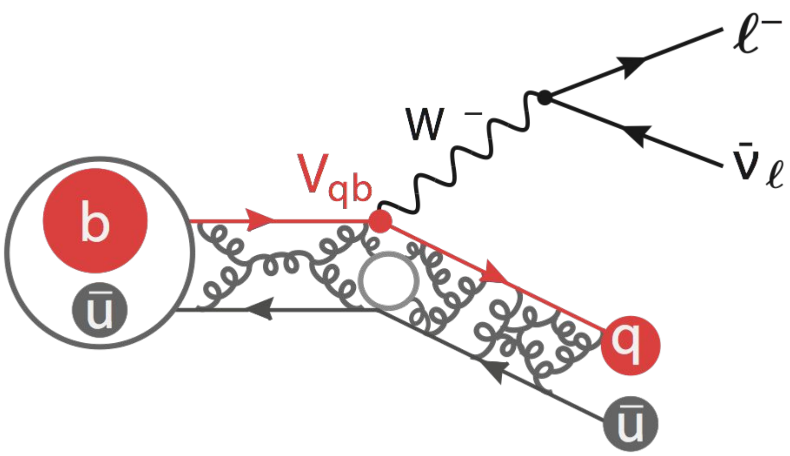
CKM 2016: WG2 Highlights

Conveners:
Aoife Bharucha
Brian Hamilton
Florian Bernlochner



CKM 2016

WG2 Parallel Sessions

We had a very productive meeting this week with talks covering

- Exclusive & Inclusive $b \to c\ell\nu$
- Exclusive & Inclusive $b \to u\ell\nu$
- SL decays to tau
- Leptonic B decays

Many thanks to all the speakers who contributed to our program!

Sessions inevitably became mixed-topic as schedules evolved

- Have tried to organize into topics for this talk

Mon 28/11

Experimental mini-review on exclusive Vub and Vcb (LHCb)	Dr. Marcello ROTONDO	AG-66, TIFR, Mumbai	15:30 - 16:00
Experimental mini-review on exclusive Vub (Belle II)	Mr. Matic LUBEJ	AG-66, TIFR, Mumbai	16:00 - 16:20
Improvements to sum rules predictions for Vub	Dr. Aoife BHARUCHA	AG-66, TIFR, Mumbai	16:20 - 16:40
Impact of Leptoquarks in semileptonic B decays	Suchismita SAHOO	AG-66, TIFR, Mumbai	16:40 - 17:00
Discussion		AG-66, TIFR, Mumbai	17:00 - 17:30

Exclusive V_{ub} (mostly)

Wed 30/11

Experimental mini-review on inclusive Vcb (Belle)	Dr. Florian BERNLOCHNER	AG-66, TIFR, Mumbai	09:00 - 09:20
Theoretical improvements to inclusive Vub and Vcb (with global shape function fits)	Mr. Frank TACKMANN	AG-66, TIFR, Mumbai	09:20 - 09:50
Improvements to inclusive Vcb	Soumitra NANDI	AG-66, TIFR, Mumbai	09:50 - 10:10
Semileptonic Bc decays from lattice QCD	Andrew LYTLE	AG-66, TIFR, Mumbai	10:10 - 10:30
Discussion		AG-66, TIFR, Mumbai	10:30 - 11:00

Exclusive V_{cb} (mostly)

Tue 29/11

Higher dimensional HQET parameters	Prof. Gil PAZ	AG-66, TIFR, Mumbai	11:30 - 11:50
Theoretical improvements to inclusive Vub	Dr. Paolo GAMBINO	AG-66, TIFR, Mumbai	11:50 - 12:10
Experimental mini-review on inclusive Vub (BaBar)	Prof. Robert KOWALEWSKI	AG-66, TIFR, Mumbai	12:10 - 12:30
Discussion		AG-66, TIFR, Mumbai	12:30 - 12:40

Inclusive V_{ub} (mostly)

Experimental mini-review on exclusive Vcb (Belle)	Dr. Christoph SCHWANDA	AG-69, TIFR, Mumbai	14:00 - 14:20
Experimental mini-review on other semileptonic B/Bs/Lambda decays (LHCb)	Dr. Patrick OWEN	AG-69, TIFR, Mumbai	14:20 - 14:40
Lattice mini-review Vcb	Dr. Matthew WINGATE	AG-69, TIFR, Mumbai	14:40 - 15:00
Improvements to QCD sum rules predictions for Vcb	Dr. Danny VAN DYK	AG-69, TIFR, Mumbai	15:00 - 15:20
Lattice mini-review on exclusive Vub	Dr. Taichi KAWANAI	AG-69, TIFR, Mumbai	15:20 - 15:40

Exclusive V_{ucb} (mostly)

Thu 1/12

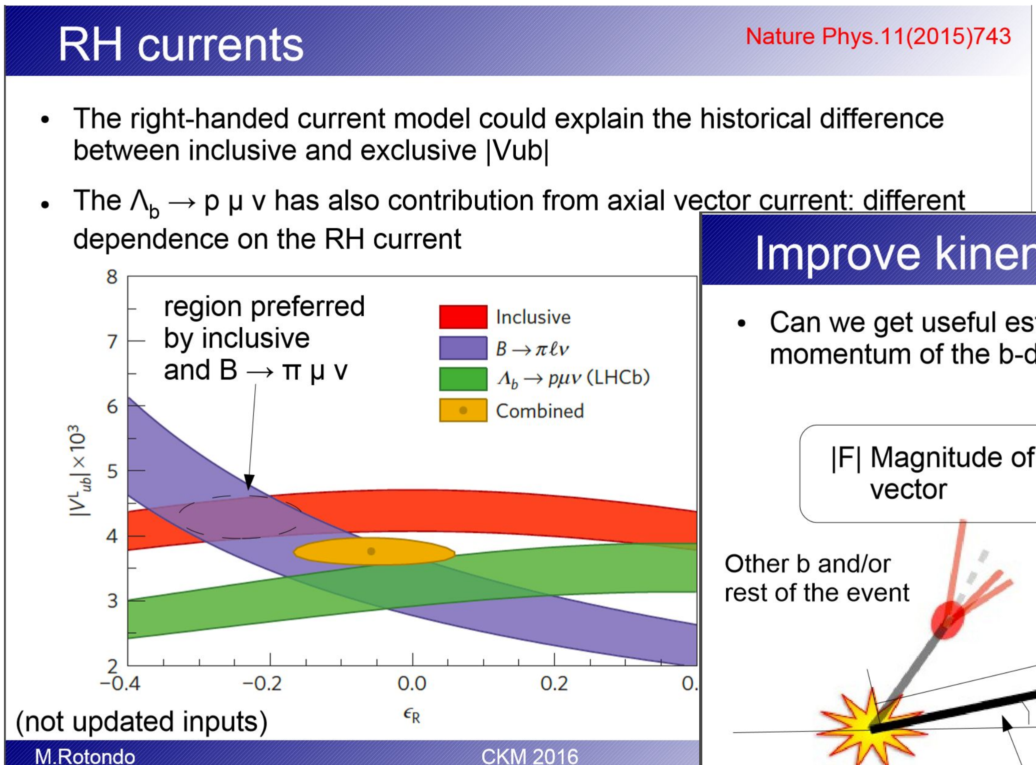
Experimental mini-review on R(D) and R(D*) measurements (LHCb)	Concezio BOZZI	AG-66, TIFR, Mumbai	11:30 - 11:50
Experimental mini-review on R(D) and R(D*) measurement (BaBar)	Dr. Marcello ROTONDO	AG-66, TIFR, Mumbai	11:50 - 12:10
Refining the SM theory predictions for R(D/D*)	Andrey TAYDUGANOV	AG-66, TIFR, Mumbai	12:10 - 12:40
D* and tau polarization measurements by Belle	Karol ADAMCZYK	AG-66, TIFR, Mumbai	12:40 - 13:00
Leptoquark resolution of B meson anomalies	Prof. Svjetlana FAJFER	AG-66, TIFR, Mumbai	14:00 - 14:20
B → D(*) tau nu decays in the noncommutative standard model	J SELVAGANAPATHY	AG-66, TIFR, Mumbai	14:20 - 14:40
A closer look at the R(D) and R(D*) anomalies	Debjyoti BARDHAN	AG-66, TIFR, Mumbai	14:40 - 14:55
Experimental mini-review on leptonic decays (Belle II)	Youngjoon KWON	AG-66, TIFR, Mumbai	14:55 - 15:15
Discussion		AG-66, TIFR, Mumbai	15:15 - 15:45

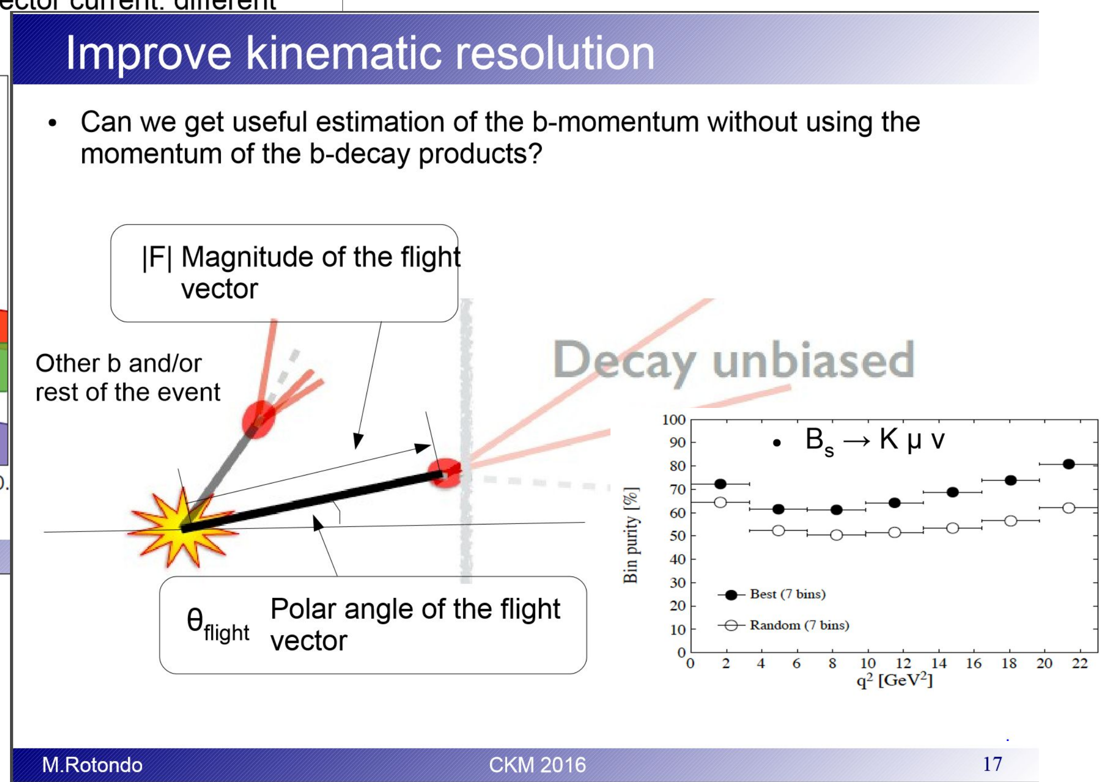
Tau and leptonic sessions

Exclusive V_{ub}

Experimental talk (LHCb) by Marcello Rotondo

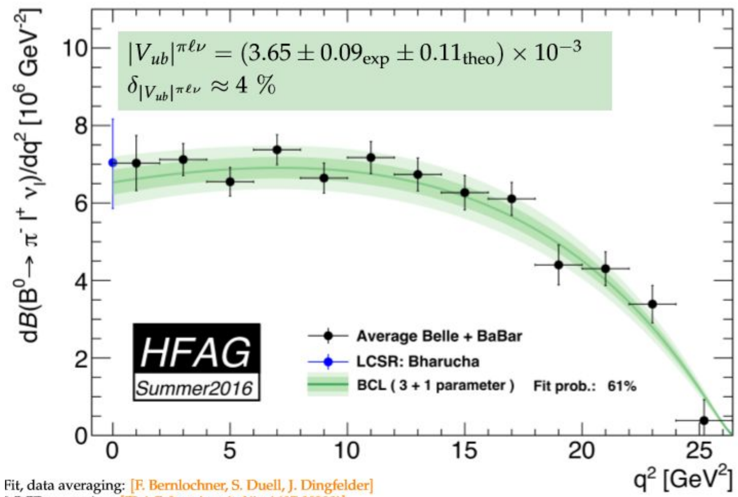
- Reviewed LHCb's 2015 Λb→pμν result
- Looked ahead at prospects for Bs→Kμν and the challenges there
- Exciting new technique to (partially) break the two-fold ambiguity in inferring the neutrino momentum at LHCb
- LHCb's plans for B+→μμμν



