our data were included in the least-squares analysis, resulting in these two sets. It is not surprising, then, that the fit is good. One of these sets of phase shifts is the one in serious qualitative disagreement with all the others.[23,26] This shows that more precise charge-exchange differential-cross-section data would not be nearly as useful as recoil-neutron polarization data.

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Photoproduction of Strange Particles*

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The photoproduction of strange particles at photon energies between 1 and 6 BeV was studied using a 12-in. hydrogen bubble chamber. 283 events were observed in a sample of 865 000 pictures. Cross sections are presented. Y_1^* (1382) and K^* (890) production were observed in the $\gamma+p \rightarrow \Lambda^0+K+\pi$ reaction. There is evidence for ϕ^0 production in the $\gamma+p \rightarrow p+K+\bar{K}$ reaction.

I. INTRODUCTION

THIS is one of a series of papers reporting on the final results of the first bubble-chamber study of meson and hyperon production by photons of energy greater than 1 BeV. This experiment, performed at the Cambridge Electron Accelerator (CEA), utilized a 12-in. hydrogen bubble chamber exposed to bremsstrahlung beams of maximum energy varying between 4.8 and 6.0 BeV. The experimental conditions[1,2] and the final results[2] on several reactions have already been published or submitted for publication. In this paper we present our data on strange-particle production and discuss possible interpretations of our results.

II. ANALYSIS

In our sample of 865 000 pictures obtained during the CEA exposure we observe 283 events involving strange-particle production. Our analysis yields a definite interpretation for events falling into two classes: (1) events in which a strange-particle decay is observed and (2) events without a visible decay in which the kinematic fit is consistent with production of charged K mesons and in which the determination of the relative bubble density of the tracks is consistent only with this hypothesis.

The first class of events is further subdivided into two divisions: (a) events in which a charged strange particle decays and (b) those in which a neutral decay takes place. The charged decaying particles were $\Sigma^{\pm}$, except for one event with a Ξ^-. $K^{\pm}$ decays were observed, but the events in which these occurred were included in class (2) with the majority of the charged K events. No corrections are necessary for the sample of events in which a $\Sigma^{\pm}$ decay is identified.

The subclass (b) of events in which a Λ^0 or K^0 is observed must be corrected for the probability of decay outside the chamber and for the branching ratio to

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[1] Crouch *et al.*, Phys. Rev. Letters **13**, 636 (1964); in *Proceedings of the International Symposium on Electron and Photon Interactions at High Energies, Hamburg, 1965* (Deutsche Physikal Gesellschaft, 1966), Vol. II, p. 1; in *Proceedings of the Second Topical Conference on Resonant Particles* (Ohio University, Athens, Ohio, 1965), p. 476.

[2] Cambridge Bubble Chamber Group, Phys. Rev. **146**, 994 (1966), and (to be published).

neutral modes. A standard potential-path calculation was carried out for each neutral decay and yielded an average probability for decay outside the chamber of 10% for Λ^0 and 12% for K_1^0. Each event was assigned a weight calculated from the potential path for the Λ^0 or K^0's involved. Each sample of events was also corrected for the probability of neutral decay and for K_2^0 decay. These corrections were checked in the $\Lambda^0K^0\pi^+$ sample by comparing the number of events (corrected for potential path length) in which only a Λ^0 was seen, to those where only a K^0 was seen, to those where both Λ^0 and K^0 were seen. The results are shown below, together with the predicted ratio.

$$(N_{\Lambda^0}:N_{K^0}:N_{\Lambda^0K^0})_{\text{observed}}=1:0.29\pm0.13:0.25\pm0.13\,,$$
$$(N_{\Lambda^0}:N_{K^0}:N_{\Lambda^0K^0})_{\text{predicted}}=1:0.25\qquad:0.5\,.$$

Events which satisfied kinematically only a hypothesis involving Σ^0, Λ^0, or K^0 production but for which no decay was observed were placed in the "excluded" strange-particle category. This category contained all events which were probably strange-particle events, but which did not satisfy some selection criterion. Their exclusion was taken into account in the corrections applied to the events throughout this paper.

