Role of neutron emission in the fission of ^{227}Pa nucleus at medium excitation energies

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Introduction

Experimental data on various fission observables and their correlations are of prime importance in understanding the nuclear fission process. For fissioning system at lower excitation energies (E*), the microscopic properties like shell effects modify the nuclear shape evolution that leads to asymmetric mass split; heavier being centered around A ∼136u [1]. With increase in E*, shell effects become less dominant and a transition to symmetric fission has been observed. However, multi-chance fission (fission after neutron emission) of fissioning nucleus can modify the modes of fission as it reduces the E*. Hence, the shape of the final mass spectra, which is the average of all chances will be influenced by the relative weight of higher chance fission even for higher excitation energies (>30 MeV).

In this report, we present the mass distribution, total kinetic energy (TKE) and pre-scission neutron multiplicity (M_{pre}) of ^{227}Pa to study the evidences of multi-chance fission on experimental observables.

Experiment details

The experiment was performed using 15UD Pelletron accelerator facility at Inter University Accelerator Centre (IUAC), New Delhi. Pulsed beam of ^{19}F at beam energies 90MeV, 105MeV and 120MeV was bombarded on a ^{208}Pb target to study heavy ion induced fusion-fission. The binary fragments from the fission of ^{227}Pa compound nucleus (CN) were detected using a pair of Multi-Wire Proportional Counters (MWPC) (20cm×10cm) mounted at 40° and 122°, on either sides, w.r.t beam direction. Fast neutrons emitted from fission fragments (FF) and CN were detected using 5in.×5in. BC501A organic scintillators installed in the neutron detector array, NAND [2].

The mass ratio of FF has been derived from their coincident Time of Flight (TOF) spectra by kinematic coincidence method. The velocity vectors of fragments were determined from their TOF in which time of flight of the scattered beam was used as the reference. The total kinetic energy (TKE) of the fragments was obtained by summing the kinetic energies of each fragment in their c.m frame. Neutron multiplicity of CN (M_{pre}) and FF (M_{post}) were extracted by moving source fitting method. The fast neutrons emitted in coincidence with fission events were discriminated from gamma-ray background by pulse shape discrimination techniques based on Z/C over. The energy spectra of neutrons at different angles w.r.t CN and FF directions were fitted with Watt expression, minimizing chi-square.

Results and Discussion

The role of neutron emission in the fission of actinide nucleus ^{227}Pa at low and medium excitation energies (E*) have been studied using a semi-empirical fission model, GEF [3]. Fig.1 shows GEF model predictions of average M_{pre} at different excitation energies along with the measurements. GEF calculation accounts the change in E^* of various fission chances. In the

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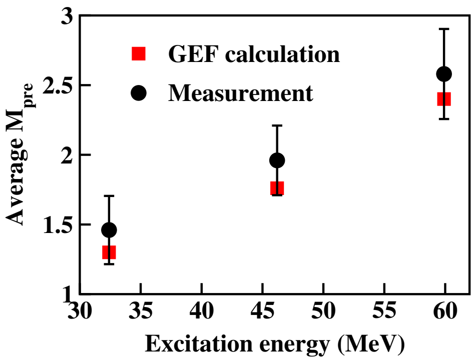

FIG. 1: Comparison of experimental M_{pre} with GEF model calculation.

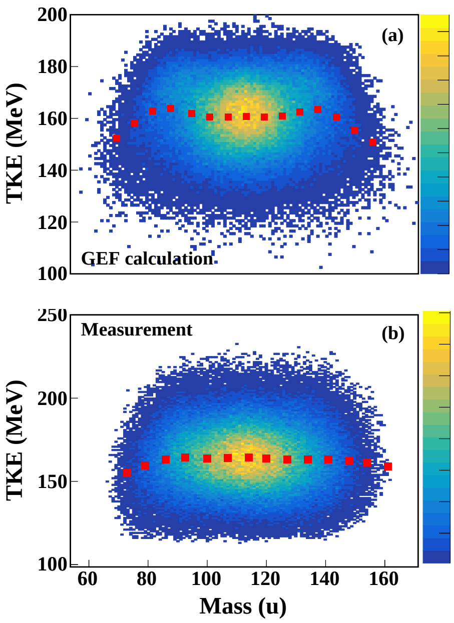

FIG. 2: Mass-TKE distribution of FF at 32.4 MeV excitation energy (see the text for details).

event of higher chance fission (n=1 or above), the available excitation energy at the saddle point (E_{sp}) decreases which leads to an interplay of other fission modes such as shell influenced mass asymmetric fission.

In Fig. 2, the Mass-TKE distributions of FF at an initial excitation energy of 32.4 MeV is compared with GEF model calculations. The average value of TKE as function of fragment mass is shown with symbols (square). Fig. 2(a) shows the sum of all fission chances broadened with 5u mass resolution. The mean of saddle point excitation energy was $\sim$ 20.8 MeV. Experimentally measured mass-TKE distribution is shown in 2(b). Though asymmetric shoulders are not visible as seen in low energy fission, it was found that the average of TKE was nearly constant for a range of fragment mass in both 2(a) and 2(b). At higher excitation energies where shell effects are negligible, TKE follows a parabolic correlation with fragment mass [4]. The near flat-top distributions in 2(a) and 2(b) can be attributed to asymmetric fission modes at higher fission chances.

Similarly, the M_{pre} as a function of fragment mass also holds systematic dependence to various fission modes. Detailed results of Mass-TKE and Mass-M_{pre} for all the energies studied will be presented.

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