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Authors
Webb, Francis H.
Chupp, Warren W.
Goldhaber, Gerson
et al.

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UNIVERSITY OF CALIFORNIA
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Berkeley, California

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THE RATIO OF K^- MASS TO K^+ MASS

Francis H. Webb, Warren W. Chupp,
Gerson Goldhaber, and Sulamith Goldhaber

December 5, 1955

Atomic Energy Commission

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Measurements on the mass of the positive K particle have recently been carried out by direct comparison of the ranges of K^+ and τ^+ mesons and by comparison of ranges of K^+ mesons and protons of the same momentum.[1, 2, 3, 4] For negative K particles no such direct comparison is possible. Hornbostel and Salant[5] determined the K^- mass by a range-momentum method as $931 \pm 24\ m_e$.

In order to compare the negative K-meson mass with the positive K-meson mass, we have exposed stacks of nuclear emulsions to the focused K^+ and K^- beams[1, 2] of the Bevatron, maintaining the geometry constant and reversing the magnetic field[6] in the focusing spectrometer.

The stacks were exposed with the plane of the emulsions in the vertical direction. The horizontal momentum dispersion in the analyzing magnet gives rise to a momentum spread across the stacks. The momentum in the K^+ stack (forty 600-μ Ilford G.5 pellicles) varies from about 315 Mev/c to 335 Mev/c, and that of the K^- stacks (one hundred thirty-two 600-μ pellicles) from about 280 Mev/c to 355 Mev/c. Immediately behind the stacks a copper absorber and wedge were placed to stop the positive and negative π mesons in the respective exposures. The geometry of the exposure is shown in Fig. 1.

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[1] Birge, Haddock, Kerth, Peterson, Sandweiss, Stork, and Whitehead, Phys. Rev. 99, 329 (1955).

[2] Birge, Peterson, Stork, and Whitehead, Phys. Rev. 100, 430 (1955).

[3] Fung, Pevsner, and Ritson (in press).

[4] Heckman, Smith, and Barkas, University of California Radiation Laboratory Report No. UCRL-3156, 1955.

[5] Hornbostel and Salant, Phys. Rev. 99, 338 (1955).

[6] The stray field of the Bevatron increases the magnetic field of the strong-focusing spectrometer for exposures to positive particles and decreases it for exposures to negative particles. A compensation for the stray field was made which almost cancelled this effect.

The scanning method used in this experiment was "scanning along the track." Tracks were picked on the basis of their ionization (grain density) at the entering edge of the emulsion in the negative stack and 1 cm from the edge (i.e., after the region in which the protons of the same momentum stop) in the positive stack. The limits of the grain density at which a particle was selected were chosen so as to include particles between the mass of 700 m_e and 1300 m_e. All K mesons that underwent a nuclear scattering (scattering $\sim 20^\circ$ for $E_K > 30$ Mev) were eliminated from the sample chosen for the K^--mass determination. Three K^- mesons and two K^+ mesons were eliminated in this fashion. The method employed for the K^-- mass determination was as follows:

1. The ranges of the positive K mesons were used to determine the momentum of the positive channel. The mass of the K^+ used for the momentum determination is $M_{K^+} = M_\tau = 965.4\ m_e$. It should be noted that the M_{K^-}/M_{K^+} ratio is not sensitive to this assumption. Figure 2 shows the range distribution of the positive K mesons.

2. Both the positive and negative π mesons were stopped with a copper absorber and wedge (under the same geometry), permitting us to determine the π^+ and π^- range difference. This was accomplished by observation of stopping π mesons in pellicles placed in the wedge. The knowledge of the momentum in the positive channel and of the difference in the π^+ and π^- ranges permits us to calculate the momentum in the negative channel. This calculation was carried out by integrating the function dp/dR, by use of Aron's tables.[7] The difference in the momenta obtained from the pion range difference ($R_{\pi^+} - R_{\pi^-} = 1.46$ cm in emulsion) is 9 Mev/c. This method is not affected by the over-all accuracy to which the range-energy relation is known since it uses dE/dx to bridge across only a small momentum difference. The range distribution of the positive and negative π mesons is shown in Fig. 3.

3. The range of the negative K mesons, and the momentum in the negative channel obtained by Method 2, permitted us to determine the K^- mass.[8]

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[7] Aron, Hoffman, and Williams, University of California Radiation Laboratory Report No. UCRL-121, 1949.

