Froggatt-Nielsen models meet the SMEFT

Eetu Loisa

DAMTP, University of Cambridge

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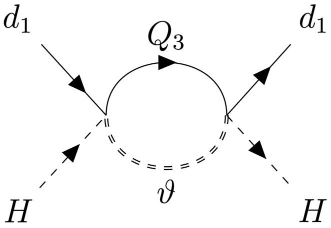


Based on work with Jim Talbert, to appear

Background

The flavour puzzle: what explains the dramatic hierarchies in fermion masses and mixings?

For instance:

$$\frac{m_u}{m_t} \sim 10^{-5}.$$

Potential solutions: introduce new symmetries, fields, extra dimensions, etc.

Froggatt-Nielsen Models

Setup:

SM + new $U(1)$ symmetry + flavon field θ.

Yukawa sector:

$$\mathcal{L} \supset y_{ij}\, \overline{\psi}_i\, H\, \psi_j \longrightarrow \mathcal{L} \supset c_{ij}\, \overline{\psi}_i\, H\, \psi_j \left(\frac{\theta}{\Lambda_{\rm UV}}\right)^{x_{ij}}$$

$$\theta = \frac{v_\theta + \vartheta}{\sqrt{2}}$$

Define $\lambda \equiv v_\theta/(\sqrt{2}\Lambda_{\rm UV}) \sim 0.1$.

Get light Yukawas: $\mathcal{L} \supset c_{ij}\, \overline{\psi}_i\, H\, \psi_j \lambda^{x_{ij}}$

Problem

Froggatt-Nielsen models predict the correct fermion masses by design.

How can we falsify these models?

$\rightarrow$ We need to understand *what else* they predict!

$\rightarrow$ Match to the SMEFT and study ensuing operator structures.

Strategy

1) Write down a Froggatt-Nielsen EFT up to a given mass dimension. E.g.

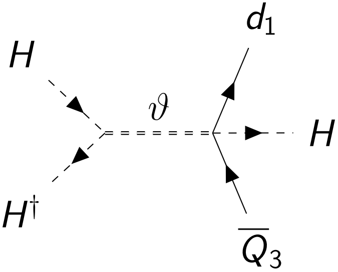
$$\mathcal{L}_{\mathsf{FN}} \supset y^d_{33}\overline{Q}_3 H d_3 + y^d_{32}\overline{Q}_3 H d_2$$

$$- \kappa(\theta^*\theta)\big(H^\dagger H\big) + c_{31}\,\overline{Q}_3 H d_1 \left(\frac{\theta}{\Lambda_{\mathsf{UV}}}\right)$$

2) Match to the SMEFT up to a given mass dimension by integrating out θ.

Can be done at tree- and 1-loop-level.

Tree-level matching



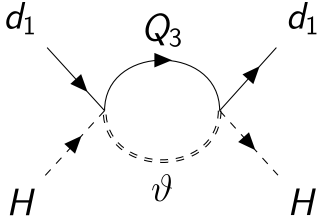
$$\longrightarrow C_{dH}^{31}\left(H^\dagger H\right)\left(\overline{Q}_3 H d_1\right)$$

where

$$C_{dH}^{31} = \frac{\lambda\kappa c_{31}}{m_\theta^2}.$$

(Recall $\lambda \sim v_\theta/\Lambda_{\rm UV} \sim 0.1$)

Loop-level matching



$$\longrightarrow C_{Hd}^{11}(H^\dagger i \overleftrightarrow{D}_\mu H)(\overline{d}_1 \gamma^\mu d_1)$$

where

$$C_{Hd}^{11} = \frac{|c_{31}|^2}{128\pi^2 \Lambda_{\mathrm{UV}}^2}\left(1 + 2\ln\frac{\mu^2}{m_\theta^2}\right).$$

Conclusions

Goal: Understand the IR imprint of Froggatt-Nielsen models.

Method: Systematically match a Froggatt-Nielsen EFT to the SMEFT.

Findings: Rich flavour structure especially in $(\overline{\psi}_i\gamma^\mu\psi_j)(\overline{\psi}_k\gamma^\mu\psi_l)$ and $(H^\dagger i\overleftrightarrow{D}_\mu H)(\overline{\psi}_i\gamma^\mu\psi_j)$ operators.

Competing sources of suppression.

The End

Thank you for listening!