In the second class of events the assignment rests ultimately on the ability to distinguish a K meson from a pion by bubble-density determinations. In our sample it was found that such distinctions were reliable only up to about 800 MeV/c. Thus events were only accepted as charged K events if one K meson had momentum less than 600 MeV/c or both had momentum less than 800 MeV/c. Events where these criteria were not satisfied but where the kinematic fit clearly indicated K meson production were placed in the excluded strange-particle category. The invariant-mass distributions for these excluded events were in all cases compared with the distributions for the accepted events to ascertain that no bias was being introduced. A further sample of events with higher momentum tracks which satisfied a pion hypothesis are in the pion-production sample and have been discussed in previous papers.[1,2] Since a quantitative cutoff was used on the events taken in the charged K sample, it was possible to calculate the fraction of the events discarded by this cutoff. Monte Carlo calculations using the program NVERTX[3] were carried out for $\gamma+p\rightarrow K^++K^-+p$ using three different models, and these yielded approximately the same results.[4] The actual correction used for this reaction was a combination of these results and was a factor of 2.0±0.4. Thus the accepted K^+K^-p sample is expected to contain only half of the actual number of events, and, indeed, the number of events in the excluded strange-particle sample and pion samples which satisfy K^+K^-p kinematics is actually 1.5±0.5 times the number of accepted K^+K^-p events. The corrections for other types of reactions involving only charged K's (see Table I) were similarly calculated using a phase-space production model.

In addition to the main sample of events which could be assigned to a unique hypothesis and for which a weight could be calculated, there was a sample of events in which there was an ambiguity between two or more $0C$ (zero constraint) kinematic hypotheses. These were included in the cross section by assigning fractions of the event with the appropriate weights to all hypotheses satisfied.

There is an additional sample of events which could not be fit kinematically, but which were clearly strange-particle events. These were placed in the unassigned strange-particle category and were not included in the cross section.

The most abundant reaction type observed involved the production of a Λ^0 or Σ^0. The Σ^0 decays at the reaction vertex to $\Lambda^0+\gamma$, and all events involving Σ^0 production can be fit kinematically by a Λ^0 hypothesis, since the mass difference between these particles is small relative to the uncertainties of the momentum determinations in our chamber. For most of the event types observed, it was not possible to separate the Σ^0 events from the Λ^0, and the results for the two samples are given together. For the two reactions, however,

$$\gamma+p\rightarrow\Lambda^0+K^+\,,\qquad(1a)$$

$$\gamma+p\rightarrow\Sigma^0+K^+\qquad(1b)$$
$$\searrow\Lambda^0+\gamma\,,$$

it was possible to make a separation. A true event of type (1a) can be fitted kinematically as an event of type (1b) only if the γ ray emitted in the decay of the hypothetical Σ^0 is in the direction of the incident photon beam. An NVERTX[3] calculation of the expected direction of the γ rays from the decay of the Σ^0 particles indicates that only 18.5% should lie within a 20° cone around the incident-beam direction, whereas it is estimated from the experimental uncertainties that 90% of the fake γ rays from (1a) fitted as (1b) should lie within this cone. Therefore, we have interpreted such ambiguous events as Λ^0 events if the direction of the decay γ ray obtained from the Σ^0 hypothesis lies inside this cone, and as Σ^0 events, if it lies outside. Each sample has then been corrected for the cross contamination. There is a further ambiguity, between $\Lambda^0K^+\pi^0$ and Σ^0K^+ events, but an NVERTX analysis[3] showed that for true Σ^0K^+ events the decay γ momentum is less than 300 MeV/c for 99% of the events, whereas for $\Lambda^0K^+\pi^0$ events fitted as Σ^0K^+ events the decay γ momentum is greater than 300 MeV/c for 98% of the events. Therefore, we have accepted such events for which the γ momentum is

[3] C. A. Bordner, Jr., A. E. Brenner, and E. E. Ronat, Rev. Sci. Instr. **37**, 36 (1966).

[4] The correction factor calculated assuming three-particle phase space was 2.0±0.6; assuming Y^*K^- production 2.0±0.6; assuming $p\phi$ production, 2.1±0.6.

TABLE I. Strange-particle events.

