Beyond the Flavour Anomalies, 20 April 2021

Status of Global Fits of Flavour Anomalies

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The need to know

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Flavour Anomalies

$b \to s\,\mu^+\mu^-$ anomaly

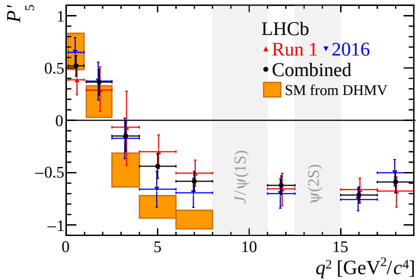
Several LHCb measurements deviate from Standard model (SM) predictions:

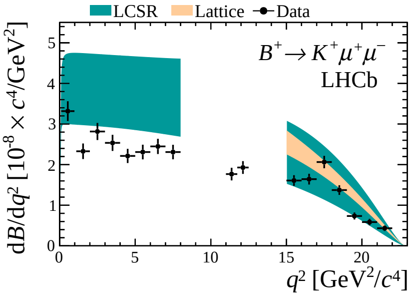
- Angular observable P_5' in $B \to K^*\mu^+\mu^-$ (two anomaly bins $\sim 3\,\sigma$ each)

  LHCb, arXiv:2003.04831, arXiv:2012.13241

- Branching ratios of $B \to K\mu^+\mu^-$, $B \to K^*\mu^+\mu^-$, and $B_s \to \phi\mu^+\mu^-$ ($\sim 2\,\sigma$).

  LHCb, arXiv:1403.8044, arXiv:1506.08777, arXiv:1606.04731





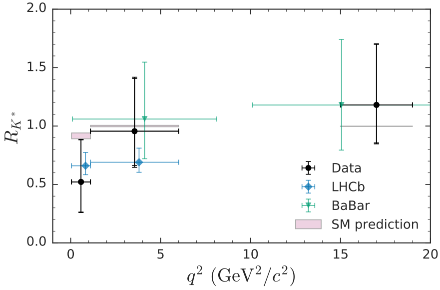
Hints for LFU violation in $b \to s\,\ell^+\ell^-$ decays

Measurements of lepton flavour universality (LFU) ratios $R_{K^*}^{[0.045,1.1]}$, $R_{K^*}^{[1.1,6]}$ show deviations from SM by about 2.5σ each.

LHCb, arXiv:1705.05802
Belle, arXiv:1904.02440

- Cancellation of all uncertainties in SM (up to lepton masses), strongly FF sensitive in presence of NP.

$$R_{K^*} = \frac{BR(B \to K^*\mu^+\mu^-)}{BR(B \to K^*e^+e^-)}$$



Hints for LFU violation in $b \to s\,\ell^+\ell^-$ decays

Measurement of LFU ratio $R_K^{[1.1,6]}$ shows deviation from SM by 3.1σ.

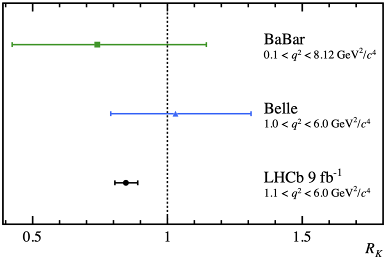
LHCb, arXiv: 2103.11769, Belle, arXiv:1908.01848

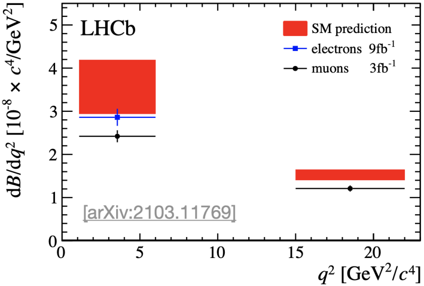
- Cancellation of all uncertainties in SM and in presence of NP (up to m_ℓ).

$$R_K = \frac{BR(B \to K\mu^+\mu^-)}{BR(B \to Ke^+e^-)}$$

$$\int_{q^2=1.1\ \mathrm{GeV}^2}^{q^2=6\ \mathrm{GeV}^2} \frac{d\mathcal{B}(B^+ \to K^+e^+e^-)}{dq^2}dq^2 = (28.6^{+1.5}_{-1.4}\ (\mathrm{stat.})\ \pm 1.3\ (\mathrm{syst.})\ ) \times 10^{-9}$$

... Electrons seem more SM-like than muons.





Hints for LFU violation in $b \to s\,\ell^+\ell^-$ decays

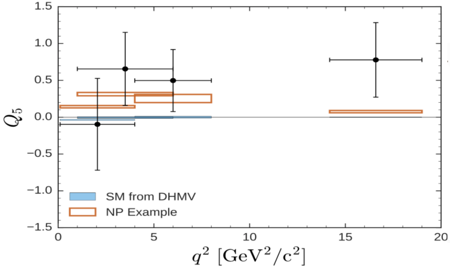
Measurement of LFU observable $Q_{4,5} = D_{P'_{4,5}} = P'^{\mu}_{4,5} - P'^{e}_{4,5}$ by Belle.

S. Wehle et al (Belle), PRL 118 (2017)

- Cancellation of all uncertainties in SM (up to lepton masses) like other LFUV R_{K,K^*}, but optimized in presence of NP, contrary to the case of R_{K^*}.
- Isospin averaged but lepton-flavour dependent channels:

$$P'^{\ell}_i = \sigma_+ P'^{\ell}_i(B^+) + (1-\sigma_+)P'^{\ell}_i(\bar{B}^0) \qquad \sigma_+ = 0.5 \pm 0.5$$

- Also electronic and muonic channel analysis, show electrons more SM-like.

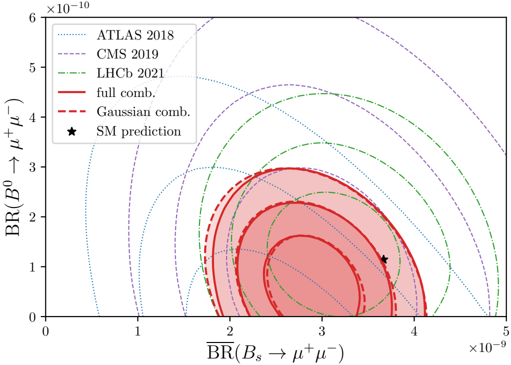


q^2 in GeV$^2/c^2$	Q_4	Q_5
[1.00, 6.00]	$0.498 \pm 0.527 \pm 0.166$	$0.656 \pm 0.485 \pm 0.103$
[0.10, 4.00]	$-0.723 \pm 0.676 \pm 0.163$	$-0.097 \pm 0.601 \pm 0.164$
[4.00, 8.00]	$0.448 \pm 0.392 \pm 0.076$	$0.498 \pm 0.410 \pm 0.095$
[14.18, 19.00]	$0.041 \pm 0.565 \pm 0.082$	$0.778 \pm 0.502 \pm 0.065$

Combination of $B_{s,d} \to \mu^+\mu^-$ measurements

Measurements of $\mathrm{BR}(B_{s,d} \to \mu^+\mu^-)$ by LHCb, CMS, and ATLAS show combined deviation from SM by about 2σ.

ATLAS, arXiv:1812.03017
CMS, arXiv:1910.12127
LHCb seminar 23 March 2021
Altmannshofer, PS, arXiv:2103.13370



QM: We take the average of ATLAS, CMS, LHCb (now closer to SM)

$$\mathcal{B}_{B_s \to \mu^+\mu^-} = (2.85^{+0.34}_{-0.31}) \times 10^{-9}$$

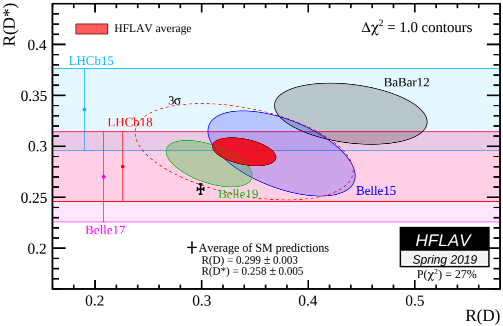
Hints for LFU violation in $b \to c\,\ell\,\nu$ decays

Measurements of LFU ratios R_D and R_{D^*} by BaBar, Belle, and LHCb show combined deviation from SM by about 3σ.

