Experimental review of CKM sides at B factories

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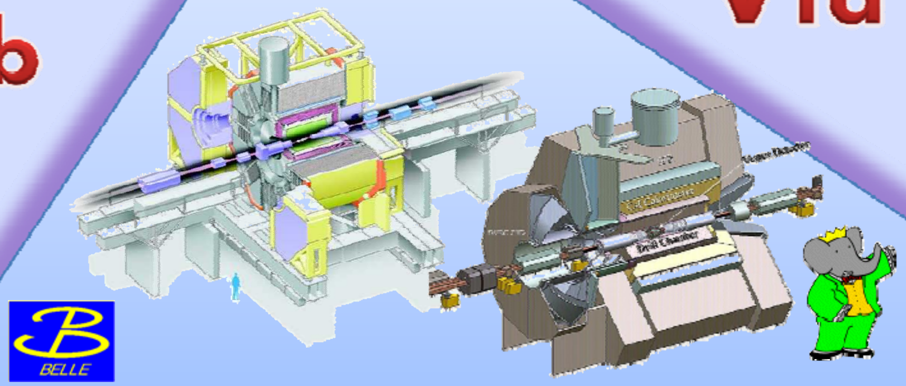
(BaBar Collaboration)

DISCRETE 2008

Vub

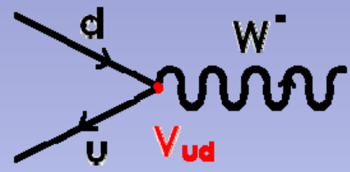
Vtd



Vcb

Introduction & outline

The Cabibbo-Kobayashi-Maskawa matrix:

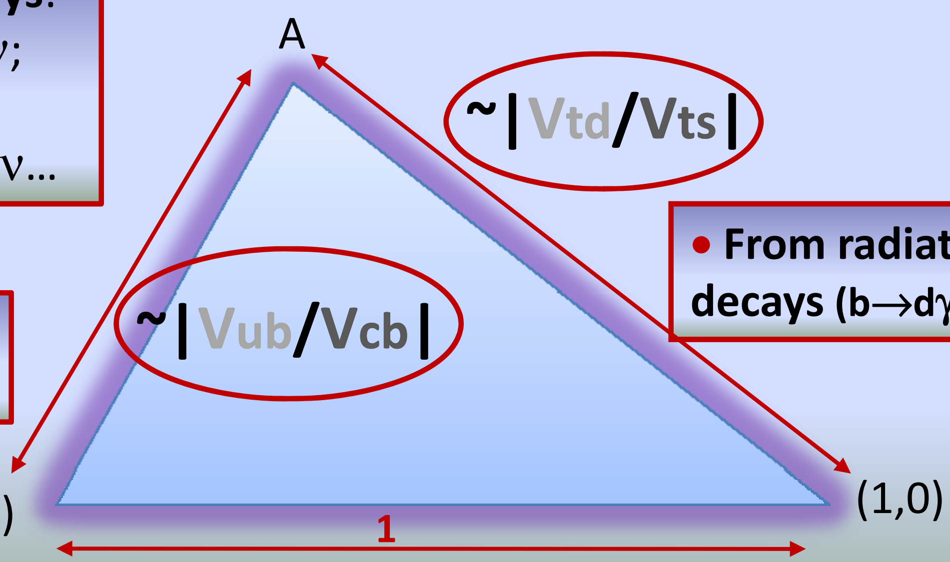


$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

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

- From B_d and B_s mixing [@ hadron colliders ($\Delta md/ \Delta ms$)]

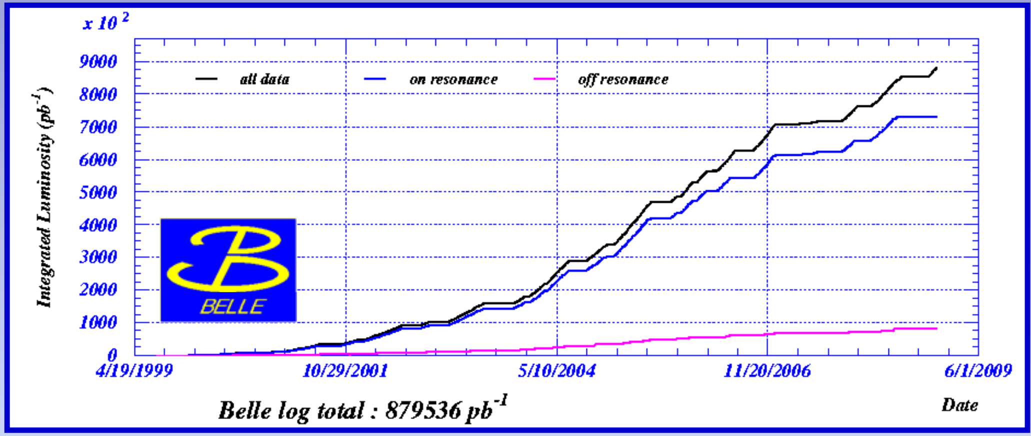
- From exclusive sl decays:
  |Vcb|: $B \to D^{*}\ell\nu$, $B \to D\ell\nu$;
  |Vub|: $B \to \pi\ell\nu$, $B \to \rho\ell\nu$
  $B \to \eta^{(\prime)}\ell\nu$, $B \to \omega\ell\nu$...

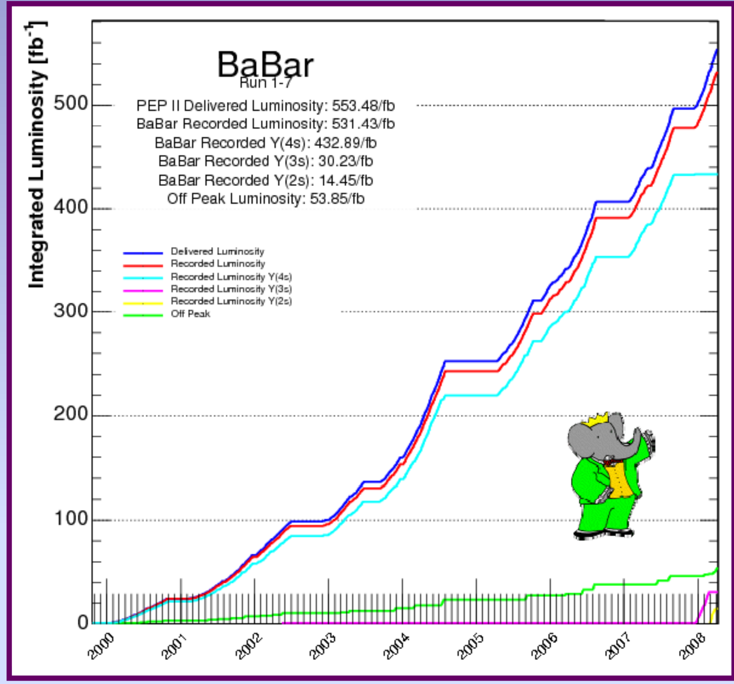


- From radiative decays ($b \to d\gamma / b \to s\gamma$)

- From inclusive $B \to X_c\ell\nu$ (|Vcb|) and $B \to X_u\ell\nu$ (|Vub|) decays

B-Factories





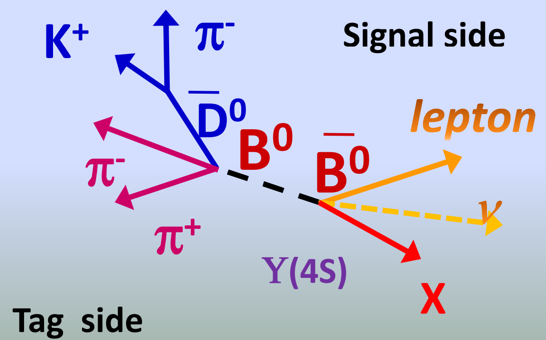
~ 1200 fb^{-1} recorded !

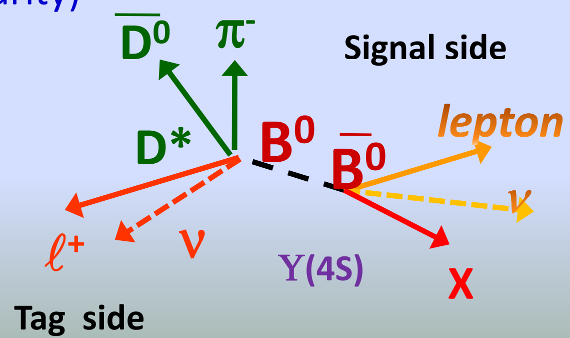
Analysis techniques:

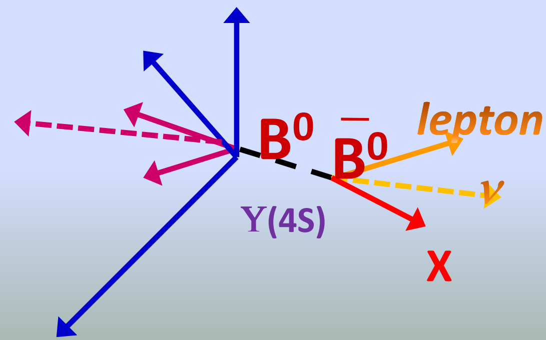
Hadronic or Semileptonic Tag

(High purity)

Untagged (High efficiency)



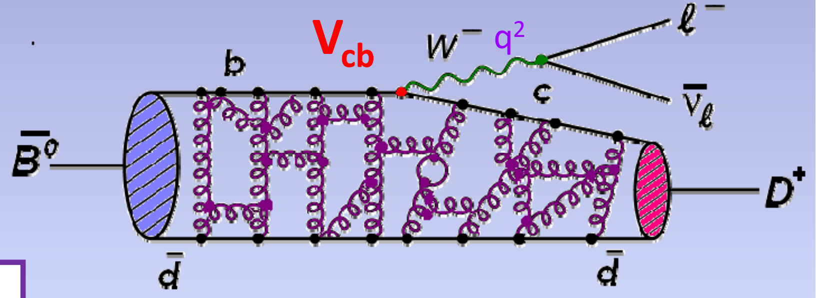




|Vcb| from exclusive sl decays

$$q^2 = (p_{\ell^-} + p_{\bar{\nu}_\ell})^2 = (p_{\overline{B}} - p_{D^*})^2$$

- From $B \to D \ell \nu$ (BR ~2% , suppressed at high q^2)
- From $B \to D^* \ell \nu$ (BR ~ 5%)



$$w = V_B \cdot V_{D^{(*)}} = \frac{(M_B^2 + M_{D^{(*)}}^2 - q^2)}{(2 M_B M_{D^{(*)}})}$$

$$\frac{d\Gamma(B \to D^{(*)} \ell \nu)}{dw} = \frac{G_F^2}{48\pi^3\hbar} \mathcal{F}^2(w)\, \mathcal{K}(w) |V_{cb}|^2$$

Form factor (shape & normalization)

Kinematic function

Theory: $\mathcal{G}(1)$* $= 1.074 \pm 0.018 \pm 0.016$

$\mathcal{F}(1)$* $= 0.921 \pm 0.013 \pm 0.020$

$B \to D$: ρ_D^2

$B \to D^*$: $\rho_{D^*}^2$, $R_1(1)$, $R_2(1)$

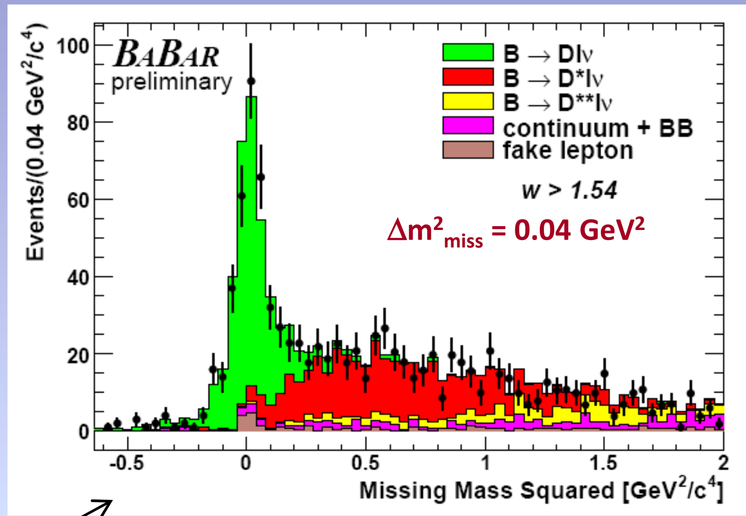
Measuring the decay rate and ff shape $\to$ $|V_{cb}|$

