Gauging Lepton Flavor

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① The idea

Is Flavor dynamical? **Are the Yukawas fields?**

Gauging the SM flavor symmetries
- Quarks ⟶ [Grinstein, Redi, Villadoro]
- *Leptons* ⟶ This work

② Motivation: The Flavor Puzzle

A) The SM Flavor puzzle

- Why three families?
- Why those masses and mixings?
- Are there RH neutrinos?

B) The New Physics Flavor problem

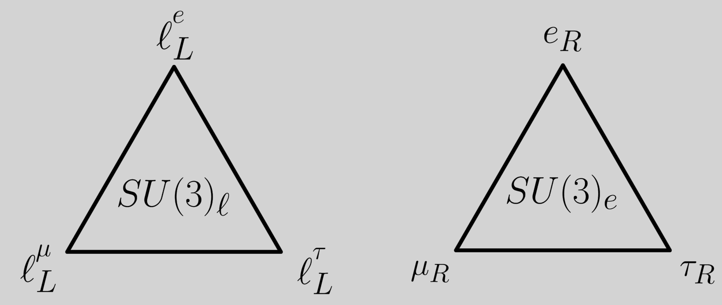
All flavor data is compatible with SM $\Longrightarrow$ Any NP flavor effect needs to be suppressed

Is there a way to protect Flavor?

⟶ Phenomenologically $\Longrightarrow$ Minimal Flavor Violation
⟶ Dynamically $\Longrightarrow$ This model

③ Flavor Symmetry of the SM

The massless limit of the SM has a global flavor symmetry, for leptons: $SU(\mathbf{3})_\ell \times SU(\mathbf{3})_e$



- Only the Yukawas break the symmetry

Are the Yukawa couplings VEVS of a dynamical field?

$$Y_e \longrightarrow \langle \mathcal{Y}_e \rangle / \Lambda_{flavor} \quad (1)$$

Spontaneous Symmetry Breaking $\Longrightarrow$ Goldstone bosons

Solution? ⟶ Gauge it!

- But which group?

Ⓐ SM flavor group: $SU(3)_\ell \times SU(3)_e$

Ⓑ SM + RH neutrinos flavor group: $SU(3)_\ell \times SU(3)_e \times SO(3)_N$

Ⓐ Gauging $SU(\mathbf{3})_\ell \times SU(\mathbf{3})_e$

Starting with the SM in the massless lepton limit

- New gauge fields (16)
- New fermionic fields to avoid ANOMALIES $\Longrightarrow$
  - Mirror leptons $\mathcal{E}_R$, $\mathcal{E}_L$
  - RH neutrinos n_R

	$SU(2)_L$	$U(1)_Y$	$SU(3)_\ell$	$SU(3)_e$
$\mathcal{E}_R$	1	−1	3	1
$\mathcal{E}_L$	1	−1	1	3
n_R	1	0	3	1
$\mathcal{Y}_E$	1	0	$\bar{3}$	3
$\mathcal{Y}_N$	1	0	$\bar{6}$	1

$$\mathscr{L}_Y = \lambda_e \bar{\ell}_L H \mathcal{E}_R + M_E \bar{\mathcal{E}}_L e_R + \lambda_{\mathcal{E}} \bar{\mathcal{E}}_L \mathcal{Y}_E \mathcal{E}_R + \lambda_\nu \bar{\ell}_L \tilde{H} n_R + \frac{\lambda_N}{2} \overline{n_R^c} \mathcal{Y}_N n_R + \text{h.c.}$$

