Dark Forces and Dark Matter in a Hidden Sector

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DESY

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in collaboration with:
M. Goodsell and A. Ringwald

Outline

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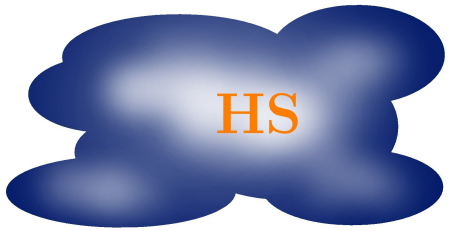
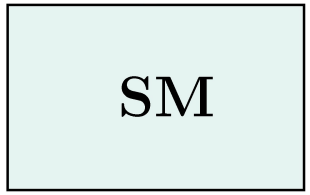
Motivation: Hidden Sector

- string theories usually predict existence of HS
- various supersymmetric models contain HS
  - HS needed as source of SUSY breaking





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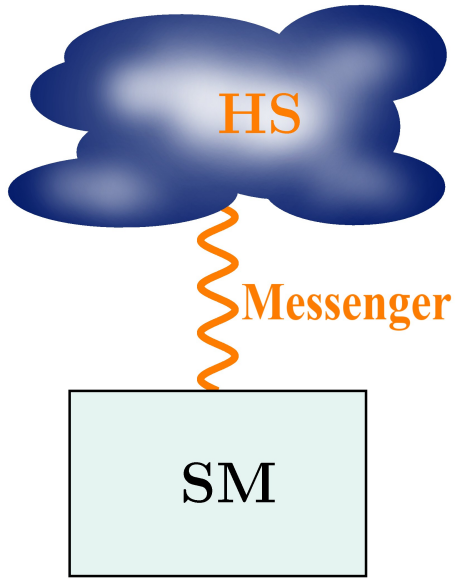

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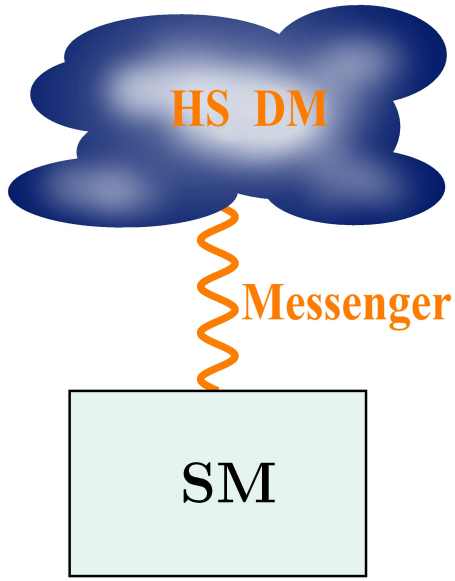
- HS can contain gauge fields and matter particles



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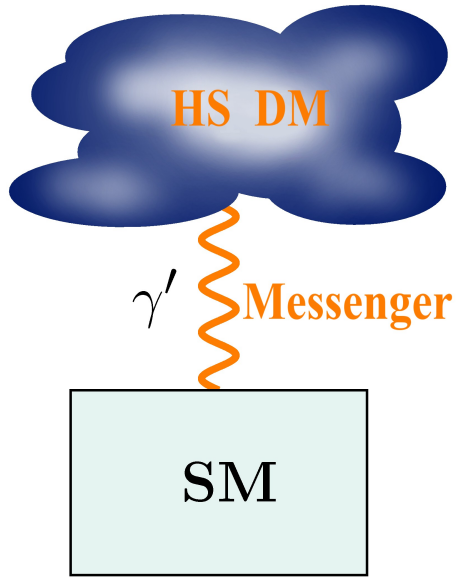

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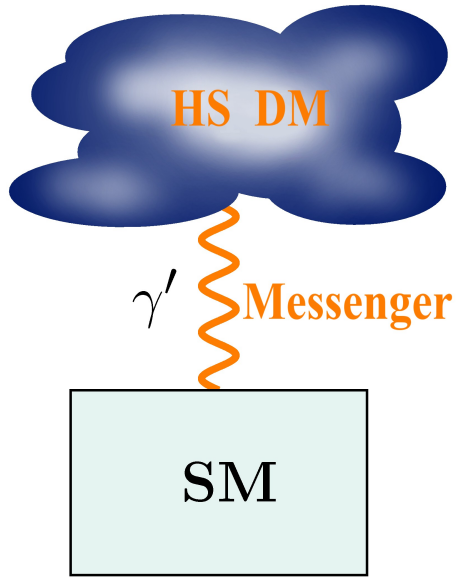

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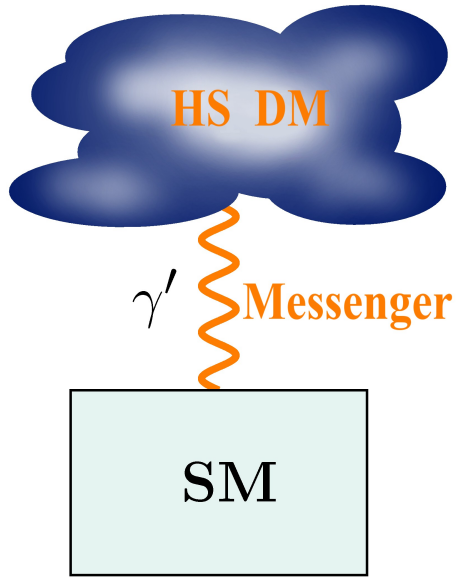

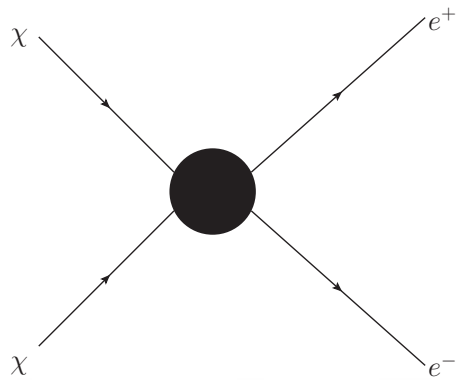

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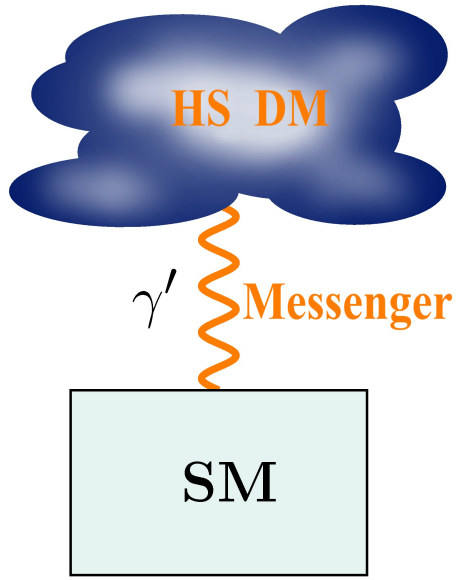
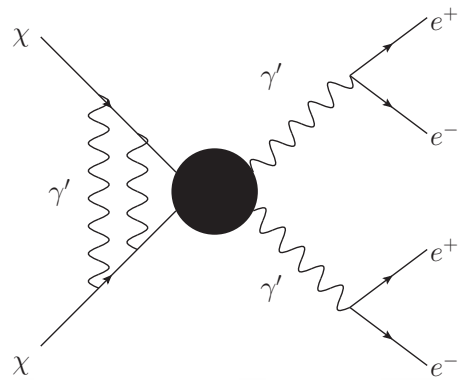
    - generates Sommerfeld enhancement,
    - allows leptophilic DM annihilation,
    - mediates scattering on nuclei

