Update on Semileptonic B Decays

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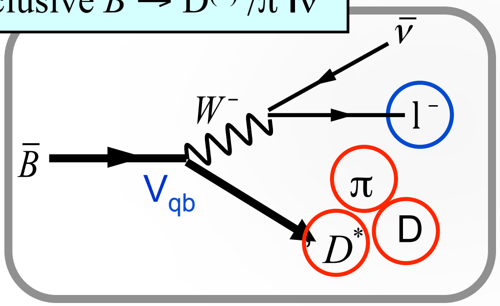
Most of the averaged results are based on HFAG End of Year 2011.

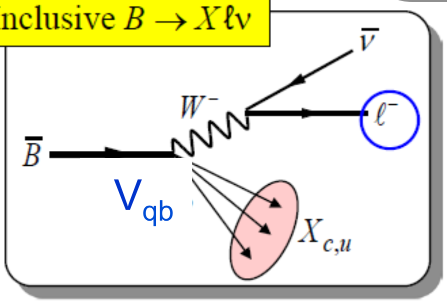
Update on Semileptonic B Decays from B Factories

- Introduction
- Exclusive Measurements
  - $B \to D \ell \nu$ and $B \to D^* \ell \nu$
  - $B \to \pi \ell \nu$
- Inclusive Measurements
  - $B \to X_c \ell \nu$
  - $B \to X_u \ell \nu$
- Status of $|V_{cb}|$ and $|V_{ub}|$
- Study of $B \to D\tau\nu$ and $B \to D^*\tau\nu$ NEW
  - Motivation
  - Experimental Results
  - Limits on Charged Higgs (Type II 2HDM)
- Conclusions and Outlook

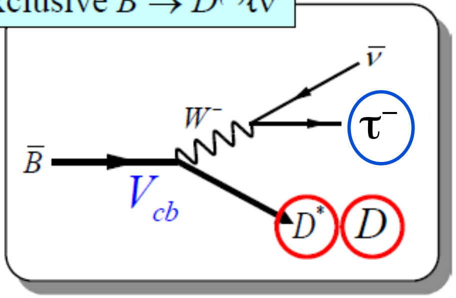
Exclusive $B \to D^{(*)}/\pi\ l\nu$



Inclusive $B \to X \ell\nu$



Exclusive $B \to D^{(*)} \ell\nu$



Semileptonic Decays at B-Factories @ 10.58 GeV

$$e^+e^- \to \Upsilon(4S) \to B\bar{B}$$

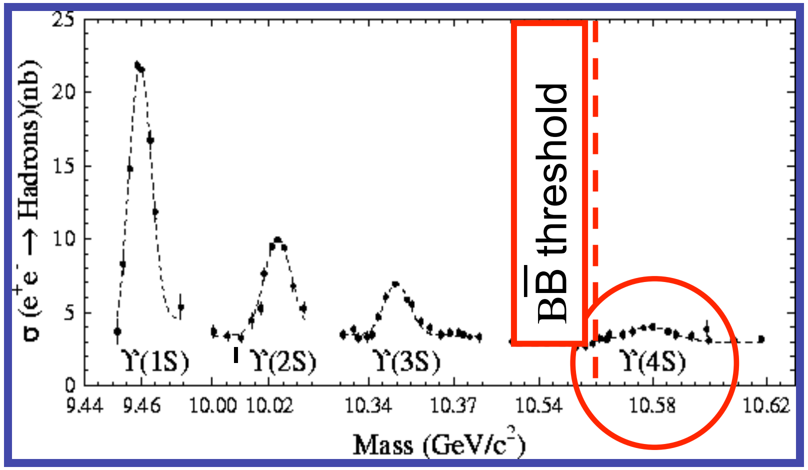
- Cleanest source of B mesons:

$$\sigma_{\Upsilon(4S)} \approx 1.05\, nb \qquad (24\% \text{ of } \sigma_{had})$$

- Reconstruction of S.L. decays
  - charged lepton: $e^\pm$, $\mu^\pm$
  - hadron: D, D*, π, ρ,…, X_c, X_u
  - ν: E_{miss}, $\vec{p}_{miss}$

$$(E_{\rm miss}, \vec{p}_{\rm miss}) = (E_{e^+e^-}, \vec{p}_{e^+e^-}) - \left(\sum_i E_i, \sum_i \vec{p}_i\right)$$

$\bar{b}b$ Spectroscopy



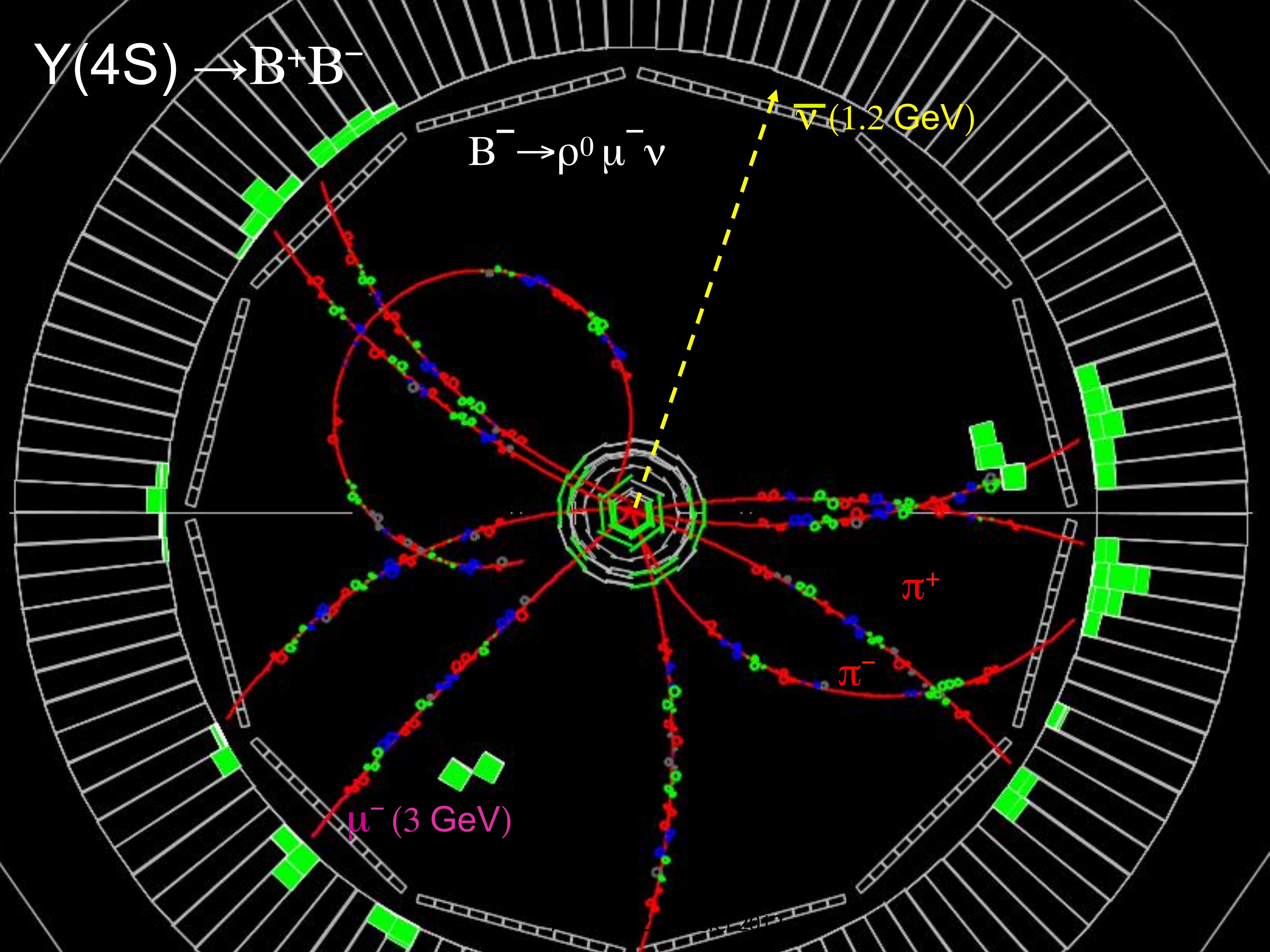
- Exclusive B decays:
  - kinematic variables:

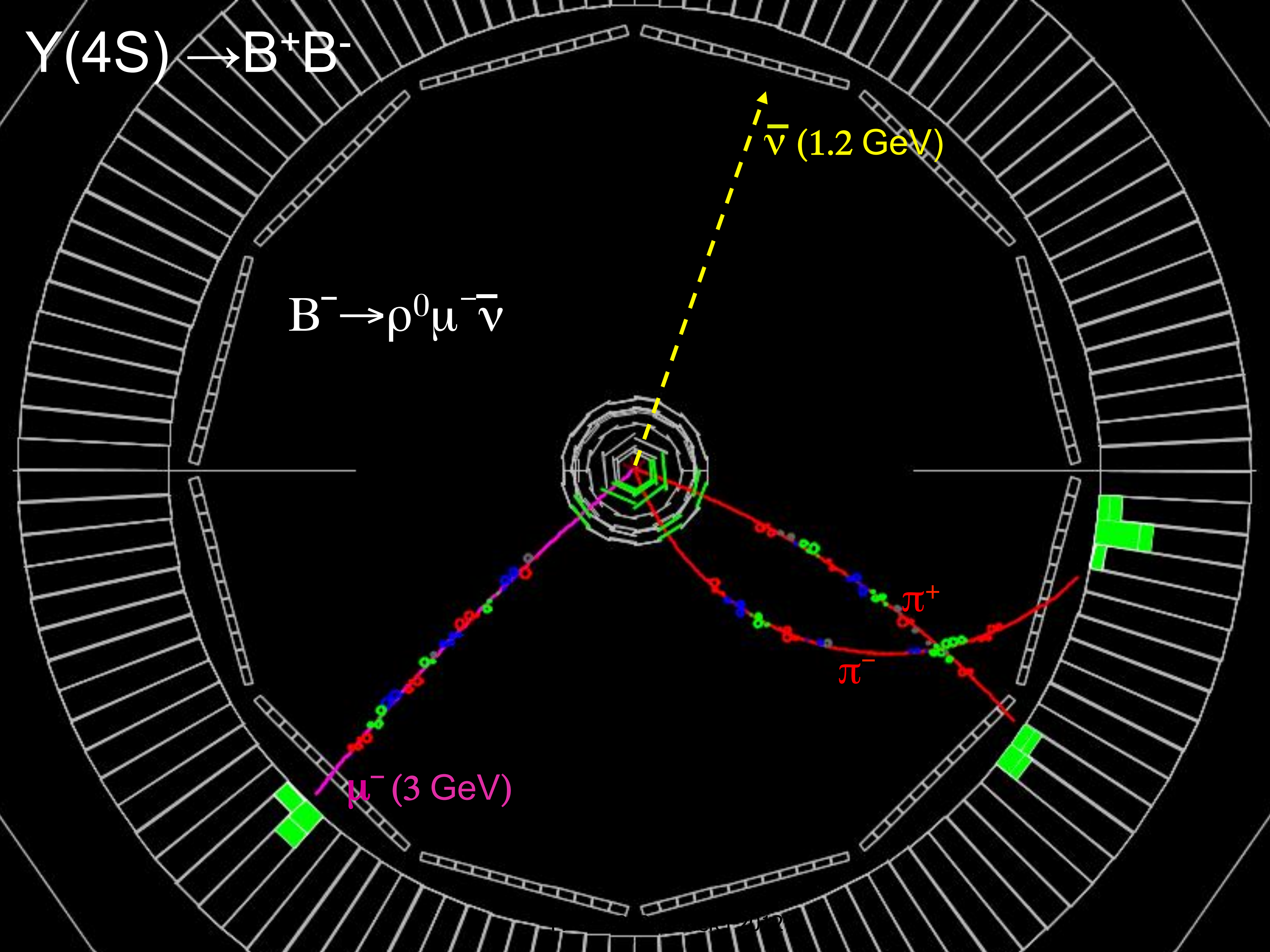
$\Delta E = E_B - E_{beam}$ signal at $\Delta E \approx 0$

