Optical Potential Parameterization in High Energy Region

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The optical potentials by Maruyama are reparameterized by new parameters. These potentials are appropriate to reproduce the total cross sections for neutron incidence with the energies in the GeV region.

1. Introduction

Some amounts of proton incident data have been published on elastic-scattering and total reaction cross sections up to 1 GeV of incident proton energies. Such results as well as experimental data obtained by polarized proton beams are useful for parameterizing global optical model potentials. However, the experimental data are poor above 1 GeV. For the neutron incidence with energies up to 1 GeV, Maruyama et al. derived the optical potentials by converting the proton incidence potentials by the use of the symmetry term that is dependent on (N-Z)/A [2]. However It is complicated to obtain the values of potentials requiring since the number of parameters is as many as about 170.

Recently the nuclear data for the energies in the GeV region are required for the engineering purposes. The High Energy Transport Code (HETC) based on the intranuclear cascade evaporation (INCE) model is used to the engineering design. The INCE model appropriately represents the neutron production double differential cross sections. However, the INCE models poorly reproduces total cross sections and the elastic scattering cross sections for the nucleon-incidence in the forward direction.

The total cross sections and the elastic scattering cross section are calculated by the optical model. To simplify the calculation of the optical potentials, the potentials by Maruyama are reparameterized by new parameter set. These potentials are appropriate to reproduce the total cross sections for neutron incidence with the energies in the GeV region.

2. Calculation model

In this work, 4-vector potential U_V and Lorentz scalar potential U_S are adopted as the phenomenological optical potentials.

$$\begin{aligned} U_V(r) &= V_V(E_{inc}, A) f_{VV}(r) + i W_V(E_{inc}, A) f_{WV}(r) \\ U_S(r) &= V_S(E_{inc}, A) f_{VS}(r) + i W_S(E_{inc}, A) f_{WS}(r) \\ f_i(r) &= \frac{1}{1+\exp(-\frac{r-r_{0i}}{a_i})} \\ & \quad i = VV, WV, VS, WS \quad . \end{aligned}$$

To simplify the calculation, Dirac equation is converted to Shrödinger form as follows,

$$[p^2 + 2E(U_{cent} + U_{so}\vec{\sigma}\cdot\vec{L})]\Phi(r) = [(E-V_c)^2 - m]\Phi(r)$$

where p is momentum, m mass, E total energy, $\vec{\sigma}$ spin, $\vec{L}$ orbital momentum, V_c coulomb potential. Central and spin orbit potentials U_{cent}, and U_{so} are represented as,

$$\begin{aligned} U_{cent} &= \frac{1}{2E}(2EU_V + 2mU_S - U_V^2 + U_S^2 - 2V_cU_V + 2EU_{Darwin}) \\ U_{so} &= -\frac{1}{2EBr}\frac{\partial B}{\partial r} \quad . \end{aligned}$$

Darwin and B terms are

$$\begin{aligned} U_{Darwin} &= -\frac{1}{2}\frac{1}{Br^2}(\frac{\partial}{\partial r}r^2 - \frac{\partial}{\partial r}B) + \frac{3}{4}\frac{1}{B}(\frac{\partial}{\partial r}B) \\ B &= \frac{E + m + U_S - U_V - V_c}{E + m} \quad . \end{aligned}$$

Maruyama et al [2]. obtained the values of V_V, W_V, V_S and W_S by modifying the potentials parametrized by Cooper [1]. The potentials by Cooper is made of about 170 parameters. to simplify the parametrization, V_V, W_V, V_S and W_S are reparameterized as follows.

$$\begin{aligned} V_S &= (7.256 \times 10^{-10}A - 2.124 \times 10^{-7})[E_{inc}^{3/2} - (-44.06A + 2.919 \times 10^4)]^2 - 0.2327A - 256.9 \\ r_{0VS} &= (1.065 - 2.924 \times 10^{-5}E_{inc})A^{1/3} \\ a_{VS} &= 0.5930 + 1.72625 \times 10^{-4}E_{inc} \end{aligned}$$

$$\begin{aligned} W_S &= -32.7A^{1/6}(\log E_{inc} - 5.496)^2 + 62.28A^{1/7} \\ r_{0WS} &= (1.144 - 1.279 \times 10^{-4}E_{inc})A^{1/3} \\ a_{WS} &= 0.5823 + 2.081 \times 10^{-4}E_{inc} \end{aligned}$$

