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THE DECAY $\tau \to \rho\nu$ (AND $\tau \to \pi\eta\nu$?)*

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ABSTRACT

Motivated by the question of missing exclusive branching fractions in τ decays, mostly suspected to be in one prong decays with neutrals, we have studied the decay $\tau \to \rho\nu$ in τ pair production by e^+e^- annihilation at $\sqrt{s} = 3.77$ GeV. The branching fraction is measured to be $B(\tau \to \rho\nu) = (23.0 \pm 1.3 \pm 1.7)\%$ consistent with known measurements and not offering a solution to the branching ratio question. No η signal in the $\gamma\gamma$ mass spectrum pointing to a decay $\tau \to \eta\pi\nu$ is obvious. An upper limit on this branching fraction is given.

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In τ decays there remains a disagreement over the possible discrepancy between the measured inclusive one-prong branching fractions and the summed branching fractions of the exclusive measurements.[1,2] Most of this difference is attributed to channels containing one or more π^0's.[3] The decay $\tau \to \rho\nu$ is the biggest contribution and here we present a detailed measurement of it. The analysis is a measurement of τ pairs in the reaction[4]

$$\begin{array}{l} e^+e^- \longrightarrow \tau\tau \longrightarrow (e\nu\bar{\nu}) \text{ or } (\mu\nu\bar{\nu}) \\ \qquad\qquad \hookrightarrow \rho\nu \\ \qquad\qquad\quad \hookrightarrow \pi\pi^0 \\ \qquad\qquad\qquad \hookrightarrow \gamma\gamma \end{array} \tag{1}$$

The observed final state allows also to look for the recently reported second class current decay $\tau \to \pi\eta\nu$.[5]

The data, 9.4 pb^{-1}, were taken with the MARK III detector at the SLAC e^+e^- storage ring SPEAR at a c.m. energy of 3.77 GeV. Details of the detector performance have been discussed elsewhere.[6,7] Charged particles are identified by the time-of-flight (TOF) counters, the shower counters and the muon detector.

The criteria for selecting τ pair events are chosen to suppress leptonic backgrounds from QED processes and charm production.[6] Candidate events are required to have two oppositely charged tracks. The individual momenta must be below $0.75 \times p_{beam}$ and at least $40\% \times E_{beam}$ has to be seen in the event. One charged track is identified as an electron or a muon, the other as a pion. The two charged tracks have to be acollinear, $2.5^\circ < \theta_{acol} < 177.5^\circ$, and acoplanar, $\theta_{acop} > 6^\circ$. In addition to the charged tracks, exactly two isolated photons are demanded. The two-photon invariant mass combinations of these events are shown in fig. 1(a). A clear π^0 signal with little background is observed. There is no structure observed in the η mass region, shown enlarged in fig. 1(b), that would point to $\tau \to \pi\eta\nu$. The two photons are constrained to the π^0 mass. Events with $\chi^2 < 6$ and both fitted photon energies above 0.040 GeV are retained.

The sources of background in this sample are τ pair production with decays into other final states. These backgrounds are due to feed-down from τ decays with more than one π^0 in which γ's are lost and by μ/π and e/π misidentification. Charm production and non-charmed background is found to be negligible. The backgrounds stemming from the mentioned τ pair production are listed in table 1.

The background-corrected $m_{\gamma\gamma}$ spectra are compared with Monte Carlo spectra for $\tau\tau \to (e\nu\nu)\ (\rho\nu)$ and $\tau\tau \to (\mu\nu\nu)(\rho\nu)$. They agree well for $m_{\gamma\gamma} < 0.25$ GeV/c^2, and we thus apply this mass cut. The remaining numbers of events are listed with and without background correction in table 1. Figures 2(a,b) show the $\pi\pi^0$ mass distributions with the backgrounds subtracted. Clear ρ signals above small residual backgrounds are evident. The signal consists of $396.2\pm21.5\pm15$ $e\pi\pi^0$ and $186.2\pm15.1\pm6.6$ $\mu\pi\pi^0$ events. Background-corrected momentum spectra for the leptons and the charged and neutral pions all agree with the Monte Carlo predictions for $\tau\tau \to (\ell\nu\nu)\ (\rho\nu) \to \ell\pi\pi^0$.[8]

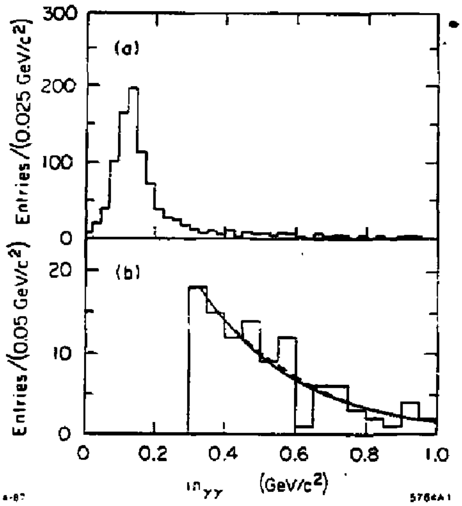

Fig. 1. Invariant $\gamma\gamma$ mass distributions are shown (a) for all selected events before π^0 fit, and (b) for all selected events with $\gamma\gamma$ mass above 0.3 GeV. The superimposed curve is the result of the fit described in the text.

