

Galactic Center excess by two Higgs doublet portal scalar dark matter

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Refs : Phys. Rev. D **89** 043525 (2014)

Phys. Rev. D **90** 083523 (2014)

With: [Nobuchika Okada](#) (U. of Alabama)

in prep.

With: [Arindam Das](#) and [Nobuchika Okada](#) (U. of Alabama)

§ Galactic center (GC) gamma
ray excess

§ Galactic center (GC) gamma ray excess

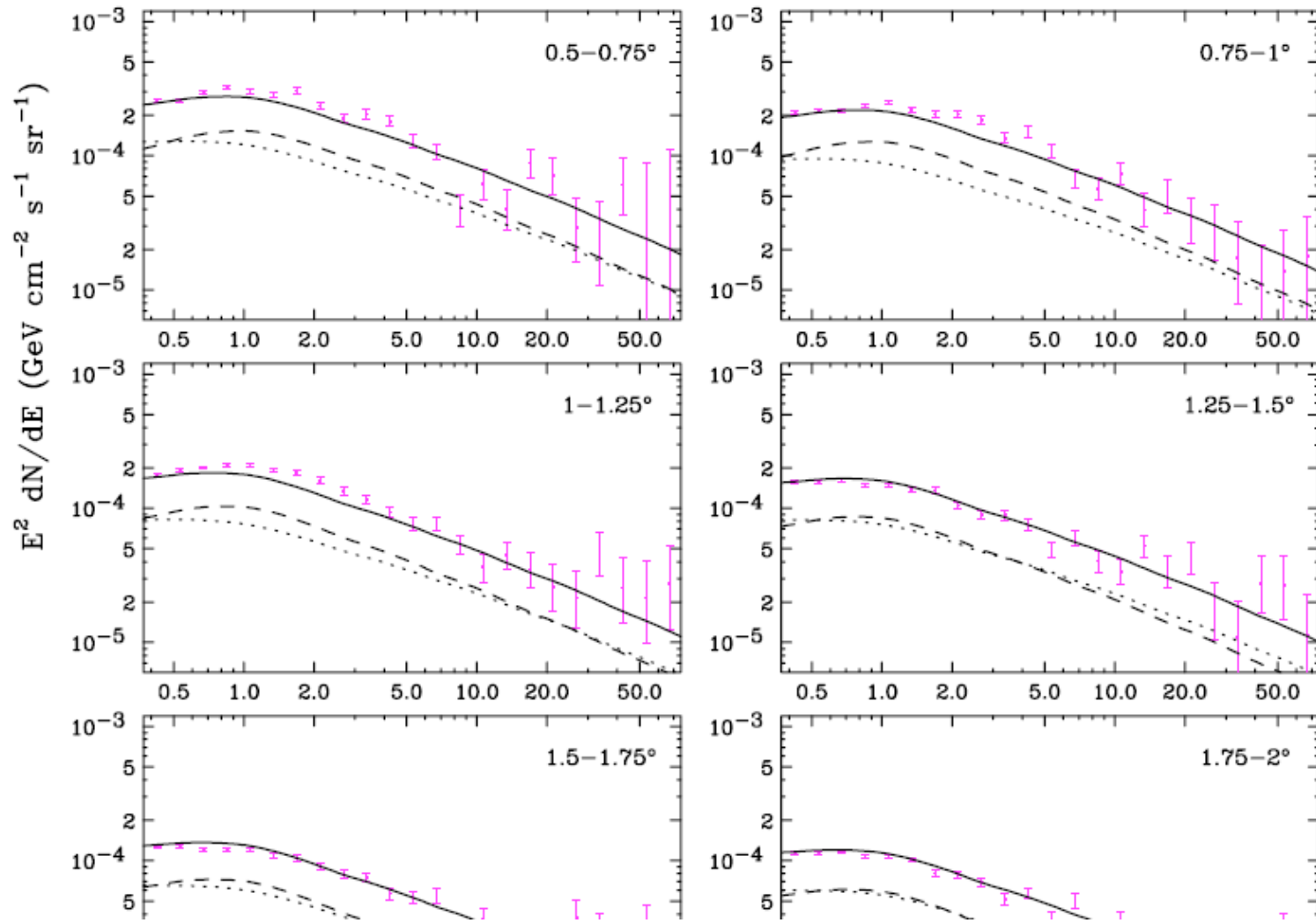
- Photons from GC [Hooper and Goodenough (2010)]

between 1.25° and 10° from the Galactic Center is well described by the processes of decaying pions produced in cosmic ray collisions with gas, and the inverse Compton scattering of cosmic ray electrons in both the disk and bulge of the Inner Galaxy, along with gamma rays from known point sources in the region. The observed spectrum and morphology of the emission within approximately 1.25° (~ 175 parsecs) of the Galactic Center, in contrast, departs from the expectations for by these

