

Barrier distributions from the fusion of $^{28}\text{Si} + ^{142}\text{Nd}$ reaction

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The investigation of heavy-ion collision dynamics at sub-barrier energies has been the focus of significant experimental and theoretical research for several decades. Empirical studies consistently report a substantial increase in sub-barrier fusion cross sections, surpassing the theoretical predictions of the One-Dimensional Barrier Penetration Model (1D-BPM) [1]. The enhancement observed arises from the coupling of the relative motion between colliding nuclei with various intrinsic degrees of freedom, including nuclear deformation, vibrational degrees of freedom, and nucleon transfer channels. Such couplings frequently lead to the emergence of a distribution of fusion barriers. In cases where coupling effects are negligible, only a single fusion barrier is present. Therefore, measuring the barrier distribution (BD) provides valuable insight into competing reaction mechanisms and the influence of nuclear structure on the fusion process. The BD can be obtained from measurements of the fusion cross section as well as from the measurements of quasi-elastic scattering cross sections. We have extracted the BD from the fusion excitation function mea-

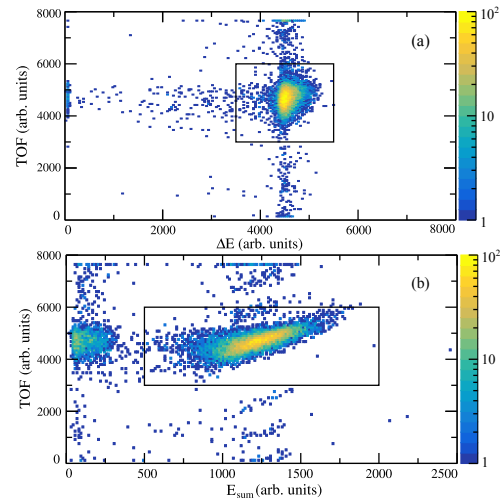


Fig.1. (a) ΔE vs TOF spectrum and (b) E_{sum} vs TOF spectrum of $^{28}\text{Si} + ^{142}\text{Nd}$ reaction at $E_{lab} = 135.2$ MeV.

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The evaporation residue (ERs) measurements were performed using the Heavy Ion Reaction Analyzer (HIRA) [2] at IUAC, with projectile energies E_{lab} ranging from 108.2 to 135.2 MeV. The ERs were detected at the HIRA focal plane using a multi-wire proportional counter (MWPC), followed by a segmented ionization chamber (IC). The unambiguous identification of the ERs were

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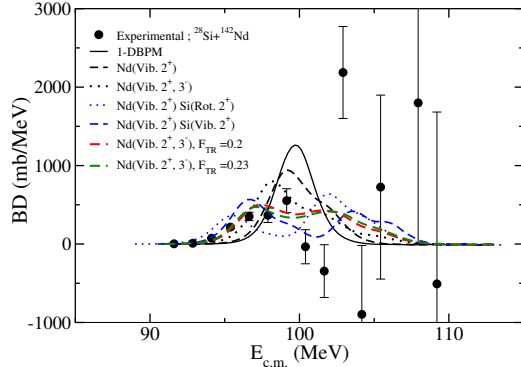


Fig.2. BD of $^{28}\text{Si} + ^{142}\text{Nd}$ reaction extracted from the double-differentiation method.

achieved using time-of-flight (TOF) and ΔE measurements over the entire energy range studied. Furthermore, ERs were distinguished from beam-like particles through E_{sum} (the sum of all individual energy signals from the IC) versus TOF.

In the present work, the BD has been extracted from the measured fusion cross sections using two approaches. The first is the conventional double-differentiation method, implemented with a point-difference formula as proposed by Rowley *et al.* [3]. A primary limitation of this technique is that the associated uncertainty scales directly with both the cross section and the energy. Consequently, at higher energies, the increased uncertainty can distort the observed structure of the BD. The second approach is the Gaussian analytic method, as demonstrated by Jiang *et al.* [4], which offers an effective alternative for determining experimental BDs. This method is independent of the energy step size and remains robust even in the presence of large uncertainties in the measured cross sections, thereby overcoming a key drawback of the double-differentiation method.

The BD extracted using the double differentiation method and the Gaussian analytic method are shown in Fig.2 and Fig.3, respectively. To gain deeper insight into the fusion dynamics of the present reaction, these extracted BDs have been compared with coupled-channels (CC) calculations [5]. When both collision partners were treated

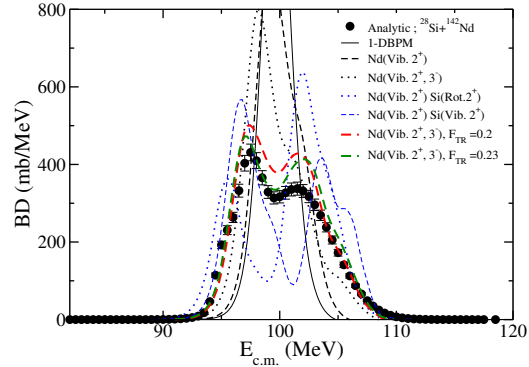


Fig.3. BD of $^{28}\text{Si} + ^{142}\text{Nd}$ reaction extracted from the 3G-analytic method.

as inert, CC calculations fail to reproduce both the analytic and experimental BD. Next, we treated ^{28}Si as inert while considering mutual excitations for both quadrupole and octupole modes in ^{142}Nd , which again failed to reproduce the extracted BD. Therefore, we incorporated projectile couplings in addition to the target couplings; however, this resulted in a noticeable shift of the peaks in the BD. Finally, transfer couplings were included in the CC calculations along with the 2^+ and 3^- excitations of the target, resulting in improved agreement with the experimental as well as analytic BD. This coupling scheme also provided better agreement with the experimental excitation function. Detailed results and analysis will be presented during the Symposium.

Acknowledgments

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