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POLARIZATION OF HIGH-ENERGY DEUTERONS

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In analogy to experiments on proton polarization[1-4] we obtained a polarized deuteron beam by the same scattering method. The trajectories of 167-Mev deuterons as produced by the cyclotron are essentially the same as those of 312-Mev protons if the magnetic field of the steering magnet is properly adjusted and the deuteron beam enters the cave through the same channel as the proton beam.

In order to polarize and analyze the deuteron beam we have used carbon as scatterers A and B. After the second scatterer we have measured the intensity of the scattered beam as a function of ϕ. We have endeavored to limit ourselves to elastically scattered deuterons by the use of absorbers, as in the proton work.

It has been shown by Lakin and Wolfenstein[5] that the most general intensity distribution produced by polarized deuterons is:

$$I(\theta, \phi) = I_o(\theta) + A(\theta) \left\langle T_{20} \right\rangle + \left(B(\theta) \left\langle T_{21} \right\rangle + C(\theta) \left| \left\langle T_{11} \right\rangle \right| \right) \sin\theta \cos\phi + D(\theta) \left\langle T_{22} \right\rangle \sin^2\theta \cos 2\phi \, . \tag{1}$$

The incident deuterons travel in the Z direction and have been polarized by scattering in the x, y plane. I, A, B; C, D are polynomials in cos θ and the T_{ik}'s are expectation values, for the beam before it undergoes the second scattering, of quantities such as

$$T_{21} = -\frac{\sqrt{3}}{2} \left[(S_x + iS_y) S_z + S_z (S_x + iS_y) \right]$$

$$T_{11} = -\frac{\sqrt{3}}{2} (S_x + iS_y)$$

$$T_{22} = \frac{\sqrt{3}}{2} (S_x + iS_y)^2$$

where $\vec{S}$ is the spin operator for the deuteron.

Experimentally we have found I $(20^\circ, \phi)$ as in Fig. 1. An analysis of this scattering gives

$$I(20^{\circ}, \phi) = p + q \cos \phi + r \cos 2 \phi \qquad (2)$$

with $p = 50.3 \pm 2.2$, $q = 15.3 \pm 1.9$, and $r = -1.8 \pm 3.6$ in units of 10^{-27} cm^2/ steradian. The errors are based on counting statistics only, and are valid for the ratios p:q:r but not necessarily for the absolute values of these parameters. Measurements at smaller values of θ give similar results with smaller values of q/p.

This equation agrees well with Eq. (1) and shows that the coefficient of $\cos 2 \phi$ is very small or zero, at least in the cases investigated up to now.

A possible explanation which is consistent with the usual spin-orbit model has been pointed out by Dr. M. Ruderman. If it is assumed that the deuteron polarization originates in an $\vec{L} \cdot \vec{S}$ coupling which acts in the scattering process in addition to a central force, and if the magnitude of the spin-orbit potential is small compared to the central part, it then follows that the $\cos 2 \phi$ term is negligible because $\langle T_{22} \rangle$ is very small.

It must be noted that the description of the polarization of a deuteron beam is substantially more complicated than the similar description for particles of spin 1/2, and that our analysis gives only a small part of the relevant information.

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[1] Oxley, Cartwright, and Rouvina, Phys. Rev. 93, 806 (1954).

[2] Chamberlain, Segrè, Tripp, Wiegand, and Ypsilantis, Phys. Rev. 93, 1430 (1954). Fig. 1 of the reference paper is applicable to the present work and the same notations are used throughout.

[3] Marshall, Marshall, and de Carvalho, Phys. Rev. 93, 1431 (1954).

[4] Dickson, and Salter, Nature 173, 946 (1954).

[5] W. Lakin and L. Wolfenstein - Unpublished report. We thank the authors for having shown us the manuscript.

