Couplings to breakup channel and its effects on elastic scattering for $^{9}Be + ^{80}Se$ system

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Very soon after the availability of radioactive ion beam (RIB) facilities, it was realized from the experimental evidences that the dynamics of reactions involving weakly bound nuclei are quite different from those induced by tightly bound nuclei. In particular, owing to low breakup threshold, the effects of couplings to breakup channel on elastic scattering and other reaction channels has attracted considerable interest [1-3]. The elastic scattering is the simplest process which occurs during nucleus – nucleus collision and is of paramount importance in understanding nuclear structures. As a result, a lot of theoretical and experimental work has already been carried out to study elastic scattering of a weakly bound projectile on a stable tightly bound target. A dramatic change in the behavior of elastic scattering angular distributions of weakly bound systems has been found in comparison to tightly bound systems in various studies but with ambiguous results.

Theoretically, the Continuum Discretized Coupled Channels (CDCC) [4] formalism provides an effective way to take into account the breakup couplings. Hence, the present work deals with the study of effects of breakup of weakly bound projectile ^{9}Be on its elastic scattering by ^{80}Se [V_B = 20MeV] target at two energies, E = 30MeV (above the barrier) and 19MeV (near below the barrier) with the help of the code FRESCO [5,6]. The three body CDCC calculations are performed by using two body (^{8}Be + n) cluster structure of the projectile ^{9}Be which has a breakup threshold of just 1.667 MeV. The discretization of the continuum is done through the binning method. The continuum up to an energy of 7MeV above breakup threshold is used in the calculations. The $1/2^{+}$ and $5/2^{+}$ resonant states with energies 1.684MeV and 5.049MeV, respectively are also involved along with the non resonant continuum. For each bin we have considered states with orbital angular momenta associated with core-neutron relative motion in the range $0 \le l \le 4$. The wave function of the fragment target relative motion is expanded in partial waves up to 200 and coupled equations are solved up to a matching radius of 60 fm.

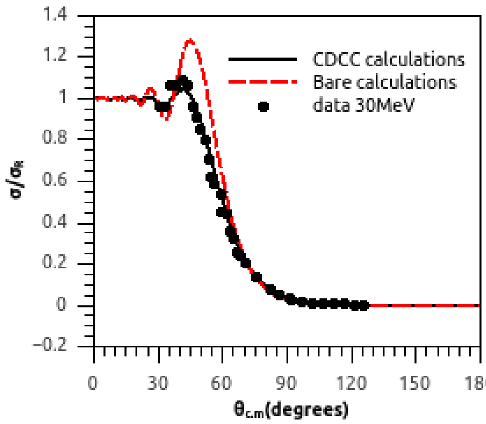

Fig. 1 (Color online) The comparison of elastic scattering data taken from ref. [7] with the predictions at 30MeV. The solid (dashed) line represents the results of calculations with (without) inclusion of breakup couplings.

The neutron-target potential used in the calculations is derived from the global parameterization of Koning et al. [8]. For core-target interaction, the Akyuz Winther (AW) parameterization [9] is used for real part of the optical potential whereas an imaginary potential with parameters (depth 50 MeV, range 0.9 fm

and diffusion parameter 0.25 fm) is used following ref. [10].
The results of the calculations along with data are shown in figs. 1 and 2. It can be clearly seen from fig. 1 that the results of the bare calculations done without inclusion of breakup couplings exhibit the standard form of heavy ion scattering called Fresnel scattering that is some oscillations about Rutherford value at smaller angles, then a peak called Coulomb - Nuclear interference peak or the Coulomb rainbow peak arising because of interference between Coulomb and nuclear amplitudes followed by an exponential fall off. However, the predictions are found to over predict the data at forward angles. A significant depletion in Coulomb – nuclear interference peak along with some reduction in cross sections is obtained which is attributed to the presence of non elastic channels which remove flux from the elastic channel. Similar kind of behavior is observed for deformed targets and halo nuclei as well [1]. The reduction obtained in cross sections for Se target is not so pronounced as obtained for heavy targets.

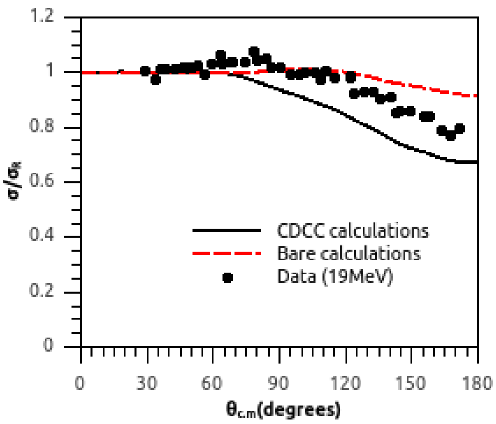

Fig. 2 (Color online) The comparison of elastic scattering data taken from ref. [7] with the predictions at 19MeV. The solid (dashed) line represents the results of calculations with (without) inclusion of breakup couplings.

However, the inclusion of breakup coupling into calculations reproduces the data reasonably well suggesting the importance of breakup channel at above barrier energies.

For 19MeV, the angular distribution with a changed pattern is observed. The ratio of cross sections remains one up to an angle and then it starts decreasing. Some discrepancies are observed between CDCC predictions and the measured data which are shown in fig. 2. The CDCC predictions significantly under predicts the data.
It either may be attributed to the importance of other direct reaction channels like inelastic excitations and transfer which are dominating at lower energies or to the use of global parameterizations for the various interaction potentials used in the calculations.
In nut shell, effects of breakup couplings are investigated for ^{9}Be + ^{80}Se system by using CDCC formalism. A dumping in the interference peak and reduction in elastic cross section at higher angles is observed at higher energies because of the breakup of weakly bound projectile. At lower energies, some discrepancies are observed reflecting the importance of other direct reaction channels.

References

[1] L.F. Canto et al., Phys. Rep. **596**, 1 (2015).
[2] N. Keeley et al., Prog. Part. Nucl. Phy. **63**, 396 (2009).
[3] N. Keeley et al., Prog. Part. Nucl. Phys. **59** 579 (2007) .
[4] H.G. Rawitscher, Phys. Rev. C **9**, 2210 (1974).
[5] I.J. Thompson, Comput. Phys. Rep. **7,** 167 (1988) .
[6] I.J. Thompson and Filomena M. Nunes, Nuclear Reactions for Astrophysics, Cambridge University Press, (2009).
[7] F. Gollan et al., Nucl. Phys. A **979**, 87 (2018).
[8] A. J. Koning et al., Nucl. Phys. A **713**, 231 (2003).
[9] A. Winther Nucl. Phys. A **572,** 191 (1994).
[10] V. Jha et al., Phys. Rev. C **89**, 034605 (2014).