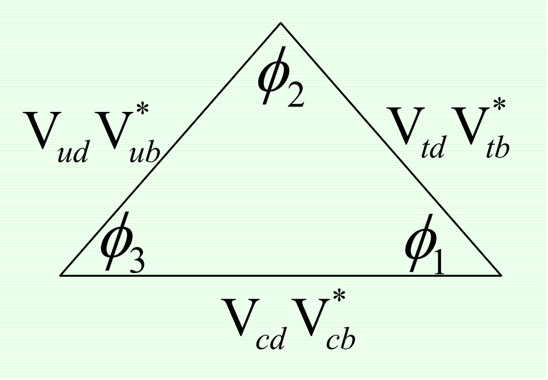
Semileptonic *B* decays and V_{ub}/V_{cb}

Youngjoon Kwon
(Yonsei Univ. / Belle)

- Introduction
- Experimental tools
- Current status of measurements
- Prospects for improvements
- Conclusions



Parameters of the minimal Standard Model

- 17 free parameters of the Electroweak interactions
  - $G_F, \ \alpha, \ \sin^2\theta_W$
  - 3 lepton masses
  - **6 quark masses**
  - **4 quark flavor mixing parameters (a.k.a. CKM)**
  - m(Higgs)
- 10 of these are related with “quark flavors”

  i.e. we don’t know much about flavor sector in the SM after all these years of learning…

Flavor mixing and CKM matrix

- For quarks,
  - weak interaction eigenstates ≠ mass eigenstates
  - flavor mixing through **CKM** matrix

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

V_{ub}: very important for CP study

V_{cb}: responsible for most b decays

Wolfenstein parametrization

$$V_{CKM} \approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

$|\lambda| \approx O(0.1)$

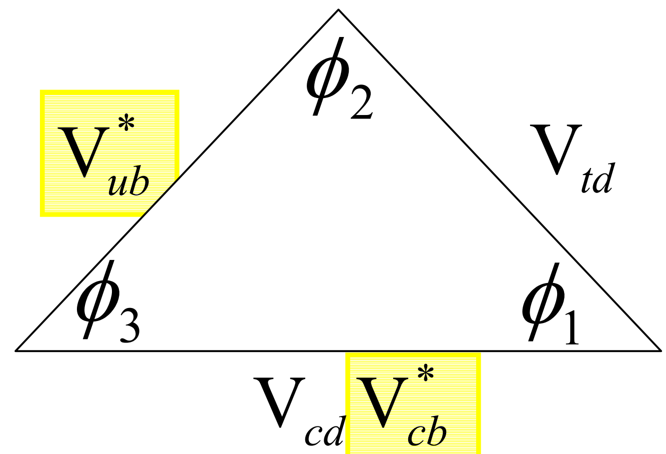
3 real parameters (λ, A, ρ) and 1 phase (η)

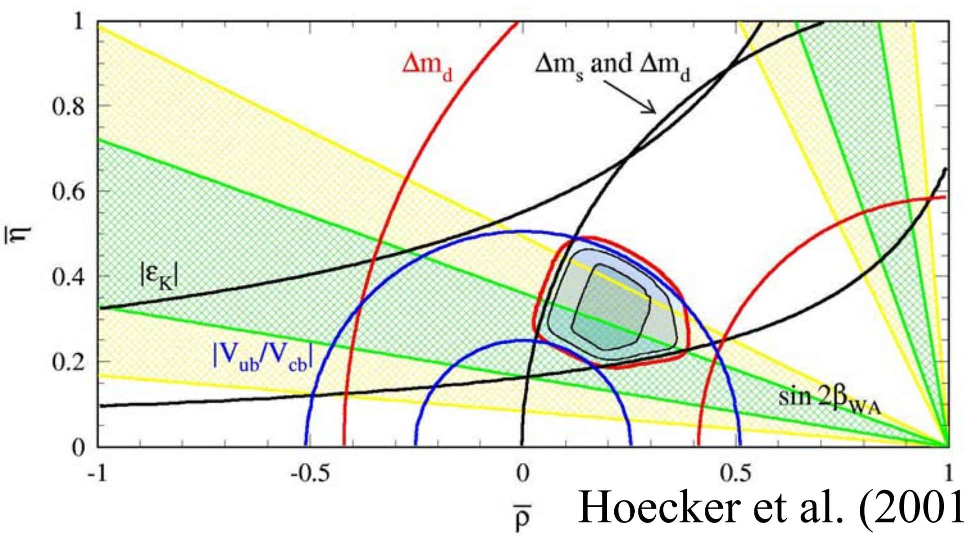
The Unitarity Trianlge

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0$$

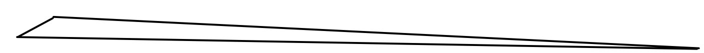
$$V_{ud} \cong V_{tb} \cong 1$$





Hoecker et al. (2001)

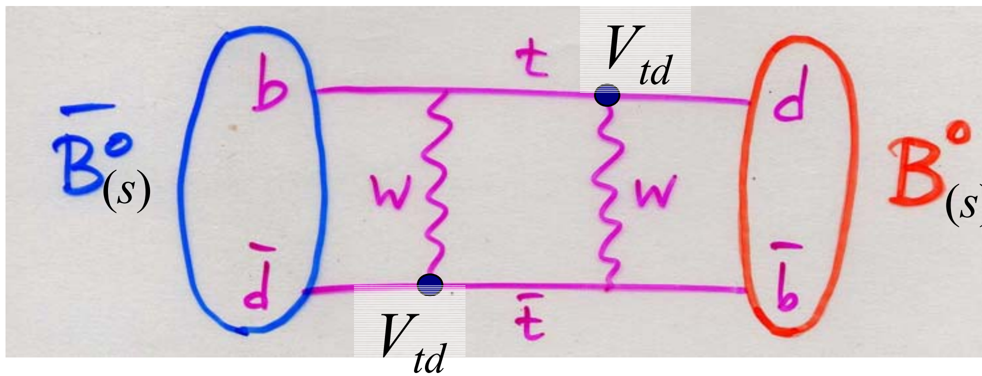
** other triangles are difficult to measure*



Experimental determinations
- only the sides, in this talk

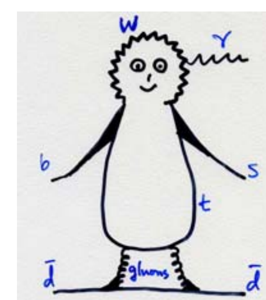
- V_{td} is very interesting and important for the unitarity triangle. But I will leave V_{td} for others to cover.

(1)



(2)

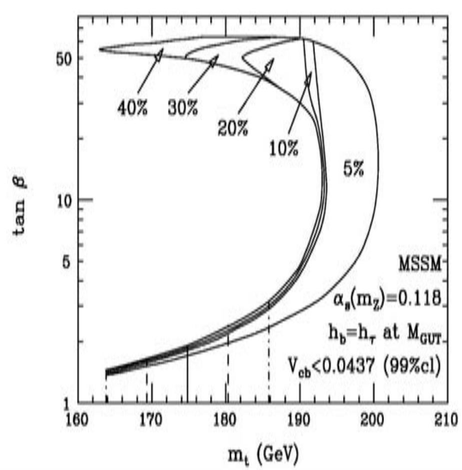
$$R_{K^*/\rho} \equiv \frac{BR(B \to \rho\gamma)}{BR(B \to K^*\gamma)} \propto \left|\frac{V_{td}}{V_{ts}}\right|^2$$

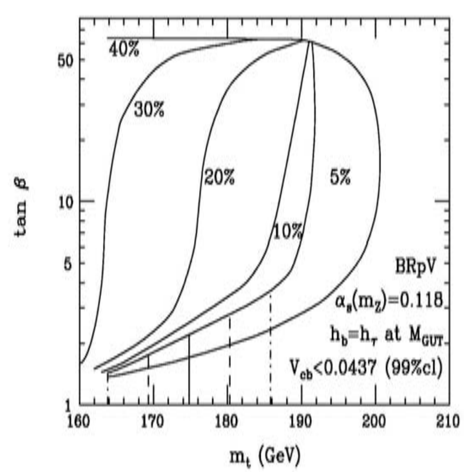


- and **focus on V_{cb} and V_{ub}.**

Any theoretical constraints?

