Investigation of fusion excitation functions for ^{9}Be + ^{144}Sm system using CDCC approach

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The complex scattering and reaction dynamics in collisions involving weakly bound nuclei have been the subject of intense investigations in recent years, both theoretically and experimentally [1-3 and refs. therein]. In addition to the conventional processes occurring during nucleus-nucleus collision, there may occur some unusual processes when weakly bound nuclei are involved in collision. For instance, owing to the low breakup threshold, the weakly bound nucleus may breaks up in the field of the partner nucleus and several novel processes, such as incomplete fusion (ICF, when some but not all fragments fuse), sequential complete fusion (SCF, when all fragments fuse one after another post breakup), and non capture breakup (NCBU, when none of the fragments fuses with the target) may occur. The sum of direct complete fusion (DCF, where the whole projectile fuses with the target) and SCF is commonly termed as complete fusion (CF) and the sum of CF and ICF is called as total fusion (TF). It is of great interest to find the contribution of these various fusion processes in TF cross sections [4].

Thus, in the present work, we have studied the ICF, CF and TF excitation function for the ^{9}Be + ^{144}Sm system at near and above barrier energies by performing the Continuum Discretized Coupled Channels (CDCC) calculations [5] with the help of code FRESCO [6,7]. The projectile ^{9}Be is assumed as a two body system (^{8}Be + n) with a breakup energy of just 1.667MeV and having spin and parity $3/2^{-}$ in its only bound state, the ground state. Both, the resonant states ($1/2^{+}$ and $5/2^{+}$ at energies 1.684MeV and 3.049MeV respectively) and the non-resonant continuum are taken into consideration for the present calculations. The continuum spectrum is discretized using the standard binning method with a maximum excitation energy of 7MeV above the breakup threshold. The coupled equations are solved for total angular momenta up to j = 200 and up to a matching radius of 60fm. The nuclear part of neutron - target potential used in the calculations is taken from the global parameterization of Koning et al. [8]. For core- target interaction, the Akyuz winther (AW) parameterization [9] is used.

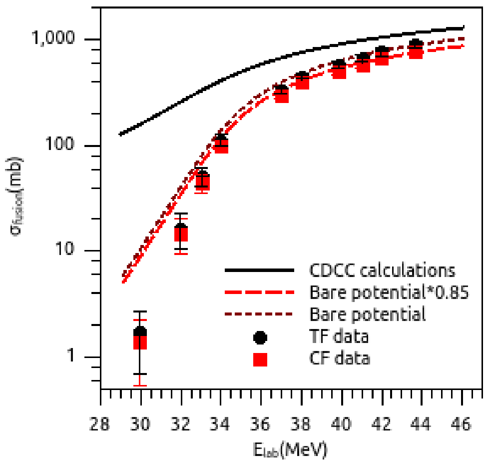

Fig. 1 (Color online) The calculated fusion excitation functions for the system ^{9}Be + ^{144}Sm are compared with the measured TF and CF data taken from ref. [10]. The solid line represents the CDCC results. The dotted line is the results of the calculations when no couplings are taken into account and the dashed line is the same multiplied by 0.85.

It can be seen from fig. 1 that the results of the bare calculations reproduce the TF data at above barrier energies and when, multiplied by 0.85, it reproduces the CF data as well showing the CF suppression of about 15% at high energies. However, the CDCC predictions are found to over predict the TF data for the entire energy range. It may be due to the inclusion of neutron ICF in the calculations which is not involved in experimental measurements.

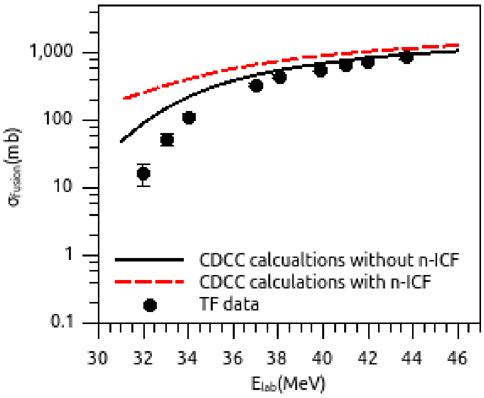

Fig. 2. (Color online) The calculated total fusion excitation functions for ^{9}Be + ^{144}Sm system are compared with the corresponding TF data taken from [10]. The dashed line (solid line) represents the CDCC results with (without) n-target imaginary potential.

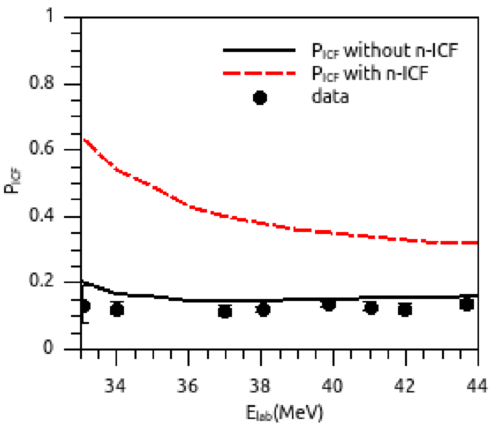

Fig. 3. (Color online) The probability of incomplete fusion for ^{9}Be + ^{144}Sm system is compared with the corresponding data taken from [10]. The dashed (solid) line represents the probability with (without) neutron incomplete fusion.

So, to remove this inconsistency, we have also performed the calculations by ignoring n-ICF channel leading to a better agreement between data and predictions as shown in Fig. 2.
A substantial mismatching between the data and predictions is still observed at low energies reflecting the importance of other direct reaction channels like transfer couplings in this energy regime. Further, we have also calculated the ICF probability by using the methodology of V. Jha et al. [11], and the so obtained results are shown in Fig 3.
The dashed line in the graph represents the ICF probability when neutron absorption is taken into account whereas solid line represents the predictions when imaginary potential for neutron-target interaction is switched off. A reasonably good agreement can be observed between the data and the predicted probabilities by neglecting neutron incomplete fusion.
To summarize, the CDCC calculations are performed for ^{9}Be + ^{144}Sm system, which are in a good agreement with TF data at above barrier energies when n-ICF is not taken into account. Further, the predicted ICF probability is around 15% for the entire enrgy range and it matches the experimental value well.

References

[1] R. Chatterjee and R. Shyam, Prog. Part. Nucl. Phys. **103,** 67 (2018).
[2] L.F. Canto et al., Phys. Rep. **596**, 1 (2015).
[3] N. Keeley et al., Prog. Part. Nucl. Phy. **63**, 396 (2009).
[4] Chetna et al., Int. J. Mod. Phy. E **30,** 2150058 (2021).
[5] H.G. Rawitscher, Phys. Rev. C **9**, 2210 (1974).
[6] I.J. Thompson, Comput. Phys. Rep. **7,** 167 (1988) .
[7] I.J. Thompson and Filomena M. Nunes, Nuclear Reactions for Astrophysics, Cambridge University Press, (2009).
[8] A. J. Koning et al., Nucl. Phys. A **713**, 231 (2003).
[9] A. Winther Nucl. Phys. A **572,** 191 (1994).
[10] P. R. S. Gomes et al., Phys. Rev. C **73,** 064606 (2006).
[11] V. Jha et al., Phys. Rev. C **89**, 034605 (2014)