Lifetimes and Decay Spectra of τ'^+ and $K_{\mu 3}^+$*

S. TAYLOR,† G. HARRIS,‡ J. OREAR,§ J. LEE, AND P. BAUMEL
Columbia University, New York, New York

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Nuclear emulsion stacks were exposed to the Bevatron ~360-Mev/c unseparated K^+ beam at two different distances from the target. The K_L to τ' and K_L to $K_{\mu 3}$ ratios at the two positions, combined with the known K_L lifetime, yield $(1.0_{-0.3}^{+0.5})\times 10^{-8}$ sec for the τ' mean life and $(1.2_{-0.4}^{+1.0})\times 10^{-8}$ sec for the $K_{\mu 3}$ mean life. These lifetimes, when compared with other K^+ lifetimes, are consistent with a single lifetime for all K^+ mesons. The π^+ energy spectrum from τ'^+ decay is obtained, using 72 events, and by Dalitz-type analysis is found to be consistent with spin zero but would be unlikely for spin one. Hence, the τ' spin is consistent with being the same as that of the τ. The μ^+ energy spectrum from $K_{\mu 3}^+$ decay is obtained from 0 to 63 Mev, using 47 events, and is found to be consistent with the energy distribution of the density of final states in the region. The relative abundances of τ^+, τ'^+, and $K_{\mu 3}^+$ are found to be 0.052±0.003, 0.015±0.002, and 0.028±0.004, respectively, the $K_{\mu 3}$ abundance having been estimated by assuming that the μ^+ spectrum above 63 Mev is proportional to the density of final states.

I. INTRODUCTION

THE purpose of the present experiment is to measure the lifetimes and decay spectra of τ'^+ and $K_{\mu 3}^+$ using nuclear emulsion stacks exposed to the Bevatron K^+ beam, one stack being six feet farther from the target than the other.

The lifetimes of $K_{\mu 2}^+$, $K_{\pi 2}^+$, and τ^+ are now well known[1–4] and are consistent with a single K^+-meson lifetime. The lifetimes of the rarer types, τ'^+, $K_{\mu 3}^+$, and K_{e3}^+ are less well known, the values being based on very few events.[3,5]

Exhaustive studies have been made of the τ decay spectrum[6–8] but relatively few data have been presented on the decay spectra of the rarer τ'^+, $K_{\mu 3}^+$, or K_{e3}^+.[4,9,10] If, as expected, the τ' is an alternate mode of decay of the τ, then $\tau'^+ \rightarrow \pi^+ + 2\pi^0$, and the π^+ energy spectrum from τ'^+ should be similar to the π^- energy spectrum from τ^+ (except for small effects such as that of the mass difference between π^0 and $\pi^\pm$), giving, by Dalitz analysis,[11] spin zero as the most likely spin of the parent particle. The maximum π^+ energy would be 53 Mev. Published results to date[4,9,10] are consistent with these predictions. Also, Dalitz pairs have been found associated with τ' decays,[12,13] indicating the presence of at least one π^0 among the neutral decay products. Hence, there is strong evidence for the above decay scheme.

For the $K_{\mu 3}$, evidence favoring the decay scheme $K_{\mu 3}^+ \rightarrow \mu^+ + \pi^0 + \nu$ has been obtained at Rochester.[14] Furuichi *et al.*[15] have calculated theoretical decay spectra for $K_{\mu 3}^+ \rightarrow \mu^+ + \pi^0 + \nu$ and $K_{e3}^+ \rightarrow e^+ + \pi^0 + \nu$, for spin-zero and spin-one K mesons, with various Fermi interactions. As they point out, it is not possible to estimate the validity of some of their assumptions. Assuming that their prodecure is valid, it is still difficult to draw conclusions from experimental data, since all the spectra obtained are very similar to a spectrum based only on the density of final states, with the exception of a spin-zero K with a tensor Fermi interaction. Furuichi *et al.* draw no firm conclusions about $K_{\mu 3}$ from their analysis. However, they conclude from early data that K_{e3} very likely has spin zero and that the tensor Fermi interaction is primarily involved, perhaps with the mixing of some scalar interaction.[15,16] The general shape of the experimental decay spectrum is not changed with the addition of subsequent data.[4,9] In a later paper,[17] Furuichi and co-workers analyze the spin-zero K_{e3}^+

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† Now at Stevens Institute of Technology, Hoboken, New Jersey.
‡ Now at Bell Telephone Laboratories, Murray Hill, New Jersey.
§ Now at Cornell University, Ithaca, New York.