No. of particles in final state	Event type[a]	No. unambiguous	No. ambiguous[b]	No. excluded[b]	Corrected number
2	$\gamma+p\rightarrow\Lambda^0+K^+$	25	0	0	41.6 ± 9.3
	Σ^0+K^+	16	0	0	26.6 ± 8.2
	Σ^++K^0	3	0	0	10.0 ± 5.8
3	$\gamma+p\rightarrow\Lambda^0(\Sigma^0)+K^++\pi^0$	12	10	0	29.0 ± 8.4
	$\Lambda^0(\Sigma^0)+K^0+\pi^+$	35	12	0	45.6 ± 7.6
	$\Sigma^++K^0+\pi^0$	2	0	0	6.1 ± 4.3
	$\Sigma^++K^++\pi^-$	11	0	0	11.0 ± 3.3
	$\Sigma^-+K^++\pi^+$	11	0	0	11.0 ± 3.3
	$\Xi^-+K^++K^+$	1	0	0	1.0 ± 1.0
	K^++K^-+p	18	0	18	35.6 ± 10.6
	$K^0+\bar{K}^0+p$	4	2	0	9.4 ± 4.1
	$K^++\bar{K}^0+n$	4	2	0	19.6 ± 9.8
4	$\gamma+p\rightarrow\Lambda^0(\Sigma^0)+K^++\pi^++\pi^-$	10	0	24	16.9 ± 5.3
	$\Lambda^0(\Sigma^0)+K^0+\pi^++\pi^0$	1	0	0	5.4 ± 5.4
	$\Sigma^++K^++\pi^-+\pi^0$	2	2	0	3.0 ± 1.7
	$\Sigma^++K^0+\pi^++\pi^-$	1	2	0	1.9 ± 1.4
	$\Sigma^-+K^0+\pi^++\pi^+$	2	0	0	2.0 ± 1.4
	$K^++K^-+p+\pi^0$	1	2	0	3.5 ± 3.5
	$K^++K^-+n+\pi^+$	4	5	4	12.7 ± 6.7
	$K^0+\bar{K}^0+p+\pi^0$	1	0	0	9.6 ± 9.6
	$K^++\bar{K}^0+p+\pi^-$	1	0	8	3.0 ± 3.0
	$K^-+\bar{K}^0+p+\pi^+$	1	0	7	3.4 ± 3.4
5	$\gamma+p\rightarrow\Lambda^0(\Sigma^0)+K^0+\pi^++\pi^++\pi^-$	1	3	0	2.9 ± 2.3
	$\Lambda^0(\Sigma^0)+K^++\pi^++\pi^-+\pi^0$	1	2	0	3.2 ± 3.2
	$K^++\bar{K}^0+n+\pi^++\pi^-$	1	1	0	4.7 ± 4.7
	$K^0+\bar{K}^0+p+\pi^++\pi^-$	1	1	0	3.4 ± 3.4

[a] Events assigned to event types involving a neutron or π^0 could in general involve additional unseen neutrals.
[b] Ambiguous events are events which satisfy the criteria for two or more event types. Excluded events are events which do not satisfy all criteria for the event type. Ambiguous events are included in the corrected number (see text). Excluded events are corrected for (see text).

less than 300 MeV/c as Σ^0K^+. Using the $\Lambda^0K^+\pi^0$ sample, we then calculated the contamination of this Σ^0K^+ sample.

III. EVENT TYPES AND CROSS SECTIONS

Table I summarizes the information on the types of events observed in our sample of 283 strange-particle events. The third column of the table gives the number of events unambiguously assigned to each event type. There are 170 unambiguous events. The fourth column gives the number of events in the ambiguous category which satisfied the particular hypothesis kinematically. Each event appears two or more times in this column, and there is a total of 36 ambiguous events. Nine of these have one hypothesis that is in the excluded category. The fifth column gives the number of events in the excluded category. There are 52 unambiguous excluded events. There are an additional 25 events in the unassigned category.

It is of interest to note that the K^+/K^- ratio observed in this experiment is

$$N(K^+)/N(K^-)=4.0\pm1.1.$$

This number is corrected for unseen events.

Figure 1 shows the cross sections for the production of various types of events as a function of photon momentum. They include the ambiguous events and have been corrected for all events which did not satisfy the selection criteria. This includes both events for which a pion hypothesis was equally probably to a strange-particle hypothesis and which were assigned to the former, and events in the excluded category. We note the expected increase above the thresholds for the various processes, but our data are insufficient to establish any resonant features of the cross sections. At high beam momenta the corrections for unseen events become large, and the poor statistics of our sample are a severe limitation. Here a single observed event is a major contribution to the cross section.

IV. ISOBAR FORMATION

Our sample is too small to permit more than a preliminary analysis, but the data do exhibit evidence for the formation of the $Y_1^*(1382)$ isobar.

Figure 2 shows the $\Lambda\pi$ invariant mass distribution for the event types:

$$\gamma+p\rightarrow\Lambda^0+K^++\pi^0, \quad (2a)$$

$$\gamma+p\rightarrow\Sigma^0+K^++\pi^0,$$

$$\gamma+p\rightarrow\Lambda^0+K^0+\pi^+, \quad (2b)$$

and

$$\gamma+p\rightarrow\Sigma^0+K^0+\pi^+.$$

The production of the Y_1^* (1382 MeV) is quite prominent. The data were fitted by a combination of Breit-Wigner ($M=1382$ MeV, $\Gamma=50$ MeV) and phase-space distributions, and the best fit was obtained for 26% Y_1^* isobar and 60% phase space.[5] The other 14% comes from the 1.725-BeV bin which could be associated with the 1660- and 1765-MeV isobars.

