Search for the Lepton-Flavor-Violating Leptonic $B^0 \to \mu^\pm \tau^\mp$ and $B^0 \to e^\pm \tau^\mp$

A. Bornheim,[1] E. Lipeles,[1] S. P. Pappas,[1] A. J. Weinstein,[1] R. A. Briere,[2] G. P. Chen,[2] T. Ferguson,[2] G. Tatishvili,[2] H. Vogel,[2] M. E. Watkins,[2] N. E. Adam,[3] J. P. Alexander,[3] K. Berkelman,[3] D. G. Cassel,[3] J. E. Duboscq,[3] K. M. Ecklund,[3] R. Ehrlich,[3] L. Fields,[3] R. S. Galik,[3] L. Gibbons,[3] B. Gittelman,[3] R. Gray,[3] S. W. Gray,[3] D. L. Hartill,[3] B. K. Heltsley,[3] D. Hertz,[3] L. Hsu,[3] C. D. Jones,[3] J. Kandaswamy,[3] D. L. Kreinick,[3] V. E. Kuznetsov,[3] H. Mahlke-Krüger,[3] T. O. Meyer,[3] P. U. E. Onyisi,[3] J. R. Patterson,[3] D. Peterson,[3] J. Pivarski,[3] D. Riley,[3] J. L. Rosner,[3,*] A. Ryd,[3] A. J. Sadoff,[3] H. Schwarthoff,[3] M. R. Shepherd,[3] W. M. Sun,[3] J. G. Thayer,[3] D. Urner,[3] T. Wilksen,[3] M. Weinberger,[3] S. B. Athar,[4] P. Avery,[4] L. Breva-Newell,[4] R. Patel,[4] V. Potlia,[4] H. Stoeck,[4] J. Yelton,[4] P. Rubin,[5] C. Cawlfield,[6] B. I. Eisenstein,[6] G. D. Gollin,[6] I. Karliner,[6] D. Kim,[6] N. Lowrey,[6] P. Naik,[6] C. Sedlack,[6] M. Selen,[6] J. J. Thaler,[6] J. Williams,[6] J. Wiss,[6] K. W. Edwards,[7] D. Besson,[8] K. Y. Gao,[9] D. T. Gong,[9] Y. Kubota,[9] S. Z. Li,[9] R. Poling,[9] A. W. Scott,[9] A. Smith,[9] C. J. Stepaniak,[9] J. Urheim,[9] Z. Metreveli,[10] K. K. Seth,[10] A. Tomaradze,[10] P. Zweber,[10] J. Ernst,[11] K. Arms,[12] K. K. Gan,[12] H. Severini,[13] P. Skubic,[13] D. M. Asner,[14] S. A. Dytman,[14] S. Mehrabyan,[14] J. A. Mueller,[14] V. Savinov,[14] Z. Li,[15] A. Lopez,[15] H. Mendez,[15] J. Ramirez,[15] G. S. Huang,[16] D. H. Miller,[16] V. Pavlunin,[16] B. Sanghi,[16] E. I. Shibata,[16] I. P. J. Shipsey,[16] G. S. Adams,[17] M. Chasse,[17] J. P. Cummings,[17] I. Danko,[17] J. Napolitano,[17] D. Cronin-Hennessy,[18] C. S. Park,[18] W. Park,[18] J. B. Thayer,[18] E. H. Thorndike,[18] T. E. Coan,[19] Y. S. Gao,[19] F. Liu,[19] R. Stroynowski,[19] M. Artuso,[20] C. Boulahouache,[20] S. Blusk,[20] J. Butt,[20] E. Dambasuren,[20] O. Dorjkhaidav,[20] N. Menaa,[20] R. Mountain,[20] H. Muramatsu,[20] R. Nandakumar,[20] R. Redjimi,[20] R. Sia,[20] T. Skwarnicki,[20] S. Stone,[20] J. C. Wang,[20] K. Zhang,[20] A. H. Mahmood,[21] S. E. Csorna,[22] G. Bonvicini,[23] D. Cinabro,[23] and M. Dubrovin[23]

(CLEO Collaboration)

