

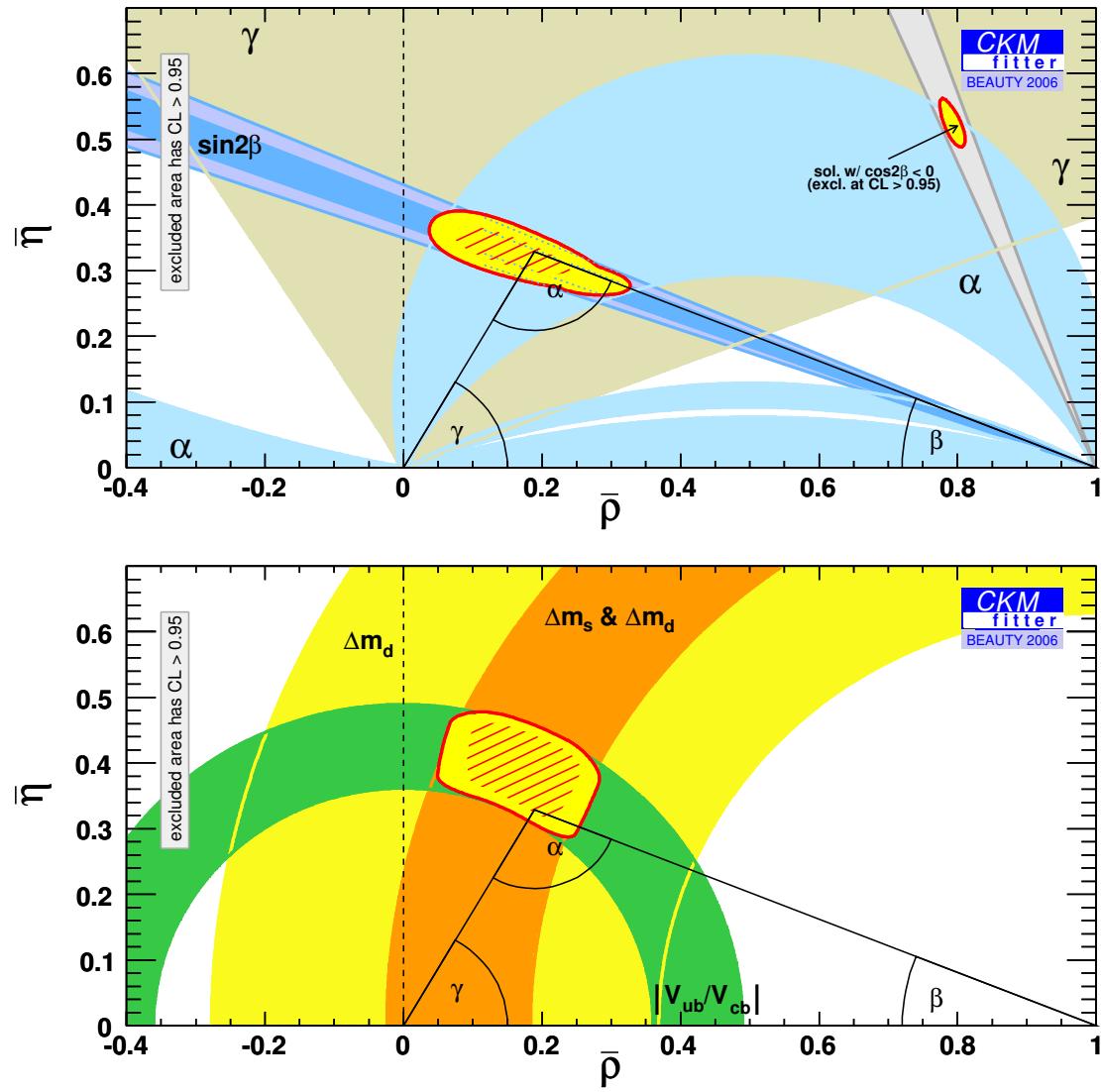
CKM sides @ B factories

XV international Workshop on DIS

München, Germany, 15-20.Apr 2007

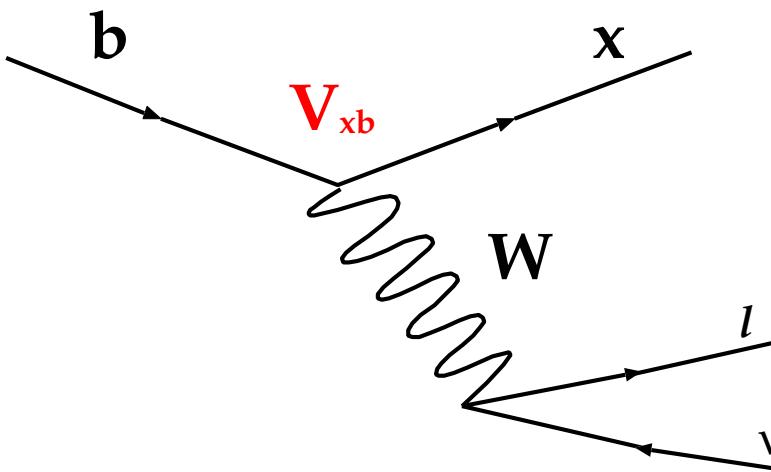
中村 勇 (Nakamura Isamu) / KEK

Introduction にかえて



- Precise Determination of $|V_{ub}/V_{cb}|$ is important for the test of CKM mechanism

Measurement of V_{xb}



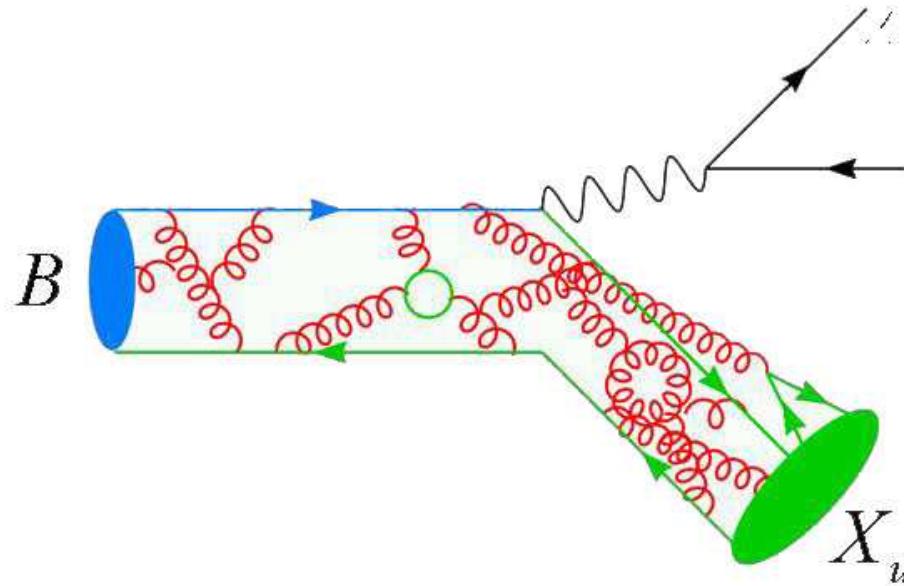
- Measurement is very straightforward, use a relation

$$\Gamma(b \rightarrow x \ell^- \bar{\nu}) = \frac{G_F^2}{192\pi^2} |V_{xb}|^2 m_b^5 \left(1 + \text{補正項}\right)$$

