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A path to break degeneracies among New Physics patterns in $b \to s\ell\ell$

Joaquim Matias Universitat Autònoma de Barcelona

Universitat Autònoma de Barcelona

ICREA
The need to know

Motivation and goals

My starting point:

The results on global fits to 254 observables presented in Bernat's talk

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Problem to face in this talk:

Only by adding more and more statistics blindly in some observables of the global analyses it will be very difficult to disentangle **the scenario realized in Nature among the preferred ones.**

Our goal:

To identify the **key observables** that can help to truly change the present paradigm guiding global fits and breaking degeneracies.

... and learn also about hadronic physics (if not marginal).

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

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

$$\mathcal{H}_{\text{eff, NP}}^{bs\ell\ell} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i \mathcal{C}_i \mathcal{O}_i + \text{h.c.}$$

We also include a small λ_u contribution.

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

$$O_7^{bs} = \frac{e}{16\pi^2} m_b (\bar{s}\sigma_{\mu\nu} P_R b) F^{\mu\nu} , \qquad O_7^{\prime bs} = \frac{e}{16\pi^2} m_b (\bar{s}\sigma_{\mu\nu} P_L b) F^{\mu\nu} ,$$

$$O_9^{bs\ell\ell} = \frac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \ell) , \qquad O_9^{\prime bs\ell\ell} = \frac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_R b)(\bar{\ell}\gamma^\mu \ell) ,$$

$$O_{10}^{bs\ell\ell} = \frac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \gamma_5 \ell) , \qquad O_{10}^{\prime bs\ell\ell} = \frac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_R b)(\bar{\ell}\gamma^\mu \gamma_5 \ell) ,$$

$O_{7,7'}$ (even if constrained by radiative decays important to let them float)

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For a long time there was a discussion among two scenarios:

a. $\mathcal{C}_{9\mu}$ large (abs.val.) and negative that can explain P_5' and all the anomalies ($\mathcal{B}_{B_s\to\mu^+\mu^-}$ requires a scalar contribution).**Caveat**: difficult for model-building.
b. $\mathcal{C}_{9\mu}=-\mathcal{C}_{10\mu}$ small that can explain some anomalies but **totally fails** with P_5' ($\mathcal{B}_{B_s\to\mu^+\mu^-}$ is explained with $\mathcal{C}_{10\mu}$). Model-building welcome.

.... now this discussion is superseded (we will see why)

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Two main conclusions:

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- The preferred scenarios in terms of $\mathrm{Pull}_{\mathrm{SM}}$:
  - All contain the coefficient of the semileptonic operator $O_9^{bs\ell\ell}$
  - They remain packed within a narrow range

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1D hypothesis:

For the complete fit, the $\mathrm{Pull}_{\mathrm{SM}}$:

- $\mathcal{C}_{9\mu}^{\mathrm{NP}}$ has been 4.5 [2016], 5.8 [2018], 5.6 [2019], 6.3 [2020], 7.0 [2021].
- $\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}$: 4.2 [2016], 5.3 [2018], 5.2 [2019], 5.8 [2020], 6.5 [2021].

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Or for the 6D fits:

	$\mathcal{C}_7^{\rm NP}$	$\mathcal{C}_{9\mu}^{\rm NP}$	$\mathcal{C}_{10\mu}^{\rm NP}$	$\mathcal{C}_{7'}$	$\mathcal{C}_{9'\mu}$	$\mathcal{C}_{10'\mu}$
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	$[-0.04, +0.06]$	$[-1.52, -0.83]$	$[-0.11, +0.49]$	$[-0.03, +0.05]$	$[-0.51, +1.12]$	$[-0.60, +0.23]$

- $\text{Pull}_{\rm SM}$: 5.1σ [2019] $\to$ 5.8σ [2020] $\to$ 6.6σ [2021] (49.9%)

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- $\mathrm{Pull}_{\mathrm{SM}}$: 5.1$\sigma$ [2019] $\rightarrow$ 5.8σ [2020] $\rightarrow$ 6.6σ [2021] (49.9%)

Some of the most relevant 2D hypotheses:

Hyp V*: ($\mathcal{C}_{9\mu} = -1.15, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu} = +0.17$) are **5.9** [2019], **6.6** [2020], **7.1** [2021]

Scn 8: ($\mathcal{C}_{9\mu}^{V} = -\mathcal{C}_{10\mu}^{V} = -0.34, \mathcal{C}_9^{U} = -0.82$) are **5.7** [2019], **6.5** [2020], **7.2** [2021]

Notice that RHCs are only $\mathcal{O}(15\%)$ w.r.t. the dominant $\mathcal{C}_{9\mu}$

This brings three main intertwined questions:

$\mathcal{Q}1$. What is **the reason** of this degeneracy?

