

A comprehensive analysis of elastic scattering of ^{35}Cl projectile from ^{24}Mg , ^{27}Al , $^{58,62}\text{Ni}$, $^{116,120,124}\text{Sn}$ and ^{141}Pr target nuclei

M. Aygun

Department of Physics, Bitlis Eren University, Bitlis, Turkey

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Abstract: Elastic scattering angular distributions of ^{35}Cl from ^{24}Mg , ^{27}Al , $^{58,62}\text{Ni}$, $^{116,120,124}\text{Sn}$ and ^{141}Pr targets are theoretically studied by using nine different density distributions of the ^{35}Cl nucleus. The theoretical results are compared with both experimental data and literature results. It is observed that our results successfully describe the data, and are in good agreement with the literature. Finally, new and practical equations of imaginary potentials are derived for all the densities of ^{35}Cl projectile. 24.10.Ht, 25.70.-z.

Keywords: Density distribution, optical model, double folding model, elastic scattering

1 Introduction

It is known that the element chlorine (Cl) with atomic number 17 has two stable isotopes; ^{35}Cl (%75.76) and ^{37}Cl (%24.24) [1]. The other chlorine isotopes are radioactive. ^{35}Cl and ^{37}Cl isotopes are synthesized in stars with the processes such as oxygen-burning and silicon-burning [2]. They can be used for nuclear magnetic resonance because of nuclear spin $3/2^+$.

The nuclear densities plays an significant role to obtain information about the structure and behaviors of nuclei. In this sense, various density distributions and studies can be found in the literature [3,4,5,6,7,8,9,10]. As a result, determining the validity of density distributions is an important issue in nuclear physics. With this goal, there are different experimental and theoretical approaches in the literature. The analysis of elastic scattering reaction is one of the approaches to be used for this purpose. Because, a suitable potential which well describes elastic scattering reaction can be determined by examining the density distributions. As a result of this, we think that a simultaneous analysis based on various density distributions of ^{35}Cl on elastic scattering cross-sections of ^{35}Cl projectile with various targets will be significant and useful in the explanation of nuclear interactions related to ^{35}Cl .

Scobel et al. [11] obtained the elastic scattering data of ^{35}Cl projectile by ^{27}Al , ^{58}Ni , ^{62}Ni , ^{116}Sn , ^{120}Sn , ^{124}Sn , and ^{141}Pr targets at different incidence energies. They examined the data using the optical and Fresnel scattering models. Then, Ferrero et al. [12] reported the experimental data of $^{35}\text{Cl} + ^{24}\text{Mg}$ elastic scattering reaction at 100 and 120 MeV, and analyzed the data using the optical model (OM). On the other hand, the effect of different density distributions of ^{35}Cl nucleus on elastic scattering cross-sections has not been investigated, and it remains as a deficiency in the literature.

In this study, we research alternative density distributions for the ^{35}Cl nucleus. We first get nine various density distributions of ^{35}Cl . Then, we calculate the elastic scattering cross-sections for 16 datasets and 144 nuclear reactions over various incident energies by using the double folding model (DFM) based on the OM. We compare our results with the literature as well as the experimental data. Finally, we obtain new equations that give the imaginary potential depths for each density distribution.

In section 2 a brief description of the theoretical model is presented. In section 3 the density distributions are reported, and the corresponding results are discussed in section 4. Section 5 is devoted to our conclusions.

* Corresponding author e-mail: murata.25@gmail.com

2 Optical Model

The calculations are performed using the DFM based on the OM. In this context, the total potential (V_T) is in the following form

$$V_T(r) = V_C(r) + V_N(r) \quad (1)$$

where V_C (Coulomb) potential [13] is

$$V_C(r) = \frac{1}{4\pi\epsilon_0} \frac{Z_P Z_T e^2}{r}, \quad r \geq R_c \quad (2)$$

$$= \frac{1}{4\pi\epsilon_0} \frac{Z_P Z_T e^2}{2R_c} \left(3 - \frac{r^2}{R_c^2}\right), \quad r < R_c \quad (3)$$

$$R_c = 1.25(A_P^{1/3} + A_T^{1/3}). \quad (4)$$

V_N (nuclear) potential consists of real and imaginary potentials. The real potential is calculated using the double folding potential in the following form

$$V(\vec{r}) = \int d\vec{r}_1 \int d\vec{r}_2 \rho_P(\vec{r}_1) \rho_T(\vec{r}_2) v_{NN}[\vec{r} - (\vec{r}_1 - \vec{r}_2)], \quad (5)$$

where $\rho_{P(T)}(\vec{r}_{1(2)})$ is the density of projectile(target) which is summarized below, and v_{NN} is nucleon-nucleon interaction given by

$$v_{NN}(r) = \beta_1 \frac{e^{-\beta_2 r}}{\beta_2 r} - \beta_3 \frac{e^{-\beta_4 r}}{\beta_4 r} - 276 \left[1 - 0.005 \frac{E_{\text{Lab}}}{A_P}\right] \delta(r), \quad (6)$$

where $\beta_1, \beta_2, \beta_3$ and β_4 are 7999 MeV, 4.0 fm⁻¹, 2134 MeV and 2.5 fm⁻¹, respectively. The imaginary part with the Woods-Saxon potential is shown as

$$W(r) = -\frac{W_0}{1 + \exp\left(\frac{r - r_w (A_P^{1/3} + A_T^{1/3})}{a_w}\right)}, \quad (7)$$

where W_0 , r_w and a_w are the depth, radius, and diffuseness parameter. The codes DF POT [14] and FRES CO [15], respectively are used in the DFM and the cross-section calculations.