$\Rightarrow$ GeV-scale Dark Force





Motivation: GeV-scale Dark Force

Stückelberg mechanism

- simplest mechanism to give mass to abelian gauge boson γ'
- in certain string compactifications e.g. D7-branes

  mass depends on volume of extra dimension i.e. string-scale

$$m_{\gamma'} \gtrsim \frac{M_S^2}{M_{Pl}}$$

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$$m_{\gamma'} \gtrsim \frac{M_S^2}{M_{Pl}}$$

- intermediate string-scale: $M_S \sim 10^{9-10}$ GeV

  gives right regime for axion decay constant and SUSY breaking scales

$$\Rightarrow m_{\gamma'} \sim \text{GeV-scale}$$

[Goodsell *et al.* '09]

Motivation: GeV-scale Dark Force

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- masses in HS roughly suppressed by χ

$$m_{\gamma'} \simeq \sqrt{g_Y g_h c_{2\beta}}\ \sqrt{\chi}\ \mathrm{v}$$

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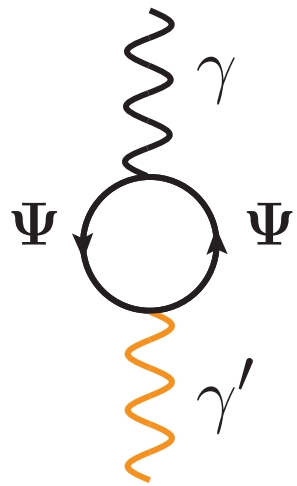
Kinetic mixing χ

- integrating out heavy particles charged under both U(1)s
- kinetic mixing generated at loop level

$$\chi \sim \frac{g_Y g_h}{16\pi^2} \times \kappa \sim 10^{-3} - 10^{-4} \qquad (\kappa \sim \mathcal{O}(1))$$



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[Baumgart *et al.* '09, and following papers]

Outline

Hidden Photon and Kinetic Mixing

- HS with extra U(1)-symmetry

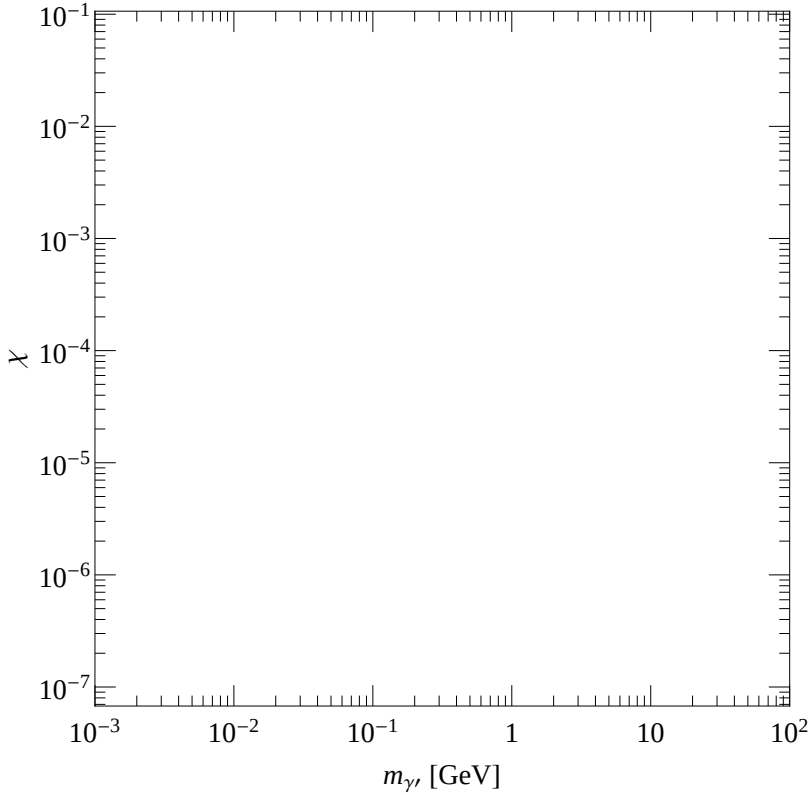
  $\Rightarrow$ hidden photon γ'

- simplest scenario:
  - mass-term for γ'
  - kinetic mixing between γ and γ'
- most general Lagrangian

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} + \frac{\chi}{2}X_{\mu\nu}F^{\mu\nu} + \frac{m^2_{\gamma'}}{2}X_\mu X^\mu + g_Y j^\mu_{\mathrm{em}} A_\mu$$

- γ' couples and can decay to SM fermions through kinetic mixing

Constraints I: Precision Measurements



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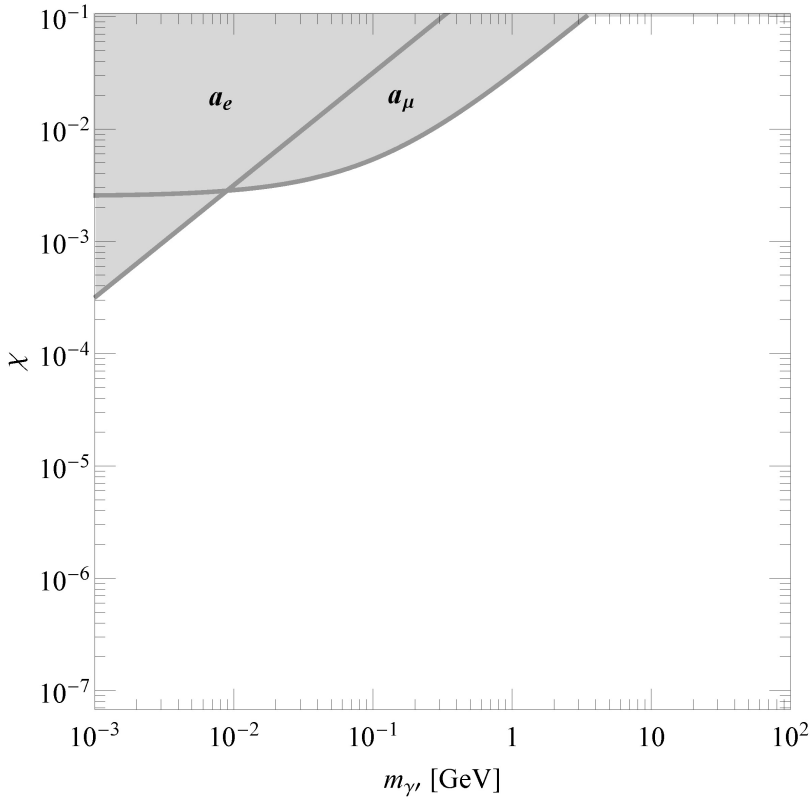