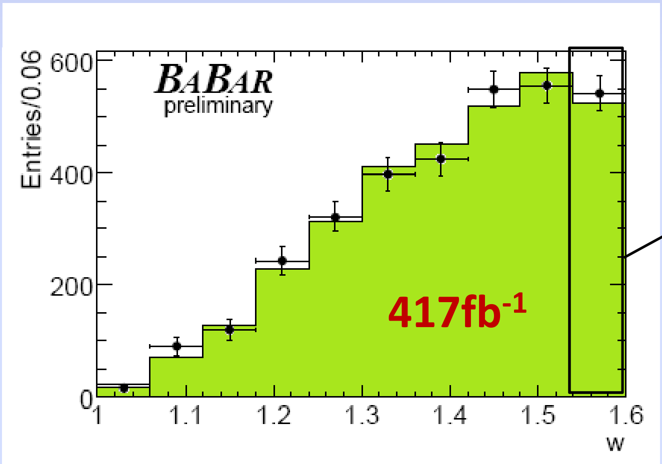
* M.Okamoto *et al* NPPS 140, 461(2005))
* C. Bernard *et al* arXiv:0808.2519 [hep-lat]

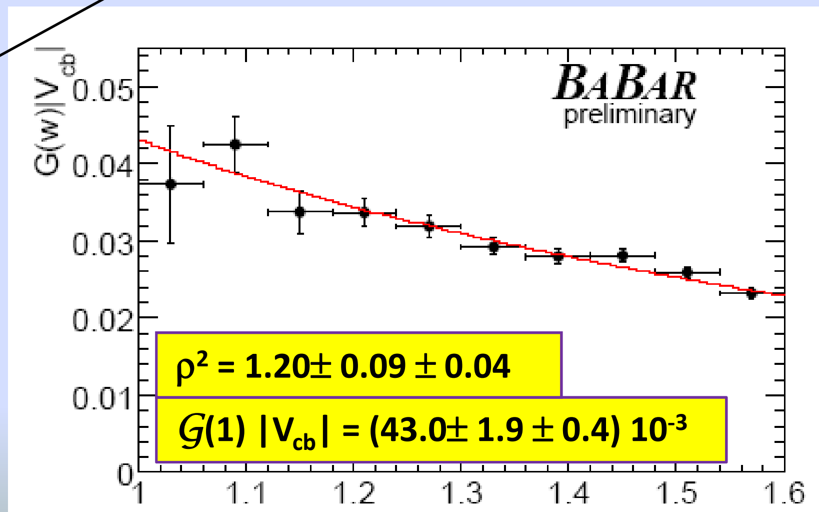
|Vcb| from $B \to D\ell\nu$

- Select the lepton,
- reconstruct the D^0 into several channels
- Reconstruct the other B into hadrons (B_{tag})
- Reconstruct the missing mass:

  $m^2_{miss} = (p_{\Upsilon(4s)} - p_{Btag} - p_D - p_\ell)^2$ →
- Fit the signal yield into 10 w bins (ML fit)







arXiv:0807.4978

- χ^2 fit to extract ρ_D^2 and $\mathcal{G}(1)|V_{cb}|$

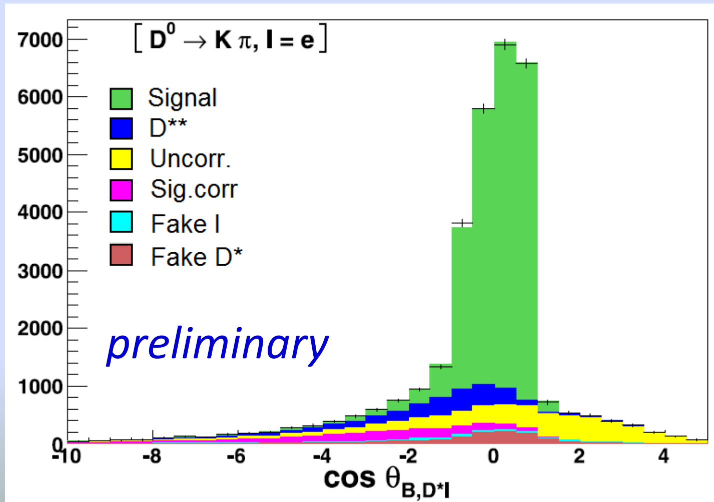
$\mathcal{B}(\bar{B}^0 \to D^+\ell\nu) = (2.17 \pm 0.06 \pm 0.07)\%$

$|V_{cb}|$ from $B \to D^* \ell \nu$

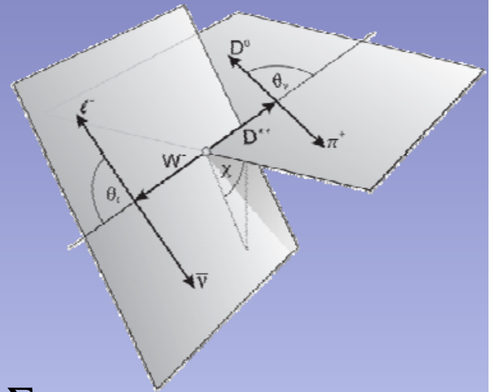
- Reconstruct the semileptonic decay $D^0 \to K\pi$, $K3\pi$ + soft π (to make D^*) + lepton
- Define the angle between the B and the $D^*\ell$ candidate

$$\cos\theta_{B,\widehat{D^*\ell}} = \frac{2E_B E_{D^*\ell} - m_B^2 - m_{D^*\ell}^2}{2|\vec{p}_B||\vec{p}_{D^*\ell}|}$$

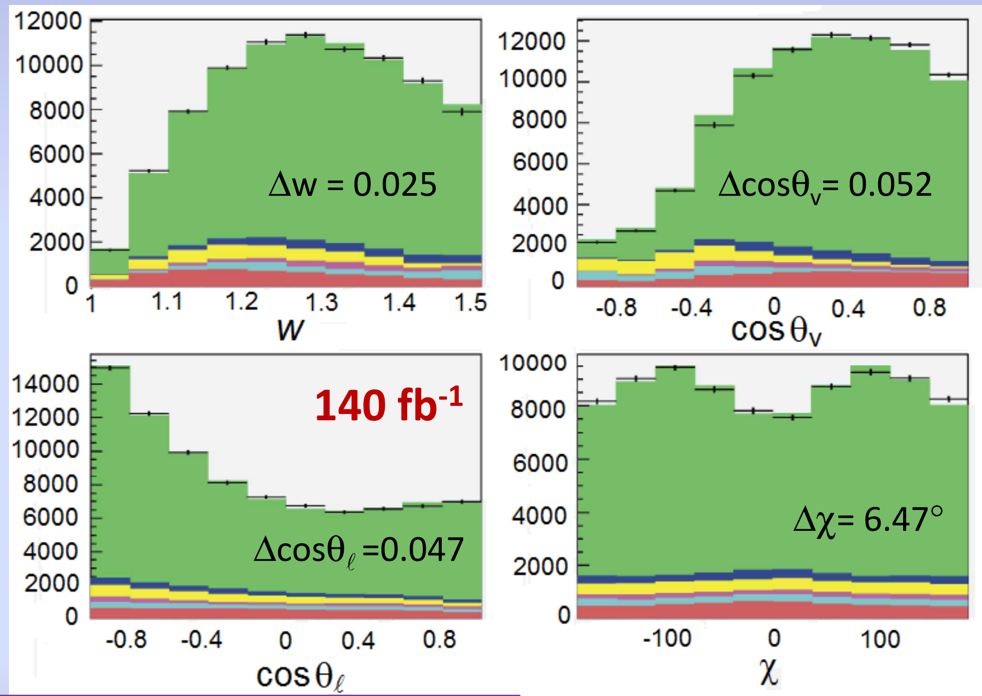
- Fit the signal yield



- The decay rate depends on w, θ_ℓ, θ_V, χ



- Constraint $p_B \sim p_{inclusive} = \Sigma p_{all\,-D^*\ell}$
- 4D χ^2 fit to extract $\rho_{D^*}^2$, R_1, R_2 and $\mathcal{F}(1)|V_{cb}|$



$\mathcal{F}(1)\,|V_{cb}| = (34.4 \pm 0.2 \pm 1.0)\,10^{-3}$

$\rho^2 = 1.293 \pm 0.045 \pm 0.029$

$\mathcal{B}(\bar{B}^0 \to D^{*+}\ell^-\nu) = (4.42 \pm 0.03 \pm 0.25)\%$

$R_1 = 1.495 \pm 0.050 \pm 0.062$

$R_2 = 0.844 \pm 0.034 \pm 0.019$

Global fit to $B \to D \ell \nu$ and $B \to D^* \ell \nu$

207fb^{-1}

- Reconstruct $D^0 \ell$ and $D^+ \ell$ candidates ($D^0 \to K^- \pi^+$, $D^+ \to K^- \pi^+ \pi^+$)
- Use p^*_ℓ, p^*_D and $\cos\theta_{B\text{-}D\ell}$ to separate $B \to D \ell \nu$ and $B \to D^* \ell \nu$ decays
- 3D $\chi 2$ fit to the yields to extract the form factor slopes, ρ_D and ρ_{D^*} and $B \to D \ell \nu$ and $B \to D^* \ell \nu$ BRs (R_1 and R_2 fixed).