- Only need to count the number of $b \rightarrow x \ell^- \bar{\nu}$ events, however in reality

Measurement of V_{xb}

- In reality,



- To get 補正項, we have to know structure of B meson
 - ◊ In inclusive case
⇒ OPE, b and c quark masses
 - ◊ in exclusive case
⇒ form factors

| V_{cb} | from Inclusive Semileptonic

$|V_{cb}|$ from Inclusive Semileptonic 壱

- Semileptonic width in HQE theory

$$\text{補正項} = (1 + A_{ew})A_{\text{nonpert}}A_{\text{pert}} = f_{\text{OPE}}(m_b, m_c, a_i)$$

- Two separate Calculation for f_{OPE}

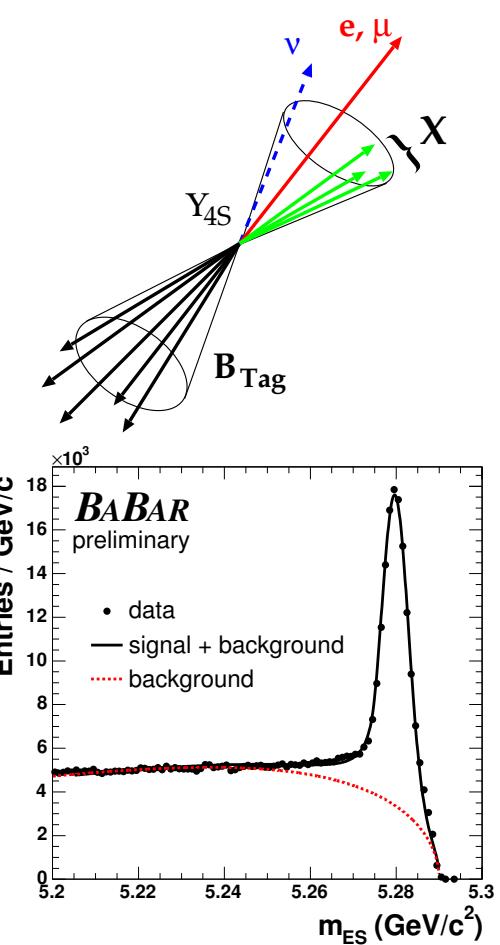
- ◊ Kinetic Scheme, P. Gambino, *et al.* Eur.Phys.J C34 181
- ◊ 1S Scheme, C. Bauer, *et al.* Rhys. Rev. D70 094017

- Predicted,

- ◊ p_ℓ distribution
- ◊ m_X distribution

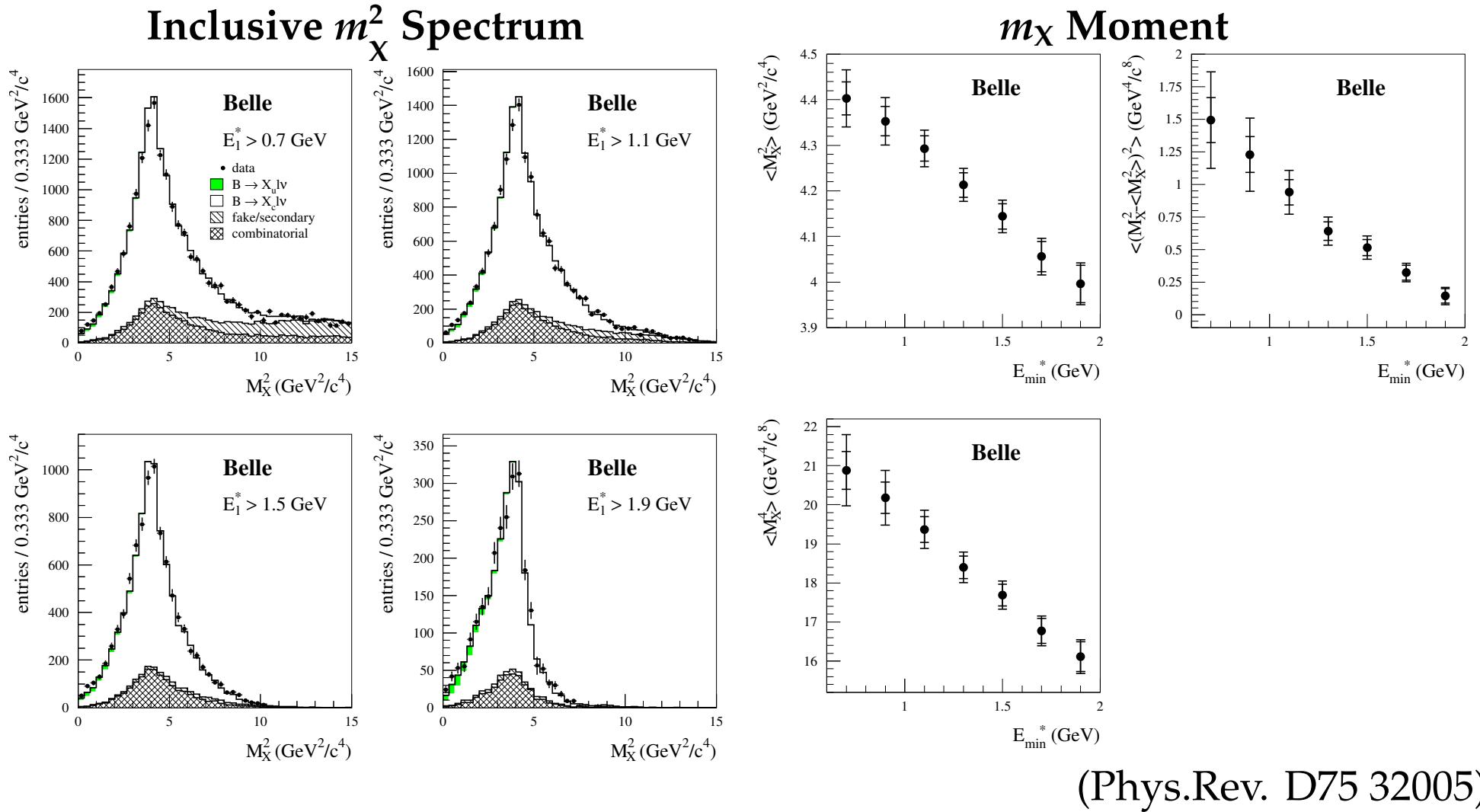
- Experimentalist measure these distributions to get HQE parameters

