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

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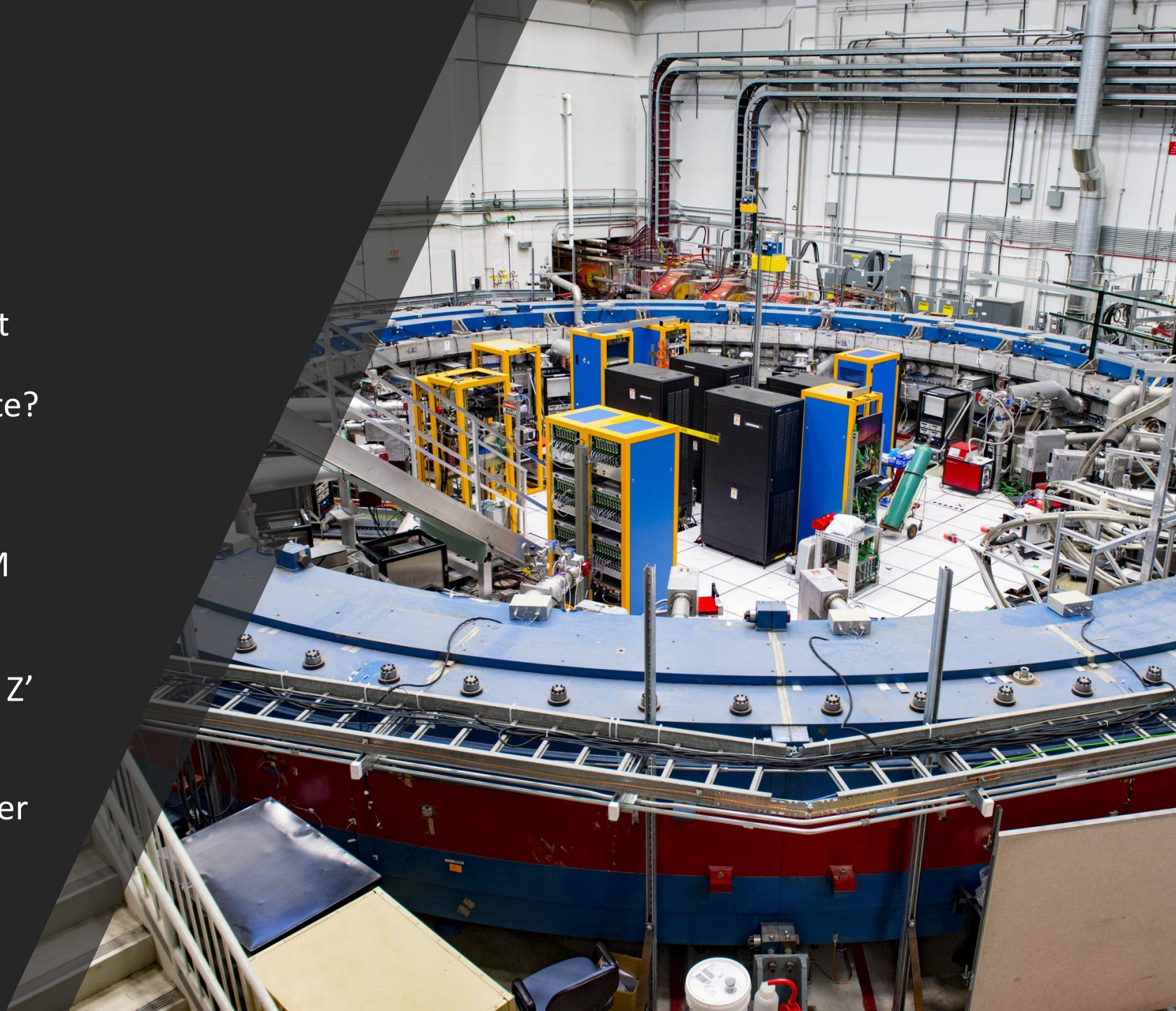
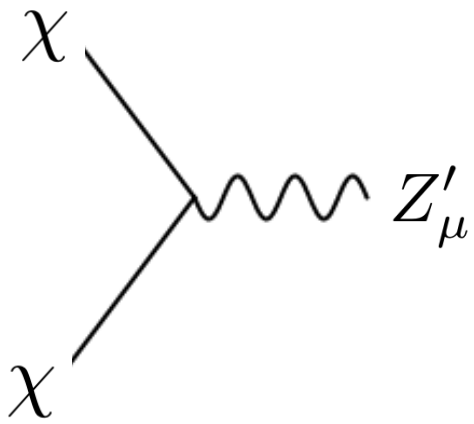
Motivation

