Study of Multi-nucleon Transfer Reactions in Light System ^{16}O+^{27}Al at an incident Energy above Coulomb Barrier

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With a motivation to understand the reaction mechanism of multinucleon transfer reactions (MNT) and the effect of nuclear deformation in multinucleon transfer, we have recently measured experimental data with various projectile and target combinations at incident energies around and above the respective Coulomb barrier. Systems studied are (i)spherical projectile–deformed target(^{16}O+^{154}Sm), (ii)both projectile and target are of spherical shape (^{16}O+^{208}Pb, ^{16}O+^{206}Pb), (iii)deformed projectile –spherical target (^{18}O+^{206}Pb). In the present contribution we report our preliminary results on lighter system ^{16}O+^{27}Al. The Hartree-Fock ground state of ^{27}Al is almost oblate with deformation parameter β = 0.27 and N/Z ratio is close to 1.

The other aim of choosing such a lighter system is the following. The reaction mechanism of MNT, despite considerable progress in this field, is not well understood[1]. On the theoretical front both the nuclear reaction calculation codes GRAZING (semi-classical model) and TDHF (quantum mechanical microscopic calculations) [2] have been used to describe MNT processes. However, these models are well suited for transfer between heavy systems and for Grazing collision and need to be investigated for light systems and at energies above Coulomb barrier like the present case.

The experiment was carried out with ^{16}O beams of 134 MeV at the Pelletron-LINAC facility, Mumbai. Silicon SSB detectors in standard ΔE-E configuration were used and charge&mass of projectile like fragments (PLF) were separated.

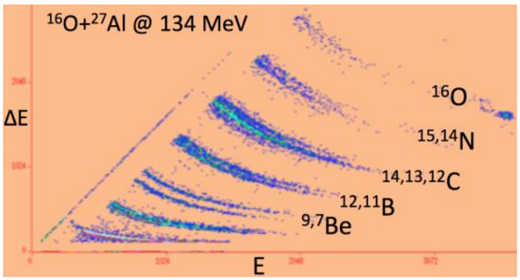

Fig.1: A typical ΔE-E plot of experimental data showing Z and M separation for the PLF.

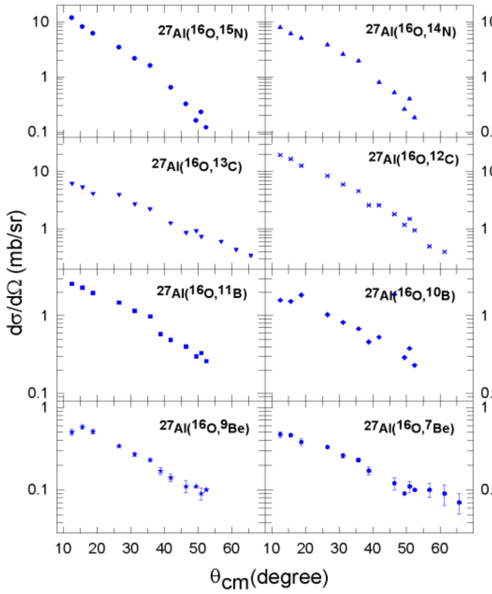

Fig2. Angular distribution for transfer reaction products (preliminary results) at $E_{Lab}(^{16}O)$ = 134MeV.

Angular distributions for Q-integrated data for the PLF were measured and are plotted in Fig.2.

The experimental angular distributions are forward peaked. The grazing angle is expected to be ~ 10 deg.

In order to understand the MNT mechanism & importance of multinucleon correlations and contribution from particle evaporation, we have performed state-of-the-art TDHF as well as GRAZING code calculations. For understanding the orientation dependence of transfer dynamics, TDHF calculations were performed in three orientations(Fig.3): symmetry axis of ^{27}Al is set (i)parallel to collision axis (x-direction) (ii) parallel to impact parameter vector (y-direction) (iii)perpendicular to the reaction plane (z-direction).

