NICPB KBFI

CONNECTING SCIENCES

A TeV scale messenger (e.g. 750 GeV) of Dark Matter

Andi Hektor
(NICPB, Tallinn, Estonia)
[in collaboration with L. Marzola, M. Raidal, S. Di Chiara, K. Kannike]

CERN, TeVPA
Sept 16, 2016

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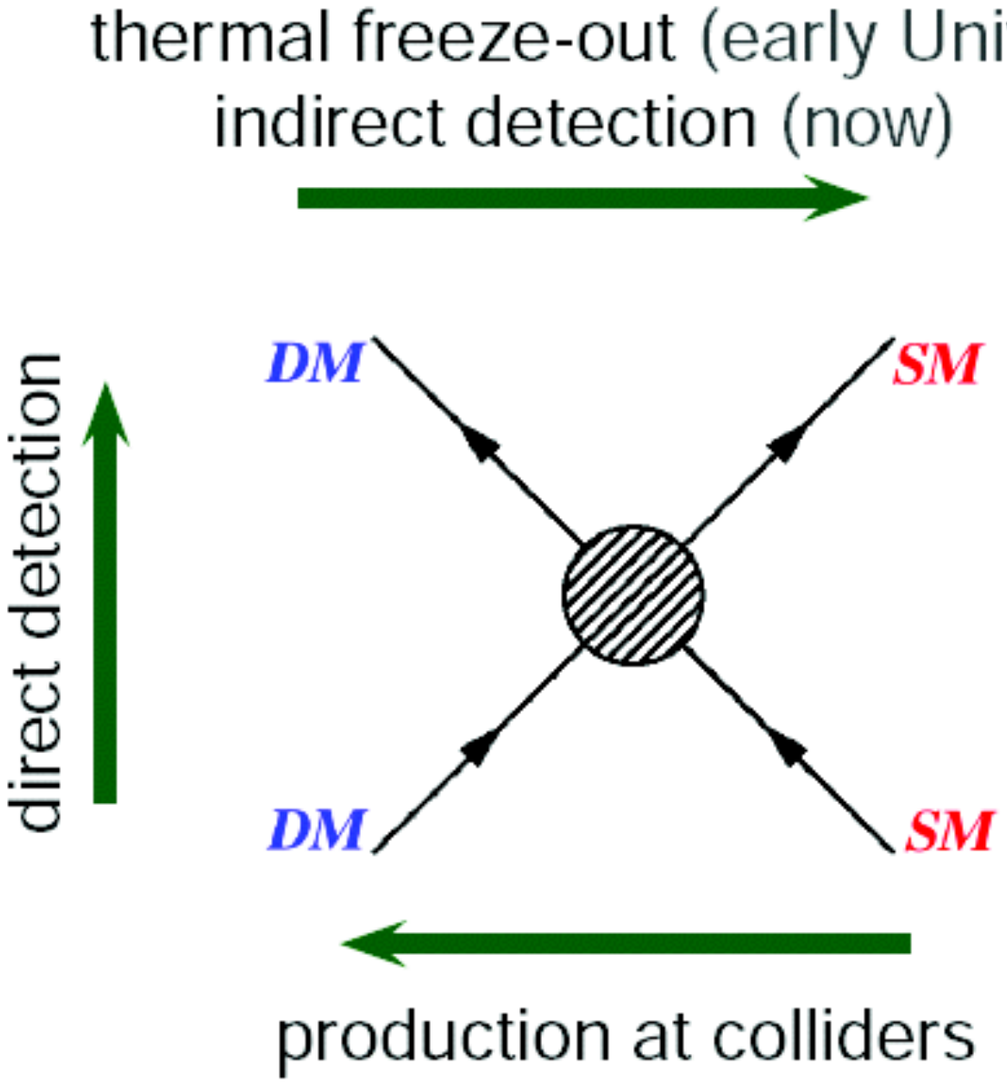
- From the effective WIMP to the simplified WIMP
- Two ways to escape from Direct Detection
  (i) 'Coy DM'
  (ii) 'Resonance Portal'
- **'Coy DM'**
  - Gamma-ray line signal from Coy DM
  - A pseudoscalar case of TeV-scale mediator
- **'Resonance portal'**
  - Life in the resonance zone is interesting — velocity dependent annihilation signal!

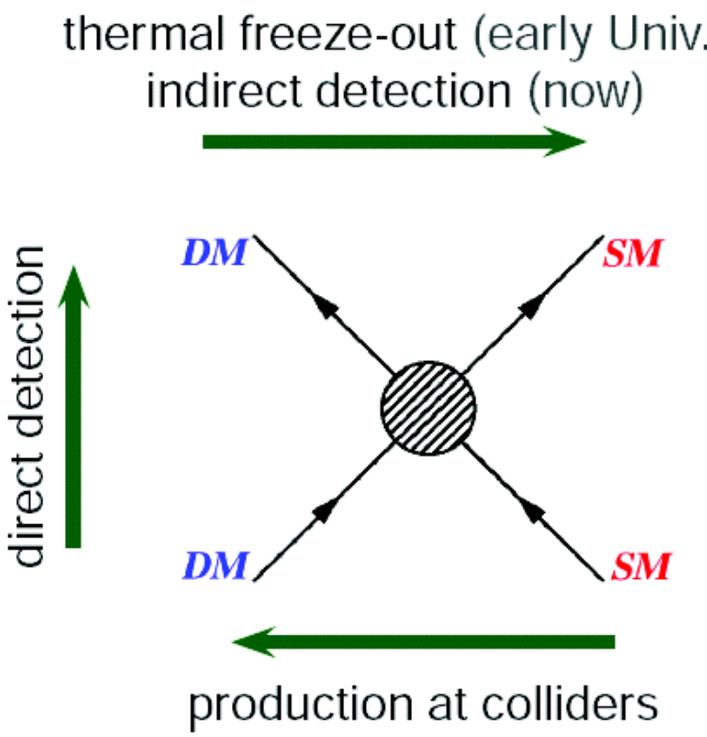
Based on:
1403.3401, 1507.05096, 1602.00004, 1603.07263
& two appearing in some next weeks

