turns out to be $_{\Lambda}He^9$ instead of $_{\Lambda}He^8$.

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π^+ PHOTOPRODUCTION BETWEEN 1.2 AND 3 GeV AT VERY SMALL ANGLES

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The reaction $\gamma + p \rightarrow \pi^+ + n$ has been investigated for photon energies between 1.2 and 3 GeV and pion c.m. angles from 2.5 to 15°. The cross section is strongly peaked in the forward direction and shows resonance structure in the region of the $N_{3/2}^*(1920)$ and $N_{1/2}^*(2190)$.

We have measured the photoproduction of single positive pions from hydrogen at angles ranging from 1° to 6° in the lab. A modified version of the magnetic spectrometer and scintillation counter-hodoscope system described earlier[1] was used. In order to reject the large electromagnetic background produced at small angles, the following changes in the apparatus[1] had to be made:

(i) The counter hodoscope $H1$ which previously measured the production angle (θ) of particles passing through the spectrometer was replaced by a collimator of variable width and height at the first angular focus in the horizontal plane ($H1$). The collimator size was chosen to optimize solid-angle acceptance while maintaining an angular resolution $\Delta\theta = \pm 4.5$ mrad at all production angles except for the one-degree measurements, where $\Delta\theta = \pm 2.5$ mrad was chosen to allow a more detailed investigation of the expected rapid variation of the cross section with angle.

(ii) Five scintillation counters, S_1 to S_5, were used to define the geometry of the beam. They were all placed behind the magnetic system to limit the highest instantaneous singles counting rate to $\lesssim 1$ Mc/sec.

(iii) A threshold gas Cherenkov counter[2] (C_e) of 25 cm diam and 2.40-m radiator length filled with ethylene at 1.2 atm was placed between S_1 and S_2 to detect positrons passing through the spectrometer. Its efficiency was $(99.93 \pm 0.03)\%$.

(iv) A second threshold gas Cherenkov counter (C_π) of the same diameter, but 3.40 m long, located between S_2 and S_3 and filled with ethylene at 3.5 atm, detected pions with momentum $p_\pi > 2.1$ GeV/c with an efficiency $\epsilon_\pi > 99\%$.

(v) The time of flight of particles was measured between counters S_1 and S_4 (7.7 m distance) with a resolution of 1.3-nsec full width at half-maximum, permitting the separation of pions from protons below 2.1 GeV/c, where the C_π counter becomes inefficient.

An event was defined as the passage of a charged particle other than a positron through the spectrometer. Its occurrence was indicated by an anticoincidence ($G\overline{C}_e$) of C_e with $G = (S_1S_2S_3S_4S_5)$, the geometry-defining coincidence between all trigger counters. Among these events, pions were distinguished from protons either by a coincidence of $G\overline{C}_e$ with C_π or by using the time-of-flight information, depending on momentum.

The number of positrons not rejected by $G\overline{C}_e$ because of the inefficiency of C_e contributed less than 1% to the pion rate except at $\theta_\pi^{\text{lab}} = 1°$, $E_\gamma = 1.37$ GeV, where it contributed 2%. Muons from pair production contribute a negligible fraction to the event rate; the proton contamination of the pion rate is estimated to be less than 1 % at all momenta. Pions from multiple production processes can be excluded by (a) making use of the fact that their energetic separation from single production (~150 MeV at small angles) is considerably larger than the energy resolution of the spectrometer and (b) setting the spectrometer momentum such that for single-pion production the energy range of the photons is restricted to $E_\gamma \gtrsim E_{\gamma\max}-150$ MeV. Kaons are excluded in the same way.

The methods used for determining particle momentum and photon energy, for calculating acceptances and energy resolution, and for recording and storing the data from each event in a PDP-5 computer on line were essentially the same as in Ref. 1. The total acceptance $A=\int d\Omega dp/p$ of the spectrometer was 0.48×10^{-5} sr except at $\theta_\pi^{\text{c.m.}}=2.5°$, where it was 0.18×10^{-5} sr.

Differential cross sections were measured at five pion center-of-mass angles ($\theta_\pi^{\text{c.m.}}$ = 2.5°, 5°, 7.5°, 10°, 15°) and at ten photon energies between 1.2 and 3.0 GeV. In addition, some measurements were made at selected angles and energies to verify structure found in the systematic survey. The data analysis was performed on the IBM 7044 of the Deutsches Elektronen-Synchrotron (DESY) computing center and included corrections for empty-target background (4 to 8 %), nuclear absorption (8 %), pion decay in flight (6 to 22 %), ambiguous events (3 %), and the effects of a thick target on the shape of the bremsstrahlung spectrum. The total systematic error is estimated to be less than 10 %.

