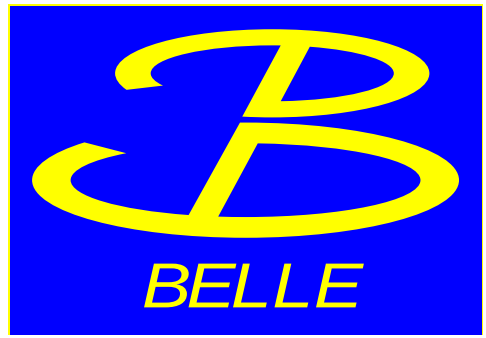
CKM matrix elements & Fits



Hidekazu Kakuno

Tokyo Institute of Technology

Beauty 2003

14 Oct. 2003

Introduction: CKM matrix

$$\mathcal{L}_{int} = -\frac{g}{\sqrt{2}}(\overline{u_L}, \overline{c_L}, \overline{t_L})\gamma^\mu V \begin{pmatrix} d_L \\ s_L \\ b_L \end{pmatrix} W_\mu + c.c.$$

quark mixing matrix (CKM matrix)

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

↓

unitarity + adjustment of relative phase

↓

3 Euler angles + 1 phase

Wolfenstein parametrization: 4 parameters(λ,A,ρ,η)

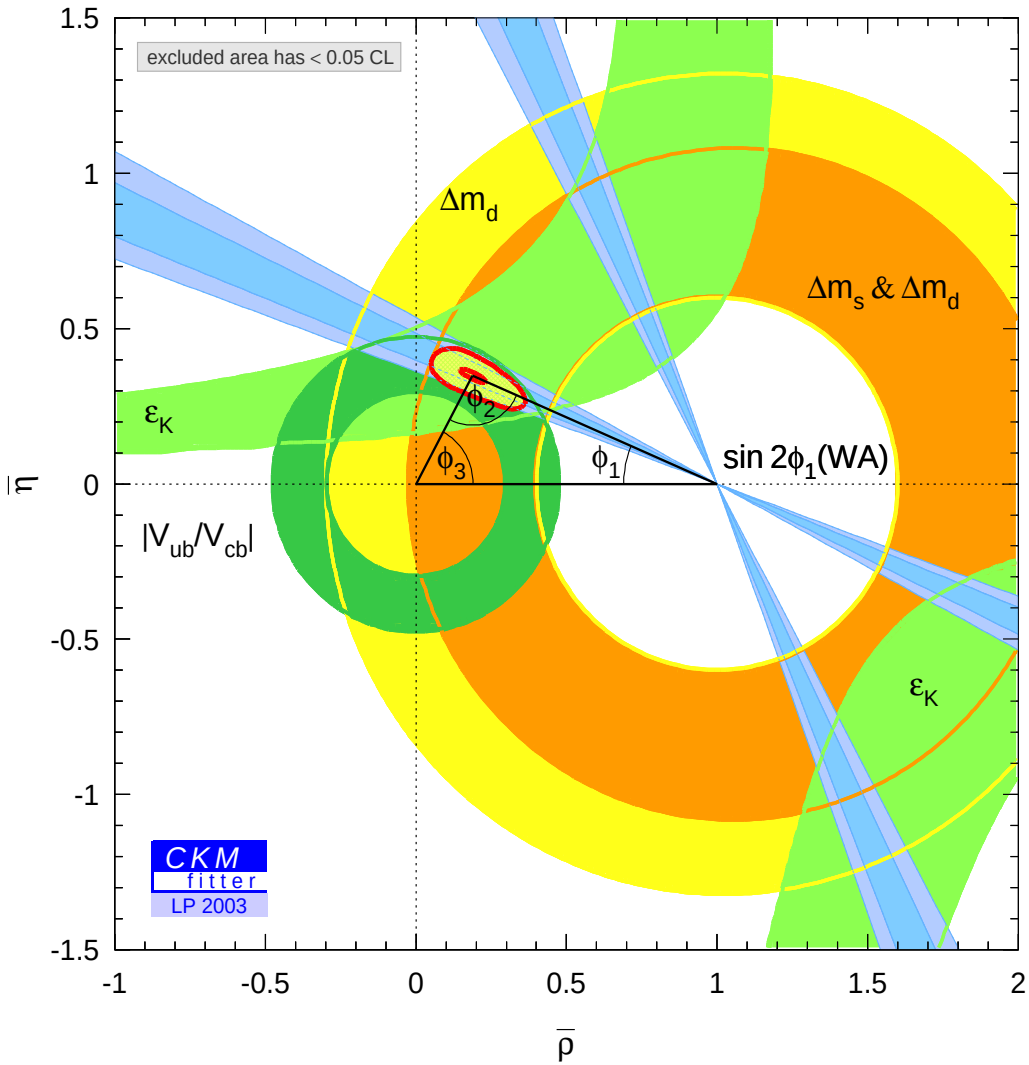
$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-(\lambda^2/2) & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & (1-\lambda^2/2)A\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

ρ, η → **not measured well**

one of the subject in B-factories

Introduction: Unitarity Triangle and Constraints

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



|Vub/Vcb| from semileptonic B-decay:
→ Insensitive to the new physics processes, i.e. one of the stable constraints

Essential for the new physics search

Precise measurement on |Vub| & |Vub|
→essential for keeping them as the "constraint"
e.g. sin2ϕ_1 is getting better and better accuracy

This talk include the status of |Vcb| & |Vub| measurements

|Vcb| measurements

1. Exclusive analyses

2. Inclusive analyses

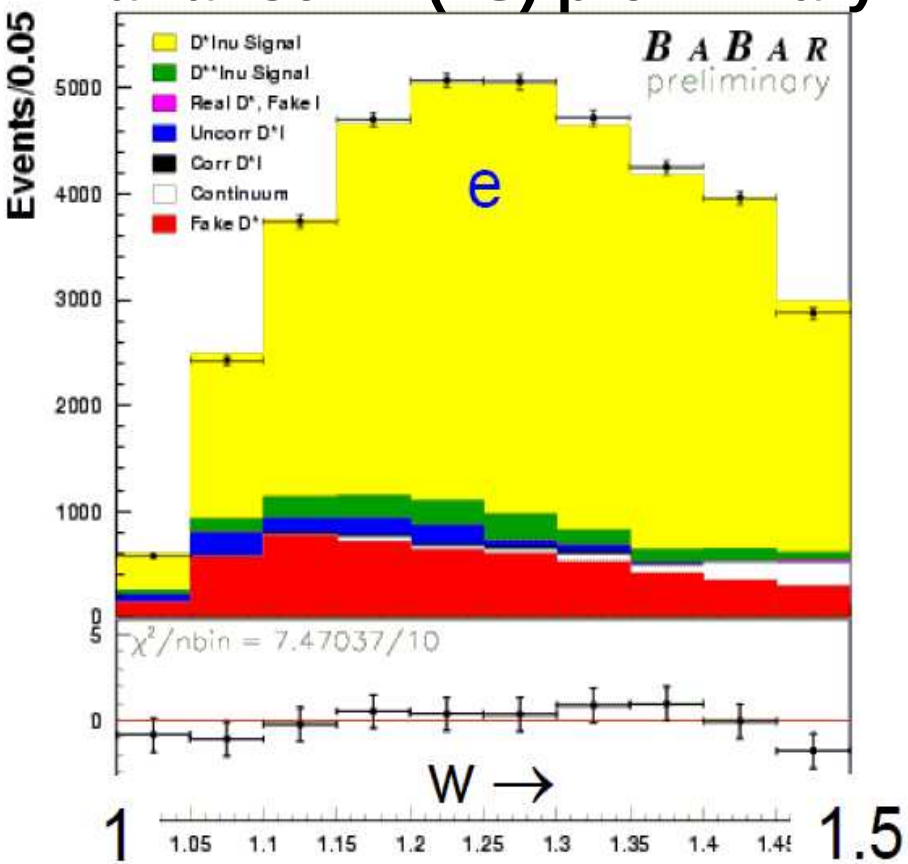
|Vcb| exclusive analysis: B→D*lν

Differential decay rate:

$$\frac{d\Gamma(B \to D^* \ell \bar{\nu})}{dw} \propto |V_{cb}^2| F(w)^2 \qquad w = \frac{M_B^2 + M_{D^*}^2 - q^2}{2 M_B M_D^*}$$

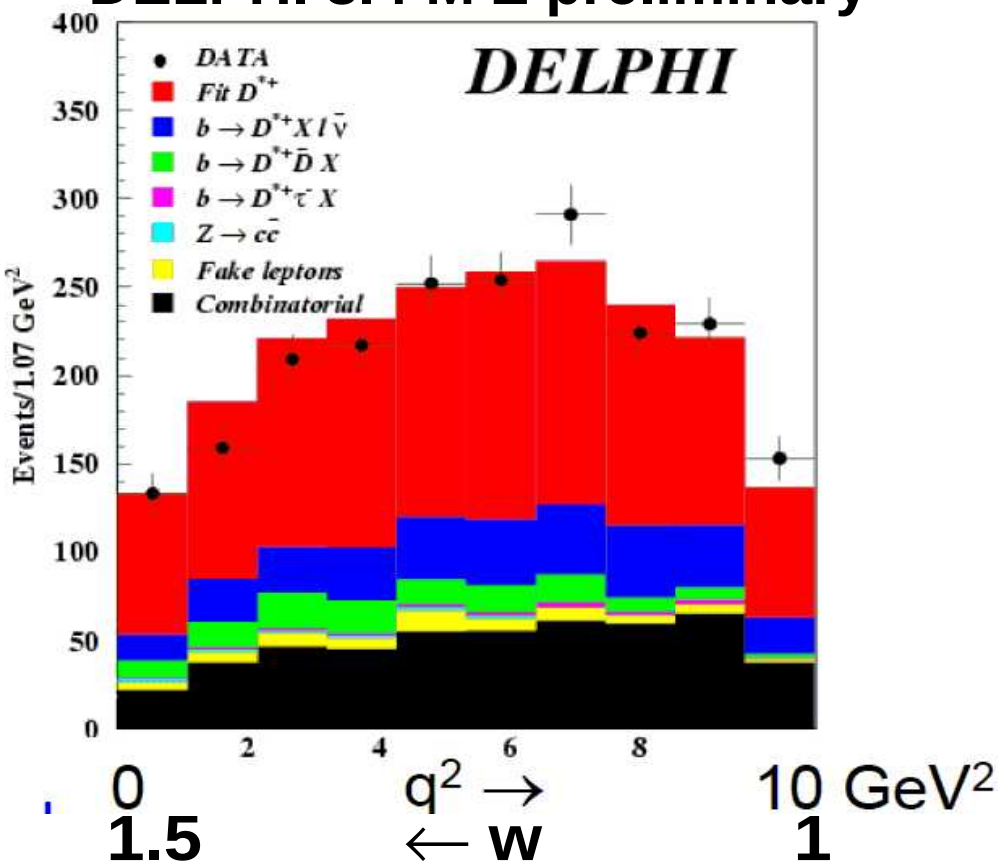
fit w and extract differential decay rate @zero recoil (w=1)
F(1): from HQET

