apart from the propagators and an implied integration over d^4k, to be

$$\epsilon_{\mu\nu\alpha\beta}A_\mu p_\nu r_\alpha k_\beta,$$

where A is a 4-vector related to the incident state and the outgoing proton, p is the 4-momentum of the outgoing κ state, and k is the 4-momentum of the internal pion at the $K^* \to K\pi\pi$ vertex. Using the method of Feynman parametrization and symmetric integration (note that the integral over the internal loop is convergent), the amplitude can be shown to be

$$\epsilon_{\mu\nu\alpha\beta}A_\mu p_\nu r_\alpha q_\beta I,$$

where q is the 4-momentum of the two spectator pions, and I is essentially the scalar triangle graph. In the center-of-mass system of the κ, this becomes

$$p_0 \mathbf{A}\cdot\mathbf{p}_K \times \mathbf{p}_{2\pi} I,$$

where $\mathbf{A}$ is a 3-vector (perhaps the momentum of one of the protons); and $\mathbf{p}_K$ and $\mathbf{p}_{2\pi}$ are, respectively, the 3-momentum of the outgoing K meson and the 3-momentum of the two spectator pions. Hence, the effect of the K^* spin can be included with a kinematical factor (a function of the external invariants) multiplying the scalar triangle graph. A further treatment will appear elsewhere.[15] In our actual calculations we have taken account of the scalar graph I and the momentum factor $\mathbf{p}_K$. Their effects are included in our expression for the amplitude (II.7).

ACKNOWLEDGMENTS

I would like to thank Professor J. D. Jackson and Professor R. Schult for invaluable criticism and guidance throughout the course of this work.

PHYSICAL REVIEW VOLUME 139, NUMBER 4B 23 AUGUST 1965

Strange-Particle Production in π^+-p Collisions*

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(Received 13 April 1965)

Strange particles produced in interactions of positive pions with protons have been studied with the Brookhaven 20-in. bubble chamber, which was exposed to π^+ beams of 2.35, 2.62, and 2.90 BeV/c. Cross sections are presented and the production of resonances is discussed. The outstanding feature of the multiparticle final states is that they are dominated by K-π, K-$\bar{K}$, and Y-π resonances. The isotopic spin of the φ is confirmed to be zero and no evidence is found for a φ decay into three pions.

APPROXIMATELY 600 strange-particle events[1] were found in an exposure of the Brookhaven 20-in. hydrogen bubble chamber to a π^+ beam at the AGS. There were 30 000 pictures taken at an incident π^+ momentum of 2.35 BeV/c, fifteen thousand at 2.62 BeV/c, and thirty thousand at 2.90 BeV/c. The reactions which were studied[2] are shown in Table I.

SCANNING, MEASURING, AND CLASSIFICATION TECHNIQUE

The film was scanned for all interactions in which a kink appeared in a track and/or one or more V's appeared. To each track an ionization number was assigned which designated whether the bubble density was light, medium, or heavy. From the ionization number and measured momentum alone, a π and K could be distinguished up to a momentum of 500 MeV/c and a π and proton could be distinguished up to 1 BeV/c. The details of this technique are described elsewhere.[3] Each of the events was digitized and processed through track reconstruction and kinematic fitting programs which tested for likely interpretations.

After imposing the conditions that the χ^2 probability for a hypothesis be greater than 5% and that the ionization code number be consistent with the momentum and mass, a logic program cataloged the events. The identification of an event was said to be ambiguous when it fit two or more hypotheses and one was not more than three times more likely than any other. Otherwise the identification was considered unambiguous and the most likely hypothesis was assumed to be

* This work is supported by the U. S. Atomic Energy Commission.

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[1] N. Gelfand and D. Berley, post deadline paper, American Physical Society, Washington meeting, 1963 (unpublished).

[2] Other studies of strange-particle production in π^+-p interactions are C. Baltay, H. Courant, W. J. Fickinger, E. C. Fowler, H. L. Kraybill, J. Sandweiss, J. R. Sanford, D. L. Stonehill, and H. D. Taft, Rev. Mod. Phys. **33**, 374 (1961); F. Grard and G. A. Smith, Phys. Rev. **127**, 607 (1962); F. Crawford, F. Grard, and G. A. Smith, *ibid.* **128**, 368 (1962); H. W. Foelsche, H. L. Kraybill, and J. R. Sanford, Bull. Am. Phys. Soc. **8**, 342 (1963); S. S. Yamamoto, L. Bertanza, G. C. Moneti, D. C. Rahm, and I. O. Skillicorn, Phys. Rev. **134**, B383 (1964).

