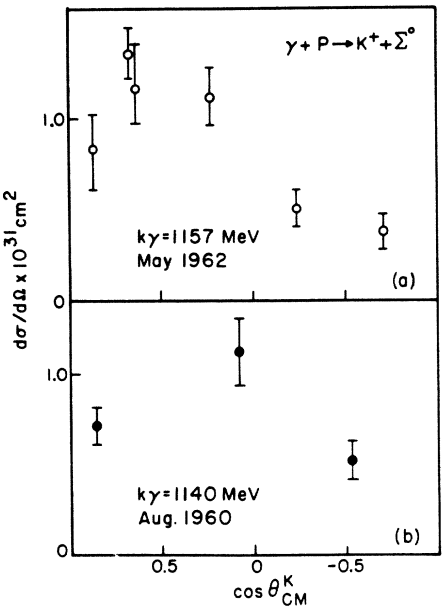

FIG. 4. Differential cross section for $\gamma+p\rightarrow K^{+}+\Sigma^{0}$. The new measurements for $k_{\gamma}=1157$ MeV are given in (a). In (b) are three points for $k_{\gamma}=1140$ MeV obtained at Cornell in 1960.

the 1054-MeV data. These results are consistent with the results of Bertanza et al. which show a resonance at a center-of-mass momentum of 275 MeV/c for the reaction $\pi+p\rightarrow K^{0}+\Lambda^{0}$.[5]

The angular distribution for K^{+}-Σ^{0} production at 1157 MeV (Fig. 4) has larger statistical errors as a result of having to measure a small difference between the yields at two different photon energies. For the same center-of-mass momentum in the K^{+}-Λ^{0} production, the corresponding photon energy would be 1020 MeV. However, as can be seen, there is a distinct difference in the nature of the angular distributions, with an indication of a decrease in cross section for K^{+}-Σ^{0} reaction at forward K-meson angles. The older Cornell data at 1140 MeV are also shown.[6]

Further measurements are in progress to determine more certainly the K^{+}-Σ^{0} angular distribution, and to extend the K^{+}-Λ^{0} measurements to higher energies.

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ω-MESON PRODUCTION IN PROTON-PROTON INTERACTIONS AT 2.85 BeV*

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An investigation has been made of multiple meson production from the interaction of 2.85-BeV kinetic energy protons on hydrogen. The occurrence of the ω resonance in the reaction $p+p\rightarrow p+p+\pi^{+}+\pi^{-}+\pi^{0}$ is indicated by a deviation from phase space in the distribution of the effective mass of the three-meson system. Hitherto the ω, which decays into $\pi^{+}\pi^{-}\pi^{0}$ and has an effective mass between 765 and 785 MeV, had been observed in the interactions of π^{-} mesons on deuterons[1] and in the annihilation of antiprotons[2]. The effective-mass distributions obtained here give no evidence of the presence of the η or α resonances at this energy.

Measurement of four-prong events from the BNL 20-in. hydrogen bubble chamber yielded the following results:

$$p+p\rightarrow p+p+\pi^{+}+\pi^{-}, \quad \text{(821 cases)} \quad (1)$$

$$\rightarrow p+n+\pi^{+}+\pi^{+}+\pi^{-}, \quad \text{(299 cases)} \quad (2)$$

$$\rightarrow p+p+\pi^{+}+\pi^{-}+\pi^{0}. \quad \text{(213 cases)} \quad (3)$$

We believe the identification of the events to be essentially unambiguous. The method of analysis is described by Hart et al.[3] One advantage of studying multiple pion resonances in proton-

