Light from Dark Matter

Juri Smirnov

Based on:
1509.04282 , 1508.04418 ,
1508.1425 , 1506.05107

Many thanks to: Pavel Fileviez Perez (MPIK)
and Michael Duerr (MPIK -> DESY)

The Plan

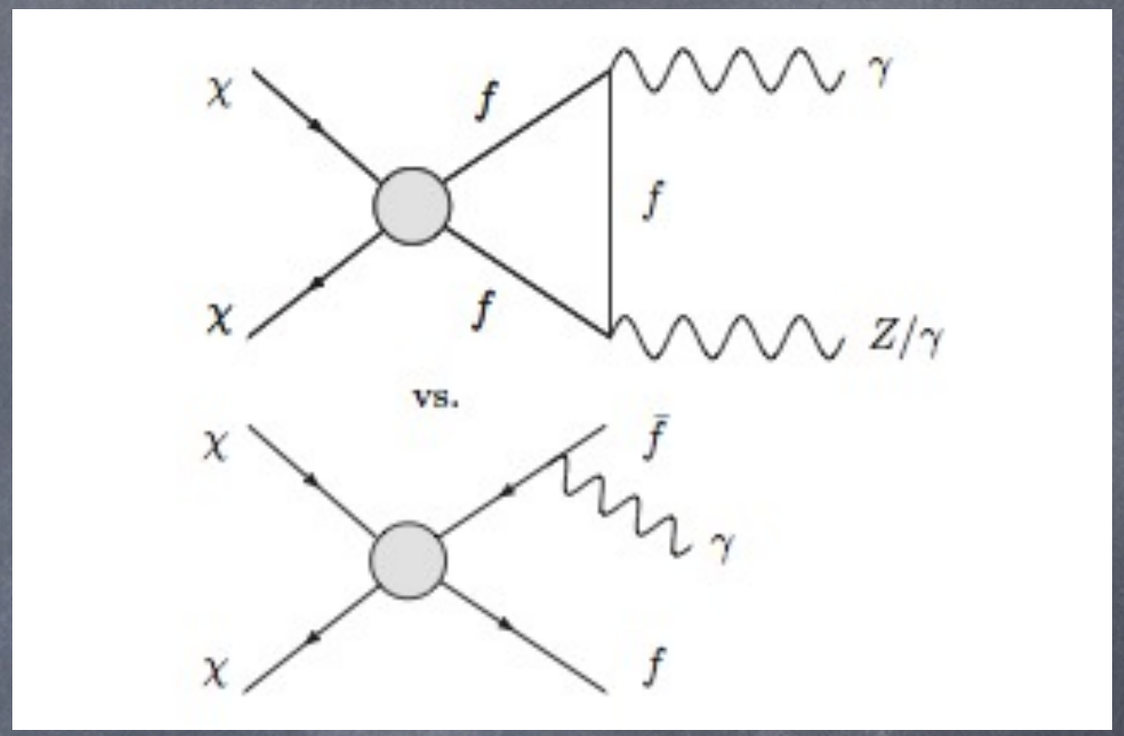
- Photons from Dark Matter, a “smoking gun”?
- End points of Photon spectra and Gamma Line visibility in Dark Matter models
- Two novel Mechanisms for prominent Gamma ray signatures from DM
- Summary

