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Study of fission dynamics in pre-actinide and actinide region

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The unexpected observation of asymmetric fission in the pre-actinide nucleus 180Hg at low excitation energy has renewed interest in understanding the role of nuclear shell effects and reaction dynamics in the fission process. In parallel, the competition between quasi-fission (QF) and fusion–fission (FF) critically governs the formation probability of super heavy elements (SHE). Since reliable theoretical models capable of quantitatively predicting QF contributions remain limited, stringent experimental validation is required.

In this context, we have undertaken a systematic experimental program [1–8] to measure fission fragment mass and total kinetic energy (TKE) distributions for a wide range of projectile–target systems using large-area multi-wire proportional counters (MWPCs) at Indian accelerator facilities, (e.g; the Kolkata Cyclotron, Mumbai and New Delhi Pelletron) and JINR, Dubna, Russia. The mass and TKE distributions provides a sensitive probe of nuclear shell effects and a clear experimental signature for distinguishing between FF and QF processes. In this conference, we will report on our recent measurements of fission fragment mass distributions for the reactions 4He+197Au and 35Cl+181Ta.

For the pre-actinide nucleus 201Tl populated in reaction 4He+197Au, the observed mass distributions at an excitation energies near the Coulomb barrier exhibit clear evidence of multimodal fission, in contrast to earlier expectations of unimodal behaviour [2]. Detailed analysis of mass and energy correlations reveals the presence of three distinct fission modes. Proton numbers Z=36 and Z=52 play a stabilizing role, with the deformed Z=36 mode dominating over the Z=38 mode. With increasing excitation energy, the symmetric fission component becomes increasingly dominant, and at an excitation energy of 45.5 MeV the asymmetric mode associated with Z=52 disappears. These observations are supported by potential energy surface calculations performed using state-of-the-art density functional theory [2].
For the 35Cl+181Ta reaction, the entrance-channel parameters place the system in the MAD3 regime, characterized by the absence of significant mass–angle correlations. We show that the resulting mass distribution of 216Th populated in the reaction 35Cl+181Ta has a contribution from asymmetric fission, which cannot be explained by multi-chance fission. Instead, the observed features are consistent with QF, as confirmed by our theoretical DNS calculations. The judicious choice of the reaction system in the present work enabled us to pin down slow quasi-fission which is an intrinsically more challenging task than identifying fast quasi-fission. For other actinide systems, such as those involving U or Pu, disentangling slow quasi-fission from multi-chance fission would be extremely difficult. In our case, a key advantage is that the daughter nuclei after multiple neutron emission exhibit symmetric mass distributions at low excitation energies [8]. The present analysis indicates that the average TKE and its variance offers the signature of slow quasi-fission [1].
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