UCRL 3046

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

DISCLAIMER

UNIVERSITY OF CALIFORNIA

Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

INTERACTIONS OF NEGATIVE K PARTICLES AT REST

W. W. Chupp, Gerson Goldhaber, S. Goldhaber
and F. H. Webb

June 14, 1955

INTERACTIONS OF NEGATIVE K PARTICLES AT REST

W. W. Chupp, Gerson Goldhaber, S. Goldhaber
and F. H. Webb

Radiation Laboratory, Department of Physics
University of California, Berkeley, California

June 14, 1955

Stacks of Ilford G.5, 600-μ stripped emulsions were exposed to the focused K^- beam[1] at the Bevatron. The 6.1 Bev proton beam was incident on a copper target, and we observed K^- mesons produced at 90° to the beam direction. The K^- momentum channels of 350 Mev/c and 410 Mev/c were used. Both K^- and π^- of the same momentum were incident on the stack. The proper time of flight for the K^- meson was about 10^{-8} second.

Along the track scanning was done from the incident edge, and all tracks of approximately twice minimum were followed to the end of their range. This scanning technique introduces no bias in size or type of stopping found.

The K_ρ^- events were identified by grain count versus residual range.

Table I gives a compilation of all K^- stoppings observed to date. For each prong the measured range, or g/g_o, and the corresponding energy is given. The total visible and binding energy per star is also given.

Among the 22 K^- stars, we have observed 6 definite cases of π-meson emission and 3 additional probable cases. One definite case of hyperon (Σ^+) emission has been observed with 3 possible additional cases.

In the above compilation there are two events which deserved special attention. Events K_2^- and K_{20}^- each have two prongs emitted which are colinear to within our accuracy of measurement. In the work done at M.I.T. and Harvard[2] two additional events were observed. In the following discussion we will consider these four events. Each event has one lightly ionizing prong, presumably a π meson which leaves the stack, and a dark prong which ends. In two of the events (K_2 and $K_{MH\ 1}$) a fast L meson is emitted from the end of the dark prong, indicating that this prong is due to a Σ^+ particle. In the other two events, K_2 and $K_{MH\ 2}$, no visible secondary was emitted from the end of the dark prong, which could be due to a Σ^- giving a zero-prong star. Table II gives the measurements on these four events. We would like to suggest that these four events are due to K^- - meson capture in hydrogen by the following reaction:

$$K^- + H \longrightarrow \Sigma^{\pm} + \pi^{\mp}$$

From the observed range of the Σ^+ and Σ^- (assumed) we consider two cases.

(A) K^- Mass from the Σ Mass

For events K_{20} and $K_{MH\ 1}$ we take the measured Σ^+ mass $2327 \pm 3\ m_e$,[3] and calculate the corresponding K^- mass by use of conservation of energy and momentum. This assumes that the Σ^+ decays occurred at rest. As the prongs here involved are rather steep, we cannot prove this point and we have to consider the masses here obtained from K_{20} and $K_{MH\ I}$ as lower limits to the K^- mass.

If the Σ^+ from $K_{MH\ 1}$ has decayed in flight, the data would be more consistent. The total moderation time for the two Σ particles observed is 5.5×10^{-11} second and the Σ^+ lifetime is $< 5 \times 10^{-10}$ second.[4] A decay in flight is thus plausible. For events K_2 and $K_{MH\ 2}$ we assumed that $M(\Sigma^+) = M(\Sigma^-)$ and we performed the same type of calculation obtaining the K^- mass. These two events cannot be decays in flight, as no visible secondaries are observed. Table III - A and Fig. 1 give the resulting K^- masses.

(B) Σ^+ and Σ^- Masses from an Assumed K^- Mass

We assume a K^- mass, $M(K^-) = M_\tau = 965.5 \pm .7 m_e$ [4] and analyze our data for the resulting Σ^+ and Σ^- masses. Events K^-_{20} and $K_{MH\ 1}$ give upper limits for the Σ^+ mass, whereas events K_2 and $K_{MH\ 2}$ give the Σ^- mass on the present assumptions. Table III - B and Fig. 2 give the resulting Σ^+ and Σ^- masses.

The range-energy table of Barkas and Young[5] was used to perform these calculations. As more such events become available one should be able to distinguish between decays in flight and particles coming to rest.

