Measurement of incomplete fusion cross-sections in ^{6,7}Li+^{238}U reactions

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Introduction

Incomplete fusion (ICF) or transfer reaction plays an important role in fission dynamics of the reactions involving heavy targets and weakly bound projectiles [1, 2]. The presence of ICF channels may modify (i) the ratio of asymmetric to symmetric fission mass distributions, (ii) the width of fission fragment (FF) folding angle distributions, and sometimes (iii) the anisotropy of FF angular distributions. So, identification of different ICF channels and measurement of their cross sections is of utmost importance to understand the above effects in a quantitative manner. Several methods are employed to identify ICF channels, e.g., (i) recoil range distribution, (ii) FF folding angle distributions, (iii) characteristic charge particle decay from composite nuclei (iv) particle-gamma coincidence and (v) coincidence of fission fragments with light charged particles. Among these, the "light charged particle-fission fragments coincidence" technique is the most reliable, as the triple coincidence of two fission fragments and one light charged particle (the non-captured projectile breakup fragment) confirms the occurrence of a specific ICF event. Whereas, the characteristic particle decay technique and the gamma counting technique have the major disadvantage that the same composite system which emits characteristics gamma or particle, can be formed by different mechanisms (ICF or particle evaporation).

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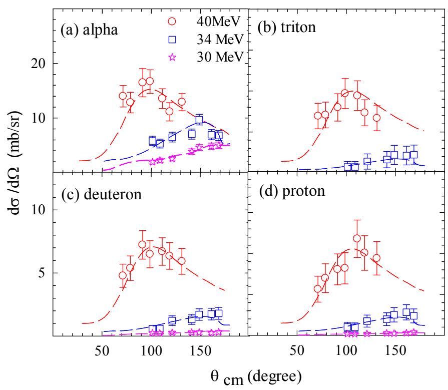

FIG. 1: (Color online) The differential ICF cross-sections corresponding to the ejectiles (a) alpha (b) triton (c) deuteron and (d) proton in ^{6}Li+^{238}U reaction. The fit to each of the data has been shown by dashed lines.

The experiment

The experiment on ^{6,7}Li + ^{238}U reactions was carried out at 15-UD Pelletron facility in Inter University Accelerator Centre (IUAC), New Delhi. Three beam energies of 30, 34 and 40 MeV were used for ^{6}Li and two beam energies of 31.4 and 41.4 MeV were used for ^{7}Li. Two position sensitive multi-wire proportional counter (MWPC) detectors were used to detect fission fragments and an array of CsI(Tl) detector were used to detect PLF [2].

The ICF cross-section which includes transfer cross-section as well, can be determined as follows. If Y_{coin} is the counts of the non-captured projectile like breakup fragments detected in coincidence with the two fission fragments, the differential ICF cross-section can be written as

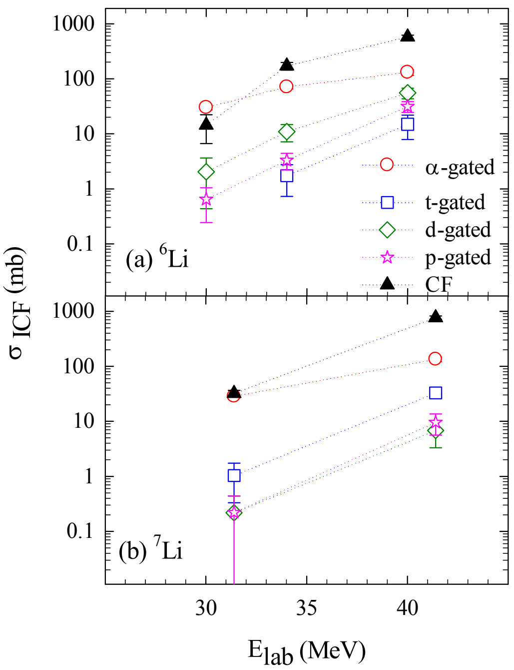

FIG. 2: (Color online) Comparison of CF cross-sections($\sigma_{TF} - \sigma_{ICF}^{total}$)(black triangle) and the angle integrated ICF cross sections corresponding to different projectile energies for (a) ^{6}Li and (b) ^{7}Li.

$$\frac{d\sigma}{d\Omega}(\theta) = \frac{Y_{coin}}{Y_M}\frac{d\Omega_M}{d\Omega_{CsI}}\frac{d\sigma_{Ruth}}{d\Omega}\frac{1}{\epsilon}\frac{1}{P_f} \qquad (1)$$

where, Y_M is the number of counts at monitor detector, $d\Omega_M$ and $d\Omega_{CsI}$ are the solid angles of monitor and CsI(Tl) scintillator detectors respectively, $\frac{d\sigma_{Ruth}}{d\Omega}$ is the Rutherford's differential scattering cross-section at the scattering angle of the monitor (θ_M), ϵ is the 'fission-PLF' coincidence efficiency and P_f is the fission probability followed by transfer or incomplete fusion. The efficiency ϵ mainly depends on two factors: (a)the FF coincidence efficiency between the two MWPC detectors (ϵ_1) and (b) the geometric efficiency of the MWPC detectors (ϵ_2).

Following equation (1), differential cross-sections are obtained as shown in Fig. 1 for the reaction with ^{6}Li. Now the ICF cross-sections have been obtained by integrating the fitted differential cross-sections over the all solid angles of PLF emission as shown in Fig. 2 for both (a)^{6}Li and (b)^{7}Li. The complete fusion (CF) cross-sections for both the reactions have also been obtained by subtracting total ICF cross-sections (σ_{ICF}^{total}) from total fusion cross-sections (σ_{TF}) and shown in the same Fig. 2.

The relative contribution of ICF to total fusion cross-section ($\frac{\sigma_{ICF}}{\sigma_{TF}}$) has been determined from the measured data and shown in Fig. 3 as red filled and red hollow circles for ^{6}Li +^{238}U and ^{7}Li +^{238}U reactions respectively. From Fig. 3, the relative contribution of ICF to TF for the present systems has been found to be the highest ($\sim$ 70%) at the lowest measured energy and then it decreases with increasing energy, consistent with the trend for several other systems obtained from the ICF and TF data available in the literature.

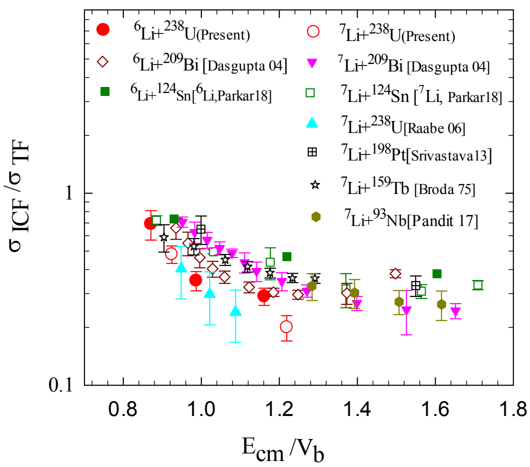

FIG. 3: (Color online) The ratios of total ICF cross-section to total fusion cross-section for the present systems ^{6}Li+^{238}U (red filled circles) and ^{7}Li+^{238}U (red hollow circles).

References

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