Flavor Physics Overview

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UC SANTA CRUZ

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$$\mathcal{L}_{\text{SM}} \sim \Lambda^4 + \Lambda^2 H^2 + \lambda H^4$$
$$+ \bar{\Psi} \not{D} \Psi + (D_\mu H)^2 + (F_{\mu\nu})^2 + F_{\mu\nu} \tilde{F}^{\mu\nu}$$
$$+ Y H \bar{\Psi} \Psi$$

Flavor in the Standard Model and Beyond

CC problem

Hierarchy problem

Vacuum stability?

Strong CP problem

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SM flavor puzzle

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$$+ Y H \bar{\Psi} \Psi + \frac{1}{\Lambda}(LH)^2 + \frac{1}{\Lambda^2}\sum_i \mathcal{O}_i^{\rm dim6} + \ldots$$

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SM flavor puzzle

Neutrino masses

Flavorful new physics?

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SM flavor puzzle

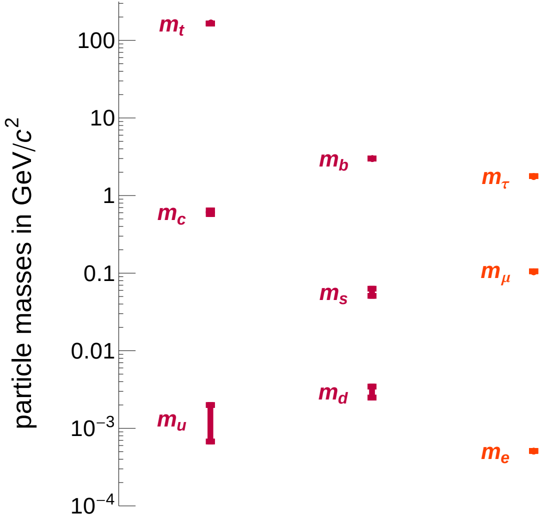
Neutrino masses

Flavorful new physics?

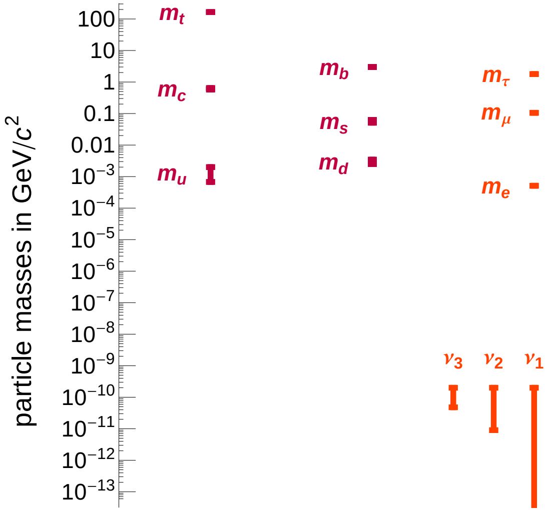
Q1: What is the origin of the hierarchies in the SM sources of flavor violation?

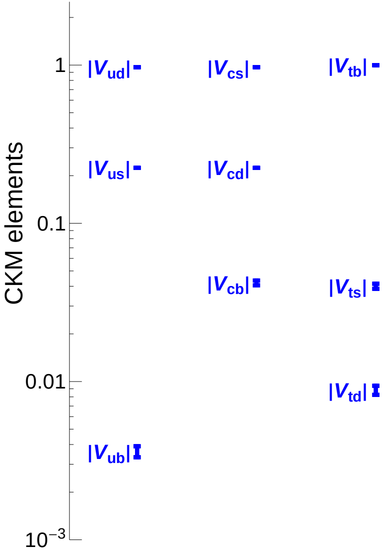
Q2: Are there other sources of flavor violation beyond the SM?

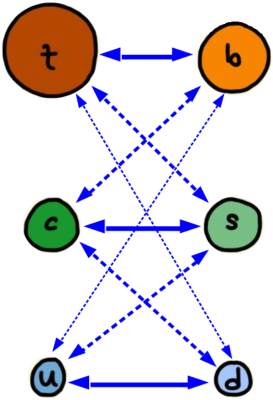
Quark and Lepton Masses



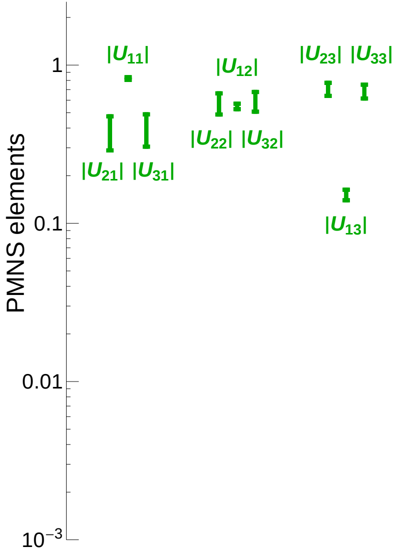
Quark and Lepton Masses

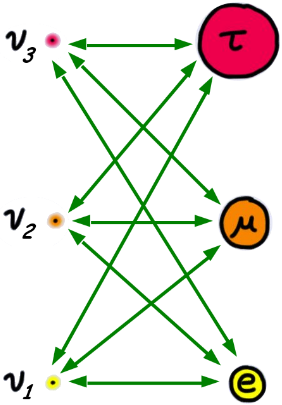



CKM elements
1
0.1
0.01
10^{-3}
$|V_{ud}|$
$|V_{us}|$
$|V_{ub}|$
$|V_{cs}|$
$|V_{cd}|$
$|V_{cb}|$
$|V_{tb}|$
$|V_{ts}|$
$|V_{td}|$


t
b
c
s
u
d

Flavor Mixing in the Lepton Sector





The Standard Model Flavor Puzzle

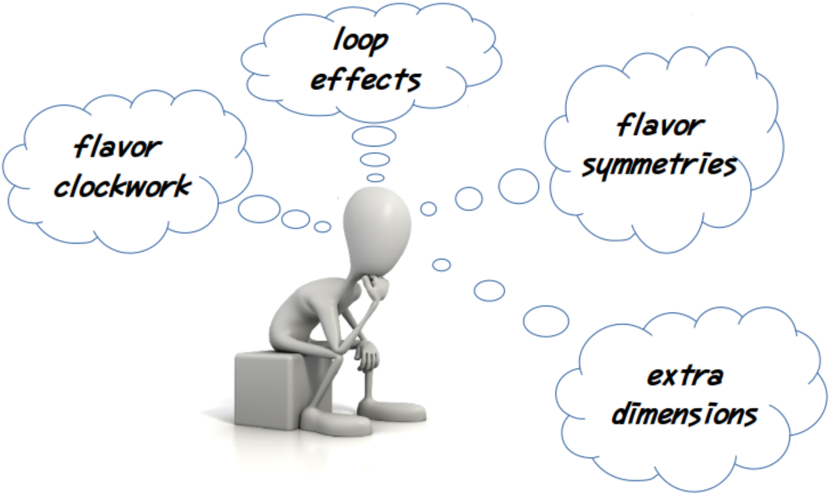
Why are there three flavors of quarks and leptons?

