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ABSTRACT

Angular distributions for the photoproduction of positive pions from hydrogen have been measured at the Berkeley synchrotron. The results are compared with the predictions of the dispersion-relation theory. Calculations of the 90° cross sections from the dispersion relations are in good agreement with Bernardini's low-energy data if the coupling constant is chosen to be 0.072.

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Berkeley, California

The results of the experimental determination of the differential cross sections for the reaction $\gamma + p \rightarrow \pi^+ + n$ at 260 and 290 Mev performed at the Berkeley synchrotron are shown below in Figs. 1 and 2. The equipment and experimental method have been described in detail elsewhere.[1]

The π mesons were detected by counters utilizing the characteristic $\pi - \mu$ decay.[1] The angular distributions were measured in two ranges, 0° to 53° and 28° to 160°, with different counter geometries because of the greatly differing electron background in these two regions. The relative measurements over the forward-angle range were normalized to the absolute cross-section measurements in the 28° to 160° interval by least-squares fitting in the overlap region.

The absolute measurements in the backward-angle range were taken with a simpler counter-telescope geometry which was readily amenable to solid-angle calculations. The efficiency of the counter-telescope was measured by exposing it to a known flux of positive pions from the 184-inch cyclotron. The major uncertainty in the absolute measurements lies in the error in photon flux determined by the "Cornell" thick-walled ion chamber. A careful recalibration of this instrument will be made in the near future. The 290-Mev data of Fig. 2 is not complete in that the small-angle points are missing. These points are being measured.

The theoretical cross sections were calculated from the dispersion-relation formulas as given by Chew et al.[2] except at the F^0 amplitude

(Eq. 22.7 of reference 3) was divided by a "phase-space" factor, $1 + w/M$, where w is the meson total energy in the barycentric system. The value 0.08 was used for f^2, and the constant $N^{(-)}$ of Eq. (22.6) was set equal to zero.

In our initial calculations the P-wave phase shifts were computed from the effective range relations given by Chew and his collaborators. The S-wave phase shifts were taken to obey the relation

$$2\,\delta_1 + \delta_3 = 0.229\,q\ ,$$

which is suggested by Orear's analysis.[3] The results of these calculations are given by the solid curves in the accompanying figures.

We note first that the theory contains the general features of the angular distributions as well as the energy dependence of the 90° cross sections. On the other hand, there appears to be a definite failure in the quantitative predictions of the theory for photon energies of about 290 Mev and higher. It seemed reasonable to ask to what extent the disagreement between theory and experiment was a reflection of our inadequate knowledge of the experimental quantities that occur in the cross-section formula. A partial answer to this question is obtained by investigating the results of varying the small P-wave phase shifts.

As a first attempt we set δ_{11} to zero, leaving the other parameters unchanged, and found that the forward cross section was depressed while the backward-angle cross section was increased. One observes that the agreement with experiment becomes even less satisfactory. On the other hand if, instead, δ_{13} and δ_{31} are set equal to zero (dashed curves in the figures) the forward and backward cross sections are, respectively, increased and lowered with the consequence that the agreement between predicted and theoretical angular distributions is improved. As a third choice we used Anderson's formulae for the three phase shifts δ_{11}, δ_{13}, and δ_{31} (the last two are no longer equal) with the results shown by the "dash-dot" curves in the figures. Empirically, this seems to be the worst choice of all.

We feel that the most important result of our calculations is the discovery that the photoproduction cross section is a very sensitive function of the "small" pion-nucleon-scattering phase shifts. This sensitivity has the unfortunate consequence that any attempt to evaluate the detailed success of the photoproduction theory as formulated by Chew et al. must be inextricably entangled with a very precise investigation of the scattering problem. To this extent we feel that the calculations described here are significant. It is to be emphasized, however, that we attach no especial significance to the particular choice of P-wave phase shifts that gives the best prediction of the experimental results except to the extent that this choice focuses our attention upon certain terms in the dispersion-relation formula.

Examination of the low-energy 90° data seems to indicate that a choice of 0.08 for the coupling constant is somewhat high. If we choose a value of the coupling constant to fit the theory to the five lowest experimental points of Fig. 3, it is found that 0.072 is somewhat more satisfactory. The high-energy predictions of the theory remain essentially unchanged.

We are indebted to Professor Geoffrey Chew and Dr. Michael Moravcsik for many discussions and suggestions, to Professor C. S. Robinson and Mr. Frank R. Tangherlini for making available to us their results from similar computations, and to Mrs. Marjory Simmons for the construction of an IBM 650 program. This work was performed under the auspices of the U.S. Atomic

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3. J. Orear, Nuovo cimento 4, 856 (1957).

4. Michael J. Moravcsik, Phys. Rev. 105, 267 (1957).

FIGURE CAPTIONS

Figure 1: Angular distribution of positive photopions from hydrogen at 260-Mev photon energy. For explanation of the curves see text.

