ANALYZING POWER AND PHASE-SHIFT ANALYSIS OF PROTON-HELIUM ELASTIC SCATTERING AT 70 AND 80 MeV

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ABSTRACT

We have used a helium-filled streamer chamber to measure the analyzing power of proton-helium elastic scattering at 70- and 80-MeV incident proton energy. We have completed phase-shift analyses of data at 63, 70, 80, and 94 MeV and obtained solutions which vary smoothly with energy and are consistent with results at lower energies.

Development of the helium-filled streamer chamber[1] has made it especially useful to know the analyzing power of helium over the complete range of energies for which the streamer chamber is a useful tool for measuring nucleon polarization. Knowledge of the analyzing power above 63 MeV is also important in extending the proton-helium phase-shift analyses[2] to higher energies. In this experiment the analyzing power of helium was measured at 70 and 80 MeV by polarizing the external proton beam of the 184-inch cyclotron and allowing it to scatter a second time in the helium gas in a streamer chamber. The polarizing target was polyethylene (CH_2); the secondary beam consisted of protons scattered elastically from hydrogen at 120 deg c.m. angle as well as some protons scattered inelastically from carbon nuclei. The net beam polarization was -0.37 ± 0.03.

The analyzing power was obtained by observing the left-right asymmetry of protons scattered from helium near the horizontal plane of the streamer chamber. The horizontal projection of the tracks was photographed through an image intensifier, and the exact scattering angles were reconstructed from the projected angles by assuming elastic kinematics. Events which also satisfied ${}^4He(p,d){}^3He$ kinematics to within the tolerances of the measured angles were rejected. The number of ${}^4He(p,np){}^3He$ events accepted as elastic events was estimated by Monte Carlo calculations and was negligible. All other inelastic reactions that are possible at these energies result in final states with three charged particles. These events were eliminated as the film was scanned.

The experimental results are listed in Table 1 and shown in Figs. 1(a) and (b). The smooth curves are the result of phase-shift analyses based on the data of this experiment, the polarization measurements at

63 and 96 MeV,[3,4] and the differential cross section measurements at 66 and 94 MeV.[5] These solutions were obtained in the customary way by least-squares fitting to the polarization and differential cross section data at each energy. In order to obtain solutions at 70 and 80 MeV it was necessary to interpolate between the differential cross section data at 66 and 94 MeV. This can be done plausibly since the differential cross sections at 55, 66, 93 and 147 MeV, when plotted as functions of momentum transfer $q = 2k \sin \theta/2$, are nearly congruent over a range of q from 0.4 to 3.0 f^{-1}; i.e., from 10 to 100 deg in the center of mass. No attempt was made to constrain the differential cross section outside this interval.

The 55-MeV p-He phase shifts given in Ref. 2 were used as the starting point for the search for these solutions. Phase-shift solutions at isolated energies are definitely not unique; however, only one set of solutions was found that was consistent with the results at lower energies and had a plausible energy dependence up to 94 MeV.

The phase shifts and absorption parameters and their standard errors are listed in Tables 2 and 3. The errors reflect not only the quality of data used for each fit but also the extent to which the data can constrain the phase shifts. The anomalously large errors on some of the 70- and 80-MeV parameters are due to the lack of any polarization or differential cross section data at backward angles rather than any defect in the fit of the extant data. The χ^2 at 94 MeV is too high, mostly because of a poor fit with the small-angle differential cross section data.

A maximum angular momentum of $\ell = 5$ was used at each energy. Including i-wave phase shifts did not noticeably improve the fit, even at 94 MeV.

The phase shifts obtained at the four energies are consistent among themselves to within the stated errors, as well as consistent with the results at lower energies. The s-wave phase shift is constant at -135 deg, while the $p_{3/2}$ term continues its gradual decline from resonance. The d-wave phase shifts persist in the order of 10 to 20 deg with the characteristic inverted doublet structure; the higher partial waves are all small. Absorption is negligible in the s state and in the high angular momentum states. The other η's decrease gradually with increasing energy.

This analysis, together with the results at lower energies, essentially determines the phase shifts and the analyzing power at forward angles from zero to 96 MeV. The forward peak in the analyzing power, which increases with increasing energy above 70 MeV, makes helium a useful analyzer for polarized nucleons at these energies.

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FOOTNOTE AND REFERENCES

* Work done under auspices of the U. S. Atomic Energy Commission.

1. V. Perez-Mendez and A. W. Stetz, Development of a Helium-Filled Streamer Chamber System, Lawrence Radiation Laboratory Report UCRL-16891, May 1968.