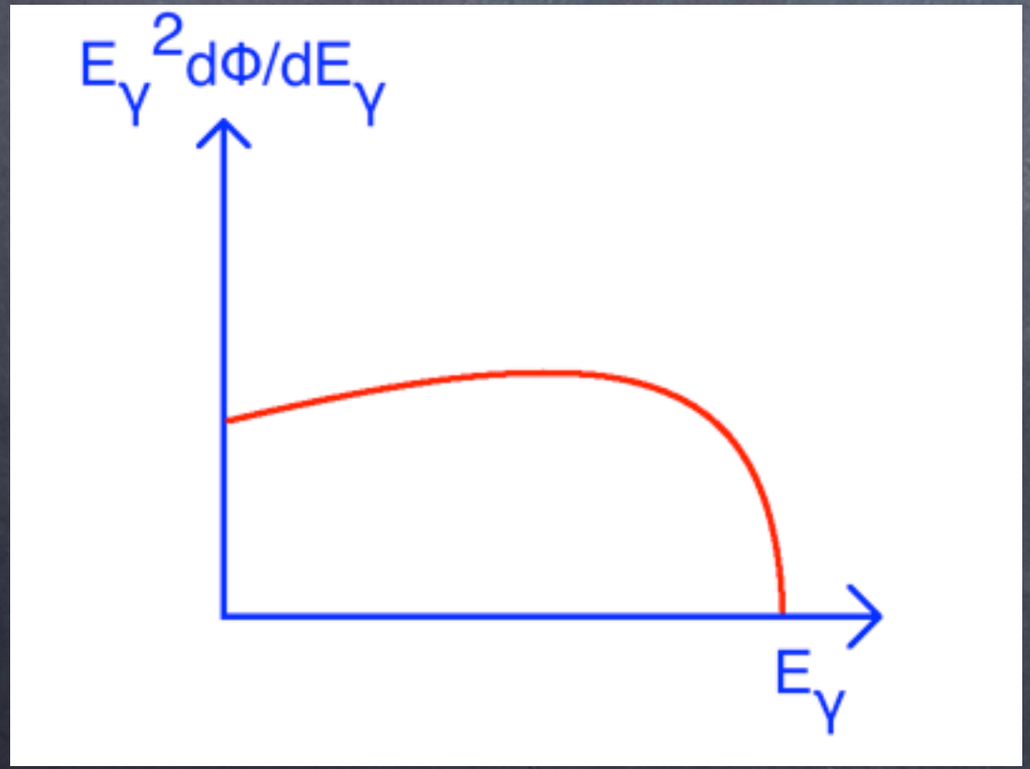
Gamma rays from DM

- Monochromatic Gamma rays
- Low probability for compact astrophysical objects to mimic DM
- Measure DM mass
- Probe the Dark Matter at quantum level

Gamma Line Visibility?

- Final State Radiation, most relevant processes close to the endpoint
- For heavy DM endpoint is close to DM mass





$$E_\gamma^{\max} = M_\chi \left(1 - \frac{M_f^2}{M_\chi^2}\right)$$

Mechanism for Majorana Fermion Dark Matter

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A Novel Mechanism

- A fermion with axial vector coupling to a new force

$$\mathcal{L}_{\rm DM} \supset \frac{c_{\rm AV}}{\Lambda^2}\bar{\chi}\gamma^\mu\gamma^5\chi\bar{f}\gamma_\mu f.$$

- <-> Majorana Fermion DM

$$\mathcal{L}_{\rm DM} \supset \frac{c_{\rm AA}}{\Lambda^2}\bar{\chi}\gamma^\mu\gamma^5\chi\bar{f}\gamma_\mu\gamma^5 f.$$

- SM fermion annihilation v^2 suppression at late times (p-wave process)

Operator	$\gamma\gamma$	$Z\gamma$	$h\gamma$
$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{f}\gamma_\mu\gamma^5 f$	OK	OK	suppressed
$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{f}\gamma_\mu f$	–	OK	suppressed

- Loop with electrically charged fermions leads to a s-wave process with photons in the final state

$$\frac{c_{AA}}{\Lambda}\bar{\chi}\gamma_0\gamma_5\chi\Gamma^{0\mu\nu}\epsilon_\mu\tilde{\epsilon}_\nu$$

- A contact type interaction arises (non-propagating)

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The UV complete Model

Talk by: Hiren Patel

$$G_B = SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_B.$$

Field	$SU(3)$	$SU(2)$	$U(1)_Y$	$U(1)_B$
Ψ_L	**1**	**2**	- $\frac{1}{2}$	B_1
Ψ_R	**1**	**2**	- $\frac{1}{2}$	B_2
η_R	**1**	**1**	- 1	B_1
η_L	**1**	**1**	- 1	B_2
χ_R	**1**	**1**	0	B_1
χ_L	**1**	**1**	0	B_2