3 Density Distributions

3.1 Densities of ³⁵Cl projectile

3.1.1 São Paulo (SP), Fermi (F), Moszkowski (M), Schechter (S) densities

The SP, F, M, S densities are evaluated as the two parameter Fermi (2pF) parameterized by

$$\rho_i(r) = \frac{\rho_{0i}}{1 + \exp\left(\frac{r - R_i}{a_i}\right)}, \quad (i = n, p) \quad (8)$$

where ρ_{0i} , R_i and a_i parameters are listed in Table 1.

3.1.2 Ngô (Ngo) density

The Ngo density is assumed as [20,21]

$$\rho_i(r) = \frac{\rho_{0i}}{1 + \exp\left(\frac{r - C}{0.55}\right)}, \quad (i = n, p) \quad (9)$$

where

$$\rho_{0n(0p)} = \frac{3}{4\pi} \frac{N(Z)}{A} \frac{1}{r_{0n(0p)}^3}, \quad C = R\left(1 - \frac{1}{R^2}\right), \quad R = \frac{NR_n + ZR_p}{A}, \quad (10)$$

and

$$R_n = (1.1375 + 1.875 \times 10^{-4}A)A^{1/3}, \quad R_p = 1.128A^{1/3}. \quad (11)$$

3.1.3 Gupta 1 (G1) density

The G1 density is parameterized by [22,23]

$$\rho_i(r) = \frac{\rho_{0i}}{1 + \exp\left(\frac{r - R_{0i}}{a_i}\right)}, \quad \rho_{0i} = \frac{3A_i}{4\pi R_{0i}^3} \left(1 + \frac{\pi^2 a_i^2}{R_{0i}^2}\right)^{-1}, \quad (12)$$

where

$$R_{0i} = 0.90106 + 0.10957A_i - 0.0013A_i^2 + 7.71458 \times 10^{-6}A_i^3 - 1.62164 \times 10^{-8}A_i^4, \quad (13)$$

$$a_i = 0.34175 + 0.01234A_i - 2.1864 \times 10^{-4}A_i^2 + 1.46388 \times 10^{-6}A_i^3 - 3.24263 \times 10^{-9}A_i^4. \quad (14)$$

3.1.4 Gupta 2 (G2) density

The G2 density with the different values of R_{0i} and a_i is presented by [24]

$$R_{0i} = 0.9543 + 0.0994A_i - 9.8851 \times 10^{-4}A_i^2 + 4.8399 \times 10^{-6}A_i^3 - 8.4366 \times 10^{-9}A_i^4, \quad (15)$$

$$a_i = 0.3719 + 0.0086A_i - 1.1898 \times 10^{-4}A_i^2 + 6.1678 \times 10^{-7}A_i^3 - 1.0721 \times 10^{-9}A_i^4. \quad (16)$$

3.1.5 Three parameter Fermi (3pF) density

The 3pF density is written as [25,26,27]

$$\rho_{3pF}(r) = \rho_{0i} \left(1 + \frac{w_i r^2}{R_{0i}^2}\right) \frac{1}{\left[1 + \exp\left(\frac{r - R_{0i}}{a_i}\right)\right]}, \quad (17)$$

where

$$\rho_{0i} = \frac{3A_i}{4\pi R_{0i}^3} \left[1 + \frac{3w_i}{5} + (1 + 2w_i) \frac{\pi^2 a_i^2}{R_{0i}^2} + \frac{7w_i}{5} \frac{\pi^4 a_i^4}{R_{0i}^4} \right]^{-1}, \quad (18)$$

$$R_{0i} = 1.56652 + 0.07285A_i - 5.3503 \times 10^{-4}A_i^2 + 1.74857 \times 10^{-6}A_i^3 - 1.23798 \times 10^{-9}A_i^4, \quad (19)$$

$$a_i = 0.33614 + 0.01938A_i - 4.79946 \times 10^{-4}A_i^2 + 4.25566 \times 10^{-6}A_i^3 - 1.23125 \times 10^{-8}A_i^4. \quad (20)$$

$$w_i = 0.05658 - 0.01174A_i + 1.75649 \times 10^{-4}A_i^2 - 8.96765 \times 10^{-7}A_i^3 + 1.7808 \times 10^{-9}A_i^4. \quad (21)$$

3.1.6 Hartree-Fock-Bogolubov (HFB) density

The HFB density based on the BSk2 Skyrme f calculations is taken from RIPL-3 [28].

