Example of τ^+-Decay in Flight*

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A τ^+-meson, of 0.83 Bev/c, is observed to undergo normal decay in flight with $Q(3\pi)=73.9\pm5.8$ Mev. The center-of-mass kinetic energies are found to be $T'=24.3\pm1.8$ and 28.7 ± 1.8 Mev for the two positive pions and $T'=20.9\pm4.3$ Mev for the negative pion.

THE fact that the masses of the τ meson[1,2] ($965.5\pm0.7\ m_e$)[3] and of the θ^0 meson[4] ($966\pm10\ m_e$) are almost identical led to the conjecture[4] that the θ^0 meson might be a neutral counterpart of the $\tau^\pm$ meson. Preliminary evidence against this identification has appeared in the analysis of τ-decay data by Dalitz,[5] in which the theoretical dependence of the distribution of decay configurations on the τ-meson spin j and parity w is calculated and compared with experiment. The preliminary results rather suggest even j and odd w for the τ meson. On the other hand, the fact that the θ^0 meson probably undergoes 2π decay[6,7] requires $w=(-1)^j$, which is incompatible with $\theta^0\equiv\tau^0$. Thus there is preliminary evidence that the θ meson and the τ meson represent different K-particle families with almost identical masses.

However, as pointed out by Dalitz,[5,8] such conclusions cannot be more than tentative at the present time, in view of possible experimental bias in the nuclear emulsion where the majority of τ decays are recorded. The effects of such bias are rather prominent in the work on V^0-decay in the emulsions,[9] hence it is to be expected that bias will also be present in the τ-decay data, although to a lesser extent. Estimates of the bias might be made from geometrical considerations. An alternate procedure would be to make comparison between τ-decay data from emulsion and from magnetic cloud chamber, since the latter would be expected to be relatively unbiased.

In view of the limited number of τ decays which have been observed in the magnetic cloud chamber, it may therefore be worthwhile to publish an example of τ^+ decay in flight, observed in the large rectangular chamber,[4] which can be analyzed in detail. A photograph of the event, film R-366, is shown in Fig. 1. The τ^+, track 0, enters from the rear at an angle of 3.5° with the plane of the chamber. After traversing about $\frac{2}{3}$ of the illuminated height, it decays into two

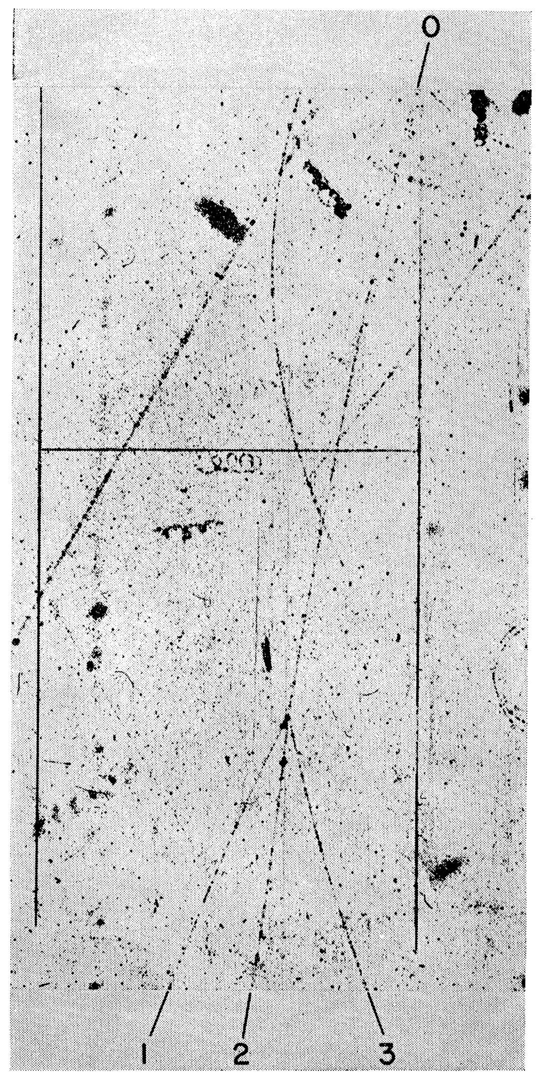

FIG. 1. Right eye view of film R-366, showing a τ^+ meson (track 0) disintegrating in flight into 3 pions (tracks 1, 2, and 3). Track 2 is that of the negative pion.

