RECENT RESULTS ON SEMILEPTONIC B DECAYS FROM CLEO

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I discuss recent measurements from CLEO of the form factors in $\bar{B}^0 \rightarrow D^{*+}\ell^-\bar{\nu}$ and of the semileptonic B branching ratio in a model independent way.

Introduction

The semileptonic decays of the heavy flavors provide a unique window to the weak interaction. Studies of semileptonic B meson branching fractions provide measures of two of the Cabibbo-Kobayashi-Miskawa matrix elements, V_{cb} and V_{ub}. Now these studies have entered a new stage where the dynamics of semileptonic heavy meson decays are being considered to test the detailed predictions of theoretical models and reduce the dependence on such models when extracting the parameters of the weak interaction. The CESR collider and the CLEO detector provide an unparalleled laboratory to study such decays. This is due to the high luminosity of the collider and efficient operation which have led to a very large data set, over 2.0/fb of integrated luminosity at the $\Upsilon(4S)$ resonance and about half that integrated luminosity at 60 MeV below the resonance for subtraction of continuum processes. With the the $\Upsilon(4S)$ cross section at roughly 1.0 nb this correspond to four million B meson decays.

The CLEO detector[1] is a multipurpose detector of charged tracks and photons over more than 90% of 4π. Electrons are identified by requiring an energy deposition in the CsI crystal, electromagnetic calorimeter that is close to the measured momentum in the drift chamber tracking system, and a specific ionization (dE/dx) consistent of that expected for an electron. The efficiency for electron identification is 94% and is confined to the central region of the detector ($|\cos\theta| < 0.71$). The fake rate is below 0.5%. Electrons are identified down to a momentum to 600 MeV/c. This lower cutoff is dictated by the requirement that the curling electron strike the carlorimeter nearly perpendicular rather than at a high grazing angle.

Muons are identified as tracks that penetrate over 5 nuclear absorbtion lengths of the instrumented iron return yoke of the supreconducting solenoid. As for electrons muon identification is confined to the central region ($|\cos\theta| < 0.61$) and has an efficiency of 93%. The muon fake rate is about 1.5%. This penetration requirement implies that muons can only be identified at momenta greater than 1.4 GeV/c.

In this submission I will be covering two recent results. The important new results on exclusive $b \to u\ell\nu$ transitions as seen in $B \to \pi\ell\nu$, which I covered in my talk, are discussed in full detail elsewhere in these proceedings.[2] Here I will discuss measurements of the form factors in $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}$ and of the semileptonic B branching ratio in a model independent way.

Form Factors in $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}$

The differential decay rate for $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}$ can be expressed in terms of three q^2, the square of the mass of the virtual W, dependent helicity amplitudes $H_\pm(q^2)$ and $H_0(q^2)$, where the subscripts refer to the helicity of either the virtual W or the D^*. The rate depends not only on q^2, but also the cosine of the decay angle of the charged lepton in the W rest frame ($\cos\theta_\ell$), the cosine of the decay angle of the D in the D^* rest frame ($\cos\theta_V$), and the angle between the W and D^* decay planes (χ). The helicity amplitudes can be expressed in terms of two axial-vector form factors, $A_1(q^2)$ and $A_2(q^2)$, and a vector form factor $V(q^2)$. In the limit of a very large b

quark mass as compared with Λ_{QCD}, these form factors are related to the Isgur-Wise function ξ:

$$V(q^2) = A_2(q^2) = A_1(q^2)\left[1 - \frac{q^2}{(m_b + m_{D^*})^2}\right]^{-1} = \frac{2\sqrt{m_B m_{D^*}}}{m_B + m_{D^*}}\xi(q^2). \tag{1}$$

Following Neubert,[3] we define the form factor ratios

$$R_1 \equiv \left[1 - \frac{q^2}{(m_B + m_{D^*})^2}\right]\frac{V(q^2)}{A_1(q^2)} \tag{2}$$

$$R_2 \equiv \left[1 - \frac{q^2}{(m_B + m_{D^*})^2}\right]\frac{A_2(q^2)}{A_1(q^2)}, \tag{3}$$

which are predicted to be unity up to $1/m_b$, $1/m_c$, and α_s corrections. The normalization is $\xi(q^2 = {q^2}_{max}) = 1$. Neubert estimates these model dependent corrections to give $R_1 \approx 1.3$, $R_2 \approx 0.8$, and introduce mild q^2 dependence. To account for this last effect we assume a linear form for the Isgur-Wise function

$$\xi(q^2) = 1 - \rho^2\left(\frac{(m_B{}^2 + m_D^*{}^2 - q^2)}{2m_B m_D^*} - 1\right), \tag{4}$$

while R_1 and R_2 are assumed to be constant. In experimental terms R_1 is related to the forward backward asymmetry of the charged lepton, R_2 is related to the ratio of longitudinal to transverse D^* polarization, and ρ^2 is the slope of the q^2 dependence.