[3] C. Alff, D. Berley, D. Colley, N. Gelfand, U. Nauenberg, D. Miller, J. Schultz, J. Steinberger, T. H. Tan, H. Brugger, P. Kramer, and R. Plano, Phys. Rev. Letters **9**, 322 (1962). N. Gelfand, thesis, Columbia University (unpublished).

TABLE I. Reactions which were studied. The table contains the data relevant to the cross-section determinations. The column which lists "decay modes required" identifies the topologies used to obtain the cross sections. The branching fractions are computed from the compilation by M. Roos [Rev. Mod. Phys. **35**, 314 (1963)]. The uncertainties listed are the statistical uncertainties.

Reaction $\pi^+p\to$	Decay modes required	Branching fraction	Number of unabmiguous events	One-half number of ambiguous events	Cross section (μb)
Σ^+K^+	$\Sigma^+\to n\pi^+$	0.50	40	$\cdots$	136 ± 21
$\Sigma^+\pi^+K^0$	$K^0\to\pi^+\pi^-$ and $\Sigma^+\to\pi^+n$	0.175	12	0	117 ± 34
$\Sigma^0K^+\pi^+$	$\Sigma^0\to\Lambda^0\gamma\to p\pi^-\gamma$	0.66	13	2.5	40 ± 12
$\Lambda^0K^+\pi^+$	$\Lambda^0\to p\pi^-$	0.66	23	2	65 ± 15
$\Sigma^+\pi^+K^0\pi^0$	$K^0\to\pi^+\pi^-$ and $\Sigma^+\to\left\{\begin{matrix}\pi^+n\\ \pi^0p\end{matrix}\right\}$	0.35	0	0	<6
$\left\{\begin{matrix}\Lambda^0\\ \Sigma^0\end{matrix}\right\}K^+\pi^+\pi^0$	$\Lambda^0\to p\pi^-$	0.66	20	4	61 ± 16
$\Lambda^0\pi^+\pi^+K^0$	$K^0\to\pi^+\pi^-$ or $\Lambda^0\to p\pi^0$	0.78	33	4	81 ± 17
$\Sigma^0\pi^+\pi^+K^0$	$K^0\to\pi^+\pi^-$ and $\Sigma^0\to\Lambda^0\gamma\to p\pi^-\gamma$	0.23	0	0	<8
pK^+K^0	$K^0\to\pi^+\pi^-$	0.35	5	0	24 ± 11
$p\pi^+K^0\bar{K}^0$	Assumed K_1, K_2; $K_1\to\pi^+\pi^-$	0.70	6	0.5	16 ± 7
$p\pi^0K^+\bar{K}^0$	$K^0\to\pi^+\pi^-$	0.35	3	0	14 ± 8
$nK^+\pi^+K^0$	$K^0\to\pi^+\pi^-$	0.35	2	1	14 ± 9

the correct one. The only exception to this rule was if an event fit

$$\pi^++p\to\Sigma^++K^+$$

it was assumed to be the two-body raection. Unless otherwise specified the data presented are from events which were unambiguously identified.

CROSS SECTIONS

The cross sections for production in the channels which were studied are shown in Table I. The data from all three energies are combined. To reduce systematic uncertainties, the topologies used in the cross section determinations were those which lead to a small number of ambiguous identifications and had a detection efficiency close to unity. These topologies are identified in the table by the corresponding kaon and hyperon decay modes. Only events with production vertices in a fiducial region were counted and the systematics of the pion flux determinations, scanning efficiency, and data processing losses are similar to those discussed elsewhere.[3] The corrections due to particles which were produced in the fiducial volume and decayed outside the visible region are small and are neglected. Events whose identification was ambiguous between two channels are divided between the two channels with equal weight. There were no examples of threefold ambiguities.