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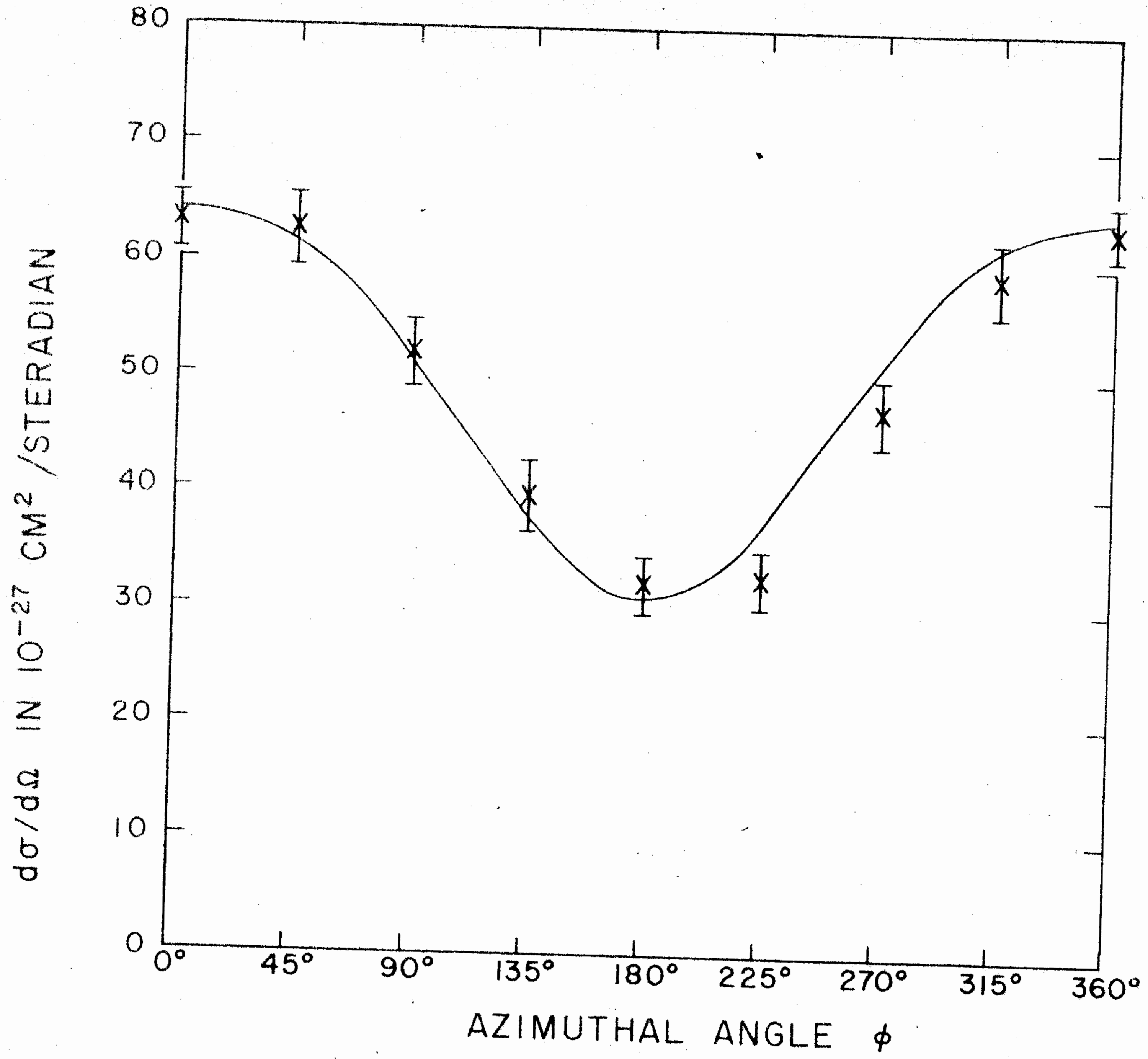
Figure 1. Differential cross section versus azimuthal angle Φ for polarized deuterons scattered elastically by carbon.



dσ/dΩ IN 10⁻²⁷ CM² /STERADIAN
0
10
20
30
40
50
60
70
80
0°
45°
90°
135°
180°
225°
270°
315°
360°
AZIMUTHAL ANGLE φ