Constraints on Lepton-Flavor Mixing with Third-Generation New Physics

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Beyond the Flavor Anomalies 2026

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Based mostly on

S. Covone, P. M. and A. Tinari 2511.15800

New physics expectations

The SM works very well… but it cannot be the full picture!

e.g. Cosmology Problems, Neutrino Masses, CP Problems…

New Physics might be hiding at some scale $\Lambda_{\rm NP}$

→ **The Higgs hierarchy problem calls for NP at the TeV scale!**

$$\Delta m_H^{2\,(loop)} \sim \Lambda_{\rm NP}^2$$

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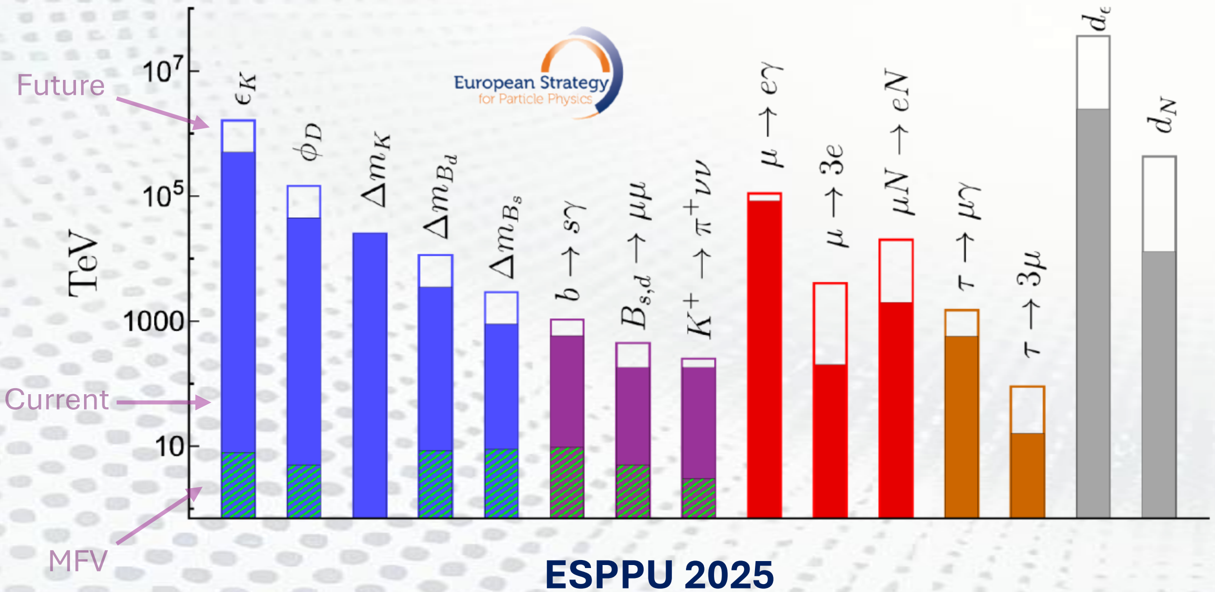

ESPPU 2025

- Current data puts stringent constraints on BSM models addressing the hierarchy problem.
- The NP scale is pushed much higher than a few TeV's...

...unless the NP has a specific flavor structure.

Hypothesis for the new physics

Strongest bounds on flavor-changing processes involving light families!

If the NP lives around the TeV scale it must have...

...predominant coupling to **third-generation fermions**.

...**weaker and quasi-degenerate** interactions with light families.

Approximate $U(2)^5$ flavor symmetry with NP mainly coupled to the 3rd gen.

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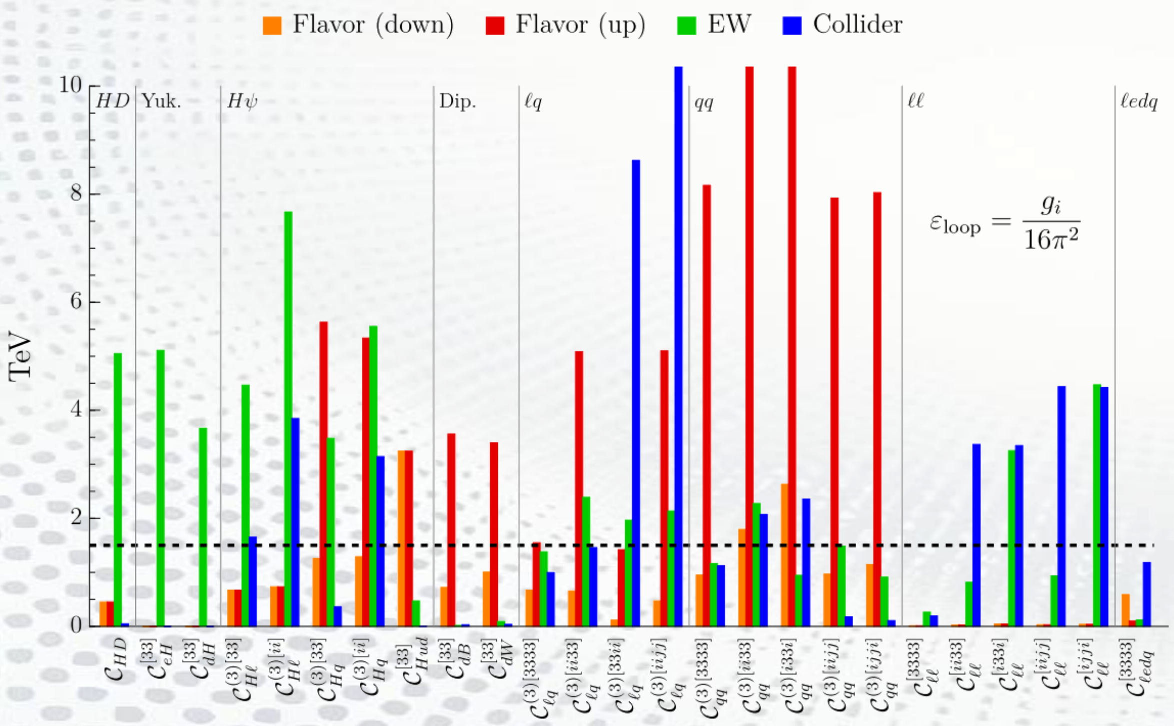
Applied via selection rules and suppression principles on the general BSM setup of the SMEFT

