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An Upper Limit on B($\tau \rightarrow \eta\pi\nu$)†

The MARK III Collaboration

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Abstract

Motivated by recent evidence for the decay $\tau \rightarrow \eta\pi\nu$, a search for this decay has been carried out in e^+e^- annihilation at $\sqrt{s} = 3.77$ GeV. No evidence for the decay is found; an upper limit of 2.5% at the 90% confidence level is set on the branching fraction $B(\tau \rightarrow \eta\pi\nu)$.

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Evidence for the decay $\tau \rightarrow \eta\pi\nu$ has recently been presented[1]. The existence of this decay mode would indicate the presence of second class hadronic weak currents, which cannot be accomodated in the standard model[2]. We report herein a search for this decay in the reaction[3]

$$e^+e^- \longrightarrow \tau\ \tau$$

$$\hookrightarrow (e\nu\bar{\nu}) \text{ or } (\mu\nu\bar{\nu})$$

$$\hookrightarrow \eta\pi\nu$$

$$\hookrightarrow (\gamma\gamma) \text{ or } (\pi^+\pi^-\pi^0).$$

The data, comprising a total integrated luminosity of 9.4 pb^{-1} , collected at $\sqrt{s} = 3.77\text{GeV}$, were taken with the Mark III detector at the e^+e^- storage ring SPEAR. The reconstruction and analysis of events through the $\eta \rightarrow \gamma\gamma$ channel closely follows that of our study of the decays $\tau \rightarrow \rho\nu$ [4]; details of the detector performance, track selection, and particle identification are found there. In the study using the channel $\eta \rightarrow \pi^+\pi^-\pi^0$, the acollinearity and acoplanarity cuts applied in the $\eta \rightarrow \gamma\gamma$ analysis are omitted.

A total of 939 events pass the selection criteria for two charged particles and two isolated photons. The $\gamma\gamma$ invariant mass distribution for these events is shown in Fig. 1(a). A π^0 signal is observed, but no significant structure in the η mass region is seen. The spectrum in the region above the π^0 peak is fitted to an exponentially falling background plus a Breit-Wigner function combined with a Gaussian resolution function to describe the η. The result of the fit, which has a χ^2 of 11.6 for 10 degrees of freedom, is shown as a dashed curve in Fig.1(b). The exponential background, shown as a solid curve, describes the spectrum well. The most probable value for the η signal is 1.9 events. By integrating the likelihood function (inset in Fig.1(b)) which includes effects of uncertainties in the background, we derive an upper limit of 20.7 events at the 90% confidence level (C.L.). The branching ratio limit, calculated using the efficiencies in Table I, includes the errors on efficiency, luminosity and cross sections for dilepton production from τ pairs. The total statistical and systematic errors are added linearly, yielding an error of 15%. This increases the limit on the number of η's to 23.8, resulting in an upper limit on B ($\tau \rightarrow \eta\pi\nu$) of 4.4% at the 90% C.L.

TABLE I. $\eta \rightarrow \gamma\gamma$ Analysis

Channel	$e\eta\pi$	$\mu\eta\pi$
Efficiency (%)	$3.9 \pm 0.2 \pm 0.2$	$1.6 \pm 0.13 \pm 0.1$
Upper Limit on Signal	23.8	
Upper Limit on B	4.4%	

The reconstruction of the final state arising from $\eta \rightarrow \pi^+\pi^-\pi^0$, while suffering from reduced efficiency, has lower background. This final state is studied in the four charged particle and two isolated photon topology, where one particle must be identified as a lepton and the remaining three as pions. The two photons are constrained to the π^0 mass by a one-constraint kinematic fit. Figure 2(a) shows the expected $\pi^+\pi^-\pi^0$ mass distribution which contains two combinations per event obtained from a Monte Carlo simulation of the signal. The decay $\tau \rightarrow \eta\pi\nu$ is simulated with a phase space distribution. A narrow η peak is seen above a background from wrong combinations. This background, shown as hatched entries in Fig.2(a), is determined by flagging the true η in the Monte Carlo calculation. An efficiency of $93.0 \pm 1.5\%$ is obtained by selection of combinations with a mass between 0.5 and 0.6 GeV/c^2. The combinatorial background within this interval is 9% of the total background.