- Of course, there is a ***unitarity constraint***, 8-)
- Other than unitarity, CKM elements are **free parameters** in the minimal SM, but there are some **predictions beyond SM**
  - Anderson, Raby, Dimopoulos & Hall (PRD 47, R3702)
  - simliar analysis by Barger, Berger & Ohmann (PRD 47, 1093)
  - also, recently, by Diaz, Ferrandis & Valle (NPB 573, 75)



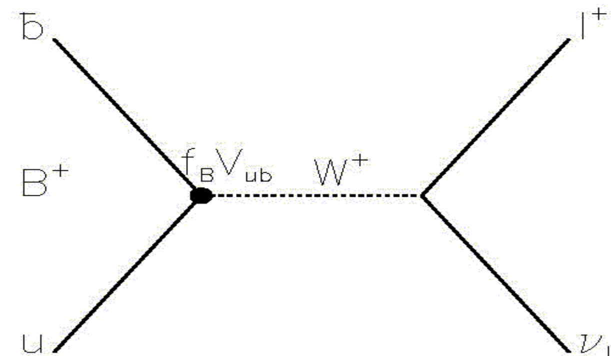


- using zero texture ansatz for fermion mass matrices
- predictions on *m*(top), tan b, and V_{cb}
- they found no solution with V_{cb} < 0.039

Experimental tools for V_{ub} and V_{cb}

- For V_{ub}, the cleanest mode might be fully leptonic *B* decays but,

$$B^+ \to \ell^+ \nu$$



  - uncertainty in f_B
  - BR is very small for (he

$$\ell = e,\ \mu$$

  - or fo:

$$\mathcal{B}(B^+ \to \ell^+ \nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

$$B \to \tau \nu$$

$B^+ \to \ell^+ \nu$: existing results

$\Gamma(e^+\nu_e)/\Gamma_{total}$ — Γ_{10}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1.5 \times 10^{-5}$	90	ARTUSO	95	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\mu^+\nu_\mu)/\Gamma_{total}$ — Γ_{11}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<2.1 \times 10^{-5}$	90	ARTUSO	95	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\tau^+\nu_\tau)/\Gamma_{total}$ — Γ_{12}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<5.7 \times 10^{-4}$	90	[27] ACCIARRI	97F	L3	$e^+e^- \to Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<1.04 \times 10^{-2}$	90	[28] ALBRECHT	95D	ARG	$e^+e^- \to \Upsilon(4S)$
$<2.2 \times 10^{-3}$	90	ARTUSO	95	CLE2	$e^+e^- \to \Upsilon(4S)$
$<1.8 \times 10^{-3}$	90	[29] BUSKULIC	95	ALEP	$e^+e^- \to Z$

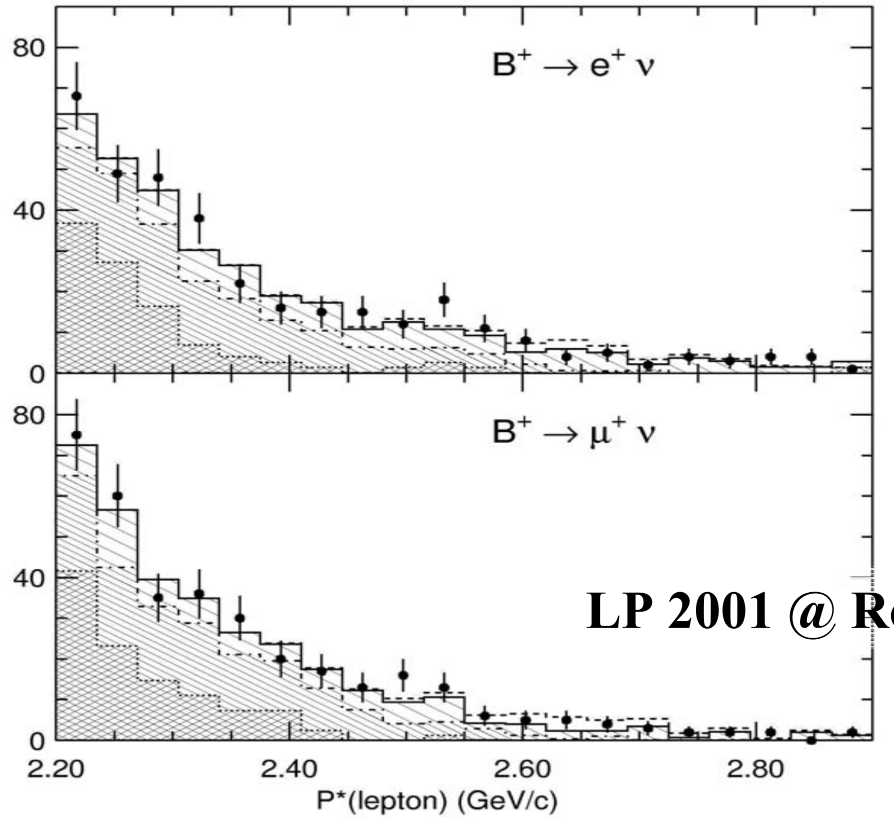
[27] ACCIARRI 97F uses missing-energy technique and $f(b \to B^-) = (38.2 \pm 2.5)\%$.
[28] ALBRECHT 95D use full reconstruction of one B decay as tag.
[29] BUSKULIC 95 uses same missing-energy technique as in $\overline{b} \to \tau^+\nu_\tau X$, but analysis is restricted to endpoint region of missing-energy distribution.

PDG 2000

$< 8.4 \times 10^{-4}$ 90% CLEO (2001) PRL 86, 2950

$B^+ \to \ell^+ \nu$

- **Preliminary new results from Belle (2001)**



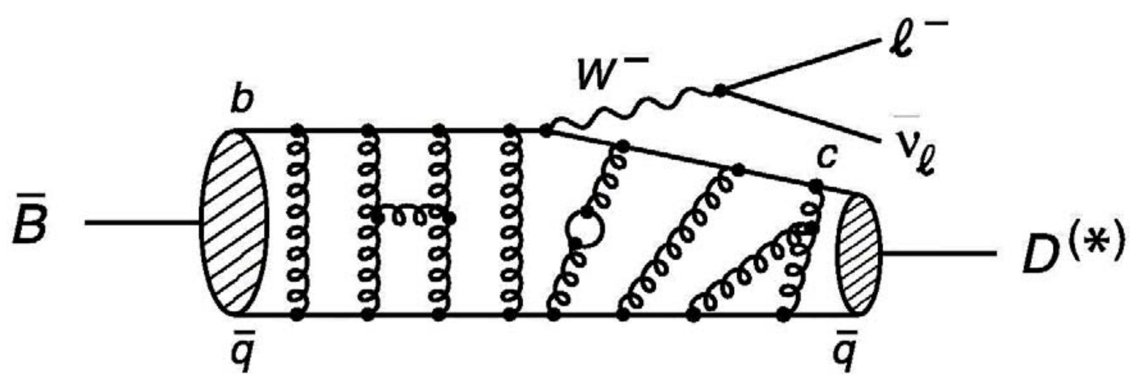
LP 2001 @ Rome

Mode	Signal Efficiency(%)	Signal yield	Branching fraction upper limit (90% CL)
$e^+\nu$	13.1 ± 1.1	$1.5 \pm 7.5 \pm 0.5$	4.7×10^{-6}
$\mu^+\nu$	13.5 ± 1.2	$9.4 \pm 6.3 \pm 1.9$	6.5×10^{-6}

Semileptonic *B* decays for V_{ub} and V_{cb}

- Semileptonic *B* decays provide the best opportunity for measuring $|V_{ub}|$ and $|V_{cb}|$,

  since the strong interaction effects are much simplified due to the two leptons in the final state



- Both **inclusive** and **exclusive** analyses can be used.

Exclusive vs. Inclusive

- Exclusive decays ⇐ need to know form factors
- Inclusive decays ⇐ OPE, quark-hadron duality

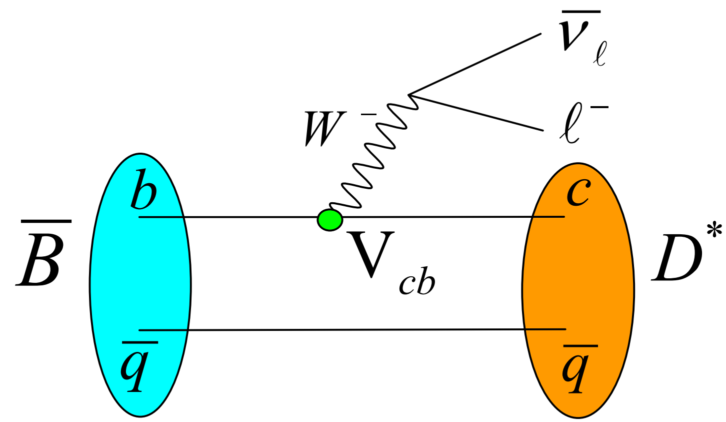
Both should be measured!