BaBar, arXiv:1205.5442, arXiv:1303.0571
LHCb, arXiv:1506.08614, arXiv:1708.08856
Belle, arXiv:1507.03233, arXiv:1607.07923, arXiv:1612.00529, arXiv:1904.08794

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

$$\ell \in \{e, \mu\}$$



HFLAV, hflav.web.cern.ch

Theoretical Framework

$b \to s\ell\ell$ in the weak effective theory

- Effective Hamiltonian at scale m_b: $\mathcal{H}_{\text{eff}}^{bs\ell\ell} = \mathcal{H}_{\text{eff, SM}}^{bs\ell\ell} + \mathcal{H}_{\text{eff, NP}}^{bs\ell\ell}$

$$\mathcal{H}_{\text{eff, NP}}^{bs\ell\ell} = -\mathcal{N}\left(C_7^{bs} O_7^{bs} + C_7^{\prime bs} O_7^{\prime bs} + \sum_{\ell=e,\mu} \sum_{i=9,10,S,P} \left(C_i^{bs\ell\ell} O_i^{bs\ell\ell} + C_i^{\prime bs\ell\ell} O_i^{\prime bs\ell\ell}\right)\right) + \text{h.c.}$$

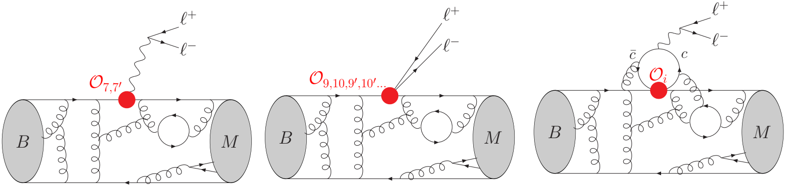
- From the set of operators ($\ell = e, \mu$)

$$\begin{aligned}
O_9^{bs\ell\ell} &= (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \ell)\,, & O_9^{\prime bs\ell\ell} &= (\bar{s}\gamma_\mu P_R b)(\bar{\ell}\gamma^\mu \ell)\,,\\
O_{10}^{bs\ell\ell} &= (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \gamma_5 \ell)\,, & O_{10}^{\prime bs\ell\ell} &= (\bar{s}\gamma_\mu P_R b)(\bar{\ell}\gamma^\mu \gamma_5 \ell)\,,\\
O_7^{bs} &= \frac{m_b}{e}(\bar{s}\sigma_{\mu\nu} P_R b)F^{\mu\nu}\,, & O_7^{\prime bs} &= \frac{m_b}{e}(\bar{s}\sigma_{\mu\nu} P_L b)F^{\mu\nu}\,,\\
O_S^{bs\ell\ell} &= m_b(\bar{s}P_R b)(\bar{\ell}\ell)\,, & O_S^{\prime bs\ell\ell} &= m_b(\bar{s}P_L b)(\bar{\ell}\ell)\,,\\
O_P^{bs\ell\ell} &= m_b(\bar{s}P_R b)(\bar{\ell}\gamma_5 \ell)\,, & O_P^{\prime bs\ell\ell} &= m_b(\bar{s}P_L b)(\bar{\ell}\gamma_5 \ell)\,.
\end{aligned}$$

QM: not considered here $O_{S,P}^{(\prime)}$
PS: not considered here $O_{7,7'}$ (strongly constrained by radiative decays)

Two sources of hadronic uncertainties for exclusive

$$A(B \to M\ell\ell) = \frac{G_F \alpha}{\sqrt{2}\pi} V_{tb} V_{ts}^* [(A_\mu + T_\mu)\bar{u}_\ell \gamma^\mu v_\ell + B_\mu \bar{u}_\ell \gamma^\mu \gamma_5 v_\ell]$$



Form factors (local) Form factors (local) Charm loop
(non-local)

- Local contributions (more terms if NP in non-SM $\mathcal{C}_i$): form factors

$$A_\mu = -\frac{2m_b q^\nu}{q^2} \mathcal{C}_7 \langle M|\bar{s}\sigma_{\mu\nu} P_R b|B\rangle + \mathcal{C}_9 \langle M|\bar{s}\gamma_\mu P_L b|B\rangle$$

$$B_\mu = \mathcal{C}_{10} \langle M|\bar{s}\gamma_\mu P_L b|B\rangle$$

- Non-local contributions (charm loops): hadronic contribs.

  T_μ contributes like $\mathcal{O}_{7,9}$, but depends on q^2 and external states

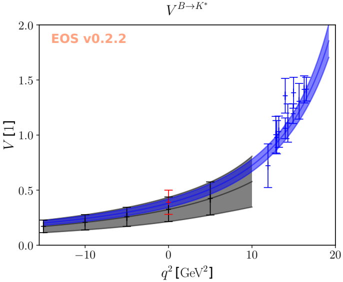
- Overal agreement about both contributions, using various tools

Hadronic uncertainties: form factors

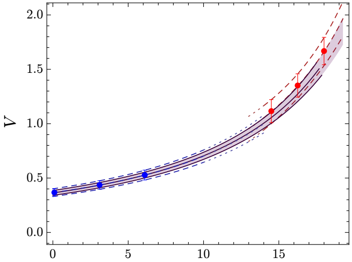
3 form factors for K, 7 form factors for K^* and ϕ

- low recoil: lattice QCD [Horgan, Liu, Meinel, Wingate; HPQCD collab]
- large recoil: Light-Cone Sum Rules (B-meson or light-meson DAs)

[Khodjamirian, Mannel, Pivovarov, Wang; Bharucha, Straub, Zwicky; Gubernari, Kokulu, van Dyk]



B-meson LCSR + lattice



Light-meson LCSR + lattice

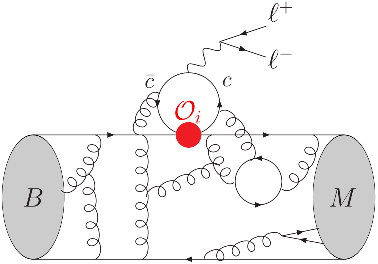
- correlations among the form factors needed
  - known from direct determination and/or combined fit to low and large recoils [PS]
  - recovered from EFT with $m_b \to \infty + O(\alpha_s) + O(1/m_b)$ [QM]

[Capdevila, SDG, Hofer, Matias; Straub, Altmannshoffer; Hurth, Mahmoudi]

- optimised observables P_i to reduce the impact of form factor uncertainties

Hadronic uncertainties: charm loops

- important for resonance regions (charmonia)
- SM effect contributing to $\mathcal{C}_{9\ell}$
- depends on q^2, lepton univ.
- quark-hadron duality approx at large q^2 (syst of few %)



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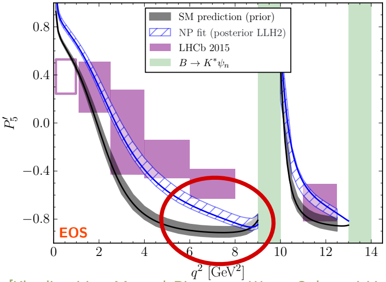


Several approaches agree at low-q^2

- LCSR estimates [Khodjamirian, Mannel, Pivovarov, Wang; Gubenari, Van Dyk]
  (see talk by Gubenari)
- order of magnitude estimate for the fits (LCSR or Λ/m_b), check with bin-by-bin fits QM: we include a nuisance parameter s_i to allow for constructive/destructive interference between charm and short-distance for each amplitude widening theo uncertainties [Crivellin, Capdevila, SDG, Hofer, Matias; Straub, Altmannshoffer; Hurth, Mahmoudi]
- fit of sum of resonances to the data [Blake, Egede, Owen, Pomery, Petridis]
- dispersive representation + J/ψ, $\psi(2S)$ data [Bobeth, Chrzaszcz, van Dyk, Virto]

Is charm-loop **overestimated** instead of **underestimated**?

