Study of ^{227}Pa nuclei around sub barrier energies

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The mechanism of mass division in fission of atomic nuclei has been an intriguing problem in nuclear physics for several year. Bi-modal nature of fission phenomenon has been observed in induced fission of light and heavy actinides [1]. The effects of A an Z and characteristics of final mass division from each fission mode has been studied extensively. For e.g, significant presence of asymmetric components influencing the mass yield ratio has been reported for nuclei ^{224,226}Th and ^{219}Ac, formed through ^{16}O + ^{204,208}Pb, ^{203}Tl reactions at lower energies [2]. The charge distribution of FF in Coulomb fission of neutron deficient isotopes (Z = 89-92) suggested that with increasing mass of the nucleus, a transition takes place from the symmetric to the asymmetric fission mode at around A_{CN} = 226 in this region of nuclei [3].

In present work, we report on experimental measurements of mass distribution of fission fragments from reactions ^{19}F + ^{208}Pb over a range of excitation energies (E = 30-50 MeV). The selected reaction has low Z_pZ_T (=736). The experiment was carried out using ^{19}F beams from the 15UD Pelletron accelerator at Inter University Accelerator Centre, New Delhi, India. Pulsed beam of width of $\sim 1.5ns$ and separation of 250 ns was used to bombard isotopically enriched ^{206,208}Pb targets of $\sim$ 110 μg/cm^2 thickness deposited on 20 μg/cm^2 carbon backings. The targets were mounted with ^{12}C backing facing the beam. The experiment was performed at different beam energy varying from 85 MeV to 112 MeV choosing the energy steps to form compound nucleus with similar excitation energies. The complimentary fission fragments were detected in coincidence using two large area position sensitive multi-wire proportional counters(MWPCs) of dimension $24x10cm^2$) [4] positioned in the forward an backward hemispheres. The fission fragments(FFs) were separated from the elastic and quasi elastic particles by time of flight and energy loss signals in the MWPC. The data analysis has been performed following the velocity reconstruction method given by [5]. From the position and time distribution of fission fragments in MWPC, the polar angles (θ, ϕ) and the two components of the velocity vector of the fissioning nucleus were determined for each event. The velocity component parallel to beam direction,$V\|$ was deduced from the velocities of two fragments and the folding angle. The velocity component, $V\perp$ in the plane perpendicular to the beam axis was determined from the projection of the fragment velocities onto the azimuthal plane. Fission events originating from complete fusion was selected by imposing the condition of full momentum transfer (FMT) of measured fission like events using the correlation of velocity components. Fig. 1 displays the spectra showing the correlation between measured $V\perp$ and $V\|$ -$V_{c.m.}$ (where $V_{c.m.}$ is the center-of-mass velocity) for fission events from the reaction ^{19}F + ^{208}Pb at beam energy 89 MeV. The

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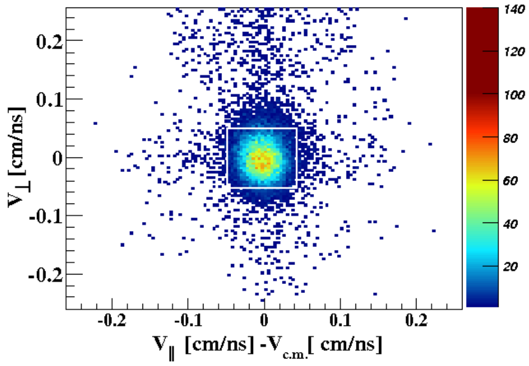

FIG. 1: Measured distribution of FFs velocity components at below barrier. Full momentum transfer fission events are shown inside rectangular box.

intense region centered around the velocity coordinates (V∥ -$V_{c.m.}$,V⊥)=(0,0) corresponds to the events originated from FMT fission. A software gate around these events, shown as black rectangle in the plot, was used to generate mass angle correlation and mass distribution analysis. The mass ratio $M_R = \frac{m1}{m1+m2}$ (m1 and m2 are two fragment masses) was determined from the ratio of the velocities in the center-of-mass frame.

The variances of mass distributions σ_M^2 (mean square deviations from the mean value M=$A_{CN/2}$)) as a function of $E_{c.m.}/V_B$ (where V_B is the barrier) for present systems are plotted in Fig 2. It can be seen that, as bombarding energy decreases, the σ_M^2 values for both system decreases monotonically but shows sudden upward rise near or below the fusion barrier(($E_{c.m.}/V_B$=1).The mass variance of the fissioning nuclei demonstrate abrupt increase in width below barrier energies. Though the relative values vary among different groups the nature of the variation is identical in all cases. This verify that, the sudden rise in σ_M^2 observed in our measurement could not be due to any systematic error. The standard deviation σ_M of the mass distribution was obtained at each energy after making best Gaussian fit to the data. As the excitation of compound nucleus increases, the σ_M is found to increase. At lower excitation energies, the standard deviation from the fit shows more wide mass distribution than expected from the standard symmetric mass division of the FFs.

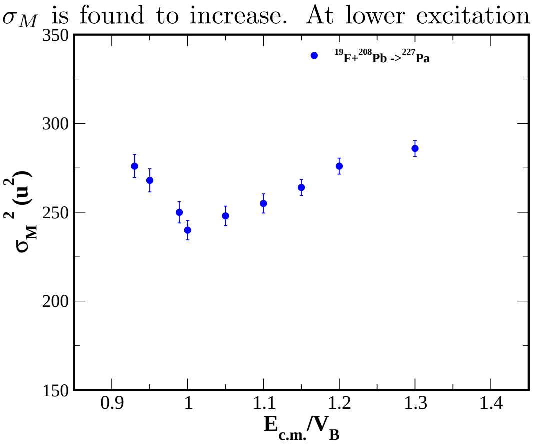

FIG. 2: Mass variance of FFs $^{19}F +^{208} Pb \longrightarrow$ $^{227}Pa^*$ neutron deficient nuclei are shown against reduced bombarding energies. Experimental mass width of FFs for compound nucleus ^{227}Pa reactions around barrier energies.

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