# Proton- $^{12}$C elastic scattering and the NN amplitude

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## Introduction

The medium energy proton scattering and microscopic studies of nuclei provides useful information about the nuclear many-body correlations and the matter density distribution. On theoretical front, it is the Glauber multiple scattering theory which has been widely used for such studies. One of the attractive features of the formalism is that it connects the directly measurable NN amplitude to the hadron-nucleus one in a mathematically tractable way. This shows that the information about the microscopic details of the target nucleus does not only depend on the validity of the reaction mechanism used, but also on the accuracy of the NN amplitude. In this work, we have taken two different forms of the NN amplitude; one we have proposed in our earlier work[1] and the other is taken from Ref.[2]. Using these NN amplitude, we have analyzed the elastic scattering of protons on $^{12}$C at 800 MeV. Our interest would be to see how far the p-nucleus scattering data are sensitive to a particular choice of the NN amplitude. Another interesting point of this work is to see how far the introduction of the phase of the NN amplitude helps to account for the p-nucleus scattering data.

The analysis is based upon the Coulomb modified[3] correlation expansion of the Glauber amplitude[4], the first term of which corresponds to the well known optical limit result, while the others depend successively upon the two-, three- and many body densities of the target nucleus. In the following, we restrict ourselves by considering up to the two body density term, which is found to be the leading correction term to the optical limit result.

## Formulation

Following Ahmad and Auger[4], the Coulomb modified [3] correlation expansion for the Glauber amplitude for describing the elastic scattering of protons with momentum k from a target nucleus in the ground state(|ψ›) takes the form:

$$F_{00}(\vec{q}) = f_c(\vec{q}) + F_0(\vec{q}) + \sum_{l=2}^{A} F_l(\vec{q}), \quad (1)$$

$$F_0(\vec{q}) = \frac{ik}{2\pi}\int d^2b e^{i\vec{q}.\vec{b}} e^{i\chi_{pt}(\vec{b}')}[1-(1-\Gamma_0)^A e^{i\chi_c(\vec{b}')}], \quad (2)$$

$$F_l(\vec{q}) = -\frac{ik}{2\pi}\int d^2b e^{i\vec{q}.\vec{b}} e^{i(\chi_{pt}(\vec{b}')+\chi_c(\vec{b}'))}$$

$$X < \psi_0 | (1-\Gamma_0)^{A-l} \sum_i \sum_{<j} .. \sum_{<k} \gamma_i \gamma_j ... \gamma_k | \psi_0 >, \quad (3)$$

with $\gamma_j = \Gamma_0(\vec{b}') - \Gamma_{NN}(\vec{b}' - \vec{S}_j),$ (4)

and $\Gamma_0(\vec{b}') = < \psi_0 | \Gamma_{NN}(\vec{b}' - \vec{S}_j) | \psi_0 >$ (5)

where $S_j$ is the projection of $j^{th}$ target nucleon coordinate $r_j$ onto a plane perpendicular to K, and the NN profile function $\Gamma_{NN}$ is related to the NN amplitude $f_{NN}$ as: $\Gamma_{NN}(\vec{b}') = \frac{1}{2\pi ik}\int d^2q e^{-i\vec{q}.\vec{b}} f_{NN}(\vec{q}).$ (6)

The quantities $f_c(q)$, $\chi_{pt}$ and $\chi_c$ are the same as defined in ref. [5], and the distance of closest approach 'b′', that takes into account the deviation in the trajectory because of Coulomb field, has the same expression as used in ref. [3].

In the present work, we restrict ourselves up to $F_2$ in the expression for $F_{00}$ as it provides a leading correction to the optical limit term $F_0$. More explicitly

$$F_2(\vec{q}) = \frac{i}{8\pi^3 k}\frac{A(A-1)}{2!}\int d^2b e^{i\vec{q}.\vec{b}} e^{i(\chi_{pt}(\vec{b}')+\chi_c(\vec{b}'))}(1-\Gamma_0)^{A-2}[G_2 - G_0^2], \quad (7)$$

$$G_2 = \int d^2q_1 d^2q_2 e^{-i(\vec{q}_1+\vec{q}_2).\vec{b}'} f_{NN}(\vec{q}_1) f_{NN}(\vec{q}_2) F^{(2)}(\vec{q}_1,\vec{q}_2). \quad (8)$$

and $G_0 = \int d^2q e^{-i\vec{q}.\vec{b}'} f_{NN}(\vec{q}) F(\vec{q}).$ (9)

The quantities F(q) and $F^{(2)}(q_1,q_2)$ in the above expressions are the one- and two-body(intrinsic) form factors respectively .For the intrinsic two-body form factor $F^{(2)}(q_1,q_2)$, we use the same expression as derived in ref.[6].