P. Fileviez Perez, M. B. Wise arXiv: 1106.0343

M. Duerr, P. Fileviez Perez, M. B. Wise arXiv:1304.0576 PRL

Anomaly

$$B_1 - B_2 = -3$$

Majorana Mass

$$B_1 = -B_2 = -\frac{3}{2}$$

Coupling to Photons

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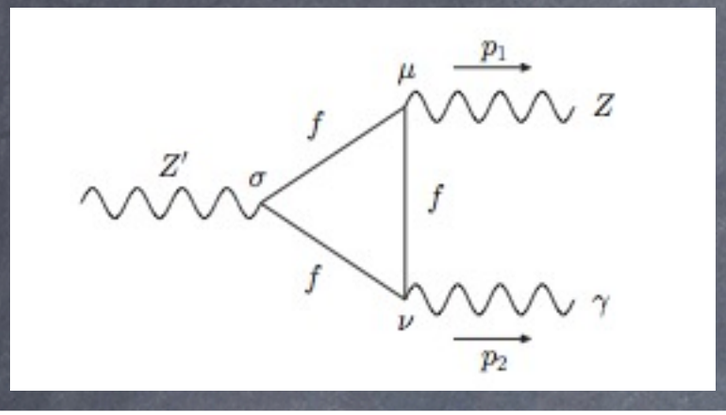
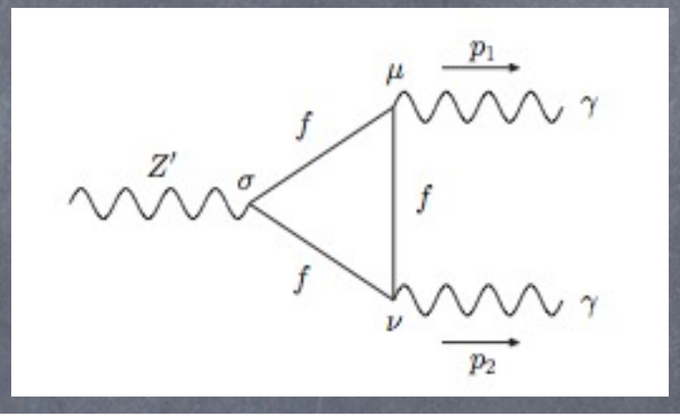
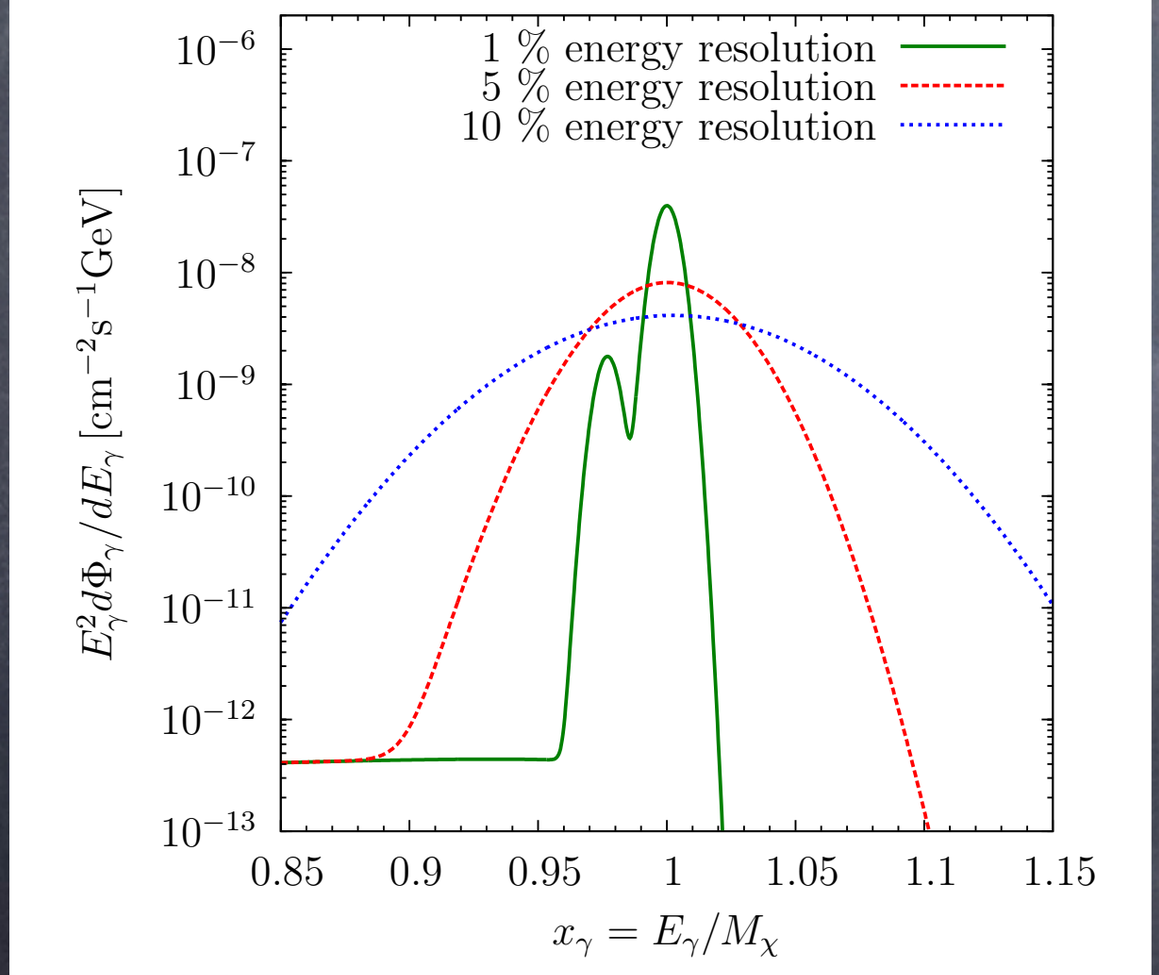
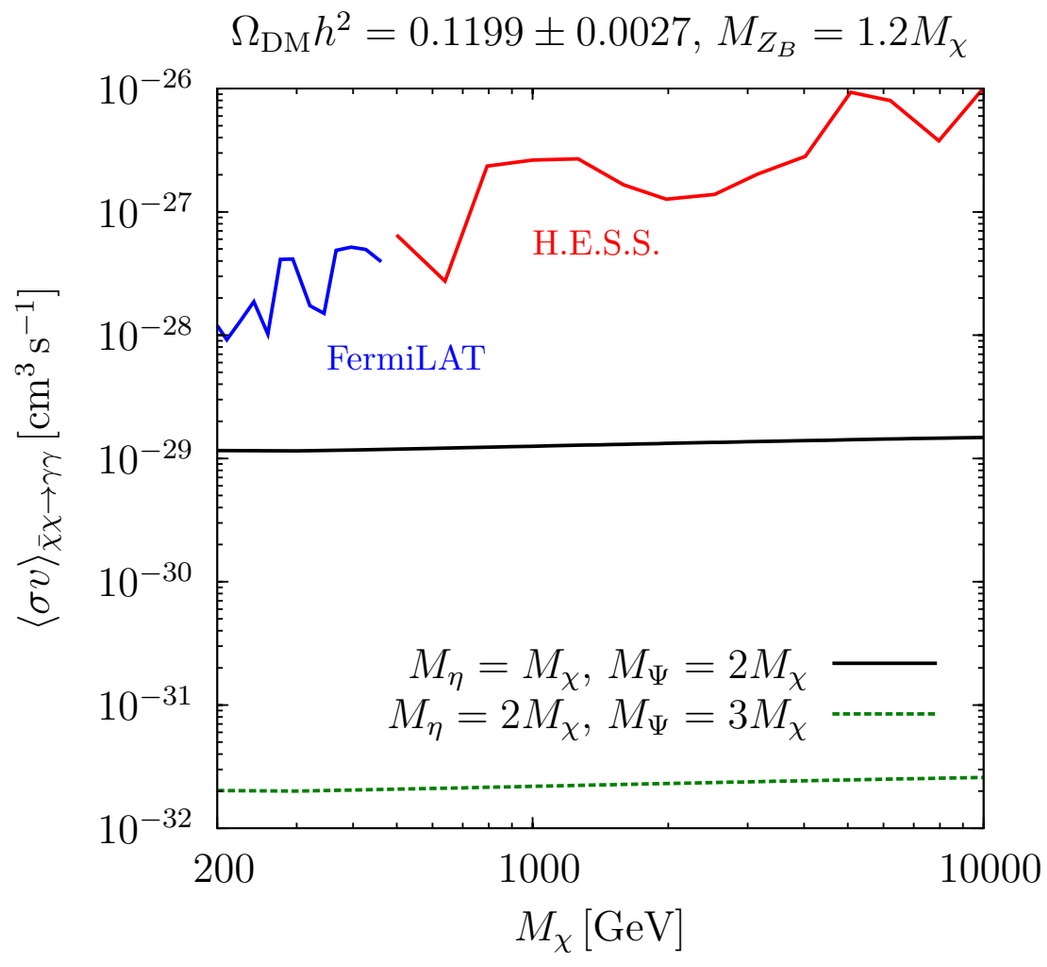