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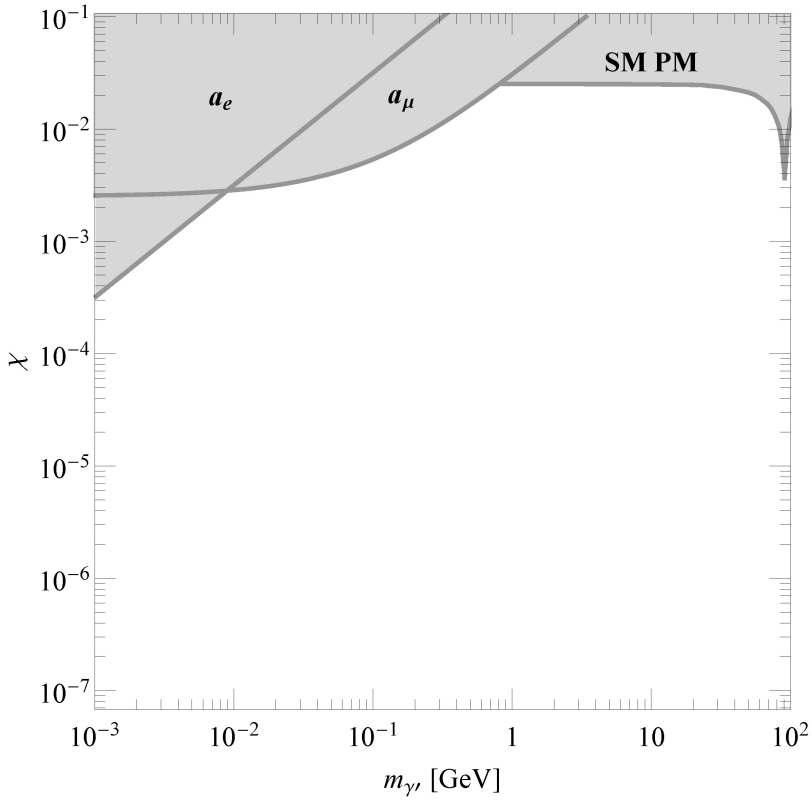
- deviations from SM measurements
- notably corrections to Z^0-mass



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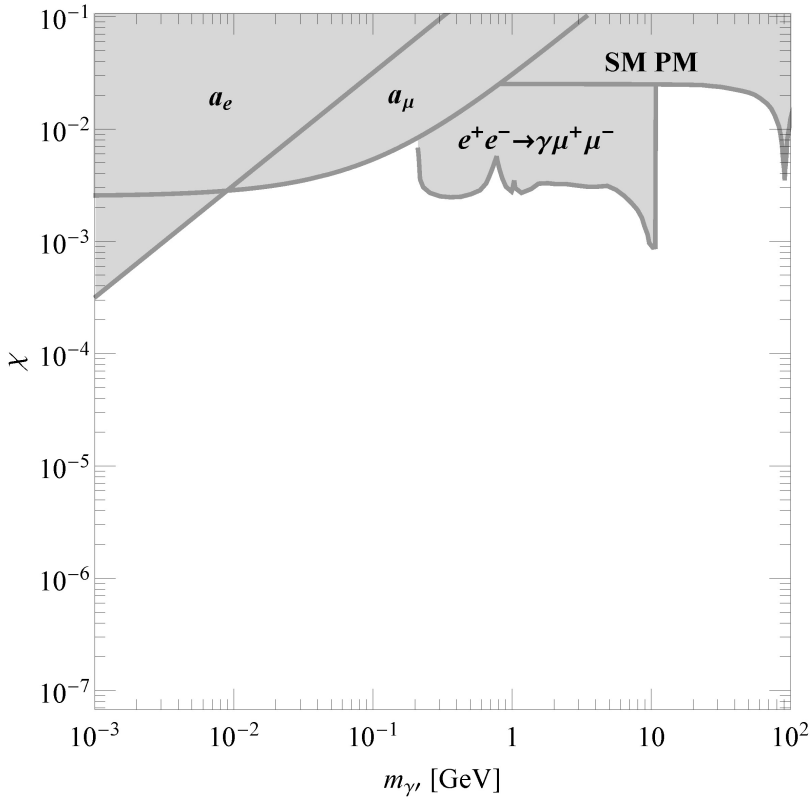
BaBar: $\Upsilon(3S)$ decay [Essig *et al.* '10]

- search for decay into pseudoscalar a
  $e^+e^- \xrightarrow{\gamma a} \gamma\mu^+\mu^-$
- reinterpretation since identical final state
  $e^+e^- \xrightarrow{\gamma\gamma'} \gamma\mu^+\mu^-$