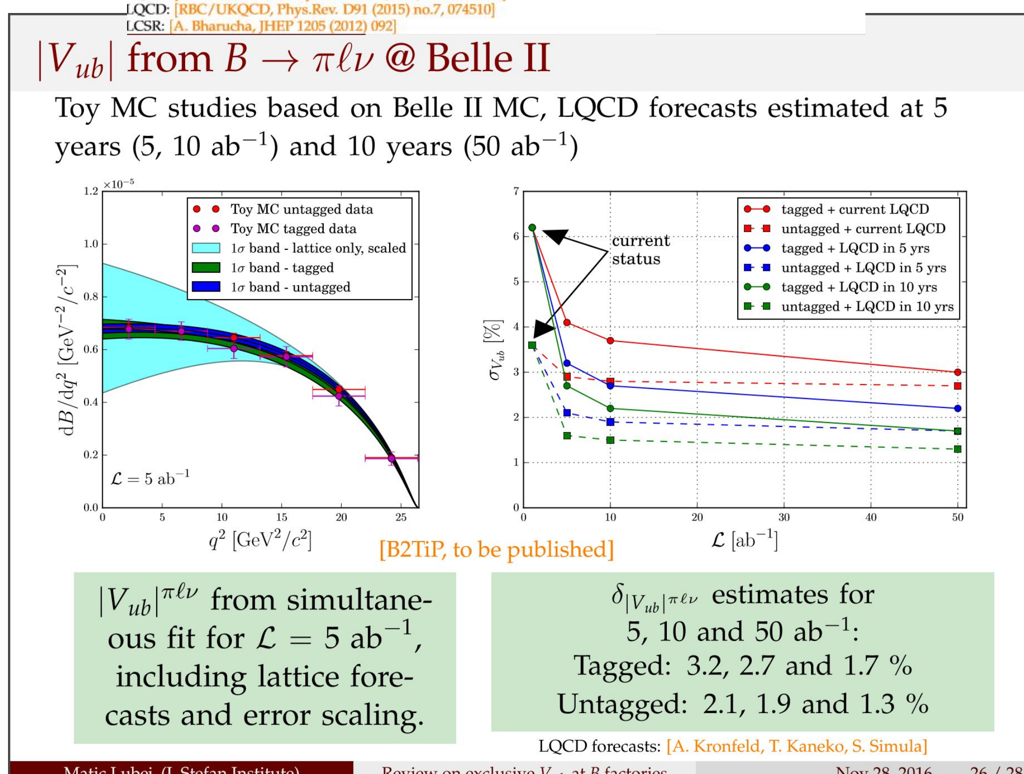


B-factories exclusive Vub overview by Matic Lubej

- Comprehensive overview of the many results available (see slides for many lovely fits)
- New $B\to\pi\ell\nu$ B-factory+lattice+LCSR average for 2016
- Reported on prospects for Belle 2, with hadronically tagged measurements catching up to the statistical power of untagged results



Fit, data averaging: [F. Bernlochner, S. Duell, J. Dingfelder]
LQCD averaging: [FLAG-3 review (arXiv:1607.00299)]
LQCD: [Fermilab/MILC, Phys.Rev. D92 (2015) no.1, 014024]
LQCD: [RBC/UKQCD, Phys.Rev. D91 (2015) no.7, 074510]
LCSR: [A. Bharucha, JHEP 1205 (2012) 092]



Exclusive $|V_{ub}|$ from LCSR: Aoife Bharucha

- Test if rad. corr. to $f_+ f_B$ and f_B cancel in SR
- Despite $\delta^{\mathcal{O}(\alpha_s^2\beta_0)} f_B \sim 9\%$, $\delta^{\mathcal{O}(\alpha_s^2\beta_0)} f_+(0)$, $\sim 2\%$

The latest HFAG simultaneous fit uses two-loop $f_+(0)$ from LCSR (AB 1203.1359)

New LCSR result for V_{ub} from $B \to \rho l \nu$ with comparable errors (AB, Straub, Zwicky 1503.05534)

Use of equation of motion. Find good agreement with V_{ub} from $B \to \pi$ within errors

TABLE 2. Status of exclusive $|V_{ub}|$ determinations and indirect fits

Exclusive decays	$\lvert V_{ub}\rvert \times 10^3$
$\bar{B} \to \pi l \bar{\nu}_l$	
FLAG 2016 [21]	3.62 ± 0.14
Fermilab/MILC 2015 [131]	3.72 ± 0.16
RBC/UKQCD 2015 [132]	3.61 ± 0.32
HFAG 2014 (lattice) [22]	3.28 ± 0.29
HFAG 2014 (LCSR) [138, 22]	3.53 ± 0.29
Imsong et al. 2014 (LCSR, Bayes an.) [143]	$3.32^{+0.26}_{-0.22}$
Belle 2013 (lattice + LCSR) [126]	3.52 ± 0.29
$\bar{B} \to \omega l \bar{\nu}_l$	
Bharucha et al. 2015 (LCSR) [146]	$3.31 \pm 0.19_{\mathrm{exp}} \pm 0.30_{\mathrm{th}}$
$\bar{B} \to \rho l \bar{\nu}_l$	
Bharucha et al. 2015 (LCSR) [146]	$3.29 \pm 0.09_{\mathrm{exp}} \pm 0.20_{\mathrm{th}}$
$\Lambda_b \to p \mu \nu_\mu$	
LHCb (PDG) [147]	3.27 ± 0.23
Indirect fits	
UTfit (2016) [94]	3.74 ± 0.21
CKMfitter (2015, 3σ) [95]	$3.71^{+0.17}_{-0.20}$

Lower result for V_{ub} from the Bayesian analysis (Imsong, Khodjamirian, Mannel, van Dyk1409.7816)

New approach to choosing SR parameters. Fit BCL simultaneously to experimental and LCSR results.

HFAG 2016 (B to pi lattice+LCSR): 3.65 +- 0.09 +- 0.1

Exclusive Vcb

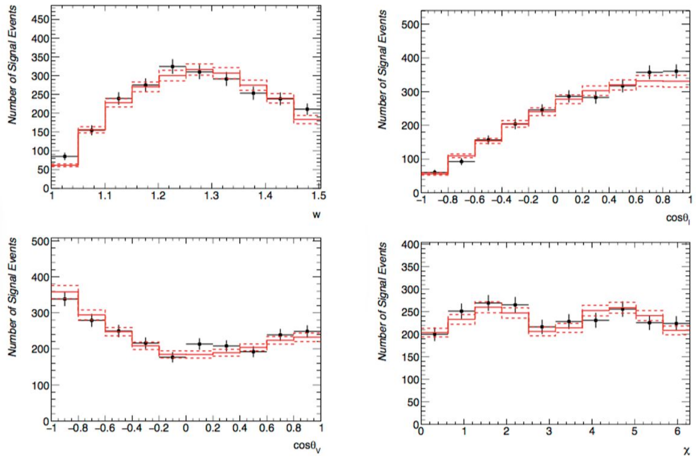
Exclusive Vcb from Belle - Christoph Schwanda

- $B \to D^{*+} \ell \nu$ and $B \to D \ell \nu$ both updated to full Belle Υ(4S) dataset in 2016
- Both include differential measurements vs w (and angles for D*)
  - Fits in missing mass squared in bins of relevant kinematics -- fairly model-independent

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

CLN fit to the differential widths

$$\chi^2 = \left(\boldsymbol{\nu}_{\mathrm{sig}} - \boldsymbol{\nu}_{\mathrm{sig}}^{\mathrm{pred}}\right) C^{-1} \left(\boldsymbol{\nu}_{\mathrm{sig}} - \boldsymbol{\nu}_{\mathrm{sig}}^{\mathrm{pred}}\right) + \left(h_{A1}(1) - h_{A1}^{\mathrm{la}}(1)\right)^2 / \left(\sigma_{h_{A1}(1)}^{\mathrm{la}}\right)^2$$



Points with error bars: Belle data,
red histogram: fit result, dashed histogram: $\Delta\chi^2$=1 contour

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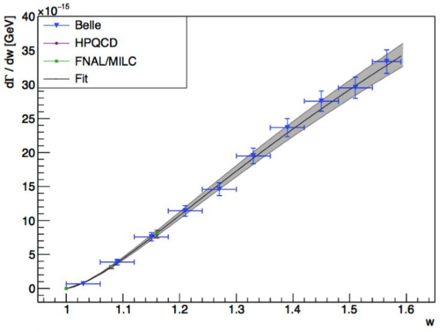
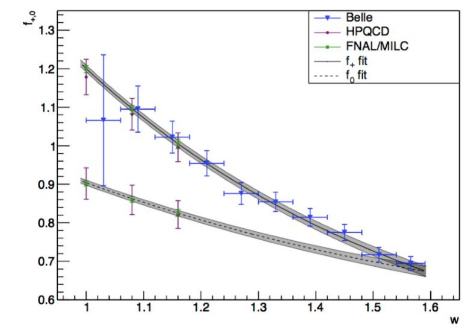
$B \to D \ell \nu$

BGL fit to differential widths and lattice data





	$N=2$	$N=3$	$N=4$
$a_{+,0}$	0.0127 ± 0.0001	0.0126 ± 0.0001	0.0126 ± 0.0001
$a_{+,1}$	-0.091 ± 0.002	-0.094 ± 0.003	-0.094 ± 0.003
$a_{+,2}$	0.34 ± 0.03	0.34 ± 0.04	0.34 ± 0.04
$a_{+,3}$	–	-0.1 ± 0.6	-0.1 ± 0.6
$a_{+,4}$	–	–	0.0 ± 1.0
$a_{0,0}$	0.0115 ± 0.0001	0.0115 ± 0.0001	0.0115 ± 0.0001
$a_{0,1}$	-0.058 ± 0.002	-0.057 ± 0.002	-0.057 ± 0.002
$a_{0,2}$	0.22 ± 0.02	0.12 ± 0.04	0.12 ± 0.04
$a_{0,3}$	–	0.4 ± 0.7	0.4 ± 0.7
$a_{0,4}$	–	–	0.0 ± 1.0
$\eta_{\mathrm{EW}}\lvert V_{cb}\rvert$	40.01 ± 1.08	41.10 ± 1.14	41.10 ± 1.14
χ^2/n_{df}	24.7/16	11.4/16	11.3/16
Prob.	0.075	0.787	0.787

Lattice data	$\eta_{\mathrm{EW}}\lvert V_{cb}\rvert[10^{-3}]$	χ^2/n_{df}	Prob.
FNAL/MILC [15]	40.96 ± 1.23	6.01/10	0.81
HPQCD [32]	41.14 ± 1.88	4.83/10	0.90
FNAL/MILC & HPQCD [15, 32]	41.10 ± 1.14	11.35/16	0.79

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Improvements from SR for Vcb: Danny van Dyk

Status 2016: $B \to D\mu\bar{\nu}$

ZRSR upper bounds/estimates of $\mathcal{G}(1)$:

- $O(\alpha_s)$ and partial $O(\alpha_s^2)$ terms (for the unit operator)
- up to $O(1/m^3)$ correction

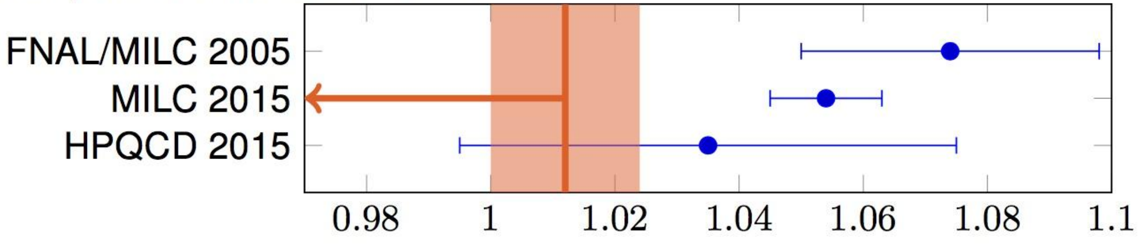
U2004 $\mathcal{G}(1) < 1.04 \pm 0.02 \pm \delta_{\text{exp}}$ [Uraltsev Phys.Lett. B585 (2004) 253-262]

GMU2010 $\mathcal{G}(1) < 1.02 \pm 0.04$ [Gambino,Mannel,Uraltsev Phys.Rev. D81 (2010) 113002]

LvD2016 $\mathcal{G}(1) < 1.012 \pm 0.012$ preliminary! [Lancierini,DvD w.i.p.]

