Mass resolved angular distribution in $^{12}C+^{232}Th$ reaction at sub-barrier energy

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Introduction

Study of the angular distribution of fission products (FPs) is an important tool to investigate the various fission channels contributing to the fission process. Depending on the various entrance channel parameters, there can be contribution from compound nucleus fission (CNF) or the non-compound nucleus fission (NCNF) [1]. The Statistical Saddle Point Model (SSPM) can explain angular distribution of FPs through CNF. However, in many fissioning systems especially in heavier actinides, deviations from the SSPM calculations were observed which may be due to the contribution from NCNF which prominently includes quasifission and pre-equilibrium fission around the barrier. Pre-equilibrium fission is expected to contribute when the entrance channel mass asymmetry (α) is less than the Businaro-Gallone critical mass asymmetry (α_{BG}) [2]. Investigation of the anisotropy in fissioning system with low Z_pZ_T can provide useful information regarding the contribution of various components of NCNF during fission.

Many studies have been carried out to investigate the angular distribution of FPs in $^{12}C+^{232}Th$ reaction [3-6]. Majumdar *et al.* observed a sudden rise in anisotropy (~2.1) as the beam energy decreases through the fusion barrier showing a peak like structure at $E_{cm} \approx 59$ MeV [3]. Karnik *et al.* also observed an increase in the anisotropy with decreasing beam energy around the barrier [4]. However, the study carried out by Lestone *et al.* [5] and Mein *et al.* [6] observed almost constant anisotropy ~1.5 in near and sub-barrier region. In the present study, the mass-resolved angular distribution of the FPs in $^{12}C+^{232}Th$ reaction has been measured using the recoil catcher technique followed by off-line γ-ray spectrometry. The study aims to investigate the mass dependence of the angular anisotropy at sub-barrier energy as well as the contribution from different fission channels.

Experimental Details

Experiment was performed at the BARC-TIFR Pelletron-LINAC facility at TIFR, Mumbai. A self-supporting ^{232}Th target of thickness ≈2 mg/cm^2 was placed inside the irradiation chamber at an inclination of 45° with respect to beam direction. The sample was irradiated with ^{12}C beam of energy 62.5 MeV corresponding to E_{cm}/V_C value of 0.98. Flux mapping was carried out to account for the fluctuations in the current during the irradiation. To capture the FPs in forward direction, superpure Al foil of thickness 6.75 mg/cm^2 was placed on the inner wall as well as on the front inner surface of semi cylindrical chamber of radius 26.5 mm and length 130 mm. The Al catcher foil was divided into 8 pieces post-irradiation corresponding to different angle subtended with the beam direction. Each piece of Al foil was mounted on separate perspex plate and counted using high-resolution γ-ray spectrometry. The measurement was followed up from ~10 mins upto ~45 days. The acquired spectra were analyzed using the PHAST software developed at BARC, Mumbai to obtain the peak areas for various γ-ray energies [7].

Results and Discussions

The nuclear data has been taken from [8]. Activities at the end of irradiation have been calculated using the peak areas for the corresponding γ-ray energies. Yield of the FPs was determined using the end of irradiation activities of the FPs in the different foils. The FP

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yields were corrected for the solid angle to obtain the angular distributions in lab frame of reference which were further transformed into centre of mass frame of reference assuming complete momentum transfer.

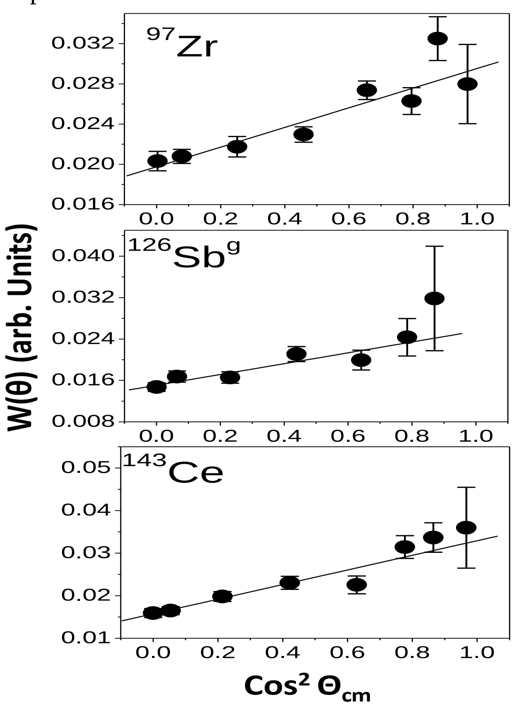

Fig. 1 Centre of mass angular distribution of few FPs in ^{12}C + ^{232}Th reaction at E_{cm} = 59.4 MeV. (Black line is the linear fit to the experimental points)

The anisotropy was calculated using the angular distribution of the identified FPs and has been plotted with the mass asymmetry (Fig. 2). Angular anisotropy was found to be higher in symmetric mass region and decreases with increasing mass asymmetry. The average anisotropy at E_{cm} = 59.4 MeV was found to be 1.46 ±0.05 which is close to the values reported by Lestone *et al.* [5] and Mein *et al.* [6]. The angular anisotropy obtained by SSPM calculations at E_{cm} = 59.4 MeV was found to be 1.11 which is lower compared to the experimental value. The higher value of the average experimental anisotropy may be due to the asymmetric fission mode in CNF resulting in lower value of effective moment of inertia at the saddle point. In addition, there may be contribution from non-compound nucleus fission. Further analysis is in progress to investigate the effect of such contributions.

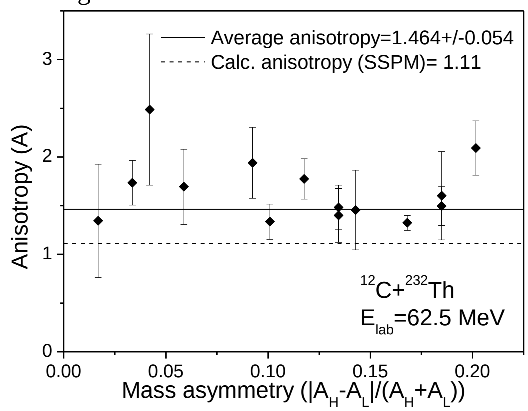

Fig. 2 Angular anisotropy of FPs in ^{12}C+^{232}Th reaction at E_{cm} = 59.4 MeV with mass asymmetry.

Conclusions

Fission product yields at different angles were measured using recoil catcher technique followed by off-line γ-ray spectrometry. Yields were corrected for solid angle and transformed into centre of mass frame of reference to obtain the angular distribution of the FPs. Angular anisotropy was found to be higher for the symmetric mass region and decreases with increasing mass asymmetry. The experimental average anisotropy was found to be higher compared to that obtained from SSPM calculations.

References

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