	32 ± 6	84.87 ± 16.20
				$RR_{mean} =$	67.02 ± 10.80
¹⁹² Hg	c	4.85H	2335.7	*	283.8 ± 61.0
			2236.9	*	270.0 ± 45.7
			316.5	*	332.3 ± 41.7
			296.0	*	332.0 ± 47.3
			274.8	50.2 ± 2.5	271.3 ± 17.0
				$RR_{mean} =$	278.0 ± 8.6
¹⁹⁰ Hg	c*	20.0M	301.8	*	183.9 ± 23.4
			295.8	*	175.3 ± 17.7
			142.6	68 ± 10	190.2 ± 29.3
				$RR_{mean} =$	180.7 ± 5.6
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.045 ± 0.255
			411.8	*	1.871 ± 0.158
				$RR_{mean} =$	1.916 ± 0.059
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	4.932 ± 0.290
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	6.803 ± 0.256

Continuation of Table 76.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{196}Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	14.46 ± 2.01
			355.7	87.0 ± 0.8	12.95 ± 0.46
			333.0	22.9 ± 0.6	13.89 ± 0.64
			$RR_{mean} =$		13.10 ± 0.48
^{195}Au	c	186.098D	129.8	0.82 ± 0.05	439.6 ± 35.2
			98.9	10.9 ± 0.9	370.2 ± 36.3
			$RR_{mean} =$		413.5 ± 36.0
^{194}Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	25.22 ± 2.24
			293.6	10.4 ± 0.8	21.99 ± 1.95
			$RR_{mean} =$		23.38 ± 1.75
$^{192}\text{Au}_i$	i(m+g)	4.94H	2335.7	1.7 ± 0.3	61.61 ± 58.01
			2236.9	5.6 ± 0.9	56.49 ± 17.57
			316.5	58 ± 7	41.71 ± 5.65
			296.0	22 ± 3	58.33 ± 15.74
			$RR_{mean} =$		42.49 ± 2.66
$^{192}\text{Au}_c$	c	4.94H	2335.7	1.7 ± 0.3	345.5 ± 69.9
			2236.9	5.6 ± 0.9	326.5 ± 54.8
			316.5	58 ± 7	374.0 ± 46.9
			296.0	22 ± 3	390.3 ± 55.5
			$RR_{mean} =$		372.3 ± 14.4
^{191}Au	c*	3.18H	586.4	17 ± 0	291.3 ± 16.0
			293.5	2.84 ± 0.19	257.3 ± 21.5
			166.5	3.32 ± 0.24	336.8 ± 28.5
			$RR_{mean} =$		289.1 ± 19.5
$^{190}\text{Au}_c$	c	42.8M	301.8	23.4 ± 1.5	217.0 ± 18.7
			295.8	71 ± 5	220.2 ± 18.2
			$RR_{mean} =$		218.7 ± 10.8
^{191}Pt	c	2.802D	538.9	13.7 ± 1.6	273.0 ± 33.2
			456.5	3.4 ± 0.4	244.0 ± 30.1
			409.4	8.0 ± 0.9	237.4 ± 27.9
			351.2	3.4 ± 0.4	307.0 ± 37.9
			172.2	3.5 ± 0.4	268.8 ± 32.5
			$RR_{mean} =$		259.7 ± 14.0
^{189}Pt	c	10.87H	721.4	9.3 ± 0.8	289.3 ± 26.8
			607.6	8.10 ± 0.16	232.5 ± 10.1
			568.8	7.1 ± 0.6	234.9 ± 23.0
			544.9	5.8 ± 0.5	256.4 ± 24.0
			243.5	7.0 ± 1.2	230.4 ± 40.6
			$RR_{mean} =$		237.6 ± 10.2
^{188}Pt	c	10.2D	1209.8	*	205.8 ± 22.1
			634.9	*	207.6 ± 34.1
			633.0	*	213.9 ± 36.4
			478.0	*	190.4 ± 10.2
			423.3	4.4 ± 0.3	194.2 ± 14.9
			381.4	7.5 ± 0.5	185.9 ± 13.9
			322.9	*	189.6 ± 19.0
			195.1	18.6 ± 1.2	188.7 ± 14.1
			187.6	19.4 ± 1.2	191.1 ± 13.9
			155.1	*	197.4 ± 21.0
			140.4	2.33 ± 0.15	182.8 ± 15.4

Continuation of Table 76.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{187}Pt	c	2.35H		$RR_{mean} =$	190.0 ± 5.9
			304.8	4.3 ± 1.0	116.8 ± 28.3
			106.4	8.8 ± 1.8	135.7 ± 28.9
				$RR_{mean} =$	132.0 ± 8.6
^{186}Pt	c	2.08H	689.4	70 ± 15	127.4 ± 27.7
^{184}Pt	c	17.3M	548.3	23 ± 4	88.03 ± 18.07
^{190}Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	0.9325 ± 0.2395
^{189}Ir	c	13.2D	275.9	0.54 ± 0.07	211.1 ± 29.3
			245.1	6.0 ± 0.6	198.5 ± 21.5
				$RR_{mean} =$	199.5 ± 8.2
$^{188}\text{Ir}_i$	i	41.5H	633.0	18 ± 3	12.33 ± 2.41
			478.0	14.7 ± 0.6	9.431 ± 1.783
			155.1	30 ± 3	11.10 ± 1.64
				$RR_{mean} =$	10.74 ± 1.08
$^{188}\text{Ir}_c$	c	41.5H	634.9	5.0 ± 0.8	206.9 ± 34.0
			633.0	18 ± 3	226.2 ± 38.5
			478.0	14.7 ± 0.6	199.9 ± 10.7
			322.9	1.62 ± 0.15	176.4 ± 18.1
			155.1	30 ± 3	208.5 ± 22.2
				$RR_{mean} =$	199.4 ± 6.9
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	192.0 ± 12.0
^{186}Ir	c	16.64H	773.3	8.9 ± 0.5	64.91 ± 4.48
			434.8	33.9 ± 1.1	66.97 ± 3.26
			137.2	41.4 ± 0.7	69.99 ± 3.28
				$RR_{mean} =$	67.94 ± 2.63
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	95.33 ± 14.63
			254.2	13.3 ± 2.4	88.69 ± 16.61
				$RR_{mean} =$	94.29 ± 5.03
^{184}Ir	c*	3.09H	841.3	8.0 ± 0.8	84.52 ± 11.58
			264.0	68 ± 4	104.9 ± 7.4
			119.8	31 ± 3	100.6 ± 10.9
				$RR_{mean} =$	103.1 ± 4.8
^{183}Ir	c	57M	392.5	10.4 ± 2.4	80.29 ± 19.80
^{185}Os	c	93.6D	880.5	5.17 ± 0.21	132.0 ± 10.3
			874.8	6.29 ± 0.25	120.0 ± 6.4
			717.4	3.94 ± 0.16	128.4 ± 7.4
			646.1	78 ± 3	120.3 ± 6.1
				$RR_{mean} =$	121.4 ± 4.1
^{183m}Os	c*	9.9H	1107.9	22.4 ± 0.6	47.62 ± 2.43
			1101.9	49.0 ± 1.3	48.83 ± 2.18
				$RR_{mean} =$	48.46 ± 1.73
^{182}Os	c	22.10H	1221.5	*	78.65 ± 5.81
			1189.2	*	83.25 ± 6.39
			1121.4	*	74.53 ± 4.58
			180.2	33.5 ± 1.7	71.85 ± 4.70
				$RR_{mean} =$	74.53 ± 2.30
^{180}Os	c	21.5M	902.8(D)	101.5 ± 3.4	35.42 ± 2.87
^{183}Re	c	70.0D	291.7	3.05 ± 0.18	80.35 ± 6.29
			208.8	2.95 ± 0.09	81.69 ± 4.94
			162.3	23.3 ± 0.7	87.81 ± 4.14

Continuation of Table 76.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	85.29 ± 3.48
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	71.99 ± 5.44
			1189.2	15 ± 1	75.46 ± 6.03
			1121.4	31.8 ± 1.6	87.06 ± 5.42
				<i>RR_{mean}</i> =	80.15 ± 5.47
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	52.00 ± 11.67
			365.5	56 ± 8	50.56 ± 7.49
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	9.369 ± 0.479
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	6.076 ± 0.607
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	2.145 ± 0.219
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	0.7053 ± 0.0580
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	2.349 ± 0.142
			172.1	25.5 ± 0.8	1.814 ± 0.314
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.685 ± 0.085
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	1.874 ± 0.103
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	2.656 ± 0.159
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.076 ± 0.095
			197.3	87.0 ± 1.1	2.525 ± 0.118
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	1.440 ± 0.165
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	5.900 ± 0.426
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	6.838 ± 0.437
			884.7	72.7 ± 0.4	6.741 ± 0.292
			657.8	94.3 ± 0.3	6.517 ± 0.320
				<i>RR_{mean}</i> =	6.678 ± 0.252
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	1.662 ± 0.218
			717.3	28.9 ± 0.8	1.049 ± 0.294
			451.0	28.2 ± 0.8	1.946 ± 0.170
				<i>RR_{mean}</i> =	1.717 ± 0.230
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	24.59 ± 1.40
¹⁰² Rh	i	207D	475.1	46 ± 5	2.464 ± 0.529
^{101m} Rh	c	4.34D	306.9	81 ± 5	2.952 ± 0.287
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	23.60 ± 0.90
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	2.121 ± 0.158
			812.5	82 ± 4	2.339 ± 0.155
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	24.27 ± 1.02
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	14.07 ± 0.69
			778.2	96.45 ± 0.22	13.66 ± 0.50
			568.9	58.0 ± 0.3	12.29 ± 0.67
			460.0	26.62 ± 0.20	12.97 ± 0.54
				<i>RR_{mean}</i> =	13.36 ± 0.52
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	15.38 ± 0.53
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	30.38 ± 1.01
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.344 ± 0.074
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	3.634 ± 0.303
⁹⁵ Zr	c	64.02D	765.8	*	15.13 ± 0.53
			756.7	54.46 ± 0.10	14.51 ± 0.62

Continuation of Table 76.					
Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			724.2	44.17 ± 0.16	15.22 ± 0.72
			$RR_{mean} =$		15.01 ± 0.46
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	4.075 ± 0.155
^{88}Zr	c	83.4D	898.0	*	0.9535 ± 0.6036
			1836.1	*	0.8760 ± 0.4233
			392.9	97.24 ± 0.00	1.289 ± 0.161
			$RR_{mean} =$		1.223 ± 0.038
^{90m}Y	i(m)	3.19H	479.5	90.74 ± 0.05	15.25 ± 0.67
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	9.381 ± 0.573
			898.0	93.7 ± 0.3	8.758 ± 0.606
			$RR_{mean} =$		9.098 ± 0.461
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	10.26 ± 0.39
			898.0	93.7 ± 0.3	9.711 ± 0.462
			$RR_{mean} =$		10.09 ± 0.40
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	5.159 ± 0.207
^{85}Sr	c	64.84D	514.0	96 ± 4	5.839 ± 0.352
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	20.28 ± 1.14
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	15.37 ± 0.97
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	6.520 ± 0.982
			529.6	29.3 ± 2.1	6.507 ± 0.622
			520.4	45 ± 4	6.871 ± 0.726
			$RR_{mean} =$		6.631 ± 0.398
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	9.591 ± 0.888
			776.5	83.5 ± 1.2	10.12 ± 0.40
			698.4	28.5 ± 0.4	9.931 ± 0.458
			554.3	70.8 ± 1.0	9.394 ± 0.432
			$RR_{mean} =$		9.861 ± 0.351
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	1.592 ± 0.112
			136.0	58.3 ± 0.8	1.492 ± 0.101
			$RR_{mean} =$		1.536 ± 0.082
^{74}As	i	17.77D	595.8	59 ± 4	3.505 ± 0.287
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	3.745 ± 0.732
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	5.951 ± 0.658
^{72}Zn	c	46.5H	2201.7	*	2.207 ± 0.266
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	2.157 ± 0.605
			1099.2	56.5 ± 1.9	1.416 ± 0.335
			$RR_{mean} =$		1.589 ± 0.317

12.6.3 Nuclide production rates for ^{208}Pb

Table 77: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.4 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	37.82 ± 3.73
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	57.67 ± 2.29
			1098.3	13.50 ± 0.21	50.17 ± 2.75
			895.1	15.66 ± 0.23	58.91 ± 2.40
			881.0	66.2 ± 1.0	53.85 ± 2.20

Continuation of Table 77.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			803.1	98.9 ± 1.4	52.30 ± 1.90
			620.5	5.76 ± 0.09	52.31 ± 2.92
			537.5	30.5 ± 0.5	48.63 ± 1.97
			516.2	40.7 ± 0.6	50.89 ± 1.95
			497.1	15.31 ± 0.22	47.38 ± 2.16
			398.0	10.74 ± 0.15	48.96 ± 1.87
			343.5	23.4 ± 0.4	49.50 ± 1.95
			184.0	15.8 ± 0.4	60.70 ± 2.94
			<i>RR_{mean}</i> =		51.87 ± 1.93
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	78.91 ± 3.88
			1775.8	3.99 ± 0.08	74.75 ± 3.76
			1764.3	32.5 ± 0.7	79.72 ± 3.27
			1614.3	2.28 ± 0.04	83.85 ± 5.95
			1190.0	2.26 ± 0.07	78.23 ± 5.75
			1043.8	7.51 ± 0.10	69.96 ± 2.91
			703.5	31.1 ± 0.1	74.11 ± 2.48
			570.6	4.34 ± 0.07	76.71 ± 4.15
			<i>RR_{mean}</i> =		74.83 ± 2.56
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	70.65 ± 5.38
			918.3	10.8 ± 0.9	85.33 ± 8.15
			899.2	98 ± 9	67.04 ± 2.26
			670.7	11.4 ± 0.9	70.74 ± 6.31
			374.8	82 ± 5	73.40 ± 15.35
			<i>RR_{mean}</i> =		67.33 ± 2.08
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	75.21 ± 7.34
			1847.3	11.4 ± 0.8	79.29 ± 6.60
			1679.6	8.8 ± 0.7	78.34 ± 7.81
			896.8	13.1 ± 0.7	81.72 ± 5.96
			820.2	29.6 ± 1.5	78.41 ± 5.08
			<i>RR_{mean}</i> =		78.93 ± 2.88
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	57.88 ± 3.41
			422.1	83.7 ± 2.5	60.87 ± 5.21
			<i>RR_{mean}</i> =		58.67 ± 3.08
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	106.2 ± 3.9
			374.7	89 ± 15	129.8 ± 22.5
			<i>RR_{mean}</i> =		106.5 ± 4.0
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	116.3 ± 4.2
			374.7	89 ± 15	139.1 ± 24.0
			<i>RR_{mean}</i> =		116.5 ± 4.2
²⁰³ Pb	c*	51.873H	401.3	3.35 ± 0.07	334.2 ± 14.7
			279.2	80.8 ± 0.2	352.2 ± 12.9
			<i>RR_{mean}</i> =		346.8 ± 13.5
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	108.3 ± 10.3
			459.7	8.6 ± 0.7	113.5 ± 11.5
			422.1	86 ± 5	123.8 ± 8.8
			<i>RR_{mean}</i> =		118.9 ± 5.9
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	348.2 ± 32.7
			1238.8	1.18 ± 0.08	299.8 ± 30.2
			1098.5	1.83 ± 0.12	308.9 ± 35.7
			946.0	7.4 ± 0.6	296.0 ± 26.4
			907.6	5.7 ± 0.4	341.8 ± 28.1

Continuation of Table 77.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			692.4	4.27 ± 0.16	296.0 ± 16.0
			331.2	79 ± 5	332.9 ± 23.9
			<i>RR_{mean}</i> =		311.3 ± 12.7
²⁰⁰ Pb	c	21.5H	1514.9	*	227.7 ± 22.7
			1407.6	*	276.0 ± 34.2
			1362.9	*	250.9 ± 31.3
			1225.5	*	242.8 ± 18.5
			1205.7	*	259.4 ± 18.2
			828.3	*	235.1 ± 20.7
			701.6	*	214.4 ± 26.1
			579.3	*	200.6 ± 15.7
			367.9	*	246.6 ± 8.6
			147.6	37.7 ± 1.4	269.9 ± 14.7
			<i>RR_{mean}</i> =		246.6 ± 7.6
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	416.4 ± 70.4
			366.9	44 ± 7	426.1 ± 70.2
			353.4	9.5 ± 1.5	466.9 ± 80.6
			<i>RR_{mean}</i> =		432.4 ± 24.7
¹⁹⁸ Pb	c	2.4H	365.4	19 ± 5	508.3 ± 135.9
			865.3	5.9 ± 1.2	271.5 ± 58.4
			173.4	18 ± 3	373.2 ± 64.3
			<i>RR_{mean}</i> =		365.3 ± 25.9
^{197m} Pb	c*	43M	387.7	25 ± 6	275.9 ± 67.0
			385.9	74 ± 15	248.5 ± 51.2
			222.8	25 ± 6	226.1 ± 55.2
			<i>RR_{mean}</i> =		248.2 ± 11.6
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	262.9 ± 32.2
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	136.4 ± 25.6
			383.6	107 ± 20	133.6 ± 25.5
			<i>RR_{mean}</i> =		135.4 ± 5.7
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	149.9 ± 5.4
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	538.5 ± 20.0
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	268.9 ± 28.8
			1407.6	1.45 ± 0.13	320.8 ± 50.8
			1362.9	3.4 ± 0.4	282.6 ± 36.4
			1225.5	3.36 ± 0.21	245.2 ± 21.3
			1205.7	29.9 ± 1.8	208.1 ± 16.3
			828.3	10.8 ± 0.7	318.0 ± 28.2
			701.6	1.29 ± 0.10	284.6 ± 42.2
			579.3	13.8 ± 0.7	311.5 ± 30.7
			367.9	87.2 ± 0.4	213.2 ± 9.0
			<i>RR_{mean}</i> =		226.9 ± 13.0
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	496.6 ± 41.9
			1407.6	1.45 ± 0.13	596.8 ± 61.3
			1362.9	3.4 ± 0.4	533.5 ± 65.5
			1225.5	3.36 ± 0.21	488.0 ± 35.2
			1205.7	29.9 ± 1.8	467.5 ± 32.5
			828.3	10.8 ± 0.7	553.1 ± 40.9
			701.6	1.29 ± 0.10	498.9 ± 46.0
			579.3	13.8 ± 0.7	512.1 ± 34.5
			367.9	87.2 ± 0.4	459.8 ± 15.9

Continuation of Table 77.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁹ Tl	c*	7.42H		$RR_{mean} =$	469.5 ± 16.8
			247.3	9.3 ± 1.1	518.6 ± 65.2
			208.2	12.3 ± 1.4	558.9 ± 68.0
			158.4	5.0 ± 0.6	679.2 ± 90.0
^{198m} Tl	i(m)	1.87H		$RR_{mean} =$	564.0 ± 43.6
			587.2	52.5 ± 2.0	184.8 ± 13.7
			282.8	28 ± 3	211.9 ± 24.4
				$RR_{mean} =$	189.7 ± 12.0
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	471.7 ± 159.8
			152.2	7.3 ± 2.3	722.9 ± 229.8
			134.0	2.0 ± 0.7	690.9 ± 254.9
				$RR_{mean} =$	627.9 ± 86.7
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	364.3 ± 63.6
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	356.7 ± 45.3
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	21.45 ± 0.81
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	654.5 ± 37.9
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	87.66 ± 3.98
^{195m} Hg	i(m)	41.6H	779.8	54.2 ± 0.1	91.10 ± 18.71
			560.3	7.0 ± 0.6	102.3 ± 9.9
			261.8	31 ± 4	113.1 ± 15.2
				$RR_{mean} =$	101.7 ± 3.1
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	471.6 ± 52.0
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	82.34 ± 13.09
			407.6	32 ± 6	113.5 ± 21.7
				$RR_{mean} =$	90.59 ± 14.03
¹⁹² Hg	c	4.85H	2335.7	*	335.7 ± 77.0
			2236.9	*	342.1 ± 58.8
			316.5	*	420.3 ± 53.0
			296.0	*	394.7 ± 56.7
			274.8	50.2 ± 2.5	325.5 ± 20.7
				$RR_{mean} =$	335.0 ± 10.3
¹⁹⁰ Hg	c*	20.0M	301.8	*	207.0 ± 32.9
			295.8	*	222.3 ± 18.7
			142.6	68 ± 10	218.2 ± 33.5
				$RR_{mean} =$	219.8 ± 6.8
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	4.006 ± 0.334
			411.8	*	4.092 ± 0.247
				$RR_{mean} =$	4.065 ± 0.125
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	7.137 ± 0.405
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	11.23 ± 0.41
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	21.78 ± 2.87
			355.7	87.0 ± 0.8	21.21 ± 0.75
			333.0	22.9 ± 0.6	20.51 ± 1.02
				$RR_{mean} =$	21.12 ± 0.71
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	600.3 ± 48.3
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	37.66 ± 3.35
			293.6	10.4 ± 0.8	36.38 ± 3.27
				$RR_{mean} =$	37.01 ± 2.11
¹⁹² Au _i	i(m+g)	4.94H	2236.9	5.6 ± 0.9	49.66 ± 31.02
			316.5	58 ± 7	58.37 ± 8.88

Continuation of Table 77.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			296.0	22 ± 3	111.7 ± 29.4
			<i>RR_{mean}</i> = 60.15 ± 7.53		
¹⁹² Au _c	c	4.94H	2236.9	5.6 ± 0.9	391.8 ± 67.4
			316.5	58 ± 7	478.6 ± 60.2
			296.0	22 ± 3	506.4 ± 72.9
			<i>RR_{mean}</i> = 475.9 ± 22.0		
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	313.1 ± 20.5
			293.5	2.84 ± 0.19	349.9 ± 37.8
			166.5	3.32 ± 0.24	486.0 ± 52.5
			<i>RR_{mean}</i> = 336.0 ± 37.1		
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	275.2 ± 23.5
			295.8	71 ± 5	269.8 ± 21.4
			<i>RR_{mean}</i> = 271.9 ± 12.9		
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	328.6 ± 40.1
			456.5	3.4 ± 0.4	293.8 ± 36.2
			409.4	8.0 ± 0.9	292.4 ± 34.4
			351.2	3.4 ± 0.4	360.6 ± 45.1
			172.2	3.5 ± 0.4	319.1 ± 38.4
			<i>RR_{mean}</i> = 312.7 ± 15.0		
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	367.6 ± 34.6
			607.6	8.10 ± 0.16	284.4 ± 13.4
			568.8	7.1 ± 0.6	305.0 ± 29.3
			544.9	5.8 ± 0.5	302.4 ± 29.2
			243.5	7.0 ± 1.2	276.2 ± 48.7
			<i>RR_{mean}</i> = 293.4 ± 14.0		
¹⁸⁸ Pt	c	10.2D	1209.8	*	246.5 ± 26.3
			634.9	*	243.9 ± 40.0
			633.0	*	257.8 ± 43.8
			478.0	*	231.6 ± 12.5
			423.3	4.4 ± 0.3	238.1 ± 18.3
			381.4	7.5 ± 0.5	225.9 ± 16.9
			322.9	*	202.3 ± 20.3
			195.1	18.6 ± 1.2	228.5 ± 17.1
			187.6	19.4 ± 1.2	235.4 ± 17.0
			155.1	*	243.5 ± 25.9
			140.4	2.33 ± 0.15	252.8 ± 20.0
			<i>RR_{mean}</i> = 233.0 ± 7.2		
¹⁸⁷ Pt	c	2.35H	304.8	4.3 ± 1.0	175.4 ± 44.8
			106.4	8.8 ± 1.8	160.5 ± 35.1
			<i>RR_{mean}</i> = 163.0 ± 12.0		
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	148.8 ± 32.4
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	103.9 ± 19.3
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.4294 ± 0.1154
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.172 ± 0.271
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	238.7 ± 33.0
			245.1	6.0 ± 0.6	242.0 ± 26.0
			<i>RR_{mean}</i> = 241.7 ± 9.5		
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	17.01 ± 3.33
			478.0	14.7 ± 0.6	9.148 ± 3.084
			155.1	30 ± 3	7.416 ± 1.612

Continuation of Table 77.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	9.238 ± 2.442
¹⁸⁸ Ir _c	c	41.5H	634.9	5.0 ± 0.8	250.8 ± 41.2
			633.0	18 ± 3	274.8 ± 46.7
			478.0	14.7 ± 0.6	240.7 ± 13.1
			322.9	1.62 ± 0.15	204.2 ± 20.9
			155.1	30 ± 3	250.9 ± 26.7
				<i>RR_{mean}</i> =	239.5 ± 8.7
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	242.4 ± 14.0
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	72.96 ± 5.25
			434.8	33.9 ± 1.1	80.16 ± 3.93
			137.2	41.4 ± 0.7	88.31 ± 4.04
				<i>RR_{mean}</i> =	82.46 ± 4.73
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	109.2 ± 16.8
			254.2	13.3 ± 2.4	97.76 ± 18.23
				<i>RR_{mean}</i> =	107.2 ± 5.8
¹⁸⁴ Ir	c*	3.09H	841.3	8.0 ± 0.8	87.33 ± 16.67
			264.0	68 ± 4	116.5 ± 8.3
			119.8	31 ± 3	120.1 ± 13.1
				<i>RR_{mean}</i> =	115.6 ± 5.5
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	116.9 ± 29.7
¹⁸⁵ Os	c	93.6D	880.5	5.17 ± 0.21	139.9 ± 8.9
			874.8	6.29 ± 0.25	144.8 ± 8.2
			717.4	3.94 ± 0.16	143.4 ± 8.6
			646.1	78 ± 3	137.4 ± 7.1
				<i>RR_{mean}</i> =	139.4 ± 4.6
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	55.69 ± 2.79
			1101.9	49.0 ± 1.3	54.71 ± 2.54
				<i>RR_{mean}</i> =	55.08 ± 2.00
¹⁸² Os	c	22.10H	1221.5	*	85.97 ± 6.36
			1189.2	*	87.53 ± 6.82
			1121.4	*	81.99 ± 5.12
			180.2	33.5 ± 1.7	81.16 ± 5.26
				<i>RR_{mean}</i> =	82.73 ± 2.55
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	41.30 ± 2.51
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	90.40 ± 7.62
			208.8	2.95 ± 0.09	89.06 ± 5.76
			162.3	23.3 ± 0.7	97.01 ± 4.64
				<i>RR_{mean}</i> =	94.34 ± 3.87
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	82.16 ± 6.33
			1189.2	15 ± 1	85.70 ± 7.01
			1121.4	31.8 ± 1.6	96.06 ± 6.10
				<i>RR_{mean}</i> =	89.81 ± 5.26
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	53.36 ± 12.12
			365.5	56 ± 8	56.72 ± 8.39
				<i>RR_{mean}</i> =	55.81 ± 6.06
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	8.525 ± 0.455
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	4.787 ± 0.760
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	2.166 ± 0.291
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	0.9961 ± 0.0753
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	2.638 ± 0.124

Continuation of Table 77.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			172.1	25.5 ± 0.8	2.701 ± 0.269
			<i>RR_{mean}</i> = 2.646 ± 0.119		
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.7831 ± 0.0811
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.222 ± 0.105
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	1.903 ± 0.114
			573.1	88.6 ± 0.1	2.168 ± 0.305
			<i>RR_{mean}</i> = 1.929 ± 0.060		
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	3.007 ± 0.258
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.519 ± 0.126
			197.3	87.0 ± 1.1	3.063 ± 0.158
			<i>RR_{mean}</i> = 2.724 ± 0.277		
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	6.535 ± 0.381
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	7.413 ± 0.476
			884.7	72.7 ± 0.4	7.322 ± 0.321
			657.8	94.3 ± 0.3	7.592 ± 0.301
			<i>RR_{mean}</i> = 7.475 ± 0.268		
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	1.868 ± 0.221
			717.3	28.9 ± 0.8	1.351 ± 0.380
			<i>RR_{mean}</i> = 1.744 ± 0.228		
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	30.12 ± 1.50
¹⁰² Rh	i	207D	475.1	46 ± 5	2.557 ± 0.370
^{101m} Rh	c	4.34D	306.9	81 ± 5	2.906 ± 0.229
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	30.05 ± 1.16
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	1.626 ± 0.118
			812.5	82 ± 4	2.443 ± 0.212
			<i>RR_{mean}</i> = 1.809 ± 0.345		
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	29.48 ± 1.22
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	17.59 ± 0.98
			778.2	96.45 ± 0.22	16.89 ± 0.69
			568.9	58.0 ± 0.3	14.38 ± 0.74
			460.0	26.62 ± 0.20	15.99 ± 0.68
			<i>RR_{mean}</i> = 16.14 ± 0.78		
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	17.96 ± 0.64
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	36.44 ± 1.23
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.968 ± 0.141
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	6.119 ± 0.281
⁹⁵ Zr	c	64.02D	765.8	*	18.65 ± 0.72
			756.7	54.46 ± 0.10	18.51 ± 0.74
			724.2	44.17 ± 0.16	19.06 ± 0.92
			<i>RR_{mean}</i> = 18.66 ± 0.58		
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	3.931 ± 0.216
⁸⁸ Zr	c	83.4D	1836.1	*	0.07931 ± 0.41611
			392.9	97.24 ± 0.00	1.180 ± 0.092
			<i>RR_{mean}</i> = 1.137 ± 0.035		
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	19.37 ± 1.03
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	10.46 ± 0.50
			898.0	93.7 ± 0.3	9.507 ± 0.600
			<i>RR_{mean}</i> = 10.12 ± 0.55		
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	10.54 ± 0.44
			898.0	93.7 ± 0.3	10.09 ± 0.46

Continuation of Table 77.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	10.35 ± 0.39
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	4.795 ± 0.195
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	6.274 ± 0.358
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	24.25 ± 1.21
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	15.64 ± 1.19
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	8.228 ± 0.820
			529.6	29.3 ± 2.1	7.088 ± 0.612
			520.4	45 ± 4	7.271 ± 0.754
			RR _{mean} =		7.395 ± 0.397
⁸² Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	12.06 ± 1.05
			776.5	83.5 ± 1.2	11.86 ± 0.47
			698.4	28.5 ± 0.4	11.37 ± 0.60
			554.3	70.8 ± 1.0	10.99 ± 0.62
		RR _{mean} =	11.63 ± 0.42		
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	1.512 ± 0.175
			136.0	58.3 ± 0.8	1.755 ± 0.173
		RR _{mean} =	1.637 ± 0.132		
⁷⁴ As	i	17.77D	595.8	59 ± 4	3.886 ± 0.390
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	6.416 ± 1.270
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	8.561 ± 1.145
⁷² Zn	c	46.5H	2201.7	*	2.145 ± 0.371
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	1.880 ± 0.302
			1099.2	56.5 ± 1.9	1.658 ± 0.369
		RR _{mean} =	1.792 ± 0.236		

12.6.4 Nuclide production rates for ^{nat}Pb

Table 78: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.4 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	27.86 ± 2.42
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	44.47 ± 1.78
			1098.3	13.50 ± 0.21	41.82 ± 1.83
			895.1	15.66 ± 0.23	47.79 ± 1.80
			881.0	66.2 ± 1.0	45.55 ± 1.66
			803.1	98.9 ± 1.4	42.20 ± 1.55
			620.5	5.76 ± 0.09	42.75 ± 1.88
			537.5	30.5 ± 0.5	39.79 ± 1.57
			516.2	40.7 ± 0.6	41.25 ± 1.57
			497.1	15.31 ± 0.22	40.38 ± 1.80
			398.0	10.74 ± 0.15	41.17 ± 1.62
			343.5	23.4 ± 0.4	41.24 ± 1.65
			184.0	15.8 ± 0.4	46.49 ± 2.24
			$RR_{mean} =$		42.80 ± 1.51
^{205}Bi	i	15.31D	1764.3	32.5 ± 0.7	74.12 ± 3.08
			1614.3	2.28 ± 0.04	79.67 ± 4.10
			1190.0	2.26 ± 0.07	70.65 ± 3.78
			1043.8	7.51 ± 0.10	66.18 ± 2.70

Continuation of Table 78.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			703.5	31.1 ± 0.1	69.47 ± 2.35
			570.6	4.34 ± 0.07	69.57 ± 3.20
			<i>RR_{mean}</i> =		70.02 ± 2.53
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	74.68 ± 5.79
			918.3	10.8 ± 0.9	91.91 ± 9.38
			899.2	98 ± 9	69.36 ± 2.32
			670.7	11.4 ± 0.9	75.27 ± 6.87
			374.8	82 ± 5	78.84 ± 16.47
			<i>RR_{mean}</i> =		69.67 ± 2.15
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	85.39 ± 8.07
			1847.3	11.4 ± 0.8	85.64 ± 7.27
			1679.6	8.8 ± 0.7	81.78 ± 7.52
			896.8	13.1 ± 0.7	90.85 ± 6.22
			820.2	29.6 ± 1.5	84.17 ± 5.22
			<i>RR_{mean}</i> =		85.28 ± 2.92
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	64.43 ± 3.88
			422.1	83.7 ± 2.5	69.04 ± 8.21
			<i>RR_{mean}</i> =		65.12 ± 3.67
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	111.3 ± 3.9
			374.7	89 ± 15	132.3 ± 22.8
			<i>RR_{mean}</i> =		111.5 ± 3.9
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	121.7 ± 4.2
			374.7	89 ± 15	142.2 ± 24.5
			<i>RR_{mean}</i> =		121.9 ± 4.2
²⁰³ Pb	c*	51.873H	401.3	3.35 ± 0.07	403.4 ± 16.7
			279.2	80.8 ± 0.2	406.0 ± 14.9
			<i>RR_{mean}</i> =		405.1 ± 14.1
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	111.4 ± 10.7
			459.7	8.6 ± 0.7	112.9 ± 12.5
			422.1	86 ± 5	122.5 ± 9.5
			<i>RR_{mean}</i> =		117.7 ± 5.7
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	369.7 ± 37.5
			1238.8	1.18 ± 0.08	382.7 ± 38.6
			1098.5	1.83 ± 0.12	376.9 ± 36.6
			946.0	7.4 ± 0.6	342.4 ± 30.4
			907.6	5.7 ± 0.4	396.1 ± 32.6
			692.4	4.27 ± 0.16	348.2 ± 21.5
			331.2	79 ± 5	384.3 ± 27.7
			<i>RR_{mean}</i> =		366.6 ± 15.4
²⁰⁰ Pb	c	21.5H	1514.9	*	286.0 ± 26.8
			1407.6	*	306.4 ± 36.6
			1362.9	*	321.4 ± 40.7
			1225.5	*	287.5 ± 21.9
			1205.7	*	312.3 ± 21.6
			828.3	*	308.1 ± 23.8
			701.6	*	269.3 ± 25.7
			579.3	*	287.7 ± 18.5
			367.9	*	283.1 ± 10.3
			147.6	37.7 ± 1.4	315.6 ± 18.5
			<i>RR_{mean}</i> =		289.0 ± 8.9
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	480.8 ± 77.7

Continuation of Table 78.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			366.9	44 ± 7	537.2 ± 88.9
			353.4	9.5 ± 1.5	505.4 ± 86.3
			<i>RR_{mean}</i> =		503.3 ± 27.3
¹⁹⁸ Pb	c	2.4H	865.3	5.9 ± 1.2	343.7 ± 74.4
			365.4	19 ± 5	482.4 ± 129.4
			173.4	18 ± 3	441.6 ± 76.1
			<i>RR_{mean}</i> =		434.3 ± 23.6
^{197m} Pb	c*	43M	387.7	25 ± 6	306.6 ± 74.5
			385.9	74 ± 15	294.9 ± 60.9
			222.8	25 ± 6	259.9 ± 64.4
			<i>RR_{mean}</i> =		292.7 ± 14.3
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	293.0 ± 37.0
^{195m} Pb	i(m)	15.0M	394.2	44 ± 8	160.4 ± 29.9
			383.6	107 ± 20	141.7 ± 27.2
			<i>RR_{mean}</i> =		155.3 ± 9.6
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	156.9 ± 5.6
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	617.1 ± 23.3
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	269.9 ± 29.5
			1407.6	1.45 ± 0.13	344.5 ± 55.9
			1362.9	3.4 ± 0.4	243.3 ± 35.4
			1225.5	3.36 ± 0.21	254.6 ± 23.2
			1205.7	29.9 ± 1.8	208.6 ± 14.8
			828.3	10.8 ± 0.7	296.2 ± 24.3
			701.6	1.29 ± 0.10	344.0 ± 36.9
			579.3	13.8 ± 0.7	252.2 ± 17.8
			367.9	87.2 ± 0.4	233.9 ± 10.8
			<i>RR_{mean}</i> =		242.3 ± 12.6
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	555.8 ± 46.7
			1407.6	1.45 ± 0.13	650.9 ± 67.7
			1362.9	3.4 ± 0.4	564.7 ± 69.8
			1225.5	3.36 ± 0.21	542.1 ± 39.2
			1205.7	29.9 ± 1.8	520.9 ± 35.8
			828.3	10.8 ± 0.7	604.4 ± 44.2
			701.6	1.29 ± 0.10	613.3 ± 53.1
			579.3	13.8 ± 0.7	539.9 ± 33.3
			367.9	87.2 ± 0.4	517.0 ± 18.2
			<i>RR_{mean}</i> =		528.1 ± 18.7
¹⁹⁹ Tl	c*	7.42H	247.3	9.3 ± 1.1	609.4 ± 76.4
			208.2	12.3 ± 1.4	636.0 ± 77.6
			158.4	5.0 ± 0.6	774.9 ± 101.5
			<i>RR_{mean}</i> =		651.9 ± 47.3
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	155.0 ± 14.2
			282.8	28 ± 3	231.8 ± 26.7
			<i>RR_{mean}</i> =		170.4 ± 31.2
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	545.4 ± 185.5
			152.2	7.3 ± 2.3	814.6 ± 259.3
			134.0	2.0 ± 0.7	791.1 ± 289.0
			<i>RR_{mean}</i> =		717.7 ± 92.6
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	401.9 ± 70.2
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	375.4 ± 45.7

Continuation of Table 78.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	17.60 ± 0.65
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	715.8 ± 38.9
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	89.05 ± 4.84
^{195m} Hg	i(m)	41.6H	779.8	54.2 ± 0.1	106.2 ± 21.7
			560.3	7.0 ± 0.6	113.8 ± 10.8
			261.8	31 ± 4	119.2 ± 16.1
			<i>RR_{mean}</i> =		113.3 ± 3.5
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	522.4 ± 57.8
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	89.52 ± 14.18
			407.6	32 ± 6	124.1 ± 23.7
			258.0	49 ± 7	183.1 ± 27.3
			<i>RR_{mean}</i> =		112.6 ± 24.6
¹⁹² Hg	c	4.85H	2335.7	*	505.9 ± 97.7
			2236.9	*	402.3 ± 68.2
			316.5	*	483.0 ± 60.8
			296.0	*	484.0 ± 68.6
			274.8	50.2 ± 2.5	382.2 ± 24.2
			<i>RR_{mean}</i> =		393.5 ± 12.1
¹⁹⁰ Hg	c*	20.0M	301.8	*	327.4 ± 52.4
			295.8	*	261.1 ± 30.7
			142.6	68 ± 10	256.4 ± 40.2
			<i>RR_{mean}</i> =		268.2 ± 8.3
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	3.997 ± 0.378
			411.8	*	3.121 ± 0.167
			<i>RR_{mean}</i> =		3.231 ± 0.100
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	7.597 ± 0.363
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	10.72 ± 0.39
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	20.42 ± 2.73
			355.7	87.0 ± 0.8	20.39 ± 0.71
			333.0	22.9 ± 0.6	20.40 ± 0.90
			<i>RR_{mean}</i> =		20.39 ± 0.68
¹⁹⁵ Au	c	186.098D	129.8	0.82 ± 0.05	769.5 ± 62.7
			98.9	10.9 ± 0.9	710.1 ± 75.9
			<i>RR_{mean}</i> =		751.9 ± 40.6
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	39.83 ± 3.54
			293.6	10.4 ± 0.8	37.96 ± 3.34
			<i>RR_{mean}</i> =		38.83 ± 2.19
¹⁹² Au _i	i(m+g)	4.94H	2236.9	5.6 ± 0.9	50.47 ± 27.49
			316.5	58 ± 7	58.60 ± 8.30
			296.0	22 ± 3	93.99 ± 20.56
			<i>RR_{mean}</i> =		60.34 ± 6.06
¹⁹² Au _c	c	4.94H	2236.9	5.6 ± 0.9	452.8 ± 76.9
			316.5	58 ± 7	541.6 ± 68.0
			296.0	22 ± 3	578.0 ± 82.0
			<i>RR_{mean}</i> =		540.0 ± 24.0
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	436.5 ± 32.8
			293.5	2.84 ± 0.19	381.4 ± 35.4
			166.5	3.32 ± 0.24	477.8 ± 45.3
			<i>RR_{mean}</i> =		426.0 ± 28.9
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	299.2 ± 31.1

Continuation of Table 78.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			295.8	71 ± 5	316.4 ± 26.7
			<i>RR_{mean}</i> =		310.7 ± 17.0
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	395.8 ± 48.2
			456.5	3.4 ± 0.4	359.3 ± 44.3
			409.4	8.0 ± 0.9	358.3 ± 42.2
			351.2	3.4 ± 0.4	411.7 ± 50.6
			172.2	3.5 ± 0.4	398.2 ± 48.2
			<i>RR_{mean}</i> =		380.7 ± 16.1
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	406.9 ± 37.9
			607.6	8.10 ± 0.16	351.7 ± 14.5
			568.8	7.1 ± 0.6	370.4 ± 35.6
			544.9	5.8 ± 0.5	368.5 ± 34.7
			243.5	7.0 ± 1.2	356.5 ± 62.8
			<i>RR_{mean}</i> =		357.1 ± 13.8
¹⁸⁸ Pt	c	10.2D	1209.8	*	290.5 ± 31.0
			634.9	*	298.3 ± 48.8
			633.0	*	308.0 ± 52.4
			478.0	*	275.8 ± 14.8
			423.3	4.4 ± 0.3	284.4 ± 21.7
			381.4	7.5 ± 0.5	271.6 ± 20.3
			322.9	*	258.0 ± 25.8
			195.1	18.6 ± 1.2	277.1 ± 20.8
			187.6	19.4 ± 1.2	284.0 ± 20.6
			155.1	*	294.5 ± 31.4
			140.4	2.33 ± 0.15	312.7 ± 25.3
			<i>RR_{mean}</i> =		279.8 ± 8.6
¹⁸⁷ Pt	c	2.35H	304.8	4.3 ± 1.0	166.6 ± 40.9
			106.4	8.8 ± 1.8	199.9 ± 44.3
			<i>RR_{mean}</i> =		188.1 ± 16.9
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	177.9 ± 38.6
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	126.8 ± 24.3
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.5063 ± 0.0520
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	1.606 ± 0.157
			518.5	34.0 ± 1.6	1.643 ± 0.204
			<i>RR_{mean}</i> =		1.619 ± 0.124
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	279.7 ± 39.1
			245.1	6.0 ± 0.6	314.1 ± 34.1
			<i>RR_{mean}</i> =		310.2 ± 14.5
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	15.23 ± 3.21
			478.0	14.7 ± 0.6	29.45 ± 2.30
			155.1	30 ± 3	18.80 ± 2.44
			<i>RR_{mean}</i> =		23.80 ± 4.34
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	291.6 ± 31.2
			634.9	5.0 ± 0.8	308.6 ± 50.6
			633.0	18 ± 3	323.3 ± 55.0
			478.0	14.7 ± 0.6	305.3 ± 16.3
			322.9	1.62 ± 0.15	288.8 ± 29.9
			155.1	30 ± 3	313.3 ± 33.4
			<i>RR_{mean}</i> =		304.8 ± 10.4
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	308.1 ± 19.3

Continuation of Table 78.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	109.6 ± 7.8
			434.8	33.9 ± 1.1	92.42 ± 4.62
			137.2	41.4 ± 0.7	110.3 ± 5.9
			<i>RR_{mean}</i> =		100.4 ± 6.9
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	139.8 ± 21.6
			254.2	13.3 ± 2.4	115.6 ± 21.6
			<i>RR_{mean}</i> =		134.8 ± 10.6
¹⁸⁴ Ir	c*	3.09H	841.3	8.0 ± 0.8	187.3 ± 24.0
			264.0	68 ± 4	152.9 ± 11.1
			119.8	31 ± 3	156.1 ± 18.0
			<i>RR_{mean}</i> =		154.8 ± 7.0
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	118.3 ± 29.9
¹⁸⁵ Os	c	93.6D	880.5	5.17 ± 0.21	179.4 ± 9.9
			874.8	6.29 ± 0.25	171.8 ± 9.0
			717.4	3.94 ± 0.16	172.1 ± 9.6
			646.1	78 ± 3	171.9 ± 8.8
			<i>RR_{mean}</i> =		172.8 ± 5.6
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	68.67 ± 3.32
			1101.9	49.0 ± 1.3	70.02 ± 3.06
			<i>RR_{mean}</i> =		69.59 ± 2.41
¹⁸² Os	c	22.10H	1221.5	*	116.5 ± 8.6
			1189.2	*	116.4 ± 8.8
			1121.4	*	116.8 ± 7.2
			180.2	33.5 ± 1.7	106.7 ± 6.9
			<i>RR_{mean}</i> =		112.0 ± 3.5
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	54.31 ± 3.64
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	111.8 ± 7.9
			208.8	2.95 ± 0.09	117.1 ± 6.4
			162.3	23.3 ± 0.7	125.2 ± 6.0
			<i>RR_{mean}</i> =		120.4 ± 5.2
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	98.25 ± 7.54
			1189.2	15 ± 1	115.3 ± 8.9
			1121.4	31.8 ± 1.6	108.6 ± 7.7
			<i>RR_{mean}</i> =		106.6 ± 5.8
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	61.37 ± 14.22
			365.5	56 ± 8	77.44 ± 11.42
			<i>RR_{mean}</i> =		72.16 ± 7.88
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	12.69 ± 0.64
¹⁷² Hf	c	1.87Y	1093.6	*	4.838 ± 0.395
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	6.065 ± 0.499
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	5.385 ± 0.420
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	2.884 ± 0.198
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.249 ± 0.093
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	3.183 ± 0.164
			172.1	25.5 ± 0.8	2.947 ± 0.283
			<i>RR_{mean}</i> =		3.138 ± 0.151
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.7493 ± 0.1054
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.612 ± 0.113
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	2.868 ± 0.132
			573.1	88.6 ± 0.1	2.672 ± 0.164

Continuation of Table 78.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	2.805 ± 0.087
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	3.420 ± 0.175
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	3.461 ± 0.161
			197.3	87.0 ± 1.1	3.912 ± 0.191
				$RR_{mean} =$	3.641 ± 0.247
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	1.482 ± 0.120
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	8.380 ± 0.550
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	9.550 ± 0.478
			884.7	72.7 ± 0.4	9.034 ± 0.368
			657.8	94.3 ± 0.3	9.324 ± 0.335
				$RR_{mean} =$	9.266 ± 0.314
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	2.448 ± 0.200
			717.3	28.9 ± 0.8	3.350 ± 0.364
			451.0	28.2 ± 0.8	2.161 ± 0.180
				$RR_{mean} =$	2.409 ± 0.265
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	34.33 ± 1.73
¹⁰² Rh	i	207D	475.1	46 ± 5	2.705 ± 0.483
^{101m} Rh	c	4.34D	306.9	81 ± 5	3.704 ± 0.276
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	34.26 ± 1.28
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	3.243 ± 0.194
			812.5	82 ± 4	3.392 ± 0.232
				$RR_{mean} =$	3.301 ± 0.165
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	32.90 ± 1.60
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	21.45 ± 1.05
			849.9	20.45 ± 0.20	24.81 ± 1.47
			778.2	96.45 ± 0.22	21.14 ± 0.77
			460.0	26.62 ± 0.20	20.50 ± 0.90
				$RR_{mean} =$	21.25 ± 0.86
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	21.90 ± 0.73
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	42.57 ± 1.40
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.798 ± 0.080
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	6.569 ± 0.405
⁹⁵ Zr	c	64.02D	765.8	*	20.86 ± 0.70
			756.7	54.46 ± 0.10	20.29 ± 0.71
			724.2	44.17 ± 0.16	21.80 ± 0.86
				$RR_{mean} =$	20.83 ± 0.64
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	5.663 ± 0.228
⁸⁸ Zr	c	83.4D	1836.1	*	1.583 ± 0.383
			392.9	97.24 ± 0.00	1.993 ± 0.183
				$RR_{mean} =$	1.922 ± 0.059
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	25.76 ± 1.49
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	12.48 ± 0.57
			898.0	93.7 ± 0.3	12.24 ± 0.47
				$RR_{mean} =$	12.31 ± 0.45
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	14.06 ± 0.53
			898.0	93.7 ± 0.3	13.59 ± 0.48
				$RR_{mean} =$	13.76 ± 0.48
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	7.096 ± 0.274
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	7.686 ± 0.423
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	25.52 ± 1.27

Continuation of Table 78.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	14.26 ± 0.70
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	9.561 ± 0.840
			529.6	29.3 ± 2.1	8.814 ± 0.742
			520.4	45 ± 4	8.638 ± 0.902
			RR _{mean} =		9.018 ± 0.439
⁸² Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	15.40 ± 0.79
			776.5	83.5 ± 1.2	15.14 ± 0.57
			698.4	28.5 ± 0.4	15.29 ± 0.67
			554.3	70.8 ± 1.0	14.65 ± 0.63
			RR _{mean} =		15.08 ± 0.51
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	2.137 ± 0.150
			136.0	58.3 ± 0.8	2.508 ± 0.154
			RR _{mean} =		2.324 ± 0.199
⁷⁴ As	i	17.77D	595.8	59 ± 4	5.222 ± 0.405
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	6.592 ± 0.661
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	9.136 ± 0.668
⁷² Zn	c	46.5H	2201.7	*	2.543 ± 0.173
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	2.708 ± 0.197
			1099.2	56.5 ± 1.9	1.939 ± 0.193
			RR _{mean} =		2.345 ± 0.391

12.6.5 Nuclide production rates for ^{209}Bi

Table 79: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.4 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	64.22 ± 2.47
²⁰⁶ Po	i	8.8D	1878.7	*	73.27 ± 7.35
			1718.7	*	77.22 ± 3.56
			1595.3	*	59.28 ± 4.60
			1098.3	*	65.34 ± 6.60
			1032.3	33 ± 5	75.33 ± 11.69
			1007.2	3.1 ± 0.4	66.11 ± 8.96
			980.2	7.1 ± 0.9	79.38 ± 10.46
			895.1	*	76.11 ± 3.66
			807.4	23 ± 3	72.91 ± 9.81
			803.1	*	72.59 ± 2.67
			620.5	*	59.58 ± 4.54
			537.5	*	65.84 ± 2.86
			522.5	15.7 ± 2.0	72.62 ± 9.62
			516.2	*	70.78 ± 2.70
			497.1	*	72.19 ± 3.31
			398.0	*	73.26 ± 4.64
			343.5	*	75.99 ± 3.28
			338.4	19.2 ± 2.5	77.10 ± 10.39
			286.4	24 ± 3	77.31 ± 10.06
			184.0	*	81.45 ± 3.89
			<i>RR_{mean}</i> =		

Continuation of Table 79.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁵ Po	i	1.66H	1001.2	28.8 ± 2.2	85.26 ± 7.83
			872.4	37 ± 2	98.01 ± 6.75
			849.8	25.5 ± 2.1	77.56 ± 7.84
			<i>RR_{mean}</i> =		92.79 ± 6.29
²⁰⁴ Po	i	3.53H	1016.3	24.1 ± 1.0	78.71 ± 5.63
			884.0	29.9 ± 1.2	92.90 ± 6.10
			<i>RR_{mean}</i> =		85.71 ± 7.57
²⁰⁷ Bi	c	31.55Y	1063.7	74.5 ± 0.2	452.5 ± 16.1
			569.7	97.74 ± 0.03	432.2 ± 15.1
			<i>RR_{mean}</i> =		440.9 ± 16.9
²⁰⁶ Bi _i	i	6.243D	1878.7	2.01 ± 0.05	300.4 ± 14.8
			1718.7	31.8 ± 0.6	290.3 ± 11.9
			1098.3	13.50 ± 0.21	283.9 ± 14.0
			895.1	15.66 ± 0.23	291.7 ± 11.2
			881.0	66.2 ± 1.0	275.1 ± 10.4
			803.1	98.9 ± 1.4	272.2 ± 9.7
			620.5	5.76 ± 0.09	289.2 ± 12.5
			537.5	30.5 ± 0.5	255.5 ± 10.0
			516.2	40.7 ± 0.6	262.1 ± 9.8
			497.1	15.31 ± 0.22	252.5 ± 9.7
			343.5	23.4 ± 0.4	255.9 ± 10.1
			184.0	15.8 ± 0.4	307.6 ± 14.1
			398.0	10.74 ± 0.15	240.3 ± 10.7
			<i>RR_{mean}</i> =		269.9 ± 9.7
²⁰⁶ Bi _c	c	6.243D	1878.7	2.01 ± 0.05	369.7 ± 16.8
			1718.7	31.8 ± 0.6	363.2 ± 14.3
			1098.3	13.50 ± 0.21	345.6 ± 14.1
			895.1	15.66 ± 0.23	363.7 ± 13.2
			881.0	66.2 ± 1.0	361.5 ± 13.1
			803.1	98.9 ± 1.4	340.8 ± 12.1
			620.5	5.76 ± 0.09	345.5 ± 13.5
			537.5	30.5 ± 0.5	317.7 ± 12.1
			516.2	40.7 ± 0.6	329.0 ± 12.2
			497.1	15.31 ± 0.22	320.7 ± 12.0
			398.0	10.74 ± 0.15	309.5 ± 11.9
			343.5	23.4 ± 0.4	327.7 ± 12.5
			184.0	15.8 ± 0.4	384.6 ± 17.7
			<i>RR_{mean}</i> =		339.6 ± 12.0
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	387.5 ± 15.3
			1775.8	3.99 ± 0.08	397.6 ± 16.4
			1764.3	32.5 ± 0.7	399.0 ± 16.1
			1614.3	2.28 ± 0.04	418.0 ± 17.0
			1551.0	0.97 ± 0.03	399.6 ± 19.8
			1351.5	1.06 ± 0.04	398.8 ± 22.6
			1190.0	2.26 ± 0.07	393.8 ± 18.3
			1043.8	7.51 ± 0.10	354.1 ± 13.0
			1014.3	0.91 ± 0.02	395.2 ± 16.9
			987.7	16.13 ± 0.17	388.9 ± 13.4
			872.0	0.42 ± 0.01	352.8 ± 19.3
			759.1	1.04 ± 0.05	408.0 ± 24.6
			703.5	31.1 ± 0.1	360.5 ± 12.1

Continuation of Table 79.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			579.8	5.44 ± 0.07	349.3 ± 12.9
			570.6	4.34 ± 0.07	351.6 ± 13.4
			549.8	2.95 ± 0.04	342.6 ± 12.8
			284.1	1.69 ± 0.02	365.5 ± 15.3
			260.5	1.09 ± 0.04	377.5 ± 21.9
			<i>RR_{mean}</i> =		370.6 ± 12.6
²⁰⁴ Bi	c*	11.22H	1274.8	2.14 ± 0.25	378.0 ± 48.0
			1211.7	3.0 ± 0.4	306.8 ± 44.1
			984.0	59 ± 4	350.1 ± 26.5
			918.3	10.8 ± 0.9	401.9 ± 36.4
			899.2	98 ± 9	327.8 ± 11.6
			670.7	11.4 ± 0.9	361.2 ± 31.1
			374.8	82 ± 5	388.8 ± 81.2
			<i>RR_{mean}</i> =		331.4 ± 10.2
²⁰³ Bi	c	11.76H	1893.0	8.2 ± 0.6	334.1 ± 27.7
			1888.0	1.94 ± 0.10	317.8 ± 21.8
			1847.3	11.4 ± 0.8	335.0 ± 26.5
			1679.6	8.8 ± 0.7	332.2 ± 29.1
			1536.5	7.5 ± 0.6	333.8 ± 30.0
			1506.7	3.7 ± 0.3	354.2 ± 33.1
			1034.0	8.8 ± 0.5	347.4 ± 23.9
			896.8	13.1 ± 0.7	334.8 ± 21.2
			866.5	1.49 ± 0.08	318.9 ± 28.7
			847.2	8.5 ± 0.5	354.1 ± 24.2
			825.2	14.6 ± 1.1	378.9 ± 31.4
			820.2	29.6 ± 1.5	343.6 ± 20.9
			816.3	4.03 ± 0.21	320.8 ± 20.8
			279.2	*	367.8 ± 13.7
			<i>RR_{mean}</i> =		363.0 ± 11.2
²⁰² Bi	c*	1.72H	960.7	99.28 ± 0.02	307.2 ± 11.8
			422.1	83.7 ± 2.5	327.4 ± 16.0
			<i>RR_{mean}</i> =		312.1 ± 12.9
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	62.22 ± 5.69
			374.7	89 ± 15	78.53 ± 14.10
			<i>RR_{mean}</i> =		64.33 ± 5.82
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	111.4 ± 6.3
			374.7	89 ± 15	127.3 ± 22.2
			<i>RR_{mean}</i> =		112.2 ± 6.2
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	167.4 ± 6.8
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	535.2 ± 19.6
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	105.1 ± 10.4
			422.1	86 ± 5	95.53 ± 7.50
			<i>RR_{mean}</i> =		97.98 ± 5.16
²⁰¹ Pb	c*	9.33H	1277.1	1.63 ± 0.12	590.7 ± 55.4
			946.0	7.4 ± 0.6	518.1 ± 45.7
			907.6	5.7 ± 0.4	566.0 ± 47.0
			692.4	4.27 ± 0.16	548.1 ± 31.3
			361.3	9.9 ± 0.5	600.2 ± 37.4
			331.2	79 ± 5	595.7 ± 42.9
			<i>RR_{mean}</i> =		568.0 ± 23.0
²⁰⁰ Pb	c	21.5H	1604.5	*	411.0 ± 45.8

Continuation of Table 79.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁹ Pb	c*	90M	1514.9	*	438.5 ± 38.0
			1362.9	*	493.9 ± 61.1
			1225.5	*	417.3 ± 30.6
			1205.7	*	471.7 ± 32.5
			579.3	*	462.2 ± 30.1
			450.5	3.33 ± 0.08	520.9 ± 23.4
			367.9	*	456.2 ± 16.5
			257.2	4.46 ± 0.17	429.1 ± 26.7
			235.6	4.30 ± 0.17	562.4 ± 31.9
			147.6	37.7 ± 1.4	493.2 ± 30.2
			<i>RR_{mean}</i> =		457.7 ± 14.1
			1502.0	2.1 ± 0.4	779.9 ± 159.7
			1135.0	7.8 ± 1.2	952.1 ± 155.8
			366.9	44 ± 7	927.4 ± 157.5
			353.4	9.5 ± 1.5	1077 ± 180
			<i>RR_{mean}</i> =		950.1 ± 59.1
¹⁹⁸ Pb	c	2.4H	2040.2	*	421.6 ± 67.4
			1447.0	*	455.4 ± 74.2
			1420.6	*	606.8 ± 114.8
			865.3	5.9 ± 1.2	421.4 ± 88.3
			675.8	*	473.3 ± 51.5
			575.0	3.1 ± 0.7	543.4 ± 126.0
			365.4	19 ± 5	643.6 ± 171.1
			259.5	5.8 ± 1.2	558.2 ± 118.3
			173.4	18 ± 3	644.0 ± 110.3
			259.5	5.8 ± 1.2	558.2 ± 118.3
			<i>RR_{mean}</i> =		483.4 ± 14.9
^{197m} Pb	c*	43M	387.7	25 ± 6	393.6 ± 95.7
			385.9	74 ± 15	423.7 ± 87.3
			222.8	25 ± 6	324.0 ± 83.0
			<i>RR_{mean}</i> =		412.7 ± 23.8
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	401.5 ± 49.1
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	232.9 ± 45.5
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	48.92 ± 1.78
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	670.2 ± 26.1
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	81.48 ± 6.86
			579.3	13.8 ± 0.7	89.10 ± 15.13
			367.9	87.2 ± 0.4	84.46 ± 6.70
			<i>RR_{mean}</i> =		83.51 ± 4.96
²⁰⁰ Tl _c	c	26.1H	1604.5	1.17 ± 0.10	571.0 ± 58.7
			1514.9	4.0 ± 0.3	567.4 ± 47.5
			1362.9	3.4 ± 0.4	588.2 ± 72.4
			1225.5	3.36 ± 0.21	601.0 ± 43.1
			1205.7	29.9 ± 1.8	553.2 ± 38.0
			579.3	13.8 ± 0.7	551.3 ± 34.2
			367.9	87.2 ± 0.4	540.6 ± 18.7
			<i>RR_{mean}</i> =		545.7 ± 18.3
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	615.7 ± 73.3
			247.3	9.3 ± 1.1	641.6 ± 81.1
			208.2	12.3 ± 1.4	665.2 ± 80.5

Continuation of Table 79.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	638.3 ± 31.6
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	92.06 ± 12.08
			282.8	28 ± 3	116.9 ± 13.6
				$RR_{mean} =$	103.3 ± 12.8
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	505.5 ± 170.7
			152.2	7.3 ± 2.3	864.6 ± 274.6
				$RR_{mean} =$	701.0 ± 180.2
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	241.6 ± 42.5
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	404.4 ± 51.3
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	1.519 ± 0.125
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	576.1 ± 33.1
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	35.31 ± 2.99
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	51.99 ± 7.39
			779.8	54.2 ± 0.1	57.43 ± 12.14
				$RR_{mean} =$	53.44 ± 1.65
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	453.7 ± 49.7
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	50.08 ± 8.21
			407.6	32 ± 6	67.91 ± 13.04
			258.0	49 ± 7	109.6 ± 16.5
				$RR_{mean} =$	63.37 ± 14.91
¹⁹² Hg	c	4.85H	2319.4	*	389.8 ± 83.0
			316.5	*	386.5 ± 48.6
			296.0	*	377.2 ± 53.6
			274.8	50.2 ± 2.5	296.2 ± 18.7
				$RR_{mean} =$	305.9 ± 9.4
¹⁹⁰ Hg	c*	20.0M	295.8	*	214.5 ± 36.0
			142.6	68 ± 10	210.6 ± 36.8
				$RR_{mean} =$	212.6 ± 6.6
¹⁹⁸ Au	i	2.69517D	411.8	95.58 ± 0.12	2.508 ± 0.119
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	4.781 ± 0.182
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	464.8 ± 51.9
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	11.10 ± 1.01
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	28.20 ± 5.23
¹⁹² Au _c	c	4.94H	2319.4	1.6 ± 0.3	364.2 ± 75.2
			316.5	58 ± 7	414.7 ± 52.1
			296.0	22 ± 3	429.6 ± 61.0
				$RR_{mean} =$	414.9 ± 16.2
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	306.6 ± 21.7
			277.9	7.2 ± 0.5	288.2 ± 24.6
				$RR_{mean} =$	298.9 ± 17.5
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	271.8 ± 33.1
			456.5	3.4 ± 0.4	245.5 ± 30.4
			409.4	8.0 ± 0.9	244.5 ± 29.0
			359.9	6.0 ± 0.7	256.6 ± 31.2
			351.2	3.4 ± 0.4	288.4 ± 35.5
			172.2	3.5 ± 0.4	247.9 ± 31.4
			129.4	3.2 ± 0.5	274.5 ± 46.4
				$RR_{mean} =$	257.5 ± 10.3
¹⁸⁹ Pt	c	10.87H	607.6	8.10 ± 0.16	254.0 ± 11.8
			568.8	7.1 ± 0.6	258.9 ± 26.1

Continuation of Table 79.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			544.9	5.8 ± 0.5	253.3 ± 24.7
			243.5	7.0 ± 1.2	231.9 ± 41.5
			$RR_{mean} =$		253.7 ± 10.8
¹⁸⁸ Pt	c	10.2D	634.9	*	221.5 ± 36.3
			633.0	*	255.9 ± 43.6
			478.0	*	180.2 ± 9.7
			423.3	4.4 ± 0.3	179.2 ± 13.8
			381.4	7.5 ± 0.5	181.7 ± 13.6
			322.9	*	190.4 ± 18.9
			195.1	18.6 ± 1.2	184.1 ± 13.8
			187.6	19.4 ± 1.2	186.3 ± 13.6
			155.1	*	194.3 ± 20.8
			140.4	2.33 ± 0.15	212.9 ± 18.3
			$RR_{mean} =$		183.8 ± 5.7
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	129.6 ± 28.2
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	188.6 ± 26.5
			245.1	6.0 ± 0.6	203.0 ± 22.0
			$RR_{mean} =$		201.6 ± 8.3
¹⁸⁸ Ir _c	c	41.5H	634.9	5.0 ± 0.8	236.8 ± 39.0
			633.0	18 ± 3	309.0 ± 54.4
			478.0	14.7 ± 0.6	207.8 ± 11.4
			322.9	1.62 ± 0.15	200.3 ± 20.3
			155.1	30 ± 3	205.3 ± 22.0
			$RR_{mean} =$		208.2 ± 7.6
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	161.8 ± 12.1
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	61.46 ± 3.09
			296.9	62.3 ± 1.9	61.71 ± 3.54
			137.2	41.4 ± 0.7	72.36 ± 4.67
			$RR_{mean} =$		63.43 ± 3.49
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	90.21 ± 13.86
			254.2	13.3 ± 2.4	75.87 ± 14.59
			$RR_{mean} =$		87.80 ± 6.01
¹⁸⁴ Ir	c*	3.09H	264.0	68 ± 4	86.13 ± 6.66
			119.8	31 ± 3	101.2 ± 12.3
			$RR_{mean} =$		87.75 ± 5.40
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	109.9 ± 5.8
			717.4	3.94 ± 0.16	110.1 ± 7.7
			646.1	78 ± 3	106.7 ± 5.5
			592.1	1.32 ± 0.06	100.1 ± 6.6
			$RR_{mean} =$		107.3 ± 3.6
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	41.28 ± 2.45
			1101.9	49.0 ± 1.3	40.59 ± 2.01
			$RR_{mean} =$		40.80 ± 1.62
¹⁸² Os	c	22.10H	1221.5	*	66.04 ± 4.89
			1189.2	*	67.64 ± 5.48
			1121.4	*	66.46 ± 4.17
			180.2	33.5 ± 1.7	55.17 ± 3.64
			$RR_{mean} =$		60.78 ± 1.87
¹⁸¹ Os	c	105M	238.8	44 ± 5	24.62 ± 3.42
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	67.59 ± 5.01

Continuation of Table 79.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			208.8	2.95 ± 0.09	68.74 ± 4.10
			162.3	23.3 ± 0.7	71.39 ± 3.49
			109.7	2.87 ± 0.09	74.66 ± 6.10
			107.9	2.17 ± 0.07	67.78 ± 6.26
			<i>RR_{mean}</i> =		70.27 ± 2.66
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	64.34 ± 5.13
			1189.2	15 ± 1	77.10 ± 7.47
			1121.4	31.8 ± 1.6	73.86 ± 4.87
			<i>RR_{mean}</i> =		71.13 ± 4.09
¹⁸¹ Re	c*	19.9H	365.5	56 ± 8	43.05 ± 6.34
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	6.420 ± 0.358
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	4.168 ± 0.503
¹⁷² Hf	c	1.87Y	1093.6	*	1.762 ± 0.380
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	2.749 ± 0.415
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	2.329 ± 0.529
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.776 ± 0.080
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	2.888 ± 0.357
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	7.344 ± 0.577
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	5.695 ± 0.425
			202.9	68.3 ± 0.5	5.575 ± 0.240
			172.1	25.5 ± 0.8	5.269 ± 0.312
			<i>RR_{mean}</i> =		5.514 ± 0.214
¹²⁶ I	i	13.11D	666.3	33.1 ± 2.5	3.864 ± 0.445
			388.6	34 ± 3	2.965 ± 0.354
			<i>RR_{mean}</i> =		3.327 ± 0.453
¹²⁴ I	i	4.1760D	602.7	62.9 ± 0.6	4.625 ± 0.243
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	4.799 ± 0.199
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	5.014 ± 0.216
			573.1	88.6 ± 0.1	5.020 ± 0.250
			<i>RR_{mean}</i> =		5.016 ± 0.155
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	6.511 ± 0.306
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.293 ± 0.143
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	1.411 ± 0.098
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	6.866 ± 0.241
			197.3	87.0 ± 1.1	7.056 ± 0.310
			<i>RR_{mean}</i> =		6.907 ± 0.236
^{118m} Sb	i(m)	5.00H	1050.7	97 ± 5	7.343 ± 0.652
^{117m} Sn	i(m)	13.60D	158.6	86.4 ± 0.4	10.52 ± 0.41
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.710 ± 0.170
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	13.28 ± 0.67
¹¹¹ In	c	2.8047D	245.4	94 ± 1	4.292 ± 0.325
¹¹⁵ Cd	c	53.46H	336.2	45.9 ± 1.0	4.617 ± 0.302
^{110m} Ag	i(m)	249.76D	1505.0	13.60 ± 0.19	16.92 ± 1.11
			937.5	34.2 ± 0.6	16.50 ± 0.71
			884.7	72.7 ± 0.4	16.24 ± 0.59
			763.9	22.62 ± 0.21	15.49 ± 0.75
			687.0	6.44 ± 0.06	16.93 ± 1.52
			657.8	94.3 ± 0.3	16.01 ± 0.55
			446.8	3.62 ± 0.04	16.38 ± 1.77
			<i>RR_{mean}</i> =		16.13 ± 0.52

Continuation of Table 79.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{106m} Ag	i(m)	8.28D	451.0	28.2 ± 0.8	3.351 ± 0.411
¹⁰⁵ Ag	c	41.29D	280.4	30.2 ± 1.8	2.310 ± 1.001
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	61.29 ± 2.97
^{102m} Rh	i(m)	2.9Y	631.3	56 ± 2	6.567 ± 0.600
			1046.6	34 ± 2	7.384 ± 0.933
			475.1	95 ± 4	8.502 ± 1.784
			<i>RR_{mean}</i> =		6.914 ± 0.509
^{101m} Rh	c	4.34D	306.9	81 ± 5	5.579 ± 0.465
¹⁰¹ Rh	c	3.3Y	127.2	68 ± 6	2.278 ± 0.361
¹⁰³ Ru	c	39.26D	610.3	5.76 ± 0.07	56.55 ± 3.52
			497.1	91.0 ± 1.3	57.67 ± 2.14
			<i>RR_{mean}</i> =		57.53 ± 2.09
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	4.462 ± 0.260
			812.5	82 ± 4	5.284 ± 0.351
			<i>RR_{mean}</i> =		4.738 ± 0.415
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	52.97 ± 2.86
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	34.88 ± 1.68
			778.2	96.45 ± 0.22	34.16 ± 1.19
			460.0	26.62 ± 0.20	33.82 ± 1.39
			<i>RR_{mean}</i> =		34.17 ± 1.14
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	36.13 ± 1.20
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	70.08 ± 2.30
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	2.066 ± 0.142
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	1.727 ± 0.342
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	9.486 ± 0.516
⁹⁵ Zr	c	64.02D	765.8	*	34.26 ± 1.15
			756.7	54.46 ± 0.10	33.76 ± 1.13
			724.2	44.17 ± 0.16	35.91 ± 1.26
			<i>RR_{mean}</i> =		34.30 ± 1.06
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	8.030 ± 0.297
⁸⁸ Zr	c	83.4D	1836.1	*	1.566 ± 0.182
			898.0	*	1.955 ± 0.602
			392.9	97.24 ± 0.00	2.060 ± 0.117
			<i>RR_{mean}</i> =		1.943 ± 0.060
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	36.88 ± 3.19
			202.5	97.3 ± 0.4	38.00 ± 2.07
			<i>RR_{mean}</i> =		37.72 ± 1.88
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	20.75 ± 0.74
			898.0	93.7 ± 0.3	18.63 ± 0.78
			<i>RR_{mean}</i> =		20.06 ± 1.17
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	22.32 ± 0.78
			898.0	93.7 ± 0.3	20.59 ± 0.74
			<i>RR_{mean}</i> =		21.50 ± 1.09
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	10.37 ± 0.38
			388.5	82.1 ± 0.5	11.39 ± 0.43
			<i>RR_{mean}</i> =		10.78 ± 0.60
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	11.31 ± 0.63
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	42.89 ± 1.62
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	13.11 ± 1.05
			529.6	29.3 ± 2.1	13.59 ± 1.10

Continuation of Table 79.					
Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			520.4	45 ± 4	13.40 ± 1.30
			$RR_{mean} =$		13.35 ± 0.60
^{82}Br	i(m+g)	35.30H	1474.9	16.32 ± 0.23	23.23 ± 1.39
			776.5	83.5 ± 1.2	22.06 ± 0.82
			698.4	28.5 ± 0.4	20.91 ± 1.00
			554.3	70.8 ± 1.0	20.86 ± 0.91
			$RR_{mean} =$		21.67 ± 0.78
^{75}Se	c	119.779D	400.7	11.47 ± 0.09	4.207 ± 0.363
			400.7	11.47 ± 0.09	4.207 ± 0.363
			264.7	58.9 ± 0.4	3.028 ± 0.202
			136.0	58.3 ± 0.8	3.345 ± 0.205
			$RR_{mean} =$		3.408 ± 0.276
^{76}As	i	1.0778D	559.1	45 ± 2	16.29 ± 1.17
^{74}As	i	17.77D	595.8	59 ± 4	7.246 ± 0.562
$^{72}\text{Ga}_i$	i	14.10H	2507.8	12.78 ± 0.23	11.18 ± 1.28
			2201.7	25.9 ± 0.5	8.549 ± 0.814
			$RR_{mean} =$		9.288 ± 1.215
$^{72}\text{Ga}_c$	c	14.10H	2507.8	12.78 ± 0.23	14.64 ± 1.29
			2201.7	25.9 ± 0.5	11.91 ± 0.84
			$RR_{mean} =$		12.69 ± 1.29
^{72}Zn	c	46.5H	2507.8	*	3.463 ± 0.278
			2201.7	*	3.360 ± 0.208
			$RR_{mean} =$		3.394 ± 0.181
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	2.958 ± 0.388
			1099.2	56.5 ± 1.9	3.743 ± 0.418
			$RR_{mean} =$		3.328 ± 0.405
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.3080 ± 0.0471
^7Be	i	53.29D	477.6	10.52 ± 0.06	8.181 ± 0.642

12.6.6 Nuclide production rates for ^{27}Al

Table 80: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.4 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	20.32 ± 1.35
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.076 ± 0.108
			1014.4	28.0 ± 0.4	2.098 ± 0.174
			$RR_{mean} =$		2.081 ± 0.100
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	105.8 ± 3.7
^{24}Na	c	14.9590H	1369.0	100 ± 0	81.30 ± 2.71
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1368.0	100 ± 0	2.781 ± 0.094
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	13.88 ± 0.56
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	1.331 ± 0.068

Continuation of Table 80.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1014.4	28.0 ± 0.4	1.283 ± 0.106
			$RR_{mean} = \mathbf{1.320 \pm 0.062}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	$\mathbf{70.32 \pm 2.44}$
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{54.09 \pm 1.80}$
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{1.820 \pm 0.062}$
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	$\mathbf{18.83 \pm 0.70}$
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.028 ± 0.100
			1014.4	28.0 ± 0.4	2.061 ± 0.242
			$RR_{mean} = \mathbf{2.031 \pm 0.097}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	$\mathbf{98.64 \pm 3.46}$
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{74.32 \pm 2.47}$
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{2.634 \pm 0.088}$
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	$\mathbf{20.52 \pm 0.76}$
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.851 ± 0.130
			1014.4	28.0 ± 0.4	2.922 ± 0.210
			$RR_{mean} = \mathbf{2.865 \pm 0.123}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	$\mathbf{105.3 \pm 3.6}$
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{79.65 \pm 2.65}$
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{2.658 \pm 0.089}$
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	$\mathbf{21.52 \pm 0.79}$
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.611 ± 0.120
			1014.4	28.0 ± 0.4	2.601 ± 0.353
			$RR_{mean} = \mathbf{2.610 \pm 0.118}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	$\mathbf{104.9 \pm 3.6}$
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{79.20 \pm 2.64}$
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	$\mathbf{2.703 \pm 0.091}$

12.7 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.6$ GeV

12.7.1 Nuclide production rates for ^{206}Pb

Table 81: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.6$ GeV, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	803.1	98.9 ± 1.4	7.778 ± 0.305
			537.5	30.5 ± 0.5	7.779 ± 0.429
			497.1	15.31 ± 0.22	8.319 ± 0.909
			343.5	23.4 ± 0.4	6.950 ± 0.647
			$RR_{mean} =$		7.741 ± 0.286
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	26.67 ± 1.58
			1764.3	32.5 ± 0.7	25.56 ± 1.21
			703.5	31.1 ± 0.1	24.67 ± 0.86
^{204}Bi	i	11.22H	$RR_{mean} =$		24.92 ± 0.86
			984.0	59 ± 4	32.92 ± 2.55
			899.2	98 ± 9	31.36 ± 1.19
			670.7	11.4 ± 0.9	39.82 ± 4.09
			374.8	82 ± 5	34.14 ± 7.13
^{203}Bi	i(m+g)	11.76H	$RR_{mean} =$		31.54 ± 0.97
			1893.0	8.2 ± 0.6	36.97 ± 4.53
			1847.3	11.4 ± 0.8	35.97 ± 3.56
			820.2	29.6 ± 1.5	40.63 ± 2.57
^{202}Bi	i	1.72H	$RR_{mean} =$		40.07 ± 1.61
			960.7	99.28 ± 0.02	25.80 ± 3.09
			422.1	83.7 ± 2.5	45.70 ± 3.34
$^{204m}\text{Pb}_i$	i(m)	67.2M	$RR_{mean} =$		35.60 ± 10.01
			899.2	99.17 ± 0.02	69.40 ± 2.64
			374.7	89 ± 15	76.19 ± 13.14
$^{204m}\text{Pb}_c$	c	67.2M	$RR_{mean} =$		69.50 ± 2.64
			899.2	99.17 ± 0.02	74.10 ± 2.77
			374.7	89 ± 15	80.48 ± 13.87
^{203}Pb	c*	51.873H	$RR_{mean} =$		74.18 ± 2.76
^{202m}Pb	i(m)	3.53H	279.2	80.8 ± 0.2	258.6 ± 9.4
			960.7	92 ± 8	67.96 ± 6.86
			422.1	86 ± 5	63.71 ± 4.68
^{201}Pb	c*	9.33H	$RR_{mean} =$		64.52 ± 3.11
			692.4	4.27 ± 0.16	221.8 ± 13.1
			331.2	79 ± 5	227.6 ± 16.5
^{200}Pb	c	21.5H	$RR_{mean} =$		223.9 ± 11.2
			1514.9	*	167.0 ± 15.0
			1205.7	*	172.8 ± 12.0
			579.3	*	154.3 ± 10.0
			367.9	*	163.3 ± 5.7
			147.6	37.7 ± 1.4	170.8 ± 9.3
^{199}Pb	c*	90M	$RR_{mean} =$		163.9 ± 5.1
^{198}Pb	c	2.4H	366.9	44 ± 7	328.9 ± 54.7
			173.4	18 ± 3	229.0 ± 39.5

Continuation of Table 81.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{197m}Pb	c^*	43M	385.9	74 ± 15	161.0 ± 33.3
			222.8	25 ± 6	150.4 ± 36.8
			$RR_{mean} =$		160.0 ± 8.0
^{196}Pb	c^*	37M	502.1	26 ± 3	155.9 ± 19.2
^{195m}Pb	i(m)	15.0M	383.6	107 ± 20	89.64 ± 17.44
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	109.2 ± 4.0
^{201}Tl	c^*	72.912H	167.4	10.00 ± 0.06	372.8 ± 13.8
$^{200}\text{Tl}_i$	i	26.1H	1514.9	4.0 ± 0.3	159.5 ± 17.0
			1205.7	29.9 ± 1.8	142.1 ± 10.7
			579.3	13.8 ± 0.7	162.5 ± 12.3
			367.9	87.2 ± 0.4	142.9 ± 6.5
			$RR_{mean} =$		146.0 ± 6.1
$^{200}\text{Tl}_c$	c	26.1H	1514.9	4.0 ± 0.3	326.5 ± 27.5
			1205.7	29.9 ± 1.8	315.0 ± 21.8
			579.3	13.8 ± 0.7	316.8 ± 19.8
			367.9	87.2 ± 0.4	306.2 ± 10.7
			$RR_{mean} =$		308.0 ± 10.5
$^{199}\text{Tl}_c$	c	7.42H	455.5	12.4 ± 1.4	279.1 ± 33.4
			208.2	12.3 ± 1.4	335.6 ± 42.2
			$RR_{mean} =$		298.0 ± 28.2
^{199}Tl	c^*	7.42H	455.5	12.4 ± 1.4	343.3 ± 40.8
			208.2	12.3 ± 1.4	375.4 ± 46.4
			$RR_{mean} =$		355.7 ± 19.8
^{198m}Tl	i(m)	1.87H	282.8	28 ± 3	129.4 ± 17.0
^{197}Tl	c^*	2.84H	1411.3	4.5 ± 1.5	282.2 ± 96.0
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	252.6 ± 44.1
^{195}Tl	c^*	1.16H	884.5	10.0 ± 1.1	259.3 ± 33.4
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	8.439 ± 0.323
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	50.49 ± 2.30
$^{195}\text{Hg}_c$	c	9.9H	779.8	6.8 ± 0.7	328.2 ± 35.8
^{195m}Hg	i(m)	41.6H	560.3	7.0 ± 0.6	73.97 ± 7.11
			261.8	31 ± 4	80.17 ± 10.78
			$RR_{mean} =$		75.11 ± 4.43
^{193m}Hg	i(m)	11.8H	407.6	32 ± 6	98.00 ± 18.71
			258.0	49 ± 7	131.5 ± 20.5
			$RR_{mean} =$		113.3 ± 17.1
^{192}Hg	c	4.85H	316.5	*	354.8 ± 44.7
			274.8	50.2 ± 2.5	279.8 ± 17.7
			$RR_{mean} =$		288.2 ± 8.9
^{190}Hg	c^*	20.0M	142.6	68 ± 10	223.5 ± 34.2
^{198m}Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.188 ± 0.194
			411.8	*	1.922 ± 0.244
			$RR_{mean} =$		2.090 ± 0.064
$^{198}\text{Au}_i$	i	2.69517D	411.8	95.58 ± 0.12	5.150 ± 0.457
$^{198}\text{Au}_c$	i(m+g)	2.69517D	411.8	95.58 ± 0.12	7.072 ± 0.315
^{196}Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	13.79 ± 1.83
			355.7	87.0 ± 0.8	14.45 ± 0.51
			333.0	22.9 ± 0.6	16.11 ± 0.80
			$RR_{mean} =$		14.60 ± 0.57
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	299.0 ± 29.3

Continuation of Table 81.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	29.90 ± 2.66
			293.6	10.4 ± 0.8	28.10 ± 2.51
			<i>RR_{mean}</i> =		28.95 ± 1.65
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	42.34 ± 6.31
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	397.1 ± 49.9
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	389.6 ± 16.2
			166.5	3.32 ± 0.24	328.3 ± 29.8
			<i>RR_{mean}</i> =		381.5 ± 23.9
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	286.9 ± 26.1
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	313.4 ± 38.2
			456.5	3.4 ± 0.4	283.0 ± 34.7
			409.4	8.0 ± 0.9	276.9 ± 32.6
			351.2	3.4 ± 0.4	319.0 ± 39.4
			172.2	3.5 ± 0.4	267.8 ± 32.3
			<i>RR_{mean}</i> =		287.7 ± 13.1
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	351.7 ± 32.7
			607.6	8.10 ± 0.16	309.4 ± 12.8
			568.8	7.1 ± 0.6	317.8 ± 29.8
			544.9	5.8 ± 0.5	359.3 ± 33.7
			243.5	7.0 ± 1.2	335.2 ± 59.5
			<i>RR_{mean}</i> =		315.5 ± 12.2
¹⁸⁸ Pt	c	10.2D	633.0	*	317.0 ± 53.9
			478.0	*	281.9 ± 15.1
			423.3	4.4 ± 0.3	291.6 ± 22.3
			381.4	7.5 ± 0.5	282.3 ± 21.1
			195.1	18.6 ± 1.2	281.6 ± 21.0
			187.6	19.4 ± 1.2	289.1 ± 20.9
			155.1	*	298.1 ± 31.7
			<i>RR_{mean}</i> =		284.2 ± 8.8
¹⁸⁷ Pt	c	2.35H	106.4	8.8 ± 1.8	255.2 ± 54.5
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	228.2 ± 49.5
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	193.4 ± 35.0
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.5142 ± 0.0888
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	1.674 ± 0.148
			518.5	34.0 ± 1.6	2.044 ± 0.172
			<i>RR_{mean}</i> =		1.833 ± 0.192
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	285.1 ± 39.7
			245.1	6.0 ± 0.6	274.4 ± 29.5
			<i>RR_{mean}</i> =		275.1 ± 10.6
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	8.265 ± 1.804
			478.0	14.7 ± 0.6	11.79 ± 1.48
			155.1	30 ± 3	9.476 ± 2.038
			<i>RR_{mean}</i> =		10.24 ± 1.14
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	297.5 ± 31.8
			633.0	18 ± 3	325.3 ± 55.3
			478.0	14.7 ± 0.6	293.6 ± 15.7
			155.1	30 ± 3	307.6 ± 32.7
			<i>RR_{mean}</i> =		294.3 ± 10.1
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	306.4 ± 17.0
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	127.5 ± 8.8

Continuation of Table 81.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			434.8	33.9 ± 1.1	120.6 ± 5.8
			<i>RR_{mean}</i> =		122.2 ± 5.4
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	192.9 ± 29.6
			254.2	13.3 ± 2.4	176.1 ± 32.8
			<i>RR_{mean}</i> =		190.2 ± 10.1
¹⁸⁴ Ir	c*	3.09H	841.3	8.0 ± 0.8	216.7 ± 24.9
			390.4	25.9 ± 2.4	208.8 ± 21.1
			264.0	68 ± 4	230.2 ± 16.4
			119.8	31 ± 3	242.2 ± 26.3
			<i>RR_{mean}</i> =		227.4 ± 9.0
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	203.8 ± 48.5
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	251.0 ± 13.2
			717.4	3.94 ± 0.16	257.7 ± 13.8
			646.1	78 ± 3	248.3 ± 12.7
			<i>RR_{mean}</i> =		250.9 ± 8.1
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	135.4 ± 6.1
			1101.9	49.0 ± 1.3	125.6 ± 6.1
			<i>RR_{mean}</i> =		131.4 ± 6.3
¹⁸² Os	c	22.10H	1121.4	*	239.3 ± 14.6
			180.2	33.5 ± 1.7	208.8 ± 13.2
			<i>RR_{mean}</i> =		222.7 ± 6.9
¹⁸¹ Os	c	105M	238.8	44 ± 5	73.23 ± 9.13
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	166.6 ± 8.5
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	208.2 ± 14.6
			162.3	23.3 ± 0.7	231.6 ± 10.9
			<i>RR_{mean}</i> =		226.4 ± 12.0
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	220.5 ± 16.2
			1189.2	15 ± 1	255.1 ± 19.9
			1121.4	31.8 ± 1.6	229.8 ± 14.5
			<i>RR_{mean}</i> =		231.5 ± 10.8
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	193.2 ± 43.1
			365.5	56 ± 8	159.2 ± 23.6
			<i>RR_{mean}</i> =		165.7 ± 18.0
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	208.9 ± 15.9
			290.0	26.9 ± 2.3	180.7 ± 17.8
			<i>RR_{mean}</i> =		204.0 ± 12.4
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	181.3 ± 22.3
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	126.4 ± 15.4
			1340.8(D)	1.03 ± 0.09	98.92 ± 11.02
			<i>RR_{mean}</i> =		106.8 ± 12.9
¹⁷⁷ W	c	135M	115.7	51 ± 5	104.2 ± 11.5
¹⁷⁶ W	c	2.5H	1159.3	*	38.01 ± 14.79
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	111.5 ± 25.4
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	118.0 ± 11.2
¹⁷⁵ Ta	c	10.5H	348.5	12.0 ± 1.1	97.42 ± 10.09
			266.9	10.52 ± 0.16	91.89 ± 4.27
			<i>RR_{mean}</i> =		92.42 ± 4.12
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	69.28 ± 8.04
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	88.09 ± 4.33
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	74.80 ± 4.59

Continuation of Table 81.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷² Hf	c	1.87Y	1093.6	*	47.73 ± 2.87
			900.7	*	49.48 ± 2.91
			181.5	*	46.71 ± 3.05
			125.8	11.3 ± 0.9	50.86 ± 5.20
			<i>RR_{mean}</i> =		48.60 ± 1.50
¹⁷⁰ Hf	c	16.01H	164.7	26 ± 8	43.07 ± 13.36
			120.2	15 ± 5	32.45 ± 11.06
			<i>RR_{mean}</i> =		37.90 ± 5.44
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	62.08 ± 3.46
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	47.80 ± 2.86
			900.7	29.8 ± 1.3	50.88 ± 2.97
			181.5	20.6 ± 1.0	47.99 ± 3.12
			<i>RR_{mean}</i> =		49.07 ± 1.84
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	48.53 ± 2.03
¹⁷⁰ Lu	c*	2.012D	2126.1	5.1 ± 0.3	46.96 ± 3.79
			1280.2	8.2 ± 0.4	48.49 ± 3.36
			<i>RR_{mean}</i> =		47.90 ± 2.37
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	26.81 ± 1.31
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	30.91 ± 1.36
			177.2	22.2 ± 0.5	28.22 ± 1.25
			130.5	11.31 ± 0.21	30.16 ± 1.95
			<i>RR_{mean}</i> =		29.54 ± 1.29
¹⁶⁶ Yb	c	56.7H	2052.4	*	14.77 ± 1.07
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	20.51 ± 3.99
¹⁶⁵ Tm	c	30.06H	242.9	35.5 ± 1.7	10.90 ± 0.81
¹⁴⁹ Gd	c	9.28D	149.7	48 ± 3	1.263 ± 0.131
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.311 ± 0.099
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	4.139 ± 0.175
			172.1	25.5 ± 0.8	4.165 ± 0.323
			<i>RR_{mean}</i> =		4.143 ± 0.167
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.140 ± 0.107
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	3.042 ± 0.206
			212.2	81.4 ± 1.1	2.997 ± 0.146
			<i>RR_{mean}</i> =		3.010 ± 0.093
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	5.756 ± 0.282
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.332 ± 0.111
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.727 ± 0.107
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.972 ± 0.230
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	9.033 ± 0.456
^{110m} Ag	i(m)	249.76D	1384.3	24.9 ± 0.8	9.126 ± 0.728
			937.5	34.2 ± 0.6	9.011 ± 0.460
			884.7	72.7 ± 0.4	8.315 ± 0.337
			<i>RR_{mean}</i> =		8.542 ± 0.355
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	4.676 ± 0.265
			717.3	28.9 ± 0.8	4.255 ± 0.259
			451.0	28.2 ± 0.8	4.657 ± 0.250
			<i>RR_{mean}</i> =		4.538 ± 0.194
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	30.28 ± 1.48
¹⁰² Rh	i	207D	475.1	46 ± 5	4.612 ± 0.600
^{101m} Rh	c	4.34D	306.9	81 ± 5	6.362 ± 0.480

Continuation of Table 81.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	27.34 ± 1.04
^{96}Tc	i(m+g)	4.28D	849.9	98 ± 4	6.034 ± 0.332
			812.5	82 ± 4	6.220 ± 0.372
			$RR_{mean} =$		6.113 ± 0.281
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	17.30 ± 0.86
			568.9	58.0 ± 0.3	16.85 ± 0.69
			$RR_{mean} =$		16.99 ± 0.65
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	21.44 ± 0.72
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	36.69 ± 1.22
^{92m}Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.978 ± 0.137
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	3.716 ± 0.232
^{95}Zr	c	64.02D	765.8	*	15.40 ± 0.56
			756.7	54.46 ± 0.10	14.89 ± 0.54
			724.2	44.17 ± 0.16	15.48 ± 0.57
			$RR_{mean} =$		15.27 ± 0.47
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	9.923 ± 0.335
^{88}Zr	c	83.4D	1836.1	*	4.317 ± 0.420
			392.9	97.24 ± 0.00	3.807 ± 0.165
			$RR_{mean} =$		3.847 ± 0.119
^{90m}Y	i(m)	3.19H	479.5	90.74 ± 0.05	19.33 ± 0.85
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	18.65 ± 0.72
			898.0	93.7 ± 0.3	18.70 ± 0.71
			$RR_{mean} =$		18.67 ± 0.65
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	22.96 ± 0.83
			898.0	93.7 ± 0.3	21.72 ± 0.76
			$RR_{mean} =$		22.21 ± 0.92
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	13.71 ± 0.49
			388.5	82.1 ± 0.5	15.07 ± 0.52
			$RR_{mean} =$		14.45 ± 0.81
^{85}Sr	c	64.84D	514.0	96 ± 4	14.49 ± 0.80
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	26.38 ± 1.09
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	16.49 ± 1.38
			529.6	29.3 ± 2.1	16.98 ± 1.38
			520.4	45 ± 4	16.08 ± 1.56
			$RR_{mean} =$		16.60 ± 0.76
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	13.95 ± 0.70
			776.5	83.5 ± 1.2	13.65 ± 0.52
			698.4	28.5 ± 0.4	14.52 ± 0.60
			554.3	70.8 ± 1.0	12.90 ± 0.52
			$RR_{mean} =$		13.65 ± 0.54
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	4.964 ± 0.217
			136.0	58.3 ± 0.8	5.297 ± 0.283
			$RR_{mean} =$		5.067 ± 0.219
^{74}As	i	17.77D	595.8	59 ± 4	8.866 ± 0.679
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	7.423 ± 0.634
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	9.578 ± 0.636
^{72}Zn	c	46.5H	2201.7	*	2.155 ± 0.205
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	3.723 ± 0.245
			1099.2	56.5 ± 1.9	3.970 ± 0.236
			$RR_{mean} =$		3.858 ± 0.182

