Recent Results on Semileptonic *B D*ecays from BaBar

- $B^- \to D^{*0} e^- \nu$ BF (branching fraction) and FF (form factor) slope
- $B \to D^{(*)}(\pi) l \nu$ BF
- $B \to D^{**} l \nu$ BF
- $B \to X_u l \nu$ BF and $|V_{ub}|$

PHENO 08, 04/29/2008
K. Hamano, University of Victoria

University of Victoria

Semileptonic *B* decays and $|V_{xb}|$

- Ideal laboratory to measure CKM matrix elements $|V_{cb}|$ and $|V_{ub}|$
- Experimentally accessible : BF ~ 10^{-1} – 10^{-4}
  - $B \to X_c l \nu$ decay rates $\propto |V_{cb}|^2$ (X_c is a charmed meson system)
  - $B \to X_u l \nu$ decay rates $\propto |V_{ub}|^2$ (X_u is a non-charmed meson system)
- Theoretically accessible
  - $B \to X_c l \nu$ decays -> HQET (Heavy Quark Effective Theory) can be applied with good precision.
  - $B \to X_u l \nu$ decays -> Since *u* quark is not heavy, QCD calculations are more challenging.

Inclusive decays : BLNP : B.O.Lange et.al. Phys.Rev.D72(2005)073006
DGE : J.R.Anderson et.al. JHEP 0601(2006)097
GGOU : P.Gambino et.al. JHEP 0710(2007)058

B^- -> $D^{*0}e^-\nu$ BF and FF (1)

arXiv:0712.3493v2[hep-ex]
Submitted to Phys.Rev.Lett.

- Motivation
  - $B \to D^* l \nu$ decay rate is proportional to the square of a FF (form factor) $F(w)$ which can be expressed by a slope ρ^2.

    $F(w) = F(1)\,[1 - \rho^2\,(w - 1)]$

    where w is the velocity transfer related to momentum transfer q^2

    $$w = \frac{m_B^2 + m_{D*}^2 - q^2}{2 m_B m_{D*}}$$

  - In practice, more complicated CLN parameterization of $F(w)$ was used (Nucl.Phys. B530 (1998) 153),
  - $B^0 \to D^{*-} l^+ \nu$ mode has already been measured.

    (BaBar : Phys. Rev. D77, 032002 (2008))

    - $\rho^2 = 1.191 \pm 0.048 \pm 0.028$

- Event selection (205 fb^{-1})
  - e momentum > 1.2 GeV
  - Reconstruct $D^{*0} \to D^0\pi^0$, $D^0 \to K^-\pi^+$ and $\pi^0 \to \gamma\gamma$
  - Energy of γ > 30 MeV

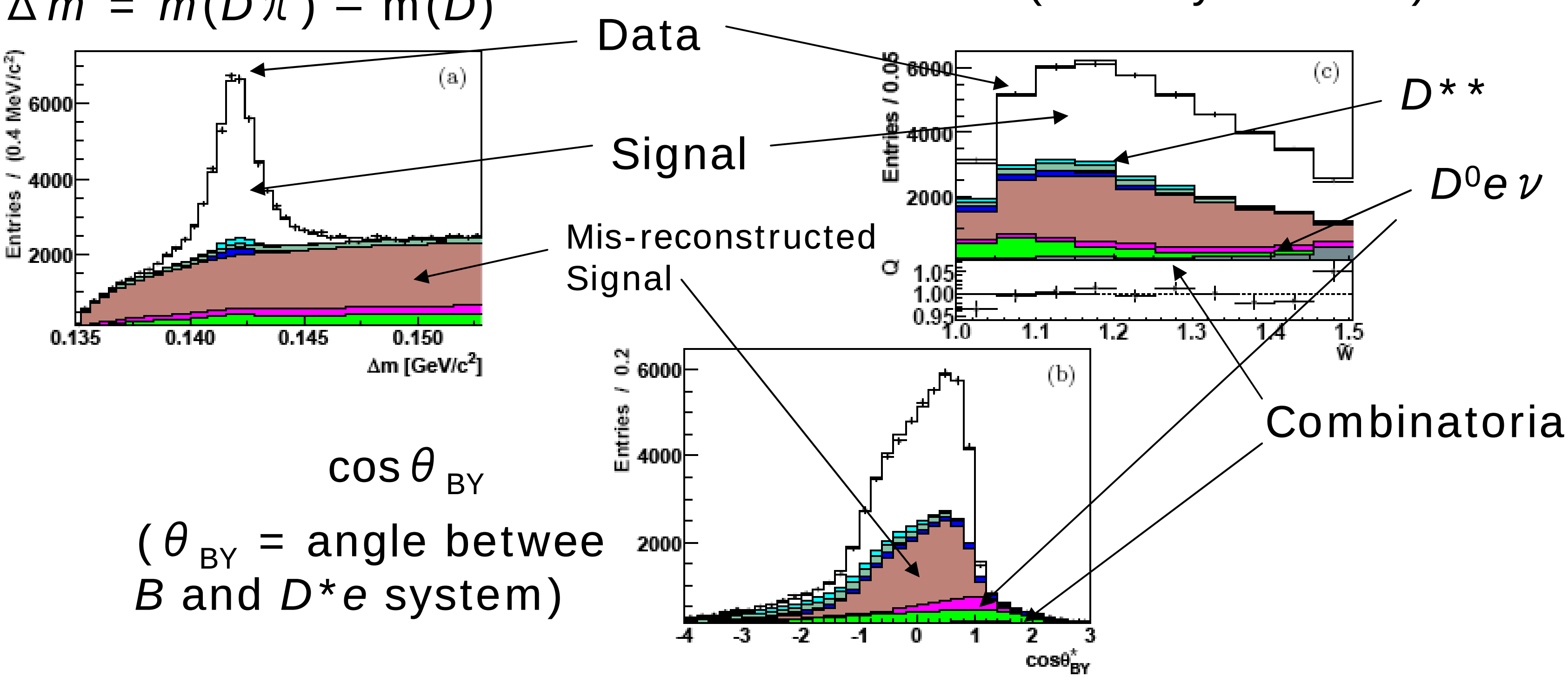
$B^- \to D^{*0} e^- \nu$ BF and FF (2)