DISCUSSION

Two-Body Final State

The only two-body final state reported here comes from the reaction

$$\pi^++p\to\Sigma^++K^+. \quad (1)$$

The Σ^+ angular distribution in the rest system of

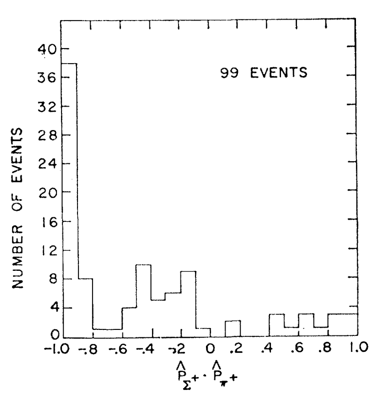

FIG. 1. Angular distribution of the Σ^+ in the reaction $\pi^++p\to\Sigma^++K^+$. The distribution is in the rest system of production. $\hat{P}_{\Sigma^+}$ is a unit vector in the direction of the Σ^+ and $\hat{P}\pi^+$ is a unit vector in the direction of the incident pion. The distribution has a sharp peak in the backward direction with a secondary peaking $\hat{P}_{\Sigma^+}\cdot\hat{P}\pi^+\cong-0.3$. The data of all the energies studied as well as the events with the π^+n and π^0p decay modes of the Σ^+ are combined together.

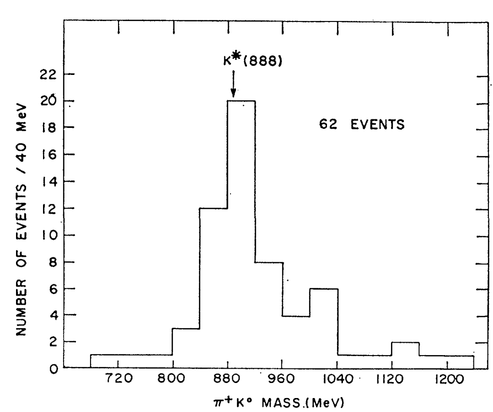

FIG. 2. π^+K^0 mass spectrum in the reaction $\pi^++p\to\Sigma^++K^0+\pi^+$. The data with all three incident-pion energies are combined. Included are all events regardless of whether the K^0 decay was visible or not. The contamination of the sample with events in which one or more neutral pions is also produced is estimated to be less than $\sim5\%$. Approximately 80% of the events fall within the K^* mass region (888 MeV, $\Gamma/2\cong25$ MeV).

TABLE II. The observed cross sections for the reaction $\pi^+ + p \rightarrow \Lambda^0\pi^+\pi^+K^0$ or $\Lambda^0\pi^+\pi^0K^+$. The available Q is the sum of the $Y_1^*(1385)$ and $K^*(888)$ kinetic energies in the reaction $\pi^+ + p \rightarrow Y_1^*(1385) + K^*(888)$.

Incident-pion momentum (BeV/c)	σ (μb)	Q (MeV)
2.35	64±19	39
2.62	190±60	148
2.90	190±30	235

production is shown in Fig. 1. The Σ^+ is emitted preferentially in the backward direction,[2] with a small secondary peak at $\hat{P}_{\Sigma^+}\cdot\hat{P}_{\pi^+} \cong -0.3$.

Multiparticle Final States

The outstanding feature of the multiparticle final states is the dominant production of the K-π, K-$\bar{K}$, and Y-π resonances. The production of these resonances will be discussed in turn.

(1) K^* production[4] in the reaction

$$\pi^+ + p \rightarrow \Sigma^+ + K^{*+} \searrow \pi^+ + K^0. \quad (2)$$

The invariant mass spectrum of the π^+-K^0 system is presented in Fig. 2. Data from events with and without visible K^0 decays are combined. When the K^0 decay is not visible it is usually impossible to distinguish reaction (2) from the one with the four-body final state $\Sigma^+\pi^+\pi^0K^0$. There is generally no such ambiguity when the K^0 decay is observed and from these events the $\Sigma^+\pi^+\pi^0K^0$ contamination is estimated to be less than 5% in the sample presented in Fig. 2. There is no similar

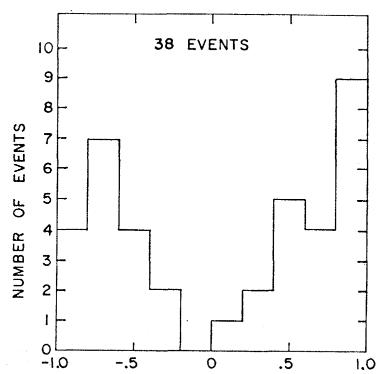

FIG. 3. Angular distribution of K^* produced in the reaction $\pi^+ + p \rightarrow \Sigma^+ + K^{*+}$. A $K^0\pi^+$ combination was identified as the decay products of a K^* if the invariant mass of the $K^0\pi^+$ combination $840 < M_{K^0\pi^+} < 940$ MeV. $\hat{P}_{K^*}$ is a unit vector in the K^* direction of motion and $\hat{P}_{\pi^+}$ is a unit vector in the incident π^+ direction of motion.

