# Role of entrance channel parameters in low energy heavy-ion induced break-up reactions

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Recent studies on heavy ion collisions have established the presence of incomplete fusion (ICF) as a significant competing channel to the complete fusion (CF) process at energies as low as 4-7 MeV/A [1-6]. Though, at such low energies, ICF is unlikely but experimental studies have indicated that a significant portion of the reaction proceeds through it. The relative strength of ICF process increases with energy. In the case of CF, within the dominance of nuclear fields of the interacting nuclei and at $\ell<\ell_{crit}$, the entire projectile merges with the target nucleus leading to the formation of an excited composite system that undergoes equilibration to become the compound nucleus. However, in the case of ICF, it is assumed that the projectile in the vicinity of the nuclear field of the target and for $\ell>\ell_{crit}$ breaks up into fragments. One of the fragments of the projectile may fuse with the target nucleus forming a composite system with relatively less charge, mass and excitation energy as compared to the completely fused composite system. The remnant flows in the forward direction without any interaction. A variety of models have been developed to study the reaction dynamics of ICF, in which the most widely and accepted models are the break-up fusion model (BUF) [7] and sum-rule mode [8] of ICF. These models are only partially successful in reproducing experimental data on ICF above 10 MeV/A but completely fail at lower energies. As such, it may be remarked that at present there is no theoretical frame work to understand ICF at low energies.

In light of the above, the study of low energy ICF process assumes special significance. Study of the dependence of low energy ICF on incident channel parameters like, (i) type of the projectile and its energy (ii) input angular momentum (iii) mass asymmetry (iv) binding energy (v) Coulomb effect (vi) α-Q-value of the projectile etc are of paramount importance.

In the present work, an attempt has been made to understand the role of entrance channel parameters on ICF process at low energies. The probability of ICF for three different systems viz., $^{12,13}C$ + $^{159}Tb$ [9] and $^{19}F$ + $^{159}Tb$ [6] involving different projectiles have been deduced from the experimentally measured excitation functions (EFs). The variation of the incomplete fusion strength function ($F_{ICF}$) has been studied in terms of projectile energy and type.

In order to get the probability of ICF in the above mentioned systems, the experiments were carried out at the Inter University Accelerator Centre (IUAC), New Delhi. The $^{12,13}C$ and $^{19}F$ beams produced by the 15UD pelletron accelerator are allowed to focus on $^{159}Tb$. An activation technique followed by off-line gamma ray spectroscopy has been used. Isotopically pure $^{159}Tb$ targets (thickness ≈ 1.0-2.0mg/cm$^2$) and Al-catcher/energy degrader foils (thickness ≈ 1.5-2.5mg/cm$^2$) were prepared by the rolling technique. To cover a wide range of energy Al-catcher foils are used as energy degraders. In the present experiment, stacks of target-catcher assemblies were irradiated separately at different energies. The irradiations were carried out in the General Purpose Scattering Chamber (GPSC). The activities induced in the samples were recorded separately using a HPGe detector coupled to CAMAC based data acquisition system CANDLE. The detailed description of experimental methodology is given elsewhere [4-6, 9].

The production cross-section of reaction residues populated via CF and/or ICF processes in $^{12,13}$C + $^{159}$Tb and $^{19}$F + $^{159}$Tb systems are measured and compared within the frame work of statistical model code PACE4 [10]. It has observed that the experimentally measured EFs of *xn/pxn* channels are found to be in good agreement with the predictions of PACE4 code and confirms the production of the *xn* and *pxn* channels via CF mode. However, a significant enhancement in the EFs of α-emitting channels has been observed as compared to the PACE4 predictions for all the above three systems. The observed enhancement in the EFs of α-emitting channels in these systems manifests the contribution of ICF reactions at low energies. A detailed explanation of EFs measurements and its comparison with PACE4 code for three systems are given in Ref. [6,9].

To understand how, different projectiles ($^{12,13}$C and $^{19}$F) on same target $^{159}$Tb affect the nature of ICF dynamics, the incomplete strength function ($F_{ICF}$) has been deduced from the experimentally measured EFs and its dependence on entrance channel parameters has been studied. Fig.1 shows the variation of $F_{ICF}$ obtained for three projectiles as a function of normalized energy ($E/V_b$). The energy axis is normalized to correct for the different Coulomb barriers of the systems under study. As can be seen from this figure, the onset of $F_{ICF}$ for various projectiles are different and found to be lower for $^{19}$F projectile as compared to others. Further, the $F_{ICF}$ for different systems are found to increase with normalized energy which clearly indicates the importance of energy dependence of low energy ICF. The difference in the strength function ($F_{ICF}$) values for different projectiles on the same target $^{159}$Tb in the entire energy range is attributed due to the entrance channel effects, which arises due to the different structural behavior of the projectile and may be explained on the basis of α-Q-value of the projectiles. Further details regarding effect of various entrance channel parameters on $F_{ICF}$ will be presented.

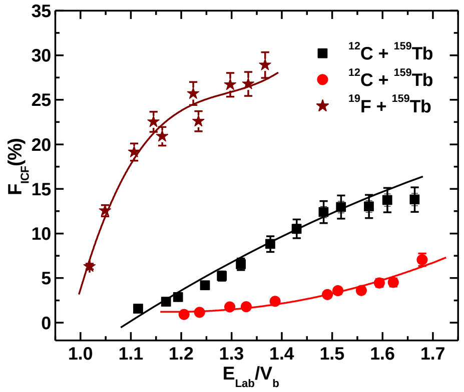


Fig.1 A comparison of $F_{ICF}$ with normalized energy for various systems (see text for details)

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