PHYSICAL REVIEW VOLUME 105, NUMBER 1 JANUARY 1, 1957

Lifetime of the τ^+ Meson*

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(Received September 20, 1956)

K^+ meson lifetime measurements by counter techniques have been extended to include the τ^+ or $K_\pi{}^+$ meson. A maximum-likelihood analysis of the data yields a mean life of $(11.7_{-0.7}{}^{+0.8})\times10^{-9}$ sec. The previously reported mean life of the $K_{\pi2}{}^+$ is $(12.1_{-1.0}{}^{+1.1})\times10^{-9}$ sec. With 95% confidence the difference between the lifetimes of the two particles is less than 20% of their arithmetic mean.

WE have continued our program of measuring the mean life of K^+ mesons as a function of decay mode and report now on the measurement of the mean life of the τ or $K_{\pi3}\rightarrow\pi^++\pi^++\pi^-$. This paper also contains some details of the experiment not included in the report on the lifetime measurements of the $K_{\pi2}$ and $K_{\mu2}$ modes.[1]

As the data on τ decay have accumulated and have been compared with the analysis of Dalitz,[2] it has become clear that the τ cannot have the same spin and parity properties as the $K_{\pi2}$ if the spin is 0 or 1.[3] On the other hand, no difference in the two particles has been revealed in the accumulation of data concerning the masses,[4] scattering,[5] production,[6] and lifetimes.[7] The previous values for the τ lifetime had rather large statistical uncertainties. Since a difference in the lifetimes would unambiguously establish that at least two distinct K particles exist, it is important to determine the mean lives with as much precision as possible.

The technique used for the selection of K^+ mesons produced in the Brookhaven Cosmotron is similar to that described previously.[1] The experimental layout with respect to the Cosmotron is shown in Fig. 1. The momentum-analyzed ($\sim$480 Mev/c) and focused beam of charged particles from the target enters the counter arrangement shown in Fig. 2. The K mesons are distinguished from the much greater number of π's and protons by momentum analysis, velocity selection, and range. In principle, the mass is overdetermined since knowledge of two out of the three parameters is sufficient. However, the contamination of the beam by particles of different momenta makes the additional condition necessary. C_1 is a velocity-selective Čerenkov counter sensitive over the range $0.62<\beta<0.78$. C_2 is a Čerenkov guard counter with a threshold velocity of 0.75. S_1, S_2, and S_3 are plastic scintillation counters. Counter S_4 is described below. The absorber between S_1 and S_2 is chosen to stop the K mesons in S_4. A $C_1C_2'S_1S_2S_3'$ coincidence (prime denotes anticoincidence) selects K mesons of 480 Mev/c ($\beta=0.7$) with high efficiency and effectively rejects the protons ($\beta=0.45$) and π mesons ($\beta=0.96$) with the same momenta. The coincidence initiates a 0.25-microsecond oscilloscope sweep on which pulses from C_1, S_2, and S_4 are displayed and photographed. The $t=0$ pulses, C_1 and S_2, are positioned at either end of the trace by appropriate cable delays to provide a continuous check on the sweep speed. In addition, the sweep is calibrated periodically throughout the runs with a 50-megacycle sine wave which is derived from a 1-megacycle crystal-controlled oscillator. The time for decay is measured by observing the time interval between the pulses in S_4 corresponding to the arrival of the K meson and the pulse from the decay product.

S_4 is a liquid scintillation counter 3 in. in diameter and $2\frac{3}{4}$ in. long, containing terphenyl in phenylcyclohexane. τ mesons are recognized upon decaying in S_4 by the characteristically large energy release. The decay to three charged particles makes it possible to detect a large fraction of the total kinetic energy involved ($Q=75$ Mev) in the relatively small volume of scintil-

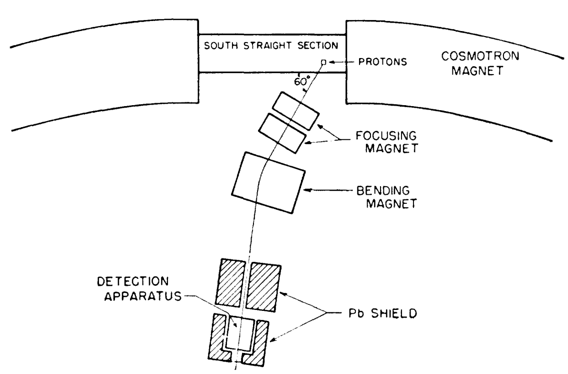

FIG. 1. Experimental layout at the Cosmotron.

* This research was supported at Princeton by the Office of Naval Research and the U. S. Atomic Energy Commission. The work at the Brookhaven National Laboratory was conducted under the auspices of the U. S. Atomic Energy Commission.

