and D_2:

$$D_b = D_1 \cos^2\theta + D_2 \sin^2\theta = (8K+1)D_1/9 \equiv rD_1,$$

where θ is the angle between the x axis and the ellipsoid major axis. Since K lies between 12 and 20 depending on impurity concentration,[2] r lies between 11 and 18.

If we assume that electrons are injected at circular frequency ω across an n-p junction at $x=0$, then the solution is obtained by superimposing four solutions of the form

$$n_a = a \exp(i\omega t + \gamma x), \quad n_b = b \exp(i\omega t + \gamma x),$$

where γ must be one of the four roots which make vanish the determinant of the coefficients in the equations

$$(i\omega + \alpha + 3\nu - D_a\gamma^2)a - \nu b = 0,$$
$$-3\nu a + (i\omega + \alpha + \nu - rD_a\gamma^2)b = 0.$$

The solution for γ^2 is readily obtained but is cumbersome. We therefore consider some limiting cases. If ν is much larger than ω or α, then there is one solution with $n_b \cong 3n_a$, and $D\gamma^2 = i\omega + \alpha$. This is the conventional solution which carries an exponentially decaying current. The other solution has $n_a \cong -rn_b$ and $rD_1\gamma^2/(1+3r) = \nu$. This corresponds to cancelling flows of the two classes of electrons.

On the other hand, if either ω or α is comparable to ν, both solutions carry currents varying exponentially in space—one predominantly the a type, and the other predominantly of the b type. The latter type has r times the diffusion constant, and thus about 4 times the diffusion length.

One possible way of observing these effects is to study the admittance of an n-p junction at high frequencies. For a junction parallel to a (100) plane, the admittance varies as $(i\omega D)^{\frac{1}{2}}$ at frequencies much higher than α. For a (111) plane, it will decrease from this value to a high-frequency value of

$$[(i\omega D_a)^{\frac{1}{2}} + 3(i\omega D_b)^{\frac{1}{2}}]/4 \cong 0.95(i\omega D)^{\frac{1}{2}}$$

for $K=15$. To look for this 5% effect, it would probably be advisable to compare (111) and (100) p-n junctions that were otherwise identical.

Another possible method is to use an n-p-n transistor with alpha cutoff comparable to ν. For this case, a (110) plane is preferable, and there are two groups of electrons n_c and n_d injected with equal concentrations at the emitter and having diffusion constants $D_c = D_2 \cong 1.45D$ and $D_d \cong 0.55D$ for $K=15$. At low frequencies, the transconductance is given by the average diffusion constant, or D. The alpha-cutoff frequencies differ by a factor of $D_c/D_d \cong 3$, so that alpha should fall by about 25% due to cutoff of the n_d group before the n_c group is much affected. Under these conditions, the base layer is a filter which passes (1–11) and (1–1–1) electrons to the collector junction. This flow is much more susceptible to a magnetic field in the (1–10) direction than are (111) and (11–1) electrons. Thus, variation with magnetic field of transconductance at high frequency can give information about the degree of filtering and hence about ν. Similar results could be obtained at zero frequency for lifetimes in the vicinity of 10^{-10} sec.

[1] G. Weinreich and H. G. White, Phys. Rev. **106**, 1104 (1957). Weinreich also points out (private communication) that he has observed τ(i. s.) of 1.5×10^{-9} sec at 35°K and that even larger times might be found for the minority-carrier experiments proposed here.

[2] M. Glicksman, Phys. Rev. **108**, 264 (1957). See also C. Herring and E. Vogt, Phys. Rev. **101**, 944 (1956).

High-Energy Photoproduction of π^0 Mesons from Hydrogen*

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The reaction $\gamma + p \rightarrow p + \pi^0$ has been studied by counting coincidences between the recoil proton and one of the meson decay quanta. Detection of the two reaction members at approximately correlated angles discriminates heavily against contributions from multiple meson production. The only other reaction having similar kinematics is the elastic scattering of gamma rays; if the cross section for this process is assumed to be negligible,[1] then coincidences can be shown to be due almost entirely to the process under investigation, even if the ionizing particle is not specifi-

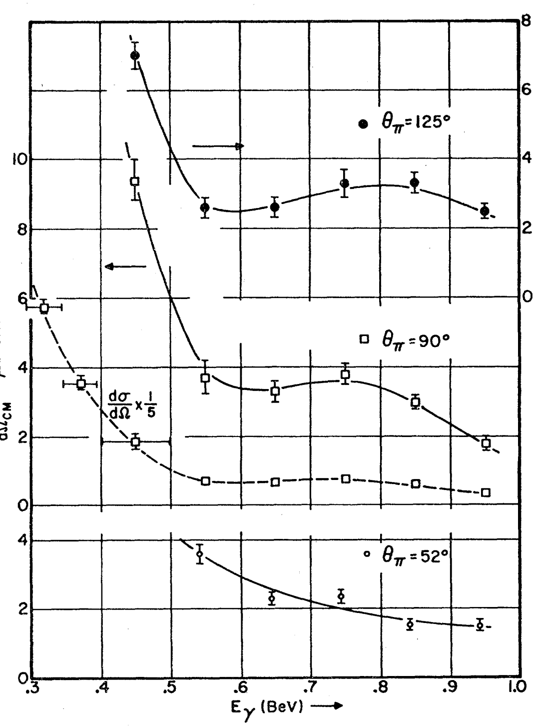

Fig. 1. Differential cross section for neutral pion photoproduction as a function of energy.

cally identified as a proton. This simplification makes it possible to count simultaneously several groups of protons falling into different range intervals; moreover, the background counting rate from target material other than hydrogen is substantially reduced.

