Glauber model analysis of ^{3}He-nucleus reaction cross section

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Introduction

Recently[1] we have analyzed the α-nucleus elastic scattering in the energy range 25-70 MeV/nucleon within the framework of the Coulomb modified Glauber model[2]. The results show specifically the importance of large q components of the NN amplitude to providing a satisfactory explanation of the α-α elastic angular distribution up to fairly large value of momentum transfer.

Motivated by the success of the Glauber model at projectile energy as low as 25 MeV/nucleon[1], we, in this work consider the analysis of ^{3}He-nucleus reaction cross section(σ_R) data[3] at 96.4, 137.8, 167.3 MeV. Our aim is to see how far the NN amplitude, used in Ref.[1], could be helpful in the analysis of the ^{3}He-nucleus reaction cross section at energies under consideration and what could be inferred about the behavior of the NN amplitude from the point of view of providing the simultaneous description of the elastic angular distribution and σ_R at relatively lower energies.

Formulation

According to the correlation expansion for the Glauber amplitude[2], the elastic S-matrix element S_{00} for nucleus-nucleus collision is written as:

$$S_{00}(\vec{b}) = (1-\Gamma_{00})^{AB} + \text{ Correlation terms} \quad (1)$$

with

$$\Gamma_{00}(\vec{b}) = \frac{1}{ik}\int J_0(qb)F_A(\vec{q})F_B(\vec{q})\,f_{NN}(\vec{q})qdq \quad (2)$$

where A(B) is the mass number of target(projectile) nucleus, $F_B(\mathbf{q})$ and $F_A(\mathbf{q})$ are the form factors of the projectile and target nuclei respectively, **b** the impact parameter vector perpendicular to the beam direction, k is the momentum of the projectile nucleon, q is the momentum transfer, and $f_{NN}(\mathbf{q})$ is the NN scattering amplitude. Here it may be noted that the eq.(1) with B=3 gives S_{00} for ^{3}He-nucleus elastic scattering.

In the present context, the study of Abdulmomen and Ahmad[4] is quite useful. In this work the authors have shown that the effect of the two-body density term in the analysis of alpha-nucleus reaction cross section is small in the energy range of our interest. Due to this the consideration of first term in eq.(1) seems to be a good approximation to the full Glauber S-matrix at energies under consideration.

With these considerations, the σ_R for nucleus-nucleus collision is given by:

$$\sigma_R = 2\pi\int[1-|S_{00}(\vec{b})|^2]bdb \quad (3)$$

Results and discussion

Following the approach outlined above, we have analyzed the reaction cross section of ^{3}He from ^{9}Be and ^{12}C at 96.4, 137.8, 167.3 MeV. The inputs needed in the calculation are the NN amplitude and the form factors of the colliding nuclei.

For computational simplicity, we parametrize the required nuclear form factors in the same form as in Ref. [2]. The NN amplitude is parametrized as follows[1]:

$$f_{NN}(\vec{q}) = \frac{ik\sigma}{4\pi}(1-i\rho)e^{-\frac{1}{2}(\beta+i\gamma)q^2}[1+T(\vec{q})] \quad (4)$$

with

$$T(\vec{q}) = \sum_{n=1,2,3.....}\lambda_n q^{2(n+1)} , \quad (5)$$

where σ is the NN total cross section, ρ is the ratio of the real to the imaginary parts of the forward NN amplitude, β is the slope parameter, γ is the phase of the NN amplitude, and the parameters λ_n take care of the higher momentum transfer components of the NN amplitude. The values of σ and ρ at the desired energies/nucleon are obtained using the parametrizations given in Refs.[5,6]. To obtain the values of the other parameters, we first calibrate them by analyzing σ_R for ^{3}He-^{9}Be system at 96.4, 137.8 and 167.3 MeV. The values of the parameters obtained in this way are given in Table 1. The corresponding result is shown by the solid line in Fig.1(a). Then we perform the calculations for σ_R for ^{3}He-^{12}C system using the same values of NN parameters as reported in Table 1, but vary only γ which could possibly be different for different target nuclei; the result is shown by the solid line in Fig.1(b). The dotted lines in Fig.1 depicts the results without considering the λ_n. Our results show that the higher momentum transfer components of f_{NN} may not play a significant role in providing an independent description of σ_R .

Table 1: NN amplitude parameters

		Energy (MeV)		
	NN	32.1	45.9	55.7
σ (fm^2)	pp	8.96	6.06	4.93
	pn	27.49	18.05	14.35
ρ	pp	1.22	1.46	1.59
	pn	0.45	0.69	0.81
β (fm^2)	pp	0.63	0.78	0.85
	pn	0.71	0.88	1.00
λ_1 (fm^4)	pp	.28+i0.37	.08+i0.12	.06+i0.09
	pn	.04+i0.31	.01+i0.15	.01+i0.09
λ_2 (fm^6)	pp	.02-i0.13	.005-i0.077	.003-i0.065
	pn	.07-i0.09	.004-i0.060	.003-i0.047

Fig. 2 shows the results for the analysis of σ_R and elastic angular distribution of ^{3}He-^{12}C scattering at 132 MeV. It is found that the consideration of λ_n is able to provide a satisfactory explanation of both σ_R and elastic angular distribution (solid line). The values of the parameters obtained in this case are given in Table 2. However if we ignore λ_n, the elastic angular distribution shows large deviations (dotted line) while σ_R is still reproduced within experimental uncertainties(σ_R^{exp} =724 ± 35mb). This shows the importance of large q components of the NN amplitude for providing a simultaneous description of σ_R and elastic angular distribution data for the given system at energies under consideration.

Table 2: NN amplitude parameters at 44 MeV

NN	σ (fm^2)	ρ	β (fm^2)	λ_1 (fm^4)	λ_2 (fm^6)
pp	6.34	1.43	0.74	.03+i0.17	.003-i.09
pn	18.9	0.66	0.90	.001+i0.27	.001-i.15

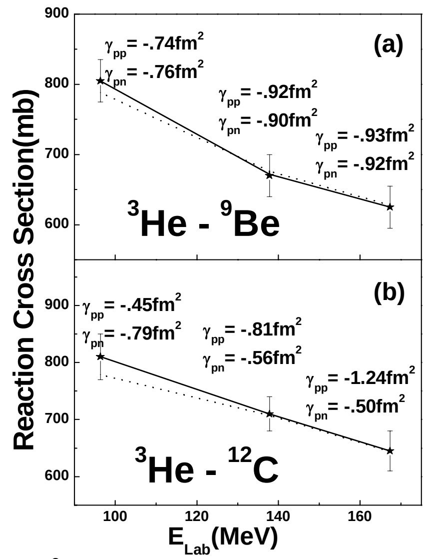

Fig.1. ^{3}**He-nucleus reaction cross section**

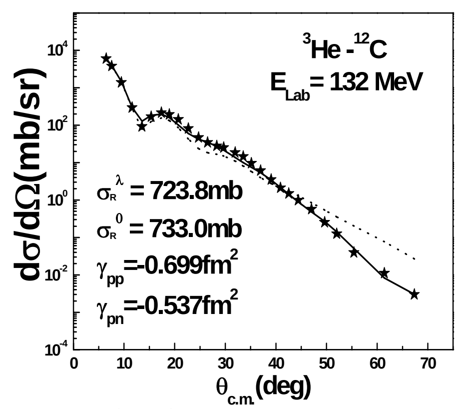

Fig.2. ^{3}**He-**^{12}**C elastic angular distribution.**

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