[1]*California Institute of Technology, Pasadena, California 91125, USA*
[2]*Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA*
[3]*Cornell University, Ithaca, New York 14853, USA*
[4]*University of Florida, Gainesville, Florida 32611, USA*
[5]*George Mason University, Fairfax, Virginia 22030, USA*
[6]*University of Illinois, Urbana-Champaign, Illinois 61801, USA*
[7]*Carleton University, Ottawa, Ontario, Canada K1S 5B6 and the Institute of Particle Physics, Canada*
[8]*University of Kansas, Lawrence, Kansas 66045, USA*
[9]*University of Minnesota, Minneapolis, Minnesota 55455, USA*
[10]*Northwestern University, Evanston, Illinois 60208, USA*
[11]*State University of New York at Albany, Albany, New York 12222, USA*
[12]*Ohio State University, Columbus, Ohio 43210, USA*
[13]*University of Oklahoma, Norman, Oklahoma 73019, USA*
[14]*University of Pittsburgh, Pittsburgh, Pennsylvania 15260, USA*
[15]*University of Puerto Rico, Mayaguez, Puerto Rico 00681*
[16]*Purdue University, West Lafayette, Indiana 47907, USA*
[17]*Rensselaer Polytechnic Institute, Troy, New York 12180, USA*
[18]*University of Rochester, Rochester, New York 14627, USA*
[19]*Southern Methodist University, Dallas, Texas 75275, USA*
[20]*Syracuse University, Syracuse, New York 13244, USA*
[21]*University of Texas-Pan American, Edinburg, Texas 78539, USA*
[22]*Vanderbilt University, Nashville, Tennessee 37235, USA*
[23]*Wayne State University, Detroit, Michigan 48202, USA*
(Received 6 August 2004; published 8 December 2004)

We have searched a sample of 9.6×10^6 $B\bar{B}$ events for the lepton-flavor-violating leptonic B decays, $B^0 \to \mu^\pm \tau^\mp$ and $B^0 \to e^\pm \tau^\mp$. The τ lepton was detected through the decay modes $\tau \to \ell \nu \bar{\nu}$, where $\ell = e, \mu$. There is no indication of a signal, and we obtain the 90% confidence level upper limits $\mathcal{B}(B^0 \to \mu^\pm \tau^\mp) < 3.8 \times 10^{-5}$ and $\mathcal{B}(B^0 \to e^\pm \tau^\mp) < 1.3 \times 10^{-4}$.

DOI: 10.1103/PhysRevLett.93.241802 PACS numbers: 13.20.He, 11.30.Hv, 14.40.Nd

We report results of a search for two lepton-flavor-violating leptonic decays of B mesons: $B^0 \to \mu^\pm\tau^\mp$ and $B^0 \to e^\pm\tau^\mp$. These modes are forbidden in the conventional standard model by the lepton-flavor conservation law. However, they are predicted to occur in many theories "beyond the standard model", for example, multi-Higgs-boson extensions, theories with leptoquarks, supersymmetric models without R parity, and Higgs-mediated decay in supersymmetric seesaw models [1]. The recent discovery of neutrino oscillation, while not leading to predictions of observable rates for lepton-flavor-violating decays, nonetheless heightens interest in them [2]. The decays we searched for involve both third generation quarks and third generation leptons. Decays of this variety have been less extensively searched for than those involving only first or second generation quarks or leptons. Discovery of such decays at levels of our sensitivity would be clear evidence of physics beyond the standard model. Currently the best limits on the branching fractions are $\mathcal{B}(B^0 \to \mu^\pm\tau^\mp) < 8.3 \times 10^{-4}$, and $\mathcal{B}(B^0 \to e^\pm\tau^\mp) < 5.3 \times 10^{-4}$, at 90% confidence level [3].

The data used in this analysis were taken with the CLEO detector [4] at the Cornell Electron Storage Ring (CESR), a symmetric e^+e^- collider operating in the $\Upsilon(4S)$ resonance region. The data sample consists of 9.2 fb^{-1} at the resonance, corresponding to 9.6×10^6 $B\bar{B}$ events, and 4.5 fb^{-1} at a c.m. energy 60 MeV below the resonance. The sample below the resonance provides information on the background from continuum processes $e^+e^- \to q\bar{q}, q = u, d, s, c$, and from two-photon fusion processes $e^+e^- \to e^+e^-\gamma^*\gamma^*, \gamma^*\gamma^* \to X$ (γ^* a virtual photon). We scale the off-resonance yields by 1.99, the luminosity ratio divided by the c.m. energy-squared ratio, and subtract them from on-resonance yields to obtain $B\bar{B}$ yields.

