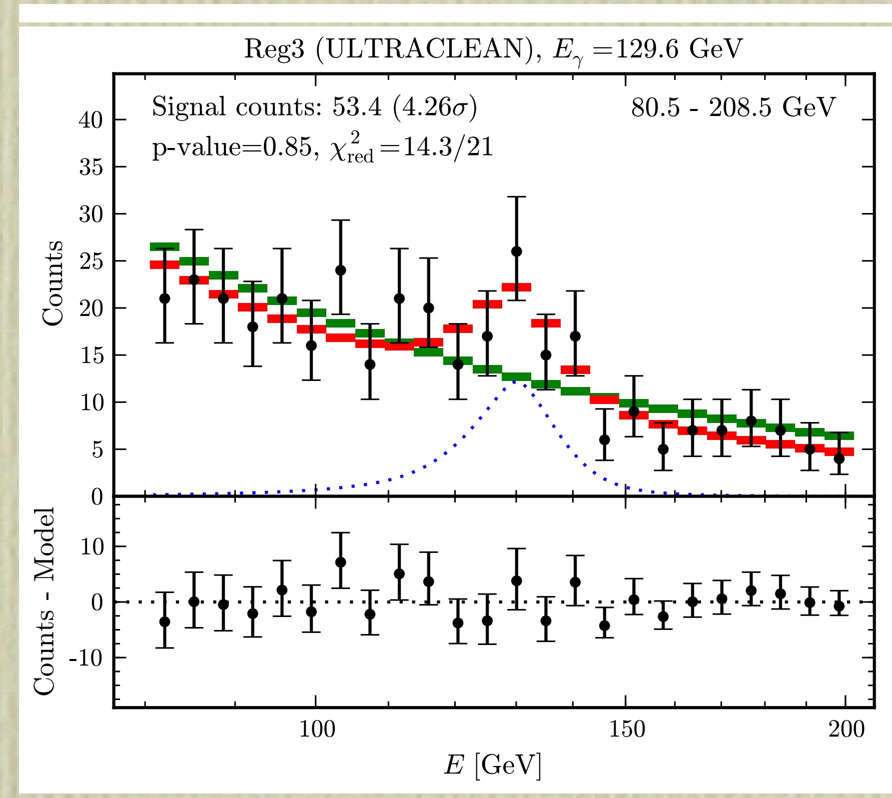
From Gamma Ray Line Signals of Dark Matter to the LHC