- use Tagged sample to get m_X with good resolution



$|V_{cb}|$ from Inclusive Semileptonic \bar{B}

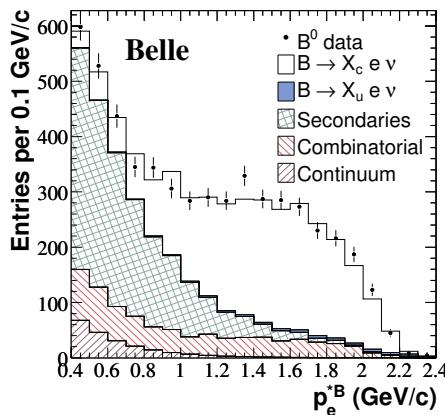
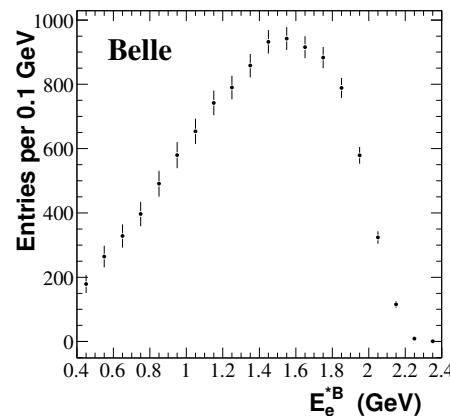
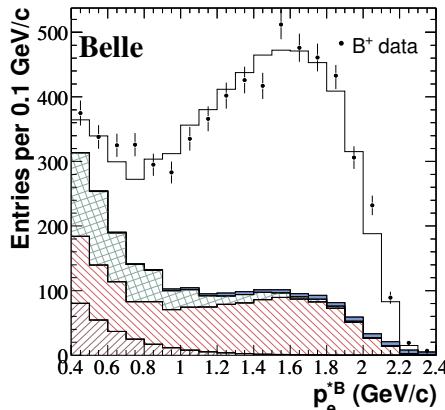
● Measurement of Hadronic Mass Moment



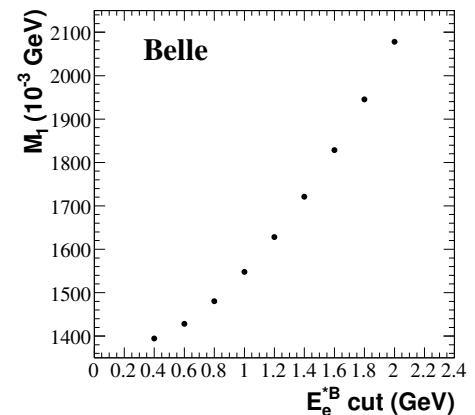
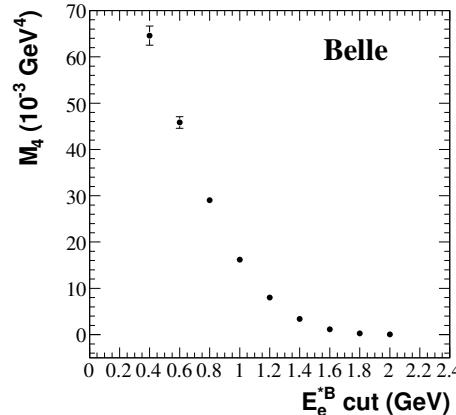
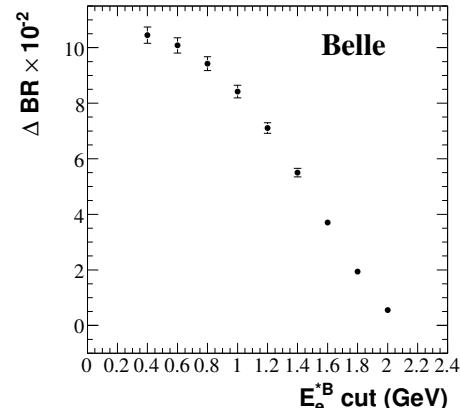
$|V_{cb}|$ from Inclusive Semileptonic 参

- Measurement of Lepton Energy Moments
- Measured 1-4th moments + Branching Fractions

E_ℓ Distributions



E_ℓ Moment



(Phys. Rev. D75 032001)

$|V_{cb}|$ from Inclusive Semileptonic 四

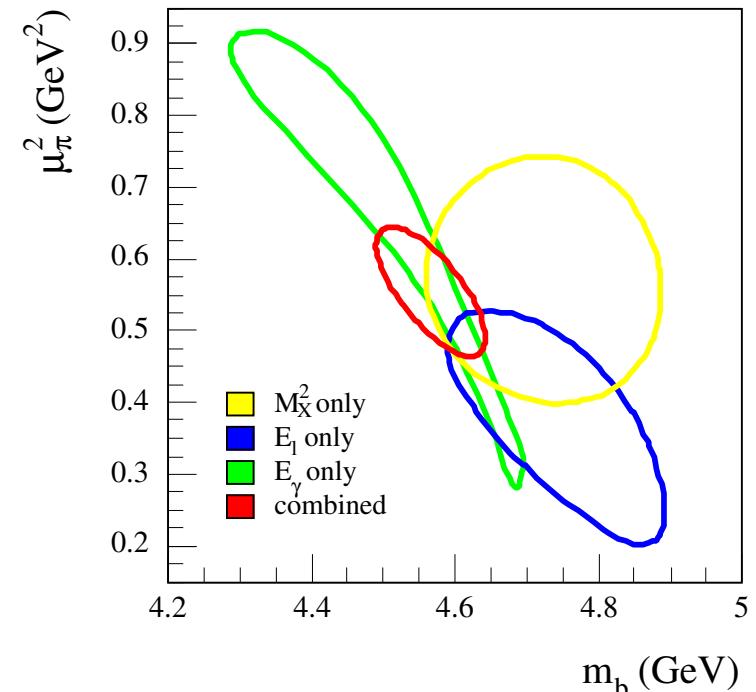
- Global Fit to Belle Data (Preliminary)

- Kinetic Scheme

$$|V_{cb}| = (41.93 \pm 0.91) \times 10^{-3}$$

$$m_b = 4.56 \pm 0.08 \text{ GeV}$$

$$m_c = 1.1 \pm 0.1 \text{ GeV}$$

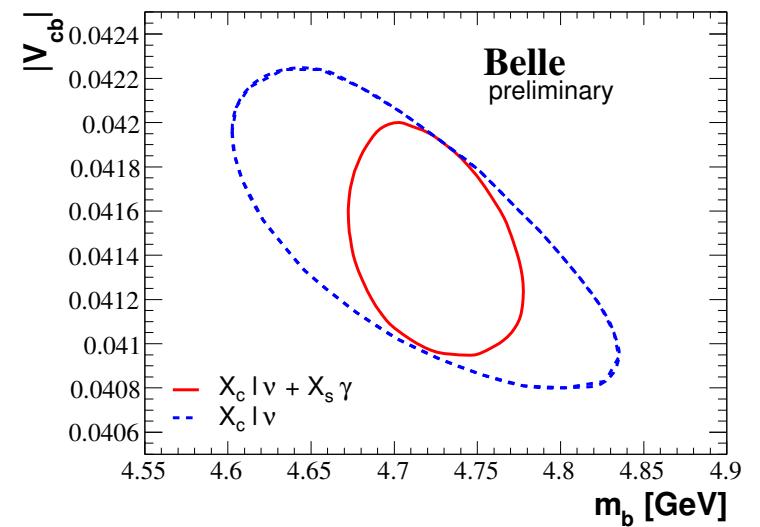


- 1S Scheme

$$|V_{cb}| = (41.49 \pm 0.56) \times 10^{-3}$$

$$m_b^{1S} = 4.73 \pm 0.05 \text{ GeV}$$

$$\lambda_1 = -0.30 \pm 0.04 \text{ GeV}^2$$



- definition of m_b is different

(hep-ex/0611047)

