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(To be presented by Dr. Arthur H. Rosenfeld)

Results are presented on the total and partial cross sections for K^- mesons incident on protons at laboratory momenta of 293, 350, 390, 434, 513, 620, 762, and 850 MeV/c. We have studied the interactions in the Lawrence Radiation Laboratory's 15-in. hydrogen bubble chamber, using a purified K^- beam. For each momentum setting, a total of several thousand interactions has been recorded and analyzed.

The value of the path length was obtained at each momentum from the number of decays; the scanning efficiency for these events (on the order of 95%) is much higher than that for the more frequent one-prong decays. This compensates for the reduction in statistics.

As they appear in the bubble chamber, the interactions fall naturally into one of the following categories (only those reactions kinematically allowed at our momenta are listed):

(a) Zero prongs. These are due to the reactions

$$K^- + p \rightarrow \overline{K^0} + \text{neutrals}$$
$$\rightarrow \Lambda + \text{neutrals},$$

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† National Academy of Sciences Fellow.

where the K^0 and the Λ decay via the neutral mode or escape from the chamber. However, the pion contamination in the beam (on the order of 10 to 30%) adds π^- charge-exchange reactions to this class; hence no measurements are practical. Instead the contribution of these reactions to the cross section are accounted for by using the known neutral-to-charged-decay branching ratios of the $\overline{K^0}$ and Λ, and the "zero-prong + V" data [see (e) below].

(b) Two-prongs. These are due to

$$\begin{aligned} K^- + p &\rightarrow K^- + p \\ &\rightarrow K^- + p + \pi^0 \\ &\rightarrow \Lambda\,(\text{or } \Sigma^0) + \pi^+ + \pi^-, \end{aligned}$$

where the Λ decays via its neutral mode or escapes observation [see (d) for the Λ-charged-mode counterpart of this case]. Reactions producing a very short Σ may also appear as a two-prong event. Analysis of the events by the PANG and KICK computer programs allows separation of the above reactions.

(c) Sigma-one-prong. These are due to

$$\begin{aligned} K^- + p &\rightarrow \Sigma^+ + \pi^- \\ &\rightarrow \Sigma^+ + \pi^- + \pi^0 \\ &\rightarrow \Sigma^- + \pi^+ \\ &\rightarrow \Sigma^- + \pi^+ + \pi^0. \end{aligned}$$

The computer programs easily separate the elastic from the inelastic processes.

(d) Two-prong + V. These are due to charged-mode decays of Λ and $\overline{K^0}$ from

$$\begin{aligned} K^- + p &\rightarrow \Lambda + \pi^+ + \pi^- \\ &\rightarrow \Sigma^0 + \pi^+ + \pi^-, \quad \Sigma^0 \rightarrow \Lambda + \gamma \\ &\rightarrow \Lambda\,(\text{or } \Sigma^0) + \pi^+ + \pi^- + \pi^0 \\ &\rightarrow \overline{K^0} + p + \pi^-. \end{aligned}$$

Separation of the reactions is accomplished by the kinematical programs plus ionization estimates in case of ambiguities. To compute cross sections for the above reactions, one multiplies the number of events with a Λ by 3/2 and those with a $\overline{K^0}$ by 3.

(e) Zero-prong + V. These are due to charged-mode decays of Λ and $\overline{K^0}$ from

$$
\begin{aligned}
K^- + p &\rightarrow \Lambda + \pi^0 , \\
&\rightarrow \Lambda + \pi^0 + \pi^0 , \\
&\rightarrow \Lambda + \pi^0 + \pi^0 + \pi^0 , \\
&\rightarrow \Sigma^0 + \pi^0 , \quad \Sigma^0 \rightarrow \Lambda + \gamma , \\
&\rightarrow \Sigma^0 + \pi^0 + \pi^0 , \\
&\rightarrow \overline{K^0} + n , \\
&\rightarrow \overline{K^0} + n + \pi^0 .
\end{aligned}
$$

In this case the separation is based on the decay fit for the V. Lambda and $\overline{K^0}$ decays are distinguished (ambiguities being resolved by ionization); then we compute the total mass recoiling against the Λ or the $\overline{K^0}$ in the K^-p center of mass. From the shape of the mass spectrum, a subdivision is further possible into the various channels. In order to account for the loss of those events without a visible decay, here as in (d) one multiplies by 3/2 for the Λ's and by 3 for the $\overline{K^0}$'s before computing cross sections.

