ICHEP94 Ref. GLS0741 **CLEO CONF 94-6**
Submitted to Pa 16,2 Pl 9,19

Measurement of the Branching Ratio of $B \to Xe\nu$ with Lepton Tags

J. Gronberg,[1] R. Kutschke,[1] S. Menary,[1] R.J. Morrison,[1] S. Nakanishi,[1] H.N. Nelson,[1] T.K. Nelson,[1] C. Qiao,[1] J.D. Richman,[1] A. Ryd,[1] H. Tajima,[1] D. Sperka,[1] M.S. Witherell,[1] R. Balest,[2] K. Cho,[2] W.T. Ford,[2] D.R. Johnson,[2] K. Lingel,[2] M. Lohner,[2] P. Rankin,[2] J.G. Smith,[2] J.P. Alexander,[3] C. Bebek,[3] K. Berkelman,[3] K. Bloom,[3] T.E. Browder,[3*] D.G. Cassel,[3] H.A. Cho,[3] D.M. Coffman,[3] D.S. Crowcroft,[3] P.S. Drell,[3] D. Dumas,[3] R. Ehrlich,[3] P. Gaidarev,[3] M. Garcia-Sciveres,[3] B. Geiser,[3] B. Gittelman,[3] S.W. Gray,[3] D.L. Hartill,[3] B.K. Heltsley,[3] S. Henderson,[3] C.D. Jones,[3] S.L. Jones,[3] J. Kandaswamy,[3] N. Katayama,[3] P.C. Kim,[3] D.L. Kreinick,[3] G.S. Ludwig,[3] J. Masui,[3] J. Mevissen,[3] N.B. Mistry,[3] C.R. Ng,[3] E. Nordberg,[3] J.R. Patterson,[3] D. Peterson,[3] D. Riley,[3] S. Salman,[3] M. Sapper,[3] F. Würthwein,[3] P. Avery,[4] A. Freyberger,[4] J. Rodriguez,[4] S. Yang,[4] J. Yelton,[4] D. Cinabro,[5] T. Liu,[5] M. Saulnier,[5] R. Wilson,[5] H. Yamamoto,[5] T. Bergfeld,[6] B.I. Eisenstein,[6] G. Gollin,[6] B. Ong,[6] M. Palmer,[6] M. Selen,[6] J. J. Thaler,[6] K.W. Edwards,[7] M. Ogg,[7] A. Bellerive,[8] D.I. Britton,[8] E.R.F. Hyatt,[8] D.B. MacFarlane,[8] P.M. Patel,[8] B. Spaan,[8] A.J. Sadoff,[9] R. Ammar,[10] P. Baringer,[10] A. Bean,[10] D. Besson,[10] D. Coppage,[10] N. Copty,[10] R. Davis,[10] N. Hancock,[10] M. Kelly,[10] S. Kotov,[10] I. Kravchenko,[10] N. Kwak,[10] H. Lam,[10] Y. Kubota,[11] M. Lattery,[11] M. Momayezi,[11] J.K. Nelson,[11] S. Patton,[11] R. Poling,[11] V. Savinov,[11] S. Schrenk,[11] R. Wang,[11] M.S. Alam,[12] I.J. Kim,[12] Z. Ling,[12] A.H. Mahmood,[12] J.J. O'Neill,[12] H. Severini,[12] C.R. Sun,[12] F. Wappler,[12] G. Crawford,[13] C. M. Daubenmier,[13] R. Fulton,[13] D. Fujino,[13] K.K. Gan,[13] K. Honscheid,[13] H. Kagan,[13] R. Kass,[13] J. Lee,[13] R. Malchow,[13] Y. Skovpen,[13†] M. Sung,[13] C. White,[13] M.M. Zoeller,[13] F. Butler,[14] X. Fu,[14] B. Nemati,[14] W.R. Ross,[14] P. Skubic,[14] M. Wood,[14] M. Bishai,[15] J. Fast,[15] E. Gerndt,[15] R.L. McIlwain,[15] T. Miao,[15] D.H. Miller,[15] M. Modesitt,[15] D. Payne,[15] E.I. Shibata,[15] I.P.J. Shipsey,[15] P.N. Wang,[15] M. Battle,[16] J. Ernst,[16] L. Gibbons,[16] Y. Kwon,[16] S. Roberts,[16] E.H. Thorndike,[16] C.H. Wang,[16] J. Dominick,[17] M. Lambrecht,[17] S. Sanghera,[17] V. Shelkov,[17] T. Skwarnicki,[17] R. Stroynowski,[17] I. Volobouev,[17] G. Wei,[17] P. Zadorozhny,[17] M. Artuso,[18] M. Gao,[18] M. Goldberg,[18] D. He,[18] N. Horwitz,[18] R. Kennett,[18] G.C. Moneti,[18] R. Mountain,[18] F. Muheim,[18] Y. Mukhin,[18] S. Playfer,[18] Y. Rozen,[18] S. Stone,[18] X. Xing,[18] G. Zhu,[18] J. Bartelt,[19] S.E. Csorna,[19] Z. Egyed,[19] V. Jain,[19] D. Gibaut,[20] K. Kinoshita,[20] P. Pomianowski,[20] B. Barish,[21] M. Chadha,[21] S. Chan,[21] D.F. Cowen,[21] G. Eigen,[21] J.S. Miller,[21] C. O'Grady,[21] J. Urheim,[21] A.J. Weinstein,[21] M. Athanas,[22] W. Brower,[22] G. Masek,[22] and H.P. Paar[22]