What is the origin of the hierarchies in the fermion spectrum?

What is the origin of the hierarchies in the quark mixing?

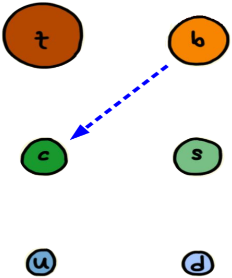
Is lepton mixing anarchic?

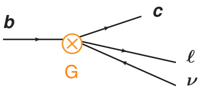
Addressing the SM Flavor Puzzle



Flavor Changing Processes in the SM

In the Standard Model, flavor changing charged currents arise at the tree level;
rates are suppressed by small CKM elements





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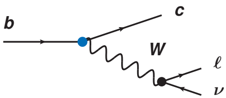
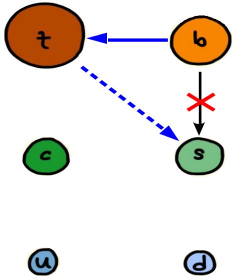
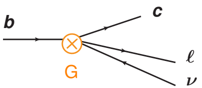


$$G \sim G_F V_{cb}$$

In the Standard Model, flavor changing charged currents arise at the tree level;
rates are suppressed by small CKM elements

Flavor changing neutral currents can arise at the loop level; they are suppressed by loop factors and small CKM elements





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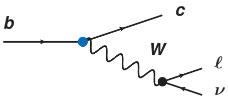

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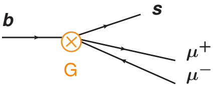
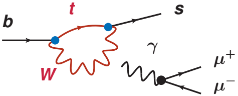
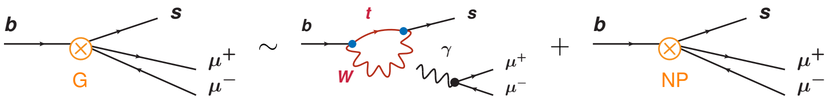


$\sim$



$$G \sim \frac{e^2}{16\pi^2} G_F \frac{m_t^2}{m_W^2} V_{tb} V_{ts}^*$$

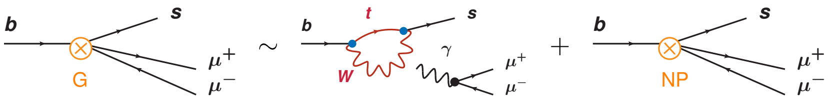
New Physics in Flavor Changing Processes



$$G \sim \frac{1}{16\pi^2}\frac{g^4}{m_W^2}\frac{m_t^2}{m_W^2} V_{tb} V_{ts}^* + \frac{C_{NP}}{\Lambda_{NP}^2}$$

measure precisely	calculate precisely the SM contribution	get information on NP coupling and scale

New Physics in Flavor Changing Processes



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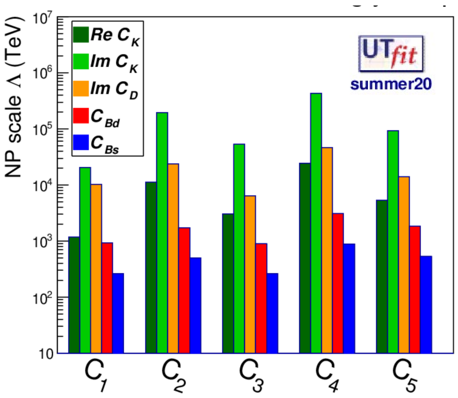
measure precisely	calculate precisely the SM contribution	get information on NP coupling and scale

“Anomalies” in flavor observables could establish
a new scale in particle physics

Measurements of meson mixing show good agreement with SM predictions



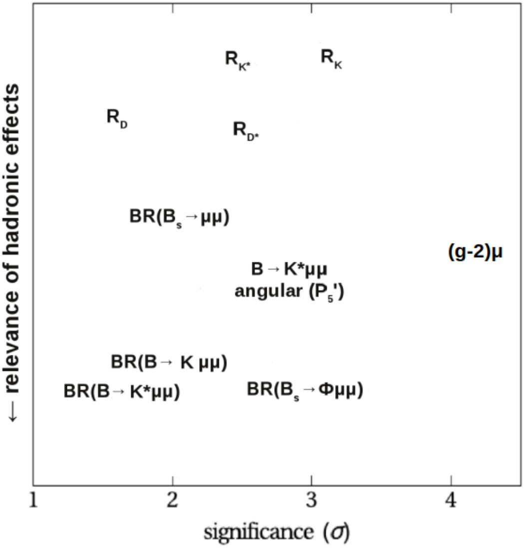
(Marcella Bona @ ICHEP 2020)

$$\mathcal{H}_{\text{eff}} = \sum_i \frac{C_i}{\Lambda^2} Q_i + \sum_i \frac{\tilde{C}_i}{\Lambda^2} \tilde{Q}_i$$

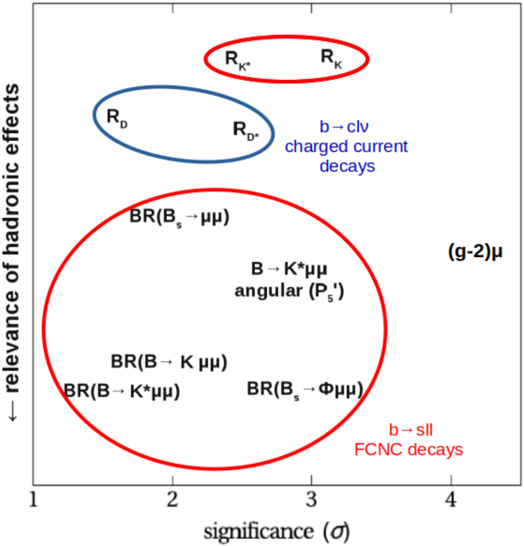
$$\begin{aligned} Q_1 &= (\bar{q}\gamma_\mu P_L q')(\bar{q}\gamma^\mu P_L q') \\ Q_2 &= (\bar{q}P_L q')(\bar{q}P_L q') \\ Q_3 &= (\bar{q}_\alpha P_L q'_\beta)(\bar{q}_\beta P_L q'_\alpha) \\ Q_4 &= (\bar{q}P_L q')(\bar{q}P_R q') \\ Q_5 &= (\bar{q}_\alpha P_L q'_\beta)(\bar{q}_\beta P_R q'_\alpha) \end{aligned}$$

- CP violation in Kaon mixing probes new physics scales as high as 10^5 TeV
- Most cases are limited by the theory uncertainties
  Notable exception:
  CP violation in $D^0 - \bar{D}^0$ mixing

Hints for Flavorful New Physics



(inspired by Zoltan Ligeti)