In order to estimate the level of background in the data, the distribution of wrong zero-charge pion combinations ($\pi^+\pi^-\pi^0$) in the Monte Carlo simulation is compared with that of doubly-charged combinations ($\pi^\pm\pi^\pm\pi^0$). The latter is found to be a good description of the background shape, as indicated by the dashed curve in Fig. 2(a). In the data, the integral of the doubly charged $\pi^\pm\pi^\pm\pi^0$ combination spectrum is weighted by the calculated fraction of background under the η signal (9%) to obtain an estimate of background contamination in the $e\eta\pi$ and $\mu\eta\pi$ samples. The detection efficiencies and estimated backgrounds for these samples are shown in Table II. When the two channels are combined, we estimate $1.9 \pm 0.6 \pm 0.3$ background events, where the systematic errors have been added linearly.

TABLE II. $\eta \to \pi^+\pi^-\pi^0$ Analysis

Channel	$e\eta\pi$	$\mu\eta\pi$
Signal	0	0
Estimated Background	$1.3 \pm 0.5 \pm 0.2$	$0.6 \pm 0.3 \pm 0.1$
Efficiency (%)	$0.65 \pm 0.05 \pm 0.03$	$0.39 \pm 0.04 \pm 0.02$
combined upper limit on B	2.5%	

The $\pi^+\pi^-\pi^0$ mass combinations in the data from both detection channels are shown in Fig. 2(b). No events are observed in the interval from 0.5 to 0.6 GeV/c^2. Including the statistical and systematic errors increases the 2.3 event limit for our null observation, obtained using Poisson statistics, to 2.6 at the 90% C.L. The resulting upper limit on the branching fraction is

$$B(\tau \to \eta\pi\nu\ ) \leq 2.5\%.$$

In summary, we have searched for $\tau \to \eta\pi\nu$ events in τ pair production using two distinct η decay modes, and find no evidence for this decay. Both analyses provide upper limits significantly below the recently reported measurement [1] of the $\tau \to \eta\pi\nu$ branching ratio of (5.1±1.5)%.

