SemiLeptonic B decays at the B factories

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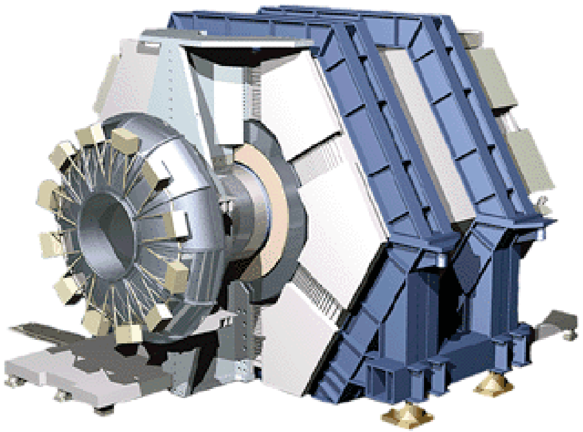
on behalf of the BaBar and Belle Collaborations

XLII Rencontres de Moriond, 10-17th March 2007, La Thuile, Italy



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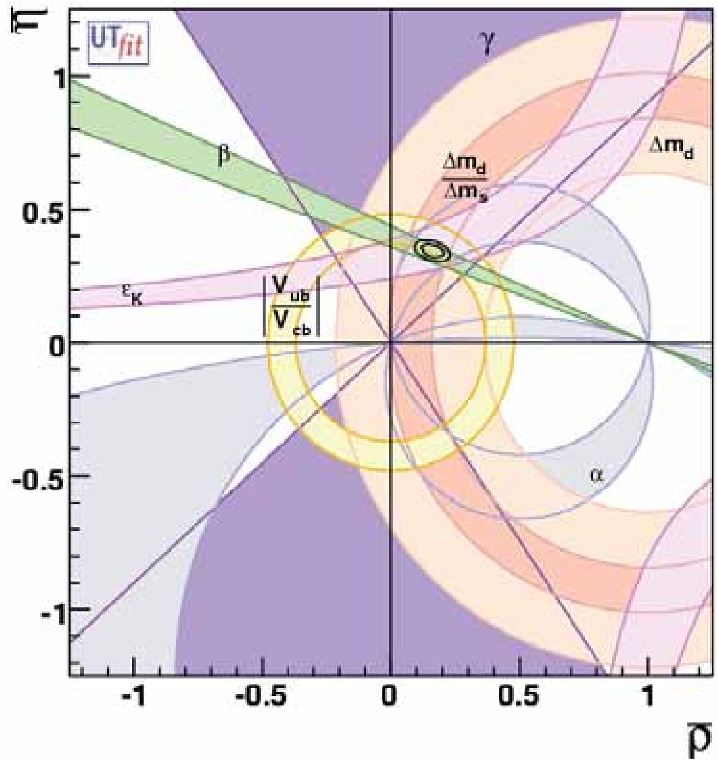
Why SemiLeptonic decays?

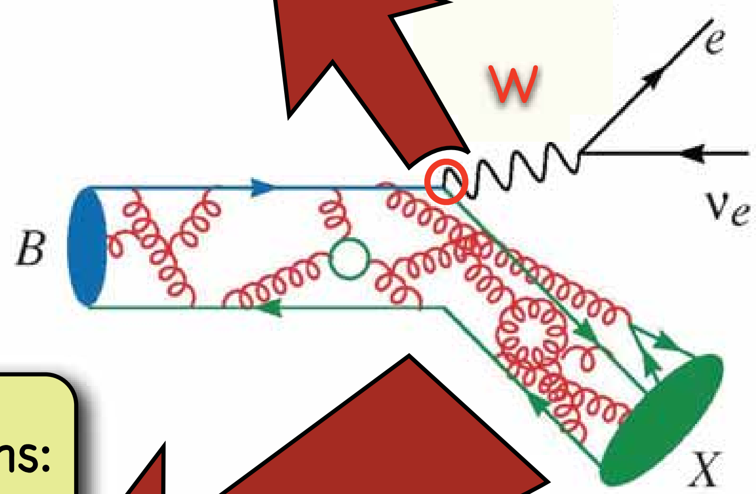
Tree level decays where we can disentangle leptonic and hadronic currents - many theoretical developments in recent years



Sensitive to quark couplings to W

⇨ decay rate depends on $|V_{ub}|$ and $|V_{cb}|$

⇨ check SM predictions

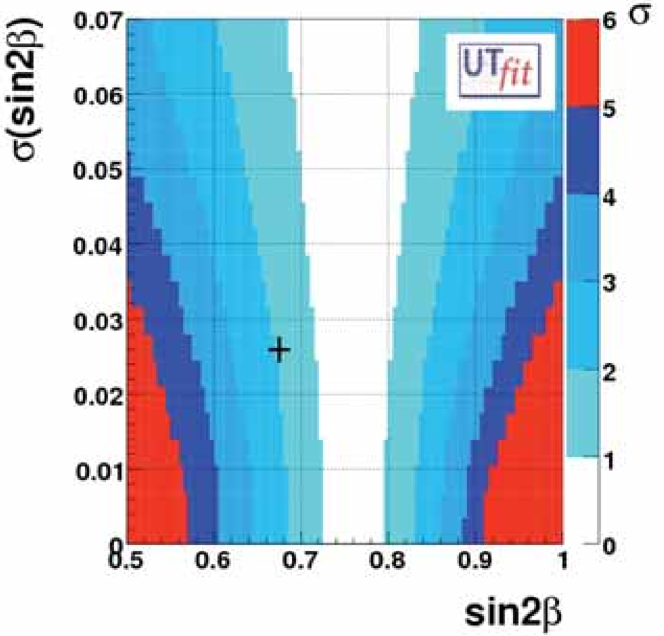


Good tool to probe the structure of B mesons:

⇨ inclusive decays: OPE, b & c quark mass

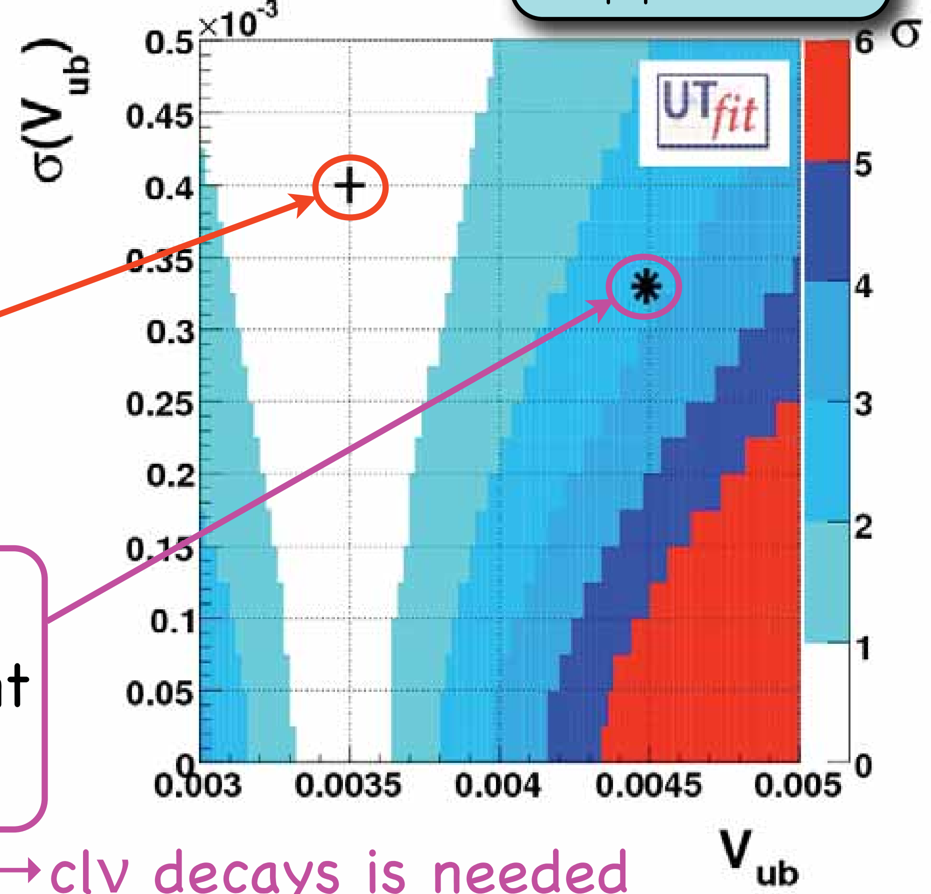
⇨ exclusive decays: form factors

The |V$_{ub}$| puzzle



almost 2σ difference between direct measurement of sin2β (0.674±0.026) and the rest of the fit (0.755±0.040)

hep-ph/0606167

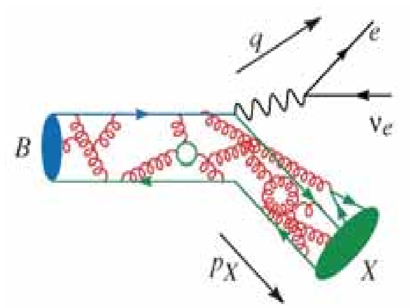


exclusive measurements (require knowledge of FFs from LQCD and QCDSR)

inclusive measurements (require knowledge of model-dependent non-perturbative parameters)

