Localization of ℓ window for low energy incomplete fusion: A case of $^{16}O+^{159}Tb$

Vijay R. Sharma[1],* Abhishek Yadav[1], Pushpendra P. Singh[2], Indu Bala[3], D. P. Singh[1], S. Gupta[4], Manoj K. Sharma[5], R. Kumar[3], R. P. Singh[3], S. Murlithar[3], B. P. Singh[1],† R. K. Bhowmik[3], and R. Prasad[1]

[1]*Department of Physics, Aligarh Muslim University, Aligarh -202 002, India*
[2]*Department of Physics, Indian Institute of Technology Ropar, PB-140 001, India*
[3]*Inter University Accelerator Centre (IUAC), Aruna Asaf Ali Marg, New Delhi - 110 067, India*
[4]*Physics Department, Agra College, Agra-282 001, India and*
[5]*Physics Department, S. V. College, Aligarh - 202 001, India*

The study of incomplete fusion (ICF) of heavy ions with different projectile-target combinations has been a topic of interest in recent years at energies near and above the Coulomb barrier. Observations show that in heavy ion reactions at the energies $\approx$ 4-7MeV/A, the dominant nuclear reaction mechanisms are complete fusion (CF) and the ICF [1]. Britt and Quinton [2] were the first to observe the production of forward-peaked fast α particles, in the breakup of the ^{12}C, ^{14}N and ^{16}O projectiles at energy $\approx$ 10.5 MeV/A originating from ICF processes. Advances in the understanding of ICF reaction dynamics were made after the charged particle-γ coincidence measurements by Inamura et al. [3]. In these measurements, significantly large yields of direct emitting α-particles of mean energy roughly corresponding to the projectile velocity at forward angels have been observed. It is suggested that the principal process involved in the production of fast-α-particles is the projectile break-up, in the nuclear field of target nucleus, in a grazing interaction of projectile and target nucleus. Since then, the fast projectile-like-fragment(PLF) production has been studied quite intensively. In one of our recent papers, the fast α particle in the forward cone at relatively low projectile energies has also been reported [4, 5]. One of the important issues related to ICF studies is the localization of ℓ-window at low energies ($\approx$ 4-7 MeV/A). It may be pertinent to mention that high spin states can also be populated through ICF reactions [4]. In order to explore the dynamics of ICF processes and to get information regarding the involvement of mean input angular momenta in such reactions, a particle-γ coincidence experiment has been performed at the IUAC, New Delhi.

An isotopically pure ^{159}Tb target (abundance $\approx$ 99.9 %) of thickness $\approx$ 1.79 mg/cm^2 was bombarded by $^{16}O^{7+}$ (E_{Lab} $\approx$ 4-7 MeV/A, beam current $\approx$ 3 pnA) beam delivered from the 15 UD-Pelletron accelerator. The experiment was carried out by using Gamma Detector Array (GDA) coupled to the Charged Particle Detector Array (CPDA). The GDA setup consists of 12 Compton-suppressed HPGe detectors at angles of 45^0, 99^0 and 153^0 with respect to the beam direction, with four detectors arranged at each of these angles along with a CPDA consisting of 14 Phoswich detectors housed in a scattering chamber arranged in the form of two truncated hexagonal pyramids. All 14 detectors of the CPDA are divided into three angular segments. There are 4 detectors at forward angles (F) (10^0 - 60^0), 4 detectors at backward angles (B) (120^0 - 170^0), and 6 detectors angled sideways (S), that is, between 60^0 and 120^0 , symmetric around 90^0, covering nearly 90% of the total solid angle so that the angular distribution of charged particles in about a 4π arrangement may be recorded. In the present

*Electronic address: phy.vijayraj@gmail.com
†Electronic address: bpsinghamu@gmail.com

experiment, two groups of α particles are expected to be detected by forward-angle CPDs: (i) the fusion-evaporation (CF) α particles and (ii) the ICF fast α particles of energy corresponding to the beam velocity. In front of each four forward-cone CPDs, aluminum absorbers of appropriate thickness were used to stop the evaporated α-particles. Hence, mainly the fast α-particles with energy greater than evaporated α-particles have been detected in the forward cone. Three gating conditions were projected onto γ spectra, to generate particle-gated spectra for each angular zone, viz., (i) backward (B)-proton (Z=1) gated spectra (for pxn channel), (ii) backward (B) α-gated spectra (for CF αxn channels), (iii) forward (F) α-gated spectra (for ICF αxn channels).

Several residues populated via CF and/or ICF i.e., ^{171}Ta ($4n$), ^{172}Hf ($p2n$), ^{170}Hf ($p4n$), ^{170}Lu (αn), ^{168}Lu ($\alpha 3n$) and ^{167}Lu ($\alpha 4n$) have been identified by using appropriate gating conditions. The production yield of identified reaction products are plotted with their observed spin J_{obs}. As a typical example the de-excitation patterns of ^{168}Lu ($\alpha 3n$) residues populated separately via CF and ICF have been shown in fig. 1. The measured spin distribution for CF channel shown in figure indicates broad spin population and/or strong feeding over a broad spin range during the de-excitation i.e., a gradual monotonic increase in intensity towards the band head can be observed. However, in case of ICF, the intensity increases upto a certain value of J_{obs} and then remains constant down to the band head (J_{obs}^{min}). This kind of pattern for the spin distribution is believed to arise from the narrow spin population only up to a certain value of J_{obs}. Further, the feeding probability of γ population in CF and/or ICF channels has also been obtained from the experimentally measured spin distributions. The feeding intensity for CF channels (xn/pxn-B) shows a sharp exponential rise towards low-spin states, which indicates a regular population with a strong feeding contribution for each γ transition up to J_{obs}^{min}. However, the feeding intensity for the ICF reaction channels, show an exponential rise up to certain value of J_{obs} and then is found to decrease towards higher spin states indicating narrow spin population in such reactions. Further, details of the results on mean input angular momenta involved will be presented.

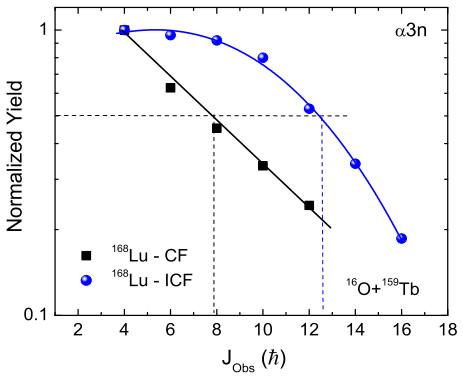

FIG. 1: Experimentally measured spin distributions for CF-α3n channel (identified from backward-alpha-gated spectra for CF and forward-alpha-gated spectra for ICF) plotted along with the spin distributions. Lines through the data points are drawn using prescription from ref. [5].

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