Study of transfer-breakup source of α-particle emission in ^{12}C (75-MeV) + ^{232}Th fission reaction

Y. K. Gupta[1],* D. C. Biswas[1], L. S. Danu[1], G. K. Prajapati[1], B. N. Joshi[1], S. Mukhopadhyay[1], B. V. John[1], S. Dubey[1,2], R. P. Vind[1], and S. Mukherjee[2]
[1]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and
[2]Physics Department, M.S. University of Baroda, Vadodara - 390002, INDIA

Introduction

α-particle emission multiplicity in heavy-ion induced fission is a promising tool to understand fission dynamics [1]. Precise information about the sources of α-particle emission is very crucial. Predominantly, α particles in heavy-ion fusion-fission originate from three sources: (i) pre-scission (compound nucleus), (ii) post-scission (fission fragments), and (iii) near-scission (neck region) emissions. 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 has been attributed to transfer-breakup process as an extra source of α-particle emission, where, one α-particle transfer makes the ^{8}Be to be produced in coincidence with fission fragments (FFs). Breakup of the ^{8}Be into 2α leads to an additional α-particle multiplicity. It would be of very much interest to confirm this transfer-breakup source by varying the beam energy. Primarily it stems out of the fact that with varying beam energy, the grazing angle of transfer reaction products changes very rapidly [3]. In the present paper, we report the results obtained for α-particle multiplicity in ^{12}C + ^{232}Th fission at a beam energy of 75-MeV.

Experimental Details and Data Analysis

The experiment was performed using ^{12}C (75 MeV) beam from BARC-TIFR 14-MV Pelletron accelerator facility at Mumbai. A self-supporting metallic foil of ^{232}Th ($\sim$1.6 mg/cm^2) was used as the target. FFs from the reaction were detected using a position sensitive ionization telescope (PST) consisting of ΔE_{gas} and E_{gas} elements [4], and a hybrid detector telescope [5]. The anode corresponding to ΔE in the PST was segmented into two parts; ΔE_1 and ΔE_2 to obtain position information using the charge division method [4]. The hybrid detector telescope consisted 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 145° and 153° with respect to the beam direction with angular openings of $\pm$15° and $\pm$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) [6] detectors including two those in the hybrid telescope. The CsI(Tl) detectors were placed at angles (θ_α) of 73°, 83°, 105°, 123°, 151°, and 155° with respect to the beam direction. The CsI(Tl) detectors were energy calibrated using ^{228,229}Th sources and also in-beam data as discussed in Refs. [1, 2].

During the data analysis, the 30° angular opening of the PST was divided into four equal parts for all the CsI(Tl) detectors excluding those two in the hybrid telescope where these were divided into two parts. Thus, a total number of 26 combinations of α-particle spectra, with each having different relative angles with respect to fission fragments ($\theta_{\alpha fd}$) and the beam (θ_α), were obtained. After correcting for random coincidences, the normalized α-particle multiplicity spectra were obtained by dividing the coincidence spectra with total number of fission single events. Fig. 1 shows typical normalized α-particle multiplicity spectra for 4 combinations of θ_α and $\theta_{\alpha fd}$ out of 26.

Results and Discussion

A moving source decomposition analysis (MSDA) has been carried out to disentangle the different components of α-multiplicity. One can refer to Refs. [1, 2] for the details on MSDA. The temperature and emission barrier for the compound nuclear and fragment emissions were determined to be 1.35, 20.35 MeV and 1.4, 13.5 MeV, respectively. It is ob-

