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Enhanced α-particle emission in $^{12}\mathrm{C} + {}^{232}\mathrm{Th}$ fission due to the transfer-breakup process

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The α-particle energy spectra have been measured in coincidence with fission fragments (FFs) in the ^{12}C (69 MeV) + ^{232}Th reaction at various relative angles with respect to FF direction. The spectra were fitted with a moving-source model calculation to extract the multiplicities corresponding to different emission stages of the fusion-fission process. The fitted value for the near-scission emission component appears anomalously enhanced in comparison to the recently developed systematics for prescission and near-scission α-particle multiplicities in heavy-ion reactions. A high-energy component corresponding to the summed energy of two α particles is observed, which suggests breakup of ^{8}Be into two α particles in α-transfer-induced fission coincidence events. The ^{8}Be breakup fits the 2α-particle multiplicity spectra very well at different laboratory angles. When ^{8}Be breakup is included exclusively as a source of α-particle emission in the moving-source analysis along with prescission, postscission, and near-scission emission, the results follow the systematics of heavy-ion data very well. The present results clearly indicate an extra source of α-particle emission due to ^{8}Be breakup in α-transfer-induced fission reactions.

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I. INTRODUCTION

Measurement of α particles in coincidence with fission fragments (FFs) has been used as a probe to understand fission dynamics [1–4]. In particular, α-particle emission near the scission configuration is very sensitive to fission dynamics [1]. In low-energy fission (thermal neutron-induced fission, photofission, and spontaneous fission) α-particle emission near the scission point is the dominant mode of charged particle emission [5–7]. However, in the case of heavy-ion-induced fission, α particles are emitted at various stages of the fusion-fission process such as from the composite system (prescission), accelerated fission fragments (postscission), and near-scission emission (NSE) [1–3]. Moving-source analysis is employed in heavy-ion-induced fission to disentangle the contributions of different sources to the inclusive α-particle multiplicity.

In a recent work, a systematic study has been carried out for prescission and near-scission α-particle multiplicities (α_{pre} and α_{nse}) as a function of Z^2/A and excitation energy of the compound nuclei (E_{CN}) for various target-projectile systems [1]. It is seen that α_{pre} values when normalized to $E_{\mathrm{CN}}^{2.3}$ show a systematic linearly increasing trend with α-particle-emission Q value (Q_α). The fraction of α_{nse} is observed to be nearly the same at around 10% of the total prescission multiplicity. In the systematics, however, it is found that reactions induced by ^{12}C and ^{16}O projectiles show somewhat larger average α_{nse}. In the work by Augustyniak *et al.* [8] for the ^{12}C (85 MeV) + ^{232}Th system, where the prescission and near-scission components were not separated in the analysis, the reported inclusive prescission α-particle multiplicity is much larger than that for neighboring systems. These anomalies need to be addressed, as α_{pre} and α_{nse} values are very important for deriving information about the collective fission dynamics, in particular for understanding nuclear viscosity [1].

At beam energies near the Coulomb barrier, the transfer-induced fission cross section becomes important [9–11]. In the case of α-cluster projectiles (such as ^{6,7}Li, ^{6}He, and ^{12}C), a portion of coincident α particles may also originate from transfer-induced fission events. In such cases, the projectile-like fragment (PLF) can be an α particle itself or it can decay subsequently to an α particle. The α particles produced from transfer events exhibit a bell-shaped angular distribution having a maximum near the grazing angle. Thus, depending on entrance channel parameters of the heavy-ion reaction, the transfer processes can also contribute to the inclusive α-particle multiplicity, adding to the complexity of the analysis of experimental data.

In the present work, α-particle spectra have been measured in coincidence with FFs in the $^{12}\mathrm{C} + {}^{232}\mathrm{Th}$ reaction at a beam energy of 69 MeV at various relative angles between FF and α-particle emission direction. The energy spectra are fitted with a moving-source model to extract the multiplicities corresponding to different emission stages of the fusion-fission process. Compared with systematic heavy-ion data an enhanced value of α_{nse} is observed [1], indicating the presence of another source of α-particle emission in addition to prescission, postscission, and near-scission emission. At the same time, in the two-dimensional particle identification plot, a high-energy component of varying intensity depending on laboratory angle is also observed; this corresponds to the summed energy of two α particles entering the particle detector simultaneously (2α events from ^{8}Be breakup). From these circumstantial evidences and also from the transfer product angular distributions measured earlier for the present reaction [12], we have identified the new source of enhanced α_{nse} as due to a single α particle entering the detector from ^{8}Be transfer product breakup. By accounting for this source in the analysis, the extracted α_{pre} and α_{nse} are in agreement with the recent heavy-ion systematics [1].