3.2 Densities of target nuclei

The density distributions of ^{24}Mg , ^{27}Al , ^{58}Ni , ^{62}Ni , ^{116}Sn , ^{120}Sn , ^{124}Sn and ^{141}Pr target nuclei are assumed as the density shown by

$$\rho(r) = \frac{\rho_0}{1 + \exp\left(\frac{r-c}{z}\right)},$$

where ρ_0 , c and z parameters are given in Table 2.

4 Results and Discussion

The research includes the analysis of elastic scattering cross-sections of ^{35}Cl projectile from ^{24}Mg , ^{27}Al , ^{58}Ni , ^{62}Ni , ^{116}Sn , ^{120}Sn , ^{124}Sn , and ^{141}Pr targets. The calculations were carried out for nine different densities of ^{35}Cl shown as SP, F, M, S, Ngo, G1, G2, 3pF and HFB in our study. The density distributions were displayed as a function of distance in Fig. 1. It was observed that SP density has the highest density in the center part while S density has the lowest density. Also, the highest tailing was observed for G1 density and the lowest for SP density. Moreover, the root mean square (rms) radii of the densities were listed as compared with the literature in Table 3.

We researched the W_0 , r_w and a_w parameters of the imaginary potential in order to get good agreement results with the experimental data. We first found r_w value as 1.30 fm varying at 0.1 and 0.01 fm intervals for fixed values of W_0 and a_w . Then, we defined a_w value as 0.50 fm varying at 0.1 and 0.01 fm intervals for fixed values of

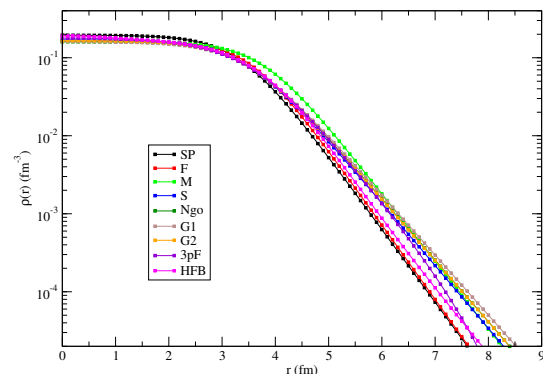


Fig. 1: The changes with distance of SP, F, M, S, Ngo, G1, G2, 3pF and HFB density distributions in logarithmic scale.

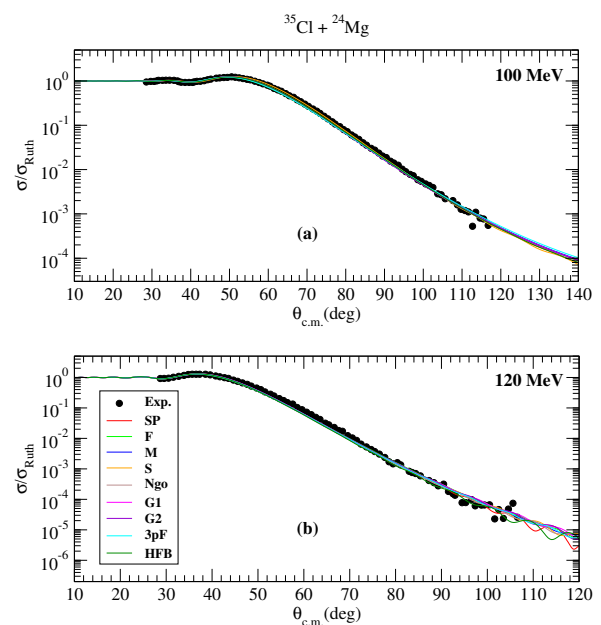


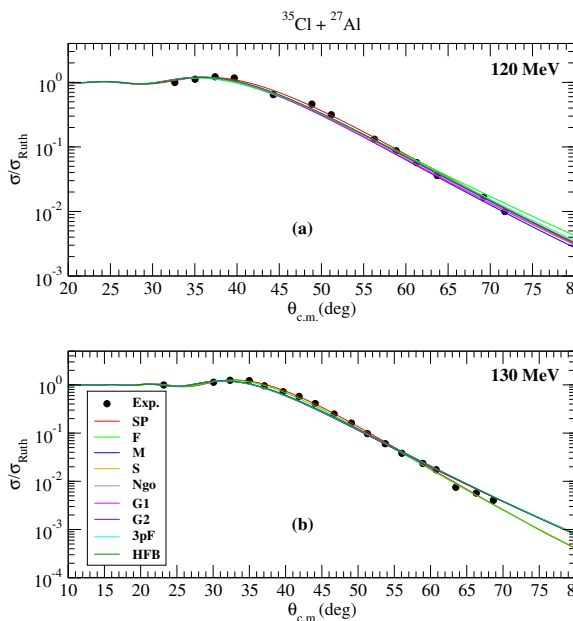
Fig. 2: The elastic scattering cross-sections calculated by using SP, F, M, S, Ngo, G1, G2, 3pF and HFB densities for $^{35}\text{Cl} + ^{24}\text{Mg}$ reaction (a) at $E_{\text{lab}}=100$ MeV, and (b) at $E_{\text{lab}}=120$ MeV. The data are taken from Ref. [12].

