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# POLARIZATION IN p-$He^4$ SCATTERING BETWEEN 27 AND 63 MeV*

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Using the polarized-proton facility at the Berkeley 88-inch cyclotron, we have measured the asymmetries in the elastic scattering of polarized protons from $^4$He at energies of 26.8, 34.2, 44.1, 54.8, and 63.3 MeV. These energies were selected so that experimental results would then be available at approximately 5-MeV intervals over the region 10 to 63 MeV, the latter being the maximum energy available at this facility. With the beam polarization $P_1$ known from experimental results, we then determined from the measured asymmetries $\epsilon(E,\theta)$ the polarizations $P(E,\theta) = \epsilon(E,\theta)/P_1$. A phase-shift analysis of these and other data available throughout this energy range has been started, and we report here preliminary results of this analysis.

Figure 1 shows our data along with those from the Rutherford Laboratory at 29, 40, and 48 MeV[1)] and 21-MeV data from Berkeley[2)]. The polarizations calculated from the phase-shift solutions are also shown. Available or interpolated differential cross-section data[3,4)] were included in the analysis at all energies, although such data at 66 MeV were limited to c.m. angles forward of 60°. The 55-MeV polarization results show a continuation of the trend established with the lower energy data, and they are in substantial disagreement with the polarization calculated by Kanada and Horikawa[5)] from phase shifts derived from analysis of 55-MeV differential cross section data[4)]. Their calculated $P(\theta)$ has three maxima, of values approximately +0.37, -0.77, and +0.93 near c.m. angles of 50, 95, and 125 degrees, respectively.

Figure 2 shows our preliminary phase-shift results. We use the notation $\eta_\ell^\pm \exp(2i\delta_\ell^\pm)$ for the (complex) amplitude of the outgoing $\ell^{th}$ partial

wave, so that $\eta_\ell^+$ ($\eta_\ell^-$) and $\delta_\ell^+$ ($\delta_\ell^-$), the absorption parameter and nuclear phase shift for the $j = \ell + 1/2$ ($j = \ell - 1/2$) state, are real. The smooth curves show the general energy dependence of the $\delta_\ell^\pm$, although the actual preliminary values show some scatter about these curves. Until further more complete searches are made, we do not ascribe physical significance to the slightly oscillatory behavior of $\delta_1^-$ and $\delta_2^-$ near and above 40 MeV. As is seen in the table listing the values of $\eta_\ell^\pm$, there are accompanying variations in these parameters in the same energy region. This behavior is not to be expected because all possible reaction thresholds occur at lower energies, and so a smoother behavior would be more plausible.

The arrows at 22.9 and 35.2 MeV in Fig. 2 mark the threshold for the first reaction channel, going to $d+{}^3He$, and the energy at which all channels are open, the last being the 3p+2n five-body channel. In this energy interval the absorption appears to be strongest in the $\ell = 2$ ($j = 5/2$) partial wave, with appreciable absorption also taking place in the $\ell = 1$ ($j = 1/2$) and $\ell = 3$ ($j = 7/2$) waves. We see no evidence of threshold effects, but data more closely spaced in energy would be required in order to study such questions.

We are grateful to A. W. Stetz for providing the computer program for phase-shift analysis and to W. F. Tivol for his considerable efforts in debugging and running the program.

## FOOTNOTES AND REFERENCES

*This work was performed under the auspices of the U. S. Atomic Energy Commission.

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## FIGURE CAPTIONS

Fig. 1. Polarization $P(\theta)$ in p-$^4$He elastic scattering. The dots are the experimental data (references in text). The curves represent values calculated in this analysis.

Fig. 2. Phase-shift parameters from preliminary analysis of the data. The symbols are defined in the text.