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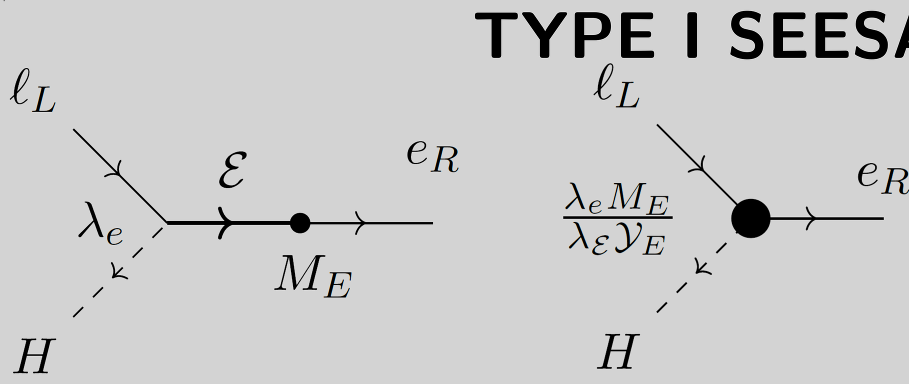
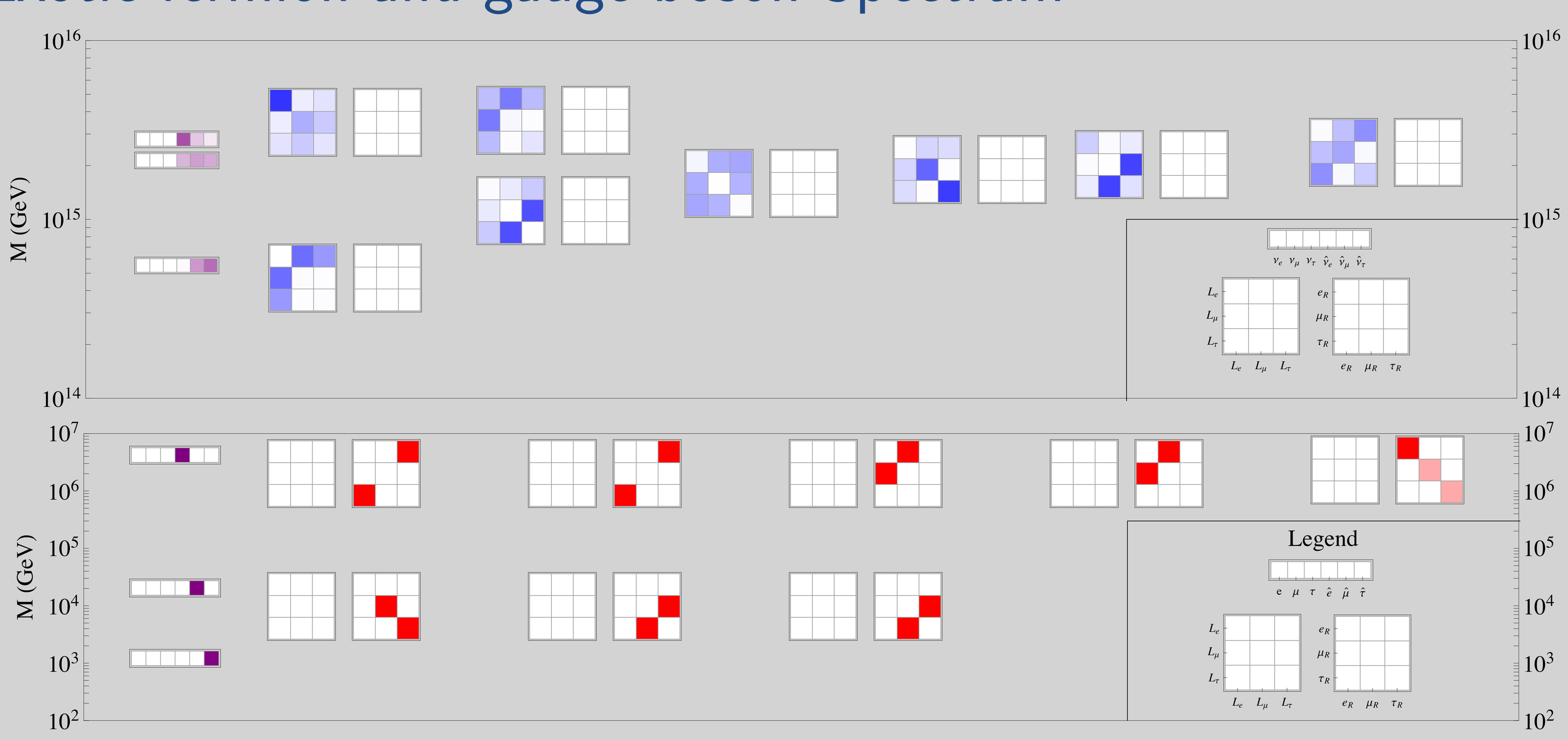


