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June 10, 1955

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To gain further information on the nature of K particles, we have embarked on a program of study of K-particle interactions. The ideas on the nature and behavior of K particles and hyperons are expressed by Gell-Mann and Pais[1] and those of M. Goldhaber[2] and R. G. Sachs[3] make rather definite predictions about the interactions of K particles.

There are two main features in the interaction of positive K particles that stand out quite clearly despite the limited data we have so far. In the first place, although the entire rest energy of the K^+ particle (about 500 Mev) together with its kinetic energy of 10 to 120 Mev is available, <u>all</u> K^+ stars here observed are of a type showing only a small visible energy release.

Thus we do not observe any interactions accompanied by π-meson emission (except for events that can be clearly ascribed to decays in flight--see below) such as are observed for negative K-particle stars,[4,5] where the excess energy available (after hyperon formation) makes π-meson production energetically possible.

The K^+ interactions here observed are all in the nature of elastic scattering and inelastic scattering, with possibly two cases that can be ascribed to a charge-exchange interaction K^+ "n" $\rightarrow K^0$ + "p". We thus feel that our data present evidence (a) in favor of the concept of the conservation of a quantum number[1,2,3] ("strangeness") by the K^+ particle and possibly by a family consisting of K^+ and K^0 (isotopic spin T = 1/2), and (b) that the value of this quantum number for the K^+ meson is different from that for the K^- mesons and hyperons.

The second feature is that the interaction cross section for K^+ mesons is quite small, about 1/3 of the geometric cross section. This feature is in accord with the ideas proposed by M. Goldhaber,[2] which are based on the assumption of a weakly interacting K^+ (and K^0) and a strongly interacting K^-

(and $\overline{K}^0$) meson. Alternately one may presume a mixture of different types of K particles, some of which are interacting while others are not.

We have exposed stacks of Ilford G.5 emulsions in the focused K^+ beam[6] at the Bevatron. The momentum selection per plate is about ± 5%. There is, however, an additional variation in momentum across the stacks. The average momentum accepted in one of our stacks is 350 Mev/c, in another it is 410 Mev/c.

The technique used was to select K-particle tracks on the basis of ionization (grain density) beyond the stopping protons. In this region the K mesons are at about twice minimum, whereas the π mesons of the same momentum are essentially at minimum ionization.

Each track between 1.8 and 3 times minimum is then picked out rather easily by visual inspection and is followed out through the stack. Except for about 15% contamination (stray protons scattered in, prongs of stars in the emulsion, etc.), all tracks so picked turn out to be K particles or τ mesons, and occasionally interact or decay in flight. In each interaction observed the K meson was identified by grain count and multiple scattering (except for those cases of elastic and inelastic scattering where the K particle ended and decayed in the stack). In this fashion we eliminated a number of spurious events, proton interactions, and prongs coming from stars.

So far we have followed 27.3 meters of K track and 1.5 meters of τ track. We have found 26 elastic scatters of angle greater than 20° and of E_K greater than 30 Mev, most of which are Coulomb scatters. We also found 16 inelastic scatters and two possible charge-exchange events. In addition we have found 16 events in which a K particle emits a lightly ionizing particle in flight, which we consider to be decays in flight.

A. Elastic Scatterings

On scanning along the track in the present work we made no attempt to pick up all elastic scattering below 20° or scatters in the last 6 mm of range (E_K < 30 Mev). Above these values, the efficiency for finding scatters should be close to 100%. Figure 1 shows a scatter diagram of all the elastic and inelastic scatters found. Table I gives a comparison between the observed data and the expected number of elastic Coulomb scatters. From Table I it can be seen that Coulomb scatters can account for a large proportion of the observed elastic scatters. One can estimate that perhaps 9 of the observed elastic scatters are due to nuclear interactions. One of these is a K-hydrogen scatter[7] and two others may be considered elastic scatters from light elements in the emulsion (as determined from the recoils, which appear to conserve momentum).

