Simple Hidden Sector Dark Matter

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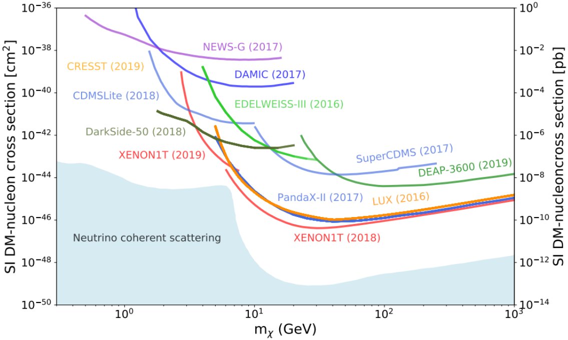
Motivation

- MSSM mitigates fine-tuning to a little hierarchy problem between weak scale and SUSY breaking scale
- DM increasingly bounded
- If SUSY breaking gravity mediated, any hidden sectors will also be ≈ weak scale, rendering WIMP miracle easily applicable



M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018)

Model

A supersymmetric hidden sector model will generically have a superpotential

$$\mathcal{W} = \mathcal{W}_{visible} + \mathcal{W}_{HS} + \mathcal{W}_{mix} \tag{1}$$

$$\tag{2}$$

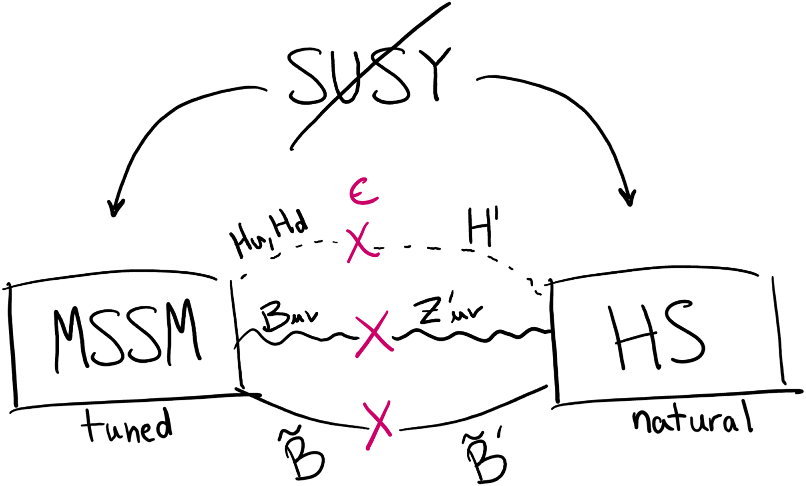
Where for simplicity we assume $\mathcal{W}_{Visible} = \mathcal{W}_{MSSM}$.
SUSY version of $\epsilon F_{\mu\nu} F'^{\mu\nu}$ is

$$\mathcal{W}_{mix} = \frac{\epsilon}{2} W_Y W' \tag{3}$$

$$\int d^2\theta \mathcal{W}_{mix} + h.c. = \epsilon D_Y D' - \frac{\epsilon}{2} F_Y^{\mu\nu} F'_{\mu\nu} \tag{4}$$

$$+ i\epsilon \tilde{B} \sigma^\mu \partial_\mu \tilde{B}'^\dagger + i\epsilon \tilde{B}' \sigma^\mu \partial_\mu \tilde{B}^\dagger \tag{5}$$

Model-Portals



Model-Hidden Sector

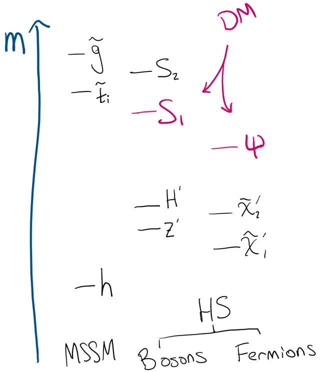
The Hidden Sector could be arbitrarily complicated, however we analyze essentially the simplest superpotential possible

$$\mathcal{W}_{HS} = \lambda S T H' \tag{6}$$

- $Q'(H') = +1,\ Q'(T) = -1$
- S, T charged under accidental $\mathbb{Z}_2$

HS summary:
Dirac $\psi = (S, T^\dagger)$, with dark photon and higgs $Z',\ H'$ + superpartners $S_1,\ S_2$, and neutralinos $\chi'_1,\ \chi'_2$