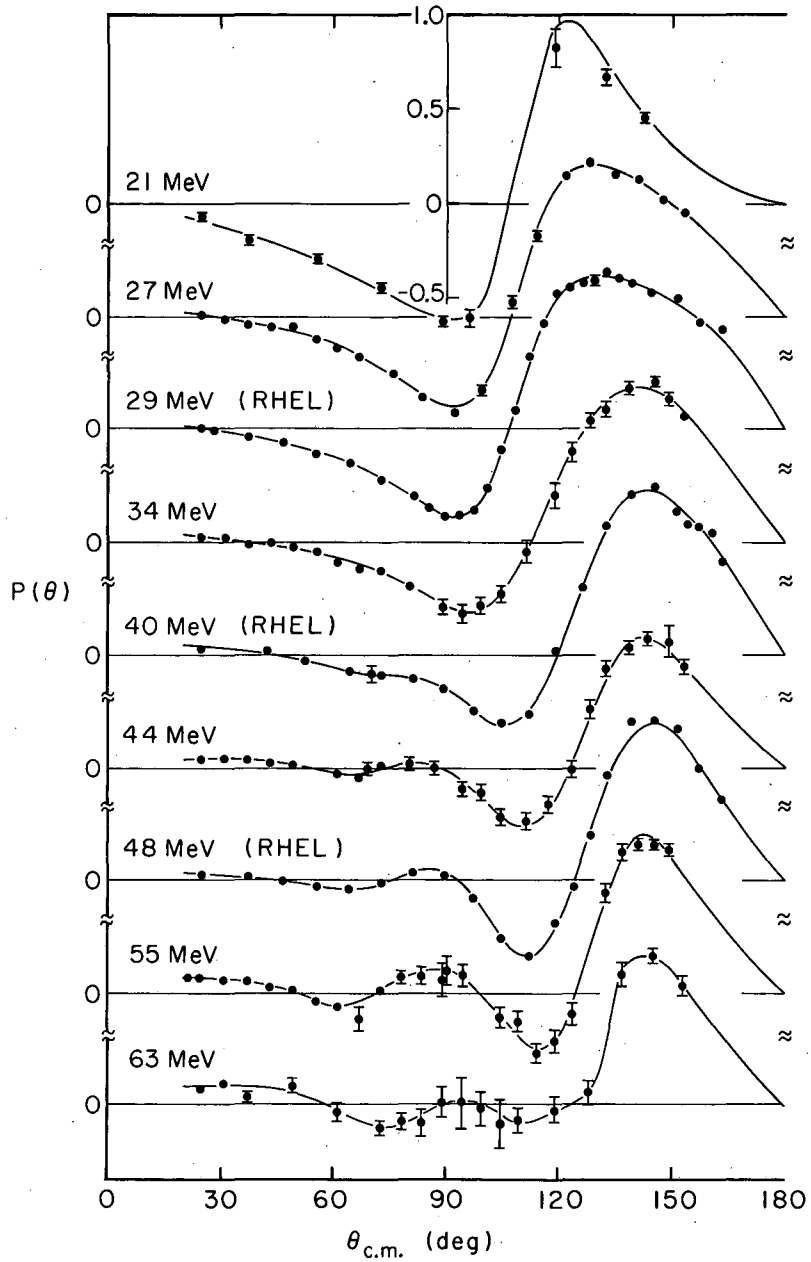


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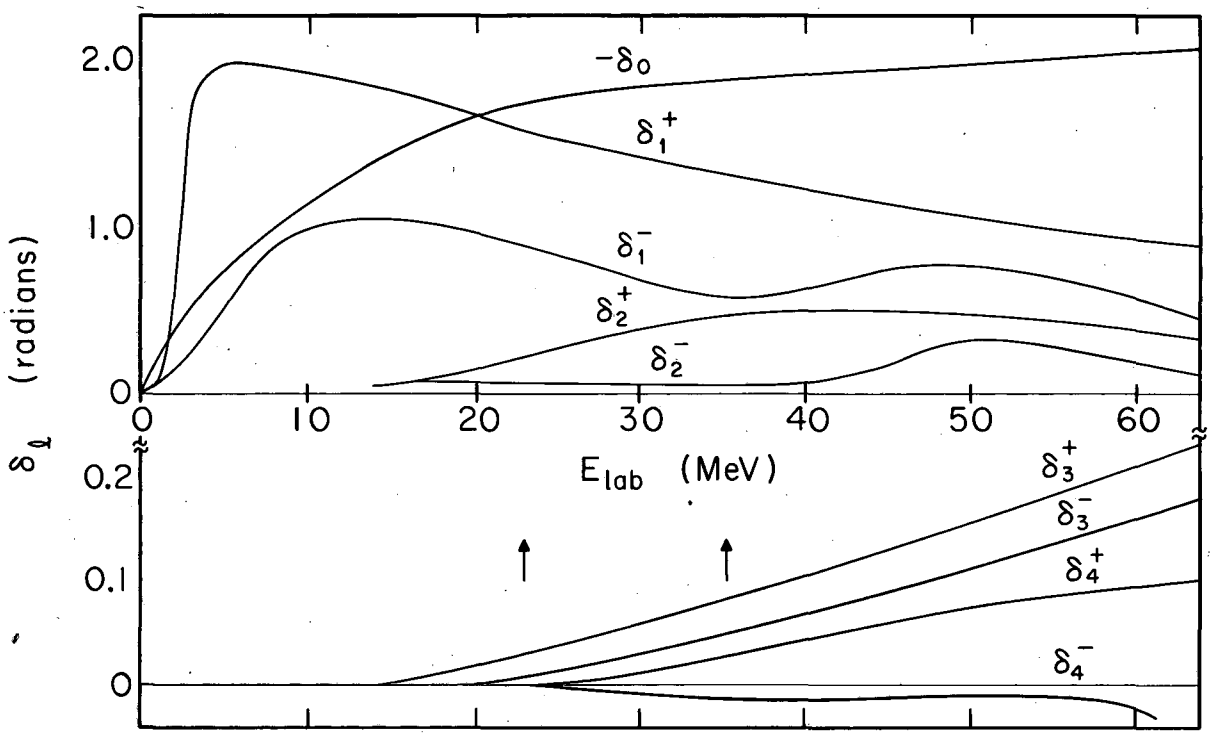
Fig. 1




Absorption parameters

| E (MeV) | 27 | 30 | 34 | 40 | 44 | 48 | 55 | 63 |
|---|---|---|---|---|---|---|---|---|
| $\eta_0$ | 1.00 | 1.00 | 1.00 | 0.92 | 0.99 | 0.94 | 1.00 | 0.96 |
| $\eta_1^+$ | 1.00 | 0.99 | 1.00 | 0.99 | 0.77 | 0.95 | 0.75 | 0.97 |
| $\eta_1^-$ | 0.92 | 0.94 | 0.97 | 0.90 | 0.84 | 0.92 | 0.84 | 0.81 |
| $\eta_2^+$ | 0.91 | 0.85 | 0.82 | 0.77 | 0.85 | 0.97 | 1.00 | 0.88 |
| $\eta_2^-$ | 1.00 | 1.00 | 1.00 | 0.80 | 0.78 | 0.85 | 0.86 | 0.92 |
| $\eta_3^+$ | 0.98 | 0.94 | 0.72 | 0.84 | 0.71 | 0.71 | 0.77 | 0.78 |
| $\eta_3^-$ | 1.00 | 1.00 | 0.97 | 0.92 | 0.83 | 0.92 | 0.85 | 0.67 |
| $\eta_4^+$ | 0.93 | 0.96 | 1.00 | 0.96 | 0.99 | 0.99 | 0.99 | 0.99 |
| $\eta_4^-$ | 1.00 | 0.98 | 0.98 | 1.00 | 0.89 | 0.93 | 0.98 | 0.98 |

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Fig. 2