Constraints on lepton-flavor mixing for third-generation new physics

Arianna Tinari (University of Zürich)
arianna.tinari@physik.uzh.ch

Based on 2511.15800, with Sebastiano Covone and Pol Morell

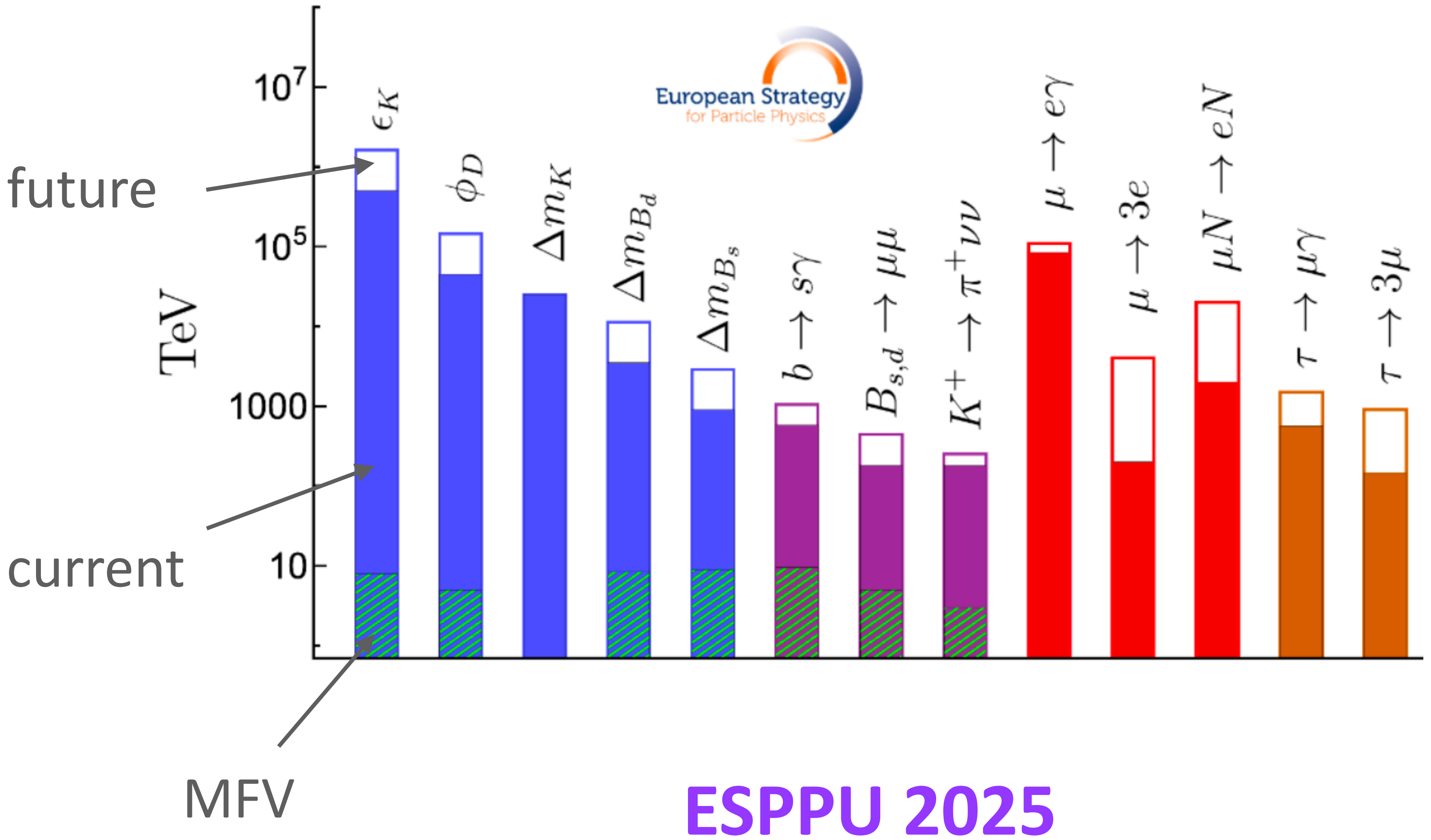
MITP July 2026 - Flavorful Opportunities in Semileptonic B Decays: Connecting Theory and Experiment

Universität Zürich UZH

Flavor structure of new physics

$$\mathscr{L}_{\rm SM} \supset \boxed{-\mu^2|H|^2 + \lambda|H|^4}$$

Higgs hierarchy problem ➔ **New physics at the TeV scale**



ESPPU 2025

- Data impose **stringent constraints** on BSM models addressing the hierarchy problem.
- Unless new physics has a specific flavor structure, the effective new scale would be higher than TeVs.
- TeV new physics must have ≈ **flavor-conserving** interactions.

Motivation for third-generation new physics

Strongest bounds on flavor-changing processes involving light families!

→ <u>If new physics is at the TeV scale, it must have:</u>

- ✦ Predominant couplings to **third-generation fermions,**
- ✦ Have **weaker and** $\sim$ **flavor-universal** interactions with light families

→ compatible with current data on **direct searches, EWPOs and flavor observables**

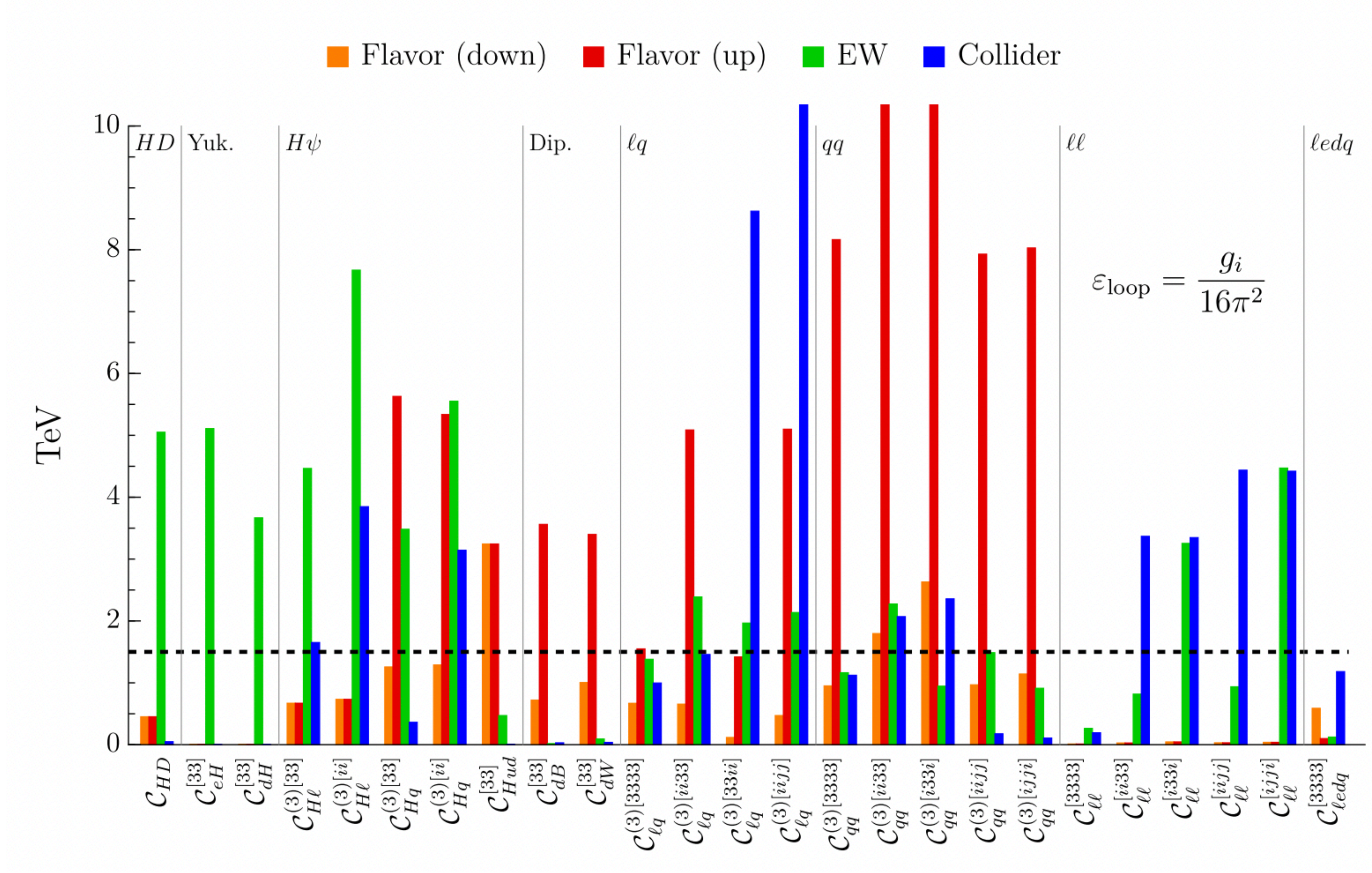
→ $\boxed{\text{Approximate } U(2)^5 \text{ flavor symmetry + NP mainly coupled to 3rd gen}}$