$\mathcal{B}(B^- \to D^{*0} \ell^- \nu) = (5.37 \pm 0.02 \pm 0.21)\%$

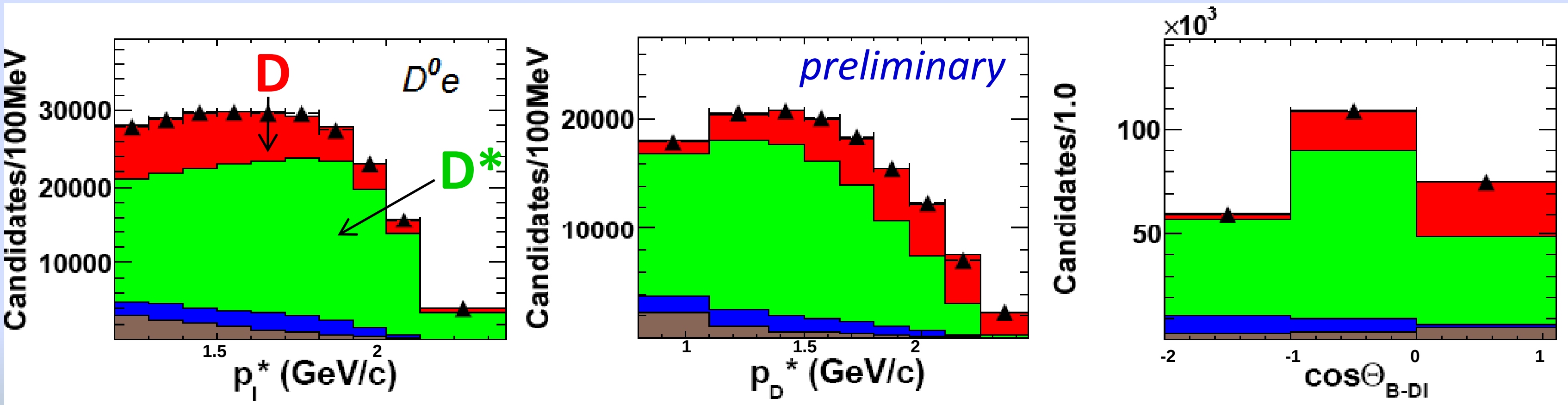
$\rho_{D^*}^2 = 1.21 \pm 0.02 \pm 0.07$

$\mathcal{F}(1)\ |V_{cb}| = (35.7 \pm 0.2 \pm 1.2)\ 10^{-3}$

$\mathcal{B}(B^- \to D^0 \ell^- \nu) = (2.36 \pm 0.03 \pm 0.12)\%$

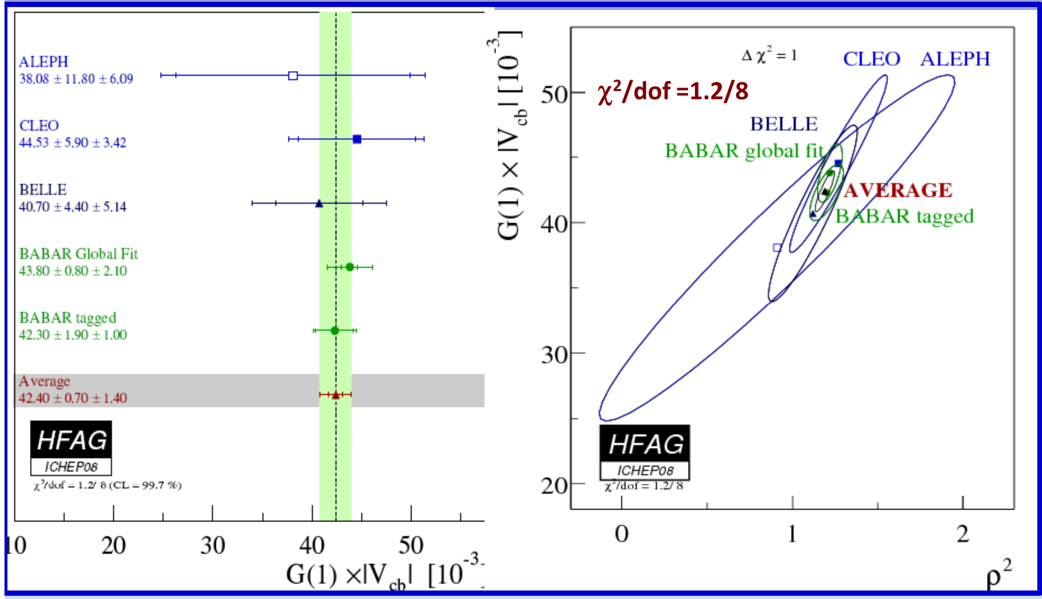
$\rho_D^2 = 1.22 \pm 0.04 \pm 0.07$

$\mathcal{G}(1)\ |V_{cb}| = (43.8 \pm 0.8 \pm 2.3)\ 10^{-3}$



arXiv:0809.0828

|Vcb| from exclusive sl decays



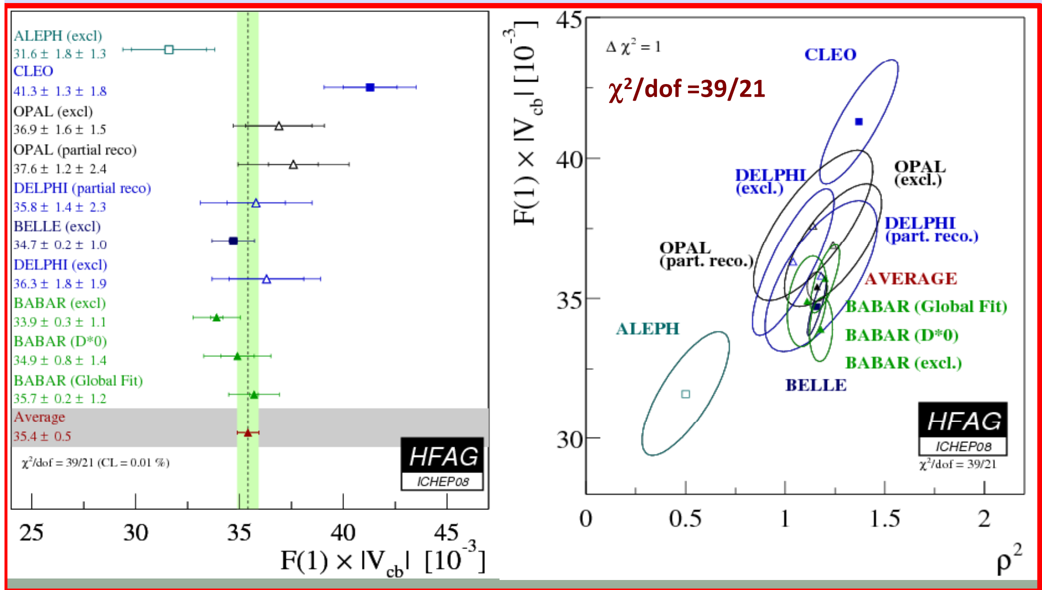
$\mathcal{G}(1)|V_{cb}|$ = (42.4 ± 1.56) x 10^{-3}

using $\mathcal{G}(1)$ =1.074 ± 0.024

$|V_{cb}|$ = (39.5 ± 1.5_{exp} ± 0.9_{latt}) x 10^{-3}

Exp: - waiting Belle update

- systematics → tracking eff, radiative corrections, D**

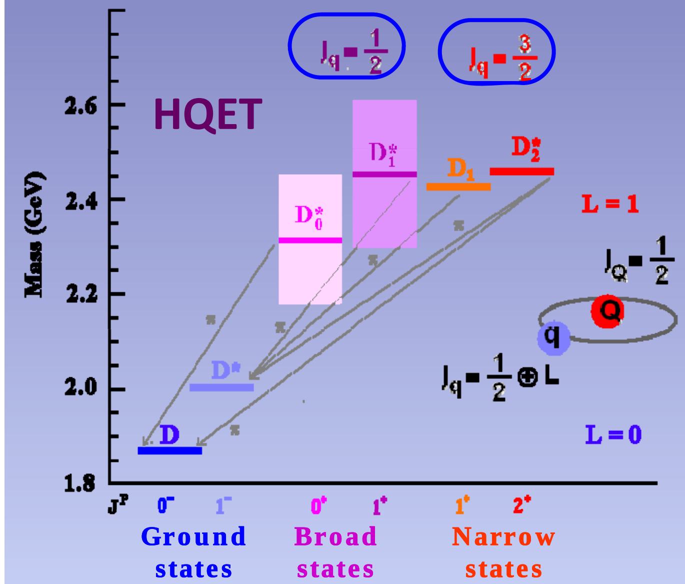


$\mathcal{F}(1)|V_{cb}|$ = (35.41 ± 0.52) x 10^{-3}

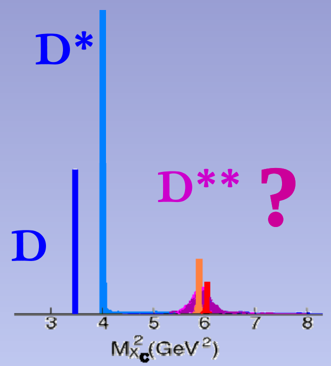
using $\mathcal{F}(1)$ =0.921 ± 0.024

$|V_{cb}|$ = (38.4 ± 0.6_{exp} ± 0.9_{latt}) x 10^{-3}

- systematics → tracking eff, D**

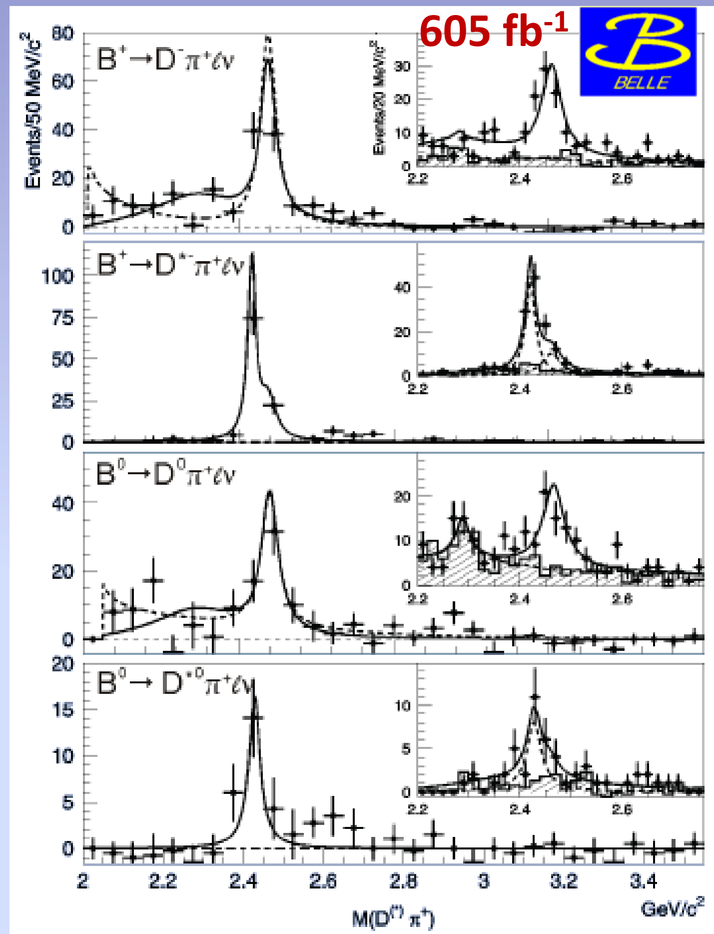


$B \to D^{**} \ell \nu$

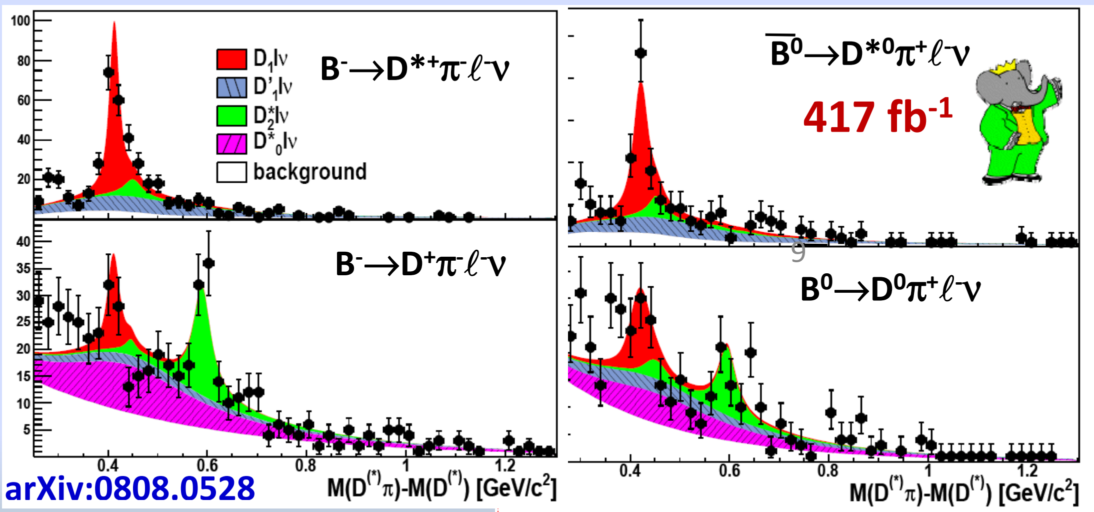


- Fully reconstructed analyses

PRD77,091503(2008)



- $\mathcal{B}(B^0 \to X_c \ell \nu)$ > $\mathcal{B}(B^0 \to D \ell \nu)$ + $\mathcal{B}(B^0 \to D^* \ell \nu)$ + $\mathcal{B}(B^0 \to D^{**} \ell \nu)$
  [10.1 ± 0.4]% > [2.17 ± 0.12]% + [5.16 ± 0.11]% + [1-2]%



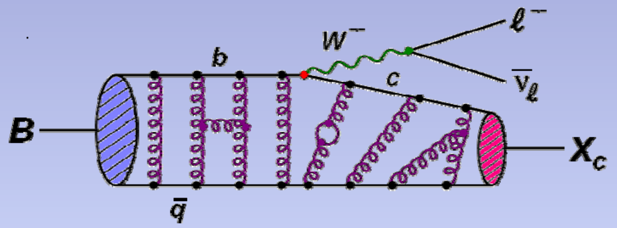
arXiv:0808.0528

- Belle does not see the D_1', BaBar does.