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[16] Furuichi, Sugahara, Wakasa, and Yonezawa, Nuovo cimento **5**, 285 (1957).
[17] Furuichi, Sawada, and Yonezawa (to be published).

problem on more general grounds and conclude from the experimental data that the interaction is an approximately equal mixture of tensor and scalar. Radicati and Rosati[18] have also obtained theoretical $K_{\mu 3}$ spectra, under slightly different assumptions. However, these spectra are again very similar to a spectrum based on the density of final states alone.

The experiment reported here is a direct extension of earlier work performed by the Columbia Nuclear Emulsions Group. In the earlier work, two emulsion stacks (designated *A* and *B*) were exposed at different distances from the target in the Bevatron 114-Mev K^+ beam. Data from these stacks were used to measure the K_L^+ and τ^+ lifetimes[3] and to obtain the τ^+ decay spectrum.[8] To extend the work, two additional stacks (*C* and *D*) have been exposed in essentially the same geometry. Stack sizes and exposure times were planned to give a sufficiently large number of τ' and $K_{\mu 3}$ decays so that the lifetimes, the entire expected τ' decay spectrum, and the low-energy part of the $K_{\mu 3}$ decay spectrum could be measured. Preliminary results have been reported previously.[4,19] Observations by this laboratory of Dalitz pairs associated with τ' and $K_{\pi 2}$ decays and the observation of an event believed to be $K^+ \rightarrow \pi^+ + \pi^0 + \gamma$ have been reported elsewhere,[12,20] as have the negative results of a search for particles of $\sim$540 electron masses as decay products of K^+ mesons.[21]

II. EXPERIMENTAL PROCEDURE

Two nuclear emulsion stacks composed of 4 in.$\times$4 in. $\times$600-μ Ilford *G*5 pellicles were exposed to the Berkeley K^+ beam[22] produced by 6.2-Bev protons on a Ta target. Stack *C*, of 49 pellicles, 161 inches from the target, had an average beam momentum of 354 Mev/*c*. Stack *D*, of 149 pellicles, 233 inches from the target, had an average beam momentum of 374 Mev/*c*. The momenta were determined from the average *K*-meson ranges in the stacks. The range-energy and grain count-energy curves of Barkas *et al.*[23] have been used throughout the experiment.

The emulsions were fast-track-scanned for K-meson endings. Assuming about 80% pickup efficiency for the *K*-meson tracks, the *K* fluxes were $\sim$240 *K*/cm² in stack *C* and $\sim$130 *K*/cm² in stack *D*. Scanners were able to find and make initial measurements on about 13 *K* endings per scanner per day. *K* secondaries were grain counted for the purpose of detecting τ' and $K_{\mu 3}$ secondaries with grain counts 1.25 times minimum or greater, corresponding to 92 Mev for pions and 70 Mev for muons. Since the maximum π energy expected from τ' is 53 Mev (1.57 times minimum grain count), the entire spectrum should be included. The $K_{\pi 2}$ has a π secondary of 109 Mev (1.18 times minimum). If secondaries are counted initially for $\sim$ 200 grains, then 1.25 times minimum grain count is about 1 standard deviation from the average $K_{\pi 2}$ secondary grain count, and hence one would expect to find that an appreciable number of secondary tracks initially classified as 1.25 times minimum or greater are actually π tracks from $K_{\pi 2}$. The μ secondary from $K_{\mu 2}$ has an energy of 152 Mev (1.05 times minimum). For 200 grains, 1.25 times minimum grain count is about 3 standard deviations from the $K_{\mu 2}$ secondary grain count. Hence one would expect very few $K_{\mu 2}$ secondaries to be initially classified as 1.25 times minimum or greater.

