Flavor models for $B \to D^{(*)}\tau\bar{\nu}$

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Implications of LHCb Measurements and Future Prospects

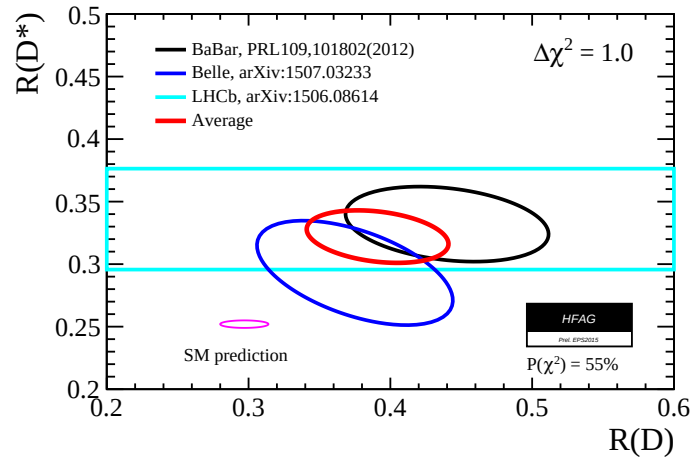
CERN, Nov 3–5, 2015

M. Freytsis, ZL, J. Ruderman, PRD 92 (2015) 054018 [1506.08896]

The most significant deviation from the SM

- Belle & LHCb results on the anomaly seen by BaBar in $R(X) = \dfrac{\Gamma(B \to X\tau\bar{\nu})}{\Gamma(B \to X(e/\mu)\bar{\nu})}$

	$R(D)$	$R(D^*)$
BaBar	$0.440 \pm 0.058 \pm 0.042$	$0.332 \pm 0.024 \pm 0.018$
Belle	$0.375 \pm 0.064 \pm 0.026$	$0.293 \pm 0.038 \pm 0.015$
LHCb		$0.336 \pm 0.027 \pm 0.030$
Average	0.391 ± 0.050	0.322 ± 0.022
my SM expectation	0.300 ± 0.010	0.252 ± 0.005
Belle II, 50/ab	± 0.010	± 0.005



SM predictions fairly robust: heavy quark symmetry + lattice QCD, only $R(D)$ [1503.07237, 1505.03925]

- Need NP at fairly low scales (leptoquarks, W', etc.), likely visible in LHC Run 2
- Next: LHCb result for $R(D)$? Using more τ decays? Measure $\Lambda_b \to \Lambda_c^{(*)}\tau\nu$?
- Question we asked: can the new physics explaining $R(D^{(*)})$ be MFV?

$B \to D^{(*)} e\bar{\nu}$ vs. $B \to D^{(*)} \mu\bar{\nu}$

- How well is the difference of the e and μ rates constrained?

Parameters	De sample	$D\mu$ sample	combined result
ρ_D^2	$1.22 \pm 0.05 \pm 0.10$	$1.10 \pm 0.07 \pm 0.10$	$1.16 \pm 0.04 \pm 0.08$
$\rho_{D^*}^2$	$1.34 \pm 0.05 \pm 0.09$	$1.33 \pm 0.06 \pm 0.09$	$1.33 \pm 0.04 \pm 0.09$
R_1	$1.59 \pm 0.09 \pm 0.15$	$1.53 \pm 0.10 \pm 0.17$	$1.56 \pm 0.07 \pm 0.15$
R_2	$0.67 \pm 0.07 \pm 0.10$	$0.68 \pm 0.08 \pm 0.10$	$0.66 \pm 0.05 \pm 0.09$
$\mathcal{B}(D^0 \ell\overline{\nu})(\%)$	$2.38 \pm 0.04 \pm 0.15$	$2.25 \pm 0.04 \pm 0.17$	$2.32 \pm 0.03 \pm 0.13$
$\mathcal{B}(D^{*0} \ell\overline{\nu})(\%)$	$5.50 \pm 0.05 \pm 0.23$	$5.34 \pm 0.06 \pm 0.37$	$5.48 \pm 0.04 \pm 0.22$
χ^2/n.d.f. (probability)	416/468 (0.96)	488/464 (0.21)	2.0/6 (0.92)

[BaBar, 0809.0828 — similar results in Belle, 1010.5620]

Individual rates appear to be systematics limited

- We assumed e/μ universality, not a necessity

- Can difference be constrained better? How much better?

