Study of interaction cross section of light proton rich nuclei on ^{12}C at intermediate energies

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Introduction

The production of unstable nuclei by radioactive nuclear beam (RNB) technology [1] has provided a renewed interest in the field of nuclear physics and nuclear astrophysics. One of the significant contributions of RNB is to predict proton/neutron halos and skins, which could be possible through the determination of matter root-mean-quare (rms) radii of nuclei near to the drip lines.

In our recent works [2, 3], we have studied the interaction cross sections (σ_I) of neon isotopes, $^{17-32}$Ne, and oxygen isotopes, $^{16-26}$O, on ^{12}C at 240 MeV/nucleon and $\sim$ 1000 MeV/nucleon, respectively, within the framework of Glauber model (GM) S-matrix. It was found that the Slater determinant description of nuclei, involving harmonic oscillator single particle wave functions (hereafter referred to as SDHO densities), is quite a convenient method in describing the σ_I, and the predicted matter rms radii of neutron rich nuclei are found to be closer to the relativistic mean field (RMF) values, except for those cases where σ_I suddenly rise as compared to their neighbouring isotopes.

Motivated by the successful use of SDHO densities in GM calculations [3], we now include the light proton rich nuclei, and propose to analyze their interaction cross sections on ^{12}C in the energy range 680-950 MeV/nucleon within the framework of GM. Our aim, in this work, to provide the estimates for the matter rms radii of the nuclei under consideration, and to compare our predicted matter rms radii with the existing values.

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Formulation

According to the Glauber model, the scattering amplitude describing the elastic scattering of a projectile nucleus with ground state wave function ψ_B on a target nucleus with ground state wave function ψ_A may be written as [3]

$$F_{el}(\vec{q}) = \frac{iK}{2\pi} \int e^{i\vec{q}.\vec{b}} \, [1 - S_{el}(\vec{b})] \, d^2b, \quad (1)$$

$$S_{el}(\vec{b}) = \langle \psi_A \psi_B | \prod_{i=1}^{A} \prod_{j=1}^{B} [1 - \Gamma_{NN}(\vec{b} - \vec{s_i} + \vec{s_j'})] |\psi_B \psi_A\rangle, \quad (2)$$

where $A(B)$ is the mass number of target(projectile) nucleus, $\vec{b}$ is the impact parameter vector perpendicular to the incident momentum $\vec{K}$, $\vec{s_i}(\vec{s_j'})$ are the projections of the target(projectile) nucleon coordinates on the impact parameter plane, and $\Gamma_{NN}(\vec{b})$ is the nucleon-nucleon (NN) profile function.

To move further, we follow the approach of Ahmad [4], according to which the S-matrix element S_{el} up to the two body density term is given by:

$$S_{el}(\vec{b}) \approx S_0(\vec{b}) + S_2(\vec{b}), \quad (3)$$

For detailed evaluation of $S_0(\vec{b})$ and $S_2(\vec{b})$, we refer Ref. [4].

With these considerations, the elastic differential cross section and the interaction cross section are calculated using the expressions

$$\frac{d\sigma}{d\Omega} = |F_{el}(\vec{q})|^2, \quad (4)$$

$$\sigma_I = \int d^2b \left[1 - |S_{el}(\vec{b})|^2\right]. \quad (5)$$

Results and Conclusions

The inputs needed in the present calculations are the elastic nucleon-nucleon (NN) scattering amplitude, the proton and neutron density distributions of the colliding nuclei and the oscillator constants.

To make our calcultaions as realistic as possible, we have obtained the in-medium behaviour of the NN amplitude that takes care of the effects due to phase variations, higher momentum transfer components, and Pauli blocking [3]. For having the minimum number of parameters in the calculation, we have chosen the elastic scattering data of p-^{4}He at 650 and 800 MeV/nucleon and p-^{16}O at 1000 MeV/nucleon. The NN parameters, at energies of our interest, have been obtained from a linear interpolation/extrapolation of their values 650, 800 and 1000 MeV (Table I).

The proton and neutron density distributions are obtained from the Slater determinants consisting of the harmonic oscillator single particle wave functions (SDHO) [3]. To describe the interaction cross sections of the considered proton rich nuclei, we have searched for the oscillator constants for both proton and neutron distributions. The predicted SDHO matter rms radii alongwith the optical limit (OL) [5] and RMF [6] values are shown in Fig. 1. Like neutron rich nuclei [3], the results of the present calculations also suggest the utility of SDHO densities in predicting the matter rms radii of proton rich nuclei.

TABLE I: The in-medium values of NN amplitude parameters.

Energy (MeV)	n	NN	σ^m_{NN} (fm^2)	ρ^m_{NN}	β^m_{NN} (fm^2)	γ^m_{NN} (fm^2)
650	04	pp	2.6545	-0.5119	0.2520	0.4143
		pn	3.7479	-0.5832	0.2492	-0.0252
800	04^a	pp	3.1131	-0.5181	0.2539	-0.2510
		pn	3.4012	-0.5900	0.2602	0.2561
800	03^b	pp	2.8820	-0.5141	0.2399	-0.3787
		pn	3.4899	-0.6813	0.2520	0.2513
1000	03	pp	2.3203	-0.2373	0.1216	-0.2282
		pn	3.5650	-0.5932	0.2582	0.4367

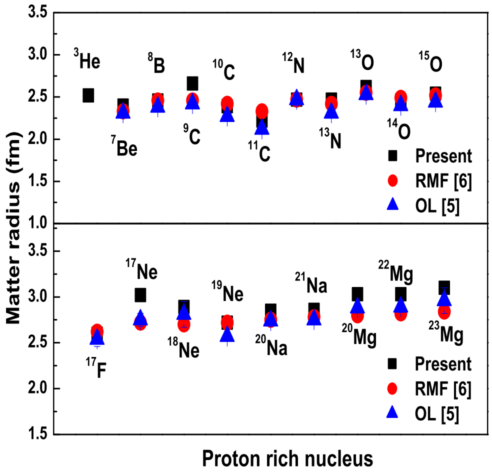

FIG. 1: Matter root-mean-square radii of proton rich nuclei.

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