Correlating Muon Anomalous Magnetic Moments with Neutrino Magnetic Moments

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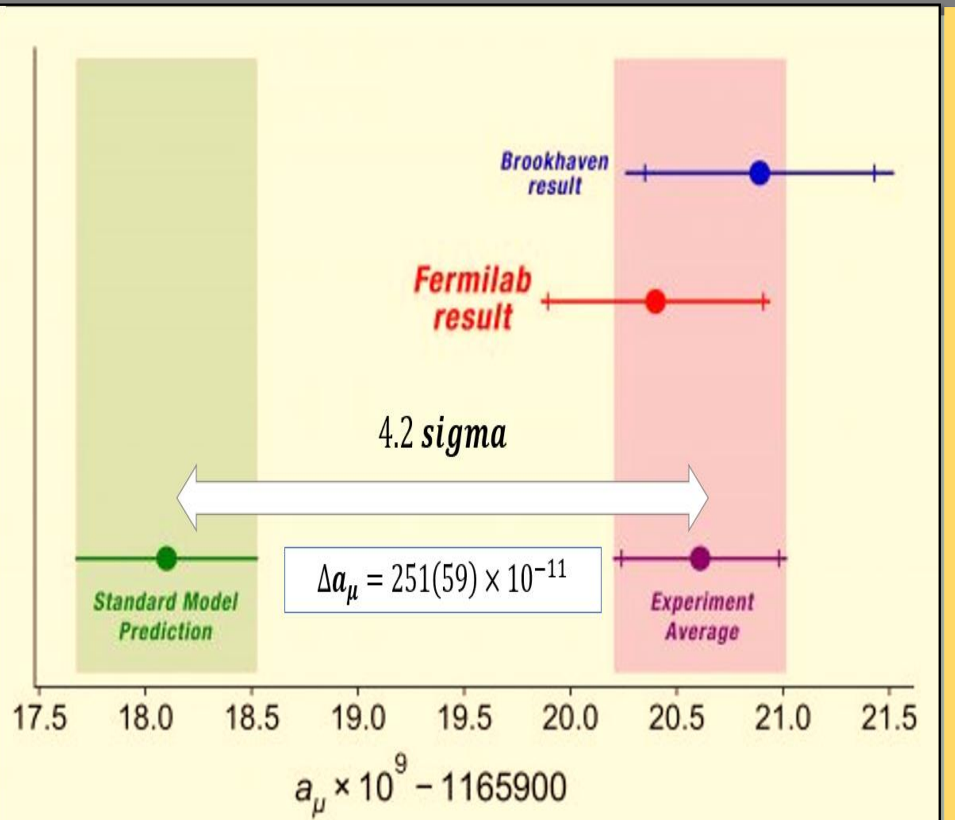
Abstract

- We have analyzed the new contributions to the muon g-2 in a class of models that generate naturally large neutrino magnetic moment.
- We have shown that the new scalars present in the theory with masses around 100 GeV can yield the right sign and magnitude for muon g-2 which has been confirmed recently by the Fermilab collaboration.
- Such a correlation is generic in models employing leptonic family symmetries.

