Influence of projectile $\alpha$-breakup threshold on complete fusion

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Abstract

Complete fusion excitation functions for $^{11,10}$B + $^{159}$Tb have been measured at energies around the respective Coulomb barriers, and the existing complete fusion measurements for $^7$Li + $^{159}$Tb have been extended to higher energies. The measurements show significant reduction of complete fusion cross sections at above-barrier energies for both the reactions, $^{10}$B + $^{159}$Tb and $^7$Li + $^{159}$Tb, when compared to those for $^{11}$B + $^{159}$Tb. The comparison shows that the extent of suppression of complete fusion cross sections is correlated with the $\alpha$-separation energies of the projectiles. Also, the two reactions, $^{10}$B + $^{159}$Tb and $^7$Li + $^{159}$Tb were found to produce incomplete fusion products at energies near the respective Coulomb barriers, with the $\alpha$-particle emitting channel being the favoured incomplete fusion process in both the cases.

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Recently a resurgence of interest has occurred in investigating the effect of breakup of weakly bound projectiles on the fusion mechanism [1–8] at energies around the barrier. This has primarily been motivated by the present availability of radioactive ion beams, some of which exhibit unusual features like halo/skin structure and large breakup probabilities. A critical understanding of the fusion mechanism with radioactive ion beams is very significant for the understanding of reactions of astrophysical interest and for the production of new nuclei near the drip lines.

It can be expected that in the fusion studies involving halo nuclei, the larger spatial extent of such nuclei may lead to a lowering of the average fusion barrier, and thus enhance the fusion cross sections over those for well-bound nuclei. On the contrary, the halo nuclei can easily breakup in the field of the other nucleus, due to their low binding energies, and can therefore lead to a loss of flux from the entrance channel thereby reducing the fusion cross sections. However, coupled channels calculations [7] carried out for the system $^{11}$Be + $^{208}$Pb show that a combination of all these effects essentially leads to enhancement of fusion cross sections at sub-barrier energies and reduction of fusion cross sections at above-barrier energies. Although presently it is possible to investigate reaction mechanisms with unstable beams, experimentally such studies are limited [1–5] owing to the low intensities of the radioactive beams currently available. On the other hand, fusion reactions with high intensity weakly bound stable beams which have a significant breakup probability may serve to be an important step towards the understanding of the influence of breakup on the fusion mechanism. Indeed in the last few years, special attention has been paid towards fusion studies at near-barrier energies using the weakly bound stable projectiles, $^9$Be, $^6$Li and $^7$Li.

In fusion with weakly bound projectiles, following the breakup of the projectile in the field of the target, one of the fragments may be captured by the target, with the other escap-
ing with the beam velocity [9]. This process of capture of partial projectile by the target is known as incomplete fusion (ICF) and has been observed even in reactions with strongly bound projectiles like $^{12}$C and $^{16}$O, but mostly at higher bombarding energies [10,11]. However, the recent observation of ICF cross sections at near-barrier energies in fusion with weakly bound projectiles [12–16] has made this field even more interesting, especially in view of the present availability of the radioactive ion beams.

In fusion of $^9$Be and $^6,^7$Li with heavy targets like, $^{208}$Pb and $^{209}$Bi [12–15] substantial suppression of complete fusion cross sections has been observed at energies above the respective Coulomb barriers. The complete fusion (CF) products correspond to the events where the whole of projectile fuses with the target. For medium and light mass systems, owing to the experimental difficulties, total (complete or incomplete) fusion cross sections were measured for the systems like, $^9$Be + $^{64}$Zn [17], $^6,^7$Li + $^{59}$Co [18], $^5,^6$Li + $^{12,13}$C [19,20] and $^6,^7$Li + $^{10}$O [21, 22]. These measurements show no suppression of total fusion cross sections at above-barrier energies.