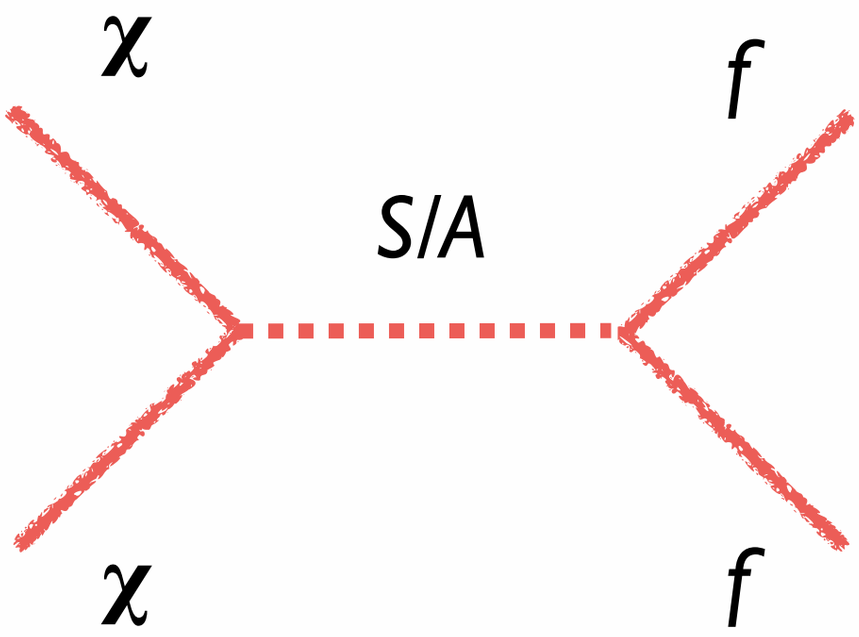
Effective WIMP



$$\mathscr{L}_{\rm EFT} = \frac{1}{M_*^2}\,(\bar{q}q)\,(\bar{\chi}\chi)$$

From the effective to the simplified DM



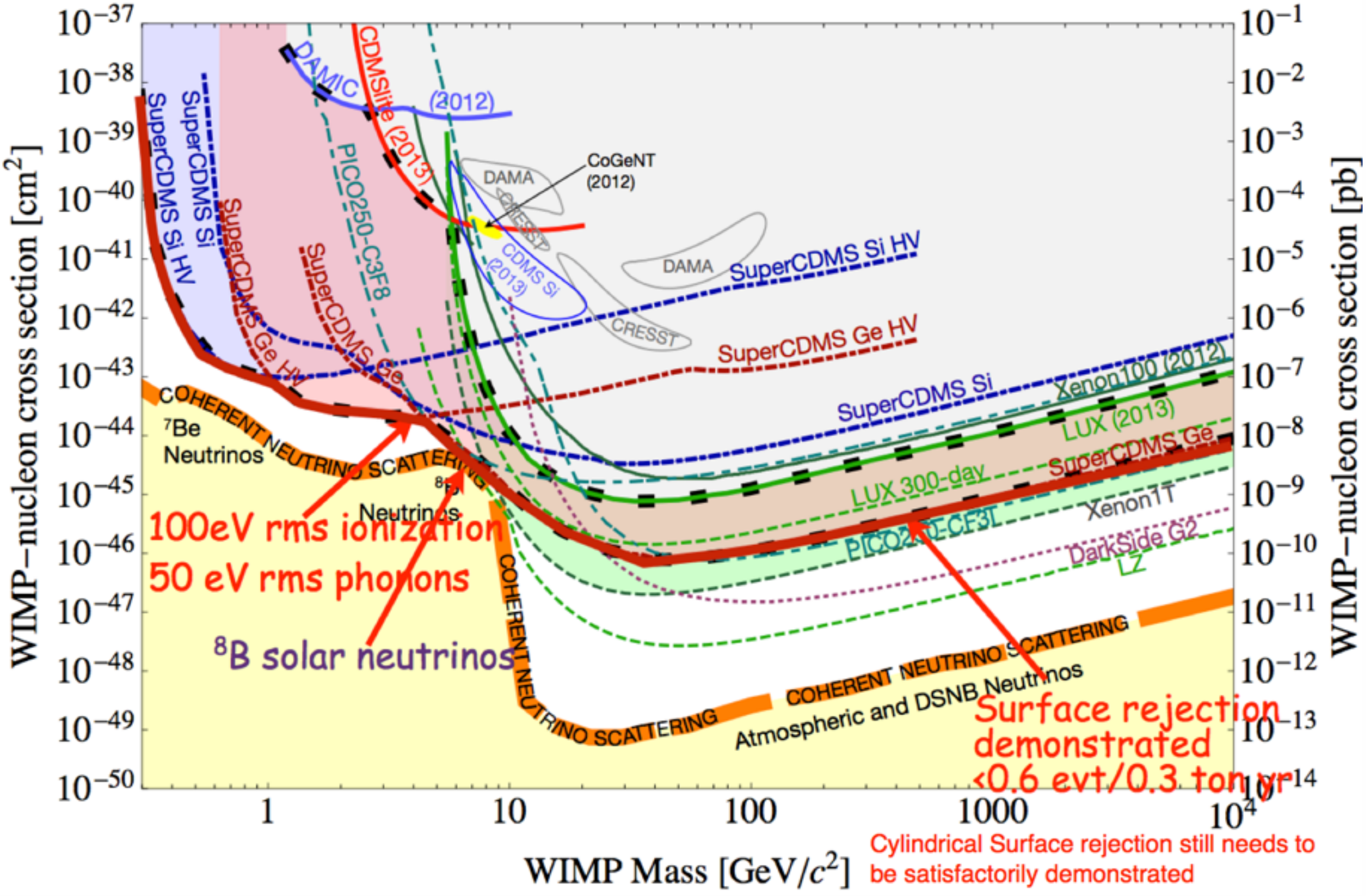


$$\mathscr{L}_{\mathrm{EFT}} = \frac{1}{M_*^2}(\bar{q}q)(\bar{\chi}\chi)$$

$$\mathscr{L}_{0_S s\frac{1}{2}} = \frac{1}{2}(\partial_\mu S)^2 - \frac{1}{2}m_S^2 S^2 + \bar{\chi}(i\partial\!\!\!/ - m_\chi)\chi - g_\chi S\bar{\chi}\chi - g_{\mathrm{SM}} S\sum_f \frac{y_f}{\sqrt{2}}\bar{f}f$$

$$\mathscr{L}_{0_A s\frac{1}{2}} = \frac{1}{2}(\partial_\mu A)^2 - \frac{1}{2}m_A^2 A^2 + \bar{\chi}(i\partial\!\!\!/ - m_\chi)\chi - ig_\chi A\bar{\chi}\gamma^5\chi - ig_{\mathrm{SM}} A\sum_f \frac{y_f}{\sqrt{2}}\bar{f}\gamma^5 f$$

The model killer, Direct Detection

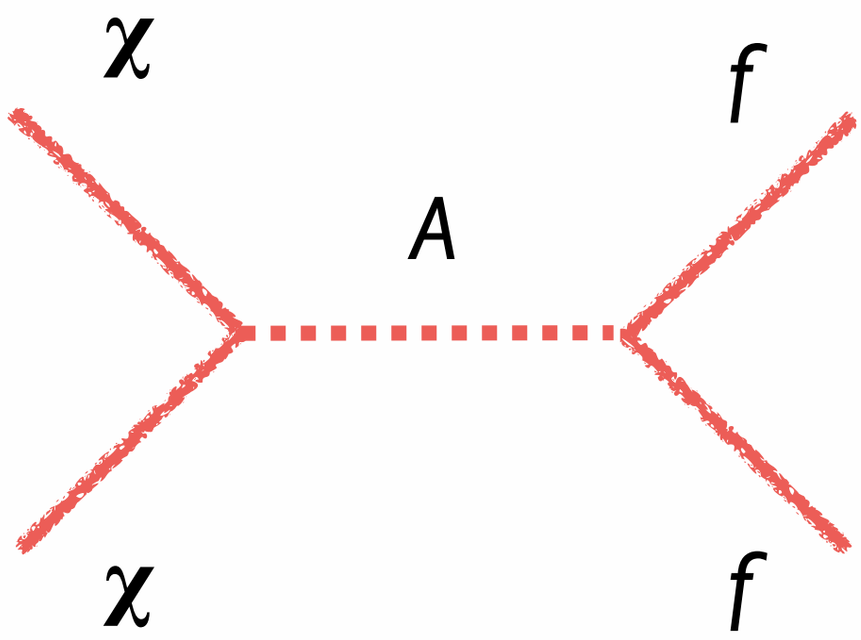


Escaping from the killer Direct Detection:

A. ‘Coy DM’

B. ‘Resonance Portal’

Coy DM



$$\sigma_{SI} \propto v^2$$

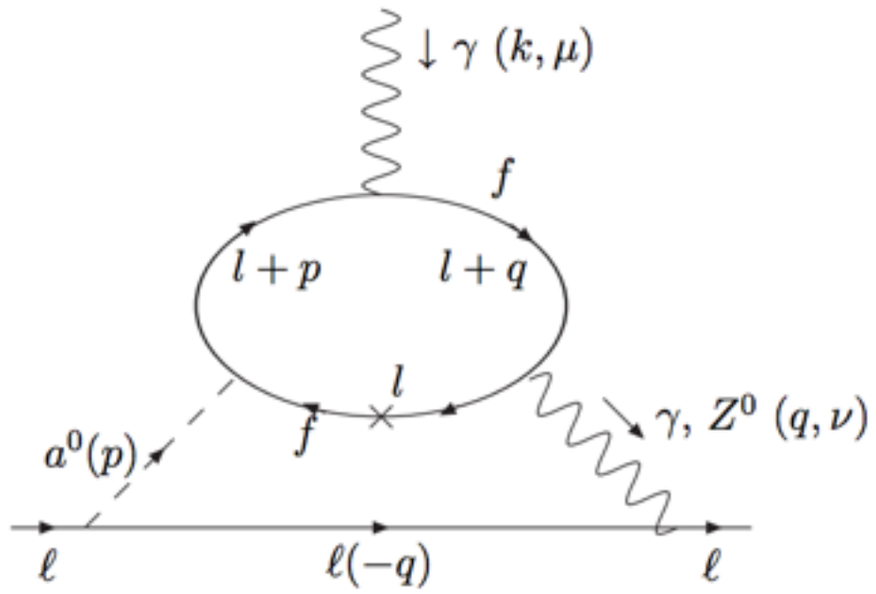
$$\mathscr{L}_{0_A s\frac{1}{2}} = \frac{1}{2}(\partial_\mu A)^2 - \frac{1}{2}m_A^2 A^2 + \bar{\chi}(i\partial\!\!\!/ - m_\chi)\chi - ig_\chi A\bar{\chi}\gamma^5\chi - ig_{SM}A\sum_f \frac{y_f}{\sqrt{2}}\bar{f}\gamma^5 f$$

