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Review of Radiative and Semileptonic B Decays *

S. H. Robertson
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

Abstract

Recent experimental results on radiative and semileptonic B meson decays are described. Measurements of inclusive and exclusive $b \to s\gamma$ and $b \to s\ell^+\ell^-$ decays, and exclusive $B \to \rho\gamma$ and $B \to K\nu\bar{\nu}$ penguin decays are presented. The extraction of $|V_{cb}|$ from inclusive $B \to X_c\ell\nu$ decays and from exclusive $B \to D^*\ell\nu$ decays is also discussed.

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REVIEW OF RADIATIVE AND SEMILEPTONIC B DECAYS

S. H. Robertson
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ABSTRACT

Recent experimental results on radiative and semileptonic B meson decays are described. Measurements of inclusive and exclusive $b \to s\gamma$ and $b \to s\ell^+\ell^-$ decays, and exclusive $B \to \rho\gamma$ and $B \to K\nu\bar{\nu}$ penguin decays are presented. The extraction of $|V_{cb}|$ from inclusive $B \to X_c\ell\nu$ decays and from exclusive $B \to D^*\ell\nu$ decays is also discussed.

1 Introduction

Radiative and semileptonic decays of B mesons are sensitive to a number of CKM matrix elements for which experimental measurements are needed to constrain the unitarity triangle describing CP-violation in the B meson system of the Standard Model (SM). In addition, radiative decays are expected to have significant sensitivity to new physics.

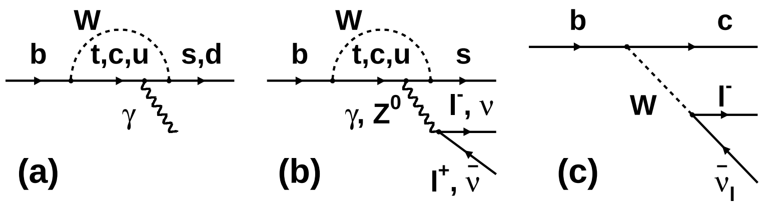

Figure 1: *Feynman diagrams for semileptonic and radiative B decays: (a)* $b \to s\gamma$ *and* $b \to d\gamma$*, (b)* $b \to s\ell^+\ell^-, s\nu\bar{\nu}$*, (c)* $b \to c\ell\bar{\nu}$*.*

Over the past few years there has been significant experimental progress in the study of these decays. This is due mainly to the large data sets ($\sim$ 50 M $B\bar{B}$ events) collected by the two asymmetric B factory experiments, Babar and Belle, but with significant contributions also from the CLEO experiment in spite of a somewhat smaller data sample. This review will discuss recent experimental results on radiative $b \to s\gamma$ and $b \to d\gamma$ decays, the related rare decays $b \to s\ell^+\ell^-, s\nu\bar{\nu}$ and the extraction of $|V_{cb}|$ from semileptonic B decays.

In a B factory environment $B\bar{B}$ events are produced at the $\Upsilon(4s)$ resonance. B meson candidates are reconstructed with the aid of two kinematic variables, $m_{ES} = \sqrt{E^{*2}_{beam} - p^{*2}_B}$ and $\Delta E = E^*_B - E^*_{beam}$, which define the reconstructed B mass and energy relative to the known beam energy, E^*_{beam}. Background from non-resonant $q\bar{q}$ ("continuum") is reduced by exploiting topological differences between the jet-like $q\bar{q}$ and spherically symmetric $B\bar{B}$ events using a combination of event-shape kinematic variables. Residual continuum backgrounds are generally estimated or explicitly subtracted using data collected for this purpose just below the $\Upsilon(4s)$ resonance.

2 Radiative B decays

Radiative B meson decays occur in the SM via effective flavour changing neutral currents mediated by so-called "penguin" loop diagrams, dominated by the t quark, as shown in figure 1a. The photon can be radiated from any of the charged lines associated with the b quark. Because the loop could potentially contain other heavy virtual particles, these decays can be used to constrain new physics at energies significantly beyond the B mass scale. Interference between the SM and non-SM processes can also potentially lead to CP-violating charge asymmetries as large as 20% [1]. Such asymmetries are small in the SM.