$\mathcal{Q}2$. Can we **break** this degeneracy?

$\mathcal{Q}3$. Is the degeneracy **linked** to the NP structure of $\mathcal{C}_{9\mu}$?

$\mathcal{Q}1$: Reason of the degeneracy

The LFUV central observables:

...R_K and R_{K^*} (to a lesser extent) have the structure in the bin [1.1,6] GeV^2

$$\begin{aligned} R_K \;=\; & [1 - \mathbf{0.26}(\mathcal{C}_{10\mu} + \mathcal{C}_{10'\mu}) + \mathbf{0.23}(\mathcal{C}_{9\mu} + \mathcal{C}_{9'\mu}) + S^K_\mu]/ \\ & [1 - \mathbf{0.26}(\mathcal{C}_{10e} + \mathcal{C}_{10'e}) + \mathbf{0.23}(\mathcal{C}_{9e} + \mathcal{C}_{9'e}) + S^K_e]\,, \end{aligned}$$

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To find an observable with a different structure is required....

$\mathcal{Q}3$: The structure of $\mathcal{C}_{9\mu}$

Let's focus on the different contributions of the semileptonic coefficient $\mathcal{C}_{9\mu}$

$$\mathcal{C}_{9\mu}^{\rm eff} \to \mathcal{C}_{9\mu}^{\rm eff} = \mathcal{C}_{9\mu\,\rm pert}^{\rm SM} + \mathcal{C}_{9\mu}^{\rm NP} + \mathcal{C}_{9\mu\,j}^{c\bar{c}\,B\to K^*}$$

- $\mathcal{C}_{9\mu\,\rm pert}^{\rm SM}$ stands for the perturbative SM contribution
- $\mathcal{C}_{9\mu}^{c\bar{c}\,B\to K^*}$ helicity & q^2-dependent, contains long-distance charm and inside $\mathcal{C}_{9\mu}^{\rm eff}$ (one soft-gluon exchange)

  where **in our conservative parametrization**:

$$\mathcal{C}_{9\,j}^{c\bar{c}\,B\to K^*} = s_j \mathcal{C}_{9\,j\,\rm KMPW}^{c\bar{c}\,B\to K^*}$$ with s_i nuisance parameters from -1 to 1

Other estimates of long-distance charm would require a separated analysis.

$\mathcal{Q}2$ and $\mathcal{Q}3$: The structure of $\mathcal{C}_{9\mu}$

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

... to remove hypothesis that NP is purely LFUV

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

- Common contribution C_i^{U} to all charged leptons.

  In particular ($i = 9$):

  - $\mathcal{C}_{9\mu}^{\mathrm{NP}}$ is then splited in two pieces: $\mathcal{C}_{9\mu}^{\mathrm{NP\,V}}$ and $\mathcal{C}_{9\mu}^{\mathrm{U}}$

Can we disentangle/measure in an efficient way these two different pieces?

$\mathcal{C}_{9\mu}^{V}$ Lepton Flavour Universal Violating piece

$\mathcal{Q}2$ and $\mathcal{Q}3$: $\mathcal{C}_{9_\mu}^V$

Solution: We need an LFUV $\mathcal{C}_{9_\mu}^V$-dominated observable.

This is Q_5: $\to$ excellent disentangling properties like R_K (contrary to R_{K^*})

$$\begin{aligned} Q_5 &= Q_5^{\rm SM} - \mathbf{0.25}\mathcal{C}_{9_\mu}^V + \mathbf{0.20}\mathcal{C}_{10'_\mu}^V - 0.02\mathcal{C}_{10_\mu}^V \\ &\quad -0.04\mathcal{C}_{9'_\mu}^V + 0.03\mathcal{C}_{9_\mu}^{V\,2} - 0.03\mathcal{C}_{9_\mu}^V\mathcal{C}_{9'_\mu}^V + R_\mathcal{C} \end{aligned}$$

- $\mathcal{C}_{i\mu}^V = \mathcal{C}_{i\mu} - \mathcal{C}_{ie}$, $R_\mathcal{C}$ is marginal, redefine $\tilde{\mathcal{C}}_{9_\mu}^V = \mathcal{C}_{9_\mu}^V - 0.8\mathcal{C}_{10'_\mu}^V$ (absorb RHC).