BaBar 86M ϒ(4S) preliminary



$$|V_{cb}| F(1) = (34.0 \pm 0.2 \pm 1.3) \times 10^{-3}$$
$$\rho_{A1}^2 = 1.23 \pm 0.02 \pm 0.28$$

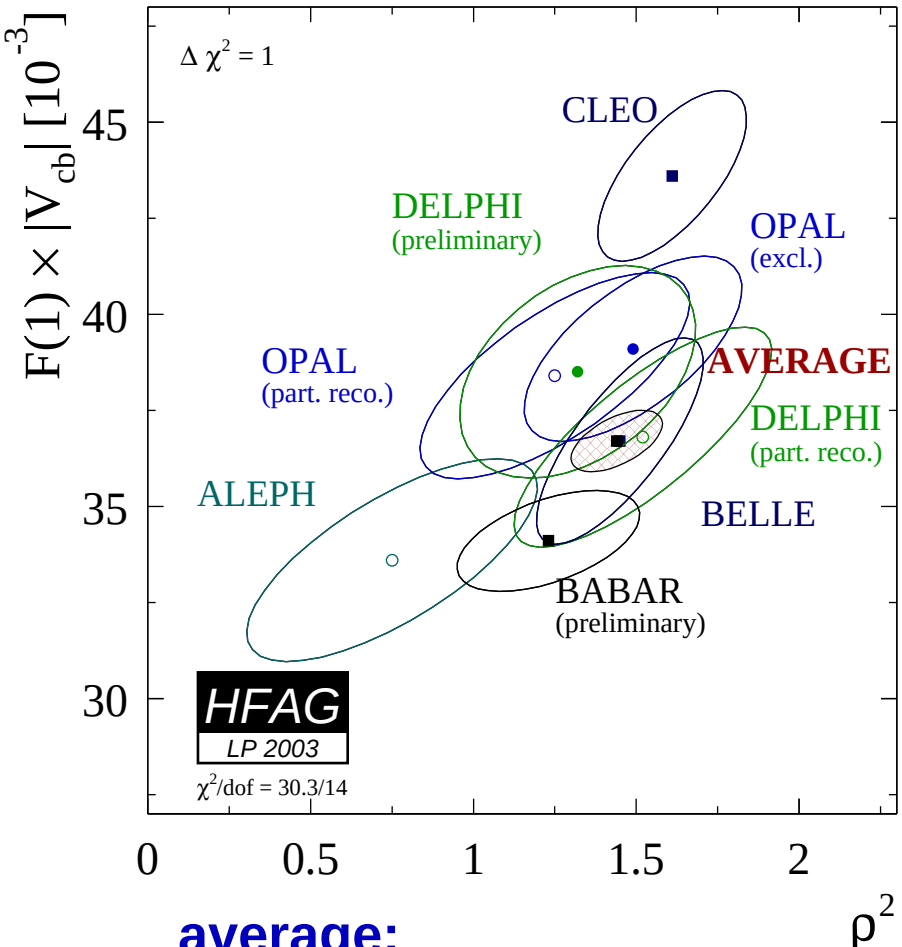
DELPHI 3.4 M Z preliminary



$$|V_{cb}| F(1) = (39.2 \pm 1.8 \pm 2.2) \times 10^{-3}$$
$$\rho_{A1}^2 = 1.32 \pm 0.15 \pm 0.33$$

|Vcb| exclusive analysis: Summary

B→D*lν (includes BaBar & DELPHI)



average:

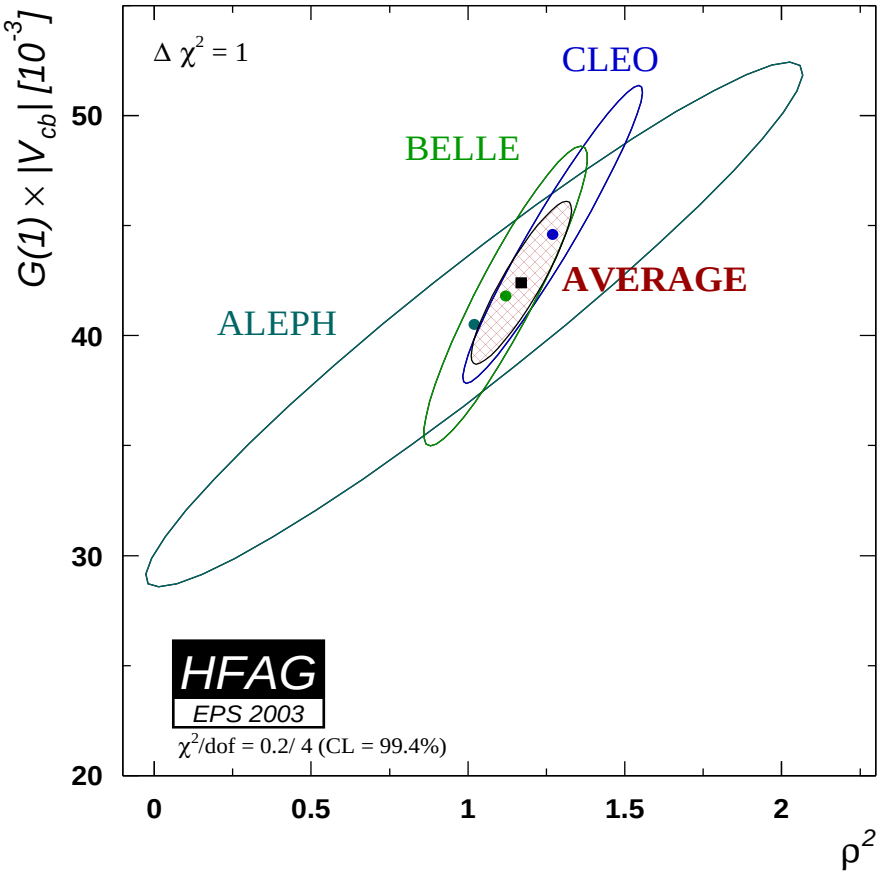
$$|V_{cb}|F(1) = (36.7 \pm 0.8) \times 10^{-3}$$

Using:

$$F(1) = 0.91 \pm 0.04$$

$$|V_{cb}| = (40.2 \pm 0.9 \pm 1.8) \times 10^{-3}$$

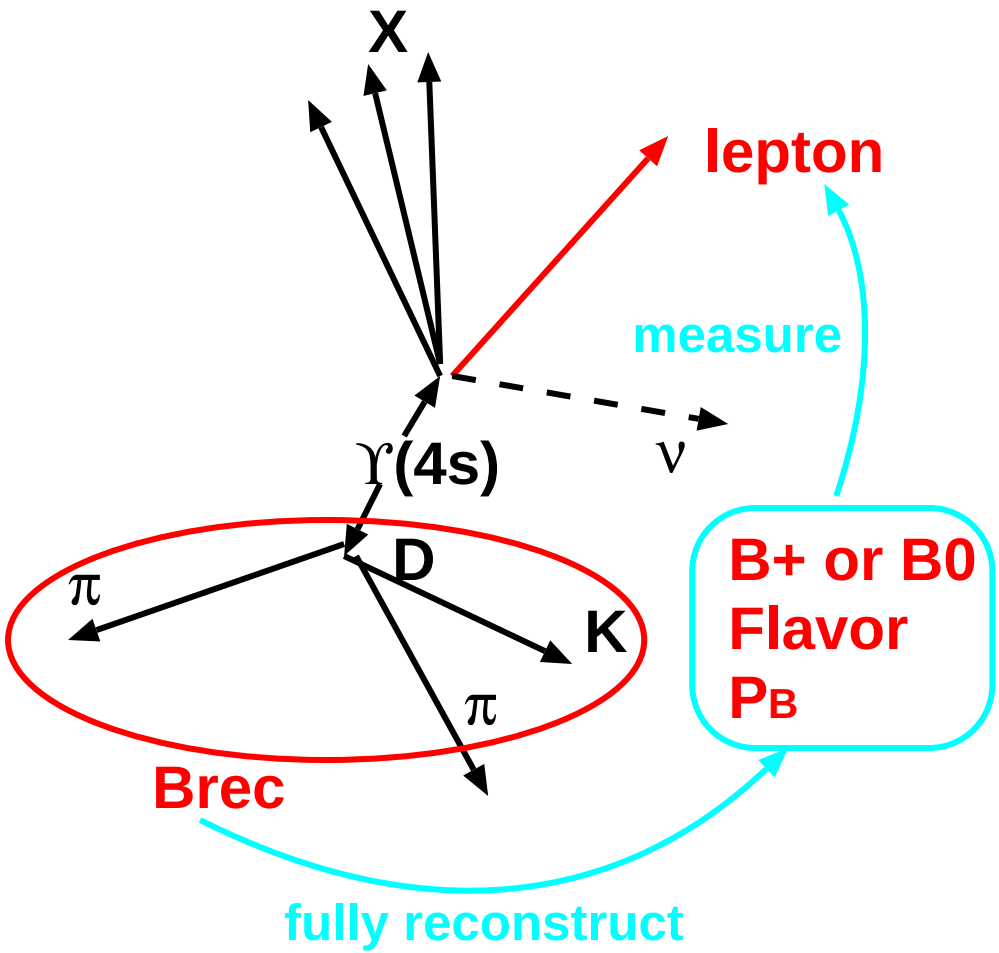
B→D lν(no updates since 2002)

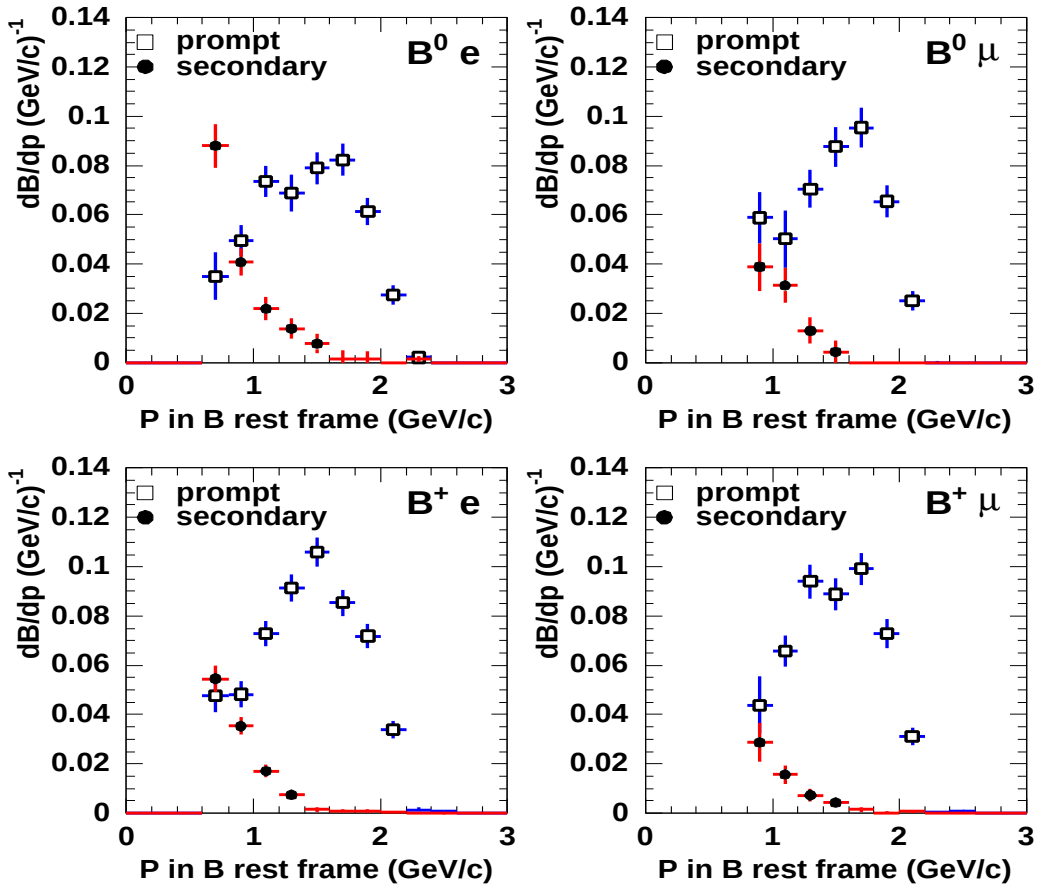


$$|V_{cb}|G(1) = (42.1 \pm 3.7) \times 10^{-3}$$

|Vcb| inclusive analysis: Lepton momentum spectrum

Lepton spectrum with full reconstruction tag (Belle 78/fb preliminary)