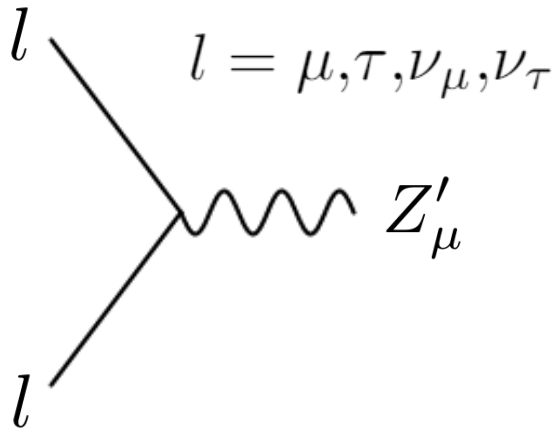
- Can we construct a model that explains the g-2 excess *and* provides a viable DM candidate?
- We consider a gauged $U(1)_{L_\mu - L_\tau}$ extension to the SM
- Introduce a new vector boson Z’
- Postulate fermionic dark matter



Model Details

$$\mathcal{L}_{int} = g_\chi \overline{\chi}\gamma^\mu \chi Z'_\mu + g'(\overline{\mu}\gamma^\mu \mu - \overline{\tau}\gamma^\mu \tau) Z'_\mu + g'(\overline{\nu_\mu}\gamma^\mu P_L \nu_\mu - \overline{\nu_\tau}\gamma^\mu P_L \nu_\tau) Z'_\mu + \frac{\kappa}{2} F_{\mu\nu} Z'^{\mu\nu}$$





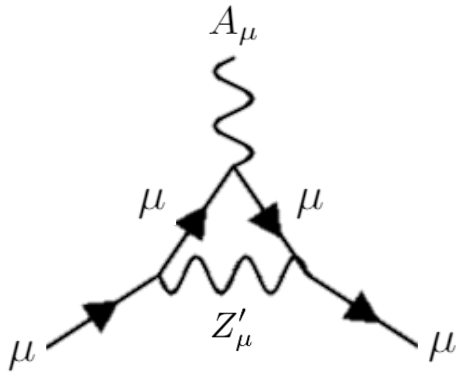
Z' couples directly to DM

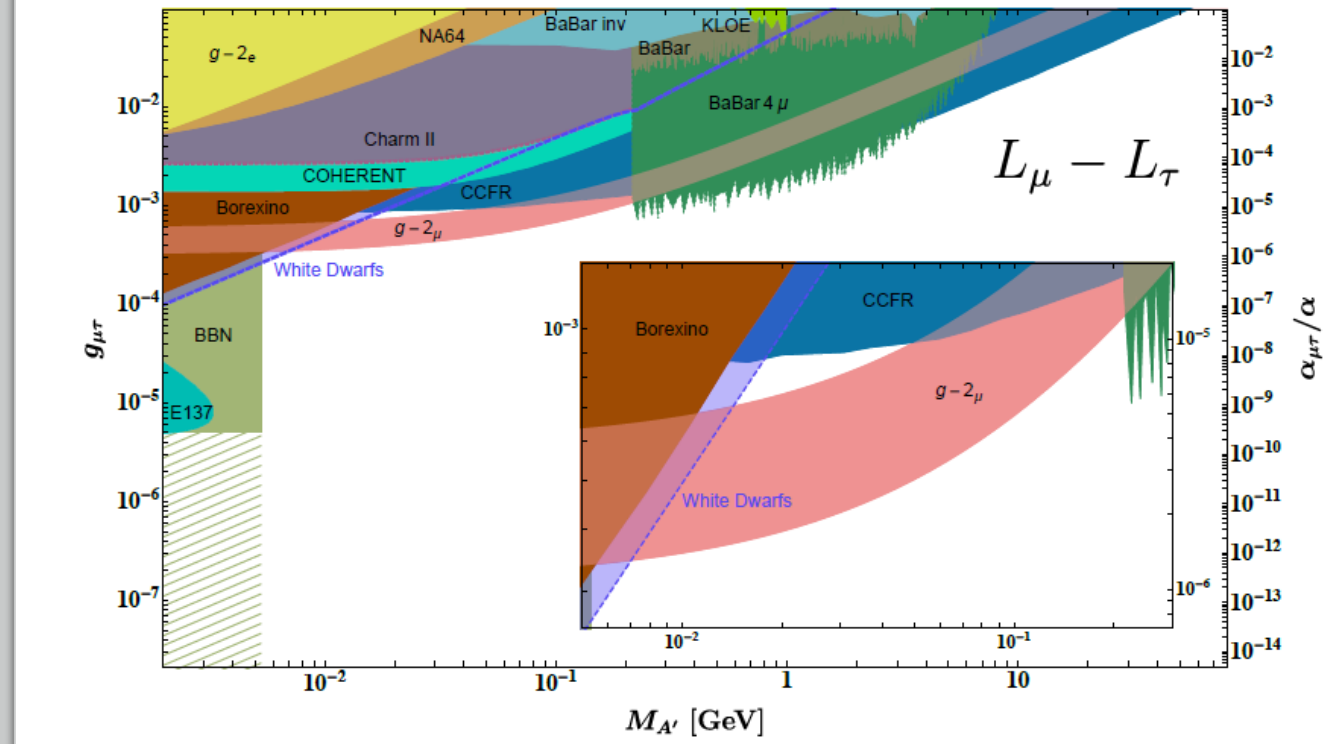
Also couples to muon + tau sector

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'

