Inclusive b→u Decays and Determination of V_{ub} at Belle

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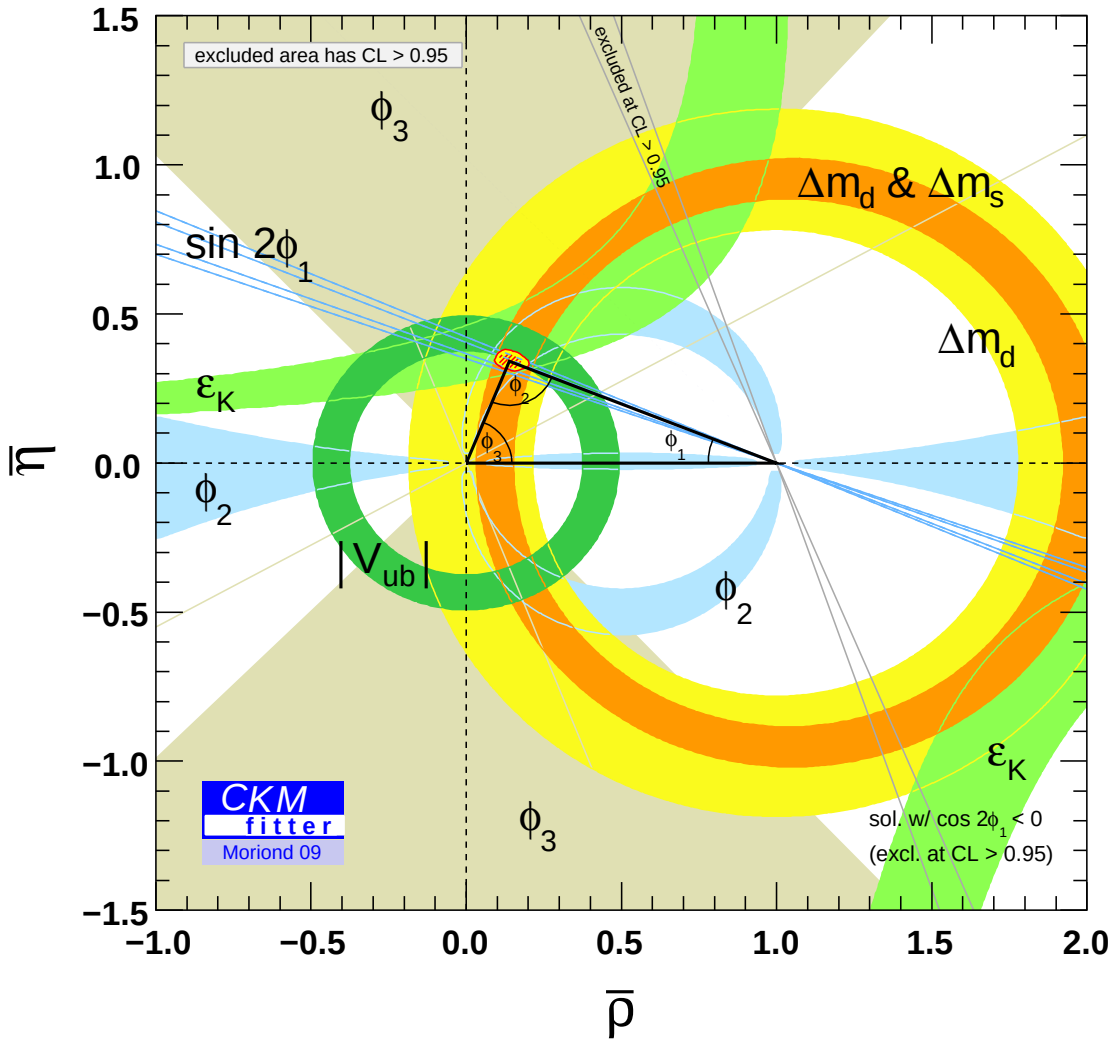
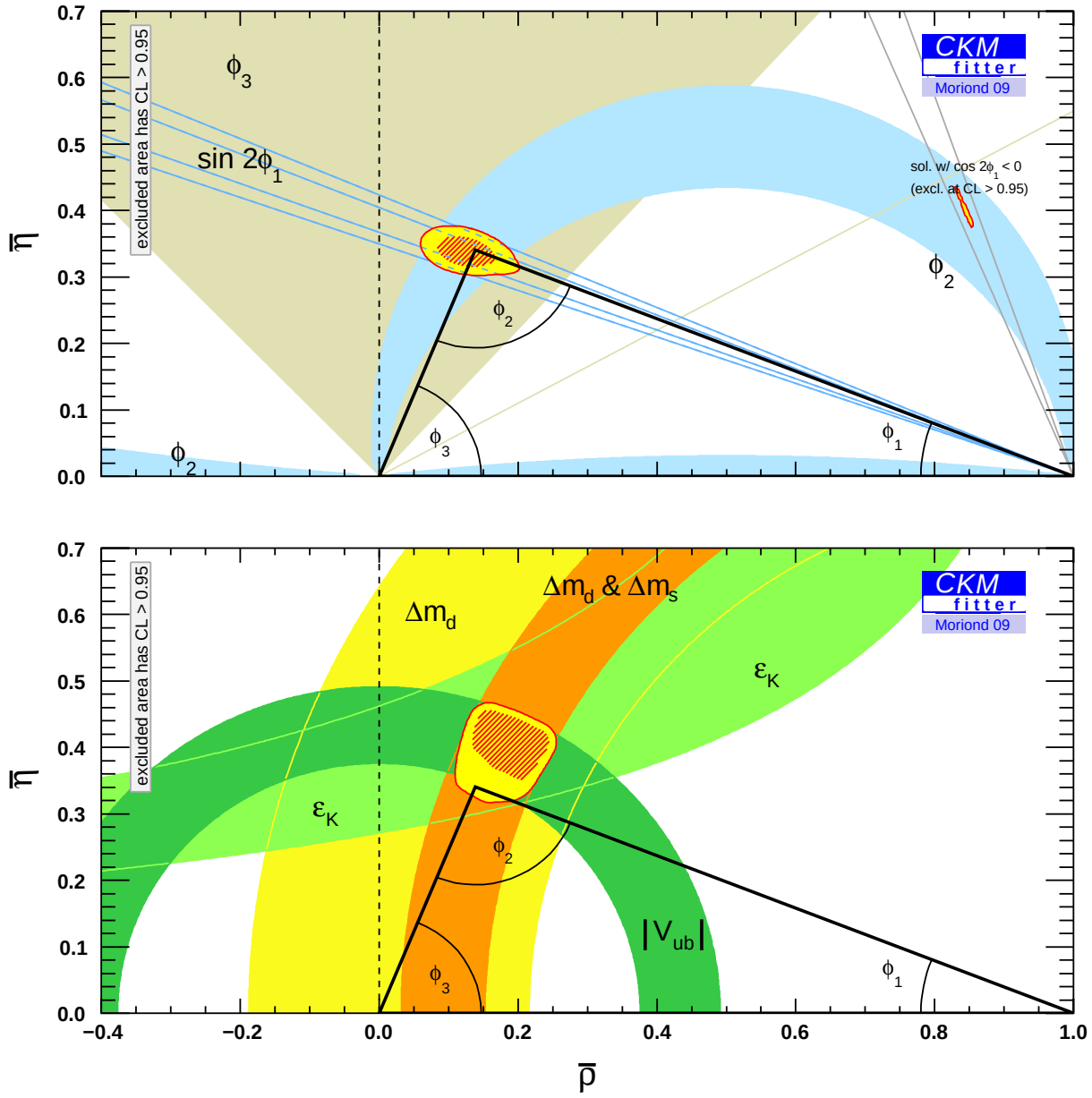
Introduction



