Probing Minimal Dark Matter Scenarios with Cherenkov Telescopes

Camilo A. Garcia Cely

Gamma Rays and Dark Matter
December 10th, 2015

Based on JCAP 1510 (2015) 10, 058, arXiv: 1512.02801 and work to be submitted soon
In collaboration with M. Gustafsson, J. Heeck, A. Ibarra, A. Lamperstorfer and M. Tytgat

WIMP Paradigm

Direct detection experiments continue to tighten limits on O(100 GeV) mass WIMPs.

8 TeV Large Hadron Collider (LHC): no evidence for WIMPs.

It is crucially important to look into the TeV-scale

Minimal Dark Matter Scenarios

Quantum numbers		
$SU(2)_L$	$U(1)_Y$	Spin

Simple assumption: extend the SM with an electroweak multiplet

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Cirelli, Fornengo, Strumia 2005

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Inert Doublet Model →

Higgsino DM →

Wino DM →

Fermionic 5-plet →

Scalar 7-plet →

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Multi-TeV DM models

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0.5-20 TeV

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Minimal Dark Matter Scenarios

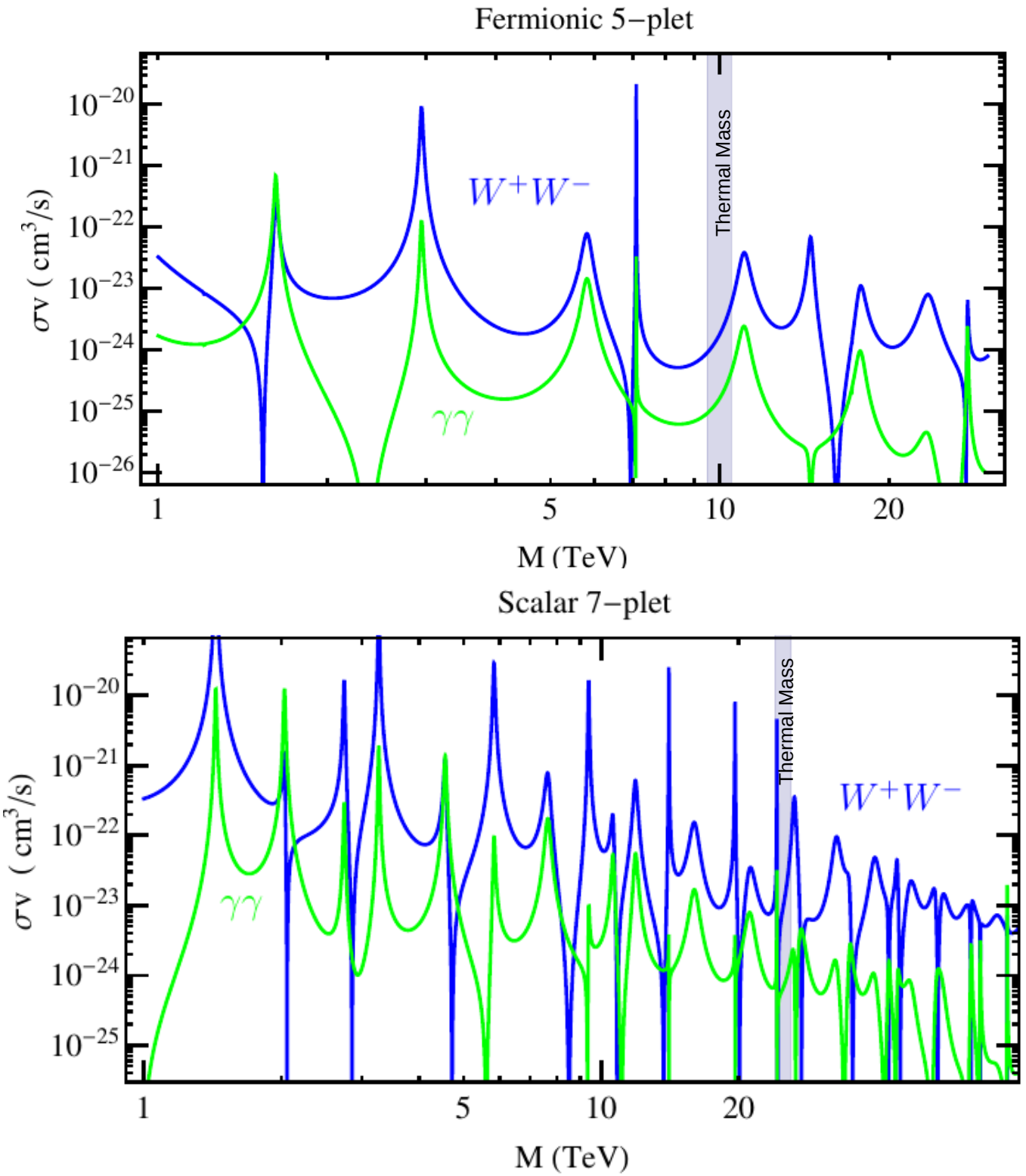
$$\chi = \begin{pmatrix} \mathrm{DM}^{2+} \\ \mathrm{DM}^{+} \\ \mathrm{DM} \\ -\mathrm{DM}^{-} \\ \mathrm{DM}^{2-} \end{pmatrix} \quad \text{for the 5-plet,} \qquad \chi = \begin{pmatrix} \mathrm{DM}^{3+} \\ \mathrm{DM}^{2+} \\ \mathrm{DM}^{+} \\ \mathrm{DM} \\ -\mathrm{DM}^{-} \\ \mathrm{DM}^{2-} \\ -\mathrm{DM}^{3-} \end{pmatrix} \quad \text{for the 7-plet.}$$

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \frac{1}{2}\bar{\chi}(i\not{D} - M)\chi \qquad \text{(fermion)}$$

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \frac{1}{2}\left(|D_\mu \chi|^2 - M^2|\chi|^2\right) \qquad \text{(scalar)}\ .$$

Only the mass is a free parameter. **Very predictive scenarios!**

Sommerfeld Effect is responsible for huge cross-sections



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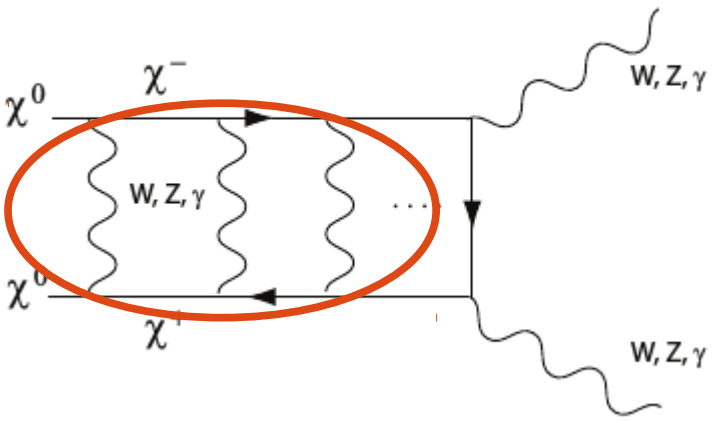
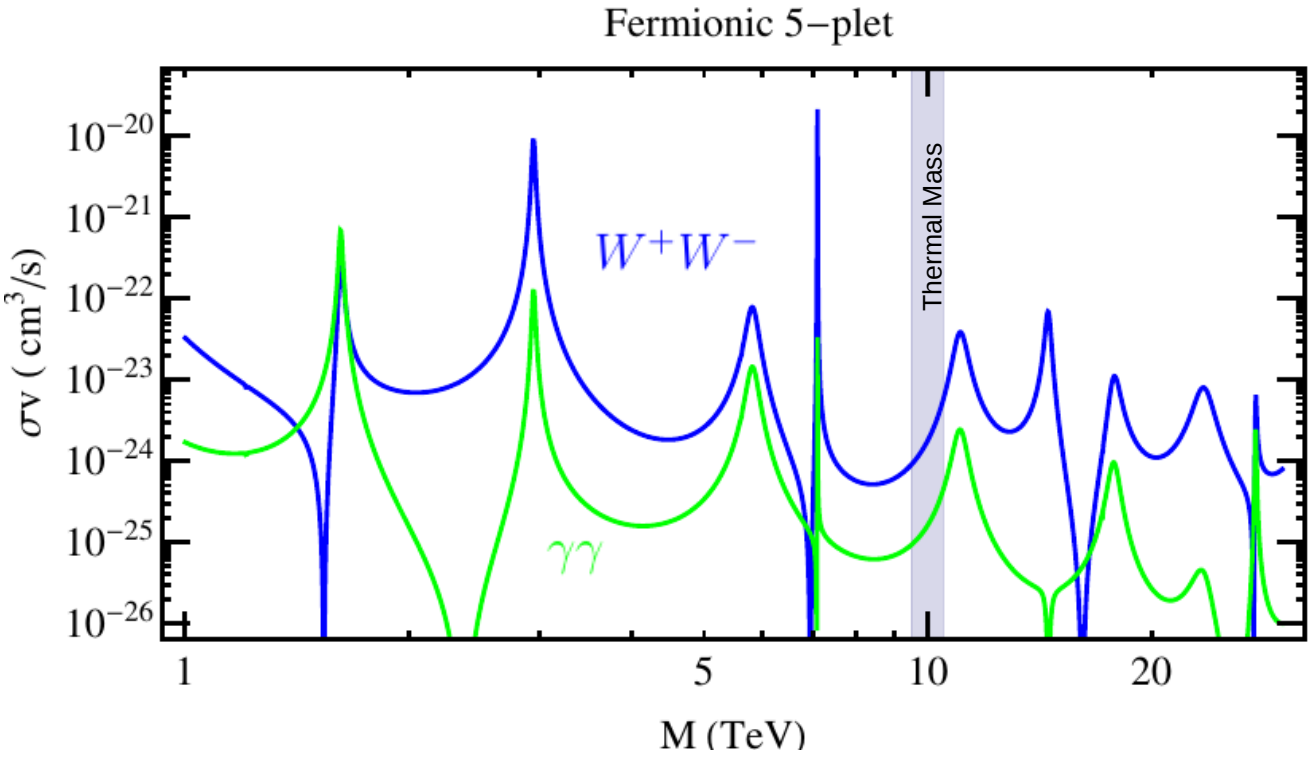
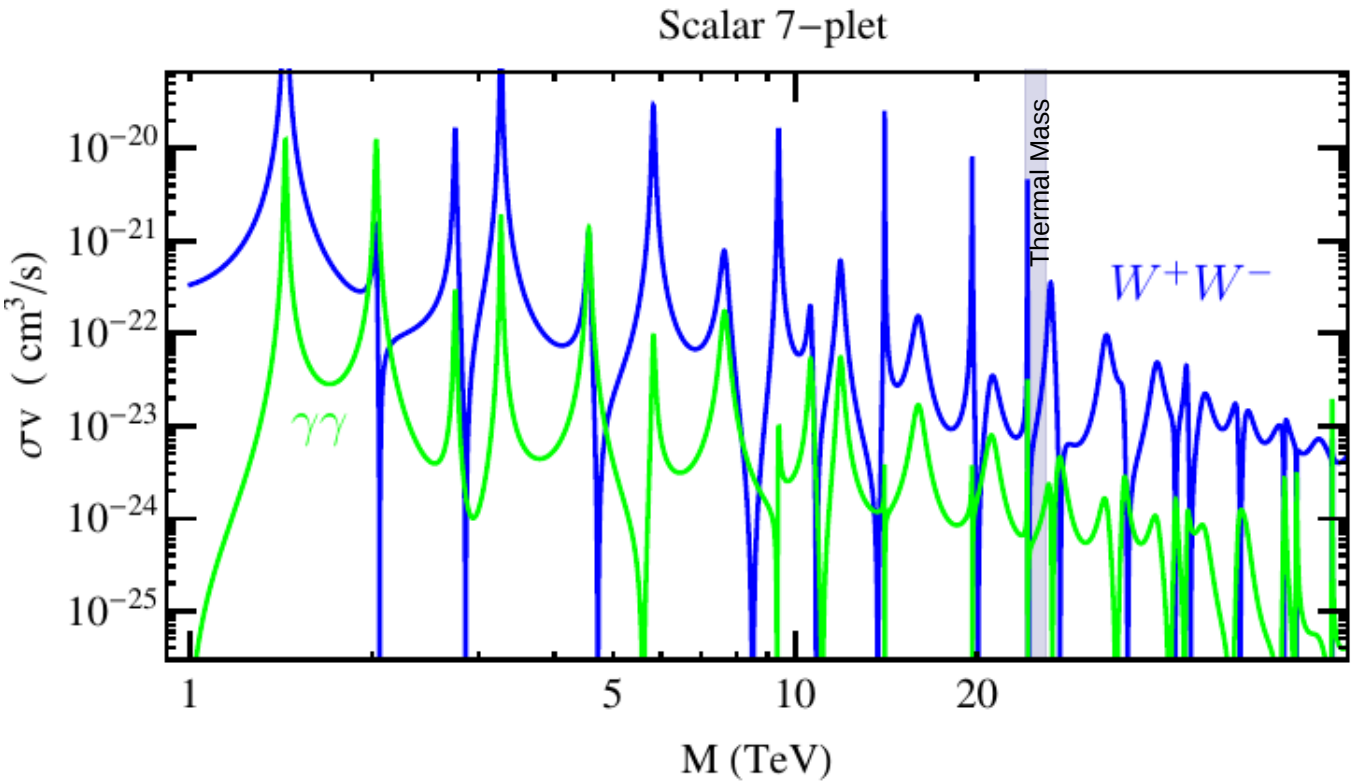