Bohm et al, 1401.6458; Berlin et al, 1404.0022; Dolan et al, 1412.5174

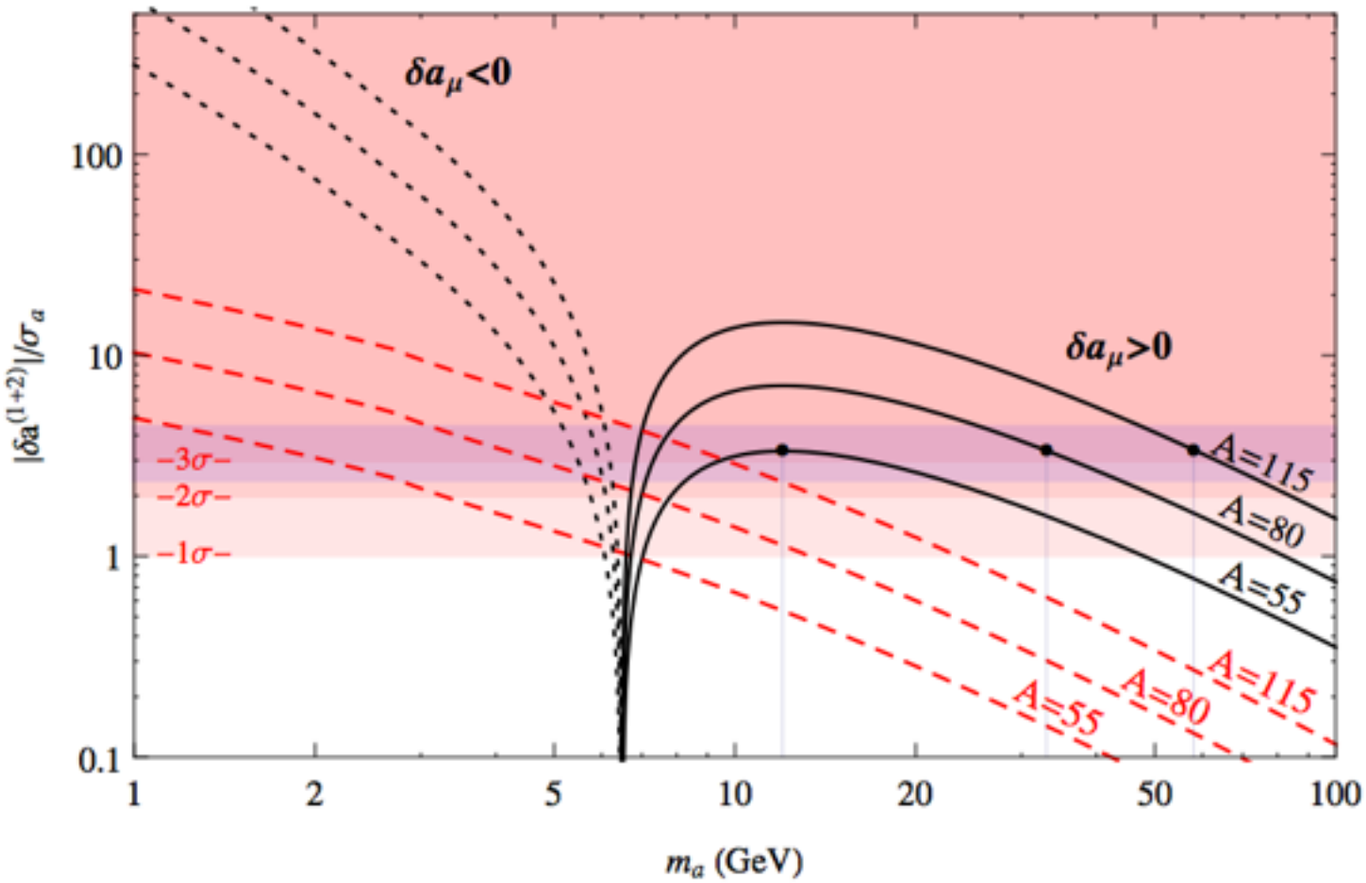
Coy DM has surprisingly many features…

- Self-interacting DM, DAMA/LIBRA etc
- Muon g-2
- γ-ray line

Coy DM & muon g-2



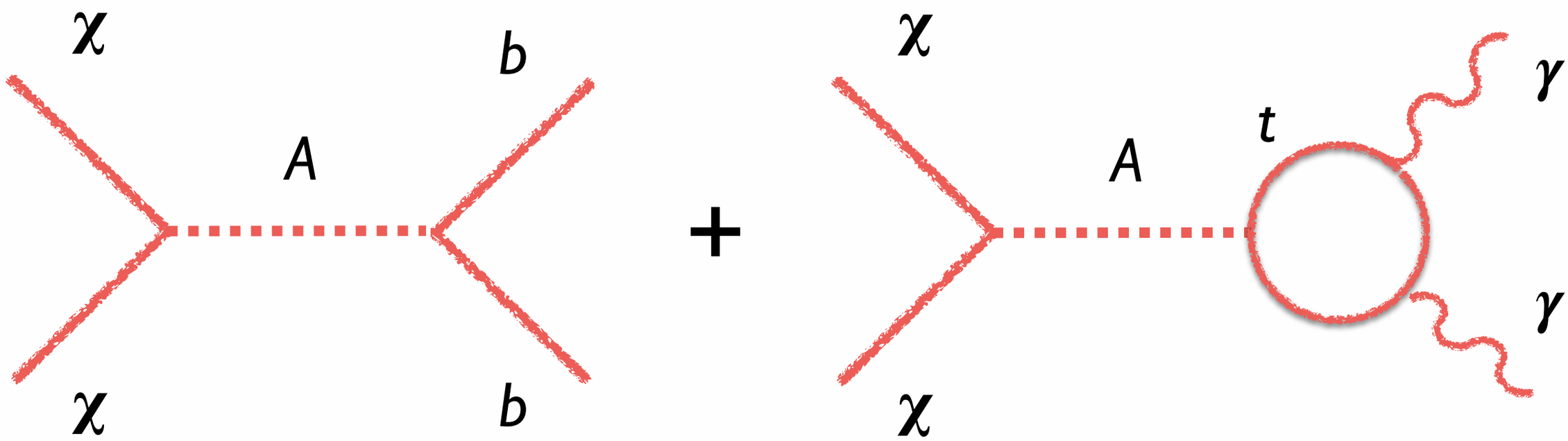
Chang et al, hep-ph/0009292



'Leptophilic' Coy DM,
Hektor & Marzola, 1403.3401

Coy DM & γ-ray line

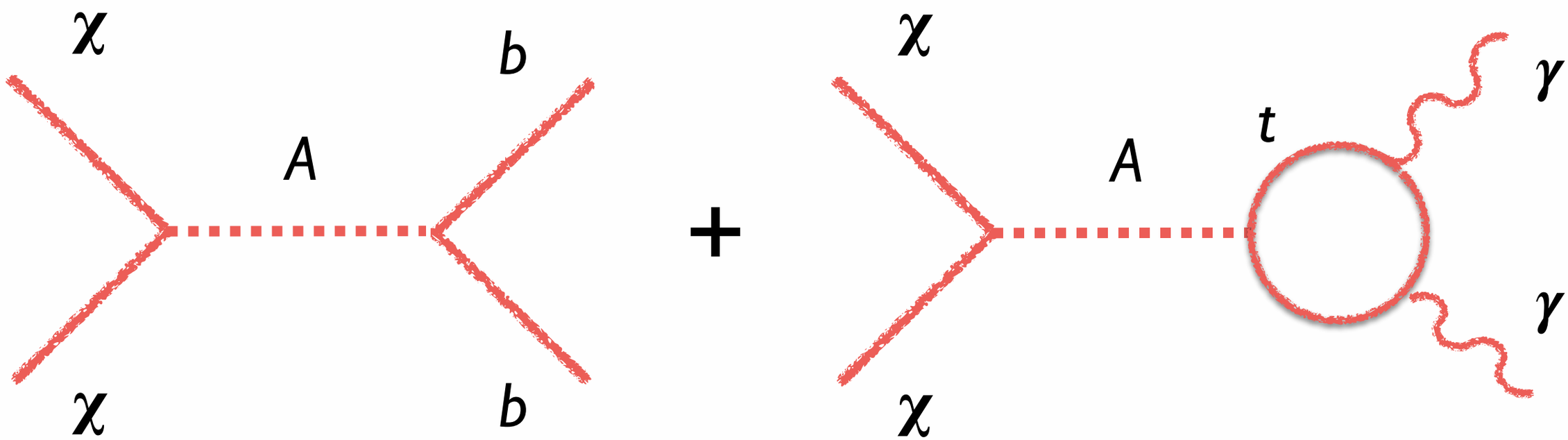
