New study of the neutron rich ^{136}Te isotope through decay spectroscopy

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Abstract. ^{136}Sb is a neutron rich nucleus with one valence proton and three valence neutrons outside the doubly-magic nucleus ^{132}Sn. It plays an important role in the rapid neutron capture process (r-process) as participates in its path further connected to the nucleosynthesis and the type II supernovae. In this work, a new β decay γ ray data on ^{136}Te is obtained. The experiment is performed at the Institute Laue-Langevin using the Lohengrin spectrometer and the thermal neutron-induced fission reaction on $^{235}_{92}U_{143}$. A specific β-β condition method is investigated for the γ-ray detection.

1 Introduction

The rapid neutron capture process (r-process) represents series of important nuclear reactions preformed at neutron-rich region in nuclear chart, responsible for creating about half of the elements heavier than iron. Nuclei around ^{132}Sn play a significant role in r-process, their nuclear structure properties, such as mass (A), half life ($T_{1/2}$), β delayed neutron emissions P_n and P_{2n} values, are essential to reproduce the r-process abundances and help us to understand the origin of the elements in our universe. Tellurium ($Z = 52$) is found at the second r-process peak ($A \approx 130$) associated with the $N = 82$ neutron shell closure in the solar system r-process distribution and predominantly produced in the main component of the r-process. The ^{136}Te isotopes reveal structure dominated by pairs of valence protons and neutrons above the ^{132}Sn core and nuclei in this neutron-rich region are mostly produced by fission reactions or the β decay of fission products [1]. The previous study about β decay of ^{136}Sb is incomplete [2], the γ ray spectrum of ^{136}Te from β decay of the mother ^{136}Sb isotope is investigated here.

2 Experiment

2.1 Setup

The experiment is performed at the Institute Laue-Langevin by the thermal neutron-induced fission reaction of ^{235}U. The fission productions go through the LOHENGRIN separator and are selected by the magnetic and electric field according to their mass (A) over ionic charge (q) ratio and kinetic energy (E_k) over ionic charge (q). The target nuclei are implanted into a movable tape which surrounded by β detectors and γ detectors. The main configuration

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of the detection system is presented in Fig.1-(a). The β signals are recorded by two plastic detectors of different thickness: thin and thick, placed in front of the detection area of the γ ray detectors, consisting by two clovers and one coaxial detector. The clover detector is made of four high purity germanium crystals, which allows to improve the statistic of high energy γ rays by add-back procedure. To prevent the affect from the long lived contaminants, time chopper signal is used to manage the measurement cycle. A movable tape is used to take away the injected nuclei after each measurement cycle. According to the lifetime of the ^{136}Sb [3], each measurement cycle is divided into three parts: the first 5 s for beam injection, the next 5 s we stop the injection and wait the implanted nuclei to decay and the last 2 s tape is moved to take away the rest decay products (background), see Fig.1-(b).

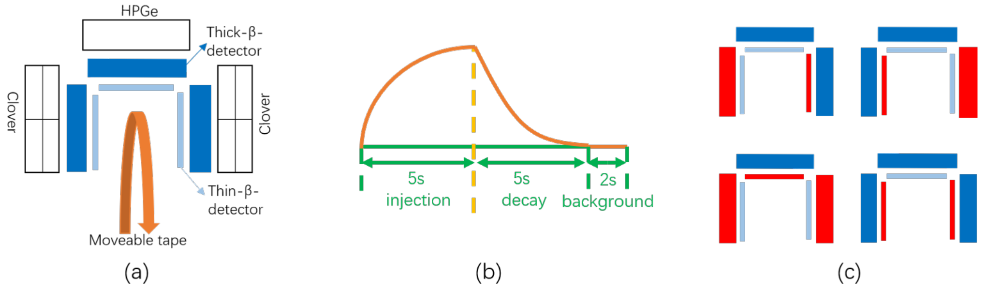

Figure 1. The main configuration of the detection system (a). The time chopper information (b). The schematic drawing of β detector combinations used to trigger the γ-ray spectra (c).