- Theory predicts $\mathcal{B}(D_1^*, D_2^*) >> \mathcal{B}(D^*_0, D_1')$, **Experiments see $\mathcal{B}(D_1^*, D_2^*)$ <~ $\mathcal{B}(D_0^*, D_1')$**

|Vcb| from inclusive sl decays

Operator Product Expansion (OPE):



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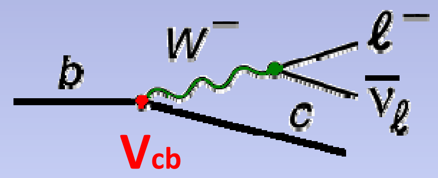


$$\times \left[1 + \frac{f(\mu_\pi^2, \mu_G^2)}{m_b^2} + \frac{f(\rho_D^3, \rho_{LS}^3)}{m_b^3} + \alpha_s \cdots \right]$$

f(parameters related with *b* quark properties inside the hadron)
→ kinetic energy, spin...

Some inclusive observables $\equiv O \rightarrow$ depend on the same parameters

(For instance: $B \rightarrow X_c \ell \nu$: the lepton energy, the mass distribution,
$B \rightarrow X_s \gamma$: the photon spectrum)

Measurement of moments: $M_n = \frac{\int \mathcal{O}^n (d\Gamma_{sl}/d\mathcal{O}) d\mathcal{O}}{\int (d\Gamma_{sl}/d\mathcal{O}) d\mathcal{O}} \rightarrow m_b, m_c, \mu_G^2, \mu_\pi^2, \rho_D^3, \rho_{LS}^3$

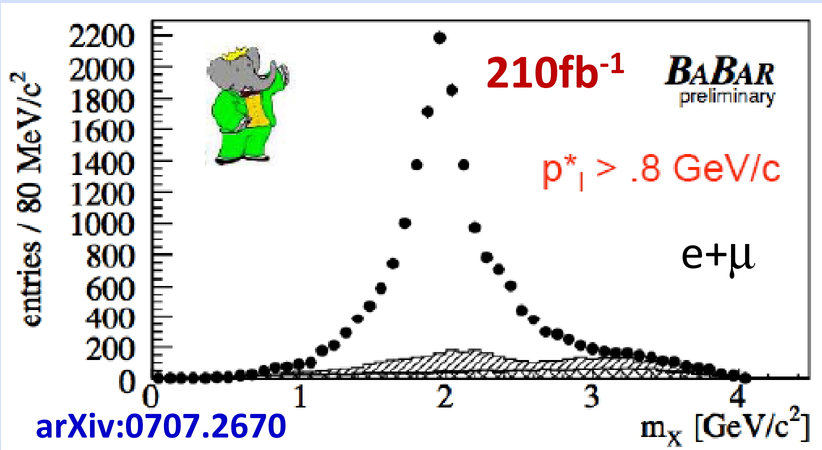
M_{X_c} and E_ℓ moments

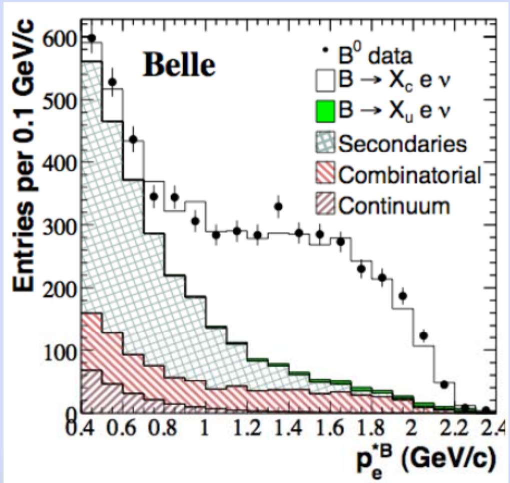
- One B fully reconstructed into hadrons (B_{tag})
- One lepton from the other B (signal)

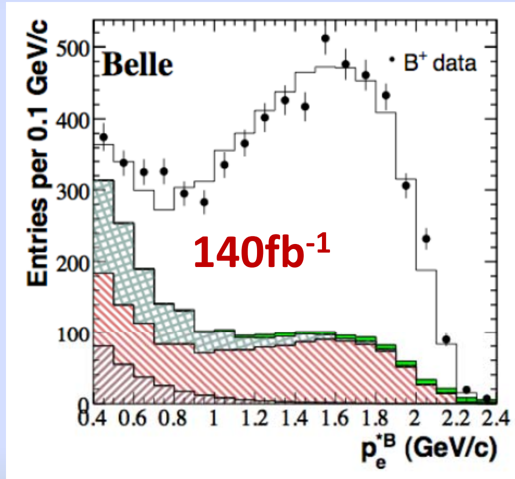
- Rest of particles $\rightarrow$ measure m_x
- Event by event calibration
- $< M_x^n >$ measured as function of p^*_ℓ cut (from 0.8 to 1.9 GeV/c)

- $\rightarrow$ measure E_ℓ (electrons)
- Unfolded with SVD algorithm
- $< E_e^n >$ measured as function of p^*_e cut (from 0.4 to 2. GeV/c)

PRD 75, 032001(2007)

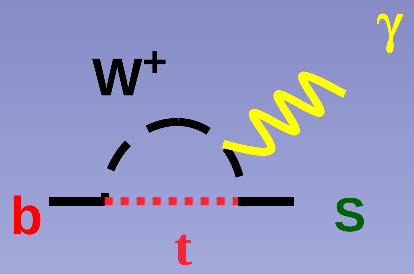






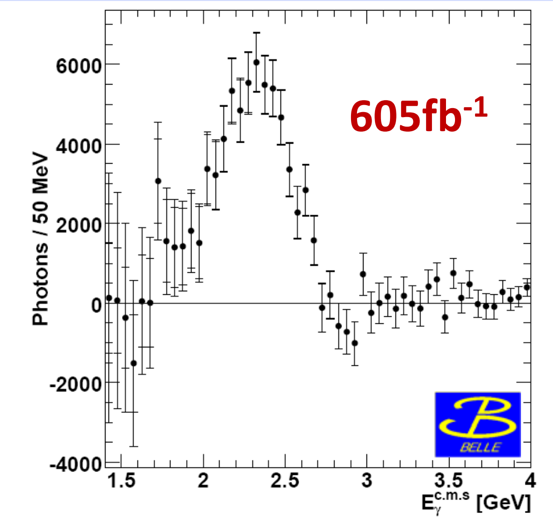
- $< M_x^n >$ for n=1,2,3,4,5,6

- $< E_e^n >$ for n=0,1,2,3,4



Eγ moments

- Select high energy photons (E_γ*> 1.4 GeV)
- Off-peak subtraction,
  veto to photons from π^0 and η
- Unfolded with SVD algorithm
- < E_γ^n> measured as function of E_γ cut (from 1.7 to 2.1 GeV)



- < E_γ^n> for n=1,2

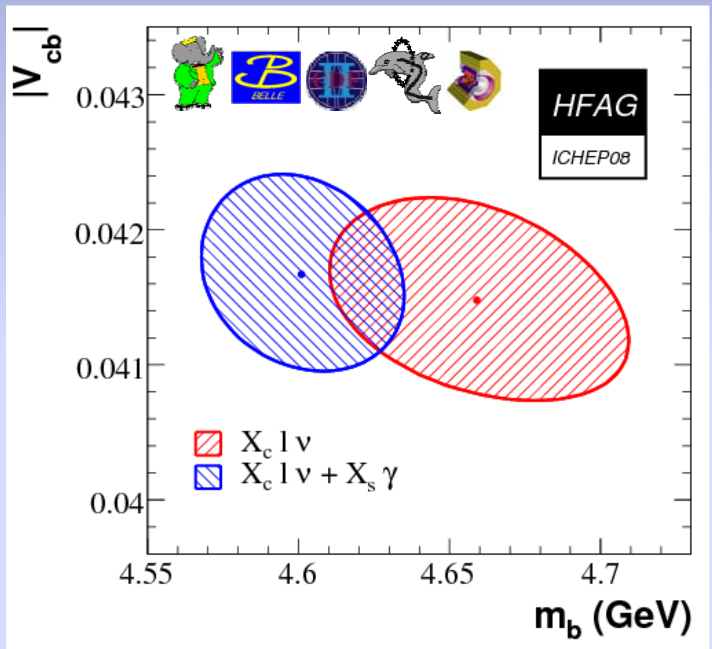
PRD 78, 032016(2008)

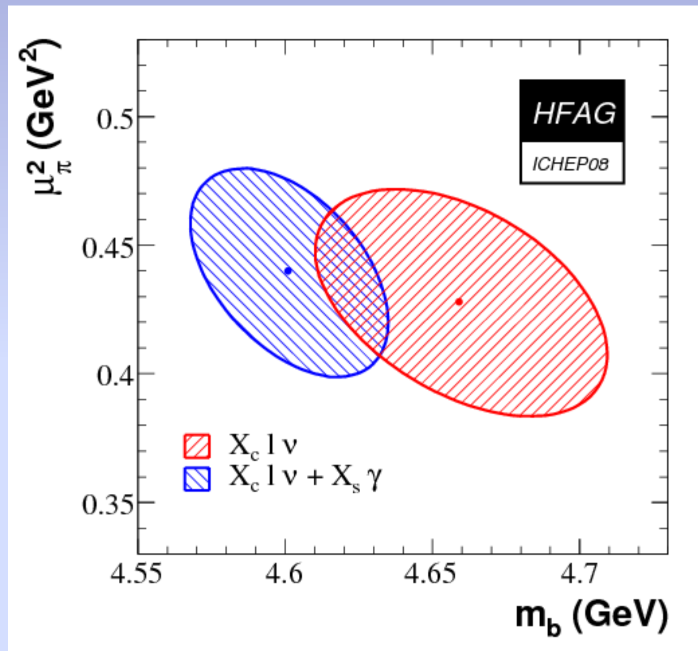
All measurements:

- Belle E_γ, 605/fb [arXiv:0804.1580] preliminary
- BaBar E_l, M^2_X, 210/fb [arXiv:0707.2670] preliminary
- Belle E_l, 140/fb [PRD 75, 032001 (2007)]
- Belle M^2_X, 140/fb [PRD 75, 032005 (2007)]
- DELPHI E_l, M^2_X, 3.4M Z [EPJ C45, 35 (2006)]
- BaBar, E_γ, 82/fb [PRL 97, 171803 (2006)]
- BaBar, E_γ, 82/fb [PRD 72, 052004 (2005)]
- CDF, M^2_X, 180/pb [PRD 71, 051103 (2005)]
- Belle, E_γ, 140/fb [PRL 93, 061803 (2004)]
- CLEO, M^2_X, 9/fb [PRD 70, 032002 (2004)]
- BaBar, E_l, 47/fb [PRD 69, 111104 (2004)]
- BaBar, M^2_X, 89M BB [PRD 69, 111103 (2004)]
- CLEO, E_γ, 9/fb [PRL 87, 251807 (2001)]

|V_{cb}| from inclusive sl decays

→ Using 27 moments from BaBar, 25 moments from Belle and 12 moments from other experiments **(http://www.slac.stanford.edu/xorg/hfag/semi/ichep08/gbl_fits/kinetic/)**