$\Delta m = m(D\pi) - m(D)$

W (velocity transfer)

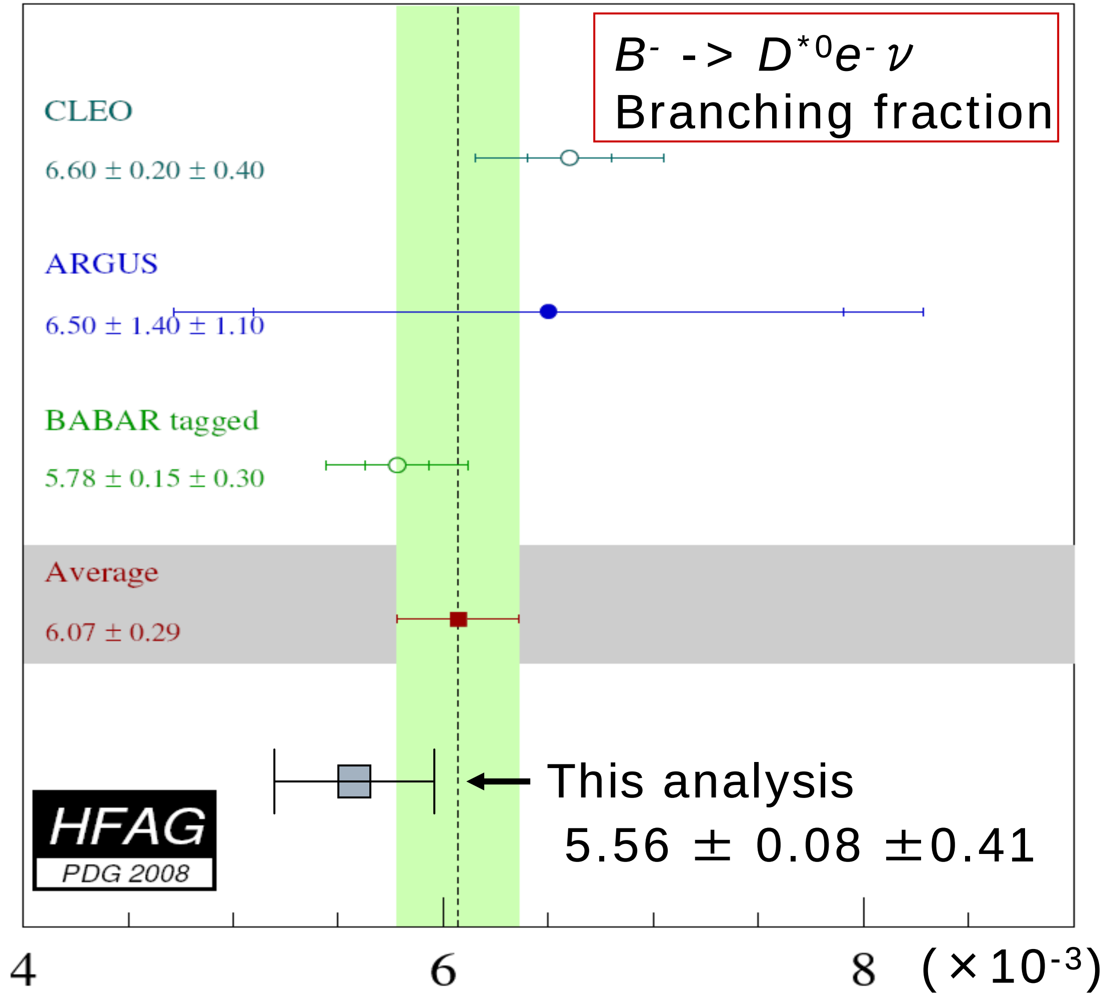
$\cos\theta_{BY}$

(θ_{BY} = angle betwee B and D^*e system)



