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TOTAL CROSS SECTION MEASUREMENTS OF $K^+$-p AND $K^+$-n INTERACTIONS IN THE MOMENTUM REGION 0.77 to 2.83 Bev/c

V. Cook, D. Keefe, L. T. Kerth, P. G. Murphy, W. A. Wenzel, and T. F. Zipf

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IN THE MOMENTUM REGION 0.77 TO 2.83 Bev/c

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July 20, 1961

Total K⁺-p and K⁺-n cross section measurements have been made
previously up to 0.8 Bev/c with emulsions,¹ counters,² and bubble chambers,³
in the region 0.8 to 2.4 Bev/c by the MIT group,⁴ and at momenta above 2.7
Bev/c by the CERN⁵ and Dubna⁶ groups. From the data of the MIT, Dubna, and
CERN experiments, it is difficult to arrive at a satisfactory description of the
K⁺-p cross section, σₚ, in the region of a few Bev/c. At the highest momentum
measured by the MIT group (2.4 Bev/c), σₚ was found to be 12.9±1.0 mb, whereas
at 2.9 Bev/c the CERN group found σₚ = 24.5±2.5 mb. The present experiment
was undertaken partly for the purpose of resolving this difficulty.

The experimental technique was similar to that used by Cook et al. to
measure K⁻-p total cross sections.⁷ The beam is illustrated in Fig. 1. A feature
of the present beam not encountered in the K⁻ beam described in Ref. 7 was that
the high proton counting rate (approx. 2×10⁶/sec) could cause accidental background.
This source of accidentals was eliminated with an anticoincidence circuit designed
to reject any K⁺ meson that was accompanied by another beam particle within a
time of ±50 μsec.

The hydrogen-deuterium target was 4 ft long, 6 in. in diameter, made of
0.007 in. stainless steel, and was vacuum insulated. Two transmission counters,
T₁ and T₂, were used. The T₁ counter was a 12 in. × 12 in. × 1/4 in. scintillator,
and T₂ was a circular scintillator 9 in. in diameter and 1/4 in. thick. The distance
of T₁ and T₂ from the target was varied between 5 ft and 10 ft, depending on the
momentum, to minimize the corrections for Coulomb scattering, decay in flight, etc. Several alternate "target full" and "target empty" runs were made at each momentum. The results are shown in Table 1 and are plotted in Figs. 2(a) and 2(b), together with data from other experiments.

Corrections have been included for the following: (a) There is a change in the decay-in-flight rate due to energy loss in the full target – this is largest at low momenta (approx 3 mb) but can be calculated reliably; (b) Forward scattering and forward recoil corrections to the hydrogen data were calculated using values for the 0 deg and 180 deg cross sections obtained by interpolation from angular-distribution measurements at 1.0, 1.2, and 2.0 Bev/c. For the larger counter this correction amounted, at most, to 0.4 mb. The forward scattering corrections to the deuterium data were calculated using optical theorem values for the forward scattering cross sections. For the larger counter this correction varied from 0.5 mb to a maximum of 1.3 mb at the highest momentum. (c) Multiple scattering in the target introduced a correction to the smaller counter results at 770 Mev/c (0.7 mb) and 970 Mev/c (0.1 mb). (d) The Glauber screening correction, used to derive $\sigma_n$ from $\sigma_d - \sigma_p$, amounted to about 5% at all energies. In arriving at $\sigma_n$ from $(\sigma_d - \sigma_p)$, a further correction should be applied for the effect of the Pauli exclusion principle in suppressing forward charge-exchange scattering in deuterium. Until relevant data becomes available this correction cannot be estimated accurately, and therefore no correction was included.

There is a small systematic difference between the cross sections measured by the counters $T_1$ and $T_2$, the former giving a smaller value at each energy. The results given in Table 1 are averages of the corrected cross sections obtained from the two counters, and may therefore contain a systematic error of – at most – $\pm 0.3$ mb, affecting all the values equally.
Both $\sigma_p$ and $\sigma_n$ appear to remain remarkably constant at about 17 to 18 mb in the momentum range 1 to 3 Bev/c, implying that the $I = 0$ and $I = 1$ interactions are of approximately equal strength. The present measurements give a value of $\sigma_p$ above that for the highest energy point of the MIT group, below that for the lowest energy point of the CERN group and in good agreement with the points of the Dubna group. At lower energies the present results are in good agreement with those of the MIT group. The $K^+\text{-}p$ cross section at 0.77 Bev/c is significantly below the value at higher energies, in agreement with recent bubble chamber measurements.\textsuperscript{10}

The $K^+\text{-}p$ interaction up to 0.8 Bev/c has been explained almost exclusively in terms of an $S$-wave interaction,\textsuperscript{1,2,3} but it is clear that the approximately constant value of $\sigma_p$ persisting to higher energies cannot be due to $I = 0$ contributions alone, since $4\pi k^2$ is 18 mb at 1.0 Bev/c and 10 mb at 1.5 Bev/c. The results of Ref. 8 show that there is a rapidly developing anisotropy in the elastic angular distribution at 1 Bev/c and above, indicating that higher angular momentum states contribute strongly to the elastic scattering at these energies. Furthermore, the $K^+\text{-}p$ interaction shows an increasing contribution from inelastic processes above 1 Bev/c.

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†On leave from the Rutherford High Energy Laboratory, Harwell, England.

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   Zipf, to be published.

Table 1. Total cross sections: $K^+ p$, $K^+ d$, and $K^+ n$. The corrections that have been included are described in the text. The quoted errors include all known random uncertainties; in addition, there may be a systematic error of at most $\pm 0.3$ mb, which would translate all values together. The $\sigma_n$ has not been corrected for Pauli principle effects in the deuteron. The $\Delta\Omega_1$ is the solid angle subtended by $T_1$ at the center of the hydrogen target.

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<th>1.17</th>
<th>1.30</th>
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<th>1.69</th>
<th>1.97</th>
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<td>18.1</td>
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<td>35.4</td>
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<tr>
<td>$\sigma_n$ (mb)</td>
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<td>17.8</td>
<td>18.2</td>
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<td>$\Delta\Omega_1$ (msr)</td>
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FIGURE LEGENDS

Fig. 1. Arrangement of the variable-momentum $K^+$ beam. $M_1$, $M_2$, and $M_3$ are bending magnets; $Q_1$, $Q_2$, and $Q_3$ are magnetic quadrupole lenses; $B_1$, $B_2$, $B_3$, and $B_4$ are coincidence counters; $A_1$ and $A_2$ anticoincidence counters; and $C_1$ and $C_2$ are gas Cerenkov counters. The transmission of the hydrogen target was measured by the scintillation counters $T_1$ and $T_2$.

Fig. 2. The $K^+$ total cross sections as a function of momentum:
(a) $K^+$-p cross section, $\sigma_p$, and (b) $K^+$-n cross section, $\sigma_n$. 
8" diameter quadrupole lens (triplets)
12" x 60" deflecting magnet

Scale (ft)
0 10

Proton-beam trajectory
Internal target

2000 psi Cerenkov counters
48" liq. H₂ or deuterium target

13" x 24" C magnets
8" diameter quadrupole lens (doublet)

Fig. 1
This experiment

\[ \sigma_p \text{ (mb)} \]

\[ P_{lab} \text{ (Bev/c)} \]

- Emulsion
- Kycia et al.
- Burrowes et al.
- Vovenko et al.
- von Dardel et al.
- This experiment

Fig. 2a
Fig. 2b