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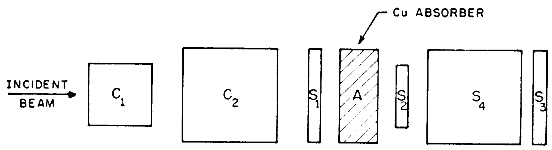

FIG. 2. Counter disposition used in measuring the lifetime of τ^+ mesons.

lating material. The distinction between the τ and the other modes of decay, where only one fast charged particle is involved, is easily made by pulse-height measurements. The maximum energy loss of the secondary by ionization from a $K_{\pi 2}$ decay is 26 Mev and from a $K_{\mu 2}$, 21 Mev. The average for either the $K_{\pi 2}$ or $K_{\mu 2}$ is $\sim$10 Mev. We classified as τ-meson decays those that exhibited an energy loss of 35 Mev or greater. Observation of the pulse height resulting from 480-Mev/c pions traversing counter S_4 provided a convenient method for energy calibration. The technique of identifying τ mesons by pulse-height analysis has the advantage of high detection efficiency and the disadvantage of being restricted to delays greater than $\sim 10^{-8}$ second because of overlap with the $t=0$ pulse.

A background of a few percent results from high-energy events in S_4 unrelated to a stopping K meson.

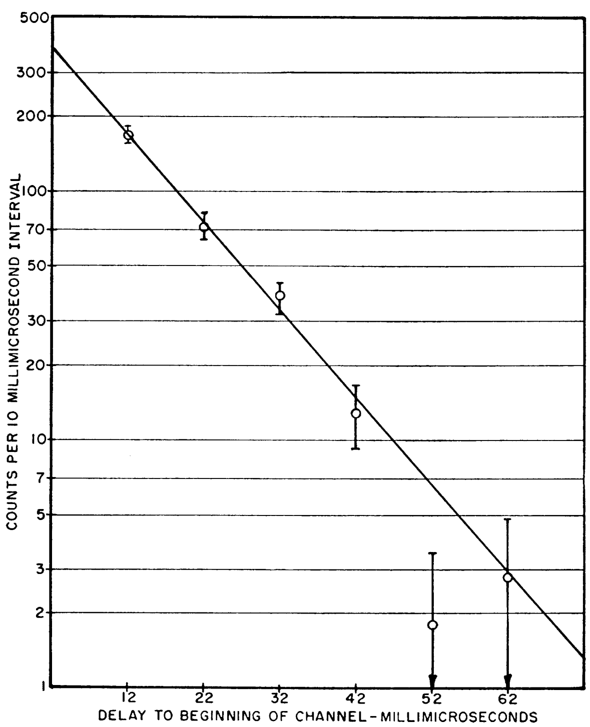

FIG. 3. Differential decay curve of the τ meson. Background has been subtracted.

The lifetime correction for events of this kind was calculated from the number of pulses above the 35-Mev threshold in an 80-millimicrosecond interval preceding the arrival of a K meson. There is a slight contamination of the τ sample from other K-meson decay modes. The charged secondary of the $K_{\pi 2}$ may interact in S_4 with a visible energy release greater than 35 Mev. An auxiliary experiment to measure the percentage of π^+ mesons which create such stars set an upper limit of 6% to the $K_{\pi 2}$ contribution. This limit is based on a relative abundance of $K_{\pi 2}$ to τ of 4 to 1. The $K_{\mu 3}$ meson is estimated to constitute less than 5% of our τ sample. The contribution of other decay modes is negligible.

Two runs on the Cosmotron were devoted to the mean life of the τ. The results are listed in Table I. The main difference in the two runs was in the use of better delay cable in the second run which reduced the width of the pulses from S_4 and made it possible to measure τ decays closer to $t=0$. It is therefore not feasible to combine all of the data into one decay curve. The

TABLE I. The results of two separate measurements of the τ^+-meson lifetime.

Run No.	No. of events	Background counts in 80 millimicroseconds	Analysis interval (millimicroseconds)	Mean rate of decay (sec^{-1})
1	150	5	17 to 67	$(7.88\pm0.78)\times10^7$
2	299	10	12 to 62	$(8.99\pm0.62)\times10^7$
Combined	449	15		$(8.54\pm0.49)\times10^7$

differential distribution of decay times of the τ's detected in the second run is shown in Fig. 3. The background has been subtracted.

A maximum-likelihood analysis of the data was made. The values for the mean rate of decay and its standard deviation include the correction for background, the correction due to the finite period of observation for decay, and a slight correction due to the dispersion in time measurements. Within the limits of the $K_{\pi 2}$ lifetime previously determined, the correction in the lifetime of our τ sample due to contamination by the $K_{\pi 2}$ mode is negligible.

The combined result from the two runs on the mean life of the τ meson is $(11.7_{-0.7}^{+0.8})\times10^{-9}$ sec. This is to be compared with the previously published value of $(12.1_{-1.0}^{+1.1})\times10^{-9}$ sec for the $K_{\pi 2}$. With 95% confidence the difference in the two lifetimes is less than 20% of their arithmetic mean.

It is a pleasure to acknowledge the assistance and most helpful cooperation of the Cosmotron staff at the Brookhaven National Laboratory.