- Results agree with previous BaBar measurements.
  - $\rho^2 = 1.16 \pm 0.06 \pm 0.08$
  - $F(1)|V_{cb}| = (35.9 \pm 0.6 \pm 1.4) \times 10^{-3}$
  - BF (branching fraction) = $(5.56 \pm 0.08 \pm 0.41)$ %

$B^- \to D^{*0} e^- \nu$ BF and FF (3)



HFAG (Heavy Flavor Averaging Group), http://www.slac.stanford.edu/xorg/hfag/

$B \to D^{(*)}(\pi)l\nu$ BF (1)

Phys.Rev.Lett.100(2008)151802
(arXiv:0712.3503v1[hep-ex])

- Motivation
  - Exclusive $B \to Dl\nu$, $B \to D^{*}l\nu$ and $B \to D^{**}l\nu$ BF do not add up to inclusive $B \to X_c l\nu$ BF
  - Existing $B \to D^{*}l\nu$ BF measurements show some disagreements.
- Simultaneously determine all three exclusive BF.
- Fully reconstruct one B_{tag} (efficiency 0.3-0.5 %) and look at the other B
- Event selection (341 fb^{-1}, 378 M $B\bar{B}$ pairs)
  - Do not explicitly identify D^{**}

    Reconstruct only $D^{*}\pi$ and $D\pi$ pairs

    -> measure inclusive $B \to D^{(*)}\pi l\nu$ BF

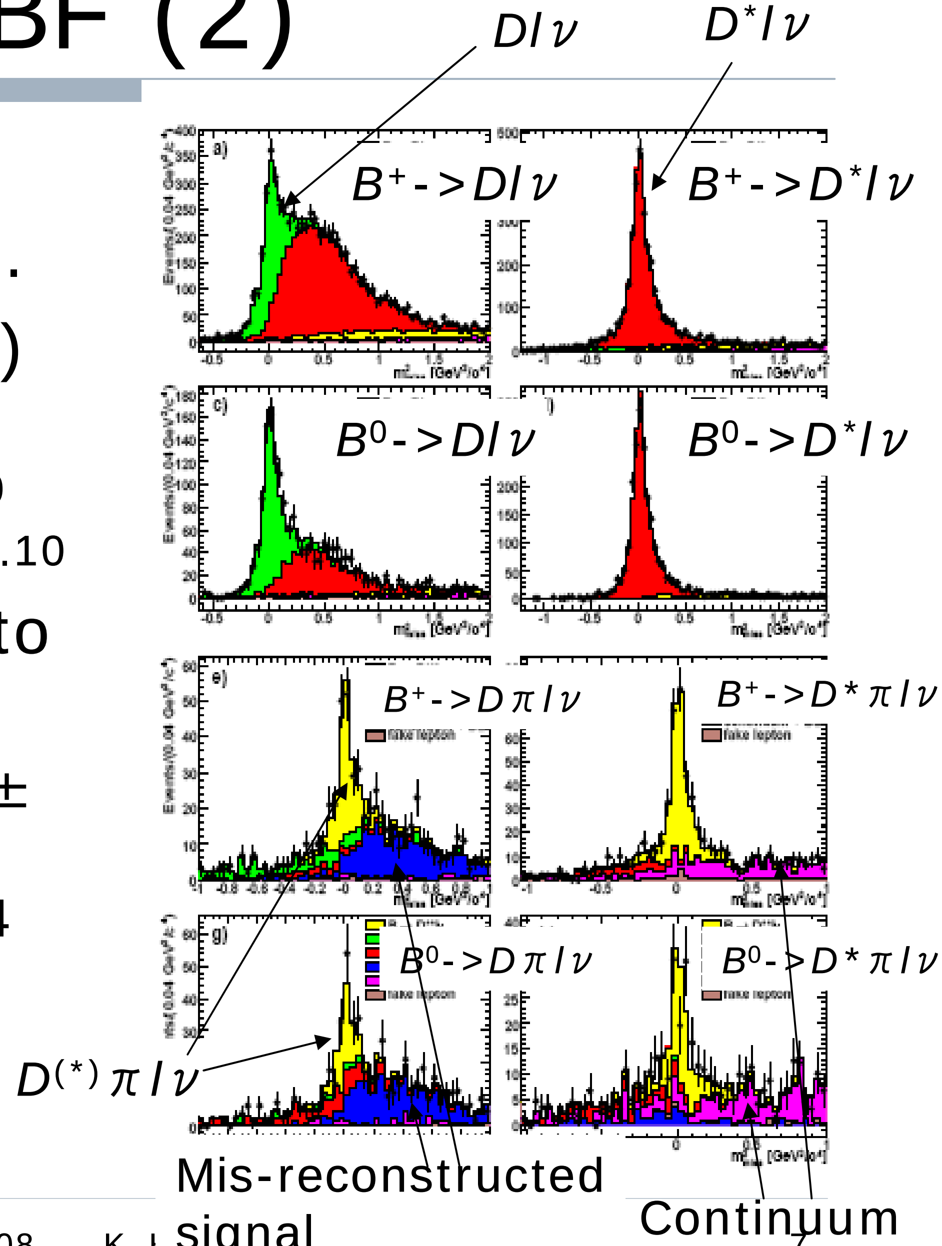
B -> $D^{(*)}(\pi)l\nu$ BF (2)

