Fission fragment mass distribution studies in ^{9}Be + ^{235}U system

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Introduction

At low excitation energies, fission reaction is strongly influenced by nuclear structure. Shell and pairing effects play a major role in the shape of the mass and nuclear charge distributions of the fission fragments[1]. In case of weakly bound projectile bombarded on nucleus with small fission barrier, a whole new set of fission mechanisms like transfer induced fission, fission followed by capture of one of the break-up fragment and incomplete fusion-fission etc., comes into picture. Apart from complete fusion-fission mechanism, the momentum transferred from light weakly bound projectile nucleus to target nucleus is different from full momentum.

In the present paper, we are describing the fission fragment mass distribution for ^{9}Be+^{235}U reaction, measured by employing two Multi-wire proportional counter on either side of the beam axis. An attempt has been made to exhibit the effect of excitation energy of the fissioning nucleus on fission fragment mass distribution in case of light weakly bound projectile nucleus bombarded on nucleus with small fission barrier.

Experimental details and data analysis

The experiment was performed using pulsed ^{9}Be beam of ≈1.5 ns width and a period of 107.3 ns from the Pelletron-LINAC facility at TIFR, Mumbai. A 250 μg/cm^2 thick ^{235}U target with 50 μg/cm^2 Nickel backing was mounted on target ladder. The orientation of target was 135° with respect to the beam axis. The ^{9}Be beam was facing the target ^{235}U and the Ni backing was on the other side of the beam. Two large area two dimension position sensitive Multi-wire proportional Counters (MWPC) were placed on either side of the beam axis to detect the coincident fission fragments. The window dimension of both the MWPCs used in the experiment were 17.5 x 7 cm^2. The distance of one of the MWPC from the center of target ladder was 27.3 cm and that of the other was 23.1 cm. The angular coverage of the first MWPC was 35.5° while that of the other was 43.4°. Isobutane gas at a pressure of 3.0 mbar was used in continuous flow mode through the MWPCs. Two silicon monitor detectors were mounted at ±20° to monitor the elastically scattered particles. The X and Y positions of fission fragments detected in MWPCs were recorded event by event in list mode. The individual time of flight of fission fragments with respect to RF beam bunching signal was also recorded event by event for both the complementary fragments. The time difference between the flight of fission fragments from target to respective detectors was also recorded event by event. The energy signals corresponding to partial energy loss of the fragments in the MWPCs were also recorded event by event. The position calibration of the detectors was carried out using the known positions of the edges of detectors, when the events were collected in singles mode using ^{252}Cf source. The time to amplitude converters (TACs) used for various timing measurements were also calibrated using time calibrator. The calibrated X and Y positions from the two detectors were then converted to θ and φ. The velocities of the two fragments were reconstructed from the position and timing information. The timing calibration for the system was achieved by imposing the condition that the mass ratio distribution of fission like events is reflection symmetric about 0.5 at $\theta_{c.m.}$ = 90°, a condition that is true for all reactions. The mass ratio distribution is obtained using conservation of linear momentum in center of mass frame as $M_R=m_1/(m_1+m_2)= v_{2cm}/(v_{1cm}+v_{2cm})$.

The two components of velocity vector of each fissioning nucleus, v_{par} and v_{perp} were determined using the prescription given in ref [2]. As shown in Fig. 1, it seems difficult to separate the contribution of partial momentum transfer events from full momentum transfer events. Nevertheless, for full momentum transfer events, v_{par} is expected to be same as that of velocity of center of mass velocity of the system and the v_{per} is expected to be zero. So as to decrease the contribution of transfer/incomplete fusion events to full momentum transfer events, we selected a small circular region with a radius of $[(v_{par}/v_{cm}-1.0)^2+(v_{per}/v_{cm})^2]^{1/2}\leq0.2$, the mass ratio distribution have been again obtained.

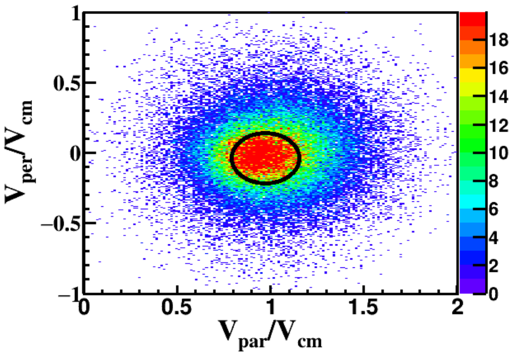

Fig.1 Correlation between the two velocity components of fissioning nucleus at E_{lab} = 47.5 MeV.

Results and discussion

The obtained mass distribution for total fission events has been shown in Fig.2. The obtained mass distribution is asymmetric with increasing Peak to Valley ratio (P/V) with decreasing energy. The peak to valley ratio has been shown in Fig. 3. The peak to valley ratio obtained for above selected circular region is less than that obtained for total fission events. It shows that as the contribution of full momentum transfer event increases the P/V ratio decreases compared to that it is for total fission events. It is because for full momentum transfer events the excitation energy available to fissioning nucleus is more as compared to those for transfer/incomplete fusion events.

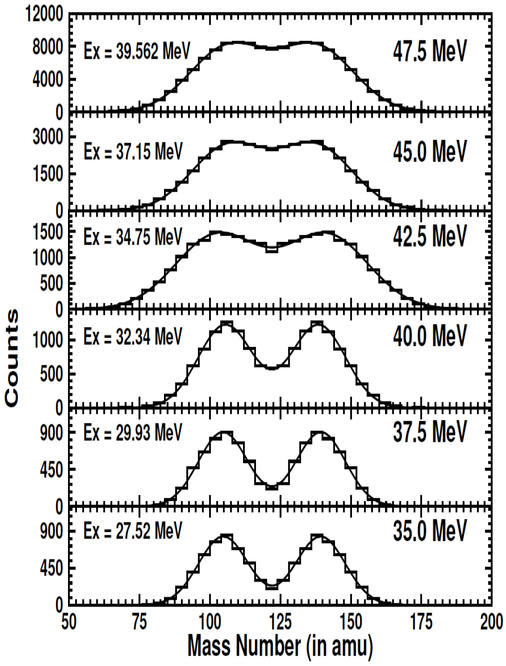

Fig.2 Mass distribution obtained at various energies.

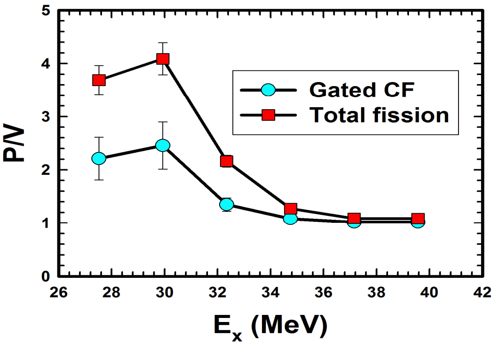

Fig.3 Peak to Valley ratio obtained at various excitation energies.

References

[1] A. Chatillon, et al., Phys. Rev. C 99, 054628(2019).

[2] D. J. Hinde, et al., Phys. Rev. C 53, 1290(1996).