It is interesting to note that if the above interpretations are correct, it implies that 4 out of 34 K^- [6] mesons have stopped in hydrogen in the emulsion. If we take 35 % of all stoppings[7] to occur in the light elements (C, O, N, H) and if we assume that the Z law for π^- and μ^- stoppings[8] applies in this case, we get $G_H = 0.35\ F_H$ where

$$F_H = \frac{\frac{\rho_H}{A_H} Z_H}{\frac{\rho_C Z_C}{A_C} + \frac{\rho_O Z_O}{A_O} + \frac{\rho_N Z_N}{A_N}} \quad \frac{2 \rho_H}{\rho_C + \rho_O + \rho_N} = 0.185$$

as the fraction of stoppings in hydrogen. Thus $G_H = 0.064$ or 6.4%, which is consistent with the observed number (within the poor statistics.) This does imply, however, that the effect observed by Panofsky, Aamodt and Hadley [9] for π^- mesons, in which a $\pi^- + H$ mesic atom moves close to a carbon or lithium nucleus and then transfers the π^- to the heavier nucleus, does not apply to K^- mesons.

This work was carried out under the auspices of the U.S. Atomic Energy Commission.

Table I

Compilation of K^- stoppings

Event	Prong and Identity	Range	g/g_o	Energy	Visible Energy + Binding Energy	Comments
		μ		Mev	Mev	
K_1^-	1 p	174		5.1	13	
	2 p	600		10.5	18	
	3 p	275		6.7	15	
	4 p	670		11.2	19	
	5 p	18900		75.6	84	
	6 π		1.43	62	200	
			± 7%		349	
K_2^-	1 (Σ^-)	695		12.7		(1) and (2) colinear - see discussion below
	2 π		1.31 ± 7%	75 ± 11		
K_3^-	1 p	2200		22.2	30	
	2 p	>11700		> 57	>65	
	3 p	87		3.3	11	
	4 p	1000		14.2	22	
	5 p	3110		27	35	
	6 p	7920		46	54	
					>217	
K_4^-	1 p	3350		28.2	36	
					36	
K_5^-	1 p	513		9.6	18	
	2 p	36		1.8	10	
	3 p	>794		>12.4	>20	
	4 π or (p)		1.44	60	200	If p, E = 220 Mev
			± 7%		>248	
K_6^-	1 p	64		2.7	11	
	2 π^-	18700		30	170	
	3 r	1		---	---	
					>181	
[illegible]	1 p	>7280		44	52	
					52	

Table I (continued)

Event	Prong and Identity		Range μ	g/g_o	Energy Mev	Visible Energy + Binding Energy Mev	Comments
K_8^-	1	p	8000		46.3	54	
	2	p	11		.8	9	
	3	p	25		1.5	9	
	4	p	1220		15.8	24	
	5	p	21000		80	88	
						184	
K_9^-	1	p	19		1.3	9	
	2	p	2750		25	33	
						42	
K_{10}^-	1	p	23		1.4	9	
	2	π		1.31 ± 7%	75	215	
						224	
K_{11}^-	1	π or e		1.13 ± 7%	93	233	assuming π
						233	
K_{12}^-	1	r	2		.2		
	2	p	70		2.9	11	
	3	π or (p)		1.60 ± 7%	50	190	If p, E = 175 Mev
						> 201	
K_{13}^-	0					0	K_ρ blob at end
						0	
K_{14}^-	1	p	84 μ		3.2	11	
	2	r	2 μ				
						11	
K_{15}^-	1	p or (Σ)	5630		38	46	Scatter (or decay) of prong 1 by 49° R_{res} 4000
	2	p	216		5.7	14	
	3	p	445		8.8	17	
						77	
K_{16}^-	1	π	3720		13.1	153	
	2	p	1850		20	28	
	3	p	326		7.7	15	
	4	p	203		5.5	14	
						210	
[illegible]7	1	p	23.5		1.4	9	
	2	p	763		12.1	20	
	3	p	420		8.6	17	
	4	p	68[illegible]		11.[illegible]	[illegible]	
						[illegible]	

Table I (continued)