- Use missing mass squared PDF for fitting.
- Results of B^+ BF (in %)

  BF($D^0 l\nu$) = 2.33 ± 0.09 ± 0.09

  BF($D^{*0} l\nu$) = 5.83 ± 0.15 ± 0.30

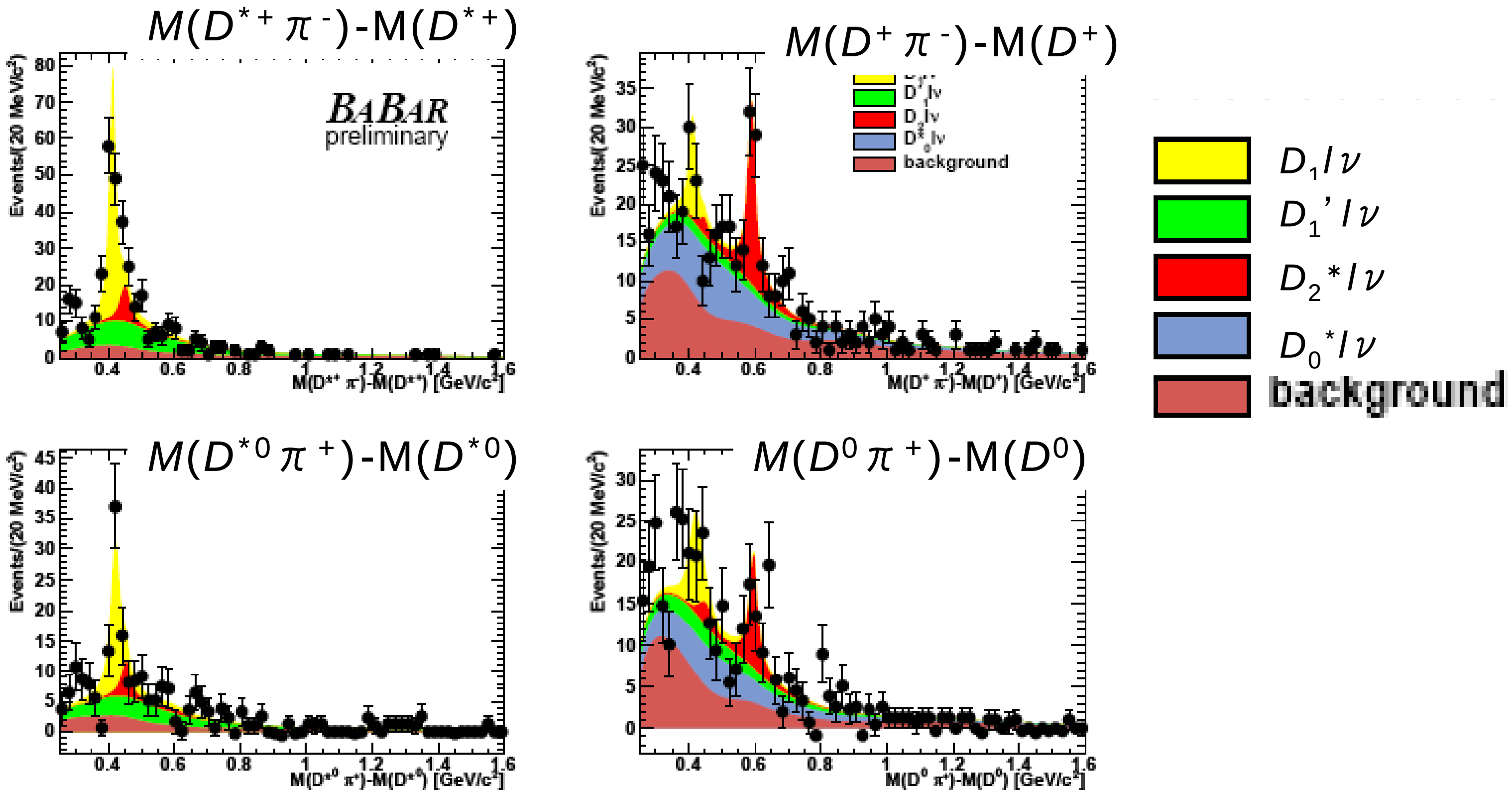
  BF($D^{(*)}\pi l\nu$) = 1.52 ± 0.12 ± 0.10
- Comparable accuracy to world average.
- Sum of exclusive BF is 11 ± 4 % smaller than inclusive BF(B^-->$X_c l\nu$) = 10.8 ± 0.4 (%)



$B \to D^{**} l\nu$ BF (1)

Presented in Moriond EW 08

- Motivation : Only BF($B \to D_1 l\nu$) and BF($B \to D_2^* l\nu$) are well measured.
  Measurement of $D^{**} l\nu$ BF and even higher mass states is crucial to understand missing portion of $b \to cl\nu$ decays
- Fully reconstruct one B and look at the other B + Missing mass squared cuts



