Two Examples of Rare K^+-Decays in Emulsion (*).

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In the course of an unbiased systematic scan (by the on track method) in a stack of stripped emulsion for K^+-mesons exposed to the 270 MeV/c focused K^+ beam of the Brookhaven Cosmotron we have observed two relatively rare examples of K^+ decay. The first event is shown in a reproduction facsimile in Fig. 1 and is interpreted as the decay at rest, $K^+_{\pi 2} \to \pi^+ + \pi^0$ ($\to e^+ + e^- + \gamma$); the second is shown in Fig. 2 and is interpreted as the decay in flight of a τ^+ meson, $\tau^+ \to 2\pi^+ + \pi^-$.

The first event (Fig. 1) is particularly significant as it gives independent support to our procedure of distinguishing between the $K_{\mu 2}$ and $K_{\pi 2}$ decay modes in emulsion on the basis of ionization alone [1]. Our emulsion stacks were cross-irradiated with 1.5 GeV π^- mesons and all ionization measurements were carefully made and normalized with respect to this beam (the normalized blob or grain density being denoted by $\bar{b}$ or $\bar{g}$). In the event of Fig. 1 the singly charged secondary had a dip angle of 11° with respect to the emulsion plane, $\bar{b} = 1.14 \pm .04$ and a value of $p\beta c = 174 \pm 25$ MeV. The lower and upper tracks of the pair (e_L and e_U) had respectively dip angles of 13° and 22°, blob densities of $1.03 \pm .04$ each and $p\beta c$ values of 60 ± 16 and 135 ± 20 MeV. The low value of $\bar{b}$ combined with $p\beta c$ establishes their identity as electrons (plateau is 1.03). The mass of the secondary is determined to be $(1.03 \pm .14)\,\mu$, where μ is the π rest mass. This, coupled with the closeness of the measured $p\beta c$ to that expected for the $K_{\pi 2}$ ($p\beta c = 169$ MeV) strongly suggests this mode.

The event can be analyzed as follows. Since momentum and energy is not conserved with the visible charged particles, at least one neutral particle (we designate it as X^0) must have been emitted. Its rest mass is given by

$$M_{X^0} = [(M_{K^-} - E_{\pi^-} - E_{e^+} - E_{e^-})^2 - - (\boldsymbol{p}_\pi + \boldsymbol{p}_{e^+} + \boldsymbol{p}_{e^-})^2]^{\frac{1}{2}}\,.$$

The spatial angles between the π^+ and

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the electron pair were determined to be

$$\theta_{\pi e_L} = 168^\circ\ 15' \pm 1.5^\circ$$

and

$$\theta_{\pi e_U} = 169^\circ\ 45' \pm 1.5^\circ\ .$$

Using the measured values of $p\beta c$ and the well known K^+ rest mass of 494 MeV we find $0 \leqq M_{X^0} \leqq 88$ MeV. This means that (in terms of known particles) X^0 must have zero rest mass. With the assumption of only the one missing neutral particle we have two possibilities; (i) a radiative decay (internally converted) of a $K^+_{\pi 2}$ or (ii) the decay $K^+_{\pi 2} \to \pi^+ + \pi^0$ $(\to \gamma + e^+ + e^-)$. The first possibility (i) can be rejected immediately since that case requires $M_{X^0} = \mu^0$, $\mu^0 = 135$ MeV and we are left only with the second case (ii). We could of course either invent a new electromagnetic interaction to give the decay to $\pi^+ + e^+ + e^- + \gamma$ directly or invent a new decay mode such as $\pi^+ + e^+ + e^- + 2\nu$ but since the event can be minimally interpreted in terms of (ii) we consider this to be the correct interpretation.