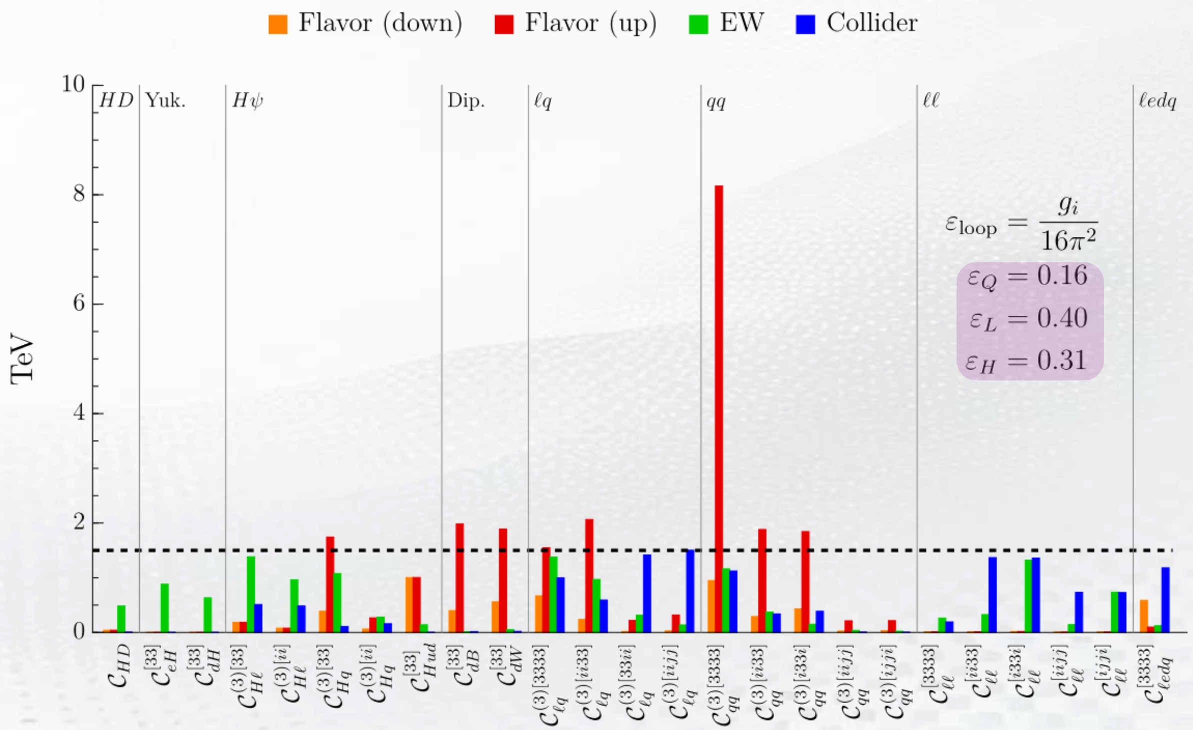
Hypothesis for the new physics

L. Allwicher, C. Cornella, G. Isidori & B.A. Stefanek, 2311.00020

Approximate $U(2)^5$ flavor symmetry with NP mainly coupled to the 3rd gen.

→ Passes current bounds on **direct searches**, **EWPOs** and **flavor observables**.





$U(2)^5$ flavor symmetry

R. Barbieri, G. Isidori, J. Jones-Pérez, P. Lodone, D. M. Straub, 1105.2296

The SM interactions respect a $\boldsymbol{U(3)^5 = U(3)_q \times U(3)_\ell \times U(3)_u \times U(3)_d \times U(3)_e}$ global flavor symmetry, by which the fermion generations are indistinguishable, everywhere **except in the Yukawa sector**.

The smaller symmetry $\boldsymbol{U(2)^5 = U(2)_q \times U(2)_\ell \times U(2)_u \times U(2)_d \times U(2)_e}$, under which the light families form doublets and the third family forms singlets, is **approximately respected by the SM Yukawa**.

$$\mathcal{L}_{\text{Yukawa}} = -\overline{q_L} Y_u u_R \tilde{\varphi} - \overline{q_L} Y_d d_R \varphi - \overline{\ell_L} Y_e e_R \tilde{\varphi} + \text{h. c.}$$

$Y_u \sim$

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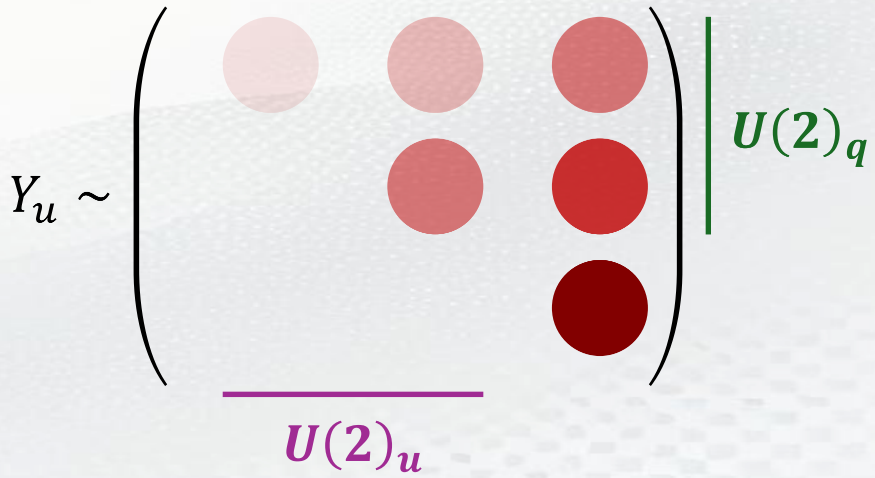
- **The leading term (top Yukawa) respects $U(2)^5$.**
- **The sub-leading terms ($\sim 1\%$) need the breaking of $U(2)_q$.**
- **Only the light-to-light mixing needs the breaking of $U(2)_u$.**



$U(2)^5$ symmetry breaking

We need to **break $U(2)^5$** to describe **light-fermion masses** and **mixing** between light- and third-generation fermions.

To break it in a controlled way, we can introduce (small) **spurion terms** with well-defined transformation properties under the flavor symmetry.

Only a handful of spurions are needed to describe all masses and mixings in the SM.

$$\tilde{V}_q \sim (2,1,1,1,1)\,,\quad \Delta_u \sim (2,1,\bar{2},1,1)\,,\quad \Delta_d \sim (2,1,1,\bar{2},1)$$

$$\tilde{V}_\ell \sim (2,1,1,1,1)\,,\quad \Delta_e \sim (2,1,1,1,\bar{2})$$

$$Y_u = y_t \begin{pmatrix} \Delta_u & x_t \tilde{V}_q \\ 0 & 1 \end{pmatrix}$$

In absence of neutrino masses, V_ℓ is not strictly necessary!

$$U(2)_q \times U(2)_\ell \times U(2)_u \times U(2)_d \times U(2)_e$$

$U(2)^5$ symmetry breaking

The hypothesis that the only sources of breaking of this flavor symmetry in a BSM model or SMEFT setup are the SM spurions, is known as **minimally broken $U(2)^5$**.

Interesting hypothesis for NP addressing the flavor puzzle!

