Determination of an upper limit for the mass of the $\tau$–neutrino at LEP

OPAL Collaboration


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Abstract. An upper limit for the $\nu_\tau$ mass is determined through the kinematic reconstruction of the decay $\tau \rightarrow 5\pi^\pm \nu_\tau$ in the OPAL detector at LEP. The limit is obtained using a new method based on the comparison of the two-dimensional distribution of energy and invariant mass of the five-pion system with expectations from different neutrino mass hypotheses. From a sample of five events surviving the selection criteria we obtain an upper limit of 74 MeV at 95% confidence level. It is the first measurement at LEP energies, where the larger average multiplicity of $e^+e^- \rightarrow q\bar{q}$ events makes the suppression of this background more robust compared to lower energies.

1 Introduction

Massive neutrinos have been proposed as possible explanations for a variety of outstanding problems in particle physics and astrophysics, including the 'dark matter' problem of the universe, the solar neutrino problem, and in various extensions of the Standard Model of electroweak interactions.

Existing upper limits on the $\nu_\tau$ mass have been derived from studies of the invariant mass spectra of high mass multi-pion decays of the $\tau$ lepton. At present the best limits are 31 MeV at 95% confidence level (c.l.) obtained by the ARGUS collaboration [1] from studies of the $\tau \rightarrow 5\pi^\pm \nu_\tau$ decay and 32.6 MeV at 95% c.l. by the CLEO collaboration [2] using a combined analysis of the $\tau \rightarrow 5\pi^\pm \nu_\tau$ and $\tau \rightarrow 3\pi^\pm 2\pi^0 \nu_\tau$ decays. Although the kinematics of $\tau$ decay mean that measurements of the $\nu_\tau$ mass are well performed at low energies, near the $\tau$ pair production threshold, the measurements at high energy possible at LEP have the advantage that their background conditions are different: in particular the background from multi-hadron events ($e^+e^- \rightarrow q\bar{q}$) is much smaller. This is due to the fact that the multiplicity of charged tracks and their topology allow a cleaner separation between the signal $\tau$-pair events and the background from multi-hadron events. The multiplicity of $e^+e^- \rightarrow q\bar{q}$ events scales logarithmically with the center of mass energy whereas the multiplicity of $\tau$ decays remains constant.

We present in this paper the first determination of an upper limit for $m_{\nu_\tau}$ from LEP data which, for the reasons given above, we consider as an important independent measurement compared to earlier results [1] [2] obtained at lower energies. We also employ here, for the first time, a two-dimensional method [3] using the invariant mass and total energy of the charged hadrons of the decay $\tau \rightarrow 5\pi^\pm \nu_\tau$. In a simple form the method is represented by the two inequalities

$$m_{\nu_\tau} \leq m_\tau - m_X,$$

$$m_{\nu_\tau} \leq E_\tau - E_X,$$

where $E_X$ is the energy of the charged hadrons and $m_X$ their invariant mass. The kinematically allowed region in the $m - E$ space for $\tau$ decays is shown in Fig. 1 for two different $\nu_\tau$ masses. Better discrimination between the different $m_{\nu_\tau}$ hypotheses is achieved by exploiting the distribution of invariant mass and energy of the $\tau$ decay rather than just using the one-dimensional missing mass method which integrates over the energy dependence. From Fig. 1 it is evident that the limit on the neutrino mass is dominated by the events in the kinematically sensitive region close to $E_\tau$ and $m_\tau$. Events far from the boundary show no sensitivity to $m_{\nu_\tau}$. Further details of the analysis can be found in [4].

The analysis presented here is based on data taken with the OPAL detector during 1992. The total integrated luminosity amounts to 24.5 pb$^{-1}$ which gives an expected sample of about 36 000 $\tau^-\tau^+$ events. Because the silicon microvertex detector installed in summer 1991 plays an important role in the analysis, data taken prior to 1992 were not used. A detailed description of the OPAL detector can be found elsewhere [5]. We present here the characteristics relevant for this analysis. The 1992 silicon microvertex detector [6] consists of two layers of single-sided silicon strip detectors with 11 inner sectors located at a radius of 61 mm.