To investigate the effect of breakup on fusion, all the reactions studied so far with weakly bound stable beams have been performed using $^9$Be, $^6,^7$Li and $^7$Li projectiles that have breakup thresholds ranging from 1.45 to 2.45 MeV. Among the stable nuclei, apart from the nuclei $^6,^7$Li and $^9$Be, the nucleus $^{10}$B also has a fairly low $\alpha$-separation energy of 4.5 MeV. Therefore like $^6,^7$Li and $^9$Be, the nucleus $^{10}$B also may be expected to breakup at low excitation energies, thereby affecting the fusion mechanism at considerably low bombarding energies. Particle-$\gamma$ coincidence measurements carried out with 75 MeV $^{10}$B beam and $^{159}$Tb target show substantial production of $\alpha$ nuclei, resulting from the ICF process [10]. In this Letter, we present the CF excitation functions for the $^{11,10}$B + $^{159}$Tb and $^7$Li + $^{159}$Tb reactions, at energies around the respective Coulomb barriers. The CF measurements for $^7$Li + $^{159}$Tb have been extended to energies higher than that reported in the literature [23]. The $^{11}$B projectile, with $\alpha$-separation energy of 8.66 MeV, is expected to behave as a normal strongly bound nucleus. Thus, $^{11}$B + $^{159}$Tb was chosen to be the reference strongly bound system. A comparison of the CF cross sections for the three systems at above-barrier energies allows to study the correlation between the extent of CF suppression and the $\alpha$-breakup thresholds of the projectiles.

Beams of $^{11,10}$B in the energy range 38–72 MeV, and $^7$Li with energies from 28–43 MeV, provided by the 14UD BARC-TIFR Pelletron Accelerator Facility at Mumbai, bombarded a self-supporting $^{159}$Tb target of thickness 1.50 ± 0.07 mg/cm$^2$. The $\gamma$-rays emitted by the evaporation residues (ERs) were detected in an absolute efficiency calibrated Compton suppressed clover detector placed at 55° with respect to the beam direction. To cross check the measured cross sections, a 125 c.c. HPGe detector was also placed at 125° with respect to the beam direction. Both online and offline spectra were taken for each exposure. The total charge of each exposure was measured in a 1 m long Faraday cup placed after the target. The target thickness was determined by measuring the Rutherford scattering cross sections and also by using the 137.5 keV Coulomb excitation line of $^{159}$Tb. The thickness of the target obtained from the two methods of measurement had excellent agreement.

The compound nuclei $^{170}$Yb, $^{169}$Yb and $^{166}$Er, formed following the fusion reactions $^{11}$B + $^{159}$Tb, $^{10}$B + $^{159}$Tb and $^7$Li + $^{159}$Tb respectively, are expected to decay predominantly by neutron evaporation producing ERs which are all well deformed nuclei. This is also predicted by the statistical model calculations done using the code PACE2 [24]. The CF cross sections in the $B$ induced reactions were obtained from the sum of the $3n - 0n$ ER cross sections and for the $^7$Li induced reaction the same was obtained by summing the $3n - 5n$ ER cross sections.

For the even–even ERs, except the $3n$ channel ($^{166}$Yb) in the reaction $^{10}$B + $^{159}$Tb, the $\gamma$-ray cross sections, $\sigma(\gamma)$, for various transitions in the ground state rotational band of the relevant nucleus were obtained using the measured $\gamma$-ray intensities after correcting for the internal conversion. The cross sections for a given even–even ER were then extracted from the extrapolated value of the $\gamma$-ray cross section at $J = 0$. For the odd-mass nuclei, the cross sections were obtained by following the respective radioactive decay. The low lying characteristic $\gamma$-rays in the ground state band of the even–even ER $^{166}$Yb, corresponding to the $3n$ channel in the $^{10}$B + $^{159}$Tb reaction, are almost identical to those in the nucleus $^{162}$Er, a probable ICF product in this reaction. So the measured cross sections for the $\gamma$-rays corresponding to the $^{166}$Yb nucleus will also include the contributions from the $^{162}$Er nucleus. In order to estimate the contribution from the $^{166}$Yb ER, and hence extract the contribution from the ICF product $^{162}$Er, if any, we adopted the following procedure. For the reaction $^{10}$B + $^{159}$Tb, it was assumed that there is no significant contribution from the ICF process at energies below the Coulomb barrier. So at energies below the Coulomb barrier the measured cross sections correspond almost wholly to the $^{166}$Yb ER. At below-barrier energies, the ratio, $F = \frac{\sigma(\gamma)}{\sigma(\gamma)_{\gamma(3n-0n)}}$ was obtained from the measured cross sections, at the same excitation energies for both the reactions. The cross sections for the $^{166}$Yb ER at above-barrier energies were then obtained using the measured $4n$ channel cross sections for $^{10}$B + $^{159}$Tb, the factor $F$, and the measured ratios of the cross sections for $3n(167$Yb)/$4n(166$Yb) in the $^{11}$B + $^{159}$Tb system at the same excitation energies as in the $^{10}$B case. By this normalisation it was assumed that the ratio, $F = \frac{\sigma(3n/4n)}{\sigma(5n/4n)}_{\gamma(166,159$Tb)}$ is constant over the whole energy region of measurement, and this constancy was checked using the statistical model calculations performed using the code PACE2. The contribution of the ICF product $^{162}$Er was then obtained using the contribution of $^{166}$Yb, determined as above, and the measured total cross sections for the $\gamma$-rays corresponding to $^{166}$Yb (or $^{162}$Er). It needs to be mentioned here that the cross sections obtained using the data from the clover detector agreed very well with those obtained with the HPGe detector.

