Letters to the Editor

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Spin of the τ^+ Meson*

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DALITZ[1] has pointed out the possibility of determining the spin and parity of the τ^+ meson by measuring the angular correlation and energy distribution of its decay products. This is a preliminary report on a study of the decay of 54 τ^+ mesons. The events were observed by area scanning in a large emulsion stack[2] irradiated in a magnetically analyzed K-meson beam from the Berkeley Bevatron.[3] The events were identified by the decay scheme $\tau^+ \rightarrow 2\pi^+ + \pi^-$. The scanning efficiency was probably greater than 90%, since the observed K/τ ratio was similar to that found by systematic "on track" scanning.

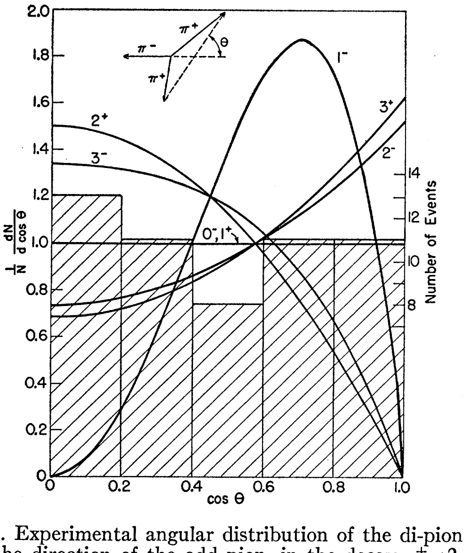

FIG. 1. Experimental angular distribution of the di-pion, relative to the direction of the odd pion, in the decay $\tau^+ \rightarrow 2\pi + \pi^-$. The theoretical curves[1] are shown for possible τ spins up to 3. In all cases, except spin 2, odd parity, and spin 3, even parity, only the lowest angular momentum decay mode need be considered. In the 2(odd) and 3(even) cases, where two decay modes are of comparable probability, these have been weighted according to the appropriate Clebsch-Gordan coefficients and on the assumption that the only energy and angular momentum dependence of the matrix elements is through the angular momentum barrier penetration factors.

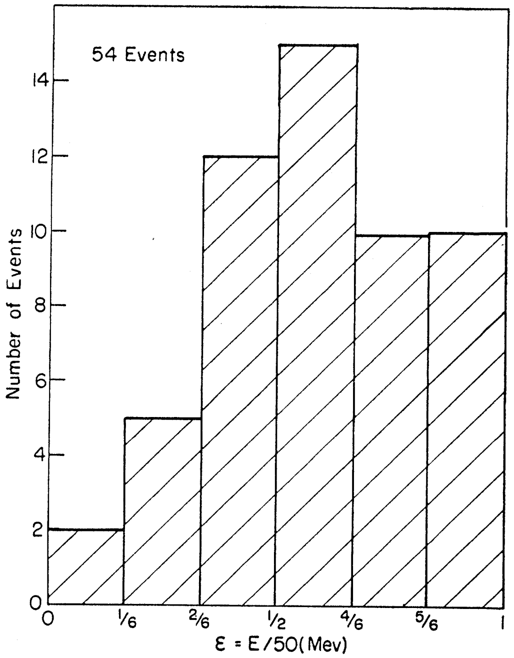

FIG. 2. Experimental energy distribution of the π^- meson in τ decay.

The identity of the negative (odd) pion was established by tracing the products of the decay through the stack to the end of their range. The relative angles of all three π mesons were measured; from these angles one obtains the angle of theoretical interest, θ, which is the angle of decay of the di-pion ($2\pi^+$), in its own center-of-mass system, relative to the direction of the π^-. The observed angular distribution is shown in Fig. 1, plotted in equal solid-angle intervals. The distribution appears to be isotropic. Also shown in Fig. 1 are the angular distributions theoretically predicted[1] for various spins and parities of the τ meson.

The energy of the π^- meson was determined from range measurements. In several cases, it was necessary to obtain the energy of the π^- meson by measuring the ranges of both π^+ mesons and assuming a Q-value of 74 Mev.[4]

Figure 2 is a histogram showing the distribution of the energy of the π^- mesons. If the spin of the τ meson were zero, the energy distribution should be symmetric about the midpoint $\epsilon = \frac{1}{2}$, where $\epsilon = E/E_{\max} \cong E/50$ Mev, provided that the matrix element is energy-independent; specifically, the π^- mesons would have an energy distribution determined only by phase-space considerations, namely:

$$dN_0/d\epsilon = (8N/\pi)(1-\epsilon)^{\frac{1}{2}}\epsilon^{\frac{1}{2}}. \quad (1)$$

Figure 3 shows the π^- energy distribution corrected for the density-of-states factor, Eq. (1). Also shown on Fig. 3 are the energy dependences one would predict for various assumed spins and parities of the τ meson.

From Figs. 1 and 3 it would appear that the 54 cases we have studied favor spin 1 and even parity for the τ^+ meson. It should also be noted, however, that the existence of an attractive π-π force in the $T=0$ state[5] or a repulsive force in the $T=2$ state, or both, would lead to deviations from a symmetrical π^- energy distribution of the type observed by us.

