Sides of the Unitarity Triangle at Belle

Les Rencontres de Physique de la Vallée d'Aosta

27.Feb-5.Mar 2005

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What's in This Talk

- Data up to 2003 Summer corresponding to ~140 fb^{-1}
  - ◇ Two Analyses for V_{ub}
    - – Inclusive B→ $X_u \ell\nu$ with full reconstruction
    - – Exclusive B→ $X_u \ell\nu$ with semileptonic tag
- Data up to 2004 Winter corresponding to ~253 fb^{-1}
  - ◇ An Analysis for V_{td}
    - – Search for b→dγ

What's Not in This Talk

- Leptonic and Hadronic Moment in B→ $X\ell\nu$
- V_{ub} from Lepton Endpoint
- Measurement of $\mathcal{B}(B \to X\ell\nu)$ with full reconstruction

All Results are Preliminary

Inclusive $\mathcal{B}(B \to X_u \ell \nu)$ with Full Reconstruction

Full Reconstruction

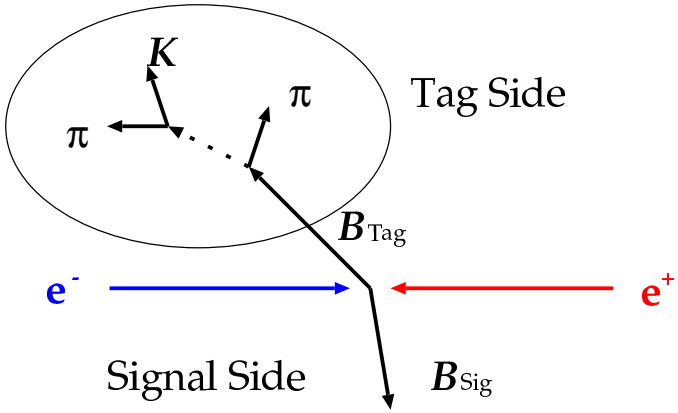
- **Fully Reconstruct one B**
  - Decay Modes

    $B \rightarrow D^{(*)} + \pi, \rho, a_1, D_s^{(*)}$

    $D^* \rightarrow D + \pi, \gamma$

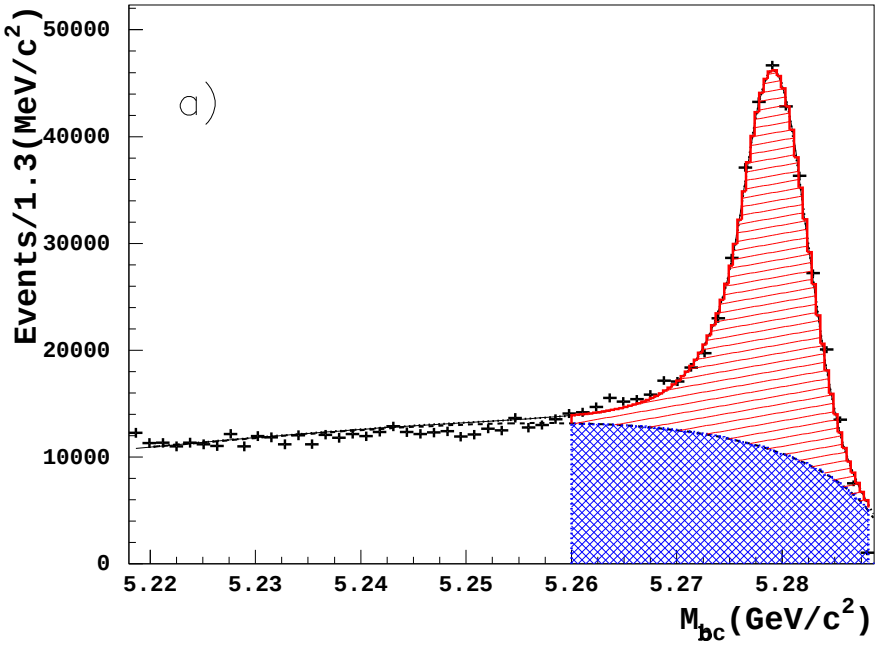
    $D \rightarrow K\pi, K\pi\pi, K\pi\pi\pi, KK...$

    .....
  - Total of ~180 modes, (~10% of B decay)
- **Advantage**
  - good signal to noise
  - signal side can be anything
  - good kinematic reconstruction
  - can know B flavor/momentum
- **Disadvantage**
  - Low efficiency $O(10^{-3})$
  - Lot of CPU time