V_{cb} (Exclusive)

- **Main concept**
  - consider $B \to D^* \ell \nu$
  - differential decay rate in y

$$\frac{d\Gamma}{dy} = K(y) F^2(y) |V_{cb}|^2$$

$$y = v_B \cdot v_{D^*} = \frac{M_B^2 + M_{D^*}^2 - q^2}{2 M_B M_{D^*}}$$



- *K(y)*: known function
- *F(y)*: **Form-factor**

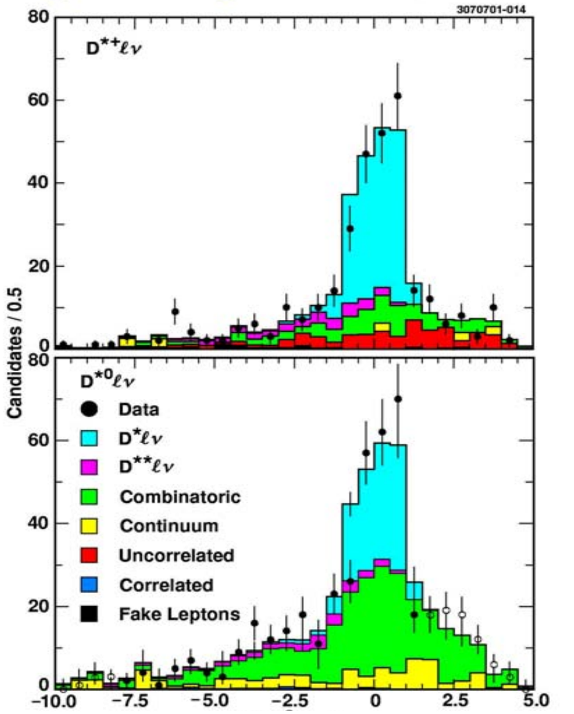
$$F(y) \equiv F(1) f(\rho, y)$$

HQET ➔ $F(1) = 1$ as $m_b \to \infty$

$$F(1) = 1 + O(\alpha_S / \pi) + \delta_{1/m_b^2} + \delta_{1/m_b^3}$$

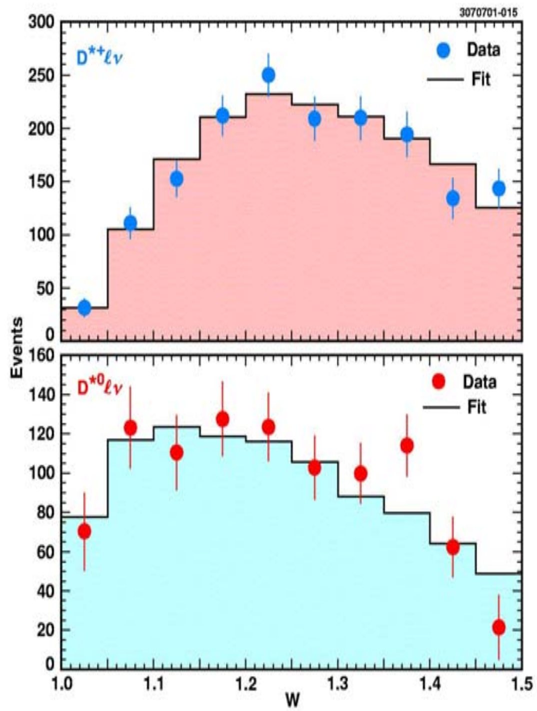
V_{cb} (Exclusive) – CLEO

Signal and Bkgnd for $1.10 < w < 1.15$

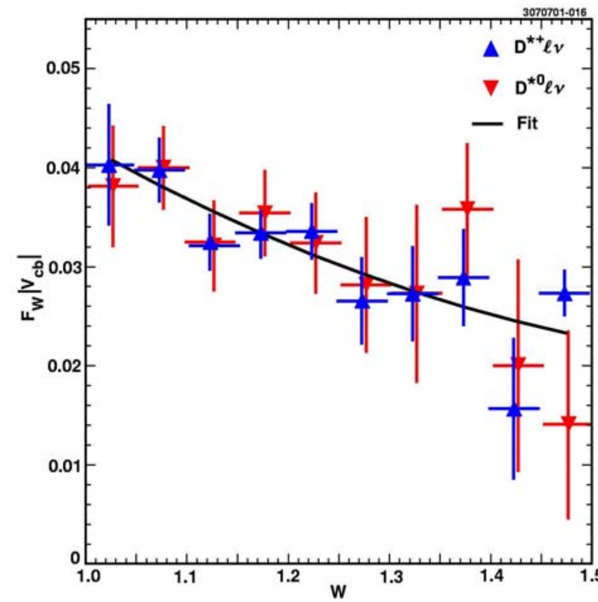


$\cos\theta_{B-D^*\ell}$

Raw rate vs. *y*

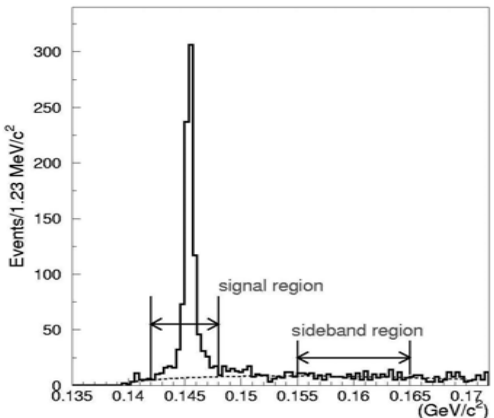


Corrected rate vs. y



$$\mathcal{B}(\bar{B}^0 \to D^{*+}\ell\bar{\nu}) = (5.82 \pm 0.19 \pm 0.37)\%$$
$$\mathcal{B}(B^- \to D^{*0}\ell\bar{\nu}) = (6.21 \pm 0.20 \pm 0.40)\%$$
$$F(1)|V_{cb}| = (4.22 \pm 0.13 \pm 0.18) \times 10^{-2}$$
$$\rho^2 = 1.61 \pm 0.09 \pm 0.21$$

V_{cb} (Exclusive) – Belle $\overline{B}^0 \to D^{*+} e^- \overline{\nu}_e$



Δm

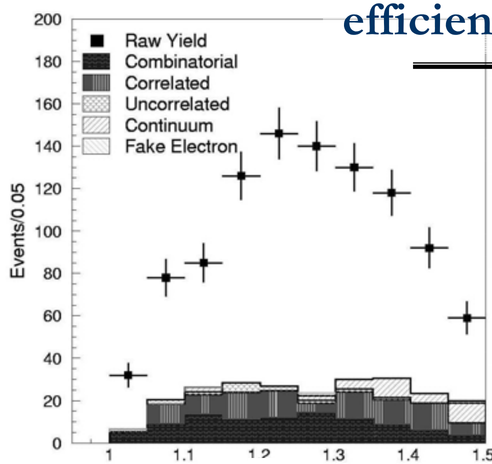
$$M^2_{\rm miss} = M^2_{\bar{B}^0} + M^2_{D^{*+}e^-} - 2E_{\bar{B}^0}E_{D^{*+}e^-} < 1\ ({\rm GeV})^2$$

$$\left| \cos\theta_{\bar{B}^0, D^{*+}e^-} = \frac{2E_{\bar{B}^0}E_{D^{*+}e^-} - M^2_{\bar{B}^0} - M^2_{D^{*+}e^-}}{2\,|\boldsymbol{p}_{\bar{B}^0}|\,|\boldsymbol{p}_{D^{*+}e^-}|} \right| < 1$$

$$|V_{cb}|F(1) = (3.54 \pm 0.19 \pm 0.18) \times 10^{-2}$$

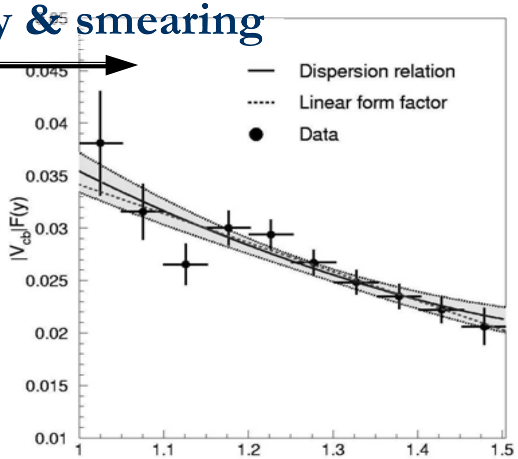
$$\rho^2_{A_1} = 1.35 \pm 0.17 \pm 0.19$$

$$BF(\overline{B}^0 \to D^{*+} e^- \overline{\nu}_e) = (4.59 \pm 0.23 \pm 0.40)\%$$



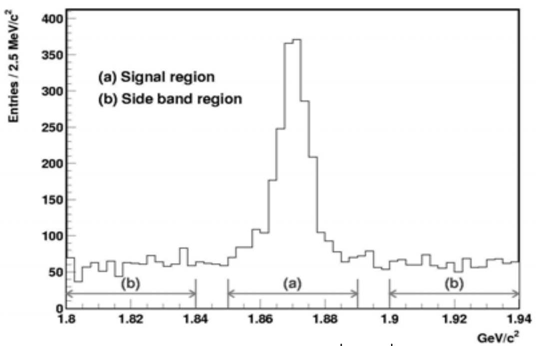
$\tilde{y}$

Unfolded for efficiency & smearing

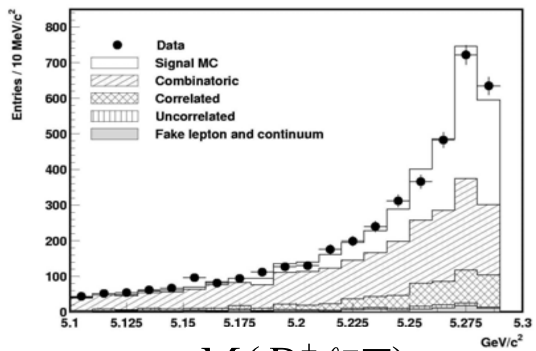


y

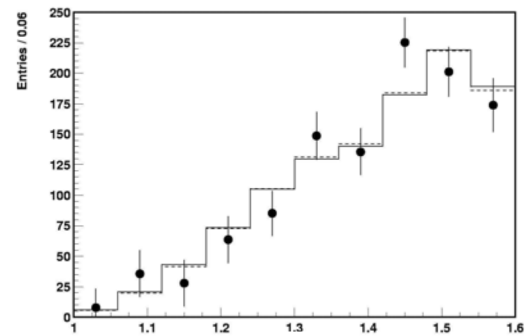
V_{cb} (Exclusive) – Belle $\overline{B}^0 \to D^+\ell^-\overline{\nu}_e$



