An EFT approach to lepton anomalies

Rupert Coy

Laboratoire Charles Coulomb (L2C), CNRS-Université de Montpellier

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Coy and Frigerio *in preparation*
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What's going on in the lepton sector?

- Massive neutrinos! Implies LFV! Δm_{ij}^2 measured at $\mathcal{O}(1\%)$, $\sin^2(\theta_{ij})$ measured at $\mathcal{O}(5-10\%)$, δ_{CP} less well known
- $(g-2)_\mu$ anomaly now $\gtrsim 3.5\sigma$, could reach 5σ in a few years at Fermilab; new $(g-2)_e$ anomaly at 2σ (in other direction)
- Various hints of LFUV in $b \to s\ell^+\ell^-$ and $b \to c\ell\nu$ channels
- LFUV already apparent in hierarchical Yukawas
- Stringent limits on CLFV: $BR(\mu \to e\gamma) \lesssim 10^{-13}$, $BR(\mu \to eee) \lesssim 10^{-12}$, while $BR(\tau \to \mu\gamma, e\gamma) \lesssim 10^{-8}$
- Hint of CLFV at LHC Run 1 in $h \to \tau\mu$ disfavoured by Run 2

Effective Field Theory

- Many anomalies and constraints, also many models
- EFT enables a model-independent analysis of the data: relate observables to Wilson Coefficients (WCs) and study the WC parameter space
- Can demonstrate relative compatibility or tension between different data
- Also useful framework to study a specific model by re-expressing it in terms of generated WCs

Type-I seesaw (in collaboration with Michele Frigerio)

- Simple neutrino mass model, add n_s RH fermions singlets ($n_s \geq 2$ for non-zero neutrino masses), with Lagrangian:

$$\mathcal{L} = \mathcal{L}_{SM} + \overline{\nu_{Ri}} i \partial\!\!\!/ \nu_{Ri} - Y_{\nu,ai} \overline{l_{La}} \tilde{H} \nu_{Ri} - \frac{1}{2} \overline{\nu_{Ri}} M_{ij} \nu_{Rj}^c + h.c., \quad (1)$$

- Aim: find $d = 5, 6$ WCs generated by Type-I seesaw at leading order, then calculate observables
- $\mathcal{O}^{(5)} = (l_L H)^2$ generated at tree-level, while $\mathcal{O}_i^{(6)}$ generated
  - at tree $C \sim Y_\nu^2 / M^2$
  - via 1-loop mixing, $C \sim \frac{g^2}{16\pi^2} \frac{Y_\nu^{2,4}}{M^2} \log\left(\frac{M}{\mu}\right)$
  - via finite 1-loop diagrams, $C \sim \frac{g^2}{16\pi^2} \frac{Y_\nu^{2,4}}{M^2}$
  - at 2-loop order (neglected)

Comparison with models

- Compare EFT with calcs made in Type-I seesaw models
- Decay widths calculated in model with exact $U(1)_L$ symmetry, Dirac masses for sterile neutrinos, for $k \neq m$ and $m_k \gg m_m$:

$$\Gamma(h \to e_k \bar{e}_m) \approx \frac{\lambda^2 m_k^2 v^2 m_h}{(4\pi)^5} \left[Y_\nu M^{-2} \log\left(\frac{M}{m_W}\right) Y_\nu^\dagger \right]_{km}^2$$

$$\Gamma(Z \to e_k \bar{e}_m) \approx \frac{m_Z^3 v^2}{3.2^{11}\pi^5} \left(\frac{17 g_2^2}{12} + \frac{g_1^2}{12}\right)^2 \left[Y_\nu M^{-2} \log\left(\frac{M}{m_W}\right) Y_\nu^\dagger \right]_{km}^2$$

  which agrees at leading order with previous calcs[1]
- Compute also $\Gamma(e_k \to e_m \gamma)$, show Type-I seesaw worsens $(g-2)_\mu$ anomaly
- Computationally simple to find this leading order result
- Also, spurion analysis!

[1] Arganda, Herrero, Marcano, Morales, and Szynkman, 1612.09290; H, M, M, S, 1807.01698

EFT analysis of B anomalies (with Michele Frigerio and Olcyr Sumensari)

- Performed basis-independent search for unique $d = 6$ operator which explains $(g-2)_\mu$ and $b \to s\ell\ell$ anomalies: none can, considering tree, 1-loop, and Barr-Zee type two-loop
- Difficulties in a combined explanation include vector vs. tensor operators, $\Delta F = 0$ vs. $\Delta F = 1$
- Next: full EFT analysis of $b \to s$ anomalies, considering full set of operators (including flavour structure) which can contribute at 1-loop
- Tree-level and one-loop analyses exist[2], however room to extend the existing studies: consider role of electrons, relax top dominance assumption, consider additional constraints on WCs, e.g. from $(g-2)_\mu$

[2] Alonso, Grinstein, and Camalich, 1407.7044; Celis, Fuentes-Martin, Vicente, Virto, 1704.05672