Barrier distribution for the ^{28}Si + ^{150}Nd system through quasi-elastic excitation function measurement

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Introduction

Experimental and theoretical investigations on the effect of couplings to the inelastic excitations and the underlying non-fusing channels between the interacting nuclei on the fusion process at energies around the Coulomb barrier have been carried out systematically over the last few decades [1, 2]. Quasi-elastic scattering process of the heavy ion projectile like particles at the backward angles is considered to be the counterpart of the corresponding heavy-ion fusion reaction. Both are inclusive processes and are sensitive to the channel coupling effects at energies close to the Coulomb barrier. However, a major difference between the two process is that the quasi-elastic scattering is related to the reflection probability of the Coulomb barrier, while the fusion is related to the transmission probability. The excitation function data reveals the most fundamental features of the underlying reaction process and is very often used for extracting the other relevant observable. It is worthwhile mentioning that the measurement of the quasi-elastic excitation function is relatively easier and there are certain advantages compared to that of fusion excitation function measurement [3]. Exploiting this fact, it has become a common practice to use the excitation function data of the quasi-elastic scattering events at large back angles for extracting the features of fusion barrier distribution of the underlying reaction process. In the present work, we have measured the quasi-elastic excitation function for the ^{28}Si + ^{150}Nd system at large backward angles.

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Experimental Details and Results

The experiment was carried out using the GPSC facility with ^{28}Si beam delivered by the 15 UD Pelletron accelerator at IUAC, New Delhi. The beam energy was varied in the range 84 - 136 MeV. The enriched ^{150}Nd (97.56 % enrichment) target was used for the experiment. The effective areal thickness of the target was $\sim$150 μg / cm^2. The target material was sandwiched properly between a carbon capping of thickness $\sim$ 10 μg / cm^2 and a carbon backing of thickness $\sim$ 25 μg / cm^2. The presence of capping and backing material helped in preventing the target from

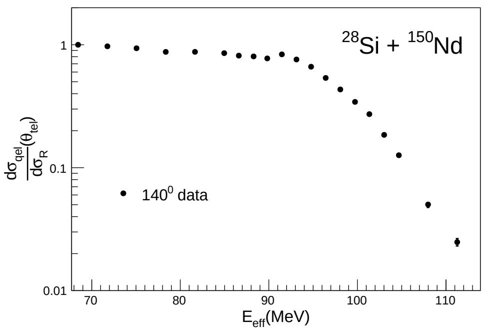

FIG. 1: Excitation function plot for the ^{28}Si + ^{150}Nd system at 140°.

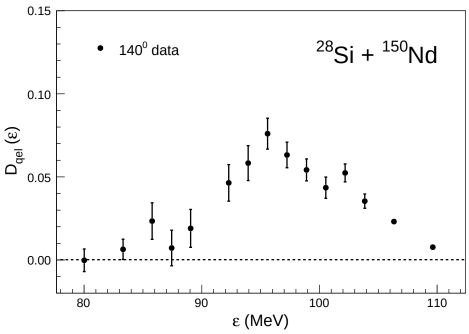

FIG. 2: Barrier distribution pattern for the ^{28}Si + ^{150}Nd system obtained from quasi-elastic scattering excitation function data at 140°.

oxidization. The beam like particles were detected at the back angles using an array of hybrid telescope detectors (HYTAR) [5]. Four detectors (two in plane and two out of plane positions) were placed at 173° with respect to the incident beam direction. Six detectors were placed on a movable arm with their angular positions at 160°, 140°, 120°, 100°, 80° and 60°. For covering the angular positions at the intermediate angles of 150°, 130°, 110°, 90°, 70° and 50°, the arm was also rotated occasionally through 10° in anticlockwise direction during the time of the experiment. Three additional detectors were placed at 36°, 48°, and 60° to collect the data at the forward angles. Two monitor detectors were placed at ±10° for beam normalization purpose. The software packages, FREEDOM and CANDLE were used for the acquisition and the subsequent analysis of the acquired data. The quasi-elastic events were identified from the recorded ΔE-E 2D spectra.

Fig. 1 shows the excitation function data acquired at an angle of 140°. The effective energy, E_{eff} (the corrected energy due to centrifugal effect) has been calculated using the relation:

$$E_{eff} = \frac{2E_{c.m.}}{1 + cosec(\theta_{c.m.}/2)} \quad (1)$$

The experimental fusion barrier distribution, obtained from quasi-elastic excitation function data using the point difference formula [4], is shown in Fig. 2.

For understanding the possible effect of nuclear structure of the colliding nuclei on barrier distribution, theoretical calculations would be carried out using the scattering version of the CCFULL [6] code. Further analysis of the data is under progress and detail results will be presented in the conference.

Acknowledgments

The authors would like to thank the Pelletron staff of IUAC, New Delhi for providing the good quality beam. Thanks are also due to D. Kabiraj and Abhilash S. R. for their help and support in preparing the targets. The help and all-round cooperation of P. Sugathan during the experiment is gratefully acknowledged. Thanks are due to N. Madhavan and S. Nath for many helpful discussions and suggestions on this work.

References

[1] M. Dasgupta *et al.*, Annu. Rev. Nucl. Part. Sci. **48**, 401 (1998).

[2] B. B. Back *et al.*, Rev. Mod. Phys. **86**, 317 (2014).

[3] K. Hagino *et al.*, Brazilian Journal of Physics **35**, 3B, 890 (2005).

[4] E. Piasecki *et al.*, Phys. Rev. C **65**, 054611 (2002).

[5] A. Jhingan *et al.*, Nucl. Instrum. Methods Phys. Res. **A 903**, 326 (2018).

[6] K. Hagino *et al.*, Comput. Phys. Commun. **123**, 143 (1999).