The values obtained for the cross sections are collected in Table I and are also shown in Figs. 1 through 3. All values at P_K = 1.15 GeV/c come from reference I. Also shown are the total cross sections obtained in counters experiments.[2]

Inspection of the graphs leads to the following observations:

1. In the low-momentum region, the presence of the excited hyperon Y_0^* (1520) is manifest from the enhancements occurring for the various channels around P_K = 400 MeV/c.[3]

2. A sudden increase in $\Lambda\pi^+\pi^-$ production occurs at about 760 MeV/c, corresponding to copious production of the excited hyperon Y_1^* (1385) via the reaction $K^- + p \rightarrow Y_1^{*\pm} \pi^{\mp}$.[4]

3. Some enhancement in the $\Sigma\pi$ channels--mainly $\Sigma^-\pi^+$--is apparent at about 760 MeV/c, corresponding to a total c.m. energy of about 1680 MeV. This observation, together with strong indications of a sudden change in the differential cross sections for the $\Sigma\pi$ reactions at this momentum, suggests the possible existence of a new excited hyperon with total mass ~ 1680 MeV.[5]

Further details on the analysis and a study of the differential cross sections will be presented in later publications.

Thanks are due to Prof. Luis W. Alvarez for his support and interest. We are also grateful to the scanning team of the 15-in. bubble chamber, in particular to Miss Nancy Milton and Mr. Ronald Tye who had major responsibilities in this work.

FOOTNOTES

1. W. Graziano and S. G. Wojcicki, K^-p Interactions at 1.15 BeV/c., Lawrence Radiation Laboratory Report UCRL-10177, April 17, 1962 (unpublished).

2. V. Cook, B. B. Cork, T. F. Hoang, D. Keefe, L. T. Kerth, W. A. Wenzel, and T. F. Zipf, Phys. Rev. 123, 320 (1961); O. Chamberlain, K. M. Crowe, D. Keefe, L. T. Kerth, A. Lemonick, Tin Maung, and T. F. Zipf, Phys. Rev. 125, 1696 (1962).

3. M. Ferro-Luzzi, R. D. Tripp and M. B. Watson, Phys. Rev. Letters 8, 28 (1962); R. D. Tripp, M. B. Watson, and M. Ferro-Luzzi, Phys. Rev. Letters 8, 175 (1962).

4. M. H. Alston and M. Ferro-Luzzi, Revs. Modern Phys. 33, 416 (1961).

5. Indications for the existence of such a 1680-MeV $\Sigma\pi$ resonance have also been observed in π^-p data by G. Alexander, L. Jacobs, G. R. Kalbfleisch, D. H. Miller, G. A. Smith, and J. A. Schwartz, Study of Strange-Particle Resonant States Produced in 1.89-2.24 BeV/c $\pi^- + p$ Interactions, Lawrence Radiation Laboratory Report UCRL-10286, June 12, 1962.

Table I. Values of the cross sections in mb for $K^- + p$ reactions as a function of the K^- laboratory momentum.

