α-particle emission in ^{11}B, ^{12}C +^{232}Th fission reactions

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Introduction

Pre- and post scission emission of the α-particles has been studied extensively to investigate fission time scale [1, 2]. In addition to pre- and post scission emission, the alpha emission spectrum contains an additional component that is due to the emission at near-scission configuration [2]. The near scission emission (NSE) component addresses the dynamics of scission configuration. Earlier work relevant to NSE is mainly from thermal neutron and spontaneous fission process which shows that NSE multiplicity increases, and peak energy and it's width remain constant, as a function of Z^2/A [3]. Data from heavy-ion fusion-fission process are rather sparse and do not shows a systematic behaviour. In the present paper, our main aim is to investigate the NSE component of coincident α-particle energy spectra in ^{11}B(62 MeV), and ^{12}C(70 MeV) +^{232}Th fission reactions.

Experimental Details

The experiment was performed using the heavy ion beams from BARC-TIFR 14 UD Pelletron facility at Mumbai. A metallic foil of natural ^{232}Th (1.5mg/cm^2) was used as a target. The α-particles emitted in the reactions were measured by using three CsI(Tl) detectors (25×25×10 mm^3) kept at laboratory angles of 72^0,102^0, and 132^0 with respect to beam direction. These detectors (with collimator of 22×22 mm^2)had a solid angle of ∼18 msr and angular spread of $\pm3.9^0$. Particle identification was achieved using the pulse shape discrimination technique. The energy calibration of CsI(Tl) detectors was done using ^{228,229}Th source and in a separate in-beam experiment. The in-beam calibration made use of the discrete alpha particle peaks corresponding to ^{20}Ne* states from the reaction ^{12}C(^{12}C, α) ^{20}Ne* at ^{12}C-beam energies of 25 and 40MeV. Fission fragments were detected using a trapezoidal-shaped position sensitive $\triangle$E$_1$- $\triangle$E$_2$-E gridded gas ionization chamber[4], centered at 145^0 with respect to beam direction. The gas-chamber had angular spread of $\pm14.9^0$. Using charge division method in both $\triangle$E segments, position information was achieved. The position spectrum, obtained by using $X_p = (\triangle E_1 - \triangle E_2)/(\triangle E_1 + \triangle E_2)$, was divided into two bins of 14.9^0. Fission fragments were well separated from light charged particles in $\triangle$E versus E$_{gas}$ plot as shown in Fig.1. Alpha spectra were converted to multiplicity spectra by dividing fission singles and solid-angle of the particle-detector.

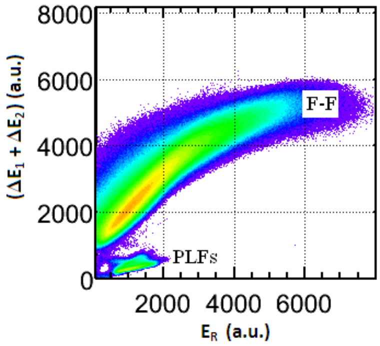

FIG. 1: 2D plot of $(\triangle E_1 + \triangle E_2)$ versus E_R for ^{11}B+^{232}Th system.

Data Analysis

Emission of particles from compound nucleus (pre-scission) and fragments (post-scission) are assumed to be isotropic in their respective rest frames. The charged parti-

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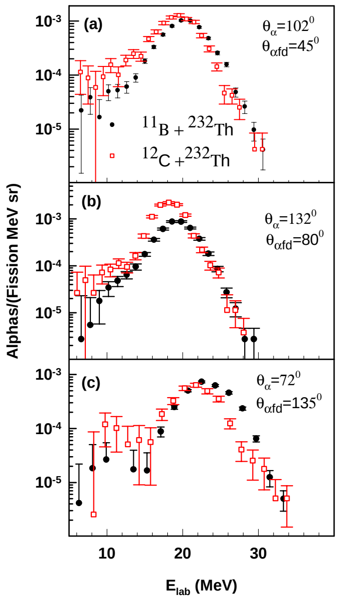

FIG. 2: Alpha energy spectra in laboratory frame for ^{11}B+^{232}Th (closed circle) and ^{12}C+^{232}Th (open squares) systems. In panels, θ_α is the particle detectors angle w.r.t beam direction and $\theta_{\alpha fd}$ is the relative angle between particle detector and fission detector.

cle evaporation spectrum in the rest frame is given by a constant temperature formula as[5];

$$n(\epsilon) \propto M\epsilon\sigma(\epsilon)exp(\frac{-\epsilon}{T}) \quad (1)$$

Where M and ϵ are the multiplicity and energy of the emitted particle in the rest frame, T is the temperature of the residual nucleus, and $\sigma(\epsilon)$ is reaction cross section for the corresponding inverse reaction. In moving-source-fits[1, 2], $\sigma(\epsilon)$ is calculated from empirical relations which usually does not fit properly the part below emission barrier energy of the α-spectrum. In the present work, instead of empirical relations, we are using the expression given by Wong [6] for inverse reaction cross section, given as;

$$\sigma(\epsilon) = \frac{R_0^2\hbar\omega_0}{2E}ln(1 + exp[\frac{2\pi}{\hbar\omega_0}(\varepsilon - E_b)]) \quad (2)$$

where, E_b is the emission barrier energy of the α-particle. This form of inverse reaction cross section fits better the part below emission barrier energy of the spectrum in comparison to empirical relations . In moving source fit, the calculated α-particle spectrum in rest frame of the source are converted to laboratory frame using the appropriate jacobian to get the best fit of the data by χ^2 minimization. A near-scission component with a Gaussian energy and angular distribution [2, 5] has been included. Detailed data analysis to extract contribution of various components such as, CN, both fragments, and NSE, in α-particle emission, is in progress.

Results and Discussion

Measured alpha particle multiplicity spectra for ^{11}B, ^{12}C +^{232}Th reactions is shown in Fig. 2 for typical different relative angles ($\theta_{\alpha fd}$) between fission fragment and α-particles. It is seen as we move from forward angle (θ_α) to back angle of the particle detector, peak of the spectrum moves from high energy to low energy, as expected from kinematics. The spectrum for forward most angle $\left(\theta_\alpha = 72^0\right)$ shows a broad peak for both the reactions, indicating mixture of pre-scission and emission from complimentary fragment. Peak position for both the reaction at each lab angle is same within 1.5 MeV. The total α-particle multiplicity is observed to be more for ^{12}C +^{232}Th than ^{11}B +^{232}Th system. Quantitative results will be presented after detailed data analysis using the moving-source-fit.

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