*Electronic address: ykgupta@barc.gov.in

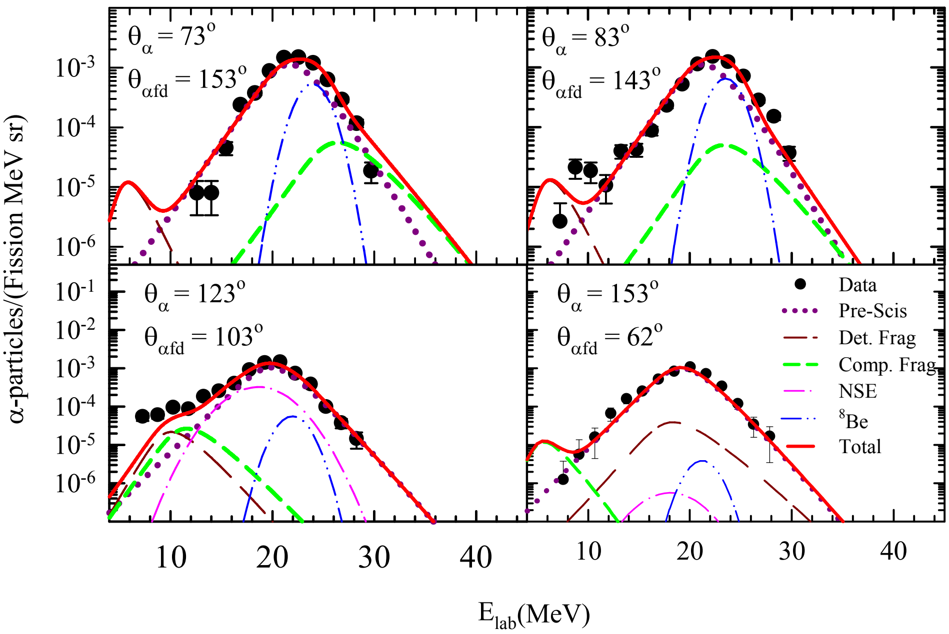

FIG. 1: The α-particle multiplicity spectra along with MSDA fits for different combination of laboratory angles of CsI(Tl) detectors with respect to the beam direction, θ_α and detected fission fragments, $\theta_{\alpha fd}$. The dotted, long-dashed, short-dashed, dash-dotted, and dash-double-dotted curves are contributions from compound nucleus, detected fission fragment, complementary fission fragment, near-scission emission, and ^{8}Be breakup, respectively. The solid curve in each panel indicates total contribution from five sources.

served that multiplicity spectra cannot be fitted without including the 2α breakup of ^{8}Be, which is produced in coincidence of fission fragments in α-transfer induced fission events. This transfer-breakup source was included in the MSDA using the formalism presented in Ref. [2], where Be transfer angular distribution was adopted from Ref. [3]. Different components of α-particle emission obtained from MSDA are shown in Fig. 1. The best fitted values of the pre-, post-, and near scission emissions multiplicities are α_{pre} = (6.1 ±0.3)×10^{-3}, α_{post}= (0.15 ±0.04)×10^{-3}, α_{nse} =(0.60±0.21)×10^{-3}. α_{pre} follows the $E_{CN}^{2.3}$ systematics, similarly, the fraction of near scission multiplicity has been observed to be 10% which is also consistent with systematics [1]. The kinetic energy of the ^{8}Be (ϵ_{br}) and its breakup multiplicity (α_{br}) have been obtained to be 46.6 ± 0.2 MeV and (0.93 ± 0.15)×10^{-3}, respectively. ϵ_{br} is very much consistent with two-body kinematics. It is interesting to compare the fraction of α_{br} with respect to the total multiplicity obtained in the present work at 75 MeV beam energy with that of 69-MeV. This fraction is 12.5% at 75-MeV and 25% at 69-MeV. Sharp reduction in the breakup multiplicity with increasing beam energy is consistent with earlier report [3], where it was shown that the transfer fraction of the total reaction cross section reduces quite noticeably with increasing beam energy.

It is therefore concluded that in fission reactions, induced by α-cluster projectiles such as the ^{12}C, transfer-breakup remains an inevitable source of α-particle emission. Therefore, while choosing particle emission as a probe to study the fission dynamics, sources other than the fusion-fission process must be examined as potential candidates for particle emission.

References

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