Yukawa Potential





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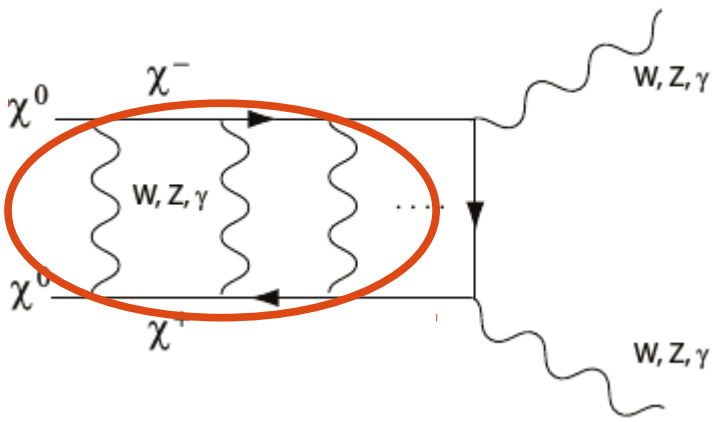
Cirelli, Strumia 2009
Cirelli, Hambye, Taoso, Panci, Sala 2015



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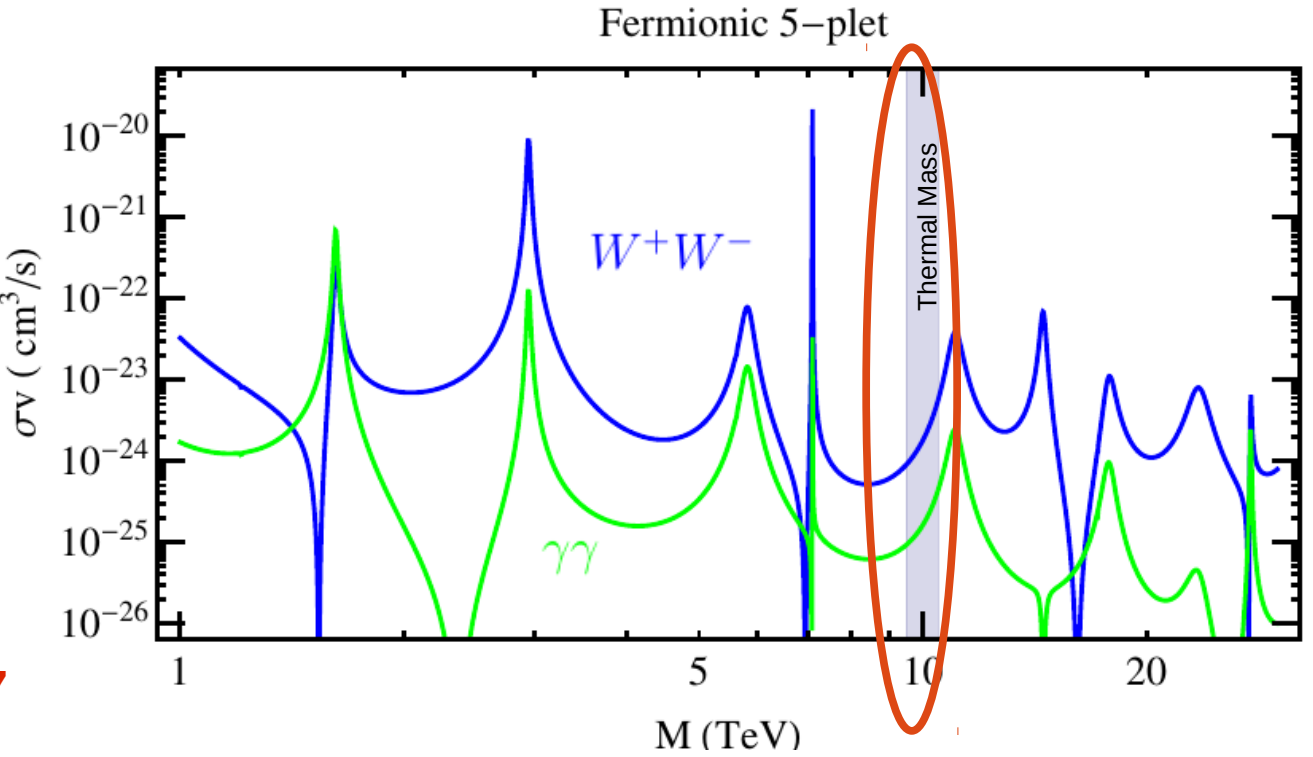
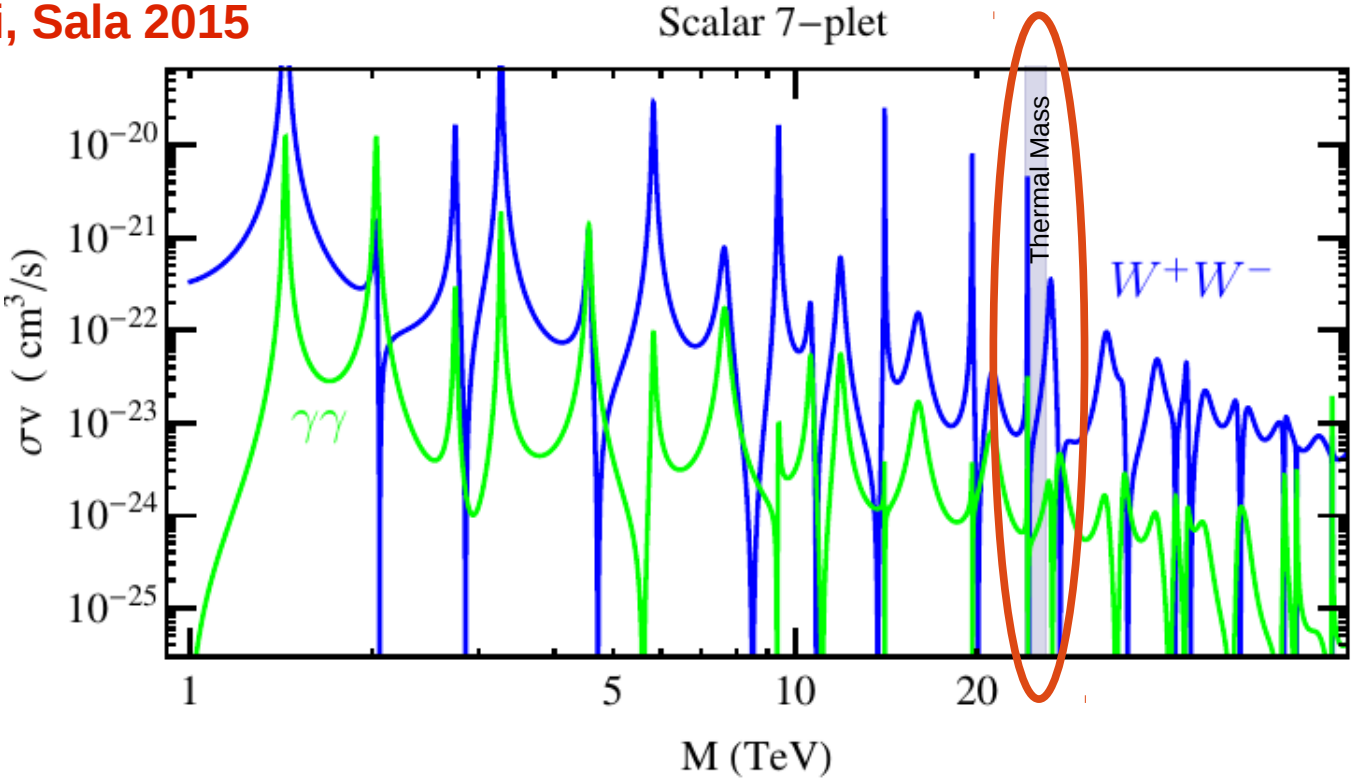
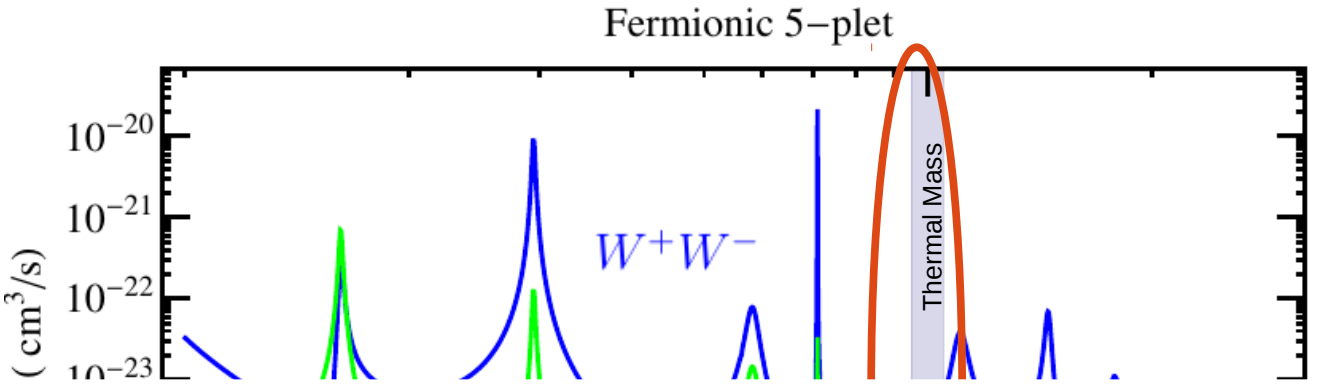
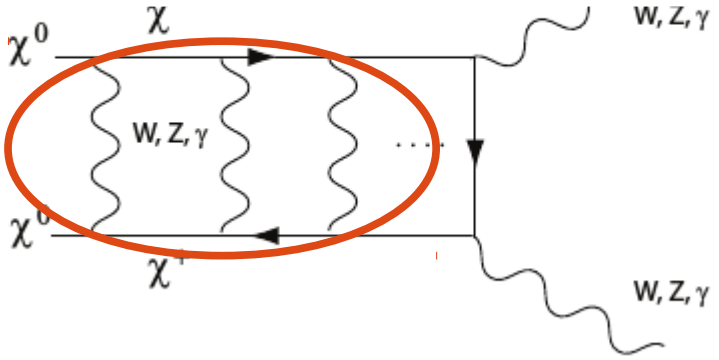






