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Measurement of the Branching Fraction for Inclusive Semileptonic B Meson Decays

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A largely model-independent measurement of the inclusive electron momentum spectrum and branching fraction for semileptonic decays of B mesons is presented based on data recorded at the $\Upsilon(4S)$ resonance with the *BABAR* detector. Backgrounds from secondary charm decays are separated from prompt B decays using charge and angular correlations between the electron from one B meson and a high momentum electron tag from the second B meson. The resulting branching fraction is $\mathcal{B}(B \to X e \nu) = (10.87 \pm 0.18(\text{stat}) \pm 0.30(\text{syst}))\%$. Based on this measurement we determine the CKM matrix element $|V_{cb}|$.

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Measurements of semileptonic B meson decays are a good way to determine the CKM matrix elements $|V_{cb}|$ and $|V_{ub}|$, two of the parameters of the Standard Model. For $|V_{cb}|$, analyses of exclusive and inclusive decays have resulted in comparable precision. While most measured values of $\mathcal{B}(B \to Xe\nu)$ are below 11% [1], theoretical calculations including perturbative QCD contributions predict values of 12% or above [2].

The measurement presented here employs the method introduced by ARGUS [3] and later used by CLEO [4], in which $B\overline{B}$ events are tagged by the presence of a high momentum lepton. As a tag, we choose electrons with momentum p^* in the interval 1.4 to 2.3 GeV/c, where p^* is measured in the center-of-mass frame. A second electron in the event is taken as the signal lepton for which we require $p^* > 0.6\,\mathrm{GeV}/c$, to avoid large backgrounds at lower momenta. Signal electrons are mostly from primary B decays if they are accompanied by a tag electron of opposite charge (unlike-sign). Those with a tag of the same charge (like-sign) originate predominantly from secondary decays of charm particles produced in the decay of the other B meson. Inversion of this charge correlation due to $B^0\overline{B}^0$ mixing is treated explicitly, and unlike-sign pairs with both electrons originating from the same B meson are isolated kinematically. With a small model-dependence on the estimated fraction of primary electrons below $p^* = 0.6\,\mathrm{GeV}/c$, we infer the semileptonic B branching fraction from the background corrected ratio of unlike-sign electron pairs to tag electrons.

This measurement is based on data recorded in the year 2000 with the *BABAR* detector [5] at the PEP-II energy asymmetric e^+e^- storage ring [6] at SLAC. The detector consists of a five-layer silicon vertex tracker (SVT), a 40-layer drift chamber (DCH), a detector of internally-reflected Cherenkov light (DIRC), and an electromagnetic calorimeter (EMC) all embedded in a solenoidal magnetic field of 1.5 T and surrounded by an instrumented flux return (IFR). To ensure the high quality of the data, we have selected the largest contiguous block of events with identical and stable detector conditions in the year 2000, corresponding to an integrated luminosity of $4.1\,\mathrm{fb}^{-1}$ collected at the $\Upsilon(4S)$ resonance, and $0.97\,\mathrm{fb}^{-1}$ recorded about 40 MeV below the $\Upsilon(4S)$ peak (off-resonance).

Multihadron events are selected by requiring a charged track multiplicity of $N_{\mathrm{ch}} > 4$, or $N_{\mathrm{ch}} = 4$ plus at least 2 neutral energy deposits above 80 MeV in the EMC. Track pairs from converted photons are not included in N_{ch}, but count as one neutral particle. For further suppression of non-$B\overline{B}$ events, we require $R_2 < 0.6$, where R_2 is the ratio of Fox-Wolfram moments H_2/H_0 [7].

The electron momentum measurement and identification are critical for this analysis. For electron candidates we require hits in at least 12 DCH layers, and a polar angle θ within the EMC acceptance, i.e. $-0.72 < \cos\theta < 0.92$. To reduce the contamination from photon conversions and beam-gas background we require the track impact parameters in the plane perpendicular to the beams and along the detector axis to be less than 0.25 cm and 3.0 cm, respectively.

The track finding efficiency ϵ_{trk} is determined from data as a function of charged multiplicity, transverse momentum, polar and azimuthal angle. For signal electrons with $p^* > 0.6\,\mathrm{GeV}/c$, the average efficiency is $(97.1 \pm 1.1)\%$.