Reaching the 1% level on ratio might be possible (but tough) even at Belle II

SM predictions fairly robust

- Measurements + heavy quark symmetry + lattice QCD calculations

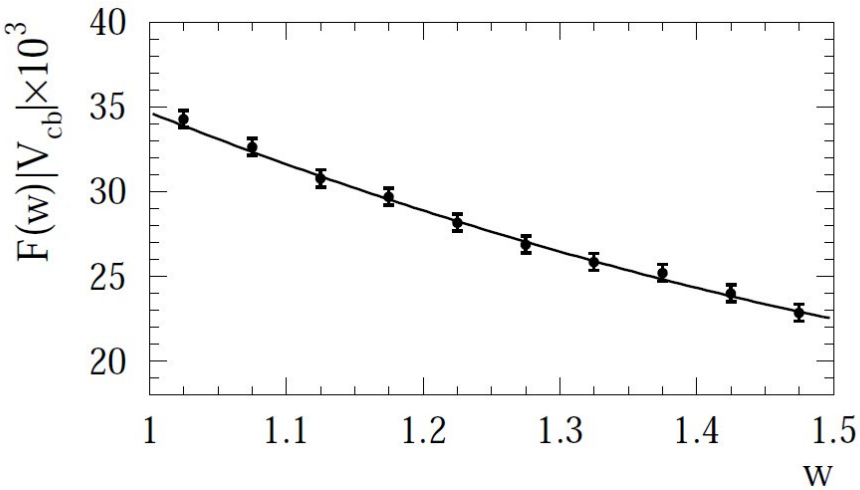
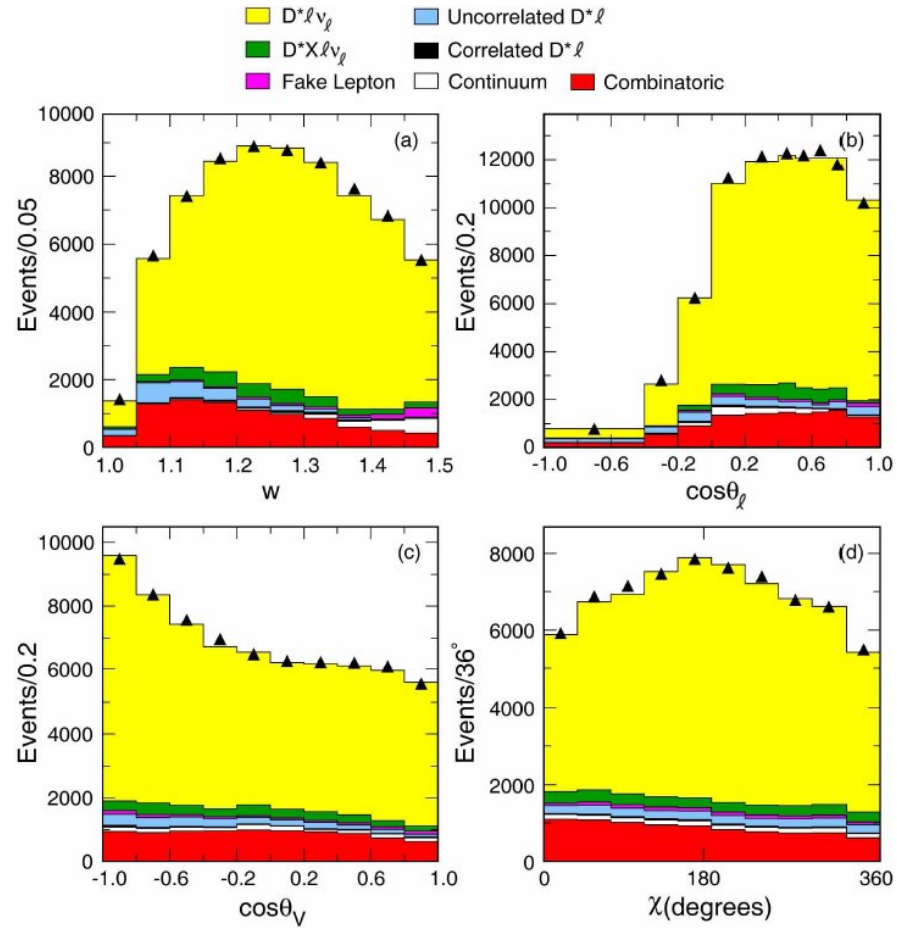


FIG. 6: The measured w dependence of $\mathcal{F}(w)|V_{cb}|$ (data points) compared to the theoretical function with the fitted parameters (solid line). The experimental uncertainties are too small to be visible.

[BaBar, 0705.4008]



Tension with SM is model independent

- Use an OPE-based analysis to constrain SM allowed range as much as possible
- Learn from inclusive $= \sum$ exclusive

$R(X_c) = 0.222 \pm 0.003$ [Freytsis, ZL, Ruderman, update of earlier results]

$\mathcal{B}(B^- \to X_c \ell \bar{\nu}) = (10.92 \pm 0.16)\%$

$\Rightarrow \mathcal{B}(B^- \to X_c \tau \bar{\nu}) = (2.42 \pm 0.05)\%$ [LEP: $\mathcal{B}(b \to X \tau^+ \nu) = (2.41 \pm 0.23)\%$]

- The $R(D^{(*)})$ data imply: $\mathcal{B}(\bar{B} \to D^* \tau \bar{\nu}) + \mathcal{B}(\bar{B} \to D \tau \bar{\nu}) = (2.78 \pm 0.25)\%$
- Estimate $\mathcal{B}(B \to D^{**} \tau \bar{\nu}) \gtrsim 0.2\%$ in the SM (the four $1P$ states)
- Tension $\gtrsim 2\sigma$, based on inclusive calculation $+$ minimal assumptions

Complementary to SM calculation of $R(D^{(*)})$ and LEP data

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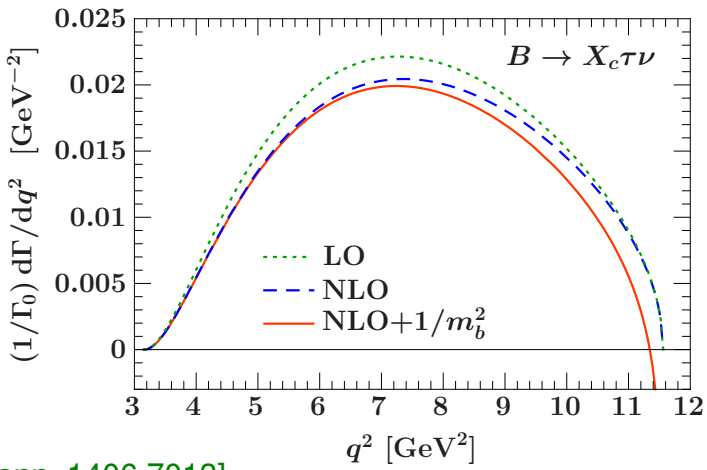
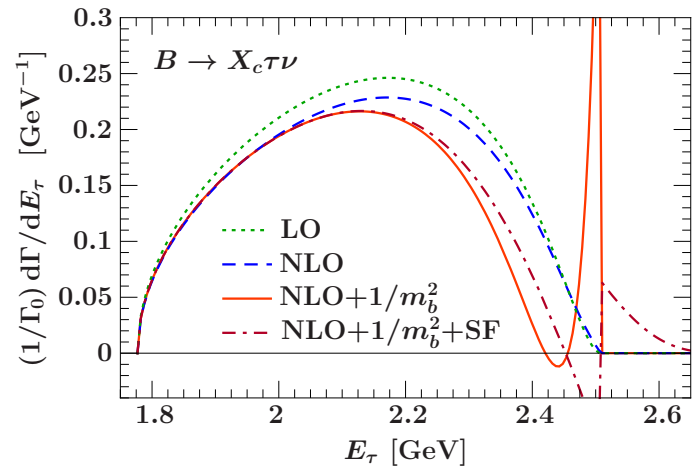
Precision $B \to X_c \tau \bar{\nu}$ predictions

