Fission fragment mass distribution studies for ^{28}Si + ^{197}Au, ^{209}Bi, ^{235}U reactions

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Introduction

In reactions with heavy ions, complete fusion and quasi-fission are the competing processes at energies above the Coulomb barrier [1]. The quasi-fission process, in which the system reseparates before reaching a compact compound nucleus, is a major hurdle in forming heavy and superheavy evaporation residues (ER) in heavy-ion reactions.

Fission fragment mass distribution for the fully equilibrated compound nucleus is decided at the scission point due to a long descent from saddle to scission. At higher excitation energies, the shell effects are washed out and the mass distribution is expected to be symmetric. The width of the distribution strongly depends on the entrance channel properties, such as mass asymmetry, deformation of interacting nuclei, collision energy, and the Coulomb factor Z_1Z_2. Any sudden change in the width of the mass distribution would indicate departure from full equilibration, while onset of mass asymmetry or a sudden increase in width would be a strong signal of quasifission [2,3].

Experimental details and Data Analysis

In the present work, we have investigated the mass distribution of fission induced by ^{28}Si ion in a number of targets, viz., ^{197}Au, ^{209}Bi, and ^{235}U at different energies from 180 MeV to 151 MeV. The experiment was performed at BARC-TIFR-Pelletron-Linac Facility, Mumbai. Pulsed beam of ^{28}Si of ∼1.5 ns width and a period of 107 ns was used. The isotopically enriched targets of ^{197}Au (300 μg/cm^2), ^{209}Bi (300 μg/cm^2), and ^{235}U (~200 μg/cm^2 on thin Ni backing) were mounted on a target ladder that was oriented at 45° to the beam direction. The fission fragments were detected in coincidence by using two position-sensitive Multi-wire proportional counter (MWPC) detectors mounted inside the general purpose scattering chamber and kept at folding angle. One of the MWPC (with entrance window dimension 15 cm X 4.8 cm) was kept at a distance of 57.72 cm away from the center target ladder on one arm of scattering chamber while the other (with entrance window dimension 20 cm X 8 cm) was placed at a distance of 39.72 cm away on the other arm of the scattering chamber. Two Silicon detectors were mounted at ±20° to monitor the elastically scattered particles. The angular coverage of the small window MWPC was 15.5° while that of the large window MWPC was 30°. The position of the fragments entering the detector, were determined via the delay line read out of the wire planes, giving a position resolution of ~1mm. The fast timing signals from the central anode plane of MWPCs were used to determine the time difference between the two fragments. The X-Y positions, the energy loss in each of the detectors, and the time difference between arrivals of coincident fragments were recorded event by event. The position calibration of the detectors was carried out using the known positions of the edges of the illuminated areas of the detectors, when the events were collected in singles mode using ^{252}Cf source. The calibrated X and Y positions from the two detectors were then converted to θ and φ. The velocities and masses of the two fragments were reconstructed from the position and time difference information.

Results and Discussion

The folding angle distribution for the three systems is shown in Fig.1. It shows a systematic decrease in compound fission component for ^{235}U with the increase of beam energy. However, a reverse trend is observed for ^{197}Au and ^{209}Bi, where the contribution of the non-compound fission component increases with the beam energy.

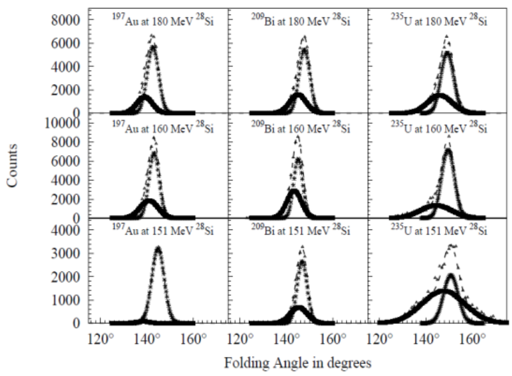

Fig.1. The folding angle distribution at three different energies of ^{28}Si beam.

The mass distribution for the compound nuclear fission events is plotted in Fig.2 for all the systems for three beam energies. It is observed that the mass width of the distribution at a given energy increases with target mass due to the increase in the fissility of the fissioning nucleus.

Fig.3 shows the variation of mass width with energy for all the three targets. For ^{235}U, the mass width increases with decrease in energy. This decrease in mass width with the increase in the beam energy for ^{235}U target, can be explained by considering the increase in the non-compound nuclear fission components at lower beam energies. Similar behavior of increase in mass width for the systems having large mass asymmetry has been reported earlier by Thomas et al [4].

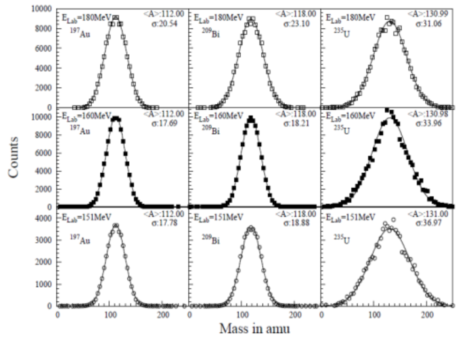

Fig.2. The mass distribution for various energies.

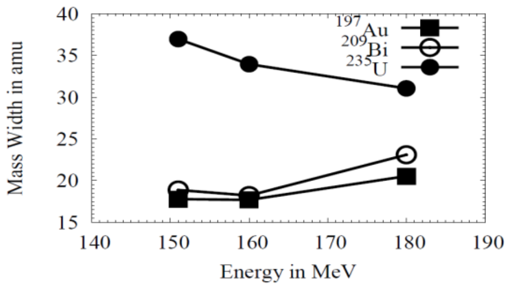

Fig.3. The variation of mass width with beam energies for ^{197}Au, ^{209}Bi and ^{235}U targets.

References

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