Studies on Elastic Scattering of ^{6}Li + ^{40}Ca Using BDM3Y-Paris and Wood-Saxon Potential

Presented by- Harun Al Rashid (*Dept. of Physics, Gauhati University, Assam-781014*)

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Introduction

- Study of elastic scattering is an important part to understand peripheral heavy ion (HI) interaction. Any nuclear interaction involves nuclear potential along with Coulomb potential and the choice of the nuclear potential reveals a wide variety of phenomenon subjected to the fitting percentage with the experimental data.
- Highly celebrated optical model (OM) formalism allows us to play with different kind of potentials such as Wood-Saxon (WS), Folding, Proximity etc. In WS formalism at least six parameters are varied in order to regenerate experimental cross-section data.
- Any HI interaction can be dissected by considering the aspects such as beam energy, charge, mass etc., however more satisfactory understanding is more probabilistic using nucleon-nucleon (NN) interaction potential.
- To construct nucleus-nucleus potential, integration is carried out over a NN potential over the whole mass distribution of colliding partners. This approach is known as folding and this method has been widely used to generate real part of the OM potential.
- M3Y is a popular choice of NN interaction potentials which generates G matrix elements for the two different forms known as Paris and Reid. Double Folding (DF) approach reduces the number of free parameters as compared to WS approach.
- In this paper we have analyzed elastic cross section of the reaction **^{6}Li+^{40}Ca** at energies **20 MeV, 26 MeV, 28 MeV, 30 MeV, 32 MeV and 34 MeV.**
- Finally OM parameters are extracted.

Theory

- The nuclei ^{6}Li and ^{40}Ca are assumed to be interact via a potential which is consists of nuclear and Coulomb potentials as $V_{total}(r) = V_{Nuc}(r) + V_{Coul}(r)$

- Coulomb potential is

$$V_{Coul}(r) = \begin{cases} \frac{1}{4\pi\varepsilon_0}\frac{Z_P Z_T e^2}{r}, r \geq R_C \\ \frac{1}{4\pi\varepsilon_0}\frac{Z_P Z_T e^2}{2R_C}(3 - \frac{r^2}{R_C^2}), r \leq R_C \end{cases}$$

- Nuclear DF potential has the form $V_F(r) = \iint \rho_1(r_1)\rho_2(r_2)v_{NN}(r - r_1 + r_2)d^3r_1 d^3r_2$

- Popular choice of DF potential is **M3Y-Paris**. $v_{NN}(r) = \left(11062\frac{e^{-4r}}{4r} - 2538\frac{e^{-2.5r}}{2.5r}\right)MeV$

- The density distribution has the following **BDM3Y** form $f(\rho) = C\left(1 - \gamma\rho^{\lambda}\right)$
- where C=1.2521 and γ=1.7452.
- The WS volume form of potential is given as $V_N(r) = \frac{-V_0}{1 + \exp(\frac{r - R_{0R}}{a_R})} + i\frac{-W_0}{1 + \exp(\frac{r - R_{0I}}{a_I})}$

Methodology

- Nuclear potentials are constructed by considering the potential as:

  M3Y Paris(Real)+WS Volume(Imaginary):Approach-1

  WS Volume(Real)+WS Volume(Imaginary):Approach-2
- Experimental data for elastic scattering of $^{6}Li+^{40}Ca$ are taken from various papers available at website: *https: nrv.jinr.ru*. Also theoretical analysis are carried out using the online code available at this website for the above two approaches.
- The online interface allows to select different potentials as well as OM parameters for regeneration of data.
- Experimental elastic cross section for $^{6}Li+^{40}Ca$ at energies 20 MeV, 26 MeV, 28 MeV, 30 MeV, 32 MeV and 34 MeV are compared with theoretical data.
- In the Approach-1, real normalization parameter (N_R) of M3Y-Paris potential is varied along with imaginary depth (V_0) of WS potential along with the radius parameter(r_0) and diffuseness parameter(a_0). In Approach-2, real and imaginary depths are varied.
- The extracted OM parameters are as shown below in the Tables.

