Widening the $U(1)_{L_\mu - L_\tau}$ Z' mass range for resolving the muon $g-2$ anomaly

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1. Research logic

U(1) Z' gauge model for muon g-2?

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Neutrino trident constrain $m_{Z'} < 300$MeV

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U(1) with $m_{Z'} > 300$**MeV is ruled out?**

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New mechanism to widen Z' mass

↓ **Type-II triplet scalar**

Analyze the relevant phenomenology

3. Model building

The flavor conserving interaction can be converted into the flavor changing one by imposing a unbroken exchange symmetry $Z' \to -Z'$, $H_1 \leftrightarrow H_1$ and $H_2 \leftrightarrow H_3$ with $v_2 = v_3 = v$. The totally off-diagonal Z'-lepton interactions in the mass eigen-states

$$-\tilde{g}(\bar{\mu}\gamma^\mu\tau + \bar{\tau}\gamma^\mu\mu + \bar{\nu}_\mu\gamma^\mu L\nu_\tau + \bar{\nu}_\tau\gamma^\mu L\nu_\mu)Z'_\mu \ .$$

This does not contribute to MNT, $\tau \to \mu\gamma$, 3μ. However, the Z' interaction will induce $\tau \to \mu\bar{\nu}_\mu\nu_\tau + \mu\bar{\nu}_\tau\nu_\mu$, which provides a very stringent constraint to exclude this model. To staisfy the constraint, we propose a mechanism by introducing type-II seesaw mechanism triplet scalar Δ, which results in the Yukawa coupling

$$\bar{\nu}_i^c L\nu_j\Delta^0 - \bar{e}_i^c Le_j\Delta^{++} - \frac{1}{\sqrt{2}}(\bar{\nu}_i^c Le_j + \bar{e}_i^c L\nu_j)\Delta^+ .$$

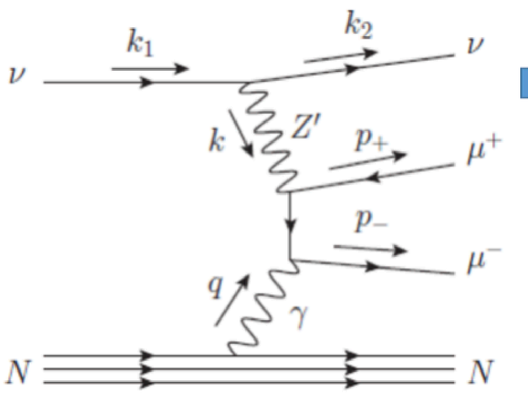
2. Research problem

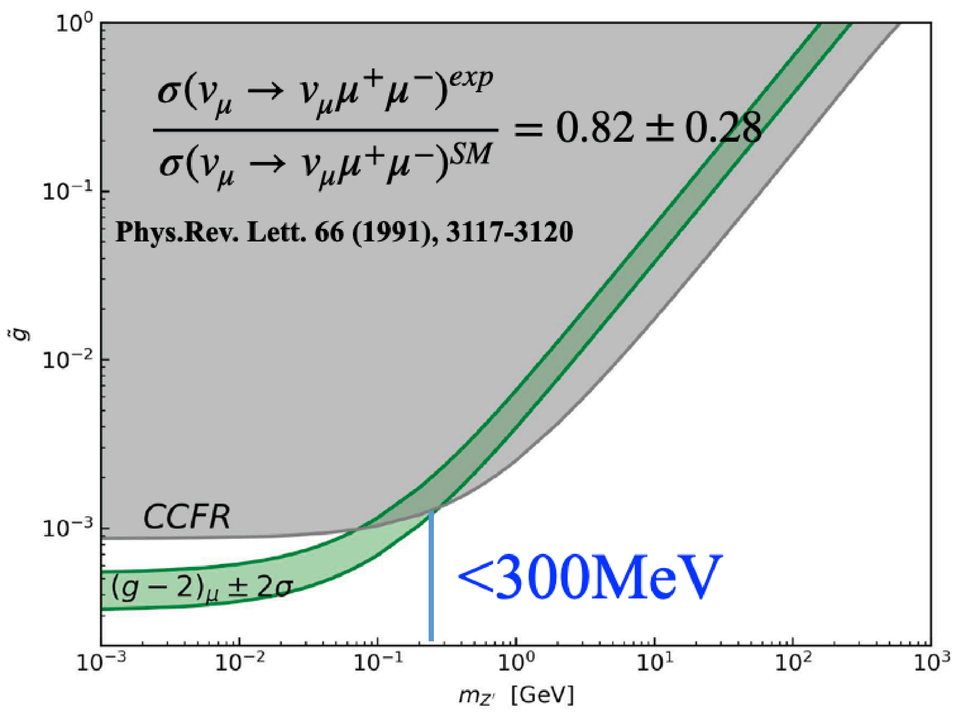
The Z' gauge boson of the model only interacts with leptons in the weak interaction basis

