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Characteristics of the Primary Fission Fragments Produced From the ^{129}Xe+ ^{nat}Sn Reaction at E = (18-25) A MeV

Aziz. AZIZ[1,3*], Khalid KEZZAR[1], Farouk AKSOUH[1], Mohammed AL-GARAWI[1], Safar AL-GHAMDI[1] and Abdu CHBIHI[2]
[1]*Department of Physics, King Saud University, Riyadh, Saudi Arabia*
[2]*GANIL, CEA et IN2P3-CNRS, Caen, France*
[3]*Ibb University, Ibb, Yemen*

**E-mail: aziaziz@ksu.edu.sa*

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Abstract

Characteristics of the primary fissioning fragments produced from the ^{129}Xe+ ^{nat}Sn reaction at E = (18-25) A MeV have been obtained. Correlation function method was improved to extract the multiplicity of the light charged particles that evaporated from the primary fissioning fragments. These multiplicities, after the subtraction of the background contribution, was used to reconstruct the mass and atomic number of the primary fissioning fragments. The mean velocity of these particles is used to build their kinetic energies, which required reconstructing the excitation energy of the primary fissioning fragments.

KEYWORDS: Heavy ion, Reaction, Fission, Fragments, Correlation, Multiplicity

1. Introduction

A heavy ion is any projectile greater than alpha particle. Heavy ion reactions have seen an active growth in activity in the last twenty years in experiments and in theories. The first outputs result of these reactions was extracted in 1970 [1]. These reactions lead to understanding the nuclear matter behavior. To form nuclear systems in the collisions, nuclear reactions between heavy ions must have enough collision energy. In this contribution, we study the nuclear reaction ^{129}Xe + ^{nat}Sn in the energy range E = (18-25) A MeV. This experiment was performed at GANIL with the multidetector INDRA. We used a method to reconstruct the average size and excitation energy of the primary fissioning fragments. The method employed is based on the light charged particles (LCPs) relative velocity correlation functions. We will give in section 2, a brief description of our experimental setup. The experimental results will be given in section 3, and then we conclude in section 4.

2. Experimental Setup

The projectile using in this experiment was ^{129}Xe ion. A beam of these ions was accelerated to bombard the target ^{nat}Sn, which has 350 μg/cm^2 thick. This target was put inside of the INDRA multidetector. It consists of seventeen rings and the total detectors are 628 detectors. INDRA designed to study the physics experiments, which requires an event-by-event detection, with precise measurements of their number, their size (charge and mass), their spatial distribution and their energy. Two cyclotrons, CSS1 and CSS2, were used to accelerate this beam. The minimum energy resulting from the combination of these cyclotrons is 27 A MeV. In order to achieve the required energies, carbon-degrader foils with different density was used. The detected fragments, which arrived to INDRA, with Z_d up to 54 are identified in the forward region. The charge resolution is one unit up to Z_d=16 and few charges above. A very good isotope identification is obtained for $Z_d \leq 3$ and for $Z_d \geq 3$ fragments; the energy calibration was made by using the $\Delta E/E$ technique [2-4].

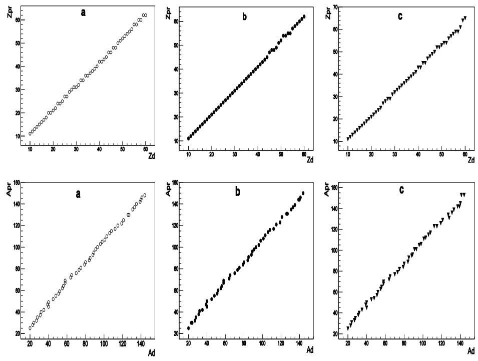

Fig. 1. Top panel: The reconstructed charge of the fissioning fragments: a) at E=18 A MeV, b) at E=20 A MeV and c) at E=25 A MeV. Bottom panel: the reconstructed mass of the fissioning fragments at the same energies.

3. Results and Discussion

The main aim of this work is to reconstruct the size of the primary fissioning fragments before its arriving to the multidetector. This will be known if we extract the multiplicity of the LCPs that evaporated from these fissioning fragments. In this work, we have improved the method to extract the signal of the evaporating particles, which is the correlation functions method, so a program written in C++ was made [5-7]. The correlation program affects one of LCPs to the most probable fission fragment. It tests the relative velocity between this particle and the two fission fragments to be the closest fragment according to Viola systematics [8].

By using the deduced average multiplicity of the LCPs, we can reconstruct the charge of the primary fragments by using the following equation:

$$\langle Z_{pr} \rangle = Z_d - \left(\sum z_{iLCP} \langle M_{iLCP} \rangle \right) \qquad 1$$

Where Z_d is the detected fragment charge, z_{iLCP} and M_{iLCP} are the charge and the average multiplicity of the evaporated particle i=p, d, t, ^{3}He and α.

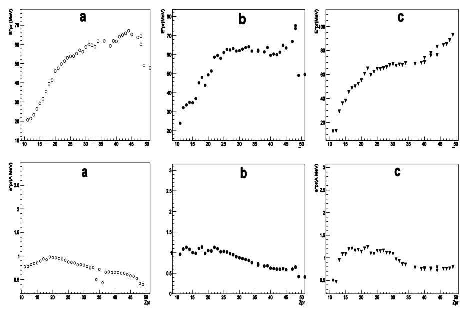

Fig. 2. Top panel: The average excitation energy of the primary fragments as a function of their atomic number: a) at E=18 A MeV, b) at E=20 A MeV and c) at E=25 A MeV. Bottom panel: The average excitation energy per nucleon at the same incident energies.

To reconstruct the mass of the primary fragments, we assume that the fragments are produced with the same N/Z ratio as the composite initial system. Figure 1 shows the result of this reconstruction at the three incident energies. Another quantity extracted using the correlation functions method is the velocity of each LCP. This quantity is used to build the average kinetic energy of LPCs required to reconstruct the average excitation energy of the primary fissioning fragments by using the following relationship:

$$\langle E^{*}{}_{pr}\rangle = \left(\sum \langle E_{iLCP}\rangle \langle M_{iLCP}\rangle\right) + (\langle E_n\rangle\langle M_n\rangle) - Q \quad 2$$

Where E_{iLCP} is the average kinetic energy of the measured LCP and Q is the mass balance of the reaction. The neutron kinetic energy En is taken as the proton kinetic energy minus the proton Coulomb barrier. The results of these reconstructions are shown in figure 2 top panel. The average excitation energy per nucleon of the primary fissioning fragments is obtained, figure 2 bottom panel. The average value of this quantity is between 0.5 and 1.5 A MeV, which indicates that, thermodynamical equilibrium was achieved at the disassembly stage of the reaction system [9-10].

3. Conclusion

This work demonstrates the use of the correlation function method. After subtracting the background contributions, we extract the average multiplicity of the light charged particles and their average velocities in the center of mass of the fission fragments. By using the average multiplicity of the LCP, we reconstruct the average charge and mass of the primary fissioning fragments. The extracted average LCPs multiplicities are low which implies that the excitation energy of the corresponding primary fragments is moderate. The values of the primary charge are larger than the detected fragments. This excess reaches the value of two charge units at bombarding energies 18 and 20 A MeV and increases to five at 25 A MeV. The excitation energy of the primary fragments was reconstructed by using the kinetic energies of the LCPs and neutrons. The results show that for a given bombarding energy, the excitation energy per nucleon is almost constant and do not exceed a value of 1.5 A MeV.

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