The differential cross sections $d\sigma/d\Omega^{\text{c.m.}}$ are presented in Table I as functions of $\theta_\pi^{\text{c.m.}}$ and E_γ. The errors shown are only due to counting statistics and do not include the systematic errors mentioned above. To improve counting statistics, events from all hodoscope counters were averaged over a photon energy interval ($\Delta E_\gamma/E_\gamma$) of typically ±2 %.

The energy and angular dependence of the differential cross sections $d\sigma/d\Omega^{\text{c.m.}}$ is shown in Figs. 1 and 2, respectively. We note the following points:

(1) The peak observed in the cross section as a function of energy becomes more pronounced at small angles (compare also Fig. 2 of Ref. 1) and shifts to smaller energies with decreasing center-of-mass angle; at $\theta_{\text{c.m.}}=2.5°$ it is found close to the position expected for the $N_{3/2}^*(1920)$ nucleon isobar.

(2) The angular dependence shows a strong peaking in the forward direction at all photon energies. At 1.2 and 1.37 GeV we observe a dip in the cross section near angles corresponding to $|t|=m_\pi^2$ which may be attributed to the interference between one-pion-exchange and nucleon-pole diagrams. This dip is less prominent at 1.5 GeV and completely disappears at higher energies. It is interesting to note that this change in the angular behavior occurs in the energy region where the cross section

Table I. $d\sigma/d\Omega^{\text{c.m.}}$ (μb/sr) as a function of pion center-of-mass angle $\theta_\pi^{\text{c.m.}}$ and incident laboratory photon energy E_γ.

E_γ (GeV) \ $\theta_\pi^{\text{c.m.}}$	2.5°	5°	7.5°	10°	15°
1.23	6.09 ± 0.41	5.45 ± 0.25	4.04 ± 0.22[a]		3.21 ± 0.20[b]
1.37	4.41 ± 0.44	4.01 ± 0.18		2.71 ± 0.16	
1.52	6.34 ± 0.43	4.81 ± 0.29	4.09 ± 0.21	2.94 ± 0.14	2.71 ± 0.19[c]
1.66	6.40 ± 0.50	5.21 ± 0.23	4.28 ± 0.22	3.41 ± 0.17	
1.80	5.58 ± 0.28	5.58 ± 0.28	4.25 ± 0.19	3.62 ± 0.19	3.34 ± 0.16[d]
1.99	4.94 ± 0.36	4.77 ± 0.19		3.61 ± 0.16	3.30 ± 0.15[e]
2.18	5.20 ± 0.29	4.20 ± 0.23		3.18 ± 0.16	2.60 ± 0.13
2.38	4.39 ± 0.35	3.17 ± 0.16		2.49 ± 0.13	2.28 ± 0.10
2.60	4.38 ± 0.25	2.96 ± 0.10		2.34 ± 0.12	2.24 ± 0.09
2.86		2.96 ± 0.12		2.19 ± 0.09	2.17 ± 0.11

[a] $\theta_\pi^{\text{c.m.}}=7.8°$.
[b] $\theta_\pi^{\text{c.m.}}=11.5°$.
[c] $\theta_\pi^{\text{c.m.}}=12.4°$.
[d] $\theta_\pi^{\text{c.m.}}=13.2°$.
[e] $\theta_\pi^{\text{c.m.}}=13.8°$.