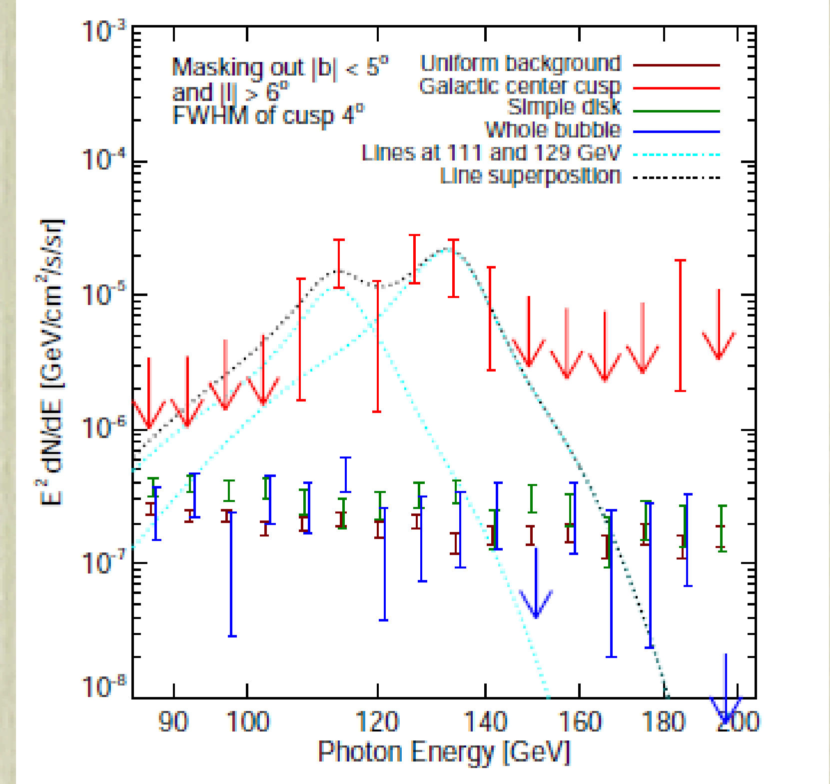
Reinard Primulando

with J. Kopp, E. Neil and J. Zupan

arXiv:1301.1683

135 GeV Line





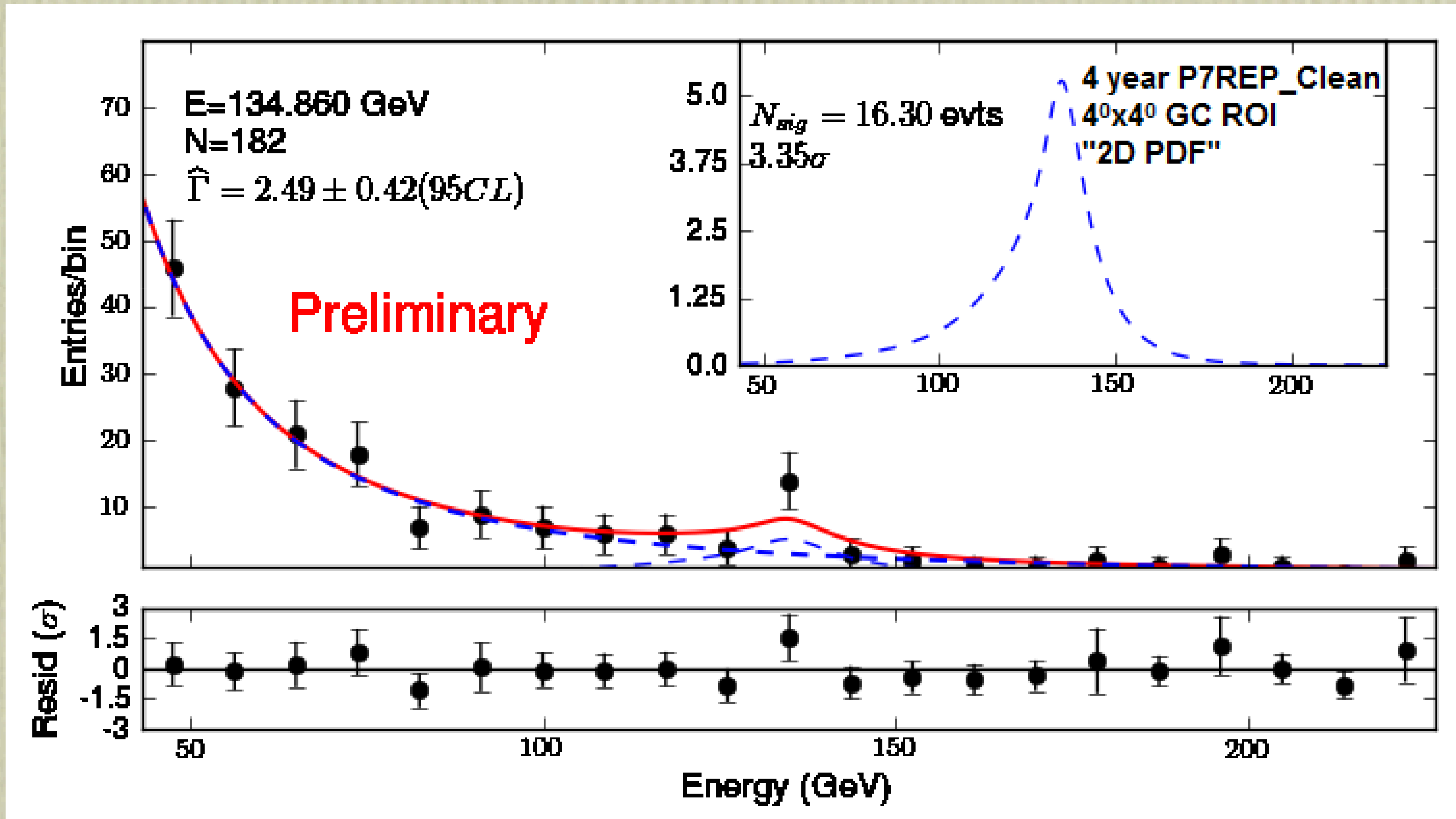
C. Weniger, arXiv:1204.2797

M. Su, D.P. Finkbeiner, arXiv:1206.1616

γX	m_χ [GeV]	$\langle\sigma v\rangle_{\gamma X}$ $[10^{-27}\mathrm{cm}^3\mathrm{s}^{-1}]$
$\gamma\gamma$	$129.8 \pm 2.4^{+7}_{-14}$	$1.27 \pm 0.32^{+0.18}_{-0.28}$
γZ	$144.2 \pm 2.2^{+6}_{-12}$	$3.14 \pm 0.79^{+0.40}_{-0.60}$