$$\mathcal{B}(B^0 \to X\ell\nu) = 10.32 \pm 0.32 \pm 0.29\%$$

$$\mathcal{B}(B^+ \to X\ell\nu) = 11.92 \pm 0.26 \pm 0.32\%$$

$$\mathcal{B}(B \to X\ell\nu) = 11.19 \pm 0.20 \pm 0.31\%$$

|Vcb| inclusive analysis: moment analyses

Extraction of |Vcb| → HQET/OPE framework

$$\frac{d\Gamma}{dE_l dm_X^2 dq^2} = f(E_l, m_X, q^2, |V_{cb}|, \bar{\Lambda}, \lambda_1, \ldots)$$

$\bar{\Lambda}$, λ1, ...: nonpurturbative quantities

Moments:

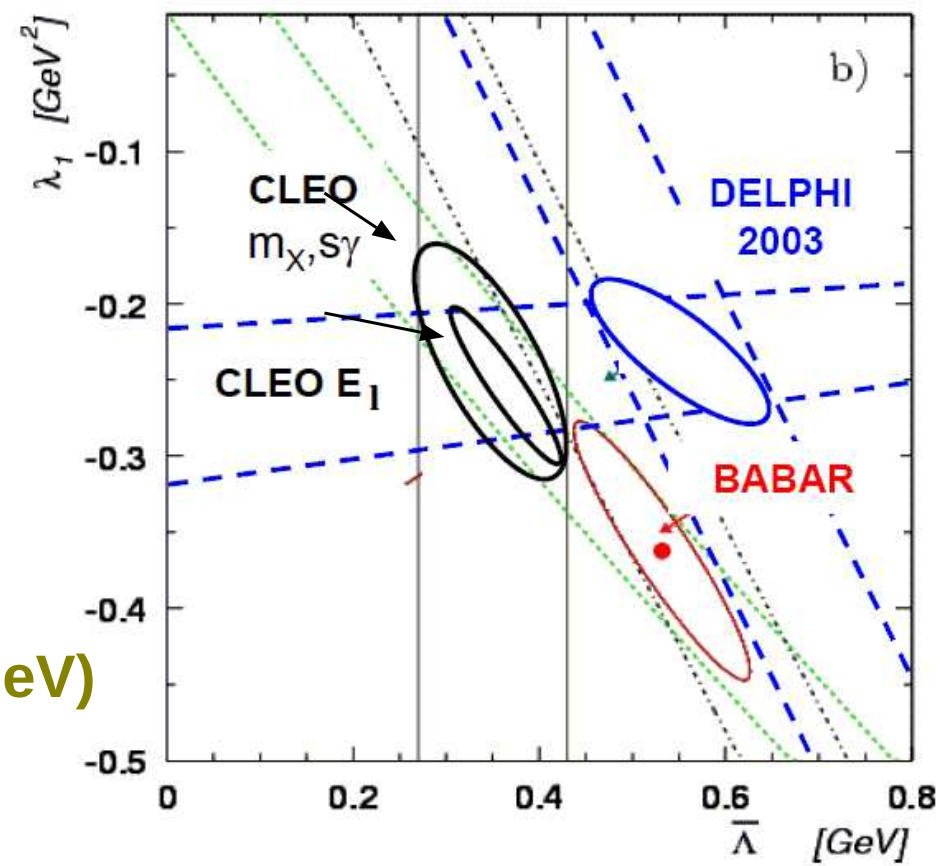
$$M_{000} = \int\int\int f dE_l dm_X^2 dq^2, \quad M_{n00} = \int\int\int E_l^n f dE_l dm_X^2 dq^2, \quad M_{0n0} = \int\int\int m_X^{2n} f dE_l dm_X^2 dq^2$$

- constrain $\bar{\Lambda}$, λ1 by measureing various moments: e.g. $\langle E_l \rangle = M_{100}/M_{000}$...
  → reduce the theoretical uncertainty in |Vcb|, |Vub|

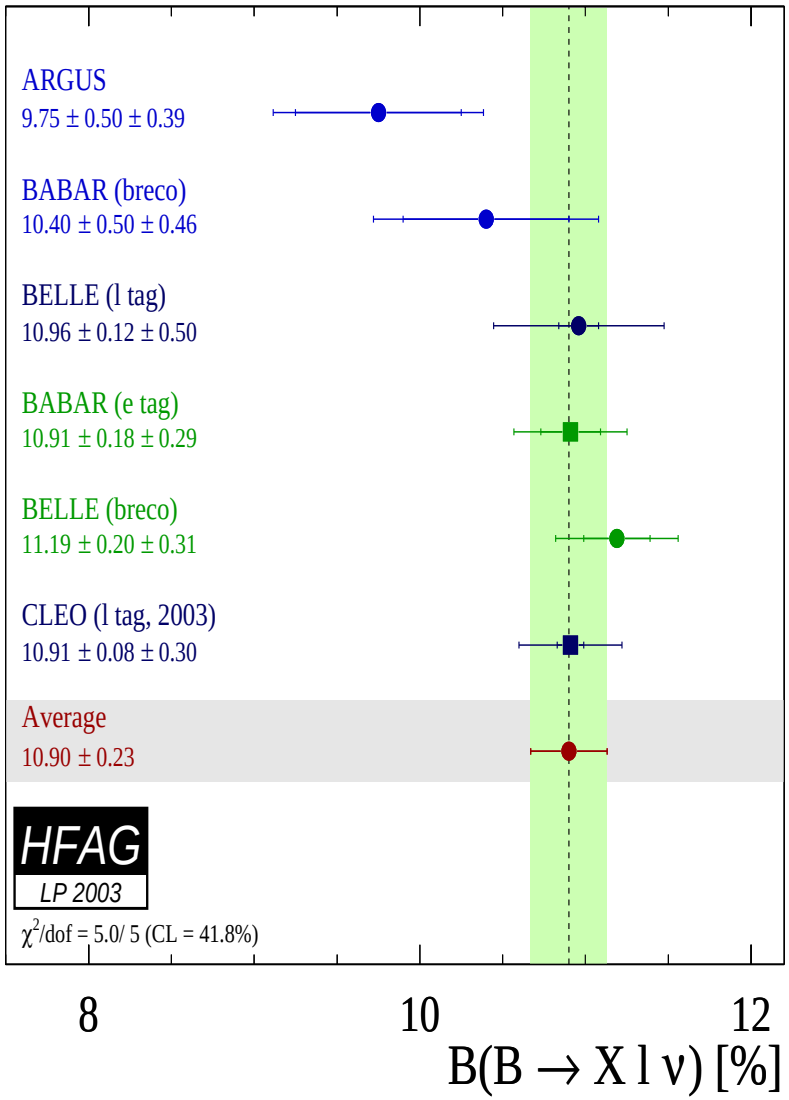
DELPHI 2002,2003:
Mi00, M0i0 (i=1,2,3)

BaBar 2003:
M100 with El>0.9, ...,1.6GeV

CLEO 2001,2003:
M010 & Eγ moment in b→sγ
M100 & M000(El>1.5GeV) / M000(El>1.7GeV)



|Vcb| inclusive analysis: summary



Br(B→Xlν) = 10.90 ± 0.23 %

Substantial efforts on reducing the theoretical uncertainty
i.e. extraction of $\overline{\Lambda}$ & λ_1
← moment analyses

For averaging of the |Vcb|, need:
1. averaged value of $\overline{\Lambda}$ and λ_1 or
2. simultanious extraction of $\overline{\Lambda}$, λ_1 and |Vcb|

