Determination of V_{ub} from Tagged and Untagged $B\bar{B}$ Events with BABAR

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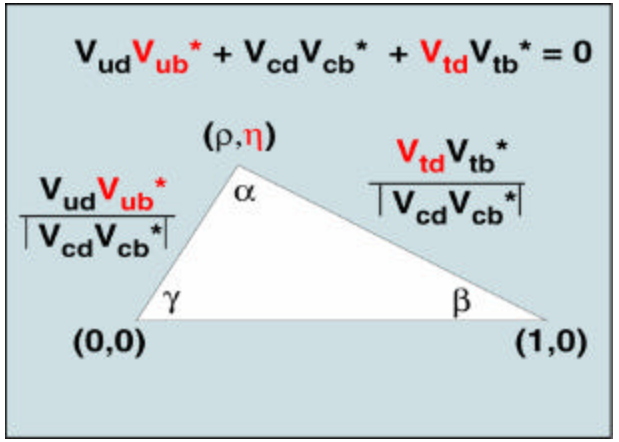
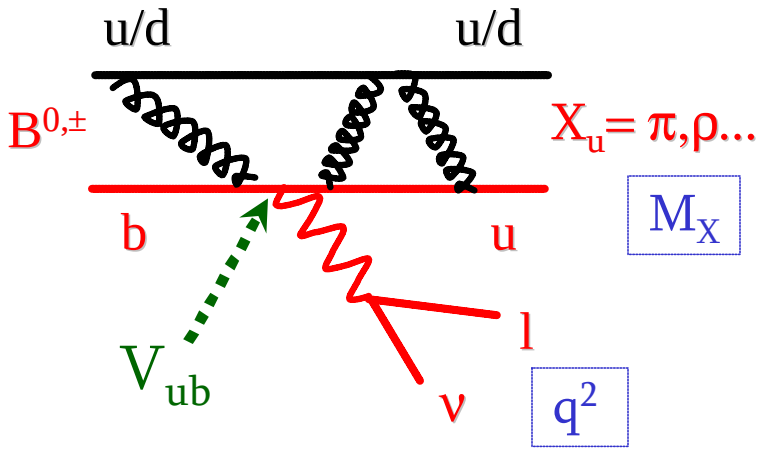
Introduction: $b \to u \ell \nu$ Decays and V_{ub}

Current progress in determination of CKM matrix element $|V_{ub}|$ comes from charmless semileptonic B decays, $B \to X_u \ell \nu$.



Experimentally challenging:

- Charm background $B \to X_c \ell \nu$ (50 x higher)
- Tight cuts needed and signal analyzed in limited region of phase space.
- Large uncertainties from extrapolation.



Two approaches:

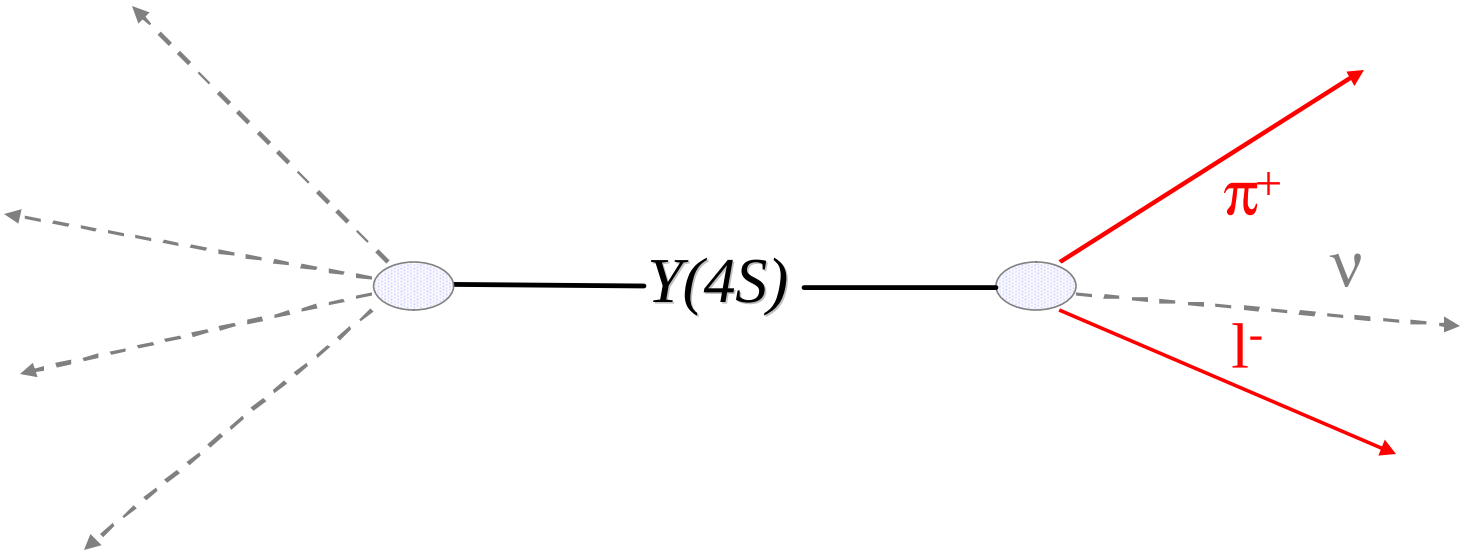
1. Inclusive: Look at kinem. quantities inclusively. Use duality assumption and study $b \to u \ell \nu$. From total $B(b \to u \ell \nu)$ extraction of $|V_{ub}|$ with small uncertainties.