$$-\tilde{g}(\bar{\mu}\gamma^\mu\mu - \bar{\tau}\gamma^\mu\tau + \bar{\nu}_\mu\gamma^\mu L\nu_\mu - \bar{\nu}_\tau\gamma^\mu L\nu_\tau)Z'_\mu \ ,$$

The interaction can contribute $(g-2)_\mu$ at one loop level, and also modify the cross section for the muon neutrino trident (MNT) process compared with the SM prediction,

$$\nu_\mu N \to \nu_\mu N\mu^+\mu^-$$





To evade the MNT constraints, we need to analyze the interaction structure.

Reduce MNT → $\mu - \tau$ **mixing** → $\tau \to \mu\gamma, 3\mu$ **Excluded**

→ **Forbid both diagonal and off-diagonal interactions**

→ **Fully off-diagonal interactions** → $\tau \to \mu\bar{\nu}_\mu\nu_\tau$

→ **New interaction to reduce the constraints**

Therefore, it is crucial to have a mechanism to widen the Z' mass range with larger than 300 MeV by forbidding flavor changing processes and to open a new window of searching for Z' physics.

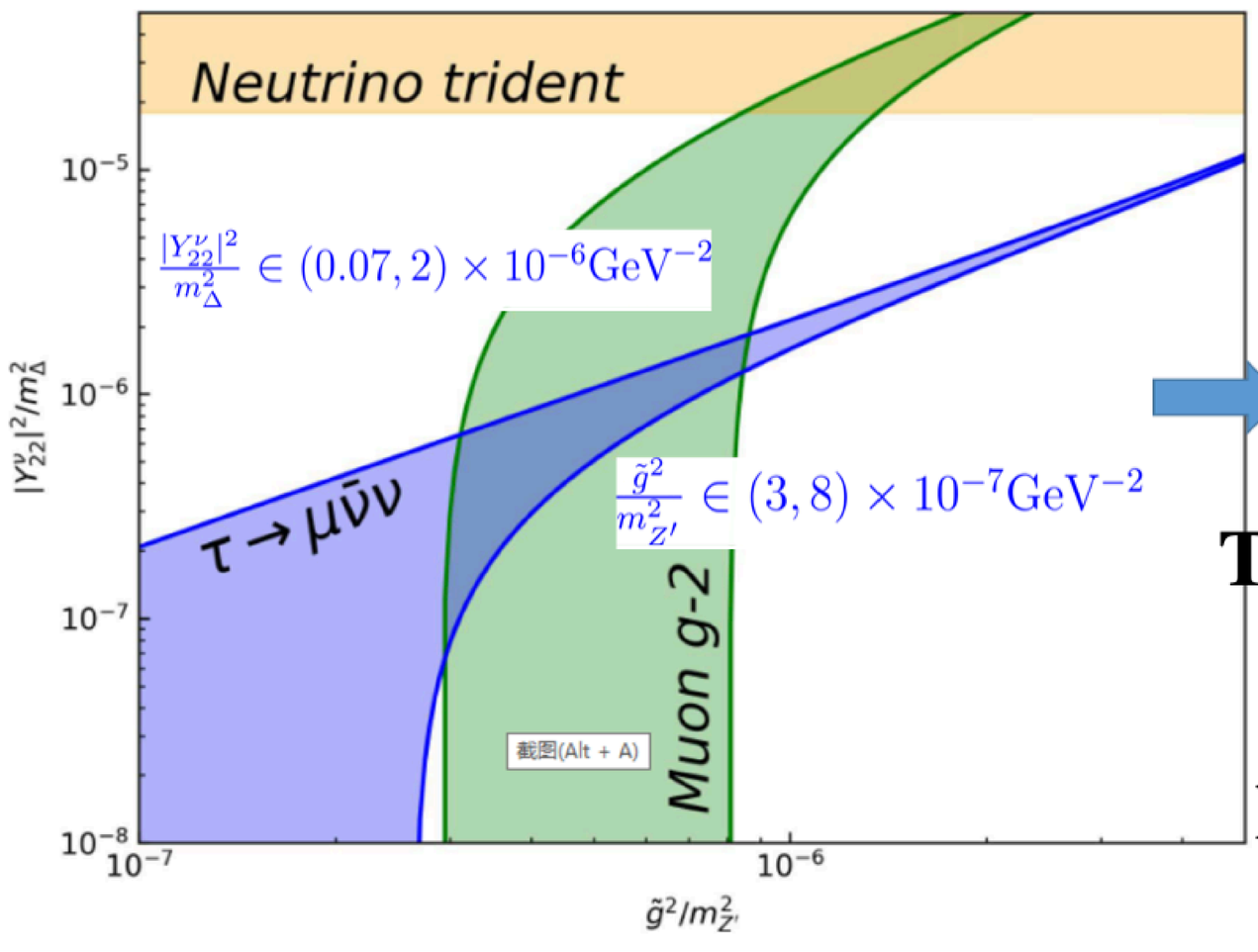
4. Phenomenology

In our flavor changing $U(1)$ model with triplet scalar, the contribution to $(g-2)_\mu$ and total amplitude $M_{total}(\tau \to \mu\nu\bar{\nu})$ are

