TABLE II. Comparison of observed branching ratios for decay of K^+ mesons produced and observed under different conditions.

Observer	Rochester (this exp't)	Berkeley[a]	Paris[b]
Mean moderation time	2.1×10^{-8} sec	1.5×10^{-8} sec	$\sim5\times10^{-10}$ sec
Production mode	2.9-Bev protons	6.2-Bev protons (focused K^+ of 330 Mev/c at 90°)	6.2-Bev protons (local production)
Decay mode			
$K_{\mu2}$	59%	57%	54%
$K_{\pi2}$	21%	29%	26%
τ	5.2%	7.5%	7%
$K_{\pi3}$	3.5%	2%	1%
$K_{\mu3}$	6%	2%	4%
K_{e3}	5%	2%	8%

[a] D. M. Ritson *et al.*, Phys. Rev. **101**, 1085 (1956).
[b] J. Crussard *et al.*, Nuovo cimento (to be published).

consistent with $K_{\pi2}$ and gave a mean of 163 ± 7 Mev for $p\beta c$. We have then $K_{\pi2}=(4/5)(11/42)(152/173)=18\%$. As for the population of $K_{\mu3}$, we have 6 cases from the K_G class (their energies are 47, 35, 30, 24, 17, and 15 Mev, respectively) and one from the K_L class. The lower limit for $K_{\mu3}$ is then $7/173=4\%$. If we prorate the $K_{\mu3}$ in group II according to the one found among the flat cases, there should have been a total of two in the 11 cases of this category. If we further assume that the spectrum of the μ is given by phase space considerations, we find that 65% of all $K_{\mu3}$ secondaries should fall in the K_L class; then, according to the number found in the K_G class, we should have been able to identify one among the K_L class with our acceptance criteria. Our observation of one is thus consistent with the phase space assumption. In fact, assuming that the spectrum is of this form and using only those in the K_G class, we find the proportion of $K_{\mu3}=17/173=10\%$. Our final results are tabulated in Table I.

It is of interest to compare our results with those obtained at other laboratories under different conditions of exposure. This comparison is made in Table II, in which the conditions of production, mean moderation times of K mesons (in their rest frame) and ratios of various decay modes are given. Though in each instance the data are statistically not very good, especially for the $K_{\mu3}$, K_{e3}, $K_{\pi3}$, and τ modes, the inference seems to be that the observed ratios of K^+ decay modes (particularly $K_{\mu2}$ and $K_{\pi2}$) are relatively independent of the production mechanism and the moderation times, at least for times as short as 10^{-10} sec. This suggests that, if indeed the K^+ meson class is a mixture of two basic types, one decaying to the other as suggested by Lee and Orear,[3] the lifetime for this decay must be significantly less than 10^{-10} sec.

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[1] For a delineation of the various decay modes and their energetics, see M. F. Kaplon *et al.*, Phys. Rev. **99**, 1528 (1955).
[2] T. F. Hoang *et al.*, Phys. Rev. **101**, 1834 (1956); evidence is presented here for the decay $K_{\mu3}{}^+\rightarrow\mu^++\pi^0+\gamma$ (or ν); $E_{\mu+}$(max) $=133$ Mev ($\beta_{\max}=0.898$).
[3] T. D. Lee and J. Orear, Phys. Rev. **100**, 932 (1955).

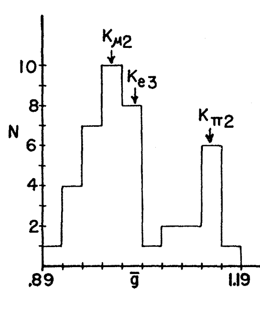

FIG. 2. Histogram of distribution of ionization (blob density) for the class of light secondaries (K_L) having dip angles less than 15°.

Decay Modes of Negative *K*-Mesons*

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AS is well known, when negative K-mesons are brought to rest they undergo capture in the atomic orbits and finally nuclear absorption. The competition between nuclear absorption and decay from the atomic orbits appears to be in favor of the absorption process. To study the decay modes of negative K-mesons it is thus necessary to observe decays in flight. In a study of negative K-meson interaction and lifetime,[1,2] we have observed four decays in flight in nuclear emulsions. In two of these cases, it was possible to establish the nature of the decay scheme. In the other two, the secondary particles were emitted with large dip angles, and such an analysis was thus not possible. One of the two cases analyzed is consistent with the decay $K^-\rightarrow\pi^-+\pi^0$, and the other with the decay $K^-\rightarrow e^-+2$ neutral particles.

The first case consisted of a K-meson track (as determined from multiple scattering and ionization measurements), that gave rise to a secondary emitted at $96.7°\pm0.2°$. The decay occurred at a velocity of $\beta_K=0.383\pm0.013$, as determined from ionization measurements (the normalized gap coefficient is $g^*=4.25\pm0.19$ at 1.4 mm from the decay point). The secondary particle had a dip angle of 13.5° and left the stack after an observed range of 4.9 cm. Scattering and blob-density measurements on the secondary in two different parts of the track are shown in Fig. 1. In the same figure are shown blob-density measurements on a calibration track, known to be a π^- meson (as it gives rise to a σ star), for which $p\beta$ has been deduced from its range. Known systematic errors—noise, effect of dip angle, and distortion—have been corrected for. These observations give the mass of the secondary as $m=(265\pm30)m_e$ and thus it was most probably a π meson. At the point of decay the momentum of the secondary, now considered as a π meson, was $p=170\pm9$ Mev/c. The transformed momentum in the rest system of the K-meson was found to be $p^*=202\pm12$ Mev/c. This value is consistent with that observed in the decay at rest of positive $K_{\pi2}$-mesons ($p^*=205$ Mev/c.). This fact suggests that the decay