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The present paper has been organized in the following way. The experimental setup is described in Sec. II. Section III contains the data analysis and results. The transfer-breakup process contributing to the excess α-particle multiplicity is discussed in Sec. IV. Finally, a summary and conclusions are presented in Sec. V.

II. EXPERIMENTAL DETAILS

The experiment was performed using a 69-MeV ^{12}C beam from the BARC-TIFR 14-MV Pelletron accelerator facility at Mumbai. A self-supporting metallic foil of ^{232}Th with a thickness of 1.6 mg/cm^2 was used as a target. FFs from the reaction were detected using a position-sensitive gridded gas ionization chamber consisting of ΔE_{gas} and E_{gas} elements [13]. The ionization chamber was centered at 145° with respect to the beam direction and subtended a solid angle of $\sim$97 msr with an angular opening of $\sim$30°. The FFs were well separated from PLFs in a ΔE versus E plot. The anode corresponding to ΔE was segmented into two parts of ΔE_1 and ΔE_2 to obtain position information using the charge division method [13].

The α particles emitted in the reaction were detected by three collimated CsI(Tl)-Si(PIN) detectors. The CsI(Tl) detectors were placed at angles (θ_α) of 75°, 100°, and 135° with respect to the beam direction. Each of these detectors had a solid angle of $\sim$18 msr and an angular opening of $\pm 3.5°$. Particle identification was achieved using a pulse shape discrimination (zero crossover) technique. The γ rays, light charged particles (p, d, t, and α), and PLFs were well separated in the two-dimensional plot of zero crossover versus pulse height, as shown in Fig. 1(a). The time correlation between light particles and FFs was recorded through a time-to-amplitude converter (TAC). The coincidence TAC spectrum between α particles and FFs is shown in Fig. 1(b). The event trigger for data collection was generated with the fission events from the gas detector. The CsI(Tl) detectors were energy calibrated using a ^{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 the ^{12}C (^{12}C, α) ^{20}Ne* reaction at ^{12}C beam energies of 25 and 40 MeV. The energy threshold for α-particle identification was $\sim$5 MeV.

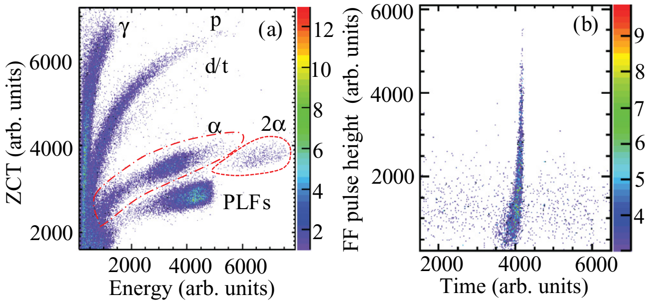

FIG. 1. (Color online) (a) A two-dimensional plot of zero crossover (ZCT) vs energy from a CsI(Tl) detector at a laboratory angle of 135° for different particles produced in the ^{12}C (69 MeV) + ^{232}Th reaction. (b) The fission fragment (FF) pulse height from a gas ionization chamber vs the time correlation between α particles and FFs (see text).

Along the α-particle band, a high-energy component of varying intensity depending on θ_α is also observed, as depicted in the Fig. 1(a) for $\theta_\alpha = 135°$. In the case of CsI(Tl) detectors, the rise time for a given particle increases with particle energy [14]. In the present measurement the high-energy component is observed to have a rise time similar to that for the lower energy α particles, suggesting that it is due to the summed energy of two lower energy α particles entering the detector simultaneously. The origin of these 2α events is discussed later.

III. DATA ANALYSIS AND RESULTS

The 30° angular opening of the fission detector is divided into four equal parts during the off-line data analysis. Thus, a total number of 12 combinations of α-particle spectra, each having different relative angles with respect to fission fragments ($\theta_{\alpha fd}$) 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 by the total number of fission single events. Figure 2 shows typical normalized α-particle multiplicity spectra for 4 combinations of θ_α and $\theta_{\alpha fd}$ out of 12.