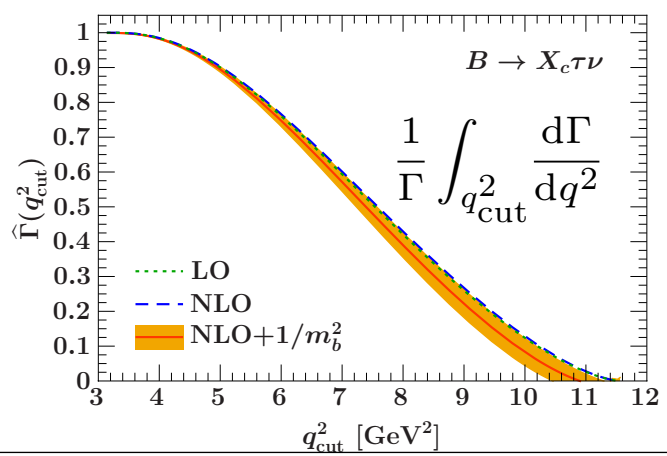
- No measurements since LEP, Belle analysis in progress (ϵ theory work in last ~ 15 yrs)

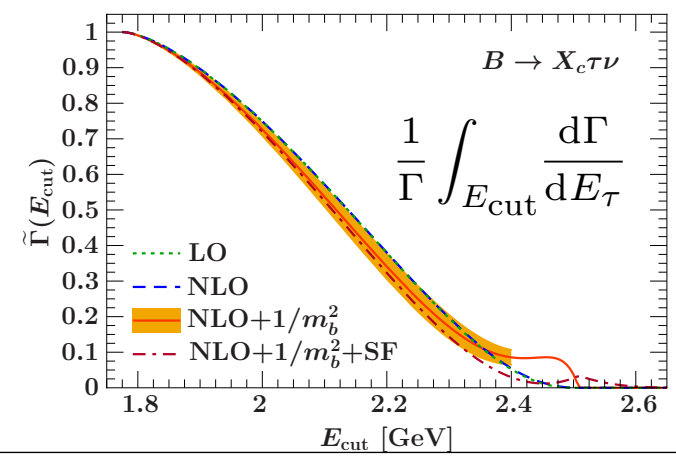
Papers in '90s used $m_b^{\rm pole}$, no study of spectra (exp. needed) & uncertainties — big $1/m^2$ terms





[ZL & Tackmann, 1406.7013]





Consider all τ modes... $b \to u\tau\bar{\nu}$?

- If deviation clearly established, huge motivation to study all decay modes with τ

  If LEP could measure $B \to X_c\tau\bar{\nu}$ with a few $\times 10^6$ $B - \overline{B}$ pairs...
  ... "surely" Belle II can measure $B \to X_u\tau\bar{\nu}$ with 5×10^{10} $B - \overline{B}$ pairs...

- The inclusive calculation is unavailable for any distribution

  $m_\tau \neq 0$ complicates things in an interesting way [ZL, Luke, Tackmann, to appear]

  $1.8\,\mathrm{GeV} < E_\tau < 2.9\,\mathrm{GeV}$ — Subtleties with shape function; full rate in SF region?

- Phase space suppression is smaller in $b \to u$:

$$\frac{\Gamma(B \to X_u\ell\bar{\nu})}{\Gamma(B \to X_u\tau\bar{\nu})} \simeq 3.0 \qquad \frac{\Gamma(B \to X_c\ell\bar{\nu})}{\Gamma(B \to X_c\tau\bar{\nu})} \simeq 4.5$$

- Can LHCb measure $b \to u\tau\bar{\nu}$ decay modes? Ratios of τ/μ or/and c/u?

  $\Lambda_b \to \Lambda\tau\bar{\nu}$? $B \to \pi\tau\bar{\nu}$? $B \to \rho\tau\bar{\nu}$? [See also P. Owen's talk]

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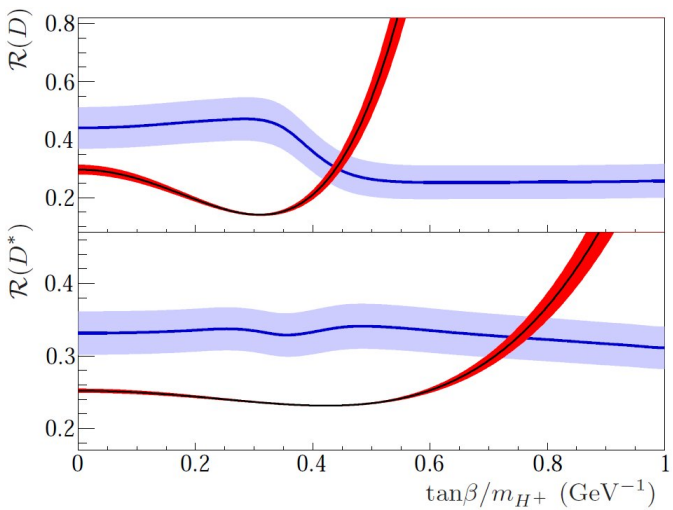
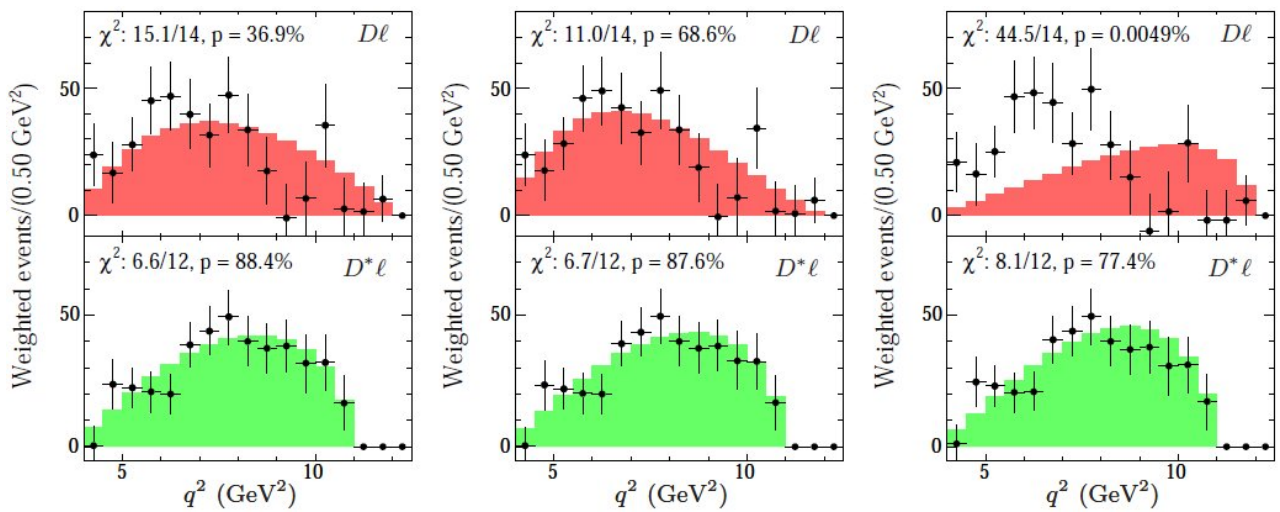
Operator analysis