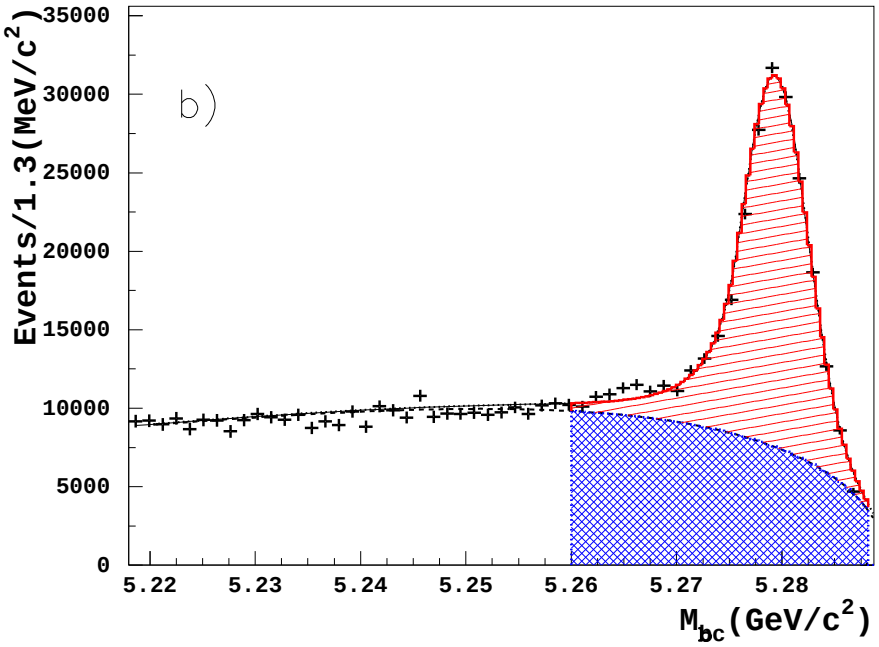
Full Reconstruction

M_{bc} for Reconstructed $B^{\pm}$



2.5×10^5 Events/140 fb^{-1}
Efficiency = 0.33 %
purity = 50 %

M_{bc} for Reconstructed B^0



1.6×10^5 Events/140 fb^{-1}
Efficiency = 0.21 %
purity = 47 %

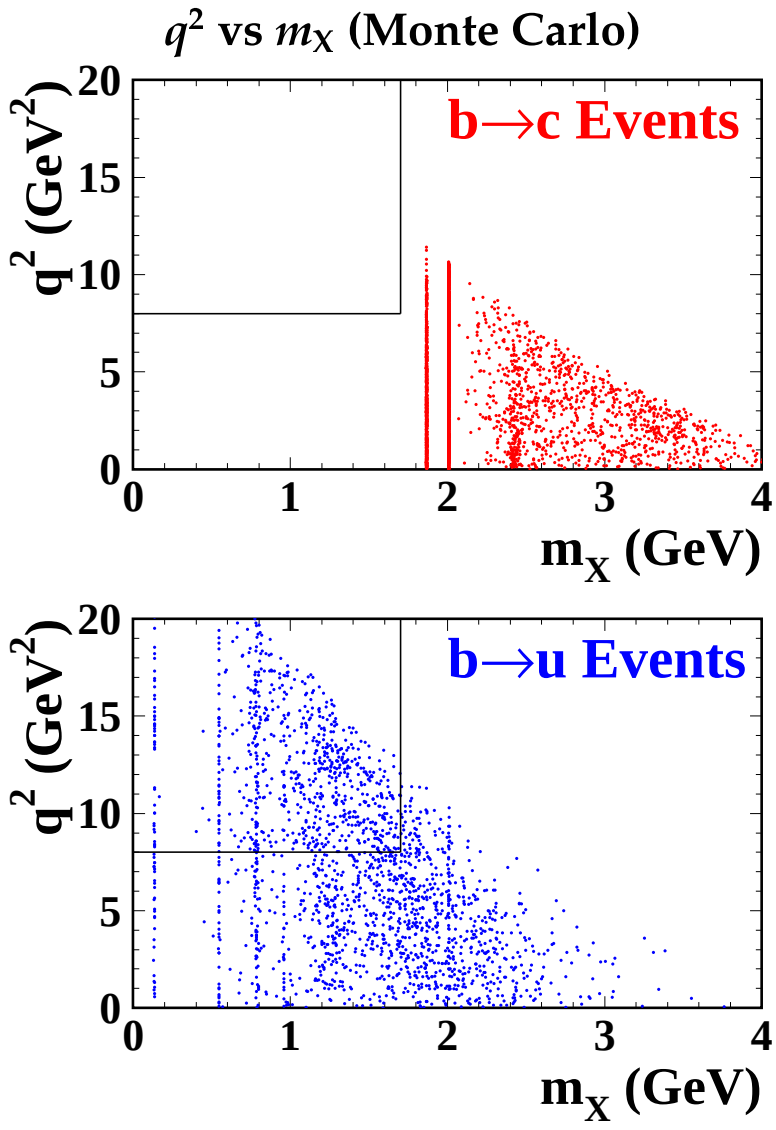
$\sim 4 \times 10^5$ unbiased/known B Mesons

Inclusive V_{ub} with Full Reconstruction

- Signal Side is $B \to X_u \ell \nu$ ($\ell = e, \mu$)
- Measure $\dfrac{\Delta\mathcal{B}(B \to X_u \ell \nu)}{\mathcal{B}(B \to X \ell \nu)} \propto |V_{ub}|^2$
- Kinematic Selection

$$m_X < 1.7\text{GeV}, \quad q^2 > 8\ \text{GeV}^2$$

  - ◇ to enhance b→u events
  - ◇ to reduce theory error
  - ◇ to satisfy theorist?
- Full reconstruction Method
  - ◇ good Signal/Noise
  - ◇ good resolution



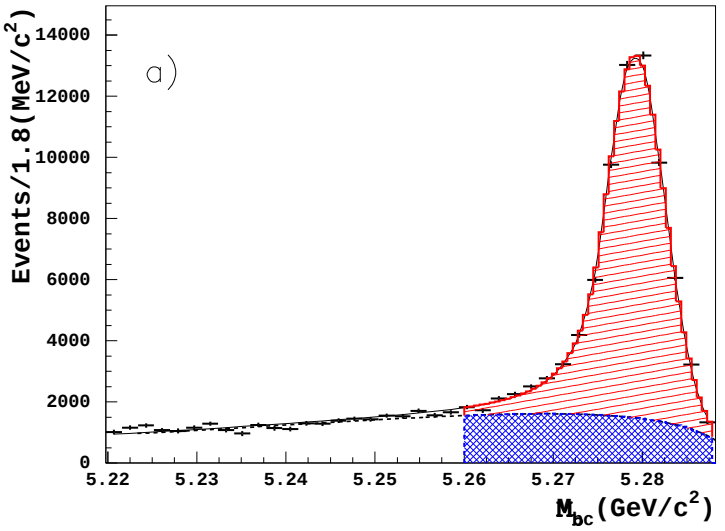
Inclusive V_{ub} with Full Reconstruction

Lepton Selection

- $p^* > 1$ GeV
- J/ψ veto, conversion veto
- Correct Charge for B^+ candidate
- No other lepton