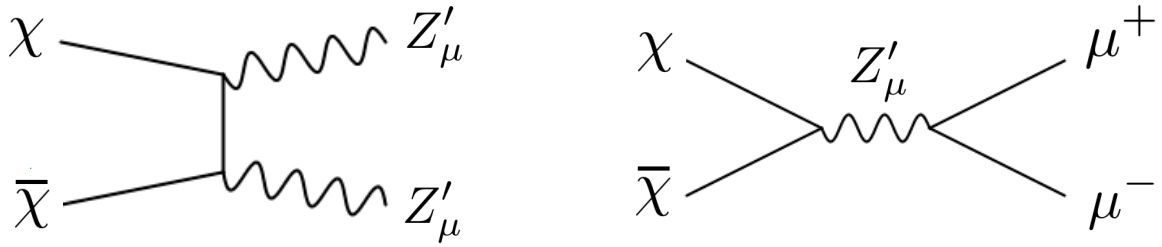




Experimental constraints on the $U(1)_{L_\mu - L_\tau}$ gauge boson [arXiv:1803.05466v2]

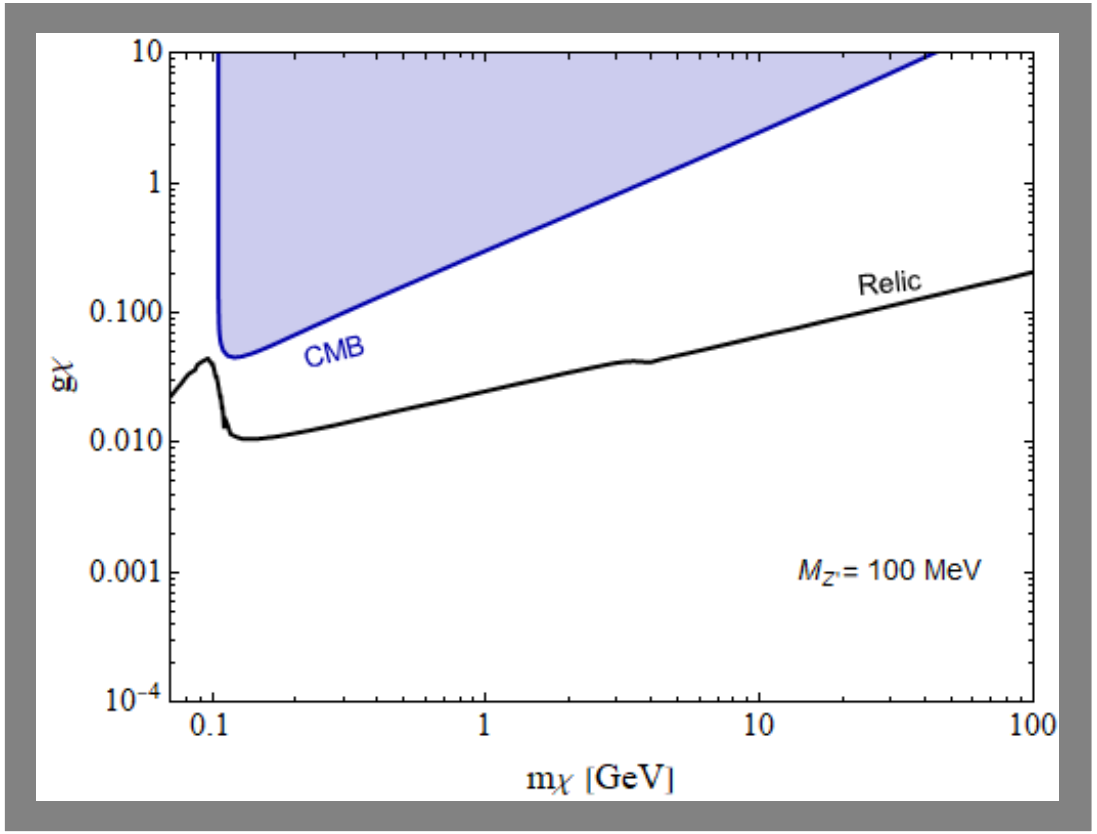
DM Parameter Space – Cosmological Constraints

Relevant Processes:



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

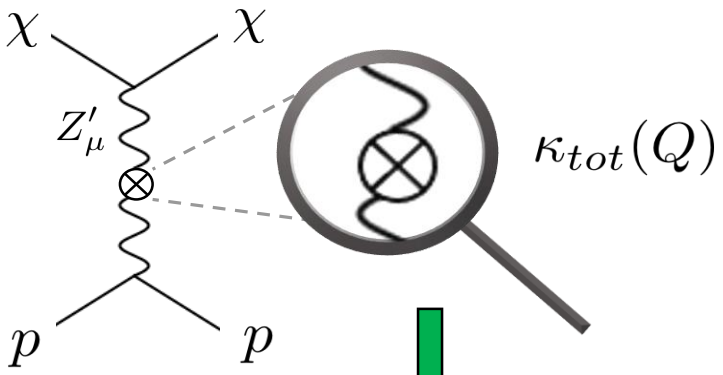
- Annihilation to a pair of Z'_μ only possible if DM is the heavier of the two.

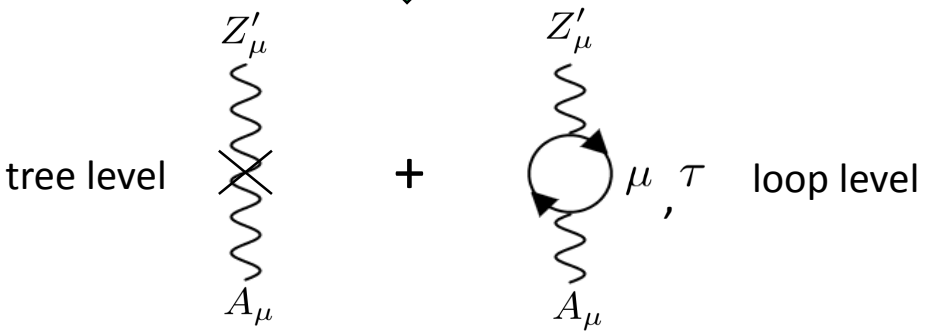


Cosmological bounds on the dark matter coupling strength

Constraints Imposed by Direct Detection

$$\sigma_{\chi p\to\chi p} = \frac{16\pi\alpha^2\mu_{\chi p}^2}{(4k^2m_{Z'}^2 + m_{Z'}^4)} \qquad \alpha = g_e g_\chi \kappa_{tot}$$





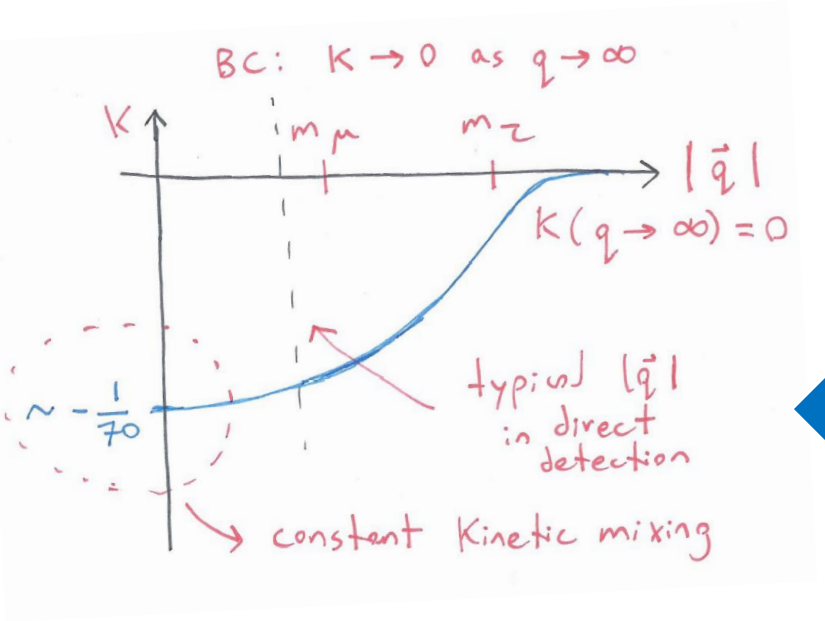
$$\kappa_{tot}(Q) = \kappa_0 + \kappa_{loop}(Q)$$

