Observation of an energy shift between fusion and quasi elastic barrier distributions

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Introduction

Heavy ion-induced fusion reactions around the Coulomb barrier have been pursued quite intensely for the past few decades [1]. Fusion cross sections are found to be enhanced, in some cases by several orders of magnitude, over the prediction from the 1-D barrier penetration model near and below the Coulomb barrier [2]. The coupling with intrinsic degrees of freedom has an effect of changing the height of the barrier. The barrier distribution (BD) are known to be highly sensitive to higher order nuclear deformation. The experimental BD can be obtained from the fusion cross section as well as from quasielastic scattering data.

In the present work, we reported an experiment on evaporation residue (ER) excitation function measurement and extracted the BD for the system ^{16}O + ^{174}Yb. We investigated the role of negative β_4 in reproducing the fusion data with the help of coupled-channel (CC) calculation. During the investigation we observed an energy shift between the BDs extracted from fusion and quasi-elastic data, which demands a systematic theoretical approach to carry forward.

Experimental details and data analysis

The experiment was performed at the 15-UD Pelletron accelerator facility of IUAC. A pulsed beam of ^{16}O with a pulse separation of 4 μs was incident upon isotopically enriched ^{174}Yb target of thickness 125 μg/cm^2 on 25 μg/cm^2 ^{nat}C backing. The experimental method and details of the data analysis were reported in Ref. [3].

Results and discussion

The CC calculations were performed by using the code CCFULL [4]. The Woods-Saxon parametrization of the Akyüz-Winther potential was used in CCFULL. The dashed-dotted line in the figures is the prediction from the one-dimensional barrier penetration model, which expectedly underestimates data. The results of CC calculation have been plotted in Fig. 1 with a fixed value of β_2 and varying β_4 as -0.020 (solid line), -0.050 (dashed line) and -0.080 (dotted line) to explain the fusion excitation function. Considering coupling to rotational $\beta_2 = 0.332$, $\beta_4 =$ -0.020 for ^{174}Yb target nucleus gave satisfactory fit to data from well above to the sub-barrier region. We also investigated the sensibility of the CC calculations with slightly changes in the above β_4 range, but no significant improvement was obtained. Therefore, we proposed the hexadecapole parameter $\beta_4 =$ -0.020, which gave satisfactory fit or near to sub-barrier fusion data for the system.

Also we extracted barrier distribution (BD) from fusion excitation functions using the point difference formula. BD obtained from the fusion excitation function and CC calculation for the reaction ^{16}O+^{174}Yb is shown in Fig. 2. The BD is reasonably well defined at low energies, but around the peak of the distribution and near the average barrier, the uncertainties were larger than the measured values. As seen in figure, the BD show a broad single peak with large fluctuations at higher energies. It is quite obvious that more precise data is needed to determine proper shape of the BD. The target thickness should be very thin for BD mesurement. Consequently, it was

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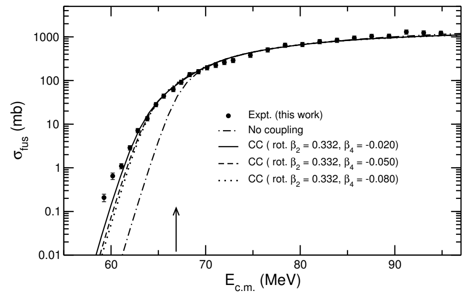

FIG. 1: The experimental fusion excitation functions for ^{16}O+^{174}Yb along with results from CC calculations using CCFULL.

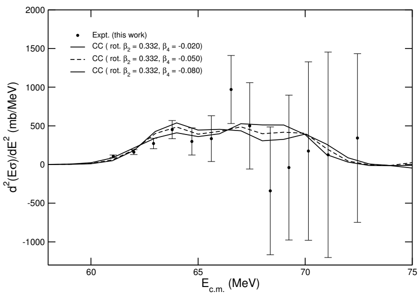

FIG. 2: Experimentally extracted BD for ^{16}O+^{174}Yb.

not possible to draw proper conclusions from BD independently. Thus, our experimental results suggested a new β_4 value of -0.020 for the present system. Experimentally determined β_4 are susceptible to systematic uncertainties

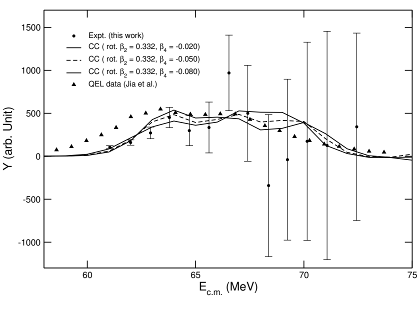

FIG. 3: Comparison of the extracted BD obtained from both fusion and quasi-elastic measurements for ^{16}O+^{174}Yb along with results from CC calculation.

and also heavily dependent on the model used in a particular work. Thus, more precision measurements in this mass region using different experimental techniques are called for to achieve convergence of the result and overcome dependence on models.

In this technique, we have shown BDs in Fig. 3 for ^{16}O+^{174}Yb obtained from both fusion (present work) and quasi-elastic (Ref. [5]) measurements along with results from CC calculations. The quasi-elastic data are arbitrarily scaled multiplying by a factor of 5000. Though it is difficult to draw definitive conclusions because of large uncertainties in the fusion data, it appears that there is an energy shift of about 1.5 MeV between the two BDs. More investigations are required to explore the energy shift between the BDs extracted from fusion and quasi-elastic data. It is also noted that quasielastic BD is found to be about 3 times larger than that of fusion. Of course, a similar energy steps were used for both methods; i.e 2 MeV for point difference formula and 2.1 MeV for quasielastic BD. Therefore, with the presently available data we observed an energy shift between the two BDs.

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