$$N_{sl} = (5.07 \pm 0.04) \times 10^4$$

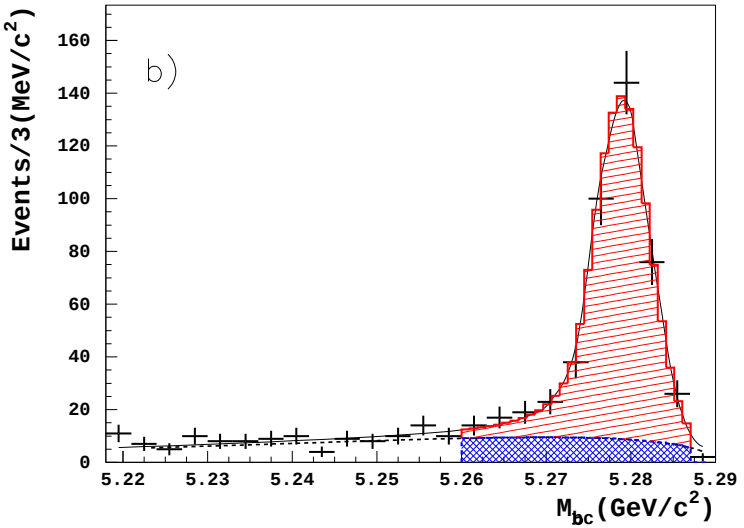
M_{bc} after Lepton Requirements



Selection for b→ u

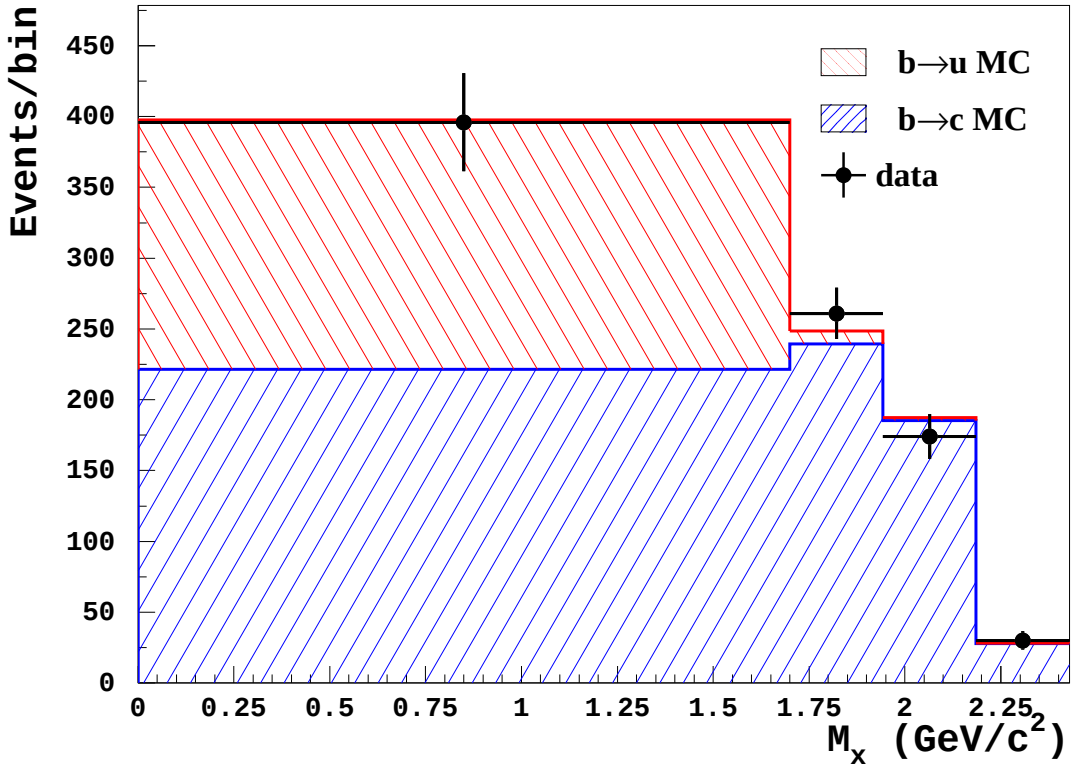
- Total charge, $\sum Q_i = 0$
- missing mass, $-1.0 < m^2_{\rm mis} < 0.5$ GeV^2
  ($p_{\rm mis} \equiv p_{\Upsilon_{4S}} - (p_{B_{\rm tag}} + p_\ell + p_X) \approx p_\nu$)
- missing direction, $|\cos\theta_{\rm mis}| < 0.95$
- No reconstructed K^0_S or $K^\pm$
- .....

M_{bc} after b→u Selection



Inclusive V_{ub} with Full Reconstruction

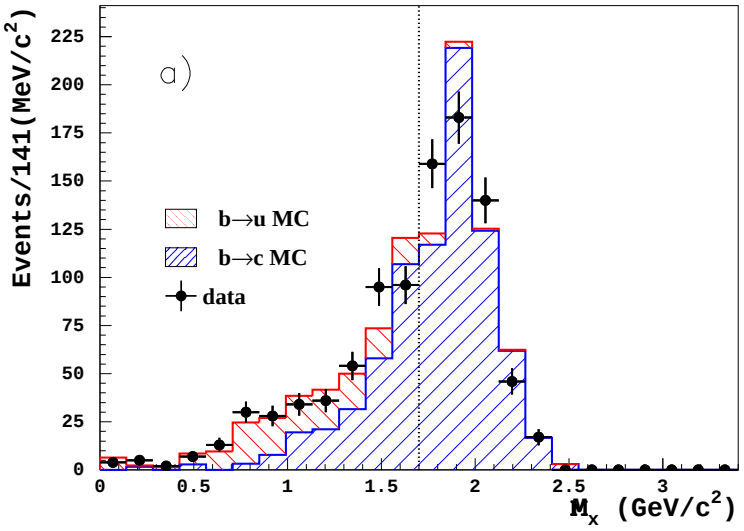
Signal Extraction



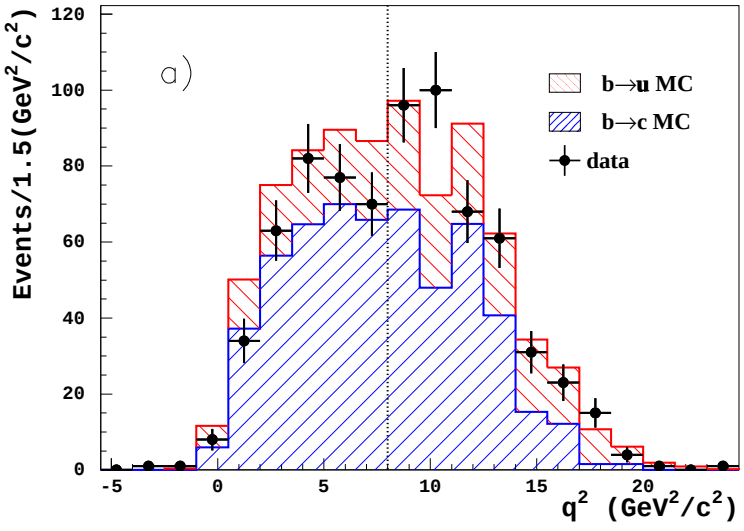
- $q^2 > 8$ GeV^2 cut applied
- Each bin content calculated from M_{bc} fit
- Two component fit to extract $N_{b\to u}$