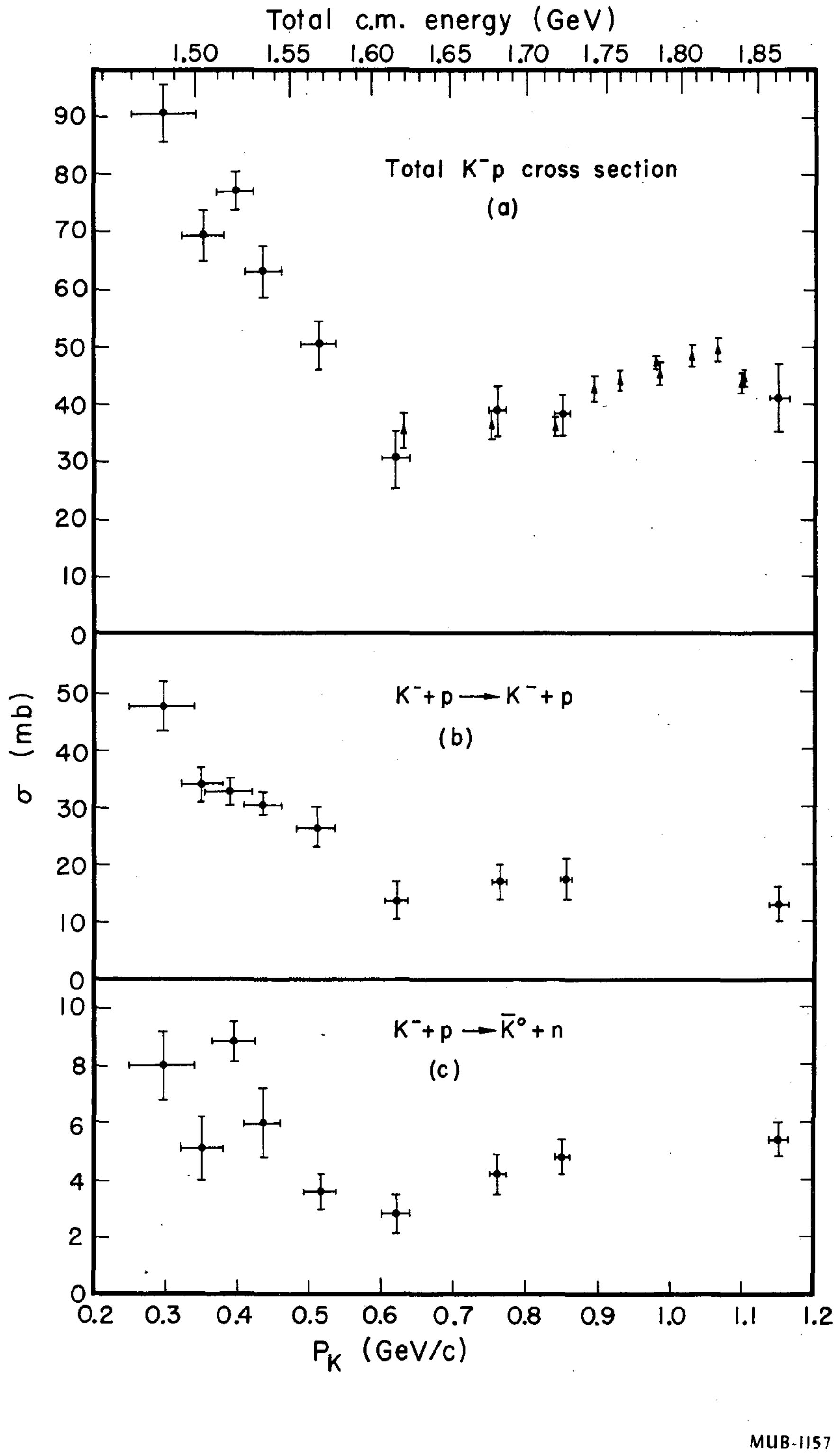
P_K(MeV/c) =	293 ± 42	350 ± 31	390 ± 30	434 ± 26	513 ± 20	620 ± 15	762 ± 8	850 ± 10
$K^- p$	48.2±4.2	34.0±3.2	32.7±1.8	30.6±3.4	26.5±3.3	13.8±3.0	17 ± 3	17.5±4
$\overline{K^0}\, n$	8.0±1.2	5.1±1.1	8.8±0.7	6.0±1.2	3.6±0.6	2.8±0.7	4.2±0.7	4.8±0.6
$\Sigma^+ \pi^-$	13.6±1.4	10.6±1.4	12.5±0.08	8.2±0.9	7.5±1.1	4.6±0.7	2.9±0.4	2.0±0.3
$\Sigma^- \pi^+$	10.0±1.1	6.9±1.0	6.9±0.5	6.1±0.7	4.9±0.8	2.1±0.4	3.3±0.3	1.6±0.2
$\Sigma^0 \pi^0$	5.2±0.9	6.3±1.4	6.7±0.6	4.9±1.3	1.7±0.3	2.3±0.5	1.8±0.4	0.9±0.3
$\Lambda \pi^0$	5.2±0.9	4.5±1.0	3.1±0.3	3.2±0.7	1.6±0.4	2.6±0.5	2.2±0.4	2.8±0.5
$\Lambda(\Sigma^0)\pi^0\pi^0$	0.3±0.2	1.9±0.6	1.5±0.2	0.8±0.4	1.1±0.3	0.8±0.2	2.0±0.4	1.4±0.3
$\Lambda \pi^+ \pi^-$	0.15±0.1	0.9±0.3	1.6±0.2	1.5±0.4	2.0±0.4	1.8±0.3	3.3±0.3	3.2±0.3
$\Lambda(\Sigma^0)\pi^+\pi^-\pi^0$	---	---	---	---	0±0.01	0±0.03	0.25±0.05	0.15±0.05
$\Sigma^+\pi^-\pi^0$	0±0.05	0.06±0.06	0.11±0.04	0.18±0.11	0.2±0.12	0.2±0.13	0.7±0.1	0.6±0.1
$\Sigma^-\pi^+\pi^0$	0.05±0.05	0±0.06	0.12±0.05	0±0.06	0.14±0.10	0.4±0.15	0.8±0.1	0.7±0.1
$\Sigma^0\pi^+\pi^-$	0±0.02	0±0.09	0.07±0.06	0±0.08	0.3±0.15	0.3±0.1	0.7±0.1	0.8±0.1
$\overline{K^0}\, p\pi^-$	---	---	---	---	---	0±0.03	0.04±0.03	0.10±0.06
$K^- p \pi^0$	---	---	---	---	---	0.06±0.06	0.13±0.1	1.0±0.4
$K^- \pi^+ n$	---	---	---	---	---	0.06±0.06	0± 0.1	0.2± 0.1
Total	90.7±4.9	70.2±4.2	73.8±2.3	61.5±4.1	49.5±3.7	31.8±5.0	39.3±4.0	37.8±4.0