B. Inelastic Events

We have considered as inelastic scatters all events in which a K meson interacts and emerges with a clear indication of energy loss. That is, events showing an appreciable change in grain density and (or) additional prongs, or recoils not conserving momentum, were placed in this class. The distinction between elastic and inelastic events is not completely clear-cut and thus the inelastic events are also given in Table I and Fig. 1 for comparison. Table II gives a description of the 16 events classified as inelastic scatters. In addition there were two possible examples of charge exchange in which the K particle did not reappear nor did its rest energy appear in visible prongs. From all the interactions it can be considered that there are about 9 + 16 + 2 = 27 events beyond the number expected from Coulomb scattering. This then corresponds to a mean free path for nuclear interaction in emulsion of ~ 100 centimeters. Our result thus corresponds to a cross section for nuclear interaction of K^+ particles of about 1/3 of the geometric cross section. No nuclear interaction of τ mesons was observed in the 1.5 meters of τ-meson track followed. However, as not all scattered K particles ended in our stacks, some of them might have been τ mesons, and thus no definite conclusion is possible on this point.

C. Decays in Flight

In the above scanning along the track of K mesons 16 decays in flight were found. These were identified by the fact that the outgoing prong has a grain density smaller than the incoming meson. In all cases the K meson is identified by multiple-scattering and grain-counting measurements. If these events were due to the nuclear interaction of K^+ particles, it would be expected that some events should occur in which one or more black evaporation prongs emerge in addition to the track of low grain density. As no such interactions were observed, we conclude that our identification as decay in flight is valid. The sum of the proper slowing-down times of all the K^+ mesons followed was calculated by use of the tables of Fay, Gottstein, and Hain.[8] Since a decay in flight occuring in the last 2 millimeters of a track might not be recognized, the time spent in this part of the track was not counted.

Excluding those tracks due to τ mesons, a total of 27.3 meters o[illegible]-meson track was scanned. This corresponds to a total proper time of 16.[illegible] x 10^{-8} second for the K-meson ranges here involved, which yields a mean life-time for K mesons of $1.1 \pm 0.3 \times 10^{-8}$ second. The error given is the statistical standard deviation with an additional allowance for an uncertainty in the length of track scanned. In addition, 1.5 meters of τ-meson track was followed, which corresponds to a total proper time of $0.95 \pm 0.14 \times 10^{-8}$ second. No decay in flight of a τ meson was observed.