W_0 and r_w . Finally, we determined W_0 value for $r_w = 1.30$ fm and $a_w = 0.50$ fm.

In the present study, the elastic scattering cross-sections of ^{35}Cl projectile were evaluated as light, medium and heavy according to the masses of target nuclei. In this context, $^{35}\text{Cl} + ^{24}\text{Mg}$ (at 100 MeV and 120 MeV) and $^{35}\text{Cl} + ^{27}\text{Al}$ (at 120 MeV and 130 MeV) reactions were investigated as light target nucleus reactions. The elastic scattering cross-sections calculated were shown in Fig. 2 for $^{35}\text{Cl} + ^{24}\text{Mg}$ reaction and in Fig. 3 for $^{35}\text{Cl} + ^{27}\text{Al}$ reaction. It was observed that the density distributions fit well the experimental data for all

Table 1: ρ_0 , R_0 and a values of SP, F, M and S densities.

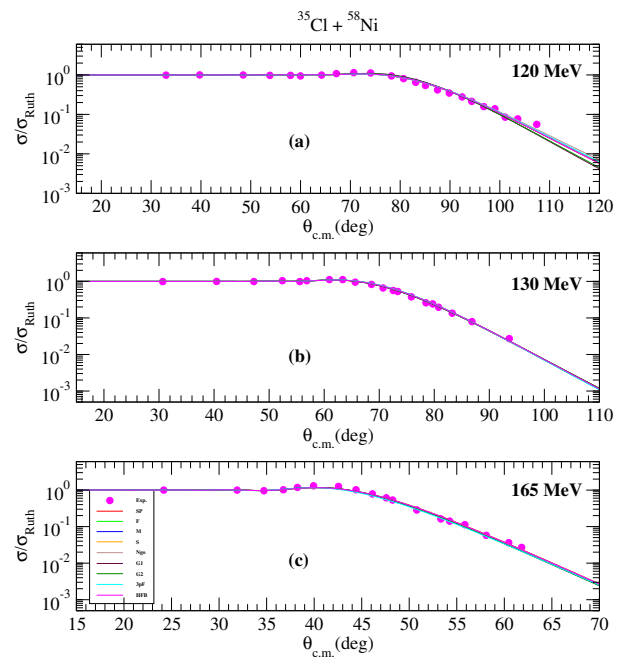
Density	ρ_0	R_0	a	Ref.
SP	$\rho_{0n}=0.115345$	$R_n = 1.49N^{1/3} - 0.79$	$a_n = 0.47 + 0.00046N$	[16]
	$\rho_{0p}=0.0789788$	$R_p = 1.81Z^{1/3} - 1.12$	$a_p = 0.47 - 0.00083Z$	
F	$\rho_{0n}=0.0842237$	$R_n = 0.953N^{1/3} + 0.015Z + 0.774$	$a_n = 0.446 + 0.0072(\frac{N}{Z})$	[17]
	$\rho_{0p}=0.0781905$	$R_p = 1.322Z^{1/3} + 0.007N + 0.022$	$a_p = 0.449 + 0.0071(\frac{Z}{N})$	
M	0.16	$1.15A^{1/3}$	0.50	[18]
S	$\frac{0.212}{1+2.66A^{-2/3}}$	$1.04A^{1/3}$	0.54	[19]

**Fig. 3:** Same as Fig. 2, but for $^{35}\text{Cl} + ^{27}\text{Al}$ reaction (a) at $E_{\text{lab}}=120$ MeV, (b) at $E_{\text{lab}}=130$ MeV. The data are taken from Ref. [11].

the reactions. However, it was noticed that the SP density is slightly better than the other densities.

$^{35}\text{Cl} + ^{58}\text{Ni}$ (at 120, 130 and 165 MeV) and $^{35}\text{Cl} + ^{62}\text{Ni}$ (at 120, 130, 160 and 170 MeV) reactions were analyzed as medium target nucleus reactions. The theoretical results of the elastic scattering cross-sections were displayed in Fig. 4 for $^{35}\text{Cl} + ^{58}\text{Ni}$ reaction and in Fig. 5 for $^{35}\text{Cl} + ^{62}\text{Ni}$ reaction. It was observed that all the density distributions were in very good agreement with the experimental data at all incident energies of both $^{35}\text{Cl} + ^{58}\text{Ni}$ and $^{35}\text{Cl} + ^{62}\text{Ni}$ reactions.

As heavy target nucleus reactions, $^{35}\text{Cl} + ^{116}\text{Sn}$ (at 165 MeV), $^{35}\text{Cl} + ^{120}\text{Sn}$ (at 165 MeV), $^{35}\text{Cl} + ^{124}\text{Sn}$ (at 165 MeV), and $^{35}\text{Cl} + ^{141}\text{Pr}$ (at 160 and 165 MeV) reactions were examined. The results were demonstrated in Fig. 6 for $^{35}\text{Cl} + ^{116}\text{Sn}$, $^{35}\text{Cl} + ^{120}\text{Sn}$, $^{35}\text{Cl} + ^{124}\text{Sn}$ reactions, and in Fig. 7 for $^{35}\text{Cl} + ^{141}\text{Pr}$ reaction. It was seen that the density distributions for $^{35}\text{Cl} + ^{116}\text{Sn}$, $^{35}\text{Cl} +$

**Fig. 4:** Same as Fig. 2, but for $^{35}\text{Cl} + ^{58}\text{Ni}$ reaction (a) at $E_{\text{lab}}=120$ MeV, (b) at $E_{\text{lab}}=130$ MeV, (c) at $E_{\text{lab}}=165$ MeV. The data are taken from Ref. [11].