Coy DM & γ-ray line



$$m_\chi < m_t$$

$$\mathscr{L}_{0_A s\frac{1}{2}} = \frac{1}{2}(\partial_\mu A)^2 - \frac{1}{2}m_A^2 A^2 + \bar{\chi}(i\partial\!\!\!/ - m_\chi)\chi - ig_\chi A\bar{\chi}\gamma^5\chi - ig_{\mathrm{SM}}A\sum_f \frac{y_f}{\sqrt{2}}\bar{f}\gamma^5 f$$

Coy DM & γ-ray line

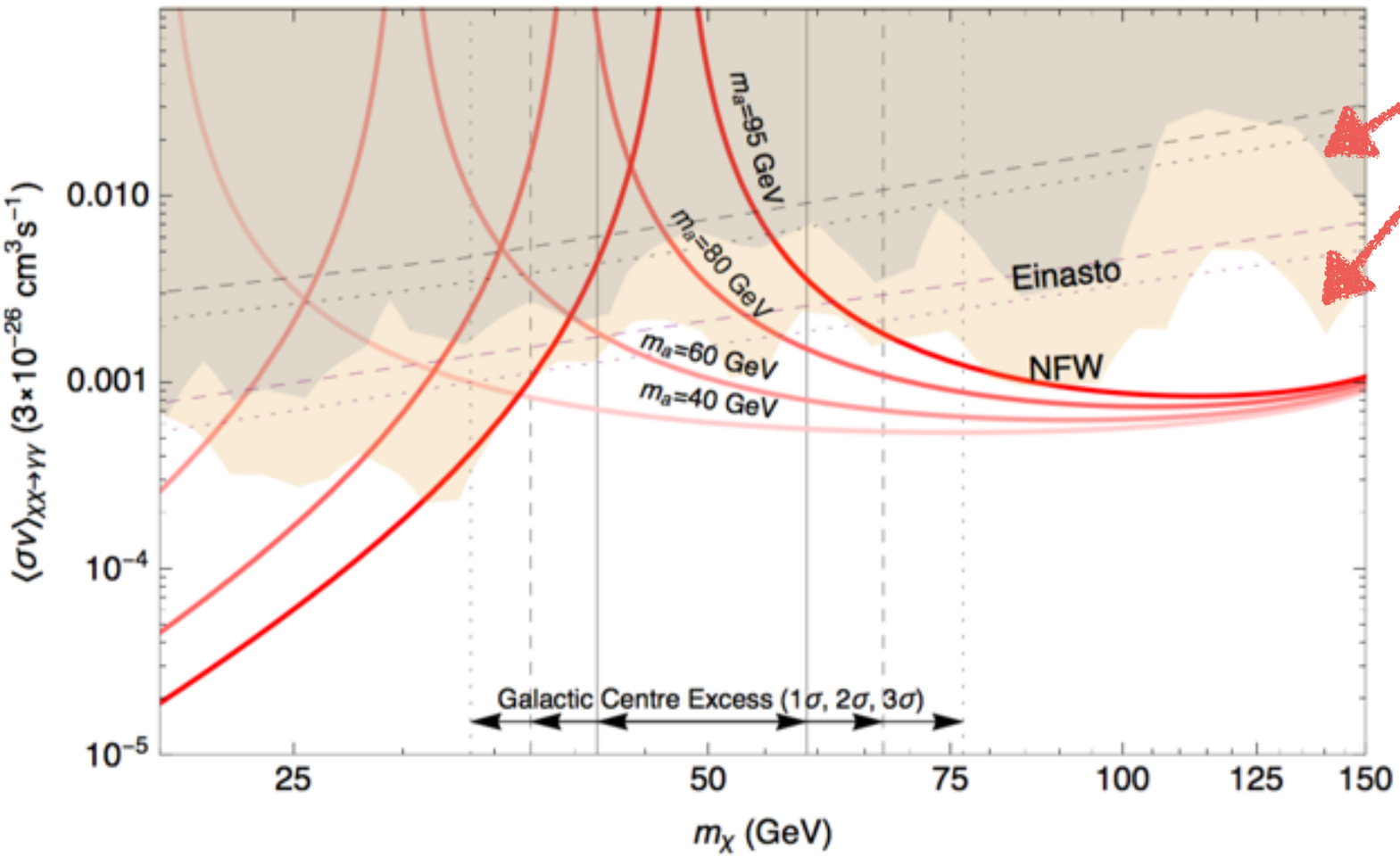


- Loop suppression, ~10^{-2}…10^{-3}
- Sensitivity of line/broader distribution search, ~10^{2}

