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Single Folding Cluster Potential for $P+^{12}C$ Elastic Scattering

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Abstract: The proton scattering from carbon has been analyzed within the framework, using the single folding optical model with a Gaussian shape of the effective alpha-nucleon interaction. In addition, the angular distributions of the differential cross-sections of the proton elastic scattering from ^{l2}C were analyzed, using the alpha-cluster structure of ^{12}C, where carbon has three atoms of helium and oxygen has four atoms of helium. Furthermore, we analyzed the $P+^{12}C$ elastic scattering at twenty energies, ranging from 7 to 494 MeV. The Gaussian shape of the effective alpha-nucleon interaction was used at two values for the depth at 36.4 MeV with the range of 0.265 fm^{-2} and 47.3 MeV with the range of 0.189 fm^{-2}. Thus, each of the two values for the depth succeeded to describe the proton scattering from carbon.

Keywords: Single Folding Model, Elastic Scattering, Nuclear Reactions, Proton Carbon Reactions

1 Introduction

We used the optical model to study the proton scattering, where the optical model is the most successful one of all nuclear models which were applied in order to understand the nucleus-nucleus interactions through the analysis of elastic scattering [1]. In this regard, a large number of studies have analyzed the proton scattering, such as M. A.Allam(2012) [2] and D. Abriolaet al. (2011) [3] for the proton elastic scattering.
We used the alpha-cluster model to generate the alpha-nucleus and alpha-nucleus single folding cluster potential, based on the alpha-nucleus interaction. In this model, we consider a nucleus of mass number B composed of an integral number (m) of alpha-particles, i.e., $B=Am$. This model was successful to describe the angular distributions of the differential cross-sections of the proton elastic scattering from carbon, where we notice a consensus between the practical and the theoretical results. On the other hand, El-Azab Faridet al. (2001, 2006) [4,5], and recently Karakoe and Boztosun(2006) [6], have all employed the alpha-cluster structure of the interacting nuclei in the folding formalism, in order to generate the alpha-particle single folding optical potentials based on an appropriate alpha-interaction.

The proton scattering has been analyzed using the optical model with the Gaussian shape of the effective alpha-nucleon interaction. Thus, some people used the depth of 36.4 MeV for the effective alpha-nucleon interaction with a range of o.265 fm^{-2}, and other people used the depth of 47.3 MeV for the effective alpha-nucleon interaction with a range 0.189 fm^{-2}; in this framework, we compared between the two values of the depth.

2 Theoretical Formalism

2.1 The Single Folding Cluster Model

When the nucleon (such as proton) collides with the nucleus, the nucleus-nucleus interaction could be written in the following form:

$$U(R)=-V(r)-iW(r)+V_c(r) \tag{1}$$

where the V(r) and W(r) are the real and imaginary parts in the optical potential respectively; and $V_c(r)$ is the repulsive coulomb potential, where this potential is represented by the interaction of the charge of the

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incident projectile with the charge distribution of protons in the target nucleus, and (r) is the separation between the centers of the two colliding nuclei.
When we analyze the nucleon-nucleus scattering by using the single folding model, we can study the Single Folding Optical (SFO) Potential in this model by folding the nuclear matter density of the target with the effective nucleon-nucleon interaction, see Fig. [1], the general form of this potential is given by:

$$V_{opt}(r,E) = \int d^3r_1\rho_1(r_1)V_{N-N}(s,\rho_1,E) \qquad (2)$$

Where $\mathbf{S}=\mathbf{r}-\mathbf{r_1}$, $\rho_1(r)$ is the matter density distribution of the target and $V_{N-N}(S,\rho_1,E)$ is the effective nucleon ? nucleon interaction. In this work, we used the cluster

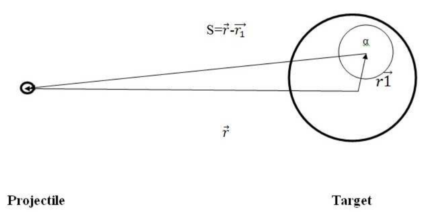

Fig. 1: The Schematic representation for the SFC interaction.

