STUDY OF KINEMATICALLY DETERMINED τ' DECAYS*

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We have studied a sample of 144 τ' decays in which, for the first time, all the kinematical quantities are determined. The dependence of the matrix element on the neutral-pion energy has been measured and a linear extrapolation has been made to zero four-momentum. The result is consistent with the soft-pion prediction of current algebra.

An exposure of the Brookhaven National Laboratory 30-in. propane bubble chamber to a stopping K^+ beam was scanned for K^+ decay into a stopping π^+ with two or more converted gamma rays associated with the K^+ decay vertex. Approximately 150 000 pictures with an average of eight stopping K^+ per picture were scanned for this topology. The events found were measured on digitized projectors and processed through the NP54 geometry program[1] and the GRIND kinematic fitting program.[2] About 140 such events are consistent with a $K^+ \rightarrow \pi^+\pi^0\pi^0$ decay from rest. To our knowledge, this is the first study of the τ' decay to measure kinematical quantities other than the π^+ energy distribution.

The scanning instructions were to search first for electron pairs and, if two were found associated with the same K^+ vertex, to examine that vertex carefully for a π-μ-e decay chain in the chamber. Since the electron-pair scanning efficiency is reasonably independent of the energy of the parent π^0 [3] and since these pairs then point out the K^+ vertex, we hoped in this way to obtain a scanning efficiency independent of the π^0 and π^+ momenta. About 75 % of the film was scanned twice, giving an overall scanning efficiency of 74 ± 8 %. All events in which the positive decay prong did not undergo a π-μ-e decay inside the chamber or scattered before doing so were discarded.

An event was selected as a τ' if the two pairs fit a π^0 with a probability greater that 5% and the event then fit a τ' decay at rest with probability greater than 1%. The only noticeable contamination came from $K_{\mu 3}$ decays which in general are easily discriminated against. The few events which did fit both were called τ' only if the π-μ-e decay sequence was unambiguous. All τ' candidates were studied by physicists on the scanning table.

Corrections were made to the π^+ energy spectrum to account for the finite size of the chamber and scattering of the π^+. The chamber has an effective diameter of 74 cm and a depth of 38 cm, while the maximum π^+ range is 22 cm, so even at the top of the spectrum, 75% of the π^+ stop and decay in the chamber. The scattering correction was obtained using the scanners' identification of scattered pions in τ decays. This correction is a maximum of 16% at the top of the π^+ spectrum. The π^0 spectrum was not corrected for the finite size of the chamber since the detection efficiency was shown to be almost independent of the π^0 momentum in a study of the $K_{\mu 3}$ decay mode made in this exposure.[3]

A possible background arises from the two detected gamma rays coming from different π^0's but fitting a single π^0. This background was checked from a sample of 15 τ' candidates with three associated electron pairs, and was found to be less than 5%.

Figure 1 shows a Dalitz plot of the 144 events

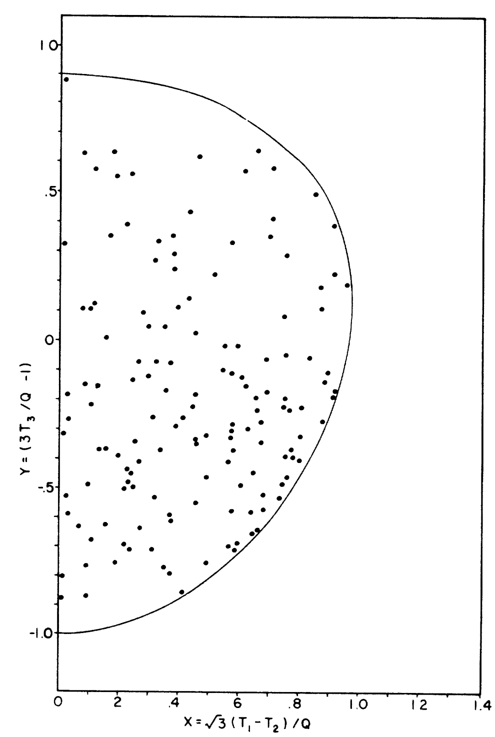

FIG. 1. Dalitz plot of the 144 $K^+ \rightarrow \pi^+\pi^0\pi^0$ decays.

which satisfied the criteria of π^0 probability greater than 5% and overall τ' probability greater that 1%. The plot is presented in terms of the Dalitz-Fabri variables $X=\sqrt{3}(T_1-T_2)/Q$ and $Y=3T_3/Q-1$ where T_1, T_2 refer to the π^0 energies, T_3 is the energy of the π^+, and $Q=m_k-m_{\pi^+}-2m_{\pi^0}=84.3$ MeV.[4]

For comparison with other experiments and theoretical predictions, we present projections of this Dalitz-Fabri plot on the Y, X, and E_{π^0} axes. Corrections are made to the data for differential scanning efficiency as a function of position on the Dalitz-Fabri plot for the finite size of the chamber and for the scattering of the π^+. Table I exhibits the raw data N_{obs}, corrections $\mathcal{E}$, normalized phase space P, and the reduced data $R=N_{\text{cor}}/(N_{\text{tot}}P)$. N_{cor} is the corrected number of events in the bin specified, N_{tot} is the total number of such events, and P represents the normalized phase space for the interval. All fits to the data were made using the least-mean-squares technique.