➠ better description of $b \to c l \nu$ decays is needed

HQE parameters determination



fit to hadronic mass moments in $B \to X_c l \nu$

fit to lepton energy moments in $B \to X_c l \nu$

$$\Gamma_{c\ell\nu} = \frac{G_F m_b^5}{192\pi^3} |V_{cb}|^2 (1 + A_{\rm ew}) A_{\rm pert} A_{\rm nonpert} \simeq |V_{cb}|^2 f_{\rm OPE}(m_b, m_c, a_i)$$

fit to photon energy moments in $B \to X_s \gamma$

Kinetic Scheme

P. Gambino and N.Uraltsev, Eur. Phys. J. C34, 181 (2004)

1S Scheme

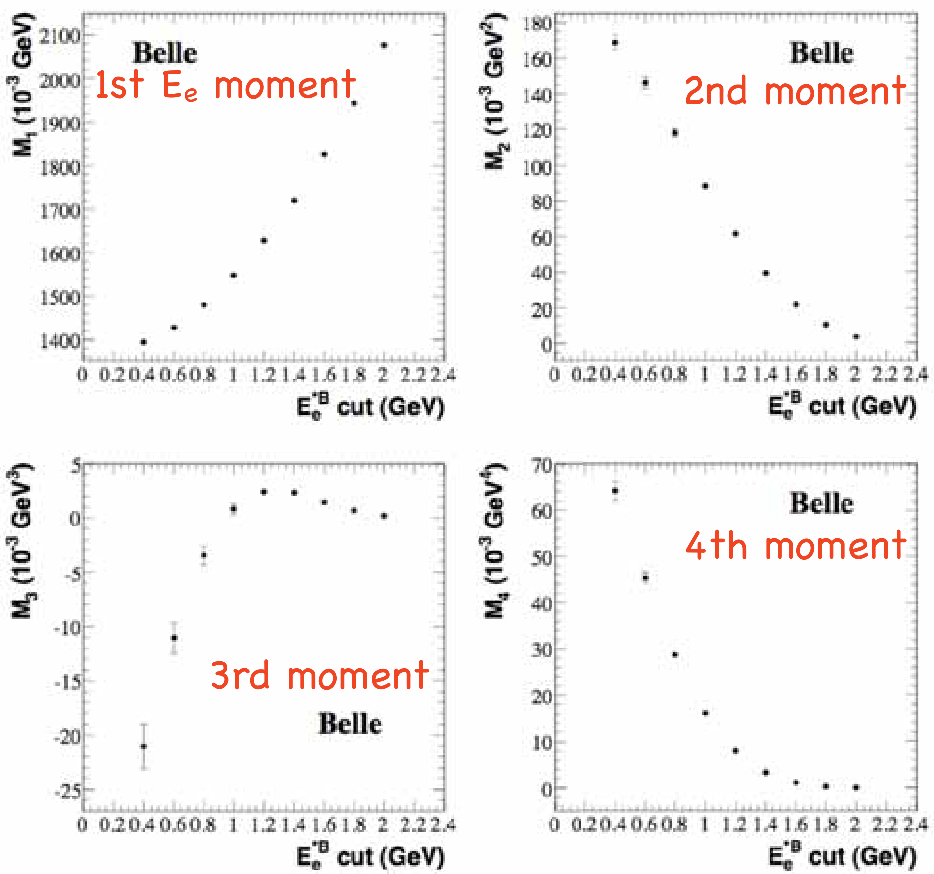
C.Bauer, Z.Ligeti, M.Luke, A.Manohar, M.Trott PRD 70 094017

E_e spectrum moments

Experimental results:

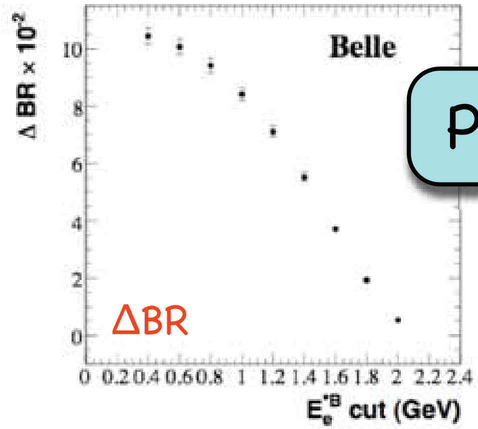
BaBar: Phys. Rev. D69 111104 (2004), CLEO: Phys. Rev. D70 032003 (2004), DELPHI: Eur. Phys. J. C45, 35 (2006)

Most recent: from Belle collaboration on 140 fb^{-1}



First four moments with threshold values for E_e from 0.4 to 2 GeV

(correlations between measurements are included)



PRD75 032001 (2007)

$BR(B^+)_{0.4GeV} = (10.79 \pm 0.25 \pm 0.27)\ 10^{-3}$

$BR(B^0)_{0.4GeV} = (10.08 \pm 0.30 \pm 0.22)\ 10^{-3}$

Hadronic mass spectrum moments

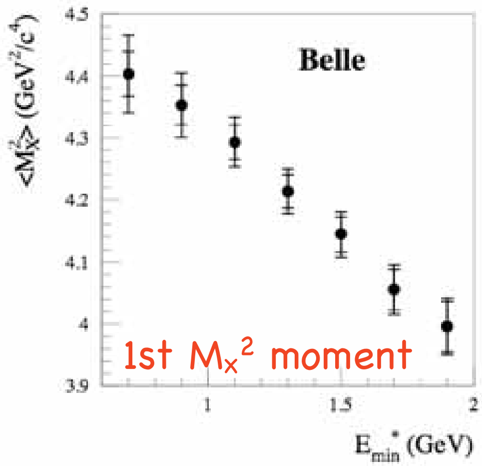
Experimental results:

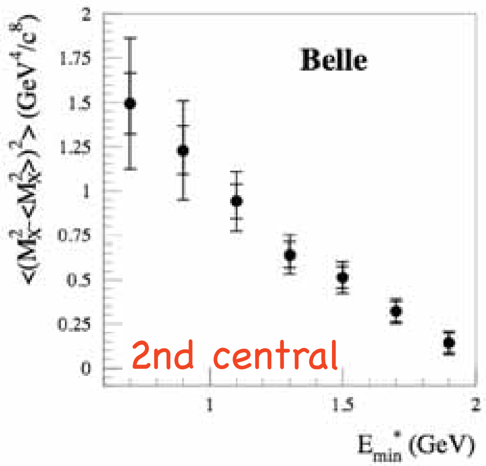
BaBar: Phys. Rev. D69 111103 (2004), CDF: Phys. Rev. D71 051103 (2005), CLEO: Phys. Rev. D70 032002 (2004), DELPHI: Eur. Phys. J. C45, 35 (2006)

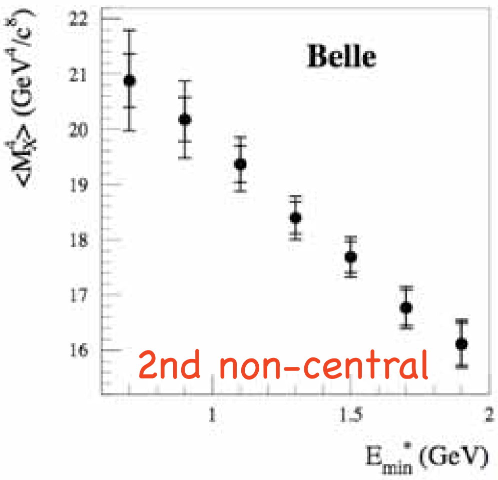
Most recent: from Belle collaboration on 140 fb^{-1}

PRD75 032005 (2007)

First, second central and second non-central moments with threshold values for E_e from 0.7 to 1.9 GeV
(correlations between measurements are included)







HQE parameters and $|V_{cb}|$: Kinetic Scheme

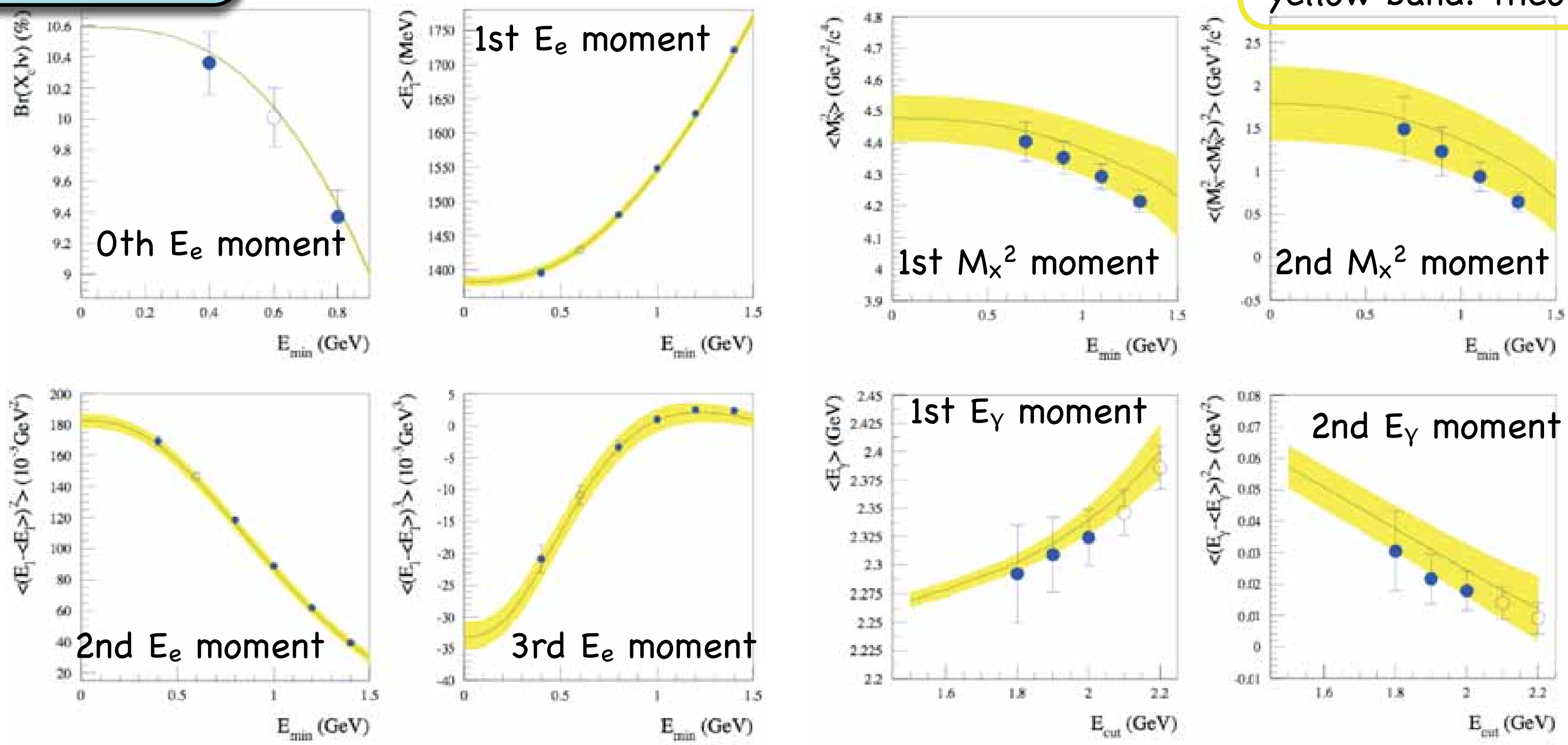
Spectral moments derived up to $O(1/m_b^3)$: determine 7 parameters

