shown on the curves are counting statistics only; the absolute cross sections should be accurate to 15%. The agreement with the low-energy data in the region of overlap is satisfactory except for the tendency of the new data to be above the old in the neighborhood of 450 Mev. This discrepancy is not yet understood.

The total cross section implied by the three excitation curves is also shown in Fig. 1. The second maximum of nearly 100 μb at E_γ of 650 Mev is strongly suggestive of another resonance in the pion-nucleon interaction.[3]

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

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Possible New Isobaric State of the Proton*

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RECENT measurements at Cornell[1–5] and at the California Institute of Technology[6–8] on the photoproduction of single and multiple π mesons in the photon energy region extending from 500 to 1000 Mev have indicated the presence of a broad and strong resonance level at about 750 Mev. This does not correspond to the second resonance peak seen in the scattering of negative pions from hydrogen which would occur at a photon energy of about 1.0 Bev. It is suggested here that the new photoproduction peak corresponds to a separate resolvable excited state of the proton characterized by an isotopic spin of $\frac{1}{2}$, an angular momentum of $\frac{3}{2}$, and a c.m. energy of about 600 Mev. This level would then be expected to dominate single- and multiple-meson production in the above photon energy interval.

The assignment of angular momentum, $\frac{3}{2}$, to the state allows the calculation of angular distributions and the assignment of isotopic spin $\frac{1}{2}$ and the resonance energy permits us to compute the branching ratios of the decay of the state p^{**} into the following decay modes:

$$p^{**}\to\pi^+ + n \qquad [\tfrac{2}{3}] \qquad (1)$$
$$\pi^0 + p \qquad [\tfrac{1}{3}] \qquad (2)$$
$$\pi^+ + p^* \qquad [\tfrac{1}{6}] \qquad (3)$$
$$\pi^0 + p^* \qquad [\tfrac{1}{3}] \qquad (4)$$
$$\pi^- + p^* \qquad [\tfrac{1}{2}] \qquad (5)$$
$$\pi^+ + \pi^- + p \qquad [\tfrac{1}{2}] \qquad (6)$$
$$\pi^0 + \pi^+ + n \qquad [\tfrac{1}{3}] \qquad (7)$$
$$\pi^0 + \pi^0 + p \qquad [\tfrac{1}{6}] \qquad (8)$$
$$K^+ + \Lambda^0 \qquad [1] \qquad (9)$$

where p^* indicates the $(\frac{3}{2},\frac{3}{2})$ isobaric state of the proton, which will subsequently decay into a meson and nucleon.

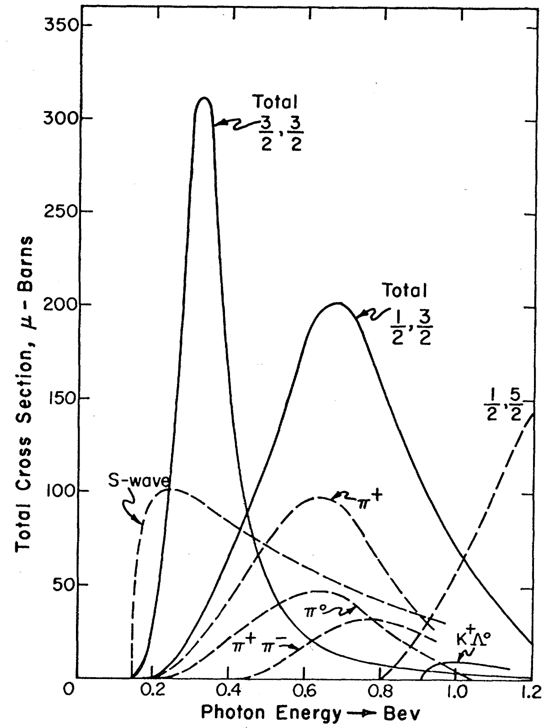

FIG. 1. The full curves show the total cross section for excitation of the $(\frac{3}{2},\frac{3}{2})$ isobaric state and of the proposed $(\frac{1}{2},\frac{3}{2})$ isobaric state plotted as a function of the photon energy. The dashed curves labeled π^+, π^0, $\pi^+\pi^-$, and $K^+\Lambda^0$ show the predicted production of single and multiple mesons as well as of K mesons through the $(\frac{1}{2},\frac{3}{2})$ state on the basis of statistical considerations only. The dashed curve labeled S indicates the direct photoelectric production of π^+. The total excitation through the $(\frac{1}{2},\frac{5}{2})$ resonant state observed in π^-p scattering might appear roughly as indicated by the curve labeled $(\frac{1}{2},\frac{5}{2})$.

Process (9) for K-particle production is energetically impossible at resonance but the width of the level is such that the process could be strongly influenced near the threshold energy of 910 Mev.

The measured angular distributions of single π^0 production[1] from 500 to 850 Mev are reasonably consistent with a $2+3\sin^2\theta$ variation as required by the $\frac{3}{2}$ spin value. The π^+ distributions are strongly peaked forward throughout this photon energy interval—an effect which might be explained by interference with the still large S-wave π^+ production.