(inspired by

Zoltan Ligeti)

Bottom-Up Approach to the Flavor Anomalies

theory input / bias

'motivated' models — address other open questions: hierarchy problem, SM flavor puzzle,...
ensure the model is renormalizable, UV complete, ...

simplified models — introduce new particles in the simplest way possible
(e.g. a single lepto-quark or a single Z' boson)

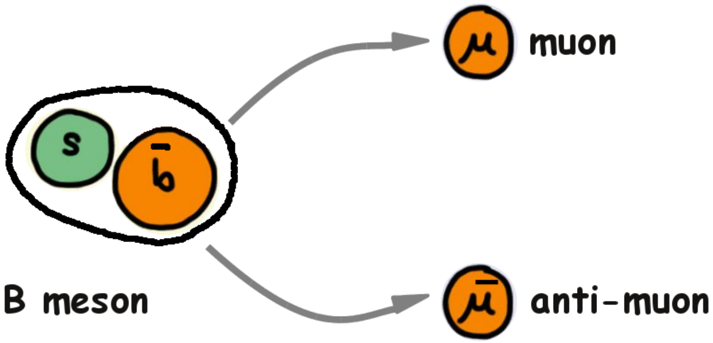
effective field theory (SMEFT / LEFT) — parameterize new physics model independently
(need to make minimal assuptions, e.g. new physics is heavy)

experimental input

(inspired by Marco Nardecchia)

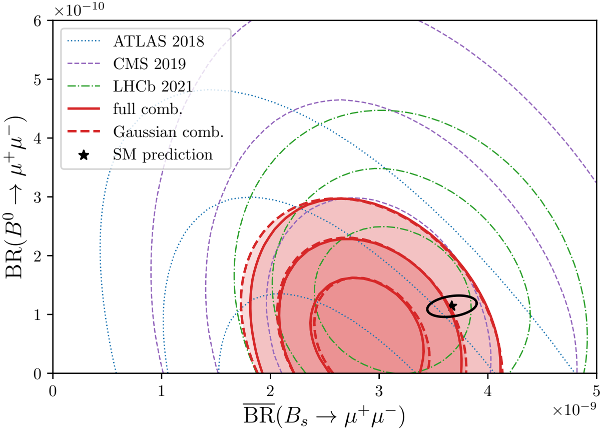
Neutral Current
B Decay Anomalies

The $B_s \to \mu^+\mu^-$ Decay



The $B_s \to \mu^+\mu^-$ Branching Ratio

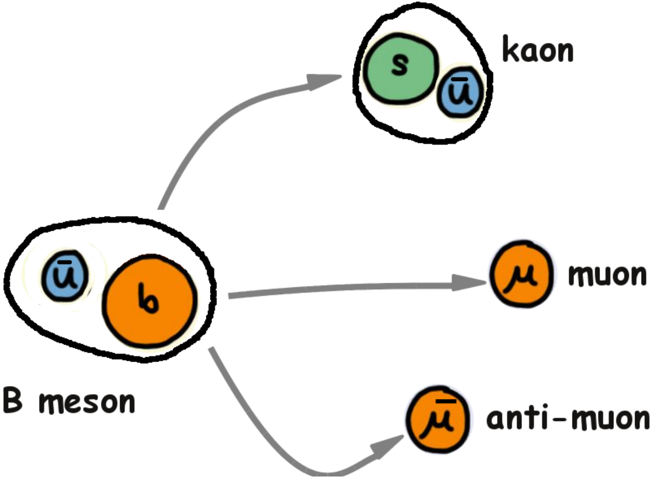
WA, Stangl 2103.13370; combination of LHCb 2108.09284, CMS 1910.12127, ATLAS 1812.03017



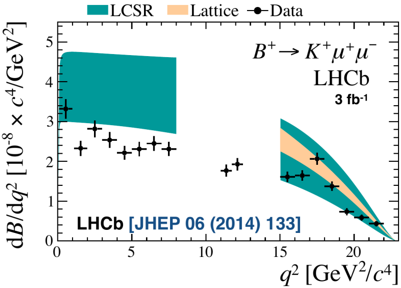
$\sim 2\sigma$ tension between SM and experiment

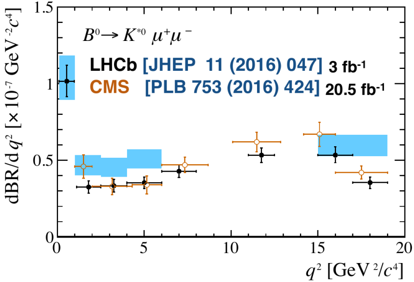
(Hadronic physics is under good control. Largest uncertainty is from CKM input.)

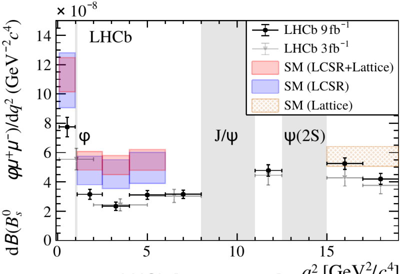
Semileptonic Decays $b \to s\mu\mu$



Semileptonic Branching Ratios



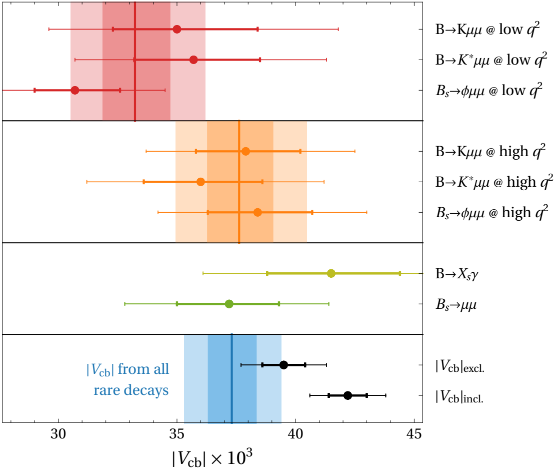




LHCb [2105.14007]

Experimental results for
$\text{BR}(B \to K\mu\mu)$
$\text{BR}(B \to K^*\mu\mu)$
$\text{BR}(B_s \to \phi\mu\mu)$
are consistently low
across many q^2 bins