| V_{ub} | from Inclusive Semileptonic

$|V_{ub}|$ from Inclusive Semileptonic

- Measure V_{ub} using ratio,

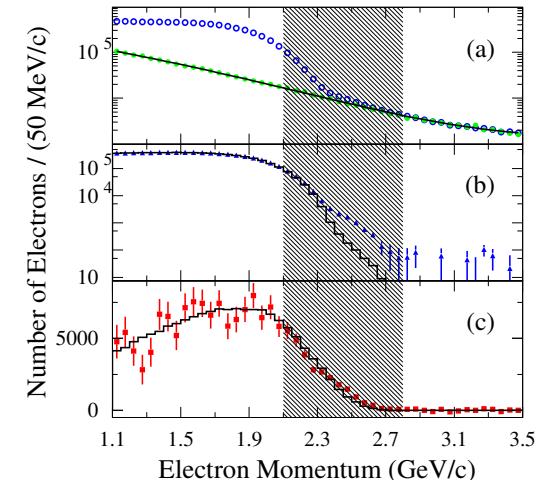
$$\frac{\Gamma(b \rightarrow u\ell^-\bar{\nu})}{\Gamma(b \rightarrow c\ell^-\bar{\nu})} \approx \frac{|V_{ub}|^2}{|V_{cb}|^2} \approx \frac{1}{50}$$

- must deal with 50 times bigger background with identical topology.
- enhance $b \rightarrow u\ell^-\bar{\nu}$ using kinematic variables,
 - E_ℓ : Lepton energy distribution around endpoint
 - m_X and q^2

hence We actually measure,

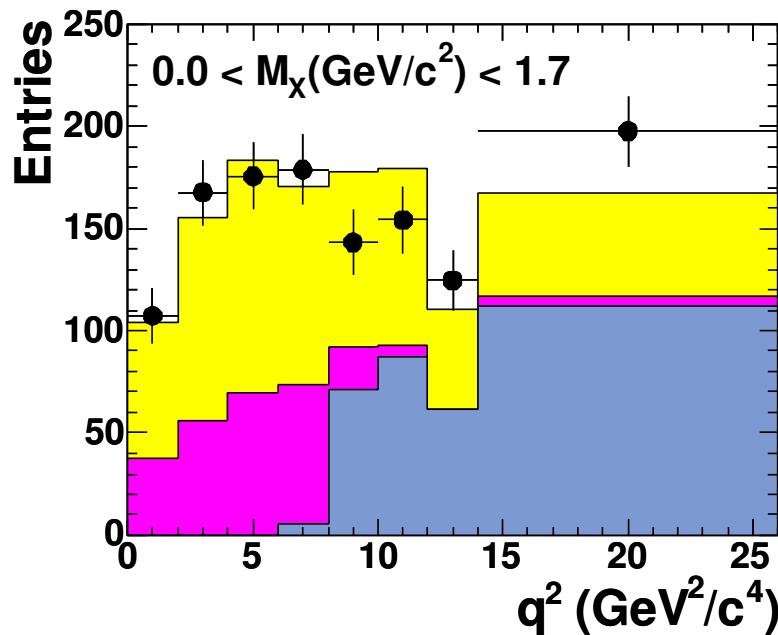
$$\Delta\mathcal{B}(b \rightarrow u\ell^-\bar{\nu}) = f_u \cdot \mathcal{B}(b \rightarrow u\ell^-\bar{\nu})$$

- f_u is the fraction of phase space



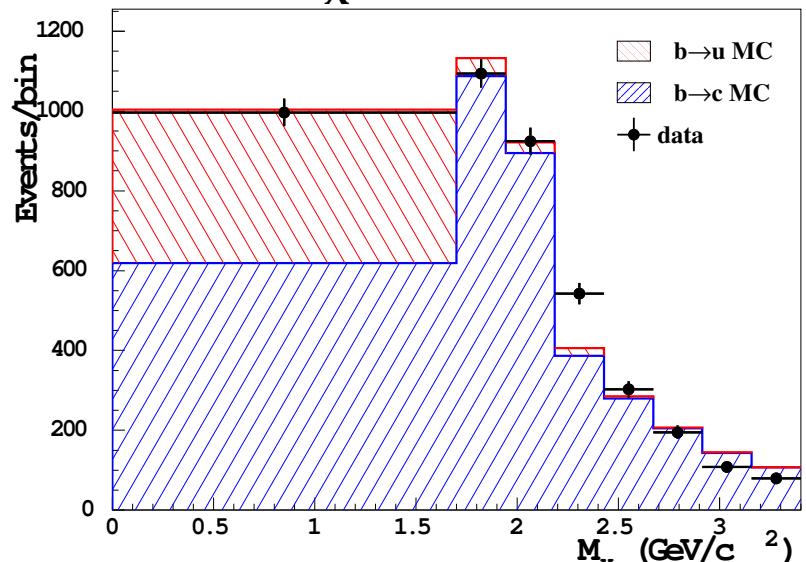
$|V_{ub}|$ from Inclusive Semileptonic

BaBar q^2 Distribution



(hep-ex/0507017)

Belle m_X Distribution



(Phys.Rev.Lett.95:241801,2005)

	$\mathcal{L}(\text{fb}^{-1})$	cut	$\Delta\mathcal{B}(10^{-4})$
BaBar	211	$m_X < 1.7 \text{ GeV}$, $q^2 > 8 \text{ GeV}^2$	$8.7 \pm 0.9 \pm 0.9$
Belle	253	$m_X < 1.7 \text{ GeV}$ $m_X < 1.7 \text{ GeV}$, $q^2 > 8 \text{ GeV}^2$	$12.4 \pm 1.1 \pm 1.2$ $8.4 \pm 0.8 \pm 1.0$

$|V_{ub}|$ from Inclusive Semileptonic

- Calculation by Bosch *et al.* (BLNP)

Phys. Rev. D72, 073006(2005)