Table 1

	$e\pi\pi^0$	$\mu\pi\pi^0$
# events	$451 \pm 21^{+13}_{-0}$	$219 \pm 14.8^{+3.7}_{-0}$
$(n\pi^0)$ background	$34 \pm 2^{+15}_{-6}$	$14.5 \pm 1.3^{+6.6}_{-2.6}$
from $\tau\tau \to \pi\rho$	7.5 ± 1.5	18.3 ± 2.6
from $(\tau\tau \to \mu\rho) \to (\tau\tau \to e\rho)$	13.3 ± 1.2	
background corrected events	$396.2 \pm 21.5 \pm 15$	$186.2 \pm 15.1 \pm 6.6$
efficiency	0.1886 ± 0.0028	0.1018 ± 0.0021
	± 0.0083	± 0.0033
$(e^+e^- \to \tau\tau \to \ell\rho)$	$(0.242 \pm 0.013 \pm 0.013)nb$	$(0.211 \pm 0.016 \pm 0.012)nb$
$B(\tau \to \rho\nu)$	$(23.6 \pm 1.6 \pm 1.7)\%$	$(21.4 \pm 2.4 \pm 1.6)\%$
B_{combined}	$(23.0 \pm 1.3 \pm 1.7)\%$	

Detection efficiencies, found from the Monte Carlo calculation, and the observed cross sections are listed in table 1. Using our measured cross sections for the leptonic τ decays[6], and the QED cross sections for $\tau\tau$ production, we obtain the weighted average for the branching fraction:

$$B(\tau \to \rho\nu) = (23.0 \pm 1.3 \pm 1.7)\% \ .$$

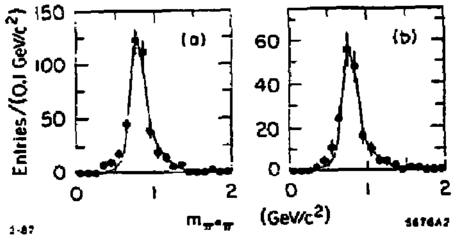

Fig. 2. Invariant $\pi\pi^0$ mass distributions are shown for (a) $e\pi\pi^0$ events and (b) $\mu\pi\pi^0$ events. The backgrounds are subtracted from these spectra. The curves show the Monte Carlo prediction.

The helicity angle θ_H between the charged pion in the ρ rest frame and the ρ's direction of flight in the laboratory is also measured. Figure 3 shows the acceptance corrected measured distribution in comparision with the prediction.[9] The prediction agrees with the data, yielding a χ^2 per degree of freedom of 1.4 for the curve shown in fig. 3, thus confirming the predicted occurrence of the different helicity states of the ρ.

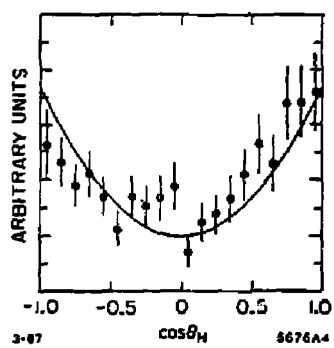

Fig. 3. The acceptance-corrected distribution of $\cos(\theta_H)$ is shown. The curve, proportional to $(1 + 2.68 \cos^2\theta)$, is the Monte Carlo prediction.

To derive an upper limit of the branching ratio for the decay $\tau \rightarrow \pi\eta\nu$ we fit the spectrum in fig. 1(a) above the π^0 peak to an exponentially falling background and an η signal. This fit, yielding a χ^2 of 11.6 for 10 degrees of freedom, is shown in fig. 1(b). The full line is the background and the dashed line represents background and signal. Investigating the likelihood profile of the assigned η fraction we obtain an upper limit on B ($\tau \rightarrow \pi\eta\nu$) of 4.4% at the 90% C.L..[10]

In summary, our measurement of $B(\tau \rightarrow \rho\nu) = (23.0 \pm 1.3 \pm 1.7)\%$ agrees well with the theoretical expectation of $1.23 \times B(\tau \rightarrow e\nu\nu)$ [1] and the accepted value[11] of $(21.8 \pm 2.0)\%$. The distribution of the helicity angle is in agreement with the expected occurrence of the different helicity states of the ρ in τ decay. The $\gamma\gamma$-mass spectrum in the studied final state shows no evidence of η production. An upper limit on the branching fraction B ($\tau \rightarrow \pi\eta\nu$) $\leq 4.4\%$ at the 90% confidence level is given. This limit is lower than the published branching ratio on this process.[5]

References

1. F. J. Gilman and S. H. Rhie, Phys. Rev. **D31**, (1985) 1066.
2. P. R. Burchat, Invited talk presented at the XXIII International Conference on High Energy Physics, Berkeley, July 16–23, 1986.
3. P. R. Burchat *et al.*, Phys. Rev. **D35**, (1987) 27.
4. Throughout this analysis a reference to a particle state implies reference to its charge conjugate.
5. M. Derrick et al., ANL–HEP–PR–86–106 (1987).
6. R. M. Baltrusaitis *et al.*, Phy. Rev. Lett. 55, (1985) 1842.
7. D. Bernstein *et al.*, Nucl. Inst. Methods 226, (1984) 30.
8. J. Adler *et al.*, SLAC–PUB–4205 (1987).
9. Y-S. Tsai, Phys. Rev. **D4**, (1971) 2821.
10. A more stringent limit of 2.5% on this branching fraction is given from an analysis of $\eta \rightarrow \pi\pi\pi^0$ (to be published in SLAC–PUB–4314).
11. M. Aguilar–Benitez *et al.*, Particle Data Group, Phys. Lett. **170B**, (1986).