model where this model considering the nucleus of the mass number B is consisted of an integral number of alpha-particles, i.e. $(B=4\alpha)$, (such as $^{12}C=3\alpha$); therefore, we fold the effective a-nucleon interaction with α-cluster distribution density of the target, in order to obtain the Single Folding Cluster (SFC) Potential; in this case, the potential take of the form is as follows:

$$V_{SFC}(r,E) = \int d^3r_1\rho_c(r_1)V_{\alpha-N}(S,\rho_c,E) \qquad (3)$$

Where $\rho_c(r_1)$ is the α-cluster distribution density and $V_{\alpha-N}(S,\rho_c,E)$ is the effective alpha ? nucleon interaction and it is given in a Gaussian form:

$$V_{\alpha-N}(S) = v_{0\alpha N}exp^{-ks^2} \qquad (4)$$

Where $v_{0\alpha N}$ is the depth and k is the range parameter. In this framework the Gaussian shape of the effective α-N interaction used at two values of the depth, describes each of the two values of the depth as shown in Table [1].

2.2 Alpha-Cluster Densities

In this work, we used the alpha ? cluster model to study the proton scattering from carbon, thus, we consider that

Table 1: The Parameters of the $\alpha-N$ Effective Interaction using the SFC Optical Potential.

$v_{0\alpha N}$ MeV	k (fm $^{-2}$)	Ref
36.4	0.2657	[7]
47.3	0.1892	[8]

Table 2: the Density parameters used in Eqs.(6),(7)and the root mean square radii in Eq.(9) where $\rho_0(M,\alpha,c)\,fm^{-3}$, w$(\gamma)\,fm^{-2}$, B$(\lambda)(\xi)\,fm^{-2}$ and Rms (fm).

NUCLEUS	$\rho_0(M,\alpha,c)$	w(γ)	B$(\lambda)(\xi)$	Rms	Ref
$\rho_M$for carbon	0.1644	0.4988	2.407	2.407	[10]
ρ_c for carbon	-1.644	-1.7852	0.8003	1.912	[10]
ρ_M for oxygen	0.1317	0.6457	0.3228	2.64	[11]
ρ_c for oxygen	-0.1286	-1.4249	0.5973	2.199	[11]
ρ_α	0.4229	0	0.7024	1.46	[11]

carbon consists of 3α nucleuses. If the α-cluster distribution density of the target is$\rho_c(r_1)$ and the alpha density is $\rho_\alpha(r)$ then, we can write the nuclear matter density distribution of the target nucleus in the following form:

$$\rho_M(r) = \int \rho_c(r_1)\rho_\alpha(\mathbf{r}-\mathbf{r_1})d\mathbf{r_1} \qquad (5)$$

In addition, we used the Gaussian form for the target density and the a-density, thus, we can write them as follows:

$$\rho_M(r) = \rho_{0M}(1+wr^2)\exp^{-\beta r^2} \qquad (6)$$

$$\rho_\alpha(r) = \rho_{0\alpha}\exp^{-\lambda r^2} \qquad (7)$$

Where w,β and λ parameters are listed in Table [2]. ρ_{0M} and $\rho_{0\alpha}$ can be determined by using the normalization condition as follows:

$$\int \rho(r)r^2dr = \frac{A}{4\pi} \qquad (8)$$

In order to calculate the $\rho_c(r_1)$ from Eq. (4) we used the Fourier transform [9] ,using Equations (5) and (6) in order to obtain it as follows:

$$\rho_c(r_1) = \rho_{0c}(1+\gamma r_1^2)\exp^{-\xi r_1^2} \qquad (9)$$

Where

$$\gamma = \frac{2w\lambda^2}{[\eta(2\eta-3w)]} \qquad (10)$$

$$\xi = \frac{\beta\lambda}{\eta}, \eta = \lambda-\beta \qquad (11)$$

And ρ_{0c} is determined by using the normalization condition in Eq. (7) where $A=B$.