2.2 Data analysis

In order to obtain the γ ray spectrum of ^{136}Te after β decay of ^{136}Sb, we used the time chopper information between 0 s and 10 s. The plastic detectors serve as a β trigger only while their β energy information was not used. Each γ ray is triggered by the combinations of thin and/or the opposite thin and/or thick plastic detector as shown in Fig.1-(c). The schematically drawn combinations represent the used thick/thin β-β coincidence condition. For example, when a set of thick/thin plastic detectors registers a β signal within the same time window (marked in red), this is considered as a β-β coincidence [4] and the γ rays are respectively registered by any of the HpGe detectors. This kind of β-β coincidence condition between two or three β detectors strongly suppresses the background without reducing the statistics of transitions or interest. On the contrary, one can use an anti-coincidence with the β signals to artificially enhance background and exploit background lines.

3 Result

Fig.2 shows part of the energy spectrum after β decay of ^{136}Sb (in blue) obtained in the 0-10 s of each measurement cycle. Adding the β-β coincidence condition by all combinations represents the β-gated spectrum (in red). One can see from the inset, an order of magnitude suppression of background using this condition. In order to find the effect of the β trigger, the β-gated spectrum is compared to the normalised unconditioned γ spectrum. The γ rays from ^{136}Sb β decay to ^{136}Te and β-n decay to ^{135}Te are marked with their energy values. For example, the 606.6 keV and 658.6 keV transitions correspond to the de-excitation of the first excited states in ^{136}Te [2] and ^{135}Te [5], respectively. It is obvious that the application of this β-β coincidence procedure is very significant in the case of weak transitions. To demonstrate this, one can point to such weak transitions in ^{136}Te as the 423.9 keV and 961.5 keV lines, which are not visible before the coincidence condition, while they can be easily identified after the β-β coincidence trigger. In the Fig.2 we can also see the main contaminants coming from the grand-daughter nuclei ^{136}I and ^{136}Xe. The ^{141}Cs is also detected by our system.

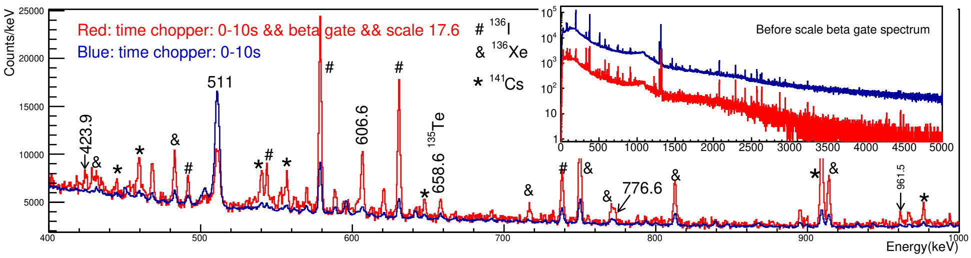

Figure 2. A β-gated (red) γ ray spectrum for ^{136}Te is compared with its un-gated γ ray spectrum (in blue). The transitions in ^{136}Te are marked with their energy values.

The efficiency of the β detectors could be measured by comparing the intensity of γ rays in the Ge spectra with and without condition on β detectors. These measurements could be executed by implanting beam with certain mass number (A) e.g. A =137 into the tape system so, that ^{137}Te and ^{137}I decay quickly to create a pure ^{137}Xe source. Based on the strongest 445 keV (^{137}Cs) [6] and 333 keV (^{136}I) [7] transitions, the results of the efficiency measurements amount to 47(5)% for this experiment. Note that similar value is obtained for the energy range up to about 1.4 MeV.

4 Summary

A specific β-β coincidence trigger is used for the study of β delayed γ ray spectrum. By applying this method to ^{136}Sb β decay experiment, one can conform weak transitions from previous work [2] and identify new transitions. The β efficiency is found to be 47(5)% for Q_β value of around 5 MeV. Note that high energy β rays may also be deposited in the HPGe detectors. Such signals would be added to γ ray detection and may cause an energy shift for these γ rays. As next step one may design a new detector system to reject these kind of synthetic signals as well as to improve the β detection efficiency.

References

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