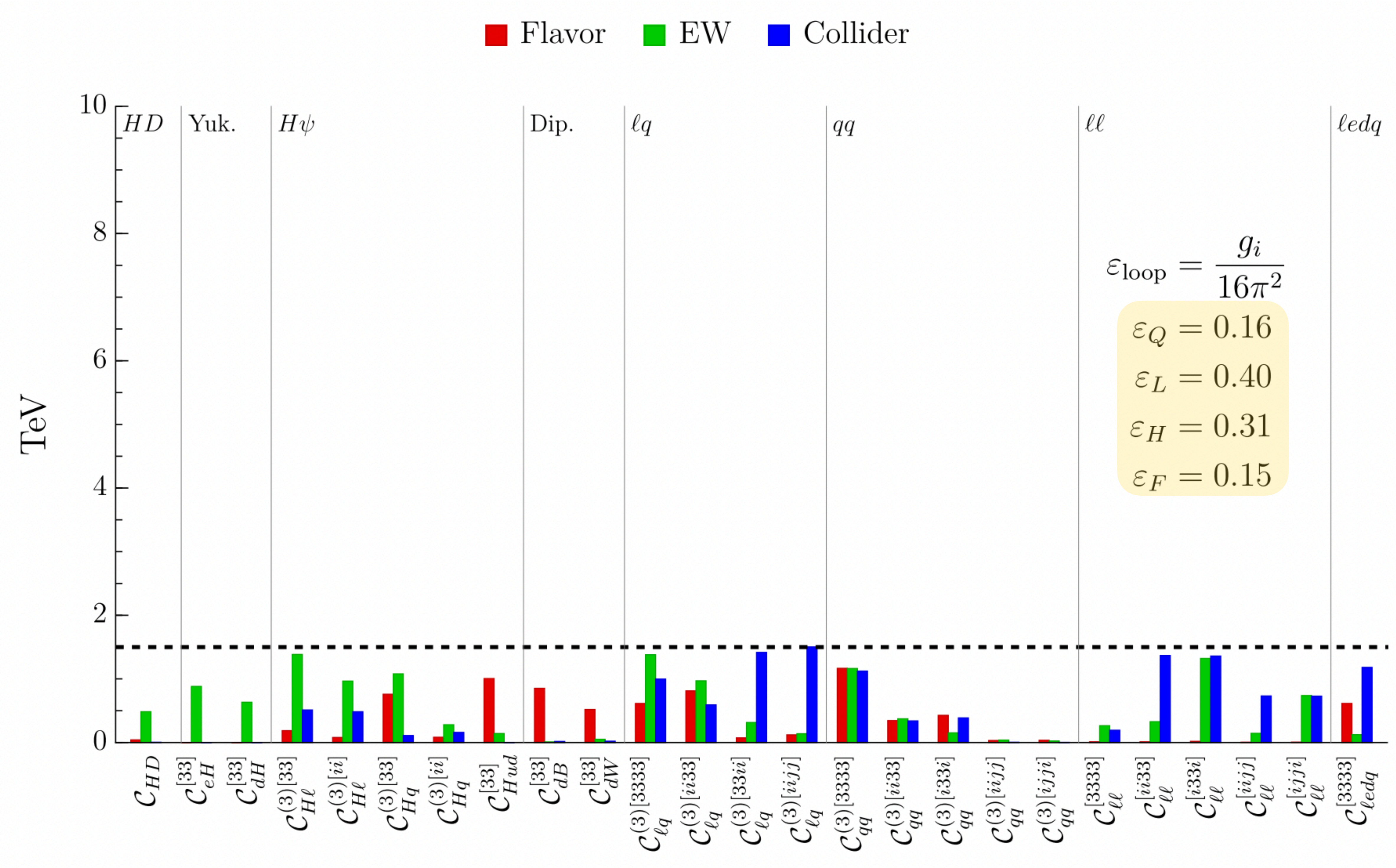
↓

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

Motivation for third-generation new physics

$\boxed{\approx U(2)^5 \text{ flavor symmetry + NP mainly coupled to 3rd gen}}$ → compatible with current data on **direct searches, EWPOs and flavor observables**





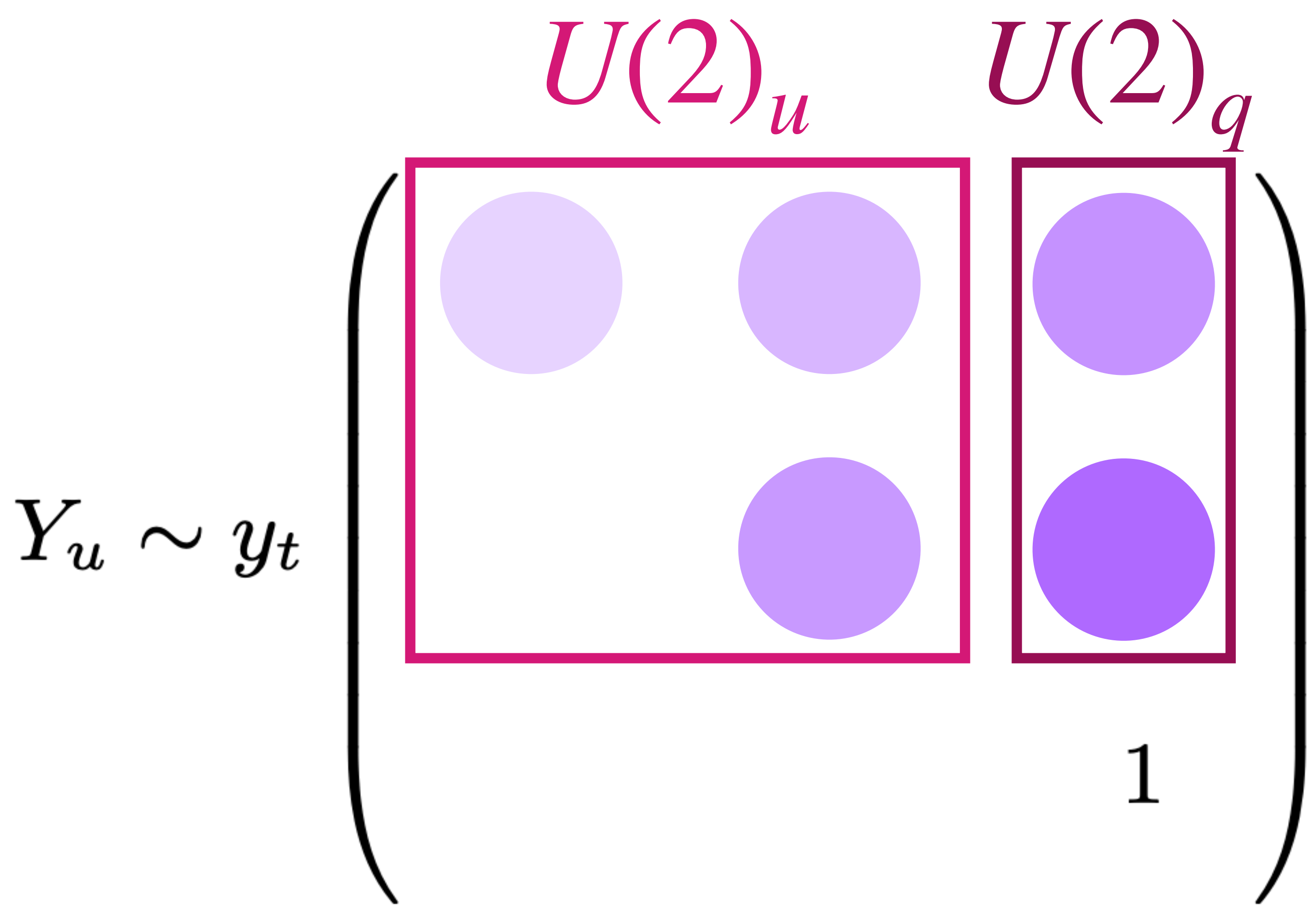
SMEFT analysis of new physics in the third generation: Allwicher, Cornella, Isidori, Stefanek, 2311.00020

$U(2)^5$ flavor symmetry

- The SM interactions respect a $U(3)^5 = U(3)_q \times U(3)_\ell \times U(3)_u \times U(3)_d \times U(3)_e$ global flavor symmetry by which each fermion generation is indistinguishable, **except for the Yukawa sector.**

→ However, the **smaller symmetry** $U(2)^5 = U(2)_q \times U(2)_\ell \times U(2)_u \times U(2)_d \times U(2)_e$ is approximately **respected by the Yukawa sector**

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



Barbieri, Isidori, Jonez-Perez, Lodone, Straub 1105.2296

$U(2)^5$ flavor symmetry

- $U(2)^5$ flavor symmetry:

  - Way to evade experimental bounds to have new physics at the TeV scale

  - Interesting hypothesis for addressing the **flavor problem**: there's an **approximate $U(2)^5$ symmetry in the SM Yukawas**

  - It is easily generated in many BSM models (supersymmetry, composite models, **flavor-non-universal gauge interactions**…).