Cross-sections today are much larger than the canonical thermal value!!!



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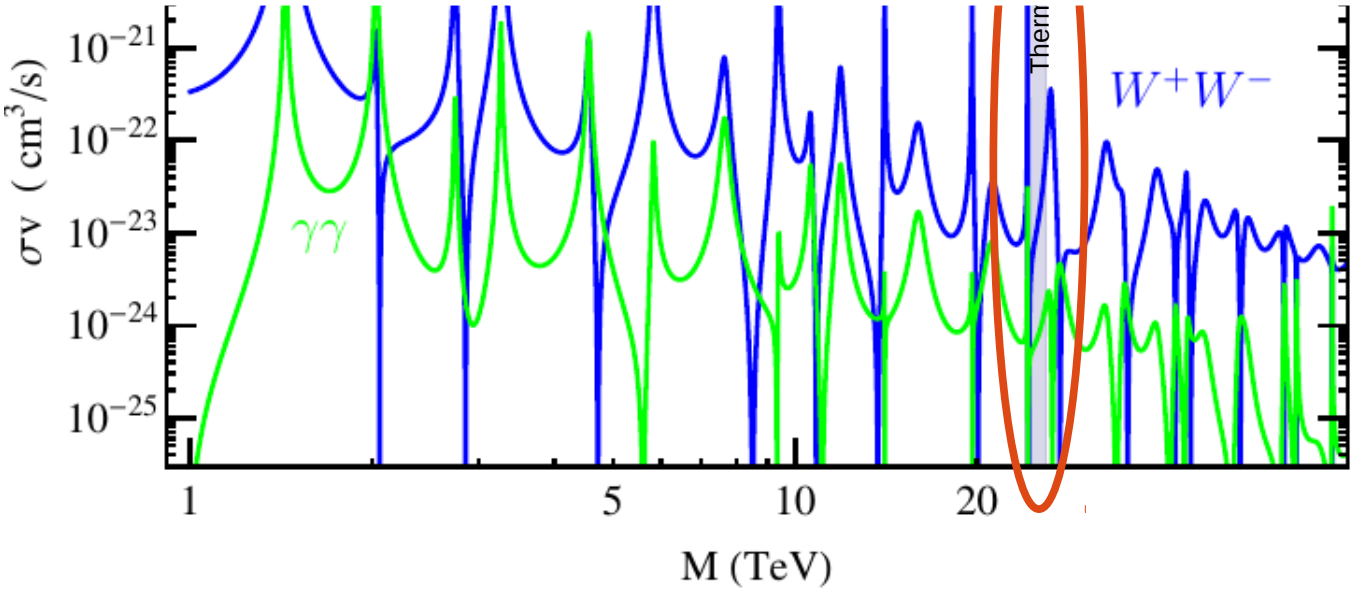
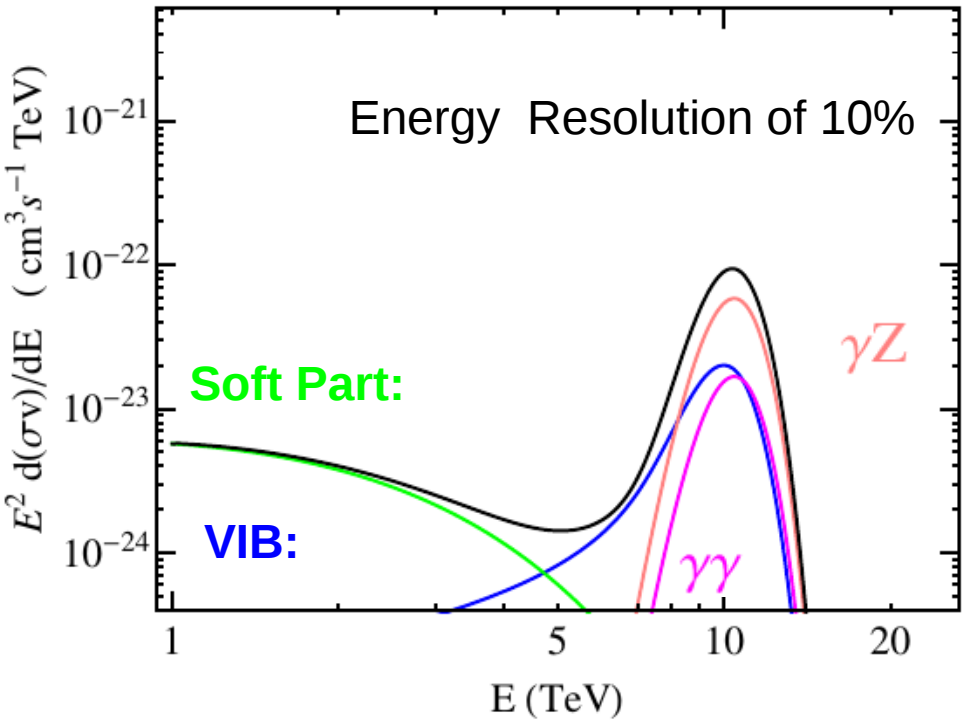
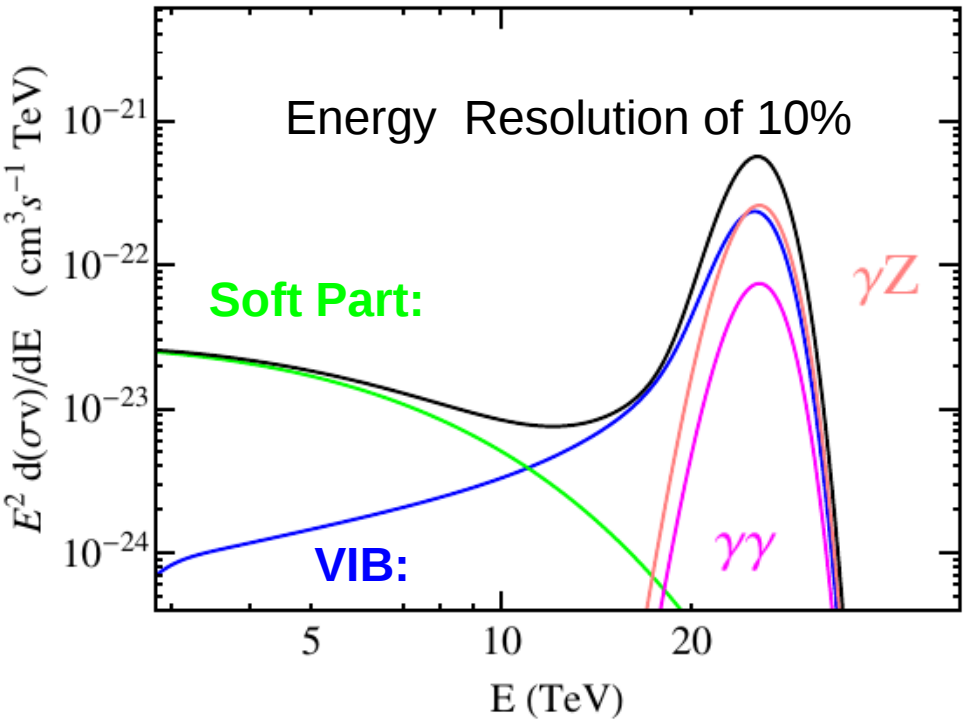


Gamma-ray spectrum

Fermionic 5-plet M ~ 10 TeV



Scalar 7-plet M ~ 25 TeV



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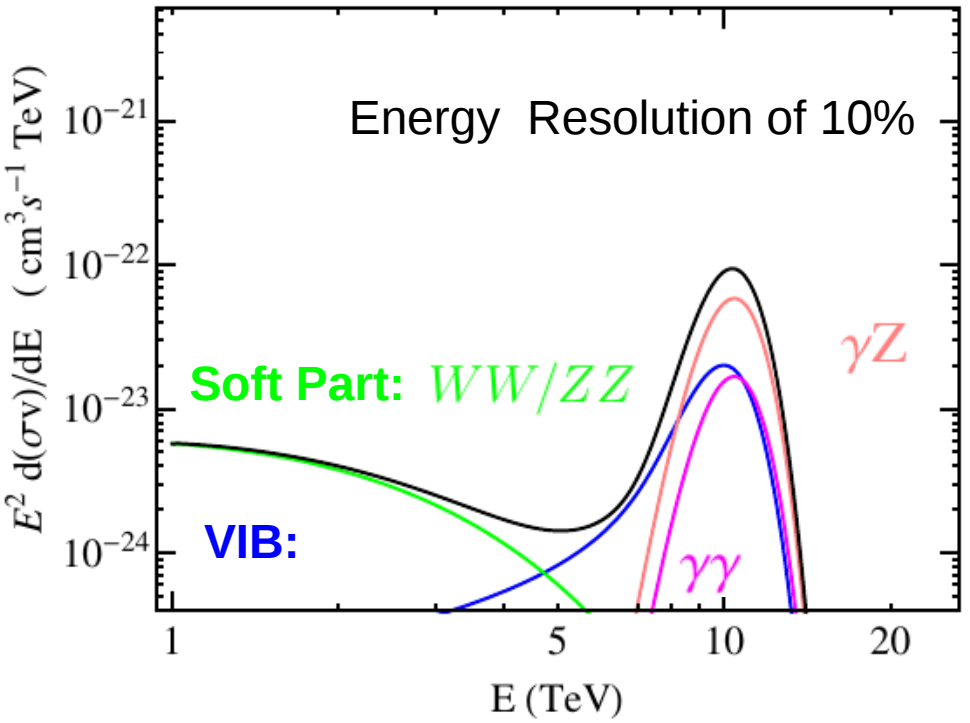