The spectra are fitted simultaneously by the moving-source model including the usual four sources, namely, the compound nucleus, the two complementary fission fragments, and the near-scission emission. In the moving-source analysis, symmetric mass division is assumed for the fragments and mean values of fragment mass and charge have been used. The α particles are assumed to be emitted isotropically in the rest frames of prescission and postscission sources. The α-particle energy spectra in the rest frames of prescission and postscission sources are calculated using the constant-temperature level-density formula with the expression [1,2]

$$n(\epsilon) \sim \alpha_p \epsilon \sigma(\epsilon) \exp\left(\frac{-\epsilon}{T}\right), \qquad (1)$$

where α_p and ϵ are the multiplicity and energy of the emitted α particles in the rest frame, T is the temperature of the source, and $\sigma(\epsilon)$ is the inverse reaction cross section. The inverse reaction cross section $\sigma(\epsilon)$ is calculated using Wong's expression [1,15],

$$\sigma(\epsilon) = \frac{\hbar\omega R_0^2}{2\epsilon} \ln\left\{1 + \exp\left[\frac{2\pi}{\hbar\omega}(\epsilon - V_B)\right]\right\}, \qquad (2)$$

where $\hbar\omega$ is the curvature of the fusion barrier for angular momentum $\ell = 0$. V_B is the emission barrier height of the α particles and is calculated using the expression [1,16]

$$V_B = \frac{1.44 Z_P (Z_S - Z_P)}{r_0\left[A_P^{1/3} + (A_S - A_P)^{1/3}\right] + \delta} \text{ MeV}, \qquad (3)$$

where A_P, Z_P and A_S, Z_S are the mass and charge of the α particle and emitting source, respectively. The value of r_0 is taken to be 1.45 fm [1,2]. δ is a factor which takes into account the reduction in emission barrier due to deformation effects and it is

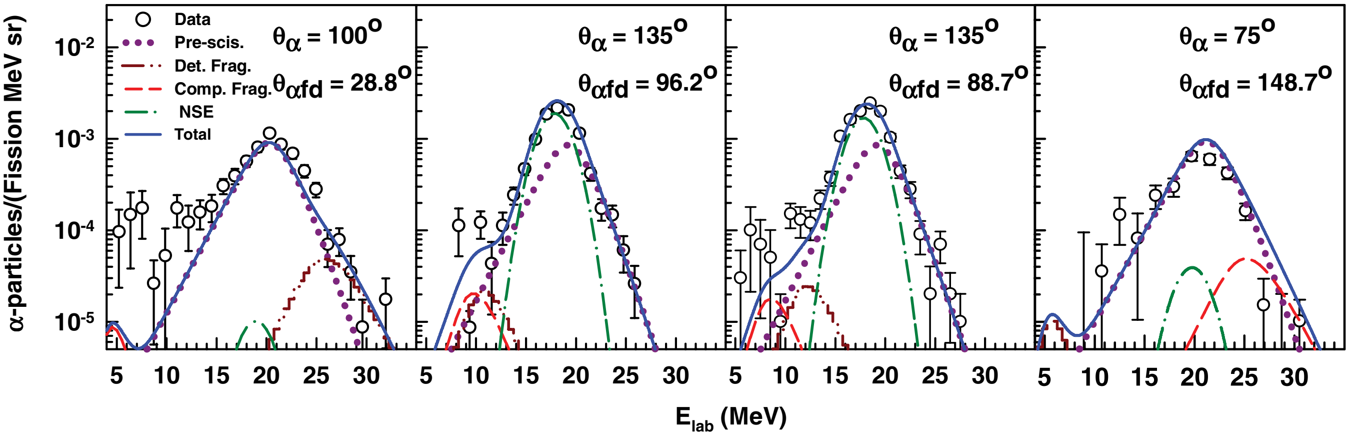

FIG. 2. (Color online) The α-particle multiplicity spectra along with fits of the moving-source model for different combinations of laboratory angles of CsI(Tl) detectors with respect to the beam direction, θ_α, and detected fission fragments, $\theta_{\alpha fd}$. The dotted, dash-dot-dot, short-dashed, and dash-dot curves are contributions from compound nucleus, detected fission fragment, complementary fission fragment, and near-scission emission, respectively. The solid curve in each panel indicates the total contribution from the four sources.

taken to be 2.0 fm for the compound nucleus [1,16] and 0.4 fm for the fission fragment [1,4]. Thus the effective emission barrier heights (V_B) calculated for the compound nucleus and the fission fragment are 20.3 and 13.5 MeV, respectively.