Summing over $\mu(e)^+\tau^-$ and $\mu(e)^-\tau^+$, we search for $B^0 \to \mu(e)^\pm\tau^\mp$ with the τ lepton detected via the $\tau \to e\nu\bar{\nu}$ and $\tau \to \mu\nu\bar{\nu}$ decay modes. In this Letter, ℓ denotes the primary lepton from the signal B and ℓ' denotes the secondary lepton from τ. (ℓ, ℓ') denotes $B^0 \to \ell^\pm\tau^\mp, \tau \to \ell'\nu\bar{\nu}$. We have four modes to analyze; (μ, e), (μ, μ), (e, e), and (e, μ).

Muons are identified by their ability to penetrate the iron return yoke of the magnet: at least five (three) interaction lengths of material for the primary (secondary) muon. Electrons are identified by shower energy to momentum ratio (E/P), track-cluster matching, dE/dx, and shower shape. Cross contamination—e's identified as μ's, μ's identified as e's—is negligible, both as applied to signal and to background.

In the rest frame of the signal B, the primary lepton is monoenergetic, with momentum 2.34 GeV/c. In the lab frame (the $\Upsilon(4S)$ rest frame), this is smeared, and ranges from 2.2 to 2.5 GeV/c. We require that the primary lepton candidate have momentum in that range. We require that the secondary lepton, from τ, be greater than 0.6(1.0) GeV/c for e (μ). We "measure" the 4-momentum of the neutrino pair as the missing visible 4-momentum in the event : $E_{\nu\bar{\nu}} = 2E_{\text{beam}} - \Sigma E_i$, $\vec{P}_{\nu\bar{\nu}} = -\Sigma\vec{P}_i$, where sums are overall observed (charged and neutral) particles.

We define two neural net variables. $\text{NN}_{B\bar{B}}$ is a neural net variable used to suppress backgrounds from $B\bar{B}$ decays. We calculate three inputs: beam-constrained mass $\sqrt{E_{\text{beam}}^2 - P_{\text{cand}}^2}$, $\Delta E \equiv E_{\text{cand}} - E_{\text{beam}}$, where P_{cand} (E_{cand}) is the momentum (energy) of the B candidate, and $\cos\theta_{\ell B}$ (the cosine of the angle between the momenta of primary lepton and B candidate). We feed them into a neural net and train it with signal and $B\bar{B}$ Monte Carlo simulations for each mode. NN_{cont} is a neural net variable to suppress backgrounds from continuum. We calculate five inputs: R_2 (the ratio of the second and zeroth Fox-Wolfram moments [5] of the event), S (the sphericity), thrust of the event, $\cos\theta_{tt}$ (the cosine of the angle between the $\vec{p}_\ell - \vec{p}_{\ell'}$ and the thrust axis of the rest of the event), and $\cos\theta_{\vec{p}_{\nu\bar{\nu}},\vec{p}_\ell+\vec{p}_{\ell'}}$ (the cosine of the angle between the momenta of neutrino pair and lepton pair), then feed them into a neural net and train it with signal and continuum Monte Carlo simulations for each mode. The nominal neural net range is from 0.0 to 1.0. We cut in the 2D space defined by $\text{NN}_{B\bar{B}}$ and NN_{cont}, requiring $\text{NN}_{B\bar{B}} > \text{NN}^{\text{cut}}{}_{B\bar{B}}$, $\text{NN}_{\text{cont}} > \text{NN}_{\text{cont}}^{\text{cut}}$ and also

$$\frac{(\text{NN}_{B\bar{B}} - \text{NN}^{\text{cut}}{}_{B\bar{B}})}{(1 - \text{NN}^{\text{cut}}{}_{B\bar{B}})} + \frac{(\text{NN}_{\text{cont}} - 1)}{(1 - NN_{\text{cont}}^{\text{cut}})} > 0.$$

