Observation of ^{8}Be breakup in α-particle multiplicities for ^{12}C + ^{232}Th system

Y. K. Gupta,* D. C. Biswas, B. K. Nayak, B. V. John, R. K. Choudhury, and A. Chatterjee
Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA

Introduction The α particles measured in coincidence with fission fragments (FFs) have been used as a probe to understand the fission dynamics. The different stages of α particle emission in the fusion-fission process have been identified such as from the composite system (pre-scission), the accelerated fission fragments (post-scission), and the near scission emission (NSE) [1]. Recently we have carried out measurements of α-particle spectra coincidence with FFs for ^{11}B, ^{12}C+^{232}Th systems. It is observed that α-particle multiplicities corresponding to various sources for ^{11}B+^{232}Th system follow certain systematic behavior with earlier measured heavy-ion data [1]. But in case of ^{12}C+^{232}Th reaction, results deviates significantly from the systematics. In the present work we have investigated the possible other sources of α-particle emission to understand the anomalous results in the ^{12}C+^{232}Th reaction.

Experimental details and data analysis

The experiment was performed using ^{12}C beam of 69 MeV at BARC-TIFR Pelletron facility at Mumbai. The α-particles were measured by using three CsI(Tl) detectors kept at laboratory angles of 75^{o}, 105^{o}, and 135^{o} with respect to the beam direction. FFs were detected using a position sensitive gridded gas ionization chamber [2]. The α-particle multiplicity spectra were obtained at various relative angles with respect to FF direction, typical spectra are shown in Fig. 1. Detailed experimental information can be obtained from the Ref. [1].

The inclusive α-particle multiplicity spectra are first fitted including only four sources

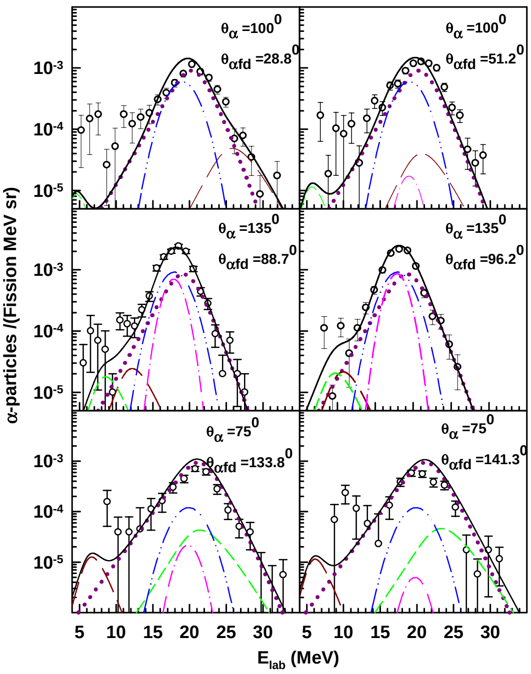

FIG. 1: The α-particle multiplicity spectra along with fits of moving source model for different combination of laboratory angles of CsI(Tl) detectors with respect to beam direction, θ_α and detected fission fragments, $\theta_{\alpha fd}$. The solid curve indicates total contribution from four sources.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

(compound nucleus, both the fission fragments, and the NSE) using moving source model [1]. The temperatures and emission barriers for pre- and post scission sources used in the moving source model are 1.18, 20.3 MeV and 1.25, 13.5 MeV, respectively. The best fitted values of the parameters are found to

*Electronic address: ykgupta@barc.gov.in

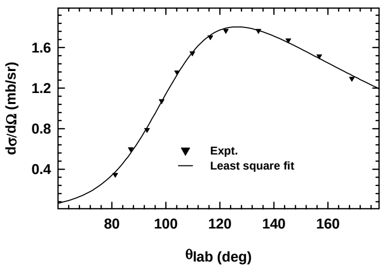

FIG. 2: Angular distribution of ^{9}Be for ^{12}C+^{232}Th system from Ref. [3]. Solid curve represent the least square fit (see text).

be α_{pre} = (5.4 ± 0.2)×10^{-3}, α_{post} = (0.13 ± 0.04)×10^{-3}, α_{nse} = (3.1 ± 0.2)×10^{-3}, ϵ_p = 19.25 ± 0.1 MeV, σ_ϵ = 1.66 ± 0.1 MeV, and σ_θ = 17.9^o ± 1.1^o corresponding to minimum χ^2/(degree of freedom) value of 3.71.