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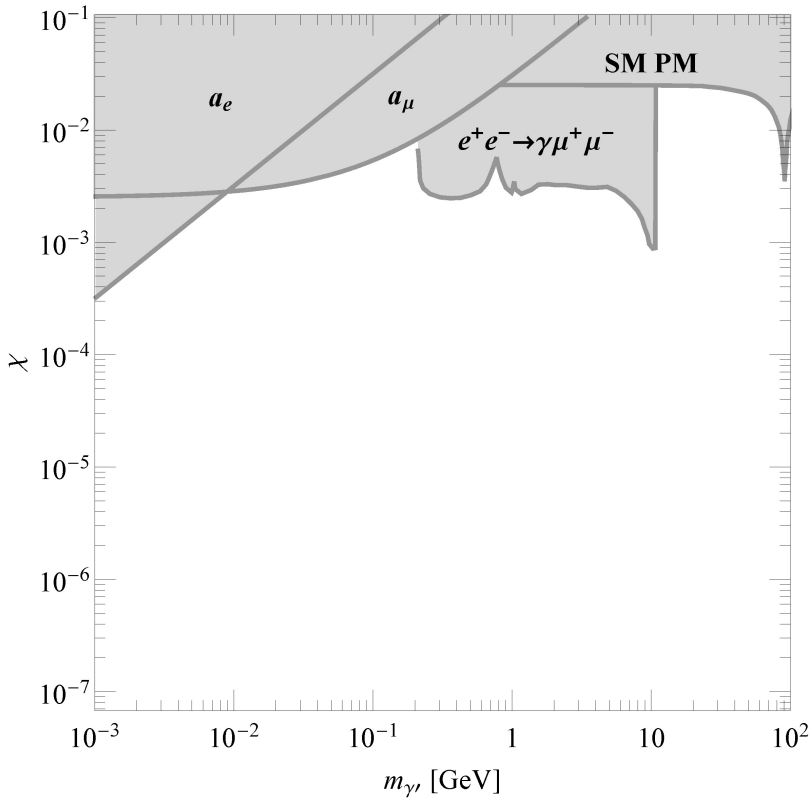

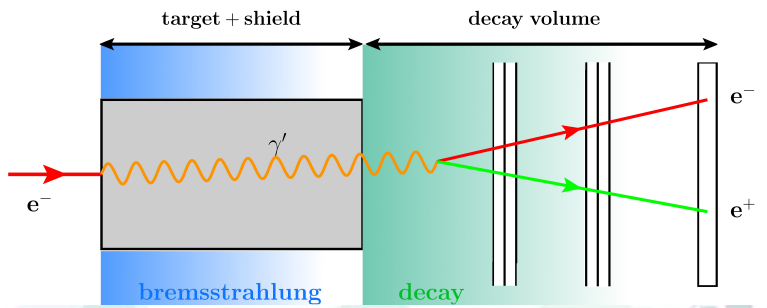

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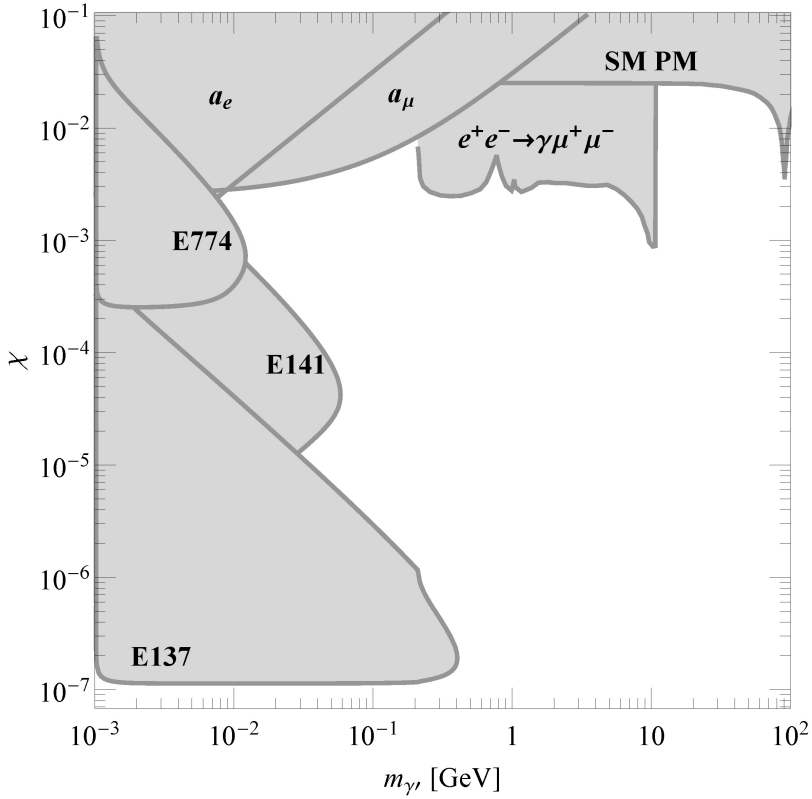

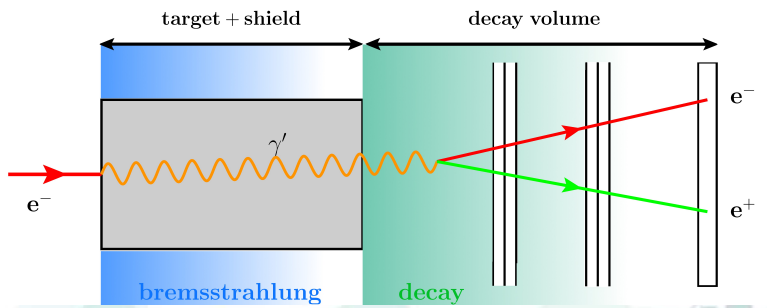

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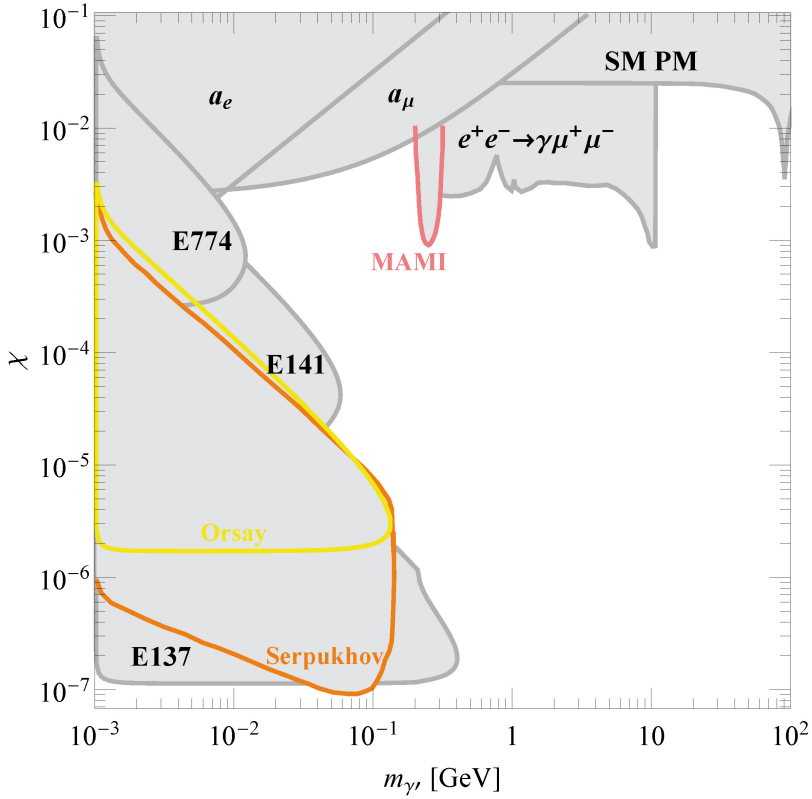
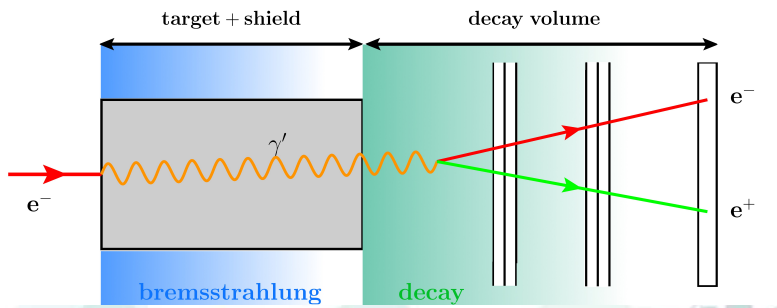
New and rediscovered experiments