γ-ray line signal alone

Fermi-LAT

1506.00013

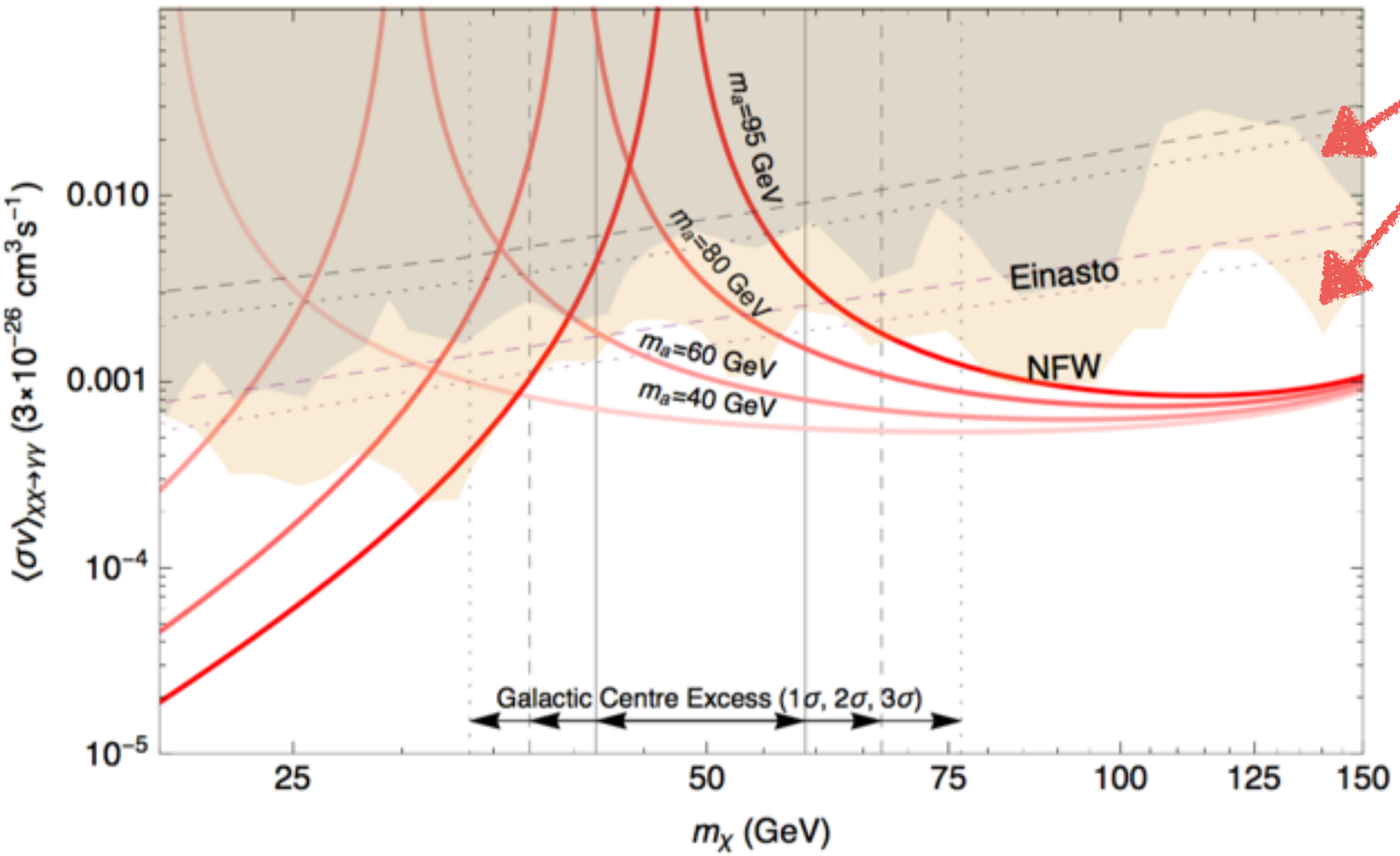


$$\sigma_{\chi\chi\to\gamma\gamma} = \frac{1}{512\pi^3}\frac{(g_\chi g_f \alpha Q_f N_c^f)^2\,(2m_\chi)^4}{(m_a^2-4m_\chi^2)^2+m_a^2\Gamma_a^2}\left|\frac{A_1(\tau_f)}{m_f}\right|^2$$

γ-ray line signal alone

Fermi-LAT

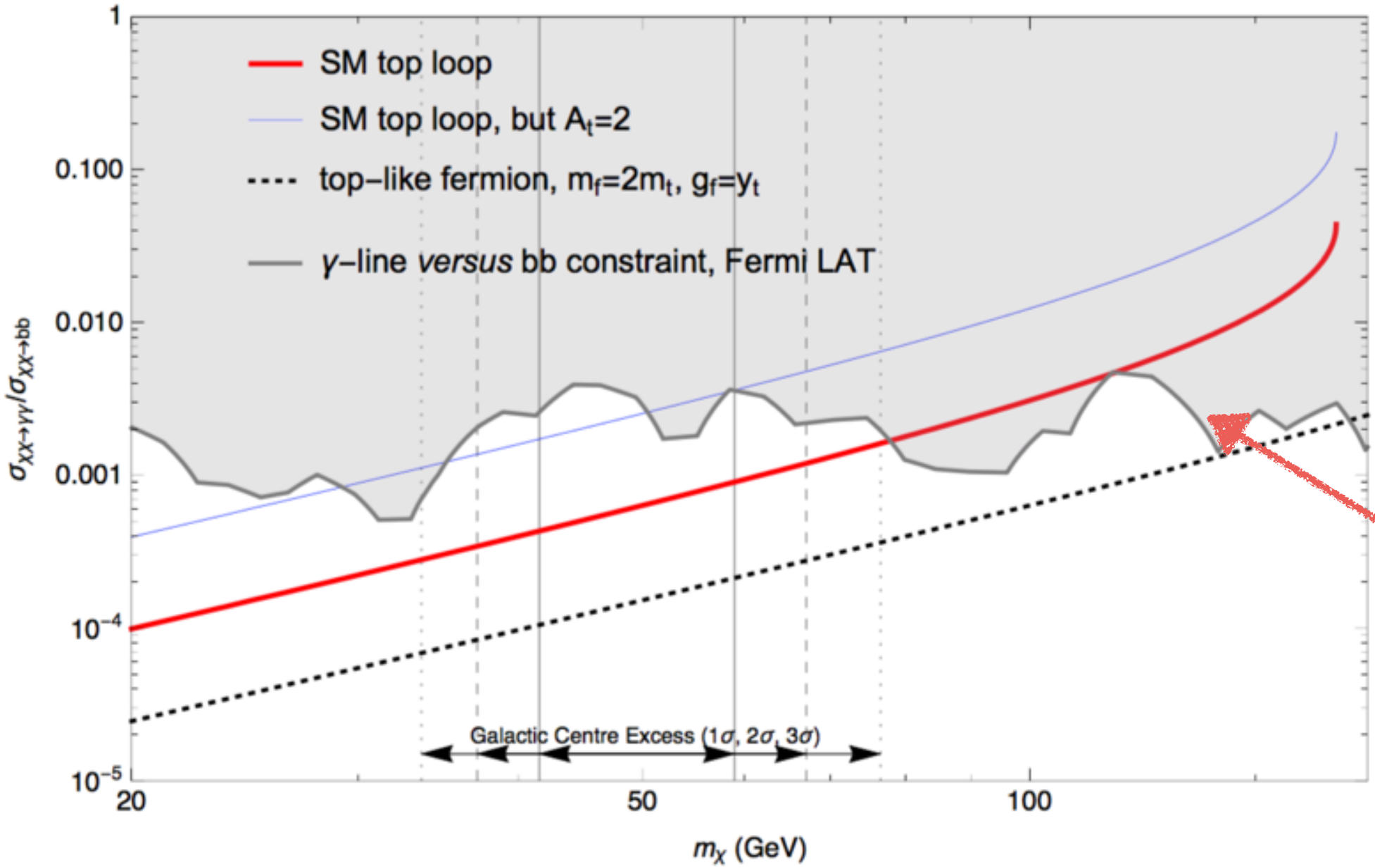
1506.00013



$$\sigma_{\chi\chi\to\gamma\gamma} = \frac{1}{512\pi^3}\frac{(g_\chi g_f \alpha Q_f N_c^f)^2\,(2m_\chi)^4}{(m_a^2-4m_\chi^2)^2+m_a^2\Gamma_a^2}\left|\frac{A_1(\tau_f)}{m_f}\right|^2$$

$$\sigma_{\chi\chi\to b\bar{b}} = \frac{N_c(g_\chi g_b)^2}{8\pi}\frac{m_\chi^2\sqrt{1-\frac{m_b^2}{m_\chi^2}}}{(m_a^2-4m_\chi^2)^2+m_a^2\Gamma_a^2}$$

