Flavour implications of SMEFT flavour assumptions

Reasons for a flavour structure on the SMEFT:

1) Reduce to a manageable number of parameters

2) Collider focus on parameters not already too constrained by flavour data

3) Restrict to most motivated UV models

4) Opportunity to correlate top/Higgs with anomalies in flavour

Q: What are the differences between the flavour effects possible within the proposed structures?
Charged currents

All flavour structures can give tree level charged currents (from operators with quark doublets)

particularly:  \( (\bar{Q}_i \gamma_\mu \tau^a Q_i)(\bar{L}_k \gamma_\mu \tau^a L_k) \supset V_{ij} (\bar{u}_i \gamma_\mu d_j)(\bar{l}_k \gamma_\mu \nu_k) \) (but also \( Q^{(3)}_{Hq} \) and \( Q^{(3)}_{Hl} \))

If aligned to 3rd gen of both quarks and leptons, this can fit LFUV in charged-current B decays (e.g. 1706.07808)

\{ \begin{aligned}
U(2)_Q \text{ or top-philic scenarios with LFUV} \\
U(3)^5 \text{ or Universal scenarios} 
\end{aligned} \}

If flavour-universal, can be constrained by kaon decays, e.g.

\( \Gamma(K^+ \rightarrow \mu^+ \nu_\mu) (\Lambda \gtrsim 5 \text{ TeV}) \)

[This also means that you need to worry about SMEFT entering CKM fits at tree level! See 1812.08163 (general flavour structure) and 2003.05432 (MFV case)]
Tree level FCNCs?

- **Exact \( U(3)^5 \)**
  - Only as part of 4-quark operators
  - \( b\bar{s}\bar{c}c \) operators run into semileptonic and dipole operators (\( b \rightarrow s\gamma \) and \( b \rightarrow s\bar{l}l \))
  - (e.g. 1910.12924)

- **Universal**
  - Any operator with a 3rd gen quark doublet current
  - \( \bar{Q}_3 \gamma^\mu Q_3 \)
  - if 'up-aligned': \( \rightarrow V_{ti}^* V_{tj} \bar{d}_i \gamma^\mu d_j \)

- **Top-philic**
  - Always proportional to CKMs

Sophie Renner - LHC EFT WG meeting on flavour assumptions - 25th January 2022
Beyond tree level

All flavour structures will give FCNCs at one loop with an MFV structure:

\[ \alpha \frac{y_t^2}{(16\pi)^2} V_{ti}^* V_{tj} (b_L \gamma^\mu s_L) \]

But details of where and how depend on the assumptions

An example:

\[ [Q_{qq}^{(1)}]_{ijji} = (\bar{q}_i \gamma^\mu q_j) (\bar{q}_j \gamma^\mu q_i) \]

\[ [Q_{qq}^{(3)}]_{ijji} = (\bar{q}_i \gamma^\mu \tau^I q_j) (\bar{q}_j \gamma^\mu \tau^I q_i) \]

each are individually invariant under \( U(3)^5 \)

\[ [Q_{qq}^{(1)}]_{ijji} \text{ and } [Q_{qq}^{(3)}]_{ijji} \]

each individually give divergent 1-loop contributions to \( bsll \) operators

But the combination \([Q_{qq}^{(1)}]_{ijji} + [Q_{qq}^{(3)}]_{ijji}\) gives zero

In Universal theories they only appear in this combination:

\[ Q_{2,iG} = (D^\nu G^A_{\mu \nu})^2 = \frac{g_s^2}{4} \left( [Q_{qq}^{(1)}]_{ijji} + [Q_{qq}^{(3)}]_{ijji} + \ldots \right) \]

other warsaw basis operators which also give no FCNCs @ 1-loop
Correlations & connections

We need to go beyond "flavour-safety"!

Fit in the flat directions of $Z$ pole observables

\[ \{ C_{HWB}, C_{HD}, C_{Hl}^{(1)}, C_{Hl}^{(3)}, C_{Hq}^{(1)}, C_{Hq}^{(3)}, C_{Hu}, C_{Hd}, C_{He}, C_{ll}' \} \]

From 2003.05432, with $U(3)^5$ flavour assumptions

We need to go beyond "flavour-safety"!