# Understanding Reaction Mechanisms of Multi-nucleon Transfer Reactions in Deformed Nuclei

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In our recent study[1,2,3] we have investigated reaction mechanism aspects of multi-nucleon (up to nine nucleons) transfer reactions at near and above Coulomb barrier energies on various target nuclei. The data for $^{18}$O+$^{206}$Pb were analyzed in a fully microscopic framework of the Time-Dependent Hartree-Fock (TDHF) theory and a reasonably good agreement with the measurement for transfer of a few nucleons was obtained. However, the TDHF calculations become less accurate as the number of nucleons transferred increases. Inclusion of effects of particle evaporation on the cross sections gives some improvement towards the measurement, however, the calculations still underestimate the measured cross sections by a significant amount especially for the cases where a large number of nucleon transfer are involved. In order to have a further understanding on these aspects, recently we have measured multi-nucleon transfer cross sections on deformed nucleus $^{154}$Sm (prolate shape, $\beta$ = 0.32). The primary motivation is of two fold as detailed below.

(i) In an earlier study on two-neutron transfer reaction on deformed nucleus (Sn+Dy), observed angular distribution for the transfer probability shows an oscillatory nature which was absent in the spherical system (Sn+Sn). In a later calculation, it was shown that the observed dip in the angular distribution is deformation dependent and may result from interference between transfer amplitudes corresponding to different orientations of the deformed target. Such deformation / orientation dependence on the two nucleon transfer cross section needs a detailed investigation. In the present proposal we have chosen $^{16}$O as projectile and the even-even nucleus $^{154}$Sm as the target, the two nucleon transfer reaction will lead to the deformed $^{152}$Sm region. This will allow us for a detailed comparison with our recent measurement[1] on spherical target ($^{206}$Pb) and deformed projectile ($^{18}$O) studied at about the same centre-of-mass energy. We have also measured, for a comparison, transfer cross section for $^{16}$O+$^{208}$Pb system (both projectile and target are of spherical shape).

(ii)The other aim of the experiment is to probe the 'neutron – proton' correlation via the two nucleon transfer reaction ($^{16}$O, $^{18}$F). Our recent measurement on two-neutron correlations studies via the reaction $^{206}$Pb($^{18}$O, $^{16}$O) and a detailed analysis in the coupled reaction channel framework, establishes dominance of a di-neutron cluster (L=0, S=0, T=1) transfer over the two step successive transfer of two neutrons. Such study can probe the isovector (S=0, T=1) component, while in the 'np' pairing both the isovector and isoscaler (S=1, T=0) components can be probed. The 'n-p' correlation is expected to be strongest in nuclei with N=Z where protons and neutrons occupy the same orbitals. The proposed reaction ($^{16}_{8}O_8$, $^{18}_{9}F_9$) is thus favorable.

The experiment was carried out with $^{16}$O beams at the Pelletron-LINAC facility, Mumbai. An enriched $^{154}$Sm target (on $^{27}$Al backing) was used and projectile like fragments (PLF) were detected with silicon SSB detectors in ΔE-E configuration. We could achieve a clear charge and mass separation for transfer products. The experimental details and particle identification procedure are described in another communication of this proceedings. Data were also collected with a pure $^{27}$Al target for background subtraction. The elastic scattering angular distribution was also measured simultaneously. The optical model analysis of the measured $(d\sigma/d\Omega)_{el}$ was performed and the potential parameters were extracted.

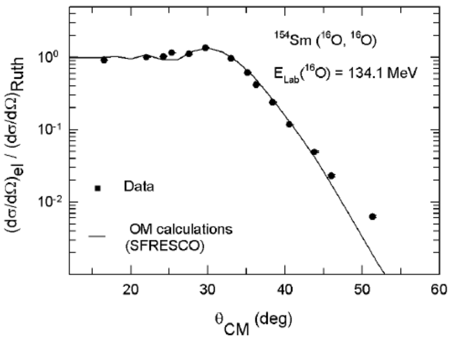


*FIG. 1: The ratio of* $\sigma_{elastic}$ *to* $\sigma_{Rutherford}$.

Angular distributions for Q-integrated data for all transfer channels are measured. Here only a few channels are plotted as representative cases. Angle integrated transfer cross sections are being extracted.

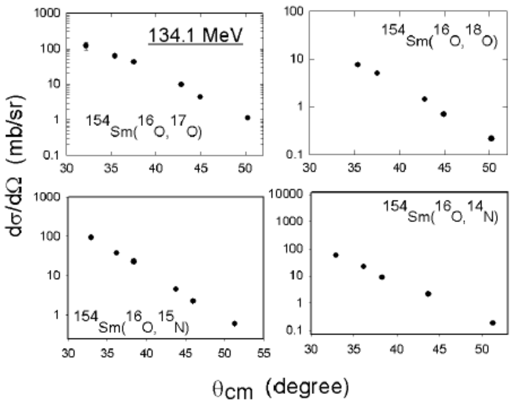


*Fig.2 Angular distribution for transfer reactions.*

Theoretical understanding of multinucleon transfer reactions is complicated and there is a lack of clear-cut theory for understanding the underlying mechanism, relative importance of various transfer paths and effect of multinucleon correlations. The present data are being analysed employing a microscopic framework of the TDHF theory developed by Sekizawa and Yabana[4]. The detailed formalism has been described in our earlier work[1]. Preliminary results for the present reactions are shown below. Detailed analysis is in progress.

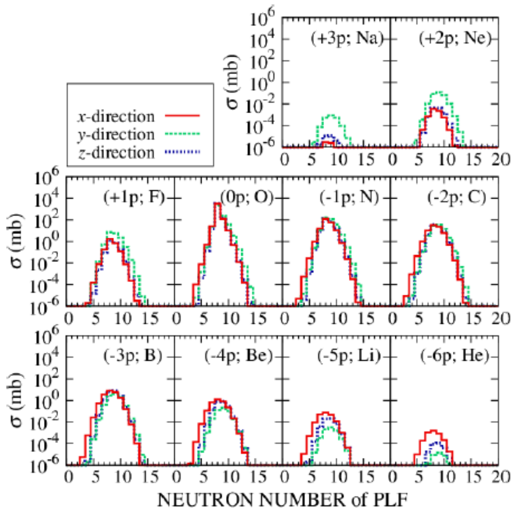


*FIG. 3: TDHF calculations for total cross-section for various transfer reactions in* $^{16}O+^{154}Sm$ *reaction at 134.1 MeV. x-, y- and z-direction represent different orientation between projectile & target during collision[2].*

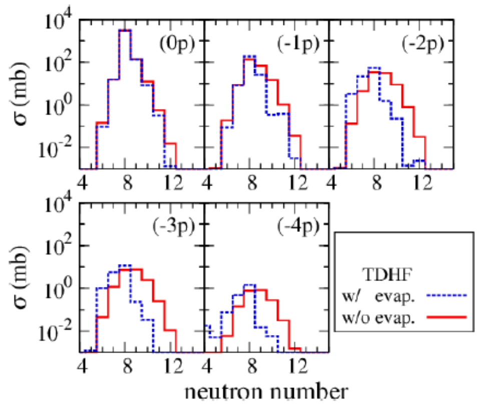


*Fig. 4 TDHF calculations showing the effect of inclusion of particle evaporation in the transfer cross sections. Only the Z-direction case is shown.*

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