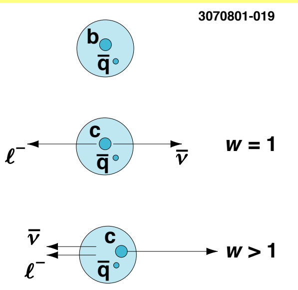
2230703-002

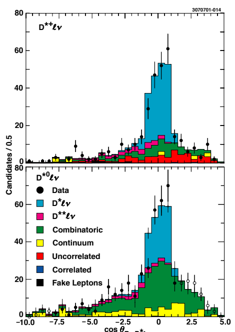
$|V_{cb}|$ and $|V_{ub}|$ from $B \to X \ell \nu$

CLEO Collaboration

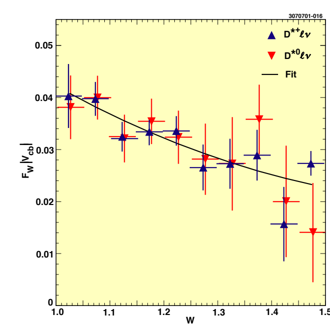
$|V_{cb}|$ from Exclusive $B \to D^{(*)} \ell \nu$ Decays



Exclusive decays such as $B \to D^* \ell \nu$ decays are an attractive way to extract V_{cb} because the form factor can be computed precisely at w=1. At w=1, the final state D^* is at rest with respect to the initial B meson, and since both quarks are heavy, the probability that the light quarks will remain intact in the meson is near unity. Deviations from unity are calculated in the heavy quark expansion. A current value is F(1) = 0.913 ± 0.042 (BaBar Physics Book).

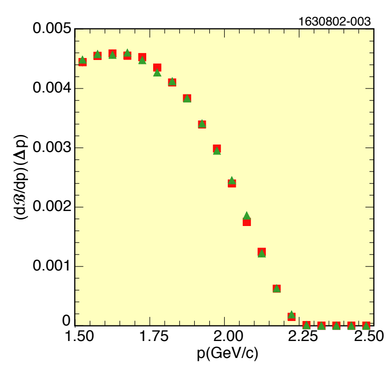


At the Υ(4S), it is possible to distinguish $D^* \ell \nu$ decays from $D^{**} \ell \nu$ and $D^* \pi \ell \nu$ decays kinematically. We reconstruct the cosine of the angle between the B and the $D^* \ell$ pair under the assumption that the neutrino is massless. $D^* \ell \nu$ populates the physical range $-1 < \cos\theta_{B-D^*\ell} < 1$, but decays such as $D^{**} \ell \nu$ in which additional particles are missing tend to have $\cos\theta_{B-D^*\ell} < -1$.



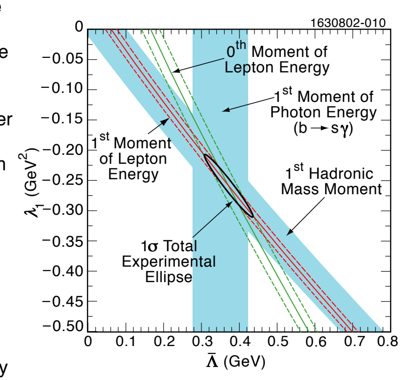
V_{cb} comes from extrapolating the differential decay rate of $B \to D^* \ell \nu$ ($\ell = e, \mu$) decays to w = 1, a kinematic point where the form factor F(w) is well-known.
We find $F(1)V_{cb} = 0.0422 \pm 0.0013 \pm 0.0018$.
Combined with the calculated value of F(1), this gives $V_{cb} = 0.0462 \pm 0.0014 \pm 0.0020 \pm 0.0021$ where the errors are statistical, systematic and theoretical. The analysis uses both $B^- \to D^{*0} \ell^- \nu$ and $B^0 \to D^{*+} \ell^- \nu$ decays in a sample of 3M $B\bar{B}$ events.