3 Procedure

We can study the Single Folding Cluster (SFC) Potential by analyzing the elastic scattering proton from carbon.

First, we calculated the SFC potential analytically by using the Eqs. (3),(4) and (9).We used the Fortran program for the result from the calculations; and the results from the Fortran program were checked by recalculating the potential numerically by the computer code DOLFIN [12],using Eq.(3) directly; and the parameters of the cluster density for the target and the effective α-N interaction were taken from Tables [1] and [2]. Each of the two ways yielded identical results. Then, we fed the resulted potentials to the computer code HIOPTIM-94[3]; and through the HIOPTIM code, we obtained the differential cross-sections for the proton elastic scattering from carbon and oxygen; and the best fits can be obtained by minimizing the chi-square x^2value, where:

$$\chi^2 = \frac{1}{N}\sum_{i=1}^{N_\sigma}[[\frac{\sigma_{th}(\theta_i) - \sigma_{ex}(\theta_i)}{\Delta\sigma_{ex}(\theta_i)}]]^2 \quad (12)$$

Where $\sigma_{ex}(\theta_i)$,$\sigma_{th}(\theta_i)$ are the experimental and theoretical differential cross sections , respectively, at the angle θ_i , $\Delta\sigma_{ex}(\theta_i)$ is the error associated with $\sigma_{ex}(\theta_i)$ and N_σ is the total number of θ_i.

4 Results and Discussion

4.1 $P+^{12}C$ Elastic Scattering

The differential cross-sections of proton from ^{12}C have been measured over a wide range of energies, as E = 7 [14], 14 [15], 17.8 [16], 21.1 [17], 22 [18], 30 [19], 30.4 [20], 40 [19], 50 [21], 59.5 [17], 69.5 [17],79.8 [17], 83.5 [17], 96 [22], 122 [23], 156 [24], 182.8 [25], 250 [26], 300 [27] and 494 [28] MeV. The Gaussian shape of α-N effective interaction was used at the two values of the depth at 36.4 MeV with a range of 0.256 fm^{-2} and 47.3 MeV with a range of 0.189 fm^{-2}, thus, we measured the differential cross-sections at these two values of the depth. The obtained values of the real normalization factor NR, the parameters of the imaginary parts of the SFC optical potential, the volume integrals, and the resulted reaction cross-sections are all listed in Tables [3] and [4] for the depth of 36.4 MeV of the α-N effective interaction; in addition, Tables [5] and [6] display the same parameters, but for the depth of 47.3 MeV of the α-N effective interaction.

The differential cross-sections are calculated by fitting our calculations with the experimental data; thus, Figures [2] and [3] display the best fit of the differential cross-sections for the protons scattered from ^{12}C. Out of Fig.[2], we can see that the differential cross-sections give a good agreement at all energies, as E = 7, 14, 17.8. 21.1, 22, 30, 30.4, 40, 50 and 59.5 MeV, with the experimental data; and they also give a good agreement between the two values of the depth of the effective α-N interactions. This fitting is found at the large angels, where it reaches the following: $\theta_{CM} = 170^o$. Fig.[3] also shows the best fit between the elastic scattering cross-sections for the two

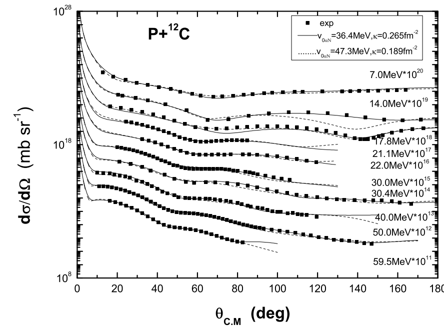

Fig. 2: A Comparison between the differential cross sections of $P+^{12}C$ for the two values of the depth of the α-N effective interaction with the experimental data at E=7,14, 17.8, 21.1, 22, 30, 30.4, 40, 50 and 59.5 MeV.

