POLARIZATION OF Λ HYPERONS FROM PHOTOPRODUCTION IN HYDROGEN*

H. Thom, E. Gabathuler, D. Jones,† B. D. McDaniel, and W. M. Woodward
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York
(Received 19 September 1963)

Polarization of the Λ hyperon, perpendicular to the production plane, has been measured for the reaction $\gamma + p \to K^+ + \Lambda$ using the Cornell synchrotron. Measurements at approximately 90° in the center-of-mass system have been made for five photon energies ranging from 1000 to 1120 MeV.

The experimental arrangement, shown in Fig. 1, consisted of a magnetic spectrometer for detecting the K^+ mesons on one side of the beam line and, on the other side, two identical counter telescopes above and below the production plane. These telescopes were used for detecting (in coincidence with the K's) protons from the asymmetric decay of the Λ. The selection of the K^+ by the magnetic spectrometer determined the kinematical parameters of the reaction and is described elsewhere.[1,2] The Λ's, which were produced at approximately 20° in the laboratory with an energy of about 250 MeV, decayed in a mean distance of 5 cm, and the decay protons were contained in a cone of 10° half-angle. The decay telescopes each consisted of two scintillation counters and copper absorber.

The asymmetric decay, $\Lambda \to p + \pi^-$, arising from parity nonconservation, was used as an analyzer to determine the polarization. The distribution of the decay protons in the rest system of the Λ is given by[3]

$$N(\phi)d\Omega = (4\pi)^{-1}(1 + \alpha P \cos\phi)d\Omega,$$

where the decay asymmetry parameter α has the value of $+0.62 \pm 0.07$, P is the polarization of the Λ, and φ is the angle between the direction of polarization and the direction of motion of the decay protons. If the decay telescopes above and below the production plane have identical detection efficiencies, the polarization $P_{\rm up}$ in the direction $\hat{p}_\gamma \times \hat{p}_\Lambda$ is given by

$$P_{\rm up} = \{[N(u) - N(d)]/[N(u) + N(d)]\}(1/\alpha\langle\cos\phi\rangle_{\rm av}),$$

where $N(u)$ and $N(d)$ are the counting rates of the telescopes above and below the production plane, respectively, and $\langle\cos\phi\rangle_{\rm av}$ is the average value of $|\cos\phi|$ for protons detected by the decay counters. The telescopes were interchanged, up for down, frequently during a run. The computed value of $\langle\cos\phi\rangle_{\rm av}$ arising from the kinematics and geometry of the experiment was typically 0.7, and the computed detection efficiency for the $p + \pi^-$ decay mode was about 55%.

Pulses from the decay telescopes were amplified and photographically recorded using a four-beam oscilloscope[4] which was triggered by K events detected and identified in the magnetic spectrometer. Two-dimensional pulse-height analysis was performed on all particles detected in either telescope during a 55-nsec time interval coincident with the triggering K's. Because of the rf bunching of the electrons in the synchrotron, these telescope pulses fell in groups separated by 11 nsec, so that real coincidences between K and proton from Λ decay, as well as four groups of accidental coincidences, were observed. Figures 2(a) and 2(b) show typical two-dimensional pulse-height distributions in the 11-nsec real coincidence interval and in the 44-nsec accidental interval. Though there was no sharp separation between decay protons and background accidentals or decay pions, the numerical asymmetry was not sensitive to bias choice. The accidental rate was about 1% of the real $K\Lambda$ coincidence rate. Real background coincidences between the magnetic spectrometer and the decay telescopes, from events produced in the hydrogen target walls or

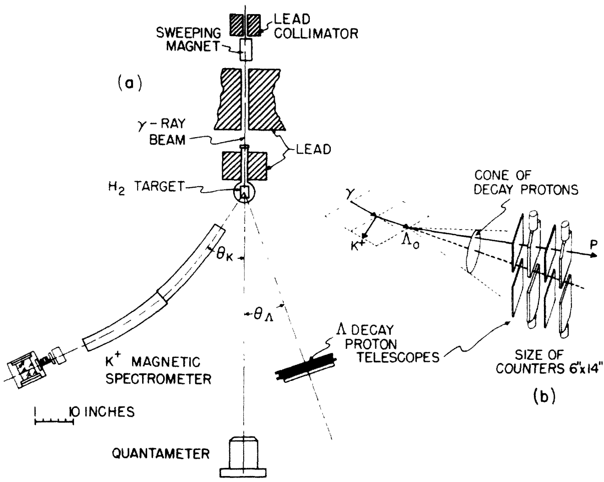

FIG. 1. Experimental arrangement for Λ polarization. (a) Plan view; (b) isometric view (not to scale).