where $\tilde{\mathcal{C}}_{9_\mu}^{\rm V}$ is obtained using

$$Q_5 \simeq Q_5^{\rm SM} - 0.25\tilde{\mathcal{C}}_{9_\mu}^{\rm V} \quad \text{and} \quad Q_5^{\rm SM} = -0.0074 \pm 0.0007$$

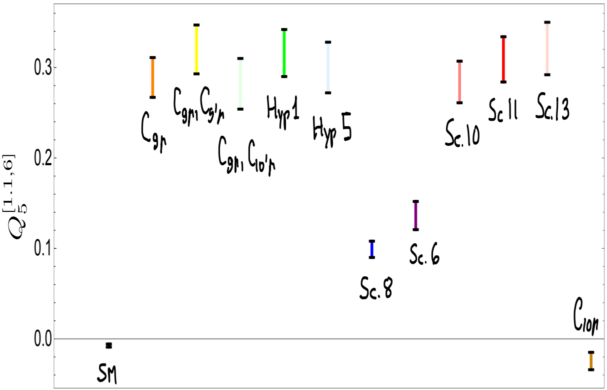
But in global fits strong correlation of sign of $\mathcal{C}_{10'} \sim -0.2$ and $\mathcal{C}_{9_\mu} \sim -1$

Lower bound on the absolute value of $|\mathcal{C}_{9_\mu}^V|$

$$|\mathcal{C}_{9_\mu}^{\rm NP\,V}| \simeq |\tilde{\mathcal{C}}_{9_\mu}^{\rm V} + 0.8\mathcal{C}_{10'_\mu}^{\rm V}| \geq |\tilde{\mathcal{C}}_{9_\mu}^{\rm V}|$$

Q_5 classifies scenarios in two groups:

- Q_5 large $\rightarrow$ all scenarios with large $\mathcal{C}_{9\mu}^{V}$ (negligible $\mathcal{C}_9^U$)
- Q_5 small $\rightarrow$ scenarios with small $\mathcal{C}_{9\mu}^{V}$ and large $\mathcal{C}_9^U$.



- $\mathcal{C}_{9\mu} = -1.01$
- $\mathcal{C}_{9\mu} = -1.12$, $\mathcal{C}_{9'\mu} = +0.36$
- $\mathcal{C}_{9\mu} = -1.15$, $\mathcal{C}_{10'\mu} = -0.26$
- Hyp 1: $\mathcal{C}_{9\mu} = -\mathcal{C}_{9'\mu} = -1.01$
  $\mathcal{C}_{10\mu} = \mathcal{C}_{10'\mu} = +0.31$
- Hyp 5: $\mathcal{C}_{9\mu} = -1.15$
  $\mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu} = +0.17$
- Scn 10: $\mathcal{C}_{9\mu}^{V} = -0.98$, $\mathcal{C}_{10}^{U} = +0.27$
- Scn 11: $\mathcal{C}_{9\mu}^{V} = -1.06$, $\mathcal{C}_{10'}^{U} = -0.23$
- Scn 13: $\mathcal{C}_{9\mu}^{V} = -1.11$, $\mathcal{C}_{9'}^{V} = +0.37$
  $\mathcal{C}_{10}^{U} = +0.28$, $\mathcal{C}_{10'}^{U} = +0.03$
- **Scn 8:** $\mathcal{C}_{9\mu}^{V} = -\mathcal{C}_{10\mu}^{V} = -0.34$
  $\mathcal{C}_9^U = -0.82$
- **Scn 6:** $\mathcal{C}_{9\mu}^{V} = -\mathcal{C}_{10\mu}^{V} = -0.52$
  $\mathcal{C}_9^U = \mathcal{C}_{10}^U = -0.38$

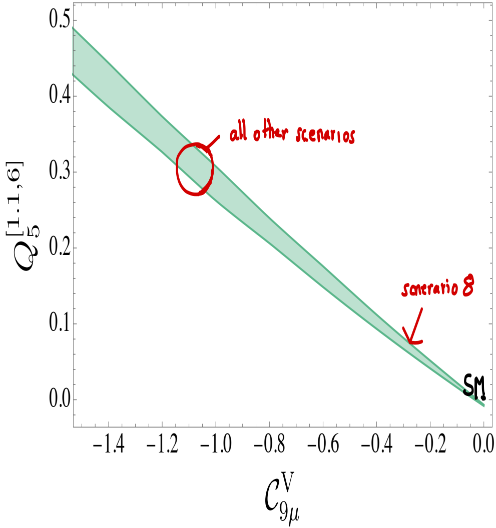
$$Q_5^{[1,6]} = 0.656 \pm 0.485 \pm 0.103 \text{ (Belle PRL 2017)}$$

All top scenarios $\mathcal{C}_{9\mu}^{V} \sim -1$

Most preferred scenarios predicts R_K far away from one.

