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65 MeV Polarized Proton Elastic Scattering and the shape of the optical potential

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Elastic scattering of 65 MeV polarized protons from ^{12}C, ^{24}Mg, ^{28}Si, ^{40}Ca, ^{58}Ni, ^{90}Zr and ^{208}Pb was measured at Research Center for Nuclear Physics of Osaka University. Analyzing powers and cross sections were measured at the angle region between 12 deg. and 160 deg. In Fig. 1 measured data for ^{40}Ca are shown. The analysis using the conventional Woods-Saxon type optical potential was not effective for the backward scattering data larger than 100 deg. So the automatic search code ECIS79 was modified to include the Fourier-Bessel (F-B) type potential in addition to the Woods-Saxon type potential. The form of the potential used is as follows

$$V(r) = -V_R f(r;r_R,a_R)+\sum_{j=1}^{14} a_j \frac{\sin(j\pi r/R_c)}{j\pi r/R_c} \qquad f(r;r_o,a_o) = \frac{1}{1+exp((r-r_o)/a_o)}$$

$$W(r) = -iW_v f(r;r_{W_v},a_{W_v})+4a_{W_s}W_s i\frac{d}{dr}f(r;r_{W_s},a_{W_s})+i\sum_{j=1}^{14} b_j \frac{\sin(j\pi r/R_c)}{j\pi r/R_c}$$

$$V_{ls}(r) = -(\frac{h}{m_\pi c})^2 (V_{ls}\frac{1}{r}\frac{d}{dr}f(r;r_{ls},a_{ls})+\sum_{j=1}^{14} c_j \frac{\sin(j\pi r/R_c)}{j\pi r/R_c})$$

Calculations using the above potential is shown as solid curves in Fig. 1. The potential shape obtained is shown as solid curves in Fig. 2. The broken curves in the same figure are microscopically derived potentials using the energy dependent three range effective nucleon-nucleon interaction derived from Hamada-Johnston potential using nuclear matter theory by S. Nagata and N. Yamaguchi[1].

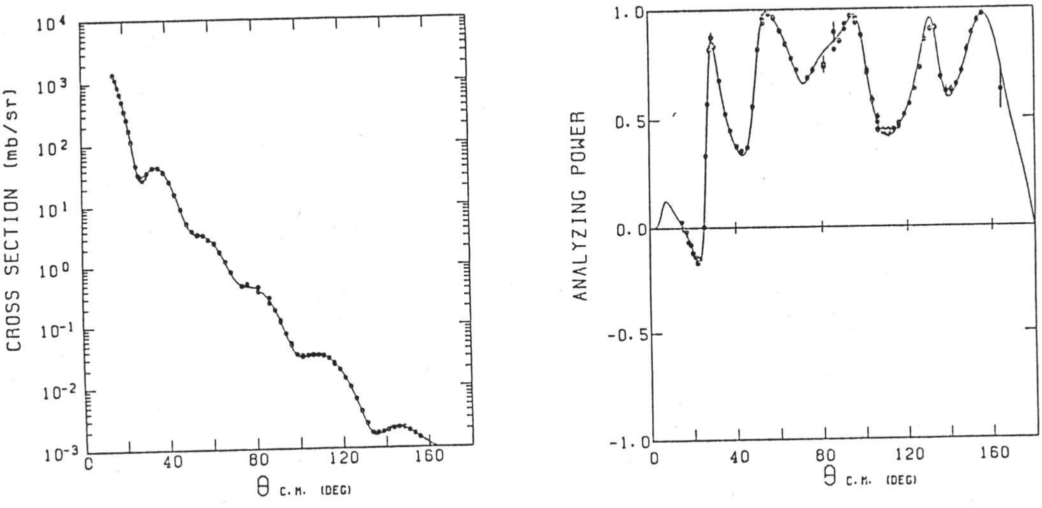

Fig. 1 ^{40}Ca(p,p)^{40}Ca cross sections and analyzing powers. Solid curves are Fourier-Bessel type optical potential calculations.

With the use of F-B potential,[2] the ambiguity region of the optical potential was derived directly from the scattering. Monte-Carlo calculation method was used to obtain the region, since the correlation among the F-B coefficients is too strong to deduce it by the usual error correlation matrix method. For the Monte-Carlo calculation we used following trial potentials $V^M=V+S\delta V$, $W^M=W+S\delta W$, $V^M_{1s}=V_{1s}+S\delta V_{1s}$.