$BF(B \to X_c l \nu)$, m_b, m_c, μ_π^2, ρ_D^3, μ_G^2, ρ_{LS}^3

$|V_{cb}|$ treated as 8th free parameter, related to SL width

hep-ex/0611047

yellow band: theory error



Belle fit 71 of their measured moments (including $B \to X_s \gamma$, hep-ex/0508005) taking into account experimental and theoretical uncertainties

HQE parameters and $|V_{cb}|$: Kinetic Scheme

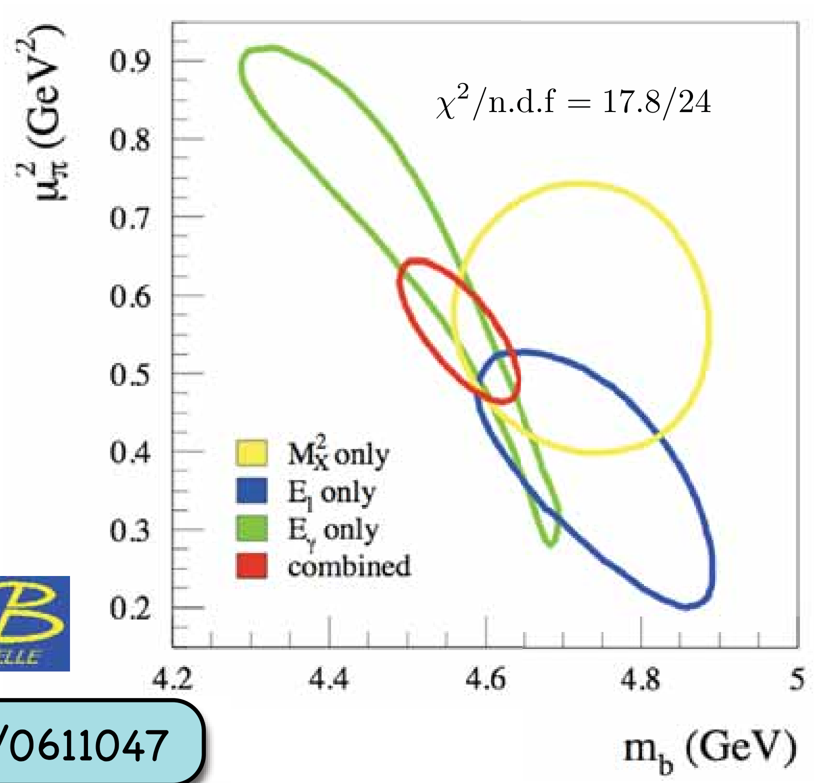
Results

$|V_{cb}| = (41.93 \pm 0.65_{fit} \pm 0.07_{\alpha s} \pm 0.63_{th})\ 10^{-3}$

$m_b = 4.564 \pm 0.076_{fit} \pm 0.003_{\alpha s}$ GeV

$m_c = 1.105 \pm 0.116_{fit} \pm 0.005_{\alpha s}$ GeV

$BR_{clv} = 10.590 \pm 0.164_{fit} \pm 0.006_{\alpha s}$ %



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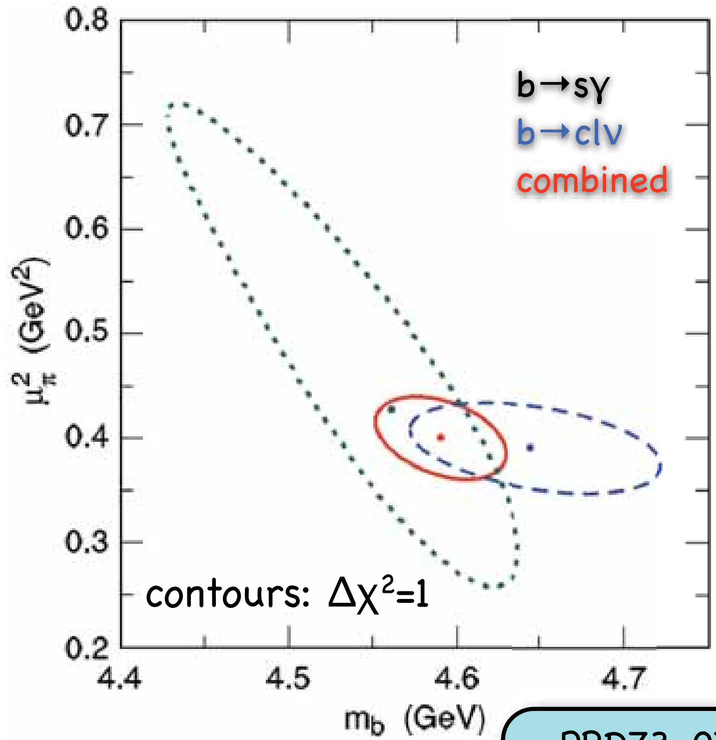


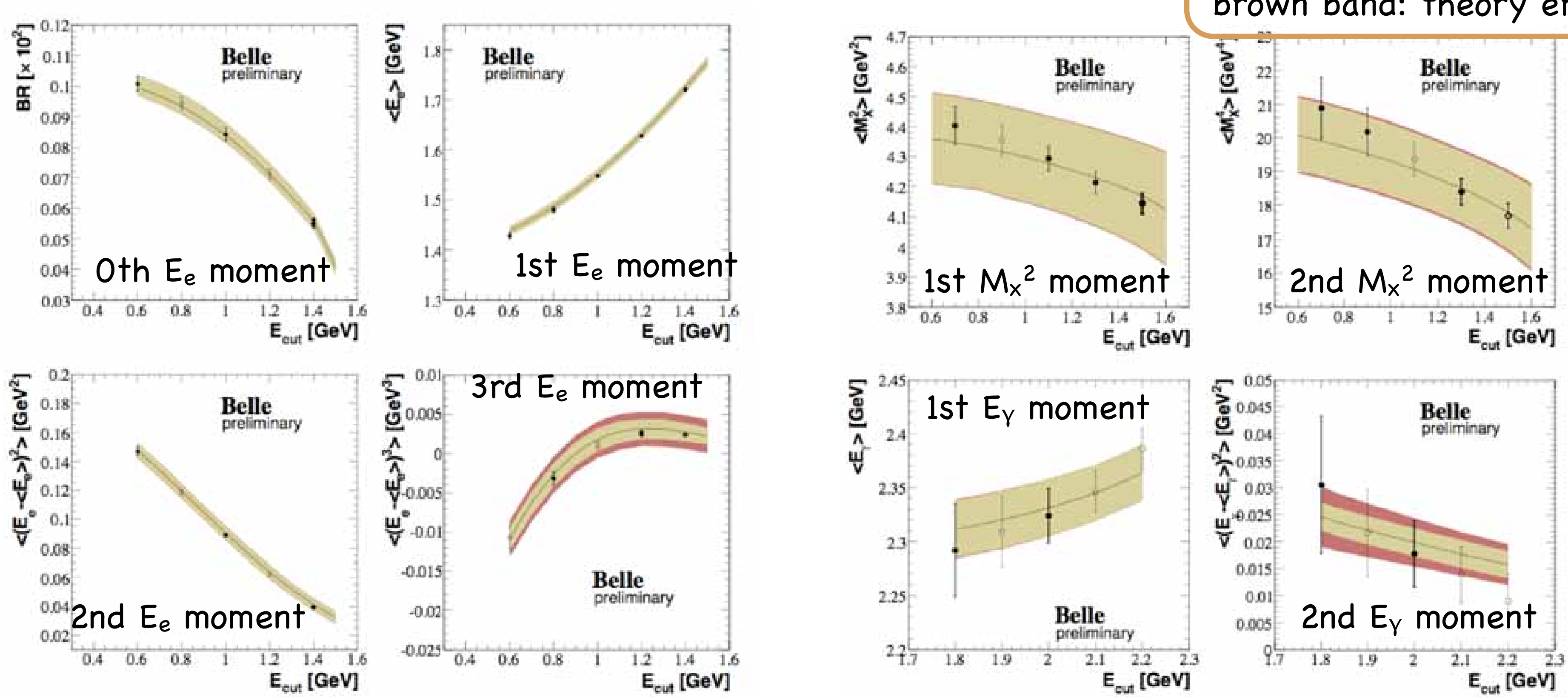
PRD73, 073008 (2006)