Setup

- PS: Likelihood in Gaussian approximation combining experimental and theoretical uncertainties
  ***NEW*: theoretical uncertainties depend on new physics Wilson coefficients**

  Altmannshofer, PS, arXiv:2103.13370

- QM: Likelihood taking into account experimental and theoretical uncertainties and correlations in Gaussian approximation

  [Algueró, Capdevila, Crivellin, SDG, Masuan Matias, Novoa-Brunet, Virto]

Two statistical quantities of interest to asses a NP scenario/hypothesis

- p-value of a given hypothesis: χ^2_{min} considering N_{dof} (in %)
  goodness of fit: does the hypothesis give an overall good fit ?
  and if not, can we exclude it ?
- Pull_{SM} : $\chi^2(\mathcal{C}_i = 0) - \chi^2_{min}$ considering N_{dof} (in σ units)
  metrology: how well does the hypothesis solve SM deviations ?

Analysis Inputs

Experimental inputs

- LFUV: R_K, R_{K^*} and $\mathbf{Q_{4,5}} = \mathbf{P}'^{\mu}_{4,5} - \mathbf{P}'^{e}_{4,5}$ isospin average* (large- low-recoil bins)
- $B \to K^* \mu\mu$ (Br and ang obs)
- $B_s \to \phi\mu\mu$ (Br and ang obs)
- $B^+ \to K^+ \mu\mu, B^0 \to K^0 \mu\mu$ (Br and ang obs)
- $B \to X_s \mu\mu, B_s \to \mu\mu$ (Br, effective $B_s \to \mu\mu$ lifetime $\tau_{\rm eff}$)
- $B \to K^* ee$ (ang obs)
- $B \to X_s\gamma, B_s \to \phi\gamma, B \to K^*\gamma$ (Br)
- $\Lambda_b \to \Lambda\mu\mu$ (Br and ang abs)

including LHCb, ATLAS, CMS, Babar and Belle data whenever available

Total: 246 obs (Global) of which LFUV ($R_K, R_{K^*}, Q_{4,5}$) from LHCb, Belle, ATLAS, CMS

Total: 130 obs (no bins at or below 1 GeV^2 (used for $C_7^{(\prime)}$) except R_{K^*}, no [6, 8] GeV^2)

* It is important not to miss any LFUV observable (like Q_i observables) for a complete analysis.

Updates

- Update: Experimental value $R_K^{\mathrm{LHCb}} = 0.846^{+0.042+0.013}_{-0.039-0.012}$ [LHCb 2103.11769]
- Update: Exp value $BR(B_s \to \mu\mu) = (3.09^{+0.46+0.15}_{-0.43-0.11}) \times 10^{-9}$ [LHCb at LHC Seminar]
- Update: Experimental value R_K^{Belle} [Belle 1908.01848]
- New: Optimised angular distribution $B^+ \to K^{*+}\mu\mu$ [LHCb 2012.13241]
- Update: Angular analysis at low $B^0 \to K^{*0}ee$ [LHCb 2010.06011]
- New: Angular analysis $B^+ \to K^+\mu\mu$ (F_H, A_{FB}) [CMS 1806.00636]
- New: Angular analysis $B^+ \to K^{*+}\mu\mu$ (F_L, A_{FB}) [CMS 2010.13968]
- New: $BR(B^{0,+} \to K^{0,+}\mu\mu)$ partners to R_K^{Belle} [Belle 1908.01848]
- New: effective $B_s \to \mu\mu$ lifetime τ_{eff} [CMS 1910.12127, LHCb at LHC Seminar]

Theoretical inputs

QM:

- Form factors: B-meson DA LCSR + lattice + EFT for correlations
- Charm-loop corrections: Perturbative contribution + magnitude of of long-distance contrib inspired by [Khodjamirian, Mannel, Pivovarov, Wang]
- Quark-duality violation at high q^2: 10% effect at the level of the amplitude
- $Br(B_s \to \mu\mu)$ modified to include latest corrections from [Misiak ; Beneke, Bobeth, Szafron]
- $Br(B^+ \to K^{*+}\ell\ell)$ and P_i^+ include mass and lifetime differences, annihilation graphs, hard spectator interactions with $\mathcal{O}_8$ and $\mathcal{O}_{1-6}$

PS:

- Form factors: For B to light vector meson from [Bharucha, Straub, Zwicky], for $B \to K$ from [Gubernari, Kokulu, van Dyk]
- Non-factorizable effects parametrized as in [Bharucha, Straub, Zwicky], [Altmannshofer, Straub], compatible with [Khodjamirian, Mannel, Pivovarov, Wang], [Bobeth, Chrzaszcz, van Dyk, Virto]
- Additional parametric uncertainties (e.g. CKM) based on [flavio v2.2.0] with default settings

Results

1D Scenarios for $\mathcal{C}_{i\mu}$ [2021]

Updated results in: M. Algueró et al. arXiv: 2104.08921

	All				LFUV	
1D Hyp.	Best fit	1 σ	Pull_{SM}	p-value	1 σ	Pull_{SM}
$\mathcal{C}_{9\mu}^{\text{NP}}$	-1.06	$[-1.20, -0.91]$	7.0	39.5 %	$[-1.06, -0.60]$	4.0
$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{10\mu}^{\text{NP}}$	-0.44	$[-0.52, -0.37]$	6.2	22.8 %	$[-0.46, -0.29]$	4.6
$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{9'\mu}$	-1.11	$[-1.25, -0.96]$	6.5	28.0 %	$[-2.13, -0.96]$	3.0
$\mathcal{C}_{9\mu}^{\text{NP}} = -3\mathcal{C}_{9e}$	-0.89	$[-1.03, -0.75]$	6.7	32.2 %	$[-0.78, -0.44]$	4.0

- LFUV fit: R_K, R_{K^*}, $\mathbf{Q_{4,5}}$ (updated isospin average), $B_s \to \mu\mu$, $b \to s\gamma$
- All : all $b \to s\ell\ell$ and $b \to s\gamma$ observables
- Pull_{SM} in σ units increased compare to [2020], scenario $\mathcal{C}_{10\mu}^{\text{NP}}$ still marginal.
- p-value of SM hyp from 11% (2019) to 1.4% (2020) to 1.1% (2021) for the fit "All"
  12.6% (2020) to 1.4% (2021) for the fit "LFUV"
- Tension between All fit preference by $C_{9\mu}$ and LFUV-fit by $C_{9\mu} = -C_{10\mu}$.

Same hierarchy of main scenarios was found by other groups, for instance:
Hurth, Mahmoudi, Neshatpour, arXiv:2012.12207

Scenarios with a single Wilson coefficients

Wilson coefficient	$b \to s\mu\mu$ best fit	$b \to s\mu\mu$ pull	LFU, $B_s \to \mu\mu$ best fit	LFU, $B_s \to \mu\mu$ pull	all rare B decays best fit	all rare B decays pull
$C_9^{bs\mu\mu}$	$-0.87^{+0.19}_{-0.18}$	4.3σ	$-0.74^{+0.20}_{-0.21}$	4.1σ	$-0.80^{+0.14}_{-0.14}$	5.7σ
$C_{10}^{bs\mu\mu}$	$+0.49^{+0.24}_{-0.25}$	1.9σ	$+0.60^{+0.14}_{-0.14}$	4.7σ	$+0.55^{+0.12}_{-0.12}$	4.8σ
$C_9^{\prime bs\mu\mu}$	$+0.39^{+0.27}_{-0.26}$	1.5σ	$-0.32^{+0.16}_{-0.17}$	2.0σ	$-0.14^{+0.13}_{-0.13}$	1.0σ
$C_{10}^{\prime bs\mu\mu}$	$-0.10^{+0.17}_{-0.16}$	0.6σ	$+0.06^{+0.12}_{-0.12}$	0.5σ	$+0.04^{+0.10}_{-0.10}$	0.4σ
$C_9^{bs\mu\mu} = C_{10}^{bs\mu\mu}$	$-0.34^{+0.16}_{-0.16}$	2.1σ	$+0.43^{+0.18}_{-0.18}$	2.4σ	$-0.01^{+0.12}_{-0.12}$	0.1σ
$C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}$	$-0.60^{+0.13}_{-0.12}$	4.3σ	$-0.35^{+0.08}_{-0.08}$	4.6σ	$-0.41^{+0.07}_{-0.07}$	5.9σ

Only small pull for

- Coefficients with $\ell = e$ (cannot explain $b \to s\mu\mu$ anomaly and $B_s \to \mu\mu$)
- Scalar coefficients (can only reduce tension in $B_s \to \mu\mu$)