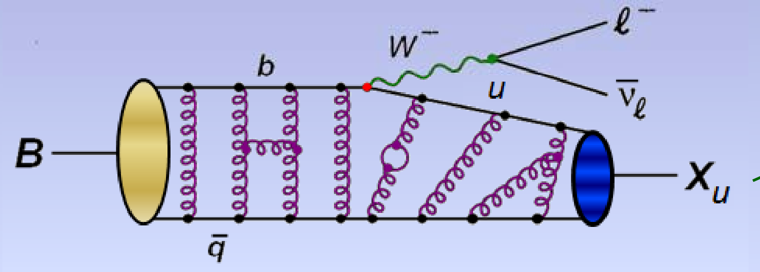
$|V_{cb}| = (41.67 \pm 0.43_{fit} \pm 0.08_{\tau B} \pm 0.58_{th}) \times 10^{-3}$

$m_b = (4.601 \pm 0.034)$ GeV **$\mu^2_\pi = (0.440 \pm 0.040)$ GeV^2**

(Exclusive ($B \to D^*$): $|V_{cb}| = (38.4 \pm 0.6_{exp} \pm 0.9_{latt}) \times 10^{-3}$ → **$|V_{cb}|^{incl} - |V_{cb}|^{excl}$: 2.5σ**

|Vub| from exclusive sl decays

$$\frac{d\Gamma(B\to\pi\ell\nu)}{dq^2} = \frac{G_F^2}{24\pi^3}|V_{ub}|^2\, p_\pi^3\, |f_+(q^2)|^2$$



Untagged $B\to\pi\ell\nu$

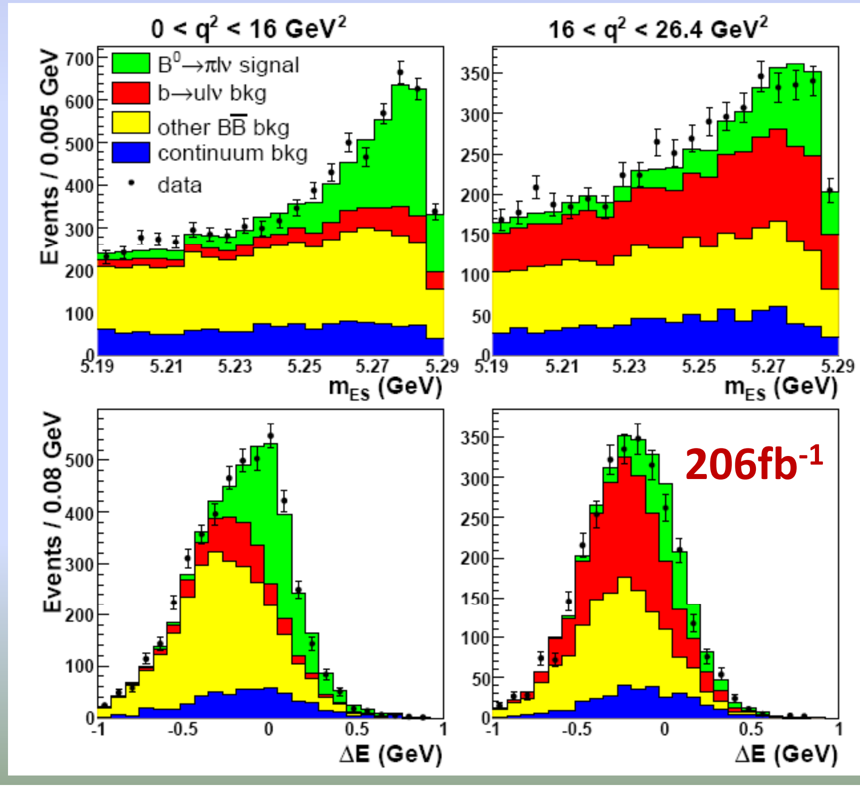
- ν reconstruction from full event ($p_\nu = p_{beams} - \Sigma p_i$)
- Fit $\Delta E = E_B - \sqrt{s}/2$ and $m_{ES} = \sqrt{s/4 - |\vec{p}^*_B|^2}$ to extract the signal yield
- $q^2 = (p_B - p_\pi)^2$ in 12 bins $\to$ Form factor fit

$\mathcal{B}(B^0\to\pi^-\ell\nu) = (1.46\pm0.07\pm0.08)\times10^{-4}$

Analysis methods:

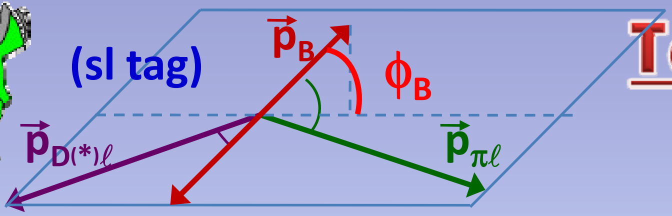
- **Untagged** (high stat., most precise)
- **Tagged** (hadron or semileptonic)

$\pi, \eta, \eta', \rho, \omega$ (BR ~ 0.01% + large $b\to c$ bkg)



PRL 98, 091801(2007)

|Vub| from exclusive sl decays

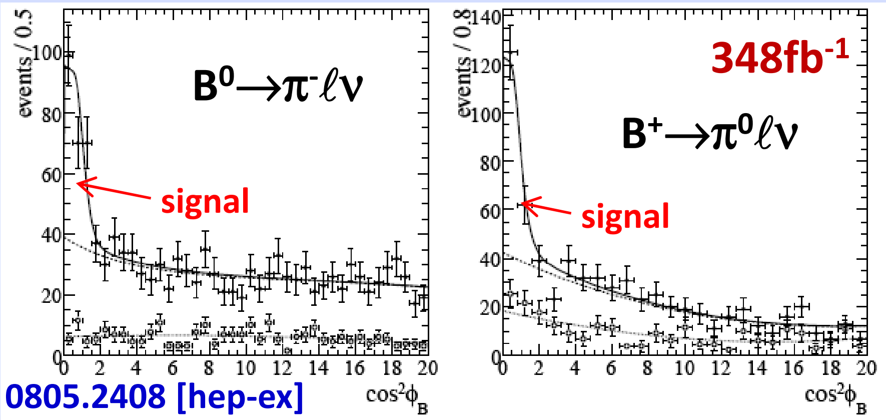


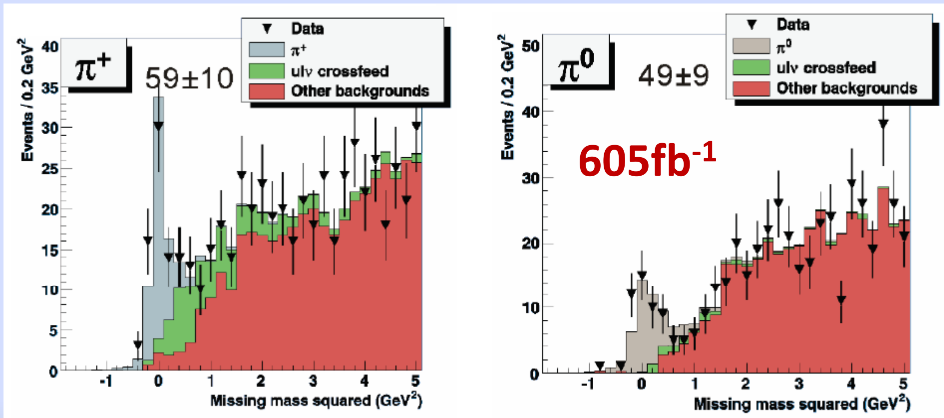
Tagged $B\to\pi\ell\nu$

(hadronic tag)

- One B decaying into $B \to D^{(*)}\ell\nu$ (B_{tag})
- Other lepton ($-q_\ell$) from the other B
- Define the systems **Y**=$D^{(*)}\ell$ and **X**=$\pi\ell$
- Fit to $\cos^2\phi_B$ in 3 q^2 bins

- Reconstruct one B into hadrons (B_{tag})
- Select the lepton from the other B
- select the π (rec. ρ or ω into pions)
- Reconstruct the missing mass:
  $m^2_{miss} = (p_{\Upsilon(4s)} - p_{Btag} - p_\pi - p_\ell)^2$
- Extract yields in 3 q^2 bins



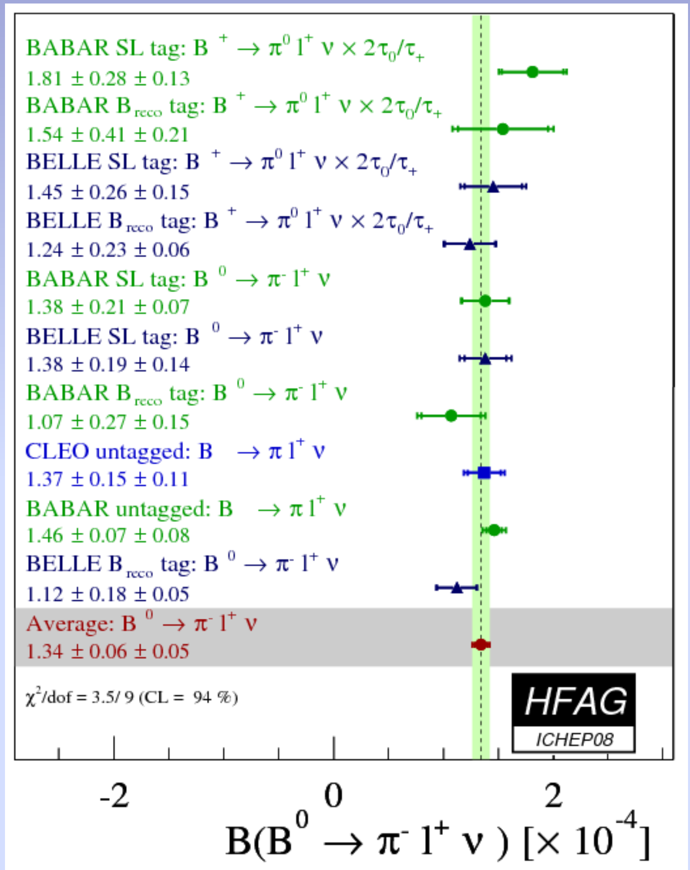


$\mathcal{B}(B^0\to\pi^-\ell\nu) = (1.54\pm0.17\pm0.09)\times10^{-4}$

$\mathcal{B}(B^0\to\pi^-\ell\nu) = (1.12\pm0.18\pm0.05)\times10^{-4}$

$\mathcal{B}(B^+\to\pi^0\ell\nu) = (0.66\pm0.12\pm0.03)\times10^{-4}$

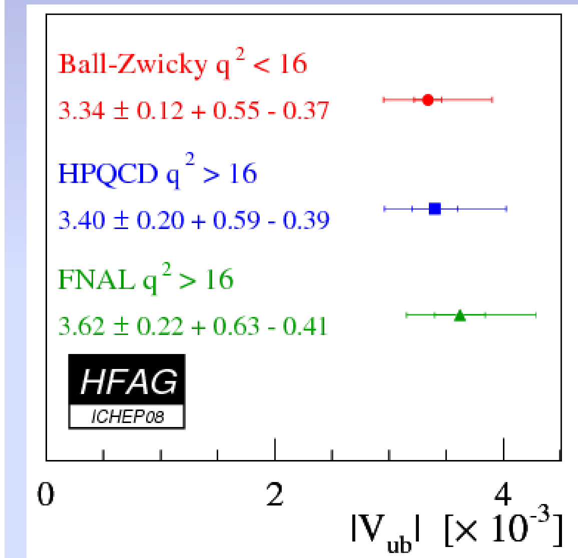
|Vub| from exclusive sl decays



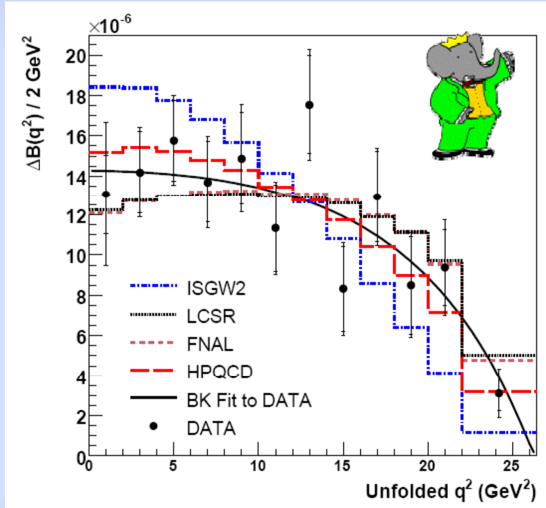
$\mathcal{B}$ ($B^0 \to \pi^- \ell \nu$)= (1.34±0.06± 0.05)x10^{-4}