$m_{ES} = \sqrt{E_{beam}^2 - \vec{p}_B^{\,2}}$ signal at $m_{ES} \approx m_B$

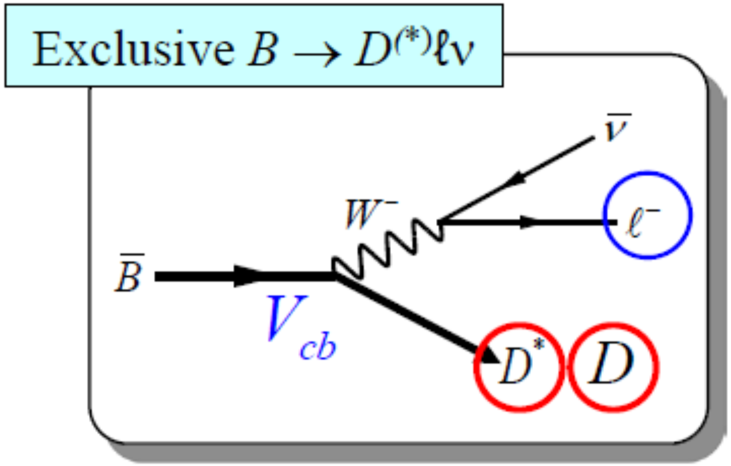
- $B\bar{B}$ tag: full reconstruction of one B decay: $B^+_{tag} \to D^-\pi^+\pi^+$, $B^- \to X_c^0 l^- \nu$
  - Significant reduction in comb. backgrounds, improvement in E_{miss}, $\vec{p}_{miss}$
  - Low tag efficiency , 0.3 – 1.0 %

$\Upsilon(4S) \rightarrow B^+B^-$





Υ(4S) →B⁺B⁻
$B^- \to \rho^0 \mu^- \bar{\nu}$
$\bar{\nu}$ (1.2 GeV)
π^+
π^-
μ^- (3 GeV)



B Factory Averages: (HFAG 2011)

$BF_{D^{*+}l^-\nu} = (4.83 \pm 0.02_{stat} \pm 0.12_{syst})\ 10^{-2}$
$BF_{D^+l^-\nu} = (2.14 \pm 0.03_{stat} \pm 0.06_{syst})\ 10^{-2}$

There used to be a very poor agreement between measurements, now fairly good consistency!

Extraction of $|V_{cb}|$ from $B \rightarrow D^{(*)}\ell\nu$ Decays

Universal Form Factor

Phase Space

- The differential decay rate

$$\frac{d\Gamma(B \rightarrow D^{*}\ell\nu_{\ell})}{dw\, d\cos\theta_{\ell}\, d\cos\theta_{V}\, d\chi} = \frac{G_F^2}{48\pi^3}|V_{cb}|^2 F^2(w,\theta_{\ell},\theta_{V},\chi)\, K(w)$$

$$w \equiv \frac{M_B^2 + M_{D^*}^2 - q^2}{2M_B M_{D^*}}$$

  - $B \rightarrow D\,\ell\nu$: a single FF: $G(w)$
  - $B \rightarrow D^*\ell\nu$: $F(w,\theta_{\lambda},\theta_{\varpi},\chi)$ incorporates 3 form factors, $A_1(w)$, $A_2(w)$, $V(w)$

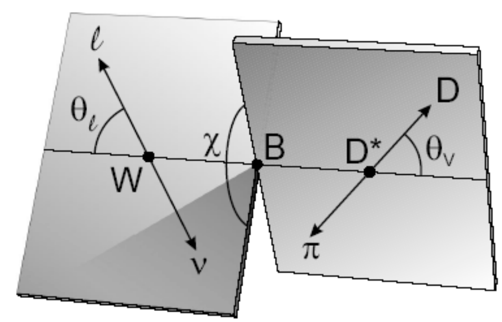
- HQ Symmetry predicts a unique universal F(w) with
  - Common shape given by ρ^2, constraints by analyticity and unitarity
  - Normalization at zero-recoil: $F(w=1)=G(w=1)=1.0$

    So, QCD correction to F(1) and G(1) needed

- Extract FF parameters by fits to differential decay rates
  - $B \rightarrow D\,\ell\nu$: Fit: 1-dim. decay distribution G(w):

    parameters: $|V_{cb}|$ G(1) and slope ρ^2
  - $B \rightarrow D^*\ell\nu$: 4-dim. decay distribution $G(w,\theta_{\lambda},\theta_{v},\chi)$

    parameters: $|V_{cb}|$ F(1), slope ρ^2, $R_1(w=1)$ and $R_2(w=1)$



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

- Fits to w-dependence give ρ and G/F(1) $|V_{ub}|$
- Recent unquenched Lattice QCD calculations: *)

$G(1) = 1.074 \pm 0.018_{stat} \pm 0.016_{syst}$ — NP Suppl. 140,461 (2005)

$F(1) = 0.908 \pm 0.005_{stat} \pm 0.016_{syst}$ — FNAL/MILC 2011

- BABAR and Belle measurements translate to

$D\ell\nu$: $|V_{cb}| = (39.46 \pm 1.54_{exp} \pm 0.88_{LQCD}) \times 10^{-3}$

$D^*\ell\nu$: $|V_{cb}| = (39.04 \pm 0.55_{exp} \pm 0.73_{LQCD}) \times 10^{-3}$

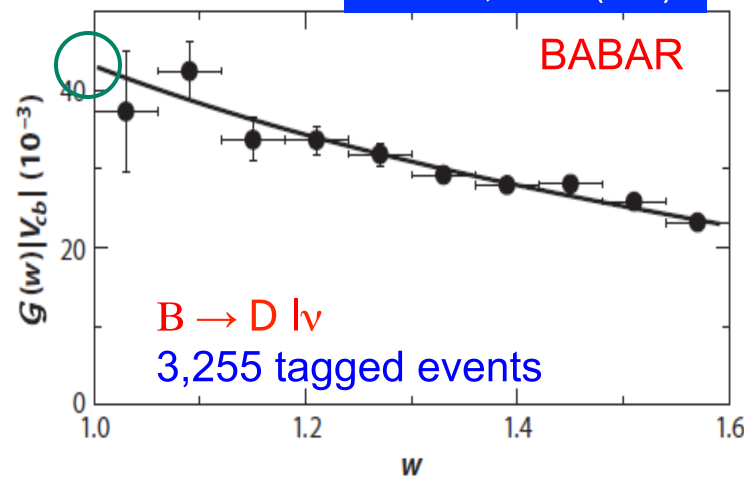
*) Calculations based on HQ sum rules result in an increase of $|V_{cb}|$ by 5.7%: — PL B585.53 (2004)

$G(1)=1.02 \pm 0.04$ $|V_{cb}| = (41.84 \pm 1.64_{exp} \pm 1.63_{SR}) \times 10^{-3}$

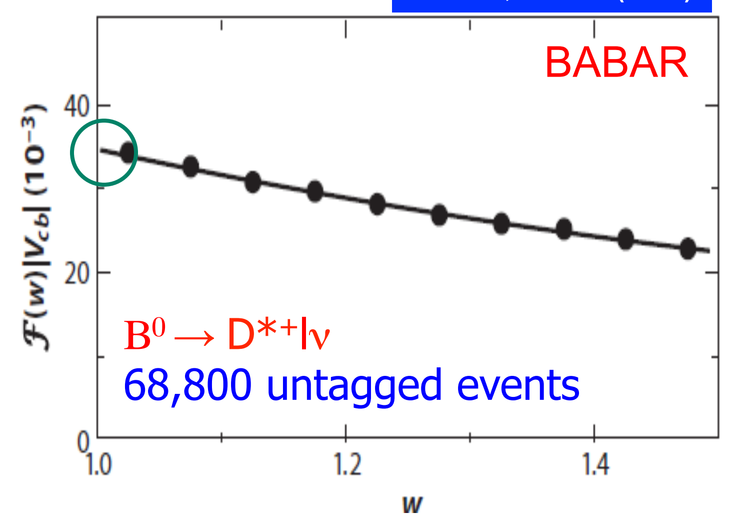
$F(1) = 0.86 \pm 0.02$ $|V_{cb}| = (41.22 \pm 0.58_{exp} \pm 0.95_{SR}) \times 10^{-3}$

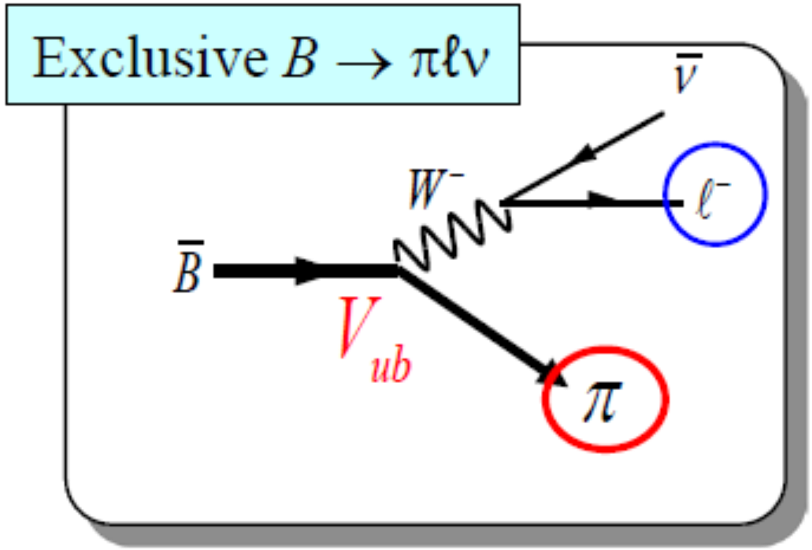
PRD 81, 113002 (2010)