[4] M. Alston, L. Alvarez, P. Eberhard, M. Good, W. Graziano, H. Ticho, and S. Wojcicki, Phys. Rev. Letters 6, 300 (1961).

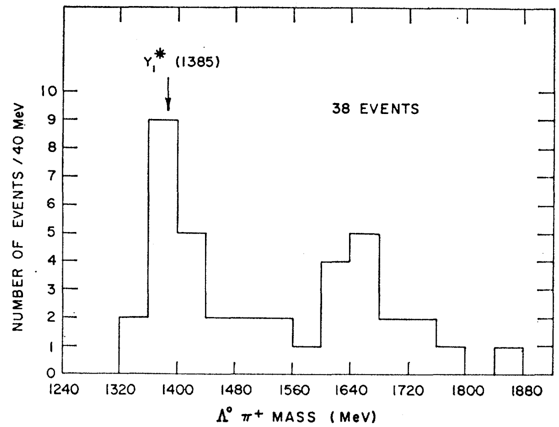

FIG. 4. $\Lambda^0\pi^+$ mass spectrum in the reaction $\pi^+ + p \rightarrow \Lambda^0 + K^+\pi^+$. All the data are combined. There is a strong enhancement in the mass region of the $Y_1^*(1385)$. The peaking in the region 1640 MeV is unexplained.

check in the reaction

$$\pi^+ + p \rightarrow \Sigma^+ + K^{*+} \searrow \pi^0 + K^+. \quad (3)$$

Since the Σ^+ momentum is in general poorly known there is no way of estimating the background of two or more π^0 events. For this reason the data are not presented.

It is observed that about 80% of the $\Sigma^+\pi^+K^0$ production proceeds through the K^* channel, mass 888 MeV. The events whose K-π invariant mass falls in the K^* peak were selected and the angular distribution for the production of the K^* is plotted in Fig. 3. The angular distribution is nearly symmetric backward and forward, and is inconsistent with K^* production via the exchange of a single boson. In this regard it is noted that if the matrix element is dominated by a single diagram in which one boson is exchanged, the K^* is emitted preferentially in the forward direction.

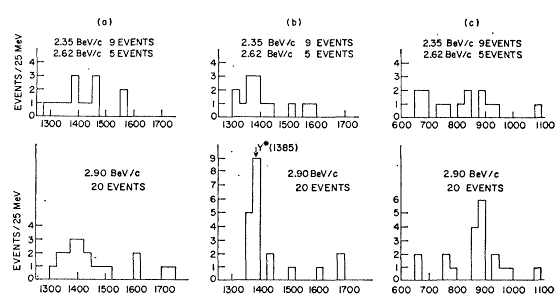

FIG. 5. Invariant-mass spectra in the reaction $\pi^+ + p \rightarrow \Lambda^0 + K^+ + \pi^+ + \pi^0$. The data from the incident-pion momenta of 2.35 and 2.62 BeV/c are combined and from the incident-pion momentum 2.90 BeV/c are presented separately. (a) The $\Lambda^0\pi^0$ invariant-mass spectra; (b) the $\Lambda^0\pi^+$ invariant-mass spectra; (c) the $K^+\pi^0$ invariant-mass spectra. There is no evidence for the production of Y_1^{*0} at any of the energies. Production of the Y_1^{*+} and the K^{*+} is in evidence only at the highest incident π^+ momentum, 2.90 BeV/c.

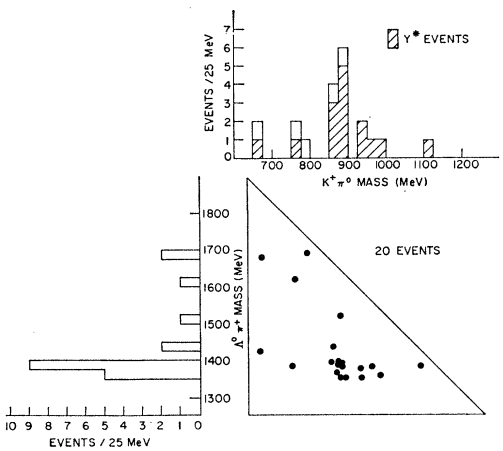

FIG. 6. Scatter plot of the $\Lambda^0\pi^+$ and $K^+\pi^0$ invariant mass in the reaction $\pi^+ + p \rightarrow \Lambda^0 + K^+ + \pi^+ + \pi^0$; incident π^+ momentum is 2.90 BeV/c. It is to be noted that the K^* and Y_1^* are often produced together.