Electron identification is based on the ratio of the energy in the EMC and the track momentum, E_{EMC}/p, the shower shape in the EMC, the specific energy loss $\mathrm{d}E/\mathrm{d}x$ in the DCH, and the number of Cherenkov photons and the Cherenkov angle measured in the DIRC. Muons are eliminated on the basis of $\mathrm{d}E/\mathrm{d}x$ and E_{EMC}/p. Taking into account the correlations between deposited energy and shape in hadronic showers, we combine probability density functions derived from data samples for each discriminating variable to construct the likelihood function $L(\xi)$, $\xi \in \{e, \pi, K, p\}$. A track is identified as an electron if

$$\frac{L(e)}{L(e) + 5\,L(\pi) + L(K) + 0.1\,L(p)} > 0.95\ .$$

The weights roughly reflect the relative abundances, their exact values not being crucial for electron identification.

We measure the electron identification efficiency as a function of p^* and center-of-mass polar angle θ^* using radiative Bhabha events. For momenta $p^* > 0.6\,\mathrm{GeV}/c$, the average efficiency is 92% (see Figure 1a). However, Monte Carlo simulations indicate that relative to radiative Bhabha events, the identification efficiency in $B\overline{B}$ events is reduced between $(4\pm2)\%$ at low momenta ($p^* < 1\,\mathrm{GeV}/c$) and $(2\pm1)\%$ above $p^* = 1.6$ GeV/c. We correct the measured efficiency for this momentum-dependent difference.

The misidentification rates for pions, kaons, and protons are extracted from control samples selected from data. Figure 1b shows the misidentification probabilities η_h per hadronic track, where the relative abundance of pions, kaons, and protons is taken from $B\overline{B}$ Monte Carlo simulation. The DCH and DIRC contribute significantly at low momenta, while the performance of the EMC increases with p^*. This leads to a minimum of 0.05% for η_h at $1 < p^* < 1.3\,\mathrm{GeV}/c$. The relative systematic error is estimated to be 15% from the purities of the control samples and the uncertainties in the relative abundances.

The branching fraction analysis makes use of three samples: (1) the tag electrons, (2) unlike-sign and (3) like-sign pairs of a tag and a signal electron candidate. Misidentified hadrons and electrons from non-$B\overline{B}$ (continuum) events, photon conversions, $\pi^0, \eta \to$

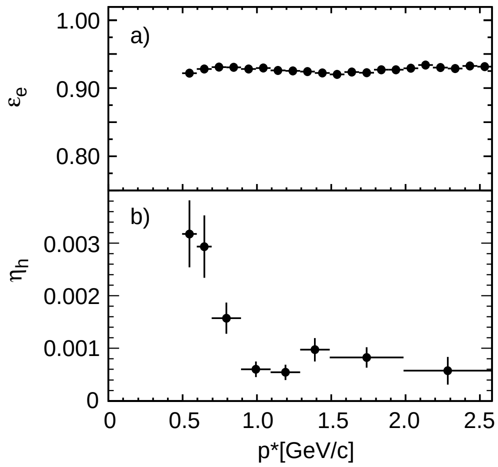

FIG. 1: Electron identification efficiency ϵ_e as obtained from radiative Bhabha events (a) and hadron misidentification rate η_h (b) as a function of p^*.

γe^+e^-("Dalitz") and $J/\psi, \psi(2S) \rightarrow e^+e^-$ decays contribute to the background in all three samples. The unlike-sign sample also contains pairs of primary and secondary electrons from the same B meson decay. Further contaminations to the like- and unlike-sign samples arise from decays of τ leptons and charmed mesons produced in $b \rightarrow c\bar{c}s$ decays. Apart from the correction for unlike-sign electron pairs from the same B, which is performed in bins of p^* only, all background corrections are performed in bins of p^* and polar angle θ^*.