The startegy of this analysis[4] is to obtain a signal with low background and fit in four dimensions (q^2, $\cos\theta_\ell$, $\cos\theta_V$, and χ) for R_1, R_2, and ρ^2. We select events with one charged lepton, a D^{*+} reconstructed in the $D^{*+} \to D^0\pi^+$ mode, a D^0 reconstructed in either $D^0 \to K^-\pi^+$ or $D^0 \to K^-\pi^+\pi^0$, and kinematics consistent with a neutrino from B^0 decay recoiling against the $D^{*+}\ell$ system. Background arises mainly from fake D^{*+} from combintorics, and feed down from $B \to D^{**}\ell\nu$ and $B \to D^*\pi\ell\nu$. We observe a total of 783 ± 28 candidates in both D^+ decay modes and estimate, both from the data and with Monte Carlo simulation, that 127 ± 28 of these are background.

The resulting resolution on the four kinematic variables are q^2 dependent, with typical values $\sigma(q^2) \approx 0.5\mathrm{GeV}^2/c^4$, $\sigma(\cos\theta_\ell) \approx 0.07$, $\sigma(\cos\theta_V) \approx 0.07$, and $\sigma(\chi) \approx 0.24$. Besides these non-negligible smearings we must take into account detector acceptance mainly brought on by poor detection efficiency for charged pions with momenta less than about 100 MeV/c and the low momentum cutoff for leptons. The four dimensional distribution is fit using the unbinned maximum likelihood method. To fully incorperate smearing and acceptance effects, we use a Monte Carlo Technique[5] to evaluate the likelihood function. Background distributions are taken from a Monte Carlo simulation, and checked with data.

Figure 1 shows the distribution of the four kinematic variables after all cuts are applied. They are well described by the fit. Table 1 shows the results of the fit. The systematic errors are dominated by uncertainties in the amount and distribution of the backgrounds, and the fit method which is sensitive to finite Monte Carlo statistics. Detector effects are small except for

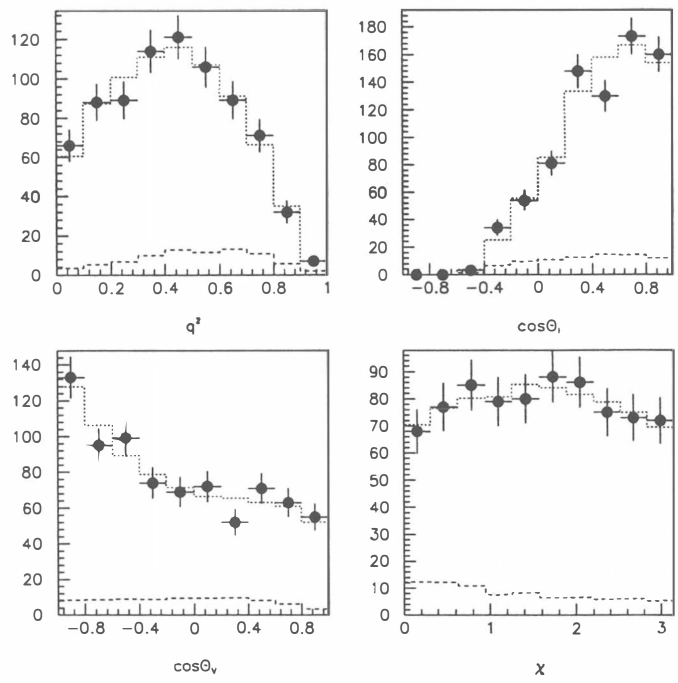

Figure 1: The distribution of the four variables used in the fit after all cuts. The points with the error bars are the data, the dotted histogram is the result of the fit, and the dashed histogram is background contribution.

Table 1: The results of the fit with the correlation coefficients.

Fit Parameters		Correlation Coefficients	
R_1	$1.30 \pm 0.36 \pm 0.16$	$C(R_1R_2) = -0.83$	$C(R_1\rho^2) = 0.63$
R_2	$0.64 \pm 0.26 \pm 0.12$		$C(R_2\rho^2) = 0.82$
ρ^2	$1.01 \pm 0.15 \pm 0.09$		

ρ^2 as the efficiency as a function of q^2 depends on the detection efficiency of the slow pion from the D^* decay. The systematic errors are displayed inTable 1.

The results we obtain agree well with the predictions of the heavy-quark symmetry limit, with the corrections predicted by Neubert. These results indicate that the corrections appear to be fairly small and calcuable. This gives confidence in the use of heavy-quark symmetry precision extraction of $|V_{cb}|$ from $B \to D^*\ell\nu$ as was done in a previous analysis from CLEO.[6)]

Model Independent Measure of $\mathcal{B}(B \to Xe\nu)$

The semileptonic branching fraction of the B meson has been a persistent puzzle in heavy flavor physics. Most experimental measurments have been below 11% while theoretical expectations have been higher. Recent theoretical work is consistent with the experimental results for the semileptonic decay,[7)] but require a branching fraction of $b \to ccs$ larger than indicated by experiment.[8)] Here we discuss a model independent measure of the B semileptonic branching fraction using dilepton events based on a technique pioneered by ARGUS.[9)] High-momentum leptons are used as a tag to seperate leptons from B decay from those from charm decay. By comparison with measurements from the single-lepton momentum spectrum[10)] a new limit is placed on the fraction of $\Upsilon(4S)$ decays to non-$B\bar{B}$ final states.