One of the most interesting scenarios (8) predicts Q_5 quite close to 0 $\Rightarrow P_5'^{\mu} \sim P_5'^{e} \neq \mathrm{SM}.$

$R_K \sim 0.8$ and $Q_5 \sim 0.1$ with tiny experimental uncertainties would be great news!!!



$\mathcal{C}_{9\mu}^{V}$ is an undoubtedly signal of New Physics

$\mathcal{C}_9^U$ Lepton Flavour Universal piece

$\mathcal{Q}3$: Measuring the whole $\mathcal{C}_{9\mu} = \mathcal{C}_{9\mu}^{V} + \mathcal{C}_9^{U}$ to get $\mathcal{C}_9^{U}$

The observable that best measures

the whole NP piece of the semileptonic coefficient $\mathcal{C}_{9\mu}$ is $P'_{5\mu}$

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\begin{aligned}
P'^{[1.1,6]}_{5\mu} \quad = \quad & P'^{\rm SM}_{5\mu} - \mathbf{0.25}\,\mathcal{C}_{9\mu} + \mathbf{0.20}\,\mathcal{C}_{10'\mu} - 0.02\,\mathcal{C}_{10\mu} \\
& -0.04\,\mathcal{C}_{9'\mu} + 0.03\,\mathcal{C}_{9\mu}^2 - 0.03\,\mathcal{C}_{9\mu}\mathcal{C}_{9'\mu}
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Approximating $P_5'^{\mu} \simeq P_5'^{\mu\,\rm SM} - 0.25\tilde{\mathcal{C}}_{9\mu}$ (with $\tilde{\mathcal{C}}_{9\mu} = \mathcal{C}_{9\mu} - 0.8\mathcal{C}_{10'\mu}$)

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- A $\mathcal{C}_{9\mu}$ of $\mathcal{O}(-1)$ is required to explain $P'^{[1.1,6]}_{5\mu}$ and $\mathcal{C}_{10\mu}$ is marginal in P'_5
- $\mathcal{C}_{9\mu} = -\mathcal{C}_{10\mu}$ fails $\Leftarrow$ it forces a too small $\mathcal{C}_{9\mu}$ due to $B_s \to \mu\mu$ constrain on $\mathcal{C}_{10\mu}$.

$\mathcal{Q}3$: Measuring the whole $\mathcal{C}_{9\mu} = \mathcal{C}_{9\mu}^V + \mathcal{C}_9^U$ to get $\mathcal{C}_9^U$

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a) If data only from Q_5 and $P_5'^{\mu}$ we obtain a lower bound on the universal piece:

$$|\mathcal{C}_9^U| \simeq |\tilde{\mathcal{C}}_{9\mu} - \tilde{\mathcal{C}}_{9\mu}^V + 0.8(\mathcal{C}_{10'\mu} - \mathcal{C}_{10'\mu}^V)| \geq |\tilde{\mathcal{C}}_{9\mu} - \tilde{\mathcal{C}}_{9\mu}^V|$$

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b) if also data on $P_5'^{e}$ is provided by LHCb then

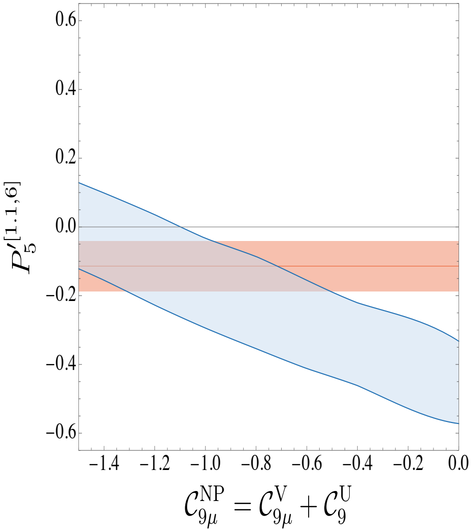
$$|\mathcal{C}_9^U| \simeq |\tilde{\mathcal{C}}_{9e} + 0.8\mathcal{C}_{10'e}| \geq |\tilde{\mathcal{C}}_{9e}|$$

P_1 (Q_1) can also help in the disentangling strategy:

c) informing on presence of RHCs (Hyp.V) d) turning $\tilde{\mathcal{C}} \to \mathcal{C}$ & bound$\to$ measurem.

