Vector dark matter and Fermi LAT gamma ray line

Osamu Seto
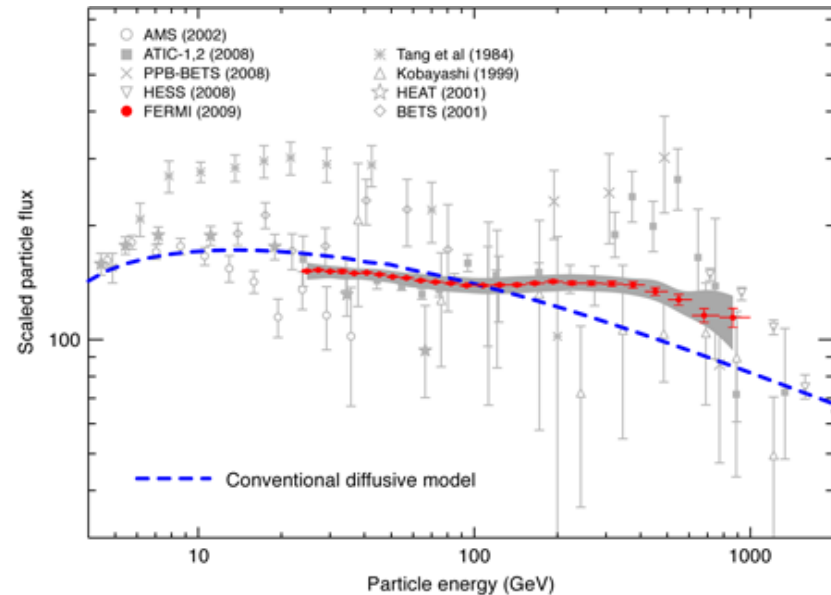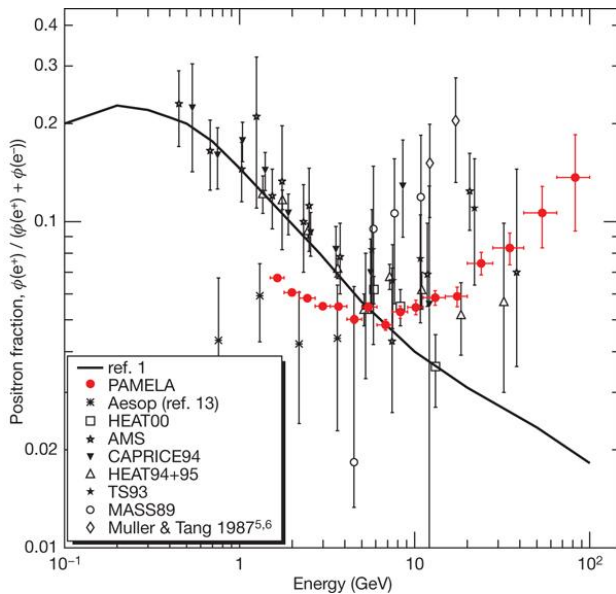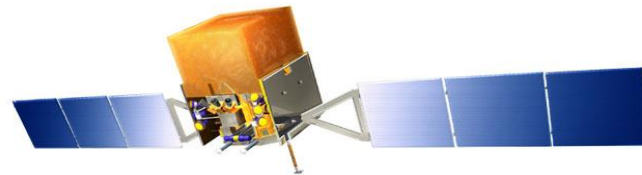
(Hokkai-Gakuen Univ.)

§ Data from dark matter searches
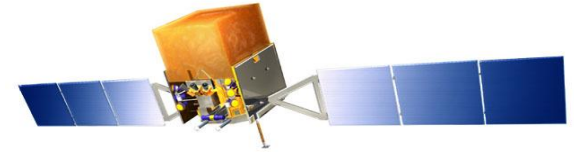
- suggestive anomalies???