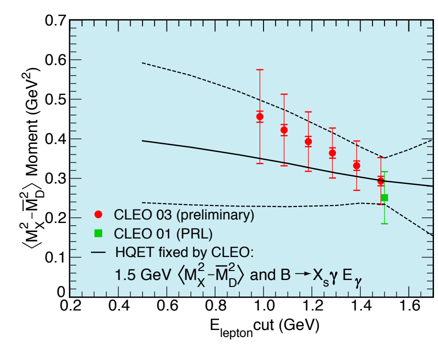
$|V_{cb}|$ from Inclusive $b \to c \ell \nu$ Decays



The inclusive semileptonic decay width for the process $b \to c \ell \nu$ is used in the extraction of V_{cb}. The value of the decay width for the parton level process differs from the hadron level width ($\Gamma(B \to X_c \ell \nu)$) due to bound state effects on the b quark inside the B meson. Heavy Quark Effective Theory (HQET) provides the parton to hadron corrections in terms of non-perturbative parameters($\bar{\Lambda}$,λ_1). These parameters can be extracted using other inclusive observables from B meson decays such as the recoil mass squared (M_X^2) and lepton momentum in $B \to X_c \ell \nu$. Shown on the left is CLEO's measurement of the lepton momentum distribution for leptons from semileptonic B decays. On the right are shown constraints on the HQET parameters provided by various CLEO moments measurements of M_X^2 and lepton momentum from $B \to X_c \ell \nu$ and photon energy in $B \to X_s \gamma$. The constraints have allowed the extraction of $V_{cb} = (40.8 \pm 0.5 \pm 0.14) \times 10^{-3}$ where the first uncertainty is experimental error on the width, the second is the experimental error on the extraction of HQET parameters and the third is theory uncertainty.

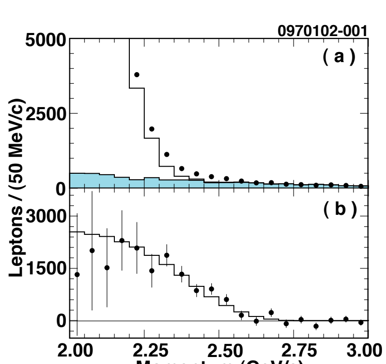
References: PRL 87 251807, 2001
PRL 87 251808, 2001
PRD 67 072001, 2003 (and references within)





CLEO's most recent tests of HQET compares measurements of the hadronic mass moments with HQET predictions for less restrictive lepton selection criteria. Shown in the figure is the value of the first hadronic mass squared moment versus the minimum allowed lepton momentum (preliminary). Also shown is the allowed region from HQET when the parameters are constrained by the first photon energy moment and the first hadronic mass moment squared as measured with a lepton momentum cut of 1.5 GeV/c.

$|V_{ub}|$ from Lepton Momentum Endpoint

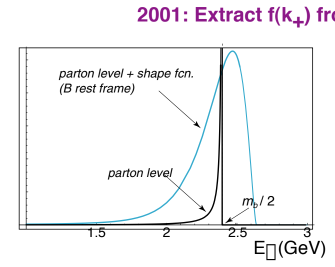


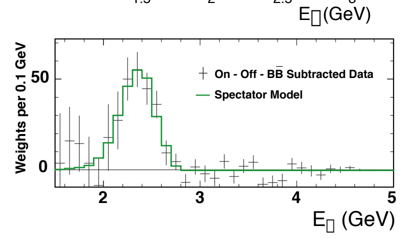
CLEO has measured the yield of leptons from B mesons arising from $b \to u \ell \nu$ transitions. This measurement is restricted to near and above the kinematic limit for leptons from $b \to c \ell \nu$ transitions. The $b \to c \ell \nu$ background completely dominates at lower lepton momentum. Shown on the left (top) is the lepton momentum distribution for data collected on the Υ(4S) resonance (points), the expected contribution from the $b \to c \ell \nu$ processes (histogram), and the expected contribution from the underlying continuum (shaded). Shown at the bottom on the left is the distribution after subtraction of $b \to c \ell \nu$ and continuum (interpreted as the $b \to u \ell \nu$ lepton momentum distribution). In order to convert the end point yield to total yield, the fraction above the lepton cut must be known. CLEO has pioneered new techniques in determining this fraction with studies of another b to light quark transition, $b \to s \gamma$.