The CF cross sections for the three reactions $^{11,10}$B + $^{159}$Tb and $^7$Li + $^{159}$Tb were then determined by summing the respective $\times n$ channel cross sections at each energy. The results are shown in Figs. 1–3. The CF data of Broda et al. [23] for the $^7$Li + $^{159}$Tb reaction are shown by the hollow points in
Fig. 3. As expected, the $^{11}$B + $^{159}$Tb system behaves as a normal strongly bound system, where no $\gamma$-lines following ICF were observed in the spectra over the energy range of present measurement. Cross sections for the 3n and 4n channels in the decay of $^{165}$Er, formed following the capture of $^6$Li by $^{159}$Tb in the $^{10}$B induced reaction, are also shown in Fig. 2. Cross sections for the dominant $\alpha2n$ channel, following the $t$ capture by $^{159}$Tb in the $^7$Li + $^{159}$Tb reaction, are shown in Fig. 3. It needs to be mentioned that the ICF cross sections plotted in Figs. 2–3 include contributions from breakup fusion and transfer from projectile to the unbound states of the target. The errors in the cross sections plotted in Figs. 1–3 are the total errors, which include statistical errors and uncertainties in the target thickness, efficiency of the detector and the integrated beam current.

In the $^7$Li + $^{159}$Tb reaction, the contribution from the capture of the lighter projectile fragment, $t$, by $^{159}$Tb was found to be the dominant ICF contribution, with the contribution from $\alpha + ^{159}$Tb being negligibly small. A similar observation was reported for the reaction $^7$Li + $^{165}$Ho [16] and was explained to be due to the higher Coulomb barrier for the $\alpha$-capture compared to the $t$-capture. By contrast, in the $^{10}$B + $^{159}$Tb reaction, the $\gamma$-spectra showed no lines corresponding to the $\alpha$ (lighter fragment) capture by $^{159}$Tb. In this reaction, the only ICF contributions which could be observed were due to the capture of $^6$Li (heavier fragment) by $^{159}$Tb, even though the Coulomb barrier for the $\alpha$-capture is lower than the $^6$Li-capture by the target. This observation is indeed consistent with the corresponding Q-values of the reactions. The Q-value for the $^{159}$Tb($^7$Li, $\alpha$) $^{162}$Dy reaction is 11.1 MeV, while it is $-3.2$ MeV for the ($^7$Li, $t$) reaction, indicating that the $\alpha$ particle emission is more favoured. In the $^{10}$B induced reaction, the Q-value for the $^{159}$Tb($^{10}$B, $\alpha$) $^{162}$Er reaction is 4.6 MeV, while it is $-5.2$ MeV for the ($^{10}$B, $^6$Li) reaction, indicating that $\alpha$ particle emission is more favoured. In fact, in both the cases, the favorable ICF channel is where the $\alpha$ particle emission occurs.