§ Data from dark matter searches
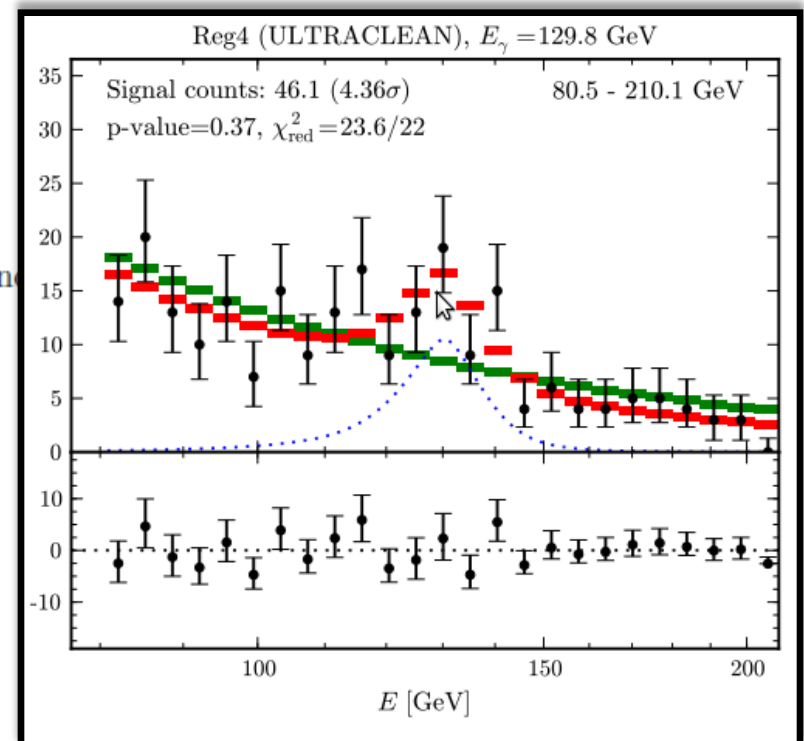
- one more???

A Tentative Gamma-Ray Line from Dark Matter Annihilation at the Fermi Large Area Telescope

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Reg4 (ULTRACLEAN), $E_\gamma = 129.8$ GeV

Signal counts: 46.1 (4.36σ)   80.5 - 210.1 GeV
p-value=0.37, $\chi^2_{\rm red}=23.6/22$

E [GeV]

§§ Where did photons come from?

