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Measurement of the Spin Rotation Parameter for Proton-Nucleus Elastic Scattering at 65 MeV

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The spin rotation parameters (R of Wolfenstein[1]) have been measured for 65 MeV proton elastic scattering with use of the polarization spectrograph DUMAS[2], the newly developed high efficiency polarimeter MUSASHI[3], and the spin precession superconducting magnet. These measurements, in conjunction with our previous data[4] of the differential cross sections (σ) and analyzing powers (A_y), make it possible to achieve a complete experiment for the proton-nucleus(spin-0) elastic scattering, i.e., the scattering amplitude can be uniquely determined except the overall phase.

The experiments were performed at RCNP using 65 MeV polarized protons. The intense polarized proton beam from AVF cyclotron, whose polarization axis is normal to the scattering plane, passes the superconducting solenoidal magnet at the entrance of the experimental course and its polarization axis is processed by just 90° . After passing through the solenoid, the beam polarization are continuously monitored. These transverse-horizontally polarized protons strike the prime target in a scattering chamber. The beam current of 500 nA and the 80% beam polarization were typically obtained. The scattered particles are analyzed their momenta on the first focal plane (FP1) of DUMAS and are again focused achromatically at the second focal point (FP2) where the polarimeter MUSASHI are placed. Non-elastically scattered particles are excluded by the tagging slits just in front of FP1 in order to obtain as many yields as possible within the allowed rate of the data acquisition. The elastic peak is monitored by the FP1 focal plane counter (MWPC) during the experiment. The polarimeter MUSASHI can measure the transeverse-horizontal components of the polarization of the scattered particle at the exit of DUMAS, using the large asymmetry of p-^{12}C elastic scattering. The detail of MUSASHI has been described elsewhere[3], and its efficiency and effective analyzing power for 65 MeV protons are about 1×10^{-4} and about 0.85 , respectively. These values are determined after the measurements of the cross sections and analyzing powers of p-^{12}C elastic scattering for the angular range 10° - 80° from 35 MeV to 84 MeV (about 5 MeV step). Owing to the magnetic field of the DUMAS, the component of the polarization in the scattering plane is precessed by an angle χ relative to the momentum direction as

$$\chi = \gamma(g/2-1)\alpha, \tag{1}$$

where γ is the Lorentz factor, $g/2$ is the proton magnetic moment and α is the bend angle(185° at the DUMAS). For 65 MeV protons, χ=354.6° , and so the directly measured observable (S) is very close to R but a small R' component is contained as

$$S = R\cos\chi + R'\sin\chi. \tag{2}$$

It is easy to derive R from S with A_y at the same angle. (But it is not unique and two possible values can be taken,) then, to compare with a model calculation, we have used the raw observable S.

Until now, the experiments were carried out for the targets of ^{40}Ca, ^{58}Ni, ^{90}Zr, ^{12}C, ^{208}Pb and ^{16}O from 16° to 80° , and ^{4}He from 45° to 100° . For ^{40}Ca, data were extended to 110° , recently. The R-parameters for ^{40}Ca are shown in Fig. 1. together with the cross sections and analyzing powers, and those for ^{58}Ni and ^{90}Zr are shown in Fig. 2. The other data are now in preparing. In Figs. 1. and 2., we have also plotted the curves derived from the conventional optical model analyses.

The calculations have been done by the code ECIS79 with the relativistic kinematics.