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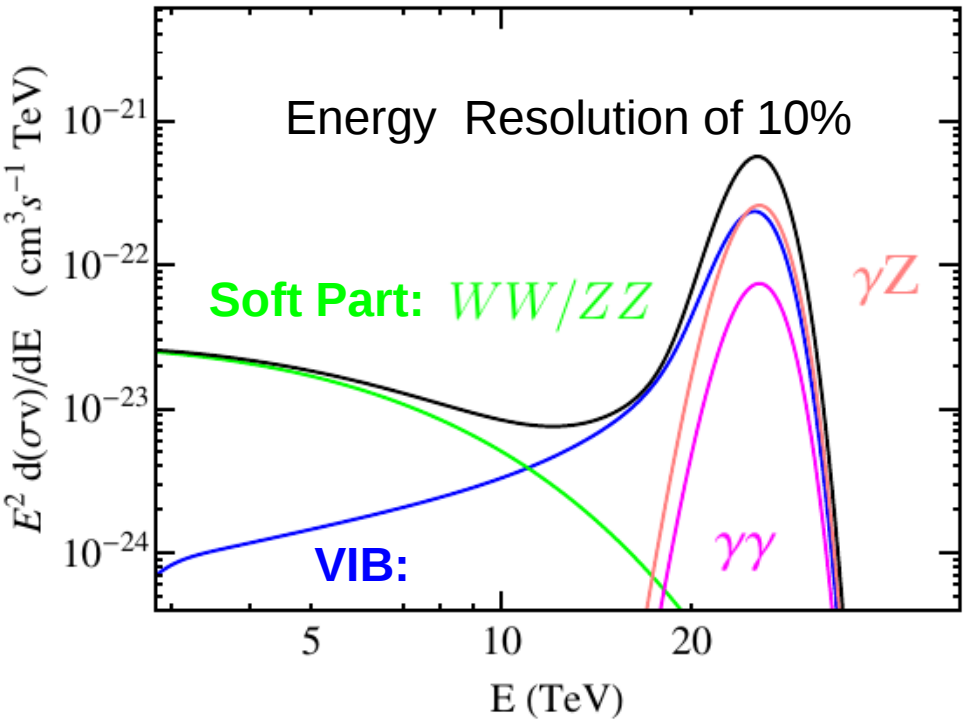

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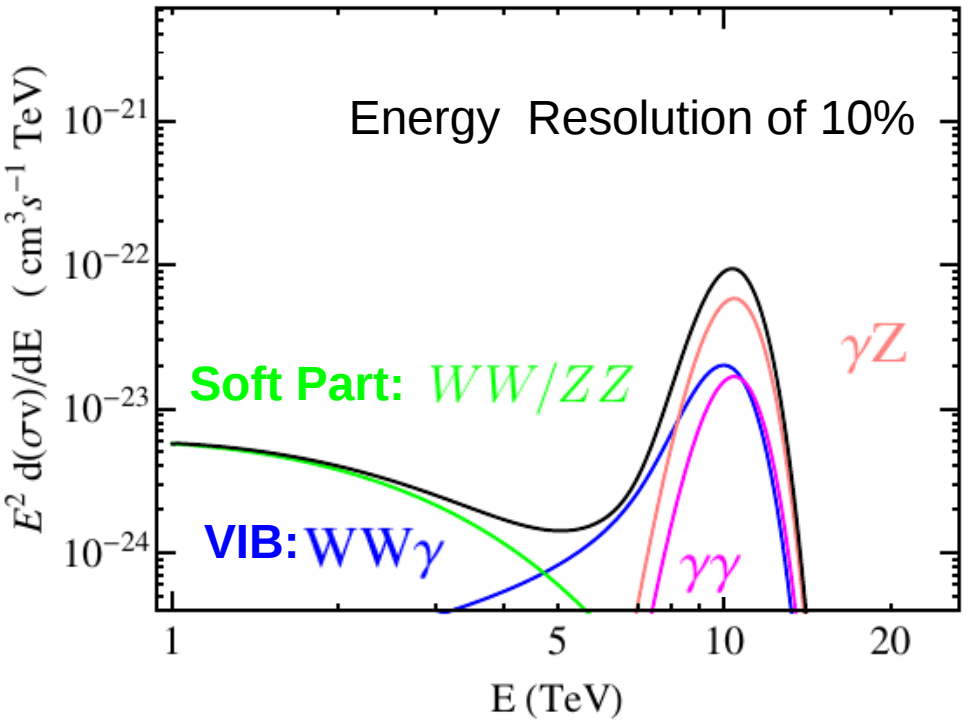

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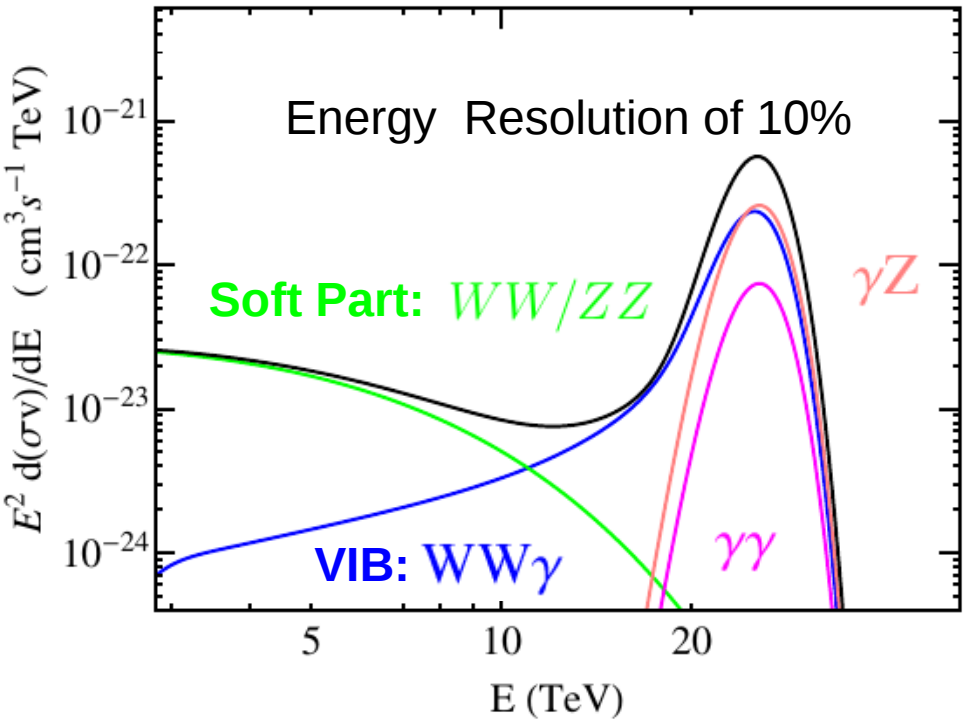
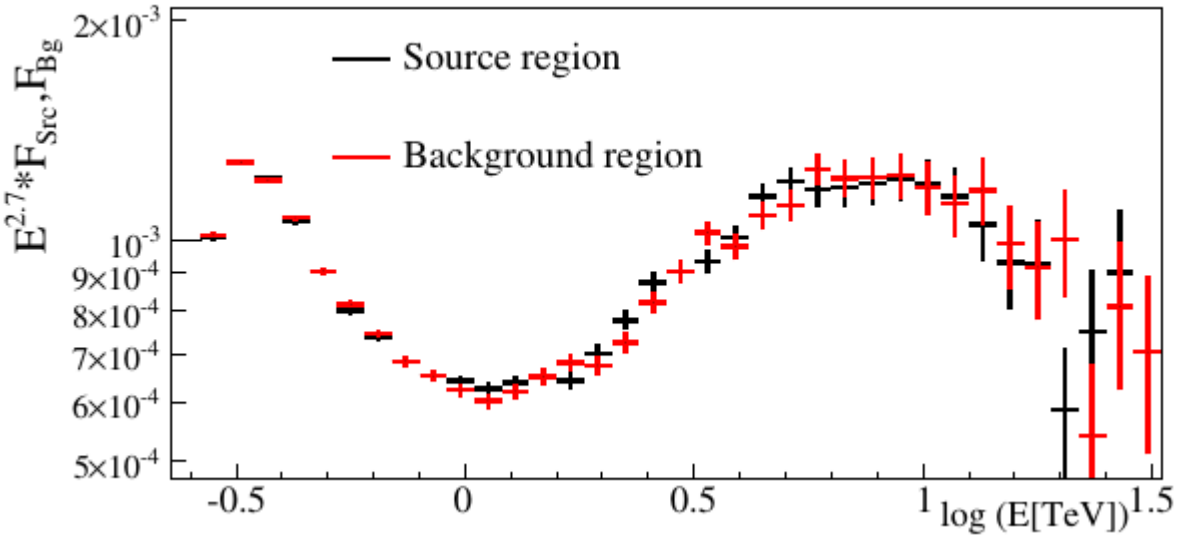


H.E.S.S. Limits from the Galatic Center Soft Part

Target region: a circle of 1° radius centered in the Milky Way Center, excluding the Galactic Plane $|b| \geq 0.3°$

- We calculate constraints on the featureless component from W^+W^- or ZZ annihilations by comparing the gamma-ray fluxes measured with the H.E.S.S. instrument in a "search region" and in a "background region". The inferred residual flux is consistent with zero, thus allowing to derive upper limits on the flux from annihilations.

(H.E.S.S.Collaboration), Phys.Rev.Lett. **106**, 161301 (2011), 1103.3266.