FIGURE LEGENDS

Fig. 1. (a) Total K^-p cross section. The triangles represent the results of the counter experiments of reference 2. The point at 1.15 GeV/c comes from reference 1. (b) $K^- + p \rightarrow K^- + p$ cross section. (c) $K^- + p \rightarrow \overline{K^0} + n$ cross section.

Fig. 2. Cross sections for the reactions (a) $K^- + p \rightarrow \Lambda + \pi^0$, (b) $K^- + p \rightarrow \Lambda$ (or Σ^0) $\pi^0 + \pi^0$, and (c) $K^- + p \rightarrow \Lambda + \pi^+ + \pi^-$. Cross section (b) includes production of $\eta_{neutral}$ (only the neutral decay mode of η falls into this category). At 760 MeV/c, $\sigma(\Lambda + \eta_{neutral})$ is estimated to be 0.48 ± 0.10 mb; at 850 MeV/c, σ is less than 0.02 ± 0.02 mb. The open circles represent upper limits from charge independence ($\sigma_{\Lambda \pi^0 \pi^0} \leq \sigma_{\pi^+\pi^-}/2$). Cross section (c) includes $Y_1^*(1385) + \pi$ production; at 760 MeV/c, $\sigma(Y_1^{*\pm} + \pi) = 2.4 \pm 0.3$ mb, at 850 MeV/c, $\sigma(Y_1^{*\pm} + \pi) = 1.9 \pm 0.5$ mb.

Fig. 3. Cross sections for the reactions (a) $K^- + p \rightarrow \Sigma^- + \pi^+$, (b) $K^- + p \rightarrow \Sigma^0 + \pi^0$, (c) $K^- + p \rightarrow \Sigma^+ + \pi^-$, (d) $K^- + p \rightarrow \Sigma^- + \pi^+ + \pi^0$ (e) $K^- + p \rightarrow \Sigma^0 + \pi^+ + \pi^-$, and (f) $K^- + p \rightarrow \Sigma^+ + \pi^- + \pi^0$.



