AN UPPER LIMIT ON THE TAU NEUTRINO MASS

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We use the distribution of total charged energy in three-track τ decay to place an upper limit on the mass of the τ neutrino. Including both statistical and systematic uncertainties, the 95% confidence limit is $m_\nu < 85$ MeV/c^2.

I. Introduction

Neutrino masses have assumed increasing prominence in recent years. Indeed, several of this workshop's major topics ; e.g., dark matter, the solar neutrino deficit, and double β-decay are deeply connected with the possibility of non-zero mass. Because the τ lepton at 1784 Mev/c^2 is the most massive charged lepton, one might expect its neutral partner, ν_τ , to be the most massive neutrino. In fact, in the class of theories (see-saw mechanism) where the neutrino mass scales as the *square* of the charged-lepton mass[1) , an electron-neutrino mass of 20 eV would imply a ν_τ mass of **125** MeV/c^2.

Several earlier experiments have presented limits on m_ν[2-5); here I report results based on a large sample of $\tau+\tau-$ events collected at the Cornell Electron Storage Ring (CESR), using the CLEO detector.[6) The data sample, acquired during 1982-1984, has been used in CLEO's recent determination of the Michel parameter[7) in τ decay. Both that work and an earlier one[8) use the characteristic 1-vs.-3 ττ topology (see fig. 1) and discuss details of the event selection criteria. Because of space limitations, these will only be sketched herein.

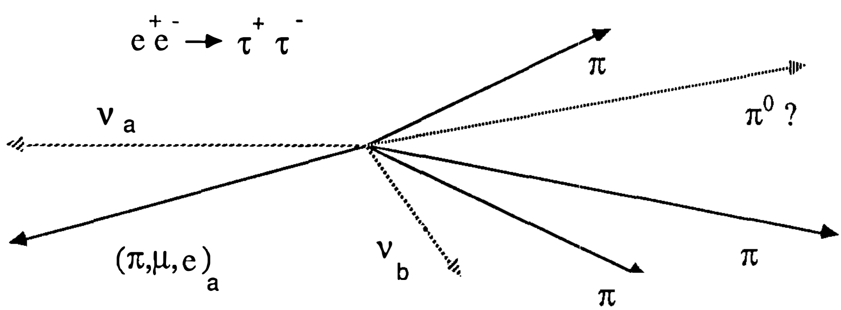

Figure 1 . *1-vs.-3 topology for ττ events .*

II. Characteristics of the sample

An integrated luminosity of 128.3 pb^{-1} , accumulated over a range of center-of-mass energy $10.34<W<11.18$ GeV, yielded 9135 ττ events of the correct topology which passed the above-mentioned criteria , which are designed to reject QED and hadronic backgrounds. No attempt was made to reject events with one or more photons/π^0's. This minimized the dependence upon CLEO's shower detector, which has c.a. 50% solid angle coverage and only modest resolution. Our primary experimental tools were the 1.0 Tesla solenoid and the CLEO drift chamber, which with >90% solid angle and $\Delta P/P=1.2\%*P(GeV/c)$, provided high efficiency tracking and good resolution in the total energy and invariant mass of the 3-track decay. A higher-purity subsample with an identified lepton (e or μ) as the single track was available to allow crosschecks and internal determination of the background fraction and 3-track invariant mass distribution (See Fig.2)

III. Method of analysis and Monte Carlo simulation

The "neutral energy" $E_n = E_{bm} - E_{3\pi}$ is computed for each 3-track decay, where E_{bm} is the beam energy and $E_{3\pi}$ is the sum of the 3-track energies, assuming the tracks to be pions. The E_n spectrum is nearly independent of the particular beam energy. It does depend on the masses of the missing neutrino and of the hadronic system. The low E_n endpoint (the edge of phase space) varies directly with m_ν; for somewhat larger E_n the spectral shape depends on a higher power of m_ν. For very large E_n the spectrum is featureless and more affected by missing pions than by m_ν.

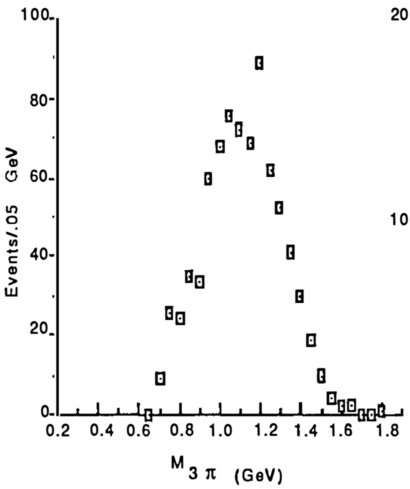

Figure 2. *Invariant mass distribution for lepton-tagged events with all particles treated as pions.*

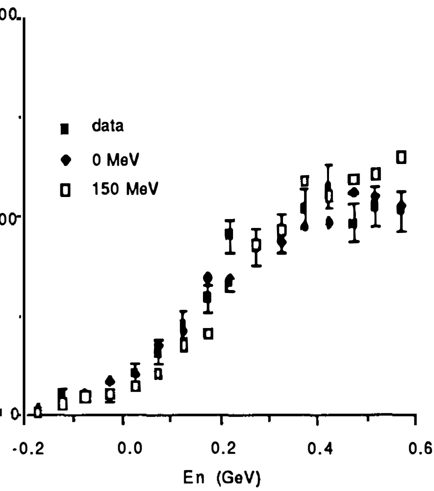

Figure 3. *E_n spectra for data and for two values of m_ν: 0 (diamonds) and 150 (closed squares).*

The E_n spectrum from the data is compared to Monte Carlo simulations in which m_ν is assigned the values 0, 25, 50, 100, and 150 MeV/c^2. These simulations include realistic branching fractions into ρ's, A_1; etc., initial state radiation down to 5 MeV, and a 22% hadronic background, determined from the relative R values and trigger efficiencies. Various distributions (decay angle, invariant mass) are checked for conformity to the data. The events are weighted so as to yield

3-track invariant mass spectra which are constrained to agree with that derived from the lepton-tagged subsample (Fig. 2). In the comparisons, the "theoretical" distributions are normalized to the total data in the fitted region. Figure 3 shows the two cases of m_ν =0, 150 MeV/c^2 compared to the data, for the range E_n<0.6 GeV/c^2.

IV. Results

The data are fitted for four ranges of E_n. For each case χ^2 is plotted versus m_ν and the minimum is found from a parabolic fit. The statistical error in m_ν is found from the curvature of the parabola in the usual way. Averaging these results gives $m_\nu = 31 \pm 25$ MeV/c^2(statistical). Dominant systematic errors are indicated as follows: 1) variation with fitted region (over and above that expected from statistics), ± 15 MeV/c^2, 2) absolute momentum scale, ±8 MeV/c^2, 3) π^0 fraction, ± 7 MeV/c^2, 4) errors in hadronic mass distribution, ± 5 MeV/c^2. Combining errors in quadrature yields $m_\nu=(31\pm25_{stat}\pm20_{sys})$ MeV/c^2. Following the Particle Data Group procedures, we extract a 95% confidence limit $m_\nu <$ **85 MeV/c^2**. This value is of comparable sensitivity and in agreement with other recent measurements of m_ν.

V. References

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