→ Impose $\mathbf{U(2)^5 = U(2)_q \times U(2)_u \times U(2)_d \times U(2)_\ell \times U(2)_e}$, under which the light generations form doublets, the third generation a singlet.

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Breaking of $U(2)^5$

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

- The breaking is described by introducing (small) **spurion terms** with well-defined transformation properties under the flavor symmetry.

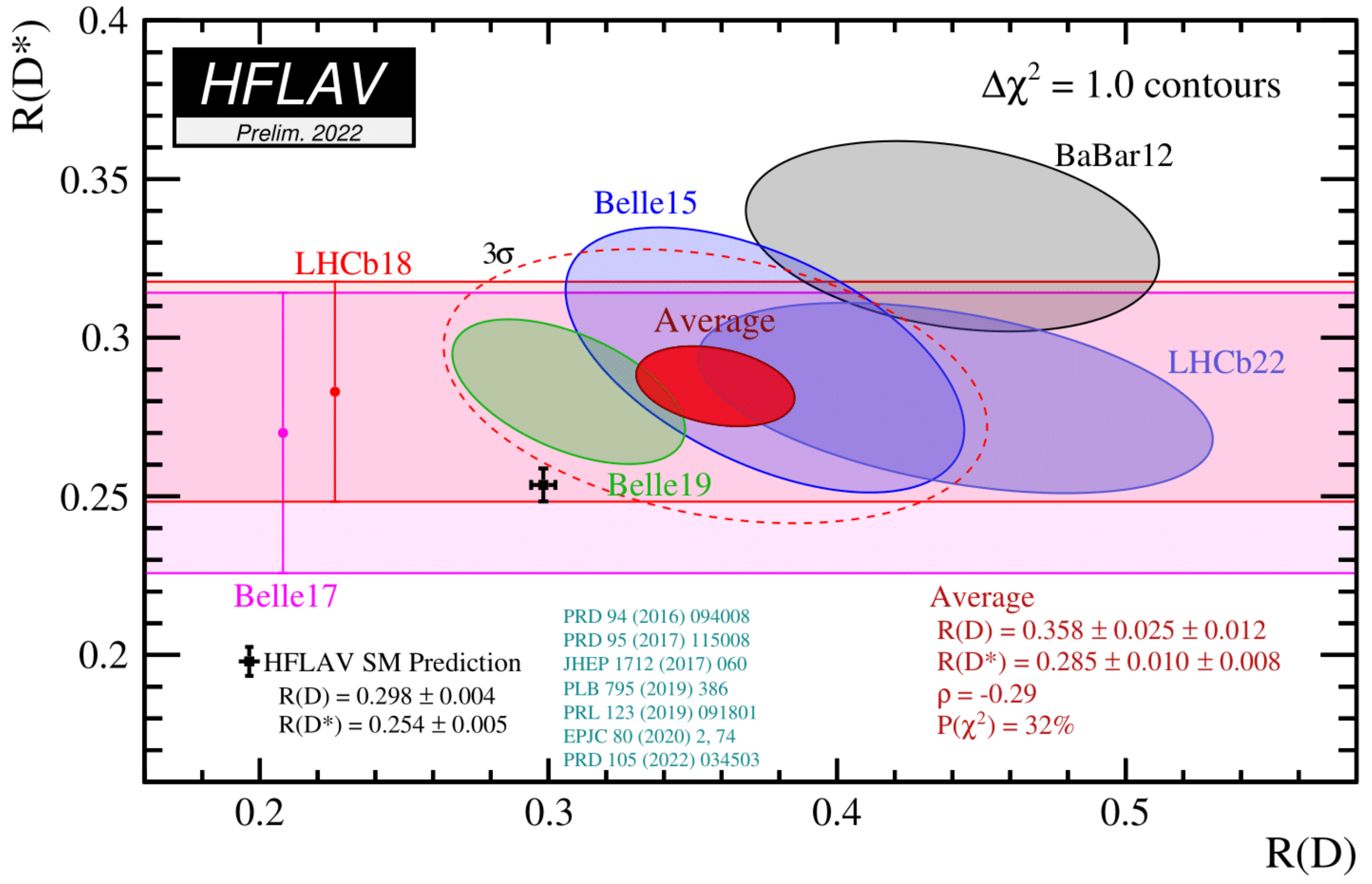
$$V_q \sim (2,1,1,1,1),\, \Delta_u \sim (2,1,\bar{2},1,1),\, \Delta_d \sim (2,1,1,\bar{2},1),\, V_\ell \sim (2,1,1,1,1),\, \Delta_e \sim (2,1,1,1,\bar{2})$$

$$\rightarrow \quad Y_u = y_t \begin{pmatrix} \Delta_u & V_q \\ 0 & 1 \end{pmatrix}$$

(V_ℓ is not strictly necessary in absence of neutrino masses!)

Tension in flavor observables

- Hints of the $U(2)_q$ breaking also come from a series of **deviations from the SM predictions** observed in **rare and semi-leptonic B decays:**



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

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

- $K \to \pi\bar{\nu}\nu$: $\mathscr{B}(K^+ \to \pi^+\bar{\nu}\nu)^{SM} = (8.09 \pm 0.63) \times 10^{-11}$
  (NA62) $\mathscr{B}(K^+ \to \pi^+\bar{\nu}\nu) = (13.0^{+3.3}_{-2.9}) \times 10^{-11}$ $\rightarrow$ $\mathscr{B}(K^+ \to \pi^+\bar{\nu}\nu) = (9.6^{+1.9}_{-1.9}) \times 10^{-11}$
  (new result)

- Simultaneous explanation of the anomalies with NP in **left-handed semi-leptonic operators**.

$U(2)^5$ flavor symmetry and fit to data

Allwicher, Bordone, Isidori, Piazza, Stanzione 2410.21444

- A simultaneous explanation of the anomalies with NP in **left-handed semi-leptonic operators** is provided by Allwicher et al.
- This hypothesis passes all constraints from EWPOs and direct searches
- Their hypothesis:
  - TeV-scale new physics in semi-leptonic operators
  - NP coupled mainly to 3rd-generation fermions
  - NP respecting an approximate $U(2)^5$ flavor symmetry, broken only in the $U(2)_q$ direction by V_q.

$$V_q = -\varepsilon V_{ts} \begin{pmatrix} \kappa V_{td}/V_{ts} \\ 1 \end{pmatrix}$$

ε: size of the spurion

$\kappa = 1$: minimal breaking of $U(2)$

Relevant SMEFT operators

Allwicher, Bordone, Isidori, Piazza, Stanzione 2410.21444

- With these assumptions, great **reduction** of number of free parameters in SMEFT.
- Only **three SMEFT operators** become relevant:

$$
\left.\begin{aligned}
\left[O_{lq}^{(1)}\right]_{3333} &= (\bar{L}_3\gamma^\mu L_3)(\bar{Q}_3\gamma_\mu Q_3) \\
\left[O_{lq}^{(3)}\right]_{3333} &= (\bar{L}_3\gamma^\mu\tau^I L_3)(\bar{Q}_3\tau^I\gamma_\mu Q_3)
\end{aligned}\right\}
\quad Q_{\ell q}^{\pm} = (\bar{q}_L^3\gamma^\mu q_L^3)(\bar{\ell}_L^3\gamma_\mu\ell_L^3) \pm (\bar{q}_L^3\gamma^\mu\sigma^a q_L^3)(\bar{\ell}_L^3\gamma_\mu\sigma^a\ell_L^3)
$$

$$
O_S = (\bar{l}_L^3\tau_R)(\bar{b}_R q_L^3)
$$

- Ambiguity on $U(2)_Q$ singlets → Down-aligned quark doublet: $q_L^3 = \begin{pmatrix} V_{ub}u_L + V_{cb}c_L + V_{tb}t_L \\ b_L \end{pmatrix}$
- Assume **NP rank-one structure** in quark-flavor space: NP is aligned to a specific direction in flavor space and the insertion of the spurion describes the misalignment of this direction with respect to q_L^3.
- The EFT framework is described by **5 independent parameters**: $\epsilon, \kappa, C_S, C_+, C_-$