- thin target at MAMI [A1 collaboration '11]
- Serpukhov p-beam dump [Blümlein,Brunner'11]
- e-beam dump at Orsay [SA, Niebuhr, Jacobsohn, Ringwald, *in prep.*]





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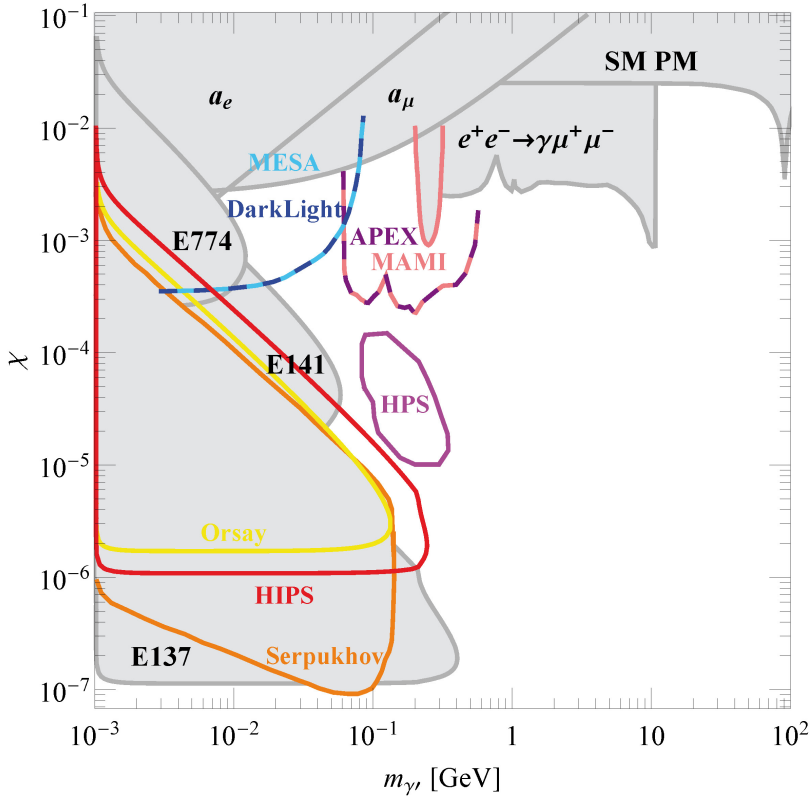
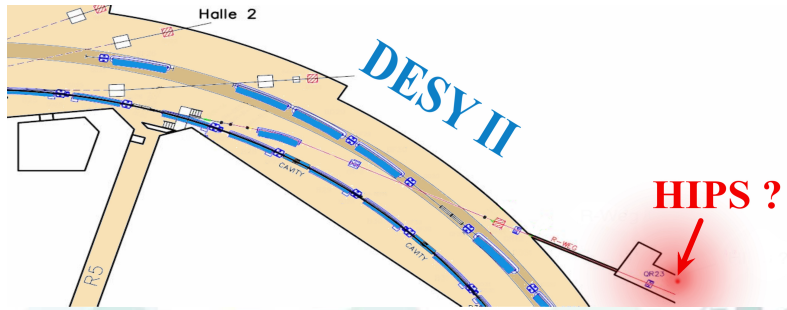
Sensitivities of future experiments

- JLab: APEX, HPS, DarkLight
- Mainz: MAMI, MESA
- DESY: HIPS at 6 GeV in 2013





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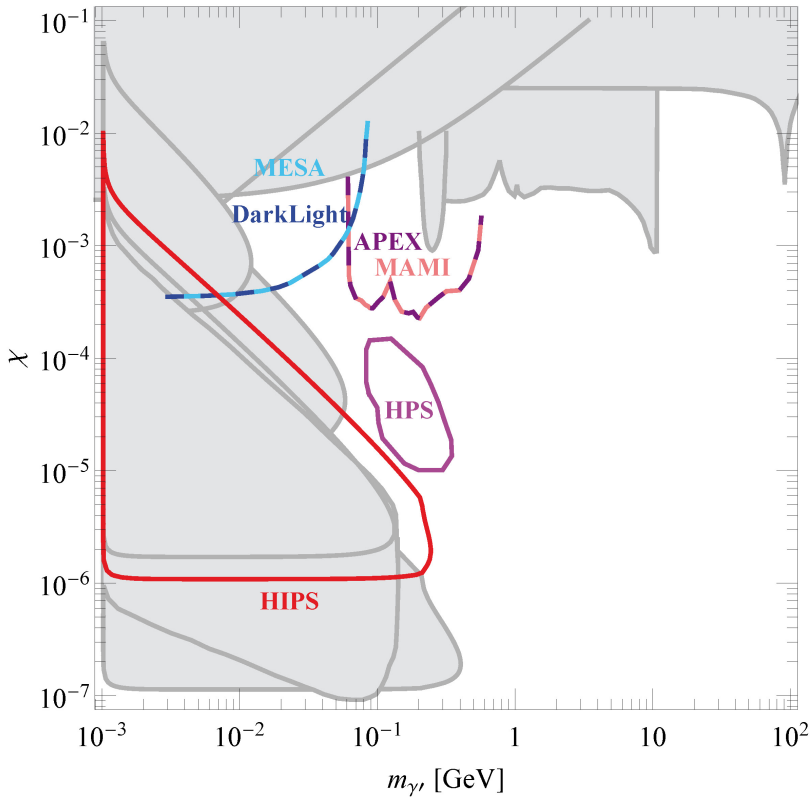
Additional Dirac fermion ψ