(CLEO Collaboration)

[1]University of California, Santa Barbara, California 93106
[2]University of Colorado, Boulder, Colorado 80309-0390
[3]Cornell University, Ithaca, New York 14853
[4]University of Florida, Gainesville, Florida 32611
[5]Harvard University, Cambridge, Massachusetts 02138
[6]University of Illinois, Champaign-Urbana, Illinois, 61801
[7]Carleton University, Ottawa, Ontario K1S 5B6 and the Institute of Particle Physics, Canada
[8]McGill University, Montréal, Québec H3A 2T8 and the Institute of Particle Physics, Canada
[9]Ithaca College, Ithaca, New York 14850
[10]University of Kansas, Lawrence, Kansas 66045
[11]University of Minnesota, Minneapolis, Minnesota 55455
[12]State University of New York at Albany, Albany, New York 12222
[13]Ohio State University, Columbus, Ohio, 43210
[14]University of Oklahoma, Norman, Oklahoma 73019
[15]Purdue University, West Lafayette, Indiana 47907
[16]University of Rochester, Rochester, New York 14627
[17]Southern Methodist University, Dallas, Texas 75275
[18]Syracuse University, Syracuse, New York 13244
[19]Vanderbilt University, Nashville, Tennessee 37235
[20]Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 24061
[21]California Institute of Technology, Pasadena, California 91125
[22]University of California, San Diego, La Jolla, California 92093

Abstract

We report a preliminary measurement of $\mathcal{B}(B \to Xe\nu)$ that has been made with dilepton events from 2.07 fb^{-1} of $\Upsilon(4S)$ data collected with the CLEO-II detector. In events with a high-momentum lepton tag and an electron we used charge and kinematic correlations to obtain the electron spectrum of B decays. By integrating above 0.6 GeV/c and making a small extrapolation to lower momenta, we obtain $\mathcal{B}(B \to Xe\nu) = (10.36 \pm 0.17 \pm 0.40)\%$. This measurement is largely independent of theoretical models and assumptions about possible non-$B\bar{B}$ decays of the $\Upsilon(4S)$. From this measurement, and measurements of the B-meson lifetime, we obtain $|V_{cb}| = 0.042 \pm 0.001 \pm 0.004$, where the first error includes all experimental uncertainties, and the second accounts for theoretical uncertainties. By comparing total electron production with that in tagged events we set a 95% confidence level upper limit on the fraction of $\Upsilon(4S)$ decays to non-$B\bar{B}$ final states of 5%.

*Permanent address: University of Hawaii at Manoa

†Permanent address: INP, Novosibirsk, Russia

The semileptonic branching fraction of the B meson has been a persistent puzzle in heavy flavor physics. While experimental measurements have consistently been smaller than 11%, theoretical expectations have remained at 12.5% or higher [1]. The most precise measurements have been based on analyses of the inclusive lepton momentum spectrum at the $\Upsilon(4S)$ resonance. A recent CLEO-II measurement of this type has achieved a statistical precision of better than 0.5% [2], but is limited by significant systematic uncertainties. The contribution of primary decays ($B \to X\ell\nu$) must be separated from that of secondary charm decays ($b \to c \to y\ell\nu$) by fitting the spectrum to the predictions of theoretical models. Results obtained with different models span a range that is greater than the experimental error [3]. For all measurements of inclusive lepton production at the $\Upsilon(4S)$, there is an additional uncertainty associated with the normalization. It must be assumed that all $\Upsilon(4S)$ decays are to the dominant $B\bar{B}$ decay mode. While this is a reasonable assumption, the published 95% confidence level upper limit on the non-$B\bar{B}$ fraction of 13% [4] leaves room for an appreciable effect.

Recently the ARGUS collaboration presented an elegant analysis that reduces both the model dependence and the sensitivity to non-$B\bar{B}$ decays by using dilepton events [5]. In this paper we describe a similar analysis based on a ten times larger data sample. High-momentum lepton tags were used to obtain a sample of events that is enriched in $B\bar{B}$. Electrons accompanying the tag were explicitly separated into primary and secondary by using charge and angular correlations. The results of the analysis include a nearly model- and normalization-independent measurement of the B semileptonic branching fraction, and an upper limit on the fraction of $\Upsilon(4S)$ decays to non-$B\bar{B}$ final states.

Our data sample was collected with the CLEO-II detector at the Cornell Electron Storage Ring (CESR). It consists of an integrated luminosity of 2.07 fb^{-1} at the $\Upsilon(4S)$ resonance, and an additional 0.99 fb^{-1} at a center-of-mass energy approximately 60 MeV below the $\Upsilon(4S)$. The off-resonance data were used to estimate the contribution of continuum processes to the $\Upsilon(4S)$ sample. The CLEO-II detector has previously been described in detail [6]. For this analysis we relied primarily on charged particle tracking and electromagnetic calorimetry. A 67-layer drift chamber system inside a 1.5-T solenoidal magnet provides both momentum and specific ionization (dE/dx) measurements. Electromagnetic energy is measured with a cesium iodide calorimeter located inside the magnet. Muons are detected in proportional counters embedded in the iron flux return enclosing the solenoid.