The NSE multiplicity for the present system is significantly larger than ^{11}B+^{232}Th system for which α_{nse} is (0.5 ± 0.05)×10^{-3} though the parameters such excitation energy, angular momentum, and fissility (x) are similar for both the systems. The fraction of NSE multiplicity (α_{nse}) to total pre-scission α-particle multiplicity (α_{pre}+α_{nse}) for the present system is ∼ 35.2% which is significantly off from the heavy-ion systmatics, where it is nearly same at around 10% for variety of compound nuclear systems [1]. This observation suggests about the presence of some other source in ^{12}C+^{232}Th reaction apart from earlier mentioned four sources.

Possible source of excess α particles The excess α-particles of energies around 20 MeV are emitted perpendicular to the scission axis and at backward angles with respect to beam direction. Due to α cluster structure of ^{12}C, the α particles may originate from other mechanisms such as ^{8}Be breakup followed by transfer induced fission. Energy and angular distributions of ^{9}Be for the present system at similar beam energy as the present one, has been measured earlier [3]. The α-transfer grazing angle for ^{12}C (69 MeV)+^{232}Th system is at 117^o therefore, angular distribution of ^{9}Be dominates at the backward angles as shown in Fig. 2. Similar to NSE α-particles, energy distribution of ^{9}Be is Gaussian shaped and peak energy is around 40 MeV. If it is assumed that energy and angular distributions of ^{9}Be are similar to ^{8}Be, ^{8}Be breakup followed by α-transfer induced fission is a possible source of the excess α-particles.

We have included ^{8}Be as another source in the moving source model analysis. The angular distribution of ^{9}Be as shown in Fig. 2 is fitted with a polynomial to be used in the moving source analysis. Gaussian shaped energy distribution for ^{8}Be has been used. The α-particles produced from ^{8}Be breakup are assumed to be moving along the direction of ^{8}Be. In the moving source fit, the peak energy ϵ_{br} of ^{8}Be, standard deviation of energy distribution (σ_{br}) and multiplicity corresponding to the breakup source (α_{br}) for α-particles are kept as free parameters. Typical fitted spectra for the individual source and after summing are shown in Fig. 1. Best fitted values of the parameters are found to be α_{pre} = (5.4 ± 0.2)×10^{-3}, α_{post} = (0.13 ± 0.04)×10^{-3}, α_{nse} = (0.88± 0.2)×10^{-3}, ϵ_p = 19.25 ± 0.1 MeV, σ_ϵ = 1.34 ± 0.2 MeV, σ_θ = 13.5^o ± 3^o α_{br} = (2.1 ± 0.1)×10^{-3}, ϵ_{br} = 38.8 ± 0.3 MeV, and σ_{br} = 1.95 ± 0.2 MeV, corresponding to minimum χ^2/(degree of freedom) value of 3.8.

Thus, by including ^{8}Be as a source in the moving source model analysis, fraction of NSE multiplicity (α_{nse}) to total pre-scission α-particle multiplicity (α_{pre}+α_{nse}+ α_{br}) reduces from (35.2 ± 3.5)% to (14 ± 3.2)% and follows the heavy-ion systematics. The peak energy (ϵ_{br}) extracted from the analysis is consistent with the kinematics including optimum Q - value (Q_{opt}). In conclusion, there is a possible significant contribution from ^{8}Be breakup to the α-particle multiplicity for ^{12}C+^{232}Th system. Systematics of α_{pre} and α_{nse} will be presented.

References

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