We select events with tag leptons of momentum greater than 1.4 GeV/c. These are predominantly from the semileptonic decay of one of the two B mesons from the $\Upsilon(4S)$ decay. When a tag is found, we search for an accompanying electron with momentum above 0.6 GeV/c. These have three possible sources. Semileptonic decays of the other B give an electron of the opposite charge as the tag. Semileptonic decays of D's from the other B give electrons of the same charge as the tag while D's from the same B as the tag yield electrons of the opposite charge as the tag. $B^0\bar{B}^0$ mixing affects a small and well known portion of these events. Since the B's are produced almost at rest tag leptons and electrons from the same B tend to be back-to-back. This correlation depends on the electron momentum, p_e, and we have found that the diagonal cut $p_e + \cos\theta_{\ell e} > 1$ supresses same-B background by a factor of 25 and keeps 67% of the opposite-B electron signal. We find 11750 ± 127 opposite sign leptons pairs and 7062 ± 96 like sign pairs after subtracting the scaled continuum data.

This selection introduces negligible selection bias for the various semileptonic B decay modes ($D\ell\nu$, $D^*\ell\nu$, $D^{**}\ell\nu$, and possible non-resonant decays), and only a 2.8 ± 0.5% fraction of unlike sign events where both leptons are from the same B decay. Various backgrounds including fake leptons, leptons from $c\bar{c}$ mesons, γ conversions, $B \to X\tau$, and false tags from charm decays are then subtracted from the unlike- and like-sign spectra. Respectively these backgrounds ammount to (15.4 ± 2.0)% and (24.7 ± 4.6)% of the continuum subtracted spectra. The background subtracted unlike- and like-sign spectra are corrected for efficiency and the effects of B^0-$\bar{B}^0$ mixing to obtain the $B \to Xe\nu$ and $b \to c \to ye\nu$ spectra as displayed in Figure 2. We

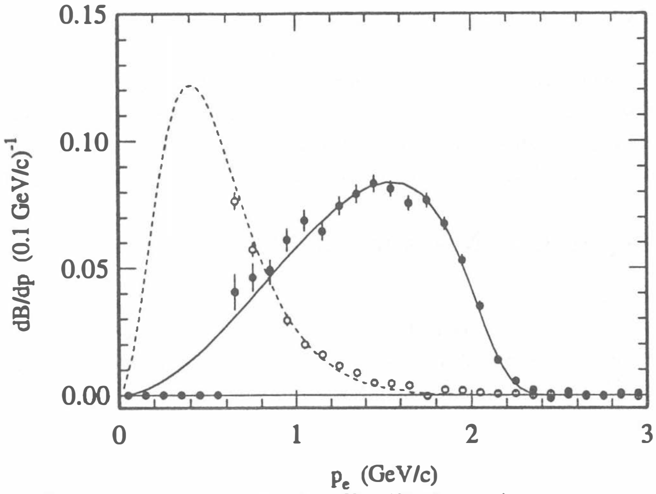

Figure 2: Spectra for electrons from $B \to Xe\nu$ (filled circles) and $b \to c \to ye\nu$ (open circles). The curves show the results of fits to the ISGW model.

then use theoretical models[11] to correct for the undetected part of the spectra below 0.6 GeV/c. We find

$$\mathcal{B}(B \to Xe\nu) = (10.49 \pm 0.17 \pm 0.43)\%. \tag{5}$$

From this we obtain $|V_cb| = 0.041 \pm 0.001 \pm 0.004$.

For the secondary electrons we find $\mathcal{B}(b \to c \to ye\nu) = (7.8 \pm 0.2 \pm 1.2)\%$ for the spectator model of Altarelli *et al.* and $(8.3 \pm 0.2 \pm 1.2)\%$ for the ISGW model. Note that these 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 have been subtracted as background.

By comparing the results of this lepton tagged measure of with the results of the single lepton spectra for $\mathcal{B}(B \to Xe\nu)$ we can set a limit on non-$B\bar{B}$ decays of the $\Upsilon(4S)$ at less than 3.4% at the 95% confidence level.

Conclusion

The two results described here are examples of the physics capabilities of CESR and CLEO. The large data set and good detector allow for low background precision measurments such as the form factors in $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}$ and tagged measurements with significantly reduced systematic errors but still with good statistical power such as $\mathcal{B}(B \to Xe\nu)$. These and other results are unlocking the secrets of the weak interaction by opening up a new level of comparison between experiment and theory.

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