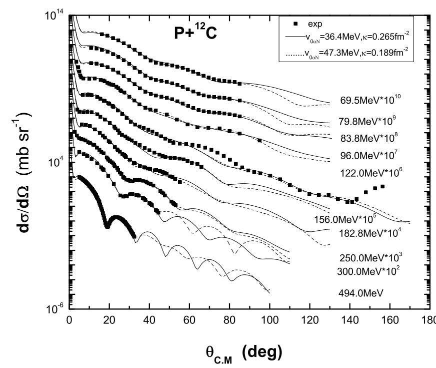

Fig. 3: A Comparison between the differential cross sections of $P+^{12}C$ for the two values of the depth of the α-N effective interaction with the experimental data at E=69.5, 79.8, 83.8, 96 , 122 , 156 , 182.8 , 250 , 300 and 494 MeV .

values of the depth of the effective α-N interactions, with the experimental data at E = 69.5, 79.8, 83.5, 96, 122, 156, 182.8, 250, 300 and 494 MeV. In addition, this fitting is also found even at the large angels reaching $\theta_{cM} = 150^o$. From these results, we notice that when the α-N effective interaction increased by 30% from 36.4 MeV to 47.3 MeV, and the range decreased by 20% from 0.265 fm^{-2} to 0.189 fm^{-2}, each of the two values of the depth of the effective α-N interaction gives a good agreement with the experimental data Figure [4] shows the relation between the reaction cross-section OR and the incident energy. Out of this figure, we see that each of the two values of the depth of the a-N effective interaction gives the same shape; and the obtained σ_R shall be close to each other in the two cases. The dependence of σ_R on the incident energy is shown in this figure. Figure [5] demonstrates the change between the imaginary volume

Table 3: The Real normalization factor NR , the parameters of the imaginary parts of the optical potential, the volume integral, the parameters of the spin ? orbit W-S potential and the reaction cross sections for $P+^{12}C$ at the depth of the α-N effective interaction equal 36.4 MeV,, these experimental values are taken from Refs.[29,30],where J_I (MeV fm^3) and $J_{S.O}$ (MeV fm^3).

E MeV	7.0	14	17.8	21.1	22
V_R MeV	46.19	52.92	53.8	47.86	52.12
W_S MeV	0	0	8.082	6.131	5.237
W_D MeV	0.221	26.47	0	0	0
R_I fm	1.6	1.361	1.358	1.514	1.687
A_I fm	0.583	0.131	0.019	0.439	0.217
USP MeV	9.405	5.311	18.24	9.716	11.14
WSP MeV	0	0	0	0	0
RSP fm	0.868	1.038	1.206	1.182	1.175
ASP fm	0.300	0.174	0.115	0.348	0.187
R_C fm	1.25	1.25	1.2	1.25	1.25
χ^2	6.93	1.74	10.46	0.89	0.12
J_I	7.85	142.5	547.0	103.3	108.6
$J_{S.O}$	39.02	26.4	105.3	55	62.75
σ_R mb	139.2	469.3	401.8	452	439.6
σ_{exp} mb					
J_R/V_R	10.16	10.16	10.16	10.16	10.16
E MeV	30	30.4	40	50	59.5
V_R MeV	43.27	48.08	40.29	38.98	35.05
W_S MeV	7.605	6.991	0	0	2.629
W_D MeV	0	0	7.316	4.014	8.517
R_I fm	1.249	1.624	1.504	1.37	1.496
A_I fm	0.8	0.162	0.344	0.626	0.195
USP MeV	0.229	7.084	5.83	5.462	7.626
WSP MeV	0	0	0	0	0
RSP fm	0.75	1.257	0.95	0.996	0.743
ASP fm	0.36	0.653	0.4	0.425	0.39
R_C fm	1.25	1.25	1.25	1.25	1.25
χ^2	1.51	2.69	3.5	1.23	0.43
J_I	110.4	127.8	129.4	117.3	356.0
$J_{S.O}$	0.82	42.75	26.54	26.07	27.22
σ_R mb	413.9	411.4	372.8	343.9	294.9
σ_{exp} mb	412.2±10		370±10	342	293±12
J_R/V_R	10.61	10.16	10.16	10.16	10.16

