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Polarization in p-He^4 and p-p Scattering at 22 MeV

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We have developed a beam of 22-MeV protons, using p-He^4 scattering as the polarizing mechanism. We have followed the method first used by Rosen and Brolley [1][2]) three years ago, but before describing a few details of the method, I should like to summarize briefly the information available on p-He^2 scattering as a proton polarizer. This can be done most conveniently in terms of the following table.

Table

E_{LAB} (MeV)	Data (θ)	Data $P(\theta)$	Reference
0.95–18	X	—	K. W. Brockmann, Phys. Rev. *108*, 1000 (1957) contains a list of authors whose work is referred to here.
39.8	X	—	M. K. Russell and J. H. Williams, Phys. Rev. *106*, 286 (1957).
1.37	—	one angle	M. J. Scott, Phys. Rev. *110*, 1398 (1958).
2.02	—	one angle	
3.58	—	one angle	
7.8	—	one angle	J. Sanada *et al.*, J. phys. Soc. Japan, to be published.
11.4	—	one angle	
14.4	—	one angle	
10	—	10 angles	Reference 1.

Phase shifts derived from analyses of the very complete differential cross section data have been used to calculate the polarizations; and finally, description of the p-α interaction in terms of an effective two-body potential with a central and a spin orbit term has resulted in inter-

[1]) On leave from the Weizmann Institute, Rehovoth, Israel.
[2]) Numbers in brackets refer to References, page 258.

polations and predictions of the phase shifts, and thus the polarizations, up to 40 MeV [2]. It should be noted here (table) that the polarization measurements at these energies are sparse; and, since the polarizations are more sensitive than the angular distributions of the differential cross sections to uncertainties in the phase shifts, it is important to extend these measurements in order to provide further checks on theory, and thus enable experimenters to use the calculated values more confidently. The results of GAMMEL and THALER's optical-model potential calculations are shown in figure 1. I want to call your attention to the fact that between 10 and 11 MeV $P(130°) > +90\%$, and in fact, ROSEN and BROLLEY's [1] measured value at 10 MeV is $P(130°) = +99^{+1}_{-2}\%$. It is precisely this measurement that we use in setting up our polarized proton beam; that is, we have incident on a H_2 gas target a 43.1 MeV α-particle beam of about 1 μA intensity. Protons knocked on at a laboratory angle of 25° are in fact equivalent to 10.8 MeV (lab. energy) protons scattered from He^4 at a centre-of-mass angle of 130°.

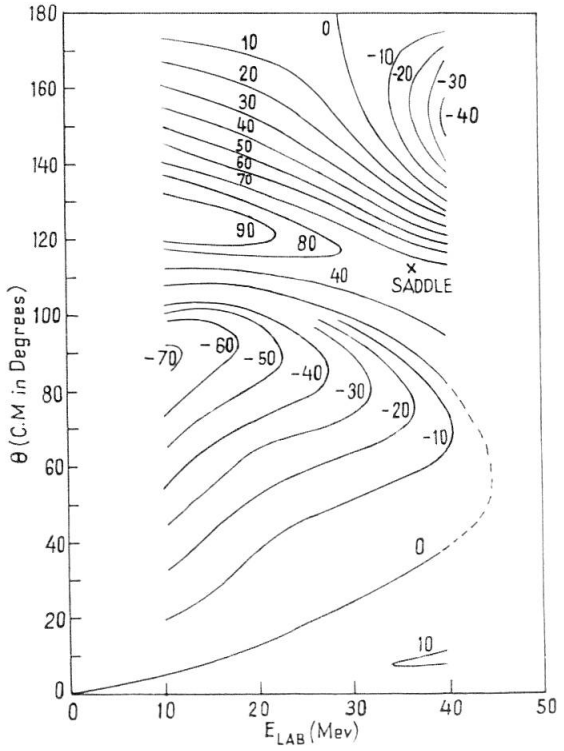

Figure 1

Figure 2 shows a sketch of our experimental set up. The region of the first scattering is imbedded in paraffin to reduce the high-energy neutron background that is most troublesome. This is shown by the dotted line. After passing through the H_2 gas target, the α-beam passes through a shielding wall, is stopped in a Faraday Cup and monitored.