$$N_{b\to u} = 174 \pm 26$$

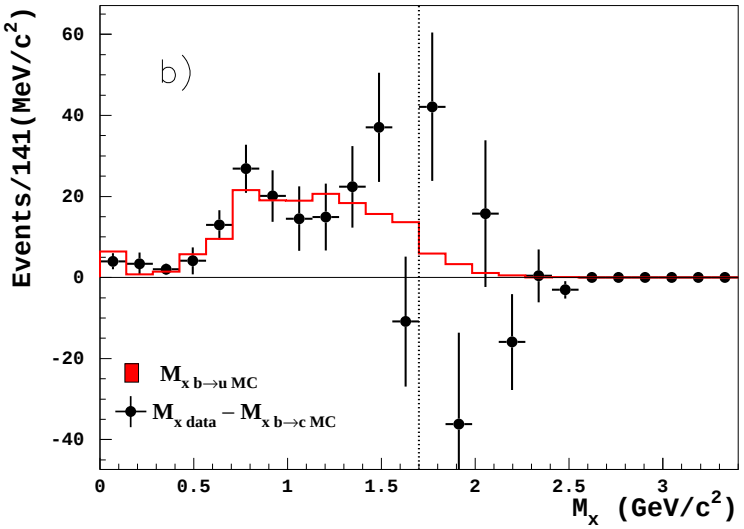
m_X Distribution (q^2 >8 GeV^2)

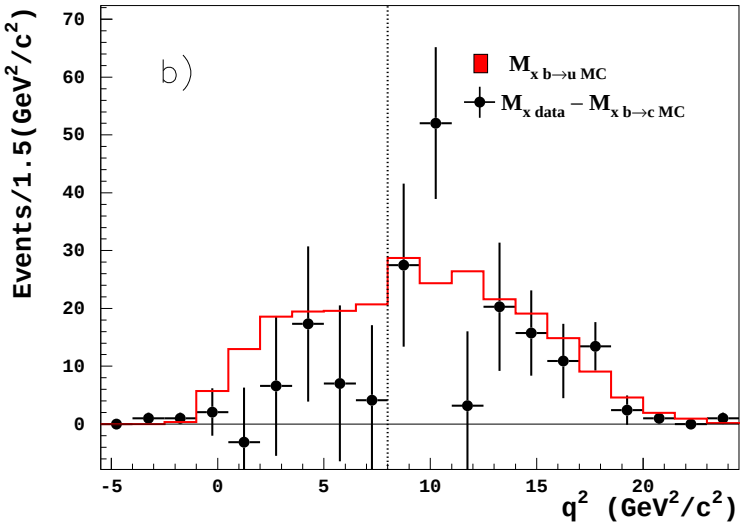


q^2 Distribution (m_X >1.7 GeV)



Subtract Background Contribution





Inclusive V_{ub} with Full Reconstruction

$\Delta\mathcal{B}$ Extraction

$$\Delta\mathcal{B}(\mathrm{B} \to \mathrm{X_u}\ell\nu) = \frac{N_{\mathrm{u}}}{N_{\mathrm{sl}}} \cdot \frac{\varepsilon_{\mathrm{b}\to\mathrm{sl}}}{\varepsilon_{\mathrm{b}\to\mathrm{u}}} \cdot \mathcal{B}(\mathrm{B} \to \mathrm{X}\ell\nu)$$

N_{u}: Number of observed (b→u) Signal Events

N_{sl}: Number of observed B semi-leptonic Events

$\mathcal{B}(\mathrm{B} \to \mathrm{X}\ell\nu)$: B→semileptonic Branching fraction

$$\mathcal{B}(\mathrm{B} \to \mathrm{X}\ell\nu) = 0.1073 \pm 0.0028$$

$\varepsilon_{\mathrm{b}\to\mathrm{sl}}$: Selection efficiency for B→X$\ell\nu$

$\varepsilon_{\mathrm{b}\to\mathrm{u}}$: Selection efficiency for B→$\mathrm{X_u}\ell\nu$

$$\Delta\mathcal{B}(\mathrm{B} \to \mathrm{X_u}\ell\nu) = (0.99 \pm 0.15(\mathrm{stat.}) \pm 0.18(\mathrm{sys.}) \pm 0.08(\mathrm{theo.})) \times 10^{-3}$$

$$\text{for } q^2 > 8\ \mathrm{GeV}^2,\ \ m_{\mathrm{X}} < 1.7\ \mathrm{GeV}$$

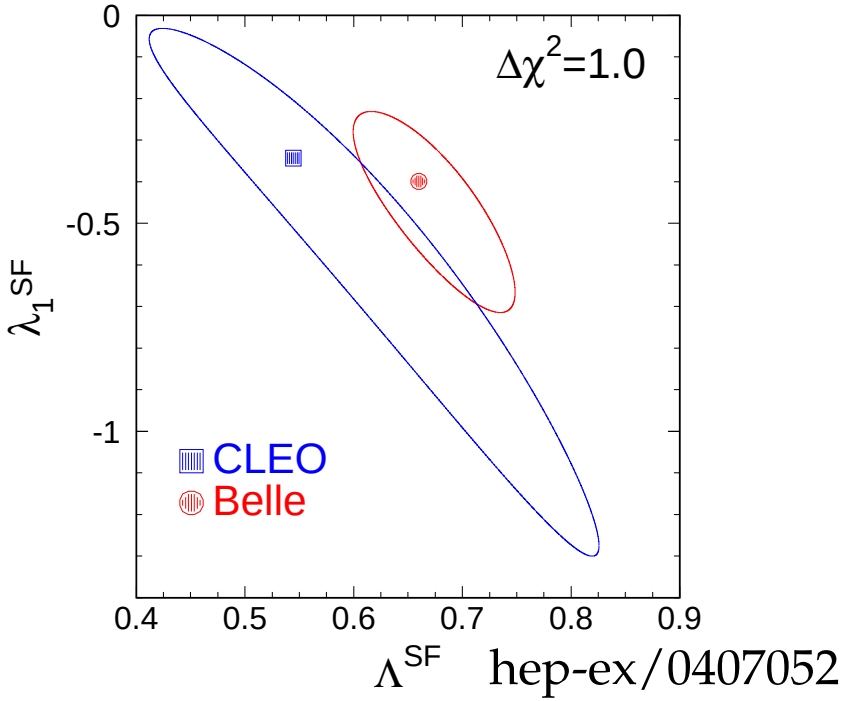
theory error comes from B and D decay modeling

Inclusive V_{ub} with Full Reconstruction

Partial to Total Branching Fraction

$$\mathcal{B}(B \to X_u \ell \nu) = \frac{\Delta\mathcal{B}(B \to X_u \ell \nu)}{f_u}$$