γH	$155.1 \pm 2.1^{+6}_{-11}$	$3.63 \pm 0.91^{+0.45}_{-0.63}$

T. Bringmann, C. Weniger, arXiv:1208.5481

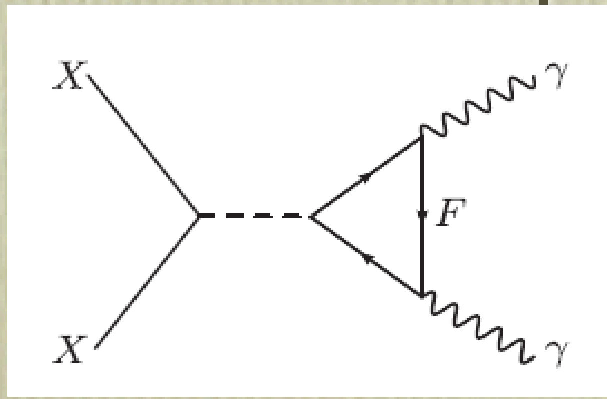
135 GeV Line

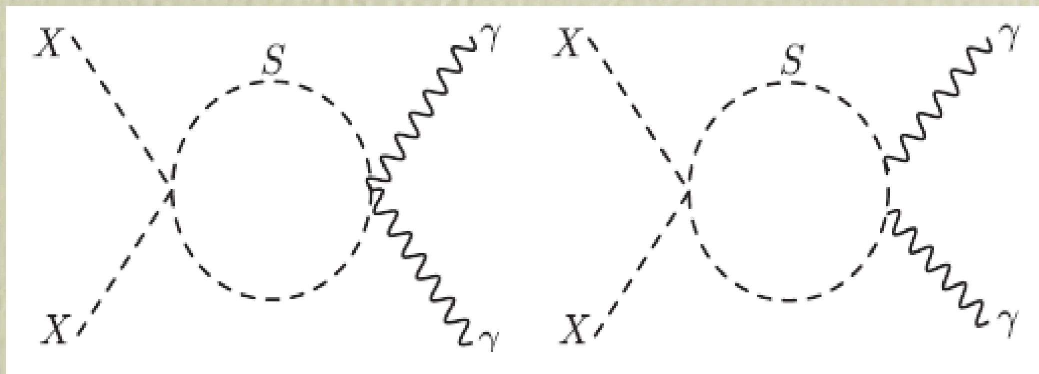


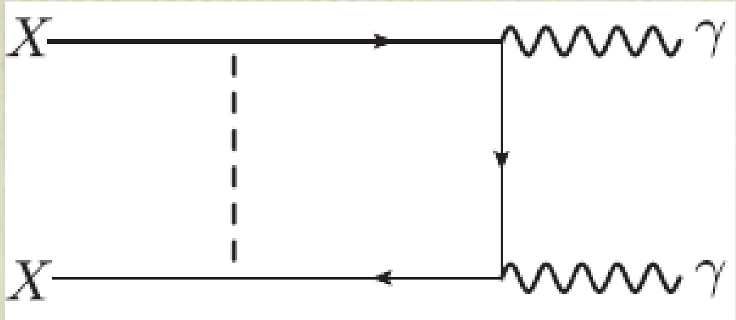
A. W. B. Albert, and E. Bloom,
4th Fermi Symposium, Monterey CA

Models for the Line

- Any model has to satisfy continuum photons bound.
- Annihilation to photons through a loop of charged particle.
- Large coupling between DM and the particle in the loop.