$B \to D^{**} l\nu$ BF (2)

- Results (with isospin symmetry) (in %)
  - BF($B^- \to D_1^0 l\nu$) = 0.42 ± 0.04 ± 0.04
  - BF($B^- \to D_1'^0 l\nu$) = 0.47 ± 0.06 ± 0.06
  - BF($B^- \to D_2^{*0} l\nu$) = 0.29 ± 0.05 ± 0.03
  - BF($B^- \to D_0^{*0} l\nu$) = 0.52 ± 0.07 ± 0.06

    (sum = 1.70 ± 0.12 ± 0.10)
- Agrees with BF($B^- \to D^{(*)} \pi l\nu$) = 1.52 ± 0.12 ± 0.10
- $B \to D^{**} l\nu$ BF saturates $B \to D^{(*)} \pi l\nu$ BF

  (Not much space for non-resonant decays.)
- BF($B \to D_1 l\nu$) disagree with BELLE measurement (arXiv:0711.3252).

$B \to X_u l\nu$ BF and $|V_{ub}|$ (1)

- Experimentally challenging because of 50 times larger $B \to X_c l\nu$ background.
- Only limited phase space can be used to separate $B \to X_c l\nu$ background. For example, cuts on
  - M_x = invariant mass of the hadronic system
- Event selection (347 fb-1, 383 M $B\bar{B}$ pairs)
  - Fully reconstruct one B and look at the other B
  - Lepton momentum > 1 GeV
  - Charge conservation
  - Missing mass squared < 0.5 GeV to reduce $B \to X_c l\nu$ background.

arXiv:0708.3702v2[hep-ex]
Accepted to Phys.Rev.Lett.

$B \to X_u l\nu$ BF and $|V_{ub}|$ (2)

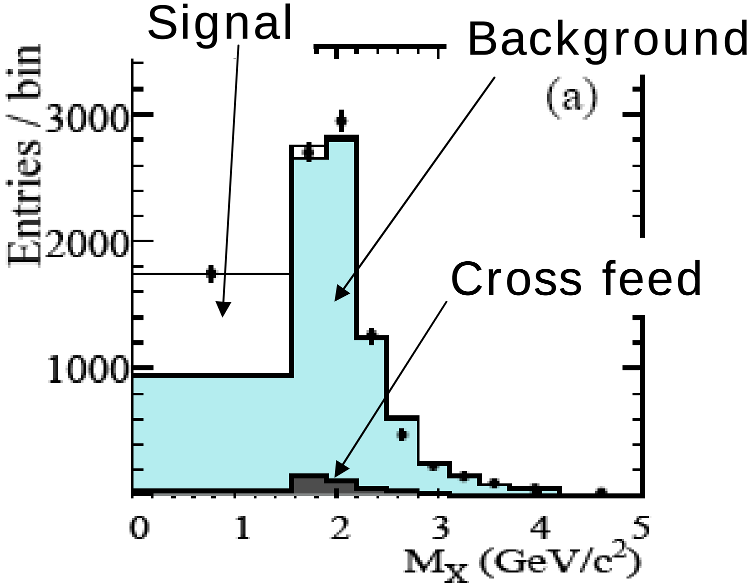
- BF in region $M_x < 1.55$ GeV (Partial branching fraction):
  BF = $(1.18 \pm 0.09 \pm 0.07 \pm 0.01) \times 10^{-3}$
- $|V_{ub}|$ in different frameworks updated by HFAG

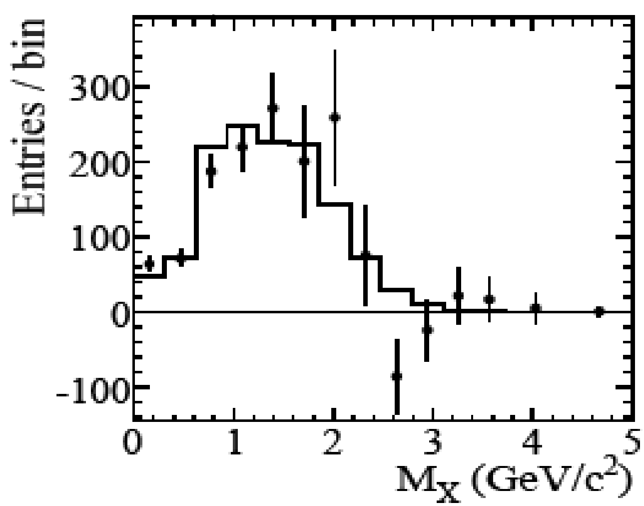
  (value ± exp err + theory err – theory err) :

