Probing the fission dynamics of ^{201,203,205}Bi nuclei

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Introduction

Even after eight decades of its discovery, fission dynamics of an excited compound nucleus (CN), where it predominantly breaks into two nearly equal fragments, is still one of the most confounding nuclear many-body problem. The complex large-scale rearrangement of nuclear matter during the process is widely interpreted by appending two complementary approaches under the *macroscopic*(LDM)-*microscopic*(shell) models. Amongst various experimental observables, pre-scission neutron multiplicities (M_{pre}) and mass-distribution of fission fragments have provided unprecedented information about the evolution of CN through various stages of deformation to reach the scission point. For instance, the dissipative nature of fission was largely manifested via the underestimation of M_{pre} by the Bohr and Wheeler's transition state model [1]. Further, unanticipated observations of mass-asymmetric fission in ^{180}Hg [2] and multimodal fission in ^{194,196}Po, ^{202}Rn [3] have led to the predictions of a new island of mass-asymmetry around the Pb region [4]. In the present work, fission dynamics of ^{201,203,205}Bi nuclei populated via ^{19}F + ^{182,184,186}W reactions has been explored using neutron multiplicity and mass-distribution measurements.

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Experimental Details

The experiment has been performed at the Inter University Accelerator Centre (IUAC), New Delhi. Pulsed beam of ^{19}F (repetition rate: 250 ns, width:$\sim$1 ns) was accelerated to the lab energies of 120-150 MeV using the 15UD Pelletron+LINAC accelerator at IUAC and bombarded on ^{182,184,186}W targets (C backed targets of thickness 390 μg/cm^2, 220 μg/cm^2 and 679 μg/cm^2 respectively). The complementary fission fragments were detected in coincidence with each other using two multi-wire proportional counters (MWPCs) placed asymmetrically at angles (θ_{lab}, ϕ_{lab}) of (40^0, 90^0) and (-109^0, 270^0) with respect to the forward beam direction. Each MWPC having an active area of 20$\times$10 cm^2 was kept at a distance of 27.5 cm (forward) and 23.5 cm (back) from the target. The neutrons were detected in coincidence with the fission fragments, using 80 organic liquid scintillator detectors placed in the NAND array [5]. Each neutron cell was kept at a flight path of 175 cm from the target, the total array covering $\sim$ 2.5% of 4π. VME based data acquisition system coupled with the Multiparameter Acquisition Root based Storage (MARS) acquisition software was used to acquire the list mode data. The time-of-flight (TOF) signals from the neutron detectors were recorded. Due to the sensitivity of these detectors to both neutrons and γ's, pulse-shape discrimination (PSD) modules, based on the zero crossover technique, were used with the TOF spectra to distinguish the two. Efficiency of the neutron detectors was calculated using the FLUKA code.

Results and Discussions

The M_{pre} values were extracted for all three nuclei by fitting the efficiency corrected double differential neutron energy spectra using the Watt's three-source (one CN and two complementary fragments) moving formula [6]. The energy spectra of at least 50 detectors were fitted simultaneously with a maximum χ^2 of 5.46 amongst all. The underestimation of M_{pre} by the Bohr-Wheeler's fission width [1] indicates the relevance of dissipation in the fission dynamics of the investigated systems. The results for ^{203}Bi are shown in FIG. 1.

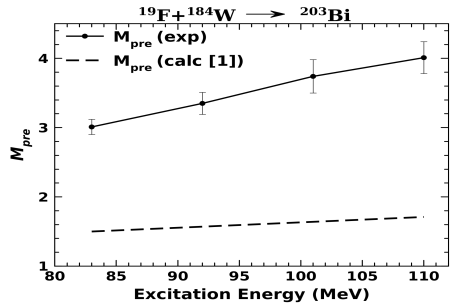

FIG. 1: Comparison of experimental M_{pre} (solid line to guide the eye) with the statistical model calculations [1] (dashed line) for ^{203}Bi.

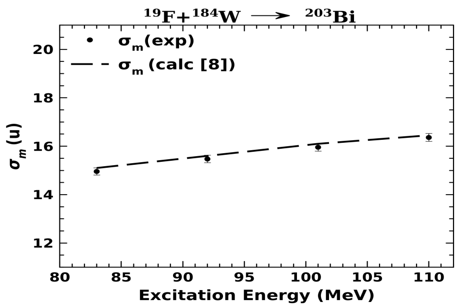

FIG. 2: Comparison of experimental fragment mass width (σ_m) with the saddle point model [8] (dashed line) for ^{203}Bi.

Also, mass-distributions have been extracted for the case of ^{203,205}Bi. Unanticipated signatures of asymmetric fission have been observed for both ^{203,205}Bi at the lowest excitation energy of ~ 80 MeV (~ 55 MeV above the saddle point), the fission-mode being symmetric at higher excitation energies. In order to discern the observed asymmetry, the experimental fragment mass width (σ_m) (obtained by fitting a single Gaussian at all energies) was compared to the saddle point model [8]. The linear variation of σ_m with excitation energy and its agreement with the saddle point model [8] at all the energies (the case of ^{203}Bi is shown in FIG. 2) recedes the contribution of quasi fission for the observed asymmetry. It is worthwhile to note that the experimental mass asymmetry ratio at the lowest excitation agrees with the predictions of the semi-empirical model GEF [7]. 2-D Langevin model calculations have been initiated to understand the role of shape dependent dissipation strength and shell effects in the observed mass asymmetry.

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