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January 4, 1956

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THE INTERACTION OF POSITIVE K MESONS

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With the availability of focused K-meson beams at the Bevatron,[1] it became possible to make a systematic study of the interactions of positive K mesons.[2] The method used was to observe interactions of K mesons in flight in nuclear emulsions.

The experimental arrangement and scanning method were described previously in the report[3] on the K^+ lifetime. The K-meson beam is a mixture of all K-meson types and (or) modes of decay and is known to consist predominantly of $K_{\mu2}$, $K_{\pi2}$, and τ mesons (~58% $K_{\mu2}$, ~30% $K_{\pi2}$, and ~7% τ).[4] In this work we have not separated the interactions of the various types of decay; however, almost all types have been seen to interact.[5]

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[1] Kerth, Stork, Birge, Haddock, and Whitehead, Phys. Rev. 99, 641A (1955).

[2] Chupp, Goldhaber, Goldhaber, Iloff, Lannutti, Pevsner, and Ritson, Proceedings of the International Conference of Elementary Particles, Pisa, Italy, June 1955 (to be published).

[3] Iloff, Chupp, Goldhaber, Goldhaber, and Lannutti, Phys. Rev. 99, 1617 (1955).

[4] Ritson, Pevsner, Fung, Widgoff, Zorn, Goldhaber, and Goldhaber, Phys. Rev., in press.

J. R. Peterson, Bull. Am. Phys. Soc. 30, Number 8, 19 (1955) (1955 Pacific Coast Winter Meeting, University of Southern California).

[5] Friedlander, Keefe, and Menon, Nuovo Cimento 1, 694 (1955) have observed the inelastic scatter of a $K_{\mu3}$.

Yash Pal, Rochester Conference, 1955, reporting on work of the Bombay group, described the inelastic scatters of two τ mesons.

We have observed one inelastic scatter of a τ meson, one of a $K_{\pi2}$ whose decay secondary interacted in flight, and one of a K whose decay secondary is consistent with that of a $K_{\mu2}$

In scanning along the track, we have observed the interactions of K mesons ranging in kinetic energy from 30 to 120 Mev. In 38.5 meters of K-meson track we have found 60 elastic[6] and inelastic scatterings greater than 20°. In addition there were four events in which no K meson was found to be reemitted. These are consistent with the charge-exchange reaction $K^{+} + N \to K^{0} + P$. In none of the above 64 interactions was any π-meson or hyperon production observed and, in fact, the visible energy release never exceeded the kinetic energy of the K meson.

These experimental facts are in good agreement with a number of schemes[7] that have recently been proposed to describe the behavior of heavy mesons and hyperons. All these schemes contain a new quantum number (e.g., "strangeness"), which is conserved in fast reactions. They predict only three types of interactions for positive K mesons, viz., elastic, inelastic, and charge-exchange scattering. Absorption reactions, including the production of π mesons and hyperons, are forbidden in the energy range studied. This behavior can be contrasted with that of negative K mesons for which absorption reactions (e.g., $K^{-} + P \to \Sigma^{\pm} + \pi^{\overset{0}{\mp}}$) are observed[8,9] and are consistent with the conservation of "strangeness" in a fast reaction.

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[6] Of these, two events were identified as elastic scatters from hydrogen in the emulsions. (Chupp, Goldhaber, Goldhaber, Johnson, and Lannutti, Phys. Rev. 99, 1042 (1955).) This corresponds to a cross section of the order of 15 mb (within the statistics of two events).

[7] M. Gell-Mann, Nuovo Cimento, in press.
A. Pais, Physica 19, 869 (1953).
T. Nakano and K. Nishijiama, Prog. Theoret. Phys. (Japan) 10, 581 (1954).
M. Goldhaber, Phys. Rev., in press.
R. G. Sachs, Phys. Rev. 99, 1576 (1955).

[8] Hornbostel and Salant, Phys. Rev. 98, 213 (1955).
Goldhaber, Goldhaber, Iloff, Lannutti, Webb, Pevsner, Ritson, and Widgoff, Proceedings of the International Conference of Elementary Particles, Pisa, Italy, June 1955 (to be published in Nuovo Cimento).

[9] Chupp, Goldhaber, Goldhaber, and Webb, Proceedings of the International Conference of Elementary Particles, Pisa, Italy, June 1955 (to be published in Nuovo Cimento).
Gilbert, Violet, and White, Bull. Am. Phys. Soc. 30, No. 8, 19 (1955) (1955 Pacific Coast Winter Meeting, University of Southern California).
Fry, Schneps, Snow, and Swami, Phys. Rev. 100, 950 (1955).

Another striking difference between K^+ and K^- interactions is the comparatively small cross section we find for K^+ interactions in emulsion. We observe a mean free path for K^+ interactions in emulsion of 95 cm (which corresponds to 6 mb per nucleon)[10] as compared to ~25 cm, which is observed in K^- interactions.[8]

Table I gives the angular distribution of the K^+ scatters in the two energy regions 30 to 75 Mev and 75 to 120 Mev, as well as the separation into elastic and inelastic events. There is some indication for a decrease in the cross section in the high-energy interval.

Figure 1 gives the differential scattering cross section in arbitrary units. It can be seen that from 40° to 180° the differential cross section is isotropic within our statistics. This fact, together with the observed energy dependence, indicates a large S-wave component in the scattering cross section. From 40° down to 20° (our cutoff angle) a steep rise in the differential cross section is observed. The extension of this work to smaller angles and the analysis in terms of Coulomb and coherent scattering is in progress.