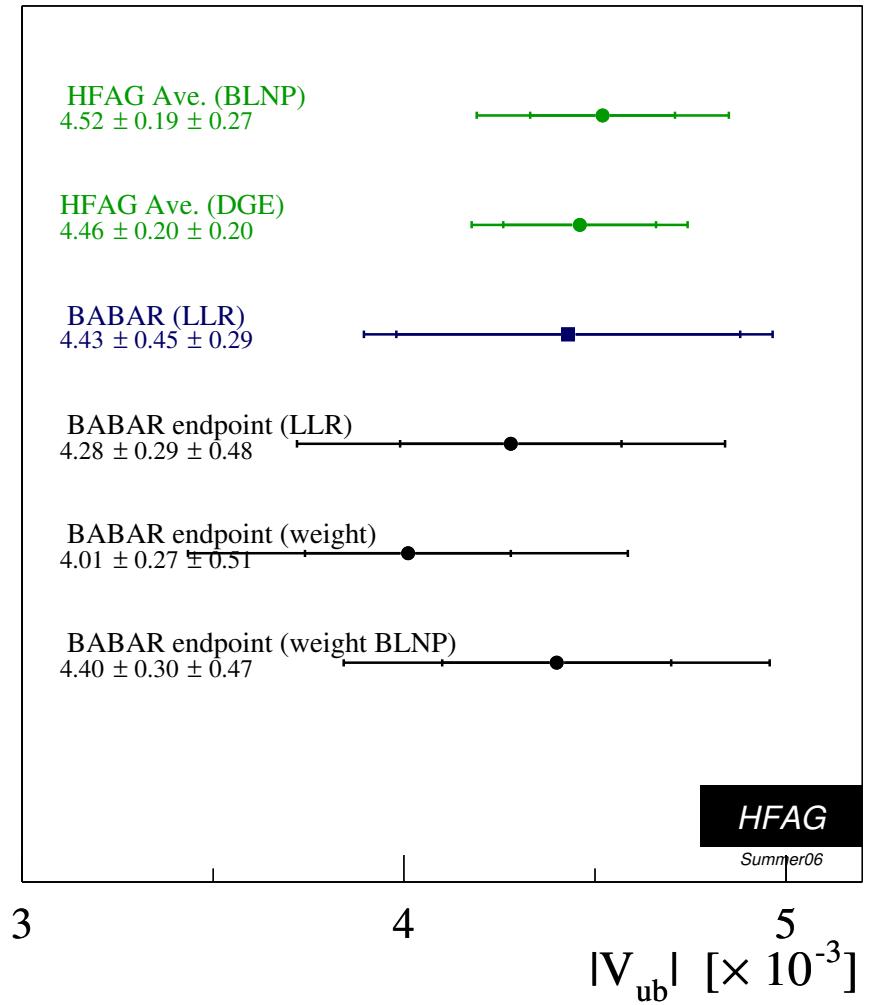
$$|V_{ub}| = (4.52 \pm 0.19_{\text{exp}} \pm 0.27_{\text{th}})$$

- Calculation by Anderson, Gardi (DGE)
JHEP 061:097(2006)

$$|V_{ub}| = (4.46 \pm 0.20_{\text{exp}} \pm 0.20_{\text{th}})$$

- Weighting Method (LLR)
Phys.Rev.D62, 014010,2000

$$|V_{ub}| = (4.43 \pm 0.45_{\text{exp}} \pm 0.29_{\text{th}})$$



| V_{cb} | from Exclusive Semileptonic

$|V_{cb}|$ from Exclusive Semileptonic $\frac{1}{\Gamma}$

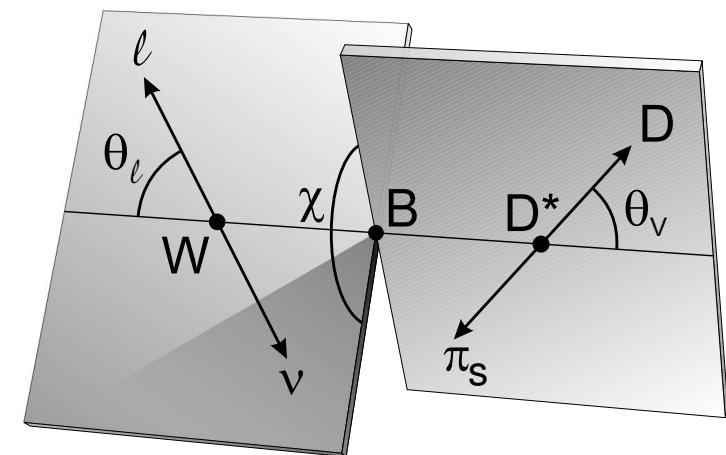
- Determination via differential rate

$$\frac{d\Gamma(B \rightarrow D^* \ell \nu)}{dw d \cos \theta_\ell d \cos \theta_\nu d\chi} = \frac{G_F^2}{48\pi^3} G(w) |V_{cb}|^2 \mathcal{F}(w, \dots)^2$$

$$\mathcal{F}(w) \Rightarrow \mathcal{F}(w, \cos \theta_\ell, \cos \theta_\nu, \chi, R_1, R_2, \rho^2)$$

$$w \equiv v_B \cdot v_{D^*} = \frac{p_B \cdot p_{D^*}}{m_B \cdot m_{D^*}} : D^* \text{ boost}$$

- Fit angular distributions, $\cos \theta_\ell, \cos \theta_\nu, \chi$
 \Rightarrow Form Factors R_1, R_2, ρ^2
- simultaneously fit w distribution to get
 $\mathcal{F}(1)|V_{cb}|$



$|V_{cb}|$ from Exclusive Semileptonic \bar{D}^*

- Select $D^*\ell\nu$ events, with

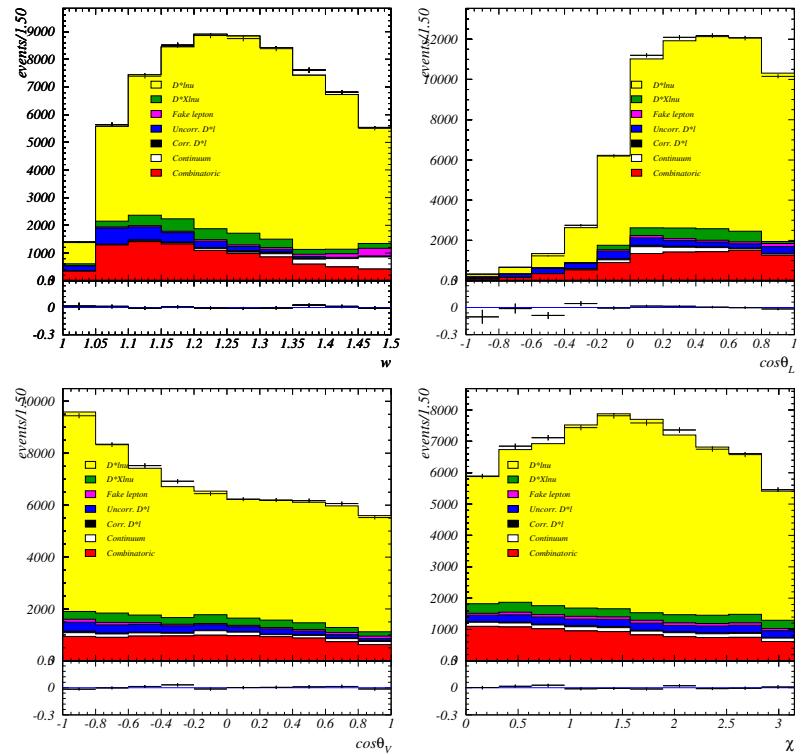
- ◊ $p_{\text{lep}} > 1.2 \text{ GeV}$
- ◊ $D^* \rightarrow D^0\pi$
- ◊ $D^0 \rightarrow K\pi, K\pi\pi^0, K\pi\pi\pi$

- Fit the measured $w, \cos\theta_\ell, \cos\theta_\nu, \chi$ distribution to the Theory prediction
- \mathcal{F} at $w = 1$ is calculated by LQCD

$$\mathcal{F}(1) = 0.919^{+0.030}_{-0.035}$$

(S. Hashimoto et al.)