BaBar statements from q^2 spectrum results

- BaBar studied consistency of rates with 2HDM, and $\mathrm{d}\Gamma/\mathrm{d}q^2$ with several models





[PRL 109 (2012) 101802, arXiv:1205.5442]

[PRD 88 (2013) 072012, arXiv:1303.0571]

- Found that type-II 2HDM gave nearly as bad fit to the data as the SM
- $\mathrm{d}\Gamma/\mathrm{d}q^2$ has additional discriminating power (no other distribution measured yet)
- Not enough public info to do real fit, eyeball which solutions are disfavored

Consider redundant set of operators

- Fits to different fermion orderings convenient to understand allowed mediators

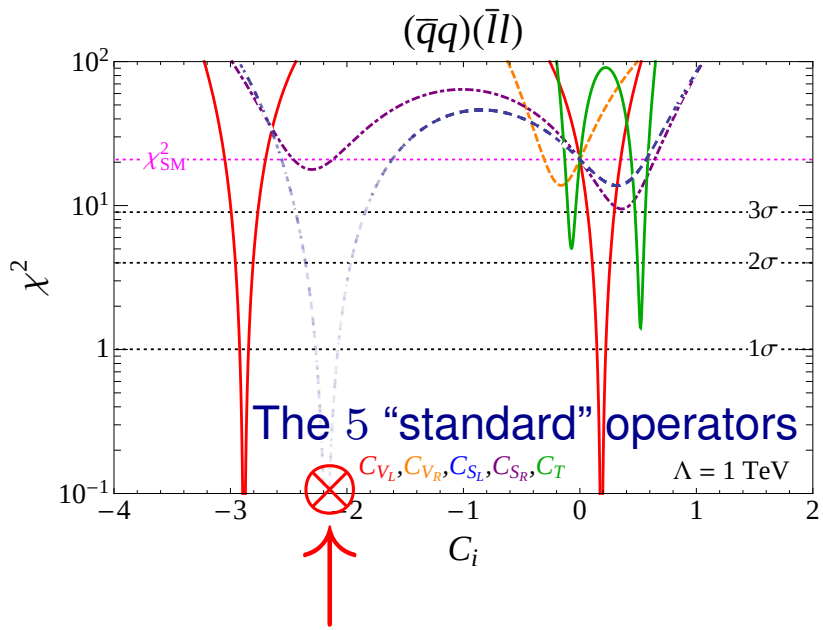
Usually only the first 5 operators considered, related by Fierz

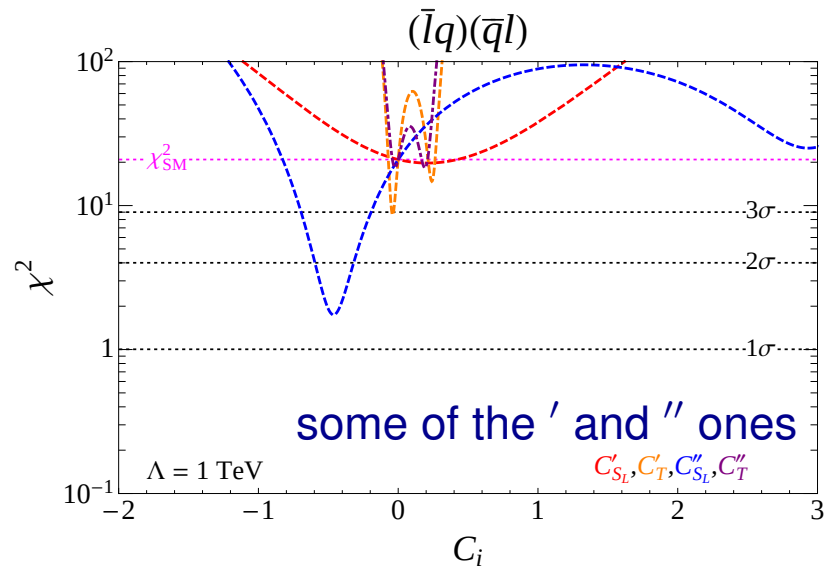
from dim-6 terms, others from dim-8 only