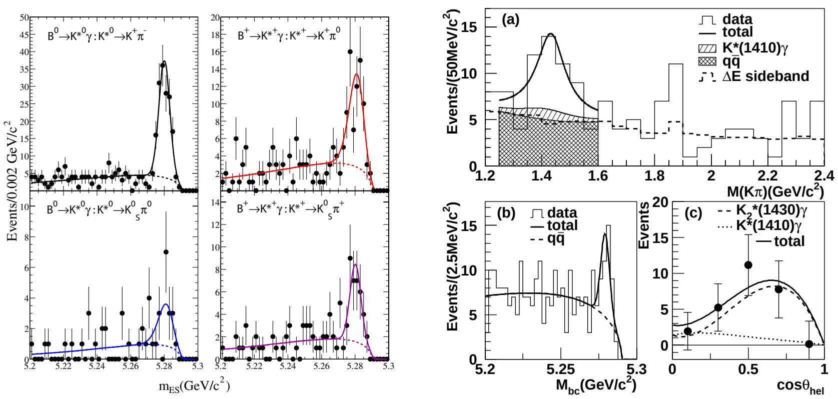

Figure 2: *(Left) Reconstructed m_{ES} of $B \to K^*(892)\gamma$ candidates obtained by Babar showing the parameterization of the combinatoric background and a signal peak at the B mass. (Right) $K\pi$ and B mass and helicity angle distributions, obtained by Belle, for $B \to K\pi\gamma$ candidates above the $K^*(982)$ mass.*

2.1 $B \to K^*(892)\gamma$

The decay $B \to K^*(892)\gamma$ provided the first evidence of the $b \to s\gamma$ process when it was observed by CLEO in 1993 [2]. This mode is now fairly well measured, with new published results from CLEO [3] and Babar [4] and a recent preliminary measurement from Belle [5] (see table 1). A $K^\pm$ or K_s^0 and a $\pi^\pm$ or π^0 are selected for which the $K\pi$ combination is close to the expected $K^*(892)$ mass. These are combined with an energetic photon (2.0 GeV $< E_\gamma <$ 2.8 GeV) to form the B meson candidate. The B mass distributions obtained by Babar are shown in the left side of figure 2. Backgrounds are predominantly from continuum $q\bar{q}$ events with a photon from ISR or π^0 or η decays. These are suppressed by a combination of event shape requirements and photon vetoes. The precision of the average of these measurements is now $\leq 10\%$ in both the charged and neutral modes.

Babar and Belle both look for CP-violating charge asymmetries, A_{CP}, by comparing the rate of $\bar{B} \to \bar{K}^*\gamma$ and $B \to K^*\gamma$, obtaining 90% confidence limits of $-0.179 < A_{CP} < 0.082$ and $-0.085 < A_{CP} < 0.149$ respectively.

Table 1: $B(B \to K^*(892)\gamma)$ *experimental results*

	$B^0 \to K^{*0}\gamma$	$B^+ \to K^{*+}\gamma$
CLEO	$(4.55 \pm 0.70 \pm 0.34) \times 10^{-5}$	$(3.76 \pm 0.86 \pm 0.28) \times 10^{-5}$
Babar	$(4.23 \pm 0.40 \pm 0.22) \times 10^{-5}$	$(3.83 \pm 0.62 \pm 0.22) \times 10^{-5}$
Belle (prelim)	$(4.08^{+0.35}_{-0.33} \pm 0.26) \times 10^{-5}$	$(4.92^{+0.59+0.38}_{-0.54-0.37}) \times 10^{-5}$
Combined	$(4.21 \pm 0.29) \times 10^{-5}$	$(4.23 \pm 0.42) \times 10^{-5}$

Table 2: *Experimental measurements of exclusive* $B \to X_s\gamma$ *for* X_s *mass above the* $K^*(892)$.

