The Dark Sector: Model Building and Lepton Jets

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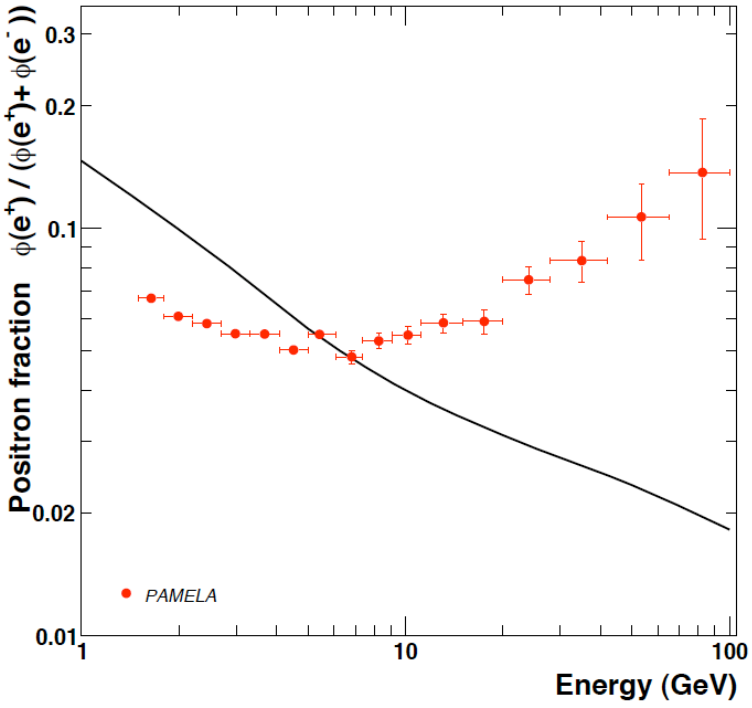
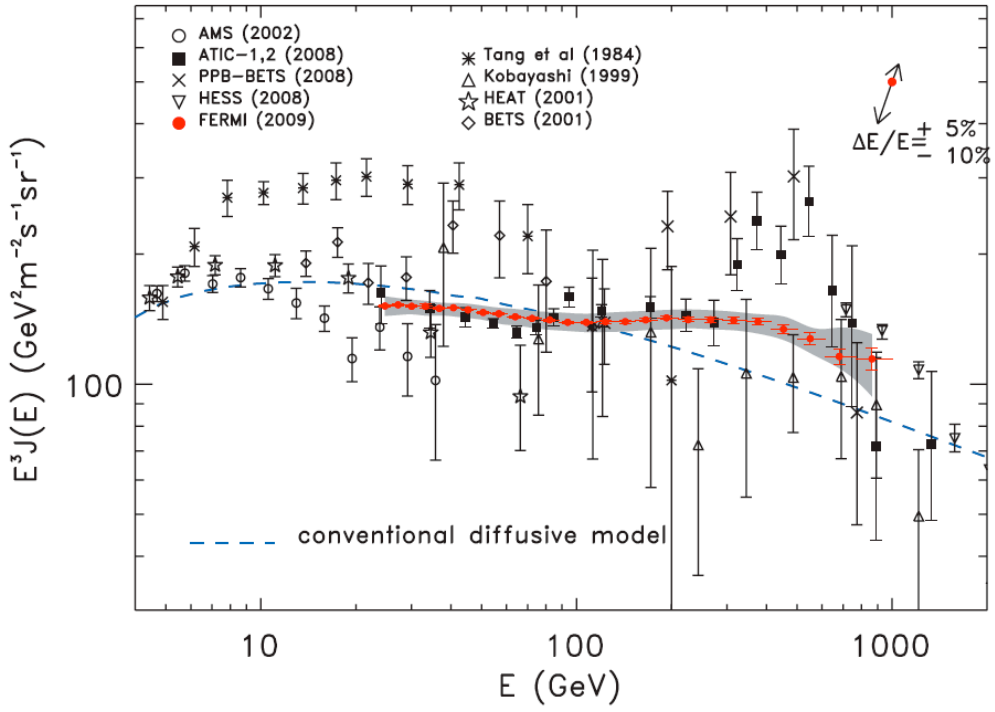
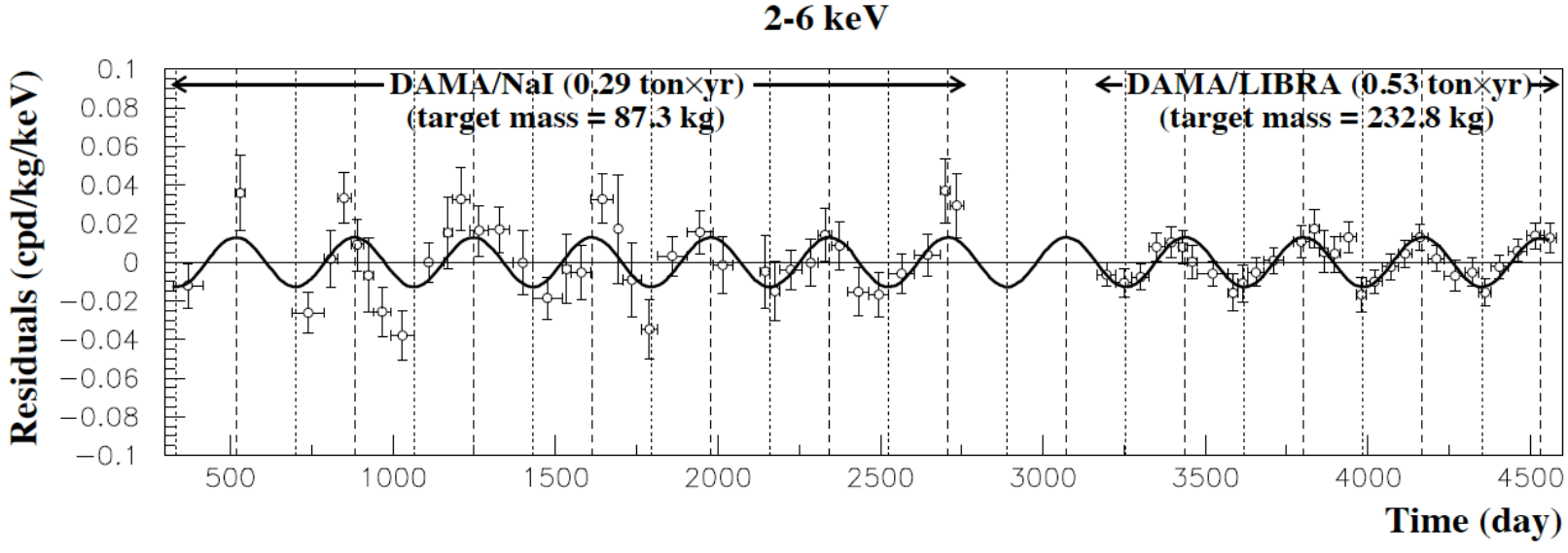
M. Baumgart, C. Cheung, LT. Wang, JTR, and I. Yavin, **0901.0283**
C. Cheung, LT. Wang, JTR, and I. Yavin, **0902.3246**