We define two τ-mass variables. The first is the conventionally defined invariant mass of the reconstructed τ, $M_{\ell'\nu\bar{\nu}} \equiv \sqrt{(E_{\ell'} + E_{\nu\bar{\nu}})^2 - (\vec{p}_{\ell'} + \vec{p}_{\nu\bar{\nu}})^2}$. The second τ-mass variable makes use of the fact that, with perfect measurements of all quantities, $\Delta E = 0$, and hence we can use $E_{\text{beam}} - E_\ell - E_{\ell'}$ for $E_{\nu\bar{\nu}}$, yielding $M_{\ell'\nu\bar{\nu},\Delta E=0} \equiv \sqrt{(E_{\text{beam}} - E_\ell)^2 - (\vec{p}_{\ell'} + \vec{p}_{\nu\bar{\nu}})^2}$. We further define $\Delta M_\tau \equiv M_{\ell'\nu\bar{\nu}} - M_\tau$ and $\Delta M_{\tau,\Delta E=0} \equiv M_{\ell'\nu\bar{\nu},\Delta E=0} - M_\tau$, where M_τ is the nominal τ mass, 1777 MeV.

By examining the angular distribution of electrons, positrons, and missing momentum, in off-resonance data in a $|\vec{p}_\ell|$ sideband region ($2.0 < |\vec{p}_\ell| < 2.2$ GeV/c and $2.5 < |\vec{p}_\ell| < 2.7$ GeV/c), we see clear evidence of the two-photon-fusion process. There are sharp peaks in the forward directions for electrons and positrons ("forward" being the direction of the beam particle of the same charge). Also, the missing momentum peaks sharply in the opposite direction from a detected e^+ or e^-, indicating an e^- or e^+ lost down the beam pipe. By eliminating events with $|\cos\theta_{\text{miss}}| > 0.90$ [0.95 for (μ, μ)], we considerably reduce this background.

We compare Monte Carlo samples with data using the $|\vec{p}_\ell|$ sideband region defined above. In Fig. 1, we show distributions in NN_{cont}, $\text{NN}_{B\bar{B}}$, ΔM_τ, and $\Delta M_{\tau,\Delta E=0}$, for

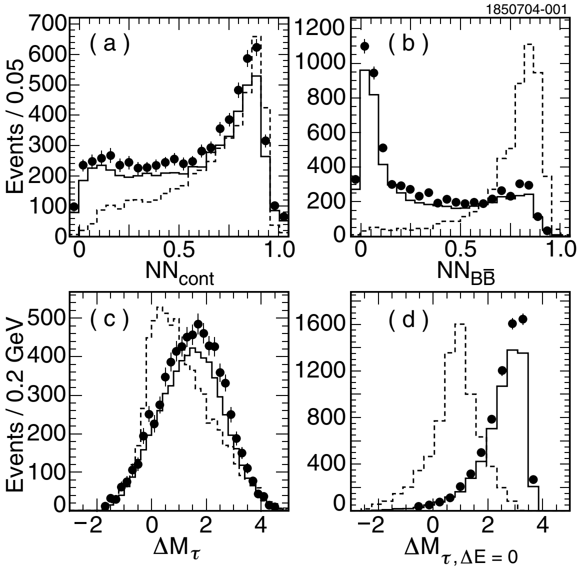

FIG. 1. (a) $\mathrm{NN_{cont}}$, (b) $\mathrm{NN}_{B\bar{B}}$, (c) ΔM_τ, and (d) $\Delta M_{\tau,\Delta E=0}$ distributions, for the comparison of $B\bar{B}$ Monte Carlo calculations (solid line) vs off-resonance-subtracted on-resonance data (points) in the $\vec{p}_\ell$ sideband region, for the (μ, e) mode. The distributions of signal Monte Carlo calculations are also displayed with a dashed line.