2. H. E. Conzett, Analysis of Proton-Alpha Cross Section and Polarization Data from 20 to 60 MeV, Lawrence Radiation Laboratory Report UCRL-16767, March 1966.

3. H. E. Conzett (Lawrence Radiation Laboratory), private communication, July 1968. Also, E. T. Boschitz, J. Chabre, H. E. Conzett, E. Shield, and R. J. Slobodrian, Polarization in p-He^4 Scattering Between 27 and 63 MeV, Lawrence Radiation Laboratory Report UCRL-16216, August 1965.

4. K. Gotow, Scattering of Polarized Protons by Helium at 203 MeV and 96 MeV, University of Rochester Report NYO-2532, January 1959.

5. A. M. Cormack, U. N. Palmieri, N. F. Ramsey, and R. Wilson, Phys. Rev. 115, (1959) 599.

FIGURE LEGENDS

Fig. 1. Analyzing power in p + He elastic scattering as a function of c.m. angle at (a) 70 MeV, (b) 80 MeV.

Table 1. Analyzing power in p + ^{4}He elastic scattering as a function of c.m. angle for 70- and 80-MeV incident kinetic energy.

70 MeV		80 MeV	
θ (deg)	Analyzing power	θ (deg)	Analyzing power
24 ± 2	0.62 ± 0.21	25 ± 3	-0.09 ± 0.19
28 ± 2	0.24 ± 0.14	30 ± 2	0.06 ± 0.18
32 ± 2	0.01 ± 0.12	34 ± 2	0.55 ± 0.17
36 ± 2	0.12 ± 0.12	38 ± 2	0.16 ± 0.19
40 ± 2	-0.18 ± 0.13	42 ± 2	0.02 ± 0.19
44 ± 2	-0.18 ± 0.15	47 ± 3	0.01 ± 0.18
48 ± 2	0.05 ± 0.17	53 ± 3	-0.14 ± 0.25
53 ± 3	0.01 ± 0.19	60 ± 4	-0.19 ± 0.24
59 ± 3	0.10 ± 0.23	69 ± 5	-0.50 ± 0.33
66 ± 4	0.04 ± 0.29		
96 ± 4	-0.15 ± 0.34		

Table 2. Phase shifts for 63-, 70-, 80-, and 94-MeV elastic p-He scattering.

State	63 MeV	70 MeV	80 MeV	94 MeV
$S_{1/2}$	-2.36 ± 0.04	-2.38 ± 0.13	-2.37 ± 0.59	-2.40 ± 0.07
$P_{3/2}$	0.81 ± 0.07	0.72 ± 0.07	0.74 ± 0.23	0.56 ± 0.07
$P_{1/2}$	0.42 ± 0.05	0.39 ± 0.18	0.42 ± 0.69	0.52 ± 0.10
$D_{5/2}$	0.45 ± 0.05	0.34 ± 0.13	0.44 ± 0.25	0.30 ± 0.08
$D_{3/2}$	0.19 ± 0.04	0.10 ± 0.17	0.11 ± 0.51	0.29 ± 0.13
$F_{7/2}$	0.22 ± 0.03	0.22 ± 0.11	0.19 ± 0.18	0.14 ± 0.06
$F_{5/2}$	0.08 ± 0.03	-0.07 ± 0.12	-0.07 ± 0.20	0.00 ± 0.09
$G_{9/2}$	0.04 ± 0.03	0.07 ± 0.07	0.16 ± 0.12	0.09 ± 0.03
$G_{7/2}$	0.00 ± 0.02	-0.10 ± 0.10	-0.05 ± 0.21	-0.07 ± 0.05
$H_{11/2}$	0.04 ± 0.02	0.12 ± 0.06	0.06 ± 0.11	0.02 ± 0.02
$H_{9/2}$	0.003± 0.01	-0.14 ± 0.10	0.06 ± 0.08	0.01 ± 0.03

Table 3. Absorption parameters for 63-, 70-, 80-, and 94-MeV elastic p-He scattering.