- one extra mass parameter m_ψ



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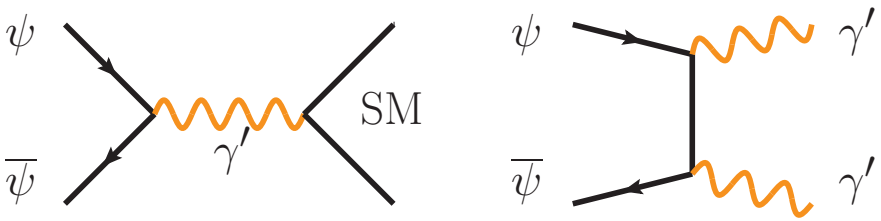
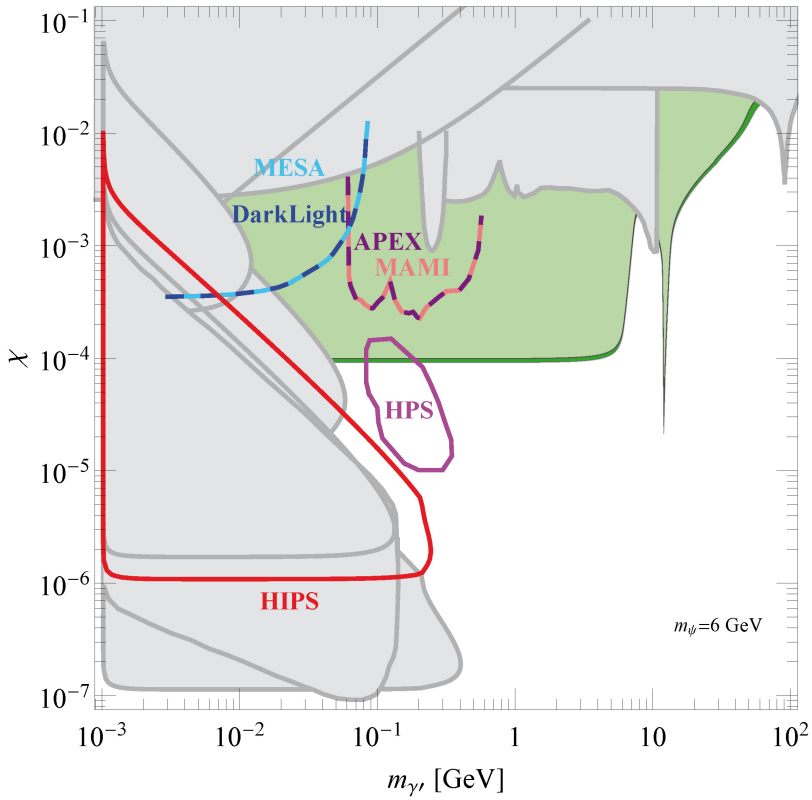
- resonance for $m_{\gamma'} = 2\ m_\psi$

$\Rightarrow$ ψ total DM or subdominant component





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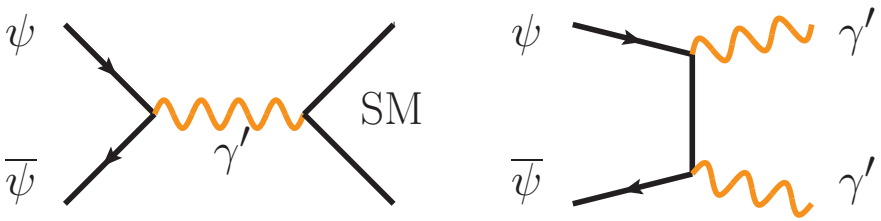

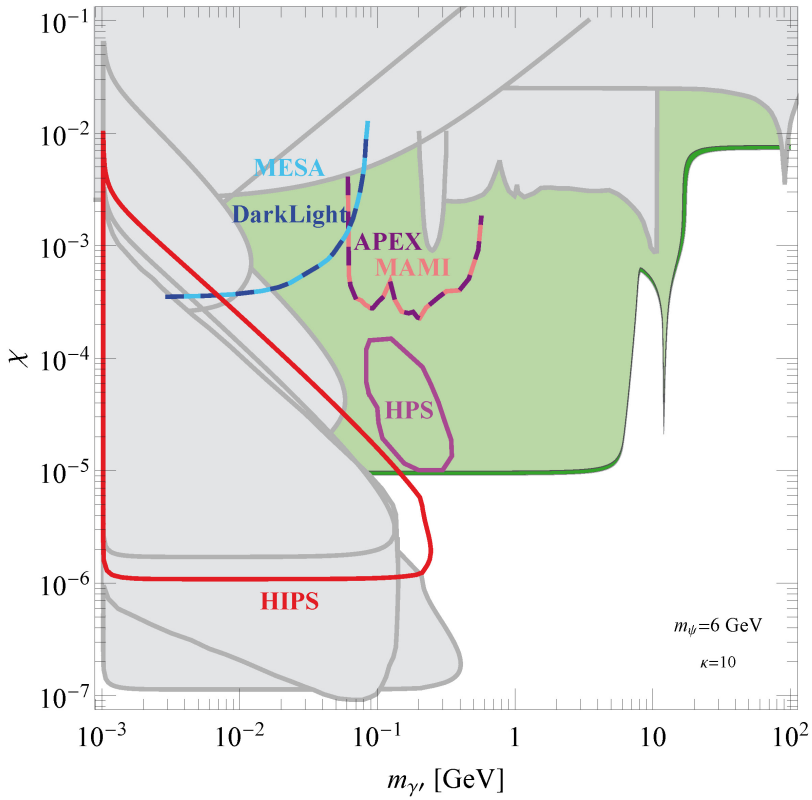

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- mediated by γ'
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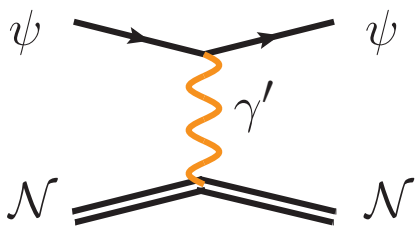

