Transfer measurements for ^{28}Si + ^{116,120,124}Sn systems near the Coulomb barrier

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Introduction

Transfer reactions have always been of great importance to understand the interplay between nuclear structure and reaction dynamics [1]. Single nucleon transfer is a selective and direct probe of single particle shell structure, while two-nucleon transfer serves as a promising tool to investigate the pairing correlations amongst nuclei. Further, transfer channels coupled with inelastic excitations influence the fusion cross-sections at sub-barrier energies [2, 3]. We have performed the fusion excitation function measurements around the Coulomb barrier with the same set of systems. The lucid role of multi-nucleon transfer channels in the sub-barrier fusion enhancement has been reflected in these measurements [4]. The different positive Q-value transfer channels make Sn systems a potential choice for transfer measurements. Sn isotopes possess extra neutrons outside their closed sub-shell, (4 in case of ^{124}Sn and, 2 in ^{116}Sn) resulting in the flow of neutrons between the colliding partners. This might take place either sequentially or simultaneously in the form of a cluster which can aid in the investigation of pairing correlation and superfluidity effects among the interacting nuclei. Therefore, to ascertain the aforementioned aspects of a heavy-ion collision, we have performed the transfer measurements for ^{28}Si + ^{116,120,124}Sn systems at energies close to and below the Coulomb barrier.

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Experimental Details

The experiment has been performed using ^{28}Si pulsed beam with a pulse separation of 1 μs from the Pelletron at the Inter-University Accelerator Centre (IUAC), New Delhi. The targets used were isotopically enriched samples of thicknesses $\sim 230\ \mu$g/cm^2 with C backing of $\sim 20\ \mu$g/cm^2. The transfer measurements particularly with heavy ions and below the Coulomb barrier are extremely challenging due to (a) low transfer cross-section along with enormous elastic background, (b) the reaction products being backward peaked with energy less than 1 MeV/u causing the identification more difficult. This difficulty in the detection and identification of the low-energy reaction products can be overcome by detecting the corresponding forward-moving target-like recoils using a recoil mass spectrometer, Heavy Ion Reaction Analyzer (HIRA) in the present measurements [5]. The spectrometer was rotated to 9° for better primary beam rejection. The forward-moving target-like recoils were detected using a 150 $\times$ 50 mm^2 Multi-Wire -Proportional Counter (MWPC) at the focal plane of the HIRA. A kinematic coincidence between the forward-moving recoils and backscattered projectile-like particles was employed using a 150 mm^2 silicon detector in the target chamber at a back angle of θ_{lab}=158°. This coincidence coupled with the Time of Flight (TOF) setup between MWPC timing and delayed Radio Frequency (RF) enabled unambiguous identification of the reaction products. The transfer measurements were performed at laboratory beam energies in the range of 97 - 108 MeV in steps of 3

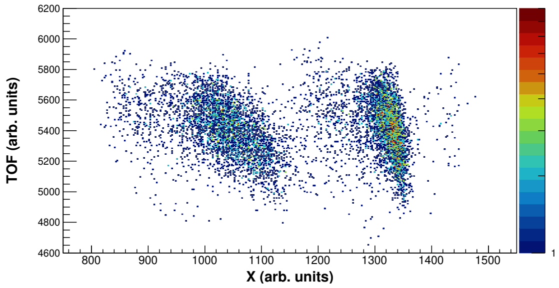

FIG. 1: Two-dimensional spectrum depicting the Time of Flight of reaction products vs MWPC position for ^{28}Si + ^{120}Sn system at E_{lab} = 106 MeV.

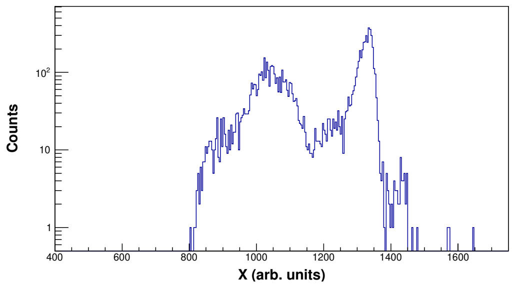

FIG. 2: Mass spectrum obtained by projecting the 2-D spectrum of Time of Flight vs MWPC position for ^{28}Si + ^{120}Sn system at E_{lab} = 106 MeV.

MeV around and below the barrier. Two silicon detectors were mounted inside the target chamber at $\theta_{lab} = 15.5°$ with respect to the beam direction for beam intensity monitoring. The HIRA was operated with acceptance of 5 mSr during the measurements.

Results

Fig. 1 shows a 2-D spectrum between MWPC position (X) and the time of flight of recoils gated with a Time to Amplitude Converter (TAC) setup between the timing signal of focal plane detector MWPC and silicon detector at back angle, for ^{28}Si + ^{120}Sn at E_{lab} = 106 MeV. Reaction products dispersed at the focal plane of the HIRA in accordance with their mass (A) to charge (q) ratio can be seen in Fig. 1. The corresponding mass spectrum obtained by projecting this 2-D spectrum on X-axis is shown in Fig. 2. A 2-D spectrum between MWPC position (X) and back angle detector $(TAC)_{coinc}$ is shown in Fig. 3. An examination of the Q-values of the systems investigated shows that neutron transfer channels are pickup in nature. Further analysis of data to understand the underlying reaction dynamics is in progress. Detailed results and analysis will be presented during the Symposium.

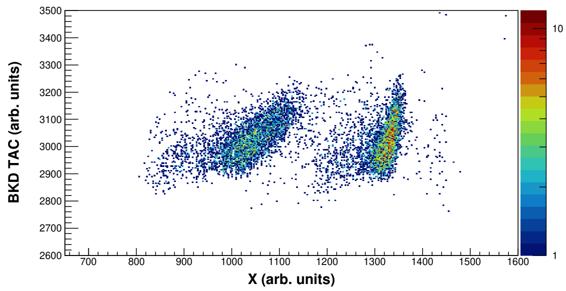

FIG. 3: 2-D spectrum of MWPC position v/s TAC setup between back angle detector and focal plane detector.

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References

[1] L. Corradi, G. Pollarolo, and S. Szilner, Journal of Phys. G **36**, 113101 (2009).
[2] Vandana Tripathi *et al.*, Pramana J. Phys. **53**, 535 (1999).
[3] S. Kalkal *et al.*, Phys. Rev. C **83**, 054607 (2011).
[4] Anjali Rani *et al.*, Proceedings of the DAE Symp. on Nucl. Phys. **65**, 403 (2021)
[5] A. K. Sinha *et al.*, Nucl. Instr. and Meth. A **339**, 543 (1994).