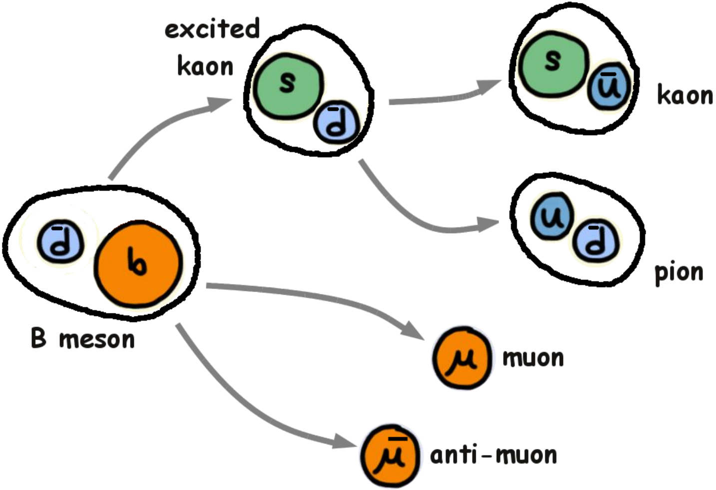
The Role of V_{cb}

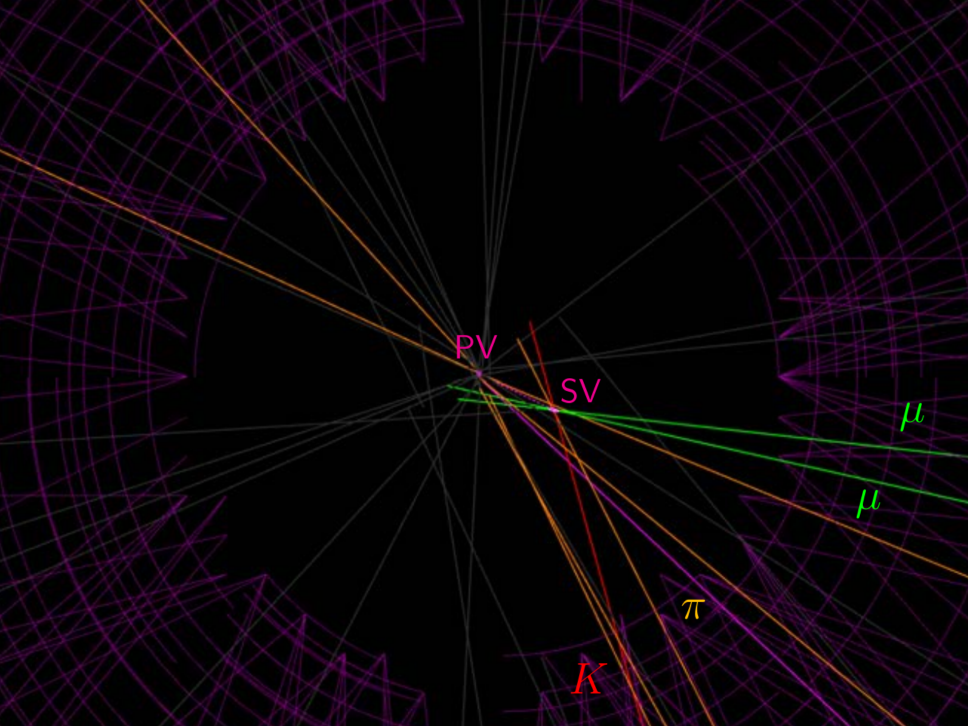


WA, Lewis 2112.03437

- Predictions for $b \to s\mu\mu$ rates depend sensitively on $|V_{cb}|$.
- For many years there are tensions between inclusive and exclusive determinations of V_{cb}.
- The anomalies in the rare B decay rates could be partially explained by a (very) low $|V_{cb}|$.

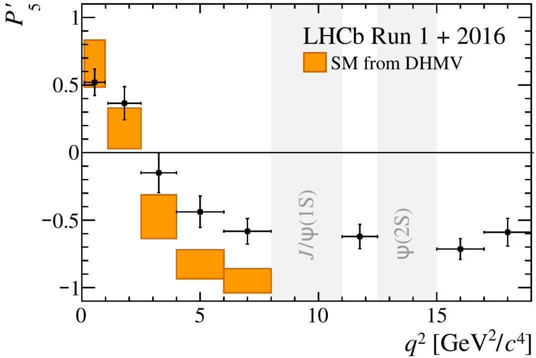
The $B \to K^*(\to K\pi)\mu^+\mu^-$ Decay




PV
SV
μ
μ
π
K

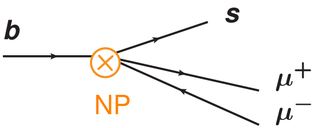
P_5' $\sim$ a moment of the $B \to K^* \mu^+ \mu^-$ angular distribution

LHCb 2003.04831

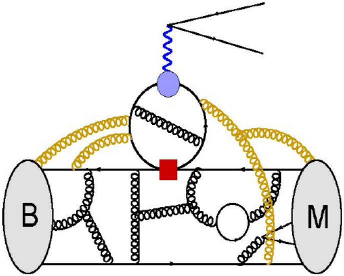


$\sim 2\sigma - 3\sigma$ anomaly persists in the latest update of $B^0 \to K^{*0} \mu^+ \mu^-$.
(Anomaly also seen in $B^\pm \to K^{*\pm} \mu^+ \mu^-$ LHCb 2012.13241)

New Physics or Hadronic Effects?

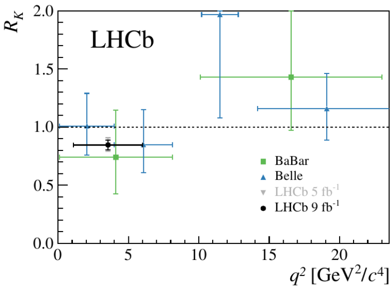


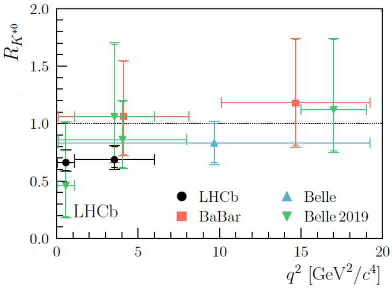
or



Lepton flavor universal new physics could be mimicked by unexpectedly large hadronic effects.

Evidence for Lepton Flavor Universality Violation





$$R_{K^{(*)}} = \frac{BR(B \to K^{(*)}\mu\mu)}{BR(B \to K^{(*)}ee)} \overset{\text{SM}}{\simeq} 1$$

$$R_{K^+}^{[1,6]} = 0.846^{+0.042}_{-0.039}{}^{+0.013}_{-0.012} \ (3.1\sigma)$$

$$R_{K^{*0}}^{[0.045,1.1]} = 0.66^{+0.11}_{-0.07} \pm 0.03 \ (\sim 2.5\sigma)$$

$$R_{K^{*0}}^{[1.1,6]} = 0.69^{+0.11}_{-0.07} \pm 0.05 \ (\sim 2.5\sigma)$$

$$R_{K_S}^{[1.1,6]} = 0.66^{+0.20}_{-0.14}{}^{+0.02}_{-0.04} \ (\sim 1.5\sigma)$$

$$R_{K^{*+}}^{[0.045,6]} = 0.70^{+0.18}_{-0.13}{}^{+0.03}_{-0.04} \ (\sim 1.5\sigma)$$

$$R_{pK}^{[0.1,6]} = 0.86^{+0.14}_{-0.11} \pm 0.05 \ (\sim 1\sigma)$$

LHCb 2103.11769, LHCb 1705.05802, 1912.08139, 2110.09501; also Belle 1904.02440, 1908.01848