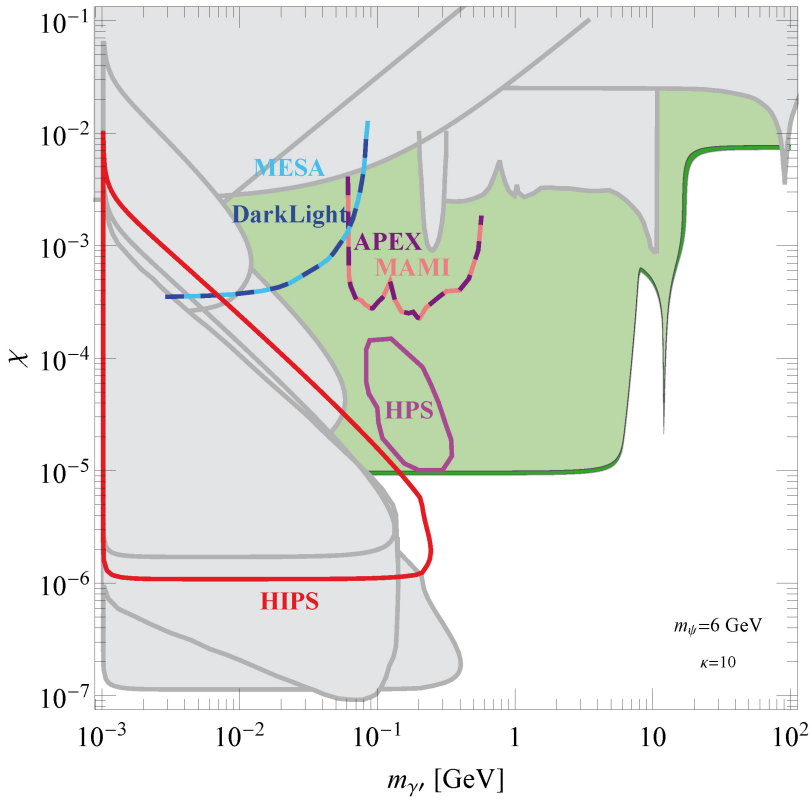

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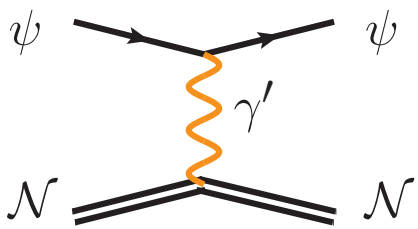

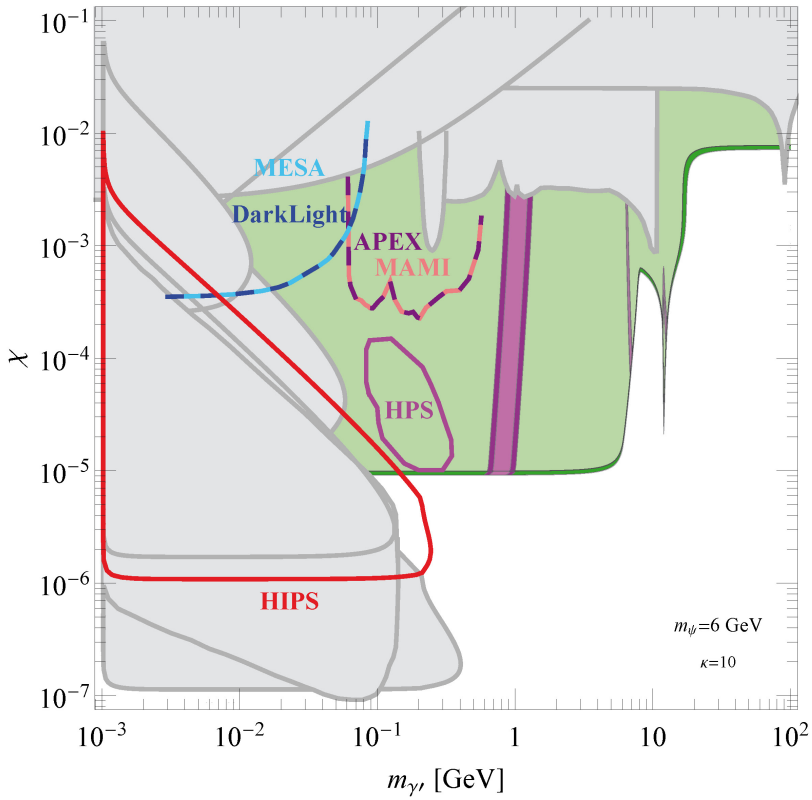

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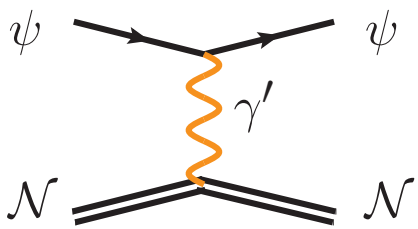

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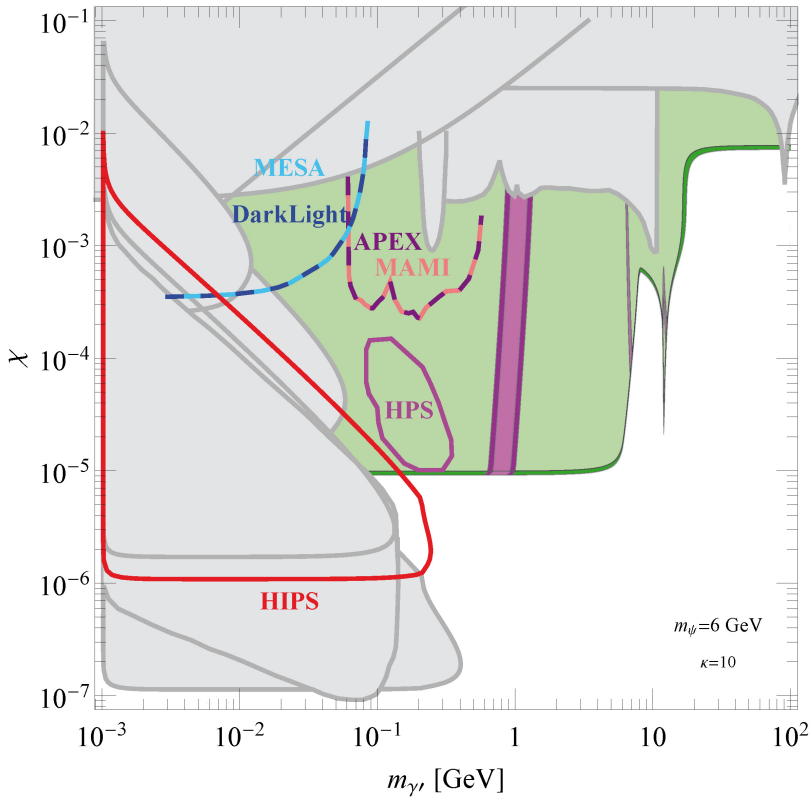