State	63 MeV	70 MeV	80 MeV	94 MeV
$S_{1/2}$	0.98 ± 0.11	1.0 ± 0.10	0.88 ± 0.59	1.0 ± 0.01
$P_{3/2}$	0.96 ± 0.12	0.89 ± 0.28	0.81 ± 0.43	0.78 ± 0.09
$P_{1/2}$	0.86 ± 0.08	0.67 ± 0.52	0.92 ± 0.47	0.92 ± 0.12
$D_{5/2}$	0.72 ± 0.14	0.70 ± 0.12	0.67 ± 0.41	0.65 ± 0.06
$D_{3/2}$	0.75 ± 0.04	0.71 ± 0.11	0.69 ± 0.46	0.57 ± 0.09
$F_{7/2}$	0.95 ± 0.06	0.76 ± 0.16	0.71 ± 0.31	0.74 ± 0.06
$F_{5/2}$	0.82 ± 0.03	0.93 ± 0.16	0.76 ± 0.35	0.52 ± 0.09
$G_{9/2}$	0.90 ± 0.04	0.71 ± 0.14	0.78 ± 0.22	0.83 ± 0.05
$G_{7/2}$	0.89 ± 0.03	0.92 ± 0.12	0.92 ± 0.31	0.67 ± 0.10
$H_{11/2}$	0.83 ± 0.04	0.69 ± 0.11	0.87 ± 0.24	0.95 ± 0.04
$H_{9/2}$	0.95 ± 0.03	0.98 ± 0.07	1.0 ± 0.10	0.94 ± 0.06

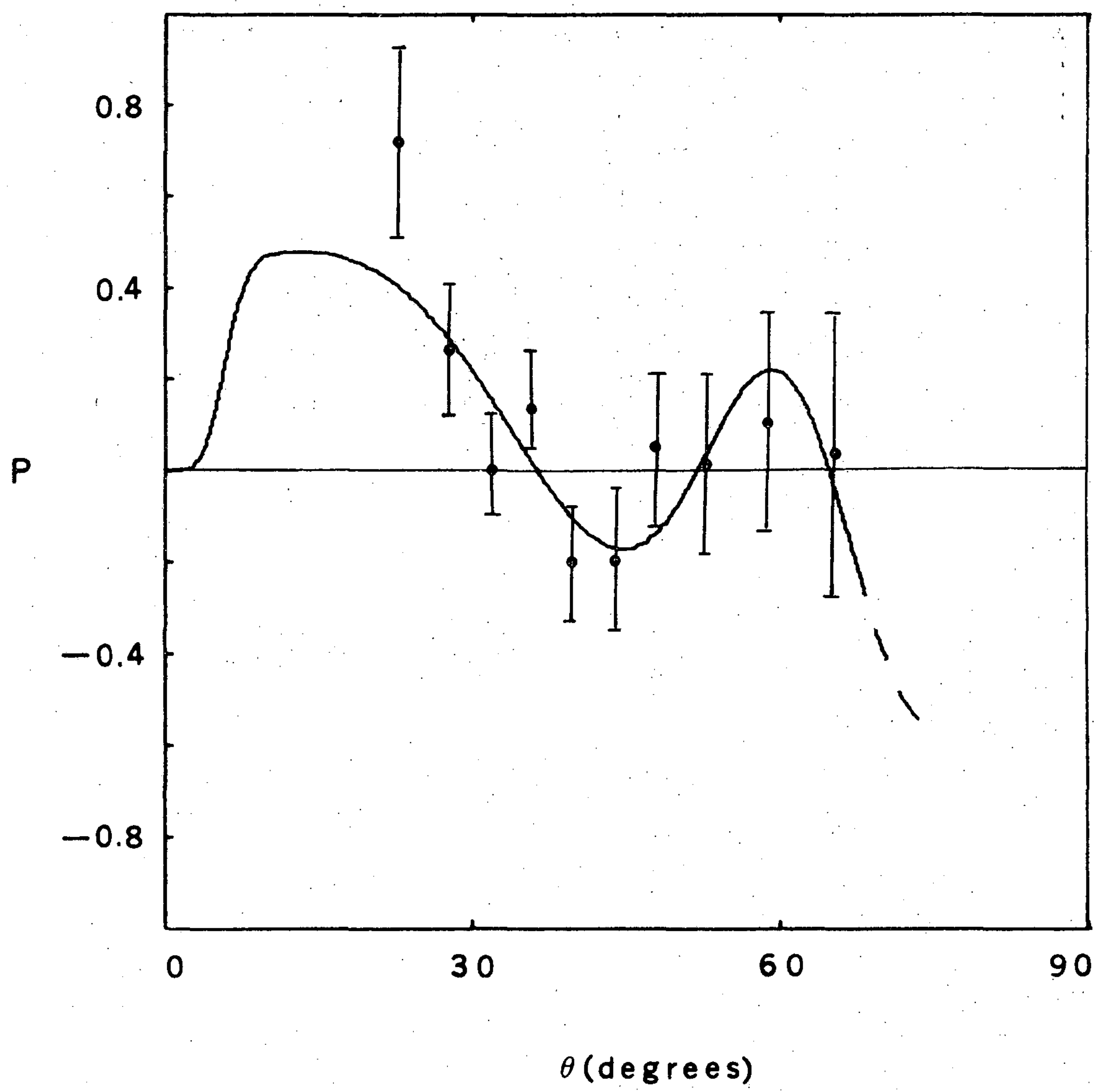

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Fig. 1(a)