How Robust Are the SM Predictions for R_K and R_{K^*}?

$$R_{K^{(*)}} = 1$$

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$$R_{K^{(*)}} = 1 + \mathcal{O}\left(\frac{m_\mu^2}{q^2}\right)$$

phase space
(tiny effect)

How Robust Are the SM Predictions for R_K and R_{K^*}?

$$R_{K^{(*)}} = 1 + \mathcal{O}\left(\frac{m_\mu^2}{q^2}\right) \times \left(1 + \mathcal{O}\left(\frac{\Lambda_{\text{QCD}}}{m_b}\right) + \mathcal{O}(\alpha_s)\right)$$

phase space
(tiny effect)

hadronic corrections
(tiny effect)

How Robust Are the SM Predictions for R_K and R_{K^*}?

$$R_{K^{(*)}} = 1 + \mathcal{O}\left(\frac{m_\mu^2}{q^2}\right) \times \left(1 + \mathcal{O}\left(\frac{\Lambda_{\rm QCD}}{m_b}\right) + \mathcal{O}(\alpha_s)\right) + \mathcal{O}\left(\frac{\alpha_{\rm em}}{\pi} \log^2\left(\frac{m_e^2}{m_\mu^2}\right)\right)$$

phase space
(tiny effect)

hadronic corrections
(tiny effect)

QED corrections
(soft and collinear photon emission)

How Robust Are the SM Predictions for R_K and R_{K^*}?

$$R_{K^{(*)}} = 1 + \mathcal{O}\left(\frac{m_\mu^2}{q^2}\right) \times \left(1 + \mathcal{O}\left(\frac{\Lambda_{\text{QCD}}}{m_b}\right) + \mathcal{O}(\alpha_s)\right) + \mathcal{O}\left(\frac{\alpha_{\text{em}}}{\pi} \log^2\left(\frac{m_e^2}{m_\mu^2}\right)\right)$$

phase space (tiny effect)

hadronic corrections (tiny effect)

QED corrections (soft and collinear photon emission)

- QED corrections seem to be under control at the level of the total rate, given the experimental cuts on e.g. the reconstructed B meson mass
  Bordone, Isidori, Pattori 1605.07633, Isidori, Nabeebaccus, Zwicky 2009.00929

$$R_K^{[1,6]} = 1.00 \pm 0.01 \ , \quad R_{K^*}^{[1.1,6]} = 1.00 \pm 0.01 \ , \quad R_{K^*}^{[0.045,1.1]} = 0.91 \pm 0.03$$

- potentially larger QED effects at the differential level

What Could It Be?

	$B_s \to \mu\mu$ rate	semileptonic rates	angular observables	LFU ratios

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	$B_s \to \mu\mu$ rate	semileptonic rates	angular observables	LFU ratios
experimental issues?	?	?	?	?

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statistical fluctuations?	✓	✓	✓	✓

What Could It Be?

	$B_s \to \mu\mu$ rate	semileptonic rates	angular observables	LFU ratios
experimental issues?	?	?	?	?
statistical fluctuations?	✓	✓	✓	✓
parametric uncertainties?	✓	✓	✗	✗

What Could It Be?

	$B_s \to \mu\mu$ rate	semileptonic rates	angular observables	LFU ratios
experimental issues?	?	?	?	?
statistical fluctuations?	✓	✓	✓	✓
parametric uncertainties?	✓	✓	✗	✗
underestimated hadronic effects?	✗	✓	✓	✗

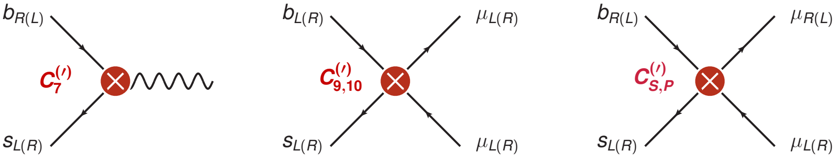
What Could It Be?

	$B_s \to \mu\mu$ rate	semileptonic rates	angular observables	LFU ratios
experimental issues?	?	?	?	?
statistical fluctuations?	✓	✓	✓	✓
parametric uncertainties?	✓	✓	✗	✗
underestimated hadronic effects?	✗	✓	✓	✗
New Physics?	✓	✓	✓	✓

Model Independent New Physics Analysis

$$\mathcal{H}_{\text{eff}}^{b\to s} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \sum_i \left(C_i \mathcal{O}_i + C_i' \mathcal{O}_i' \right)$$

magnetic dipole operators | semileptonic operators | scalar operators



$C_7^{(\prime)} (\bar{s}\sigma_{\mu\nu} P_{R(L)} b) F^{\mu\nu}$, $C_9^{(\prime)} (\bar{s}\gamma_\mu P_{L(R)} b)(\bar{\mu}\gamma^\mu \mu)$, $C_S^{(\prime)} (\bar{s} P_{R(L)} b)(\bar{\mu} P_{L(R)} \mu)$

$C_{10}^{(\prime)} (\bar{s}\gamma_\mu P_{L(R)} b)(\bar{\mu}\gamma^\mu \gamma_5 \mu)$

neglecting tensor operators and additional scalar operators
(they are dimension 8 in SMEFT: Alonso, Grinstein, Martin Camalich 1407.7044)

Complementary Sensitivity

	C_7, C_7'	C_9, C_9'	C_{10}, C_{10}'	C_S, C_S'
$B \to (X_s, K^*)\gamma$	★			
$B_s \to \phi\gamma$	★			
$B \to (X_s, K, K^*)\, \mu^+\mu^-$	★	★	★	⋆
$B_s \to \phi\, \mu^+\mu^-$	★	★	★	⋆
$\Lambda_b \to \Lambda\, \mu^+\mu^-$	★	★	★	⋆
$B_s \to \mu^+\mu^-$			★	★

many processes and many observables are modified simultaneously

$\Rightarrow$ global fits are required

recent papers:

Geng, Grinstein, Jäger, Li, Martin Camalich, Shi 2103.12738

WA, Stangl 2103.13370

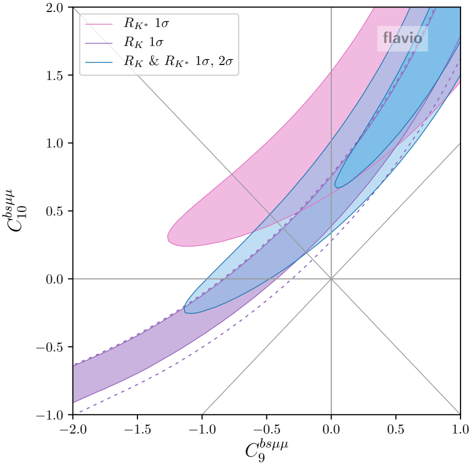
Cornella, Faroughy, Fuentes-Martin, Isidori, Neubert 2103.16558