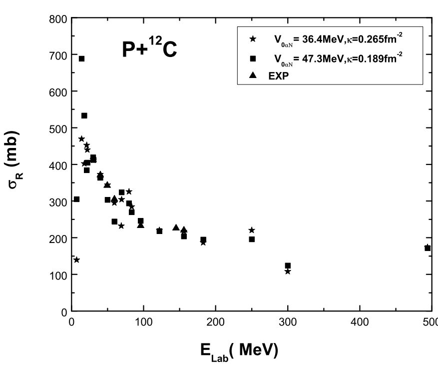

Fig. 4: The Relation between the reaction cross section and incident energy for $P+^{12}C$.

Table 4: The same parameters in Table [3] but at energies E=69.5 to 494 MeV, these experimental values are taken from Refs.[29, 30].

E MeV	69.5	79.8	83.8	96	122
V_R MeV	34.398	38.3	32.942	33.597	25.88
W_S MeV	7.55	0	12.41	4.867	19.346
W_D MeV	0	8.83	0.261	8.014	0
R_I fm	1.503	1.08	1.08	0.892	1.019
A_I fm	0.517	0.57	0.75	0.54	0.557
USP MeV	7.987	6.57	3.788	3.052	2.005
WSP MeV	0	0	0	0	0
RSP fm	0.75	0.87	0.897	0.861	0.93
ASP fm	0.36	0.449	0.33	0.276	0.429
R_C fm	1.25	1.25	1.25	1.51	1.51
χ^2	2.49	3.002	0.84	5.68	15.01
J_I	131.44	389.7	131.91	117.51	134.3
$J_{S.O}$	28.73	27.7	16.28	12.63	8.94
σ_R mb	304.3	325.4	284.6	232.2	220
σ_{exp} mb				232.5	
J_R/V_R	10.157	10.16	10.158	10.16	10.16
E MeV	156	182.8	250	300	494
V_R MeV	18.3	19.146	17.726	26.353	36.254
W_S MeV	9.15	0	15	5.172	16.291
W_D MeV	0	7.09	0	0	0
R_I fm	1.383	1.074	1.3229	1.332	1.285
A_I fm	0.572	0.562	0.546	0.77	0.511
USP MeV	3.96	2.509	2.614	1.25	1.525
WSP MeV	0	0	-3.071	-1.659	0
RSP fm	0.945	0.983	0.989	1.11	1.23
ASP fm	0.406	0.411	0.475	0.429	0.292
R_C fm	1.51	1.25	1.51	1.51	1.51
χ^2	5.82	6.48	2.81	3.79	1.73
J_I	186.1	118.23	192.26	83.59	188.24
$J_{S.O}$	17.9	11.81	12.41	6.65	9.02
σ_R mb	217.1	186.6	220	107.8	174
σ_{exp} mb				220	
J_R/V_R	10.16	10.16	10.16	10.16	10.16

integrals with the incident energy for both two depths. Out of this Figure, we can see that each of the two values of the depth gives the same behaviour with the incident energy. Figure [6] shows the relation between the real depths V_R of the SFC optical potential with the incident energy. At a low energy down to 200 MeV, we see that the V_R decreased with the increased energy; and at a high energy up to 494 MeV, we see the V_R increased with the increased energy. In addition, each of the two cases of the depth gives the same behaviour. As for the two cases of the depth, we see that the relation between the spin-orbit volume integral with the energy gives the same fitting as shown in Figure [7].

5 Conclusions

In this current study, we used the single folding cluster model to calculate the proton scattering from ^{12}C. This

Table 5: The real normalization factor NR, the parameters of the imaginary parts of the optical potential, the volume integral, the parameters of the spin ? orbit W-S potential and the reaction cross sections for P+^{12}C at the depth of the α-N effective interaction equal 47.3 MeV, these experimental values are taken from Refs.[29,30].