$$\begin{aligned} V_V &= (-8.12 \times 10^{-9}A + 3.3684 \times 10^{-6})E_{inc}^{1.3} - (5.963A - 7737)^2 + 0.1447A + 155.5 \\ r_{0VV} &= (1.075 - 4.4 \times 10^{-5}E_{inc})A^{1/3} \\ a_{VV} &= 0.5748 + 1.321 \times 10^{-4}E_{inc} \end{aligned}$$

$$\begin{aligned} W_V &= 13.62A^{1/6.5}(\log E_{inc} - 5.685)^2 - 57.9A^{1/8} \\ r_{0WV} &= (1.154 - 1.237 \times 10^{-4}E_{inc})A^{1/3} \\ a_{WV} &= 0.6554 - 2.396 \times 10^{-5}E_{inc} \end{aligned}$$

3. Results

Figures 1 to 4 stand for the optical potentials V_V, W_V, V_S and W_S, respectively. In these figures crosses is the values from Reference [2] and solid lines the results by this parameter set. One can see that the potentials by this parameter sets are represent the values from Ref.[2] for the incident neutron energies up to 1000 MeV.

Fig. 5 shows the 4-vector and Lorentz scalar potentials in the case of 500 MeV neutron incident on ^{208}Pb target. In this figure, dashed lines with cross are the values from Ref. [2] and the solid lines the results by this parameter set.

Figs. 6 and 7 indicates the total cross sections for the neutron incidence on ^{27}Al, ^{40}Ca, ^{56}Fe, ^{63}Cu, ^{90}Zr, ^{93}Nb, ^{181}Ta, ^{208}Pb, ^{209}Bi and ^{238}U targets. In these figures, closed circles, cross marks and solid lines stand for the experimental values [3], the values from Ref. [2] and the results by this parameter set, respectively. The optical potentials by this parameter set reproduce the experimental values in the incident neutron energy up to 1000 MeV.

4. Summary

To simplify the calculation of the total cross section by he optical potentials, the parameter set by Maruyama is reparameterized by new parameters. the reparameterized potentials are appropriate to reproduce the total cross sections for neutron incidence with the energies in the GeV region.

References

[1] Cooper, E.D., *et al.*: *Phys. Rev.*, **C47**, 297 (1993).

[2] Maruyama, S., *et al.*: *Proc. Int. Conf. Nuclear Data for Science and Technology*, 336, Trieste (1998), and their in.

[3] OECD/NEA Data Bank <http://www.nea.fr/html/databank >

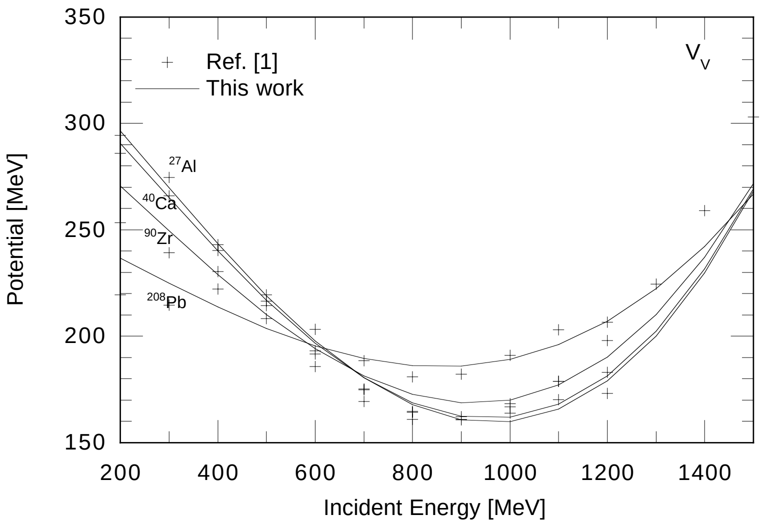

Fig. 1: V_V for neutron incidence on ^{27}Al, ^{40}Ca, ^{90}Zr and ^{208}Pb targets.