The mean free path of 95 ± 16 cm in emulsion and the resulting cross section $\sigma \cong$ 6 mb per nucleon[10] ($\sigma \approx \frac{(\sigma_n + \sigma_p)}{2}$) were obtained by extrapolating the isotropic distribution to 0°, and thus do not include diffraction and Coulomb effects. A contribution due to charge-exchange events was also included. There were four charge-exchange and 36 non-charge-exchange events (extrapolated isotropically to 0°). This proportion of charge-exchange events is consistent with perturbation theory results.[11]

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[10] B. Rossi, High Energy Particles (Prentice-Hall, Inc., New York, 1952), p. 359.

[11] It has been pointed out to us independently by Brueckner and by Pais that our data are understandable in terms of a perturbation theory in which the K^+ -nucleon scattering process is described as follows: The nucleon first emits a K meson to give an intermediate state with two K mesons and a Σ or Λ^0 particle, and the Σ or Λ^0 particle reabsorbs the K meson to give the final state. This theory predicts for $g^2 \sim 1/2$ a cross section of the order of 5 mb. In addition, for a Σ in the intermediate state it gives a ratio of charge exchange to non-charge exchange of 1 : 5 and for a Λ^0 in the intermediate state, a ratio of 1 : 1. The potentials for the charge-exchange part are opposite in sign, and a mixture of intermediate states could give a ratio even smaller than 1 : 5 for the charge-exchange to non-charge-exchange cross sections.

We wish to thank Dr. Edward J. Lofgren and the entire Bevatron crew for their help in making these exposures possible. We also wish to thank the scanning groups at Berkeley and M. I. T. for their help in scanning the plates.

Table I

The observed distribution of elastic and inelastic K^+ meson scatters in emulsion.

K-Meson Energy (Mev)	K-meson Scattering Angle (Lab)								Path Length (Meters)
	20^o-40^o		40^o-60^o		60^o-120^o		120^o-180^o		
	Elastic	Inelastic[(a)]	Elastic	Inelastic	Elastic	Inelastic	Elastic	Inelastic	
30-75	11	3	3	1	4	7	-	5	18.6
75-120	13	1	2	1	2	3	-	4	19.9

[(a)]Inelastic events include (1) scatters with a clear energy loss and (or) emission of two or more additional prongs, (2) scatters in which one additional prong is emitted without momentum conservation, and (3) those in which an allowance was made for single neutron emission corresponding to cases of single proton emission in class (2). All other events were classified as elastic scatters. As we cannot separate "slightly inelastic" scatters (energy loss of a few Mev) from elastic scatters, such events, if present, would be classified as "elastic" here.

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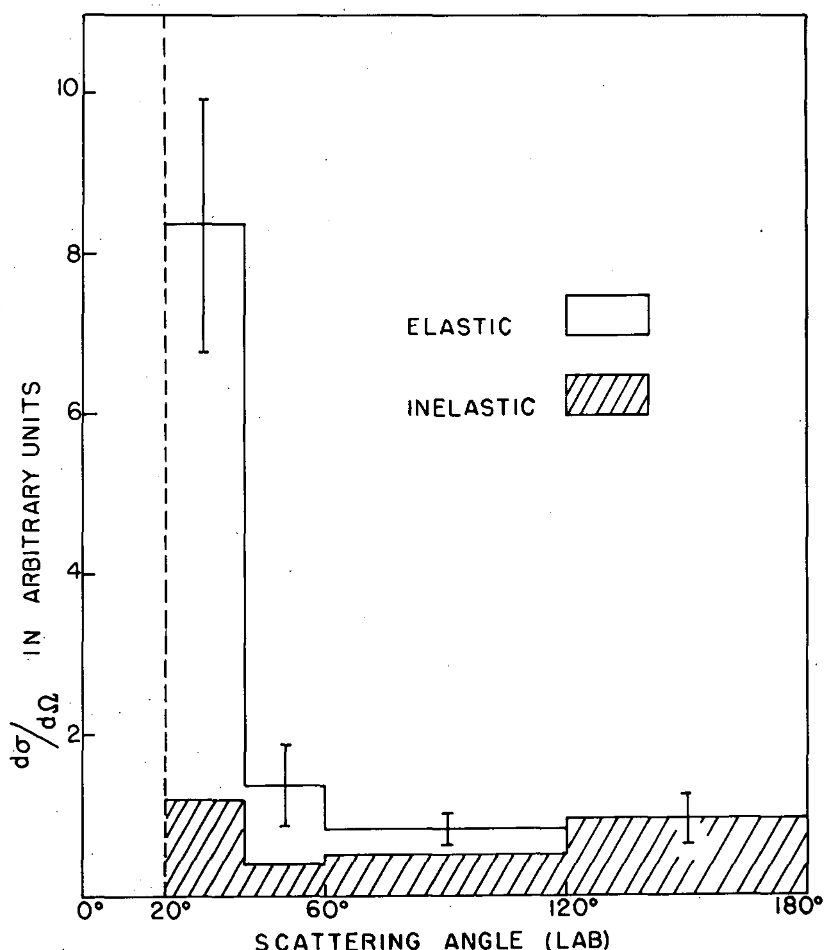
FIGURE CAPTION

Fig. 1. The differential scattering cross section of K^+ mesons in arbitrary units.



10
8
6
4
2
dσ/dΩ IN ARBITRARY UNITS
ELASTIC
INELASTIC
0°
20°
60°
120°
180°
SCATTERING ANGLE (LAB)

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