$\Downarrow$

	Operator		Fierz identity	Allowed Current	$\delta\mathcal{L}_{\rm int}$
$\mathcal{O}_{V_L}$	$(\bar{c}\gamma_\mu P_L b)\,(\bar{\tau}\gamma^\mu P_L \nu)$			$(1,3)_0$	$(g_q \bar{q}_L \boldsymbol{\tau}\gamma^\mu q_L + g_\ell \bar{\ell}_L \boldsymbol{\tau}\gamma^\mu \ell_L) W'_\mu$
$\mathcal{O}_{V_R}$	$(\bar{c}\gamma_\mu P_R b)\,(\bar{\tau}\gamma^\mu P_L \nu)$				
$\mathcal{O}_{S_R}$	$(\bar{c}P_R b)\,(\bar{\tau}P_L \nu)$			$(1,2)_{1/2}$	$(\lambda_d \bar{q}_L d_R \phi + \lambda_u \bar{q}_L u_R i\tau_2 \phi^\dagger + \lambda_\ell \bar{\ell}_L e_R \phi)$
$\mathcal{O}_{S_L}$	$(\bar{c}P_L b)\,(\bar{\tau}P_L \nu)$				
$\mathcal{O}_T$	$(\bar{c}\sigma^{\mu\nu}P_L b)\,(\bar{\tau}\sigma_{\mu\nu}P_L \nu)$				
$\mathcal{O}'_{V_L}$	$(\bar{\tau}\gamma_\mu P_L b)\,(\bar{c}\gamma^\mu P_L \nu)$	$\longleftrightarrow$	$\mathcal{O}_{V_L}$	$(3,3)_{2/3}$	$\lambda\, \bar{q}_L \boldsymbol{\tau}\gamma_\mu \ell_L \boldsymbol{U}^\mu$
$\mathcal{O}'_{V_R}$	$(\bar{\tau}\gamma_\mu P_R b)\,(\bar{c}\gamma^\mu P_L \nu)$	$\longleftrightarrow$	$-2\mathcal{O}_{S_R}$	$(3,1)_{2/3}$	$(\lambda\, \bar{q}_L \gamma_\mu \ell_L + \tilde{\lambda}\, \bar{d}_R \gamma_\mu e_R) U^\mu$
$\mathcal{O}'_{S_R}$	$(\bar{\tau}P_R b)\,(\bar{c}P_L \nu)$	$\longleftrightarrow$	$-\frac{1}{2}\mathcal{O}_{V_R}$		
$\mathcal{O}'_{S_L}$	$(\bar{\tau}P_L b)\,(\bar{c}P_L \nu)$	$\longleftrightarrow$	$-\frac{1}{2}\mathcal{O}_{S_L} - \frac{1}{8}\mathcal{O}_T$	$(3,2)_{7/6}$	$(\lambda\, \bar{u}_R \ell_L + \tilde{\lambda}\, \bar{q}_L i\tau_2 e_R) R$
$\mathcal{O}'_T$	$(\bar{\tau}\sigma^{\mu\nu}P_L b)\,(\bar{c}\sigma_{\mu\nu}P_L \nu)$	$\longleftrightarrow$	$-6\mathcal{O}_{S_L} + \frac{1}{2}\mathcal{O}_T$		
$\mathcal{O}''_{V_L}$	$(\bar{\tau}\gamma_\mu P_L c^c)\,(\bar{b}^c\gamma^\mu P_L \nu)$	$\longleftrightarrow$	$-\mathcal{O}_{V_R}$		
$\mathcal{O}''_{V_R}$	$(\bar{\tau}\gamma_\mu P_R c^c)\,(\bar{b}^c\gamma^\mu P_L \nu)$	$\longleftrightarrow$	$-2\mathcal{O}_{S_R}$	$(\bar{3},2)_{5/3}$	$(\lambda\, \bar{d}^c_R \gamma_\mu \ell_L + \tilde{\lambda}\, \bar{q}^c_L \gamma_\mu e_R) V^\mu$
$\mathcal{O}''_{S_R}$	$(\bar{\tau}P_R c^c)\,(\bar{b}^c P_L \nu)$	$\longleftrightarrow$	$\frac{1}{2}\mathcal{O}_{V_L}$	$(\bar{3},3)_{1/3}$	$\lambda\, \bar{q}^c_L i\tau_2 \boldsymbol{\tau} \ell_L \boldsymbol{S}$
$\mathcal{O}''_{S_L}$	$(\bar{\tau}P_L c^c)\,(\bar{b}^c P_L \nu)$	$\longleftrightarrow$	$-\frac{1}{2}\mathcal{O}_{S_L} + \frac{1}{8}\mathcal{O}_T$	$(\bar{3},1)_{1/3}$	$(\lambda\, \bar{q}^c_L i\tau_2 \ell_L + \tilde{\lambda}\, \bar{u}^c_R e_R) S$
$\mathcal{O}''_T$	$(\bar{\tau}\sigma^{\mu\nu}P_L c^c)\,(\bar{b}^c\sigma_{\mu\nu}P_L \nu)$	$\longleftrightarrow$	$-6\mathcal{O}_{S_L} - \frac{1}{2}\mathcal{O}_T$		

Fits to a single operator





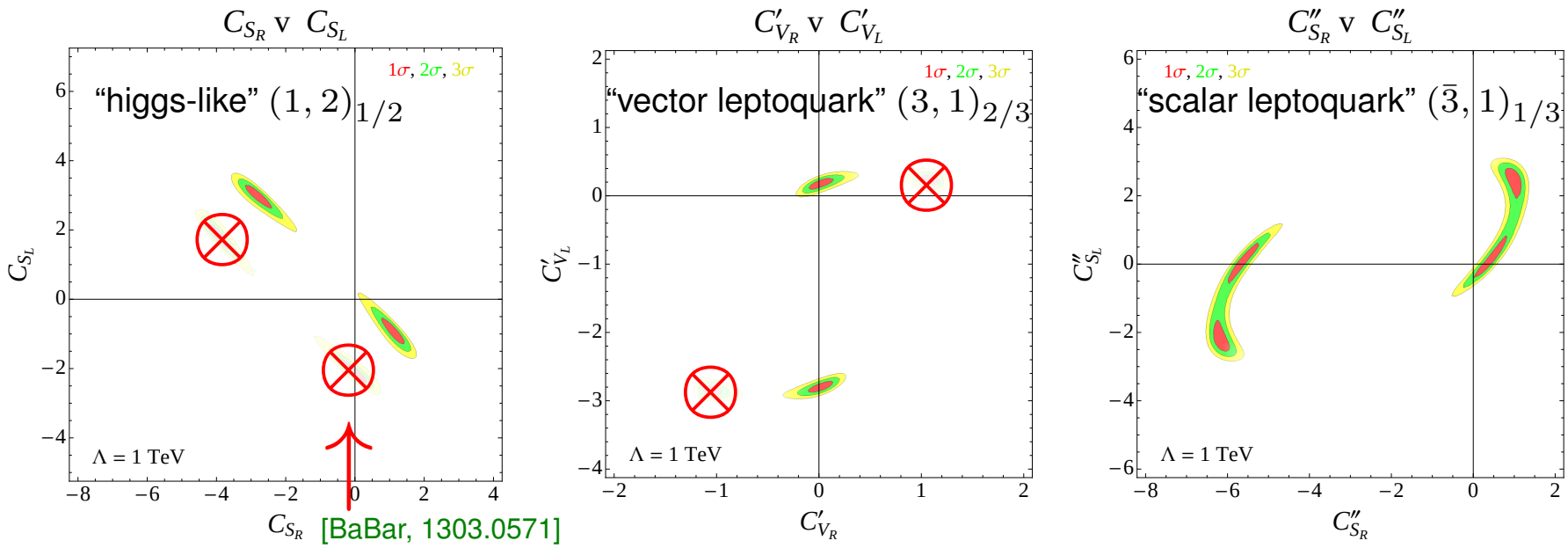
[BaBar, 1303.0571]

