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LIFETIME OF K MESONS

Luis W. Alvarez, Frank S. Crawford, Myron L. Good
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Since the various species of K mesons produced at the Bevatron are found to have masses equal within the rather small experimental error,[1,2] it becomes a critical matter to see if the lifetimes of the different species are different--as one would expect if they have separate identities--or if the lifetimes are all the same--as they would be if there is but one primary K meson which has several alternate modes of decay. This letter describes preliminary results of a counter experiment investigating this point.

The magnet arrangement devised by Kerth and Stork[3] was used (Fig. 1, A), with the quadrupoles set to focus an image of the target at the central counter C. The momentum dispersion was such that counter C was traversed by positive particles of 340 Mev/c at its right-hand end, and 400 Mev/c at the left end. The momentum at each point was fairly well defined, so that it was possible, by tapering the absorber between counters No. 1 and C, to compensate for the dispersion and bring all K particles incident on counter C to rest in C. Counters No. 0 and No. 1 served as beam-defining counters. At each momentum, there are about 400 protons and 40 π^+ mesons for every K^+. The protons have shorter ranges, and are stopped in the absorber between No. 1 and C; the π's go through C and through the anticoincidence counter No. 2. Since about one in six of the π's interacts in C and misses No. 2, No. 2 has an effective efficiency of only 5/6, and was therefore augmented by a lucite Cerenkov counter (Cer) placed in front of counter No. 1. The K-particle velocities are all below Cerenkov threshold, whereas the π velocities are all well above it. The Cerenkov counter provided a rejection factor of about 40 for π's; with both Cer and No. 2 in anticoincidence, about

$$40 \times 1/6 \times 1/40 \cong 0.15$$ π's should be counted for every K.

The coincidence 0 + 1 + C - 2-Cer $\equiv$ G should then denote a K^+ particle stopping in C. Figure 2 shows the counting rate G vs thickness of the absorber in front of C. The expected peak at the range corresponding to mass ≈ 965 is present, as well as a background of $\approx 15\%$, measured at large absorber thicknesses, caused by π's.

The rise at small absorber thickness is probably caused by protons scattered from the magnet.

As a further check, a curve of G vs cable delay between counters 0 and (1 + C) was taken. This distribution was centered at the expected K-particle time of flight, but was too broad to be of very great use in eliminating π's.

From these facts we conclude that the G counts are chiefly caused by stopping K particles.

The identification of the individual K particles according to type, and the measurement of the lifetime of each event, is accomplished by the side-counter telescope ABCDE (Fig. 1B).

An oscilloscope sweep is triggered by each G coincidence, and the outputs of counters A, B, C, D, and E (separated by appropriate cable delays) are displayed on the sweep. A C pulse is present on each sweep, since it is associated with the G coincidence that triggered the sweep. The lifetime is measured by observing the time delay between the C pulse and the side-counter pulses.

The $K_{\mu 2}$, $K_{\pi 2}$, and τ are identified by the following configurations:

$$K^+_{\mu 2}\ (\rightarrow \mu^+ + \nu) = G + D + E - A - B,$$

$$K^+_{\pi 2}\ (\rightarrow \pi^+ + \pi^0) = G + D - E + A - B,$$

$$\tau^+\ (\rightarrow \pi^+ + \pi^- + \pi^+) = G + D - E - A + B.$$

(The two side-counter pulses on each "signature" -- as D, E for the $K_{\mu 2}$ -- are required to be simultaneous.)

Thus the $K_{\mu 2}$ is identified by having a secondary capable of penetrating 2 inches of Cu, greater than the range of any of the $K_{\pi 2}$ or τ decay products. The $K_{\pi 2}$ is identified by having a charged secondary with range $<$ 2 inches of Cu, as well as a neutral secondary that converts in the absorber between A and B; and the τ by having at least two charged secondaries of small range. These properties are sufficiently decisive that there will be very little "cross-talk" between the different types of K decays. Other types of K mesons are known, from emulsion experiments, to be too rare to influence our results.[4]

As a check on the reality of the signatures $K_{\pi 2}$ and $K_{\mu 2}$, the absorber between D and E was increased to more than the expected range of the μ from $K_{\mu 2} \rightarrow \mu + \nu$, and the converter between A and B was removed. When this was done the $K_{\mu 2}$ and $K_{\pi 2}$ events disappeared. A similar check on the τ's led to inconclusive results.

The raw data of the lifetime experiment are shown in Fig. 3, in the form of integral decay curves.