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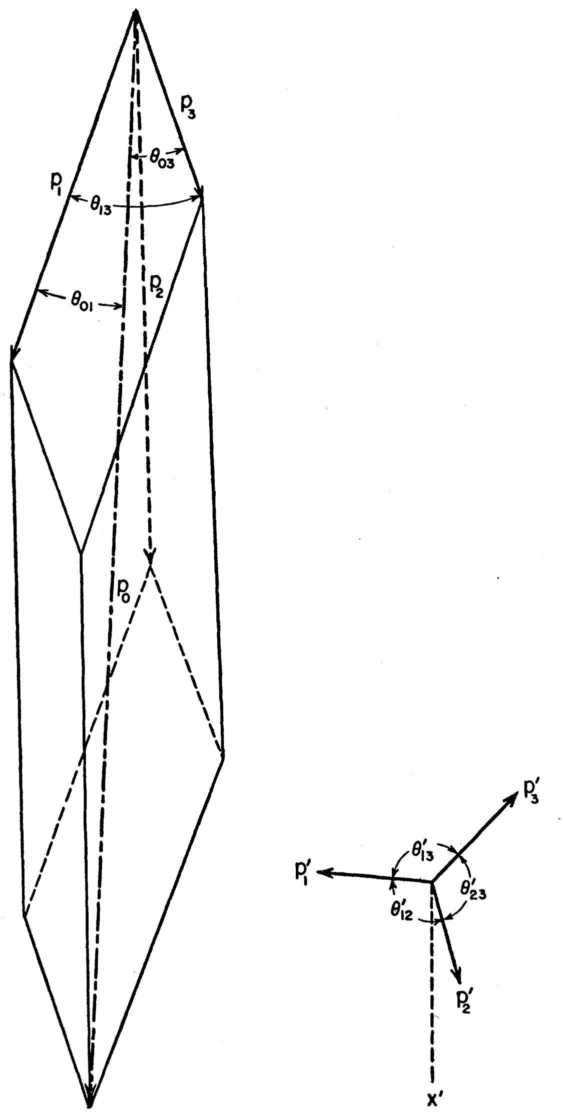


(a) (b)

FIG. 2. (a) Isometric drawing of the momentum parallelopiped in the laboratory frame. (b) τ-decay configuration in the center-of-mass system.

positive fragments, tracks 1 and 3, and a negative fragment, track 2. The measured momenta and angles are given in columns 1 and 2 of Table I. Within the experimental errors, the sum of the observed fragment momenta is equal to the observed primary momentum. Figure 2(a) shows an isometric drawing of the momentum parallelopiped, with the momenta drawn approximately to scale. If we denote $\Delta\mathbf{p}=\mathbf{p}_1+\mathbf{p}_2+\mathbf{p}_3-\mathbf{p}_0$, then $\Delta p_x=69$ Mev/c, $\Delta p_y=-0.3$ Mev/c and $\Delta p_z=-3.0$ Mev/c; where the x-axis coincides with track 0 and the (x,y)-plane contains track 1. Actually, the measurements on track 2 are not altogether satisfactory from the point of view of scatter in the comparator plots and of agreement between the three stereoscopic views. Thus, uncertainty in track 2 may easily account for the residual momentum in the x-direction (about 8 percent of the total). For this reason, the remaining analysis is based on the six measured quantities relative to the other tracks: p_0, p_1, p_3, θ_{01}, θ_{03}, and θ_{13}, as given in column 1 of Table I; and assumption of momentum conservation. Column 3 of Table I gives the momentum and direction of track 2 as calculated from the data in column 1. Comparison with the corresponding directly measured quantities in column 2 indicates agreement, again within the estimated errors.

