g-2 Dark Sector Portal: 
$U(1)_{L\mu - L\tau}$ Solution to Dark Matter

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Motivation

• Can we construct a model that explains the g-2 excess and provides a viable DM candidate?

• We consider a gauged $U(1)_{L_\mu-L_\tau}$ extension to the SM

• Introduce a new vector boson Z’

• Postulate fermionic dark matter
Model Details

\[ \mathcal{L}_{int} = g_x \bar{\chi} \gamma^\mu \chi Z'_\mu + g' (\bar{\mu} \gamma^\mu \mu - \bar{\tau} \gamma^\mu \tau) Z'_\mu + g' (\bar{\nu} \gamma^\mu P_L \nu - \bar{\nu} \gamma^\mu P_L \nu) Z'_\mu + \frac{\kappa}{2} F_{\mu \nu} Z'^{\mu \nu} \]

- **Z’ couples directly to DM**
- **Also couples to muon + tau sector**
- **Kinetic mixing with SM photon**
Established constraints on the Z’ parameter space

- g-2 favored region shown in salmon-pink

- **Key takeaway:** mass of Z’ is restricted to lie in the range 10 MeV – 200 MeV

- g’ central value is fixed as a function of mZ’

Experimental constraints on the $U(1)_{L_H - L_T}$ gauge boson [arXiv:1803.05466v2]
DM Parameter Space – Cosmological Constraints

Relevant Processes:

• Both contribute to relic abundance. Only process relevant for CMB constraint is muon/anti-muon pair production.

• Annihilation to a pair of $Z'_{\mu}$ only possible if DM is the heavier of the two.

Cosmological bounds on the dark matter coupling strength
Constraints Imposed by Direct Detection

Consider several experiments: XENON1T, DarkSide-50, CDMSlite, CRESST-III, DarkSide-LM, SuperCDMS

Typically consider low Q limit of loop level kinetic mixing (mixing at tree level taken to be 0)

We consider mixing at both tree and loop level with full Q dependence of \( \kappa_{\text{loop}}(Q) \) along with BC \( \kappa_{\text{tot}} \to 0 \) as \( Q \to 0 \):

\[
\kappa_{\text{tot}}(Q) = \kappa_0 + \kappa_{\text{loop}}(Q)
\]

\[
\kappa_{\text{loop}}(Q) = \kappa_1(Q, m_\mu) - \kappa_1(Q, m_\tau)
\]

\[
\kappa_1(Q, m_\mu) - \kappa_1(Q, m_\tau) \approx \begin{cases} 
0 + \mathcal{O}(m^2/Q^2), & Q \gg m_{\mu,\tau} \\
\frac{e^2}{12\pi^2} \ln \frac{m_\mu^2}{m_\mu^2} + \mathcal{O}(Q^2/m^2), & Q \ll m_{\mu,\tau}
\end{cases}
\]
Scaling Direct Detection Upper Bounds

- Running kinetic mixing is very suppressed in low Q region
- Leads to a different event rate for direct detection, suggesting we may modify the constraints found for constant kinetic mixing
- We scale the constant mixing bounds by $\sqrt{\frac{R_{K0}}{R_{K_{tot}}}}$
• Constant kinetic mixing limits DM mass range to $\approx < 2(1)$ GeV for $m_{Z'} = 100(20)$ MeV

• Considering running kinetic mixing loosens up the parameter space (upper bound on DM mass increased to $\approx 6$ GeV)
• An extension to the SM with the gauge group $U(1)_{L\mu - L\tau}$ can explain the observed $g$-$2$ excess.

• Considering full momentum dependence of kinetic mixing in this model leads to a viable DM parameter space

• Work in Progress: We expect a stronger annual modulation effect due to increased rate contribution from higher recoil energies (higher DM velocity)

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