- <u>Dark matter annihilation</u>

- Astrophysical, e.g. pulsar wind [Aharonian et al 2012]
- Instrumental [Whiteson 2012, …]
- Earth limb [Hektor et al 2012]
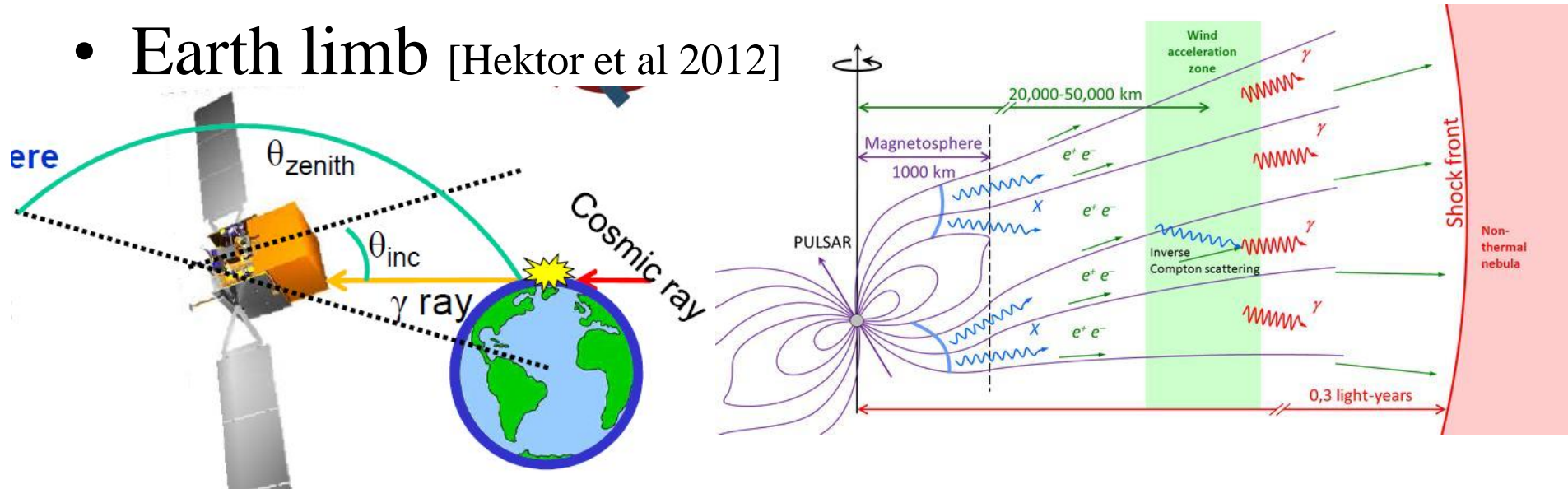
§§ $\mathcal{O}(0.1)$ Br problem
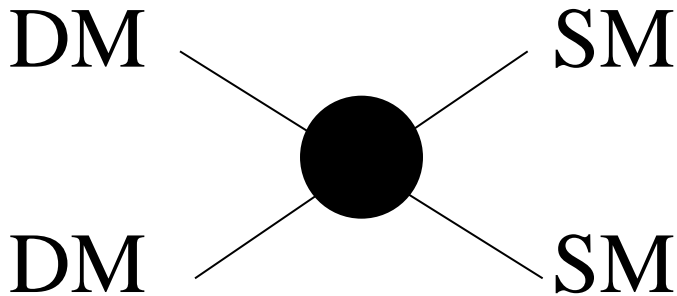
- Weniger's claim

$$\langle \sigma v \rangle_{\chi\chi \to \gamma\gamma} = (1.27 \pm 0.32^{+0.18}_{-0.28}) \times 10^{-27} \text{ cm}^3 \text{ s}^{-1}$$

looks too large

$$\langle \sigma v \rangle_{\text{thermal}} \simeq 3 \times 10^{-26} \text{ cm}^3 \text{ s}^{-1}$$

DM   SM

DM   SM

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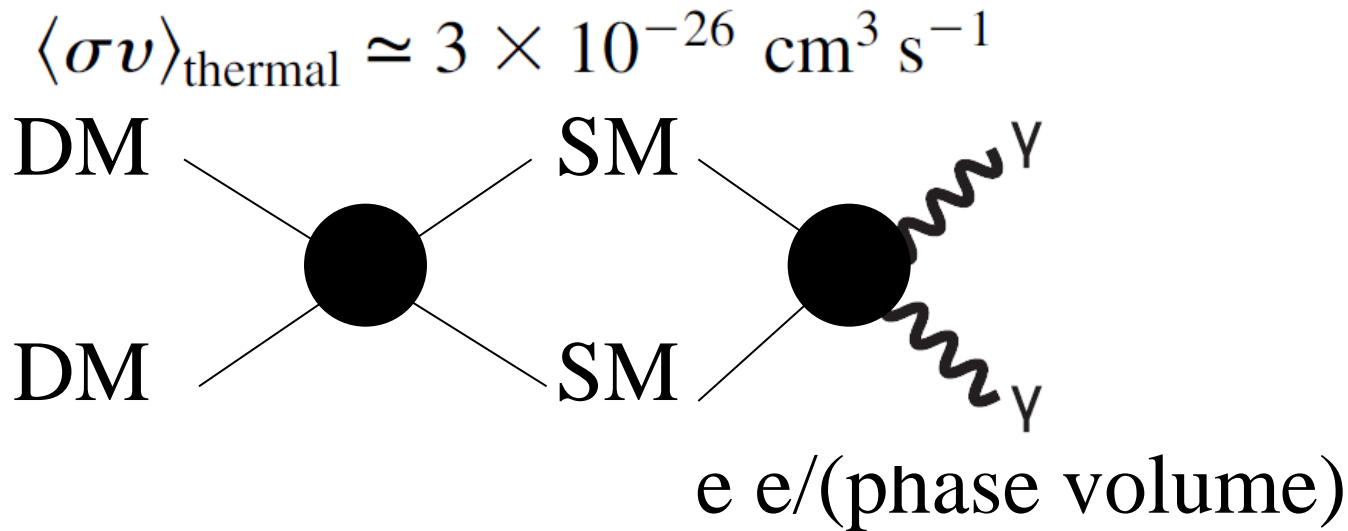
DM   SM   γ