$M(K^-\pi^+\pi^+)$



$M(D^+\ell^-\overline{\nu})$



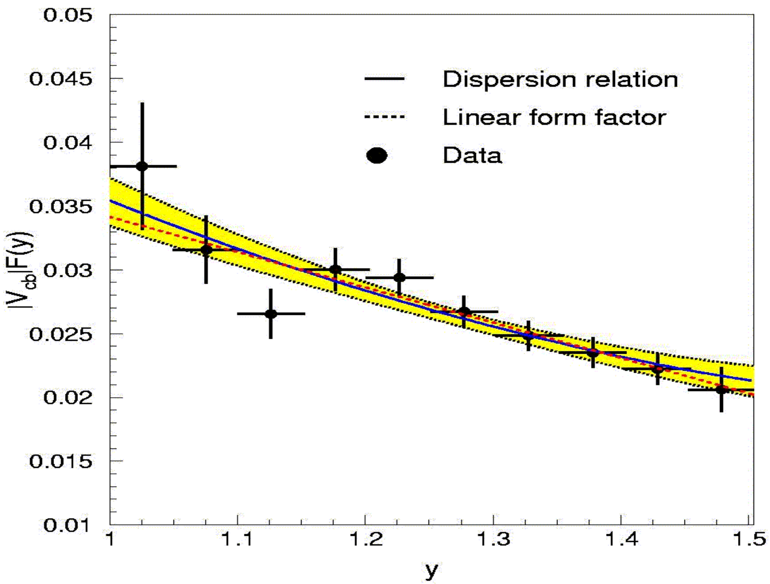
$\tilde{y}$

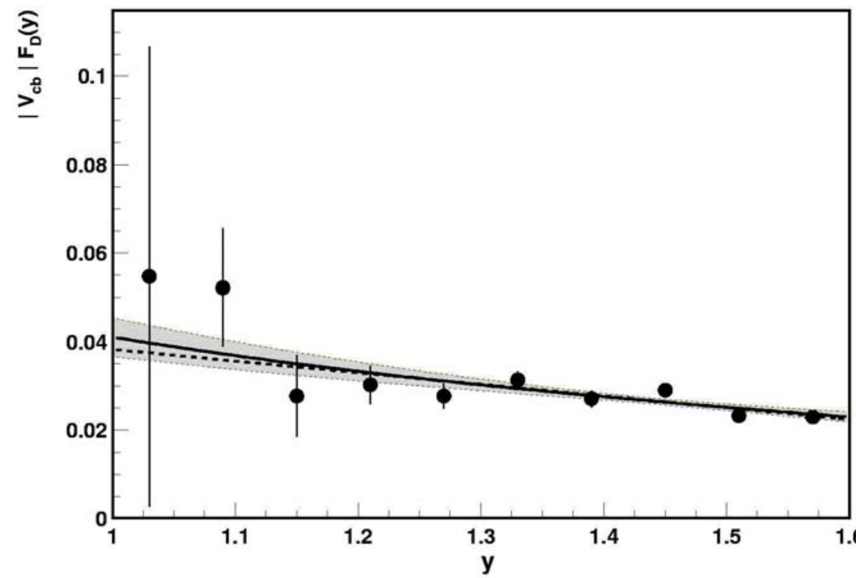
- similar physics process as in $B \to D^*\ell\nu$
- using full neutrino reconstruction based on detector hermiticity

$$E_{\text{miss}} = 2E_{\text{beam}} - \Sigma E_i,$$
$$\boldsymbol{p}_{\text{miss}} = -\Sigma \boldsymbol{p}_i,$$
$$M^2_{\text{miss}} = E^2_{\text{miss}} - |\boldsymbol{p}_{\text{miss}}|^2$$

$$BF(\overline{B}^0 \to D^+\ell^-\overline{\nu}) = (2.13 \pm 0.12 \pm 0.39)\%$$
$$F_D(1)|V_{cb}| = (4.11 \pm 0.44 \pm 0.52) \times 10^{-2}$$

$D^*\ell\nu$ and $D^+\ell\nu$ (Belle)

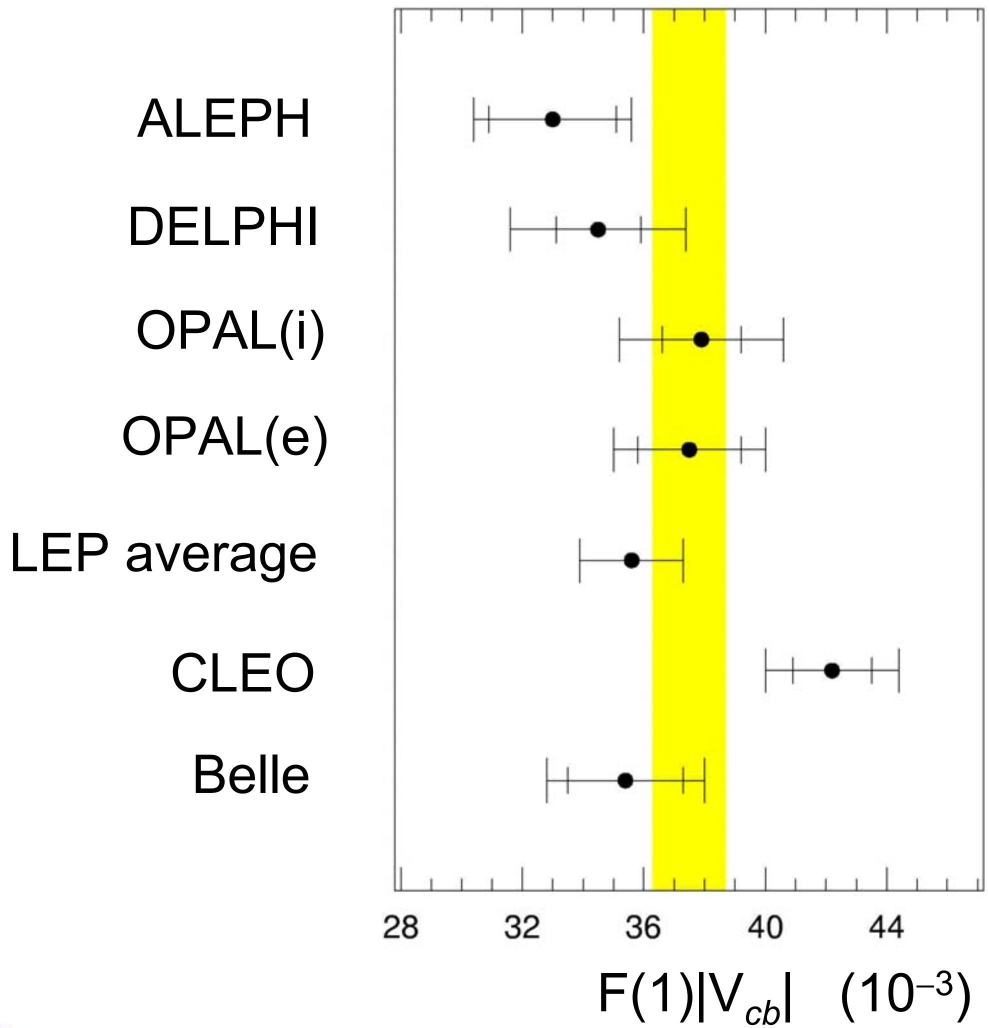




$$\frac{F_D(1)}{F_{D^*}(1)} = \begin{cases} 1.12 \pm 0.12 \pm 0.12 \text{ (Linear form factor)} \\ 1.16 \pm 0.14 \pm 0.12 \text{ (Caprini } et\ al. \text{ form factor)}, \end{cases}$$

$$\hat{\rho}_D^2 - \hat{\rho}_{D^*}^2 = \begin{cases} -0.12 \pm 0.18 \pm 0.13 \text{ (Linear form factor)} \\ -0.23 \pm 0.29 \pm 0.20 \text{ (Caprini } et\ al. \text{ form factor)}, \end{cases}$$

$|V_{cb}|$ Exclusive Summary



V_{cb} with Inclusive decays

- **main procedure**
  - $\Gamma_{\rm sl} \equiv \Gamma(B \to X_c \ell\nu)$ calculable with OPE — Chay, Georgi, Grinstein (1990)
  - no $O(1/m_b)$ corrections
  - perturbative corrections known to $O(\alpha_s^2 \beta_0)$
  - non-perturbative parameters λ_1, $\bar{\Lambda}(m_b)$

$$\Gamma_{\rm sl} = 0.3689 \frac{G_F^2 |V_{cb}|^2 m_b^5}{192\pi^3} \left[1 + 0 \times \frac{1}{m_b} + O\left(\alpha_s^2 \beta_0\right) + O\left(\frac{1}{m_b^2}\right) \right]$$

