Nuclear Reaction Studies of unstable nuclei using RMF theory in conjunction with the Glauber Model.

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Introduction

Study of the structure and reactions of unstable nuclei is highly required to improve our basic understanding of nuclear interaction in general and specially for the nuclei lying at drip line. Nuclei lying at neutron and proton drip lines exhibit many interesting nuclear structure features such as halos, skins, deformations, bubbleness, magicity/ emergence of new shell gap [1]. The large and unexpected increase of the size of the neutron-rich calcium isotopes beyond N=28 challenges the doubly-magic nature of ^{52}Ca and opens new intriguing questions on the evolution of nuclear sizes away from stability [2]. The total reaction cross section is one of the most fundamental quantities characterizing the nuclear reaction and to probe for nuclear structure details. In the present work, we have studied the nuclear structure and reaction properties of even-even Ca, Ni isotopes extending from proton drip line to neutron drip line. We have also evaluated total reaction cross section for these isotopes on ^{12}C target using Glauber model.

Mathematical Formalism

The spin–orbit strength and associated nuclear shell structure effects naturally arise from meson–nucleon interaction in Relativistic mean field (RMF) theory[3]. Hence theoretical framework based on relativistic mean field approach becomes a preferable choice in comparison to other available nuclear structure models. In the present work, the ground state observables of Ca and Ni isotopes are calculated using relativistic mean field RHB formalism with DDME2 parameter set. The main input required for calculating the cross sections using the Glauber model includes the target and projectile nuclear densities. The nuclear densities, obtained from the DDME2 model, are fitted by a sum Gaussian functions, with appropriate coefficients c_i and ranges a_i chosen for the respective nuclei, as

$$\rho\,(r)=\sum_{i=1}^{N} c_i \exp(-a_i r^2) \qquad (1)$$

Here, we have taken n = 2, i.e. the densities are fitted as a sum of two Gaussians. This fitting makes it possible to obtain an analytical expression for the transparency functions and hence simplify further numerical calculations. The Glauber model agrees very well with the experimental data at high energies. However, this model fails to describe reasonably, the collisions induced at relatively low energies. In such a case the present version of the Glauber model is modified to take care of finite range effects in profile functions and Coulomb modified trajectories. The Glauber model is based on the independent, individual nucleon-nucleon collision in the overlap zone of the colliding nuclei and has been used to calculate the total reaction cross section for both the stable and unstable nuclei at high energy [4].

Results and Discussion

As the reliability of any theoretical model depends on the fact that how accurately the model predicted experimental data, therefore we have calculated ground state observables using RHB and compared the same with the available experimental results. In table 1 we have shown results the calculated binding energy and radii of Ca isotopes.

In fig. 1, we have shown the mass number dependence of the binding energy per nucleon and charge radii of calcium isotopes obtained in the present study (along with the experimental values). The solid line connects the plot for binding energy per nucleon plotted on primary axis. In fig. 2, we have shown the radial plot of densities from DDME2 of projectile nuclei. Recent measurement of the very neutron rich calcium isotopes $^{40-46}$Ca have similar charge radii, for neutron- rich isotopes ^{48}Ca and beyond, our calculation consistently predict an increase in charge radii. Study of Ca and Ni isotopes offer critical nuclear structure challenge in terms of deformation and shell gaps, to be described consistently. Further the nuclear densities calculated using RHB formalism have been employed for calculating nuclear reaction observables.

TABLE 1. Binding energy in Mev, charge radii in fm for Calcium isotopes obtained from DDME2 calculation are compared with experimental values.

Nuclei	B.E./A (Cal) in MeV	B.E./A (Exp) in MeV	r_c (Cal) (in fm)	r_c (Exp) (in fm)
^{40}Ca	-8.569	-8.551	3.460	3.477
^{42}Ca	-8.628	-8.617	3.467	3.508
^{44}Ca	-8.655	-8.658	3.471	3.511
^{46}Ca	-8.658	-8.669	3.476	3.495
^{48}Ca	-8.642	-8.669	3.480	3.453
^{50}Ca	-8.502	-8.550	3.508	3.516
^{52}Ca	-8.355	-8.432	3.535	

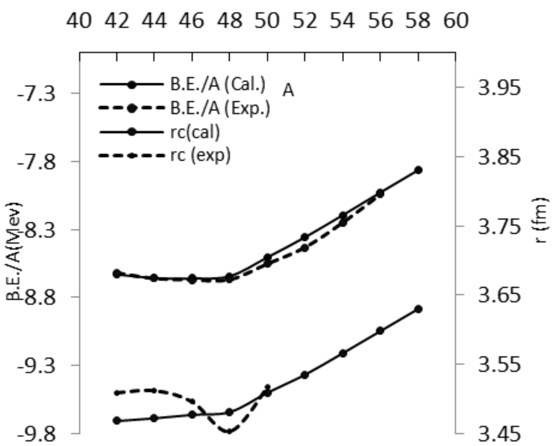

FIG. 1: Mass number dependence of the Binding Energy per nucleon and charge radii of calcium isotopes obtained in the present study along with experimental values.

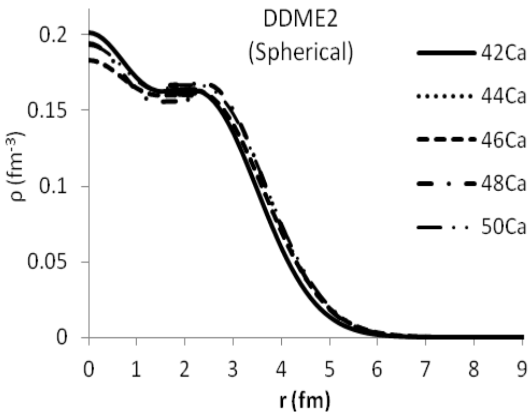

FIG.2. The radial plots of densities from DDME2 (spherical) calculations of projectile nuclei.

Conclusion

In summary, we have used the Glauber model to calculate nuclear reaction cross section with densities obtained from RHB calculation using the DDME2 parameter set. From the results obtained, one can see that overall, the present set of calculations reproduces the experimental observation for nuclear structure as well as nuclear reaction data well. Detailed result for nuclear structure as well reactions for Ca isotopes will be presented in the conference. The work along this direction is underway and would be communicated soon [5].

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