Alguero, Capdevila, Descotes-Genon, Matias, Novoa-Brunet 2104.08921

Hurth, Mahmoudi, Martinez Santos, Neshatpour 2104.10058

Ciuchini, Fedele, Franco, Paul, Silvestrini 2110.10126

Fits of Pairs of Wilson Coefficients



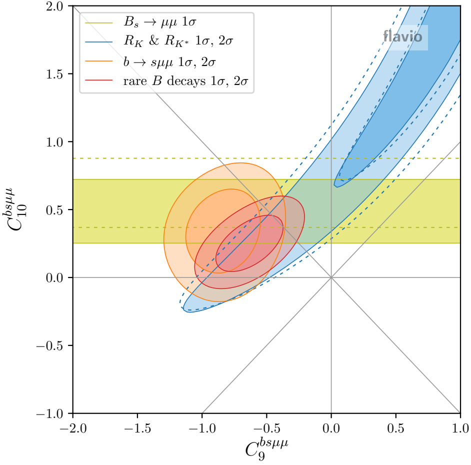
WA, Stangl 2103.13370

$$C_9^{bs\mu\mu}(\bar{s}\gamma_\alpha P_L b)(\bar{\mu}\gamma^\alpha \mu)$$

$$C_{10}^{bs\mu\mu}(\bar{s}\gamma_\alpha P_L b)(\bar{\mu}\gamma^\alpha \gamma_5 \mu)$$

- LFU ratios prefer non-standard C_{10}, but large degeneracy

Fits of Pairs of Wilson Coefficients



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- $B_s \to \mu^+\mu^-$ branching ratio shows slight preference for non-standard C_{10}
- $b \to s\mu\mu$ observables prefer non-standard C_9
- best fit point

$$C_9^{bs\mu\mu} \simeq -0.63\,, \quad C_{10}^{bs\mu\mu} \simeq +0.25$$

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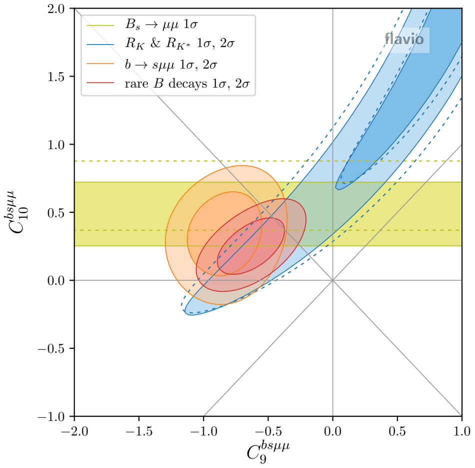

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- Note: LFU ratios could also be explained by new physics in electrons

(B. Capdevilla, M. Fedele, S. Neshatpour, P. Stangl @ Flavour Anomaly Workshop, CERN, Oct. 20 2021)

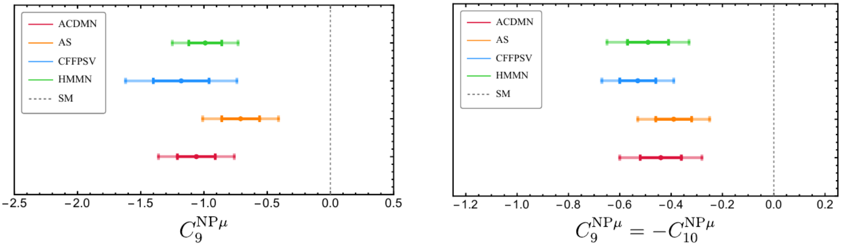
- ACDMN (M. Algueró, B. Capdevila, S. Descotes-Genon, J. Matias, M. Novoa-Brunet)
  Statistical framework: χ^2-fit, based on private code — arXiv:2104.08921
- AS (W. Altmannshofer, P. Stangl)
  Statistical framework: χ^2-fit, based on public code `flavio` — arXiv:2103.13370
- CFFPSV (M. Ciuchini, M. Fedele, E. Franco, A. Paul, L. Silvestrini, M. Valli)
  Statistical framework: Bayesian MCMC fit, based on public code `HEPfit` — arXiv:2011.01212
- HMMN (T. Hurth, F. Mahmoudi, D. Martínez-Santos, S. Neshatpour)
  Statistical framework: χ^2-fit, based on public code `SuperIso` — arXiv:2104.10058

See also similar fits by other groups:
Geng et al., arXiv:2103.12738, Alok et al., arXiv:1903.09617, Datta et al., arXiv:1903.10086, Kowalska et al., arXiv:1903.10932, D'Amico et al., arXiv:1704.05438, Hiller et al., arXiv:1704.05444, ...

- Global fits have reached a high level of sophistication. Are done by many groups with different statistical approaches, different treatment of theory uncertainties, different selection of observables, ...

Fits of One Single Wilson Coefficient

(B. Capdevilla, M. Fedele, S. Neshatpour, P. Stangl @ Flavour Anomaly Workshop, CERN, Oct. 20 2021)



- small differences among the groups due to different approaches, but overall remarkable agreement
- NP scenarios are preferred over SM with pulls $> 5\sigma$
- Warning: pull $\neq$ global significance.
- Global significance $\simeq 4.3\sigma$ determined in Isidori et al. arXiv:2104.05631

Fits of Pairs of Wilson Coefficients

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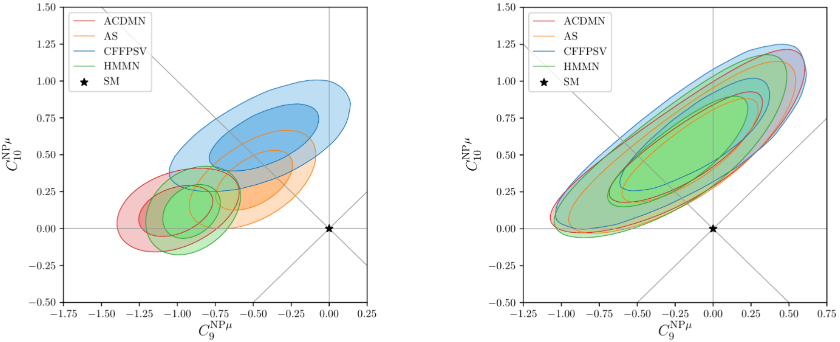
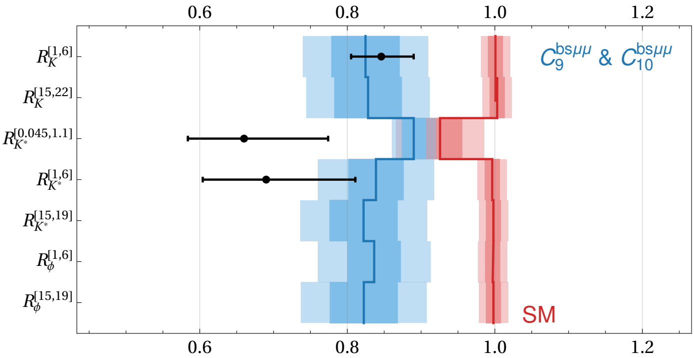


global fit

fit to LFU observables + $B_s \to \mu\mu$

- Perfect agreement if only theoretically clean observables are used.