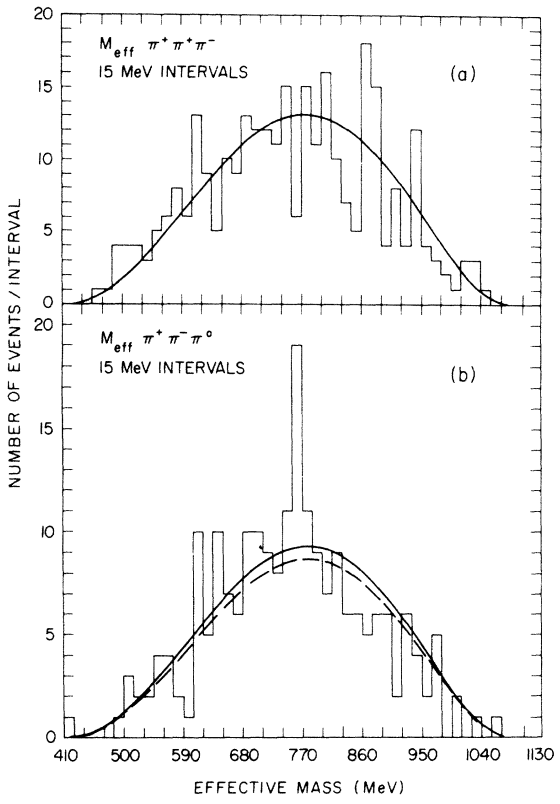

FIG. 1. Histograms of the effective-mass distributions of the three pions from the reactions $p+p \rightarrow p+n+\pi^+ +\pi^+ +\pi^-$ (a) and $p+p+\pi^+ +\pi^- +\pi^0$ (b). The solid curves represent phase space. The four distributions are normalized to the same area. The dashed curve is the phase-space distribution normalized to the area of the histogram excluding the peak.

proton interactions is that there are no extra pions to create a background.

Figures 1(a) and 1(b) are the effective-mass distributions of the three pions of Reactions (2) and (3) plotted in intervals of 15 MeV. The effective mass is defined as $m^* = \{(\sum_i E_i)^2 - (\sum_i \vec{p}_i)^2\}^{1/2}$ The solid curves represent relativistically invariant phase space distributions normalized to the same total area. The peak in the effective-mass plot for the $\pi^+\pi^-\pi^0$ reaction is attributed to the ω meson. Its mass, $m^* = 766 \pm 4$ MeV, is about 15 MeV lower than that reported in reference 2, but agrees within the errors with reference 1. The full width at half maximum, Γ, is about 25 MeV. This is consistent with a resolution of ~30 MeV obtained for events of type (3) in the effective mass region 700 to 800 MeV. The resolution function is obtained by plotting an ideogram of the uncertainty in the effective mass, as obtained from the variance-covariance matrix calculated by the IBM-7090 program GUTS.[4]

To obtain a cross section for the reaction $p+p \rightarrow p+p+\omega$, the phase space distribution of Fig. 1(b) has been renormalized. The dashed curve in the figure represents phase space normalized to the total number of events, less those in the region between 750 and 785 MeV which lie above the solid curve. The dashed curve fits the rest of the histogram well. The fourteen events in the peak above the curve yield a cross section $\sigma_{p+p \rightarrow p+p+\omega} = 48 \pm 13$ μb. No excess of $\pi^+\pi^+\pi^-$ events above phase space is observed in this effective mass region, again confirming that the ω is in an $I=0$ state.

An examination of Fig. 1 gives no indication of the η or α resonances, both of which are reported in proton-proton interactions at 2 BeV kinetic energy.[5] The η resonance, with an effective mass of ~550 MeV and $I=0$, has also been observed in the reactions $\pi^+ + d \rightarrow p+p+\eta$[1] and $K^- + p \rightarrow \Lambda + \eta$.[4] The α resonance with a mass of ~625 MeV and $I=1$ or 2 is observed by Pickup et al.,[5] in both $\pi^+\pi^-\pi^0$ and $\pi^+\pi^+\pi^-$ final states of the p-p reaction. It is interesting that at 2 BeV, η production has a cross section of ~50 μb and the ω resonance is not observed (although there may be an indication of it), while at 2.85 BeV the situation is just the reverse. It is true that in each case, the resonance which is not observed is near the end of the permitted phase-space region of the three-meson system, but this is not necessarily an explanation for the behavior. It may be possible that as the threshold is crossed for the ω, the η is in some way inhibited. The α resonance is more centrally located in phase space and would be expected to be observed in both cases.