2. Exclusive: Full reconstruction of resonances. Need decay form factors to extract branching ratio and $|V_{ub}|$.

Experimental Techniques

Tag Side

Signal Side



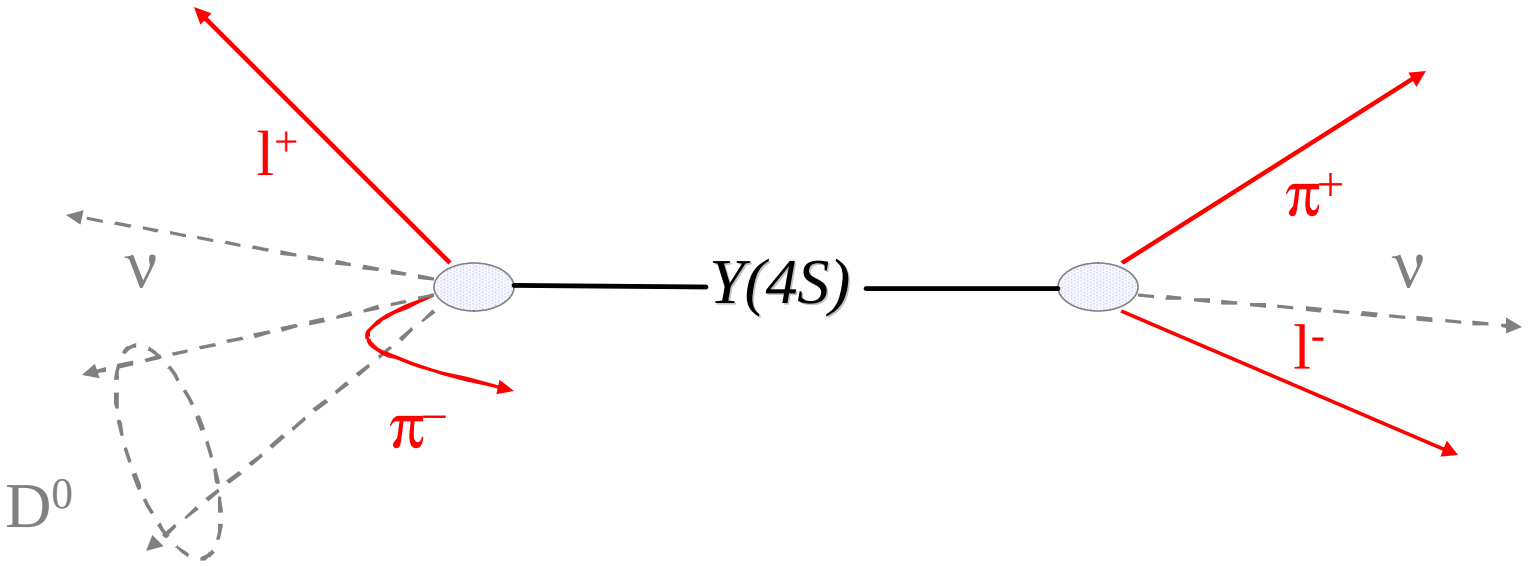
Untagged

No recoil, n reco.
from miss. momentum

Experimental Techniques

Tag Side

Signal Side



Untagged

No recoil, n reco.
from miss. momentum

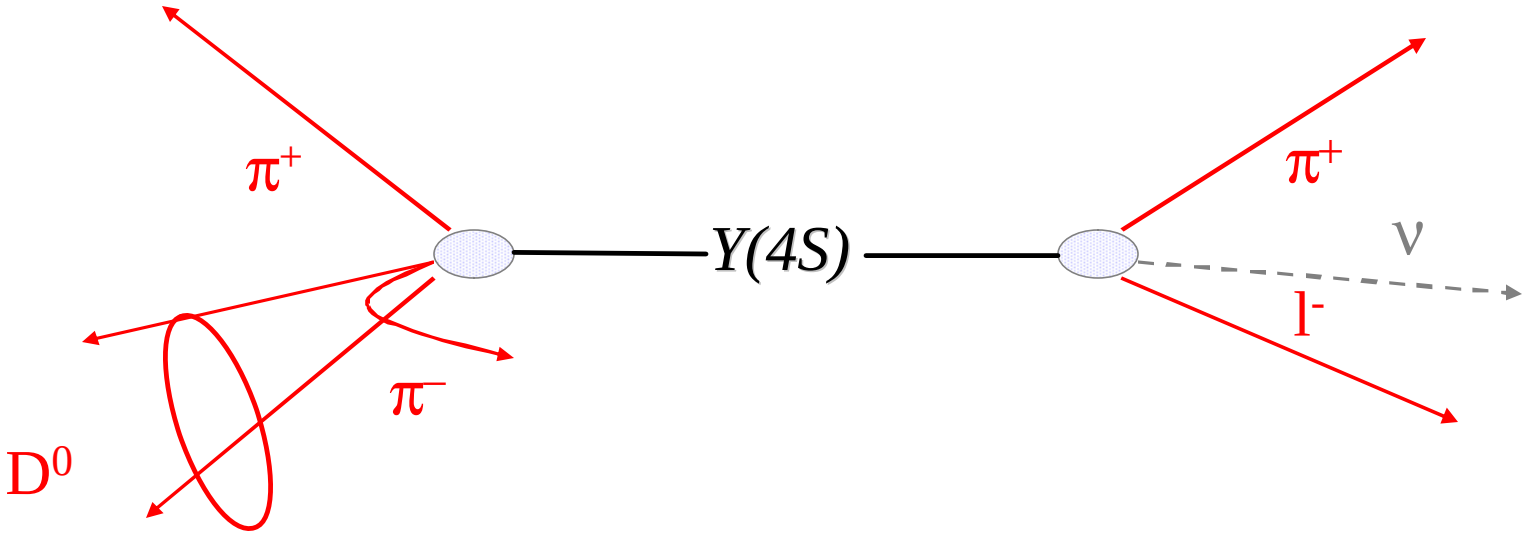
Partial Tags

Recoil of partially
reco. D*

Experimental Techniques

Tag Side

Signal Side



Untagged

No recoil, n reco.
from miss. momentum

Partial Tags

Recoil of partially
reco. D*

Breco Tags

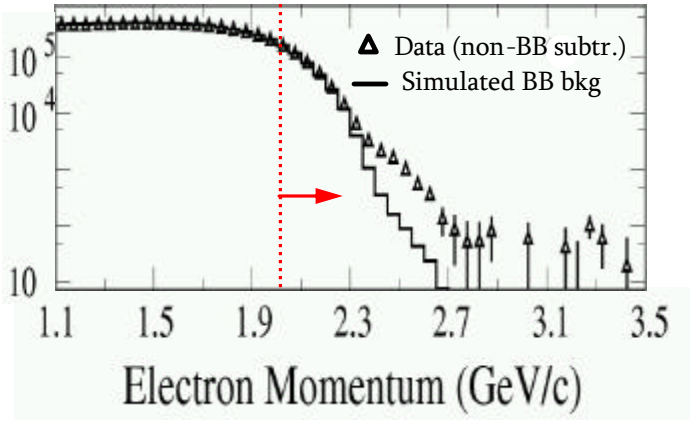
Recoil of fully