Predictions for Other LFU Ratios



WA, Stangl 2103.13370

LFU ratios of branching fractions are all predicted to show a similar devitation from the SM

$$R_K \simeq R_{K^*} \simeq R_\phi \simeq 0.8$$

Implications for the New Physics Scale

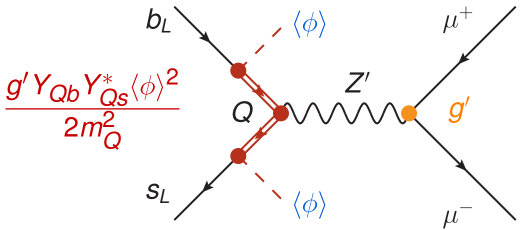
unitarity bound	$\frac{4\pi}{\Lambda_{\rm NP}^2}(\bar{s}\gamma_\nu P_L b)(\bar{\mu}\gamma^\nu \mu)$	$\Lambda_{\rm NP} \simeq 120 \text{ TeV} \times (C_9^{\rm NP})^{-1/2}$
generic tree	$\frac{1}{\Lambda_{\rm NP}^2}(\bar{s}\gamma_\nu P_L b)(\bar{\mu}\gamma^\nu \mu)$	$\Lambda_{\rm NP} \simeq 35 \text{ TeV} \times (C_9^{\rm NP})^{-1/2}$
MFV tree	$\frac{1}{\Lambda_{\rm NP}^2} V_{tb} V_{ts}^* (\bar{s}\gamma_\nu P_L b)(\bar{\mu}\gamma^\nu \mu)$	$\Lambda_{\rm NP} \simeq 7 \text{ TeV} \times (C_9^{\rm NP})^{-1/2}$
generic loop	$\frac{1}{\Lambda_{\rm NP}^2}\frac{1}{16\pi^2}(\bar{s}\gamma_\nu P_L b)(\bar{\mu}\gamma^\nu \mu)$	$\Lambda_{\rm NP} \simeq 3 \text{ TeV} \times (C_9^{\rm NP})^{-1/2}$
MFV loop	$\frac{1}{\Lambda_{\rm NP}^2}\frac{1}{16\pi^2} V_{tb} V_{ts}^* (\bar{s}\gamma_\nu P_L b)(\bar{\mu}\gamma^\nu \mu)$	$\Lambda_{\rm NP} \simeq 0.6 \text{ TeV} \times (C_9^{\rm NP})^{-1/2}$

(MFV = Minimal Flavor Violation)

My Favorite Simplified Model

Z' based on gauging $L_\mu - L_\tau$ (He, Joshi, Lew, Volkas PRD 43, 22-24)
with effective flavor violating couplings to quarks

WA, Gori, Pospelov, Yavin 1403.1269; WA, Yavin 1508.07009;
WA, Davighi, Nardecchia 1909.02021



Q: heavy vectorlike fermions with mass $\sim 1 - 10$ TeV
ϕ: scalar that breaks $L_\mu - L_\tau$

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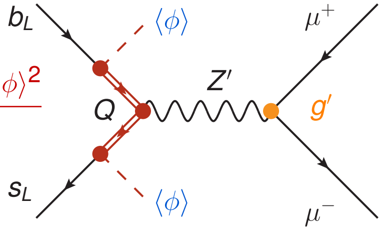
$$\frac{g' Y_{Qb} Y^*_{Qs} \langle\phi\rangle^2}{2 m_Q^2}$$



predicted Lepton Universality Violation!

Q: heavy vectorlike fermions with mass $\sim 1 - 10$ TeV
ϕ: scalar that breaks $L_\mu - L_\tau$

Neutrino Tridents

B_s mixing

$(g-2)_\mu$

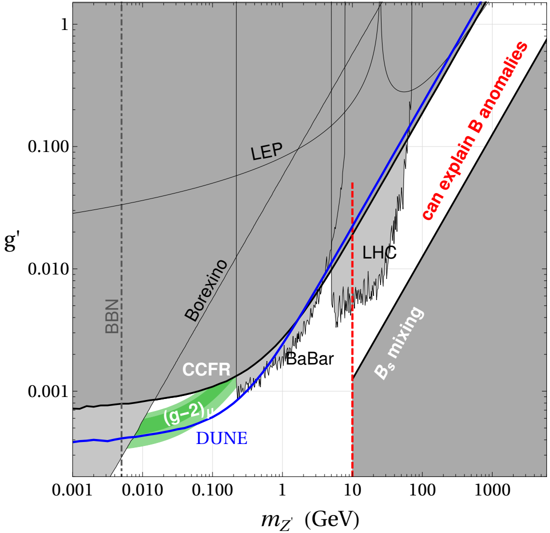
νe scattering

$Z \to \ell\ell$

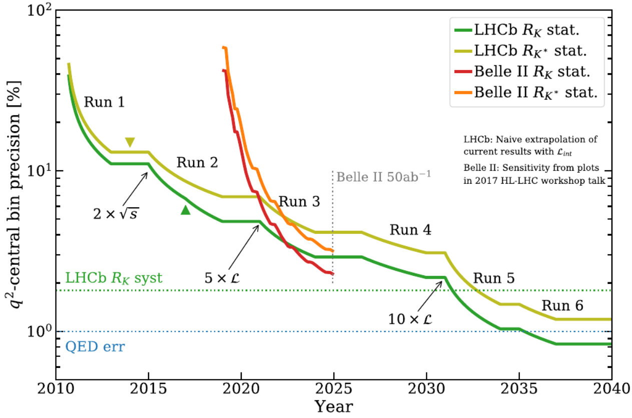
$Z \to 4\mu$

$e^+e^- \to 4\mu$

WA, Gori, Martin-Albo, Sousa, Wallbank 1902.06765



- LHCb and Belle II can push uncertainties down to few percent
- (can ATLAS and CMS say something?)
- with sufficient statistics, LFU of angular distributions can be tested

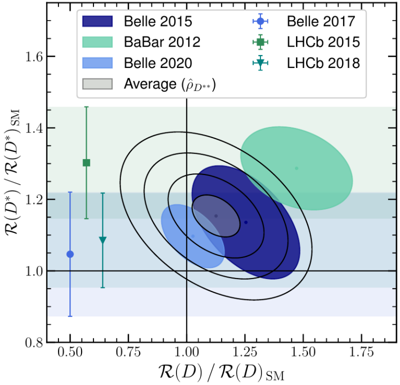


talk by Polci and Alvarez Cartelle @ Beyond the flavor anomalies workshop, Durham April 2020

- LHCb can cross check in other modes: R_ϕ , R_{pK} , ...