...

which peaks at energies between 1-4 GeV (in E^2 units), can be well fit by a 7-10 GeV dark matter particle annihilating primarily to tau leptons with a cross section in the range of $\langle\sigma v\rangle = 4.6 \times 10^{-27}$ to 5.3×10^{-26} cm^3/s , depending on how the dark matter distribution is normalized. We also discuss

§ Galactic center (GC) gamma ray excess



•
between pions and
electron sources
1.25°

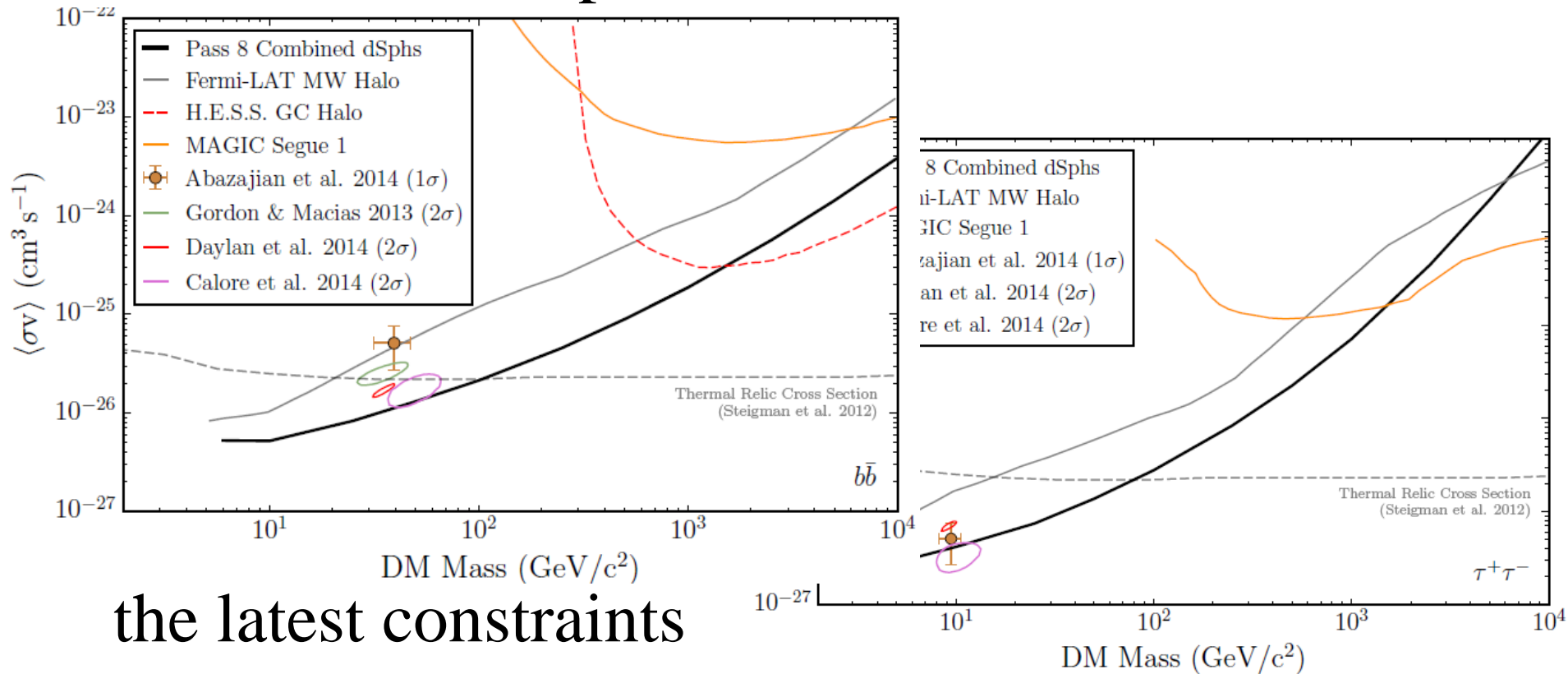
•
which particle
to 5.3 ×

decaying
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by these