The detailed scanning procedure was as follows. Grey tracks were picked up at a position corresponding to about 2-cm residual range for *K* mesons. These tracks could be abandoned at the discretion of the scanner at any point before reaching the ending. Most background protons were eliminated in this manner. To avoid scanning bias, once the end of the track was reached it was required that the track be identified. If no secondary were seen, the track was grain counted at 2-cm residual range in order to separate *K* mesons from protons. If the track gave a *K* grain count, it was classified as a *K* and a further search was made for the secondary. In 23 of these cases, no secondaries were found. It is assumed that in these cases a lightly ionizing secondary existed but was difficult to observe, and hence these tracks were classified as K_L's. (The K_L category is to include all $K_{\mu 2}$, $K_{\pi 2}$, K_{e3}, and $K_{\mu 3}$ with high-energy secondaries.)

All single secondaries with grain count visibly heavier than 1.25 times minimum were followed. All other single secondaries with original dip angles $\leq 40.5°$ were grain counted for $\sim$200 grains. If the grain count were 1.25 times minimum or greater, the secondary was followed. If the secondary stopped in the emulsion, it was identified by the decay product as a π^+ or a μ^+ and its range was measured. Energies obtained from these ranges are accurate to $\sim$3%.

In those cases where the heavy secondary track left the emulsion, the track was grain counted for $\sim$500 grains at the point of leaving the emulsion and also at the *K*-meson decay. About 5 beam π tracks (at $\sim$360 Mev/*c*) were counted for $\sim$200 grains each at both positions in order to determine minimum grain count in the particular region of the emulsion. The grain counts relative to minimum at the two positions of the secondary track and the range of track between the points served to identify the secondary as a π or μ and to establish the energy to $\sim$7%. In the energy region where the secondary could be either a π^+ from τ'^+ or a μ^+ from $K_{\mu 3}{}^+$, some errors may have been made in identification. However, assuming the expected maximum π^+ energy of 53 Mev, only 5 π's and 2 μ's were in

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[22] F. S. Crawford, University of California Radiation Laboratory Engineering Note 4310-03 (unpublished).
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this category. Due to possible differences between stacks C and D in calibration of grain counts relative to minimum, in variation of grain density with depth in the emulsion, in local variations in grain density, and in scanners' counting criteria, all K's with heavy secondaries of energy greater than that corresponding to 1.3 times minimum grain count (63 Mev for muons and 83 Mev for pions) were classified as K_L's. Five $K_{\mu3}$'s were thus eliminated. About 80% of all secondary tracks followed which left the emulsion proved to be of high energy, corresponding to average grain densities less than 1.25 times minimum. Presumably these were mostly π's from $K_{\pi2}$'s, and were all classified as K_L secondaries.

A summary of stack C and D data is given in Table I.

III. RESULTS

A. Lifetimes

About 90% of the K_L category consists of $K_{\mu2}$ and $K_{\pi2}$.[4,9,24] Since $K_{\pi2}$ and $K_{\mu2}$ have equal lifetimes within experimental error,[4] it is meaningful to consider a "K_L lifetime." Since all K-meson masses are experimentally the same,[24,25] the lifetime of any category of K, say K_i, can be calculated using the ratios of the number of K_i endings to the number of K_L endings in the two stacks, combined with the known K_L lifetime. The formula for the K_i mean life is

$$\tau(K_i)=\left[\frac{1}{\tau(K_L)}+\frac{1}{t_D-t_C}\ln\frac{[N(K_i)]_C[N(K_L)]_D}{[N(K_L)]_C[N(K_i)]_D}\right]^{-1}. \quad (1)$$

Here subscripts C and D refer to the two stacks, the t's are the proper times of flight, and the N's are the numbers of events observed. For the K_L mean life, the Berkeley value[4] $\tau(K_L)=(1.24\pm0.018)1\times0^{-8}$ sec was used. The difference in proper times of flihgt was calculated to be $t_D-t_C=0.70\times10^{-8}$ sec.