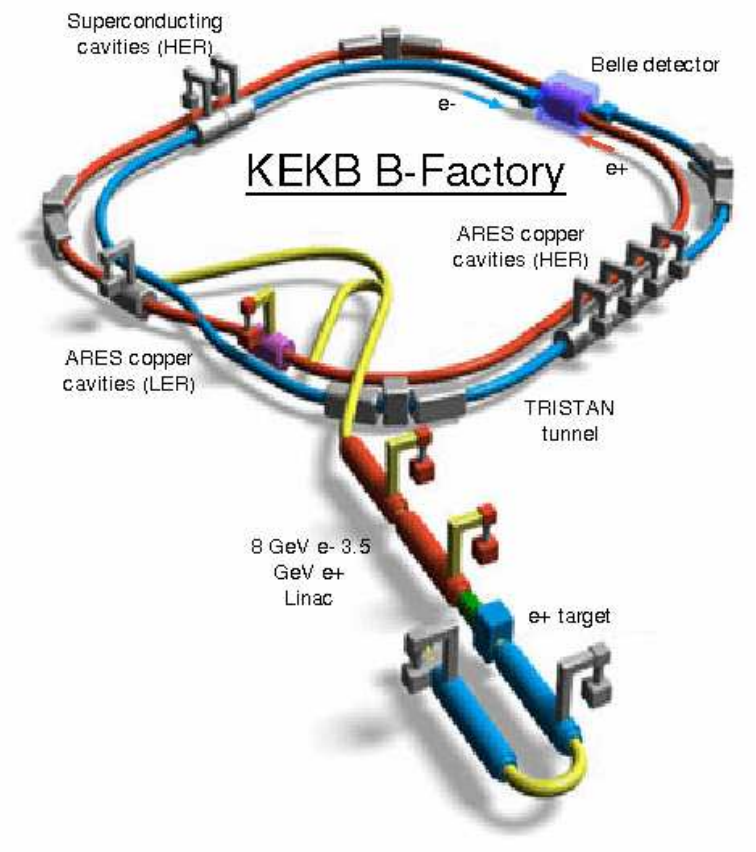
- Precise Determination of $|V_{ub}|$ is important for the test of CKM mechanism