Contains axial vector coupling





FSR is suppressed by quark to DM mass ratio



Gamma line strongest astrophysical signal

Mechanism For Scalar Dark Matter

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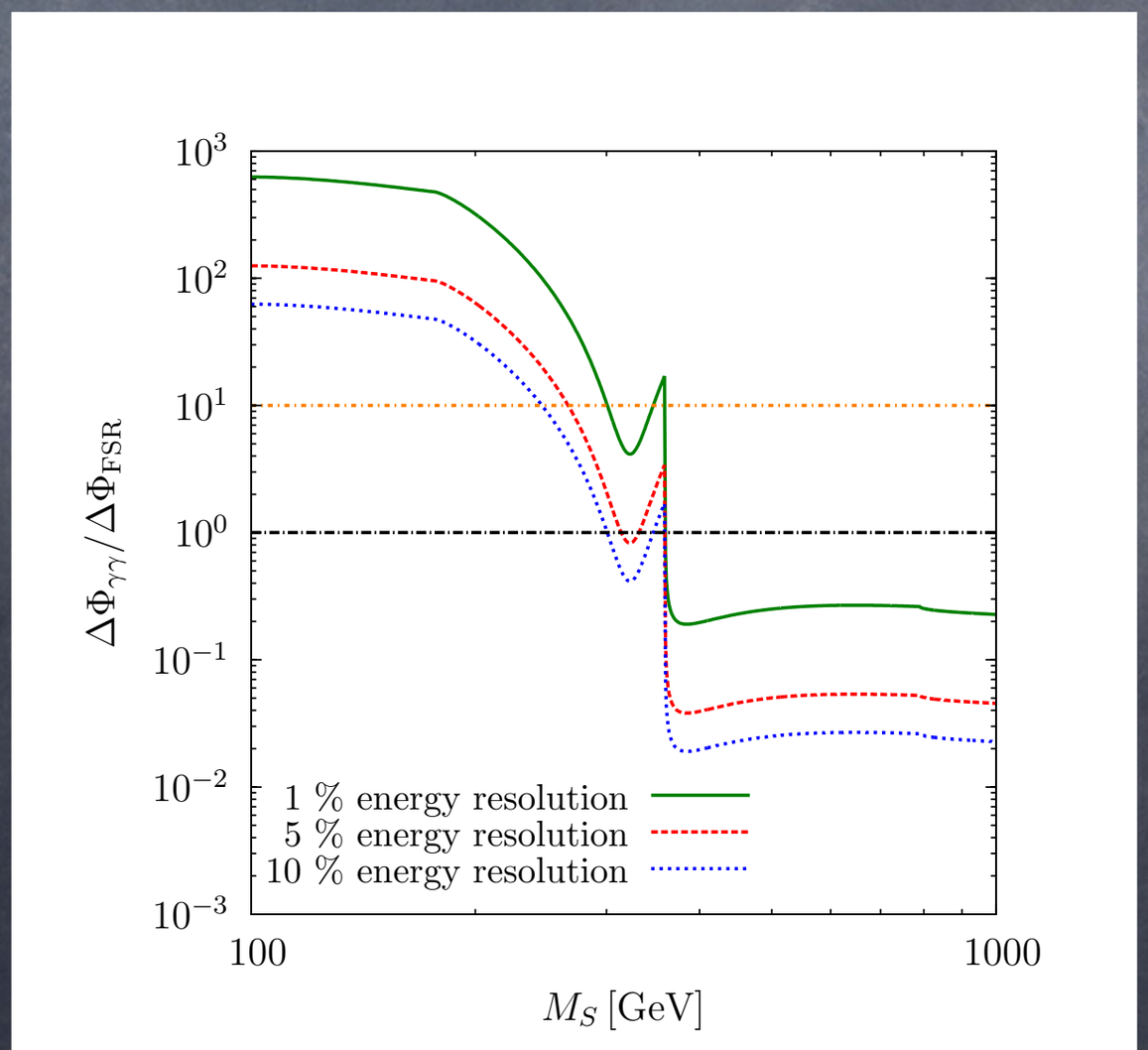
Old Model & New Facts

$$\mathcal{L}_{\rm SDM} = \mathcal{L}_{\rm SM} + \frac{1}{2}\partial_\mu S \partial^\mu S - \frac{1}{2} m_S^2 S^2 - \lambda_S S^4 - \lambda_p H^\dagger H S^2,$$

$$SS \to h \to \gamma\gamma$$
$$SS \to h \to Z\gamma$$

vs.