[8] Range-energy tables of Barkas and Hahn, (University of California Radiation Laboratory Report No. UCRL-2579 were used in this work.

For the K^-- mass determination we used the ranges of 42 K^- mesons found in the central part of the stack. Any error in the mass due to the error in the measurement of the momentum dispersion is thus negligible. The momentum dispersion was measured by wire trajectories[1] and checked by us with the range of protons in the positive channel. The uncertainties that contribute to the error in the K^- mass are (a) statistical errors; (b) alignment errors, which are of the same order as the statistical errors; (c) errors in range measurements, which are negligible compared with (a) and (b). As all our measurements were carried out relative to the K^+ range, systematic errors would tend to cancel.

The ratio of the negative K-meson mass to positive K-meson mass thus obtained is

$$M_{K^-}/M_{K^+} = 0.998 \pm 0.013.$$

The mass of the K^-, if we assume $M_{K^+} = M_\tau = 965.4\ m_e$, is

$$M_{K^-} = 963 \pm 12\ m_e.$$

The above mass determination corresponds to the mass of K mesons present, after a time of flight of 1.4×10^{-8} sec in the proper system of the K mesons.

We are greatly indebted to Dr. E. J. Lofgren and the Bevatron crew for their assistance in carrying out the exposures. We also wish to thank Mr. H. H. Bayona, G. M. Wike and Mrs. C. Toche for their help in scanning the emulsions.

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

FIGURE LEGENDS

Fig. 1. Exposure geometry.

Fig. 2. Range distribution of positive K mesons.

Fig. 3. Range distribution of positive and negative pions. The mesons traversed the stack and the copper absorber and wedge. The equivalent emulsion range is given by $\xi_{emulsion} = 3.85\ g/cm^2$.

Fig. 4. Mass histogram of the negative K mesons (assuming $M_{K^+} = M_{\pi^+} = 965.4\ m_e$).

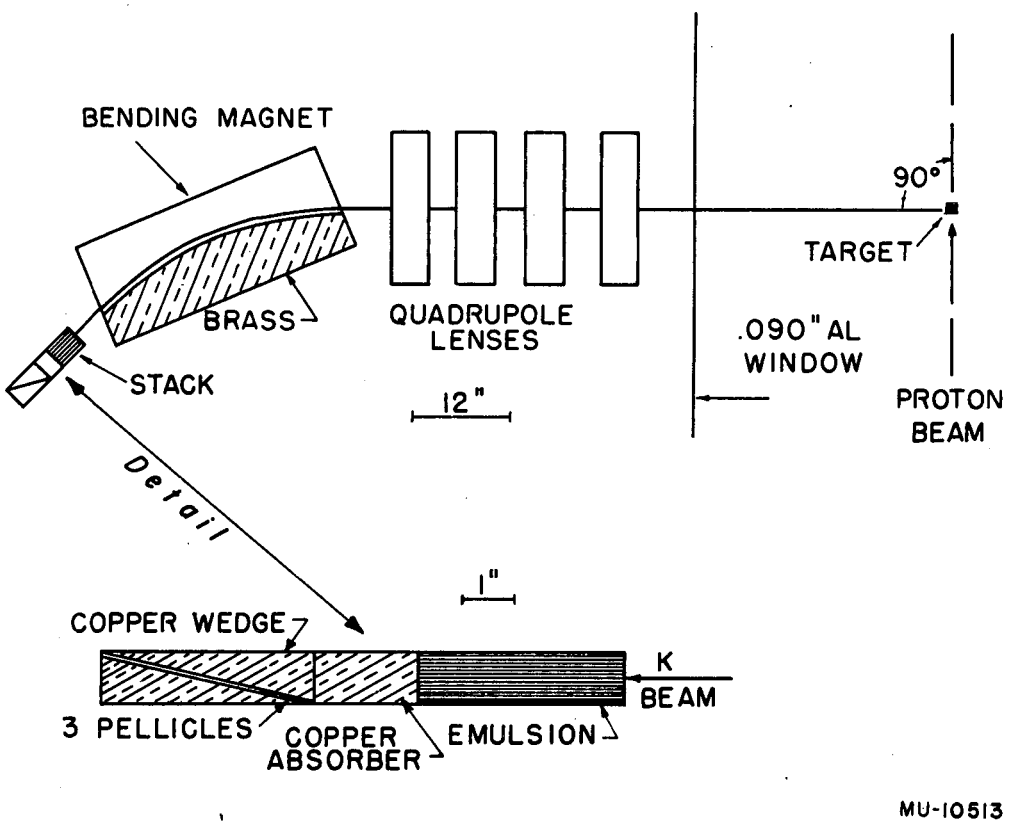

Fig. 1. Exposure geometry.