The lifetime of the $K_{\pi 2}$ and $K_{\mu 2}$ are equal within the experimental error.

The lifetimes were calculated from $\tau = \frac{\Sigma ti}{N}$, correcting N for a measured background of zero-time events arising from scattered π's. The scattered-proton contribution to the zero-time events is small, since coincidences involving G plus one or more side counters did not show the rise at small absorber that is seen in Fig. 2. Accidental background was negligible. This analysis gave, for the mean lives,

$$K_{\mu 2} = 1.4 \pm 0.2 \cdot 10^{-8} \text{ sec},$$

$$K_{\pi 2} = 1.3 \pm 0.2 \cdot 10^{-8} \text{ sec}.$$

A more accurate lifetime, for a mixture of K particles, was obtained from coincidences GD, GB, and GBA. Each of these categories corresponds to K mesons whose decay products fall in an angular range where they do not produce a signature. These events gave:

$$K = 1.3 \pm 0.1 \cdot 10^{-8} \text{ sec}.$$

The GD decay curve (Fig. 3) may be fitted by a single exponential.

Results for the less abundant τ are not yet clear-cut; however, the independent measurement by Alvarez and Goldhaber[5] gave

$$\tau = 1.0 {}^{+0.7}_{-0.3} \cdot 10^{-8} \text{ sec}$$

which is equal, within statistics, to the above $K_{\pi 2}$ and $K_{\mu 2}$ lifetimes.

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

A preliminary report of this work was presented at the Chicago Meeting of the American Physical Society.[6]

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2. R. W. Birge, R. P. Haddock, L. T. Kerth, J. R. Peterson, J. Sandweiss, D. H. Stork, and M. N. Whitehead, "Positive Heavy Mesons Produced at the Bevatron," University of California Radiation Laboratory Report No. UCRL-3031; also Proceedings of the Pisa Conference on Elementary Particles, 1955 (Supplemento del Nuovo Cimento, to appear).
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6. L. W. Alvarez, F. S. Crawford, M. L. Good, M. L. Stevenson, Bull. Am. Phys. Soc., 1955, to appear.

List of Figures

Fig. 1. (A) Top view of apparatus

(B) Side view of counter telescope

Fig. 2. K-particle range curve

Fig. 3. Integral decay curves

Ordinates are the actual numbers of events observed, uncorrected for detection efficiencies. The data are uncorrected for zero-time contribution caused by scattered π's. The solid lines are exponentials of $1.3 \cdot 10^{-8}$ sec decay constant, and are not necessarily best fits to the data.

The decays are each well represented by a single exponential, and are consistent with equality of lifetimes for the $K_{\pi 2}$ and $K_{\mu 2}$.

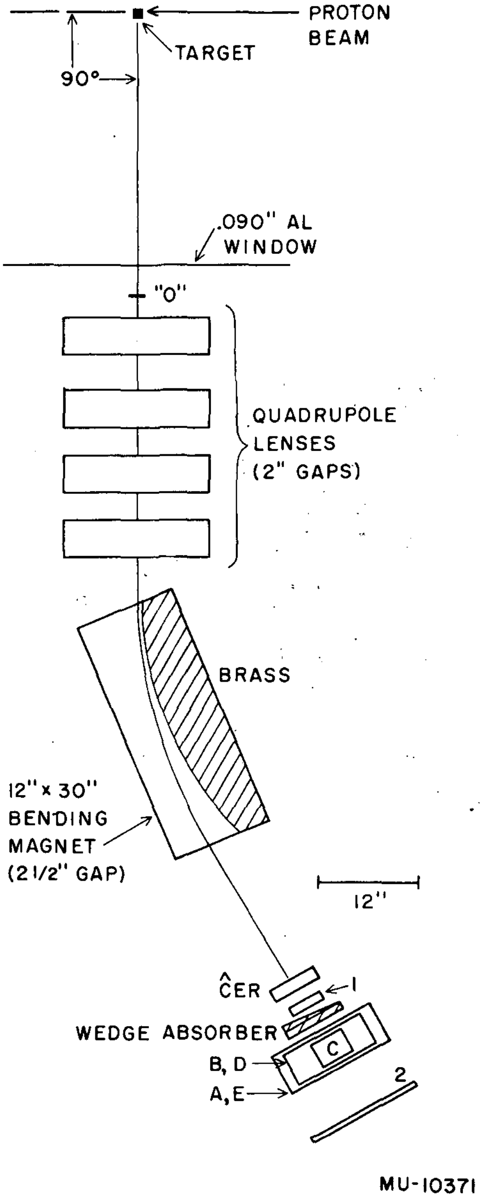
PROTON
BEAM
TARGET
90°
.090" AL
WINDOW
"0"
QUADRUPOLE
LENSES
(2" GAPS)
BRASS
12" x 30"
BENDING
MAGNET
(2 1/2" GAP)
12"
ĈER
1
WEDGE ABSORBER
C
B, D
A, E
2
MU-10371