Ratio of the γ-ray line and *bb* signal



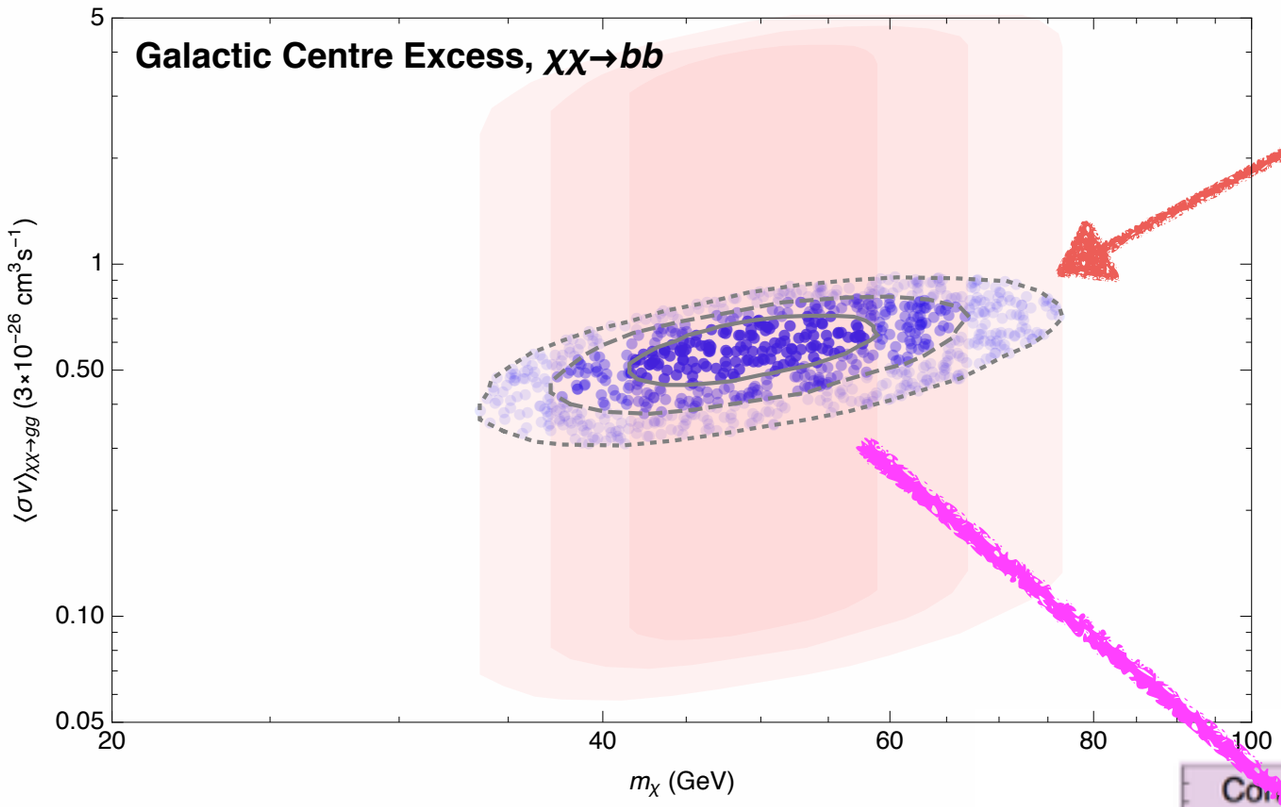
Fermi-LAT

1506.00013,

1503.02641

$$R = \frac{(N_c^t \alpha Q_t y_t)^2}{2\pi^2 N_c^b y_b^2} \frac{m_t^2}{m_\chi^2 \sqrt{1 - \frac{m_t^2}{m_\chi^2}}} \left| \arcsin^2\left(\frac{m_\chi}{m_t}\right) \right|^2$$

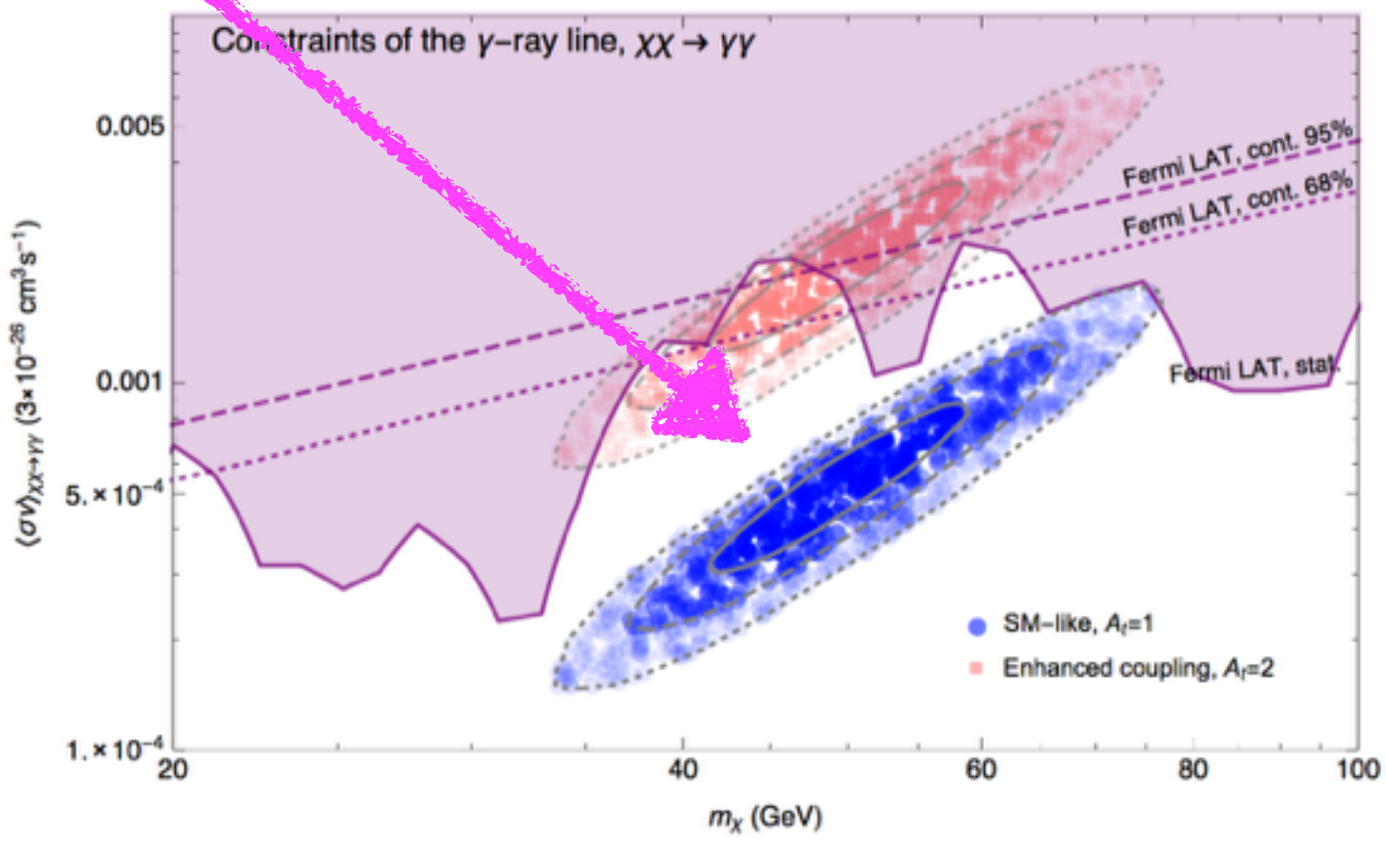
The γ-ray line and the Galactic Centre Excess