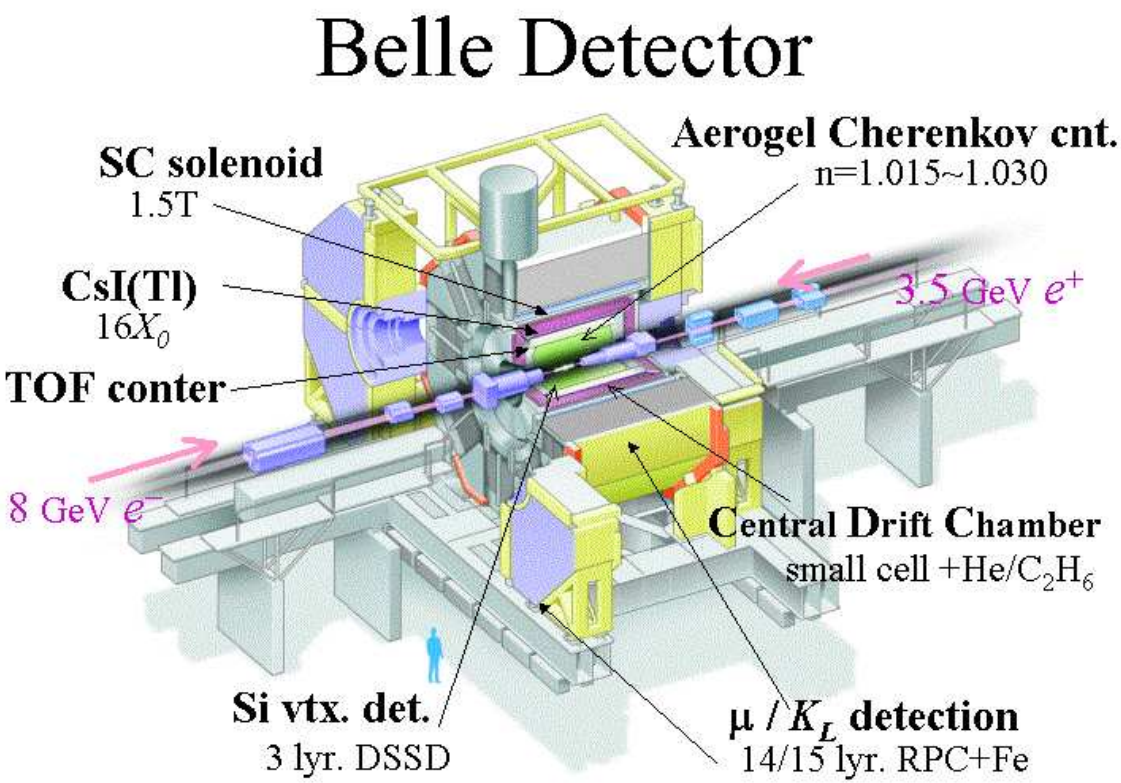
Introduction



- Sides measurement not as accurate as angles

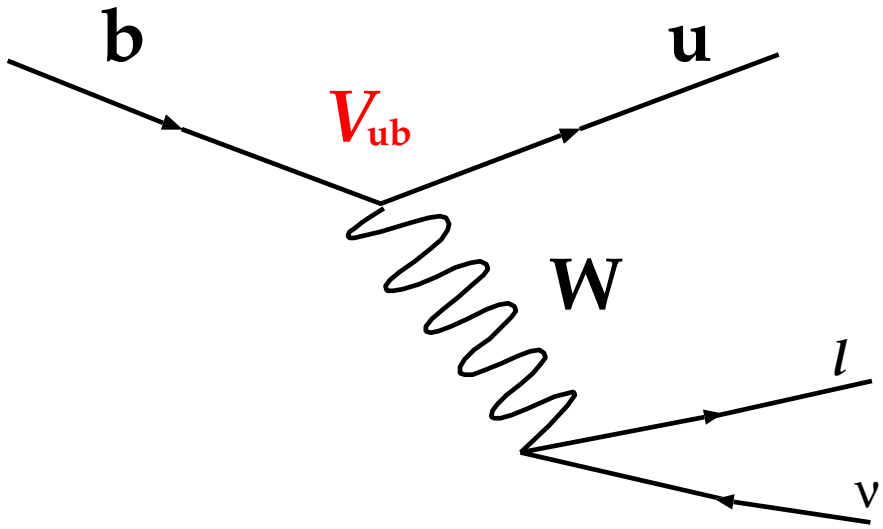
KEKB and Belle





- Belle Detector, KEKB collider at KEK, Tsukuba, Japan
- World brightest collider $\mathcal{L} = 21$ nb^{-1}/s
- Accumulated ~ 950 fb^{-1}

Measurement of V_{ub}



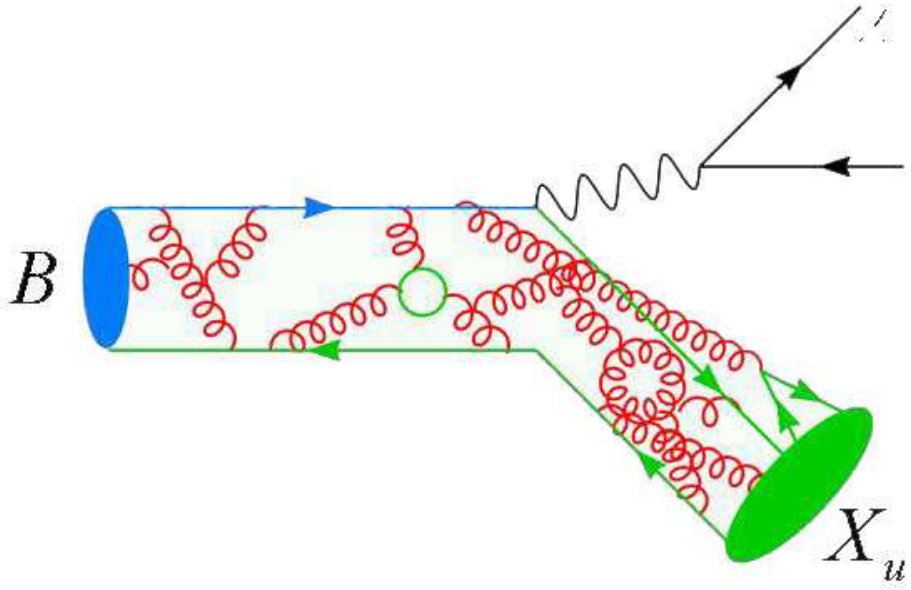
- Measurement is very straightforward, use a relation

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

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

Measurement of V_{ub}

- In reality,



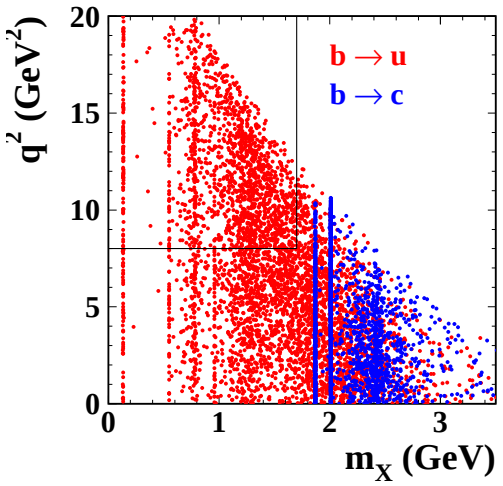
- To get 補正項, we have to know structure of B meson
  - ◇ In inclusive case
    ⇒ HQET parameters, b and c quark masses
  - ◇ in exclusive case
    ⇒ form factors

$|V_{ub}|$ from Inclusive Semileptonic

- must deal with 50 times bigger background with identical topology.

