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Glauber Optical Limit Approximation for $\vec{d}$ - Nucleus Elastic Scattering at Intermediate Energies

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The Glauber theory can provide a simple description of $\vec{p}$ - nucleus scattering cross section and spin observables at intermediate energies[1]. The optical limit of this approach is also able to reasonably predict nucleus-nucleus reaction cross sections [2,3]. In the present work, this approximation is extended to an analysis of the deuteron elastic scattering from nucleus. Calculations are compared to recent data at 700 MeV for ^{16}O, ^{40}Ca and ^{58}Ni targets [3]. There have been several studies [4] dealing with d-nucleus scattering, but the spin observables have not yet been considered.

The Glauber optical limit approximation [5] provides an integral relationship between the phase shift function $\chi(\vec{b},\vec{s})$ and the d - nucleus scattering amplitudes $F(\vec{q})$:

$$F(\vec{q}) = \frac{k}{2\pi i}\int d^2b \exp(i\vec{q}.\vec{b}) \int d\vec{r}_d \phi^*(\vec{r}_d) \left[\exp(i\chi(\vec{b},\vec{s}))-1\right] \phi(\vec{r}_d), \qquad (1)$$

where k is the momentum of the incident deuteron, $\vec{q}$ the momentum transfer, $\vec{b}$ the impact parameter between the deuteron and nucleus c.m, s the projection of the deuteron intrinsic coordinate r_d onto the impact parameter plane, and $\phi(\vec{r}_d)$ the deuteron wave function. Assuming Gaussian forms for the N-N scattering amplitudes [6] the phase-shift function can be expressed as follows :

$$\chi(\vec{b},\vec{s}) = \chi_p(\vec{b}_p) + \chi_n(\vec{b}_n) + \chi_{pn}(\vec{b},\vec{s}) \qquad (2)$$

where the single particle terms $\chi_i(\vec{b}_i)$ is similar to those for p - nucleus scattering [6] while the cross term $\chi_{pn}(\vec{b},\vec{s})$ is composed of four parts :

$$\chi_{pn} = a_c + a_p \vec{\sigma}_p.\hat{l}_p + a_n \vec{\sigma}_n . \hat{l}_n + a_{pn}(\vec{\sigma}_p.\hat{l}_p)(\vec{\sigma}_n . \hat{l}_n), \qquad (3)$$

where $\hat{l}_i = \vec{l}_i/l_i$

The last term in Eq.3 is expected to be small, so that in a preliminary approach it is neglected. The phase-shift function in Eq. 1 is then in the form

$$\chi(\vec{b},\vec{s}) = d_c + d_p \vec{\sigma}_p.\hat{l}_p + d_n \vec{\sigma}_n . \hat{l}_n \qquad (4)$$

Introducting Eq. 4 in Eq. 1 and carrying out the folding calculations[7] over Gaussian deuteron wave function [6] one obtains

$$F(\vec{q}) = \frac{ik}{2\pi}\int d^2b \exp(i\vec{q}.\vec{b}) \left[\Gamma_c(\vec{b}) + i\,\Gamma_s(\vec{b})\,\hat{L}.\vec{S}_d\right], \qquad (5)$$

where $\vec{S}_d$ is the spin of deuteron, $\Gamma_c(\vec{b})$ and $\Gamma_s(\vec{b})$ the central and spin-orbit parts of the profile function defined by

$$\Gamma_c(\vec{b}) = \int d\vec{r}_d\, |\phi(\vec{r}_d)|^2 \left[1-\exp(id_c)\cos(d_p)\cos(d_n)\right]$$
$$\Gamma_s(\vec{b}) = -\int d\vec{r}_d |\phi(\vec{r}_d)|^2 \exp(id_c)\cos(d_p)\sin(d_n) \left[2b+s\cos(\hat{b}.\hat{s})\right] b_p^{-1}. \qquad (6)$$

The integration of Eq.(5) over the azimuthal angle leads to :

$$F(q) = G(q) + H(q)\, S_y, \qquad (7)$$

where S_y is a 3 x 3 matrix according to the Madison conventions and

$$G(q) = ik \int bdb\, J_0(qb)\, \Gamma_c(b),$$
$$H(q) = -ik \int bdb\, J_1(qb)\, \Gamma_s(b) \qquad (8)$$

are the central and spin-orbit amplitudes, respectively. All observables can then be constructed through G(q) and H(q). Eq. 7 is similar to that obtained for proton scattering.

In Fig. 1 the calculations of cross-section, and vector A_y and tensor A_{yy} analyzing powers for the $\vec{d}$ - ^{40}Ca elastic scattering at 700 MeV are compared to experimental data [3]. The N-N amplitude parameters [6] λ_c and λ_s are deduced from Arndt phase-shifts [8]. The nuclear matter density is assumed to have a Fermi distribution. The Coulomb potential is included as in ref.[5]. And the best-fit is obtained with the density and N - N range parameters :

$r = 0.91$ fm, $a = 0.512$ fm, $\beta_c = 0.34 fm^2$ and $\beta_s = 1.1 fm^2$, fairly compatible with previous results [6]. The cross section and A_y are well reproduced while A_{yy} is only partially described. Such a discrepancy for the tensor analyzing power is understandable since the cross term a_{np} is not taken into account in the calculations displayed.

The present results make it worth performing a complete treatment of the phase-shift function (Eq.2). In fact such a treatment leads to an additionnal tensor term $(\vec{L}.\vec{S}_d)^2$ in the total scattering amplitude (5), which may appreciably intervene in the tensor analyzing powers. Relevant calculations are in progress.

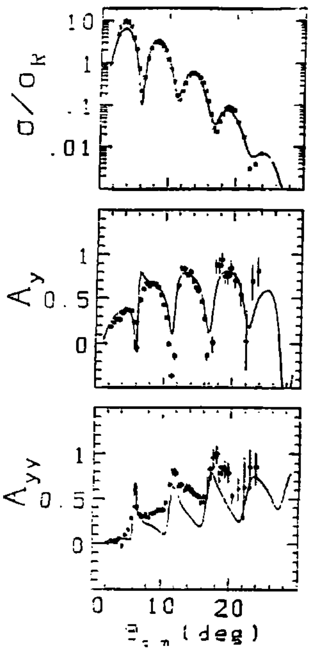

Fig. 1. Glauber theory calculations compared to experimental data for $\vec{d}$ + ^{40}Ca elastic scattering at 700 MeV.

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