Examining the transfer-breakup source of α-particle emission in ^{13}C + ^{232}Th fission

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Introduction

α-particle multiplicity in heavy-ion fission is a promising tool to understand the fission dynamics [1]. A precise information about the sources of α-particle emission is very crucial. Dominantly, α particles in heavy-ion fission originate from three sources: (i) pre-scission (compound nucleus), (ii) post-scission (fission fragments), and (iii) near-scission emission (neck region). Recently, an enhancement in the α-particle multiplicity was observed in ^{12}C + ^{232}Th fission at a beam energy of 69-MeV [2]. It was attributed to transfer-breakup process as an extra source of α-particle emission. In case of ^{12}C + ^{232}Th reaction at 69-MeV, one α-particle transfer makes the ^{8}Be to be produced in coincidence with fission fragments (FFs). 2α breakup of the ^{8}Be leads to an additional α-particle multiplicity. Although experimental observations are consistent with this transfer-breakup source, still it is very important to confirm it through other reaction channels. In the present paper, we report the results obtained for α-particle multiplicity in ^{13}C (75 MeV) + ^{232}Th fission, where α-transfer would lead to ^{9}Be not the ^{8}Be.

Experimental Details and Data Analysis

The experiment was performed using ^{13}C beam of energy 75 MeV from BARC-TIFR 14-MV Pelletron accelerator facility at Mumbai. A self supporting metallic foil of ^{232}Th (1.6 mg/cm^2) was used as the target. FFs from the reaction were detected using a position sensitive gridded gas ionization telescope consisting of ΔE_{gas} and E_{gas} elements [3] and a newly developed hybrid detector telescope [4]. The anode corresponding to ΔE in position sensitive telescope (PST) was segmented into two parts of ΔE_1 and ΔE_2 to obtain position information using the charge division method [3]. The hybrid detector telescope also consists of ΔE_{gas} and E_{gas} elements for the FFs and additionally two CsI(Tl) detectors at the rear for the detection of light charged particles. The PST and hybrid detector telescopes were centered at 215° and 153° with respect to the beam direction with angular openings of ±15° and ±8.5°, respectively. The FFs were well separated from projectile like fragments (PLFs) in ΔE versus E plots in both the fission telescopes. The α particles emitted in the reaction were detected by six collimated CsI(Tl)-Si(PIN) [5] detectors including those two of the hybrid telescope. The CsI(Tl) detectors were placed at angles (θ_α) of 73°, 83°, 123°, 151°, 155°, and 255° with respect to

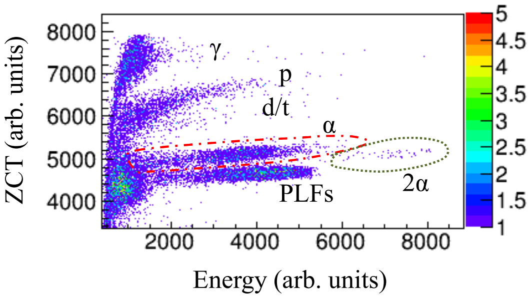

FIG. 1: A two dimensional plot of zero cross over (ZCT) versus energy from a CsI(Tl) detector at laboratory angle of 123° for different particles produced in the ^{13}C (75 MeV) + ^{232}Th reaction.

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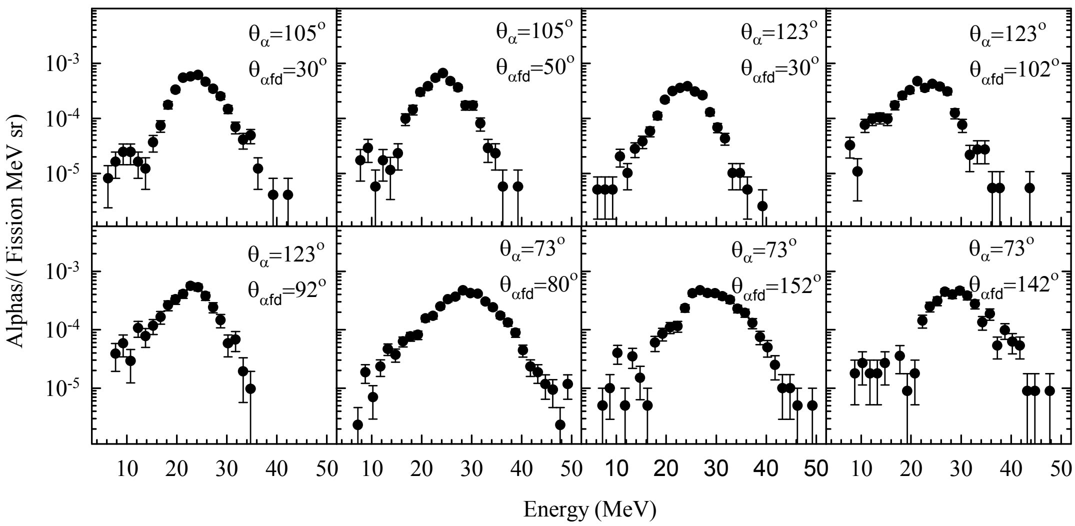

FIG. 2: The α-particle multiplicity spectra for different combination of laboratory angles of CsI(Tl) detectors with respect to beam direction, θ_α and detected fission fragments, $\theta_{\alpha\text{fd}}$.

the beam direction. The particle identification was achieved using pulse shape discrimination (zero cross over) technique as shown in Fig. 1 for laboratory angle of 123°.

During the data analysis, the 30° angular opening of the fission detector is divided into three equal parts. Thus, a total number of 22 combinations of α-particle spectra each having different relative angles with respect to fission fragments ($\theta_{\alpha\text{fd}}$) and the beam (θ_α), are obtained. After correcting for random coincidence, the normalized α-particle multiplicity spectra are obtained by dividing the coincidence spectra with total number of fission single events. Fig. 2 shows typical normalized α-particle multiplicity spectra for 8 combinations of θ_α and $\theta_{\alpha\text{fd}}$ out of 22. The CsI(Tl) detectors are energy calibrated using ^{228,229}Th source and in an in-beam experiment that made use of the discrete α-particle peaks corresponding to ^{20}Ne* states from ^{12}C (^{12}C, α) ^{20}Ne* reaction at ^{12}C beam energies of 25 MeV.

Results and Discussion

Each spectrum in the Fig. 2 includes contributions from different sources, namely, the compound nucleus, the two complementary fission fragments, and the near scission emission. A moving source model analysis is being carried out to disentangle the different contributions. In the preliminary analysis as evident from the two dimensional plot of Fig. 1, it appears that in contrast to expectations there are some 2α events in ^{13}C + ^{232}Th fission which may be attributed to 1nα transfer followed by ^{8}Be breakup. Quantitative results from moving source model analysis would be presented.

Acknowledgments

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