## Results and discussion

Following the above mentioned approach, we have analyzed the elastic angular distribution and polarization of 0.8 GeV protons on $^{12}C$. The inputs needed in the calculations are the elementary NN amplitude, the nuclear form factor, and the oscillator constant. For computational simplicity we parametrize the required nuclear form factor as a sum of Gaussians and the value of the oscillator constant is taken from Bassel and Wilkin[7]

As mentioned above, our analysis uses two different parametrizations of the NN amplitude. The results of the calculations for the scattering of 800 MeV protons from $^{12}C$, using both the forms (without phase) of the NN amplitude, are presented in Fig.1. The results show that it is the NN amplitude of Ref.[1] which is able to provide better agreement with the data.

The corresponding results for NN scattering with both these forms of the NN amplitude are presented in Fig.2. Here also we find that the NN amplitude of Ref. [1] is able to provide better description of the NN scattering observables. Thus we find that the study of p-nucleus scattering at intermediate energies could provide a test to have a better understanding of the NN amplitude.

Another part of this work is the inclusion of phase in both the forms of the NN amplitude. The results of the calculations are presented in Fig. 3. The inclusion of phase is found to improves the results. But if we analyze NN scattering observables with both the forms of the amplitude having phase, the results of the calculations are presented in Fig.4. The results indicate that inclusion of phase does not improve the results for NN scattering observables, though it strongly improves the results for the p-nucleus scattering. Thus we conclude that the form of amplitude which provides satisfactory results for proton-nucleus scattering data, may not necessarily good for NN scattering observables.

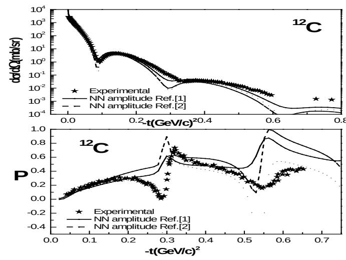


Fig.1

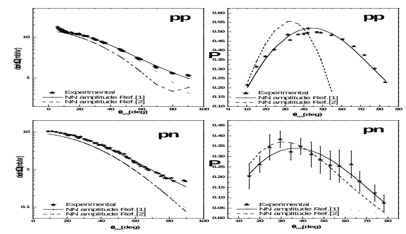


Fig.2

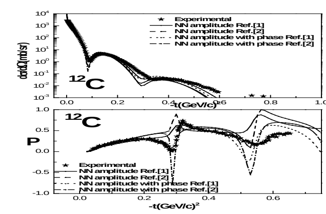


Fig.3

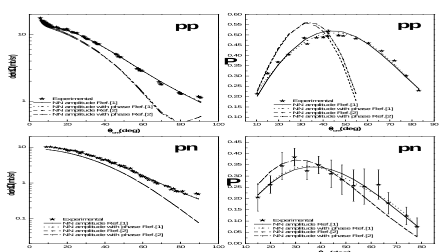


Fig.4

**References**

[1] Z.A.Khan and M.Singh, IJMP **E14** (2005) 787.
[2] R.Wenying and L.Youyan, Phys.G: Nucl. Phys. **21 (**1995) 537.
[3] S.M.Lenzi et al.Phys. Rev. **C40**(1989) 2114.
[4] I.Ahmad and J.P.Auger, Nucl.Phys. **A352** (1981)425.
[5] I.Ahmad, Nucl.Phys. **A247** (1975) 418.
[6] I. Ahmad, J.Phys. G: Nucl.Phy.**6** (1980)947.
[7] R. Bessel and C.Wilkin, Phys. Rev. 174 (1968) 1179.