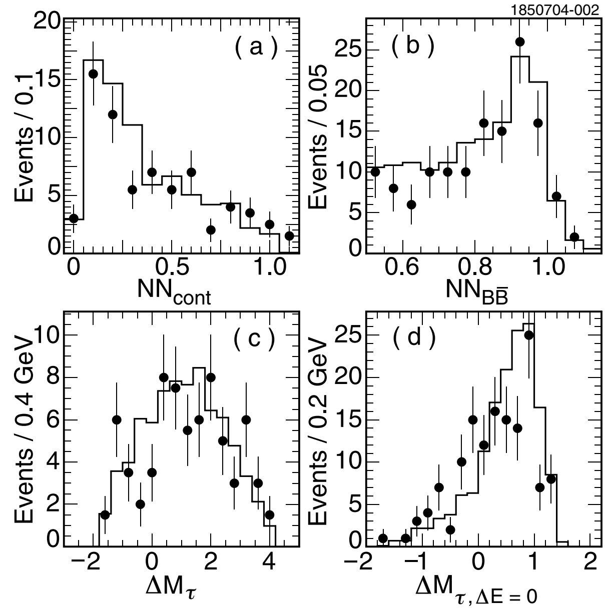

FIG. 2. (a) $\mathrm{NN_{cont}}$, (b) $\mathrm{NN}_{B\bar{B}}$, (c) ΔM_τ, and (d) $\Delta M_{\tau,\Delta E=0}$ distributions, for the comparison of continuum Monte Carlo ($e^+e^- \to q\bar{q}, q = u, d, s, c$: histogram) calculations vs off-vresonance data (points) in the $\vec{p}_\ell$ sideband region, for the (μ, e) mode.

off-resonance-subtracted on-resonance data and absolutely normalized $B\bar{B}$ Monte Carlo calculations. Agreement is good. In Fig. 2, we show distributions for the same variables for off-resonance data and absolutely normalized continuum ($e^+e^- \to q\bar{q}, q = u, d, s, c$) Monte Carlo calculations. We have *not* included a Monte Carlo calculation for the inclusive multihadronic two-photon-fusion process, lacking a trustworthy simulation of this process. For (μ, e), shown in Fig. 2, agreement is good, indicating that the remaining contribution from two-photon fusion is small. For (e, e), not shown, data exceeds continuum Monte Carlo calculations, indicating a sizeable remaining contribution from two-photon fusion. The distributions for the (e, e) off resonance, sideband data agree reasonably well in shape with the continuum Monte Carlo distributions, for all variables except $\mathrm{NN_{cont}}$.

We measure the ratio of data to Monte Carlo yields in the $|\vec{p}_\ell|$ sideband region, denoting by $\mathcal{R}_{B\bar{B}}$ the ratio of off-resonance-subtracted on-resonance data to $B\bar{B}$ Monte Carlo calculations, and by $\mathcal{R}_{\mathrm{cont}}$ the ratio of off-resonance data to continuum Monte Carlo calculations. $\mathcal{R}$'s are measured with loose selection criteria applied: $\mathrm{NN_{cont}} > 0.5$, $\mathrm{NN}_{B\bar{B}} > 0.5$, $|\cos\theta_{\mathrm{miss}}| < 0.9$ (0.95 for [μ, μ)], and $|\Delta M_\tau| < 2.0$ GeV, for all cases except $\mathcal{R}_{\mathrm{cont}}$ of (e, e) mode. There, because continuum Monte Carlo calculations poorly model the $\mathrm{NN_{cont}}$ distribution, we use the tight $\mathrm{NN_{cont}^{cut}}$ value, 0.70. Values so obtained are given in Table I. One sees that $\mathcal{R}_{B\bar{B}}$ differs little from 1.0, while $\mathcal{R}_{\mathrm{cont}}$ is less well behaved, particularly for the (e, e) mode, indicating that the two-photon-fusion background is present. To estimate backgrounds in the signal $|\vec{p}_\ell|$ region correctly, we scale the signal-region yields from Monte Carlo calculations by $\mathcal{R}$. Because we perform a direct subtraction of off-resonance data, the accuracy of the continuum background prediction is not critical for our results. The error assigned to $\mathcal{R}_{\mathrm{cont}}$ covers this disagreement.

In Fig. 1, we also show the distributions obtained from signal Monte Carlo calculations. Comparing the signal Monte Carlo distributions with the background distributions shown in Fig. 1 and 2, one sees that $\mathrm{NN_{cont}}$ is good for separating signal from continuum background, but not for separating signal from $B\bar{B}$ background. $\mathrm{NN}_{B\bar{B}}$ plays the opposite role, while $\Delta M_{\tau,\Delta E=0}$ is useful for discriminating against both backgrounds. ΔM_τ is useful for discriminating against the two-photon background.

We optimized our selection criteria on $\mathrm{NN}_{B\bar{B}}$, $\mathrm{NN_{cont}}$, ΔM_τ, and $\Delta M_{\tau,\Delta E=0}$ to obtain the best upper limit when the true branching fraction is zero. This optimization procedure made use of signal and background Monte Carlo samples, and scaled the background samples by $\mathcal{R}_{B\bar{B}}$ or $\mathcal{R}_{\mathrm{cont}}$ as described above. The optimized selection criteria, found separately for each mode, are shown in Table I.