$$\delta V_R = \sum_{j=1}^{14}\delta a_j\ h_j\frac{\sin(j\pi r/R_c)}{j\pi r/R_c} \qquad \delta W = \sum_{j=1}^{14}\delta b_j\ k_j\frac{\sin(j\pi r/R_c)}{j\pi r/R_c} \qquad \delta V_{ls} = \sum_{j=1}^{14}\delta c_j\ g_j\frac{\sin(j\pi r/R_c)}{j\pi r/R_c}$$

where h_j, k_j, g_j are random numbers between -1 and 1 and each δa_j, δk_j, δc_j are defined so as to give $|\chi^2(0,\cdots,0,\delta a_j,0\cdots)-\chi^2_{min}|=(N-F)$ for a_j for example. For one trial, the error potentials V^M, W^M, V^M_{1s} are fixed by selecting the 14×3 random numbers h_j, k_j, g_j and then by choosing the scaling value S[3] so as to give $|\chi^2(S)-\chi^2_{min}|=(N-F)$. For a given point r, a maximum value and a minimum value of V^M's, W^M's, V^M_{1s}'s for the whole trials define the uncertainty regions of the potential. In Fig. 3 the \\\\ shaded area shows the potential uncertainty for the data (θ_{Lab}<160°), while the //// shaded area indicates the region of uncertainty for the scattering data (θ_{Lab}<80°) each for 50,000 trials. Also uncertainties of the volume integral of the potential (J_R) and the mean square radius of the potential (MSR) are $J_R/A=-325.3^{+7.9}_{-9.7}$ and $\langle r^2\rangle_{pot}=18.0\pm0.70$ for ^{40}Ca. The phenomenological optical potential shows marked difference from the theoretical curve at the nuclear centeral region.

References

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3) L. Ray, W.R. Coker and G.W. Hoffman, Phys. Rev. C18 (1978) 2641.

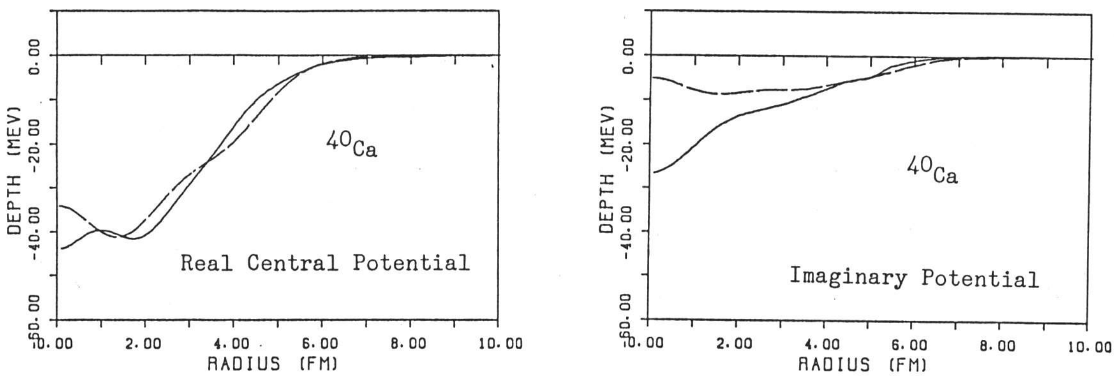

Fig. 2 Fourier-Bessel type potential (solid curve) and the microscopically derived potential (dashed curve) for ^{40}Ca.

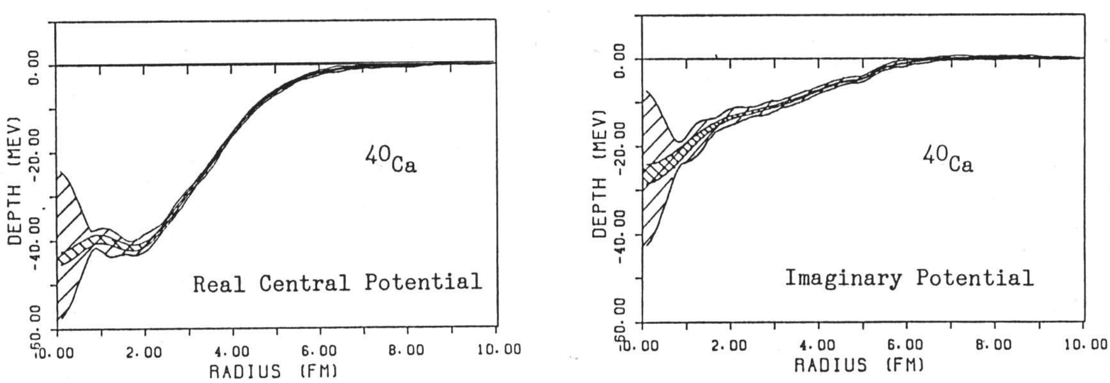

Fig. 3 Optical potential uncertainty region. The //// area shows the calculation for the data (θ_{Lab}<80°) and the \\\\ area for the data (θ_{lab}<160°).