- **master formula** — Bigi, Shifman, Uraltsev (1997)
  - LEP(x4), BaBar, Belle

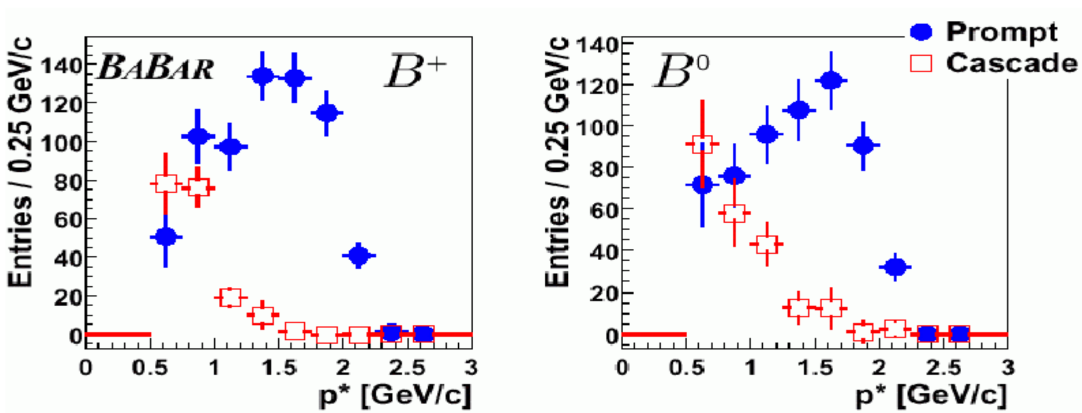
$$|V_{cb}| = 0.0411 \sqrt{\frac{\mathcal{B}\left(B \to X_c \ell\nu\right)}{0.105} \frac{1.55}{\tau_B(\rm ps)}} \left(1 \pm 0.015_{pert} \pm 0.010_{m_b} \pm 0.012_{1/m_b^3}\right)$$

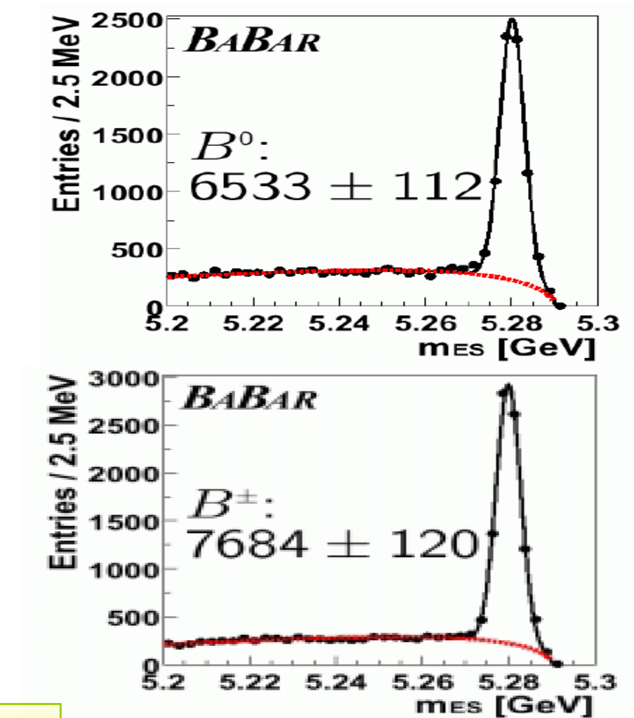
- **using moments to obtain HQET parameters**
  - CLEO (2001)

V_{cb} inclusive methods (1)

- **LEP average** $BF(b \to X\ell\nu) = (10.56 \pm 0.11_{stat} \pm 0.18_{stat})\%$

- **BaBar - two methods**
  - (1) full reconstruction of the other *B*
  - (2) lepton tagging method (*next page*)

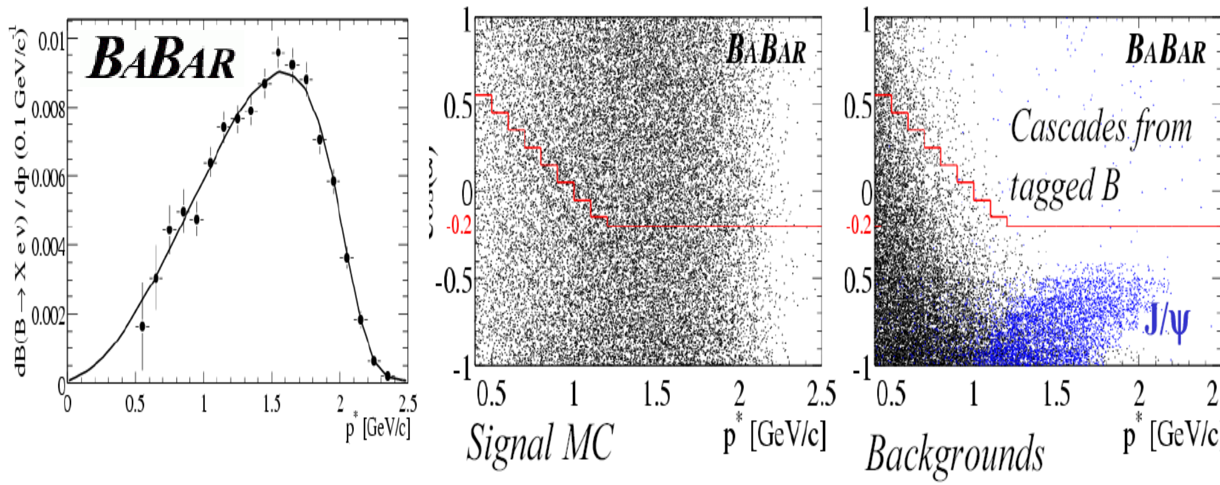




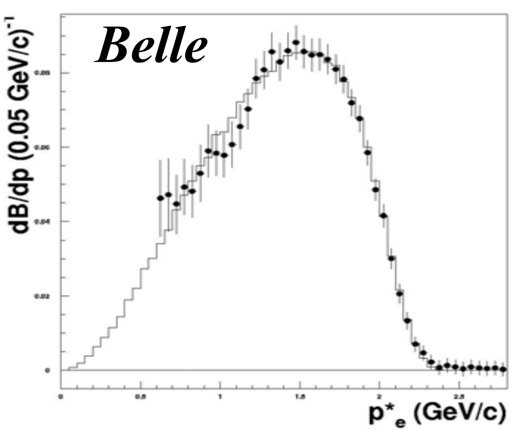
$$BF(B \to Xe\nu) = (10.4 \pm 0.5_{stat} \pm 0.5_{stat})\%$$
$$BF(B^+ \to Xe\nu) / BF(B^0 \to Xe\nu) = 0.99 \pm 0.10_{stat} \pm 0.04_{stat}$$

Purity B^0: (84.4 ±0.4) %
Purity $B^\pm$: (81.6 ±0.4) %

V_{cb} inclusive (2) with lepton-tagging (BaBar, Belle)



$$BF\left(b \rightarrow X\ell\nu\right) = \left(10.82 \pm 0.21_{stat} \pm 0.38_{stat}\right)\%$$



$$\frac{dN_{+-}}{dp} = N_{tag}\eta(p)\varepsilon_{k1}(p)\left[\frac{dB(b \to x\ell\nu)}{dp}(1-\chi) + \frac{dB(b \to c \to y\ell\nu)}{dp}\chi\right]$$

$$\frac{dN_{\pm\pm}}{dp} = N_{tag}\eta(p)\varepsilon_{k2}(p)\left[\frac{dB(b \to x\ell\nu)}{dp}\chi + \frac{dB(b \to c \to y\ell\nu)}{dp}(1-\chi)\right]$$

$$BF\left(b \rightarrow X\ell\nu\right) = \left(10.86 \pm 0.14_{stat} \pm 0.47_{stat}\right)\%$$

V_{cb} from M_X moments and $b \to s\gamma$

CLEO

$\Gamma(\bar{B} \to X_c \ell \bar{\nu})$ can be written in the form

$$\Gamma^c_{SL} = \frac{G_F^2 |V_{cb}|^2 M_B^5}{192\pi^3} \left[\mathcal{G}_0 + \frac{1}{M_B} \mathcal{G}_1(\bar{\Lambda}) + \frac{1}{M_B^2} \mathcal{G}_2(\bar{\Lambda}, \lambda_1, \lambda_2) + \frac{1}{M_B^3} \mathcal{G}_3(\bar{\Lambda}, \lambda_1, \lambda_2 | \rho_1, \rho_2, \mathcal{T}_1, \mathcal{T}_2, \mathcal{T}_3, \mathcal{T}_4) + \mathcal{O}\left(\frac{1}{M_B^4}\right) \right]$$