reco. B®D(*)X

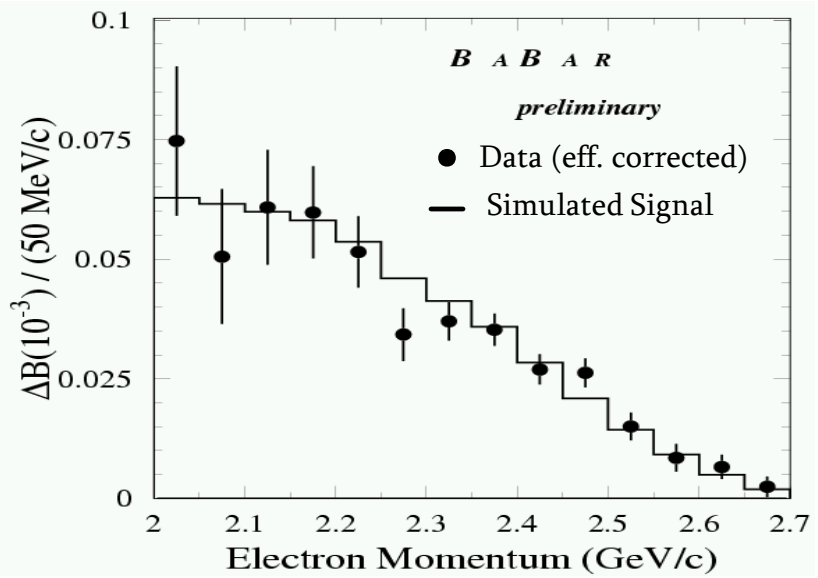
Inclusive: Lepton Endpoint

Untagged, 80 fb^{-1}

Analysis Strategy:

- One high energy electron
  2.0 GeV < E_e < 2.6 GeV
- Cut on missing momentum
  $p_n = p_{e+e-} - p_{visible}$
- Event shape to suppress continuum:
  $e^+e^- \rightarrow l^+l^- / qq$
  Non-BB bkg taken from off-peak data
  (on-peak data for E_e >2.8 GeV).
- BB bkg from fit to E_e spectrum
  (Den, D*en, D**en, D$^{(*)}$pen, $X_u$en, non-sl)





$$BR(B \rightarrow X_u e n) = (1.73 \pm 0.22_{exp} \pm 0.33_{f_u}) \times 10^{-3}$$

$$|V_{ub}| = (3.94 \pm 0.25_{exp} \pm 0.37_{f_u} \pm 0.19_{theo}) \times 10^{-3}$$