^{120}Sn , and $^{35}\text{Cl} + ^{124}\text{Sn}$ reactions exhibit a similar behavior with each other, and good fits to the experimental data were obtained. On the other hand, little differences in the results of the density distributions for $^{35}\text{Cl} + ^{141}\text{Pr}$ reaction were observed. In addition, it can be said that the SP density is slightly better than the other densities.

One of the aims of our study was to suggest alternative density distributions for the analysis of the nuclear interactions of ^{35}Cl projectile with different target nuclei. For this purpose, the DFM was used in obtaining the real part of the nuclear potential. One of the parameters of this model is the renormalization factor (N_R). This value is desired to be unity. However, the deviation from this value can be due to the inadequacy of the model, or the specificity of the experimental data. The N_R values for all reactions and energy values were given

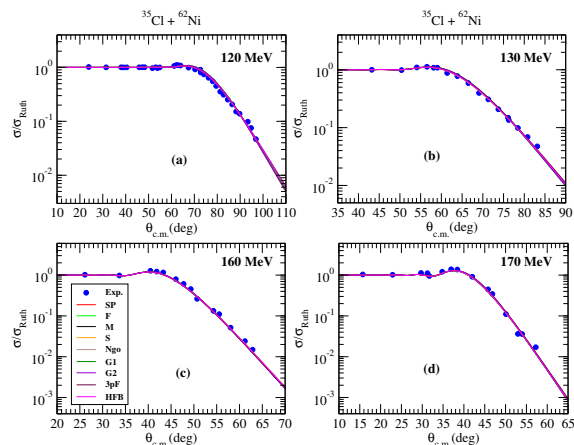


Fig. 5: Same as Fig. 2, but for $^{35}\text{Cl} + ^{62}\text{Ni}$ reaction (a) at $E_{lab}=120$ MeV, (b) at $E_{lab}=130$ MeV, (c) at $E_{lab}=160$ MeV (d) at $E_{lab}=170$ MeV. The data are taken from Ref. [11].

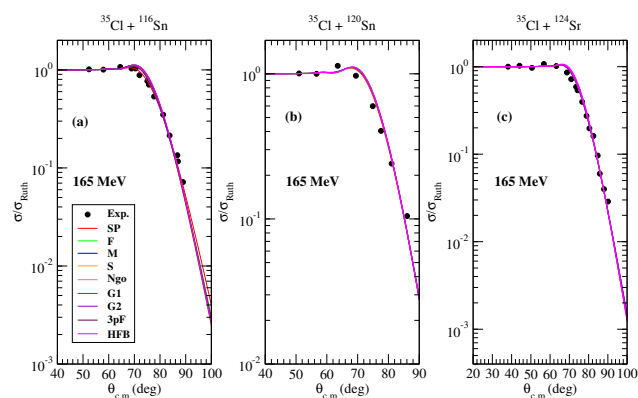


Fig. 6: Same as Fig. 2, but for (a) $^{35}\text{Cl} + ^{116}\text{Sn}$ at $E_{lab}=165$ MeV, (b) $^{35}\text{Cl} + ^{120}\text{Sn}$ at $E_{lab}=165$ MeV, and (c) $^{35}\text{Cl} + ^{124}\text{Sr}$ at $E_{lab}=165$ MeV. The data are taken from Ref. [11].

in Table 4, and displayed the changes with E/A_p in Fig. 8. In this sense, it can be said that the SP density is better than the other densities according to the N_R value. In addition, Ferrero et al. [12] showed N_R values for $^{35}\text{Cl} + ^{24}\text{Mg}$ reaction. These values were 1.17 ± 0.03 for 100 MeV and 0.98 ± 0.05 for 120 MeV. When these values were compared with N_R values found for the density distributions, it can be seen that N_R values of SP density are 1.00, and are better than the literature results. Thus, we can conclude that the SP density is the best density distribution among all the density distributions.

