Universität Zürich[UZH]

Flavored Circular Collider: cornering New Physics at FCC-ee via flavor-changing processes

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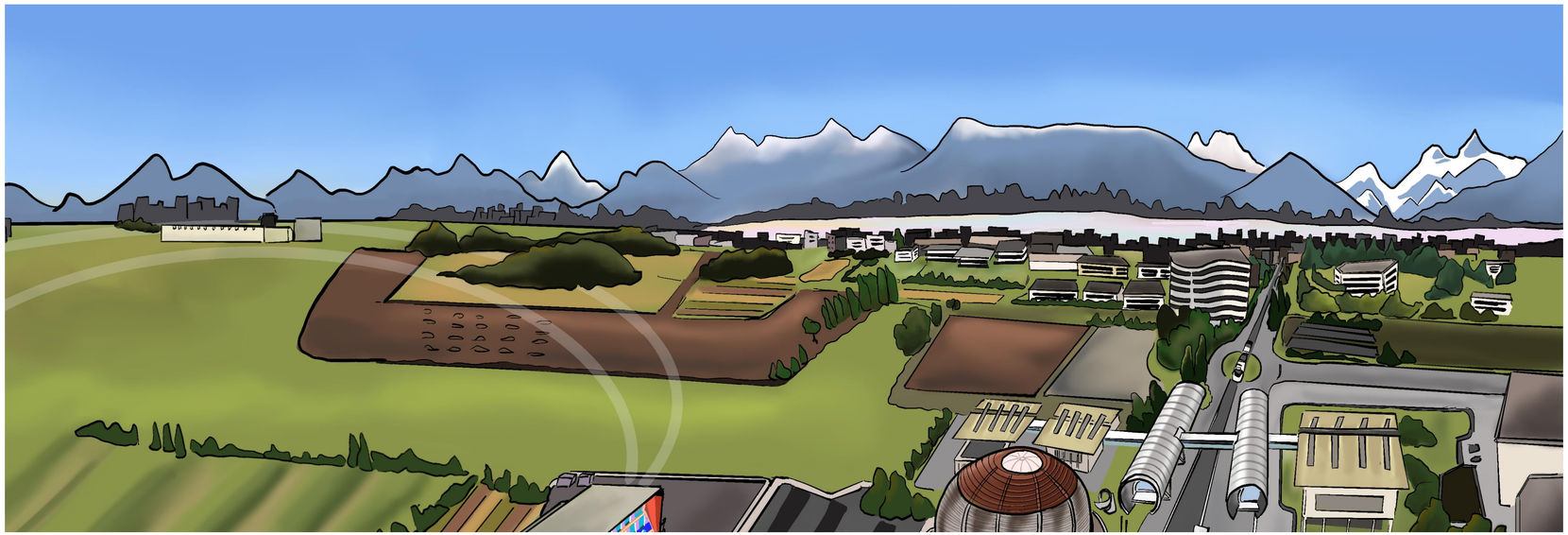

[2503.17019]: Lukas Allwicher (DESY), Gino Isidori (UZH) & M.P (UZH)

Cornering New Physics at FCC-ee via flavor-changing processes

Aim: *illustrate the discovery potential of a high-intensity e^+e^- collider @ Z pole via precision flavour measurements + flavour-EW interplay to constrain TeV-scale BSM models*

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See also Cari's talk

➡ Tremendous improvement in flavour from tera-$\boldsymbol{Z}$ run! Monteil & Wilkinson [2106.01259]

Of the 10^{12} $\boldsymbol{Z}$-bosons produced at tera-$\boldsymbol{Z}$:

- 15% decay to b
- 12% decay to c
- 3% decay to τ

FCC-ee combines advantages of *B* factories and LHC + opens new frontiers

➡ Clean environment + huge statistics + full range of (boosted) *B* mesons

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See also Marzia's theory colloquium talk on Wednesday

Model-Building Motivation:

TeV-scale flavour non-universal NP mainly coupled to 3rd family

- Approximate $U(2)^5$ flavour symmetry (Yukawa + flavour protection vs NP)
- Exp. bounds compatible with TeV-scale NP in 3rd family
- Allows to minimize the hierarchy problem

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Experimental Motivation:

Tensions in semi-leptonic *B* decays

- LFU ratios (R_D and R_{D*}) -> 3σ tension w.r.t the SM
- Enhancement of $B^+ \to K^+\nu\bar{\nu}$ and $K^+ \to \pi^+\nu\bar{\nu}$ w.r.t the SM See also Chang's talk
- Tension in C_9 from $b \to s\ell\bar{\ell}$ -> 2σ tension w.r.t the SM See also Bordone, Cornella & Davighi [2503.22635]

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Precision flavour & EW measurements, via RGE effects, can constrain wide classes of BSM models

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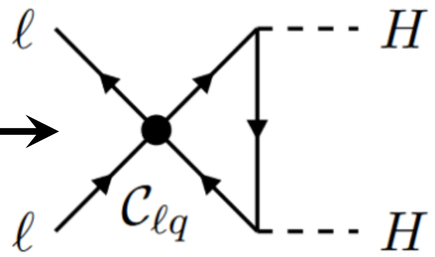
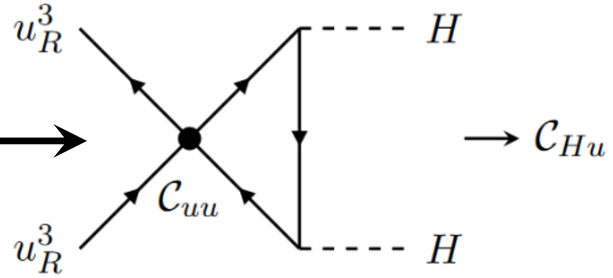
Precision flavour & EW measurements, via RGE effects, can constrain wide classes of BSM models

