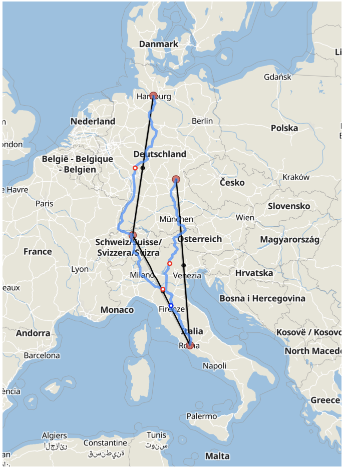
Probing flavour across energy scales

Lukas Allwicher
DESY, Hamburg, 18.11.2024

HELMHOLTZ

About me

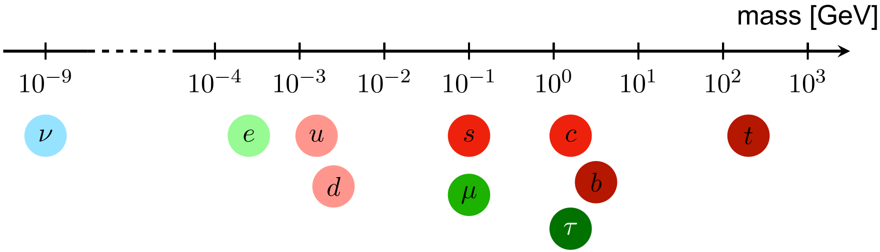


- Born in Bayreuth, Germany
- German/Italian
- Undergrad studies in Rome
- PhD in Zurich with Gino Isidori
- Now in Hamburg

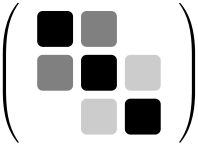
What I work on:

- Beyond the Standard Model
- Flavour Physics
- (SM)EFT
- FCC-ee

Flavour puzzle (SM)



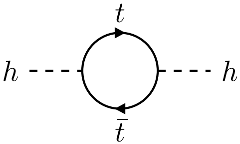
$V_{\text{CKM}} \sim$



- **SM flavour puzzle**: no explanation for the observed pattern of masses and mixings

New Physics Flavour Problem

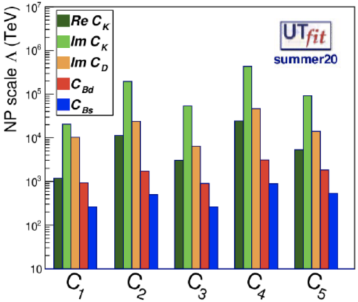
> **Hierarchy problem**: Higgs mass term quadratically sensitive to UV physics:



$$\longrightarrow \delta m_h^2 \approx \frac{3y_t^2}{4\pi^2}\Lambda_{\text{NP}}^2$$

$\Rightarrow$ Need “light” NP to avoid tuning

[**Barbieri** 2103.15635]



> Stringent flavour bounds: what is the flavour structure of NP?
$\rightarrow$ Non-trivial if we want TeV-scale

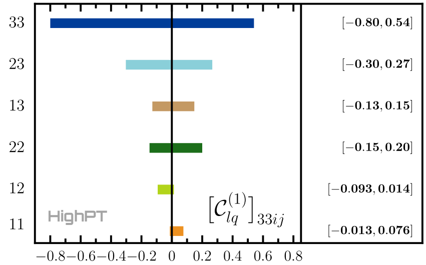
$\boxed{\text{NP flavour problem}}$

Exploring the flavour structure

[LA, Faroughy, Jaffredo, Sumensari, Wilsch 2207.10714]