$$\Delta a_\mu = \frac{\tilde{g}^2 m_\mu^2}{12\pi^2 m_{Z'}^2}\left(\frac{3m_\tau}{m_\mu} - 2\right) - \frac{m_\mu^2}{16\pi^2}\left[\left(\frac{|Y_{22}^\nu|^2}{m_{\Delta_2}^2} + \frac{|Y_{22}^\nu|^2}{m_{\Delta_3}^2}\right) + \frac{|Y_{23}^\nu|^2}{m_{\Delta_1}^2}\right] ,$$

$$M_{total} = \left(\frac{\rho_{\tau\mu}}{2} - \frac{g^2}{4m_W^2} - \frac{\tilde{g}^2}{m_{Z'}^2}\right)\bar{\mu}\gamma_\mu\tau\bar{\nu}_\tau\gamma^\mu L\nu_\mu - \left(\frac{\rho_{\tau\mu}}{2} - \frac{g^2}{4m_W^2}\right)\bar{\mu}\gamma_\mu\gamma_5\tau\bar{\nu}_\tau\gamma^\mu L\nu_\mu + \left[\left(\frac{\rho_{\mu\tau}}{2} - \frac{\tilde{g}^2}{m_{Z'}^2}\right)\bar{\mu}\gamma_\mu\tau - \left(\frac{\rho_{\mu\tau}}{2}\right)\bar{\mu}\gamma_\mu\gamma_5\tau\right]\bar{\nu}_\mu\gamma^\mu L\nu_\tau \ ,$$

with $\rho_{\tau\mu} = \left(|Y_{22}^\nu|^2/m_{\Delta_2}^2 \mp |Y_{22}^\nu|^2/m_{\Delta_3}^2\right)/4$, $\rho_{\mu\tau} = \rho_{\tau\mu} - |Y_{23}^\nu|^2/m_{\Delta_1}^2$.



U(1) model for muon g-2

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Off-diagonal Z' interaction

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Triplet scalar to widen mass

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New window for Z' physics