$$SS \to h \to \bar{b}b\gamma$$
$$SS \to h \to W^+W^-\gamma$$



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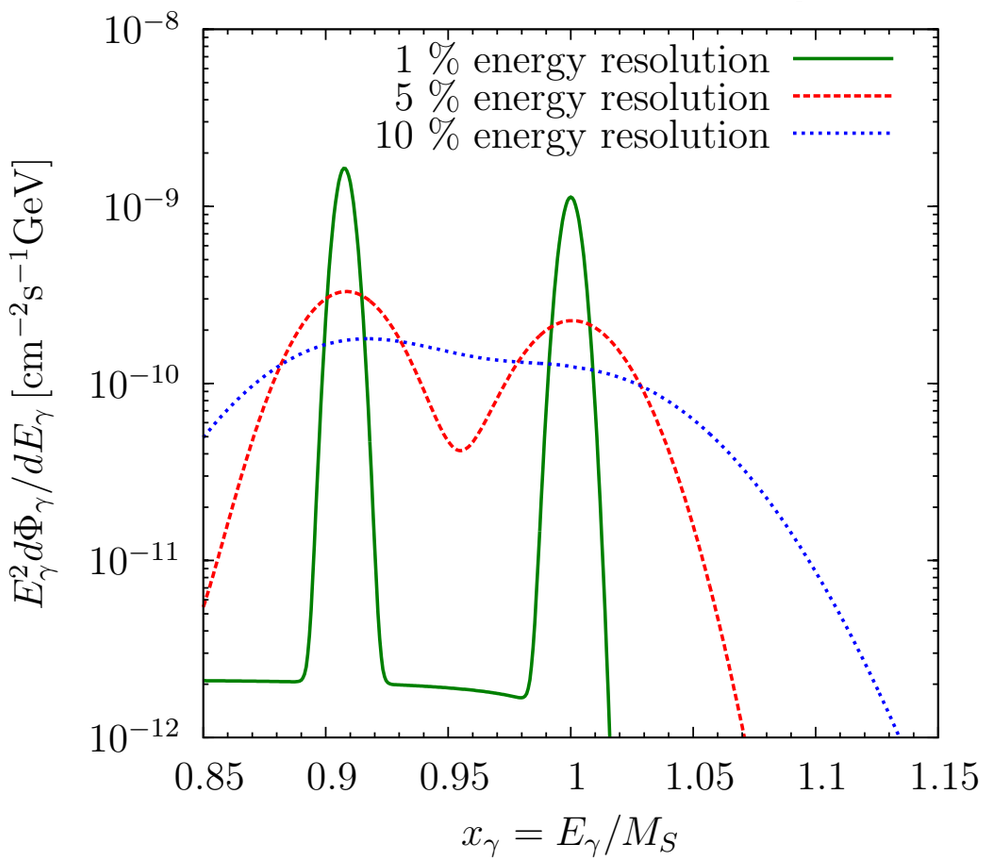
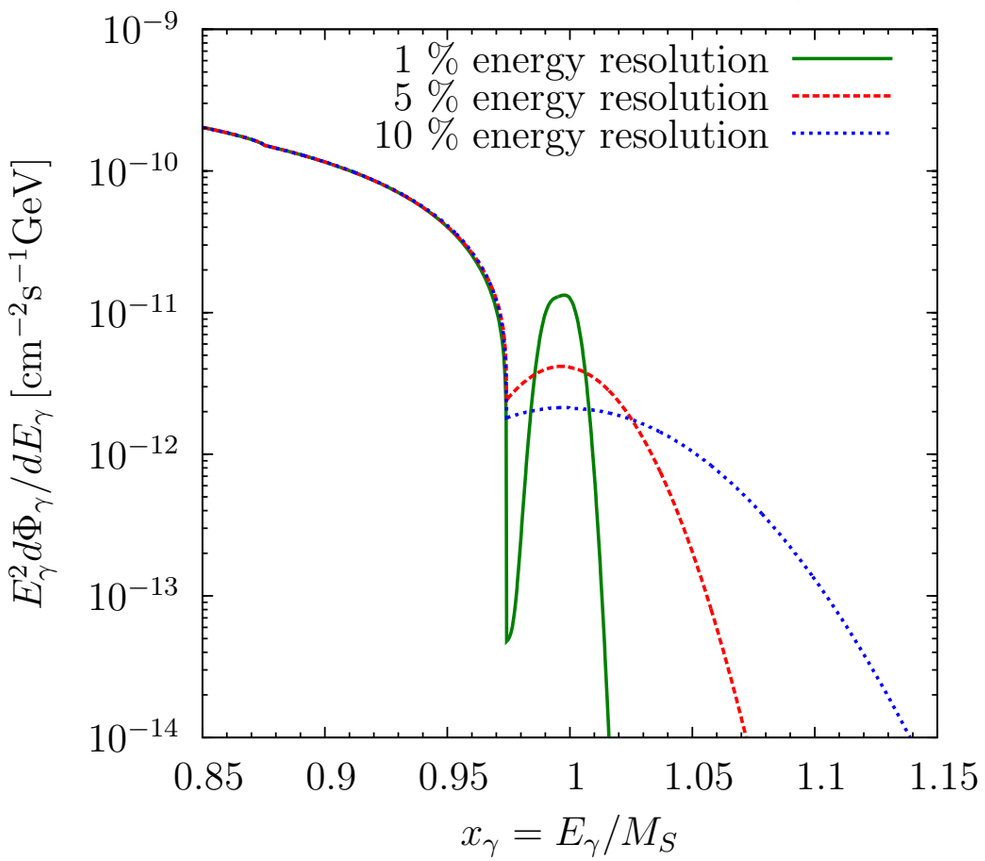
Old Model & New Facts II