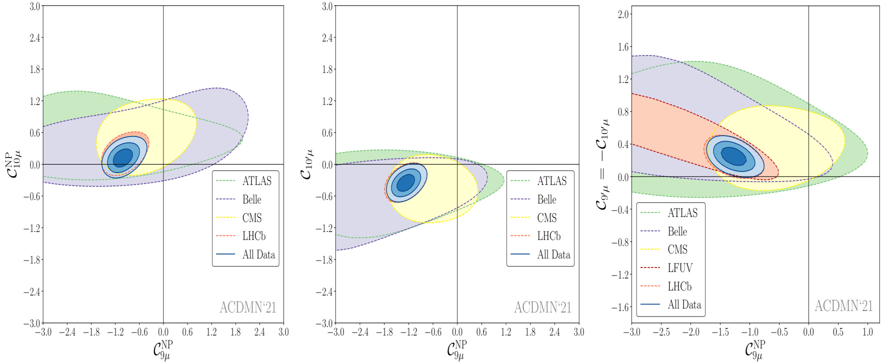
see also similar fits by other groups:
Algueró et al., arXiv:1903.09578 Ciuchini et al., arXiv:2011.01212 Datta et al., arXiv:1903.10086
Kowalska et al., arXiv:1903.10932 Arbey et al., arXiv:1904.08399 Geng et al., arXiv:2103.12738

Scenarios with a single Wilson coefficients

	Wilson coefficient	$b \to s\mu\mu$ best fit	pull	LFU, $B_s \to \mu\mu$ best fit	pull	all rare B decays best fit	pull
NP err.	$C_9^{bs\mu\mu}$	$-0.87^{+0.19}_{-0.18}$	4.3σ	$-0.74^{+0.20}_{-0.21}$	4.1σ	$-0.80^{+0.14}_{-0.14}$	5.7σ
	$C_{10}^{bs\mu\mu}$	$+0.49^{+0.24}_{-0.25}$	1.9σ	$+0.60^{+0.14}_{-0.14}$	4.7σ	$+0.55^{+0.12}_{-0.12}$	4.8σ
	$C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}$	$-0.60^{+0.13}_{-0.12}$	4.3σ	$-0.35^{+0.08}_{-0.08}$	4.6σ	$-0.41^{+0.07}_{-0.07}$	5.9σ
SM err.	$C_9^{bs\mu\mu}$	$-0.96^{+0.19}_{-0.18}$	4.6σ	$-0.74^{+0.20}_{-0.21}$	4.1σ	$-0.83^{+0.14}_{-0.14}$	5.9σ
	$C_{10}^{bs\mu\mu}$	$+0.51^{+0.22}_{-0.22}$	2.3σ	$+0.60^{+0.14}_{-0.14}$	4.7σ	$+0.56^{+0.12}_{-0.12}$	4.9σ
	$C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}$	$-0.64^{+0.16}_{-0.17}$	4.3σ	$-0.35^{+0.08}_{-0.08}$	4.6σ	$-0.41^{+0.07}_{-0.07}$	5.9σ

Visible effect of theory errors depending on new physics

2D Scenarios for $\mathcal{C}_{i\mu}$ [2021]: Hints for RHC?



- Now $\mathcal{C}_{10\mu}^{\rm NP}$ compatible with zero at 1σ in $(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10\mu}^{\rm NP})$ due to $B_s \to \mu^+\mu^-$.
- RHCs appear quite naturally: large increase in scenario $(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10'\mu})$ and Hyp. V ($[C_{9\mu}, C_{9'\mu} = -C_{10'\mu}]$) due to R_K at level of 3σ w.r.t. RHCs.

2D and 6D Scenarios for $\mathcal{C}_{i\mu}$ [2021]

	All			LFUV		
2D Hyp.	Best fit	Pull$_{\rm SM}$	p-value	Best fit	Pull$_{\rm SM}$	p-value
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{10\mu}^{\rm NP})$	(-1.00,+0.11)	6.8	39.4 %	(-0.12,+0.54)	4.3	65.6 %
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{9'\mu})$	(-1.22,+0.56)	7.2	49.8 %	(-1.80,+1.12)	4.1	53.6 %
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{10'\mu})$	(-1.26,-0.35)	7.4	55.9 %	(-1.82,-0.59)	4.7	84.1 %
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{9'\mu}=-\mathcal{C}_{10'\mu})$	(-1.26,+0.25)	7.4	55.8 %	(-2.08,+0.51)	4.7	86.0 %
$(\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{10\mu}^{\rm NP},\mathcal{C}_{9'\mu}=-\mathcal{C}_{10'\mu})$	(-0.48,+0.11)	6.0	24.0 %	(-0.46,+0.15)	4.5	74.5 %

- No change in the hierarchy of scenarios w.r.t. 2020.
- From last two rows: Vector preference in left sector ($C_{9\mu}^{\rm NP}$) (vs $C_{9\mu}^{\rm NP}=-C_{10\mu}^{\rm NP}$) and $C_{9'\mu}=-C_{10'\mu}$ preference in right sector.

	$\mathcal{C}_7^{\rm NP}$	$\mathcal{C}_{9\mu}^{\rm NP}$	$\mathcal{C}_{10\mu}^{\rm NP}$	$\mathcal{C}_{7'}$	$\mathcal{C}_{9'\mu}$	$\mathcal{C}_{10'\mu}$
Bfp	+0.01	-1.21	+0.15	+0.01	+0.37	-0.21
1 σ	$[-0.02,+0.04]$	$[-1.38,-1.01]$	$[+0.00,+0.34]$	$[-0.02,+0.03]$	$[-0.12,+0.80]$	$[-0.42,+0.02]$
2 σ	$[-0.04,+0.06]$	$[-1.52,-0.83]$	$[-0.11,+0.49]$	$[-0.03,+0.05]$	$[-0.51,+1.12]$	$[-0.60,+0.23]$

- Pull$_{\rm SM}$: 5.1σ [2019] $\to$ 5.8σ [2020] $\to$ 6.6σ [2021] (49.9%)
- 6D Fit shows coherence and stability with time.

Solution of the tension between All fit and LFUV fit: LFU New Physics

In [Algueró, Capdevila, Descotes-Genon, Masjuan, JM, PRD'19, 1809.08447] it was proposed:

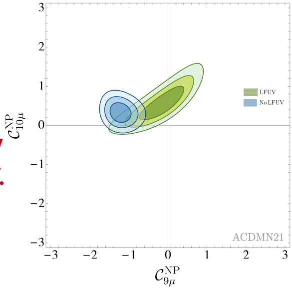
... to remove hypothesis that NP is purely LFUV

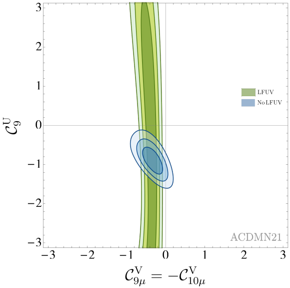
$$\begin{aligned} C_{ie}^{\mathrm{NP}} &= C_i^{\mathrm{U}} \\ C_{i\mu}^{\mathrm{NP}} &= C_{i\mu}^{\mathrm{V}} + C_i^{\mathrm{U}} \end{aligned}$$

- Common New Physics contribution C_i^{U} to charged leptons.
- Allow to accommodate that LFUV-NP prefers $SU(2)_L$ and LFU-NP is vectorial.

$[C_{9\mu}, C_{10\mu}]$

TENSION between LFUV and non-LFUV. Pull$_{SM}$ = 6.8σ.





$[C_{9\mu}^V = -C_{10\mu}^V, C_9^U]$

PERFECT agreement and higher Pull$_{SM}$ significance of 7.3σ.