The τ-decay data presented at the Pisa Conference[4] do not show the pronounced energy asymmetry which we observe in 54 cases. Our method of scanning could not have introduced an asymmetry in the energy of the type observed. The question also arises as to whether our observations represent a statistical accident or a sample which is less subject to bias than one obtained by an accumulation of data from many laboratories. We plan to continue this work and improve our statistics in the hope of resolving this question.

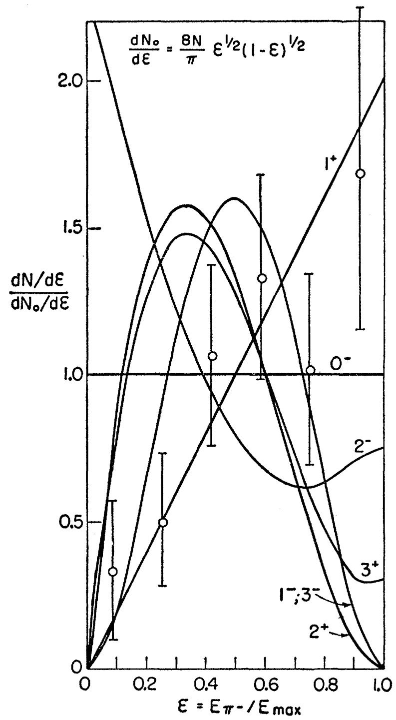

FIG. 3. Energy distribution of the odd pion in τ decay, corrected for the phase-space factor, Eq. (1). Theoretical energy distributions[1] are computed on the assumptions outlined in the caption to Fig. 1.

Note added in proof.—G. Harris and J. Orear (Columbia University, private communication) find in a similar sample a large number of low energy π^-'s associated with their τ decays. These additional data, even in combination with ours, rule out 1^+, and make 0^- the preferred solution, although some deviation from isotropy in the direction indicated by our results is not ruled out.

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[1] R. H. Dalitz, Phys. Rev. 94, 1046 (1954).

[2] Ritson, Pevsner, Fung, Widgoff, Zorn, Goldhaber, and Goldhaber, Phys. Rev. (to be published).

[3] We wish to express our gratitude to E. Lofgren and G. Goldhaber for their kind assistance in arranging this exposure.

[4] Proceedings of the International Conference on Elementary Particles, Pisa, 1955 (to be published).

[5] F. Dyson, Phys. Rev. 99, 1037 (1955).

Angular Distribution of Λ^0 and θ^0 Decays*

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QUALITATIVELY, it is clear that the angular distribution of the decay products of the Λ^0 and θ^0 must be related to the spins of these particles. In particular, it is well known[1,2] that the complexity of the angular distribution of decay particles is limited by the magnitude of the spin of the parent state. If the angular distribution about an arbitrary direction is written as a polynomial in $\cos\vartheta$, only even powers of $\cos\vartheta$ will appear in the terms and the highest power will be equal to $2a$, where a is equal to the spin of the particle for bosons and to the spin minus one-half for fermions. The use of this rather loose restriction can only establish a lower limit to the spin of a state.

It is the purpose of this note to point out that an examination of the angular correlations of the Λ^0 and θ^0 decay products is particularly informative when restricted to Λ^0 and θ^0 particles produced in the backward or forward direction by the $\pi^-+p\rightarrow\theta^0+\Lambda^0$ reaction, at energies near threshold. In particular, the determination of the angular distributions of those Λ^0 decays which are in coincidence with θ^0 mesons which decay in the forward or backward direction, uniquely determines the spin of the Λ^0. Likewise, a measurement of the decay distribution of those θ^0 mesons in coincidence with Λ^0 particles which decay in the forward or backward direction will determine a number which will generally be equal to the spin of the θ^0, and will always be as great as the spin minus one.

A general expression for the reaction amplitude for the $\pi^-+p\rightarrow\Lambda^0+\theta^0$ is:

$$\begin{aligned}A=&\sum_{\pi j m_j L S m_L m_A m_l} a_{\pi j L S}(j+\tfrac{1}{2})^{\frac{1}{2}}(LSjm_j|LSm_L,\, m_j-m_L)\\ &\times\Theta_L{}^{m_L}(ABS,\, m_j-m_L|ABm_A,\, m_j-m_L-m_A)\Theta_A{}^{m_A}\\ &\times(l\tfrac{1}{2}\Lambda,\, m_j-m_L-m_A|l\tfrac{1}{2}m_l,\, m_j-m_L-m_A-m_l)\\ &\times\Theta_l{}^{m_l}\chi^{m_j-m_L-m_A-m_l}\,\delta(\pi,\,(-1)^{L+l+A+1})\alpha(m_j),\end{aligned}\qquad(1)$$

where the complex constants, a, are determined by the dynamics of the reaction and the magnetic quantum numbers represent values in the direction of the beam. In this equation π represents the parity of the state formed with total angular momentum, j; L and S represent the relative orbital angular momentum and the total spin of the $\Lambda^0-\theta^0$ system, respectively; while the A, B, l, and χ stand for the spin of the θ^0, the spin of the Λ^0, the π^--p relative orbital angular momentum in the decay of the Λ^0, and the proton spin function in that order. The $\alpha(m_j)$, which are unit vectors such that $\alpha(m)\alpha(m')=\delta(m,m')$, establish that the bombarded protons are unpolarized. The value of m_j must be equal to the spin component of the bombarded proton since