Continuation of Table 81.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.5948 $\pm$ 0.0736
^7Be	i	53.29D	477.6	10.52 ± 0.06	5.899 $\pm$ 0.971

12.7.2 Nuclide production rates for ^{207}Pb

Table 82: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 0.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	803.1	98.9 ± 1.4	17.27 ± 0.62
			537.5	30.5 ± 0.5	17.15 ± 0.71
			343.5	23.4 ± 0.4	16.28 ± 0.86
			497.1	15.31 ± 0.22	18.64 ± 1.12
			$RR_{mean} =$		17.21 $\pm$ 0.60
^{205}Bi	i	15.31D	1764.3	32.5 ± 0.7	34.99 ± 1.46
			703.5	31.1 ± 0.1	33.47 ± 1.14
			1861.7	6.17 ± 0.10	34.44 ± 1.94
			$RR_{mean} =$		33.80 $\pm$ 1.12
^{204}Bi	i	11.22H	899.2	98 ± 9	32.90 ± 1.17
			374.8	82 ± 5	35.93 ± 7.51
			984.0	59 ± 4	34.13 ± 2.68
			670.7	11.4 ± 0.9	37.19 ± 3.49
			$RR_{mean} =$		33.08 $\pm$ 1.02
^{203}Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	37.73 ± 2.75
			1847.3	11.4 ± 0.8	36.37 ± 3.71
			1893.0	8.2 ± 0.6	30.37 ± 3.28
			$RR_{mean} =$		35.97 $\pm$ 2.34
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	25.51 ± 2.28
			422.1	83.7 ± 2.5	39.07 ± 3.50
			$RR_{mean} =$		29.55 $\pm$ 6.27
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	67.80 ± 2.40
			374.7	89 ± 15	78.75 ± 13.58
			$RR_{mean} =$		67.88 $\pm$ 2.40
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	72.73 ± 2.55
			374.7	89 ± 15	83.25 ± 14.35
			$RR_{mean} =$		72.81 $\pm$ 2.55
^{203}Pb	c*	51.873H	279.2	80.8 ± 0.2	222.7 $\pm$ 8.1
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	65.23 ± 6.36
			422.1	86 ± 5	65.83 ± 4.95
			$RR_{mean} =$		65.67 $\pm$ 3.24
^{201}Pb	c*	9.33H	331.2	79 ± 5	197.7 ± 14.3
			692.4	4.27 ± 0.16	186.5 ± 11.2
			$RR_{mean} =$		190.4 $\pm$ 9.6
^{200}Pb	c	21.5H	1205.7	*	154.3 ± 10.8
			1514.9	*	159.4 ± 14.2
			579.3	*	128.6 ± 8.6
			367.9	*	142.3 ± 4.9
			147.6	37.7 ± 1.4	148.1 ± 8.1
			$RR_{mean} =$		143.2 $\pm$ 4.4

Continuation of Table 82.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	284.3 ± 47.9
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	197.5 ± 34.1
^{197m} Pb	c*	43M	385.9	74 ± 15	137.9 ± 28.4
			222.8	25 ± 6	135.3 ± 33.2
			<i>RR_{mean}</i> =		137.8 ± 6.6
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	133.6 ± 16.9
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	69.95 ± 13.39
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	102.8 ± 3.7
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	331.0 ± 12.2
²⁰⁰ Tl _i	i	26.1H	367.9	87.2 ± 0.4	135.1 ± 5.4
			1205.7	29.9 ± 1.8	123.2 ± 9.6
			579.3	13.8 ± 0.7	158.5 ± 12.4
			1514.9	4.0 ± 0.3	101.1 ± 14.7
			<i>RR_{mean}</i> =		133.9 ± 7.1
²⁰⁰ Tl _c	c	26.1H	367.9	87.2 ± 0.4	277.4 ± 9.6
			1205.7	29.9 ± 1.8	277.6 ± 19.3
			579.3	13.8 ± 0.7	287.1 ± 18.2
			1514.9	4.0 ± 0.3	260.5 ± 22.6
			<i>RR_{mean}</i> =		277.4 ± 9.3
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	245.5 ± 29.9
			208.2	12.3 ± 1.4	293.2 ± 38.5
			<i>RR_{mean}</i> =		260.5 ± 23.5
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	309.4 ± 36.8
			208.2	12.3 ± 1.4	319.9 ± 39.2
			<i>RR_{mean}</i> =		313.9 ± 17.3
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	126.4 ± 15.5
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	272.4 ± 92.9
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	232.5 ± 40.8
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	194.3 ± 23.5
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	13.90 ± 0.56
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	55.49 ± 2.49
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	290.4 ± 31.6
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	76.90 ± 7.41
			261.8	31 ± 4	82.60 ± 11.10
			<i>RR_{mean}</i> =		77.98 ± 4.62
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	92.74 ± 17.71
			258.0	49 ± 7	123.0 ± 18.5
			<i>RR_{mean}</i> =		107.3 ± 15.5
¹⁹² Hg	c	4.85H	316.5	*	318.3 ± 40.1
			274.8	50.2 ± 2.5	247.7 ± 15.8
			<i>RR_{mean}</i> =		255.6 ± 7.9
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	192.0 ± 29.4
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.840 ± 0.228
			411.8	*	2.536 ± 0.170
			<i>RR_{mean}</i> =		2.638 ± 0.081
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	6.566 ± 0.352
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	9.102 ± 0.338
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	17.17 ± 2.22
			355.7	87.0 ± 0.8	16.94 ± 0.61
			333.0	22.9 ± 0.6	18.56 ± 0.82

Continuation of Table 82.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	17.23 ± 0.69
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	341.6 ± 33.6
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	33.16 ± 2.95
			293.6	10.4 ± 0.8	32.69 ± 2.82
				<i>RR_{mean}</i> =	32.91 ± 1.83
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	52.86 ± 7.37
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	371.2 ± 46.6
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	342.7 ± 15.9
			166.5	3.32 ± 0.24	353.7 ± 32.6
				<i>RR_{mean}</i> =	344.1 ± 15.3
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	269.3 ± 21.8
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	288.9 ± 35.2
			456.5	3.4 ± 0.4	262.8 ± 32.2
			409.4	8.0 ± 0.9	255.1 ± 30.0
			351.2	3.4 ± 0.4	296.8 ± 36.6
			172.2	3.5 ± 0.4	247.9 ± 30.0
				<i>RR_{mean}</i> =	266.1 ± 12.2
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	318.4 ± 29.7
			607.6	8.10 ± 0.16	278.1 ± 11.3
			568.8	7.1 ± 0.6	299.3 ± 28.0
			544.9	5.8 ± 0.5	324.8 ± 30.7
			243.5	7.0 ± 1.2	305.4 ± 53.9
				<i>RR_{mean}</i> =	284.3 ± 11.2
¹⁸⁸ Pt	c	10.2D	1209.8	*	269.5 ± 28.8
			633.0	*	287.6 ± 48.9
			478.0	*	255.4 ± 13.7
			423.3	4.4 ± 0.3	266.1 ± 20.3
			381.4	7.5 ± 0.5	254.5 ± 19.0
			195.1	18.6 ± 1.2	256.8 ± 19.2
			187.6	19.4 ± 1.2	262.7 ± 19.0
			155.1	*	271.5 ± 28.8
				<i>RR_{mean}</i> =	258.0 ± 8.0
¹⁸⁷ Pt	c	2.35H	106.4	8.8 ± 1.8	215.7 ± 47.0
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	199.7 ± 43.4
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	160.4 ± 29.0
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.5344 ± 0.0885
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.019 ± 0.186
			518.5	34.0 ± 1.6	2.220 ± 0.156
				<i>RR_{mean}</i> =	2.147 ± 0.118
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	255.5 ± 34.9
			245.1	6.0 ± 0.6	249.3 ± 26.8
				<i>RR_{mean}</i> =	249.7 ± 9.6
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	11.15 ± 2.26
			478.0	14.7 ± 0.6	13.78 ± 1.49
			155.1	30 ± 3	9.997 ± 2.102
				<i>RR_{mean}</i> =	12.36 ± 1.23
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	272.6 ± 29.2
			633.0	18 ± 3	298.8 ± 50.8
			478.0	14.7 ± 0.6	269.2 ± 14.4
			155.1	30 ± 3	281.4 ± 29.9

Continuation of Table 82.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	269.8 ± 9.3
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	264.7 ± 16.1
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	107.3 ± 8.2
			434.8	33.9 ± 1.1	114.2 ± 5.6
				<i>RR_{mean}</i> =	112.5 ± 5.1
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	170.4 ± 26.1
			254.2	13.3 ± 2.4	156.8 ± 29.1
				<i>RR_{mean}</i> =	168.2 ± 8.8
¹⁸⁴ Ir	c*	3.09H	841.3	8.0 ± 0.8	199.9 ± 22.9
			390.4	25.9 ± 2.4	179.1 ± 18.0
			264.0	68 ± 4	202.6 ± 14.4
			119.8	31 ± 3	212.0 ± 23.0
				<i>RR_{mean}</i> =	200.1 ± 7.9
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	183.0 ± 43.3
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	236.0 ± 12.4
			717.4	3.94 ± 0.16	232.4 ± 12.7
			646.1	78 ± 3	221.9 ± 11.3
				<i>RR_{mean}</i> =	227.1 ± 8.3
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	116.7 ± 5.1
			1101.9	49.0 ± 1.3	105.7 ± 5.2
				<i>RR_{mean}</i> =	112.9 ± 6.3
¹⁸² Os	c	22.10H	1121.4	*	208.6 ± 12.6
			180.2	33.5 ± 1.7	184.4 ± 11.6
				<i>RR_{mean}</i> =	195.8 ± 6.0
¹⁸¹ Os	c	105M	238.8	44 ± 5	57.69 ± 7.23
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	131.1 ± 6.5
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	192.6 ± 13.9
			162.3	23.3 ± 0.7	203.1 ± 9.5
				<i>RR_{mean}</i> =	201.2 ± 8.1
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	189.9 ± 14.2
			1189.2	15 ± 1	224.1 ± 17.3
			1121.4	31.8 ± 1.6	198.1 ± 12.1
				<i>RR_{mean}</i> =	200.2 ± 9.9
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	159.1 ± 35.8
			365.5	56 ± 8	137.2 ± 20.3
				<i>RR_{mean}</i> =	141.6 ± 15.4
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	176.0 ± 13.6
			290.0	26.9 ± 2.3	131.2 ± 13.2
				<i>RR_{mean}</i> =	165.0 ± 20.0
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	140.2 ± 17.3
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	122.2 ± 18.7
			1340.8(D)	1.03 ± 0.09	85.09 ± 9.22
				<i>RR_{mean}</i> =	89.05 ± 11.79
¹⁷⁷ W	c	135M	115.7	51 ± 5	85.01 ± 9.53
¹⁷⁶ W	c	2.5H	1159.3	*	41.82 ± 15.07
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	101.9 ± 23.3
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	91.79 ± 9.44
¹⁷⁵ Ta	c	10.5H	348.5	12.0 ± 1.1	77.46 ± 7.80
			266.9	10.52 ± 0.16	74.39 ± 3.53
				<i>RR_{mean}</i> =	74.73 ± 3.38

Continuation of Table 82.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	56.73 ± 6.68
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	70.93 ± 3.49
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	57.94 ± 3.62
¹⁷² Hf	c	1.87Y	1093.6	*	36.93 ± 2.21
			900.7	*	39.03 ± 2.37
			181.5	*	37.31 ± 2.55
			125.8	11.3 ± 0.9	38.92 ± 3.96
			<i>RR_{mean}</i> =		37.95 ± 1.17
¹⁷⁰ Hf	c	16.01H	164.7	26 ± 8	34.04 ± 10.56
			120.2	15 ± 5	23.80 ± 8.15
			<i>RR_{mean}</i> =		28.74 ± 5.19
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	49.17 ± 3.10
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	37.26 ± 2.23
			900.7	29.8 ± 1.3	40.05 ± 2.41
			181.5	20.6 ± 1.0	39.42 ± 2.65
			<i>RR_{mean}</i> =		38.70 ± 1.50
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	37.30 ± 1.56
¹⁷⁰ Lu	c*	2.012D	2126.1	5.1 ± 0.3	33.70 ± 2.97
			1280.2	8.2 ± 0.4	39.95 ± 2.65
			<i>RR_{mean}</i> =		37.83 ± 3.18
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	20.04 ± 1.18
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	24.05 ± 1.06
			177.2	22.2 ± 0.5	21.77 ± 1.01
			130.5	11.31 ± 0.21	24.02 ± 1.30
			<i>RR_{mean}</i> =		23.13 ± 1.06
¹⁶⁶ Yb	c	56.7H	2052.4	*	10.96 ± 0.85
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	15.63 ± 3.05
¹⁶⁵ Tm	c	30.06H	242.9	35.5 ± 1.7	8.040 ± 0.568
¹⁴⁹ Gd	c	9.28D	149.7	48 ± 3	1.150 ± 0.113
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.056 ± 0.072
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	3.498 ± 0.156
			172.1	25.5 ± 0.8	3.443 ± 0.266
			<i>RR_{mean}</i> =		3.488 ± 0.147
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.5043 ± 0.0629
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.976 ± 0.120
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	2.279 ± 0.195
			212.2	81.4 ± 1.1	2.710 ± 0.136
			<i>RR_{mean}</i> =		2.599 ± 0.080
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	4.447 ± 0.233
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.711 ± 0.152
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.478 ± 0.090
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.539 ± 0.263
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	8.976 ± 0.459
			937.5	34.2 ± 0.6	7.208 ± 0.419
			884.7	72.7 ± 0.4	7.320 ± 0.309
			<i>RR_{mean}</i> =		7.389 ± 0.365
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	3.557 ± 0.211
			717.3	28.9 ± 0.8	3.121 ± 0.240
			451.0	28.2 ± 0.8	3.672 ± 0.238

Continuation of Table 82.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	3.471 ± 0.190
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	26.42 ± 1.38
¹⁰² Rh	i	207D	475.1	46 ± 5	3.565 ± 0.523
^{101m} Rh	c	4.34D	306.9	81 ± 5	4.763 ± 0.361
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	23.98 ± 0.92
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	4.445 ± 0.247
			812.5	82 ± 4	4.536 ± 0.281
			<i>RR_{mean}</i> =		4.483 ± 0.209
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	15.29 ± 0.78
			568.9	58.0 ± 0.3	14.07 ± 0.61
			<i>RR_{mean}</i> =		14.46 ± 0.72
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	18.42 ± 0.64
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	32.65 ± 1.12
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.671 ± 0.091
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	3.928 ± 0.259
⁹⁵ Zr	c	64.02D	765.8	*	14.36 ± 0.63
			756.7	54.46 ± 0.10	14.07 ± 0.66
			724.2	44.17 ± 0.16	13.89 ± 0.54
			<i>RR_{mean}</i> =		14.06 ± 0.43
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	7.545 ± 0.261
⁸⁸ Zr	c	83.4D	1836.1	*	3.400 ± 0.433
			392.9	97.24 ± 0.00	2.840 ± 0.133
			<i>RR_{mean}</i> =		2.869 ± 0.089
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	16.08 ± 0.78
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	14.82 ± 0.60
			898.0	93.7 ± 0.3	14.22 ± 0.53
			<i>RR_{mean}</i> =		14.45 ± 0.53
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	18.22 ± 0.69
			898.0	93.7 ± 0.3	17.02 ± 0.59
			<i>RR_{mean}</i> =		17.41 ± 0.78
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	10.28 ± 0.37
			388.5	82.1 ± 0.5	11.56 ± 0.40
			<i>RR_{mean}</i> =		10.92 ± 0.72
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	11.27 ± 0.62
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	21.20 ± 1.21
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	11.87 ± 1.25
			529.6	29.3 ± 2.1	12.09 ± 1.05
			520.4	45 ± 4	12.40 ± 1.21
			<i>RR_{mean}</i> =		12.12 ± 0.63
⁸² Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	12.34 ± 0.58
			776.5	83.5 ± 1.2	12.01 ± 0.48
			698.4	28.5 ± 0.4	12.75 ± 0.57
			554.3	70.8 ± 1.0	11.14 ± 0.45
			<i>RR_{mean}</i> =		11.87 ± 0.50
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	4.063 ± 0.211
			136.0	58.3 ± 0.8	4.298 ± 0.245
			<i>RR_{mean}</i> =		4.158 ± 0.184
⁷⁴ As	i	17.77D	595.8	59 ± 4	7.001 ± 0.540
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	5.592 ± 1.022
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	7.697 ± 0.963

Continuation of Table 82.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{72}Zn	c	46.5H	2201.7	*	2.105 ± 0.265
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	3.236 ± 0.295
			1099.2	56.5 ± 1.9	3.135 ± 0.403
			$RR_{mean} =$		3.203 ± 0.243
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.5059 ± 0.0631
^7Be	i	53.29D	477.6	10.52 ± 0.06	4.316 ± 0.918

12.7.3 Nuclide production rates for ^{208}Pb

Table 83: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	20.58 ± 3.59
^{206}Bi	i	6.243D	803.1	98.9 ± 1.4	23.75 ± 0.86
			537.5	30.5 ± 0.5	22.48 ± 0.89
			497.1	15.31 ± 0.22	21.63 ± 1.16
			343.5	23.4 ± 0.4	22.86 ± 0.98
			$RR_{mean} =$		23.03 ± 0.82
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	35.62 ± 1.92
			1764.3	32.5 ± 0.7	35.11 ± 1.49
			703.5	31.1 ± 0.1	33.64 ± 1.16
			$RR_{mean} =$		34.07 ± 1.17
^{204}Bi	i	11.22H	984.0	59 ± 4	30.57 ± 2.35
			899.2	98 ± 9	29.63 ± 1.01
			670.7	11.4 ± 0.9	32.76 ± 3.49
			374.8	82 ± 5	32.38 ± 6.77
			$RR_{mean} =$		29.72 ± 0.92
^{203}Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	27.08 ± 3.14
			1847.3	11.4 ± 0.8	25.78 ± 2.37
			820.2	29.6 ± 1.5	32.73 ± 2.09
			$RR_{mean} =$		31.35 ± 2.13
^{202}Bi	i	1.72H	960.7	99.28 ± 0.02	23.34 ± 2.76
			422.1	83.7 ± 2.5	28.38 ± 2.71
			$RR_{mean} =$		25.95 ± 2.64
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	61.31 ± 2.16
			374.7	89 ± 15	74.35 ± 12.84
			$RR_{mean} =$		61.40 ± 2.18
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	65.75 ± 2.29
			374.7	89 ± 15	78.42 ± 13.53
			$RR_{mean} =$		65.83 ± 2.30
^{203}Pb	c*	51.873H	279.2	80.8 ± 0.2	182.8 ± 6.7
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	55.77 ± 5.50
			422.1	86 ± 5	62.76 ± 4.45
			$RR_{mean} =$		61.20 ± 3.47
^{201}Pb	c*	9.33H	692.4	4.27 ± 0.16	143.3 ± 8.8
			331.2	79 ± 5	164.0 ± 11.8
			$RR_{mean} =$		150.3 ± 10.8

Continuation of Table 83.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁰ Pb	c	21.5H	1514.9	*	117.6 ± 11.9
			1205.7	*	128.7 ± 8.9
			579.3	*	107.4 ± 7.1
			367.9	*	117.3 ± 4.1
			147.6	37.7 ± 1.4	125.7 ± 6.9
<i>RR_{mean}</i> =				118.2 ± 3.6	
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	233.6 ± 39.2
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	162.1 ± 28.0
^{197m} Pb	c*	43M	385.9	74 ± 15	115.6 ± 23.8
			222.8	25 ± 6	111.1 ± 27.2
<i>RR_{mean}</i> =				115.3 ± 5.6	
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	108.8 ± 13.5
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	62.51 ± 12.17
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	92.48 ± 3.42
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	282.4 ± 10.4
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	127.5 ± 16.9
			1205.7	29.9 ± 1.8	114.8 ± 8.3
			579.3	13.8 ± 0.7	146.4 ± 10.8
			367.9	87.2 ± 0.4	123.1 ± 5.2
			<i>RR_{mean}</i> =		124.1 ± 5.9
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	245.1 ± 21.4
			1205.7	29.9 ± 1.8	243.6 ± 16.8
			579.3	13.8 ± 0.7	253.8 ± 15.9
			367.9	87.2 ± 0.4	240.4 ± 8.4
			<i>RR_{mean}</i> =		241.5 ± 8.2
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	227.2 ± 27.4
			208.2	12.3 ± 1.4	256.2 ± 31.9
			<i>RR_{mean}</i> =		238.5 ± 15.9
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	268.4 ± 31.9
			208.2	12.3 ± 1.4	293.5 ± 35.8
			<i>RR_{mean}</i> =		278.8 ± 15.4
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	107.8 ± 13.3
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	235.8 ± 80.2
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	208.2 ± 36.3
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	155.9 ± 19.1
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	17.66 ± 0.66
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	55.83 ± 2.50
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	240.8 ± 26.3
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	71.07 ± 6.64
			261.8	31 ± 4	79.20 ± 10.65
			<i>RR_{mean}</i> =		72.31 ± 4.05
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	81.70 ± 15.62
			258.0	49 ± 7	109.5 ± 16.6
			<i>RR_{mean}</i> =		94.86 ± 14.19
¹⁹² Hg	c	4.85H	316.5	*	273.2 ± 34.3
			274.8	50.2 ± 2.5	211.0 ± 13.3
			<i>RR_{mean}</i> =		217.8 ± 6.7
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	165.4 ± 25.3
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	3.191 ± 0.281
			411.8	*	3.308 ± 0.178

Continuation of Table 83.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	3.280 ± 0.101
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	6.924 ± 0.331
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	10.23 ± 0.36
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	18.36 ± 0.65
			333.0	22.9 ± 0.6	20.04 ± 0.96
				RR _{mean} =	18.57 ± 0.79
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	293.7 ± 28.7
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	34.54 ± 3.06
			293.6	10.4 ± 0.8	32.02 ± 2.76
				RR _{mean} =	33.12 ± 1.84
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	44.87 ± 6.01
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	318.1 ± 39.9
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	291.2 ± 14.3
			166.5	3.32 ± 0.24	297.6 ± 26.8
				RR _{mean} =	292.3 ± 13.6
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	226.9 ± 17.3
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	252.2 ± 30.7
			456.5	3.4 ± 0.4	228.4 ± 28.1
			409.4	8.0 ± 0.9	222.6 ± 26.2
			351.2	3.4 ± 0.4	255.7 ± 31.5
			172.2	3.5 ± 0.4	221.1 ± 27.1
				RR _{mean} =	233.3 ± 10.1
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	271.2 ± 25.3
			607.6	8.10 ± 0.16	243.6 ± 10.0
			568.8	7.1 ± 0.6	232.5 ± 22.9
			544.9	5.8 ± 0.5	279.1 ± 26.2
			243.5	7.0 ± 1.2	267.6 ± 47.2
				RR _{mean} =	246.6 ± 9.5
¹⁸⁸ Pt	c	10.2D	1209.8	*	230.5 ± 24.7
			633.0	*	247.3 ± 42.0
			478.0	*	217.3 ± 11.7
			423.3	4.4 ± 0.3	220.8 ± 16.9
			381.4	7.5 ± 0.5	218.0 ± 16.3
			195.1	18.6 ± 1.2	217.6 ± 16.3
			187.6	19.4 ± 1.2	224.2 ± 16.2
			155.1	*	228.5 ± 24.3
				RR _{mean} =	219.1 ± 6.8
¹⁸⁷ Pt	c	2.35H	106.4	8.8 ± 1.8	171.7 ± 36.7
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	167.4 ± 36.4
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	130.7 ± 23.9
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.6971 ± 0.0603
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	1.793 ± 0.151
			518.5	34.0 ± 1.6	2.352 ± 0.179
				RR _{mean} =	2.039 ± 0.284
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	231.5 ± 32.1
			245.1	6.0 ± 0.6	220.5 ± 23.7
				RR _{mean} =	221.2 ± 8.6
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	11.74 ± 2.20
			478.0	14.7 ± 0.6	12.47 ± 1.58
			155.1	30 ± 3	13.05 ± 1.54

Continuation of Table 83.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	12.58 ± 0.98
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	236.5 ± 25.3
			633.0	18 ± 3	259.1 ± 44.1
			478.0	14.7 ± 0.6	229.7 ± 12.3
			155.1	30 ± 3	241.5 ± 25.6
				<i>RR_{mean}</i> =	230.4 ± 8.0
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	212.8 ± 12.0
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	95.33 ± 6.60
			434.8	33.9 ± 1.1	94.89 ± 4.56
				<i>RR_{mean}</i> =	95.00 ± 4.17
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	141.2 ± 21.7
			254.2	13.3 ± 2.4	131.7 ± 24.5
				<i>RR_{mean}</i> =	139.6 ± 7.5
¹⁸⁴ Ir	c*	3.09H	841.3	8.0 ± 0.8	148.9 ± 17.1
			390.4	25.9 ± 2.4	149.9 ± 15.2
			264.0	68 ± 4	171.6 ± 12.2
			119.8	31 ± 3	172.6 ± 18.7
				<i>RR_{mean}</i> =	167.0 ± 7.4
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	141.9 ± 33.9
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	193.0 ± 10.1
			717.4	3.94 ± 0.16	193.4 ± 10.5
			646.1	78 ± 3	186.1 ± 9.5
				<i>RR_{mean}</i> =	189.2 ± 6.3
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	93.49 ± 4.33
			1101.9	49.0 ± 1.3	80.46 ± 3.86
				<i>RR_{mean}</i> =	86.76 ± 7.04
¹⁸² Os	c	22.10H	1121.4	*	171.6 ± 10.4
			180.2	33.5 ± 1.7	158.4 ± 10.1
				<i>RR_{mean}</i> =	164.9 ± 5.1
¹⁸¹ Os	c	105M	238.8	44 ± 5	47.72 ± 5.90
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	104.5 ± 5.7
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	153.9 ± 10.8
			162.3	23.3 ± 0.7	167.2 ± 7.9
				<i>RR_{mean}</i> =	164.4 ± 7.4
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	153.3 ± 11.4
			1189.2	15 ± 1	181.0 ± 14.5
			1121.4	31.8 ± 1.6	155.6 ± 9.6
				<i>RR_{mean}</i> =	158.6 ± 8.1
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	128.1 ± 28.9
			365.5	56 ± 8	117.2 ± 17.5
				<i>RR_{mean}</i> =	119.6 ± 13.1
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	129.7 ± 10.2
			290.0	26.9 ± 2.3	115.8 ± 12.2
				<i>RR_{mean}</i> =	127.0 ± 6.8
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	117.1 ± 14.6
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	90.68 ± 11.56
			1340.8(D)	1.03 ± 0.09	66.71 ± 12.50
				<i>RR_{mean}</i> =	82.00 ± 11.80
¹⁷⁷ W	c	135M	115.7	51 ± 5	66.00 ± 7.37
¹⁷⁶ W	c	2.5H	1159.3	*	37.53 ± 8.93

Continuation of Table 83.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	79.71 ± 18.71
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	68.09 ± 6.39
¹⁷⁵ Ta	c	10.5H	348.5	12.0 ± 1.1	60.26 ± 6.13
			266.9	10.52 ± 0.16	56.02 ± 3.12
			<i>RR_{mean}</i> =		56.71 ± 2.93
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	47.29 ± 6.03
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	54.33 ± 2.67
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	41.65 ± 2.60
¹⁷² Hf	c	1.87Y	1093.6	*	26.63 ± 1.61
			900.7	*	28.11 ± 1.96
			181.5	*	27.83 ± 1.82
			125.8	11.3 ± 0.9	27.72 ± 2.94
			<i>RR_{mean}</i> =		27.36 ± 0.84
¹⁷⁰ Hf	c	16.01H	164.7	26 ± 8	23.55 ± 7.32
			120.2	15 ± 5	20.77 ± 7.16
			<i>RR_{mean}</i> =		22.44 ± 2.89
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	37.03 ± 2.05
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	26.78 ± 1.61
			900.7	29.8 ± 1.3	29.66 ± 2.02
			181.5	20.6 ± 1.0	29.80 ± 1.93
			<i>RR_{mean}</i> =		28.22 ± 1.36
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	27.04 ± 1.15
¹⁷⁰ Lu	c*	2.012D	2126.1	5.1 ± 0.3	23.88 ± 1.88
			1280.2	8.2 ± 0.4	28.59 ± 2.22
			<i>RR_{mean}</i> =		25.86 ± 2.46
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	15.96 ± 0.91
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	17.29 ± 0.80
			177.2	22.2 ± 0.5	15.47 ± 0.76
			130.5	11.31 ± 0.21	18.42 ± 1.22
			<i>RR_{mean}</i> =		16.63 ± 0.92
¹⁶⁶ Yb	c	56.7H	2052.4	*	7.528 ± 0.566
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	10.89 ± 2.13
¹⁶⁵ Tm	c	30.06H	242.9	35.5 ± 1.7	4.914 ± 0.396
¹⁴⁹ Gd	c	9.28D	149.7	48 ± 3	0.6018 ± 0.0920
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.085 ± 0.103
¹²⁷ Xe	c	36.4D	202.9	68.3 ± 0.5	2.708 ± 0.146
			172.1	25.5 ± 0.8	2.369 ± 0.350
			<i>RR_{mean}</i> =		2.672 ± 0.138
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.5347 ± 0.0672
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.832 ± 0.150
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	1.834 ± 0.164
			212.2	81.4 ± 1.1	2.039 ± 0.114
			<i>RR_{mean}</i> =		1.982 ± 0.061
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	3.500 ± 0.191
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.109 ± 0.081
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.009 ± 0.095
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	1.606 ± 0.155
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	6.490 ± 0.469
^{110m} Ag	i(m)	249.76D	1384.3	24.9 ± 0.8	7.393 ± 0.565
			937.5	34.2 ± 0.6	6.093 ± 0.374

Continuation of Table 83.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			884.7	72.7 ± 0.4	5.998 ± 0.269
			$RR_{mean} =$		
^{106m}Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	2.071 ± 0.196
			717.3	28.9 ± 0.8	2.032 ± 0.225
			451.0	28.2 ± 0.8	2.419 ± 0.230
			$RR_{mean} =$		
^{105}Rh	c	35.36H	318.9	19.1 ± 0.6	22.73 ± 1.12
^{102}Rh	i	207D	475.1	46 ± 5	2.910 ± 0.421
^{101m}Rh	c	4.34D	306.9	81 ± 5	3.415 ± 0.283
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	21.01 ± 0.81
^{96}Tc	i(m+g)	4.28D	849.9	98 ± 4	3.206 ± 0.180
			812.5	82 ± 4	3.294 ± 0.204
			$RR_{mean} =$		
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	12.04 ± 0.65
			568.9	58.0 ± 0.3	13.91 ± 0.61
			$RR_{mean} =$		
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	14.59 ± 0.52
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	27.20 ± 0.93
^{92m}Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.427 ± 0.080
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	3.752 ± 0.173
^{95}Zr	c	64.02D	765.8	*	12.72 ± 0.52
			756.7	54.46 ± 0.10	11.74 ± 0.87
			724.2	44.17 ± 0.16	12.57 ± 0.48
			$RR_{mean} =$		
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	5.034 ± 0.185
^{88}Zr	c	83.4D	1836.1	*	2.056 ± 0.307
			392.9	97.24 ± 0.00	2.036 ± 0.119
			$RR_{mean} =$		
^{90m}Y	i(m)	3.19H	479.5	90.74 ± 0.05	14.34 ± 0.64
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	10.90 ± 0.46
			898.0	93.7 ± 0.3	10.75 ± 0.39
			$RR_{mean} =$		
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	12.96 ± 0.49
			898.0	93.7 ± 0.3	12.39 ± 0.42
			$RR_{mean} =$		
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	7.291 ± 0.265
			388.5	82.1 ± 0.5	8.754 ± 0.308
			$RR_{mean} =$		
^{85}Sr	c	64.84D	514.0	96 ± 4	7.920 ± 0.437
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	17.90 ± 1.13
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	10.01 ± 0.88
			529.6	29.3 ± 2.1	9.103 ± 0.788
			520.4	45 ± 4	8.723 ± 0.865
			$RR_{mean} =$		
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	9.425 ± 0.563
			776.5	83.5 ± 1.2	9.894 ± 0.382
			698.4	28.5 ± 0.4	10.53 ± 0.48
			554.3	70.8 ± 1.0	9.448 ± 0.397
			$RR_{mean} =$		
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	2.567 ± 0.145

Continuation of Table 83.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			136.0	58.3 ± 0.8	2.648 ± 0.158
			<i>RR_{mean}</i> =		
⁷⁴ As	i	17.77D	595.8	59 ± 4	4.894 ± 0.390
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	4.679 ± 0.849
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	6.291 ± 0.780
⁷² Zn	c	46.5H	2201.7	*	1.612 ± 0.170
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	2.195 ± 0.194
			1099.2	56.5 ± 1.9	2.302 ± 0.180
			<i>RR_{mean}</i> =		
⁴⁶ Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.4787 ± 0.0629
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	4.866 ± 0.870

12.7.4 Nuclide production rates for ^{nat}Pb

Table 84: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.6$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	569.7	97.74 ± 0.03	18.95 ± 3.61
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	22.10 ± 0.94
			803.1	98.9 ± 1.4	20.93 ± 0.75
			537.5	30.5 ± 0.5	20.55 ± 0.83
			497.1	15.31 ± 0.22	21.76 ± 1.22
			343.5	23.4 ± 0.4	19.22 ± 0.90
			<i>RR_{mean}</i> =		
			20.83 ± 0.76		
²⁰⁵ Bi	i	15.31D	1764.3	32.5 ± 0.7	37.00 ± 1.56
			1861.7	6.17 ± 0.10	34.81 ± 1.93
			703.5	31.1 ± 0.1	35.59 ± 1.24
			<i>RR_{mean}</i> =		
			35.80 ± 1.20		
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	38.57 ± 3.00
			899.2	98 ± 9	34.88 ± 1.28
			670.7	11.4 ± 0.9	38.30 ± 3.99
			374.8	82 ± 5	38.60 ± 8.06
			<i>RR_{mean}</i> =		
			35.20 ± 1.09		
²⁰³ Bi	i(m+g)	11.76H	1893.0	8.2 ± 0.6	32.45 ± 3.40
			1847.3	11.4 ± 0.8	35.99 ± 3.19
			820.2	29.6 ± 1.5	40.87 ± 2.59
			<i>RR_{mean}</i> =		
			39.56 ± 2.26		
²⁰² Bi	i	1.72H	960.7	99.28 ± 0.02	30.59 ± 4.30
			422.1	83.7 ± 2.5	41.88 ± 3.42
			<i>RR_{mean}</i> =		
			37.78 ± 5.55		
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	75.82 ± 2.95
			374.7	89 ± 15	83.06 ± 14.37
			<i>RR_{mean}</i> =		
			75.94 ± 2.94		
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	81.06 ± 3.08
			374.7	89 ± 15	87.90 ± 15.19
			<i>RR_{mean}</i> =		
			81.15 ± 3.08		
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	242.7 ± 8.9

Continuation of Table 84.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	67.27 ± 7.46
			422.1	86 ± 5	68.77 ± 5.01
			$RR_{mean} =$		68.52 ± 3.32
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	215.4 ± 15.5
			692.4	4.27 ± 0.16	203.6 ± 11.2
			$RR_{mean} =$		207.2 ± 10.0
²⁰⁰ Pb	c	21.5H	1205.7	*	161.4 ± 11.2
			1514.9	*	175.3 ± 15.4
			579.3	*	146.3 ± 9.5
			367.9	*	153.6 ± 5.3
			147.6	37.7 ± 1.4	163.2 ± 9.1
			$RR_{mean} =$		154.9 ± 4.8
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	284.7 ± 47.0
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	207.3 ± 35.6
^{197m} Pb	c*	43M	385.9	74 ± 15	153.7 ± 31.7
			222.8	25 ± 6	147.3 ± 36.4
			$RR_{mean} =$		153.2 ± 7.5
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	168.0 ± 21.0
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	86.92 ± 18.35
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	112.7 ± 4.1
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	359.8 ± 13.3
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	148.1 ± 10.6
			1514.9	4.0 ± 0.3	133.5 ± 14.7
			367.9	87.2 ± 0.4	143.4 ± 5.8
			579.3	13.8 ± 0.7	164.8 ± 11.9
			$RR_{mean} =$		145.3 ± 5.9
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	309.4 ± 21.3
			1514.9	4.0 ± 0.3	308.8 ± 25.9
			579.3	13.8 ± 0.7	311.2 ± 19.3
			367.9	87.2 ± 0.4	296.9 ± 10.3
			$RR_{mean} =$		298.7 ± 10.1
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	283.8 ± 34.9
			208.2	12.3 ± 1.4	319.1 ± 39.8
			$RR_{mean} =$		298.7 ± 19.7
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	338.0 ± 40.1
			208.2	12.3 ± 1.4	360.3 ± 43.9
			$RR_{mean} =$		347.5 ± 19.1
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	126.4 ± 15.5
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	369.4 ± 125.0
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	261.0 ± 45.5
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	225.0 ± 29.0
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	16.35 ± 0.64
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	62.07 ± 3.10
¹⁹⁵ Hg _c	c	9.9H	779.8	6.8 ± 0.7	311.4 ± 34.1
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	82.89 ± 7.85
			261.8	31 ± 4	90.48 ± 12.19
			$RR_{mean} =$		84.17 ± 4.84
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	132.1 ± 19.8
			407.6	32 ± 6	100.6 ± 19.2
			$RR_{mean} =$		116.1 ± 16.2

Continuation of Table 84.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹² Hg	c	4.85H	316.5	*	340.7 ± 42.8
			274.8	50.2 ± 2.5	267.4 ± 16.7
			<i>RR_{mean}</i> =		275.5 ± 8.5
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	215.2 ± 33.0
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	3.632 ± 0.299
			411.8	*	3.052 ± 0.215
			<i>RR_{mean}</i> =		3.241 ± 0.100
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	7.484 ± 0.426
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	10.53 ± 0.40
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	20.51 ± 2.65
			355.7	87.0 ± 0.8	19.43 ± 0.68
			333.0	22.9 ± 0.6	20.38 ± 0.92
			<i>RR_{mean}</i> =		19.57 ± 0.65
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	386.3 ± 38.2
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	37.34 ± 3.32
			293.6	10.4 ± 0.8	35.30 ± 3.05
			<i>RR_{mean}</i> =		36.22 ± 2.02
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	59.19 ± 7.65
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	399.9 ± 50.2
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	377.7 ± 14.6
			166.5	3.32 ± 0.24	360.7 ± 31.2
			<i>RR_{mean}</i> =		376.2 ± 14.4
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	257.9 ± 28.2
			295.8	71 ± 5	278.0 ± 23.0
			<i>RR_{mean}</i> =		272.2 ± 14.8
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	315.2 ± 38.4
			456.5	3.4 ± 0.4	282.0 ± 34.6
			409.4	8.0 ± 0.9	274.1 ± 32.2
			351.2	3.4 ± 0.4	316.7 ± 39.1
			172.2	3.5 ± 0.4	265.3 ± 32.0
			<i>RR_{mean}</i> =		285.9 ± 13.4
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	343.5 ± 31.8
			607.6	8.10 ± 0.16	296.9 ± 12.6
			568.8	7.1 ± 0.6	325.9 ± 30.4
			544.9	5.8 ± 0.5	343.7 ± 32.2
			243.5	7.0 ± 1.2	320.8 ± 56.6
			<i>RR_{mean}</i> =		305.0 ± 12.5
¹⁸⁸ Pt	c	10.2D	1209.8	*	286.3 ± 30.6
			633.0	*	309.2 ± 52.6
			478.0	*	271.4 ± 14.6
			322.9	*	267.9 ± 26.7
			155.1	*	290.3 ± 30.8
			187.6	19.4 ± 1.2	281.1 ± 20.3
			195.1	18.6 ± 1.2	274.3 ± 20.5
			423.3	4.4 ± 0.3	276.0 ± 21.1
			381.4	7.5 ± 0.5	268.9 ± 20.1
			<i>RR_{mean}</i> =		273.7 ± 8.4
¹⁸⁷ Pt	c	2.35H	106.4	8.8 ± 1.8	219.2 ± 46.7
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	212.2 ± 46.1
			137.1	*	183.8 ± 26.2

Continuation of Table 84.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	190.6 $\pm$ 5.9
¹⁸⁴ Pt	c	17.3M	548.3	23 $\pm$ 4	179.5 $\pm$ 33.2
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 $\pm$ 0.21	0.6374 $\pm$ 0.0717
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 $\pm$ 1.9	2.145 $\pm$ 0.170
			518.5	34.0 $\pm$ 1.6	2.549 $\pm$ 0.199
				$RR_{mean} =$	2.318 $\pm$ 0.212
¹⁸⁹ Ir	c	13.2D	245.1	6.0 $\pm$ 0.6	270.0 $\pm$ 29.0
			275.9	0.54 $\pm$ 0.07	278.7 $\pm$ 38.3
				$RR_{mean} =$	270.6 $\pm$ 10.5
¹⁸⁸ Ir _i	i	41.5H	633.0	18 $\pm$ 3	11.12 $\pm$ 2.53
			478.0	14.7 $\pm$ 0.6	14.19 $\pm$ 2.41
			155.1	30 $\pm$ 3	12.84 $\pm$ 2.25
				$RR_{mean} =$	12.79 $\pm$ 1.38
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 $\pm$ 0.7	289.1 $\pm$ 30.9
			633.0	18 $\pm$ 3	320.4 $\pm$ 54.5
			478.0	14.7 $\pm$ 0.6	285.6 $\pm$ 15.4
			322.9	1.62 $\pm$ 0.15	264.4 $\pm$ 27.1
			155.1	30 $\pm$ 3	303.1 $\pm$ 32.2
				$RR_{mean} =$	285.6 $\pm$ 9.9
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 $\pm$ 0.11	276.2 $\pm$ 14.8
¹⁸⁶ Ir	c	16.64H	434.8	33.9 $\pm$ 1.1	122.1 $\pm$ 5.9
			773.3	8.9 $\pm$ 0.5	116.5 $\pm$ 8.0
			137.2	41.4 $\pm$ 0.7	125.7 $\pm$ 5.9
				$RR_{mean} =$	122.8 $\pm$ 4.8
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 $\pm$ 1.5	182.4 $\pm$ 28.0
			254.2	13.3 $\pm$ 2.4	171.9 $\pm$ 32.0
				$RR_{mean} =$	180.8 $\pm$ 9.6
¹⁸⁴ Ir	c*	3.09H	264.0	68 $\pm$ 4	213.8 $\pm$ 15.1
			841.3	8.0 $\pm$ 0.8	175.1 $\pm$ 19.9
			390.4	25.9 $\pm$ 2.4	192.8 $\pm$ 19.2
			119.8	31 $\pm$ 3	230.6 $\pm$ 25.1
				$RR_{mean} =$	208.7 $\pm$ 10.2
¹⁸³ Ir	c	57M	392.5	10.4 $\pm$ 2.4	181.5 $\pm$ 44.3
¹⁸⁵ Os	c	93.6D	646.1	78 $\pm$ 3	237.1 $\pm$ 12.1
			874.8	6.29 $\pm$ 0.25	246.3 $\pm$ 12.9
			717.4	3.94 $\pm$ 0.16	238.9 $\pm$ 12.9
				$RR_{mean} =$	239.9 $\pm$ 7.9
^{183m} Os	c*	9.9H	1101.9	49.0 $\pm$ 1.3	119.6 $\pm$ 5.3
			1107.9	22.4 $\pm$ 0.6	118.0 $\pm$ 5.3
				$RR_{mean} =$	118.8 $\pm$ 4.1
¹⁸² Os	c	22.10H	1221.5	*	208.0 $\pm$ 15.4
			180.2	33.5 $\pm$ 1.7	204.9 $\pm$ 13.1
				$RR_{mean} =$	206.1 $\pm$ 6.4
¹⁸¹ Os	c	105M	238.8	44 $\pm$ 5	66.19 $\pm$ 8.15
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 $\pm$ 3.4	133.7 $\pm$ 7.0
¹⁸³ Re	c	70.0D	291.7	3.05 $\pm$ 0.18	206.0 $\pm$ 14.5
			162.3	23.3 $\pm$ 0.7	214.0 $\pm$ 10.1
				$RR_{mean} =$	212.4 $\pm$ 8.6
^{182m} Re _c	c	12.7H	1221.5	24.8 $\pm$ 1.6	202.1 $\pm$ 15.0
			1189.2	15 $\pm$ 1	232.3 $\pm$ 18.0

Continuation of Table 84.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1121.4	31.8 ± 1.6	201.7 ± 13.0
			$RR_{mean} =$		207.4 ± 10.5
^{181}Re	c*	19.9H	639.0	6.4 ± 1.4	164.4 ± 36.8
			365.5	56 ± 8	159.4 ± 24.1
			$RR_{mean} =$		160.7 ± 17.8
^{179}Re	c*	19.5M	430.2	28.0 ± 1.8	190.3 ± 15.3
			290.0	26.9 ± 2.3	165.6 ± 16.8
			$RR_{mean} =$		184.1 ± 12.2
^{178}Re	c*	13.2M	237.3	45 ± 5	159.1 ± 20.5
^{178}W	c	21.6D	1340.8(D)	1.03 ± 0.09	87.25 ± 10.45
			1350.6(D)	1.18 ± 0.11	103.4 ± 19.2
			$RR_{mean} =$		89.62 ± 7.04
^{177}W	c	135M	115.7	51 ± 5	95.71 ± 10.61
^{176}W	c	2.5H	1159.3	*	77.21 ± 13.27
^{177}Ta	c*	56.56H	112.9	7.2 ± 1.6	113.1 ± 25.8
$^{176}\text{Ta}_c$	c	8.09H	1159.3	24.7 ± 1.9	89.84 ± 8.49
^{175}Ta	c	10.5H	266.9	10.52 ± 0.16	79.45 ± 3.92
			348.5	12.0 ± 1.1	84.43 ± 8.40
			$RR_{mean} =$		80.07 ± 3.74
^{173}Ta	c	3.14H	172.2	17.5 ± 1.8	56.86 ± 6.53
^{175}Hf	c	70D	343.4	84 ± 3	75.62 ± 3.71
^{173}Hf	c*	23.6H	311.2	10.7 ± 0.5	64.05 ± 3.85
^{172}Hf	c	1.87Y	1093.6	*	37.40 ± 2.33
			900.7	*	42.80 ± 3.05
			181.5	*	36.23 ± 2.43
			125.8	11.3 ± 0.9	59.48 ± 6.74
			$RR_{mean} =$		40.33 ± 1.24
^{170}Hf	c	16.01H	164.7	26 ± 8	36.79 ± 11.44
			120.2	15 ± 5	25.18 ± 8.71
			$RR_{mean} =$		30.73 ± 5.88
^{173}Lu	c	1.37Y	272.1	21.2 ± 0.8	51.92 ± 2.93
$^{172}\text{Lu}_c$	c	6.70D	1093.6	63 ± 3	37.70 ± 2.33
			900.7	29.8 ± 1.3	44.46 ± 3.08
			181.5	20.6 ± 1.0	37.17 ± 2.48
			$RR_{mean} =$		38.84 ± 2.30
^{171}Lu	c*	8.24D	739.8	47.8 ± 1.2	39.29 ± 1.67
^{170}Lu	c*	2.012D	1280.2	8.2 ± 0.4	45.61 ± 3.43
			2126.1	5.1 ± 0.3	39.29 ± 3.80
			$RR_{mean} =$		43.18 ± 3.35
^{169}Lu	c	34.06H	960.6	23.4 ± 0.7	22.14 ± 1.57
^{169}Yb	c*	32.026D	198.0	35.8 ± 0.7	25.27 ± 1.11
			177.2	22.2 ± 0.5	23.10 ± 1.02
			130.5	11.31 ± 0.21	25.12 ± 1.56
			$RR_{mean} =$		24.23 ± 1.06
^{166}Yb	c	56.7H	2052.4	*	12.54 ± 1.01
^{167}Tm	c	9.25D	207.8	42 ± 8	16.63 ± 3.26
^{165}Tm	c	30.06H	242.9	35.5 ± 1.7	8.297 ± 0.619
^{149}Gd	c	9.28D	149.7	48 ± 3	0.8612 ± 0.1055
^{139}Ce	c	137.640D	165.9	79.89 ± 0.01	1.367 ± 0.125
^{127}Xe	c	36.4D	202.9	68.3 ± 0.5	3.617 ± 0.155

Continuation of Table 84.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			172.1	25.5 ± 0.8	3.384 ± 0.259
			$RR_{mean} =$		
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.7733 ± 0.0932
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.926 ± 0.154
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	2.386 ± 0.203
			212.2	81.4 ± 1.1	2.672 ± 0.156
			$RR_{mean} =$		
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	4.912 ± 0.252
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.042 ± 0.118
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.576 ± 0.137
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.080 ± 0.190
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	8.575 ± 0.816
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	7.797 ± 0.404
			1384.3	24.9 ± 0.8	8.824 ± 0.855
			937.5	34.2 ± 0.6	7.177 ± 0.735
			$RR_{mean} =$		
			$RR_{mean} =$		
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	3.594 ± 0.235
			717.3	28.9 ± 0.8	3.575 ± 0.279
			451.0	28.2 ± 0.8	3.188 ± 0.228
			$RR_{mean} =$		
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	28.74 ± 1.55
¹⁰² Rh	i	207D	475.1	46 ± 5	3.500 ± 0.525
^{101m} Rh	c	4.34D	306.9	81 ± 5	5.158 ± 0.394
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	26.12 ± 0.99
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	4.763 ± 0.275
			812.5	82 ± 4	4.884 ± 0.296
			$RR_{mean} =$		
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	16.31 ± 0.87
			568.9	58.0 ± 0.3	15.03 ± 0.67
			$RR_{mean} =$		
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	19.67 ± 0.66
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	34.97 ± 1.16
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.721 ± 0.095
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	4.533 ± 0.210
⁹⁵ Zr	c	64.02D	765.8	*	15.43 ± 0.56
			756.7	54.46 ± 0.10	14.84 ± 0.54
			724.2	44.17 ± 0.16	14.98 ± 0.56
			$RR_{mean} =$		
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	8.113 ± 0.284
⁸⁸ Zr	c	83.4D	1836.1	*	2.612 ± 0.375
			392.9	97.24 ± 0.00	2.851 ± 0.137
			$RR_{mean} =$		
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	18.07 ± 0.78
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	16.09 ± 0.60
			898.0	93.7 ± 0.3	16.01 ± 0.52
			$RR_{mean} =$		
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	18.71 ± 0.68
			898.0	93.7 ± 0.3	17.92 ± 0.59
			$RR_{mean} =$		
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	11.09 ± 0.40

Continuation of Table 84.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			388.5	82.1 ± 0.5	11.45 ± 0.48
			$RR_{mean} =$		11.19 ± 0.38
^{85}Sr	c	64.84D	514.0	96 ± 4	11.81 ± 0.67
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	19.98 ± 1.34
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	14.07 ± 1.27
			529.6	29.3 ± 2.1	13.49 ± 1.16
			520.4	45 ± 4	13.54 ± 1.41
			$RR_{mean} =$		13.69 ± 0.68
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	13.25 ± 0.61
			776.5	83.5 ± 1.2	12.86 ± 0.50
			698.4	28.5 ± 0.4	13.93 ± 0.61
			554.3	70.8 ± 1.0	12.28 ± 0.52
			$RR_{mean} =$		12.96 ± 0.51
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	4.180 ± 0.197
			136.0	58.3 ± 0.8	4.268 ± 0.223
			$RR_{mean} =$		4.216 ± 0.173
^{74}As	i	17.77D	595.8	59 ± 4	7.219 ± 0.556
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	6.004 ± 0.487
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	7.798 ± 0.497
^{72}Zn	c	46.5H	2201.7	*	1.793 ± 0.141
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	3.164 ± 0.224
			1099.2	56.5 ± 1.9	3.416 ± 0.230
			$RR_{mean} =$		3.289 ± 0.170
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.7309 ± 0.1024
^7Be	i	53.29D	477.6	10.52 ± 0.06	5.916 ± 1.052

12.7.5 Nuclide production rates for ^{209}Bi

Table 85: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	25.10 ± 1.05
^{206}Po	i	8.8D	1718.7	*	28.69 ± 1.38
			1595.3	*	17.84 ± 5.14
			1098.3	*	24.16 ± 1.80
			1032.3	33 ± 5	28.99 ± 4.50
			980.2	7.1 ± 0.9	32.87 ± 4.38
			895.1	*	32.42 ± 1.48
			807.4	23 ± 3	29.35 ± 3.97
			803.1	*	28.61 ± 1.09
			620.5	*	25.61 ± 2.11
			537.5	*	26.79 ± 1.34
			522.5	15.7 ± 2.0	27.33 ± 3.62
			516.2	*	27.76 ± 1.42
			497.1	*	28.51 ± 2.13
			398.0	*	26.74 ± 1.55
			343.5	*	29.38 ± 1.59
			338.4	19.2 ± 2.5	29.69 ± 4.00

Continuation of Table 85.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			286.4	24 ± 3	29.35 ± 3.83
			184.0	*	26.84 ± 1.72
			<i>RR_{mean}</i> =		28.24 ± 0.87
²⁰⁵ Po	i	1.66H	872.4	37 ± 2	31.80 ± 3.81
²⁰⁴ Po	i	3.53H	884.0	29.9 ± 1.2	35.43 ± 2.36
²⁰⁷ Bi	c	31.55Y	1063.7	74.5 ± 0.2	254.9 ± 13.2
			569.7	97.74 ± 0.03	224.0 ± 10.1
			<i>RR_{mean}</i> =		233.9 ± 16.2
²⁰⁶ Bi _i	i	6.243D	1718.7	31.8 ± 0.6	147.6 ± 5.8
			1595.3	5.01 ± 0.08	164.6 ± 7.7
			1098.3	13.50 ± 0.21	137.1 ± 5.2
			895.1	15.66 ± 0.23	146.4 ± 5.3
			881.0	66.2 ± 1.0	143.6 ± 5.3
			803.1	98.9 ± 1.4	138.5 ± 4.9
			620.5	5.76 ± 0.09	139.1 ± 5.7
			537.5	30.5 ± 0.5	128.1 ± 5.0
			516.2	40.7 ± 0.6	132.6 ± 5.0
			497.1	15.31 ± 0.22	127.9 ± 5.0
			398.0	10.74 ± 0.15	127.8 ± 4.8
			343.5	23.4 ± 0.4	132.4 ± 5.1
			184.0	15.8 ± 0.4	169.7 ± 8.0
			<i>RR_{mean}</i> =		137.6 ± 5.0
²⁰⁶ Bi _c	c	6.243D	1718.7	31.8 ± 0.6	174.7 ± 6.8
			1595.3	5.01 ± 0.08	181.4 ± 7.6
			1098.3	13.50 ± 0.21	159.9 ± 5.9
			895.1	15.66 ± 0.23	177.1 ± 6.4
			881.0	66.2 ± 1.0	181.0 ± 6.5
			803.1	98.9 ± 1.4	165.5 ± 5.9
			620.5	5.76 ± 0.09	163.3 ± 6.2
			537.5	30.5 ± 0.5	153.5 ± 5.9
			516.2	40.7 ± 0.6	158.8 ± 5.9
			497.1	15.31 ± 0.22	154.8 ± 5.8
			398.0	10.74 ± 0.15	153.1 ± 5.6
			343.5	23.4 ± 0.4	160.2 ± 6.1
			184.0	15.8 ± 0.4	195.1 ± 9.0
			<i>RR_{mean}</i> =		164.8 ± 5.9
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	180.7 ± 7.2
			1775.8	3.99 ± 0.08	179.6 ± 7.7
			1764.3	32.5 ± 0.7	181.8 ± 7.4
			1614.3	2.28 ± 0.04	182.2 ± 8.6
			1190.0	2.26 ± 0.07	182.6 ± 10.1
			1043.8	7.51 ± 0.10	168.3 ± 6.1
			987.7	16.13 ± 0.17	185.6 ± 6.8
			759.1	1.04 ± 0.05	173.4 ± 11.2
			703.5	31.1 ± 0.1	169.7 ± 5.7
			579.8	5.44 ± 0.07	159.9 ± 6.1
			570.6	4.34 ± 0.07	159.8 ± 6.9
			549.8	2.95 ± 0.04	160.9 ± 6.5
			284.1	1.69 ± 0.02	171.4 ± 7.8
			<i>RR_{mean}</i> =		171.4 ± 5.8
²⁰⁴ Bi	c*	11.22H	1211.7	3.0 ± 0.4	143.3 ± 20.6

Continuation of Table 85.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			984.0	59 ± 4	150.3 ± 11.4
			918.3	10.8 ± 0.9	172.1 ± 15.7
			899.2	98 ± 9	142.1 ± 4.9
			374.8	82 ± 5	164.5 ± 34.4
			<i>RR_{mean}</i> =		142.9 ± 4.4
²⁰³ Bi	c	11.76H	1893.0	8.2 ± 0.6	133.7 ± 11.2
			1888.0	1.94 ± 0.10	114.7 ± 9.9
			1847.3	11.4 ± 0.8	141.7 ± 11.4
			1679.6	8.8 ± 0.7	142.1 ± 13.2
			1536.5	7.5 ± 0.6	161.0 ± 14.5
			896.8	13.1 ± 0.7	138.9 ± 9.1
			847.2	8.5 ± 0.5	144.5 ± 10.9
			825.2	14.6 ± 1.1	157.6 ± 13.3
			820.2	29.6 ± 1.5	143.1 ± 9.0
			816.3	4.03 ± 0.21	148.2 ± 11.0
			279.2	*	127.5 ± 7.3
			264.2	5.2 ± 0.4	180.7 ± 21.5
			<i>RR_{mean}</i> =		132.9 ± 4.1
²⁰² Bi	c*	1.72H	960.7	99.28 ± 0.02	114.8 ± 4.7
			422.1	83.7 ± 2.5	130.6 ± 7.3
			<i>RR_{mean}</i> =		118.1 ± 7.4
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	40.44 ± 2.13
			374.7	89 ± 15	51.67 ± 9.06
			<i>RR_{mean}</i> =		40.84 ± 2.44
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	61.74 ± 2.59
			374.7	89 ± 15	72.31 ± 12.55
			<i>RR_{mean}</i> =		61.95 ± 2.58
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	115.4 ± 8.3
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	242.8 ± 9.0
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	53.62 ± 5.41
			422.1	86 ± 5	54.15 ± 4.23
			<i>RR_{mean}</i> =		54.00 ± 2.82
²⁰¹ Pb	c*	9.33H	946.0	7.4 ± 0.6	231.5 ± 20.7
			907.6	5.7 ± 0.4	275.4 ± 23.6
			692.4	4.27 ± 0.16	237.7 ± 16.1
			361.3	9.9 ± 0.5	252.9 ± 17.7
			331.2	79 ± 5	257.7 ± 18.6
			<i>RR_{mean}</i> =		248.9 ± 10.8
²⁰⁰ Pb	c	21.5H	1514.9	*	193.7 ± 17.9
			1362.9	*	206.8 ± 26.3
			1205.7	*	189.3 ± 13.1
			450.5	3.33 ± 0.08	212.0 ± 10.3
			367.9	*	182.6 ± 6.3
			235.6	4.30 ± 0.17	223.5 ± 13.2
			147.6	37.7 ± 1.4	195.6 ± 12.7
			<i>RR_{mean}</i> =		186.3 ± 5.7
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	312.9 ± 54.3
			366.9	44 ± 7	389.4 ± 65.0
			<i>RR_{mean}</i> =		348.6 ± 39.7
¹⁹⁸ Pb	c	2.4H	2040.2	*	190.4 ± 30.7
			1447.0	*	189.1 ± 41.5

Continuation of Table 85.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1420.6	*	216.6 ± 44.2
			865.3	5.9 ± 1.2	174.5 ± 37.3
			675.8	*	177.6 ± 28.8
			365.4	19 ± 5	287.1 ± 76.9
			259.5	5.8 ± 1.2	220.8 ± 47.3
			173.4	18 ± 3	271.2 ± 46.6
			<i>RR_{mean}</i> =		198.6 ± 6.1
^{197m} Pb	c*	43M	387.7	25 ± 6	180.9 ± 44.0
			385.9	74 ± 15	181.2 ± 37.3
			222.8	25 ± 6	152.5 ± 37.2
			<i>RR_{mean}</i> =		178.6 ± 8.3
¹⁹⁶ Pb	c*	37M	502.1	26 ± 3	194.2 ± 23.9
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	100.0 ± 19.1
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	29.38 ± 1.07
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	300.1 ± 11.6
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	57.55 ± 5.27
			367.9	87.2 ± 0.4	54.95 ± 4.04
			<i>RR_{mean}</i> =		55.87 ± 3.41
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	246.9 ± 17.1
			579.3	13.8 ± 0.7	252.2 ± 15.8
			367.9	87.2 ± 0.4	237.5 ± 8.4
			<i>RR_{mean}</i> =		239.1 ± 8.2
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	284.2 ± 34.1
			247.3	9.3 ± 1.1	303.1 ± 38.0
			208.2	12.3 ± 1.4	341.4 ± 42.5
			<i>RR_{mean}</i> =		303.9 ± 18.7
^{198m} Tl	i(m)	1.87H	587.2	52.5 ± 2.0	51.89 ± 6.51
			282.8	28 ± 3	76.08 ± 9.63
			<i>RR_{mean}</i> =		59.47 ± 11.37
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	275.8 ± 93.1
			152.2	7.3 ± 2.3	418.9 ± 133.2
			<i>RR_{mean}</i> =		360.6 ± 71.2
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	131.4 ± 23.4
¹⁹⁵ Tl	c*	1.16H	884.5	10.0 ± 1.1	179.2 ± 22.5
¹⁹⁷ Hg	c*	64.14H	191.4	0.63 ± 0.02	214.8 ± 27.1
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	21.99 ± 1.56
¹⁹⁵ Hg	c	9.9H	779.8	6.8 ± 0.7	228.8 ± 25.3
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	36.48 ± 4.93
^{193m} Hg	i(m)	11.8H	573.2	26 ± 4	43.99 ± 7.02
			407.6	32 ± 6	47.73 ± 9.13
			<i>RR_{mean}</i> =		45.37 ± 5.64
¹⁹² Hg	c	4.85H	316.5	*	234.8 ± 29.6
			296.0	*	246.5 ± 34.9
			274.8	50.2 ± 2.5	193.2 ± 12.2
			<i>RR_{mean}</i> =		198.4 ± 6.1
¹⁹⁰ Hg	c*	20.0M	301.8	*	192.1 ± 28.9
			295.8	*	166.4 ± 13.8
			142.6	68 ± 10	152.2 ± 24.1
			<i>RR_{mean}</i> =		165.3 ± 5.1
^{198m} Au	i(m)	2.27D	411.8	*	0.2199 ± 0.1553

Continuation of Table 85.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	1.752 ± 0.262
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	1.972 ± 0.130
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	3.779 ± 0.141
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	245.1 ± 27.7
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	9.801 ± 0.879
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	22.39 ± 4.89
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	257.2 ± 32.3
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	212.0 ± 12.1
			277.9	7.2 ± 0.5	213.0 ± 18.4
			<i>RR_{mean}</i> =		212.3 ± 11.0
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	164.7 ± 16.4
			295.8	71 ± 5	184.0 ± 14.6
			<i>RR_{mean}</i> =		177.8 ± 10.5
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	189.0 ± 23.0
			456.5	3.4 ± 0.4	167.3 ± 20.7
			409.4	8.0 ± 0.9	171.9 ± 20.3
			359.9	6.0 ± 0.7	169.5 ± 20.6
			351.2	3.4 ± 0.4	194.7 ± 24.5
			172.2	3.5 ± 0.4	170.3 ± 20.8
			129.4	3.2 ± 0.5	182.9 ± 30.7
			<i>RR_{mean}</i> =		175.6 ± 7.0
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	271.0 ± 25.2
			607.6	8.10 ± 0.16	186.4 ± 9.1
			568.8	7.1 ± 0.6	192.5 ± 19.1
			544.9	5.8 ± 0.5	219.2 ± 20.7
			243.5	7.0 ± 1.2	215.0 ± 38.1
			<i>RR_{mean}</i> =		195.9 ± 12.4
¹⁸⁸ Pt	c	10.2D	478.0	*	163.6 ± 8.8
			423.3	4.4 ± 0.3	169.7 ± 13.1
			381.4	7.5 ± 0.5	164.6 ± 12.6
			322.9	*	171.1 ± 17.1
			195.1	18.6 ± 1.2	165.3 ± 12.4
			187.6	19.4 ± 1.2	169.2 ± 12.3
			155.1	*	176.0 ± 18.8
			<i>RR_{mean}</i> =		165.5 ± 5.1
¹⁸⁷ Pt	c	2.35H	106.4	8.8 ± 1.8	112.5 ± 26.5
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	135.3 ± 29.4
			630.3	*	96.09 ± 14.09
			<i>RR_{mean}</i> =		103.3 ± 3.2
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	121.3 ± 22.5
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	127.8 ± 23.4
			245.1	6.0 ± 0.6	157.0 ± 17.0
			<i>RR_{mean}</i> =		155.6 ± 7.9
¹⁸⁸ Ir _c	c	41.5H	478.0	14.7 ± 0.6	160.7 ± 8.7
			322.9	1.62 ± 0.15	160.4 ± 16.6
			155.1	30 ± 3	180.1 ± 19.3
			<i>RR_{mean}</i> =		161.2 ± 5.6
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	145.9 ± 9.3
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	63.87 ± 5.51
			434.8	33.9 ± 1.1	65.46 ± 3.42

Continuation of Table 85.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			296.9	62.3 ± 1.9	80.01 ± 4.71
			137.2	41.4 ± 0.7	75.59 ± 4.61
			$RR_{mean} =$		70.50 ± 4.31
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	106.0 ± 16.4
			1668.0	3.6 ± 0.6	94.75 ± 16.74
			254.2	13.3 ± 2.4	95.93 ± 18.02
			$RR_{mean} =$		102.2 ± 5.3
^{184}Ir	c*	3.09H	390.4	25.9 ± 2.4	117.2 ± 11.8
			264.0	68 ± 4	129.9 ± 9.4
			119.8	31 ± 3	146.4 ± 17.3
			$RR_{mean} =$		128.9 ± 6.1
^{185}Os	c	93.6D	874.8	6.29 ± 0.25	146.4 ± 7.9
			717.4	3.94 ± 0.16	135.9 ± 7.6
			646.1	78 ± 3	136.2 ± 6.9
			592.1	1.32 ± 0.06	124.2 ± 9.3
			$RR_{mean} =$		137.5 ± 5.1
^{183m}Os	c*	9.9H	1107.9	22.4 ± 0.6	65.61 ± 3.18
			1101.9	49.0 ± 1.3	66.59 ± 2.98
			$RR_{mean} =$		66.23 ± 2.33
^{182}Os	c	22.10H	1221.5	*	127.3 ± 9.4
			1189.2	*	127.7 ± 9.8
			1121.4	*	122.6 ± 7.4
			180.2	33.5 ± 1.7	108.0 ± 6.9
			130.8	3.30 ± 0.17	115.0 ± 9.9
			$RR_{mean} =$		116.4 ± 3.6
^{181}Os	c	105M	238.8	44 ± 5	40.37 ± 5.45
^{180}Os	c	21.5M	902.8(D)	101.5 ± 3.4	84.62 ± 4.57
			103.5(D)	25.0 ± 0.8	75.92 ± 7.37
			$RR_{mean} =$		82.67 ± 4.43
^{183}Re	c	70.0D	291.7	3.05 ± 0.18	113.3 ± 8.1
			208.8	2.95 ± 0.09	117.0 ± 6.7
			162.3	23.3 ± 0.7	122.0 ± 5.9
			109.7	2.87 ± 0.09	109.3 ± 9.9
			107.9	2.17 ± 0.07	117.0 ± 9.8
			$RR_{mean} =$		118.2 ± 4.4
$^{182m}\text{Re}_c$	c	12.7H	1221.5	24.8 ± 1.6	121.1 ± 9.3
			1189.2	15 ± 1	131.8 ± 10.5
			1121.4	31.8 ± 1.6	126.6 ± 7.8
			$RR_{mean} =$		126.2 ± 5.1
^{181}Re	c*	19.9H	639.0	6.4 ± 1.4	97.74 ± 21.96
			365.5	56 ± 8	97.50 ± 14.36
			$RR_{mean} =$		97.56 ± 10.51
^{179}Re	c*	19.5M	430.2	28.0 ± 1.8	95.29 ± 8.73
			290.0	26.9 ± 2.3	81.10 ± 8.93
			$RR_{mean} =$		89.70 ± 7.47
^{178}Re	c*	13.2M	237.3	45 ± 5	91.07 ± 11.22
^{178}W	c	21.6D	1340.8(D)	1.03 ± 0.09	91.68 ± 15.56
^{177}W	c	135M	115.7	51 ± 5	57.41 ± 7.02
^{177}Ta	c*	56.56H	112.9	7.2 ± 1.6	62.48 ± 14.66
^{176}Ta	c*	8.09H	1159.3	24.7 ± 1.9	62.31 ± 5.66

Continuation of Table 85.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷⁵ Ta	c	10.5H	348.5	12.0 ± 1.1	41.90 ± 4.49
			266.9	10.52 ± 0.16	43.18 ± 2.67
			<i>RR_{mean}</i> =		42.89 ± 2.42
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	38.38 ± 4.83
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	39.27 ± 1.95
¹⁷³ Hf	c*	23.6H	306.6	6.4 ± 0.3	13.16 ± 4.03
			311.2	10.7 ± 0.5	25.26 ± 2.19
			297.0	33.9 ± 1.4	18.82 ± 2.48
			123.7	83 ± 5	33.81 ± 3.00
			<i>RR_{mean}</i> =		24.34 ± 3.70
¹⁷² Hf	c	1.87Y	1093.6	*	20.39 ± 1.41
			900.7	*	19.96 ± 1.11
			181.5	*	18.83 ± 1.35
			125.8	11.3 ± 0.9	27.46 ± 3.22
			<i>RR_{mean}</i> =		20.41 ± 0.63
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	17.84 ± 5.18
			164.7	26 ± 8	18.49 ± 5.79
			<i>RR_{mean}</i> =		18.04 ± 1.69
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	26.46 ± 1.53
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	20.67 ± 1.41
			900.7	29.8 ± 1.3	20.52 ± 1.15
			181.5	20.6 ± 1.0	19.26 ± 1.82
			<i>RR_{mean}</i> =		20.45 ± 0.76
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	20.28 ± 0.88
¹⁷⁰ Lu	c*	2.012D	2126.1	5.1 ± 0.3	18.91 ± 2.07
			1280.2	8.2 ± 0.4	21.67 ± 1.61
			<i>RR_{mean}</i> =		20.86 ± 1.41
¹⁶⁹ Lu	c	34.06H	1449.7	9.9 ± 0.3	11.00 ± 1.12
			191.2	20.6 ± 0.6	11.25 ± 1.27
			<i>RR_{mean}</i> =		11.11 ± 0.86
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	11.93 ± 0.56
			177.2	22.2 ± 0.5	11.62 ± 0.58
			<i>RR_{mean}</i> =		11.79 ± 0.46
¹⁶⁵ Tm	c	30.06H	242.9	35.5 ± 1.7	3.185 ± 0.360
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	1.251 ± 0.075
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	4.782 ± 0.532
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	4.331 ± 0.454
			202.9	68.3 ± 0.5	4.322 ± 0.187
			172.1	25.5 ± 0.8	4.236 ± 0.260
			<i>RR_{mean}</i> =		4.303 ± 0.171
¹²⁶ I	i	13.11D	388.6	34 ± 3	1.498 ± 0.221
¹²⁴ I	i	4.1760D	602.7	62.9 ± 0.6	3.693 ± 0.212
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.635 ± 0.176
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	3.265 ± 0.300
			212.2	81.4 ± 1.1	3.393 ± 0.193
			<i>RR_{mean}</i> =		3.362 ± 0.104
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	5.448 ± 0.344
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.948 ± 0.100
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.6108 ± 0.0624
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	3.994 ± 0.203

Continuation of Table 85.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			197.3	87.0 ± 1.1	4.772 ± 0.290
			RR _{mean} = 4.223 ± 0.378		
^{117m} Sn	i(m)	13.60D	158.6	86.4 ± 0.4	6.561 ± 0.302
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.386 ± 0.163
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	8.579 ± 0.549
¹¹¹ In	c	2.8047D	245.4	94 ± 1	4.375 ± 0.229
			171.3	90.2 ± 1.0	4.842 ± 0.233
			RR _{mean} = 4.618 ± 0.273		
¹¹⁵ Cd	c	53.46H	336.2	45.9 ± 1.0	2.295 ± 0.136
^{110m} Ag	i(m)	249.76D	1505.0	13.60 ± 0.19	8.224 ± 1.139
			1384.3	24.9 ± 0.8	11.17 ± 0.72
			937.5	34.2 ± 0.6	10.10 ± 0.54
			884.7	72.7 ± 0.4	10.15 ± 0.41
			763.9	22.62 ± 0.21	8.497 ± 0.698
			657.8	94.3 ± 0.3	10.10 ± 0.41
			RR _{mean} = 10.05 ± 0.39		
^{106m} Ag	i(m)	8.28D	717.3	28.9 ± 0.8	4.890 ± 0.378
			451.0	28.2 ± 0.8	3.436 ± 0.272
			RR _{mean} = 3.933 ± 0.701		
¹⁰⁵ Ag	c	41.29D	280.4	30.2 ± 1.8	3.471 ± 0.364
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	31.77 ± 1.58
^{102m} Rh	i(m)	2.9Y	475.1	95 ± 4	7.283 ± 3.045
^{101m} Rh	c	4.34D	306.9	81 ± 5	6.172 ± 0.461
¹⁰³ Ru	c	39.26D	610.3	5.76 ± 0.07	28.81 ± 5.25
			497.1	91.0 ± 1.3	32.04 ± 1.22
			RR _{mean} = 31.98 ± 1.21		
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	5.274 ± 0.311
			812.5	82 ± 4	5.364 ± 0.352
			RR _{mean} = 5.312 ± 0.260		
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	29.77 ± 1.65
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	18.08 ± 0.89
			849.9	20.45 ± 0.20	19.55 ± 1.93
			778.2	96.45 ± 0.22	21.06 ± 0.79
			568.9	58.0 ± 0.3	18.44 ± 0.77
			460.0	26.62 ± 0.20	20.03 ± 0.81
RR _{mean} = 19.68 ± 0.85					
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	22.69 ± 0.76
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	41.87 ± 1.38
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.691 ± 0.078
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	4.299 ± 0.264
⁹⁵ Zr	c	64.02D	765.8	*	19.35 ± 0.66
			724.2	44.17 ± 0.16	19.54 ± 0.89
			RR _{mean} = 19.38 ± 0.60		
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	9.011 ± 0.342
⁸⁸ Zr	c	83.4D	898.0	*	2.815 ± 0.361
			392.9	97.24 ± 0.00	3.129 ± 0.139
			RR _{mean} = 3.105 ± 0.096		
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	22.94 ± 1.10
			202.5	97.3 ± 0.4	28.64 ± 1.66
			RR _{mean} = 24.45 ± 2.62		

Continuation of Table 85.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{88}\text{Y}_i$	i	106.65D	898.0	93.7 ± 0.3	16.98 ± 0.63
$^{88}\text{Y}_c$	c	106.65D	898.0	93.7 ± 0.3	19.79 ± 0.67
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	11.76 ± 0.43
			388.5	82.1 ± 0.5	12.31 ± 0.43
			$RR_{mean} =$		12.06 ± 0.46
^{85}Sr	c	64.84D	514.0	96 ± 4	12.79 ± 0.70
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	25.88 ± 1.17
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	14.47 ± 1.23
			529.6	29.3 ± 2.1	14.48 ± 1.23
			520.4	45 ± 4	14.50 ± 1.40
			$RR_{mean} =$		14.48 ± 0.69
^{82}Br	i(m+g)	35.30H	1474.9	16.32 ± 0.23	16.19 ± 0.83
			1317.5	26.5 ± 0.4	14.90 ± 0.79
			776.5	83.5 ± 1.2	14.34 ± 0.54
			698.4	28.5 ± 0.4	12.85 ± 0.68
			554.3	70.8 ± 1.0	13.14 ± 0.54
			$RR_{mean} =$		14.01 ± 0.63
^{75}Se	c	119.779D	279.5	24.99 ± 0.14	5.812 ± 0.758
			264.7	58.9 ± 0.4	4.064 ± 0.192
			136.0	58.3 ± 0.8	5.079 ± 0.362
			$RR_{mean} =$		4.280 ± 0.352
^{76}As	i	1.0778D	559.1	45 ± 2	10.28 ± 0.72
^{74}As	i	17.77D	595.8	59 ± 4	7.744 ± 0.611
$^{72}\text{Ga}_i$	i	14.10H	2507.8	12.78 ± 0.23	10.80 ± 3.55
			2201.7	25.9 ± 0.5	7.549 ± 0.627
			$RR_{mean} =$		7.635 ± 0.621
$^{72}\text{Ga}_c$	c	14.10H	2507.8	12.78 ± 0.23	12.71 ± 3.40
			2201.7	25.9 ± 0.5	9.207 ± 0.621
			$RR_{mean} =$		9.298 ± 0.626
^{72}Zn	c	46.5H	2507.8	*	1.909 ± 0.400
			2201.7	*	1.658 ± 0.154
			$RR_{mean} =$		1.687 ± 0.146
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	3.893 ± 0.313
			1099.2	56.5 ± 1.9	3.245 ± 0.262
			$RR_{mean} =$		3.512 ± 0.337
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.3610 ± 0.0749
^7Be	i	53.29D	477.6	10.52 ± 0.06	6.609 ± 0.891

12.7.6 Nuclide production rates for ^{27}Al

Table 86: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.6 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	25.13 ± 1.04
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.447 ± 0.119
			1014.4	28.0 ± 0.4	2.163 ± 0.198

Continuation of Table 86.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$RR_{mean} =$					2.391 $\pm$ 0.135
^{22}Na	c	2.6019Y	1274.5	99.94 $\pm$ 0.01	82.21 $\pm$ 2.81
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	66.92 $\pm$ 2.22
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	3.144 $\pm$ 0.106
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 $\pm$ 0.06	23.41 $\pm$ 0.86
^{27}Mg	c	9.458M	843.8	71.8 $\pm$ 0.4	2.271 $\pm$ 0.109
			1014.4	28.0 $\pm$ 0.4	2.420 $\pm$ 0.183
$RR_{mean} =$					2.301 $\pm$ 0.103
^{22}Na	c	2.6019Y	1274.5	99.94 $\pm$ 0.01	75.25 $\pm$ 2.57
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	61.26 $\pm$ 2.04
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	2.868 $\pm$ 0.096
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 $\pm$ 0.06	20.80 $\pm$ 0.76
^{27}Mg	c	9.458M	843.8	71.8 $\pm$ 0.4	1.901 $\pm$ 0.097
			1014.4	28.0 $\pm$ 0.4	2.327 $\pm$ 0.166
$RR_{mean} =$					1.990 $\pm$ 0.184
^{22}Na	c	2.6019Y	1274.5	99.94 $\pm$ 0.01	68.24 $\pm$ 2.35
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	55.95 $\pm$ 1.86
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	2.497 $\pm$ 0.083
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 $\pm$ 0.06	25.17 $\pm$ 0.92
^{27}Mg	c	9.458M	843.8	71.8 $\pm$ 0.4	2.338 $\pm$ 0.123
			1014.4	28.0 $\pm$ 0.4	2.880 $\pm$ 0.229
$RR_{mean} =$					2.437 $\pm$ 0.222
^{22}Na	c	2.6019Y	1274.5	99.94 $\pm$ 0.01	82.45 $\pm$ 2.83
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	67.39 $\pm$ 2.24
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	2.879 $\pm$ 0.096
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 $\pm$ 0.06	18.51 $\pm$ 0.71
^{27}Mg	c	9.458M	843.8	71.8 $\pm$ 0.4	2.486 $\pm$ 0.111
			1014.4	28.0 $\pm$ 0.4	2.652 $\pm$ 0.190
$RR_{mean} =$					2.516 $\pm$ 0.107
^{22}Na	c	2.6019Y	1274.5	99.94 $\pm$ 0.01	61.40 $\pm$ 2.11
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	50.81 $\pm$ 1.69
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 $\pm$ 0	2.077 $\pm$ 0.070

12.8 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 0.8$ GeV

12.8.1 Nuclide production rates for ^{206}Pb

Table 87: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 0.8$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	7.008 ± 0.436
			803.1	98.9 ± 1.4	6.560 ± 0.246
			537.5	30.5 ± 0.5	6.448 ± 0.339
			343.5	23.4 ± 0.4	5.811 ± 0.719
			RR _{mean} =		6.561 ± 0.234
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	22.89 ± 2.96
			1764.3	32.5 ± 0.7	19.54 ± 0.85
			703.5	31.1 ± 0.1	19.71 ± 0.72
			RR _{mean} =		19.70 ± 0.69
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	23.44 ± 1.91
			899.2	98 ± 9	24.44 ± 0.90
			670.7	11.4 ± 0.9	27.32 ± 2.88
			374.8	82 ± 5	24.90 ± 5.21
			RR _{mean} =		24.45 ± 0.75
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	27.33 ± 1.94
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	33.75 ± 2.85
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	62.62 ± 2.58
			374.7	89 ± 15	66.62 ± 11.52
			RR _{mean} =		62.71 ± 2.56
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	66.29 ± 2.66
			374.7	89 ± 15	69.74 ± 12.05
			RR _{mean} =		66.36 ± 2.65
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	224.0 ± 8.2
^{202m} Pb	i(m)	3.53H	422.1	86 ± 5	53.99 ± 3.97
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	182.0 ± 13.1
²⁰⁰ Pb	c	21.5H	1205.7	*	140.0 ± 9.7
			1514.9	*	133.1 ± 12.1
			828.3	*	120.5 ± 12.0
			579.3	*	124.6 ± 8.0
			450.5	3.33 ± 0.08	153.2 ± 8.1
			367.9	*	128.9 ± 4.5
			147.6	37.7 ± 1.4	134.2 ± 7.3
			RR _{mean} =		129.5 ± 4.0
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	232.1 ± 38.0
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	169.6 ± 29.1
^{197m} Pb	c*	43M	385.9	74 ± 15	125.7 ± 25.9
			222.8	25 ± 6	122.4 ± 30.1
			RR _{mean} =		125.4 ± 6.2
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	66.99 ± 12.92
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	100.7 ± 3.7
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	307.5 ± 11.3
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	103.4 ± 12.6

Continuation of Table 87.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			579.3	13.8 ± 0.7	128.2 ± 9.3
			1205.7	29.9 ± 1.8	121.2 ± 8.8
			367.9	87.2 ± 0.4	121.9 ± 4.8
			<i>RR_{mean}</i> =		121.6 ± 4.6
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	261.2 ± 18.0
			1514.9	4.0 ± 0.3	236.5 ± 20.1
			579.3	13.8 ± 0.7	252.8 ± 15.7
			367.9	87.2 ± 0.4	250.8 ± 8.6
			<i>RR_{mean}</i> =		250.9 ± 8.5
			455.5	12.4 ± 1.4	224.6 ± 27.5
			455.5	12.4 ± 1.4	285.8 ± 33.9
			282.8	28 ± 3	117.6 ± 14.2
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	196.8 ± 34.4
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	9.031 ± 0.362
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	45.95 ± 2.21
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	63.54 ± 6.11
			261.8	31 ± 4	68.00 ± 9.16
			<i>RR_{mean}</i> =		64.38 ± 3.80
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	76.68 ± 14.63
			258.0	49 ± 7	114.8 ± 17.1
			<i>RR_{mean}</i> =		92.94 ± 19.07
¹⁹² Hg	c	4.85H	316.5	*	269.9 ± 33.9
			274.8	50.2 ± 2.5	213.9 ± 13.5
			<i>RR_{mean}</i> =		220.3 ± 6.8
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	169.8 ± 26.2
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	1.805 ± 0.185
			411.8	*	1.720 ± 0.132
			<i>RR_{mean}</i> =		1.747 ± 0.054
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	5.771 ± 0.301
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	7.491 ± 0.280
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	12.93 ± 1.75
			355.7	87.0 ± 0.8	14.13 ± 0.50
			333.0	22.9 ± 0.6	15.68 ± 0.73
			<i>RR_{mean}</i> =		14.31 ± 0.58
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	255.5 ± 26.0
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	28.22 ± 2.51
			293.6	10.4 ± 0.8	25.81 ± 2.34
			<i>RR_{mean}</i> =		26.95 ± 1.55
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	43.96 ± 5.65
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	313.8 ± 39.4
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	337.4 ± 28.0
			586.4	17 ± 0	310.0 ± 14.1
			166.5	3.32 ± 0.24	288.4 ± 27.4
			<i>RR_{mean}</i> =		310.7 ± 13.2
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	222.3 ± 21.2
			295.8	71 ± 5	243.1 ± 23.0
			<i>RR_{mean}</i> =		232.0 ± 13.5
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	256.3 ± 31.2
			456.5	3.4 ± 0.4	239.8 ± 29.5
			409.4	8.0 ± 0.9	223.2 ± 26.2

Continuation of Table 87.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			351.2	3.4 ± 0.4	259.3 ± 31.9
			172.2	3.5 ± 0.4	215.0 ± 26.1
			$RR_{mean} =$		234.7 ± 11.3
^{189}Pt	c	10.87H	721.4	9.3 ± 0.8	288.3 ± 26.8
			607.6	8.10 ± 0.16	255.2 ± 10.7
			568.8	7.1 ± 0.6	257.2 ± 24.4
			544.9	5.8 ± 0.5	276.9 ± 26.1
			243.5	7.0 ± 1.2	281.2 ± 49.9
			$RR_{mean} =$		259.1 ± 10.1
^{188}Pt	c	10.2D	1209.8	*	251.3 ± 26.9
			633.0	*	273.3 ± 46.5
			195.1	18.6 ± 1.2	244.0 ± 18.2
			478.0	*	238.8 ± 12.8
			423.3	4.4 ± 0.3	242.8 ± 18.5
			381.4	7.5 ± 0.5	240.4 ± 18.1
			187.6	19.4 ± 1.2	246.5 ± 17.8
			$RR_{mean} =$		241.3 ± 7.4
^{187}Pt	c	2.35H	106.4	8.8 ± 1.8	191.7 ± 42.0
^{186}Pt	c	2.08H	689.4	70 ± 15	203.1 ± 44.1
^{184}Pt	c	17.3M	548.3	23 ± 4	190.1 ± 36.7
^{192}Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.6050 ± 0.0570
^{190}Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	1.729 ± 0.142
			569.3	28.5 ± 1.3	1.349 ± 0.181
			$RR_{mean} =$		1.603 ± 0.186
^{189}Ir	c	13.2D	275.9	0.54 ± 0.07	242.9 ± 33.3
			245.1	6.0 ± 0.6	226.3 ± 24.3
			$RR_{mean} =$		227.3 ± 8.8
$^{188}\text{Ir}_i$	i	41.5H	633.0	18 ± 3	10.40 ± 1.89
			478.0	14.7 ± 0.6	15.19 ± 1.50
			$RR_{mean} =$		13.60 ± 2.30
$^{188}\text{Ir}_c$	c	41.5H	1209.8	6.9 ± 0.7	254.6 ± 27.3
			633.0	18 ± 3	283.7 ± 48.2
			478.0	14.7 ± 0.6	254.0 ± 13.6
			$RR_{mean} =$		254.2 ± 8.7
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	272.1 ± 17.1
^{186}Ir	c	16.64H	434.8	33.9 ± 1.1	111.3 ± 5.6
			773.3	8.9 ± 0.5	110.9 ± 7.8
			$RR_{mean} =$		111.2 ± 5.1
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	181.3 ± 27.8
			254.2	13.3 ± 2.4	159.9 ± 30.4
			$RR_{mean} =$		177.9 ± 9.5
^{184}Ir	c*	3.09H	264.0	68 ± 4	230.6 ± 16.3
			841.3	8.0 ± 0.8	194.2 ± 22.9
			390.4	25.9 ± 2.4	200.3 ± 19.9
			119.8	31 ± 3	236.8 ± 25.6
			$RR_{mean} =$		224.4 ± 10.4
^{183}Ir	c	57M	392.5	10.4 ± 2.4	220.8 ± 53.1
^{185}Os	c	93.6D	874.8	6.29 ± 0.25	245.3 ± 12.9
			717.4	3.94 ± 0.16	238.6 ± 12.9
			646.1	78 ± 3	235.0 ± 12.0

Continuation of Table 87.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	238.4 ± 8.0
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	139.4 ± 6.2
			1101.9	49.0 ± 1.3	132.0 ± 5.8
				<i>RR_{mean}</i> =	135.3 ± 5.6
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	209.6 ± 11.8
			180.2	33.5 ± 1.7	228.0 ± 14.4
				<i>RR_{mean}</i> =	216.3 ± 11.1
¹⁸¹ Os	c	105M	238.8	44 ± 5	82.80 ± 10.30
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	191.2 ± 11.0
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	226.8 ± 16.3
			162.3	23.3 ± 0.7	238.7 ± 11.4
				<i>RR_{mean}</i> =	236.3 ± 9.6
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	235.9 ± 17.4
			1189.2	15 ± 1	269.0 ± 22.6
			1121.4	31.8 ± 1.6	258.1 ± 15.8
				<i>RR_{mean}</i> =	253.4 ± 11.3
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	225.1 ± 50.1
			365.5	56 ± 8	217.0 ± 32.1
				<i>RR_{mean}</i> =	219.0 ± 23.7
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	262.8 ± 21.3
			290.0	26.9 ± 2.3	227.5 ± 22.5
				<i>RR_{mean}</i> =	252.4 ± 17.9
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	278.6 ± 35.7
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	159.0 ± 17.5
			1340.8(D)	1.03 ± 0.09	128.8 ± 13.7
				<i>RR_{mean}</i> =	139.3 ± 15.0
¹⁷⁷ W	c	135M	115.7	51 ± 5	156.9 ± 17.2
¹⁷⁶ W	c	2.5H	1823.7	*	123.0 ± 31.1
			1159.3	*	125.5 ± 18.3
			710.5	*	128.0 ± 36.4
				<i>RR_{mean}</i> =	125.4 ± 13.2
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	172.2 ± 39.4
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	162.3 ± 18.4
			1159.3	24.7 ± 1.9	158.8 ± 14.3
			710.5	5.4 ± 0.4	171.4 ± 18.8
				<i>RR_{mean}</i> =	161.5 ± 7.2
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	120.5 ± 19.3
			348.5	12.0 ± 1.1	169.3 ± 16.7
			266.9	10.52 ± 0.16	157.2 ± 6.7
				<i>RR_{mean}</i> =	156.2 ± 7.8
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	125.7 ± 11.8
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	139.6 ± 15.4
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	68.35 ± 7.02
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	147.8 ± 7.2
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	157.2 ± 11.9
			311.2	10.7 ± 0.5	153.4 ± 9.1
			306.6	6.4 ± 0.3	170.4 ± 11.3
			139.6	12.7 ± 0.6	169.4 ± 11.2
				<i>RR_{mean}</i> =	160.8 ± 6.7
¹⁷² Hf	c	1.87Y	1093.6	*	101.7 ± 5.9

Continuation of Table 87.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			900.7	*	105.3 ± 5.9
			181.5	*	103.7 ± 6.6
			125.8	11.3 ± 0.9	97.39 ± 10.27
			<i>RR_{mean}</i> =		102.7 ± 3.2
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	117.1 ± 32.8
			164.7	26 ± 8	110.8 ± 34.4
			120.2	15 ± 5	116.7 ± 39.3
			<i>RR_{mean}</i> =		115.9 ± 8.2
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	122.7 ± 6.6
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	102.1 ± 6.0
			900.7	29.8 ± 1.3	106.3 ± 5.9
			181.5	20.6 ± 1.0	105.2 ± 6.7
			<i>RR_{mean}</i> =		104.7 ± 3.7
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	114.9 ± 5.2
			780.7	4.36 ± 0.11	126.4 ± 7.0
			689.3	2.37 ± 0.06	117.0 ± 5.2
			667.4	11.0 ± 0.3	114.3 ± 5.0
			<i>RR_{mean}</i> =		116.4 ± 4.1
¹⁷⁰ Lu	c*	2.012D	1280.2	8.2 ± 0.4	125.9 ± 7.7
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	69.63 ± 3.36
¹⁶⁷ Lu	c	51.5M	176.2	*	45.98 ± 3.76
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	84.74 ± 3.63
			177.2	22.2 ± 0.5	80.54 ± 3.56
			130.5	11.31 ± 0.21	85.59 ± 4.17
			<i>RR_{mean}</i> =		83.33 ± 3.00
¹⁶⁶ Yb	c	56.7H	2079.5	*	52.96 ± 4.14
			2052.4	*	56.98 ± 3.97
			1374.2	*	53.96 ± 4.41
			785.9	*	52.07 ± 3.95
			691.2(D)	8.56 ± 0.58	50.21 ± 3.97
			<i>RR_{mean}</i> =		53.24 ± 1.64
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	66.84 ± 12.99
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	50.74 ± 3.80
			242.9	35.5 ± 1.7	46.53 ± 2.89
			<i>RR_{mean}</i> =		47.58 ± 2.34
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	46.78 ± 3.66
¹⁶⁰ Er	c	28.58H	966.2	*	25.98 ± 3.57
			962.4	*	25.02 ± 3.44
			728.2(D)	34 ± 5	24.89 ± 3.77
			<i>RR_{mean}</i> =		25.29 ± 0.78
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	31.00 ± 6.07
			962.4	16.6 ± 2.1	15.20 ± 14.42
			<i>RR_{mean}</i> =		28.78 ± 5.56
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	13.50 ± 0.83
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	8.661 ± 0.551
¹⁵⁵ Tb	c*	5.32D	105.3	25.1 ± 1.3	9.481 ± 0.701
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	6.215 ± 0.516
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	5.541 ± 0.672
			97.4	29.0 ± 0.8	5.893 ± 0.531
			<i>RR_{mean}</i> =		5.765 ± 0.426