k matter
× 10⁻²⁷
o discuss

§ Galactic center (GC) gamma ray excess

Dark matter interpretation



the latest constraints

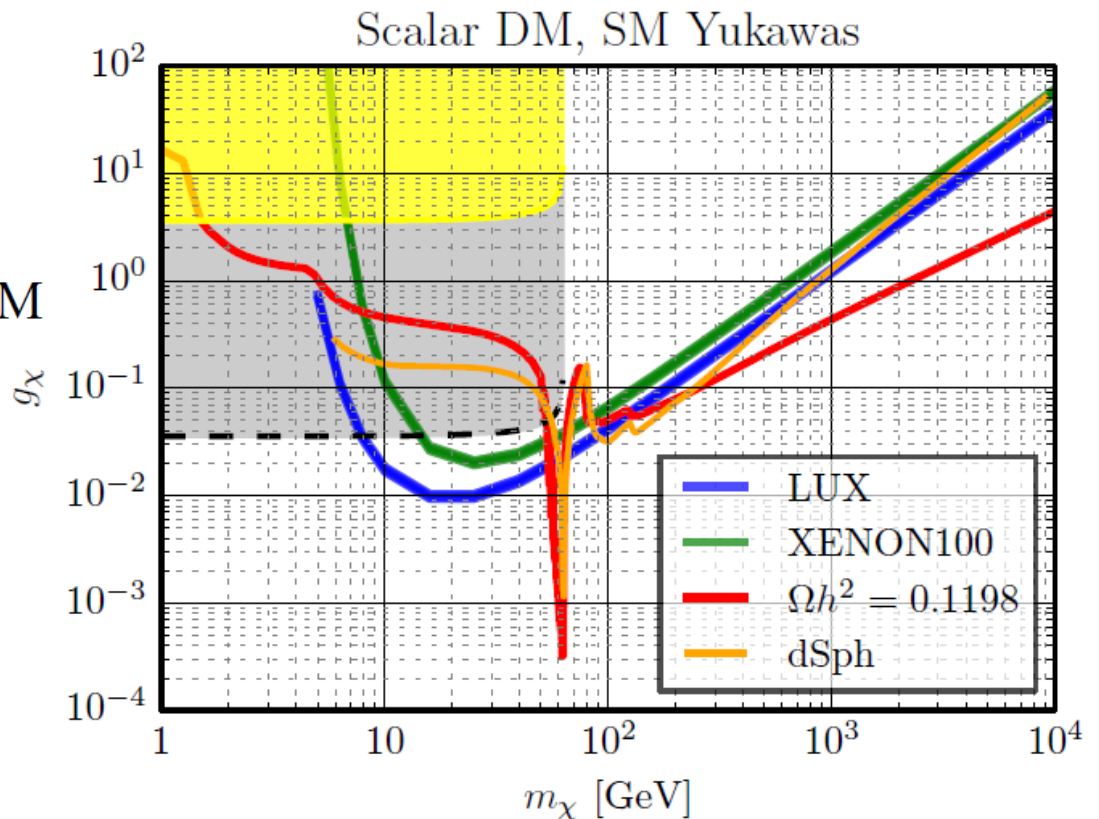
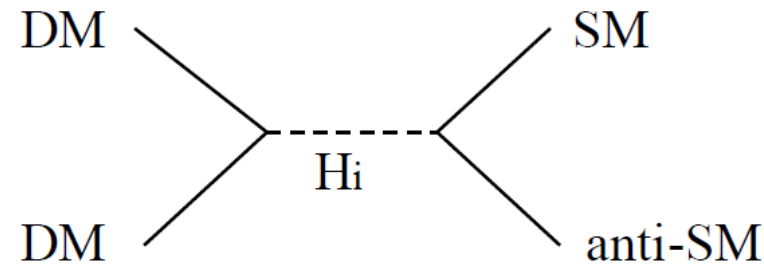
from dSph data [Fermi-LAT Coll. (1503.02641)]

§ GC excess from two Higgs
doublet portal DM

§ Higgs portal dark matter

McDonald (1994), Burgess et al, ...

$$\mathcal{L}_S = \mathcal{L}_{\text{SM}} + \frac{1}{2} (\partial\phi)^2 - \frac{M_S^2}{2} \phi^2 - \frac{c_S}{2} |H|^2 \phi^2 - \frac{d_S}{4!} \phi^4$$