The continuum background is subtracted from all three samples. It is obtained by normalizing the observed off-resonance spectra by the ratio of on- to off-resonance integrated luminosities. The relative systematic error in this ratio is estimated to be 0.5%, attributed to variations in the detector performance over time. The continuum momenta are scaled by the ratio $\sqrt{s_{on}}/\sqrt{s_{off}}$ to compensate for the 0.4% lower center-of-mass energy.

Electrons from photon conversions and Dalitz decays are identified by pairing them with any oppositely charged track with transverse momentum $p_t > 0.1\,\mathrm{GeV}/c$. We distinguish the two sources of pairs by the distance R_{pair} of the pair vertex from the detector axis. Photon conversions are identified by requiring $R_{pair} > 1.6\,\mathrm{cm}$, a pair invariant mass $M_{ee} < 100\,\mathrm{MeV}/c^2$, and the transverse and longitudinal distances between the two tracks at the point of closest approach $\Delta_{xy} < 0.3\,\mathrm{cm}$ and $\Delta_z < 1.0\,\mathrm{cm}$. For Dalitz pairs, we require $R_{pair} < 1.6\,\mathrm{cm}$, $M_{ee} < 200\,\mathrm{MeV}/c^2$, $\Delta_{xy} < 0.2\,\mathrm{cm}$ and $\Delta_z < 1.0\,\mathrm{cm}$. The momentum- and polar angle-dependent pair finding efficiency, which is obtained from a full detector simulation, is low since, in most cases, the momentum of the second track is too small to produce a track in the DCH. It varies between 30% and 40% for photon conversions and between 20% and 30% for Dalitz pairs. From a detailed comparison between data and simulation, including the energy spectra of the pairs, the relative systematic uncertainties are estimated to be 13% and 19% for the conversion and Dalitz background rates, respectively.

In the unlike-sign sample, electrons from primary and charm decays of the same B tend to be produced in opposite directions. Defining $\hat{p}^*_e$ as the center of the signal electron momentum bin, this background is reduced by a factor of 24 by imposing the condition

$$\cos\alpha > 1.0 - \hat{p}^*_e/\ (\mathrm{GeV}/c) \quad \text{and} \quad \cos\alpha > -0.2 \qquad (1)$$

on the opening angle α of e^+e^- pairs, measured in the $\Upsilon(4S)$ frame. Since B mesons are nearly at rest in this frame, there is no angular correlation between two electrons from different B mesons, and the loss in signal efficiency can be calculated on the basis of geometrical acceptance.

This selection also eliminates most e^+e^- pairs from inclusive $B \rightarrow J/\psi X$ decays. Electron candidates that can be combined with an oppositely charged electron to form an invariant mass consistent with the J/ψ hypothesis, $2.90 < M_{ee} < 3.15\,\mathrm{GeV}/c^2$, are excluded from the tag sample if $\cos\alpha < -0.2$.

The contribution of unlike-sign pairs from the same B decay satisfying Eq. 1 is approximately 2%. After subtraction of background contributions from continuum, photon conversions and Dalitz decays, the observed opening angle distribution (without the requirement) contains a flat contribution from electron pairs from different B mesons and a contribution from electron pairs from the same B, which peaks at $\cos\alpha = -1$. The shape of the non-flat background is taken from Monte Carlo simulation and the relative normalization of the two contributions is determined by a fit to the data, which is performed separately for each 100 MeV/c-wide momentum bin below 1.2 GeV/c. The integral over the fitted non-flat contribution between the minimal allowed value of $\cos\alpha$ and 1 is taken as the residual background (Figure 2). The very small background above 1.2 GeV/c (0.8% of the total contribution) is determined from Monte Carlo simulation with a relative uncertainty of 50%.

We have studied systematic uncertainties in the predicted opening angle distributions by varying the branching fractions of $B \rightarrow De\nu$, $B \rightarrow D^*e\nu$, $B \rightarrow D^{**}e\nu$ and non-resonant $B \rightarrow D^{(*)}\pi e\nu$ decays by one standard deviation around current average values [1]. Based on detailed studies and variations of the fit, the combined systematic error for this background is estimated to be 5%.