(see more LFU scenarios in back-up)

Solution of the tension between All fit and LFUV fit: LFU New Physics

In [Algueró, Capdevila, Descotes-Genon, Masjuan, JM, PRD'19, 1809.08447] it was proposed:
... to remove hypothesis that NP is purely LFUV

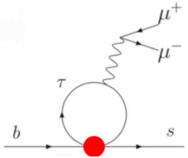
$$\begin{aligned} C_{ie}^{\mathrm{NP}} &= C_i^{\mathrm{U}} \\ C_{i\mu}^{\mathrm{NP}} &= C_{i\mu}^{\mathrm{V}} + C_i^{\mathrm{U}} \end{aligned}$$

- Common New Physics contribution C_i^{U} to charged leptons.
- LFU naturally generated by τ-loop linking it to future $b \to s\tau\tau$ and R_{D,D^*} anomalies (discussed later)

[Capdevila, Crivellin, Descotes-Genon, Hofer, Matias, PRL'18, arxiv 1712.01919]

[Crivellin, Greub, Muller, Saturnino, PRL'19, arxiv 1807.02068]

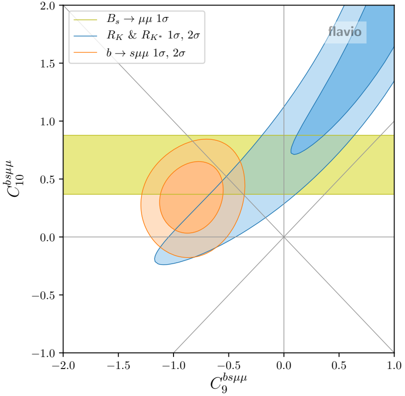
[Algueró et al. EPJC79 (2019) 8,714.]



Assuming a generic flavour structure and NP at the scale Λ:

* Notice that C_9^U should not be confused with the q^2- dependent, amplitude and process dependent charm-loop.

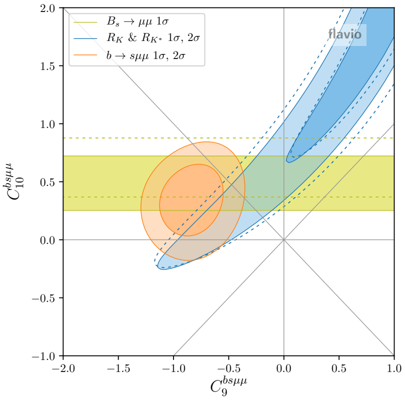
Scenarios with two Wilson coefficients



- **Before Moriond 2021**

WET at 4.8 GeV

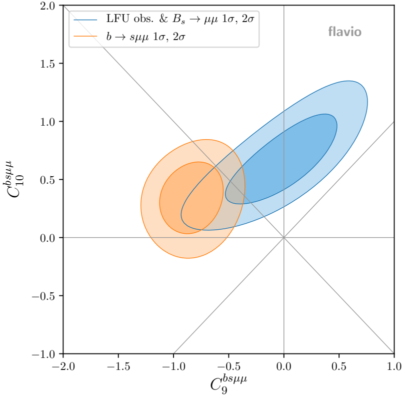
Scenarios with two Wilson coefficients



WET at 4.8 GeV

- **After Moriond 2021**:
  - $\boldsymbol{R_K}$: smaller uncertainty
  - $\boldsymbol{B_s \to \mu\mu}$: smaller uncertainty, better agreement with $b \to s\mu\mu$

Scenarios with two Wilson coefficients

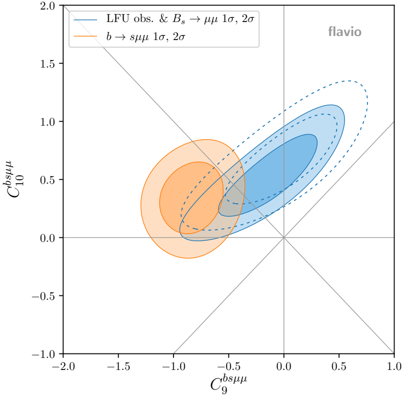


Combination of $B_s \to \mu^+\mu^-$ and NC LFU observables ($R_K, R_{K^*}, D_{P_{4',5'}}$)

- NCLFU obs. & $B_s \to \mu\mu$: very clean theory prediction, insensitive to universal $C_9^{\text{univ.}}$
- $b \to s\mu\mu$ sensitive to univ. coeff. possibly afflicted by underestimated hadr. uncert.
- **Before Moriond 2021**

WET at 4.8 GeV

Scenarios with two Wilson coefficients



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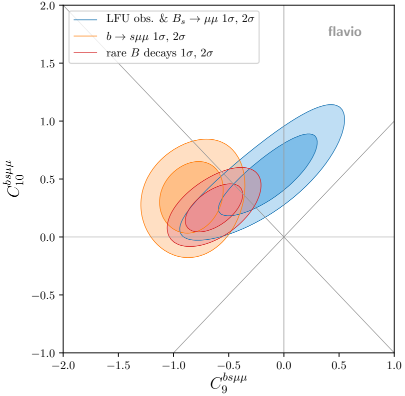
- $b \to s\mu\mu$ sensitive to univ. coeff. possibly afflicted by underestimated hadr. uncert.

- **After Moriond 2021**:
  - **LFU obs. & $B_s \to \mu\mu$**: smaller uncertainty, better agreement with $b \to s\mu\mu$

Scenarios with two Wilson coefficients

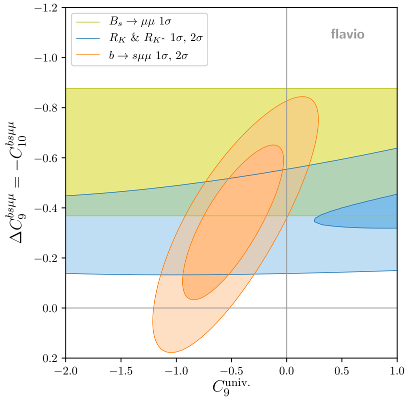


- Global fit in $C_9^{bs\mu\mu}$-$C_{10}^{bs\mu\mu}$ plane prefers negative $C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}$
- Tension between fits to $b \to s\mu\mu$ observables and R_K & R_{K^*} could be reduced by **LFU** contribution to $\boldsymbol{C_9}$

WET at 4.8 GeV

Scenarios with two Wilson coefficients

- **Before Moriond 2021**



WET at 4.8 GeV

- Perform two-parameter fit in space of $C_9^{\text{univ.}}$ and $\Delta C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}$:

$$C_9^{bsee} = C_9^{bs\tau\tau} = C_9^{\text{univ.}}$$
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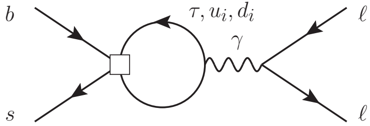
scenario first considered in
Algueró et al., arXiv:1809.08447

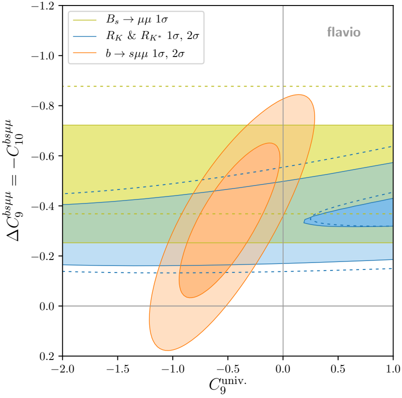
- Preference for **non-zero $C_9^{\text{univ.}}$**
  - could be mimicked by hadronic effects
  - can arise from RG effects:



Bobeth, Haisch, arXiv:1109.1826
Crivellin, Greub, Müller, Saturnino, arXiv:1807.02068

Scenarios with two Wilson coefficients

- **After Moriond 2021**: smaller uncertainty, better agreement between R_K & R_{K^*} and $B_s \to \mu\mu$



WET at 4.8 GeV

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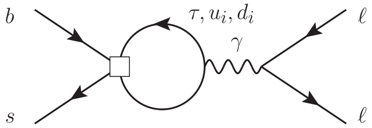

Bobeth, Haisch, arXiv:1109.1826
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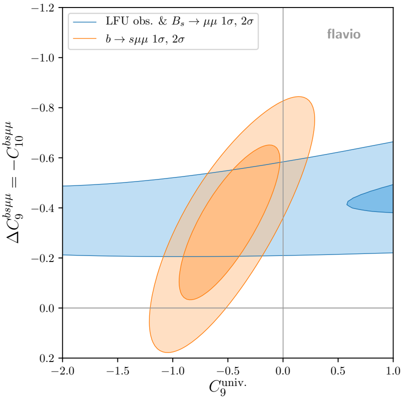
Scenarios with two Wilson coefficients

- **Before Moriond 2021**



WET at 4.8 GeV

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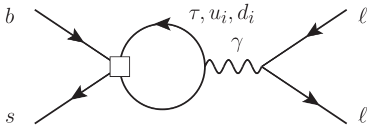