Hadronic event-selection criteria included at least five charged tracks, a minimum visible energy, and an event vertex consistent with the nominal interaction point. Electron candidates were selected by requiring an energy deposit in the calorimeter approximately equal to the measured momentum, and dE/dx consistent with that expected for an electron. Muon candidates were identified as charged tracks that matched muon-detector hits at absorber depths of at least five nuclear interaction lengths. We used electrons in the polar angle region $|\cos\theta| < 0.71$, and muons in the range $|\cos\theta| < 0.61$. Our lepton-selection procedures provide momentum-dependent detection efficiencies generally above 90%, and misidentification probabilities per hadron track below 1%.

In each event the presence of a lepton with a momentum above 1.4 GeV/c was required, since high-momentum leptons at the $\Upsilon(4S)$ are predominantly from $b \to c\ell\nu$ transitions. We then looked for an additional electron accompanying this tag, with a minimum momentum requirement of 0.6 GeV/c to allow measurement of most of the B-meson semileptonic decay spectrum. Electrons selected in this way include contributions from three distinct sources. The charge correlation between the tag lepton and the accompanying electron provides a powerful tool for disentangling these contributions. We begin with the assumption that all tag leptons are from the primary decay of one of the B mesons in the event. (Corrections for false tags will be described later.) When the other B decays semileptonically, the daughter electron usually has a charge that is opposite to that of the tag. Only in the small portion of events with $B^0 - \bar{B}^0$ mixing do these primary electrons contribute to the like-sign sample. When the second electron is from the semileptonic decay of a charmed particle produced in the decay of the other B, the charge is usually the same as the tag's, with a small unlike-sign component from mixing. Secondary electrons from charm decay on the same side as the tag lepton can also contribute. In this case the charges are opposite, and events of this type complicate the charge-correlation pattern. Fortunately, this "same-B" contribution can be suppressed using kinematic correlations.

At the $\Upsilon(4S)$, the B and the $\bar{B}$ are produced nearly at rest. There is no kinematic correlation between leptons produced in primary or secondary decays of different B mesons. For a combination of a tag lepton and an electron from the same B, however, there is a strong correlation. These features are illustrated in Fig. 1, which shows the two-dimensional distribution of the electron momentum p_e and the cosine of the dilepton opening angle $\cos\theta_{\ell e}$ for Monte Carlo simulations of both the opposite-B and same-B contributions. To suppress electrons from the same B and retain those from the opposite B, we imposed the "diagonal" cut, $p_e + \cos\theta_{\ell e} > 1$, on the unlike-sign sample. This requirement suppresses the same-B background by a factor of 25, while keeping 67% of the signal.

Systematic effects that may be introduced by this cut have been studied with a Monte Carlo simulation using the form-factor model of Isgur *et. al.* (ISGW) [7] for the decay modes $B \to D\ell\nu$, $B \to D^*\ell\nu$, and $B \to D^{**}\ell\nu$, with an additional component to account for possible higher multiplicity nonresonant decays. We find that the efficiency $\epsilon(p)$ of the diagonal cut on signal (opposite-B) events varies insignificantly among the different decay channels that give rise to the tag lepton. The same-side background surviving this cut is dominated by $B \to D^*\ell\nu$ (73%). The contribution of $B \to D\ell\nu$ (17%), and that from $B \to D^{**}\ell\nu$ and nonresonant decays (10%), are not as large, because of smaller branching fractions and softer lepton spectra. We have varied the fractions of the individual modes, and conclude that the uncertainty in the background after the diagonal cut is 20%.

The raw Υ(4S) electron yields for the unlike-sign sample with the diagonal cut applied, and for the like-sign without this cut, are shown in Fig. 2. The continuum contribution was subtracted by scaling the lepton yields in the off-resonance data by 2.10 ± 0.01, the ratio of the on- and off-resonance integrated luminosities, corrected for the energy dependence of the continuum cross section.

While the unlike-sign spectrum is dominated by the primary decay $B \to \mathrm{X}e\nu$, and the like-sign is dominantly $b \to c \to e$ transtions, there remain several background contributions. These are summarized in Table I. Fakes are hadrons that were misidentified as leptons. Their contributions both to the tags and to the raw electron spectra have been calculated using misidentification probabilities and hadron track momentum spectra found from data. The uncertainty in this correction is primarily from the determination of the misidentification probabilities, which relies on lepton-poor Υ(1S) data, and on pion, kaon and proton track samples from Υ(4S) data. We estimate the uncertainty to be 50% above 1.4 GeV/c and

25% at lower momenta.

Leptons from J/ψ mesons produced in B decays were vetoed by using the invariant mass of oppositely charged lepton pairs. This veto was not perfect, and the residual background of unvetoed leptons from J/ψ was estimated by Monte Carlo. Background from $\pi^0 \to e^+e^-\gamma$ was treated similarly. Electrons from photons that converted in the beam pipe and drift chamber walls were vetoed by using the coplanarity of oppositely charged electrons, and again the remaining background was estimated with a Monte Carlo simulation. Leptons from decays of τ's produced in $B \to X\tau^-\bar{\nu}_\tau$ were also estimated by Monte Carlo. We assumed a branching fraction of 2.5%, consistent with the Standard Model expectation, and with the experimental result of ALEPH [10]. The uncertainties in these corrections were estimated to be 20%. Secondary leptons can occasionally be above 1.4 GeV/c, and contribute false tags. In the CLEO-II study of the B-meson inclusive lepton spectrum [2], we found that approximately 2.8% of the identified leptons above 1.4 GeV/c are secondary, with an estimated uncertainty of 25%. Our study of the background of unlike-sign electrons from the same B that survived the diagonal cut was described above, and has an estimated uncertainty of 20%. Note that the background uncertainties given include both correlated and uncorrelated components.

