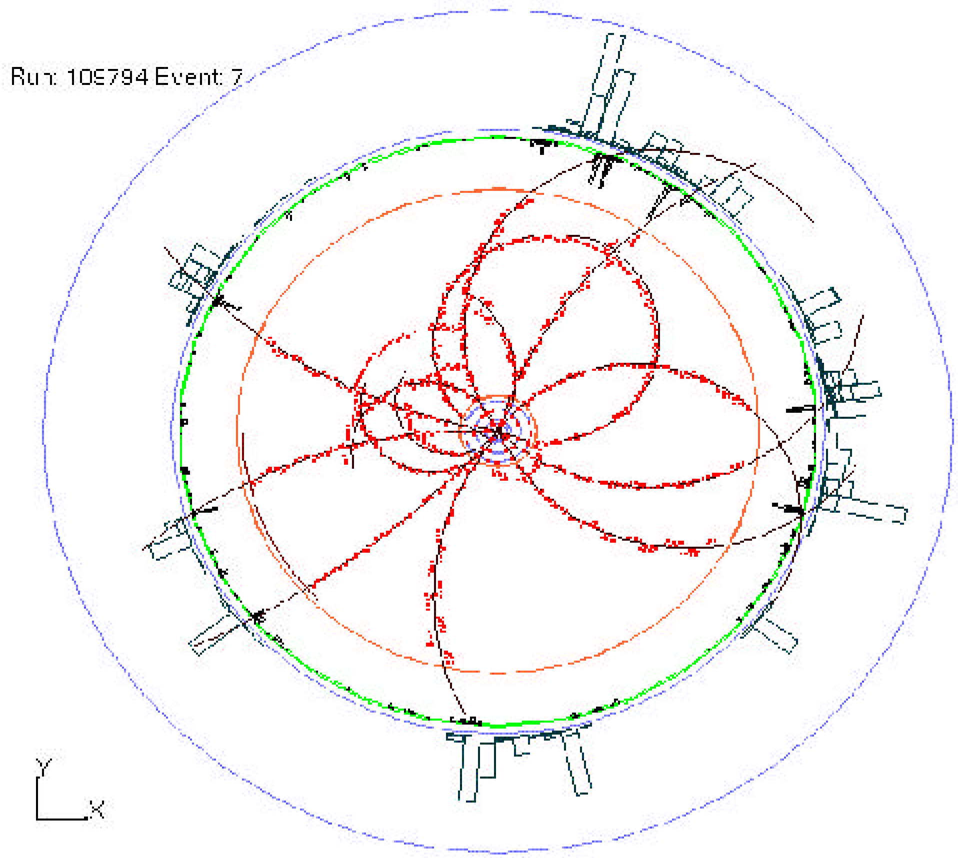
Recent results on B meson decays from CLEO

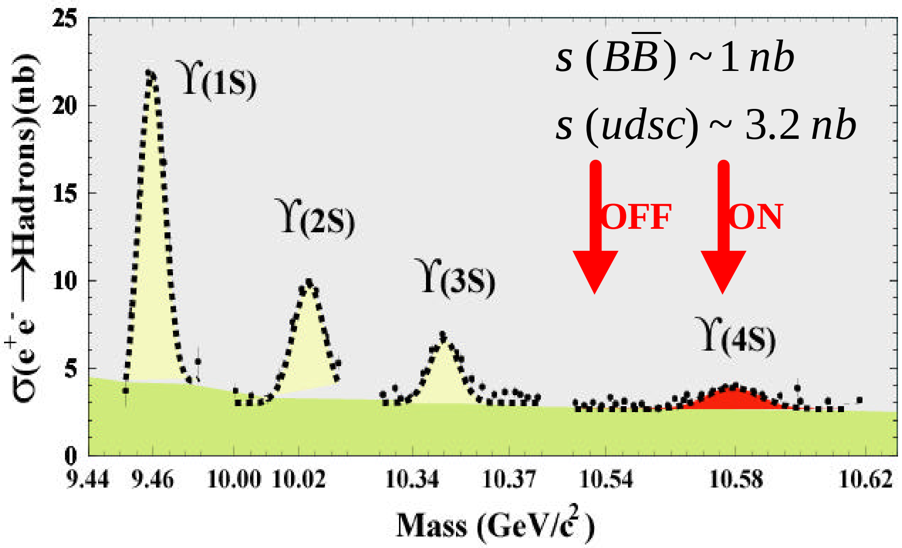
$\Upsilon(4S) \to B\overline{B}$

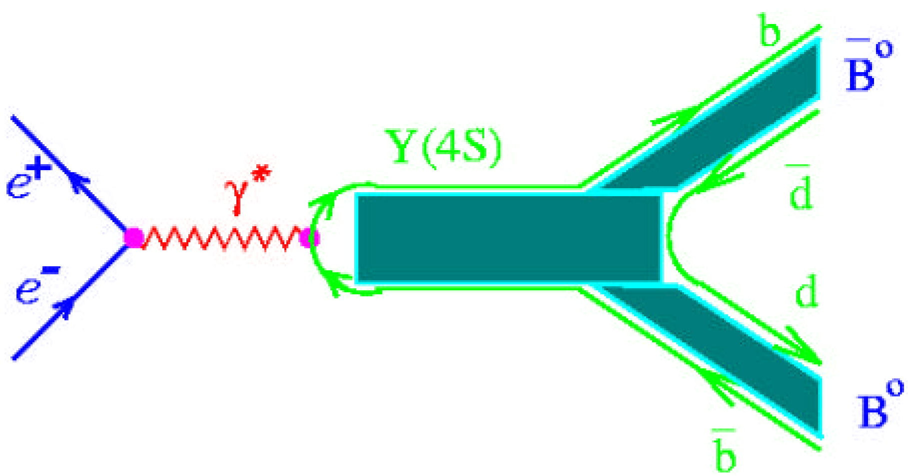


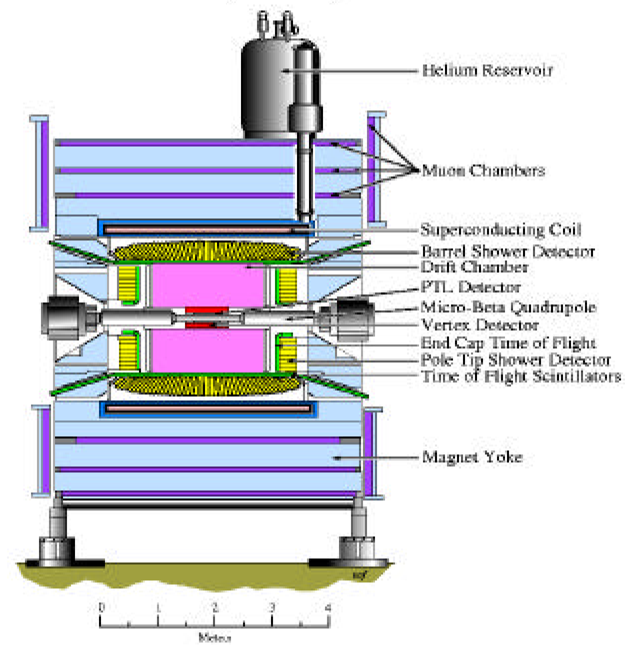
Alan Weinstein,
Caltech
Representing the
CLEO Collaboration

CLEO $e^+e^- \to$ Y(4S) $\to$ BB

- CESR - symmetric e^+e^- storage ring
  - operates on Y(4S)
  - BB produced near threshold
- Data sets
  - CLEO II, II.V
    - ~ 9.1 fb^{-1} on Y(4S) => 9.7 x 10^6 BB Events
    - ~ 4.4 fb^{-1} off Y(4S)
  - CLEO III
    - ~ 6.9 fb^{-1} on Y(4S) => 7.4 x 10^6 BB Events
    - ~ 2.3 fb^{-1} off Y(4S)

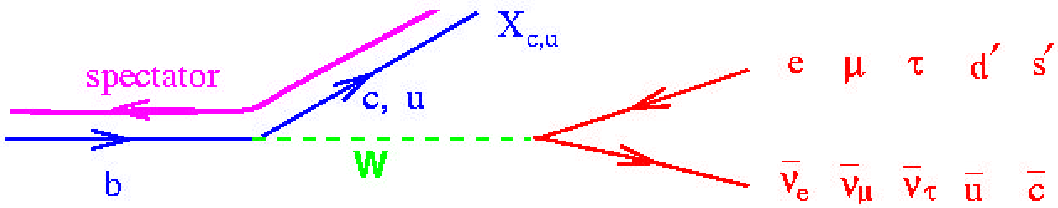




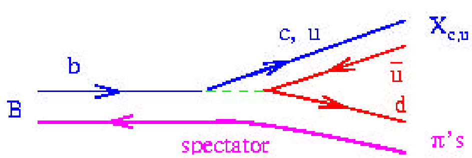


Rich B decay phenomenology

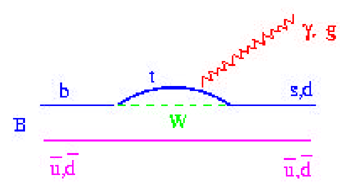
$$\Gamma_q = \text{decay rate} = \frac{G_F^2 m_b^5}{192\pi^3} |V_{bc}|^2 N_c f_{ps}$$



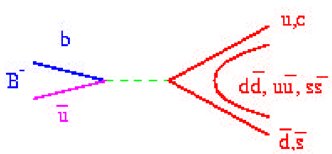
Other diagrams:



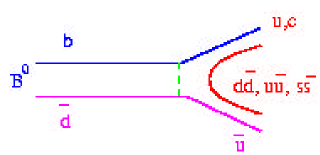
Color-suppressed



penguin $b \rightarrow s$



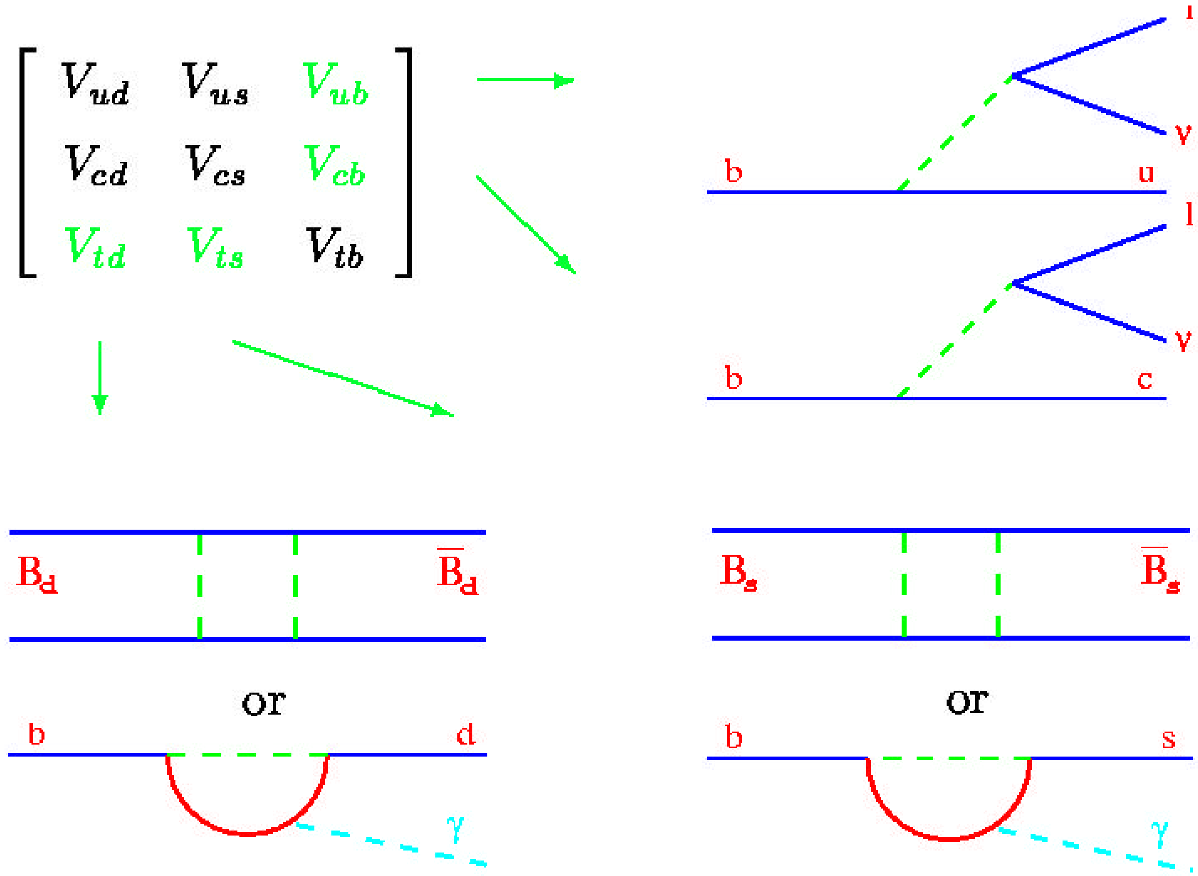
annihilation



W-exchange

- $b \rightarrow c\, l\, \nu$ inclusive (V_{cb}, HQET parameters)
- $B \rightarrow X_c\, l\, \nu$ exclusive (V_{cb}, form factors)
- $b \rightarrow u\, l\, \nu$ inclusive (V_{ub})
- $B \rightarrow X_u\, l\, \nu$ exclusive (V_{ub}, form factors)
- $B \rightarrow X_c$ hadrons exclusive (tests of factorization, charm counting, …)
- $B \rightarrow X_c^0\, (n\pi)^0$ exclusive (color-suppressed)
- $B \rightarrow$ charmless hadrons ($b \rightarrow u$, $b \rightarrow sg$, $b \rightarrow dg$, direct CPviolation, etc)
- $b \rightarrow s\gamma$ inclusive
- $B \rightarrow s\gamma$ exclusive
- …

Measuring CKM with B decays



Goals for the decade:

Precision measurements of magnitudes and phases of V_{ub}, V_{cb}, V_{ts}, V_{td}.

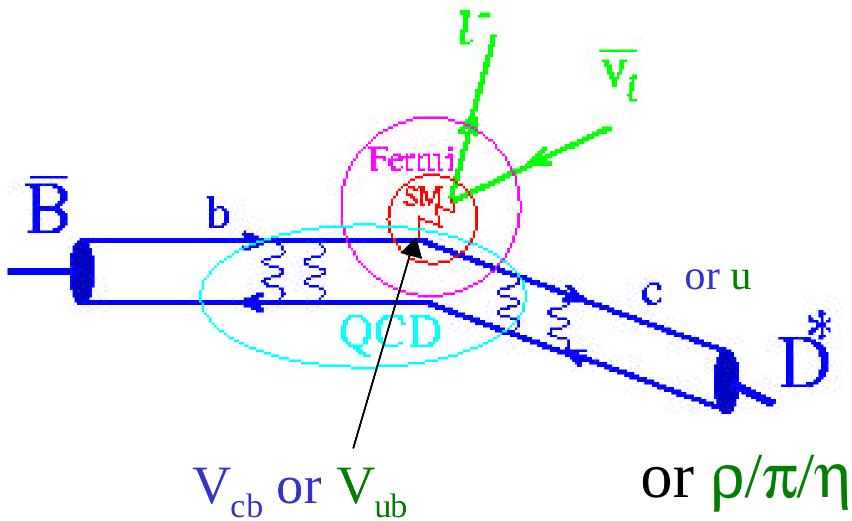
Rates determine magnitudes; CP violation measures phases.

Test SM description of CP violation and search for new physics.

Determination of V_{cb} & V_{ub} from semileptonic B decay

- Semileptonic decays are used to determine the quark couplings as they are simple: strong interaction is confined to the lower vertex
- Gµ½V_{cb}½^2 for final states with charm (D /D* etc.)
- Gµ½V_{ub}½^2 for final states without charm (r/p/h…)
- We observe hadrons rather than quarks. theory is needed to relate the underlying quark decay to hadronic decay properties (quark-hadron duality)

Semileptonic decay of meson containing heavy quark:

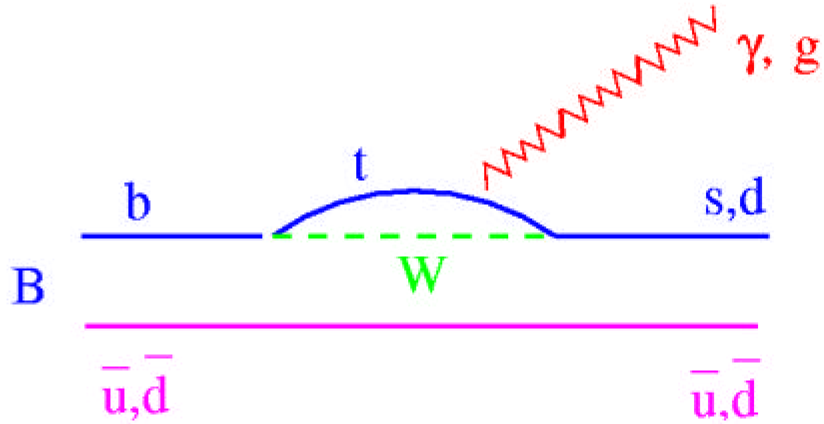


- Two approaches: inclusive $B \to X_c\, \ell\, n$, $X_u\, \ell\, n$

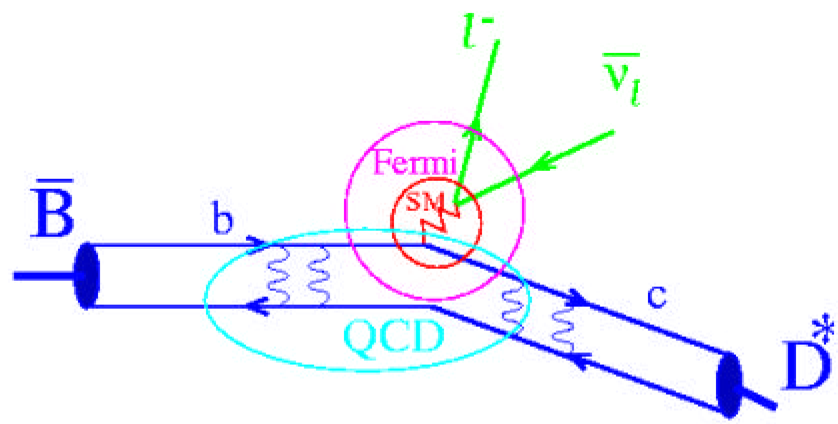
  or exclusive $B \to D^*\, \ell\, n$, $(\rho/\pi/\eta)\, \ell\, n$

Topics discussed here

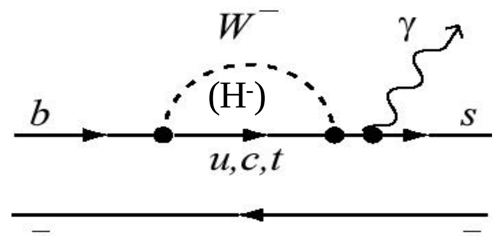
- E_γ spectrum of $B \to X_s \gamma$
- Hadronic moments in $B \to X_c\, l\, \nu$
- Inclusive semileptonic rate and $|V_{cb}|$
- Lepton endpoint and $|V_{ub}|$
- $|V_{cb}|$ from $B \to D^*\, l\, \nu$
- Future work