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Table I

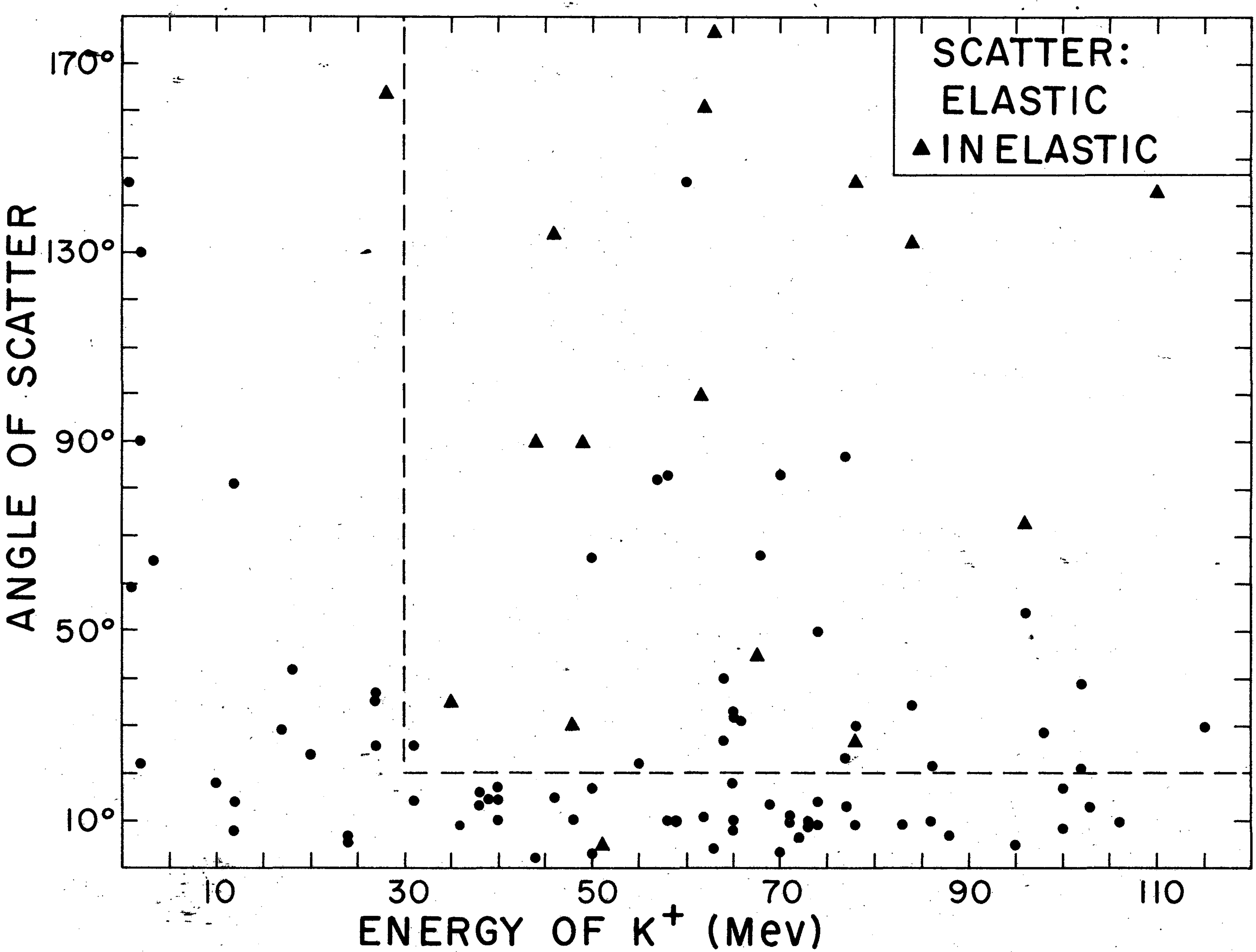
Energy (Mev)	Scattering Angle of K^+ Mesons: $20^\circ - 30^\circ$ Observed Inelastic	$20^\circ - 30^\circ$ Observed Elastic	$20^\circ - 30^\circ$ Expected Coulomb	$30^\circ - 90^\circ$ Observed Inelastic	$30^\circ - 90^\circ$ Observed Elastic	$30^\circ - 90^\circ$ Expected Coulomb	$90^\circ - 180^\circ$ Observed Inelastic	$90^\circ - 180^\circ$ Observed Elastic	$90^\circ - 180^\circ$ Expected Coulomb	Path Length (Meters)
30-60	0.5	2.0	8.0	3.0	4.0	5.2	2.5	0.5	0.4	9.3
60-90	1.0	4.5	2.3	1.0	9.5	1.6	4.0	0.5	0.12	8.7
90-120	0.0	2.5	1.2	1.0	2.5	0.75	1.0	0.0	0.06	7.2
Total	1.5	9.0	11.5	5.0	16.0	7.55	7.5	1.0	0.58	25.2

Table II

Inelastic Events					
No.	Energy of Scattering E_K (Mev)	Energy of Scattered K Meson E_K' (Mev)	Scattering Angle θ	Additional Prongs	Comments
1	28 ± 8	28	164°	recoil	No momentum conservation with recoil
2	35 ± 9		35°	-----	
3	44 ± 9	17.5	90°	17.6-Mev proton	Inelastic
4	46 ± 9	19	134°	Auger electron	
5	48 ± 8		30°	200-μ proton	
6	49 ± 8	21	90°	-----	
7	51 ± 8	51	5°	recoil	No momentum conservation with recoil
8	62 ± 6		100°	-----	
9	62 ± 6		161°	one proton	
10	63 ± 6		177°	3-mm proton	
11	68 ± 6		45°	-----	
12	78 ± 6		145°	-----	
13	78 ± 6		27°	recoil	No momentum conservation with recoil
14	84 ± 6		132°	3 short protons or alphas	
15	96 ± 5		73°	120-μ proton and 7-μ recoil	
16	110 ± 5		143°	-----	
17	47 ± 9	----	----	500-μ proton	Possible charge-exchange scattering
18	93 ± 5	----	----	10-mm proton	Possible charge-exchange scattering

Figure Caption

Fig. 1. A scatter diagram of angle versus energy for all the elastic and inelastic K^+ scatters found. The lines drawn show the region of $\theta_K > 20^\circ$ and $E_K > 30$ Mev as described in Table I.


SCATTER:
ELASTIC
INELASTIC
ANGLE OF SCATTER
170°
130°
90°
50°
10°
10
30
50
70
90
110
ENERGY OF K^+ (Mev)

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