[based on inputs from Alberti,Gambino,Healy,Nandi Phys.Rev.Lett. 114 (2015) no.6, 061802]

Comparison with lattice results



FNAL/MILC 2005 $G(1) = 1.074(18)_{\text{stat}}(16)_{\text{syst}}$

[Fermilab Lattice and MILC Collaborations Nucl. Phys. Proc. Suppl. 140, 461 (2005)]

MILC 2015 $G(1) = 1.054(4)_{\text{stat}}(8)_{\text{syst}}$ [MILC Collaboration Phys.Rev. D92 (2015) no.3, 034506]

HPQCD 2015 $G(1) = 1.035(40)$ [Phys.Rev. D92 (2015) no.5, 054510]

(mainly parameter update)

Zero recoil sum rules still at odds with (some) lattice inputs

$B \to D$ MILC 2015 at ~ 3σ tension, HPQCD 2014 compatible

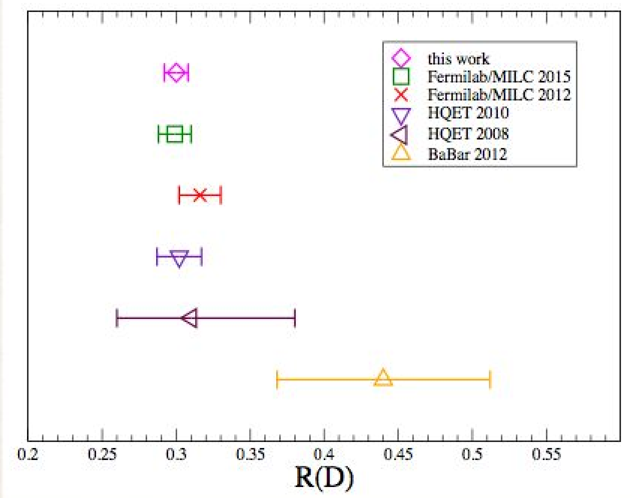
$B \to D^*$ FNAL/MILC 2015 at ~ 5σ tension, HPQCD prel. compatible

Lattice mini-review Vcb: Matthew Wingate

Final results for HPQCD $B_s \to D_s$ (MILC asqtad) and HPQCD $B \to D^*$ (MILC HISQ) soon

Underway: $B_{(s)} \to D^*_{(s)}$ at nonzero recoil by FNAL/MILC (asqtad) and HPQCD (HISQ)

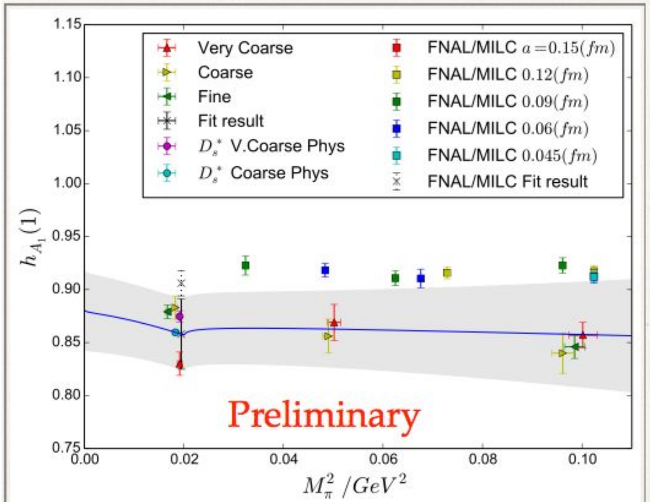
HPQCD also working on $B \to D$ (HISQ)



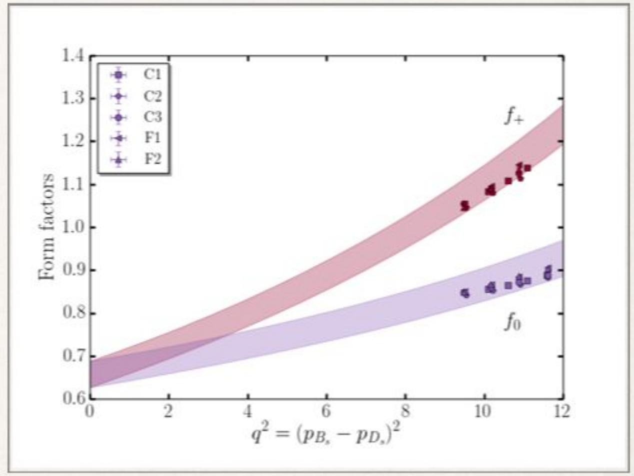
Na *et al.* (HPQCD), arXiv:1505.03925

HQET 2010 = Tanaka, Watanabe
HQET 2008 = Nierste, Trine, Westhoff

$B \to D^*$



Harrison et al, Lattice 2016



Monahan et al.,Lattice 2016

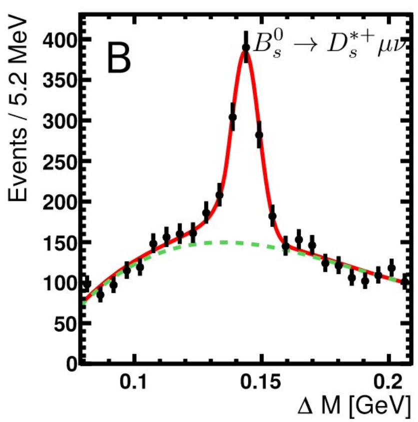
$B_s \to D_s$

Other b→c semileptonics - Patrick Owen

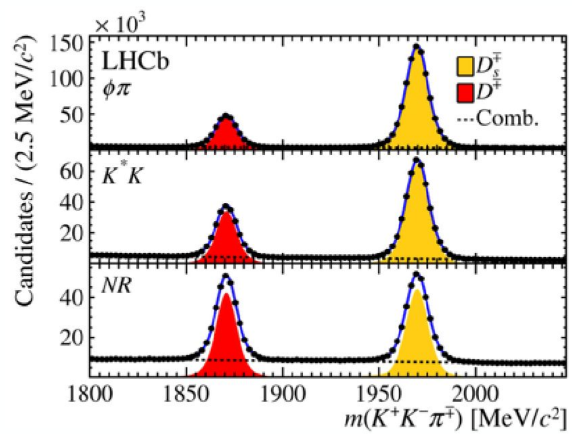
- Reviewed experimental status of b→excited charm states
- Important puzzle:
  - D$\ell\nu$ + D*$\ell\nu$ + Dπ$\ell\nu$ + Dππ$\ell\nu$ < inclusive e, μ rate
  - D$\tau\nu$ + D*$\tau\nu$ ≳ inclusive τ

Other b-hadron species

- We can learn more from other b-hadron species.
- For the excited cs system, the 1/2 states are narrow - could shed light on the 1/2 vs 3/2 puzzle?
- Not so well studied, most precise measurement from Belle.



Belle, Phys. Rev. D 92, 072013 (2015)



Phys. Rev. Lett. 117, 061803 (2016)

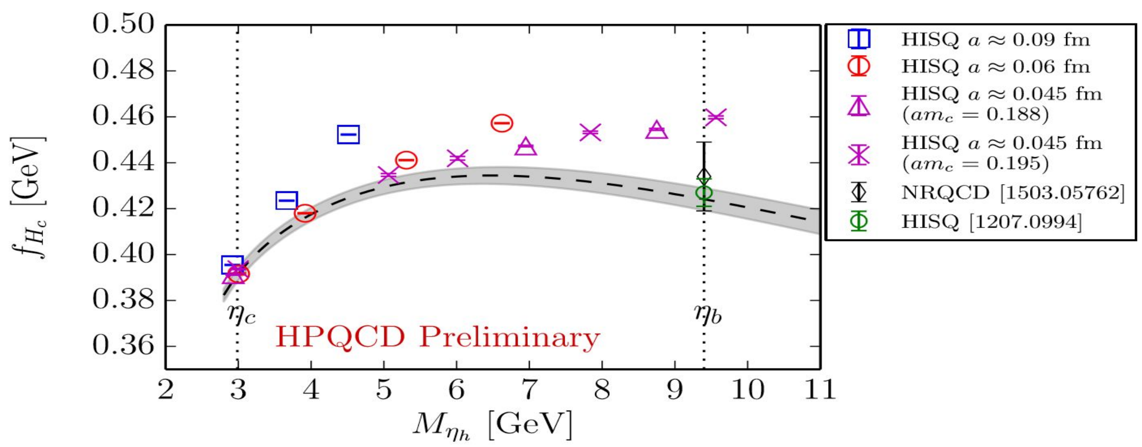
- Only two helicity states for D_s^{*+}, form factor measurement would be interesting.

Semileptonic B_c on the lattice: Andrew Lytle

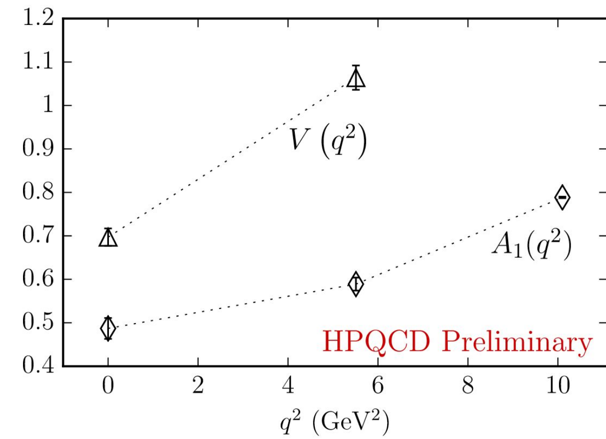
- Presented an approach to heavy quarks on the lattice, exploiting both HISQ and NRQCD with a fully relativistic formulation to extrapolate $m_c \leq m_h \leq m_b$ in fine lattices

- First target: understanding (hc) meson systems
  - Good control over full q^2 of $B_c \rightarrow \eta_c$ form factors
  - $Bc \rightarrow J/\psi$ form factors are imidate output (nice for LHCb) with $B \rightarrow D(*)$ in the future

f_{H_c} from HISQ.



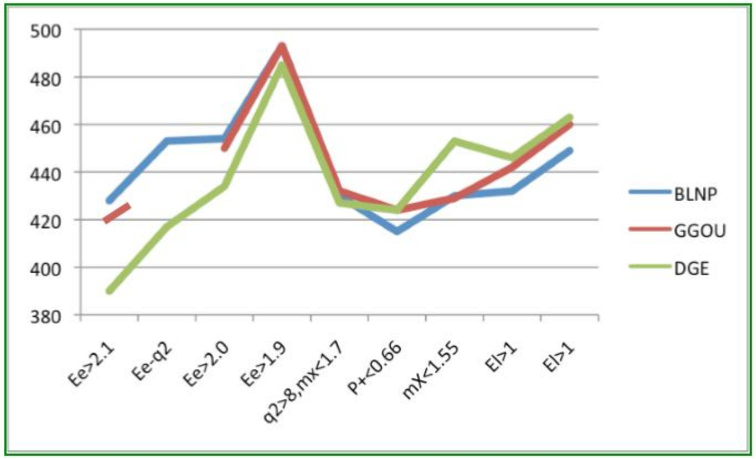
$B_c \to J/\psi$.