PRL 104, 011802 (2010)



PRD 77, 032002 (2008)





B Factory Average (HFAG 2011):

$BF_{\pi - l + \nu} = (1.44 \pm 0.03_{stat} \pm 0.05_{syst})\ 10^{-4}$

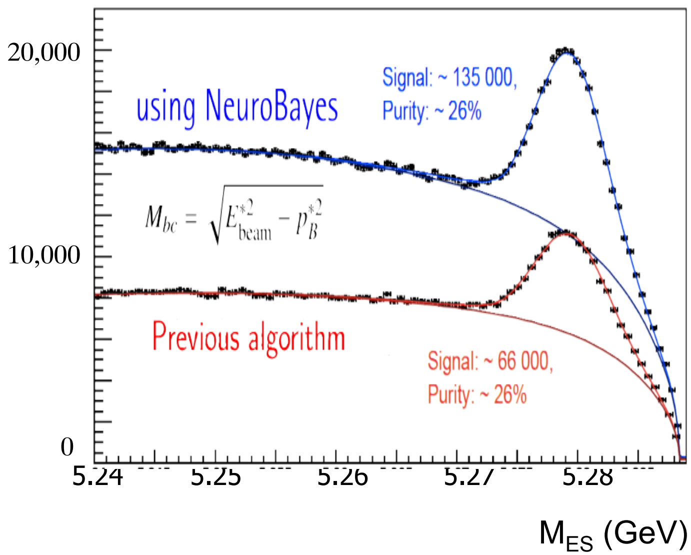
Excellent agreement between BABAR and Belle.
Systematic uncertainties dominated by BG and ν reconstruction

Also, new tagged measurement from Belle (unpublished)

$BF_{\pi - l + \nu} = (1.49 \pm 0.09_{stat} \pm 0.09_{syst})\ 10^{-4}$

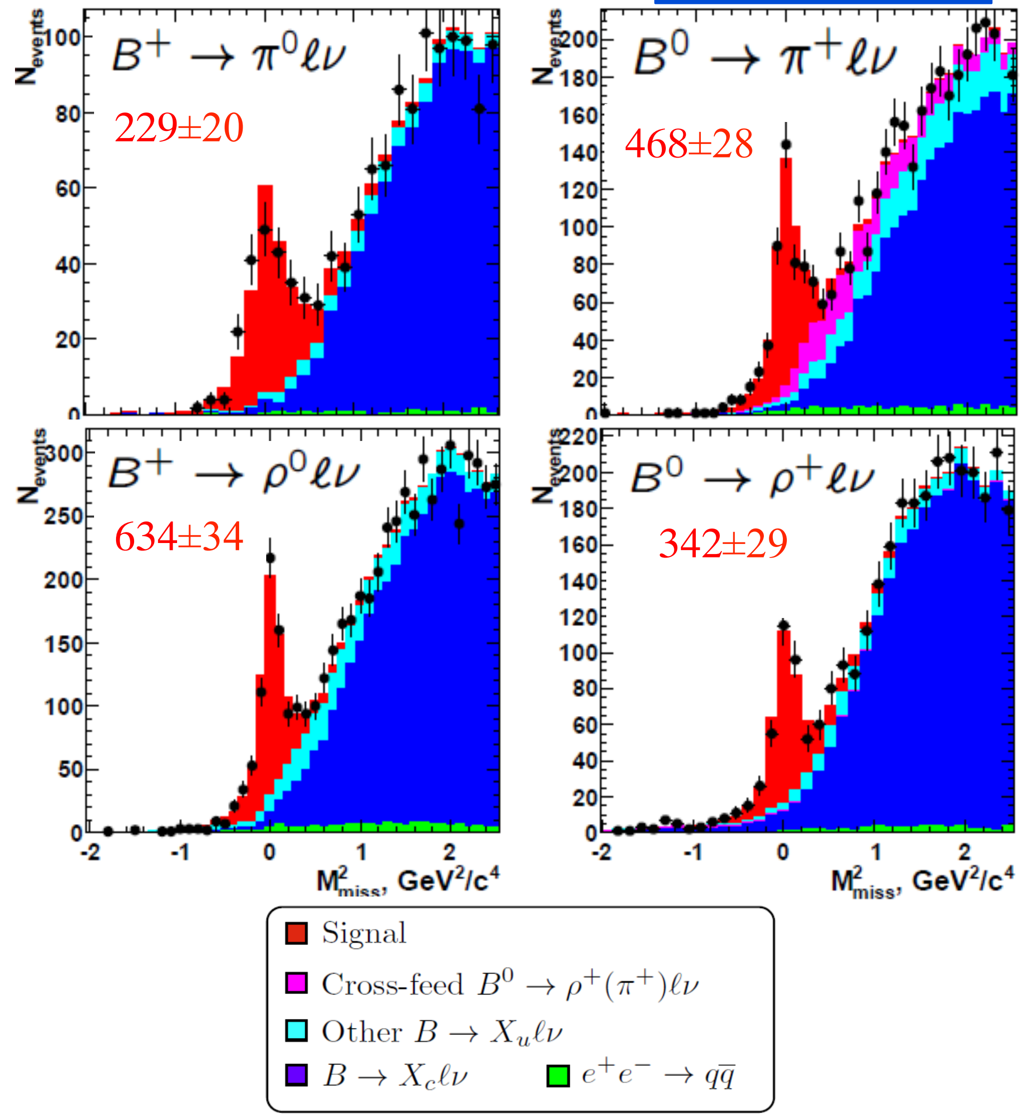
Belle: B → (π, ρ, ω, η, η’) ℓ ν with Hadronic Tags

- Full Υ(4S) data set 710/fb
- New hadronic tag procedure with gain 2x
  Maintain purity of 26%



- Extended binned max. likelihood fit to M^2_{miss} distribution
- Also B → (ω, η, η’) ℓ ν measurements

Belle Unpublished



Belle: $B^0 \rightarrow \pi^+ \ell \nu$ with Hadronic Tags

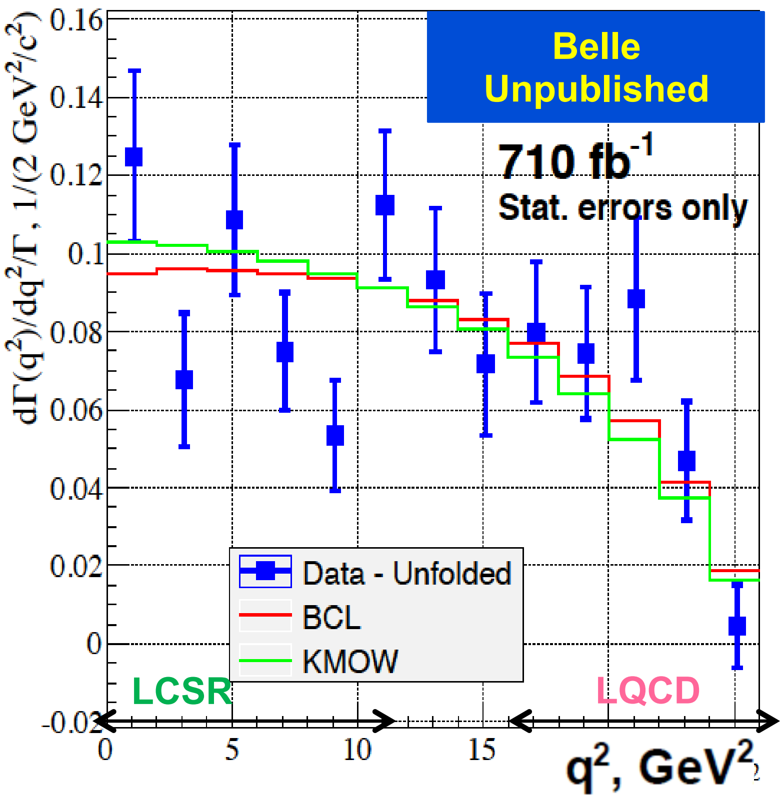
Improved hadronic tags open new opportunities:

- First look at q^2 dependence
- Extraction of $|V_{ub}|$ based on partial integral
- Results agree very well with previous untagged measurements – almost too well!

Stay tuned - much more to come!

Theory	q^2 [GeV^2]	$\lvert V_{ub}\rvert \times 10^{-3}$
KMOW[1]	<12	$3.38 \pm 0.14 \pm 0.09^{+0.37}_{-0.31}$
Ball/Zwicky[2]	<16	$3.57 \pm 0.13 \pm 0.09^{+0.47}_{-0.47}$
FNAL[3]	>16	$3.69 \pm 0.22 \pm 0.09^{+0.39}_{-0.35}$
HPQCD[4]	>16	$3.86 \pm 0.23 \pm 0.10^{+0.53}_{-0.53}$

$B^0 \rightarrow \pi^+ \ell \nu$



Extraction of $|V_{ub}|$ from $B \to \pi \ell \nu$ Decays

- Extract $|V_{ub}|$ from combined fit to data and LQCD prediction based on BCL expansion

$$f_+(q^2) = \frac{1}{P(q^2)\phi(q^2, q_0^2)} \sum_{k=0}^{k_{max}} a_k(q_0^2)[z(q^2, q_0^2)]^k,$$

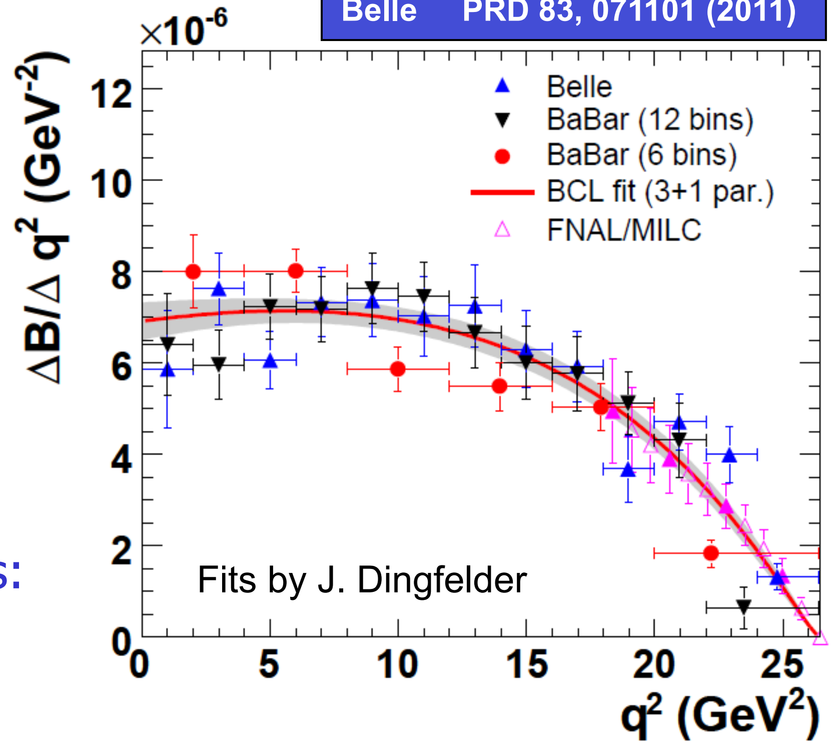
2nd order polynomial plus normalization.