$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$



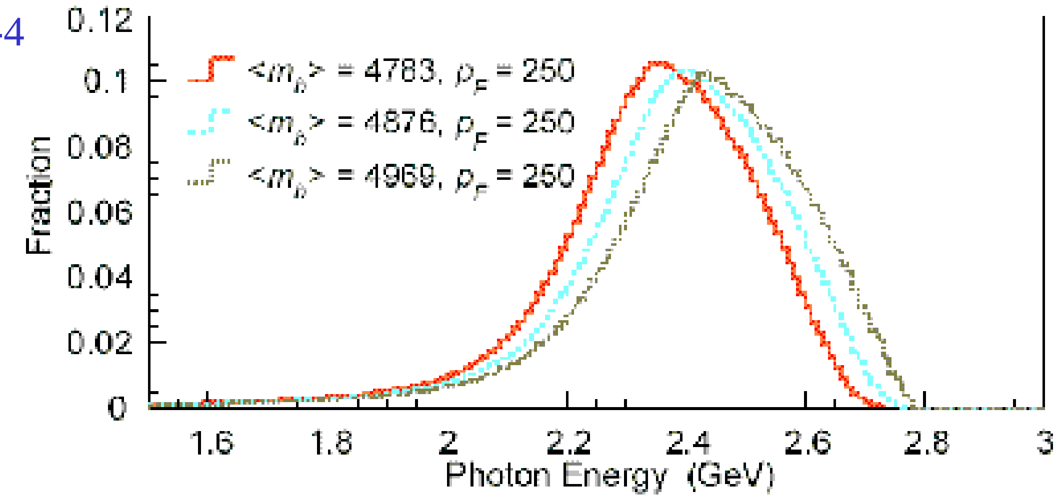
Inclusive EM penguins: $b \to s\gamma$



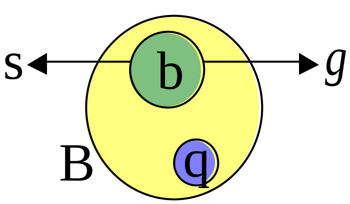
- No tree level FCNC in SM
- Sensitive to new physics in loop H^-…
- Calculated to NLO in SM

$BR(B \to X_s\gamma) = (3.3\text{-}3.7) \times 10^{-4}$

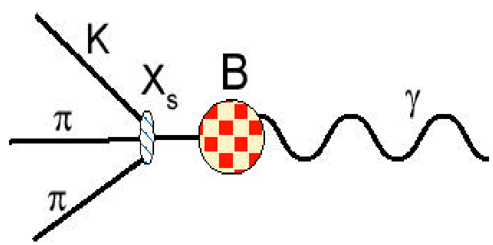
- Measure: inclusive γ spectrum
- Past: Branching ratio & Acp.
- Now: (+ shape of g spectrum)



quark level



hadron level

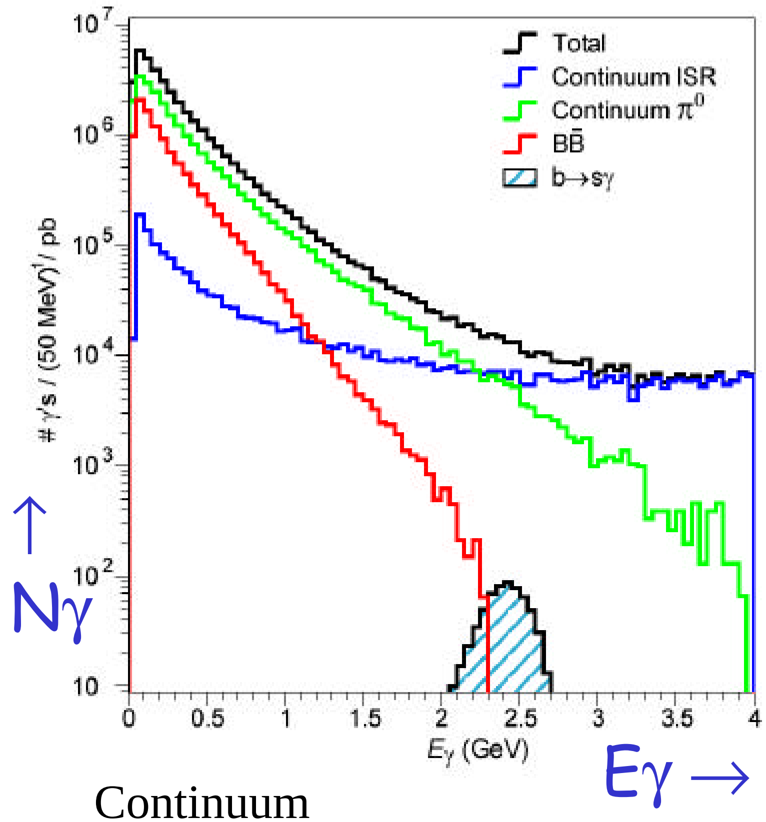


Mean : $<E_g> \sim m_b/2$
Width: non-perturbative interactions between b quark and light degrees of freedom in hadron (Fermi motion)
Both quantities needed for extraction of V_{cb} & V_{ub} from $B \to Xl\nu$

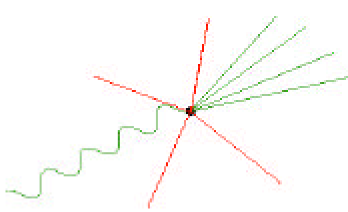
b ® *s*γ: Measuring the γ spectrum

- Signal: isolated γ 2.0 < E γ < 2.7 GeV
- In principle: Measure γ spectrum for ON and OFF resonance and subtract
- But: *b* ® *sg* isn't only source of γ
- Background from *p* ^{0}→γγ η→γγ
  - Veto photons making *p* ^{0}, η with other γ's
  - Model remainder from data and subtract, significantly reducing model dependence
- Huge continuum background: reduce by:
  - Event shape cuts
  - leptons (tags BB event)
  - Identify (Knπ) hadronic system recoiling against γ

Expected raw contributions:

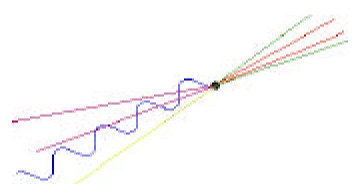


Signal

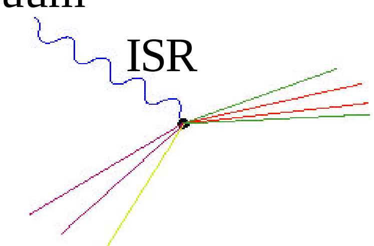


vs.

Continuum

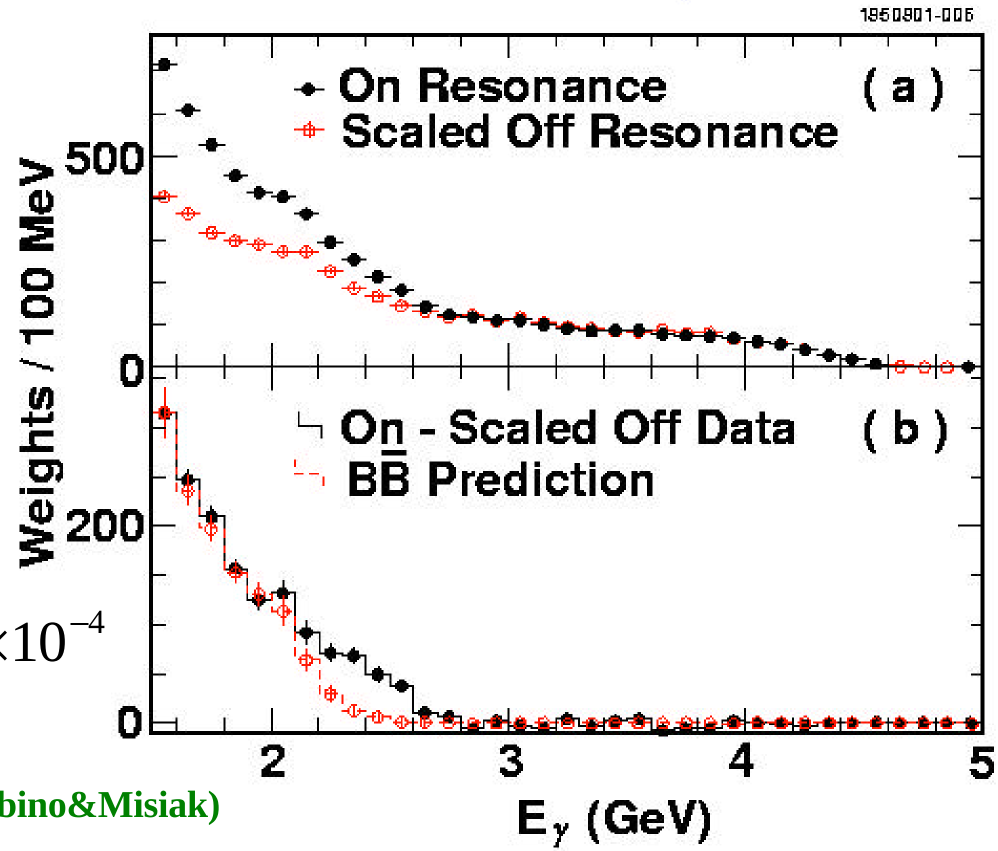


or



$B \rightarrow X_s\gamma$ results

- Full Cleo II + II.V dataset (9.6 M BB)
- *BF* for ~90% of spectrum (2.0 GeV cutoff)
- Weight events accd to how consistent they are with $b \rightarrow s\gamma$
- No excess > 2.7 GeV or < 2.0 GeV



$$\mathrm{B}(B \rightarrow X_s\gamma) = 3.21 \pm 0.43 \pm 0.27^{+0.18}_{-0.10} \times 10^{-4}$$

Theory: (3.3 - 3.7) × 10^{-4}

(Chetyrkin, Misiak,& Münz/ Kagan &Neubert,Gambino&Misiak)

CLEO PRL 87:251807, 2001

- **Expt. & theory agree**
- **Expt. error close to theoretical uncertainty**
- **not much room for new physics**
- **Belle (BCP4) measures (2.25 GeV cutoff):** $\left(3.37 \pm 0.53 \pm 0.42^{+0.50}_{-0.54}\right) \times 10^{-4}$