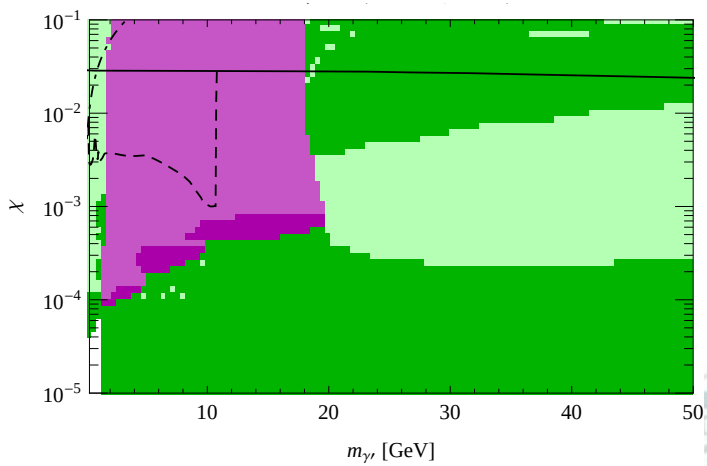

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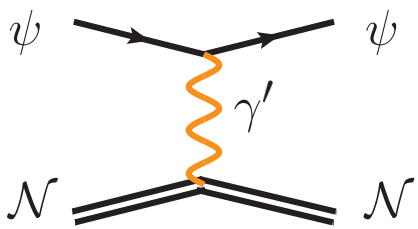

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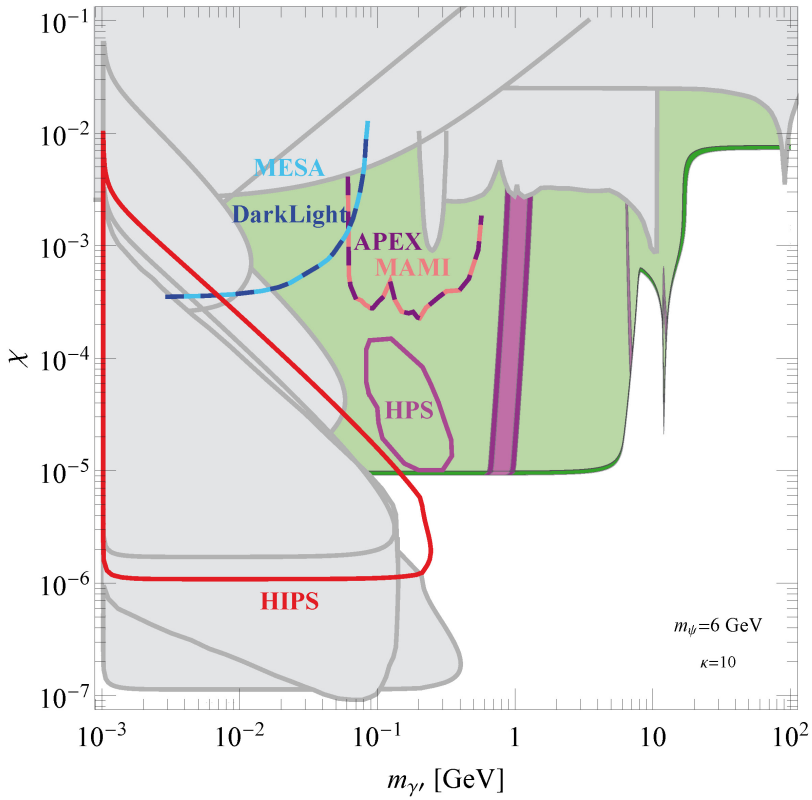

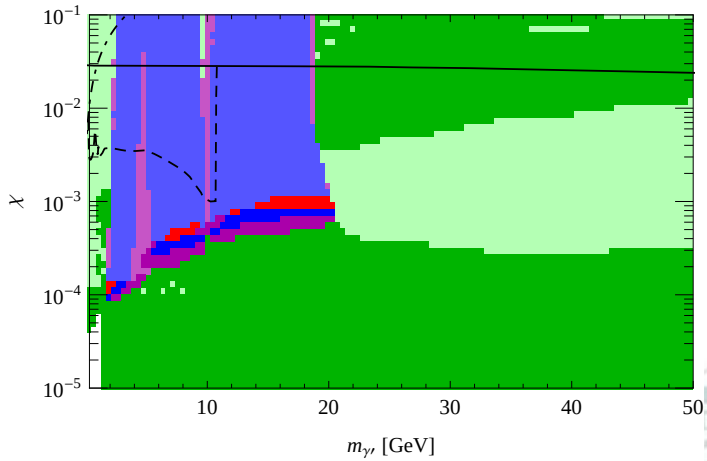

SUSY U(1) HS

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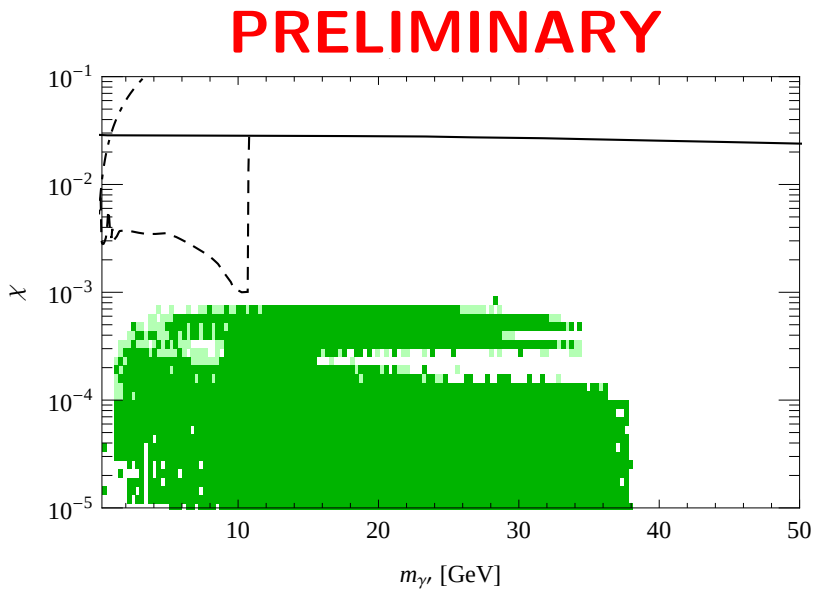

Gravity mediation

- lightest particle is Majorana fermion
- annihilation through $\gamma' \Rightarrow$ total or subdominant DM
- axial coupling gives spin-dependent scattering
  - Picasso, COUPP & KIMS constrain σ_{SD}

[SA, M. Goodsell, A. Ringwald, *work in progress*]

Outline

Conclusions

- HS motivated by various aspects

  both from top-down (string theory, SUSY) and bottom-up (DM)
- potentially rich content: dark forces and dark matter
- weakly coupled but still phenomenologically interesting
- hidden photons as dark force

  $\Rightarrow$ constrained by past & further tested in future experiments
- HS can contain viable dark matter candidates
- many SUSY & string inspired models give well motivated HS dark matter

  $\Rightarrow$ interesting phenomenology still to be studied