Title

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Publication Date
1954-08-01

UCRL 2684

UNCLASSIFIED

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

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UCRL-2684

UNIVERSITY OF CALIFORNIA
Radiation Laboratory

Contract No. W-7405-eng-48

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We have previously reported[1] results of experiments concerning polarization of proton beams by scattering from complex nuclei. Other authors[2] have also dealt with this problem. Particular interest has been attached to polarization by elastic scattering and several publications[3-5] have treated the theory for this case.

As previously, we have attempted to isolate elastic scattering by insertion of an absorber into the counter telescope used to detect the scattered protons. Owing to range straggling in the absorber and to inhomogeneity of the beam, it is impossible to exclude with certainty all protons resulting from inelastic scattering. For example, we mention the

[1] Chamberlain, Segrè, Tripp, Wiegand, and Ypsilantis, Phys. Rev. 93, 1430 (1954), and Phys. Rev. 95, 1105 (1954).

[2] Oxley, Cartwright, and Rouvina, Phys. Rev. 93, 806 (1954); Marshall, Marshall, and de Carvalho, Phys. Rev. 93, 1431 (1954); also J. M. Dickson and D. C. Salter, Nature 173, 946 (1954).

[3] E. Fermi, Nuovo cimento 11, 407 (1954), and private communication; Snow, Sternheimer, and Yang, Phys. Rev. 94, 1073 (1954); B. J. Malenka, Phys. Rev. 95, 522 (1954).

[4] W. Heckrotte and J. V. Lepore, Phys. Rev. 94, 500 (1954); W. Heckrotte, Phys. Rev. 94, 1797 (1954); R. M. Sternheimer, Phys. Rev. 95, 587 (1954).

[5] S. Tamor, Phys. Rev. 94, 1087 (1954).

scattering by carbon in which the lowest excited state is at 4.4 Mev, while our counting arrangement could be guaranteed to reject scattering events only if at least 20 Mev were lost to the scattering nucleus.

At small angles of scattering from any target the elastic scattering is easily determined simply because it is strongly predominant over inelastic scattering. However, at angles larger than about 20°

the so-called elastic scattering is contaminated with an appreciable fraction of protons from inelastic scattering.

Helium is of special interest in this regard because there are no excited or unbound states at energies lower than 20 Mev. Therefore, our existing method of detection is adequate to exclude all protons inelastically scattered by helium at any angle.

We have measured the elastic-scattering cross sections of helium for 315-Mev 74 %-polarized protons, and of carbon for 290-Mev 64 %-polarized protons. Our second targets were 1.7 g/cm^2 of liquid helium and 3.2 g/cm^2 of graphite respectively. The polarized beams were obtained by scattering 340-Mev protons to the left at 15° and 18° respectively, from a beryllium first target inside the cyclotron as previously described.[1] The beam polarizations were determined in separate experiments by external scattering from beryllium at 15° and 18°.

The results for both left and right scattering from helium are shown in Fig. 1(a), in which the differential-scattering cross sections have been corrected for nuclear attenuation in the absorber. Figure 1(b) shows the polarization $P(\Theta)$ in the elastic scattering by helium as computed from the points shown in Fig. 1(a) and the known beam polarization. The relation used is

$$e(\Theta) = P_B P(\Theta) \qquad (1)$$

in which $$e(\Theta) = \left[\sigma_{left}(\Theta) - \sigma_{right}(\Theta)\right] \Big/ \left[\sigma_{left}(\Theta) + \sigma_{right}(\Theta)\right] .$$

P_B is the polarization of the beam, and $P(\Theta)$ is the polarization that would be produced by scattering an unpolarized beam at angle Θ on the substance in question (in the present experiment, helium or carbon). Figure 2 shows the corresponding results for carbon second target.

An interesting feature of the helium results is that they show a definite change in sign of the polarization. Changes in sign near minima of the diffraction scattering curve of carbon have been predicted by Fermi, by Malenka, and by Snow, Sternheimer, and Yang.[3] However, it is not clear that the observed change in sign should be attributed to the mechanism implied by these theoretical considerations. On the other hand Tamor[5] assumed the validity of the impulse approximation for light nuclei, and on that basis predicted that the polarization of carbon and helium should be the same. That they are the same seems fairly well borne out for angles small enough (up to 20^{o}) that the carbon experiment can be deemed to represent purely elastic scattering. In the framework of Tamor's theory either helium or carbon polarization data should be viewed as exemplifications of that part of the nucleon-nucleon scattering that involves no change in spin state of the target nucleons.

The authors have relied heavily on discussions with Drs. B. D. Fried, J. V. Lepore, W. Heckrotte, and S. Tamor.