Energy (MeV)	N_R	W_0 (MeV)	r_{0I} (fm)	a_{0I} (fm)
20	**1.45**	**30**	**1.1**	**0.65**
26	1.36	39	1.1	0.65
28	1.35	40	1.1	0.65
30	1.30	43	1.1	0.65
32	1.28	48.1	1.1	0.65
34	**1.25**	**50**	**1.1**	**0.65**

Approach-1

Energy (MeV)	V_0 (MeV)	r_{0R} (fm)	a_{0R} (fm)	W_0 (MeV)	r_{0I} (fm)	a_{0I} (fm)
20	**123**	**1.1**	**0.63**	**35**	**1.1**	**0.63**
26	110	1.1	0.63	40	1.1	0.63
28	108	1.1	0.63	42	1.1	0.63
30	107.5	1.1	0.63	44	1.1	0.63
32	107	1.1	0.63	45	1.1	0.63
34	105.5	1.1	0.63	46.24	1.1	0.63

Approach-2

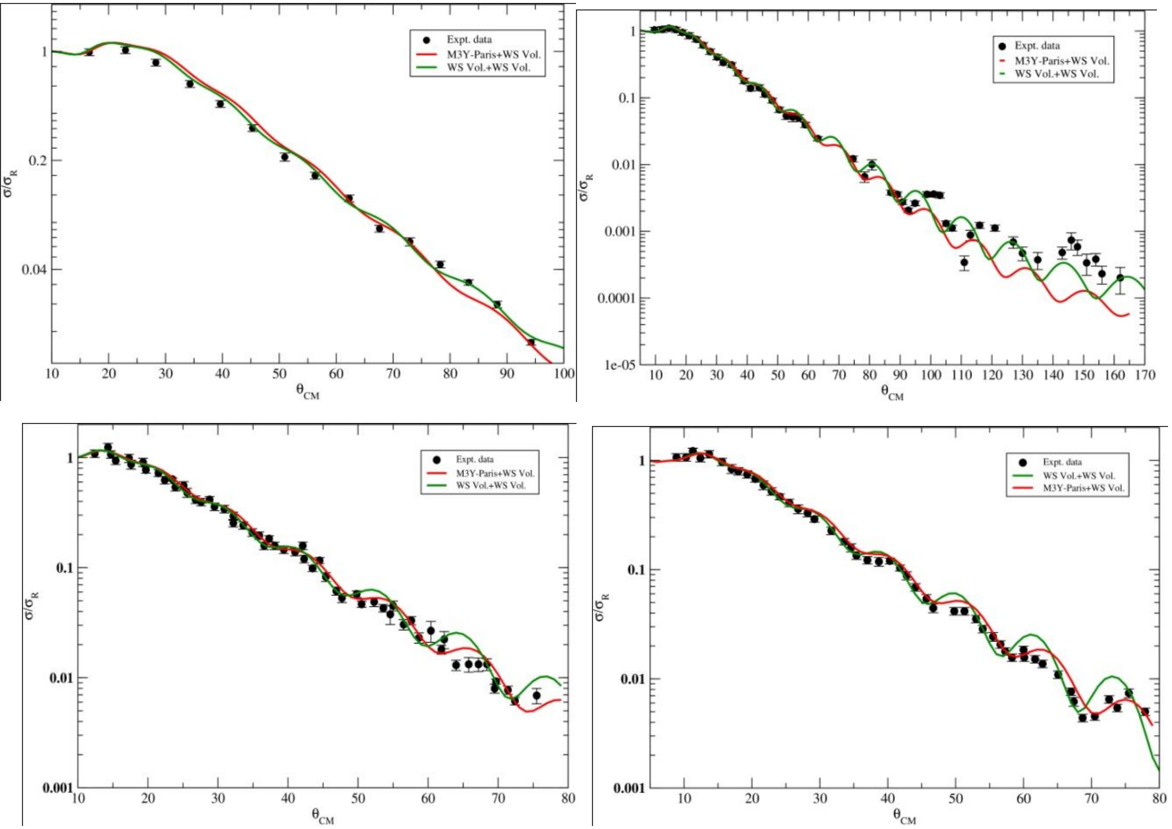

Fig: Angular distribution of elastic scattering of ^{6}Li + ^{40}Ca at energies 20 MeV (top left), 26 MeV (top right), 28 MeV (bottom left) and 30 MeV(bottom left).

Conclusion

- Normalization factor decreases with increase of beam energy.
- In the second approach real depth is found to be around 110 MeV whereas imaginary depth decreases gradually with increase of beam energy.
- In the first approach, radius parameter is fixed around 1 fm whereas diffuseness parameter has variation around 0.65 fm.
- Global potential by J. Cook can be used to fit data for energies 28 MeV and 30 MeV.
- OM parameters are extracted as given in the Tables.
- Correlation between normalization parameter (NR) with incident energy (Elab) is concluded in the form of an equation:

$$N_R = -0.014E_{Lab} + 1.74$$

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