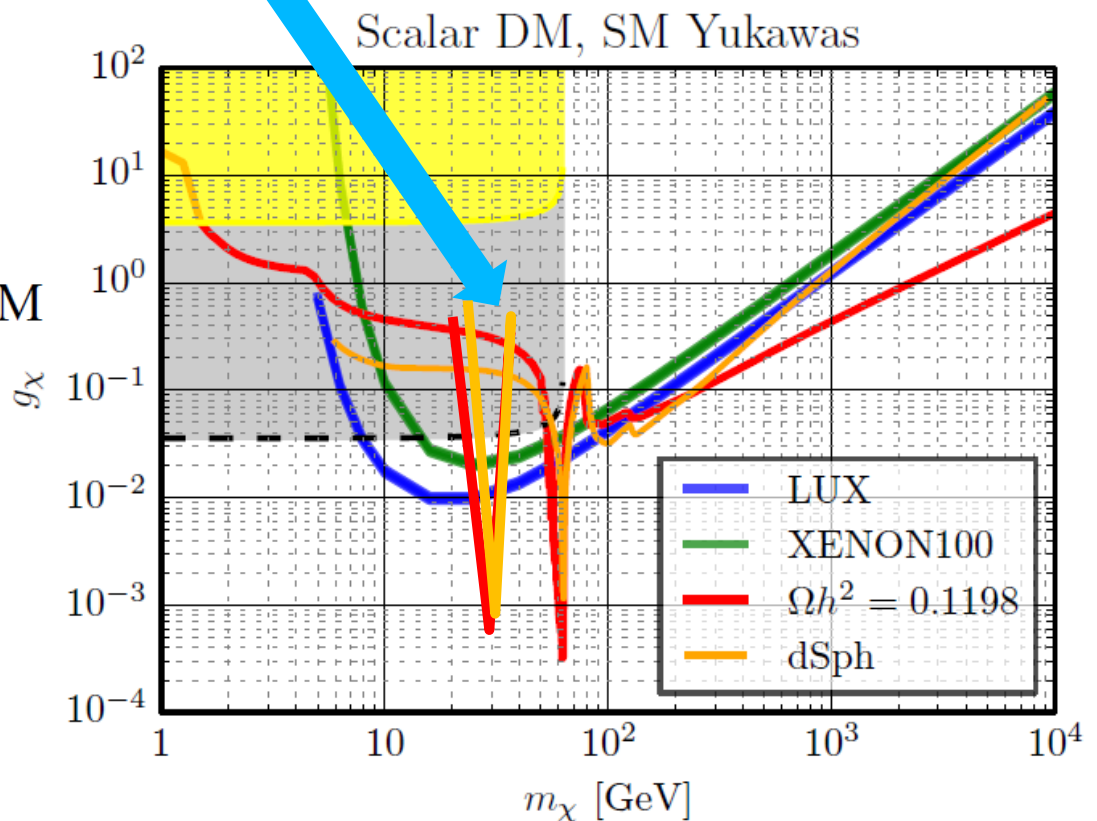
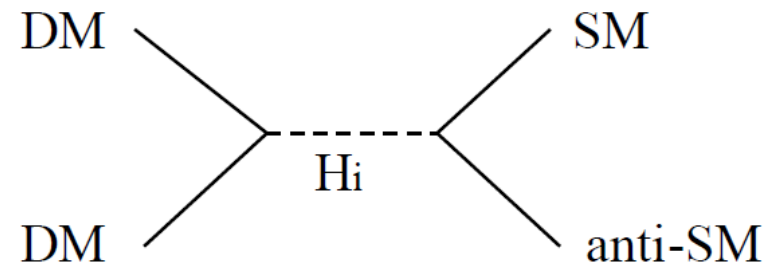


[Bishara et al 1504.04022]

§ § How to realize desired DM mass and annihilation modes

- Two Higgs doublet model

Extra Higgs bosons ($m_H \sim 2m_{DM}$) contribution



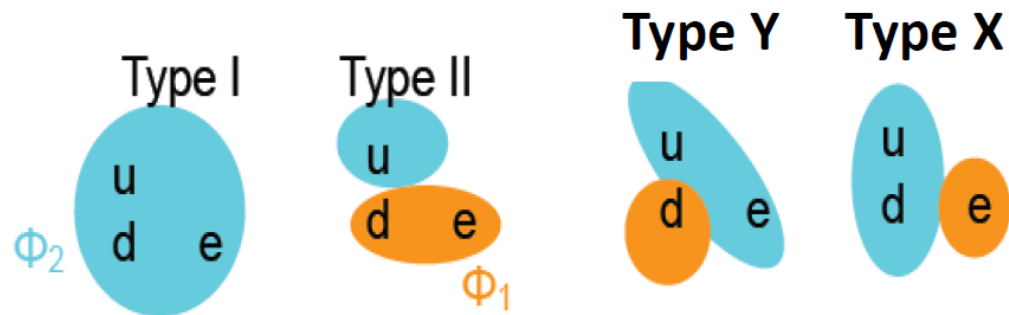
§ § How to realize desired DM mass and annihilation modes

Those DM properties are determined by **mediator**!

