Study of interaction cross sections of oxygen isotopes on ^{12}C using Glauber model

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Introduction

Motivated by the successful application of Glauber multiple scattering theory (GMST) for proton-nucleus and nucleus-nucleus scattering at relatively low and intermediate energies, authors have extended GMST to study the matter distributions of radioactive neutron rich (exotic) nuclei. One of the most exciting features of some of the exotic nuclei is the neutron halo which demonstrates a large spatial extension of neutron distributions. Such a feature was first noticed in ^{11}Li by Tanihata *et al.* [1] who observed a sudden rise in interaction cross section on ^{12}C as compared to its neighboring isotopes. The other good examples for neutron halo nuclei are ^{11}Be, ^{19,22}C and ^{31}Ne.

Recently [2], we have analyzed the interaction cross section (σ_I) of neon isotopes, $^{17-32}$Ne, on ^{12}C at 240 MeV/nucleon within the framework of Glauber model. The results suggested that the use of Slater determinant description of colliding nuclei, involving harmonic oscillator single particle wave functions (hereafter referred to as SDHO densities), can be considered as a fairly good starting point to predict the matter (rms) radii of exotic neutron rich nuclei.

Among the list of light neutron rich nuclei, the interaction cross-section data of the oxygen isotopes up to the drip-line nucleus ^{24}O are available at intermediate energies. The data [3] shows a smooth increase with increasing neutron number from ^{16}O to ^{21}O and then a sudden increase up to ^{23}O. The sharp increase in σ_I for ^{23}O though supports the idea of ^{23}O being a one-neutron halo and having large matter radius, its relatively high one-neutron separation energy (~2.7 MeV) inhibits the tunneling of the wave function into the classically forbidden region to form a halo. To address this crucial issue, Kanungo *et al.* [4] have revised the measurements of σ_I of ^{22,23}O-^{12}C at ~ 900 MeV/nucleon. The new data shows that σ_I for ^{23}O is smaller than that reported earlier. The value of σ_I of ^{23}O in the revised data is only ~8-9% larger than ^{22}O, which may not be sufficient to classify ^{23}O as a one-neutron halo.

In this work, we systematically calculate the σ_I of oxygen isotopes, $^{16-26}$O, on ^{12}C at 1.0 GeV/nucleon within the framework of Glauber model. The colliding nuclei are described with SDHO and relativistic mean-field (RMF) densities. Our aim, in this work, is to see how far the considered densities account for the available experimental data, specially the revised one. Moreover, SDHO would be used to predict the rms matter radii of neutron rich oxygen isotopes.

Formulation

According to the Glauber model, the S-matrix element S_{00} describing the elastic scattering of the projectile nucleus with ground state wave function ψ_B on a target nucleus with ground state wave function ψ_A may be written as

$$S_{00}(\vec{b}) = \left(\psi_A\psi_B \mid \prod_{i=1}^{A}\prod_{j=1}^{B}[1-\Gamma_{NN}(\vec{b}-\vec{s_i}+\vec{s_j})] \mid \psi_B\psi_A \right) \quad (1)$$

where A and B are the mass numbers of the target and projectile nuclei, respectively, $\vec{s_i}$ ($\vec{s_j}$) is the projection of the target (projectile) i^{th} (j^{th}) nucleon coordinate on a plane perpendicular to the incident direction, and the NN profile function Γ_{NN} is related to the NN scattering amplitude f_{NN} as

$$\Gamma_{NN}(\vec{b}) = \frac{1}{2\pi ik}\int d^2q \exp(-i\vec{q}.\vec{b}) f_{NN}(\vec{q}) \quad (2)$$

where k is the incident nucleon momentum corresponding to the projectile kinetic energy per nucleon.

Following Ahmad [5], the S-matrix element S_{00} is written as

$$S_{00}(\vec{b}) = S_0(\vec{b}) + \sum_{l=2}^{AB} S_l(\vec{b}) \qquad (3)$$

The term $S_0(\vec{b})$ in Eq. (3) corresponds to the so-called optical limit approximation (OLA). It depends upon the one-body densities of the colliding nuclei, and it is this term that has been used in most of the applications of the Glauber model at medium energies. The next term, $S_2(\vec{b})$, involves the two-body densities and we will include it in the present analysis.

With these considerations, the interaction cross section is calculated using the expression

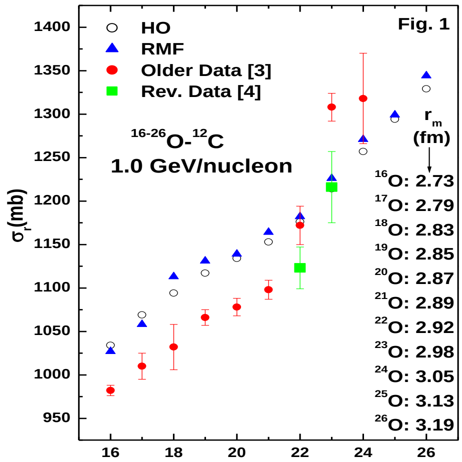
$$\sigma_I = \int d^2b[1 - |S_{00}(\vec{b})|^2] \qquad (4)$$

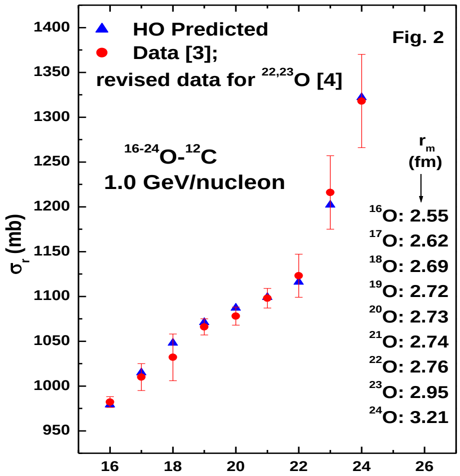
Results and Discussion

We have calculated the interaction cross sections of $^{16\text{-}26}$O on ^{12}C target at 1.0 GeV/nucleon. The inputs require in the calculation are **(i)** the NN scattering amplitude, **(ii)** the proton and neutron density distributions of colliding nuclei, and **(iii)** the oscillator constants.

The NN scattering amplitude is parameterized in the same form as in Ref. [2]. Its parameters at 1.0 GeV are taken from Ref. [6]. The oscillator constants for proton and neutron SDHO distributions are fixed from the corresponding RMF rms radii for nuclei under consideration [2]. The results of the calculations are presented in Fig. 1. It is found that the theoretical predictions though show the increasing trend as observed in experimental data, we observe large deviations in all the cases except ^{23}O which has been accounted for in the revised data, showing the non-halo structure of ^{23}O unlike the one predicted earlier.

To account for the large discrepancies between theory and experiment, the calculations have been revised with SDHO densities in such a way that we are now able to reproduce the experimental data. The results of such calculations and the predicted matter rms radii are presented in Fig. 2.





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