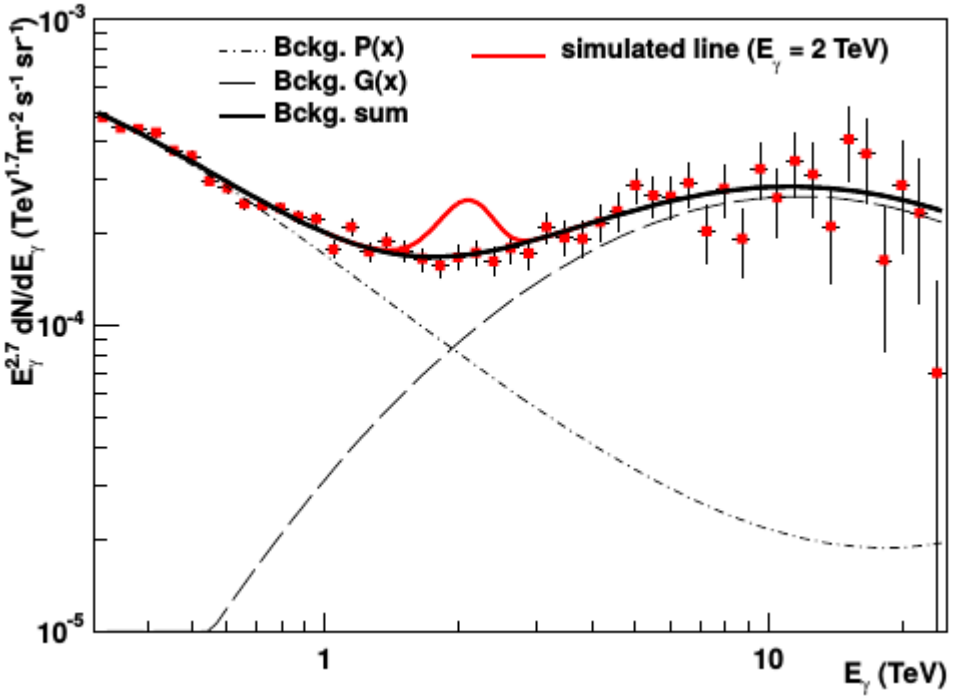


H.E.S.S. Limits from the Galatic Center Sharp Spectral Feature

Target region: a circle of 1° radius centered in the Milky Way Center, excluding the Galactic Plane $|b| \geq 0.3°$

- To calculate limits on the DM annihilation cross section into sharp spectral features, we adopt the phenomenological background model proposed by the H.E.S.S. collaboration, which is described by 7 parameters.

(H.E.S.S. Collaboration), Phys.Rev.Lett. **110**, 041301 (2013), 1301.1173.



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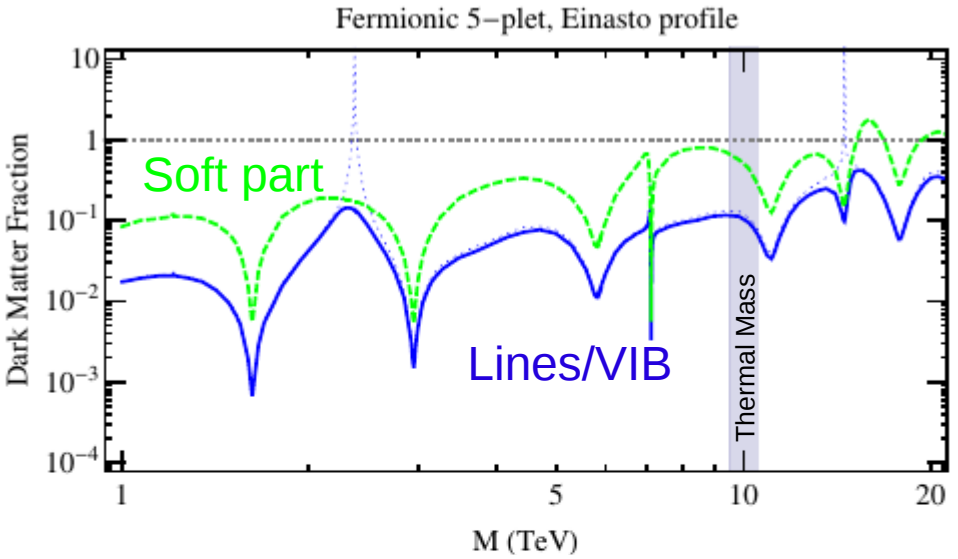

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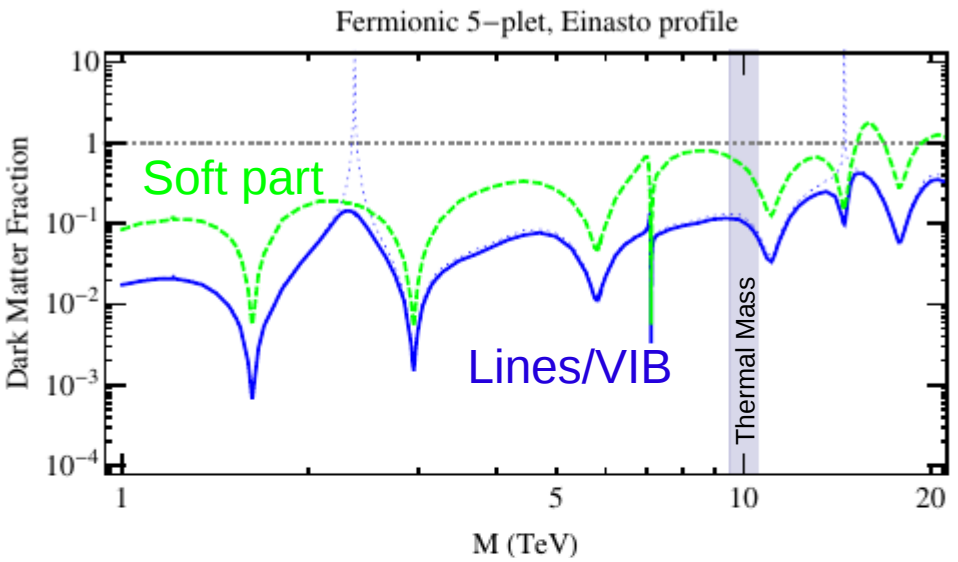

