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A SEARCH FOR LEPTON FLAVOR VIOLATION IN TAU DECAYS AT *BaBar*

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We present a recent *BABAR* search for lepton flavor violation in tau decays. The search for $\tau \to \ell\ell\ell$ ($\ell = e, \mu$) decays is based on a data sample of 91.6 fb^{-1}. No signal is found in any of six channels and 90% CL upper limits are set in the range of $(1-3) \times 10^{-7}$. The search for $\tau \to \mu\gamma$ decay is done with a 63 fb^{-1} data sample. The number of observed events is consistent with expected background level and a preliminary upper limit is set at 2×10^{-6} at 90% CL.

Keywords: Tau decays; lepton flavor violation

Lepton flavor violation (LFV) involving charged leptons is not yet observed in experiment[1]. In the Standard Model (SM) such decays are allowed if one includes neutrino mixing, however the expected branching fraction is very low: 10^{-40} for $\tau \to \ell\gamma$[a] and 10^{-14} for $\tau \to \ell\ell\ell$ [2]. On the other hand, many extensions to the SM predict branching fractions up to $10^{-10} - 10^{-7}$ in tau LFV decays[3].

The *BABAR* experiment[4] provides an excellent base to search for LFV tau decays. The accumulated sample of more than 160 million tau decays and sophisticated detector allow to probe LFV decay up to 10^{-7} order with prospects to improve the sensitivity range as the integrated luminosity increases. In this paper we review the recent *BABAR* search of tau decays to $e^-e^+e^-$, $\mu^-e^+e^-$, $\mu^+e^-e^-$, $e^-\mu^+\mu^-$, $e^+\mu^-\mu^-$, $\mu^-\mu^+\mu^-$ [5] and preliminary search of $\tau \to \mu\gamma$.

To identify events with $\tau \to \ell\ell\ell$ decays, the 1-3 topology characteristic for $\tau\tau$ events is used. For that four tracks with net zero charge pointing towards a common region are required, with one track separated from the others by at least 90° in the center-of-mass frame (CM). All tracks on the 3-prong side must be identified as a lepton, muon or electron, with invariant mass (m_{rec}) close to the mass of tau $m_\tau = 1.777$ GeV/c^2 and a measured energy in the CM (E^{CM}_{rec}) equal to $\sqrt{s}/2$. The 6 modes under consideration are contaminated by QED (Bhabha and di-muon), generic $\tau\tau$ and $q\bar{q}$ events. The cuts to suppress these backgrounds consist of a veto on the 1-prong lepton identification, a cut on the momentum of the 1-prong charged particle, on the angle between 1- and 3-prong momenta and cuts on the number of photon and Kaon candidates on the 3-prong side as detailed in Ref. 5. The selection

[a]Through the text, the symbol ℓ denotes an electron or muon.

efficiency for signal events (ε) depends on the decay mode and varies from 7 to 12% as shown in Table 1.

Table 1. Efficiency estimates, number of expected background events ($N_{\rm bgd}$), number of observed events ($N_{\rm obs}$), and branching fraction upper limits for each decay mode.

Decay mode	$e^-e^+e^-$	$\mu^+e^-e^-$	$\mu^-e^+e^-$	$e^+\mu^-\mu^-$	$e^-\mu^+\mu^-$	$\mu^-\mu^+\mu^-$
ε [%]	7.3 ± 0.2	11.6 ± 0.4	7.7 ± 0.3	9.8 ± 0.5	6.8 ± 0.4	6.7 ± 0.5
$N_{\rm bgd}$	1.51 ± 0.11	0.37 ± 0.08	0.62 ± 0.10	0.21 ± 0.07	0.39 ± 0.08	0.31 ± 0.09
$N_{\rm obs}$	1	0	1	0	1	0
$\mathcal{B}^{90}_{\rm UL}$	2.0×10^{-7}	1.1×10^{-7}	2.7×10^{-7}	1.3×10^{-7}	3.3×10^{-7}	1.9×10^{-7}

The selected events are studied using $\Delta M = m_{rec} - m_\tau$ and $\Delta E = E^{CM}_{rec} - E^{CM}_{beam}$ variables. The backgrounds remaining after selection have distinctive distribution in the (ΔM,ΔE) plane: $q\bar{q}$ tend to populate the plane uniformly, while QED backgrounds are restricted to a narrow band at positive values of ΔE, and $\tau\tau$ are restricted to negative values of both ΔM and ΔE. A negligible two-photon background remains. The background rates for each decay mode are estimated by fitting a set of probability density functions (*PDFs*) to the observed data in (ΔM, ΔE) in the region surrounding a signal region (*SB*) indicated with a box in Fig. 1. The parameters of the PDFs are determined from MC and data control samples. The expected number of background events in the SB is calculated from the PDFs and is compared with observed number of events (see Table. 1).

