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Characteristics of the fission fragments induced by the ^{129}Xe + ^{nat}Sn reactions at $E = 8$–15 A MeV

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Summary. — The study of nuclear multifragmentation is important for understanding the reaction mechanisms in heavy-ion collisions. In the present work, we study the nuclear reaction ^{129}Xe + ^{nat}Sn in the energy range $E = 8$ to 15 A MeV. This experiment was performed at GANIL with the multidetector INDRA. We study the charge distributions produced in this reaction, which are broad and cover a large atomic number range. By using the data of this experiment, we identify four channels differing by the number of fragments: 1, 2, 3 and 4 fragments. In this contribution we will show a method to reconstruct the average size and excitation energy of the primary fission fragments, before their decay. The method employed is based on the fragment-light charged particles relative velocity correlation functions. Preliminary results will be presented.

1. – Introduction

Heavy-ion collisions are the only terrestrial means to explore the properties of nuclear matter under extreme conditions [1]. Consider a central collision of two heavy ions, nucleons from one nucleus will collide with nucleons from the other nucleus. After a few collisions a given nucleon may lose the identity of its source. Depending upon the original beam energy, this system may undergo an initial compression and then begins to decompress. In central heavy-ion collisions at bombarding energies above the Coulomb barrier but below the Fermi energy regime, different types of reaction mechanisms leading to the production of one, two, three, or more heavy fragments in the exit channel are possible, namely fusion-fission, quasi-fission, and deeply inelastic collisions [2-4].

In this contribution we study the nuclear reaction ^{129}Xe + ^{nat}Sn in the energy range $E = 8$ to 15 A MeV. This experiment was performed at GANIL with the multidetector INDRA. We will give in sect. **2**, a brief description of this detector. The experimental results are then given in sect. **3**, and we conclude in sect. **4**.

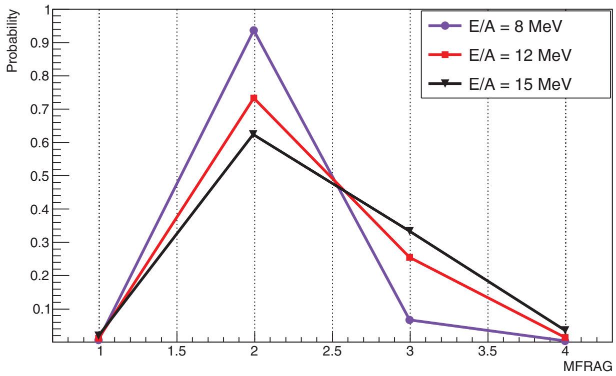

Fig. 1. – Probability of exit channels decay for $E = 8$ A MeV, $E = 12$ A MeV and $E = 15$ A MeV.

2. – Experimental setup

The experiment was performed at GANIL with the multidetector INDRA [5-7]. This charged product detector covers about 90% of the 4π solid angle. The total number of detection cells is 336 arranged according to 17 rings centered on the beam axis. The first ring is made of fast NE102/NE115 phoswich detectors. Rings two to nine cover the angular range from 3 to 45, and are made of three detector layers: a low pressure gas-ionization chamber, a 300 m thick silicon detector, and a 14 to 10 cm thick CsI(Tl) scintillator. The remaining eight rings cover the angular range from 45 to 176 and have two detection layers: ionization chamber and 7.6 to 5 cm thick CsI(Tl) scintillators.

3. – Experimental results

3˙1. *Exit channel decomposition.* – Four channels differing by the number of fragments (1, 2, 3 and 4 fragments) are identified with $Z \geq 10$, where $Z = 10$ is a relative minimum observed in the fragments charge distributions as will be shown in the next section.

The probabilities of one and four-fragment exit channels, fig. 1, are very low at the three energies, whatever the energy is, the sum of (one-four) fragments is very low, down 5%. The probability of three exit channels is low at the lowest energy, it increases at $E = 12$ and 15 A MeV.

The two-fragment exit channel (fission) is the dominant process in the three energies, its probability represents more than 90% at the lowest energy. It decreases monotonically down to 62% at the highest energy.

3˙2. *Charge distributions of fragments.* – The charge distributions produced in central collisions of the ^{129}Xe+$^{\mathrm{nat}}$Sn at $E = 15$ A MeV are presented in fig. 2. The distributions are broad and cover a large atomic number. A relative minimum in the distributions is at $Z_{min} = 10$, then two regions in the charge distributions are defined: one with $Z \geq Z_{min}$ corresponding to residues (1, 2, 3 or 4 fragments); the second, with $Z < Z_{min}$ corresponding to LCPs and light clusters which result from evaporation.