  BNLP : $|V_{ub}| = (3.74 \pm 0.18 + 0.33 - 0.28) \times 10^{-3}$

  DGE : $|V_{ub}| = (4.56 \pm 0.22 + 0.30 - 0.30) \times 10^{-3}$

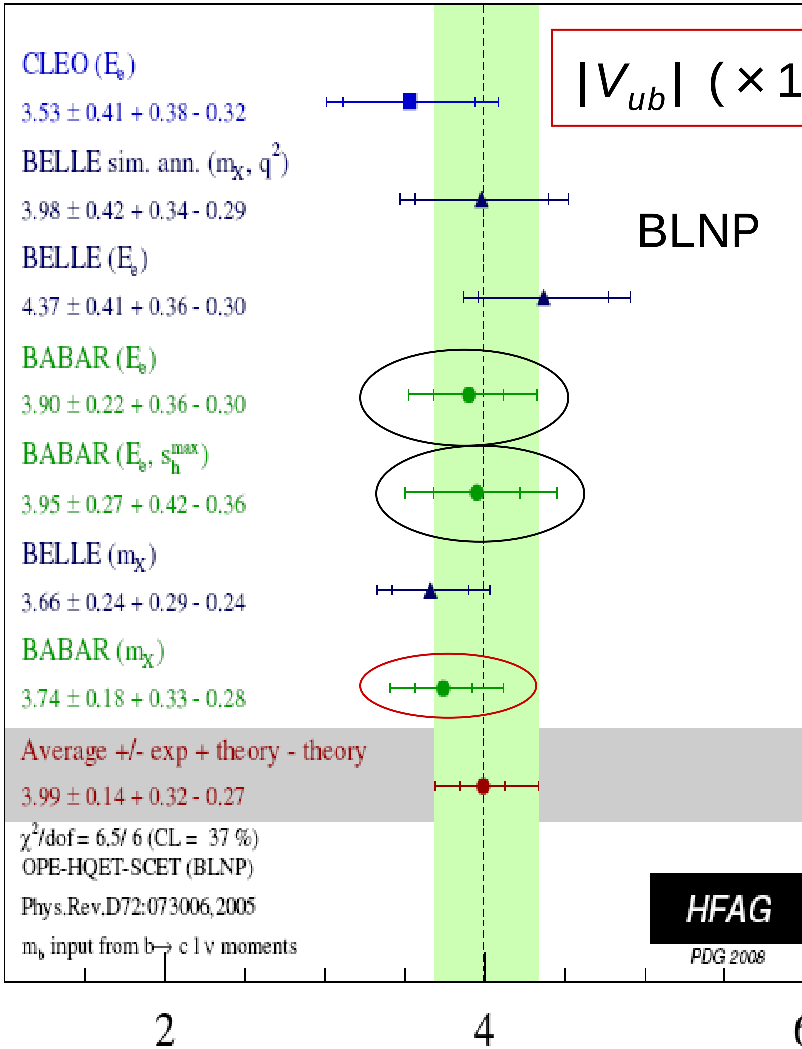
  GGOU : $|V_{ub}| = (4.02 \pm 0.19 + 0.26 - 0.29) \times 10^{-3}$

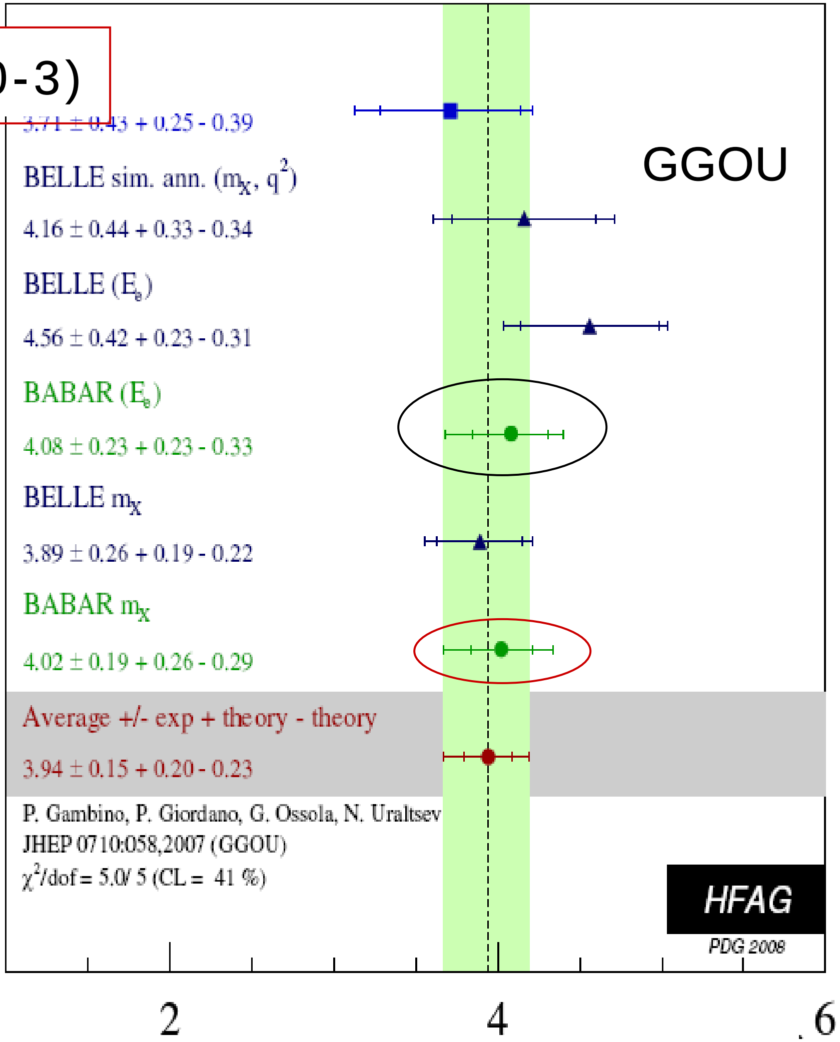




$B \to X_u l\nu$ BF and $|V_{ub}|$ (3)