This observable measures $\tilde{\mathcal{C}}_{9\mu}^{\rm NPV} + \tilde{\mathcal{C}}_9^U$ that in absence of RHC is $\mathcal{C}_{9\mu}^{\rm NPV} + \mathcal{C}_9^U$

An explanation of P_5' purely in terms of hadronic SM is simply **wrong ($\mathcal{C}_{9\mu}^{\rm NP\,V} \neq 0$ for R_K) .**



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Non-exclusive (and non-exhaustive) possibilities

- **Direct NP contribution.... a Z'?**
- **Loop-effects with SM particles**
  - τ-loops with or without connection with $R_{D^{(*)}}$.

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$\mathcal{C}_9^U$ Possible Origins?

Non-exclusive (and non-exhaustive) possibilities

- **Direct NP contribution.... a Z'?**
- **Loop-effects with SM particles**
  - τ-loops with or without connection with $R_{D^{(*)}}$.
- **Contrived** hadronic contribution beyond those already included
  - Unlikely considering recent theoretical progress.
  - Nicely it can be bounded using info on Q_5, $b \to s\tau\tau$ (or other LFU NP sources).

LFU via tau-loops: 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]

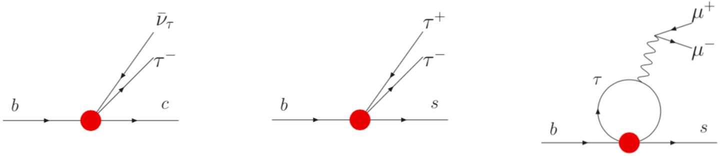
- Two ops. with left-handed doublets

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

- 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 $C^{(1)}_{2333} = C^{(3)}_{2333}$ (assumed $C^{(3)}_{33} = 0$)

[Capdevila, Crivellin, SDG, Hofer, Matias]

  - Avoids bounds from $B \to K^{(*)}\nu\nu$, Z decays, direct production in $\tau\tau$
    - Large NP contribution $b \to s\tau\tau$ through $\mathcal{C}^{\rm V}_{9\tau} = -\mathcal{C}^{\rm V}_{10\tau}$
    - Through radiative effects, NP contribution to $\mathcal{C}^{\rm U}_9$



Hyp: link between charged-neutral anomalies in SMEFT in scenario 8: $\mathcal{C}_9^V = -\mathcal{C}_{10}^V, \mathcal{C}_9^U$

$$\Downarrow$$

Huge $B_s \to \tau^+\tau^-$ and $B \to K^{(*)}\tau^+\tau^-$

$$\Downarrow$$

off-shell photon penguin with $O_9^{\tau\tau}$ generates LFU-NP in $\mathcal{C}_9$

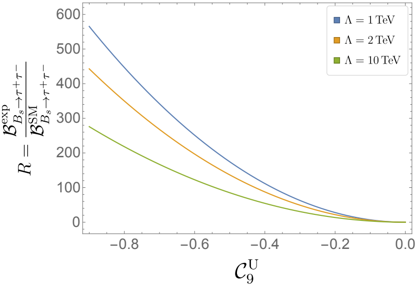
Combining all leads to:

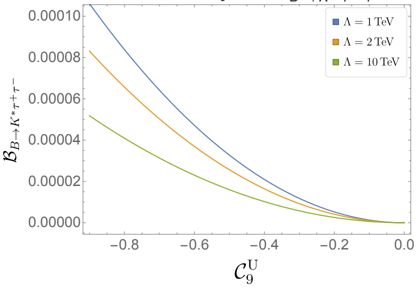
$$\mathcal{C}_9^U \propto \mathcal{C}_{10}^{\rm SM} \log(\Lambda^2/\mu_b^2)\, R^{\frac{1}{2}} \qquad \left(\text{assuming } \frac{R_{D^{(*)}}}{R_{D^{(*)}}^{\rm SM}} > 1\right)$$

where

$$R = \frac{\mathcal{B}^{\rm exp}_{B_s\to\tau^+\tau^-}}{\mathcal{B}^{\rm SM}_{B_s\to\tau^+\tau^-}}$$

and similarly for $\mathcal{B}_{B\to K^*\tau^+\tau^-}$:





Hypothesis: link between charged and neutral anomalies in SMEFT in scenario 8

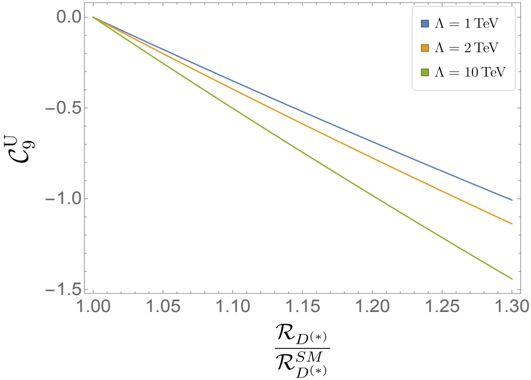
$$\Downarrow$$

Huge $B_s \to \tau^+\tau^-$ and $B \to K^{(*)}\tau^+\tau^-$

$$\Downarrow$$

off-shell photon penguin with $O_9^{\tau\tau}$ generates LFU-NP in $\mathcal{C}_9$

Furthermore if the link with $R_{D(*)}$ exists it should fulfill:



... also without R_D connection

Also a more general link between $\mathcal{C}_9^U$ and $b \to s\tau\tau$ is possible

...(without R_D connection)

Mixing of $\mathcal{O}_9^{\tau\tau}$ into O_9^U

$$\mathcal{C}_9^{\tau\tau} \to \mathcal{C}_9^U \tag{1}$$

IF assumed that LQs is the most plausible solution also $C_{10}^{\tau\tau}$ is present

- $\mathcal{C}_9^{\tau\tau} = \mathcal{C}_{10}^{\tau\tau}$ in case of S_2 LQ
- $\mathcal{C}_9^{\tau\tau} = -\mathcal{C}_{10}^{\tau\tau}$ in case of U_1 or $S_1 + S_3$ LQs

In both cases same plots of $\mathcal{C}_9^U$ versus $\mathcal{B}_{B_s\to\tau\tau}$ and $\mathcal{B}_{B\to K^*\tau\tau}$ holds (but not $R_{D^{(*)}}$)

Anything else?

Once identified:

- $\mathcal{C}_{9\mu}^{V}$ from Q_5
- $\mathcal{C}_{9}^{U}$ from $(P_5'^{\mu} - Q_5 = P_5'^{e})$

Δ between $\mathcal{C}_9^U$ from $P_5'^e$ and $\mathcal{C}_9^{\mathrm{NP\ U}}$ generated from τ-loops or other LFU NP sources:

quantitative upper bound on the existence (or not) of some marginal non-perturbative contribution.

A raw estimate of it is the difference between:

- $\mathcal{C}_9^U$ from global fit without the connection with R_{D,D^*}
- $\mathcal{C}_9^{\mathrm{NP\ U}}$ from τ-loop with R_{D,D^*} link (at a scale of $\Lambda = 2$ TeV)

With present data this amount in scenario 8 to an upper bound of $|\Delta| < 0.3$

- Compatible with zero at 1σ
- The larger the Λ scale the smaller the contribution
- Other LFU-NP sources may contribute and further reduce Δ

Disentangling scenarios

$(Q_5 = 0.3 \pm 0.1)$	All			LFUV		
Dominant Hyp.	Best fit	$\text{Pull}_{\rm SM}$	p-value	Best fit	$\text{Pull}_{\rm SM}$	p-value
$[\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{V}, \mathcal{C}_9^{U}]$	[-0.34,-0.82]	7.4	31.8 %	[-0.39,-1.86]	5.2	46.4 %
$[\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu}]$	[-1.15,+0.22]	7.5	35.6 %	[-1.45,+0.33]	5.7	77.9 %

$(Q_5 = 0.1 \pm 0.1)$	All			LFUV		
Dominant Hyp.	Best fit	$\text{Pull}_{\rm SM}$	p-value	Best fit	$\text{Pull}_{\rm SM}$	p-value
$[\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{V}, \mathcal{C}_9^{U}]$	[-0.31,-0.83]	7.1	38.0 %	[-0.40,+0.15]	4.7	66.7 %
$[\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu}]$	[-1.04,+0.20]	6.7	30.1 %	[-1.08,+0.23]	4.5	49.8 %