The values of $\hbar\omega$ for prescission and postscission sources are determined from the fusion excitation functions corresponding to ^{4}He + ^{237}Np [17] and ^{4}He + ^{59}Co [18] reactions, respectively, using the computer code CCFUS [19]. Thus, $\hbar\omega_{\text{pre}}$ and $\hbar\omega_{\text{post}}$ values used in the moving-source model for prescission and postscission sources are 4.8 and 4.0 MeV, respectively [1]. The temperatures T_{pre} and T_{post} are calculated using the relation $T = \sqrt{E_X/a}$, where E_X is the intrinsic excitation energy of the source and a is the level-density parameter, which is taken as $A/11$ for the compound nucleus and $A/7$ for the fission fragment [1,2]. T_{pre} is scaled down by a factor of 11/12 to account for multistep evaporation [1,2]. Thus T_{pre} and T_{post} values are calculated to be 1.18 and 1.25 MeV, respectively. The energy and angular distributions for NSE are assumed to be Gaussian in the rest frame as given by the expression [1,2]

$$n(\epsilon,\theta) \sim \alpha_{\text{nse}} \exp\left[\frac{-(\epsilon-\epsilon_p)^2}{2\sigma_\epsilon^2}\right] \exp\left[\frac{-(90^\circ-\theta)^2}{2\sigma_\theta^2}\right], \quad (4)$$

where α_{nse}, ϵ_p, θ, σ_ϵ, and σ_θ are the α-particle multiplicity of near-scission emission, peak (or mean) energy, relative angle of α particles with respect to the scission axis, and standard deviations of the energy and the angular distributions, respectively, in the rest frame.

The α-particle spectra calculated in the rest frames of the four sources are converted to laboratory frames using the appropriate Jacobians and finally summed to fit the measured spectra. In the moving-source fit, the parameters T_{pre}, T_{post}, V_B^{pre}, and V_B^{post} are kept fixed whereas the prescission and postscission multiplicities (α_{pre} and α_{post}) and the parameters related to NSE are kept as free parameters. The mean fragment velocities are determined using Viola's systematics [20] for the total kinetic energy released in the fission process. The fitted spectra for the individual source and after summing are shown in Fig. 2. The best-fit values of the parameters are found to be $\alpha_{\text{pre}} = (5.4 \pm 0.2) \times 10^{-3}$, $\alpha_{\text{post}} = (0.13 \pm 0.04) \times 10^{-3}$, $\alpha_{\text{nse}} = (3.1 \pm 0.2) \times 10^{-3}$, $\epsilon_p = 19.25 \pm 0.10$ MeV, $\sigma_\epsilon = 1.66 \pm 0.10$ MeV, and $\sigma_\theta = 17.9^\circ \pm 1.1^\circ$, corresponding to a minimum χ^2/(degree of freedom) value of 3.71.

For the present system, α_{pre} is consistent with recently developed heavy-ion systematics, where it is established that α_{pre} values when normalized to $E_{\text{CN}}^{2.3}$ show a linearly increasing trend with α-particle-emission Q value [1]. The NSE multiplicity for the present system is significantly larger than that for the ^{11}B + ^{232}Th system having similar fissility, excitation energy, and angular momentum for which α_{nse} is $(0.5 \pm 0.05) \times 10^{-3}$ [1]. The fraction of NSE multiplicity (α_{nse}) to total prescission α-particle multiplicity ($\alpha_{\text{pre}} + \alpha_{\text{nse}}$) for the present system is ~36%, which is also significantly off from the heavy-ion systematics, where it is nearly the same at around 10% for a variety of compound nuclear systems [1]. These observations provide a strong indicator that there is an admixture of some other source of α-particle emission to the NSE component in the ^{12}C + ^{232}Th reaction apart from the earlier mentioned four conventional sources involved in the fusion-fission process.