E MeV	7.0	14	17.8	21.1	22
V_R MeV	46.11	31.73	37.5	36.51	38.83
W_S MeV	1.57	6.029	4.803	5.24	0.076
W_D MeV	0	0	0	0	29.1
R_I fm	1.25	1.923	1.725	1.32	1.51
A_I fm	0.318	0.043	0.45	0.569	0.073
USP MeV	28.69	16.89	15.81	17.93	19.76
WSP MeV	0	0	0	0	0
RSP fm	0.762	0.654	1.262	1.33	1.249
ASP fm	0.561	0.579	0.12	0.136	0.233
R_C fm	1.25	1.25	1.2	1.25	1.25
chi^2	3.22	21.7	5.69	0.045	1.74
J_I	14.76	179.7	634.6	68.17	657.0
$J_{S.O}$	106.1	54.39	95.6	113.0	118.1
σ_R mb	304.9	688	532.8	383.9	404.5
σ_{exp} mb					
J_R/V_R	16.91	16.91	16.91	16.9	16.91
E MeV	30	30.4	40	50	59.5
V_R MeV	27.71	28.23	24.12	24.69	23.46
W_S MeV	7.17	10.86	10	0	0
W_D MeV	0	0	0	3.143	3.885
R_I fm	1.287	1.25	1.475	1.47	1.14
A_I fm	0.8	0.562	0.261	0.591	0.638
USP MeV	13.95	8.671	16.65	8.45	8.76
WSP MeV	0	0	0	2.341	0
RSP fm	0.493	0.631	0.75	0.589	0.511
ASP fm	0.36	0.019	0.36	0.335	0.362
R_C fm	1.25	1.25	1.25	1.25	1.25
chi^2	7.05	6.55	4.43	4.24	0.86
J_I	110.8	122.7	142.4	417.5	396.5
$J_{S.O}$	33.4	26.78	59.9	23.98	21.7
σ_R mb	419	412.2	363.4	303.2	244.4
σ_{exp} mb	412.2±10		370.0±10	342	293.0±12
J_R/V_R	16.92	16.91	16.91	16.9	16.92

Table 6: The same parameters in Table [5] at energies E=69.5 to 494 MeV, these experimental values are taken from Refs.[29, 30].

E MeV	69.5	79.8	83.8	96	122
V_R MeV	24.359	22.656	17.1699	21.332	18.494
W_S MeV	10.04	9.394	0	9.215	12.666
W_D MeV	0	0	6.734	0	0
R_I fm	1.493	1.493	1.25	1.434	1.216
A_I fm	0.367	0.367	0.487	0.365	0.532
USP MeV	9.553	7.731	8.555	6.303	2.333
WSP MeV	0	0	0	0	-2.454
RSP fm	0.864	0.869	1.024	0.835	0.944
ASP fm	0.512	0.464	0.554	0.37	0.473
$R_C fm$	1.25	1.25	1.25	1.25	1.51
χ^2	0.609	0.723	0.861	5.87	15.69
J_I	155.89	145.85	123.36	127.79	129.89
$J_{S.O}$	39.74	32.27	42.1	25.23	10.57
σ_R mb	323.8	293.6	269.7	245.8	218
σ_{exp} mb				232.5	
J_R/V_R	16.91	16.91	16.91	16.91	16.92
E MeV	156	182.8	250	300	494
V_R MeV	14.71	11.683	11.115	15.23	17.595
W_S MeV	10.04	14.385	21.682	12.506	23.045
W_D MeV	0	0	0	0	0
R_I fm	1.36	1.21	1.134	1.265	1.25
A_I fm	0.46	0.485	0.483	0.264	0.307
USP MeV	4.229	3.056	2.708	0.899	0.662
WSP MeV	0	0	-2.299	-2.667	0
RSP fm	0.93	0.93	0.914	0.953	1.073
ASP fm	0.492	0.429	0.463	0.471	0.202
R_C fm	1.51	1.51	1.51	1.51	1.51
χ^2	3.73	2.92	2.25	1.03	2.22
J_I	128.83	139.27	177.95	114.86	210.25
$J_{S.O}$	18.85	13.62	11.88	4.11	3.4
σ_R mb	203.5	195	195.8	124.2	171.5
σ_{exp} mb	220				
J_R/V_R	16.89	16.91	16.88	16.9	16.9