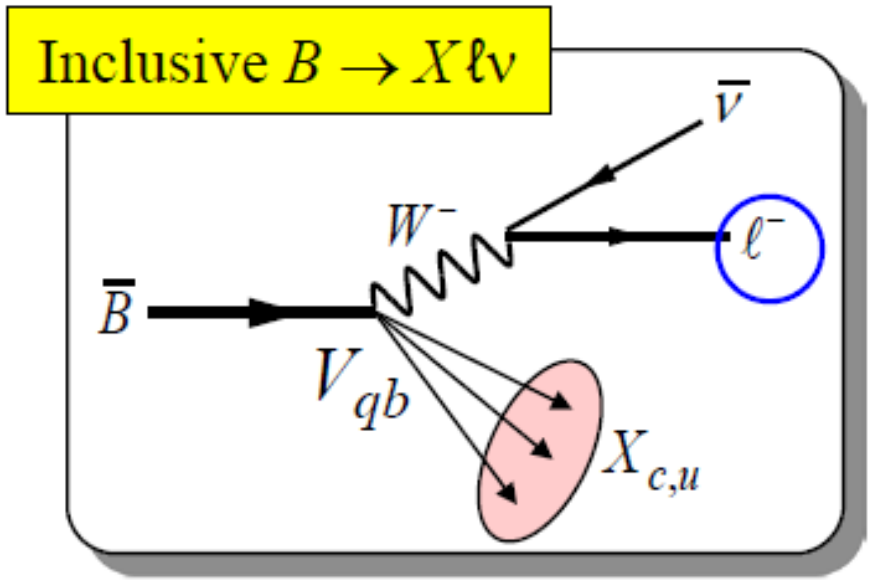
- Experimental and theoretical errors reduced
  - Measured q^2 spectrum constrains the FF shape
  - LQCD provides normalization (only 4/12 points)
- Combined fit to Belle (1) and BABAR (2) results:

$$|V_{ub}| = (3.23 \pm 0.18_{exp} \pm 0.24_{th})\ 10^{-3}$$
$$= (3.23 \pm 0.30)\ 10^{-3}$$

- LCSR predicts: $f_+(0) = 0.28 \pm 0.02$,
  fit result: $f+(0) = 0.29 \pm 0.03$

BABAR PRD 83, 032007 (2011)
BABAR PRD 83, 052011 (2011)
Belle PRD 83, 071101 (2011)





Inclusive $B \to X\ell\nu$
$\bar{\nu}$
W^-
ℓ^-
$\bar{B}$
V_{qb}
$X_{c,u}$

$|V_{cb}|$ from Inclusive $B \rightarrow X_c \ell \nu$ Decays: OPE

- Operator Product Expansion relates parton to meson decay rate: $1/m_b$, $\alpha_s(m_b)$

$$\Gamma_{SL} = \underbrace{|V_{cb}|^2 \frac{G_F^2 m_b^5}{192\pi^3}}_{\text{free quark decay}} \underbrace{(1 + A_{EW}) A_{pert}}_{\text{perturbative corrections}} \times \underbrace{[c_0(r) + \frac{0}{m_b} + c_2(r, \frac{\mu_\pi^2}{m_b^2}, \frac{\mu_G^2}{m_b^2}) + c_3(r, \frac{\rho_D^3}{m_b^3}, \frac{\rho_{LS}^3}{m_b^3}) + \ldots]}_{\text{Non-perturbative power corrections}}$$

$r = m_c/m_b$

- Contrary to differential distributions, low-order moments over large phase space avoid problem with quark-hadron duality
- Moments can be calculated for cut-off in E_l (add $B \rightarrow X_s\gamma$, sensitivity to m_b)

$$\left\langle M_x^n \right\rangle |_{E\ell > E_0} = \tau_B \int_{E_0} M_x^n d\Gamma = f(E_0, \underbrace{m_b, m_c}_{\text{quark masses}}, \underbrace{\mu_\pi^2, \mu_G^2, \rho_D^3, \rho_{LS}^3}_{\text{Non-perturbative parameters}})$$

Cut-off

- Calculations in "kinetic" and "1S" mass schemes

Benson, Bigi, Gambino, Mannel, Uraltsev   Bauer, Ligeti, Luke, Manohar, Trott,

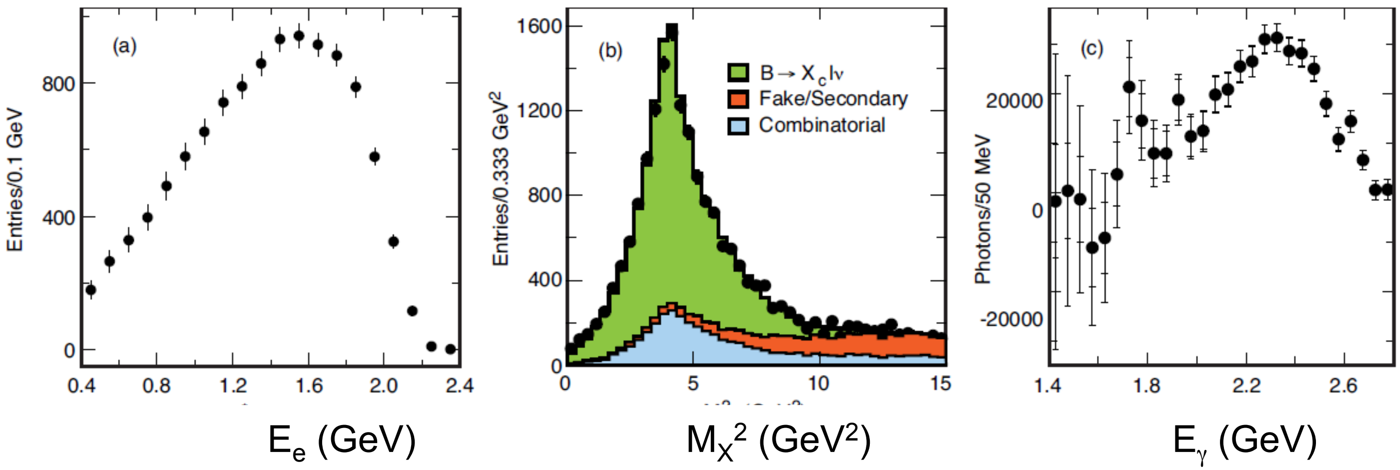
- Global fit to extract 8 parameters: $|V_{ub}|$, BF, m_c, m_b, μ_π^2, μ_G^2, ρ_D^3, ρ_{LS}^3
- >60 measured moments available from DELPHI, CLEO, BABAR, Belle, CDF

$|V_{cb}|$: Moment Measurements

- Inclusive s. l. decays recoiling against a fully reconstructed hadonic B tags
- Measure inclusive distributions
  - Lepton momentum p^*_l
  - Hadronic mass $m_{X,}$ q^2, P_+
- Correct or unfold measured spectra to obtain true distributions
- Also include $B \to X_s \gamma$ energy moments (sensitivity to m_b)

Belle: PRD 75, 032001 (2007), PRD 75, 032005(2007), PRL 103, 241801 (2009)

Belle:
Examples of inclusive distributions used in Moments Analysis by Belle

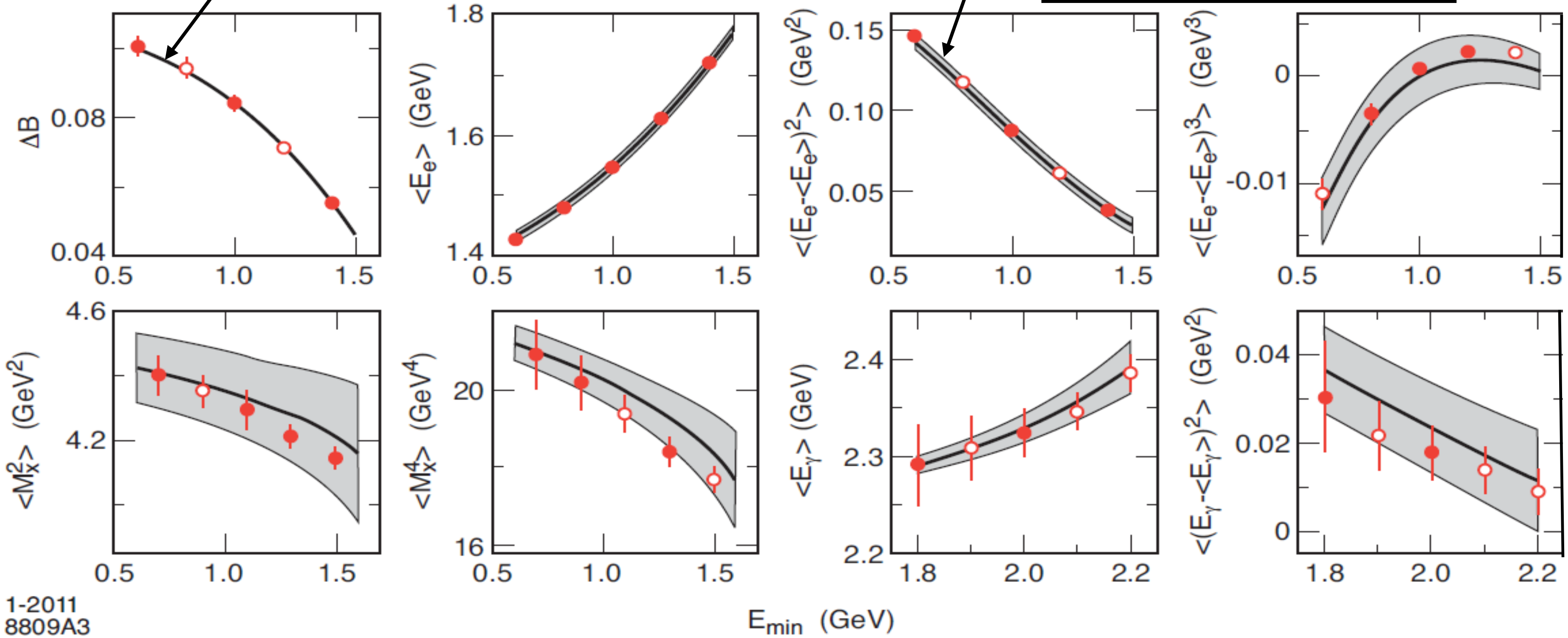


$|V_{cb}|$ from OPE Fits to Moments (Belle)

Belle: PRD 78, 032016

● = used, ○ =unused in the nominal fit

Black line: HQE fit
grey band: theory errors



N.B. Each points integrates data above E_{min}, i.e. points are highly correlated !!
Treatment of those correlations somewhat ad-hoc for data and theory!