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

- enhance $b \to u\ell^-\bar{\nu}$ using kinematic variables,
  - E_ℓ: Lepton energy distribution around endpoint
  - m_X, q^2 or $P_+ \equiv E_x - |p_x|$



hence We actually measure,

$$\Delta\mathcal{B}(B \to X_u\ell^-\bar{\nu}) = f_u \cdot \mathcal{B}(B \to X_u\ell^-\bar{\nu})$$

- f_u is the fraction of phase space

Belle Endpoint Measurement

- Phys.Lett.B621:28-40,2005
- 27 fb^{-1}
- Measure $\Delta\mathcal{B}$ for $p_e^* > p_{\text{cut}}$
  (p_e^*: electron momentum in $\Upsilon(4S)$ frame)
- Lowest $p_{\text{cut}} = 1.9$ GeV
- Systematic error dominant because of large background

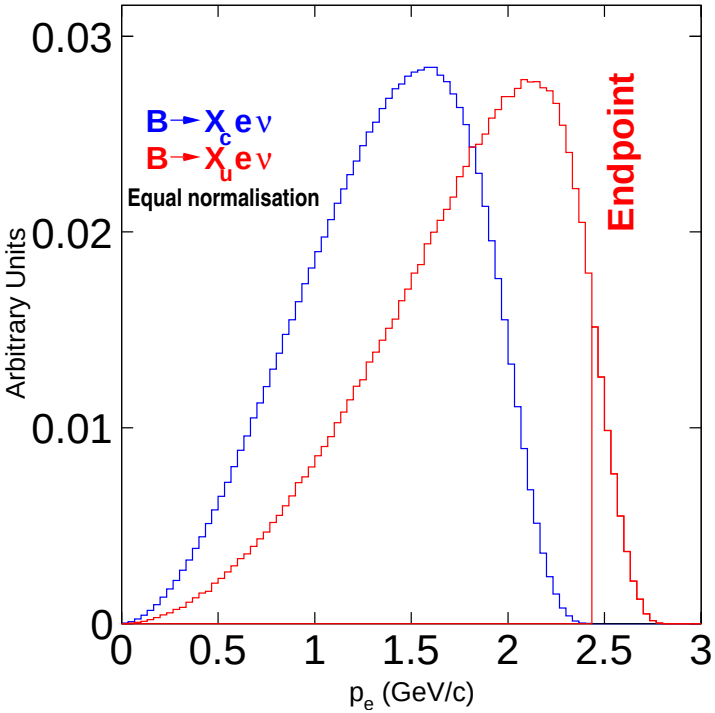
$$\Delta\mathcal{B} = (8.47 \pm 0.37(\text{stat.}) \pm 1.53(\text{syst.})) \times 10^{-4}$$

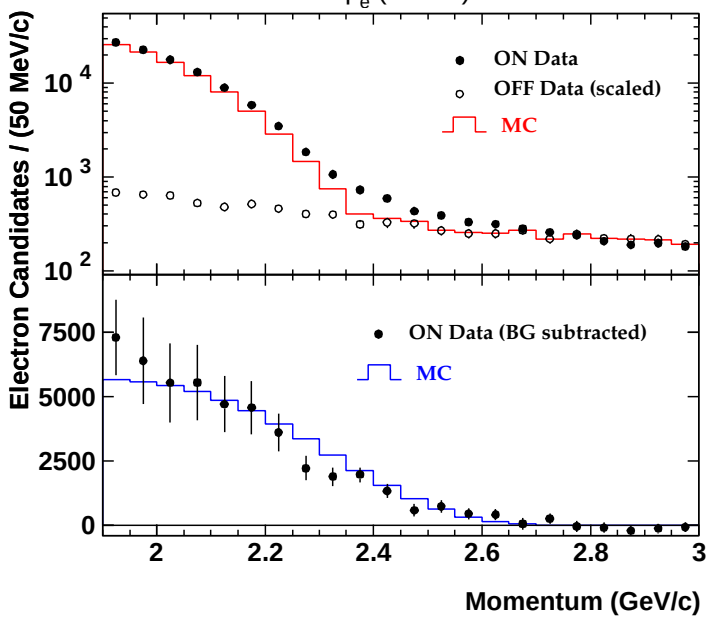
$$\text{for } p^* > 1.9 \text{ GeV}$$

with **BLNP**, Phys. Rev. D **72**, 073006 (2005)