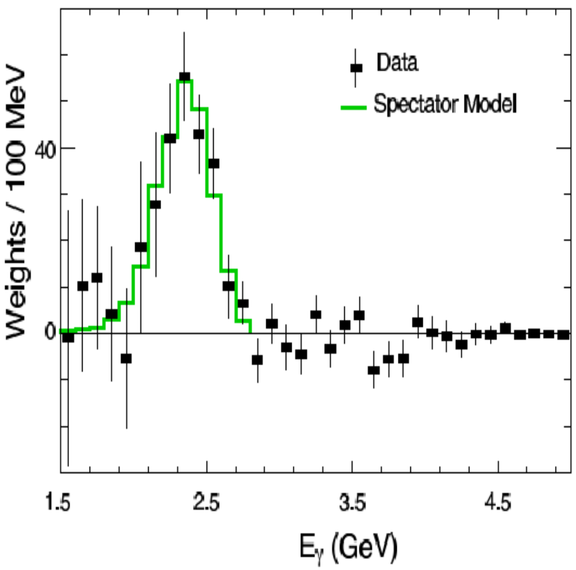
- Use theoretical estimates for $\rho_1, \rho_2, \mathcal{T}_1, \mathcal{T}_2, \mathcal{T}_3, \mathcal{T}_4$
- and use the following for $\bar{\Lambda}, \lambda_1, \lambda_2$

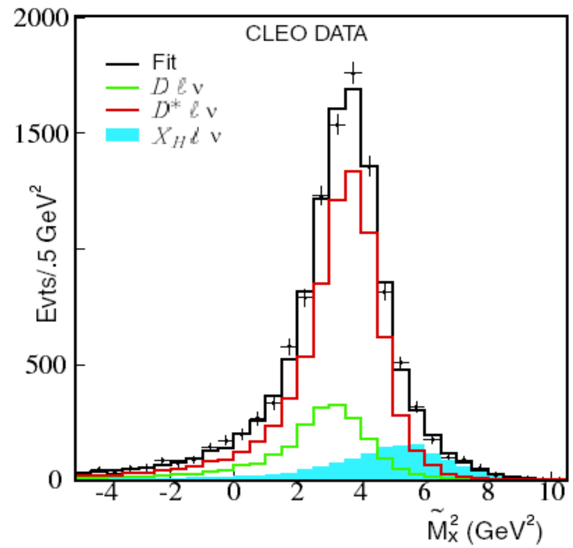
  $\langle (M_X^2 - \bar{M}_D^2) \rangle$ of the $\bar{B} \to X_c \ell \bar{\nu}$ mass spectrum

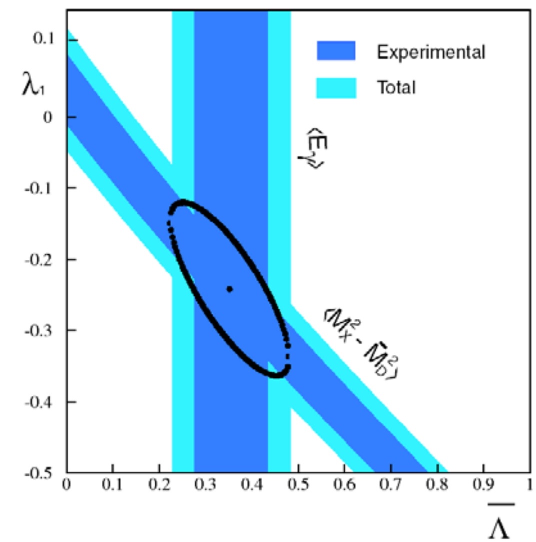
  $\langle E_\gamma \rangle$ of the $b \to s\gamma$ energy spectrum

V_{cb} from M_X moments and $b \to s\gamma$

CLEO





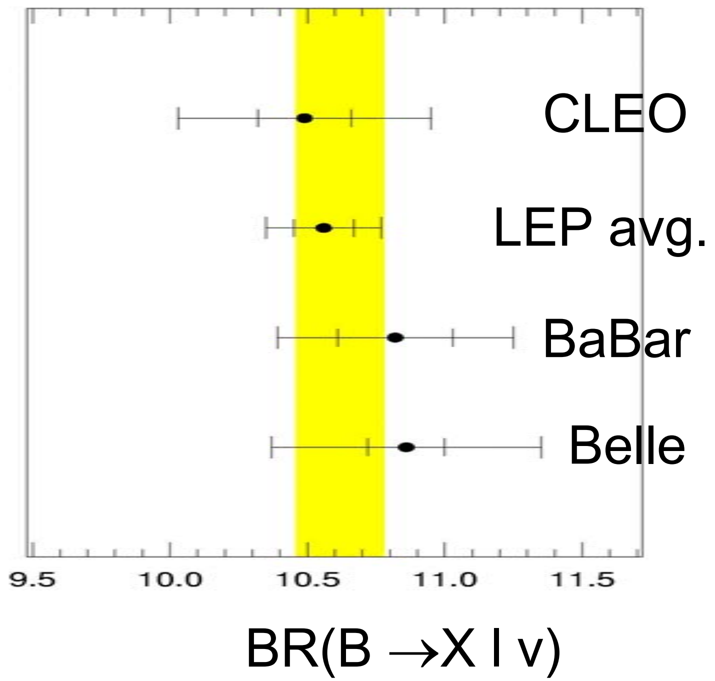


$$\lambda_1 = -0.236 \pm 0.071 \pm 0.078 \quad \text{GeV}^2$$
$$\bar{\Lambda} = 0.35 \pm 0.07 \pm 0.10 \quad \text{GeV}$$

For the experimental determination of Γ_{sl}, we use: $\mathcal{B}(B \to X_c \ell \nu) = (10.39 \pm 0.46)\%$ [19], $\tau_{B^\pm} = (1.548 \pm 0.032)$ ps [15], $\tau_{B^0} = (1.653 \pm 0.028)$ ps [15], $f_{+-}/f_{00} = 1.04 \pm 0.08$ [20], giving $\Gamma_{sl} = (0.427 \pm 0.020) \times 10^{-10}$ MeV.

$$|V_{cb}| = (4.04 \pm 0.09 \pm 0.05 \pm 0.08) \times 10^{-2}$$

$|V_{cb}|$ Inclusive Summary



personal average

BR(B →X l ν) = 10.62 ± 0.16 (%)

personal average

$|V_{cb}|$ = 40.6 ± 0.9 (10^{-3})

Compare with exclusive average **$|V_{cb}|$ = 41.1 ± 1.3 ± 1.9 (10^{-3})**

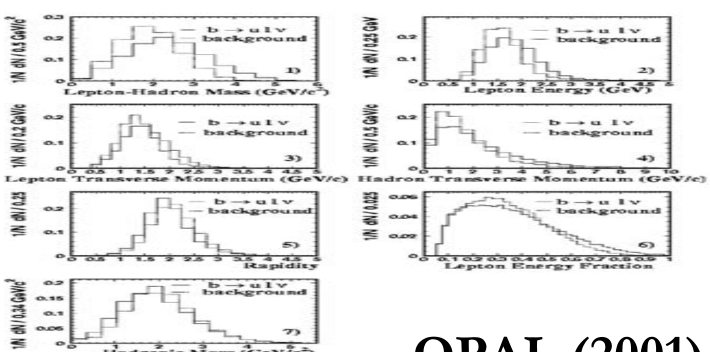
$|V_{ub}|$ measurements

- V_{ub} vs. V_{cb}
  - ~99% of all B decays occur via $b \to c$ transition
  - ~1% of all B decays occur via $b \to u$ transition

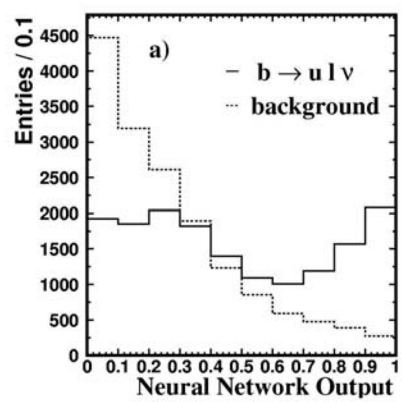
- V_{ub} is much harder to measure
  - for exclusive, HQET doesn't work very well
    → *large form factor uncertainty*
  - for inclusive, $b \to c$ background is dominant,
    therefore, have to look at very limited phase-space region
    → *theoretical prediction (with cuts) is not reliable*

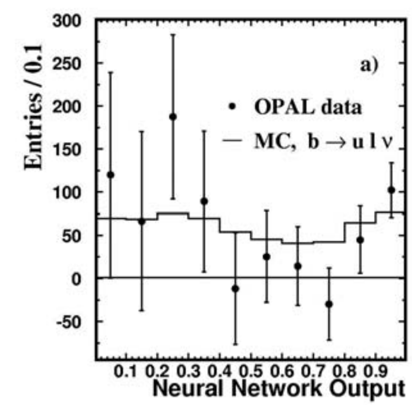
$|V_{ub}|$ LEP results

- **Main features**
  - Measure $B \to X_u \ell \nu$ and convert it to V_{ub}
  - $X_u \ell \nu$ final states are separated from $X_c \ell \nu$ using jet shape variables
  - no single variable is good enough – combining several with neural networks
  - u/c discrimination is mostly based on the properties of the hadronic system
  - analyses are sensitive to the whole lepton spectrum
  - estimation of large charm background uncertainty is critical