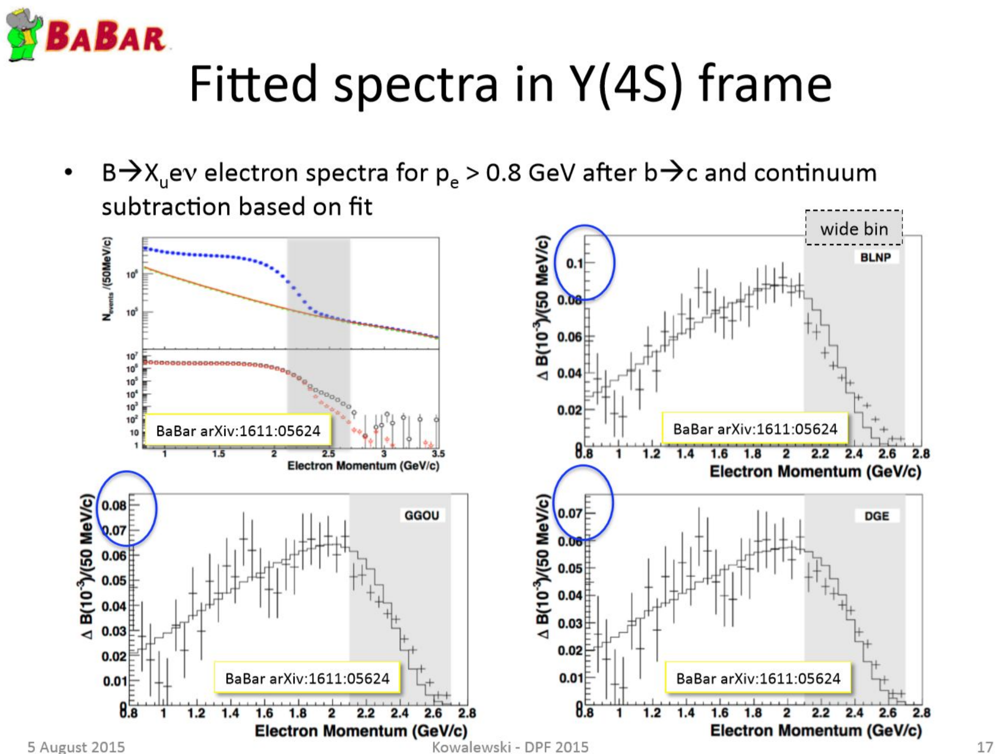


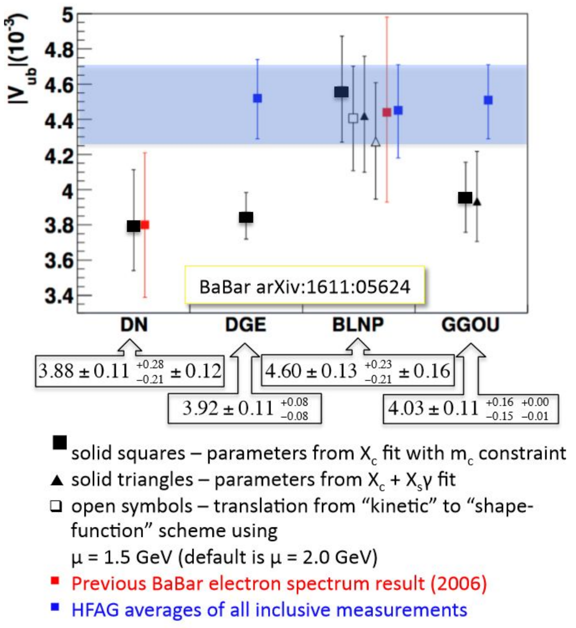
Inclusive semileptonics

Experimental situation ($b \to u$): Bob Kowaleski

- Despite inclusive-exclusive tension, results in different regions/techniques look quite consistent
- 2015: new BaBar result
- Message from experiment: fit sensitivities come from high El region regardless of cuts
    - Embrace the shape function region!







Discussion of HQET Operators for b→u from Gil Paz

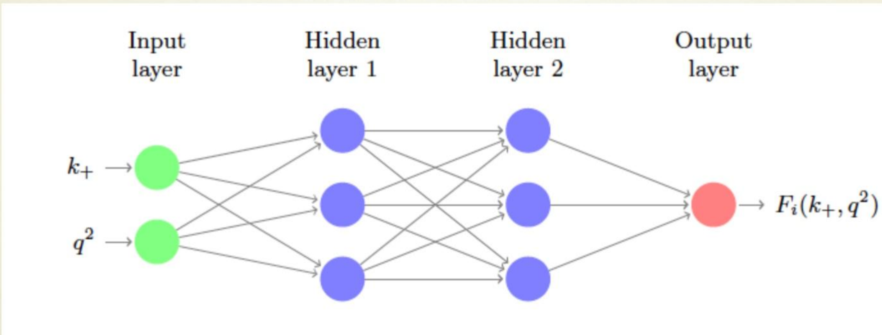
- No slides on indico! From my notes, so apologies if any errors or misrepresentations

- New systematic approach to writing down all possible HQET operators at a given dimension
  - Interested in objects like $\bar{h}(iD^{\mu 1} \ldots iD^{\mu n})h$
  - Make use of:
    - PT Symmetry
    - Hermeticity
    - # of independent directions
  - To systematically expand in a basis of
    - $\mathbf{v}^{\mu}$
    - $g^{\mu 1 \mu 2}$
    - $\epsilon^{\mu\nu\varrho\sigma}$

- Presented all spin-dependent and spin-independent dimension 7&8 combinations, as well as spin-independent dimension 9

- Hints at relationship between HQET and NRQCD EFT frameworks

NNVub: Neural networks for incl. V_{ub}: Paolo

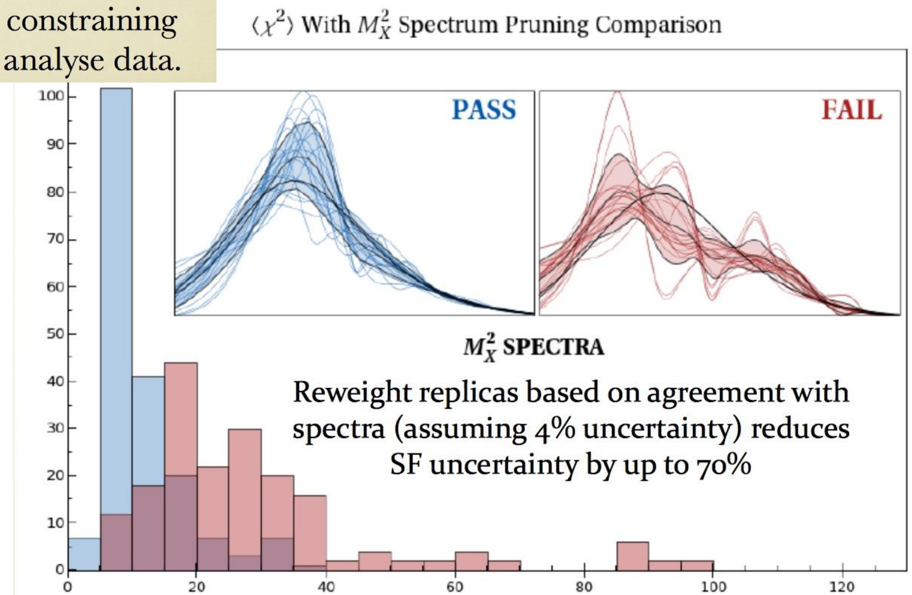


- Use **Artificial Neural Networks** to parameterize shape functions without bias and extract V_{ub} from theoretical constraints and data, together with HQE parameters in a model independent way (without assumptions on functional form). Similar to NNPDF. Applies to *b→ulν, b→sγ, b→sl+l-*
- Belle-II will be able to measure some kinematic distributions, thus constraining directly the shape functions. NNVub will provide a flexible tool to analyse data.

NNs useful and flexible tool to estimate Shape function uncertainties in B→Xulν.

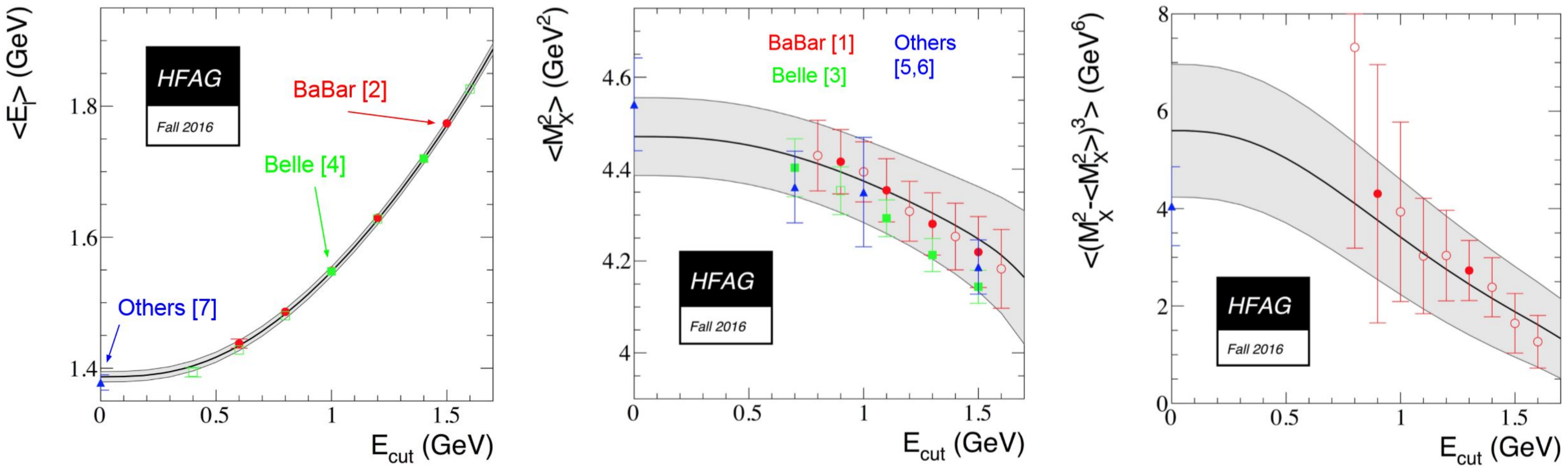
At Belle-II can expect to bring inclusive Vub at almost the same level as Vcb.