$|V_{ub}|$ (×10-3)





Summary

- $B \to X_c l \nu$ decays and $|V_{cb}|$
  - $B^- \to D^{*0} e^- \nu$ measurement is a good cross check on the existing $B^0 \to D^{*-} l \nu$ measurement.
  - $B \to D^{(*)} \pi l \nu$ BF and $B \to D^{**} l \nu$ BF are measured in good precision.
  - Missing component ($B \to D^{(*)} \pi \pi l \nu$?) need to be determined.
- $B \to X_u l \nu$ decays and $|V_{ub}|$
  - Improved precision from previous Babar measurement.
  - Keys to a better precision :
    - Better understanding of $B \to X_c l \nu$ background.
    - Better theoretical method of QCD calculation.

Backup : PDG 2007

- B^+ Semileptonic BF (%)
  - BF(B^-->$D^0 l\nu$) = 2.15 ± 0.22
  - BF(B^-->$D^{*0} l\nu$) = 6.5 ± 0.5
  - BF(B^-->$D_1^0 l\nu$) = 0.56 ± 0.16
  - BF(B^--> $D^+ \pi^- l\nu$) = 0.52 ± 0.10
  - BF(B^--> $D^{*+} \pi^- l\nu$) = 0.63 ± 0.15
  - BF(B^-->$X l\nu$) = 10.99 ± 0.28
  - BF(B^-->$X_c l\nu$) = 10.8 ± 0.4
- B^0 Semileptonic BF (%)
  - BF(B^0->$D^- l\nu$) = 2.08 ± 0.18
  - BF(B^0->$D^{*-} l\nu$) = 5.29 ± 0.19
  - BF(B^0-> $\underline{D}^0 \pi^+ l\nu$) = 0.32 ± 0.10
  - BF(B^0-> $\underline{D}^{*0} \pi^+ l\nu$) = 0.65 ± 0.15
  - BF(B^0->$X l\nu$) = 10.33 ± 0.28
  - BF(B^0->$X_c l\nu$) = 10.1 ± 0.4
- B^+ / B^0 Admixture Semileptonic BF (%)
  - BF(B->$X l\nu$) = 10.24 ± 0.15
  - BF(B->$X_c l\nu$) = 10.57 ± 0.15
  - BF(B->$X_u l\nu$) = 0.233 ± 0.022

Backup : HFAG (LP2007) BF

- Semileptonic BF (%)
  - BF($B^0 \to D^- l \nu$) = 2.09 ± 0.18
  - BF($B^0 \to D^{*-} l \nu$) = 5.11 ± 0.12
  - BF(B(Admixuture)$\to X l \nu$) = 10.24 ± 0.15
  - BF($B^0 \to X l \nu$) = 10.33 ± 0.28
  - BF($B^+ \to X l \nu$) = 10.99 ± 0.28

Backup : HFAG (LP2007) V_{cb}

- Exclusive mode
  - $B \to D^* l \nu$
    - $F(1)|V_{cb}| = (35.89 \pm 0.56) \times 10^{-3}$, $\rho^2 = 1.23 \pm 0.05$

    (We can estimate $|V_{cb}| = (38.6 \pm 0.9_{exp} \pm 1.0_{theo}) \times 10^{-3}$

    with $F(1) = 0.930 \pm 0.23$: J.Laiho et.al.,arXiv:0710.111)
  - $B \to D l \nu$
    - $G(1)|V_{cb}| = (42.3 \pm 4.5) \times 10^{-3}$, $\rho_D^2 = 1.17 \pm 0.18$
- Inclusive mode
  - Kinematic Scheme : $|V_{cb}| = (41.68 \pm 0.39 \pm 0.58) \times 10^{-3}$
  - 1S Scheme : $|V_{cb}| = (41.56 \pm 0.39 \pm 0.08) \times 10^{-3}$

Kinetic Scheme : P. Gambino et.al. Eur. Phys. J. C34 (2004) 181
D. Benson et.al. Nucl. Phys. B710 (2005) 371
1S Scheme : C. W. Bauer et.al. Phys. Rev. D64 (2001) 113004