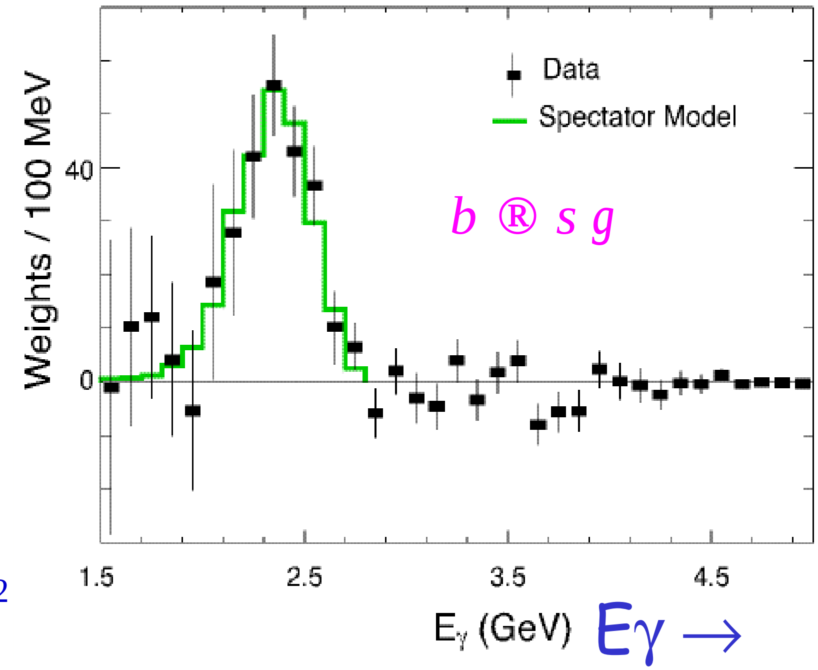
b ® *sg* photon spectrum

- At quark level, spectrum is a sharp line
  - broadened by b quark Fermi motion
  - broadened by varying recoil mass (glue)
  - smeared by B boost (known)
  - smeared by resolution (small)
- Fit to theory spectra propogated through MC:
  - Ali-Greub model
  - Kagan-Neubert theory
- Moments of the distribution

$\langle E_g \rangle = 2.346 \pm 0.032 \pm 0.011$ GeV

$\langle E^2_g \rangle - \langle E_g \rangle^2 = 0.0226 \pm 0.0066 \pm 0.0020$ GeV^2

Subtract BB bkgd:



$\langle E_g \rangle$ ~ $m_b/2$ effectively measures HQET parameter

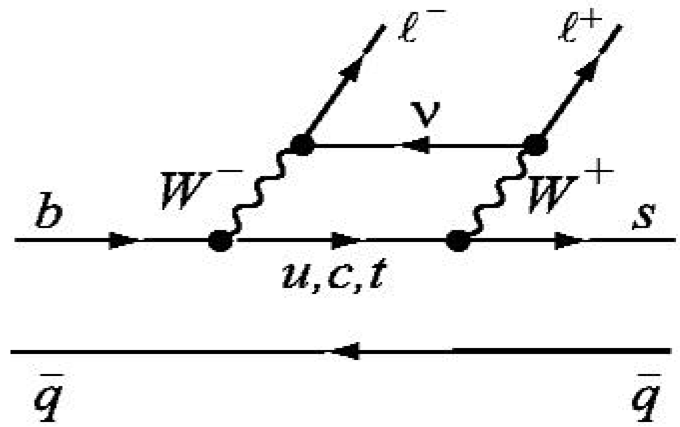
Λ ~ $(m_B - m_b)$ ~ energy of light degrees of freedom in meson

$$\langle E_\gamma\rangle = \frac{M_B}{2}\Big[1 - .385\frac{\alpha_s}{\pi} - .620\beta_0\Big(\frac{\alpha_s}{\pi}\Big)^2 - \frac{\bar\Lambda}{M_B}\Big(1 - .954\frac{\alpha_s}{\pi} - 1.175\beta_0\Big(\frac{\alpha_s}{\pi}\Big)^2\Big) - \frac{13\rho_1 - 33\rho_2}{12M_B^3} - \frac{\mathcal{T}_1+3\mathcal{T}_2+\mathcal{T}_3+3\mathcal{T}_4}{4M_B^3} - \frac{\rho_2 C_2}{9M_B M_D^2 C_7} + \mathcal{O}(1/M_B^4)\Big],$$

$$\bar\Lambda = (0.35 \pm 0.08 \pm 0.10)\,\text{GeV}$$

Search for $B \rightarrow K^{(*)} \ell^+ \ell^-$

- **Rare penguin FCNC**
  ($V_{ts}^* V_{tb}$, like $b \rightarrow s\gamma$)
- **SM BR ~ $10^{-6} - 10^{-7}$**
- **Probes more operators in OPE expansion (C_7, C_9, C_{10})**
- **More sensitive to SUSY, other beyond-SM contributions**
- **Must suppress $K^{(*)}$ $\psi^{(\prime)}$, continuum, BB semileptonic**



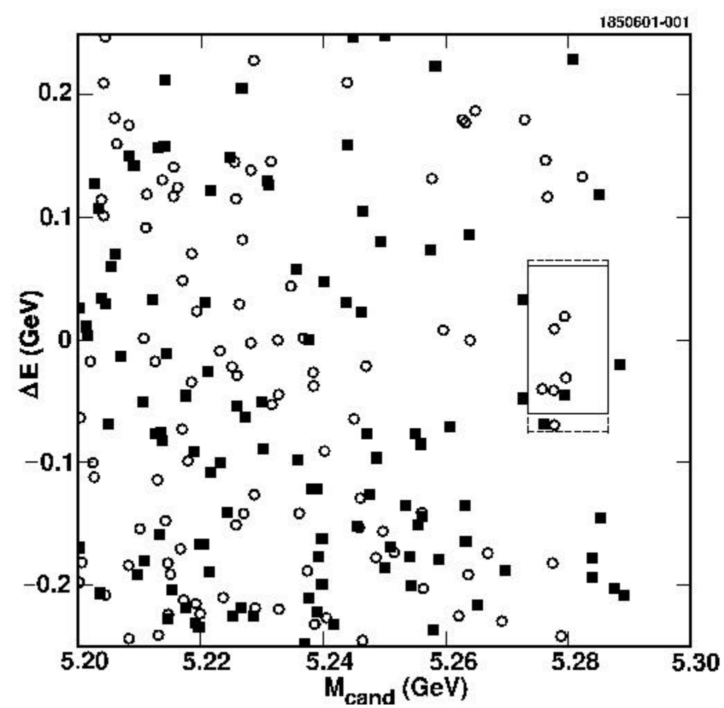
BR($K \ell^+ \ell^-$) < 1.7 × 10^{-6} (3 events)

BR($K^* \ell^+ \ell^-$) < 3.3 × 10^{-6} (4 events)

(both at 90% CL)

Within 50% of SM predictions

CLEO PRL 87:181803, 2001



Extracting V_{cb} from inclusive semileptonic decay rate

- Semileptonic decay of a meson containing a heavy quark can be rigorously (in QCD) related to free quark decay (the spectator model) by HQET+OPE, a controlled expansion in a_s and $1/M_B$. (Falk, Ligeti, Luke, Wise, Savage, Manohar, Bauer, Bigi). Schematically:

$$\Gamma(B \to X_c \ell n) \propto |V_{cb}|^2 \frac{G_F^2 M_B^5}{192p^3}\left[1 + f_1\left(\frac{\overline{\Lambda}, \overline{\Lambda}a_s}{M_B}\right) + f_2\left(\frac{(l_1, l_2, \overline{\Lambda}^2)}{M_B^2}\right) + O\left(\frac{1}{M_B^3}\right)\right] + rad\ cor...$$

- ➢ $\overline{L}$ ~ $(M_B - M_b)$ ~ energy of light degrees of freedom in meson
- ➢ l_1 ~ average kinetic energy of b quark in B meson
- ➢ l_2 » 0.12 ~ hyperfine interaction M(B*)-M(B)
- Measure inclusive rate $G(B ® X_c \ell n) = BR / t_B$
  - BR(B ® $X_c \ell n$) = (10.39 ±0.46)% (CLEO 1996)
  - Lifetime $t(B^{\pm})$ = (1.653 ±0.028) ps; $t(B^0)$ = (1.548 ±0.032) ps (PDG2000)
  - Ratio on Y(4S): f_{+-} / f_{00} = 1.04 ± 0.08 (CLEO 2001)
- Measure $<E_g>$ in $b ® sg$, use theory to extract $\overline{L}$
- Measure moments of $M(X_c)$ distribution, use theory to extract l_1
- From the above formula, extract $|V_{cb}|$
- Estimate errors due to neglected $1/M_B^3$ terms, scale of a_S, etc.
- All of this relies on assumption of quark-hadron duality

B ® $X_c \ell n$ Hadronic Mass Moments

Want B® $X_c ln$ hadronic mass distribution

- Identify lepton (1.5 GeV < P < 2.5 GeV)
- Hermiticity: p_ν
- Calculate hadronic recoil mass from $\ell\nu$

$$M_X^2 = M_B^2 + M_{\ell n}^2 - 2(E_B E_{\ell n} - P_B P_{\ell n} \cos q_{B-\ell n})$$

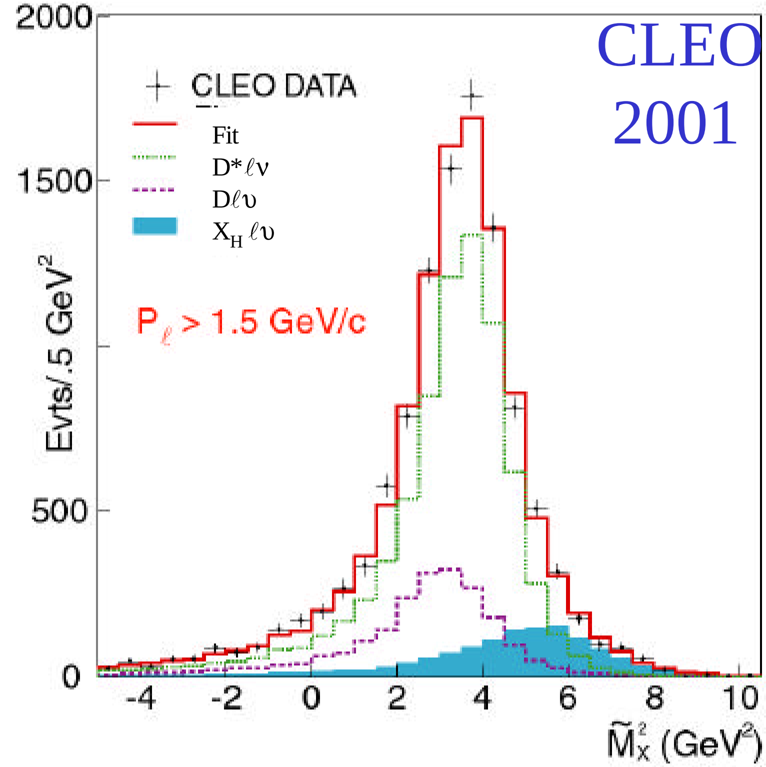
- Drop $\cos q_{B-\ell n}$ because P_B is small

$$\tilde{M}_X^2 = M_B^2 + M_{\ell n}^2 - 2E_B E_{\ell n}$$

- Fit spectrum with
  - B® Dln
  - B® $D^* ln$
  - B ® $X_H ln$ (X_H = D**, $D^{(*)}n\pi$… ISGW2, Goity-Roberts, for X_H)
- Find moments of true M_X^2 spectrum