After the background corrections the only remaining contributions to the electron spectra are primary B semileptonic decays and secondary charm semileptonic decays. In both cases the tag and the second electron are daughters of different parent B mesons. The unlike- and like-sign electron momentum spectra can be expressed algebraically in terms of the primary and secondary branching fractions as

$$\frac{dN(\ell^\pm e^\mp)}{dp} = N_\ell \eta(p) \left[\frac{d\mathcal{B}(b)}{dp}(1-\chi) + \frac{d\mathcal{B}(c)}{dp}\chi \right] \epsilon(p), \tag{1}$$

$$\frac{dN(\ell^\pm e^\pm)}{dp} = N_\ell \eta(p) \left[\frac{d\mathcal{B}(b)}{dp}\chi + \frac{d\mathcal{B}(c)}{dp}(1-\chi) \right], \tag{2}$$

where $\eta(p)$ is the efficiency of electron identification and $\epsilon(p)$ is the efficiency of the diagonal cut that we applied to the unlike-sign electrons.

The number of tags N_ℓ was determined by counting lepton candidates above 1.4 GeV/c. We subtracted continuum, fake, J/ψ, π^0 and γ conversion backgrounds, and corrected for the slightly smaller efficiency for selecting dilepton events compared to that for single-lepton events. This relative efficiency was determined by Monte Carlo to be 0.98 ± 0.01. Our final value for the number of tag leptons in the full $\Upsilon(4S)$ data sample was $N_\ell = 247811 \pm 771$.

The effect of neutral B-meson mixing is parameterized by $\chi = f_0\chi_0$, where χ_0 is the $B^0\bar{B}^0$ mixing parameter and f_0 is the fraction of $\Upsilon(4S)$ decays which produce neutral B mesons. Using the yields of like- and unlike-sign dileptons in CLEO-II $\Upsilon(4S)$ data, χ has been directly measured to be 0.079 ± 0.012 [8]. The error includes both statistical and systematic components, but the measurement is immune to uncertainty in f_0.

Eqs. 1 and 2 have been solved to obtain the primary and secondary electron spectra shown in Fig. 3. By integrating the primary spectrum from 0.6 GeV/c to 2.5 GeV/c we calculate the partial branching ratio $\mathcal{B}(B \to Xe\nu, p > 0.6 \text{ GeV/c}) = (9.76 \pm 0.16)\%$, where the error is only statistical. This result is almost completely model-independent. To determine the total semileptonic branching fraction, we must extrapolate to the momentum region below 0.6 GeV/c to account for undetected electrons. This requires the use of models, but the dependence introduced is small because nearly all of the spectrum is measured. We use the average of the predictions of the ISGW model and the enhanced spectator model of Altarelli *et al.* (ACCMM) [9], corrected for internal and external bremsstrahlung. The resulting fraction of electrons from semileptonic B decays which are below 0.6 GeV/c is $(5.8 \pm 0.5)\%$. The error in this correction was determined from the difference between the two models. With this extrapolation, we obtain the semileptonic branching fraction of B mesons $\mathcal{B}(B \to Xe\nu) = (10.36 \pm 0.17 \pm 0.40)\%$. The systematic error in this result includes all of the contributions which have been discussed, a 2% uncertainty in our electron identification efficiency, a 1% uncertainty in the tracking efficiency, and the uncertainty in the mixing parameter χ.

While our determination of the semileptonic branching fraction did not require fitting the lepton momentum spectrum with theoretical models, such fits allow comparison with the predictions of those models, and with the results of our study of the $\Upsilon(4S)$ inclusive lepton spectrum [2]. We fixed the model parameters to the values found in the corresponding inclusive fits. The fit of our primary electron spectrum to the ACCMM prediction gave $\mathcal{B}(B \to Xe\nu) = (10.1 \pm 0.1)\%$, with a χ^2 of 28 for 19 degrees of freedom. For ISGW the fit result was $(9.9 \pm 0.1)\%$, and the χ^2 was 36 for 19 degrees of freedom. For a variation of the ISGW model with 21% of B semileptonic decays to $D^{**}\ell\nu$ (optimal for the inclusive spectrum, and slightly larger than the ISGW prediction), we found $\mathcal{B}(B \to Xe\nu) = (10.3 \pm 0.1)\%$, and a χ^2 of 20 for 19 degrees of freedom. The branching fractions obtained from these fits are somewhat smaller than those of the inclusive analysis. Along with the somewhat poor χ^2 values, this may reveal shortcomings in the ability of the models to describe the full semileptonic momentum spectrum.

The secondary electron spectrum can also be compared with models and earlier measurements. In this case we use ISGW and ACCMM parameters determined by fitting the DELCO D semileptonic momentum spectrum [11], boosted according to D^0 and D^+ momentum distributions measured by CLEO [12]. With the ACCMM model we found $\mathcal{B}(b \to c \to ye\nu) = (7.7 \pm 0.3 \pm 1.2)\%$ (χ^2=27 for 13 degrees of freedom), and with the ISGW model we obtained $\mathcal{B}(b \to c \to ye\nu) = (8.3 \pm 0.3 \pm 1.2)\%$ (χ^2=33 for 13 degrees of freedom). These branching fractions do not include the contributions of $B \to X\Lambda_c, \Lambda_c \to Y\ell\nu$ or $B \to XD_s, D_s \to Y\ell\nu$, which are subtracted as background in our analysis. Within errors these results are consistent with expectations, and with the CLEO-II inclusive measurement.