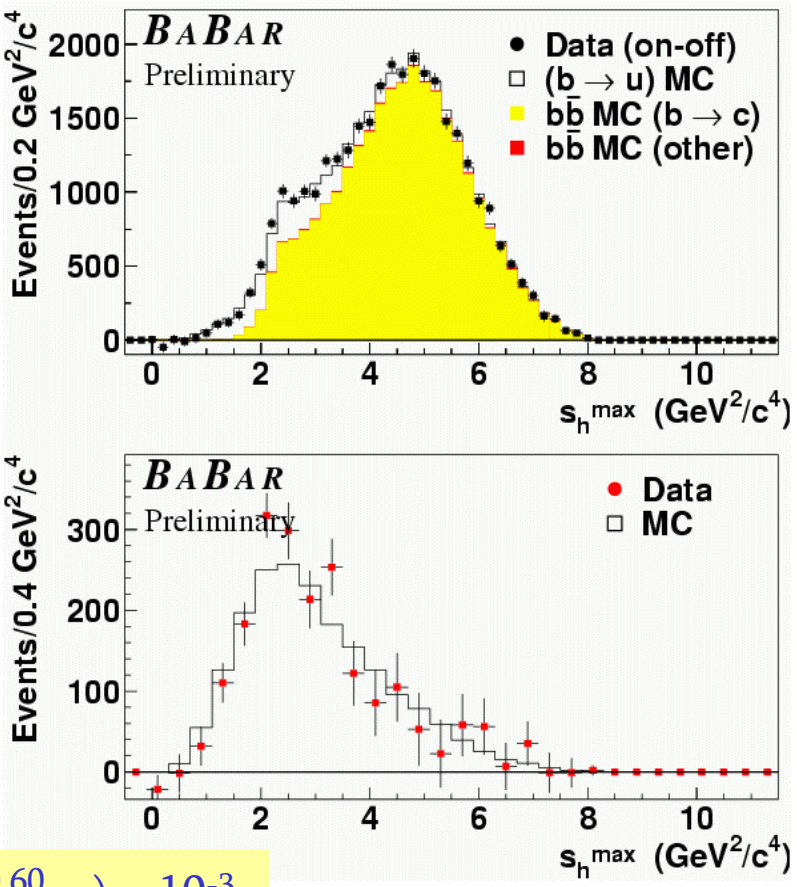
Inclusive: n Reconstruction

Untagged, 80 fb^{-1}

- Similar approach as endpoint method ($p_e^* > 2$ GeV/c) and n reco. from missing momentum and energy. Improved S/B in restricted region of q^2-E_e plane ($q^2 = (p_e + p_n)^2$).
- b ® cln background separated using max. kinem. allowed hadronic mass squared:

  $s_h^{max}(E_e, q^2) < 3.5$ GeV^2/c^4 ~ m_D^2

  Less sensitive to SF parameters than M_X.
- Use B ® D^{0}ln(X) control sample to check efficiency and shape modeling



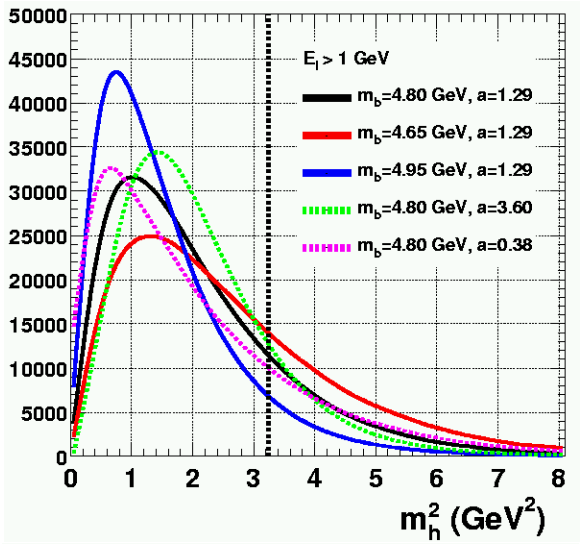
$$BR(B \to X_u e \nu) = (2.37 \pm 0.22_{stat} \pm 0.26_{exp} \pm 0.34_{bkg}\ ^{+0.60}_{-0.30\ SF}) \times 10^{-3}$$

$$|V_{ub}| = (4.57 \pm 0.21_{stat} \pm 0.25_{exp} \pm 0.34_{bkg}\ ^{+0.59}_{-0.29\ SF} \pm 0.22_{HQE}) \times 10^{-3}$$

Incl. Decays: Theoretical Issues

Sources of theo. uncertainties:

- Hadronization effects
- b quark mass and Fermi motion inside B meson, described by non-perturbative Shape Function (SF).



Two approaches to extract $|V_{ub}|$:

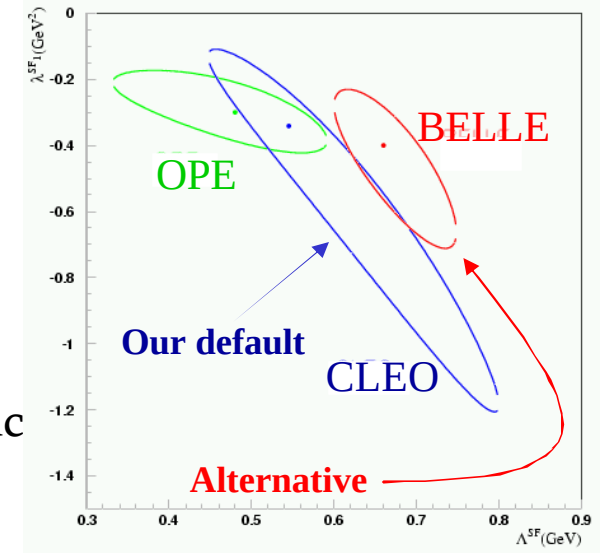
1. DeFazio-Neubert (DFN):
   Extrapolation to total BR using $d^3G/dq^2dE_ldM_X$.

$$|V_{ub}| = 0.00424 \sqrt{\frac{B(B \to X_u l n)}{0.002} \frac{1.61 ps}{t_B}} \times (1 \pm 0.028_{OPE} \pm 0.039_{m_b})$$

2. Bauer-Ligeti-Luke (BLL):
   Relates partial BR in restricted q^2 –M_X region to $|V_{ub}|$.

$$|V_{ub}| = \sqrt{\frac{192 p^3}{t_B G_F^2 m_b^5} \frac{\Delta B(B \to X_u l n; m_x < 1.7 GeV/c^2, q^2 > 8 GeV^2/c^4)}{G}}$$

Reduced dependence on SF in this region of phase spac



Estimate uncertainties from non-perturbative effects using l^{SF} and L^{SF} ellipse from CLEO b®sg (also recent result from BELLE available).