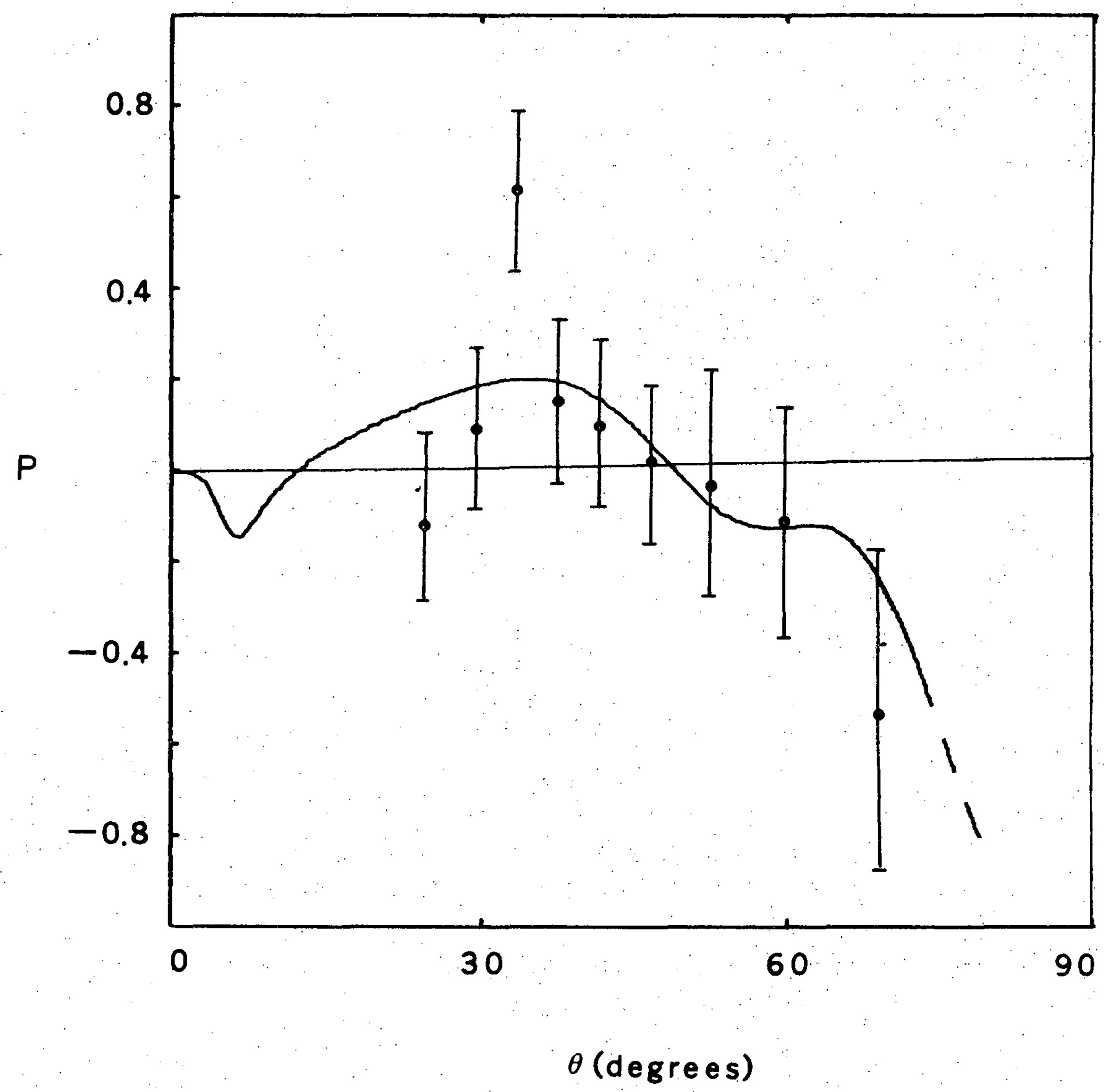

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Fig. 1(b)

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