Our result for the mean B semileptonic branching fraction, $(10.36 \pm 0.17 \pm 0.40)\%$, is in good agreement with the CLEO-II measurement using the inclusive lepton momentum spectrum [2]. This agreement was not guaranteed. If the charged and neutral B mesons have different semileptonic branching fractions, the mixture of B's in lepton-tagged events can differ from that in generic Υ(4S) decays. Since nonspectator effects in B decays are thought to be small, however, significant differences between the semileptonic branching fractions are not expected. Experimental support for this expectation comes from measurements of the charged and neutral B lifetimes [13], and from CLEO-II measurements of the exclusive semileptonic branching fractions $\mathcal{B}(B^- \to D^{*0}\ell^-\bar{\nu})$ and $\mathcal{B}(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu})$ [14]. Applying 90% confidence level limits from these measurements, we find that the systematic upward shift from the inclusive result to the lepton-tagged measurement can be no greater than

1.5% of the measured value.

Because of the lepton-tag requirement this measurement does not require us to assume that all Υ(4S) decays are to $B\bar{B}$ final states. The agreement between the inclusive measurement and the tagged measurement is evidence that the rate for such decays is not large. Comparison of the total electron yield in $B\bar{B}$ events with that in events with a lepton tag allows us to set a quantitative limit on the Υ(4S) non-$B\bar{B}$ branching fraction. The inclusive electron spectrum after all fake and background corrections can be expressed as

$$\frac{dN(e^{\pm})}{dp} = 2N_{\Upsilon(4\mathrm{S})}(1-f)\eta(p)\left[\frac{d\mathcal{B}(b)}{dp} + \frac{d\mathcal{B}(c)}{dp}\right], \tag{3}$$

where $N_{\Upsilon(4\mathrm{S})}$ is the number of Υ(4S) events and f is the fraction of $\Upsilon(4S)$ decays to final states other than $B\bar{B}$. By substituting the solutions of Eqs. 1 and 2 into Eq. 3 and integrating, we can compute an upper limit on the non-$B\bar{B}$ fraction f,

$$f \leq 1 - \frac{N_\ell}{2N_{\Upsilon(4\mathrm{S})}} \frac{\int_{p_{min}}^{p_{max}} \frac{dN(e^{\pm})}{dp} dp}{\int_{p_{min}}^{p_{max}} \frac{1}{\epsilon(p)} \frac{dN(\ell^{\pm}e^{\mp})}{dp} dp + \int_{p_{min}}^{p_{max}} \frac{dN(\ell^{\pm}e^{\pm})}{dp} dp}. \tag{4}$$

The inequality in this equation accommodates the possibility of differences in the charged and neutral B semileptonic branching fractions and production fractions. The integrated yields are summarized in Table II, in two regions, 0.6–1.4 GeV/c and 1.4–2.6 GeV/c. We have calculated the upper limit on the non-$B\bar{B}$ fraction f for several values of p_{min}, and obtain consistent results. For $p_{min} = 0.6$ GeV/c, corresponding to the full tagged sample, the value of the right-hand side of Eq. 4 is $0.010 \pm 0.014 \pm 0.011$, leading to $f < 0.04$ at the 95% confidence level. In deriving this limit we have ignored the possibility that non-$B\bar{B}$ decays might contribute directly to the lepton yields we attribute to B decays. While there is little theoretical guidance on possible mechanisms for these decays, our investigations of plausible processes for lepton production (primarily involving charmed and charmonium mesons) revealed little potential effect. To be conservative, however, we choose to raise our limit by 20% of itself, quoting a 95% confidence level upper limit on the $\Upsilon(4S)$ non-$B\bar{B}$ fraction of 0.05.

The B-meson inclusive branching fraction is related in a straightforward, if model-dependent, way to the CKM matrix elements V_{ub} and V_{cb}. The semileptonic width of the B meson is given by the following equation:

$$\Gamma(B \to X\ell\nu) = \gamma_c|V_{cb}|^2 + \gamma_u|V_{ub}|^2, \tag{5}$$

where the factors γ_c and γ_u must be obtained from theory. The term involving V_{ub} makes a negligible contribution [16]. While the computation of γ_c is straightforward for any given model, conventional wisdom holds that an uncertainty in its value of 20% is prudent. This translates into a 10% theoretical uncertainty in $|V_{cb}|$. With the ACCMM model ($\gamma_c = 40 \pm 8\ ps^{-1}$) our semileptonic branching fraction measurement of $(10.36 \pm 0.17 \pm 0.40)\%$, and the average lifetime for charged and neutral B mesons of $1.49 \pm 0.05\ ps$ [13] lead to $|V_{cb}| = 0.042 \pm 0.001 \pm 0.004$. In this result the first error combines all of the experimental uncertainties, both statistical and systematic. It is much smaller than the second error, which is the theoretical uncertainty in the computation of γ_c. Using the same inputs with the

ISGW model ($\gamma_c = 41 \pm 8\ ps^{-1}$), we find $|V_{cb}| = 0.041 \pm 0.001 \pm 0.004$. In a recent theoretical analysis, based on a QCD heavy quark expansion [17], Shifman *et al.* have asserted that the uncertainty in determining $|V_{cb}|$ from the inclusive rate can be made considerably smaller if experimental and theoretical constraints on the quark-mass difference $m_b - m_c$ are taken into account. Following their prescription, we find $|V_{cb}| = 0.042 \pm 0.001 \pm 0.002$.