Inclusive: M_X and q^2

Extension of measurement published in PRL92, 071802.

Breco Tags

Recoil selection and reconstruction of hadronic system X:

Exactly one lepton with $p^* > 1$ GeV/c
Correlation lepton charge - B_{reco} flavor
Missing mass $M_{miss}^2 < 0.5$ GeV^2,
$B^0 \to D^* l \nu$ suppression: partial ν reconstruction
Kaon veto
Kinematic fit (2-C) to improve M_X resolution

- Measure ratio of branching fractions: $R_{u/sl} = \frac{B(B \to X_u l \nu)}{B(B \to X l \nu)}$

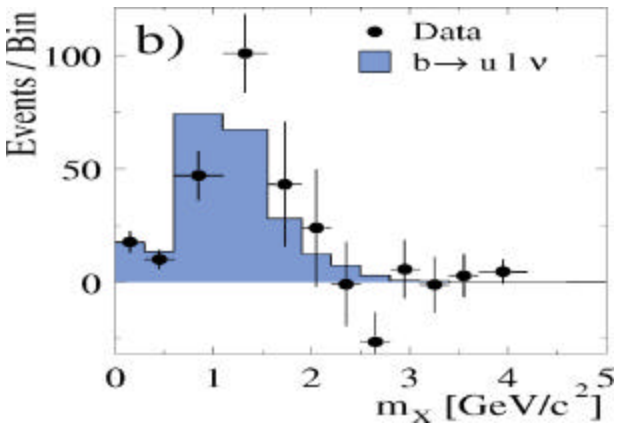
  ➡ reduced systematics (from lepton ID , tag normalization)

- Unfold the M_X spectrum using same approach and selection

- Approach suggested by Bauer et al.: Cut on M_X and q^2

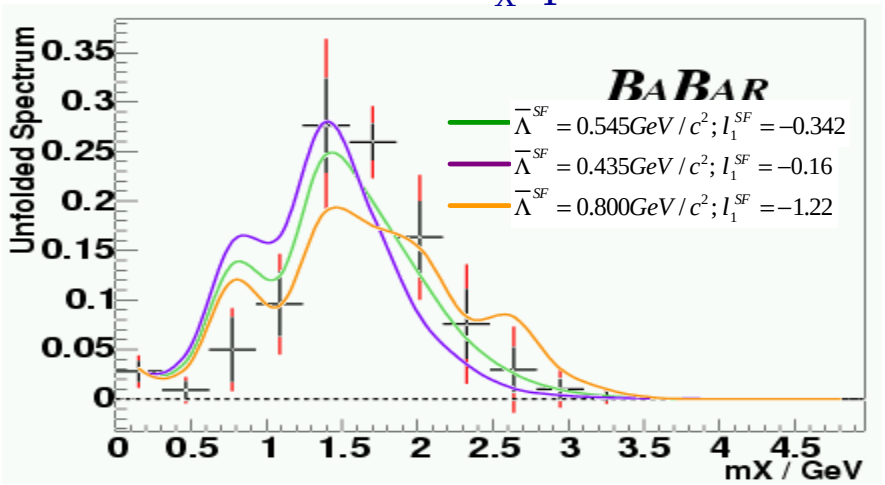
  ➡ reduced dependence on shape function parameters

