Effects of deformation on total reaction cross-section

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Introduction

The production of (exotic) neutron-rich unstable nuclei and their reactions with a proton and/or nuclear targets have added an interesting topic in the field of nuclear structure physics. In the past few decades, heavy ion fusion reactions are extensively investigated, which is used to probe the role of nuclear structure for fusing nuclei and is also associated with the compound nucleus formation dynamics [1–4].

In the present work, our interest is to investigate the reaction cross-sections (σ_R) for $^{27}Al+\ ^{12}C$, $^{27}Al\ +\ ^{20}Ne$ and $^{64}Zn\ +\ ^{12}C$ reactions in the framework of Glauber formalism [1], using densities from well-known relativistic mean field (RMF) models with NL3, DD-PC1 and DD-ME2 parameter sets.

Formalism

The microscopic Glauber theory is based on the individual nucleon-nucleon collisions in the overlapping region of the colliding nuclei [3]. The nucleus-nucleus reaction cross-section in the framework of Glauber model can be written as

$$\sigma_R = 2\pi \int_0^\infty b[1 - T(b)]db \qquad (1)$$

where T (b) is the transparency function with impact parameter b.

Results and Discussions

The ground state properties i.e. binding energy (BE), the rms charge radius (r_{ch}) and quadrupole deformation parameter (β_2) for ^{12}C, ^{20}Ne, ^{27}Al and ^{64}Zn nuclei are being estimated within the RMF approximation. Table I shows the measured BE, r_{ch} and β_2 with NL3, DD-PC1 and DD-ME2 parameter

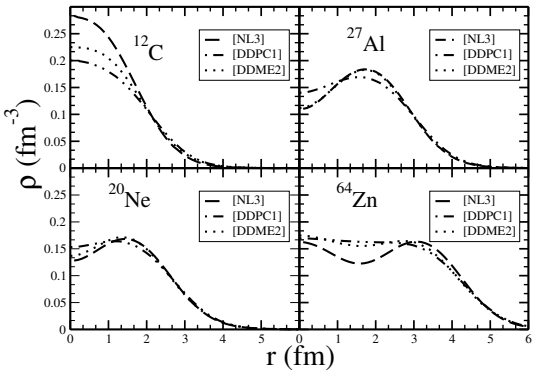

FIG. 1: Radial density plots for ^{12}C, ^{20}Ne, ^{27}Al, and ^{64}Zn obtained from NL3, DD-PC1 and DD-ME2 parameters for spherical densities.

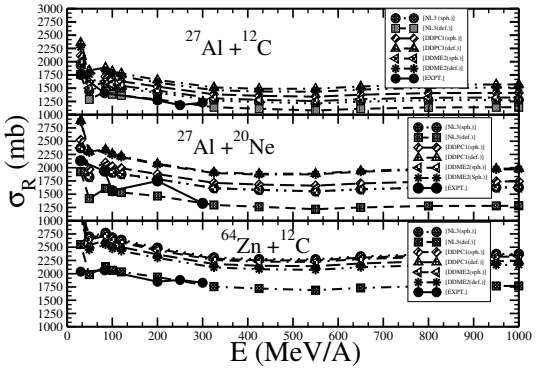

FIG. 2: shows the variation of coulomb-modified reaction cross-sections σ_R in mb of $^{27}Al\ +\ ^{12}C$, $^{27}Al\ +\ ^{20}Ne$ and $^{64}Zn\ +\ ^{12}C$ reactions obtained from various densities as a function of projectile energy in 1 GeV/A range, the experimental data are also given for comparison.

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TABLE I: Binding energy (BE), charge radius (r_{ch}) and quadrupole deformation parameter (β_2) for the projectiles and targets i.e ^{12}C, ^{20}Ne ,^{27}Al and ^{64}Zn obtained from RMF formalism using NL3, DD-PC1 and DD-ME2 parameter sets, are then compared with the experimental data whichever is available. The BE is in MeV and charge radius is in fm.

Nucleus	BE				r_{ch}				β_2			
	NL3	DD-PC1	DD-ME2	Expt.	NL3	DD-PC1	DD-ME2	Expt.	NL3	DD-PC1	DD-ME2	Expt.
^{12}C	91.35	87.2	87.32	92.2	2.31	2.55	2.5	2.47	0.007	0.00	0.038	0.577
^{20}Ne	156.56	156.08	156.39	160.64	2.97	2.998	2.98	3.005	0.54	0.525	0.55	0.7
^{27}Al	221.7	220.7	220.73	224.91	3.05	3.11	3.04	3.06	0.57	0.24	0.16	0.448
^{64}Zn	553.37	554.95	553.86	559.104	3.92	3.93	3.92	3.93	0.234	0.238	0.234	0.219

sets together with the available experimental data [5–8]. It is observed from the Table that the theoretical measured values of these properties are in a good agreement with the experimental values.

To check the validity of the Glauber model, and also the role of nuclear deformation, we compare the reaction cross section σ_R obtained from NL3, DD-PC1 and DD-ME2 parameter sets for both spherical and deformed densities of the targets and projectiles with the experimental data [5–8].

The nuclear spherical densities obtained using all the mentioned parameter sets in RMF formalism are plotted in Fig 1. Whereas, Fig 2. shows the behaviour of reaction cross-section as a function of projectile energy for ^{27}Al + ^{12}C, ^{27}Al + ^{20}Ne and ^{64}Zn + ^{12}C respectively, in the intermediate energy range.

If we go deep into the figure then it could be clearly noticed that, the experimental values are more closer with the results obtained from NL3 parameter sets with deformed densities. Moreover, it can be seen that the DD-ME2 results are also comparable to the data, while considering the spherical density. Further in case of ^{64}Zn + ^{12}C, the obtained results from the NL3 parameter set with deformed densities are more closer to the experimental values than that of the other two sets.

Summary and Conclusion

In summary, the ground state properties like BE, r_{ch} and β_2 of ^{12}C, ^{20}Ne, ^{27}Al and ^{64}Zn nuclei are estimated using the well known RMF formalism with NL3, DD-PC1 and DD-ME2 parameter sets. The structural properties predicted by the sets are in good agreement with the experimental data. The reaction cross section obtained with the deformed densities are in good agreement with the data for all the parameter sets considered here. However, the results of NL3 sets are closest with data. Further detail studies are in progress with new sets of reactions for various combinations of projectiles and targets.

Acknowledgement

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