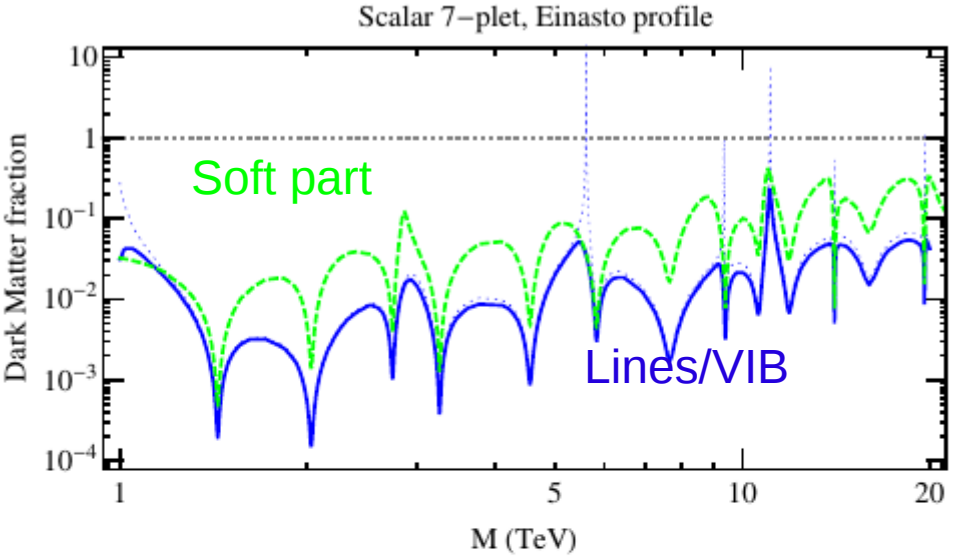

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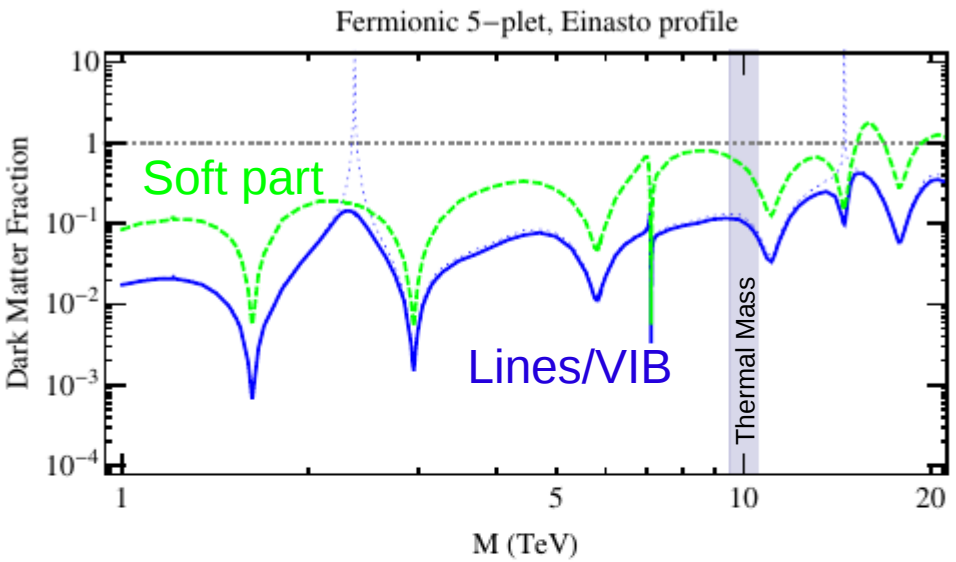
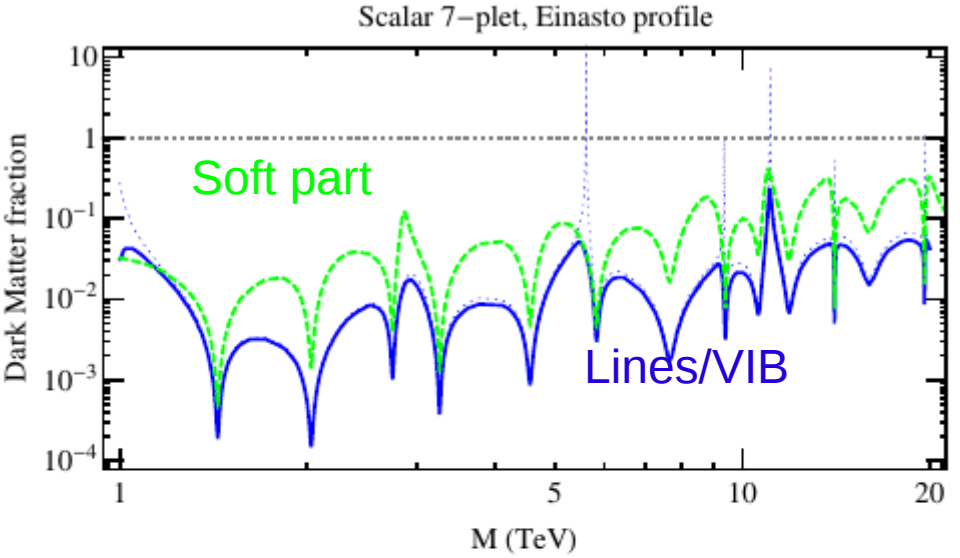
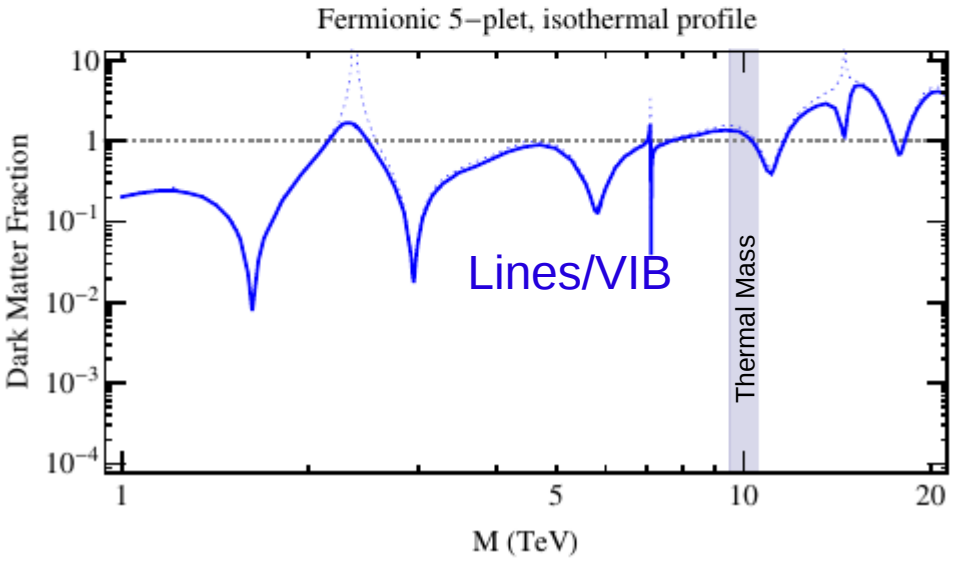
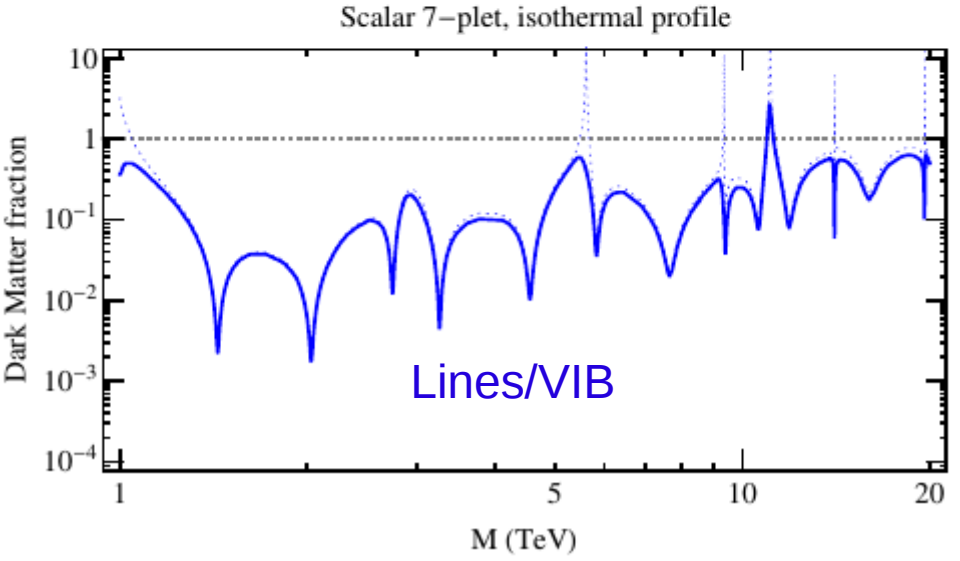
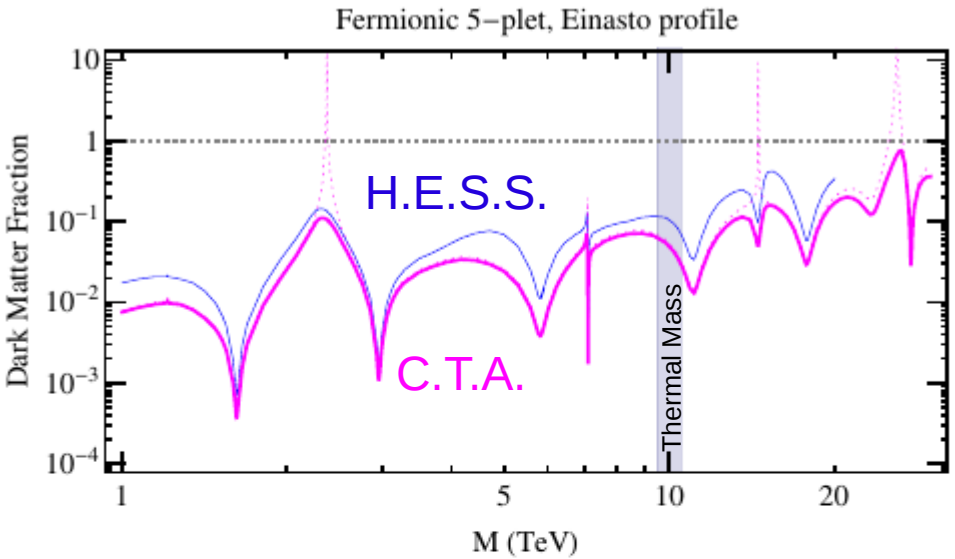


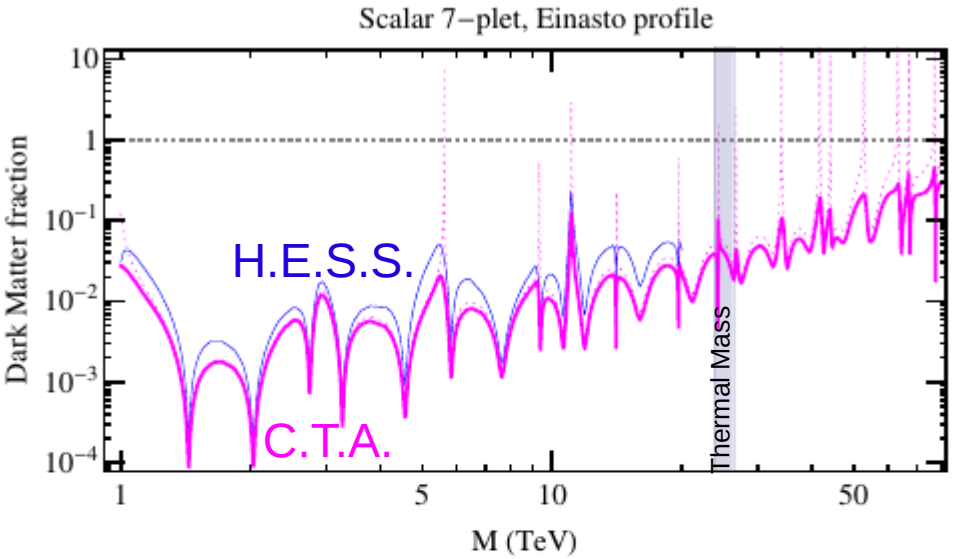


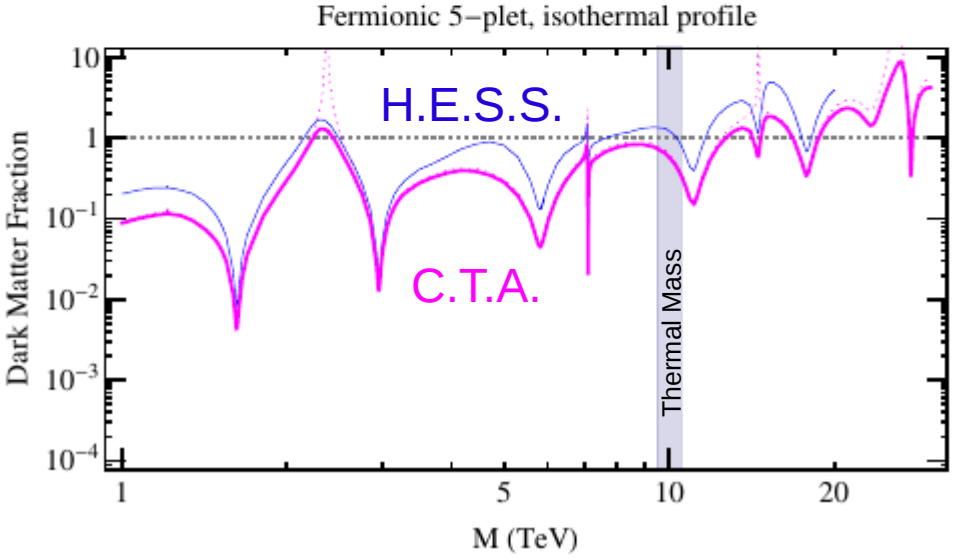


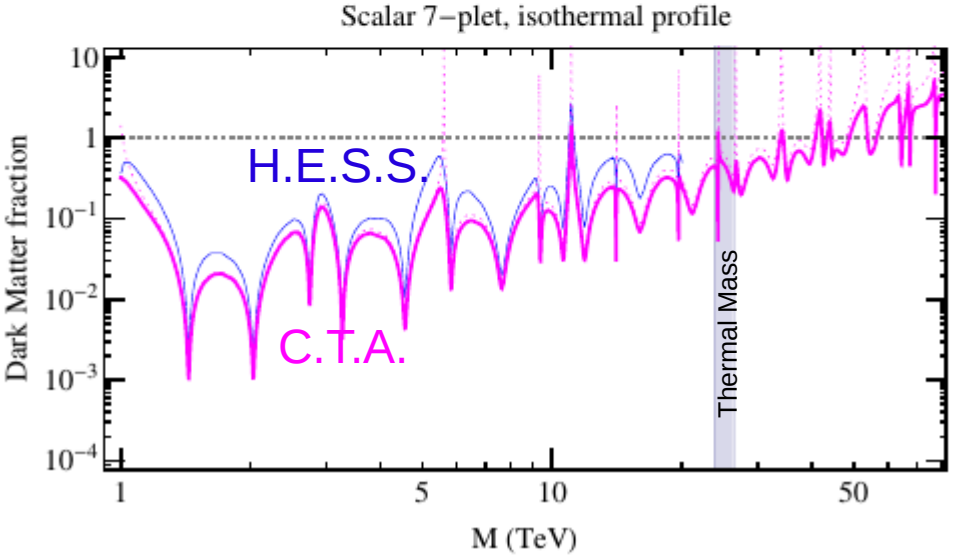


C.T.A. Prospects on VIB+Lines









- We consider the same region around the Galactic Center and 112h of observation time.