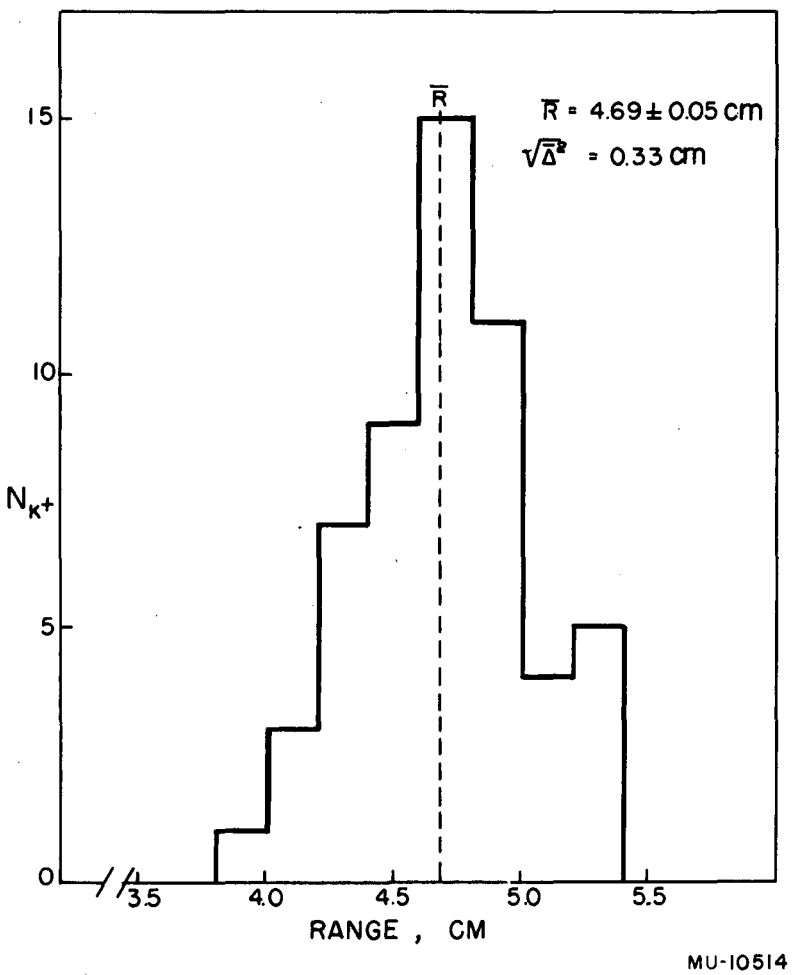

Fig. 2. Range distribution of positive K mesons.

