# Barrier distribution for $^{16}$O+$^{169}$Tm system through quasi-elastic back-scattering

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In recent years, there is a great interest in fusion barrier studies due to the advances in experimental methods and theoretical interpretations [1–7]. The heavy-ion collisions at energies around the Coulomb barrier are strongly affected by the internal structure of colliding nuclei [1–6]. The coupling between relative motion and internal degrees of freedom of colliding ions (such as static deformations, collective excitations; rotation and/or vibration, nucleon transfer, projectile break-up, etc.) results in a number of distributed barriers in place of a single potential barrier ($B_{fus}$). It is now well known that a barrier distribution (BD) can be extracted experimentally from the fusion excitation function $\sigma_{fus}$(E), using the relation $D_{fus}$=$d^2(E\sigma_{fus})/dE_2$ [1] [1]. The extracted BD can be treated as a fingerprint of the reaction mechanism characterizing the importance of channel couplings because the nature and strengths of the couplings lies in the distribution of barriers. Further, it was suggested that the same information can also be obtained from the cross-section of quasi-elastic scattering (QE) (as the total flux is conserved) measured at large angles using the prescription $D_{qel}$=-d$(d\sigma_{qel}/d\sigma_R)$/dE, which gives an alternative representation of fusion BD [3], where

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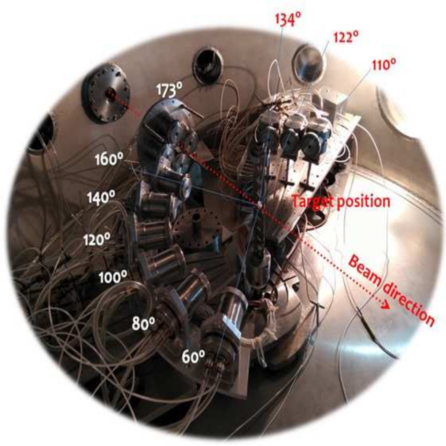


FIG. 1: A pictorial representation of the experimental set-up.

$\sigma_{qel}$ and $\sigma_R$ are cross-sections of quasi-elastic and Rutherford scattering processes. The quasi-elastic events are defined as a sum of all the reaction processes other than fusion (elastic + inelastic + transfer + breakup, etc.). In the present work, the QE-scattering measurements have been performed for $^{16}$O+$^{169}$Tm system, which will be translated to the BD. It should be noticed that the doubly closed $^{16}$O projectile will behave as an inert, and therefore any effect of the coupling of different degrees of freedom on BD should be pronounced for the target nuclei only.

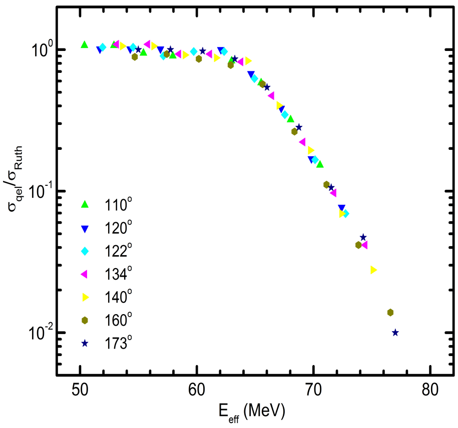


FIG. 2: Measured quasi-elastic (QE) excitation function at different angles.

In order to ascertain the above aspects in a consistent way, the experiments have been planned and performed at the Inter-University Accelerator Centre (IUAC), New Delhi using HYTAR detector system in GPSC [7]. The isotopically pure $^{169}$Tm target of areal density $\approx 600\ \mu$g/cm$^2$ were prepared using rolling technique. The composition and thickness of the target were measured using Rutherford back-scattering (RBS) facility at IUAC. The beam energy of $^{16}$O were varied in steps of 3 MeV ranging from 17% below barrier to 16% above barrier. The bombarding energies were corrected for energy loss in half of the target thickness. The QE-measurements were performed employing hybrid telescope detectors comprising of $\Delta$E and E detectors. Four telescope detectors each at an angle of 173° have been arranged in a symmetrical cone geometry to measure the back-scattered quasi-elastic events. Nine telescopes, six at angles from +60° to +160° with angular separation of 20° and other three telescopes at angles -110°, -122° and -134° were, also, placed. Two monitor detectors have been placed at ±10° for beam normalization purpose. A pictorial view of the set-up is shown in Fig.1. The QE-events have been identified by E-$\Delta$E, 2D spectra. Fig. 2 shows the excitation function as a function of $E_{eff}$. As each scattering angle corresponds to scattering at a certain angular momentum, hence the cross section is scaled in energy by taking into account the centrifugal correction using $E_{eff}=2E_{CM}/(1+\text{cosec}(\theta_{CM}/2))$. From experimentally measured QE-excitation function, the experimental BD for the $^{16}$O+$^{169}$Tm system has been derived by combining the data from all detectors, the QE-excitation function with energy step of less than 1 MeV is obtained. The nuclear potential parameters will be extracted from angular distribution measurements for the theoretical calculations. Further, analysis of the data is underway and the details will be presented during the conference. The authors thank to the Director, IUAC, New Delhi, India, for providing all the necessary facilities to carry out this work. One of authors A.Y. thanks the DST for providing support through Young Scientist Scheme under start-up research grant ref: SB/FTP/PS-194/2013.

## References

[1] N. Rowley, G.R. Satchler, and P.H. Stelson, Phys. Lett. B254, 25 (1991).
[2] M. Dasgupta et al., Annu. Rev. Nucl. Part. Sci. 48, 401 (1998).
[3] H. Timmers et al., Nucl. Phys. A 584, 190 (1995).
[4] K. Hagino, N. Rowley, and A. T. Kruppa, Comp. Phys. Comm. 123, 143 (1999).
[5] G. Kaur et al., Phys. Rev. C 94, 034613 (2016).
[6] Md. Moin Shaikh et al., Phys. Rev. C 91, 034615 (2015).
[7] Akhil Jhingan et al., Proceedings of the DAE Symp. on Nucl. Phys. 830, 59 (2014).