$$V_{ub} = \left(4.64 \pm 0.43^{+0.29}_{-0.31}\right) \times 10^{-3}$$

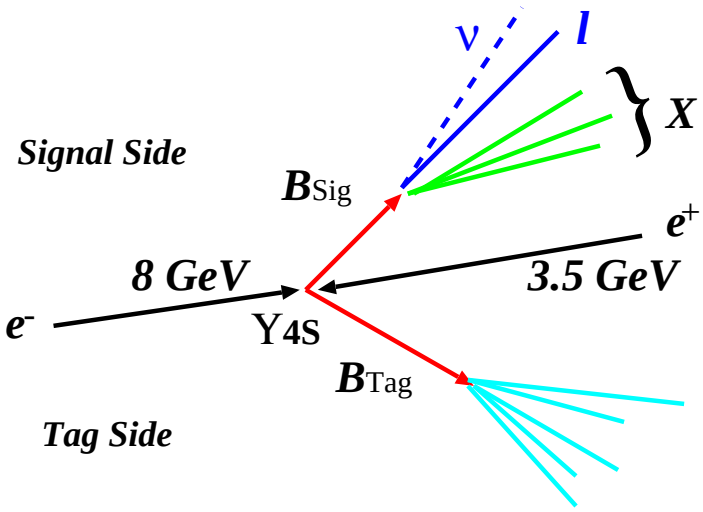
HFAG Winter 2009 combination





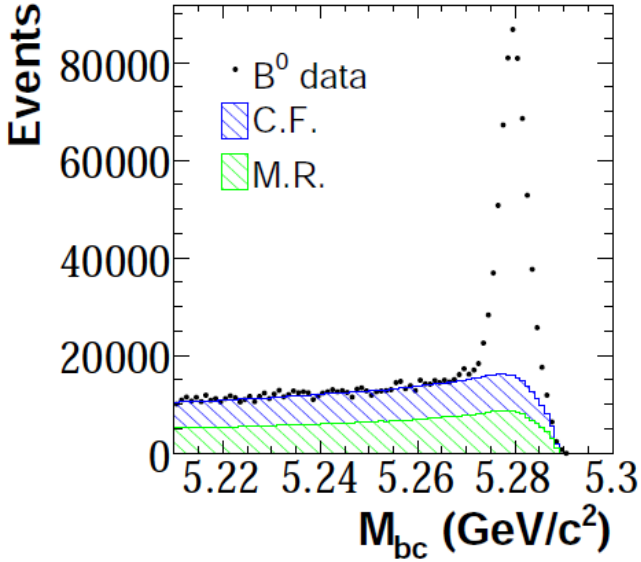
Belle Hadronic Tag Measurement

- arXiv:0907.0379 (July 2009)
- "Fully" reconstruct one B (B_{tag}), exclusively
  - Total of ~180 exclusive modes
  - Known B_{sig} 4-momentum
  - High purity, low efficiency
  - need many events
- 605 fb^{-1} Belle Data (–2005)