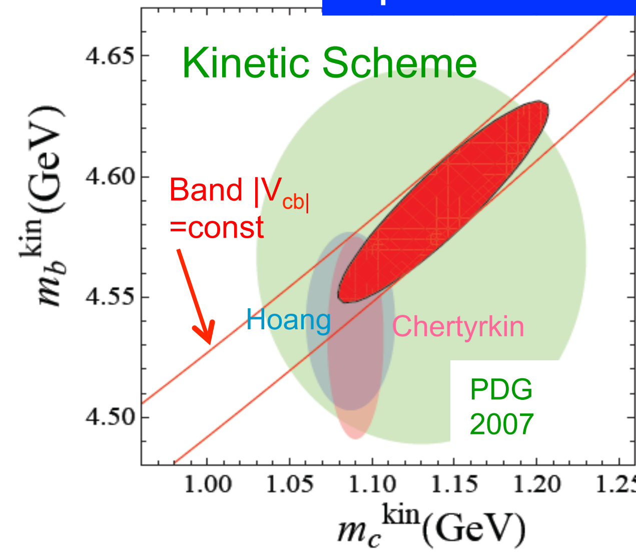
$|V_{cb}|$ from OPE Fits to Moments

- Quark masses are critical and not a priori known
  - Fit determines precisely linear combination of m_b and m_c, In the past, $B \to s\gamma$ moments improved the sensitivity
  - Now input m_c(3GeV)=0.998 ± 0.029 GeV ($\overline{\text{MS}}$ Scheme)

    3 independent calculations of m_b and m_c with uncertainties of 6 -15 MeV

hep-ph/0008102 (2000)
PRD 80, 074010 (2009)
PRD 82, 034512 (2010)

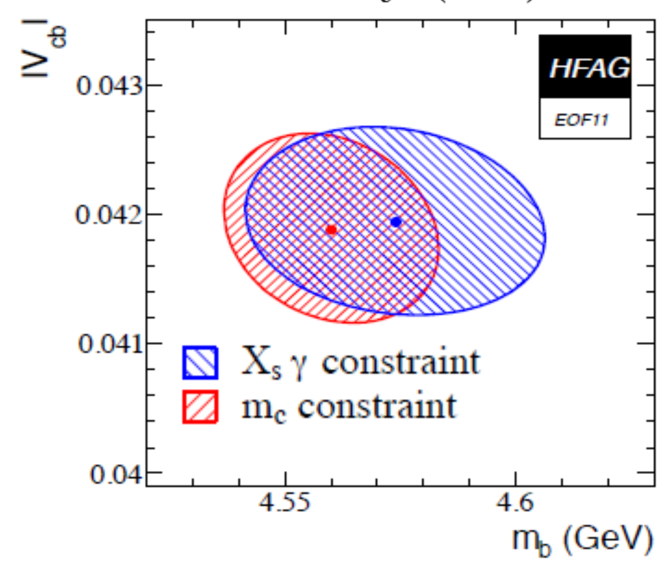
hep-ex: 1102.0210



- Global Fit by HFAG to 64 moments (kinetic scheme)

$$|V_{cb}| = (41.88 \pm 0.44_{fit} \pm 0.59_{theory}) \times 10^{-3}$$
$$m_b = 4.560 \pm 0.023 \text{ GeV}$$
$$\mu_\pi^2 = 0.453 \pm 0.036 \text{ GeV}^2$$

Very similar results for fits to 1S scheme calculations



- Considerable improvements underway
  - higher order QCD terms beyond $O(\alpha_s^2)$ and $O(m_b^3)$
  - m_c mass error might be reduced by ½
  - Treatment of correlations ?!

$|V_{ub}|$ from Inclusive $B \rightarrow X_u \ell \nu$

- Experimental challenges
  - Large $B \rightarrow X_c l \nu$ background (50x larger) requires restriction in phase space
  - Full event reconstruction to measure variables like M_X and q^2

- Theoretical challenges - OPE convergence destroyed in limited phase space
  - Rates become more sensitive
    - Unknown higher orders terms in α_s and $1/m_b$ expansions
    - Dynamics of b-quark inside B meson - Unknown Shape functions (SF)
  - Uncertainties in input parameters
    - m_b: total rate $\Gamma \sim |V_{ub}|^2 m_b^5$, partial rates $\Delta\Gamma \sim |V_{ub}|^2 m_b^{10}$

- Several QCD calculations available to predict the normalization:

BLNP	multi-scale OPE based on SCET	NP B699, 335 (2004).
DGE	resummed perturbations theory	JHEP 0601, 096 (2006)
GGOU	large range of distributions fct.	JHEP 0710, 058 (2007)
ADFR	relates partial Bf to total BF	Eur. Phys. J. C59, 831 (2009)

$|V_{ub}|$ from Inclusive $B \rightarrow X_u \ell \nu$ Decays

- Best measurements from fit to M_X vs q^2 with low restriction on $p_\ell > 1$ GeV
- BABAR and Belle results in very good agreement.

  Arithmetic average for the 4 QCD calculations:

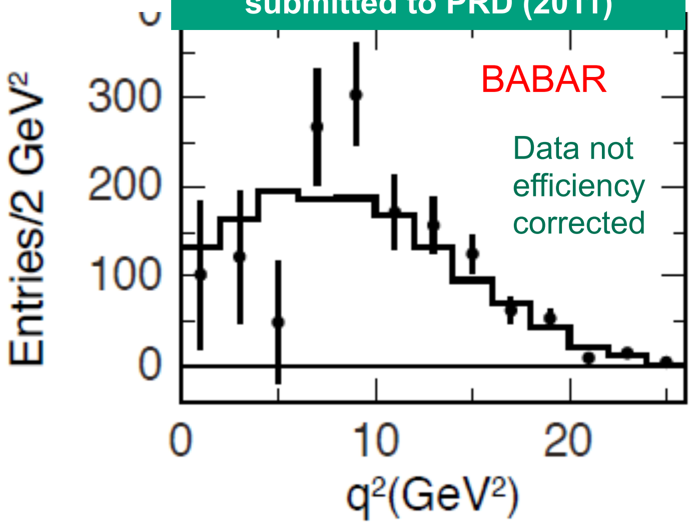
  $$|V_{ub}| = (4.41 \pm 0.15_{exp} \pm 0.17_{theory}) \times 10^{-3}$$

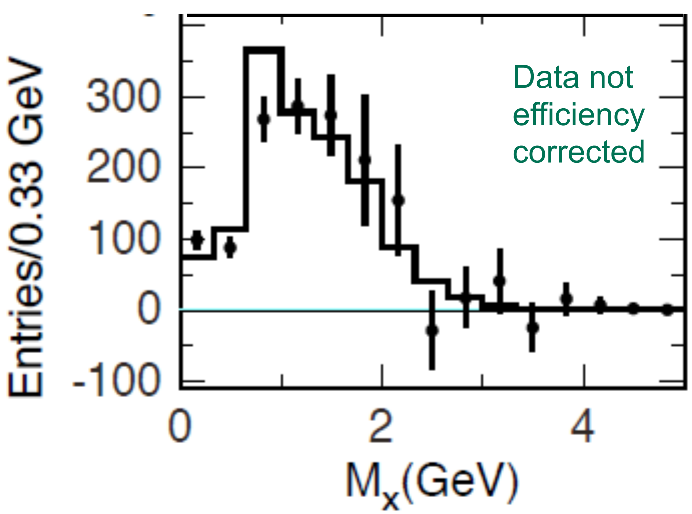
  Systematic error mostly from $B \rightarrow X_u l \nu$ and BG simulation

  BABAR measurements in different kinematic regions agree!

- Expected improvements
  - Develop Global Fit to moments from $B \rightarrow X_u l \nu$ and $B \rightarrow X_s \gamma$ to extract $|V_{ub}|$, μ_π^2, with precise quark masses as input.
  - Factorize Shape Fct. into non-perturbative (from data) and perturbative (from theory)

submitted to PRD (2011)





Exclusive vs Inclusive $|V_{xb}|$ Measurements: Tension!!

(HFAG averages for B Factory results only)

- $|V_{cb}|$ Exclusive (D*lν)
  - expt. error: 1.4%
  - LQCD normalization: 1.9%
- $|V_{cb}|$ Inclusive
  - expt. error: 1.1 %
  - Theory error 1.4%
- $|V_{ub}|$ Exclusive (πlν)
  - expt. error: 5.5 %
  - LQCD normalization 7.5%
- $|V_{ub}|$ Inclusive
  - improved expt. error: 3.6%
  - much improved theory 3.9%
- Another Problem: B→τν

$$\left|V_{cb}\right| = (39.04 \pm 0.55 \pm 0.73) \cdot 10^{-3}$$

$$\left|V_{cb}\right| = (41.88 \pm 0.44 \pm 0.59) \cdot 10^{-3}$$

2.4σ

$$\left|\mathrm{V}_{\mathrm{ub}}\right| = (3.23 \pm 0.18 \pm 0.24) \cdot 10^{-3}$$

$$\left|V_{ub}\right| = (4.41 \pm 0.15 \pm 0.17) \cdot 10^{-3}$$

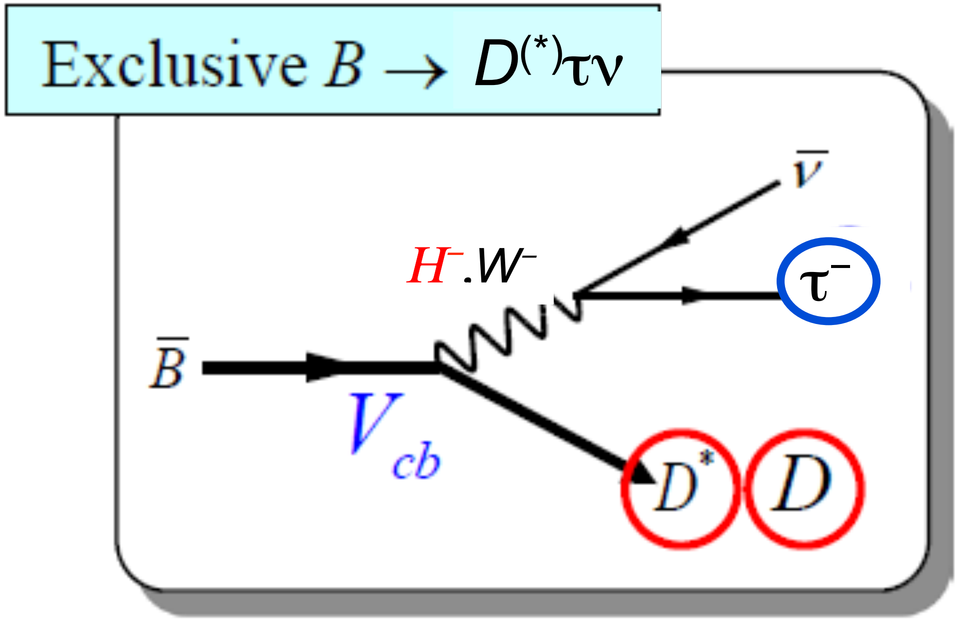
2.7σ

$$\left|\mathrm{V}_{\mathrm{ub}}\right| = (5.0 \pm 0.6) \times 10^{-3}$$

??