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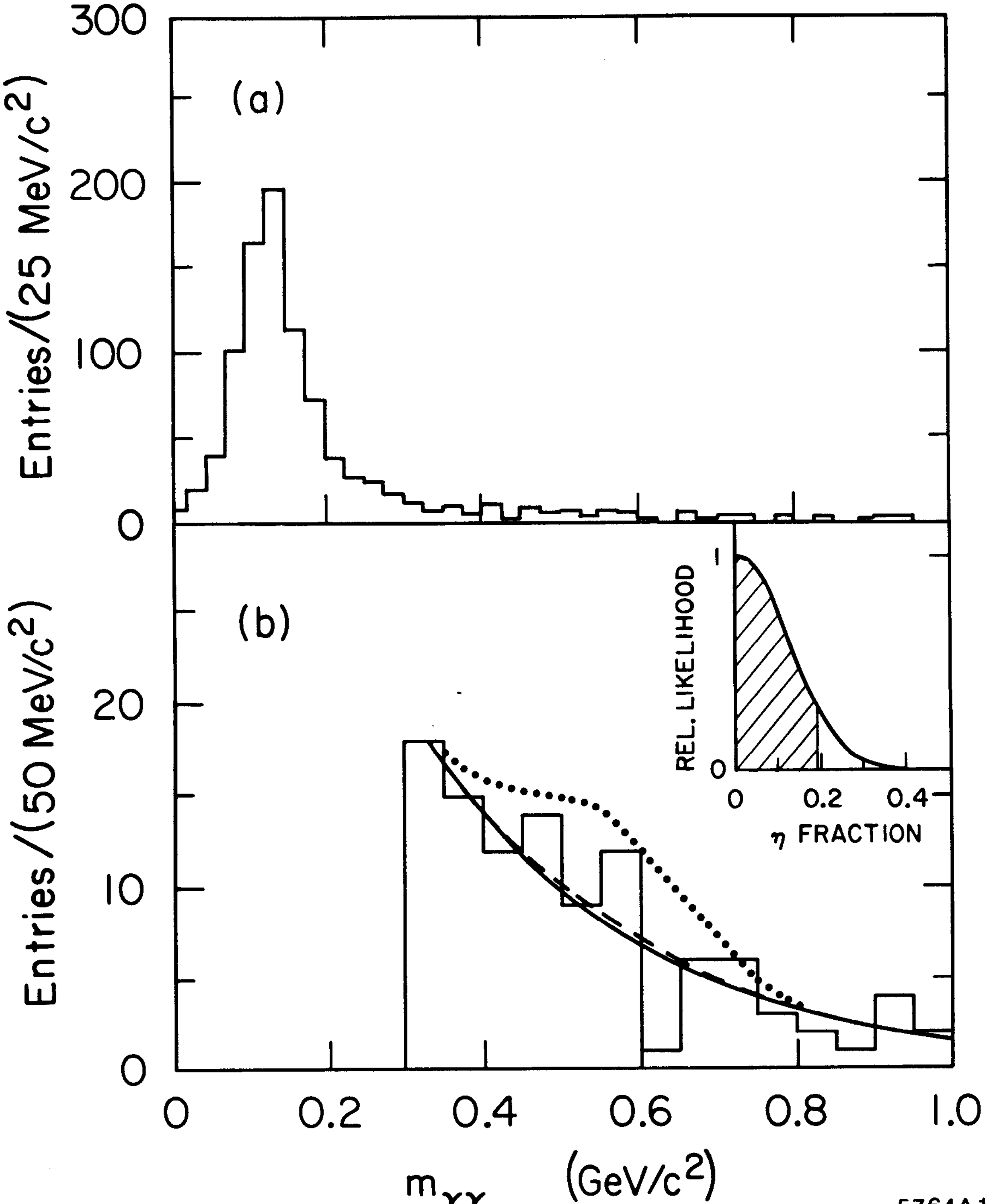
References

1. M. Derrick *et al.*, ANL-HEP-PR-86-106 (1987) (to be published in Physics Letters).
2. F. J. Gilman, SLAC-PUB-4265 (1987) (submitted to Physical Review Rapid Communications).
3. A reference to a particle state implies reference to its charge conjugate.
4. J. Adler *et al.*, SLAC-PUB-4205 (submitted to Physical Review Letters).