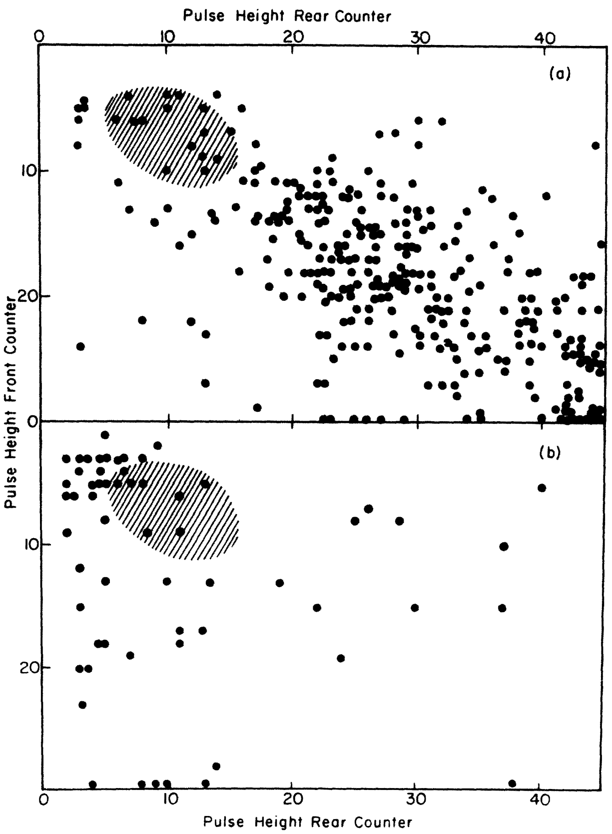

FIG. 2. Sample of two-dimensional pulse-height distribution for one decay telescope. (a) Events during the 11-nsec interval coincident with the K^+. (b) Accidental events during a 44-nsec interval not coincident with the K^+. (Each circle is one event. Pulse heights obtained from fast pion calibration fall in cross-hatched area.)

by photons below threshold, were found to be less than 1% of the $K\Lambda$ rate. About 600 decay protons were observed for each experimental point; these give a statistical error for the numerical asymmetry $[N(u)-N(d)]/[N(u)+N(d)]$ of about ± 0.04.

Exact determination of the production plane was necessary. The mean vertical angle of the magnetic spectrometer was determined both geometrically, and also experimentally using coincidences of the reaction $\gamma+p\to\pi^++n$, to determine the vertical acceptance profile. The geometrical mean vertical angle differed by 1.0 ± 1.1 mrad from the experimentally measured mean angle. The decay telescopes were aligned symmetrically above and below the mean direction of the Λ's to within approximately 2 mrad. The maximum error in numerical asymmetry caused by this possible misalignment was ± 0.022, or about ± 0.05 in polarization.

The experimental results of the numerical asymmetry and polarization are given in Table I along with the calculated values of $\langle\cos\phi\rangle_{\rm av}$. The errors indicated in the polarization are only statistical and do not include errors in α or in geometrical alignment. The observed Λ detection efficiency was approximately 0.35 with a statistical error of ± 0.02. The observed and calculated total efficiencies agreed within this error when a decay branching ratio[5] of $0.66^{+0.04}_{-0.03}$ was used. An earlier, less precise polarization measurement[6] is listed as the last entry in Table I. Preliminary results of Λ polarization measurements in progress at Frascati[7] are in approximate agreement with those in Table I.

Theoretical calculations of both the cross section and polarization have been made using two models. One model[8,9] uses only contributions from the N, K, and K^* and the $K_0\Lambda$ resonance terms. In this model, though the calculated cross sections are in reasonable agreement with experimental values, the polarization, which arises from interference of the resonance term, is op-

Table I. Polarization for $\gamma+p\to K^++\Lambda$. E_γ is the mean photon energy and $\theta_{K{\rm c.m.}}$ is the center-of-mass production angle of the K. Approximate spectrometer resolution is indicated. Errors in the numerical asymmetry and polarization are statistical only.

E_γ (MeV)	$\theta_{K{\rm c.m.}}$ (deg)	$[N(u)-N(d)]/[N(u)+N(d)]$	$\langle\cos\phi\rangle_{\rm av}$	Polarization along $\hat{p}_\gamma\times\hat{p}_\Lambda$
1000 ± 19	93 ± 4.3	0.10 ± 0.05	0.71	0.23 ± 0.11
1026 ± 23	87 ± 4.3	0.09 ± 0.04	0.71	0.21 ± 0.10
1056 ± 29	80 ± 4.6	0.19 ± 0.06	0.76	0.40 ± 0.13
1056 ± 29[a]	80 ± 4.6	0.17 ± 0.06	0.76	0.36 ± 0.13
1095 ± 30	91 ± 4.0	0.04 ± 0.05	0.69	0.09 ± 0.11
1121 ± 33	90 ± 3.5	0.16 ± 0.05	0.69	0.37 ± 0.11
1000 ± 30[b]	32^{+10}_{-6}	0.03 ± 0.08		0.06 ± 0.18

[a]Measurement using a different technique: H. Thom et al., Bull. Am. Phys. Soc. 7, 297 (1962).
[b]See reference 6.