Continuation of Table 87.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁴⁹ Gd	c	9.28D	346.6	23.9 ± 1.3	4.054 ± 0.429
			298.6	28.6 ± 1.7	3.740 ± 0.336
			149.7	48 ± 3	4.471 ± 0.393
			RR _{mean} =		4.055 ± 0.258
¹⁴⁶ Gd	c	48.27D	747.2	*	2.484 ± 0.136
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	0.4627 ± 0.1421
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	2.947 ± 0.187
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.02	2.428 ± 0.136
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	2.942 ± 0.428
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	4.249 ± 0.299
			202.9	68.3 ± 0.5	4.722 ± 0.217
			172.1	25.5 ± 0.8	4.474 ± 0.495
			RR _{mean} =		4.591 ± 0.201
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.4929 ± 0.0659
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.999 ± 0.099
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	2.788 ± 0.155
			573.1	88.6 ± 0.1	2.643 ± 0.211
			RR _{mean} =		2.744 ± 0.085
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	5.984 ± 0.298
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.582 ± 0.131
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.235 ± 0.095
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	3.790 ± 0.210
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	8.180 ± 0.424
			171.3	90.2 ± 1.0	5.847 ± 0.262
¹¹¹ In	c	2.8047D	RR _{mean} =		5.649 ± 0.288
^{110m} Ag	i(m)	249.76D	1384.3	24.9 ± 0.8	7.278 ± 0.641
			884.7	72.7 ± 0.4	7.259 ± 0.292
			937.5	34.2 ± 0.6	7.115 ± 0.471
			657.8	94.3 ± 0.3	6.749 ± 0.259
			RR _{mean} =		6.976 ± 0.258
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	5.420 ± 0.354
			717.3	28.9 ± 0.8	5.037 ± 0.305
			451.0	28.2 ± 0.8	5.434 ± 0.276
			RR _{mean} =		5.305 ± 0.220
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.4127 ± 0.0374
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	28.13 ± 1.49
¹⁰² Rh	i	207D	475.1	46 ± 5	6.750 ± 0.830
^{101m} Rh	c	4.34D	306.9	81 ± 5	7.569 ± 0.566
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	3.661 ± 0.179
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	4.074 ± 0.190
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	22.49 ± 0.84
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	7.294 ± 0.391
			812.5	82 ± 4	7.401 ± 0.440
			RR _{mean} =		7.339 ± 0.333
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	18.99 ± 0.84
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	15.20 ± 0.75
			568.9	58.0 ± 0.3	14.64 ± 0.65
			RR _{mean} =		14.85 ± 0.59
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	19.53 ± 0.66

Continuation of Table 87.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	32.47 ± 1.08
^{92m}Nb	i(m)	10.15D	934.4	99.07 ± 0.04	2.021 ± 0.086
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	3.518 ± 0.250
^{95}Zr	c	64.02D	765.8	*	13.06 ± 0.48
			756.7	54.46 ± 0.10	11.67 ± 0.46
			724.2	44.17 ± 0.16	12.70 ± 0.49
			$RR_{mean} =$		12.89 ± 0.40
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	12.56 ± 0.42
^{88}Zr	c	83.4D	1836.1	*	4.911 ± 0.443
			898.0	*	5.367 ± 0.509
			392.9	97.24 ± 0.00	5.572 ± 0.216
			$RR_{mean} =$		5.503 ± 0.170
^{90m}Y	i(m)	3.19H	479.5	90.74 ± 0.05	18.35 ± 0.77
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	21.67 ± 0.81
			898.0	93.7 ± 0.3	19.94 ± 0.75
			$RR_{mean} =$		20.75 ± 1.07
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	26.58 ± 0.96
			898.0	93.7 ± 0.3	25.31 ± 0.87
			$RR_{mean} =$		25.79 ± 1.00
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	17.14 ± 0.60
			388.5	82.1 ± 0.5	18.91 ± 0.66
			$RR_{mean} =$		17.98 ± 1.04
^{85}Sr	c	64.84D	514.0	96 ± 4	17.73 ± 0.97
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	24.92 ± 1.12
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	21.10 ± 1.67
			529.6	29.3 ± 2.1	20.54 ± 1.69
			520.4	45 ± 4	20.34 ± 1.95
			$RR_{mean} =$		20.74 ± 0.93
^{82m}Rb	i(m)	6.472H	776.5	84.39 ± 0.21	7.061 ± 0.538
			554.3	62.4 ± 0.9	8.214 ± 0.895
			$RR_{mean} =$		7.347 ± 0.547
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	12.34 ± 0.58
			776.5	83.5 ± 1.2	12.69 ± 0.50
			554.3	70.8 ± 1.0	11.74 ± 0.50
			$RR_{mean} =$		12.30 ± 0.48
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	7.603 ± 0.305
			136.0	58.3 ± 0.8	7.780 ± 0.357
			$RR_{mean} =$		7.665 ± 0.284
^{74}As	i	17.77D	595.8	59 ± 4	10.95 ± 0.83
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	6.418 ± 0.828
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	8.471 ± 0.781
^{72}Zn	c	46.5H	2201.7	*	2.053 ± 0.202
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	3.906 ± 0.265
			1099.2	56.5 ± 1.9	4.033 ± 0.250
			$RR_{mean} =$		3.975 ± 0.194
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	1.837 ± 0.174
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.9286 ± 0.0913
^7Be	i	53.29D	477.6	10.52 ± 0.06	7.210 ± 1.191

12.8.2 Nuclide production rates for ^{207}Pb

Table 88: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 80$ M α B, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	14.66 ± 0.66
			803.1	98.9 ± 1.4	14.63 ± 0.53
			537.5	30.5 ± 0.5	14.07 ± 0.57
			343.5	23.4 ± 0.4	12.03 ± 0.87
			$RR_{mean} =$		14.31 ± 0.57
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	27.55 ± 1.74
			1764.3	32.5 ± 0.7	28.21 ± 1.20
			703.5	31.1 ± 0.1	27.01 ± 0.93
			$RR_{mean} =$		27.26 ± 0.91
^{204}Bi	i	11.22H	984.0	59 ± 4	25.74 ± 2.02
			899.2	98 ± 9	26.61 ± 0.98
			670.7	11.4 ± 0.9	26.73 ± 2.76
			374.8	82 ± 5	28.34 ± 5.92
			$RR_{mean} =$		26.57 ± 0.82
^{203}Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	28.56 ± 1.93
^{202}Bi	i	1.72H	422.1	83.7 ± 2.5	26.18 ± 2.69
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	64.31 ± 2.62
			374.7	89 ± 15	71.72 ± 12.38
			$RR_{mean} =$		64.46 ± 2.61
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	68.31 ± 2.72
			374.7	89 ± 15	75.27 ± 12.99
			$RR_{mean} =$		68.43 ± 2.71
^{203}Pb	c*	51.873H	279.2	80.8 ± 0.2	190.8 ± 7.0
^{202m}Pb	i(m)	3.53H	422.1	86 ± 5	57.06 ± 4.23
^{201}Pb	c*	9.33H	331.2	79 ± 5	163.2 ± 11.7
^{200}Pb	c	21.5H	1205.7	*	120.0 ± 8.4
			1514.9	*	117.6 ± 10.5
			828.3	*	115.7 ± 9.2
			579.3	*	102.6 ± 7.1
			450.5	3.33 ± 0.08	127.5 ± 6.2
			367.9	*	111.1 ± 3.9
			147.6	37.7 ± 1.4	116.5 ± 6.4
			$RR_{mean} =$		112.1 ± 3.5
^{199}Pb	c*	90M	366.9	44 ± 7	215.2 ± 35.4
^{198}Pb	c	2.4H	173.4	18 ± 3	143.6 ± 24.9
^{197m}Pb	c*	43M	385.9	74 ± 15	111.6 ± 23.1
			222.8	25 ± 6	114.5 ± 28.1
			$RR_{mean} =$		111.8 ± 5.9
^{195m}Pb	i(m)	15.0M	383.6	107 ± 20	54.21 ± 10.59
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	94.46 ± 3.40
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	276.7 ± 10.2
$^{200}\text{Tl}_i$	i	26.1H	1514.9	4.0 ± 0.3	101.9 ± 11.1
			579.3	13.8 ± 0.7	134.4 ± 10.8
			367.9	87.2 ± 0.4	121.4 ± 4.9
			1205.7	29.9 ± 1.8	116.0 ± 8.6
			$RR_{mean} =$		120.5 ± 5.2

Continuation of Table 88.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	219.5 ± 18.5
			579.3	13.8 ± 0.7	237.0 ± 15.1
			367.9	87.2 ± 0.4	232.4 ± 8.0
			1205.7	29.9 ± 1.8	236.1 ± 16.3
			RR _{mean} =		232.4 ± 7.9
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	209.6 ± 25.4
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	246.0 ± 29.3
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	114.5 ± 14.4
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	178.8 ± 31.4
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	15.00 ± 0.57
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	50.74 ± 2.40
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	66.47 ± 6.30
			261.8	31 ± 4	71.33 ± 9.60
			RR _{mean} =		67.32 ± 3.88
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	77.88 ± 14.87
			258.0	49 ± 7	111.5 ± 16.7
			RR _{mean} =		92.86 ± 16.95
¹⁹² Hg	c	4.85H	316.5	*	252.8 ± 31.7
			274.8	50.2 ± 2.5	197.8 ± 12.7
			RR _{mean} =		204.1 ± 6.3
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	149.5 ± 23.1
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.689 ± 0.228
			411.8	*	3.050 ± 0.143
			RR _{mean} =		2.976 ± 0.092
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	6.113 ± 0.276
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	9.163 ± 0.323
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	18.43 ± 2.58
			355.7	87.0 ± 0.8	17.02 ± 0.59
			333.0	22.9 ± 0.6	18.33 ± 0.81
			RR _{mean} =		17.23 ± 0.63
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	321.3 ± 32.0
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	32.30 ± 2.87
			293.6	10.4 ± 0.8	30.96 ± 2.69
			RR _{mean} =		31.58 ± 1.77
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	48.21 ± 6.34
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	301.0 ± 37.8
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	297.9 ± 25.6
			586.4	17 ± 0	270.0 ± 14.1
			166.5	3.32 ± 0.24	282.4 ± 26.3
			RR _{mean} =		276.2 ± 12.8
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	220.6 ± 18.3
			295.8	71 ± 5	217.2 ± 21.2
			RR _{mean} =		219.5 ± 11.5
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	246.9 ± 30.1
			456.5	3.4 ± 0.4	226.9 ± 27.9
			409.4	8.0 ± 0.9	214.3 ± 25.2
			351.2	3.4 ± 0.4	251.8 ± 31.0
			172.2	3.5 ± 0.4	200.9 ± 24.3
			RR _{mean} =		223.5 ± 11.6
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	282.1 ± 26.2

Continuation of Table 88.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			607.6	8.10 ± 0.16	248.0 ± 10.3
			568.8	7.1 ± 0.6	262.0 ± 24.9
			544.9	5.8 ± 0.5	257.9 ± 24.4
			243.5	7.0 ± 1.2	276.1 ± 49.1
			<i>RR_{mean}</i> =		252.0 ± 9.8
¹⁸⁸ Pt	c	10.2D	1209.8	*	242.4 ± 25.9
			633.0	*	260.9 ± 44.4
			195.1	18.6 ± 1.2	233.6 ± 17.5
			478.0	*	229.5 ± 12.2
			423.3	4.4 ± 0.3	237.8 ± 18.2
			381.4	7.5 ± 0.5	228.1 ± 17.1
			187.6	19.4 ± 1.2	238.9 ± 17.3
			<i>RR_{mean}</i> =		232.1 ± 7.2
¹⁸⁷ Pt	c	2.35H	106.4	8.8 ± 1.8	158.7 ± 35.2
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	187.9 ± 40.8
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	158.7 ± 29.0
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.9040 ± 0.1115
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.261 ± 0.156
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	211.9 ± 32.6
			245.1	6.0 ± 0.6	220.4 ± 23.7
			<i>RR_{mean}</i> =		220.0 ± 8.5
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	12.38 ± 2.28
			478.0	14.7 ± 0.6	15.21 ± 1.00
			<i>RR_{mean}</i> =		15.00 ± 0.87
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	242.9 ± 25.9
			633.0	18 ± 3	273.3 ± 46.5
			478.0	14.7 ± 0.6	244.7 ± 13.0
			<i>RR_{mean}</i> =		244.9 ± 8.3
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	252.5 ± 17.1
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	106.2 ± 5.6
			773.3	8.9 ± 0.5	101.1 ± 7.0
			<i>RR_{mean}</i> =		104.4 ± 4.9
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	169.7 ± 26.0
			254.2	13.3 ± 2.4	153.9 ± 29.3
			<i>RR_{mean}</i> =		167.3 ± 8.9
¹⁸⁴ Ir	c*	3.09H	264.0	68 ± 4	214.6 ± 15.2
			841.3	8.0 ± 0.8	196.2 ± 22.3
			390.4	25.9 ± 2.4	197.8 ± 19.8
			119.8	31 ± 3	220.8 ± 24.0
			<i>RR_{mean}</i> =		211.6 ± 8.3
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	225.8 ± 53.1
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	236.4 ± 12.3
			717.4	3.94 ± 0.16	233.3 ± 12.8
			646.1	78 ± 3	226.4 ± 11.6
			<i>RR_{mean}</i> =		230.5 ± 7.8
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	129.6 ± 5.7
			1101.9	49.0 ± 1.3	122.0 ± 5.4
			<i>RR_{mean}</i> =		125.4 ± 5.4
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	208.4 ± 11.5
			180.2	33.5 ± 1.7	208.4 ± 13.2

Continuation of Table 88.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	208.4 $\pm$ 9.3
^{181}Os	c	105M	238.8	44 ± 5	78.21 $\pm$ 10.59
^{180}Os	c	21.5M	902.8(D)	101.5 ± 3.4	169.5 $\pm$ 8.5
^{183}Re	c	70.0D	291.7	3.05 ± 0.18	221.9 ± 17.9
			162.3	23.3 ± 0.7	226.5 ± 10.9
				$RR_{mean} =$	225.8 $\pm$ 9.3
$^{182m}\text{Re}_c$	c	12.7H	1221.5	24.8 ± 1.6	224.0 ± 16.6
			1189.2	15 ± 1	240.7 ± 19.0
			1121.4	31.8 ± 1.6	233.2 ± 14.8
				$RR_{mean} =$	232.1 $\pm$ 9.6
^{181}Re	c*	19.9H	639.0	6.4 ± 1.4	206.6 ± 45.9
			365.5	56 ± 8	204.6 ± 30.2
				$RR_{mean} =$	205.1 $\pm$ 22.1
^{179}Re	c*	19.5M	430.2	28.0 ± 1.8	233.9 ± 18.0
			290.0	26.9 ± 2.3	200.8 ± 19.8
				$RR_{mean} =$	227.2 $\pm$ 15.0
^{178}Re	c*	13.2M	237.3	45 ± 5	234.1 $\pm$ 28.7
^{178}W	c	21.6D	1350.6(D)	1.18 ± 0.11	154.5 ± 16.9
			1340.8(D)	1.03 ± 0.09	121.5 ± 14.0
				$RR_{mean} =$	136.3 $\pm$ 17.0
^{177}W	c	135M	115.7	51 ± 5	144.4 $\pm$ 15.9
^{176}W	c	2.5H	1159.3	*	84.56 ± 21.48
			710.5	*	135.4 ± 43.7
				$RR_{mean} =$	94.15 $\pm$ 20.11
^{177}Ta	c*	56.56H	112.9	7.2 ± 1.6	156.4 $\pm$ 35.7
$^{176}\text{Ta}_c$	c	8.09H	1159.3	24.7 ± 1.9	148.5 ± 14.7
			710.5	5.4 ± 0.4	147.4 ± 20.5
				$RR_{mean} =$	148.3 $\pm$ 8.9
^{175}Ta	c	10.5H	1793.1	4.6 ± 0.7	115.0 ± 18.4
			348.5	12.0 ± 1.1	152.6 ± 15.0
			266.9	10.52 ± 0.16	137.1 ± 6.3
				$RR_{mean} =$	137.3 $\pm$ 6.4
$^{174}\text{Ta}_c$	c	1.14H	206.5	60 ± 5	113.4 $\pm$ 10.9
^{173}Ta	c	3.14H	172.2	17.5 ± 1.8	122.1 $\pm$ 13.6
^{172}Ta	c*	36.8M	214.1	55 ± 5	55.95 $\pm$ 5.85
^{175}Hf	c	70D	343.4	84 ± 3	135.0 $\pm$ 6.6
^{173}Hf	c*	23.6H	123.7	83 ± 5	137.3 ± 10.3
			311.2	10.7 ± 0.5	132.1 ± 7.8
			306.6	6.4 ± 0.3	151.9 ± 9.8
			139.6	12.7 ± 0.6	148.1 ± 9.4
				$RR_{mean} =$	140.5 $\pm$ 6.5
^{172}Hf	c	1.87Y	1093.6	*	92.50 ± 5.54
			900.7	*	89.47 ± 4.92
			181.5	*	89.87 ± 5.65
			125.8	11.3 ± 0.9	94.54 ± 9.06
				$RR_{mean} =$	91.01 $\pm$ 2.81
^{170}Hf	c	16.01H	620.7	18 ± 5	103.0 ± 28.9
			164.7	26 ± 8	97.32 ± 30.16
			120.2	15 ± 5	102.0 ± 34.4
				$RR_{mean} =$	101.8 $\pm$ 7.3

Continuation of Table 88.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	110.1 ± 5.9
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	92.94 ± 5.56
			900.7	29.8 ± 1.3	91.64 ± 5.03
			181.5	20.6 ± 1.0	90.65 ± 5.69
			<i>RR_{mean}</i> =		91.77 ± 3.19
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	100.9 ± 4.6
			780.7	4.36 ± 0.11	106.5 ± 4.9
			689.3	2.37 ± 0.06	103.6 ± 4.8
			667.4	11.0 ± 0.3	99.43 ± 4.31
			<i>RR_{mean}</i> =		102.1 ± 3.5
¹⁷⁰ Lu	c*	2.012D	1280.2	8.2 ± 0.4	111.7 ± 7.4
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	60.45 ± 2.81
¹⁶⁷ Lu	c	51.5M	176.2	*	40.32 ± 2.75
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	72.58 ± 3.11
			177.2	22.2 ± 0.5	68.97 ± 3.02
			130.5	11.31 ± 0.21	72.06 ± 3.45
			<i>RR_{mean}</i> =		71.08 ± 2.49
¹⁶⁶ Yb	c	56.7H	2079.5	*	43.92 ± 3.34
			2052.4	*	47.90 ± 3.34
			1374.2	*	48.70 ± 4.18
			785.9	*	44.19 ± 3.21
			691.2(D)	8.56 ± 0.58	41.27 ± 3.19
			<i>RR_{mean}</i> =		44.85 ± 1.38
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	56.59 ± 10.99
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	40.28 ± 3.04
			242.9	35.5 ± 1.7	38.70 ± 2.42
			<i>RR_{mean}</i> =		39.13 ± 1.66
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	38.54 ± 3.05
¹⁶⁰ Er	c	28.58H	966.2	*	20.86 ± 2.88
			962.4	*	21.32 ± 2.89
			728.2(D)	34 ± 5	20.97 ± 3.17
			<i>RR_{mean}</i> =		21.05 ± 0.65
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	22.41 ± 7.94
			962.4	16.6 ± 2.1	16.38 ± 11.18
			<i>RR_{mean}</i> =		20.41 ± 6.45
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	10.27 ± 0.69
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	7.086 ± 0.475
¹⁵⁵ Tb	c*	5.32D	105.3	25.1 ± 1.3	7.389 ± 0.585
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	5.242 ± 0.487
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	5.227 ± 0.566
			97.4	29.0 ± 0.8	4.338 ± 0.428
			<i>RR_{mean}</i> =		4.656 ± 0.450
¹⁴⁹ Gd	c	9.28D	346.6	23.9 ± 1.3	2.881 ± 0.349
			298.6	28.6 ± 1.7	2.859 ± 0.228
			149.7	48 ± 3	3.509 ± 0.265
			<i>RR_{mean}</i> =		3.128 ± 0.245
¹⁴⁶ Gd	c	48.27D	747.2	*	1.923 ± 0.104
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	0.2365 ± 0.0746
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	2.160 ± 0.119
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.02	1.977 ± 0.133

Continuation of Table 88.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	2.742 ± 0.311
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	4.048 ± 0.426
			202.9	68.3 ± 0.5	3.889 ± 0.190
			172.1	25.5 ± 0.8	5.038 ± 0.343
			RR _{mean} =		4.095 ± 0.325
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.833 ± 0.136
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	2.591 ± 0.201
			573.1	88.6 ± 0.1	2.223 ± 0.170
			RR _{mean} =		2.376 ± 0.073
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	4.978 ± 0.247
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.833 ± 0.178
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.204 ± 0.094
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.729 ± 0.245
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	8.330 ± 0.505
¹¹¹ In	c	2.8047D	245.4	94 ± 1	4.426 ± 0.208
			171.3	90.2 ± 1.0	4.667 ± 0.215
			RR _{mean} =		4.545 ± 0.185
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	6.837 ± 0.312
			937.5	34.2 ± 0.6	7.132 ± 0.452
			657.8	94.3 ± 0.3	6.380 ± 0.276
			RR _{mean} =		6.639 ± 0.285
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	4.545 ± 0.250
			717.3	28.9 ± 0.8	4.027 ± 0.268
			451.0	28.2 ± 0.8	4.347 ± 0.234
			RR _{mean} =		4.332 ± 0.194
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	25.11 ± 1.29
¹⁰² Rh	i	207D	475.1	46 ± 5	5.019 ± 0.667
^{101m} Rh	c	4.34D	306.9	81 ± 5	5.900 ± 0.436
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	21.66 ± 0.82
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	6.081 ± 0.325
			812.5	82 ± 4	6.077 ± 0.362
			RR _{mean} =		6.080 ± 0.275
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	17.69 ± 0.77
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	13.59 ± 0.68
			568.9	58.0 ± 0.3	12.56 ± 0.60
			RR _{mean} =		12.99 ± 0.65
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	17.52 ± 0.60
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	30.41 ± 1.02
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.850 ± 0.075
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	3.421 ± 0.231
⁹⁵ Zr	c	64.02D	765.8	*	13.00 ± 0.52
			756.7	54.46 ± 0.10	12.05 ± 0.48
			724.2	44.17 ± 0.16	11.91 ± 0.50
			RR _{mean} =		12.32 ± 0.38
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	10.23 ± 0.35
⁸⁸ Zr	c	83.4D	898.0	*	4.332 ± 0.148
			1836.1	*	4.474 ± 0.309
			392.9	97.24 ± 0.00	4.242 ± 0.196
			RR _{mean} =		4.325 ± 0.133
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	16.60 ± 0.78

Continuation of Table 88.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	17.32 ± 0.64
			898.0	93.7 ± 0.3	16.97 ± 0.56
			$RR_{mean} =$		17.05 ± 0.55
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	21.79 ± 0.78
			898.0	93.7 ± 0.3	21.31 ± 0.70
			$RR_{mean} =$		21.43 ± 0.69
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	13.88 ± 0.49
			388.5	82.1 ± 0.5	15.43 ± 0.54
			$RR_{mean} =$		14.61 ± 0.89
^{85}Sr	c	64.84D	514.0	96 ± 4	14.69 ± 0.80
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	22.37 ± 1.05
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	16.60 ± 1.47
			529.6	29.3 ± 2.1	16.10 ± 1.32
			520.4	45 ± 4	16.64 ± 1.63
			$RR_{mean} =$		16.38 ± 0.78
^{82m}Rb	i(m)	6.472H	776.5	84.39 ± 0.21	6.671 ± 0.642
			554.3	62.4 ± 0.9	6.206 ± 0.688
			$RR_{mean} =$		6.458 ± 0.490
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	11.66 ± 0.52
			776.5	83.5 ± 1.2	11.80 ± 0.46
			554.3	70.8 ± 1.0	11.13 ± 0.44
			$RR_{mean} =$		11.49 ± 0.42
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	6.283 ± 0.317
			136.0	58.3 ± 0.8	6.577 ± 0.313
			$RR_{mean} =$		6.438 ± 0.263
^{74}As	i	17.77D	595.8	59 ± 4	9.227 ± 0.708
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	6.714 ± 0.671
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	8.882 ± 0.668
^{72}Zn	c	46.5H	2201.7	*	2.168 ± 0.189
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	3.748 ± 0.255
			1099.2	56.5 ± 1.9	4.333 ± 0.309
			$RR_{mean} =$		3.981 ± 0.311
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	1.847 ± 0.221
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	1.107 ± 0.298
^7Be	i	53.29D	477.6	10.52 ± 0.06	6.646 ± 2.382

12.8.3 Nuclide production rates for ^{208}Pb

Table 89: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 0.8 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	569.7	97.74 ± 0.03	27.32 ± 3.74
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	23.01 ± 0.96
			803.1	98.9 ± 1.4	21.50 ± 0.77
			537.5	30.5 ± 0.5	20.65 ± 0.85
			343.5	23.4 ± 0.4	19.39 ± 1.14

Continuation of Table 89.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	32.95 ± 1.84
			1764.3	32.5 ± 0.7	31.38 ± 1.41
			703.5	31.1 ± 0.1	30.22 ± 1.02
			<i>RR_{mean}</i> =		30.53 ± 1.07
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	26.19 ± 2.08
			899.2	98 ± 9	26.39 ± 1.00
			670.7	11.4 ± 0.9	27.48 ± 2.91
			374.8	82 ± 5	27.90 ± 5.84
			<i>RR_{mean}</i> =		26.43 ± 0.82
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	25.43 ± 1.87
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	24.99 ± 2.80
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	65.75 ± 2.70
			374.7	89 ± 15	69.52 ± 12.10
			<i>RR_{mean}</i> =		65.83 ± 2.68
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	69.71 ± 2.79
			374.7	89 ± 15	73.02 ± 12.69
			<i>RR_{mean}</i> =		69.77 ± 2.78
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	174.0 ± 6.4
^{202m} Pb	i(m)	3.53H	422.1	86 ± 5	57.00 ± 4.12
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	150.2 ± 10.8
²⁰⁰ Pb	c	21.5H	579.3	*	94.25 ± 6.13
			1514.9	*	107.5 ± 10.1
			1205.7	*	109.1 ± 7.6
			828.3	*	94.79 ± 9.11
			450.5	3.33 ± 0.08	131.7 ± 6.7
			367.9	*	102.3 ± 3.6
			147.6	37.7 ± 1.4	108.4 ± 5.9
			<i>RR_{mean}</i> =		102.3 ± 3.2
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	216.0 ± 35.7
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	135.0 ± 23.3
^{197m} Pb	c*	43M	385.9	74 ± 15	102.1 ± 21.1
			222.8	25 ± 6	95.81 ± 24.12
			<i>RR_{mean}</i> =		101.6 ± 5.2
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	47.21 ± 9.23
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	94.99 ± 3.44
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	264.3 ± 9.7
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	108.9 ± 13.0
			1205.7	29.9 ± 1.8	120.7 ± 8.7
			579.3	13.8 ± 0.7	138.8 ± 9.6
			367.9	87.2 ± 0.4	122.2 ± 4.7
			<i>RR_{mean}</i> =		122.9 ± 4.9
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	216.4 ± 18.5
			1205.7	29.9 ± 1.8	229.8 ± 15.9
			579.3	13.8 ± 0.7	233.1 ± 14.5
			367.9	87.2 ± 0.4	224.5 ± 7.7
			<i>RR_{mean}</i> =		225.0 ± 7.6
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	206.2 ± 24.8
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	247.6 ± 29.5
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	113.4 ± 13.4
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	187.8 ± 32.8

Continuation of Table 89.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	21.08 ± 0.79
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	56.18 ± 2.54
^{195m}Hg	i(m)	41.6H	560.3	7.0 ± 0.6	76.16 ± 7.16
			261.8	31 ± 4	77.54 ± 10.43
			$RR_{mean} =$		76.41 ± 4.34
^{193m}Hg	i(m)	11.8H	407.6	32 ± 6	78.86 ± 15.10
			258.0	49 ± 7	114.4 ± 17.1
			$RR_{mean} =$		94.65 ± 17.92
^{192}Hg	c	4.85H	316.5	*	242.2 ± 30.5
			274.8	50.2 ± 2.5	189.1 ± 12.3
			$RR_{mean} =$		195.4 ± 6.0
^{190}Hg	c*	20.0M	142.6	68 ± 10	140.6 ± 21.7
^{198m}Au	i(m)	2.27D	204.1	40.8 ± 2.4	3.680 ± 0.331
			411.8	*	4.259 ± 0.197
			$RR_{mean} =$		4.153 ± 0.128
$^{198}\text{Au}_i$	i	2.69517D	411.8	95.58 ± 0.12	7.433 ± 0.348
$^{198}\text{Au}_c$	i(m+g)	2.69517D	411.8	95.58 ± 0.12	11.69 ± 0.41
^{196}Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	21.36 ± 2.74
			355.7	87.0 ± 0.8	20.73 ± 0.72
			333.0	22.9 ± 0.6	22.33 ± 1.01
			$RR_{mean} =$		20.95 ± 0.75
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	305.6 ± 30.1
^{194}Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	37.82 ± 3.36
			293.6	10.4 ± 0.8	36.59 ± 3.19
			$RR_{mean} =$		37.17 ± 2.08
$^{192}\text{Au}_i$	i(m+g)	4.94H	316.5	58 ± 7	60.31 ± 7.97
$^{192}\text{Au}_c$	c	4.94H	316.5	58 ± 7	302.5 ± 38.0
^{191}Au	c*	3.18H	674.2	6.8 ± 0.5	296.5 ± 25.5
			586.4	17 ± 0	296.3 ± 14.9
			166.5	3.32 ± 0.24	268.6 ± 26.4
			$RR_{mean} =$		292.2 ± 13.2
$^{190}\text{Au}_c$	c	42.8M	301.8	23.4 ± 1.5	222.6 ± 19.4
			295.8	71 ± 5	205.2 ± 19.5
			$RR_{mean} =$		214.6 ± 11.7
^{191}Pt	c	2.802D	538.9	13.7 ± 1.6	246.0 ± 29.9
			456.5	3.4 ± 0.4	227.3 ± 27.9
			409.4	8.0 ± 0.9	213.4 ± 25.1
			351.2	3.4 ± 0.4	260.1 ± 31.9
			172.2	3.5 ± 0.4	204.6 ± 24.9
			$RR_{mean} =$		225.4 ± 11.9
^{189}Pt	c	10.87H	721.4	9.3 ± 0.8	283.7 ± 26.5
			607.6	8.10 ± 0.16	244.7 ± 9.9
			568.8	7.1 ± 0.6	253.3 ± 24.8
			544.9	5.8 ± 0.5	261.2 ± 24.7
			243.5	7.0 ± 1.2	279.3 ± 49.6
			$RR_{mean} =$		248.6 ± 9.5
^{188}Pt	c	10.2D	1209.8	*	235.8 ± 25.2
			633.0	*	260.2 ± 44.2
			195.1	18.6 ± 1.2	231.6 ± 17.3
			478.0	*	229.9 ± 12.3

Continuation of Table 89.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			423.3	4.4 ± 0.3	240.0 ± 18.4
			381.4	7.5 ± 0.5	226.8 ± 17.0
			187.6	19.4 ± 1.2	237.3 ± 17.1
			$RR_{mean} =$		231.8 ± 7.2
^{187}Pt	c	2.35H	106.4	8.8 ± 1.8	180.5 ± 39.3
^{186}Pt	c	2.08H	689.4	70 ± 15	186.7 ± 40.5
^{184}Pt	c	17.3M	548.3	23 ± 4	157.4 ± 28.9
^{192}Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.7820 ± 0.0891
^{190}Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.656 ± 0.191
			569.3	28.5 ± 1.3	2.597 ± 0.314
			$RR_{mean} =$		2.643 ± 0.158
^{189}Ir	c	13.2D	275.9	0.54 ± 0.07	243.2 ± 35.6
			245.1	6.0 ± 0.6	224.2 ± 24.0
			$RR_{mean} =$		225.0 ± 8.7
$^{188}\text{Ir}_i$	i	41.5H	633.0	18 ± 3	14.55 ± 2.74
			478.0	14.7 ± 0.6	18.88 ± 1.66
			$RR_{mean} =$		17.97 ± 1.85
$^{188}\text{Ir}_c$	c	41.5H	1209.8	6.9 ± 0.7	242.6 ± 25.9
			633.0	18 ± 3	274.8 ± 46.7
			478.0	14.7 ± 0.6	248.8 ± 13.3
			$RR_{mean} =$		248.8 ± 8.5
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	234.9 ± 13.8
^{186}Ir	c	16.64H	434.8	33.9 ± 1.1	110.6 ± 5.6
			773.3	8.9 ± 0.5	113.5 ± 7.7
			$RR_{mean} =$		111.5 ± 5.0
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	173.8 ± 26.6
			254.2	13.3 ± 2.4	157.9 ± 29.3
			$RR_{mean} =$		171.3 ± 9.0
^{184}Ir	c*	3.09H	264.0	68 ± 4	208.0 ± 14.9
			841.3	8.0 ± 0.8	177.2 ± 21.0
			390.4	25.9 ± 2.4	190.0 ± 19.1
			119.8	31 ± 3	218.7 ± 23.9
			$RR_{mean} =$		203.8 ± 8.8
^{183}Ir	c	57M	392.5	10.4 ± 2.4	200.3 ± 47.2
^{185}Os	c	93.6D	874.8	6.29 ± 0.25	234.8 ± 12.3
			717.4	3.94 ± 0.16	233.5 ± 12.5
			646.1	78 ± 3	225.5 ± 11.5
			$RR_{mean} =$		229.4 ± 7.7
^{183m}Os	c*	9.9H	1107.9	22.4 ± 0.6	123.2 ± 5.7
			1101.9	49.0 ± 1.3	120.2 ± 5.3
			$RR_{mean} =$		121.4 ± 4.2
^{182}Os	c	22.10H	263.3	6.71 ± 0.25	205.8 ± 11.5
			180.2	33.5 ± 1.7	205.0 ± 13.0
			$RR_{mean} =$		205.5 ± 9.3
^{181}Os	c	105M	238.8	44 ± 5	77.08 ± 10.09
^{180}Os	c	21.5M	902.8(D)	101.5 ± 3.4	165.4 ± 8.6
^{183}Re	c	70.0D	291.7	3.05 ± 0.18	212.7 ± 16.0
			161.4	0.61 ± 0.14	270.3 ± 63.8
			$RR_{mean} =$		215.3 ± 15.0
$^{182m}\text{Re}_c$	c	12.7H	1221.5	24.8 ± 1.6	219.6 ± 16.4

Continuation of Table 89.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1189.2	15 ± 1	235.6 ± 18.7
			1121.4	31.8 ± 1.6	220.1 ± 13.9
			<i>RR_{mean}</i> =		222.8 ± 9.2
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	203.4 ± 45.2
			365.5	56 ± 8	197.4 ± 29.1
			<i>RR_{mean}</i> =		198.9 ± 21.4
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	230.6 ± 18.0
			290.0	26.9 ± 2.3	180.5 ± 18.6
			<i>RR_{mean}</i> =		219.1 ± 22.1
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	216.3 ± 27.2
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	154.1 ± 16.7
			1340.8(D)	1.03 ± 0.09	126.4 ± 13.7
			<i>RR_{mean}</i> =		137.6 ± 14.2
¹⁷⁷ W	c	135M	115.7	51 ± 5	134.3 ± 14.8
¹⁷⁶ W	c	2.5H	1159.3	*	83.17 ± 16.41
			710.5	*	97.84 ± 30.50
			<i>RR_{mean}</i> =		86.19 ± 13.62
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	150.1 ± 34.3
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	142.3 ± 13.2
			710.5	5.4 ± 0.4	153.1 ± 17.0
			<i>RR_{mean}</i> =		145.0 ± 7.3
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	100.4 ± 16.2
			348.5	12.0 ± 1.1	143.1 ± 14.2
			266.9	10.52 ± 0.16	128.9 ± 5.7
			<i>RR_{mean}</i> =		128.4 ± 6.7
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	104.3 ± 9.7
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	111.9 ± 12.7
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	48.70 ± 5.81
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	126.1 ± 6.2
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	127.3 ± 9.5
			311.2	10.7 ± 0.5	122.1 ± 7.3
			306.6	6.4 ± 0.3	142.8 ± 9.2
			139.6	12.7 ± 0.6	137.4 ± 9.0
			<i>RR_{mean}</i> =		130.6 ± 6.4
			1093.6	*	81.82 ± 4.76
			900.7	*	84.82 ± 4.66
¹⁷² Hf	c	1.87Y	181.5	*	79.66 ± 5.35
			125.8	11.3 ± 0.9	86.15 ± 9.37
			<i>RR_{mean}</i> =		83.53 ± 2.58
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	91.76 ± 25.70
			164.7	26 ± 8	86.85 ± 26.94
			120.2	15 ± 5	75.67 ± 25.59
			<i>RR_{mean}</i> =		88.71 ± 6.28
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	102.8 ± 5.6
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	82.53 ± 4.80
			900.7	29.8 ± 1.3	86.67 ± 4.76
			181.5	20.6 ± 1.0	81.65 ± 5.42
			<i>RR_{mean}</i> =		84.59 ± 3.05
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	85.29 ± 5.13
			780.7	4.36 ± 0.11	103.2 ± 5.2

Continuation of Table 89.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			689.3	2.37 ± 0.06	95.14 ± 4.54
			667.4	11.0 ± 0.3	92.49 ± 4.02
			<i>RR_{mean}</i> =		94.01 ± 4.06
¹⁷⁰ Lu	c*	2.012D	1280.2	8.2 ± 0.4	98.97 ± 6.09
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	53.08 ± 2.53
¹⁶⁷ Lu	c	51.5M	176.2	*	48.54 ± 5.77
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	65.93 ± 2.84
			177.2	22.2 ± 0.5	61.77 ± 2.68
			130.5	11.31 ± 0.21	67.03 ± 3.17
			<i>RR_{mean}</i> =		64.49 ± 2.56
¹⁶⁶ Yb	c	56.7H	2079.5	*	38.18 ± 2.88
			2052.4	*	41.34 ± 2.89
			1374.2	*	41.82 ± 3.63
			785.9	*	38.96 ± 2.84
			691.2(D)	8.56 ± 0.58	35.60 ± 2.81
			<i>RR_{mean}</i> =		38.94 ± 1.20
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	50.77 ± 9.87
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	37.21 ± 2.87
			242.9	35.5 ± 1.7	33.10 ± 2.07
			<i>RR_{mean}</i> =		34.02 ± 2.01
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	34.07 ± 3.09
¹⁶⁰ Er	c	28.58H	966.2	*	16.64 ± 2.29
			962.4	*	18.54 ± 2.48
			728.2(D)	34 ± 5	17.21 ± 2.62
			<i>RR_{mean}</i> =		17.42 ± 0.54
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	19.44 ± 5.89
			962.4	16.6 ± 2.1	15.33 ± 10.01
			<i>RR_{mean}</i> =		18.40 ± 5.04
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	8.727 ± 0.525
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	6.058 ± 0.494
¹⁵⁵ Tb	c*	5.32D	105.3	25.1 ± 1.3	5.959 ± 0.450
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	4.391 ± 0.425
¹⁵³ Gd	c	240.4D	97.4	29.0 ± 0.8	4.135 ± 0.691
			103.2	21.1 ± 0.7	3.451 ± 0.401
			<i>RR_{mean}</i> =		3.616 ± 0.350
¹⁴⁹ Gd	c	9.28D	346.6	23.9 ± 1.3	2.417 ± 0.214
			298.6	28.6 ± 1.7	2.394 ± 0.206
			149.7	48 ± 3	3.088 ± 0.240
			<i>RR_{mean}</i> =		2.633 ± 0.242
¹⁴⁶ Gd	c	48.27D	747.2	*	1.459 ± 0.105
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	0.4969 ± 0.1061
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	1.956 ± 0.138
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.02	1.870 ± 0.092
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	2.463 ± 0.213
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	3.789 ± 0.278
			202.9	68.3 ± 0.5	3.716 ± 0.168
			172.1	25.5 ± 0.8	4.019 ± 0.406
			<i>RR_{mean}</i> =		3.751 ± 0.156
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.3624 ± 0.0587
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.523 ± 0.121

Continuation of Table 89.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	2.304 ± 0.175
			573.1	88.6 ± 0.1	2.185 ± 0.175
			<i>RR_{mean}</i> = 2.245 ± 0.069		
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	4.482 ± 0.226
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.893 ± 0.115
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.252 ± 0.111
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.642 ± 0.161
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	7.578 ± 0.511
¹¹¹ In	c	2.8047D	245.4	94 ± 1	3.594 ± 0.182
			171.3	90.2 ± 1.0	4.217 ± 0.216
			<i>RR_{mean}</i> = 3.851 ± 0.329		
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	6.295 ± 0.263
			657.8	94.3 ± 0.3	6.309 ± 0.272
			937.5	34.2 ± 0.6	7.070 ± 0.409
			<i>RR_{mean}</i> = 6.396 ± 0.266		
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	3.709 ± 0.219
			717.3	28.9 ± 0.8	3.366 ± 0.223
			451.0	28.2 ± 0.8	3.619 ± 0.222
			<i>RR_{mean}</i> = 3.571 ± 0.156		
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	24.96 ± 1.38
¹⁰² Rh	i	207D	475.1	46 ± 5	5.135 ± 0.661
^{101m} Rh	c	4.34D	306.9	81 ± 5	5.184 ± 0.387
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	21.15 ± 0.80
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	4.842 ± 0.261
			812.5	82 ± 4	5.057 ± 0.303
			<i>RR_{mean}</i> = 4.929 ± 0.224		
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	18.20 ± 0.79
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	13.43 ± 0.66
			568.9	58.0 ± 0.3	12.35 ± 0.69
			<i>RR_{mean}</i> = 12.96 ± 0.67		
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	16.36 ± 0.55
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	28.97 ± 0.95
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.505 ± 0.069
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	3.079 ± 0.166
⁹⁵ Zr	c	64.02D	765.8	*	12.72 ± 0.44
			756.7	54.46 ± 0.10	12.28 ± 0.49
			724.2	44.17 ± 0.16	12.39 ± 0.47
			<i>RR_{mean}</i> = 12.54 ± 0.39		
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	8.491 ± 0.285
⁸⁸ Zr	c	83.4D	1836.1	*	3.890 ± 0.304
			392.9	97.24 ± 0.00	3.570 ± 0.149
			<i>RR_{mean}</i> = 3.606 ± 0.111		
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	15.25 ± 0.85
⁸⁸ Y _i	i	106.65D	898.0	93.7 ± 0.3	15.63 ± 0.53
			1836.1	99.2 ± 0.3	15.37 ± 0.57
			<i>RR_{mean}</i> = 15.54 ± 0.51		
⁸⁸ Y _c	c	106.65D	898.0	93.7 ± 0.3	17.81 ± 0.59
			1836.1	99.2 ± 0.3	19.26 ± 0.69
			<i>RR_{mean}</i> = 18.24 ± 0.87		
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	11.86 ± 0.42

Continuation of Table 89.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			388.5	82.1 ± 0.5	13.18 ± 0.48
			$RR_{mean} =$		12.39 ± 0.75
^{85}Sr	c	64.84D	514.0	96 ± 4	12.22 ± 0.66
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	21.54 ± 1.09
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	14.49 ± 1.21
			529.6	29.3 ± 2.1	14.34 ± 1.18
			520.4	45 ± 4	14.65 ± 1.41
			$RR_{mean} =$		14.46 ± 0.67
^{82m}Rb	i(m)	6.472H	776.5	84.39 ± 0.21	4.702 ± 0.550
			554.3	62.4 ± 0.9	5.651 ± 0.797
			$RR_{mean} =$		5.003 ± 0.468
^{82}Br	i(m+g)	35.30H	1317.5	26.5 ± 0.4	11.29 ± 0.49
			776.5	83.5 ± 1.2	11.34 ± 0.44
			698.4	28.5 ± 0.4	11.89 ± 0.60
			554.3	70.8 ± 1.0	10.88 ± 0.44
			$RR_{mean} =$		11.24 ± 0.39
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	4.979 ± 0.221
			136.0	58.3 ± 0.8	5.097 ± 0.273
			$RR_{mean} =$		5.019 ± 0.202
^{74}As	i	17.77D	595.8	59 ± 4	8.116 ± 0.625
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	7.234 ± 0.690
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	8.886 ± 0.673
^{72}Zn	c	46.5H	2201.7	*	1.652 ± 0.178
^{59}Fe	c	44.472D	1099.2	56.5 ± 1.9	4.215 ± 0.257
			1291.6	43.2 ± 1.4	3.778 ± 0.242
			$RR_{mean} =$		3.990 ± 0.251
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	1.570 ± 0.135
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.9722 ± 0.1855
^7Be	i	53.29D	477.6	10.52 ± 0.06	7.217 ± 0.949

12.8.4 Nuclide production rates for ^{nat}Pb

Table 90: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 0.8 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	15.51 ± 2.68
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	15.99 ± 0.79
			803.1	98.9 ± 1.4	15.67 ± 0.59
			537.5	30.5 ± 0.5	15.38 ± 0.69
			343.5	23.4 ± 0.4	14.77 ± 1.16
			$RR_{mean} =$		15.60 ± 0.54
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	24.63 ± 1.58
			1861.7	6.17 ± 0.10	24.63 ± 1.58
			1764.3	32.5 ± 0.7	26.65 ± 1.14
			703.5	31.1 ± 0.1	26.03 ± 0.96
			$RR_{mean} =$		25.96 ± 0.89
^{204}Bi	i	11.22H	984.0	59 ± 4	25.34 ± 2.02
			899.2	98 ± 9	25.78 ± 0.97

Continuation of Table 90.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			670.7	11.4 ± 0.9	28.31 ± 2.98
			374.8	82 ± 5	27.10 ± 5.67
			<i>RR_{mean}</i> =		25.83 ± 0.80
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	26.36 ± 1.79
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	27.76 ± 2.27
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	57.71 ± 2.26
			374.7	89 ± 15	66.42 ± 11.46
			<i>RR_{mean}</i> =		57.84 ± 2.26
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	61.57 ± 2.36
			374.7	89 ± 15	69.82 ± 12.04
			<i>RR_{mean}</i> =		61.69 ± 2.36
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	187.4 ± 6.9
^{202m} Pb	i(m)	3.53H	422.1	86 ± 5	52.74 ± 3.83
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	154.8 ± 11.2
²⁰⁰ Pb	c	21.5H	1514.9	*	114.6 ± 10.4
			1205.7	*	115.9 ± 8.2
			828.3	*	111.4 ± 9.6
			450.5	3.33 ± 0.08	121.9 ± 6.2
			367.9	*	107.3 ± 3.7
			147.6	37.7 ± 1.4	119.3 ± 6.7
			<i>RR_{mean}</i> =		109.7 ± 3.4
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	203.8 ± 33.7
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	136.7 ± 23.6
^{197m} Pb	c*	43M	385.9	74 ± 15	108.0 ± 22.3
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	53.94 ± 10.38
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	91.70 ± 3.31
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	267.9 ± 10.0
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	93.00 ± 10.43
			1205.7	29.9 ± 1.8	109.3 ± 8.1
			579.3	13.8 ± 0.7	129.7 ± 11.5
			367.9	87.2 ± 0.4	115.7 ± 4.6
			<i>RR_{mean}</i> =		114.2 ± 5.3
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	207.6 ± 17.4
			1205.7	29.9 ± 1.8	225.2 ± 15.6
			579.3	13.8 ± 0.7	228.2 ± 14.7
			367.9	87.2 ± 0.4	223.0 ± 7.7
			<i>RR_{mean}</i> =		222.8 ± 7.6
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	194.2 ± 23.1
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	243.4 ± 29.2
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	108.9 ± 13.9
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	183.5 ± 32.0
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	15.52 ± 0.58
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	50.79 ± 2.54
^{195m} Hg	i(m)	41.6H	560.3	7.0 ± 0.6	66.16 ± 6.36
			261.8	31 ± 4	72.41 ± 9.79
			<i>RR_{mean}</i> =		67.28 ± 3.97
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	72.85 ± 13.92
			258.0	49 ± 7	107.9 ± 16.2
			<i>RR_{mean}</i> =		87.90 ± 17.56
¹⁹² Hg	c	4.85H	316.5	*	242.4 ± 30.4

Continuation of Table 90.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			274.8	50.2 ± 2.5	188.3 ± 11.9
			<i>RR_{mean}</i> =		194.2 ± 6.0
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	155.2 ± 24.1
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.788 ± 0.255
			411.8	*	2.673 ± 0.201
			<i>RR_{mean}</i> =		2.715 ± 0.084
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	6.934 ± 0.444
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	9.608 ± 0.386
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	17.31 ± 2.29
			355.7	87.0 ± 0.8	17.26 ± 0.60
			333.0	22.9 ± 0.6	18.40 ± 0.89
			<i>RR_{mean}</i> =		17.39 ± 0.59
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	279.6 ± 28.7
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	32.47 ± 2.89
			293.6	10.4 ± 0.8	31.79 ± 2.92
			<i>RR_{mean}</i> =		32.14 ± 1.86
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	46.44 ± 5.87
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	288.8 ± 36.2
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	287.0 ± 24.1
			586.4	17 ± 0	284.2 ± 13.4
			166.5	3.32 ± 0.24	261.2 ± 24.1
			<i>RR_{mean}</i> =		281.4 ± 12.2
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	207.3 ± 15.4
			295.8	71 ± 5	205.7 ± 17.2
			<i>RR_{mean}</i> =		206.8 ± 9.0
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	237.8 ± 29.0
			456.5	3.4 ± 0.4	215.9 ± 26.7
			409.4	8.0 ± 0.9	202.1 ± 23.8
			351.2	3.4 ± 0.4	249.0 ± 31.9
			172.2	3.5 ± 0.4	204.1 ± 25.0
			<i>RR_{mean}</i> =		216.3 ± 10.8
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	269.2 ± 25.0
			607.6	8.10 ± 0.16	230.8 ± 9.7
			568.8	7.1 ± 0.6	242.7 ± 23.7
			544.9	5.8 ± 0.5	258.1 ± 24.8
			243.5	7.0 ± 1.2	235.2 ± 42.5
			<i>RR_{mean}</i> =		235.6 ± 9.3
¹⁸⁸ Pt	c	10.2D	1209.8	*	228.6 ± 24.4
			633.0	*	250.3 ± 42.5
			195.1	18.6 ± 1.2	223.4 ± 16.7
			478.0	*	219.1 ± 11.7
			423.3	4.4 ± 0.3	224.1 ± 17.1
			381.4	7.5 ± 0.5	216.2 ± 16.2
			187.6	19.4 ± 1.2	227.3 ± 16.5
			<i>RR_{mean}</i> =		221.0 ± 6.8
¹⁸⁷ Pt	c	2.35H	106.4	8.8 ± 1.8	169.6 ± 36.6
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	186.0 ± 40.4
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	157.7 ± 28.6
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.6950 ± 0.0583
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.073 ± 0.149

Continuation of Table 90.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			569.3	28.5 ± 1.3	1.996 ± 0.209
			<i>RR_{mean}</i> = 2.051 ± 0.119		
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	214.9 ± 29.9
			245.1	6.0 ± 0.6	210.8 ± 22.6
			<i>RR_{mean}</i> = 211.1 ± 8.2		
¹⁸⁸ Ir _i	i	41.5H	633.0	18 ± 3	12.05 ± 2.26
			478.0	14.7 ± 0.6	15.45 ± 1.22
			<i>RR_{mean}</i> = 14.92 ± 1.31		
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	237.7 ± 25.4
			633.0	18 ± 3	262.4 ± 44.6
			478.0	14.7 ± 0.6	234.5 ± 12.5
			<i>RR_{mean}</i> = 234.8 ± 8.0		
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	240.6 ± 16.4
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	105.1 ± 5.3
			773.3	8.9 ± 0.5	107.5 ± 7.4
			<i>RR_{mean}</i> = 105.7 ± 4.8		
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	159.4 ± 24.6
			254.2	13.3 ± 2.4	147.6 ± 27.8
			<i>RR_{mean}</i> = 157.3 ± 8.8		
¹⁸⁴ Ir	c*	3.09H	264.0	68 ± 4	210.8 ± 15.0
			390.4	25.9 ± 2.4	183.1 ± 18.3
			119.8	31 ± 3	215.8 ± 24.2
			<i>RR_{mean}</i> = 207.2 ± 9.5		
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	203.5 ± 47.8
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	226.5 ± 12.3
			717.4	3.94 ± 0.16	218.4 ± 11.8
			646.1	78 ± 3	215.7 ± 11.0
			<i>RR_{mean}</i> = 218.2 ± 7.3		
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	120.4 ± 5.3
			1101.9	49.0 ± 1.3	119.8 ± 5.2
			<i>RR_{mean}</i> = 120.0 ± 4.0		
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	196.3 ± 11.4
			180.2	33.5 ± 1.7	207.5 ± 13.2
			<i>RR_{mean}</i> = 200.8 ± 9.3		
¹⁸¹ Os	c	105M	238.8	44 ± 5	70.25 ± 8.98
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	160.3 ± 8.4
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	207.3 ± 14.8
			161.4	0.61 ± 0.14	253.4 ± 59.3
			161.4	0.61 ± 0.14	209.6 ± 14.5
			<i>RR_{mean}</i> = 209.5 ± 10.8		
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	210.2 ± 15.5
			1189.2	15 ± 1	218.4 ± 19.8
			1121.4	31.8 ± 1.6	208.5 ± 13.1
			<i>RR_{mean}</i> = 210.2 ± 8.8		
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	200.3 ± 44.5
			365.5	56 ± 8	191.6 ± 28.3
			<i>RR_{mean}</i> = 193.7 ± 20.9		
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	226.5 ± 20.0
			290.0	26.9 ± 2.3	188.0 ± 18.3
			<i>RR_{mean}</i> = 208.3 ± 20.3		

Continuation of Table 90.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	246.7 ± 29.7
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	143.6 ± 15.4
			1340.8(D)	1.03 ± 0.09	119.9 ± 12.1
			<i>RR_{mean}</i> =		127.3 ± 11.6
¹⁷⁷ W	c	135M	115.7	51 ± 5	134.1 ± 15.2
¹⁷⁶ W	c	2.5H	1823.7	*	108.8 ± 44.9
			1159.3	*	111.2 ± 12.9
			710.5	*	108.5 ± 31.9
			<i>RR_{mean}</i> =		110.8 ± 9.4
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	158.8 ± 37.3
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	135.1 ± 19.3
			1159.3	24.7 ± 1.9	136.2 ± 11.8
			710.5	5.4 ± 0.4	151.5 ± 16.6
			<i>RR_{mean}</i> =		138.1 ± 5.9
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	99.31 ± 16.15
			348.5	12.0 ± 1.1	151.0 ± 15.0
			266.9	10.52 ± 0.16	130.4 ± 5.8
			<i>RR_{mean}</i> =		130.1 ± 7.7
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	101.3 ± 9.5
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	120.6 ± 13.5
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	51.25 ± 5.23
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	125.8 ± 6.2
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	131.7 ± 10.4
			311.2	10.7 ± 0.5	126.4 ± 7.7
			306.6	6.4 ± 0.3	143.8 ± 9.3
			139.6	12.7 ± 0.6	145.0 ± 9.7
			<i>RR_{mean}</i> =		135.1 ± 6.4
¹⁷² Hf	c	1.87Y	1093.6	*	84.40 ± 4.99
			900.7	*	85.41 ± 4.88
			181.5	*	89.49 ± 5.68
			125.8	11.3 ± 0.9	88.82 ± 8.97
			<i>RR_{mean}</i> =		86.35 ± 2.66
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	98.92 ± 27.72
			164.7	26 ± 8	92.24 ± 28.59
			120.2	15 ± 5	95.56 ± 32.45
			<i>RR_{mean}</i> =		97.27 ± 6.92
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	106.2 ± 5.9
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	85.14 ± 5.03
			900.7	29.8 ± 1.3	86.90 ± 4.92
			181.5	20.6 ± 1.0	90.96 ± 5.75
			<i>RR_{mean}</i> =		87.09 ± 3.09
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	98.05 ± 4.73
			780.7	4.36 ± 0.11	99.91 ± 4.66
			689.3	2.37 ± 0.06	98.12 ± 4.48
			667.4	11.0 ± 0.3	96.94 ± 4.23
			<i>RR_{mean}</i> =		98.08 ± 3.29
¹⁷⁰ Lu	c*	2.012D	1280.2	8.2 ± 0.4	104.2 ± 6.9
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	56.73 ± 2.62
¹⁶⁷ Lu	c	51.5M	176.2	*	46.86 ± 3.53
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	69.83 ± 3.01

Continuation of Table 90.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			177.2	22.2 ± 0.5	66.84 ± 2.94
			130.5	11.31 ± 0.21	69.63 ± 3.60
			$RR_{mean} =$		68.58 ± 2.40
¹⁶⁶ Yb	c	56.7H	2079.5	*	40.50 ± 3.10
			2052.4	*	41.20 ± 2.87
			1374.2	*	47.45 ± 4.21
			785.9	*	44.18 ± 3.30
			691.2(D)	8.56 ± 0.58	38.36 ± 3.12
			$RR_{mean} =$		41.73 ± 1.29
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	53.54 ± 10.40
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	37.25 ± 2.91
			242.9	35.5 ± 1.7	39.34 ± 2.52
			$RR_{mean} =$		38.68 ± 1.70
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	35.93 ± 2.87
¹⁶⁰ Er	c	28.58H	966.2	*	20.64 ± 2.93
			962.4	*	18.61 ± 2.48
			728.2(D)	34 ± 5	19.29 ± 2.96
			$RR_{mean} =$		19.40 ± 0.60
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	23.21 ± 9.05
			962.4	16.6 ± 2.1	26.48 ± 6.19
			$RR_{mean} =$		25.46 ± 5.05
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	10.82 ± 0.66
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	7.299 ± 0.521
¹⁵⁵ Tb	c*	5.32D	105.3	25.1 ± 1.3	6.587 ± 0.552
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	3.794 ± 0.381
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	4.093 ± 0.425
			97.4	29.0 ± 0.8	4.588 ± 0.395
			$RR_{mean} =$		4.367 ± 0.298
¹⁴⁹ Gd	c	9.28D	346.6	23.9 ± 1.3	3.006 ± 0.287
			298.6	28.6 ± 1.7	2.900 ± 0.253
			149.7	48 ± 3	3.695 ± 0.289
			$RR_{mean} =$		3.221 ± 0.277
¹⁴⁶ Gd	c	48.27D	747.2	*	1.757 ± 0.087
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	0.5386 ± 0.0547
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	2.296 ± 0.116
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.02	2.129 ± 0.102
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	2.489 ± 0.207
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	3.837 ± 0.269
			202.9	68.3 ± 0.5	3.946 ± 0.180
			172.1	25.5 ± 0.8	3.686 ± 0.322
			$RR_{mean} =$		3.892 ± 0.160
¹²⁴ Sb	i(m1+m2+g)	60.20D	602.7	98.3 ± 0.4	0.5406 ± 0.0582
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.739 ± 0.149
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	2.400 ± 0.142
			573.1	88.6 ± 0.1	2.382 ± 0.580
			$RR_{mean} =$		2.399 ± 0.074
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	5.043 ± 0.424
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.957 ± 0.187
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	2.157 ± 0.091
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.940 ± 0.182

Continuation of Table 90.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	8.245 ± 0.402
^{111}In	c	2.8047D	245.4	94 ± 1	4.349 ± 0.240
			171.3	90.2 ± 1.0	4.298 ± 0.226
			$RR_{mean} =$		4.321 ± 0.186
^{110m}Ag	i(m)	249.76D	1384.3	24.9 ± 0.8	6.974 ± 0.559
			884.7	72.7 ± 0.4	6.344 ± 0.251
			657.8	94.3 ± 0.3	6.130 ± 0.234
			937.5	34.2 ± 0.6	6.262 ± 0.358
			$RR_{mean} =$		6.252 ± 0.216
^{106m}Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	4.042 ± 0.288
			717.3	28.9 ± 0.8	3.688 ± 0.267
			451.0	28.2 ± 0.8	3.799 ± 0.229
			$RR_{mean} =$		3.829 ± 0.176
^{105}Rh	c	35.36H	318.9	19.1 ± 0.6	24.30 ± 1.31
^{102}Rh	i	207D	475.1	46 ± 5	6.255 ± 0.762
^{101m}Rh	c	4.34D	306.9	81 ± 5	5.924 ± 0.451
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	20.49 ± 0.78
^{96}Tc	i(m+g)	4.28D	849.9	98 ± 4	5.450 ± 0.302
			812.5	82 ± 4	5.558 ± 0.346
			$RR_{mean} =$		5.494 ± 0.257
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	17.64 ± 0.82
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	13.57 ± 0.70
			568.9	58.0 ± 0.3	11.87 ± 0.62
			$RR_{mean} =$		12.64 ± 0.93
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	16.51 ± 0.57
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	28.48 ± 0.95
^{92m}Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.640 ± 0.103
^{97}Zr	c	16.744H	743.4	93.06 ± 0.16	3.143 ± 0.187
^{95}Zr	c	64.02D	765.8	*	12.07 ± 0.47
			756.7	54.46 ± 0.10	11.52 ± 0.44
			724.2	44.17 ± 0.16	11.96 ± 0.47
			$RR_{mean} =$		11.85 ± 0.37
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	9.446 ± 0.323
^{88}Zr	c	83.4D	898.0	*	3.840 ± 0.223
			1836.1	*	3.691 ± 0.187
			392.9	97.24 ± 0.00	4.159 ± 0.168
			$RR_{mean} =$		3.967 ± 0.122
^{90m}Y	i(m)	3.19H	479.5	90.74 ± 0.05	14.92 ± 0.76
$^{88}\text{Y}_i$	i	106.65D	898.0	93.7 ± 0.3	15.49 ± 0.53
			1836.1	99.2 ± 0.3	16.81 ± 0.59
			$RR_{mean} =$		15.98 ± 0.80
$^{88}\text{Y}_c$	c	106.65D	898.0	93.7 ± 0.3	19.34 ± 0.64
			1836.1	99.2 ± 0.3	20.50 ± 0.72
			$RR_{mean} =$		19.72 ± 0.82
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	13.35 ± 0.48
			388.5	82.1 ± 0.5	14.14 ± 0.53
			$RR_{mean} =$		13.66 ± 0.57
^{85}Sr	c	64.84D	514.0	96 ± 4	13.67 ± 0.75
^{86}Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	23.95 ± 1.05
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	16.10 ± 1.32

Continuation of Table 90.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{82m}Rb	i(m)	6.472H	529.6	29.3 ± 2.1	15.49 ± 1.26
			520.4	45 ± 4	15.80 ± 1.55
			$RR_{mean} =$		15.78 ± 0.72
			776.5	84.39 ± 0.21	5.394 ± 0.514
			554.3	62.4 ± 0.9	6.062 ± 0.961
^{82}Br	i(m+g)	35.30H	$RR_{mean} =$		5.534 ± 0.464
			1317.5	26.5 ± 0.4	10.77 ± 0.58
			776.5	83.5 ± 1.2	11.69 ± 0.46
			698.4	28.5 ± 0.4	11.56 ± 0.72
			554.3	70.8 ± 1.0	11.27 ± 0.49
^{75}Se	c	119.779D	$RR_{mean} =$		11.41 ± 0.40
			264.7	58.9 ± 0.4	5.491 ± 0.251
			136.0	58.3 ± 0.8	5.923 ± 0.323
			$RR_{mean} =$		5.632 ± 0.267
			595.8	59 ± 4	8.516 ± 0.651
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	7.405 ± 0.674
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	8.783 ± 0.652
^{72}Zn	c	46.5H	2201.7	*	1.378 ± 0.160
^{59}Fe	c	44.472D	1099.2	56.5 ± 1.9	3.891 ± 0.328
			1291.6	43.2 ± 1.4	4.237 ± 0.245
			$RR_{mean} =$		4.135 ± 0.205
			834.8	99.98 ± 0.00	1.640 ± 0.123
			889.3	99.98 ± 0.00	1.089 ± 0.067
^{7}Be	i	53.29D	477.6	10.52 ± 0.06	6.155 ± 0.790

12.8.5 Nuclide production rates for ^{209}Bi

Table 91: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 0.8 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	25.02 ± 1.11
^{206}Po	i	8.8D	1718.7	*	27.63 ± 1.62
			1595.3	*	26.58 ± 3.47
			1032.3	33 ± 5	27.83 ± 4.33
			1007.2	3.1 ± 0.4	29.01 ± 4.44
			980.2	7.1 ± 0.9	30.39 ± 4.06
			807.4	23 ± 3	29.12 ± 3.96
			803.1	*	27.01 ± 1.14
			657.2	*	21.96 ± 4.66
			620.5	*	26.40 ± 2.09
			537.5	*	25.55 ± 1.06
			522.5	15.7 ± 2.0	26.12 ± 3.50
			516.2	*	27.42 ± 1.11
			398.0	*	26.05 ± 1.56
			343.5	*	27.44 ± 1.29
			338.4	19.2 ± 2.5	28.27 ± 3.82
			286.4	24 ± 3	28.82 ± 3.77
			$RR_{mean} =$		26.75 ± 0.82

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	c	31.55Y	1063.7	74.5 ± 0.2	265.5 ± 12.7
			569.7	97.74 ± 0.03	256.4 ± 9.4
			<i>RR_{mean}</i> =		258.4 ± 9.2
²⁰⁶ Bi _i	i	6.243D	1718.7	31.8 ± 0.6	162.4 ± 6.6
			1595.3	5.01 ± 0.08	164.6 ± 8.2
			881.0	66.2 ± 1.0	161.4 ± 5.9
			803.1	98.9 ± 1.4	151.5 ± 5.5
			657.2	1.91 ± 0.04	134.1 ± 8.0
			620.5	5.76 ± 0.09	145.8 ± 6.2
			537.5	30.5 ± 0.5	139.7 ± 5.3
			516.2	40.7 ± 0.6	144.5 ± 5.4
			398.0	10.74 ± 0.15	141.1 ± 5.5
			343.5	23.4 ± 0.4	145.3 ± 5.5
			<i>RR_{mean}</i> =		148.5 ± 5.4
²⁰⁶ Bi _c	c	6.243D	1718.7	31.8 ± 0.6	188.5 ± 7.5
			1595.3	5.01 ± 0.08	189.8 ± 8.0
			881.0	66.2 ± 1.0	197.2 ± 7.1
			803.1	98.9 ± 1.4	177.0 ± 6.3
			620.5	5.76 ± 0.09	170.7 ± 6.7
			537.5	30.5 ± 0.5	163.9 ± 6.2
			516.2	40.7 ± 0.6	170.4 ± 6.3
			398.0	10.74 ± 0.15	165.7 ± 6.2
			343.5	23.4 ± 0.4	171.2 ± 6.5
			<i>RR_{mean}</i> =		175.7 ± 6.6
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	182.6 ± 7.5
			1775.8	3.99 ± 0.08	190.9 ± 8.1
			1764.3	32.5 ± 0.7	189.0 ± 7.7
			1614.3	2.28 ± 0.04	180.7 ± 7.6
			1190.0	2.26 ± 0.07	180.9 ± 8.9
			1043.8	7.51 ± 0.10	164.6 ± 6.4
			987.7	16.13 ± 0.17	189.6 ± 6.9
			759.1	1.04 ± 0.05	183.4 ± 11.9
			703.5	31.1 ± 0.1	173.1 ± 5.9
			579.8	5.44 ± 0.07	166.4 ± 6.4
			570.6	4.34 ± 0.07	155.5 ± 6.3
			549.8	2.95 ± 0.04	167.4 ± 6.4
			284.1	1.69 ± 0.02	173.6 ± 8.3
			<i>RR_{mean}</i> =		174.3 ± 6.1
²⁰⁴ Bi	c*	11.22H	984.0	59 ± 4	144.8 ± 11.0
			918.3	10.8 ± 0.9	168.2 ± 15.7
			899.2	98 ± 9	140.6 ± 5.0
			670.7	11.4 ± 0.9	159.3 ± 14.4
			374.8	82 ± 5	165.8 ± 34.6
			<i>RR_{mean}</i> =		141.8 ± 4.4
²⁰³ Bi	c	11.76H	1893.0	8.2 ± 0.6	126.4 ± 10.6
			1847.3	11.4 ± 0.8	128.1 ± 10.7
			1679.6	8.8 ± 0.7	117.4 ± 10.7
			847.2	8.5 ± 0.5	153.7 ± 11.0
			820.2	29.6 ± 1.5	138.1 ± 8.4
			279.2	*	127.0 ± 6.3
			264.2	5.2 ± 0.4	187.1 ± 24.1

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰² Bi	c*	1.72H		<i>RR_{mean}</i> =	130.0 ± 4.0
			960.7	99.28 ± 0.02	114.1 ± 4.6
			422.1	83.7 ± 2.5	120.0 ± 6.2
^{204m} Pb _i	i(m)	67.2M		<i>RR_{mean}</i> =	115.7 ± 4.4
			899.2	99.17 ± 0.02	48.96 ± 2.51
			374.7	89 ± 15	50.56 ± 8.88
^{204m} Pb _c	c	67.2M		<i>RR_{mean}</i> =	49.04 ± 2.47
			899.2	99.17 ± 0.02	70.04 ± 2.94
			374.7	89 ± 15	71.36 ± 12.39
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	120.1 ± 7.0
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	247.1 ± 9.2
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	71.97 ± 7.11
			422.1	86 ± 5	60.54 ± 4.49
				<i>RR_{mean}</i> =	62.55 ± 4.76
²⁰¹ Pb	c*	9.33H	946.0	7.4 ± 0.6	221.2 ± 20.6
			361.3	9.9 ± 0.5	277.1 ± 18.1
			331.2	79 ± 5	249.9 ± 18.0
²⁰⁰ Pb	c	21.5H		<i>RR_{mean}</i> =	252.9 ± 17.4
			1514.9	*	163.2 ± 14.6
			1205.7	*	180.2 ± 12.4
¹⁹⁹ Pb	c*	90M	579.3	*	165.0 ± 11.6
			450.5	3.33 ± 0.08	206.6 ± 10.1
			367.9	*	170.5 ± 6.0
¹⁹⁸ Pb	c	2.4H	147.6	37.7 ± 1.4	188.3 ± 12.4
				<i>RR_{mean}</i> =	172.8 ± 5.3
^{197m} Pb	c*	43M	1135.0	7.8 ± 1.2	271.3 ± 44.5
			455.5	*	225.6 ± 36.0
			366.9	44 ± 7	369.8 ± 61.5
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	89.13 ± 17.07
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	33.43 ± 1.21
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	295.5 ± 11.4
²⁰⁰ Tl _i	i	26.1H	1514.9	4.0 ± 0.3	69.91 ± 11.49
			1205.7	29.9 ± 1.8	67.43 ± 4.91
			579.3	13.8 ± 0.7	73.67 ± 9.42
²⁰⁰ Tl _c	c	26.1H	367.9	87.2 ± 0.4	65.47 ± 4.58
				<i>RR_{mean}</i> =	67.26 ± 3.46
¹⁹⁹ Tl	c*	7.42H	1514.9	4.0 ± 0.3	233.1 ± 19.8
			1205.7	29.9 ± 1.8	247.7 ± 17.0
			579.3	13.8 ± 0.7	238.6 ± 15.2
¹⁹⁹ Tl	c*	7.42H	367.9	87.2 ± 0.4	235.9 ± 8.5
				<i>RR_{mean}</i> =	236.8 ± 8.2
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	279.2 ± 33.3
			247.3	9.3 ± 1.1	290.4 ± 36.5
				<i>RR_{mean}</i> =	283.6 ± 16.1

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	82.16 ± 10.33
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	223.1 ± 75.9
			152.2	7.3 ± 2.3	374.5 ± 119.5
			RR _{mean} =		303.9 ± 76.1
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	164.1 ± 28.7
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	24.50 ± 1.63
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	44.07 ± 6.20
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	51.96 ± 9.94
			258.0	49 ± 7	74.32 ± 11.35
			RR _{mean} =		61.75 ± 11.26
¹⁹² Hg	c	4.85H	316.5	*	238.6 ± 30.0
			274.8	50.2 ± 2.5	196.6 ± 12.4
			RR _{mean} =		201.7 ± 6.2
¹⁹⁰ Hg	c*	20.0M	597.7	*	170.6 ± 26.5
			301.8	*	188.9 ± 26.1
			295.8	*	158.1 ± 13.2
			142.6	68 ± 10	161.9 ± 25.3
			RR _{mean} =		162.5 ± 5.0
^{198m} Au	i(m)	2.27D	411.8	*	0.1457 ± 0.0682
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	2.740 ± 0.156
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	2.886 ± 0.116
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	4.819 ± 0.188
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	230.1 ± 25.7
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	11.88 ± 1.11
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	27.10 ± 4.00
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	265.7 ± 33.4
¹⁹¹ Au	c*	3.18H	586.4	17 ± 0	266.3 ± 12.3
			277.9	7.2 ± 0.5	221.6 ± 18.8
			166.5	3.32 ± 0.24	243.2 ± 25.8
			RR _{mean} =		255.4 ± 14.9
¹⁹⁰ Au _c	c	42.8M	597.7	9.4 ± 0.9	167.7 ± 19.2
			301.8	23.4 ± 1.5	197.3 ± 17.8
			295.8	71 ± 5	184.4 ± 14.6
			RR _{mean} =		185.1 ± 8.8
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	202.0 ± 24.7
			456.5	3.4 ± 0.4	177.7 ± 22.1
			409.4	8.0 ± 0.9	180.1 ± 21.3
			359.9	6.0 ± 0.7	181.9 ± 22.2
			351.2	3.4 ± 0.4	207.5 ± 25.6
			172.2	3.5 ± 0.4	178.7 ± 22.0
			129.4	3.2 ± 0.5	187.8 ± 31.7
			RR _{mean} =		186.3 ± 7.4
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	230.6 ± 23.7
			607.6	8.10 ± 0.16	212.2 ± 9.3
			568.8	7.1 ± 0.6	227.7 ± 24.3
			544.9	5.8 ± 0.5	223.3 ± 21.5
RR _{mean} =		215.2 ± 8.8			
¹⁸⁸ Pt	c	10.2D	1209.8	*	201.9 ± 21.5
			633.0	*	228.8 ± 38.9
			478.0	*	193.2 ± 10.3

Continuation of Table 91.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			423.3	4.4 ± 0.3	193.4 ± 14.8
			381.4	7.5 ± 0.5	189.5 ± 14.3
			195.1	18.6 ± 1.2	192.3 ± 14.5
			187.6	19.4 ± 1.2	195.1 ± 14.2
			155.1	*	204.6 ± 21.9
			140.4	2.33 ± 0.15	219.9 ± 18.9
			$RR_{mean} =$		194.7 ± 6.0
^{187}Pt	c	2.35H	106.4	8.8 ± 1.8	147.0 ± 33.1
^{186}Pt	c	2.08H	689.4	70 ± 15	170.8 ± 37.1
			630.3	*	119.4 ± 14.0
			$RR_{mean} =$		125.6 ± 3.9
^{184}Pt	c	17.3M	548.3	23 ± 4	144.2 ± 27.0
^{189}Ir	c	13.2D	275.9	0.54 ± 0.07	202.9 ± 28.4
$^{188}\text{Ir}_c$	c	41.5H	1209.8	6.9 ± 0.7	203.5 ± 21.7
			633.0	18 ± 3	242.6 ± 41.4
			478.0	14.7 ± 0.6	201.4 ± 10.8
			155.1	30 ± 3	212.9 ± 22.8
			$RR_{mean} =$		202.0 ± 7.0
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	192.5 ± 13.7
			400.8	3.94 ± 0.14	217.5 ± 18.2
			$RR_{mean} =$		201.2 ± 13.4
^{186}Ir	c	16.64H	773.3	8.9 ± 0.5	81.08 ± 5.79
			434.8	33.9 ± 1.1	85.98 ± 4.21
			296.9	62.3 ± 1.9	99.96 ± 7.62
			137.2	41.4 ± 0.7	93.94 ± 5.47
			$RR_{mean} =$		88.39 ± 4.32
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	137.1 ± 21.1
			1668.0	3.6 ± 0.6	129.2 ± 23.0
			254.2	13.3 ± 2.4	126.9 ± 23.9
			$RR_{mean} =$		134.3 ± 6.9
^{184}Ir	c*	3.09H	1105.3	5.3 ± 0.7	145.6 ± 21.4
			390.4	25.9 ± 2.4	152.2 ± 15.2
			264.0	68 ± 4	176.6 ± 12.8
			119.8	31 ± 3	193.2 ± 22.6
			$RR_{mean} =$		171.5 ± 8.9
^{183}Ir	c	57M	392.5	10.4 ± 2.4	164.8 ± 39.3
^{185}Os	c	93.6D	874.8	6.29 ± 0.25	196.4 ± 10.4
			717.4	3.94 ± 0.16	182.5 ± 9.8
			646.1	78 ± 3	182.2 ± 9.3
			592.1	1.32 ± 0.06	178.1 ± 11.8
			$RR_{mean} =$		185.1 ± 6.7
^{183m}Os	c*	9.9H	1107.9	22.4 ± 0.6	106.9 ± 5.4
			1101.9	49.0 ± 1.3	101.9 ± 4.8
			$RR_{mean} =$		103.8 ± 4.0
^{182}Os	c	22.10H	1221.5	*	195.9 ± 14.6
			1189.2	*	199.2 ± 15.4
			1121.4	*	193.0 ± 12.2
			180.2	33.5 ± 1.7	171.5 ± 11.1
			$RR_{mean} =$		183.5 ± 5.7
^{181}Os	c	105M	238.8	44 ± 5	56.81 ± 7.19

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	148.6 ± 7.4
			103.5(D)	25.0 ± 0.8	128.6 ± 12.4
			<i>RR_{mean}</i> =		144.6 ± 9.2
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	172.3 ± 12.1
			208.8	2.95 ± 0.09	175.1 ± 8.9
			162.3	23.3 ± 0.7	179.6 ± 8.7
			161.4	0.61 ± 0.14	223.6 ± 52.6
			109.7	2.87 ± 0.09	170.7 ± 15.0
			<i>RR_{mean}</i> =		176.6 ± 6.5
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	187.7 ± 14.1
			1189.2	15 ± 1	215.9 ± 16.6
			1121.4	31.8 ± 1.6	187.9 ± 11.8
			<i>RR_{mean}</i> =		192.7 ± 9.6
¹⁸¹ Re	c*	19.9H	953.6	3.6 ± 1.0	170.6 ± 48.2
			639.0	6.4 ± 1.4	162.6 ± 36.4
			365.5	56 ± 8	159.4 ± 23.6
			<i>RR_{mean}</i> =		161.4 ± 16.4
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	192.9 ± 15.6
			290.0	26.9 ± 2.3	154.8 ± 16.2
			<i>RR_{mean}</i> =		182.3 ± 18.0
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	190.2 ± 23.0
¹⁷⁸ W	c	21.6D	1340.8(D)	1.03 ± 0.09	129.1 ± 17.8
			1106.1(D)	0.54 ± 0.05	157.5 ± 18.4
			<i>RR_{mean}</i> =		145.2 ± 14.7
¹⁷⁷ W	c	135M	115.7	51 ± 5	115.0 ± 13.8
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	125.9 ± 29.7
¹⁷⁶ Ta	c*	8.09H	1823.7	4.5 ± 0.4	137.8 ± 14.8
			1584.0	5.3 ± 0.4	118.1 ± 11.0
			1555.1	4.0 ± 0.3	133.3 ± 15.1
			1159.3	24.7 ± 1.9	149.8 ± 12.8
			<i>RR_{mean}</i> =		137.1 ± 9.1
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	79.63 ± 13.19
			348.5	12.0 ± 1.1	109.4 ± 11.0
			266.9	10.52 ± 0.16	112.1 ± 5.8
			<i>RR_{mean}</i> =		108.6 ± 7.5
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	84.89 ± 7.84
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	97.86 ± 11.01
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	46.41 ± 5.09
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	100.3 ± 4.9
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	95.85 ± 5.80
			306.6	6.4 ± 0.3	92.49 ± 10.03
			297.0	33.9 ± 1.4	107.1 ± 8.8
			139.6	12.7 ± 0.6	116.2 ± 9.9
			123.7	83 ± 5	100.9 ± 8.9
			<i>RR_{mean}</i> =		99.88 ± 4.65
¹⁷² Hf	c	1.87Y	1093.6	*	68.64 ± 4.00
			929.1	*	70.49 ± 4.15
			900.7	*	68.52 ± 3.85
			181.5	*	69.18 ± 4.29
			125.8	11.3 ± 0.9	73.29 ± 7.59

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	69.70 ± 2.15
¹⁷⁰ Hf	c	16.01H	1280.2	*	49.37 ± 8.55
			620.7	18 ± 5	77.11 ± 21.67
			164.7	26 ± 8	68.56 ± 21.29
			120.2	15 ± 5	63.67 ± 21.69
				<i>RR_{mean}</i> =	52.90 ± 1.63
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	83.48 ± 4.48
			171.4	2.90 ± 0.15	88.90 ± 7.03
			100.7	5.24 ± 0.20	71.59 ± 7.78
				<i>RR_{mean}</i> =	83.14 ± 3.86
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	69.38 ± 4.05
			929.1	3.04 ± 0.14	79.29 ± 5.79
			900.7	29.8 ± 1.3	70.90 ± 3.98
			181.5	20.6 ± 1.0	69.33 ± 4.31
				<i>RR_{mean}</i> =	70.73 ± 2.61
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	73.90 ± 4.51
			839.9	3.04 ± 0.08	83.20 ± 4.28
			780.7	4.36 ± 0.11	76.19 ± 3.83
			739.8	47.8 ± 1.2	73.73 ± 3.12
			712.7	1.13 ± 0.03	71.08 ± 5.88
			667.4	11.0 ± 0.3	77.78 ± 3.46
				<i>RR_{mean}</i> =	75.99 ± 2.71
¹⁷⁰ Lu	c*	2.012D	2126.1	5.1 ± 0.3	75.69 ± 6.62
			1280.2	8.2 ± 0.4	78.38 ± 4.91
				<i>RR_{mean}</i> =	77.76 ± 3.55
¹⁶⁹ Lu	c	34.06H	1449.7	9.9 ± 0.3	38.94 ± 2.28
			960.6	23.4 ± 0.7	41.67 ± 2.05
				<i>RR_{mean}</i> =	40.63 ± 1.83
¹⁶⁷ Lu	c	51.5M	106.2	*	22.52 ± 6.85
			113.3	*	40.57 ± 3.71
				<i>RR_{mean}</i> =	36.81 ± 7.42
¹⁶⁹ Yb	c*	32.026D	307.7	10.05 ± 0.19	58.03 ± 2.37
			198.0	35.8 ± 0.7	54.75 ± 2.40
			177.2	22.2 ± 0.5	51.80 ± 2.32
			130.5	11.31 ± 0.21	55.70 ± 3.53
			109.8	17.5 ± 0.4	52.16 ± 4.05
				<i>RR_{mean}</i> =	55.15 ± 2.12
¹⁶⁶ Yb	c	56.7H	2079.5	*	32.58 ± 2.61
			2052.4	*	32.71 ± 2.32
			1374.2	*	32.70 ± 3.15
			1176.7	*	31.87 ± 2.38
			691.2(D)	8.56 ± 0.58	29.95 ± 2.48
				<i>RR_{mean}</i> =	31.92 ± 0.98
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	39.97 ± 7.77
¹⁶⁵ Tm	c	30.06H	242.9	35.5 ± 1.7	28.69 ± 1.90
¹⁶⁰ Er	c	28.58H	728.2(D)	34 ± 5	15.19 ± 2.35
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	7.267 ± 0.496
¹⁵⁵ Tb	c*	5.32D	105.3	25.1 ± 1.3	5.177 ± 0.531
¹⁴⁹ Gd	c	9.28D	346.6	23.9 ± 1.3	2.339 ± 0.277
			298.6	28.6 ± 1.7	2.340 ± 0.222

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			149.7	48 ± 3	3.970 ± 0.326
			<i>RR_{mean}</i> =		
¹⁴⁶ Gd	c	48.27D	747.2	*	1.560 ± 0.106
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	0.9859 ± 0.3827
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	2.546 ± 0.372
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	2.347 ± 0.110
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	3.556 ± 0.389
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	7.371 ± 0.596
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	5.936 ± 0.373
			202.9	68.3 ± 0.5	5.809 ± 0.242
			172.1	25.5 ± 0.8	6.222 ± 0.356
			<i>RR_{mean}</i> =		
¹²⁶ I	i	13.11D	388.6	34 ± 3	1.690 ± 0.232
¹²⁴ I	i	4.1760D	602.7	62.9 ± 0.6	4.230 ± 0.208
¹²¹ I	c*	2.12H	212.2	84.3 ± 0.3	10.07 ± 0.74
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.781 ± 0.175
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	3.991 ± 0.205
			573.1	88.6 ± 0.1	3.796 ± 0.209
			<i>RR_{mean}</i> =		
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	7.167 ± 0.338
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	3.350 ± 0.171
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	4.089 ± 0.171
			1023.3	99.4 ± 0.3	3.472 ± 0.174
			<i>RR_{mean}</i> =		
^{118m} Sb	i(m)	5.00H	1050.7	97 ± 5	5.040 ± 0.564
^{117m} Sn	i(m)	13.60D	158.6	86.4 ± 0.4	6.927 ± 0.284
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	4.554 ± 0.238
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	11.06 ± 0.54
¹¹¹ In	c	2.8047D	245.4	94 ± 1	6.799 ± 0.377
			171.3	90.2 ± 1.0	7.076 ± 0.331
			<i>RR_{mean}</i> =		
^{110m} Ag	i(m)	249.76D	1505.0	13.60 ± 0.19	10.32 ± 0.87
			937.5	34.2 ± 0.6	10.19 ± 0.48
			884.7	72.7 ± 0.4	10.61 ± 0.44
			657.8	94.3 ± 0.3	10.29 ± 0.37
			<i>RR_{mean}</i> =		
^{106m} Ag	i(m)	8.28D	717.3	28.9 ± 0.8	5.885 ± 0.358
			451.0	28.2 ± 0.8	5.724 ± 0.332
			406.2	13.4 ± 0.4	5.438 ± 0.595
			<i>RR_{mean}</i> =		
¹⁰⁵ Ag	c	41.29D	280.4	30.2 ± 1.8	4.766 ± 0.445
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.2871 ± 0.1612
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	39.26 ± 1.92
^{102m} Rh	i(m)	2.9Y	631.3	56 ± 2	9.092 ± 1.125
			1046.6	34 ± 2	7.320 ± 1.269
			475.1	95 ± 4	8.556 ± 1.609
			<i>RR_{mean}</i> =		
¹⁰² Rh	i	207D	475.1	46 ± 5	1.909 ± 0.915
^{101m} Rh	c	4.34D	306.9	81 ± 5	8.521 ± 0.654
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	4.692 ± 0.381

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	4.979 ± 0.317
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	33.38 ± 1.26
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	8.344 ± 0.449
			812.5	82 ± 4	8.379 ± 0.504
			<i>RR_{mean}</i> =		8.359 ± 0.381
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	28.19 ± 1.57
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	4.776 ± 0.490
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	20.06 ± 1.06
			849.9	20.45 ± 0.20	22.32 ± 1.45
			568.9	58.0 ± 0.3	20.61 ± 0.99
			<i>RR_{mean}</i> =		20.69 ± 0.84
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	25.96 ± 0.86
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	44.05 ± 1.45
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	1.819 ± 0.111
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	3.897 ± 0.354
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	5.092 ± 0.271
⁹⁵ Zr	c	64.02D	765.8	*	18.26 ± 0.63
			756.7	54.46 ± 0.10	17.92 ± 0.70
			724.2	44.17 ± 0.16	17.68 ± 0.69
			<i>RR_{mean}</i> =		18.05 ± 0.56
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	13.43 ± 0.46
⁸⁸ Zr	c	83.4D	1836.1	*	5.549 ± 0.746
			898.0	*	4.742 ± 0.327
			392.9	97.24 ± 0.00	5.518 ± 0.215
			<i>RR_{mean}</i> =		5.399 ± 0.167
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	23.82 ± 1.00
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	24.31 ± 1.06
			898.0	93.7 ± 0.3	23.26 ± 0.79
			<i>RR_{mean}</i> =		23.44 ± 0.82
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	29.86 ± 1.12
			898.0	93.7 ± 0.3	28.00 ± 0.93
			<i>RR_{mean}</i> =		28.43 ± 1.17
⁸⁷ Y	c*	79.8H	388.5	82.1 ± 0.5	19.40 ± 0.68
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	18.90 ± 1.03
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	30.19 ± 1.19
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	21.69 ± 1.71
			529.6	29.3 ± 2.1	22.13 ± 1.78
			520.4	45 ± 4	21.83 ± 2.09
			<i>RR_{mean}</i> =		21.88 ± 0.97
^{82m} Rb	i(m)	6.472H	1474.9	15.5 ± 0.3	14.29 ± 7.15
			554.3	62.4 ± 0.9	7.491 ± 1.165
			<i>RR_{mean}</i> =		7.661 ± 1.152
⁸² Br	i(m+g)	35.30H	1474.9	16.32 ± 0.23	15.86 ± 0.93
			698.4	28.5 ± 0.4	15.57 ± 0.81
			554.3	70.8 ± 1.0	15.33 ± 0.62
			<i>RR_{mean}</i> =		15.46 ± 0.56
⁷⁵ Se	c	119.779D	400.7	11.47 ± 0.09	9.916 ± 0.879
			264.7	58.9 ± 0.4	7.583 ± 0.333
			136.0	58.3 ± 0.8	8.372 ± 0.483
			<i>RR_{mean}</i> =		7.906 ± 0.489

Continuation of Table 91.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁷⁶ As	i	1.0778D	559.1	45 ± 2	13.93 ± 1.01
⁷⁴ As	i	17.77D	595.8	59 ± 4	11.92 ± 0.91
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	9.219 ± 0.580
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	11.20 ± 0.60
⁷² Zn	c	46.5H	2201.7	*	1.982 ± 0.146
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	4.904 ± 0.301
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	1.778 ± 0.206
⁴⁸ Sc	i	43.67H	1037.5	97.6 ± 0.7	1.374 ± 0.136
⁴⁶ Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	1.420 ± 0.125
			889.3	99.98 ± 0.00	1.305 ± 0.210
			<i>RR_{mean}</i> =		1.392 ± 0.111
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	8.730 ± 0.837

12.8.6 Nuclide production rates for ^{27}Al

Table 92: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 0.8 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	32.26 ± 1.17
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.821 ± 0.138
			1014.4	28.0 ± 0.4	3.614 ± 0.273
$RR_{mean} = \mathbf{2.944 \pm 0.302}$					
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	79.81 ± 2.75
^{24}Na	c	14.9590H	1369.0	100 ± 0	67.79 ± 2.25
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.870 ± 0.099
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	29.70 ± 1.08
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.786 ± 0.162
			1014.4	28.0 ± 0.4	3.023 ± 0.296
$RR_{mean} = \mathbf{2.832 \pm 0.151}$					
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	72.50 ± 2.49
^{24}Na	c	14.9590H	1369.0	100 ± 0	62.69 ± 2.09
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.179 ± 0.073
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	30.39 ± 1.11
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	2.700 ± 0.129
			1014.4	28.0 ± 0.4	2.809 ± 0.202
$RR_{mean} = \mathbf{2.725 \pm 0.121}$					
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	73.29 ± 2.53
^{24}Na	c	14.9590H	1369.0	100 ± 0	64.20 ± 2.14
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.324 ± 0.080
^{27}Al -monitor for ^{nat}Pb					

Continuation of Table 92.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^7Be	i	53.29D	477.6	10.52 ± 0.06	28.85 ± 1.05
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	3.583 ± 0.163
			1014.4	28.0 ± 0.4	3.510 ± 0.254
$RR_{mean} =$					3.568 ± 0.153
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	71.00 ± 2.46
^{24}Na	c	14.9590H	1369.0	100 ± 0	60.22 ± 2.01
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.133 ± 0.072
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	27.28 ± 1.04
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	3.882 ± 0.183
			1014.4	28.0 ± 0.4	4.302 ± 0.303
$RR_{mean} =$					3.968 ± 0.209
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	67.25 ± 2.28
^{24}Na	c	14.9590H	1369.0	100 ± 0	59.57 ± 1.99
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.177 ± 0.073