Model- Mass Spectrum



The dark higgs vev $\langle H \rangle = v'/\sqrt{2}$ gives

$$m_\psi = \lambda v'/\sqrt{2}$$
$$m_Z' = g'v'$$
$$m_H' = g'v' + loops$$

Neutralinos and scalars depend on other soft masses

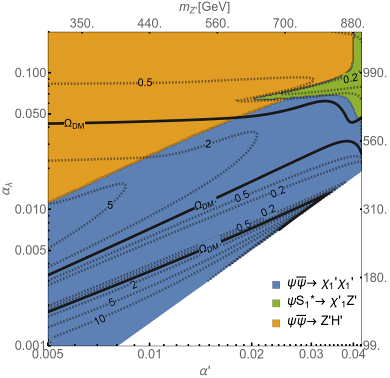
$$M_{\chi'} = \begin{pmatrix} m_{\tilde{B}'} & m_{Z'} \\ m_{Z'} & 0 \end{pmatrix},$$

$$m^2_{scalar} = \begin{pmatrix} \tilde{m}_S^2 + m_\psi^2 & m_\psi^* A_\lambda^* \\ m_\psi A_\lambda & \tilde{m}_T^2 + m_\psi^2 - \frac{1}{2} m_{Z'}^2 \end{pmatrix}.$$

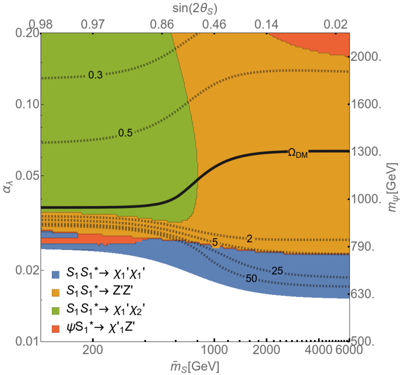
Thermal History

Two DM candidates- ψ, and light scalar partner S_1
Two couplings, $\alpha_\lambda = \lambda^2/4\pi$, $\alpha' = g'^2/4\pi$

What sets the abundance?

