Analysis of p-^{16}O differential cross section at 1.0 GeV and the effects of nuclear medium

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Introduction

The Glauber multiple scattering theory (GMST) offers a powerful and handy framework for the description of intermediate and high energy nuclear reactions. This theory provides quite a satisfactory explanation of proton-nucleus and nucleus-nucleus reactions. Usually, the calculations based on the Glauber theory are performed using a one-body density calculated from a nuclear wave function. However, Bassel and Wilkin [1] calculated Glauber's scattering amplitude using a Slater determinant wave function, and were able to examine the effect of Pauli blocking, which is impossible to discuss using just the one-body density.

In a recent work [2], we have systematically calculated the total reaction cross sections of oxygen isotopes, $^{16-26}$O, on a ^{12}C target at 1.0 GeV/nucleon within the framework of Glauber model by retaining terms up to two-body density in the correlation expansion of the Glauber S-matrix. The oxygen isotopes were described with Slater determinants involving harmonic oscillator single particle wave functions (hereafter referred to as SDHO densities) and the relativistic mean field (RMF) approach. It was demonstrated that the use of SDHO densities is able to predict the matter rms radii of oxygen isotopes that may provide satisfactory explanation of the reaction cross section data; it was found that the matter rms radius (r_m) of ^{16}O though comes closer to the one obtained in Ref. [3], but it is slightly lower (~7%) than that obtained earlier from the electron scattering experiments [4].

In this work, we propose to analyze the p-^{16}O differential cross section at 1.0 GeV within the framework of GMST. Our aim is to see how far the results of the present analysis are sensitive to different forms of the matter distributions of ^{16}O and what could be said about the matter rms radius of ^{16}O. Moreover, we shall also study the effects of nuclear medium and provide the information about the NN amplitude in nuclear medium at energy under consideration.

Formulation

According to the Glauber model, the scattering amplitude describing the elastic scattering of protons from a target nucleus is given by

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

where $\vec{q}$ is the momentum transfer, $\vec{b}$ the impact parameter, and $S_{el}(\vec{b})$ is the elastic S-matrix element, expressed as

$$S_{el}(\vec{b}) = (\psi_A|\prod_{i=1}^{A}[1 - \Gamma_{NN}(\vec{b} - \vec{s}_i)|\psi_A) \qquad (2)$$

where ψ_A is the target ground state wave function, $\vec{s}_i$ is the i^{th} nucleon coordinate in a plane perpendicular to the scattering (z) axis, and Γ_{NN} is the NN profile function, which is related to the NN amplitude $f_{NN}(\vec{q})$ as follows

$$\Gamma_{NN}(\vec{b}) = \frac{1}{2\pi ik}\int e^{-i\vec{q}.\vec{b}} f_{NN}(\vec{q})\, d^2q \qquad (3)$$

Further, following Ahmad [5], the required correlation expansion for the elastic scattering amplitude is given by

$$F_{el}(\vec{q}) = F_0(\vec{q}) + \sum_{l=2}^{AB} F_l(\vec{q}) \qquad (4)$$

the term F_0 in eq.(4) depends upon the one body density, whereas the other terms, F_l, involve the l^{th} body density of the target nucleus; the terms F_l may be regarded as providing corrections to the uncorrelated part F_0.

With these considerations, the elastic differential cross section is calculated using the expression

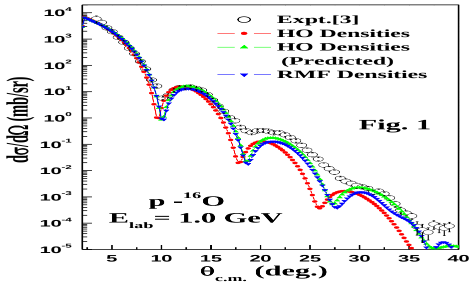
$$\frac{d\sigma}{d\Omega} = \left| F_{el}(\vec{q}) \right|^2 \qquad (5)$$

Results and Discussion

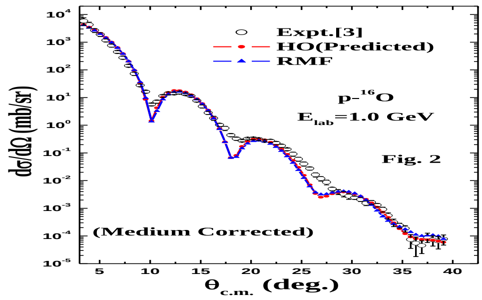
We have calculated the p-^{16}O differential cross section at 1.0 GeV, involving up to two body correlation term in the Glauber amplitude (eq.(4)). The inputs required in the calculation are **(i)** the NN scattering amplitude, and **(ii)** the proton and neutron density distributions of the target nucleus..

For the NN scattering amplitude, we have used single Gaussian parametrization [1], whose parameter values, at 1.0 GeV, are taken from Ref. [3].

For the matter (proton and neutron) distribution of ^{16}O, we have involved SDHO and RMF densities. In the first phase of our calculations, both SDHO and RMF densities provide similar value of r_m for ^{16}O (2.73 fm). In order to see how far the results are sensitive to r_m, we have also performed calculations with that SDHO density which predicts the similar value of r_m for ^{16}O (2.55 fm), as obtained in our recent work [2]; calling this density as the HO predicted density. The results of such calculations are present in Fig. 1. It is found that although both SDHO (solid circles) and RMF (inverted triangles) densities provide similar r_m value for ^{16}O, the theoretical predictions for the cross sections deviate from each other; the results with RMF density are found to be closer to the experiment up to moderate scattering angles. Further, we find that the results with HO predicted density (triangles) are as good as those obtained with RMF density. Thus, our results suggest that the differential cross section alone favors both RMF and HO predicted densities for ^{16}O; the RMF density may be considered as a better choice as it predicts r_m closer to the electron scattering value. However, the consideration of both the differential and reaction cross sections at 1.0 GeV/nucleon favor HO predicted density, giving rise lower r_m value for ^{16}O.



To assess nuclear medium effects, we recall some earlier studies [6, 7] in which it was revealed that the parameters of the NN amplitude get modified in the nuclear medium. Keeping this in view, we reanalyze the p-^{16}O scattering data by varying the NN parameters, except the NN total cross-section whose in-medium value has been fixed using the parametrization of Xiangzhou *et al.* [8]. The results of such calculations are presented in Fig. 2. It is found that we now have quite a satisfactory explanation of the scattering data over the whole range of momentum transfer. The in-medium behavior of the NN amplitude is reflected through its parameter values, which are found to be different (not shown) from the corresponding parameter values for the free NN amplitude [3] at 1.0 GeV.



References

[1] R. Bassel, C. Wilkin, Phys. Rev. **174**, 1179(1968).
[2] Suhel Ahmad *et al.*, DAE Symposium, 2016 (Submitted).
[3] B. Abu-Ibrahim *et al.*, PRC **77**,034607(2008).
[4] I. Sick and J. S. McCarthy, Nucl. Phys.A**150**, 631 (1970).
[5] I. Ahmad, J. Phys. G **6**, 947(1980).
[6] C.A. Bertulani, J. Phys. G **27**, L67(2001).
[7] D. Chauhan, Z.A. Khan, PRC **75**, 054614(2007).
[8] C. Xiangzhou *et al.*, PR C **58**, 572(1998).