Form factor necessary to extract $|V_{ub}| \to$ **theory**

Models depend on q^2 region:



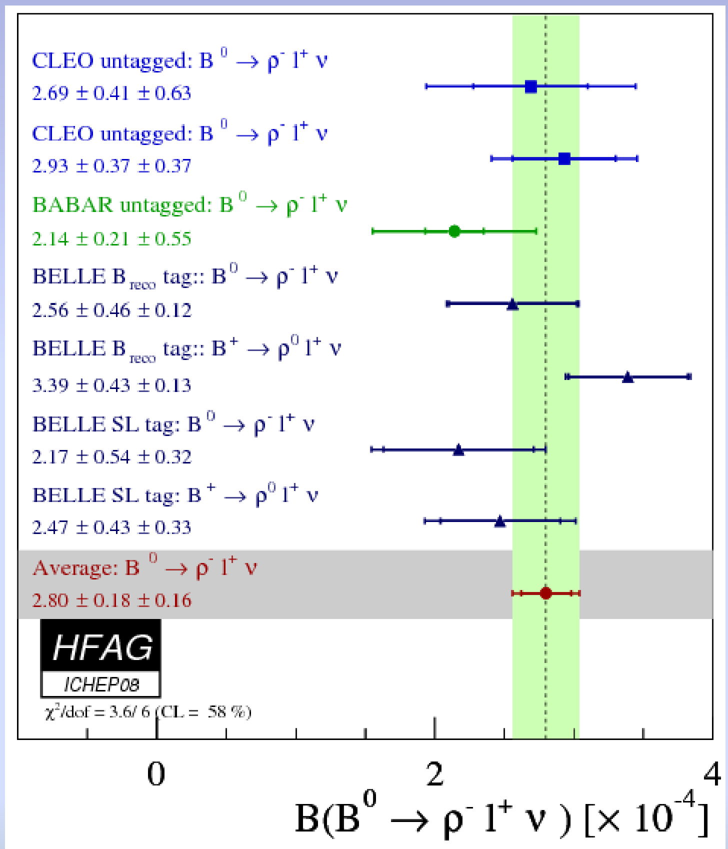
(Untagged analysis can measure the form factor from data)



PRL 98, 091801(2007)

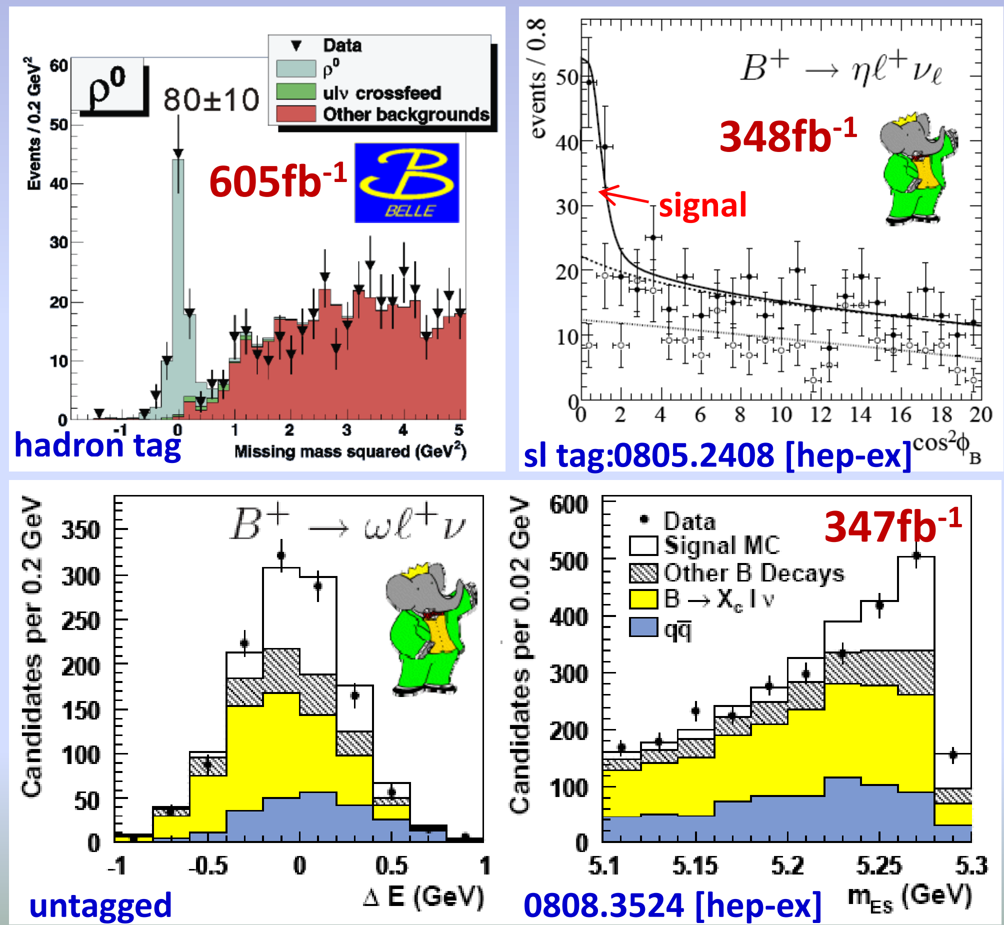
|Vub| from exclusive sl decays

$B \to (\rho, \eta, \eta', \omega)\, \ell\nu$



$\mathcal{B}(B^0 \to \rho^- \ell\nu) = (2.80 \pm 0.18 \pm 0.16) \times 10^{-4}$

- Check theoretical calculations
- Composition of $B \to X_u \ell\nu$

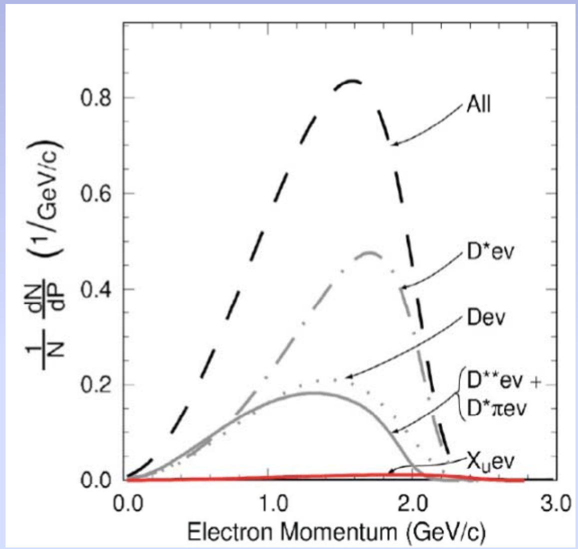


|Vub| from inclusive sl decays

50 : 1

$B \to X\ell\nu = B \to X_c\ell\nu + B \to X_u\ell\nu$

$$|V_{ub}| = \sqrt{\frac{\Delta B(B \to X_u \ell \nu)}{\Delta\zeta \cdot \tau_B}}$$

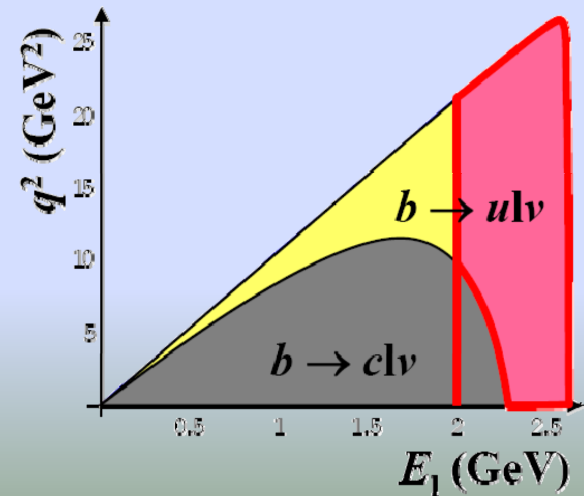


- Theory needs low momentum cuts to extract $|V_{ub}|$ (OPE breaks down in the Shape Function (SF) region: low m_x^2 and q^2)
- OPE parameteres (m_b, μ^2_π) from moments in $B \to X_c\ell\nu$ and $B \to X_s\gamma$
- Experiments need high momentum cuts to suppress $b \to c$ bkg

Experimental technique: **Measure partial BR**

- Tagged (sl or hadronic) or untagged
- Use kinematic variables to suppress as much as possible $b \to c$ (keeping reliable theoretical calculations):

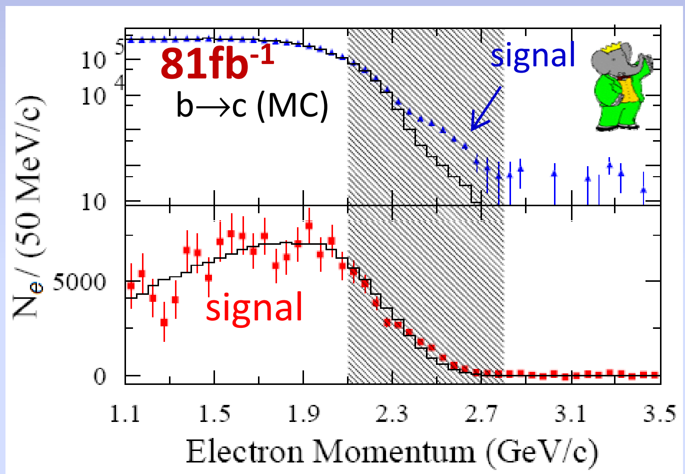
E_ℓ, q^2, m_X and $P_+ = E_X - |p_X|$



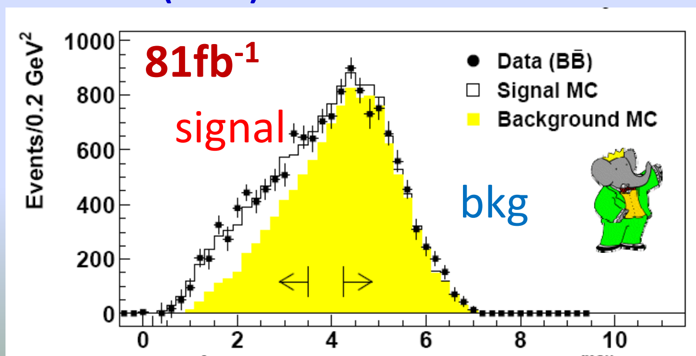
Untagged: endpoint method

- Select regions below charm threshold
- Key: bkg subtraction (off-peak data, endpoint, MC…)

⇒ $b \to c$ bkg constrained by data in the low energy region



PRB601:28(2005)