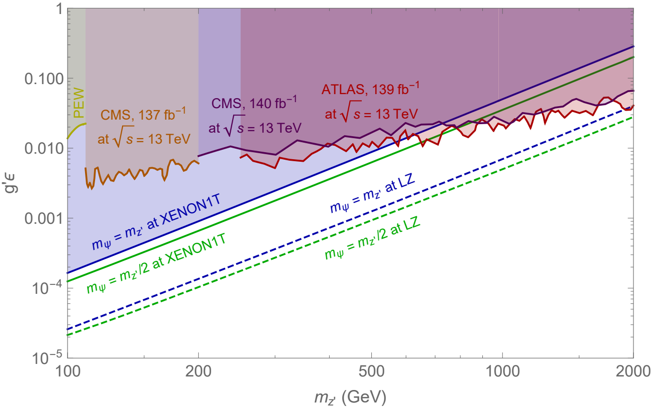


a) ψ *DM* **abundance**



b)S_1 *DM* **abundance**

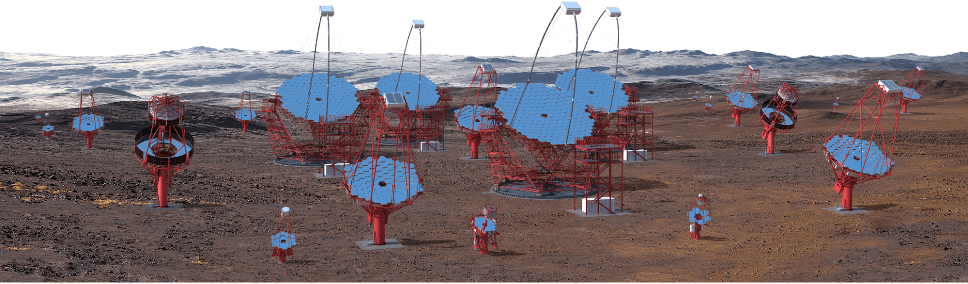
Bounds



Dilepton resonances: CMS(orange) [Sirunyan et al.(2019)], CMS(purple)[Collaboration(2019)] ATLAS(red) [Aad et al.(2019)]. Precision electroweak constraints: [Hook et al.(2011)Hook, Izaguirre, and Wacker](yellow). Direct Detection: XENON1T(blue)[Aprile et al.(2018)], LZ projected(blue dashed) [Akerib et al.(2018)]

Conclusions and Future Work

- Can naturally achieve DM abundance
- Even simplest hidden superpotential can realize a large variety of thermal WIMP scenarios
- Indirect Detection- very promising as it is not limited by the ϵ suppressed coupling to the SM
- Upcoming Cherenkov Telescope Array (CTA) allows a high energy indirect detection search 20 GeV to 300 TeV



References

Georges Aad et al.

Search for high-mass dilepton resonances using 139 fb^{-1} of pp collision data collected at $\sqrt{s}$ =13 TeV with the ATLAS detector.
Phys. Lett., B796:68–87, 2019.
doi: 10.1016/j.physletb.2019.07.016.

D. S. Akerib et al.

Projected WIMP Sensitivity of the LUX-ZEPLIN (LZ) Dark Matter Experiment.
2018.

E. Aprile et al.

Dark Matter Search Results from a One Ton-Year Exposure of XENON1T.
Phys. Rev. Lett., 121(11):111302, 2018.
doi: 10.1103/PhysRevLett.121.111302.

CMS Collaboration.

Search for a narrow resonance in high-mass dilepton final states in proton-proton collisions using 140 fb^{-1} of data at $\sqrt{s} = 13$ TeV.
2019.

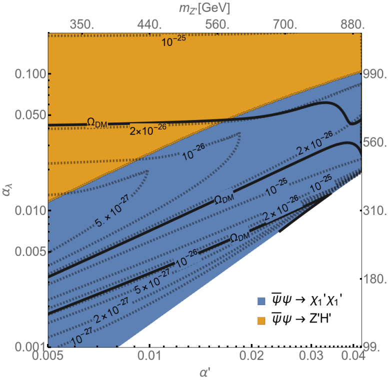
Anson Hook, Eder Izaguirre, and Jay G. Wacker.

Model Independent Bounds on Kinetic Mixing.
Adv. High Energy Phys., 2011:859762, 2011.
doi: 10.1155/2011/859762.

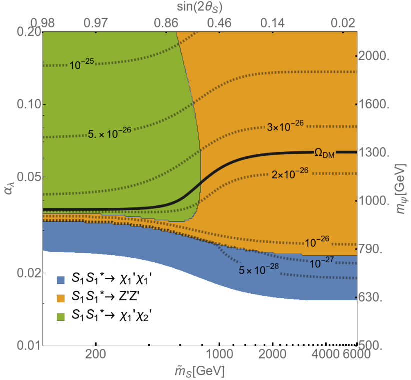
Albert M Sirunyan et al.

Search for a narrow resonance lighter than 200 GeV decaying to a pair of muons in proton-proton collisions at $\sqrt{s} = 13$ TeV.
2019.

Supplemental Slides I

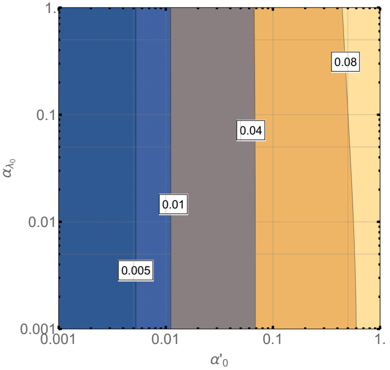


a) ψ *DM* $\langle\sigma v\rangle$



b) S_1 *DM* $\langle\sigma v\rangle$

Supplemental Slides II



a) α' b)α_λ

Supplemental Slides III