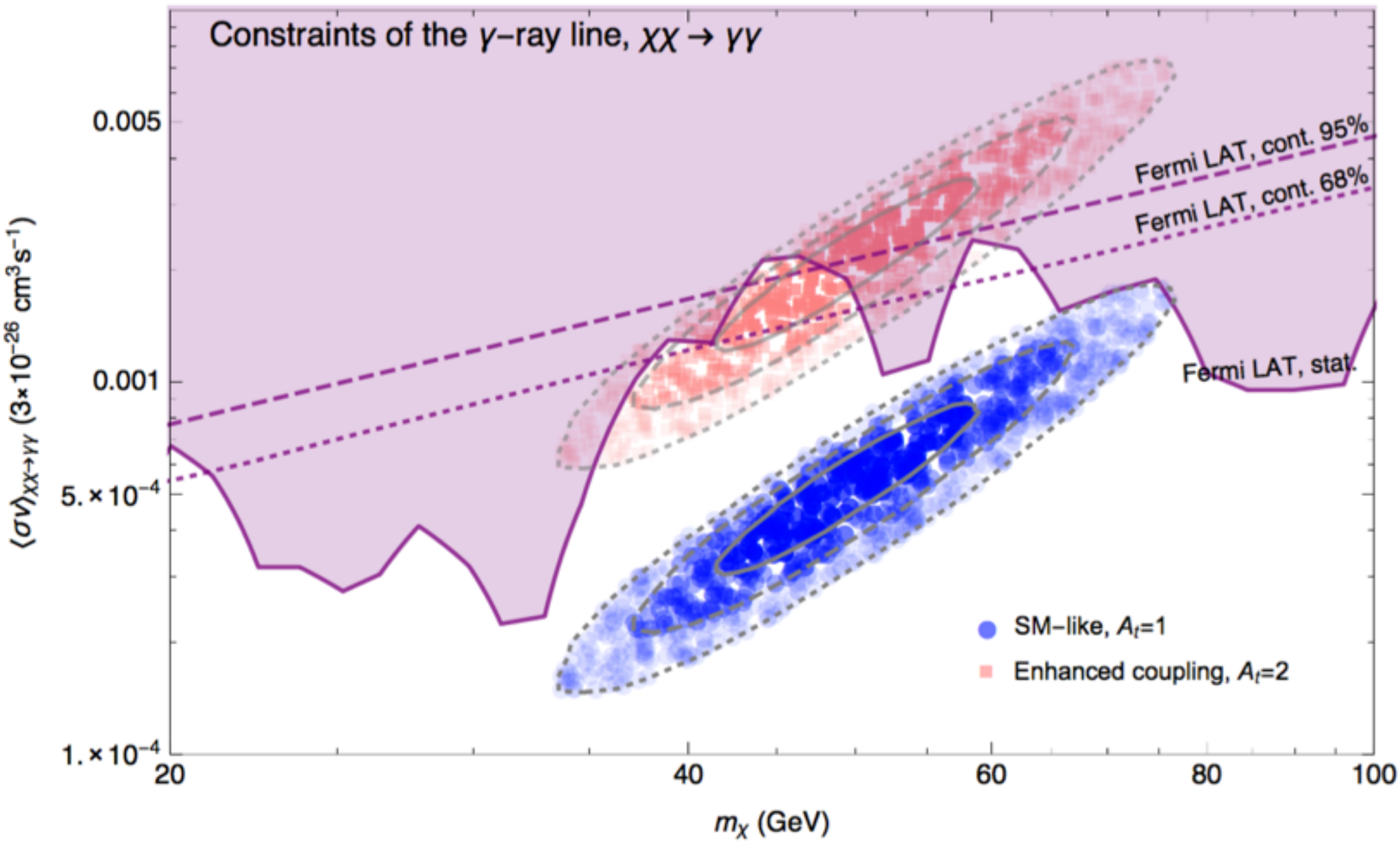
Calore et al,

1411.4647

$$R = \frac{(N_c^t \alpha Q_t y_t)^2}{2\pi^2 N_c^b y_b^2} \frac{m_t^2}{m_\chi^2 \sqrt{1-\frac{m_t^2}{m_\chi^2}}} \left| \arcsin^2\left(\frac{m_\chi}{m_t}\right) \right|^2$$

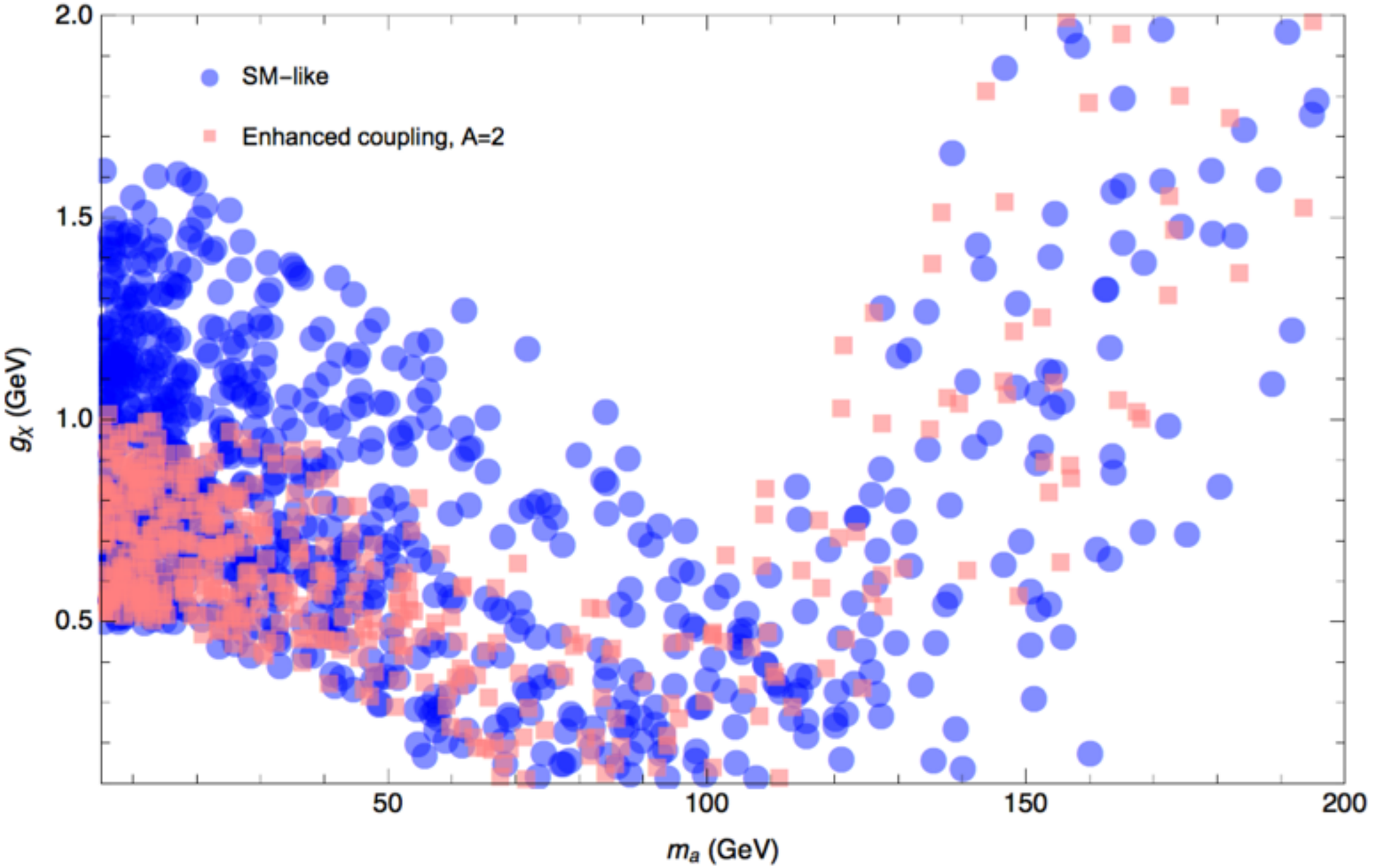


The γ-ray line and the Galactic Centre Excess



$$R = \frac{(N_c^t \alpha Q_t y_t)^2}{2\pi^2 N_c^b y_b^2} \frac{m_t^2}{m_\chi^2 \sqrt{1 - \frac{m_t^2}{m_\chi^2}}} \left| \arcsin^2\left(\frac{m_\chi}{m_t}\right) \right|^2$$