- 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 $\kappa_{loop}(Q)$ along with BC $\kappa_{tot} \to 0$ as $Q \to 0$:

$$\kappa_{loop}(Q) = \kappa_1(Q, m_\mu) - \kappa_1(Q, m_\tau)$$

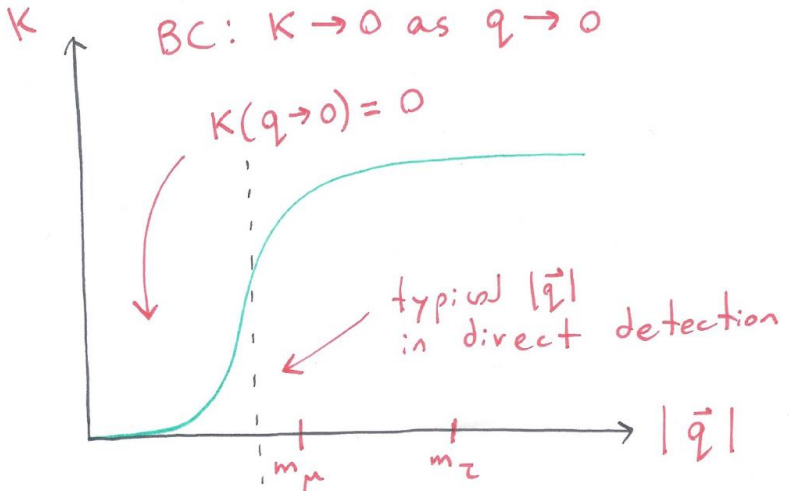
$$\kappa_1(Q, m_\mu) - \kappa_1(Q, m_\tau) \simeq \begin{cases} 0 + \mathcal{O}(m^2/Q^2)\ , & Q \gg m_{\mu,\tau} \\ \frac{eg'}{12\pi^2} \ln\frac{m_\tau^2}{m_\mu^2} + \mathcal{O}(Q^2/m^2)\ , & Q \ll m_{\mu,\tau} \end{cases}$$