The reaction cross-section (σ_R) is one of significant parameters in the analysis of nuclear interactions. The σ_R values for all the reactions and the densities at various incident energies were listed as compared with the literature in Table 5, and their changes according to E/A_p were presented in Fig. 9. If σ_R values close to each

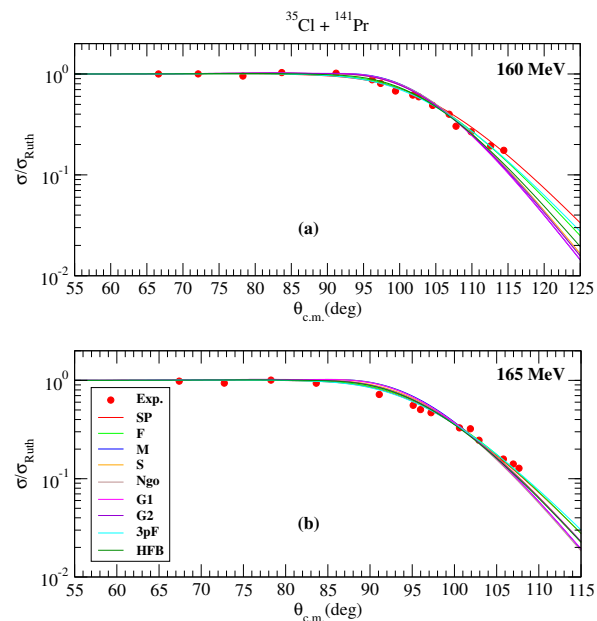


Fig. 7: Same as Fig. 2, but for $^{35}\text{Cl} + ^{141}\text{Pr}$ reaction (a) at $E_{lab}=160$ MeV, (b) at $E_{lab}=165$ MeV. The data are taken from Ref. [11].

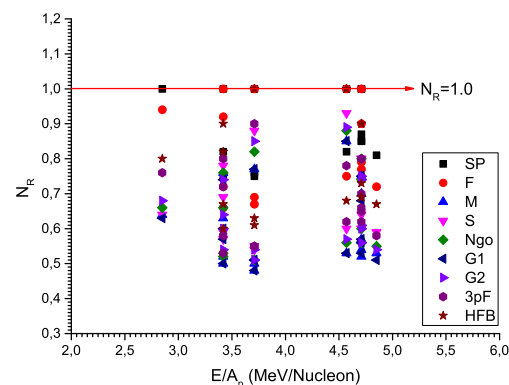


Fig. 8: The renormalization values (N_R) for the calculations with SP, F, M, S, Ngo, G1, G2, 3pF and HFB densities versus E/A_p (MeV/Nucleon).

other for different calculations of the OM, the suitability of the fitting procedure can be expressed. In this respect, we can say that the σ_R values obtained with this study are in agreement with both each other and literature.

In order to compare our results with the literature results, we plotted in Fig. 10 the literature results together with the SP density distribution which gives the best results. We observed that the agreement between both results was quite good. In this sense, we can specify this

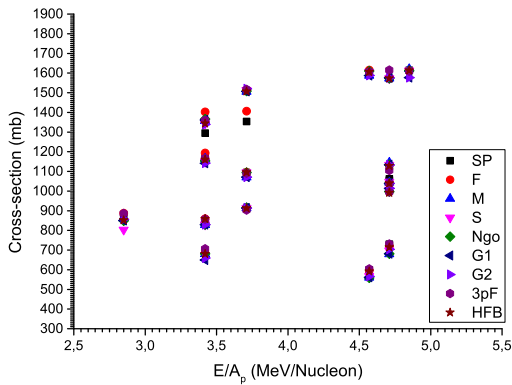


Fig. 9: The cross-sections (in mb) for the calculations with SP, F, M, S, Ngo, G1, G2, 3pF and HFB densities versus E/A_p (MeV/Nucleon).

as another parameter showing the suitability of our results.

It is desirable to determine the parameters of the potential used in the analysis of nuclear reactions such as elastic, inelastic and transfer. Thus, the equations giving the potential parameters will be very useful in the realization of these studies. For this purpose, we derived the expressions that give the imaginary potential depths for the density distributions examined in our study. For this, we evaluated the parameters that are used in obtaining elastic scattering cross-sections. Thus, we obtained the equations given in the following form

$$\text{SP density} \rightarrow W^{SP} = 15.68 + 0.06E - \frac{0.75Z_T}{A_T^{1/3}} \quad (23)$$

$$\text{F density} \rightarrow W^F = 26.90 + 0.05E - \frac{1.95Z_T}{A_T^{1/3}} \quad (24)$$

$$\text{M density} \rightarrow W^M = 19.29 + 0.14E - \frac{2.81Z_T}{A_T^{1/3}} \quad (25)$$

$$\text{S density} \rightarrow W^S = 14.92 + 0.17E - \frac{2.73Z_T}{A_T^{1/3}} \quad (26)$$

$$\text{Ngo density} \rightarrow W^{Ngo} = 19.60 + 0.14E - \frac{2.91Z_T}{A_T^{1/3}} \quad (27)$$

$$\text{G1 density} \rightarrow W^{G1} = 17.70 + 0.15E - \frac{2.78Z_T}{A_T^{1/3}} \quad (28)$$

$$\text{G2 density} \rightarrow W^{G2} = 17.64 + 0.14E - \frac{2.62Z_T}{A_T^{1/3}} \quad (29)$$

$$\text{3pF density} \rightarrow W^{3pF} = 22.45 + 0.12E - \frac{2.64Z_T}{A_T^{1/3}} \quad (30)$$

$$\text{HFB density} \rightarrow W^{HFB} = 20.79 + 0.11E - \frac{2.35Z_T}{A_T^{1/3}} \quad (31)$$

where E , Z_T and A_T are the incident energy of the projectile, atomic number and mass number of target, respectively.