Caveat: Based on BF average of 4 low statistics BF measurements! Wait for more data!

S.L. Decays Involving the Heavy Lepton τ



Ratio of $B \to D^{(*)}\tau\nu$ vs $B \to D^{(*)}\ell\nu$ Decays

- S.L. decays involving a $\tau^{\pm}$ have an additional helicity amplitude (for $D^*\tau\nu$):

$$\frac{d\Gamma_\tau}{dq^2} = \frac{G_F^2|V_{cb}|^2|\mathrm{p}|q^2}{96\pi^3 m_B^2}\left(1-\frac{m_\tau^2}{q^2}\right)^2\left[\left(|H_{++}|^2+|H_{--}|^2+|H_{00}|^2\right)\left(1+\frac{m_\tau^2}{2q^2}\right)+\frac{3}{2}\frac{m_\tau^2}{q^2}|H_t|^2\right]$$

For $D\tau\nu$, only H_{00} and H_t contribute!

- To test the SM Prediction, we measure

$$\boxed{R(D)=\frac{\Gamma(\overline{B}\to D\tau\nu)}{\Gamma(\overline{B}\to D\ell\nu)} \qquad R(D^*)=\frac{\Gamma(\overline{B}\to D^*\tau\nu)}{\Gamma(\overline{B}\to D^*\ell\nu)}}$$

Leptonic τ decays only

Several experimental and theoretical uncertainties cancel in the ratio!

- BB events are fully reconstructed:
  - full reconstruction of hadronic B decay: Btag (tag efficiency improved)
  - reconstruction of $D^{(*)}$ and $e^{\pm}$ or $\mu^{\pm}$ (extend to lower momenta)
  - no additional charged particles
  - kinematic selections: $q^2 > 4\ \mathrm{GeV}^2$

  Background suppression by BDT (combinatorial and $D^{**}l\nu$)

- Full BABAR data sample, MC correction based on data control samples

B→ D$^{(*)}$ τν: Extraction of Yields from M.L. Fit

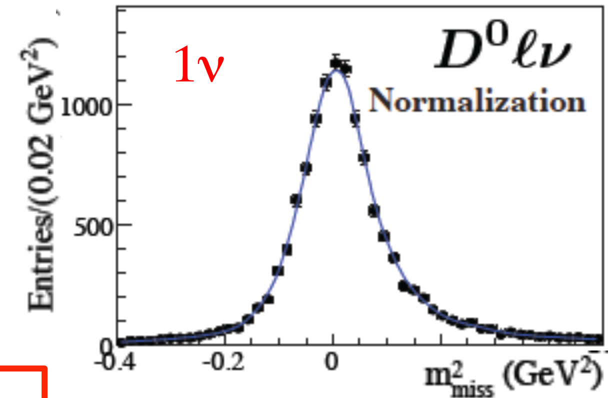
to be submitted to PRL

- Unbinned M.L. fit
  - 2-D distributions:

$$m^2_{miss} = (P_{ee} - P_{Btag} - P_{D(*)} - P_\ell)^2$$

Missing mass sq

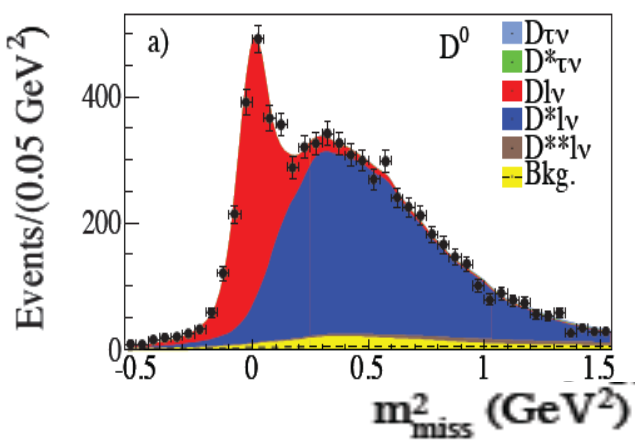
p^*_ℓ Lepton momentum in B rest frame

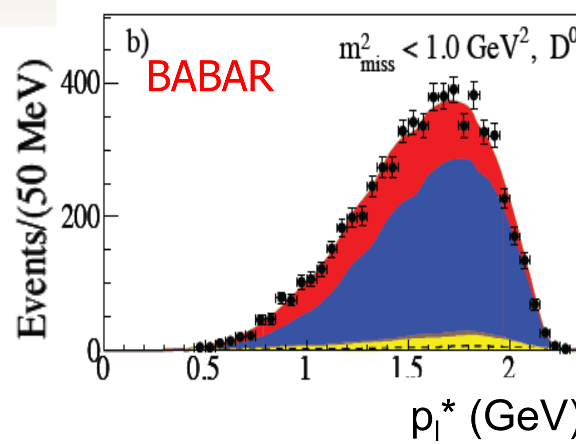


  - 4 signal samples: D⁰ℓ, D*⁰ℓ, D⁺ℓ, D*⁺ℓ, (e± or μ±)
  - 4 D$^{(*)}$ π⁰ℓν Control samples
- PDFs from MC (approximated using Keys fct.)
- Fitted Yields
  - 4 D$^{(*)}$ τν Signal
  - 4 D$^{(*}$ ℓν Normalization
  - 4 D** ℓν Backgrounds
- Fixed Backgrounds
  - B⁰–B⁺ cross feed
  - $B\overline{B}$ combinatorial BG
  - Continuum e⁺e⁻→f f(γ)

Large D* → D feed down

MC Simulation





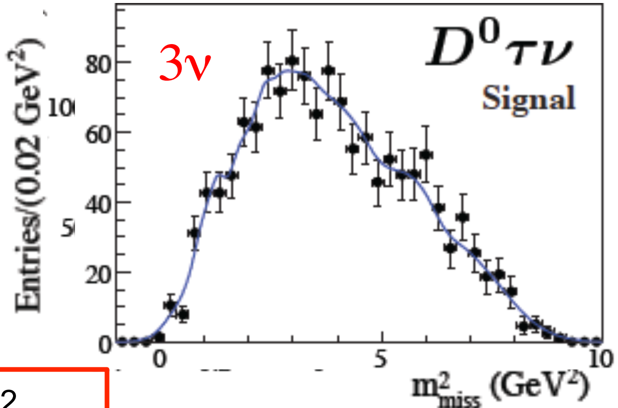
$B \to D^{(*)} \tau\nu$: Extraction of Yields from M.L. Fit

- Unbinned M.L. fit
  - 2-D distributions:
  - 4 signal samples: $D^0\ell$, $D^{*0}\ell$, $D^+\ell$, $D^{*+}\ell$, ($e^\pm$ or $\mu^\pm$)
  - 4 $D^{(*)}\pi^0\ell\nu$ Control samples

$$m^2_{miss} = (P_{ee} - P_{Btag} - P_{D(*)} - P_\ell)^2$$

Missing mass sq

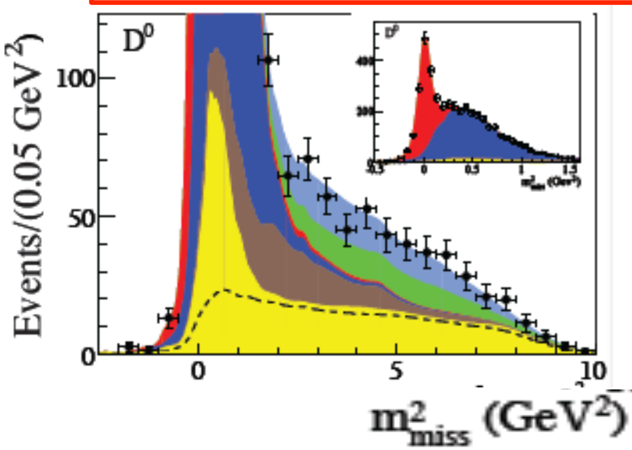
p^*_ℓ Lepton momentum in B rest frame

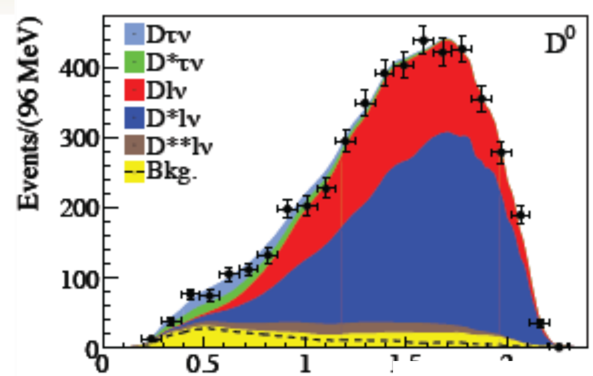


MC Simulation

- PDFs from MC (approximated using Keys fct.)
- Fitted Yields
  - 4 $D^{(*)}\tau\nu$ Signal
  - 4 $D^{(*)}\ell\nu$ Normalization
  - 4 $D^{**}\ell\nu$ backgrounds
- Fixed Backgrounds
  - B^0–B^+ cross feed
  - BB combinatorial BG
  - Continuum $e^+e^- \to f\,f(\gamma)$

