nal detectable. This was accomplished most simply by operating in a weak field $H_0 \approx 0.01$ gauss and an observed Larmor frequency $\omega_0/2\pi$ of 24 kc/sec. The $g=4$ resonance at 48 kc/sec was clearly observable on the oscilloscope with or without a linear polarizer in the light beam. Rotation of the linear polarizer verified, within signal-to-noise limitations, that the signal amplitude obeyed the $\sin^2\theta$ dependence to be expected by generalizing the above arguments (θ is the angle between light axis and H_0).

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PION-PION INTERACTION IN PION PRODUCTION BY π^+-p COLLISIONS*

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Since the first conjectures[1] that rise in the total π^--p cross section between 300 and 600 Mev might be caused by a pion-pion interaction, this subject has received considerable attention. Theoretical analysis[2] of high-energy electron scattering on protons and neutrons has predicted a resonance in the pion-pion interaction at a total di-pion energy (ω) of 4 to 5 pion masses, with isotopic spin and angular momentum both equal to one. Several analyses of π^--p experiments[3] in the 1-Bev energy range have tended to confirm this prediction, and application[4] of the Chew-Low method has indicated a steep rise in the pion-pion cross section above $\omega=4$. Recent work[5] with 1.9-Bev π^--p collisions shows a peak in the pion-pion interaction at $\omega \sim 5.5$. We report here evidence of pion-pion interaction in π^+-p collisions at three separate energies, which show striking effects attributable to a pion-pion resonance with ω of about 5.5 pion masses.

The data presented are results of a systematic study of pion-proton reactions at kinetic energies of 910 Mev, 1090 Mev, and 1260 Mev, which is still in progress. Photographs taken at the Cosmotron in the Brookhaven 20-inch hydrogen bubble chamber have been scanned for all interactions. All two-pronged collisions have been measured on a projection microscope of the Franckenstein type and have been processed by the Yale spatial reconstruction and kinematical fitting programs on the IBM 704 of the New York University Computing Center. Each possible identification assigned by the computation has been compared by a physicist with other information (including ionization densities) available from the photographs, to establish the final identification. Cross sections for the various reactions, based upon the first compilation of these events, are shown in Table I.

The influence of pion-pion interaction will appear most readily in the single pion production processes: $\pi^+ + p \rightarrow p + \pi^+ + \pi^0$ and $\pi^+ + p \rightarrow n + \pi^+ + \pi^+$. Accordingly, the Q value of the two outgoing pions (that is, the kinetic energy of their relative motion in their mutual center of momentum) has been computed for each individual occurrence of single pion production. The distribution of Q values at each energy is shown in Fig. 1. This figure includes all identified events, without additional selection.

In the reaction $\pi^+ + p \rightarrow p + \pi^+ + \pi^0$, a definite peak appears at each energy in the Q-value region of 400-500 Mev, extending well above the number of events to be expected from a uniform momentum-space distribution of secondary particles. The peaks also extend well above the distribution to

Table I. π^+-p cross sections (in mb) at 910-Mev, 1090-Mev, and 1260-Mev kinetic energy.

	910 Mev	1090 Mev	1260 Mev
σ_{total}	24.5 ± 1.3	30.1 ± 1.6	40.3 ± 2.2
σ_{elastic}	10.3 ± 0.9	12.6 ± 1.1	16.5 ± 1.4
$\sigma(p\pi^+\pi^0)$	10.4 ± 0.9	10.8 ± 1.0	11.9 ± 1.2
$\sigma(n\pi^+\pi^+)$	2.6 ± 0.4	2.5 ± 0.5	4.6 ± 0.7
$\sigma_{\text{multiple } \pi \text{ prod.}}$	1.3 ± 0.3	3.9 ± 0.6	6.9 ± 0.9
$\sigma(\Sigma$-$K)$	$0.034^{+0.018}_{-0.012}$	0.25 ± 0.02	0.42 ± 0.07

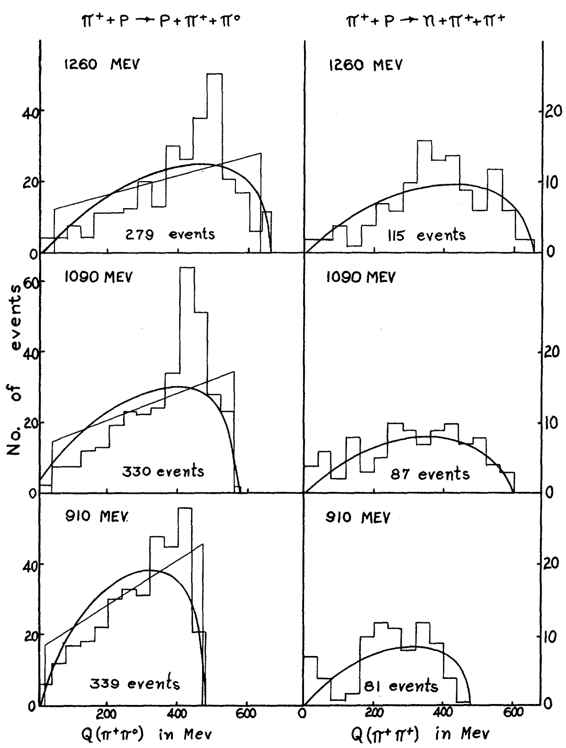

FIG. 1. Distribution of pion-pion Q values (that is, kinetic energy of the two outgoing pions in their mutual center-of-momentum system) for the reactions $\pi^+ + p \rightarrow p + \pi^+ + \pi^0$ and $\pi^+ + p \rightarrow n + \pi^+ + \pi^+$ at 910-Mev, 1090-Mev, and 1260-Mev laboratory kinetic energy of the incident pion. The curved lines are the Q distribution resulting from uniform distribution of the secondary particles in momentum space. The straight lines give the Q distribution resulting from isotropic decay of a pion-proton isobar of unique mass 1230 Mev.

be expected from isotropic decay of the $\frac{3}{2}$-$\frac{3}{2}$ pion-nucleon isobar, which is known to influence this reaction.[6]

In the pion-pion Q distributions for $\pi^+ + p \rightarrow n + \pi^+ + \pi^+$, on the other hand, no peaks appear in the region 400 to 500 Mev. (There may be a peak for the 1260-Mev pion energy in the vicinity of 350 Mev, but this is not statistically certain.)

Now, two π^+ mesons can only have a total isotopic spin of 2, whereas the π^+-π^0 combination contains isotopic spin values of 1 and 2. Therefore, a resonance in the $I=1$ state can only appear in the $p\pi^+\pi^0$ reaction. On the other hand, if charge independence is assumed, a resonance in the $I=2$ state should appear 80% as $n\pi^+\pi^+$ reactions and 20% as $p\pi^+\pi^0$. We conclude that the interaction responsible for the observed peaks is overwhelming in the state $I=1$, and possibly not at all in the state $I=2$. This is consistent both with theoretical predictions[1,2] and with the conclusions of Walker et al.[5]

At present, only an approximate estimate of the pion-pion resonance energy can be made from these data. At 910 Mev, the peak is attenuated and shifted to lower energies by the lack of available momentum space at higher Q values. The peak at 1090 Mev also seems to be about 50 Mev lower than at 1260 Mev. However, the data are not inconsistent with a single resonance with ω between 5.0 and 5.5, corresponding to a total dipion mass of 700 to 770 Mev. The full width at half maximum appears to be ~90 Mev. (The rms error in the determination of Q values is less than 10 Mev.)

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