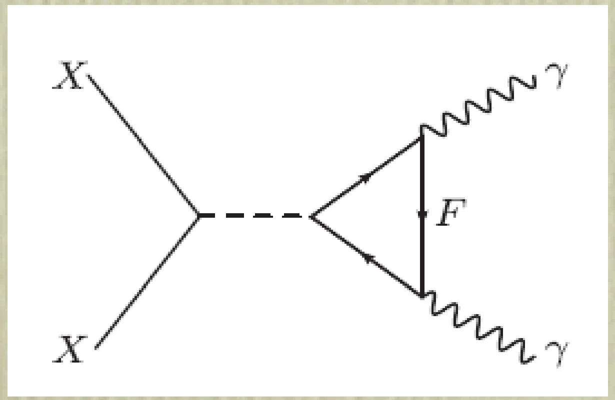


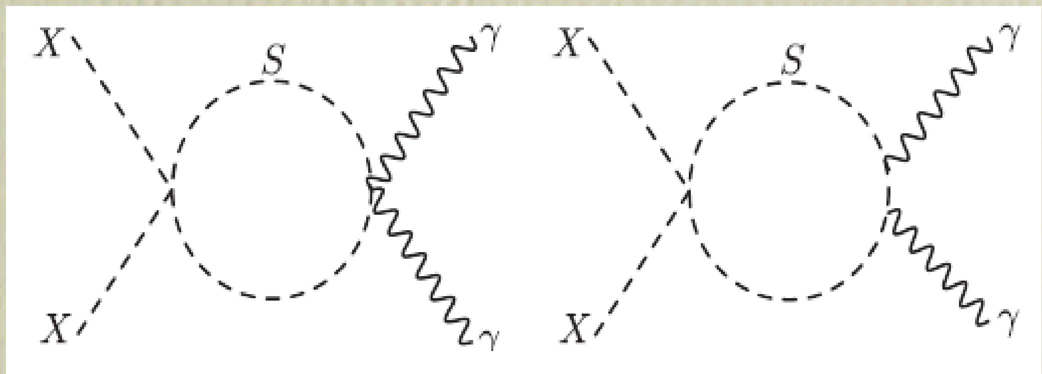


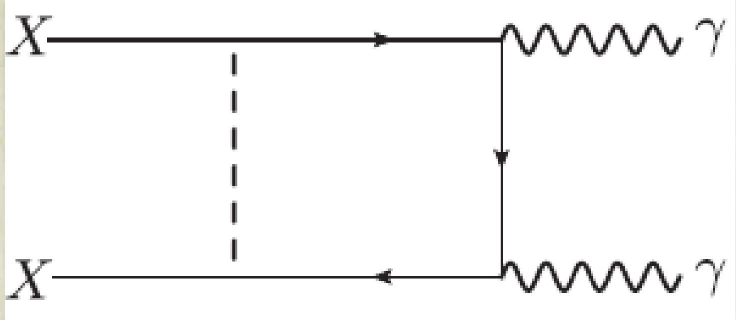


Models for the Line

- We want to trade the large coupling with large electric charge and study the LHC signature of the model.







Model Setup

- Consider a scalar electroweak N-plet (ϕ) and dark matter (χ).

$$\mathcal{L} \supset |D_\mu \phi|^2 - m_\phi^2 \phi^\dagger \phi - \lambda_{\phi H} \phi^\dagger \phi H^\dagger H - \lambda'_{\phi H} (\phi^\dagger T_N^a \phi)(H^\dagger \tau^a H) - \lambda_4 (\phi^\dagger \phi)^2$$

$$\mathcal{L} \supset \frac{1}{2} \partial_\mu \chi \partial^\mu \chi - \frac{1}{2} m_\chi^2 \chi^2 - \lambda_{\chi H} \chi^2 H^\dagger H - \lambda_{\chi \phi} \chi^2 \phi^\dagger \phi.$$

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Annihilation cross section is determined by $\lambda_{\chi\varphi}$

