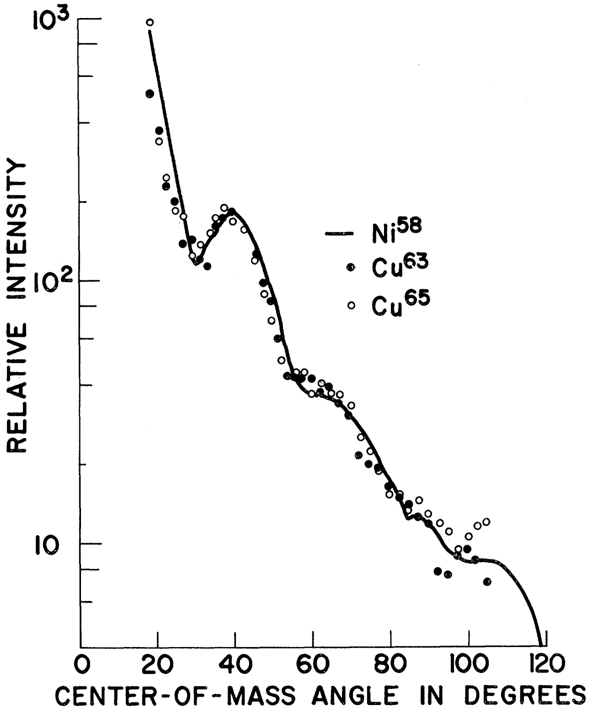

FIG. 2. Angular distribution of the cross section of the 1.45-Mev level in Ni^{58} (solid line) and the groups near 1.3 Mev in Cu^{63} and Cu^{65}.

normalized to each other at 40°. The experimental result strongly suggests that the angular distributions from the groups of levels near 1.3 Mev in Cu^{63} and Cu^{65} are due to the same process as that from the 2^+ level in Ni^{58}.

In particular, the experimental result is not inconsistent with the considerations of Lawson and Uretsky.[9] According to their view, the single state at 1.4 Mev in Ni^{58} is due to pair rearrangement in the neutron configuration $(f_{5/2})^2$ and four of the closely-spaced states in each of the Cu isotopes are due to the coupling of the $p_{3/2}$ proton to such an excited neutron state. However, it should be observed that the peaks of the inelastic groups are not at the measured energies of the 2^+ levels in Ni^{62} and Ni^{64}. The measured position of the 2^+ level in Ni^{62} is 1.17 Mev while the position of the peak for Cu^{63} is closer to 1.3 Mev. Similarly the position of the peak in the Cu^{65} group is somewhat higher than the measured 2^+ level at 1.34 Mev in Ni^{64}. In view of the excellent agreement of our energy calibration with the 1.45-Mev level in Ni^{58}, the discrepancy, though slight, appears to be significant. Actually, there are five levels in the excited group in each of the Cu isotopes, and it is reasonable to assume that one of them is due to single-particle excitation of the $p_{3/2}$ protons to the $f_{5/2}$ state. In this case the gross structure can be definitely explained in terms of a $0 \to 2$ excitation by pair rearrangement. It seems very striking that the scattering process is so insensitive to the presence of the extra proton and to the number of neutron pairs apparently involved in the configurations $(f_{5/2})^2$, $(p_{3/2})^4(f_{5/2})^2$, and $(p_{3/2})^4(f_{5/2})^4$.

It does seem plausible that a careful measurement of the angular dependence of the gross structure will result in the unambiguous assignment of an l value in the inelastic scattering process, at least in a number of cases. It also appears likely that in many cases pair-rearrangement excitation will provide a satisfactory explanation of the effect.

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[†] Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] B. L. Cohen, Phys. Rev. 105, 1549 (1957); B. L. Cohen and A. G. Rubin, Phys. Rev. 111, 1568 (1958).

[2] J. L. Yntema and B. Zeidman, Phys. Rev. (to be published).

[3] D. R. Sweetman and N. S. Wall (unpublished).

[4] J. L. Yntema and B. Zeidman (unpublished).

[5] Schiffer, Lee, Yntema, and Zeidman, Phys. Rev. 110, 1216 (1958).

[6] A. Tomasini, Nuovo cimento 6, 927 (1957); A. M. Lane and E. P. Pendlebury (private communication to J. P. Schiffer); T. Tamura and D. C. Choudhury, Phys. Rev. (to be published).

[7] J. L. Yntema, Phys. Rev. (to be published).

[8] The targets were obtained from the Atomic Energy Research Establishment, Harwell, England.

[9] R. D. Lawson and J. L. Uretsky, Phys. Rev. 108, 1300 (1957).

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p-p TRIPLE SCATTERING AT 143 Mev*

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The depolarization parameter D as defined by Wolfenstein[1] for proton-proton scattering at an energy near 150 Mev was first measured by

Taylor and Wood.[2] Another measurement of this parameter has been made at the Harvard Cyclotron Laboratory using a polarized proton beam of $P_1 = 0.67$, $E_{\text{mean}} = 147$ Mev, and an energy spread of ±2 Mev.