In conclusion, we have made a new measurement of $\mathcal{B}(B \rightarrow Xe\nu)$ using events with an electron and a high-momentum lepton tag. We used kinematic correlations to suppress events in which the electron is from the decay of the same B as the tag lepton, and we separated the primary and secondary electron spectra by using charge correlations. By integrating over the primary spectrum above 0.6 GeV/c and extrapolating to lower momenta, we obtain a preliminary result of $\mathcal{B}(B \rightarrow Xe\nu) = (10.36 \pm 0.17 \pm 0.40)\%$, in agreement with other recent measurements, and significantly below theoretical expectations. This measurement is largely independent of theoretical models, and is insensitive to possible non-$B\bar{B}$ decays of the $\Upsilon(4S)$. We used the ratio of the total inclusive electron yield and the yield of electrons in tagged events to set a 95% confidence level upper limit on the non-$B\bar{B}$ fraction of less than 5%. We have used our result to extract measurements of the CKM matrix element $|V_{cb}|$ for different theoretical approaches.

We gratefully acknowledge the effort of the CESR staff in providing us with excellent luminosity and running conditions. We thank A. Vainshtein and M. Shifman for stimulating discussions. This work was supported by the National Science Fundation, the U.S. Department of Energy, the Heisenberg Foundation, the SSC Fellowship program of TNRLC, the Natural Sciences and Engineering Research Council of Canada, and the A.P. Sloan Foundation.

REFERENCES

[1] G. Altarelli and S. Petrarca, Phys. Lett. **B 261** (1991), 303; I. Bigi, B. Blok, M.A. Shifman and A. Vainshtein, Phys. Lett. **B 323**, 408 (1994).

[2] J. Bartelt *et al.* (CLEO), preprint CLEO CONF 93-19, to be published.

[3] Fits of the inclusive lepton momentum spectrum from 952 pb^{-1} of CLEO-II $\Upsilon(4S)$ data [2] yielded measurements of $\mathcal{B}(B \to X\ell\nu) = (10.65 \pm 0.05 \pm 0.22)\%$ for the model of Altarelli *et al.* [9], $\mathcal{B}(B \to X\ell\nu) = (10.42 \pm 0.05 \pm 0.22)\%$ for the model of Isgur *et al.* [7], and $\mathcal{B}(B \to X\ell\nu) = (10.98 \pm 0.10 \pm 0.22)\%$ for a variation of the model of Isgur *et al.* in which the proportion of B semileptonic decays to $D^{**}\ell\nu$ was left as a free parameter.

[4] S. Henderson *et al.* (CLEO), Phys. Rev. D **45**, 2212 (1992).

[5] H. Albrecht *et al.* (ARGUS), Phys. Lett. **B 318**, 397 (1993).

[6] Y. Kubota *et al.* (CLEO), Nucl. Instr. Meth. **A 320**, 66 (1992).

[7] N. Isgur, D. Scora, B. Grinstein and M.B. Wise Phys. Rev. D **39**, 799 (1989).

[8] D. Buskulic *et al.* (ALEPH), Phys. Lett. **B 298**, 479 (1993).

[9] J. Bartelt *et al.* (CLEO), Phys. Rev. Lett. **71**, 1680 (1993).

[10] G. Altarelli, N. Cabibbo, G. Corbo, L. Maiani and G. Martinelli, Nucl. Phys. **B 208**, 365 (1982).

[11] W. Bacino *et al.* (DELCO), Phys. Rev. Lett. **43**, 1073 (1979).

[12] D. Bortoletto *et al.* (CLEO), Phys. Rev. D **45**, 21 (1992); J. Lewis, Ph. D. thesis, Cornell University, 1991.

[13] W. Venus, Proc. of XVI Int. Symp. on Lepton-Photon Interactions, Eds. P. Drell and D. Rubin, AIP Press, New York (1994).

[14] B. Barish *et al.* (CLEO), ICHEP paper GLS0251, Cornell University preprint CLNS 94/1285 and submitted to Phys. Rev. D.

[15] M. Athanas *et al.* (CLEO), ICHEP paper GLS0863 and Cornell University preprint CLNS 94/1286.

[16] J. Bartelt *et al.* (CLEO), Phys. Rev. Lett. **71**, 4111 (1993).

[17] M. Shifman, N.G. Uraltsev and A. Vainshtein TPI-MINN-94/13-T, UMN-TH-1251-94 (1994).

TABLE I. Background corrections for tag ℓ and the electron e. Both statistical and estimated systematic errors are included.

