Investigation of Coulomb reorientation effect on fusion barrier distribution in the ^{24}Mg+^{90}Zr reaction

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Introduction

Internal degrees of freedom of the fusing nuclei, such as vibrational (spherical), rotational (deformed), and neutron transfer play crucial role in the fusion dynamics. Coupling of these degrees of freedom with relative motion during fusion at energies around the barrier enhance the fusion cross section over one-dimensional barrier transmission predictions [1]. It has been proposed [2] that in case of static quadrupole deformation, the fusion cross section which is anticipated to be enhanced due to the above mentioned channel coupling would be suppressed owing to reorientation of the fusing partner in the mutual Coulomb field. In principle, experimental signatures of this "Coulomb reorientation effect" can be seen through fusion barrier distribution (FBD).

FBDs have been determined for numerous target-projectile combinations from quasi-elastic as well as fusion-excitation functions; however, only in few studies influence of "Coulomb reorientation effect" has been witnessed [3]. It is shown in Ref. [2] that the magnitude of the reorientation effect depends not on the charges and relative kinetic energy of the fusing nuclei, rather, only on deformation and relative size of the nuclei. Ref. [2] suggests a large "Coulomb reorientation effect" for ^{24}Mg+ ^{208}Pb system, however, a perceptible effect should also be observed for ^{24}Mg+ ^{90}Zr system. In the present paper we report our investigations for the "Coulomb reorientation effect" on the FBD for ^{24}Mg+ ^{90}Zr and ^{16}O+ ^{90}Zr systems using quasi-elastic measurements.

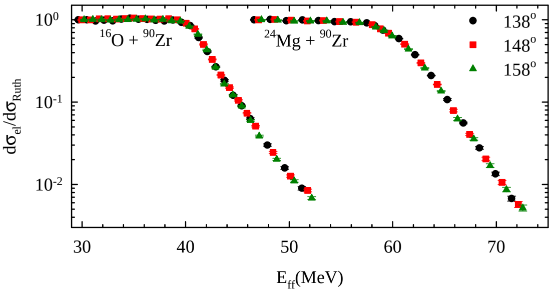

FIG. 1: Quasi-elastic excitation function for both the target-projectile combinations.

Experimental Details and Data Analysis

Quasi-elastic measurements were carried out using ^{16}O and ^{24}Mg beams from the FN accelerator facility at Nuclear Science Laboratory, University of Notre Dame, USA. Highly enriched (>95%) ^{90}Zr (150 μg/cm^2) deposited in oxide form on ^{12}C (50 μg/cm^2) was used as the target. Beam energies were used in the range of 36 to 62 MeV (for ^{16}O) and 61 to 91 MeV (for ^{24}Mg) in steps of 1-MeV (for ^{16}O) and 2-MeV (for ^{24}Mg). Quasi-elastic events were extracted using three silicon surface barrier (SSB) ΔE (15 μm)-E (1 mm) tele-

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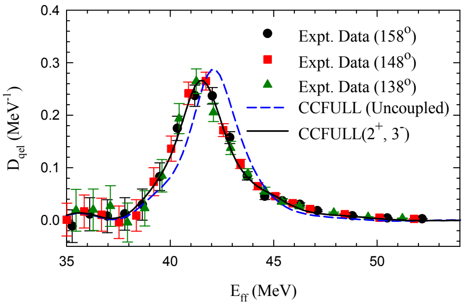

FIG. 2: Experimental $D_{\rm qel}$ for ^{16}O+ ^{90}Zr system. Dashed and solid lines represent CCFULL calculation for uncoupled and low lying excitations (2^+, 3^-) of ^{90}Zr, respectively.

scopes placed at 158°, 148°, and 138° with respect to the beam direction. Two SSB detectors placed at ±20° were used to measure Rutherford scattering events for normalization. Quasi-elastic scattering peak of ^{90}Zr was well separated from that of the ^{12}C (backing) and ^{16}O (target is ZrO$_2$). Differential cross section for quasi-elastic events normalized with Rutherford scattering cross section is plotted in Fig. 1 as a function of centrifugal corrected center-of-mass energy for each telescope, $E_{\rm eff} = 2E_{\rm c.m.}/(1 + {\rm cosec}(\theta_{\rm c.m.}/2))$, where $\theta_{\rm c.m.}$ is the center-of-mass angle of the telescope. It is seen from Fig. 1 that the quasi-elastic excitation functions determined from three different back angles are overlapping.

Fusion barrier distribution $D_{\rm qel}$ ($E_{\rm eff}$) from quasi-elastic excitation function was determined using the relation [1]:

$$D_{qel}(E_{\rm eff}) = -\frac{d}{dE_{\rm eff}}\left[\frac{d\sigma_{\rm qel}(E_{\rm eff})}{d\sigma_{\rm R}(E_{\rm eff})}\right], \qquad (1)$$

where $\sigma_{\rm qel}$ and $\sigma_{\rm R}$ are the differential cross sections for the quasi-elastic and Rutherford scatterings, respectively.

Results and Discussion

FBDs determined from three back angle measurements of quasi-elastic scattering for ^{16}O+ ^{90}Zr system are shown in Fig. 2. Coupled channel (CC) calculations for fusion excitation function in ^{16}O+ ^{90}Zr reaction was performed using the program CCFULL [4]. It can be seen from Fig. 2 that without including any couplings (uncoupled) calculations do not reproduce experimentally determined FBD. However, calculation with including low lying excitations (2^+, 3^-) of ^{90}Zr reproduce experimentally determined FBD quite well. β_2 and β_3 values used in the calculation are 0.089 and 0.211, respectively. Thus, channel coupling parameters due to ^{90}Zr are frozen from FBD study in ^{16}O+ ^{90}Zr reaction. Fusion barrier distribution for ^{24}Mg+ ^{90}Zr system is shown in Fig. 3. One can see from Figs. 2 and 3 that FBDs determined from quasi-elastic measurements of three different back angles are also overlapping. It is evident that the FBD for ^{24}Mg+ ^{90}Zr system is significantly broader than ^{16}O+ ^{90}Zr system. Quantitative analysis using coupled channel code CCFULL is being carried out to investigate the role of "Coulomb reorientation effect" on fusion barrier distribution in ^{24}Mg+ ^{90}Zr reaction. Detailed results would be presented.

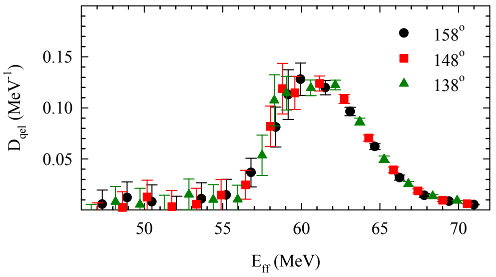

FIG. 3: Same as Fig. 2, it is for ^{24}Mg+ ^{90}Zr system.

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