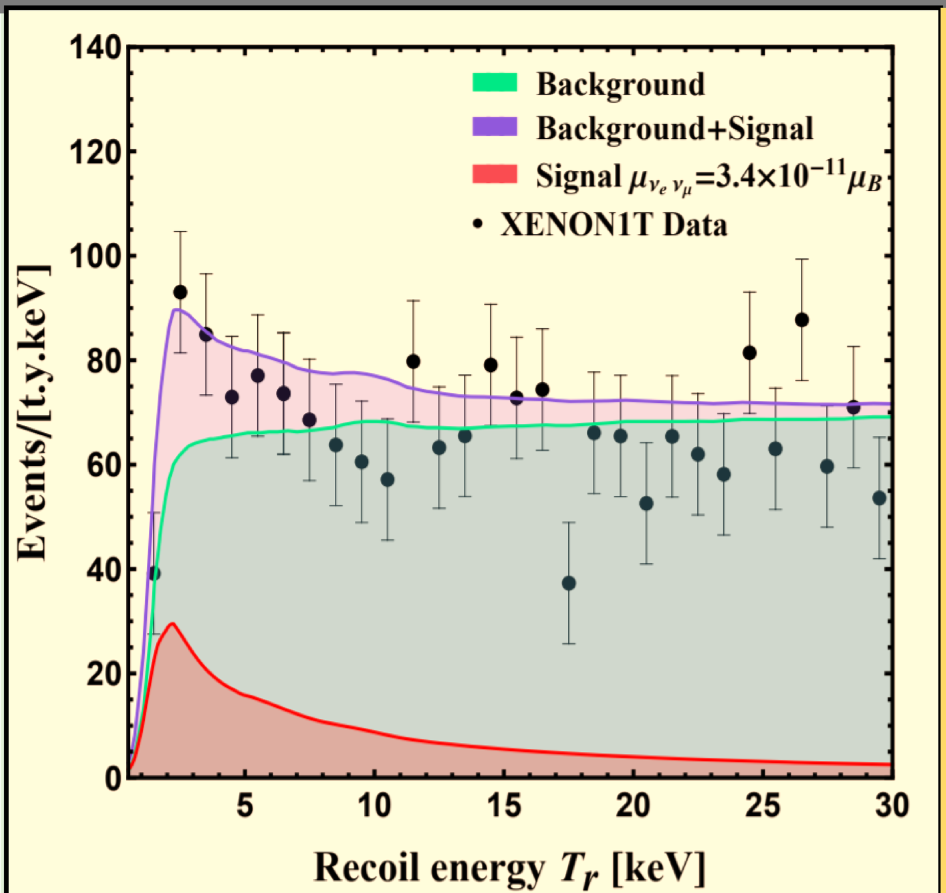
Current Status of Muon g-2



Fermilab Muon g-2 Collaboration, B. Abi *et al.* (2021)

- There has been a long-standing tension between the measured value of muon g-2 at the BNL and the corresponding SM prediction.
- Recently the Fermilab Muon g-2 collaboration has announced their findings, the discrepancy has increased to 4.2 sigma.

Xenon1T Excess – Neutrino Mag.Moment



XENON Collaboration, E. Aprile *et al.* (2020)

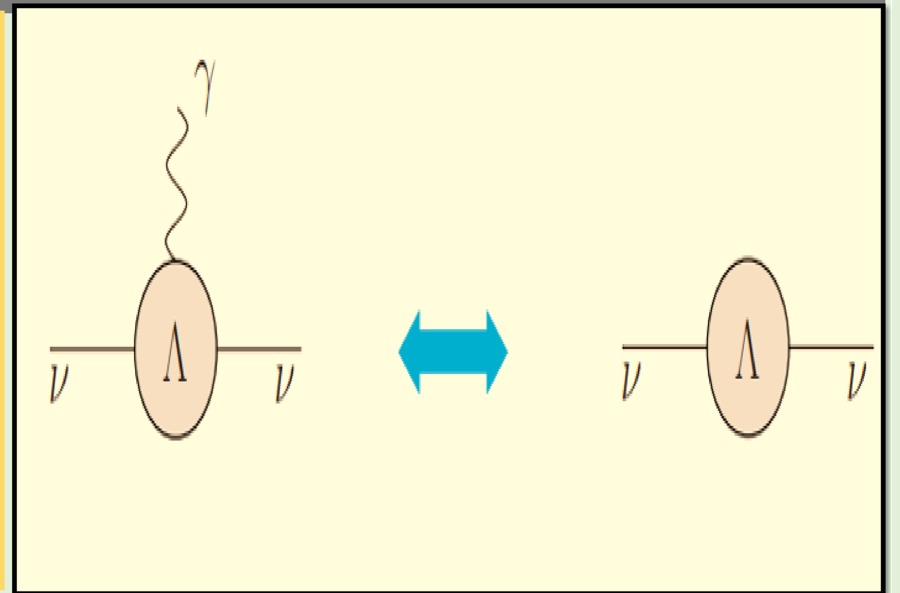
- Recently the Xenon1T collaboration observed an excess in electron recoil events in the 1-7 KeV recoil energy range.
- This excess can be explained by solar neutrinos which have nonzero magnetic moments.