CLEO	$B(B \to K_2^*(1430)\gamma)$	$(1.66^{+0.59}_{-0.53} \pm 0.13) \times 10^{-5}$
Belle	$B(B \to K_2^*(1430)\gamma)$	$(1.5^{+0.6}_{-0.5} \pm 0.1) \times 10^{-5}$
	$B(B^+ \to K^+\pi^-\pi^+\gamma)$	$(2.4 \pm 0.5^{+0.4}_{-0.2}) \times 10^{-5}$
	$B(B^+ \to K^{*0}\pi^+\gamma)$	$(2.0^{+0.4}_{-0.2} \pm 0.2) \times 10^{-5}$
	$B(B^+ \to K^+\rho^0\gamma)$	$(1.0 \pm 0.5^{+0.2}_{-0.3}) \times 10^{-5}$
	$B(B^+ \to K^+\pi^-\pi^+\gamma$ non resonant)	$< 0.9 \times 10^{-5}$

2.2 Higher mass $B \to X_s\gamma$ modes

CLEO [3] and Belle [6] have both studied $B \to K\pi\gamma$ decays in which the mass of the $K\pi$ system is above the $K^*(892)$. CLEO reported an observation, now confirmed by a new measurement from Belle, of $B \to K_2^*(1430)\gamma$ in which the $K_2^*(1430)$ decays via $K_2^{*0} \to K^+\pi^-, K_s^0\pi^0$ or $K_2^{*+} \to K^+\pi^0, K_s^0\pi^+$. Contributions from $K_2^*(1430)$ and $K^*(1410)$ are distinguished by fitting the helicity angle distribution (shown in figure 2) of the $B \to K\pi\gamma$ candidates. The $K_2^*(1430)$ component is found to dominate. Belle has also considered the three-body X_s final state $K\pi\pi\gamma$ using a similar analysis method, and has found that it is dominated by resonant contributions from $K^*\pi$ and $K\rho$. The results are listed in table 2.

2.3 Inclusive $B \to X_s\gamma$

The inclusive $B \to X_s\gamma$ rate is more robust theoretically than the exclusive predictions since it is insensitive to non-perturbative long-distance QCD effects. It has been calculated at NLO to be $3.57 \pm 0.30 \times 10^{-4}$ for $E_\gamma > 1.6$ GeV [7]. Combining the measured branching ratios for the $K^*(892)\gamma$, $K_2^*(1430)\gamma$ and

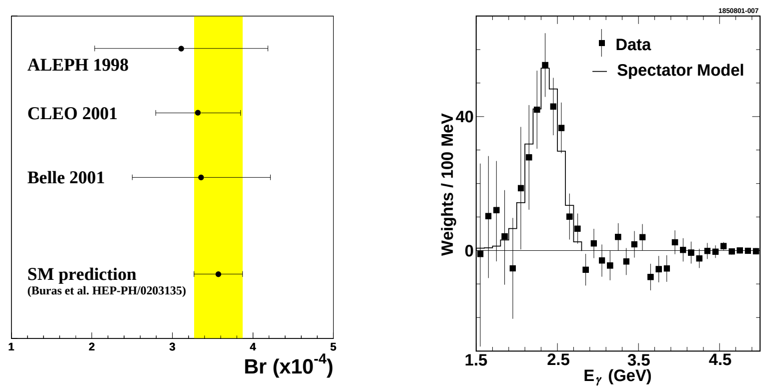

Figure 3: *(Left) Summary of inclusive $b \to s\gamma$ branching ratio measurements. The vertical band represents the SM expectation. (Right) The background-subtracted inclusive $b \to s\gamma$ photon energy spectrum obtained by CLEO.*

$K\pi\pi\gamma$ final states gives about a quarter of the predicted total $b \to s\gamma$ width.