ArXiv:1507.05536

Another Example: Inert Doublet

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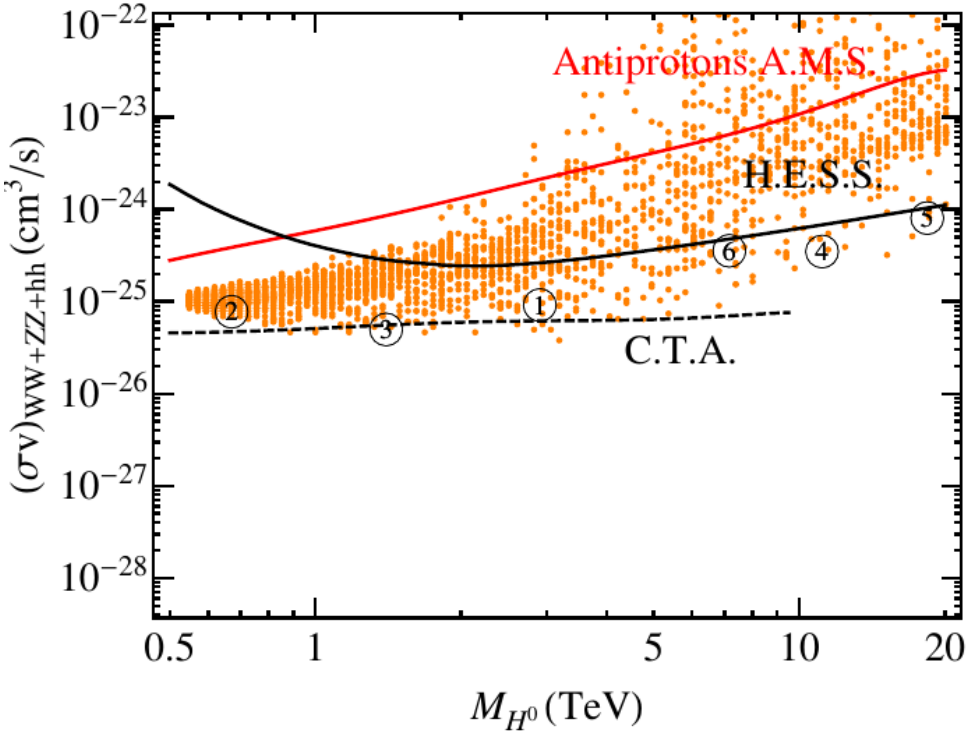

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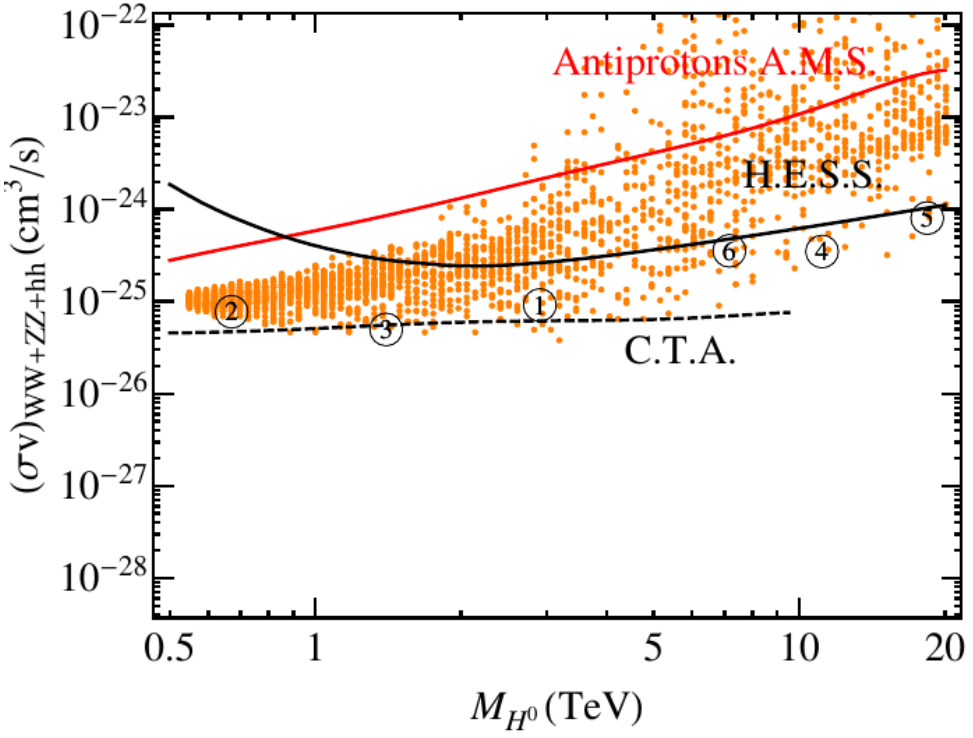

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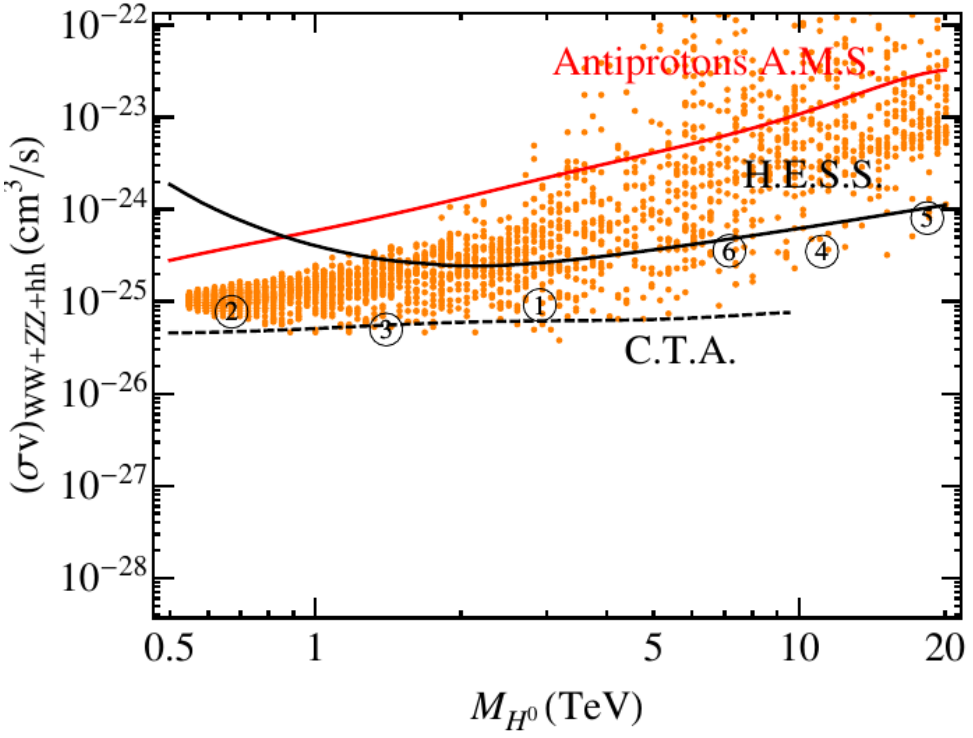

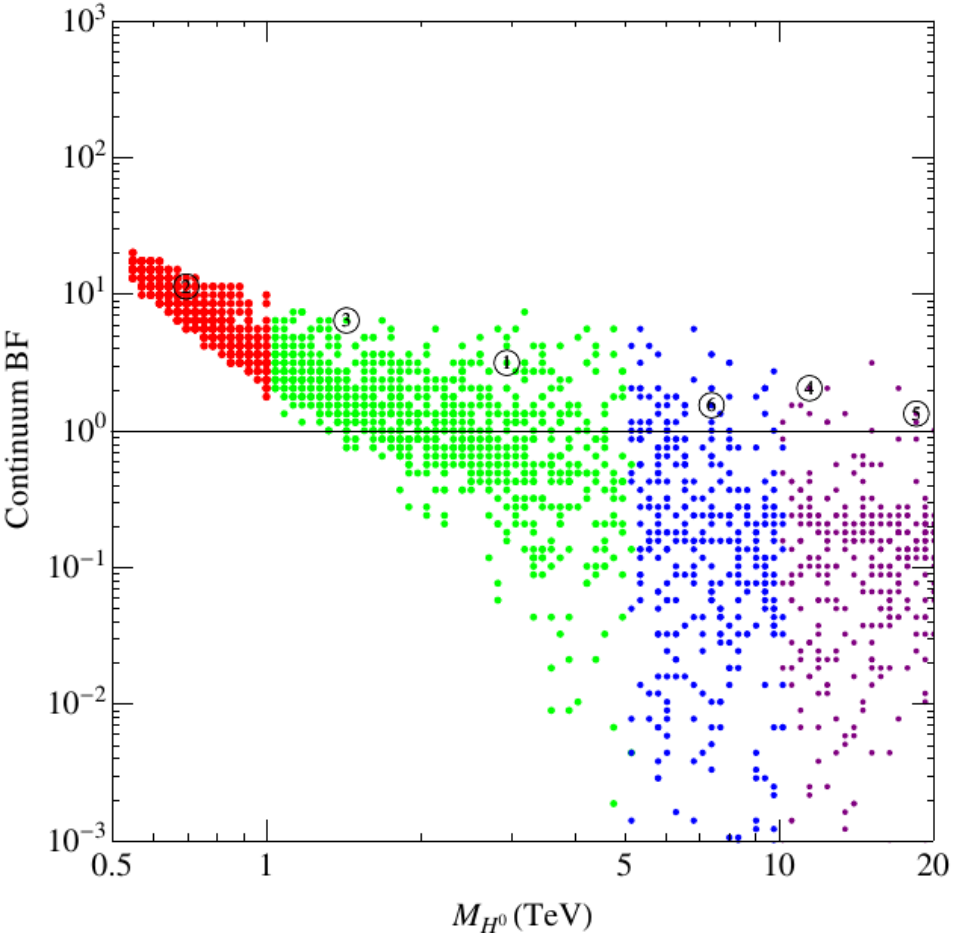

Another Example: Left-Right Symmetric Dark Matter

Extend the idea of only one multiplet, but considering the group

Heeck and Patra, 2015

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Fermion representation
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$(\mathbf{5},\mathbf{1},0) \oplus (\mathbf{1},\mathbf{5},0)$
$(\mathbf{2},\mathbf{2},0)$
$(\mathbf{3},\mathbf{3},0)$