Scaling Direct Detection Upper Bounds



Constant kinetic mixing

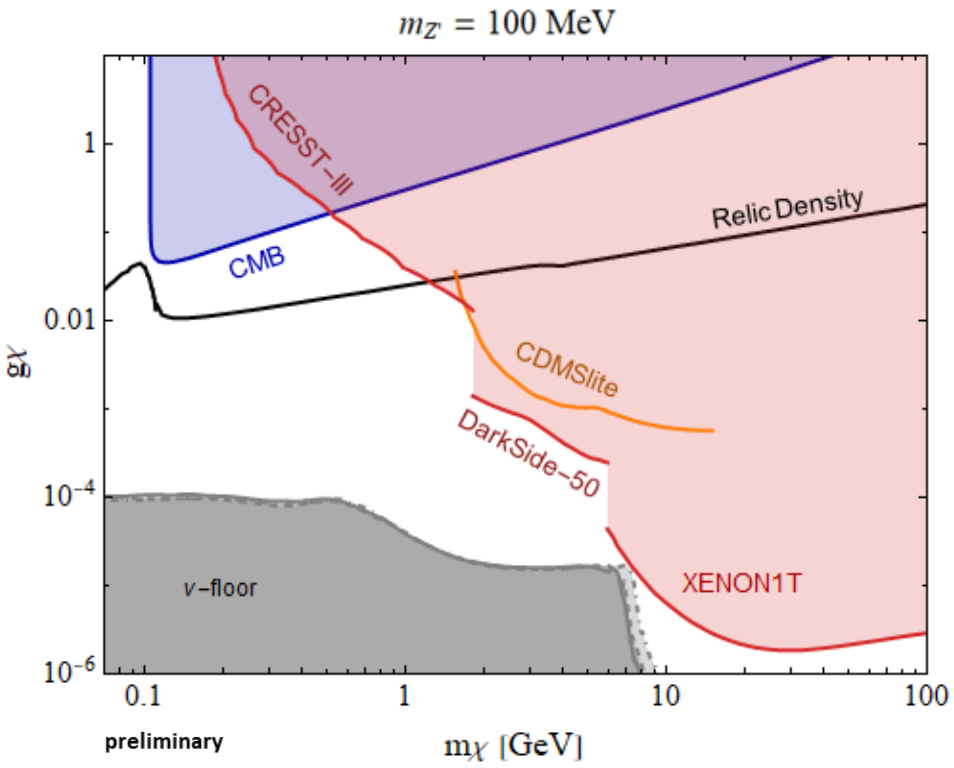
Running kinetic mixing

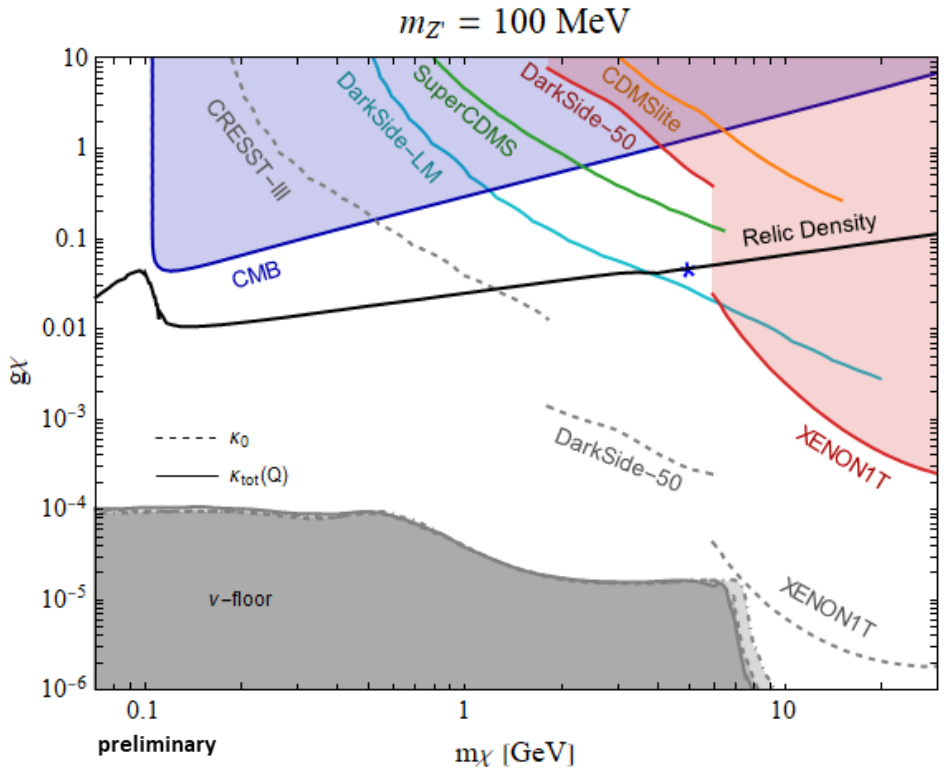


- Running kinetic mixing is very supressed in low Q region
- Leads to a different event rate for direct detection, suggesting we may modify the constraints found for constant kinetic mixing
- We scale the constant mixing bounds by $\sqrt{\frac{R_{\kappa_0}}{R_{\kappa_{tot}}}}$

Resulting DM Parameter Space

- Constant kinetic mixing limits DM mass range to ≈ < 2(1) GeV for mZ' = 100(20) MeV
- Considering running kinetic mixing loosens up the parameter space (upper bound on DM mass increased to ≈ 6 GeV)