12.9 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 1.2$ GeV

12.9.1 Nuclide production rates for ^{206}Pb

Table 93: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 1.2$ GeV, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	8.497 ± 0.531
			803.1	98.9 ± 1.4	8.882 ± 0.384
			537.5	30.5 ± 0.5	8.472 ± 0.491
			$RR_{mean} =$		8.710 ± 0.337
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	20.79 ± 1.52
			1764.3	32.5 ± 0.7	24.30 ± 1.10
			$RR_{mean} =$		23.42 ± 1.69
^{204}Bi	i	11.22H	984.0	59 ± 4	30.76 ± 2.80
			899.2	98 ± 9	26.83 ± 1.25
			374.8	82 ± 5	27.02 ± 5.67
			$RR_{mean} =$		27.26 ± 0.84
^{203}Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	32.69 ± 2.29
^{202}Bi	i	1.72H	422.1	83.7 ± 2.5	42.49 ± 3.34
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	80.17 ± 4.52
			374.7	89 ± 15	85.94 ± 14.92
			$RR_{mean} =$		80.53 ± 4.42
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	84.19 ± 4.58
			374.7	89 ± 15	89.33 ± 15.50
			$RR_{mean} =$		84.49 ± 4.50
^{203}Pb	c*	51.873H	279.2	80.8 ± 0.2	274.6 ± 10.0
^{202m}Pb	i(m)	3.53H	422.1	86 ± 5	58.82 ± 4.47
^{201}Pb	c*	9.33H	331.2	79 ± 5	209.2 ± 15.1
^{200}Pb	c	21.5H	1205.7	*	152.6 ± 10.6
			367.9	*	140.7 ± 5.0
			257.2	4.46 ± 0.17	150.7 ± 13.9
			147.6	37.7 ± 1.4	159.4 ± 8.8
			$RR_{mean} =$		143.7 ± 4.4
^{199}Pb	c*	90M	366.9	44 ± 7	289.1 ± 47.8
^{198}Pb	c	2.4H	173.4	18 ± 3	206.3 ± 35.7
^{197m}Pb	c*	43M	385.9	74 ± 15	128.3 ± 26.5
^{195m}Pb	i(m)	15.0M	383.6	107 ± 20	60.84 ± 11.71
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	128.8 ± 4.6
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	358.9 ± 13.3
$^{200}\text{Tl}_i$	i	26.1H	1205.7	29.9 ± 1.8	151.1 ± 11.1
			579.3	13.8 ± 0.7	174.6 ± 13.5
			367.9	87.2 ± 0.4	150.3 ± 6.2
			$RR_{mean} =$		152.4 ± 6.7
$^{200}\text{Tl}_c$	c	26.1H	1205.7	29.9 ± 1.8	303.7 ± 21.0
			579.3	13.8 ± 0.7	307.2 ± 19.5
			367.9	87.2 ± 0.4	290.9 ± 10.1
			$RR_{mean} =$		292.6 ± 10.0
$^{199}\text{Tl}_c$	c	7.42H	455.5	12.4 ± 1.4	263.3 ± 31.7

Continuation of Table 93.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	305.0 ± 36.4
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	129.4 ± 15.4
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	218.8 ± 38.3
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	12.99 ± 0.53
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	58.09 ± 2.77
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	89.99 ± 12.32
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	122.5 ± 18.6
			407.6	32 ± 6	78.11 ± 14.99
			<i>RR_{mean}</i> =		95.75 ± 21.93
¹⁹² Hg	c	4.85H	316.5	*	263.0 ± 33.1
			274.8	50.2 ± 2.5	221.7 ± 14.1
			<i>RR_{mean}</i> =		227.0 ± 7.0
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	164.8 ± 25.3
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	2.940 ± 0.300
			411.8	*	2.201 ± 0.225
			<i>RR_{mean}</i> =		2.467 ± 0.076
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	8.150 ± 0.514
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	10.35 ± 0.42
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	18.14 ± 0.65
			426.1	6.6 ± 0.8	17.77 ± 2.37
			333.0	22.9 ± 0.6	19.71 ± 0.93
			<i>RR_{mean}</i> =		18.36 ± 0.69
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	234.0 ± 23.1
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	34.35 ± 3.07
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	61.18 ± 8.59
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	324.2 ± 40.7
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	323.7 ± 31.7
¹⁹⁰ Au _c	c	42.8M	597.7	9.4 ± 0.9	168.1 ± 23.5
			301.8	23.4 ± 1.5	233.8 ± 18.8
			295.8	71 ± 5	242.3 ± 20.0
			<i>RR_{mean}</i> =		228.0 ± 18.5
			<i>RR_{mean}</i> =		236.1 ± 18.3
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	281.5 ± 34.4
			456.5	3.4 ± 0.4	224.2 ± 27.6
			409.4	8.0 ± 0.9	223.3 ± 26.3
			<i>RR_{mean}</i> =		236.1 ± 18.3
			<i>RR_{mean}</i> =		236.1 ± 18.3
¹⁸⁹ Pt	c	10.87H	544.9	5.8 ± 0.5	282.2 ± 29.0
			721.4	9.3 ± 0.8	283.9 ± 27.2
			607.6	8.10 ± 0.16	272.8 ± 12.6
			568.8	7.1 ± 0.6	292.3 ± 29.2
			243.5	7.0 ± 1.2	322.6 ± 60.5
			<i>RR_{mean}</i> =		277.0 ± 11.6
¹⁸⁸ Pt	c	10.2D	1209.8	*	254.5 ± 27.3
			478.0	*	269.4 ± 14.4
			423.3	4.4 ± 0.3	249.2 ± 19.2
			381.4	7.5 ± 0.5	241.4 ± 18.1
			195.1	18.6 ± 1.2	251.6 ± 18.8
			187.6	19.4 ± 1.2	249.8 ± 18.1
			<i>RR_{mean}</i> =		258.2 ± 8.0
			<i>RR_{mean}</i> =		258.2 ± 8.0
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	206.8 ± 45.0
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	203.4 ± 37.2

Continuation of Table 93.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{192}Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.7425 ± 0.1006
^{190}Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.734 ± 0.226
			569.3	28.5 ± 1.3	2.636 ± 0.309
			$RR_{mean} =$		2.704 ± 0.180
^{189}Ir	c	13.2D	245.1	6.0 ± 0.6	221.9 ± 24.2
$^{188}\text{Ir}_i$	i	41.5H	478.0	14.7 ± 0.6	20.95 ± 4.39
$^{188}\text{Ir}_c$	c	41.5H	1209.8	6.9 ± 0.7	262.3 ± 28.2
			478.0	14.7 ± 0.6	290.4 ± 15.9
			$RR_{mean} =$		289.0 ± 10.8
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	247.3 ± 21.6
^{186}Ir	c	16.64H	434.8	33.9 ± 1.1	116.5 ± 5.8
			137.2	41.4 ± 0.7	128.4 ± 6.3
			$RR_{mean} =$		121.8 ± 7.0
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	196.9 ± 30.4
			254.2	13.3 ± 2.4	177.9 ± 33.1
			$RR_{mean} =$		193.4 ± 10.6
^{184}Ir	c*	3.09H	264.0	68 ± 4	231.1 ± 16.8
			390.4	25.9 ± 2.4	246.8 ± 24.7
			119.8	31 ± 3	263.7 ± 29.6
			$RR_{mean} =$		235.5 ± 9.9
^{185}Os	c	93.6D	646.1	78 ± 3	252.1 ± 12.9
			874.8	6.29 ± 0.25	265.6 ± 13.9
			717.4	3.94 ± 0.16	258.6 ± 14.4
			$RR_{mean} =$		256.8 ± 8.9
^{183m}Os	c*	9.9H	1101.9	49.0 ± 1.3	146.4 ± 6.5
			1107.9	22.4 ± 0.6	155.7 ± 7.4
			$RR_{mean} =$		149.6 ± 6.4
^{182}Os	c	22.10H	263.3	6.71 ± 0.25	253.6 ± 15.5
			180.2	33.5 ± 1.7	250.9 ± 16.3
			$RR_{mean} =$		252.4 ± 12.0
^{180}Os	c	21.5M	902.8(D)	101.5 ± 3.4	217.9 ± 11.2
^{183}Re	c	70.0D	162.3	23.3 ± 0.7	270.4 ± 12.7
			291.7	3.05 ± 0.18	250.2 ± 17.7
			$RR_{mean} =$		266.3 ± 11.6
$^{182m}\text{Re}_c$	c	12.7H	1221.5	24.8 ± 1.6	277.9 ± 20.6
			1189.2	15 ± 1	273.9 ± 23.2
			$RR_{mean} =$		276.3 ± 14.4
^{181}Re	c*	19.9H	365.5	56 ± 8	219.6 ± 32.4
			639.0	6.4 ± 1.4	257.4 ± 57.2
			$RR_{mean} =$		227.1 ± 24.5
^{179}Re	c*	19.5M	430.2	28.0 ± 1.8	335.3 ± 25.8
			290.0	26.9 ± 2.3	280.5 ± 27.3
			$RR_{mean} =$		323.9 ± 24.4
^{178}Re	c*	13.2M	237.3	45 ± 5	342.5 ± 41.1
^{178}W	c	21.6D	1350.6(D)	1.18 ± 0.11	217.2 ± 24.2
			1340.8(D)	1.03 ± 0.09	175.2 ± 23.9
			$RR_{mean} =$		200.6 ± 21.4
^{177}W	c	135M	115.7	51 ± 5	223.6 ± 24.8
^{176}W	c	2.5H	1159.3	*	186.5 ± 38.1
			1823.7	*	243.6 ± 114.0

Continuation of Table 93.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			710.5	*	181.8 ± 129.5
			<i>RR_{mean}</i> =		190.9 ± 32.9
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	241.0 ± 54.8
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	247.0 ± 23.9
			1823.7	4.5 ± 0.4	206.2 ± 44.6
			710.5	5.4 ± 0.4	240.5 ± 53.7
			<i>RR_{mean}</i> =		243.0 ± 14.4
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	193.8 ± 31.6
			348.5	12.0 ± 1.1	279.4 ± 27.6
			266.9	10.52 ± 0.16	234.4 ± 10.3
			<i>RR_{mean}</i> =		235.4 ± 12.5
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	233.3 ± 21.5
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	239.9 ± 26.7
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	119.1 ± 12.3
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	232.4 ± 11.4
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	283.0 ± 21.3
			311.2	10.7 ± 0.5	269.9 ± 15.9
			139.6	12.7 ± 0.6	286.6 ± 18.2
			<i>RR_{mean}</i> =		277.3 ± 10.9
¹⁷² Hf	c	1.87Y	1093.6	*	200.0 ± 11.6
			1002.7(D)	5.55 ± 0.38	176.9 ± 18.8
			181.5	*	194.0 ± 12.2
			125.8	11.3 ± 0.9	199.9 ± 18.9
			<i>RR_{mean}</i> =		195.8 ± 6.0
¹⁷¹ Hf	c	12.1H	739.8	*	214.3 ± 15.5
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	262.1 ± 73.4
			164.7	26 ± 8	253.4 ± 78.5
			120.2	15 ± 5	250.5 ± 84.6
			<i>RR_{mean}</i> =		259.3 ± 18.3
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	225.7 ± 12.1
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.9509 ± 0.1307
			181.5	20.6 ± 1.0	2.936 ± 0.732
			<i>RR_{mean}</i> =		1.006 ± 0.329
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	200.9 ± 11.7
			181.5	20.6 ± 1.0	197.0 ± 12.3
			<i>RR_{mean}</i> =		199.4 ± 7.6
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	219.9 ± 9.1
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	235.1 ± 10.5
			780.7	4.36 ± 0.11	250.3 ± 10.8
			667.4	11.0 ± 0.3	236.2 ± 10.3
			<i>RR_{mean}</i> =		240.7 ± 8.9
¹⁷⁰ Lu _c	c	2.012D	1280.2	8.2 ± 0.4	191.8 ± 14.5
			2126.1	5.1 ± 0.3	174.1 ± 16.8
			1054.3	4.76 ± 0.24	167.6 ± 16.2
			985.1	5.5 ± 0.3	201.9 ± 21.6
			<i>RR_{mean}</i> =		183.1 ± 9.1
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	164.3 ± 7.5
			191.2	20.6 ± 0.6	176.7 ± 8.6
			<i>RR_{mean}</i> =		169.1 ± 8.0
¹⁶⁷ Lu	c	51.5M	176.2	*	151.8 ± 9.5

Continuation of Table 93.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			113.3	*	181.6 ± 14.0
			<i>RR_{mean}</i> =		160.4 ± 14.4
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	195.1 ± 8.5
			177.2	22.2 ± 0.5	196.3 ± 8.5
			130.5	11.31 ± 0.21	199.0 ± 9.3
			<i>RR_{mean}</i> =		196.6 ± 6.8
¹⁶⁶ Yb	c	56.7H	2079.5	*	166.8 ± 12.7
			2052.4	*	180.3 ± 12.8
			1867.9	*	173.7 ± 12.7
			1374.2	*	171.7 ± 14.1
			1176.7	*	164.8 ± 11.9
			785.9	*	172.0 ± 12.2
			705.3	*	155.7 ± 11.2
			691.2(D)	8.56 ± 0.58	147.5 ± 11.4
			<i>RR_{mean}</i> =		165.6 ± 5.1
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	190.1 ± 36.9
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	156.5 ± 11.7
			242.9	35.5 ± 1.7	163.3 ± 10.1
			<i>RR_{mean}</i> =		161.3 ± 6.7
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	161.4 ± 11.7
¹⁶⁰ Er	c	28.58H	966.2	*	124.5 ± 16.8
			962.4	*	123.3 ± 16.2
			872.0(D)	6.8 ± 1.1	111.8 ± 18.8
			728.2(D)	34 ± 5	131.2 ± 19.8
			<i>RR_{mean}</i> =		122.6 ± 3.8
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	133.3 ± 17.3
			132.0	*	151.9 ± 11.8
			<i>RR_{mean}</i> =		146.5 ± 4.5
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	130.1 ± 18.5
			962.4	16.6 ± 2.1	128.9 ± 19.5
			<i>RR_{mean}</i> =		129.6 ± 13.0
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	97.26 ± 4.89
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	92.27 ± 5.21
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	72.88 ± 3.45
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	33.96 ± 1.85
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	64.84 ± 5.24
			105.3	25.1 ± 1.3	75.56 ± 5.47
			<i>RR_{mean}</i> =		70.93 ± 5.74
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	53.60 ± 3.96
¹⁵² Tb	c*	17.5H	344.3	65 ± 4	51.29 ± 3.72
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	35.42 ± 2.63
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	51.24 ± 3.28
			97.4	29.0 ± 0.8	49.88 ± 3.08
			<i>RR_{mean}</i> =		50.50 ± 2.39
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	38.31 ± 3.60
¹⁴⁹ Gd	c	9.28D	149.7	48 ± 3	48.15 ± 3.55
			788.9	7.3 ± 0.4	53.32 ± 3.74
			346.6	23.9 ± 1.3	42.91 ± 2.80
			298.6	28.6 ± 1.7	43.51 ± 3.05
			<i>RR_{mean}</i> =		45.31 ± 2.59

Continuation of Table 93.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	36.14 ± 2.77
			396.0	34.3 ± 2.1	33.39 ± 2.38
			$RR_{mean} =$		34.48 ± 1.71
¹⁴⁶ Gd	c	48.27D	747.2	*	32.90 ± 1.48
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	60.79 ± 3.47
¹⁴⁷ Eu	c*	24.1D	677.5	9.8 ± 0.5	40.32 ± 2.72
			955.8	3.84 ± 0.20	40.83 ± 2.96
			798.7	4.8 ± 0.3	47.51 ± 4.13
			601.5	5.9 ± 0.3	40.66 ± 2.82
			121.2	22.9 ± 1.3	37.09 ± 2.74
			$RR_{mean} =$		40.34 ± 1.76
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	4.319 ± 0.236
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	37.22 ± 1.67
¹⁴⁵ Eu	c	5.93D	1658.5	14.9 ± 1.0	21.95 ± 1.84
			653.5	15 ± 1	24.51 ± 1.89
			$RR_{mean} =$		23.26 ± 1.47
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	21.00 ± 1.56
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.02	15.10 ± 0.56
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	8.262 ± 0.599
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	4.821 ± 0.624
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	9.237 ± 0.564
			202.9	68.3 ± 0.5	9.046 ± 0.371
			$RR_{mean} =$		9.083 ± 0.351
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.785 ± 0.177
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	3.346 ± 0.306
			573.1	88.6 ± 0.1	3.406 ± 0.318
			$RR_{mean} =$		3.375 ± 0.104
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	10.40 ± 0.51
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	4.005 ± 0.198
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	2.872 ± 0.164
			1023.3	99.4 ± 0.3	2.464 ± 0.115
			$RR_{mean} =$		2.579 ± 0.200
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	7.575 ± 0.369
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	11.21 ± 0.72
¹¹¹ In	c	2.8047D	171.3	90.2 ± 1.0	9.909 ± 0.418
			245.4	94 ± 1	9.993 ± 0.462
			171.3	90.2 ± 1.0	9.886 ± 0.422
			$RR_{mean} =$		9.922 ± 0.347
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	7.345 ± 0.363
			657.8	94.3 ± 0.3	7.612 ± 0.322
			$RR_{mean} =$		7.512 ± 0.289
^{106m} Ag	i(m)	8.28D	451.0	28.2 ± 0.8	8.422 ± 0.471
			1045.8	29.6 ± 1.0	9.101 ± 0.821
			717.3	28.9 ± 0.8	7.702 ± 0.460
			$RR_{mean} =$		8.181 ± 0.419
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	9.837 ± 1.067
			280.4	30.2 ± 1.8	8.866 ± 0.699
			$RR_{mean} =$		9.137 ± 0.605
¹⁰⁰ Pd	c	3.63D	2376.0	*	1.301 ± 0.150
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	33.37 ± 1.85

Continuation of Table 93.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁰² Rh	i	207D	475.1	46 ± 5	7.096 ± 0.922
^{101m} Rh	c	4.34D	306.9	81 ± 5	12.75 ± 0.95
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	7.206 ± 0.480
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	8.506 ± 0.480
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	23.81 ± 0.95
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	11.53 ± 0.61
			812.5	82 ± 4	11.92 ± 0.72
			<i>RR_{mean}</i> =		11.68 ± 0.53
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	21.02 ± 0.93
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	16.81 ± 1.08
			568.9	58.0 ± 0.3	14.44 ± 0.90
			<i>RR_{mean}</i> =		15.40 ± 1.26
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	23.23 ± 0.81
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	35.56 ± 1.21
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	6.745 ± 0.571
			1129.2	92.7 ± 0.5	7.718 ± 0.485
			<i>RR_{mean}</i> =		7.342 ± 0.525
⁹⁵ Zr	c	64.02D	765.8	*	12.45 ± 0.64
			756.7	54.46 ± 0.10	11.99 ± 0.56
			<i>RR_{mean}</i> =		12.18 ± 0.38
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	21.01 ± 0.70
⁸⁸ Zr	c	83.4D	1836.1	*	12.05 ± 1.34
			898.0	*	9.530 ± 0.390
			392.9	97.24 ± 0.00	10.13 ± 0.37
			<i>RR_{mean}</i> =		10.05 ± 0.31
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	27.80 ± 1.29
			898.0	93.7 ± 0.3	27.44 ± 0.91
			<i>RR_{mean}</i> =		27.48 ± 0.90
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	39.86 ± 1.59
			898.0	93.7 ± 0.3	36.97 ± 1.22
			<i>RR_{mean}</i> =		37.41 ± 1.55
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	28.77 ± 1.02
⁸⁶ Y _c	c	14.74H	1076.6	82.5 ± 0.4	12.02 ± 0.71
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	28.48 ± 1.73
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	33.61 ± 2.72
			529.6	29.3 ± 2.1	30.99 ± 2.74
			520.4	45 ± 4	32.26 ± 3.09
			<i>RR_{mean}</i> =		32.40 ± 1.52
^{82m} Rb	i(m)	6.472H	776.5	84.39 ± 0.21	13.51 ± 1.23
			554.3	62.4 ± 0.9	16.36 ± 1.68
			<i>RR_{mean}</i> =		14.48 ± 1.43
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	13.01 ± 0.61
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	13.38 ± 0.53
			136.0	58.3 ± 0.8	14.74 ± 0.65
			121.1	17.2 ± 0.4	15.02 ± 1.31
			<i>RR_{mean}</i> =		13.90 ± 0.64
⁷⁴ As	i	17.77D	595.8	59 ± 4	17.56 ± 1.35
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	2.400 ± 0.153
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	7.121 ± 0.997
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	10.05 ± 0.98

Continuation of Table 93.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁷² Zn	c	46.5H	2201.7	*	2.926 ± 0.248
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	7.479 ± 0.455
			1099.2	56.5 ± 1.9	8.137 ± 0.431
			<i>RR_{mean}</i> =		7.857 ± 0.406
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	5.066 ± 0.515
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	0.6186 ± 0.0678
			983.5	100.0 ± 0.3	0.6929 ± 0.1627
			<i>RR_{mean}</i> =		0.6290 ± 0.0634
⁴⁸ Sc	i	43.67H	1037.5	97.6 ± 0.7	2.940 ± 0.207
⁴⁶ Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	4.021 ± 0.210
			1120.6	99.99 ± 0.00	3.914 ± 0.291
			<i>RR_{mean}</i> =		3.990 ± 0.188
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	17.54 ± 1.83

12.9.2 Nuclide production rates for ²⁰⁷Pb

Table 94: Detailed calculation of nuclide production rates for ²⁰⁷Pb for $E_p = 1.2$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	16.57 ± 0.75
			803.1	98.9 ± 1.4	15.79 ± 0.60
			537.5	30.5 ± 0.5	14.91 ± 0.82
			<i>RR_{mean}</i> =		15.83 ± 0.61
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	26.32 ± 2.05
			1764.3	32.5 ± 0.7	26.57 ± 1.35
			<i>RR_{mean}</i> =		26.51 ± 1.24
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	29.49 ± 2.43
			899.2	98 ± 9	25.64 ± 1.00
			374.8	82 ± 5	26.05 ± 5.48
			<i>RR_{mean}</i> =		25.91 ± 0.80
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	23.84 ± 2.69
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	25.97 ± 3.49
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	65.33 ± 3.08
			374.7	89 ± 15	77.81 ± 13.50
			<i>RR_{mean}</i> =		65.70 ± 3.06
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	69.17 ± 3.15
			374.7	89 ± 15	81.08 ± 14.06
			<i>RR_{mean}</i> =		69.50 ± 3.13
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	201.6 ± 7.4
^{202m} Pb	i(m)	3.53H	422.1	86 ± 5	58.60 ± 4.88
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	157.4 ± 11.4
²⁰⁰ Pb	c	21.5H	1205.7	*	121.0 ± 8.4
			367.9	*	106.3 ± 3.9
			257.2	4.46 ± 0.17	136.8 ± 12.3
			147.6	37.7 ± 1.4	115.6 ± 6.7
			<i>RR_{mean}</i> =		109.4 ± 3.4
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	212.5 ± 35.0

Continuation of Table 94.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	149.6 ± 25.8
^{197m} Pb	c*	43M	385.9	74 ± 15	95.07 ± 19.67
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	45.31 ± 8.74
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	104.9 ± 3.8
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	287.4 ± 10.6
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	122.2 ± 8.6
			579.3	13.8 ± 0.7	150.8 ± 11.2
			367.9	87.2 ± 0.4	124.2 ± 5.9
			<i>RR_{mean}</i> =		127.2 ± 7.5
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	243.2 ± 16.7
			579.3	13.8 ± 0.7	245.0 ± 15.4
			367.9	87.2 ± 0.4	230.5 ± 8.3
			<i>RR_{mean}</i> =		232.4 ± 8.1
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	233.3 ± 28.3
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	244.3 ± 29.2
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	137.4 ± 16.6
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	186.5 ± 32.5
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	18.39 ± 0.70
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	52.42 ± 2.68
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	80.14 ± 10.95
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	98.11 ± 14.85
			407.6	32 ± 6	69.19 ± 13.21
			<i>RR_{mean}</i> =		82.09 ± 14.60
¹⁹² Hg	c	4.85H	316.5	*	216.0 ± 27.4
			274.8	50.2 ± 2.5	184.6 ± 11.9
			<i>RR_{mean}</i> =		188.8 ± 5.8
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	134.7 ± 20.7
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	3.422 ± 0.312
			411.8	*	2.716 ± 0.114
			<i>RR_{mean}</i> =		2.761 ± 0.085
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	9.049 ± 0.330
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	11.77 ± 0.40
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	18.94 ± 0.67
			426.1	6.6 ± 0.8	17.83 ± 2.40
			333.0	22.9 ± 0.6	20.02 ± 0.92
			<i>RR_{mean}</i> =		19.10 ± 0.66
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	263.2 ± 26.6
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	33.91 ± 3.02
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	50.19 ± 7.68
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	266.2 ± 33.5
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	266.4 ± 25.4
¹⁹⁰ Au _c	c	42.8M	597.7	9.4 ± 0.9	165.2 ± 22.2
			301.8	23.4 ± 1.5	211.7 ± 16.7
			295.8	71 ± 5	217.7 ± 17.8
			<i>RR_{mean}</i> =		208.3 ± 13.2
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	242.2 ± 29.6
			456.5	3.4 ± 0.4	182.0 ± 22.7
			409.4	8.0 ± 0.9	190.1 ± 22.4
			<i>RR_{mean}</i> =		198.5 ± 17.3
¹⁸⁹ Pt	c	10.87H	544.9	5.8 ± 0.5	231.7 ± 23.6

Continuation of Table 94.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			721.4	9.3 ± 0.8	245.6 ± 23.1
			607.6	8.10 ± 0.16	231.8 ± 11.4
			568.8	7.1 ± 0.6	225.7 ± 22.1
			243.5	7.0 ± 1.2	248.5 ± 51.9
			$RR_{mean} =$		232.9 ± 10.1
^{188}Pt	c	10.2D	1209.8	*	217.6 ± 23.3
			478.0	*	228.2 ± 12.2
			423.3	4.4 ± 0.3	216.1 ± 16.7
			381.4	7.5 ± 0.5	204.1 ± 15.3
			195.1	18.6 ± 1.2	213.3 ± 16.0
			187.6	19.4 ± 1.2	212.6 ± 15.4
			$RR_{mean} =$		219.5 ± 6.8
^{186}Pt	c	2.08H	689.4	70 ± 15	175.4 ± 38.1
^{184}Pt	c	17.3M	548.3	23 ± 4	142.5 ± 28.3
^{192}Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.8643 ± 0.0873
^{190}Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.709 ± 0.283
			569.3	28.5 ± 1.3	2.123 ± 0.332
			$RR_{mean} =$		2.477 ± 0.297
^{189}Ir	c	13.2D	245.1	6.0 ± 0.6	202.1 ± 21.8
$^{188}\text{Ir}_i$	i	41.5H	478.0	14.7 ± 0.6	16.72 ± 1.64
$^{188}\text{Ir}_c$	c	41.5H	1209.8	6.9 ± 0.7	230.0 ± 24.7
			478.0	14.7 ± 0.6	244.9 ± 13.1
			$RR_{mean} =$		244.5 ± 8.4
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	226.5 ± 18.0
^{186}Ir	c	16.64H	434.8	33.9 ± 1.1	103.0 ± 5.4
			137.2	41.4 ± 0.7	106.1 ± 6.5
			$RR_{mean} =$		104.2 ± 4.7
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	159.0 ± 24.6
			254.2	13.3 ± 2.4	156.3 ± 29.1
			$RR_{mean} =$		158.6 ± 8.9
^{184}Ir	c*	3.09H	264.0	68 ± 4	204.8 ± 14.6
			390.4	25.9 ± 2.4	197.0 ± 19.7
			119.8	31 ± 3	221.0 ± 24.1
			$RR_{mean} =$		205.1 ± 8.3
^{185}Os	c	93.6D	646.1	78 ± 3	217.9 ± 11.1
			874.8	6.29 ± 0.25	226.2 ± 12.4
			717.4	3.94 ± 0.16	215.8 ± 12.0
			$RR_{mean} =$		219.1 ± 7.2
^{183m}Os	c*	9.9H	1101.9	49.0 ± 1.3	126.2 ± 5.5
			1107.9	22.4 ± 0.6	136.5 ± 6.6
			$RR_{mean} =$		128.9 ± 6.0
^{182}Os	c	22.10H	263.3	6.71 ± 0.25	205.8 ± 13.1
			180.2	33.5 ± 1.7	217.3 ± 14.3
			$RR_{mean} =$		211.0 ± 10.3
^{180}Os	c	21.5M	902.8(D)	101.5 ± 3.4	185.2 ± 11.0
^{183}Re	c	70.0D	162.3	23.3 ± 0.7	229.4 ± 11.0
			291.7	3.05 ± 0.18	220.0 ± 16.9
			$RR_{mean} =$		227.7 ± 9.4
$^{182m}\text{Re}_c$	c	12.7H	1221.5	24.8 ± 1.6	232.6 ± 17.3
			1189.2	15 ± 1	225.9 ± 19.4

Continuation of Table 94.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	229.9 ± 12.1
¹⁸¹ Re	c*	19.9H	365.5	56 ± 8	191.3 ± 28.6
			639.0	6.4 ± 1.4	218.4 ± 48.8
				<i>RR_{mean}</i> =	197.1 ± 21.6
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	288.8 ± 25.0
			290.0	26.9 ± 2.3	264.5 ± 25.5
				<i>RR_{mean}</i> =	279.0 ± 14.7
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	280.3 ± 33.7
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	177.9 ± 19.9
			1340.8(D)	1.03 ± 0.09	170.9 ± 22.6
				<i>RR_{mean}</i> =	175.5 ± 11.2
¹⁷⁷ W	c	135M	115.7	51 ± 5	195.2 ± 21.4
¹⁷⁶ W	c	2.5H	1159.3	*	189.3 ± 25.9
			1823.7	*	201.8 ± 51.7
			710.5	*	146.4 ± 43.6
				<i>RR_{mean}</i> =	183.4 ± 18.4
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	214.8 ± 48.9
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	201.0 ± 18.2
			1823.7	4.5 ± 0.4	185.9 ± 23.8
			710.5	5.4 ± 0.4	230.0 ± 23.7
				<i>RR_{mean}</i> =	205.1 ± 11.7
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	163.4 ± 26.1
			348.5	12.0 ± 1.1	227.2 ± 22.4
			266.9	10.52 ± 0.16	198.5 ± 8.7
				<i>RR_{mean}</i> =	198.8 ± 9.8
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	192.9 ± 17.7
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	210.1 ± 23.2
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	102.6 ± 10.5
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	196.1 ± 9.7
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	237.8 ± 17.9
			311.2	10.7 ± 0.5	230.0 ± 13.6
			139.6	12.7 ± 0.6	229.1 ± 15.3
				<i>RR_{mean}</i> =	231.1 ± 9.2
¹⁷² Hf	c	1.87Y	1093.6	*	170.8 ± 10.0
			1002.7(D)	5.55 ± 0.38	163.4 ± 16.2
			181.5	*	166.6 ± 10.4
			125.8	11.3 ± 0.9	163.5 ± 15.6
				<i>RR_{mean}</i> =	167.6 ± 5.2
¹⁷¹ Hf	c	12.1H	739.8	*	167.2 ± 14.2
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	221.7 ± 62.1
			164.7	26 ± 8	212.8 ± 65.9
			120.2	15 ± 5	211.5 ± 71.5
				<i>RR_{mean}</i> =	219.0 ± 15.5
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	184.5 ± 9.9
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.8738 ± 0.1482
			181.5	20.6 ± 1.0	2.088 ± 0.515
				<i>RR_{mean}</i> =	0.9624 ± 0.3172
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	171.7 ± 10.1
			181.5	20.6 ± 1.0	168.7 ± 10.6
				<i>RR_{mean}</i> =	170.5 ± 6.6

Continuation of Table 94.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	183.7 ± 7.6
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	201.9 ± 9.7
			780.7	4.36 ± 0.11	215.6 ± 10.3
			667.4	11.0 ± 0.3	197.6 ± 8.6
			<i>RR_{mean}</i> =		202.9 ± 8.1
¹⁷⁰ Lu _c	c	2.012D	1280.2	8.2 ± 0.4	165.3 ± 11.3
			2126.1	5.1 ± 0.3	153.1 ± 12.6
			1054.3	4.76 ± 0.24	150.7 ± 11.8
			985.1	5.5 ± 0.3	169.4 ± 21.2
			<i>RR_{mean}</i> =		158.4 ± 7.0
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	139.3 ± 6.5
			191.2	20.6 ± 0.6	144.3 ± 7.0
			<i>RR_{mean}</i> =		141.5 ± 5.4
¹⁶⁷ Lu	c	51.5M	176.2	*	122.6 ± 9.0
			113.3	*	156.2 ± 11.8
			<i>RR_{mean}</i> =		134.8 ± 16.7
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	160.1 ± 7.2
			177.2	22.2 ± 0.5	160.6 ± 7.0
			130.5	11.31 ± 0.21	161.1 ± 8.0
			<i>RR_{mean}</i> =		160.5 ± 5.6
¹⁶⁶ Yb	c	56.7H	2079.5	*	138.2 ± 10.4
			2052.4	*	147.1 ± 10.2
			1867.9	*	131.8 ± 9.3
			1374.2	*	137.8 ± 11.2
			1176.7	*	134.5 ± 9.8
			785.9	*	134.8 ± 9.9
			705.3	*	130.5 ± 9.5
			691.2(D)	8.56 ± 0.58	118.5 ± 9.4
			<i>RR_{mean}</i> =		133.7 ± 4.1
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	155.3 ± 30.2
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	132.4 ± 9.6
			242.9	35.5 ± 1.7	131.5 ± 8.2
			<i>RR_{mean}</i> =		131.8 ± 5.5
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	141.5 ± 10.4
¹⁶⁰ Er	c	28.58H	966.2	*	99.53 ± 13.51
			962.4	*	95.86 ± 12.60
			872.0(D)	6.8 ± 1.1	95.69 ± 16.91
			728.2(D)	34 ± 5	103.4 ± 15.6
			<i>RR_{mean}</i> =		98.52 ± 3.04
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	111.3 ± 14.6
			132.0	*	112.9 ± 11.3
			<i>RR_{mean}</i> =		112.3 ± 3.5
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	101.1 ± 14.7
			962.4	16.6 ± 2.1	113.2 ± 16.3
			<i>RR_{mean}</i> =		106.6 ± 10.6
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	77.70 ± 4.23
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	74.56 ± 4.21
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	57.13 ± 2.71
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	27.95 ± 1.36
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	50.01 ± 4.19

Continuation of Table 94.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			105.3	25.1 ± 1.3	61.29 ± 4.50
			$RR_{mean} =$		56.31 ± 5.87
^{153}Tb	c*	2.34D	212.0	31.0 ± 1.9	44.36 ± 3.23
^{152}Tb	c*	17.5H	344.3	65 ± 4	37.81 ± 2.95
^{151}Tb	c	17.609H	479.4	15.4 ± 0.7	24.17 ± 2.87
^{153}Gd	c	240.4D	103.2	21.1 ± 0.7	43.28 ± 3.34
			97.4	29.0 ± 0.8	38.40 ± 2.46
			$RR_{mean} =$		39.96 ± 2.59
^{151}Gd	c	124D	243.3	5.6 ± 0.4	30.01 ± 3.13
^{149}Gd	c	9.28D	149.7	48 ± 3	36.41 ± 2.70
			788.9	7.3 ± 0.4	42.24 ± 3.09
			346.6	23.9 ± 1.3	33.10 ± 2.14
			298.6	28.6 ± 1.7	34.05 ± 2.38
			$RR_{mean} =$		34.68 ± 1.93
^{147}Gd	c	38.06H	929.0	20.2 ± 1.2	27.24 ± 2.65
			396.0	34.3 ± 2.1	25.94 ± 1.87
			$RR_{mean} =$		26.29 ± 1.42
^{146}Gd	c	48.27D	747.2	*	24.29 ± 1.10
^{149}Eu	c*	93.1D	327.5	4.03 ± 0.12	42.87 ± 4.53
^{147}Eu	c*	24.1D	677.5	9.8 ± 0.5	32.01 ± 2.28
			955.8	3.84 ± 0.20	31.29 ± 2.99
			798.7	4.8 ± 0.3	39.08 ± 3.48
			601.5	5.9 ± 0.3	27.73 ± 3.52
			121.2	22.9 ± 1.3	28.42 ± 2.20
			$RR_{mean} =$		31.16 ± 1.88
$^{146}\text{Eu}_i$	i	4.61D	747.2	99 ± 3	3.988 ± 0.229
$^{146}\text{Eu}_c$	c	4.61D	747.2	99 ± 3	28.27 ± 1.28
^{145}Eu	c	5.93D	1658.5	14.9 ± 1.0	17.66 ± 1.51
			653.5	15 ± 1	17.47 ± 1.44
			$RR_{mean} =$		17.56 ± 1.00
^{143}Pm	c	265D	742.0	38.5 ± 2.4	14.77 ± 1.16
^{139}Ce	c	137.640D	165.9	79.89 ± 0.02	11.89 ± 0.49
^{131}Ba	c	11.50D	123.8	29.0 ± 0.3	6.769 ± 0.441
^{128}Ba	c	2.43D	442.9	26.8 ± 1.4	4.767 ± 0.482
^{127}Xe	c	36.4D	375.0	17.2 ± 0.6	7.880 ± 0.538
			202.9	68.3 ± 0.5	6.539 ± 0.300
			$RR_{mean} =$		6.770 ± 0.547
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.901 ± 0.258
^{121m}Te	i(m)	154D	212.2	81.4 ± 1.1	2.746 ± 0.174
			573.1	88.6 ± 0.1	2.377 ± 0.311
			$RR_{mean} =$		2.671 ± 0.082
$^{121}\text{Te}_c$	c	19.16D	573.1	80.3 ± 2.5	8.420 ± 0.447
^{119m}Te	i(m)	4.70D	1212.7	66.2 ± 0.3	3.815 ± 0.236
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	2.589 ± 0.152
			1023.3	99.4 ± 0.3	2.176 ± 0.117
			$RR_{mean} =$		2.323 ± 0.210
^{113}Sn	c	115.09D	391.7	64.97 ± 0.17	5.233 ± 0.402
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	8.631 ± 0.836
^{111}In	c	2.8047D	171.3	90.2 ± 1.0	7.079 ± 0.410
			245.4	94 ± 1	7.156 ± 0.344

Continuation of Table 94.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{110m} Ag	i(m)	249.76D	171.3	90.2 ± 1.0	7.571 ± 0.367
			<i>RR_{mean}</i> =		7.287 ± 0.277
			884.7	72.7 ± 0.4	6.659 ± 0.331
			657.8	94.3 ± 0.3	5.928 ± 0.345
^{106m} Ag	i(m)	8.28D	<i>RR_{mean}</i> =		6.337 ± 0.412
			451.0	28.2 ± 0.8	5.699 ± 0.370
			1045.8	29.6 ± 1.0	6.655 ± 0.387
			717.3	28.9 ± 0.8	5.915 ± 0.382
¹⁰⁵ Ag	c	41.29D	<i>RR_{mean}</i> =		6.091 ± 0.347
			443.4	10.5 ± 0.6	7.160 ± 0.858
			280.4	30.2 ± 1.8	6.444 ± 0.598
			<i>RR_{mean}</i> =		6.668 ± 0.504
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.6339 ± 0.2199
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	23.70 ± 1.47
¹⁰² Rh	i	207D	475.1	46 ± 5	5.310 ± 0.736
^{101m} Rh	c	4.34D	306.9	81 ± 5	9.368 ± 0.688
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	4.902 ± 0.492
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	5.536 ± 0.430
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	20.03 ± 0.77
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	8.405 ± 0.473
			812.5	82 ± 4	8.623 ± 0.518
			<i>RR_{mean}</i> =		8.501 ± 0.395
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	17.10 ± 0.77
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	12.89 ± 0.74
			568.9	58.0 ± 0.3	12.87 ± 0.74
			<i>RR_{mean}</i> =		12.88 ± 0.59
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	18.81 ± 0.76
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	29.66 ± 1.06
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	4.805 ± 0.597
			1129.2	92.7 ± 0.5	6.189 ± 0.395
			<i>RR_{mean}</i> =		5.825 ± 0.635
⁹⁵ Zr	c	64.02D	765.8	*	10.95 ± 0.70
			756.7	54.46 ± 0.10	11.05 ± 0.51
			<i>RR_{mean}</i> =		11.02 ± 0.34
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	15.63 ± 0.53
⁸⁸ Zr	c	83.4D	1836.1	*	5.817 ± 0.814
			898.0	*	6.373 ± 0.481
			392.9	97.24 ± 0.00	7.562 ± 0.350
			<i>RR_{mean}</i> =		7.146 ± 0.220
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	23.17 ± 1.05
			898.0	93.7 ± 0.3	22.07 ± 0.79
			<i>RR_{mean}</i> =		22.30 ± 0.82
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	28.98 ± 1.09
			898.0	93.7 ± 0.3	28.44 ± 0.96
			<i>RR_{mean}</i> =		28.60 ± 0.94
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	21.28 ± 0.76
⁸⁶ Y _c	c	14.74H	1076.6	82.5 ± 0.4	8.320 ± 0.701
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	21.39 ± 1.17
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	25.95 ± 2.17
			529.6	29.3 ± 2.1	24.02 ± 1.98

Continuation of Table 94.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			520.4	45 ± 4	24.20 ± 2.33
			<i>RR_{mean}</i> =		24.72 ± 1.15
^{82m} Rb	i(m)	6.472H	776.5	84.39 ± 0.21	9.686 ± 0.787
			554.3	62.4 ± 0.9	10.62 ± 1.30
			<i>RR_{mean}</i> =		9.920 ± 0.700
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	11.08 ± 0.60
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	9.854 ± 0.446
			136.0	58.3 ± 0.8	10.84 ± 0.49
			121.1	17.2 ± 0.4	11.96 ± 1.61
			<i>RR_{mean}</i> =		10.34 ± 0.50
⁷⁴ As	i	17.77D	595.8	59 ± 4	12.98 ± 1.02
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	1.102 ± 0.215
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	9.090 ± 0.786
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	10.87 ± 0.75
⁷² Zn	c	46.5H	2201.7	*	1.776 ± 0.276
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	6.163 ± 0.448
			1099.2	56.5 ± 1.9	6.531 ± 0.390
			<i>RR_{mean}</i> =		6.387 ± 0.312
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	3.819 ± 0.436
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	0.4082 ± 0.0816
			983.5	100.0 ± 0.3	0.5207 ± 0.1267
			<i>RR_{mean}</i> =		0.4410 ± 0.0692
⁴⁸ Sc	i	43.67H	1037.5	97.6 ± 0.7	2.532 ± 0.228
⁴⁶ Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	3.220 ± 0.164
			1120.6	99.99 ± 0.00	2.286 ± 0.308
			<i>RR_{mean}</i> =		3.072 ± 0.354
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	11.60 ± 0.70

12.9.3 Nuclide production rates for ²⁰⁸Pb

Table 95: Detailed calculation of nuclide production rates for ²⁰⁸Pb for $E_p = 1.2$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	19.93 ± 0.86
			803.1	98.9 ± 1.4	18.71 ± 0.68
			537.5	30.5 ± 0.5	17.99 ± 0.82
			<i>RR_{mean}</i> =		18.82 ± 0.73
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	23.90 ± 1.44
			1764.3	32.5 ± 0.7	25.18 ± 1.20
			<i>RR_{mean}</i> =		24.72 ± 1.06
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	24.49 ± 1.98
			899.2	98 ± 9	22.15 ± 1.00
			374.8	82 ± 5	21.88 ± 4.59
			<i>RR_{mean}</i> =		22.46 ± 0.69
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	19.69 ± 1.54
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	22.40 ± 3.16
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	50.46 ± 3.30
			374.7	89 ± 15	65.41 ± 11.32

Continuation of Table 95.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	51.42 ± 3.98
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	53.78 ± 3.33
			374.7	89 ± 15	68.16 ± 11.79
				<i>RR_{mean}</i> =	54.62 ± 3.76
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	152.6 ± 5.6
^{202m} Pb	i(m)	3.53H	422.1	86 ± 5	48.46 ± 4.05
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	120.4 ± 8.7
²⁰⁰ Pb	c	21.5H	1205.7	*	86.26 ± 6.59
			367.9	*	83.80 ± 3.16
			257.2	4.46 ± 0.17	90.98 ± 7.35
			147.6	37.7 ± 1.4	89.25 ± 4.98
				<i>RR_{mean}</i> =	85.00 ± 2.62
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	168.6 ± 27.7
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	118.2 ± 20.6
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	34.48 ± 6.82
^{197m} Pb	c*	43M	385.9	74 ± 15	75.23 ± 15.52
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	87.65 ± 3.13
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	222.6 ± 8.2
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	109.5 ± 9.5
			579.3	13.8 ± 0.7	128.5 ± 10.5
			367.9	87.2 ± 0.4	100.5 ± 5.0
				<i>RR_{mean}</i> =	105.2 ± 7.3
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	195.8 ± 13.9
			579.3	13.8 ± 0.7	197.2 ± 12.8
			367.9	87.2 ± 0.4	184.3 ± 6.7
				<i>RR_{mean}</i> =	186.1 ± 6.5
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	168.4 ± 20.9
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	190.6 ± 23.0
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	95.21 ± 11.42
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	154.3 ± 27.0
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	21.25 ± 0.80
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	50.76 ± 2.40
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	63.53 ± 8.70
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	92.88 ± 13.95
			407.6	32 ± 6	60.67 ± 11.60
				<i>RR_{mean}</i> =	73.98 ± 16.02
¹⁹² Hg	c	4.85H	316.5	*	177.1 ± 22.3
			274.8	50.2 ± 2.5	149.3 ± 9.4
				<i>RR_{mean}</i> =	152.8 ± 4.7
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	113.1 ± 17.4
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	3.781 ± 0.307
			411.8	*	3.301 ± 0.407
				<i>RR_{mean}</i> =	3.617 ± 0.112
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	9.237 ± 0.744
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	12.54 ± 0.53
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	19.49 ± 0.69
			426.1	6.6 ± 0.8	17.63 ± 2.38
			333.0	22.9 ± 0.6	20.24 ± 0.90
				<i>RR_{mean}</i> =	19.60 ± 0.66
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	237.2 ± 23.3

Continuation of Table 95.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	33.08 ± 2.95
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	49.24 ± 6.55
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	226.4 ± 28.4
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	227.3 ± 20.2
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	182.0 ± 14.2
			295.8	71 ± 5	184.3 ± 15.1
			RR _{mean} =		183.0 ± 8.3
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	198.2 ± 24.2
			456.5	3.4 ± 0.4	171.3 ± 21.4
			409.4	8.0 ± 0.9	163.0 ± 19.2
			RR _{mean} =		173.9 ± 11.4
¹⁸⁹ Pt	c	10.87H	544.9	5.8 ± 0.5	189.4 ± 18.8
			721.4	9.3 ± 0.8	214.1 ± 20.8
			607.6	8.10 ± 0.16	198.6 ± 8.8
			568.8	7.1 ± 0.6	212.4 ± 21.0
			243.5	7.0 ± 1.2	243.7 ± 45.5
			RR _{mean} =		200.6 ± 8.2
¹⁸⁸ Pt	c	10.2D	1209.8	*	183.5 ± 19.7
			478.0	*	191.9 ± 10.3
			423.3	4.4 ± 0.3	179.3 ± 13.7
			381.4	7.5 ± 0.5	172.1 ± 12.9
			195.1	18.6 ± 1.2	181.0 ± 13.6
			187.6	19.4 ± 1.2	181.3 ± 13.1
			RR _{mean} =		184.9 ± 5.7
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	143.6 ± 31.2
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	127.3 ± 23.5
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	1.053 ± 0.080
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.860 ± 0.215
			569.3	28.5 ± 1.3	2.833 ± 0.296
			RR _{mean} =		2.852 ± 0.171
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	175.5 ± 19.2
¹⁸⁸ Ir _i	i	41.5H	478.0	14.7 ± 0.6	22.42 ± 2.36
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	191.5 ± 20.6
			478.0	14.7 ± 0.6	214.3 ± 11.5
			RR _{mean} =		213.5 ± 7.9
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	181.5 ± 14.0
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	89.65 ± 4.41
			137.2	41.4 ± 0.7	90.90 ± 5.67
			RR _{mean} =		90.05 ± 3.94
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	143.9 ± 22.1
			254.2	13.3 ± 2.4	131.6 ± 24.5
			RR _{mean} =		141.8 ± 7.6
¹⁸⁴ Ir	c*	3.09H	264.0	68 ± 4	181.9 ± 12.9
			390.4	25.9 ± 2.4	177.9 ± 17.8
			119.8	31 ± 3	181.8 ± 19.9
			RR _{mean} =		181.4 ± 7.3
¹⁸⁵ Os	c	93.6D	646.1	78 ± 3	188.1 ± 9.6
			874.8	6.29 ± 0.25	193.3 ± 10.2
			717.4	3.94 ± 0.16	190.1 ± 10.5
			RR _{mean} =		189.7 ± 6.1

Continuation of Table 95.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	103.4 ± 4.5
			1107.9	22.4 ± 0.6	109.3 ± 5.0
			$RR_{mean} =$		105.5 ± 4.3
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	171.7 ± 10.9
			180.2	33.5 ± 1.7	174.7 ± 12.0
			$RR_{mean} =$		173.0 ± 8.6
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	161.2 ± 9.5
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	201.4 ± 9.5
			291.7	3.05 ± 0.18	189.2 ± 13.5
			$RR_{mean} =$		199.0 ± 8.0
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	201.0 ± 15.3
			1189.2	15 ± 1	189.2 ± 19.1
			$RR_{mean} =$		197.2 ± 11.1
¹⁸¹ Re	c*	19.9H	365.5	56 ± 8	165.0 ± 24.3
			639.0	6.4 ± 1.4	189.1 ± 42.1
			$RR_{mean} =$		169.9 ± 18.3
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	229.9 ± 19.2
			290.0	26.9 ± 2.3	215.9 ± 21.0
			$RR_{mean} =$		225.3 ± 10.7
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	236.8 ± 30.5
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	170.5 ± 21.1
			1340.8(D)	1.03 ± 0.09	107.4 ± 12.2
			$RR_{mean} =$		120.8 ± 26.1
¹⁷⁷ W	c	135M	115.7	51 ± 5	168.9 ± 18.5
¹⁷⁶ W	c	2.5H	1159.3	*	151.9 ± 32.9
			1823.7	*	192.1 ± 57.8
			710.5	*	67.88 ± 82.94
			$RR_{mean} =$		152.3 ± 25.9
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	175.6 ± 39.9
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	169.8 ± 17.9
			1823.7	4.5 ± 0.4	158.4 ± 24.8
			710.5	5.4 ± 0.4	197.0 ± 35.0
			$RR_{mean} =$		170.0 ± 11.0
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	148.5 ± 24.9
			348.5	12.0 ± 1.1	209.9 ± 21.0
			266.9	10.52 ± 0.16	164.5 ± 7.4
			$RR_{mean} =$		166.7 ± 9.7
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	163.7 ± 15.2
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	172.8 ± 19.2
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	85.51 ± 9.25
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	168.5 ± 8.3
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	201.0 ± 15.1
			311.2	10.7 ± 0.5	188.1 ± 11.2
			139.6	12.7 ± 0.6	200.3 ± 13.2
			$RR_{mean} =$		194.0 ± 7.8
¹⁷² Hf	c	1.87Y	1093.6	*	139.7 ± 8.2
			1002.7(D)	5.55 ± 0.38	120.4 ± 12.0
			181.5	*	139.3 ± 9.5
			125.8	11.3 ± 0.9	144.5 ± 13.4
			$RR_{mean} =$		138.3 ± 4.3

Continuation of Table 95.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷¹ Hf	c	12.1H	739.8	*	139.6 ± 15.0
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	175.8 ± 49.2
			164.7	26 ± 8	175.8 ± 54.5
			120.2	15 ± 5	181.4 ± 61.1
			<i>RR_{mean}</i> =		176.3 ± 12.5
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	159.7 ± 8.5
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	1.049 ± 0.122
			181.5	20.6 ± 1.0	2.158 ± 0.934
			<i>RR_{mean}</i> =		1.064 ± 0.134
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	140.7 ± 8.2
			181.5	20.6 ± 1.0	141.5 ± 9.5
			<i>RR_{mean}</i> =		140.9 ± 5.6
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	154.1 ± 6.4
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	155.1 ± 7.7
			780.7	4.36 ± 0.11	181.2 ± 7.8
			667.4	11.0 ± 0.3	161.0 ± 7.0
			<i>RR_{mean}</i> =		167.1 ± 9.3
¹⁷⁰ Lu _c	c	2.012D	1280.2	8.2 ± 0.4	128.4 ± 8.5
			2126.1	5.1 ± 0.3	121.2 ± 10.0
			1054.3	4.76 ± 0.24	127.2 ± 13.9
			985.1	5.5 ± 0.3	159.3 ± 19.8
			<i>RR_{mean}</i> =		127.9 ± 6.1
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	112.6 ± 5.2
			191.2	20.6 ± 0.6	114.9 ± 5.6
			<i>RR_{mean}</i> =		113.6 ± 4.3
¹⁶⁷ Lu	c	51.5M	176.2	*	94.75 ± 6.07
			113.3	*	125.2 ± 9.5
			<i>RR_{mean}</i> =		103.1 ± 14.0
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	137.8 ± 5.9
			177.2	22.2 ± 0.5	135.0 ± 5.9
			130.5	11.31 ± 0.21	138.2 ± 6.5
			<i>RR_{mean}</i> =		136.8 ± 4.7
¹⁶⁶ Yb	c	56.7H	2079.5	*	112.0 ± 8.6
			2052.4	*	117.7 ± 8.2
			1867.9	*	107.8 ± 7.8
			1374.2	*	112.1 ± 8.9
			1176.7	*	107.3 ± 7.8
			785.9	*	115.7 ± 8.1
			705.3	*	102.9 ± 7.4
			691.2(D)	8.56 ± 0.58	99.13 ± 7.59
			<i>RR_{mean}</i> =		108.9 ± 3.4
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	128.7 ± 25.0
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	107.0 ± 8.0
			242.9	35.5 ± 1.7	106.6 ± 6.6
			<i>RR_{mean}</i> =		106.7 ± 4.4
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	113.9 ± 8.5
¹⁶⁰ Er	c	28.58H	966.2	*	77.56 ± 10.44
			962.4	*	77.61 ± 10.27
			872.0(D)	6.8 ± 1.1	68.51 ± 11.53
			728.2(D)	34 ± 5	80.68 ± 12.20

Continuation of Table 95.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	76.07 ± 2.35
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	69.98 ± 9.67
			132.0	*	97.99 ± 8.90
				$RR_{mean} =$	85.63 ± 2.64
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	86.95 ± 14.93
			962.4	16.6 ± 2.1	87.60 ± 47.12
				$RR_{mean} =$	87.01 ± 13.79
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	57.86 ± 3.43
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	56.08 ± 3.24
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	44.79 ± 2.15
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	20.98 ± 1.15
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	42.35 ± 3.92
			105.3	25.1 ± 1.3	47.85 ± 3.47
				$RR_{mean} =$	46.21 ± 2.90
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	34.53 ± 2.53
¹⁵² Tb	c*	17.5H	344.3	65 ± 4	31.29 ± 2.60
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	21.34 ± 1.83
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	32.47 ± 2.23
			97.4	29.0 ± 0.8	31.43 ± 1.88
				$RR_{mean} =$	31.83 ± 1.52
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	27.44 ± 2.72
¹⁴⁹ Gd	c	9.28D	149.7	48 ± 3	27.91 ± 2.06
			788.9	7.3 ± 0.4	31.52 ± 2.21
			346.6	23.9 ± 1.3	24.14 ± 1.56
			298.6	28.6 ± 1.7	25.71 ± 1.83
				$RR_{mean} =$	25.94 ± 1.69
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	18.44 ± 1.59
			396.0	34.3 ± 2.1	18.15 ± 1.33
				$RR_{mean} =$	18.26 ± 0.97
¹⁴⁶ Gd	c	48.27D	747.2	*	17.75 ± 0.80
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	39.27 ± 4.99
¹⁴⁷ Eu	c*	24.1D	677.5	9.8 ± 0.5	21.29 ± 1.46
			955.8	3.84 ± 0.20	24.94 ± 2.14
			798.7	4.8 ± 0.3	28.59 ± 3.59
			601.5	5.9 ± 0.3	22.17 ± 1.99
			121.2	22.9 ± 1.3	22.06 ± 1.68
				$RR_{mean} =$	22.38 ± 1.09
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	3.402 ± 0.168
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	21.15 ± 0.95
¹⁴⁵ Eu	c	5.93D	1658.5	14.9 ± 1.0	11.74 ± 0.98
			653.5	15 ± 1	12.49 ± 1.08
				$RR_{mean} =$	12.07 ± 0.70
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	11.05 ± 0.95
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.02	9.311 ± 0.355
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	5.770 ± 0.535
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	3.382 ± 0.500
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	5.902 ± 0.511
			202.9	68.3 ± 0.5	5.523 ± 0.235
				$RR_{mean} =$	5.560 ± 0.227
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.785 ± 0.177

Continuation of Table 95.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{121m}Te	i(m)	154D	212.2	81.4 ± 1.1	1.988 ± 0.165
			573.1	88.6 ± 0.1	1.851 ± 0.334
			$RR_{mean} = \mathbf{1.964 \pm 0.061}$		
$^{121}\text{Te}_c$	c	19.16D	573.1	80.3 ± 2.5	$\mathbf{6.230 \pm 0.363}$
^{119m}Te	i(m)	4.70D	1212.7	66.2 ± 0.3	$\mathbf{2.510 \pm 0.196}$
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	2.097 ± 0.116
			1023.3	99.4 ± 0.3	1.852 ± 0.114
			$RR_{mean} = \mathbf{1.977 \pm 0.137}$		
^{113}Sn	c	115.09D	391.7	64.97 ± 0.17	$\mathbf{4.094 \pm 0.246}$
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	$\mathbf{6.711 \pm 0.335}$
^{111}In	c	2.8047D	171.3	90.2 ± 1.0	5.379 ± 0.251
			245.4	94 ± 1	5.479 ± 0.320
			171.3	90.2 ± 1.0	5.379 ± 0.251
			$RR_{mean} = \mathbf{5.398 \pm 0.202}$		
^{110m}Ag	i(m)	249.76D	884.7	72.7 ± 0.4	5.370 ± 0.303
			657.8	94.3 ± 0.3	4.977 ± 0.254
			$RR_{mean} = \mathbf{5.129 \pm 0.248}$		
^{106m}Ag	i(m)	8.28D	451.0	28.2 ± 0.8	4.755 ± 0.393
			1045.8	29.6 ± 1.0	5.082 ± 0.338
			717.3	28.9 ± 0.8	4.735 ± 0.334
			$RR_{mean} = \mathbf{4.870 \pm 0.237}$		
^{105}Ag	c	41.29D	443.4	10.5 ± 0.6	6.076 ± 0.901
			280.4	30.2 ± 1.8	4.210 ± 0.458
			$RR_{mean} = \mathbf{4.579 \pm 0.756}$		
^{100}Pd	c	3.63D	2376.0	*	$\mathbf{0.6796 \pm 0.1174}$
^{105}Rh	c	35.36H	318.9	19.1 ± 0.6	$\mathbf{21.83 \pm 1.31}$
^{102}Rh	i	207D	475.1	46 ± 5	$\mathbf{4.347 \pm 0.670}$
^{101m}Rh	c	4.34D	306.9	81 ± 5	$\mathbf{6.930 \pm 0.536}$
$^{100}\text{Rh}_i$	i(m+g)	20.8H	2376.0	32.6 ± 0.4	$\mathbf{3.993 \pm 0.274}$
$^{100}\text{Rh}_c$	c	20.8H	2376.0	32.6 ± 0.4	$\mathbf{4.672 \pm 0.261}$
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	$\mathbf{17.32 \pm 0.67}$
^{96}Tc	i(m+g)	4.28D	849.9	98 ± 4	6.432 ± 0.381
			812.5	82 ± 4	6.636 ± 0.402
			$RR_{mean} = \mathbf{6.527 \pm 0.311}$		
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	$\mathbf{15.65 \pm 0.66}$
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	9.521 ± 0.540
			568.9	58.0 ± 0.3	9.875 ± 0.588
			$RR_{mean} = \mathbf{9.679 \pm 0.450}$		
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	$\mathbf{14.93 \pm 0.54}$
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	$\mathbf{25.00 \pm 0.85}$
^{90}Nb	c*	14.60H	2319.0	82.0 ± 0.3	3.582 ± 0.403
			1129.2	92.7 ± 0.5	4.497 ± 0.277
			$RR_{mean} = \mathbf{4.243 \pm 0.430}$		
^{95}Zr	c	64.02D	765.8	*	10.16 ± 0.47
			756.7	54.46 ± 0.10	9.616 ± 0.394
			$RR_{mean} = \mathbf{9.814 \pm 0.303}$		
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	$\mathbf{11.86 \pm 0.42}$
^{88}Zr	c	83.4D	1836.1	*	6.305 ± 0.441
			898.0	*	5.423 ± 0.238
			392.9	97.24 ± 0.00	5.576 ± 0.218

Continuation of Table 95.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	5.573 ± 0.172
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	16.82 ± 0.63
			898.0	93.7 ± 0.3	16.76 ± 0.56
			RR _{mean} =		16.78 ± 0.55
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	23.12 ± 0.84
			898.0	93.7 ± 0.3	22.18 ± 0.73
			RR _{mean} =		22.42 ± 0.80
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	15.93 ± 0.57
⁸⁶ Y _c	c	14.74H	1076.6	82.5 ± 0.4	6.538 ± 0.951
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	16.14 ± 0.88
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	20.90 ± 1.80
			529.6	29.3 ± 2.1	18.85 ± 1.63
			520.4	45 ± 4	18.47 ± 1.79
			RR _{mean} =		19.42 ± 0.95
^{82m} Rb	i(m)	6.472H	776.5	84.39 ± 0.21	7.842 ± 0.855
			554.3	62.4 ± 0.9	7.100 ± 1.731
			RR _{mean} =		7.704 ± 0.777
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	9.499 ± 0.471
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	7.445 ± 0.349
			136.0	58.3 ± 0.8	8.549 ± 0.395
			121.1	17.2 ± 0.4	6.371 ± 1.272
			RR _{mean} =		7.899 ± 0.484
⁷⁴ As	i	17.77D	595.8	59 ± 4	10.47 ± 0.80
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	0.7159 ± 0.1128
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	6.801 ± 0.654
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	8.499 ± 0.617
⁷² Zn	c	46.5H	2201.7	*	1.698 ± 0.224
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	4.977 ± 0.290
			1099.2	56.5 ± 1.9	5.294 ± 0.372
			RR _{mean} =		5.084 ± 0.243
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	2.912 ± 0.211
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	0.3978 ± 0.0652
			983.5	100.0 ± 0.3	0.5224 ± 0.0567
			RR _{mean} =		0.4701 ± 0.0632
⁴⁸ Sc	i	43.67H	1037.5	97.6 ± 0.7	2.175 ± 0.126
⁴⁶ Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	2.140 ± 0.152
			1120.6	99.99 ± 0.00	2.712 ± 0.272
			RR _{mean} =		2.264 ± 0.246
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	14.45 ± 1.85

12.9.4 Nuclide production rates for ^{nat}Pb

Table 96: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 1.2 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	26.86 $\pm$ 4.47
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	23.75 ± 1.07
			803.1	98.9 ± 1.4	22.81 ± 0.82

Continuation of Table 96.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			537.5	30.5 ± 0.5	21.89 ± 0.90
			<i>RR_{mean}</i> =		22.70 ± 0.82
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	36.01 ± 1.82
			1764.3	32.5 ± 0.7	36.88 ± 1.53
			<i>RR_{mean}</i> =		36.59 ± 1.40
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	41.04 ± 3.44
			899.2	98 ± 9	34.12 ± 1.39
			374.8	82 ± 5	33.33 ± 7.00
			<i>RR_{mean}</i> =		34.61 ± 1.07
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	32.07 ± 2.17
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	30.01 ± 3.52
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	89.79 ± 4.59
			374.7	89 ± 15	99.46 ± 17.38
			<i>RR_{mean}</i> =		90.22 ± 4.53
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	94.91 ± 4.68
			374.7	89 ± 15	103.6 ± 18.1
			<i>RR_{mean}</i> =		95.26 ± 4.63
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	261.8 ± 9.6
^{202m} Pb	i(m)	3.53H	422.1	86 ± 5	73.73 ± 5.43
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	201.7 ± 14.6
²⁰⁰ Pb	c	21.5H	1205.7	*	144.7 ± 10.2
			367.9	*	127.7 ± 5.4
			257.2	4.46 ± 0.17	136.0 ± 13.2
			147.6	37.7 ± 1.4	145.3 ± 8.1
			<i>RR_{mean}</i> =		136.4 ± 4.2
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	251.3 ± 41.8
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	184.4 ± 31.8
^{197m} Pb	c*	43M	385.9	74 ± 15	120.7 ± 24.9
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	61.09 ± 12.11
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	135.4 ± 4.9
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	357.2 ± 13.2
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	161.6 ± 12.1
			579.3	13.8 ± 0.7	181.6 ± 12.9
			367.9	87.2 ± 0.4	170.1 ± 10.4
			<i>RR_{mean}</i> =		170.6 ± 7.9
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	306.3 ± 21.2
			579.3	13.8 ± 0.7	304.3 ± 19.0
			367.9	87.2 ± 0.4	297.8 ± 11.7
			<i>RR_{mean}</i> =		299.6 ± 11.1
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	258.6 ± 32.7
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	312.3 ± 37.7
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	151.2 ± 21.3
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	229.4 ± 40.1
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	25.10 ± 0.94
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	68.89 ± 3.35
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	99.03 ± 13.58
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	123.8 ± 18.5
			407.6	32 ± 6	86.07 ± 16.43
			<i>RR_{mean}</i> =		102.9 ± 19.0
¹⁹² Hg	c	4.85H	316.5	*	273.0 ± 34.4

Continuation of Table 96.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			274.8	50.2 ± 2.5	226.4 ± 14.4
			<i>RR_{mean}</i> =		232.2 ± 7.2
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	168.9 ± 26.2
^{198m} Au	i(m)	2.27D	204.1	40.8 ± 2.4	4.418 ± 0.360
			411.8	*	4.709 ± 0.447
			<i>RR_{mean}</i> =		4.529 ± 0.140
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	9.860 ± 0.913
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	14.57 ± 0.67
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	25.28 ± 0.89
			426.1	6.6 ± 0.8	21.64 ± 2.85
			333.0	22.9 ± 0.6	25.96 ± 1.16
			<i>RR_{mean}</i> =		25.34 ± 0.86
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	325.3 ± 32.5
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	44.65 ± 3.97
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	67.62 ± 9.17
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	340.6 ± 42.8
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	324.1 ± 28.4
¹⁹⁰ Au _c	c	42.8M	597.7	9.4 ± 0.9	172.5 ± 26.4
			301.8	23.4 ± 1.5	246.4 ± 21.4
			295.8	71 ± 5	266.9 ± 22.5
			<i>RR_{mean}</i> =		243.6 ± 23.7
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	292.4 ± 35.7
			456.5	3.4 ± 0.4	244.2 ± 30.1
			409.4	8.0 ± 0.9	234.8 ± 27.7
			<i>RR_{mean}</i> =		250.6 ± 17.9
¹⁸⁹ Pt	c	10.87H	544.9	5.8 ± 0.5	298.4 ± 28.7
			721.4	9.3 ± 0.8	307.8 ± 28.9
			607.6	8.10 ± 0.16	291.1 ± 12.3
			568.8	7.1 ± 0.6	302.3 ± 31.3
			243.5	7.0 ± 1.2	372.5 ± 68.8
			<i>RR_{mean}</i> =		294.4 ± 11.6
¹⁸⁸ Pt	c	10.2D	1209.8	*	277.3 ± 29.6
			478.0	*	285.8 ± 15.2
			423.3	4.4 ± 0.3	263.2 ± 20.1
			381.4	7.5 ± 0.5	253.9 ± 19.1
			195.1	18.6 ± 1.2	265.5 ± 19.9
			187.6	19.4 ± 1.2	264.6 ± 19.1
			<i>RR_{mean}</i> =		273.3 ± 8.4
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	225.9 ± 49.1
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	233.6 ± 45.2
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	1.271 ± 0.073
¹⁹⁰ Ir	i(m1+g)	11.78D	605.1	39.9 ± 1.9	2.910 ± 0.272
			569.3	28.5 ± 1.3	3.120 ± 0.380
			<i>RR_{mean}</i> =		2.976 ± 0.219
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	253.9 ± 27.7
¹⁸⁸ Ir _i	i	41.5H	478.0	14.7 ± 0.6	29.27 ± 3.65
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	286.1 ± 30.6
			478.0	14.7 ± 0.6	315.1 ± 17.0
			<i>RR_{mean}</i> =		314.0 ± 11.2
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	274.2 ± 15.9

Continuation of Table 96.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	136.6 ± 6.8
			137.2	41.4 ± 0.7	144.3 ± 6.9
			<i>RR_{mean}</i> =		140.5 ± 5.8
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	203.5 ± 31.3
			254.2	13.3 ± 2.4	201.6 ± 37.3
			<i>RR_{mean}</i> =		203.2 ± 10.9
¹⁸⁴ Ir	c*	3.09H	264.0	68 ± 4	270.7 ± 19.3
			390.4	25.9 ± 2.4	262.7 ± 26.2
			119.8	31 ± 3	278.2 ± 30.7
			<i>RR_{mean}</i> =		270.3 ± 10.9
¹⁸⁵ Os	c	93.6D	646.1	78 ± 3	274.3 ± 14.0
			874.8	6.29 ± 0.25	281.7 ± 14.6
			717.4	3.94 ± 0.16	283.3 ± 15.6
			<i>RR_{mean}</i> =		278.0 ± 9.0
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	159.5 ± 7.1
			1107.9	22.4 ± 0.6	170.1 ± 8.0
			<i>RR_{mean}</i> =		163.3 ± 7.1
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	261.5 ± 15.2
			180.2	33.5 ± 1.7	270.6 ± 17.5
			<i>RR_{mean}</i> =		265.1 ± 12.3
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	218.1 ± 14.6
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	291.9 ± 13.8
			291.7	3.05 ± 0.18	266.7 ± 18.6
			<i>RR_{mean}</i> =		286.3 ± 13.7
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	287.2 ± 21.2
			1189.2	15 ± 1	298.4 ± 23.3
			<i>RR_{mean}</i> =		292.0 ± 14.7
¹⁸¹ Re	c*	19.9H	365.5	56 ± 8	237.3 ± 35.4
			639.0	6.4 ± 1.4	267.6 ± 59.7
			<i>RR_{mean}</i> =		243.9 ± 26.6
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	362.0 ± 34.9
			290.0	26.9 ± 2.3	305.7 ± 30.7
			<i>RR_{mean}</i> =		331.5 ± 29.9
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	380.5 ± 46.9
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	224.0 ± 23.1
			1340.8(D)	1.03 ± 0.09	184.5 ± 18.4
			<i>RR_{mean}</i> =		197.9 ± 19.6
¹⁷⁷ W	c	135M	115.7	51 ± 5	257.1 ± 28.1
¹⁷⁶ W	c	2.5H	1159.3	*	178.6 ± 25.3
			1823.7	*	316.8 ± 93.2
			710.5	*	155.3 ± 100.4
			<i>RR_{mean}</i> =		184.5 ± 22.3
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	260.9 ± 59.4
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	270.8 ± 23.9
			1823.7	4.5 ± 0.4	230.8 ± 39.3
			710.5	5.4 ± 0.4	302.2 ± 46.2
			<i>RR_{mean}</i> =		269.7 ± 12.4
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	196.8 ± 31.4
			348.5	12.0 ± 1.1	301.1 ± 29.6
			266.9	10.52 ± 0.16	255.0 ± 10.9

Continuation of Table 96.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	254.8 ± 14.6
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	244.4 ± 22.6
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	264.9 ± 29.4
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	139.1 ± 15.2
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	247.7 ± 12.2
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	299.5 ± 22.6
			311.2	10.7 ± 0.5	285.9 ± 17.0
			139.6	12.7 ± 0.6	290.1 ± 19.1
				<i>RR_{mean}</i> =	289.6 ± 11.6
¹⁷² Hf	c	1.87Y	1093.6	*	211.8 ± 12.3
			1002.7(D)	5.55 ± 0.38	224.2 ± 20.3
			181.5	*	205.3 ± 12.9
			125.8	11.3 ± 0.9	217.6 ± 20.8
				<i>RR_{mean}</i> =	212.2 ± 6.5
¹⁷¹ Hf	c	12.1H	739.8	*	216.1 ± 22.5
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	275.4 ± 77.1
			164.7	26 ± 8	260.8 ± 80.8
			120.2	15 ± 5	263.1 ± 88.7
				<i>RR_{mean}</i> =	271.4 ± 19.1
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	235.2 ± 12.5
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	1.396 ± 0.138
			181.5	20.6 ± 1.0	1.915 ± 0.770
				<i>RR_{mean}</i> =	1.408 ± 0.125
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	213.2 ± 12.4
			181.5	20.6 ± 1.0	207.2 ± 13.0
				<i>RR_{mean}</i> =	210.9 ± 8.1
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	229.6 ± 9.6
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	242.5 ± 10.8
			780.7	4.36 ± 0.11	269.8 ± 11.5
			667.4	11.0 ± 0.3	246.8 ± 10.7
				<i>RR_{mean}</i> =	253.4 ± 11.5
¹⁷⁰ Lu _c	c	2.012D	1280.2	8.2 ± 0.4	188.9 ± 12.0
			2126.1	5.1 ± 0.3	184.5 ± 13.9
			1054.3	4.76 ± 0.24	193.6 ± 14.4
			985.1	5.5 ± 0.3	212.3 ± 19.9
				<i>RR_{mean}</i> =	191.0 ± 7.7
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	172.0 ± 7.7
			191.2	20.6 ± 0.6	176.8 ± 8.8
				<i>RR_{mean}</i> =	173.8 ± 6.6
¹⁶⁷ Lu	c	51.5M	176.2	*	144.4 ± 10.4
			113.3	*	200.9 ± 15.5
				<i>RR_{mean}</i> =	161.5 ± 26.4
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	201.7 ± 8.7
			177.2	22.2 ± 0.5	202.1 ± 8.7
			130.5	11.31 ± 0.21	208.0 ± 9.7
				<i>RR_{mean}</i> =	203.4 ± 7.0
¹⁶⁶ Yb	c	56.7H	2079.5	*	169.3 ± 12.7
			2052.4	*	179.9 ± 12.6
			1867.9	*	168.4 ± 12.0
			1374.2	*	173.7 ± 14.0

Continuation of Table 96.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1176.7	*	168.2 ± 12.1
			785.9	*	174.8 ± 12.2
			705.3	*	1622 ± 369
			691.2(D)	8.56 ± 0.58	148.9 ± 11.3
			$RR_{mean} =$		164.1 ± 5.1
^{167}Tm	c	9.25D	207.8	42 ± 8	194.7 ± 37.8
^{165}Tm	c	30.06H	806.4	9.5 ± 0.6	165.7 ± 12.1
			242.9	35.5 ± 1.7	163.5 ± 10.1
			$RR_{mean} =$		164.2 ± 6.8
^{161}Er	c*	3.21H	826.6	64 ± 4	178.9 ± 13.0
^{160}Er	c	28.58H	966.2	*	123.4 ± 16.6
			962.4	*	121.0 ± 15.9
			872.0(D)	6.8 ± 1.1	115.7 ± 19.4
			728.2(D)	34 ± 5	127.8 ± 19.3
			$RR_{mean} =$		122.0 ± 3.8
^{159}Er	c*	36M	624.5	33 ± 4	147.4 ± 19.4
			132.0	*	158.0 ± 9.2
			$RR_{mean} =$		156.5 ± 4.8
$^{160m}\text{Ho}_c$	c	5.02H	966.2	15.4 ± 2.0	141.7 ± 19.8
			962.4	16.6 ± 2.1	128.6 ± 19.6
			$RR_{mean} =$		135.2 ± 13.6
^{156}Ho	c*	56M	266.5	54.7 ± 1.1	92.09 ± 5.16
^{157}Dy	c	8.14H	326.2	92 ± 4	92.54 ± 5.19
^{155}Dy	c*	9.9H	226.9	68.4 ± 1.6	72.81 ± 3.44
^{152}Dy	c	2.38H	256.9	97.50 ± 0.07	35.47 ± 1.96
^{155}Tb	c*	5.32D	180.1	7.5 ± 0.5	57.73 ± 4.66
			105.3	25.1 ± 1.3	75.50 ± 5.46
			$RR_{mean} =$		66.79 ± 9.12
^{153}Tb	c*	2.34D	212.0	31.0 ± 1.9	53.38 ± 3.91
^{152}Tb	c*	17.5H	344.3	65 ± 4	51.30 ± 3.74
^{151}Tb	c	17.609H	479.4	15.4 ± 0.7	38.75 ± 2.75
^{153}Gd	c	240.4D	103.2	21.1 ± 0.7	53.08 ± 3.41
			97.4	29.0 ± 0.8	49.44 ± 3.02
			$RR_{mean} =$		50.99 ± 2.41
^{151}Gd	c	124D	243.3	5.6 ± 0.4	42.06 ± 3.81
^{149}Gd	c	9.28D	149.7	48 ± 3	45.54 ± 3.35
			788.9	7.3 ± 0.4	52.33 ± 3.51
			346.6	23.9 ± 1.3	41.54 ± 2.69
			298.6	28.6 ± 1.7	41.94 ± 2.90
			$RR_{mean} =$		44.17 ± 2.75
^{147}Gd	c	38.06H	929.0	20.2 ± 1.2	36.18 ± 2.80
			396.0	34.3 ± 2.1	28.98 ± 2.08
			$RR_{mean} =$		31.35 ± 3.51
^{146}Gd	c	48.27D	747.2	*	30.27 ± 1.37
^{149}Eu	c*	93.1D	327.5	4.03 ± 0.12	49.74 ± 3.47
^{147}Eu	c*	24.1D	677.5	9.8 ± 0.5	37.10 ± 2.34
			955.8	3.84 ± 0.20	34.73 ± 2.46
			798.7	4.8 ± 0.3	45.55 ± 3.48
			601.5	5.9 ± 0.3	36.43 ± 2.64
			121.2	22.9 ± 1.3	36.08 ± 2.65

Continuation of Table 96.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	37.08 ± 1.83
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	5.047 ± 0.274
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	35.32 ± 1.59
¹⁴⁵ Eu	c	5.93D	1658.5	14.9 ± 1.0	20.88 ± 1.72
			653.5	15 ± 1	21.96 ± 1.66
				<i>RR_{mean}</i> =	21.46 ± 1.15
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	18.80 ± 1.44
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.02	14.84 ± 0.57
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	9.247 ± 0.655
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	5.045 ± 0.492
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	9.390 ± 0.692
			202.9	68.3 ± 0.5	8.203 ± 0.341
				<i>RR_{mean}</i> =	8.335 ± 0.453
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.170 ± 0.226
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	3.478 ± 0.272
			573.1	88.6 ± 0.1	3.380 ± 0.332
				<i>RR_{mean}</i> =	3.440 ± 0.106
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	10.05 ± 0.51
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	3.803 ± 0.192
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	3.011 ± 0.175
			1023.3	99.4 ± 0.3	2.821 ± 0.107
				<i>RR_{mean}</i> =	2.849 ± 0.111
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	6.634 ± 0.341
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	9.833 ± 0.493
¹¹¹ In	c	2.8047D	171.3	90.2 ± 1.0	9.125 ± 0.398
			245.4	94 ± 1	9.318 ± 0.481
			171.3	90.2 ± 1.0	9.058 ± 0.384
				<i>RR_{mean}</i> =	9.132 ± 0.325
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	8.160 ± 0.329
			657.8	94.3 ± 0.3	7.791 ± 0.313
				<i>RR_{mean}</i> =	7.965 ± 0.307
^{106m} Ag	i(m)	8.28D	451.0	28.2 ± 0.8	7.313 ± 0.378
			1045.8	29.6 ± 1.0	8.094 ± 0.457
			717.3	28.9 ± 0.8	6.592 ± 0.501
				<i>RR_{mean}</i> =	7.398 ± 0.443
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	12.11 ± 1.04
			280.4	30.2 ± 1.8	8.260 ± 0.648
				<i>RR_{mean}</i> =	9.301 ± 1.733
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.7719 ± 0.2139
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	31.27 ± 2.09
¹⁰² Rh	i	207D	475.1	46 ± 5	7.706 ± 0.942
^{101m} Rh	c	4.34D	306.9	81 ± 5	11.55 ± 0.84
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	7.853 ± 0.726
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	8.625 ± 0.683
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	25.84 ± 0.97
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	10.66 ± 0.58
			812.5	82 ± 4	10.94 ± 0.66
				<i>RR_{mean}</i> =	10.78 ± 0.49
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	22.32 ± 0.97
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	16.67 ± 0.88

Continuation of Table 96.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			568.9	58.0 ± 0.3	15.53 ± 1.06
			$RR_{mean} =$		16.25 ± 0.76
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	22.80 ± 0.82
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	37.37 ± 1.27
^{90}Nb	c*	14.60H	2319.0	82.0 ± 0.3	6.765 ± 0.409
			1129.2	92.7 ± 0.5	7.977 ± 0.381
			$RR_{mean} =$		7.485 ± 0.638
^{95}Zr	c	64.02D	765.8	*	14.70 ± 0.67
			756.7	54.46 ± 0.10	14.68 ± 0.53
			$RR_{mean} =$		14.68 ± 0.45
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	20.13 ± 0.70
^{88}Zr	c	83.4D	1836.1	*	10.44 ± 0.44
			898.0	*	8.679 ± 0.596
			392.9	97.24 ± 0.00	9.447 ± 0.359
			$RR_{mean} =$		9.490 ± 0.293
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 ± 0.3	27.40 ± 0.97
			898.0	93.7 ± 0.3	27.27 ± 0.95
			$RR_{mean} =$		27.34 ± 0.90
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	37.84 ± 1.32
			898.0	93.7 ± 0.3	35.95 ± 1.22
			$RR_{mean} =$		36.70 ± 1.46
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	26.53 ± 0.94
$^{86}\text{Y}_c$	c	14.74H	1076.6	82.5 ± 0.4	10.94 ± 0.62
^{85}Sr	c	64.84D	514.0	96 ± 4	26.48 ± 1.44
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	33.63 ± 2.63
			529.6	29.3 ± 2.1	28.85 ± 2.35
			520.4	45 ± 4	30.57 ± 2.92
			$RR_{mean} =$		31.02 ± 1.80
^{82m}Rb	i(m)	6.472H	776.5	84.39 ± 0.21	12.98 ± 0.87
			554.3	62.4 ± 0.9	13.78 ± 1.27
			$RR_{mean} =$		13.21 ± 0.76
^{82}Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	15.03 ± 0.63
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	12.50 ± 0.49
			136.0	58.3 ± 0.8	14.05 ± 0.68
			121.1	17.2 ± 0.4	15.10 ± 1.16
			$RR_{mean} =$		13.03 ± 0.71
^{74}As	i	17.77D	595.8	59 ± 4	16.95 ± 1.29
^{71}As	c	65.28H	174.9	82.0 ± 2.1	1.545 ± 0.099
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	10.12 ± 1.21
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	13.08 ± 1.17
^{72}Zn	c	46.5H	2201.7	*	2.959 ± 0.296
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	8.325 ± 0.420
			1099.2	56.5 ± 1.9	8.688 ± 0.449
			$RR_{mean} =$		8.490 ± 0.339
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	4.578 ± 0.397
^{48}V	c	15.9735D	1312.1	97.5 ± 0.9	0.5147 ± 0.0677
			983.5	100.0 ± 0.3	0.6894 ± 0.0603
			$RR_{mean} =$		0.6154 ± 0.0884
^{48}Sc	i	43.67H	1037.5	97.6 ± 0.7	3.066 ± 0.180
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	4.186 ± 0.300

Continuation of Table 96.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1120.6	99.99 ± 0.00	4.179 ± 0.287
			$RR_{mean} =$		4.182 ± 0.227
^7Be	i	53.29D	477.6	10.52 ± 0.06	16.97 ± 1.65

12.9.5 Nuclide production rates for ^{209}Bi

Table 97: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 1.2 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	24.58 ± 1.24
²⁰⁶ Po	i	8.8D	1718.7	*	25.70 ± 1.33
			1595.3	*	26.28 ± 3.69
			1032.3	33 ± 5	26.75 ± 4.15
			1007.2	3.1 ± 0.4	23.58 ± 3.63
			980.2	7.1 ± 0.9	31.84 ± 4.25
			881.0	*	13.09 ± 3.20
			807.4	23 ± 3	26.82 ± 3.63
			803.1	*	25.69 ± 1.06
			620.5	*	17.96 ± 2.22
			537.5	*	22.80 ± 1.17
			522.5	15.7 ± 2.0	25.56 ± 3.39
			516.2	*	24.43 ± 1.10
			398.0	*	23.45 ± 2.56
			343.5	*	24.60 ± 2.15
			338.4	19.2 ± 2.5	26.21 ± 3.54
			311.6	4.2 ± 0.6	32.87 ± 5.02
			286.4	24 ± 3	26.88 ± 3.52
RR _{mean} =				24.44 ± 0.75	
²⁰⁷ Bi	c	31.55Y	1063.7	74.5 ± 0.2	297.7 ± 11.2
			569.7	97.74 ± 0.03	295.6 ± 11.3
RR _{mean} =				296.7 ± 10.2	
²⁰⁶ Bi _i	i	6.243D	1718.7	31.8 ± 0.6	176.3 ± 7.0
			1595.3	5.01 ± 0.08	187.9 ± 8.3
			881.0	66.2 ± 1.0	185.4 ± 6.9
			803.1	98.9 ± 1.4	165.1 ± 6.0
			620.5	5.76 ± 0.09	165.7 ± 7.0
			537.5	30.5 ± 0.5	156.3 ± 6.1
			516.2	40.7 ± 0.6	160.9 ± 6.0
			398.0	10.74 ± 0.15	154.0 ± 6.4
			343.5	23.4 ± 0.4	158.8 ± 6.4
RR _{mean} =				166.3 ± 6.4	
²⁰⁶ Bi _c	c	6.243D	1718.7	31.8 ± 0.6	200.6 ± 7.8
			1595.3	5.01 ± 0.08	212.7 ± 8.3
			881.0	66.2 ± 1.0	197.7 ± 7.2
			803.1	98.9 ± 1.4	189.4 ± 6.8
			620.5	5.76 ± 0.09	182.6 ± 7.1
			537.5	30.5 ± 0.5	177.9 ± 6.8
			516.2	40.7 ± 0.6	184.0 ± 6.9

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			398.0	10.74 ± 0.15	176.2 ± 6.6
			343.5	23.4 ± 0.4	182.1 ± 7.0
			<i>RR_{mean}</i> =		187.7 ± 6.8
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	186.8 ± 8.0
			1775.8	3.99 ± 0.08	196.2 ± 7.9
			1764.3	32.5 ± 0.7	193.2 ± 7.8
			1614.3	2.28 ± 0.04	193.9 ± 9.1
			1190.0	2.26 ± 0.07	193.4 ± 9.2
			1043.8	7.51 ± 0.10	174.5 ± 6.8
			987.7	16.13 ± 0.17	186.6 ± 6.5
			759.1	1.04 ± 0.05	197.0 ± 12.7
			703.5	31.1 ± 0.1	182.3 ± 6.1
			579.8	5.44 ± 0.07	167.9 ± 6.3
			570.6	4.34 ± 0.07	167.7 ± 6.8
			549.8	2.95 ± 0.04	190.9 ± 7.6
			284.1	1.69 ± 0.02	180.6 ± 7.6
			<i>RR_{mean}</i> =		182.6 ± 6.2
²⁰⁴ Bi	c*	11.22H	984.0	59 ± 4	153.1 ± 11.9
			918.3	10.8 ± 0.9	178.1 ± 16.4
			899.2	98 ± 9	138.2 ± 4.8
			670.7	11.4 ± 0.9	150.7 ± 13.4
			374.8	82 ± 5	162.1 ± 33.8
			<i>RR_{mean}</i> =		139.5 ± 4.3
²⁰³ Bi	c	11.76H	1893.0	8.2 ± 0.6	136.7 ± 12.0
			1847.3	11.4 ± 0.8	119.5 ± 9.5
			1679.6	8.8 ± 0.7	116.7 ± 10.6
			847.2	8.5 ± 0.5	140.9 ± 10.2
			820.2	29.6 ± 1.5	130.6 ± 8.1
			279.2	*	122.1 ± 6.2
			<i>RR_{mean}</i> =		124.7 ± 3.8
²⁰² Bi	c*	1.72H	960.7	99.28 ± 0.02	104.7 ± 4.4
			422.1	83.7 ± 2.5	112.0 ± 5.8
			<i>RR_{mean}</i> =		106.9 ± 4.7
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	52.59 ± 2.92
			374.7	89 ± 15	54.09 ± 9.39
			<i>RR_{mean}</i> =		52.69 ± 2.86
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	73.32 ± 3.32
			374.7	89 ± 15	74.43 ± 12.86
			<i>RR_{mean}</i> =		73.35 ± 3.29
²⁰³ Pb _i	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	122.8 ± 7.1
²⁰³ Pb _c	c	51.873H	279.2	80.8 ± 0.2	244.9 ± 9.1
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	68.41 ± 7.00
			422.1	86 ± 5	57.43 ± 4.26
			<i>RR_{mean}</i> =		59.20 ± 4.43
²⁰¹ Pb	c*	9.33H	946.0	7.4 ± 0.6	227.2 ± 21.1
			361.3	9.9 ± 0.5	269.5 ± 18.7
			331.2	79 ± 5	233.2 ± 16.9
			<i>RR_{mean}</i> =		244.3 ± 15.1
²⁰⁰ Pb	c	21.5H	1514.9	*	146.6 ± 13.4
			1205.7	*	166.9 ± 11.5
			579.3	*	156.5 ± 10.8

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			450.5	3.33 ± 0.08	183.4 ± 9.0
			367.9	*	159.4 ± 5.5
			147.6	37.7 ± 1.4	175.3 ± 11.0
			<i>RR_{mean}</i> =		161.9 ± 5.0
¹⁹⁹ Pb	c*	90M	1135.0	7.8 ± 1.2	269.9 ± 43.6
			366.9	44 ± 7	303.3 ± 49.6
			<i>RR_{mean}</i> =		283.7 ± 18.6
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	222.7 ± 38.3
^{197m} Pb	c*	43M	385.9	74 ± 15	143.0 ± 29.4
			222.8	25 ± 6	137.4 ± 34.4
			<i>RR_{mean}</i> =		142.6 ± 6.8
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	69.42 ± 13.35
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	35.71 ± 1.29
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	279.3 ± 10.8
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	67.05 ± 4.96
			579.3	13.8 ± 0.7	68.78 ± 8.87
			367.9	87.2 ± 0.4	61.21 ± 3.21
			<i>RR_{mean}</i> =		63.05 ± 2.91
²⁰⁰ Tl _c	c	26.1H	1514.9	4.0 ± 0.3	227.4 ± 19.4
			1205.7	29.9 ± 1.8	233.9 ± 16.1
			579.3	13.8 ± 0.7	225.3 ± 14.3
			367.9	87.2 ± 0.4	220.6 ± 7.7
			<i>RR_{mean}</i> =		221.7 ± 7.5
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	273.8 ± 33.6
			247.3	9.3 ± 1.1	289.8 ± 36.3
			<i>RR_{mean}</i> =		280.9 ± 16.5
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	62.08 ± 8.10
¹⁹⁷ Tl	c*	2.84H	1411.3	4.5 ± 1.5	167.1 ± 58.3
			152.2	7.3 ± 2.3	329.7 ± 105.2
			<i>RR_{mean}</i> =		252.2 ± 81.6
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	147.7 ± 25.8
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	23.67 ± 1.46
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	36.62 ± 4.97
^{193m} Hg	i(m)	11.8H	407.6	32 ± 6	46.23 ± 8.83
			258.0	49 ± 7	69.51 ± 10.44
			<i>RR_{mean}</i> =		56.05 ± 11.63
¹⁹² Hg	c	4.85H	316.5	*	201.6 ± 25.4
			274.8	50.2 ± 2.5	171.5 ± 10.8
			<i>RR_{mean}</i> =		175.4 ± 5.4
¹⁹⁰ Hg	c*	20.0M	301.8	*	122.5 ± 17.7
			142.6	68 ± 10	131.8 ± 20.7
			<i>RR_{mean}</i> =		126.4 ± 3.9
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	5.760 ± 0.247
			333.0	22.9 ± 0.6	6.077 ± 0.309
			<i>RR_{mean}</i> =		5.861 ± 0.233
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	200.6 ± 22.6
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	13.16 ± 1.17
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	24.24 ± 3.59
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	225.8 ± 28.4
¹⁹¹ Au	c*	3.18H	277.9	7.2 ± 0.5	162.5 ± 14.9

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	185.0 ± 15.8
			295.8	71 ± 5	181.4 ± 15.3
			<i>RR_{mean}</i> =		183.1 ± 9.1
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	183.7 ± 22.4
			456.5	3.4 ± 0.4	153.7 ± 19.1
			409.4	8.0 ± 0.9	152.2 ± 17.9
			359.9	6.0 ± 0.7	158.0 ± 19.3
			351.2	3.4 ± 0.4	184.6 ± 22.8
			129.4	3.2 ± 0.5	167.9 ± 28.3
			<i>RR_{mean}</i> =		163.3 ± 7.9
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	223.6 ± 21.6
			607.6	8.10 ± 0.16	185.4 ± 8.0
			568.8	7.1 ± 0.6	201.0 ± 19.7
			544.9	5.8 ± 0.5	203.5 ± 19.4
			<i>RR_{mean}</i> =		190.0 ± 8.3
¹⁸⁸ Pt	c	10.2D	478.0	*	167.6 ± 9.1
			423.3	4.4 ± 0.3	170.3 ± 13.0
			195.1	18.6 ± 1.2	174.8 ± 13.1
			187.6	19.4 ± 1.2	173.8 ± 12.7
			155.1	*	180.1 ± 19.3
			140.4	2.33 ± 0.15	191.0 ± 16.1
			<i>RR_{mean}</i> =		171.5 ± 5.3
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	154.9 ± 33.6
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	142.3 ± 26.3
¹⁸⁹ Ir	c	13.2D	275.9	0.54 ± 0.07	156.7 ± 22.3
			245.1	6.0 ± 0.6	159.5 ± 17.2
			<i>RR_{mean}</i> =		159.3 ± 6.4
¹⁸⁸ Ir _c	c	41.5H	478.0	14.7 ± 0.6	182.0 ± 10.0
			155.1	30 ± 3	186.4 ± 20.0
			<i>RR_{mean}</i> =		182.2 ± 6.7
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	178.1 ± 12.4
¹⁸⁶ Ir	c	16.64H	773.3	8.9 ± 0.5	78.46 ± 5.85
			434.8	33.9 ± 1.1	78.23 ± 3.94
			296.9	62.3 ± 1.9	79.09 ± 7.35
			<i>RR_{mean}</i> =		78.39 ± 3.47
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	127.0 ± 19.6
			1668.0	3.6 ± 0.6	125.2 ± 21.6
			254.2	13.3 ± 2.4	117.2 ± 22.1
			<i>RR_{mean}</i> =		125.3 ± 6.4
¹⁸⁴ Ir	c*	3.09H	1105.3	5.3 ± 0.7	157.8 ± 22.9
			390.4	25.9 ± 2.4	157.4 ± 15.9
			264.0	68 ± 4	181.3 ± 13.0
			119.8	31 ± 3	184.1 ± 21.8
			<i>RR_{mean}</i> =		176.6 ± 7.8
¹⁸³ Ir	c	57M	392.5	10.4 ± 2.4	170.4 ± 40.3
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	182.3 ± 9.5
			717.4	3.94 ± 0.16	180.5 ± 9.6
			646.1	78 ± 3	175.9 ± 9.0
			592.1	1.32 ± 0.06	167.8 ± 10.5
			<i>RR_{mean}</i> =		177.9 ± 5.9