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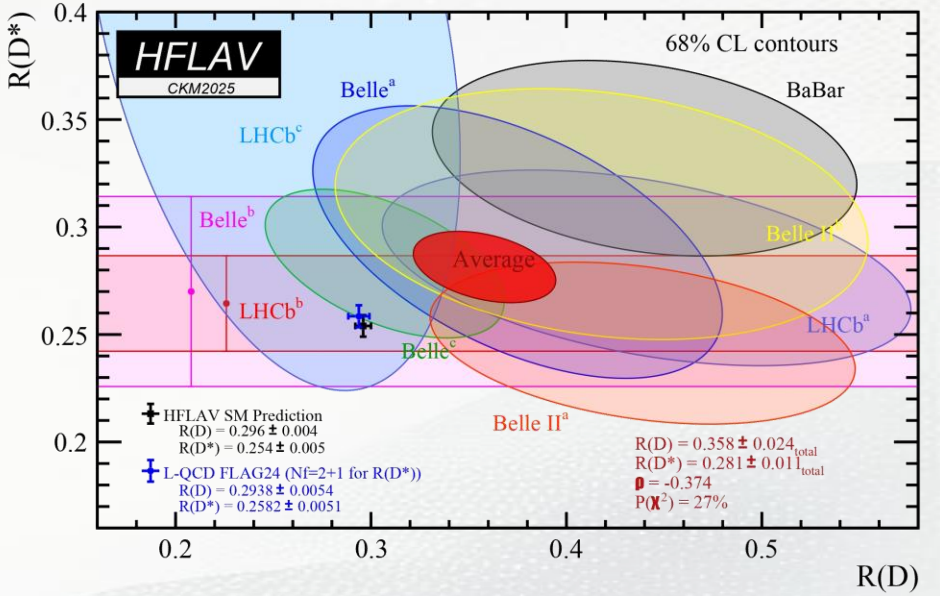
Tensions in flavor observables

A series of **deviations from the SM predictions** observed in several **rare and semi-leptonic B-decays** also seem to point toward the **breaking of $U(2)_q$**:

- R_D, R_{D^*}: $$R(D^{(*)}) = \frac{\mathcal{B}(\overline{B} \to D^{(*)}\tau^-\overline{\nu}_\tau)}{\mathcal{B}(\overline{B} \to D^{(*)}\ell^-\overline{\nu}_\ell)}$$



- $B \to K\bar{\nu}\nu$: (Belle II) $$\mathcal{B}(B \to K\bar{\nu}\nu)/\mathcal{B}(B \to K\bar{\nu}\nu)^{SM} = 5.4 \pm 1.5$$

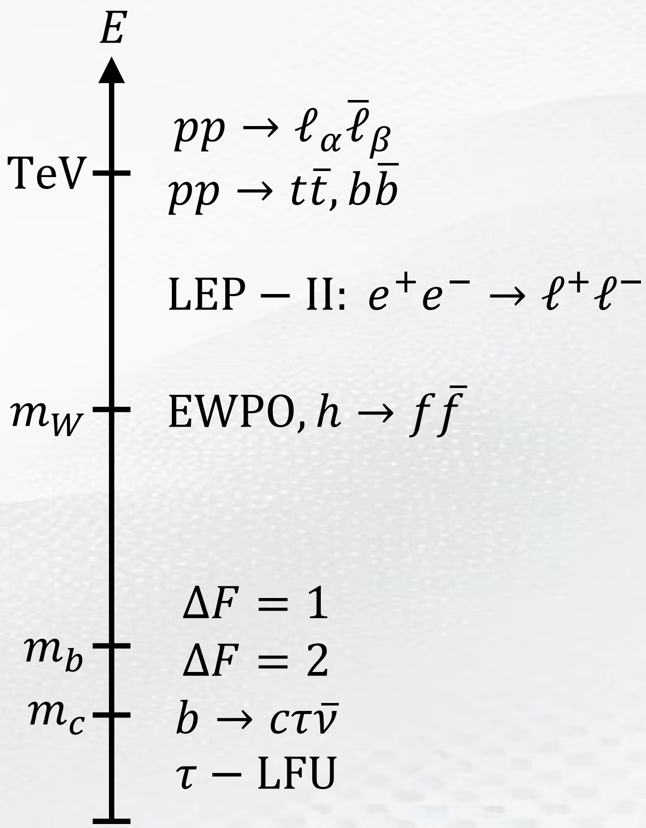
- $K \to \pi\bar{\nu}\nu$: (NA62) $$\mathcal{B}(K^+ \to \pi^+\bar{\nu}\nu)^{SM} = (8.09 \pm 0.63) \times 10^{-11}$$ $$\mathcal{B}(K^+ \to \pi^+\bar{\nu}\nu) = (13.0^{+3.3}_{-2.9}) \times 10^{-11}$$ ← **(This might be old now!)**

Conclusions along $U(2)_q$

L. Allwicher, M. Bordone, G. Isidori, G. Piazza, A. Stanzione, 2410.21444

In this context, Lukas et al. (2410.21444) provide a combined explanation to $B \to K\bar{\nu}\nu$, $K \to \pi\bar{\nu}\nu$, and other hints of deviations such as $R_{D^{(*)}}$ and $b \to s\bar{\ell}\ell$ while passing all constraints from EWPOs and direct searches (also flavor constraints).

Employing the SMEFT for an EFT-based model-independent analysis.



<u>**Their BSM hypotheses:**</u>

❖ **TeV-scale new physics** in semi-leptonic operators.

❖ NP coupled predominantly to the **third-generation**.

❖ NP respecting an **approximate $U(2)^5$** flavor symmetry, broken ***only*** in the $U(2)_q$ direction.

$$\tilde{V}_q^i = -\varepsilon \begin{pmatrix} \kappa V_{td} \\ V_{ts} \end{pmatrix}$$