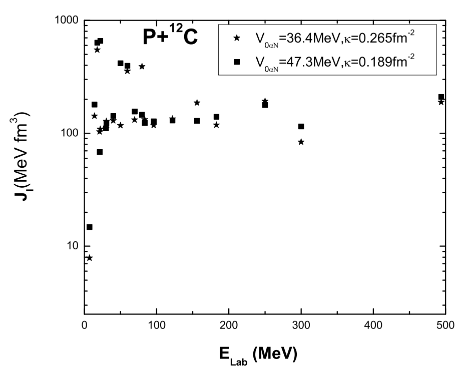

Fig. 5: The Energy dependence of the Imaginary Volume Integral of the depth 36.4 MeV and 47.3 MeV.

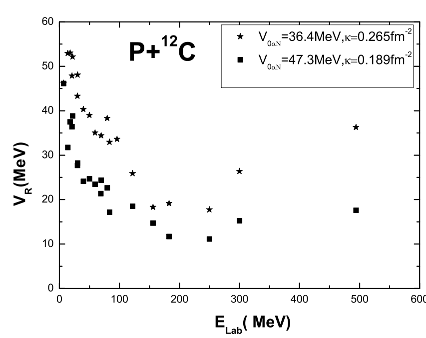

Fig. 6: The Energy dependence of the real depths of the SFC optical potential.

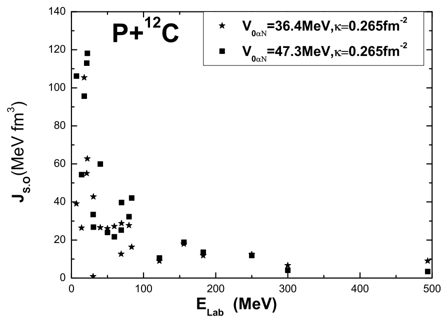

Fig. 7: The Energy dependence of the spin-orbit volume integral of the SFC optical potential.

analysis was based on folding the cluster density distribution with the α-N effective interaction. We used two values of the depth of the α-N effective interaction as follows: 36.4 MeV with a range of 0.265 fm^{-2}, and 47.3 MeV with a range of 0.189 fm^{-2}. From these results, we notice that when the α-N effective interaction increased by 30% from 36.4 MeV to 47.3 MeV, and the range decreased by 20% from 0,265 fm^{-2} to 0.189 fm^{-2}, each of the two values of the depth of the effective α-N interaction gave a good agreement with the experimental data. The predictions were successful similar to or some time better than those obtained by previous phenomenological and microscopic potential analyses. In addition, each of the two values of the depth gives a good agreement with the experimental data; and the resulted differential cross-sections are similar to or some time better than those obtained by previous works for all energies each of the reactions $P+^{12}C$.

References

[1] G.R. Satchler, Direct Nuclear Reactions, Oxford Univ. Press, Oxford, 1983.

[2] M.A. Allam, microscopic optical potential for $P+^{12}C$ elastic scattering at intermediate energies, IJRRAS. 2012.

[3] D.Abriola, F.A.Gunbich, M.Kokkoris, A.Lagoyannis and V.Paneta,Proton elastic scattering differential cross-sections for ^{12}C, Nuclear Instruments and Methods in Physics Research B 269 (2011).

[4] M. El-Azab Farid, Z. M. M. Mahmoud, and G. S. Hassan, Nucl. Phys. A691 (2001), 671; Phys. Rev. C 64 (2001), 014310.

[5] M. El-Azab Farid, Phys. Rev. C 65 (2002), 067303; 74 (2006), 064616.

[6] M. Karakoc and I. Boztosun, Phys. Rev. C 73, 047601 (2006); Int. J. Mod. Phys. E 15 (2006), 1317.