Backup : HFAG (Update for PDG2008) V_{ub}

- Inclusive mode
  - BLNP : $|V_{ub}| = (3.99 \pm 0.14 + 0.35 - 0.27) \times 10^{-3}$
  - DGE : $|V_{ub}| = (4.48 \pm 0.16 + 0.25 - 0.26) \times 10^{-3}$
  - GGOU : $|V_{ub}| = (3.94 \pm 0.15 + 0.20 - 0.23) \times 10^{-3}$
- Exclusive mode
  - $B \to \pi l \nu$

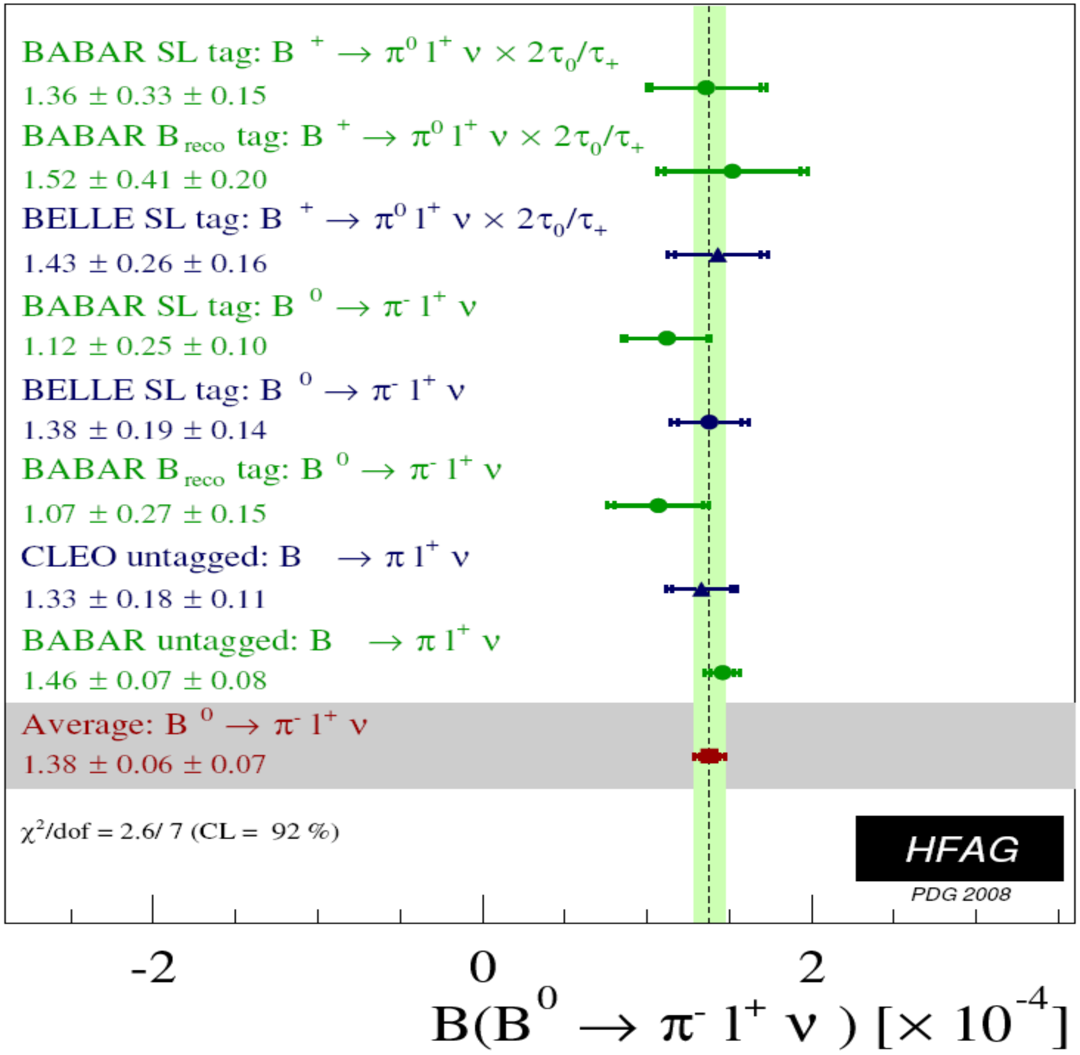
    Ball-Zwicky : $|V_{ub}| = (3.38 \pm 0.13 + 0.56 - 0.37) \times 10^{-3}$
    (Phys.Rev.D71(2005)014015)

    HPQCD : $|V_{ub}| = (3.47 \pm 0.20 + 0.60 - 0.39) \times 10^{-3}$
    (Phys.Rev.D73(2006)074502)

    FNAL : $|V_{ub}| = (3.69 \pm 0.21 + 0.64 - 0.42) \times 10^{-3}$
    (Nucl.Phys.Proc.Suppl.140(2005)461)

    APE : $|V_{ub}| = (3.72 \pm 0.21 + 1.43 - 0.66) \times 10^{-3}$
    (Nucl.Phys.B619(2001)565)

Backup : HFAG (Update for PDG2008) BF



Backup : Fully reconstructed B and m_{ES}

- For fully reconstructed B (B_{reco}), to separated signal from background, we use
  - Beam energy substituted mass :

    m_{ES} = sqrt(s/4 – p_B^2)