The Motivation







Scales in the Dark Sector

These experiments can be explained if dark matter is charged under a hidden sector that involves the following three scales:

- **TeV:** Dark matter charged under the hidden sector
- **GeV:** Higgsing scale of dark sector. This scale is naturally generated in SUSY and leads to a Sommerfeld enhanced annihilation cross-section.
- **MeV:** Dark matter splitting, allowing for inelastic explanation of DAMA. This scale naturally arises when integrating out TeV scale fields because GeV^2 / TeV $\sim$ MeV

D. Tucker-Smith and N. Weiner, **hep-ph/0101138**.

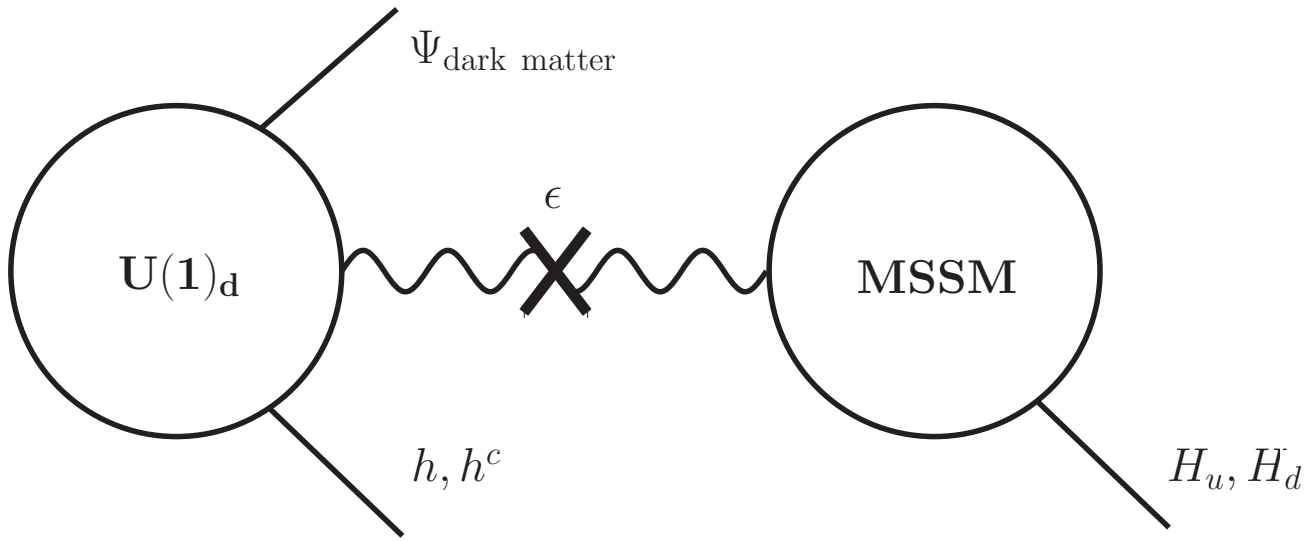
N. Arkani-Hamed, D. Finkbeiner, T. Slatyer, and N. Weiner, **0810.0713**.

