Effect of projectile structure on incomplete fusion reaction dynamics

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With the appearance of forward peaked α-particles in the very first experimental observation, during early sixties by Britt and Quinton [1] in the bombardment of ^{197}Au and ^{209}Bi by ^{12}C, ^{14}N and ^{16}O projectiles at energies $\approx$ 10.5 MeV/nucleon, the incomplete fusion (ICF) of the projectile has become an important process. One of the characteristic features of the ICF reactions is the forward peaked out going alpha particles with the most probable energy corresponding to the beam velocity. Moreover, the studies of coincidence relationships between these particles and the discrete γ-rays of the heavy residues unambiguously proved that in these reactions outgoing alpha particles escape at forward angles carrying a significant part of the kinetic energy and angular momentum of the projectile while the remaining part fuses with the target. However, the influence of the projectile breakup on fusion is not yet well understood, thus continues to be an active area of investigations.

In fact, the alpha clustered structure of the projectile has been considered as one of the factors leading to the forward peaked alpha-particles in ICF reactions. Therefore, for perfect understanding of ICF reaction dynamics at near Coulomb barrier energies, excitation functions (EFs) for several evaporation residues produced in the ^{16}O+^{165}Ho system have been measured in the projectile energy range $\approx$ 73-105 MeV. In order to find out some systematics, the re-analysis of nearby projectile-target combinations, in the light of the present data, has been incorporated and the acquired incomplete fusion fraction (F_{ICF}) has been compared for all these systems [2–6]. Besides, to examine the effect of projectile structure on ICF reaction dynamics, an attempt has been employed. In this regard, results of two other systems [2, 3](the systems of different projectiles with same target) are compared with the present work. The experimental details of present work has already been presented in Ref.[7].

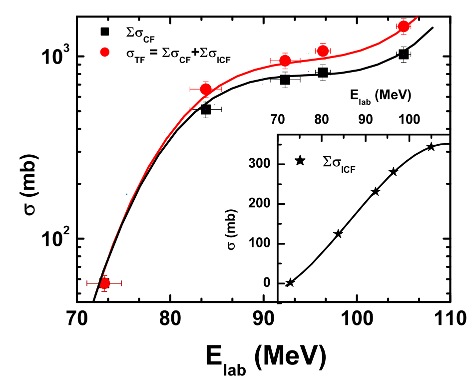

FIG. 1: σ_{TF}=$\Sigma\sigma_{CF}$+$\Sigma\sigma_{ICF}$ is plotted along with $\Sigma\sigma_{CF}$ and $\Sigma\sigma_{ICF}$. The separation between σ_{TF} and $\Sigma\sigma_{CF}$ increases due to the enhancement of ICF with the projectile energy. Solid lines are just to guide the eyes.

In the present work, twelve residues such as $^{178-175}$Re, $^{177-175}$W, $^{176-173}$Ta and ^{166}Tm have been obtained by the identification of their characteristic γ-rays. The analysis of these residues has been carried out in the frame work of statistical model code

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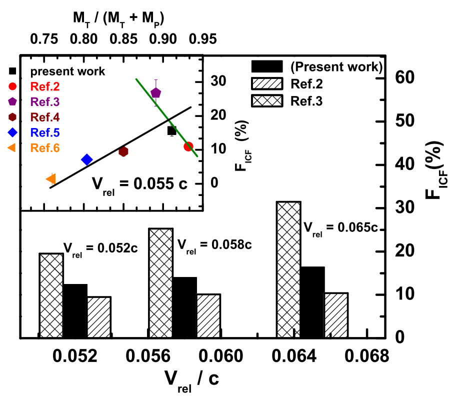

FIG. 2: In inset deduced percentage ICF fraction (F_{ICF}) as a function of mass asymmetry for different systems at a constant (v_{rel}=0.055c) is given. Solid lines are just to guide the eyes. The (F_{ICF}) for the different projectiles on the same target combinations at different relative velocities is also plotted.

PACE4 [8]. All pxn and αxn channels have contribution from their higher charge isobar precursors, which is deducted to have independent yields of these residues. All CF channels were reproduced very well with this code while enhancement in α-emitting channels is observed due to ICF contribution [7].

Total Fusion cross section i.e. (σ_{TF}= $\Sigma\sigma_{CF}$+$\Sigma\sigma_{ICF}$) is plotted along with ($\Sigma\sigma_{CF}$) and ($\Sigma\sigma_{ICF}$) in Fig.1. Moreover, to observe some systematics, incomplete fusion fraction (F_{ICF}) has been extracted. In this sequence, F_{ICF} for different projectile-target combination [2–6] has been plotted against the mass-asymmetry at a constant relative velocity (v_{rel}=0.055c), as shown in inset of Fig.2. As can be seen, in general, the data points suggest more ICF probability for more mass asymmetric than symmetric systems, which is in accordance with Morgenstern et al. [9]. However, the values of F_{ICF} for ^{12}C+^{165}Ho [2] and ^{20}Ne+^{165}Ho [3] along with the present work follow an unusual trend. This observed trend is quite interesting as for more mass asymmetric system F_{ICF} is less. The above conflict in the measurements may be due to the projectile structure effect on ICF reaction dynamics. Hence, in order to check the validity of this effect, F_{ICF} for the three different systems ([2], present work and [3]) of different α-clustered projectiles with the same target at different relative velocities have been plotted in Fig.2. In this figure we can see that with the increasing v_{rel} the ICF fraction increases while at a particular v_{rel}, with the increase in α-Q-values of projectiles, the F_{ICF} decreases. The α-Q-values of ^{20}Ne, ^{16}O and ^{12}C are found to be -4.73 MeV, -7.16 MeV and -7.37 MeV respectively. Hence, the α-Q-value [10] may be liable for this unusual trend in Fig.2 . So, it may be worthy to note that along with mass asymmetry and projectile energy, projectile structure effect (which predominantly depends on the α-Q-value of the projectile) is also accountable for ICF reaction dynamics. The details of the work will be presented.

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