$$\mu_{\nu_e\nu_\mu} \in (1.65 - 3.42) \times 10^{-11}\, \mu_B$$

Babu, Jana, Lindner (2020) arXiv:2007.04291

Neutrino Mag.Moment– Mass Conundrum

- Neutrino Magnetic Moment (NMM) operator and neutrino mass operator having the same chirality structure.
- Generating large neutrino magnetic moment will induce unacceptably large neutrino masses.



$$m_\nu \sim \frac{M^2 \mu_\nu}{2\, m_e \mu_B} \sim 0.1\mathrm{MeV} \quad \text{for } M\sim 100 \text{ GeV and } \mu_\nu \sim 10^{-11}\, \mu_B$$

- To decouple the neutrino magnetic moment from its mass, one need introduce additional symmetries.

SU(2)$_H$ Symmetry for Enhanced NMM

- The mass operator, being a Lorentz scalar, is symmetric, while the magnetic moment, being a Lorentz tensor operator is antisymmetric in the two fermion fields.

$$\mathcal{L}_{\rm mag.} = (\nu_e^T \;\; \nu_\mu^T) C^{-1} \sigma_{\mu\nu} \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix} F^{\mu\nu}$$

$$\mathcal{L}_{\rm mass} = (\nu_e^T \;\; \nu_\mu^T) C^{-1} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix}$$

- A horizontal symmetry SU(2)$_H$ acting on the electron and the muon families, under which only neutrino magnetic moment interaction is invariant can serve the purpose.
- This allows a nonzero transition magnetic moment, while neutrino mass terms are forbidden.

$$\psi_L = \begin{pmatrix} \nu_e & \nu_\mu \\ e & \mu \end{pmatrix}_L \quad (2, -\tfrac{1}{2}, 2)$$

$$\psi_R = (e \quad \mu)_R \quad (1, -1, 2)$$

$$\psi_{3L} = \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix} \quad (2, -\tfrac{1}{2}, 1)$$

$$\tau_R \quad (1, -1, 1)$$

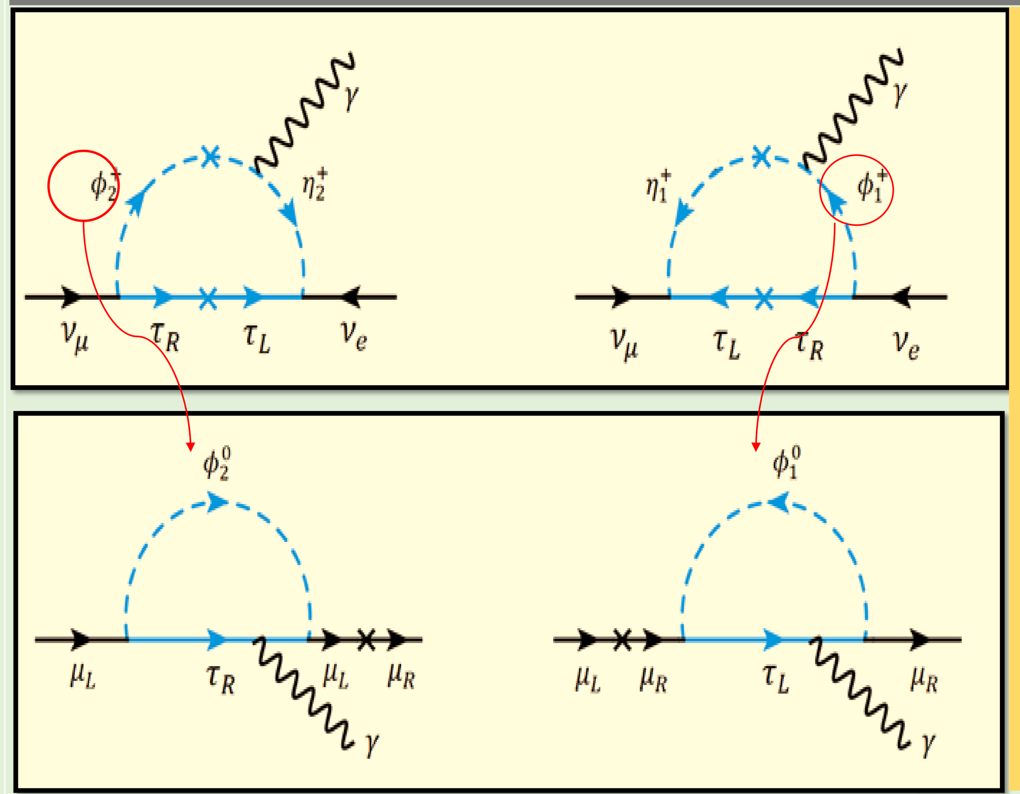
$$\phi_S = \begin{pmatrix} \phi_S^+ \\ \phi_S^0 \end{pmatrix} \quad (2, \tfrac{1}{2}, 1)$$