Fig. 1-A

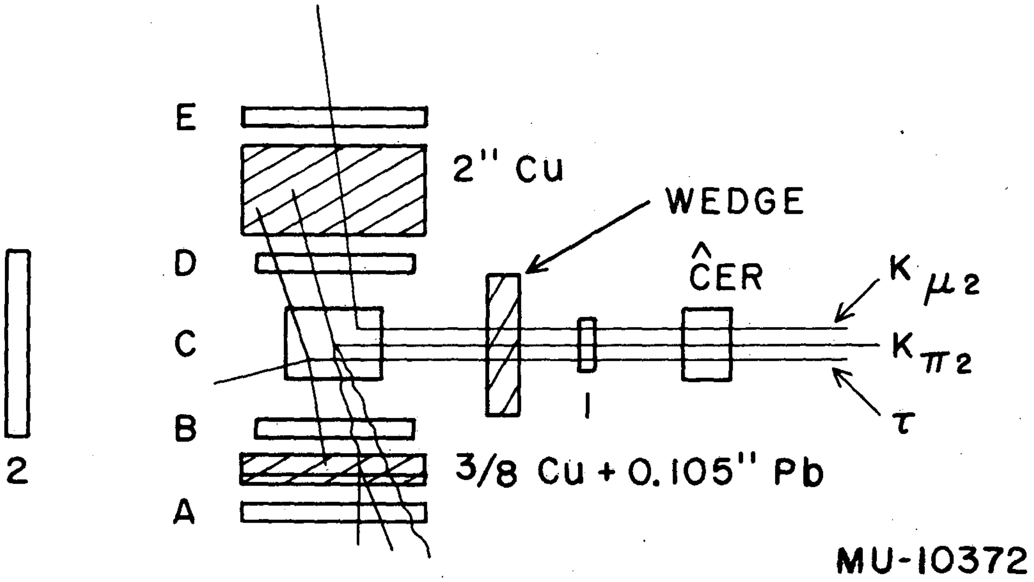

Fig. 1-B

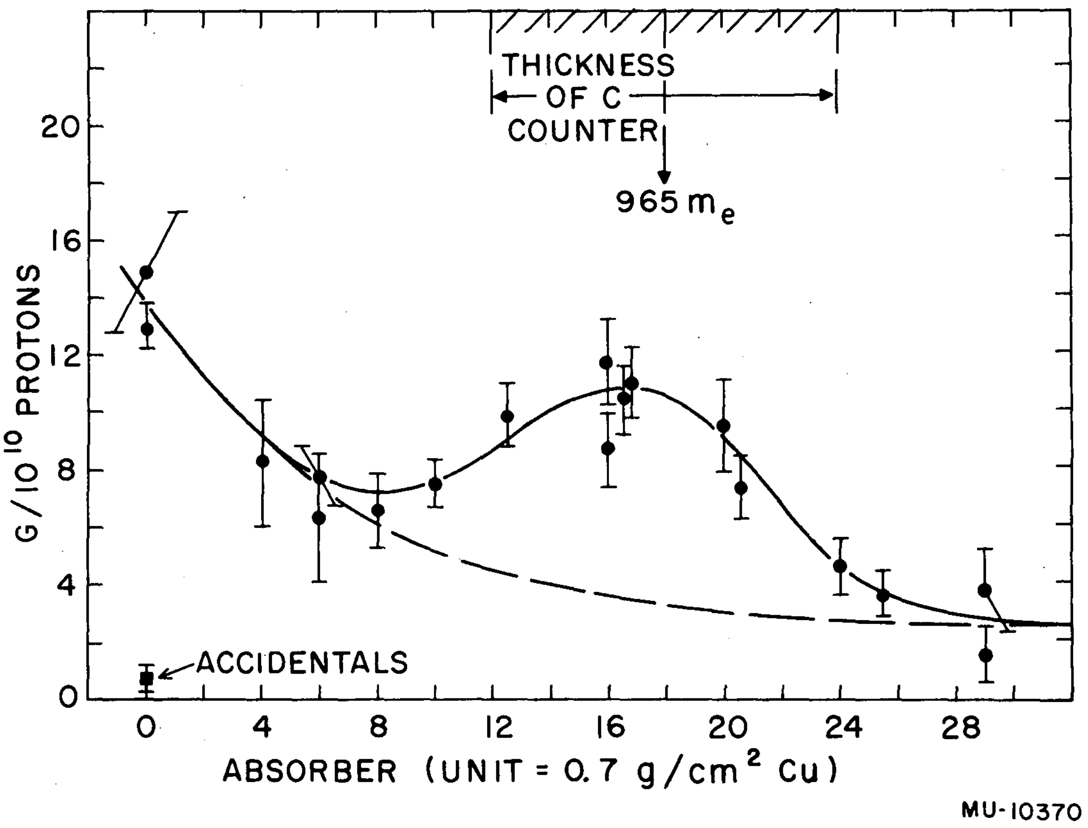
THICKNESS
OF C
COUNTER
965 m_e
G/10^{10} PROTONS
0
4
8
12
16
20
ACCIDENTALS
0
4
8
12
16
20
24
28
ABSORBER (UNIT = 0.7 g/cm^2 Cu)
MU-10370