Observables

Allwicher, Bordone, Isidori, Piazza, Stanzione 2410.21444

- Implications of $U(2)_q$ breaking assumptions:

$$V_q = -\varepsilon V_{ts} \begin{pmatrix} \kappa V_{td}/V_{ts} \\ 1 \end{pmatrix}$$

ε: size of the spurion

$\kappa = 1$: minimal breaking of $U(2)$

$$\frac{R_{D^{(*)}}}{R^{\text{SM}}_{D^{(*)}}} \approx 1 - v^2 (1+\varepsilon) \left(C^+_{\ell q} - C^-_{\ell q} \right)$$

$$B \to K\bar{\nu}\nu : \ |C^{\text{SM}}_{\tau,bs}| \to \left| C^{\text{SM}}_{\tau,bs} - \varepsilon \frac{\pi v^2}{\alpha} C^-_{\ell q} \right| ,$$

$$K \to \pi\bar{\nu}\nu : \ |C^{\text{SM}}_{\tau,sd}| \to \left| C^{\text{SM}}_{\tau,sd} + \kappa\varepsilon^2 \frac{\pi v^2}{\alpha} C^-_{\ell q} \right|$$

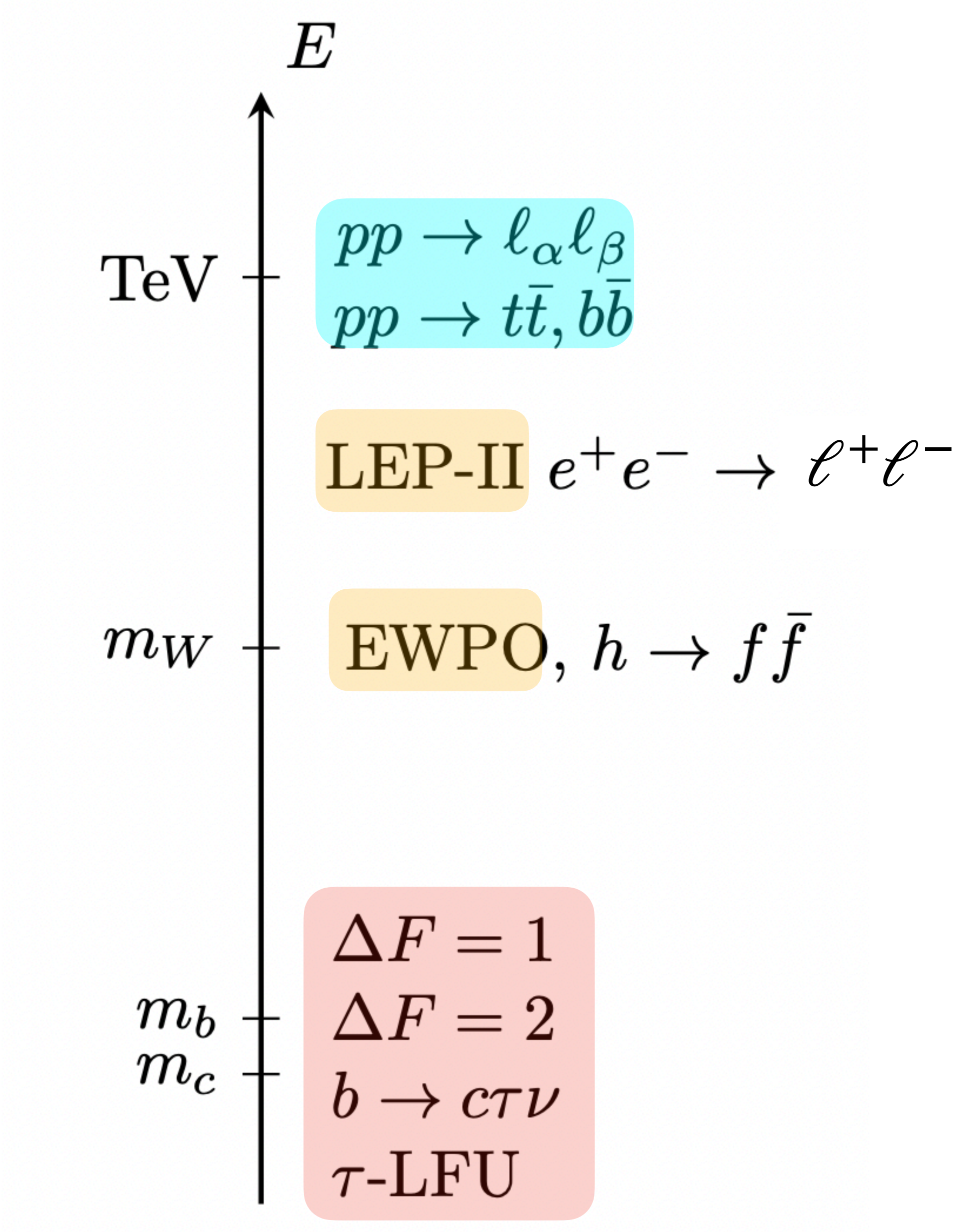
$b \to s\bar{\ell}\ell$ comes from the QED running of

$$(\bar{b}_L \gamma^\mu s_L)(\bar{\tau}_L \gamma_\mu \tau_L)$$

Set of observables and fit results

Allwicher, Bordone, Isidori, Piazza, Stanzione 2410.21444

Observables at different energy scales:



	C_S	$C^+_{\ell q}$	$C^-_{\ell q}$	ε	κ	Exp. indication
$\sigma(pp \to \ell\ell)$	✓	✓	✓			bounds on $\mathcal{A}_{\rm NP}$
EWPO		✓	✓			bounds on $\mathcal{A}_{\rm NP}$
R_D, R_{D^*}	✓	✓	✓	✓		$\mathcal{A}_{\rm NP}/\mathcal{A}_{\rm SM} > 0$
$\mathcal{B}(B \to K^{(*)}\mu\bar{\mu})$		✓		✓		$\mathcal{A}_{\rm NP}/\mathcal{A}_{\rm SM} < 0$
$\mathcal{B}(B \to K\nu\bar{\nu})$			✓	✓		$\lvert\mathcal{A}_{\rm SM} + \mathcal{A}_{\rm NP}\rvert^2 > \lvert\mathcal{A}_{\rm SM}\rvert^2$
$\mathcal{B}(K \to \pi\nu\bar{\nu})$			✓		✓	$\lvert\mathcal{A}_{\rm SM} + \mathcal{A}_{\rm NP}\rvert^2 > \lvert\mathcal{A}_{\rm SM}\rvert^2$