$SU(3)$ symmetry[6] predicts that the production matrix elements for the reactions

$$\gamma+p\rightarrow N^{*0}+\pi^+, \tag{3a}$$

$$\gamma+p\rightarrow Y^{*0}+K^+, \tag{3b}$$

should have the ratio

$$|M(\gamma p|N^{*0}\pi^+)|^2/|M(\gamma p|Y^{*0}K^+)|^2=2 \tag{4}$$

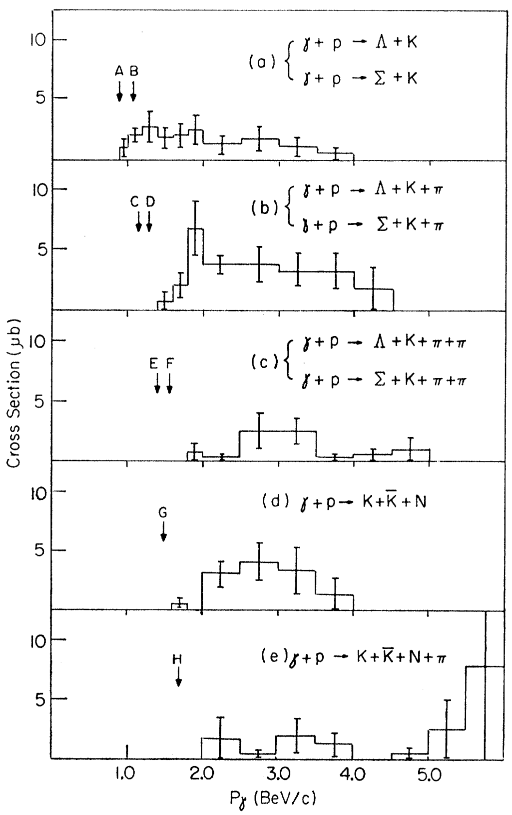

FIG. 1. Cross sections for production of various types of strange particles as a function of photon momentum. Threshold momenta for various event types: (A) Λ^0K^+, (B) ΣK, (C) $\Lambda K\pi$, (D) $\Sigma K\pi$, (E) $\Lambda K\pi\pi$, (F) $\Sigma K\pi\pi$, (G) $K\bar{K}N$, (H) $K\bar{K}N\pi$.

in regions of incident photon momentum where resonance production of N^* and Y^* are not dominant. The cross section for (3b) was calculated from the percentage obtained in the fit discussed above and was found to be 0.3 ± 0.2 μb for values of Q between 0.5 and 0.8 BeV (p_γ from 2.5 to 3.5 BeV/c). The cross section foı (3a)

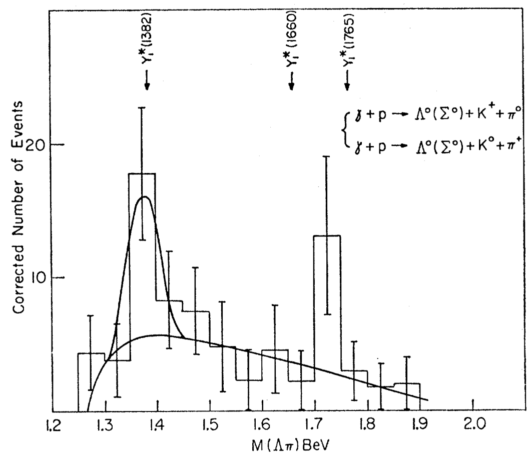

FIG. 2. $\Lambda\pi$ invariant mass distribution from 35 $\Lambda^0(\Sigma^0)K^0\pi^+$ and 12 $\Lambda^0(\Sigma^0)K^+\pi^0$ events corrected for unseen decays. The smooth curve is 26% Breit-Wigner ($M=1382$ MeV, $\Gamma=50$ MeV) and 60% phase-space distribution.

was taken to be the cross section for

$$\gamma+p\rightarrow N_{3/2}^{*0}+\pi^+ \atop \searrow p+\pi^- \tag{5}$$

multiplied by three to correct for neutral decay of the N^{*0}. The cross section for (5) has been previously reported.[2] For values of Q between 0.5 and 0.8 BeV (p_γ from 1.4 to 2.2 BeV/c), the cross section for (3a) is 3.0 ± 2.0 μb. The ratio of the cross sections for (3a) and (3b) corrected by the necessary kinematical factors[7] is found to be 6 ± 6, a value not in significant disagree-