CLEO PRL 87:251808, 2001

Observed recoil mass: ON-OFF



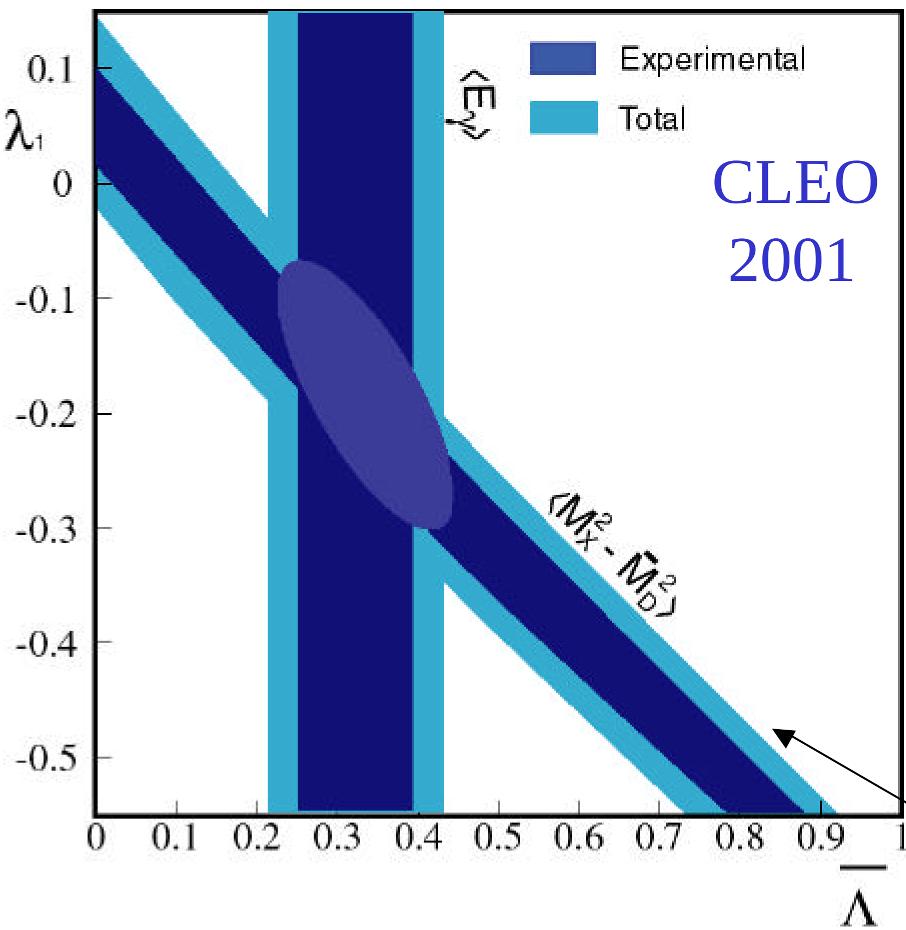
$$\left\langle M_x^2 - \overline{M}_D^2 \right\rangle = 0.251 \pm 0.023 \pm 0.062\ \text{GeV}^2$$

$$\left\langle \left(M_x^2 - \overline{M}_D^2\right)^2 \right\rangle = 0.639 \pm 0.056 \pm 0.178\ \text{GeV}^4$$

$\overline{M}_D$ is spin averaged D, D^* mass

$\bar{\Lambda}$ and l_1

b→sγ 1st moment f($\bar{\Lambda}$)



- b → s γ measures Λ, independently of λ_1
- <$M^2(X_c)$> measures a linear combination of Λ, λ_1
- Higher moments are less reliable in the theory
- Action is in Λ- λ_1 plane

$$\bar{\Lambda} = 0.35 \pm 0.07 \pm 0.10 \text{ GeV}$$

$$l_1 = -0.238 \pm 0.071 \pm 0.078 \text{ GeV}^2$$

Moments (ν recon, non-res models) — $1/\bar{M}_B^3$

B→Xlν 1st moment f(l_1 Λ)

Extraction of $|V_{cb}|$

Measured Γ_{sl}

$\mathcal{B}(B \to X_c \ell \nu) = (10.39 \pm 0.46)\%$ [CLEO]

$$\tau_{B^+} = (1.653 \pm 0.028) \times 10^{-12}\ \text{sec} \quad [\text{PDG}]$$

$$\tau_{B^0} = (1.548 \pm 0.032) \times 10^{-12}\ \text{sec} \quad [\text{PDG}]$$

$f_{+-}/f_{00} = 1.04 \pm 0.08$ [CLEO]

$$\Gamma_{s\ell} = (0.427 \pm 0.020) \times 10^{-10}\ \text{MeV}$$

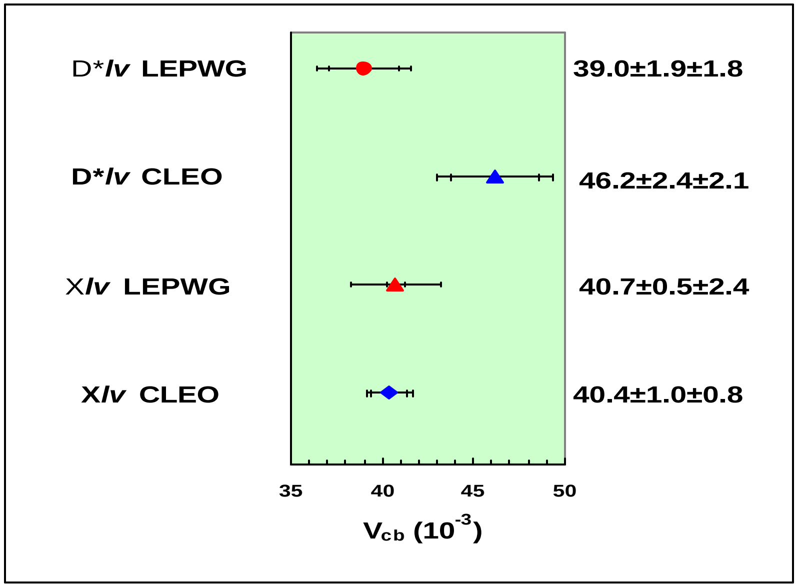
Combine with $\bar{\Lambda}$ and λ_1:

$$|V_{cb}| = (40.4 \pm 0.9 \pm 0.5 \pm 0.8) \times 10^{-3}$$

(the three errors arise from $\Gamma_{s\ell}$; $\bar{\Lambda}, \lambda_1$; $1/M_B^3, \alpha_S$)

$$\boxed{|V_{cb}| = (40.4 \pm 1.3) \times 10^{-3}} \quad (3.2\% \text{ error !})$$

CLEO, PRL 87:251808, 2001

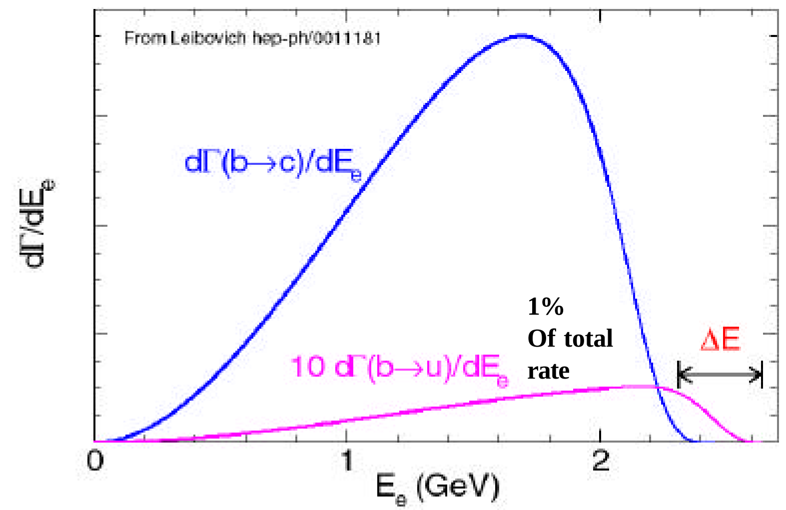


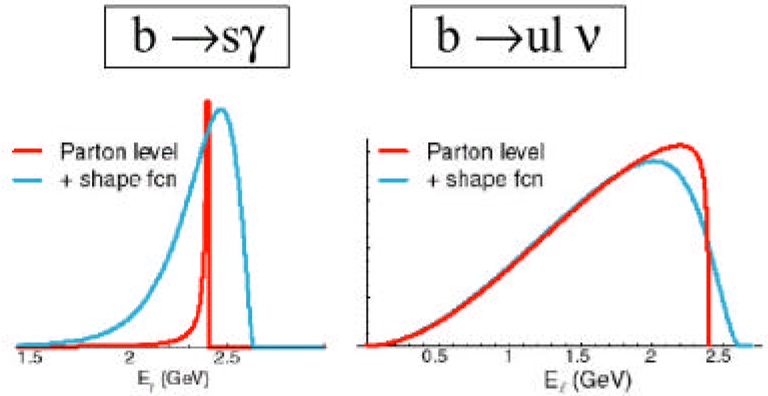
- A 3.2% measurement!
- Inclusive assumes quark - hadron duality.
- Moments can validate inclusive method.
- Inclusive & exclusive methods both needed.
- Agreement: confidence in V_{cb} determination, and good test of quark - hadron duality.