Inclusive: M_X

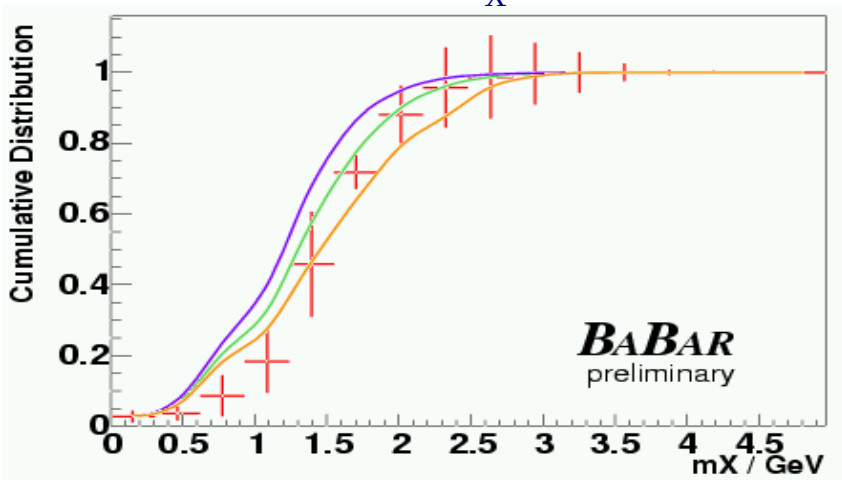


Breco Tags, 80 fb^{-1}

Unfolded M_X spectrum



Cumulative M_X distribution

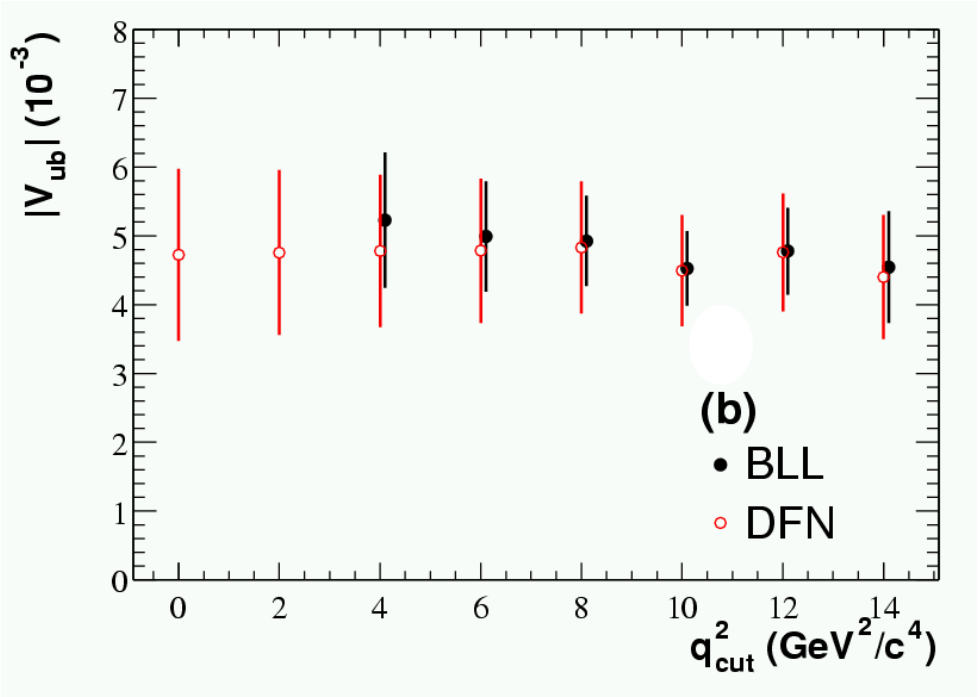


- Unfolding of detector and selection effects: $\vec{x}_{meas} = A_{detector\text{-}resp.} \vec{x}_{true}$
- With higher statistics, M_X moments can be used to constrain SF parameters.

Inclusive: M_X vs. q^2

Breco Tags, 80 fb^{-1}

$|V_{ub}|$ as a function of q^2 cut



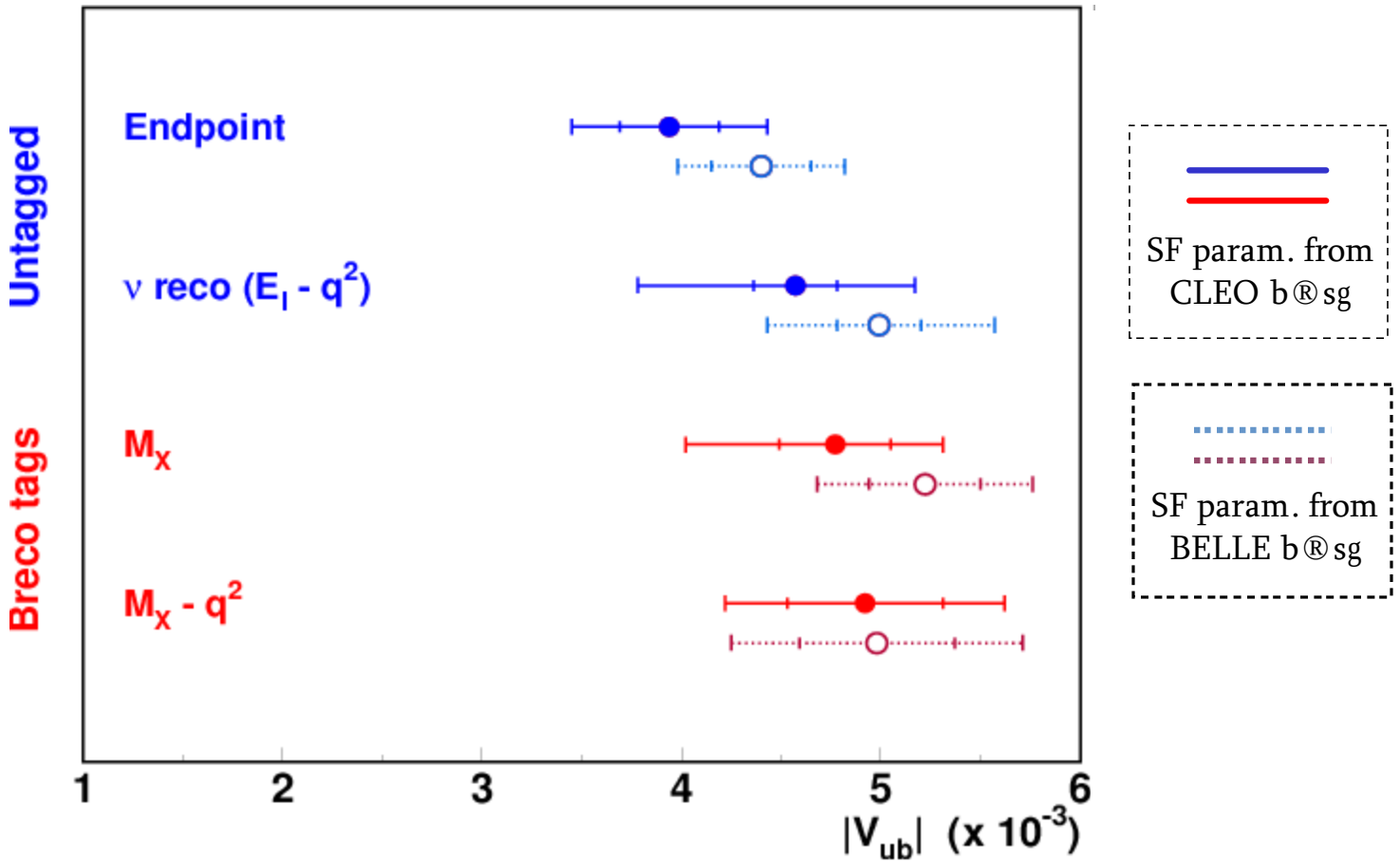
- DBR from phase space region where SF effects are small:
  $M_X < 1.7$ GeV and $q^2 > 8$ GeV^2
- $|V_{ub}|$ stable wrt variation of cut on q^2
- Good consistency between theoretical frameworks