Figure 3 shows the observed momentum spectra and the individual background contributions discussed so far, corrected for tracking efficiency; a summary of yields is

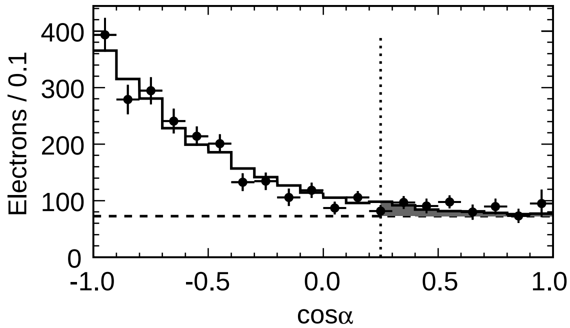

FIG. 2: Distribution of the cosine of the opening angle of unlike-sign pairs for $0.7 < p^* < 0.8\,\mathrm{GeV}/c$. The points represent the data and the histogram is the result of a fit. The shaded area represents the estimated contribution of background electrons, and the vertical dashed line indicates the requirement on the opening angle.

given in Table I. Following this initial set of background corrections, the electron yield is corrected for electron identification efficiency.

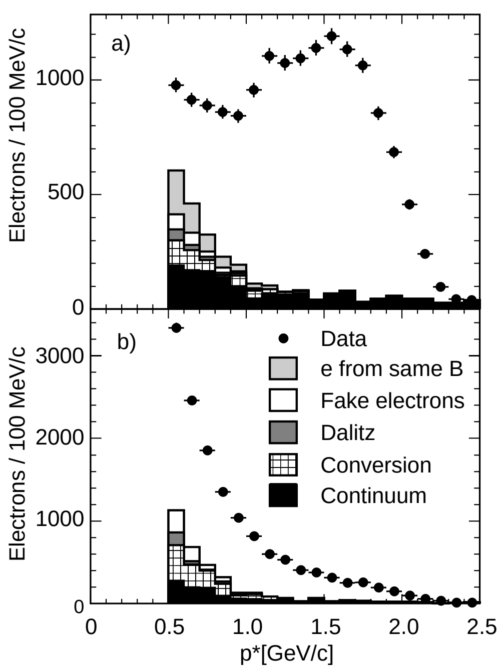

FIG. 3: Total measured spectrum (points) and estimated backgrounds (histograms) for signal electron candidates in (a) the e^+e^- sample, and (b) the $e^\pm e^\pm$ sample.

Background contributions from $B \to \overline{D}D_{(s)}X$, $D_{(s)} \to e\nu_e Y$ decays and $B \to \tau \to e$ decays are estimated by Monte Carlo simulation, using the currently known branching fractions. Combining $\mathcal{B}(D_s \to Xe\nu) = (8.12 \pm 0.68)\%$, which is computed from the average D branching fraction $\mathcal{B}(D^{0,+} \to Xe\nu)$ [1] and the lifetime ratios $\tau_{D^{0,+}}/\tau_{D_s}$, with $\mathcal{B}(B \to D_s X) = (9.8 \pm 3.7)\%$ [8] yields $\mathcal{B}(B \to D_s \to e) = (0.80 \pm 0.31)\%$. We take the inclusive branching fraction $\mathcal{B}(B \to \overline{D}D^{(*)}X)$ to be $(8.2 \pm 1.3)\%$ [8]. Assuming equal production rates of D and D^*, but allowing for any ratio in the systematic error, we arrive at $\mathcal{B}(B \to D \to e) = (0.84 \pm 0.21)\%$. To estimate the contribution of electrons from τ decays, we use $\mathcal{B}(B \to X\tau\nu) = (2.6 \pm 0.2)\%$, $\mathcal{B}(D_s \to \tau\nu) = (5.79 \pm 2.00)\%$ [9] and $\mathcal{B}(\tau \to e\ \nu_e\overline{\nu}_\tau) = (17.83 \pm 0.06)\%$ [1]. This leads to $\mathcal{B}(B \to \tau \to e) = (0.565 \pm 0.063)\%$, where the τ lepton originates either directly from a B decay or a $B \to D_s \to \tau$ cascade. The background from J/ψ and $\psi(2S)$ decays into two electrons is also estimated from Monte Carlo simulation, with $\mathcal{B}(B \to J/\psi \to e^+e^-) = (6.82 \pm 0.38) \times 10^{-4}$ and $\mathcal{B}(B \to \psi(2S) \to e^+e^-) = (3.1 \pm 0.6) \times 10^{-5}$ [1].