The protons knocked on at 25° with respect to the incident beam are collimated into the second scattering chamber. Measured left-right asymmetries in the second scattering then give us P_2, the polarization

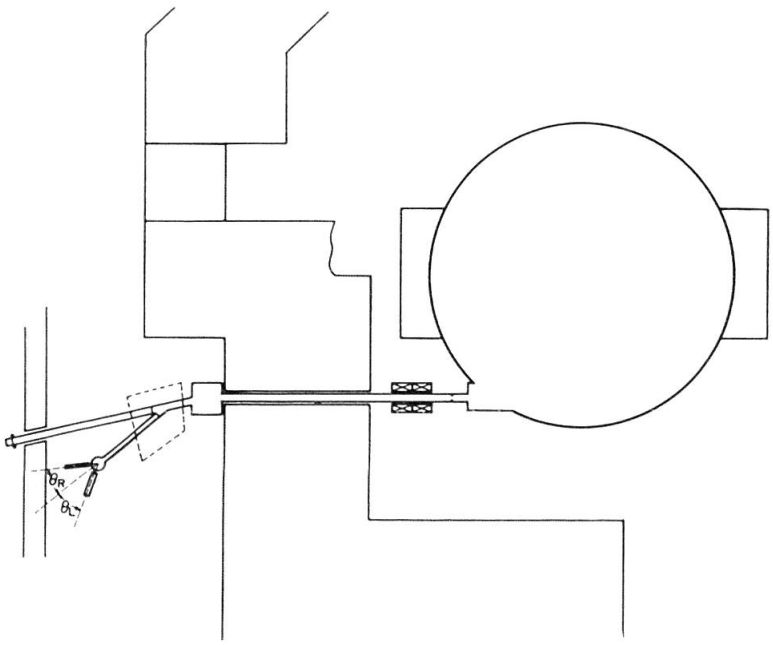

Figure 2

that would be induced in the second scattering if the proton beam were unpolarized. Figure 3 is a schematic drawing of our scattering geometry; the α-particle energy of 45.5 MeV is that just on the downstream side of the entrance foil. The following conditions apply:

1. First scattering: 8 atm. of H_2, $E_\alpha = 43.1$ MeV, $E_p = 23$ MeV.
2. Second scattering: 6 atm. of He^4 or H_2, $E_p = 22$ MeV, Polarization essentially 100%, and a beam of $\approx 6 \cdot 10^6$ protons/s.
3. $\Delta\Theta_1$, the angle subtended at the first scattering volume by the 11/16″ collimator defining the proton beam, is about 1.4°. This angular spread is kept small in order to minimize the inherent asymmetry in the second scattering due to non-uniform illumination across the second target.
4. $\Delta\Theta_2$, the angular resolution of our counters, including beam width, is about 9°.
5. This geometry gives us second-scattered counting rates in each counter of about 3000/h in p-He^4 scattering at an angle of 45°.
6. We use a simple coincidence counting arrangement to reduce the background to the point where it constitutes no problem, at least for measurements in the forward hemisphere. A pulse from the plastic scintillator-photomultiplier tube is used to gate on the pulse-height

analyzer which records the pulses from the CsI crystal counter. Figure 4 shows a spectrum of the second-scattered protons, note the small background measured with a brass absorber placed in front of the counter.

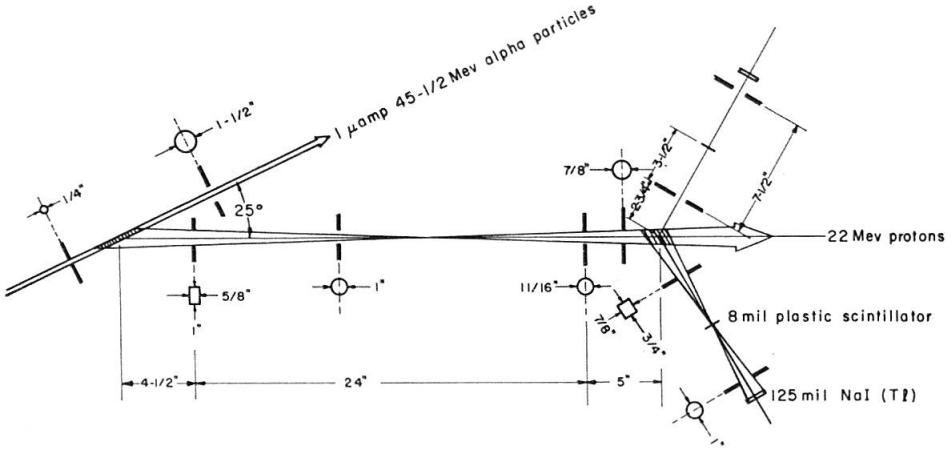

Figure 3

A measurement of P_2 comes directly from the asymmetry measurement because $\varepsilon = (L - R)/(L + R) = P_1P_2$ and our P_1 is 100% within something like 2 or $3^0/_{00}$ figure 5 shows, then our results to date on p-He^4 polarization at 22 MeV. The probable errors indicated are statistical. The solid curve represents GAMMEL and THALER's calculated values. This experiment is in progress and we will extend the measurements to the backward angles and will reduce the statistical errors on the points measured on this first run. We can also degrade our proton beam and extend the measurements to lower energies.