Total c.m. energy (GeV)
1.50
1.55
1.60
1.65
1.70
1.75
1.80
1.85
Total K⁻p cross section
(a)
K⁻+p ⟶ K⁻+p
(b)
K⁻+p ⟶ K̄° + n
(c)
σ (mb)
P_K (GeV/c)
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
MUB-1157

Fig. 1

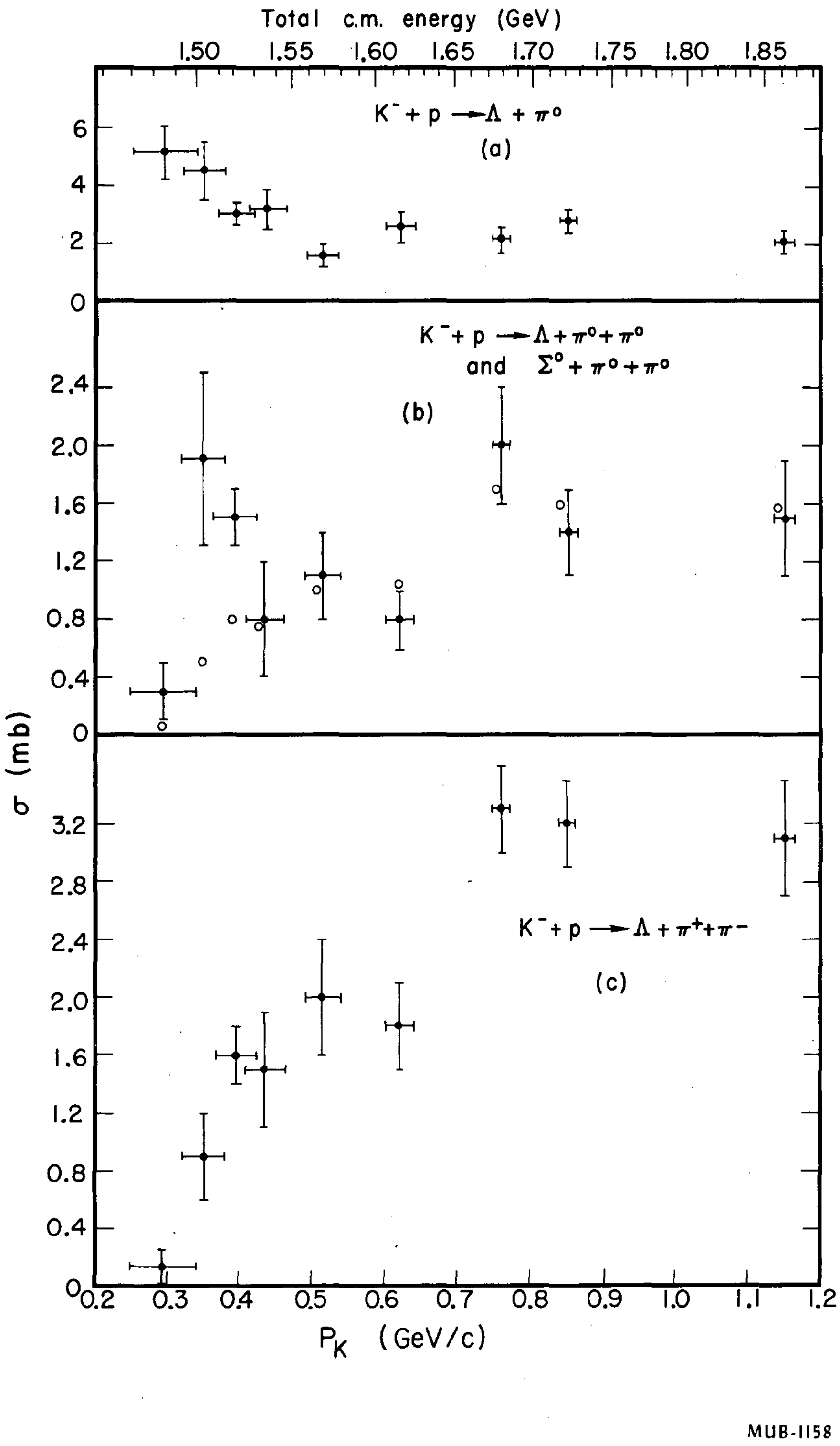

Total c.m. energy (GeV)
1.50 1.55 1.60 1.65 1.70 1.75 1.80 1.85
K⁻ + p → Λ + π°
(a)
K⁻ + p → Λ + π° + π°
and Σ° + π° + π°
