ν_τ and lepton flavor at colliders

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The question

We probe Lepton Flavor Violation (LFV) in two ways

- Neutrino oscillations: LFV was established
- In colliders with charged lepton: Only bounds

The topic of this talk

What are the connections between these two probes

Bottom line: There are connections, but they are non-trivial

Notations

- SM: The renormalizable old SM where $m_\nu = 0$
- νSM: The new SM where we include dim-5 operators. All neutrinos are massive with Majornama masses. No significant changes to anything else.
- BSM/NP: Going beyond the νSM
  - New light states, like ν_s or light gauge bosons
  - New interactions
- LFV: Lepton flavor violation
- LNU: Lepton non-universality

More notations

- NSI: Non standard interactions for the known neutrinos. Usually

$$\epsilon_{ij} \, G_F \, \nu_i \nu_j \psi_k \psi_k$$

  - Diagonal NSI, $i = j$. Violate lepton universality but not flavor violating
  - Non-diagonal NSI, $i \neq j$. Violate flavor. Usually NSI refer to this
- PMNS-NU: The effective 3×3 PMNS matrix is non unitary
- CLFV: Charged LFV

LFV in the νSM

In the νSM we do have LFV

- We can see it only in neutrino oscillation experiments

We can see deviation from the νSM predictions

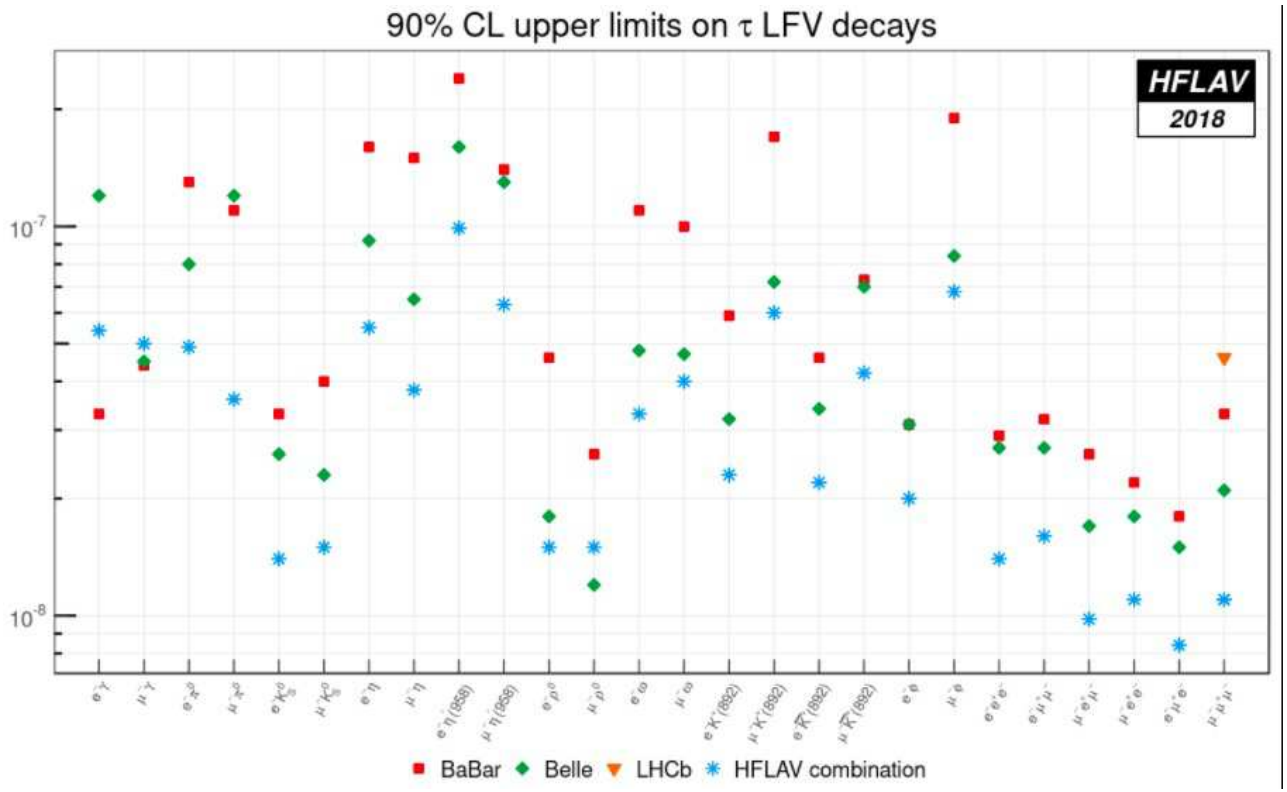
- Deviations in fitting *all* oscillation experiments
  - Usually can be explained with sterile neutrinos
- Deviation of an oscillation experiments from $\cos \Delta m t$
  - It may be explained by NSI, decay, PMNS-NU, or violation of QM
- CLFV, like $\mu \to e\gamma$ or μ-e conversion
  - Usually can be explained by new LFV dim-6 operators