HQE parameters and $|V_{cb}|$: 1S Scheme

Truncated moments derived up to $O(1/m_b^3)$

7 parameters can be determined with a χ^2fit to moments: $|V_{cb}|$, Λ, λ_1, τ_1, τ_2, τ_3, ρ_1

brown band: theory error



Belle fit 71 of their measured moments (including $B\to X_s\gamma$, hep-ex/0508005) taking into account experimental and theoretical uncertainties

hep-ex/0611047

HQE parameters and $|V_{cb}|$: 1S Scheme

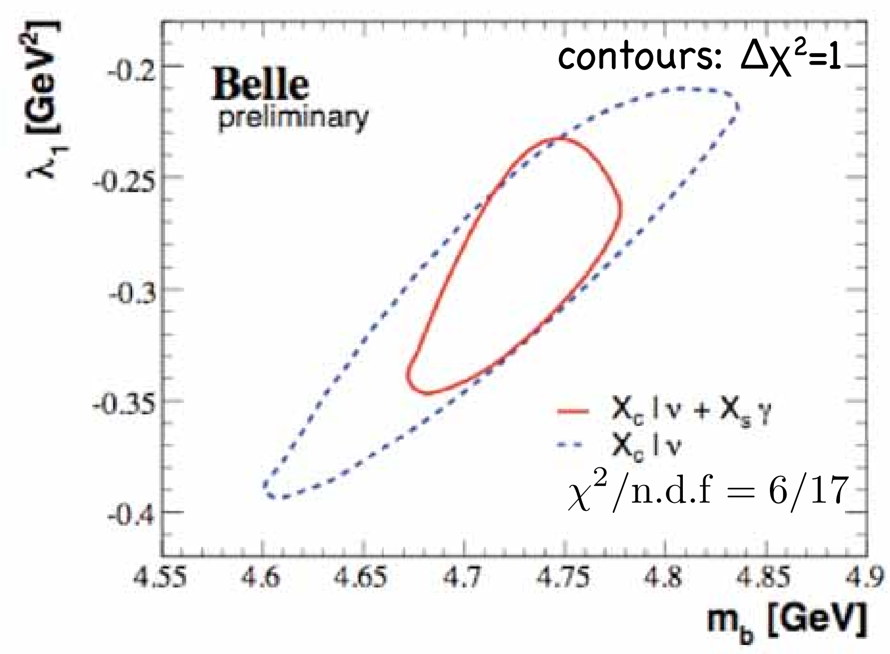
$$\Lambda = m_{\Upsilon(1S)}/2 - m_b^{1S}$$

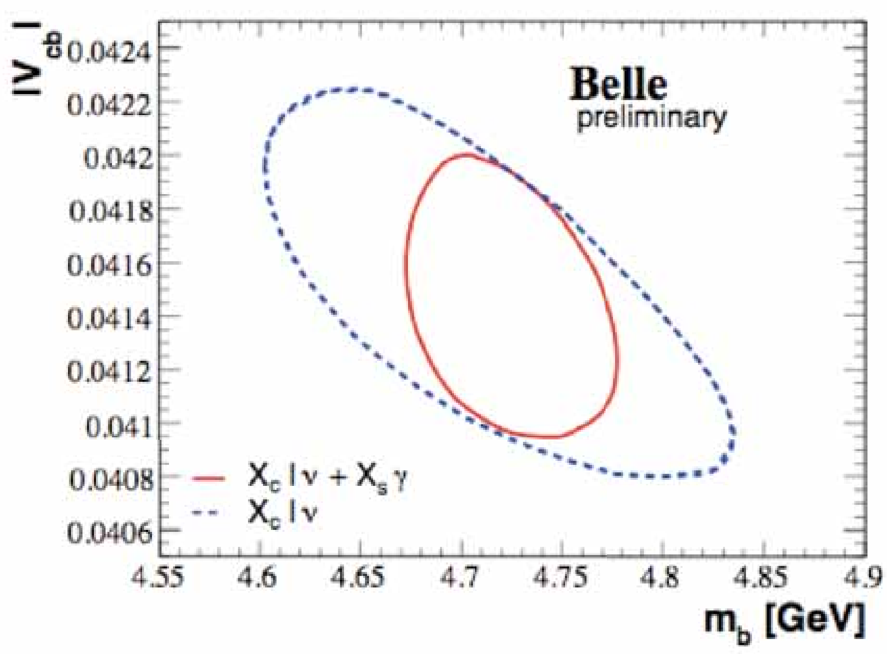
Results

$|V_{cb}|$ = $(41.49 \pm 0.52_{fit} \pm 0.20_{TB})\ 10^{-3}$

m_b^{1S} = 4.729 ± 0.048 GeV

λ_1 = -0.30 ± 0.04 GeV^2





hep-ex/0611047

HQE parameters from moments: conclusions

$|V_{cb}|$ - Kinetic Scheme: $(41.93 \pm 0.65_{fit} \pm 0.07_{\alpha s} \pm 0.63_{th})\ 10^{-3}$

$|V_{cb}|$ - 1S Scheme: $(41.49 \pm 0.52_{fit} \pm 0.20_{TB})\ 10^{-3}$

Good agreement with measurements done using different data samples (BaBar, CLEO, CDF, DELPHI):

$|V_{cb}|$ - Kinetic Scheme: $(41.96 \pm 0.23 \pm 0.35 \pm 0.59)\ 10^{-3}$

O. Buchmüller and H. Flächer, PRD73, 073008 (2006)

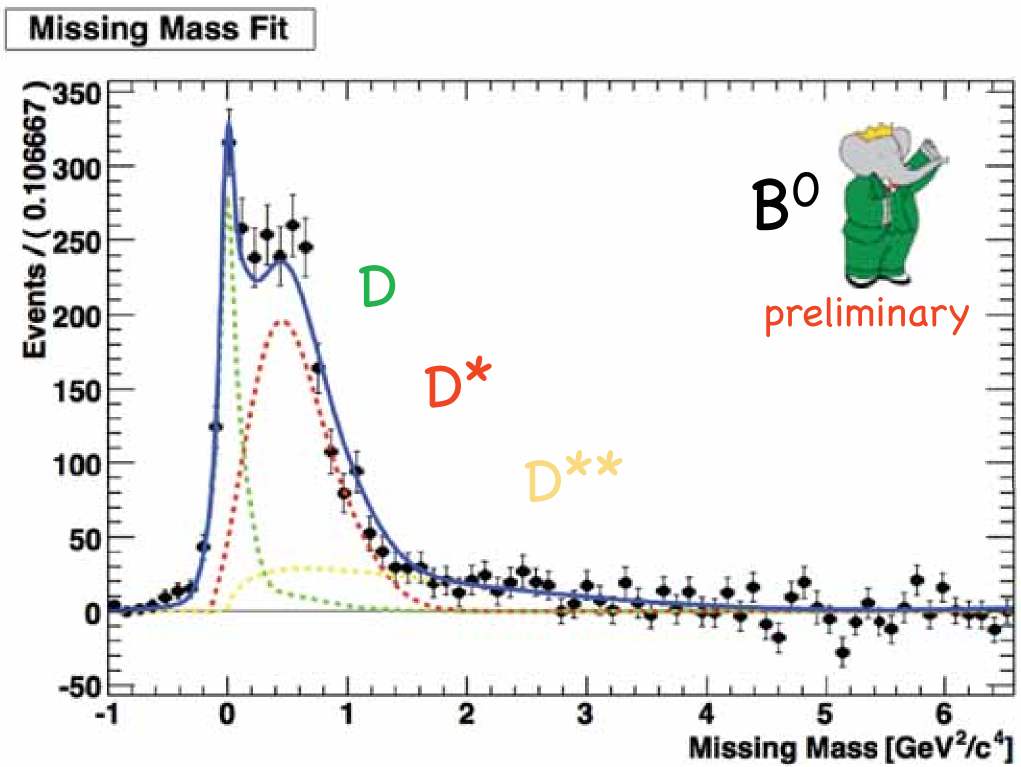
Good agreement for other HQE parameters as well

$|V_{cb}|$ measured at <2%

Relative BFs for B→D/D*/D**lν

Event selection: reconstruct D+lepton (p_{lep}>0.6 GeV/c) system, then fully reconstruct non-overlapping hadronic tag

Measure simultaneously D, D*, D** components using a global fit to lepton momentum, missing mass squared and additional charged particle multiplicity distributions



PDFs are built using exclusive D(*)(π)lν data samples (minimize MC dependence and limited knowledge of D** states)

Relative BFs for $B \to D/D^*/D^{**} l \nu$

On 340 fb^{-1} BaBar measures:

NEW!

preliminary

Ratio	B^- (%)	B^0 (%)
$\frac{\Gamma(B \to D \ell \bar{\nu}_\ell)}{\Gamma(B \to D X \ell \bar{\nu}_\ell)}$	$22.7 \pm 1.4 \pm 1.6$	$21.5 \pm 1.6 \pm 1.3$
$\frac{\Gamma(B \to D^* \ell \bar{\nu}_\ell)}{\Gamma(B \to D X \ell \bar{\nu}_\ell)}$	$58.2 \pm 1.8 \pm 3.0$	$53.7 \pm 3.1 \pm 3.6$
$\frac{\Gamma(B \to D^{**} \ell \bar{\nu}_\ell)}{\Gamma(B \to D X \ell \bar{\nu}_\ell)}$	$19.1 \pm 1.3 \pm 1.9$	$24.8 \pm 3.2 \pm 3.0$

BF($B \to D^0 l \nu$)	2.42 ± 0.15 ± 0.17 %
BF($B \to D^{*0} l \nu$)	6.20 ± 0.19 ± 0.32 %
BF($B \to D^{**0} l \nu$)	2.04 ± 0.14 ± 0.20 %
BF($B \to D^+ l \nu$)	2.19 ± 0.16 ± 0.13 %
BF($B \to D^{*+} l \nu$)	5.46 ± 0.33 ± 0.37 %
BF($B \to D^{**+} l \nu$)	2.52 ± 0.32 ± 0.31 %

Precision comparable to the current world knowledge of $B \to D/D^*/D^{**} l \nu$ decays

Important input to all the analysis relying on accurate description of $D/D^*/D^{**}$ hadronic mass region