The τ' and $K_{\mu3}$ mean lives obtained from (1) are:

$$\tau_{\tau'}=(1.0_{-0.3}^{+0.5})\times10^{-8}\text{ sec},$$

$$\tau(K_{\mu3})=(1.2_{-0.4}^{+1.0})\times10^{-8}\text{ sec}.$$

The errors are the statistical standard deviations. Errors in $\tau(K_L)$ and t_D-t_C are negligible in comparison. As a check, the τ lifetime was also calculated, giving $\tau_\tau=(1.0\pm0.2)\times10^{-8}$ sec. This result is in good agreement with the more precise Berkeley value for the τ lifetime.[4]

TABLE I. Stack C and D data.

Stack	Distance from target (in.)	Momentum (Mev/c)	Proper time (sec)	Number of events observed K_L	τ	τ'	$K_{\mu3}$
C	161	354	1.90×10^{-8}	1611	98	30	19
D	233	374	2.60×10^{-8}	1755	94	29	20

[24] Birge, Perkins, Peterson, Stork, and Whitehead, Nuovo cimento 4, 834 (1956).
[25] J. R. Peterson, Phys. Rev. **105**, 693 (1957).

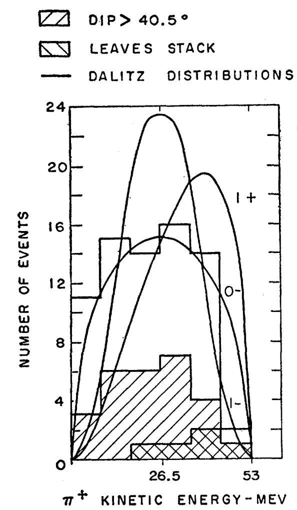

FIG. 1. Histogram of π^+ energies from τ'^+ decays.

B. π^+ Energy Spectrum from τ'^+ Decay

The 59 K events from stacks C and D having secondary pions of energy 53 Mev or less have been combined with the 13 events previously reported from stacks A and B[3]. These data are presented in Fig. 1. In addition, three K secondaries initially classified as pions were in the energy range 53–83 Mev (1.59–1.30 times minimum grain count). Excluding these three events, the data are consistent with the accepted decay scheme $\tau'^+\rightarrow\pi^++2\pi^0$. Two of the three secondaries do not end in the stack, and the identifications as pions were made by grain counting. However, the grain counts are not inconsistent with identifications as muons, and hence these two tracks have been classified as $K_{\mu3}$ secondaries. The third event has been interpreted as a radiative $K_{\pi2}$ decay, and has been previously reported.[20]

The remaining events are assumed to be $\tau'^+\rightarrow\pi^++2\pi^0$. Scanning efficiency is believed to be high for both steep and flat secondaries throughout the entire energy range (see Discussion). Using a procedure similar to that previously used for spin-parity analysis of the τ^+ decay spectrum by the Dalitz method,[8,11] the likelihood ratios P_{0-}/P_{1+} and P_{0-}/P_{1-} have been calculated. Here the subscripts refer to the spin and parity of the final three-pion state. The results are:

$$P_{0-}/P_{1+}=10^{9.0},$$

$$P_{0-}/P_{1-}=10^{5.1}.$$

Six interval χ^2 tests give $\chi^2=6.1$ for $0-$ with a probability of 0.30, $\chi^2=95$ for $1+$ with a probability $\ll0.001$, and $\chi^2=22.3$ for $1-$ with a probability <0.001. If the final state of the decay is taken as a mixture of $1-$ and $1+$, no appreciable improvement is obtained, since the major disagreement with the data is at low energy for both $1-$ and $1+$. Hence the observed distribution is

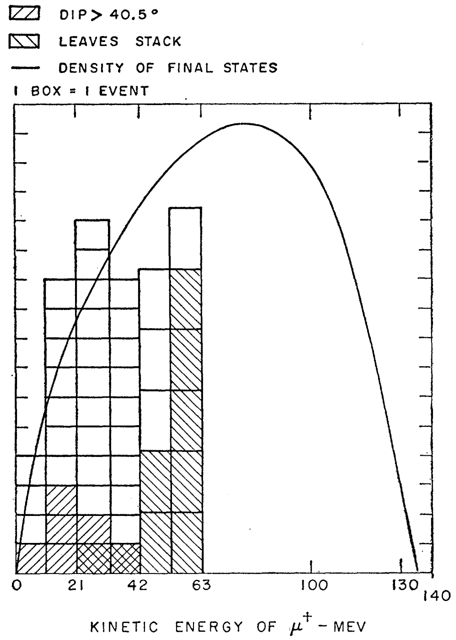

FIG. 2. Histogram of μ^+ energies from $K_{\mu 3}^+$ decays. Between 42 and 63 Mev, the events have been weighted by the efficiency factor 2.07. Events with energies greater than 63 Mev have been excluded. The smooth curve is proportional to the density of final states for the process $K_{\mu 3}^+ \to \mu^+ + \pi^0 + \nu$, normalized such that the area under the curve below 63 Mev is equal to the area of the histogram.