IV. SOURCE OF EXCESS α PARTICLES

The enhanced α_{nse} value in the present reaction indicates that excess α particles of energies of around 20 MeV are emitted dominantly perpendicular to the detected FF and at backward angles with respect to the beam direction. The observation of the 2α events, as shown in Fig. 1(a), suggests that, due to the α-cluster structure of ^{12}C, excess α particles may originate from ^{8}Be breakup following α-transfer-induced fission coincidence events. The folding angle between the two α particles produced from ^{8}Be breakup will depend on their relative energy (E_{rel}) and kinetic energies [21,22]:

$$\cos\theta_{12} = \frac{E_{\alpha 1} + E_{\alpha 2} - 2E_{\text{rel}}}{2\sqrt{E_{\alpha 1}E_{\alpha 2}}}, \quad (5)$$

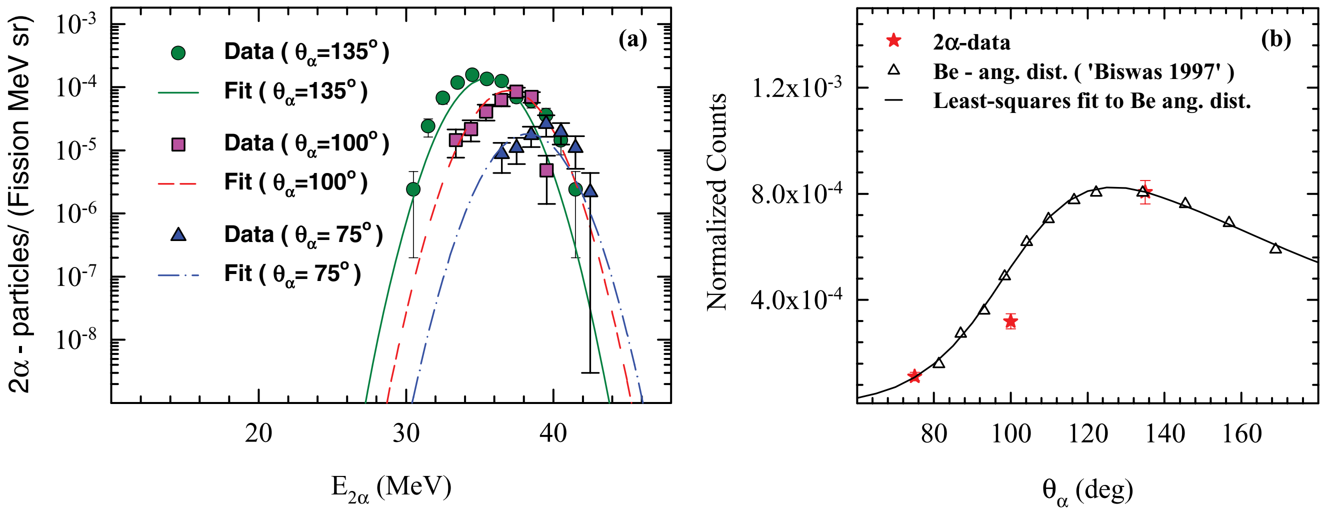

FIG. 3. (Color online) (a) The 2α-particle multiplicity spectra produced from ^{8}Be breakup at three laboratory angles (θ_α), where different lines are the moving-source fits. (b) The energy-integrated 2α-particle yield as a function of θ_α (stars) and (b) the experimental data (triangles, from [12]) and least-squares fit (solid line) of the Be angular distribution after normalizing with the 2α-particle yield at $\theta_\alpha = 135^\circ$ (see text).

where $E_{\alpha 1}$ and $E_{\alpha 2}$ are the kinetic energies of the α particles produced from ^{8}Be breakup. E_{rel} is calculated using the relation $E_{\text{rel}} = E^* + Q_{\text{BU}}$, where E^* is the excitation energy of the state from where breakup occurs and Q_{BU} is the breakup Q value, which is 92 keV [22]. For a given value of the ^{8}Be kinetic energy (E_{Be}), θ_{12} varies from 0° to a certain maximum value, θ_{12}^{max}, depending on E_{rel}. For instance, for $E_{\text{Be}} = 40$ MeV, θ_{12}^{max} varies from 5.5° to 12.8° in going from $E_{\text{rel}} = 92$ to 500 keV. Therefore, in some of the coincidence events the angular acceptance of each CsI detector ($\pm 3.5^\circ$) allows both the α particles produced from ^{8}Be breakup to reach the detector simultaneously. The high-energy 2α events shown in Fig. 1(a) correspond to these smaller folding angle events.