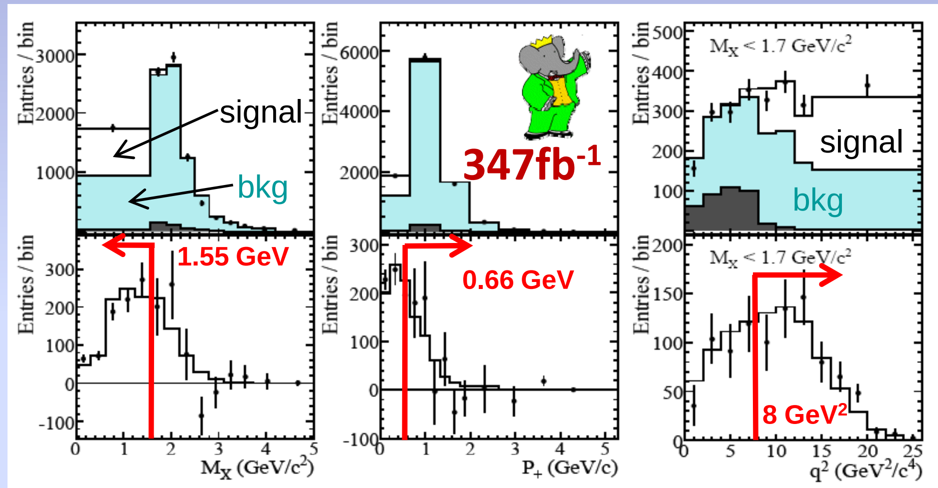


S_h^{max}=f(E_ℓ, q^2) = maximum m_x squared s_h^{max} (GeV^2)

PRL95:111801(2005)

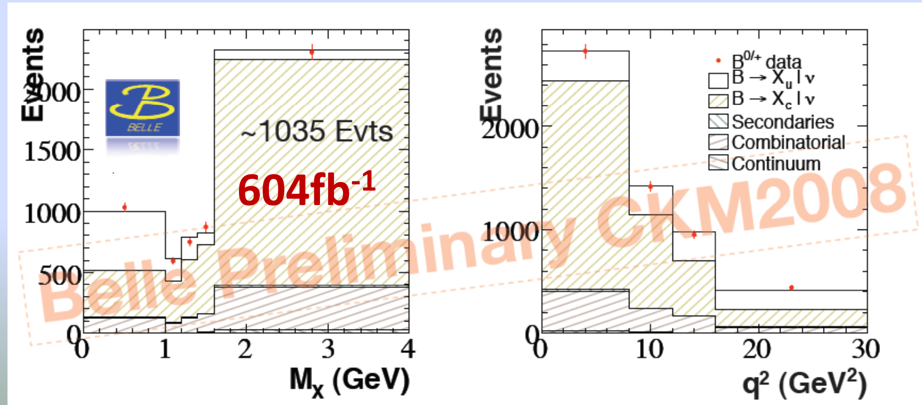
Tagged (hadrons or sl)

- One B fully reconstructed
- Access to all kinematics (m_x, q^2, P_+) for the signal side



~40-60% acceptance

arXiv:0708.3702

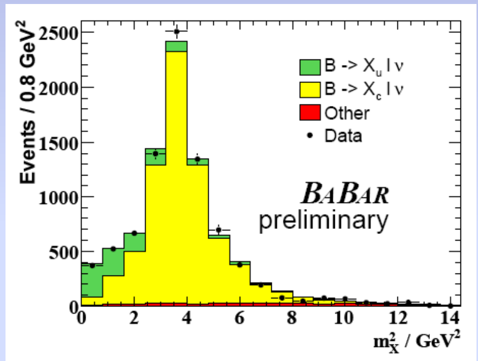


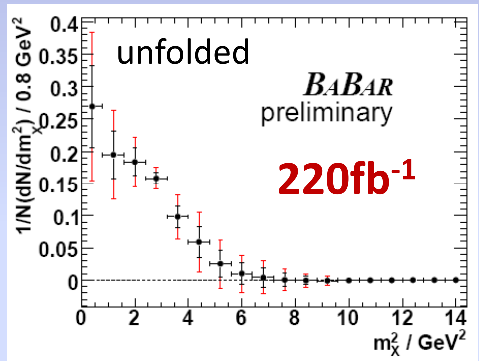
(new Belle multivariate analysis → no hard cuts, 90% PS)

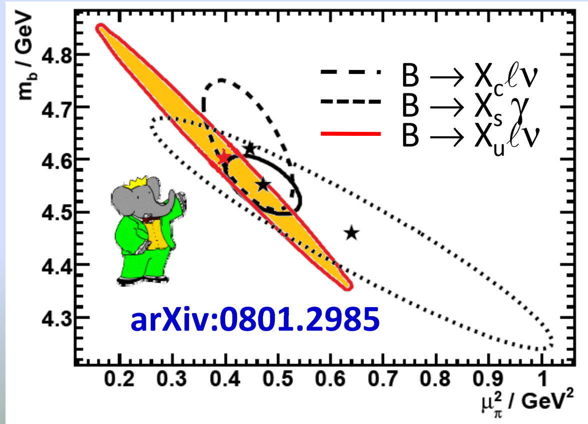
|Vub| from inclusive sl decays

Tagged (hadrons or sl)

- Moments of the full mass spectrum
- OPE fit to extract m_b, μ_π^2 and ρ.





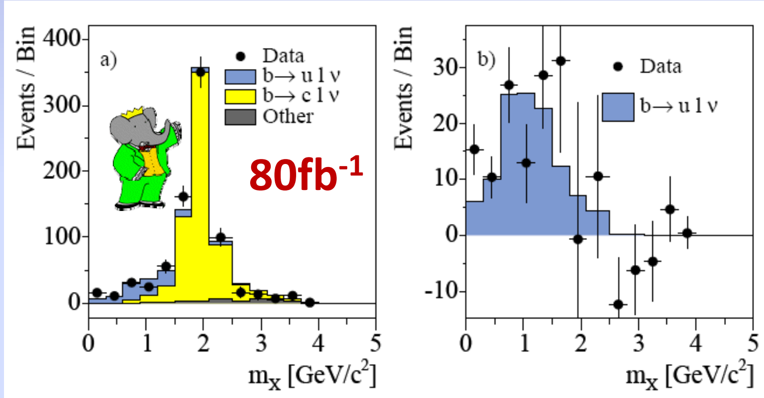


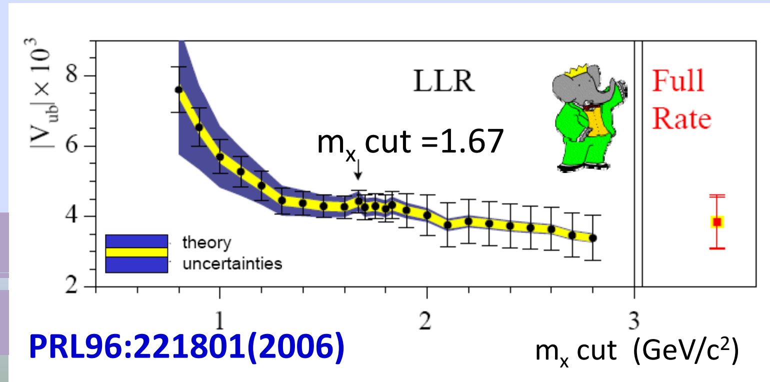
m_b =(4.604 ± 0.250) GeV

μ^2_π =(0.398 ± 0.240) GeV^2

- Relating the rate to $b \to s\gamma$ to reduce model dependence (LLR method)

$$\Gamma(B \to X_u \ell \nu) = \frac{|V_{ub}|^2}{|V_{ts}|^2} \int W(E_\gamma) \frac{d\Gamma(B \to X_s \gamma)}{dE_\gamma} dE_\gamma$$





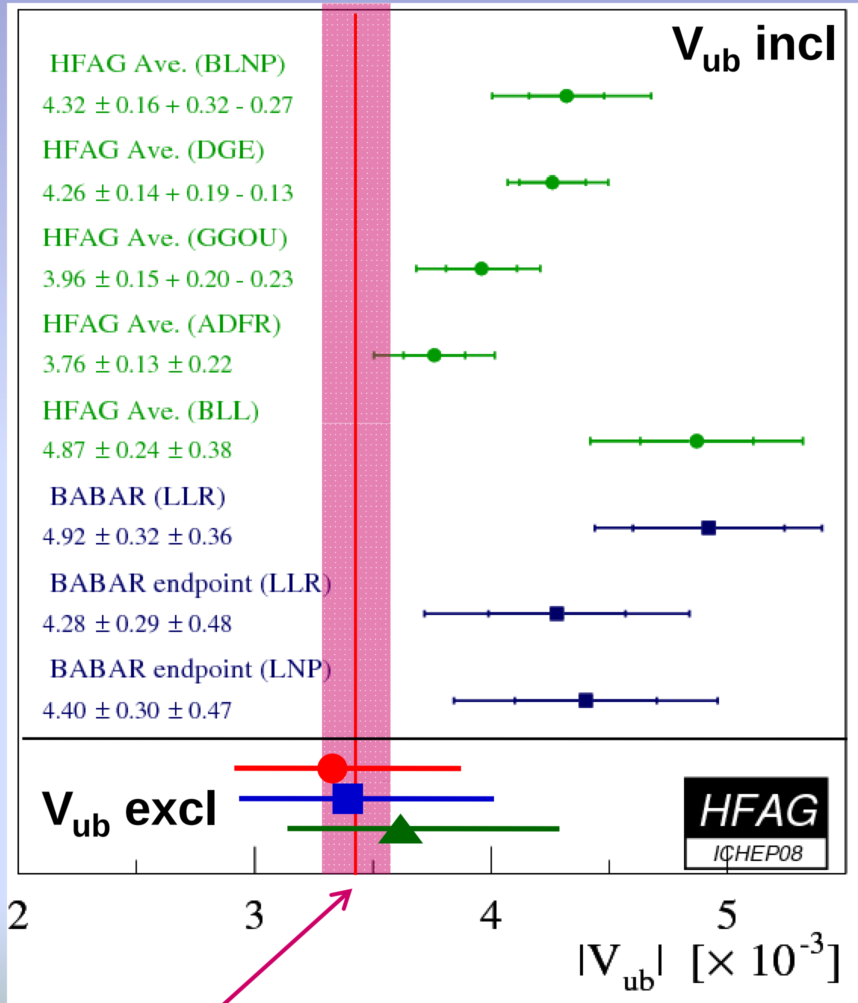
|Vub| from inclusive sl decays

OPE based + SF

- BLNP: HQE with systematic introduction of SF
  PRD71:073006 (2005)
- BLL: phase space in m_x-q^2 *with reduced SF*
  PRD64:113004 (2001)
- GGOU: kinetic scheme
  JHEP 10(2007) 058
- LNP (LLR): $b \to s\gamma$ directly related to $b \to u\ell\nu$
  JHEP 0510:084 (PLB 486:86)

No SF introduced (model non-perturbative QCD)

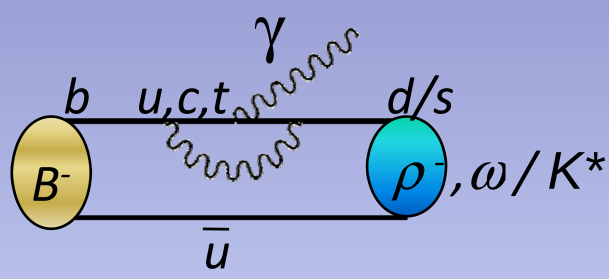
- DGE: Dressed Gluon Exponentiation
  JHEP 0601:097 (2006)
- ADFR: Analytic coupling
  PRD74:03400(4,5,6) (2006)



More data, more SP + improvements from theory needed

$|V_{ub}|$ from UTfit =$(3.44 \pm 0.16)10^{-3}$

|Vtd/Vts| from radiative decays



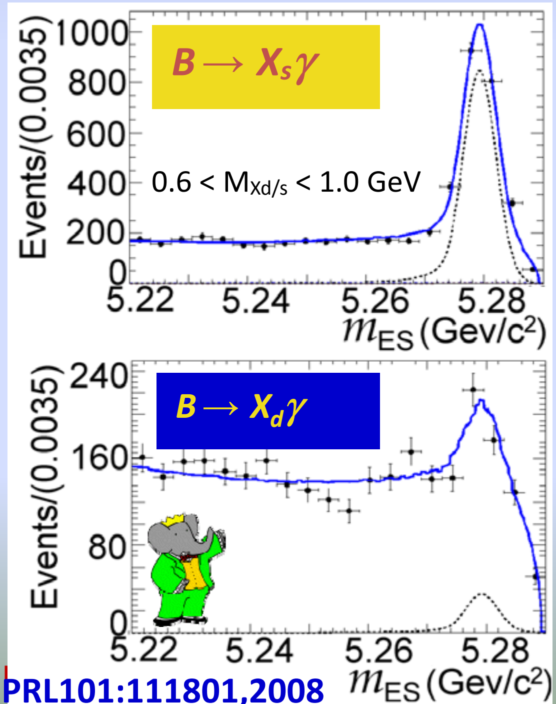
Exclusive

$$\frac{B(B\to\rho,\omega\gamma)}{B(B\to K^*\gamma)} \sim \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{1}{\xi^2}$$