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	109.5 ± 4.8
			1101.9	49.0 ± 1.3	103.9 ± 4.6
			RR _{mean} =		106.5 ± 4.3
¹⁸² Os	c	22.10H	1221.5	*	213.4 ± 15.7
			1189.2	*	222.7 ± 16.9
			1121.4	*	218.2 ± 13.5
			180.2	33.5 ± 1.7	190.1 ± 12.4
			RR _{mean} =		204.6 ± 6.3
¹⁸¹ Os	c	105M	238.8	44 ± 5	63.98 ± 8.24
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	160.7 ± 8.6
			103.5(D)	25.0 ± 0.8	169.3 ± 15.6
			RR _{mean} =		162.3 ± 8.1
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	176.1 ± 12.2
			208.8	2.95 ± 0.09	162.4 ± 8.9
			162.3	23.3 ± 0.7	185.8 ± 9.0
			107.9	2.17 ± 0.07	191.2 ± 15.6
			RR _{mean} =		176.9 ± 8.4
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	198.5 ± 14.7
			1189.2	15 ± 1	210.1 ± 17.8
			1121.4	31.8 ± 1.6	191.8 ± 12.7
			RR _{mean} =		196.9 ± 8.4
¹⁸¹ Re	c*	19.9H	953.6	3.6 ± 1.0	175.8 ± 49.5
			639.0	6.4 ± 1.4	187.8 ± 41.7
			365.5	56 ± 8	177.1 ± 26.0
			RR _{mean} =		179.0 ± 18.0
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	236.7 ± 18.5
			290.0	26.9 ± 2.3	213.0 ± 21.4
			RR _{mean} =		232.0 ± 11.9
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	247.7 ± 30.0
¹⁷⁸ W	c	21.6D	1340.8(D)	1.03 ± 0.09	133.2 ± 17.4
			1106.1(D)	0.54 ± 0.05	150.3 ± 17.6
			RR _{mean} =		142.6 ± 9.6
¹⁷⁷ W	c	135M	115.7	51 ± 5	165.6 ± 19.8
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	181.9 ± 42.6
¹⁷⁶ Ta	c*	8.09H	1823.7	4.5 ± 0.4	221.7 ± 24.7
			1584.0	5.3 ± 0.4	200.7 ± 19.0
			1555.1	4.0 ± 0.3	206.8 ± 18.1
			1159.3	24.7 ± 1.9	223.0 ± 19.0
			RR _{mean} =		213.6 ± 8.5
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	124.6 ± 19.8
			348.5	12.0 ± 1.1	176.2 ± 17.7
			266.9	10.52 ± 0.16	161.8 ± 7.6
			RR _{mean} =		160.5 ± 9.1
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	154.5 ± 14.3
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	178.4 ± 19.8
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	94.34 ± 9.64
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	161.4 ± 7.9
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	182.8 ± 10.8
			306.6	6.4 ± 0.3	182.8 ± 13.1
			297.0	33.9 ± 1.4	256.0 ± 16.7

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			139.6	12.7 ± 0.6	208.5 ± 15.0
			123.7	83 ± 5	193.3 ± 17.0
			$RR_{mean} =$		197.5 ± 13.9
¹⁷² Hf	c	1.87Y	1093.6	*	133.0 ± 7.7
			1002.7(D)	5.55 ± 0.38	132.4 ± 12.1
			929.1	*	121.5 ± 7.7
			900.7	*	134.6 ± 7.4
			125.8	11.3 ± 0.9	138.3 ± 14.1
			$RR_{mean} =$		132.4 ± 4.1
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	180.1 ± 50.5
			481.3	3.7 ± 1.0	158.3 ± 43.5
			164.7	26 ± 8	170.9 ± 53.0
			120.2	15 ± 5	178.4 ± 60.7
			$RR_{mean} =$		164.7 ± 8.2
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	151.8 ± 8.2
			171.4	2.90 ± 0.15	143.7 ± 14.4
			100.7	5.24 ± 0.20	140.6 ± 14.7
			$RR_{mean} =$		150.0 ± 6.1
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	134.2 ± 7.8
			929.1	3.04 ± 0.14	123.1 ± 7.7
			900.7	29.8 ± 1.3	136.2 ± 7.5
			$RR_{mean} =$		132.9 ± 5.5
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	159.7 ± 7.2
			839.9	3.04 ± 0.08	168.2 ± 7.4
			780.7	4.36 ± 0.11	164.9 ± 7.2
			739.8	47.8 ± 1.2	157.5 ± 6.5
			712.7	1.13 ± 0.03	153.5 ± 8.6
			667.4	11.0 ± 0.3	165.5 ± 7.2
			$RR_{mean} =$		161.9 ± 5.4
¹⁷⁰ Lu	c*	2.012D	2126.1	5.1 ± 0.3	187.5 ± 13.5
			1280.2	8.2 ± 0.4	175.5 ± 10.8
			1054.3	4.76 ± 0.24	183.8 ± 11.6
			$RR_{mean} =$		180.8 ± 7.0
¹⁶⁹ Lu	c	34.06H	1449.7	9.9 ± 0.3	108.4 ± 5.2
			960.6	23.4 ± 0.7	108.0 ± 4.9
			889.8	5.36 ± 0.17	104.1 ± 5.2
			191.2	20.6 ± 0.6	119.2 ± 5.8
			$RR_{mean} =$		109.4 ± 4.5
¹⁶⁷ Lu	c	51.5M	239.0	0.9 ± 0.5	147.2 ± 84.1
			113.3	*	124.7 ± 11.0
			106.2	*	104.5 ± 11.7
			$RR_{mean} =$		115.6 ± 3.6
¹⁶⁹ Yb	c*	32.026D	307.7	10.05 ± 0.19	142.6 ± 5.6
			198.0	35.8 ± 0.7	132.5 ± 5.8
			177.2	22.2 ± 0.5	131.4 ± 5.8
			130.5	11.31 ± 0.21	137.1 ± 8.4
			118.2	1.87 ± 0.04	136.4 ± 10.2
			109.8	17.5 ± 0.4	128.6 ± 9.7
			$RR_{mean} =$		136.7 ± 4.8
¹⁶⁶ Yb	c	56.7H	2079.5	*	104.7 ± 7.9
			1374.2	*	110.5 ± 8.9

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			1176.7	*	105.5 ± 7.7
			785.9	*	119.9 ± 9.1
			691.2(D)	8.56 ± 0.58	100.3 ± 7.7
			<i>RR_{mean}</i> =		107.3 ± 3.3
¹⁶² Yb	c	18.87M	163.4	40 ± 5	82.41 ± 11.05
¹⁶⁷ Tm	c	9.25D	531.5	1.61 ± 0.22	120.7 ± 17.2
			207.8	42 ± 8	121.2 ± 23.6
			<i>RR_{mean}</i> =		120.8 ± 6.2
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	103.9 ± 7.7
			242.9	35.5 ± 1.7	109.0 ± 6.8
			<i>RR_{mean}</i> =		107.3 ± 4.5
¹⁶³ Tm	c	1.810H	104.3	18.6 ± 0.7	78.93 ± 7.50
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	83.73 ± 6.51
¹⁶⁰ Er	c	28.58H	966.2	*	78.47 ± 10.57
			962.4	*	76.70 ± 10.06
			879.4(D)	22.6 ± 2.8	78.18 ± 10.08
			872.0(D)	6.8 ± 1.1	71.18 ± 11.86
			728.2(D)	34 ± 5	82.00 ± 12.38
			<i>RR_{mean}</i> =		77.31 ± 2.38
¹⁵⁹ Er	c*	36M	649.1	23 ± 3	98.54 ± 13.78
			624.5	33 ± 4	83.43 ± 11.21
			121.0	*	72.15 ± 7.25
			<i>RR_{mean}</i> =		78.54 ± 2.42
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	81.16 ± 14.46
			962.4	16.6 ± 2.1	105.3 ± 15.1
			<i>RR_{mean}</i> =		93.07 ± 12.39
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	58.23 ± 3.26
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	55.97 ± 3.13
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	43.13 ± 2.22
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	41.65 ± 3.48
			163.3	4.44 ± 0.24	40.47 ± 3.26
			148.6	2.65 ± 0.14	52.52 ± 4.68
			105.3	25.1 ± 1.3	44.92 ± 4.04
			<i>RR_{mean}</i> =		43.43 ± 2.71
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	32.68 ± 2.40
			102.2	6.4 ± 0.5	22.94 ± 2.70
			<i>RR_{mean}</i> =		29.08 ± 4.78
¹⁵⁰ Tb	c	3.48H	638.0	72 ± 10	12.85 ± 2.21
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	30.85 ± 2.56
			97.4	29.0 ± 0.8	27.61 ± 2.22
			<i>RR_{mean}</i> =		28.99 ± 1.84
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	23.75 ± 2.14
			153.6	6.2 ± 0.4	24.93 ± 2.47
			<i>RR_{mean}</i> =		24.19 ± 1.28
¹⁴⁹ Gd	c	9.28D	346.6	23.9 ± 1.3	24.54 ± 1.65
			298.6	28.6 ± 1.7	25.72 ± 1.79
			149.7	48 ± 3	29.37 ± 2.30
			<i>RR_{mean}</i> =		25.58 ± 1.35
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	20.76 ± 1.57
			396.0	34.3 ± 2.1	20.68 ± 1.51

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			370.0	17.2 ± 0.9	17.65 ± 1.16
			229.3	63 ± 4	20.39 ± 1.57
			<i>RR_{mean}</i> =		19.33 ± 1.04
¹⁴⁶ Gd	c	48.27D	1533.7	*	17.56 ± 1.29
			1297.0	*	18.79 ± 1.38
			747.2	*	18.54 ± 0.83
			154.6	46.6 ± 0.5	19.44 ± 1.09
			115.5	44.0 ± 0.7	21.56 ± 1.51
			114.7	44.0 ± 0.7	21.29 ± 1.50
			<i>RR_{mean}</i> =		19.01 ± 0.59
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	35.67 ± 2.24
			277.1	3.56 ± 0.06	34.60 ± 2.72
			<i>RR_{mean}</i> =		35.26 ± 1.89
¹⁴⁷ Eu	c*	24.1D	798.7	4.8 ± 0.3	24.38 ± 1.88
			677.5	9.8 ± 0.5	24.78 ± 1.77
			601.5	5.9 ± 0.3	23.28 ± 1.89
			121.2	22.9 ± 1.3	21.56 ± 1.89
			<i>RR_{mean}</i> =		23.68 ± 1.01
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	2.957 ± 0.152
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	21.50 ± 0.96
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	13.27 ± 1.15
			1658.5	14.9 ± 1.0	12.35 ± 0.99
			893.7	66 ± 5	11.44 ± 1.00
			653.5	15 ± 1	13.22 ± 1.06
			542.6	4.5 ± 0.4	15.12 ± 2.03
			<i>RR_{mean}</i> =		12.64 ± 0.60
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	11.50 ± 1.29
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	9.801 ± 0.382
¹³² La _c	c	4.8H	464.5	76 ± 6	3.500 ± 0.783
¹³³ Ba	c	3848.9D	356.0	62.05 ± 0.19	7.594 ± 3.614
¹³¹ Ba	c	11.50D	373.2	14.04 ± 0.20	7.293 ± 0.374
			123.8	29.0 ± 0.3	6.957 ± 0.569
			<i>RR_{mean}</i> =		7.212 ± 0.341
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	4.193 ± 0.431
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	11.36 ± 0.83
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	8.468 ± 0.475
			202.9	68.3 ± 0.5	9.053 ± 0.379
			172.1	25.5 ± 0.8	8.578 ± 0.534
			<i>RR_{mean}</i> =		8.833 ± 0.332
¹²³ Xe	c	2.08H	148.9	48.9 ± 0.6	11.98 ± 1.30
¹²⁶ I	i	13.11D	388.6	34 ± 3	1.293 ± 0.236
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	2.835 ± 0.186
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	3.587 ± 0.185
			573.1	88.6 ± 0.1	3.788 ± 0.208
			<i>RR_{mean}</i> =		3.672 ± 0.113
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	9.642 ± 0.450
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	4.075 ± 0.175
¹¹⁶ Te	c	2.49H	1293.6	95 ± 8	7.002 ± 1.113
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	3.260 ± 0.210
			1023.3	99.4 ± 0.3	3.152 ± 0.114

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	3.162 ± 0.113
^{118m} Sb	i(m)	5.00H	1050.7	97 ± 5	4.533 ± 0.493
^{117m} Sn	i(m)	13.60D	158.6	86.4 ± 0.4	6.166 ± 0.287
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	6.679 ± 0.262
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	11.47 ± 0.63
¹¹¹ In	c	2.8047D	245.4	94 ± 1	9.868 ± 0.428
			171.3	90.2 ± 1.0	9.538 ± 0.437
				$RR_{mean} =$	9.716 ± 0.365
			1505.0	13.60 ± 0.19	9.355 ± 0.880
			1384.3	24.9 ± 0.8	9.503 ± 0.675
^{110m} Ag	i(m)	249.76D	937.5	34.2 ± 0.6	8.763 ± 0.502
			884.7	72.7 ± 0.4	9.263 ± 0.354
			657.8	94.3 ± 0.3	9.287 ± 0.374
				$RR_{mean} =$	9.232 ± 0.317
			1045.8	29.6 ± 1.0	7.738 ± 0.400
^{106m} Ag	i(m)	8.28D	717.3	28.9 ± 0.8	6.973 ± 0.368
			451.0	28.2 ± 0.8	6.993 ± 0.370
				$RR_{mean} =$	7.212 ± 0.331
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	8.904 ± 0.718
			280.4	30.2 ± 1.8	8.484 ± 0.692
				$RR_{mean} =$	8.687 ± 0.526
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.8521 ± 0.1601
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	33.30 ± 1.75
^{102m} Rh	i(m)	2.9Y	1046.6	34 ± 2	10.20 ± 1.35
			631.3	56 ± 2	8.497 ± 1.770
				$RR_{mean} =$	9.590 ± 1.089
^{101m} Rh	c	4.34D	306.9	81 ± 5	11.79 ± 0.88
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	6.420 ± 0.523
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	7.272 ± 0.502
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	28.78 ± 1.08
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	10.82 ± 0.59
			812.5	82 ± 4	10.71 ± 0.65
				$RR_{mean} =$	10.77 ± 0.49
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	26.05 ± 1.40
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	4.988 ± 0.460
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	19.14 ± 1.01
			568.9	58.0 ± 0.3	18.70 ± 0.75
				$RR_{mean} =$	18.82 ± 0.71
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	24.57 ± 0.82
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	39.95 ± 1.32
^{92m} Nb	i(m)	10.15D	934.4	99.07 ± 0.04	2.134 ± 0.191
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	6.391 ± 0.348
⁹⁷ Zr	c	16.744H	743.4	93.06 ± 0.16	5.115 ± 0.261
⁹⁵ Zr	c	64.02D	765.8	*	15.52 ± 0.56
			756.7	54.46 ± 0.10	15.76 ± 0.55
			724.2	44.17 ± 0.16	16.96 ± 0.59
				$RR_{mean} =$	15.67 ± 0.48
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	19.34 ± 0.65
⁸⁸ Zr	c	83.4D	898.0	*	9.613 ± 0.523
			392.9	97.24 ± 0.00	9.121 ± 0.321

Continuation of Table 97.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	9.177 ± 0.283
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	21.62 ± 0.94
⁸⁸ Y _i	i	106.65D	898.0	93.7 ± 0.3	26.15 ± 0.90
⁸⁸ Y _c	c	106.65D	898.0	93.7 ± 0.3	35.76 ± 1.20
⁸⁷ Y	c*	79.8H	388.5	82.1 ± 0.5	26.76 ± 0.94
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	25.68 ± 1.39
⁸⁶ Rb	i(m+g)	18.631D	1077.0	8.64 ± 0.04	26.98 ± 1.32
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	26.82 ± 1.37
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	30.46 ± 2.43
			529.6	29.3 ± 2.1	29.28 ± 2.36
			520.4	45 ± 4	29.19 ± 2.80
			RR _{mean} =		29.73 ± 1.33
^{82m} Rb	i(m)	6.472H	554.3	62.4 ± 0.9	11.51 ± 1.32
⁸² Br	i(m+g)	35.30H	1474.9	16.32 ± 0.23	17.64 ± 1.18
			1317.5	26.5 ± 0.4	17.65 ± 0.74
			554.3	70.8 ± 1.0	14.90 ± 0.60
			RR _{mean} =		16.04 ± 1.08
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	11.61 ± 0.46
			136.0	58.3 ± 0.8	13.21 ± 0.77
			121.1	17.2 ± 0.4	14.43 ± 1.29
			RR _{mean} =		12.00 ± 0.67
⁷⁶ As	i	1.0778D	559.1	45 ± 2	22.67 ± 1.45
⁷⁴ As	i	17.77D	595.8	59 ± 4	16.07 ± 1.22
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	1.860 ± 0.110
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	10.27 ± 0.79
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	12.19 ± 0.78
⁷² Zn	c	46.5H	2201.7	*	1.917 ± 0.214
⁶⁵ Zn	c	244.26D	1115.6	50.60 ± 0.24	5.482 ± 0.380
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	7.048 ± 0.366
			1099.2	56.5 ± 1.9	7.430 ± 0.391
			RR _{mean} =		7.224 ± 0.294
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	3.991 ± 0.177
⁴⁸ V	c	15.9735D	983.5	100.0 ± 0.3	0.6538 ± 0.0526
⁴⁸ Sc	i	43.67H	1312.1	100.1 ± 0.7	2.863 ± 0.130
⁴⁶ Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	3.070 ± 0.192
			889.3	99.98 ± 0.00	2.837 ± 0.154
			RR _{mean} =		2.922 ± 0.144
²⁴ Na	c	14.9590H	1369.0	100 ± 0	4.377 ± 0.261
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	19.08 ± 1.19

12.9.6 Nuclide production rates for ^{27}Al

Table 98: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 1.2 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					

Continuation of Table 98.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^7Be	i	53.29D	477.6	10.52 ± 0.06	56.82 ± 2.03
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	4.922 ± 0.212
			1014.4	28.0 ± 0.4	5.028 ± 0.324
			$RR_{mean} = \mathbf{4.945 \pm 0.201}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	98.46 ± 3.33
^{24}Na	c	14.9590H	1369.0	100 ± 0	90.26 ± 3.01
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	3.554 ± 0.119
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	48.64 ± 1.72
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	4.249 ± 0.186
			1014.4	28.0 ± 0.4	4.480 ± 0.299
			$RR_{mean} = \mathbf{4.296 \pm 0.178}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	86.18 ± 2.91
^{24}Na	c	14.9590H	1369.0	100 ± 0	77.37 ± 2.58
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.828 ± 0.095
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	41.71 ± 1.49
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	3.673 ± 0.167
			1014.4	28.0 ± 0.4	3.493 ± 0.236
			$RR_{mean} = \mathbf{3.627 \pm 0.154}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	72.17 ± 2.46
^{24}Na	c	14.9590H	1369.0	100 ± 0	65.88 ± 2.19
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.647 ± 0.088
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	63.18 ± 2.25
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	8.077 ± 0.333
			1014.4	28.0 ± 0.4	8.114 ± 0.458
			$RR_{mean} = \mathbf{8.086 \pm 0.314}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	111.8 ± 3.8
^{24}Na	c	14.9590H	1369.0	100 ± 0	104.7 ± 3.5
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	3.889 ± 0.130
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	41.85 ± 1.50
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	5.538 ± 0.242
			1014.4	28.0 ± 0.4	5.378 ± 0.435
			$RR_{mean} = \mathbf{5.514 \pm 0.232}$		
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	72.84 ± 2.47
^{24}Na	c	14.9590H	1369.0	100 ± 0	68.59 ± 2.28
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	2.992 ± 0.100

12.10 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 1.6$ GeV

12.10.1 Nuclide production rates for ^{206}Pb

Table 99: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 1.6$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	4.992 ± 0.383
			803.1	98.9 ± 1.4	5.433 ± 0.213
			537.5	30.5 ± 0.5	6.232 ± 0.374
			497.1	15.31 ± 0.22	16.80 ± 5.85
			RR _{mean} =		5.493 ± 0.281
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	11.24 ± 1.24
			1764.3	32.5 ± 0.7	14.16 ± 0.66
			RR _{mean} =		13.73 ± 1.12
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	13.56 ± 1.20
			899.2	98 ± 9	16.11 ± 0.58
			374.8	82 ± 5	15.25 ± 3.20
			RR _{mean} =		15.94 ± 0.49
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	17.47 ± 1.33
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	12.97 ± 1.52
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	43.99 ± 1.71
			374.7	89 ± 15	49.88 ± 8.63
			RR _{mean} =		44.08 ± 1.71
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	46.41 ± 1.77
			374.7	89 ± 15	51.79 ± 8.95
			RR _{mean} =		46.48 ± 1.77
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	153.1 ± 5.6
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	30.34 ± 3.43
			422.1	86 ± 5	38.16 ± 2.74
			RR _{mean} =		36.53 ± 3.37
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	110.5 ± 8.0
²⁰⁰ Pb	c	21.5H	1205.7	*	75.59 ± 5.36
			579.3	*	70.96 ± 5.88
			450.5	3.33 ± 0.08	82.56 ± 4.95
			367.9	*	75.96 ± 2.66
			147.6	37.7 ± 1.4	80.89 ± 4.50
			RR _{mean} =		76.47 ± 2.36
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	134.3 ± 22.0
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	99.87 ± 17.17
^{197m} Pb	c*	43M	385.9	74 ± 15	64.22 ± 13.25
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	27.95 ± 5.50
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	71.54 ± 2.59
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	191.5 ± 7.1
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	82.75 ± 5.97
			579.3	13.8 ± 0.7	87.18 ± 8.45
			367.9	87.2 ± 0.4	78.57 ± 3.15
			RR _{mean} =		79.48 ± 3.05
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	158.3 ± 10.9

Continuation of Table 99.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			579.3	13.8 ± 0.7	158.1 ± 10.3
			367.9	87.2 ± 0.4	154.5 ± 5.3
			$RR_{mean} =$		154.9 ± 5.2
$^{199}\text{Tl}_c$	c	7.42H	455.5	12.4 ± 1.4	134.5 ± 16.3
^{199}Tl	c*	7.42H	455.5	12.4 ± 1.4	157.2 ± 18.7
^{198m}Tl	i(m)	1.87H	282.8	28 ± 3	66.04 ± 7.67
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	115.6 ± 20.2
^{203}Hg	c	46.612D	279.2	81.46 ± 0.13	7.378 ± 0.297
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	29.83 ± 1.48
^{195m}Hg	i(m)	41.6H	261.8	31 ± 4	46.84 ± 7.13
^{193m}Hg	i(m)	11.8H	258.0	49 ± 7	59.51 ± 8.91
^{192}Hg	c	4.85H	316.5	*	127.5 ± 16.1
			274.8	50.2 ± 2.5	109.1 ± 6.9
			$RR_{mean} =$		111.5 ± 3.4
^{190}Hg	c*	20.0M	142.6	68 ± 10	74.90 ± 11.56
^{198m}Au	i(m)	2.27D	411.8	*	1.551 ± 0.128
$^{198}\text{Au}_i$	i	2.69517D	411.8	95.58 ± 0.12	3.560 ± 0.261
$^{198}\text{Au}_c$	i(m+g)	2.69517D	411.8	95.58 ± 0.12	5.111 ± 0.212
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	9.774 ± 0.365
			333.0	22.9 ± 0.6	10.66 ± 0.56
			$RR_{mean} =$		9.910 ± 0.442
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	180.2 ± 17.6
^{194}Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	18.40 ± 1.66
$^{192}\text{Au}_i$	i(m+g)	4.94H	316.5	58 ± 7	25.44 ± 3.89
$^{192}\text{Au}_c$	c	4.94H	316.5	58 ± 7	152.9 ± 19.2
^{191}Au	c*	3.18H	674.2	6.8 ± 0.5	164.6 ± 14.2
$^{190}\text{Au}_c$	c	42.8M	301.8	23.4 ± 1.5	110.7 ± 9.5
			295.8	71 ± 5	128.7 ± 11.7
			$RR_{mean} =$		117.3 ± 9.4
^{191}Pt	c	2.802D	538.9	13.7 ± 1.6	136.3 ± 16.7
			456.5	3.4 ± 0.4	117.6 ± 14.6
			409.4	8.0 ± 0.9	108.2 ± 12.8
			$RR_{mean} =$		117.3 ± 8.6
^{189}Pt	c	10.87H	721.4	9.3 ± 0.8	139.3 ± 13.0
			607.6	8.10 ± 0.16	144.5 ± 6.5
			568.8	7.1 ± 0.6	124.9 ± 13.0
			544.9	5.8 ± 0.5	125.9 ± 12.3
			243.5	7.0 ± 1.2	143.9 ± 30.6
			$RR_{mean} =$		140.2 ± 5.8
^{188}Pt	c	10.2D	1209.8	*	119.2 ± 12.8
			423.3	4.4 ± 0.3	117.0 ± 9.1
			381.4	7.5 ± 0.5	115.4 ± 8.6
			195.1	18.6 ± 1.2	117.6 ± 8.8
			187.6	19.4 ± 1.2	117.2 ± 8.5
			$RR_{mean} =$		117.2 ± 3.6
^{186}Pt	c	2.08H	689.4	70 ± 15	99.27 ± 21.55
^{184}Pt	c	17.3M	548.3	23 ± 4	92.64 ± 17.40
^{192}Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.4885 ± 0.0828
^{190}Ir	i(m1+g)	11.78D	569.3	28.5 ± 1.3	1.512 ± 0.272
^{189}Ir	c	13.2D	245.1	6.0 ± 0.6	103.4 ± 11.4

Continuation of Table 99.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	115.7 ± 12.6
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	122.5 ± 7.5
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	52.71 ± 3.05
			137.2	41.4 ± 0.7	56.75 ± 4.16
			<i>RR_{mean}</i> =		53.99 ± 2.69
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	91.04 ± 14.27
			254.2	13.3 ± 2.4	77.51 ± 14.65
			<i>RR_{mean}</i> =		87.84 ± 6.36
¹⁸⁴ Ir	c*	3.09H	390.4	25.9 ± 2.4	113.7 ± 11.3
			264.0	68 ± 4	111.2 ± 8.0
			119.8	31 ± 3	109.8 ± 12.1
			<i>RR_{mean}</i> =		111.4 ± 4.6
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	129.6 ± 6.9
			717.4	3.94 ± 0.16	117.3 ± 7.0
			646.1	78 ± 3	117.6 ± 6.0
			<i>RR_{mean}</i> =		120.5 ± 5.2
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	75.24 ± 3.40
			1101.9	49.0 ± 1.3	66.61 ± 2.97
			<i>RR_{mean}</i> =		70.17 ± 4.77
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	125.9 ± 7.7
			180.2	33.5 ± 1.7	121.2 ± 7.8
			<i>RR_{mean}</i> =		123.6 ± 5.9
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	97.59 ± 5.71
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	120.3 ± 8.8
			162.3	23.3 ± 0.7	126.1 ± 6.0
			<i>RR_{mean}</i> =		125.0 ± 5.1
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	126.6 ± 9.3
			1189.2	15 ± 1	124.2 ± 10.6
			<i>RR_{mean}</i> =		125.7 ± 6.5
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	119.1 ± 26.6
			365.5	56 ± 8	112.0 ± 16.8
			<i>RR_{mean}</i> =		113.7 ± 12.5
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	177.9 ± 16.5
			290.0	26.9 ± 2.3	139.0 ± 14.4
			<i>RR_{mean}</i> =		158.2 ± 20.1
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	169.6 ± 20.5
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	96.23 ± 10.51
			1340.8(D)	1.03 ± 0.09	83.42 ± 9.09
			<i>RR_{mean}</i> =		88.86 ± 6.90
¹⁷⁷ W	c	135M	115.7	51 ± 5	101.8 ± 11.2
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	114.3 ± 26.0
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	81.93 ± 14.81
			1159.3	24.7 ± 1.9	107.5 ± 9.3
			710.5	5.4 ± 0.4	153.9 ± 15.2
			<i>RR_{mean}</i> =		112.0 ± 12.7
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	93.39 ± 14.99
			348.5	12.0 ± 1.1	133.5 ± 13.2
			266.9	10.52 ± 0.16	116.0 ± 5.2
			<i>RR_{mean}</i> =		116.1 ± 6.1
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	118.4 ± 11.0

Continuation of Table 99.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	125.6 ± 13.9
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	72.84 ± 7.66
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	114.8 ± 5.6
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	136.9 ± 8.6
			139.6	12.7 ± 0.6	135.8 ± 8.8
			123.7	83 ± 5	142.3 ± 10.7
			RR _{mean} =		137.6 ± 5.6
¹⁷² Hf	c	1.87Y	1093.6	*	100.2 ± 5.9
			1002.7(D)	5.55 ± 0.38	99.51 ± 9.47
			181.5	*	102.3 ± 6.4
			125.8	11.3 ± 0.9	104.6 ± 9.8
		RR _{mean} =		101.3 ± 3.1	
¹⁷¹ Hf	c	12.1H	739.8	*	100.0 ± 12.5
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	142.7 ± 40.0
			164.7	26 ± 8	132.6 ± 41.1
			120.2	15 ± 5	137.0 ± 46.2
			RR _{mean} =		140.2 ± 9.9
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	115.1 ± 6.3
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.3884 ± 0.0917
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	100.6 ± 5.9
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	116.9 ± 6.8
			780.7	4.36 ± 0.11	136.8 ± 6.2
			667.4	11.0 ± 0.3	125.3 ± 5.5
			RR _{mean} =		127.9 ± 6.4
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	117.0 ± 4.9
¹⁷⁰ Lu _c	c	2.012D	2126.1	5.1 ± 0.3	102.3 ± 8.2
			1280.2	8.2 ± 0.4	100.1 ± 6.7
			1054.3	4.76 ± 0.24	89.42 ± 6.67
			RR _{mean} =		96.82 ± 4.90
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	91.70 ± 4.20
			191.2	20.6 ± 0.6	101.0 ± 4.9
		RR _{mean} =		95.30 ± 5.40	
¹⁶⁷ Lu	c	51.5M	176.2	*	86.80 ± 4.85
			113.3	*	107.5 ± 7.8
		RR _{mean} =		91.89 ± 9.36	
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	111.4 ± 5.1
			177.2	22.2 ± 0.5	108.7 ± 4.7
			130.5	11.31 ± 0.21	113.0 ± 5.3
			RR _{mean} =		110.7 ± 3.9
¹⁶⁶ Yb	c	56.7H	2079.5	*	96.05 ± 7.30
			2052.4	*	104.0 ± 7.3
			1867.9	*	104.0 ± 7.5
			1374.2	*	102.5 ± 8.3
			1176.7	*	100.1 ± 7.3
			785.9	*	104.1 ± 7.5
			691.2(D)	8.56 ± 0.58	92.96 ± 7.23
RR _{mean} =		100.4 ± 3.1			
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	112.6 ± 21.9
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	105.2 ± 7.7
			242.9	35.5 ± 1.7	104.1 ± 6.5

Continuation of Table 99.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	104.4 $\pm$ 4.3
^{161}Er	c*	3.21H	826.6	64 $\pm$ 4	111.1 $\pm$ 8.2
^{160}Er	c	28.58H	966.2	*	96.18 $\pm$ 12.95
			962.4	*	94.27 $\pm$ 12.37
			879.4(D)	22.6 $\pm$ 2.8	102.7 $\pm$ 13.3
			872.0(D)	6.8 $\pm$ 1.1	102.1 $\pm$ 17.1
			728.2(D)	34 $\pm$ 5	101.9 $\pm$ 15.4
				$RR_{mean} =$	99.05 $\pm$ 3.06
^{159}Er	c*	36M	624.5	33 $\pm$ 4	111.9 $\pm$ 14.3
			132.0	*	126.7 $\pm$ 8.7
				$RR_{mean} =$	123.2 $\pm$ 3.8
$^{160m}\text{Ho}_c$	c	5.02H	966.2	15.4 $\pm$ 2.0	99.08 $\pm$ 13.41
			962.4	16.6 $\pm$ 2.1	93.34 $\pm$ 12.93
				$RR_{mean} =$	96.12 $\pm$ 9.01
^{156}Ho	c*	56M	266.5	54.7 $\pm$ 1.1	102.7 $\pm$ 4.9
^{157}Dy	c	8.14H	326.2	92 $\pm$ 4	84.88 $\pm$ 4.72
^{155}Dy	c*	9.9H	226.9	68.4 $\pm$ 1.6	73.73 $\pm$ 3.43
^{152}Dy	c	2.38H	256.9	97.50 $\pm$ 0.07	41.93 $\pm$ 1.76
^{155}Tb	c*	5.32D	180.1	7.5 $\pm$ 0.5	64.82 $\pm$ 5.12
			105.3	25.1 $\pm$ 1.3	75.44 $\pm$ 5.47
				$RR_{mean} =$	70.56 $\pm$ 5.72
^{153}Tb	c*	2.34D	212.0	31.0 $\pm$ 1.9	57.99 $\pm$ 4.24
^{152}Tb	c*	17.5H	344.3	65 $\pm$ 4	51.67 $\pm$ 3.67
^{151}Tb	c	17.609H	479.4	15.4 $\pm$ 0.7	46.30 $\pm$ 3.00
			251.9	26.3 $\pm$ 1.2	41.02 $\pm$ 2.68
				$RR_{mean} =$	43.38 $\pm$ 2.95
^{149}Tb	c	4.118H	165.0	26.4 $\pm$ 0.9	18.01 $\pm$ 1.84
^{148}Tb	c	60M	784.4	84.0 $\pm$ 1.6	27.74 $\pm$ 1.35
^{153}Gd	c	240.4D	103.2	21.1 $\pm$ 0.7	54.89 $\pm$ 3.36
			97.4	29.0 $\pm$ 0.8	52.29 $\pm$ 3.02
				$RR_{mean} =$	53.40 $\pm$ 2.41
^{151}Gd	c	124D	243.3	5.6 $\pm$ 0.4	47.38 $\pm$ 4.03
^{149}Gd	c	9.28D	788.9	7.3 $\pm$ 0.4	62.34 $\pm$ 4.15
			346.6	23.9 $\pm$ 1.3	54.43 $\pm$ 3.49
			298.6	28.6 $\pm$ 1.7	55.41 $\pm$ 3.84
			149.7	48 $\pm$ 3	60.56 $\pm$ 4.44
				$RR_{mean} =$	56.98 $\pm$ 2.62
^{147}Gd	c	38.06H	929.0	20.2 $\pm$ 1.2	46.86 $\pm$ 3.60
			396.0	34.3 $\pm$ 2.1	43.26 $\pm$ 3.05
			370.0	17.2 $\pm$ 0.9	46.43 $\pm$ 3.00
				$RR_{mean} =$	45.43 $\pm$ 1.90
^{146}Gd	c	48.27D	747.2	*	46.74 $\pm$ 2.09
			154.6	46.6 $\pm$ 0.5	48.62 $\pm$ 2.28
				$RR_{mean} =$	47.56 $\pm$ 1.47
^{149}Eu	c*	93.1D	327.5	4.03 $\pm$ 0.12	67.41 $\pm$ 3.70
^{147}Eu	c*	24.1D	955.8	3.84 $\pm$ 0.20	53.93 $\pm$ 3.81
			798.7	4.8 $\pm$ 0.3	61.81 $\pm$ 4.50
			677.5	9.8 $\pm$ 0.5	57.50 $\pm$ 3.56
			601.5	5.9 $\pm$ 0.3	57.79 $\pm$ 3.63
			121.2	22.9 $\pm$ 1.3	52.66 $\pm$ 3.84

Continuation of Table 99.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	56.71 $\pm$ 2.21
$^{146}\text{Eu}_i$	i	4.61D	747.2	99 ± 3	6.290 $\pm$ 0.306
$^{146}\text{Eu}_c$	c	4.61D	747.2	99 ± 3	53.03 $\pm$ 2.37
^{145}Eu	c	5.93D	1997.0	7.2 ± 0.5	38.05 ± 3.22
			1658.5	14.9 ± 1.0	34.59 ± 2.69
			893.7	66 ± 5	37.14 ± 3.11
			653.5	15 ± 1	35.49 ± 2.68
				$RR_{mean} =$	36.04 $\pm$ 1.59
^{143}Pm	c	265D	742.0	38.5 ± 2.4	31.58 $\pm$ 2.28
^{139}Ce	c	137.640D	165.9	79.89 ± 0.01	27.74 $\pm$ 1.01
^{135}Ce	c	17.7H	265.6	41.8 ± 1.5	17.11 $\pm$ 1.05
^{132}Ce	c	3.51H	182.1	77.4 ± 0.5	12.01 $\pm$ 0.76
$^{132}\text{La}_c$	c	4.8H	464.5	76 ± 6	12.46 $\pm$ 1.13
^{133}Ba	c	3848.9D	356.0	62.05 ± 0.19	17.29 $\pm$ 1.79
^{131}Ba	c	11.50D	496.3	46.8 ± 0.2	13.09 ± 1.46
			373.2	14.04 ± 0.20	15.43 ± 0.64
			123.8	29.0 ± 0.3	14.43 ± 0.73
				$RR_{mean} =$	14.97 $\pm$ 0.65
^{128}Ba	c	2.43D	442.9	26.8 ± 1.4	9.553 ± 0.819
			273.4	14.5 ± 0.7	10.36 ± 0.91
				$RR_{mean} =$	9.906 $\pm$ 0.552
^{129}Cs	c	32.06H	371.9	30.6 ± 1.7	17.09 $\pm$ 1.20
^{127}Xe	c	36.4D	375.0	17.2 ± 0.6	13.47 ± 0.73
			202.9	68.3 ± 0.5	12.20 ± 0.48
				$RR_{mean} =$	12.45 $\pm$ 0.63
^{123}Xe	c	2.08H	148.9	48.9 ± 0.6	13.38 $\pm$ 1.26
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.100 $\pm$ 0.076
^{121m}Te	i(m)	154D	212.2	81.4 ± 1.1	1.876 ± 0.150
			573.1	88.6 ± 0.1	1.837 ± 0.305
				$RR_{mean} =$	1.869 $\pm$ 0.058
$^{121}\text{Te}_c$	c	19.16D	573.1	80.3 ± 2.5	9.819 $\pm$ 0.504
^{119m}Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.832 $\pm$ 0.185
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	1.523 ± 0.082
			1023.3	99.4 ± 0.3	1.349 ± 0.070
				$RR_{mean} =$	1.420 $\pm$ 0.096
^{113}Sn	c	115.09D	391.7	64.97 ± 0.17	5.696 $\pm$ 0.263
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	4.773 $\pm$ 0.966
^{111}In	c	2.8047D	245.4	94 ± 1	7.971 ± 0.377
			171.3	90.2 ± 1.0	6.877 ± 0.333
				$RR_{mean} =$	7.367 $\pm$ 0.590
^{110m}Ag	i(m)	249.76D	884.7	72.7 ± 0.4	3.539 ± 0.239
			657.8	94.3 ± 0.3	3.577 ± 0.175
				$RR_{mean} =$	3.566 $\pm$ 0.159
^{106m}Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	4.920 ± 0.317
			717.3	28.9 ± 0.8	4.923 ± 0.365
			451.0	28.2 ± 0.8	4.402 ± 0.267
				$RR_{mean} =$	4.681 $\pm$ 0.233
^{105}Ag	c	41.29D	443.4	10.5 ± 0.6	8.083 ± 0.957
			280.4	30.2 ± 1.8	6.427 ± 0.505
				$RR_{mean} =$	6.754 $\pm$ 0.692

Continuation of Table 99.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{100}Pd	c	3.63D	2376.0	*	1.174 $\pm$ 0.178
^{102}Rh	i	207D	475.1	46 $\pm$ 5	3.616 $\pm$ 0.469
^{101m}Rh	c	4.34D	306.9	81 $\pm$ 5	8.156 $\pm$ 0.729
$^{100}\text{Rh}_i$	i(m+g)	20.8H	2376.0	32.6 $\pm$ 0.4	5.280 $\pm$ 0.513
$^{100}\text{Rh}_c$	c	20.8H	2376.0	32.6 $\pm$ 0.4	6.454 $\pm$ 0.491
^{103}Ru	c	39.26D	497.1	91.0 $\pm$ 1.3	11.16 $\pm$ 0.46
^{96}Tc	i(m+g)	4.28D	849.9	98 $\pm$ 4	6.682 $\pm$ 0.365
			812.5	82 $\pm$ 4	7.222 $\pm$ 0.433
			$RR_{\text{mean}} =$		6.896 $\pm$ 0.339
^{99}Mo	c	65.94H	140.5	90.27 $\pm$ 0.33	9.574 $\pm$ 0.413
^{93m}Mo	i(m)	6.85H	684.7	99.7 $\pm$ 2.0	4.434 $\pm$ 0.273
^{96}Nb	i	23.35H	1091.3	48.5 $\pm$ 1.6	7.537 $\pm$ 0.543
			568.9	58.0 $\pm$ 0.3	7.023 $\pm$ 0.555
			$RR_{\text{mean}} =$		7.291 $\pm$ 0.420
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 $\pm$ 0.03	10.53 $\pm$ 0.40
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 $\pm$ 0.03	16.86 $\pm$ 0.58
^{90}Nb	c*	14.60H	2319.0	82.0 $\pm$ 0.3	5.816 $\pm$ 0.403
			1129.2	92.7 $\pm$ 0.5	5.802 $\pm$ 0.337
			$RR_{\text{mean}} =$		5.808 $\pm$ 0.287
^{95}Zr	c	64.02D	765.8	*	6.391 $\pm$ 0.322
			756.7	54.46 $\pm$ 0.10	5.492 $\pm$ 0.296
			$RR_{\text{mean}} =$		5.922 $\pm$ 0.183
^{89}Zr	c	78.41H	909.2	99.04 $\pm$ 0.03	13.04 $\pm$ 0.45
^{88}Zr	c	83.4D	1836.1	*	7.525 $\pm$ 0.395
			898.0	*	7.049 $\pm$ 0.645
			392.9	97.24 $\pm$ 0.00	7.156 $\pm$ 0.278
			$RR_{\text{mean}} =$		7.227 $\pm$ 0.223
$^{88}\text{Y}_i$	i	106.65D	1836.1	99.2 $\pm$ 0.3	14.99 $\pm$ 0.56
			898.0	93.7 $\pm$ 0.3	15.09 $\pm$ 0.65
			$RR_{\text{mean}} =$		15.02 $\pm$ 0.53
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 $\pm$ 0.3	22.52 $\pm$ 0.80
			898.0	93.7 $\pm$ 0.3	22.14 $\pm$ 0.80
			$RR_{\text{mean}} =$		22.34 $\pm$ 0.75
^{87}Y	c*	79.8H	484.8	89.7 $\pm$ 0.7	17.63 $\pm$ 0.64
$^{86}\text{Y}_c$	c	14.74H	1076.6	82.5 $\pm$ 0.4	7.776 $\pm$ 0.374
^{85}Sr	c	64.84D	514.0	96 $\pm$ 4	17.16 $\pm$ 0.94
^{84}Rb	i(m+g)	32.77D	881.6	69.0 $\pm$ 1.6	15.49 $\pm$ 0.79
^{83}Rb	c	86.2D	552.6	16.0 $\pm$ 1.1	21.06 $\pm$ 1.67
			529.6	29.3 $\pm$ 2.1	19.52 $\pm$ 1.59
			520.4	45 $\pm$ 4	19.47 $\pm$ 1.88
			$RR_{\text{mean}} =$		20.11 $\pm$ 0.90
^{82m}Rb	i(m)	6.472H	554.3	62.4 $\pm$ 0.9	7.895 $\pm$ 0.787
^{82}Br	i(m+g)	35.30H	554.3	70.8 $\pm$ 1.0	6.713 $\pm$ 0.329
^{75}Se	c	119.779D	264.7	58.9 $\pm$ 0.4	8.818 $\pm$ 0.352
			136.0	58.3 $\pm$ 0.8	9.767 $\pm$ 0.431
			121.1	17.2 $\pm$ 0.4	10.94 $\pm$ 0.97
			$RR_{\text{mean}} =$		9.213 $\pm$ 0.487
^{74}As	i	17.77D	595.8	59 $\pm$ 4	10.60 $\pm$ 0.81
^{71}As	c	65.28H	174.9	82.0 $\pm$ 2.1	1.983 $\pm$ 0.158
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 $\pm$ 0.5	4.589 $\pm$ 0.945

Continuation of Table 99.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	6.070 ± 0.872
^{72}Zn	c	46.5H	2201.7	*	1.481 ± 0.386
^{58}Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	3.501 ± 0.299
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	4.739 ± 0.257
			1099.2	56.5 ± 1.9	4.709 ± 0.256
			$RR_{mean} =$		4.724 ± 0.199
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	4.318 ± 0.214
^{48}V	c	15.9735D	1312.1	97.5 ± 0.9	0.6487 ± 0.0798
			983.5	100.0 ± 0.3	0.7455 ± 0.0504
			$RR_{mean} =$		0.7211 ± 0.0476
^{48}Sc	i	43.67H	1312.1	100.1 ± 0.7	2.399 ± 0.227
			1037.5	97.6 ± 0.7	2.166 ± 0.127
			$RR_{mean} =$		2.213 ± 0.118
^{46}Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	3.646 ± 0.230
			889.3	99.98 ± 0.00	4.247 ± 0.163
			$RR_{mean} =$		4.135 ± 0.267
^{28}Mg	c	20.915H	1778.8	100.2 ± 0.0	1.872 ± 0.200
^{24}Na	c	14.9590H	1369.0	100 ± 0	6.214 ± 0.294
^7Be	i	53.29D	477.6	10.52 ± 0.06	17.40 ± 1.21

12.10.2 Nuclide production rates for ^{207}Pb

Table 100: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 1.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	7.396 ± 0.371
			803.1	98.9 ± 1.4	7.301 ± 0.269
			537.5	30.5 ± 0.5	7.304 ± 0.418
			497.1	15.31 ± 0.22	10.00 ± 2.43
			$RR_{mean} =$		7.325 ± 0.257
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	9.488 ± 0.801
			1764.3	32.5 ± 0.7	10.79 ± 0.52
			$RR_{mean} =$		10.49 ± 0.63
^{204}Bi	i	11.22H	984.0	59 ± 4	13.96 ± 1.31
			899.2	98 ± 9	11.01 ± 0.46
			374.8	82 ± 5	10.09 ± 2.12
			$RR_{mean} =$		11.16 ± 0.34
^{203}Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	11.84 ± 0.84
^{202}Bi	i	1.72H	422.1	83.7 ± 2.5	8.699 ± 1.023
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	27.35 ± 1.48
			374.7	89 ± 15	30.94 ± 5.38
			$RR_{mean} =$		27.53 ± 1.46
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	29.00 ± 1.51
			374.7	89 ± 15	32.21 ± 5.60
			$RR_{mean} =$		29.15 ± 1.49
^{203}Pb	c*	51.873H	279.2	80.8 ± 0.2	80.19 ± 2.93
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	21.91 ± 2.37
			422.1	86 ± 5	23.64 ± 1.75

Continuation of Table 100.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	23.27 ± 1.15
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	59.97 ± 4.36
²⁰⁰ Pb	c	21.5H	579.3	*	37.87 ± 3.25
			1205.7	*	42.10 ± 3.31
			450.5	3.33 ± 0.08	49.34 ± 4.15
			367.9	*	40.75 ± 1.46
			257.2	4.46 ± 0.17	33.29 ± 4.80
			147.6	37.7 ± 1.4	45.02 ± 2.45
				<i>RR_{mean}</i> =	40.86 ± 1.26
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	78.89 ± 13.06
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	58.67 ± 10.16
^{197m} Pb	c*	43M	385.9	74 ± 15	35.49 ± 7.40
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	15.45 ± 3.14
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	42.47 ± 1.54
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	111.0 ± 4.1
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	50.71 ± 4.30
			579.3	13.8 ± 0.7	54.21 ± 5.68
			367.9	87.2 ± 0.4	47.01 ± 1.93
				<i>RR_{mean}</i> =	47.67 ± 1.94
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	92.82 ± 6.52
			579.3	13.8 ± 0.7	92.08 ± 6.17
			367.9	87.2 ± 0.4	87.76 ± 3.03
				<i>RR_{mean}</i> =	88.22 ± 2.99
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	66.98 ± 9.12
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	87.15 ± 10.70
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	44.42 ± 5.39
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	70.00 ± 12.24
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	7.470 ± 0.283
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	21.72 ± 1.07
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	30.30 ± 4.40
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	41.11 ± 6.13
¹⁹² Hg	c	4.85H	316.5	*	73.95 ± 9.40
			274.8	50.2 ± 2.5	63.87 ± 4.05
				<i>RR_{mean}</i> =	65.19 ± 2.01
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	46.19 ± 7.23
^{198m} Au	i(m)	2.27D	411.8	*	1.230 ± 0.184
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	3.095 ± 0.346
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	4.325 ± 0.229
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	7.420 ± 0.281
			333.0	22.9 ± 0.6	7.851 ± 0.368
				<i>RR_{mean}</i> =	7.521 ± 0.295
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	85.75 ± 8.46
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	12.82 ± 1.14
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	18.43 ± 2.85
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	92.38 ± 11.64
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	99.53 ± 9.80
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	67.23 ± 7.19
			295.8	71 ± 5	71.11 ± 9.87
				<i>RR_{mean}</i> =	68.40 ± 5.25
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	87.95 ± 11.01

Continuation of Table 100.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			456.5	3.4 ± 0.4	65.75 ± 8.23
			409.4	8.0 ± 0.9	68.11 ± 8.03
			<i>RR_{mean}</i> =		70.97 ± 6.14
			721.4	9.3 ± 0.8	83.26 ± 7.89
			607.6	8.10 ± 0.16	84.41 ± 4.55
¹⁸⁹ Pt	c	10.87H	568.8	7.1 ± 0.6	85.16 ± 9.36
			544.9	5.8 ± 0.5	76.18 ± 7.58
			243.5	7.0 ± 1.2	107.1 ± 22.5
			<i>RR_{mean}</i> =		83.42 ± 3.82
			1209.8	*	73.19 ± 7.89
¹⁸⁸ Pt	c	10.2D	423.3	4.4 ± 0.3	71.12 ± 5.52
			381.4	7.5 ± 0.5	68.50 ± 5.18
			195.1	18.6 ± 1.2	69.12 ± 5.17
			187.6	19.4 ± 1.2	71.12 ± 5.19
			<i>RR_{mean}</i> =		70.44 ± 2.17
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	59.68 ± 12.96
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	56.17 ± 12.30
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.4604 ± 0.0992
¹⁹⁰ Ir	i(m1+g)	11.78D	569.3	28.5 ± 1.3	1.083 ± 0.191
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	71.11 ± 8.11
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	74.83 ± 8.12
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	73.55 ± 5.24
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	35.23 ± 1.74
			137.2	41.4 ± 0.7	35.97 ± 3.30
			<i>RR_{mean}</i> =		35.35 ± 1.64
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	54.71 ± 8.56
			254.2	13.3 ± 2.4	45.70 ± 11.06
			<i>RR_{mean}</i> =		53.75 ± 3.32
¹⁸⁴ Ir	c*	3.09H	390.4	25.9 ± 2.4	68.43 ± 6.87
			264.0	68 ± 4	69.55 ± 4.93
			119.8	31 ± 3	69.13 ± 7.63
			<i>RR_{mean}</i> =		69.39 ± 2.76
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	75.94 ± 4.12
			717.4	3.94 ± 0.16	76.03 ± 4.54
			646.1	78 ± 3	73.22 ± 3.74
			<i>RR_{mean}</i> =		74.10 ± 2.46
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	44.69 ± 2.56
			1101.9	49.0 ± 1.3	42.12 ± 1.87
			<i>RR_{mean}</i> =		42.58 ± 1.64
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	74.60 ± 5.74
			180.2	33.5 ± 1.7	78.50 ± 5.12
			<i>RR_{mean}</i> =		76.89 ± 4.03
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	61.23 ± 3.21
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	70.55 ± 5.09
			162.3	23.3 ± 0.7	77.35 ± 3.66
			<i>RR_{mean}</i> =		75.94 ± 3.62
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	81.11 ± 6.21
			1189.2	15 ± 1	64.20 ± 5.84
			<i>RR_{mean}</i> =		73.03 ± 8.74
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	73.16 ± 16.34

Continuation of Table 100.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			365.5	56 ± 8	68.11 ± 10.03
			<i>RR_{mean}</i> =		69.24 ± 7.45
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	96.53 ± 7.84
			290.0	26.9 ± 2.3	80.28 ± 9.38
			<i>RR_{mean}</i> =		93.22 ± 7.15
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	102.5 ± 12.6
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	71.24 ± 8.05
			1340.8(D)	1.03 ± 0.09	51.92 ± 6.03
			<i>RR_{mean}</i> =		59.23 ± 9.55
¹⁷⁷ W	c	135M	115.7	51 ± 5	70.20 ± 7.80
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	77.67 ± 17.74
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	73.96 ± 11.24
			1159.3	24.7 ± 1.9	70.70 ± 6.03
			710.5	5.4 ± 0.4	78.30 ± 10.47
			<i>RR_{mean}</i> =		71.25 ± 2.94
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	63.40 ± 10.24
			348.5	12.0 ± 1.1	85.88 ± 8.81
			266.9	10.52 ± 0.16	72.67 ± 3.38
			<i>RR_{mean}</i> =		73.18 ± 3.72
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	74.24 ± 6.92
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	82.51 ± 9.29
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	49.95 ± 5.21
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	71.60 ± 3.53
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	86.21 ± 5.18
			139.6	12.7 ± 0.6	89.12 ± 5.97
			123.7	83 ± 5	86.86 ± 6.55
			<i>RR_{mean}</i> =		87.18 ± 3.52
¹⁷² Hf	c	1.87Y	1093.6	*	61.23 ± 3.59
			1002.7(D)	5.55 ± 0.38	57.88 ± 7.44
			181.5	*	61.71 ± 3.93
			125.8	11.3 ± 0.9	65.22 ± 6.22
			<i>RR_{mean}</i> =		61.75 ± 1.90
¹⁷¹ Hf	c	12.1H	739.8	*	64.00 ± 6.13
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	87.22 ± 24.57
			164.7	26 ± 8	84.05 ± 26.07
			120.2	15 ± 5	85.00 ± 28.66
			<i>RR_{mean}</i> =		86.32 ± 6.38
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	70.51 ± 3.80
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.5557 ± 0.0910
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	61.79 ± 3.62
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	76.52 ± 3.73
			780.7	4.36 ± 0.11	82.54 ± 3.72
			667.4	11.0 ± 0.3	77.47 ± 3.48
			<i>RR_{mean}</i> =		78.95 ± 3.06
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	72.35 ± 3.02
¹⁷⁰ Lu _c	c	2.012D	2126.1	5.1 ± 0.3	66.19 ± 5.33
			1280.2	8.2 ± 0.4	63.61 ± 4.49
			1054.3	4.76 ± 0.24	59.80 ± 4.14
			<i>RR_{mean}</i> =		62.49 ± 2.71
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	55.99 ± 2.63

Continuation of Table 100.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{167}Lu	c	51.5M	191.2	20.6 ± 0.6	60.79 ± 3.00
			$RR_{mean} =$		57.94 ± 2.96
			176.2	*	58.37 ± 3.42
			113.3	*	66.51 ± 5.03
^{169}Yb	c*	32.026D	$RR_{mean} =$		60.70 ± 4.13
			198.0	35.8 ± 0.7	65.22 ± 2.93
			177.2	22.2 ± 0.5	67.00 ± 2.92
			130.5	11.31 ± 0.21	66.21 ± 3.13
^{166}Yb	c	56.7H	$RR_{mean} =$		66.17 ± 2.31
			2079.5	*	63.60 ± 4.78
			2052.4	*	62.94 ± 4.44
			1867.9	*	62.27 ± 4.71
			1374.2	*	66.99 ± 5.58
			1176.7	*	62.01 ± 4.66
			785.9	*	67.71 ± 4.94
			691.2(D)	8.56 ± 0.58	58.04 ± 4.50
			$RR_{mean} =$		63.07 ± 1.95
^{167}Tm	c	9.25D	207.8	42 ± 8	68.17 ± 13.25
^{165}Tm	c	30.06H	806.4	9.5 ± 0.6	68.34 ± 5.24
			242.9	35.5 ± 1.7	63.06 ± 3.92
			$RR_{mean} =$		64.29 ± 2.99
^{161}Er	c*	3.21H	826.6	64 ± 4	68.60 ± 5.02
^{160}Er	c	28.58H	966.2	*	59.35 ± 7.98
			962.4	*	58.26 ± 7.70
			879.4(D)	22.6 ± 2.8	62.42 ± 8.06
			872.0(D)	6.8 ± 1.1	57.66 ± 9.63
			728.2(D)	34 ± 5	60.03 ± 9.07
			$RR_{mean} =$		59.67 ± 1.84
^{159}Er	c*	36M	624.5	33 ± 4	63.86 ± 8.37
			132.0	*	69.34 ± 4.50
			$RR_{mean} =$		68.29 ± 2.11
$^{160m}\text{Ho}_c$	c	5.02H	966.2	15.4 ± 2.0	59.64 ± 8.17
			962.4	16.6 ± 2.1	51.32 ± 7.70
			$RR_{mean} =$		55.30 ± 5.44
^{156}Ho	c*	56M	266.5	54.7 ± 1.1	60.05 ± 3.00
^{157}Dy	c	8.14H	326.2	92 ± 4	51.38 ± 2.88
^{155}Dy	c*	9.9H	226.9	68.4 ± 1.6	42.69 ± 1.99
^{152}Dy	c	2.38H	256.9	97.50 ± 0.07	25.05 ± 1.14
^{155}Tb	c*	5.32D	180.1	7.5 ± 0.5	40.25 ± 3.23
			105.3	25.1 ± 1.3	44.20 ± 3.26
			$RR_{mean} =$		42.46 ± 2.36
^{153}Tb	c*	2.34D	212.0	31.0 ± 1.9	35.86 ± 2.62
^{152}Tb	c*	17.5H	344.3	65 ± 4	32.57 ± 2.42
^{151}Tb	c	17.609H	479.4	15.4 ± 0.7	26.27 ± 1.84
			251.9	26.3 ± 1.2	25.06 ± 1.72
			$RR_{mean} =$		25.61 ± 1.27
^{149}Tb	c	4.118H	165.0	26.4 ± 0.9	10.06 ± 1.84
^{148}Tb	c	60M	784.4	84.0 ± 1.6	13.99 ± 0.78
^{153}Gd	c	240.4D	103.2	21.1 ± 0.7	32.47 ± 2.13
			97.4	29.0 ± 0.8	30.56 ± 1.81

Continuation of Table 100.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	31.31 $\pm$ 1.47
^{151}Gd	c	124D	243.3	5.6 ± 0.4	26.87 $\pm$ 2.59
^{149}Gd	c	9.28D	788.9	7.3 ± 0.4	37.35 ± 2.48
			346.6	23.9 ± 1.3	31.93 ± 2.05
			298.6	28.6 ± 1.7	31.71 ± 2.19
			149.7	48 ± 3	34.68 ± 2.55
				$RR_{mean} =$	33.38 $\pm$ 1.67
^{147}Gd	c	38.06H	929.0	20.2 ± 1.2	26.57 ± 1.85
			396.0	34.3 ± 2.1	24.75 ± 1.77
			370.0	17.2 ± 0.9	26.51 ± 1.74
				$RR_{mean} =$	25.98 $\pm$ 1.07
^{146}Gd	c	48.27D	747.2	*	26.70 ± 1.20
			154.6	46.6 ± 0.5	26.66 ± 1.07
				$RR_{mean} =$	26.67 $\pm$ 0.82
^{149}Eu	c*	93.1D	327.5	4.03 ± 0.12	38.14 $\pm$ 2.50
^{147}Eu	c*	24.1D	955.8	3.84 ± 0.20	33.02 ± 2.21
			798.7	4.8 ± 0.3	38.21 ± 2.86
			677.5	9.8 ± 0.5	32.19 ± 2.01
			601.5	5.9 ± 0.3	31.78 ± 2.06
			121.2	22.9 ± 1.3	30.45 ± 2.26
				$RR_{mean} =$	32.54 $\pm$ 1.40
$^{146}\text{Eu}_i$	i	4.61D	747.2	99 ± 3	3.933 $\pm$ 0.192
$^{146}\text{Eu}_c$	c	4.61D	747.2	99 ± 3	30.63 $\pm$ 1.37
^{145}Eu	c	5.93D	1997.0	7.2 ± 0.5	18.79 ± 1.65
			1658.5	14.9 ± 1.0	20.76 ± 1.61
			893.7	66 ± 5	21.62 ± 1.82
			653.5	15 ± 1	20.44 ± 1.58
				$RR_{mean} =$	20.38 $\pm$ 0.91
^{143}Pm	c	265D	742.0	38.5 ± 2.4	19.41 $\pm$ 1.41
^{139}Ce	c	137.640D	165.9	79.89 ± 0.01	15.66 $\pm$ 0.57
^{135}Ce	c	17.7H	265.6	41.8 ± 1.5	10.43 $\pm$ 0.59
^{132}Ce	c	3.51H	182.1	77.4 ± 0.5	8.335 $\pm$ 0.442
$^{132}\text{La}_c$	c	4.8H	464.5	76 ± 6	7.420 $\pm$ 0.743
^{133}Ba	c	3848.9D	356.0	62.05 ± 0.19	10.91 $\pm$ 1.31
^{131}Ba	c	11.50D	496.3	46.8 ± 0.2	8.819 ± 1.069
			373.2	14.04 ± 0.20	8.684 ± 0.374
			123.8	29.0 ± 0.3	8.325 ± 0.453
				$RR_{mean} =$	8.578 $\pm$ 0.336
^{128}Ba	c	2.43D	442.9	26.8 ± 1.4	5.584 ± 0.696
			273.4	14.5 ± 0.7	6.133 ± 0.669
				$RR_{mean} =$	5.881 $\pm$ 0.458
^{129}Cs	c	32.06H	371.9	30.6 ± 1.7	9.773 $\pm$ 0.707
^{127}Xe	c	36.4D	375.0	17.2 ± 0.6	6.973 ± 0.413
			202.9	68.3 ± 0.5	6.903 ± 0.273
				$RR_{mean} =$	6.916 $\pm$ 0.260
^{123}Xe	c	2.08H	148.9	48.9 ± 0.6	7.230 $\pm$ 0.640
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.5598 $\pm$ 0.0961
^{121m}Te	i(m)	154D	212.2	81.4 ± 1.1	1.165 ± 0.116
			573.1	88.6 ± 0.1	1.125 ± 0.131
				$RR_{mean} =$	1.148 $\pm$ 0.035

Continuation of Table 100.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	5.705 ± 0.274
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.002 ± 0.100
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	0.9399 ± 0.0546
			1023.3	99.4 ± 0.3	0.7830 ± 0.0549
			<i>RR_{mean}</i> =		0.8665 ± 0.0827
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	2.511 ± 0.228
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	2.411 ± 0.355
¹¹¹ In	c	2.8047D	245.4	94 ± 1	4.044 ± 0.215
			171.3	90.2 ± 1.0	4.210 ± 0.229
			<i>RR_{mean}</i> =		4.121 ± 0.178
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	2.395 ± 0.203
			657.8	94.3 ± 0.3	2.068 ± 0.163
			<i>RR_{mean}</i> =		2.194 ± 0.173
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	2.750 ± 0.203
			717.3	28.9 ± 0.8	2.640 ± 0.221
			451.0	28.2 ± 0.8	2.838 ± 0.194
		<i>RR_{mean}</i> =		2.754 ± 0.137	
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	4.081 ± 0.795
			280.4	30.2 ± 1.8	3.260 ± 0.283
			<i>RR_{mean}</i> =		3.342 ± 0.267
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.6424 ± 0.0700
¹⁰² Rh	i	207D	475.1	46 ± 5	2.096 ± 0.306
^{101m} Rh	c	4.34D	306.9	81 ± 5	4.573 ± 0.370
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	3.048 ± 0.260
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	3.691 ± 0.249
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	6.537 ± 0.303
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	3.862 ± 0.219
			812.5	82 ± 4	4.189 ± 0.253
			<i>RR_{mean}</i> =		3.998 ± 0.203
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	5.835 ± 0.310
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	2.603 ± 0.166
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	4.569 ± 0.284
			568.9	58.0 ± 0.3	4.128 ± 0.366
			<i>RR_{mean}</i> =		4.419 ± 0.250
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	6.462 ± 0.238
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	10.39 ± 0.36
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	2.949 ± 0.208
			1129.2	92.7 ± 0.5	3.477 ± 0.259
			<i>RR_{mean}</i> =		3.152 ± 0.275
⁹⁵ Zr	c	64.02D	765.8	*	3.969 ± 0.198
			756.7	54.46 ± 0.10	3.813 ± 0.186
			<i>RR_{mean}</i> =		3.885 ± 0.120
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	7.288 ± 0.265
⁸⁸ Zr	c	83.4D	1836.1	*	4.740 ± 0.378
			898.0	*	3.585 ± 0.371
			392.9	97.24 ± 0.00	3.633 ± 0.156
		<i>RR_{mean}</i> =		3.651 ± 0.113	
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	8.057 ± 0.334
			898.0	93.7 ± 0.3	8.520 ± 0.358
			<i>RR_{mean}</i> =		8.268 ± 0.344

Continuation of Table 100.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	12.80 ± 0.51
			898.0	93.7 ± 0.3	12.10 ± 0.46
			$RR_{mean} =$		12.39 ± 0.51
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	9.681 ± 0.345
$^{86}\text{Y}_c$	c	14.74H	1076.6	82.5 ± 0.4	3.958 ± 0.433
^{85}Sr	c	64.84D	514.0	96 ± 4	9.703 ± 0.531
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	9.951 ± 0.514
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	13.54 ± 1.10
			529.6	29.3 ± 2.1	11.78 ± 1.01
			520.4	45 ± 4	10.89 ± 1.05
			$RR_{mean} =$		12.15 ± 0.85
^{82m}Rb	i(m)	6.472H	554.3	62.4 ± 0.9	4.481 ± 0.472
^{82}Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	4.142 ± 0.210
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	4.906 ± 0.208
			136.0	58.3 ± 0.8	5.246 ± 0.262
			121.1	17.2 ± 0.4	6.320 ± 0.970
			$RR_{mean} =$		5.036 ± 0.221
^{74}As	i	17.77D	595.8	59 ± 4	5.883 ± 0.451
^{71}As	c	65.28H	174.9	82.0 ± 2.1	1.128 ± 0.083
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	3.124 ± 0.327
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	3.991 ± 0.291
^{72}Zn	c	46.5H	2201.7	*	0.8669 ± 0.1267
^{58}Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	1.818 ± 0.153
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	3.265 ± 0.194
			1099.2	56.5 ± 1.9	2.752 ± 0.145
			$RR_{mean} =$		2.915 ± 0.256
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	2.734 ± 0.154
^{48}V	c	15.9735D	1312.1	97.5 ± 0.9	0.3750 ± 0.0389
			983.5	100.0 ± 0.3	0.4377 ± 0.0412
			$RR_{mean} =$		0.4049 ± 0.0337
^{48}Sc	i	43.67H	1312.1	100.1 ± 0.7	1.421 ± 0.146
			1037.5	97.6 ± 0.7	1.428 ± 0.087
			$RR_{mean} =$		1.427 ± 0.079
^{46}Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	2.280 ± 0.152
			889.3	99.98 ± 0.00	2.240 ± 0.111
			$RR_{mean} =$		2.252 ± 0.101
^{28}Mg	c	20.915H	1778.8	100.2 ± 0.0	0.8296 ± 0.0681
^{24}Na	c	14.9590H	1369.0	100 ± 0	4.564 ± 0.300
^7Be	i	53.29D	477.6	10.52 ± 0.06	8.210 ± 0.763

12.10.3 Nuclide production rates for ^{208}Pb

Table 101: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 1.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	569.7	97.74 ± 0.03	16.88 ± 3.06
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	13.49 ± 0.64

Continuation of Table 101.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			803.1	98.9 ± 1.4	13.41 ± 0.48
			537.5	30.5 ± 0.5	13.05 ± 0.58
			497.1	15.31 ± 0.22	15.02 ± 2.90
			<i>RR_{mean}</i> =		13.35 ± 0.46
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	16.11 ± 1.49
			1764.3	32.5 ± 0.7	17.96 ± 0.82
			<i>RR_{mean}</i> =		17.67 ± 0.86
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	13.96 ± 1.14
			899.2	98 ± 9	15.14 ± 0.59
			374.8	82 ± 5	14.86 ± 3.11
			<i>RR_{mean}</i> =		15.01 ± 0.46
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	13.89 ± 1.04
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	10.05 ± 1.37
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	44.46 ± 1.90
			374.7	89 ± 15	42.93 ± 7.41
			<i>RR_{mean}</i> =		44.41 ± 1.88
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	46.73 ± 1.95
			374.7	89 ± 15	44.80 ± 7.73
			<i>RR_{mean}</i> =		46.67 ± 1.93
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	98.69 ± 3.62
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	29.03 ± 3.19
			422.1	86 ± 5	31.38 ± 2.33
			<i>RR_{mean}</i> =		30.90 ± 1.54
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	76.13 ± 5.49
²⁰⁰ Pb	c	21.5H	1205.7	*	51.97 ± 4.14
			450.5	3.33 ± 0.08	63.09 ± 3.74
			367.9	*	58.09 ± 2.41
			147.6	37.7 ± 1.4	55.54 ± 3.03
			<i>RR_{mean}</i> =		57.44 ± 1.77
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	93.56 ± 15.51
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	73.13 ± 12.71
^{197m} Pb	c*	43M	385.9	74 ± 15	45.62 ± 9.46
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	19.67 ± 3.90
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	56.84 ± 2.05
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	138.8 ± 5.6
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	67.94 ± 6.03
			579.3	13.8 ± 0.7	74.16 ± 6.14
			367.9	87.2 ± 0.4	59.40 ± 3.19
			<i>RR_{mean}</i> =		62.84 ± 4.39
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	119.9 ± 8.5
			579.3	13.8 ± 0.7	119.8 ± 7.7
			367.9	87.2 ± 0.4	117.5 ± 4.3
			<i>RR_{mean}</i> =		117.9 ± 4.2
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	80.09 ± 11.03
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	116.0 ± 14.0
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	53.16 ± 7.19
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	92.05 ± 16.09
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	14.32 ± 0.56
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	31.17 ± 1.50
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	44.12 ± 6.11

Continuation of Table 101.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{193m}Hg	i(m)	11.8H	258.0	49 ± 7	51.98 ± 7.87
^{192}Hg	c	4.85H	316.5	*	97.89 ± 12.46
			274.8	50.2 ± 2.5	83.51 ± 5.31
			$RR_{mean} =$		85.36 ± 2.63
^{190}Hg	c*	20.0M	142.6	68 ± 10	53.97 ± 8.38
^{198m}Au	i(m)	2.27D	411.8	*	2.685 ± 0.169
$^{198}\text{Au}_i$	i	2.69517D	411.8	95.58 ± 0.12	4.700 ± 0.335
$^{198}\text{Au}_c$	i(m+g)	2.69517D	411.8	95.58 ± 0.12	7.385 ± 0.303
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	12.20 ± 0.43
			333.0	22.9 ± 0.6	12.99 ± 0.61
			$RR_{mean} =$		12.31 ± 0.47
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	135.9 ± 13.4
^{194}Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	19.90 ± 1.78
$^{192}\text{Au}_i$	i(m+g)	4.94H	316.5	58 ± 7	29.06 ± 4.40
$^{192}\text{Au}_c$	c	4.94H	316.5	58 ± 7	127.0 ± 16.0
^{191}Au	c*	3.18H	674.2	6.8 ± 0.5	127.3 ± 12.7
$^{190}\text{Au}_c$	c	42.8M	301.8	23.4 ± 1.5	86.20 ± 8.77
			295.8	71 ± 5	96.27 ± 8.00
			$RR_{mean} =$		92.67 ± 5.61
^{191}Pt	c	2.802D	538.9	13.7 ± 1.6	118.4 ± 14.6
			456.5	3.4 ± 0.4	98.88 ± 12.71
			409.4	8.0 ± 0.9	91.22 ± 10.75
			$RR_{mean} =$		99.04 ± 8.18
^{189}Pt	c	10.87H	721.4	9.3 ± 0.8	115.8 ± 10.9
			607.6	8.10 ± 0.16	113.5 ± 5.5
			568.8	7.1 ± 0.6	116.2 ± 11.3
			544.9	5.8 ± 0.5	107.0 ± 10.5
			243.5	7.0 ± 1.2	121.0 ± 25.7
			$RR_{mean} =$		113.4 ± 4.9
^{188}Pt	c	10.2D	1209.8	*	99.56 ± 10.67
			423.3	4.4 ± 0.3	98.71 ± 7.64
			381.4	7.5 ± 0.5	93.72 ± 7.14
			195.1	18.6 ± 1.2	98.41 ± 7.37
			187.6	19.4 ± 1.2	97.75 ± 7.08
			$RR_{mean} =$		97.49 ± 3.01
^{186}Pt	c	2.08H	689.4	70 ± 15	79.78 ± 17.34
^{184}Pt	c	17.3M	548.3	23 ± 4	73.69 ± 13.82
^{192}Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.6928 ± 0.0846
^{190}Ir	i(m1+g)	11.78D	569.3	28.5 ± 1.3	1.746 ± 0.193
^{189}Ir	c	13.2D	245.1	6.0 ± 0.6	88.77 ± 10.40
$^{188}\text{Ir}_i$	i	41.5H	1209.8	6.9 ± 0.7	9.455 ± 1.662
$^{188}\text{Ir}_c$	c	41.5H	1209.8	6.9 ± 0.7	109.0 ± 11.7
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	102.8 ± 7.7
^{186}Ir	c	16.64H	434.8	33.9 ± 1.1	51.26 ± 2.56
			137.2	41.4 ± 0.7	47.17 ± 4.42
			$RR_{mean} =$		50.51 ± 2.37
^{185}Ir	c	14.4H	1829.0	10.1 ± 1.5	76.82 ± 11.91
			254.2	13.3 ± 2.4	51.06 ± 11.17
			$RR_{mean} =$		71.99 ± 10.30
^{184}Ir	c*	3.09H	390.4	25.9 ± 2.4	95.47 ± 9.58

Continuation of Table 101.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			264.0	68 ± 4	94.11 ± 6.68
			119.8	31 ± 3	83.76 ± 9.88
			<i>RR_{mean}</i> =		93.39 ± 3.74
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	107.9 ± 5.7
			717.4	3.94 ± 0.16	107.0 ± 6.3
			646.1	78 ± 3	101.7 ± 5.2
			<i>RR_{mean}</i> =		104.0 ± 3.8
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	60.87 ± 2.76
			1101.9	49.0 ± 1.3	57.98 ± 2.57
			<i>RR_{mean}</i> =		59.21 ± 2.32
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	93.81 ± 5.55
			180.2	33.5 ± 1.7	104.4 ± 7.0
			<i>RR_{mean}</i> =		97.59 ± 5.89
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	89.06 ± 4.77
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	95.59 ± 6.88
			162.3	23.3 ± 0.7	111.1 ± 5.3
			<i>RR_{mean}</i> =		107.5 ± 7.3
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	106.8 ± 8.2
			1189.2	15 ± 1	111.1 ± 9.9
			<i>RR_{mean}</i> =		108.4 ± 5.9
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	103.1 ± 23.0
			365.5	56 ± 8	94.31 ± 13.91
			<i>RR_{mean}</i> =		96.25 ± 10.37
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	133.3 ± 11.0
			290.0	26.9 ± 2.3	118.0 ± 11.7
			<i>RR_{mean}</i> =		128.4 ± 8.2
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	148.5 ± 18.1
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	85.61 ± 9.58
			1340.8(D)	1.03 ± 0.09	60.78 ± 8.89
			<i>RR_{mean}</i> =		75.56 ± 12.41
¹⁷⁷ W	c	135M	115.7	51 ± 5	89.72 ± 10.00
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	103.2 ± 23.6
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	95.77 ± 16.88
			1159.3	24.7 ± 1.9	99.60 ± 8.52
			710.5	5.4 ± 0.4	120.3 ± 16.4
			<i>RR_{mean}</i> =		100.4 ± 4.4
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	76.63 ± 12.83
			348.5	12.0 ± 1.1	117.9 ± 11.8
			266.9	10.52 ± 0.16	100.1 ± 5.0
			<i>RR_{mean}</i> =		100.1 ± 6.9
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	100.3 ± 9.3
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	103.8 ± 11.6
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	63.86 ± 6.63
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	99.30 ± 4.90
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	118.9 ± 7.2
			139.6	12.7 ± 0.6	124.0 ± 7.9
			123.7	83 ± 5	120.0 ± 9.1
			<i>RR_{mean}</i> =		120.8 ± 4.8
¹⁷² Hf	c	1.87Y	1093.6	*	87.20 ± 5.06
			1002.7(D)	5.55 ± 0.38	83.49 ± 8.51

Continuation of Table 101.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			181.5	*	89.34 ± 5.63
			125.8	11.3 ± 0.9	85.72 ± 7.96
			<i>RR_{mean}</i> =		87.09 ± 2.69
¹⁷¹ Hf	c	12.1H	739.8	*	82.83 ± 7.17
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	119.1 ± 33.4
			164.7	26 ± 8	115.4 ± 35.8
			120.2	15 ± 5	109.1 ± 36.8
			<i>RR_{mean}</i> =		117.3 ± 8.3
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	97.96 ± 5.24
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.9549 ± 0.0732
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	88.15 ± 5.12
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	105.8 ± 5.0
			780.7	4.36 ± 0.11	117.3 ± 5.0
			667.4	11.0 ± 0.3	108.3 ± 4.7
			<i>RR_{mean}</i> =		111.0 ± 4.9
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	99.92 ± 4.15
¹⁷⁰ Lu _c	c	2.012D	2126.1	5.1 ± 0.3	84.95 ± 6.41
			1280.2	8.2 ± 0.4	87.97 ± 6.07
			1054.3	4.76 ± 0.24	86.63 ± 6.95
			<i>RR_{mean}</i> =		86.65 ± 3.83
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	78.32 ± 3.54
			191.2	20.6 ± 0.6	82.45 ± 4.01
			<i>RR_{mean}</i> =		79.94 ± 3.18
¹⁶⁷ Lu	c	51.5M	176.2	*	67.60 ± 4.32
			113.3	*	86.91 ± 6.62
			<i>RR_{mean}</i> =		73.03 ± 8.97
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	92.40 ± 4.26
			177.2	22.2 ± 0.5	91.08 ± 4.00
			130.5	11.31 ± 0.21	94.42 ± 4.46
			<i>RR_{mean}</i> =		92.39 ± 3.24
¹⁶⁶ Yb	c	56.7H	2079.5	*	89.53 ± 6.70
			2052.4	*	91.42 ± 6.36
			1867.9	*	91.00 ± 6.67
			1374.2	*	90.15 ± 7.53
			1176.7	*	85.65 ± 6.23
			785.9	*	89.96 ± 6.69
			691.2(D)	8.56 ± 0.58	79.51 ± 6.23
			<i>RR_{mean}</i> =		87.96 ± 2.71
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	94.72 ± 18.40
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	87.23 ± 6.33
			242.9	35.5 ± 1.7	85.39 ± 5.28
			<i>RR_{mean}</i> =		85.93 ± 3.56
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	88.29 ± 6.63
¹⁶⁰ Er	c	28.58H	966.2	*	79.74 ± 10.74
			962.4	*	77.76 ± 10.20
			879.4(D)	22.6 ± 2.8	79.28 ± 10.30
			872.0(D)	6.8 ± 1.1	73.56 ± 12.53
			728.2(D)	34 ± 5	79.79 ± 12.04
			<i>RR_{mean}</i> =		78.20 ± 2.41
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	88.75 ± 11.64

Continuation of Table 101.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			132.0	*	92.30 ± 5.94
			<i>RR_{mean}</i> =		91.68 ± 2.83
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	82.81 ± 11.57
			962.4	16.6 ± 2.1	73.27 ± 10.19
			<i>RR_{mean}</i> =		77.44 ± 7.41
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	82.44 ± 4.08
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	68.57 ± 3.83
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	58.70 ± 2.75
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	31.02 ± 1.64
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	55.65 ± 4.58
			105.3	25.1 ± 1.3	59.84 ± 4.40
			<i>RR_{mean}</i> =		58.17 ± 2.72
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	47.48 ± 3.44
¹⁵² Tb	c*	17.5H	344.3	65 ± 4	41.74 ± 2.98
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	34.37 ± 2.24
			251.9	26.3 ± 1.2	31.28 ± 2.13
			<i>RR_{mean}</i> =		32.78 ± 1.85
¹⁴⁹ Tb	c	4.118H	165.0	26.4 ± 0.9	9.848 ± 2.683
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	17.96 ± 1.35
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	44.33 ± 2.84
			97.4	29.0 ± 0.8	42.11 ± 2.48
			<i>RR_{mean}</i> =		43.02 ± 1.99
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	36.31 ± 3.38
¹⁴⁹ Gd	c	9.28D	788.9	7.3 ± 0.4	47.95 ± 3.18
			346.6	23.9 ± 1.3	40.83 ± 2.62
			298.6	28.6 ± 1.7	41.10 ± 2.85
			149.7	48 ± 3	44.92 ± 3.31
			<i>RR_{mean}</i> =		42.88 ± 2.16
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	36.07 ± 2.51
			396.0	34.3 ± 2.1	31.42 ± 2.24
			370.0	17.2 ± 0.9	33.72 ± 2.17
			<i>RR_{mean}</i> =		33.62 ± 1.62
¹⁴⁶ Gd	c	48.27D	747.2	*	33.20 ± 1.49
			154.6	46.6 ± 0.5	34.30 ± 1.41
			<i>RR_{mean}</i> =		33.83 ± 1.04
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	54.05 ± 3.13
¹⁴⁷ Eu	c*	24.1D	955.8	3.84 ± 0.20	40.45 ± 2.88
			798.7	4.8 ± 0.3	47.86 ± 3.50
			677.5	9.8 ± 0.5	41.77 ± 2.60
			601.5	5.9 ± 0.3	44.13 ± 2.83
			121.2	22.9 ± 1.3	39.69 ± 2.92
			<i>RR_{mean}</i> =		42.45 ± 1.79
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	5.606 ± 0.275
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	38.81 ± 1.74
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	27.00 ± 2.31
			1658.5	14.9 ± 1.0	27.11 ± 2.29
			893.7	66 ± 5	25.32 ± 2.16
			653.5	15 ± 1	26.81 ± 2.02
			<i>RR_{mean}</i> =		26.55 ± 1.20
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	24.19 ± 1.76

Continuation of Table 101.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{139}Ce	c	137.640D	165.9	79.89 ± 0.01	20.38 ± 0.75
^{135}Ce	c	17.7H	265.6	41.8 ± 1.5	12.55 ± 0.79
^{132}Ce	c	3.51H	182.1	77.4 ± 0.5	8.819 ± 0.536
$^{132}\text{La}_c$	c	4.8H	464.5	76 ± 6	9.867 ± 0.926
^{133}Ba	c	3848.9D	356.0	62.05 ± 0.19	12.33 ± 1.44
^{131}Ba	c	11.50D	496.3	46.8 ± 0.2	11.19 ± 1.02
			373.2	14.04 ± 0.20	11.19 ± 0.47
			123.8	29.0 ± 0.3	10.65 ± 0.61
			$RR_{mean} =$		11.05 ± 0.43
^{128}Ba	c	2.43D	442.9	26.8 ± 1.4	8.117 ± 0.639
			273.4	14.5 ± 0.7	6.157 ± 0.558
			$RR_{mean} =$		7.120 ± 1.004
^{129}Cs	c	32.06H	371.9	30.6 ± 1.7	12.05 ± 0.89
^{127}Xe	c	36.4D	375.0	17.2 ± 0.6	9.189 ± 0.534
			202.9	68.3 ± 0.5	8.797 ± 0.355
			$RR_{mean} =$		8.873 ± 0.337
^{123}Xe	c	2.08H	148.9	48.9 ± 0.6	9.991 ± 0.851
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.9792 ± 0.0690
^{121m}Te	i(m)	154D	212.2	81.4 ± 1.1	1.561 ± 0.087
			573.1	88.6 ± 0.1	1.755 ± 0.195
			$RR_{mean} =$		1.586 ± 0.049
$^{121}\text{Te}_c$	c	19.16D	573.1	80.3 ± 2.5	7.481 ± 0.372
^{119m}Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.383 ± 0.146
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	1.197 ± 0.072
			1023.3	99.4 ± 0.3	1.231 ± 0.065
			$RR_{mean} =$		1.216 ± 0.055
^{113}Sn	c	115.09D	391.7	64.97 ± 0.17	4.230 ± 0.207
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	4.408 ± 0.443
^{111}In	c	2.8047D	245.4	94 ± 1	5.196 ± 0.305
			171.3	90.2 ± 1.0	5.291 ± 0.243
			$RR_{mean} =$		5.261 ± 0.216
^{110m}Ag	i(m)	249.76D	884.7	72.7 ± 0.4	3.136 ± 0.169
			657.8	94.3 ± 0.3	3.008 ± 0.152
			$RR_{mean} =$		3.063 ± 0.131
^{106m}Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	3.663 ± 0.272
			717.3	28.9 ± 0.8	3.729 ± 0.306
			451.0	28.2 ± 0.8	3.924 ± 0.216
			$RR_{mean} =$		3.813 ± 0.174
^{105}Ag	c	41.29D	443.4	10.5 ± 0.6	5.010 ± 0.578
			280.4	30.2 ± 1.8	4.063 ± 0.335
			$RR_{mean} =$		4.284 ± 0.422
^{100}Pd	c	3.63D	2376.0	*	0.4434 ± 0.3190
^{102}Rh	i	207D	475.1	46 ± 5	3.104 ± 0.394
^{101m}Rh	c	4.34D	306.9	81 ± 5	5.748 ± 0.440
$^{100}\text{Rh}_i$	i(m+g)	20.8H	2376.0	32.6 ± 0.4	3.681 ± 0.436
$^{100}\text{Rh}_c$	c	20.8H	2376.0	32.6 ± 0.4	4.125 ± 0.284
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	9.143 ± 0.392
^{96}Tc	i(m+g)	4.28D	849.9	98 ± 4	4.854 ± 0.272
			812.5	82 ± 4	5.214 ± 0.314
			$RR_{mean} =$		5.004 ± 0.235

Continuation of Table 101.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	8.171 ± 0.396
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	3.080 ± 0.206
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	6.737 ± 0.395
			568.9	58.0 ± 0.3	5.483 ± 0.330
			<i>RR_{mean}</i> =		6.003 ± 0.645
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	8.809 ± 0.346
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	14.16 ± 0.50
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	3.769 ± 0.254
			1129.2	92.7 ± 0.5	4.337 ± 0.409
			<i>RR_{mean}</i> =		3.914 ± 0.275
⁹⁵ Zr	c	64.02D	765.8	*	5.395 ± 0.298
			756.7	54.46 ± 0.10	5.437 ± 0.233
			<i>RR_{mean}</i> =		5.424 ± 0.167
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	8.853 ± 0.300
⁸⁸ Zr	c	83.4D	1836.1	*	4.444 ± 0.233
			898.0	*	4.695 ± 0.219
			392.9	97.24 ± 0.00	4.625 ± 0.179
			<i>RR_{mean}</i> =		4.608 ± 0.142
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	11.00 ± 0.40
			898.0	93.7 ± 0.3	10.84 ± 0.37
			<i>RR_{mean}</i> =		10.89 ± 0.36
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	15.44 ± 0.55
			898.0	93.7 ± 0.3	15.53 ± 0.52
			<i>RR_{mean}</i> =		15.50 ± 0.50
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	11.76 ± 0.42
⁸⁶ Y _c	c	14.74H	1076.6	82.5 ± 0.4	4.822 ± 0.271
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	11.92 ± 0.65
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	11.82 ± 0.64
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	16.30 ± 1.32
			529.6	29.3 ± 2.1	13.88 ± 1.22
			520.4	45 ± 4	13.48 ± 1.32
			<i>RR_{mean}</i> =		14.69 ± 1.00
^{82m} Rb	i(m)	6.472H	554.3	62.4 ± 0.9	5.897 ± 0.732
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	5.675 ± 0.280
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	6.152 ± 0.250
			136.0	58.3 ± 0.8	6.736 ± 0.325
			121.1	17.2 ± 0.4	7.670 ± 0.786
			<i>RR_{mean}</i> =		6.369 ± 0.318
⁷⁴ As	i	17.77D	595.8	59 ± 4	7.518 ± 0.582
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	1.339 ± 0.097
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	4.937 ± 0.563
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	6.276 ± 0.523
⁷² Zn	c	46.5H	2201.7	*	1.339 ± 0.184
⁵⁸ Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	2.816 ± 0.273
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	4.112 ± 0.231
			1099.2	56.5 ± 1.9	4.281 ± 0.251
			<i>RR_{mean}</i> =		4.187 ± 0.184
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	3.210 ± 0.234
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	0.5543 ± 0.0520
			983.5	100.0 ± 0.3	0.4954 ± 0.0488

Continuation of Table 101.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
RR _{mean} =					0.5231 ± 0.0374
⁴⁸ Sc	i	43.67H	1312.1	100.1 ± 0.7	2.143 ± 0.156
			1037.5	97.6 ± 0.7	2.043 ± 0.109
RR _{mean} =					2.071 ± 0.098
⁴⁶ Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	2.745 ± 0.203
			889.3	99.98 ± 0.00	3.034 ± 0.125
RR _{mean} =					2.986 ± 0.142
²⁸ Mg	c	20.915H	1778.8	100.2 ± 0.0	1.386 ± 0.099
²⁴ Na	c	14.9590H	1369.0	100 ± 0	6.403 ± 0.382
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	19.60 ± 1.80

12.10.4 Nuclide production rates for ^{nat}Pb

Table 102: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 1.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	569.7	97.74 ± 0.03	19.85 ± 4.30
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	18.39 ± 0.87
			803.1	98.9 ± 1.4	16.70 ± 0.61
			537.5	30.5 ± 0.5	16.96 ± 0.77
			497.1	15.31 ± 0.22	20.00 ± 2.30
			RR _{mean} =		17.04 ± 0.65
²⁰⁵ Bi	i	15.31D	1861.7	6.17 ± 0.10	22.05 ± 1.76
			1764.3	32.5 ± 0.7	25.21 ± 1.12
			RR _{mean} =		24.59 ± 1.47
²⁰⁴ Bi	i	11.22H	984.0	59 ± 4	28.85 ± 2.91
			899.2	98 ± 9	25.16 ± 1.03
			374.8	82 ± 5	20.97 ± 4.42
			RR _{mean} =		25.27 ± 0.78
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	27.56 ± 2.03
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	14.56 ± 2.17
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	60.50 ± 3.29
			374.7	89 ± 15	69.44 ± 12.02
			RR _{mean} =		60.95 ± 3.24
^{204m} Pb _c	c	67.2M	899.2	99.17 ± 0.02	64.28 ± 3.35
			374.7	89 ± 15	72.07 ± 12.47
			RR _{mean} =		64.64 ± 3.31
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	178.7 ± 6.5
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	41.78 ± 4.69
			422.1	86 ± 5	51.90 ± 3.72
			RR _{mean} =		49.85 ± 4.35
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	130.6 ± 9.4
²⁰⁰ Pb	c	21.5H	1205.7	*	93.93 ± 6.66
			579.3	*	84.53 ± 6.58
			450.5	3.33 ± 0.08	89.22 ± 6.71
			367.9	*	89.08 ± 3.17
			257.2	4.46 ± 0.17	114.1 ± 10.5
			147.6	37.7 ± 1.4	90.68 ± 5.19

Continuation of Table 102.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	89.34 ± 2.76
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	187.7 ± 30.7
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	117.1 ± 20.7
^{197m} Pb	c*	43M	385.9	74 ± 15	76.66 ± 15.82
^{195m} Pb	i(m)	15.0M	383.6	107 ± 20	31.14 ± 6.08
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	91.72 ± 3.33
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	234.3 ± 8.8
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	99.43 ± 7.77
			579.3	13.8 ± 0.7	104.8 ± 10.8
			367.9	87.2 ± 0.4	98.11 ± 4.21
			<i>RR_{mean}</i> =		98.71 ± 4.00
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	193.4 ± 13.5
			579.3	13.8 ± 0.7	189.3 ± 12.7
			367.9	87.2 ± 0.4	187.2 ± 6.5
			<i>RR_{mean}</i> =		187.6 ± 6.4
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	160.4 ± 21.0
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	194.6 ± 23.8
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	82.02 ± 9.99
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	147.3 ± 25.8
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	17.59 ± 0.67
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	47.23 ± 2.56
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	66.55 ± 9.21
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	88.96 ± 13.33
¹⁹² Hg	c	4.85H	316.5	*	155.7 ± 19.7
			274.8	50.2 ± 2.5	134.8 ± 8.5
			<i>RR_{mean}</i> =		137.6 ± 4.2
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	87.27 ± 13.68
^{198m} Au	i(m)	2.27D	411.8	*	3.551 ± 0.396
¹⁹⁸ Au _i	i	2.69517D	411.8	95.58 ± 0.12	6.017 ± 0.735
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	9.569 ± 0.491
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	16.76 ± 0.59
			333.0	22.9 ± 0.6	18.49 ± 0.83
			<i>RR_{mean}</i> =		17.02 ± 0.81
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	209.6 ± 21.8
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	28.11 ± 2.50
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	43.48 ± 6.12
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	199.2 ± 25.1
¹⁹¹ Au	c*	3.18H	674.2	6.8 ± 0.5	186.0 ± 17.6
¹⁹⁰ Au _c	c	42.8M	301.8	23.4 ± 1.5	154.1 ± 14.0
			295.8	71 ± 5	170.5 ± 14.0
			<i>RR_{mean}</i> =		163.4 ± 9.6
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	188.6 ± 23.0
			456.5	3.4 ± 0.4	150.8 ± 18.9
			409.4	8.0 ± 0.9	144.4 ± 17.0
			<i>RR_{mean}</i> =		155.9 ± 13.3
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	177.4 ± 16.8
			607.6	8.10 ± 0.16	198.5 ± 10.3
			568.8	7.1 ± 0.6	173.1 ± 17.3
			544.9	5.8 ± 0.5	174.1 ± 17.6
			243.5	7.0 ± 1.2	245.3 ± 45.9