consistent with spin zero for the τ', but would be unlikely for spin one.

C. μ^+ Energy Spectrum from $K_{\mu 3}^+$ Decay

Thirty-seven events from stacks C and D have been combined with the 10 events from stacks A and B[3]. The data are presented in Fig. 2. Scanning efficiency is believed to be high for both flat and steep secondaries up to 42 Mev (see Discussion). Between 42 and 63 Mev the scanning efficiency is believed to be low except for flat secondaries (dip $\leq 40.5°$) in stacks C and D. Hence in this region the two steep μ's found have been eliminated and the number of events has been adjusted by the factor 2.07, based on the geometrical fraction of flat tracks and the ratio of the number of K endings found in stacks C and D to the total number of K endings (3656/4910). The smooth curve plotted in Fig. 2 is proportional to the density of final states for the $K_{\mu 3}$ decay (assuming $K_{\mu 3}^+ \to \mu^+ + \pi^\circ + \nu$), the normalization being such that the area under the curve between 0 and 63 Mev is equal to the area of the experimental histogram. The experimental data are consistent with this curve.

D. Relative Abundances of τ^+, τ'^+, and $K_{\mu 3}^+$

Using the combined data of stacks A, B, C, and D, the relative abundances presented in Table II are obtained. The errors are the statistical standard deviations. The relative abundance of $K_{\mu 3}$ before extrapolation, with μ^+ energy ≤ 63 Mev only, is 0.012 ± 0.002.

The ratio of the number of τ' events to τ events, say R, has been discussed theoretically by Dalitz,[26] assuming $\tau'^+ \to \pi^+ + 2\pi^\circ$. If the final 3π state is a pure isotopic spin state, and $\Delta T = \frac{1}{2}$ for the decay, then the final state would have $T=1$ and R should lie between $\frac{1}{4}$ and 1. If in addition the final state is predominantly symmetric in the three pions (the Dalitz 0− state) as indicated by the experimental data, then R should equal $\frac{1}{4}$. Dalitz shows that if one includes the mass difference between π° and $\pi^\pm$ and the Coulomb interaction in the final state, then one obtains 0.316 instead of $\frac{1}{4}$ as the predicted value of R. However, experimental measurement of R is only a weak test for a general $\Delta T = \frac{1}{2}$ rule, since for $\Delta T = \frac{3}{2}$, no symmetric state is accessible. A $\Delta T = \frac{5}{2}$ contribution is possible, and would lead to a lower value of R if the contribution is small. The experimental value from the data of the present experiment is $R = 0.28 \pm 0.04$, consistent with $\Delta T = \frac{1}{2}$, but not ruling out a small $\Delta T = \frac{5}{2}$ contribution.

IV. DISCUSSION

The τ'^+ and $K_{\mu 3}^+$ lifetimes are in agreement with the earlier Columbia estimates based on 13 and 10 events, respectively.[3] The $K_{\mu 3}$ lifetime is also in agreement with the value of Hoang *et al.* based on $8\frac{1}{2}$ events.[5] The τ lifetime obtained from the data serves as a check on possible systematic errors and is in good agreement with the best available value.[4] Comparing the τ'^+ and $K_{\mu 3}^+$ lifetimes obtained in the present experiment to the Berkeley values for the $K_{\mu 2}^+$, $K_{\pi 2}^+$, and τ^+ lifetimes[4] and to the value of Hoang *et al.* for the K_{e3}^+ lifetime,[5] it is seen that the results are consistent with a single lifetime for all K^+ mesons. See Table III.