Figure Captions

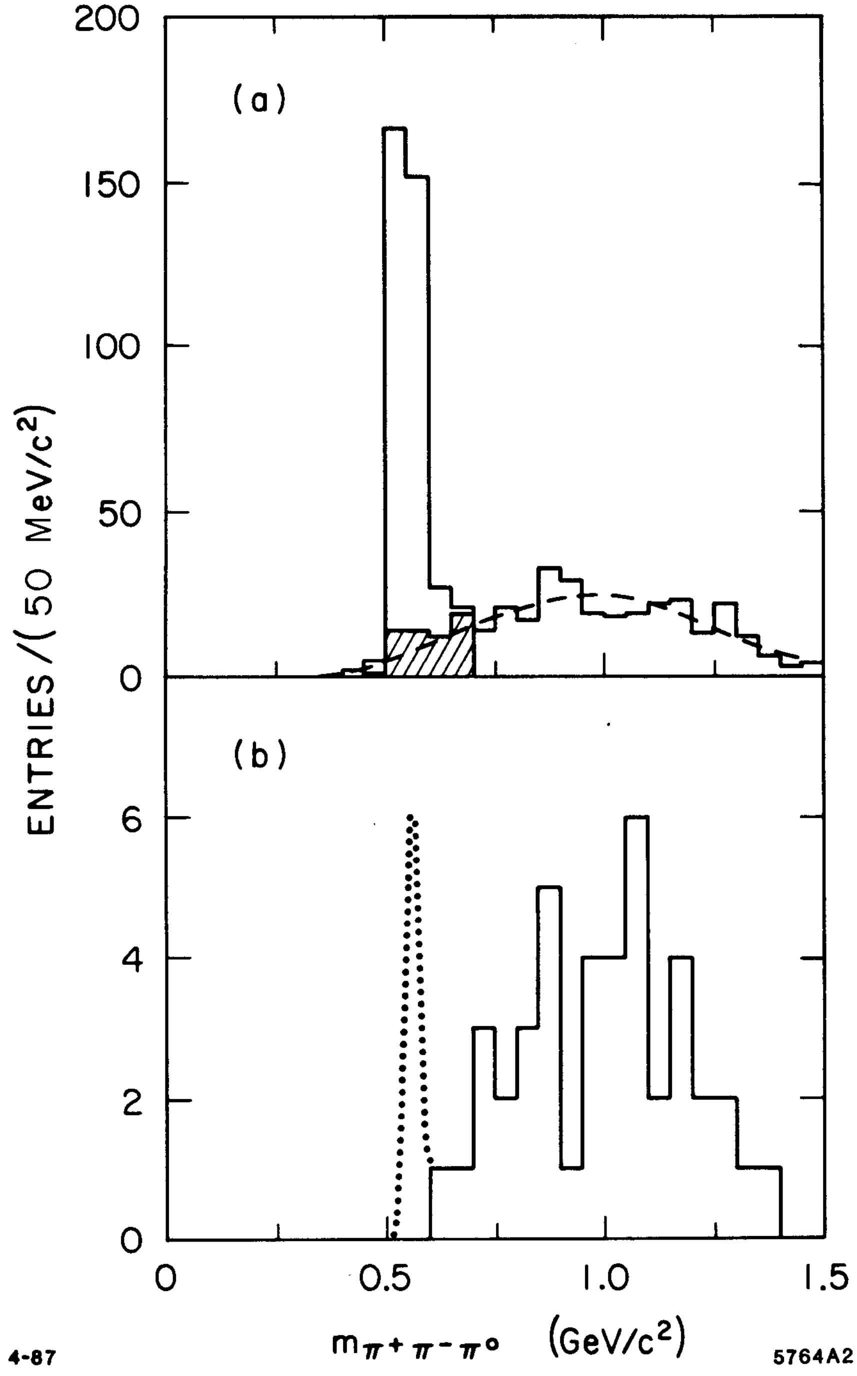
Fig. 1. $\gamma\gamma$ invariant mass distributions are shown (a) for all selected events and (b) for all selected events with $\gamma\gamma$ mass above 0.3 GeV/c^2. The curves are the results of the fit described in the text. The solid curve describes the exponentially falling background; the dashed curve includes the fitted η signal. The inset shows the truncated relative likelihood function for the fit, with the shaded part representing 90% of the area. The dotted curve shows the expected[1] η signal, corresponding to B($\tau \to \eta\pi\nu$)=5.1%, added to the exponential background.

Fig. 2. (a) $\pi^+\pi^-\pi^0$ invariant mass distributions are shown for $e\pi\pi\pi^0$ and $\mu\pi\pi\pi^0$ events from a Monte Carlo calculation. The hatched entries under the peak are combinatorial background events. The dashed curve is the background estimate using doubly charged $\pi\pi\pi^0$ combinations. (b) $\pi^+\pi^-\pi^0$ invariant mass distributions are shown for $e\pi\pi\pi^0$ and $\mu\pi\pi\pi^0$ events as observed in the data. The dotted curve shows the expected[1] η signal corresponding to B($\tau \to \eta\pi\nu$)=5.1%.



(a)
(b)
Entries/(25 MeV/c^2)
Entries/(50 MeV/c^2)
REL. LIKELIHOOD
η FRACTION
$m_{\gamma\gamma}$ (GeV/c^2)
5-87
5764A1

Fig. 1



200
150
100
50
0
(a)
(b)
6
4
2
0
ENTRIES /(50 MeV/c^2)
0
0.5
1.0
1.5
$m_{\pi^+\pi^-\pi^0}$ (GeV/c^2)
4-87
5764A2

Fig. 2