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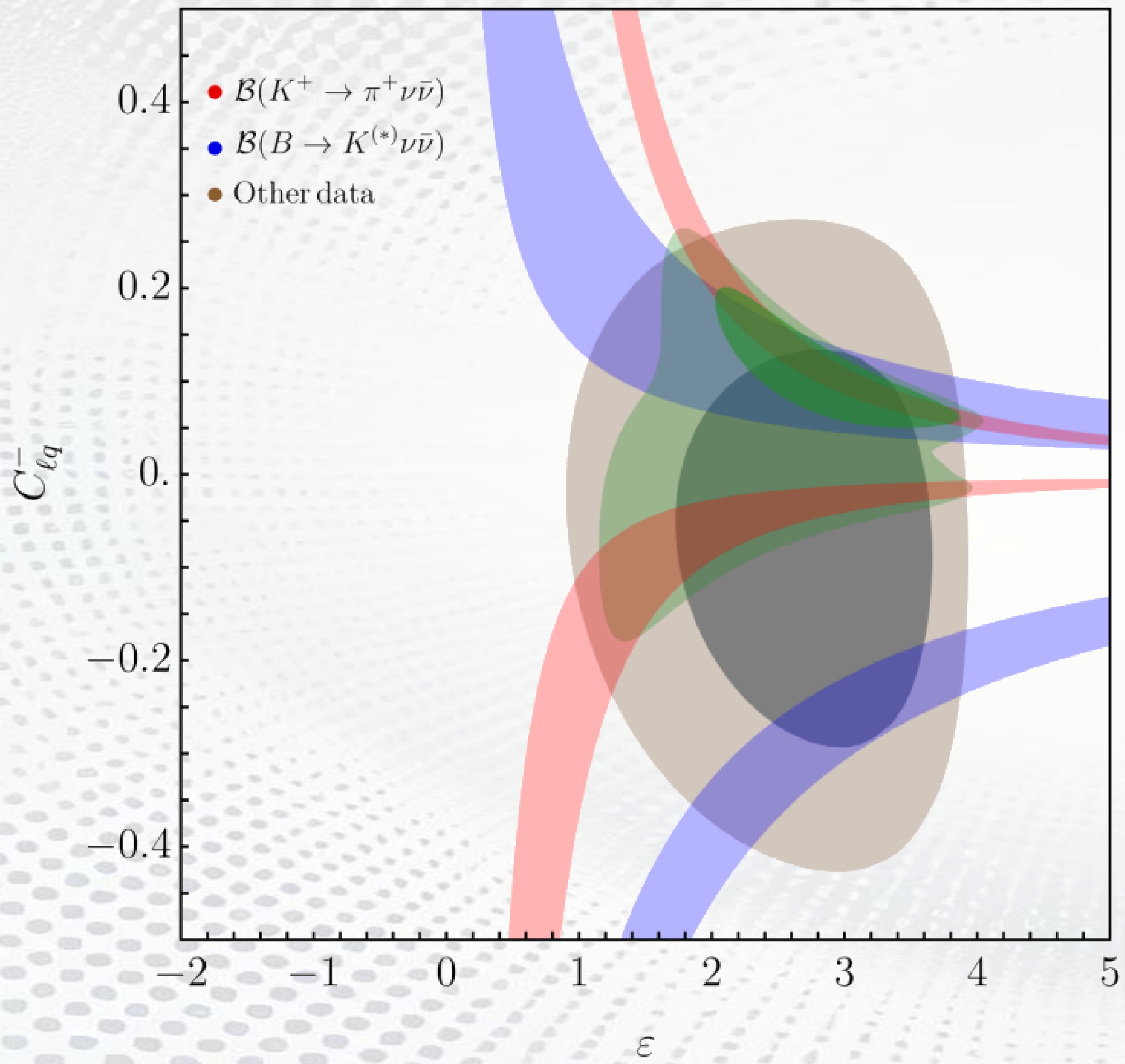

