Production of Positive Mesons by Photons on Hydrogen*

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A SHORT time ago we reported some features of the production of mesons on carbon and hydrogen by photons.[1] The hydrogen cross sections had been obtained by a paraffin-carbon subtraction. The experiment has been repeated, using the same counting technique, but liquid hydrogen as a target. The new data have better energy resolution and statistical accuracy.

The reaction is $\gamma+P\rightarrow\pi^{+}+N$. The photons are produced in the Berkeley synchrotron with a bremsstrahlung spectrum of 330-Mev maximum energy. In the experiment both meson range and angle of production with respect to the beam are measured. The energy of the meson is computed by means of the range-energy relation, and that of the responsible photon by the conservation laws. It is possible, therefore, to measure cross sections as a function of photon energy, despite the continuous character of the x-ray spectrum.

Figure 1 shows the energy spectrum of mesons produced at 90° to the beam direction, as well as the number of photons as a function of the energy of the mesons which they produce. The

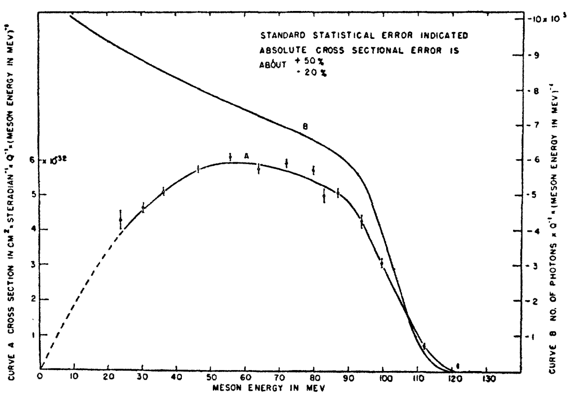

Fig. 1. Energy distribution of π^{+}-mesons at 90° from hydrogen. Also shown is the energy distribution of the photons responsible for meson production (see text). The quantity Q is defined to be the energy in the x-ray beam divided by the maximum photon energy.

x-ray spectrum is the theoretical bremsstrahlung spectrum[2] corrected for: (a) thickness of target producing the x-rays, (b) variation of electron energy due to variations in the magnetic field of the synchrotron during the 2×10^{-3}-sec. period of x-ray emission, (c) angular resolution of the meson production angle.[3]

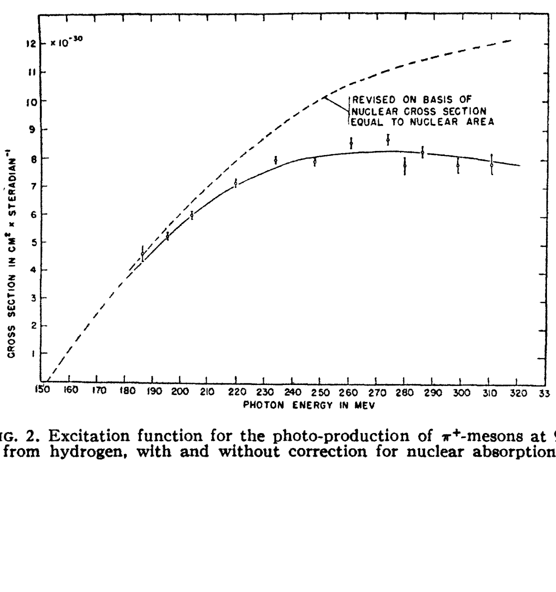

Fig. 2. Excitation function for the photo-production of π^{+}-mesons at 90° from hydrogen, with and without correction for nuclear absorption.

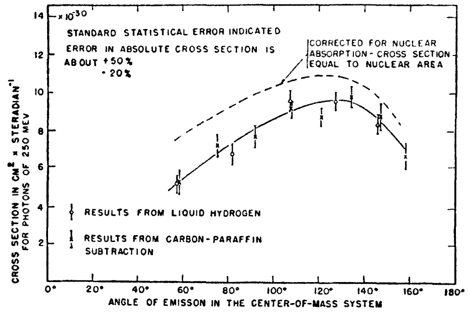

Fig. 3. Angular distribution (in center-of-mass system) of π^{+}-mesons produced in hydrogen by 250-Mev photons (laboratory system), with and without corrections for nuclear absorption.

Dividing the meson spectrum by the photon spectrum, one obtains the cross section for meson production at 90° in the laboratory system as a function of photon energy (Fig. 2) One source of error is the nuclear absorption of the mesons, which discriminates against the higher energy mesons. It is improbable that the nuclear absorption proceeds with larger cross section than nuclear area. To show the upper limit of this effect, we include in Fig. 2 the excitation function, revised on the basis that the nuclear absorption cross section is equal to the nuclear area.[4]

The angular distribution of mesons produced by 250-Mev photons is shown in Fig. 3 together with the older results.[1] Since no attempt has yet been made to obtain an accurate absolute cross section, the results from the two experiments were normalized in absolute magnitude to give the best fit. As has already been pointed out, the angular distribution shows clearly that photomeson production is not a dipole photo-effect, as predicted by scalar meson theory, but that the interaction of the nuclear spin with the photon must play an important role.

A full account of these experiments, together with a discussion of their theoretical significance, is being prepared.

We are indebted to Dr. V. Z. Peterson for the use of his hydrogen target in the angular distribution measurements, and to Professor E. M. McMillan for stimulating discussions about this work. The bombardments were carried out by the synchrotron crew under the direction of W. Gibbins and G. McFarland.

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[1] J. Steinberger and A. S. Bishop, Phys. Rev. **78**, 494 (1950).
[2] This spectrum has been checked and shown to be correct within the accuracy of their experiment by Hartsough, Hill, and Powell (to be published).
[3] Since the meson production angle enters into the correspondence between photon and meson energies, any lack of angular resolution will result in a dispersion in the photon energy in this analysis.
[4] The cross section for producing nuclear events at high meson energies is approximately equal to the nuclear area, according to the experiments of Camerini, Fowler, Lock, and Muirhead, Phil. Mag. **41**, 413 (1950).

On the Gravitational Self-Energy of Light

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ONE of the well-known divergence difficulties in the quantum theory of fields relates to the gravitational effects of light. Indeed, Rosenfeld's result[1] for the self-energy of a photon due to its gravitational field is not only infinite, but the formal expression does not transform as the fourth component of a vector.

To elucidate this point, the problem was taken up using the invariant methods of Schwinger[2] and others, with the following results (in first approximation). (1) The vacuum expectation value of the energy-momentum tensor (properly, pseudotensor) of the