Analysis of α - ^{40,42,44,48}Ca elastic scattering at 1.37 GeV

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Introduction

In the intermediate energy range, the Glauber model analyses of hadron-nucleus collision though provided valuable information about the nuclear correlations and matter density distributions, but our recent work[1] showed that the basic (input) NN amplitude need to be modified in order to provide a better account of the experimental data. This modification considers that form of the NN amplitude which is valid for a wide range of angles. In other words, the analysis[1] highlights the importance of higher momentum transfer components at intermediate energies. In order to see how far the similar considerations of the NN amplitude account for the nucleus-nucleus scattering data in the same energy domain, we, in this work undertake the analysis of the elastic scattering of α particles from Ca-isotopes at 1.37 GeV within the framework of the Coulomb modified Glauber model. The calculations involve a semiphenomenological parametrization of the NN amplitude which preserves its low q behavior, while the higher momentum transfer components are treated phenomenologically through some adjustable parameters. In fact our aim is to see how far the consideration of higher momentum transfer components of the NN amplitude helps in accounting for the data and what could be said about the behavior of the NN amplitude at 344 MeV.

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:

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

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

where A(B) is the target(projectile) mass number, **b** the impact parameter, $F_B(\mathbf{q})$ and $F_A(\mathbf{q})$ are the form factors of the projectile and target nuclei, respectively, and $f_{NN}(\mathbf{q})$ is the NN scattering amplitude. The elastic scattering for the nucleus-nucleus scattering takes the form:

$$F_{el}(\vec{q}) = \frac{iK}{2\pi}\int e^{i\vec{q}.\vec{b}}[1 - S_{00}(\vec{b})]d^2b \quad (3)$$

where K is the c.m. momentum of the system. Eq.(3) has, however been modified to account for the Coulomb effects and the deviation in the straight line trajectory of the Glauber model due to Coulomb field[3].

With these considerations, the elastic angular distribution for the nucleus-nucleus collision is given by:

$$\frac{d\sigma}{d\Omega} = \left|F_{el}(\vec{q})\right|^2 \quad (4)$$

Results and discussion

Following the approach outlined above, we have analyzed the elastic scattering of α particles from ^{40,42,44,48}Ca at 1.37 GeV. The inputs needed in the calculation are the nuclear form factors and the NN amplitude.

For computational simplicity, the required nuclear form factors are parametrized in the same form as in Ref. [2], in which the values of the parameters are obtained by fitting the electron scattering form factors after correcting for the finite size of the proton. The NN amplitude, that plays a key role in the present analysis, is parametrized as:

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

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

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 variation parameter, and λ_n are the free parameters. Here it may be mentioned that since the free variation of λ_n is expected to simulate the nuclear medium effects, we consider only the uncorrelated part in Eq.(1).

As we know, the Glauber model calculations are physically meaningful only when one could have consistently a good description of the given set of data for different target nuclei at the same incident energy, using the same input for the NN amplitude. Keeping this in view, we have first analysed the α-^{40}Ca elastic angular distribution data at 1.37 GeV. The result of such calculation is presented by the solid line in Fig. 1(a) and the values of the NN amplitude parameters are reported in Table 1; the values of the phase variation parameter are given in Table 2. It is found that the consideration of two terms in Eq.(5) provides quite a satisfactory explanation of the data up to the available range of momentum transfer. The solid lines in Fig. 1(b)-(d) depict the results for ^{42}Ca, ^{44}Ca, and ^{48}Ca, respectively, using the same values of the parameters as given in Table 1, but vary only the phase of the NN amplitude which may be different for different target nuclei; the values of the phase variation parameter obtained in this case are also reported in Table 2. The results are as good as the one obtained in α-^{40}Ca case. In order to assess the role of high q components, we have also shown in Fig 1 the results(dotted lines) without considering T(**q**) in Eq.(4); these results show large deviations from the experimental data throughout the range of momentum transfer. Thus the results of our analysis show the importance of high q components of the NN amplitude in any realistic study of the α-nucleus scattering data in the energy range under consideration.

Table 1: NN amplitude parameters

	NN	E_{Lab} = 344 MeV
σ (fm^2)	pp	2.53
	pn	3.46
ρ	pp	0.585
	pn	0.063
β (fm^2)	pp	0.845
	pn	0.969
λ_1 (fm^4)	pp	0.335+i0.021
	pn	0.237+i0.003
λ_2 (fm^6)	pp	-0.813-i0.712
	pn	0.906-i0.245

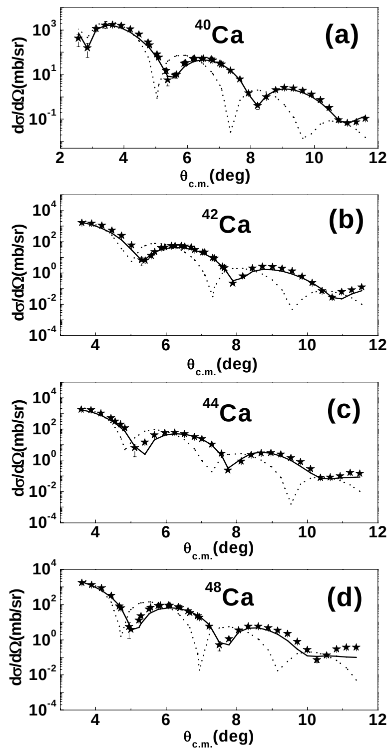

Fig.1 α -^{40,42,44,48}Ca elastic angular distribution at 1.37 GeV.

Table 2: NN amplitude phase variation parameters at 344 MeV

Target nucleus	NN	γ (fm^2) (with λ_n)	γ (fm^2) (without λ_n)
^{40}Ca	pp	-1.058	-0.061
	pn	-1.202	-0.075
^{42}Ca	pp	-1.049	-0.013
	pn	-1.183	-0.035
^{44}Ca	pp	-0.693	0.007
	pn	-0.838	-0.016
^{48}Ca	pp	-0.751	-0.171
	pn	-0.880	0.055

References

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