Learning @ Belle-II from kinematic distributions, e.g. MX spectrum, OPE parameters checked/ improved in b→ulν (moments): global NN+OPE fit



Experimental status (b→c): Christoph Schwanda for Florian

- No new experimental results since 2010, but updated global fits in 2014/15
- New HFAG result for 2016:



$|V_{cb}|$ and m_b (New HFAG Fall 2016 result)

Br(B -> $X_c$lnu) (%)	$|V_{cb}|$ (10^{-3})	m_b^{kin} (GeV)	mu^2_{pi} (GeV^2)	
10.65 +/- 0.16	42.19 +/- 0.78	4.554 +/- 0.018	0.464 +/- 0.076	details

Improvements to inclusive Vcb: Soumitra Nandi

Alberti, Gambino , Healy and Nandi, PRL 2015; Gambino, Healy , Turczyk, PLB 2016

$$\Gamma_{sl} = \Gamma_0 \left[1 + a^{(1)} \frac{\alpha_s(m_b)}{\pi} + a^{(2,\beta_0)} \beta_0 \left(\frac{\alpha_s}{\pi}\right)^2 + a^{(2)} \left(\frac{\alpha_s}{\pi}\right)^2 + \left(-\frac{1}{2} + p^{(1)} \frac{\alpha_s}{\pi}\right) \frac{\mu_\pi^2}{m_b^2} + \left(g^{(0)} + g^{(1)} \frac{\alpha_s}{\pi}\right) \frac{\mu_G^2(m_b)}{m_b^2} + d^{(0)} \frac{\rho_D^3}{m_b^3} - g^{(0)} \frac{\rho_{LS}^3}{m_b^3} + \text{higher orders} \right]$$

$\overline{m}_c(3\ \text{GeV}) = 0.986(13)\ \text{GeV}$

$\rho_{LS}^3 = -0.15(10) GeV^3$

$\mu_G^2(4.6\ GeV) = 0.35(7) GeV^2$

After fitting the parameters with the available data on width and moments :

$$\frac{\Gamma}{z(r)\Gamma_0} = 1 - 0.116_{\alpha_s} - 0.030_{\alpha_s^2} - 0.042_{1/m^2} - 0.002_{\alpha_s/m^2} - 0.030_{1/m^3} + 0.005_{1/m^4} + 0.005_{1/m^5}$$

$1 - 8r + 8r^3 - r^4 - 12r^2 \ln r$

$A_{ew} |V_{cb}^2| G_F^2 m_b^5 / 192\pi^3$

1.014

$|V_{cb}| = (42.42 \pm 0.86) \times 10^{-3}$ → Fit without (α_s / m_b^2) and ($1/m_b^{4,5}$) and h.o. contributions , Gambino and Schwanda, PRD 2014

$|V_{cb}| = (42.21 \pm 0.78) \times 10^{-3}$ → Fit without ($1/m_b^{4,5}$) and h.o. contributions , Alberti, Gambino , Healy and Nandi, PRL 2015

$|V_{cb}| = (42.11 \pm 0.74) \times 10^{-3}$ → Fit includes all the known h.o. corrections, Gambino, Healy , Turczyk, PLB 2016

- ✓ $O(\alpha_s^2 \beta_0)$ are known !! …Aquila, Gambino, Ridolfi and Uraltsev NPB 2005
- ✓ $\alpha_s \mu_\pi^2 / m_b^2$ only numerically ! ….Becher, Boss and Lunghi, JHEP, 2007
- ✓ $\alpha_s \mu_\pi^2 / m_b^2$ and $\alpha_s \mu_G^2 / m_b^2$ corrections are calculated with analytical expressions!

Aberti, Ewerth, Gambino, Nandi , NPB(2013)

Alberti, Gambino, Nandi, JHEP(2014)
Mannel, Pivovarov, Rosenthal, PRD(2015)

α_s / m_b^3 In progress….Alberti, Gambino, Healy , Nandi

The onset of SUPER-B (BELLE-II) factory will bring us to a high precision era

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12/1/201

Global Fit Strategy for B→XL: Frank Tackmann

Status Overview.

Inclusive $|V_{cb}|$ [see previous talk]

- Current global moment fits are dominated by theory uncertainties, and in particular theory correlations
- Goal for Belle II will really be to reduce the current uncertainty (50-100%) on the uncertainty ($\sim$ 2%)

Inclusive $|V_{ub}|$ [see Bob's and Paolo's talks yesterday]

- Current $\sim$ 5-7% uncertainties are probably underestimated
(which contributes to the tension with excl. $|V_{ub}|$)
- Current methods do not extrapolate to 3% total uncertainty, need qualitative improvements to get there

Both are (or will be) theory limited, but not in a way that more calculations alone will help

- Overall only little room for improvement in perturbative inputs
- Parametric uncertainties dominate, require coordinated effort between theory and experiment

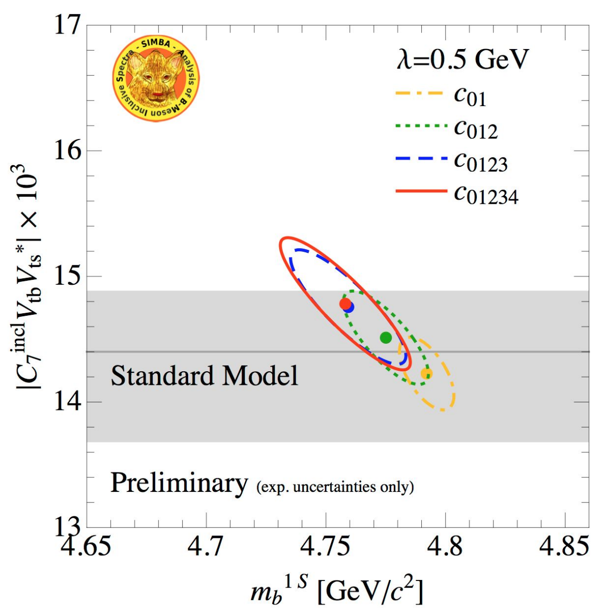
Global Fit Strategy for B→XL: Frank Tackmann

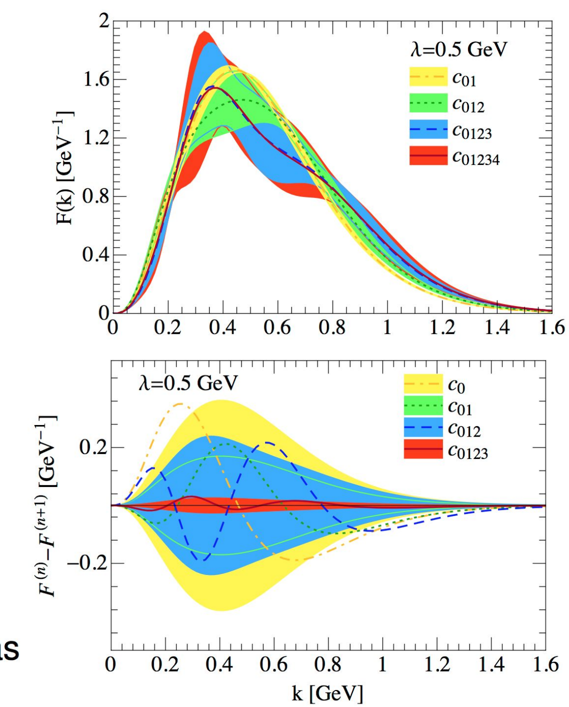
SIMBA [Bernlochner, Lacker, Ligeti, Stewart, FT, K Tackmann, arXiv:1303.0958]

- Global fit combining all available information
- Employs model-independent treatment for SF
  [Ligeti, Stewart, FT, arXiv:0807.1926]

NNVub [Healey, Mondino, Gambino, arXiv:1604.07598]

- Based on same idea, quite different approach [see Paolo's talk yesterday]

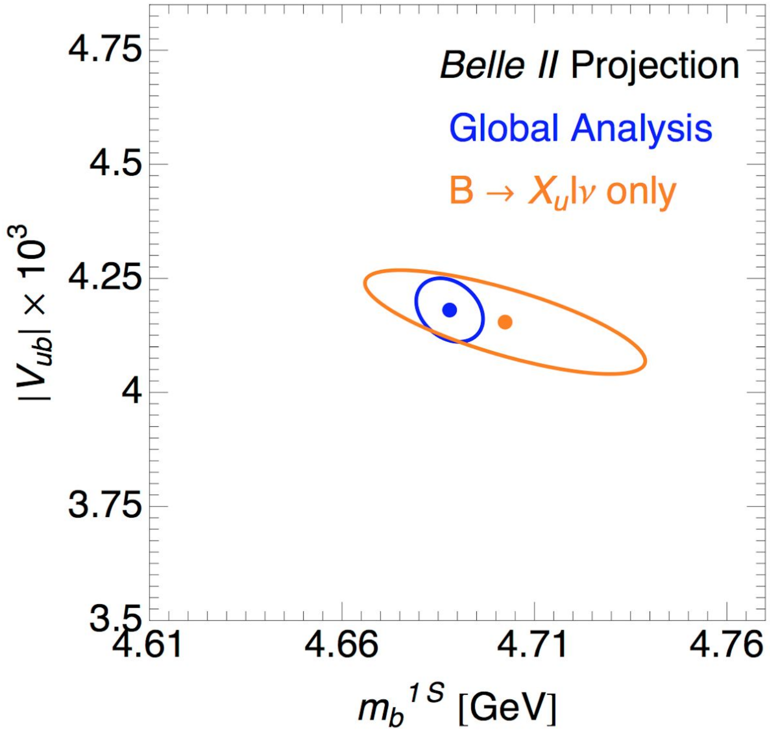


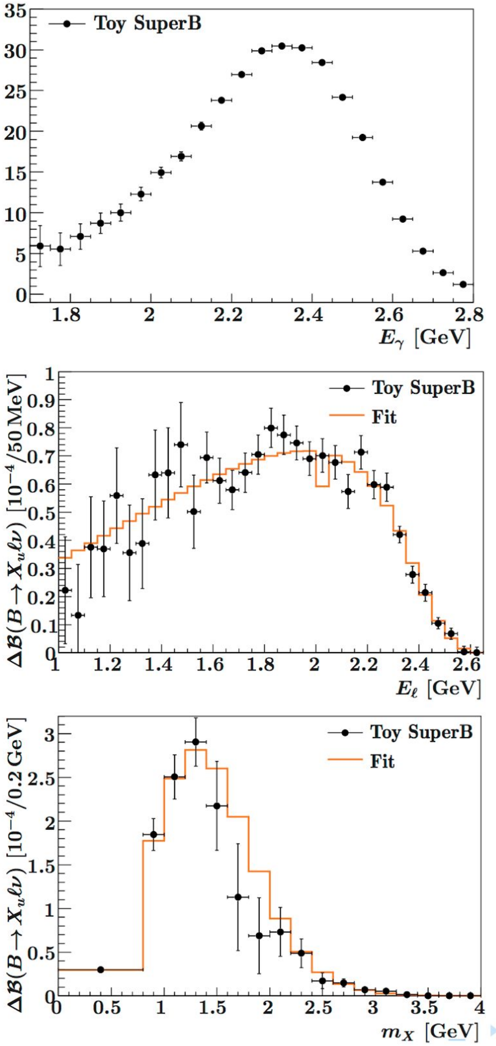


- Too few coefficients lead to clear bias and underestimated uncertainties
- Extracted $|C_7^{\rm incl} V_{tb} V_{ts}^*|$ consistent with SM

Global Fit Strategy for B→XL: Frank Tackmann

Projections for Belle 2.