In order to understand the role of ^{8}Be breakup in the fission observables, the normalized 2α-particle multiplicity spectra are obtained at first by dividing the 2α-particle coincidence spectra by the total number of fission single events. The normalized 2α-particle multiplicity spectra are shown in Fig. 3(a) at three laboratory angles (θ_α). In Fig. 3(b), the energy-integrated 2α-yield is shown as a function of θ_α. Earlier, angular distributions of Be transfer products produced in the $^{12}\text{C} + {}^{232}\text{Th}$ reaction have been measured at the same beam energy as in the present one [12]. Since the angular distribution of Be transfer products peaks around the grazing angle ($\sim 120^\circ$) [12], the angular distribution of 2α-yield is also expected to dominate at similar backward angles. The 2α-yield angular distribution observed in the present work is consistent with that for Be, as seen in Fig. 3(b), where the Be angular distribution (from Ref. [12]) is plotted after normalizing at $\theta_\alpha = 135^\circ$.

These 2α-particle multiplicity spectra shown in Fig. 3(a) are fitted simultaneously with the moving-source calculation using the ^{8}Be breakup as a source of 2α-particle emission. For simplicity, the 2α particles are assumed to be moving together along the direction of ^{8}Be, so that the angular distribution of the 2α particles follows that of ^{8}Be. The following expression for the energy and angular distributions of the 2α particles is used in the rest frame:

$$n(\epsilon^{2\alpha}, \theta') \sim \alpha_{\text{br}}^{2\alpha} W_{\text{c.m.}}(\theta) \exp\left[\frac{-(\epsilon^{2\alpha} - \epsilon_{\text{br}}^{2\alpha})^2}{2\sigma_{\text{br}}^{2\alpha\,2}}\right], \tag{6}$$

where $\epsilon^{2\alpha}$, $\alpha_{\text{br}}^{2\alpha}$, $\epsilon_{\text{br}}^{2\alpha}$, and $\sigma_{\text{br}}^{2\alpha}$ are the 2α-particle summed energy, multiplicity, summed peak energy, and standard deviation of the summed energy distribution, respectively, in the rest frame. $W_{\text{c.m.}}(\theta')$ is the angular distribution of ^{8}Be in the rest frame, which is calculated using the relation $W_{\text{c.m.}}(\theta') = G(x, \theta_L) W_L(\theta_L)$, where $G(x, \theta_L)$ is the Jacobian and x is the ratio of velocities of the compound nucleus to that of ^{8}Be in the center-of-mass frame. $W_L(\theta_L)$ is the angular distribution of ^{8}Be in the laboratory frame at an angle of θ_L with respect to the beam direction. In the moving-source analysis, $W_L(\theta_L)$ is obtained by using the parameters from least-squares fitting of the experimental angular distribution of Be, as shown in Fig. 3(b). The 2α-particle spectra calculated in the rest frame are converted to the laboratory frame using the appropriate Jacobian to fit the measured spectra. The fitted spectra at different laboratory angles are shown in Fig. 3(a). The best-fit values of the parameters are found to be $\alpha_{\text{br}}^{2\alpha} = (2.6 \pm 0.3) \times 10^{-4}$, $\epsilon_{\text{br}}^{2\alpha} = 37.6 \pm 0.2$ MeV, and $(\sigma_{\text{br}}^{2\alpha}) = 1.6 \pm 0.2$ MeV, corresponding to a minimum χ^2/(degree of freedom) value of 4.1. The value of $\epsilon_{\text{br}}^{2\alpha}$ extracted from the analysis is close to the calculated center-of-mass kinetic energy of ^{8}Be from kinematics including the optimum Q value (Q_{opt}) [12].

With the above values for the ^{8}Be breakup process, we carried out a reanalysis of the α-particle multiplicity spectra including five sources in the moving-source model: the compound nucleus, both fission fragments, the NSE, and the ^{8}Be breakup. When only one of the α particles produced from the ^{8}Be breakup enters the CsI detector, its kinetic energy E_α overlaps with that of the α particles produced from prescission, postscission, and near-scission emission. For simplicity in the