$$DBR(B \to X_u e \nu) = (0.88 \pm 0.14_{stat} \pm 0.13_{exp} \pm 0.13_{theo}) \times 10^{-3}$$

$$|V_{ub}| = (4.92 \pm 0.39_{stat} \pm 0.36_{exp} \pm 0.46_{theo}) \times 10^{-3}$$

BABAR Inclusive Measurements Overview

Comparison of $|V_{ub}|$ measurements using different techniques



- Dominant systematic uncertainty from modeling of non-perturbative effects.
- Results compared for SF parameters from CLEO (2001) and BELLE (2004).

Exclusive Decays on the Recoil

Partial Tags

s.l. tags $B^0 \to D^* l n$

Fits to missing mass M_n^2 spectrum to extract signal yields.
Measurement in three bins of q^2 $(0 - 8 - 16\ \mathrm{GeV}^2/c^4)$.

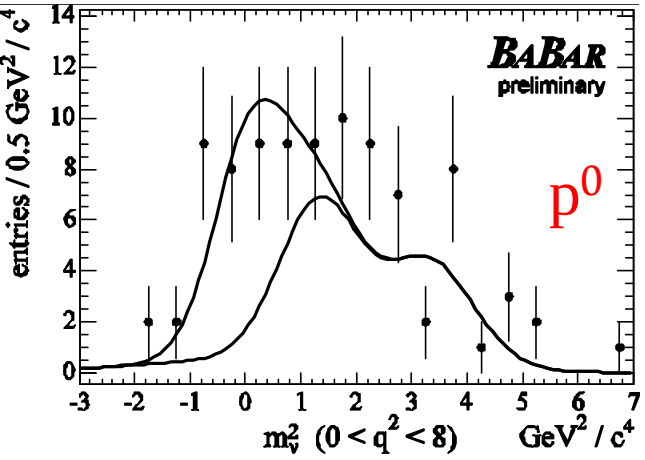
$$BR(B^0 \to p^- l^+ n) = (1.46 \pm 0.27_{stat} \pm 0.35_{syst}) \times 10^{-4}$$

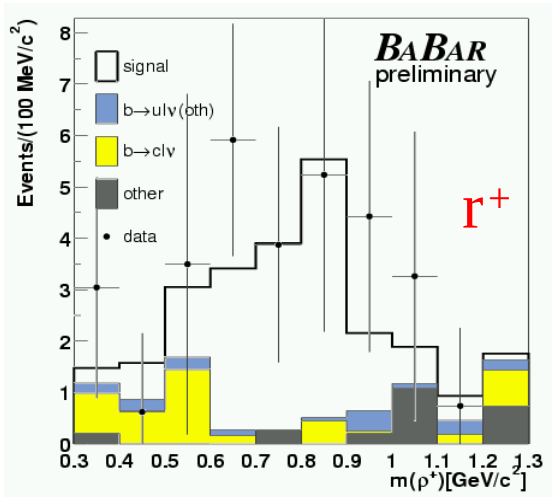
Breco Tags

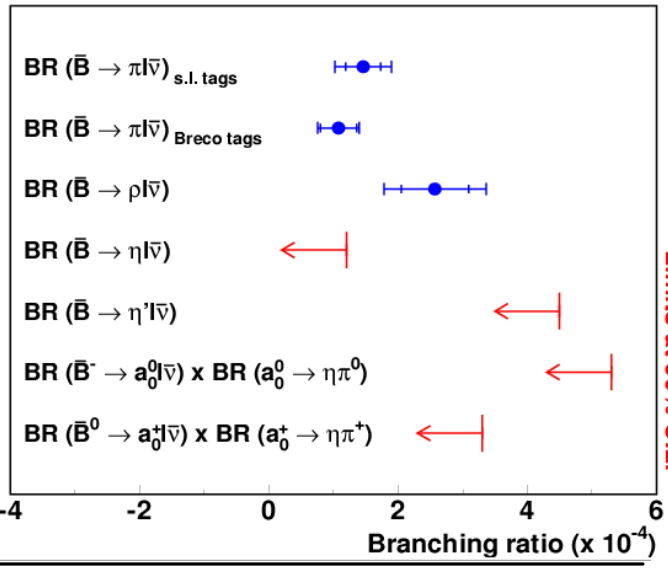
$B \to X_u l n$ modes: $X_u =$ p+, p^0, r^+, r^0, w, h, h', a_0^0, a_0^+
Similar to inclusive Breco analysis, but with exclusively fully reconstructed resonances.