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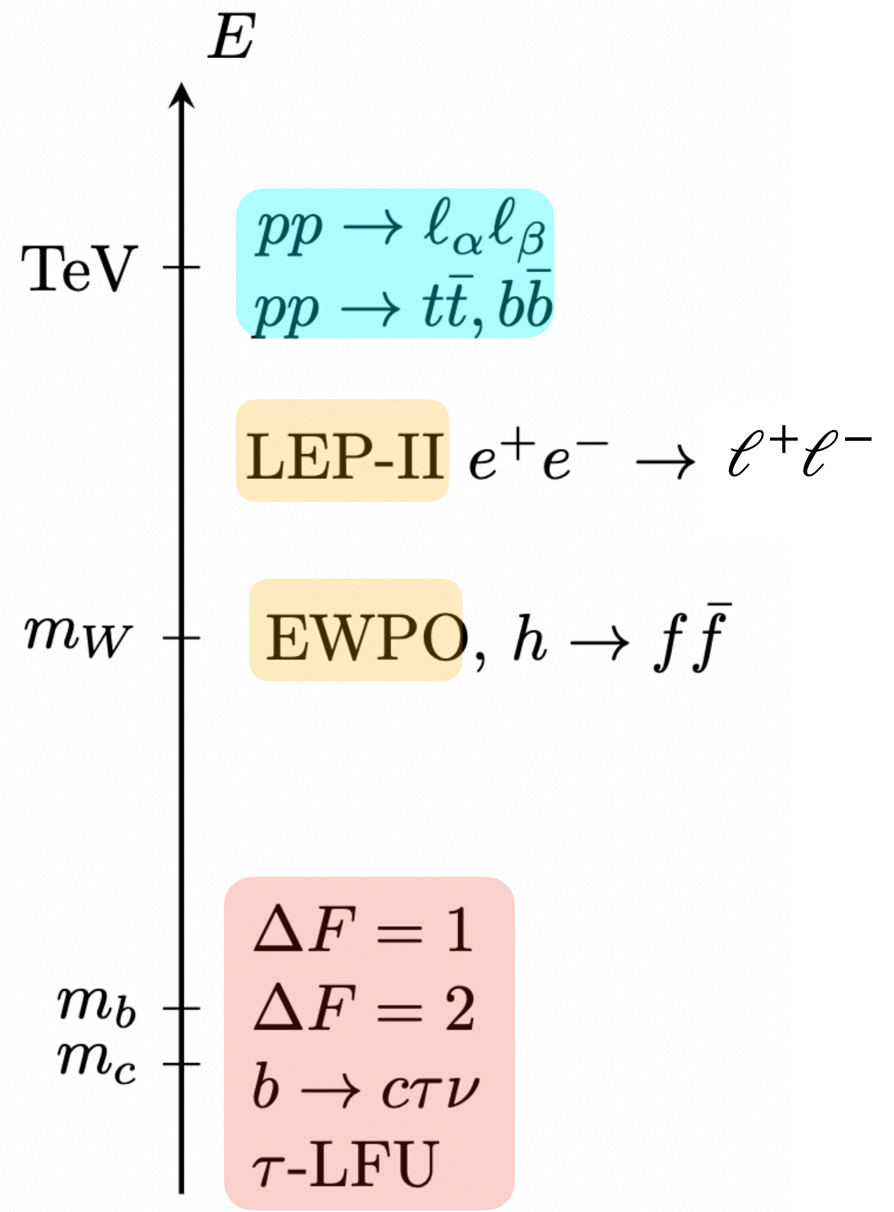

	C_S	$C^+_{\ell q}$	$C^-_{\ell q}$	ε	κ	Exp. indication
$\sigma(pp \to \ell\ell)$	✓	✓	✓			bounds on $\mathcal{A}_{\rm NP}$
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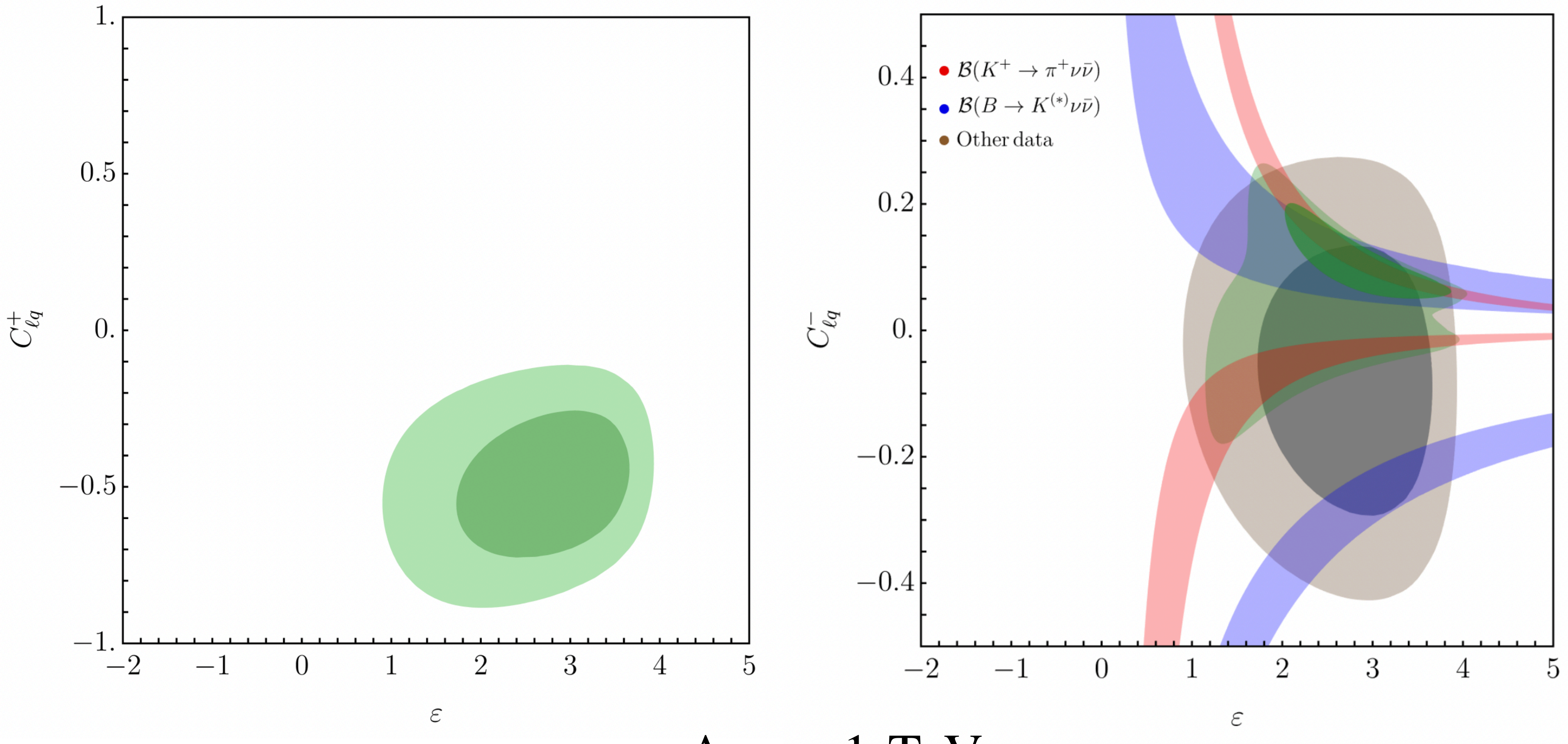
R_D, R_{D^*}	✓	✓	✓	✓		$\mathcal{A}_{\rm NP}/\mathcal{A}_{\rm SM} > 0$
$\mathcal{B}(B \to K^{(*)}\mu\bar{\mu})$		✓		✓		$\mathcal{A}_{\rm NP}/\mathcal{A}_{\rm SM} < 0$
$\mathcal{B}(B \to K\nu\bar{\nu})$			✓	✓		$\lvert\mathcal{A}_{\rm SM} + \mathcal{A}_{\rm NP}\rvert^2 > \lvert\mathcal{A}_{\rm SM}\rvert^2$
$\mathcal{B}(K \to \pi\nu\bar{\nu})$			✓		✓	$\lvert\mathcal{A}_{\rm SM} + \mathcal{A}_{\rm NP}\rvert^2 > \lvert\mathcal{A}_{\rm SM}\rvert^2$

→ **Results of the fit:**

$\kappa \sim 1$ (minimal breaking)