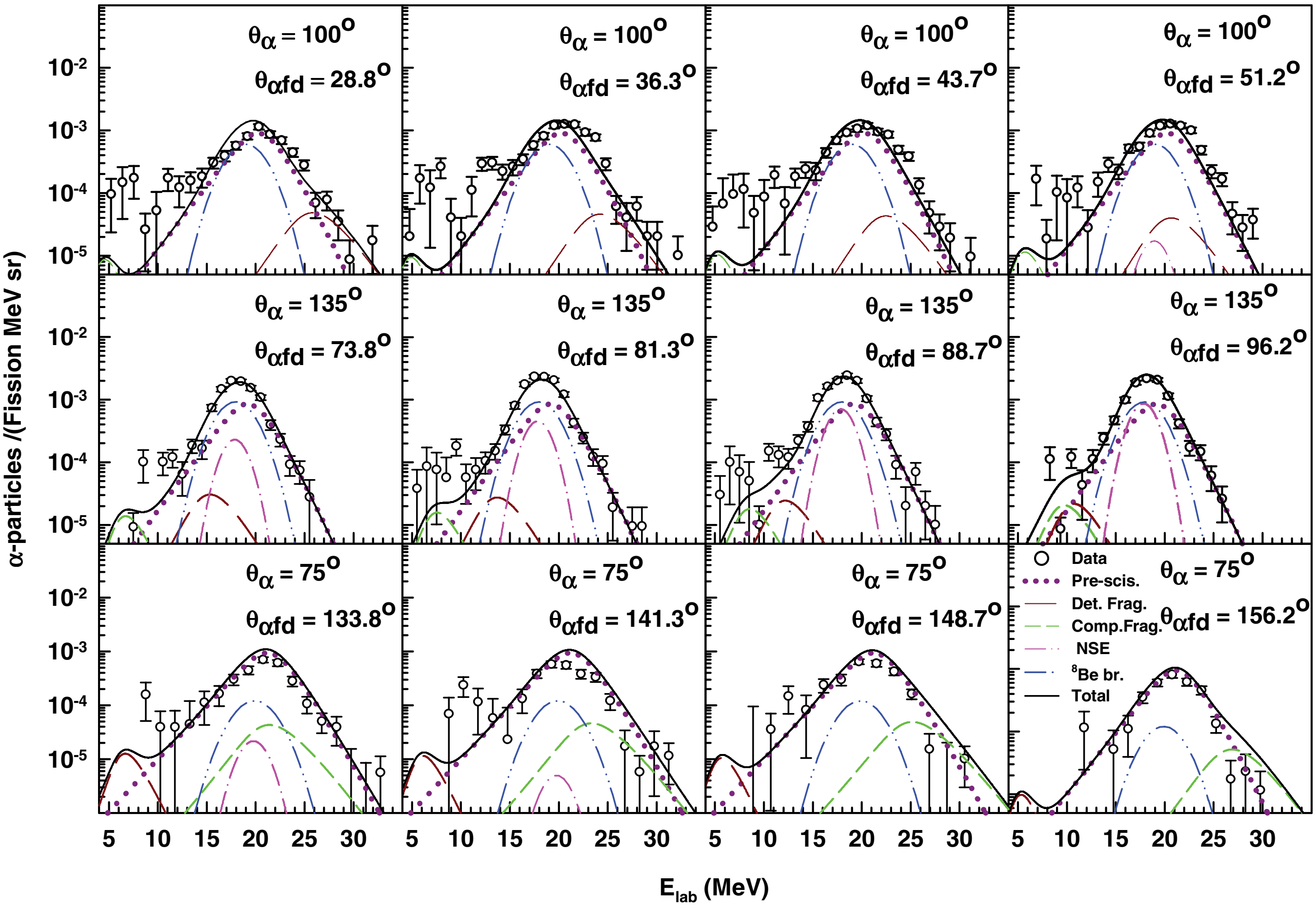

FIG. 4. (Color online) The α-particle multiplicity spectra along with fits of the moving-source model for different combinations of laboratory angles of CsI(Tl) detectors with respect to the beam direction, θ_α, and detected fission fragments, $\theta_{\alpha fd}$. The dotted, long-dashed, short-dashed, dash-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. The solid curve indicates the total contribution from all five sources.