0.6-2.6 GeV/c Source	Unlike Sign $p_e + cos(\ell, e) > 1$	Like Sign no cut
ON $\Upsilon(4S)$	13022 ± 114	7625 ± 87
Continuum	$1333 \pm 52 \pm 7$	$606 \pm 35 \pm 3$
Fake tag ℓ	$108 \pm 1 \pm 42$	$65 \pm 1 \pm 19$
Fake e	$283 \pm 2 \pm 75$	$692 \pm 3 \pm 175$
Tag ℓ or e from J/ψ	$161 \pm 4 \pm 32$	$162 \pm 4 \pm 30$
Tag ℓ or e from π^0	$39 \pm 4 \pm 8$	$123 \pm 7 \pm 26$
Tag ℓ or e from γ conv.	$56 \pm 5 \pm 11$	$152 \pm 8 \pm 30$
Tag ℓ or e from $B \to X\tau, \tau \to Y\ell$	$270 \pm 11 \pm 54$	$70 \pm 5 \pm 14$
Tag ℓ or e from Λ_c or D_s	$245 \pm 11 \pm 61$	$151 \pm 8 \pm 38$
Tag ℓ from $B \to XD, D \to Y\ell\nu$	$205 \pm 10 \pm 51$	$401 \pm 13 \pm 100$
e from same B	$295 \pm 12 \pm 59$	–
Total Background	$2995 \pm 57 \pm 146$	$2422 \pm 40 \pm 212$
Background subtracted yield	$10027 \pm 127 \pm 146$	$5203 \pm 96 \pm 212$

TABLE II. Lepton and dilepton yields as represented by the integrals in Eq. 4.

p range (GeV/c)	inclusive	unlike-sign	like-sign
$0.6 - 1.4$	247624 ± 1699	7702 ± 226	5891 ± 106
$1.4 - 2.6$	146067 ± 618	7253 ± 111	904 ± 40
$N_{\Upsilon(4S)} = 2221848 \pm 5474$		$N_\ell = 247811 \pm 711$	

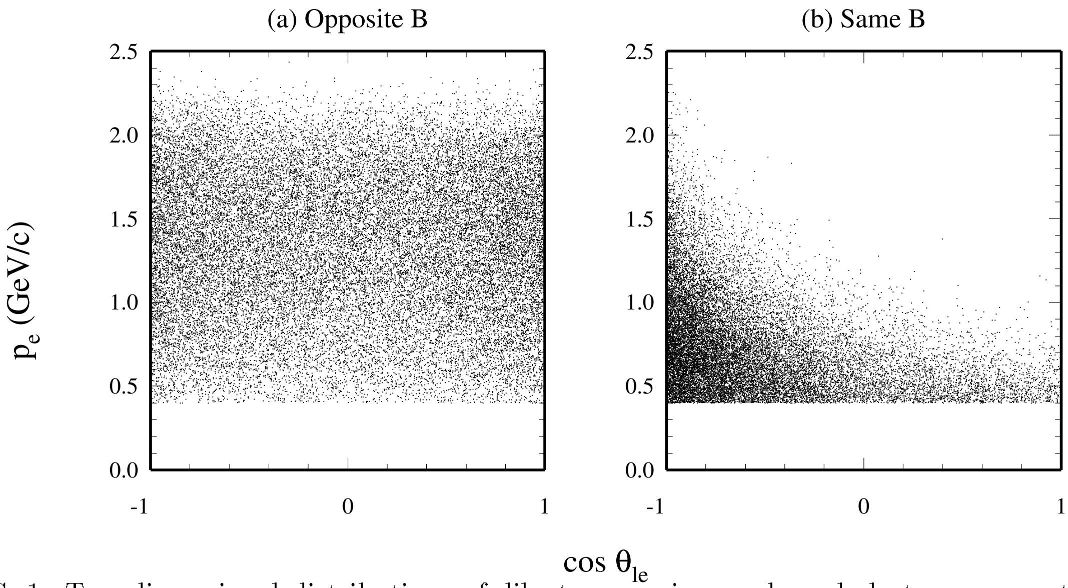

FIG. 1. Two-dimensional distributions of dilepton opening angle and electron momentum for (a) opposite B and (b) same B.