Belle [8] and CLEO [9] have measured $B(B \to X_s\gamma)$ using a method in which the X_s system is reconstructed by combining a $K^\pm$ or K_s^0 with up to four pions, including a maximum of one π^0. X_s candidates are combined with an energetic photon to form B candidates, which are then selected based on m_{ES} and ΔE. A significant continuum background which remains even after exploiting event-shape differences necessitates background subtraction using off-peak data. The CLEO and Belle inclusive $b \to s\gamma$ measurements along with an older ALEPH measurement [10], are summarized in figure 3 (left). The agreement with the SM prediction is good, leaving relatively little room for non-SM physics. The CLEO result, the most precise single measurement, is statistically limited while the Belle measurement was based on less than 10% of their present data statistics. This suggest that further improvements in this measurement can be expected in the near future.

CLEO has also studied the moments of the inclusive $b \to s\gamma$ photon energy spectrum [11], shown in figure 3 (right). The mean energy $\langle E_\gamma \rangle$ is approximately half the b quark mass, while the mean square width $\langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2$ is related to the b quark momentum in the meson. CLEO obtains $\langle E_\gamma \rangle = 2.346 \pm 0.032 \pm 0.011$ GeV and $\langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2 = 0.0226 \pm 0.0066 \pm 0.0020$ GeV^2 for the first and second moments, from which they extract the HQET parameter (in $\overline{MS}$, to order $1/m_B^3$ and $\beta_0\alpha_s^2$) $\bar{\Lambda} = 0.35 \pm 0.08 \pm 0.10$ GeV (see section 4.3).

Table 3: $B \to \rho\gamma$ *experimental results*

	$B(B^+ \to \rho^+\gamma)$	$B(B^0 \to \rho^0\gamma)$
Babar (prelim)	$< 2.8 \times 10^{-6}$	$< 1.5 \times 10^{-6}$
Belle (prelim)	$< 9.9 \times 10^{-6}$	$< 10.6 \times 10^{-6}$
CLEO	$< 13 \times 10^{-6}$	$< 17 \times 10^{-6}$

2.4 Exclusive $b \to d\gamma$

$b \to d\gamma$ transitions occur via radiative penguin diagrams similar to $b \to s\gamma$ (figure 1a). Although exclusive radiative decay branching ratios have large uncertainties, it has been argued [12] that these uncertainties largely cancel in the ratio $B(B \to \rho\gamma)/B(B \to K^*\gamma)$, given by

$$\frac{B(B \to \rho\gamma)}{B(B \to K^*\gamma)} = S_\rho |\frac{V_{td}}{V_{ts}}|^2 \left(\frac{1 - m_\rho^2/M^2}{1 - m_K^{*2}/M^2}\right)^3 \xi^2 \left(1 + \Delta R[\rho/K^*]\right) \qquad (1)$$

where $S_\rho = 1(1/2)$ for $\rho^{\pm(0)}$, $\xi = 0.76 \pm 0.06$ [13] is the ratio of the form factors and $\Delta R < 0.15$. This implies that the ratio $|V_{td}/V_{ts}|^2$ could be extracted from experimental measurements with $\sim 20\%$ theoretical uncertainty.

Experimentally $B(B \to \rho\gamma)$ is considerably more difficult than $B(B \to K^*\gamma)$ due to the smaller SM branching ratio, intrinsically higher backgrounds and the less stringent constraint imposed by the width of the ρ compared to the K^*. Babar has recently released a preliminary measurement [14] of $B(B \to \rho\gamma)$ which represents a considerable improvement over previous limits (see table 3) [15, 3]. The limit imposed on the ratio $|V_{td}/V_{ts}|$ by this measurement translates to a constraint on the B meson unitarity triangle, represented in figure 4 as a exclusion contour in the $\rho - \eta$ plane. A Babar result on $B(B \to \omega\gamma)$ using a similar method is expected soon.

3 Rare $b \to s\,\ell\bar{\ell}$ decays

The process $b \to s\,\ell\bar{\ell}$ proceeds via radiative penguin diagrams as shown in figure 1b with either a Z^0 or γ coupling to the charged leptons, or in the case of neutrinos, only a Z^0. W box diagrams also contribute.