- **Model**

$$\begin{aligned}
 V = & -\mu_1^2|\Phi_1|^2 - \mu_2^2|\Phi_2|^2 - (\mu_{12}^2\Phi_1^\dagger\Phi_2 + \text{h.c.}) \\
 & +\lambda_1|\Phi_1|^4 + \lambda_2|\Phi_2|^4 + \lambda_3|\Phi_1|^2|\Phi_2|^2 + \lambda_4|\Phi_1^\dagger\Phi_2|^2 + \left\{ \frac{\lambda_5}{2}(\Phi_1^\dagger\Phi_2)^2 + \text{h.c.} \right\} \\
 & +\frac{1}{2}\mu_\phi^2\phi^2 + \lambda_\eta\phi^4 + (\sigma_1|\Phi_1|^2 + \sigma_2|\Phi_2|^2)\frac{\phi^2}{2}.
 \end{aligned}$$

$$\begin{pmatrix} h_1 \\ h_2 \end{pmatrix} = \begin{pmatrix} \cos \alpha & -\sin \alpha \\ \sin \alpha & \cos \alpha \end{pmatrix} \begin{pmatrix} H \\ h \end{pmatrix}$$



§ § $\tau+\tau^-$ annihilation case possible?

- ~ 10 GeV DM can kinematically annihilate into b-quark
- Favored σv is several times smaller than the canonical...
- If large coupling to τ
- If near resonance

... another Higgs boson

in THDM

Type-X

(aka. lepton specific)

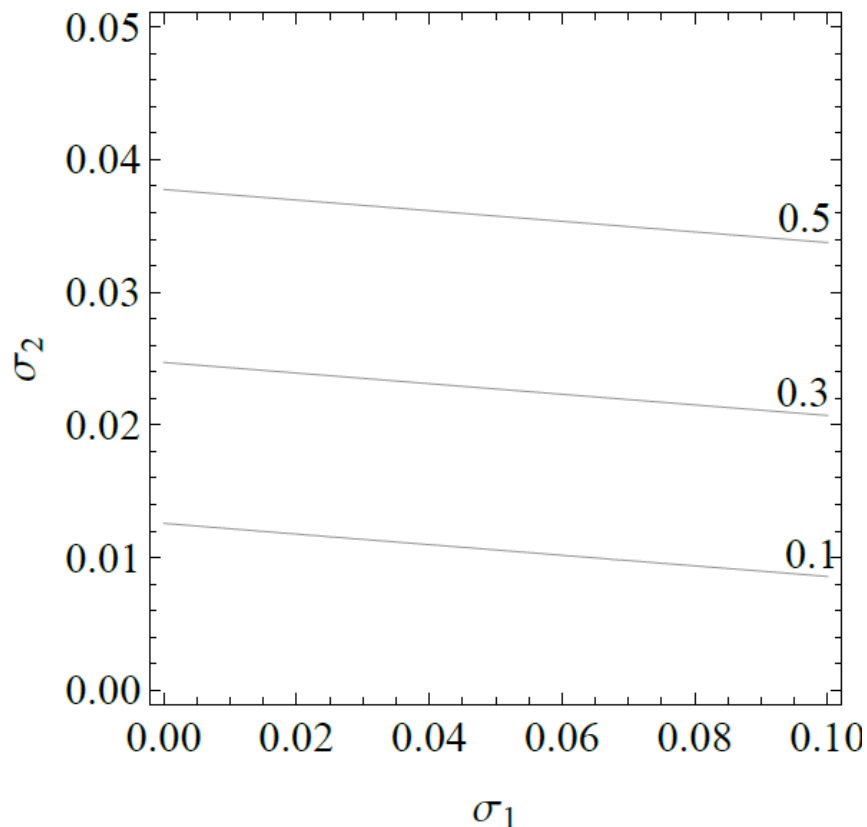
§ § $\tau^+\tau^-$ annihilating DM
: Type- X two Higgs portal DM

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§ § $\tau+\tau^-$ annihilation case possible? : Type-X two Higgs portal DM

- Invisible decay Br. of SM-like Higgs

$\text{Br}(h_{\text{SM}} \rightarrow \text{inv})$



$$\sin(\beta - \alpha) = 1$$

$$m_h = 125 \text{ GeV}$$

$$\tan \beta = 5$$

$$\Gamma_h^{(\text{inv})} = (-\sigma_1 \sin \alpha \cos \beta + \sigma_2 \cos \alpha \sin \beta)^2 \times \frac{v^2}{32\pi m_h} \sqrt{1 - \frac{4m_\phi^2}{m_h^2}},$$