(2) Y_1^* production[5] in the reaction

$$\pi^+ + p \rightarrow Y_1^* + K^+ \quad \searrow \quad \Lambda^0 + \pi^+ . \qquad (4)$$

The Y_1^* (mass 1385 MeV) resonance production is strong in the reactions in which a $\Lambda^0\pi^+K^+$ appears in the final state. This is observed in the $\Lambda^0\pi^+$ invariant-mass plot shown in Fig. 4. The peaking in the region about 1640 MeV is unexplained but may be related to the 1660-MeV resonance first reported by Alexander *et al.*[6] All of the events in the Y_1^* peak are produced with the Y_1^* backwards in the rest system of production. Because of the paucity of events, the angular distributions are not presented. There were only five events in which the Λ^0 was ambiguous with a Σ^0 and these are not plotted.

(3) Y_1^* and K^* production in the reactions

$$\pi^+ + p \rightarrow \Lambda^0 + \pi^+ + \pi^0 + K^+ \qquad (5)$$

and

$$\pi^+ + p \rightarrow \Lambda^0 + \pi^+ + \pi^+ + K^0 . \qquad (6)$$

Among the events identified as reaction (5), the contamination of $\Sigma^0\pi^+\pi^0K^+$ is unknown. This does not affect the conclusions because in the sample of interest almost all of the events are examples of $Y_1^{*+}(1385)$ production.[7] For reaction (6) a more direct check of the Σ^0 contamination can be made. If both the Λ^0 and K^0 decays are visible, Λ^0 and Σ^0 production can usually be distinguished. The $\Sigma^0\pi^+\pi^+K^0$ cross section is found to be much less than the $\Lambda^0\pi^+\pi^+K^0$ cross section. The data presented therefore include events in which only one neutral decay is observed as well as those in which both the K^0 and Λ^0 are visible.

The cross section for the production of the four-body state is found to increase rapidly with increasing available energy. This increase is attributed to the strong dependence of the production into the $K^*(888)$-$Y_1^*(1385)$ channel near the threshold for that reaction. The available Q for the reaction

$$\pi^+ + p \rightarrow Y_1^* + K^*$$

at the three energies which were studied is shown in Table II. The four-body production cross section at each of these energies is also shown. The lowest energy is close to the double-resonance-production threshold. The double-resonance production

$$\pi^+ + p \rightarrow Y_1^{*+} + K^{*+} \quad \searrow \Lambda^0 + \pi^+ \quad \searrow K^+ + \pi^0 \qquad (7a)$$

is clearly observed in the $\Lambda^0\pi^+\pi^0K^+$ events. In Fig. 5, the invariant-mass spectra for the $K^+\pi^0$, $\Lambda^0\pi^+$, and $\Lambda^0\pi^0$ combinations are presented. The events produced by 2.90-BeV/c incident pions are presented separately. It is observed that in the 2.90-BeV/c data the Y_1^{*+} dominates and the K^* is evident. When the available energy is lower, the Y_1^{*+} is produced weakly, if at all, and the K^* is absent. The Y_1^{*0} is not prolific at any of the energies. The scatter diagram presented in Fig. 6 illustrates that the K^{*+} is produced together with the Y_1^{*+}.