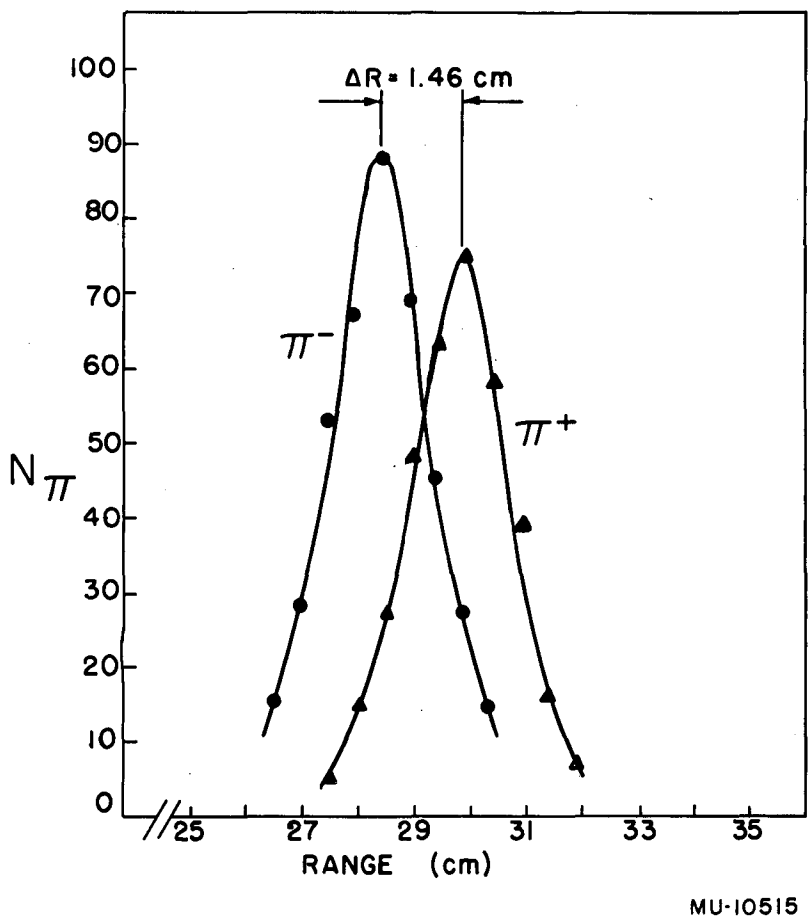

Fig. 3. Range distribution of positive and negative pions. The mesons traversed the stack and the copper absorber and wedge. The equivalent emulsion range is given by ρ emulsion = 3.85 g/cm^2.

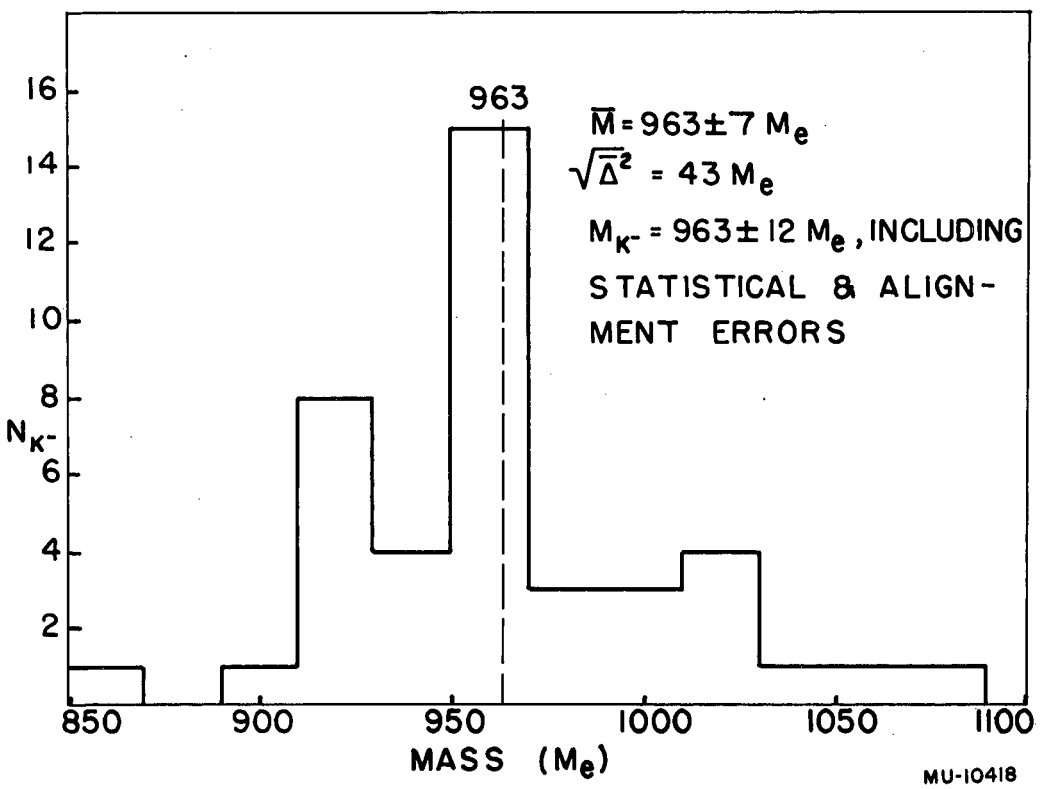

Fig. 4. Mass histogram of the negative K mesons (assuming $M_{K^+} = M_{\pi^+} = 965.4\ m_e$).