Solution marked ⊗ ruled out by the q^2 spectrum

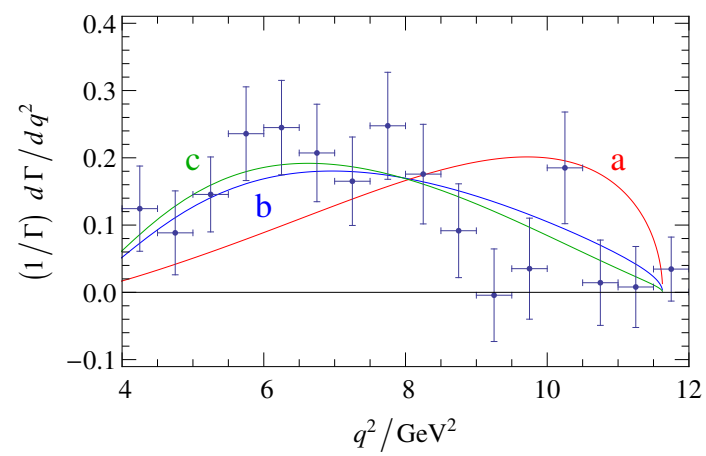
- We rederived all rates from scratch

Agree with the "classic" paper (up to a minor typo) [Goldberger, hep-ph/9902311]

Fits to two operators



Operator coefficients	
$C'_{V_L} = 0.24$	$C'_{V_R} = 1.10$
$C'_{V_L} = 0.18$	$C'_{V_R} = -0.01$
$C''_{S_R} = 0.96$	$C''_{S_L} = 2.41$



Flavor symmetries for $b \to c\tau\bar{\nu}$

Several viable mediators

- Good fits for several mediators: scalar, "Higgs-like" $(1,2)_{1/2}$
  vector, "W'-like" $(1,3)_0$
  "scalar leptoquark" $(\bar{3},1)_{1/3}$ or $(\bar{3},3)_{1/3}$
  "vector leptoquark" $(3,1)_{2/3}$ or $(3,3)_{2/3}$

- If there is NP within reach, its flavor structure must be highly non-generic
  Surprising if only BSM operator had $(\bar{b}c)(\bar{\tau}\nu)$ structure
- MFV probably a useful organizing principle / starting point
  Global $U(3)_Q \times U(3)_u \times U(3)_d$ flavor sym.; $Y_u \sim (\mathbf{3},\bar{\mathbf{3}},\mathbf{1})$, $\quad Y_d \sim (\mathbf{3},\mathbf{1},\bar{\mathbf{3}})$
- Which BSM scenarios can be MFV?
  Bounds: $b \to s\nu\bar{\nu}$, D^0 & K^0 mixing, $Z \to \tau^+\tau^-$, LHC contact int., $pp \to \tau^+\tau^-$, etc.
- If central values & patterns change, more "conventional" models may fit

Excluding MFV scalars and vectors

- Scalars: Need comparable values of C_{S_L} and C_{S_R}

  If $H^\pm$ flavor singlet, $C_{S_L} \propto y_c$, so cannot fit $R(D^{(*)})$ keeping y_t perturbative

  If $H^\pm$ is charged under flavor (combination of Y-s, to couple to quarks & leptons), to generate $C_{S_L} \sim C_{S_R}$, some $\mathcal{O}(1)$ coupling to 1st generation quarks unavoidable
  Bounds on $4q$ or $2q2\ell$ operators exclude it

- Vectors: Rescaling the SM operator (O_{V_L}) gives good fit to the data

  Flavor singlet w/ W-like couplings: $m_{W'} \gtrsim 1.8\,\mathrm{TeV} \Longleftrightarrow 0.2 \sim g^2|V_{cb}|(1\,\mathrm{TeV}/m_{W'})^2$

  Couplings to u, d suppressed for $(\bar{\mathbf{3}},\mathbf{3},\mathbf{1})$ and $(\bar{\mathbf{3}},\mathbf{1},\mathbf{3})$ under $U(3)_Q \times U(3)_u \times U(3)_d$
  $(\bar{\mathbf{3}},\mathbf{3},\mathbf{1})$: $b \to c$ transitions suppressed by y_c, too small
  $(\bar{\mathbf{3}},\mathbf{1},\mathbf{3})$: can fit data if $y_b = \mathcal{O}(1)$, but excluded by tree-level FCNC via W'^0

  (If dynamics allows $W'\bar{Q}^3_L Q^3_L$, but not $W'\bar{Q}^i_L Q^i_L$, viable models exist; beyond MFV [Greljo, Isidori, Marzocca, 1506.0170])

MFV leptoquarks

- Assign charges under flavor sym.: [viable MFV LQs: Freytsis, ZL, Ruderman]

$$U(3)_Q \times U(3)_u \times U(3)_d$$

- Simplest choices — leptoquarks could be electroweak $SU(2)_L$ singlets or triplets:

scalars: $S \sim (\bar{\mathbf{3}}, \mathbf{1}, \mathbf{1})\,, \quad (\mathbf{1}, \bar{\mathbf{3}}, \mathbf{1})\,, \quad (\mathbf{1}, \mathbf{1}, \bar{\mathbf{3}})$

vectors: $U_\mu \sim (\mathbf{3}, \mathbf{1}, \mathbf{1})\,, \quad (\mathbf{1}, \mathbf{3}, \mathbf{1})\,, \quad (\mathbf{1}, \mathbf{1}, \mathbf{3})$

$S(\bar{\mathbf{3}}, \mathbf{1}, \mathbf{1})$ and $U_\mu(\mathbf{3}, \mathbf{1}, \mathbf{1})$ give large $pp \to \tau^+\tau^-$, excluded by Z' searches

$S(\mathbf{1}, \bar{\mathbf{3}}, \mathbf{1})$ and $U_\mu(\mathbf{1}, \mathbf{3}, \mathbf{1})$ give y_c suppressed $B \to D^{(*)}\tau\bar{\nu}$ contributions
$\Rightarrow$ too large couplings, or too light leptoquarks

- Possibly viable: $S(\mathbf{1}, \mathbf{1}, \bar{\mathbf{3}})$ and $U_\mu(\mathbf{1}, \mathbf{1}, \mathbf{3})$ $\Rightarrow$ consider in more detail