Continuation of Table 102.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸⁸ Pt	c	10.2D		$RR_{mean} =$	189.5 ± 9.1
			1209.8	*	155.2 ± 16.7
			423.3	4.4 ± 0.3	147.9 ± 11.5
			381.4	7.5 ± 0.5	152.6 ± 11.6
			195.1	18.6 ± 1.2	150.9 ± 11.3
			187.6	19.4 ± 1.2	153.9 ± 11.2
				$RR_{mean} =$	152.0 ± 4.7
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	124.0 ± 26.9
¹⁸⁴ Pt	c	17.3M	548.3	23 ± 4	106.2 ± 22.6
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	0.6652 ± 0.0758
¹⁹⁰ Ir	i(m1+g)	11.78D	569.3	28.5 ± 1.3	1.802 ± 0.479
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	164.7 ± 17.8
¹⁸⁸ Ir _i	i	41.5H	1209.8	6.9 ± 0.7	8.195 ± 2.951
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	163.4 ± 17.6
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	142.0 ± 17.7
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	75.81 ± 4.02
			137.2	41.4 ± 0.7	77.33 ± 4.01
				$RR_{mean} =$	76.58 ± 3.27
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	118.2 ± 18.9
			254.2	13.3 ± 2.4	105.9 ± 21.3
				$RR_{mean} =$	115.6 ± 7.6
¹⁸⁴ Ir	c*	3.09H	390.4	25.9 ± 2.4	156.5 ± 15.6
			264.0	68 ± 4	149.8 ± 10.7
			119.8	31 ± 3	150.3 ± 17.0
				$RR_{mean} =$	150.5 ± 6.0
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	165.1 ± 9.2
			717.4	3.94 ± 0.16	159.9 ± 9.5
			646.1	78 ± 3	160.3 ± 8.3
				$RR_{mean} =$	161.3 ± 5.3
^{183m} Os	c*	9.9H	1107.9	22.4 ± 0.6	95.19 ± 4.41
			1101.9	49.0 ± 1.3	85.74 ± 3.76
				$RR_{mean} =$	88.93 ± 5.24
¹⁸² Os	c	22.10H	263.3	6.71 ± 0.25	154.5 ± 10.1
			180.2	33.5 ± 1.7	158.4 ± 10.5
				$RR_{mean} =$	156.4 ± 7.8
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	142.1 ± 7.1
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	154.0 ± 10.8
			162.3	23.3 ± 0.7	169.0 ± 8.0
				$RR_{mean} =$	165.7 ± 8.1
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	160.7 ± 12.2
			1189.2	15 ± 1	142.5 ± 15.4
				$RR_{mean} =$	155.2 ± 9.6
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	147.9 ± 33.1
			365.5	56 ± 8	142.8 ± 21.1
				$RR_{mean} =$	144.0 ± 15.5
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	211.5 ± 16.6
			290.0	26.9 ± 2.3	191.2 ± 19.5
				$RR_{mean} =$	207.6 ± 10.3
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	219.9 ± 27.5
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	135.3 ± 16.5

Continuation of Table 102.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1340.8(D)	1.03 ± 0.09	112.3 ± 13.8
			$RR_{mean} =$		121.8 ± 11.9
^{177}W	c	135M	115.7	51 ± 5	146.0 ± 16.9
^{177}Ta	c*	56.56H	112.9	7.2 ± 1.6	174.0 ± 40.0
$^{176}\text{Ta}_c$	c	8.09H	1823.7	4.5 ± 0.4	129.8 ± 21.5
			1159.3	24.7 ± 1.9	148.4 ± 14.0
			710.5	5.4 ± 0.4	231.9 ± 30.0
			$RR_{mean} =$		152.6 ± 17.5
^{175}Ta	c	10.5H	1793.1	4.6 ± 0.7	151.7 ± 30.5
			348.5	12.0 ± 1.1	177.6 ± 17.8
			266.9	10.52 ± 0.16	148.8 ± 6.8
			$RR_{mean} =$		151.1 ± 7.2
$^{174}\text{Ta}_c$	c	1.14H	206.5	60 ± 5	160.3 ± 15.1
^{173}Ta	c	3.14H	172.2	17.5 ± 1.8	185.3 ± 21.0
^{172}Ta	c*	36.8M	214.1	55 ± 5	94.07 ± 11.00
^{175}Hf	c	70D	343.4	84 ± 3	156.6 ± 7.7
^{173}Hf	c*	23.6H	311.2	10.7 ± 0.5	183.8 ± 10.8
			139.6	12.7 ± 0.6	192.8 ± 13.0
			123.7	83 ± 5	195.4 ± 15.6
			$RR_{mean} =$		187.9 ± 7.5
^{172}Hf	c	1.87Y	1093.6	*	133.1 ± 7.8
			1002.7(D)	5.55 ± 0.38	146.4 ± 13.1
			181.5	*	139.8 ± 8.9
			125.8	11.3 ± 0.9	136.4 ± 13.5
			$RR_{mean} =$		137.1 ± 4.2
^{171}Hf	c	12.1H	739.8	*	122.7 ± 18.7
^{170}Hf	c	16.01H	620.7	18 ± 5	188.2 ± 52.7
			164.7	26 ± 8	182.2 ± 56.5
			120.2	15 ± 5	183.2 ± 61.9
			$RR_{mean} =$		186.6 ± 13.3
^{173}Lu	c	1.37Y	272.1	21.2 ± 0.8	154.5 ± 8.5
$^{172}\text{Lu}_i$	i(m+g)	6.70D	1093.6	63 ± 3	1.182 ± 0.134
$^{172}\text{Lu}_c$	c	6.70D	1093.6	63 ± 3	134.3 ± 7.8
$^{171}\text{Lu}_c$	c	8.24D	739.8	47.8 ± 1.2	154.7 ± 6.5
^{171}Lu	c*	8.24D	853.0	2.55 ± 0.07	157.9 ± 8.2
			780.7	4.36 ± 0.11	179.6 ± 8.1
			667.4	11.0 ± 0.3	165.0 ± 7.1
			$RR_{mean} =$		168.1 ± 7.8
$^{170}\text{Lu}_c$	c	2.012D	2126.1	5.1 ± 0.3	129.6 ± 12.7
			1280.2	8.2 ± 0.4	127.6 ± 23.2
			$RR_{mean} =$		129.2 ± 10.6
^{169}Lu	c	34.06H	960.6	23.4 ± 0.7	119.8 ± 5.4
			191.2	20.6 ± 0.6	129.4 ± 6.2
			$RR_{mean} =$		123.6 ± 6.0
^{167}Lu	c	51.5M	176.2	*	121.5 ± 7.8
			113.3	*	144.9 ± 11.7
			$RR_{mean} =$		128.3 ± 11.3
^{169}Yb	c*	32.026D	198.0	35.8 ± 0.7	144.5 ± 6.5
			177.2	22.2 ± 0.5	146.5 ± 6.4
			130.5	11.31 ± 0.21	152.6 ± 8.1

Continuation of Table 102.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁶⁶ Yb	c	56.7H		<i>RR_{mean}</i> =	146.8 ± 5.2
			2079.5	*	134.1 ± 10.0
			2052.4	*	136.7 ± 9.5
			1867.9	*	137.9 ± 10.5
			1374.2	*	133.4 ± 10.6
			1176.7	*	126.7 ± 9.2
			785.9	*	134.2 ± 9.6
			691.2(D)	8.56 ± 0.58	121.7 ± 9.3
				<i>RR_{mean}</i> =	131.8 ± 4.1
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	144.2 ± 28.0
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	134.9 ± 9.7
			242.9	35.5 ± 1.7	135.0 ± 8.3
				<i>RR_{mean}</i> =	134.9 ± 5.6
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	145.5 ± 10.8
¹⁶⁰ Er	c	28.58H	966.2	*	121.6 ± 16.3
			962.4	*	118.7 ± 15.6
			879.4(D)	22.6 ± 2.8	133.3 ± 17.1
			872.0(D)	6.8 ± 1.1	114.5 ± 19.0
			728.2(D)	34 ± 5	124.0 ± 18.7
				<i>RR_{mean}</i> =	122.6 ± 3.8
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	133.3 ± 17.5
			132.0	*	153.3 ± 14.6
				<i>RR_{mean}</i> =	145.4 ± 4.5
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	125.2 ± 17.1
			962.4	16.6 ± 2.1	116.4 ± 17.4
				<i>RR_{mean}</i> =	120.9 ± 11.8
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	133.7 ± 6.2
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	106.9 ± 6.0
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	88.39 ± 4.35
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	53.22 ± 2.59
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	89.14 ± 7.34
			105.3	25.1 ± 1.3	95.42 ± 7.66
				<i>RR_{mean}</i> =	92.24 ± 4.57
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	69.37 ± 5.05
¹⁵² Tb	c*	17.5H	344.3	65 ± 4	65.55 ± 4.73
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	59.18 ± 3.95
			251.9	26.3 ± 1.2	50.60 ± 3.27
				<i>RR_{mean}</i> =	54.00 ± 4.51
¹⁴⁹ Tb	c	4.118H	165.0	26.4 ± 0.9	23.45 ± 3.63
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	31.31 ± 2.85
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	71.03 ± 5.03
			97.4	29.0 ± 0.8	64.67 ± 4.37
				<i>RR_{mean}</i> =	67.35 ± 3.77
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	55.19 ± 4.77
¹⁴⁹ Gd	c	9.28D	788.9	7.3 ± 0.4	75.42 ± 4.95
			346.6	23.9 ± 1.3	67.02 ± 4.29
			298.6	28.6 ± 1.7	67.65 ± 4.68
			149.7	48 ± 3	74.63 ± 5.61
				<i>RR_{mean}</i> =	69.95 ± 3.08
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	50.30 ± 3.62

Continuation of Table 102.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			396.0	34.3 ± 2.1	50.53 ± 3.55
			370.0	17.2 ± 0.9	54.08 ± 3.41
			$RR_{mean} =$		51.97 ± 2.12
¹⁴⁶ Gd	c	48.27D	747.2	*	56.11 ± 2.51
			154.6	46.6 ± 0.5	57.88 ± 2.31
			$RR_{mean} =$		57.19 ± 1.76
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	88.88 ± 5.28
¹⁴⁷ Eu	c*	24.1D	955.8	3.84 ± 0.20	68.49 ± 4.82
			798.7	4.8 ± 0.3	77.07 ± 5.67
			677.5	9.8 ± 0.5	65.18 ± 4.03
			601.5	5.9 ± 0.3	67.42 ± 4.47
			121.2	22.9 ± 1.3	65.66 ± 5.13
			$RR_{mean} =$		67.63 ± 2.74
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	7.972 ± 0.376
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	64.08 ± 2.87
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	47.22 ± 3.85
			1658.5	14.9 ± 1.0	44.39 ± 3.44
			893.7	66 ± 5	45.94 ± 3.94
			653.5	15 ± 1	41.65 ± 3.13
			$RR_{mean} =$		44.32 ± 1.95
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	37.94 ± 2.90
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	33.84 ± 1.26
¹³⁵ Ce	c	17.7H	265.6	41.8 ± 1.5	21.29 ± 1.27
¹³² Ce	c	3.51H	182.1	77.4 ± 0.5	18.86 ± 1.24
¹³² La _c	c	4.8H	464.5	76 ± 6	15.89 ± 2.13
¹³³ Ba	c	3848.9D	356.0	62.05 ± 0.19	18.80 ± 1.82
¹³¹ Ba	c	11.50D	496.3	46.8 ± 0.2	18.73 ± 1.20
			373.2	14.04 ± 0.20	18.52 ± 0.79
			123.8	29.0 ± 0.3	17.82 ± 1.08
			$RR_{mean} =$		18.41 ± 0.71
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	11.59 ± 0.83
			273.4	14.5 ± 0.7	11.89 ± 0.89
			$RR_{mean} =$		11.72 ± 0.53
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	20.89 ± 1.41
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	15.62 ± 0.82
			202.9	68.3 ± 0.5	14.49 ± 0.59
			$RR_{mean} =$		14.76 ± 0.67
¹²³ Xe	c	2.08H	148.9	48.9 ± 0.6	18.34 ± 2.42
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.351 ± 0.123
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	2.538 ± 0.184
			573.1	88.6 ± 0.1	2.538 ± 0.154
			$RR_{mean} =$		2.538 ± 0.078
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	12.15 ± 0.56
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	3.765 ± 0.184
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	2.178 ± 0.115
			1023.3	99.4 ± 0.3	1.765 ± 0.090
			$RR_{mean} =$		1.921 ± 0.208
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	6.881 ± 0.316
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	8.121 ± 3.527
¹¹¹ In	c	2.8047D	245.4	94 ± 1	8.373 ± 0.375

Continuation of Table 102.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{110m} Ag	i(m)	249.76D	171.3	90.2 ± 1.0	9.046 ± 0.380
			<i>RR_{mean}</i> =		8.732 ± 0.430
			884.7	72.7 ± 0.4	5.052 ± 0.256
			657.8	94.3 ± 0.3	4.683 ± 0.218
^{106m} Ag	i(m)	8.28D	<i>RR_{mean}</i> =		4.828 ± 0.234
			1045.8	29.6 ± 1.0	6.615 ± 0.367
			717.3	28.9 ± 0.8	5.509 ± 0.480
			451.0	28.2 ± 0.8	5.472 ± 0.370
¹⁰⁵ Ag	c	41.29D	<i>RR_{mean}</i> =		5.975 ± 0.437
			443.4	10.5 ± 0.6	7.469 ± 0.909
			280.4	30.2 ± 1.8	7.347 ± 0.610
			<i>RR_{mean}</i> =		7.382 ± 0.521
¹⁰⁰ Pd	c	3.63D	2376.0	*	1.430 ± 0.322
¹⁰² Rh	i	207D	475.1	46 ± 5	4.877 ± 0.598
^{101m} Rh	c	4.34D	306.9	81 ± 5	9.336 ± 0.691
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	5.953 ± 1.112
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	7.382 ± 0.938
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	14.28 ± 0.61
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	7.901 ± 0.458
			812.5	82 ± 4	8.148 ± 0.486
			<i>RR_{mean}</i> =		8.016 ± 0.376
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	12.66 ± 0.63
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	6.671 ± 0.659
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	9.054 ± 0.623
			568.9	58.0 ± 0.3	8.770 ± 0.610
			<i>RR_{mean}</i> =		8.910 ± 0.477
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	14.02 ± 0.49
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	22.24 ± 0.75
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	6.265 ± 0.530
			1129.2	92.7 ± 0.5	6.024 ± 0.361
			<i>RR_{mean}</i> =		6.092 ± 0.322
⁹⁵ Zr	c	64.02D	765.8	*	8.290 ± 0.331
			756.7	54.46 ± 0.10	7.812 ± 0.397
			<i>RR_{mean}</i> =		8.144 ± 0.251
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	14.65 ± 0.49
⁸⁸ Zr	c	83.4D	1836.1	*	6.820 ± 0.366
			898.0	*	7.279 ± 0.571
			392.9	97.24 ± 0.00	7.964 ± 0.314
			<i>RR_{mean}</i> =		7.591 ± 0.234
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	19.85 ± 0.72
			898.0	93.7 ± 0.3	17.67 ± 0.68
			<i>RR_{mean}</i> =		18.83 ± 1.23
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	26.67 ± 0.94
			898.0	93.7 ± 0.3	24.95 ± 0.87
			<i>RR_{mean}</i> =		25.73 ± 1.17
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	19.51 ± 0.70
⁸⁶ Y _c	c	14.74H	1076.6	82.5 ± 0.4	9.980 ± 0.582
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	20.06 ± 1.09
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	18.57 ± 0.84
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	23.39 ± 1.97

Continuation of Table 102.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			529.6	29.3 ± 2.1	23.95 ± 2.03
			520.4	45 ± 4	22.63 ± 2.18
			$RR_{mean} =$		23.40 ± 1.10
^{82m}Rb	i(m)	6.472H	554.3	62.4 ± 0.9	11.72 ± 0.94
^{82}Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	8.296 ± 0.359
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	10.45 ± 0.42
			136.0	58.3 ± 0.8	11.54 ± 0.69
			121.1	17.2 ± 0.4	12.78 ± 1.14
			$RR_{mean} =$		10.75 ± 0.55
^{74}As	i	17.77D	595.8	59 ± 4	12.67 ± 0.97
^{71}As	c	65.28H	174.9	82.0 ± 2.1	2.823 ± 0.144
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	4.785 ± 0.209
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	5.954 ± 0.261
^{72}Zn	c	46.5H	2201.7	*	1.168 ± 0.051
^{58}Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	4.068 ± 0.297
^{59}Fe	c	44.472D	1291.6	43.2 ± 1.4	6.723 ± 0.370
			1099.2	56.5 ± 1.9	6.559 ± 0.366
			$RR_{mean} =$		6.641 ± 0.284
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	5.259 ± 0.277
^{48}V	c	15.9735D	1312.1	97.5 ± 0.9	0.9196 ± 0.0649
			983.5	100.0 ± 0.3	0.7943 ± 0.1501
			$RR_{mean} =$		0.9027 ± 0.0610
^{48}Sc	i	43.67H	1312.1	100.1 ± 0.7	2.362 ± 0.205
			1037.5	97.6 ± 0.7	2.958 ± 0.216
			$RR_{mean} =$		2.653 ± 0.309
^{46}Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	3.586 ± 0.394
			889.3	99.98 ± 0.00	4.539 ± 0.204
			$RR_{mean} =$		4.413 ± 0.351
^{24}Na	c	14.9590H	1369.0	100 ± 0	10.22 ± 0.52
^7Be	i	53.29D	477.6	10.52 ± 0.06	19.15 ± 1.11

12.10.5 Nuclide production rates for ^{209}Bi

Table 103: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 1.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	15.34 ± 0.71
^{206}Po	i	8.8D	1032.3	33 ± 5	17.05 ± 2.65
			286.4	24 ± 3	18.25 ± 2.38
			807.4	23 ± 3	18.45 ± 2.51
			338.4	19.2 ± 2.5	16.88 ± 2.28
			522.5	15.7 ± 2.0	15.81 ± 2.10
			980.2	7.1 ± 0.9	19.65 ± 2.68
			311.6	4.2 ± 0.6	22.19 ± 3.37
			1007.2	3.1 ± 0.4	15.54 ± 2.40
			803.1	*	16.62 ± 0.65
			1718.7	*	16.34 ± 0.93
			1595.3	*	16.02 ± 1.41

Continuation of Table 103.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			657.2	*	12.47 ± 3.95
			620.5	*	15.49 ± 1.91
			537.5	*	14.44 ± 0.66
			516.2	*	15.38 ± 0.64
			343.5	*	16.10 ± 1.20
			$RR_{mean} =$		15.74 ± 0.49
^{207}Bi	c	31.55Y	1063.7	74.5 ± 0.2	204.0 ± 8.2
			569.7	97.74 ± 0.03	202.0 ± 7.5
$^{206}\text{Bi}_i$	i	6.243D	$RR_{mean} =$		202.8 ± 7.1
			803.1	98.9 ± 1.4	109.0 ± 3.9
			1718.7	31.8 ± 0.6	116.9 ± 4.7
			516.2	40.7 ± 0.6	105.2 ± 3.9
			537.5	30.5 ± 0.5	102.8 ± 3.9
			343.5	23.4 ± 0.4	105.8 ± 4.1
			620.5	5.76 ± 0.09	106.0 ± 4.9
			1595.3	5.01 ± 0.08	118.9 ± 4.7
			657.2	1.91 ± 0.04	114.9 ± 6.4
			$RR_{mean} =$		108.6 ± 3.9
$^{206}\text{Bi}_c$	c	6.243D	803.1	98.9 ± 1.4	124.7 ± 4.4
			1718.7	31.8 ± 0.6	132.4 ± 5.2
			516.2	40.7 ± 0.6	119.7 ± 4.5
			537.5	30.5 ± 0.5	116.4 ± 4.4
			343.5	23.4 ± 0.4	121.1 ± 4.6
			620.5	5.76 ± 0.09	120.6 ± 4.8
			1595.3	5.01 ± 0.08	134.0 ± 5.1
			657.2	1.91 ± 0.04	126.7 ± 5.7
			$RR_{mean} =$		123.7 ± 4.4
^{205}Bi	c	15.31D	1764.3	32.5 ± 0.7	124.1 ± 5.1
			987.7	16.13 ± 0.17	120.0 ± 4.4
			1861.7	6.17 ± 0.10	118.2 ± 4.7
			1043.8	7.51 ± 0.10	108.3 ± 4.3
			703.5	31.1 ± 0.1	114.4 ± 4.0
			1775.8	3.99 ± 0.08	117.7 ± 5.1
			1190.0	2.26 ± 0.07	116.5 ± 6.2
			579.8	5.44 ± 0.07	103.2 ± 3.9
			759.1	1.04 ± 0.05	125.7 ± 9.6
			1614.3	2.28 ± 0.04	120.7 ± 5.0
			284.1	1.69 ± 0.02	112.6 ± 5.2
			872.0	0.42 ± 0.01	95.27 ± 10.18
			$RR_{mean} =$		114.5 ± 4.0
^{204}Bi	c*	11.22H	899.2	98 ± 9	86.23 ± 3.14
			374.8	82 ± 5	100.5 ± 21.0
			984.0	59 ± 4	88.77 ± 7.27
			670.7	11.4 ± 0.9	89.65 ± 7.90
			918.3	10.8 ± 0.9	100.2 ± 9.2
^{203}Bi	c	11.76H	$RR_{mean} =$		86.93 ± 2.68
			820.2	29.6 ± 1.5	79.74 ± 4.91
			1847.3	11.4 ± 0.8	70.74 ± 5.98
			1679.6	8.8 ± 0.7	68.90 ± 6.41
			1893.0	8.2 ± 0.6	74.18 ± 6.82
			279.2	*	80.04 ± 7.31

Continuation of Table 103.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	78.70 $\pm$ 2.43
^{202}Bi	c^*	1.72H	422.1	83.7 ± 2.5	66.04 ± 3.58
			960.7	99.28 ± 0.02	69.48 ± 3.43
				$RR_{mean} =$	67.93 $\pm$ 2.88
$^{204m}\text{Pb}_i$	i(m)	67.2M	374.7	89 ± 15	35.68 ± 6.21
			899.2	99.17 ± 0.02	35.16 ± 2.57
				$RR_{mean} =$	35.23 $\pm$ 2.43
$^{204m}\text{Pb}_c$	c	67.2M	374.7	89 ± 15	48.29 ± 8.35
			899.2	99.17 ± 0.02	48.09 ± 2.74
				$RR_{mean} =$	48.10 $\pm$ 2.67
$^{203}\text{Pb}_i$	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	67.20 $\pm$ 8.93
$^{203}\text{Pb}_c$	c	51.873H	279.2	80.8 ± 0.2	147.2 $\pm$ 5.7
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	39.58 ± 4.43
			422.1	86 ± 5	34.99 ± 2.79
				$RR_{mean} =$	35.87 $\pm$ 2.12
^{201}Pb	c^*	9.33H	331.2	79 ± 5	134.4 $\pm$ 9.7
^{200}Pb	c	21.5H	147.6	37.7 ± 1.4	103.5 ± 7.2
			450.5	3.33 ± 0.08	100.4 ± 6.3
			1205.7	*	92.57 ± 6.39
			579.3	*	89.23 ± 5.80
			367.9	*	93.10 ± 3.27
				$RR_{mean} =$	93.62 $\pm$ 2.89
^{199}Pb	c^*	90M	366.9	44 ± 7	158.4 ± 26.4
			353.4	9.5 ± 1.5	172.0 ± 29.9
			1135.0	7.8 ± 1.2	124.7 ± 20.4
				$RR_{mean} =$	142.6 $\pm$ 14.7
^{198}Pb	c	2.4H	173.4	18 ± 3	128.2 $\pm$ 22.3
^{197m}Pb	c^*	43M	385.9	74 ± 15	81.32 ± 16.75
			222.8	25 ± 6	72.66 ± 18.09
				$RR_{mean} =$	80.63 $\pm$ 3.88
^{195m}Pb	i(m)	15.0M	383.6	107 ± 20	41.40 $\pm$ 8.01
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	22.54 $\pm$ 0.82
^{201}Tl	c^*	72.912H	167.4	10.00 ± 0.06	158.7 $\pm$ 6.3
$^{200}\text{Tl}_i$	i	26.1H	1205.7	29.9 ± 1.8	45.08 ± 3.36
			579.3	13.8 ± 0.7	34.61 ± 4.15
			367.9	87.2 ± 0.4	35.49 ± 2.66
				$RR_{mean} =$	38.35 $\pm$ 3.45
$^{200}\text{Tl}_c$	c	26.1H	1205.7	29.9 ± 1.8	137.6 ± 9.5
			579.3	13.8 ± 0.7	123.8 ± 7.9
			367.9	87.2 ± 0.4	128.6 ± 4.6
				$RR_{mean} =$	128.7 $\pm$ 4.5
^{199}Tl	c^*	7.42H	455.5	12.4 ± 1.4	148.8 ± 18.0
			247.3	9.3 ± 1.1	160.0 ± 20.1
				$RR_{mean} =$	153.3 $\pm$ 8.9
^{198m}Tl	i(m)	1.87H	282.8	28 ± 3	32.90 $\pm$ 4.95
^{197}Tl	c^*	2.84H	152.2	7.3 ± 2.3	178.1 $\pm$ 56.8
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	81.61 $\pm$ 14.27
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	14.23 $\pm$ 1.10
^{193m}Hg	i(m)	11.8H	407.6	32 ± 6	25.77 $\pm$ 4.93
^{192}Hg	c	4.85H	274.8	50.2 ± 2.5	90.13 ± 5.84

Continuation of Table 103.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			316.5	*	104.3 ± 13.1
			$RR_{mean} =$		92.11 ± 2.84
^{190}Hg	c*	20.0M	142.6	68 ± 10	66.91 ± 10.64
			295.8	*	43.10 ± 8.56
			597.7	*	65.89 ± 16.44
			301.8	*	98.23 ± 13.96
			$RR_{mean} =$		65.12 ± 2.01
^{196}Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	3.624 ± 0.135
			333.0	22.9 ± 0.6	4.079 ± 0.235
			$RR_{mean} =$		3.673 ± 0.182
^{195}Au	c	186.098D	98.9	10.9 ± 0.9	104.8 ± 12.3
^{194}Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	7.676 ± 0.720
$^{192}\text{Au}_i$	i(m+g)	4.94H	316.5	58 ± 7	15.56 ± 2.31
$^{192}\text{Au}_c$	c	4.94H	316.5	58 ± 7	119.9 ± 15.1
^{191}Au	c*	3.18H	277.9	7.2 ± 0.5	84.10 ± 10.41
$^{190}\text{Au}_c$	c	42.8M	295.8	71 ± 5	100.8 ± 8.7
			301.8	23.4 ± 1.5	79.75 ± 8.81
			597.7	9.4 ± 0.9	73.45 ± 10.23
			$RR_{mean} =$		88.55 ± 8.86
^{191}Pt	c	2.802D	538.9	13.7 ± 1.6	96.50 ± 11.76
			409.4	8.0 ± 0.9	81.92 ± 9.67
			359.9	6.0 ± 0.7	84.92 ± 10.45
			129.4	3.2 ± 0.5	91.57 ± 15.76
			$RR_{mean} =$		86.73 ± 4.32
^{189}Pt	c	10.87H	568.8	7.1 ± 0.6	104.2 ± 14.6
			544.9	5.8 ± 0.5	122.9 ± 13.7
			607.6	8.10 ± 0.16	105.1 ± 5.7
			$RR_{mean} =$		106.8 ± 5.3
^{188}Pt	c	10.2D	195.1	18.6 ± 1.2	91.40 ± 6.91
			187.6	19.4 ± 1.2	90.34 ± 6.61
			381.4	7.5 ± 0.5	86.89 ± 6.54
			423.3	4.4 ± 0.3	87.78 ± 6.77
			478.0	*	89.29 ± 4.85
			$RR_{mean} =$		89.18 ± 2.75
^{186}Pt	c	2.08H	689.4	70 ± 15	82.58 ± 17.94
^{184}Pt	c	17.3M	548.3	23 ± 4	84.01 ± 16.84
^{189}Ir	c	13.2D	245.1	6.0 ± 0.6	89.18 ± 9.74
$^{188}\text{Ir}_c$	c	41.5H	478.0	14.7 ± 0.6	92.91 ± 5.29
^{187}Ir	c*	10.5H	977.5	3.14 ± 0.11	83.03 ± 7.47
^{186}Ir	c	16.64H	296.9	62.3 ± 1.9	42.73 ± 3.45
			434.8	33.9 ± 1.1	42.11 ± 2.19
			$RR_{mean} =$		42.26 ± 2.01
^{185}Ir	c	14.4H	254.2	13.3 ± 2.4	52.57 ± 10.34
			1829.0	10.1 ± 1.5	64.27 ± 9.98
			1668.0	3.6 ± 0.6	66.33 ± 11.79
			$RR_{mean} =$		62.75 ± 3.73
^{184}Ir	c*	3.09H	264.0	68 ± 4	89.24 ± 6.40
			119.8	31 ± 3	97.43 ± 12.12
			390.4	25.9 ± 2.4	83.48 ± 8.53
			1105.3	5.3 ± 0.7	98.99 ± 14.64

Continuation of Table 103.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	89.24 ± 3.63
¹⁸⁵ Os	c	93.6D	646.1	78 ± 3	93.40 ± 4.77
			874.8	6.29 ± 0.25	92.54 ± 4.97
			717.4	3.94 ± 0.16	94.54 ± 5.14
			592.1	1.32 ± 0.06	94.43 ± 6.49
				<i>RR_{mean}</i> =	93.46 ± 3.03
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	55.62 ± 2.63
			1107.9	22.4 ± 0.6	58.91 ± 3.57
				<i>RR_{mean}</i> =	56.35 ± 2.21
¹⁸² Os	c	22.10H	180.2	33.5 ± 1.7	91.86 ± 6.19
			1221.5	*	120.9 ± 9.1
			1189.2	*	110.5 ± 9.2
			1121.4	*	116.1 ± 7.5
				<i>RR_{mean}</i> =	103.3 ± 3.2
¹⁸¹ Os	c	105M	238.8	44 ± 5	27.10 ± 3.86
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	92.67 ± 4.95
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	98.85 ± 4.93
			291.7	3.05 ± 0.18	89.01 ± 6.44
			208.8	2.95 ± 0.09	92.32 ± 5.17
			107.9	2.17 ± 0.07	87.76 ± 8.14
				<i>RR_{mean}</i> =	94.33 ± 3.82
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	99.33 ± 7.62
			1121.4	31.8 ± 1.6	108.7 ± 7.4
			1189.2	15 ± 1	98.07 ± 8.57
				<i>RR_{mean}</i> =	103.2 ± 4.7
¹⁸¹ Re	c*	19.9H	365.5	56 ± 8	96.89 ± 14.27
			639.0	6.4 ± 1.4	91.89 ± 21.74
				<i>RR_{mean}</i> =	95.66 ± 10.44
¹⁷⁹ Re	c*	19.5M	290.0	26.9 ± 2.3	130.1 ± 13.7
			430.2	28.0 ± 1.8	136.0 ± 10.7
				<i>RR_{mean}</i> =	135.0 ± 5.9
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	131.6 ± 16.3
¹⁷⁸ W	c	21.6D	1340.8(D)	1.03 ± 0.09	85.05 ± 9.15
			1106.1(D)	0.54 ± 0.05	88.02 ± 11.81
				<i>RR_{mean}</i> =	85.80 ± 5.18
¹⁷⁷ W	c	135M	115.7	51 ± 5	95.12 ± 11.99
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	98.04 ± 23.13
¹⁷⁶ Ta	c*	8.09H	1159.3	24.7 ± 1.9	123.2 ± 10.5
			1823.7	4.5 ± 0.4	125.1 ± 17.3
			1584.0	5.3 ± 0.4	106.2 ± 10.3
				<i>RR_{mean}</i> =	119.1 ± 6.4
¹⁷⁵ Ta	c	10.5H	348.5	12.0 ± 1.1	100.7 ± 10.0
			1793.1	4.6 ± 0.7	71.54 ± 11.66
				<i>RR_{mean}</i> =	88.74 ± 14.58
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	96.58 ± 9.18
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	110.9 ± 12.6
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	60.44 ± 6.20
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	93.48 ± 4.59
¹⁷³ Hf	c*	23.6H	123.7	83 ± 5	117.2 ± 10.7
			297.0	33.9 ± 1.4	157.6 ± 9.7

Continuation of Table 103.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			139.6	12.7 ± 0.6	117.6 ± 9.8
			311.2	10.7 ± 0.5	108.1 ± 6.5
			306.6	6.4 ± 0.3	129.3 ± 8.4
			$RR_{mean} =$		123.3 ± 9.8
^{172}Hf	c	1.87Y	125.8	11.3 ± 0.9	82.64 ± 8.87
			1002.7(D)	5.55 ± 0.38	82.55 ± 7.06
			1093.6	*	83.35 ± 4.85
			929.1	*	89.71 ± 7.69
			912.1	*	91.84 ± 5.70
			697.3	*	119.6 ± 7.6
			181.5	*	84.64 ± 5.35
			$RR_{mean} =$		85.96 ± 2.65
^{170}Hf	c	16.01H	164.7	26 ± 8	99.89 ± 31.01
			620.7	18 ± 5	110.1 ± 30.9
			120.2	15 ± 5	119.1 ± 40.6
			$RR_{mean} =$		108.6 ± 7.8
^{168}Hf	c	25.95M	979.2	22.3 ± 5.6	85.22 ± 22.25
^{173}Lu	c	1.37Y	272.1	21.2 ± 0.8	91.74 ± 4.96
$^{172}\text{Lu}_i$	i(m+g)	6.70D	1093.6	63 ± 3	0.5030 ± 0.0802
$^{172}\text{Lu}_c$	c	6.70D	1093.6	63 ± 3	83.85 ± 4.88
			181.5	20.6 ± 1.0	86.12 ± 5.44
			912.1	15.3 ± 0.7	91.39 ± 9.40
			$RR_{mean} =$		85.02 ± 3.24
^{171}Lu	c*	8.24D	739.8	47.8 ± 1.2	99.64 ± 4.13
			667.4	11.0 ± 0.3	105.2 ± 4.6
			780.7	4.36 ± 0.11	101.3 ± 5.2
			839.9	3.04 ± 0.08	110.8 ± 5.0
			853.0	2.55 ± 0.07	99.27 ± 4.61
			689.3	2.37 ± 0.06	92.57 ± 4.33
			712.7	1.13 ± 0.03	103.6 ± 5.7
			$RR_{mean} =$		101.3 ± 3.8
^{170}Lu	c*	2.012D	1280.2	8.2 ± 0.4	115.7 ± 7.5
			2126.1	5.1 ± 0.3	119.2 ± 8.8
			1054.3	4.76 ± 0.24	127.7 ± 8.1
			$RR_{mean} =$		120.9 ± 5.3
^{169}Lu	c	34.06H	960.6	23.4 ± 0.7	71.56 ± 3.36
			191.2	20.6 ± 0.6	79.93 ± 3.93
			1449.7	9.9 ± 0.3	68.21 ± 3.56
			889.8	5.36 ± 0.17	71.12 ± 3.88
			$RR_{mean} =$		72.54 ± 3.30
^{167}Lu	c	51.5M	113.3	*	89.63 ± 8.47
			106.2	*	72.03 ± 8.83
			$RR_{mean} =$		81.41 ± 9.13
^{169}Yb	c*	32.026D	198.0	35.8 ± 0.7	89.38 ± 3.97
			177.2	22.2 ± 0.5	89.45 ± 4.01
			130.5	11.31 ± 0.21	92.94 ± 6.18
			307.7	10.05 ± 0.19	95.29 ± 3.83
			118.2	1.87 ± 0.04	84.85 ± 6.85
			$RR_{mean} =$		91.91 ± 3.24
^{166}Yb	c	56.7H	2052.4	*	76.40 ± 5.44
			2079.5	*	82.43 ± 6.47

Continuation of Table 103.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1374.2	*	80.31 ± 6.48
			1176.7	*	77.02 ± 5.55
			785.9	*	82.61 ± 5.87
			691.2(D)	*	71.73 ± 5.46
			$RR_{mean} =$		77.99 ± 3.24
^{162}Yb	c	18.87M	163.4	40 ± 5	76.93 ± 10.37
^{167}Tm	c	9.25D	207.8	42 ± 8	88.39 ± 17.19
			531.5	1.61 ± 0.22	86.66 ± 12.80
			$RR_{mean} =$		86.91 ± 5.39
^{165}Tm	c	30.06H	242.9	35.5 ± 1.7	82.74 ± 5.14
			806.4	9.5 ± 0.6	89.59 ± 7.26
			$RR_{mean} =$		84.12 ± 3.78
^{163}Tm	c	1.810H	104.3	18.6 ± 0.7	68.44 ± 7.31
^{161}Er	c*	3.21H	826.6	64 ± 4	79.16 ± 6.08
^{160}Er	c	28.58H	728.2(D)	34 ± 5	77.64 ± 11.77
			879.4(D)	22.6 ± 2.8	70.42 ± 9.25
			645.4(D)	18.0 ± 2.3	86.08 ± 11.63
			872.0(D)	6.8 ± 1.1	72.01 ± 12.01
			966.2	*	75.62 ± 10.20
			962.4	*	69.79 ± 9.22
			$RR_{mean} =$		74.56 ± 2.30
^{159}Er	c*	36M	624.5	33 ± 4	78.70 ± 10.09
			649.1	23 ± 3	89.87 ± 12.54
			309.6	*	79.83 ± 8.61
			132.0	*	77.93 ± 11.38
			121.0	*	79.23 ± 8.24
			$RR_{mean} =$		80.25 ± 2.48
$^{160m}\text{Ho}_c$	c	5.02H	962.4	16.6 ± 2.1	74.85 ± 10.96
			966.2	15.4 ± 2.0	76.03 ± 10.54
			$RR_{mean} =$		75.47 ± 7.37
^{156}Ho	c*	56M	266.5	54.7 ± 1.1	71.80 ± 3.46
^{157}Dy	c	8.14H	326.2	92 ± 4	61.62 ± 3.57
^{155}Dy	c*	9.9H	226.9	68.4 ± 1.6	50.86 ± 2.45
^{152}Dy	c	2.38H	256.9	97.50 ± 0.07	30.29 ± 1.38
^{155}Tb	c*	5.32D	105.3	25.1 ± 1.3	54.14 ± 5.19
			180.1	7.5 ± 0.5	52.36 ± 4.17
			163.3	4.44 ± 0.24	49.66 ± 4.17
			148.6	2.65 ± 0.14	56.65 ± 4.95
			$RR_{mean} =$		52.67 ± 2.28
^{153}Tb	c*	2.34D	212.0	31.0 ± 1.9	42.01 ± 3.07
			102.2	6.4 ± 0.5	31.47 ± 4.27
			$RR_{mean} =$		39.20 ± 4.82
^{152}Tb	c*	17.5H	344.3	65 ± 4	39.34 ± 3.02
^{151}Tb	c	17.609H	287.4	28.3 ± 1.2	33.96 ± 1.99
			108.1	24.3 ± 1.1	30.06 ± 3.05
			587.5	15.6 ± 0.7	37.38 ± 2.66
			479.4	15.4 ± 0.7	31.09 ± 2.21
			395.4	10.8 ± 0.5	35.07 ± 3.32
			$RR_{mean} =$		33.48 ± 1.59
^{150}Tb	c	3.48H	638.0	72 ± 10	17.97 ± 2.74

Continuation of Table 103.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁴⁹ Tb	c	4.118H	165.0	26.4 ± 0.9	17.19 ± 2.25
			352.2	29.4 ± 0.9	17.12 ± 1.32
			<i>RR_{mean}</i> =		17.14 ± 1.12
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	23.90 ± 1.50
¹⁵³ Gd	c	240.4D	97.4	29.0 ± 0.8	34.97 ± 2.95
			103.2	21.1 ± 0.7	39.58 ± 3.46
			<i>RR_{mean}</i> =		36.89 ± 2.54
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	35.81 ± 3.05
			153.6	6.2 ± 0.4	32.30 ± 2.71
			174.7	2.96 ± 0.21	35.41 ± 3.06
			<i>RR_{mean}</i> =		34.25 ± 1.57
¹⁴⁹ Gd	c	9.28D	149.7	48 ± 3	45.03 ± 3.61
			298.6	28.6 ± 1.7	40.60 ± 2.82
			346.6	23.9 ± 1.3	40.35 ± 2.60
			788.9	7.3 ± 0.4	45.32 ± 2.96
			<i>RR_{mean}</i> =		42.17 ± 1.87
¹⁴⁷ Gd	c	38.06H	229.3	63 ± 4	34.76 ± 2.61
			396.0	34.3 ± 2.1	29.37 ± 2.09
			929.0	20.2 ± 1.2	31.96 ± 2.23
			370.0	17.2 ± 0.9	32.99 ± 2.15
			<i>RR_{mean}</i> =		32.01 ± 1.46
¹⁴⁶ Gd	c	48.27D	154.6	46.6 ± 0.5	34.83 ± 1.45
			747.2	*	33.12 ± 1.48
			1533.7	*	30.27 ± 1.91
			1297.0	*	32.52 ± 1.89
			<i>RR_{mean}</i> =		33.35 ± 1.03
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	54.16 ± 2.86
			277.1	3.56 ± 0.06	50.15 ± 2.29
			<i>RR_{mean}</i> =		51.53 ± 2.48
¹⁴⁷ Eu	c*	24.1D	121.2	22.9 ± 1.3	39.46 ± 3.56
			677.5	9.8 ± 0.5	41.44 ± 2.61
			798.7	4.8 ± 0.3	41.19 ± 3.07
			601.5	5.9 ± 0.3	42.68 ± 2.79
			955.8	3.84 ± 0.20	43.33 ± 2.95
			933.0	3.44 ± 0.18	40.32 ± 3.06
			856.9	2.70 ± 0.14	36.75 ± 2.57
			<i>RR_{mean}</i> =		40.85 ± 1.54
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	4.581 ± 0.217
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	37.70 ± 1.69
¹⁴⁵ Eu	c	5.93D	893.7	66 ± 5	26.10 ± 2.18
			1658.5	14.9 ± 1.0	24.72 ± 1.90
			653.5	15 ± 1	25.72 ± 2.04
			1997.0	7.2 ± 0.5	26.76 ± 2.30
			542.6	4.5 ± 0.4	30.10 ± 3.05
			<i>RR_{mean}</i> =		26.07 ± 1.13
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	22.86 ± 1.64
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	19.82 ± 0.77
¹³⁵ Ce	c	17.7H	265.6	41.8 ± 1.5	12.59 ± 0.75
¹³² Ce	c	3.51H	182.1	77.4 ± 0.5	10.71 ± 0.59
			464.5	*	9.136 ± 0.859

Continuation of Table 103.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	10.30 ± 0.32
¹³² La _c	c	4.8H	464.5	76 ± 6	8.982 ± 0.805
¹³³ Ba	c	3848.9D	356.0	62.05 ± 0.19	12.28 ± 0.97
¹³¹ Ba	c	11.50D	123.8	29.0 ± 0.3	10.98 ± 0.78
			373.2	14.04 ± 0.20	11.33 ± 0.48
				$RR_{mean} =$	11.27 ± 0.45
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	7.158 ± 0.696
			273.4	14.5 ± 0.7	7.301 ± 0.614
				$RR_{mean} =$	7.245 ± 0.419
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	14.44 ± 1.10
¹²⁷ Xe	c	36.4D	172.1	25.5 ± 0.8	10.72 ± 0.61
			375.0	17.2 ± 0.6	10.47 ± 0.55
			202.9	68.3 ± 0.5	10.40 ± 0.43
				$RR_{mean} =$	10.47 ± 0.38
¹²⁵ Xe	c	16.9H	188.4	54.0 ± 0.3	12.84 ± 0.81
¹²³ Xe	c	2.08H	148.9	48.9 ± 0.6	12.80 ± 1.16
¹²⁶ I	i	13.11D	388.6	34 ± 3	0.8295 ± 0.1390
¹²¹ I	c*	2.12H	212.2	84.3 ± 0.3	9.868 ± 0.769
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.389 ± 0.072
^{121m} Te	i(m)	154D	212.2	81.4 ± 1.1	2.316 ± 0.112
			573.1	88.6 ± 0.1	2.439 ± 0.205
				$RR_{mean} =$	2.336 ± 0.072
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	8.736 ± 0.434
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	2.928 ± 0.190
¹¹⁶ Te	c	2.49H	1293.6	95 ± 8	4.386 ± 0.763
^{120m} Sb	i(m)	5.76D	1023.3	99.4 ± 0.3	1.843 ± 0.095
			1171.7	100 ± 0	1.910 ± 0.095
				$RR_{mean} =$	1.877 ± 0.079
¹¹⁵ Sb	c*	32.1M	497.3	97.9 ± 0.4	7.780 ± 0.726
^{117m} Sn	i(m)	13.60D	158.6	86.4 ± 0.4	3.768 ± 0.158
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	5.437 ± 0.236
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	5.474 ± 0.574
¹¹¹ In	c	2.8047D	245.4	94 ± 1	7.370 ± 0.328
			171.3	90.2 ± 1.0	6.986 ± 0.327
				$RR_{mean} =$	7.187 ± 0.293
^{110m} Ag	i(m)	249.76D	1384.3	24.9 ± 0.8	5.508 ± 0.443
			937.5	34.2 ± 0.6	5.073 ± 0.362
			884.7	72.7 ± 0.4	4.780 ± 0.216
			657.8	94.3 ± 0.3	4.922 ± 0.189
				$RR_{mean} =$	4.916 ± 0.175
^{106m} Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	5.087 ± 0.281
			717.3	28.9 ± 0.8	4.704 ± 0.255
			451.0	28.2 ± 0.8	5.004 ± 0.273
			406.2	13.4 ± 0.4	4.564 ± 0.314
				$RR_{mean} =$	4.856 ± 0.190
¹⁰⁵ Ag	c	41.29D	280.4	30.2 ± 1.8	6.275 ± 0.469
			443.4	10.5 ± 0.6	6.857 ± 0.785
				$RR_{mean} =$	6.413 ± 0.415
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.8840 ± 0.1013
¹⁰⁵ Rh	c	35.36H	318.9	19.1 ± 0.6	16.89 ± 1.13

Continuation of Table 103.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁰² Rh	i	207D	475.1	46 ± 5	4.597 ± 0.553
^{101m} Rh	c	4.34D	306.9	81 ± 5	8.328 ± 0.612
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	5.068 ± 0.455
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	5.952 ± 0.455
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	15.16 ± 0.57
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	6.990 ± 0.380
			812.5	82 ± 4	7.323 ± 0.446
			<i>RR_{mean}</i> =		7.123 ± 0.327
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	13.14 ± 0.78
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	3.603 ± 0.502
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	10.11 ± 0.55
			568.9	58.0 ± 0.3	10.26 ± 0.88
			<i>RR_{mean}</i> =		10.15 ± 0.51
⁹⁵ Nb _i	i(m+g)	34.975D	765.8	99.81 ± 0.03	13.40 ± 0.53
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	22.10 ± 0.77
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	4.971 ± 0.332
⁹⁵ Zr	c	64.02D	724.2	44.17 ± 0.16	9.112 ± 0.355
			756.7	54.46 ± 0.10	8.377 ± 0.295
			765.8	*	8.780 ± 0.414
			<i>RR_{mean}</i> =		8.696 ± 0.268
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	12.68 ± 0.43
⁸⁸ Zr	c	83.4D	1836.1	*	7.358 ± 0.414
			898.0	*	6.754 ± 0.506
			392.9	97.24 ± 0.00	6.715 ± 0.240
			<i>RR_{mean}</i> =		6.779 ± 0.209
^{90m} Y	i(m)	3.19H	479.5	90.74 ± 0.05	11.33 ± 0.70
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	16.16 ± 0.62
			898.0	93.7 ± 0.3	15.98 ± 0.62
			<i>RR_{mean}</i> =		16.07 ± 0.56
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	23.51 ± 0.83
			898.0	93.7 ± 0.3	22.73 ± 0.79
			<i>RR_{mean}</i> =		23.06 ± 0.81
⁸⁷ Y	c*	79.8H	388.5	82.1 ± 0.5	17.77 ± 0.62
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	17.30 ± 0.94
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	16.05 ± 0.77
⁸³ Rb	c	86.2D	520.4	45 ± 4	19.37 ± 1.85
			529.6	29.3 ± 2.1	19.01 ± 1.52
			552.6	16.0 ± 1.1	20.24 ± 1.58
			<i>RR_{mean}</i> =		19.58 ± 0.86
^{82m} Rb	i(m)	6.472H	554.3	62.4 ± 0.9	9.318 ± 0.967
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	7.439 ± 0.351
⁷⁵ Se	c	119.779D	136.0	58.3 ± 0.8	9.758 ± 0.625
			264.7	58.9 ± 0.4	9.404 ± 0.376
			400.7	11.47 ± 0.09	10.94 ± 0.78
			<i>RR_{mean}</i> =		9.591 ± 0.429
⁷⁶ As	i	1.0778D	559.1	45 ± 2	16.51 ± 1.73
⁷⁴ As	i	17.77D	595.8	59 ± 4	10.41 ± 0.80
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	1.657 ± 0.105
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	4.155 ± 0.413
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	6.125 ± 0.426

Continuation of Table 103.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁷² Zn	c	46.5H	2201.7	*	1.971 ± 0.146
⁶⁵ Zn	c	244.26D	1115.6	50.60 ± 0.24	4.446 ± 0.256
⁵⁸ Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	3.269 ± 0.232
⁵⁹ Fe	c	44.472D	1099.2	56.5 ± 1.9	5.213 ± 0.315
			1291.6	43.2 ± 1.4	5.051 ± 0.255
			RR _{mean} =		5.105 ± 0.214
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	3.967 ± 0.305
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	0.5116 ± 0.0447
			983.5	100.0 ± 0.3	0.5830 ± 0.1014
			RR _{mean} =		0.5222 ± 0.0418
⁴⁸ Sc	i	43.67H	1312.1	100.1 ± 0.7	1.953 ± 0.125
			1037.5	97.6 ± 0.7	1.938 ± 0.113
			983.5	100.1 ± 0.6	2.111 ± 0.505
			RR _{mean} =		1.948 ± 0.093
⁴⁶ Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	3.473 ± 0.257
			889.3	99.98 ± 0.00	3.364 ± 0.128
			RR _{mean} =		3.374 ± 0.126
²⁸ Mg	c	20.915H	1778.8	100.2 ± 0.0	1.242 ± 0.111
²⁴ Na	c	14.9590H	1369.0	100 ± 0	6.112 ± 0.372
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	18.01 ± 0.83

12.10.6 Nuclide production rates for ^{27}Al

Table 104: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 1.6 \text{ GeV}$, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	36.30 ± 1.39
^{27}Mg	c	9.458M	1014.4	28.0 ± 0.4	4.023 ± 0.246
			843.8	71.8 ± 0.4	3.568 ± 0.162
				$RR_{mean} =$	3.677 ± 0.225
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	53.78 ± 1.86
^{24}Na	c	14.9590H	1369.0	100 ± 0	50.81 ± 1.69
^{24}Ne	c	3.38M	472.2	100 ± 0	2.102 ± 1.394
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.685 ± 0.056
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	20.94 ± 0.77
^{27}Mg	c	9.458M	1014.4	28.0 ± 0.4	2.125 ± 0.184
			843.8	71.8 ± 0.4	1.998 ± 0.129
				$RR_{mean} =$	2.037 ± 0.114
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	29.94 ± 1.07
^{24}Na	c	14.9590H	1369.0	100 ± 0	28.92 ± 0.96
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.9596 ± 0.0328
^{27}Al -monitor for ^{207}Pb					

Continuation of Table 104.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	31.45 ± 1.15
²⁷ Mg	c	9.458M	1014.4	28.0 ± 0.4	3.119 ± 0.206
			843.8	71.8 ± 0.4	3.049 ± 0.141
			<i>RR_{mean}</i> =		3.067 ± 0.131
²² Na	c	2.6019Y	1274.5	99.94 ± 0.01	44.89 ± 1.58
²⁴ Na	c	14.9590H	1369.0	100 ± 0	42.61 ± 1.42
²⁴ Ne	c	3.38M	472.2	100 ± 0	3.488 ± 0.731
²⁷ Al-plate for ²⁰⁷ Pb					
²⁴ Na	c	14.9590H	1369.0	100 ± 0	1.500 ± 0.051
²⁷ Al-monitor for ^{nat} Pb					
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	48.76 ± 1.74
²⁷ Mg	c	9.458M	1014.4	28.0 ± 0.4	6.077 ± 0.383
			843.8	71.8 ± 0.4	6.097 ± 0.271
			<i>RR_{mean}</i> =		6.092 ± 0.252
²² Na	c	2.6019Y	1274.5	99.94 ± 0.01	71.57 ± 2.47
²⁴ Na	c	14.9590H	1369.0	100 ± 0	67.18 ± 2.23
²⁷ Al-plate for ^{nat} Pb					
²⁴ Na	c	14.9590H	1369.0	100 ± 0	2.391 ± 0.080
²⁷ Al-monitor for ²⁰⁹ Bi					
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	30.22 ± 1.11
²⁷ Mg	c	9.458M	843.8	71.8 ± 0.4	5.237 ± 0.223
			1014.4	28.0 ± 0.4	5.071 ± 0.385
			<i>RR_{mean}</i> =		5.210 ± 0.214
²² Na	c	2.6019Y	1274.5	99.94 ± 0.01	44.63 ± 1.57
²⁴ Na	c	14.9590H	1369.0	100 ± 0	43.56 ± 1.45
²⁷ Al-plate for ²⁰⁹ Bi					
²⁴ Na	c	14.9590H	1369.0	100 ± 0	1.518 ± 0.051

12.11 Detailed calculation of nuclide production rates for ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{nat}Pb and ^{209}Bi for $E_p = 2.6$ GeV

12.11.1 Nuclide production rates for ^{206}Pb

Table 105: Detailed calculation of nuclide production rates for ^{206}Pb for $E_p = 2.6$ GeV, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	1.969 ± 0.108
			803.1	98.9 ± 1.4	1.797 ± 0.081
			537.5	30.5 ± 0.5	1.839 ± 0.109
			RR _{mean} =		1.846 ± 0.075
²⁰⁵ Bi	i	15.31D	1764.3	32.5 ± 0.7	4.144 ± 0.226
			987.7	16.13 ± 0.17	5.935 ± 0.307
			RR _{mean} =		4.797 ± 0.875
²⁰⁴ Bi	i	11.22H	374.8	82 ± 5	4.392 ± 0.919
			899.2	98 ± 9	4.388 ± 0.163
			984.0	59 ± 4	3.658 ± 0.375
			RR _{mean} =		4.344 ± 0.134
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	4.388 ± 0.340
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	3.272 ± 0.505
^{204m} Pb _i	i(m)	67.2M	374.7	89 ± 15	14.48 ± 2.50
			899.2	99.17 ± 0.02	14.44 ± 0.58
			RR _{mean} =		14.44 ± 0.58
^{204m} Pb _c	c	67.2M	374.7	89 ± 15	15.09 ± 2.61
			899.2	99.17 ± 0.02	15.18 ± 0.60
			RR _{mean} =		15.17 ± 0.60
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	41.85 ± 1.53
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	11.45 ± 1.18
			422.1	86 ± 5	10.07 ± 0.76
			RR _{mean} =		10.32 ± 0.62
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	28.96 ± 2.08
²⁰⁰ Pb	c	21.5H	1205.7	*	19.38 ± 1.46
			579.3	*	18.83 ± 1.27
			367.9	*	18.42 ± 0.74
			147.6	37.7 ± 1.4	19.26 ± 1.07
			RR _{mean} =		18.69 ± 0.58
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	37.62 ± 6.16
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	28.20 ± 4.88
^{197m} Pb	c*	43M	385.9	74 ± 15	15.75 ± 3.26
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	19.28 ± 0.70
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	49.95 ± 1.96
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	21.14 ± 1.65
			579.3	13.8 ± 0.7	21.93 ± 1.57
			367.9	87.2 ± 0.4	20.99 ± 1.05
			RR _{mean} =		21.21 ± 0.92
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	40.51 ± 2.81
			579.3	13.8 ± 0.7	40.76 ± 2.52
			367.9	87.2 ± 0.4	39.41 ± 1.39
			RR _{mean} =		39.58 ± 1.36

Continuation of Table 105.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	32.72 ± 4.16
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	42.80 ± 5.24
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	18.39 ± 2.30
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	29.91 ± 5.26
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	1.857 ± 0.141
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	7.568 ± 0.341
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	13.25 ± 1.78
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	15.64 ± 2.33
¹⁹² Hg	c	4.85H	2236.9	*	24.28 ± 4.18
			316.5	*	28.36 ± 3.57
			274.8	50.2 ± 2.5	24.90 ± 1.60
			<i>RR_{mean}</i> =		25.34 ± 0.78
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	15.82 ± 2.51
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	1.398 ± 0.161
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	2.609 ± 0.094
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	32.87 ± 3.21
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	4.488 ± 0.404
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	7.928 ± 1.079
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	36.28 ± 4.56
¹⁹⁰ Au _c	c	42.8M	295.8	71 ± 5	33.47 ± 3.53
¹⁹¹ Pt	c	2.802D	409.4	8.0 ± 0.9	24.49 ± 2.89
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	33.35 ± 3.17
			568.8	7.1 ± 0.6	29.37 ± 3.00
			544.9	5.8 ± 0.5	29.90 ± 2.99
			<i>RR_{mean}</i> =		30.79 ± 1.92
¹⁸⁸ Pt	c	10.2D	423.3	4.4 ± 0.3	23.33 ± 1.91
			195.1	18.6 ± 1.2	25.46 ± 1.91
			<i>RR_{mean}</i> =		24.45 ± 1.31
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	22.52 ± 4.89
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	26.60 ± 3.10
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	27.12 ± 2.96
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	28.02 ± 2.23
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	11.47 ± 0.60
			137.2	41.4 ± 0.7	11.88 ± 0.53
			<i>RR_{mean}</i> =		11.72 ± 0.47
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	20.02 ± 3.10
			254.2	13.3 ± 2.4	15.83 ± 2.98
			<i>RR_{mean}</i> =		19.07 ± 1.85
¹⁸⁴ Ir	c*	3.09H	264.0	68 ± 4	25.01 ± 1.78
			119.8	31 ± 3	24.47 ± 2.66
			<i>RR_{mean}</i> =		24.96 ± 1.03
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	26.07 ± 1.48
			646.1	78 ± 3	25.73 ± 1.32
			<i>RR_{mean}</i> =		25.80 ± 0.86
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	13.97 ± 0.66
¹⁸² Os	c	22.10H	180.2	33.5 ± 1.7	24.43 ± 1.57
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	23.07 ± 1.43
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	26.18 ± 1.24
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	29.64 ± 2.23
			1189.2	15 ± 1	27.97 ± 2.35

Continuation of Table 105.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸¹ Re	c*	19.9H		$RR_{mean} =$	28.91 ± 1.52
			639.0	6.4 ± 1.4	24.51 ± 5.44
			365.5	56 ± 8	24.01 ± 3.56
¹⁷⁹ Re	c*	19.5M		$RR_{mean} =$	24.13 ± 2.61
			430.2	28.0 ± 1.8	37.59 ± 3.59
			290.0	26.9 ± 2.3	42.03 ± 4.99
¹⁷⁸ Re	c*	13.2M		$RR_{mean} =$	38.76 ± 2.37
			237.3	45 ± 5	38.08 ± 5.05
¹⁷⁷ W	c	135M	115.7	51 ± 5	22.66 ± 2.47
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	26.42 ± 6.08
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	24.30 ± 3.63
			1159.3	24.7 ± 1.9	24.41 ± 2.12
			710.5	5.4 ± 0.4	29.95 ± 5.81
¹⁷⁵ Ta	c	10.5H		$RR_{mean} =$	24.52 ± 1.09
			348.5	12.0 ± 1.1	28.84 ± 2.85
			266.9	10.52 ± 0.16	24.23 ± 1.09
¹⁷⁴ Ta _c	c	1.14H		$RR_{mean} =$	24.57 ± 1.43
			206.5	60 ± 5	25.46 ± 2.37
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	28.17 ± 3.35
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	17.20 ± 1.83
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	23.48 ± 1.15
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	28.19 ± 1.66
			123.7	83 ± 5	28.10 ± 2.08
				$RR_{mean} =$	28.17 ± 1.20
¹⁷² Hf	c	1.87Y	1093.6	*	20.60 ± 1.25
			125.8	11.3 ± 0.9	21.50 ± 2.11
				$RR_{mean} =$	20.80 ± 0.64
¹⁷¹ Hf	c	12.1H	739.8	*	17.42 ± 2.63
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	28.65 ± 8.03
			164.7	26 ± 8	27.05 ± 8.38
			120.2	15 ± 5	27.02 ± 9.09
¹⁷³ Lu	c	1.37Y		$RR_{mean} =$	28.17 ± 1.99
			272.1	21.2 ± 0.8	22.39 ± 1.26
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.2067 ± 0.0332
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	20.81 ± 1.26
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	24.58 ± 1.03
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	25.63 ± 1.07
¹⁷⁰ Lu _c	c	2.012D	2126.1	5.1 ± 0.3	20.56 ± 1.65
			1280.2	8.2 ± 0.4	21.56 ± 1.41
			985.1	5.5 ± 0.3	23.45 ± 1.92
¹⁶⁹ Lu	c	34.06H		$RR_{mean} =$	21.65 ± 0.96
			960.6	23.4 ± 0.7	19.29 ± 0.89
			191.2	20.6 ± 0.6	20.05 ± 0.99
¹⁶⁷ Lu	c	51.5M		$RR_{mean} =$	19.60 ± 0.75
			176.2	*	21.53 ± 1.37
			113.3	*	21.45 ± 1.59
¹⁶⁹ Yb	c*	32.026D		$RR_{mean} =$	21.50 ± 1.14
			198.0	35.8 ± 0.7	23.40 ± 1.06
			177.2	22.2 ± 0.5	22.81 ± 0.99
			130.5	11.31 ± 0.21	23.43 ± 1.09

Continuation of Table 105.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	23.16 ± 0.81
¹⁶⁶ Yb	c	56.7H	2079.5	*	21.50 ± 1.81
			2052.4	*	23.00 ± 1.64
			1867.9	*	22.82 ± 1.73
			1176.7	*	20.53 ± 1.49
			785.9	*	24.77 ± 1.78
			691.2(D)	8.56 ± 0.58	19.37 ± 1.53
				<i>RR_{mean}</i> =	21.76 ± 0.67
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	24.25 ± 4.71
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	22.89 ± 1.68
			242.9	35.5 ± 1.7	24.16 ± 1.53
				<i>RR_{mean}</i> =	23.71 ± 1.01
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	29.73 ± 2.17
¹⁶⁰ Er	c	28.58H	966.2	*	23.58 ± 3.16
			879.4(D)	22.6 ± 2.8	24.51 ± 3.17
			872.0(D)	6.8 ± 1.1	24.73 ± 4.12
			728.2(D)	*	24.62 ± 3.61
				<i>RR_{mean}</i> =	24.31 ± 0.75
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	28.54 ± 3.84
			309.6	*	29.79 ± 3.27
			132.0	*	26.78 ± 2.89
				<i>RR_{mean}</i> =	28.21 ± 0.87
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	25.67 ± 3.52
			728.2	28 ± 4	26.33 ± 3.88
				<i>RR_{mean}</i> =	25.96 ± 2.53
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	27.81 ± 1.30
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	22.39 ± 1.25
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	20.51 ± 0.98
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	13.94 ± 0.61
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	19.62 ± 1.55
			105.3	25.1 ± 1.3	20.61 ± 1.46
				<i>RR_{mean}</i> =	20.24 ± 0.88
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	17.74 ± 1.30
¹⁵² Tb _c	c	17.5H	344.3	65 ± 4	14.26 ± 1.03
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	15.55 ± 0.96
			251.9	26.3 ± 1.2	15.93 ± 0.96
				<i>RR_{mean}</i> =	15.74 ± 0.69
¹⁴⁹ Tb	c	4.118H	352.2	29.4 ± 0.9	8.181 ± 0.627
			165.0	26.4 ± 0.9	9.404 ± 0.725
				<i>RR_{mean}</i> =	8.703 ± 0.662
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	10.35 ± 0.47
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	14.98 ± 0.93
			97.4	29.0 ± 0.8	15.18 ± 0.88
				<i>RR_{mean}</i> =	15.09 ± 0.68
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	14.84 ± 1.30
¹⁴⁹ Gd	c	9.28D	788.9	7.3 ± 0.4	21.94 ± 1.50
			346.6	23.9 ± 1.3	18.85 ± 1.21
			298.6	28.6 ± 1.7	19.15 ± 1.32
			149.7	48 ± 3	20.83 ± 1.52
				<i>RR_{mean}</i> =	19.66 ± 0.92

Continuation of Table 105.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	16.71 ± 1.15
			396.0	34.3 ± 2.1	14.99 ± 1.07
			370.0	17.2 ± 0.9	16.79 ± 1.07
			<i>RR_{mean}</i> =		16.21 ± 0.76
¹⁴⁶ Gd	c	48.27D	747.2	*	18.14 ± 0.81
			154.6	46.6 ± 0.5	17.58 ± 0.67
			<i>RR_{mean}</i> =		17.75 ± 0.55
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	24.59 ± 1.33
¹⁴⁷ Eu	c*	24.1D	955.8	3.84 ± 0.20	22.68 ± 1.53
			798.7	4.8 ± 0.3	25.32 ± 1.89
			677.5	9.8 ± 0.5	21.75 ± 1.37
			601.5	5.9 ± 0.3	22.38 ± 1.44
			<i>RR_{mean}</i> =		22.57 ± 0.93
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	2.488 ± 0.119
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	20.63 ± 0.92
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	15.89 ± 1.28
			1658.5	14.9 ± 1.0	15.59 ± 1.22
			893.7	66 ± 5	15.59 ± 1.29
			653.5	15 ± 1	14.93 ± 1.13
			<i>RR_{mean}</i> =		15.45 ± 0.68
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	15.02 ± 1.11
¹³⁶ Nd	c	50.65M	539.8(D)	70.7 ± 2.6	10.65 ± 0.91
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	15.61 ± 0.57
¹³⁵ Ce	c	17.7H	783.6	10.6 ± 0.4	15.36 ± 1.17
			265.6	41.8 ± 1.5	13.42 ± 0.70
			<i>RR_{mean}</i> =		13.69 ± 0.79
¹³⁴ Ce	c	3.16D	604.7	5.04 ± 0.20	11.77 ± 0.88
¹³² Ce	c	3.51H	464.5	*	10.59 ± 0.95
			182.1	77.4 ± 0.5	10.13 ± 0.59
			<i>RR_{mean}</i> =		10.24 ± 0.32
¹³² La _c	c	4.8H	464.5	76 ± 6	10.73 ± 0.94
¹³³ Ba	c	3848.9D	356.0	62.05 ± 0.19	10.91 ± 1.02
¹³¹ Ba	c	11.50D	373.2	14.04 ± 0.20	11.58 ± 0.46
			216.1	19.66 ± 0.25	12.26 ± 0.56
			123.8	29.0 ± 0.3	11.42 ± 0.51
			<i>RR_{mean}</i> =		11.69 ± 0.42
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	8.351 ± 0.590
			273.4	14.5 ± 0.7	10.07 ± 0.65
			<i>RR_{mean}</i> =		9.324 ± 0.902
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	12.98 ± 0.87
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	10.89 ± 0.58
			202.9	68.3 ± 0.5	10.33 ± 0.40
			172.1	25.5 ± 0.8	9.937 ± 0.499
			<i>RR_{mean}</i> =		10.33 ± 0.38
¹²³ Xe	c	2.08H	148.9	48.9 ± 0.6	9.929 ± 0.473
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.2571 ± 0.0809
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	0.6365 ± 0.1124
			212.2	81.4 ± 1.1	0.6616 ± 0.0558
			<i>RR_{mean}</i> =		0.6571 ± 0.0203
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	8.048 ± 0.377

Continuation of Table 105.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.696 ± 0.072
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	0.3323 ± 0.0345
			1023.3	99.4 ± 0.3	0.4389 ± 0.0230
			<i>RR_{mean}</i> = 0.4133 ± 0.0473		
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	4.898 ± 0.206
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	1.585 ± 0.115
¹¹¹ In	c	2.8047D	245.4	94 ± 1	5.116 ± 0.214
			171.3	90.2 ± 1.0	5.038 ± 0.200
			<i>RR_{mean}</i> = 5.071 ± 0.179		
¹¹⁰ In	i	4.9H	937.5	68.4 ± 1.4	3.443 ± 0.195
			884.7	92.9 ± 1.9	3.155 ± 0.186
			<i>RR_{mean}</i> = 3.293 ± 0.176		
¹⁰⁹ In	c	4.2H	203.5	73.5 ± 0.5	4.690 ± 0.328
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	0.8498 ± 0.0887
			657.8	94.3 ± 0.3	0.7624 ± 0.0639
			<i>RR_{mean}</i> = 0.7912 ± 0.0544		
^{106m} Ag	i(m)	8.28D	1527.7	16.3 ± 1.4	1.955 ± 0.232
			1045.8	29.6 ± 1.0	1.970 ± 0.128
			717.3	28.9 ± 0.8	1.910 ± 0.150
			451.0	28.2 ± 0.8	2.014 ± 0.141
			<i>RR_{mean}</i> = 1.967 ± 0.091		
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	4.132 ± 0.405
			344.5	41.4 ± 0.6	3.800 ± 0.190
			<i>RR_{mean}</i> = 3.839 ± 0.177		
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.8674 ± 0.0638
¹⁰² Rh	i	207D	475.1	46 ± 5	1.086 ± 0.162
^{101m} Rh	c	4.34D	306.9	81 ± 5	3.993 ± 0.301
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	2.172 ± 0.155
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	3.039 ± 0.174
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	2.636 ± 0.123
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	2.399 ± 0.133
			812.5	82 ± 4	2.509 ± 0.151
			<i>RR_{mean}</i> = 2.445 ± 0.113		
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	2.480 ± 0.115
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	1.741 ± 0.099
⁹⁶ Nb	i	23.35H	568.9	58.0 ± 0.3	1.504 ± 0.123
			1091.3	48.5 ± 1.6	1.614 ± 0.102
			<i>RR_{mean}</i> = 1.572 ± 0.085		
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	3.795 ± 0.133
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	3.033 ± 0.149
⁹⁵ Zr	c	64.02D	756.7	54.46 ± 0.10	1.382 ± 0.079
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	4.746 ± 0.162
⁸⁸ Zr	c	83.4D	1836.1	*	3.864 ± 0.316
			898.0	*	3.222 ± 0.400
			392.9	97.24 ± 0.00	3.043 ± 0.114
			<i>RR_{mean}</i> = 3.067 ± 0.095		
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	3.585 ± 0.195
			898.0	93.7 ± 0.3	3.739 ± 0.249
			<i>RR_{mean}</i> = 3.638 ± 0.171		
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	7.449 ± 0.306

Continuation of Table 105.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			898.0	93.7 ± 0.3	6.961 ± 0.311
			$RR_{mean} =$		
^{87}Y	c*	79.8H	484.8	89.7 ± 0.7	6.063 ± 0.223
$^{86}\text{Y}_c$	c	14.74H	1076.6	82.5 ± 0.4	3.166 ± 0.126
^{85}Sr	c	64.84D	514.0	96 ± 4	5.745 ± 0.314
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	3.869 ± 0.205
^{83}Rb	c	86.2D	529.6	29.3 ± 2.1	6.592 ± 0.574
			520.4	45 ± 4	6.013 ± 0.615
			$RR_{mean} =$		
^{82m}Rb	i(m)	6.472H	554.3	62.4 ± 0.9	2.732 ± 0.167
^{82}Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	1.532 ± 0.068
^{75}Se	c	119.779D	264.7	58.9 ± 0.4	3.322 ± 0.140
^{74}As	i	17.77D	595.8	59 ± 4	2.985 ± 0.239
^{71}As	c	65.28H	174.9	82.0 ± 2.1	0.9602 ± 0.0639
^{58}Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	1.743 ± 0.162
^{59}Fe	c	44.472D	1099.2	56.5 ± 1.9	1.712 ± 0.109
^{54}Mn	i	312.11D	834.8	99.98 ± 0.00	2.220 ± 0.111
^{48}V	c	15.9735D	1312.1	97.5 ± 0.9	0.5192 ± 0.0347
			983.5	100.0 ± 0.3	0.5225 ± 0.0305
			$RR_{mean} =$		
^{48}Sc	i	43.67H	1312.1	100.1 ± 0.7	1.150 ± 0.059
			1037.5	97.6 ± 0.7	1.004 ± 0.048
			$RR_{mean} =$		
^{46}Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	2.271 ± 0.083
^{28}Mg	c	20.915H	1778.8	100.2 ± 0.0	1.264 ± 0.052
^{24}Na	c	14.9590H	1369.0	100 ± 0	5.471 ± 0.192
^7Be	i	53.29D	477.6	10.52 ± 0.06	8.407 ± 0.768

12.11.2 Nuclide production rates for ^{207}Pb

Table 106: Detailed calculation of nuclide production rates for ^{207}Pb for $E_p = 2.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	1.094 ± 0.057
			803.1	98.9 ± 1.4	0.9988 ± 0.0394
			537.5	30.5 ± 0.5	1.080 ± 0.067
			$RR_{mean} =$		
^{205}Bi	i	15.31D	1764.3	32.5 ± 0.7	1.545 ± 0.087
			987.7	16.13 ± 0.17	1.779 ± 0.098
			$RR_{mean} =$		
^{204}Bi	i	11.22H	374.8	82 ± 5	1.250 ± 0.262
			899.2	98 ± 9	1.256 ± 0.046
			984.0	59 ± 4	1.290 ± 0.123
			$RR_{mean} =$		
^{203}Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	1.197 ± 0.084
^{202}Bi	i	1.72H	422.1	83.7 ± 2.5	1.077 ± 0.288
$^{204m}\text{Pb}_i$	i(m)	67.2M	374.7	89 ± 15	4.446 ± 0.774

Continuation of Table 106.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			899.2	99.17 ± 0.02	4.161 ± 0.200
			<i>RR_{mean}</i> =		4.172 ± 0.198
^{204m} Pb _c	c	67.2M	374.7	89 ± 15	4.620 ± 0.804
			899.2	99.17 ± 0.02	4.370 ± 0.204
			<i>RR_{mean}</i> =		4.379 ± 0.202
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	10.28 ± 0.38
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	4.012 ± 0.410
			422.1	86 ± 5	2.894 ± 0.248
			<i>RR_{mean}</i> =		3.142 ± 0.475
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	7.399 ± 0.533
²⁰⁰ Pb	c	21.5H	1205.7	*	5.528 ± 0.404
			579.3	*	5.053 ± 0.372
			367.9	*	5.013 ± 0.183
			147.6	37.7 ± 1.4	5.117 ± 0.284
			<i>RR_{mean}</i> =		5.056 ± 0.156
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	10.19 ± 1.68
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	7.597 ± 1.313
^{197m} Pb	c*	43M	385.9	74 ± 15	4.355 ± 0.912
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	5.320 ± 0.195
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	12.95 ± 0.52
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	5.345 ± 0.407
			579.3	13.8 ± 0.7	5.512 ± 0.449
			367.9	87.2 ± 0.4	5.337 ± 0.229
			<i>RR_{mean}</i> =		5.357 ± 0.214
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	10.87 ± 0.75
			579.3	13.8 ± 0.7	10.56 ± 0.66
			367.9	87.2 ± 0.4	10.35 ± 0.36
			<i>RR_{mean}</i> =		10.39 ± 0.35
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	8.579 ± 1.143
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	10.58 ± 1.27
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	4.352 ± 0.569
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	9.033 ± 1.589
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	0.8400 ± 0.0388
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	2.578 ± 0.122
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	3.790 ± 0.515
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	4.487 ± 0.667
¹⁹² Hg	c	4.85H	2236.9	*	6.119 ± 1.125
			316.5	*	7.764 ± 0.979
			274.8	50.2 ± 2.5	7.167 ± 0.457
			<i>RR_{mean}</i> =		7.235 ± 0.223
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	6.387 ± 1.102
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	0.7404 ± 0.1490
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	0.9142 ± 0.0367
			333.0	22.9 ± 0.6	0.9577 ± 0.0529
			<i>RR_{mean}</i> =		0.9232 ± 0.0346
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	10.45 ± 1.07
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	1.548 ± 0.139
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	2.272 ± 0.323
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	10.04 ± 1.26
¹⁹⁰ Au _c	c	42.8M	295.8	71 ± 5	10.24 ± 0.98

Continuation of Table 106.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹¹ Pt	c	2.802D	409.4	8.0 ± 0.9	7.185 ± 0.849
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	9.130 ± 0.874
			568.8	7.1 ± 0.6	9.208 ± 1.268
			544.9	5.8 ± 0.5	8.623 ± 0.879
			<i>RR_{mean}</i> =		8.940 ± 0.597
¹⁸⁸ Pt	c	10.2D	423.3	4.4 ± 0.3	7.467 ± 0.592
			195.1	18.6 ± 1.2	7.564 ± 0.567
			187.6	19.4 ± 1.2	7.614 ± 0.552
			<i>RR_{mean}</i> =		7.555 ± 0.345
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	6.617 ± 1.439
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	6.423 ± 0.762
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	8.125 ± 0.886
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	9.177 ± 0.597
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	3.640 ± 0.182
			137.2	41.4 ± 0.7	3.562 ± 0.209
			<i>RR_{mean}</i> =		3.609 ± 0.157
			1829.0	10.1 ± 1.5	5.590 ± 0.874
¹⁸⁵ Ir	c	14.4H	254.2	13.3 ± 2.4	4.253 ± 0.858
			<i>RR_{mean}</i> =		5.302 ± 0.573
			264.0	68 ± 4	7.854 ± 0.562
			119.8	31 ± 3	7.794 ± 0.889
¹⁸⁴ Ir	c*	3.09H	<i>RR_{mean}</i> =		7.848 ± 0.328
			874.8	6.29 ± 0.25	8.141 ± 0.552
			646.1	78 ± 3	7.639 ± 0.392
			<i>RR_{mean}</i> =		7.678 ± 0.273
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	4.240 ± 0.190
¹⁸² Os	c	22.10H	180.2	33.5 ± 1.7	7.576 ± 0.493
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	7.962 ± 0.475
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	8.337 ± 0.404
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	8.450 ± 0.630
			1189.2	15 ± 1	8.431 ± 0.758
			<i>RR_{mean}</i> =		8.443 ± 0.452
			639.0	6.4 ± 1.4	7.379 ± 1.646
¹⁸¹ Re	c*	19.9H	365.5	56 ± 8	7.134 ± 1.055
			<i>RR_{mean}</i> =		7.193 ± 0.777
			430.2	28.0 ± 1.8	13.93 ± 1.62
			290.0	26.9 ± 2.3	14.90 ± 1.98
¹⁷⁹ Re	c*	19.5M	<i>RR_{mean}</i> =		14.29 ± 1.11
			237.3	45 ± 5	14.41 ± 1.87
			115.7	51 ± 5	7.119 ± 0.788
			112.9	7.2 ± 1.6	8.066 ± 1.874
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	7.055 ± 1.437
¹⁷⁶ Ta _c	c	8.09H	1159.3	24.7 ± 1.9	6.977 ± 0.629
			710.5	5.4 ± 0.4	9.457 ± 1.247
			<i>RR_{mean}</i> =		7.166 ± 0.511
			348.5	12.0 ± 1.1	8.182 ± 0.819
¹⁷⁵ Ta	c	10.5H	266.9	10.52 ± 0.16	6.954 ± 0.328
			<i>RR_{mean}</i> =		7.064 ± 0.412
			206.5	60 ± 5	7.483 ± 0.741
			172.2	17.5 ± 1.8	8.766 ± 0.981

Continuation of Table 106.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	6.319 ± 0.796
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	7.041 ± 0.348
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	7.918 ± 0.475
			123.7	83 ± 5	8.761 ± 0.657
			<i>RR_{mean}</i> =		8.126 ± 0.441
¹⁷² Hf	c	1.87Y	1093.6	*	6.235 ± 0.418
			125.8	11.3 ± 0.9	6.967 ± 0.785
			<i>RR_{mean}</i> =		6.378 ± 0.197
¹⁷¹ Hf	c	12.1H	739.8	*	4.490 ± 0.428
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	8.554 ± 2.396
			164.7	26 ± 8	8.039 ± 2.492
			120.2	15 ± 5	8.561 ± 2.887
			<i>RR_{mean}</i> =		8.455 ± 0.598
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	6.809 ± 0.402
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.06450 ± 0.02071
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	6.300 ± 0.418
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	7.264 ± 0.302
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	7.511 ± 0.313
¹⁷⁰ Lu _c	c	2.012D	2126.1	5.1 ± 0.3	5.814 ± 0.425
			1280.2	8.2 ± 0.4	6.758 ± 0.443
			<i>RR_{mean}</i> =		6.322 ± 0.509
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	5.782 ± 0.285
			191.2	20.6 ± 0.6	5.975 ± 0.296
			<i>RR_{mean}</i> =		5.874 ± 0.231
¹⁶⁷ Lu	c	51.5M	176.2	*	7.565 ± 0.698
			113.3	*	7.030 ± 0.519
			<i>RR_{mean}</i> =		7.212 ± 0.443
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	6.917 ± 0.320
			177.2	22.2 ± 0.5	6.924 ± 0.301
			130.5	11.31 ± 0.21	7.111 ± 0.334
			<i>RR_{mean}</i> =		6.973 ± 0.244
¹⁶⁶ Yb	c	56.7H	2079.5	*	6.013 ± 0.477
			2052.4	*	6.381 ± 0.459
			1867.9	*	6.694 ± 0.515
			785.9	*	7.104 ± 0.556
			691.2(D)	8.56 ± 0.58	5.284 ± 0.651
			<i>RR_{mean}</i> =		6.359 ± 0.196
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	7.104 ± 1.381
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	6.534 ± 0.494
			242.9	35.5 ± 1.7	7.389 ± 0.463
			<i>RR_{mean}</i> =		7.099 ± 0.460
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	8.488 ± 0.630
¹⁶⁰ Er	c	28.58H	966.2	*	6.983 ± 0.940
			879.4(D)	22.6 ± 2.8	7.459 ± 0.966
			872.0(D)	6.8 ± 1.1	7.662 ± 1.279
			728.2(D)	*	7.260 ± 1.066
			<i>RR_{mean}</i> =		7.309 ± 0.225
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	8.885 ± 1.209
			309.6	*	10.65 ± 0.98
			132.0	*	11.53 ± 1.16

Continuation of Table 106.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				$RR_{mean} =$	10.45 ± 0.32
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	7.458 ± 1.025
			728.2	28 ± 4	7.176 ± 1.066
				$RR_{mean} =$	7.324 ± 0.717
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	9.179 ± 0.495
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	6.796 ± 0.378
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	6.076 ± 0.285
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	4.209 ± 0.179
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	5.936 ± 0.484
			105.3	25.1 ± 1.3	6.567 ± 0.475
				$RR_{mean} =$	6.318 ± 0.365
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	5.149 ± 0.378
¹⁵² Tb _c	c	17.5H	344.3	65 ± 4	4.261 ± 0.344
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	4.708 ± 0.291
			251.9	26.3 ± 1.2	4.418 ± 0.272
				$RR_{mean} =$	4.553 ± 0.203
¹⁴⁹ Tb	c	4.118H	352.2	29.4 ± 0.9	2.555 ± 0.187
			165.0	26.4 ± 0.9	2.389 ± 0.187
				$RR_{mean} =$	2.474 ± 0.134
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	2.914 ± 0.186
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	4.829 ± 0.320
			97.4	29.0 ± 0.8	5.003 ± 0.333
				$RR_{mean} =$	4.912 ± 0.245
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	4.628 ± 0.651
¹⁴⁹ Gd	c	9.28D	788.9	7.3 ± 0.4	5.990 ± 0.429
			346.6	23.9 ± 1.3	5.388 ± 0.348
			298.6	28.6 ± 1.7	5.406 ± 0.375
			149.7	48 ± 3	6.063 ± 0.446
				$RR_{mean} =$	5.559 ± 0.235
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	5.239 ± 0.364
			396.0	34.3 ± 2.1	4.485 ± 0.320
			370.0	17.2 ± 0.9	4.864 ± 0.306
				$RR_{mean} =$	4.841 ± 0.248
¹⁴⁶ Gd	c	48.27D	747.2	*	5.150 ± 0.232
			154.6	46.6 ± 0.5	4.878 ± 0.205
				$RR_{mean} =$	4.989 ± 0.154
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	6.937 ± 0.934
¹⁴⁷ Eu	c*	24.1D	955.8	3.84 ± 0.20	5.770 ± 0.436
			798.7	4.8 ± 0.3	6.651 ± 0.517
			677.5	9.8 ± 0.5	6.114 ± 0.405
			601.5	5.9 ± 0.3	5.962 ± 0.402
				$RR_{mean} =$	6.070 ± 0.242
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	0.7714 ± 0.0403
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	5.922 ± 0.266
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	4.380 ± 0.363
			1658.5	14.9 ± 1.0	4.121 ± 0.323
			893.7	66 ± 5	4.472 ± 0.377
			653.5	15 ± 1	4.321 ± 0.328
				$RR_{mean} =$	4.305 ± 0.190
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	4.432 ± 0.342

Continuation of Table 106.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{136}Nd	c	50.65M	539.8(D)	70.7 ± 2.6	3.092 ± 0.318
^{139}Ce	c	137.640D	165.9	79.89 ± 0.01	4.621 ± 0.170
^{135}Ce	c	17.7H	783.6	10.6 ± 0.4	4.236 ± 0.574
			265.6	41.8 ± 1.5	3.723 ± 0.199
			$RR_{mean} =$		3.744 ± 0.161
^{134}Ce	c	3.16D	604.7	5.04 ± 0.20	3.669 ± 0.355
^{132}Ce	c	3.51H	464.5	*	2.910 ± 0.256
			182.1	77.4 ± 0.5	3.409 ± 0.158
			$RR_{mean} =$		3.312 ± 0.102
$^{132}\text{La}_c$	c	4.8H	464.5	76 ± 6	2.963 ± 0.259
^{133}Ba	c	3848.9D	356.0	62.05 ± 0.19	3.137 ± 0.721
^{131}Ba	c	11.50D	373.2	14.04 ± 0.20	3.146 ± 0.160
			216.1	19.66 ± 0.25	3.535 ± 0.178
			123.8	29.0 ± 0.3	3.424 ± 0.159
			$RR_{mean} =$		3.361 ± 0.153
^{128}Ba	c	2.43D	442.9	26.8 ± 1.4	2.649 ± 0.174
			273.4	14.5 ± 0.7	2.837 ± 0.182
			$RR_{mean} =$		2.746 ± 0.126
^{129}Cs	c	32.06H	371.9	30.6 ± 1.7	3.709 ± 0.251
^{127}Xe	c	36.4D	375.0	17.2 ± 0.6	2.949 ± 0.167
			202.9	68.3 ± 0.5	2.899 ± 0.116
			172.1	25.5 ± 0.8	2.875 ± 0.146
			$RR_{mean} =$		2.901 ± 0.105
^{123}Xe	c	2.08H	148.9	48.9 ± 0.6	3.021 ± 0.164
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.08314 ± 0.01494
^{121m}Te	i(m)	154D	573.1	88.6 ± 0.1	0.1340 ± 0.0459
			212.2	81.4 ± 1.1	0.2269 ± 0.0169
			$RR_{mean} =$		0.2174 ± 0.0067
$^{121}\text{Te}_c$	c	19.16D	573.1	80.3 ± 2.5	2.219 ± 0.106
^{119m}Te	i(m)	4.70D	1212.7	66.2 ± 0.3	0.5598 ± 0.0331
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	0.1364 ± 0.0130
			1023.3	99.4 ± 0.3	0.1041 ± 0.0124
			$RR_{mean} =$		0.1198 ± 0.0165
^{113}Sn	c	115.09D	391.7	64.97 ± 0.17	1.295 ± 0.062
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	0.3592 ± 0.0783
^{111}In	c	2.8047D	245.4	94 ± 1	1.459 ± 0.060
			171.3	90.2 ± 1.0	1.427 ± 0.059
			$RR_{mean} =$		1.442 ± 0.051
^{110}In	i	4.9H	937.5	68.4 ± 1.4	0.9625 ± 0.0885
			884.7	92.9 ± 1.9	0.6816 ± 0.0646
			$RR_{mean} =$		0.7798 ± 0.1361
^{109}In	c	4.2H	203.5	73.5 ± 0.5	1.153 ± 0.062
^{110m}Ag	i(m)	249.76D	884.7	72.7 ± 0.4	0.2391 ± 0.0564
			657.8	94.3 ± 0.3	0.2805 ± 0.0451
			$RR_{mean} =$		0.2646 ± 0.0356
^{106m}Ag	i(m)	8.28D	1527.7	16.3 ± 1.4	0.7134 ± 0.0810
			1045.8	29.6 ± 1.0	0.6229 ± 0.0464
			717.3	28.9 ± 0.8	0.6435 ± 0.0548
			451.0	28.2 ± 0.8	0.4446 ± 0.0508
			$RR_{mean} =$		0.5891 ± 0.0563

Continuation of Table 106.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	0.9235 ± 0.0977
			344.5	41.4 ± 0.6	0.9931 ± 0.0677
			<i>RR_{mean}</i> = 0.9732 ± 0.0579		
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.2101 ± 0.0362
¹⁰² Rh	i	207D	475.1	46 ± 5	0.3654 ± 0.0650
^{101m} Rh	c	4.34D	306.9	81 ± 5	1.211 ± 0.094
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	0.5102 ± 0.0539
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	0.7203 ± 0.0482
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	0.8004 ± 0.0464
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	0.6412 ± 0.0379
			812.5	82 ± 4	0.6766 ± 0.0428
			<i>RR_{mean}</i> = 0.6563 ± 0.0317		
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	0.6331 ± 0.0359
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	0.5394 ± 0.0311
⁹⁶ Nb	i	23.35H	568.9	58.0 ± 0.3	0.2993 ± 0.1400
			1091.3	48.5 ± 1.6	0.5004 ± 0.0380
			<i>RR_{mean}</i> = 0.4887 ± 0.0494		
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	1.070 ± 0.037
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	0.7378 ± 0.0489
			1129.2	92.7 ± 0.5	0.7518 ± 0.0371
			<i>RR_{mean}</i> = 0.7475 ± 0.0333		
⁹⁵ Zr	c	64.02D	756.7	54.46 ± 0.10	0.4509 ± 0.0288
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	1.261 ± 0.043
⁸⁸ Zr	c	83.4D	1836.1	*	0.7643 ± 0.2738
			898.0	*	0.7706 ± 0.1101
			392.9	97.24 ± 0.00	0.8869 ± 0.0406
			<i>RR_{mean}</i> = 0.8772 ± 0.0271		
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	1.131 ± 0.099
			898.0	93.7 ± 0.3	1.135 ± 0.063
			<i>RR_{mean}</i> = 1.134 ± 0.058		
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	1.895 ± 0.203
			898.0	93.7 ± 0.3	1.906 ± 0.092
			<i>RR_{mean}</i> = 1.905 ± 0.089		
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	1.598 ± 0.058
⁸⁶ Y _c	c	14.74H	1076.6	82.5 ± 0.4	0.8110 ± 0.0339
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	1.606 ± 0.089
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	1.223 ± 0.116
⁸³ Rb	c	86.2D	529.6	29.3 ± 2.1	1.760 ± 0.162
			520.4	45 ± 4	1.779 ± 0.173
			<i>RR_{mean}</i> = 1.768 ± 0.105		
^{82m} Rb	i(m)	6.472H	554.3	62.4 ± 0.9	0.7715 ± 0.0494
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	0.4060 ± 0.0200
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	0.9088 ± 0.0418
⁷⁴ As	i	17.77D	595.8	59 ± 4	0.8459 ± 0.0693
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	0.2710 ± 0.0225
⁵⁸ Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	0.5976 ± 0.0993
⁵⁹ Fe	c	44.472D	1099.2	56.5 ± 1.9	0.5009 ± 0.0349
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	0.6343 ± 0.0796
			983.5	100.0 ± 0.3	0.1418 ± 0.0135

Continuation of Table 106.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	0.1314 ± 0.0086
⁴⁸ Sc	i	43.67H	1312.1	100.1 ± 0.7	0.2914 ± 0.0151
			1037.5	97.6 ± 0.7	0.3010 ± 0.0171
				RR _{mean} =	0.2954 ± 0.0130
⁴⁶ Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	0.6668 ± 0.0340
²⁸ Mg	c	20.915H	1778.8	100.2 ± 0.0	0.3659 ± 0.0201
²⁴ Na	c	14.9590H	1369.0	100 ± 0	1.536 ± 0.058
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	3.307 ± 0.218