$D^{(*)}\tau\nu$ Signal at larger m^2_{miss}





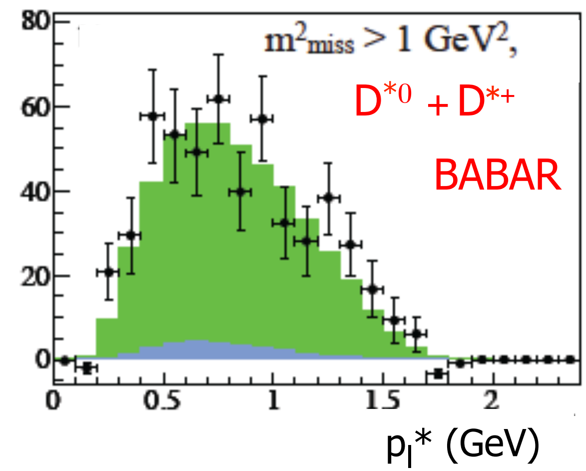
p_l^* (GeV)

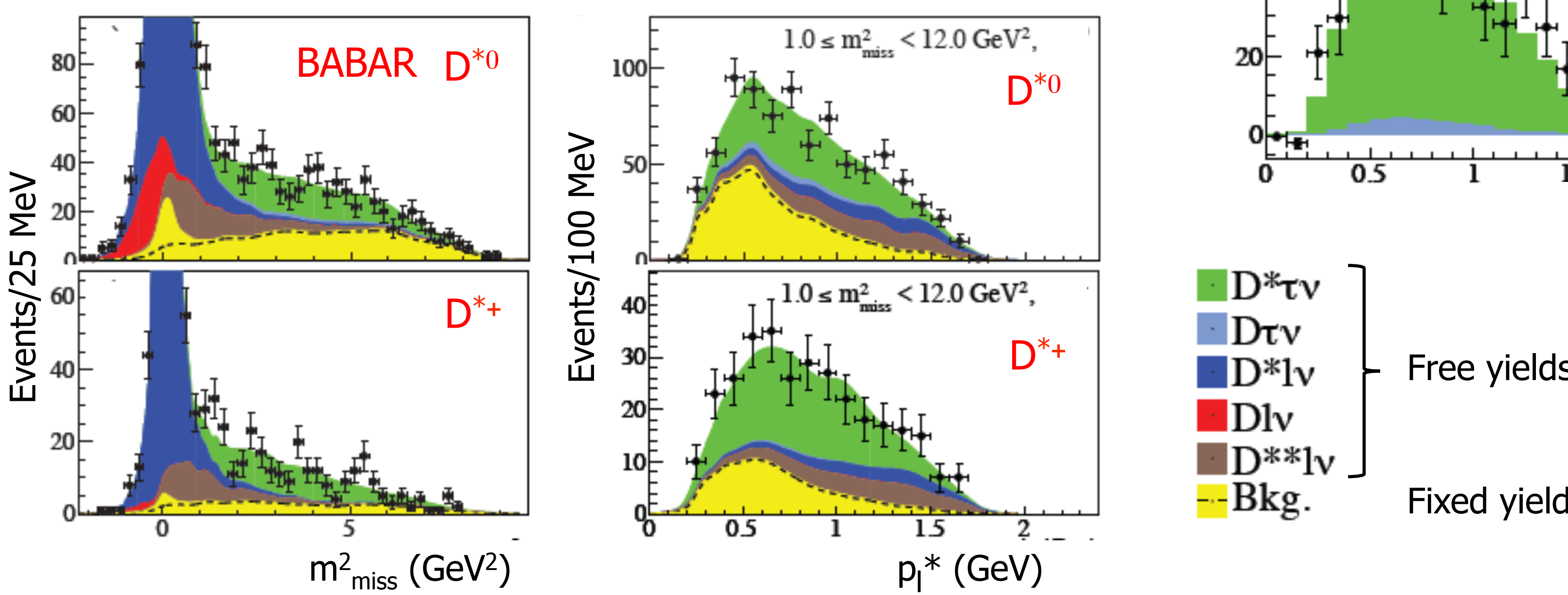
Results of Fit: B→ D*τν

	$D^{*0}\tau\nu$	$D^{*+}\tau\nu$	$D^{*}\tau\nu$
$N_{\rm sig}$	639 ± 62	245 ± 27	888 ± 63
Significance (σ)	11.3	11.6	16.4
$R(D^*)$	0.322 ± 0.032	0.355 ± 0.039	0.332 ± 0.024

Isospin contrained

Statistical errors only



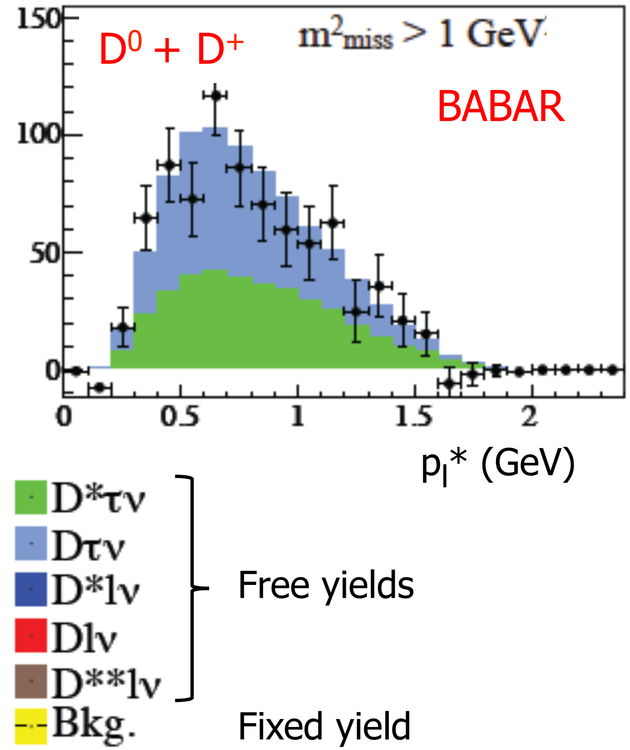


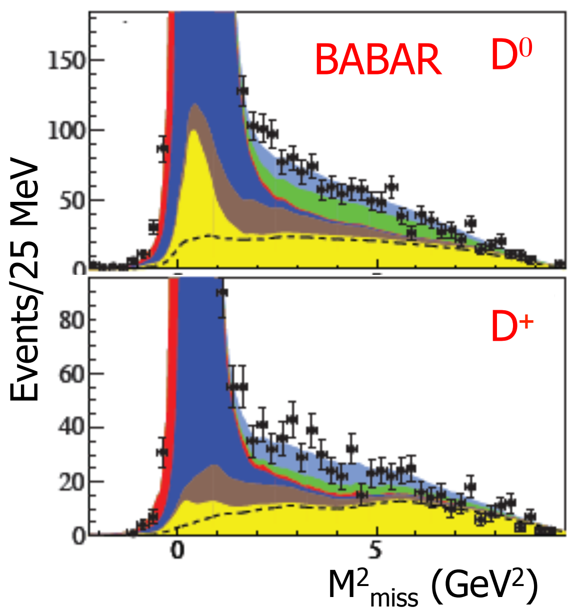
Results of Fit: B → Dτν

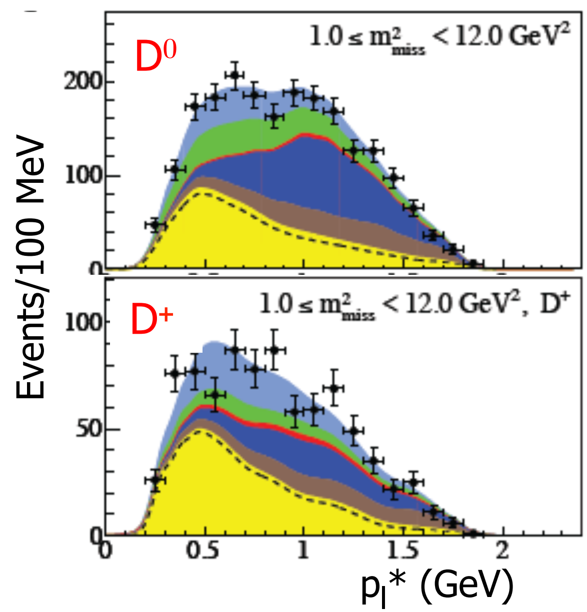
	$D^0\tau\nu$	$D^+\tau\nu$	$D\tau\nu$
N_{sig}	314 ± 60	177 ± 31	489 ± 63
Significance (σ)	5.5	6.1	8.4
$R(D)$	0.429 ± 0.082	0.469 ± 0.084	0.440 ± 0.058

Statistical errors only

Isospin constrained







Systematic Uncertainties

ρ Correlation between R(D) and R(D*)

Principal Uncertainties:

- $D^{**} l\ \nu$: conservative 15%
  constraints and fit to $D\pi$ sample,
- Limited MC signal samples
  2-dim PDFs with ~2000 events
- Continuum and BB background
  Corrections and MC statistics

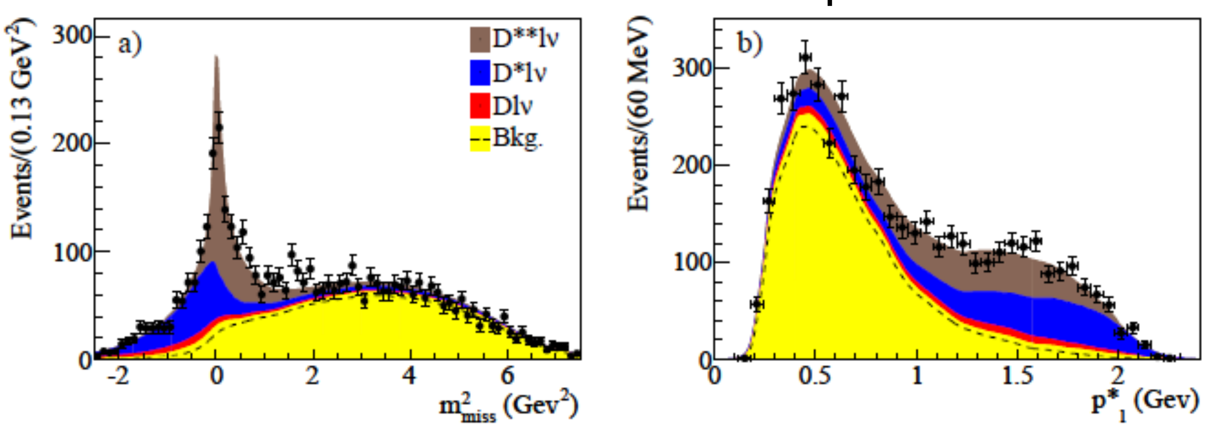
Source	Uncertainty (%) $R(D)$	$R(D^*)$	ρ
$D^{**}\ell\nu$ background	5.8	3.7	0.62
MC statistics	5.0	2.5	-0.48
Cont. and $B\overline{B}$ bkg.	4.9	2.7	-0.30
$\varepsilon_{sig}/\varepsilon_{norm}$	2.6	1.6	0.22
Systematic uncertainty	9.5	5.3	0.05
Statistical uncertainty	13.1	7.1	-0.45
Total uncertainty	16.2	9.0	-0.27

Largest errors are Gaussian distributed!