$$\Phi = \begin{pmatrix} \phi_1^+ & \phi_2^+ \\ \phi_1^0 & \phi_2^0 \end{pmatrix} \quad (2, \tfrac{1}{2}, 2)$$

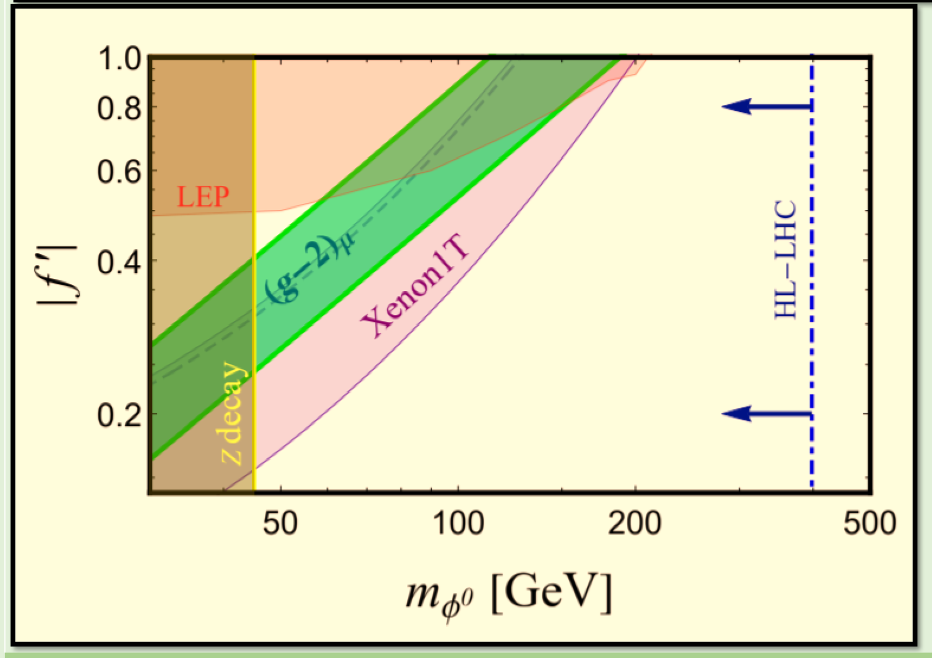
$$\eta = (\eta_1^+ \quad \eta_2^+) \quad (1, 1, 2)\,.$$

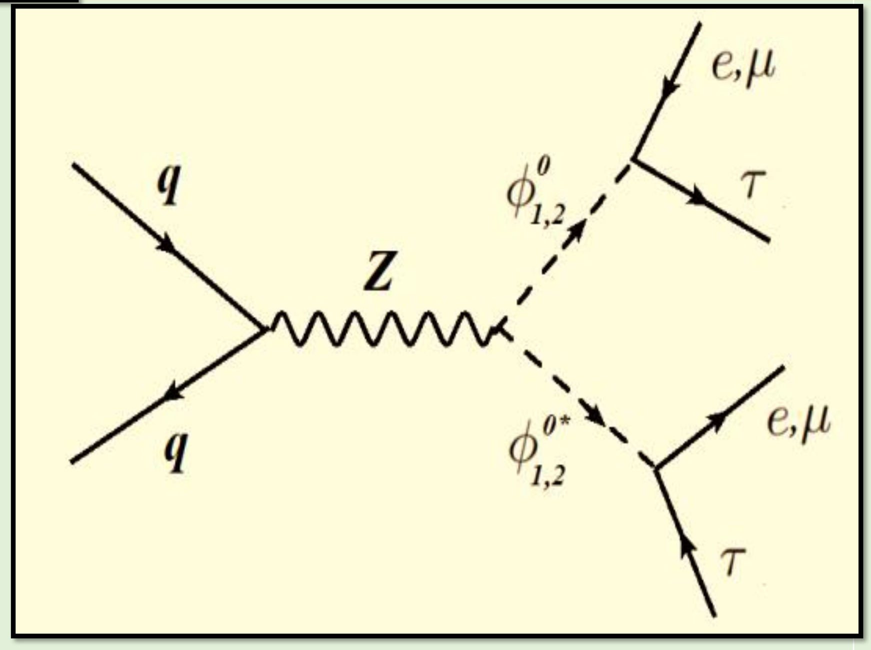
Babu, Mohapatra (1989)
Babu, Jana, Lindner (2020)