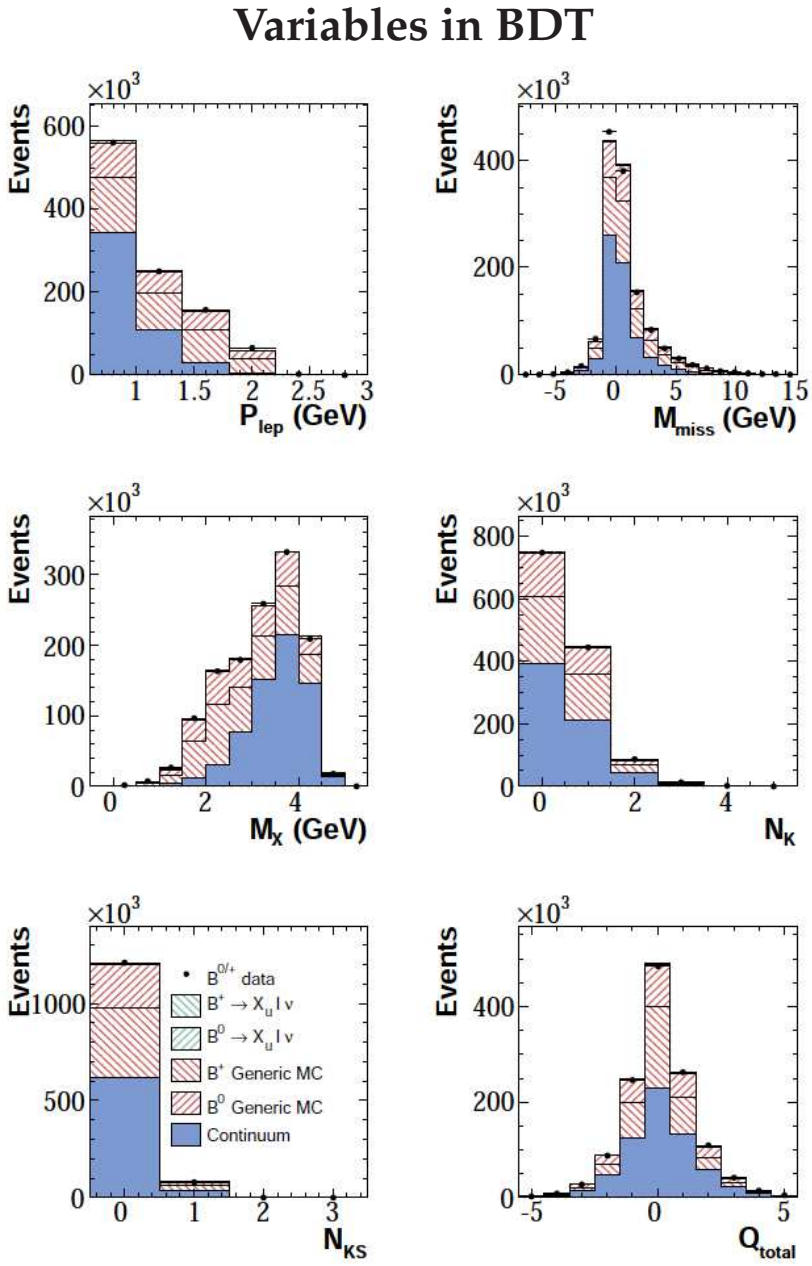
	eff. (%)	purity	N_{tag} ($\times 10^3$)
charged	0.29	0.25	689
neutral	0.28	0.30	479

- $m_{bc} > 5.27$ GeV, $|\Delta E| < 0.05$ GeV
- more than million reconstructed B



Event Selection with BDT

- One Lepton with $p^B > 1$ GeV
- Further suppression of b→c events with Boosted Decision Tree method
- 17 variables with correlations
  - Number of Kaons (charged and K^0_S)
  - m_X
  - q^2
  - m^2_{mis}
  - $P_+ \equiv E_X - |p_X|$
  - m_{bc}, ΔE
  - Impact parameters
  - Total charge of the Event
  - ...
- single optimised cut in BDT classifier
- efficiency ~ 22%