The double resonance production should also appear

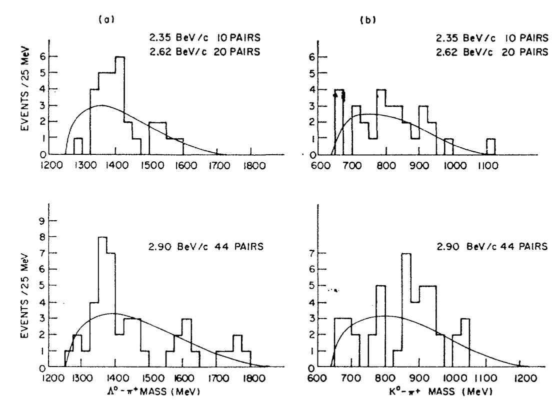

FIG. 7. Invariant mass spectra in the reaction $\pi^+ + p \rightarrow \Lambda^0 + K^0 + \pi^+ + \pi^+$. The data from the incident-pion momenta of 2.35 and 2.62 BeV/c are combined and from the incident-pion momentum 2.90 BeV/c are presented separately. Each event is plotted twice. (a) The $\Lambda^0\pi^+$ invariant mass spectra; (b) the $K^0\pi^+$ invariant mass spectra. At 2.35 and 2.62 BeV/c the observed spectra are consistent with the four-body phase-space spectra (solid curves), while at 2.90 MeV/c there is a strong enhancement at the $Y_1^*(1385)$ mass. The shift in the $K^0\pi^+$ mass spectrum to high mass values in the 2.90 BeV/c data is attributed to the production of the K^* resonance.

[5] M. Alston, L. Alvarez, P. Eberhard, M. Good, W. Graziano, H. Ticho, and S. Wojcicki, Phys. Rev. Letters **5**, 520 (1960).

[6] G. Alexander, L. Jacobs, G. R. Kalbfleisch, D. H. Miller, G. A. Smith, and J. Schwartz, in *Proceedings of the International Conference on High Energy Physics, Geneva*, 1962 (CERN Scientific Information Service, Geneva, 1962), p. 320.

[7] The data do not rule out the production of the $T=2$ resonance suggested by Y. Pan and R. P. Ely, Phys. Rev. Letters **13**, 277 (1964). In the discussion it is assumed that the hyperon-pion resonance which is produced is the Y_1^* (1385).

when the K^* decays via the $K^0\pi^+$ mode

$$\pi^+ + p \to Y_1^{*+} + K^{*+}, \quad Y_1^{*+} \to \Lambda^0 + \pi^+, \quad K^{*+} \to K^0 + \pi^+ . \tag{7b}$$

Since there are two π^+ mesons present in this reaction, there is an ambiguity about which π^+ is associated with the Y_1^* decay and which with the K^* decay. The ambiguity results in a background which, because of the small number of events masks the K^* contribution.

The $\Lambda^0\pi^+$ invariant mass spectra are plotted in Fig. 7. Events from the low- and high-energy incident pions are presented separately as before and again a prominent Y_1^{*+} peak is observed at 2.90 BeV/c. To increase the sensitivity to observe $Y_1^* + K^*$ production a scatter plot of the $\Lambda^0\pi^+ - K^0\pi^+$ invariant mass is shown in Fig. 8. In the case of those events in which a Y_1^* appears, there is a statistically significant excess of events in the K^* peak

It is expected that the K^*, with isotopic spin $\frac{1}{2}$ should decay via the $K^0\pi^+$ mode with twice the frequency as the decay via the $K^+\pi^0$ mode.[4] This is supported by the data. It is noted moreover that even with 2.90 BeV/c incident pions, the available energy for the production is still relatively small and s-wave production may dominate the reaction. For Y_1^* ($P_{3/2}$ resonance)[8] and K^* (p-wave resonance)[9] emission in a relative s state, the symmetry of the two final-state pion wave functions suppresses the K^* decay into π^+K^0.

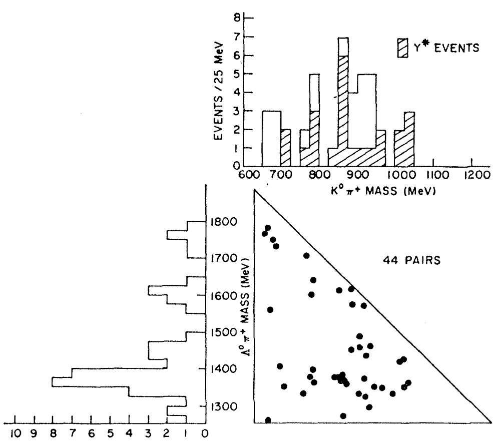

FIG. 8. Scatter plot of the $\Lambda^0\pi^+$ and $K^0\pi^+$ invariant mass in the reaction $\pi^+ + p \to \Lambda^0 + K^0 + \pi^+ + \pi^+$; incident π^+ momentum is 2.90 BeV/c. Each event is plotted twice. There is a statistically significant excess of events which simultaneously fall in the K^* and Y_1^* peaks.