$$(\bar{\ell}_3\gamma_\mu\ell_3)\,(\bar{q}_3\gamma^\mu q_3)$$

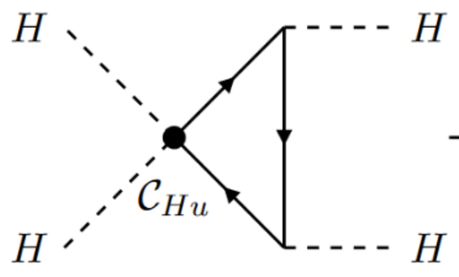


- Particularly relevant if y_t is involved
- Effects e.g. in $Z \to \tau\,\tau$

$$(\bar{t}_R\gamma_\mu t_R)\,(\bar{t}_R\gamma^\mu t_R)$$



$\to \mathcal{C}_{Hu}$

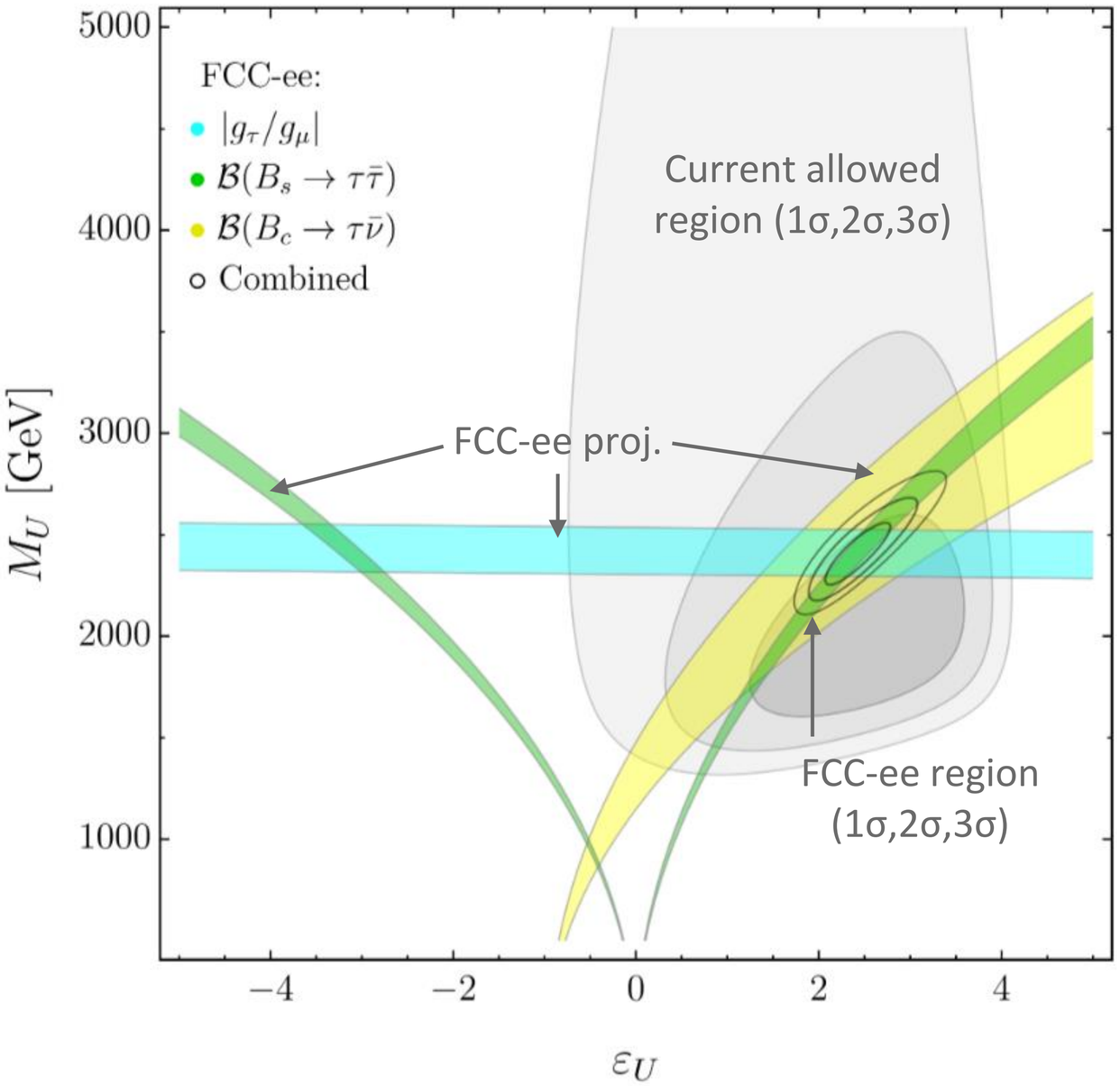


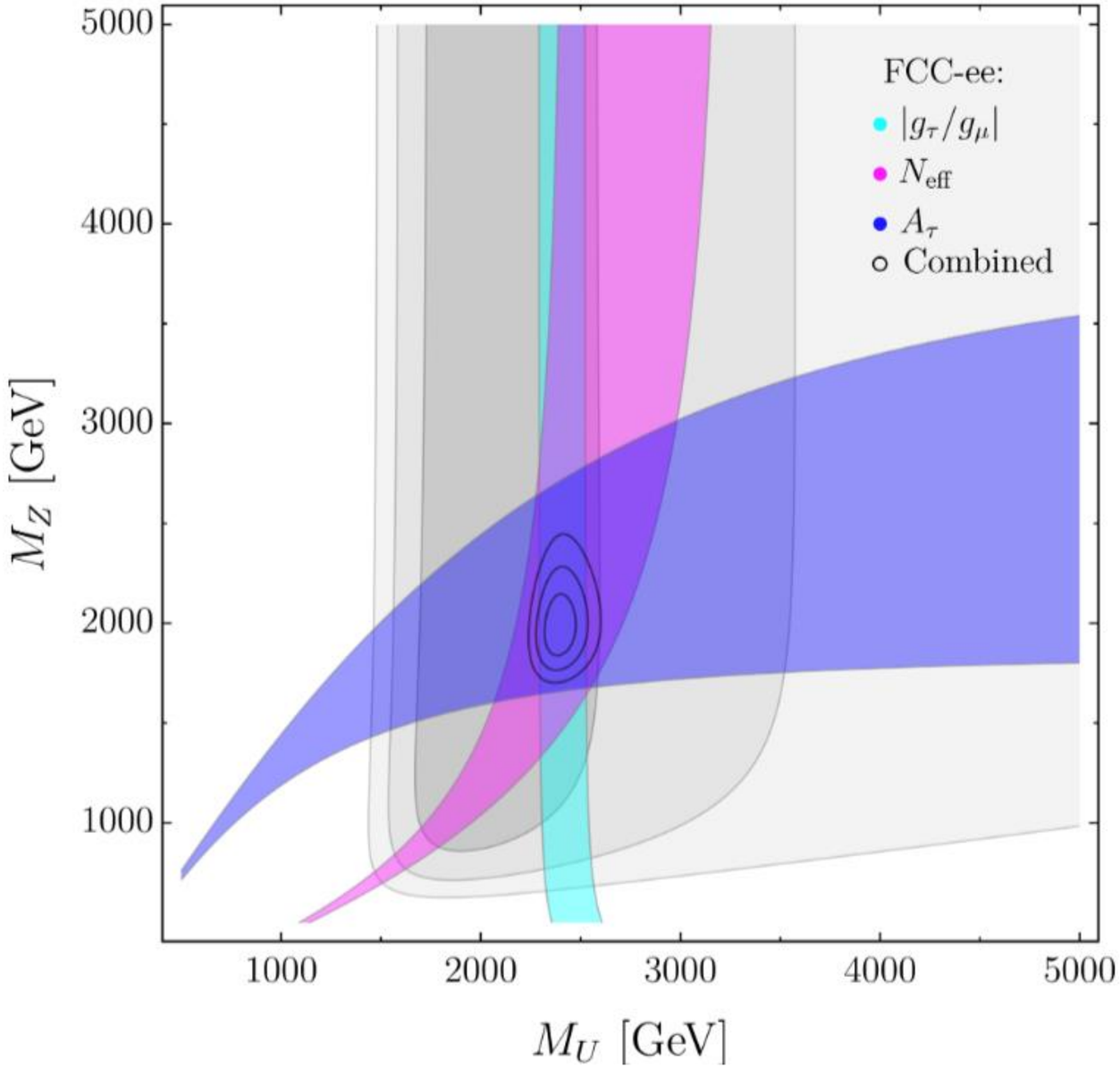
$\to \mathcal{C}_{HD} \quad \to \delta m_W$

See also Allwicher, McCullough & Renner [2408.03992]

Simplified Models: U_1 Vector Leptoquark