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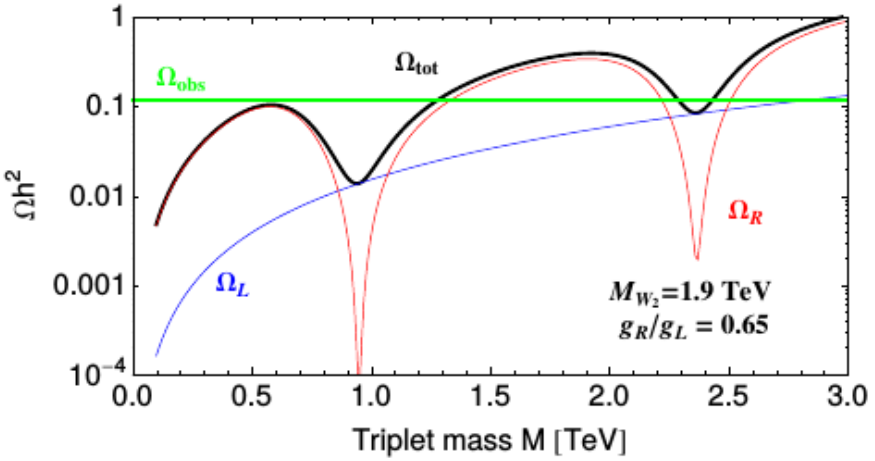
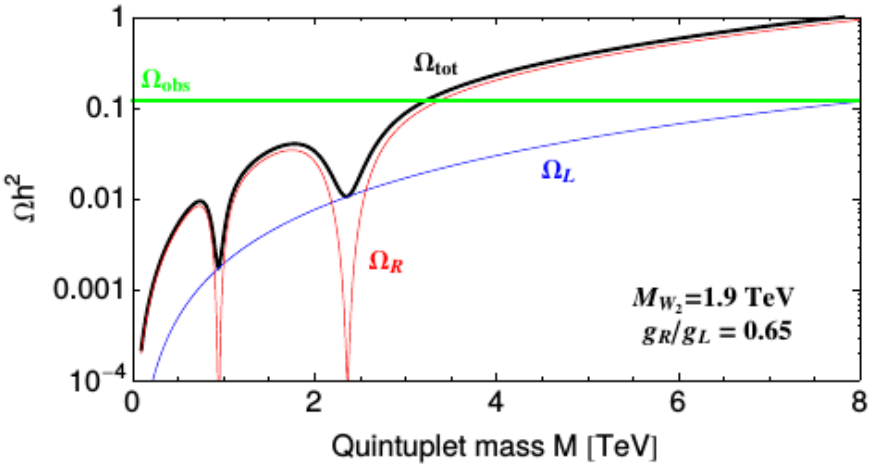
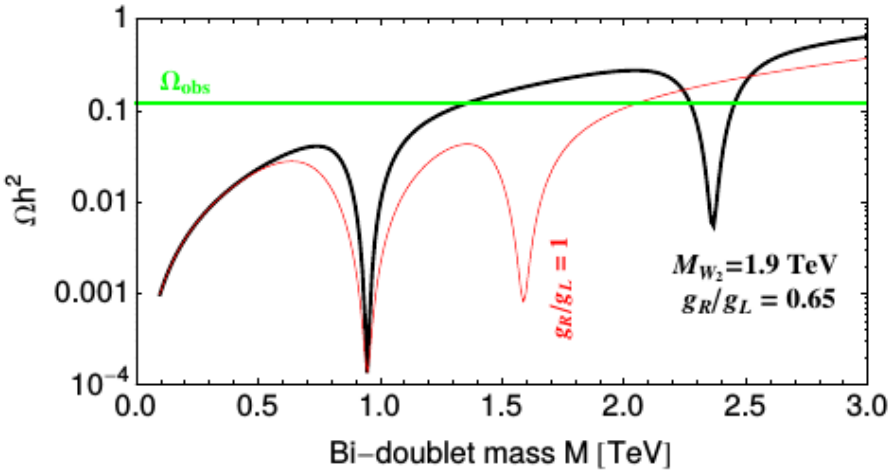
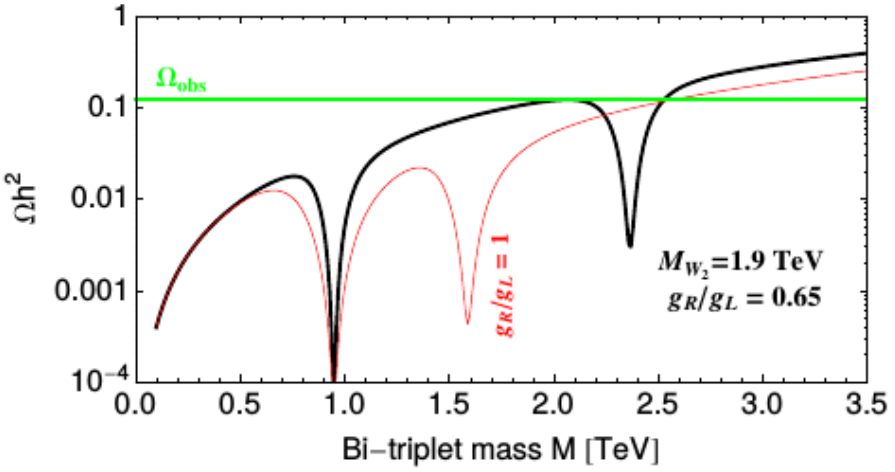


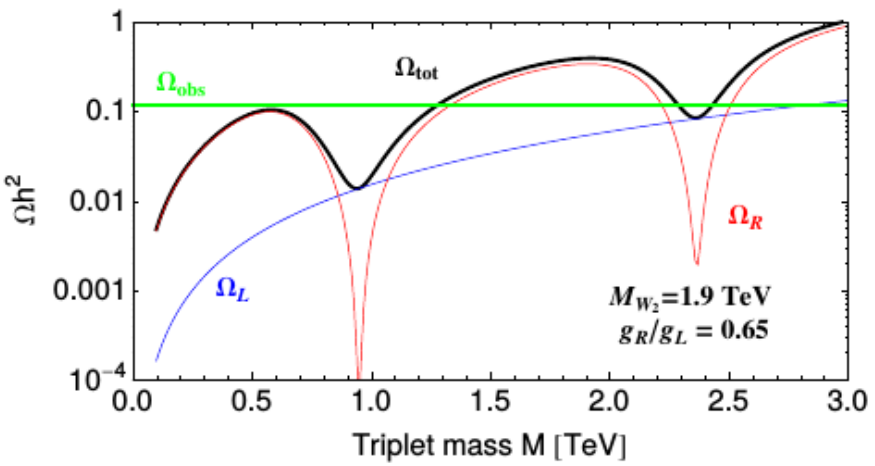


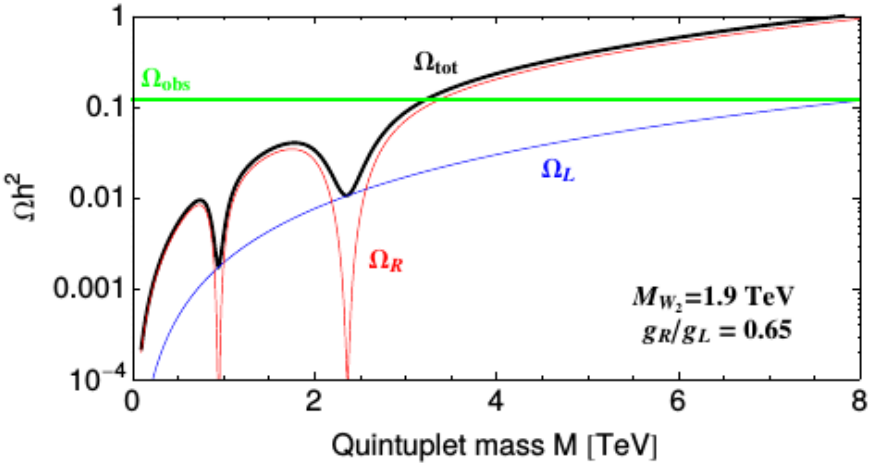


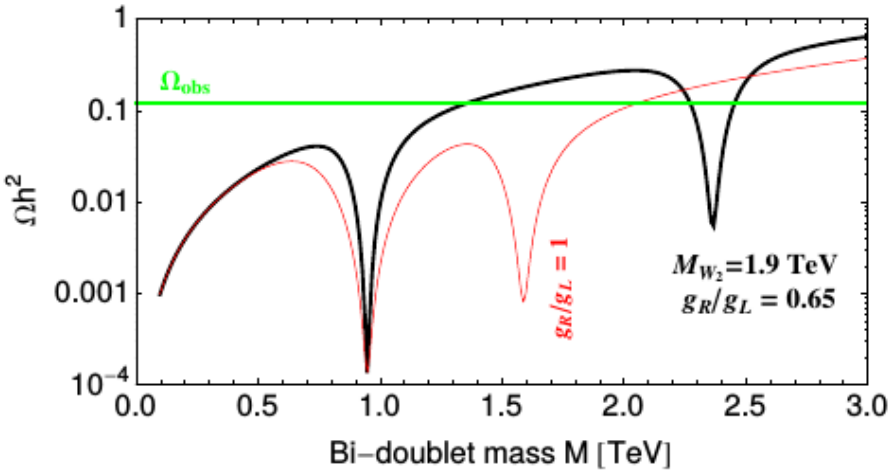


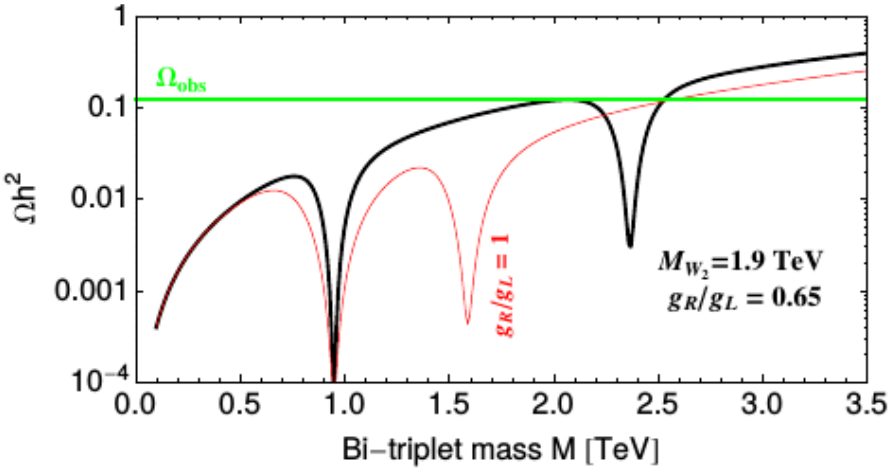
Preliminary

Fermion representation	DM mass M/TeV
$(\mathbf{3},\mathbf{1},0)\oplus(\mathbf{1},\mathbf{3},0)$	1.3, 2.3*, 2.4*
$(\mathbf{5},\mathbf{1},0)\oplus(\mathbf{1},\mathbf{5},0)$	3.2**
$(\mathbf{2},\mathbf{2},0)$	1.4, 2.3, 2.5
$(\mathbf{3},\mathbf{3},0)$	2.0*–2.1*, 2.5*









Preliminary

Fermion representation	DM mass M/TeV
$(\mathbf{3},\mathbf{1},0)\oplus(\mathbf{1},\mathbf{3},0)$	1.3, 2.3*, 2.4*
$(\mathbf{5},\mathbf{1},0)\oplus(\mathbf{1},\mathbf{5},0)$	3.2**
$(\mathbf{2},\mathbf{2},0)$	1.4, 2.3, 2.5
$(\mathbf{3},\mathbf{3},0)$	2.0*–2.1*, 2.5*

Because of Sommerfeld Enhancement

Table I: DM candidates that yield the observed abundance for $M_{W_2} = 1.9\,\text{TeV}$ and $g_R/g_L = 0.65$. Solutions with one asterisk are robustly excluded by indirect detection, while those with two asterisks are only excluded for the Einasto profile.

Conclusions

- Minimal DM models predict a significant annihilation cross-sections into gamma-rays due to the Sommerfeld Enhancement. Much above the canonical thermal value.

- This sort of scenarios are very predictive because they have few parameters and include known cases as Wino and Higgsino DM. They are a testing ground for new ideas and can be compared with experiments easily.

- These can be searched for with Cherenkov telescopes and eventually found or excluded in the near future.

Thanks for your attention!