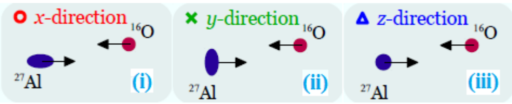

Fig.3 Orientations in ^{16}O+^{27}Al for TDHF calculation.

The calculations were done for impact parameter(b) from 6.4 to 12fm with a very small step size (b<6 fm would result in fusion reactions). The present system shows some interesting "orbiting" region in the Wilczysnki plot of Total kinetic energy vs. θ (Fig.4).

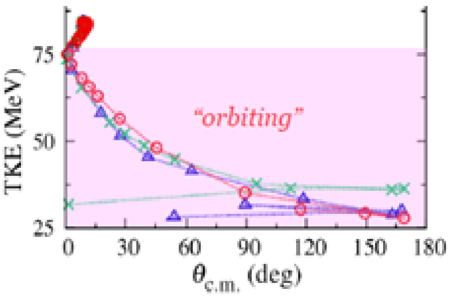

Fig.4 Wilczysnki Plot for total kinetic energy.

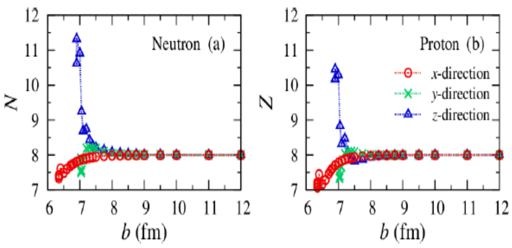

Fig.5 Average number of nucleons in the PLF.

The average no. of nucleons in the PLF is plotted in Figs.5. The z-direction shows neutron/proton pick up favourable where as nucleon stripping is dominated in the other two configurations. The N/Z ratio has also been plotted for both the PLF and TLF (Fig.6). The calculations show that in the Z-direction case fragments tend to be mass symmetric.

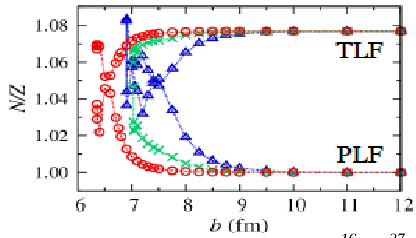

Fig.7. The N/Z ratio of PLF and TLF for ^{16}O+^{27}Al.

The calculated total cross section for various transfer reactions are plotted in Fig.8. GRAZING calculations are also shown. It is observed that the GRAZING gives cross section mainly for pickup reactions and somehow fails to calculate the stripping reactions (in contrast to our experimental data, Figs1&2) and needs further investigation. Present results will be compared with our experimentally measured data.

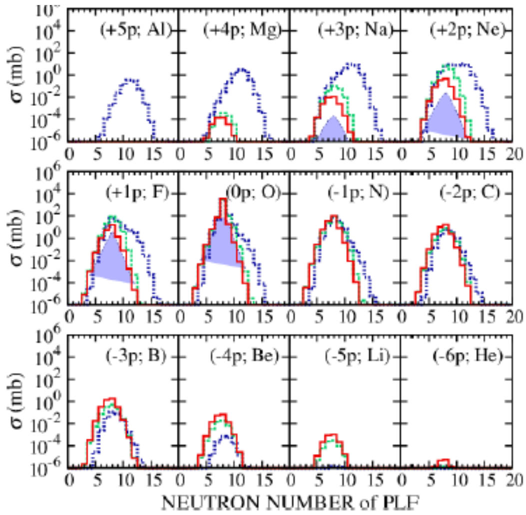

FIG. 8: TDHF calculated total cross section. The blue shaded region are the results from GRAZING code.

References:
[1] Sonika, B.J.Roy et al, PRC **92**, 024603 (2015)
[2] K.Sekizawa, K.Yabana, PRC **88**, 014614 (2013)

We thank Pelletron-Linac staff for smooth operation of the machine and R.Tripathi for providing the target.