More on NSI

- NSI could affects ν oscillation in three ways
  - In production: $\pi \to \mu\nu_\tau$
  - In detection: $\nu_\mu + n \to \tau + p$
  - In propagation via matter: $\nu_\mu + e \to \nu_\tau + e$

- Not easy to separate if from PMNS-NU
  - Deviation from “simple” oscillation can be due to NSI or due to something else
- The effect is linear in ϵ

τ LFV at collider



- Bounds of order 10^{-8} for τ decays
- Much stronger bounds for muon decays, $O(10^{-12})$
- The effects scale like ϵ^2

τ LNU at collider

See Gligorov's talk.

- All the indications of flavor anomalies refer to LNU
- We do not have any indication for CLFV in colliders

How can we look for LNU in ν?

CLFV and ν_τ

- The νSM predicts CLFV at the level of 10^{-50} aka zero
- Any signal of CFLV implies NP in the lepton sector
- If we find CLFV we then expect NSI: We expect deviation from the νSM predictions for oscillation also for neutrinos
- In particular we concentrate on ν_τ since the bounds on CLFV in tau decays are weaker than in muon decays

Why "expect" and not "must have"?

NSI vs CLFV

The point is that

$$\text{NSI} \implies \text{CLFV} \qquad \text{CLFV} \not\Rightarrow \text{NSI}$$

- The ν_τ is part of a doublet
- The τ comes from a double and a singlet
- NP in ν_τ implies NP in tau
- NP in tau may or may not imply NP in ν_τ
- Bounds on CLFV tau imply bounds on NSI in ν_τ
- Bounds on NSI in ν_τ give bounds on some of the NP tau interactions

Higher dim operators

How strict is the relation between the operators?

- To leading order, $d = 6$, we have the same parameter

$$L_\tau\, L_\mu\, Q\, Q \to \nu_\tau \nu_\mu QQ + \tau^+ \mu^- QQ$$

- But higher dim operators could break this

$$\phi\phi L_\tau\, L_\mu\, Q\, Q \to v^2 \nu_\tau \nu_\mu QQ$$

  There is no term with charged letpons

- These higher dim operators are “likely” to be suppressed

Bounds on NSI and CLFV

What is the order of the effect?

- NSI: Interference $O(\epsilon)$
- CLFV: All the effect $O(\epsilon^2)$
- The bound on the CFLV are $O(10^{-8})$ implies that $\epsilon \lesssim 10^{-4}$
- Any signal of NSI larger than 10^{-4} implies higher-dimension operator

Conclusion

- The νSM predicts no NSI and no CLVF
- Deviation from simple oscillation and CLFV are connected but they are not identical
- Current bounds from CLFV imply that any signal of deviation from the νSM is not a "simple" NSI
- What about LNU? We may see it in coliders. How can we look for it in neutrinos?