POLARIZATION IN NEUTRON-PROTON SCATTERING AT 16 AND 24 Mev*

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Except for thermal energies the only previous measurements of the polarization in neutron-proton scattering below 77 Mev have been performed by the cyclotron group at Harwell[1] who used neutrons with a continuous energy distribution from 20 to 100 Mev and a time-of-flight spectrometer. Because of the low polarization (14%) of the neutrons employed, their method did not give a very accurate measurement of the small polarization in neutron-proton scattering expected near 20 Mev.

In the present experiment the polarization was determined from measurements of the asymmetry in scattering of polarized monoenergetic neutrons by protons. The neutrons were produced by bombardment of a tritium gas target with deuterons. The scattering was observed by detecting the recoil protons and scattered neutrons in fast coincidence. The proton recoils were produced and detected in a plastic scintillator. Use of a solenoid, which rotated the spin of the incident neutrons, and two symmetric neutron counters reduced asymmetries caused by misalignment and variation in the neutron flux. Figure 1 contains a schematic drawing of the experimental setup showing the proton recoil counter (A), the two neutron counters (B and C), the solenoid, and the target. Also shown in Fig. 1 is a block diagram of the fast-slow coincidence system. The chance background was measured to be less than 15%. The background measured with the target cell evacuated was also less than 15%. The acceptance angle of the counters in the n-p scattering plane was 18° in the laboratory system, and the energy spread of the incident neutrons was approximately 300 kev.

The asymmetry at each neutron energy E_n and laboratory scattering angle θ_2 was measured twice, once for $T(d,n)He^4$ neutrons emitted to the right of the deuteron beam and once to the left at the same laboratory angle θ_1. These two measured asymmetries, corrected for background, are listed in Table I as R_r and R_l. Also included in Table I is $P_2(\theta_2)$, the polarization in

Table I. Polarization in n-p scattering as a function of angle and energy.

E_n (Mev)	θ_2 (deg, lab)	R_r (%)	R_l (%)	$P_2(\theta_2)$ (%)
16.4	50	0.1 ±2.1	0.8 ±1.0	1.1 ±2.1
16.4	60	-2.1 ±1.6	2.0 ±1.4	5.2 ±2.7
16.4	70	-1.6 ±1.5	0.3 ±1.1	2.3 ±2.3
23.7	40	1.2 ±1.4	-1.4 ±1.3	3.4 ±2.5
23.7	50	1.3 ±1.1	-0.8 ±1.1	2.8 ±2.1
23.7	60	0.9 ±1.0	-1.2 ±1.0	2.8 ±1.9
23.7	70	0.5 ±1.0	0.0 ±1.3	0.7 ±2.1

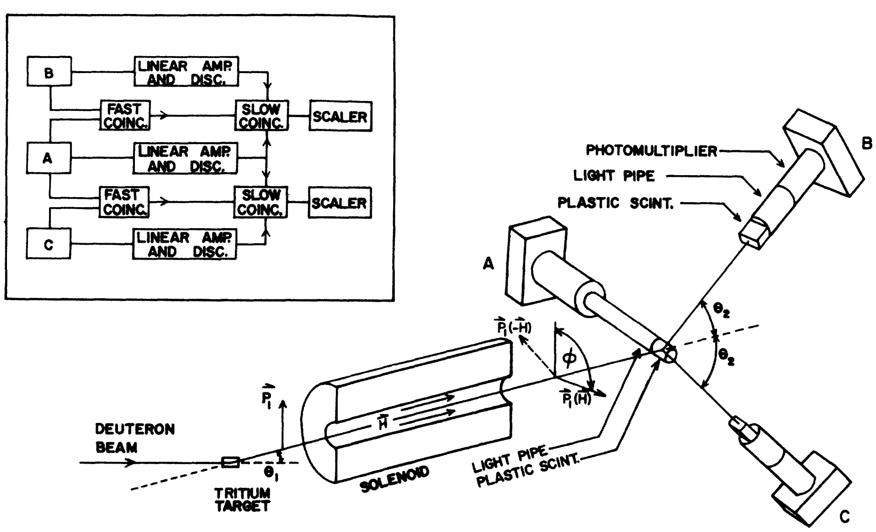

FIG. 1. Schematic diagram of experimental arrangement and block diagram of electronics.