The $Q(3\pi)$ value computed from the data and errors in column 1 is 73.9±5.8 Mev. The agreement with the well-established Q-value[3] of 74.7±0.3 Mev gives assurance that the event is correctly interpreted as normal τ decay.

The center-of-mass kinetic energies, momenta, and angles computed from the data and errors in column 1 of Table I are given in Table II. The center-of-mass decay configuration is shown in Fig. 2(b). The equation of the unit normal to the decay plane (in the direction of $\mathbf{p}_1'\times\mathbf{p}_3'$) is

$$\mathbf{n}'=-0.0998\mathbf{i}'+0.0042\mathbf{j}'-0.9950\mathbf{k}'.$$

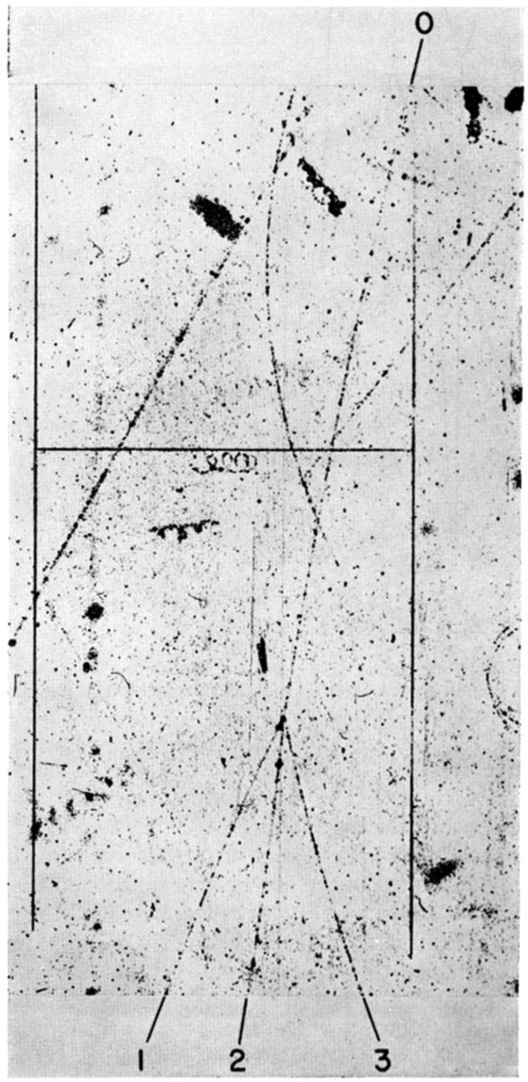
The direction of motion of the τ makes an angle $\theta'=84.3°$ with $\mathbf{n}'$; thus the event is almost planar in the laboratory system. For isotropic decay this is a probable configuration, since the element of available solid angle goes as $\sin\theta' d\theta'$. As to the orientation of the fragment momenta in the decay plane, $\mathbf{p}_1'$ makes an angle of 2.1°, in the backward direction, with the y'-axis.

TABLE I. Basic data.

Momenta-Bev/c angles-degrees	1 Measured data used in analysis	2 Measured data for track 2	3 Calculated data for track 2
p_0	0.83±0.03		
p_1	0.28±0.01		
p_2		0.49±0.06	0.42±0.03
p_3	0.154±0.005		
θ_{01}	17.7±0.1°		
θ_{02}		3.3±0.5°	3.8±1.1°
θ_{03}	22.9±0.3°		
θ_{12}		20.8±0.5°	21.3±0.8°
θ_{23}		19.8±0.5°	19.5±1.2°
θ_{13}	40.4±0.3°		

TABLE II. Decay parameters in center-of-mass system.

Fragment	Sign	Kinetic energy Mev	Momentum Mev/c	Angle opposite
1	+	24.3±1.8	86±3	58.7±5.0°
2	−	20.9±4.3	79±9	52.0±5.5°
3	+	28.7±1.8	94±3	69.3±1.4°



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