The tag electron sample is first corrected for continuum background and hadron misidentification. The remaining background is from secondary decays of charm particles and unvetoed $J/\psi \to e^+e^-$ decays. All these contributions are estimated by Monte Carlo simulation, leading to the background-subtracted number of tag electrons $N_{\mathrm{tag}} = 304{,}048 \pm 880(\mathrm{stat}) \pm 2{,}100(\mathrm{syst})$ (Table I), including a correction for signal loss due to the J/ψ-veto.

Due to $B^0\overline{B}^0$ flavor oscillations, electrons from primary B decays and $B \to \overline{D}X$, $\overline{D} \to e^-\nu_e Y$ cascades contribute to both unlike- and like-sign spectra. Denoting the efficiency of the opening angle cut as $\epsilon_\alpha(p^*)$, their p^* distributions can be written as

$$\frac{1}{\epsilon_\alpha(p^*)}\frac{dN^{+-}}{dp^*} = \frac{dN_{B\to Xe\nu}}{dp^*}\,(1-\chi) + \frac{dN_{B\to\overline{D}\to Xe\nu}}{dp^*}\,\chi\ ,$$

$$\frac{dN^{\pm\pm}}{dp^*} = \frac{dN_{B\to Xe\nu}}{dp^*}\,\chi + \frac{dN_{B\to\overline{D}\to Xe\nu}}{dp^*}\,(1-\chi)\ ,$$

where χ is the product of the $B^0\overline{B}^0$ mixing parameter $\chi_0 = 0.174 \pm 0.009$ [1] and $f_0 = \mathcal{B}(\Upsilon(4S) \to B^0\overline{B}^0)$. Since the measured ratio of charged to neutral $\Upsilon(4S)$ decays is consistent with unity [10], we assume $f_0 = 0.500 \pm 0.025$, where the error is taken from [10]. We use these linear equations to determine the primary electron spectrum from B decays, $dN_{B\to Xe\nu}/dp^*$. Integration of this spectrum between 0.6 and 2.5 GeV/c yields $N_{B\to Xe\nu} = 25{,}070 \pm 410(\mathrm{stat})$. Using Monte Carlo simulation, we determine the relative efficiency for selecting events with two electrons compared to events with a single tag to be $\epsilon_{evt} = (98.0 \pm 0.5)\%$. Together with the polar angle acceptance $\epsilon_{geom} = 84\%$, we obtain the partial branching

TABLE I: Electron yield for the three samples and corrections with statistical and systematic errors.

	(1) tag sample $1.4 < p^* < 2.3$ GeV/c	(2) e^+e^- sample , cut on α $0.6 < p^* < 2.5$ GeV/c	(3) $e^\pm e^\pm$ sample, all α $0.6 < p^* < 2.5$ GeV/c
On $\Upsilon(4S)$	$395{,}791 \pm 630$	$14{,}692 \pm 120$	$10{,}838 \pm 110$
Continuum	$82{,}073 \pm 590 \pm 410$	$1{,}301 \pm 76 \pm 7$	$939 \pm 64 \pm 5$
$\gamma \to e^+e^-$	$561 \pm 23 \pm 140$	$283 \pm 40 \pm 37$	$856 \pm 82 \pm 110$
$\eta, \pi^0 \to \gamma e^+e^-$	$92 \pm 9 \pm 23$	$51 \pm 22 \pm 10$	$80 \pm 82 \pm 15$
Faked e	$1{,}455 \pm 140 \pm 360$	$136 \pm 16 \pm 20$	$348 \pm 48 \pm 52$
e from same B		$317 \pm 7 \pm 16$	
Yield before and	$311{,}610 \pm 870 \pm 570$	$12{,}603 \pm 150 \pm 46$	$8{,}616 \pm 180 \pm 120$
after eff. corr.		$14{,}134 \pm 180 \pm 170$	$9{,}734 \pm 190 \pm 200$
$B \to \tau \to e$		$353 \pm 17 \pm 42$	$93 \pm 9 \pm 11$
$B \to D_s \to e$		$293 \pm 19 \pm 110$	$72 \pm 9 \pm 28$
$B \to D \to e$		$226 \pm 16 \pm 57$	$65 \pm 8 \pm 16$
Secondary tags	$8{,}073 \pm 91 \pm 2{,}000$	$296 \pm 17 \pm 74$	$886 \pm 29 \pm 220$
e from J/ψ or $\psi(2S)$	$1{,}925 \pm 42 \pm 120$	$77 \pm 8 \pm 5$	$119 \pm 10 \pm 7$
e removed by J/ψ veto	$-(2{,}435 \pm 50 \pm 220)$		
Net e yield	$304{,}048 \pm 880 \pm 2{,}100$	$12{,}890 \pm 180 \pm 230$	$8{,}500 \pm 200 \pm 300$