DM   SM   γ

e e/(phase volume)

§ Extra U(1) gauge boson DM

- Matter content

- $U(1)_X$ gauge field
- Complex scalar field S_1 to break $U(1)_X$

- Charged singlet scalar S_2

§§ Extra U(1) gauge boson DM

- Lagrangian

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + |D_\mu S_1|^2 + |D_\mu S_2|^2 - V(\Phi, S_1, S_2) + f_{ij}L_i C \cdot L_j S_2^+$$

- Scalar potential

$$V(\Phi, S_1, S_2) = \mu_1^2|\Phi|^2 + \mu_2^2|S_1|^2 + \mu_3^2|S_2|^2 + \frac{1}{2}\lambda_1|\Phi|^4 + \frac{1}{2}\lambda_2|S_1|^4 + \frac{1}{2}\lambda_3|S_2|^4$$
$$+ \lambda_4|\Phi|^2|S_1|^2 + \lambda_5|\Phi|^2|S_2|^2 + \lambda_6|S_1|^2|S_2|^2.$$

- Model is symmetric under the Z2 parity

$$S_1 \to S_1^* \text{ and } X_\mu \to -X_\mu \qquad \text{DM stability}$$

§ § At the vacuum

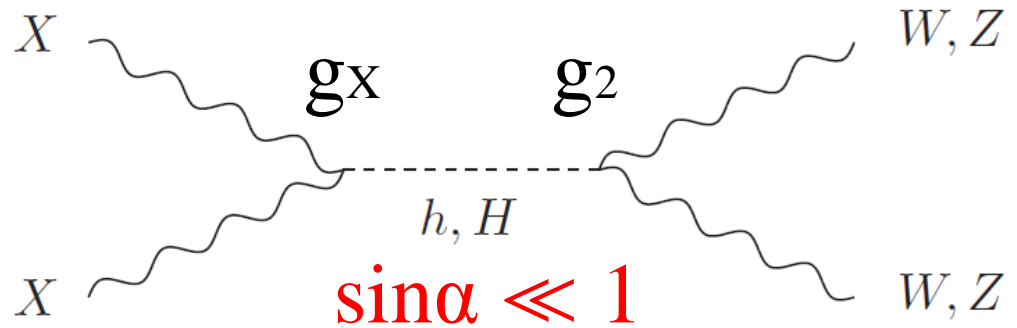- *X* gets the mass

$$M_X^2 = g_X^2 v_S^2$$

- Higgs bosons

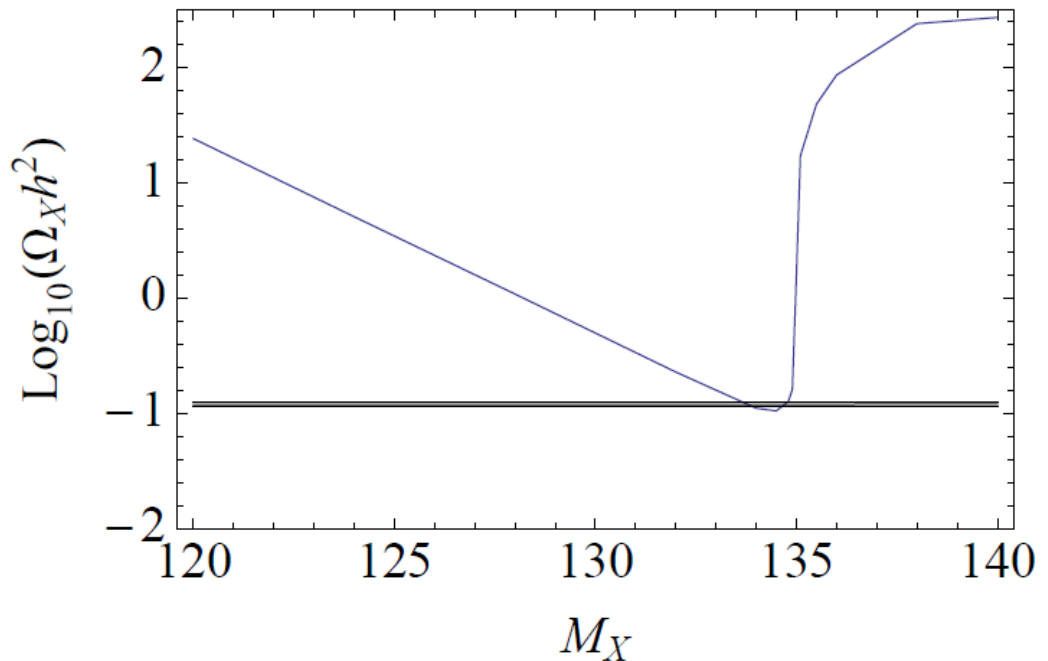$$h = \cos\alpha\,\phi - \sin\alpha\,\phi_S, \qquad H = \sin\alpha\,\phi + \cos\alpha\,\phi_S$$

$$\tan 2\alpha = \frac{2\lambda_4 v v_S}{\lambda_1 v^2 - \lambda_2 v_S^2}$$
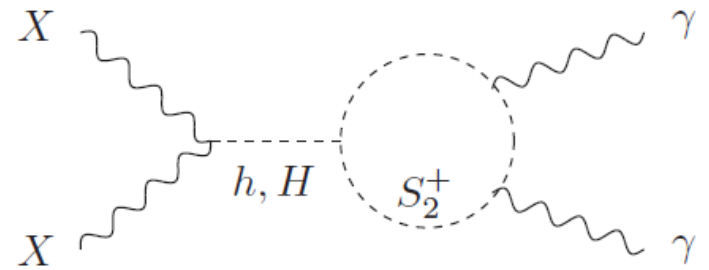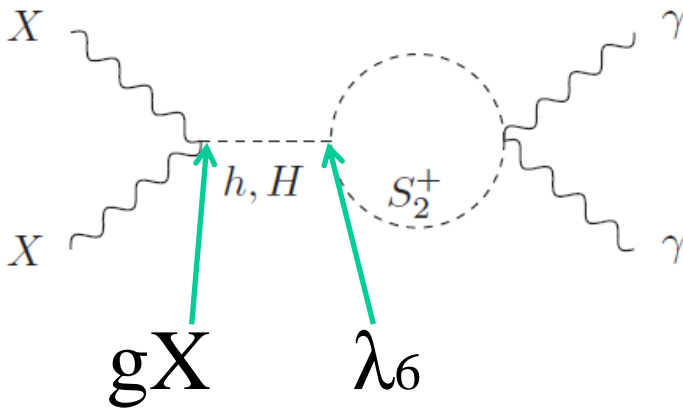
§§ Thermal relic density