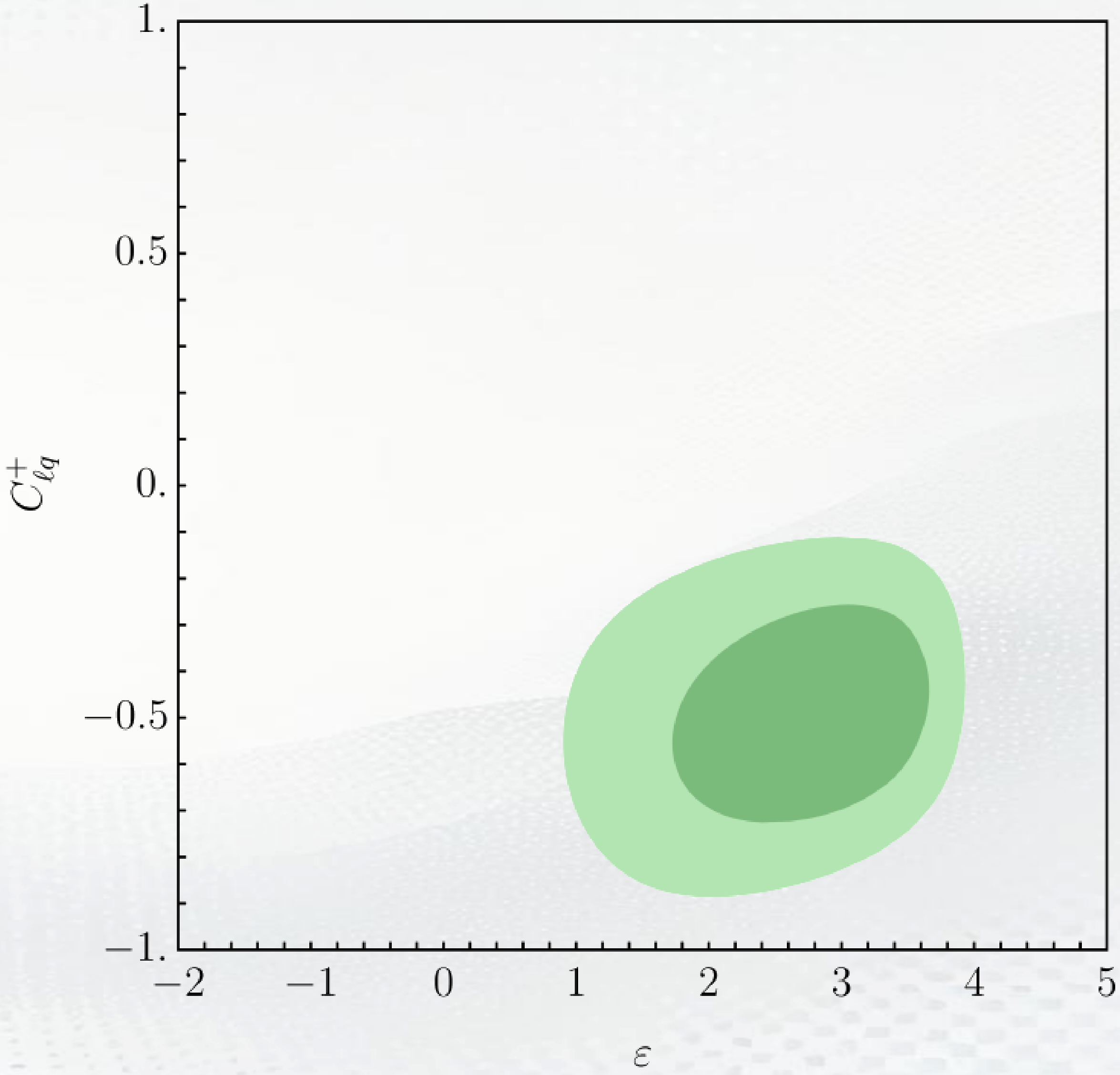

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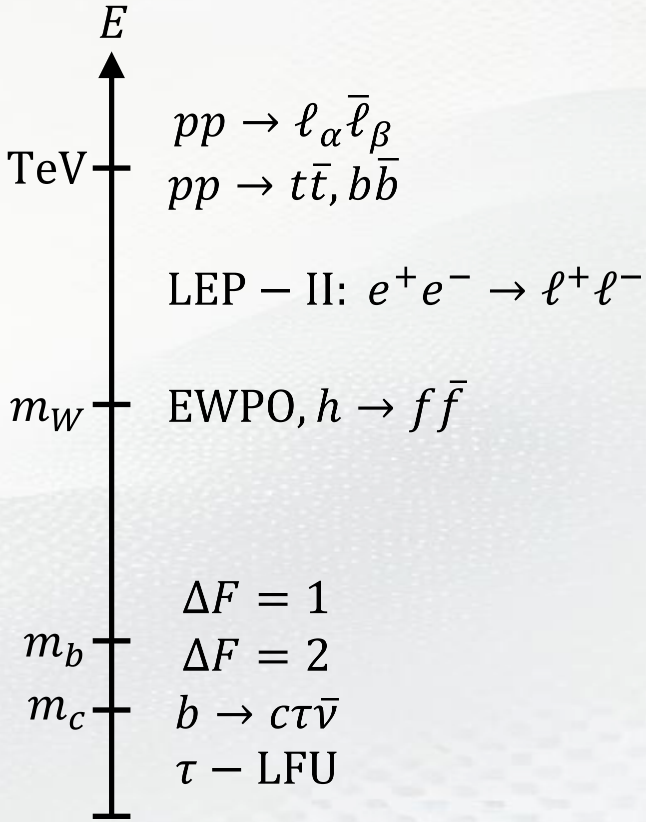

Important takeaways (for this talk):

❖ Data supports a setup with only vector-like left-handed operators:

$$Q^{\pm}_{\ell q} = (\bar{q}_L \gamma^\mu q_l)(\bar{\ell}\gamma_\mu \ell) \pm (\bar{q}_L \gamma^\mu \sigma^a q_l)(\bar{\ell}\gamma_\mu \sigma^a \ell)$$

❖ No evidence of **non-minimal breaking** of $U(2)_q$ ($\kappa \sim 1$).

What about $U(2)_\ell$?

The situation in the **lepton sector** is less clear, given that $\tilde{V}_\ell$ is not strictly necessary to reproduce the fermion masses and mixing of the SM...

Does current data allow for the breaking of $U(2)_\ell$?

How big can this breaking be?

→ **That's our main goal!**

We build upon the work of Lukas et al. (2410.21444), extending their SMEFT framework with an additional spurion breaking $U(2)_\ell$!

$$U(2)_q \times U(2)_\ell \times U(2)_u \times U(2)_d \times U(2)_e$$

We take a conservative approach to seize the **maximal breaking of $U(2)_\ell$** compatible with current data, then study the resulting implications for future measurements, with special emphasis on **LFV**.

SMEFT setup for breaking $U(2)_\ell$

We start with the left-handed vector-like semi-leptonic operators in the SMEFT Lagrangian:

$$\mathcal{L}_{\rm SMEFT}^{\rm NP} \supset \frac{1}{\Lambda_{\rm NP}^2}\left[C_{\ell q}^{+}\right]_{\alpha\beta ij}\left[Q_{\ell q}^{+}\right]_{\alpha\beta ij} + \frac{1}{\Lambda_{\rm NP}^2}\left[C_{\ell q}^{-}\right]_{\alpha\beta ij}\left[Q_{\ell q}^{-}\right]_{\alpha\beta ij} \qquad (\Lambda_{\rm NP} = 1\text{TeV})$$

We only allow operators **invariant under the $U(2)^5$ global symmetry**, either *per se* or built out of the minimal set of spurions breaking $U(2)_q$ and $U(2)_\ell$.

$$\left[Q_{\ell q}^{\pm}\right]^{\alpha\beta ij} = (\bar{q}_L^i\gamma^\mu q_L^j)(\bar{\ell}_L^\alpha\gamma_\mu\ell_L^\beta) \pm (\bar{q}_L^i\gamma^\mu\sigma^a q_L^j)(\bar{\ell}_L^\alpha\gamma_\mu\sigma^a\ell_L^\beta)$$

$$\left[C_{\ell q}^{\pm}\right]_{\alpha\beta ij} = C_{\ell q}^{\pm}\,(\mathcal{V}_\ell^\dagger)_\alpha\,(\mathcal{V}_\ell)_\beta\,(\mathcal{V}_q^\dagger)_i\,(\mathcal{V}_q)_j$$

$$\text{with} \quad \mathcal{V}_{\ell,q} = \begin{pmatrix} \tilde{V}_{\ell,q} \\ 1 \end{pmatrix}$$

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$$\text{with} \quad \mathcal{V}_{\ell,q} = \begin{pmatrix} \tilde{V}_{\ell,q} \\ 1 \end{pmatrix}$$

This runs on the additional assumption of a **rank-one structure in the NP**: The NP is coupled to the third generation, and all flavor misalignment from there stems from the spurions alone!

↳ Very useful to avoid parameter proliferation, and validated by 2410.21444!

SMEFT setup for breaking $U(2)_\ell$

To resolve the ambiguity on what constitutes the third generation, we chose a **down-aligned basis**.

Mostly to remain consistent with 2410.21444.
Added benefit of yielding more conservative constraints.

$$q_L^i = \begin{pmatrix} V_{ui}u_L + V_{ci}c_L + V_{ti}t_L \\ d_L^i \end{pmatrix}$$

The spurions themselves are parameterized as:

$$\tilde{V}_q^i = \begin{pmatrix} -\varepsilon V_{td} \\ -\varepsilon V_{ts} \end{pmatrix} \qquad \tilde{V}_\ell^\alpha = \begin{pmatrix} \delta \sin\theta_e \\ \delta \cos\theta_e \end{pmatrix}$$

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Constrained by 2410.21444

Minimally broken $U(2)_q$

Main focus of our analysis!

Free angle in $U(2)_\ell$

Four independent parameters! $\left(C_{\ell q}^+, C_{\ell q}^-, \varepsilon, \delta\right)$

For our analysis, we set $\boldsymbol{\theta_e = 0}$, which is the most conservative approach given the tightness of LFV bounds involving electrons...

SMEFT setup for breaking $U(2)_\ell$

Disclaimer

Our setup doesn't address the anarchic structure of the neutrino mass matrix.

It's been proven that neutrino anarchy can still arise under hierarchical setups like $U(2)^5$.

(A. Greljo and G. Isidori, 2406.01696)

Therefore, we mostly disregard neutrino flavor-violating processes for our analysis.

RG Evolution and Matching

Our SMEFT Wilson coefficients are defined at the **high-energy NP scale** (1 TeV), but we use **low-energy observables** (m_B, m_τ,) for our analysis, so we need to connect the NP scale with the low-energy scales (a few GeV).