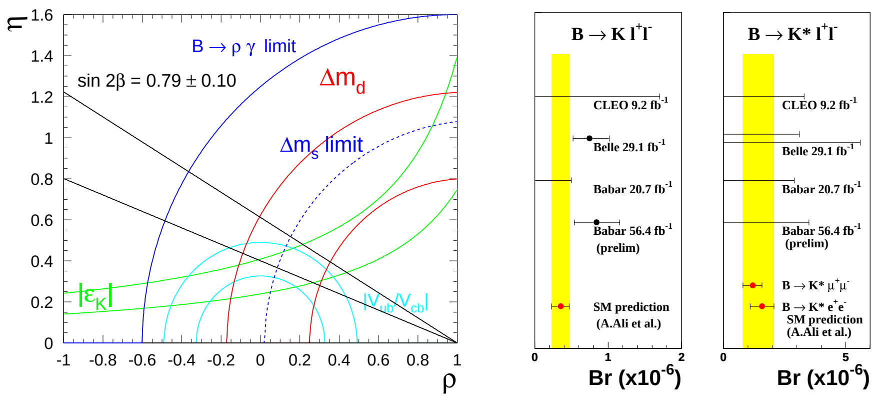

Figure 4: *(Left) The constraint on the $\rho - \eta$ plane imposed by the preliminary Babar $B \to \rho\gamma$, along with constraints from other measurements. (Right) Summary of $B \to K\ell^+\ell^-$ and $B \to K^*\ell^+\ell^-$ branching ratio measurements.*

3.1 $B \to K^{(*)}\ell^+\ell^-$

Belle reported an observation of $B \to K\ell^+\ell^-$ in 2001 [16] with a central value about a factor of two high compared with the SM expectation [17] and in apparent conflict with a recently published Babar result [18]. An update Babar preliminary result [19] with a significantly enlarged data sample now appears to confirm the Belle result, although no evidence was reported which would suggest that the published Babar result is invalid. $B \to K^*\ell^+\ell^-$ has yet to be observed, although experimental limits are now approaching the SM range. $B \to K^{(*)}\ell^+\ell^-$ results are summarized in figure 4 [20].

3.2 Inclusive $B \to X_s\ell^+\ell^-$

The theoretical predictions for inclusive $B \to X_s\ell^+\ell^-$ are more robust than for the exclusive modes. The branching ratios have been calculated at NNLO to be [17] $B(B \to X_s e^+e^-) = (6.89 \pm 1.01) \times 10^{-6}$ and $B(B \to X_s\mu^+\mu^-) = (4.14 \pm 0.70) \times 10^{-6}$. Belle has recently produced a preliminary measurement of this branching ratio [21] based on 43 fb^{-1} of data. The X_s system is identified using the same "pseudo-reconstruction" method as for the inclusive $B \to X_s\gamma$: a $K\pm$ or K_s^0 is combined with up to four additional pions, of which a maximum of one may be a π^0. A signal is reported with a significance of 4.8σ on the combined $\ell = e, \mu$ mode with a branching ratio of $B(B \to X_s\ell^+\ell^-) = (7.1^{+1.6+1.4}_{-1.6-1.2}) \times 10^{-6}$.

3.3 $B^- \to K^- \nu\bar{\nu}$

The decay $B^- \to K^- \nu\bar{\nu}$ has a SM rate which is estimated to be $B(B^- \to K^- \nu\bar{\nu}) \simeq 4 \times 10^-6$ [22]. Babar has also recently produced a preliminary limit on this mode [23]. The previous best limit was $B^- \to K^- \nu\bar{\nu} < 2.4 \times 10^{-4}$ from CLEO [24]. The Babar analysis looks for a signature of a high momentum $K^\pm$ recoiling against a exclusively reconstructed $B^\pm \to D\ell\nu X$, where X represents possible photons or π^0s from from higher mass charm states. In contrast, the CLEO measurement used a reconstruction method based on hadronic B decays. Other than the reconstructed B and the signal kaon, no additional tracks and $<$ 0.5 GeV of calorimeter energy are permitted in the event. A preliminary limit of $B^- \to K^- \nu\bar{\nu} < 9.4 \times 10^{-5}$ is obtained using 50.7 fb^{-1} of data. Although this limit is an order of magnitude above the SM expectation, the method shows promise of reaching the theoretically interesting region [22] $B(B \to K\nu\bar{\nu}) < 5 \times 10^{-5}$ in the future. The B factories have not yet reported results on the experimentally difficult inclusive $B \to X_s\nu\bar{\nu}$ mode.

