PHOTOPRODUCTION OF K^+ MESONS IN HYDROGEN*

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This Letter is a report on the progress of a new series of measurements being made on the photoproduction of K^+ mesons from hydrogen using the Cornell 1.4-BeV electronsynchrotron. The two reactions studied are:

$$\gamma + p \to K^+ + \Lambda^0 \quad 911\text{-MeV threshold},$$

$$\gamma + p \to K^+ + \Sigma^0 \quad 1046\text{-MeV threshold}.$$

The reactions are studied using a magnetic spectrometer and counter telescope to determine the laboratory angle and momentum of the K^+ mesons. The arrangement is very similar to that which has been used in our earlier measurements.[1] The requirements for selection include specific ionization, minimum range, Čerenkov veto against relativistic particles, and the observation of an energetic decay particle from the K meson. In addition, the new measurements include an accurate determination of the time of flight through the analyzing magnet. This provides a redundance in the selection which in some cases makes the detection of the decay products of the K meson unnecessary and hence permits a direct calibration of the efficiency in detection of the decay products.

The time-of-flight system is unique in that it makes use of the inherent bunching of the electrons in the synchrotron to produce a sharply modulated bremsstrahlung beam at the hydrogen target. The timing circuit[2] employs the vernier chronotron principle devised by Cottini and Gatti[3] to compare the phase of arrival of particles at the exit of the spectrometer to that of the synchrotron cavity. Figure 1 demonstrates the separation in phase of arrival which was obtained for the highest momentum of the K mesons which were studied. The flight path was 180 cm and the time-of-flight difference between the K mesons and the relativistic particles was in this case 1.6 nanoseconds. The typical resolution of the system is about 0.5 nanosecond although resolutions of better than 0.3 nanosecond have been obtained.

Figure 2 gives a plot of the yield per equivalent photon as a function of the synchrotron energy. Two steps are observed corresponding to exceeding the kinematical threshold first for K^+-Λ^0 and then for K^+-Σ^0 production.[1] The yields are determined from the magnitudes of these steps. In the case shown here, the central plateau is very narrow and care must be exercised to insure the proper choice of operating energy for the synchrotron.

Backgrounds are measured both with the hydrogen cup empty and below threshold. The resulting rates are usually 1 to 3 % of the K-meson rates when the decay counters are used.

The absolute values of the cross sections of the

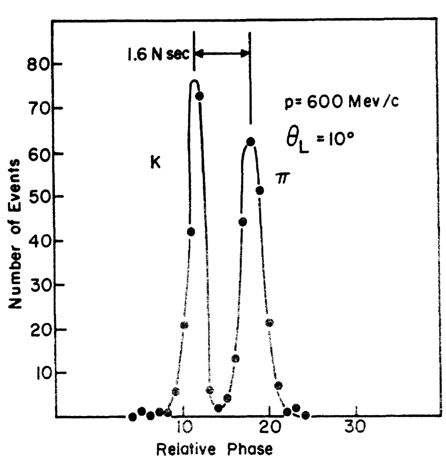

FIG. 1. Time-of-flight distribution at the highest momentum observed. The K's are still well separated from the relativistic background of pions with a time difference of 1.6 nsec.

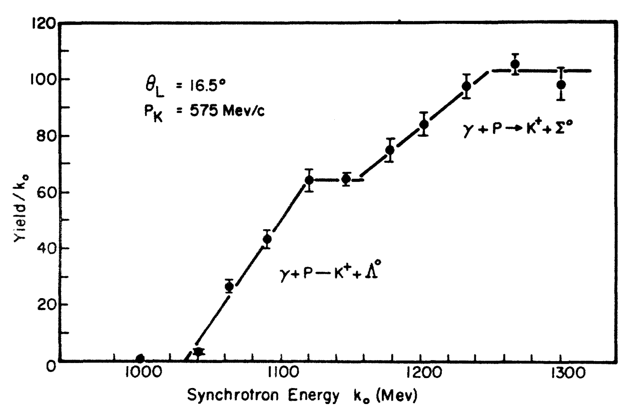

FIG. 2. Yield for K production per equivalent number of photons as a function of synchrotron energy. The first step is due to Λ^0 production. The second step is due to Σ^0 production.

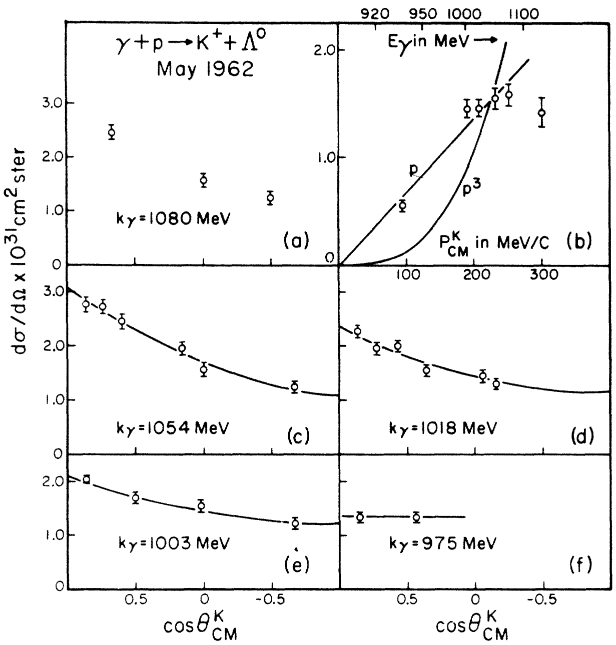

FIG. 3. Differential cross sections for $\gamma+p\rightarrow K^++\Lambda^0$. In (b) the excitation function for the cross section at 90° in the center of mass is plotted against the center-of-mass momentum. For pure s-wave production a linear result is expected. For pure p-wave production the cross section should go as p^3 as indicated.