- Annihilation

X $\quad$ g_X $\quad$ g_2 $\quad$ W, Z

h, H

X $\quad$ sinα ≪ 1 $\quad$ W, Z

- Relic density
  with small α

§§ Annihilation into γ

- Annihilation into 2 γ

gX   λ6

No sinα suppression

§§ Annihilation into γ

- Annihilation into 2 γ

M_X (Red: $\gamma\gamma$, Blue: WW, Green: ZZ final states)
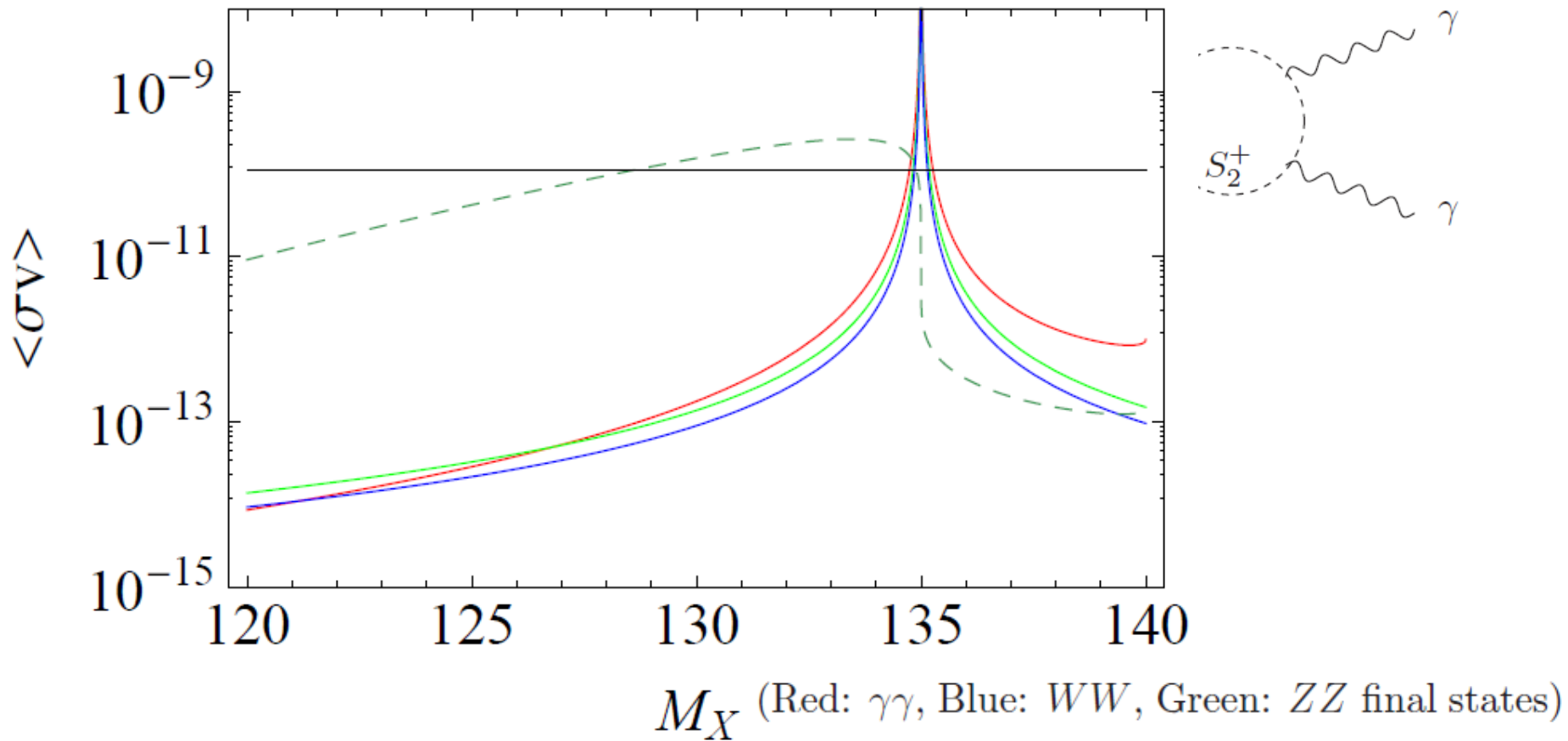
§ Summary

- We have constructed models where dark matter candidate pair-annihilate into photons.

- Vector DM: Small α _relatively_ suppresses annihilation into _WW(ZZ)_ modes and enhances $\gamma\gamma$ mode in _H_ exchange process.