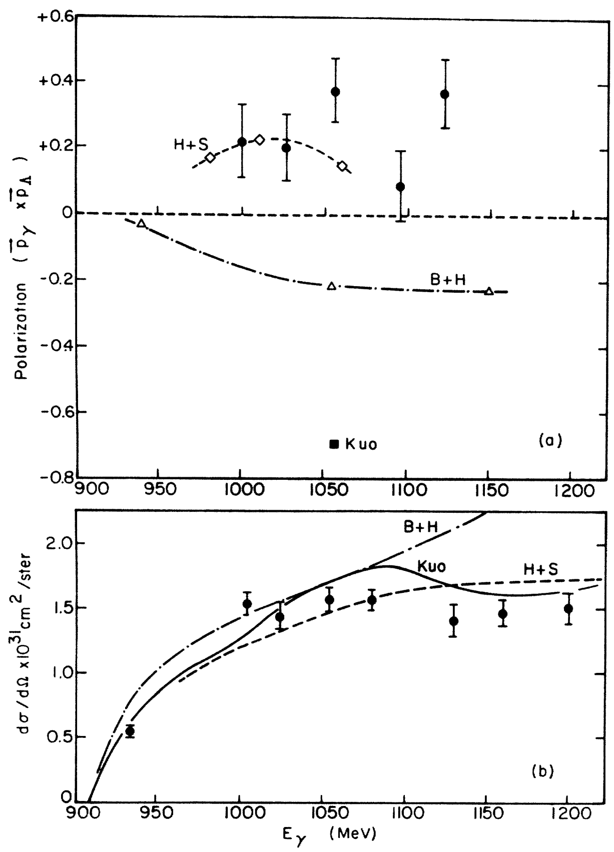

FIG. 3. Comparison of the measured polarization (a) and the cross section at 90° (b) with the theoretical calculations. Values given by Kuo (reference 8) and by Beauchamp and Holladay (reference 9) are for a $p_{1/2}$ $K_0\Lambda$ resonance. The values of Hatsukade and Schnitzer (reference 10) are obtained taking $\mu_\Lambda = 1.5\ \mu_N$ and choosing the sign of the polarization to agree with the experiment.

posite in direction from that measured here. The other model[10] uses contributions from the N, K, K^* and from the second and third πN resonances. In this case the polarization, which comes from interference of the third resonance term, is unfortunately indeterminate in sign and only more extensive measurements, under different kinematical conditions, will confirm or disprove the validity of the model. Figures 3(a) and 3(b), respectively, compare the experimental values of the polarization and the cross section[2,11] at 90° with those given by the calculations. It is clear that more work is necessary before a model can be conclusively established.

We would like to thank Dr. R. L. Anderson, Mr. A. J. Sadoff, and Mr. S. Mori for their assistance in making these measurements.

---

*Work supported by the U. S. Office of Naval Research.

†Present address: National Institute for Research in Nuclear Science, Chilton, Didcot, Berkshire, England.

[1]B. D. McDaniel, A. Silverman, R. R. Wilson, and G. Cortellessa, Phys. Rev. 115, 1039 (1959).

[2]R. L. Anderson, E. Gabathuler, D. Jones, B. D. McDaniel, and A. J. Sadoff, Phys. Rev. Letters 9, 131 (1962).

[3]J. W. Cronin and O. E. Overseth, Phys. Rev. 129, 1795 (1963).

[4]H. G. Jackson, Rev. Sci. Instr. 29, 527 (1958).

[5]M. Roos, Rev. Mod. Phys. 35, 314 (1963).

[6]B. D. McDaniel, P. Joos, D. McLeod, S. Richert, and D. Zipoy, Phys. Rev. Letters 4, 33 (1960).

[7]L. Mezzetti (private communication). For E_γ from 1000 to 1050 MeV, and $\theta_{K\mathrm{c.m.}}$ equals 90°, $\alpha P = 0.20 \pm 0.05$. This corresponds to $P = 0.32 \pm 0.08$ in the direction $\hat{p}_\gamma \times \hat{p}_\Lambda$.

[8]T. K. Kuo, Phys. Rev. 129, 2264 (1963).

[9]N. A. Beauchamp and W. G. Holladay, Phys. Rev. 131, 2719 (1963).

[10]S. Hatsukade and H. S. Schnitzer, Phys. Rev. (to be published).

[11]A. J. Sadoff (private communication). Results of recent measurements at 1160 and 1200 MeV (to be published).