$$C_S \sim 0$$

$$C_+, \varepsilon \neq 0$$



$\Lambda_{\rm NP} = 1$ TeV

Set of observables and fit results

Allwicher, Bordone, Isidori, Piazza, Stanzione 2410.21444

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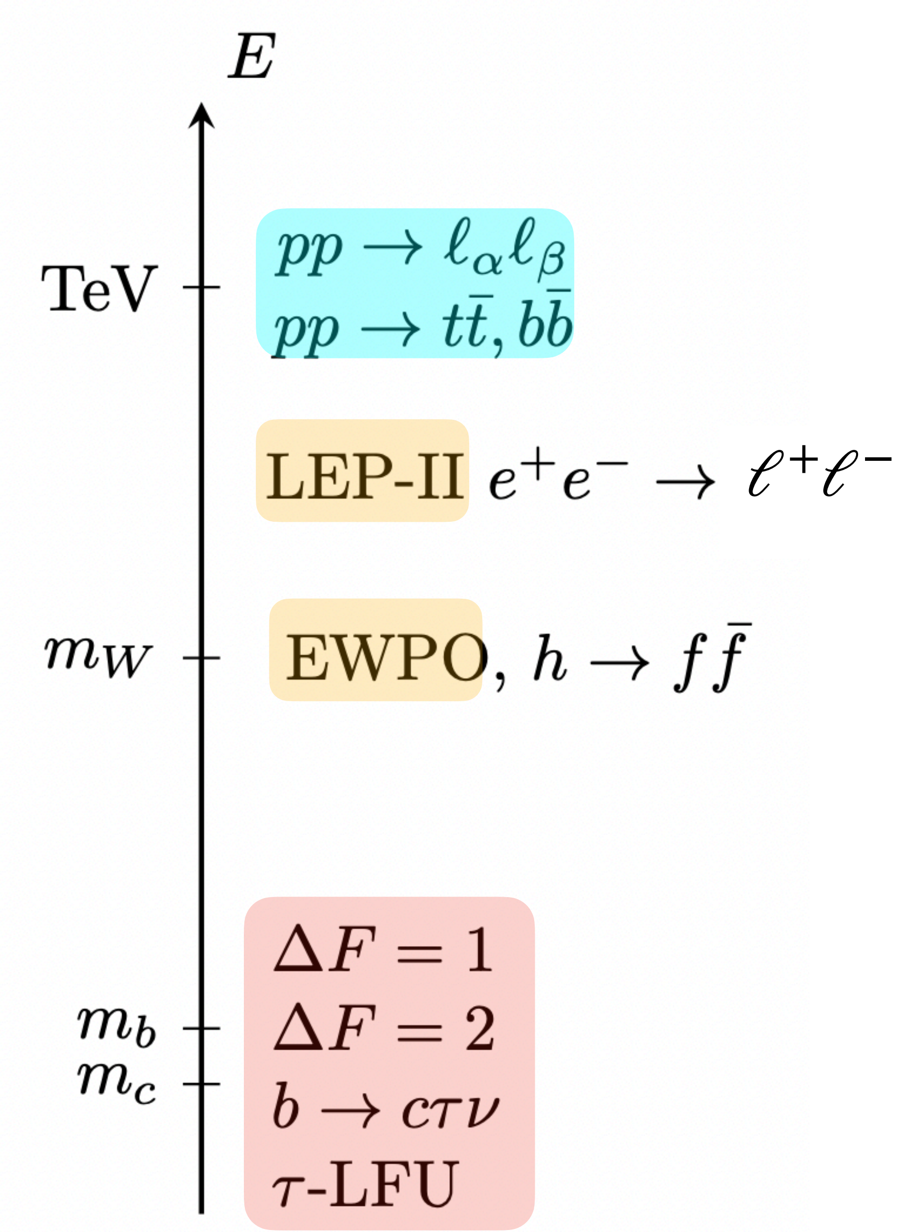

	C_S	$C^+_{\ell q}$	$C^-_{\ell q}$	ε	κ	Exp. indication
$\sigma(pp \to \ell\ell)$	✓	✓	✓			bounds on $\mathcal{A}_{\rm NP}$
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R_D, R_{D^*}	✓	✓	✓	✓		$\mathcal{A}_{\rm NP}/\mathcal{A}_{\rm SM} > 0$
$\mathcal{B}(B \to K^{(*)}\mu\bar{\mu})$		✓		✓		$\mathcal{A}_{\rm NP}/\mathcal{A}_{\rm SM} < 0$
$\mathcal{B}(B \to K\nu\bar{\nu})$			✓	✓		$\lvert\mathcal{A}_{\rm SM} + \mathcal{A}_{\rm NP}\rvert^2 > \lvert\mathcal{A}_{\rm SM}\rvert^2$
$\mathcal{B}(K \to \pi\nu\bar{\nu})$			✓		✓	$\lvert\mathcal{A}_{\rm SM} + \mathcal{A}_{\rm NP}\rvert^2 > \lvert\mathcal{A}_{\rm SM}\rvert^2$

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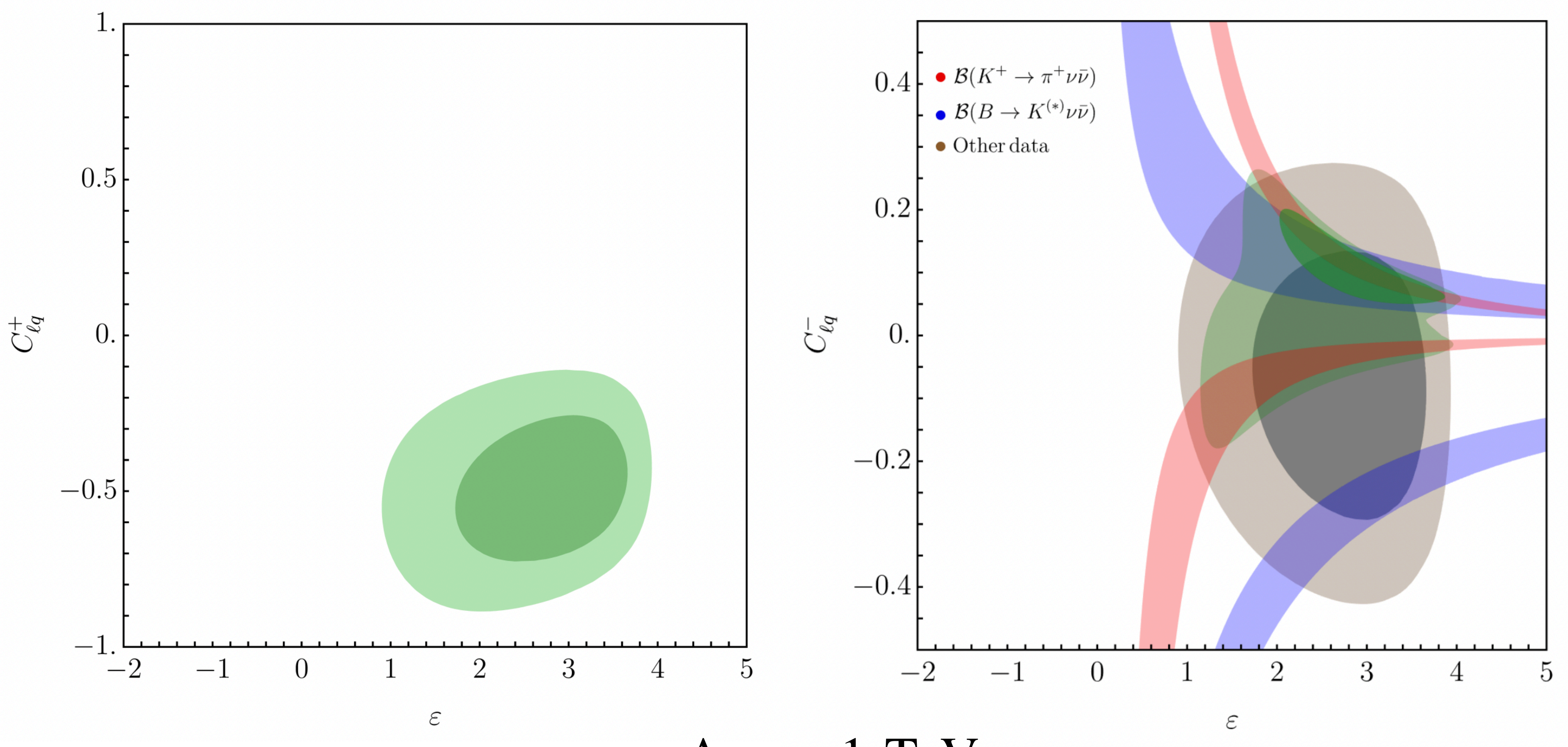

$\Lambda_{\rm NP} = 1$ TeV

- All data can be explained by **one effective operator (Q^+),** with an alignment in flavor space following from the hypothesis of a **minimally broken $U(2)_q$ flavor symmetry.**
- In this framework we can explain the **di-neutrino modes $B \to K\nu\nu$, $K \to \pi\nu\nu$** and other hints of deviations such as **$R_{D^{(*)}}$ and $b \to s\bar{\ell}\ell$**, while being compatible with bounds from **EW and direct searches**.

Extension to the lepton sector

S. Covone, P. Morell, AT, 2511.15800

✦ How large can the breaking of $U(2)$ in the **lepton sector** be?

Extension to the lepton sector

S. Covone, P. Morell,
AT, 2511.15800

✦ How large can the breaking of $U(2)$ in the **lepton sector** be?

✦ The situation in the lepton sector is less clear, given that V_ℓ isn't strictly necessary to reproduce the fermion masses and mixing of the SM

✦ **Does current data allow for the breaking of $U(2)_\ell$? How large can the breaking be?**

✦ **We build upon the previous work, extending their SMEFT framework:**

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

Extension to the lepton sector

S. Covone, P. Morell, AT, 2511.15800

- How large can the breaking of $U(2)$ in the lepton sector be?