BaBar has also a preliminary result on D^{**} narrow resonances

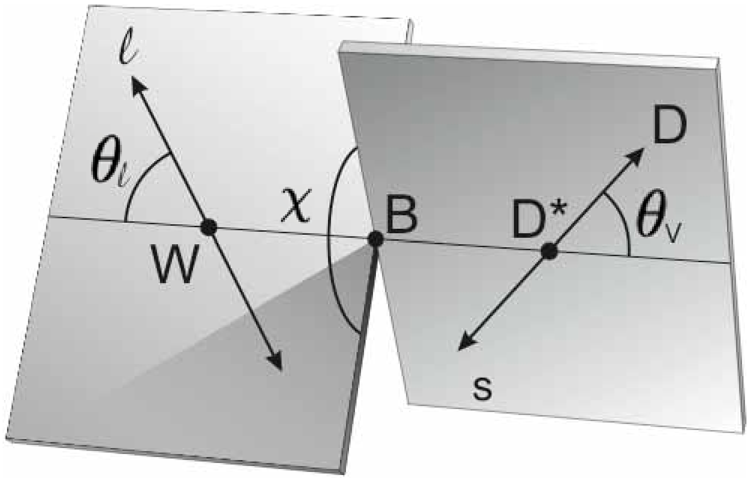
$|V_{cb}|$ from $B^0 \to D^{*-} l^+ \nu$

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

w: D* boost

expressed in terms of helicity amplitudes (D* polarization)

expressed, in turn, by form factor ratios R_1, R_2 and the slope h_{A1} à la Caprini, Lellouch, Neubert



$$h_{A_1}(w) = h_{A_1}(1)[1 - \rho^2_{h_{A_1}} z + (53\rho^2_{h_{A_1}} - 15)z^2 - (231\rho^2_{h_{A_1}} - 91)z^3]$$

$$z = \frac{\sqrt{w+1} - \sqrt{2}}{\sqrt{w+1} + \sqrt{2}}$$

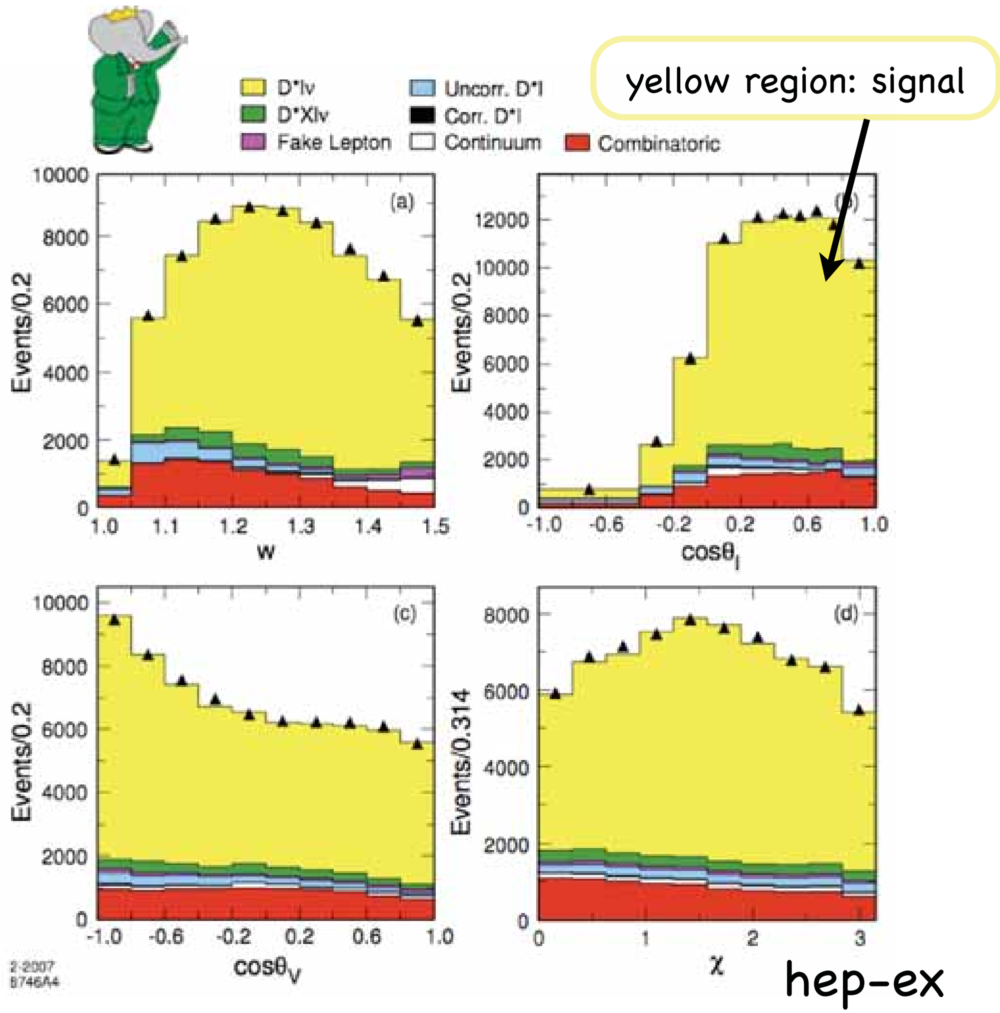
$|V_{cb}|$ from $B^0 \to D^{*-} l^+ \nu$

On 79fb^{-1}, select $D^{*-} l^+ \nu$ events, with p_{lep}>1.2 GeV/c, $D^* \to D^0 \pi^-$
$D^0 \to K\pi$, $K\pi\pi^0$, $K\pi\pi\pi$

Data sample is divided in 10 bins of w, $\cos\theta_l$, $\cos\theta_V$ and a combined least χ^2 fit is performed

combine this result with Phys. Rev. D74 (2006) 092004 to obtain:

$$R_1 = 1.417 \pm 0.061 \pm 0.044$$
$$R_2 = 0.836 \pm 0.037 \pm 0.022$$
$$\rho^2 = 1.179 \pm 0.048 \pm 0.028$$



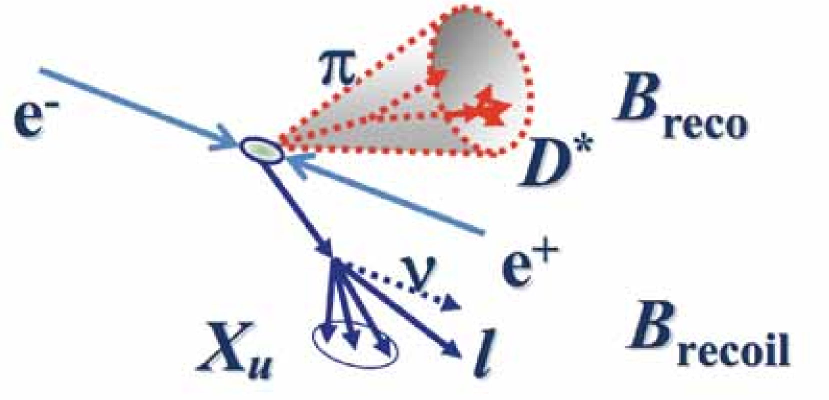
hep-ex

Using F(1)=0.919$^{+0.030}_{-0.035}$ estimate [Hashimoto et al, PRD 66 (2002) 014503]:

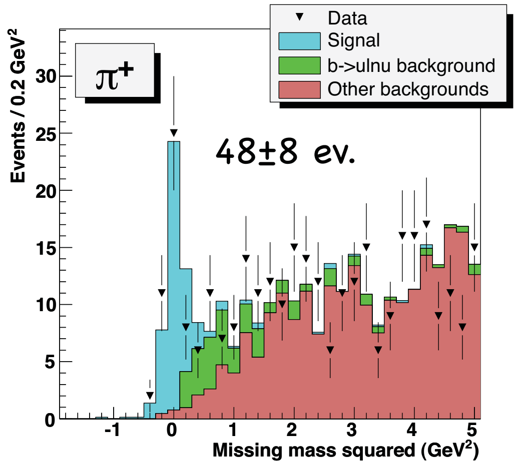
$$|V_{cb}| = (37.74 \pm 0.35_{(stat)} \pm 1.25_{(syst)}\ {}^{+1.23}_{-1.44(th)})\ 10^{-3}$$

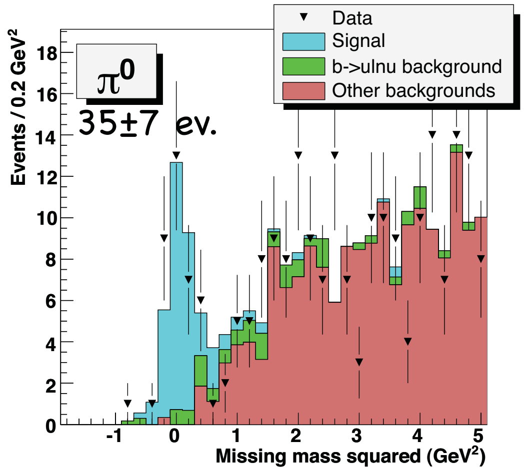
BRs for exclusive $B \to X_u l \nu$ decays

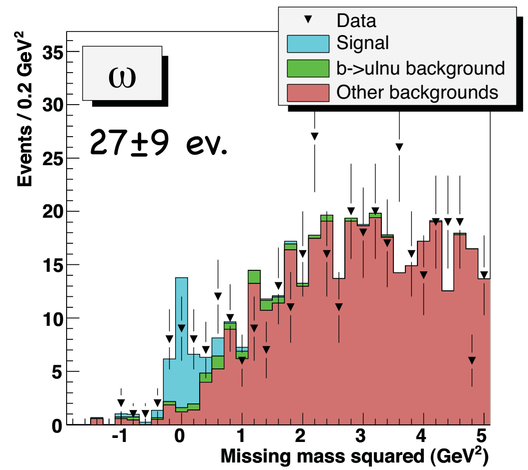
Recoil technique
highest S/B ratio, low efficiencies