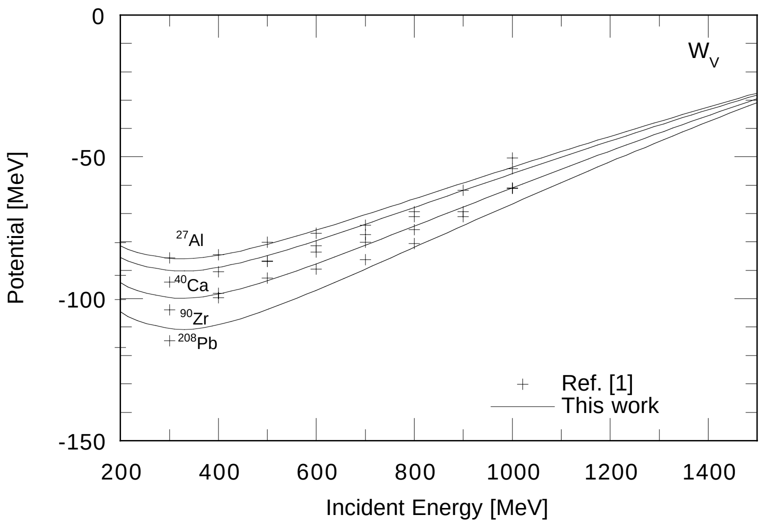

Fig. 2: W_V for neutron incidence on ^{27}Al, ^{40}Ca, ^{90}Zr and ^{208}Pb targets.

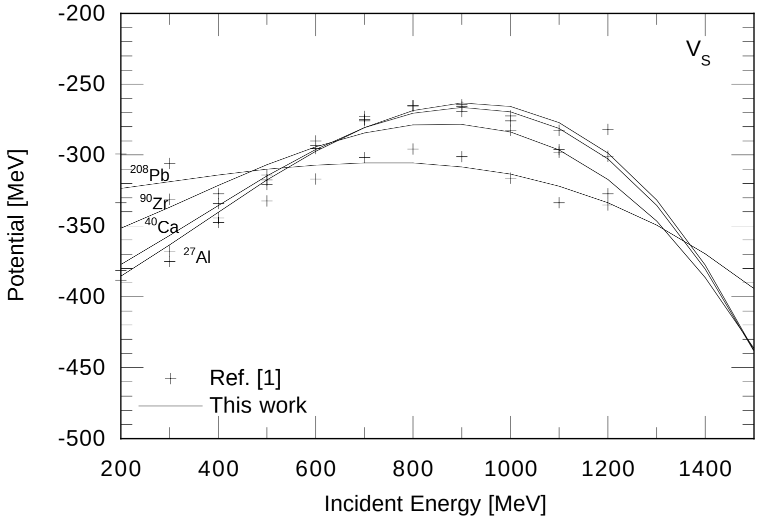

Fig. 3: V_S for neutron incidence on ^{27}Al, ^{40}Ca, ^{90}Zr and ^{208}Pb targets.

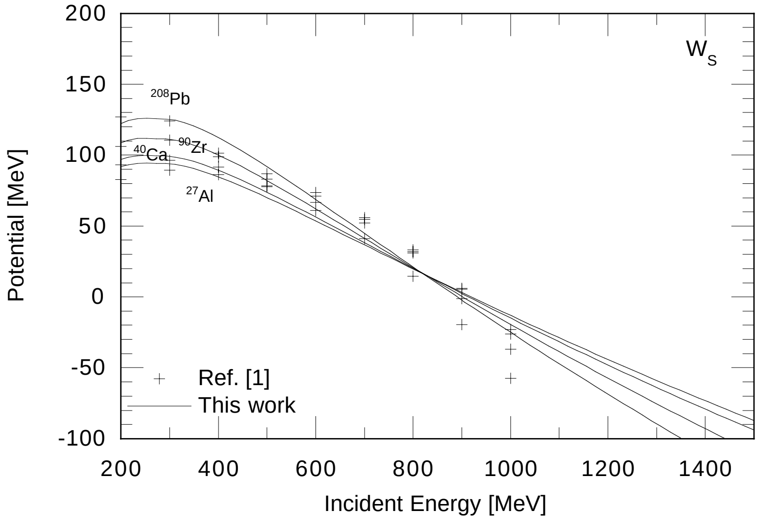

Fig. 4: W_V for neutron incidence on ^{27}Al, ^{40}Ca, ^{90}Zr and ^{208}Pb targets.