Table 2: The 2pF density parameters for ^{24}Mg , ^{27}Al , $^{58,62}\text{Ni}$, $^{116,120,124}\text{Sn}$, and ^{141}Pr targets.

Nucleus	ρ_0 (fm $^{-3}$)	c (fm)	z (fm)	Ref.
^{24}Mg	0.16180	2.9800	0.551	[25]
^{27}Al	0.20150	2.8400	0.569	[25]
^{58}Ni	0.17200	4.0940	0.540	[29]
^{62}Ni	0.16420	4.2850	0.584	[30]
^{116}Sn	0.17100	5.2750	0.539	[30]
^{120}Sn	0.17100	5.3150	0.576	[30]
^{124}Sn	0.17220	5.3890	0.540	[31]
^{141}Pr	0.17133	5.6484	0.540	[32]

^a Determined via Ref. [25].

^b Determined via Ref. [33].

5 Conclusions

We analyzed the elastic scattering experimental data of ^{35}Cl projectile from ^{24}Mg , ^{27}Al , $^{58,62}\text{Ni}$, $^{116,120,124}\text{Sn}$, and

Table 3: The root mean square (rms) radii of SP, F, M, S, Ngo, G1, G2, 3pF and HFB densities together with the literature.

Density	rms (fm)
SP	3.107
F	3.218
M	3.456
S	3.312
Ngo	3.363
G1	3.395
G2	3.349
3pF	3.314
HFB	3.255
Literature	3.388 ^a
	3.371 ^b

Table 4: The renormalization (N_R) parameters applied in the analysis with SP, F, M, S, Ngo, G1, G2, 3pF and HFB densities.

Reaction	E_{lab}	N_R^{SP}	N_R^F	N_R^M	N_R^S	N_R^{Ngo}	N_R^{G1}	N_R^{G2}	N_R^{3pF}	N_R^{HFB}
$^{35}\text{Cl} + ^{24}\text{Mg}$	100	1.00	0.94	0.64	0.64	0.66	0.63	0.68	0.76	0.80
	120	1.00	0.92	0.63	0.69	0.66	0.60	0.64	0.72	0.82
$^{35}\text{Cl} + ^{27}\text{Al}$	120	1.00	1.00	0.76	0.78	0.76	0.74	0.74	0.80	0.90
	130	1.00	1.00	0.77	0.88	0.82	0.77	0.85	0.90	1.00
$^{35}\text{Cl} + ^{58}\text{Ni}$	120	0.82	0.72	0.52	0.59	0.52	0.57	0.60	0.58	0.67
	130	0.75	0.67	0.48	0.54	0.51	0.48	0.51	0.55	0.61
	165	0.85	0.77	0.54	0.60	0.56	0.56	0.60	0.66	0.69
$^{35}\text{Cl} + ^{62}\text{Ni}$	120	0.75	0.66	0.50	0.57	0.53	0.50	0.54	0.53	0.60
	130	0.76	0.69	0.50	0.55	0.51	0.51	0.54	0.55	0.63
	160	0.82	0.75	0.53	0.60	0.56	0.53	0.57	0.62	0.68
	170	0.81	0.72	0.53	0.59	0.55	0.51	0.54	0.58	0.67
$^{35}\text{Cl} + ^{116}\text{Sn}$	165	1.00	1.00	0.70	0.80	0.74	0.68	0.74	0.80	0.90
$^{35}\text{Cl} + ^{120}\text{Sn}$	165	0.87	0.79	0.57	0.64	0.60	0.57	0.61	0.65	0.73
$^{35}\text{Cl} + ^{124}\text{Sn}$	165	0.85	0.75	0.52	0.60	0.56	0.53	0.56	0.62	0.69
$^{35}\text{Cl} + ^{141}\text{Pr}$	160	1.00	1.00	0.85	0.93	0.88	0.85	0.89	0.78	1.00
	165	1.00	0.90	0.75	0.80	0.80	0.75	0.75	0.70	0.90

Table 5: The cross-sections (in mb) calculated for SP, F, M, S, Ngo, G1, G2, 3pF and HFB densities together with the literature.