fraction

$$\mathcal{B}(B \to Xe\nu, p^* > 0.6\,\mathrm{GeV}/c) = \frac{N_{B\to Xe\nu}}{N_{tag}\ \epsilon_{brem}\ \epsilon_{evt}\ \epsilon_{geom}} = (10.24 \pm 0.17(\mathrm{stat}) \pm 0.26(\mathrm{syst}))\%\ ,$$

which includes a correction for the small loss of electrons due to bremsstrahlung in the detector material and the limited momentum resolution, $1-\epsilon_{brem} = (2.20\pm0.35)\%$. The contributions to the systematic error are listed in Table II. Figure 4 shows the momentum spectrum of primary electrons.

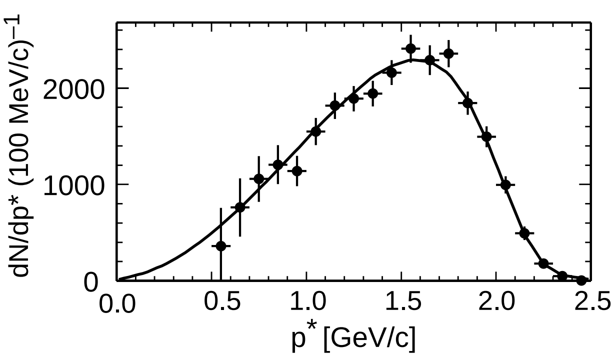

FIG. 4: Momentum spectrum of electrons from decays $B \to Xe\nu$ after correction for efficiencies and external bremsstrahlung, with combined statistical and systematic errors. The curve indicates the fit used for the extrapolation to $p^* = 0$.

To determine the total semileptonic branching fraction, we need to extrapolate the spectrum to $p^* = 0$. This is achieved by fitting the data to the sum of the spectra from the various exclusive decays. We use a parameterization of HQET-derived form factors [11, 12] to model the decays $B \to De\nu$ and $B \to D^*e\nu$, and the work of Goity and Roberts [13] for non-resonant $B \to D^{(*)}\pi e\nu$ decays. Semileptonic B decays to $D^{**}e\nu$ and charmless mesons are described by the ISGW2 model [14], which is also used as an alternative description for the processes $B \to De\nu$ and $B \to D^*e\nu$. Photon radiation in the final state is modeled by PHOTOS [15]. The relative contributions of the different exclusive decay modes are constrained to be within two standard deviations of the measured average branching fractions [1]. The best estimate for the extrapolation factor is $1+\kappa = 1.061 \pm 0.009$, where the error accounts for the observed variations of the fit results for different decay models and branching fractions. This extrapolation leads to a total semileptonic branching fraction $\mathcal{B}_{SL}$ of

$$\mathcal{B}(B \to Xe\nu) = (10.87 \pm 0.18(\mathrm{stat}) \pm 0.30(\mathrm{syst}))\%\ .$$

One of the limiting factors of this analysis is the background at low momenta, especially semileptonic decays of charmed mesons produced in $b \to c\bar{c}s$ decays. As shown in Table III, raising the minimum momentum requirement p^*_{min} reduces the systematic uncertainty due to this background substantially, but also increases the error on the extrapolation to $p^* = 0$. We choose $p^*_{min} = 0.6$ GeV/c for the final result, since the systematic error is com-

TABLE II: Impact of systematic uncertainties on $\mathcal{B}_{SL}$.