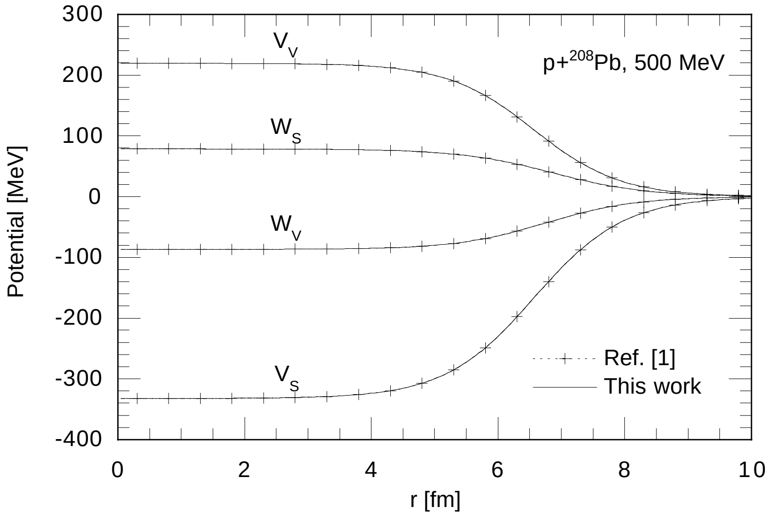

Fig. 5: The scalar and vector potentials for 500 MeV neutron incidence on ^{208}Pb target.

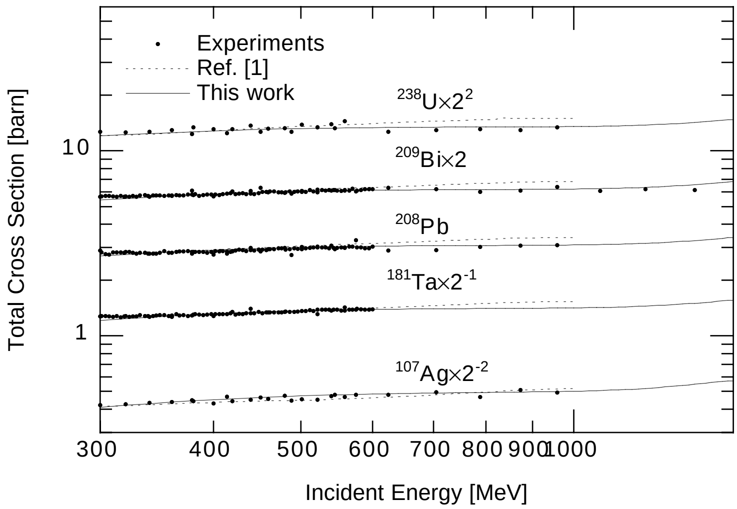

Fig. 6: Neutron incident total cross sections.

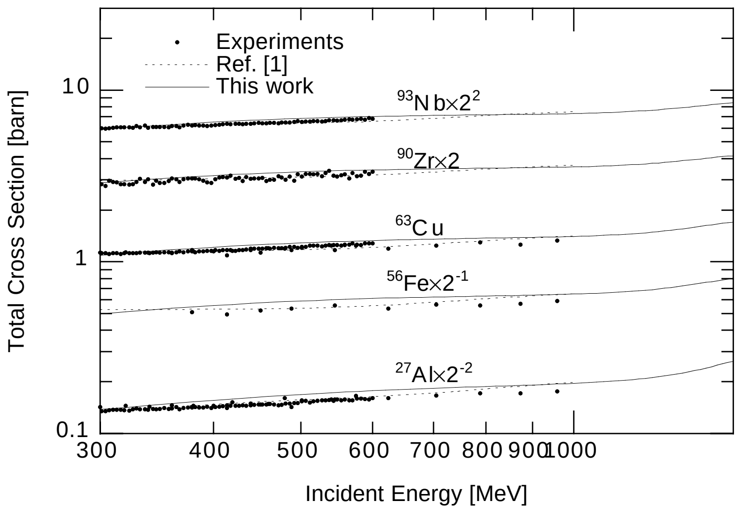

Fig. 7: Neutron incident total cross sections.

日本語表題

高エネルギー領域における光学ポテンシャルのパラメータ化

著者名

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