$$m_\ell \sim \frac{1}{M_{\mathcal{E}}}, \quad m_\nu \sim \frac{1}{M_N}$$

∴ inverse proportionality $\Longrightarrow$ FCNC bounds easily avoided

- Exotic fermion and gauge boson Spectrum



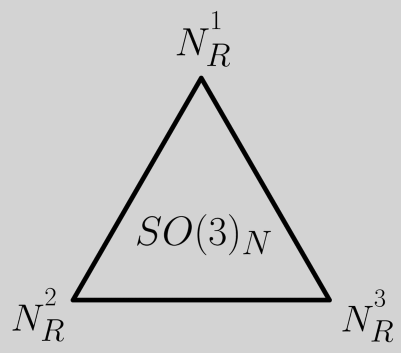
- Aproximate $SU(2)$ in the $\mu - \tau$ sector
- **Direct Detection:** Lightest exotic lepton ⟶ **tau mirror** $\hat{\tau}$
- **Lepton Universality Violation (LUV)**, esp. **τ-related**
- **No charged Lepton Flavor Violation (cLFV)**
- **Bounds:**
  - Mixing $\hat{\tau} - \tau < 3.1 \times 10^{-2} \Leftarrow \Gamma(Z \longrightarrow \tau^- \tau^+)$
  - Tau mirror mass $M_{\hat{\tau}} > 100.8$GeV $\Leftarrow$ LEP $W\nu$ data
  - Gauge boson mass $M_{A^{E,i}} \gtrsim \mathcal{O}(200)$GeV $\Leftarrow$ muon (g-2)

Ⓑ Gauging $SU(\mathbf{3})_\ell \times SU(\mathbf{3})_e \times SO(\mathbf{3})_N$

Starting with the SM in the massless limit with RH neutrinos

Adding 3 degenerate RH Majorana neutrinos N_R the SM Flavor Symmetry is enlarged:

$$SU(\mathbf{3})_\ell \times SU(\mathbf{3})_e \times SO(\mathbf{3})_N$$



⟶ **SEESAW** ⟶ charged leptons
⟶ **INVERSE SEESAW** ⟶ neutrinos

- Richer phenomenology including charged Lepton Flavor Violation e.g. $\tau \longrightarrow e\,\mu\,e$

④ Relation to MFV

Integrating out heavy fields $\Longrightarrow$ Low energy Effective operators

- Flavor mirror lepton effects ⊂ MFV operators
- Flavor gauge boson effects ⊄ MFV operators

⑤ Conclusions

- Gauging the SM Lepton Flavor symmetries leads automatically to a Seesaw Mechanism:
  - ⟶ $SU(3)_\ell \times SU(3)_e$ ⟶ **TYPE I SEESAW**
  - ⟶ $SU(3)_\ell \times SU(3)_e \times SO(3)_N$ ⟶ **INVERSE SEESAW**
- Phenomenology
  - ⟶ $SU(3)_\ell \times SU(3)_e$ ⟶ **LUV**
  - ⟶ $SU(3)_\ell \times SU(3)_e \times SO(3)_N$ ⟶ **cLFV**
  - ⟶ Both ⟶ Direct detection $\hat{\tau}$ and $SU(3)_e$ gauge bosons
- Low Energy effects almost resemble MFV