|Vub| measurements

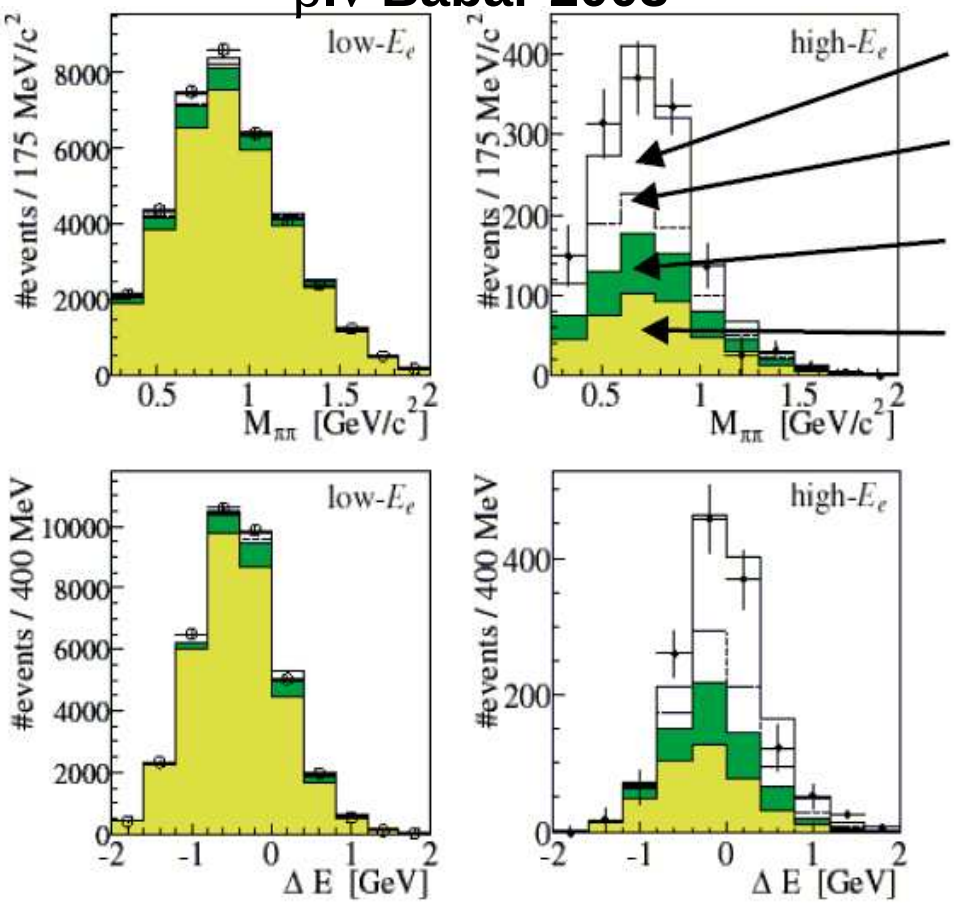
1. Exclusive analyses

2. Inclusive analyses

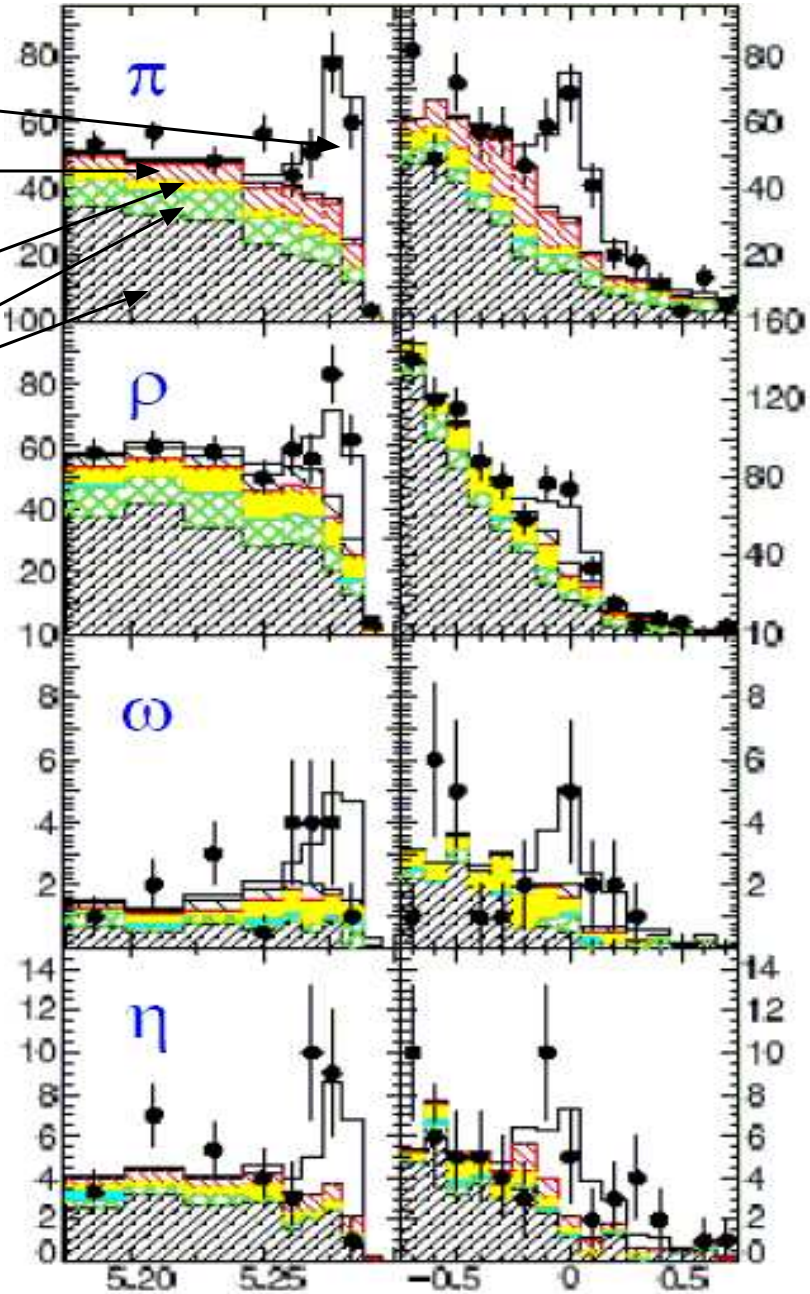
|Vub| exclusive analyses

Measure ΔE, m_{bc} with neutrino reconstruction

ρlν Babar 2003



CLEO 2003



CLEO $\pi\ell\nu + \rho\ell\nu$:

$$|V_{ub}| = (3.17 \pm 0.17^{+0.16+0.53}_{-0.17-0.39}) \times 10^{-3}$$

BaBar $\rho\ell\nu$:

$$|V_{ub}| = (3.64 \pm 0.22 \pm 0.25^{+0.39}_{-0.56}) \times 10^{-3}$$

|Vub| inclusive analysis: Introduction

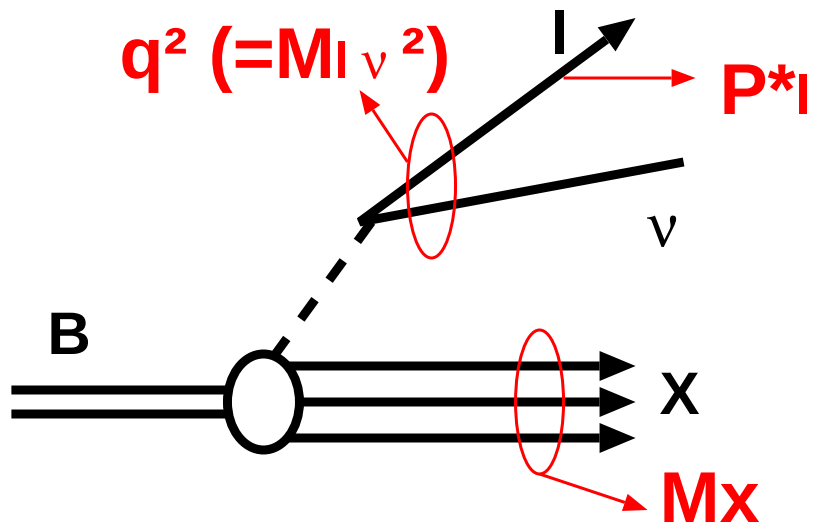
Inclusive Xulnu mesurement:

→ suffer from large Xc lnu background

→ measure the rate in limited kenematical region

Use three kinematical valiables:

	P^*_l	Mx	q^2
experimental accesibility	✓	X	X
frac. beyond Xclν limit	10%	70%	20%

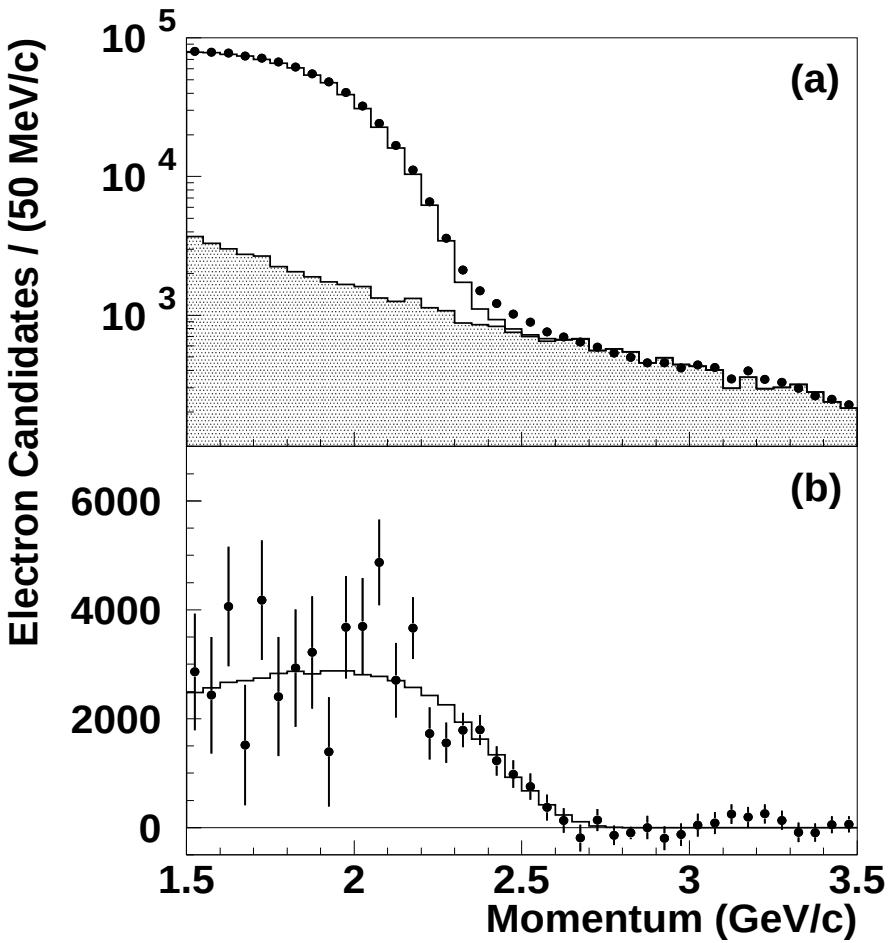


Two types of analysis

1. **P^*_l endpoint analysis**
2. **Mx, q^2 measurement**

|Vub| inclusive analysis: p*l endpoint analysis

p*l spectrum Belle 29/fb preliminaly



Measure partial Br. around lepton momentum endpoint:

$\Delta Br(B \to X_u l \nu;\ 2.3 < p_e < 2.6 GeV) = (1.18 \pm 0.11 \pm 0.10)\ 10^{-4}$

Extrapolation factor w/ CLEO's $b \to s\gamma$ measurement ← reduce the theoretical uncertainty