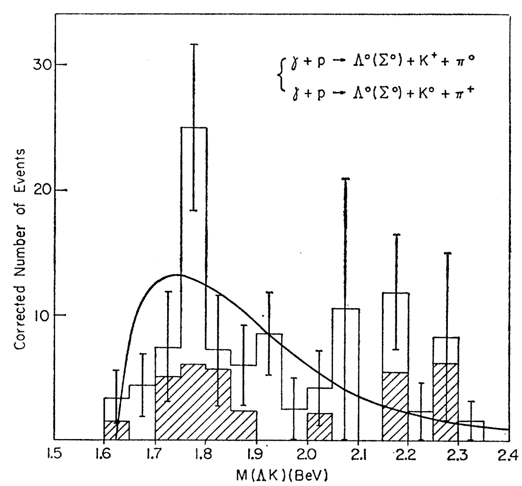

FIG. 3. ΛK invariant mass distribution from 35 $\Lambda^0(\Sigma^0)K^0\pi^+$ and 12 $\Lambda^0(\Sigma^0)K^+\pi^0$ events corrected for events lost because of unseen decays. The smooth curve is the phase-space distribution. The shaded blocks correspond to events for which the $\Lambda(\Sigma)\pi$ invariant mass was outside the Y_1^* mass region (1332 to 1432 MeV) and the $K\pi$ invariant mass was outside the K^* region (830 to 930 MeV).

[5] The 50% confidence limits are 2 to 48% Y_1^*. The 95% confidence limits are 0 to 70% Y_1^*.

[6] C. A. Levinson, H. J. Lipkin, and S. Meshkov, in *Proceedings of the International Conference on Nucleon Structure, Stanford University, 1963*, edited by R. Hofstadter and L. I. Schiff (Stanford University Press, Stanford, California, 1964).

[7] S. Meshkov, G. A. Show, and G. Yodh, Phys. Rev. Letters **12**, 87 (1964).

ment with 2, the prediction of $SU(3)$ given in relation (4).

Figure 3 shows the invariant-mass distribution for $\Lambda(\Sigma)K$ combinations from $\Lambda(\Sigma)K\pi$ events. There is a peak at $\sim$1775 MeV, but it is apparently a reflection of Y_1^* and K^* production since it is not observed in the events remaining when those events were removed for which the relevant invariant masses were in the Y_1^* or K^* region.

Figure 4 shows the invariant-mass distributions of three other strangeness -1 baryon-meson combinations. There is an enhancement in (4a) that could be due to production of the $Y_0^*(1519)$ in the reaction

$$\gamma+p\rightarrow p+K^++K^-, \tag{6}$$

but this could also be a statistical fluctuation. The pK^- invariant-mass distribution from excluded events of type (6) does not show any evidence for Y_0^*. The distributions in (4b) and (4c) are in very close agreement with the phase-space predictions.

V. K^* AND ϕ PRODUCTION

Figure 5 shows the invariant-mass distribution for $K\pi$ combinations from several event types. There appears to be evidence for the production of K^* (890 MeV) in $\Lambda^0(\Sigma^0)K\pi$ and $\Sigma^+K^+\pi^-$ events. The low-mass shoulder in the distribution may be due to the production of K^* (725 MeV). The $K\pi$ invariant-mass distribution does not change significantly when the events with $\Lambda\pi$ mass in the Y_1^* region are removed from the sample. These data can be fit by a combination of 27% Breit-Wigner ($M=890$ MeV, $\Gamma=50$ MeV), and 65% phase-space distribution.[8] The remaining 8% corresponds to the excess in the 725-MeV bin.

The invariant-mass distribution for the neutral $K\bar{K}$ combinations form $K\bar{K}N$ events is given in Fig. 6. There is evidence for the production of the ϕ^0 meson. The K^+K^- invariant-mass distribution from the events of type (6) in the excluded category does not differ significantly. These data are best fit by a combination of 20% Breit-Wigner ($M=1020$ MeV, $\Gamma\leqslant 20$ MeV) and 80% phase-space distribution.[9] This corresponds to a cross section of $0.5_{-0.5}^{+0.7}$ μb for ϕ^0 production, corrected for decay branching ratio. The ratio of $K^0\bar{K}^0$ events to K^+K^- events is 0.6 ± 0.6 in the ϕ^0 mass region. The known branching ratio of the ϕ^0 would predict 0.7. The cross section for ϕ^0 production calculated from these