4 Semileptonic decays and $|V_{cb}|$

Semileptonic B decays occur via tree level EW processes mediated by a $W^\pm$ as shown in figure 1c and are therefore sensitive to the CKM matrix elements $|V_{cb}|$ and $|V_{ub}|$. Only the favoured $b \to c$ mode is discussed here.

4.1 $|V_{cb}|$ from exclusive $B \to D^*\ell\nu$

The "classic" determination of $|V_{cb}|$ in semileptonic B decay involves extracting it from from the differential decay rate of exclusive $B \to D^*\ell\nu$ decays in the limit of zero recoil of the heavy quark. The differential rate

$$d\Gamma(B \to D^*\ell\nu)/dw \;\propto\; |V_{cb}|^2 \cdot |F_{D^*}(w)|^2 \tag{2}$$

is expressed in terms of the HQET variable w, defined as the scalar product of the B and D^* 4-velocities:

$$w = v_{\bar{B}} \cdot v_{D^*} = \frac{m_{\bar{B}}^2 + m_{D^*}^2 - q^2}{2m_{\bar{B}}m_{D^*}}, \qquad q^2 = (p_{\bar{B}} - p_{D^*})^2 \quad . \tag{3}$$

The form factor $F_{D^*}(w)$ is precisely calculable in the limit $w = 1$ by exploiting HQS, and has been estimated to be 0.913 ± 0.042 [25]. Since there is little phase space available at this limit, the entire $d\Gamma(B \to D^* \ell\nu)/dw$ spectrum is measured and $|V_{cb}| \cdot F_{D^*}(1)$ is obtained from an extrapolation of the fit to $w = 1$. $F(w)$ is constrained by dispersion relations and consequently is governed by a single shape parameter, ρ^2, corresponding to the slope at $w = 1$.

Recent experimental measurements available from CLEO [26], Belle [27] are summarized in table 4. At the B factories, the analysis proceeds by exclusively reconstructing the D^0 and D^* candidate and combining it with an identified lepton. Backgrounds from B decays are reduced using the kinematic variable

$$\cos\theta_{B-D^*\ell} = \frac{2E_B E_{D^*\ell} - m_B^2 - m_{D^*\ell}}{2|p_B||p_D^*\ell|} \quad , \tag{4}$$

which defines the angle between the B and the reconstructed $D^*\ell$ candidate. CLEO obtains the $D^*\ell\nu$ yield by fitting the $\cos\theta_{B-D^*\ell}$ distribution in bins of w. The result is shown in the left-hand plot of figure 5. The CLEO result is nominally the most precise single measurement, but shows a $\sim 3\sigma$ discrepancy relative to other analyses. This could potentially indicate correlated systematics in the LEP measurements, or other similar effects associated with Monte Carlo modeling, however it should also be noted that the combined results [28] are consistent at the level of $\sim 5\%$.

Table 4: *Experimental measurements of the product* $|V_{cb}| \cdot F(1)$

Experiment	$\lvert V_{cb}\rvert \cdot F(1)$
CLEO	$(4.31 \pm 0.13 \pm 0.18) \times 10^{-2}$
Belle	$(3.54 \pm 0.19 \pm 0.18) \times 10^{-2}$
LEP Combined	$(3.82 \pm 0.05 \pm 0.09) \times 10^{-2}$