Both the τ' and $K_{\mu 3}$ decay spectra may have small contaminations. Radiative decays of $K_{\pi 2}$'s or $K_{\mu 2}$'s would appear as false τ' and $K_{\mu 3}$ events, respectively, but the abundances are expected to be small.[15,27] If the accepted decay scheme $\tau'^+ \to \pi^+ + 2\pi^\circ$ is taken as correct, then radiative $K_{\pi 2}$ decays can be eliminated for π energies above 53 Mev (if the secondaries end in the stack), but not below. It is not thought that the three

TABLE II. Relative abundances of K types.

K_i	$N(K_i)/N(K)$ Present experiment	$N(K_i)/N(K)$ Berkeley[a]	$N(K_i)/N(K)$ Dublin[b]
τ	0.052 ± 0.003	0.0556 ± 0.0041	0.0677 ± 0.0043
τ'	0.015 ± 0.002	0.0215 ± 0.0047	0.0215 ± 0.0042
$K_{\mu 3}$	0.028 ± 0.004[c]	0.0283 ± 0.0095	0.0590 ± 0.013

[a] See reference 24.
[b] See reference 9.
[c] Extrapolated beyond 63 Mev assuming spectrum is proportional to density of final states only.

[26] R. H. Dalitz, Proc. Phys. Soc. (London) **A69**, 527 (1956).
[27] R. H. Dalitz, Phys. Rev. **99**, 915 (1955).

apparent pion secondaries of energy greater than 53 Mev, mentioned above, constitute sufficient evidence for questioning the accepted decay scheme. In fact, once these events are eliminated, the Dalitz analysis of the remainder of the spectrum and also the ratio of the numbers of τ' to τ constitute additional support for the three-pion decay. Another small source of contamination in both the τ' and $K_{\mu 3}$ decay spectra, as already mentioned, is the possible misidentification of a few secondaries identified by grain counting. Finally, τ, τ', and $K_{\mu 3}$ events with very low-energy secondaries can under certain circumstances be mistaken for one another. However, all such events have been very carefully re-examined.

The shape of the observed π^+ energy spectrum from τ'^+ decay (Fig. 1) is in agreement with that obtained by other laboratories.[4,9,10] These experiments are also consistent with spin zero for the τ'. In the present experiment it is believed that the small number of events in the energy region 44.2–53 Mev (1.74–1.59 times minimum grain count) is not primarily due to scanning bias. It is unlikely that the grain counting for secondaries heavier than 1.25 times minimum in the region of dips $\leq 40.5°$ would have missed any events in this energy region. It is possible that some steep tracks (dips $>40.5°$) were missed, but it is unlikely that the loss was appreciable, since one of the two events observed in this energy region was steep, and since two steep $K_{\mu 3}$ secondaries with even lower ionization were found. However, as a check on the conclusion that spin one is unlikely, the cases hav been considered where the number of events expected for the Dalitz $1+$ or $1-$ distributions in the energy region 44.2–53 Mev is reduced by 35.1% (the geometrical percentage of tracks with dips $>40.5°$) and in the energy region 35.3–44.2 Mev by half that amount. After renormalizing, six-interval χ^2 tests for these modified distributions give $\chi^2=78$ for $1+$ with a probability $\ll 0.001$, and $\chi^2=22$ for $1-$ with a probability <0.001. Hence spin one is still unlikely. Actually, the serious lack of fit for the spin-one distributions arises in the low-energy region. The first two intervals only of the χ^2 tests give $\chi^2=73$ and 20 for the unmodified $1+$ and $1-$ distributions, respectively. One could consider a mixed-parity spin-one final state, mixing the Dalitz $1+$ and $1-$

TABLE III. Lifetimes of K types.