Model Setup

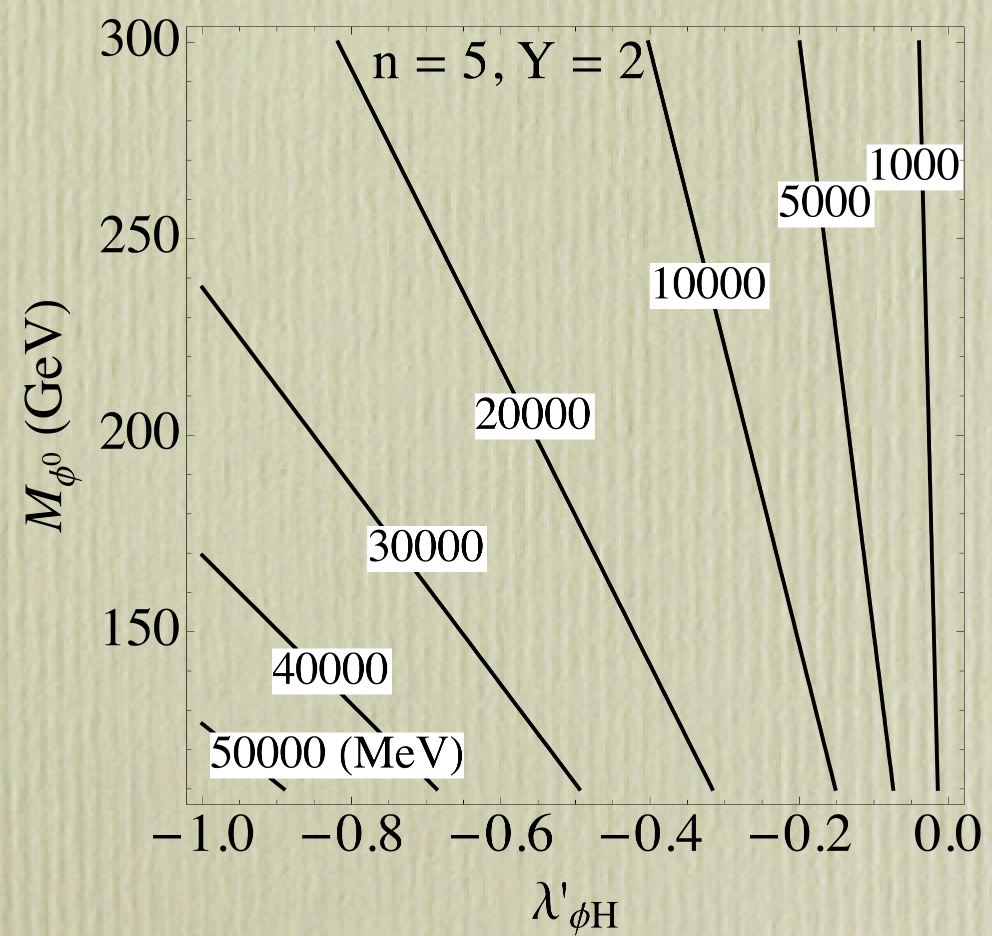
- Consider a scalar electroweak N-plet (ϕ) and dark matter (χ).

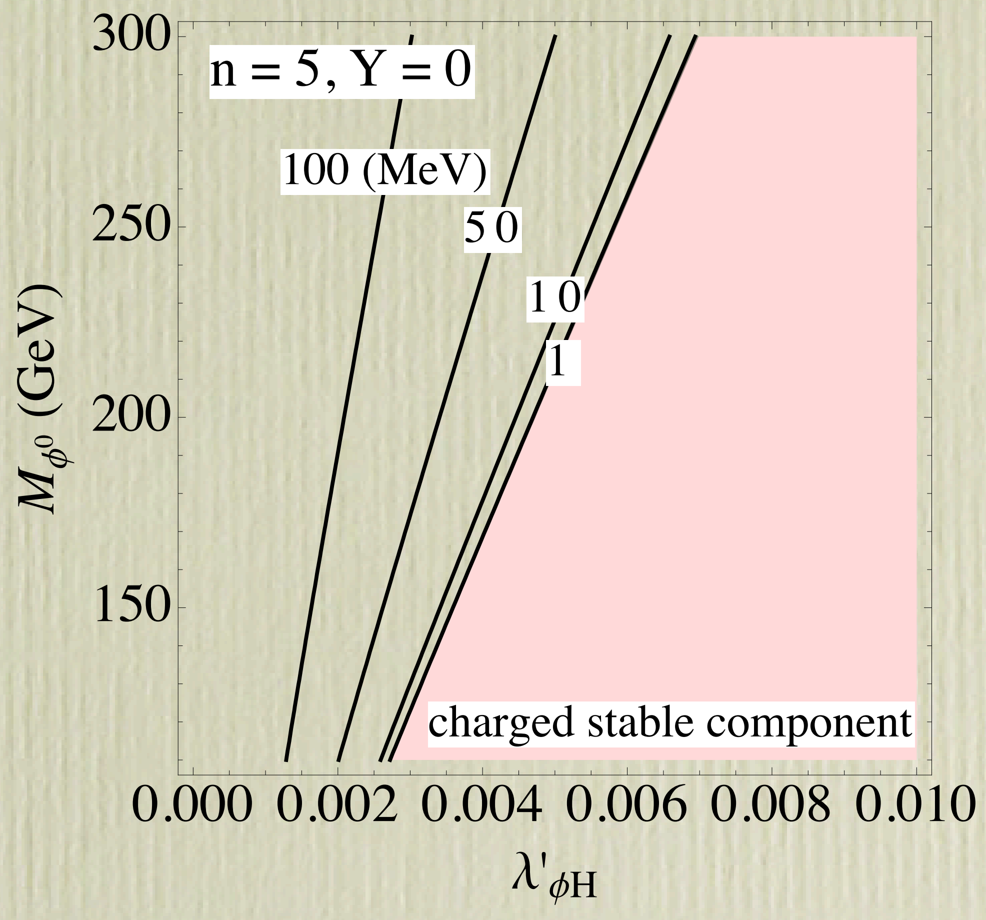
Mass splitting is determined by electroweak correction and $\lambda'_{\phi H}$

$$\mathcal{L} \supset |D_\mu \phi|^2 - m_\phi^2 \phi^\dagger \phi - \lambda_{\phi H} \phi^\dagger \phi H^\dagger H - \lambda'_{\phi H} (\phi^\dagger T_N^a \phi)(H^\dagger \tau^a H) - \lambda_4 (\phi^\dagger \phi)^2$$

$$\mathcal{L} \supset \frac{1}{2} \partial_\mu \chi \partial^\mu \chi - \frac{1}{2} m_\chi^2 \chi^2 - \lambda_{\chi H} \chi^2 H^\dagger H - \lambda_{\chi \phi} \chi^2 \phi^\dagger \phi.$$