$fu(\Delta p) = 0.130 \pm 0.024 \pm 0.015$

$Br(B \to X_u l \nu) = \Delta Br / fu(\Delta p) = (1.60 \pm 0.15 \pm 0.14 \pm 0.44)\ 10^{-3}$

$$|V_{ub}| = (3.96 \pm 0.18 \pm 0.17 \pm 0.55 \pm 0.22) \times 10^{-3}$$

stat syst fu $\Gamma \to$ Vub

|Vub| inclusive analysis: Mx, q² measurement

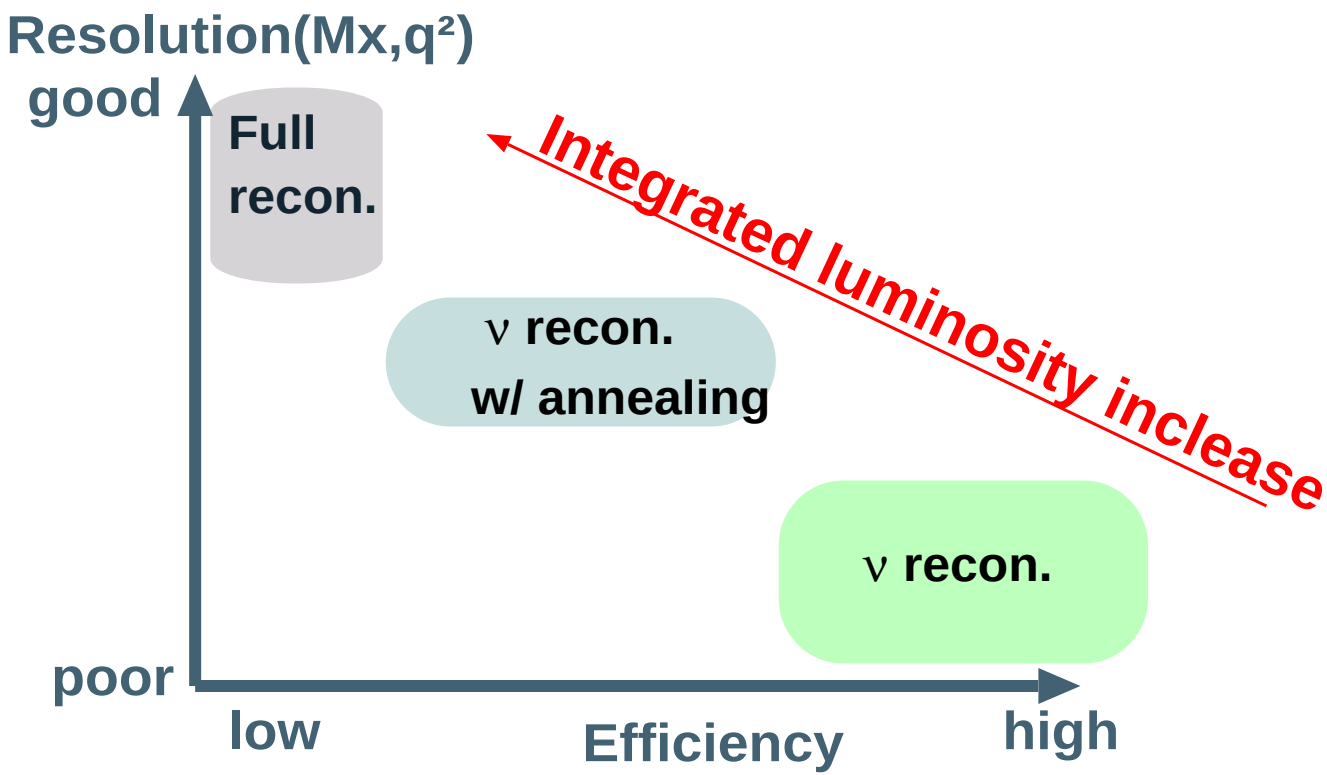
Measureing Mx: good separation from Xclν can be achieved

Using Mx&q² cuts: theoretical uncertainty can be much reduced

← avoid the region where the OPE breaks down

Mx, q² measurements:

have different strategies according to the amount of Luminosity



|Vub| inclusive analysis: Mx,q² from neutrino recon.

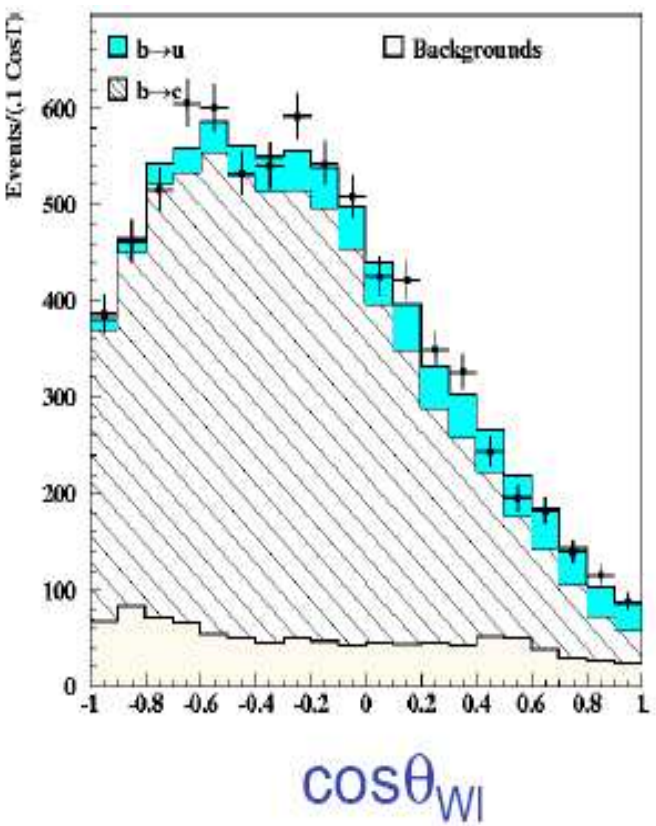
CLEO 9.4/fb preliminary

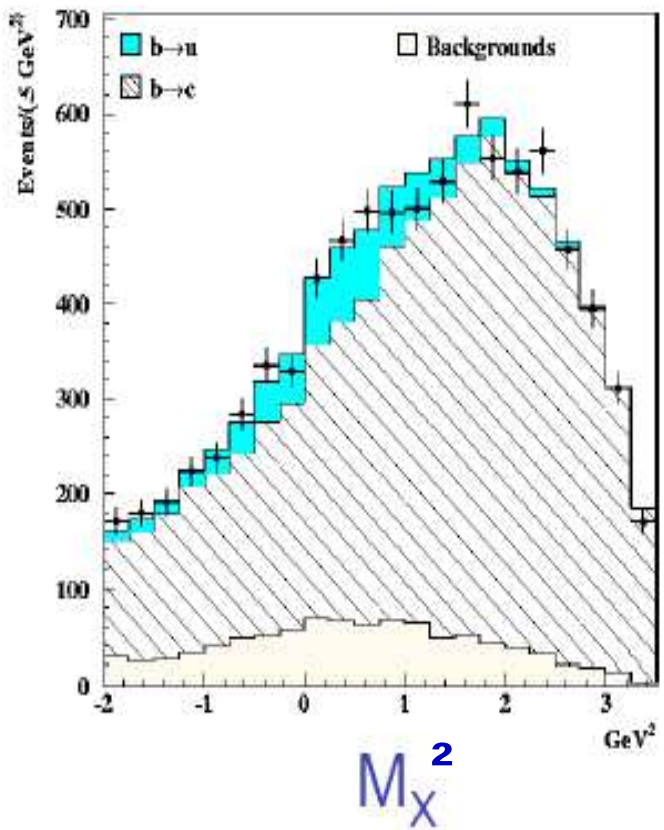
Neutrino reconstruction:

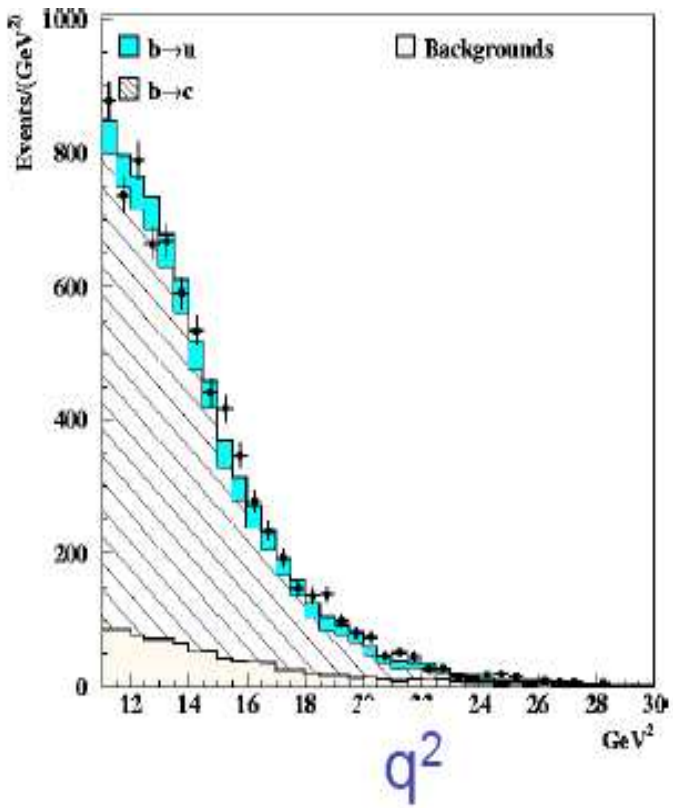
$p_\nu = p_{beam} - p_{vis.}$, $E_\nu = E_{beam} - E_{vis.}$ $\quad \Delta p_\nu \sim 120$MeV

$\rightarrow \quad q^2 = (E_l + E_\nu)^2 - |\, p_l + p_\nu \,|^2$

$M_X^2 \sim M_B^2 + q^2 - 2 E_{beam} (E_l + E_\nu) + 2|p_B||p_{l\nu}| \cos\theta_{B,l\nu}$







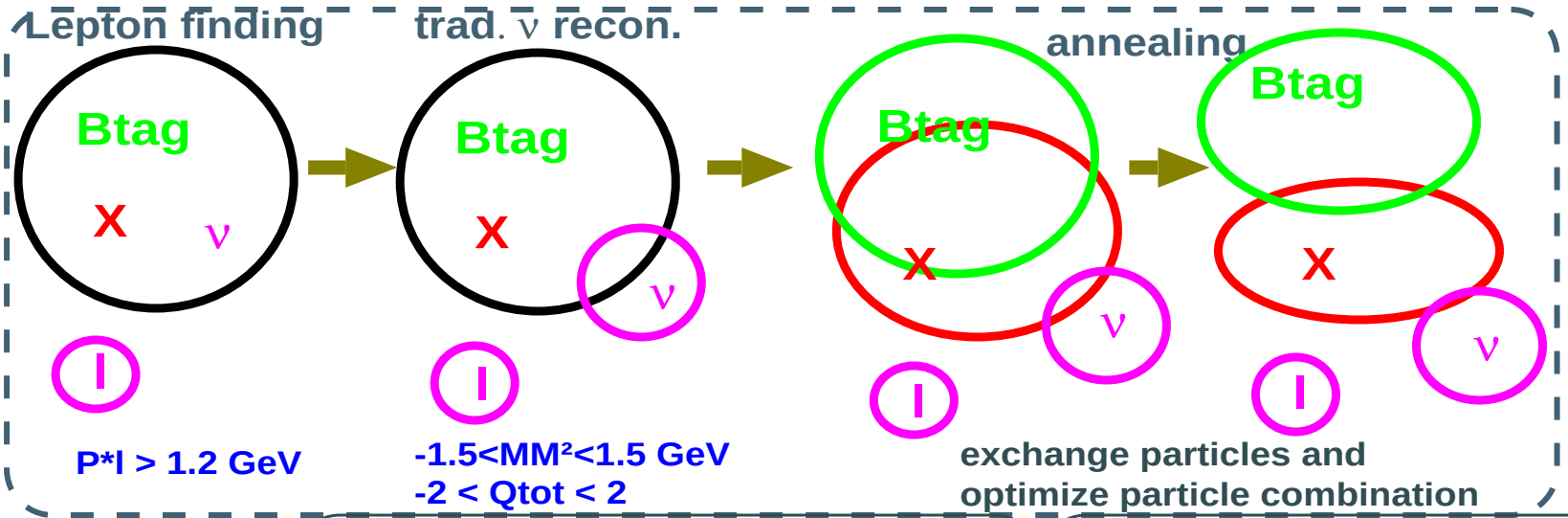
Use: $q^2 > 11$ GeV², $M_X < 1.5$GeV

$$|V_{ub}| = (4.05 \pm 0.18 \pm 0.58 \pm 0.25 \pm 0.21 \pm 0.56) \times 10^{-3}$$

stat syst b→c b→u theory

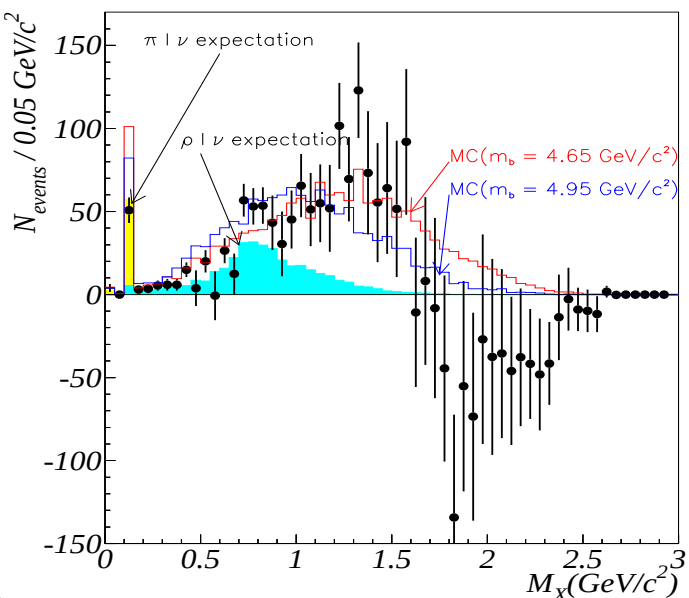
|Vub| inclusive analysis: Mx,q² from ν recon. w/ annealing