4.2 $|V_{cb}|$ from inclusive $B \to X_c \ell\nu$ decays

The inclusive semileptonic width $\Gamma(B \to X_c \ell\nu)$ is calculated using HQET and can be expressed as an OPE in powers of $1/m_B$ schematically as

$$\Gamma(B \to X_c \ell\nu) \propto |V_{cb}|^2 \frac{G_F^2 m_B^5}{192\pi^3} \left(1 + f_1 \left[\frac{\bar{\Lambda}, \alpha_s}{m_B}\right] + f_2 \left[\frac{\bar{\Lambda}, \lambda_1, \lambda_2}{m_B^2}\right] + \mathcal{O}\left[\frac{1}{m_B^3}\right]\right) + ... \tag{5}$$

The $1/m_B$ term contains the perturbative expansion in α_s, and the parameter $\bar{\Lambda}$ which expresses the energy carried by the light quarks and gluons in the B

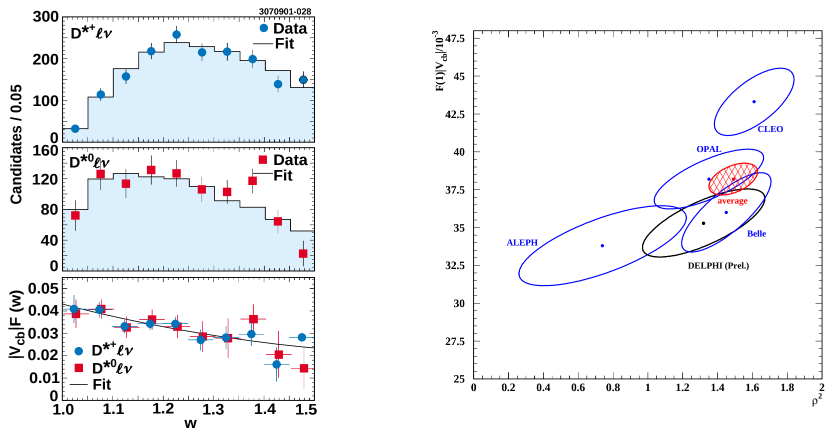

Figure 5: *(Left) CLEO $B \to D * \ell\nu$ data yield and fit as a function of w, and the extracted product $|V_{cb} \cdot F(w)|$. (Right) $|V_{cb} \cdot F(1)|$ vs the slope parameter ρ^2 and the combined fit to the LEP plus B factory data* [28].

meson. The parameters λ_1 and λ_2 are related to the average momentum of the b quark and the hyperfine interaction energy of the b quark spin with the light degree of freedom respectively, and enter at order $1/m_B^2$. Several additional parameters enter at order $1/m_B^3$. Extraction of $|V_{cb}|$ from the inclusive spectrum therefore requires knowledge of these parameters, as well as an underlying assumption of quark-hadron duality which introduces an additional unknown theoretical uncertainty.

4.3 Hadronic mass moments

CLEO has attempted to reduce the theoretical uncertainty on the extraction of $|V_{cb}|$ from inclusive $B \to X_c \ell\nu$ by constraining the HQET parameters $\bar{\Lambda}$ and λ_1 directly from experimental data [29]. This is accomplished by measuring the moments of the hadronic invariant mass spectrum in $B \to X_c \ell\nu$ decays and combining the results with data from the moments of the $b \to s\gamma$ photon energy spectrum. The inclusive hadronic mass spectrum is obtained indirectly by combining the identified lepton ℓ with the neutrino 4-vector obtained from the missing energy and momentum in the event. The mass of the hadronic system is estimated from $m_X^2 = m_B^2 + m_{\ell\nu}^2 - 2E_B E_{\ell\nu}$, where a small term $\sim P_B P_{\ell\nu} \cos\Theta_{B-\ell\nu}$ is neglected. The moments are extracted from a fit to the m_X^2 spectrum