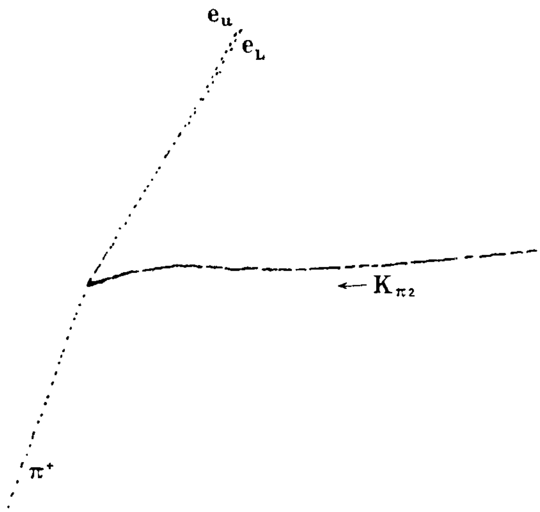

Fig. 1. – A facsimile drawing of an event interpreted as the decay, $K^+_{\pi 2} \to \pi^+ + \pi^0\ (\to e^+ + e^- + \gamma)$.

The event of Fig. 2, might appear at first sight to be a 4 prong star of which one of the prongs (*b*) is observed to be a π^- meson. However the track labelled τ is observed to increase its ionization in the direction of the « star ». At the « star » it has a $\bar{g} = 3.85 \pm .13$ and a $p\beta c = 86 \pm 12$ MeV. This is consistent with the measured values of $\bar{g}$ and $p\beta c$ of stopping K-mesons in our emulsions when measured at the same distance from entrance to the stack. In view of the fact that a nucleon of this energy could not make a single π-meson, the event must represent either the interaction or decay in flight of a K-meson. Since there is no evidence to date for K^+ interactions in which the K^+-mass is used for excitation it is important (2) to see whether this event is consistent with a decay in flight. Since the incoming particle is positively charged and one of the outgoing is observed to be negative the possibility of a τ^+ decay in flight suggests itself.

(2) One of the strong features of the Gell-Mann scheme which has been so successful in its characterization of the strange particles is the prediction that the K^+ rest mass is conserved in nuclear interactions.

We can proceed to test this assumption by determining the mass of the parent (labeled τ) and its Q-value for 3π decay. The range of track b is 14.5 mm corresponding to a kinetic energy of 28.5 MeV. The direction co- to be 76.8 ± 2 MeV. The velocity of the τ at the point of decay is .384 c corresponding to a $p\beta c = 78.5$ MeV in good agreement with the measured value of 86 ± 12 MeV. We conclude that the event is a τ^+ decay in flight and note

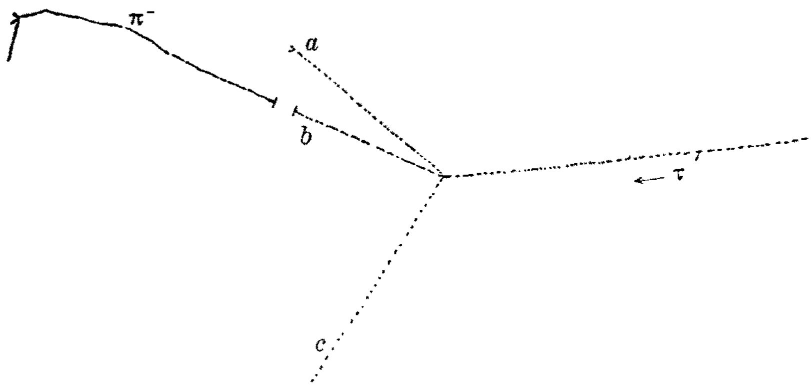

Fig. 2. – A facsimile drawing of an event interpreted as a $\tau^+ (\to 2\pi^+ + \pi^-)$ decay in flight.

sines of tracks a, b, and c with respect to the incoming track (defining the X-direction) are $\boldsymbol{a} = (.530,\ .521,\ .669)$, $\boldsymbol{b} = (.759,\ .429,\ -.489)$ and $\boldsymbol{c} = (.586,\ -.777,\ -.230)$ given in X, Y, Z order. An application of momentum conservation (using only track b) determines the momenta of a, c and τ and with the assumption that a and c are π-mesons, their energies are also determined. The mass of τ can then be calculated from its momentum and energy and yields a value of 495.3 ± 6 MeV, in excellent agreement with other measurements; the Q-value of the decay is determined that the accuracy of the mass determination is comparable with that obtained in elastic K+-p scatterings and that of the Q-value is comparable to that obtained from τ^+ decays at rest.

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