12.11.3 Nuclide production rates for ^{208}Pb

Table 107: Detailed calculation of nuclide production rates for ^{208}Pb for $E_p = 2.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰⁷ Bi	i	31.55Y	569.7	97.74 ± 0.03	6.104 ± 1.284
²⁰⁶ Bi	i	6.243D	1718.7	31.8 ± 0.6	3.234 ± 0.144
			803.1	98.9 ± 1.4	3.090 ± 0.113
			537.5	30.5 ± 0.5	3.013 ± 0.152
			RR _{mean} =		3.108 ± 0.108
²⁰⁵ Bi	i	15.31D	1764.3	32.5 ± 0.7	3.992 ± 0.211
			987.7	16.13 ± 0.17	4.982 ± 0.228
			RR _{mean} =		4.495 ± 0.514
²⁰⁴ Bi	i	11.22H	374.8	82 ± 5	3.227 ± 0.675
			899.2	98 ± 9	3.412 ± 0.136
			984.0	59 ± 4	3.057 ± 0.265
			RR _{mean} =		3.371 ± 0.104
²⁰³ Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	3.154 ± 0.213
²⁰² Bi	i	1.72H	422.1	83.7 ± 2.5	2.024 ± 0.380
^{204m} Pb _i	i(m)	67.2M	374.7	89 ± 15	10.45 ± 1.80
			899.2	99.17 ± 0.02	10.31 ± 0.44
			RR _{mean} =		10.32 ± 0.44
^{204m} Pb _c	c	67.2M	374.7	89 ± 15	10.90 ± 1.88
			899.2	99.17 ± 0.02	10.88 ± 0.45
			RR _{mean} =		10.88 ± 0.45
²⁰³ Pb	c*	51.873H	279.2	80.8 ± 0.2	23.16 ± 0.85
^{202m} Pb	i(m)	3.53H	960.7	92 ± 8	8.587 ± 0.887
			422.1	86 ± 5	7.554 ± 0.547
			RR _{mean} =		7.709 ± 0.439
²⁰¹ Pb	c*	9.33H	331.2	79 ± 5	16.73 ± 1.20
²⁰⁰ Pb	c	21.5H	1205.7	*	10.97 ± 0.79
			579.3	*	11.37 ± 0.87
			367.9	*	11.61 ± 0.43
			147.6	37.7 ± 1.4	11.80 ± 0.65
			RR _{mean} =		11.57 ± 0.36
¹⁹⁹ Pb	c*	90M	366.9	44 ± 7	21.04 ± 3.49
¹⁹⁸ Pb	c	2.4H	173.4	18 ± 3	14.94 ± 2.59
^{197m} Pb	c*	43M	385.9	74 ± 15	9.967 ± 2.066

Continuation of Table 107.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
²⁰² Tl	c	12.23D	439.6	91.4 ± 1.0	13.70 ± 0.49
²⁰¹ Tl	c*	72.912H	167.4	10.00 ± 0.06	31.34 ± 1.17
²⁰⁰ Tl _i	i	26.1H	1205.7	29.9 ± 1.8	15.20 ± 1.10
			579.3	13.8 ± 0.7	15.05 ± 1.24
			367.9	87.2 ± 0.4	13.57 ± 0.57
			<i>RR_{mean}</i> =		13.90 ± 0.62
²⁰⁰ Tl _c	c	26.1H	1205.7	29.9 ± 1.8	26.17 ± 1.80
			579.3	13.8 ± 0.7	26.42 ± 1.66
			367.9	87.2 ± 0.4	25.18 ± 0.87
			<i>RR_{mean}</i> =		25.30 ± 0.85
¹⁹⁹ Tl _c	c	7.42H	455.5	12.4 ± 1.4	22.56 ± 3.32
¹⁹⁹ Tl	c*	7.42H	455.5	12.4 ± 1.4	25.47 ± 3.05
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	12.07 ± 1.45
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	20.63 ± 3.61
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	3.401 ± 0.133
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	6.705 ± 0.355
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	10.64 ± 1.44
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	11.19 ± 1.66
¹⁹² Hg	c	4.85H	2236.9	*	17.47 ± 3.50
			316.5	*	19.11 ± 2.41
			274.8	50.2 ± 2.5	17.05 ± 1.10
			<i>RR_{mean}</i> =		17.35 ± 0.54
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	14.90 ± 2.50
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	1.361 ± 0.226
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	2.867 ± 0.102
			333.0	22.9 ± 0.6	2.972 ± 0.143
			<i>RR_{mean}</i> =		2.882 ± 0.097
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	28.86 ± 2.82
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	4.475 ± 0.400
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	7.621 ± 1.006
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	26.73 ± 3.36
¹⁹⁰ Au _c	c	42.8M	295.8	71 ± 5	24.67 ± 2.30
¹⁹¹ Pt	c	2.802D	409.4	8.0 ± 0.9	18.71 ± 2.21
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	23.02 ± 2.20
			568.8	7.1 ± 0.6	21.50 ± 2.36
			544.9	5.8 ± 0.5	23.98 ± 2.34
			<i>RR_{mean}</i> =		22.86 ± 1.44
¹⁸⁸ Pt	c	10.2D	423.3	4.4 ± 0.3	19.97 ± 1.55
			195.1	18.6 ± 1.2	20.02 ± 1.50
			187.6	19.4 ± 1.2	19.95 ± 1.45
			<i>RR_{mean}</i> =		19.98 ± 0.91
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	16.24 ± 3.53
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	20.38 ± 2.27
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	20.90 ± 2.29
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	20.42 ± 1.62
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	8.911 ± 0.454
			137.2	41.4 ± 0.7	9.795 ± 0.448
			<i>RR_{mean}</i> =		9.393 ± 0.527
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	15.12 ± 2.34
			254.2	13.3 ± 2.4	11.83 ± 2.21

Continuation of Table 107.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁸⁴ Ir	c*	3.09H		$RR_{mean} =$	14.33 ± 1.47
			264.0	68 ± 4	18.81 ± 1.33
			119.8	31 ± 3	19.32 ± 2.11
¹⁸⁵ Os	c	93.6D		$RR_{mean} =$	18.85 ± 0.77
			874.8	6.29 ± 0.25	19.98 ± 1.13
			646.1	78 ± 3	20.35 ± 1.04
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	10.99 ± 0.50
¹⁸² Os	c	22.10H	180.2	33.5 ± 1.7	19.30 ± 1.32
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	18.00 ± 1.02
¹⁸³ Re	c	70.0D	162.3	23.3 ± 0.7	21.68 ± 1.04
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	22.15 ± 1.68
			1189.2	15 ± 1	21.19 ± 1.73
				$RR_{mean} =$	21.71 ± 1.13
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	18.19 ± 4.05
			365.5	56 ± 8	18.93 ± 2.79
				$RR_{mean} =$	18.73 ± 2.02
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	25.82 ± 2.67
			290.0	26.9 ± 2.3	33.11 ± 3.53
				$RR_{mean} =$	28.38 ± 3.59
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	30.84 ± 3.94
¹⁷⁷ W	c	135M	115.7	51 ± 5	17.68 ± 1.93
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	19.76 ± 4.51
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	19.17 ± 4.30
			1159.3	24.7 ± 1.9	19.09 ± 1.69
			710.5	5.4 ± 0.4	25.82 ± 2.47
				$RR_{mean} =$	20.54 ± 2.05
¹⁷⁵ Ta	c	10.5H	348.5	12.0 ± 1.1	21.14 ± 2.11
			266.9	10.52 ± 0.16	17.86 ± 0.82
				$RR_{mean} =$	18.13 ± 1.05
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	19.65 ± 1.82
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	22.43 ± 2.52
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	14.48 ± 1.52
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	18.60 ± 0.91
¹⁷³ Hf	c*	23.6H	311.2	10.7 ± 0.5	21.97 ± 1.29
			123.7	83 ± 5	22.42 ± 1.66
				$RR_{mean} =$	22.09 ± 0.94
¹⁷² Hf	c	1.87Y	1093.6	*	16.77 ± 1.12
			125.8	11.3 ± 0.9	17.17 ± 1.68
				$RR_{mean} =$	16.89 ± 0.52
¹⁷¹ Hf	c	12.1H	739.8	*	16.01 ± 1.76
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	22.16 ± 6.21
			164.7	26 ± 8	20.63 ± 6.40
			120.2	15 ± 5	20.79 ± 7.00
				$RR_{mean} =$	21.72 ± 1.53
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	18.08 ± 1.01
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.1972 ± 0.0535
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	16.97 ± 1.12
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	19.25 ± 0.80
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	20.18 ± 0.84

Continuation of Table 107.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁷⁰ Lu _c	c	2.012D	2126.1	5.1 ± 0.3	15.48 ± 1.20
			1280.2	8.2 ± 0.4	17.67 ± 1.27
			985.1	5.5 ± 0.3	17.84 ± 2.36
			<i>RR_{mean}</i> =		16.69 ± 0.93
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	15.20 ± 0.70
			191.2	20.6 ± 0.6	15.79 ± 0.76
			<i>RR_{mean}</i> =		15.45 ± 0.58
¹⁶⁷ Lu	c	51.5M	176.2	*	15.98 ± 1.27
			113.3	*	17.52 ± 1.31
			<i>RR_{mean}</i> =		16.74 ± 0.98
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	18.96 ± 0.85
			177.2	22.2 ± 0.5	17.86 ± 0.77
			130.5	11.31 ± 0.21	18.34 ± 0.85
			<i>RR_{mean}</i> =		18.33 ± 0.65
¹⁶⁶ Yb	c	56.7H	2079.5	*	17.82 ± 1.34
			2052.4	*	16.71 ± 1.19
			1867.9	*	16.66 ± 1.29
			1176.7	*	15.98 ± 1.19
			1176.7	*	15.98 ± 1.19
			785.9	*	18.27 ± 1.29
			691.2(D)	8.56 ± 0.58	14.23 ± 1.16
			<i>RR_{mean}</i> =		16.43 ± 0.51
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	19.17 ± 3.73
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	17.41 ± 1.26
			242.9	35.5 ± 1.7	19.61 ± 1.23
			<i>RR_{mean}</i> =		18.79 ± 1.21
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	22.35 ± 1.62
¹⁶⁰ Er	c	28.58H	966.2	*	18.08 ± 2.43
			879.4(D)	22.6 ± 2.8	19.34 ± 2.49
			872.0(D)	6.8 ± 1.1	19.81 ± 3.30
			728.2(D)	*	18.92 ± 2.78
			<i>RR_{mean}</i> =		18.96 ± 0.58
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	19.99 ± 2.73
			309.6	*	20.81 ± 2.18
			132.0	*	20.09 ± 1.57
			<i>RR_{mean}</i> =		20.27 ± 0.63
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	18.85 ± 2.59
			728.2	28 ± 4	18.93 ± 2.81
			<i>RR_{mean}</i> =		18.88 ± 1.85
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	20.81 ± 0.99
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	17.55 ± 0.98
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	16.11 ± 0.76
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	10.38 ± 0.43
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	16.15 ± 1.28
			105.3	25.1 ± 1.3	17.26 ± 1.24
			<i>RR_{mean}</i> =		16.81 ± 0.75
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	13.73 ± 1.01
¹⁵² Tb _c	c	17.5H	344.3	65 ± 4	11.51 ± 0.99
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	11.54 ± 0.70
			251.9	26.3 ± 1.2	10.79 ± 0.66

Continuation of Table 107.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁴⁹ Tb	c	4.118H	352.2	$RR_{mean} =$	11.14 ± 0.51
				29.4 ± 0.9	5.177 ± 0.332
				165.0	6.125 ± 0.517
				$RR_{mean} =$	5.404 ± 0.437
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	7.171 ± 0.386
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	13.28 ± 0.80
			97.4	29.0 ± 0.8	12.68 ± 0.76
				$RR_{mean} =$	12.96 ± 0.59
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	11.78 ± 1.01
¹⁴⁹ Gd	c	9.28D	788.9	7.3 ± 0.4	15.84 ± 1.12
			346.6	23.9 ± 1.3	13.84 ± 0.90
			298.6	28.6 ± 1.7	14.11 ± 0.98
			149.7	48 ± 3	15.42 ± 1.13
				$RR_{mean} =$	14.42 ± 0.64
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	12.55 ± 0.88
			396.0	34.3 ± 2.1	11.63 ± 0.82
			370.0	17.2 ± 0.9	12.30 ± 0.77
				$RR_{mean} =$	12.17 ± 0.49
¹⁴⁶ Gd	c	48.27D	747.2	*	12.98 ± 0.58
			154.6	46.6 ± 0.5	12.42 ± 0.49
				$RR_{mean} =$	12.60 ± 0.39
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	18.01 ± 1.73
¹⁴⁷ Eu	c*	24.1D	955.8	3.84 ± 0.20	15.55 ± 1.08
			798.7	4.8 ± 0.3	16.81 ± 1.26
			677.5	9.8 ± 0.5	15.65 ± 0.99
			601.5	5.9 ± 0.3	15.87 ± 1.04
				$RR_{mean} =$	15.85 ± 0.60
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	2.274 ± 0.108
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	15.25 ± 0.68
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	11.35 ± 0.93
			1658.5	14.9 ± 1.0	11.21 ± 0.86
			893.7	66 ± 5	11.30 ± 0.95
			653.5	15 ± 1	10.76 ± 0.82
				$RR_{mean} =$	11.12 ± 0.49
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	11.14 ± 0.81
¹³⁶ Nd	c	50.65M	539.8(D)	70.7 ± 2.6	5.560 ± 0.500
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	11.73 ± 0.43
¹³⁵ Ce	c	17.7H	783.6	10.6 ± 0.4	10.75 ± 0.74
			265.6	41.8 ± 1.5	9.539 ± 0.516
				$RR_{mean} =$	9.802 ± 0.585
¹³⁴ Ce	c	3.16D	604.7	5.04 ± 0.20	10.27 ± 0.72
¹³² Ce	c	3.51H	464.5	*	7.272 ± 0.646
			182.1	77.4 ± 0.5	8.208 ± 0.379
				$RR_{mean} =$	8.042 ± 0.248
¹³² La _c	c	4.8H	464.5	76 ± 6	7.427 ± 0.648
¹³³ Ba	c	3848.9D	356.0	62.05 ± 0.19	10.90 ± 0.84
¹³¹ Ba	c	11.50D	373.2	14.04 ± 0.20	8.361 ± 0.326
			216.1	19.66 ± 0.25	9.730 ± 0.411
			123.8	29.0 ± 0.3	8.608 ± 0.394
				$RR_{mean} =$	8.768 ± 0.486

Continuation of Table 107.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	6.278 ± 0.428
			273.4	14.5 ± 0.7	7.462 ± 0.512
			$RR_{mean} = 6.756 \pm 0.617$		
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	9.540 ± 0.638
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	7.833 ± 0.391
			202.9	68.3 ± 0.5	7.636 ± 0.298
			172.1	25.5 ± 0.8	7.400 ± 0.368
			$RR_{mean} = 7.622 \pm 0.270$		
¹²³ Xe	c	2.08H	148.9	48.9 ± 0.6	7.315 ± 0.352
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.2197 ± 0.0326
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	0.6339 ± 0.1580
			212.2	81.4 ± 1.1	0.7184 ± 0.0530
			$RR_{mean} = 0.7111 \pm 0.0219$		
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	5.809 ± 0.287
^{119m} Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.336 ± 0.052
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	0.3371 ± 0.0199
			1023.3	99.4 ± 0.3	0.3305 ± 0.0237
			$RR_{mean} = 0.3345 \pm 0.0168$		
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	3.308 ± 0.153
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	1.152 ± 0.168
¹¹¹ In	c	2.8047D	245.4	94 ± 1	3.592 ± 0.146
			171.3	90.2 ± 1.0	3.459 ± 0.139
			$RR_{mean} = 3.521 \pm 0.127$		
¹¹⁰ In	i	4.9H	937.5	68.4 ± 1.4	2.339 ± 0.119
			884.7	92.9 ± 1.9	1.964 ± 0.113
			$RR_{mean} = 2.154 \pm 0.199$		
¹⁰⁹ In	c	4.2H	203.5	73.5 ± 0.5	2.996 ± 0.148
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	0.5702 ± 0.0578
			657.8	94.3 ± 0.3	0.7269 ± 0.0564
			$RR_{mean} = 0.6535 \pm 0.0807$		
^{106m} Ag	i(m)	8.28D	1527.7	16.3 ± 1.4	1.133 ± 0.149
			1045.8	29.6 ± 1.0	1.429 ± 0.086
			717.3	28.9 ± 0.8	1.304 ± 0.084
			451.0	28.2 ± 0.8	1.395 ± 0.100
			$RR_{mean} = 1.352 \pm 0.065$		
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	2.551 ± 0.289
			344.5	41.4 ± 0.6	2.321 ± 0.144
			$RR_{mean} = 2.357 \pm 0.132$		
¹⁰⁰ Pd	c	3.63D	2376.0	*	0.5725 ± 0.0377
¹⁰² Rh	i	207D	475.1	46 ± 5	0.6472 ± 0.1045
^{101m} Rh	c	4.34D	306.9	81 ± 5	2.721 ± 0.200
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	1.564 ± 0.102
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	2.137 ± 0.114
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	1.940 ± 0.093
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	1.588 ± 0.091
			812.5	82 ± 4	1.685 ± 0.102
			$RR_{mean} = 1.630 \pm 0.077$		
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	1.771 ± 0.083
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	1.310 ± 0.076
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	1.412 ± 0.092

Continuation of Table 107.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			568.9	58.0 ± 0.3	1.091 ± 0.160
			RR _{mean} = 1.344 ± 0.137		
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	2.817 ± 0.102
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	1.604 ± 0.106
			1129.2	92.7 ± 0.5	1.643 ± 0.071
			RR _{mean} = 1.635 ± 0.067		
⁹⁵ Zr	c	64.02D	756.7	54.46 ± 0.10	1.191 ± 0.069
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	3.004 ± 0.103
⁸⁸ Zr	c	83.4D	1836.1	*	1.466 ± 0.144
			898.0	*	1.518 ± 0.252
			392.9	97.24 ± 0.00	1.967 ± 0.075
			RR _{mean} = 1.910 ± 0.059		
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	2.989 ± 0.123
			898.0	93.7 ± 0.3	2.887 ± 0.169
			RR _{mean} = 2.964 ± 0.116		
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	4.455 ± 0.176
			898.0	93.7 ± 0.3	4.405 ± 0.195
			RR _{mean} = 4.436 ± 0.162		
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	4.084 ± 0.145
⁸⁶ Y _c	c	14.74H	1076.6	82.5 ± 0.4	1.968 ± 0.086
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	3.820 ± 0.209
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	2.642 ± 0.154
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	4.886 ± 0.405
			529.6	29.3 ± 2.1	3.871 ± 0.345
			520.4	45 ± 4	3.983 ± 0.387
			RR _{mean} = 4.240 ± 0.350		
^{82m} Rb	i(m)	6.472H	554.3	62.4 ± 0.9	2.064 ± 0.127
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	1.022 ± 0.050
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	2.196 ± 0.095
⁷⁴ As	i	17.77D	595.8	59 ± 4	2.062 ± 0.160
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	0.5843 ± 0.0339
⁵⁸ Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	1.151 ± 0.207
⁵⁹ Fe	c	44.472D	1099.2	56.5 ± 1.9	1.313 ± 0.106
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	1.670 ± 0.082
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	0.2897 ± 0.0234
			983.5	100.0 ± 0.3	0.3120 ± 0.0188
			RR _{mean} = 0.3041 ± 0.0159		
⁴⁸ Sc	i	43.67H	1312.1	100.1 ± 0.7	0.7548 ± 0.0375
			1037.5	97.6 ± 0.7	0.7685 ± 0.0337
			RR _{mean} = 0.7630 ± 0.0299		
⁴⁶ Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	1.581 ± 0.069
²⁸ Mg	c	20.915H	1778.8	100.2 ± 0.0	0.9869 ± 0.0445
²⁴ Na	c	14.9590H	1369.0	100 ± 0	3.946 ± 0.143
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	5.466 ± 0.331

12.11.4 Nuclide production rates for ^{nat}Pb

Table 108: Detailed calculation of nuclide production rates for ^{nat}Pb for $E_p = 2.6$ GeV, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Bi	i	31.55Y	1063.7	74.5 ± 0.2	55.38 ± 5.13
^{206}Bi	i	6.243D	1718.7	31.8 ± 0.6	23.89 ± 0.96
			803.1	98.9 ± 1.4	22.09 ± 0.86
			537.5	30.5 ± 0.5	23.17 ± 0.93
			$RR_{mean} =$		22.96 ± 0.89
^{205}Bi	i	15.31D	1861.7	6.17 ± 0.10	33.24 ± 1.64
			1764.3	32.5 ± 0.7	33.30 ± 1.39
			987.7	16.13 ± 0.17	37.68 ± 2.07
			$RR_{mean} =$		33.99 ± 1.56
^{204}Bi	i	11.22H	899.2	98 ± 9	28.75 ± 1.06
			374.8	82 ± 5	27.97 ± 5.85
			984.0	59 ± 4	28.14 ± 2.43
			$RR_{mean} =$		28.71 ± 0.89
^{203}Bi	i(m+g)	11.76H	820.2	29.6 ± 1.5	29.51 ± 1.92
^{202}Bi	i	1.72H	422.1	83.7 ± 2.5	24.25 ± 2.90
$^{204m}\text{Pb}_i$	i(m)	67.2M	899.2	99.17 ± 0.02	82.91 ± 3.32
			374.7	89 ± 15	79.80 ± 13.79
			$RR_{mean} =$		82.84 ± 3.30
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	87.22 ± 3.43
			374.7	89 ± 15	83.31 ± 14.39
			$RR_{mean} =$		87.14 ± 3.41
^{203}Pb	c*	51.873H	279.2	80.8 ± 0.2	218.2 ± 8.0
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	56.73 ± 5.83
			422.1	86 ± 5	57.12 ± 4.40
			$RR_{mean} =$		57.03 ± 2.94
^{201}Pb	c*	9.33H	331.2	79 ± 5	146.0 ± 10.5
^{200}Pb	c	21.5H	1205.7	*	103.6 ± 7.3
			828.3	*	90.87 ± 7.37
			579.3	*	91.98 ± 6.06
			367.9	*	101.5 ± 4.2
			147.6	37.7 ± 1.4	96.44 ± 5.79
			$RR_{mean} =$		98.52 ± 3.04
^{199}Pb	c*	90M	455.5	*	171.3 ± 32.3
			366.9	44 ± 7	180.2 ± 30.1
			$RR_{mean} =$		176.1 ± 5.4
^{198}Pb	c	2.4H	173.4	18 ± 3	131.3 ± 22.6
^{197m}Pb	c*	43M	385.9	74 ± 15	70.15 ± 14.72
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	108.0 ± 3.9
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	268.2 ± 10.0
$^{200}\text{Tl}_i$	i	26.1H	1205.7	29.9 ± 1.8	117.0 ± 8.7
			579.3	13.8 ± 0.7	128.9 ± 9.0
			367.9	87.2 ± 0.4	116.7 ± 4.9
			$RR_{mean} =$		118.2 ± 4.6
$^{200}\text{Tl}_c$	c	26.1H	1205.7	29.9 ± 1.8	220.6 ± 15.3
			579.3	13.8 ± 0.7	220.9 ± 13.8
			367.9	87.2 ± 0.4	218.1 ± 7.6
			$RR_{mean} =$		218.5 ± 7.4
^{199}Tl	c*	7.42H	455.5	12.4 ± 1.4	174.0 ± 21.3

Continuation of Table 108.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			455.5	12.4 ± 1.4	213.7 ± 25.5
			<i>RR_{mean}</i> =		190.3 ± 5.9
^{198m} Tl	i(m)	1.87H	282.8	28 ± 3	80.49 ± 9.51
^{196m} Tl	i(m)	1.41H	695.4	41 ± 7	165.0 ± 28.8
²⁰³ Hg	c	46.612D	279.2	81.46 ± 0.13	20.98 ± 0.77
^{197m} Hg	i(m)	23.8H	134.0	33.5 ± 0.4	49.04 ± 2.51
^{195m} Hg	i(m)	41.6H	261.8	31 ± 4	81.69 ± 11.14
^{193m} Hg	i(m)	11.8H	258.0	49 ± 7	94.24 ± 14.03
¹⁹² Hg	c	4.85H	2236.9	*	123.0 ± 23.2
			316.5	*	150.7 ± 19.0
			274.8	50.2 ± 2.5	132.6 ± 8.4
			<i>RR_{mean}</i> =		134.8 ± 4.2
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	84.25 ± 14.05
¹⁹⁸ Au _c	i(m+g)	2.69517D	411.8	95.58 ± 0.12	10.04 ± 0.73
¹⁹⁶ Au	i(m1+m2+g)	6.183D	426.1	6.6 ± 0.8	15.81 ± 2.06
			355.7	87.0 ± 0.8	18.89 ± 0.67
			333.0	22.9 ± 0.6	18.94 ± 1.22
			<i>RR_{mean}</i> =		18.84 ± 0.65
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	233.8 ± 24.3
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	32.22 ± 2.90
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	48.85 ± 6.59
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	199.5 ± 25.1
¹⁹⁰ Au _c	c	42.8M	295.8	71 ± 5	188.4 ± 16.8
¹⁹¹ Pt	c	2.802D	456.5	3.4 ± 0.4	150.1 ± 18.7
			409.4	8.0 ± 0.9	138.1 ± 16.4
			351.2	3.4 ± 0.4	165.9 ± 20.5
			<i>RR_{mean}</i> =		148.0 ± 9.1
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	185.1 ± 17.4
			607.6	8.10 ± 0.16	134.1 ± 14.7
			568.8	7.1 ± 0.6	188.1 ± 18.6
			544.9	5.8 ± 0.5	182.0 ± 17.4
			<i>RR_{mean}</i> =		168.7 ± 14.7
¹⁸⁸ Pt	c	10.2D	1209.8	*	151.4 ± 16.2
			478.0	*	143.6 ± 7.7
			423.3	4.4 ± 0.3	146.3 ± 11.2
			381.4	7.5 ± 0.5	142.7 ± 10.7
			195.1	18.6 ± 1.2	143.2 ± 10.7
			187.6	19.4 ± 1.2	143.1 ± 10.4
			140.4	2.33 ± 0.15	142.9 ± 11.8
			<i>RR_{mean}</i> =		143.7 ± 4.4
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	121.2 ± 26.3
¹⁹² Ir	i(m1+g)	73.827D	316.5	82.71 ± 0.21	1.107 ± 0.057
¹⁹⁰ Ir	i(m1+g)	11.78D	569.3	28.5 ± 1.3	2.716 ± 0.234
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	151.3 ± 16.3
¹⁸⁸ Ir _c	c	41.5H	1209.8	6.9 ± 0.7	157.0 ± 16.9
			478.0	14.7 ± 0.6	159.1 ± 8.8
			<i>RR_{mean}</i> =		159.0 ± 5.8
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	126.1 ± 10.5
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	74.94 ± 3.62
			137.2	41.4 ± 0.7	76.96 ± 4.16

Continuation of Table 108.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	75.74 ± 3.16
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	110.8 ± 17.1
			254.2	13.3 ± 2.4	71.79 ± 13.93
			<i>RR_{mean}</i> =		
¹⁸⁴ Ir	c*	3.09H	390.4	25.9 ± 2.4	133.6 ± 13.5
			264.0	68 ± 4	135.8 ± 9.7
			119.8	31 ± 3	148.8 ± 16.9
			<i>RR_{mean}</i> =		
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	155.2 ± 8.0
			717.4	3.94 ± 0.16	159.1 ± 8.5
			646.1	78 ± 3	150.1 ± 7.7
			<i>RR_{mean}</i> =		
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	84.25 ± 3.74
¹⁸² Os	c	22.10H	1221.5	*	172.1 ± 13.6
			1189.2	*	181.1 ± 14.2
			263.3	6.71 ± 0.25	176.3 ± 10.4
			180.2	33.5 ± 1.7	157.8 ± 10.5
			<i>RR_{mean}</i> =		
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	111.3 ± 5.7
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	143.0 ± 10.0
			162.3	23.3 ± 0.7	157.1 ± 7.5
			<i>RR_{mean}</i> =		
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	168.7 ± 13.2
			1189.2	15 ± 1	150.7 ± 12.4
			<i>RR_{mean}</i> =		
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	147.1 ± 32.7
			365.5	56 ± 8	146.4 ± 21.6
			<i>RR_{mean}</i> =		
¹⁷⁹ Re	c*	19.5M	430.2	28.0 ± 1.8	189.0 ± 23.4
			290.0	26.9 ± 2.3	132.4 ± 18.1
			<i>RR_{mean}</i> =		
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	173.3 ± 22.2
¹⁷⁸ W	c	21.6D	1350.6(D)	1.18 ± 0.11	121.2 ± 12.5
			1340.8(D)	1.03 ± 0.09	99.47 ± 10.67
			<i>RR_{mean}</i> =		
¹⁷⁷ W	c	135M	115.7	51 ± 5	133.2 ± 15.1
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	151.4 ± 34.9
¹⁷⁶ Ta _c	c	8.09H	1823.7	4.5 ± 0.4	157.3 ± 18.4
			1159.3	24.7 ± 1.9	146.4 ± 12.7
			710.5	5.4 ± 0.4	215.8 ± 26.4
			<i>RR_{mean}</i> =		
¹⁷⁵ Ta	c	10.5H	348.5	12.0 ± 1.1	169.7 ± 16.7
			266.9	10.52 ± 0.16	129.2 ± 5.9
			<i>RR_{mean}</i> =		
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	145.4 ± 14.4
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	159.9 ± 17.8
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	93.21 ± 9.68
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	138.2 ± 6.8
¹⁷³ Hf	c*	23.6H	139.6	12.7 ± 0.6	171.2 ± 11.4
			123.7	83 ± 5	168.6 ± 13.6

Continuation of Table 108.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				RR _{mean} =	170.3 ± 8.3
¹⁷² Hf	c	1.87Y	1093.6	*	124.4 ± 7.2
			1002.7(D)	5.55 ± 0.38	123.7 ± 10.3
			181.5	*	119.5 ± 7.5
			125.8	11.3 ± 0.9	130.0 ± 12.4
				RR _{mean} =	123.4 ± 3.8
¹⁷¹ Hf	c	12.1H	739.8	*	125.8 ± 13.2
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	178.0 ± 49.8
			164.7	26 ± 8	146.0 ± 45.3
			120.2	15 ± 5	162.4 ± 54.9
				RR _{mean} =	168.9 ± 12.0
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	128.7 ± 6.9
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	1.514 ± 0.099
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	125.9 ± 7.3
			181.5	20.6 ± 1.0	122.5 ± 7.7
				RR _{mean} =	124.6 ± 4.8
¹⁷¹ Lu _c	c	8.24D	739.8	47.8 ± 1.2	141.5 ± 5.9
¹⁷¹ Lu	c*	8.24D	739.8	47.8 ± 1.2	149.7 ± 6.2
¹⁷⁰ Lu _c	c	2.012D	2126.1	5.1 ± 0.3	118.4 ± 8.9
			1280.2	8.2 ± 0.4	126.6 ± 10.8
				RR _{mean} =	121.4 ± 6.5
¹⁶⁹ Lu	c	34.06H	960.6	23.4 ± 0.7	110.3 ± 5.0
			191.2	20.6 ± 0.6	128.0 ± 6.2
				RR _{mean} =	116.2 ± 9.1
¹⁶⁷ Lu	c	51.5M	176.2	*	101.0 ± 6.5
			113.3	*	121.4 ± 10.9
				RR _{mean} =	105.9 ± 9.3
¹⁶⁹ Yb	c*	32.026D	198.0	35.8 ± 0.7	137.1 ± 6.0
			177.2	22.2 ± 0.5	134.2 ± 5.9
			130.5	11.31 ± 0.21	142.1 ± 7.5
				RR _{mean} =	136.7 ± 4.8
¹⁶⁶ Yb	c	56.7H	2079.5	*	120.6 ± 9.6
			2052.4	*	135.8 ± 9.4
			1867.9	*	135.8 ± 9.6
			1374.2	*	130.2 ± 10.5
			1176.7	*	123.8 ± 9.0
			785.9	*	131.8 ± 9.3
			691.2(D)	8.56 ± 0.58	119.1 ± 9.1
				RR _{mean} =	128.0 ± 3.9
¹⁶⁷ Tm	c	9.25D	207.8	42 ± 8	137.2 ± 26.7
¹⁶⁵ Tm	c	30.06H	806.4	9.5 ± 0.6	128.5 ± 9.3
			242.9	35.5 ± 1.7	132.9 ± 8.4
				RR _{mean} =	131.4 ± 5.5
¹⁶¹ Er	c*	3.21H	826.6	64 ± 4	165.7 ± 11.9
¹⁶⁰ Er	c	28.58H	966.2	*	132.3 ± 17.8
			962.4	*	129.9 ± 17.0
			879.4(D)	22.6 ± 2.8	149.2 ± 19.2
			872.0(D)	6.8 ± 1.1	143.5 ± 23.8
			728.2(D)	*	142.3 ± 20.9
				RR _{mean} =	138.9 ± 4.3

Continuation of Table 108.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁵⁹ Er	c*	36M	624.5	33 ± 4	155.4 ± 20.6
			309.6	*	183.9 ± 13.0
			132.0	*	184.8 ± 14.6
			<i>RR_{mean}</i> =		179.6 ± 5.5
^{160m} Ho _c	c	5.02H	966.2	15.4 ± 2.0	138.2 ± 18.8
			962.4	16.6 ± 2.1	130.2 ± 17.5
			728.2	28 ± 4	141.7 ± 20.9
			<i>RR_{mean}</i> =		136.0 ± 10.9
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	155.6 ± 7.4
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	129.4 ± 7.2
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	114.7 ± 5.4
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	78.14 ± 3.33
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	114.9 ± 8.9
			105.3	25.1 ± 1.3	124.3 ± 9.9
			<i>RR_{mean}</i> =		118.9 ± 5.9
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	100.6 ± 7.3
¹⁵² Tb _c	c	17.5H	344.3	65 ± 4	86.01 ± 6.20
¹⁵¹ Tb	c	17.609H	479.4	15.4 ± 0.7	93.38 ± 5.80
			395.4	10.8 ± 0.5	99.07 ± 8.72
			251.9	26.3 ± 1.2	75.94 ± 4.88
			<i>RR_{mean}</i> =		85.25 ± 7.25
¹⁴⁹ Tb	c	4.118H	352.2	29.4 ± 0.9	34.97 ± 2.28
			165.0	26.4 ± 0.9	43.34 ± 4.60
			<i>RR_{mean}</i> =		36.20 ± 3.16
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	52.29 ± 2.51
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	100.1 ± 7.0
			97.4	29.0 ± 0.8	88.17 ± 5.88
			<i>RR_{mean}</i> =		93.00 ± 6.53
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	87.62 ± 7.36
¹⁴⁹ Gd	c	9.28D	788.9	7.3 ± 0.4	118.8 ± 7.7
			346.6	23.9 ± 1.3	105.0 ± 6.7
			298.6	28.6 ± 1.7	106.7 ± 7.4
			149.7	48 ± 3	116.6 ± 8.7
			<i>RR_{mean}</i> =		110.2 ± 5.0
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	96.20 ± 6.58
			396.0	34.3 ± 2.1	88.21 ± 6.24
			370.0	17.2 ± 0.9	95.63 ± 6.08
			<i>RR_{mean}</i> =		93.56 ± 3.81
¹⁴⁶ Gd	c	48.27D	747.2	*	100.1 ± 4.5
			154.6	46.6 ± 0.5	105.0 ± 4.1
			<i>RR_{mean}</i> =		103.2 ± 3.2
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	146.2 ± 6.7
¹⁴⁷ Eu	c*	24.1D	955.8	3.84 ± 0.20	120.7 ± 7.6
			798.7	4.8 ± 0.3	136.2 ± 9.7
			677.5	9.8 ± 0.5	122.7 ± 7.6
			601.5	5.9 ± 0.3	122.8 ± 7.5
			121.2	22.9 ± 1.3	112.7 ± 8.9
			<i>RR_{mean}</i> =		122.6 ± 4.7
¹⁴⁶ Eu _i	i	4.61D	747.2	99 ± 3	15.91 ± 0.73
¹⁴⁶ Eu _c	c	4.61D	747.2	99 ± 3	116.0 ± 5.2

Continuation of Table 108.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	86.65 ± 6.86
			1658.5	14.9 ± 1.0	84.97 ± 6.40
			893.7	66 ± 5	81.76 ± 6.80
			653.5	15 ± 1	81.75 ± 6.11
			RR _{mean} =		
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	86.21 ± 6.11
¹³⁶ Nd	c	50.65M	539.8(D)	70.7 ± 2.6	47.45 ± 4.21
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	88.78 ± 3.28
¹³⁵ Ce	c	17.7H	783.6	10.6 ± 0.4	82.37 ± 4.71
			606.8	18.8 ± 0.7	75.32 ± 6.08
			265.6	41.8 ± 1.5	76.64 ± 4.47
			RR _{mean} =		
¹³⁴ Ce	c	3.16D	604.7	5.04 ± 0.20	75.38 ± 5.33
¹³² Ce	c	3.51H	464.5	*	56.59 ± 5.02
			182.1	77.4 ± 0.5	64.86 ± 2.90
			RR _{mean} =		
¹³² La _c	c	4.8H	464.5	76 ± 6	58.01 ± 5.07
¹³³ Ba	c	3848.9D	356.0	62.05 ± 0.19	72.86 ± 2.93
¹³¹ Ba	c	11.50D	496.3	46.8 ± 0.2	61.57 ± 2.20
			373.2	14.04 ± 0.20	63.72 ± 2.36
			216.1	19.66 ± 0.25	73.86 ± 3.08
			123.8	29.0 ± 0.3	66.05 ± 3.50
			RR _{mean} =		
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	46.79 ± 4.44
			273.4	14.5 ± 0.7	50.89 ± 3.48
			RR _{mean} =		
¹²⁹ Cs	c	32.06H	371.9	30.6 ± 1.7	72.14 ± 4.88
¹²⁷ Xe	c	36.4D	375.0	17.2 ± 0.6	61.20 ± 3.02
			202.9	68.3 ± 0.5	56.47 ± 2.22
			172.1	25.5 ± 0.8	56.78 ± 2.89
			RR _{mean} =		
¹²³ Xe	c	2.08H	148.9	48.9 ± 0.6	53.29 ± 2.82
^{123m} Te	i(m)	119.7D	159.0	84.0 ± 0.4	1.518 ± 0.105
^{121m} Te	i(m)	154D	573.1	88.6 ± 0.1	4.920 ± 0.319
			212.2	81.4 ± 1.1	4.232 ± 0.243
			RR _{mean} =		
¹²¹ Te _c	c	19.16D	573.1	80.3 ± 2.5	45.03 ± 2.07
^{119m} Te _i	i(m)	4.70D	1212.7	66.2 ± 0.3	9.880 ± 0.338
^{120m} Sb	i(m)	5.76D	1171.7	100 ± 0	2.373 ± 0.183
			1023.3	99.4 ± 0.3	2.316 ± 0.116
			RR _{mean} =		
¹¹³ Sn	c	115.09D	391.7	64.97 ± 0.17	26.17 ± 0.92
^{114m} In	i(m)	49.51D	190.3	15.56 ± 0.16	9.006 ± 0.605
¹¹¹ In	c	2.8047D	245.4	94 ± 1	28.05 ± 1.13
			171.3	90.2 ± 1.0	28.38 ± 1.12
			RR _{mean} =		
¹¹⁰ In	i	4.9H	937.5	68.4 ± 1.4	18.63 ± 1.06
			884.7	92.9 ± 1.9	14.76 ± 1.13
			RR _{mean} =		
¹⁰⁹ In	c	4.2H	203.5	73.5 ± 0.5	23.72 ± 1.14

Continuation of Table 108.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
^{110m} Ag	i(m)	249.76D	884.7	72.7 ± 0.4	5.147 ± 0.206
			657.8	94.3 ± 0.3	4.902 ± 0.216
			<i>RR_{mean}</i> =		5.044 ± 0.197
^{106m} Ag	i(m)	8.28D	1527.7	16.3 ± 1.4	11.82 ± 1.12
			1045.8	29.6 ± 1.0	11.82 ± 0.58
			717.3	28.9 ± 0.8	11.04 ± 0.49
			451.0	28.2 ± 0.8	10.55 ± 0.51
			<i>RR_{mean}</i> =		11.11 ± 0.45
¹⁰⁵ Ag	c	41.29D	443.4	10.5 ± 0.6	22.81 ± 1.78
			344.5	41.4 ± 0.6	20.32 ± 0.77
			280.4	30.2 ± 1.8	21.96 ± 1.55
			<i>RR_{mean}</i> =		20.52 ± 0.77
¹⁰⁰ Pd	c	3.63D	2376.0	*	5.277 ± 0.271
¹⁰² Rh	i	207D	475.1	46 ± 5	5.279 ± 0.680
^{101m} Rh	c	4.34D	306.9	81 ± 5	22.50 ± 1.61
¹⁰⁰ Rh _i	i(m+g)	20.8H	2376.0	32.6 ± 0.4	13.56 ± 0.96
¹⁰⁰ Rh _c	c	20.8H	2376.0	32.6 ± 0.4	18.84 ± 1.11
¹⁰³ Ru	c	39.26D	497.1	91.0 ± 1.3	14.00 ± 0.56
⁹⁶ Tc	i(m+g)	4.28D	849.9	98 ± 4	13.09 ± 0.71
			812.5	82 ± 4	13.05 ± 0.78
			<i>RR_{mean}</i> =		13.07 ± 0.60
⁹⁹ Mo	c	65.94H	140.5	90.27 ± 0.33	12.95 ± 0.65
^{93m} Mo	i(m)	6.85H	684.7	99.7 ± 2.0	9.883 ± 0.660
⁹⁶ Nb	i	23.35H	1091.3	48.5 ± 1.6	9.658 ± 0.947
			568.9	58.0 ± 0.3	6.980 ± 0.697
			<i>RR_{mean}</i> =		7.923 ± 1.302
⁹⁵ Nb _c	c	34.975D	765.8	99.81 ± 0.03	21.20 ± 0.71
⁹⁰ Nb	c*	14.60H	2319.0	82.0 ± 0.3	13.00 ± 0.68
			1129.2	92.7 ± 0.5	13.94 ± 0.61
			<i>RR_{mean}</i> =		13.58 ± 0.62
⁹⁵ Zr	c	64.02D	765.8	*	8.409 ± 0.482
			756.7	54.46 ± 0.10	7.846 ± 0.291
			<i>RR_{mean}</i> =		7.923 ± 0.244
⁸⁹ Zr	c	78.41H	909.2	99.04 ± 0.03	25.14 ± 0.90
⁸⁸ Zr	c	83.4D	1836.1	*	17.41 ± 1.28
			898.0	*	15.71 ± 1.19
			392.9	97.24 ± 0.00	15.39 ± 0.53
			<i>RR_{mean}</i> =		15.47 ± 0.48
⁸⁸ Y _i	i	106.65D	1836.1	99.2 ± 0.3	21.27 ± 0.97
			898.0	93.7 ± 0.3	21.33 ± 0.90
			<i>RR_{mean}</i> =		21.31 ± 0.80
⁸⁸ Y _c	c	106.65D	1836.1	99.2 ± 0.3	38.69 ± 1.47
			898.0	93.7 ± 0.3	37.04 ± 1.35
			<i>RR_{mean}</i> =		37.73 ± 1.42
⁸⁷ Y	c*	79.8H	484.8	89.7 ± 0.7	31.03 ± 1.25
			388.5	82.1 ± 0.5	29.95 ± 6.92
			<i>RR_{mean}</i> =		31.01 ± 1.23
⁸⁶ Y	c	14.74H	1076.6	82.5 ± 0.4	18.35 ± 0.93
⁸⁵ Sr	c	64.84D	514.0	96 ± 4	29.89 ± 1.64
⁸⁴ Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	21.56 ± 0.90

Continuation of Table 108.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁸³ Rb	c	86.2D	552.6	16.0 ± 1.1	41.61 ± 3.28
			529.6	29.3 ± 2.1	33.49 ± 2.73
			520.4	45 ± 4	32.54 ± 3.12
			RR _{mean} =		35.94 ± 3.03
^{82m} Rb	i(m)	6.472H	554.3	62.4 ± 0.9	16.88 ± 1.04
⁸² Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	8.674 ± 0.410
⁷⁵ Se	c	119.779D	264.7	58.9 ± 0.4	17.57 ± 0.69
⁷⁴ As	i	17.77D	595.8	59 ± 4	16.72 ± 1.27
⁷¹ As	c	65.28H	174.9	82.0 ± 2.1	6.052 ± 0.285
⁷² Ga _i	i	14.10H	2201.7	25.9 ± 0.5	8.310 ± 1.380
⁷² Ga _c	c	14.10H	2201.7	25.9 ± 0.5	9.896 ± 1.362
⁷² Zn	c	46.5H	2201.7	*	1.586 ± 0.260
⁵⁸ Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	8.787 ± 0.458
⁵⁶ Co	c	77.233D	846.8	99.94 ± 0.03	0.7364 ± 0.0442
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	10.38 ± 0.51
			1099.2	56.5 ± 1.9	9.979 ± 0.485
			RR _{mean} =		10.16 ± 0.39
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	11.73 ± 0.50
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	2.726 ± 0.112
			983.5	100.0 ± 0.3	2.572 ± 0.122
			RR _{mean} =		2.666 ± 0.111
⁴⁸ Sc	i	43.67H	1312.1	100.1 ± 0.7	6.587 ± 0.279
			1037.5	97.6 ± 0.7	6.218 ± 0.239
			RR _{mean} =		6.349 ± 0.264
⁴⁶ Sc	i(m+g)	83.79D	1120.6	99.99 ± 0.00	12.69 ± 0.92
			889.3	99.98 ± 0.00	13.01 ± 0.44
			RR _{mean} =		12.99 ± 0.44
²⁸ Mg	c	20.915H	1778.8	100.2 ± 0.0	7.222 ± 0.325
²⁴ Na	c	14.9590H	1369.0	100 ± 0	31.49 ± 1.12
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	49.27 ± 1.82

12.11.5 Nuclide production rates for ^{209}Bi

Table 109: Detailed calculation of nuclide production rates for ^{209}Bi for $E_p = 2.6 \text{ GeV}$, used to determine the cross sections for their production.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{207}Po	i(m+g)	5.80H	992.3	59.3 ± 0.9	4.224 ± 0.173
^{206}Po	i	8.8D	1032.3	33 ± 5	4.265 ± 0.664
			980.2	7.1 ± 0.9	4.652 ± 0.633
			807.4	23 ± 3	4.288 ± 0.589
			522.5	15.7 ± 2.0	4.083 ± 0.542
			338.4	19.2 ± 2.5	4.439 ± 0.604
			311.6	4.2 ± 0.6	4.841 ± 0.875
			286.4	24 ± 3	4.417 ± 0.581
			1718.7	*	4.106 ± 0.208
			803.1	*	4.008 ± 0.158
			620.5	*	4.101 ± 0.535
			516.2	*	3.773 ± 0.218

Continuation of Table 109.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			343.5	*	4.623 ± 0.290
			<i>RR_{mean}</i> =		4.053 ± 0.125
²⁰⁷ Bi	c	31.55Y	1063.7	74.5 ± 0.2	56.58 ± 2.33
			569.7	97.74 ± 0.03	52.08 ± 4.37
			<i>RR_{mean}</i> =		56.01 ± 2.28
²⁰⁶ Bi _i	i	6.243D	1718.7	31.8 ± 0.6	29.80 ± 1.17
			881.0	66.2 ± 1.0	29.00 ± 1.05
			803.1	98.9 ± 1.4	27.93 ± 1.00
			657.2	1.91 ± 0.04	29.32 ± 1.59
			620.5	5.76 ± 0.09	29.78 ± 1.30
			537.5	30.5 ± 0.5	26.33 ± 1.02
			516.2	40.7 ± 0.6	27.44 ± 1.04
			343.5	23.4 ± 0.4	26.73 ± 1.03
			<i>RR_{mean}</i> =		28.01 ± 0.97
²⁰⁶ Bi _c	c	6.243D	1718.7	31.8 ± 0.6	33.68 ± 1.31
			881.0	66.2 ± 1.0	34.93 ± 1.26
			803.1	98.9 ± 1.4	31.71 ± 1.13
			657.2	1.91 ± 0.04	30.01 ± 1.36
			620.5	5.76 ± 0.09	33.66 ± 1.32
			537.5	30.5 ± 0.5	29.75 ± 1.14
			516.2	40.7 ± 0.6	31.00 ± 1.16
			343.5	23.4 ± 0.4	31.10 ± 1.18
			<i>RR_{mean}</i> =		32.00 ± 1.18
²⁰⁵ Bi	c	15.31D	1861.7	6.17 ± 0.10	29.63 ± 1.21
			1775.8	3.99 ± 0.08	30.73 ± 1.28
			1764.3	32.5 ± 0.7	30.99 ± 1.27
			1614.3	2.28 ± 0.04	30.21 ± 1.29
			1190.0	2.26 ± 0.07	27.65 ± 1.35
			1043.8	7.51 ± 0.10	27.54 ± 1.09
			987.7	16.13 ± 0.17	29.59 ± 1.07
			703.5	31.1 ± 0.1	28.54 ± 0.96
			579.8	5.44 ± 0.07	26.58 ± 1.04
			284.1	1.69 ± 0.02	27.84 ± 1.18
			<i>RR_{mean}</i> =		28.75 ± 0.98
²⁰⁴ Bi	c*	11.22H	918.3	10.8 ± 0.9	23.90 ± 2.18
			899.2	98 ± 9	21.09 ± 0.72
			670.7	11.4 ± 0.9	22.11 ± 1.97
			374.8	82 ± 5	24.36 ± 5.09
			<i>RR_{mean}</i> =		21.19 ± 0.65
²⁰³ Bi	c	11.76H	1893.0	8.2 ± 0.6	18.50 ± 1.62
			1847.3	11.4 ± 0.8	17.10 ± 1.45
			1679.6	8.8 ± 0.7	17.16 ± 1.61
			896.8	13.1 ± 0.7	18.34 ± 1.23
			820.2	29.6 ± 1.5	18.62 ± 1.15
			279.2	*	16.83 ± 1.16
			<i>RR_{mean}</i> =		17.68 ± 0.55
²⁰² Bi	c*	1.72H	960.7	99.28 ± 0.02	14.79 ± 0.64
			422.1	83.7 ± 2.5	14.52 ± 0.77
			<i>RR_{mean}</i> =		14.70 ± 0.58
^{204m} Pb _i	i(m)	67.2M	899.2	99.17 ± 0.02	8.900 ± 0.505
			374.7	89 ± 15	8.575 ± 1.497

Continuation of Table 109.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
				$RR_{mean} =$	8.875 $\pm$ 0.491
$^{204m}\text{Pb}_c$	c	67.2M	899.2	99.17 ± 0.02	12.06 ± 0.56
			374.7	89 ± 15	11.63 ± 2.02
				$RR_{mean} =$	12.04 $\pm$ 0.56
$^{203}\text{Pb}_i$	i(m1+m2+g)	51.873H	279.2	80.8 ± 0.2	19.08 $\pm$ 1.44
$^{203}\text{Pb}_c$	c	51.873H	279.2	80.8 ± 0.2	35.91 $\pm$ 1.35
^{202m}Pb	i(m)	3.53H	960.7	92 ± 8	10.02 ± 0.99
			422.1	86 ± 5	9.228 ± 0.680
				$RR_{mean} =$	9.383 $\pm$ 0.452
^{201}Pb	c*	9.33H	946.0	7.4 ± 0.6	31.62 ± 2.86
			331.2	79 ± 5	31.70 ± 2.29
				$RR_{mean} =$	31.67 $\pm$ 1.91
^{200}Pb	c	21.5H	1205.7	*	21.68 ± 1.54
			828.3	*	21.33 ± 2.17
			579.3	*	20.17 ± 1.42
			367.9	*	21.00 ± 0.74
			257.2	4.46 ± 0.17	26.19 ± 1.82
			235.6	4.30 ± 0.17	27.09 ± 1.95
			147.6	37.7 ± 1.4	22.50 ± 1.58
				$RR_{mean} =$	21.16 $\pm$ 0.65
^{199}Pb	c*	90M	1135.0	7.8 ± 1.2	30.93 ± 5.26
			366.9	44 ± 7	41.66 ± 6.86
			353.4	9.5 ± 1.5	48.12 ± 8.08
				$RR_{mean} =$	38.07 $\pm$ 5.08
^{198}Pb	c	2.4H	173.4	18 ± 3	29.53 $\pm$ 5.09
^{197m}Pb	c*	43M	385.9	74 ± 15	17.38 ± 3.59
			222.8	25 ± 6	15.43 ± 3.81
				$RR_{mean} =$	17.18 $\pm$ 0.87
^{195m}Pb	i(m)	15.0M	383.6	107 ± 20	8.821 $\pm$ 1.736
^{202}Tl	c	12.23D	439.6	91.4 ± 1.0	5.584 $\pm$ 0.202
^{201}Tl	c*	72.912H	167.4	10.00 ± 0.06	37.60 $\pm$ 1.45
$^{200}\text{Tl}_i$	i	26.1H	1205.7	29.9 ± 1.8	9.471 ± 0.907
			579.3	13.8 ± 0.7	10.01 ± 1.66
			367.9	87.2 ± 0.4	8.781 ± 0.637
				$RR_{mean} =$	9.075 $\pm$ 0.537
$^{200}\text{Tl}_c$	c	26.1H	1205.7	29.9 ± 1.8	31.15 ± 2.17
			579.3	13.8 ± 0.7	30.18 ± 2.06
			367.9	87.2 ± 0.4	29.78 ± 1.07
				$RR_{mean} =$	29.90 $\pm$ 1.05
^{199}Tl	c*	7.42H	455.5	12.4 ± 1.4	34.18 ± 4.09
			247.3	9.3 ± 1.1	37.28 ± 4.69
				$RR_{mean} =$	35.35 $\pm$ 2.02
^{198m}Tl	i(m)	1.87H	282.8	28 ± 3	9.298 $\pm$ 1.164
^{197}Tl	c*	2.84H	1411.3	4.5 ± 1.5	23.42 $\pm$ 8.05
^{196m}Tl	i(m)	1.41H	695.4	41 ± 7	18.40 $\pm$ 3.22
^{197m}Hg	i(m)	23.8H	134.0	33.5 ± 0.4	3.489 $\pm$ 0.268
^{193m}Hg	i(m)	11.8H	407.6	32 ± 6	5.360 $\pm$ 1.031
^{192}Hg	c	4.85H	316.5	*	21.45 ± 2.70
			274.8	50.2 ± 2.5	18.88 ± 1.21
				$RR_{mean} =$	19.24 $\pm$ 0.59

Continuation of Table 109.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
¹⁹⁰ Hg	c*	20.0M	142.6	68 ± 10	15.04 ± 2.41
¹⁹⁶ Au	i(m1+m2+g)	6.183D	355.7	87.0 ± 0.8	0.8301 ± 0.0370
			333.0	22.9 ± 0.6	0.9385 ± 0.0837
			RR _{mean} =		0.8407 ± 0.0413
¹⁹⁵ Au	c	186.098D	98.9	10.9 ± 0.9	23.89 ± 2.71
¹⁹⁴ Au	i(m1+m2+g)	38.02H	328.5	61 ± 5	1.874 ± 0.170
¹⁹² Au _i	i(m+g)	4.94H	316.5	58 ± 7	3.969 ± 0.567
¹⁹² Au _c	c	4.94H	316.5	58 ± 7	25.42 ± 3.19
¹⁹¹ Au	c*	3.18H	277.9	7.2 ± 0.5	19.99 ± 1.97
¹⁹⁰ Au _c	c	42.8M	295.8	71 ± 5	24.64 ± 2.35
¹⁹¹ Pt	c	2.802D	538.9	13.7 ± 1.6	22.69 ± 2.77
			409.4	8.0 ± 0.9	17.14 ± 2.02
			359.9	6.0 ± 0.7	16.83 ± 2.07
			129.4	3.2 ± 0.5	17.75 ± 3.00
			RR _{mean} =		18.10 ± 1.38
¹⁸⁹ Pt	c	10.87H	721.4	9.3 ± 0.8	24.47 ± 2.55
			568.8	7.1 ± 0.6	25.55 ± 2.78
			544.9	5.8 ± 0.5	24.74 ± 2.47
RR _{mean} =		24.88 ± 1.62			
¹⁸⁸ Pt	c	10.2D	423.3	4.4 ± 0.3	18.27 ± 1.42
			381.4	7.5 ± 0.5	17.45 ± 1.31
			195.1	18.6 ± 1.2	18.08 ± 1.37
			187.6	19.4 ± 1.2	18.09 ± 1.32
RR _{mean} =		17.96 ± 0.76			
¹⁸⁶ Pt	c	2.08H	689.4	70 ± 15	16.42 ± 3.57
¹⁸⁹ Ir	c	13.2D	245.1	6.0 ± 0.6	18.18 ± 1.98
¹⁸⁷ Ir	c*	10.5H	977.5	3.14 ± 0.11	16.61 ± 1.33
¹⁸⁶ Ir	c	16.64H	434.8	33.9 ± 1.1	8.183 ± 0.422
			296.9	62.3 ± 1.9	8.446 ± 0.692
RR _{mean} =		8.239 ± 0.390			
¹⁸⁵ Ir	c	14.4H	1829.0	10.1 ± 1.5	12.49 ± 1.96
			254.2	13.3 ± 2.4	10.38 ± 1.97
RR _{mean} =		11.98 ± 0.98			
¹⁸⁴ Ir	c*	3.09H	390.4	25.9 ± 2.4	16.40 ± 1.65
			264.0	68 ± 4	17.79 ± 1.28
			119.8	31 ± 3	17.91 ± 2.15
RR _{mean} =		17.60 ± 0.72			
¹⁸⁵ Os	c	93.6D	874.8	6.29 ± 0.25	19.20 ± 1.03
			717.4	3.94 ± 0.16	19.12 ± 1.12
			646.1	78 ± 3	18.00 ± 0.92
RR _{mean} =		18.40 ± 0.69			
^{183m} Os	c*	9.9H	1101.9	49.0 ± 1.3	10.47 ± 0.47
¹⁸² Os	c	22.10H	1221.5	*	22.57 ± 1.72
			1189.2	*	21.54 ± 1.61
			1121.4	*	22.78 ± 1.46
			180.2	33.5 ± 1.7	18.18 ± 1.19
RR _{mean} =		20.19 ± 0.62			
¹⁸¹ Os	c	105M	238.8	44 ± 5	7.198 ± 0.991
¹⁸⁰ Os	c	21.5M	902.8(D)	101.5 ± 3.4	18.39 ± 1.53
¹⁸³ Re	c	70.0D	291.7	3.05 ± 0.18	18.12 ± 1.29

Continuation of Table 109.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			162.3	23.3 ± 0.7	19.32 ± 0.95
			<i>RR_{mean}</i> =		19.03 ± 0.80
^{182m} Re _c	c	12.7H	1221.5	24.8 ± 1.6	20.46 ± 1.64
			1189.2	15 ± 1	21.13 ± 1.67
			1121.4	31.8 ± 1.6	20.16 ± 1.76
			<i>RR_{mean}</i> =		20.61 ± 0.99
¹⁸¹ Re	c*	19.9H	639.0	6.4 ± 1.4	17.04 ± 3.80
			365.5	56 ± 8	16.77 ± 2.52
			<i>RR_{mean}</i> =		16.84 ± 1.85
¹⁷⁹ Re	c*	19.5M	290.0	26.9 ± 2.3	24.52 ± 2.72
¹⁷⁸ Re	c*	13.2M	237.3	45 ± 5	27.99 ± 3.64
¹⁷⁸ W	c	21.6D	1340.8(D)	1.03 ± 0.09	16.15 ± 2.15
			1106.1(D)	0.54 ± 0.05	22.20 ± 3.08
			<i>RR_{mean}</i> =		18.05 ± 2.86
¹⁷⁷ W	c	135M	115.7	51 ± 5	18.02 ± 2.17
¹⁷⁷ Ta	c*	56.56H	112.9	7.2 ± 1.6	19.08 ± 4.46
¹⁷⁶ Ta	c*	8.09H	1584.0	5.3 ± 0.4	20.93 ± 1.92
			1159.3	24.7 ± 1.9	23.07 ± 2.00
			<i>RR_{mean}</i> =		22.24 ± 1.25
¹⁷⁵ Ta	c	10.5H	1793.1	4.6 ± 0.7	13.57 ± 2.24
			348.5	12.0 ± 1.1	18.56 ± 1.88
			<i>RR_{mean}</i> =		16.57 ± 2.50
¹⁷⁴ Ta _c	c	1.14H	206.5	60 ± 5	18.18 ± 1.74
¹⁷³ Ta	c	3.14H	172.2	17.5 ± 1.8	23.53 ± 2.63
¹⁷² Ta	c*	36.8M	214.1	55 ± 5	13.96 ± 1.46
¹⁷⁵ Hf	c	70D	343.4	84 ± 3	17.35 ± 0.85
¹⁷³ Hf	c*	23.6H	306.6	6.4 ± 0.3	25.87 ± 1.83
			297.0	33.9 ± 1.4	30.82 ± 1.88
			139.6	12.7 ± 0.6	24.84 ± 1.84
			123.7	83 ± 5	22.52 ± 1.96
			<i>RR_{mean}</i> =		26.73 ± 1.98
¹⁷² Hf	c	1.87Y	1093.6	*	15.97 ± 0.93
			181.5	*	14.80 ± 0.98
			125.8	11.3 ± 0.9	15.68 ± 1.77
			<i>RR_{mean}</i> =		15.58 ± 0.48
¹⁷⁰ Hf	c	16.01H	620.7	18 ± 5	22.23 ± 6.24
			164.7	26 ± 8	19.13 ± 5.94
			120.2	15 ± 5	22.30 ± 7.59
			<i>RR_{mean}</i> =		21.52 ± 1.56
¹⁶⁸ Hf	c	25.95M	979.2	22.3 ± 5.6	18.39 ± 4.80
¹⁷³ Lu	c	1.37Y	272.1	21.2 ± 0.8	16.50 ± 0.94
¹⁷² Lu _i	i(m+g)	6.70D	1093.6	63 ± 3	0.1544 ± 0.0182
¹⁷² Lu _c	c	6.70D	1093.6	63 ± 3	16.12 ± 0.94
¹⁷¹ Lu	c*	8.24D	853.0	2.55 ± 0.07	19.86 ± 0.99
			839.9	3.04 ± 0.08	22.99 ± 1.25
			780.7	4.36 ± 0.11	19.46 ± 0.86
			739.8	47.8 ± 1.2	19.25 ± 0.80
			667.4	11.0 ± 0.3	20.45 ± 0.91
			<i>RR_{mean}</i> =		19.83 ± 0.76
¹⁷⁰ Lu	c*	2.012D	2126.1	5.1 ± 0.3	24.02 ± 1.83

Continuation of Table 109.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			1280.2	8.2 ± 0.4	23.73 ± 1.43
			1138.7	3.60 ± 0.18	23.86 ± 1.56
			1054.3	4.76 ± 0.24	24.21 ± 1.51
			$RR_{mean} =$		23.93 ± 0.88
$^{170}\text{Lu}_c$	c	2.012D	2126.1	5.1 ± 0.3	14.85 ± 1.70
			1280.2	8.2 ± 0.4	14.46 ± 1.11
			1138.7	3.60 ± 0.18	17.28 ± 3.54
			985.1	5.5 ± 0.3	17.80 ± 3.23
^{169}Lu	c	34.06H	$RR_{mean} =$		14.84 ± 0.84
			1449.7	9.9 ± 0.3	15.29 ± 0.74
			960.6	23.4 ± 0.7	14.53 ± 0.66
			191.2	20.6 ± 0.6	15.59 ± 0.77
^{167}Lu	c	51.5M	$RR_{mean} =$		15.03 ± 0.57
			113.3	*	16.94 ± 1.58
			106.2	*	18.15 ± 1.97
			$RR_{mean} =$		17.41 ± 1.29
^{169}Yb	c*	32.026D	307.7	10.05 ± 0.19	19.23 ± 0.77
			198.0	35.8 ± 0.7	17.42 ± 0.78
			177.2	22.2 ± 0.5	17.48 ± 0.78
			130.5	11.31 ± 0.21	18.80 ± 1.19
^{166}Yb	c	56.7H	$RR_{mean} =$		18.29 ± 0.76
			2079.5	*	17.74 ± 1.37
			2052.4	*	14.78 ± 1.05
			1374.2	*	16.89 ± 1.36
^{162}Yb	c	18.87M	1176.7	*	15.82 ± 1.14
			785.9	*	17.05 ± 1.35
			691.2(D)	*	15.12 ± 1.18
			$RR_{mean} =$		16.02 ± 0.69
^{167}Tm	c	9.25D	163.4	40 ± 5	18.40 ± 2.64
^{167}Tm	c		531.5	1.61 ± 0.22	17.75 ± 2.59
			207.8	42 ± 8	17.34 ± 3.37
			$RR_{mean} =$		17.70 ± 1.04
^{165}Tm	c	30.06H	806.4	9.5 ± 0.6	16.25 ± 1.25
			242.9	35.5 ± 1.7	18.53 ± 1.15
			$RR_{mean} =$		17.83 ± 1.19
^{163}Tm	c	1.810H	104.3	18.6 ± 0.7	15.94 ± 1.48
^{161}Er	c*	3.21H	826.6	64 ± 4	19.57 ± 1.45
^{160}Er	c	28.58H	966.2	*	17.02 ± 2.29
			962.4	*	16.84 ± 2.21
			879.4(D)	22.6 ± 2.8	18.67 ± 2.41
			872.0(D)	6.8 ± 1.1	19.91 ± 3.34
			728.2(D)	34 ± 5	18.77 ± 2.83
			$RR_{mean} =$		18.00 ± 0.56
^{159}Er	c*	36M	649.1	23 ± 3	24.02 ± 3.55
			624.5	33 ± 4	21.77 ± 2.86
			309.6	*	21.68 ± 2.05
			132.0	*	23.21 ± 1.69
			121.0	*	19.73 ± 1.87
$^{160m}\text{Ho}_c$	c	5.02H	$RR_{mean} =$		21.86 ± 0.67
			966.2	15.4 ± 2.0	17.68 ± 2.55

Continuation of Table 109.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
			962.4	16.6 ± 2.1	16.80 ± 2.31
			<i>RR_{mean}</i> =		17.19 ± 1.66
¹⁵⁶ Ho	c*	56M	266.5	54.7 ± 1.1	22.10 ± 1.02
¹⁵⁷ Dy	c	8.14H	326.2	92 ± 4	16.80 ± 0.94
¹⁵⁵ Dy	c*	9.9H	226.9	68.4 ± 1.6	15.40 ± 0.74
¹⁵² Dy	c	2.38H	256.9	97.50 ± 0.07	10.60 ± 0.44
¹⁵⁵ Tb	c*	5.32D	180.1	7.5 ± 0.5	14.69 ± 1.16
			163.3	4.44 ± 0.24	14.17 ± 1.01
			105.3	25.1 ± 1.3	15.98 ± 1.44
			<i>RR_{mean}</i> =		14.59 ± 0.63
¹⁵³ Tb	c*	2.34D	212.0	31.0 ± 1.9	13.23 ± 0.96
			102.2	6.4 ± 0.5	11.42 ± 1.28
			<i>RR_{mean}</i> =		12.70 ± 0.91
¹⁵² Tb	c*	17.5H	344.3	65 ± 4	12.46 ± 0.97
¹⁵¹ Tb	c	17.609H	731.2	8.32 ± 0.04	10.21 ± 0.47
			587.5	15.6 ± 0.7	12.09 ± 1.06
			479.4	15.4 ± 0.7	11.49 ± 0.71
			395.4	10.8 ± 0.5	12.48 ± 1.44
			287.4	28.3 ± 1.2	11.06 ± 0.64
			251.9	26.3 ± 1.2	11.49 ± 0.71
			108.1	24.3 ± 1.1	11.49 ± 1.04
			<i>RR_{mean}</i> =		10.94 ± 0.44
¹⁵⁰ Tb	c	3.48H	638.0	72 ± 10	5.917 ± 0.859
¹⁴⁹ Tb	c	4.118H	352.2	29.4 ± 0.9	5.664 ± 0.324
			165.0	26.4 ± 0.9	6.501 ± 0.586
			<i>RR_{mean}</i> =		5.792 ± 0.350
¹⁴⁸ Tb	c	60M	784.4	84.0 ± 1.6	6.817 ± 0.454
¹⁵³ Gd	c	240.4D	103.2	21.1 ± 0.7	12.03 ± 1.00
			97.4	29.0 ± 0.8	11.05 ± 0.89
			<i>RR_{mean}</i> =		11.48 ± 0.69
¹⁵¹ Gd	c	124D	243.3	5.6 ± 0.4	11.24 ± 0.94
			174.7	2.96 ± 0.21	11.12 ± 0.96
			<i>RR_{mean}</i> =		11.19 ± 0.50
¹⁴⁹ Gd	c	9.28D	788.9	7.3 ± 0.4	16.30 ± 1.06
			346.6	23.9 ± 1.3	14.00 ± 0.90
			298.6	28.6 ± 1.7	14.03 ± 0.97
			272.3	3.21 ± 0.19	14.69 ± 1.18
			149.7	48 ± 3	15.64 ± 1.22
			<i>RR_{mean}</i> =		14.80 ± 0.68
¹⁴⁷ Gd	c	38.06H	929.0	20.2 ± 1.2	12.28 ± 0.87
			396.0	34.3 ± 2.1	11.45 ± 0.81
			370.0	17.2 ± 0.9	12.63 ± 0.80
			229.3	63 ± 4	13.67 ± 1.02
			<i>RR_{mean}</i> =		12.40 ± 0.56
¹⁴⁶ Gd	c	48.27D	1533.7	*	13.19 ± 0.71
			1297.0	*	13.68 ± 0.80
			747.2	*	13.18 ± 0.59
			154.6	46.6 ± 0.5	14.01 ± 0.56
			115.5	44.0 ± 0.7	15.47 ± 1.08
			114.7	44.0 ± 0.7	14.87 ± 1.04

Continuation of Table 109.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
				<i>RR_{mean}</i> =	13.67 ± 0.42
¹⁴⁹ Eu	c*	93.1D	327.5	4.03 ± 0.12	18.19 ± 0.94
			277.1	3.56 ± 0.06	18.40 ± 0.81
				<i>RR_{mean}</i> =	18.33 ± 0.73
¹⁴⁷ Eu	c*	24.1D	955.8	3.84 ± 0.20	16.14 ± 1.11
			933.0	3.44 ± 0.18	19.63 ± 1.38
			856.9	2.70 ± 0.14	14.66 ± 0.97
			798.7	4.8 ± 0.3	16.75 ± 1.22
			677.5	9.8 ± 0.5	15.66 ± 0.98
			601.5	5.9 ± 0.3	15.81 ± 1.02
			121.2	22.9 ± 1.3	15.46 ± 1.35
				<i>RR_{mean}</i> =	15.99 ± 0.71
¹⁴⁶ Eu _i	i	4.61D	1533.7	6.08 ± 0.19	3.725 ± 1.370
			1297.0	5.39 ± 0.15	3.525 ± 1.433
			747.2	99 ± 3	1.815 ± 0.086
				<i>RR_{mean}</i> =	1.823 ± 0.101
¹⁴⁶ Eu _c	c	4.61D	1533.7	6.08 ± 0.19	16.92 ± 1.48
			1297.0	5.39 ± 0.15	17.20 ± 1.37
			747.2	99 ± 3	14.99 ± 0.67
				<i>RR_{mean}</i> =	15.44 ± 0.77
¹⁴⁵ Eu	c	5.93D	1997.0	7.2 ± 0.5	10.79 ± 0.88
			1658.5	14.9 ± 1.0	10.49 ± 0.81
			893.7	66 ± 5	11.14 ± 0.93
			653.5	15 ± 1	10.68 ± 0.80
			542.6	4.5 ± 0.4	10.13 ± 1.08
				<i>RR_{mean}</i> =	10.67 ± 0.45
¹⁴³ Pm	c	265D	742.0	38.5 ± 2.4	11.19 ± 0.80
¹³⁶ Nd	c	50.65M	539.8(D)	70.7 ± 2.6	7.627 ± 0.718
¹³⁴ Pr	c*	17M	409.2	87.1 ± 0.0	6.763 ± 0.554
¹³⁹ Ce	c	137.640D	165.9	79.89 ± 0.01	11.47 ± 0.44
¹³⁵ Ce	c	17.7H	783.6	10.6 ± 0.4	11.09 ± 0.71
			300.1	23.5 ± 0.6	10.62 ± 0.58
			265.6	41.8 ± 1.5	9.361 ± 0.503
				<i>RR_{mean}</i> =	10.11 ± 0.60
¹³⁴ Ce	c	3.16D	604.7	5.04 ± 0.20	9.418 ± 0.587
¹³² Ce	c	3.51H	464.5	*	7.287 ± 0.651
			182.1	77.4 ± 0.5	8.728 ± 0.377
				<i>RR_{mean}</i> =	8.500 ± 0.262
¹³⁰ Ce	c	25M	357.4	*	4.952 ± 0.453
¹³² La _c	c	4.8H	567.1	15.7 ± 1.5	6.236 ± 0.770
			464.5	76 ± 6	7.398 ± 0.645
				<i>RR_{mean}</i> =	7.024 ± 0.584
¹³³ Ba	c	3848.9D	356.0	62.05 ± 0.19	8.986 ± 0.747
¹³¹ Ba	c	11.50D	373.2	14.04 ± 0.20	8.378 ± 0.314
			249.4	2.81 ± 0.03	9.426 ± 0.504
			216.1	19.66 ± 0.25	8.911 ± 0.386
			133.6	2.12 ± 0.03	7.889 ± 0.735
			123.8	29.0 ± 0.3	8.641 ± 0.551
				<i>RR_{mean}</i> =	8.612 ± 0.324
¹²⁸ Ba	c	2.43D	442.9	26.8 ± 1.4	6.318 ± 0.422

Continuation of Table 109.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
			273.4	14.5 ± 0.7	7.193 ± 0.453
			$RR_{mean} =$		6.809 ± 0.482
^{129}Cs	c	32.06H	371.9	30.6 ± 1.7	9.559 ± 0.636
^{127}Xe	c	36.4D	375.0	17.2 ± 0.6	7.831 ± 0.383
			202.9	68.3 ± 0.5	7.498 ± 0.299
			172.1	25.5 ± 0.8	7.333 ± 0.383
			$RR_{mean} =$		7.538 ± 0.270
^{125}Xe	c	16.9H	188.4	54.0 ± 0.3	7.829 ± 0.353
^{123}Xe	c	2.08H	148.9	48.9 ± 0.6	7.173 ± 0.394
^{121}I	c*	2.12H	212.2	84.3 ± 0.3	6.893 ± 0.366
^{123m}Te	i(m)	119.7D	159.0	84.0 ± 0.4	0.3091 ± 0.0287
^{121m}Te	i(m)	154D	212.2	81.4 ± 1.1	0.6717 ± 0.0319
			573.1	88.6 ± 0.1	0.5587 ± 0.0657
			507.6	88.6 ± 0.1	0.9740 ± 0.2882
			$RR_{mean} =$		0.6650 ± 0.0205
$^{121}\text{Te}_c$	c	19.16D	573.1	80.3 ± 2.5	5.828 ± 0.270
			507.6	17.7 ± 0.6	6.393 ± 0.357
			$RR_{mean} =$		5.975 ± 0.309
^{119m}Te	i(m)	4.70D	1212.7	66.2 ± 0.3	1.331 ± 0.050
^{119}Te	c	16.05H	644.0	84.0 ± 0.5	3.533 ± 0.166
^{116}Te	c	2.49H	1293.6	95 ± 8	3.627 ± 0.374
^{120m}Sb	i(m)	5.76D	1171.7	100 ± 0	0.4037 ± 0.0217
			1023.3	99.4 ± 0.3	0.3995 ± 0.0172
			$RR_{mean} =$		0.4008 ± 0.0159
^{118m}Sb	i(m)	5.00H	1050.7	97 ± 5	1.014 ± 0.081
^{115}Sb	c*	32.1M	497.3	97.9 ± 0.4	5.459 ± 0.324
^{117m}Sn	i(m)	13.60D	158.6	86.4 ± 0.4	0.8139 ± 0.0421
^{113}Sn	c	115.09D	391.7	64.97 ± 0.17	3.468 ± 0.129
^{114m}In	i(m)	49.51D	190.3	15.56 ± 0.16	1.505 ± 0.080
^{111}In	c	2.8047D	245.4	94 ± 1	3.995 ± 0.162
			171.3	90.2 ± 1.0	4.016 ± 0.168
			$RR_{mean} =$		4.004 ± 0.143
^{109}In	c	4.2H	203.5	73.5 ± 0.5	3.309 ± 0.214
^{110m}Ag	i(m)	249.76D	937.5	34.2 ± 0.6	1.007 ± 0.080
			884.7	72.7 ± 0.4	1.054 ± 0.048
			657.8	94.3 ± 0.3	0.9622 ± 0.0451
			$RR_{mean} =$		1.006 ± 0.044
^{106m}Ag	i(m)	8.28D	1045.8	29.6 ± 1.0	1.699 ± 0.093
			717.3	28.9 ± 0.8	1.564 ± 0.086
			451.0	28.2 ± 0.8	1.695 ± 0.083
			$RR_{mean} =$		1.654 ± 0.067
^{105}Ag	c	41.29D	443.4	10.5 ± 0.6	2.957 ± 0.220
			344.5	41.4 ± 0.6	2.541 ± 0.161
			331.5	4.10 ± 0.22	3.010 ± 0.283
			$RR_{mean} =$		2.727 ± 0.174
^{100}Pd	c	3.63D	2376.0	*	0.6411 ± 0.0408
^{102}Rh	i	207D	475.1	46 ± 5	1.012 ± 0.123
^{101m}Rh	c	4.34D	306.9	81 ± 5	3.373 ± 0.244
$^{100}\text{Rh}_i$	i(m+g)	20.8H	2376.0	32.6 ± 0.4	1.633 ± 0.134
$^{100}\text{Rh}_c$	c	20.8H	2376.0	32.6 ± 0.4	2.274 ± 0.144

Continuation of Table 109.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{99m}Rh	c	4.7H	340.8	70 ± 5	1.577 ± 0.143
^{103}Ru	c	39.26D	497.1	91.0 ± 1.3	3.261 ± 0.137
^{96}Tc	i(m+g)	4.28D	849.9	98 ± 4	2.069 ± 0.113
			812.5	82 ± 4	2.138 ± 0.128
			$RR_{mean} =$		2.098 ± 0.096
^{99}Mo	c	65.94H	140.5	90.27 ± 0.33	2.915 ± 0.162
^{93m}Mo	i(m)	6.85H	1477.1	99.1 ± 2.5	1.437 ± 0.080
			684.7	99.7 ± 2.0	1.314 ± 0.079
			$RR_{mean} =$		1.376 ± 0.075
^{96}Nb	i	23.35H	1091.3	48.5 ± 1.6	1.720 ± 0.135
			568.9	58.0 ± 0.3	1.613 ± 0.139
			$RR_{mean} =$		1.669 ± 0.103
$^{95}\text{Nb}_i$	i(m+g)	34.975D	765.8	99.81 ± 0.03	2.730 ± 0.097
$^{95}\text{Nb}_c$	c	34.975D	765.8	99.81 ± 0.03	4.396 ± 0.147
^{90}Nb	c*	14.60H	2319.0	82.0 ± 0.3	1.926 ± 0.099
			1129.2	92.7 ± 0.5	2.101 ± 0.086
			$RR_{mean} =$		2.042 ± 0.104
^{95}Zr	c	64.02D	765.8	*	1.681 ± 0.076
			756.7	54.46 ± 0.10	1.684 ± 0.072
			$RR_{mean} =$		1.683 ± 0.052
^{89}Zr	c	78.41H	909.2	99.04 ± 0.03	4.008 ± 0.132
^{88}Zr	c	83.4D	898.0	*	2.709 ± 0.206
			392.9	97.24 ± 0.00	2.420 ± 0.087
			$RR_{mean} =$		2.435 ± 0.075
^{90m}Y	i(m)	3.19H	479.5	90.74 ± 0.05	2.175 ± 0.130
$^{88}\text{Y}_i$	i	106.65D	898.0	93.7 ± 0.3	3.522 ± 0.149
$^{88}\text{Y}_c$	c	106.65D	1836.1	99.2 ± 0.3	5.916 ± 0.211
			898.0	93.7 ± 0.3	6.231 ± 0.232
			$RR_{mean} =$		6.044 ± 0.242
^{87}Y	c*	79.8H	388.5	82.1 ± 0.5	5.449 ± 0.192
^{85}Sr	c	64.84D	514.0	96 ± 4	4.804 ± 0.261
^{84}Rb	i(m+g)	32.77D	881.6	69.0 ± 1.6	3.539 ± 0.242
^{83}Rb	c	86.2D	552.6	16.0 ± 1.1	5.663 ± 0.444
			529.6	29.3 ± 2.1	5.278 ± 0.429
			520.4	45 ± 4	5.307 ± 0.507
			$RR_{mean} =$		5.441 ± 0.242
^{82m}Rb	i(m)	6.472H	554.3	62.4 ± 0.9	2.921 ± 0.239
^{82}Br	i(m+g)	35.30H	554.3	70.8 ± 1.0	1.622 ± 0.081
^{75}Se	c	119.779D	400.7	11.47 ± 0.09	3.775 ± 0.171
			264.7	58.9 ± 0.4	2.874 ± 0.112
			136.0	58.3 ± 0.8	3.086 ± 0.178
			$RR_{mean} =$		3.084 ± 0.267
^{76}As	i	1.0778D	559.1	45 ± 2	2.989 ± 0.302
^{74}As	i	17.77D	595.8	59 ± 4	2.691 ± 0.206
^{71}As	c	65.28H	174.9	82.0 ± 2.1	0.8262 ± 0.0414
$^{72}\text{Ga}_i$	i	14.10H	2201.7	25.9 ± 0.5	1.382 ± 0.088
$^{72}\text{Ga}_c$	c	14.10H	2201.7	25.9 ± 0.5	1.564 ± 0.087
^{72}Zn	c	46.5H	2201.7	*	0.1822 ± 0.0249
^{65}Zn	c	244.26D	1115.6	50.60 ± 0.24	1.962 ± 0.085
^{58}Co	i(m+g)	70.86D	810.8	99.45 ± 0.01	1.303 ± 0.154

Continuation of Table 109.

Nuclide	Type	T _{1/2}	E _γ , keV	γ-yield, %	Reaction Rate, 10 ⁻¹⁷ s ⁻¹
⁵⁶ Co	c	77.233D	846.8	99.94 ± 0.03	0.07337 ± 0.01595
⁵⁹ Fe	c	44.472D	1291.6	43.2 ± 1.4	1.500 ± 0.086
			1099.2	56.5 ± 1.9	1.591 ± 0.084
			RR _{mean} =		1.549 ± 0.066
⁵⁴ Mn	i	312.11D	834.8	99.98 ± 0.00	1.750 ± 0.068
⁵² Mn	c	5.591D	1434.1	100.0 ± 0.6	0.1936 ± 0.0192
⁴⁸ V	c	15.9735D	1312.1	97.5 ± 0.9	0.4129 ± 0.0191
			983.5	100.0 ± 0.3	0.3320 ± 0.0186
			RR _{mean} =		0.3759 ± 0.0419
⁴⁸ Sc	i	43.67H	1312.1	100.1 ± 0.7	0.7165 ± 0.0355
			1037.5	97.6 ± 0.7	0.8134 ± 0.0326
			RR _{mean} =		0.7791 ± 0.0522
⁴⁶ Sc	i(m+g)	83.79D	889.3	99.98 ± 0.00	1.834 ± 0.064
²⁸ Mg	c	20.915H	1778.8	100.2 ± 0.0	1.015 ± 0.045
²⁴ Na	c	14.9590H	1369.0	100 ± 0	4.277 ± 0.154
⁷ Be	i	53.29D	477.6	10.52 ± 0.06	8.000 ± 0.318

12.11.6 Nuclide production rates for ^{27}Al

Table 110: Detailed calculation of nuclide production rates for in ^{27}Al -monitors and ^{27}Al -plates for $E_p = 2.6$ GeV, used for calculating proton flux (including total over the plate area), cross sections for production of ^7Be , ^{24}Na and neutron background.

Nuclide	Type	$T_{1/2}$	E_γ , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{27}Al -monitor for ^{206}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	11.11 ± 0.40
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	1.066 ± 0.056
			1014.4	28.0 ± 0.4	1.094 ± 0.076
$RR_{mean} =$					1.074 ± 0.050
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	13.68 ± 0.48
^{24}Na	c	14.9590H	1369.0	100 ± 0	12.89 ± 0.43
^{27}Al -plate for ^{206}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	1.356 ± 0.045
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	3.645 ± 0.129
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.5042 ± 0.0229
			1014.4	28.0 ± 0.4	0.5045 ± 0.0341
$RR_{mean} =$					0.5042 ± 0.0214
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	4.516 ± 0.162
^{24}Na	c	14.9590H	1369.0	100 ± 0	4.246 ± 0.141
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.4794 ± 0.0161
^{27}Al -monitor for ^{207}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	9.278 ± 0.327
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.9817 ± 0.0434
			1014.4	28.0 ± 0.4	1.014 ± 0.066
$RR_{mean} =$					0.9888 ± 0.0410
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	11.44 ± 0.39

Continuation of Table 110.