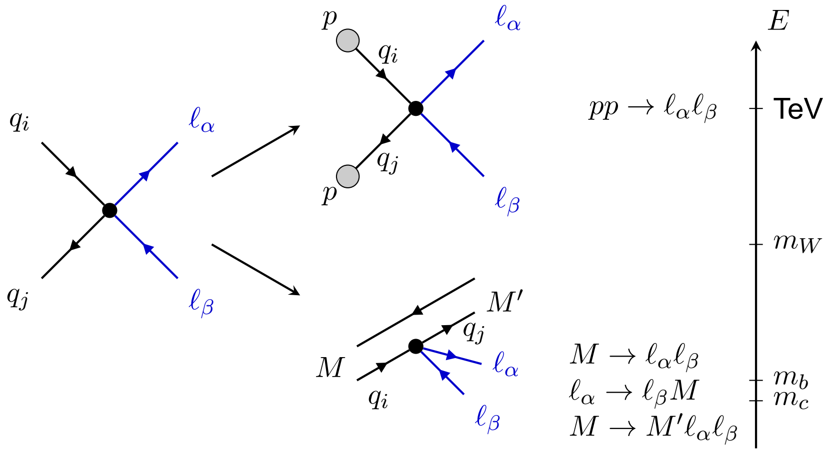
- Take e.g. **Drell-Yan** at LHC: $pp \to \ell_\alpha \ell_\beta$
- Lighter quark flavours are more constrained
- The same applies also to other observables (see flavour, electroweak)

$pp \to \tau\tau$



NP coupling mostly to the third generation is still compatible with $\Lambda_{\rm NP} \sim \mathcal{O}(1)$ TeV

Searches at different energy scales



High-p_T searches can probe the same operators
directly constrained by flavour-physics experiments (and more)

Data at different energy scales

E

TeV — $pp \to \ell_\alpha \ell_\beta$, $pp \to t\bar{t}, b\bar{b}$

LEP-II $e^+e^- \to \ell^+\ell^-$

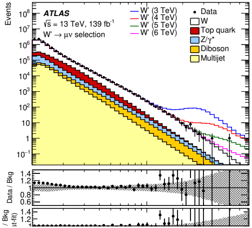
m_W — EWPO, $h \to f\bar{f}$

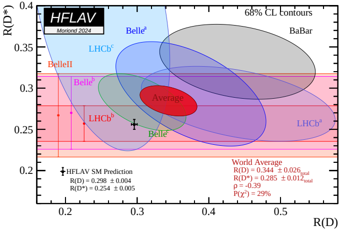
$\Delta F = 1$

m_b — $\Delta F = 2$

m_c — $b \to c\tau\nu$

τ-LFU





SMEFT

- Instead of studying particular UV scenarios, model-independent approach with SMEFT
- Complement the SM with a tower of higher-dimensional operators, with SM fields and gauge symmetry

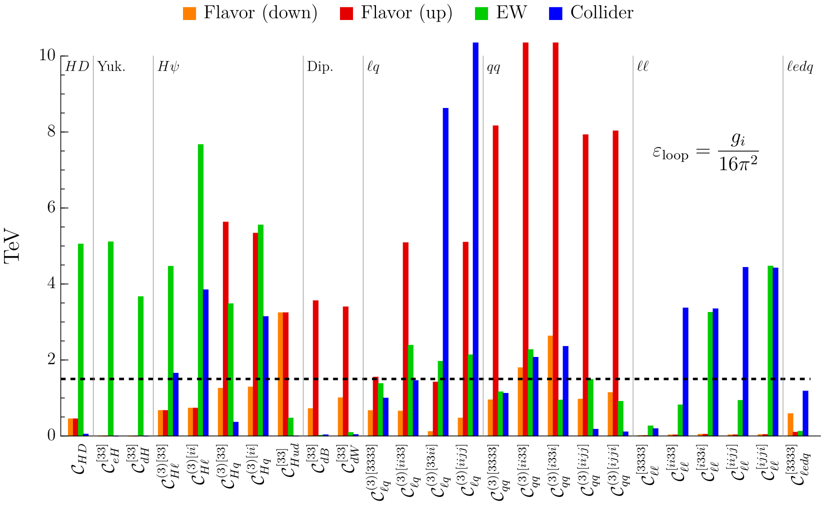
$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \frac{1}{\Lambda^2} \sum_i \mathcal{C}_i \mathcal{O}_i^{(6)} + \cdots$$

- Stop the expansion at $d = 6$
- 59 operator structures, 2499 independent coefficients
- Most of the parameters come from flavour
  $\rightarrow$ flavour assumptions can help to reduce the number of parameters, as well as avoid some constraints

[LA, Cornella, Isidori, Stefanek 2311.00020]