Figure 2: Angular distribution of positive photopions from hydrogen at 290-Mev photon energy. For explanation of the curves see text.

Figure 3: Differential cross section for photopions from hydrogen at 90° (cm.) as a function of energy. For explanation of the curves see text. Experimental data is quoted from Beneventano, Bernardini, Carlson-Lee, Stoppini, and Tau, Nuovo cimento 4, 323 (1956); Tollestrup, Keck, and Warlock, Phys. Rev. 99, 220 (1955); and Walker, Teasdale, Peterson, and Vette, Phys. Rev. 99, 210 (1956). The Tollestrup and Walker points have been increased 7% from the originally quoted values.[4]

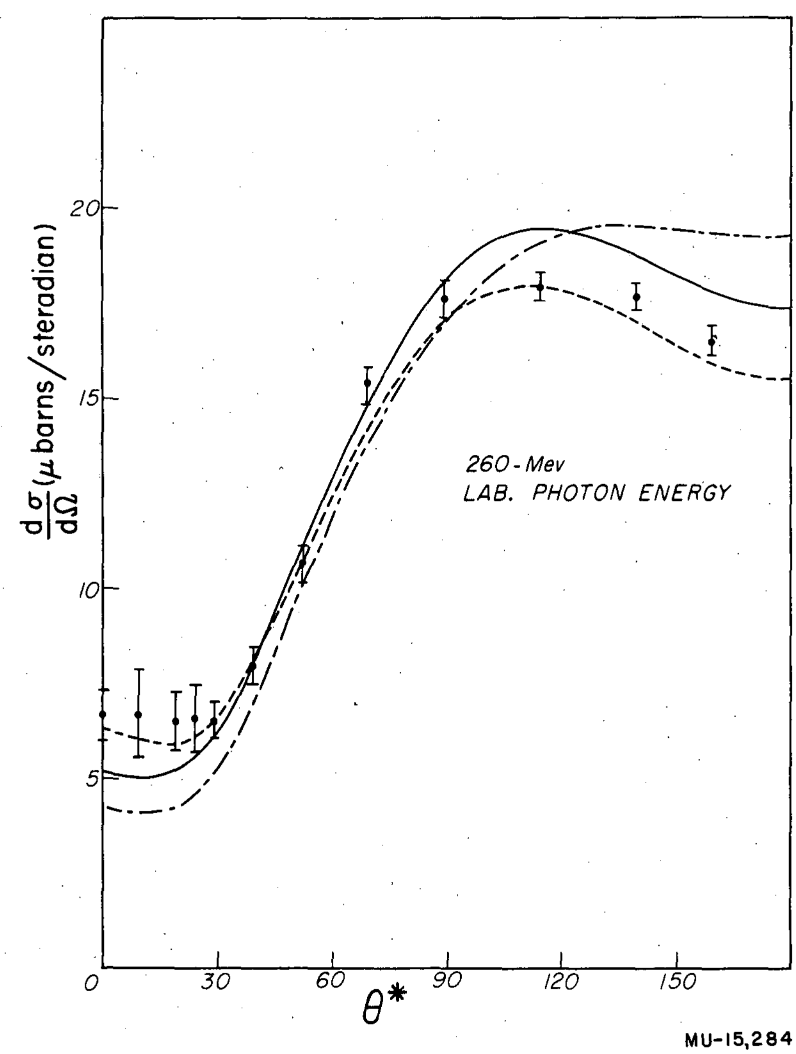
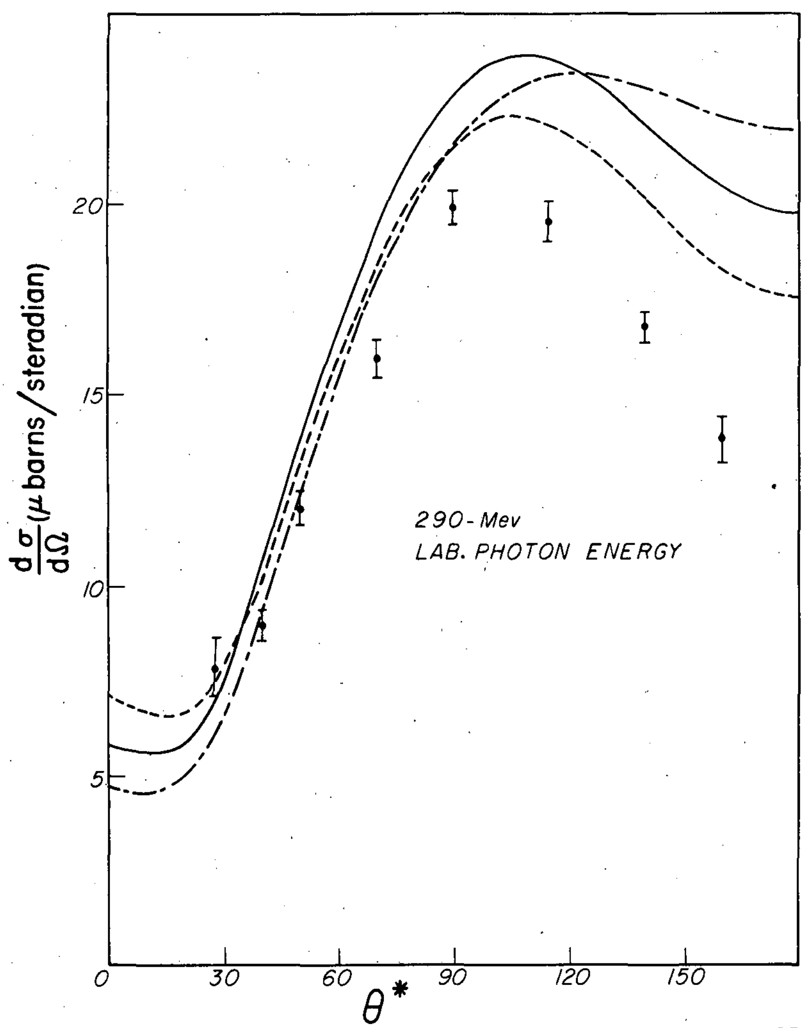