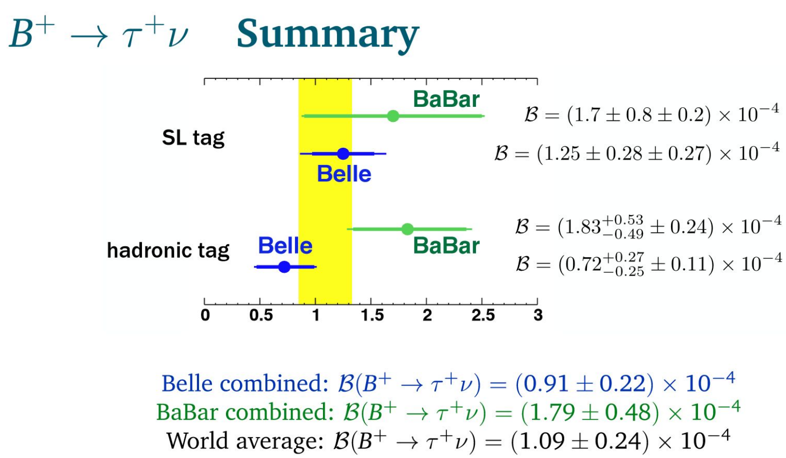


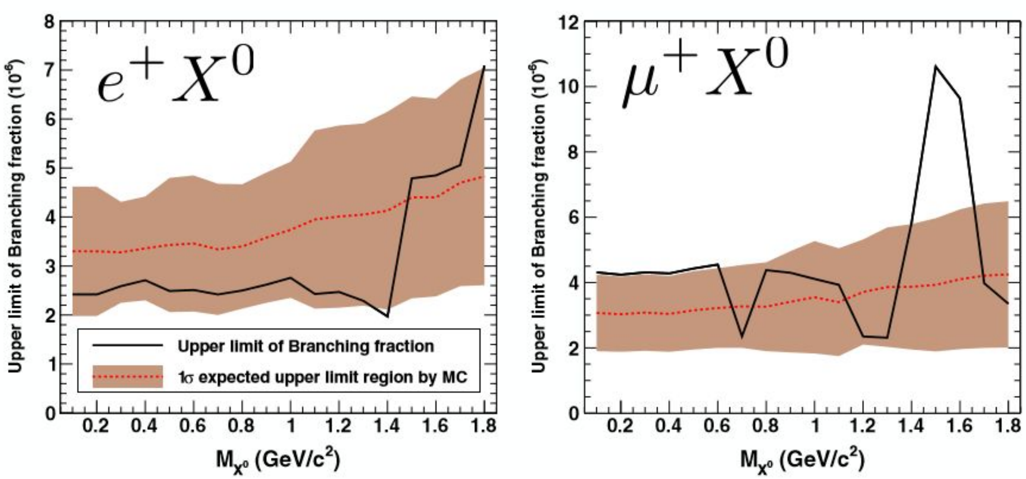
- No perturbative uncertainties included (but they clearly won't scale with statistics)
- At Belle 2 can use $B \to X_u \ell\nu$ alone to determine SF, m_b, and $|V_{ub}|$

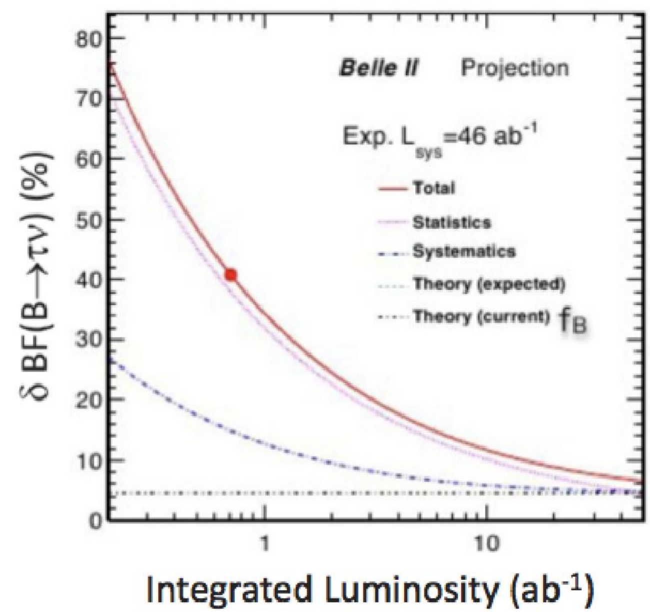
Leptonic B decays

Experimental status and prospects: Youngjoon Kwon

- 2015 Belle semileptonic tag result for $B^+ \to \tau\nu$ in good agreement with hadronic tag result - consistent picture of this mode emerging with excellent prospects at Belle2
- Beyond tau, Belle has a broad program of searches for $B^+ \to \ell\nu$, $B^+ \to \gamma\ell\nu$, $B^+ \to \ell X^0$







R(D) and R(D*)

Experimental $b \to c\tau\nu$: LHCb (Concezio Bozzi)

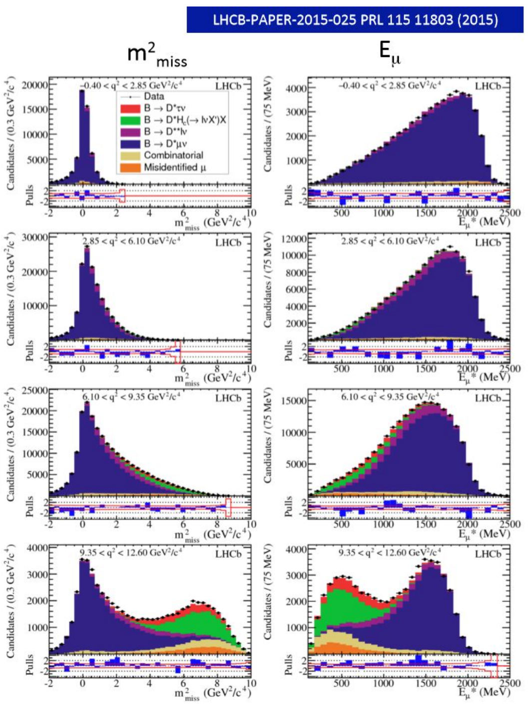
- 2015 LHCb measurement has similar central value to 2012/13 BaBar R(D*)
- Promising near term prospects:
  - $B \to D^*\tau[\to \pi\pi\pi\nu]\nu$
  - No obstacles to $\mathcal{R}(D)$ (only more complexity)

Fit results

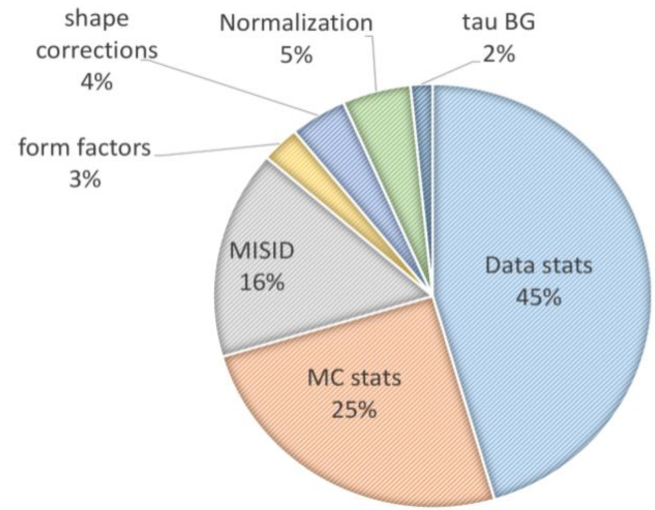
- No additional particles
- 3D fit to m^2_{miss}, E_μ, in 4 bins of q^2.
- Simultaneously fit 3 control regions defined by isolation criteria
- Signal yield: 16500 events

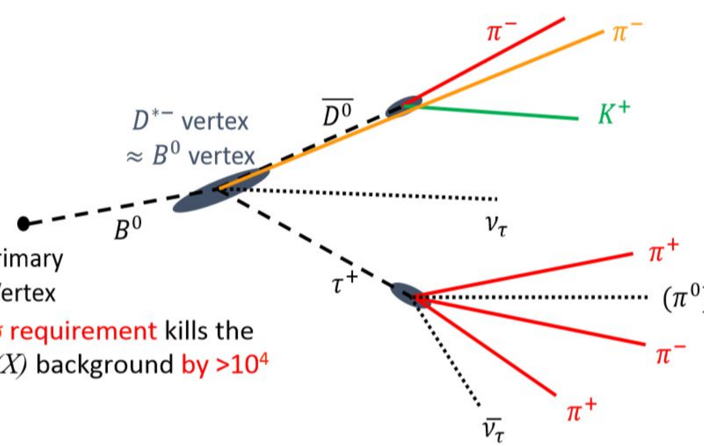
R(D*) = 0.336 ± 0.027 ± 0.030

- In agreement with Babar and Belle
- 2.1σ higher than the SM



C. Bozzi - R(D(*)) at LHCb - CKM2016



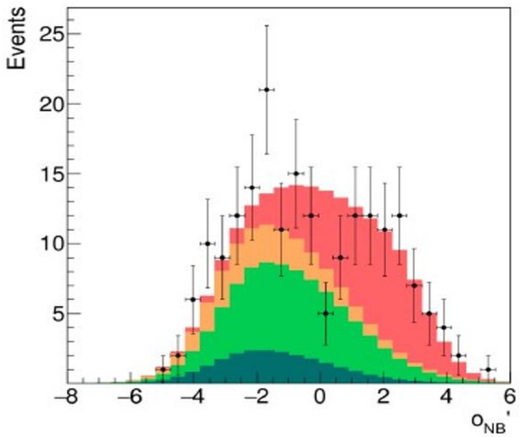


A 5 σ requirement kills the $D^*3\pi(X)$ background by >10^4

B-factories $b \to c\tau[\to \mu\nu\overline{\nu}]\nu$: (Marcello Rotondo)

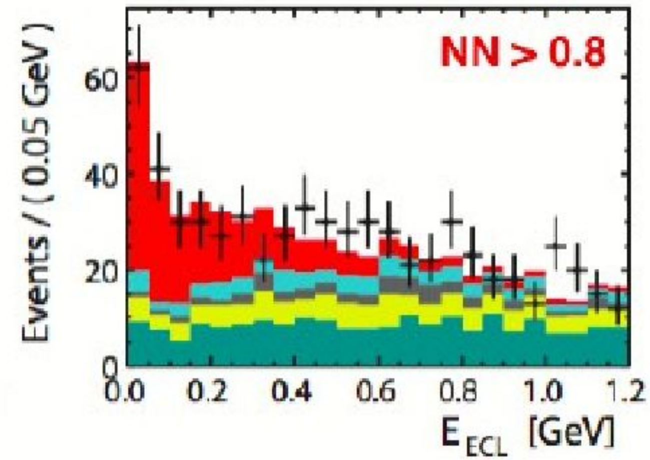
- Since CKM2014, now have 3(!) new measurements from B-factories, two with leptonic taus:

R(D) vs R(D*), Hadronic tag, leptonic tau



	R(D)	R(D*)
Belle	0.375 ± 0.064 ± 0.026	0.293 ± 0.038 ± 0.038
SM [*]	0.300 ± 0.008	0.252 ± 0.003
∞	1.4σ	1.8σ

R(D*), Semileptonic tag, leptonic tau



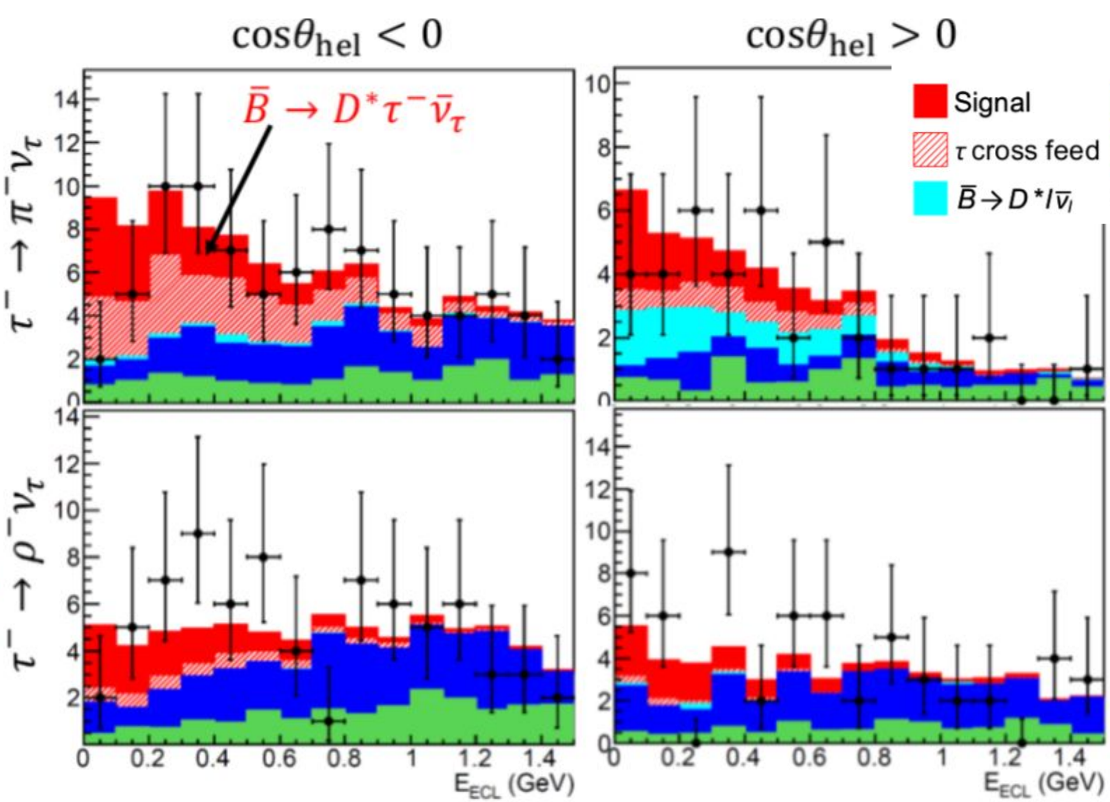
$$\mathcal{R}(D^*) = 0.302 \pm 0.030(\text{stat}) \pm 0.011(\text{syst})$$