OPAL (2001)





$|V_{ub}|$ LEP results

- Combining the LEP results,

$$\mathcal{B}(B \to X_u \ell \nu) = (1.71 \pm 0.31_{(\text{exp.})} \pm 0.37_{(b\to c)} \pm 0.21_{(b\to u)}) \times 10^{-3}$$

- Using the OPE-based formula (Uraltsev *et al.*),

$$\begin{aligned} |V_{ub}| &= 0.00445 \sqrt{\frac{\mathcal{B}(B \to X_u \ell \nu)}{0.002} \frac{1.55\text{ps}}{\tau_B}} \times (1 \pm 0.020_{\text{QCD}} \pm 0.035_{m_b}) \\ &= \left(4.09^{+0.59}_{-0.69}\right) \times 10^{-3} \end{aligned}$$

- comments
  - ⋆ 17% total fractional error
  - ⋆ 11% comes from $b \to c$ modelling
  - ⋆ 4% from theory

$|V_{ub}|$ at $\Upsilon(4S)$

- Lepton momentum endpoint analysis (CLEO, 1993)
  - ⋆ clean $b \to u$, but $p_\ell > 2.3$ GeV/c results in
  - ⋆ large uncertainty from extrapolation (model-dependence)
  - ⋆ with $\mathcal{L}_{\rm on} = 0.9$ fb^{-1}

$$\frac{|V_{ub}|}{|V_{cb}|} = 0.076 \pm 0.008_{\rm exp} \pm 0.016_{\rm thy}$$

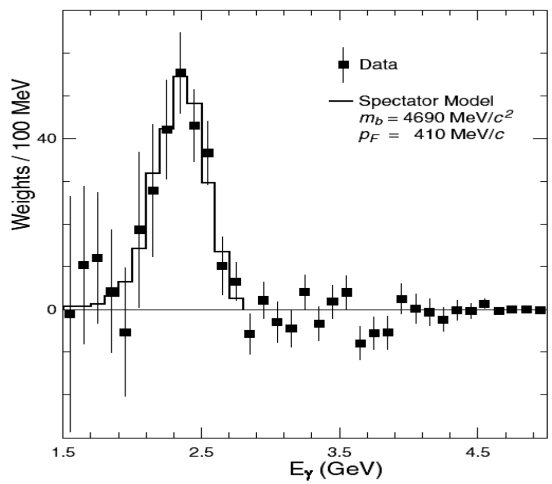
- Exclusive $B \to \pi\ell\nu$, $\rho\ell\nu$ decays (CLEO, 1996, 2000)
  - ⋆ relying on detector hermiticicy for missing neutrino
  - ⋆ more coverage of phase-space, but
  - ⋆ uncertainty in the form-factor
  - ⋆ with $\mathcal{L}_{\rm on} = 3.1$ fb^{-1}

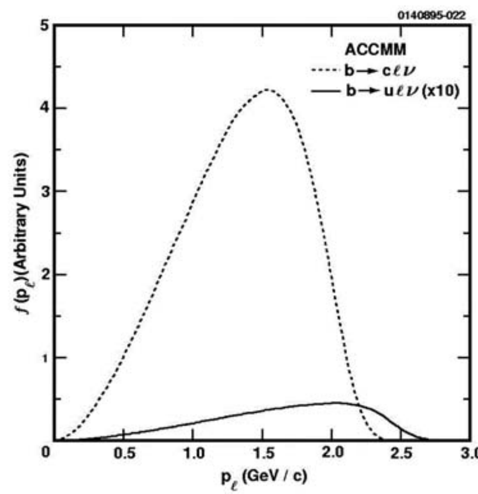
source	fractional error on $|V_{ub}|$
exp. syst.	9%
thy. extrapolation	8%
thy. form-factor	15%
total	20%

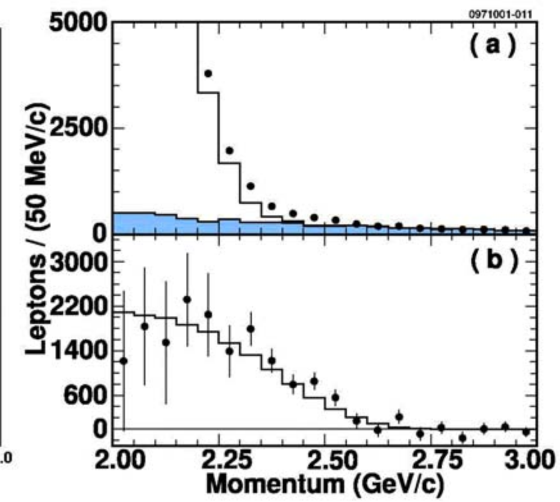
$$\mathcal{B}(B^0 \to \rho^- \ell^+ \nu) = \left(2.57 \pm 0.29^{+0.33}_{-0.46} \pm 0.41\right) \times 10^{-4}$$

$$|V_{ub}| = \left(3.25 \pm 0.14^{+0.21}_{-0.29} \pm 0.55\right) \times 10^{-3}$$

$|V_{ub}|$ from the lepton end-point, *revisited* (CLEO, 2001)







- measure $\mathcal{B}(B \to X_u \ell\nu)(\equiv \mathcal{B}_{bu})$ in a p_ℓ interval Δp $(2.2 < p_\ell < 2.6$ GeV$/c)$

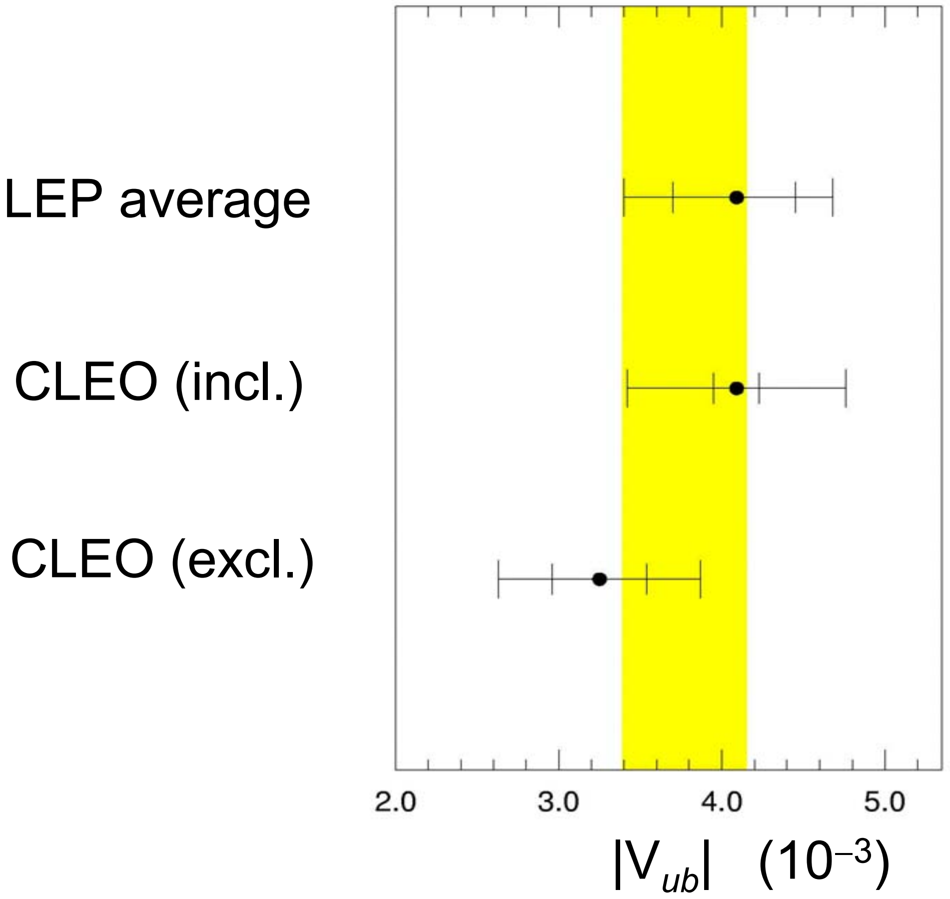
$$\Delta\mathcal{B}_{bu} = f_u(\Delta p)\mathcal{B}_{bu}$$

- reduce (extrapolation) error in $f_u(\Delta p)$ by using $b \to s\gamma$ (Neubert, *et al.*)

$$\mathcal{B}(b \to u\ell\nu, E > E_c) \propto \left|\frac{V_{ub}}{V_{ts}V_{tb}}\right|^2 \int_{E_c}^{M_B/2} E_\gamma N(E_\gamma) dE_\gamma$$

- $\Delta\mathcal{B}_{bu} = (2.35 \pm 0.15 \pm 0.45) \times 10^{-4}$
- $f_u(\Delta p) = 0.138 \pm 0.034$
- $|V_{ub}| = (4.09 \pm 0.14 \pm 0.66) \times 10^{-3}$
- total frac. error on $|V_{ub}| \sim 16\%$
- $\sim 10\%$ from $\Delta\mathcal{B}_{bu}$
- $\sim 10\%$ due to E_γ