- f_u is determined by theory
- Shape Function
  - ◇ similar contribution to b→ sγ events
  - ◇ fitting γ spectrum
- with $f_u = 0.294 \pm 0.044$



$$\mathcal{B}(B \to X_u \ell \nu) = (3.37 \pm 0.42 \pm 0.50 \pm 0.28 \pm 0.42(f_u)) \times 10^{-3}$$

Inclusive V_{ub} with Full Reconstruction

Branching Fraction to V_{ub}

$$|V_{ub}| = 0.00424 \sqrt{\frac{\mathcal{B}(B \to X_u \ell \nu)}{0.002} \cdot \frac{1.61\text{ps}}{\tau_B}} \cdot (1 \pm 0.05)$$

$$\mathbf{|V_{ub}| = (5.54 \pm 0.42 \pm 0.50 \pm 0.22 \pm 0.42 \pm 0.27) \times 10^{-3}}$$

(1) Statistical error
(2) Experimental systematic error
(3) Error from uncertainty of b/c decay modeling
(4) Error from f_u determination
(5) Error from converting $\mathcal{B}$ to V_{ub}

Exclusive $\mathcal{B}(B \to (\pi, \rho)\ell\nu)$ with Semileptonic Tag

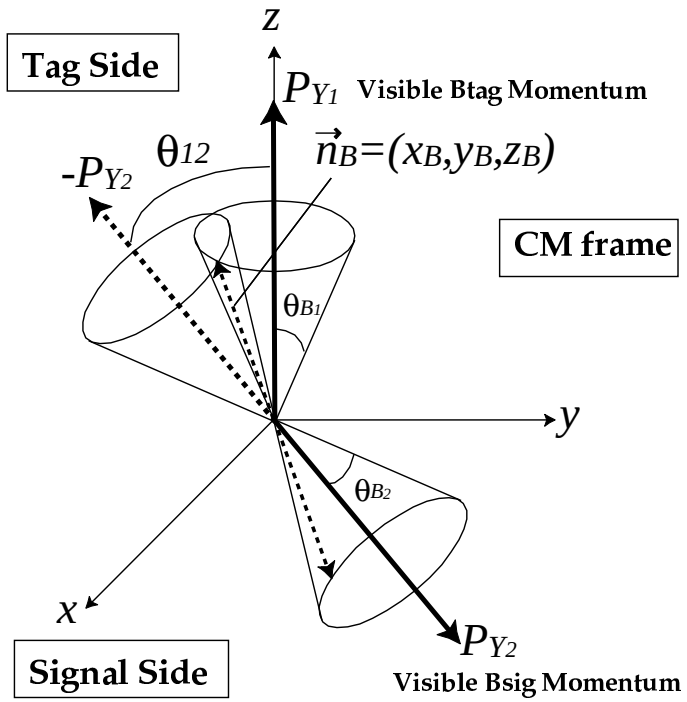
Exclusive V_{ub} with Semileptonic Tag

Tag Side

- $B_{tag} \rightarrow D^{*+}\ell^-\bar{\nu}/D^+\ell^-\bar{\nu}$
  $D^{*+} \rightarrow D^0\pi^+/D^+\pi^0$
- $D^0 \rightarrow K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^+\pi^-$...(7 Modes)
- $D^+ \rightarrow K^-\pi^+\pi^+, K^-\pi^+\pi^+\pi^0$...(4 Modes)

Signal Side

- $B_{sig} \rightarrow X_u\ell^+\nu$
- Lepton with p >0.8 GeV
- $X_u = \pi^-, \pi^-\pi^0$



Kinematic Reconstruction

- B directions are constrained to the intersections of two cones

$$0 < x_B^2 \equiv 1 - \frac{1}{\sin\theta_{12}}\left(\cos^2\theta_{B_1} + \cos^2\theta_{B_2} - 2\cos\theta_{B_1}\cos\theta_{B_2}\cos\theta_{12}\right) < 1$$

- q^2 is calculated, assuming the B is stopping at CM frame,

$$q^2 = \left(E^*_{beam} - E^*_{X_u}\right)^2 - p^{*\,2}_{X_u}$$

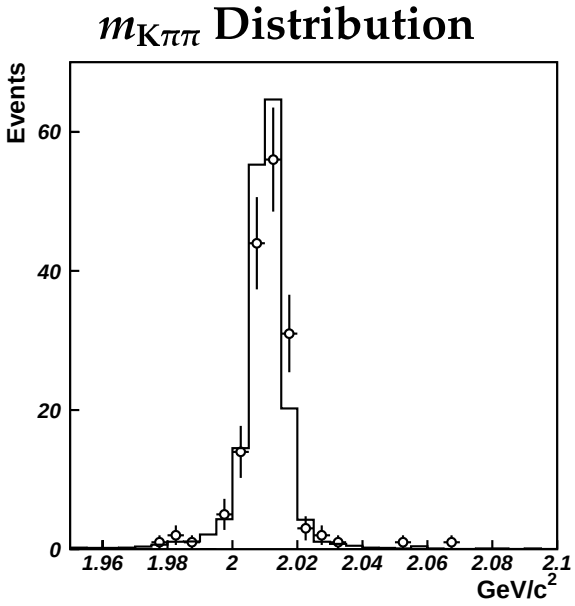
Exclusive V_{ub} with Semileptonic Tag

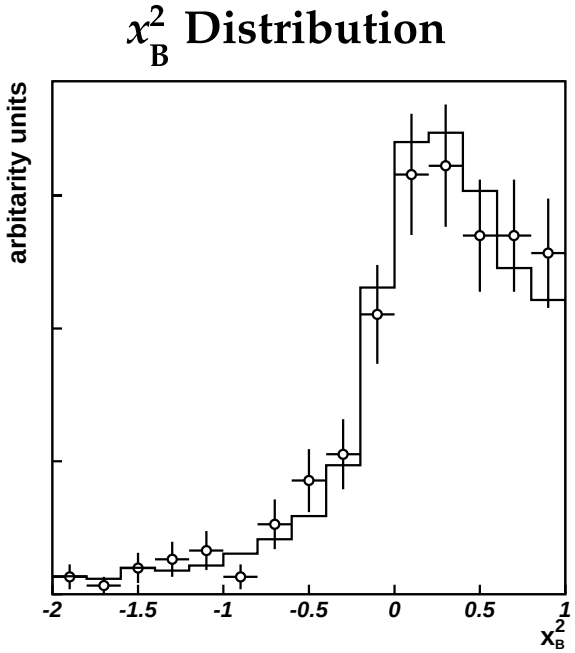
Efficiency Calibration

- Calibration Mode

  $B_{sig} \to D^{*-}\ell^+\bar{\nu}$
  $\to \bar{D}^0\pi^-$
  $\to K^+\pi^-$

- $N_{obs} = 147 \pm 12$
- $N_{exp} = 165 \pm 9$
- $\dfrac{N_{obs}}{N_{exp}} = 0.89 \pm 0.08$
  $\Rightarrow$ taken as a calibration constant
- x_B^2 distribution looks reasonable