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- **We build upon the previous work, extending their SMEFT framework:**

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

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

Extension to the lepton sector

S. Covone, P. Morell, AT, 2511.15800

- How large can the breaking of $U(2)$ in the lepton sector be?
- Introduce **spurion** term breaking $U(2)_\ell$:

$$\tilde{V}_q^i = \begin{pmatrix} -\varepsilon V_{td} \\ -\varepsilon V_{ts} \end{pmatrix}, \qquad \tilde{V}_\ell^\alpha = \begin{pmatrix} 0 \\ \delta \end{pmatrix}$$

δ controls the mixing between 2nd- and 3rd-gen LH leptons

We restrict our analysis to the mixing between 3rd and 2nd

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

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

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

Extension to the lepton sector

- Additional hypothesis of a **rank-one structur**e in the NP: the NP is coupled to the third generation, and all flavor misalignment from there stems from the spurious alone!

- **Down alignment**, to be consistent with 2410.21444 + conservative constraints

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.

The EFT framework is described by 4 **independent parameters**: $\epsilon, C_+, C_-, \delta$,

RGE and matching

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

$$\vec{C}(\Lambda_{\mathrm{NP}}) \underset{\mathrm{RGE}}{\longleftrightarrow} \vec{C}(\Lambda_{\mathrm{EW}}) \underset{\mathrm{matching}}{\longleftrightarrow} \vec{L}(\Lambda_{\mathrm{EW}}) \underset{\mathrm{RGE}}{\longleftrightarrow} \vec{L}(m_b)$$

- We use a matrix approach (given that double insertions are negligible in out setup)

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

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

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 → we obtain analytical expressions for the low-energy observables in terms of our four parameters

Observables considered to constrain lepton mixing

- SMEFT framework described by $C_+, C_-, \varepsilon, \delta$

- We are interested in fitting δ, using the likelihood of the previous fit on the other parameters.

	Observable	Experimental Bound/Measurement
LFV: 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: LFV quarkonium 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: LFV B decays	$\mathcal{B}(B_s \to \mu\tau)$	$< 4.2 \times 10^{-5}$
	$\mathcal{B}(B \to K\mu\tau)$	$< 4.1 \times 10^{-5}$
	$\mathcal{B}(B \to K^*\mu\tau)$	$< 2.2 \times 10^{-5}$
	$\mathcal{B}(B_s \to \phi\mu\tau)$	$< 1.3 \times 10^{-5}$
	$\mathcal{B}(B_s \to \tau\tau)$	$< 6.8 \times 10^{-3}$
	$\mathcal{B}(B_s \to \mu\mu)$	$(3.34 \pm 0.27) \times 10^{-9}$
LFU	$R_K[0.1, 1.1]$	$0.994^{+0.090}_{-0.082}$ (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)
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Transition	SMEFT Scaling	LEFT Scaling
$b \to s\tau\tau$	$C^+_{\ell q}\, V_{ts}\, \epsilon$	$C^+_{\ell q}\, V_{ts}\, \epsilon$
$b \to s\mu\mu$	$C^+_{\ell q}\, V_{ts}\, \epsilon\, c_e^2\, \delta^2$	$C^+_{\ell q}\, V_{ts}\, \epsilon\, (0.005 - c_e^2\, \delta^2)$
$b \to see$	$C^+_{\ell q}\, V_{ts}\, \epsilon\, s_e^2\, \delta^2$	$C^+_{\ell q}\, V_{ts}\, \epsilon\, (0.005 - s_e^2\, \delta^2)$
$b \to s\tau\mu$	$C^+_{\ell q}\, V_{ts}\, \epsilon\, c_e\, \delta$	$C^+_{\ell q}\, V_{ts}\, \epsilon\, c_e\, \delta$
$b\bar{b} \to \tau\mu$	$C^+_{\ell q}\, c_e\, \delta$	$(C^+_{\ell q} + 0.05\, C^-_{\ell q})\, c_e\, \delta$
$c\bar{c} \to \tau\mu$	$C^-_{\ell q}\, \lvert V_{ts}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$
$\tau \to \mu ss$	$C^+_{\ell q}\, \lvert V_{ts}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$
$\tau \to \mu dd$	$C^+_{\ell q}\, \lvert V_{td}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$
$\tau \to \mu uu$	$C^-_{\ell q}\, \lvert V_{td}\rvert^2 \epsilon^2\, c_e\, \delta$	$(C^+_{\ell q} - 0.7\, C^-_{\ell q})\, c_e\, \delta$

$$\tilde{V}^{\alpha}_{\ell} = \begin{pmatrix} \delta \sin\theta_e \\ \delta \cos\theta_e \end{pmatrix}$$

S. Covone, P. Morell, AT, 2511.15800

Results on lepton-flavor mixing parameter

S. Covone, P. Morell, AT,
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✦ We clearly identify R_K, R_{K^*}, and $B_s \to \mu\mu$ as the observables imposing the **strongest constraints** on δ

Observable	Experimental Bound/Measurement
$\mathcal{B}(\tau \to \mu\gamma)$	$< 5.6 \times 10^{-8}$
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$\mathcal{B}(\tau \to \mu\rho)$	$< 1.6 \times 10^{-8}$
$\mathcal{B}(\tau \to \mu\phi)$	$< 2.9 \times 10^{-8}$
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$\mathcal{B}(\Upsilon \to \mu\tau)$	$< 3.6 \times 10^{-6}$
$\mathcal{B}(B_s \to \mu\tau)$	$< 4.2 \times 10^{-5}$
$\mathcal{B}(B \to K\mu\tau)$	$< 4.1 \times 10^{-5}$
$\mathcal{B}(B \to K^*\mu\tau)$	$< 2.2 \times 10^{-5}$
$\mathcal{B}(B_s \to \phi\mu\tau)$	$< 1.3 \times 10^{-5}$
$\mathcal{B}(B_s \to \tau\tau)$	$< 6.8 \times 10^{-3}$
$\mathcal{B}(B_s \to \mu\mu)$	$(3.34 \pm 0.27) \times 10^{-9}$
$R_K[0.1, 1.1]$	$0.994^{+0.090}_{-0.082}$ (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)
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$$|\delta| < 0.051 \quad \text{(at 95\% CL)}$$

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

✳ $|\tilde{V}_\ell| \sim |V_{ts}|$, which is the natural size of the $U(2)_q$-breaking spurion inferred from quark Yukawa couplings

✳ $|\tilde{V}_\ell|/|\tilde{V}_q| < 0.69 \quad$ (at 95% CL)

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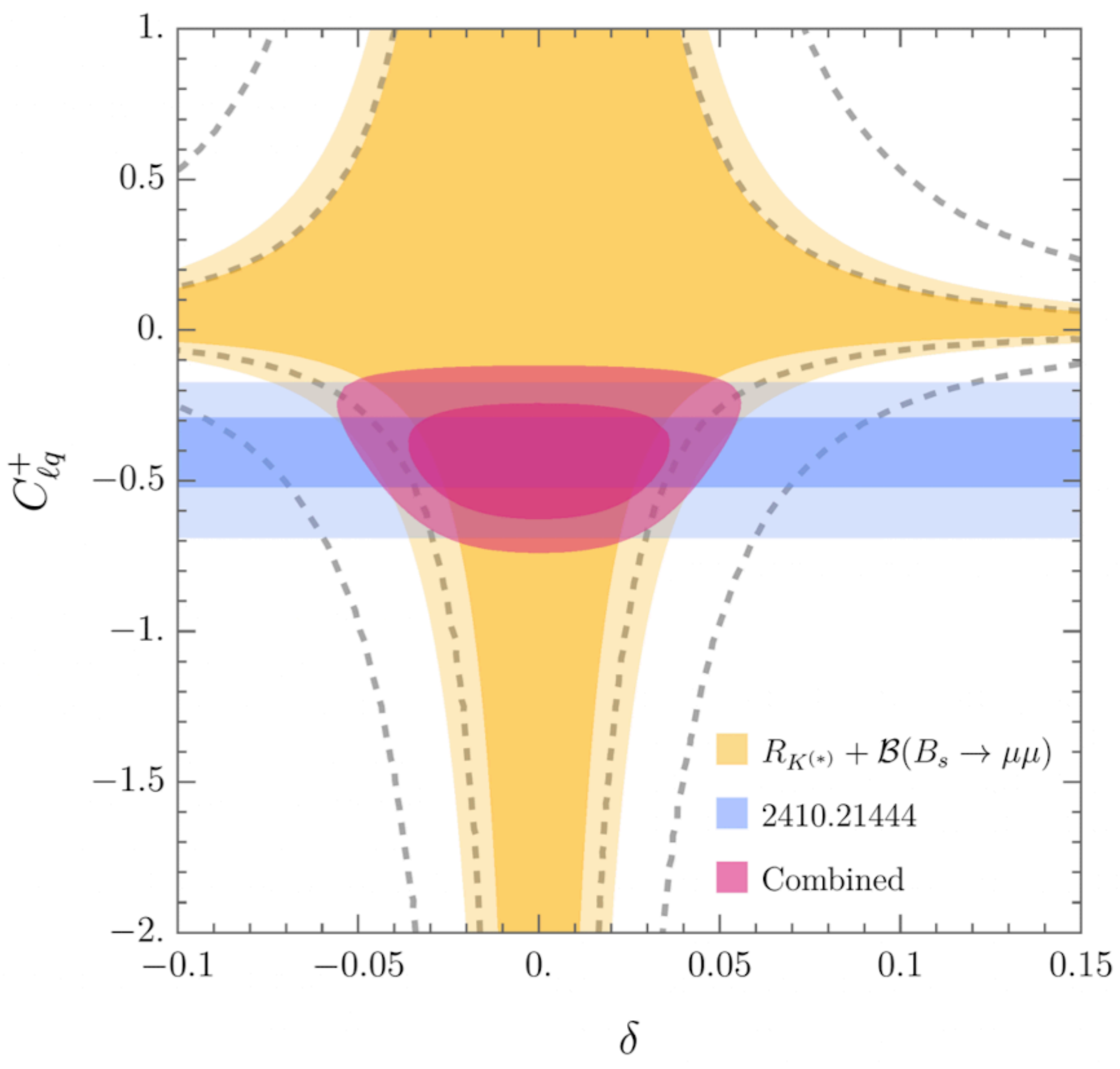