Our apparatus and experimental procedure followed essentially that of Chamberlain et al.[3] The beam was scattered off liquid hydrogen at an angle θ_2 and analyzed by carbon scattering at an angle θ_3. D was measured at 5° intervals from 20° to 40° lab. The angular resolution of the second scattering (θ_2) is determined by the intersection of the $1\frac{1}{4}$ in. wide beam with the 4-in. diameter hydrogen target, and the 1-in. wide defining counter located 46 in. from the center of the hydrogen target. It varies from ±2.3° at 20° lab to 3.0° at 40° lab.

At each angle we observed a counting rate of about 20 counts/min of triply scattered protons. Random coincidences (1 %) and background (2 %) were separately determined and corrected for. The analyzing power P_1P_3 was measured at the mean third scattering energy corresponding to each θ_2. The measurement of D depends critically upon the alignment of θ_3. We align at each θ_2 by sweeping a profile of the twice scattered beam at small angles of θ_3, checking after the asymmetry measurement.

The directions of the second and third scatterings are represented by further subscripts N and S. Thus θ_{3S} and θ_{3N} represent scatterings in the same and opposite directions, respectively, as the first scattering inside the cyclotron, and $I(\theta_{2N}, \theta_{3N})$ is the corrected, normalized, counting rate at the angles $(\theta_{2N}, \theta_{3N})$. Then

$$e_{3n}(\theta_2) = \frac{I(\theta_2, \theta_{3S}) - I(\theta_2, \theta_{3N})}{I(\theta_2, \theta_{3S}) + I(\theta_2, \theta_{3N})}, \qquad (1)$$

$$D(\theta_2) = \frac{1}{2P_1P_3}[(1+P_1P_2)e_{3n}(\theta_{2S}) + (1-P_1P_2)e_{3n}(\theta_{2N})], \qquad (2)$$

$$P_2'(\theta_2) = \frac{1}{2P_3}[(1+P_1P_2)e_{3n}(\theta_{2S}) - (1-P_1P_2)e_{3n}(\theta_{2N})], \qquad (3)$$

$$P_2(\theta_2) = \frac{1}{P_1}\left(\frac{I(S) - I(N)}{I(S) + I(N)}\right),$$

where

$$I(S) = I(\theta_{2S}, \theta_{3S}) + I(\theta_{2S}, \theta_{3N}),$$

$$I(N) = I(\theta_{2N}, \theta_{3S}) + I(\theta_{2N}, \theta_{3N}).$$

Our values of D and those of Taylor and Wood along with the theoretical predictions of Gammel and Thaler[4] and Signell and Marshak,[5] are given in Fig. 1. Our values of P_2 and P_2' are compared with the P_2 results of Palmieri et al.[6] in Fig. 2. Note that $P_2 = P_2'$ if time reversal is valid for the p-p interaction.

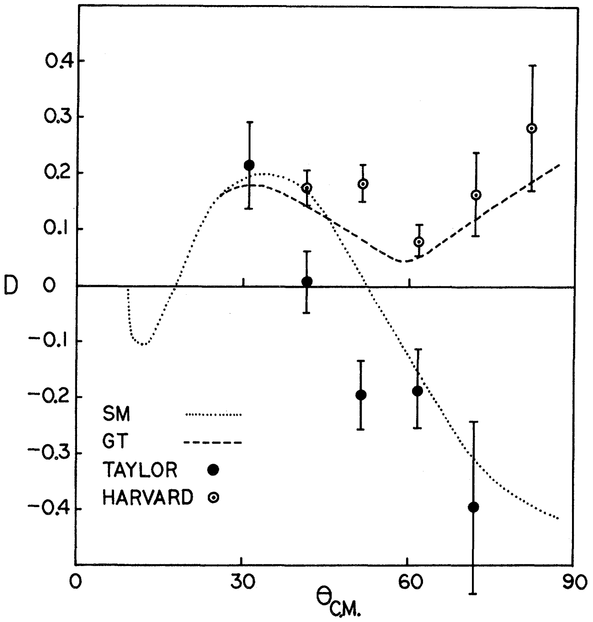

FIG. 1. Experimental measurement and theoretical predictions of the triple scattering parameter $D(\theta)$.

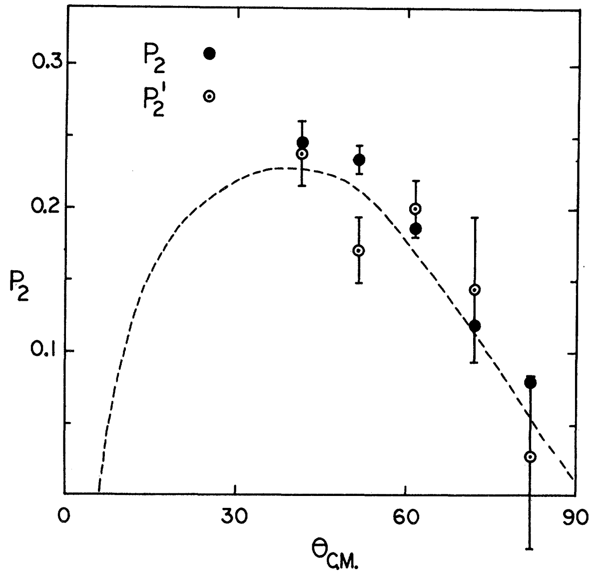

FIG. 2. Comparison of P_2 and P_2' with p-p polarization data (corrected for a small difference of incident proton energy) of Palmieri et al. (The latter data are represented by the dashed curve.)