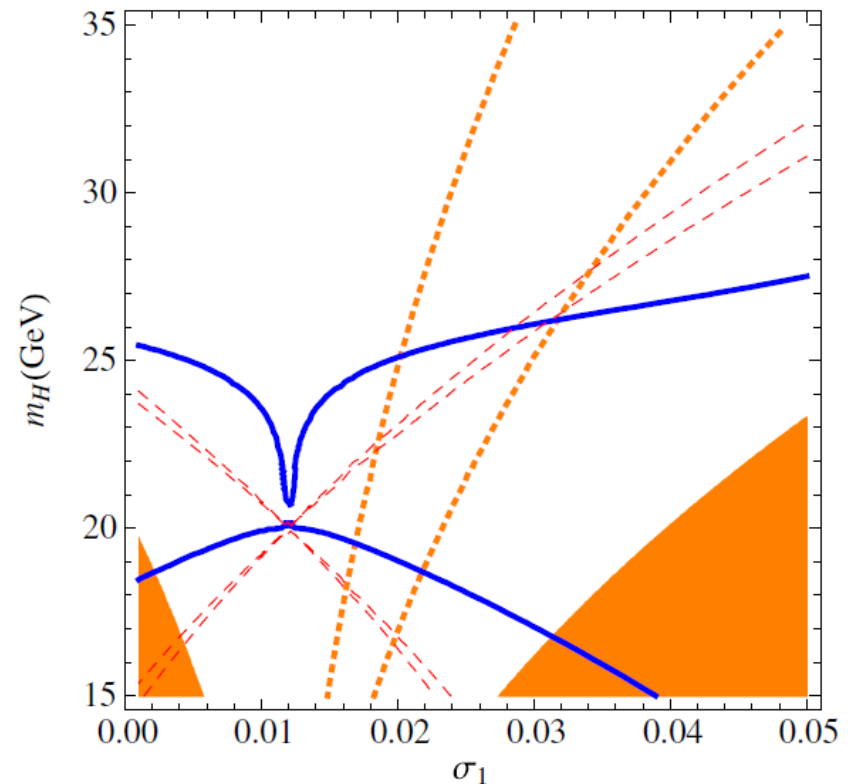
§ § $\tau+\tau-$ annihilation case possible? : Type-X two Higgs portal DM

- DM calculation for 10 GeV DM
- $(0.5\sim 0.6)\times 10^{-26} \text{ cm}^3/\text{s}$
- XENON100 and 1T

An example ; $\sigma_2 = 0.012$



$\text{Br}(h \rightarrow \text{inv}) \approx 10\%$



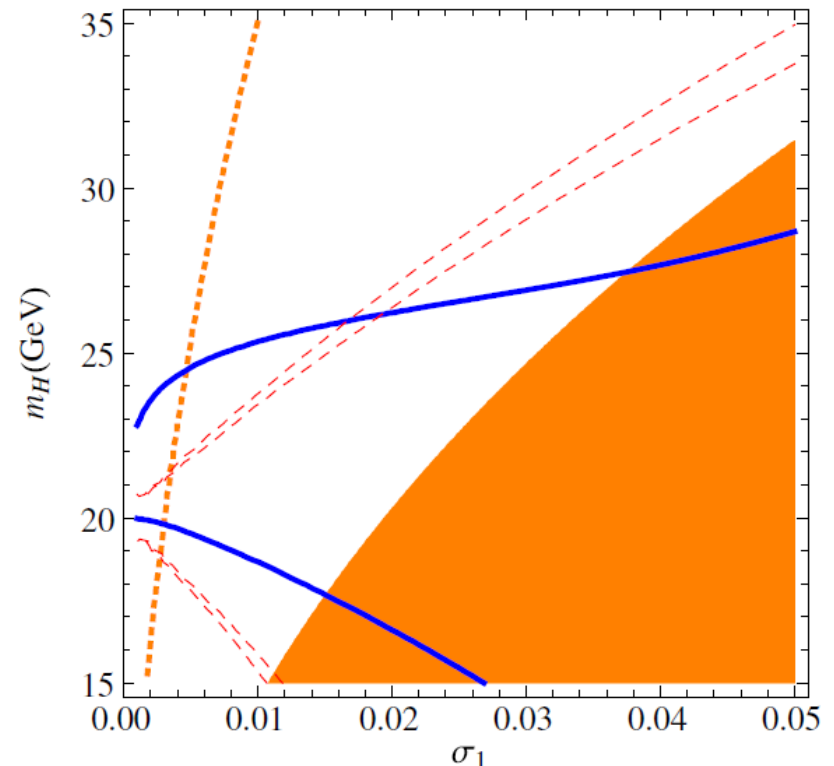
§ § $\tau+\tau-$ annihilation case possible? : Type-X two Higgs portal DM

- DM calculation for 10 GeV DM
- $(0.5\sim 0.6)\times 10^{-26} \text{ cm}^3/\text{s}$
- XENON100 and 1T