Event	Prong and Identity*	Range μ	g/g_o	Energy Mev	Visible Energy + Binding Energy Mev	Comment
K^-_{18}	1 p o (Σ^-)	815		12.5	20	Prong (1) [illegible] 1.1 ± .4 M_p has two short co-linear prongs at its end. Ranges 9.5 and 17μ could be coincidence (or Σ^- star).
	2 p	134		3.7	12	
	3 p	3360		28.2	36	
	4 p	268		5.7	14	
	5 p	315		7.3	15	
	6 p	108		3.8	12	
					109	
K^-_{19}	1 p	>8250		47	>55	
	2 p	181		5.2	13	
	3 p	223		5.8	14	
	4 p	125		4.1	12	
					>94	
K^-_{20}	1 Σ^+	809		14		(1) and (2) colinear see discussion below
	2 π		~1.1	~ 85		
K^-_{21}	1 p	4000		31.2	39	
					39	
K^-_{22}	1 p	17		1.1	9	
	2 p	10		.8	9	
	3 p	2160		22	30	
					48	

* Energies are computed on the assumptions that all prongs are protons unless otherwise stated.

Table II
Measurements on Colinear* Events

Event	Prong 1 (Σ)				Prong 2 (π)	
	Range μ	Dip $\Delta z/100\,\mu$	Moderation time in units of 10^{-11} sec.	Notes	g/g_o	Dip $\Delta z/100\,\mu$
K_{20}	309 ± 40	-41.4	2.5	(Σ^+) secondary	~1.1 ± .2	+ 41.3
$K_{MH\ 1}$	579 ± 25		2.0	(Σ^+) secondary		
K_2	695 ± 25	+24.3	2.3	Σ^- No visible secondary	1.31 ± 7%	- 24.5
K_{MH-2}	691 ± 45		2.3	(Σ^-) No visible secondary		

* The projected colinearity of prongs 1 and 2 in all four events is better than 0.5^o.

Table III

K^- and (or) Σ^+ and Σ^- Masses from the suggested reaction $K^- + H \rightarrow \Sigma^\pm + \pi^\pm$

Event	Emitted Particle	Case A $M(K^-)$ in m_e $(M_{\Sigma^+} = 2327 \pm 3\ m_e)$[3]	Case B Assume $M(K^-) = M(\tau^+) = 965.5 \pm .7$[4]	
			$M(\Sigma^+)$	$M(\Sigma^-)$
K^-_{20}	Σ^+	$\geq 966 \pm 6\ m_e$	$\leq 2324 \pm 4$	————
$K^-_{MH\ 1}$	Σ^+	$\geq 935 \pm 5\ m_e$	$\leq 2355 \pm 4$	————
Assume $M_{\Sigma^-} = M_{\Sigma^+} = 2327 \pm 3\ m_e$				
K^-_2	(Σ^-)	$= 952 \pm 5\ m_e$	————	2338 ± 4
$K^-_{M\text{-}H\ 2}$	(Σ^-)	$= 951 \pm 7\ m_e$	————	2338 ± 6

Figure Captions

Fig. 1 Mass of K^- particle versus range of Σ particle for the reaction $K^- + H \longrightarrow \Sigma^{\pm} + \pi^{\mp}$.
Assumption A: $M(\Sigma^+) = M(\Sigma^-) = 2327 \pm 3\ m_e$. The 4 experimental Σ ranges and their corresponding K^- masses are shown.

Fig. 2 Mass of Σ^+ and Σ^- versus range of Σ particle for the reaction $K^- + H \longrightarrow \Sigma^{\pm} + \pi^{\mp}$.
Assumption B: $M(K^-) = M(\tau) = 965.5$. The 4 experimental Σ ranges and the corresponding Σ^+ and Σ^- masses are shown.

References

1. Kerth, Stork, Birge, Haddock and Whitehead, Bull. Am. Phys. Soc. 30 41, (1955).

2. Pevsner, Ritson, and Widgoff (private communication). We are grateful to these authors for making their data available to us.

3. Astbury et al., Report of Charged Hyperons, Nuovo cimento, Suppl. XII, 458 (1954).

4. Amaldi et al., Report of Committee on τ- mesons, Nuovo cimento, Suppl. XII, 419 (1954).

5. Barkas and Young, UCRL-2579 (Revised), unpublished.

6. Two Colinear events were found in 22 stars at Berkeley and 2 in 12 stars at Massachusetts Institute of Technology and Harvard.

7. R. E. Marshak, Meson Physics, p. 171 (McGraw-Hill 1952).

8. Fermi and Teller, Phys. Rev. 72 399 (1947).

9. Panofsky, Aamodt and Hadley, Phys. Rev. 81 565 (1951).