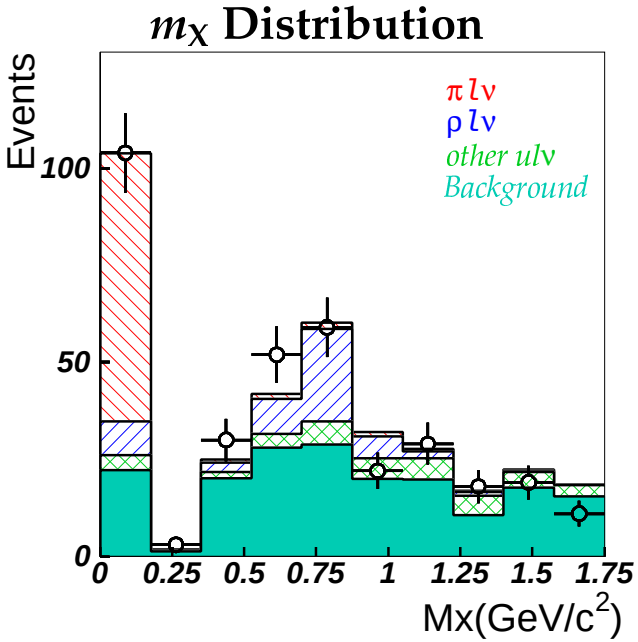


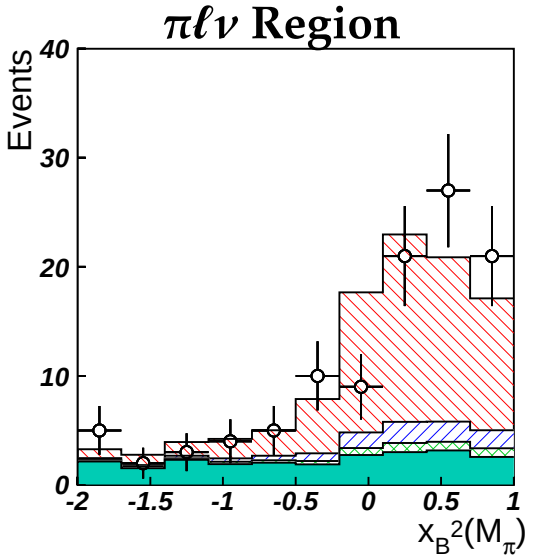


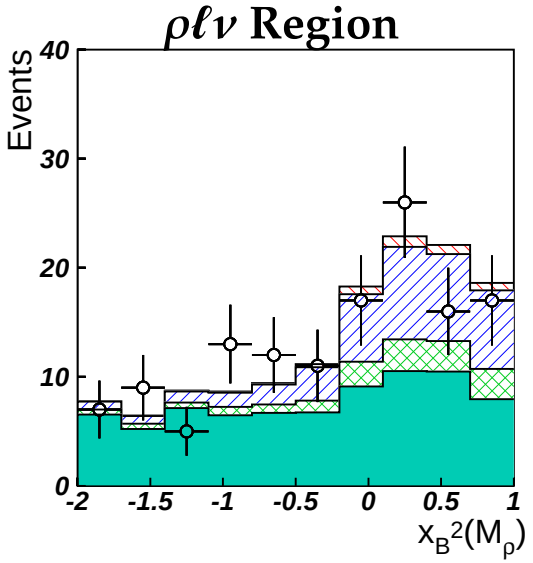
Exclusive V_{ub} with Semileptonic Tag

Signal Extraction

- fitting in 2D m_X– x_B^2 plane







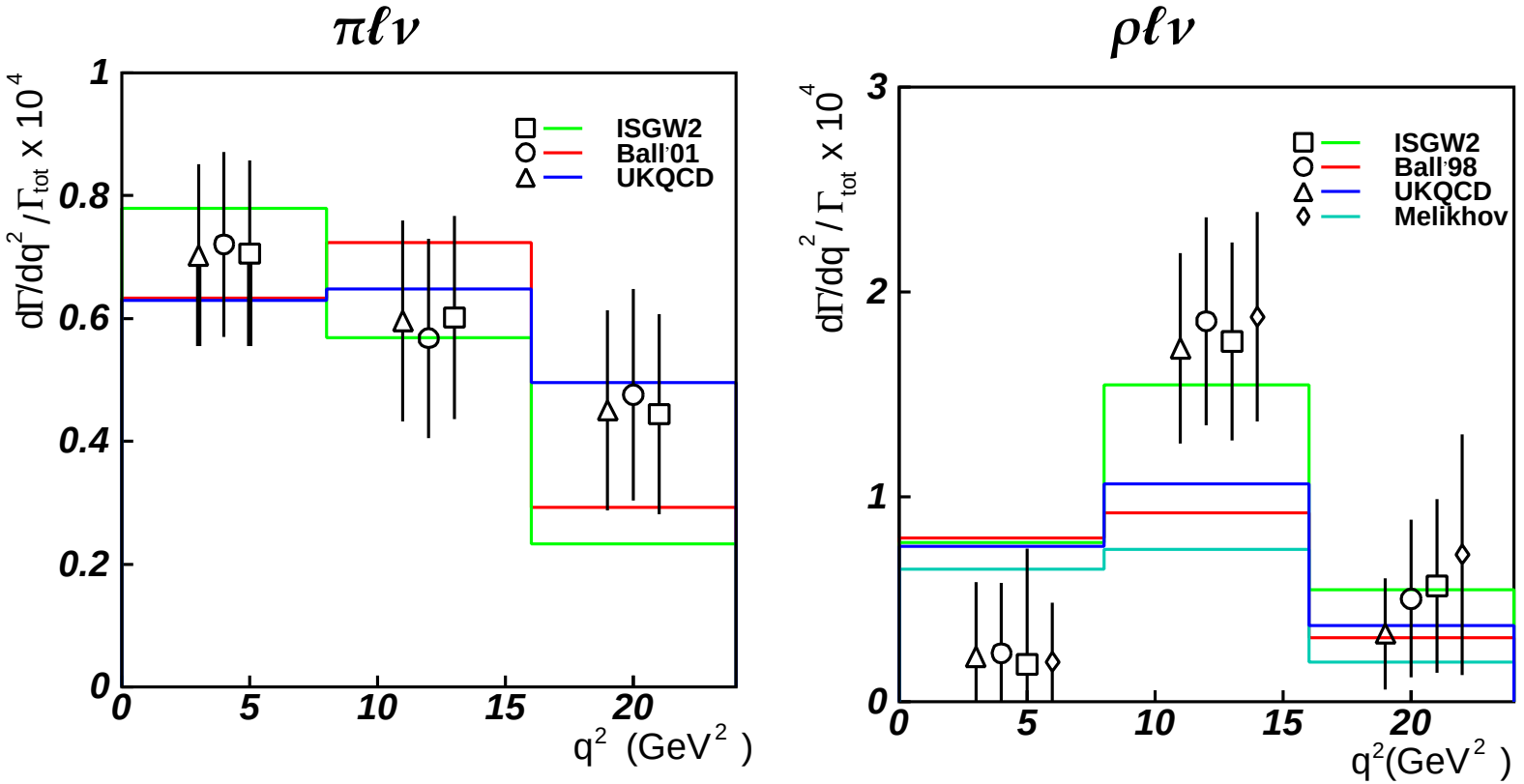
- Four component fit
  - ◇ B → $\pi\ell\nu$
  - ◇ B → $\rho\ell\nu$
  - ◇ B → $X_u\ell\nu$
  - ◇ BB background