Belle 78/fb preliminary

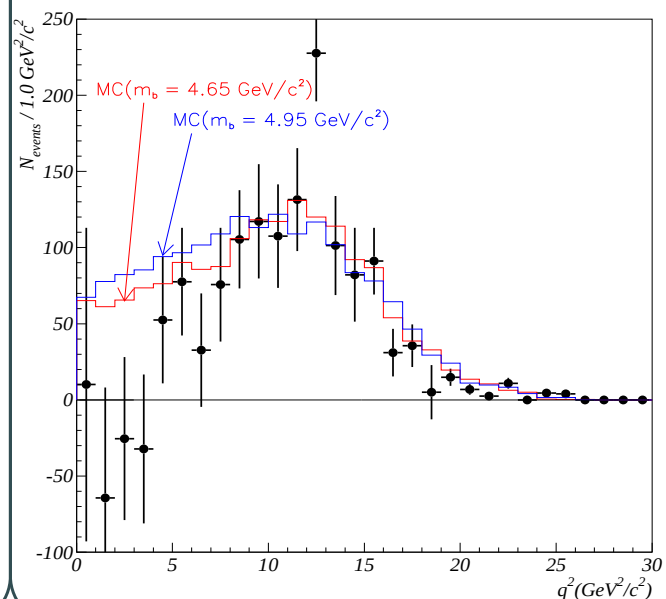


Combinned cuts on Mx & q²:
Mx < 1.5GeV
q² > 7 GeV²

Mx for q² > 7GeV



q² for Mx < 1.5GeV



$$|V_{ub}| = (3.96 \pm 0.17 \pm 0.44 \pm 0.34 \pm 0.26 \pm 0.29) \times 10^{-3}$$

stat syst b→c shape Γ→|Vub|

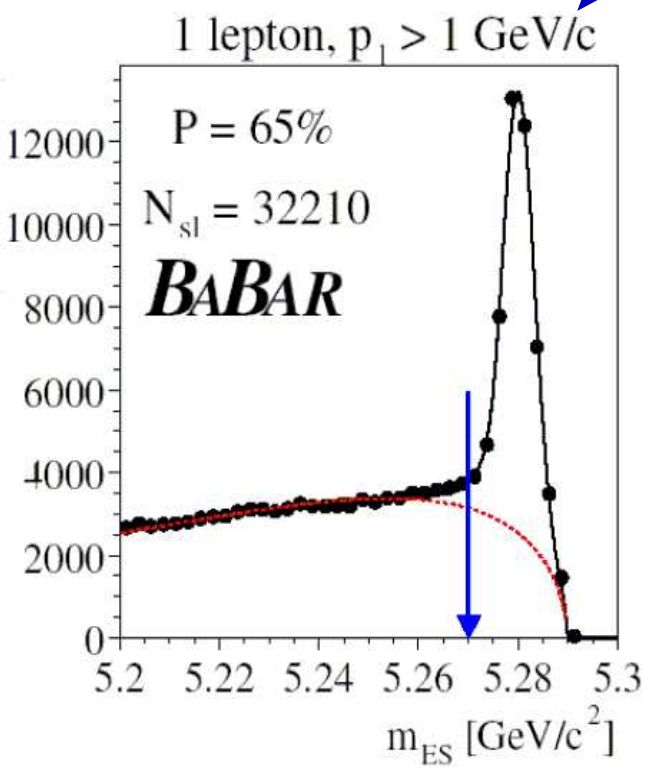
|Vub| inclusive analysis: Mx from full recon.

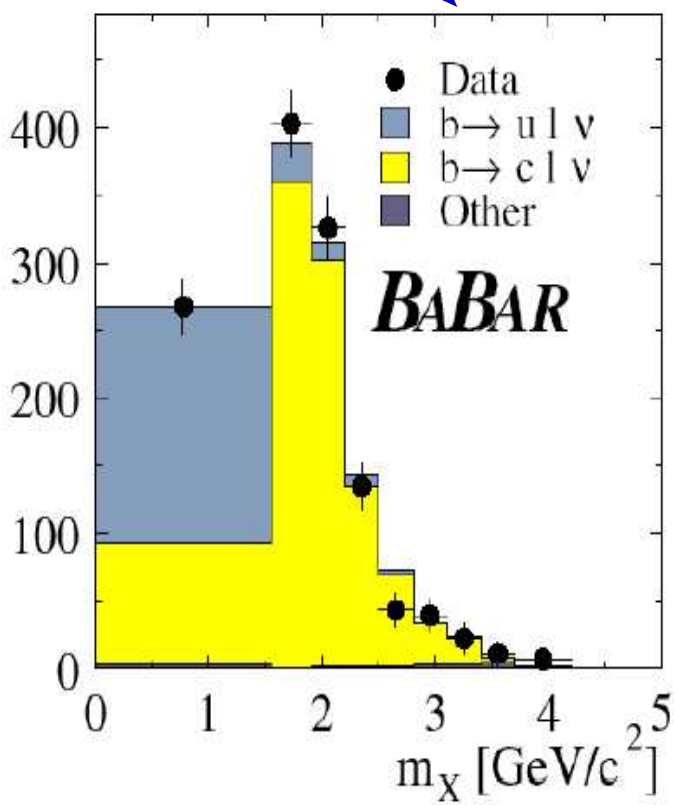
Babar 89M Υ(4S)