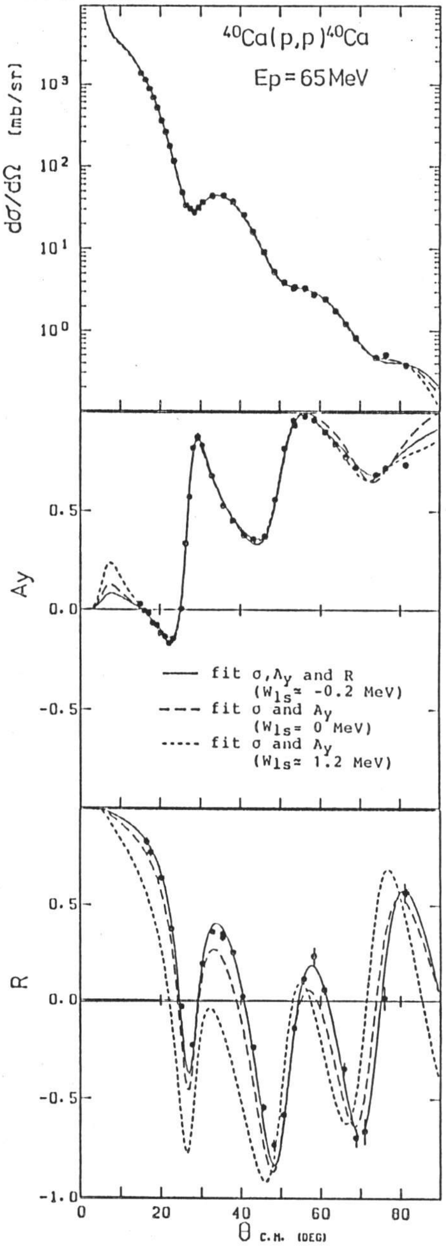

Fig. 1. Angular distributions of the cross sections, the analyzing powers and the spin rotation parameters (R) for ^{40}Ca at E_p=65MeV. The explanations of three curves are in the text.

So far, in this energy region, the imaginary spin-orbit potential has almost been neglected, because its effect was not so remarkable for the σ and the A_y data. However, as shown in Fig. 1., the difference between the dashed line (W_{ls} = 0 MeV) and dotted line (W_{ls} = 1.2 MeV), which are the results of the best fit potentials for the σ and the A_y in the case of not using the imaginary spin-orbit part and of using it respectively, is rather large in the R-parameters. The former explains the R data much better than the latter, although for the σ and the A_y the fit of the latter is slightly better. Thus, the spin rotation paramerters are found to provide the new and useful information and especially to be sensitive to the imaginary spin-orbit potential. The fit to the R data are very improved without sacrificing the fit to the σ and the A_y so much, if the potential is searched again containing also the R data. (see the solid line in Fig. 1.) In the case of ^{58}Ni and ^{90}Zr, the sensitivity of the R for W_{ls} is also seen (in Fig. 2.), but is not so distinct as in ^{40}Ca case. The solid lines are similar to that in ^{40}Ca, and the fits to the R are very good. (χ^2/point=1.1, 1.7 and 0.8 for ^{40}Ca, ^{58}Ni and ^{90}Zr, respectively.) In this energy region and in this angular range (15° - 80°), the conventional optical model with the Woods-Saxon form factors is found to be still applied sufficiently to the complete set of the observables in proton elastic scattering. Further analyses are now in progress.

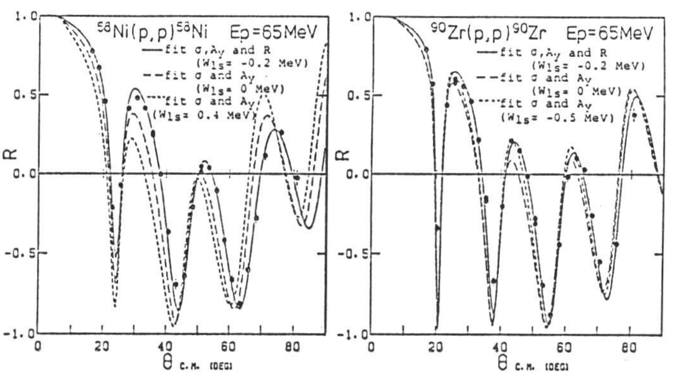

Fig. 2. Angular distributions of the spin rotation parameters (R) for ^{58}Ni and ^{90}Zr at E_p=65MeV. The curves are similar to those in Fig. 1.

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