20
15
10
5
0
30
60
90
120
150
$\frac{d\sigma}{d\Omega}$ (μ barns/steradian)
θ*
260-Mev
LAB. PHOTON ENERGY
MU-15,284

Fig. 1



20
15
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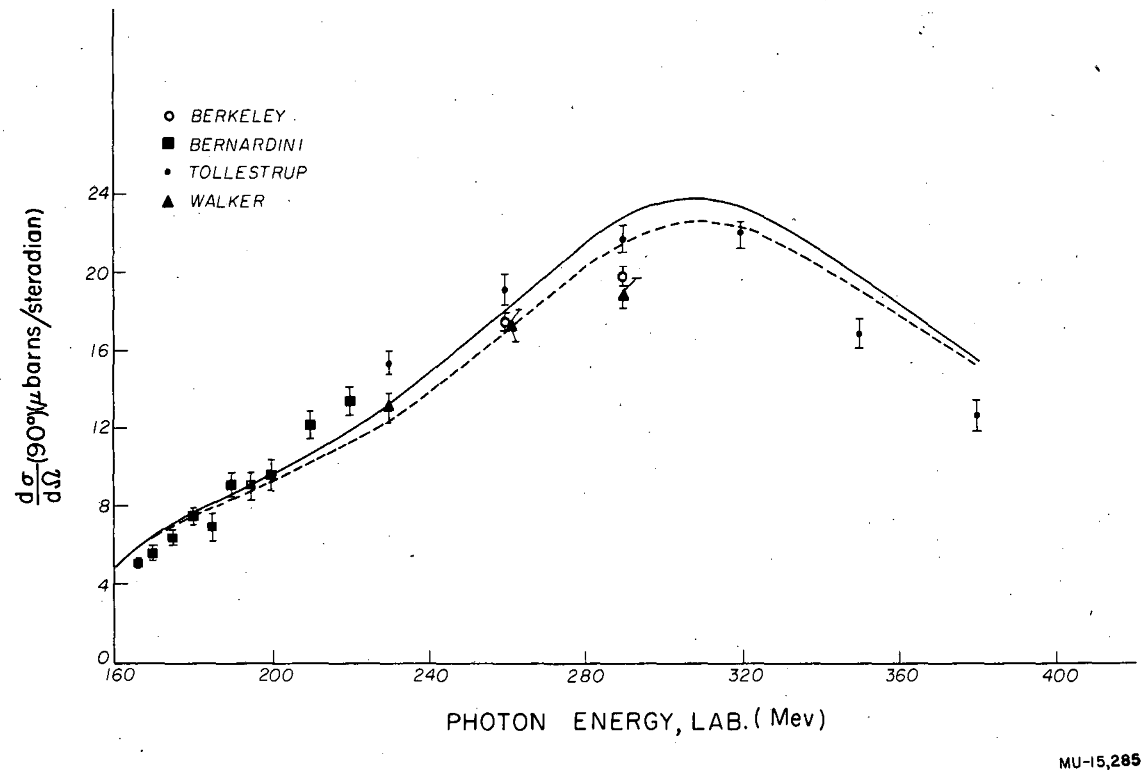
30
60
90
120
150
θ^*
$\frac{d\sigma}{d\Omega}$ (μ barns/steradian)
290-Mev
LAB. PHOTON ENERGY
MU-15,283

Fig. 2



BERKELEY
BERNARDINI
TOLLESTRUP
WALKER
dσ/dΩ (90°)(μ barns/steradian)
0
4
8
12
16
20
24
160
200
240
280
320
360
400
PHOTON ENERGY, LAB. (Mev)
MU-15,285

Fig. 3