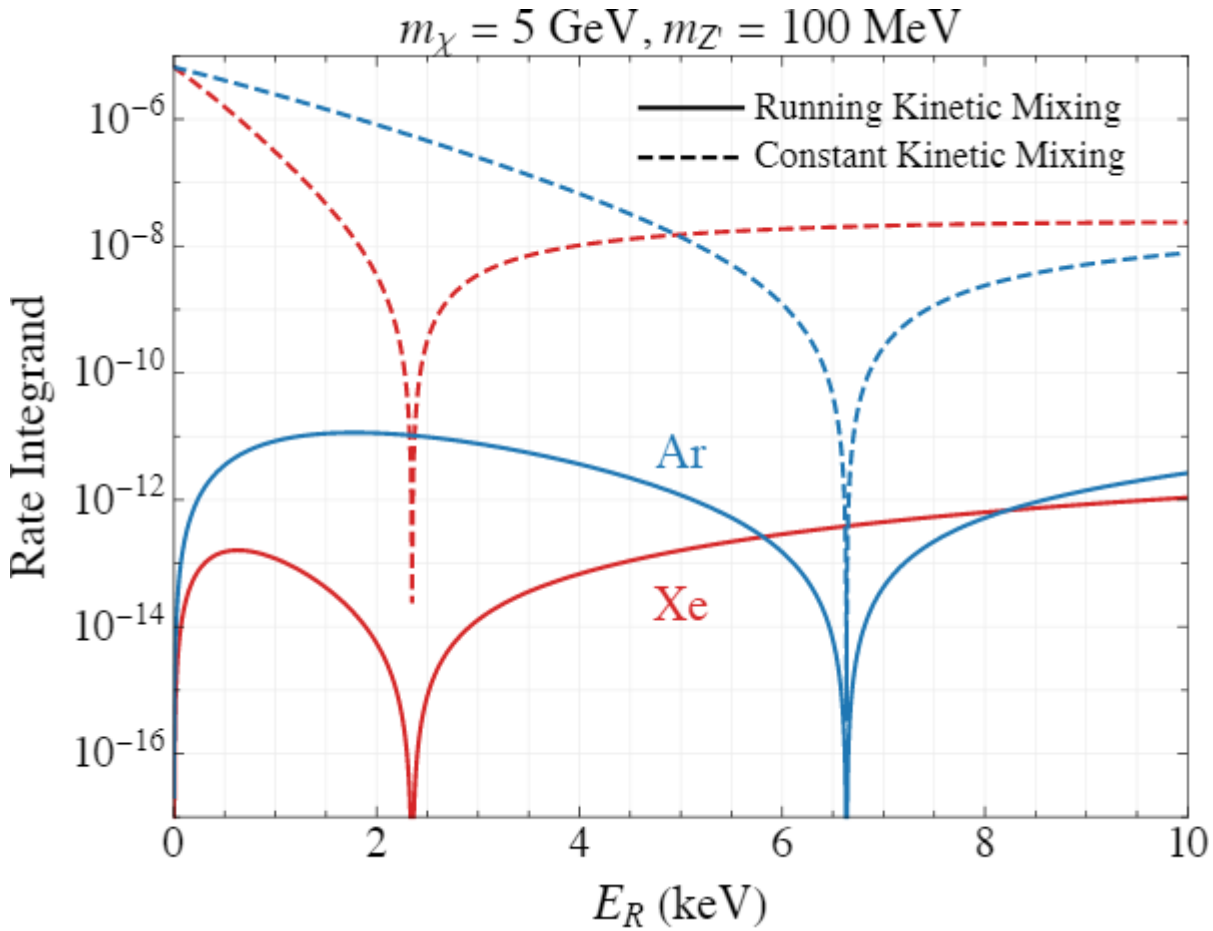


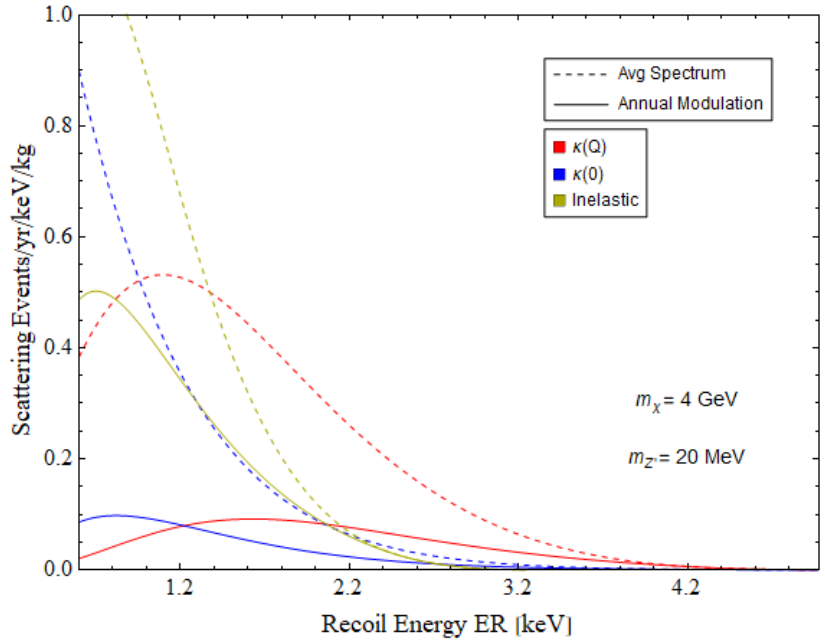
Parameter space of DM candidate χ considering constant and total kinetic mixing