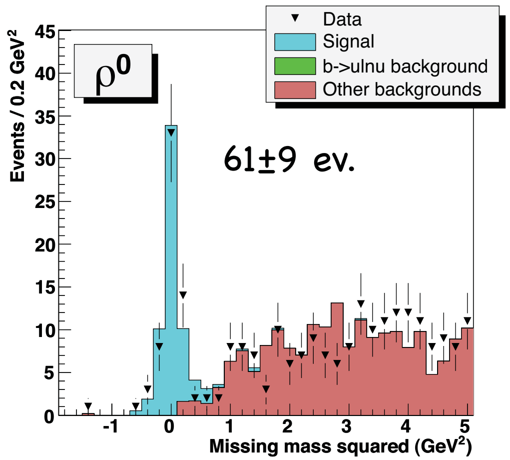


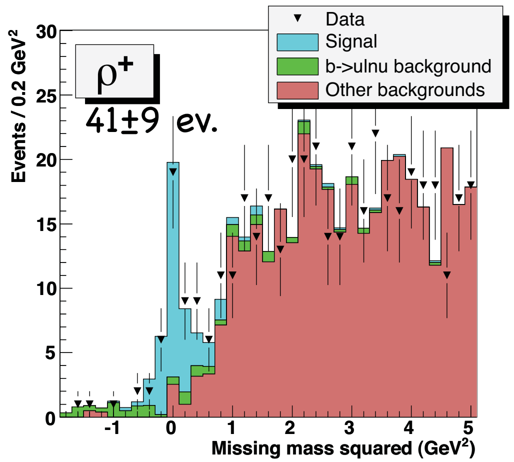
535M $B\bar{B}$ pairs











BELLE

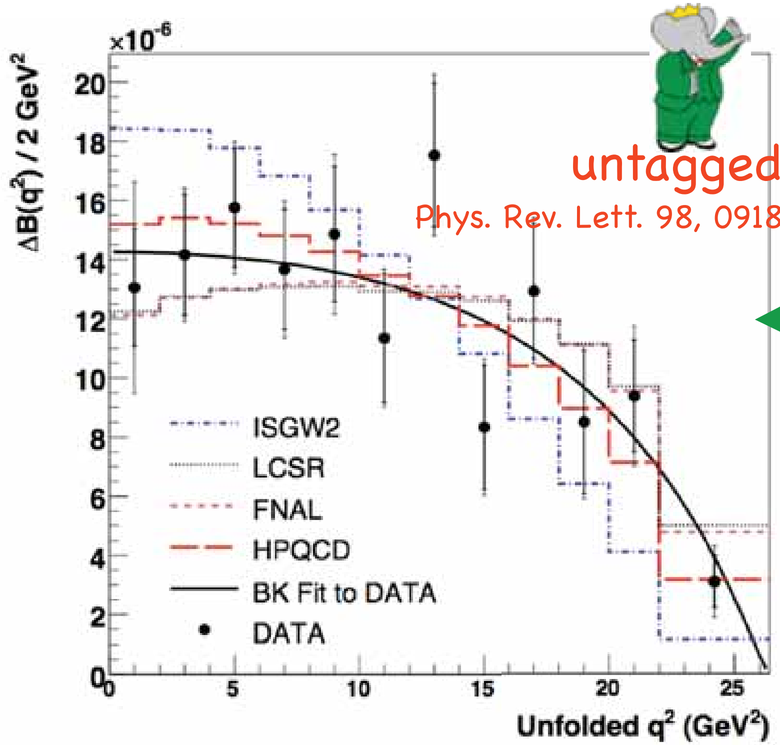
hep-ex/0610054

BRs for exclusive $B \to X_u l \nu$ decays

Belle measures ΔBFs for ρ and ω, in addition to π, extracting them in 3 bins of q^2 to minimize errors from FF modelling

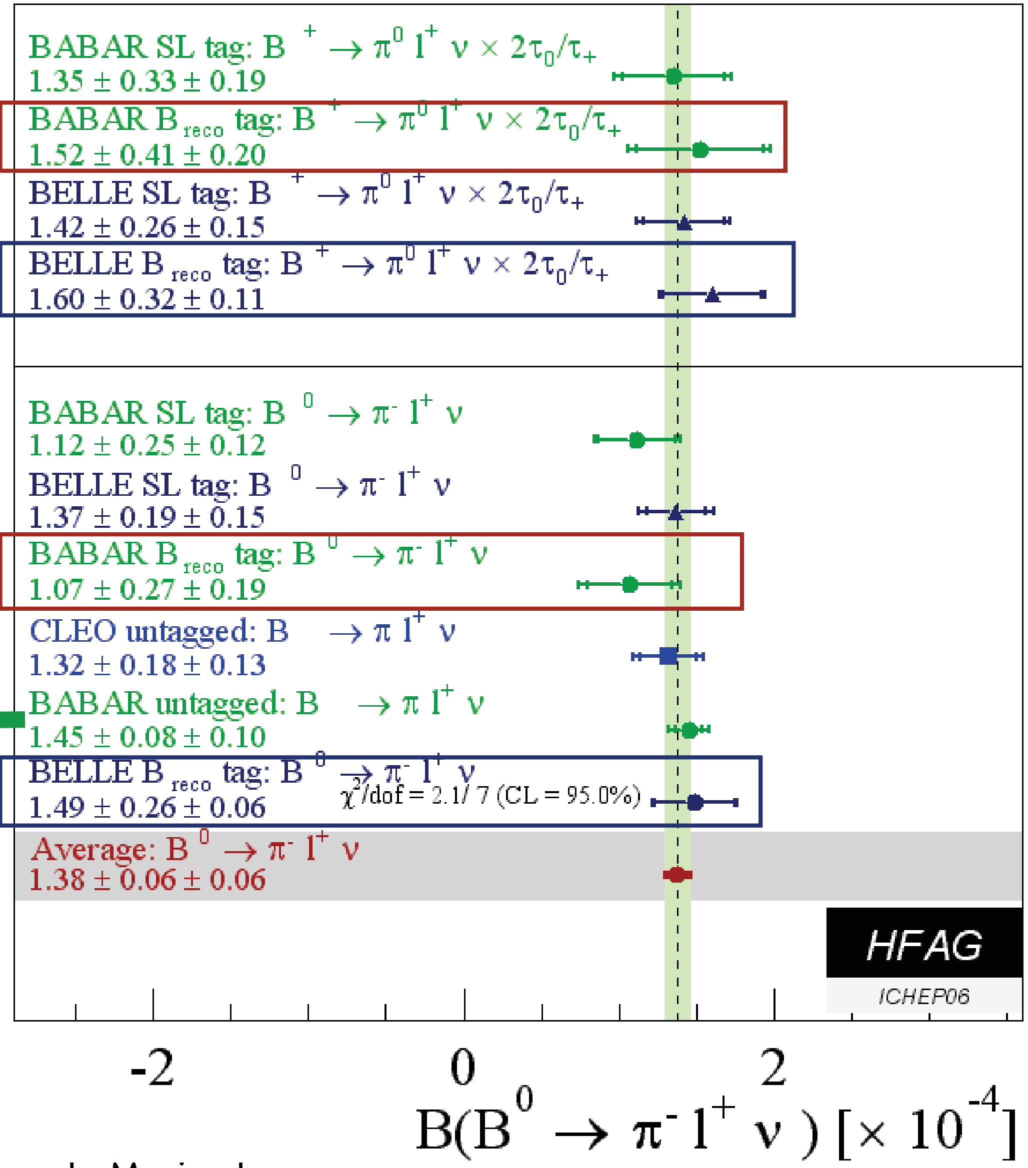
B_{reco}-tag analyses have smaller syst. uncertainties, still statistically limited

⇒ improvements are expected with larger dataset



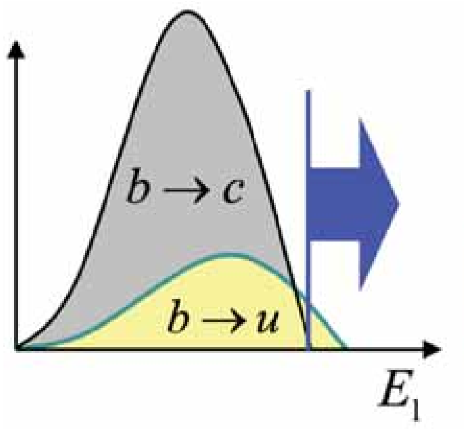
untagged

Phys. Rev. Lett. 98, 091801 (2007)