To compare the CF cross sections for the three reactions at above-barrier energies, they have been plotted in a reduced scale in Fig. 4. In this figure only statistical uncertainties have been plotted, as the present measurements for the three systems were taken in one run using the same setup. The data of Ref. [23] have been plotted with the errors quoted in the ref-
ference. The figure clearly shows in a model independent way that the CF cross sections for $^{10}\text{B} + ^{159}\text{Tb}$ and $^{7}\text{Li} + ^{159}\text{Tb}$ are suppressed at above-barrier energies compared to those for $^{11}\text{B} + ^{159}\text{Tb}$, with the cross sections for $^{10}\text{B} + ^{159}\text{Tb}$ being intermediate between those for $^{11}\text{B} + ^{159}\text{Tb}$ and $^{7}\text{Li} + ^{159}\text{Tb}$. This observation is quite consistent with the $\alpha$-breakup thresholds of the projectiles. As discussed earlier, of the three projectiles, $^{11}\text{B}$ is the most strongly bound nucleus with $Q_\alpha = -8.46$ MeV and $^{7}\text{Li}$ is the most weakly bound nucleus with $Q_\alpha = -2.47$ MeV. The $^{10}\text{B}$ nucleus has $Q_\alpha = -4.5$ MeV, intermediate between that of $^{11}\text{B}$ and $^{7}\text{Li}$. Thus, lower the $\alpha$-breakup threshold of the projectile, larger is the suppression of CF. Moreover, Fig. 4 also shows that the onset of suppression depends on the $\alpha$-separation energy of the projectile. Higher the breakup threshold, higher is the energy where the suppression starts. This perhaps explains why ICF products are observed in strongly bound systems at much higher bombarding energies [10,11].

To study the extent of above-barrier fusion suppression in a theoretical framework, the realistic coupled channels (CC) code CCFULL [25] was employed to calculate the total fusion cross sections. It needs to be pointed out here that these calculations do not consider couplings to unbound or continuum states. Thus the breakup of the projectiles $^{10}\text{B}$ and $^{7}\text{Li}$ is not included. In CCFULL the number of CC equations is reduced by means of the isocentrifugal approximation, and an ingoing-wave boundary condition is placed inside the barrier.

The Akyüz–Winther (AW) [26] (bare) potential parameters ($V_0$, $r_0$, and $a$) for the three systems are given in Table 1. The corresponding uncoupled fusion barrier parameters ($V_b$, $R_b$, and $h_{\omega}$) are also mentioned in the table. The CCFULL calculations with the shallow AW potentials lead to oscillations of transmission coefficients of high partial waves, especially at high energies. To minimize such oscillations, the potential wells for the three systems were chosen to be deeper so that the ingoing-wave boundary condition is correctly applied. The diffuseness parameter was chosen to be $a = 0.85$ fm for all the three systems, following the systematic trend of high diffuseness required to fit the high energy part of the fusion excitation functions [27]. The radius parameter had to be changed accordingly. For $^{11}\text{B} + ^{159}\text{Tb}$, with $a = 0.85$ fm, $V_0$ and $r_0$ were varied so as to fit the high-energy cross sections (> 200 mb) [28]. This modified potential for CC calculations are given in Table 1. For $^{10}\text{B} + ^{159}\text{Tb}$, the same potential parameters were used in the CC calculations as they are very nearby systems. The similarity in the potential parameters for the two systems can also be observed in the AW potentials. In the case of $^{7}\text{Li} + ^{159}\text{Tb}$, keeping $a$ fixed at 0.85 fm, $V_0$ and $r_0$ were varied so that the corresponding one-dimensional barrier penetration model (1D BPM) cross sections for the $^{7}\text{Li} + ^{159}\text{Tb}$ agree with those with the AW potential parameters at higher energies. The 1D BPM calculations were done using the code CCFULL, in the no coupling limit.