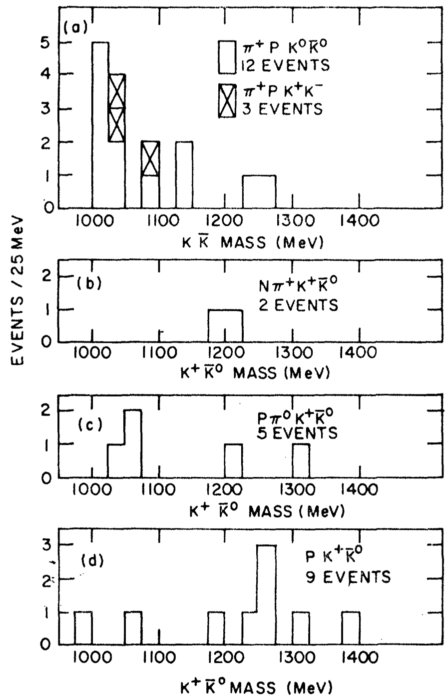

FIG. 9. $K\bar{K}$ invariant mass spectra from the reactions:

(a) $\pi^+ + p \to K^+ + K^- + \pi^+ + p$, $\pi^+ + p \to K^0 + \bar{K}^0 + \pi^+ + p$ combined,
(b) $\pi^+ + p \to K^+ + \bar{K}^0 + \pi^+ + n$,
(c) $\pi^+ + p \to K^+ + \bar{K}^0 + \pi^0 + p$,
(d) $\pi^+ + p \to K^+ + \bar{K}^0 + p$.

The events from all incident-pion momenta are combined. There is an enchancement in the $K^0\bar{K}^0$ and K^+K^- states which corresponds to the φ meson.

The production of the Y_1^{*+} appears to be enhanced in the channel in which the K^{*+} is produced in association with the Y_1^{*+}. Because of charge conservation, the Y_1^{*0} cannot be produced with the K^{*+} and this may account for the relatively small number of neutral Y_1^* observed in the four-body reaction.

(4) φ production[10] in the reaction

$$\pi^+ + p \to \varphi^0 + \pi^+ + p, \quad \varphi^0 \to K + \bar{K} . \tag{8}$$

The $K\bar{K}$ mass distributions are shown in Fig. 9 for $K\bar{K}$ combinations produced in the following reactions:

$$\left.\begin{aligned} \pi^+ + P &\to K^+ + K^- + \pi^+ + p \\ &\quad K^0 + \bar{K}^0 + \pi^+ + p \end{aligned}\right\}, \tag{9a}$$

$$K^+ + \bar{K}^0 + \pi^+ + n , \tag{9b}$$

[8] D. Colley, N. Gelfand, U. Nauenberg, J. Steinberger, S. Wolf, H. Brugger, P. Kramer, and R. Plano, Phys. Rev. **128**, 1930 (1962); L. Bertanza, V. Brisson, P. L. Connolly, E. L. Hart, I. S. Mitra, G. C. Moneti, R. R. Rau, N. P. Samios, I. O. Skillicorn, S. S. Yamamoto, M. Goldberg, J. Leitner, S. Lichtman, and J. Westgard, Phys. Rev. Letters **10**, 176 (1963); J. B. Shafer, J. J. Murray, and D. O. Huwe, *ibid.* **10**, 179 (1963). R. P. Ely, S. Y. Fung, G. Gidal, Y. L. Pan, W. M. Powell, and H. W. White, *ibid.* **7**, 461 (1961).

[9] R. Armenteros, L. Montanet, D. R. O. Morrison, S. Nilsson, A. Shapira, J. Vandermeulen, C. d'Andlau, A. Astier, C. Ghesquiere, B. P. Gregory, D. Rahm, P. Rivet, and F. Solmitz, in *Proceedings of the International Conference on High-Energy Physics, Geneva, 1962* (CERN Scientific Information Service, Geneva, Switzerland, 1962), p. 295.

[10] P. L. Connolly, E. L. Hart, K. Lai, G. London, G. C. Moneti, R. R. Rau, N. P. Samios, I. O. Skillicorn, S. S. Yamamoto, M. Goldberg, M. Gundzik, J. Leitner, and S. Lichtman, Phys. Rev. Letters **10**, 371 (1963). P. Schlein, W. Slater, L. Smith, D. Stork, and H. Ticho, *ibid.* **10**, 368 (1963).

