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Author
Bludman, S.

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S. Bludman

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INTERPRETATION OF K-MESON DECAYS

S. Bludman

Radiation Laboratory, University of California
Berkeley, California

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This note is concerned with a possible explanation of the K-meson lifetimes that may be subject to experimental verification. The only previous explanation[1] of the near equality of the τ and θ lifetimes involves the assumption of a very rapid ($\sim 10^{-14}$ second) electromagnetic conversion of one meson into the other. If τ and θ are not both spin-zero particles, then Lee and Orear require either different strangeness assignments for τ and θ, or a finite but exceptionally small mass difference ($\lesssim$ 100 kev) between τ and θ. While this latter possibility would be very hard to rule out experimentally, such an accidental near-coincidence of masses would be exceptional. If τ and θ are 0^- and 0^+ particles respectively, a large mass difference ($\gtrsim$ 10 Mev) is needed. The mass differences, if any, are smaller than this.[2]

Unless τ and θ have rather high spins or a very peculiar internal structure, only one can decay into three pions and only the other into two pions. They are both, however, capable of decaying in the $K_{\mu 2}$, $K_{\mu 3}$, and K_β modes. (For simplicity in what follows $K_{\mu 3}$ and K_β will be included in the $K_{\mu 2}$ mode.) The explanation of the nearly equal lifetimes to be

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[1] Lee and Orear, Phys. Rev. 100, 932 (1955).

[2] Birge et al (private communication). I am indebted to members of the emulsion and counter experimental groups at the Radiation Laboratory for information on the K-meson abundances and lifetimes in advance of publication.

proposed here is as follows: If τ and θ decay into $\mu + \nu$ at the same rate $R_{\tau\mu} = R_{\theta\mu}$ --and for both this is the predominant decay mode--then the τ and θ lifetimes are bound to be approximately equal, the differences in lifetime arising through the remaining $K_{\pi 3}$ and $K_{\pi 2}$ modes.

The $K_{\mu 2}$ should show a composite differential decay curve unless the τ and θ lifetimes are equal. The present data show no significant difference in $R_{\tau} = 1/\tau_{\tau}$ and $R_{\theta} = 1/\tau_{\theta}$, the total transition rates for τ and θ. (The τ lifetimes is very uncertain.) From the fractional abundances N_{μ}, N_2, N_3 of $\mu 2$, $\pi 2$, $\pi 3$, respectively one finds:

(a) If, as proposed here, $R_{\tau\mu} = R_{\theta\mu} = R_{\mu}$, then the fraction f of τ's in the K-beam at production must be small,

$$f = N_3/1 - N_{\mu} = 0.18 ,$$

and

$$R_{\mu}/R = N_{\mu} = 0.62.$$

(b) Lee and Yang[3] and Gell-Mann[4] have proposed describing the strange particles by a new operator $\mathcal{R}$, which is conserved in strong interactions. A prediction of their theory is that τ and θ should be produced in equal fractions $f = 1 - f = \frac{1}{2}$. Then the small amount N_3 of $\pi 3$ observed requires that τ decay predominantly into the $\mu 2$ mode,

$$R_{\theta\mu}/R = 1 - 2N_2 = 0.38 , \quad R_{\tau\mu}/R = 1 - 2N_3 = 0.87, \quad \text{if } R_{\theta} = R_{\tau} = R.$$

The conjecture of equal θ and τ transition rates into $\mu + \nu$ and the $\mathcal{R}$-degeneracy picture are definitely incompatible. In fact, assuming both

[3] Lee and Yang (to be published).

[4] M. Gell-Mann (private communication).

$R_{\theta\mu} = R_{\tau\mu}$ and $f = \frac{1}{2}$, the observed ratios $N_\mu : N_2 : N_3$ can only be obtained[5] if the τ lifetime is unreasonably short ($\sim$ one-third the θ lifetime).

An attractive feature of possibility (a) is that one can assume a universal meson-lepton interaction.[6] If this interaction is vector or axial--which helps explain the absence of $e + \nu$ decays--and if the universal coupling constant is fitted to the pion lifetime, one then obtains $\tau_\theta = \tau_\tau = 1/R = 1.1 \times 10^{-8}$ second. This quantity is in good agreement with experiment.[7]

The whole question admits of an experimental determination. If different transition rates R_τ and R_θ are detected, then an analysis of the $K_{\mu 2}$ decay rate

$$\frac{d}{dt} N_\mu = R_{\tau\mu} f e^{-R_\tau t} + R_{\theta\mu}(1 - f) e^{-R_\theta t}$$

and of the abundances overdetermines the quantities f, $R_{\tau\mu}$, $R_{\theta\mu}$. It may turn out that neither $f = \frac{1}{2}$ nor $R_{\tau\mu} = R_{\theta\mu}$ is tenable!

The $K_{\mu\nu}$ lifetime now observed is the mean,

$$\bar{\tau}_\mu = \int t \, dN_\mu / \int dN_\mu \quad .$$

If $\tau_\tau \approx \tau_\theta$, then

$$\bar{\tau}_\tau \approx \tau_\theta + f(\tau_\tau - \tau_\theta) = \tau_\tau + (1 - f)(\tau_\theta - \tau_\tau) ,$$

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5 Lynn Stevenson (private communication).

6 Bludman and Ruderman, Phys. Rev. (in press).

7 Alvarez et al, Bull. Am. Phys. Soc. 30, No. 7, 37 (1955); Fitch and Motley (to be published).

independently of $R_{\tau\mu}$ and $R_{\theta\mu}$. By way of illustration only, since the present experimental errors make the lifetime differences not significant, if $\bar{\tau}_{\mu} \approx \tau_{\theta}$ [7] and $\tau_{\tau} < \tau_{\theta}$,[8] f must be small. Of course once f is determined, the abundance ratios

$$N_{\mu}:N_2:N_3 = f\,\frac{R_{\tau\mu}}{R_{\tau}}\,e^{-R_{\tau}t} + (1-f)\,\frac{R_{\theta\mu}}{R_{\theta}}\,e^{-R_{\theta}t} : (1-f)\,\frac{R_{\theta}-R_{\theta\mu}}{R_{\theta}}\,e^{-R_{\theta}t}$$

$$: f\,\frac{R_{\tau}-R_{\tau\mu}}{R_{\tau}}\,e^{-R_{\tau}t}$$

enables one to find $R_{\tau\mu}$ and $R_{\theta\mu}$.

The theoretical reason for conjecturing equal transition rates for $\tau \rightarrow \mu + \nu$ and $\theta \rightarrow \mu + \nu$ is that, since the neutrino is massless, we have the pseudovector decay of a pseudoscalar meson $\equiv$ the vector decay of a scalar meson. In fact, it is precisely the neutrino processes that are unaffected by the presence or absence of a γ_5.[9] If τ and θ turn out to have equal masses and spins and to differ only in parity, it seems reasonable to assume that they have similar couplings to the field. The rate and equality of the K-meson-decay lifetimes is then directly connected with the slow pion decay. Only the "minor" K decays involving pions then remain strange.

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

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[8] Alvarez and Goldhaber, Nuovo cimento 2, 344 (1955); Harris, Orear, and Taylor, Phys. Rev. 100, 932 (1955).

[9] See Yang and Tiomno, Phys. Rev. 79, 495 (1950), on nucleon β-decay.