N. Arkani-Hamed and N. Weiner, **0810.0714**

A Simple $U(1)$ Model

SUSY + kinetic mixing $\rightarrow$ GeV scale $\rightarrow$ GeV^2/TeV $\sim$ MeV scale

$$\mathcal{L} \supset \epsilon F_{\mu\nu} b^{\mu\nu} \qquad \epsilon \sim 10^{-3} - 10^{-4}$$



$$W = M\Psi\Psi^c + \frac{1}{4\Lambda}\Psi^2 (h^c)^2$$

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SUSY Kinetic Mixing as the Origin of Light Scales

The SUSY version of kinetic mixing automatically generates the GeV scale.

$$\mathcal{L} \supset \int d^2\theta W_d W_Y$$

In components this results in D-term mixing:

$$V \supset \epsilon D_d D_Y$$

Integrating out the Standard Model fields induces an effective FI term for the hidden sector:

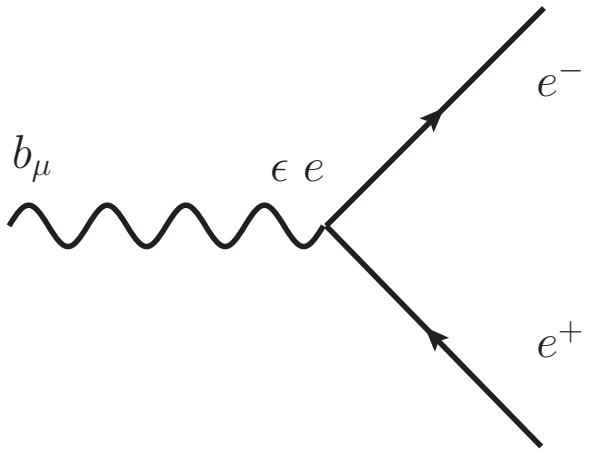
$$\xi_d = \epsilon \langle D_Y \rangle \sim \ \mathrm{GeV}^2$$

Testing the DM interpretation of PAMELA and FERMI at the LHC

- It may be difficult to determine the source of the cosmic ray anomalies from the astrophysics alone, because the backgrounds are not well understood.

- But a new source of leptons in the sky may also imply new sources of leptons in colliders.

- Kinetic mixing provides a portal to the hidden sector, and can lead to characteristic lepton signatures in colliders.

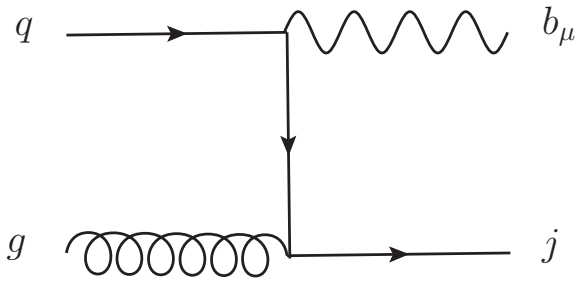


Dark Sector Production

Kinetic mixing implies several production mechanisms in colliders:

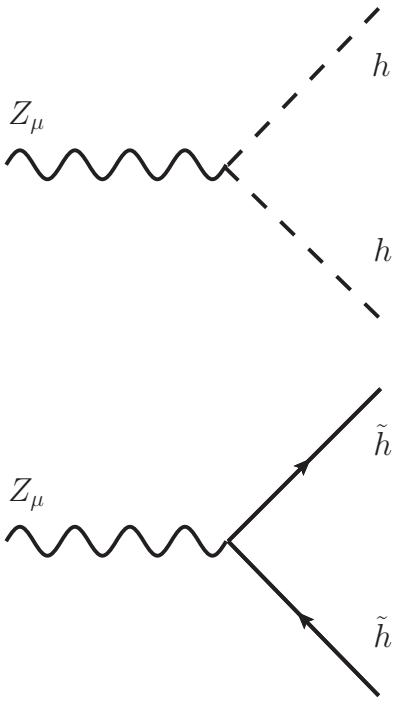
Direct b production

$\epsilon b_\mu J^\mu_{\rm EM}$



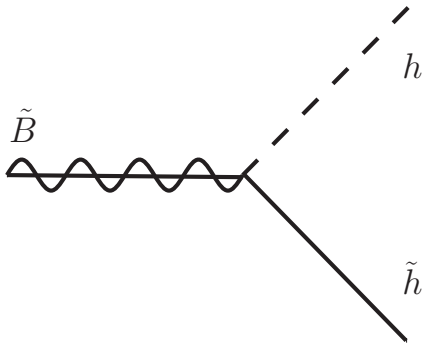
rare Z decay

$\epsilon Z_\mu J^\mu_b$



LSP decay

$\epsilon \lambda_{\tilde{B}} \tilde{J}_b$



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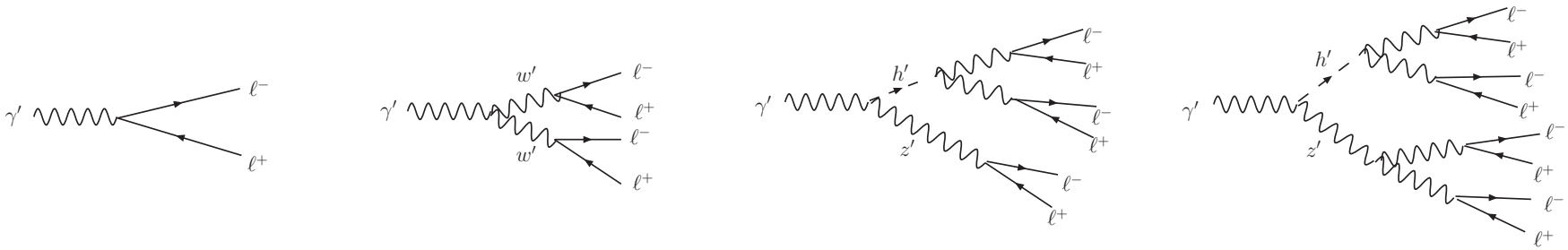
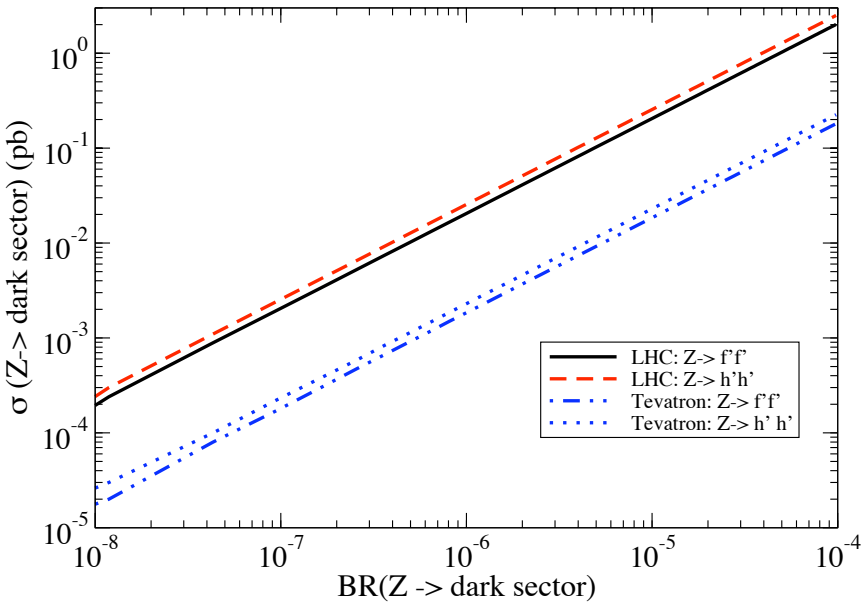
Dark Sector Decay: Lepton Jets