Bremsstrahlung from the Cornell electron synchrotron passed through a liquid hydrogen target[2] and was monitored in a Quantameter.[3] The end-point energy was set in each case sufficiently above the maximum energy being studied so that the detailed shape of the spectra was unimportant; thin-target Bethe-Heitler spectra were assumed.

Protons were counted in a range telescope of six scintillators with copper absorbers. The first counter (4 in.×4 in. at 52 in. from the target) was the smallest and defined the solid angle. The angle and energy of the proton determine the reaction completely and are used to measure the energy of the incident photons. To minimize the effect of the finite angular resolution on the energy spread, the absorbers in the proton telescope were suitably tapered in steps equal to the width of the target. Incident energies were defined in 100- or 50-Mev intervals; only at the forward meson angles did the angular spread contribute significantly to smearing out these intervals.

Pion decay quanta passed through an aperture in a 6-in. thick lead wall and were detected in a total-absorption lead glass Čerenkov counter 12 in. in diameter and 14 in. long. The aperture was 3 in. square and was 16 in. from the target, except at the forward meson angle, where the distance was 21 in. Charged particle counts were excluded by a scintillation counter placed behind the aperture and operated in anticoincidence.

Since the meson angle and energy are known from the proton parameters, the efficiency for detecting one of the decay quanta can be calculated readily; its value ranged from 0.06 to 0.4, with an estimated uncertainty of 5%.

Subsidiary experiments showed that only protons were counted in the telescope, and that the kinematics of the reaction agreed with those expected. Also, observations of the pulse-height spectrum delivered by the Čerenkov counter gave distributions as calculated for pion decay quanta under the experimental geometry.

The empty-target background was about 10% of the total. Corrections were made as follows: for random coincidences, at most 8%; for nuclear absorption of protons in the copper absorbers, from 2% to a factor[4] of 2.6; for conversion of decay quanta ahead of the anticoincidence counter, up to 12%. The absolute calibration of the beam monitor is known to within a few percent.

Differential center-of-mass cross sections for pions produced at 52°, 90°, and 125° are shown in Fig. 1. These exhibit results substantially similar to those obtained by other workers[5] and join smoothly with the cross sections measured at lower energies.[6] A simple extension of the $(\frac{3}{2},\frac{3}{2})$ resonance production to these energies would not appear to account well for the results; contribution from one or more higher levels is strongly suggested.[7]

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] T. Yamagata, thesis, University of Illinois (unpublished). By measuring the angular distribution of quanta associated with a given proton, it should be possible to determine the contribution from elastic scattering in the present experiment. Such a measurement is planned.

[2] Raphael Littauer, Rev. Sci. Instr. **29**, 178 (1958).

[3] Robert R. Wilson, Nuclear Instr. **1**, 101 (1957).

[4] A constant absorption cross section of 0.7 barn was used for copper. To check this correction at the worst point, a bremsstrahlung end-point subtraction was taken to define the energy interval 0.9–1.0 Bev, and the protons were allowed to traverse the telescope without stopping. The results agreed to within the statistical accuracy of 20%. The effects of proton scattering were also checked and found to be negligible.

[5] J. I. Vette, Phys. Rev. (to be published); P. C. Stein and K. C. Rogers, Phys. Rev. **110**, 1209 (1958), following Letter.

[6] McDonald, Peterson, and Corson, Phys. Rev. **107**, 577 (1957). This paper also summarizes earlier results of other workers.

[7] Robert R. Wilson, Phys. Rev. **110**, 1212 (1958), this issue.

Photoproduction of π^0 Mesons from Hydrogen at 500–900 Mev*

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THE photoproduction of single π^0 mesons from hydrogen has been studied using the bremsstrahlung beam of the 1.5-Bev Cornell electron synchrotron. Differential cross sections were measured at meson angles of 60°, 90°, and 120° in the center-of-mass system and photon energies in the range 500–900 Mev. The process was identified by counting the recoil protons. Since the reaction is a two-body one, an identification of the recoil proton energy and lab angle suffices to fix the meson center-of-mass angle and the incident photon energy.

A diagram of the apparatus is shown in Fig. 1. Protons were counted in a seven-counter range telescope. Counters 1–6 were scintillation counters, and

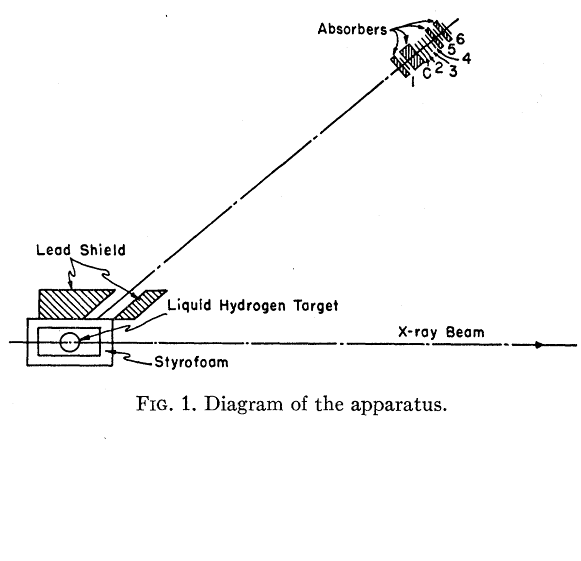

FIG. 1. Diagram of the apparatus.