(b)
K⁻ + p → Λ + π⁺ + π⁻
(c)
σ (mb)
P_K (GeV/c)
MUB-1158

Fig. 2

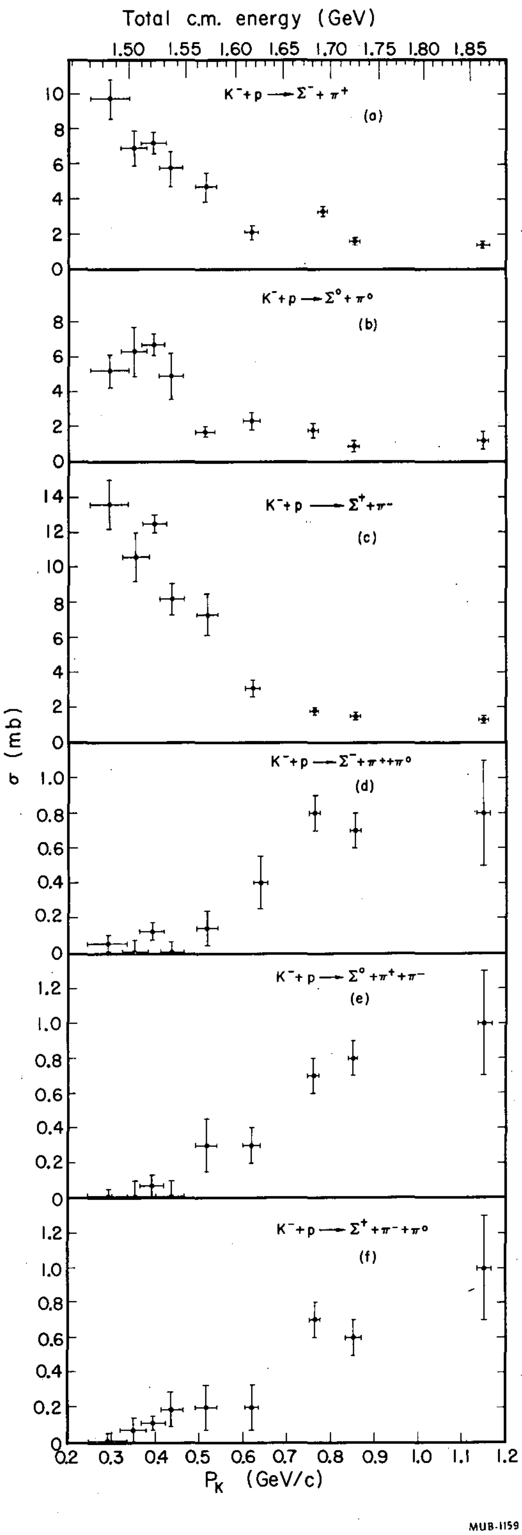

Total c.m. energy (GeV)
1.50 1.55 1.60 1.65 1.70 1.75 1.80 1.85
K⁻+p → Σ⁻+π⁺
(a)
K⁻+p → Σ⁰+π⁰
(b)
K⁻+p → Σ⁺+π⁻
(c)
K⁻+p → Σ⁻+π⁺+π⁰
(d)
K⁻+p → Σ⁰+π⁺+π⁻
(e)
K⁻+p → Σ⁺+π⁻+π⁰
(f)
σ (mb)
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2
P_K (GeV/c)
MUB-1159

Fig. 3