An example ; $\sigma_2 = 0.0$



$\text{Br}(h \rightarrow \text{inv}) \approx \text{negligible}$



§ § b b-bar annihilating DM : Type-II two Higgs portal DM Phys. Rev. D **90** 083523 (2014)

PHYSICAL REVIEW D **90**, 083523 (2014)

Galactic Center gamma ray excess from two Higgs doublet portal dark matter

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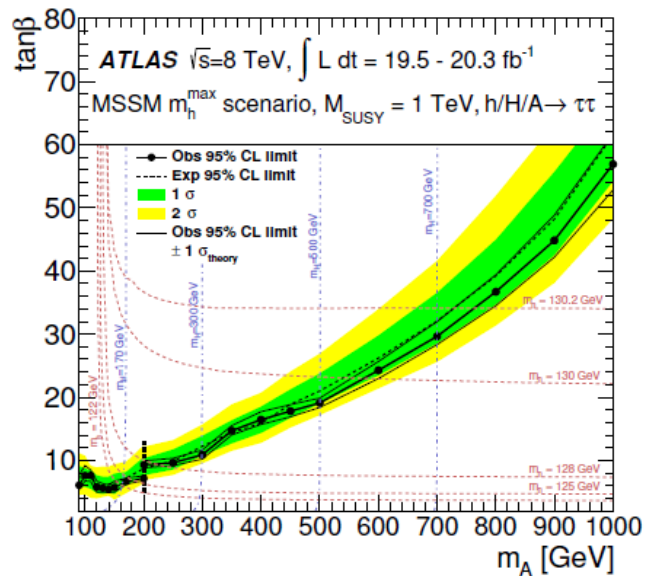
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(Received 19 August 2014; published 21 October 2014)

We consider a simple extension of the type-II two-Higgs-doublet model by introducing a real scalar as a candidate for dark matter in the present Universe. The main annihilation mode of the dark matter particle

§ § $b\bar{b}$ annihilating DM : Type-II two Higgs portal DM: Sequel

- ‘‘ $H \rightarrow \tau\tau$ constraint is stringent’’



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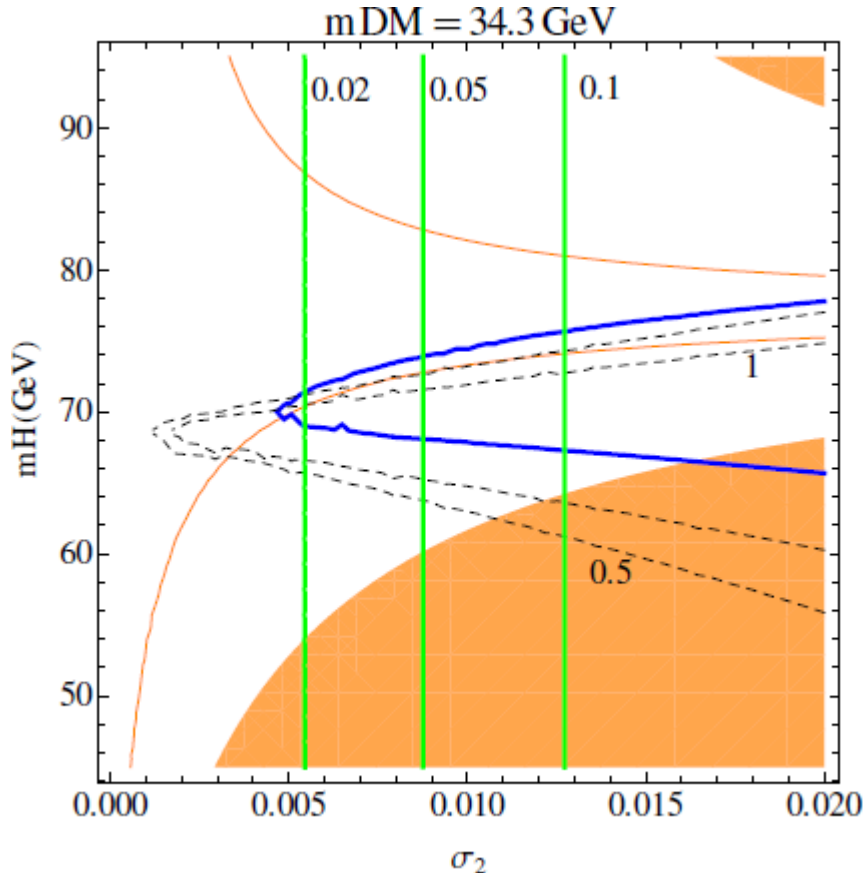
PUBLISHED: November 12, 2014

Search for neutral Higgs bosons of the minimal supersymmetric standard model in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

§ § $b\bar{b}$ annihilating DM
: Type-Y two Higgs portal DM
in prep.