Reference: PRL 88 231803, 2001

$$|V_{ub}| = (4.09 \pm 0.14 \pm 0.66) \times 10^{-3}$$

2001: Extract $f(k_+)$ from $b \to s \gamma$ Photon Spectrum





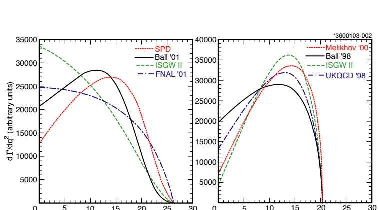
Shown on the left (top) is a parton level calculation of the photon energy spectrum (black) from $b \to s \gamma$ and the hadron level ($B \to X_s \gamma$) photon energy (blue). These spectra are connected by a two-parameter shape function at leading order in Λ_{QCD}/M_X^2. With a measurement of the hadron level photon energy distribution, CLEO has extracted the parameters defining the shape function. To leading order the shape function for the photon energy in $b \to s \gamma$ is the same as that for the lepton momentum in the $b \to u \ell \nu$ transitions. Precise knowledge of the shape function translates into reliable estimates for the lepton endpoint fraction with reduced uncertainties on V_{ub}.

References:
M. Neubert PRD 49 3392 1994
I.I. Bigi et al. Int J Mod Phys A9, 2467, 1994
F. De Fazio and M. Neubert, JHEP06, 017,1999

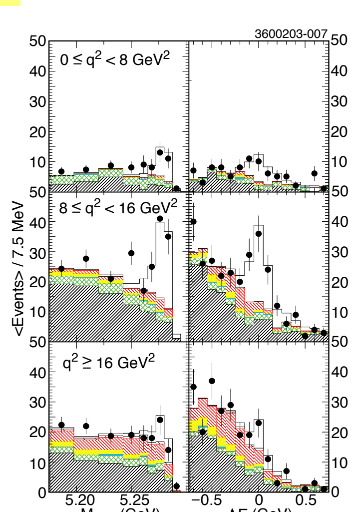
Shown above is CLEO's measured photon energy spectrum with a spectator model prediction.

Reference: PRL 87 2511808, 2001

$|V_{ub}|$ from Exclusive Decays



CLEO provided the first measurements of exclusive charmless semileptonic B decays and extracted a value for V_{ub} based on these measurements (PRL 77, 5000 1996). Our update to the exclusive $B \to X_u \ell \nu$ measurements is based on a larger sample of approximately 10 million $B\bar{B}$ pairs collected on the Υ(4S) resonance. The refined analysis reduces uncertainties arising from form factor dependence on momentum transfer, q^2 (initially suggested by C.W. Bauer, Z. Ligeti, M. Luke, PL B479, 395 2000). Various models for the q^2 dependence are shown in the above figure. By using a lower minimum allowed lepton momentum than the previous analysis and by measuring the branching fraction in bins of q^2, our new analysis not only reduces the uncertainty in the extracted value of V_{ub} but also increases the discrimination among models.



The good hermiticity of the CLEO detector allows reliable reconstruction of the neutrino four-vector. With the neutrino, meson, and lepton four-vectors we can employ full reconstruction techniques to identify the signal. The figures on the left show beam constrained mass, $M_{bc} = (E_{beam}^2 - |P_{\pi \ell \nu}^2|)^{1/2}$, and the energy difference, $\Delta E = E_{\pi \ell \nu} - E_{beam}$, for $B \to \pi \ell \nu$ candidates. The points are data and the histograms are, from bottom to top, $b \to c$ continuum, fake leptons, feed down from other $b \to u$ modes, cross feed from vector modes, cross feed among the π modes and signal. The peaks at $\Delta E = 0$ and beam constrained mass equal to the B meson mass are evident for all three q^2 bins. The figure on the right shows the measured branching fractions in each of the q^2 bins for $B^0 \to \pi^- \ell^+ \nu$ (points) as well as the best fit to the predicted $d\Gamma/dq^2$ for the three models used in the extraction of the rates. To extract V_{ub} we use Light-Cone Sum Rules for $q^2 < 16$ GeV^2 and Lattice QCD for $q^2 > 16$ GeV^2. The combined $\pi \ell \nu$ and $\rho \ell \nu$ result is $\mathbf{V_{ub} = (3.17^{+0.23}_{-0.24}{}^{+0.53}_{-0.39}) \times 10^{-3}}$ where the first uncertainty is experimental and the second is theory/model.

Reference: hep-ex/0304019 (Accepted by PRD)