Mass Splitting

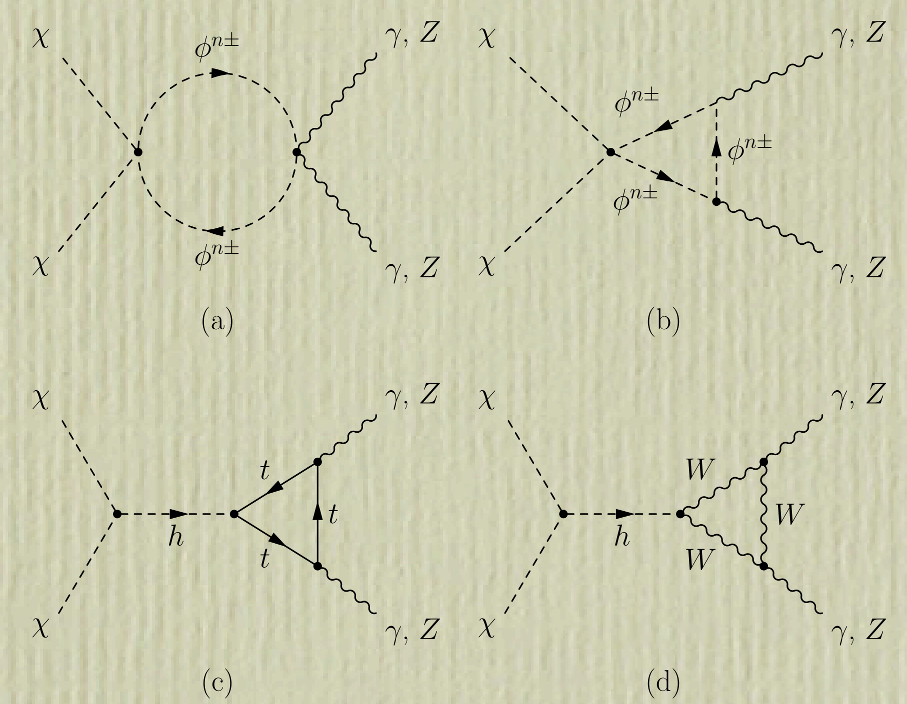


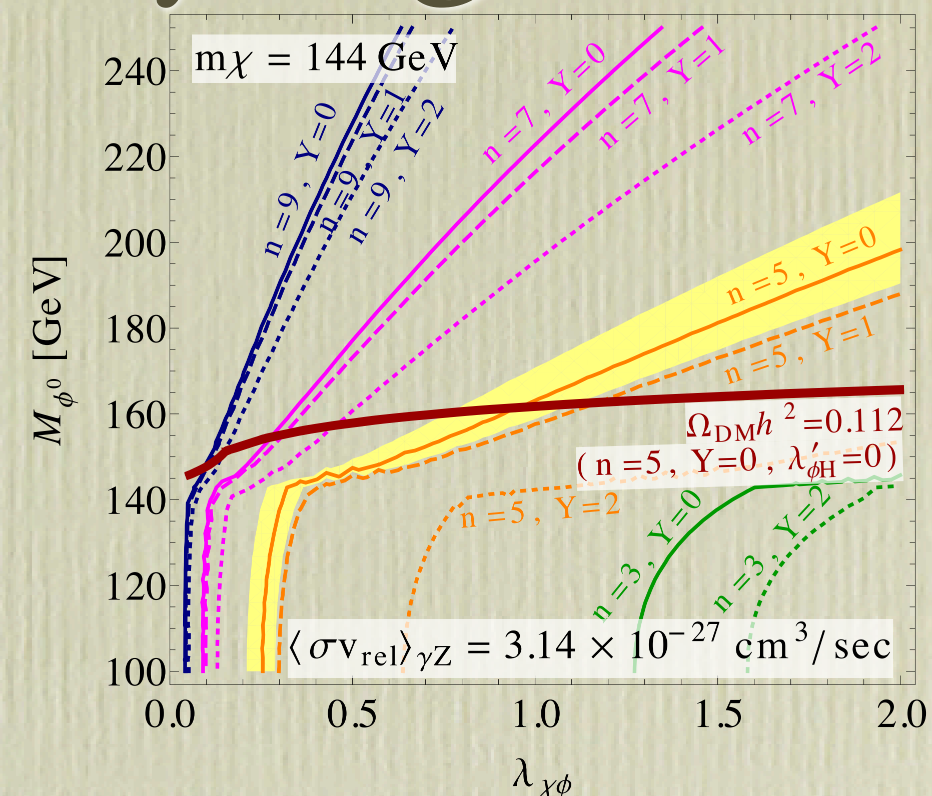


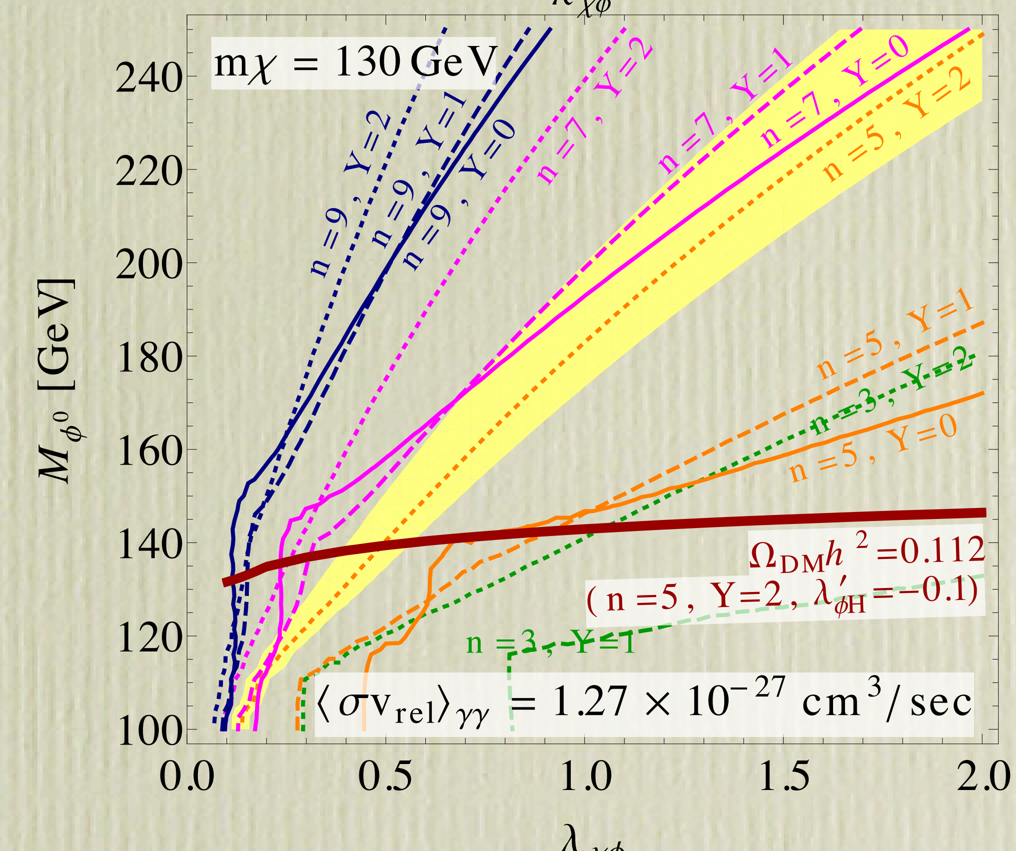
Benchmark Models

	Benchmark model 1: stable ϕ^0		Benchmark model 2: unstable ϕ^0	
Multiplet $SU(2)$ representation	N	5	N	5
Multiplet hypercharge	Y_ϕ	0	Y_ϕ	2
DM mass	M_χ	144 GeV	M_χ	130 GeV
Multiplet mass parameter	m_ϕ	199.65 GeV	m_ϕ	168.5 GeV
DM–Higgs coupling	$\lambda_{\chi H}$	0	$\lambda_{\chi H}$	0
DM–multiplet coupling	$\lambda_{\chi\phi}$	0.954	$\lambda_{\chi\phi}$	0.493
T^3_N-indep. $\phi - H$ coupling	$\lambda_{\phi H}$	-0.45	$\lambda_{\phi H}$	-0.2
T^3_N-dep. $\phi - H$ couplings	$\lambda'_{\phi H}$	0	$\lambda'_{\phi H}$	-0.1
Physical multiplet masses	$M_{\phi^{\pm\pm}}$	162.65 GeV	$M_{\phi^{++++}}$	159.2 GeV
	$M_{\phi^\pm}$	162.11 GeV	$M_{\phi^{+++}}$	154.4 GeV
	M_{ϕ^0}	161.92 GeV	$M_{\phi^{++}}$	149.4 GeV
			M_{ϕ^+}	144.2 GeV
			M_{ϕ^0}	138.9 GeV
Multiplet relic density	$\Omega_{\phi_0} h^2$	3.6×10^{-4}		