BaBar 79 fb^{-1}



$|V_{cb}|$ from Exclusive Semileptonic 参

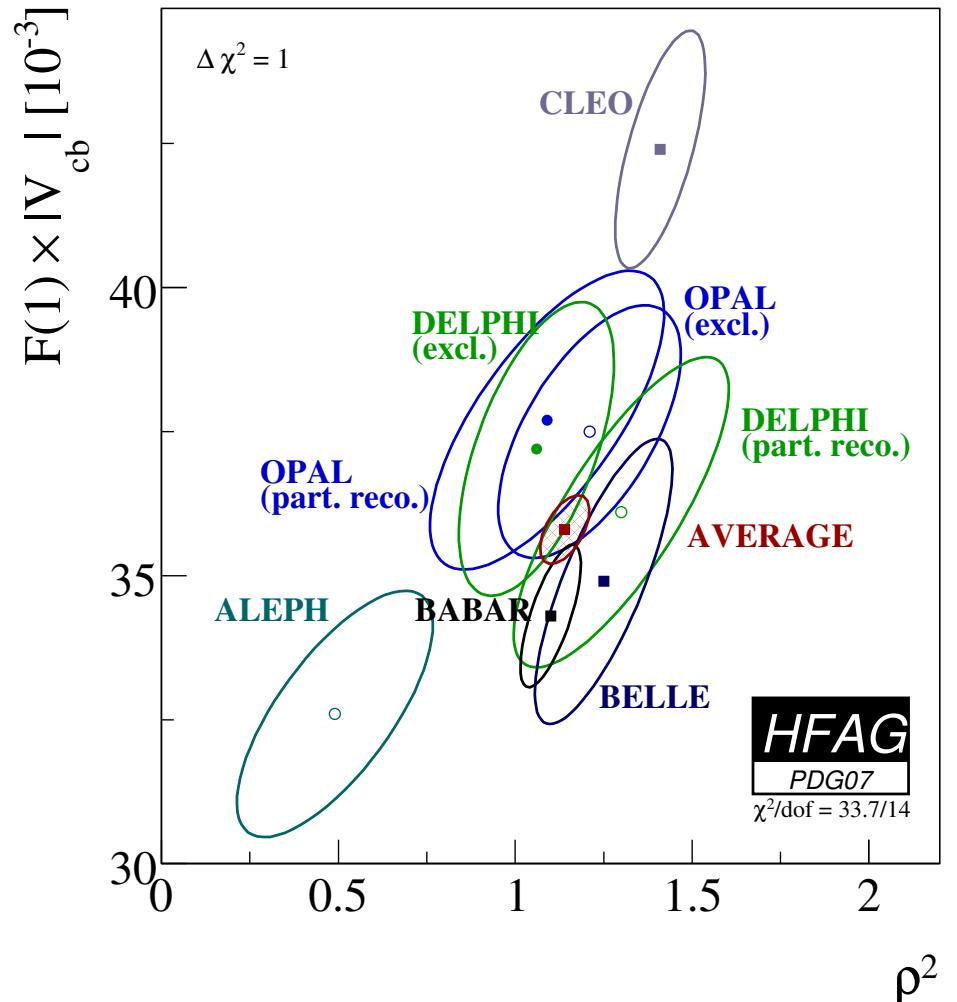
HFAG 2007

- HFAG Average

$$\mathcal{F}(1)|V_{cb}| = (35.8 \pm 0.6) \times 10^{-3}$$

- with $\mathcal{F}(1) = 0.919^{+0.030}_{-0.035}$

$$|V_{cb}| = 39.0 \pm 0.7^{+1.3}_{-1.5}$$



- Error Dominated by lattice QCD

| V_{ub} | from Exclusive Semileptonic

$|V_{ub}|$ from Exclusive Semileptonic $\overline{\text{B}}$

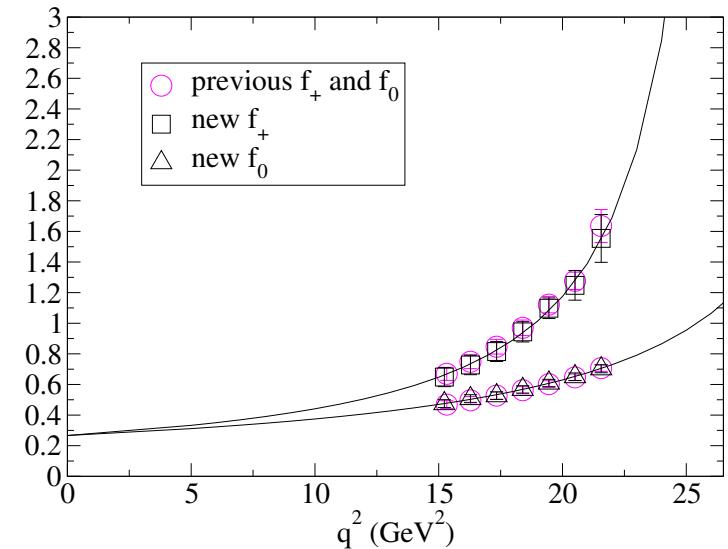
- Determination via differential rate

$$\frac{d\Gamma(\text{B} \rightarrow \pi\ell\nu)}{dq^2} = \frac{G_F^2 |V_{ub}|^2}{192\pi^2 m_b^3} \lambda(q^2)^{\frac{3}{2}} |f_+(q^2)|^2$$

$$q^2 = (p_\ell + p_\nu)^2$$

- form factor, $|f_+(q^2)|$, from

- Relativistic quark models (ISGW2)
- Light cone sum rules for $q^2 < 14 \text{ GeV}^2$ (Ball-Zwicky)
- Lattice QCD for $q^2 > 16 \text{ GeV}^2$ (HPQCD, FNAL)



F.F. from HPQCD2006
(Phys.Rev.D73, 074502 (2006))

$|V_{ub}|$ from Exclusive Semileptonic 式

- Experimentally, there are three different analyses by tagging method

	No Tag	Semileptonic	Full reconstruction
Signal eff	High	Middle	Low
Background	High	Middle	Low
$\mathcal{L}dt$ (fb^{-1})	~ 10	~ 100	~ 1000