Neutrino Magnetic Moment and Muon g-2



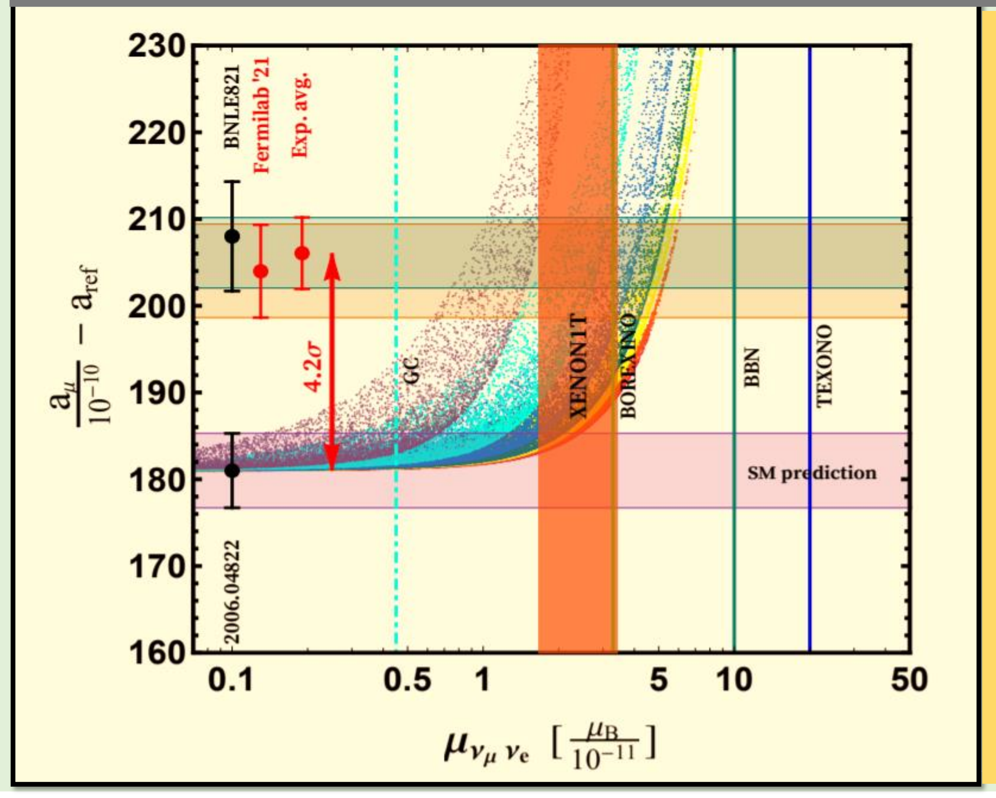
- The charged scalars contribute to NMM, whereas the corresponding neutral partners leads to Δa_μ.
- Therefore, generating large NMM would naturally leads to new contributions to muon g-2.





- The most promising signal of the model is $pp \to e^- e^+ \tau^- \tau^+, \mu^- \mu^+ \tau^- \tau^+$ at the LHC.
- At the HL-LHC with an integrated luminosity of $1\ \mathrm{ab}^{-1}$, the neutral scalars mass up to 400 GeV can be probed.

Conclusions



- We have presented a minimal unified framework for large NMM, neutrino masses and mixings, and muon g-2 anomaly.
- In these class of models there exist a direct correlation between NMM and muon g-2.