Fig. 2

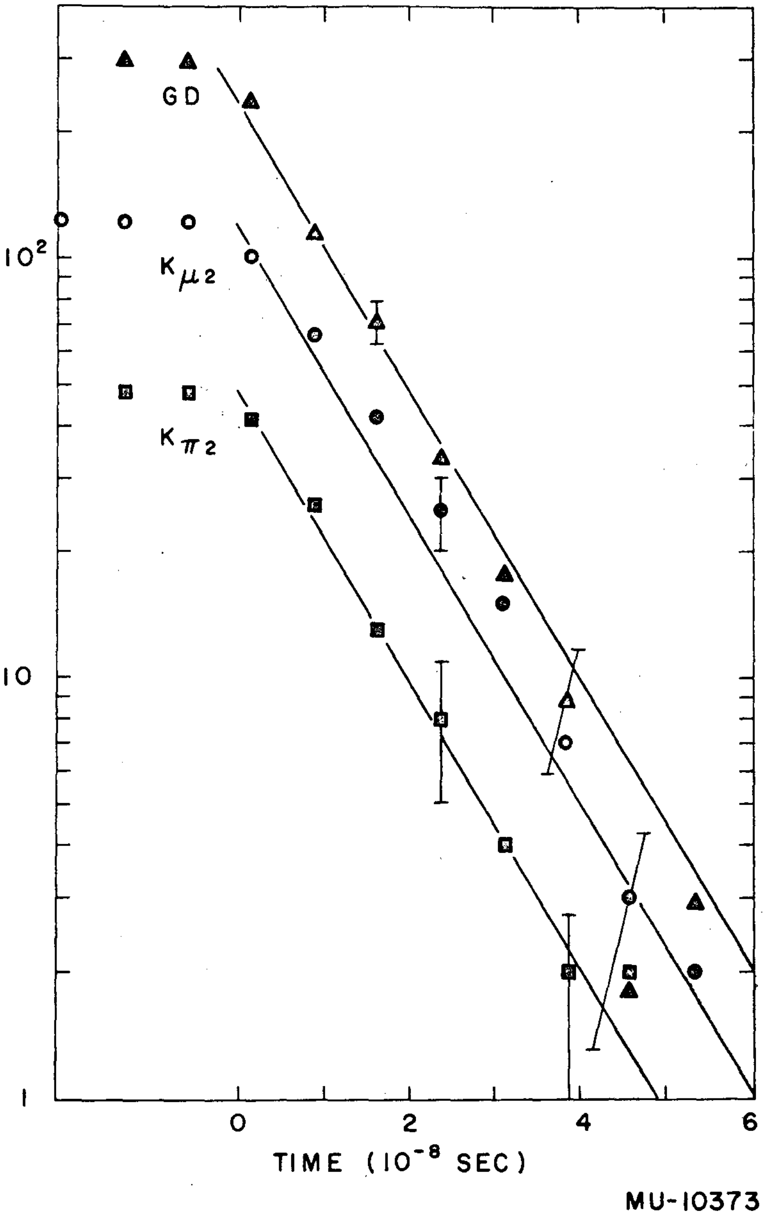

Fig. 3