Effect of neutron shell closure in fission fragment mass distributions of ^{206,210}Po

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In recent years, many theoretical as well as experimental investigations were conducted to understand if large ground state shell corrections affect the saddle point shapes of the nucleus and thus it's eventual decay dynamics. The measurement of fission fragment angular anisotropy of the N=126 shell closed nuclei ^{210}Po showed anomalous anisotropy as compared to ^{206}Po which is not shell closed [1]. The result speculated that the shell effects survives at the saddle. However, it was found that good agreement between the anisotropy data [1] and the statistical model calculation could be obtained by taking multichance nature of fission into account [2]. The pre-scission neutron multiplicity data for both ^{206,210}Po required substantial shell correction in both ^{210}Po and ^{206}Po [3]. Both the angular anisotropy and pre-scission neutron data were analyzed within the framework of statistical model. However, from dynamical calculations based on the four-dimensional Langevin equation using a macroscopic potential energy landscape it was shown that both the angular anisotropy pre-scission neutron multiplicity data could be well explained with purely macroscopic potential energy landscape without considering any shell effect at saddle point [4]. A recent study [5] of the decay of ^{210}Po compound nucleus also indicated no significant shell correction at the saddle point. Since fission fragment mass distribution is directly correlated to the saddle ridge structure for single barriered distribution, it would provide an independent signature about the role of shell correction at the saddle point.

An experiment to measure the fission fragment mass distributions of the compound nuclei ^{206}Po and ^{210}Po, populated using ^{12}C on ^{194,198}Pt targets was carried out at the BARC-TIFR Pelletron facility with bunched beam of ^{12}C (58-78 MeV). Fission fragments were detected with two large area position sensitive MWPCs [6]. The detectors were placed at 48 cm and 37 cm from the target on either side of the beam axis with their centers at an angle of 45° and 121° to the beam axis respectively. The detectors were operated at a pressures of 3 torr of iso-butane gas. The flight times of the complementary fragments, the position of the impact points of the fragments on the detectors, and the energy losses in the gas detectors were measured in an event by event basis. From these measurements, masses of the correlated fission events could be extracted assuming full momentum transfer from target to projectile. Partial momentum transfer events could be excluded from the folding angle distribution. A Faraday cup and elastic events collected by a silicon surface barrier detector

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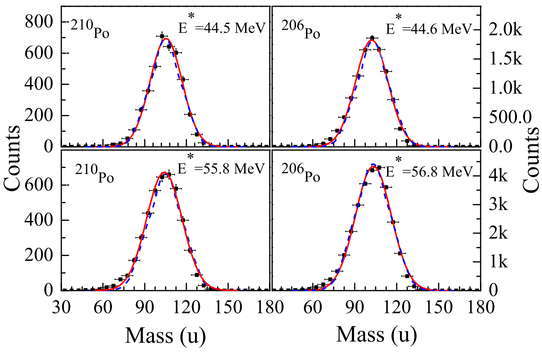

FIG. 1: Measured of fragment mass distributions at different excitation energies. Single Gaussian fits are shown by solid (red) lines. Theoretical fits are shown by the dashed (blue) lines.

placed at 15° were used for beam flux monitoring and normalization. The extracted mass distributions are all found to be symmetric and were fitted with a symmetric Gaussian. The mass distribution and their fits are shown in Fig. 1 (red line) at a few representative excitation energies.

As the fission barriers are single peaked for both the systems, the measured mass distributions were reproduced theoretically using the Finite Range Liquid Drop Model (FRLDM) formulation, considering only realistic macroscopic potential without any microscopic shell effect. The nuclear shapes were defined in two dimensions with Funny Hill parameters [7], elongation (c) and mass-asymmetry (α). The fragment masses at the saddle ridge were decided by dividing the compound nucleus at the neck of the deformed shape, corresponding to a particular combination of c and α. An estimate of the fission fragment mass distribution was obtained from multi-dimensional Kramers formula for the fission width

$$\Gamma_f = N(\alpha)exp(-V(\alpha)/T) \qquad (1)$$

where $V(\alpha)$ was multiplied with a constant factor B to take care of dynamical effects. It was found that this procedure reproduced the experimental data very well for both the systems (shown by dashed blue line in Fig. 1). The standard deviations of the theoretical mass distributions are also found to reproduce the experimental data reasonably well at all excitation energies (shown by dotted lines in Fig. 2(a)(b)).

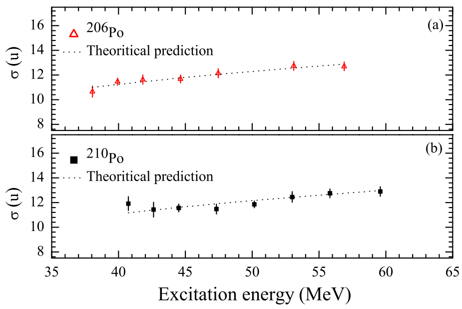

FIG. 2: (a),(b):Variation of the standard deviation of the fitted mass distribution with excitation energy. The standard deviations calculated theoretically were shown by dotted lines.

It is thus clearly evident that there is no anomaly between fragment mass distributions of the two systems, ^{206,210}Po. Experimentally, they are symmetric without any appreciable change of shape in the whole range of excitation energy under consideration. The mass distributions obtained theoretically without incorporating shell correction are able to reproduce the respective experimental data in both cases indicating the absence of shell correction at saddle.

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