$$BR(B^0 \to p^- l^+ n) = (1.08 \pm 0.28_{stat} \pm 0.16_{svst}) \times 10^{-4}$$
$$BR(B^0 \to r^- l^+ n) = (2.57 \pm 0.52_{stat} \pm 0.59_{syst}) \times 10^{-4}$$

Set upper limits for h, h', a_0^0, a_0^+



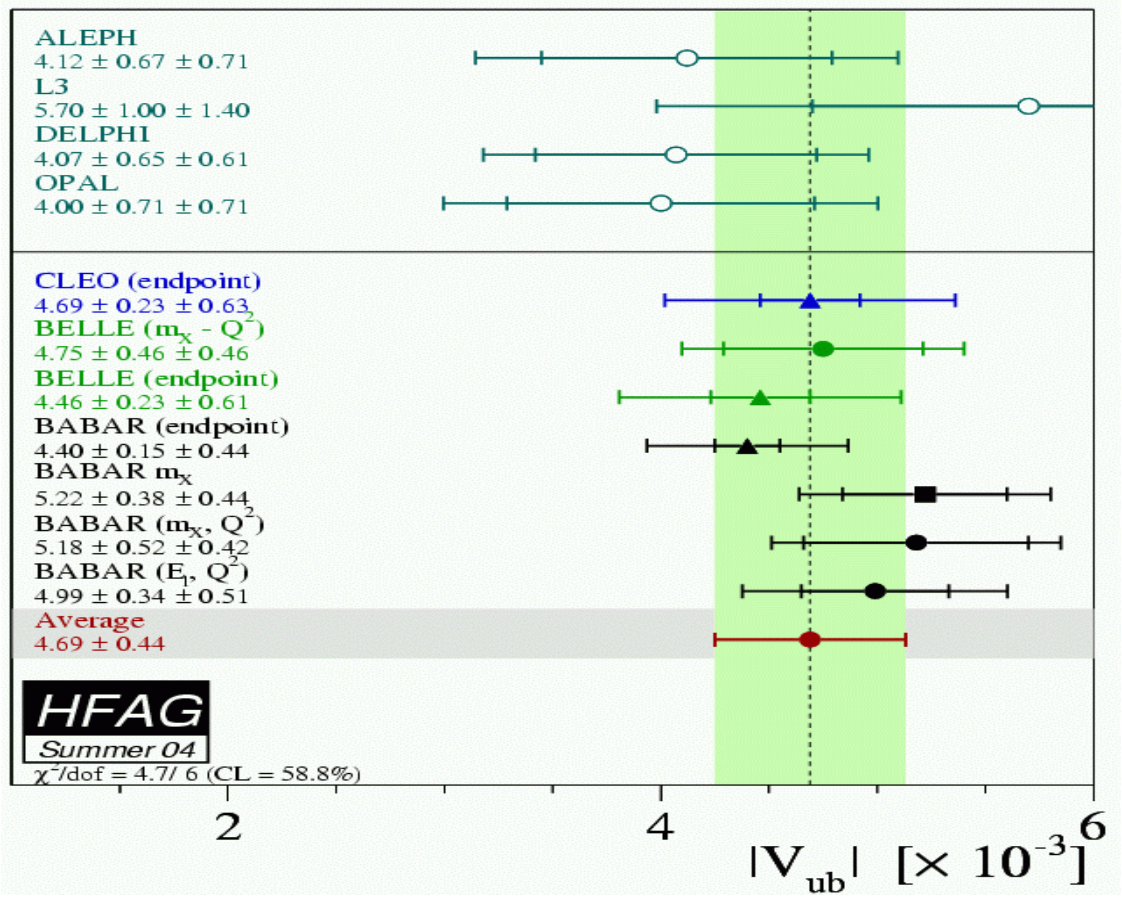




Summary: V_{ub} at BABAR

	Analysis Method	S/B	Pros & Cons	V_{ub} ($\times 10^{-3}$)
Electron endpoint	Inclusive, untagged E_e>2.0GeV Total rate using DFN	0.05 .. 0.2	·High statistics ·Duality valid for harsh E_e cuts? ·Bkg subtraction	$3.94 \pm 0.25_{exp} \pm 0.42_{theo}$
n reconstruction (E_e vs. q^2)	Inclusive, untagged $E_e > 2.0$ GeV and $s_h < 3.5$ GeV^2/c^4 Total rate using DFN	0.5	·High statistics ·Lower syst. on shape functions ·Bkg subtraction	$4.57 \pm 0.47_{exp}{}^{+0.62}_{-0.36\ theo}$
M_X analysis	Inclusive, Breco tag $m_X < 1.55$ GeV/c^2 Total rate using DFN	1.7	·Low background ·High resolution ·Low statistics ·Shape func. syst.	$4.77 \pm 0.40_{exp}{}^{+0.69}_{-0.45\ theo}$
M_X vs. q^2 analysis	Inclusive, Breco tag m_X<1.7 GeV/c^2 , q^2 >8.0 GeV^2/c^4 V_{ub} using BLL	2	·Low background ·Very small syst. on SF param. ·Small statistics	$4.92 \pm 0.53_{exp} \pm 0.46_{theo}$
Exclusive analyses on recoil	Exclusive, Partial or Breco tags Total rate using Form Factor calculations	1 .. 20	·Very small bkg ·Almost no cut on kinematics ·Small statistics	Future (larger statistics)

Current Status of V_{ub}



- In the near future, syst. errors will decrease due to new measurements of inclusive photon spectrum and advances in theo. understanding of the SF.
- With higher statistics, the novel "clean" recoil methods will be very fruitful.