D has been measured at 635 Mev by Kumekin, Mescheryakov, Nuruschev, and Stolotov,[7] and at 315 Mev by Chamberlain et al.[3] The angular dependence of their results is similar to ours. Gammel and Thaler[4,8] try to fit data with a static potential plus a term linear in momentum ($\vec{L}\cdot\vec{S}$ term). They always find that the curves for D at various energies are parallel to each other. To reconcile the results of Taylor and Wood with those at higher energies, they would have to include a term of higher order in momentum.

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[†] Corning Glass Works Foundation Predoctoral Fellow.

[‡] National Science Foundation Predoctoral Fellow.

[1] L. Wolfenstein, Annual Review of Nuclear Science (Annual Reviews, Inc., Palo Alto, 1956), Vol. 6, p. 65.

[2] 1958 Annual International Conference on High-Energy Physics at CERN, edited by B. Ferretti (CERN, Geneva, 1958), p. 56. A. E. Taylor (private communication).

[3] Chamberlain, Segrè, Tripp, Wiegand, and Ypsilantis, Phys. Rev. 105, 288 (1957).

[4] J. L. Gammel and R. M. Thaler, Phys. Rev. 108, 163 (1957).

[5] Signell, Zinn, and Marshak, Phys. Rev. Lett. 1, 416 (1958).

[6] Palmieri, Cormack, Ramsey, and Wilson, Ann. Phys. 5, 299 (1958).

[7] 1958 Annual International Conference on High-Energy Physics at CERN, edited by B. Ferretti (CERN, Geneva, 1958), p. 57. V. P. Dzhelepov (private communication).

[8] J. L. Gammel and R. M. Thaler (private communication).

K^--HYDROGEN CHARGE-EXCHANGE SCATTERING*

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In the course of a bubble chamber investigation of the interaction of low-energy K^- mesons in hydrogen, we have observed forty-five reactions of the type $K^- + p \to \bar{K}^0 + n$ followed by the observable decay $K_1 \to \pi^+ + \pi^-$.[1]

The only other type of event which could be confused with the observed type is the much more frequent sequence $K^- + p \to \Lambda + \pi^0$, $\Lambda \to p + \pi^-$. However, in Λ decay, the proton usually stops, but if it does not, its greater ionization generally permits identification. In order to certify the identification, all V's in which the positive decay product did not stop in the chamber were measured and fitted to both the Λ and K_1 interpretations. All events fitted one or the other–there were no ambiguities.

The calculated momentum of the K^- at the point of interaction P_{K^-} depends sensitively on the $\bar{K}^0$-K^- mass excess, which has been measured in this and other experiments to be 3.9 ± 0.6 Mev.[2] The threshold for charge exchange is then 89 ± 5 Mev/c.

For each event, P_{K^-} was adjusted to give a simultaneous best fit to the production kinematics, by the use of the momentum of the K^- (computed from its decay kinematics), the curvature of the K^-, and the known momentum distribution of the K^- beam. The cross section below 300 Mev/c was then obtained by constructing an ideogram which gave the fraction of events in each of the four momentum intervals below 300 Mev/c shown in Fig. 1.

Data were also taken with the beam momentum adjusted for 310 ± 22 Mev/c and 410 ± 15 Mev/c. Even at these higher momenta the K^- velocity is low enough that ionization can be used to distinguish K^- from μ^- and π^- contamination in the beam.

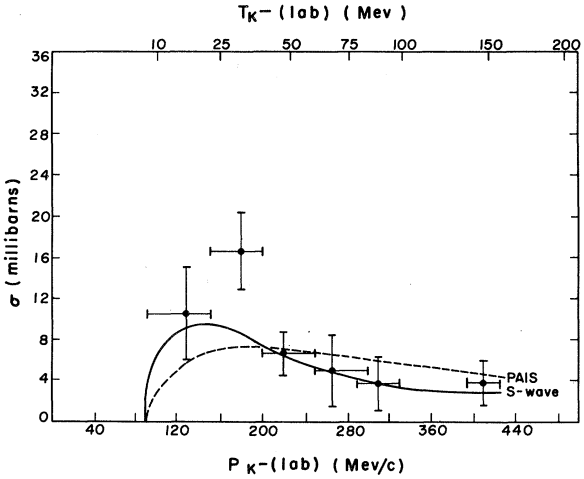

FIG. 1. K^--hydrogen charge-exchange cross section vs K^- laboratory momentum. The solid curve is the prediction of the S-wave zero-effective-range theory. The dashed curve (arbitrary ordinate) is the prediction of the Pais theory with $\lambda = -1$.