$\Delta = 0'4\text{-}0'5\sigma$

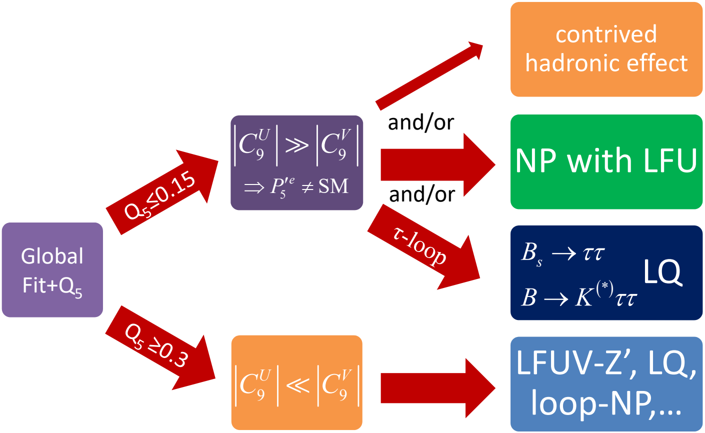
$(Q_5 = 0.30 \pm 0.05)$	All			LFUV		
Dominant Hyp.	Best fit	$\text{Pull}_{\rm SM}$	p-value	Best fit	$\text{Pull}_{\rm SM}$	p-value
$[\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{V}, \mathcal{C}_9^{U}]$	[-0.42,-0.79]	8.5	19 %	[-0.49,-2.61]	7.0	19.2 %
$[\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu}]$	[-1.15,+0.21]	9.2	35.6 %	[-1.29,+0.29]	7.7	74.5 %

$(Q_5 = 0.10 \pm 0.05)$	All			LFUV		
Dominant Hyp.	Best fit	$\text{Pull}_{\rm SM}$	p-value	Best fit	$\text{Pull}_{\rm SM}$	p-value
$[\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{V}, \mathcal{C}_9^{U}]$	[-0.30,-0.84]	7.3	38.0 %	[-0.40,-0.07]	5.1	66.6 %
$[\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu}]$	[-0.85,+0.18]	6.6	22.2 %	[-0.76,+0.16]	4.4	30.2 %

$\Delta = 0'7\sigma$

Conclusions

$\mathcal{C}_{9\mu}$ decision tree



or in words...

- We pointed out that:
  - the degeneracy among dominant scenarios ($\text{Pull}_{\rm SM} > 7\sigma$) is due to the similar weight of WC entering R_X observables.
  - the breaking of this degeneracy requires a $\mathcal{C}_{9\mu}$-dominated observable
- Understanding the structure of NP of $\mathcal{C}_{9\mu}^{\rm NP} = \mathcal{C}_{9\mu}^{V} + \mathcal{C}_{9}^{U}$ is crucial to disentangle the two main scenarios:
  - Hypothesis V $\to (\mathcal{C}_{9\mu}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$
  - Scenario 8 $\to (\mathcal{C}_{9\mu}^{V} = -\mathcal{C}_{10\mu}^{V}, \mathcal{C}_{9}^{U})$
- Size of $\mathcal{C}_{9\mu}^{V}$ can be determined (up to a small RHC) by Q_5
- Size of $\mathcal{C}_{9}^{U}$ can be determined (up to a small RHC) by $P_5'^{e}$ (or Q_5 and $P_5'^{\mu}$)
  - If the link between $\frac{R_D^{(*)}}{R_D^{(*)\rm SM}}$ and $b \to s\ell\ell$ holds a large $b \to s\tau\tau$ is generated.
  - $C_9^{U\,\rm NP}$ can be induced by τ-loops and connected with $\mathcal{B}_{B_s\to\tau^+\tau^-}$ and $\mathcal{B}_{B\to K^*\tau^+\tau^-}$
  - Other NP sources of LFU are possible (Z').
- The difference between $\mathcal{C}_9^{U}$ and $C_9^{U\,\rm NP}$ (if any) is all the possible space for a marginal extra hadronic contribution.

Questions:

- What is the expected precision achievable for Q_5 in the short and long-term?
- How large have to be $B_s \to \tau\tau$ and $B \to K^*\tau\tau$ to be measurable at LHCb? What are the short term perspectives?