Form factors

Inclusive **(Sum of all channels)**

$$\frac{B(B\to X_d\gamma)}{B(B\to X_s\gamma)} \sim \left|\frac{V_{td}}{V_{ts}}\right|^2 \text{ x theory}$$

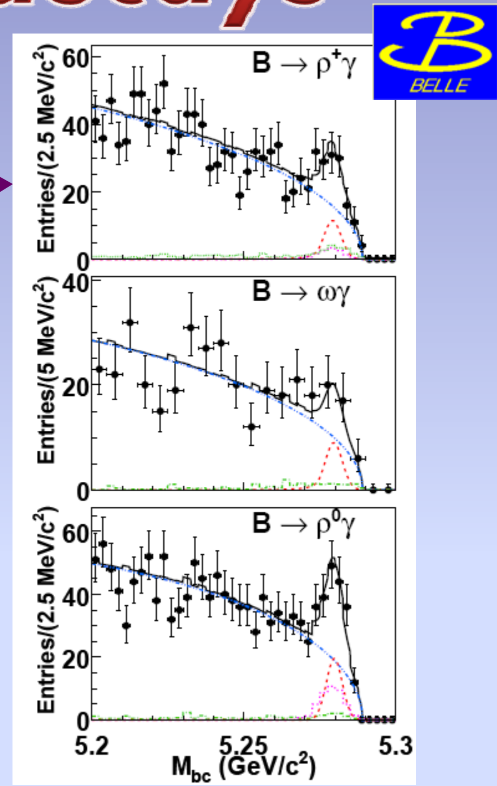


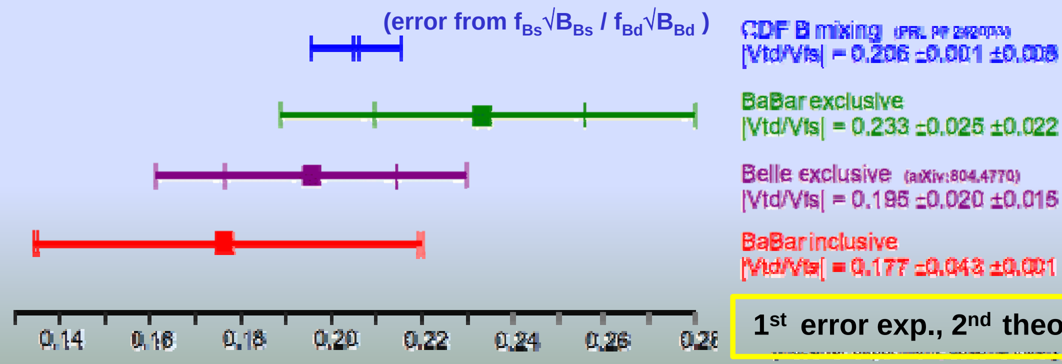
PRL101:111801,2008

arXiv:0804.4770

- Select high energy photons
- veto to photons from π^0 and η
- remove bkg from continuum
- Yield from $\Delta E = E_B - \sqrt{s}/2$

and $m_{ES} = \sqrt{s/4 - |\vec{p^*_B}|^2}$





1st error exp., 2nd theo.

Need SuperB!

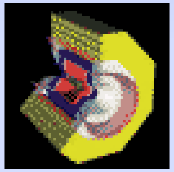
Summary

The CKM matrix:

β Decays ($0^+ \to 0^+$) — τ decays

δVud/Vud ~ 0.03%	δVus/Vus ~ 0.4%	δVub/Vub ~ 8%
δVcd/Vcd ~ 5%	δVcs/Vcs ~ 11%	δVcb/Vcb ~ 2%
δ(Vtd/Vts)/(Vtd/Vts) ~ 3%		δVtb/Vtb ~ 15%

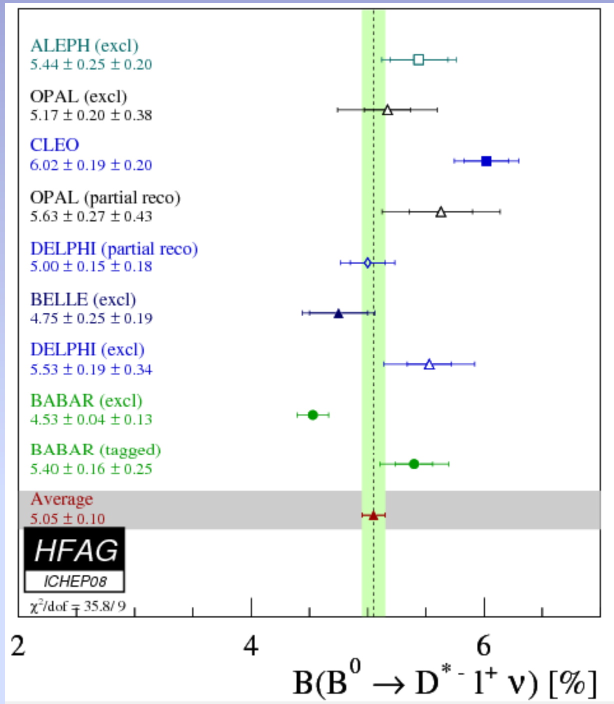
Need theory improvements (excl . vs incl. ??)



charm sl decays

HFAG

Backup

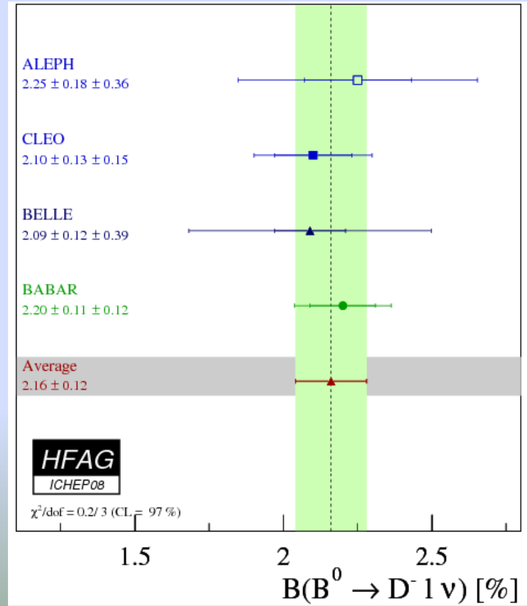


Exclusive Branching Fraction: B^0 -> D*lnu

Experiment	BF (rescaled) [%]	Remarks
ALEPH (excl)	5.44 +/- 0.25 +/- 0.20	Phys.Lett.B395:373-387,1997 [Spires]
OPAL (excl)	5.17+/- 0.20 +/- 0.38	Exclusive reco, Phys.Lett.B482:15-30,2000 [hep-ex/0003013]
CLEO	6.02 +/- 0.19 +/- 0.20	Phys.Rev.Lett.89:081803,2002
OPAL (partial reco)	5.63 +/- 0.27 +/- 0.43	Partial reco, Phys.Lett.B482:15-30,2000 [hep-ex/0003013]
DELPHI (partial reco)	5.00 +/- 0.15 +/- 0.18	Partial reco, Phys.Lett.B510:55-74,2001 [hep-ex/0104026]
BELLE (excl)	4.75 +/- 0.25 +/- 0.19	Phys.Lett.B526:247-257,2002 [hep-ex/0111060]
DELPHI (excl)	5.53 +/- 0.19 +/- 0.34	Eur.Phys.J.C33:213,2004 [hep-ex/0401023]
BABAR (excl)	4.53 +/- 0.04 +/- 0.13	Phys.Rev.D77:032002,2008 [arXiv:0705.4008 [hep-ex]]
BABAR (tagged)	5.40 +/- 0.16 +/- 0.25	arXiv:0712.3503 [arXiv:0712.3503 [hep-ex]]
Average	**5.05 +/- 0.10**	**chi2/dof = 35.8/9 (CL = 0.00005)** eps pdf gif

Exclusive Branching Fraction: B^0 -> Dlnu

Experiment	BF (rescaled) [%]	Parameters		Remarks
ALEPH	2.25 +/- 0.18+/- 0.36	input	parameters	Phys.Lett.B395:373-387,1997 [Spires]
CLEO	2.10+/- 0.13+/- 0.15	input	parameters	Phys.Rev.Lett.82:3746,1999 [hep-ex/9811042]
BELLE	2.09+/- 0.12+/- 0.39	input	parameters	Phys.Lett.B526:258-268,2002 [hep-ex/0111082]
BABAR	2.20+/- 0.11+/- 0.12	input	parameters	[arXiv:0712.3503 [hep-ex]]
Average	**2.16+/- 0.12**	**chi2/dof = 0.2/3 (CL = 0.97)**		eps pdf gif



HFAG

Backup

Global Fit in the Kinetic Scheme to the Moments in B -> $X_c$lnu and B -> $X_s$gamma

Fit Results in the Kinetic Scheme

Input	$\|V_{cb}\|$ (10^{-3})	m_b^{kin} (GeV)	mu^2_{pi} (GeV^2)		chi^2/ndf.
all moments ($X_c$lnu and $X_s$gamma)	41.67 +/- 0.43(fit) +/- 0.08(tau_B) +/- 0.58(th)	4.601 +/- 0.034	0.440 +/- 0.040	details	29.7 / (64-7)
$X_c$lnu only	41.48 +/- 0.47(fit) +/- 0.08(tau_B) +/- 0.58(th)	4.659 +/- 0.049	0.428 +/- 0.044	details	24.1 / (53-7)

Experiment	Hadron moments	Lepton moments	Photon moments	References
BaBar	n=2 c=0.9,1.1,1.3,1.5 n=4 c=0.8,1.0,1.2,1.4 [1]	n=0 c=0.6,1.2,1.5 n=1 c=0.6,0.8,1.0,1.2,1.5 n=2 c=0.6,1.0,1.5 n=3 c=0.8,1.2 [2]	n=1 c=1.9,2.0 n=2 c=1.9 [3,4]	[1] arXiv:0707.2670 [2] Phys.Rev. D69 (2004) 111104 [3] Phys.Rev. D72 (2005) 052004 [4] Phys. Rev. Lett. 97, 171803 (2006)
Belle	n=2 c=0.7,1.1,1.3,1.5 n=4 c=0.7,0.9,1.3 [5]	n=0 c=0.6,1.0,1.4 n=1 c=0.6,0.8,1.0,1.2,1.4 n=2 c=0.6,1.0,1.4 n=3 c=0.8,1.0, 1.2 [6]	n=1 c=1.8,1.9 n=2 c=1.8,2.0 [7]	[5] Phys.Rev. D75 (2007) 032005 [6] Phys.Rev. D75 (2007) 032001 [7] arXiv:0804.1580
CDF	n=2 c=0.7 n=4 c=0.7 [8]	.	.	[8] Phys.Rev. D71 (2005) 051103
CLEO	n=2 c=1.0,1.5 n=4 c=1.0,1.5 [9]	.	n=1 c=2.0 [10]	[9] Phys.Rev. D70 (2004) 032002 [10] Phys.Rev.Lett. 87 (2001) 251807
DELPHI	n=2 c=0.0 n=4 c=0.0 [11]	n=1 c=0.0 n=2 c=0.0 n=3 c=0.0 [11]	.	[11] Eur.Phys.J. C45 (2006) 35-59