Gamma Ray Signal



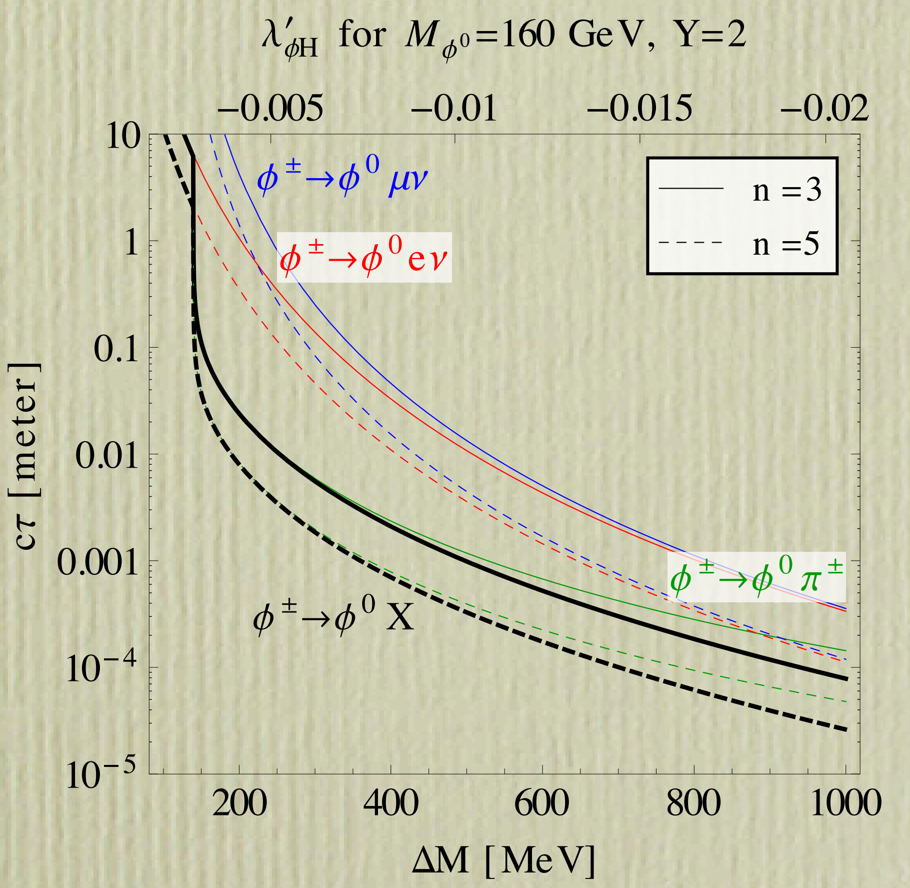




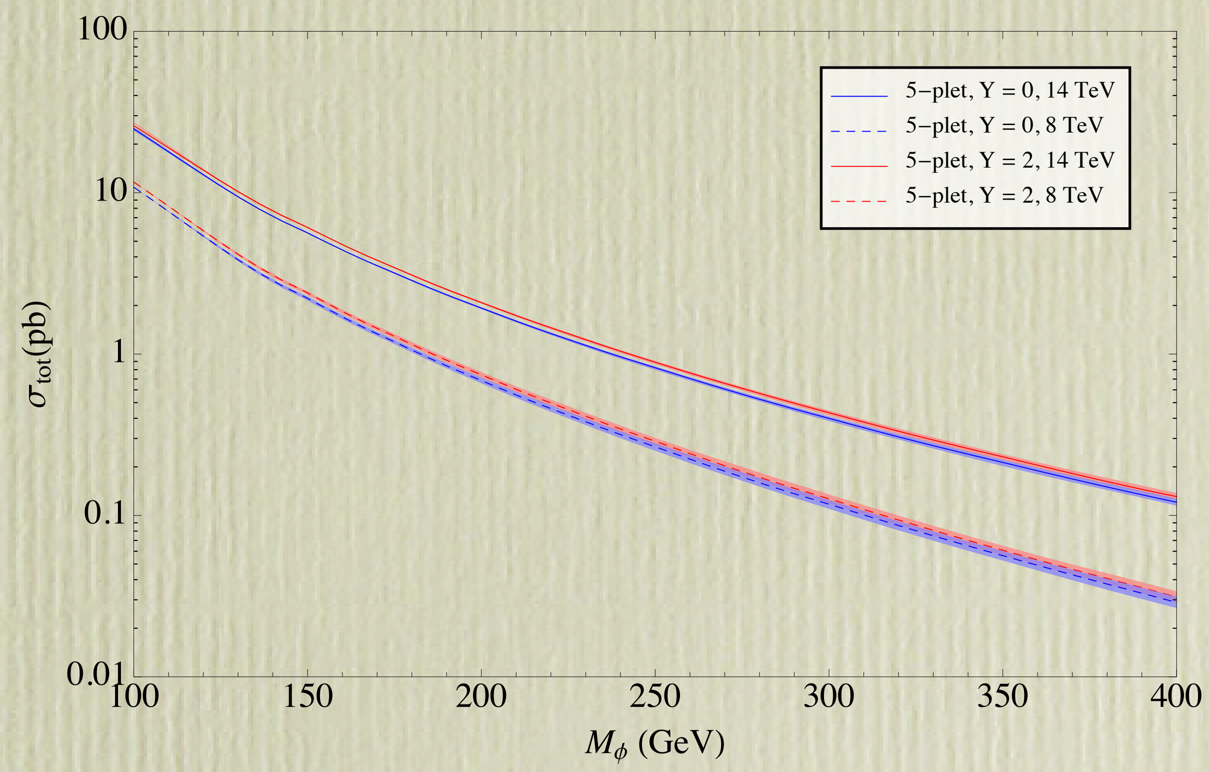
- The relic density is achieved by annihilation to forbidden channel.
- The model can give a large annihilation cross section to photons while having the correct relic density.

Charged Track at the LHC

- For a small mass splitting between the multiplets components, the charged components can have a long lifetime.