- ❖ Fixed-order leading logarithms can get big, given that $\log\left(\Lambda_{\mathrm{NP}}^2/\mu^2\right) \sim 10$...
- ❖ Decoupling of the heaviest d.o.f. (m_t, m_H, m_W, m_Z) should be taken into account...

It is convenient to use the **Renormalization-Group evolution** of the Wilson coefficients, together with the **matching** to the **Low-Energy Effective Field Theory (LEFT):**

$$C_i(\Lambda_{\mathrm{NP}}) \xrightarrow{\text{RGE}} C_i(\Lambda_{\mathrm{EW}}) \xrightarrow{\text{Matching}} L_i(\Lambda_{\mathrm{EW}}) \xrightarrow{\text{RGE}} L_i(\Lambda_{\mathrm{obs}})$$

SMEFT | LEFT

RG Evolution and Matching

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$$C_i(\Lambda_{\rm NP}) \xrightarrow{\text{RGE}} C_i(\Lambda_{\rm EW}) \xrightarrow{\text{Matching}} L_i(\Lambda_{\rm EW}) \xrightarrow{\text{RGE}} L_i(\Lambda_{\rm obs})$$

SMEFT | LEFT

We use a matrix approach, given that double insertions are negligible in our setup:

$$L_i(\mu_{\rm low}) = L_i^{\rm (SM)}(\mu_{\rm low}) + \mathcal{U}_{ij}(\mu_{\rm low}, \mu_m, \Lambda_{\rm NP})\, C_j(\Lambda_{\rm NP})$$

$$L_i^{\rm (SM)} = U^L_{ik}(\mu_{\rm low}, \mu_m)\, L_k^{\rm (SM)}(\mu_m)$$

$$\mathcal{U}_{ij} = U^L_{ik}(\mu_{\rm low}, \mu_m)\, M_{kl}(\mu_m)\, U^C_{lj}(\Lambda_{\rm EW}, \Lambda_{\rm NP})$$

For the RGE matrices, we use the one-loop running (LL resummation)

We use the one-loop matching for this matrix.

These matrices are built using the current one-loop version of **DsixTools**.

This way we obtain **analytic expressions** for the low-energy WCs in terms of our four parameters!

Observables to constrain lepton mixing

S. Covone, P. M. and A. Tinari 2511.15800

	Observable	Experimental Bound/Measurement
LFV τ-decays	$\mathcal{B}(\tau \to \mu\gamma)$	$< 5.6 \times 10^{-8}$
	$\mathcal{B}(\tau \to \mu ee)$	$< 2.4 \times 10^{-8}$
	$\mathcal{B}(\tau \to \mu\mu\mu)$	$< 2.8 \times 10^{-8}$
	$\mathcal{B}(\tau \to \mu\rho)$	$< 1.6 \times 10^{-8}$
	$\mathcal{B}(\tau \to \mu\phi)$	$< 2.9 \times 10^{-8}$
LFV $Q\bar{Q}$-decays	$\mathcal{B}(J/\psi \to \mu\tau)$	$< 2.7 \times 10^{-6}$
	$\mathcal{B}(\Upsilon \to \mu\tau)$	$< 3.6 \times 10^{-6}$
LFV B-decays	$\mathcal{B}(B_s \to \mu\tau)$	$< 4.2 \times 10^{-5}$
	$\mathcal{B}(B \to K\mu\tau)$	$< 4.1 \times 10^{-5}$
	$\mathcal{B}(B \to K^*\mu\tau)$	$< 2.2 \times 10^{-5}$
	$\mathcal{B}(B_s \to \phi\mu\tau)$	$< 1.3 \times 10^{-5}$
Rare B-decays	$\mathcal{B}(B_s \to \tau\tau)$	$< 6.8 \times 10^{-3}$
	$\mathcal{B}(B_s \to \mu\mu)$	$(3.34 \pm 0.27) \times 10^{-9}$
LFU Ratios	$R_K[0.1, 1.1]$	$0.994^{+0.090}_{-0.082}$ (stat) $^{+0.029}_{-0.027}$ (syst)
	$R_K[1.1, 6]$	$0.949^{+0.042}_{-0.041}$ (stat) $^{+0.023}_{-0.023}$ (syst)
	$R_K[14.3, 22.9]$	$1.08^{+0.11}_{+0.04}$ (stat) $^{+0.09}_{-0.04}$ (syst)
	$R_{K^*}[0.1, 1.1]$	$0.927^{+0.093}_{-0.087}$ (stat) $^{+0.034}_{-0.033}$ (syst)
	$R_{K^*}[1.1, 6]$	$1.027^{+0.072}_{-0.068}$ (stat) $^{+0.027}_{-0.027}$ (syst)

Our BSM SMEFT setup is governed by $C^+_{\ell q}, C^-_{\ell q}, \varepsilon, \delta$, but we are mostly interested in fitting $\boldsymbol{\delta}$.

We use the likelihood of the previous fit (2410.21444) for the other parameters!

Transition	SMEFT Scaling	LEFT Scaling
$b \to s\tau\tau$	$C^+_{\ell q} V_{ts}\, \epsilon$	$C^+_{\ell q} V_{ts}\, \epsilon$
$b \to s\mu\mu$	$C^+_{\ell q} V_{ts}\, \epsilon\, c_e^2\, \delta^2$	$C^+_{\ell q} V_{ts}\, \epsilon\, (0.005 - c_e^2\, \delta^2)$
$b \to see$	$C^+_{\ell q} V_{ts}\, \epsilon\, s_e^2\, \delta^2$	$C^+_{\ell q} V_{ts}\, \epsilon\, (0.005 - s_e^2\, \delta^2)$
$b \to s\tau\mu$	$C^+_{\ell q} V_{ts}\, \epsilon\, c_e\, \delta$	$C^+_{\ell q} V_{ts}\, \epsilon\, c_e\, \delta$
$b\bar{b} \to \tau\mu$	$C^+_{\ell q}\, c_e\, \delta$	$(C^+_{\ell q} + 0.05\, C^-_{\ell q})\, c_e\, \delta$
$c\bar{c} \to \tau\mu$	$C^-_{\ell q}\, \lvert V_{ts}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$
$\tau \to \mu ss$	$C^+_{\ell q}\, \lvert V_{ts}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$
$\tau \to \mu dd$	$C^+_{\ell q}\, \lvert V_{td}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$
$\tau \to \mu uu$	$C^-_{\ell q}\, \lvert V_{td}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$

$$\tilde{V}_q^i = \begin{pmatrix} -\varepsilon V_{td} \\ -\varepsilon V_{ts} \end{pmatrix} \qquad \tilde{V}_\ell^\alpha = \begin{pmatrix} \delta \sin\theta_e \\ \delta\cos\theta_e \end{pmatrix}$$