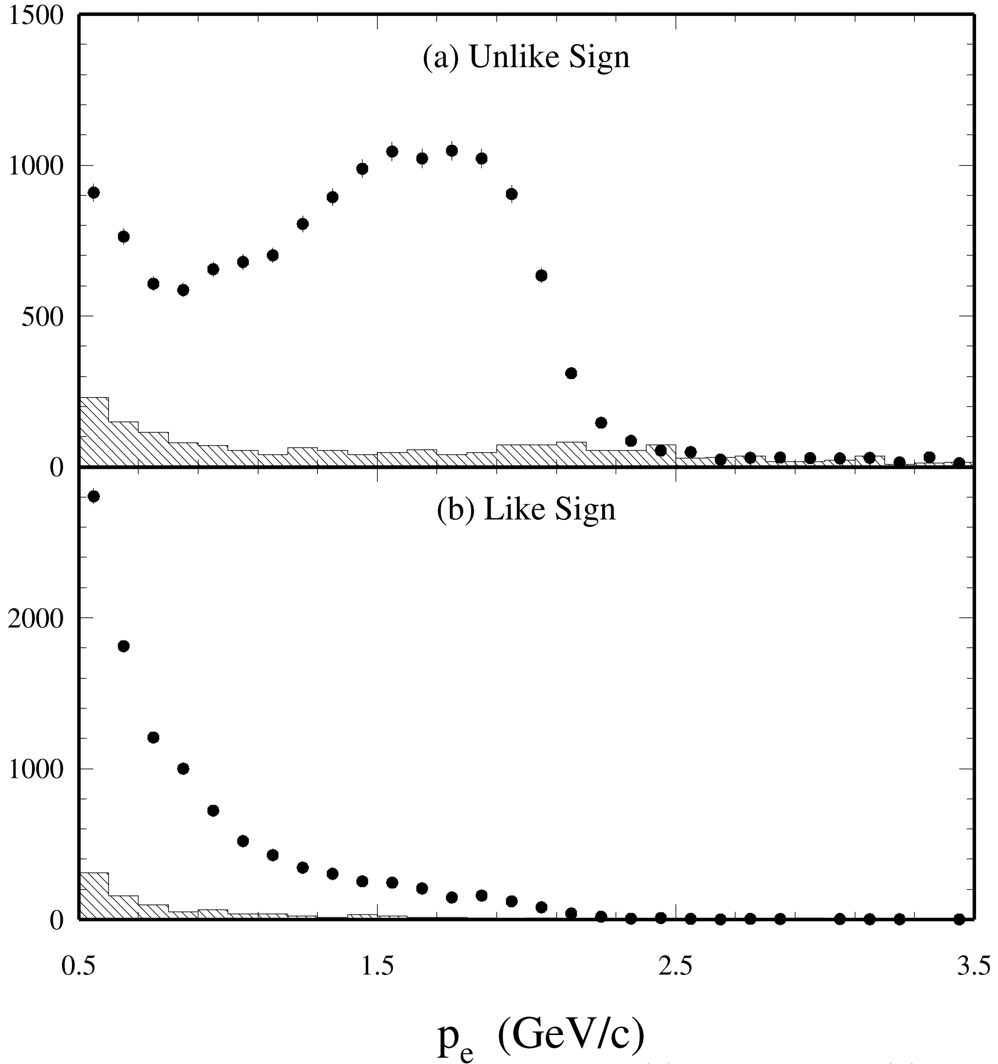

FIG. 2. Raw electron momentum spectra for events with (a) unlike-sign and (b) like-sign lepton tags. The points represent $\Upsilon(4S)$ data and the shaded histograms nearby continuum.

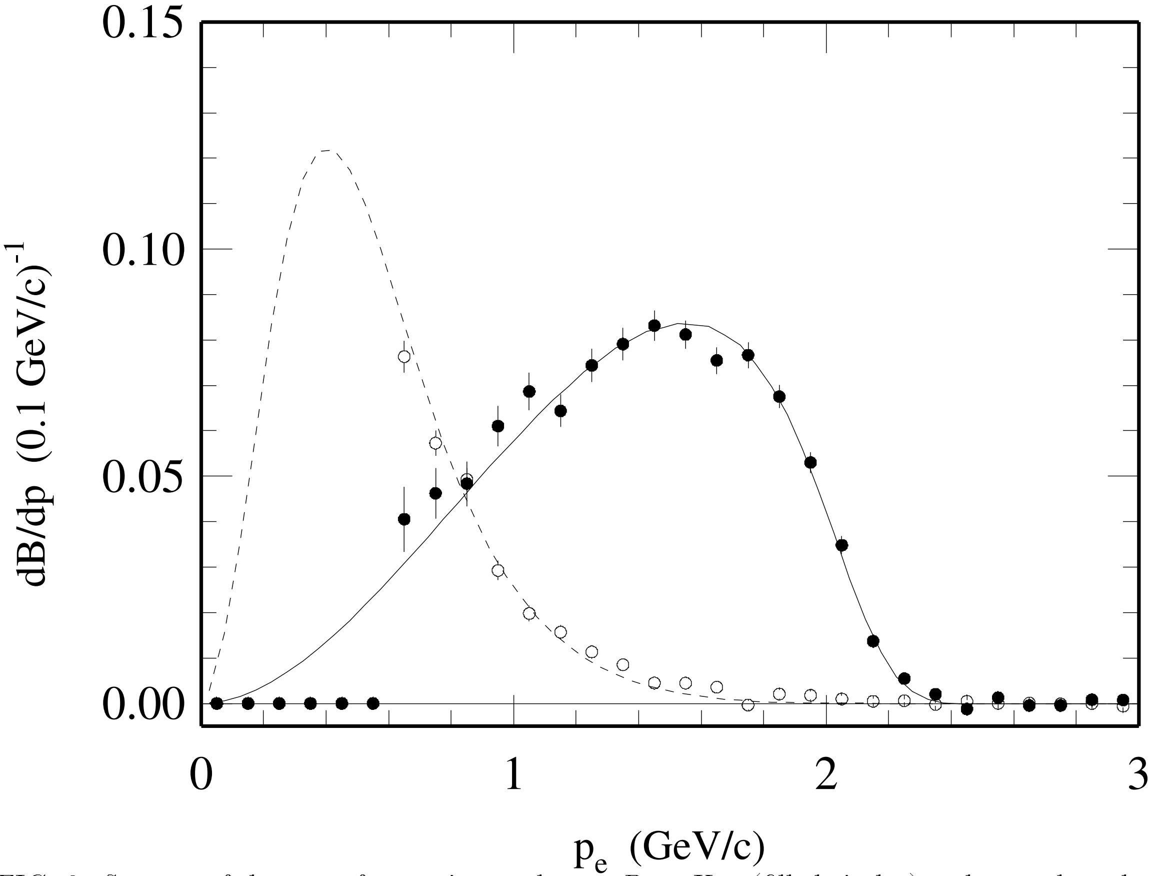

FIG. 3. Spectra of electrons from primary decays $B \to Xe\nu$ (filled circles) and secondary decays $b \to c \to y\ell\nu$ (open circles) from the analysis of $B\bar{B}$ events tagged by a high-momentum lepton. The curves show the results of fits to the ACCMM model.