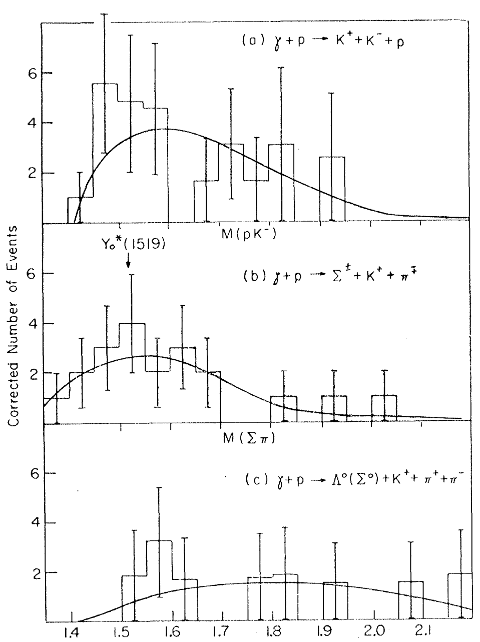

FIG. 4. Invariant-mass distributions for neutral, strangeness -1 meson-baryon combinations. The smooth curves are the appropriate phase-space distributions. (a) K^-p invariant-mass distribution from 17 K^+K^-p events corrected for events lost because of high K meson momentum. (b) $\Sigma\pi$ invariant-mass distribution from 20 $\Sigma K\pi$ events. (c) $\Lambda^0\pi^+\pi^-$ invariant-mass distribution from 10 $\Lambda^0K^+\pi^+\pi^-$ events corrected for unseen decays.

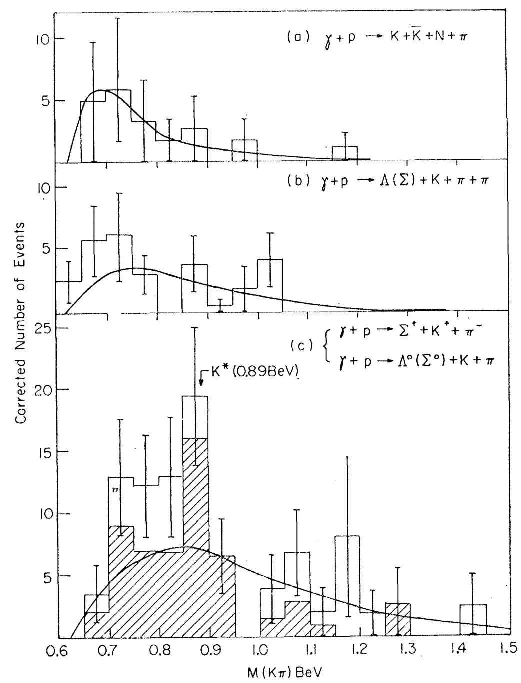

FIG. 5. $K\pi$ invariant-mass distributions. The smooth curves are the appropriate phase-space distributions. (a) Distribution from 10 $KKN\pi$ events corrected for events lost because of high K meson momentum or due to unseen decays. (b) Distribution from 16 $\Lambda(Z)K\pi\pi$ events corrected for events lost due to unseen decays. (c) Distribution from 35 $\Lambda^0(\Sigma^0)K^0\pi^+$, 12 $\Lambda^0(\Sigma^0)K^+\pi^0$, and 9 $\Sigma^+K^+\pi^+$ events corrected for events lost because of unseen decays. The shaded blocks correspond to events for which the $\Lambda(\Sigma)\pi$ invariant mass was outside the Y_1^* mass region (1332 to 1432 MeV). The phase-space distribution is normalized to 65% of the events.

[8] The 50% confidence limits are 14 to 51% K^* (890 MeV). The 95% confidence limits are 0 to 65% K^* (890 MeV).

[9] The 50% confidence limits are 0 to 46% ϕ^0. The 95% confidence limits are 0 to 70% ϕ^0.

data is given in Table II, where it is compared with our previously published ρ^0 and ω^0 production cross sections.[2] Three theoretical predictions for the ratios of these cross sections are also presented.[10–12] It is seen that the data do not agree well with any prediction.[13] This is also the observation of the Aachen-Berlin-Bonn-Hamburg-Heidelberg-München Collaboration,[14] whose results are in agreement with ours.

Elings and Osborne[15] have derived the following two inequalities from $SU(3)$ symmetry:

$$M(\gamma p|p\pi^+\pi^-)\leqslant M(\gamma p|K^+K^-p)+M(\gamma p|\Sigma^+K^+\pi^-), \quad (7a)$$

$$M(\gamma p|p\pi^+\pi^-)\geqslant M(\gamma p|K^+K^-p)-M(\gamma p|\Sigma^+K^+\pi^-). \quad (7b)$$

They have shown that our previously published data[1]

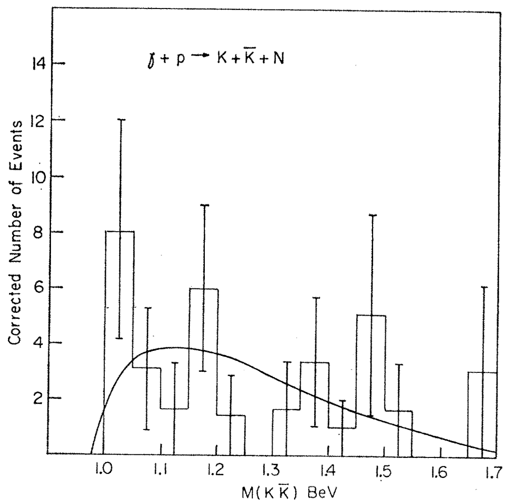

FIG. 6. $K\bar{K}$ invariant mass distribution for neutral $K\bar{K}$ combinations from 21 $K\bar{K}N$ events corrected for events lost because of high K-meson momentum or due to unseen decays. The smooth curve is the phase-space distribution corresponding to 80% of the events.