$$K^+ + \bar{K}^0 + \pi^0 + p, \tag{9c}$$

$$K^+ + \bar{K}^0 + p. \tag{9d}$$

The mass plots show an enhancement in the mass region between 1000 and 1050 MeV for the production of the neutral $K\bar{K}$ combinations. No such enhancement is observed in the charged mode. Furthermore, all of the $K^0\bar{K}^0$ combinations are events in which only a single V is produced and it is concluded that the kaons are observed in the state K_1K_2. The observed enhancement is therefore a state which is odd under charge conjugation[11] and is associated with the φ meson[10] whose mass is reported to be 1018 MeV.[12] The observation of only the neutral φ confirms that the isotopic spin of the φ is 0. Since the initial state is pure $T=\frac{3}{2}$, the ratio of the rates

$$\frac{(\pi^+p \to \pi^+n\varphi^+)+(\pi^+p \to \pi^0p\varphi^+)}{(\pi^+p \to \pi^+p\varphi^0)} \begin{array}{ll} =0 & \text{if } T=0 \\ \geq \frac{3}{2} & \text{if } T=1. \end{array}$$

The probability that a $T=1$ state would result in the observed distribution (seven or more φ^0 decays into K_1K_2, and one φ^+ decay into K^+K^0 less an estimated background of one event) is ~ 0.1, while a $T=0$ state would almost always produce the observed distribution.

The three-pion decay of the φ^0, if it proceeds with a branching comparable to the K_1K_2 decay, should be observed in the $\pi^+\pi^-\pi^0$ invariant mass spectrum from the reactions

$$\pi^+ + p \to p + \pi^+ + \pi^+ + \pi^- + \pi^0. \tag{10}$$

Four-pion events found in the same film have already been reported[3] and the $\pi^+\pi^-\pi^0$ mass spectrum exhibits no enhancement near the φ mass. The relevant part of the $\pi^+\pi^-\pi^0$ mass spectrum is plotted in Fig. 10. It is concluded that the branching ratio

$$\varphi^0 \to \pi^+\pi^-\pi^0/\varphi^0 \to K_1K_2 \leq 0.3 \text{ with } 60\% \text{ confidence.}$$

(5) Other resonances. We have searched for evidence of other resonances and have found none. The suggested[7,13] $T=2$ Σ-π resonances if produced with a frequency comparable with those observed, would have appeared in the $\Sigma^+\pi^+$ invariant mass spectrum shown in Fig. 11. No such resonances appear.

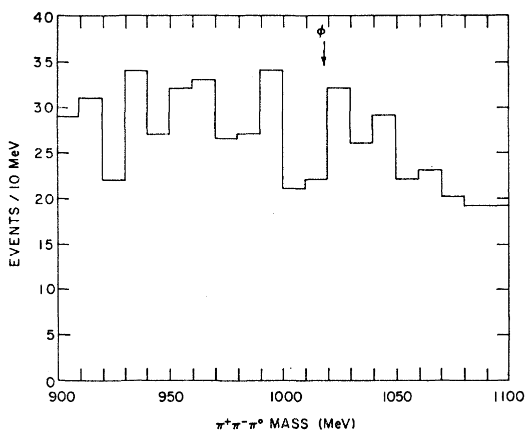

FIG. 10. $\pi^+\pi^-\pi^0$ invariant mass spectrum from the reaction $\pi^+ + p \to \pi^+ + \pi^+ + \pi^- + \pi^0 + p$. ω^0 events (750<mass<810) and η^0 events (530<mass<570) are not included.

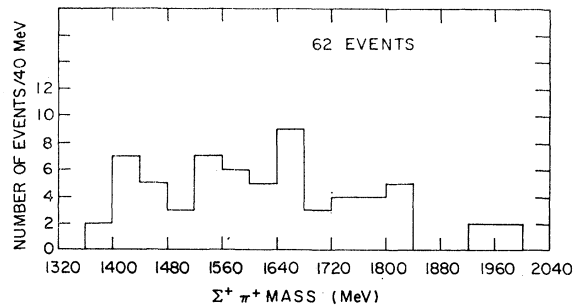

FIG. 11. $\Sigma^+\pi^+$ invariant mass spectrum from the reaction $\pi^+ + p \to \Sigma^+ + K^0 + \pi^+$. The events from all incident-pion momenta are combined. There is no evidence for a resonance in the $\Sigma^+\pi^+$ system.

ACKNOWLEDGMENTS

We thank Professor Jack Steinberger for his support and advice in the course of this experiment. Dr. David Miller collaborated with us in the early stages of the experiment. We also wish to thank our measurers, scanners, and secretarial staff for their conscientious efforts.

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