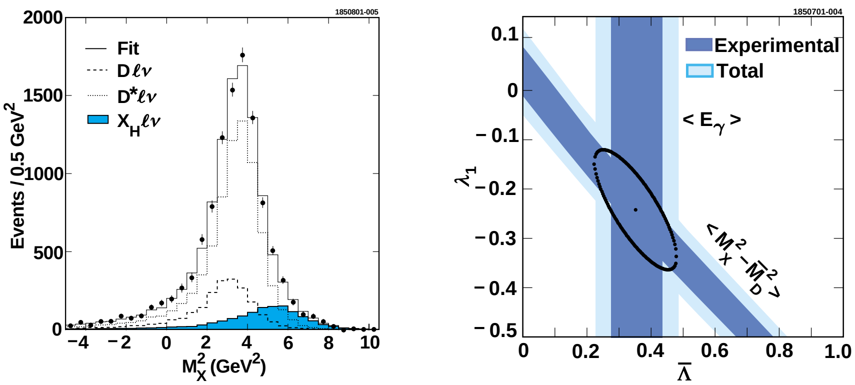

Figure 6: *Invariant mass squared, m_X^2, of the $B \to X_c \ell\nu$ hadronic system obtained by CLEO (left), and the allowed region of the $\bar{\Lambda} - \lambda_1$ plane.*

for the lepton momentum range $p_\ell \geq 1.5$ GeV/c, yielding $\langle m_X^2 - \bar{m}_D^2 \rangle =$ (0.251 ± 0.066) GeV^2, and $\langle (m_X^2 - \langle m_X^2 \rangle)^2 \rangle = 0.576 \pm 0.170$ GeV^4 where $\bar{m}_D$ is the spin-averaged D meson mass. Uncertainties in the extracted moments are dominated by systematic errors associated with the simulation of the neutrino reconstruction. Appropriate expressions for the moments have been computed to order $\beta_0 \alpha_s^2$ and $1/m_B^3$ [30]. The first moment, $\langle m_X^2 - \bar{m}_D^2 \rangle$, defines an allowed region in the $\lambda_1 - \bar{\Lambda}$ plane (see figure 6). This can be combined with the result for $\bar{\Lambda}$ obtained from the previously described inclusive $b \to s\gamma$ measurement to constrain $\bar{\Lambda}$ and λ_1. CLEO obtains $\bar{\Lambda} = 0.35 \pm 0.07 \pm 0.10$ GeV and $\lambda_1 = -0.236 \pm 0.71 \pm 0.078$ where the errors are experimental and theoretical. Additional bands can be defined using the measurements of the second moments, but these are theoretically less robust. It should be noted that both CLEO [31] and DELPHI [32] have also very recently released preliminary measurements of $\bar{\Lambda}$ and λ_1 obtained from the moments of the lepton spectra in $B \to X_c \ell\nu$. Additional moments measurements are anticipated for summer 2002. CLEO extracts $|V_{cb}|$ using separate CLEO measurements of the $B(B \to X_c \ell\nu)$ and the ratio, f_{+-}/f_{00}, of the relative branching fractions of the $\Upsilon(4s)$ to B^+B^- and $B^0\bar{B}^0$, and the average $B^\pm$ and B^0 lifetimes [33], yielding $|V_{cb}| = (4.04 \pm 0.09 \pm 0.05 \pm 0.08) \times 10^{-2}$ where the first uncertainty is experimental, the second is due to the $\bar{\Lambda}$ and λ_1 determination, and the third represents theory errors from α_s scale and $1/m_B^3$ terms. Clearly there is still some room for improvement of $B(B \to X_c \ell \nu)$, but it is worth noting that the $\bar{\Lambda}$, λ_1 determination has nearly equal contributions from theory and experimental errors, and in any case the theory error on $|V_{cb}|$ will soon dominate.

5 Conclusion

Numerous new experimental results have recently appeared on radiative and rare penguin B decays. Several exclusive channels have now been observed or have had stringent limits set, and inclusive modes, specifically $b \to s\gamma$ and $b \to s\ \ell^+\ell^-$, have been studied. Prospects also appear good for experimental extraction of HQET parameters from spectral moments, reducing the theory uncertainty on $|V_{cb}|$ extraction from inclusive semileptonic decays.

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