Elastic scattering of 800 MeV protons with ^{40}Ca

Minita Singh[1],* Z.A. Khan[2] and Deeksha Chauhan[3]
[1]Mangalayatan University, Aligarh, U.P., INDIA
[2]Deptartment of Physics, Aligarh Muslim University, Aligarh, U.P., INDIA
[3] Department of Physics, University of Allahabad, Allahabad,U.P., INDIA
* email: minita.singh@mangalayatan.edu.in

Introduction

The application of the Glauber multiple scattering theory to analyze the proton nucleus scattering has a long tradition. As is well known, any microscopic description of proton nucleus scattering requires two elementary inputs, one is the NN interaction and other is the wave function representing the nuclear structure. The Glauber model has the advantage to allow the expression of nucleon-nucleus amplitude in terms of the NN scattering amplitude, which can be measured rather directly. The present work considers four different parametrizations of the NN amplitude, which provide equally good description of the NN scattering observables; out of these four forms, three forms have already been considered in our earlier work[1]. The analysis is based upon the Coulomb modified[2] correlation expansion of the Glauber amplitude[3], 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[3], the Coulomb modified [2] 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:

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

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

$$F_l(\vec{q}) = -\frac{ik}{2\pi}\int d^2 b e^{i\vec{q}.\vec{b}} e^{i(\chi_{pt}(\vec{b}')+\chi_c(\vec{b}'))}$$
$$X < \psi_0 | (1-\Gamma_0)^{A-l} \sum_i \sum_{<j} .. \sum_{<k} \gamma_i \gamma_j ... \gamma_k | \psi_0 >, \qquad (3)$$

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 Γ_{NN} is related to the NN amplitude f_{NN} as: $\Gamma_{NN}(\vec{b}') = \frac{1}{2\pi ik}\int d^2 q e^{-i\vec{q}.\vec{b}} f_{NN}(\vec{q})$. (6)

The quantities $f_c(q)$, χ_{pt} and χ_c are the same as defined in ref. [4], 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. [2].

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

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

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

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

The quantities F(q) and $F^{(2)}(q_1,q_2)$ in the above expressions are the one- and -body(intrinsic) form factors respectively.For the intrinsic two-body form factor $F^{(2)}(q_1,q_2)$, we use the expression as derived in ref.[5].

Results and discussions

Following the above mentioned approach, we have analysed the elastic angular distribution and polarization of 0.8 GeV protons on ^{40}Ca. The inputs needed in the calculations are the elementary NN amplitude, the nuclear form factor, and the oscillator constant.

Following ref.[6], we parameterize the NN amplitude as follows:

$$f_{NN}(\vec{q}) = \frac{ik\sigma}{4\pi}\sum_{n=0}^{\infty} A_{n+1}[(\frac{\sigma}{4\pi\beta^2})^n \frac{(1-i\rho)^{n+1}}{n+1}\exp(\frac{-\beta^2 q^2}{2(n+1)})e^{-i\gamma_c q^2/2}$$
$$+ i(q^2/4m^2)^{1/2}(\frac{\sigma}{4\pi\beta_s^2})^n \frac{[D_s(1-i\rho_s)]^{n+1}}{n+1}\exp(\frac{-\beta_s^2 q^2}{2(n+1)})e^{-i\gamma_s q^2/2}\vec{\sigma}.\hat{n}]. \qquad (10)$$

where $A_{n+1} = \frac{A_1}{n(n+1)} + \frac{A_2}{(n-1)n} + ... + \frac{An}{1.2}$ with A_1=1.

This amplitude has ten adjustable parameters, but we invoke them in such a way that they lead to four different q-dependences in the NN amplitude. In first case (B1) we treat β^2 and β_s^2 as real but assumes constant phase ($\gamma_c = \gamma_c = 0$) in both the central(f_c) and spin-dependent(f_s) part of the NN amplitude. The second case(B2) also considers β^2 and β_s^2 as real but assumes different phase variations($\gamma_c \neq \gamma_c$) in f_c and f_s. The third possibility (B3) assumes β^2 and β_s^2 as complex, and the constant phase in f_c and f_s. The fourth possibility (B4), which is an additional choice in the present work, assumes β^2 and β_s^2 as complex as well as different phase variations($\gamma_c \neq \gamma_c$) in f_c and f_s. In all the four cases, the value of the corresponding parameters are chosen under the conditions (i) the Optical theorem be valid (ii) the ratio Re $f_{NN}(0)$/Im $f_{NN}(0)$ be equal to the experimental value, and (iii) experimental NN elastic angular distribution polarization data be correctly reproduced.