Bounds on $U(2)$-symmetric SMEFT operators

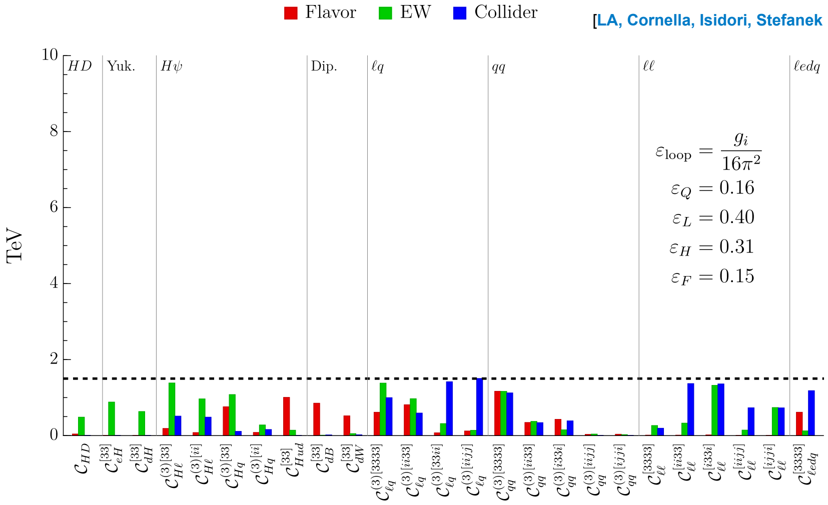
- $\mathcal{O}(5-10)$ TeV bounds, nice **complementarity** between sectors



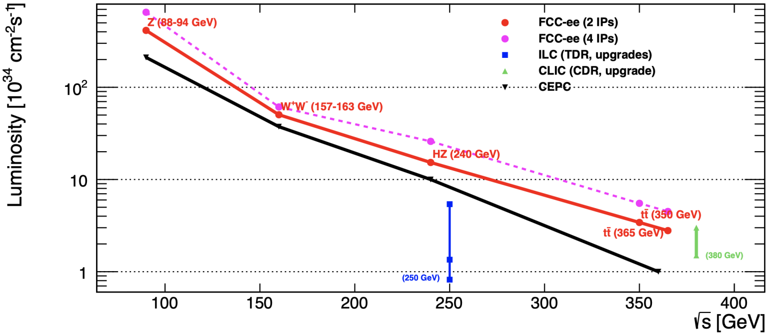
Third-generation New Physics

> Suppressed light families $\rightarrow$ NP compatible with $\mathcal{O}(1)$ TeV!

[LA, Cornella, Isidori, Stefanek 2311.00020]



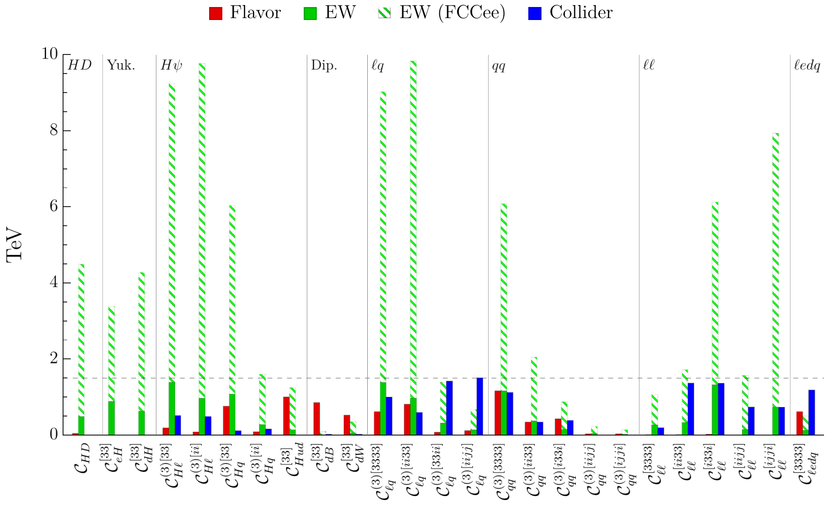
FCC-ee



- Z-pole run: 1 LEP dataset every 32 seconds!
- Improve electroweak precision observables by $\sim$2 orders of magnitude
- Great opportunities for flavour as well

[LA, Cornella, Isidori, Stefanek 2311.00020]

Projections for FCC-ee (Z-pole obs.)



Thank you

...and looking forward to my time at DESY!

Bldg. 2a, room 401
lukas.allwicher@desy.de