new data are, on the average, higher than the old ones due to the redetermination of the various calibration constants. The main systematic correction which can affect the angular distribution arises from nuclear absorption. In the worst case, a correction of (25 ± 5) percent is made. The errors indicated on the graphs are the standard statistical errors. It is expected that the systematic errors in the cross section are limited to about 10 percent.

Figure 3 shows the results of the new measurements of cross section as a function of the cosine of the angle of emission of the K meson. We have partially completed angular distributions for photon energies of 976, 1003, 1018, 1054, and 1080 MeV, the data for which are given in Table I. At 1054 a least-squares fit has been made with both $a+b\cos\theta$ and $a+b\cos\theta+c\cos^2\theta$. The fit with the $\cos^2$ term is significantly better. In Fig. 3(b) we have plotted the cross section at 90° in the center of mass as a function of the center-of-mass momentum.

We note that at low energies, the K^+-Λ^0 angular distribution seems to be isotropic, consistent with s-wave production as indicated by earlier published results.[1,4] Above 1000 MeV, a rather large p-wav interference becomes apparent. The dependence of the cross section at 90° in the center of mass as a function of the center-of-mass momentum is consistent with s-wave production at lower energies, but its peculiar behavior at 1050 MeV suggests the existence of a resonance phenomena. The peculiarity is also emphasized by the fact that the three values for the cross section obtained at 1080 fall essentially on the curve for

Table I. Differential results for $\gamma+p\rightarrow K^++\Lambda^0$ and $\gamma+p\rightarrow K^++\Sigma^0$. θ is the angle of emission of the K-meson in the center of mass. k_γ is the central γ-ray energy for the analyzing magnet. The results are grouped into nominal γ-ray energies to form angular distributions. σ is the differential cross section.

k_γ nominal (MeV)	k_γ (MeV)	θ (deg)	σ (10^{-31} cm²/sr)
	$\gamma+p\rightarrow K^++\Lambda^0$		
934	934	90.0	0.55 ± 0.04
975	976	31.1	1.34 ± 0.8
	974	64.0	1.33 ± 0.8
1003	1002	30.0	2.04 ± 0.07
	1003	60.3	1.69 ± 0.09
	1004	88.6	1.54 ± 0.09
	1004	132.0	1.21 ± 0.10
1018	1013	30.3	2.28 ± 0.11
	1020	43.6	1.96 ± 0.11
	1018	55.6	2.00 ± 0.10
	1022	69.8	1.55 ± 0.08
	1024	94.2	1.45 ± 0.11
	1018	97.0	1.33 ± 0.06
1038	1036	45.0	2.30 ± 0.08
	1040	27.5	2.81 ± 0.14
1054	1054	30.0	2.76 ± 0.15
	1055	42.5	2.71 ± 0.13
	1054	53.5	2.44 ± 0.14
	1051	80.2	1.96 ± 0.12
	1054	89.7	1.57 ± 0.09
	1060	132.3	1.23 ± 0.11
1080	1080	46.5	2.44 ± 0.12
	1080	90.0	1.58 ± 0.08
	1080	119.7	1.25 ± 0.08
1130	1130	90.0	1.42 ± 0.13
	$\gamma+p\rightarrow K^++\Sigma^0$		
1157	1157	30.0	0.83 ± 0.20
	1157	49.5	1.17 ± 0.18
	1152	76.0	1.12 ± 0.17
	1157	104.0	0.51 ± 0.10
	1157	134.5	0.38 ± 0.15
	1174	47.7	1.50 ± 0.17
	1142	46.0	1.19 ± 0.11
	1158[a]	46.8	1.35 ± 0.14

[a] Average of points at 1174 and 1142 MeV.

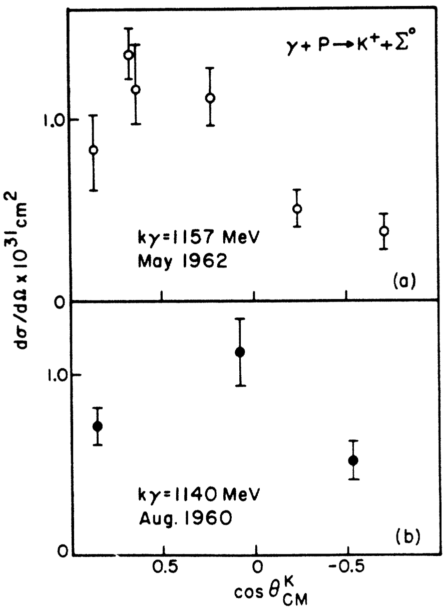

FIG. 4. Differential cross section for $\gamma+p\rightarrow K^{+}+\Sigma^{0}$. The new measurements for $k_\gamma=1157$ MeV are given in (a). In (b) are three points for $k_\gamma=1140$ MeV obtained at Cornell in 1960.

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-