Bobeth, Haisch, arXiv:1109.1826
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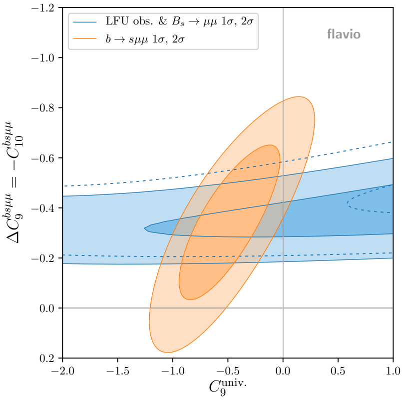
Scenarios with two Wilson coefficients

- **After Moriond 2021**:
  smaller uncertainty, better agreement



WET at 4.8 GeV

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\end{aligned}
$$

scenario first considered in
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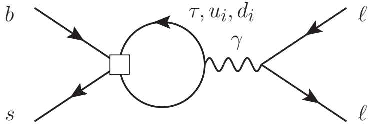

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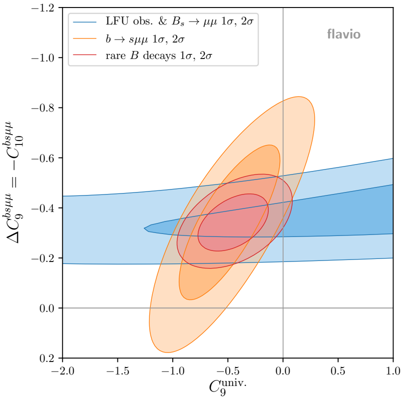

WET at 4.8 GeV

- Perform two-parameter fit in space of $\boldsymbol{C_9^{\text{univ.}}}$ and $\boldsymbol{\Delta C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}}$:

$$C_9^{bsee} = C_9^{bs\tau\tau} = C_9^{\text{univ.}}$$
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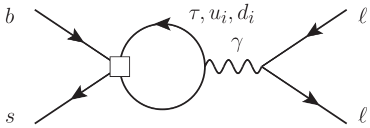

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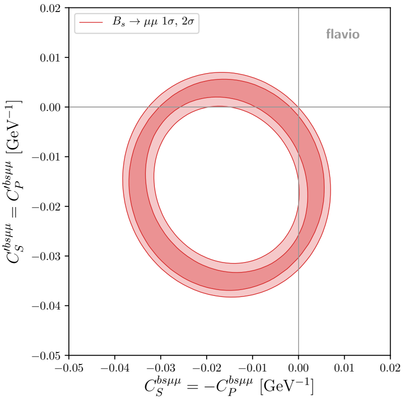
Scenarios with two Wilson coefficients

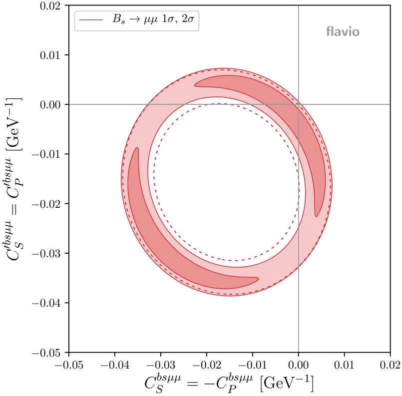


WET at 4.8 GeV

Constraint on scalar coefficients

- **Before Moriond 2021**

Scenarios with two Wilson coefficients

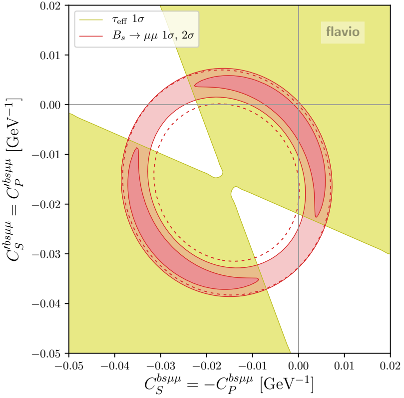


WET at 4.8 GeV

Constraint on scalar coefficients

- **After Moriond 2021**:
  - Region corresponding to mass eigenstate rate asymmetry $A_{\Delta\Gamma} = -1$ excluded at 1σ

Scenarios with two Wilson coefficients

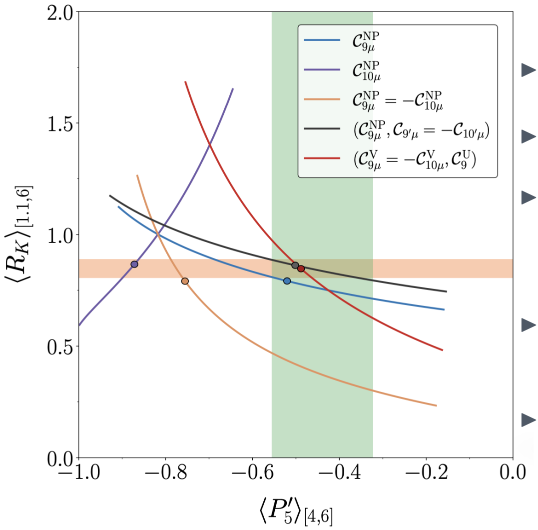


WET at 4.8 GeV

Constraint on scalar coefficients

- **After Moriond 2021**:
  - Region corresponding to mass eigenstate rate asymmetry $A_{\Delta\Gamma} = -1$ excluded at 1σ
  - Clear effect of new, more precise measurement of effective $B_s \to \mu\mu$ lifetime τ_{eff}

Consistency of scenarios with $B \to K^* \mu\mu$: $\langle P_5' \rangle_{[4,6]}$ vs $\langle R_K \rangle_{[1.1,6]}$



- Bfps not significantly changed in 2021.
- Increase of significance for some scenarios, but same hierarchies
- Better internal coherences of the fit
  - for P_5'
  - between P_5' and R_K

  for some of the scenarios
- $C_{9\mu}$ on the edge with R_K. $C_{9\mu} = -C_{10\mu}$ and $C_{10\mu}$ completely fail to explain P_5'.
- **RHCs counterbalance a very large and negative $C_{9\mu}$ in R_K**

An EFT interpretation: SMEFT

Connect $b \to s\ell\ell$ and $b \to c\ell\nu$ anomalies within SMEFT ($\Lambda_{NP} \gg m_{t,W,Z}$)

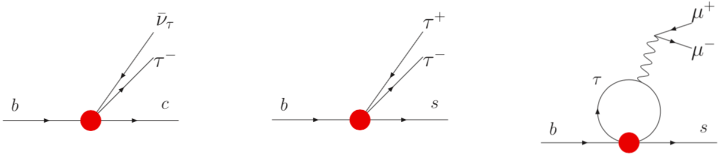
$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM} + \mathcal{L}_{d>4}$ with higher-dim ops involving only SM fields

[Grzadkowski, Iskrzynski, Misiak, Rosiek ; Alonso, Grinstein, Camalich]

- Two ops. with left-handed doublets

$$\mathcal{O}^{(1)}_{ijkl} = [\bar{Q}_i \gamma_\mu Q_j][\bar{L}_k \gamma^\mu L_l] \qquad \mathcal{O}^{(3)}_{ijkl} = [\bar{Q}_i \gamma_\mu \vec{\sigma} Q_j][\bar{L}_k \gamma^\mu \vec{\sigma} L_l]$$

- FCCC part of $\mathcal{O}^{(3)}_{2333}$ can describe $R_{D^{(*)}}$ (rescaling of G_F for $b \to c\tau\nu$)
- FCNC part of $\mathcal{O}^{(1,3)}_{2333}$ with $C^{(1)}_{2333} = C^{(3)}_{2333}$ [Capdevila, Crivellin, SDG, Hofer, Matias]
  - Large NP contribution $b \to s\tau\tau$ through $\mathcal{C}^{\rm V}_{9\tau} = -\mathcal{C}^{\rm V}_{10\tau}$
  - Avoids bounds from $B \to K^{(*)}\nu\nu$, Z decays, direct production in $\tau\tau$
  - Through radiative effects, (small) NP contribution to $\mathcal{C}^{\rm U}_9$