Constraining power and fit results

S. Covone, P. M. and A. Tinari 2511.15800

Observable	Experimental Bound/Measurement
$\mathcal{B}(\tau \to \mu\gamma)$	$< 5.6 \times 10^{-8}$
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$\mathcal{B}(B_s \to \mu\tau)$	$< 4.2 \times 10^{-5}$
$\mathcal{B}(B \to K\mu\tau)$	$< 4.1 \times 10^{-5}$
$\mathcal{B}(B \to K^*\mu\tau)$	$< 2.2 \times 10^{-5}$
$\mathcal{B}(B_s \to \phi\mu\tau)$	$< 1.3 \times 10^{-5}$
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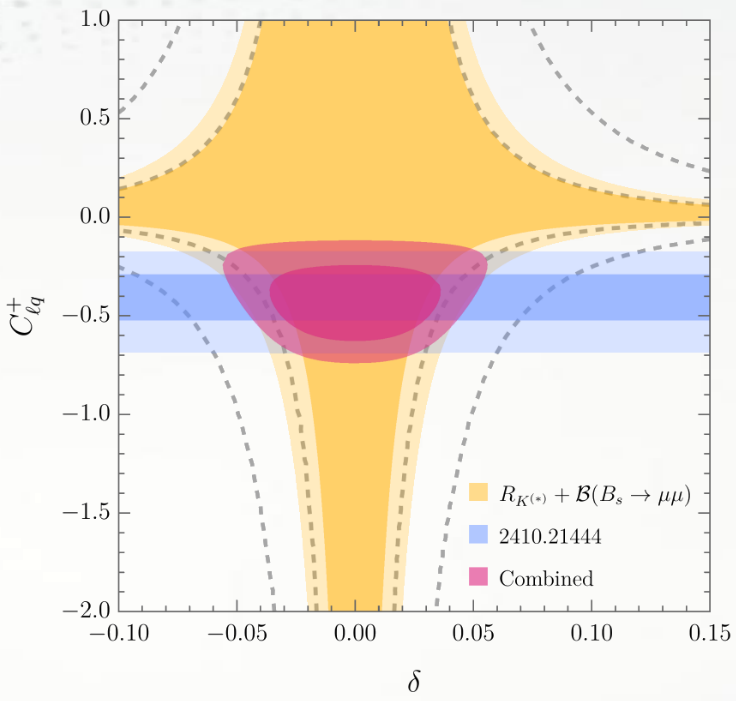
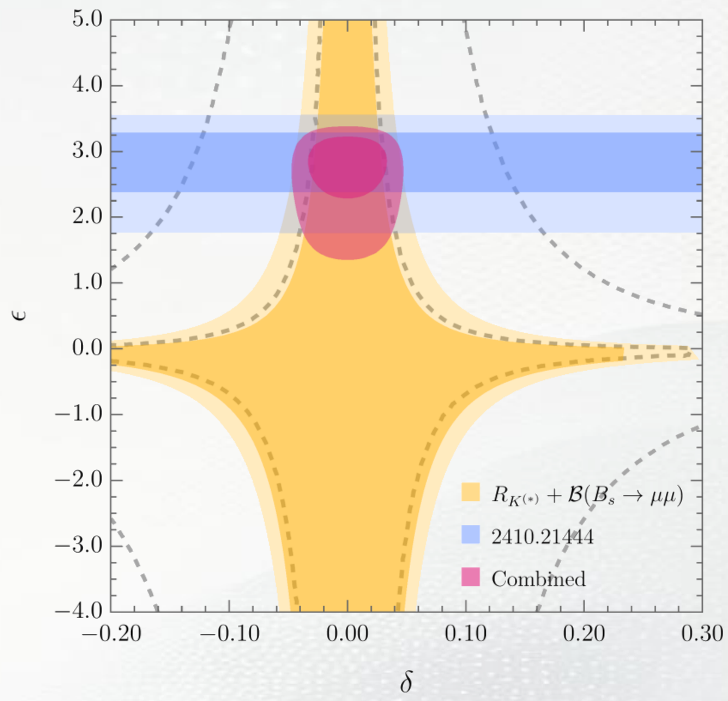
$R_K[0.1, 1.1]$	$0.994^{+0.090}_{-0.082}$ (stat) $^{+0.029}_{-0.027}$ (syst)
$R_K[1.1, 6]$	$0.949^{+0.042}_{-0.041}$ (stat) $^{+0.023}_{-0.023}$ (syst)
$R_K[14.3, 22.9]$	$1.08^{+0.11}_{+0.04}$ (stat) $^{+0.09}_{-0.04}$ (syst)
$R_{K^*}[0.1, 1.1]$	$0.927^{+0.093}_{-0.087}$ (stat) $^{+0.034}_{-0.033}$ (syst)
$R_{K^*}[1.1, 6]$	$1.027^{+0.072}_{-0.068}$ (stat) $^{+0.027}_{-0.027}$ (syst)





We clearly identify these four observables as the most constraining!

$|\delta| < 0.051 \quad (95\%\ \mathrm{CL})$

$\chi^2/\mathrm{d.o.f.} \approx 0.94$

- $|\delta| = |\tilde{V}_\ell| \lesssim |V_{ts}|$
- $|\tilde{V}_\ell|/|\tilde{V}_q| < 0.69 \quad (95\%\ CL)$
- Largely independent of $\boldsymbol{\mu}$!

Bounds on LFV observables and future sensitivity

S. Covone, P. M. and A. Tinari 2511.15800

We can then provide bounds for the rest of observables, mainly **LFV decays**:

Observable	Prediction	Current Bound
$\mathcal{B}(\tau \to \mu\gamma)$	$< 8.4 \times 10^{-11}$	$\times 700$
$\mathcal{B}(\tau \to \mu ee)$	$< 7.6 \times 10^{-10}$	$\times 30$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$< 1.2 \times 10^{-9}$	$\times 20$
$\mathcal{B}(\tau \to \mu\rho)$	$< 1.6 \times 10^{-9}$	$\times 10$
$\mathcal{B}(\tau \to \mu\phi)$	$< 9.8 \times 10^{-10}$	$\times 30$
$\mathcal{B}(J/\psi \to \mu\tau)$	$< 3.0 \times 10^{-16}$	$\times 10^{10}$
$\mathcal{B}(\Upsilon \to \mu\tau)$	$< 4.6 \times 10^{-11}$	$\times 10^{5}$
$\mathcal{B}(B_s \to \mu\tau)$	$< 1.8 \times 10^{-7}$	$\times 200$
$\mathcal{B}(B \to K\mu\tau)$	$< 2.0 \times 10^{-7}$	$\times 200$
$\mathcal{B}(B \to K^*\mu\tau)$	$< 3.3 \times 10^{-7}$	$\times 70$
$\mathcal{B}(B_s \to \phi\mu\tau)$	$< 3.6 \times 10^{-7}$	$\times 40$

(ratio between current bound and prediction)

These numbers tend to fall on the restrictive side of the literature, due to the correlation with the very constrained $b \to s\mu\mu$ channels.