82 ± 13 Events

65 ± 20 Events

Exclusive V_{ub} with Semileptonic Tag

Signal Yield in q^2 bin



- average Form-Factor Models
- variation as theory error

$$\mathcal{B}(\mathrm{B}^0 \to \pi^- \ell^+ \nu) = (1.76 \pm 0.28(\mathrm{stat.}) \pm 0.20(\mathrm{sys.}) \pm 0.03(\mathrm{FF})) \times 10^{-4}$$
$$\mathcal{B}(\mathrm{B}^0 \to \rho^- \ell^+ \nu) = (2.54 \pm 0.78(\mathrm{stat.}) \pm 0.85(\mathrm{sys.}) \pm 0.33(\mathrm{FF})) \times 10^{-4}$$

Exclusive V_{ub} with Semileptonic Tag

- V_{ub} determined with relation

$$|V_{ub}| = \sqrt{\frac{\Delta\mathcal{B}(B^0 \to \pi^-\ell^+\nu)}{\Gamma_{th} \cdot \tau_B}}$$

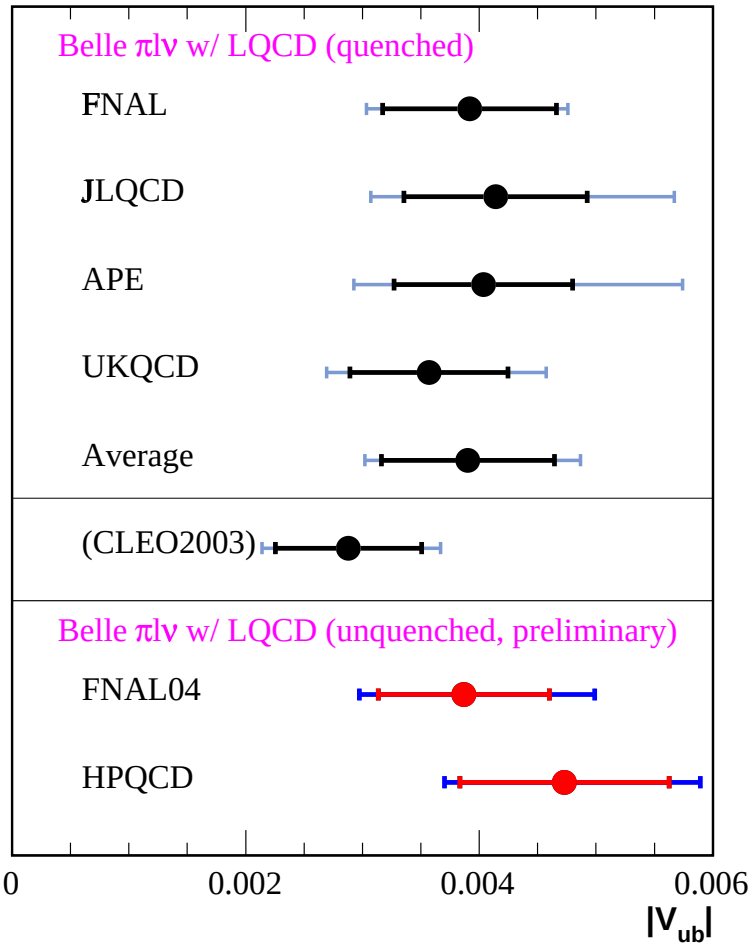
- only $\pi^-\ell^+\nu$ with $q^2 > 16\text{GeV}^2$ is used
- with Γ_{th} from Quenched LQCD

$$|V_{ub}| = (3.90 \pm 0.71 \pm 0.23^{+0.62}_{-0.48}) \times 10^{-3}$$

- with Γ_{th} from Unquenched LQCD

$$|V_{ub}| = (3.87 \pm 0.70 \pm 0.22^{+0.85}_{-0.51}) \times 10^{-3} \quad \text{(FNAL04)}$$

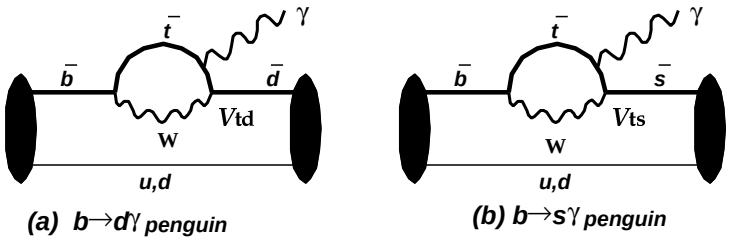
$$|V_{ub}| = (4.73 \pm 0.85 \pm 0.27^{+0.74}_{-0.50}) \times 10^{-3} \quad \text{(HPQCD)}$$