In CCFULL, the effects of deformation are calculated by coupling to the ground state rotational band of the deformed target nucleus. The target $^{159}\text{Tb}$ is a well-deformed nucleus with an unpaired valence proton. This last valence proton particle (or proton hole) can be expected to couple with the $0^+, 2^+, 4^+, \ldots$ rotational states present in the neighbouring even–even rotational nucleus $^{158}\text{Gd}$ (or $^{160}\text{Dy}$) to build up the low-lying rotational states of $^{159}\text{Tb}$. To remain within the model space of CCFULL, the excitation energies and deformation parameters for $^{159}\text{Tb}$ were taken to be the averages of the corresponding values for the neighbouring even–even nuclei $^{158}\text{Gd}$ and $^{160}\text{Dy}$ [29]. The ground state rotational band of the corresponding average spectrum ($\beta_2 = 0.344$ [30] and $\beta_4 = +0.062$ [31]) upto $12^+$, were included in the calculations [28]. Projectile excitations were not considered in any of the cases. The results of the 1D BPM are shown by the dot-dot-dashed lines in Figs. 1–3. The CC calculations for $^{11}\text{B} + ^{159}\text{Tb}$ are shown by the solid lines in Fig. 1 and those for $^{10}\text{B} + ^{159}\text{Tb}$ and $^{7}\text{Li} + ^{159}\text{Tb}$ are shown by the dashed lines in Figs. 2–3.

![Fig. 4. Reduced complete fusion excitation functions for the $^{11,10}\text{B} + ^{159}\text{Tb}$ and $^{7}\text{Li} + ^{159}\text{Tb}$ systems.](image)

### Table 1

The parameters of the AW potential and of the modified potential used for the CC calculations (see text). Also shown are the corresponding derived uncoupled barrier heights $V_b$, radii $R_b$ and curvatures $h_{\omega}$.

| System          | Potential | $V_0$ (MeV) | $r_0$ (fm) | $a$ (fm) | $V_b$ (MeV) | $R_b$ (fm) | $h_{\omega}$ (MeV) |
|-----------------|-----------|-------------|------------|----------|-------------|------------|-------------------|
| $^{11}\text{B} + ^{159}\text{Tb}$ | AW        | 54.54       | 1.18       | 0.64     | 40.34       | 10.89      | 4.42              |
|                 | CC        | 140         | 1.01       | 0.85     | 39.72       | 10.84      | 3.87              |
| $^{10}\text{B} + ^{159}\text{Tb}$ | AW        | 54.54       | 1.11       | 0.64     | 40.71       | 10.79      | 4.68              |
|                 | CC        | 140         | 1.01       | 0.85     | 40.00       | 10.75      | 4.08              |
| $^{7}\text{Li} + ^{159}\text{Tb}$ | AW        | 46.43       | 1.18       | 0.62     | 24.70       | 10.69      | 4.48              |
|                 | CC        | 132         | 0.98       | 0.85     | 24.17       | 10.68      | 3.81              |
The CC calculations are found to be in reasonably good agreement with the measured fusion cross sections for the $^{11}\text{B} + ^{159}\text{Tb}$. But for $^{10}\text{B} + ^{159}\text{Tb}$ and $^7\text{Li} + ^{159}\text{Tb}$, at above-barrier energies the measured CF cross sections lie below the calculated cross sections. Using the data above $E_{\text{c.m.}} \sim 45$ MeV for $^{10}\text{B} + ^{159}\text{Tb}$ and those above $E_{\text{c.m.}} \sim 25$ MeV for $^7\text{Li} + ^{159}\text{Tb}$, the measured CF cross sections for the two systems are found to be, respectively, $\sim 86\%$ and $\sim 74\%$ of the theoretical predictions. This observation is consistent with the aforementioned model-independent comparison of the three systems. The CC calculations for $^{10}\text{B} + ^{159}\text{Tb}$ and $^7\text{Li} + ^{159}\text{Tb}$ when scaled by the factors 0.86 and 0.74, respectively, are shown by the solid curves in Figs. 2–3. A suppression factor of $\sim 0.74$ was also obtained for other $^7\text{Li}$ induced reactions, like $^7\text{Li} + ^{209}\text{Bi}$ [14,15] and $^7\text{Li} + ^{165}\text{Ho}$ [16].