$U_1 \sim (3, 1, 2/3)$ *: best mediator to address charged B decay tensions + SU(4)-inspired unification*

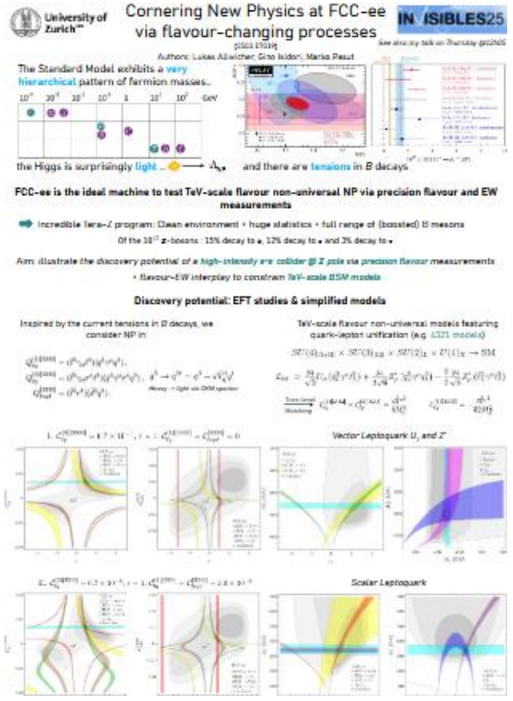




Take-Home Message

- With no clear indication of the NP scale -> indirect + precision flavour & EW searches allow to probe, via RGE effects, *broad classes* of *well-motivated* BSM models up to *high scales*

- FCC-ee -> amazing machine for precision physics in several (*redundancy*) flavour & EW obs. (*complementarity*) + interplay with near future facilities: HL-LHC, *B* factories, ...