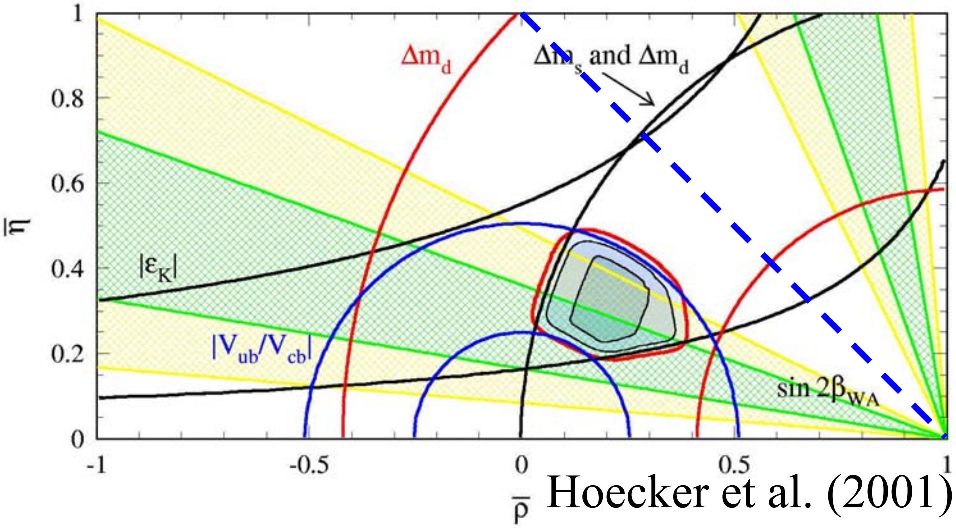
$|V_{ub}|$ Summary



V_{ub} plan for future ($L > 10^{35}$)

Full reconstruction of the other B for improved S/N ; eff. ≈ 0.2%

- Inclusive $B \to X_u \ell \nu$
  - E_ℓ combined with E_γ from $b \to s\gamma$
  - $M_{\rm had}$ (inv. mass of X_u): $M_{\rm had} < M_{D^0}$, acceptance $\sim 80\%$
  - q^2 (inv. mass-squared of $\ell\nu$): $q^2 > 2M_B M_{D^0} - M_{D^0}^2$, acceptance $\sim 20\%$
- Exclusive $B \to X_u \ell \nu$ and lattice QCD
- Hadronic decays $B \to D_s^{(*)} X_u$



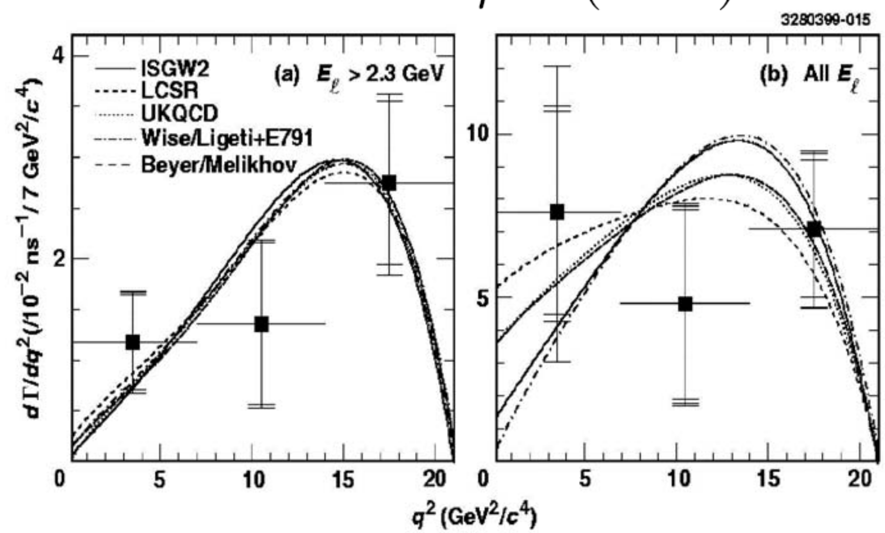
Hoecker et al. (2001)

Exclusive $B \rightarrow X_u l \nu$ and lattice QCD

- In BCP4 conference, Jik Lee & Ian Shipsey stated that "lattice QCD is capable of predicting the absolute normalization of the form factor in $B \to \pi \ell \nu$ or $D \to \pi \ell \nu$ to $\sim$ few%", hence making $\delta|V_{ub}|/|V_{ub}|(\text{theory}) \sim (1-2)\%$

- Step 1: Calibrate lattice!
  - with $D \to \pi \ell \nu$
  - charm-factory ($D\bar{D}$ threshold e^+e^- collider) is crucial!
- Step 2: Measure $d\Gamma/dq^2$ in $B \to \pi \ell \nu$.
  - Use fully reconstructed B sample!
- Step 3: $\Gamma(B \to \pi \ell \nu)$ and lattice $\Longrightarrow |V_{ub}|$

CLEO $B \to \rho \ell \nu$ (2000)

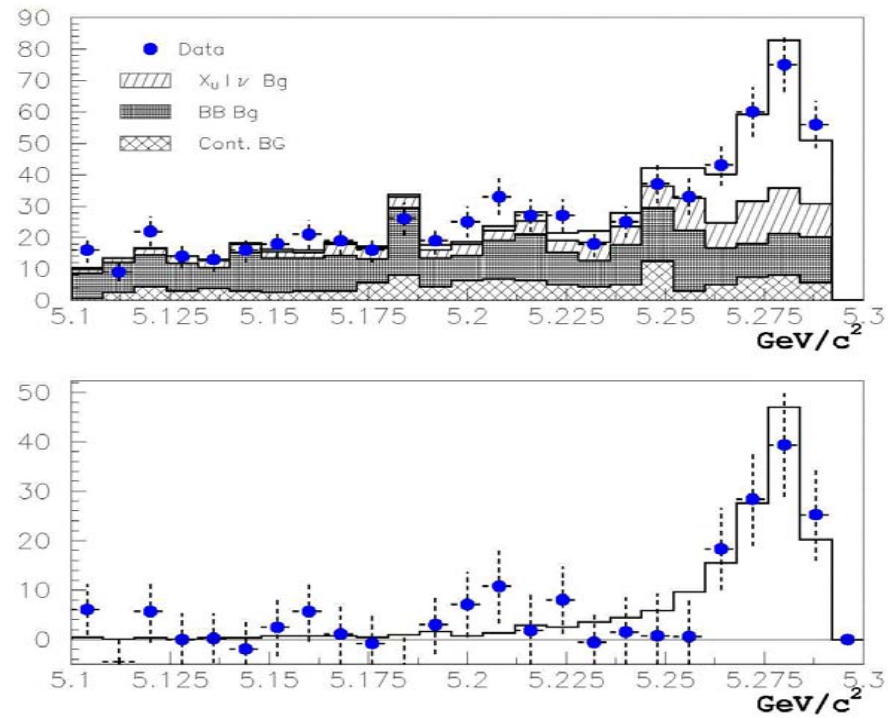


Lee & Shipsey simulation (BCP4)
$\delta V_{ub}/V_{ub} \sim O(1\%)$ with L=10 ab^{-1}

Belle activities for V_{ub}

$$B^0 \to \pi^- \ell^+ \nu$$

- $\int \mathcal{L} dt = 21.3 \text{ fb}^{-1}$
- Event selection
  - single lepton of $1.2 < p_\ell < 2.8$ GeV/c
  - $|\cos\theta_{p_{\rm miss}}| < 0.8$
  - $|\sum Q| \leq 1$
  - $|M^2| < 2$ GeV^2
  - $p_\ell + p_\pi > 3.1$ GeV/c
  - $|\cos\theta_{B-\pi}| < 1$
  - $|\Delta E| < 0.3$ GeV



$$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu) = (1.28 \pm 0.20 \pm 0.26) \times 10^{-4}$$

preliminary

V_{ub} from $B \to D_s^{(*)} X_u$ decays

- Instead of $\ell\nu$, we have $D_s^{(*)}$
- signal B is fully reconstructed; no need to worry about missing neutrino
  LHC-b and B-TeV may become competitors in $|V_{ub}|$!
- Currently, the largest uncertainty is in the D_s sub-decay branching fractions: $\delta\mathcal{B}/\mathcal{B} \approx (25 \sim 30)\%$
- Such uncertainties can be removed by taking the ratios, *e.g.*

$$\frac{\Gamma(B \to D_s^{(*)}\pi)}{\Gamma(B \to D_s^{(*)}D)}$$

  (Kim, Kwon, Lee & Namgung, PRD (2001))
  - Theory error from form factor uncertainty is $O(10\%)$: within the generalized factorization scheme; penguin effects are considered
  - L-QCD may help eventually..

Conclusion

- Impressive progress for V_{ub} , V_{cb} over the last few years
- Many different analysis methods are applied
  - exclusive (HQET, L-QCD, …)
  - inclusive (moments from $b \to s\gamma$)
- Future prospects
  - Full-reconstruction technique to improve S/N for V_{ub} seems promising for inclusive analyses
  - L-QCD may be crucial for exclusive analyses