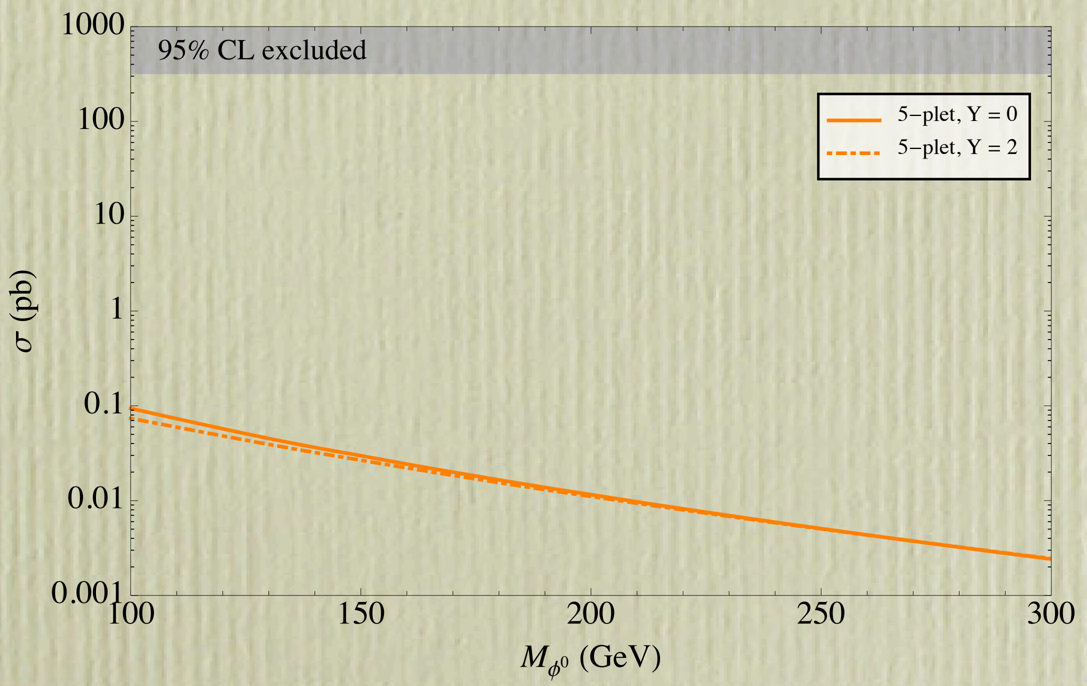
Multiplet lifetime



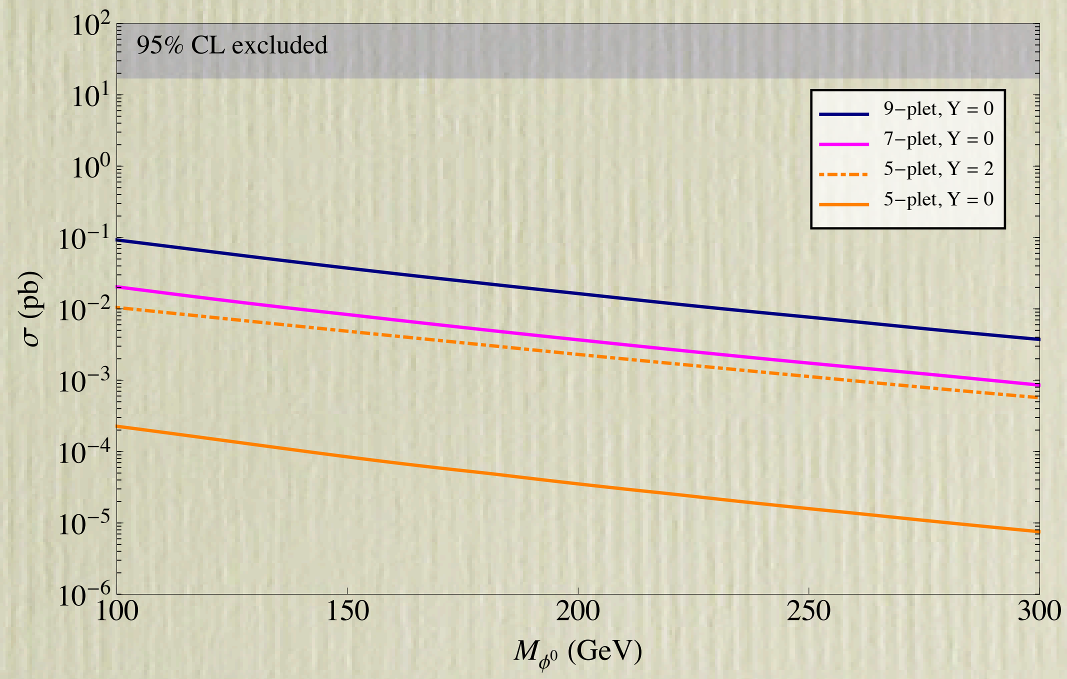
Total production cross section

Monojet and Monophoton Signature

- ϕ can be pair-produced at the LHC, and the charged components decay to neutral components with soft jets and leptons.
- Stable neutral component can not be detected, therefore monojet and monophotons can give constraints to the model.

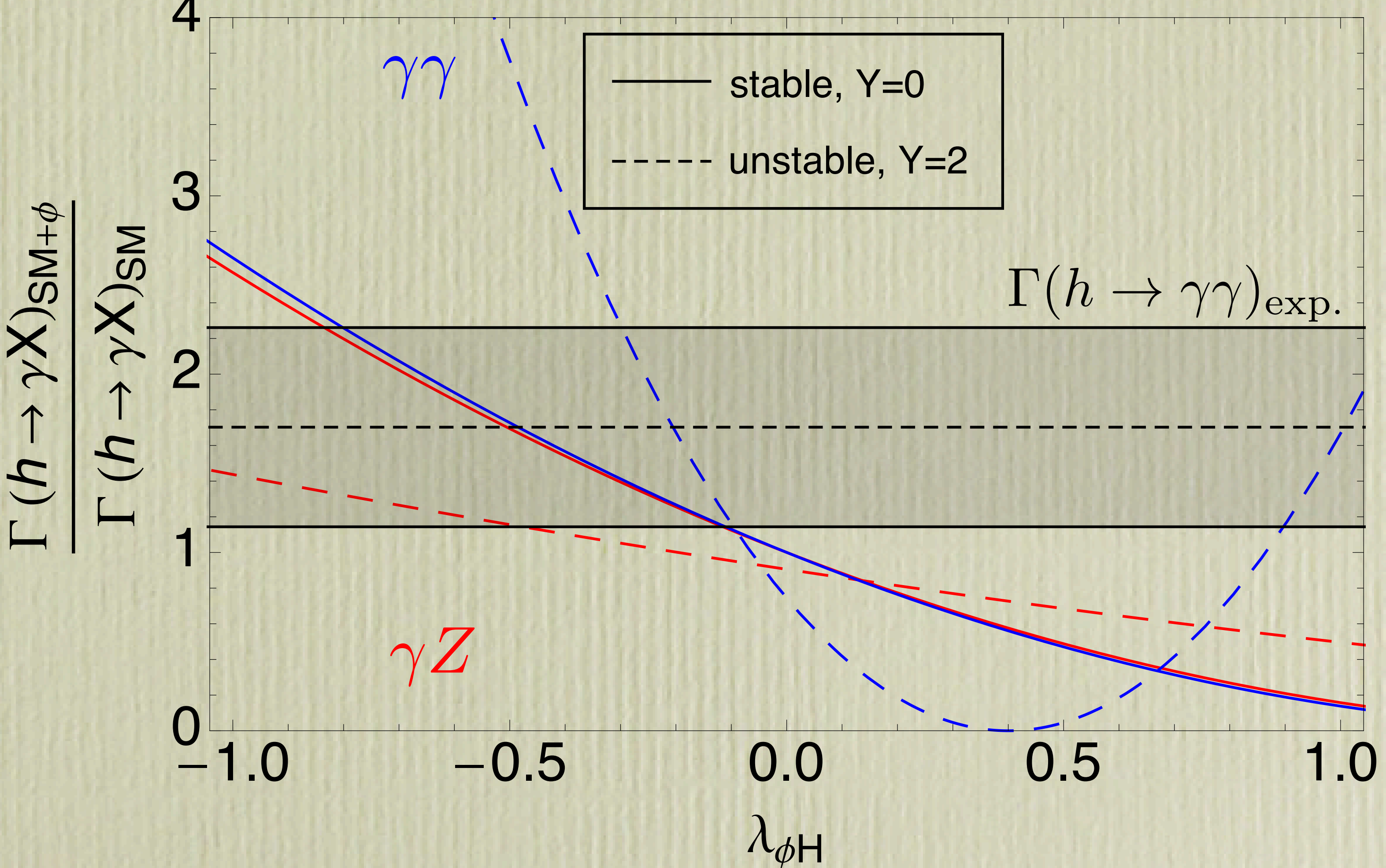


Monojet



Monophoton

h → γ γ



4
3
2
1
0
−1.0
−0.5
0.0
0.5
1.0
$\lambda_{\phi H}$
$\frac{\Gamma(h \to \gamma X)_{SM+\phi}}{\Gamma(h \to \gamma X)_{SM}}$
$\gamma\gamma$
γZ
stable, Y=0
unstable, Y=2
$\Gamma(h \to \gamma\gamma)_{\mathrm{exp.}}$

Conclusion

- We can explain the large DM annihilation to photons with parameters that are still perturbative at experimentally relevant energy scales.
- A large portion of parameter space is still allowed.
- There are some interesting LHC signatures for future searches.