K_i^+	Mean lives (10^{-8} sec)	Reference
$K_{\mu 2}$	1.24 ± 0.018	Berkeley[a]
$K_{\pi 2}$	1.21 ± 0.030	Berkeley[a]
τ	1.19 ± 0.046	Berkeley[a]
τ'	$1.0{+0.5 \atop -0.3}$	Present experiment
$K_{\mu 3}$	$1.2{+1.0 \atop -0.4}$	Present experiment
K_{e3}	$1.4{+3.6 \atop -0.9}$	Rochester[b]

[a] See reference 4.
[b] See reference 5.

distributions, but the fit would still be poor in the low-energy region. Higher spins have not been considered in detail. However, the fact that spin zero is a good fit and spin one a poor fit indicates that the π^+ spectrum from τ'^+ is similar to that of the π^- from τ^+.[6–8] For the τ, spin two is a reasonable possibility, and spin three a weak possibility.[8] Any spin possibility for the τ would also be a spin possibility for the τ', if the decay spectra are similar, only more strongly so, since for the τ' discrimination must be made on the energy distribution alone, and not on the angular distribution.

The observed μ^+ energy spectrum from $K_{\mu 3}^+$ decay in the energy region 0–63 Mev is in agreement with that obtained by other laboratories.[4,9,10] That the data of the present experiment are consistent with the density of final states is not surprising, since the data would agree with almost any distribution which rises smoothly with energy in the energy region 0–63 Mev. All that can be said is that there is no evidence for prominent peaks or valleys in this energy region. The data would not be inconsistent with any of the theoretical μ^+ energy spectra presented by Radicati and Rosati[18] or by Furuichi *et al.*[15] for spin-zero or spin-one $K_{\mu 3}$'s. With the exception of the Furuichi μ^+ spectrum for a spin-zero $K_{\mu 3}$ with tensor interaction, all the spectra are quite similar to a spectrum based on the density of final states alone. In the present case, not even the spectrum for spin zero with tensor interaction, showing a peak at ~ 25 Mev, could be ruled out, due to the small number of events in the energy region 42–63 Mev. Experiments detecting the entire spectrum of μ's with high efficiency and with a large number of events could make an apparent distinction between the various theoretical spectra. However, except for a spin-zero $K_{\mu 3}$ with tensor interaction, it is questionable whether such a distinction would be meaningful because of the assumptions and approximations made in obtaining the theoretical spectra.

For μ^+ secondaries in the energy region 52.5–63 Mev, the scanning loss is estimated as not more than $\sim 10\%$ of the flat μ's (dips $\leq 40.5°$) in stacks C and D. No correction has been introduced for this possible loss As a check, 11 additional secondaries were traced, having initial grain densities between 1.22 and 1.25 times minimum. No additional μ's with energies less than 63 Mev were found. No data have been presented above 63 Mev, since the scanning efficiency for secondaries is believed to drop rapidly above this energy.

The relative abundances presented here are in good agreement with those of Berkeley[4,24] but the τ and $K_{\mu 3}$ abundances are low compared with those of O'Cealleigh.[4,9] See Table II. The procedure for finding K-meson endings is essentially unbiased by the appearance of the K-meson decay. If it is assumed that all K-meson endings where no secondaries were seen were actually proton endings, which is unlikely, the number of K endings found in stacks C and D would be decreased by a total of 23 events and in stacks A and B by 177, making a total reduction of $\sim 4\%$. This would change the abundances by a negligible amount. If the scanning efficiency for finding heavy secondaries were low, the abundances would be low, but the scanning efficiencies are believed to be high, as discussed above. If the μ^+ spectrum from $K_{\mu 3}{}^+$ departs markedly from being proportional to the density of final states in the energy region above 63 Mev, then the calculated total $K_{\mu 3}$ abundance could be low. However, O'Cealleigh's μ^+ spectrum is also consistent with the density of final states.

V. SUMMARY

The τ^+ and $K_{\mu 3}{}^+$ mean lives are found to be $(1.0_{-0.3}{}^{+0.5})\times 10^{-8}$ sec and $(1.2_{-0.4}{}^{+1.0})\times 10^{-8}$ sec, respectively, and are consistent with a single K^+ lifetime. The π^+ energy spectrum from τ'^+ decay is found to be consistent with spin zero for the τ' but would be unlikely for spin one, and hence the τ' spin is consistent with being the same as that of the τ. The μ^+ energy spectrum from $K_{\mu 3}{}^+$ decay is found to be consistent with the density of final states for the process $K_{\mu 3}{}^+ \rightarrow \mu^+ + \pi^\circ + \nu$ in the energy region 0–63 Mev.

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