Charged Current B Decay Anomalies

Bernlochner, Franco Sevilla, Robinson, 2101.08326



$$R_D = \frac{BR(B \to D\tau\nu)}{BR(B \to D\ell\nu)}$$

$$R_{D^*} = \frac{BR(B \to D^*\tau\nu)}{BR(B \to D^*\ell\nu)}$$

$\ell = \mu, e$ (BaBar/Belle)
$\ell = \mu$ (LHCb)

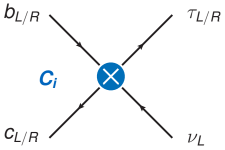
$$R_D^{\rm exp}/R_D^{\rm SM} = 1.13 \pm 0.10\ , \quad R_{D^*}^{\rm exp}/R_{D^*}^{\rm SM} = 1.15 \pm 0.06$$

combined discrepancy with the SM: 3.6σ

(the heavy flavor averaging group quotes 3.1σ)

Model Independent New Physics Analysis

$$\mathcal{H}_{\text{eff}} = \frac{4G_F}{\sqrt{2}} V_{cb} \mathcal{O}_{V_L} + \frac{1}{\Lambda^2} \sum_i C_i \mathcal{O}_i$$



$\mathcal{O}_i$ = contact interactions
with vector, scalar
or tensor currents

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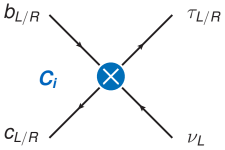
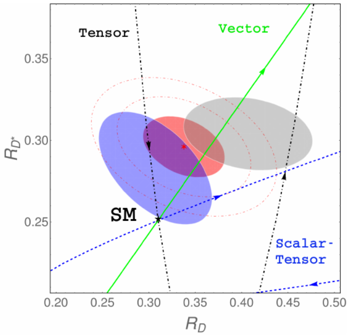


$\mathcal{O}_i$ = contact interactions
with vector, scalar
or tensor currents

rescaling of the SM vector operator fits the data best

combinations of operators are also possible

Shi et al. 1905.08498



(also Murgui et al. 1904.09311, Asadi, Shih 1905.03311, Cheung et al. 2002.07272, ...)

Implications for the New Physics Scale

unitarity bound	$\frac{4\pi}{\Lambda_{NP}^2}(\bar{c}\gamma_\nu P_L b)(\bar{\tau}\gamma^\nu P_L \nu)$	$\Lambda_{NP} \simeq 8.4$ TeV
generic tree	$\frac{1}{\Lambda_{NP}^2}(\bar{c}\gamma_\nu P_L b)(\bar{\tau}\gamma^\nu P_L \nu)$	$\Lambda_{NP} \simeq 2.4$ TeV
MFV tree	$\frac{1}{\Lambda_{NP}^2}\, V_{cb}\, (\bar{c}\gamma_\nu P_L b)(\bar{\tau}\gamma^\nu P_L \nu)$	$\Lambda_{NP} \simeq 0.5$ TeV

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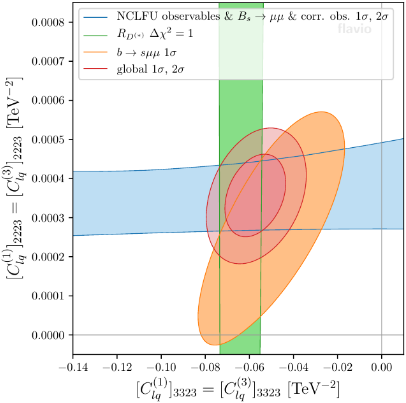
(MFV = Minimal Flavor Violation)

rather low scale $\rightarrow$ model building is non-trivial

Combined Explanations of All B Anomalies

(Peter Stangl; update of 1903.10434)



model independent EFT approach:

two new physics parameters describe consistently a dozen $(2-3)\sigma$ discrepancies

remarkable!

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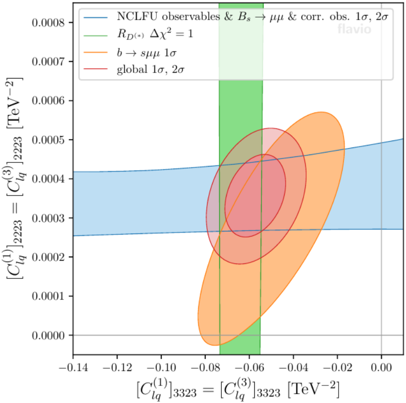


model independent EFT approach:

two new physics parameters describe consistently a dozen $(2-3)\sigma$ discrepancies

remarkable!

- operators point to leptoquarks with masses of few TeV

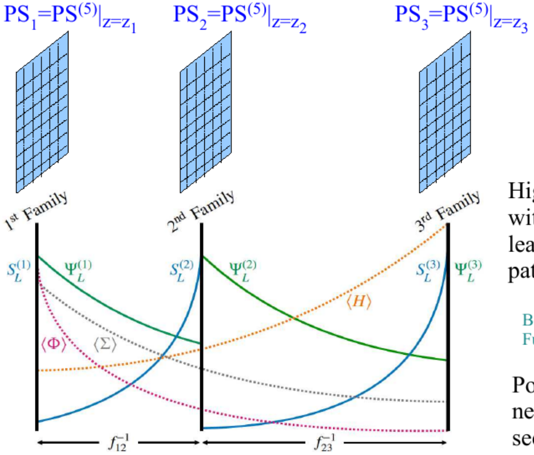
- Leptoquark could be the remnant of an extended gauge group

  Di Luzio et al. 1708.08450; Bordone et al. 1712.01368, ...

- also attempts with RPV SUSY

  Deshpande, He, 1608.04817; WA, Dev, Soni 1704.06659; Earl, Gregoire 1806.01343; Trifinopoulos 1807.01638; WA, Dev, Soni, Sui 2002.12910; Dev, Soni, Xu 2106.15647; ...

Flavor anomalies from the U_1 leptoquark of (Pati-Salam)^3



Flavor ↔ special position (*topological defect*) in an extra (compact) space-like dimension

Dvali & Shifman, '00

Higgs and SU(4)-breaking fields with oppositely-peaked profiles, leading to the desired flavor pattern for masses & anomalies

Bordone, Cornella, Fuentes-Martin, GI '17
Fuentes-Martin, GI, Pages, Stefanek '20

Possible to implement anarchic neutrino masses via an inverse see-saw mechanism

(Gino Isidori @ Beyond the Anomalies workshop, Durham 2021)

Summary

- B decay data continues to show intriguing discrepancies with SM predictions.
- If significance of LFU violation continues to grow with more statistics $\Rightarrow$ clear indication of new physics. (Recent R_K update be LHCb is reassuring!)
- Maybe gauged $L_\mu - L_\tau$? RPV SUSY? Leptoquarks? (Pati-Salam)^3?
- Looking forward to the next round of experimental updates!