[7] F.E. Bertrand, G.R. Satchler, D.J. Horen, J.R. Wu, A.D. Bacher, G.T. Emery, W.P. Jones, D.W.Miller, A. van der Woude, Phys. Rev. C 22 (1980), 1832.

[8] S. Sack, L. C. Biedenharn, and G. Breit, Phys. Rev. 93 (1954), 321.

[9] G. R. Satchler and W. G. Love, Phys. Rep. 55 (1979), 183.

[10] M. El-Azab Farid, Z. M. M. Mahmoud, and G. S. Hassan, Nucl.Phys. A691 (2001), 671; Phys. Rev. C 64 (2001), 014310.

[11] M. E. Kurkcuoglu, H. Aytekin, and I. Boztosun, Mod. Phys.Lett. A 21 (2006) , 2217.

[12] L.D. Rickertsen, 1978, unpublished.

[13] N.M. Clarke, University of Birmingham, 1994, unpublished.

[14] L. Sydow, S . Vohl, S. Lemaitre, P. Nieben, K.R. Nyga, R. Reckenfelderbumer, G. Rauprich and H. Paetz gen. Schieck, Nuclear Instruments and Methods in Physics Research .A327 (1993) 441-455.

[15] W. Peelle,Phys.Rev,105 (1957), 1311.

[16] I.E.Dayton and G.Schrank,Phys.Rev, 101 (1956), 1358.

[17] M.Ieiri, H.Sakaguchi, M.Nakamura, H.Sakamoto, H.Ogawa, M.Yosoi, T.Ichihara, N.Isshiki, Y.Takeuchi, H.Togawa, T.Tsutsumi, S.Hirata, T.Nakano, S.Kobayashi, T.Noro and H.Ikegami, Nucl.Phys.A257 (1987), 235.

[18] An Zhu, Chen Quan, Cheng Ye-Hao, Shen Dong-Jun and Guo Gang,Chin.Phys.Lett.20 (2003), 478.

[19] B.W.Ridley and J.F.Turner, Nucl.Phys.58(1964),497.

[20] P.D.Greaves,V.Hnizdo,J.Lowe and O.Karban,Nucl.Phys.A179 (1972) ,1-22.

[21] J.A.Fannon, E.J.Burge, D.A.Smith and N.K.Ganguly, Nucl.Phys.A97(1967),263.

[22] G.Gerstein, J.Niderer and K.Strauch,Phys.Rev. 108(1957),427.

[23] H.O.Merer,P.Schwandt,W.W.Jacobs and J.R.Hall,Phys.Rev.C27 (1983) ,459.

[24] V.Compart,R.Frascaria,N.Marty,M.Morty and A.Willis, Nucl.Phys.A221(1974),403.

[25] A.Johansson,U.Svanberg,P.E.Hodgson, Arkiv Fysik.19(1961),541.

[26] H. O. Meyer, P. Schwandt, R. Abegg, C. A. Miller, K. P. Jackson, S. Yen, G. Gaillard, M. Hugi, R. Helmer, D. Frekers, and A. Saxena,Phys.Rev.C37 (1988) ,544.

[27] A. Okamoto, T. Yamagata, H. Akimune, M. Fujiwara, K. Fushimi, M. B. Greenfield, K. Hara, K. Y. Hara, H. Hashimoto, R. Hayami, K. Kawase, M. Kinoshita, K. Nakanishi, S. Nakayama, M. Tanaka, H. Utsunomiya, N. Warashina, and M. Yosoi ,Phys.Rev.C81 (2010) ,054604.

[28] G. W. Hoffmann, M. L. Barlett, D. Ciskowski, G. Pauletta, M. Purcell, L. Ray, J. F. Amann, J. J. Jarmer, K. W. Jones, S. Penttil*ä*, N. Tanaka, M. M. Gazzaly, J. R. Comfort, B. C. Clark, and S. Hama, ,Phys.Rev.C41 (1990) ,1651.

[29] I.Abdul-Jalil and D.F.Jackson, J.Phys.G5 (1979), 1699.

[30] R.M.Devries and J.C.Peng,Phys.Rev.Lett.43 (1979), 1373.