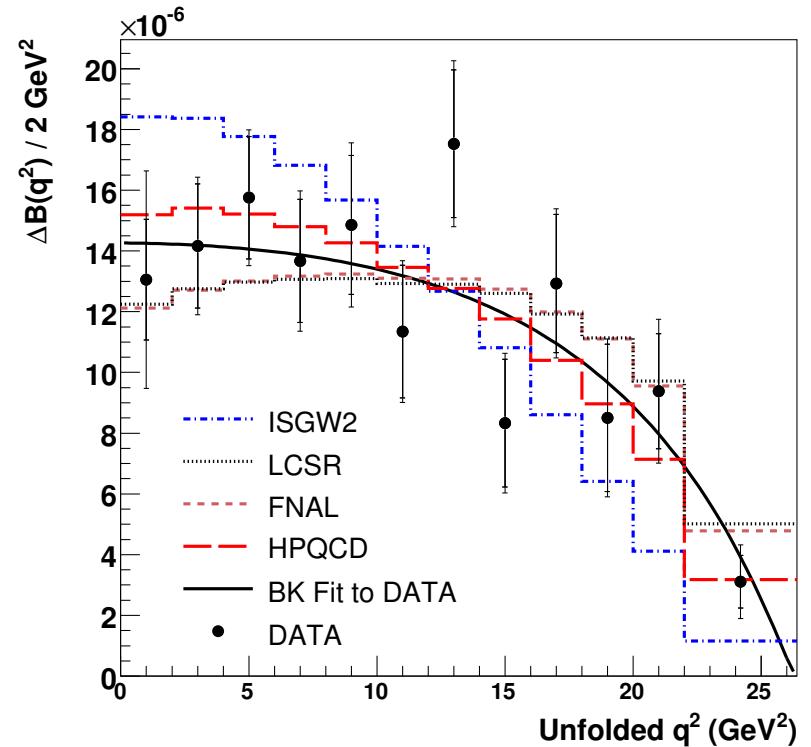
- Neutrino Reconstruction to calculate $p_\nu \rightarrow q^2$
- Tagged analyses better with higher Luminosity

$|V_{ub}|$ from Exclusive Semileptonic 参

BaBar Untagged Analysis (hep-ex/0612020)

- No requirement on the other B
- Loose neutrino reconstruction
- Unfolding q^2 distribution

$$\begin{aligned}\mathcal{B} &= (1.46 \pm 0.07_{\text{stat}} \pm 0.08_{\text{syst}}) \times 10^{-4} \\ \Delta\mathcal{B} &= (0.38 \pm 0.04_{\text{stat}} \pm 0.03_{\text{syst}}) \times 10^{-4} \\ &\quad (q^2 > 16 \text{ GeV}^2)\end{aligned}$$



$|V_{ub}|$ from Exclusive Semileptonic 四

Belle Full-reconstruction analysis (hep-ex/0610054)

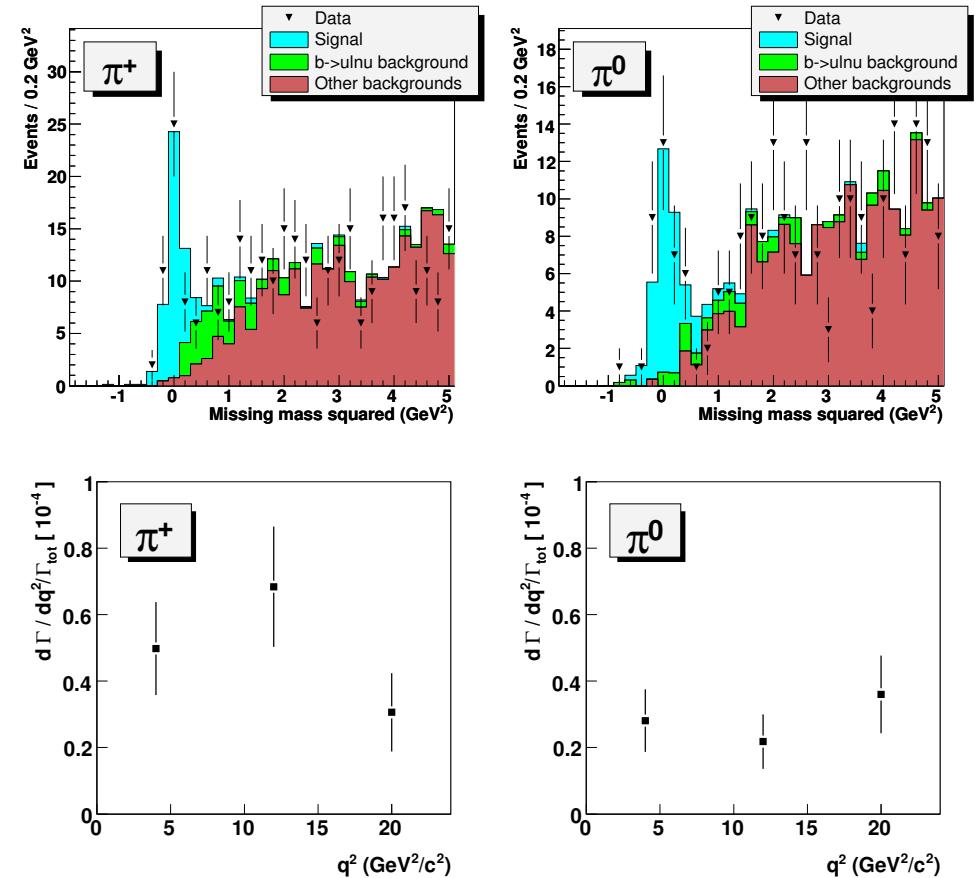
- Full-reconstruction of other B
- Very good S/N
- Nice q^2 reconstruction