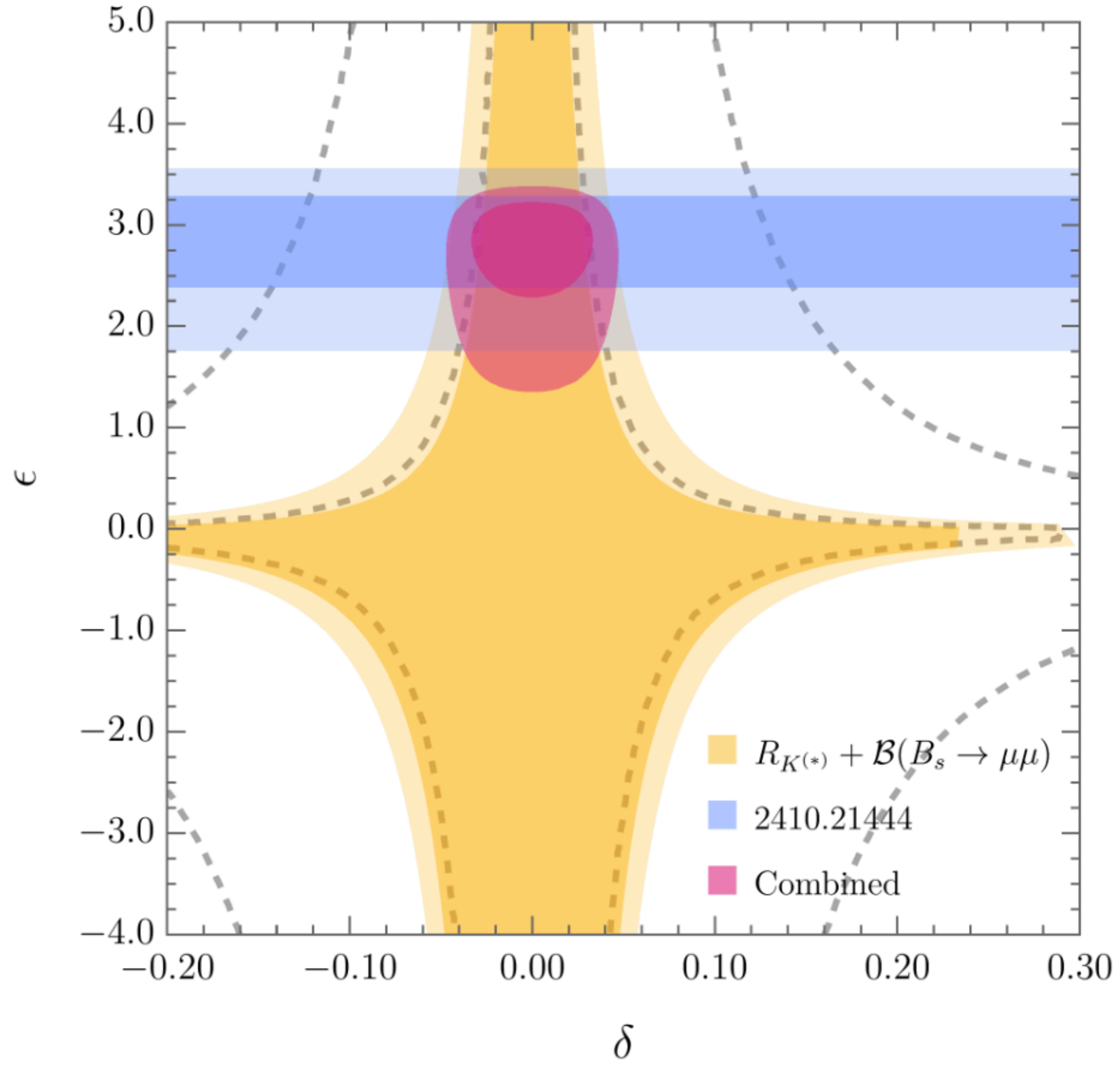

Bounds on LFV observables and future sensitivity

S. Covone, P. Morell, AT, 2511.15800

- We can now provide bounds on LFV decays:

Observable	Prediction	Current Bound
$\mathcal{B}(\tau \to \mu\gamma)$	$< 8.4 \times 10^{-11}$	$\times 700$
$\mathcal{B}(\tau \to \mu ee)$	$< 7.6 \times 10^{-10}$	$\times 30$
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$\mathcal{B}(B_s \to \phi\mu\tau)$	$< 3.6 \times 10^{-7}$	$\times 40$

ratio between our prediction and current experimental bound

Could become the most constraining observables if Belle II reaches the expected sensitivity:

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

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LFV B decays are somewhere in the middle, with some promising numbers and mixing prospects

Bounds on LFV observables and future sensitivity

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

$$\underbrace{\begin{array}{c} \mathcal{B}(B_s \to \mu\mu) \text{ to } \sim 5\% \text{ precision} \\[1em] R_K^{(*)} \text{ to } \sim 1\% \text{ precision} \end{array}}_{}$$

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

Enhancement in $bs\tau\tau$

S. Covone, P. Morell, AT,
2511.15800

Observable	Prediction	Current Bound
$\mathcal{B}(B_s \to \tau\tau)$	$(8.3^{+12.6}_{-4.1}) \times 10^{-5}$	$\times 25$
$\mathcal{B}(B \to K\tau\tau)^{[15,22]}$	$(1.5^{+2.3}_{-0.7}) \times 10^{-5}$	x40
$\mathcal{B}(B \to K^*\tau\tau)^{[15,19]}$	$(1.3^{+2.0}_{-0.7}) \times 10^{-5}$	x11
$\mathcal{B}(B_s \to \phi\tau\tau)^{[15,18.8]}$	$(1.2^{+1.9}_{-0.6}) \times 10^{-5}$	x6

LHCb 2510.13716,
indirect bounds

These modes have a central role in most frameworks based on NP coupled predominantly to the third generation.

$B_s \to \tau\tau$: prediction 150 times bigger than SM and future sensitivity at LHCb at the end of Upgrade II $\sim$ 4 times smaller

Choosing a q^2-range that avoids the $\psi(2S)$ resonance, **central values enhanced by $\sim$ two order of magnitude** wrt the SM prediction

- The sensitivity expected by LHCb at the end of Upgrade II would fall in a similar ballpark as our predictions
- Future Z-factory experiments, such as FCC-ee, have been pointed out as ideal candidates to probe well below these bounds (see 2503.17019 Allwicher, Isidori, Pesut)

Conclusions

- These bounds 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 also resolving the **tensions in the B-meson channels**.

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

- The **lepton mixing can be as big as $|V_{ts}|$**, giving experimental signatures in a variety of channels that are $O(10)$ away from current bounds, like **LFV τ decays** and $B_s \to \phi\mu\tau$

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Thank you for your attention!