However, some τ-decays fall closer to the optimistic predictions, thanks to penguin-loop effects softening the impact of those correlations.

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(ratio between current bound and prediction)

If Belle II reaches the expected sensitivity, LFV τ-decays could become the most constraining:

$$\mathcal{B}(\tau \to \mu\rho) < 5.5 \times 10^{-10} \quad \text{(expected)}$$
$$\mathcal{B}(\tau \to \mu\mu\mu) < 3.5 \times 10^{-10} \quad \text{(expected)}$$

$$|\delta|_{\text{future}} < 0.033 \quad \text{(at 95\% CL)}$$

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LFV $Q\bar{Q}$-decays completely out of reach for now...

Bounds on LFV observables and future sensitivity

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LFV $Q\bar{Q}$-decays completely out of reach for now...

LFV B-decays sit in a middle ground, with some promising numbers and mixed prospects.

Bounds on LFV observables and future sensitivity

S. Covone, P. M. and A. Tinari 2511.15800

We can then provide bounds for the rest of observables, mainly **LFV decays**.

Concerning the $b \to s\mu\mu$ channels, now leading in constraining power, at 300 fb^{-1} after Upgrade II of LHCb they expect:

$$\mathcal{B}(B_s \to \mu\mu) \text{ to } \sim 5\% \text{ precision}$$

$$R_K^{(*)} \text{ to } \sim 1\% \text{ precision}$$

$$|\delta|_{\text{future}} < 0.030 \quad (\text{at } 95\% \text{ CL})$$

If Belle II reaches the expected sensitivity, LFV τ-decays could become the most constraining:

$$\mathcal{B}(\tau \to \mu\rho) < 5.5 \times 10^{-10} \quad (\text{expected})$$
$$\mathcal{B}(\tau \to \mu\mu\mu) < 3.5 \times 10^{-10} \quad (\text{expected})$$

$$|\delta|_{\text{future}} < 0.033 \quad (\text{at } 95\% \text{ CL})$$

LFV $Q\bar{Q}$-decays completely out of reach for now...

LFV B-decays sit in a middle ground, with some promising numbers but no clear prospects.

The qualitative picture of $|\tilde{V}_\ell|/|\tilde{V}_q|$ remains the same in any case...

Enhancement in $bs\tau\tau$

S. Covone, P. M. and A. Tinari 2511.15800

While $b \to s\tau\tau$ modes **do not** depend significantly on δ (fully determined by 2410.21444), as they third-generation in the lepton side, we can also produce predictions for them...

Observable	Prediction	Current Bound
$\mathcal{B}(B_s \to \tau\tau)$	$(8.3^{+12.6}_{-4.1}) \times 10^{-5}$	$\times 25$
$\mathcal{B}(B \to K\tau\tau)^{[15,22]}$	$(1.5^{+2.3}_{-0.7}) \times 10^{-5}$	$\times 40$
$\mathcal{B}(B \to K^*\tau\tau)^{[15,19]}$	$(1.3^{+2.0}_{-0.7}) \times 10^{-5}$	$\times 11$
$\mathcal{B}(B_s \to \phi\tau\tau)^{[15,18.8]}$	$(1.2^{+1.9}_{-0.6}) \times 10^{-5}$	$\times 6$

LHCb, 2510.13716

***O*(100) enhancement w.r.t. the SM!**

Central role in most frameworks based on NP coupled predominantly to the third generation!

Sensitivities for $b \to s\tau\tau$ expected by LHCb at the end of Upgrade II would fall in a similar ballpark as our predictions!

Future Z-factory experiments (e.g. FCC-ee) have been pointed out as ideal candidates to probe well below the bounds we provide for these channels!

(L. Allwicher, G. Isidori and M. Pesut, 2503.17019)

Conclusions

❖ The hypothesis of **third-generation NP with an approximate $U(2)^5$ global flavor symmetry** performs very well in explaining the **hints/deviations in several flavor observables** while **respecting the bounds from current data**.

❖ The bounds obtained on the quark- and lepton-mixing parameters can be used to **constrain a wide class of NP models** addressing the **flavor structure of the SM** while resolving **tensions in flavor observables**.

❖ Our results show that, if there is heavy NP responsible for the deviations, **cLFV processes can provide complementary probes** of the underlying BSM dynamics.

❖ The **breaking of $U(2)_\ell$ can be as big as $|V_{ts}|$**, giving experimental signatures in a variety of channels lying about one order of magnitude away from current bounds, like **LFV τ-decays** or even $B_s \to \phi\mu\tau$.

Experimental sensitivities in the near future will be able to reach the predicted BRs on these classes of observables!

The End

Thank You!

Backup

Main Inputs

Input Parameter	Value
$\mathcal{B}(B_s \to \mu\mu)_{\text{SM}}$	$(3.64 \pm 0.12) \times 10^{-9}$
$R_K[0.1, 1.1]_{\text{SM}}$	0.99 ± 0.01
$R_K[1.1, 6]_{\text{SM}}$	1.00 ± 0.01
$R_K[14.3, 22.9]_{\text{SM}}$	1.00 ± 0.01
$R_{K^*}[0.1, 1.1]_{\text{SM}}$	0.983 ± 0.014
$R_{K^*}[1.1, 6]_{\text{SM}}$	1.00 ± 0.01
A	0.816 ± 0.017
λ	0.2251 ± 0.0008
$\bar{\rho}$	0.144 ± 0.016
$\bar{\eta}$	0.343 ± 0.012

RG Evolution and Matching: Shortcomings

$$L_i(\mu_{\text{low}}) = L_i^{(\text{SM})}(\mu_{\text{low}}) + \mathcal{U}_{ij}(\mu_{\text{low}}, \mu_m, \Lambda_{\text{NP}})\, C_j(\Lambda_{\text{NP}})$$

$$L_i^{(\text{SM})} = U_{ik}^L(\mu_{\text{low}}, \mu_m)\, L_k^{(\text{SM})}(\mu_m)$$

$$\mathcal{U}_{ij} = U_{ik}^L(\mu_{\text{low}}, \mu_m)\, M_{kl}(\mu_m)\, U_{lj}^C(\Lambda_{\text{EW}}, \Lambda_{\text{NP}})$$

For the RGE matrices, we use the one-loop running (LL resummation)

We use the one-loop matching for this matrix.

<u>This setup incurs in a few simplifications/shortcomings:</u>

- ❖ No true NLL precision (missing **two-loop RGE**). ← Soon to be implemented in DsixTools!
- ❖ We use mostly tree-level observables, which is only LL precision (**except if dipole-dominated**).
- ❖ Neglects higher-dimension contributions to the SM matching. ← Can be easily included!