Quasi-elastic barrier distribution study with deformed actinide target

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The work presented in this article is based on the quasi-elastic (QE) scattering measurement for a super heavy system, ^{48}Ti+^{232}Th, leading to a super-heavy nucleus ^{280}Cn$_{112}$ (Copernicium). It is an attempt to obtain the barrier distribution (BD) by exploiting unitarity, that is by measuring the flux reflected from the barrier at large backward angles. It is found, however that there are complications arising from events in the detectors coming from deep inelastic collision (DIC). An approximate experimental method is used to unfold these DIC events. The remaining pure QE events are used to extract the BD structure for ^{48}Ti+^{232}Th system which in turn gives information about the coupling effects. Apart from this, systematic comparison of the obtained BD for ^{48}Ti+^{232}Th system is performed with the existing BD for similar systems.

The details about the experimental techniques are given in ref. [1]. The characteristics of the detector help to separate out all peripheral processes, QE events (sum of elastic, inelastic and transfer etc.) and DIC events from fission events (FF) and other light particles. Hence in the analysis, the gate is applied on the two dimensional spectra of all the energies to get rid of fission events and other light particles. The two dimensional spectra of the remaining events, which are peripheral events, are transformed to energy spectra. The obtained energy spectrum at 225 MeV, which is around 30 MeV below the Coulomb barrier, is a pure gaussian. This is an indication of pure Rutherford scattering. However with increase in the incident beam energy, a tail starts appearing in the lower energy side of the spectrum. At energies above the Coulomb barrier, the elastic peak diminishes and the contribution of the tail part seems to be dominating.

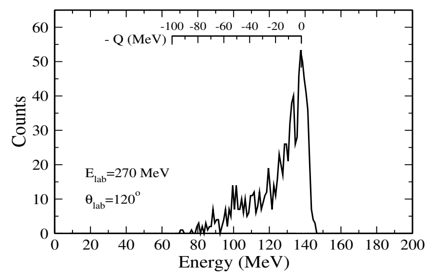

FIG. 1: Energy spectra at 120° in ^{48}Ti+^{232}Th system at E_{lab}= 270 MeV along with the reaction Q-value scale for inelastic exit channel.

To understand the processes responsible for the dominating tail part at higher energies, we consider the reaction Q-value corresponding to the inelastic exit channel. Fig. 1 shows the energy spectra measured at 120° for the ^{48}Ti+^{232}Th system for E_{lab}= 270 MeV. Two overlapping components can been seen, namely, a high energy peak located around Q=0 MeV and a low energy hump associated with large negative Q-value up to -100 MeV for E_{lab}= 270 MeV. The component with large negative Q-value becomes dominant at higher incident energies and corresponds to deep inelastic events.

To separate the QE events from the energy spectra, a simple method is to set an energy borderline between the QE and the deep inelastic components at Q-values around -20 MeV. This choice comes from the detailed studies of the correlations between QE and deep inelastic processes in ^{46,48,50}Ti and also ^{64}Ni, ^{80}Se induced reactions on ^{208}Pb by Rehm et al. [2]. Hence the QE events at differ-

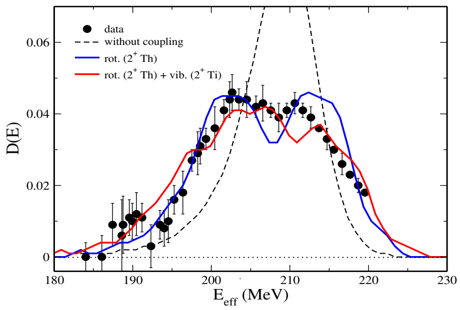

FIG. 2: Experimental and calculated barrier distribution for the ^{48}Ti+^{232}Th system represented with filled circles and solid line, respectively.

ent incident energies give the excitation function from which the BD is extracted by taking its first derivative (shown in Fig. 2).

To address the influence of coupling in the present analyses, the coupled channel calculations have been performed by using the scattering version of CCFULL code. First the rotational excitation to 2^+ state of Th is considered as it has very low energy and large deformation (β_2 =0.2608, E^*= 0.049 MeV). Significant influence of excitation of Th has been observed on the excitation function as well as the BD. However, it is not sufficient to reproduce the data completely. Hence the vibrational excitation of Ti (β_2 =0.26, E^*= 0.9835 MeV) is considered in the calculations. It also shows the significant influence with improved results to reproduce the data (Fig. 2).

From extracted experimental BD, it is observed that the average experimental barrier for ^{48}Ti+^{232}Th system is lying close to its Bass value. This observation seems to be in contrast with that for the ^{70}Zn+^{208}Pb system [3] forming same compound nucleus where the average experimental barrier is reported as lying on lower energy side of the Bass barrier. The first major differences between the above mentioned two systems is deformation of the target nucleus and other is the positive Q-value neutron transfer channels. Hence the permanent deformation of target ^{232}Th (whereas ^{208}Pb is spherical) due to its orientation effect may lead to some increase in the barrier energy.

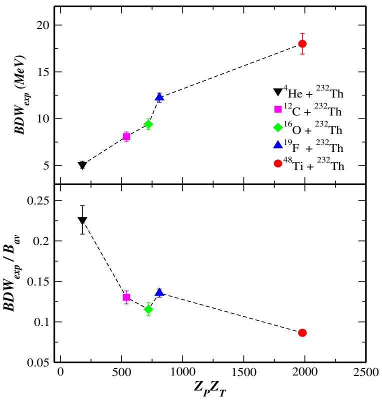

FIG. 3: The experimental width of the barrier distribution BDW_{exp} (upper panel) and BDW_{exp}/B_{av} as a function of the target projectile charge product (lower panel).

In order to investigate the dependence of barrier width as a function of projectile and target charge product ($Z_P Z_T$), the width of the experimental BD (BDW_{exp}) is plotted as a function of $Z_P Z_T$ as shown in Fig. 3. The BD for ^{4}He, ^{12}C, ^{16}O and ^{19}F + ^{232}Th reactions is available in ref. [4]. The correlation of BDW_{exp}/B_{av} with $Z_P Z_T$ is shown in Fig. 3, where B_{av} is the average barrier height. It can be seen that for ^{4}He, ^{12}C, ^{16}O, ^{19}F and ^{48}Ti + ^{232}Th reactions, BDW_{exp} increases linearly while BDW_{exp}/B_{av} decreases systematically as a function of the $Z_P Z_T$.

References

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