From $|V_{cb}|$ to $|V_{ub}|$

- Why not another expansion in $\Lambda, \lambda_1, \lambda_2$?
  - Very large $b \to c$ backgrounds!
  - Only isolate $b \to u\, \ell\nu$ in corner of phase space (here, endpoint of lepton momentum)
- Expansion is no longer in $1/M_B$:
  - This is a heavy $\to$ light transition
  - Expansion in: $1/(1-x)M_B$, $x = 2p_\ell/M_B$
- Very sensitive to smearing of spectrum at endpoint!
- Can relate to another heavy $\to$ light transition: $b \to s\,\gamma$ (Neubert; Liebovich, Low, and Rothstein)
  - Both are smeared by a common non-perturbative light-cone shape function
- Extract shape function from $b \to s\,\gamma$
- Use to predict fraction of $b \to u\, \ell\nu$ rate above experimental lepton momentum cut

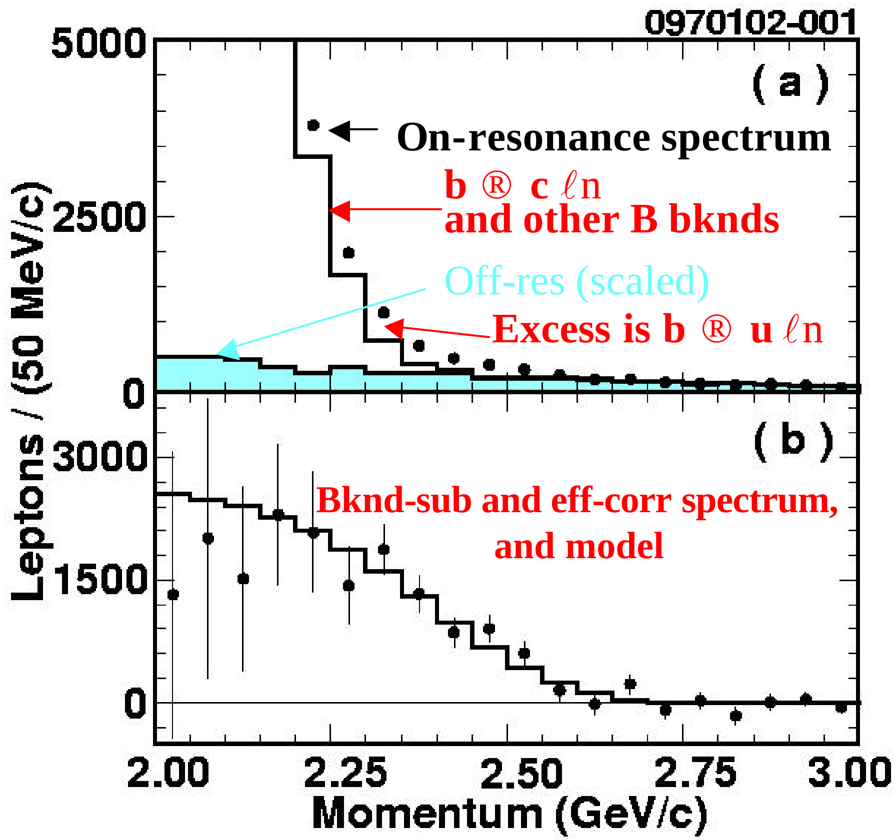
(and try to make this cut as low as possible!)





The b $\rightarrow$ u $\ell\nu$ endpoint

- Use 9.13 fb^{-1} (ON), 4.35 fb^{-1} (OFF)
- $2.2 < p_\ell < 2.6$ GeV/c **(VARY)**
- Neural-net continuum subtraction
- Subtract remaining continuum using off-res data
- Shape of b $\rightarrow$ c $\ell\nu$ and other B bknds estimated using detailed MC simulation (including PHOTOS for radiation), and subtracted
- Syst error dominated by model uncertainty in B backgrounds



N(B $\rightarrow X_u \ell\nu$) events = 1901 ± 122 ± 256

Partial branching ratio:

ΔBR (B $\rightarrow X_u \ell\nu$) (2.2 – 2.6 GeV) = $(2.30 \pm 0.15 \pm 0.35) \times 10^{-4}$

CLEO hep-ex/0202019, submitted to PRL

Extracting $|V_{ub}|$ from inclusive spectrum

- From Hoang, Ligeti and Manohar (1999) ("Upsilon Expansion"):
- $|V_{ub}| = [(3.06 \pm 0.08 \pm 0.08) \times 10^{-3}] \times [(B_{ub} / 0.001) \cdot (1.6\ \text{ps})/\tau_B)]^{1/2}$
- Need $B_{ub} \equiv BR\ (B \to X_u\ \ell\nu\ )$ from $\Delta BR\ (B \to X_u\ \ell\nu\ )$
- Determine fraction of B_{ub} in lepton momentum endpoint using $b \to s\ \gamma$
  - Fit light-cone shape function (Kagan-Neubert; 2 parameterizations)
  - Convolute with parton-level $b \to u\ \ell\nu$ rate
  - determine fraction $f_u(p)$ for different windows
  - $f_u(p) = 0.130 \pm 0.024 \pm 0.015$ for $2.2 < p_\ell < 2.6$ GeV/c
  - Vary the momentum window: consistent results.
- $\Rightarrow BR\ (B \to X_u\ \ell\nu\ ) = (1.77 \pm 0.29 \pm 0.38) \times 10^{-3}$
- $\Rightarrow |V_{ub}| = (4.08 \pm 0.34 \pm 0.44 \pm 0.16 \pm 0.24) \times 10^{-3}$
- Errors: ΔBR $\quad f_u(p)$ $\quad B_{ub} \to |V_{ub}|$ $\quad$ shape fcn
- Result assumes quark-hadron duality.

Determination of V_{cb} from Exclusive B → D* $\ell^+\nu$

- The differential decay rate in $q^2 = m^2(\ell^+ n)$, or better,

  the *HQET* variable $w = v_B \bullet v_{D*} = (m^2_B + m^2_{D*} - q^2)/(2\, m_B m_{D*})$, is

$$dG/dw\ (B \text{ ® } D^* \ell^+ n) = (G^2_F/48p^2)\ |V_{cb}|^2\ |F_{D*}(w)|^2\ PS(w)$$

- ***PS(w)*** contains kinematic factors and is *known*
- $F_{D*}(w)$ is the form-factor describing the B → D* transition
- There's actually 3 form-factors, but their ratios are measured by CLEO and others, and they boil down to one in *w* (Isgur-Wise function).

• HQS normalizes at zero recoil (**q^2_{max}, w=1**):

  as $m_Q \to \infty$, $F_{D*}(w) \to 1$

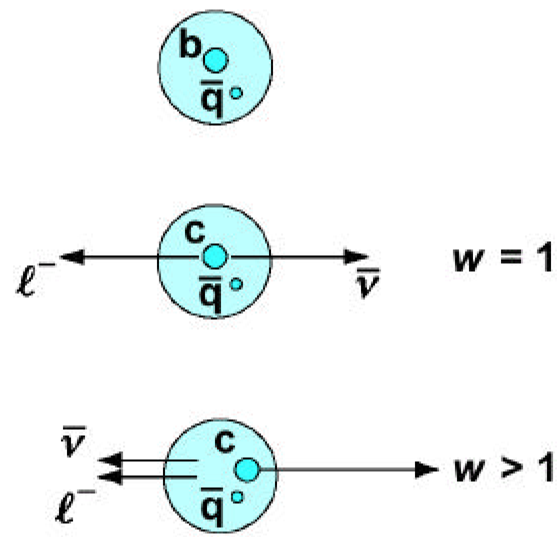
• PLAN: measure ***dG/dw***, extrapolate to *w*=1

  to extract $F_{D*}(w)\ |V_{cb}|^2$

• QCD dispersion relations contsrain the shape of $F_{D*}(w)$, in terms of one parameter:

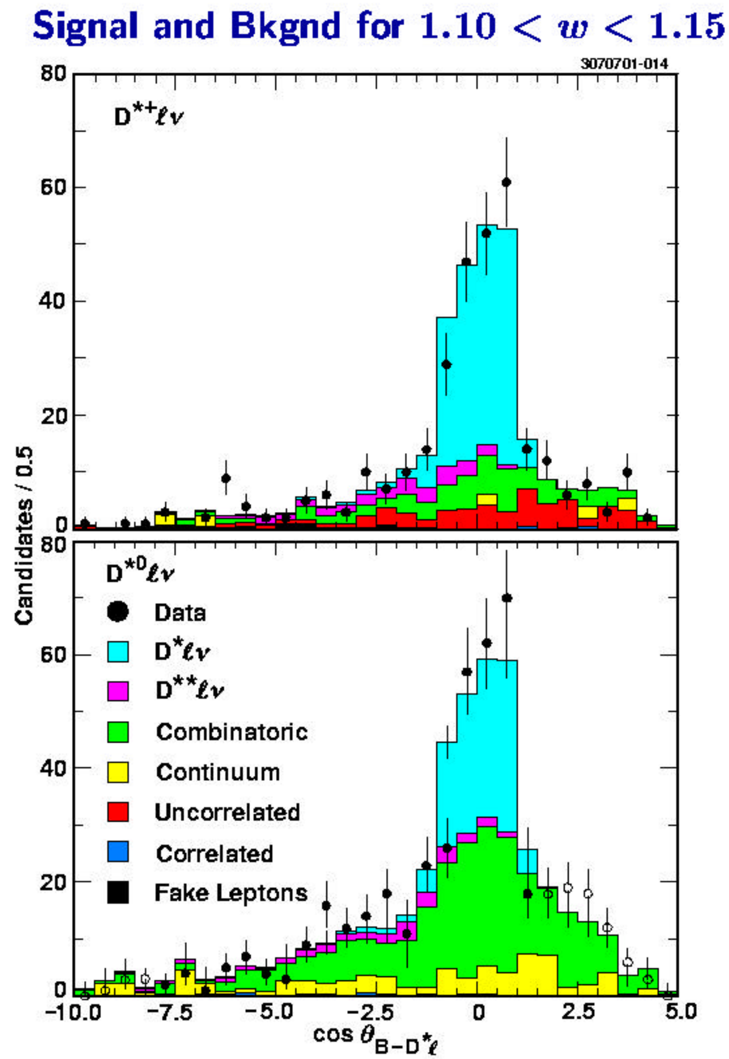
  r^2, the slope at w = 1.