Both can be electroweak singlets or triplets

The $S(1,1,\bar{3})$ scalar LQ

- Interactions terms for electroweak singlet:

$$\begin{aligned}\mathcal{L} &= S(\lambda Y_d^\dagger\, \bar{q}_L^c i\tau_2 \ell_L + \tilde{\lambda} Y_d^\dagger Y_u\, \bar{u}_R^c e_R) \\ &= S_i(\lambda y_{d_i} V_{ji}^*\, \bar{u}_{Lj}^c e_L - \lambda y_{d_i} \bar{d}_{Li}^c \nu_L + \tilde{\lambda} y_{d_i} y_{u_j} V_{ji}^*\, \bar{u}_{Rj}^c e_R)\end{aligned}$$

Integrating out S, contribution to $R(X_c)$ via: $(m_{S_3} \neq m_{S_1} = m_{S_2})$

$$-\frac{V_{cb}^*}{m_{S_3}^2}\left(\lambda^2 y_b^2\, \mathcal{O}''_{S_R} + \lambda\tilde{\lambda} y_c y_b^2\, \mathcal{O}''_{S_L}\right)$$

[electroweak triplet has no $\tilde{\lambda}$ term]

- Can fit $R(D^{(*)})$ data if $y_b = \mathcal{O}(1)$ Check $Z\tau^+\tau^-$ constraints, etc.

- Leptons: (i) τ alignment, charge LQ and 3rd gen. leptons opposite under $U(1)_\tau$
  (ii) lepton MFV, $(\mathbf{1},\bar{\mathbf{3}})$ under $U(3)_L \times U(3)_e$ [constraints differ]

- LHC Run 1 bounds on pair-produced LQ decaying to $t\tau$ or $b\nu$, $m_{S_3} \gtrsim 560\,\mathrm{GeV}$

Constraints from $b \to s\nu\bar{\nu}$

- With three Yukawa spurion insertions, one can write:

$$\delta\mathcal{L}' = \lambda' S Y_d^\dagger Y_u Y_u^\dagger \, \bar{q}_L^c i\tau_2 \ell_L$$

- Generates four-fermion operator:

$$\frac{V_{tb}^* V_{ts}}{2m_{S_3}^2} \, y_t^2 y_b^2 \, \lambda'\lambda \, (\bar{b}_L \gamma^\mu s_L \, \bar{\nu}_L \gamma_\mu \nu_L)$$

- Current limits on $B \to K\nu\bar{\nu}$ imply: $\lambda'/\lambda \lesssim 0.1$ — some suppression of λ' required

- Electroweak singlet vector LQ is the only one of the four models w/o this constraint

(E.g., vector triplet has $\lambda' \, \bar{q}_L Y_u Y_u^\dagger Y_d \, \boldsymbol{\tau} \gamma_\mu \ell_L \boldsymbol{U}^\mu$ term)

The $U^\mu(1,1,3)$ vector LQ

- Interactions terms for electroweak singlet:

$$\begin{aligned}\mathcal{L} &= (\lambda\, \bar{q}_L Y_d \gamma_\mu \ell_L + \tilde{\lambda}\, \bar{d}_R \gamma_\mu e_R)\, U^\mu \\ &= (\lambda y_{d_i} V_{ji}\, \bar{u}_{Lj} \gamma_\mu \nu_L + \lambda y_{d_i} \bar{d}_{Li} \gamma_\mu \tau_L + \tilde{\lambda} \bar{d}_{Ri} \gamma_\mu \tau_R)\, U_i^\mu\end{aligned}$$

As before, contribution to $R(X_c)$ via: $(m_{U_3} \neq m_{U_1} = m_{U_2})$

$$\frac{C'_{V_L}}{\Lambda^2} = \frac{V_{cb}}{m_{U_3}^2}\, \lambda^2 y_b^2$$

- Can fit data if $y_b = \mathcal{O}(1)$; good fit for $\lambda y_b / m_{U_3} = (2.2 \pm 0.4)/\mathrm{TeV}$
- Only τ alignment seems viable (lepton MFV not)

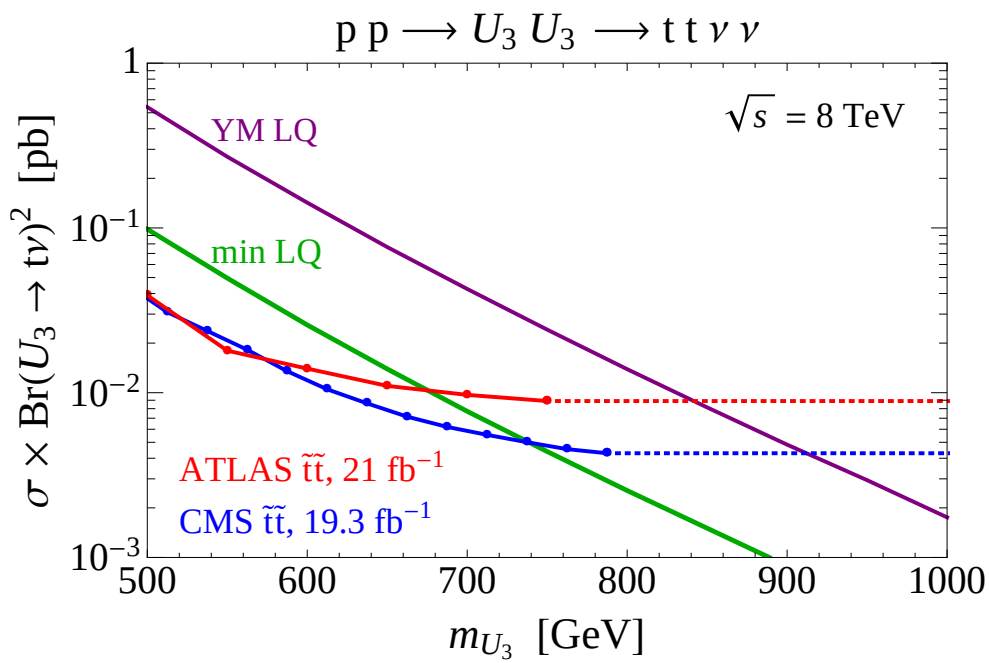
[NB: vector leptoquarks are hard to make sense of as a low energy effective theory, without knowing the UV completion — divergences]

$U^\mu(1,1,3)$ — LHC constraints

- The $\tilde{\lambda}$ term for electroweak singlet vector leptoquark gives unsuppressed coupling to 1st generation
  $\Rightarrow$ constraints from t-channel exchange in $pp \to \tau^+\tau^-$ $\Rightarrow$ $\tilde{\lambda} \lesssim 0.15\,\lambda$