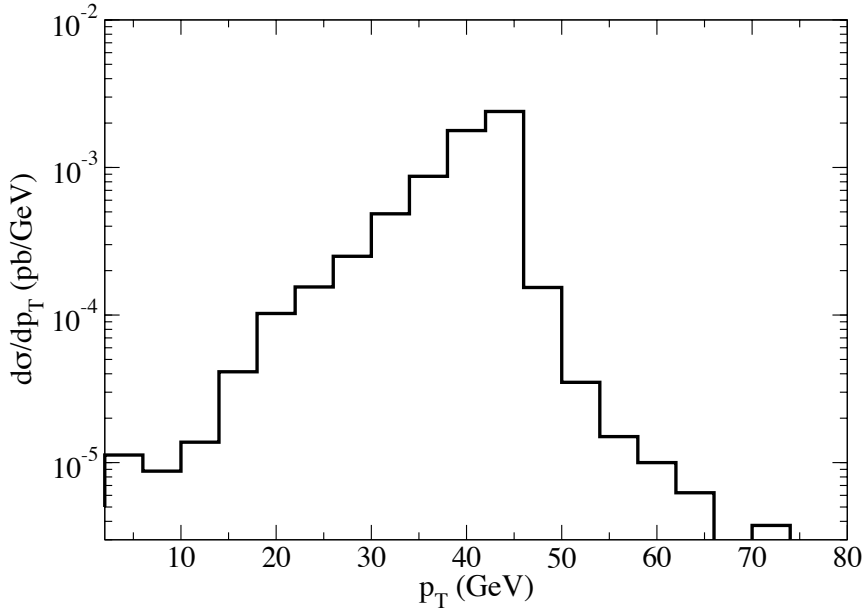
The dark sector decays back through the operator $\epsilon b_\mu J^\mu_{\mathrm{EM}}$, producing "Lepton Jets."

A non-Abelian dark sector will have richer lepton jets with higher lepton multiplicity.



Rare Z Decay



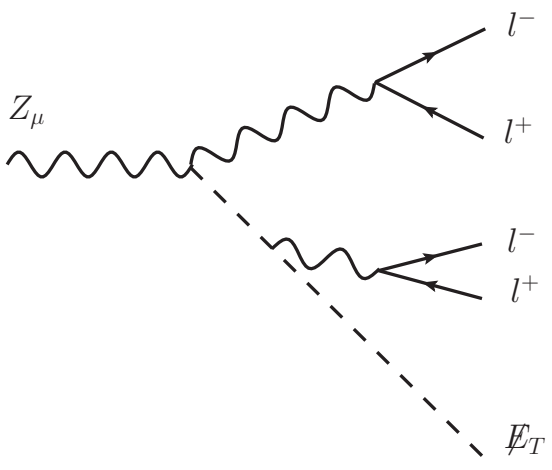


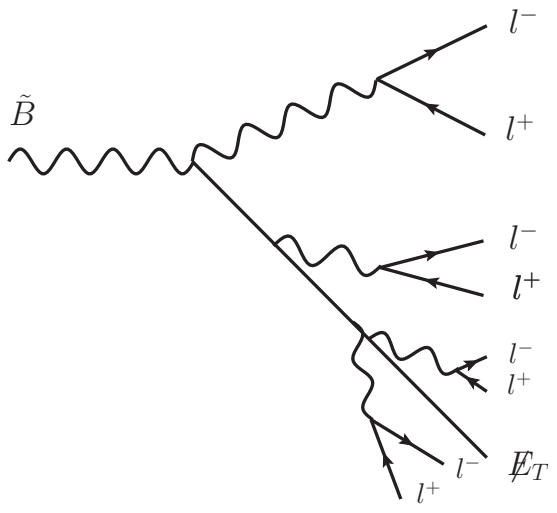
Cut: $|\eta| < 2.4$

Soft Radiation In the Dark Sector

Coming Attraction, also featuring C. Cheung, I. Yavin, and LT Wang:

- Soft radiation in the dark sector can greatly enhance the lepton multiplicity in high-energy colliders.





- Sudakov double Log $\sim \frac{\alpha_{\rm dark}}{4\pi} \log\left(\frac{p_T^2}{m_\phi^2}\right) \log\left(\frac{p_T^2}{m_b^2}\right)$
- Monte Carlo code on the way!

Conclusions

- TeV scale dark matter charged under a GeV scale hidden sector with MeV scale splittings naturally explains PAMELA, FERMI, and DAMA.
- SUSY and kinetic mixing together imply that the GeV scale is special. We have constructed a simple $U(1)$ model that generates all scales from the kinetic mixing.
- Light hidden sectors connected by kinetic mixing produce lepton jets in colliders. The LHC (or Tevatron) may spectacularly confirm dark matter models of this type.