• Use HQET to estimate $F_{D*}(w=1) = 0.913 \pm 0.042$



Isolating $B \to \mathbf{D^*} \ell^+ \nu$

- $B \to \mathbf{D^{*-}} \ell^+ \nu$ Osaka (2000) , now also
- $B \to \mathbf{D^{*0}} \ell^+ \nu$ Rome (2001)
- Use 3.1 fb^{-1} (ON), 1.6 fb^{-1} (OFF)
  systematics limited;
  use best-studied ~1/3 of CLEO data
- Electrons: $0.8 < p_e < 2.4$ GeV/c
- Muons: $1.4 < p_\mu < 2.4$ GeV/c
- Discriminate signal from backgrounds:
  - Angle between B and $D^* \ell$
  - If more than one ν missing,
    can have $|\cos\theta_{B-D^*\ell}| > 1$
- Analysis requires rate vs q^2 or w
  - Fit $\cos\theta_{B-D^*\ell}$ distribution to
    signal+backgrounds in bins of w

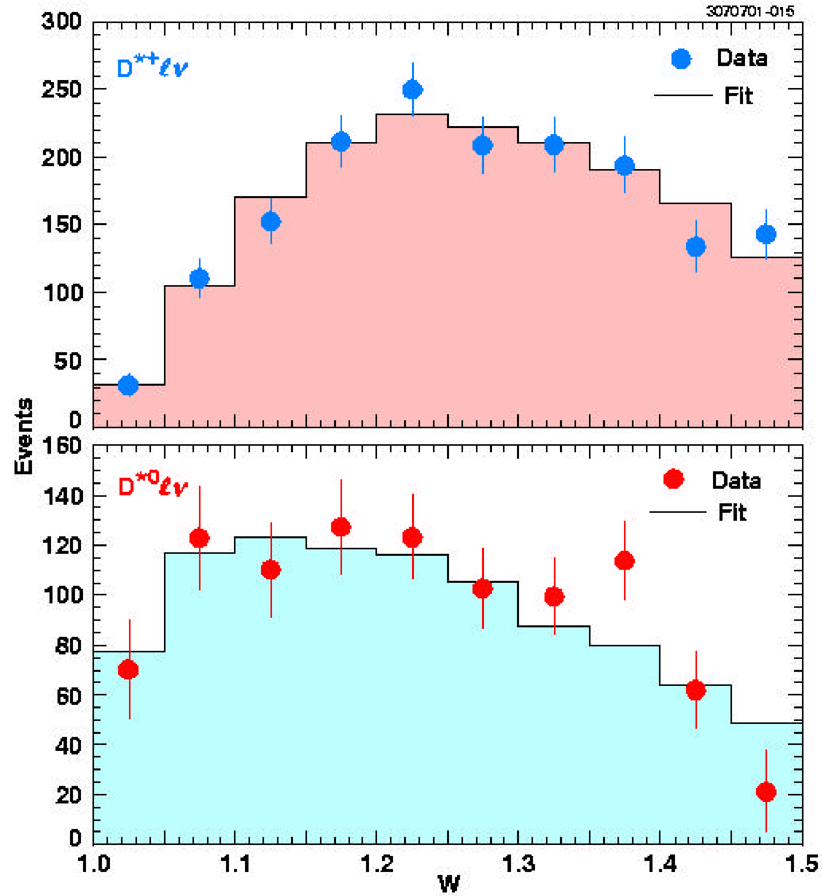


$d\Gamma/dw$ (B→ **D*** $\ell^+\nu$)

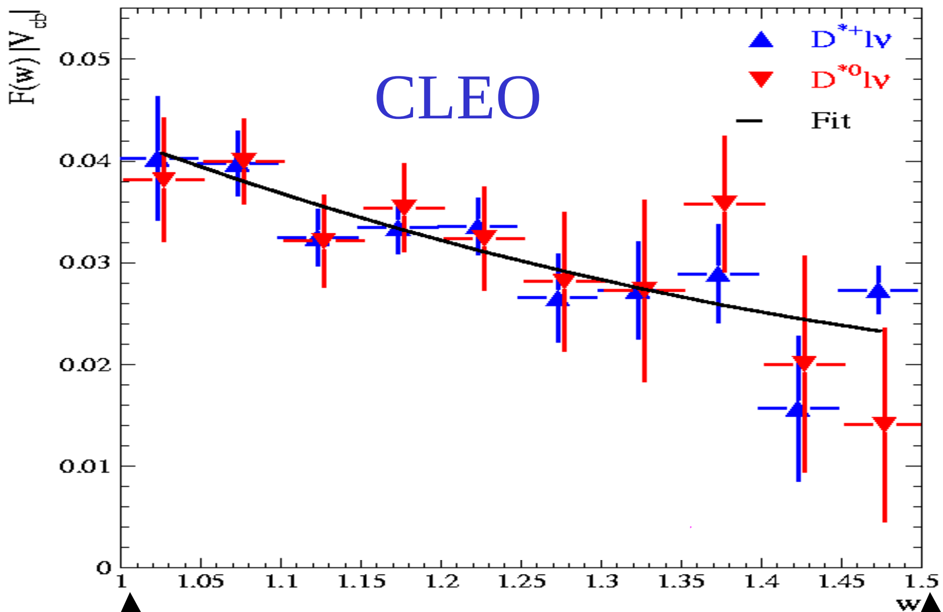
- Extract signal in bins of *w*
- Rate for B→ **D** $\ell^+\nu$ near w=1 is zero; for B→ **D*** $\ell^+\nu$ it is finite.
- Better D^* signal and efficiency for D^{*+}; better acceptance at w=1 for D^{*0}
- Integrating over *w*:
- **BR(D^{*-} ℓ^+n) = (6.09** ± 0.19 ± 0.40)%

  BR(D^{*0} ℓ^+n) = (6.50 ± 0.20 ± 0.44)%

  G(**D^*** ℓ^+**n) = (39.4** ± 1.2 ± 2.6) **fs^{-1}**
- Systematics:
  - Efficiency (slow pions)
  - D^*, D branching fractions
  - Backgrounds
  - Form factors



Fit for V_{cb} from $B \rightarrow D^* \ell^+ \nu$



$q^2 = q^2_{max}$ $\qquad$ $q^2 = 0$

$$w = \frac{m_B^2 + m_{D^*}^2 - q^2}{2 m_B m_{D^*}}$$

$$\frac{d\Gamma}{dw} = \frac{G_F^2}{48p^2} |V_{cb}|^2 F_{D^*}(w)^2 \; PS(w)$$

- Convert from $d\Gamma/dw$ to $F(w)|V_{cb}|$
- Extrapolate to w=1 via fit for $F(w)$ to polynomial; curvature related to slope r by theory (Caprini-Lellouch-Neubert)
- Slope $r = (1.61 \pm 0.09 \pm 0.21)$
- Intercept $F(1)|V_{cb}| = (4.31 \pm 0.13 \pm 0.18) \times 10^{-2}$
- Use $F(1) = 0.91 \pm 0.04$ (Lattice QCD)

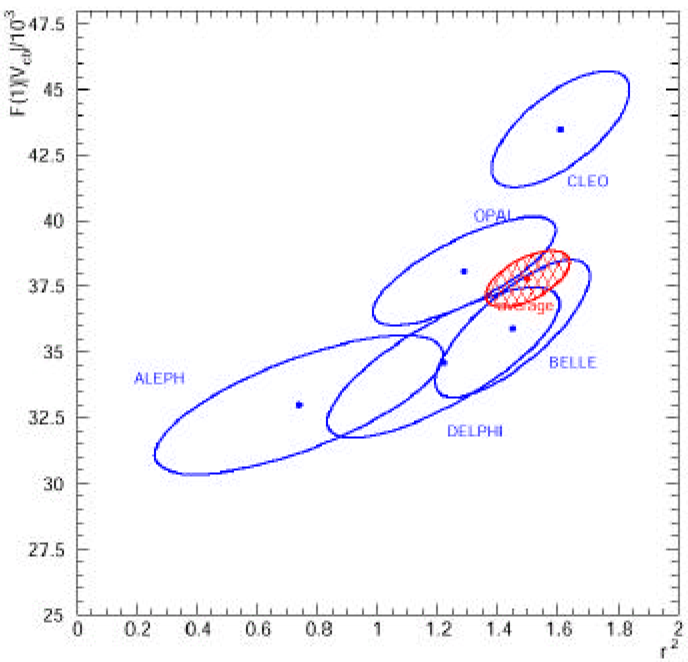
theory

$$|V_{cb}| = (47.4 \pm 1.4 \pm 2.0 \pm 2.1) \times 10^{-3}$$

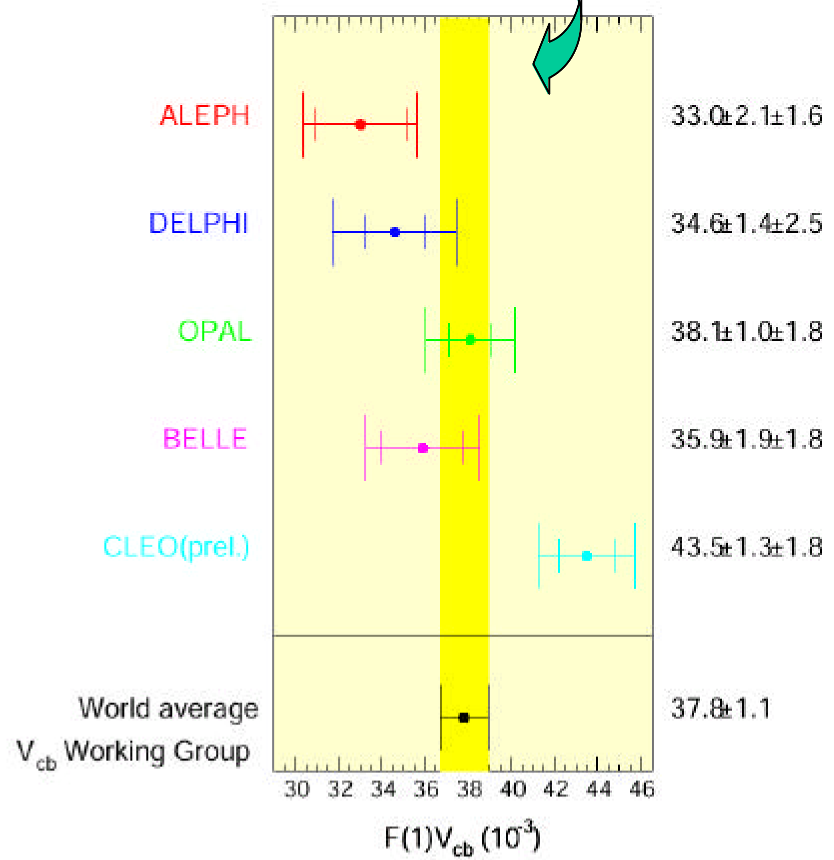
- Dominant sys errors: $\varepsilon_\pi$slow, form factors, $B(D \rightarrow K\pi)$
- Single most precise excl. V_{cb}