3˙3. *Correlation functions.* – In order to extract the intrinsic properties of the fragments, one needs to estimate the amount of evaporated light charged particles from these primary fragments, but there are three different stages at least to produce these particles:

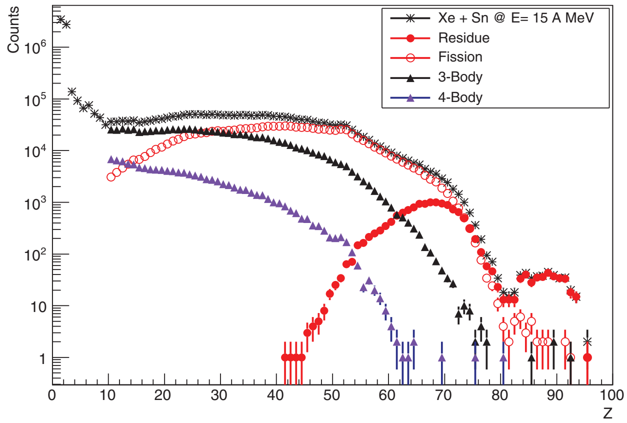

Fig. 2. – Charge distributions for $E = 15$ A MeV.

i) in the early stage of the collision, ii) at the same time as the formation of the fragments and iii) they can be emitted from the excited primary fragments. To extract the true contribution, correlation functions method will be used. The two-particle correlation function, $1 + R(V_{rel})$ is defined experimentally by the following equation:

$$1 + R(V_{rel}) = \frac{Y_{12}^{cor}}{Y_{12}^{unco}}, \tag{1}$$

where Y_{12}^{corr} is the correlated yield spectrum, which is constructed with the fragments (here fission fragments) and one LCP (here a proton particle) detected in the same event (This spectrum is sorted with respect to the relative velocity, V_{rel}, between the fragment

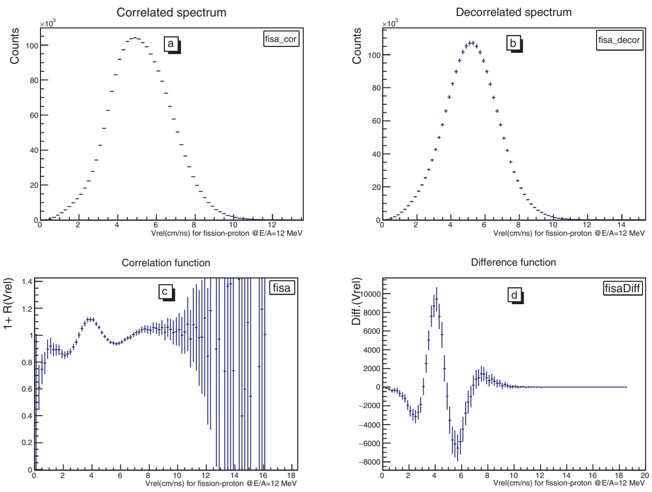

Fig. 3. – Top panel: relative velocity spectra of fission-proton pairs observed at 12 A MeV. a) the correlated events, b) the uncorrelated events. Bottom panel: c) the correlation function and d) the difference function.

and the LCP) and Y_{12}^{unco} is the uncorrelated two-particle yields, which is constructed by taking the fragment from a given event and the LCP from another event. Also the difference function $\Delta(V_{rel})$ is defined as

$$\Delta(V_{rel}) = Y_{12}^{corr} - Y_{12}^{unco}. \tag{2}$$

This is the method, which will be used to extract, on the average, the LCPs emitted from each fragment. Relative velocity spectra of fission-proton pairs for the correlated events and the uncorrelated events, the correlation function and the difference functions observed at $E = 12$ A MeV are presented in fig. 3.

4. – Conclusion

Four channels differing by the number of fragments are identified. The relative yield of these exit channels indicates that fission is the dominant decay mode at the three energies. The charge distributions are obtained, they are broad and cover a large atomic number range. Correlation functions method will be used to extract the LCP from each fragment. After the background (the contributions induced by other effects) is subtracted, one can access the amount of evaporated particles from the primary fragments. Then one can reconstruct the size and excitation energy of the primary fragments.

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