Analysis of proton elastic scattering from $^{9,12}C$ at 300 MeV

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Introduction

Reactions of unstable nuclei with a proton is a field of current interest [1,2], as it is the only method to probe information about the proton and neutron density distributions in the absence of electron scattering experiments for such nuclei. For stable nuclei, the electron scattering experiments could provide reliable information about the proton density distribution. Then it is the proton elastic scattering that can be used to deduce the neutron density distribution. The study of matter distributions in unstable nuclei, however, depends upon the reliability of other inputs needed to analyzing the proton scattering from these nuclei.

In the present analysis, we propose to analyze the recently measured angular distribution [2] of p-^{9}C elastic scattering at 277-300 MeV. Our main concern in this work is to see how far the results of calculations for p-^{9}C scattering are sensitive to the available density distributions of target nucleus [1,2]. To achieve this goal, it is necessary to perform parameter free calculations so that we may provide some useful information about the matter distribution in ^{9}C. For if we consider ^{12}C as a test nucleus where the proton density distribution can be reliably determined through electron scattering and the neutron density distribution can be safely assumed to be the same as proton density distribution, one may undertake the analysis of p-^{12}C elastic scattering [2] to fix the values of input parameters. The analysis is based upon the well known Glauber formalism, which is found to provide satisfactory account of elastic nuclear scattering data at intermediate and also at relatively low energies.

Formulation

Neglecting the effects of nuclear correlations, the elastic S matrix element S_{el} may be written as [3]

$$S_{el} \approx (1-\Gamma_0)^A, \qquad (1)$$

with

$$\Gamma_0 = \int \rho_A(\mathbf{r})\ \Gamma_{NN}(\mathbf{b} - \mathbf{s})\ d\mathbf{r}, \qquad (2)$$

where A is the target mass number, b the impact parameter, **s** the projection of the target nucleon coordinate **r** on the plane perpendicular to beam direction **k**, and $\rho_A(\mathbf{r})$ is the ground state (one-body) density of the target nucleus. The quantity Γ_{NN} is related to the NN amplitude (f_{NN}) as follows

$$\Gamma_{NN} = 1/(2\pi\ ik) \int d^2q \exp(-i\mathbf{q}.\mathbf{b})\ f_{NN}(\mathbf{q}), \quad (3)$$

Here, it is to be noted that Eq. (1) has been modified to account for the (i) Coulomb effects, and (ii) deviation in the straight line trajectory of the Glauber model because of the Coulomb field [3].

Results and discussion

We analyze the elastic angular distribution of p-^{9,12}C at 300 MeV. The inputs needed in the theory are the elementary NN amplitude and the nuclear (one-body) densities. For ^{9}C and ^{12}C we have taken the matter densities as given in Refs. [1,2] and [4], respectively.

Following Alkhazov et al. [5], the NN amplitude is parametrized as

$$f_{NN}(q) = (ik\sigma/4\pi)\{(1-i\rho)\exp[-(\beta+i\gamma_c)q^2/2] +$$
$$i(q^2/4m^2)^{1/2}(1-i\rho_s)D_s \exp[-(\beta_s+i\gamma_s)q^2/2]\ \vec{\sigma}.\hat{n}\}, \quad (4)$$

where σ is the NN total cross section, $\rho(\rho_s)$ the ratio of the real to the imaginary parts of the forward NN amplitude, $\beta(\beta_s)$ the slope parameter, $\gamma_c(\gamma_s)$ the phase parameter, D_s the relative strength of the spin-dependent amplitude, M the nucleon mass, $\vec{\sigma}$ the spin operator of the projectile, and $\hat{n}$ is the unit vector normal to the scattering plane. The values of σ, β, and ρ at 300 MeV are taken from Ref. [6]. Here it should be mentioned that the values of other parameters, namely D_s, β_s, and ρ_s, though given in [6], but their use in the present work is not justified, as they were determined in relation to total p-nucleus cross sections only, where the spin part of the NN amplitude is of minute importance. Therefore, it seems necessary to re-examine the spin part of the NN amplitude in the context of the present work. For this purpose, as mentioned above, we undertake the analysis of p-^{12}C elastic angular distribution to fix the values of the required (input) parameters. The results of such calculations are presented in Fig. 1(a), and the corresponding NN parameters are given in Table 1. The NN parameters, obtained in this way, are then used to analyze the p-^{9}C elastic angular distribution at 277-300 MeV [2], using (i) the RMF densities [1], and (ii) the one extracted in [2]. The results of the calculations are given in Fig. 1(b). It is found that the results with RMF densities [1] (dotted lines) are much better than those obtained with the densities given in [2] (dashed lines). And we are able to provide satisfactory explanation of p-^{9}C angular distribution up to a large section of experimental data. Still, some part of the data beyond $\theta_{c.m.}\sim 30^o$ shows large discrepancy between theory and experiment. One hopes that the inclusion of higher momentum transfer components [3] in NN amplitude, medium modifications due to Pauli blocking, and nuclear correlations may be helpful in providing a better understanding of experiment beyond $\theta_{c.m.}\sim 30^o$. Another source of discrepancy beyond $\theta_{c.m.}\sim 30^o$ may be related to the (input) NN amplitude whose parameters are obtained at 300 MeV, whereas the measurement for p-^{9}C angular distribution shows incident energy range 277-300 MeV. Thus it is quite likely that some reasonable variation in NN parameters may improve the situation beyond $\theta_{c.m.}\sim 30^o$. Keeping this in mind, we have repeated our p-^{9}C calculations at 277 MeV, with the hope of getting some reasonable range of NN parameters which can accommodate the energy range of 277-300 MeV. The results of such calculations are also presented in Fig. 1(b) (solid lines) and the corresponding NN parameters are given in table 1. It is found that a reasonable variation in NN parameters helps in providing better description of the data beyond $\theta_{c.m.}\sim 30^o$. Still, one feels to have more and precise data on p-^{9}C scattering.

Table 1

NN amplitude parameters at 277-300 MeV

σ_{pp} fm^2	σ_{pn} fm^2	β_{pp} fm^2	β_{pn} fm^2	ρ_{pp}	ρ_{pn}	γ_{cpp} fm^2	γ_{cpn} fm^2
2.29 2.37	3.56 3.51	.75 .67	.96 1.04	.77 .69	.21 .14	-.72 -1.2	-.97 -1.01

D_{sNN}	β_{sNN} fm^2	ρ_{sNN}	γ_{sNN} fm^2
-6.278 -5.538	0.29 0.43	-3.33 -2.81	0.188 0.354

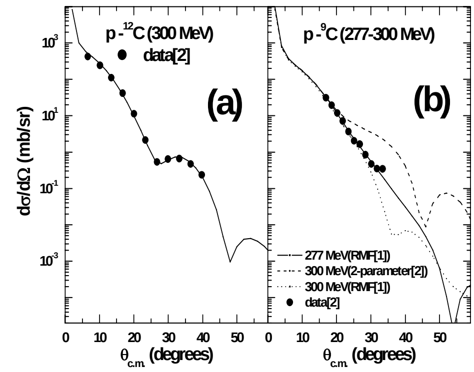

Fig. 1. Angular distribution for p-^{12}C at 300 MeV and ^{9}C at 277-300 MeV

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