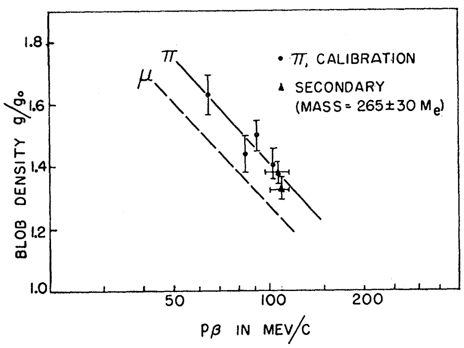

FIG. 1. Blob density *versus* $p\beta$ for the secondary particle (case I).

scheme was $K^-\rightarrow\pi^-+\pi^0$. Assuming this to be the correct decay scheme, we obtain the mass of the negative K-meson as $m_K=(957\pm40)m_e$, which is in good agreement with other measurements.[3]

Figure 2 shows the expected momentum of the secondary particle, (in the laboratory system) as a function of the K-meson momentum (assuming $m_{K^-}=m_{\tau^+}=965m_e$). The experimental point (full circle) again shows good agreement with the $K_{\pi2}$-mode. If we omit the evidence on the mass of the secondary, shown in Fig. 1, and make the assumption that the secondary was a μ meson (triangle in Fig. 2), the $K_{\mu2}$-mode can be definitely ruled out for this case. However, the $K_{\mu3}$-decay mode is a dynamically possible one, contradicted only by the observed mass of the secondary particle.

In the second case the K-meson had a momentum of $p=350\pm25$ Mev/c at the decay point. The secondary particle was emitted at an angle of 79.6°. The measured relative ionization was, from blob density $g/g_{\min}=1.04\pm0.05$. Multiple-scattering measurements gave $p\beta=37\pm4$ Mev/c over the first 3.5 mm of track, and $p\beta=25\pm4$ Mev/c over the following 2 mm. From these observations we concluded that the secondary particle was an electron of about 30-Mev energy. A trans-

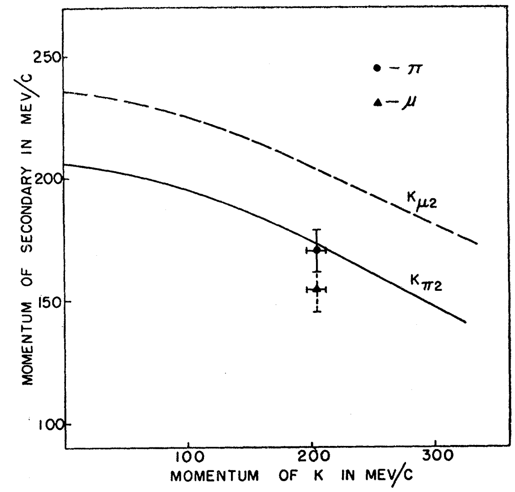

FIG. 2. Computed curves for the momentum of the secondary particle (in the laboratory system, for 96.7° emission angle) as a function of K-meson momentum (case I). The experimental point is plotted for the assumptions (a) that the secondary is a π (circle), (b) that the secondary is a μ (triangle).

formation to the rest system of the K-meson leaves the energy of the electron practically unaltered. This case is thus consistent with the decay mode $K_{e3}^-\rightarrow e^-+2$ neutral particles.[4]

The two cases discussed above showed no evidence of any blobs, which implies that we are dealing with decays in flight rather than nuclear interactions. As discussed previously,[2] there is an upper limit of 15% to the number of apparent decays in flight that could actually be interactions in flight.

It may thus be noted that negative K-meson decay modes so far observed include the $K_{\pi2}^-$, K_{e3}^-, and τ^- (the last was established in cloud-chamber work.[5])

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[1] Goldhaber, Goldhaber, Iloff, Lannutti, Webb, Widgoff, Pevsner, and Ritson, Proceedings of the 1955 Pisa Conference, Nuovo cimento (to be published).

[2] Iloff, Goldhaber, Goldhaber, Lannutti, Gilbert, Violet, White, Fournet, Pevsner, Ritson, and Widgoff, Phys. Rev. **102**, 927 (1956).

[3] J. Hornbostel and E. O. Salant, Phys. Rev. **99**, 338 (1955); Chupp, Goldhaber, Goldhaber, and Webb, Proceedings of the 1955 Pisa Conference, Nuovo cimento (to be published); Webb, Chupp, Goldhaber, and Goldhaber, Phys. Rev. **101**, 1212 (1956); Gilbert, Violet, and White (private communication).

[4] Williams, Haskin, Koshiba, and Schein, Phys. Rev. **100**, 1547 (1955), discuss an example of a 74-Mev electron emitted as the only prong from a K^--meson assumed to be at rest.

[5] V. A. J. Van Lint and G. H. Trilling, Phys. Rev. **92**, 1089 (1953); L. Leprince-Ringuet, *Proceedings of the Annual Rochester Conference on High-Energy Physics, 1955* (Interscience Publishers, Inc., New York, 1955); Aggson, Fretter, Friesen, Hansen, Kepler, and Lagarrigue, Phys. Rev. **102**, 243 (1956).