With the relatively high 2nd-scattered yields we have available, it was overwhelmingly tempting to try a quick measurement of the p–p polarization before this conference convened; especially, since in principle it was necessary only to change the gas in the 2nd-scattering chamber. Our preliminary result is

$P(50°) = (+\ 0.6 \pm 1.0)\%$ at 22 MeV to be compared with
$P(60°) = (+\ 1.2 \pm 2.0)\%$ at 17.7 MeV [3] and
$P(50°) = (0.6 \pm 0.5)\%$ at 16.2 MeV [4].

Our probable error is that due to counting statistics alone, and we have not yet refined our equipment to the point where we can claim that the other sources of error are small in comparison. In fact, a qualitative estimate is $\pm$ 4% due to the other sources, the major contribution coming from the fact that an electronic difficulty during part of a run made the data from one counter unuseable. Thus we had data from each counter only in one position and not with the counters inter-

changed, and so the differences in counter-detection efficiences were not cancelled out.

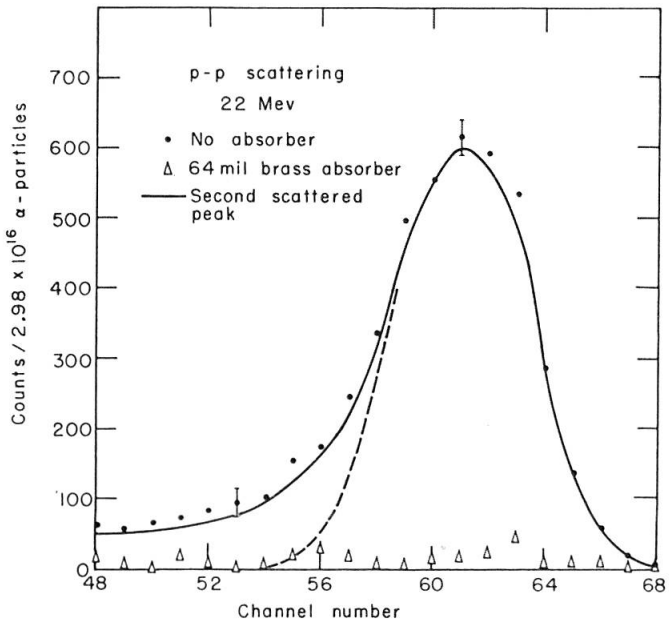

Figure 4

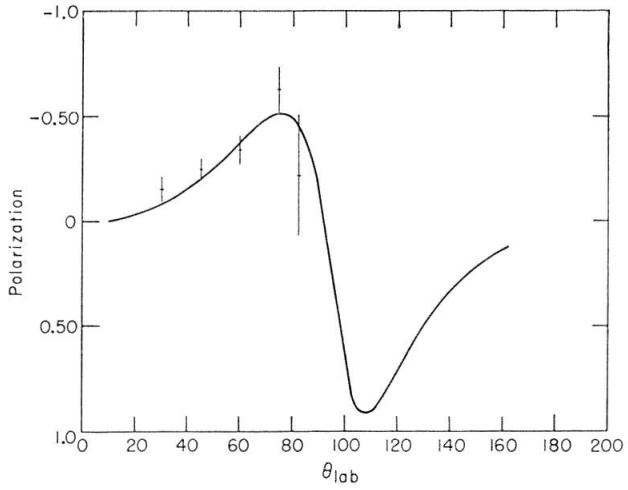

Figure 5

This raises the question of the importance of a measurement of the p–p polarization at these energies. MAC GREGOR's phase-shift analyses [5] of the differential cross section data result in four possible solutions, i.e. sets of phase shifts. Two of them predict small negative polarizations in the energy and angular regions of the above results and hence, seem to be ruled out by the polarization measurements. The other two solu-

tions predict small positive polarizations and even a very precise measurement cannot distinguish between them. Hence, in closing, we would welcome any expression of theoretical opinion on this question.

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