$|V_{ub}|$ with reduced model dependence

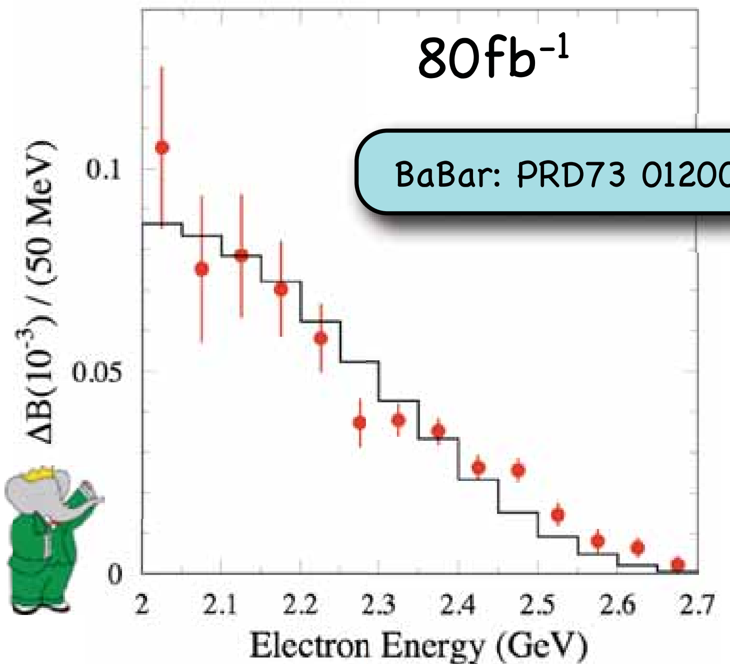
in inclusive SL decays



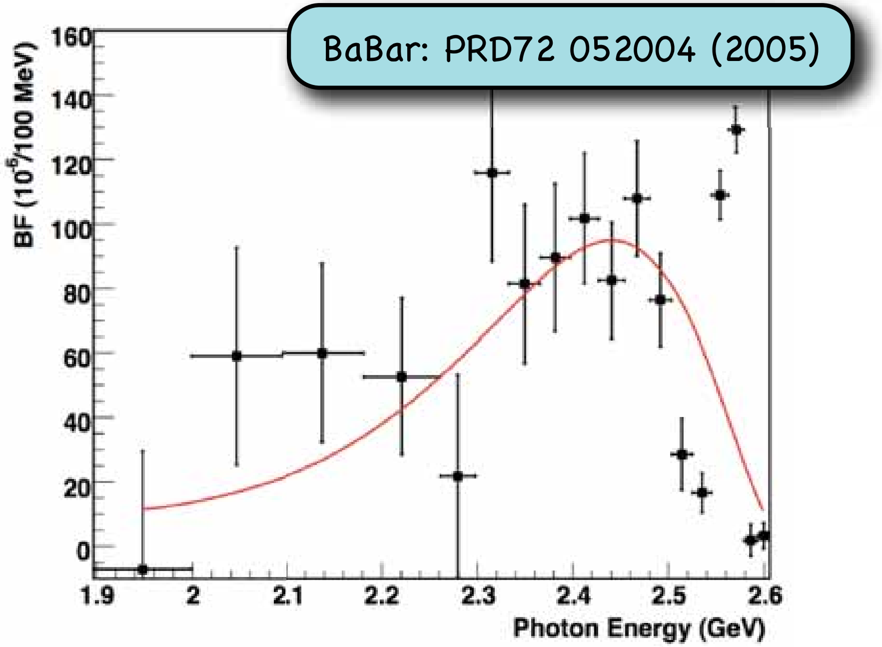
$|V_{ub}|^2$ is proportional to $B \to X_u l \nu$ branching fraction in limited region of phase space

In this region the theory (OPE) breaks down, acceptance sensitive to Fermi motion of b quark inside B meson, parameterised by Shape Functions

SFs are assumed to be universal, at leading order, for $b \to u$ and $b \to s$ decays ⇒ Combine lepton-endpoint spectrum in $B \to X_u e \nu$ decays with weighted photon-endpoint spectrum in $B \to X_s \gamma$



BaBar: PRD73 012006 (2006)



BaBar: PRD72 052004 (2005)

$|V_{ub}|$ with reduced model dependence

Different prescriptions to extract $|V_{ub}|$:

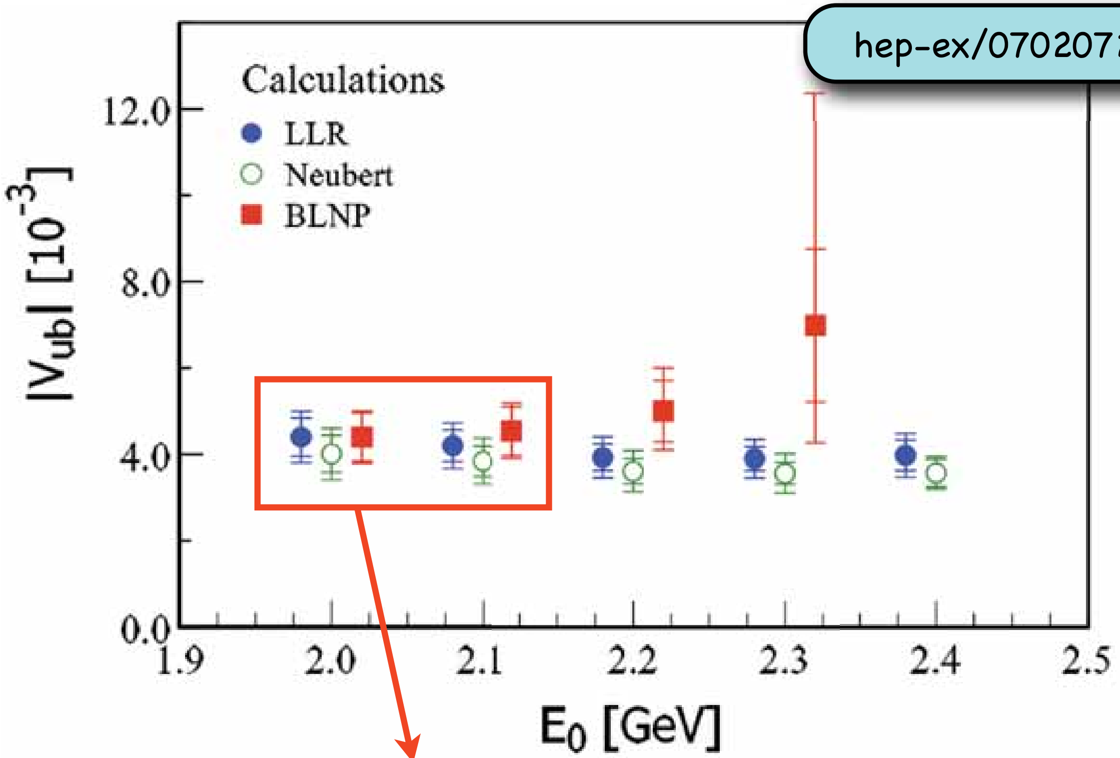
I - Leibovich, Low and Rothstein [Phys. Lett B513, 83 (2001)]

II - Neubert [Phys. Lett. B513, 88 (2001)]

III - Lange, Neubert and Paz [JHEP 0510, 084 (2005)]
Lange, JHEP 0601, 104 (2006)

two-loop calculation

hep-ex/0702072



measurement dominated by 12% uncertainty on ΔBF ($B \rightarrow X_u e\nu$) and integral over $B \rightarrow X_s \gamma$

⇒ improvements are expected with larger dataset

good agreement of 3 calculations
lowest theory error ~5%

LNP: $(4.40 \pm 0.30 \pm 0.41 \pm 0.23)\ 10^{-3}$

SF-based: $(4.44 \pm 0.25\ ^{+0.42}_{-0.38} \pm 0.22)\ 10^{-3}$

Conclusions

B factories are doing an excellent job of overconstraining the unitarity triangle:

$\|V_{cb}\| = (41.49 \pm 0.52_{fit} \pm 0.20_{TB})\ 10^{-3}$	inclusive decays fits to moments
$\|V_{cb}\| = (37.74 \pm 0.35_{(stat)} \pm 1.25_{(syst)}\ {}^{+1.23}_{-1.44(th)})\ 10^{-3}$	exclusive decays

$\|V_{ub}\| = (4.1 \pm 0.2_{st} \pm 0.20_{sys}{}^{+0.6}_{-0.4FF})10^{-3}$	exclusive decays, untagged using HPQCD, $q^2>16$ GeV^2
$\|V_{ub}\| = (4.40 \pm 0.30 \pm 0.41 \pm 0.23)\ 10^{-3}$	inclusive decays, reduced model dependence

Extraction of $|V_{ub}|$ with reduced model dependence is giving encouraging results

➠ improvements expected with larger dataset

Relative BFs for $B \to D/D^*/D^{**}l\nu$ improve our understanding of such decays

Backup Slides

HQE parameters and $|V_{cb}|$: Kinetic Scheme

BELLE

hep-ex/0611047

O. Buchmüller and H. Flächer, PRD73, 073008 (2006)

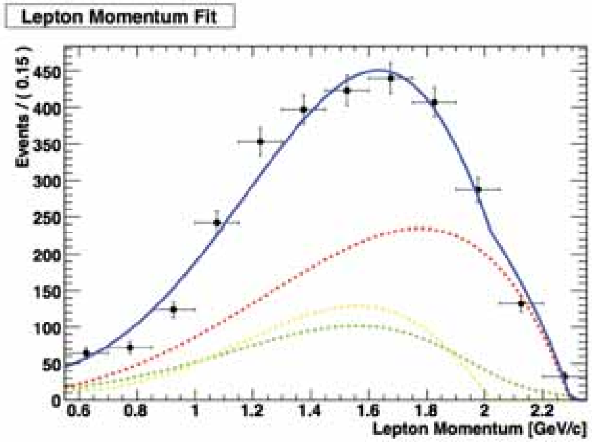
Results (Belle)

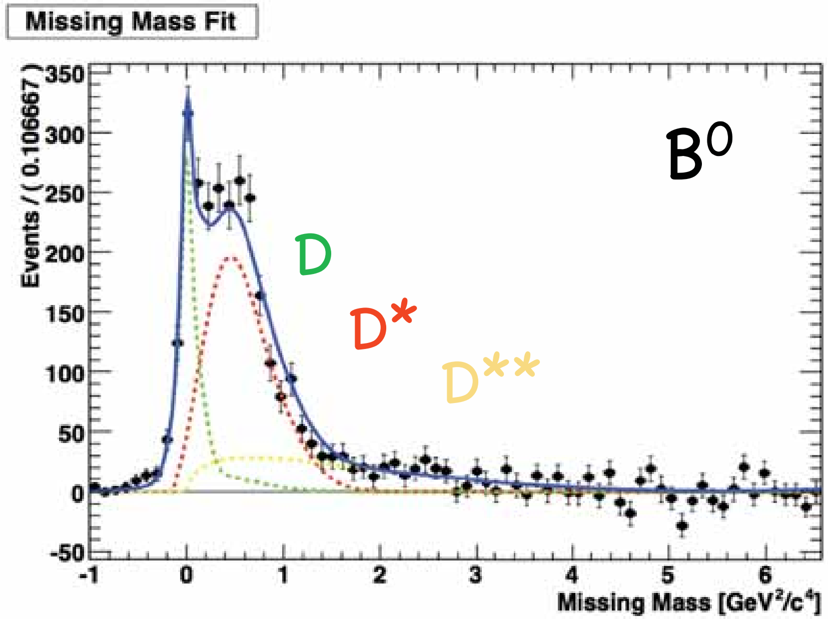
$|V_{cb}|$ =	$(41.93 \pm 0.65 \pm 0.07 \pm 0.63)\ 10^{-3}$
m_b =	$4.564 \pm 0.076 \pm 0.003$ GeV
m_c =	$1.105 \pm 0.116 \pm 0.005$ GeV
μ_π^2=	$0.557 \pm 0.091 \pm 0.013$ GeV^2
μ_G^2=	$0.358 \pm 0.060 \pm 0.003$ GeV^2
ρ_D^3=	$0.162 \pm 0.053 \pm 0.008$ GeV^3
ρ_{LS}^3=	$-0.174 \pm 0.098 \pm 0.003$ GeV^3
$BR_{cl\nu}$=	$10.590 \pm 0.164 \pm 0.006$ %