Nuclide	Type	$T_{1/2}$	E_{γ} , keV	γ -yield, %	Reaction Rate, 10^{-17} s^{-1}
^{24}Na	c	14.9590H	1369.0	100 ± 0	10.96 ± 0.36
^{27}Al -plate for ^{207}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.7769 ± 0.0263
^{27}Al -monitor for ^{nat}Pb					
^7Be	i	53.29D	477.6	10.52 ± 0.06	64.65 ± 2.27
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	0.09826 ± 0.00388
			1014.4	28.0 ± 0.4	0.09976 ± 0.00514
			$RR_{mean} =$		0.09864 ± 0.00369
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	79.54 ± 2.72
^{24}Na	c	14.9590H	1369.0	100 ± 0	74.95 ± 2.50
^{27}Al -plate for ^{nat}Pb					
^{24}Na	c	14.9590H	1369.0	100 ± 0	3.614 ± 0.125
^{27}Al -monitor for ^{209}Bi					
^7Be	i	53.29D	477.6	10.52 ± 0.06	8.745 ± 0.307
^{27}Mg	c	9.458M	843.8	71.8 ± 0.4	1.506 ± 0.063
			1014.4	28.0 ± 0.4	1.505 ± 0.097
			$RR_{mean} =$		1.506 ± 0.060
^{22}Na	c	2.6019Y	1274.5	99.94 ± 0.01	11.14 ± 0.38
^{24}Na	c	14.9590H	1369.0	100 ± 0	10.93 ± 0.36
^{27}Al -plate for ^{209}Bi					
^{24}Na	c	14.9590H	1369.0	100 ± 0	0.7347 ± 0.0246

13 Appendix 2. Radioactive decay chains ised in simulation.

The analyzed decay chains presented in the Tables are broken, for convenience, into

- the $^{208,207,206,nat}\text{Pb}$ decay chains (the left-hand or upper sides of the Tables)
- the ^{209}Bi decay chains (the right-hand or bottom sides of the Tables)

In cases the $^{208,207,206,nat}\text{Pb}$ and ^{209}Bi chains are the same they are According to the decay chain fragments presented, the measured nuclides for both Pb and Bi have been classified to be the independent yields of ground sttes **i**, the independent yields of metastable states **i**(Σm_j) , the sums of the independent yields of metastable and ground states **i**($\Sigma m_j + \mathbf{g}$), the cumulative yields of metastable and ground states **c**, and the supracumulative yields of metastable and ground states c^*

Table 111: Chain for $^{207}_{84}\text{Po} - i(m+g)$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
					84207	0	

Table 112: Chain of $^{206}_{84}\text{Po} - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
					84206	0	

Table 113: Chain of $^{205}_{84}\text{Po} - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
					84205	0	

Table 114: Chain of $^{204}_{84}\text{Po} - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
					84204	0	

Table 115: Chain of $^{203}_{84}Po - i(m + g)$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
						84203	0

Table 116: Chain of $^{202}_{84}Po - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
						84202	0

Table 117: Chain of $^{201}_{84}Po - i(m + g)$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
						84201	0

Table 118: Chain of $^{207}_{83}Bi - i, c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83207	0					83207	1
						84207	0
						0.99979	84207

Table 119: Chain of $^{206}_{83}Bi - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83206	0					83206	0

Table 120: Chain of $^{206}_{83}Bi - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
						83206	1
						84206	0
						0.9455	84206

Table 121: Chain of $^{205}_{83}Bi - i, c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83205	0				83205	1	0.9996
					84205	0	

Table 122: Chain of $^{204}_{83}Bi - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83204	0				83204	0	

Table 123: Chain of $^{204}_{83}Bi - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
					83204	1	0.9934
					84204	0	

Table 124: Chain of $^{204}_{83}Bi - c^*$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
					83204	1	1.44937
					84204	0	

Table 125: Chain of $^{203}_{83}Bi - i(m + g), c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83203	0				83203	1	0.9989
					84203	0	

Table 126: Chain of $^{202}_{83}Bi - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83202	0				83202	0	

Table 127: Chain of $^{202}_{83}\text{Bi} - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
					83202	1	0.9808
					84202	0	

Table 128: Chain of $^{202}_{83}\text{Bi} - c^*$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
					83202	1	1.73023
					84202	0	

Table 129: Chain of $^{201}_{83}\text{Bi} - i, c^*$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83201	0				83201	1	1.14636
					84201	0	

Table 130: Chain of $^{199}_{83}\text{Bi} - i, c^*$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
83199	0				83199	1	1.11398
					84199	0	

Table 131: Chain of $^{203}_{82}\text{Pb} - i(m1 + m2 + g)$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor
82203	0				82203	0	

Table 132: Chain of $^{203}_{82}\text{Pb} - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
82203	1	1	83203	82203	2	1	83203 0.00021
83203	0			83203	1	0.9989	84203
				84207	0		
				84203	0		

Table 133: Chain of $^{201}_{82}\text{Pb} - i(m + g)$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
82201	0						

Table 134: Chain of $^{201}_{82}\text{Pb} - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
82201	1	1	83201	82201	2	1	83201 0.0004
83201	0			83201	1	0.984	84201
				84205	0		
				84201	0		

Table 135: Chain of $^{201}_{82}\text{Pb} - c^*$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
82201	1	1.239	83201	82201	2	1.239	83201 0.0004
83201	0			83201	1	0.984	84201
				84205	0		
				84201	0		

Table 136: Chain of $^{200}_{82}\text{Pb} - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
82200	1	1	83200	82200	2	1	83200 0.0066
83200	0			83200	1	0.889	84200
				84204	0		
				84200	0		

Table 137: Chain of $^{199}_{82}Pb - c^*$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
82199	1	1.4286	83199		82199	2	1.4286	83199	0.0011
83199	0				83199	1	0.925	84199	
					84203	0			
					84199	0			

Table 138: Chain of $^{198}_{82}Pb - c$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
82198	1	1	83198		82198	2	1	83198	0.0192
83198	0				83198	1	0.43	84198	
					84202	0			
					84198	0			

Table 139: Chain of $^{196}_{82}Pb - c^*$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
82196	1	1.1611	83196		82196	2	1.1611	83196	0.111
83196	0				83196	1	0.02	84196	
					84200	0			
					84196	0			

Table 140: Chain of $^{202}_{81}Tl - i$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
81202	0				81202	0			

Table 141: Chain of $^{202}_{81}Tl - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
			81202	1	1	82202	
			82202	2	1	83202	0.0545
			83202	1	0.9808	84202	84206
			84206	0			
			84202	0			

Table 142: Chain of $^{201}_{81}Tl - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
81201	1	1	82201		81201	1	82201
82201	1	1	83201		82201	2	1
83201	0				83201	0.984	84201
					84205	0	
					84201	0	

Table 143: Chain of $^{200}_{81}Tl - i$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
81200	0				81200	0	

Table 144: Chain of $^{200}_{81}Tl - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
81200	1	1	82200		81200	1	82200
82200	1	1	83200		82200	2	1
83200	0				83200	0.889	84200
					84204	0	
					84200	0	

Table 145: Chain of $^{199}_{81}Tl - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
81199	2	1.2534	82199	1.0E-07	83203	81199	2	1	82199	1.0E-07	83203
82199	1	1	83199			82199	2	1	83199	0.0011	84203
83203	0					83203	1	0.9989	84203		
83199	0					83199	1	0.925	84199		
						84203	0				
						84199	0				

Table 146: Chain of $^{197}_{81}Tl - c$

Pb					Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
81197	2	1	82197	1.0E-06	83201	81197	2	1	82197	1.0E-06
82197	1	1	83197			82197	2	1	83197	0.016
83201	0					83201	1	0.984	84201	
83197	0					83197	1	0.56	84197	
						84201	0			
						84197	0			

Table 147: Chain of $^{195}_{81}Tl - c^*$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
81195	1	1.2747	82195		81195	1	1.2747	82195	
82195	1	0.9997	83195		82195	2	0.9997	83195	0.075
83195	0				83195	1	0.25	84195	
					84199	0			
					84195	0			

Table 148: Chain of $^{203}_{80}Hg - c$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
80203	1	1	79203		80203	1	1	79203	
79203	0				79203	0			

Table 149: Chain of $^{197}_{80}\text{Hg} - c^*$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
80197	1	1.0463	81197			80197	1	1.0463	81197		
81197	2	1	82197	1.0E-06	83201	81197	2	1	82197	1.0E-06	83201
82197	1	1	83197			82197	2	1	83197	0.016	84201
83201	0					83201	1	0.984	84201		
83197	0					83197	1	0.56	84197		
						84201	0				
						84197	0				

Table 150: Chain of $^{195}_{80}\text{Hg} - c_t$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
80195	1	1	81195			80195	1	1	81195		
81195	1	1	82195			81195	1	1	82195		
82195	1	0.9997	83195			82195	2	0.9997	83195	0.075	84199
83195	0					83195	1	0.25	84195		
						84199	0				
						84195	0				

Table 151: Chain of $^{192}_{80}\text{Hg} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
80192	2	1	81192	3.00E-07	82196	80192	2	1	81192	3.00E-07	82196
81192	2	0.99994	82192	1.15E-05	83196	81192	2	0.99994	82192	1.15E-05	83196
82196	1	1	83196			82196	2	1	83196	0.111	84200
82192	1	0.88	83192			82192	2	0.88	83192	0.98	84196
83196	0					83196	1	0.02	84196		
83192	0					84200	0				
						83192	1	0.005	84192		
						84196	0				
						84192	0				

Table 152: Chain of $^{190}_{80}\text{Hg} - c^*$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
80190	2	1.227	81190	7.30E-08	82194	80190	2	1.227	81190	7.30E-08	82194
81190	2	0.996	82190	0.0046	83194	81190	2	0.996	82190	0.0046	83194
82194	1	0.9954	83194			82194	2	0.9954	83194	0.57	84198
82190	1	0.1	83190			82190	2	0.1	83190	1	84194
83194	0					83194	0				
83190	0					84198	0				
						83190	0				
						84194	0				

Table 153: Chain of $^{198}_{79}\text{Au} - i(m + g)$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
79198	0				79198	0			

Table 154: Chain of $^{196}_{79}\text{Au} - i(m1 + m2 + g)$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
79196	0				79196	0			

Table 155: Chain of $^{195}_{79}\text{Au} - c$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
79195	1	1	80195		79195	1	1	80195	
80195	1	1	81195		80195	1	1	81195	
81195	1	1	82195		81195	1	1	82195	
82195	1	0.9997	83195		82195	2	0.9997	83195	0.075
83195	0				83195	1	0.25	84195	
					84199	0			
					84195	0			

Table 156: Chain of $^{194}_{79}\text{Au} - i(m1 + m2 + g)$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
79194	0				79194	0			

Table 157: Chain of $^{192}_{79}\text{Au} - i(m + g)$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
79192	0				79192	0			

Table 158: Chain of $^{192}_{79}\text{Au} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
79192	1	1	80192			79192	1	1	80192		
80192	2	1	81192	3.00E-07	82196	80192	2	1	81192	3.00E-07	82196
81192	2	0.99994	82192	1.15E-05	83196	81192	2	0.99994	82192	1.15E-05	83196
82196	1	1	83196			82196	2	1	83196	0.111	84200
82192	1	0.88	83192			82192	2	0.88	83192	0.98	84196
83196	0					83196	1	0.02	84196		
83192	0					84200	0				
						83192	1	0.005	84192		
						84196	0				
						84192	0				

Table 159: Chain of $^{191}_{79}\text{Au} - c^*$

Pb					Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
79191	1	1.3456	80191		79191	79191	1	1.3456	80191	
80191	1	1	81191		80191	80191	1	1	81191	
81191	2	0.99987	82191	0.0003	83195	81191	2	0.99987	82191	0.0003
82191	1	0.4	83191		82191	82191	2	0.4	83191	0.75
83195	0				83195	83195	1	0.25	84195	
83191	0				83191	83191	0			
					84195	84195	0			

Table 160: Chain of $^{190}_{79}\text{Au} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
79190	2	1	80190	1.00E-09	81194	79190	2	1	80190	1.00E-09	81194
80190	2	1	81190	7.30E-08	82194	80190	2	1	81190	7.30E-08	82194
81194	1	1	82194			81194	1	1	82194		
81190	2	0.996	82190	0.0046	83194	81190	2	0.996	82190	0.0046	83194
82194	1	0.9954	83194			82194	2	0.9954	83194	0.57	84198
82190	1	0.1	83190			82190	2	0.1	83190	1	84194
83194	0					83194	0				
83190	0					84198	0				
						83190	0				
						84194	0				

Table 161: Chain of $^{191}_{78}Pt - c$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
78191	1	1	79191		78191	1	1	79191	
79191	1	1	80191		79191	1	1	80191	
80191	1	1	81191		80191	1	1	81191	
81191	2	0.99987	82191	0.0003	81191	2	0.99987	82191	0.0003
82191	1	0.4	83191		82191	2	0.4	83191	0.75
83195	0				83195	1	0.25	84195	
83191	0				83191	0			
					84195	0			

Table 162: Chain of $^{189}_{78}Pt - c$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
78189	1	1	79189		78189	1	1	79189	
79189	1	1	80189		79189	1	1	80189	
80189	1	1	81189		80189	1	1	81189	
81189	2	0.006	82189	0.035	81189	2	0.006	82189	0.035
82189	1	0.5	83189		82189	2	0.5	83189	1
83193	0				83193	0			
83189	0				83189	0			
					84193	0			

Table 163: Chain of $^{188}_{78}Pt - c$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
78188	1	1	79188		78188	1	1	79188	
79188	1	1	80188		79188	1	1	80188	
80188	2	1	81188	5.90E-05	80188	2	1	81188	5.90E-05
81188	2	0.907	82188	0.12	81188	2	0.907	82188	0.12
82192	1	0.88	83192		82192	2	0.88	83192	0.98
82188	1	1	83188		82188	2	1	83188	0.995
83192	0				83192	1	0.005	84192	
83188	0				84196	0			
					83188	1	1	84188	
					84192	0			
					84188	0			

Table 164: Chain of $^{187}_{78}Pt - c$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
78187	1	1	79187		78187	1	1	79187	
79187	1	1	80187		79187	1	1	80187	
80187	2	1	81187	0.00013	80187	2	1	81187	0.00013
81187	2	0.93	82187	0.6	81187	2	0.93	82187	0.6
82191	1	0.4	83191		82191	2	0.4	83191	0.75
82187	1	0.5	83187		82187	2	0.5	83187	1
83191	0				83191	0			
83187	0				84195	0			
					83187	0			
					84191	0			

Table 165: Chain of $^{186}_{78}Pt - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
78186	2	1	79186	3.40E-09	80190	78186	2	1	79186	3.40E-09	80190
79186	1	0.99984	80186			79186	1	0.99984	80186		
80190	2	1	81190	7.30E-08	82194	80190	2	1	81190	7.30E-08	82194
80186	2	1	81186	0.004	82190	80186	2	1	81186	0.004	82190
81190	2	0.996	82190	0.0046	83194	81190	2	0.996	82190	0.0046	83194
82194	1	0.9954	83194			82194	2	0.9954	83194	0.57	84198
81186	2	0.6	82186	0.9	83190	81186	2	0.6	82186	0.9	83190
82190	1	0.1	83190			82190	2	0.1	83190	1	84194
83194	0					83194	0				
82186	0					84198	0				
83190	0					82186	1	1	84190		
						83190	0				
						84194	0				
						84190	0				

Table 166: Chain of $^{184}_{78}Pt - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
78184	2	0.99984	79184	3.70E-07	80188	78184	2	0.99984	79184	3.70E-07	80188
79184	1	0.9889	80184			79184	1	0.9889	80184		
80188	2	1	81188	5.90E-05	82192	80188	2	1	81188	5.90E-05	82192
80184	2	0.979	81184	0.093	82188	80184	2	0.979	81184	0.093	82188
81188	2	0.907	82188	0.12	83192	81188	2	0.907	82188	0.12	83192
82192	1	0.88	83192			82192	2	0.88	83192	0.98	84196
81184	1	0.77	82184			81184	1	0.77	82184		
82188	1	1	83188			82188	2	1	83188	0.995	84192
83192	0					83192	1	0.005	84192		
82184	1	0.85	83185			84196	0				
83188	0					82184	1	0.85	83185		
83185	0					83188	1	1	84188		
						84192	0				
						83185	0				
						84188	0				

Table 167: Chain of $^{192}_{\gamma\gamma}Ir - i(m1 + g)$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
77192	0								

Table 168: Chain of $^{190}_{\gamma\gamma}Ir - i(m1 + g)$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
77190	0								

Table 169: Chain of $^{189}_{\gamma\gamma}Ir - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
77189	1	1	78189			77189	1	1	78189		
78189	1	1	79189			78189	1	1	79189		
79189	1	1	80189			79189	1	1	80189		
80189	1	1	81189			80189	1	1	81189		
81189	2	0.006	82189	0.035	83193	81189	2	0.006	82189	0.035	83193
82189	1	0.5	83189			82189	2	0.5	83189	1	84193
83193	0					83193	0				
83189	0					83189	0				
						84193	0				

Table 170: Chain of $^{188}_{\gamma\gamma}Ir - i$

Pb					Bi				
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
77188	0								

Table 171: Chain of $^{188}_{77}\text{Ir} - c$

Pb					Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor
77188	1	1	78188		77188	77188	1	1	78188	
78188	1	1	79188		78188	78188	1	1	79188	
79188	1	1	80188		79188	79188	1	1	80188	
80188	2	1	81188	5.90E-05	80188	80188	2	1	81188	5.90E-05
81188	2	0.907	82188	0.12	81188	81188	2	0.907	82188	0.12
82192	1	0.88	83192		82192	82192	2	0.88	83192	0.98
82188	1	1	83188		82188	82188	2	1	83188	0.995
83192	0				83192	83192	1	0.005	84192	
83188	0				84196	84196	0			
					83188	83188	1	1	84188	
					84192	84192	0			
					84188	84188	0			

Table 172: Chain of $^{187}_{77}\text{Ir} - c^*$

Pb					Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
77187	1	1.2883	78187		77187	77187	1	1.2883	78187		
78187	1	1	79187		78187	78187	1	1	79187		
79187	1	1	80187		79187	79187	1	1	80187		
80187	2	1	81187	0.00013	80187	80187	2	1	81187	0.00013	82191
81187	2	0.93	82187	0.6	81187	81187	2	0.93	82187	0.6	83191
82191	1	0.4	83191		82191	82191	2	0.4	83191	0.75	84195
82187	1	0.5	83187		82187	82187	2	0.5	83187	1	84191
83191	0				83191	83191	0				
83187	0				84195	84195	0				
					83187	83187	0				
					84191	84191	0				

Table 173: Chain of $^{186}_{77}\text{Ir} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
77186	2	1	78186	1.00E-08	79190	77186	2	1	78186	1.00E-08	79190
78186	2	1	79186	3.40E-09	80190	78186	2	1	79186	3.40E-09	80190
79190	2	1	80190	1.00E-09	81194	79190	2	1	80190	1.00E-09	81194
79186	1	0.99984	80186			79186	1	0.99984	80186		
80190	2	1	81190	7.30E-08	82194	80190	2	1	81190	7.30E-08	82194
81194	1	1	82194			81194	1	1	82194		
80186	2	1	81186	0.004	82190	80186	2	1	81186	0.004	82190
81190	2	0.996	82190	0.0046	83194	81190	2	0.996	82190	0.0046	83194
82194	1	0.9954	83194			82194	2	0.9954	83194	0.57	84198
81186	2	0.6	82186	0.9	83190	81186	2	0.6	82186	0.9	83190
82190	1	0.1	83190			82190	2	0.1	83190	1	84194
83194	0					83194	0				
82186	0					84198	0				
83190	0					82186	1	1	84190		
						83190	0				
						84194	0				
						84190	0				

Table 174: Chain of $^{185}_{77}\text{Ir} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
77185	2	1	78185	3.00E-07	79189	77185	2	1	78185	3.00E-07	79189
78185	2	0.9974	79185	3.00E-07	80189	78185	2	0.9974	79185	3.00E-07	80189
79189	1	1	80189			79189	1	1	80189		
79185	1	0.94	80185			79185	1	0.94	80185		
80189	1	1	81189			80189	1	1	81189		
80185	2	1	81185	0.004	82189	80185	2	1	81185	0.004	82189
81189	2	0.006	82189	0.035	83193	81189	2	0.006	82189	0.035	83193
81185	1	0.5	83189			81185	1	0.5	83189		
82189	1	0.5	83189			82189	2	0.5	83189	1	84193
83193	0					83193	0				
83189	0					83189	0				
						84193	0				

Table 175: Chain of $^{184}_{77}\text{Ir} - c^*$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
77184	1	1.1029	78184			77184	1	1.1029	78184		
78184	2	0.99984	79184	3.70E-07	80188	78184	2	0.99984	79184	3.70E-07	80188
79184	1	0.9889	80184			79184	1	0.9889	80184		
80188	2	1	81188	5.90E-05	82192	80188	2	1	81188	5.90E-05	82192
80184	2	0.979	81184	0.093	82188	80184	2	0.979	81184	0.093	82188
81188	2	0.907	82188	0.12	83192	81188	2	0.907	82188	0.12	83192
82192	1	0.88	83192			82192	2	0.88	83192	0.98	84196
81184	1	0.77	82184			81184	1	0.77	82184		
82188	1	1	83188			82188	2	1	83188	0.995	84192
83192	0					83192	1	0.005	84192		
82184	1	0.85	83185			84196	0				
83188	0					82184	1	0.85	83185		
83185	0					83188	1	1	84188		
						84192	0				
						83185	0				
						84188	0				

Table 176: Chain of $^{183}_{77}\text{Ir} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
77183	2	1	78183	3.00E-05	79187	77183	2	1	78183	3.00E-05	79187
78183	2	0.9945	79183	1.20E-06	80187	78183	2	0.9945	79183	1.20E-06	80187
79187	1	1	80187			79187	1	1	80187		
79183	1	0.883	80183			79183	1	0.883	80183		
80187	2	1	81187	0.00013	82191	80187	2	1	81187	0.00013	82191
80183	2	1	81183	0.07	82187	80183	2	1	81183	0.07	82187
81187	2	0.93	82187	0.6	83191	81187	2	0.93	82187	0.6	83191
82191	1	0.4	83191			82191	2	0.4	83191	0.75	84195
81183	2	0.1	82183	0.5	83187	81183	2	0.1	82183	0.5	83187
82187	1	0.5	83187			82187	2	0.5	83187	1	84191
83191	0					83191	0				
82183	0					84195	0				
83187	0					82183	0				
						83187	0				
						84191	0				

Table 177: Chain of $^{185}_{76}\text{Os} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
76185	1	1	77185			76185	1	1	77185		
77185	2	1	78185	3.00E-07	79189	77185	2	1	78185	3.00E-07	79189
78185	2	0.9974	79185	3.00E-07	80189	78185	2	0.9974	79185	3.00E-07	80189
79189	1	1	80189			79189	1	1	80189		
79185	1	0.94	80185			79185	1	0.94	80185		
80189	1	1	81189			80189	1	1	81189		
80185	2	1	81185	0.004	82189	80185	2	1	81185	0.004	82189
81189	2	0.006	82189	0.035	83193	81189	2	0.006	82189	0.035	83193
81185	1	0.5	83189			81185	1	0.5	83189		
82189	1	0.5	83189			82189	2	0.5	83189	1	84193
83193	0					83193	0				
83189	0					83189	0				
						84193	0				

Table 178: Chain of $^{182}_{76}\text{Os} - c$

Pb									
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
76182	2	1	77182	1.40E-06	78186				
77182	2	0.99962	78182	8.00E-06	79186				
78186	2	1	79186	3.40E-09	80190				
78182	3	0.9987	79182	2.60E-06	80183	1.60E-04	80186		
79186	1	0.99984	80186						
80190	2	1	81190	7.30E-08	82194				
79182	2	0.848	80182	6.00E-05	81186				
80183	2	1	81183	0.07	82187				
80186	2	1	81186	0.004	82190				
81190	2	0.996	82190	0.0046	83194				
82194	1	0.9954	83194						
80182	2	0.96	81182	0.4	82186				
81186	2	0.6	82186	0.9	83190				
81183	2	0.1	82183	0.5	83187				
82187	1	0.5	83187						
82190	1	0.1	83190						
83194	0								
81182	1	1	83186						
82186	0								
83190	0								
82183	0								
83187	0								
83186	0								
Bi									
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
76182	2	1	77182	1.40E-06	78186				
77182	2	0.99962	78182	8.00E-06	79186				
78186	2	1	79186	3.40E-09	80190				
78182	3	0.9987	79182	2.60E-06	80183	1.60E-04	80186		
79186	1	0.99984	80186						
80190	2	1	81190	7.30E-08	82194				
79182	2	0.848	80182	6.00E-05	81186				
80183	2	1	81183	0.07	82187				
80186	2	1	81186	0.004	82190				
81190	2	0.996	82190	0.0046	83194				
82194	2	0.9954	83194	0.57	84198				
80182	2	0.96	81182	0.4	82186				
81186	2	0.6	82186	0.9	83190				
81183	2	0.1	82183	0.5	83187				
82187	2	0.5	83187	1	84191				
82190	2	0.1	83190	1	84194				
83194	0								
84198	0								
81182	1	1	83186						
82186	1	1	84190						
83190	0								
82183	0								
83187	0								
84191	0								
84194	0								
83186	0								
84190	0								

Table 179: Chain of $^{181}_{76}\text{Os} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
76181	1	1	77181		79185	76181	1	1	77181		79185
77181	2	1	78181	0.0026	80185	77181	2	1	78181	0.0026	80185
78181	2	0.973	79181	0.06		78181	2	0.973	79181	0.06	80185
79185	1	0.94	80185			79185	1	0.94	80185		
79181	1	0.68984	80181			79181	1	0.68984	80181		
80185	2	1	81185	0.004	82189	80185	2	1	81185	0.004	82189
80181	2	0.5	81181	1	82185	80181	2	0.5	81181	1	82185
81185	1	0.5	83189			81185	1	0.5	83189		
82189	1	0.5	83189			82189	2	0.5	83189	1	84193
81181	1	0.15	83185			81181	1	0.15	83185		
82185	0					82185	0				
83189	0					83189	0				
83185	0					84193	0				
						83185	0				

Table 180: Chain of $^{180}_{76}\text{Os} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
76180	2	1	77180	1.00E-05	78184		
77180	2	1	78180	0.00016	79184		
78184	2	0.99984	79184	3.70E-07	80188		
78180	3	0.982	79180	0.00016	80181	0.0111	80184
79184	1	0.9889	80184				
80188	2	1	81188	5.90E-05	82192		
79180	2	0.52	80180	0.021	81184		
80181	2	0.5	81181	1	82185		
80184	2	0.979	81184	0.093	82188		
81188	2	0.907	82188	0.12	83192		
82192	1	0.88	83192				
80180	2	0.93	81180	0.23	82184		
81184	1	0.77	82184				
81181	1	0.15	83185				
82185	0						
82188	1	1	83188				
83192	0						
81180	1	1	83184				
82184	1	0.85	83185				
83185	0						
83188	0						
83184	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
76180	2	1	77180	1.00E-05	78184		
77180	2	1	78180	0.00016	79184		
78184	2	0.99984	79184	3.70E-07	80188		
78180	3	0.982	79180	0.00016	80181	0.0111	80184
79184	1	0.9889	80184				
80188	2	1	81188	5.90E-05	82192		
79180	2	0.52	80180	0.021	81184		
80181	2	0.5	81181	1	82185		
80184	2	0.979	81184	0.093	82188		
81188	2	0.907	82188	0.12	83192		
82192	2	0.88	83192	0.98	84196		
80180	2	0.93	81180	0.23	82184		
81184	1	0.77	82184				
81181	1	0.15	83185				
82185	0						
82188	2	1	83188	0.995	84192		
83192	1	0.005	84192				
84196	0						
81180	1	1	83184				
82184	1	0.85	83185				
83185	0						
83188	1	1	84188				
84192	0						
83184	0						
84188	0						

Table 181: Chain of $^{183}_{75}Re - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
75183	1	1	76183			75183	1	1	76183		
76183	1	1	77183			76183	1	1	77183		
77183	2	1	78183	3.00E-05	79187	77183	2	1	78183	3.00E-05	79187
78183	2	0.9945	79183	1.20E-06	80187	78183	2	0.9945	79183	1.20E-06	80187
79187	1	1	80187			79187	1	1	80187		
79183	1	0.883	80183			79183	1	0.883	80183		
80187	2	1	81187	0.00013	82191	80187	2	1	81187	0.00013	82191
80183	2	1	81183	0.07	82187	80183	2	1	81183	0.07	82187
81187	2	0.93	82187	0.6	83191	81187	2	0.93	82187	0.6	83191
82191	1	0.4	83191			82191	2	0.4	83191	0.75	84195
81183	2	0.1	82183	0.5	83187	81183	2	0.1	82183	0.5	83187
82187	1	0.5	83187			82187	2	0.5	83187	1	84191
83191	0					83191	0				
82183	0					84195	0				
83187	0					82183	0				
						83187	0				
						84191	0				

Table 182: Chain of $^{181}_{75}Re - c$

Pb					Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
75181	1	1	76181		75181	75181	1	1	76181		76181
76181	1	1	77181		76181	76181	1	1	77181		77181
77181	2	1	78181	0.0026	79185	77181	2	1	78181	0.0026	79185
78181	2	0.973	79181	0.06	80185	78181	2	0.973	79181	0.06	80185
79185	1	0.94	80185		79185	79185	1	0.94	80185		80185
79181	1	0.68984	80181		79181	79181	1	0.68984	80181		80181
80185	2	1	81185	0.004	82189	80185	2	1	81185	0.004	82189
80181	2	0.5	81181	1	82185	80181	2	0.5	81181	1	82185
81185	1	0.5	83189		81185	81185	1	0.5	83189		83189
82189	1	0.5	83189		82189	82189	2	0.5	83189	1	84193
81181	1	0.15	83185		81181	81181	1	0.15	83185		83185
82185	0				82185	82185	0				
83189	0				83189	83189	0				
83185	0				84193	84193	0				
					83185	83185	0				

Table 183: Chain of $^{179}_{75}\text{Re} - c^*$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
75179	1	1.5	76179			75179	1	1.5	76179		
76179	2	1	77179	1.30E-05	78183	76179	2	1	77179	1.30E-05	78183
77179	2	0.9976	78179	0.0055	79183	77179	2	0.9976	78179	0.0055	79183
78183	2	0.9945	79183	1.20E-06	80187	78183	2	0.9945	79183	1.20E-06	80187
78179	2	0.78	79179	0.117	80183	78179	2	0.78	79179	0.117	80183
79183	1	0.883	80183			79183	1	0.883	80183		
80187	2	1	81187	0.00013	82191	80187	2	1	81187	0.00013	82191
79179	2	0.4685	80179	1	81183	79179	2	0.4685	80179	1	81183
80183	2	1	81183	0.07	82187	80183	2	1	81183	0.07	82187
81187	2	0.93	82187	0.6	83191	81187	2	0.93	82187	0.6	83191
82191	1	0.4	83191			82191	2	0.4	83191	0.75	84195
80179	1	0.9	82183			80179	1	0.9	82183		
81183	2	0.1	82183	0.5	83187	81183	2	0.1	82183	0.5	83187
82187	1	0.5	83187			82187	2	0.5	83187	1	84191
83191	0					83191	0				
82183	0					84195	0				
83187	0					82183	0				
						83187	0				
						84191	0				

Table 184: Chain of $^{178}_{75}\text{Re} - c^*$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
75178	1	1.6098	76178				
76178	2	1	77178	0.00038	78182		
77178	2	0.923	78178	0.0013	79182		
78182	3	0.9987	79182	2.60E-06	80183	1.60E-04	80186
78178	3	0.6	79178	0.0015	80179	0.152	80182
79182	2	0.848	80182	6.00E-05	81186		
80183	2	1	81183	0.07	82187		
80186	2	1	81186	0.004	82190		
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
81186	2	0.6	82186	0.9	83190		
81183	2	0.1	82183	0.5	83187		
82187	1	0.5	83187				
82190	1	0.1	83190				
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	0						
83190	0						
83187	0						
82182	0						
83186	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
75178	1	1.6098	76178				
76178	2	1	77178	0.00038	78182		
77178	2	0.923	78178	0.0013	79182		
78182	3	0.9987	79182	2.60E-06	80183	1.60E-04	80186
78178	3	0.6	79178	0.0015	80179	0.152	80182
79182	2	0.848	80182	6.00E-05	81186		
80183	2	1	81183	0.07	82187		
80186	2	1	81186	0.004	82190		
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
81186	2	0.6	82186	0.9	83190		
81183	2	0.1	82183	0.5	83187		
82187	2	0.5	83187	1	84191		
82190	2	0.1	83190	1	84194		
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	1	1	84190				
83190	0						
83187	0						
84191	0						
84194	0						
82182	0						
83186	0						
84190	0						

Table 185: Chain of $^{178}_{74}\text{W} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
74178	1	1	75178				
75178	1	1	76178				
76178	2	1	77178	0.00038	78182		
77178	2	0.923	78178	0.0013	79182		
78182	3	0.9987	79182	2.60E-06	80183	1.60E-04	80186
78178	3	0.6	79178	0.0015	80179	0.152	80182
79182	2	0.848	80182	6.00E-05	81186		
80183	2	1	81183	0.07	82187		
80186	2	1	81186	0.004	82190		
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
81186	2	0.6	82186	0.9	83190		
81183	2	0.1	82183	0.5	83187		
82187	1	0.5	83187				
82190	1	0.1	83190				
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	0						
83190	0						
83187	0						
82182	0						
83186	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
74178	1	1	75178				
75178	1	1	76178				
76178	2	1	77178	0.00038	78182		
77178	2	0.923	78178	0.0013	79182		
78182	3	0.9987	79182	2.60E-06	80183	1.60E-04	80186
78178	3	0.6	79178	0.0015	80179	0.152	80182
79182	2	0.848	80182	6.00E-05	81186		
80183	2	1	81183	0.07	82187		
80186	2	1	81186	0.004	82190		
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
81186	2	0.6	82186	0.9	83190		
81183	2	0.1	82183	0.5	83187		
82187	2	0.5	83187	1	84191		
82190	2	0.1	83190	1	84194		
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	1	1	84190				
83190	0						
83187	0						
84191	0						
84194	0						
82182	0						
83186	0						
84190	0						

Table 186: Chain of $^{177}_{74}\text{W} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
74177	1	1	75177				
75177	1	1	76177				
76177	2	0.9994	77177	0.0008	78181		
77177	3	0.943	78177	1.10E-07	80181	2.70E-02	79181
78181	2	0.973	79181	0.06	80185		
78177	1	0.31	80181				
80181	2	0.5	81181	1	82185		
79181	1	0.68984	80181				
80185	2	1	81185	0.004	82189		
81181	1	0.15	83185				
82185	0						
81185	1	0.5	83189				
82189	1	0.5	83189				
83185	0						
83189	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
74177	1	1	75177				
75177	1	1	76177				
76177	2	0.9994	77177	0.0008	78181		
77177	3	0.943	78177	1.10E-07	80181	2.70E-02	79181
78181	2	0.973	79181	0.06	80185		
78177	1	0.31	80181				
80181	2	0.5	81181	1	82185		
79181	1	0.68984	80181				
80185	2	1	81185	0.004	82189		
81181	1	0.15	83185				
82185	0						
81185	1	0.5	83189				
82189	2	0.5	83189	1	84193		
83185	0						
83189	0						
84193	0						

Table 187: Chain of $^{176}_{74}W - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
74176	1	1	75176				
75176	1	1	76176				
76176	2	0.969	77176	0.003	78180		
77176	2	0.62	78176	0.018	79180		
78180	3	0.982	79180	0.00016	80181	0.0111	80184
78176	2	0.5	79176	0.48	80180		
79180	2	0.52	80180	0.021	81184		
80181	2	0.5	81181	1	82185		
80184	2	0.979	81184	0.093	82188		
79176	1	0.07	81180				
80180	2	0.93	81180	0.23	82184		
81184	1	0.77	82184				
81181	1	0.15	83185				
82185	0						
82188	1	1	83188				
81180	1	1	83184				
82184	1	0.85	83185				
83185	0						
83188	0						
83184	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)

Table 188: Chain of $^{177}_{73}\text{Ta} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73176	1	1	74176				
74176	1	1	75176				
75176	1	1	76176				
76176	2	0.969	77176	0.003	78180		
77176	2	0.62	78176	0.018	79180		
78180	3	0.982	79180	0.00016	80181	0.0111	80184
78176	2	0.5	79176	0.48	80180		
79180	2	0.52	80180	0.021	81184		
80181	2	0.5	81181	1	82185		
80184	2	0.979	81184	0.093	82188		
79176	1	0.07	81180				
80180	2	0.93	81180	0.23	82184		
81184	1	0.77	82184				
81181	1	0.15	83185				
82185	0						
82188	1	1	83188				
81180	1	1	83184				
82184	1	0.85	83185				
83185	0						
83188	0						
83184	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73176	1	1.4472	74176				
74176	1	1	75176				
75176	1	1	76176				
76176	2	0.969	77176	0.003	78180		
77176	2	0.62	78176	0.018	79180		
78180	3	0.982	79180	0.00016	80181	0.0111	80184
78176	2	0.5	79176	0.48	80180		
79180	2	0.52	80180	0.021	81184		
80181	2	0.5	81181	1	82185		
80184	2	0.979	81184	0.093	82188		
79176	1	0.07	81180				
80180	2	0.93	81180	0.23	82184		
81184	1	0.77	82184				
81181	1	0.15	83185				
82185	0						
82188	2	1	83188	0.995	84192		
81180	1	1	83184				
82184	1	0.85	83185				
83185	0						
83188	1	1	84188				
84192	0						
83184	0						
84188	0						

Table 189: Chain of $^{176}_{73}\text{Ta} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73177	1	1	74177				
74177	1	1	75177				
75177	1	1	76177				
76177	2	0.9994	77177	0.0008	78181		
77177	3	0.943	78177	1.10E-07	80181	2.70E-02	79181
78181	2	0.973	79181	0.06	80185		
78177	1	0.31	80181				
80181	2	0.5	81181	1	82185		
79181	1	0.68984	80181				
80185	2	1	81185	0.004	82189		
81181	1	0.15	83185				
82185	0						
81185	1	0.5	83189				
82189	1	0.5	83189				
83185	0						
83189	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73177	1	1	74177				
74177	1	1	75177				
75177	1	1	76177				
76177	2	0.9994	77177	0.0008	78181		
77177	3	0.943	78177	1.10E-07	80181	2.70E-02	79181
78181	2	0.973	79181	0.06	80185		
78177	1	0.31	80181				
80181	2	0.5	81181	1	82185		
79181	1	0.68984	80181				
80185	2	1	81185	0.004	82189		
81181	1	0.15	83185				
82185	0						
81185	1	0.5	83189				
82189	2	0.5	83189	1	84193		
83185	0						
83189	0						
84193	0						

Table 190: Chain of $^{175}_{73}\text{Ta} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73175	1	1	74175			73175	1	1	74175		
74175	1	1	75175			74175	1	1	75175		
75175	1	1	76175			75175	1	1	76175		
76175	2	0.9915	77175	0.0024	78179	76175	2	0.9915	77175	0.0024	78179
77175	2	0.36	78175	0.22	79179	77175	2	0.36	78175	0.22	79179
78179	2	0.78	79179	0.117	80183	78179	2	0.78	79179	0.117	80183
78175	2	0.06	79175	0.53	80179	78175	2	0.06	79175	0.53	80179
79179	2	0.4685	80179	1	81183	79179	2	0.4685	80179	1	81183
80183	2	1	81183	0.07	82187	80183	2	1	81183	0.07	82187
79175	1	1	81179			79175	1	1	81179		
80179	1	0.9	82183			80179	1	0.9	82183		
81183	2	0.1	82183	0.5	83187	81183	2	0.1	82183	0.5	83187
82187	1	0.5	83187			82187	2	0.5	83187	1	84191
81179	0					81179	0				
82183	0					82183	0				
83187	0					83187	0				
						84191	0				

Table 191: Chain of $^{174}_{73}\text{Ta} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73174	1	1	74174				
74174	1	1	75174				
75174	1	0.9998	76174				
76174	2	0.995	77174	0.077	78178		
77174	2	0.24	78174	0.4	79178		
78178	3	0.6	79178	0.0015	80179	0.152	80182
78174	1	0.7	80178				
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	0						
82182	0						
83186	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73174	1	1	74174				
74174	1	1	75174				
75174	1	0.9998	76174				
76174	2	0.995	77174	0.077	78178		
77174	2	0.24	78174	0.4	79178		
78178	3	0.6	79178	0.0015	80179	0.152	80182
78174	1	0.7	80178				
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	1	1	84190				
82182	0						
83186	0						
84190	0						

Table 192: Chain of $^{173}_{73}\text{Ta} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73173	1	1	74173				
74173	1	1	75173				
75173	2	0.99979	76173	0.0006	77177		
76173	2	0.93	77173	0.057	78177		
77177	3	0.943	78177	1.10E-07	80181	2.70E-02	79181
77173	2	0.16	78173	1	79177		
78177	1	0.31	80181				
80181	2	0.5	81181	1	82185		
79181	1	0.68984	80181				
78173	2	0.06	79173	0.85	80177		
79177	2	0.15	80177	0.5	81181		
81181	1	0.15	83185				
82185	0						
79173	1	0.73	81177				
80177	1	1	82181				
83185	0						
81177	0						
82181	0						

Table 193: Chain of $^{172}_{73}\text{Ta} - c^*$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
73172	1	1.2185	74172				
74172	1	1	75172				
75172	2	0.998	76172	0.031	77176		
76172	2	0.98	77172	0.38	78176		
77176	2	0.62	78176	0.018	79180		
77172	2	0.06	78172	0.5	79176		
78176	2	0.5	79176	0.48	80180		
79180	2	0.52	80180	0.021	81184		
78172	2	0.03	79173	1	80176		
79176	1	0.07	81180				
80180	2	0.93	81180	0.23	82184		
81184	1	0.77	82184				
79173	1	0.73	81177				
80176	2	0.27	81177	1	82180		
81180	1	1	83184				
82184	1	0.85	83185				
81177	0						
82180	0						
83184	0						
83185	0						

Table 194: Chain of $^{175}_{72}\text{Hf} - c$

Pb						Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
72175	1	1	73175				72175	1	1	73175	
73175	1	1	74175				73175	1	1	74175	
74175	1	1	75175				74175	1	1	75175	
75175	1	1	76175				75175	1	1	76175	
76175	2	0.9915	77175	0.0024	78179		76175	2	0.9915	77175	0.0024
77175	2	0.36	78175	0.22	79179		77175	2	0.36	78175	0.22
78179	2	0.78	79179	0.117	80183		78179	2	0.78	79179	0.117
78175	2	0.06	79175	0.53	80179		78175	2	0.06	79175	0.53
79179	2	0.4685	80179	1	81183		79179	2	0.4685	80179	1
80183	2	1	81183	0.07	82187		80183	2	1	81183	0.07
79175	1	1	81179				79175	1	1	81179	
80179	1	0.9	82183				80179	1	0.9	82183	
81183	2	0.1	82183	0.5	83187		81183	2	0.1	82183	0.5
82187	1	0.5	83187				82187	2	0.5	83187	1
81179	0						81179	0			
82183	0						82183	0			
83187	0						83187	0			
							84191	0			

Table 195: Chain of $^{173}_{72}\text{Hf} - c$

Pb, Bi								
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
72173	1	1	73173					
73173	1	1	74173					
74173	1	1	75173					
75173	2	0.99979	76173	0.0006	77177			
76173	2	0.93	77173	0.057	78177			
77177	3	0.943	78177	1.10E-07	80181	2.70E-02	79181	
77173	2	0.16	78173	1	79177			
78177	1	0.31	80181					
80181	2	0.5	81181	1	82185			
79181	1	0.68984	80181					
78173	2	0.06	79173	0.85	80177			
79177	2	0.15	80177	0.5	81181			
81181	1	0.15	83185					
82185	0							
79173	1	0.73	81177					
80177	1	1	82181					
83185	0							
81177	0							
82181	0							

Table 196: Chain of $^{172}_{72}Hf - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
72172	1	1	73172				
73172	1	1	74172				
74172	1	1	75172				
75172	2	0.998	76172	0.031	77176		
76172	2	0.98	77172	0.38	78176		
77176	2	0.62	78176	0.018	79180		
77172	2	0.06	78172	0.5	79176		
78176	2	0.5	79176	0.48	80180		
79180	2	0.52	80180	0.021	81184		
78172	2	0.03	79173	1	80176		
79176	1	0.07	81180				
80180	2	0.93	81180	0.23	82184		
81184	1	0.77	82184				
79173	1	0.73	81177				
80176	2	0.27	81177	1	82180		
81180	1	1	83184				
82184	1	0.85	83185				
81177	0						
82180	0						
83184	0						
83185	0						

Table 197: Chain of $^{171}_{72}Hf - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
72171	1	1	73171				
73171	1	1	74171				
74171	1	1	75171				
75171	2	0.982	76171	0.0085	77175		
76171	2	0.5	77171	0.64	78175		
77175	2	0.36	78175	0.22	79179		
77171	2	0.02	78171	0.94	79175		
78175	2	0.06	79175	0.53	80179		
79179	2	0.4685	80179	1	81183		
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80179	1	0.9	82183				
81183	2	0.1	82183	0.5	83187		
79172	0						
80175	0						
81179	0						
82183	0						
83187	0						

Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)

Table 198: Chain of $^{170}_{72}\text{Hf} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
72170	1	1	73170				
73170	1	1	74170				
74170	2	1	75170	0.0002	76174		
75170	2	0.914	76170	0.005	77174		
76174	2	0.995	77174	0.077	78178		
76170	3	0.948	77170	0.5	77171	0.76	78174
77174	2	0.24	78174	0.4	79178		
78178	3	0.6	79178	0.0015	80179	0.152	80182
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	0						
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						
83186	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
72170	1	1	73170				
73170	1	1	74170				
74170	2	1	75170	0.0002	76174		
75170	2	0.914	76170	0.005	77174		
76174	2	0.995	77174	0.077	78178		
76170	3	0.948	77170	0.5	77171	0.76	78174
77174	2	0.24	78174	0.4	79178		
78178	3	0.6	79178	0.0015	80179	0.152	80182
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	1	1	84190				
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						
83186	0						
84190	0						

Table 199: Chain of $^{168}_{72}\text{Hf} - c$

Pb				Bi			
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor
				72168	1	1	73168
				73168	1	1	74168
				74168	2	1	75168 0.002 76172
				75168	2	0.51	76168 0.02 77172
				76172	2	0.98	77172 0.38 78176
				76168	2	0.51	77168 0.94 78172
				77172	2	0.06	78172 0.5 79176
				78176	2	0.5	79176 0.48 80180
				77168	1	1	79172
				78172	2	0.03	79173 1 80176
				79176	1	0.07	81180
				80180	2	0.93	81180 0.23 82184
				79172	0		
				79173	1	0.73	81177
				80176	2	0.27	81177 1 82180
				81180	1	1	83184
				82184	1	0.85	83185
				81177	0		
				82180	0		
				83184	0		
				83185	0		

Table 200: Chain of $^{173}_{71}\text{Lu} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A) Branch. factor	(Z, A)	Branch. factor	(Z, A) Branch. factor	(Z, A) Branch. factor
71173	1	1	72173				
72173	1	1	73173				
73173	1	1	74173				
74173	1	1	75173				
75173	2	0.99979	76173	0.0006	77177		
76173	2	0.93	77173	0.057	78177		
77177	3	0.943	78177	1.10E-07	80181	2.70E-02	79181
77173	2	0.16	78173	1	79177		
78177	1	0.31	80181				
80181	2	0.5	81181	1	82185		
79181	1	0.68984	80181				
78173	2	0.06	79173	0.85	80177		
79177	2	0.15	80177	0.5	81181		
81181	1	0.15	83185				
82185	0						
79173	1	0.73	81177				
80177	1	1	82181				
83185	0						
81177	0						
82181	0						

Table 201: Chain of $^{172}_{71}\text{Lu} - i(m + g)$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
71172	0					

Table 202: Chain of $^{172}_{71}\text{Lu} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
71172	1	1	72172			
72172	1	1	73172			
73172	1	1	74172			
74172	1	1	75172			
75172	2	0.998	76172	0.031	77176	
76172	2	0.98	77172	0.38	78176	
77176	2	0.62	78176	0.018	79180	
77172	2	0.06	78172	0.5	79176	
78176	2	0.5	79176	0.48	80180	
79180	2	0.52	80180	0.021	81184	
78172	2	0.03	79173	1	80176	
79176	1	0.07	81180			
80180	2	0.93	81180	0.23	82184	
81184	1	0.77	82184			
79173	1	0.73	81177			
80176	2	0.27	81177	1	82180	
81180	1	1	83184			
82184	1	0.85	83185			
81177	0					
82180	0					
83184	0					
83185	0					

Table 203: Chain of $^{171}_{71}\text{Lu} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
71171	1	1	72171				
72171	1	1	73171				
73171	1	1	74171				
74171	1	1	75171				
75171	2	0.982	76171	0.0085	77175		
76171	2	0.5	77171	0.64	78175		
77175	2	0.36	78175	0.22	79179		
77171	2	0.02	78171	0.94	79175		
78175	2	0.06	79175	0.53	80179		
79179	2	0.4685	80179	1	81183		
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80179	1	0.9	82183				
81183	2	0.1	82183	0.5	83187		
79172	0						
80175	0						
81179	0						
82183	0						
83187	0						

Table 204: Chain of $^{170}_{71}\text{Lu} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
71170	1	1	72170				
72170	1	1	73170				
73170	1	1	74170				
74170	2	1	75170	0.0002	76174		
75170	2	0.914	76170	0.005	77174		
76174	2	0.995	77174	0.077	78178		
76170	3	0.948	77170	0.5	77171	0.76	78174
77174	2	0.24	78174	0.4	79178		
78178	3	0.6	79178	0.0015	80179	0.152	80182
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	0						
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						
83186	0						
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
71170	1	1	72170				
72170	1	1	73170				
73170	1	1	74170				
74170	2	1	75170	0.0002	76174		
75170	2	0.914	76170	0.005	77174		
76174	2	0.995	77174	0.077	78178		
76170	3	0.948	77170	0.5	77171	0.76	78174
77174	2	0.24	78174	0.4	79178		
78178	3	0.6	79178	0.0015	80179	0.152	80182
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
79178	2	0.3	80178	0.04	81182		
80179	1	0.9	82183				
80182	2	0.96	81182	0.4	82186		
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
81182	1	1	83186				
82183	0						
82186	1	1	84190				
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						
83186	0						
84190	0						

Table 205: Chain of $^{169}_{71}\text{Lu} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
71169	1	1	72169			
72169	1	1	73169			
73169	1	1	74169			
74169	2	0.5	75169	0.00021	76173	
75169	2	0.89	76169	0.07	77173	
76173	2	0.93	77173	0.057	78177	
76169	1	0.84	78173			
77173	2	0.16	78173	1	79177	
78177	1	0.31	80181			
78173	2	0.06	79173	0.85	80177	
79177	2	0.15	80177	0.5	81181	
80181	2	0.5	81181	1	82185	
79173	1	0.73	81177			
80177	1	1	82181			
81181	1	0.15	83185			
82185	0					
81177	0					
82181	0					
83185	0					

Table 206: Chain of $^{167}_{71}\text{Lu} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
71167	1	1	72167			
72167	1	1	73167			
73167	1	0.9996	74167			
74167	2	0.99	75167	0.018	76171	
75167	1	0.43	76167			
76171	2	0.5	77171	0.64	78175	
76167	2	0.2	77167	0.98	78171	
77171	2	0.02	78171	0.94	79175	
78175	2	0.06	79175	0.53	80179	
77167	0					
78171	2	0.02	79172	1	80175	
79175	1	1	81179			
80179	1	0.9	82183			
79172	0					
80175	0					
81179	0					
82183	0					

Table 207: Chain of $^{169}_{70}\text{Yb} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
70169	1	1	71169				
71169	1	1	72169				
72169	1	1	73169				
73169	1	1	74169				
74169	2	0.5	75169	0.00021	76173		
75169	2	0.89	76169	0.07	77173		
76173	2	0.93	77173	0.057	78177		
76169	1	0.84	78173				
77173	2	0.16	78173	1	79177		
78177	1	0.31	80181				
78173	2	0.06	79173	0.85	80177		
79177	2	0.15	80177	0.5	81181		
80181	2	0.5	81181	1	82185		
79173	1	0.73	81177				
80177	1	1	82181				
81181	1	0.15	83185				
82185	0						
81177	0						
82181	0						
83185	0						

Table 208: Chain of $^{166}_{70}\text{Yb} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
70166	1	1	71166				
71166	1	1	72166				
72166	1	1	73166				
73166	1	0.99965	74166				
74166	2	0.92	75166	0.086	76170		
75166	2	0.1	76166	0.052	77170		
76170	3	0.948	77170	0.5	77171	0.76	78174
76166	2	0.32	77167	0.98	78170		
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
77167	0						
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						

Table 209: Chain of $^{162}_{70}\text{Yb} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
70162	1	1	71162				
71162	1	0.99992	72162				
72162	2	0.99926	73162	0.00035	74166		
73162	2	0.548	74162	0.08	75166		
74166	2	0.92	75166	0.086	76170		
74162	2	0.06	75162	0.72	76166		
75166	2	0.1	76166	0.052	77170		
76170	3	0.948	77170	0.5	77171	0.76	78174
75162	1	0.931	77166				
76166	2	0.32	77167	0.98	78170		
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
77166	1	0.15	79170				
77167	0						
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
79170	0						
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						

Table 210: Chain of $^{167}_{69}Tm - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
69167	1	1	70167			
70167	1	1	71167			
71167	1	1	72167			
72167	1	1	73167			
73167	1	0.9996	74167			
74167	2	0.99	75167	0.018	76171	
75167	1	0.43	76167			
76171	2	0.5	77171	0.64	78175	
76167	2	0.2	77167	0.98	78171	
77171	2	0.02	78171	0.94	79175	
78175	2	0.06	79175	0.53	80179	
77167	0					
78171	2	0.02	79172	1	80175	
79175	1	1	81179			
80179	1	0.9	82183			
79172	0					
80175	0					
81179	0					
82183	0					

Table 211: Chain of $^{165}_{69}Tm - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
69165	1	1	70165			
70165	1	1	71165			
71165	1	1	72165			
72165	1	1	73165			
73165	2	1	74165	0.5	75169	
74165	2	1	75165	0.11	76169	
75169	2	0.89	76169	0.07	77173	
75165	2	0.4	76165	1	77169	
76169	1	0.84	78173			
77173	2	0.16	78173	1	79177	
76165	2	0.069	77166	1	78169	
77169	1	0.94	79173			
78173	2	0.06	79173	0.85	80177	
79177	2	0.15	80177	0.5	81181	
77166	1	0.15	79170			
78169	2	0.85	79170	1	80173	
79173	1	0.73	81177			
80177	1	1	82181			
81181	1	0.15	83185			
79170	0					
80173	0					
81177	0					
82181	0					
83185	0					

Table 212: Chain of $^{163}_{69}Tm - c$

Pb						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
69163	1	1	70163			
70163	1	1	71163			
71163	1	1	72163			
72163	2	0.998	73163	0.0004	74167	
73163	2	0.87	74163	0.01	75167	
74167	2	0.99	75167	0.018	76171	
74163	2	0.68	75163	0.57	76167	
75167	1	0.43	76167			
76171	2	0.5	77171	0.64	78175	
75163	1	0.48	77167			
76167	2	0.2	77167	0.98	78171	
77171	2	0.02	78171	0.94	79175	
78175	2	0.06	79175	0.53	80179	
77167	0					
78171	2	0.02	79172	1	80175	
79175	1	1	81179			
80179	1	0.9	82183			
79172	0					
80175	0					
81179	0					
82183	0					

Table 213: Chain of $^{161}_{68}Er - c^*$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
68161	1	1.2068	69161			
69161	1	1	70161			
70161	1	1	71161			
71161	1	0.9987	72161			
72161	2	0.955	73161	0.002	74165	
73161	2	0.27	74161	0.002	75165	
74165	2	1	75165	0.11	76169	
74161	1	0.6	76165			
75165	2	0.4	76165	1	77169	
76169	1	0.84	78173			
76165	2	0.069	77166	1	78169	
77169	1	0.94	79173			
78173	2	0.06	79173	0.85	80177	
77166	1	0.15	79170			
78169	2	0.85	79170	1	80173	
79173	1	0.73	81177			
80177	1	1	82181			
79170	0					
80173	0					
81177	0					
82181	0					

Table 214: Chain of $^{160}_{68}\text{Er} - c$

Pb, Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
68160	1	1	69160		
69160	1	1	70160		
70160	1	1	71160		
71160	1	0.993	72160		
72160	2	0.66	73160	0.038	74164
73160	2	0.13	74160	0.58	75164
74164	2	0.42	75164	0.49	76168
74160	2	1	75161	0.98	76164
75164	2	0.02	76164	0.49	77168
76168	2	0.51	77168	0.94	78172
75161	0				
76164	1	1	78168		
77168	1	1	79172		
78172	2	0.03	79173	1	80176
78168	0				
79172	0				
79173	1	0.73	81177		
80176	2	0.27	81177	1	82180
81177	0				
82180	0				

Table 215: Chain of $^{159}_{68}\text{Er} - c^*$

Pb, Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
68159	1	1.3398	69159		
69159	1	1	70159		
70159	2	1	71159	1.00E-06	72163
71159	2	0.65	72159	0.002	73163
72163	2	0.998	73163	0.0004	74167
72159	2	0.66	73159	0.13	74163
73163	2	0.87	74163	0.01	75167
74167	2	0.99	75167	0.018	76171
73159	2	0.001	74159	0.32	75163
74163	2	0.68	75163	0.57	76167
75167	1	0.43	76167		
76171	2	0.5	77171	0.64	78175
74159	2	0.91	75160	1	76163
75163	1	0.48	77167		
76167	2	0.2	77167	0.98	78171
77171	2	0.02	78171	0.94	79175
78175	2	0.06	79175	0.53	80179
75160	0				
76163	2	1	77164	1	78167
77167	0				
78171	2	0.02	79172	1	80175
79175	1	1	81179		
80179	1	0.9	82183		
77164	0				
78167	1	1	80171		
79172	0				
80175	0				
81179	0				
82183	0				
80171	0				

Table 216: Chain of $^{156}_{67}\text{Ho} - c^*$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. (Z, A) factor
67156	1	1.5342	68156			
68156	1	0.99936	69156			
69156	2	0.9	70156	1.00E-06	71160	
70156	2	0.05	71156	0.007	72160	
71160	1	0.993	72160			
71156	1	0.34	73160			
72160	2	0.66	73160	0.038	74164	
73160	2	0.13	74160	0.58	75164	
74164	2	0.42	75164	0.49	76168	
74160	2	1	75161	0.98	76164	
75164	2	0.02	76164	0.49	77168	
76168	2	0.51	77168	0.94	78172	
75161	0					
76164	1	1	78168			
77168	1	1	79172			
78172	2	0.03	79173	1	80176	
78168	0					
79172	0					
79173	1	0.73	81177			
80176	2	0.27	81177	1	82180	
81177	0					
82180	0					

Table 217: Chain of $^{157}_{66}Dy - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
66157	1	1	67157				
67157	1	1	68157				
68157	1	1	69157				
69157	1	0.995	70157				
70157	1	0.0013	72161				
72161	2	0.955	73161	0.002	74165		
73161	2	0.27	74161	0.002	75165		
74165	2	1	75165	0.11	76169		
74161	1	0.6	76165				
75165	2	0.4	76165	1	77169		
76169	1	0.84	78173				
76165	2	0.069	77166	1	78169		
77169	1	0.94	79173				
78173	2	0.06	79173	0.85	80177		
77166	1	0.15	79170				
78169	2	0.85	79170	1	80173		
79173	1	0.73	81177				
80177	1	1	82181				
79170	0						
80173	0						
81177	0						
82181	0						

Table 218: Chain of $^{155}_{66}Dy - c^*$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
66155	1	1.0879	67155				
67155	1	0.99978	68155				
68155	1	0.9911	69155				
69155	2	0.11	70155	0.001	71159		
70155	2	0.1	71155	0.35	72159		
71159	2	0.65	72159	0.002	73163		
71155	2	1	72155	0.34	73159		
72159	2	0.66	73159	0.13	74163		
73163	2	0.87	74163	0.01	75167		
72155	2	1	73156	0.999	74159		
73159	2	0.001	74159	0.32	75163		
74163	2	0.68	75163	0.57	76167		
75167	1	0.43	76167				
73156	1	0.09	75160				
74159	2	0.91	75160	1	76163		
75163	1	0.48	77167				
76167	2	0.2	77167	0.98	78171		
75160	0						
76163	2	1	77164	1	78167		
77167	0						
78171	2	0.02	79172	1	80175		
77164	0						
78167	1	1	80171				
79172	0						
80175	0						
80171	0						

Table 219: Chain of $^{152}_{66}\text{Dy} - c$

Pb, Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
66152	2	0.88	67152	1.70E-07	68156
67152	2	0.1	68152	0.00064	69156
68156	1	0.99936	69156		
68152	2	1	69152	0.1	70156
69156	2	0.9	70156	1.00E-06	71160
69152	2	1	70152	0.95	71156
70156	2	0.05	71156	0.007	72160
71160	1	0.993	72160		
70152	2	0.85	71152	1	72156
71156	1	0.34	73160		
72160	2	0.66	73160	0.038	74164
71152	0				
72156	2	0.034	73157	0.87	74160
73160	2	0.13	74160	0.58	75164
74164	2	0.42	75164	0.49	76168
73157	0				
74160	2	1	75161	0.98	76164
75164	2	0.02	76164	0.49	77168
76168	2	0.51	77168	0.94	78172
75161	0				
76164	1	1	78168		
77168	1	1	79172		
78172	2	0.03	79173	1	80176
78168	0				
79172	0				
79173	1	0.73	81177		
80176	2	0.27	81177	1	82180
81177	0				
82180	0				

Table 220: Chain of $^{155}_{65}\text{Tb} - c^*$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
65155	1.0841	1	66155			
66155	1	1	67155			
67155	1	0.99978	68155			
68155	1	0.9911	69155			
69155	2	0.11	70155	0.001	71159	
70155	2	0.1	71155	0.35	72159	
71159	2	0.65	72159	0.002	73163	
71155	2	1	72155	0.34	73159	
72159	2	0.66	73159	0.13	74163	
73163	2	0.87	74163	0.01	75167	
72155	2	1	73156	0.999	74159	
73159	2	0.001	74159	0.32	75163	
74163	2	0.68	75163	0.57	76167	
75167	1	0.43	76167			
73156	1	0.09	75160			
74159	2	0.91	75160	1	76163	
75163	1	0.48	77167			
76167	2	0.2	77167	0.98	78171	
75160	0					
76163	2	1	77164	1	78167	
77167	0					
78171	2	0.02	79172	1	80175	
77164	0					
78167	1	1	80171			
79172	0					
80175	0					
80171	0					

Table 221: Chain of $^{153}_{65}\text{Tb} - c^*$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
65153	1	1.04771	66153			
66153	1	0.99949	67153			
67153	1	0.47	68153			
68153	2	0.09	69153	0.005	70157	
69153	2	0.5	70153	0.01	71157	
70157	1	0.0013	72161			
70153	2	0.3	71153	0.86	72157	
71157	2	0.14	72157	0.045	73161	
72161	2	0.955	73161	0.002	74165	
71153	1	0.966	73157			
72157	1	0.73	74161			
73161	2	0.27	74161	0.002	75165	
74165	2	1	75165	0.11	76169	
73157	0					
74161	1	0.6	76165			
75165	2	0.4	76165	1	77169	
76169	1	0.84	78173			
76165	2	0.069	77166	1	78169	
77169	1	0.94	79173			
78173	2	0.06	79173	0.85	80177	
77166	1	0.15	79170			
78169	2	0.85	79170	1	80173	
79173	1	0.73	81177			
80177	1	1	82181			
79170	0					
80173	0					
81177	0					
82181	0					

Table 222: Chain of $^{152}_{65}Tb - c$

Pb, Bi					
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)
65152	1	0.999	66152		
66152	2	0.88	67152	1.70E-07	68156
67152	2	0.1	68152	0.00064	69156
68156	1	0.99936	69156		
68152	2	1	69152	0.1	70156
69156	2	0.9	70156	1.00E-06	71160
69152	2	1	70152	0.95	71156
70156	2	0.05	71156	0.007	72160
71160	1	0.993	72160		
70152	2	0.85	71152	1	72156
71156	1	0.34	73160		
72160	2	0.66	73160	0.038	74164
71152	0				
72156	2	0.034	73157	0.87	74160
73160	2	0.13	74160	0.58	75164
74164	2	0.42	75164	0.49	76168
73157	0				
74160	2	1	75161	0.98	76164
75164	2	0.02	76164	0.49	77168
76168	2	0.51	77168	0.94	78172
75161	0				
76164	1	1	78168		
77168	1	1	79172		
78172	2	0.03	79173	1	80176
78168	0				
79172	0				
79173	1	0.73	81177		
80176	2	0.27	81177	1	82180
81177	0				
82180	0				

Table 223: Chain of $^{151}_{65}Tb - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A) Branch. factor
65151	1	0.944	66151				
66151	2	0.78	67151	0.00022	68155		
67151	2	1	68151	0.0089	69155		
68155	1	0.9911	69155				
68151	2	1	69151	0.89	70155		
69155	2	0.11	70155	0.001	71159		
69151	3	1	70151	0.15	71152	0.9	71155
70155	2	0.1	71155	0.35	72159		
71159	2	0.65	72159	0.002	73163		
70151	0						
71152	0						
71155	2	1	72155	0.34	73159		
72159	2	0.66	73159	0.13	74163		
73163	2	0.87	74163	0.01	75167		
72155	2	1	73156	0.999	74159		
73159	2	0.001	74159	0.32	75163		
74163	2	0.68	75163	0.57	76167		
75167	1	0.43	76167				
73156	1	0.09	75160				
74159	2	0.91	75160	1	76163		
75163	1	0.48	77167				
76167	2	0.2	77167	0.98	78171		
75160	0						
76163	2	1	77164	1	78167		
77167	0						
78171	2	0.02	79172	1	80175		
77164	0						
78167	1	1	80171				
79172	0						
80175	0						
80171	0						

Table 224: Chain of $^{150}_{65}Tb - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
65150	2	0.64	66150	0.00019	67154		
66150	2	1	67150	0.0047	68154		
67154	1	0.9953	68154				
67150	2	1	68150	0.54	69154		
68154	2	0.46	69154	2.10E-05	70158		
68150	2	1	69150	0.926	70154		
69154	2	0.074	70154	0.0091	71158		
70158	2	0.9909	71158	8.00E-05	72162		
69150	0						
70154	1	0.443	72158				
71158	2	0.557	72158	0.00074	73162		
72162	2	0.99926	73162	0.00035	74166		
72158	2	0.09	73158	0.452	74162		
73162	2	0.548	74162	0.08	75166		
74166	2	0.92	75166	0.086	76170		
73158	1	0.94	75162				
74162	2	0.06	75162	0.72	76166		
75166	2	0.1	76166	0.052	77170		
76170	3	0.948	77170	0.5	77171	0.76	78174
75162	1	0.931	77166				
76166	2	0.32	77167	0.98	78170		
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
77166	1	0.15	79170				
77167	0						
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
79170	0						
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						

Table 225: Chain of $^{149}_{65}Tb - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
65149	2	1	66149	0.00051	67153		
66149	2	1	67149	0.53	68153		
67153	1	0.47	68153				
67149	2	0.93	68149	0.91	69153		
68153	2	0.09	69153	0.005	70157		
68149	2	0.998	69149	0.5	70153		
69153	2	0.5	70153	0.01	71157		
70157	1	0.0013	72161				
69149	1	0.7	71153				
70153	2	0.3	71153	0.86	72157		
71157	2	0.14	72157	0.045	73161		
72161	2	0.955	73161	0.002	74165		
71153	1	0.966	73157				
72157	1	0.73	74161				
73161	2	0.27	74161	0.002	75165		
74165	2	1	75165	0.11	76169		
73157	0						
74161	1	0.6	76165				
75165	2	0.4	76165	1	77169		
76169	1	0.84	78173				
76165	2	0.069	77166	1	78169		
77169	1	0.94	79173				
78173	2	0.06	79173	0.85	80177		
77166	1	0.15	79170				
78169	2	0.85	79170	1	80173		
79173	1	0.73	81177				
80177	1	1	82181				
79170	0						
80173	0						
81177	0						
82181	0						

Table 226: Chain of $^{148}_{65}Tb - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
65148	2	1	66148	0.12	67152		
66148	3	1	67148	0.07	68149	0.9	68152
67152	2	0.1	68152	0.00064	69156		
67148	2	1	68148	0.002	69149		
68149	2	0.998	69149	0.5	70153		
68152	2	1	69152	0.1	70156		
69156	2	0.9	70156	1.00E-06	71160		
68148	2	1	69148	1	70149		
69149	1	0.7	71153				
70153	2	0.3	71153	0.86	72157		
69152	2	1	70152	0.95	71156		
70156	2	0.05	71156	0.007	72160		
71160	1	0.993	72160				
69148	0						
70149	1	0.7	71150				
71153	1	0.966	73157				
72157	1	0.73	74161				
70152	2	0.85	71152	1	72156		
71156	1	0.34	73160				
72160	2	0.66	73160	0.038	74164		
71150	0						
73157	0						
74161	1	0.6	76165				
71152	0						
72156	2	0.034	73157	0.87	74160		
73160	2	0.13	74160	0.58	75164		
74164	2	0.42	75164	0.49	76168		
76165	2	0.069	77166	1	78169		
74160	2	1	75161	0.98	76164		
75164	2	0.02	76164	0.49	77168		
76168	2	0.51	77168	0.94	78172		
77166	1	0.15	79170				
78169	2	0.85	79170	1	80173		
75161	0						
76164	1	1	78168				
77168	1	1	79172				
78172	2	0.03	79173	1	80176		
79170	0						
80173	0						
78168	0						
79172	0						
79173	1	0.73	81177				
80176	2	0.27	81177	1	82180		
81177	0						
82180	0						

Table 227: Chain of $^{153}_{64}\text{Gd} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
64153	1	1	65153				
65153	1	0.99991	66153				
66153	1	0.99949	67153				
67153	1	0.47	68153				
68153	2	0.09	69153	0.005	70157		
69153	2	0.5	70153	0.01	71157		
70157	1	0.0013	72161				
70153	2	0.3	71153	0.86	72157		
71157	2	0.14	72157	0.045	73161		
72161	2	0.955	73161	0.002	74165		
71153	1	0.966	73157				
72157	1	0.73	74161				
73161	2	0.27	74161	0.002	75165		
74165	2	1	75165	0.11	76169		
73157	0						
74161	1	0.6	76165				
75165	2	0.4	76165	1	77169		
76169	1	0.84	78173				
76165	2	0.069	77166	1	78169		
77169	1	0.94	79173				
78173	2	0.06	79173	0.85	80177		
77166	1	0.15	79170				
78169	2	0.85	79170	1	80173		
79173	1	0.73	81177				
80177	1	1	82181				
79170	0						
80173	0						
81177	0						
82181	0						

Table 228: Chain of $^{151}_{64}\text{Gd} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
64151	1	1	65151				
65151	1	0.944	66151				
66151	2	0.78	67151	0.00022	68155		
67151	2	1	68151	0.0089	69155		
68155	1	0.9911	69155				
68151	2	1	69151	0.89	70155		
69155	2	0.11	70155	0.001	71159		
69151	3	1	70151	0.15	71152	0.9	71155
70155	2	0.1	71155	0.35	72159		
71159	2	0.65	72159	0.002	73163		
70151	0						
71152	0						
71155	2	1	72155	0.34	73159		
72159	2	0.66	73159	0.13	74163		
73163	2	0.87	74163	0.01	75167		
72155	2	1	73156	0.999	74159		
73159	2	0.001	74159	0.32	75163		
74163	2	0.68	75163	0.57	76167		
75167	1	0.43	76167				
73156	1	0.09	75160				
74159	2	0.91	75160	1	76163		
75163	1	0.48	77167				
76167	2	0.2	77167	0.98	78171		
75160	0						
76163	2	1	77164	1	78167		
77167	0						
78171	2	0.02	79172	1	80175		
77164	0						
78167	1	1	80171				
79172	0						
80175	0						
80171	0						

Table 229: Chain of $^{149}_{64}\text{Gd} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
64149	2	0.833	65149	9.40E-05	66153		
65149	2	1	66149	0.00051	67153		
66153	1	0.99949	67153				
66149	2	1	67149	0.53	68153		
67153	1	0.47	68153				
67149	2	0.93	68149	0.91	69153		
68153	2	0.09	69153	0.005	70157		
68149	2	0.998	69149	0.5	70153		
69153	2	0.5	70153	0.01	71157		
70157	1	0.0013	72161				
69149	1	0.7	71153				
70153	2	0.3	71153	0.86	72157		
71157	2	0.14	72157	0.045	73161		
72161	2	0.955	73161	0.002	74165		
71153	1	0.966	73157				
72157	1	0.73	74161				
73161	2	0.27	74161	0.002	75165		
74165	2	1	75165	0.11	76169		
73157	0						
74161	1	0.6	76165				
75165	2	0.4	76165	1	77169		
76169	1	0.84	78173				
76165	2	0.069	77166	1	78169		
77169	1	0.94	79173				
78173	2	0.06	79173	0.85	80177		
77166	1	0.15	79170				
78169	2	0.85	79170	1	80173		
79173	1	0.73	81177				
80177	1	1	82181				
79170	0						
80173	0						
81177	0						
82181	0						

Table 230: Chain of $^{147}_{64}\text{Gd} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
64147	2	1	65147	0.056	66151		
65147	2	1	66147	0.22	67151		
66151	2	0.78	67151	0.00022	68155		
66147	1	1	67147				
67151	2	1	68151	0.0089	69155		
68155	1	0.9911	69155				
67147	1	1	68147				
68151	2	1	69151	0.89	70155		
69155	2	0.11	70155	0.001	71159		
68147	1	0.85	69147				
69151	3	1	70151	0.15	71152	0.9	71155
70155	2	0.1	71155	0.35	72159		
71159	2	0.65	72159	0.002	73163		
69147	0						
70151	0						
71152	0						
71155	2	1	72155	0.34	73159		
72159	2	0.66	73159	0.13	74163		
73163	2	0.87	74163	0.01	75167		
72155	2	1	73156	0.999	74159		
73159	2	0.001	74159	0.32	75163		
74163	2	0.68	75163	0.57	76167		
75167	1	0.43	76167				
73156	1	0.09	75160				
74159	2	0.91	75160	1	76163		
75163	1	0.48	77167				
76167	2	0.2	77167	0.98	78171		
75160	0						
76163	2	1	77164	1	78167		
77167	0						
78171	2	0.02	79172	1	80175		
77164	0						
78167	1	1	80171				
79172	0						
80175	0						
80171	0						

Table 231: Chain of $^{146}_{64}\text{Gd} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
64146	2	1	65146	0.36	66150		
65146	1	1	66146				
66150	2	1	67150	0.0047	68154		
66146	1	1	67146				
67150	2	1	68150	0.54	69154		
68154	2	0.46	69154	2.10E-05	70158		
67146	0						
68150	2	1	69150	0.926	70154		
69154	2	0.074	70154	0.0091	71158		
70158	2	0.9909	71158	8.00E-05	72162		
69150	0						
70154	1	0.443	72158				
71158	2	0.557	72158	0.00074	73162		
72162	2	0.99926	73162	0.00035	74166		
72158	2	0.09	73158	0.452	74162		
73162	2	0.548	74162	0.08	75166		
74166	2	0.92	75166	0.086	76170		
73158	1	0.94	75162				
74162	2	0.06	75162	0.72	76166		
75166	2	0.1	76166	0.052	77170		
76170	3	0.948	77170	0.5	77171	0.76	78174
75162	1	0.931	77166				
76166	2	0.32	77167	0.98	78170		
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
77166	1	0.15	79170				
77167	0						
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
79170	0						
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						

Table 232: Chain of $^{149}_{63}\text{Eu} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
63149	1	1	64149			
64149	2	0.833	65149	9.40E-05	66153	
65149	2	1	66149	0.00051	67153	
66153	1	0.99949	67153			
66149	2	1	67149	0.53	68153	
67153	1	0.47	68153			
67149	2	0.93	68149	0.91	69153	
68153	2	0.09	69153	0.005	70157	
68149	2	0.998	69149	0.5	70153	
69153	2	0.5	70153	0.01	71157	
70157	1	0.0013	72161			
69149	1	0.7	71153			
70153	2	0.3	71153	0.86	72157	
71157	2	0.14	72157	0.045	73161	
72161	2	0.955	73161	0.002	74165	
71153	1	0.966	73157			
72157	1	0.73	74161			
73161	2	0.27	74161	0.002	75165	
74165	2	1	75165	0.11	76169	
73157	0					
74161	1	0.6	76165			
75165	2	0.4	76165	1	77169	
76169	1	0.84	78173			
76165	2	0.069	77166	1	78169	
77169	1	0.94	79173			
78173	2	0.06	79173	0.85	80177	
77166	1	0.15	79170			
78169	2	0.85	79170	1	80173	
79173	1	0.73	81177			
80177	1	1	82181			
79170	0					
80173	0					
81177	0					
82181	0					

Table 233: Chain of $^{147}_{63}\text{Eu} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
63147	2	1	64147	9.50E-05	65151		
64147	2	1	65147	0.056	66151		
65151	1	0.944	66151				
65147	2	1	66147	0.22	67151		
66151	2	0.78	67151	0.00022	68155		
66147	1	1	67147				
67151	2	1	68151	0.0089	69155		
68155	1	0.9911	69155				
67147	1	1	68147				
68151	2	1	69151	0.89	70155		
69155	2	0.11	70155	0.001	71159		
68147	1	0.85	69147				
69151	3	1	70151	0.15	71152	0.9	71155
70155	2	0.1	71155	0.35	72159		
71159	2	0.65	72159	0.002	73163		
69147	0						
70151	0						
71152	0						
71155	2	1	72155	0.34	73159		
72159	2	0.66	73159	0.13	74163		
73163	2	0.87	74163	0.01	75167		
72155	2	1	73156	0.999	74159		
73159	2	0.001	74159	0.32	75163		
74163	2	0.68	75163	0.57	76167		
75167	1	0.43	76167				
73156	1	0.09	75160				
74159	2	0.91	75160	1	76163		
75163	1	0.48	77167				
76167	2	0.2	77167	0.98	78171		
75160	0						
76163	2	1	77164	1	78167		
77167	0						
78171	2	0.02	79172	1	80175		
77164	0						
78167	1	1	80171				
79172	0						
80175	0						
80171	0						

Table 234: Chain of $^{146}_{63}\text{Eu} - i$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
63146	0						

Table 235: Chain of $^{146}_{63}\text{Eu} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
63146	2	1	64146	0.0005	65150		
64146	2	1	65146	0.36	66150		
65150	2	0.64	66150	0.00019	67154		
65146	1	1	66146				
66150	2	1	67150	0.0047	68154		
67154	1	0.9953	68154				
66146	1	1	67146				
67150	2	1	68150	0.54	69154		
68154	2	0.46	69154	2.10E-05	70158		
67146	0						
68150	2	1	69150	0.926	70154		
69154	2	0.074	70154	0.0091	71158		
70158	2	0.9909	71158	8.00E-05	72162		
69150	0						
70154	1	0.443	72158				
71158	2	0.557	72158	0.00074	73162		
72162	2	0.99926	73162	0.00035	74166		
72158	2	0.09	73158	0.452	74162		
73162	2	0.548	74162	0.08	75166		
74166	2	0.92	75166	0.086	76170		
73158	1	0.94	75162				
74162	2	0.06	75162	0.72	76166		
75166	2	0.1	76166	0.052	77170		
76170	3	0.948	77170	0.5	77171	0.76	78174
75162	1	0.931	77166				
76166	2	0.32	77167	0.98	78170		
77170	2	0.02	78170	0.01	79174		
77171	2	0.02	78171	0.94	79175		
78174	1	0.7	80178				
77166	1	0.15	79170				
77167	0						
78170	2	1	79171	0.996	80174		
79174	1	0.004	80174				
78171	2	0.02	79172	1	80175		
79175	1	1	81179				
80178	1	1	82182				
79170	0						
79171	0						
80174	0						
79172	0						
80175	0						
81179	0						
82182	0						

Table 236: Chain of $^{145}_{63}\text{Eu} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
63145	2	1	64145	0.167	65149		
64145	1	1	65145				
65149	2	1	66149	0.00051	67153		
65145	1	1	66145				
66149	2	1	67149	0.53	68153		
67153	1	0.47	68153				
66145	1	1	67145				
67149	2	0.93	68149	0.91	69153		
68153	2	0.09	69153	0.005	70157		
67145	1	1	68145				
68149	2	0.998	69149	0.5	70153		
69153	2	0.5	70153	0.01	71157		
70157	1	0.0013	72161				
68145	1	0.5	69146				
69149	1	0.7	71153				
70153	2	0.3	71153	0.86	72157		
71157	2	0.14	72157	0.045	73161		
72161	2	0.955	73161	0.002	74165		
69146	0						
71153	1	0.966	73157				
72157	1	0.73	74161				
73161	2	0.27	74161	0.002	75165		
74165	2	1	75165	0.11	76169		
73157	0						
74161	1	0.6	76165				
75165	2	0.4	76165	1	77169		
76169	1	0.84	78173				
76165	2	0.069	77166	1	78169		
77169	1	0.94	79173				
78173	2	0.06	79173	0.85	80177		
77166	1	0.15	79170				
78169	2	0.85	79170	1	80173		
79173	1	0.73	81177				
80177	1	1	82181				
79170	0						
80173	0						
81177	0						
82181	0						

Table 237: Chain of $^{143}_{61}Pm - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
61143	2	1	62143	2.20E-05	63147		
62143	1	1	63143				
63147	2	1	64147	9.50E-05	65151		
63143	1	1	64143				
64147	2	1	65147	0.056	66151		
65151	1	0.944	66151				
64143	1	1	65143				
65147	2	1	66147	0.22	67151		
66151	2	0.78	67151	0.00022	68155		
65143	2	1	66143	1	67144		
66147	1	1	67147				
67151	2	1	68151	0.0089	69155		
68155	1	0.9911	69155				
66143	1	1	67143				
67144	0						
67147	1	1	68147				
68151	2	1	69151	0.89	70155		
69155	2	0.11	70155	0.001	71159		
67143	0						
68147	1	0.85	69147				
69151	3	1	70151	0.15	71152	0.9	71155
70155	2	0.1	71155	0.35	72159		
71159	2	0.65	72159	0.002	73163		
69147	0						
70151	0						
71152	0						
71155	2	1	72155	0.34	73159		
72159	2	0.66	73159	0.13	74163		
73163	2	0.87	74163	0.01	75167		
72155	2	1	73156	0.999	74159		
73159	2	0.001	74159	0.32	75163		
74163	2	0.68	75163	0.57	76167		
75167	1	0.43	76167				
73156	1	0.09	75160				
74159	2	0.91	75160	1	76163		
75163	1	0.48	77167				
76167	2	0.2	77167	0.98	78171		
75160	0						
76163	2	1	77164	1	78167		
77167	0						
78171	2	0.02	79172	1	80175		
77164	0						
78167	1	1	80171				
79172	0						
80175	0						
80171	0						

Table 238: Chain of $^{136}_{60}\text{Nd} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
60136	1	1	61136				
61136	1	1	62136				
62136	1	0.9991	63136				
63136	0						

Table 239: Chain of $^{134}_{59}\text{Pr} - c^*$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
59134	1	2	60134				
60134	2	1	61134	0.0002	62135		
61134	1	1	62134				
62135	1	1	63135				
62134	2	1	63134	0.02	64135		
63135	1	0.98	64135				
63134	0						
64135	0						

Table 240: Chain of $^{139}_{58}\text{Ce} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
58139	1	1	59139				
59139	1	1	60139				
60139	1	1	61139				
61139	1	1	62139				
62139	1	1	63139				
63139	2	0.005	64139	0.0026	65140		
64139	1	0.0026	66140				
65140	1	0.9974	66140				
66140	1	1	67141				
67141	0						

Table 241: Chain of $^{135}_{58}\text{Ce} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
58135	1	1	59135				
59135	1	1	60135				
60135	1	1	61135				
61135	2	0.9998	62135	0.0009	63136		
62135	1	1	63135				
63136	0						
63135	1	0.98	64135				
64135	0						

Table 242: Chain of $^{134}_{58}\text{Ce} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
58134	1	1	59134				
59134	1	1	60134				
60134	2	1	61134	0.0002	62135		
61134	1	1	62134				
62135	1	1	63135				
62134	2	1	63134	0.02	64135		
63135	1	0.98	64135				
63134	0						
64135	0						

Table 243: Chain of $^{132}_{58}\text{Ce} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
58132	1	1	59132				
59132	1	1	60132				
60132	1	1	61132				
61132	1	1	62132				
62132	0						

Table 244: Chain of $^{130}_{58}\text{Ce} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
58130	1	1	59130				
59130	1	1	60130				
60130	1	1	61130				
61130	1	1	62130				
62130	1	0.879	63131				
63131	0						

Table 245: Chain of $^{132}_{57}\text{La} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
57132	1	1	58132				
58132	1	1	59132				
59132	1	1	60132				
60132	1	1	61132				
61132	1	1	62132				
62132	0						

Table 246: Chain of $^{133}_{56}\text{Ba} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
56133	1	1	57133				
57133	1	1	58133				
58133	1	1	59133				
59133	1	1	60133				
60133	1	1	61133				
61133	1	1	62133				
62133	0						

Table 247: Chain of $^{131}_{56}\text{Ba} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
56131	1	1	57131				
57131	1	1	58131				
58131	1	1	59131				
59131	2	1	60131	5.00E-07	61132		
60131	0						
61132	1	1	62132				
62132	0						

Table 248: Chain of $^{128}_{56}\text{Ba} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
56128	1	1	57128				
57128	1	1	58128				
58128	2	1	59128	0.005	60129		
59128	1	1	60128				
60129	0						
60128	1	1	61128				
61128	0						

Table 249: Chain of $^{129}_{55}\text{Cs} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
55129	1	1	56129				
56129	1	1	57129				
57129	1	0.01	58129				
58129	1	0.01	59129				
59129	1	0.005	60129				
60129	0						

Table 250: Chain of $^{127}_{54}\text{Xe} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
54127	1	1	55127				
55127	1	1	56127				
56127	1	1	57127				
57127	1	1	58127				
58127	1	1	59127				
59127	1	1	60127				
60127	0						

Table 251: Chain of $^{125}_{54}\text{Xe} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
54125	1	1	55125				
55125	1	1	56125				
56125	1	1	57125				
57125	1	1	58125				
58125	1	1	59125				
59125	1	1	60125				
60125	0						

Table 252: Chain of $^{123}_{54}\text{Xe} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
54123	1	1	55123				
55123	1	1	56123				
56123	1	1	57123				
57123	1	1	58123				
58123	0						

Table 253: Chain of $^{126}_{53}\text{I} - i$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
53126	0						

Table 254: Chain of $^{124}_{53}I - i$

Pb						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
53124	0					

Table 255: Chain of $^{121}_{53}I - c^*$

Pb						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
53121	1	1.4604	54121			
54121	1	1	55121			
55121	1	1	56121			
56121	1	1	57121			
57121	1	0.99	58121			
58121	0					

Table 256: Chain of $^{121}_{52}Te - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
52121	1	1	53121			
53121	1	1	54121			
54121	1	1	55121			
55121	1	1	56121			
56121	1	1	57121			
57121	1	0.99	58121			
58121	0					

Table 257: Chain of $^{119}_{52}\text{Te} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
52119	1	1	53119				
53119	2	1	54119	7.00E-08	55120		
54119	1	1	55119				
55120	1	1	56120				
55119	1	0.75	56119				
56120	2	1	57120	0.01	58121		
56119	0						
57120	0						
58121	0						

Table 258: Chain of $^{116}_{52}\text{Te} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
52116	3	1	53116	2.90E-05	54117	2.00E-07	55120
53116	1	1	54116				
54117	1	1	55117				
55120	1	1	56120				
54116	1	1	55116				
55117	1	1	56117				
56120	2	1	57120	0.01	58121		
55116	1	0.97	56116				
56117	1	0.061	57117				
57120	0						
58121	0						
56116	1	0.939	57117				
57117	0						

Table 259: Chain of $^{124}_{51}\text{Sb} - i(m1 + m2 + g)$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
51124	0						

Table 260: Chain of $^{122}_{51}\text{Sb} - i(m + g)$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
51122	0						

Table 261: Chain of $^{115}_{51}\text{Sb} - c^*$

Pb						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
51115	1	1.2205	52115			
52115	1	1	53115			
53115	1	0.9966	54115			
54115	2	0.9993	55115	0.03	56116	
55115	1	1	56115			
56116	1	0.939	57117			
56115	0					
57117	0					

Table 262: Chain of $^{113}_{50}\text{Sn} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
50113	1	1	51113			
51113	1	1	52113			
52113	1	1	53113			
53113	2	0.92993	54113	0.087	55114	
54113	0					
55114	0					

Table 263: Chain of $^{111}_{49}\text{In} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
49111	1	1	50111			
50111	1	1	51111			
51111	1	1	52111			
52111	1	0.999	53111			
53111	1	0.92	54111			
54111	1	1	55112			
55112	0					

Table 264: Chain of $^{110}_{49}\text{In} - i$

Pb						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
49110	0					
Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor

Table 265: Chain of $^{109}_{49}\text{In} - c$

Pb, Bi									
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
49109	1	1	50109						
50109	1	1	51109						
51109	4	0.86695	52109	0.11	53110	7.00E-05	54113	3.31E-09	53113
52109	2	0.11	54110	0.00011	54113				
53110	2	0.709	54110	0.00018	55114				
54113	0								
53113	2	0.92993	54113	0.087	55114				
54110	0								
55114	0								

Table 266: Chain of $^{115}_{48}\text{Cd} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
48115	1	1	47115				
47115	1	1	46115				
46115	1	1	45115				
45115	1	1	44115				
44115	0						

Table 267: Chain of $^{105}_{47}\text{Ag} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
47105	1	1	48105				
48105	1	1	49105				
49105	2	1	50105	5.00E-05	52109		
50105	2	0.99	51105	0.039	52109		
52109	2	0.11	54110	0.00011	54113		
51105	0						
54110	0						
54113	0						

Table 268: Chain of $^{100}_{46}\text{Pd} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
46100	1	1	47100				
47100	1	1	48100				
48100	2	0.961	49100	1	50101		
49100	1	0.83	50100				
50101	0						
50100	0						

Table 269: Chain of $^{107}_{45}Rh - c$

Pb									
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi									
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
45107	1	1	44107						
44107	1	1	43107						
43107	1	1	42107						
42107	2	1	41107	0.062	41108				
41107	2	1	40107	1	40108				
41108	0								
40107	2	1	39107	1	39108				
40108	0								
39107	0								
39108	1	0.01	40109						
40109	0								

 Table 270: Chain of $^{105}_{45}Rh - c$

Pb, Bi									
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
45105	1	1	44105						
44105	1	1	43105						
43105	1	1	42105						
42105	1	1	41105						
41105	1	1	40105						
40105	0								

 Table 271: Chain of $^{102}_{45}Rh - i$

Pb, Bi									
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
45102	0								

Table 272: Chain of $^{101}_{45}Rh - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
45101	1	1	46101				
46101	1	1	47101				
47101	2	1	48101	9.30E-05	49102		
48101	1	1	49101				
49102	1	1	50102				
49101	0						
50102	1	1	52106				
52106	1	0.17	54110				
54110	0						

Table 273: Chain of $^{100}_{45}Rh - i(m + g)$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
45100	0						

Table 274: Chain of $^{100}_{45}Rh - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
45100	1	1	46100				
46100	1	1	47100				
47100	1	1	48100				
48100	2	0.961	49100	1	50101		
49100	1	0.83	50100				
50101	0						
50100	0						

Table 275: Chain of $^{106}_{44}Ru - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
44106	1	1	43106				
43106	1	1	42106				
42106	1	1	41106				
41106	0						

Table 276: Chain of $^{103}_{44}Ru - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
44103	1	1	43103				
43103	1	1	42103				
42103	2	1	41103	0.0006	41104		
41103	1	1	40103				
41104	1	1	40104				
40103	1	0.92	39103				
40104	0						
39103	1	1	38103				
38103	0						

Table 277: Chain of $^{96}_{43}Tc - i(m + g)$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
43096	0						

Table 278: Chain of $^{99}_{42}Mo - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
42099	1	1	41099				
41099	1	1	40099				
40099	2	0.981	39099	0.0092	39100		
39099	2	0.999	38099	0.0078	38100		
39100	2	0.9922	38100	0.0237	38101		
38099	2	0.841	37099	0.06	37100		
38100	2	0.94	37100	0.28	37101		
38101	2	0.72	37101	0.18	37102		
37099	1	1	36099				
37100	1	1	36100				
37101	0						
37102	0						
36099	0						
36100	0						

Table 279: Chain of $^{96}_{41}\text{Nb} - i$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
41096	0						

Table 280: Chain of $^{95}_{41}\text{Nb} - i(m + g)$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
41095	0						

Table 281: Chain of $^{95}_{41}\text{Nb} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
41095	1	1	40095				
40095	1	1	39095				
39095	1	1	38095				
38095	2	0.9127	37095	0.14	37096		
37095	1	1	36095				
37096	0						
36095	1	1	35095				
35095	0						

Table 282: Chain of $^{90}_{41}\text{Nb} - c^*$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
41090	1	1.615	42090				
42090	1	1	43090				
43090	1	1	44090				
44090	0						

Table 283: Chain of $^{97}_{40}\text{Zr} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
40097	2	0.99945	39097	0.00331	39098	
39097	2	0.9995	38097	0.0025	38098	
39098	2	0.9975	38098	0.001	38099	
38097	2	0.749	37097	0.138	37098	
38098	2	0.862	37098	0.159	37099	
38099	2	0.841	37099	0.06	37100	
37097	1	0.005	36098			
37098	1	0.005	36098			
37099	1	1	36099			
37100	1	1	36100			
36098	0					
36099	0					
36100	0					

Table 284: Chain of $^{95}_{40}\text{Zr} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
40095	1	1	39095			
39095	1	1	38095			
38095	2	0.9127	37095	0.14	37096	
37095	1	1	36095			
37096	0					
36095	1	1	35095			
35095	0					

Table 285: Chain of $^{89}_{40}\text{Zr} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
40089	1	1	41089			
41089	1	1	42089			
42089	1	1	43089			
43089	1	0.9985	44089			
44089	1	1	45089			
45089	0					

Table 286: Chain of $^{88}_{40}\text{Zr} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
40088	1	1	41088			
41088	1	1	42088			
42088	2	1	43088	0.0015	44089	
43088	0					
44089	1	1	45089			
45089	0					

Table 287: Chain of $^{88}_{39}\text{Y} - i$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
39088	0					

Table 288: Chain of $^{88}_{39}\text{Y} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
39088	1	1	40088			
40088	1	1	41088			
41088	1	1	42088			
42088	2	1	43088	0.0015	44089	
43088	0					
44089	1	1	45089			
45089	0					

Table 289: Chain of $^{86}_{39}Y - c$

Pb						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
39086	1	1	40086			
40086	2	1	41086	0.15	42087	
41086	1	1	42086			
42087	1	1	43087			
42086	1	1	43086			
43087	0					
43086	0					
Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor

Table 290: Chain of $^{85}_{38}Sr - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
38085	1	1	39085			
39085	1	1	40085			
40085	1	1	41085			
41085	1	1	42085			
42085	0					

Table 291: Chain of $^{86}_{37}Rb - i(m + g)$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
37086	0					

Table 292: Chain of $^{84}_{37}Rb - i(m + g)$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
37084	0					

Table 293: Chain of $^{83}_{37}\text{Rb} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
37083	1	1	38083				
38083	1	1	39083				
39083	1	1	40083				
40083	1	1	41083				
41083	1	1	42083				
42083	0						

Table 294: Chain of $^{82}_{35}\text{Br} - i(m + g)$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
35082	0						

Table 295: Chain of $^{75}_{34}\text{Se} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
34075	1	1	35075				
35075	1	1	36075				
36075	1	1	37075				
37075	1	0.935	38075				
38075	0						

Table 296: Chain of $^{76}_{33}\text{As} - i$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
33076	0						

Table 297: Chain of $^{74}_{33}\text{As} - i$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
33074	0						

Table 298: Chain of $^{71}_{33}\text{As} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
33071	1	1	34071				
34071	1	1	35071				
35071	1	0.948	36071				
36071	1	1	37072				
37072	0						

Table 299: Chain of $^{72}_{31}\text{Ga} - i$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
31072	0						

Table 300: Chain of $^{72}_{31}\text{Ga} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
31072	1	1	30072				
30072	1	1	29072				
29072	1	1	28072				
28072	0						

Table 301: Chain of $^{72}_{30}\text{Zn} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
30072	1	1	29072				
29072	1	1	28072				
28072	0						

Table 302: Chain of $^{65}_{30}\text{Zn} - c$

Pb							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
30065	1	1	31065				
31065	1	1	32065				
32065	1	1	33065				
33065	1	1	34065				
34065	0						

Table 303: Chain of $^{58}_{27}\text{Co} - i(m + g)$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
27058	0					

Table 304: Chain of $^{56}_{27}\text{Co} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
27056	1	1	28056			
28056	2	0.65	30057	0.00023	31060	
30057	0					
31060	0					

Table 305: Chain of $^{59}_{26}\text{Fe} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
26059	1	1	25059			
25059	1	1	24059			
24059	1	1	23059			
23059	1	1	22059			
22059	0					

Table 306: Chain of $^{54}_{25}\text{Mn} - i$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
25054	0					

Table 307: Chain of $^{52}_{25}\text{Mn} - c$

Pb						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
25052	1	1	26052			
26052	2	1	27052	0.45	28053	
27052	1	0.83	28052			
28053	2	0.5	29053	1	29054	
28052	2	0.83	29052	0.5	29053	
29053	0					
29054	1	0.5	30055			
29052	0					
30055	0					

Table 308: Chain of $^{48}_{23}\text{V} - c$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
23048	1	1	24048			
24048	2	0.99719	25048	0.52	26049	
25048	1	0.964	26048			
26049	1	0.5	27049			
26048	1	0.5	27049			
27049	1	0.5	28049			
28049	0					

Table 309: Chain of $^{48}_{21}\text{Sc} - i$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
21048	0					

Table 310: Chain of $^{46}_{21}\text{Sc} - i(m + g)$

Pb, Bi						
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor
21046	0					

Table 311: Chain of $^{28}_{12}\text{Mg} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
12028	2	0.9942	11028	0.215	11029		
11028	2	0.84	10028	0.27	10029		
11029	2	0.73	10029	0.26	10030		
10028	1	1	9029				
10029	0						
10030	0						
9029	0						

Table 312: Chain of $^{24}_{11}\text{Na} - c$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
11024	1	1	10024				
10024	2	0.941	9024	0.14	9025		
9024	1	0.82	8024				
9025	0						
8024	1	1	8025				
8025	0						

Table 313: Chain of $^7_4\text{Be} - i$

Pb, Bi							
(Z, A)	Number of entries	Branch. factor	(Z, A)	Branch. factor	(Z, A)	Branch. factor	(Z, A)
4007	0						

14 Appendix 3. The changes introduced into the LAHET code

The main change in the pre-equilibrium model was to substitute the value $g = A/12$ for the level density parameter of single-particle state nuclei with $g = 6a/\pi^2$ (the nuclear level density parameter of the Pb group nuclei is $a \cong 9$).

In the end of the routine

Function getg(e, iz, in, mode, is, getg0)

Getg = $a/12$ was replaced with *Getg0* = $a/12$

This means that, in the case of the proton interactions of interest with the PB and Bi isotopes, the LAHETO-estimated pre-equilibrium mechanism contribution is about two times as small as the LAHET code calculation data. The resulting value of the parameter g is close to the value $g = A/13$ used in the GHASH code to calculate nuclear reactions in the range of scattered particle energies below 0.2 GeV. It is this particular choice of the single-particle state density that permits the integral particle spectra to be quite properly described by the LAHETO code. The LAHET code Coulomb barrier parameters that define the charged particle evaporation widths were modified with a view of constructing a sufficiently reliable evaporation model.

In the LAHET subroutine

Subroutine CLECT(a, z, ja, jz, u, kfiss)

the line

$Coulef = 0.846927 * d0 * flkcou(j) * flz(j) * zz / (rmass(mm) + rho(j))$

in the section

C/////RALchannelprobabilitysection/////

has been replaced with

$Coulef = 0.846927 * d0 * flkcou(j) * flz(j) * zz / (rmass(mm) * 0.9 * d0 + rho(j))$

An updated fission-channel parametrization procedure has been adopted. The cross sections for fission of high-energy proton-irradiated Pb and Bi are known to rise with increasing particle energies up to 400-600 MeV, to reach saturation afterwards. This type energy dependence of the fission cross section at the proton-scattered proton energies of 50-200 MeV can well be described in terms of the LAHETO code mainly by introducing the energy function in the relation a_f/a_n .

The common block *common/comon/apr, cosks, cosphi, costh, d, delsig, dkwt, emax*, has been introduced to the routine *Functionfprob(z, a, u)*, while the line

$af = an * (c1 + c2 * af * af)$

is replaced with

$acorre = dmax1(0.006 * d0, 0.000012 * d0 * emax)$

$af = an * (c1 + c2 * af * af + acorre)$

Besides, the fission barriers have been corrected with a view of getting a fission cross section that would agree with experimental data or with the Prokofiev approximation.

In the routine

Functionfprob(z, a, u),

the line

$ef = x * (a1 * x - a2) + a3 + se$

has been replaced with

$$ef = x^*(a1*x - a2) + a3 + se - 0.7*d0.$$

The parameters of the fission fragment mass distribution have been also specified.

In the subroutine *Subroutine fissioned(ja,jz,u,erec)*,
the line

$$sigmas = 0.425*d0*(upr*(dp1 - 0.005*d0*upr) + 9.35*d0)$$

has been replaced with

$$sigmas = 0.300*d0*(upr*(dp1 - 0.005*d0*upr) + 9.35*d0)$$

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