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

FIGURE CAPTIONS

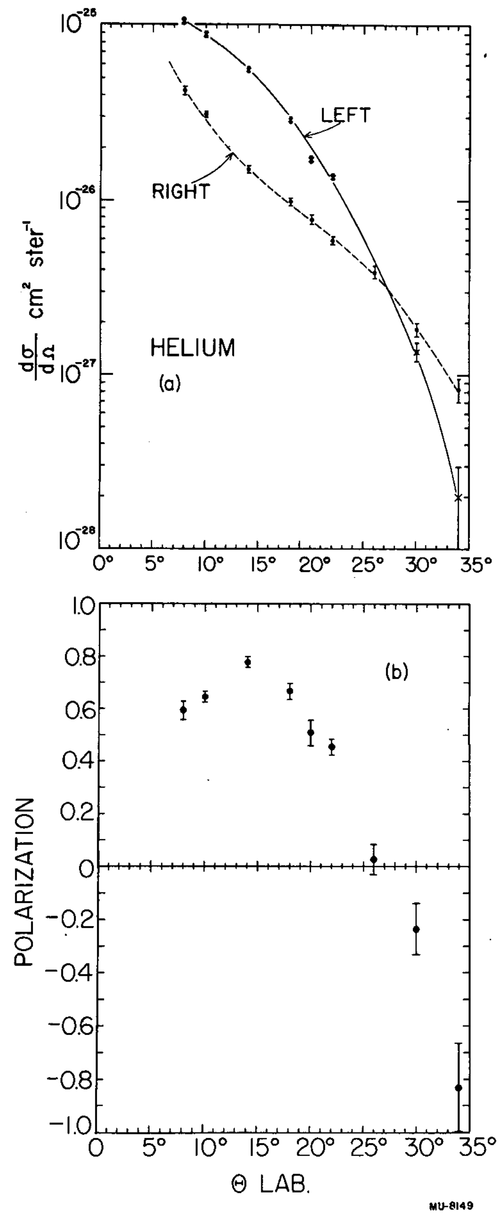
Fig. 1 (a) Differential-scattering cross sections *versus* left and right scattering angles for 74 %-polarized 315-Mev protons scattered elastically by helium.

(b) Polarization $P(\Theta)$ of protons elastically scattered by helium *versus* scattering angle.

Fig. 2 (a) Differential-scattering cross sections *versus* left and right scattering angles for 64 % polarized 290-Mev protons scattered elastically by carbon.

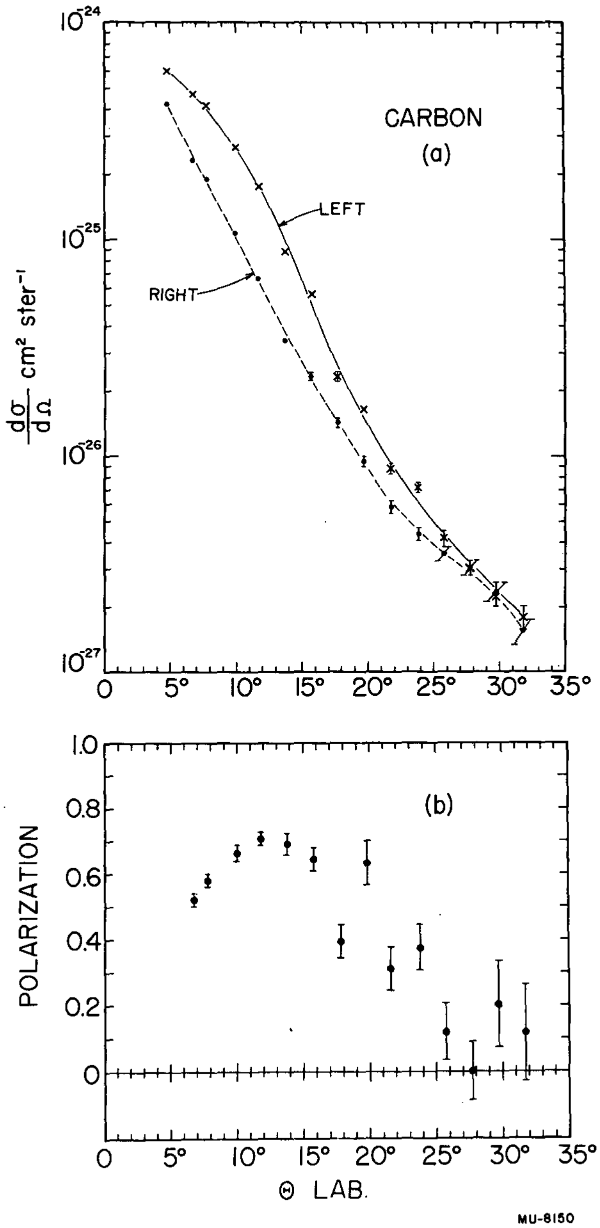
(b) Polarization $P(\Theta)$ of protons elastically scattered by carbon *versus* scattering angles.

At angles greater than 20° the so-called elastic scattering from carbon is contaminated by inclusion of some inelastically scattered protons.



LEFT
RIGHT
HELIUM
(a)
10^{-25}
10^{-26}
10^{-27}
10^{-28}
$\frac{d\sigma}{d\Omega}$ cm^2 ster^{-1}
0° 5° 10° 15° 20° 25° 30° 35°
(b)
POLARIZATION
1.0 0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6 -0.8 -1.0
0 5° 10° 15° 20° 25° 30° 35°
Θ LAB.
MU-8149

Fig. 1



CARBON
(a)
LEFT
RIGHT
$\frac{d\sigma}{d\Omega}$ cm² ster⁻¹
(b)
POLARIZATION
Θ LAB.
MU-8150

Fig. 2