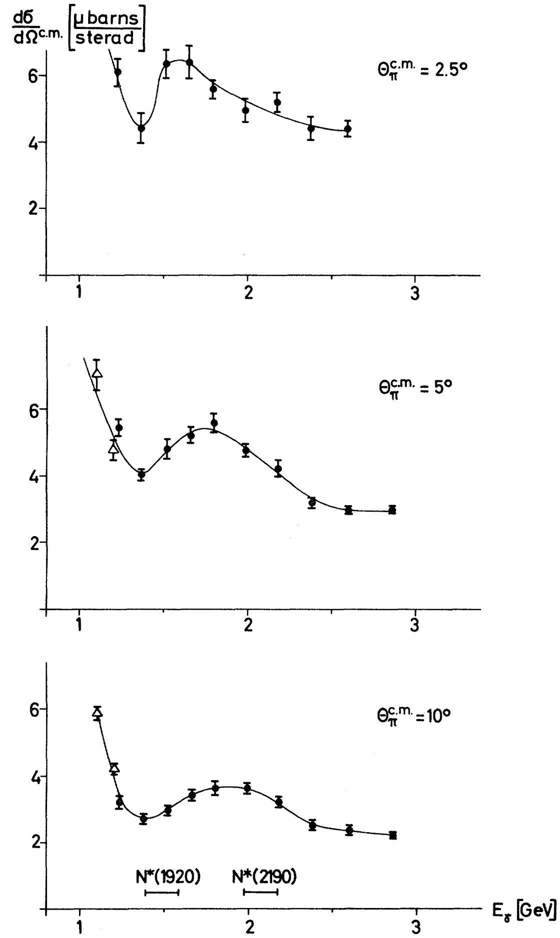

FIG. 1. Center-of-mass differential cross sections as a function of incident photon energy E_γ for different pion c.m. angles $\theta_\pi^{\text{c.m.}}$. ●, this experiment; △, J. R. Kilner, thesis, California Institute of Technology, 1963 (unpublished). Smooth curves are drawn through the data points to guide the reader.

rises to a peak as a function of energy, suggesting that the same mechanism may be responsible for the changes observed in both energy and angular distributions.

At 1.20 and 1.37 GeV we have made a Moravcsik fit[3] to the combined data of this and our previous experiment as well as the large-angle data of Kilner.[4] From the pole extrapolation of a fifth-order fit we obtain values for the pion-nucleon coupling constant f^2 of 0.10 from the 1.20-GeV fit and 0.095 from the 1.37-GeV fit. The errors in f^2 are estimated to be of the order of 15-20% and are due to counting statistics, systematic errors, and uncertainties in choosing the correct order of fit. Therefore, the disagreement with the value of f^2

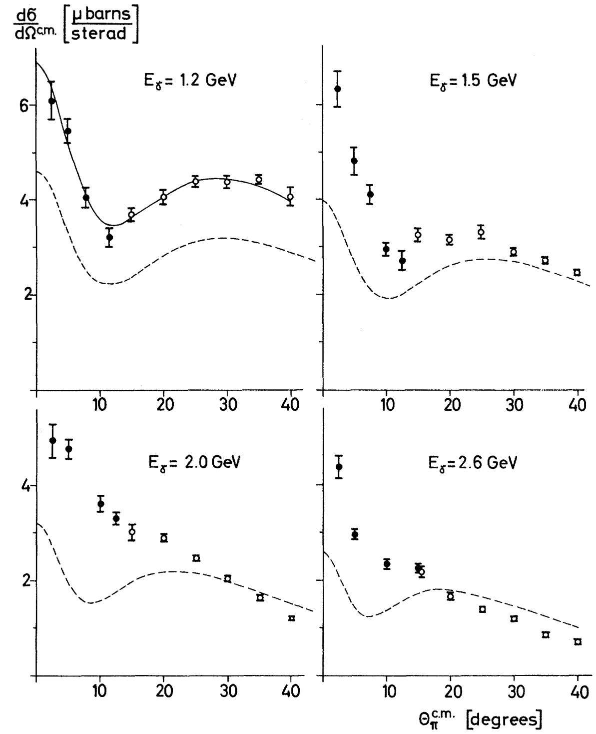

FIG. 2. Center-of-mass differential cross sections as a function of pion c.m. angle $\theta_\pi^{\text{c.m.}}$ for different incident photon energies E_γ. ●, this experiment; ○, Ref. 1. For $E_\gamma = 1.2$ GeV a fifth-order Moravcsik fit is given (solid line). Broken lines give the predictions of the absorption model [K. Schilling, Deutsches Elektronen-Synchrotron Report No. 66/9, 1966 (unpublished); and private communication].

$= 0.0822 \pm 0.0018$ obtained in pion-nucleon scattering[5] does not seem to be significant.

The observed forward peaking of $d\sigma/d\Omega^{\text{c.m.}}$ vs $\theta_\pi^{\text{c.m.}}$ is in contradiction with simple peripheral models (one-pion exchange)[6] and their Reggeized versions,[7] which predict a vanishing cross section in the forward direction. Models which take into account the interference of pole diagrams in the t and s channel and also final-state absorption[8] are in qualitative agreement with our data only at small angles and low energies (see Fig. 2). A recent $U(6)_w \otimes O(2)_w$ symmetry model[9] agrees with our previous data[1] at 1.5 GeV. At small angles, however, the agreement is poor.

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ERRATUM

OBSERVATION OF NAGOAKA'S BOUND STATE FOR CONDUCTION ELECTRONS IN DILUTE MAGNETIC ALLOYS. M. D. Daybell and W. A. Steyert [Phys. Rev. Letters 18, 398 (1967)].

The first paragraph on p. 400 should read, "It is now possible to···," instead of, "It is not possible to···."