Table I. The raw data N_{obs}, corrections $\mathcal{E}$, corrected number of events N_{cor}, phase space P, and the reduced data R. The corrections made were $\mathcal{E}_{\text{scatt}}$ for events rejected due to the π^+ leaving the chamber before stopping, $\mathcal{E}_{\text{geom}}$ for the π^+ leaving the chamber before stopping, and $\mathcal{E}_{\text{scan}}$ for differential scanning efficiency. The error on R includes the statistical error and an estimate of the uncertainty in the corrections. Note that $R \propto |\text{amplitude}|^2$.

π^+ ENERGY SPECTRUM

Y	N_{obs}	$\mathcal{E}_{\text{scatt}}$	$\mathcal{E}_{\text{geom}}$	$\mathcal{E}_{\text{scan}}$	N_{cor}	P	R
-.8	24	.93	1.00	.57	45	.135	1.42 ± .32
-.4	53	.91	1.00	.76	77	.234	1.40 ± .24
0.0	40	.89	.98	.67	69	.280	1.05 ± .19
.4	22	.86	.94	.88	31	.255	.52 ± .12
.75	5	.84	.80	.63	12	.108	.46 ± .23

X DISTRIBUTION

X	N_{obs}	$\mathcal{E}_{\text{scan}}$	N_{cor}	P	R
.1	31	.80	39	.268	.75 ± .14
.3	36	.74	49	.256	.98 ± .18
.5	29	.76	38	.230	.85 ± .17
.7	35	.67	52	.182	1.47 ± .28
.88	12	.71	17	.065	1.34 ± .40

E_{π^0} DISTRIBUTION

E_{π^0}	N_{obs}	$\mathcal{E}_{\text{scan}}$	N_{cor}	P	$\sqrt{R}$
140	18	.86	21	.111	.70 ± .09
150	57	.78	73	.193	.99 ± .07
160	60	.82	78	.229	.90 ± .07
170	65	.61	107	.234	1.09 ± .08
182	88	.74	114	.234	1.12 ± .07

The fit to the Y distribution assuming $|\text{amplitude}|^2 \propto 1+aY^4$ has a probability of 40% and yields $a=-0.88\pm0.23$, in good agreement with other statistically richer experiments.[5]

The X distribution is fitted adequately by a flat distribution since this fit has a chi-squared probability of 15%, but a fit of the form $|\text{amplitude}|^2 \propto 1+bx^2$ yields a somewhat better fit (chi-squared probability of 55%) with b two standard deviations from zero: $b=1.2\pm0.6$.

One of current-algebra's soft-pion predictions, first pointed out by Callan and Treiman,[6] is that the amplitude for K decay should vanish for zero four-momentum of the π^0 in τ' decay. This limiting point corresponds to zero total energy of the π^0 and is far from the physical region. Since reliable off-mass-shell corrections are not available, we use the procedure first suggested by Nefkens[7] of extrapolating the reduced π^0 energy spectrum to zero total energy of the π^0. Since this spectrum is consistent with being linear in the physical region, we may attempt to extrapolate this linear form into the unphysical region. This procedure yields an amplitude of -0.37

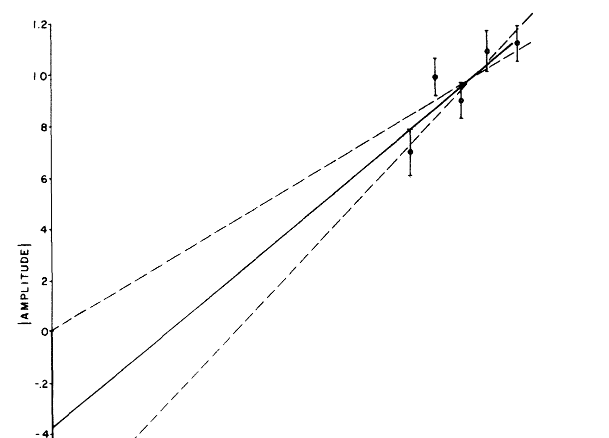

FIG. 2. Plot of the reduced data as a function of E_{π^0}. The straight line is a linear fit to the data and predicts an amplitude of -0.37 ± 0.38 at $E_{\pi^0}=0$. The dashed lines correspond to one standard deviation.

± 0.38 at zero total π^0 energy, clearly consistent with the soft-pion prediction of current algebra. The spectrum and the extrapolation are shown in Fig. 2.

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[2]R. Böck, CERN Report No. 61-29, 1961 (unpublished).

[3]F. R. Eisler, S. Y. Fung, S. Marateck, S. L. Meyer, and R. J. Plano, Phys. Rev. 169, 1090 (1968).

[4]Other authors have analyzed their results in terms of the Mandelstam variables $S_i = (P_k - P_{\pi_i})^2 = (m_k - m_{\pi_i})^2 - 2m_k T_{\pi_i}$ and expanded the amplitude $M \propto 1-(b/m_\pi^2) \times (S_3 - S_0)$ where $S_0 = \frac{1}{3}(S_1 + S_2 + S_3)$. For purposes of comparison, we note that $b = 0.351a$ where $|M|^2 \propto 1 + aY$.

[5]G. E. Kalmus et al., Phys. Rev. Letters 13, 99 (1964), obtained $a = -0.69 \pm 0.06$. V. Bisi et al., Nuovo Cimento 35, 768 (1965), obtained $a = -0.85 \pm 0.14$.

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