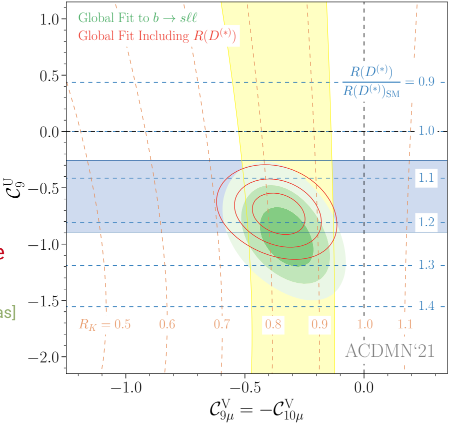


An EFT interpretation: *B* anomalies in Scenario 8

- $\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}$ from small $\mathcal{O}_{2322}$ [$b \to s\mu\mu$]
- $\mathcal{C}_{9}^{\rm U}$ from radiative corr from large $\mathcal{O}_{2333}$ [$b \to c\tau\nu$ and $b \to s\mu\mu$]
- Agreement with (R_D, R_{D^*}) for $\Lambda = 1 - 10$ TeV
- Scenario 8 has $\mathrm{Pull}_{\rm SM}$ of 8.1 σ once R_{D^*} included. Global fit $b \to s\ell\ell$ would prefer slightly higher tension in $R_{D^{(*)}}$ or large Λ scale
- Huge enhancement of $b \to s\tau\tau$ modes $O(10^{-4})$ [Capdevila, Crivellin, SDG, Hofer, Matias]

$$\mathrm{Br}\left(B_s \to \tau^+\tau^-\right)_{\rm LHCb} \leq 6.8 \times 10^{-3}\,,$$

$$\mathrm{Br}\left(B \to K\tau^+\tau^-\right)_{\rm Babar} \leq 2.25 \times 10^{-3}$$



$\Lambda = 2$ TeV

Scenario 8 LFU fits & $R(D^{(*)})/R(D^{(*)})_{\rm SM}$

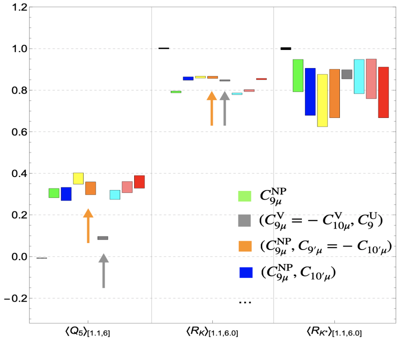
Scenario	Best fit	1σ	$\mathrm{Pull}_{\rm SM}$ (σ)	p-value (%)
$(\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}, \mathcal{C}_9^{\rm U})$	(-0.36, -0.74)	([-0.43, -0.28], [-0.86, -0.61])	8.1	51.4

Summary and Outlook

Summary of dominant scenarios and future outlook

Hypotheses	Param.	$P_5'^{[4,6]}$	R_K	$Q_5^{[1,6]}$	$\mathrm{Pull}_{\mathrm{SM}}$
$\mathcal{C}_{9\mu}^{\mathrm{NP}}$	1	✓	✓	$+0.29$	7.0
$[\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}, \mathcal{C}_9^{\mathrm{U}}]^*$	2	✓	✓	$+0.09$	7.3
$[\mathcal{C}_{9\mu}^{\mathrm{NP}}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu}]$	2	✓	✓	$+0.31$	7.4

With only 1 or 2 parameters one gets excellent fit to data. Scenario (*) moreover link with $b \to c\tau\nu$ anomaly and naturally generates LFU in C_9+imply large $b \to s\tau\tau$.



Can we disentangle the two most interesting ones?:

1) $[\mathcal{C}_{9\mu}^{\mathrm{NP}}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu}] \Rightarrow \mathrm{Pull}_{\mathrm{SM}} = 7.4\sigma$

2) $[\mathcal{C}_{9\mu}^{V} = -\mathcal{C}_{10\mu}^{V}, \mathcal{C}_9^{U}] \Rightarrow \mathrm{Pull}_{\mathrm{SM}} = 7.3\sigma$

- R_K and R_{K^*} **cannot**.
- Q_5 **can**. It is a discriminator that can tell us if NP prefers a $SU(2)_L$ structure $C_{9\mu}$=-$C_{10\mu}$ or a vector one $C_{9\mu}$.

Outlook: a) large $b \to s\tau\tau$ would point in favour of LFU (C_9^{U}). b) large and $Q_5 > 0$ would point in favour of large $C_{9\mu}^{\mathrm{NP}} < 0$ + possible RHCs.

Backup slides

Other possible LFU scenarios

Other possible LFU scenarios

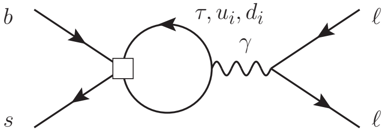
Scenario		Best-fit point	1 σ	2 σ	$\mathrm{Pull}_{\mathrm{SM}}$	p-value
Scenario 5	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-0.67	$[-1.12, -0.24]$	$[-1.58, +0.18]$	6.6	38.6 %
	$\mathcal{C}_{10\mu}^{\mathrm{V}}$	$+0.42$	$[+0.01, +0.77]$	$[-0.54, +1.08]$		
	$\mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}$	-0.31	$[-0.68, +0.17]$	$[-0.97, +0.65]$		
Scenario 6	$\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}$	-0.52	$[-0.60, -0.44]$	$[-0.68, -0.36]$	6.8	40.1 %
	$\mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}$	-0.41	$[-0.54, -0.28]$	$[-0.66, -0.15]$		
Scenario 7	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-0.76	$[-1.00, -0.52]$	$[-1.25, -0.30]$	6.9	41.7 %
	$\mathcal{C}_{9}^{\mathrm{U}}$	-0.39	$[-0.68, -0.09]$	$[-0.94, +0.19]$		
Scenario 8	$\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}$	-0.30	$[-0.39, -0.21]$	$[-0.47, -0.13]$	7.3	53.8 %
	$\mathcal{C}_{9}^{\mathrm{U}}$	-0.92	$[-1.10, -0.72]$	$[-1.27, -0.51]$		
Scenario 9	$\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}$	-0.51	$[-0.64, -0.39]$	$[-0.77, -0.28]$	6.0	24.2 %
	$\mathcal{C}_{10}^{\mathrm{U}}$	-0.27	$[-0.49, -0.05]$	$[-0.69, +0.16]$		
Scenario 10	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-1.02	$[-1.18, -0.85]$	$[-1.32, -0.68]$	6.9	42.8 %
	$\mathcal{C}_{10}^{\mathrm{U}}$	$+0.27$	$[+0.11, +0.44]$	$[-0.04, +0.60]$		
Scenario 11	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-1.12	$[-1.28, -0.95]$	$[-1.43, -0.78]$	7.1	48.4 %
	$\mathcal{C}_{10'}^{\mathrm{U}}$	-0.31	$[-0.46, -0.15]$	$[-0.60, -0.01]$		
Scenario 12	$\mathcal{C}_{9'\mu}^{\mathrm{V}}$	-0.22	$[-0.37, -0.06]$	$[-0.51, +0.09]$	2.7	2.3 %
	$\mathcal{C}_{10}^{\mathrm{U}}$	$+0.46$	$[+0.29, +0.64]$	$[+0.13, +0.82]$		
Scenario 13	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-1.22	$[-1.37, -1.05]$	$[-1.50, -0.87]$	7.0	52.6 %
	$\mathcal{C}_{9'\mu}^{\mathrm{V}}$	$+0.59$	$[+0.31, +0.84]$	$[+0.03, +1.04]$		
	$\mathcal{C}_{10}^{\mathrm{U}}$	$+0.27$	$[+0.07, +0.48]$	$[-0.13, +0.69]$		
	$\mathcal{C}_{10'}^{\mathrm{U}}$	-0.04	$[-0.23, +0.16]$	$[-0.43, +0.37]$		

Several of these scenarios either have been related or motivated specific models:

$\Rightarrow$ Scn. **8** can be realized in any model with large $b \to s\tau^+\tau^-$ couplings like the LQ singlet-triplet model [1912.04224] or vector LQ or two scalar LQs like [1703.09226].
$\Rightarrow$ Scn. **9** can be motivated by 2HDMS and **10 to 13** by Z' models with vector-like quarks.