Source	$\Delta\mathcal{B}_{SL}(\%)$	Source	$\Delta\mathcal{B}(\%)$
e efficiency	0.144	$B \to \tau \to e$	0.044
$B \to D_s \to e$	0.130	$\gamma \to e^+e^-$	0.042
ϵ_{trk}	0.120	ϵ_{brem}	0.039
extrapolation	0.092	faked e	0.024
N_{tag}	0.075	e from same B	0.022
$B \to D \to e$	0.067	$\pi^0, \eta \to \gamma\, e^+e^-$	0.014
mistagged e	0.061	continuum	0.008
$f_0\chi_0$	0.059	$J/\psi\,, \psi(2S) \to e^+e^-$	0.003
ϵ_{evt}	0.054		
Total			0.296

parable with higher values of p^*_{min}, while the model-dependence is significantly lower.

TABLE III: Determination of κ, $\mathcal{B}_{SL}$, and the contributions to the systematic error for different signal electron momentum cut-offs. All numbers are stated in percent.

p^*_{min}[GeV/c]	0.5	0.6	0.7	0.8	0.9	1.0
κ	3.8	6.1	9.3	13.6	19.2	27.2
$\mathcal{B}_{SL}$	10.79	10.87	10.87	10.82	10.80	10.93
$\Delta\mathcal{B}_{SL}(\gamma, \pi^0)$	0.07	0.04	0.03	0.02	0.02	0.01
$\Delta\mathcal{B}_{SL}(\epsilon_{trk})$	0.12	0.12	0.12	0.12	0.12	0.12
$\Delta\mathcal{B}_{SL}(e$ eff.$)$	0.15	0.14	0.14	0.12	0.11	0.10
$\Delta\mathcal{B}_{SL}(B \to D_s)$	0.17	0.13	0.09	0.06	0.05	0.04
$\Delta\mathcal{B}_{SL}(B \to D)$	0.10	0.07	0.05	0.03	0.02	0.01
$\Delta\mathcal{B}_{SL}(B \to \tau)$	0.05	0.04	0.04	0.03	0.03	0.02
$\Delta\mathcal{B}_{SL}$(extrapolation)	0.06	0.09	0.13	0.19	0.25	0.33
$\Delta\mathcal{B}_{SL}$(other)	0.15	0.14	0.14	0.15	0.15	0.17
$\Delta\mathcal{B}_{SL}$(syst)	0.33	0.30	0.29	0.30	0.34	0.41
$\Delta\mathcal{B}_{SL}$(stat)	0.21	0.18	0.16	0.16	0.15	0.15

Based on the work by Hoang *et al.* [16], we relate the decay rate and the modulus of the CKM matrix element V_{cb} by

$$|V_{cb}| = (41.9 \pm 2.0) \times 10^{-3} \times \sqrt{\mathcal{B}(B \to X_c e\nu)/\, 0.105}\, \sqrt{1.6\,\mathrm{ps}/\tau_B}.$$

Using $\tau_B = (1.601 \pm 0.021)$ ps and $\mathcal{B}(B \to X_u e\nu) = (1.7 \pm 0.6) \times 10^{-3}$ [1] , we obtain $|V_{cb}| = 0.0423 \pm 0.0007(\mathrm{exp}) \pm 0.0020(\mathrm{theory})$.

In conclusion, we have used electrons in $\Upsilon(4S)$ decays tagged by a high momentum electron to measure $\mathcal{B}(B \to Xe\nu)$= $(10.87 \pm 0.18(\mathrm{stat}) \pm 0.30(\mathrm{syst}))\%$. This measurement is largely model-independent. The result is in agreement with previous measurements [4, 17], but the systematic uncertainties are reduced. However, the poorly known branching fractions in B and $D_{(s)}$ decays lead to significant systematic uncertainties in the background subtraction. The resulting measurement of $|V_{cb}|$ remains dominated by theoretical uncertainties. It has recently been shown that non-perturbative effects can be assessed by measurements of moments of inclusive distributions [18].

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