Link between flavor and HEP: Flavor in SMEFT

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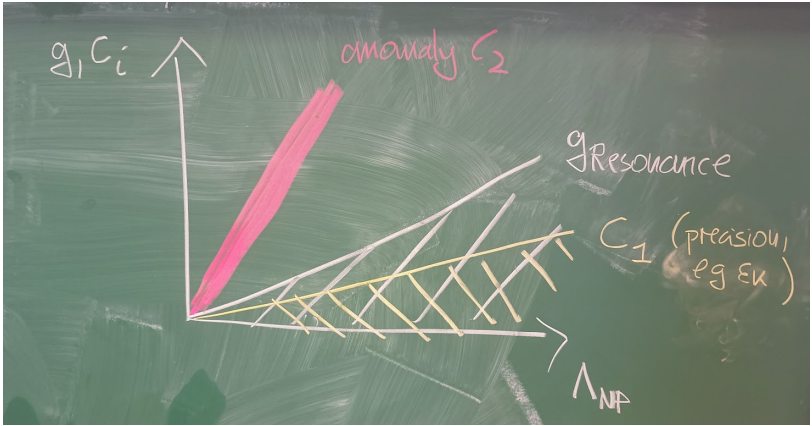
MITP Workshop

14 Oct 2025

Why do we impose flavour assumptions?

- **Data reality:** FCNCs and CPV beyond CKM are extremely suppressed
  $\Rightarrow$ NP flavour must be structured.
- **Practicality:** Global SMEFT/model fits explode without structure
  (in practice: dozens–hundreds of flavour parameters).
- **Interpretability:** Assumptions convert experimental limits into UV messages
  (NP scales, textures, symmetries, ...).
- **Goal:** Be *predictive enough* to guide measurements without over-constraining possibilities.



to combine constraints from

- *direct searches (resonances)*
- *precision (flavour) constraints (e.g. ϵ_K)*
- *(flavour) anomalies (e.g. Cabibbo anomaly)*

we need to know the "natural size" of the relevant couplings !

Experimental guardrails (where danger lives)

- $\Delta F{=}2$: K (ϵ_K, Δm_K), $B_{d,s}$ (mixing, CPV), D mixing.
- Rare & LFU: $b \to s\ell\ell$, $b \to s\gamma$, $B_s \to \mu\mu$, $K \to \pi\nu\bar{\nu}$, $K_{\ell 2}$, $\pi_{\ell 2}$, D rare.
- Leptons: $\mu \to e\gamma$, $\mu \to e$ conversion, τ LFV, $(g-2)_\mu$.
- CP/EDMs: d_e, d_n, diamagnetic atoms.
- Top/Higgs/EW: $t \to cZ$, $t \to uh$, Higgs y_f modifiers; EWPO; CKM unitarity tests.

Exact $U(3)^5$ flavour symmetry

Idea

New physics is flavour-blind; only the SM part breaks flavour symmetry in the Yukawa sector.

- **Motivation:** A baseline closest to the SM; only indirect flavour effects.
- **Pros:** Minimal number of parameters; simplest SMEFT starting point.
- **Cons:** Too restrictive to address flavour anomalies; not RG-invariant.
- **Usage:** obtain NP bounds from non-flavour observables.

Minimal Flavour Violation (MFV)

Idea

All flavour/CP breaking from SM Yukawas treated as spurions; e.g.

$$\frac{C_{ij}}{\Lambda^2}\,\bar{Q}^i(\ldots)D^j \quad \longrightarrow \quad C_{ij} = \#\,(Y_D)_{ij} + \ldots \qquad \# \sim \mathcal{O}(1)$$

no additional sources of flavour symmetry breaking

- **Motivation:** RG-covariance; strong FCNC protection.
- **Pros:** Predictive K, B correlations; systematic EFT.
- **Cons:** Hard to explain sizable flavour anomalies; UV completions can be contrived.
- **Usage:** address relatively low NP scales; SM-like flavour observables.

Technical issue: top Yukawa is large: $SU(3)_Q \times SU(3)_U \to SU(2)_Q \times SU(2)_U \times U(1)$

$U(2)^3$ for quarks (3rd generation singled out)

Idea

First two generations form flavour doublets; third is special.
Minimal set of spurions to reproduce CKM.

- **Pros:** Suppresses K/D; allows visible B shifts; neat hierarchies.
- **Cons:** Predictivity depends on the choice of spurions
- **Usage:** Want room in B physics while keeping kaon/charm clean.

What about correlations with rare top decays?
How to incorporate e.g. Cabibbo anomaly?

Froggatt–Nielsen (FN) & family symmetries

Idea

Broken horizontal symmetry ($U(1)_H$ or non-Abelian/discrete)

$$\frac{C_{ij}}{\Lambda^2}\,\bar{Q}^i(\ldots)D^j \quad \longrightarrow \quad C_{ij} = \#\,\epsilon^{|a_i - b_j|} + \ldots \qquad a_i, b_j \in \mathbb{Z}$$

with flavon spurion $\varepsilon = \frac{\langle \phi_{\rm FN} \rangle}{\Lambda_{\rm FN}} \ll 1$ controls Yukawa hierarchies and NP couplings.

- **Pros:** flavour hierarchies originate in the UV: $\Lambda_{\rm FN} \gg \langle \phi_{\rm FN} \rangle \gg \Lambda$
- **Cons:** FCNCs and right-handed currents can be large.
- **Usage:** book-keeping device for flavour hierarchies; gives benchmark for valid spurion configurations

Questions to discuss

How to combine flavour and collider/EWP observables in global fits:

- systematic exploration of consistent flavour power-counting schemes ?
- automated implementation of flavour assumptions in EFT/BSM models ?
- how important is a UV interpretation á la FN?
- how do different priors on size of flavour-specific Wilson coefficients influence the constraints on viable NP scales?
- ...

???