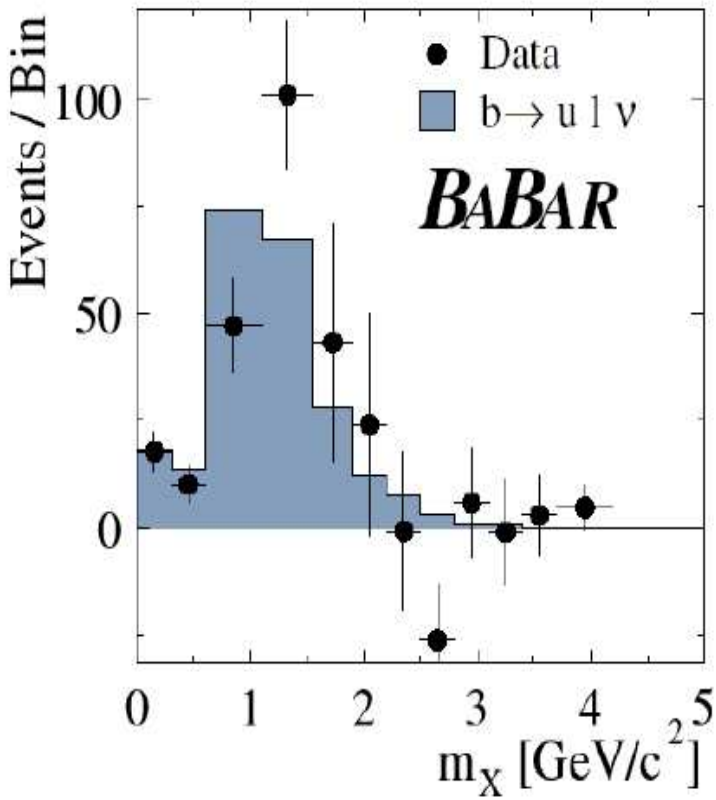
Υ(4S)$\rightarrow$ Breco Bsig

Fully reconstruct

Reconstruct Mx in Xlν





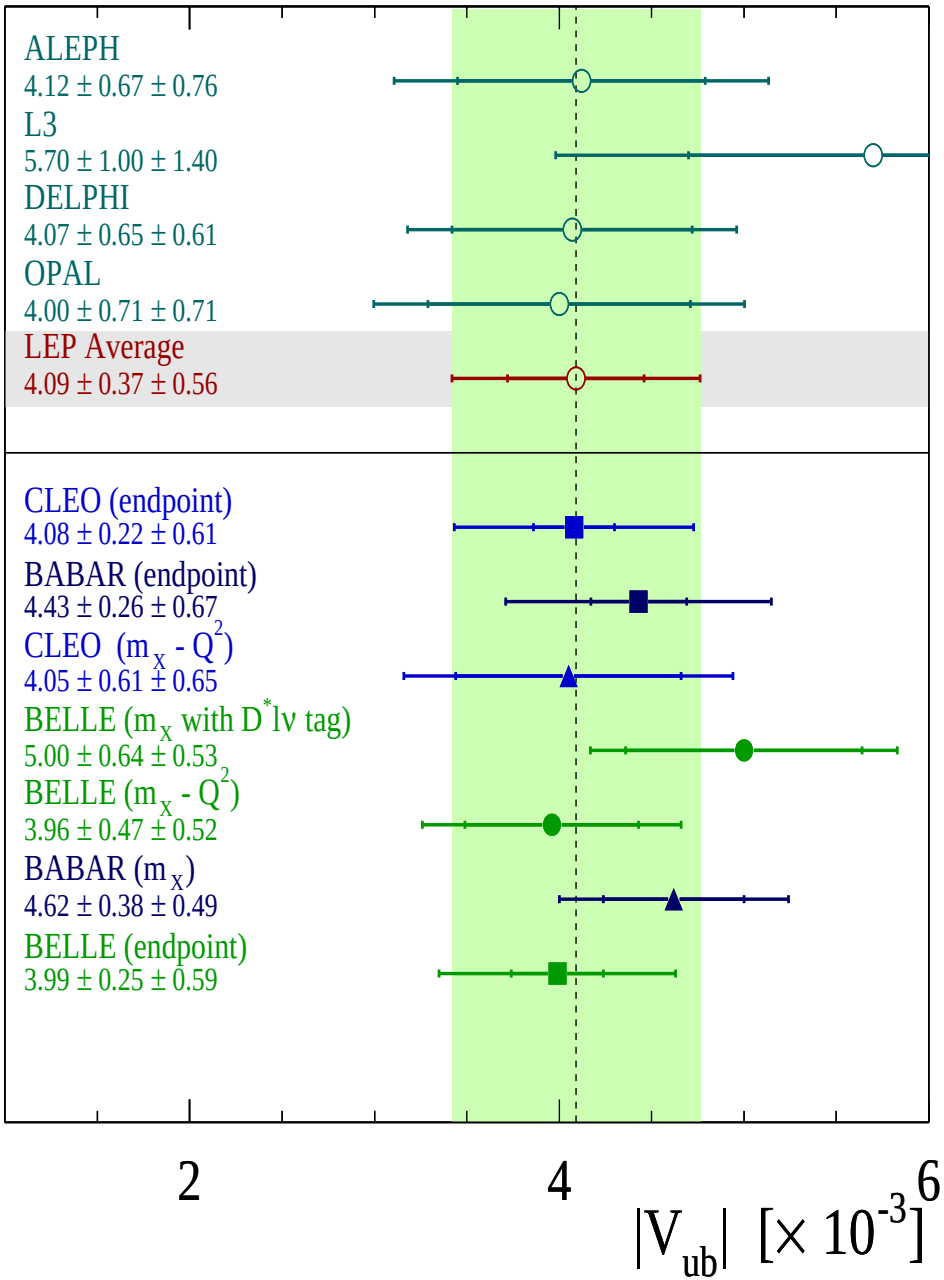


Use Mx < 1.55 GeV region

With $\overline{\Lambda}$ = 0.48 ± 0.12 GeV, λ_1 = -0.30 ± 0.11 GeV:

$$|V_{ub}| = (4.62 \pm 0.28_{\text{stat}} \pm 0.27_{\text{syst}} \pm 0.40_{\text{shape}} \pm 0.26_{\Gamma\rightarrow Vub}) \times 10^{-3}$$

|Vub| inclusive measurements summary



What about averaged value of |Vub|?

Evaluation of uncertainty with same theory error is necessary

↓

Updated Belle's ν recon with annealing with same $\overline{\Lambda}$ error as BaBar

→ go out soon

Summary

- Extensive studies for |Vcb|, |Vub| measurements are carrying on

|Vcb| & |Vub| values:
→ theoretical uncertainty limit its precision
→ moment analyses are of great impotance
for reducing the theoretical uncertainty

Belle & BaBar are accumulating > 100/fb
Large number of fully reconstructed B samples are available
→ much reduce the experimental systematics of various inclusive analyses

⟶ |Vub|, |Vcb| are kept updating to be a good constraint on the unitarity triangle

- |Vub| averaging among the various mesurements are needed!
Belle will provide updated results of ν recon. with annealing with Δmb=0.12GeV (compatible to BaBar's)
→ first step for the |Vub| averaging

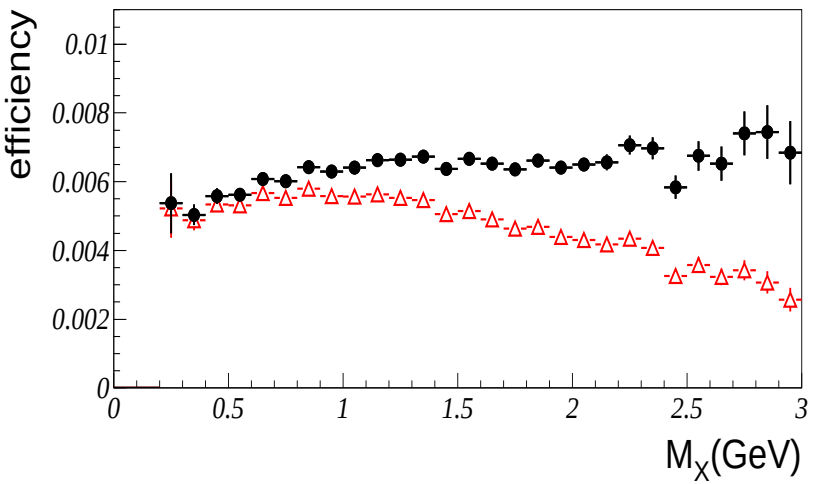
More details of |Vcb|, |Vub|, moment analyses will be discussed at morning sessions on Thursday

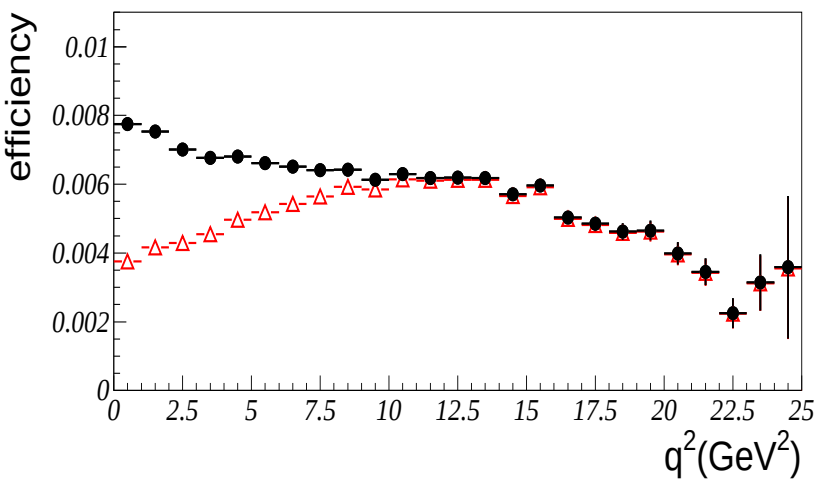
Backup slides

|Vub| inclusive analysis: Neutrino reconstruction w/ annealing

Qualities of reconstruction

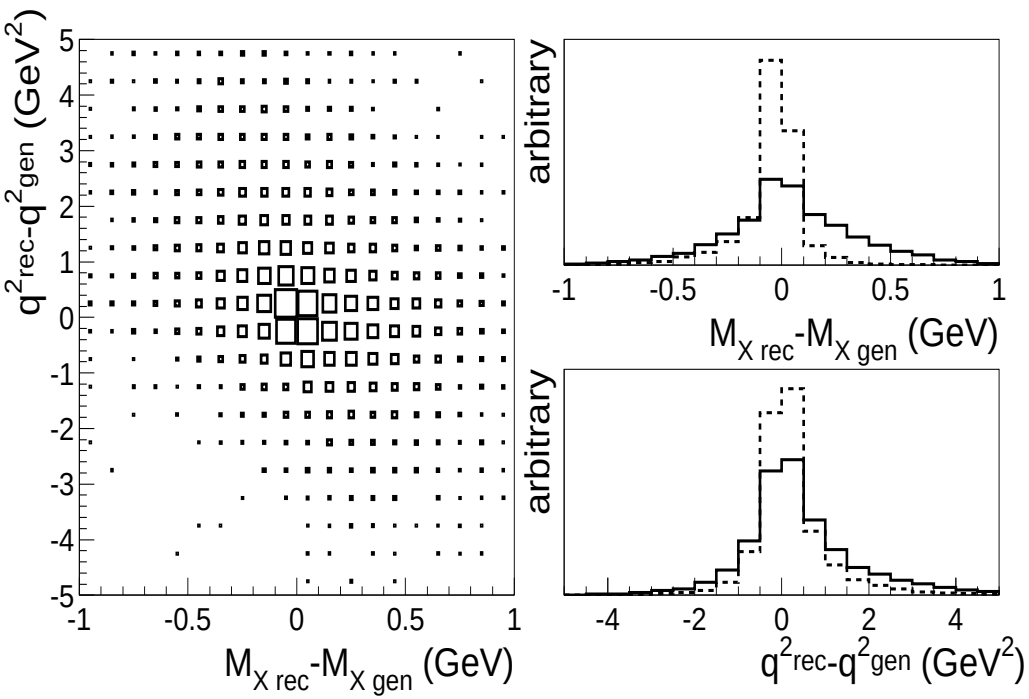
Mx, q² dependence of efficiency





closed circle: efficiency against P*l>1.2GeV
open triangle: efficiency against the whole events

Mx and q² resolution



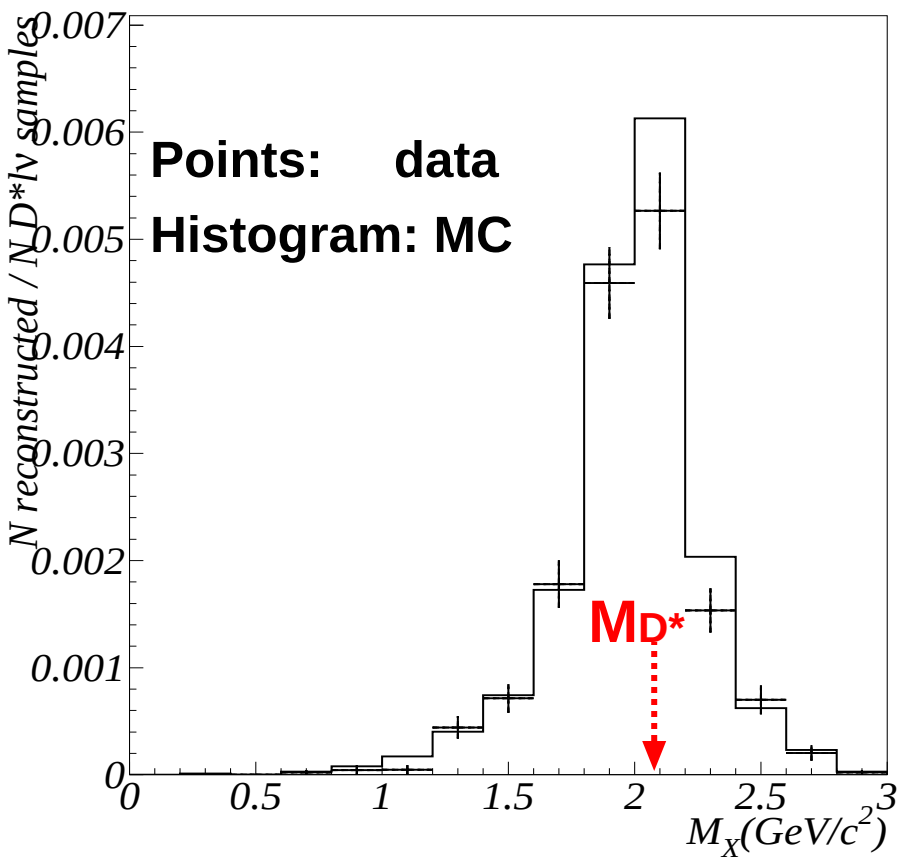
dashed histogram : resolutions by perfect identification of Xu and Btag
closed histo.& 2dim. hist.: resolutions by annealing