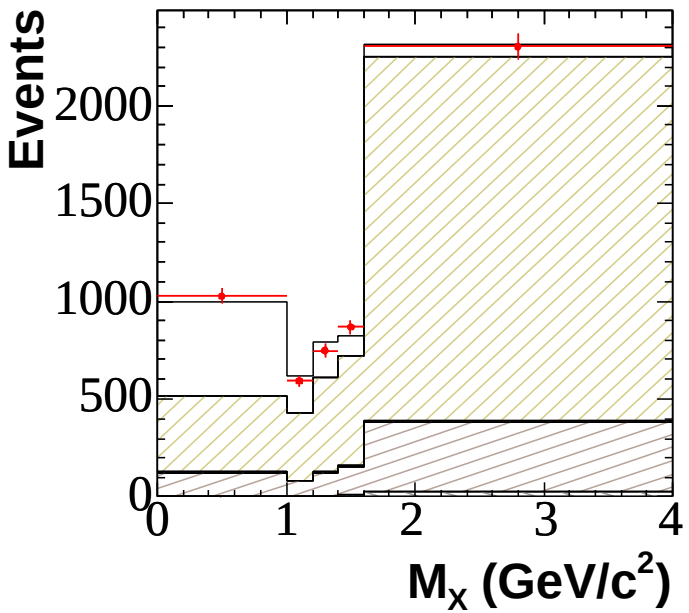


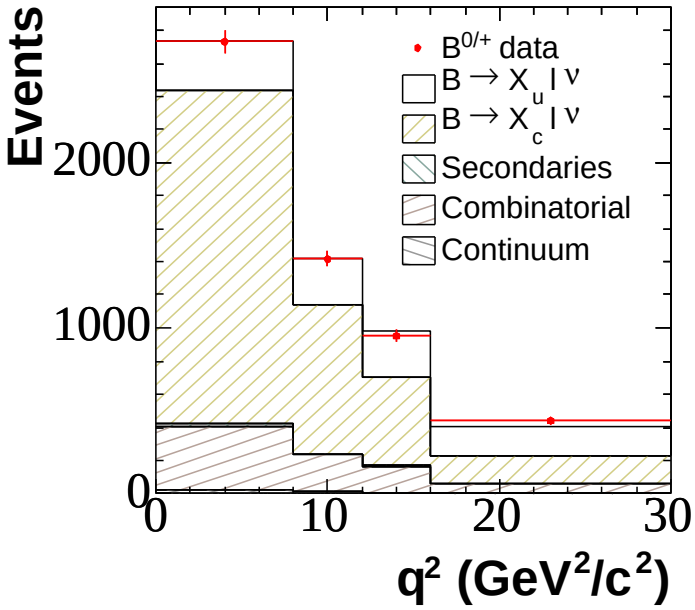
Signal Extraction

- Background subtracted prior to fit
  - not from B decay (scaled off resonance)
  - not correctly reconstructed B_{tag} (MC shape scaled to m_{bc} sideband)
- Fit in 2D $m_X - q^2$ distribution (5×4 bins)
- 3 components (MC driven)
  - $X_u \ell \nu$ contribution
  - $X_c \ell \nu$ contribution
  - Secondary and fakes

Source	# Events
BDT selected	5544 ± 54
scaled off-resonance	35 ± 18
wrong B_{tag}	825 ± 38
$X_u \ell \nu$	1032 ± 91
$X_c \ell \nu$	3615 ± 32
Secondary and fakes	38 ± 2

Projected Distributions





Result

- Partial branching fraction expressed by

$$\Delta\mathcal{B}(B \to X_u \ell^- \bar{\nu}, \Delta) = \frac{N^{\Delta}_{b\to u}}{\varepsilon^{\Delta}_{b\to u} N_{tag}}(1 - \delta_{rad})$$

- δ_{rad}: correction from QED radiation
- $\varepsilon^{\Delta}_{b\to u}$: selection efficiency $\sim 22\,\%$

$$\Delta\mathcal{B} = 1.963(1 \pm 0.088 \pm 0.081) \times 10^{-3}$$

$$\text{for } p^B_\ell > 1\,\text{GeV}$$

Systematic Errors

$p^B_\ell > 1.0$ GeV	$\Delta\mathcal{B}/\mathcal{B}$ (%)
$\mathcal{B}(D^{(*)}\ell\nu)$	1.2
$(D^{(*)}\ell\nu)$ form factors	1.2
$\mathcal{B}(D^{**}e\nu)$ & form factors	0.2
$B\to X_u\ell\nu$ (SF)	3.6
$B\to X_u\ell\nu$ ($g \to s\bar{s}$)	1.5
$\mathcal{B}(B\to \pi/\rho/\omega\ell\nu)$	2.3
$\mathcal{B}(B\to \eta,\ \eta'\ell\nu)$	3.2
$\mathcal{B}(B\to X_u\ell\nu)$ un-meas.	2.9
Cont./Comb.	1.8
Sec./Fakes/Fit.	1.0
PID/Reconstruction	3.1
BDT	3.1
Systematics	8.1
Statistics	8.8

$\Delta\mathcal{B}$ to V_{ub}

V_{ub} is obtained by relation,

$$|V_{ub}|^2 = \frac{\Delta\mathcal{B}(B \to X_u \ell^- \bar{\nu}, \Delta)}{\tau_B \Delta\mathcal{R}}$$

- τ_B average B lifetime
- $\Delta\mathcal{R}$: partial rate from theory
  - **BLNP**, Phys. Rev. D **72**, 073006 (2005)
  - **DGE**, arXiv:0806.4524 [hep-ph] (2008)
  - **GGOU**, JHEP **0710**, 058 (2007)

Theory	$\lvert V_{ub}\rvert \times 10^3$	stat.	sys.	m_b	th.
BLNP	4.37	4.3	4.0	$^{+3.1}_{-2.7}$	$^{+4.3}_{-4.0}$
DGE	4.46	4.3	4.0	$^{+3.2}_{-3.3}$	$^{+1.0}_{-1.5}$
GGOU	4.41	4.3	4.0	1.9	$^{+2.1}_{-4.5}$

relative errors in %

- New combination will come later

Summary of V_{ub}