are not in disagreement with these predictions. Using the larger sample reported in this paper and our recent publications[2] on the reaction,

$$\gamma+p\rightarrow p+\pi^++\pi^-, \quad (8)$$

TABLE II. Comparison of ρ^0, ω^0, and ϕ^0 production.

	σ_{ρ^0}	σ_{ω^0}	σ_{ϕ^0}
Experimental values $1.6<p_\gamma<3.5$ BeV/c	21.9±1.7	3.5±0.4	$0.5_{-0.5}^{+0.7}$
Theoretical predictions			
One-pion exchange and $SU(6)$ and ω-ϕ mixing.[a]	1	9	0.01
$SU(6)$ and Berman-Drell and ω-ϕ mixing.[b]	9	1	0.01
$SU(6)$ and direct photon-vector meson coupling and ω-ϕ mixing.[c,d]	9	1	2

[a] Reference 10.
[b] Reference 11.
[c] Reference 12.
[d] Reference 16.

the agreement is improved. The numerical results are

for (7a) $302\pm70\leqslant 206\pm52$,

for (7b) $302\pm70\geqslant 33\pm52$.

VI. ANGULAR DISTRIBUTIONS

In Fig. 7 the center-of-mass (c.m.) angular distributions of the K mesons from reactions (1a), (1b), and (2a) and (2b) are presented. We see that the distributions of (1a) (Λ^0K^+) and (1b) (Σ^0K^+) are quite different, the Σ^0K^+ distribution peaking quite sharply forward, whereas the Λ^0K^+ distribution also has an appreciable contribution in the backward direction. The question whether the criteria used to separate the Λ^0K^+ and Σ^0K^+ events could be responsible for this was investigated with an NVERTX[3] calculation assuming invariant phase-space production of the Σ^0K^+ events. The results were that the criteria would have discarded 6% of the events

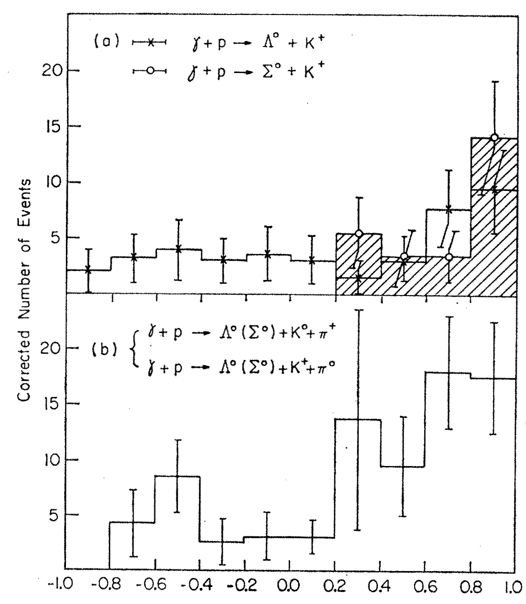

FIG. 7. Center-of-mass angular distributions of K mesons from: (a) 24 Λ^0K^+ events (unshaded blocks) and 15 Σ^0K^+ events (shaded blocks) and (b) 35 $\Lambda^0(\Sigma^0)K^0\pi^+$ and 12 $\Lambda^0(\Sigma^0)K^+\pi^0$ events corrected for events lost due to unseen decay.

