Quasi-elastic scattering measurement for ^{28}Si+^{232}Th reaction

Gurpreet Kaur[1,*], B. R. Behera[1], A. Jhingan[2], N. Saneesh[2], Mohit Kumar[2], Meenu Thakur[1], Ruchi Mahajan[1], Kavita[1], Shruti[1], Abhishek Yadav[2], and P. Sugathan[2]

[1]*Department of Physics, Panjab University, Chandigarh-160014, India*
[2]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi-110067, India and*
[*]*Present affiliation: Instituto de Física, Universidade de São Paulo, Rua do Matao, 1371, 05508-090 São Paulo, Brazil*

Introduction

The cold-fusion reactions based on lead or bismuth targets [1] and the hot-fusion reactions based on the actinide targets [2], are successfully used in the synthesis of heavy and super-heavy elements (SHE). These two types of reactions significantly differ by the amount of released thermal energy and the static deformation of the associated target nuclei. It is revealed from the experimentally measured excitation functions that in cold-fusion, the highest cross-sections are obtained at beam energies where a contact configuration between the projectile and the spherical target nucleus is just reached. However in hot fusion, the maximum cross-sections are obtained at beam energies which are high enough so that projectile (like ^{48}Ca) and prolate target nuclei can come into contact at minimal distance (equatorial collisions) and thus form a most compact starting configuration on the way to the compound nucleus [3, 4]. The cross-sections decrease rapidly with drop in energy to values where the interaction is limited to polar collisions and the probability for re-separation of the reaction partners is high.

However, it is observed that the results are different in the case of projectiles significantly lighter than ^{48}Ca. For example, in the reaction ^{16}O + ^{238}U, the experimental data show a large enhancement of evaporation residue (ER) cross-sections at sub-barrier energies, indicating fusion independent of the orientation of the target nucleus. Hence one may expect a transition from the orientation-independent fusion using light projectiles to the case of equatorial fusion using ^{48}Ca projectiles. In order to study the anticipated transition we chosen the reaction ^{28}Si + ^{232}Th with a projectile right in the middle between ^{16}O and ^{48}Ca; the chosen target ^{232}Th has similar collective states as ^{238}U. To study the effect of projectile and target excitation on fusion, we measured the barrier distribution (BD) for the ^{28}Si+^{232}Th system forming SHE ^{260}Rf$_{104}$. To extract the BD, the technique of quasi-elastic (QE) scattering at large backward angles is utilized.

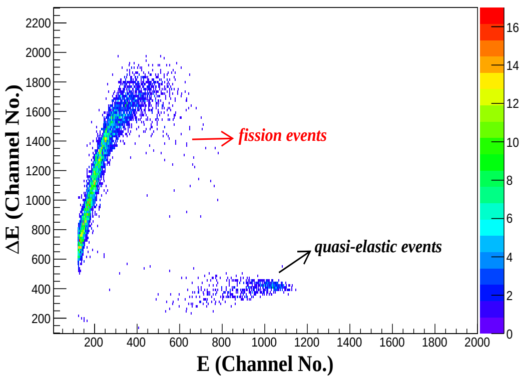

FIG. 1: Two-dimensional correlation plot of ΔE-E energy signals from the hybrid telescope detector at 173° with respect to the beam direction in the ^{28}Si + ^{232}Th reaction at E_{lab} = 170 MeV.

Experimental Setup

The experiment was performed using the Pelletron + LINAC accelerator facility of the IUAC, New Delhi. To measure the QE events,

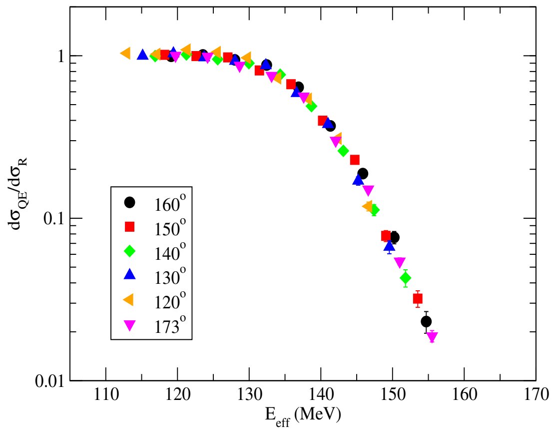

FIG. 2: Experimental Quasi-elastic (QE) excitation function for the $^{28}Si+^{232}Th$ system obtained by combining the data at different angle. The angle θ_{lab} is also mentioned.

the HYTAR facility [5]: an array of hybrid telescope detectors comprising of ΔE and E detectors is employed. The detectors were placed at angles from 160° to 120° with an angular pitch of 10°. A dome arrangement containing four detectors each at 173° w.r.t the beam direction is also used. The detail about the detector system is available in Ref. [5]. Fig. 1 shows the two-dimensional correlation plot of ΔE-E energy signals from the hybrid telescope detector at 173° with respect to the beam direction in the $^{28}Si+^{232}Th$ reaction at E_{lab}= 170 MeV.

Preliminary Results

For a heavy system like $^{28}Si+^{232}Th$, probability of fission is very high at energies above the Coulomb barrier. Hence the fission fragments are observed around as well as above the Coulomb barrier. The characteristics of the detector help to resolve different types of events. As seen in Fig. 1 the QE events, which are sum of all peripheral processes (elastic, inelastic and transfer etc.), are well separated from fission events and other light particles. Hence in the analysis, a gate is ap- plied on the two dimensional spectra of all the energies to get rid of fission events and other light particles.

Fig. 2 shows the excitation function obtained from data measured at θ_{lab}= 173^0 and 160^0 to 140^0 as a function of E_{eff}. As each scattering angle corresponds to scattering at a certain angular momentum, hence the cross-sections has been scaled in energy by taking into account the centrifugal correction, i.e., as a function of E_{eff}, where E_{eff}=$2E_{cm}/(1+\text{cosec}(\theta_{cm}/2))$. So combining the data from all detectors, the final QE cross-section σ_{QE}(E), relative to the Rutherford scattering cross-section σ_R(E) with energy step of less than 1 MeV is obtained [6]. Using this excitation function, the BD will be extracted by taking its first derivative, that is d(σ_{QE}(E)/σ_R(E))/dE. The analysis and the theoretical interpretation of BD are under progress.

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