The number of events satisfying all selection criteria is shown, for each mode, in Table I, along with the background estimate. We find 15 (μ, e) candidates, with 23.7 expected from background; we find 4 (μ, μ) candidates, with 9.0 expected from background; we find 14 (e, e)

TABLE I. The rows of $\mathrm{NN}_{B\bar{B}}$, $\mathrm{NN}_{\mathrm{cont}}^{\mathrm{cut}}$, ΔM_τ(GeV), and $\Delta M_{\tau,\Delta E=0}$(GeV) indicate the optimized selection criteria for each mode. $\mathcal{R}_{B\bar{B}}$ and $\mathcal{R}_{\mathrm{cont}}$ are measured ratios between data yields and Monte Carlo calculations with loose selection criteria in the $|\vec{p}_\ell|$ sideband region. (For $\mathcal{R}_{\mathrm{cont}}$ of (e, e), we use $\mathrm{NN}_{\mathrm{cont}}^{\mathrm{cut}} = 0.70$.) N_{ON}(N_{OFF}) is the number of observed events satisfying the optimized selection criteria in the signal region of $|\vec{p}_\ell|$ from on(off)-resonance data samples. N_{obs} is the number of observed events from off-resonance-subtracted on-resonance data, N_{ON}–$1.99N_{\mathrm{OFF}}$. $\mathrm{NN}_{B\bar{B}}$ is the $B\bar{B}$ background estimate from Monte Carlo calculations, scaled by $\mathcal{R}_{B\bar{B}}$; in the absence of signal it should be comparable with N_{obs}. $0.5N_{\mathrm{cont}}$ is (1/1.99) times the continuum background estimate from Monte Carlo calculations, scaled by $\mathcal{R}_{\mathrm{cont}}$, which should be comparable with N_{OFF}. ϵ is the signal detection efficiency including τ decay branching fraction. $BR\,UL$ is the branching ratio upper limit at 90% confidence level with systematic error considered.

(ℓ, ℓ')	(μ, e)	(μ, μ)	(e, e)	(e, μ)
$\mathrm{NN}_{B\bar{B}}$	0.725	0.875	0.675	0.825
$\mathrm{NN}_{\mathrm{cont}}^{\mathrm{cut}}$	0.700	0.775	0.700	0.475
$-2.0 < \Delta M_\tau$	<2.00	<1.40	<1.50	<1.40
$-2.0 < \Delta M_{\tau,\Delta E=0}$	<0.25	<0.25	<0.30	<0.25
$\mathcal{R}_{B\bar{B}}$	1.21 ± 0.06	1.06 ± 0.07	1.04 ± 0.07	0.94 ± 0.07
$\mathcal{R}_{\mathrm{cont}}$	1.03 ± 0.27	1.52 ± 0.32	6.57 ± 1.74	0.64 ± 0.38
N_{ON}	19	10	28	6
N_{OFF}	2	3	7	0
N_{obs}	15.0 ± 5.2	4.0 ± 4.7	14.0 ± 7.5	6.0 ± 2.4
$\mathrm{NN}_{B\bar{B}}$	23.7 ± 2.7	9.0 ± 1.4	11.6 ± 1.4	5.1 ± 0.8
$0.5N_{\mathrm{cont}}$	1.8 ± 0.6	0.4 ± 0.2	4.7 ± 1.6	0.5 ± 0.3
ϵ(%)	1.57	0.63	0.96	0.58
$BR\,UL(10^{-4})$	0.55	0.87	1.83	1.46

candidates, with 11.6 expected from background; we find 6 (e, μ) candidates, with 5.1 expected from background. Thus there are a total of 39 events with 49.4 expected from background. The probability that a true mean of 49.4 will give rise to a yield of 39 or more events is 93%. With no indication of signal, we obtain the branching fraction upper limits.