$D\pi^0\ \ell\ \nu$ Control Sample

Results of fit to $D^{**}l$ nu control sample for the sum of the 4 channels:

$D^0\pi^0 l\nu$,, $D^{*0}\pi^0 \ell\ \nu$,
$D^+\pi^0 l\nu$,, $D^{*+}\pi^+ \ell\ \nu$,



Summary of R(D) and R(D*) Measurement

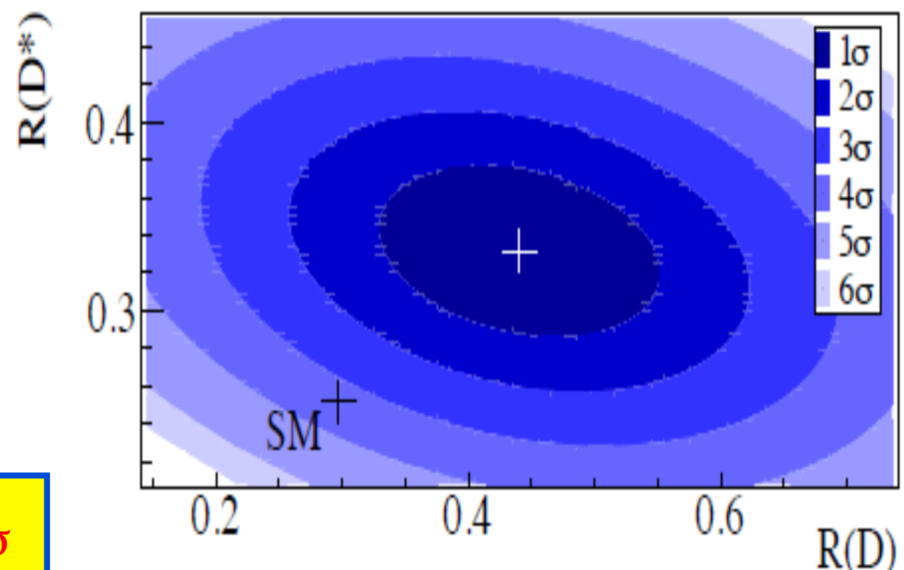
to be submitted to PRL

Decay	N_{sig}	N_{norm}	$R(D^{(*)})$	$\mathcal{B}(B \to D^{(*)}\tau\nu)$ (%)	$\Sigma_{tot}(\sigma)$
$D^0\tau^-\overline{\nu}_\tau$	314 ± 60	1995 ± 55	$0.429 \pm 0.082 \pm 0.052$	$0.99 \pm 0.19 \pm 0.13$	4.7
$D^{*0}\tau^-\overline{\nu}_\tau$	639 ± 62	8766 ± 104	$0.322 \pm 0.032 \pm 0.022$	$1.71 \pm 0.17 \pm 0.13$	9.4
$D^+\tau^-\overline{\nu}_\tau$	177 ± 31	986 ± 35	$0.469 \pm 0.084 \pm 0.053$	$1.01 \pm 0.18 \pm 0.12$	5.2
$D^{*+}\tau^-\overline{\nu}_\tau$	245 ± 27	3186 ± 61	$0.355 \pm 0.039 \pm 0.021$	$1.74 \pm 0.19 \pm 0.12$	10.4
$D\tau^-\overline{\nu}_\tau$	489 ± 63	2981 ± 65	$0.440 \pm 0.058 \pm 0.042$	$1.02 \pm 0.13 \pm 0.11$	6.8
$D^*\tau^-\overline{\nu}_\tau$	888 ± 63	11953 ± 122	$0.332 \pm 0.024 \pm 0.018$	$1.76 \pm 0.13 \pm 0.12$	13.2

Comparison with SM calculation:

	R(D)	R(D*)
BABAR	0.440 ± 0.071	0.332 ± 0.029
SM	0.297 ± 0.017	0.252 ± 0.003
Difference	**2.0 σ**	**2.7 σ**

BABAR

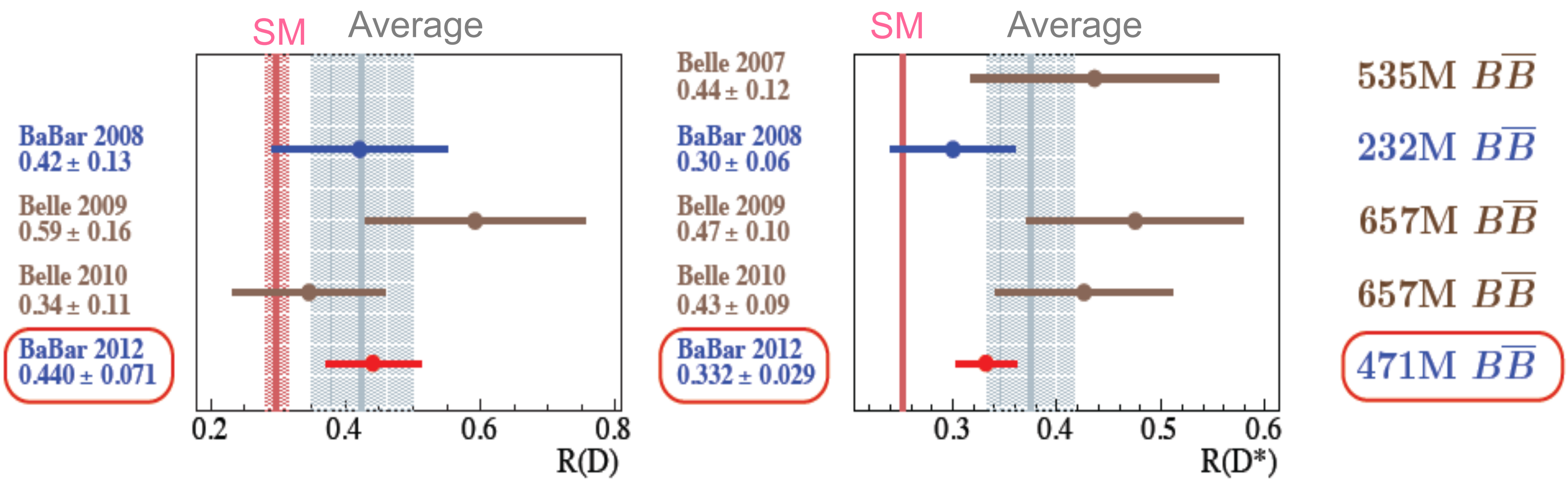


The combination of the two measurements (-0.27 correlation) yields χ^2/NDF=14.6/2, i.e. Prob. = 6.9 x10^{-4} !!

Thus the SM prediction is excluded at 3.4 σ

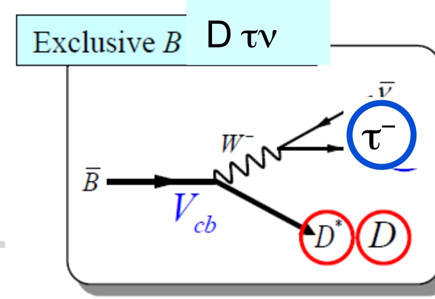
Comparison to Previous Measurements

NB: Average does not include this measurement



The new measurements are fully compatible with earlier results!

Can we explain the excess events?



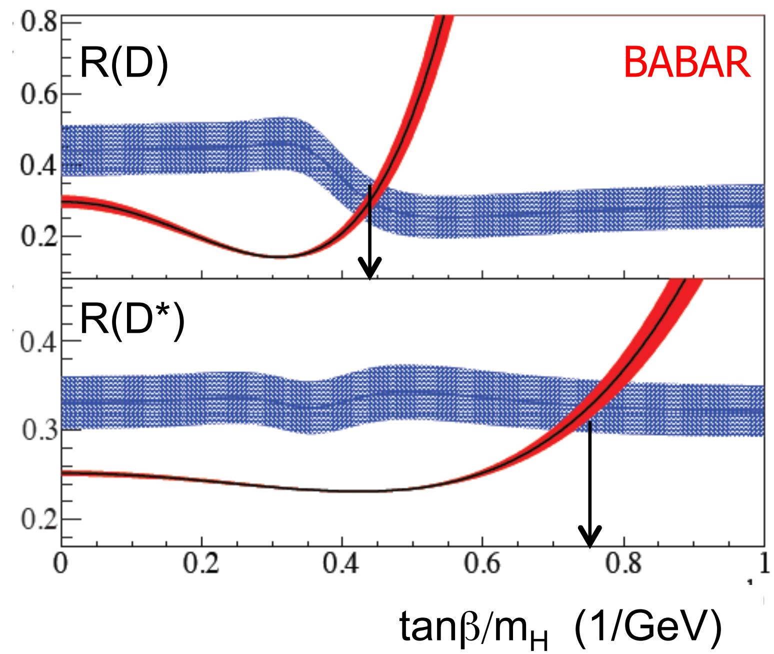
- A charged Higgs (2HDM type II) of spin 0 couples to the τ and will only affect H_t

$$H_t^{\rm 2HDM} = H_t^{\rm SM} \times \left(1 - \frac{\tan^2\beta}{m^2_{H\pm}} \frac{q^2}{1 \mp m_c/m_b}\right)$$

- for $D\tau\nu$
+ for $D^*\tau\nu$

This could enhance or decrease the ratios R(D*) depending on $\tan\beta/m_H$

- We estimate the effect of 2DHM, accounting for difference in efficiency, and its uncertainty
- The data match 2DHM Type II at
  - $\tan\beta/m_H = 0.44 \pm 0.02$ for R(D)
  - $\tan\beta/m_H = 0.75 \pm 0.04$ for R(D*)
- However, the combination of R(D) and R(D*) excludes the Type II 2HDM in the full $\tan\beta$-m_H parameter space with a probability of >99.8%, provided M_H>10GeV !



Summary

- Studies of semileptonic decays have been challenging for both theory and experiment.
- Current measurements are based on the full BABAR and Belle data
- At present, there are two interesting puzzles:
  - The “tension” between inclusive and exclusive analyses remains, while stated uncertainties on BF and $|V_{ub}|$ and $|V_{cb}|$ are being reduced.
  - The search for non-SM B decay rates has revealed a significant excess (3.4 σ) of events in $B \to D\tau\nu$ and $B \to D^*\tau\nu$. This feature cannot be explained by contributions expected from a 2DHM Higgs of Type II.
- To solve these puzzles, we need
  - more data – expected from LHCb and future B Factories
  - continued close collaboration between experimenters and theorists!

谢谢