[10] S. L. Glashow and R. H. Socolow, Phys. Rev. Letters **15**, 329 (1965); S. Meshkov (private communication); S. Badier and C. Bouchiat, Phys. Letters **15**, 96 (1965).
[11] S. M. Berman and S. D. Drell, Phys. Rev. **133**, B791 (1964); B. Sakita and K. C. Wali, *ibid.* **139**, B1355 (1965).
[12] P. G. O. Freund, Enrico Fermi Institute Report No. EFINS 66-4-(1966) (unpublished).
[13] *Note added in proof.* M. Ross and L. Stodolsky [Phys. Rev. **149**, 1172 (1966)] obtained the values 5:1:0.1 for the cross-section ratios from their photon-dissociation model. These are in excellent agreement with our experimental values.
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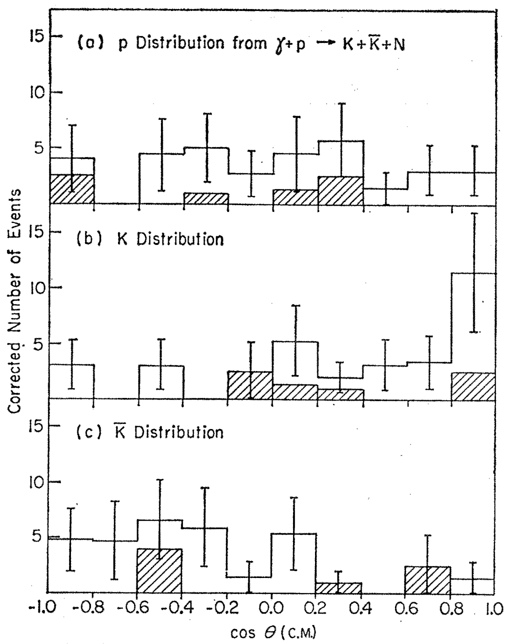

FIG. 8. Center-of-mass angular distribution of (a) proton, (b) K meson, (c) $\bar{K}$ meson, from 19 $K\bar{K}N$ events corrected for events lost because of high K-meson momentum or due to unseen decays. The shaded blocks correspond to events for which the $K\bar{K}$ invariant mass was inside the ϕ^0 region (1000 to 1050 MeV).

in the interval, $\cos\theta = 1.0$ to 0.5, 10%, $\cos\theta = 0.5$ to 0.0, 18%, $\cos\theta = 0.0$ to -0.5, and 33%, $\cos\theta = -0.5$ to -1.0. Thus the difference between the Λ^0K^+ and Σ^0K^+ distributions cannot be accounted for by this effect of the method of selecting the Σ^0K^+ events. A reasonable theoretical explanation is that in the region of photon momentum between threshold and 1.5 BeV/c where most of the observed Λ^0K^+ and Σ^0K^+ production takes place, a resonance mechanism probably dominates. Since the Λ^0K^+ can only be formed through a $T=\frac{1}{2}$ channel, whereas the Σ^0K^+ can come from both $T=\frac{1}{2}$ and $\frac{3}{2}$, this difference is not surprising. Reactions (2a) and (2b) have very similar K-meson angular distributions and so they are summed in Fig. 7(b). It is seen that more K mesons are produced in the forward direction. This is characteristic both of events where the $\Lambda^0\pi$ mass is in the Y_1^* region (1332 to 1432 MeV) and those where this is not true. This observation is consistent with a peripheral mechanism for photokaon production in reactions (2a) and (2b), comparable to that suggested for pion production of K mesons.[16]

Figure 8 shows the c.m. angular distributions for the nucleon, K meson and $\bar{K}$ meson from

$$\gamma+p\rightarrow K+\bar{K}+N \qquad (9)$$

reactions. It is interesting that there is a difference between the K and the $\bar{K}$ distributions, with more K mesons produced in the forward direction and more $\bar{K}$ mesons produced in the backward direction. This is what would be expected from Y_0^* production and this evidence, taken together with the weak indication in the K^-p mass distribution [Fig. 4(a)], may indicate a small amount of Y_0^* production. The shaded blocks correspond to those events for which the $K\bar{K}$ invariant mass is in the ϕ^0 region (1000–1050 MeV). For ϕ^0 events the kaons would be expected to both emerge in the forward direction, whereas the protons would emerge in the backward direction. Our events do not appear to display this type of angular distribution, but the sample is too small for a statistically significant analysis. Furthermore, the momentum cutoff used in selecting events would affect the angular distribution in a model-dependent fashion.

VII. CONCLUSIONS

We have observed 283 photoproduced strange particles of which 170 had unambiguous assignments, 36 were ambiguous, 52 were excluded, and 25 were unassigned. The 206 events in the first two categories were divided between 26 event types. The event types with the largest number of events were Λ^0K^+, Σ^0K^+, $\Lambda^0(\Sigma^0)K^+\pi^0$, $\Lambda^0(\Sigma^0)K^0\pi^+$, and K^+K^-p. There was a difference in the K meson c.m. angular distributions from Λ^0K^+ and Σ^0K^+ events, understandable on the assumption of a resonance mechanism for the formation of both types with Λ^0K^+ being formed through a $T=\frac{1}{2}$ channel and Σ^0K^+, through both $T=\frac{1}{2}$ and $\frac{3}{2}$. In the $\Lambda^0(\Sigma^0)K\pi$ events Y_1^* (1382 MeV) isobar formation was observed in about one quarter of the events and K^* (890 MeV) in about another quarter. In the $K\bar{K}N$ events there is weak evidence for ϕ^0 (1020 MeV) production.

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