In summary, the CF excitation functions for the three reactions, $^{11,10}\text{B} + ^{159}\text{Tb}$ and $^7\text{Li} + ^{159}\text{Tb}$ have been measured. The CF cross sections for $^{10}\text{B} + ^{159}\text{Tb}$ and $^7\text{Li} + ^{159}\text{Tb}$ show suppressions of $\sim 86\%$ and $\sim 74\%$, respectively. The extent of this suppression is found to be correlated with the $\alpha$-separation energies of the projectiles. Besides, it has also been observed that fusion with a projectile having a higher $\alpha$-breakup threshold results in the onset of CF suppression at a higher bombarding energy. Both $^{10}\text{B} + ^{159}\text{Tb}$ and $^7\text{Li} + ^{159}\text{Tb}$ reactions were found to produce ICF products at energies near the respective Coulomb barriers, with the $\alpha$-particle emitting channel being the favoured ICF process in both the cases. The present study with weakly bound stable nuclei and more such in the near future will perhaps, lead to a deeper systematic understanding of the effect of very weak binding of the unstable nuclei on the fusion process.

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References

[1] A. Yoshida, et al., Phys. Lett. B 389 (1996) 457.
[2] K.E. Rehm, et al., Phys. Rev. Lett. 81 (1998) 3341.
[3] J.J. Kolata, et al., Phys. Rev. Lett. 81 (1998) 4580.
[4] C. Signorini, et al., Nucl. Phys. A 735 (2004) 329.
[5] A. Di Pietro, et al., Phys. Rev. C 69 (2004) 044613.
[6] C.H. Dasso, A. Vitturi, Phys. Rev. C 47 (1993) 2470(R).
[7] K. Hagino, et al., Phys. Rev. C 61 (2000) 037602.
[8] A. Diaz-Torres, J.J. Thompson, Phys. Rev. C 65 (2002) 024606.
[9] H. Uschomnik, et al., Phys. Rev. C 28 (1983) 1975.
[10] D.R. Zolnowski, et al., Phys. Rev. Lett. 41 (1978) 92.
[11] J.H. Barker, et al., Phys. Rev. Lett. 43 (1980) 424.
[12] M. Dasgupta, et al., Phys. Rev. Lett. 82 (1999) 1395.
[13] C. Signorini, et al., Eur. Phys. J. A 5 (1999) 7.
[14] M. Dasgupta, et al., Phys. Rev. C 66 (2002) 041602(R).
[15] M. Dasgupta, et al., Phys. Rev. C 70 (2004) 024606, and references therein.
[16] V. Tripathi, et al., Phys. Rev. Lett. 88 (2002) 172701; V. Tripathi, et al., Phys. Rev. C 72 (2005) 017601.
[17] S.B. Moraes, et al., Phys. Rev. C 61 (2000) 064608.
[18] C. Beck, et al., Phys. Rev. C 67 (2003) 054602.
[19] A. Mukherjee, et al., Phys. Lett. B 526 (2002) 295.
[20] A. Mukherjee, et al., Nucl. Phys. A 596 (1996) 299.
[21] A. Mukherjee, et al., Nucl. Phys. A 635 (1998) 205.
[22] A. Mukherjee, et al., Nucl. Phys. A 645 (1999) 13.
[23] A. Mukherjee, B. Dasmahapatra, Phys. Rev. C 63 (2000) 017604.
[24] R. Broda, et al., Nucl. Phys. A 248 (1975) 356.
[25] K. Hagino, et al., Comput. Phys. Commun. 123 (1999) 143.
[26] R.A. Broglia, A. Winther, Heavy Ion Reactions, vol. 1, Benjamin/Cummings, Reading, MA, 1981.
[27] J.O. Newton, et al., Phys. Lett. B 586 (2004) 219.
[28] A. Mukherjee, et al., in preparation.
[29] A. Mukherjee, et al., Phys. Rev. C 66 (2002) 034607.
[30] S. Raman, et al., At. Data Nucl. Data Tables 36 (1987) 1.
[31] P. Möller, et al., At. Data Nucl. Data Tables 59 (1995) 185.