A number of decay modes involving two charged prongs, other than the well-known $\pi^+\pi^-\pi^0$, have been proposed for the ω and η. Nambu and Sakurai[6] have suggested that if the η and ω are vector mesons (spin and parity 1^-) associated with the isoscalar form factor of the nucleon, they could have branching ratios of a few percent for $\omega, \eta \rightarrow e^+ + e^-$. In an attempt to find this decay mode, we have examined twenty-three four-prong events which have two prongs identified as electrons. All were Dalitz pairs from neutral pions produced in the interaction; none fit $\omega, \eta \rightarrow e^+ + e^-$.

As a second possibility, Feinberg[7] has calculated branching ratios for (a) $\omega \rightarrow \pi^+ + \pi^-$ and (b) $\omega \rightarrow \eta + \pi^0$. If the ρ^0 and ω resonances have the

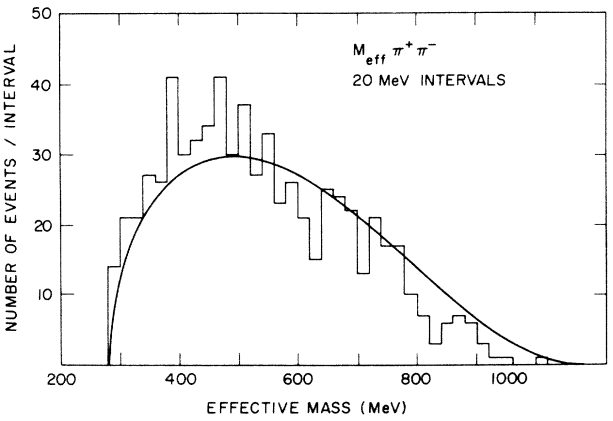

FIG. 2. Histogram of the effective mass distribution of the two pions from the reaction $p+p \rightarrow p+p+\pi^+ +\pi^-$. The solid curve is the phase-space distribution normalized to the same total area.

same spin and parity, and if the ζ resonance does not exist, electromagnetic mixing could lead to an order of magnitude higher rate for (a) and (b) than for the usual $\omega \rightarrow \pi^+ + \pi^- + \pi^0$ (c). On the other hand, Gell-Mann et al.[8] calculate the decay mode ratio a/c to be only ~5%.

To search for the mode $\omega \rightarrow \pi^+ + \pi^-$, we have plotted in Fig. 2 the effective mass m^* of the $\pi^+\pi^-$ combination from 683 events of the type $p+p \rightarrow p+p+\pi^+ +\pi^-$. The ω decay should appear as a peak at ~770 MeV, within the broad band (700-800 MeV) of the ρ^0 decay. Neither the two-π decay of the ω nor any sign of the expected $\rho^0 \rightarrow \pi^+ + \pi^-$ is observed. The absence of the ρ^0 can possibly be explained by the fact that it has a cross section comparable to the ω, and this small number of events, spread over the broad effective-mass range of the ρ^0, would not be observed. Considering the strength of the $\frac{3}{2}, \frac{3}{2}$ πp isobar, and the possibility of final state interactions, it is not surprising that multiple-pion resonances appear to have small cross sections when there are two nucleons present.

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K^+-p INTERACTION FROM 140 TO 642 MeV/c*

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A detailed investigation of the energy dependence of the K^+-proton scattering cross section at low momenta has been carried out. In the region from 140 to 642 MeV/c, the nuclear cross section varies little with energy. The cross sections are distinctly lower than values quoted earlier.[1] The momentum dependence of the phase shifts below 300 MeV/c can only be interpreted as s-wave scattering and does not admit isotropic p-wave solutions such as were obtained as possible ambiguities at 810 MeV/c.[2] The isotropy in the differential cross sections and the constructive interference with Coulomb scattering at each of the momenta show that the repulsive s-wave character of the K^+-p $T=1$ state persists throughout this region.

An s-wave effective-range fit to the experimental