Table II. Polarization of $T(d,n)He^4$ neutrons used in the present experiment.

E_d (Mev)	θ_1 (deg, lab)	E_n (Mev)	A_1 (%)	A_2 (%)	$P_1(\theta_1)$ (%)
6.0	90	16.4	-43 ± 3	-34 ± 3	-43 ± 4
7.7	30	23.7	40 ± 3	33 ± 3	46 ± 5

n-p scattering, which was determined from the relation

$$R = P_1(\theta_1)P_2(\theta_2)\sin\phi,$$

where $P_1(\theta_1)$ is the polarization of the incident $T(d,n)He^4$ neutrons, R is the weighted mean of R_r and R_l, and ϕ is the angle through which the spin vector of the incident neutrons was rotated by the solenoid. The errors cited in Table I are statistical only, and the sign of the polarization follows the Basel convention.

Estimates of $P_1(\theta_1)$, the polarization of the $T(d,n)He^4$ neutrons, have been made on the basis of measurements of the asymmetry in scattering of the neutrons from He^4 by Perkins and Simmons[2] and by the present authors. The results of these measurements for an n-He^4 laboratory scattering angle of 120° are given in Table II. For each deuteron energy E_d and laboratory emission angle θ_1 are listed the neutron energy E_n and the asymmetries measured by Perkins and Simmons (A_1) and in this laboratory (A_2). The values of $P_1(\theta_1)$ cited in Table II are the values used in analyzing the data to obtain the polarization in n-p scattering and were determined from the average of A_1 and A_2. The analyzing power of the n-He^4 scattering at 16.4 Mev was calculated from the set of phase shifts given by Seagrave[3] in which $\delta_2^+ = 0$. This set of phase shifts was extrapolated to 23.7 Mev, and the n-He^4 analyzing power at that energy was calculated from the extrapolated values. The $\delta_2^+ = 0$ phase shifts of Seagrave seem to give a better fit to angular distributions at 18 and 21 Mev measured in this laboratory[4] than the other existing sets of phase shifts. The two values of the polarization of the $T(d,n)He^4$ neutrons determined in this way differ from the polarization of the protons from the mirror reaction $He^3(d,p)He^4$ at the same excitation energies and angles of emission[5] by less than 10% in the polarization. New information on n-He^4 scattering and the possible elimination of the difference between the two asymmetry measurements is expected to change the values of the polarization in n-p scattering by amounts smaller than the statistical errors of the measurements. Such changes would appear as changes in scale, i.e., the polarization and its error would be multiplied by a common factor which is probably between 0.8 and 1.1 for the 16.4-Mev point and between 0.7 and 1.3 for the 24-Mev point.

Some of the theoretical implications of the results of the present experiment are given in the following paper by Hull, McDonald, Ruppel, and Breit.[6]

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[1]P. H. Bowen, G. C. Cox, G. B. Huxtable, A. Langsford, J. P. Scanlon, and J. J. Thresher, Phys. Rev. Letters 7, 248 (1961).

[2]R. B. Perkins and J. E. Simmons, Phys. Rev. 124, 1153 (1961).

[3]J. D. Seagrave, Phys. Rev. 92, 1222 (1953).

[4]S. M. Austin, H. H. Barschall, and R. E. Shamu (to be published).

[5]R. I. Brown and W. Haeberli, Bull Am. Phys. Soc. 6, 307 (1961).

[6]M. H. Hull, Jr., F. A. McDonald, H. M. Ruppel, and G. Breit, following Letter [Phys. Rev. Letters 8, 68 (1962)].