No signal is observed in any decay mode (see Fig. 1). An upper limit on branching fractions ($\mathcal{B}^{90}_{UL}$) is estimated as: $\mathcal{B}^{90}_{UL} = N^{90}_{UL}/(2\varepsilon N_{\tau\tau})$, where N^{90}_{UL}, $N_{\tau\tau}$ are the 90% confidence upper limit for the number of signal events for the given mode and the number of $\tau\tau$ pairs, respectively. $N_{\tau\tau} = 81 \times 10^6$. The N^{90}_{UL} is calculated using Counsins, Highland method[6] which includes the estimated systematic uncertainties on the signal efficiency (3-7%), on the expected background (8-33%) and on the $N_{\tau\tau}$ (2.4%).

For the $\tau \to \mu\gamma$ search, events with a 1-1 topology are selected, with an electron or a rho meson identified on the tag side. The signal side track must be identified as a muon and there should be only one photon candidate. The photon energy is required to be larger than 400 MeV in CM. The invariant mass $m^{'}_{rec}$ and the measured CM energy $E^{'CM}_{rec}$ of the muon and photon pair should be close to m_τ and $\sqrt{s}/2$, respectively. The backgrounds are suppressed with cuts on missing momentum, missing mass and total transverse momentum in the event. The remaining backgrounds are $e^+e^- \to \mu^+\mu^-\gamma$ and $\tau \to \mu\bar{\nu}_\mu\nu_\tau\gamma$ decays. The background in the signal region is estimated from the linear extrapolation of the sidebands of the m'_{rec} distribution in the -176 MeV $< \Delta E' <$ 264 MeV band. The asymmetrical elliptical signal region is chosen and geometrical correction is applied to the background estimation.

The signal efficiency of the selection is 5.2 ± 0.5% and the estimated background

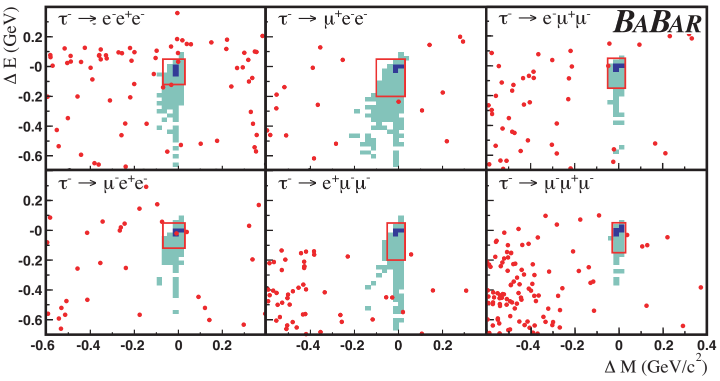

Fig. 1. Observed data shown as dots in the $(\Delta M, \Delta E)$ plane and the boundaries of the signal region for each decay mode. The dark and light shading indicates contours containing 50% and 90% of the selected MC signal events, respectively.

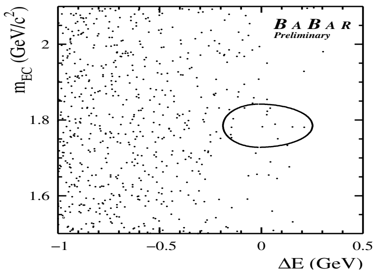

Fig. 2. Data distribution of m'_{rec} versus $\Delta E'^{CM}_{rec}$ for $\tau \to \mu\gamma$ search. The signal region is indicated with solid line.

level is 7.8 ± 1.4. The number of observed events in the signal region is 13 out of sample of 56 million tau pairs (see Fig. 2), which is compatible with no signal hypothesis. The branching fraction of $\tau \to \mu\gamma$ decay is found to be $\mathcal{B}(\tau \to \mu\gamma) < 2.0 \times 10^{-6}$ at 90% CL.

The *BABAR* experiment has performed a search for the LFV tau decays $\tau \to \ell\ell\ell$ ($\ell = e, \mu$) and $\tau \to \mu\gamma$. No signal is found in any of 7 channels and upper limits on branching fractions are set at 90% CL to $1 - 3 \times 10^{-7}$ for $\tau \to \ell\ell\ell$ and 2.0×10^{-6} for $\tau \to \mu\gamma$.

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