Nuclear Reaction Studies of Carbon isotopes in conjunction with RMF theory and Glauber Model.

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Introduction

Advances in measurements of unstable nuclei are instrumental for enhancing our basic understanding of nuclear interaction in general and particularly for the nuclei lying at driplines. Nuclei lying at neutron and proton driplines exhibit many interesting nuclear structure features such as halos, skins, deformations, bubbleness, magicity/emergence of new shell gaps [1]. Recent measurements for the interaction cross sections of the very neutron-rich carbon isotopes, e.g. deducing ^{22}C to be 2 neutron halo nuclei with much lesser matter radius [2] than the previous measurements, have posed more nuclear structure queries than it has answered. Also, latest reaction cross section results on C isotopes too, specifically for ^{20,22}C suggest [3] a major change may be needed in our understanding which has been the main objective of this work too. The observation of such nuclear halo and other novel features, closely connected with the evolution of the shell structure in carbon isotopes has stimulated several theoretical studies in past, yet it needs further refinement to reduce the theoretical uncertainty and to constrain the theoretical approaches.

In the present work, we have studied the nuclear structure and reaction properties of even - even carbon isotopes $^{10-22}$C, extending from proton drip line to neutron drip line. This has been done by calculating ground state observables of C isotopes as well as through a systematic analysis of the total reaction cross sections of C isotopes on ^{12}C target.

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Mathematical Formalism

Relativistic mean field (RMF) model arising from meson-meson interaction, containing the spin-orbit naturally, has been successfully used to understand and explain many nuclear features of nuclei [4]. Here, the ground state observables of C isotopes are calculated using relativistic mean field formalism using NL-SH and NL3* parameter sets. The densities thus obtained from relativistic mean field are further employed for reaction calculations to study high-energy nucleus-nucleus collisions, described using the Glauber model, as 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 RMF calculations are fitted by a sum of Gaussian functions with appropriate coefficients c_i and ranges a_i chosen for the respective nuclei as

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

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, in general, has been found to agree well with the experimental data at high energies, yet it fails to describe, reasonably, the collisions induced at relatively low energies. In such case, the Glauber model is modified in order to take care of finite range effects in the profile function and Coulomb-modified trajectories. In our earlier work also, we have demonstrated that densities obtained using RMF approaches through this mechanism, are quite useful to understand the available reaction data [5].

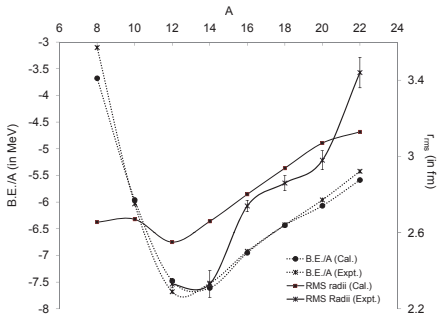

FIG. 1: Mass number dependence of the Binding Energy per nucleon and root-mean-squared radii of carbon isotopes obtained in the present study along with experimental values.

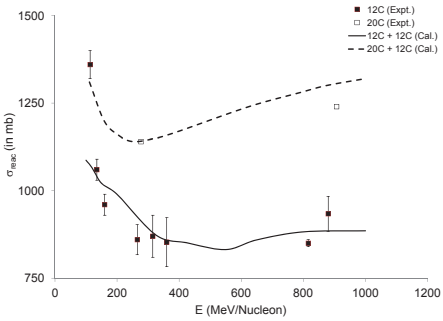

FIG. 2: Energy dependence of the reaction cross sections for ^{12}C and ^{20}C on ^{12}C target.

Results and Discussion

Study of carbon isotopes offer critical nuclear structure challenge in terms of halo formation and shell gaps along with the appropriate deformation, to be described consistently. In fig. 1, we have shown the mass number dependence of the binding Energy per nucleon and RMS radii of carbon isotopes obtained in the present study (along with the experimental values). The dashed line connects the plot for binding energy per nucleon plotted on primary axis, where as solid lines connect the RMS radii plotted on secondary axis. In fig. 2, we have shown results the calculated reaction cross sections for ^{12}C and ^{20}C on ^{12}C target, along with the experimental values. The dashed line represents the plot for calculated reaction cross section for ^{20}C, whereas solid lines represents the same for ^{12}C, both on ^{12}C target. It can be noted that, although the calculation produces a smooth neutron number dependence, the measured cross sections show an irregular decrease at about 250 MeV/A. Overall, the present set of calculations reproduces the experimental observation for total reaction data well. Detailed results for nuclear structure as well reactions for C isotopes will be presented in the conference.

Conclusion

In summary, we have studied eveneven carbon isotopes using RMF formalism. It is evident from the results that RMF-based approaches determine the ground-state observables and nuclear density distributions of nuclei fairly well and could further be used to understand the nuclear reaction data. However, the present work is primitive and it would be of further interest to examine the total reaction cross sections of C isotopes on different targets as they could reveal different but complimentary information due to density profile sensitivity. The work along this direction is underway and would be communicated soon [6].

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