At 90° in the c.m. system the measured ratio of single π^+ to π^0 production is roughly 2:1 as required by the assignment of isotopic spin $\frac{1}{2}$, and this is also roughly true of the ratios of these total cross sections.

To obtain a more detailed but still qualitative picture of meson production through this state, the one-level resonance formula that was applied successfully by Brueckner[9] to the $(\frac{3}{2},\frac{3}{2})$ state has been used to compute the total excitation of the $(\frac{1}{2},\frac{3}{2})$ state as a function of energy. The resonance energy of 750 Mev, i.e., 600 Mev in the c.m. system, was chosen by inspection; the reduced width, 58 Mev, was arbitrarily taken to be the same as for the $(\frac{3}{2},\frac{3}{2})$ state, as was the channel width of

$0.88\hbar/\mu c$; finally, the reaction width was adjusted to agree with the total observed cross section at 700 Mev. The resultant variation of the total excitation of the $(\frac{1}{2},\frac{3}{2})$ level with photon energy is shown in Fig. 1. It can be seen to be large in comparison with the excitation of the $(\frac{3}{2},\frac{3}{2})$ level which is also shown. Of course, at such high energies the resonance formula is but an approximation. The formula also makes an absolute prediction for π^-p scattering; this has been computed with the above constants and compared to the experiments of Cool, Piccioni, and Clark.[10] Their measurements are not inconsistent with the presence of the $(\frac{1}{2},\frac{3}{2})$ level but in π^-p scattering the $(\frac{1}{2},\frac{3}{2})$ level is not resolved from their higher $(\frac{1}{2},\frac{5}{2})$ level; it should appear in differential measurements, however.

The branching ratios for decay into the various modes (1) to (9) have been roughly approximated on the basis of momentum space,[11] together with the statistical weight in isotopic spin space.[12] The quantity shown in brackets in the above list of decay modes, Eqs. (1)–(9), is proportional to the statistical weight in isotopic spin space. The result of multiplying the branching ratio by the total excitation of the state is plotted in Fig. 1 for some of the observable decay modes; the qualitative agreement with the measured meson photoproduction cross sections[1–8] is rather striking. The prediction of $\pi^-\pi^+$ multiple production is somewhat low but could be raised by assuming a smaller isobaric radius. Furthermore, direct electric-dipole production of the final state π^-+p^+ can occur in an S wave with a fuzzy threshold at about 450 Mev. This can augment and interfere with the P-wave production of π^- through the $(\frac{1}{2},\frac{3}{2})$ state, i.e., decay mode (5).

The measured photoproduction of K particles[13,14] is about ten times less than a simple momentum-space argument would allow, showing that the coupling into the $K^+-\Lambda^0$ decay mode is considerably weaker than for decay into meson-nucleon systems. If the $(\frac{1}{2},\frac{3}{2})$ state is important in K^+ production, then the angular distribution should be of the form $2+3\sin^2\theta$, if the $K^+-\Lambda^0$ system is pseudoscalar.

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

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[12] I am indebted to Dr. E. Salpeter for the calculation of the statistical weights in isotopic spin space on the basis of the Clebsch-Gordan coefficients and on the basis of the equality in number of symmetrical and antisymmetrical states.

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Photoproduction of K^+ Particles in Hydrogen at Forward Angles*

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THE method of Donoho and Walker[1] for measuring K^+-particle photoproduction in hydrogen has been improved in order to provide a clearer identification of the K particles and to allow measurements at a more forward angle, 10° in the lab system. The apparatus used is very similar to that shown in Fig. 1 of the Letter of Donoho and Walker.[1] It consists of a magnetic spectrometer with a counter telescope placed at the rear focus. The telescope is composed of three scintillation counters, a Čerenkov counter, and sufficient absorber to prevent protons from entering the last scintillator. A special thin counter is used to define the aperture of the magnet and as the first counter in a time-of-flight measurement. This aperture counter is designed to avoid the possibility of protons (or other particles) emitted from the hydrogen scattering from the pole pieces or lead slits and hitting the scintillation counters. Such scattered protons had been found previously, and were easily confused with K particles. Unfortunately, protons from other sources, such as the target walls and air path, could pass through this counter and scatter into the detectors.

The Čerenkov counter proved to be better than 98% efficient in eliminating pions with $\beta=0.95$, but also eliminated 8% of the protons with $\beta=0.5$, presumably because of weak scintillation in the U. V. T. Lucite used.

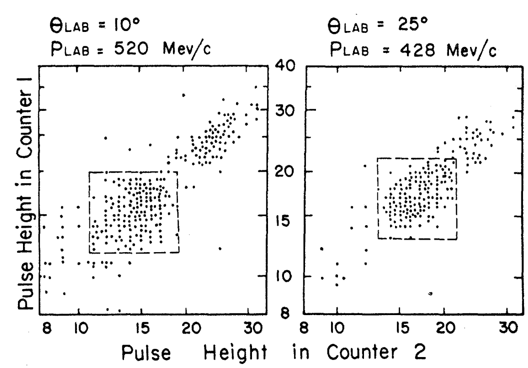

FIG. 1. Correlation in pulse height for counters 1 and 2. The K^+ mesons are 1.47 and 1.75 times minimum-ionizing, respectively. The points with greater pulse heights correspond to scattered protons.