Search for the $b \to d\gamma$

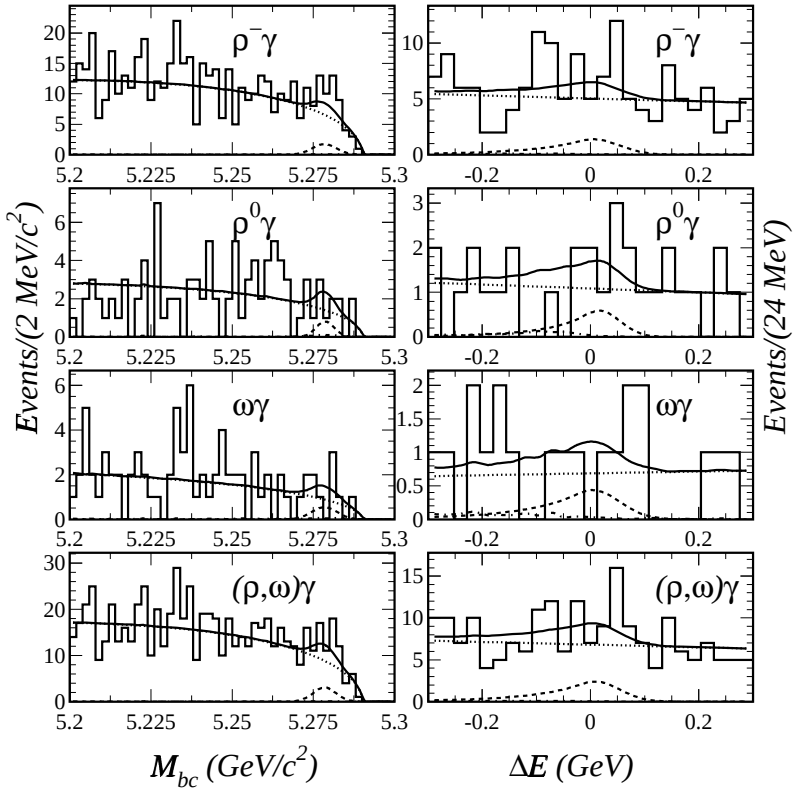
Search for the b→dγ

- b→dγ via penguin process



- Searched for the processes,
  - ◇ B→ $\rho\gamma$
  - ◇ B→ $\omega\gamma$
- Event Selection
  - ◇ Likelihood Ratio using, Fisher discriminant, B-direction and Δz
  - ◇ Flavor tagging quality
  - ◇ Helicity angle
  - ◇ ...
- Signal Yield from fit in $M_{\rm bc}$ and ΔE
- No significant excess observed

$M_{\rm bc}$ and ΔE



Search for the b→dγ

$$\mathcal{B}(B \to (\rho,\omega)\gamma) < 1.4 \times 10^{-6}$$

$$\frac{\mathcal{B}(B \to (\rho,\omega)\gamma)}{\mathcal{B}(B \to K^*\gamma)} < 0.035 \quad (90\ \%\ \text{C.L})$$

using the relation

$$\frac{\mathcal{B}(B \to (\rho,\omega)\gamma)}{\mathcal{B}(B \to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{\left(1 - m^2_{(\rho,\omega)}/m^2_B\right)^3}{\left(1 - m^2_{K^*}/m^2_B\right)^3} \zeta^2 (1 + \Delta R)$$

- ζ : Form factor ratio, 0.85 ± 0.10 (Ali 2004)
- ΔR : SU(3) breaking effect, 0.1 ± 0.1

$$\left|\frac{V_{td}}{V_{ts}}\right| < 0.21 \quad (90\ \%\ \text{C.L})$$

Summary

- V_{ub} from Inclusive $X_u \ell \nu$ (140 fb^{-1})

$$|V_{ub}| = (5.54 \pm 0.42 \pm 0.50 \pm 0.25) \times 10^{-3}$$

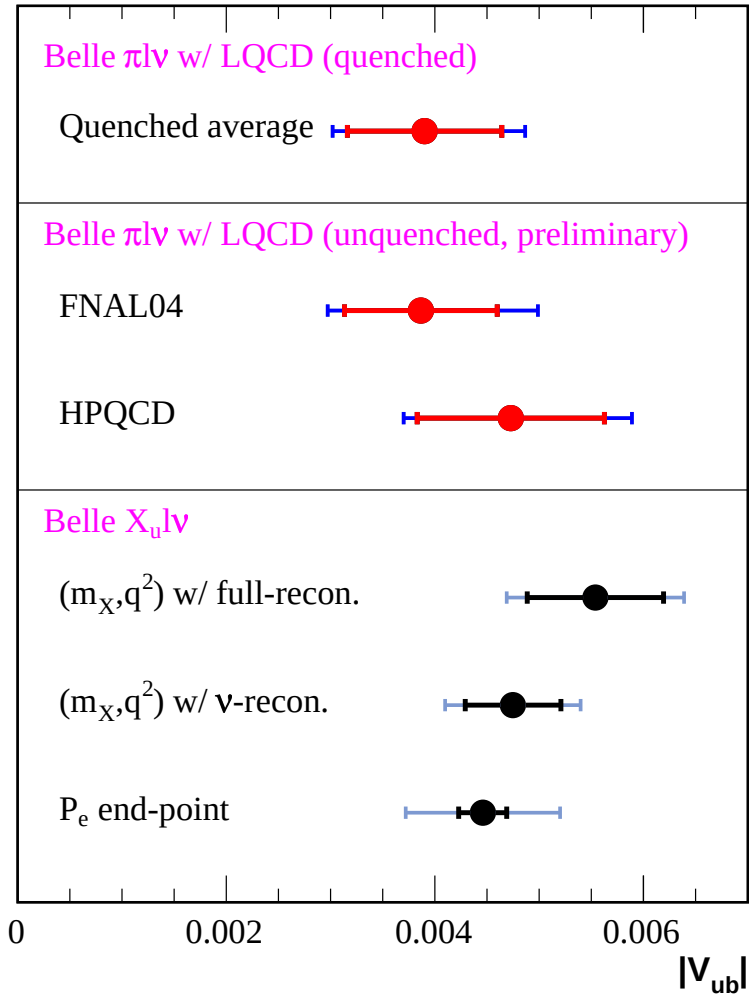
- V_{ub} from Exclusive $X_u \ell \nu$ (140 fb^{-1})

$$|V_{ub}| = (3.87 \pm 0.70 \pm 0.22^{+0.85}_{-0.51}) \times 10^{-3} \quad \text{(FNAL04)}$$

$$|V_{ub}| = (4.73 \pm 0.85 \pm 0.27^{+0.74}_{-0.50}) \times 10^{-3} \quad \text{(HPQCD)}$$

- $\left|\frac{V_{td}}{V_{ts}}\right|$ from search for $b \to d\gamma$ (253 fb^{-1})

$$\left|\frac{V_{td}}{V_{ts}}\right| < 0.21 \qquad \text{(90 \% C.L)}$$



All Results are Preliminary