The corresponding parameter values of these parametrizations are listed in following Table.

	f^c_{NN}	σ (fm^2)	β_r^2 (fm^2)	β_i^2 (fm^2)	ρ	γ^c_{NN} $(GeV/c)^{-2}$
B1	pp	3.11	0.26	0.0	-0.11	0.0
	pn	2.90	0.26	0.0	-0.32	0.0
B2	pp	3.43	0.33	0.0	-0.01	-5.68
	pn	2.92	0.27	0.0	-0.32	8.71
B3	pp	3.58	0.31	0.17	-0.18	0.0
	pn	3.18	0.27	-0.06	-0.24	0.0
B4	pp	2.92	0.23	-0.01	-0.01	-0.53
	pn	2.91	0.26	-0.05	-0.32	2.36

	f^s_{NN}	D_s	β_{sr}^2 (fm^2)	β_{si}^2 (fm^2)	ρ_s	γ^s_{NN} $(GeV/c)^{-2}$
B1	pp	1.98	0.46	0.0	0.75	0.0
	pn	1.38	0.51	0.0	0.85	0.0
B2	pp	1.96	0.42	0.0	0.25	-8.05
	pn	1.37	0.41	0.0	0.96	-2.31
B3	pp	1.64	0.38	0.01	0.321	0.0
	pn	1.08	0.49	-0.10	1.06	0.0
B4	pp	2.5	0.62	0.10	0.49	9.05
	pn	0.98	0.44	0.37	1.64	8.48

For computation simplicity we parameterize the required nuclear form factor as sum of Gaussians: $F(\vec{q}) = \sum_i a_i e^{-b_i q^2}$ Where a_i and b_i are parameters whose values are obtained by fitting the electron scattering form factor after correcting for the finite size of the proton. The value of oscillator is taken from ref.[7]

The results of the calculations are presented in figure 1. It is found that the results make a clear distinction among the parametrizations B1, B2, B3 and B4, and we notice that the parametrization B2 seems to be the best possible choice of the NN amplitude out of our suggested parametrizations.

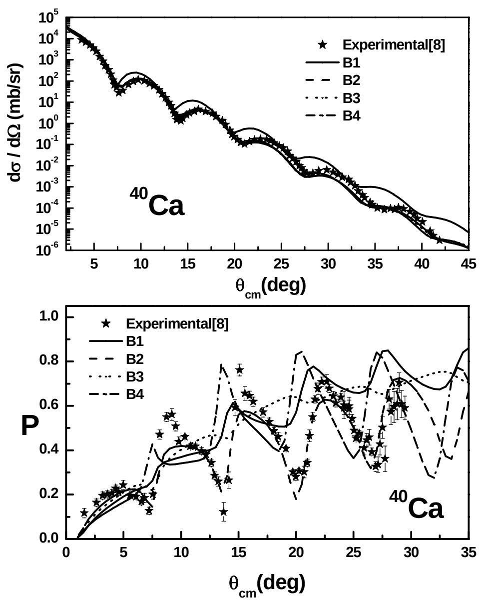

Fig.1 Angular distribution and polarization of p-^{40}Ca

References

[1] Z.A.Khan and M.Singh, IJMP **E16**(2007)1741.

[2] S.M.Lenzi etal.Phys. Rev.**C40**(1989)2114.

[3] I.Ahmad and J.P.Auger, Nucl.Phys. **A352**(1981)425.

[4] I.Ahmad, Nucl.Phys. **A247**(1975)418.

[5] I. Ahmad, J.Phys.G:Nucl.Phy.**6**(1980)947.

[6] Z.A.Khan and M.Singh, IJMP **E14**(2005)787.

[7] J.P.Auger and R.J.Lombard, J. Phys.G: Nucl.Phys.**4**(1978)L261.

[8] E.Bleszynski et al., Phys. Rev. **C25**(1982)2563.