- And we can expect good things from Belle-II

Assuming $50ab^{-1}$ (no improvements on syst.)	$50ab^{-1}$ and syst. reduced by factor 2
$\sigma(R_D) \sim 6\%$	$\sigma(R_D) \sim 3\%$
$\sigma(R_{D^*}) \sim 3\%$	$\sigma(R_{D^*}) \sim 1.7\%$

Belle result for $b\to c\tau[\to\pi(\pi^0)\nu]\nu$: (Karol Adamczyk)

- New Belle result to measure R(D*) with hadronic tau decays exploits the angular information due to the single (left handed!) neutrino in $\tau\to\pi/\varrho\nu$
- Hadronic Btag, fit in missing mass squared and E_{ECL} in two bins of tau helicity

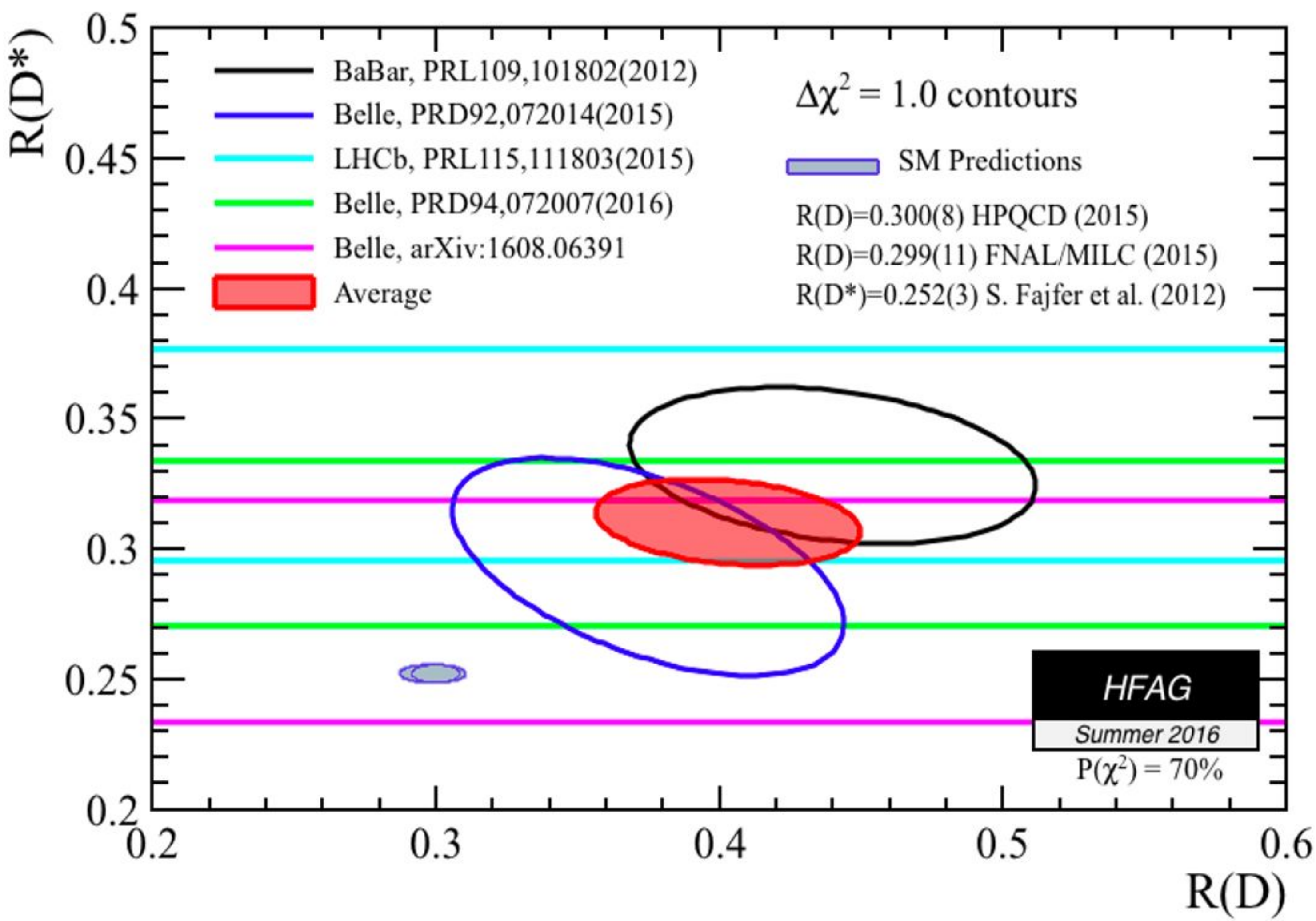


(preliminary)

$$P_\tau(D^*) = -0.44 \pm 0.47(stat.)^{+0.20}_{-0.17}(syst.)$$
$$R(D^*) = 0.276 \pm 0.034(stat.)^{+0.029}_{-0.026}(syst.)$$

First measurement of the polarization in semitauonic decay!

CKM16 HFAG average of R(D) and R(D*)



~4.0σ combined deviation from the SM including correlations

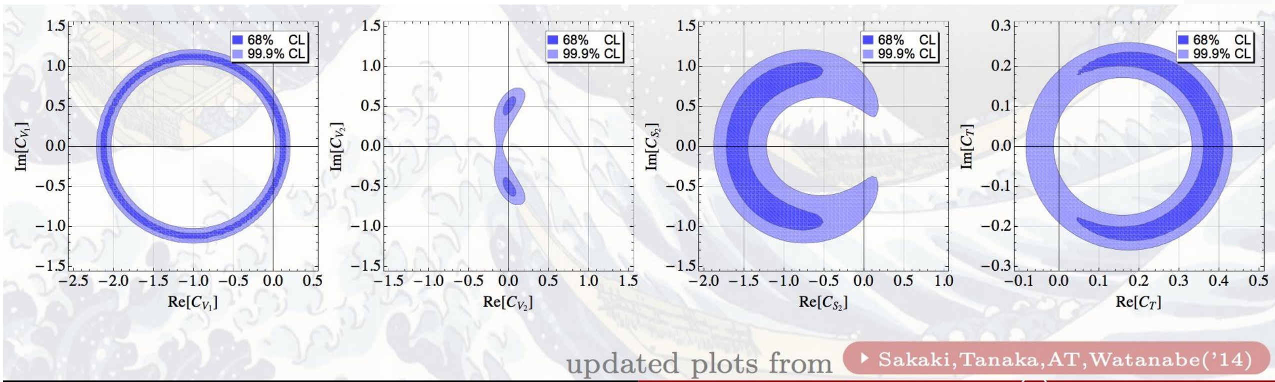
http://www.slac.stanford.edu/xorg/hfag/semi/summer16/main.shtml

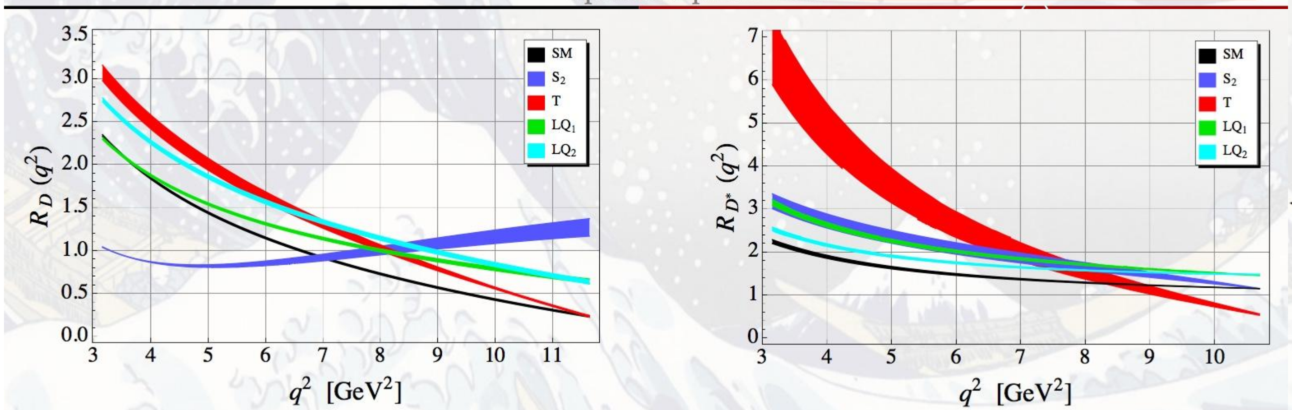
New physics search in B → D(∗)τν: Andrey Tayduganov

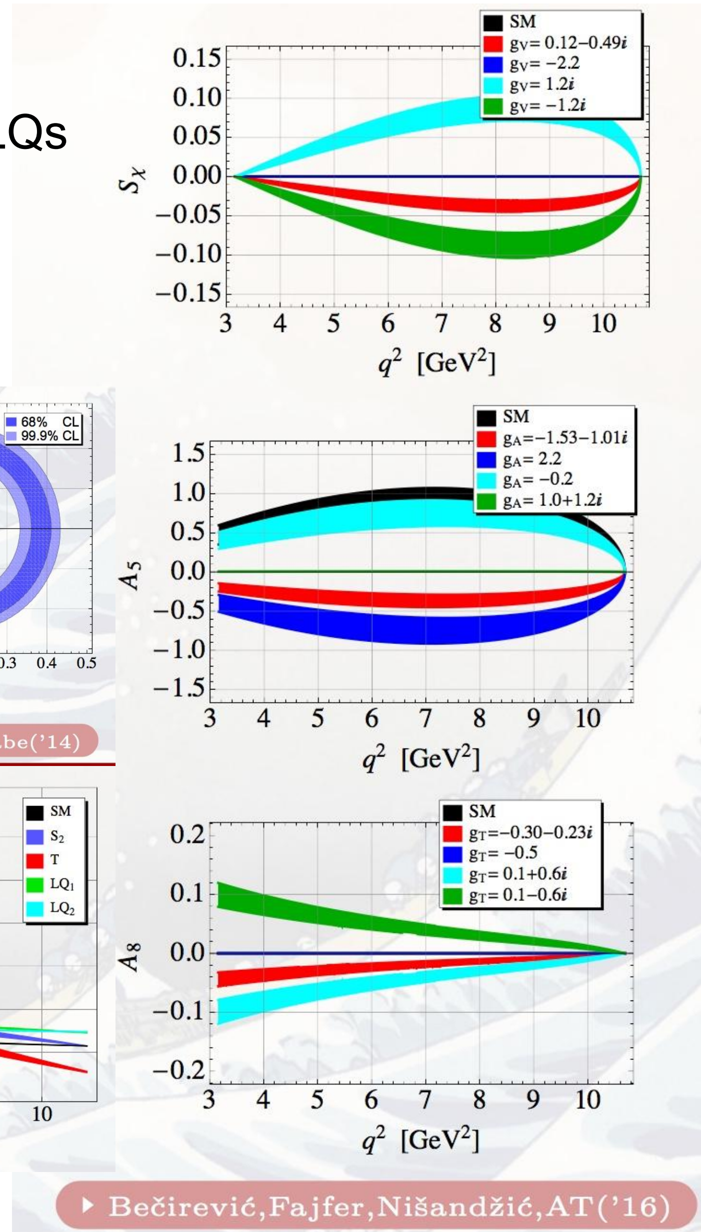
2HDM-III with MSSM-like Higgs potential and FV in up sector can explain R(D/D*)

R(D/D∗) and RK can be explained simultaneously by LQs

τ and D∗ polarizations/q2 dependence of dΓ/dq2 and RD(∗) (q2) / angular observables can be useful in distinguishing among NP scenarios.