FSR from WW does NOT reach endpoint



FSR from WW has reached the endpoint



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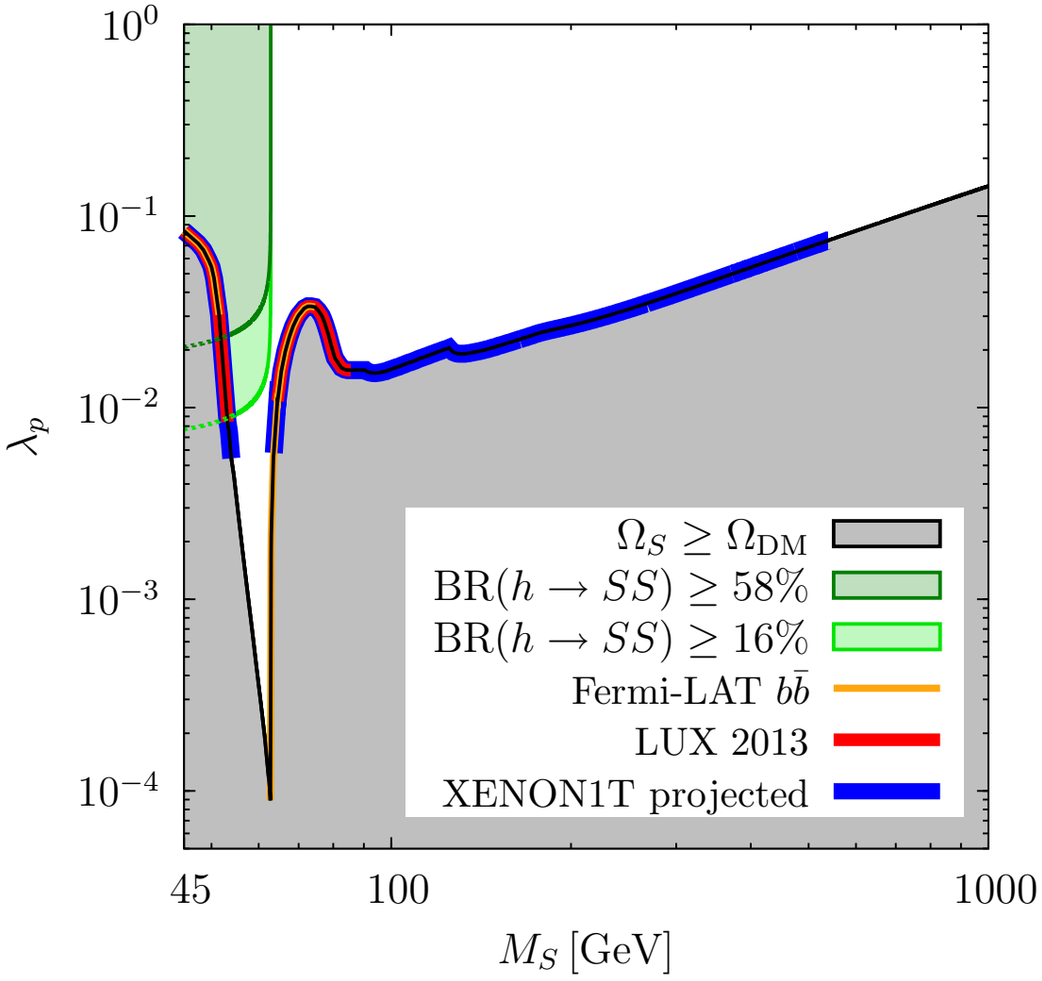
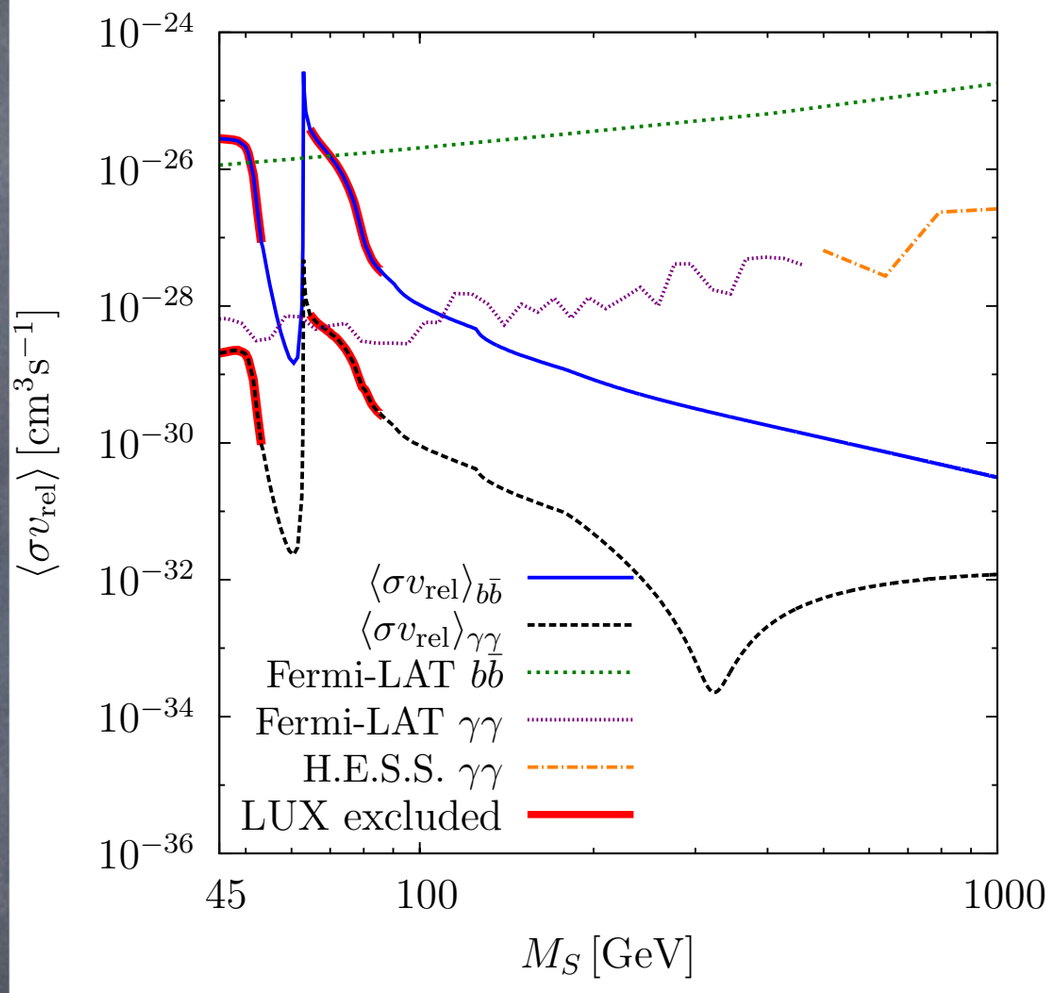
Constraints and Future Prospects





- At the resonance indirect searches might be the only chance in near future
- Between 80 and 300 GeV direct and indirect searches can provide complementary information

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Conclusion

- Gamma lines are not generically visible in a DM model
- We found two mechanisms which allow for Gamma lines in DM models
- Setting limits from line searches w.o. the visibility study (FSR vs. Lines) is meaningless
- Future experiments can improve the situation, once energy resolution reaches 1%

Details in:
1509.04282 , 1508.04418 ,
1508.1425 , 1506.05107

Scalar DM
Gamma Gamma & Z Gamma

$$SS \to h \to \gamma\gamma$$
$$SS \to h \to Z\gamma$$

vs.

$$SS \to h \to \bar{b}b\gamma$$
$$SS \to h \to W^+W^-\gamma$$