moving-source fit, $E_{\rm rel}$ is neglected so that, at a given θ_α, $E_\alpha = \frac{1}{2}E_{\rm Be}$. The energy and angular distributions of one of the two breakup α particles are calculated in the rest frame of the compound nucleus by using the corresponding expression of Eq. (6). In the moving-source fit, except for the parameters $T_{\rm pre}$, $T_{\rm post}$, $V_B^{\rm pre}$, and $V_B^{\rm post}$, which are set to old values, all other parameters are kept as free parameters. The fitted spectra for the individual source and after summing are shown in Fig. 4. The best-fit values of the parameters are now obtained as $\alpha_{\rm pre} = (5.4 \pm 0.2) \times 10^{-3}$, $\alpha_{\rm post} = (0.13 \pm 0.04) \times 10^{-3}$, $\alpha_{\rm nse} = (0.88 \pm 0.20) \times 10^{-3}$, $\epsilon_p = 19.25 \pm 0.10$ MeV, $\sigma_\epsilon = 1.34 \pm 0.20$ MeV, $\sigma_\theta = 13.5^\circ \pm 3.0^\circ$, $\alpha_{\rm br} = (2.1 \pm 0.1) \times 10^{-3}$, $\epsilon_{\rm br} = 19.4 \pm 0.2$ MeV, and $\sigma_{\rm br} = 1.95 \pm 0.20$ MeV, corresponding to a minimum χ^2/(degree of freedom) value of 3.8. The errors quoted in the extracted parameters include only statistical uncertainties. Thus, by including ^{8}Be as a source in the moving-source analysis, only the value of $\alpha_{\rm nse}$ has changed significantly, whereas other values are nearly unchanged from the earlier four-source analysis. The fraction of NSE multiplicity ($\alpha_{\rm nse}$) to total prescission α-particle multiplicity ($\alpha_{\rm pre} + \alpha_{\rm nse}$) is reduced from $(36.4 \pm 3.2)\%$ to $(14.0 \pm 3.8)\%$ and follows the heavy-ion systematics [1]. The peak energy ($\epsilon_{\rm br}$) extracted from the analysis is also nearly one-half of the value of $\epsilon_{\rm br}^{2\alpha}$.

It is to be noted here that the fraction of 2α events is observed to be ~12% of single α-particle events generated from ^{8}Be breakup in coincidence with fission fragments. A Monte Carlo calculation is carried out for the present experimental geometry, where 10^5 ^{8}Be nuclei are distributed in the reaction plane according to the measured angular distribution of Be (from Ref. [12]) and a $\pm 3.5^\circ$ azimuthal random spread is allowed. It is seen that for ^{8}Be center-of-mass kinetic energy $E_{\rm Be}^{\rm c.m.} = 38$ MeV and $E_{\rm rel} = 92$ keV, the fraction of 2α events is 27.2% of single α-particle events. A larger calculated fraction of 2α events in comparison to the measured value indicates the involvement of higher values of $E_{\rm rel}$ in the reaction, as pointed out earlier also in related works [21,22]. In those works, it is shown that the $E_{\rm rel}$ spectra have peaks at 92 keV with about half of all the ^{8}Be breakup yield and a broad continuum in the higher $E_{\rm rel}$ region with the remainder of the breakup yield. The sharp increase of folding angle with $E_{\rm rel}$ as mentioned earlier would result in lowering of the measured fraction of 2α events if higher values of $E_{\rm rel}$ are involved in the reaction.

V. SUMMARY AND CONCLUSION

In summary, we have measured the α-particle energy spectra in coincidence with FFs in the ^{12}C (69 MeV) + ^{232}Th reaction at different relative angles with respect to FF direction. The α-particle multiplicity spectra are fitted with the moving-source model to determine prefission and postfission components of α-particle emission. In this analysis, the near-scission multiplicity is observed to be anomalously enhanced in comparison to the heavy-ion systematics, indicating the presence of another source of α-particle emission in the ^{12}C + ^{232}Th reaction in addition to prescission, postscission, and near-scission emission stages. In the two-dimensional particle identification plot, a high-energy component corresponding to the summed energy of two α particles is observed. The observation of these 2α events suggests that, due to the α-cluster structure of ^{12}C, there is a significant component of ^{8}Be breakup followed by α-transfer-induced fission events. Since the α-transfer grazing angle for the ^{12}C (69 MeV) + ^{232}Th system is at ~120°, the intensity of these 2α events dominates at the backward angles with respect to the beam direction. The analysis of ^{8}Be breakup explains very well the 2α-particle multiplicity spectra at different laboratory angles. For the first time, a new component corresponding to the transfer-breakup process has been considered in the moving-source model to disentangle the different contributions to the inclusive α-particle multiplicity. Reanalysis of the α-particle multiplicity spectra including five sources in the moving-source model—the compound nucleus, both fission fragments, the NSE, and ^{8}Be breakup—has been carried out. The results obtained for prescission and near-scission multiplicities follow the recently developed heavy-ion systematics very well. The present results clearly indicate a possible extra source of α-particle emission in the α-cluster-projectile-induced fusion-fission reactions. It would be of further interest to carry out these measurements at different beam energies and also using the ^{13}C projectile where α transfer will result in ^{9}Be having a high threshold for breakup.

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