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ANALYSIS OF THE TAU-MESON DECAY

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ABSTRACT

In G.5 emulsion stacks exposed to secondary particles from targets bombarded by 4.8 to 5.7 Bev protons, six τ mesons were observed. Measurements of the ranges and directions of the emission of the decay products have been made. From these measurements a Q value of 74.9 ± 0.2 Mev for the τ decay is obtained. Data are also provided for a study of the statistical correlation between the initial direction of the τ meson and the plane of decay and the direction of the unlike-sign pion.

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One of the first experimental techniques employed in Bevatron research programs was the exposure of stacks of Ilford G. 5 emulsions to the secondary particles from a target bombarded by 4.8- to 5.7-Bev protons. A re-entrant well permitted placement of the emulsions at 90° to the beam direction and within 10 inches of the bombarded target. With this geometry, the proper flight time plus the proper time for 125-Mev K-particles to be brought to rest in the emulsion was about 1.5×10^{-9} second. This report describes some of the results obtained from two such exposures: first, a 2-by-4-inch stack of 20 sheets of emulsion 600 μ thick, and second, a 2-inch cube of emulsion. The latter exposure was primarily for a τ meson study.

All together, six τ -mesons were observed in the 10.7 cm³ of emulsion scanned by area. In five cases, the charges of all three pions could be determined. All decays were consistent with $\tau^+ \rightarrow \pi^- + 2\pi^+$. No alternate modes of decay, i. e., $\tau^+ \rightarrow \pi^+ + 2\pi^0$, were specifically sought. The tabulation of the data is given in Table I, where the entries in parentheses were calculated from the measured quantities. Particles 1 and 2 refer to the π^+ mesons and Particle 3 refers to the π^- meson. Only in the events (τ_7 , τ_3 and τ_6), where not all pions came to rest in the emulsion stack, were angle measurements taken. Here δ is a measure of the coplanarity of these events, and is the amount (in degrees) by which the vector \vec{r}_3 lies out of the plane formed by the vectors \vec{r}_1 and \vec{r}_2 . The range-energy relation for the pions in emulsion was evaluated from Vigneron's calculated data, extended by Barkas,¹ and using a pion mass of $0.1487 M_p$.

The error listed on each Q value includes estimations for range straggle of the pions (generally about 1.8%) and observer error in range and angle measurements (taken to be 1% and 0.5° , respectively). From these data the average value of Q for the decay of the τ meson is 74.9 ± 0.4 Mev from internal consistency and 74.9 ± 0.2 Mev from external consistency.

Pertinent to the problem of the spin and parity of the τ meson is the energy distribution of the odd-charged pion (Particle 3). No attempt will be made to compare the five events reported herein with the theories of Dalitz² and Fabri³ other than to comment that the energy distribution is consistent with a symmetric, and perhaps flat, distribution.⁴

Another possible means for detecting the spin of the τ meson is the study of the orientation of the plane of the decay of the τ meson with respect to the direction of emission of the τ particle.^{5,6} In the decays where the charges of the pions are known, information related to this problem can also be obtained from the relative directions of the unlike pion and the τ meson at its point of production.

The geometry used in the well exposures afford an opportunity for the measurements of these parameters. The direction of emission of the τ meson is known to $\pm 5^\circ$. The uncertainty arises from the finite extent of the target, and from assuming no large angle scattering in the target. In all cases, the initial direction of the τ meson was taken to be along the "x" direction of the emulsion and parallel to the surface. The magnetic field in the region of the target and re-entrant well was approximately 100 gauss.

Table II tabulates the following data:

- a) $\theta_{n\tau}$, the angle between the emission of the τ and the normal to the plane of decay.
- b) δ_n , the angle between the normal to the plane of decay and the plane of the emulsion.
- c) $\theta_{\pi\tau}$, the angle between the direction of emission of the unlike π meson and the direction of the emission of the τ .
- d) δ_π , the angle between the direction of the unlike π meson and the plane of the emulsion.

δ_n and δ_π were measured primarily as a check for observational bias. For isotropic distributions of δ_n and δ_π , 50% of the events should have angles greater than 30° . The observed ratio is 5/9.

I wish to acknowledge the aid given me by the Bevatron crew, under the directorship of Dr. Edward Lofgren, in making the exposures. Miss Roberta Dalley and Miss Hester Lowe contributed their skills in scanning a large part of the emulsions required for this report.

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Table I

τ -Meson Data												
	R_1^+ (mm)	R_2^+ (mm)	R_3^- (mm)	T_1^+ (Mev)	T_2^+ (Mev)	T_3^- (Mev)	θ_{12}°	θ_{23}°	θ_{31}°	$\Sigma\theta^\circ$	δ°	\bar{O} Mev
τ_1	5.39	10.84	--	16.2	24.3	(34.0)	$96^\circ 45'$	$139^\circ 8'$	$123^\circ 2'$	$358^\circ 55'$	$1^\circ 23'$	74.5 ± 0.75
τ_2	6.15	28.32	4.53	17.6	43.2	14.7	$(150^\circ 23')$	$(147^\circ 6')$	$(62^\circ 31')$			75.5 ± 0.86
τ_3	6.01	7.46	--	17.3	19.6	$(37.5)^a$	$85^\circ 42'$	$138^\circ 22'$	$135^\circ 58'$	$360^\circ 2'$	$0^\circ 37'$	74.4 ± 0.71
τ_4	6.51	19.53	9.43	18.2	34.7	22.4	$(128^\circ 27')$	$(135^\circ 30')$	$(96^\circ 3')$			75.3 ± 0.81
τ_5	6.65	22.21	7.17	18.3	37.4	19.2	$(136^\circ 2')$	$(137^\circ 25')$	$(86^\circ 35')$			74.9 ± 0.87
τ_6	3.48	--	--	12.6	$(27.3)^b$	$(35.2)^b$	$95^\circ 13'$	$144^\circ 54'$	$119^\circ 55'$	$360^\circ 2'$	$1^\circ 04'$	75.1 ± 1.6

^aNegative pion suffered an inelastic collision (2-prong star) 12.4 mm from point of decay, i. e. at $T_{\pi^-} = 23.0$ Mev.

^bCharge unknown.

Table II

Angular Correlations in τ -Meson Decay				
	$\theta_{n\tau}$	δ_n	$\theta_{\pi\tau}$	δ_π
τ_1	$14^\circ 12'$	0°	$90^\circ 39'$	$83^\circ 16'$
τ_2	$51^\circ 4'$	$46^\circ 22'$	$63^\circ 48'$	$1^\circ 52'$
τ_3	$26^\circ 30'$	$17^\circ 6'$	$118^\circ 51'$	$28^\circ 58'$
τ_4	$55^\circ 40'$	$55^\circ 24'$	$41^\circ 56'$	$31^\circ 45'$
τ_6	$38^\circ 39'$	$36^\circ 22'$		