$$\mathcal{B}(B \rightarrow \pi^+ \ell \nu) =$$

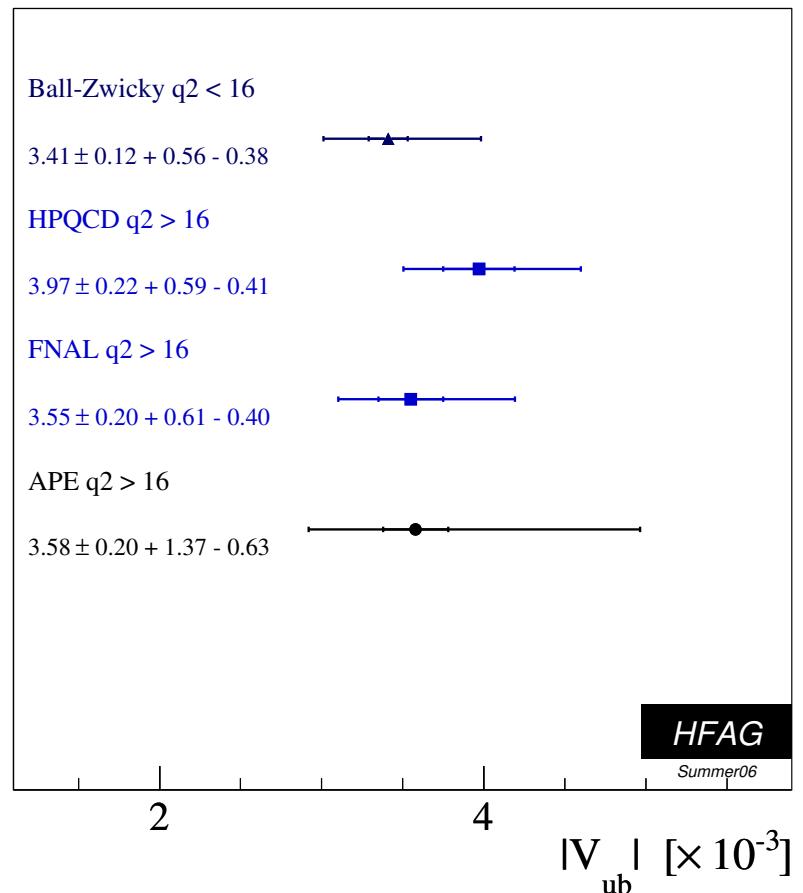
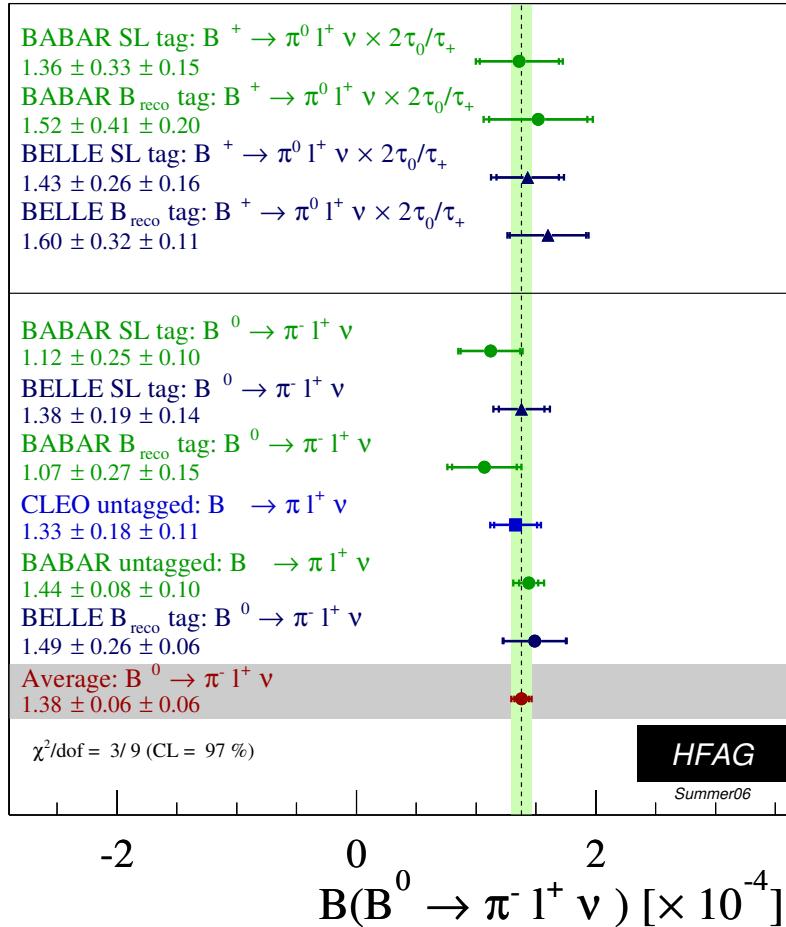
$$(1.49 \pm 0.26_{\text{stat}} \pm 0.06_{\text{syst}}) \times 10^{-4}$$

$$\mathcal{B}(B \rightarrow \pi^0 \ell \nu) =$$

$$(0.86 \pm 0.17_{\text{stat}} \pm 0.06_{\text{syst}}) \times 10^{-4}$$



$|V_{ub}|$ from Exclusive Semileptonic 五



	q^2	$ V_{ub} (10^{-3})$
LCSR	$< 16 \text{ GeV}^2$	$3.41 \pm 0.12_{\text{exp}}^{+.56}_{-.38} \text{ th}$
HPQCD	$> 16 \text{ GeV}^2$	$3.97 \pm 0.22_{\text{exp}}^{+.59}_{-.41} \text{ th}$

Theory Error Dominated

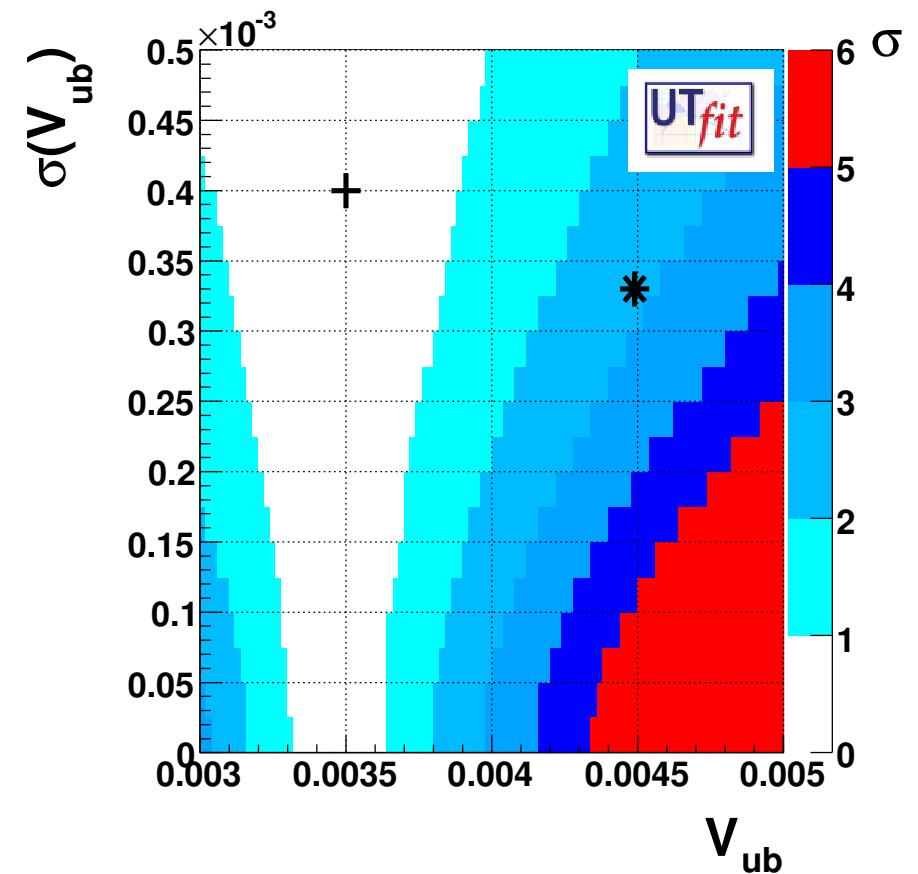
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● Summary of the Measurement

	$ V_{cb} (10^{-3})$	$ V_{ub} (10^{-3})$
Exclusive	39.4 ± 1.6	4.0 ± 0.6
Inclusive	41.5 ± 0.6	4.5 ± 0.3

● Good consistency

- ◊ Different schemes
- ◊ Different Theories



- Some says inconsistency between inclusive and exclusive $|V_{ub}|$
- Need both experimental and theoretical effort for more Precision