- Limits on m_{U_3} from direct leptoquark search ($b\tau$) or recasting stop ($t\nu$) searches

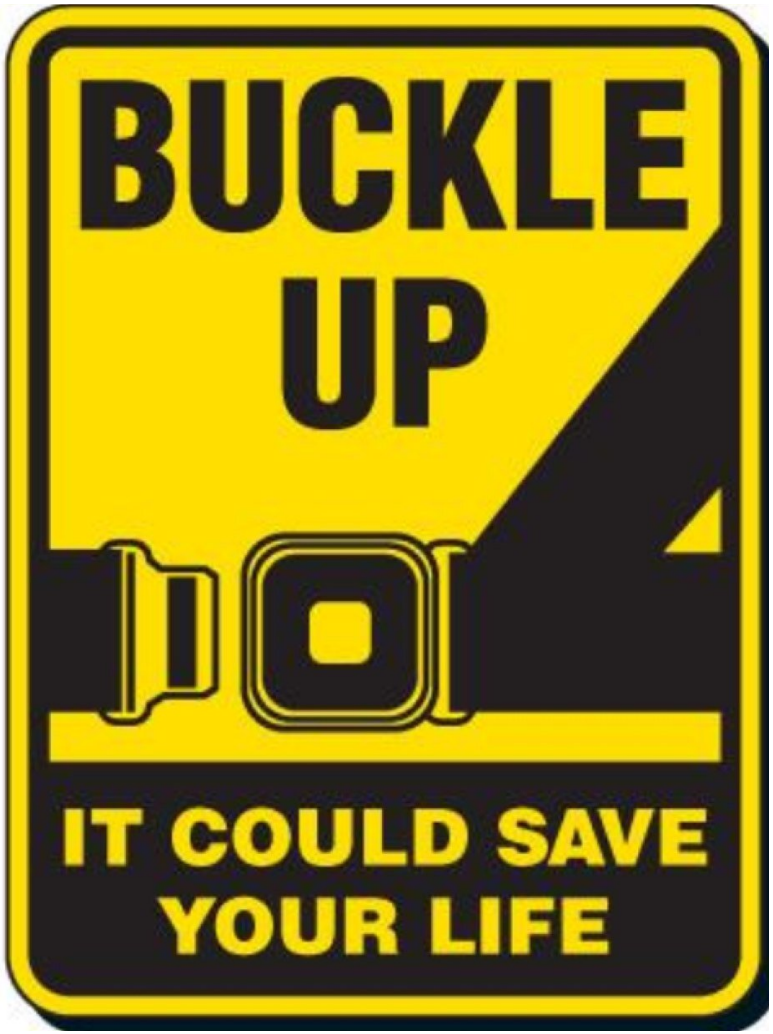
- LQ direct production rate is higher than that of stops, data up to the leptoquark exclusion limit is not available
  Show conservative extrapolation $\Longrightarrow$



Ambiguities related to possible "dipole" term:

$$-ig_s\kappa\, U^{i\dagger}_\mu t^a_{ij} U^j_\nu\, G^{\mu\nu}_a$$

- Obtain: $m_{U_3} \gtrsim 750$ GeV


BUCKLE
UP
IT COULD SAVE
YOUR LIFE

How strange models can be viable?

- All papers enhance the τ mode compared to the SM

  Can we suppress the e and μ modes instead? [Freytsis, ZL, Ruderman, to appear]

  Good fit with: $V_{cb}^{(\mathrm{exp})} \sim V_{cb}^{(\mathrm{SM})} \times 0.9 \qquad V_{ub}^{(\mathrm{exp})} \sim V_{ub}^{(\mathrm{SM})} \times 0.9$

- Strongest constraint is from ϵ_K

$$|\epsilon_K| = \frac{G_F^2\, m_W^2\, m_K f_K^2}{6\sqrt{2}\,\pi^2\,\Delta m_K}\,\hat{B}_K\,\kappa_\epsilon |V_{cb}|^2\,\lambda^2\,\bar{\eta}\Big[|V_{cb}|^2(1-\bar{\rho})\eta_{tt}S_0(x_t) + \eta_{ct}S_0(x_c,x_t) - \eta_{cc}x_c\Big]$$

  - Current central values cannot be accommodated by such models
  - If $R(D^{(*)})$ excess shrinks to $\sim$half of present size, such models become viable
  - Or make cocktails...

- Even an enhancement much smaller than today can become 5σ in the future

Final comments

Many signals, tests, consequences

- LHC: several extensions to current searches would be interesting
  - Searches for $t\tau$ and $b\tau$ resonances
  - Extensions of stop/sbottom searches to higher prod. cross sections ($t\nu$ and $b\nu$)
  - Searches for states appearing on-shell in t- but not in s-channel in pp collisions
  - Enhanced $h \to \tau^+\tau^-$ rate (and $t \to b\tau\bar{\nu}$ and/or $t \to c\tau^+\tau^-$)

- Low energy probes:
  - Firm up $B \to D^{(*)}\tau\bar{\nu}$ rate and kinematic distributions; Cross checks w/ inclusive
  - Smaller theor. error in $[\mathrm{d}\Gamma(B \to D^{(*)}\tau\bar{\nu})/\mathrm{d}q^2]/[\mathrm{d}\Gamma(B \to D^{(*)}l\bar{\nu})/\mathrm{d}q^2]$ at same q^2
  - Improve bounds on $\mathcal{B}(B \to K^{(*)}\nu\bar{\nu})$
  - $\mathcal{B}(D \to \pi\nu\bar{\nu}) \sim 10^{-5}$ possible, maybe BES III; enhanced $\mathcal{B}(D \to \mu^+\mu^-)$
  - $\mathcal{B}(B_s \to \tau^+\tau^-) \sim 10^{-3}$ possible

Conclusions

- Amusing if NP shows up in an operator without much CKM and loop suppression
- There are (somewhat) sensible MFV models for $B \to D^{(*)}\tau\bar{\nu}$ excesses, not requiring ad-hoc flavor assignments
- Several simple extensions to current LHC searches could cover much of this parameter space (see anomalies or rule out models)
- Measurements of $b \to c\tau\bar{\nu}$ will improve in the next decade by order of magnitude

(Even if central values change, plenty of room for significant deviations from SM)