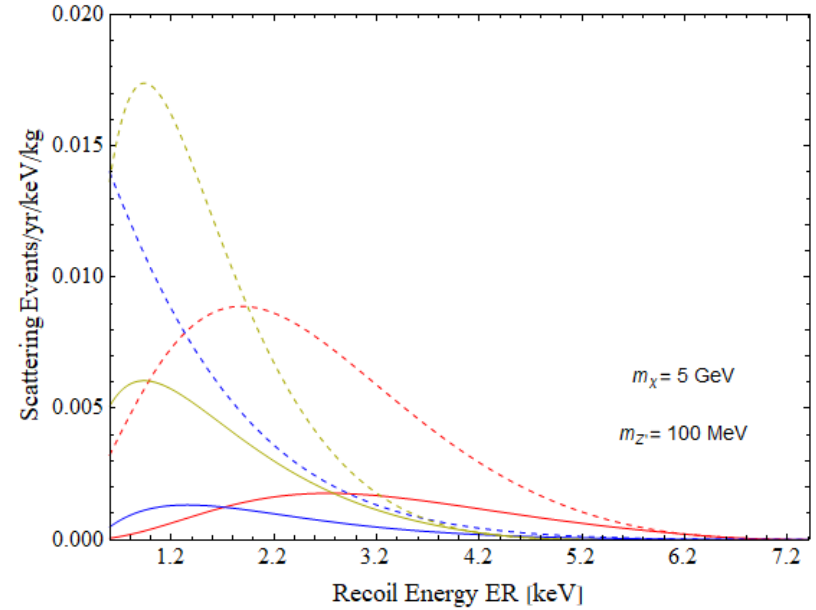
Summary + Future Work

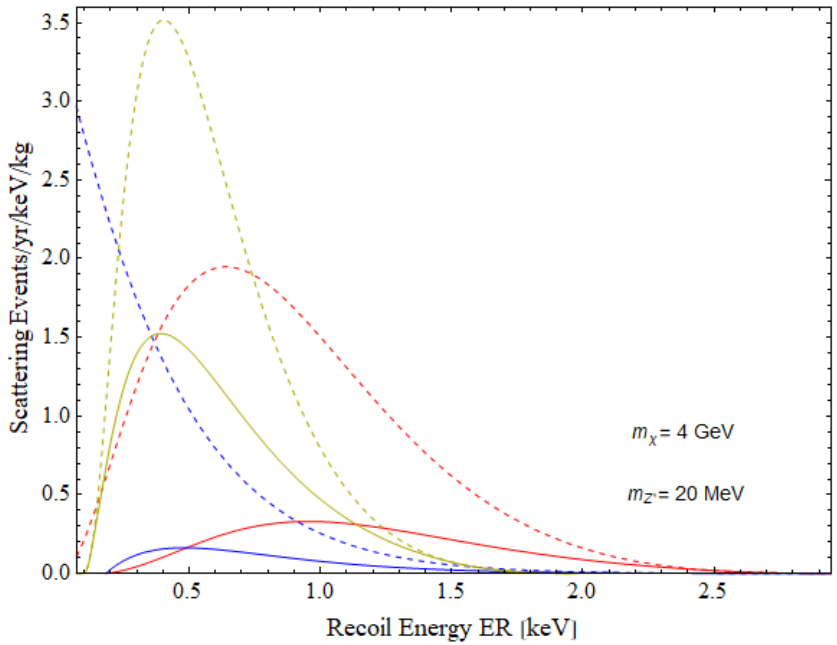
- An extension to the SM with the gauge group $U(1)_{L_\mu - L_\tau}$ can explain the observed g-2 excess.
- Considering full momentum dependence of kinetic mixing in this model leads to a viable DM parameter space
- Work in Progress: We expect a stronger annual modulation effect due to increased rate contribution from higher recoil energies (higher DM velocity)

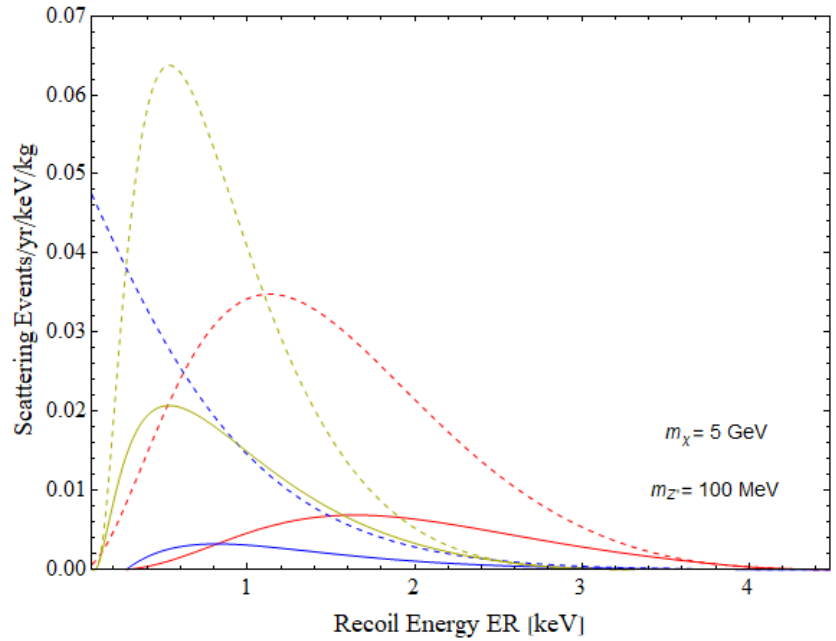
Hapitas, Tuckler, Zhang, 2107.xxxxx


$m_\chi = 5$ GeV, $m_{Z'} = 100$ MeV
Running Kinetic Mixing
Constant Kinetic Mixing
Ar
Xe
Rate Integrand
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
0
2
4
6
8
10
E_R (keV)


Avg Spectrum
Annual Modulation
κ(Q)
κ(0)
Inelastic
m_χ = 4 GeV
$m_{Z'}$ = 20 MeV
Scattering Events/yr/keV/kg
Recoil Energy ER [keV]


m_χ = 5 GeV
$m_{Z'}$ = 100 MeV
Scattering Events/yr/keV/kg
Recoil Energy ER [keV]


m_χ = 4 GeV
$m_{Z'}$ = 20 MeV
Scattering Events/yr/keV/kg
Recoil Energy ER [keV]


m_χ = 5 GeV
$m_{Z'}$ = 100 MeV
Scattering Events/yr/keV/kg
Recoil Energy ER [keV]