Understanding the reaction dynamics of $^{16}O+^{165}Ho$ interactions using the quasi-elastic barrier distribution

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Introduction

The study of residual nuclear potential is a topic of great interest which may be influenced by distinct entrance channels or structure parameters such as the static deformations, nucleons transfer, etc [1–3]. The coupling between relative motion and internal degrees of freedom of interacting particles leads to a number of barriers instead of a single potential barrier. Several attempts has been made to investigate the effect of various entrance channels, through the extraction of barrier distributions (BDs) using the method proposed by N. Rowley et al., as $D_f(E)=\frac{1}{\pi R^2}\ \frac{d^2}{dE^2}(E\sigma_f)$; where E is the energy with respect center of mass and σ_f is the fusion cross-section and R is the barrier radius. Further, using the complementary relation between the fusion and quasi-elastic (QE) reaction processes, M.V Andres and N. Rowley [4] proposed another method to extract the fusion BD from the QE scattering (a sum of elastic, inelastic and transfer etc.) at large angles, which was experimentally extracted by Timmer et al. [5], where BD is obtained through the first derivative of the ratio of the QE cross-section σ_{qe} to the Rutherford cross-section σ_R with respect to energy, $D_{qe}(E)= -\ \frac{d}{dE}\frac{\sigma_{qe}(E,\pi)}{\sigma_R(E,\pi)}$. This method works as a powerful tool to probe the dynamics of nucleus-nucleus collisions around the barrier energies, where fusion cross-section is very challenging to measure such as for very heavy systems. In the present work, The QE-scattering measurements have been preformed for $^{16}O+^{165}Ho$ system in order to understand the effect of different entrance channel parameters.

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Experimental Details

The experiments have been preformed at the IUAC, New Delhi using HYTAR detecting set up, which consists of 13 △E-E type hybrid detectors to measure the QE-events along with two beam monitoring detectors [6]. A detailed schematic diagram of the experimental setup has shown in Fig. 1. In the present experiment, ^{165}Ho target of thickness $\approx$288μg/cm^2 (100% enriched) were used. The incident energy of the ^{16}O beam was varied from 61 MeV (17% below the barrier) to 85 MeV (16% above the barrier) in the steps of 3 MeV. The bombarding energies were corrected for the energy loss in half of the target thickness ranging from 0.15 to 0.35 MeV.

Analysis and Results

The desired QE events have been measured from the 2D spectra of the scattered particles. The cross-sections have been calculated

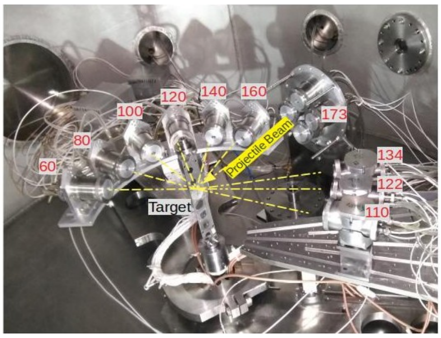

FIG. 1: Pictorial representation of the experimental set-up used.

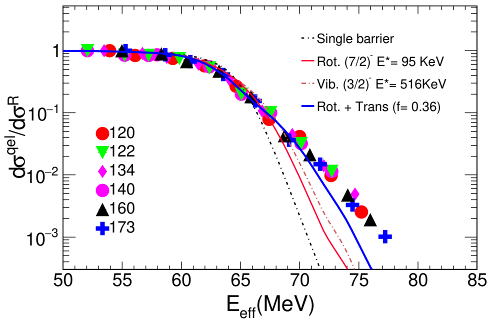

FIG. 2: Experimentally measured QE excitation function compared with CCFULL-SC calculations done for different coupling schemes.

using the standard formulations. Using centrifugal approximation the QE events at these angles were converted to those for 180^0 by mapping to an effective energy E_{eff} using relation $E_{eff}=2E_{CM}/(1+\mathrm{cosec}(\theta_{CM}/2))$. The detector beyond 120^0 were considered to derive the BD in the present work. The measured QE excitation function is shown in Fig. 2, where different symbols have been used for data at different angles, and one can observed that all are satisfactorily matching with each other, putting confidence in using multi detector set-up. The barrier distribution have also been derived from the measured QE-excitation function.

Further, in order to understand the experimental results, the coupled-channels calculations have been carried out using the CCFULL-SC code [7]. The woods-Saxon form of the potential is used and the potential parameters were chosen in such a way that the barrier height becomes equal to the average Bass barrier. As can be seen from Fig. 2 that the excitation function do not reproduced through 1D BPM calculations and hence, subsequent calculations were carried out using different possible coupling schemes. Inelastic states of target's rotational bands having ground state excitation energy E^*=95 KeV have been incorporated in the calculations and is shown by the solid red line in Fig 2. A keen observation shows that the experimental data and theory at above barrier energies are not reproduced satisfactorily, which signify that some other coupling or physical phenomenon is, still, needed to be included in the coupled channel calculations. The coupling scheme involving positive Q-value transfer channels can also affect the BD. Thus, in the present work low negative (2n-pickup, Q$\sim$ -2.45MeV) transfer channel have been included in the coupling scheme along with the inelastic rotational coupling, and one can clearly observed that the inclusion of transfer coupling can satisfactorily reproduced the experimental data. Further, analysis of the data and results will be presented.

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