For more colourful plots -> see my poster or come chat ;-) !

Thank You !

Credits: Armin Ilg

Backup Slides

Working Assumptions

- Heavy NP -> (dim-6) SMEFT to parametrize NP effects in flavour and EW

$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} - \frac{2}{v^2}\sum_k \mathcal{C}_k^{[f]} Q_k$$

Experimental Hints

➡ Recent interest in TeV-scale NP motivated by **exp. data**

- LFU ratios (R_D and R_{D*}) -> 3σ tension w.r.t the SM

- Enhancement of $B^+ \to K^+ \nu\bar{\nu}$ and $K^+ \to \pi^+ \nu\bar{\nu}$ w.r.t the SM

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Bordone, Cornella & Davighi [2503.22635]

➡ Interesting coherent picture with NP effects in third-family semileptonic operators

$$Q_{\ell q}^{(1)[3333]} = (\bar{\ell}^3 \gamma_\mu \ell^3)(\bar{q}^3 \gamma^\mu q^3)\,,$$
$$Q_{\ell q}^{(3)[3333]} = (\bar{\ell}^3 \gamma_\mu \sigma^a \ell^3)(\bar{q}^3 \gamma^\mu \sigma^a q^3)\,,$$
$$Q_{\ell e q d}^{[3333]} = (\bar{\ell}^3 e^3)(\bar{d}^3 q^3)\,.$$

EFT Analysis

- Discrepancies in *B* decays

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$$q^3 \to q^{3\prime} = q^3 - \varepsilon \tilde{V}_q^i q^i$$

Heavy -> light via CKM spurion

- Global four-dimensional fit with current flavour, EW and Colliders data

R_D	$\mathcal{B}(B \to K\nu\bar{\nu})$	Γ_Z	A_b
R_{D*}	$\mathcal{B}(B \to K^*\nu\bar{\nu})$	$\sigma^0_{\rm had}$	A_τ
$\mathcal{B}(B_c \to \tau\bar{\nu})$	$\mathcal{B}(B \to K\tau\bar{\tau})$	R_b	m_W
	$\mathcal{B}(B \to K^*\tau\bar{\tau})$	R_μ	Γ_W
	$\mathcal{B}(B_s \to \tau\bar{\tau})$	R_e	$\mathcal{B}(W \to \tau\nu)$
		R_τ	$\mu(H \to b\bar{b})$
		$N_{\rm eff}$	$\mu(H \to \tau\bar{\tau})$

L. Allwicher, C. Cornella, G. Isidori and B.Stefanek, New physics in the third generation [2311.00020]

EFT Analysis

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Heavy -> light via CKM spurion

- Global four-dimensional fit with current flavour, EW and Colliders data

- Projected FCC-ee measurements assuming benchmark scenarios for NP

→ *Compatible and preferred by the current fit*

I. $\mathcal{C}_{\ell q}^{(3)[3333]} = 6.7 \times 10^{-3},\ \varepsilon = 1,\ \mathcal{C}_{\ell q}^{(1)[3333]} = \mathcal{C}_{\ell e q d}^{[3333]} = 0$

II. $\mathcal{C}_{\ell q}^{(3)[3333]} = 6.7 \times 10^{-3},\ \varepsilon = 1,\ \mathcal{C}_{\ell q}^{(1)[3333]} = \mathcal{C}_{\ell e q d}^{[3333]} = 3.0 \times 10^{-3}$