Reaction	E_{lab}	σ_R^{SP}	σ_R^F	σ_R^M	σ_R^S	σ_R^{Ngo}	σ_R^{G1}	σ_R^{G2}	σ_R^{3pF}	σ_R^{HFB}	$\sigma_R^{Literature}$
$^{35}\text{Cl} + ^{24}\text{Mg}$	100	862	887	865	803	849	850	856	886	852	853-Ref. [12]
	120	1170	1194	1166	1149	1153	1141	1142	1167	1160	1173-Ref. [12]
$^{35}\text{Cl} + ^{27}\text{Al}$	120	1295	1403	1357	1344	1366	1361	1339	1360	1344	1284-Ref. [11]
	130	1354	1406	1506	1513	1508	1507	1520	1517	1507	1365-Ref. [11]
$^{35}\text{Cl} + ^{58}\text{Ni}$	120	684	683	680	675	681	649	660	707	680	687-Ref. [11]
	130	913	913	914	914	915	914	914	903	913	956-Ref. [11]
	165	1573	1574	1573	1573	1573	1576	1576	1615	1573	1559-Ref. [11]
$^{35}\text{Cl} + ^{62}\text{Ni}$	120	851	859	828	829	829	829	829	857	858	895-Ref. [11]
	130	1094	1095	1070	1094	1094	1071	1071	1091	1095	1116-Ref. [11]
	160	1605	1615	1587	1606	1611	1587	1588	1607	1606	1571-Ref. [11]
	170	1614	1613	1621	1612	1612	1577	1577	1610	1613	1629-Ref. [11]
$^{35}\text{Cl} + ^{116}\text{Sn}$	165	1053	997	1010	1006	997	1013	1014	995	991	1101-Ref. [11]
$^{35}\text{Cl} + ^{120}\text{Sn}$	165	1062	1039	1044	1047	1039	1039	1039	1039	1039	1110-Ref. [11]
$^{35}\text{Cl} + ^{124}\text{Sn}$	165	1127	1132	1145	1133	1134	1134	1133	1105	1128	1261-Ref. [11]
$^{35}\text{Cl} + ^{141}\text{Pr}$	160	599	597	560	567	559	561	566	604	591	600-Ref. [11]
	165	730	721	679	697	681	681	704	731	714	772-Ref. [11]

^{141}Pr target nuclei. The theoretical results successfully described the experimental data of nucleus reactions with light, medium and heavy target nuclei at various incident energies. Additionally, it was found that the SP density is better than the other densities in general sense. Then, new and practical sets of imaginary potentials were derived for nine different density distributions of ^{35}Cl projectile. We believe that these equations would be useful in explaining of elastic, inelastic and transfer reactions of the ^{35}Cl nucleus.

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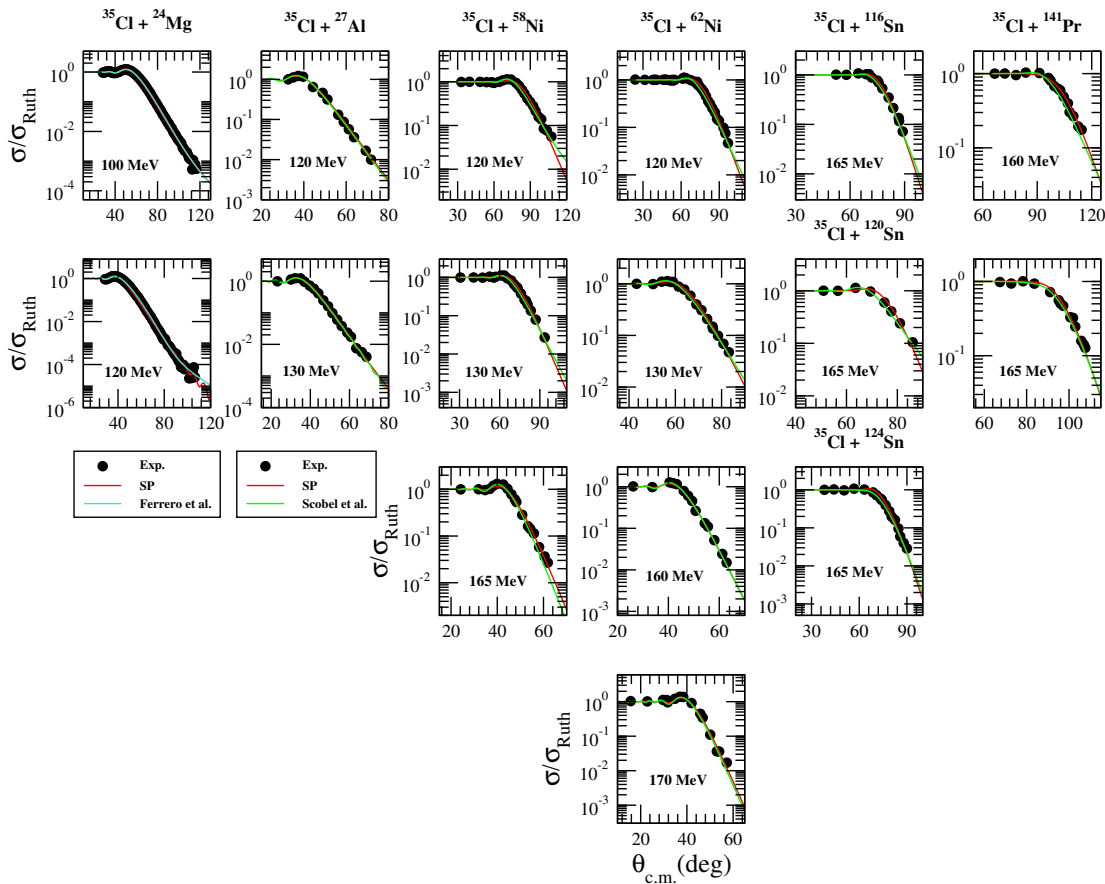


Fig. 10: A comparison of the elastic scattering results of SP density with the literature results.

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