RG effect in SMEFT

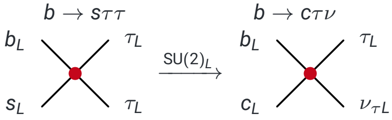
RG effect in SMEFT



RG effects require scale separation

- Consider **SMEFT**

Possible operators:

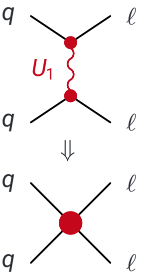


- $[O_{lq}^{(3)}]_{3323} = (\bar{l}_3 \gamma_\mu \tau^a l_3)(\bar{q}_2 \gamma^\mu \tau^a q_3)$:
  Might also **explain $R_{D^{(*)}}$ anomalies!**
- $[O_{lq}^{(1)}]_{3323} = (\bar{l}_3 \gamma_\mu l_3)(\bar{q}_2 \gamma^\mu q_3)$:
  Strong constraints from $B \to K\nu\nu$ require $[C_{lq}^{(1)}]_{3323} \approx [C_{lq}^{(3)}]_{3323}$

Buras et al., arXiv:1409.4557

- **U_1 vector leptoquark** $(\mathbf{3}, \mathbf{1})_{2/3}$ couples LH fermions

$$\mathcal{L}_{U_1} \supset g_{lq}^{ji} \left(\bar{q}^i \gamma^\mu l^j \right) U_\mu + \text{h.c.}$$



- Generates **semi-leptonic operators at tree-level**

$$[C_{lq}^{(1)}]_{ijkl} = [C_{lq}^{(3)}]_{ijkl} = -\frac{g_{lq}^{jk}\, g_{lq}^{il*}}{2M_U^2}$$

Correlation effects in the global likelihood

Slightly different results by different groups

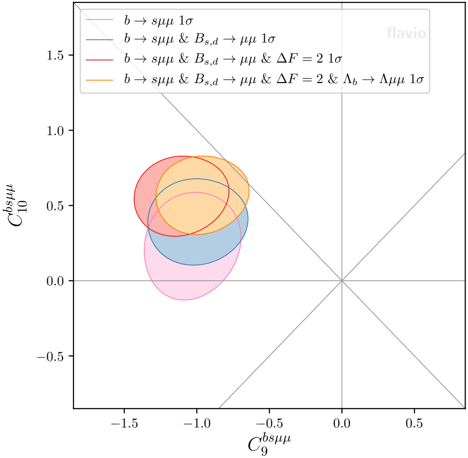
Descotes-Genon, PS, Talk at Beyond the Flavour Anomalies
https://conference.ippp.dur.ac.uk/event/876/

	All			LFUV		
1D Hyp.	$1\,\sigma$	Pull_{SM}	p-value	$1\,\sigma$	Pull_{SM}	p-value
$\mathcal{C}_{9\mu}^{\rm NP}$	$[-1.19, -0.88]$	6.3	37.5 %	$[-1.25, -0.61]$	3.3	60.7 %
$\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}$	$[-0.59, -0.41]$	5.8	25.3 %	$[-0.50, -0.28]$	3.7	75.3 %
$\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}$	$[-1.17, -0.87]$	6.2	34.0 %	$[-2.15, -1.05]$	3.1	53.1 %

Coefficient	type	best fit	1σ	$\text{pull}_{\text{1D}} = \sqrt{\Delta\chi^2}$
$\boldsymbol{C_9^{bs\mu\mu}}$	$\boldsymbol{L \otimes V}$	-0.93	$[-1.07, -0.79]$	$\boldsymbol{6.2\sigma}$
$C_9^{\prime bs\mu\mu}$	$R \otimes V$	$+0.14$	$[-0.02, +0.31]$	0.9σ
$\boldsymbol{C_{10}^{bs\mu\mu}}$	$\boldsymbol{L \otimes A}$	$+0.71$	$[+0.58, +0.84]$	$\boldsymbol{5.7\sigma}$
$C_{10}^{\prime bs\mu\mu}$	$R \otimes A$	-0.20	$[-0.29, -0.08]$	1.7σ
$C_9^{bs\mu\mu} = C_{10}^{bs\mu\mu}$	$L \otimes R$	$+0.15$	$[+0.02, +0.29]$	1.2σ
$\boldsymbol{C_9^{bs\mu\mu} = -C_{10}^{bs\mu\mu}}$	$\boldsymbol{L \otimes L}$	-0.53	$[-0.61, -0.46]$	$\boldsymbol{6.9\sigma}$

C_9 vs. $C_9 = -C_{10}$ with global likelihood

Likelihood contours for different sets of observables taken into account



- **Most groups** doing fits of $b \to s\ell\ell$ observables **do not include $\Delta F = 2$** obs.: They do not depend on $b \to s\ell\ell$ Wilson coefficients
- In **global likelihood**, **$\Delta F = 2$** obs. naturally **included** (global!)
- Choice whether to include them or not: **clear difference** in $C_{10}^{bs\mu\mu}$ direction (red contour vs. blue contour)
- This explained the differences between the different groups!

Why does the inclusion of $\Delta F = 2$ observables
has such an impact on the fit in the $C_{10}^{bs\mu\mu}$ direction if
$\Delta F = 2$ observables do not depend on $C_{10}^{bs\mu\mu}$?

Why does the inclusion of $\Delta F = 2$ observables has such an impact on the fit in the $C_{10}^{bs\mu\mu}$ direction if **$\Delta F = 2$ observables do not depend on $C_{10}^{bs\mu\mu}$**?

Theory correlations...

Correlations in a toy example

- Correlations for observables O_1, O_2 (uncertainties $\sigma_{1,2}$, correlation coeff. ρ):

$$-2\ln\mathcal{L}(O_1,O_2)=\frac{1}{1-\rho^2}\left(\frac{D_1^2}{\sigma_1^2}+\frac{D_2^2}{\sigma_2^2}-2\rho\frac{D_1\,D_2}{\sigma_1\,\sigma_2}\right),\qquad D_{1,2}=(O_{1,2}-\hat{O}_{1,2})$$

- If $D_1(C_{10})$ depends on C_{10} and D_2 is constant in C_{10}, then $\Delta\ln\mathcal{L}$ between $C_{10}=0$ and $C_{10}=\tilde{C}_{10}$ yields

$$\Delta\ln\mathcal{L}\propto\frac{D_1^2(0)-D_1^2(\tilde{C}_{10})}{\sigma_1^2}-2\,\rho\,D_2\frac{D_1(0)-D_1(\tilde{C}_{10})}{\sigma_1\,\sigma_2}$$

- First term is present whether we include O_2 or not (up to $\frac{1}{1-\rho^2}$ prefactor)
- **Second term makes a difference**
  - if $\rho\neq 0$, i.e. $\boldsymbol{O_1}$ **and** $\boldsymbol{O_2}$ **are correlated**
  - if $D_2\neq 0$, i.e. experimental estimate $\boldsymbol{\hat{O}_2}$ **shows deviation from SM prediction** O_2

Correlations in the global likelihood

The same is true for $\Delta F = 2$ observables, in particular ϵ_K:

- theory predictions of ϵ_K and $BR(B_s \to \mu\mu)$ are correlated, $BR(B_s \to \mu\mu)$ depends on C_{10}
- experimental estimate of ϵ_K shows deviation from SM prediction

Should we include $\boldsymbol{\Delta F = 2}$ observables in $b \to s\ell\ell$ fit or not?

Two different assumptions:

- **Including them** and only varying C_{10} means we assume all other Wilson Coefficients $C_i = 0$, i.e. we fix the SM point in these directions
- **Excluding them** is (nearly) equivalent to setting certain $C_i \neq 0$ such that theory prediction and experimental estimate of $\Delta F = 2$ observables agree

Bayesian approach: marginalise over "nuisance coefficients" C_i

- **Including them** and only varying C_{10} corresponds to prior on C_i strongly peaked around SM value $C_i = 0$
- **Excluding them** is equivalent to flat prior that allows the posterior for C_i to be peaked around $C_i \neq 0$

What can we learn from this?

- There are different assumptions we can make by including or excluding certain observables
- It is not obvious if there is a “correct” one, but we should be aware of the differences
- The $\Delta\chi^2$ values between best-fit point and SM point can be different and one has to think about what “SM point” actually means if one does not fix $C_i = 0$