§ § b b-bar annihilating DM : Type-Y two Higgs portal DM

- DM and SM Higgs constraints and prospects



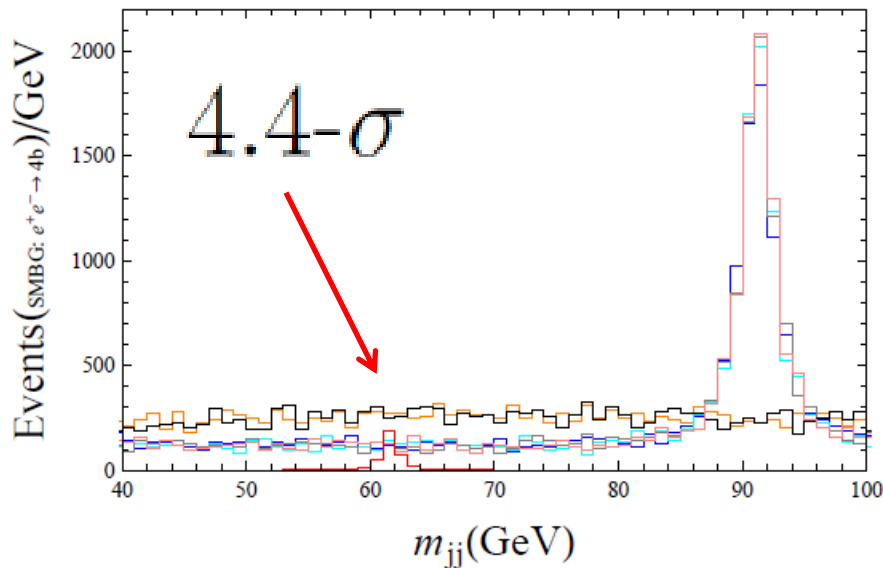
LUX and XENON1T
 Ωh^2

indirect in $10^{-26} \text{ cm}^3/\text{s}$

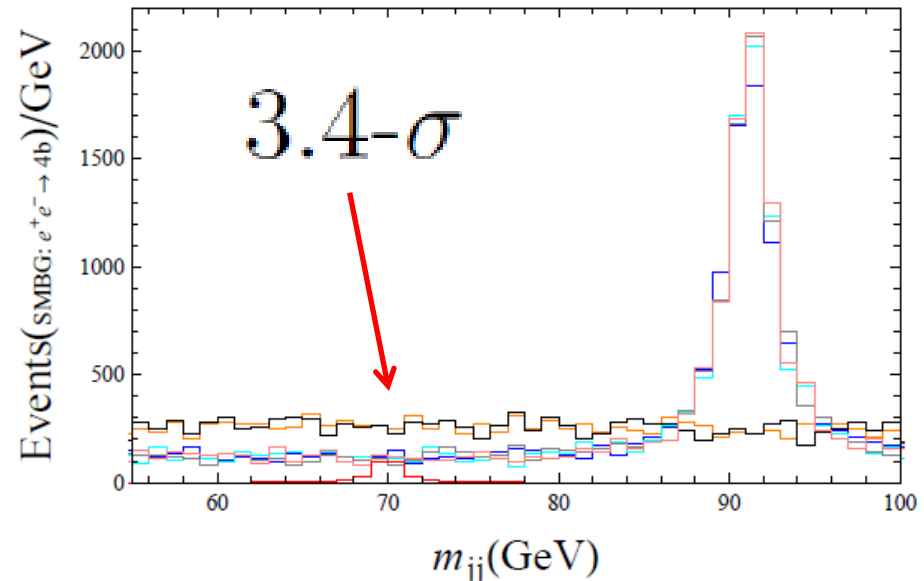
SM Higgs invisible

§ § b b-bar annihilating DM : Type-Y two Higgs portal DM

- Extra Higgs boson H discovery prospects @ ILC
- Event count for $\tan\beta=20$
- $\sqrt{s} = 250$ GeV, $\mathcal{L} = 500/\text{fb}$




$m_H \cong 61.6$ GeV



70 GeV

§ Summary

- Extra component in gamma ray flux from GC may be explained by Higgs portal scalar dark matter.
- Specific particle models have been proposed
 1. Type-X THDM + 10 GeV DM ($\tau\tau$)
 2. Type-II THDM + (30~40) GeV DM (bb)
 $H \rightarrow \tau\tau$ constraint
 3. Type-Y THDM + (30~40) GeV DM (bb)