|Vub| inclusive analysis: Neutrino reconstruction w/ annealing

control samples

B→D*lν samples

Mx distribution

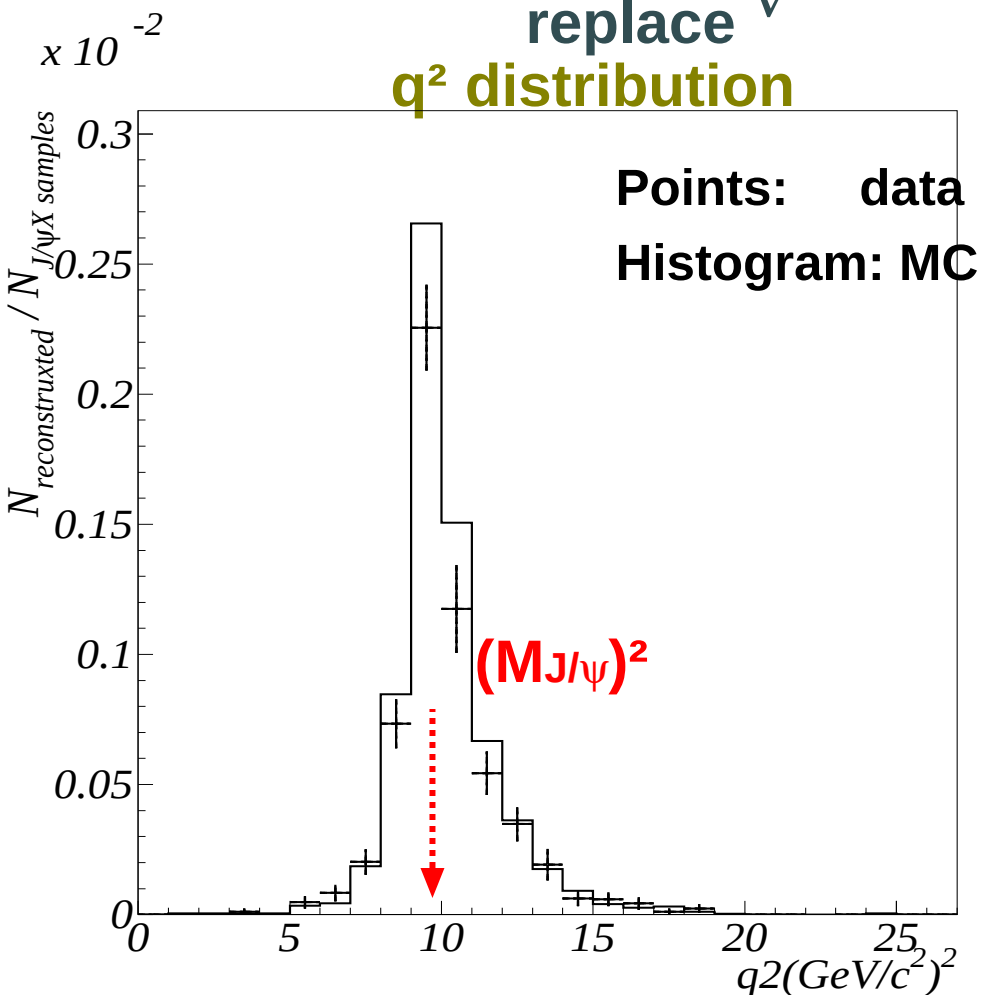


	mean (GeV/c²)	RMS(GeV/c²)
data	1.98	0.29
MC	1.99	0.30

B→J/ψ(J/ψ→ l l) X samples

replace ν

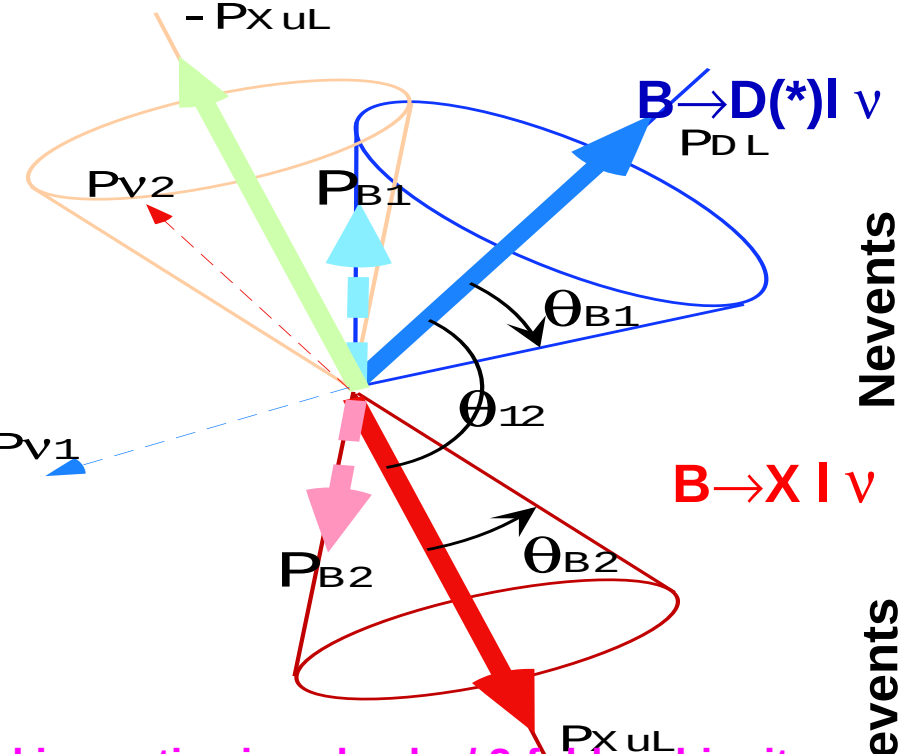
q² distribution



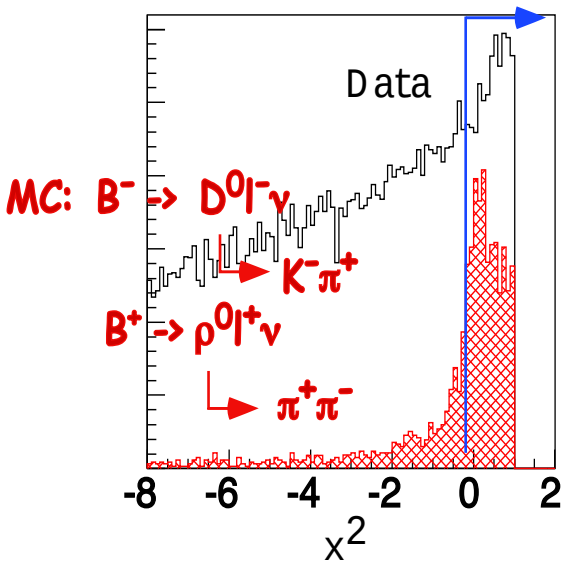
	mean (GeV²/c²)	RMS(GeV²/c²)
data	10.2	1.9
MC	10.2	1.8

|Vub| inclusive analysis: Mx from D(*) l ν tag

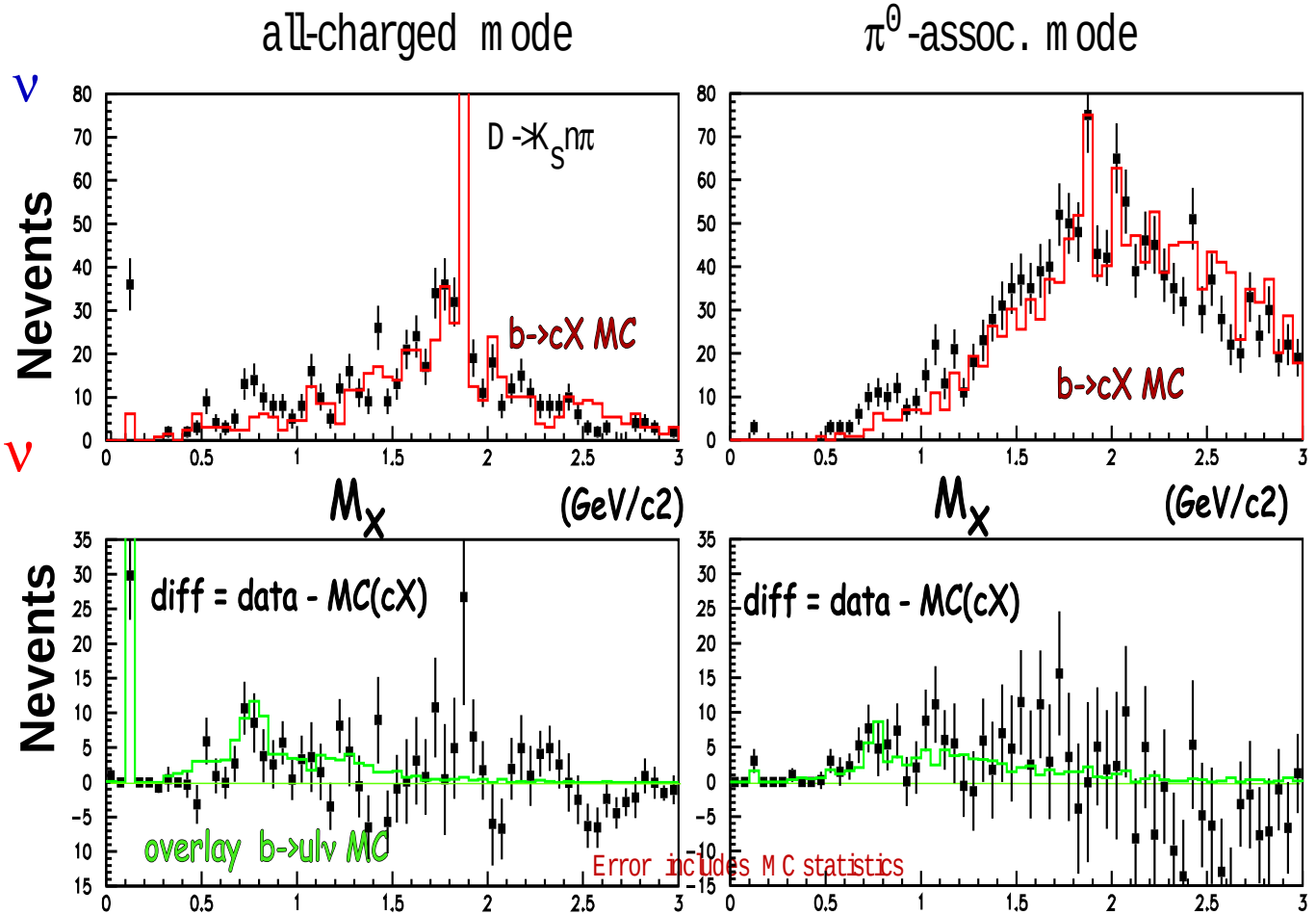
Direction of B-mesons



kinematics is solved w/ 2-fold ambiguity



Belle 78/fb preliminary



82 ± 19 events in Mx < 1.5 GeV

92 ± 21 events in Mx < 1.5 GeV

$$|V_{ub}| = (5.00 \pm 0.60_{\text{stat}} \pm 0.23_{\text{syst}} \pm 0.05_{\text{b}\to\text{c}} \pm 0.39_{\text{b}\to\text{u}} \pm 0.36_{\text{theory}}) \times 10^{-3}$$