We calculate upper limits at 90% confidence level. There is some probability of observing the off-resonance-subtracted on-resonance yield that we do observe, or less, if the branching fractions for $B^0 \to \mu^\pm\tau^\mp$ and $B^0 \to e^\pm\tau^\mp$ are zero. We take the 90% confidence level upper limit to be that value of the branching fraction which reduces the above-mentioned probability by a factor of 10. The ingredients needed for the calculation are: (1) the observed off-resonance-subtracted on-resonance yield; (2) the true mean for the background contribution from $B\bar{B}$ processes, and (3) less critically, the true mean of the background contribution from nonresonance processes. To allow for the uncertainty in the background estimates, we changed $\mathcal{R}_{B\bar{B}}$ and $\mathcal{R}_{\mathrm{cont}}$ in the unfavorable directions by 1σ, i.e., -1σ for $\mathcal{R}_{B\bar{B}}$ and $+1\sigma$ for $\mathcal{R}_{\mathrm{cont}}$.

We use Monte Carlo simulation to determine the efficiency for detecting the signal modes. The decays $B \to \mu(e)^\pm\tau^\mp$ are generated with the τ lepton unpolarized. For a τ lepton polarization as given by $V - A$, the secondary lepton is boosted (has its average lab energy increased), which in turn increases the efficiency. For the opposite polarization, as given by $V + A$, the secondary lepton is deboosted, and the efficiency is lowered. The fractional changes in efficiency, averaged over the four modes, are $+11\%$ for $V - A$, -8% for $V + A$. Our upper limits are quoted for unpolarized τ's.

Systematic errors are of two varieties—those on the estimate of signal detection efficiencies, and those on the estimate of backgrounds. The dominant contributors to the former are lepton identification efficiency uncertainties (contributing $\pm3.5\%$ per lepton, relative, in the efficiency), and missing-four-vector-simulation uncertainties ($\pm 5.4\%$), giving a relative uncertainty in the overall efficiency of $\pm7.4\%$ for (e, μ) and (μ, e), and $\pm8.9\%$ for (e, e) and (μ, μ). The background uncertainties are handled by varying the $\mathcal{R}_{B\bar{B}}$ and $\mathcal{R}_{\mathrm{cont}}$ as mentioned above. The errors shown on the backgrounds in Table I include statistical and systematic errors.

There is no universally agreed upon procedure for including systematic errors in upper-limit estimates. We conservatively vary the background by 1.0 standard deviations, and decrease the efficiency by 1.0 standard deviations for each mode and the results are as shown in Table I.

To combine the results from two leptonic modes, $\tau \to e\nu\bar{\nu}$ and $\tau \to \mu\nu\bar{\nu}$, we simply add the yields, add the backgrounds, and add the efficiencies.

In this way we obtain our final results

$$\mathcal{B}(B \to \mu^\pm\tau^\mp) < 3.8 \times 10^{-5},$$

$$\mathcal{B}(B \to e^\pm\tau^\mp) < 1.3 \times 10^{-4},$$

both at 90% confidence level. These results are significant improvements over previously published limits [3].

In summary, we have searched for the decays $B \to \mu^{\pm}\tau^{\mp}$ and $B \to e^{\pm}\tau^{\mp}$. We find no indication of a signal, and obtain upper limits on the branching fractions.

We gratefully acknowledge the effort of the CESR staff in providing us with excellent luminosity and running conditions. This work was supported by the National Science Foundation, the U.S. Department of Energy, the Research Corporation, and the Texas Advanced Research Program.

*On leave of absence from University of Chicago.

[1] M. Sher and Y. Yuan, Phys. Rev. D **44**, 1461 (1991); J. Pati and A. Salam, Phys. Rev. D **10**, 275 (1974); D. Guetta, J. M. Mira, and E. Nardi, Phys. Rev. D **59**, 034019 (1999); A. Dedes, J. Ellis, and M. Raidal, Phys. Lett. B **549**, 159 (2002).

[2] Super-Kamiokande Collaboration, S. Fukuda *et al.*, Phys. Rev. Lett. **85**, 3999 (2000); SNO Collaboration, Q. R. Ahmad *et al.*, Phys. Rev. Lett. **89**, 011301 (2002); KamLand Collaboration, K. Eguchi *et al.*, Phys. Rev. Lett. **90**, 021802 (2003); M. H. Ahn *et al.*, Phys. Rev. Lett. **90**, 041801 (2003).

[3] CLEO Collaboration, R. Ammar *et al.*, Phys. Rev. D **49**, 5701 (1994).

[4] CLEO Collaboration, Y. Kubota *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **320**, 66 (1992); T. Hill, Nucl. Instrum. Methods Phys. Res., Sect. A **418**, 32 (1998).

[5] G. C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).