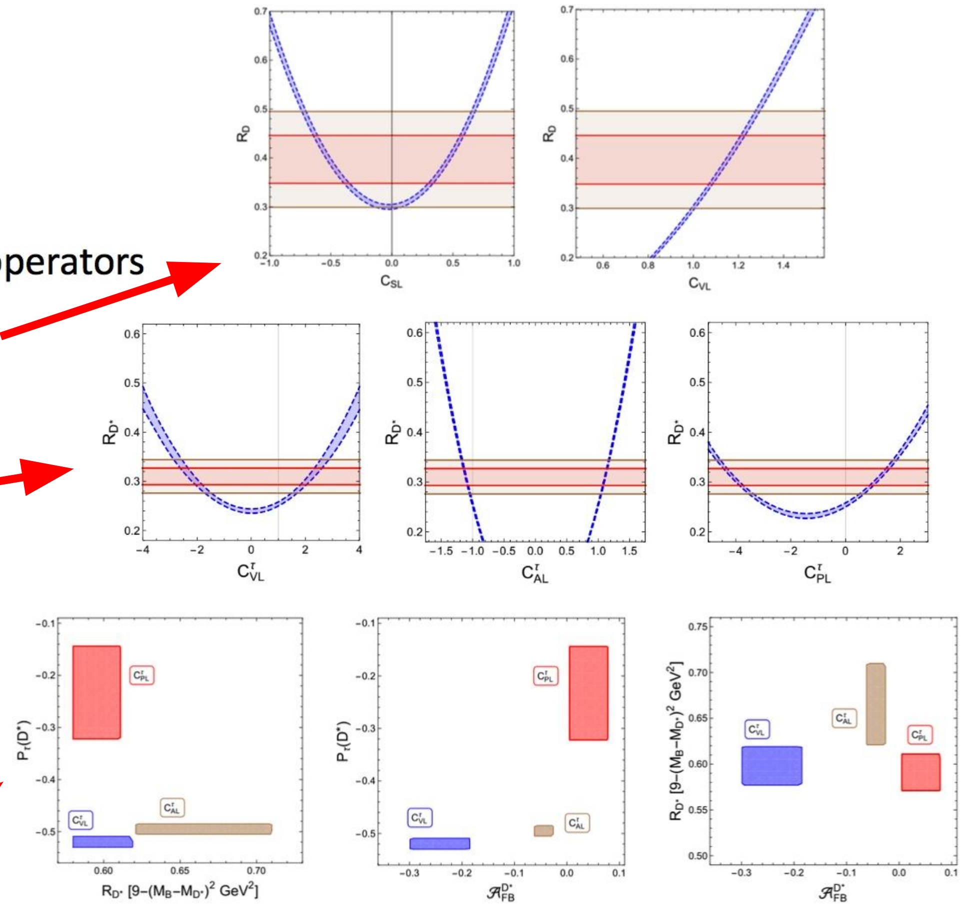


A Closer Look at R_D/R_{D*} anomalies: Debjyoti Bardhan

- R_D and R_{D^*} - long standing anomaly with the SM
- Model independent analysis using six-dimensional operators
- Independent explanations
- P_τ, binned R_{D^*} and forward-backward asymmetry:

Dependence of RD/RD* on different Wilson coefficients

Can differentiate between the different Wilson coefficients



Leptoquark resolution of B meson anomalies: Svjetlana Fajfer

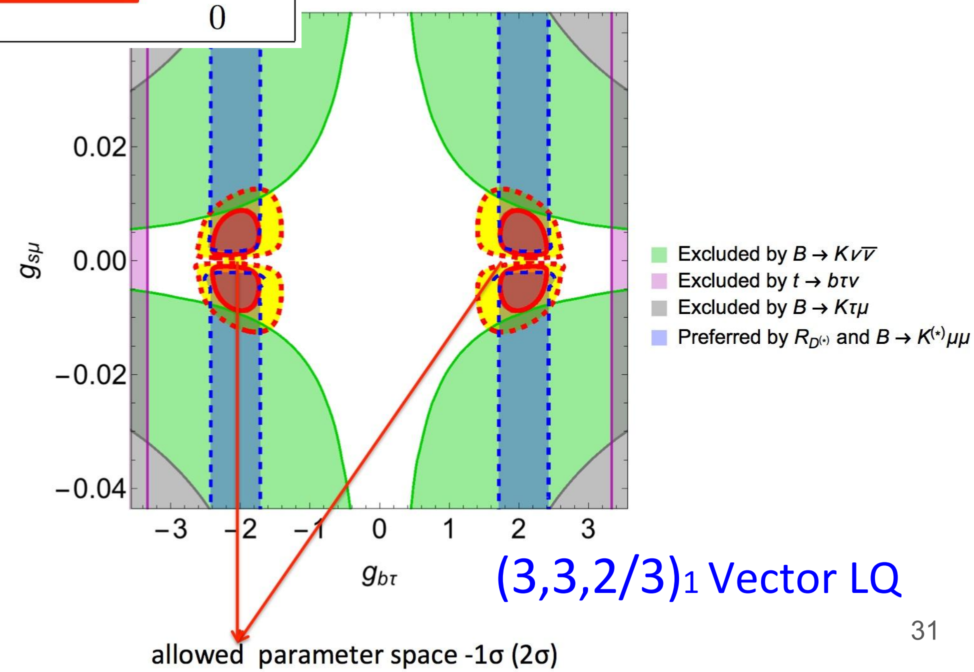
$SU(3)\times SU(2)\times U(1)$	Spin	Symbol	Type	$3B+L$
$(\bar{\mathbf{3}},\mathbf{3},1/3)$	0	S_3	$LL\,(S_1^L)$	-2
$(\mathbf{3},\mathbf{2},7/6)$	0	R_2	$RL\,(S_{1/2}^L)$, $LR\,(S_{1/2}^R)$	0
$(\mathbf{3},\mathbf{2},1/6)$	0	$\tilde{R}_2$	$RL\,(\tilde{S}_{1/2}^L)$, $\overline{LR}$	0
$(\bar{\mathbf{3}},\mathbf{1},4/3)$	0	$\tilde{S}_1$	$RR\,(\tilde{S}_0^R)$	-2
$(\bar{\mathbf{3}},\mathbf{1},1/3)$	0	S_1	$LL\,(S_0^L)$, $RR\,(S_0^R)$, $\overline{RR}$	-2
$(\bar{\mathbf{3}},\mathbf{1},-2/3)$	0	$\bar{S}_1$	$\overline{RR}$	-2
$(\mathbf{3},\mathbf{3},2/3)$	1	U_3	$LL\,(V_1^L)$	0
$(\bar{\mathbf{3}},\mathbf{2},5/6)$	1	V_2	$RL\,(V_{1/2}^L)$, $LR\,(V_{1/2}^R)$	-2
$(\bar{\mathbf{3}},\mathbf{2},-1/6)$	1	$\tilde{V}_2$	$RL\,(\tilde{V}_{1/2}^L)$, $\overline{LR}$	-2
$(\mathbf{3},\mathbf{1},5/3)$	1	$\tilde{U}_1$	$RR\,(\tilde{V}_0^R)$	0
$(\mathbf{3},\mathbf{1},2/3)$	1	U_1	$LL\,(V_0^L)$, $RR\,(V_0^R)$, $\overline{RR}$	0
$(\mathbf{3},\mathbf{1},-1/3)$	1	$\bar{U}_1$	$\overline{RR}$	0

$(3,2,1/6)_0$ $(3,3,2/3)_1$ are our favorable candidates (do not destabilize proton); Light scalar leptoquarks are simpler to accommodate in GUT framework than vector LQs

(3,2,⅙) scalar LQ

Is this model a final solution? NO! But it has some interesting features:

- Accommodates $R_K^{NP} < R_K^{SM}$ and predicts $R_{K^*}^{NP} > R_{K^*}^{SM}$
- Naturally accommodates $R_{D^*}^{NP} > R_{D^*}^{SM}$
- LFUV in the charged sector depends on the existence of ν_R



$(3,3,2/3)_1$ Vector LQ

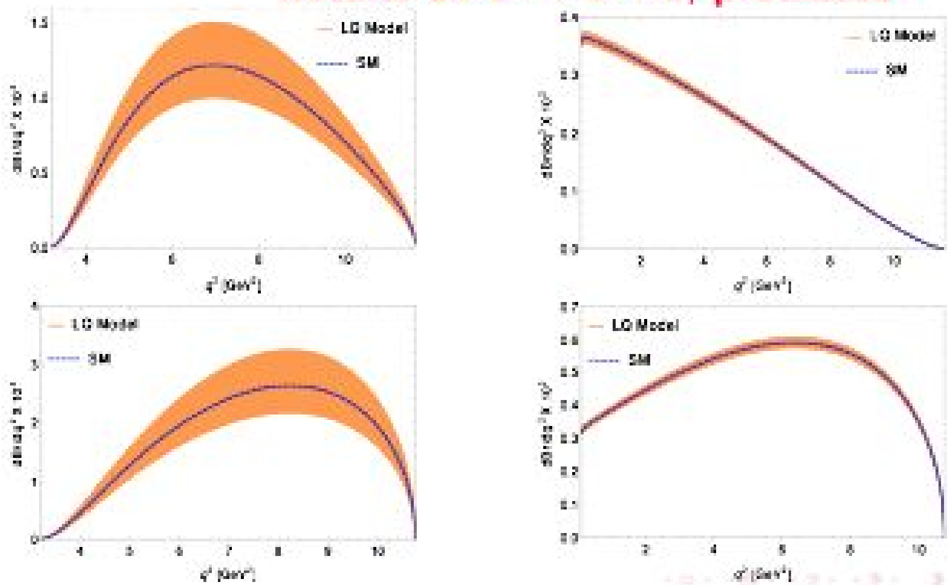
Leptoquarks in SL decays: Suchismita Sahoo (Monday)

- There are 6 relevant LQ invariant under the $SU(3) \times SU(2) \times U(1)$ gauge group.
- $(3, 1, 2/3)$ and $(3, 3, 2/3)$ vector LQ can mediate both $b \to c l \nu_l$ and $b \to s l^+ l^-$ processes.
- Conserve baryon number.
- avoid rapid proton decay.
- The interaction Lagrangian of $U_{1,3}$ LQ with the SM fermion bilinear is

$$\mathcal{L}^{LQ} = \left(h_{1L}^{ij}\bar{Q}_{iL}\gamma^{\mu}L_{jL} + h_{1R}^{ij}\bar{d}_{iR}\gamma^{\mu}l_{jR}\right)U_{1\mu} + h_{3L}^{ij}\bar{Q}_{iL}\boldsymbol{\sigma}\gamma^{\mu}L_{jL}\mathbf{U}_{3\mu},$$

Leptoquarks	Spin	$F = 3B + L$	$(SU(3)_C, SU(2)_L, U(1))$
S_1	0	-2	$(\bar{3}, 1, 1/3)$
S_3	0	-2	$(\bar{3}, 3, 1/3)$
R_2	0	0	$(3, 2, 7/6)$
U_1	1	0	$(3, 1, 2/3)$
U_3	1	0	$(3, 3, 2/3)$
V_2	1	-2	$(\bar{3}, 2, 5/6)$

Results on $B \to D^{(*)} l \nu_l$ processes



B to Dlv in the non-commutative SM: Selvaganapathy J

Several models e.g. 2HDM , Leptoquark to explain RD and RD∗ measurement
NCSM can also explain deviation without introducing any additional particle
Preliminary results: Noncommutative scale near 350 GeV to 600GeV

Wrapping Up

Many thanks to:

- Our speakers
- The conference organizers
- The LOC