Flavorless physics with flavor

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Outline

- MFV
- MFV as a tool for EFT and flavor
- MFV instead of R-parity
- MFV for the spectrum
- Conclusions

EFTs

EFTs

The basic idea of EFTs is that we have NR operators. Consider the effective Fermi theory

$$a\,\frac{\bar{\mu}\nu_\mu\bar{\nu}_e e}{\Lambda^2} \quad \Longrightarrow \quad \mu \to e\nu\bar{\nu}$$

- If we know nothing, we assume $a \sim 1$, and get $\Lambda \sim m_W$
- Unless we have more input, we assume that all dim 6 operators are roughly the same
- We could also have

$$a\,\frac{\bar{\mu}e\bar{e}e}{\Lambda^2} \quad \Longrightarrow \quad \mu \to eee$$

- Why is it not observed?

SM and Fermi theory

The Fermi theory is more than a simple EFT

- In the Fermi EFT we have an operator that gives $\mu \to eee$
- Yet, the full theory is not generic, it is the SM
- We add the GIM mechanism as a guide for the size of FCNC operators
- Flavor is broken in a very specific way, and $\mu \to eee$ is highly suppressed by small neutrino masses
- Can the full theory above the SM also be non-generic?

The flavor problem

In fact, we know the full theory must be non-generic!

- Many reasons to expect NP at $\Lambda \sim 1$ TeV
- Naive flavor bounds imply $\Lambda > 10^4$ TeV
- This tension is called

The NP flavor problem

- The full theory must have a non-trivial flavor structure

MFV

MFV

Minimal Flavor Violation (MFV)

- In this way of thinking let us define MFV as a guide to the full theory
- The NP flavor structure comes from the SM Yukawas
- We think about the Yukawas as small (other than top) so we have approximate flavor symmetries
- This idea can be realized in many NP models
- It basically solves the NP flavor problem: the NP operators are suppressed by small Yukawas

MFV: Definition

- Without Yukawas the flavor group is

$$U(3)_Q \times U(3)_U \times U(3)_D$$

- The Yukawas are spurions
- Recall $U(3) = SU(3) \times U(1)$. The diagonal $U(1)$ is baryon number

$$Q(3,1,1) \quad U(1,3,1) \quad D(1,1,3) \quad Y_D(3,1,\bar{3}) \quad Y_U(3,\bar{3},1)$$

- The idea of MFV is that the Yukawas are the only spurions that break the flavor symmetry
- Linear MFV is the idea that these Yukawas are small and it is justified to keep only leading order terms

MFV: Can it do more?

MFV is a nice idea to solve the NP flavor problem

Q: Can we use it to solve other problems or make other predictions?

A: Yes!

MFV instead of R-parity

Susy and R-parity

SUSY without imposing R-parity (R_p)

- It leads to rapid proton decay

$$W = \mu LH + \lambda LLE + \lambda' LQD + \lambda'' UDD$$

- For example, using λ' and λ'' we have

$$A(P^+ \to \pi^0 e^+) \propto \lambda' \lambda''$$

- Standard way out: impose R_P or just Baryon number
- Flavor symmetries could be used, but these ideas are not very elegant

MFV instead of R-parity

Idea based on E. Nikolidakis and C. Smith (0710.3129, 0809.3152)

- We impose $SU(3)$ MFV. The $U(1)$ is baryon number, and it is “unfair” to impose it
- We can get the B violating term already with two Ys

$$(Y_u Y_d^\dagger)\,(UUD)$$

- Some $SU(3)$ algebra (Q, U, D)

$$(\bar{3},3,1)\times(3,1,\bar{3})\times(1,3,1)\times(1,3,1)\times(1,1,3)\sim(1,1,1)$$

- This is not a huge suppression

MFV for L violation

The big effect comes from the leptons

- The MFV symmetry is $SU(3)_L \times SU(3)_E$

$$L(3,1) \quad E(1,3) \quad Y_e(3,\bar{3})$$

- Using powers of Y_e we cannot get the L violating terms!
- The L violating terms can be generated if we have neutrino masses $m_\nu(6,1)$

$$m_\nu Y_e LLE$$

Huge suppression!

MFV for proton decay

- The small Yukawas and the need for neutrino mass save the proton

$$\mathcal{A} \sim Y_u^3 Y_d^2 Y_e^2 m_\nu$$

- Still, close to the current limit (depends on $\tan\beta$)
- The LSP decays hadronically
- May get "large" $\Delta B = 2$ effects (N-$\bar{N}$ oscillations)
- We can understand it all in terms of symmetries. MFV implies that all L violating terms will be $\Delta L = 3$ (and $\Delta B = 1$)

MFV for the spectrum

Heavy quarks

Idea based on YG, Nir, Thaler, Volansky, Zupan, 0706.1845

- What can MFV tell us about new vector-like quarks, D_i?
- We assume that these new quarks are heavy and decay into SM quarks
- MFV tells us there must be 3 of them!

$$Y_{ij}^{Dd}\bar{d}_i D_j H$$

- There are four different triplet flavor representations of the new quarks
- There are always three new quarks

Spectrum

- Depending on the details we can have several spetra
  - Degenerate
  - $2 + 1$
  - Hierarchical
- MFV predicts that in the LHC we can only see degenerate heavy quarks!
- Observation of two non-degenerate heavy quarks can rule out MFV using a “flavorless” observable

Conclusions

MFV has a lot of flavor

- MFV is an effective idea that is an addition to the EFT description
- MFV can replace R-parity
- MFV can be probed by heavy states