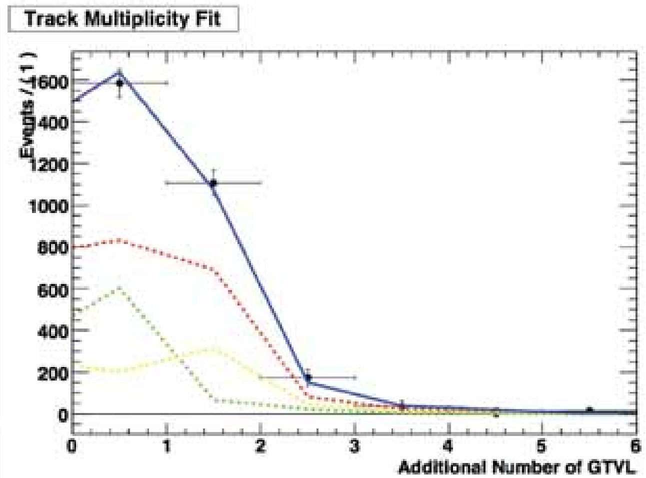
Results (Buchmüller and Flächer)

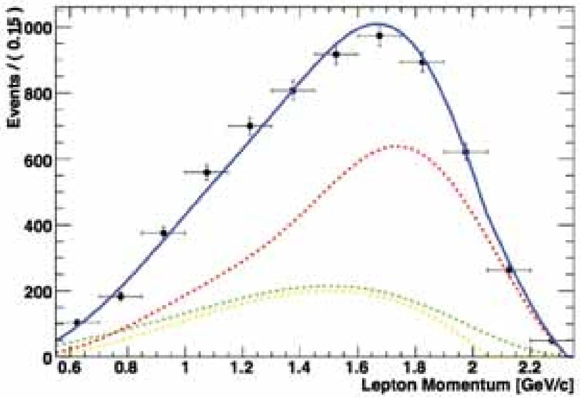
$|V_{cb}|$ =	$(41.96 \pm 0.23 \pm 0.35 \pm 0.59)\ 10^{-3}$
m_b =	$4.590 \pm 0.025 \pm 0.030$ GeV
m_c =	$1.142 \pm 0.037 \pm 0.045$ GeV
μ_π^2=	$0.401 \pm 0.019 \pm 0.035$ GeV^2
μ_G^2=	$0.297 \pm 0.024 \pm 0.046$ GeV^2
ρ_D^3=	$0.174 \pm 0.009 \pm 0.022$ GeV^3
ρ_{LS}^3=	$-0.183 \pm 0.054 \pm 0.071$ GeV^3
$BR_{cl\nu}$=	$10.71 \pm 0.10 \pm 0.08$ %

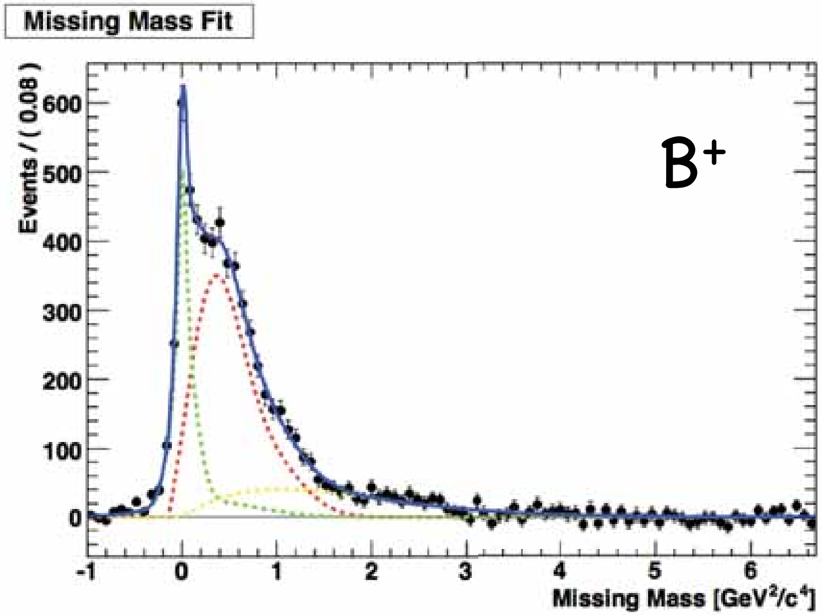
Relative BFs for B→D/D*/D**lν

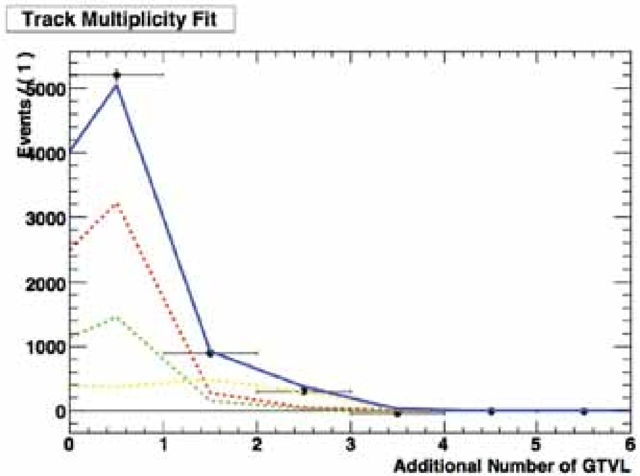










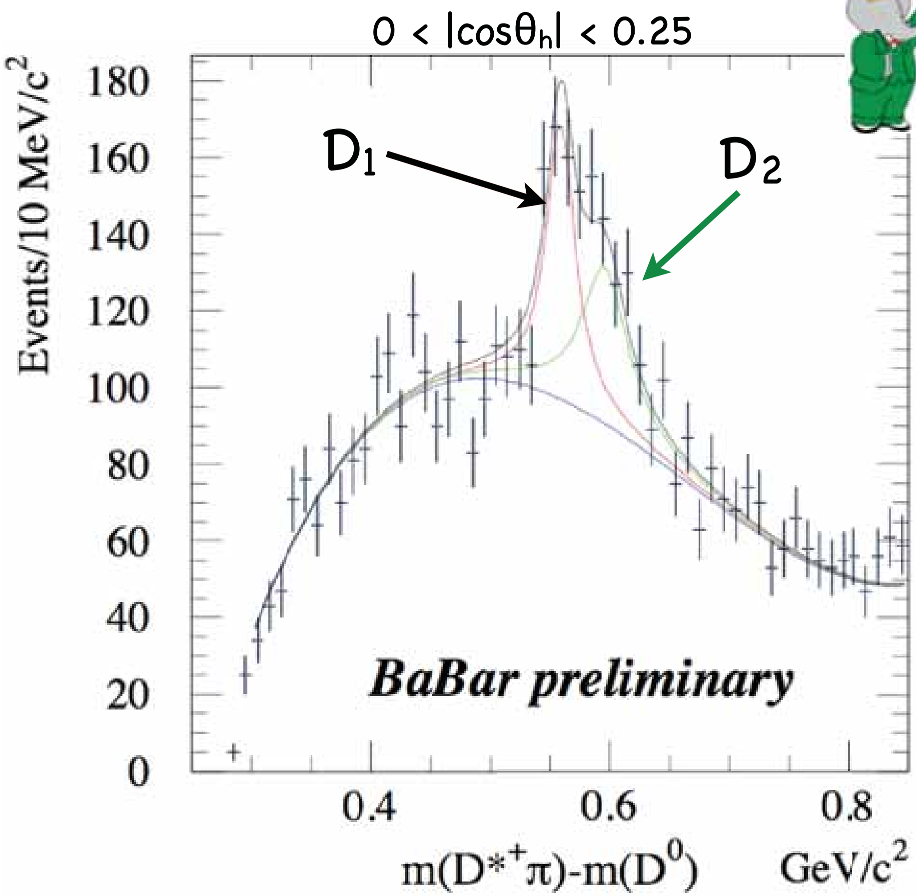


B→D**lν narrow resonances

D** is a nickname for states D*(nπ) with n>0, including narrow resonances D_1,D_2^* + broad resonances D_0^*, D_1^* + non-resonant?

Uncertainty of D_1, D_2^* branching fractions still ~20-30%

BaBar does an inclusive selection of $B \rightarrow D^{(**)} l \nu$ candidates, combining $D^{\pm}$ or D^* with $\pi^{\pm}$ to create D** states



Simultaneous fit of D_1 and D_2^* in $\Delta m = m(D^{**}) - m(D)$

D_1 vs. D_2^* components fit using 4 bins of $D^* \rightarrow D\pi$ helicity angle $|\cos\theta_h|$

$$\mathcal{B}(B^+ \to D_1^0 \ell^+ \nu_\ell) = (4.48 \pm 0.26 \pm 0.35) \times 10^{-3}$$
$$\mathcal{B}(B^+ \to D_2^{*0} \ell^+ \nu_\ell) = (3.54 \pm 0.32 \pm 0.54) \times 10^{-3}$$
$$\mathcal{B}(B^0 \to D_1^- \ell^+ \nu_\ell) = (3.64 \pm 0.32 \pm 0.49) \times 10^{-3}$$
$$\mathcal{B}(B^0 \to D_2^{*-} \ell^+ \nu_\ell) = (2.70 \pm 0.35 \pm 0.43) \times 10^{-3}$$