V_{cb} from $B \to D^* \ell^+ \nu$

- Comparison with other recent exclusive measurements:



Consistency at the 5% CL



- CLEO includes D^{*0}
- CLEO fits for $D^* X \ell^+ \nu$ component; LEP uses models
- CLEO uses $F(1) = 0.913$; LEP WG uses 0.88

V_{ub} from Exclusive Reconstruction of B ® (p/r/w) $\ell^{+}\nu$

- CLEO 1996 measured BRs for

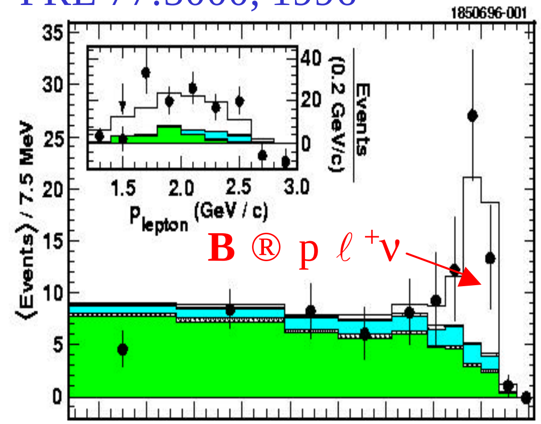
  B ® p $\ell^{+}\nu$ and **(**r/w**)** $\ell^{+}\nu$,
  reconstructing ν from missing E-p

- **BR(**p ℓ^{+}n**) = (1.8** ± 0.4 ± 0.4) ´ 10^{-4}

  BR(r/w ℓ^{+}n**) = (2.5** ± 0.4 ± 0.8) ´ 10^{-4}

- **|V$_{ub}$| = (3.25 ± 0.30 ± 0.55)** ´ 10^{-3}

CLEO, PRL 77:5000, 1996

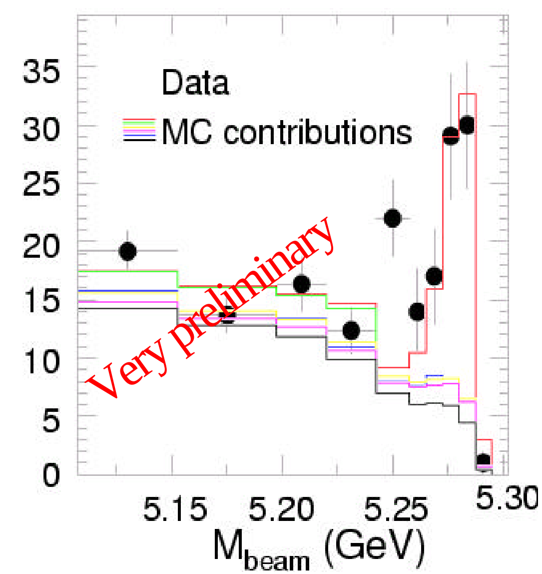


•**New (2002) analysis** uses > 3 × N_{BB} , permitting measurement in bins of q^2

•Analysis nearing completion

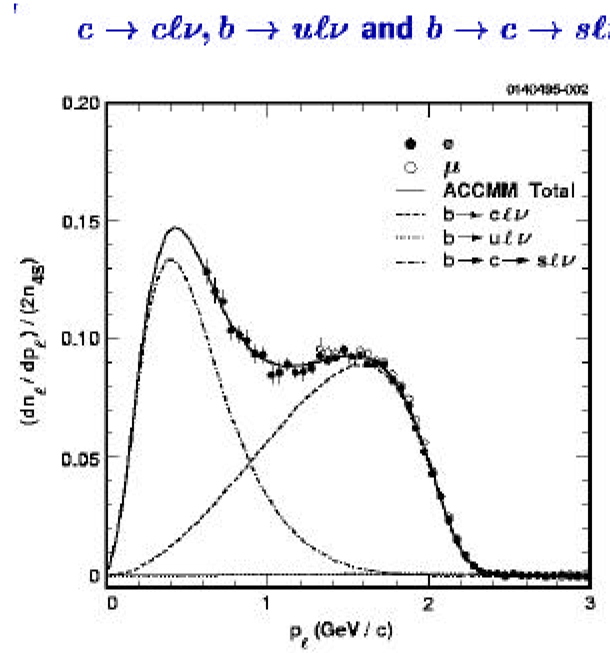
•To reduce model dependence of |V$_{ub}$| result, HQET relates **B** ® p $\ell^{+}\nu$ to **D** ® p $\ell^{+}\nu$, which will be well measured in CLEO-c

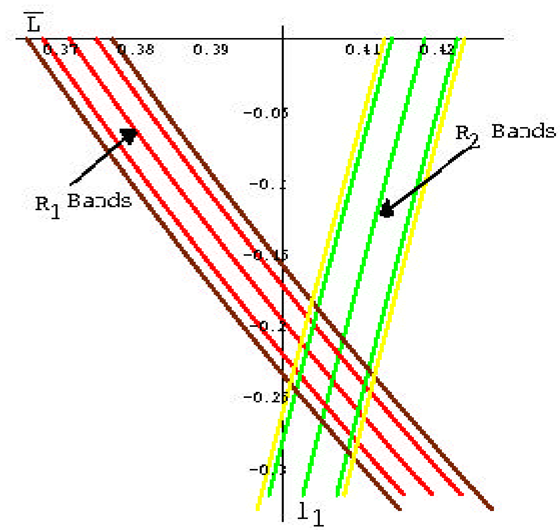
B→ πlν data: 8 < q^2 < 16 GeV^2



More CKM measurements to come

- $B \rightarrow X_c \ell \nu$ inclusive lepton spectrum moments ($\langle E_\ell \rangle$)
  - Another band in $\Lambda - \lambda_1$ plane
  - low-background tagged (di-leptons) and high-stat untagged
- $B \rightarrow X \ell \nu$ inclusive $\ell \nu$ distribution (neutrino reconstruction)
  - Simultaneously measure components of $b \rightarrow c \ell \nu$ and $b \rightarrow u \ell \nu$ in full 3-D kinematic space (E_ℓ , E_ν , q^2)
  - Extract Λ / λ_1, from moments of $b \rightarrow c \ell \nu$ and V_{ub} from $b \rightarrow u \ell \nu$





Summary of Recent CLEO Results

- New measurement of B(*b* ® *s g*) and $\langle E_\gamma \rangle \rightarrow \bar{\Lambda}\ (m_b)$

  B(*b* ® *s g*) = (3.21 ± 0.43 ± 0.32) ´ 10^{-4}

- New limits on $B \rightarrow K^{(*)} \ell^+ \ell^-$:

  B(K $\ell^+ \ell^-$) < 1.7 ´ 10^{-6} , **B(K* $\ell^+ \ell^-$) < 3.3** ´ 10^{-6}

- New V_{cb} from moments analysis of $b \rightarrow s\gamma$ & $B \rightarrow Xl\nu$

  $|V_{cb}|$ = (40.4 ± 1.3) ´ 10^{-3}

- New V_{ub} from endpoint of lepton spectrum, where fraction of rate in endpoint constrained by analysis of $b \rightarrow s\gamma$ spectrum.

  $|V_{ub}|$ = (4.08 ± 0.63) ´ 10^{-3}

- New V_{cb} from $B \rightarrow D^* l\nu$

  $|V_{cb}|$ = (46.4 ± 1.4 ± 2.4 ± 2.1) ´ 10^{-3}

More results

- New measurement of V_{ub} from exclusive **B** ® p $\ell^{+}\nu$ and **(**r/w**)** $\ell^{+}\nu$ coming soon. Also more inclusive V_{cb}, V_{ub}.
- Color-suppressed decays, first observation (hep-ex/0110055 ® PRL):

$$\mathcal{B}(\overline{\mathrm{B}}^{0}\to \mathrm{D}^{0}\pi^{0}) = (2.74^{+0.36}_{-0.32}\pm 0.55)\times 10^{-4}$$

$$\mathcal{B}(\overline{\mathrm{B}}^{0}\to \mathrm{D}^{*0}\pi^{0}) = (2.20^{+0.59}_{-0.52}\pm 0.79)\times 10^{-4}$$

- First observation of B → $D^{(*)}$ K* (hep-ex/0112033 ® PRL):

$$\mathcal{B}(B^{-}\to D^{0}K^{*-}) = (6.1 \pm 1.6 \pm 1.7)\times 10^{-4},$$

$$\mathcal{B}(\bar{B}^{0}\to D^{+}K^{*-}) = (3.7 \pm 1.5 \pm 1.0)\times 10^{-4},$$

$$\mathcal{B}(\bar{B}^{0}\to D^{*+}K^{*-}) = (3.8 \pm 1.3 \pm 0.8)\times 10^{-4},$$

$$\mathcal{B}(B^{-}\to D^{*0}K^{*-}) = (7.7 \pm 2.2 \pm 2.6)\times 10^{-4}.$$

useful for measuring CKM angle γ

- Many rare B decays observed by CLEO-III. Branching ratios in good agreement with theory. No CPV observed in rates.