The γ-ray line and the Galactic Centre Excess



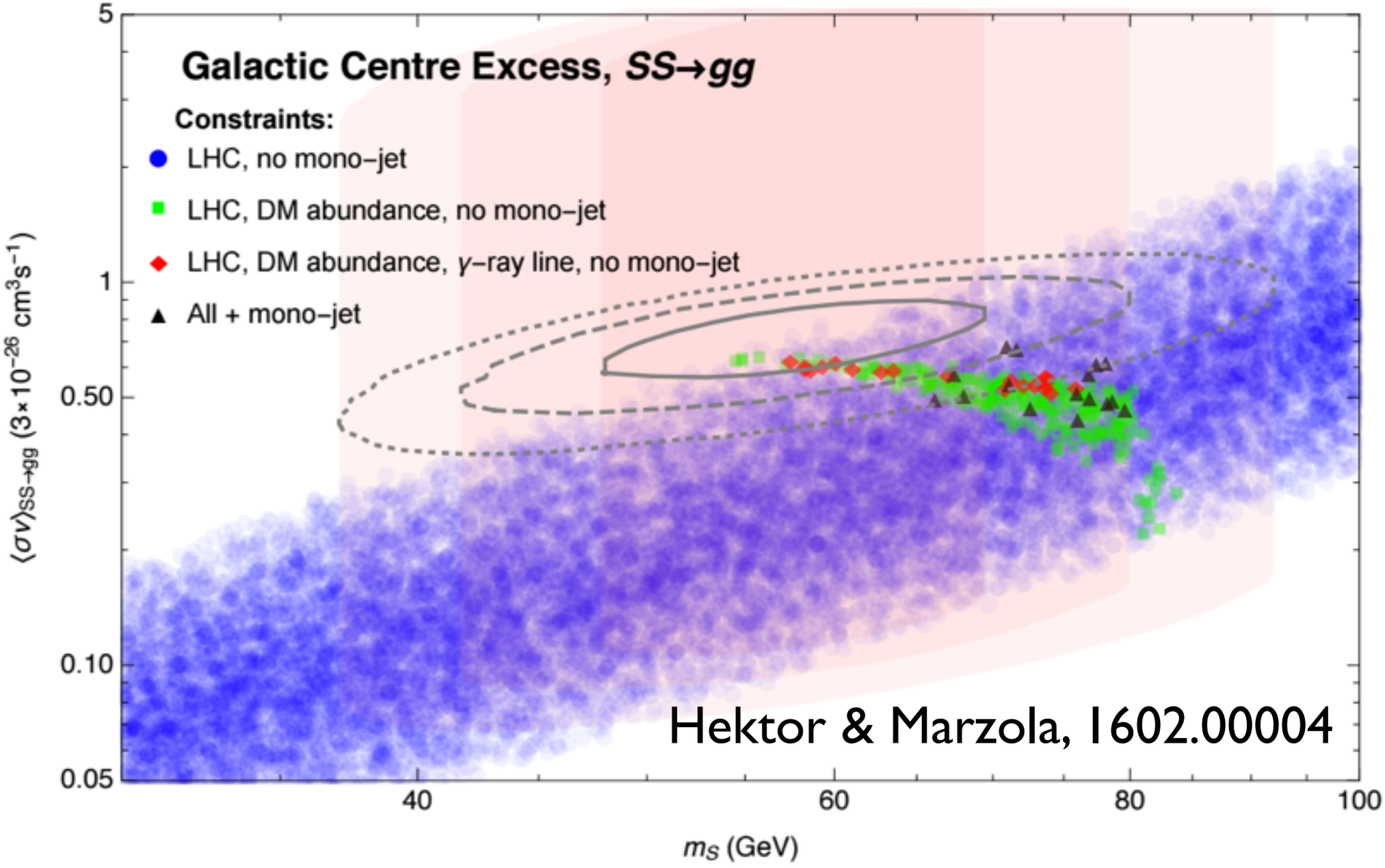
$$R = \frac{(N_c^t \alpha Q_t y_t)^2}{2\pi^2 N_c^b y_b^2} \frac{m_t^2}{m_\chi^2 \sqrt{1 - \frac{m_t^2}{m_\chi^2}}} \left| \arcsin^2\left(\frac{m_\chi}{m_t}\right) \right|^2$$

Galactic Centre Excess & TeV-scale pseudoscalar mediator

or

What did we learn from the 750 GeV pseudo-particle?

Coy DM & Galactic Centre Excess & TeV-scale mediator



- Pseudoscalar mediator, m_A = 750 GeV
- Scalar DM particle

Life in ‘Resonance portal’

Escaping from the killer Direct Detection:

A. ‘Coy DM’
B. ‘Resonance Portal’

Is the Resonance Portal fine tuning?

1. Yes
2. No. There can be theoretical motivation, e.g. hep-ph/9207234, hep-ph/9704403, hep-ph/9804231

RP offers interesting phenomenology for indirect section

$$\sigma_{\chi\chi\to S\to ff} = \frac{N_c\,(g_\chi\,A\,y_f)^2}{16\,\pi}\,\frac{m^2\left(1-\frac{m_f^2}{m^2}\right)^{3/2}}{\left(M^2-s[m^2,v_{rel}]\right)^2+M^2\,\Gamma^2}\,v_{rel}$$

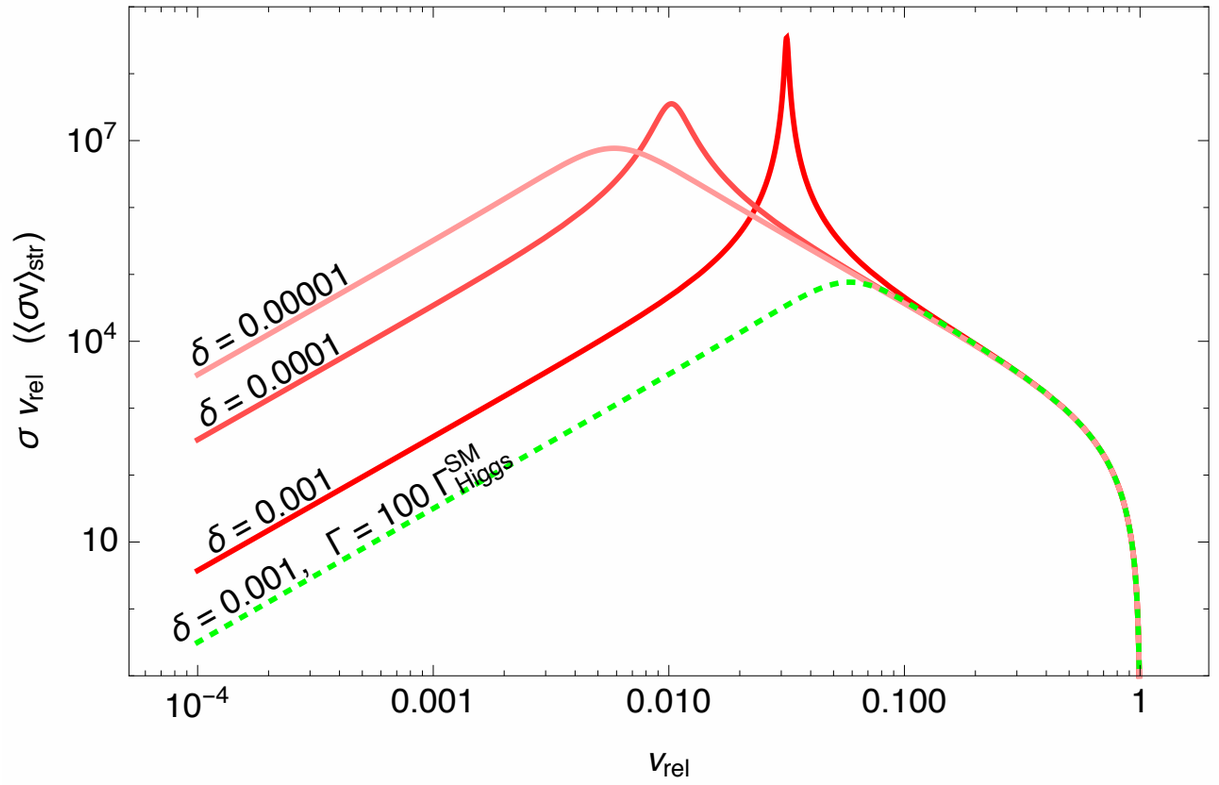
$$\sigma_{\chi\chi\to A\to ff} = \frac{N_c\,(g_\chi\,A\,y_f)^2}{16\,\pi}\,\frac{m^2\left(1-\frac{m_f^2}{m^2}\right)^{1/2}}{\left(M^2-s[m^2,v_{rel}]\right)^2+M^2\,\Gamma^2}\,v_{rel}^{-1}$$

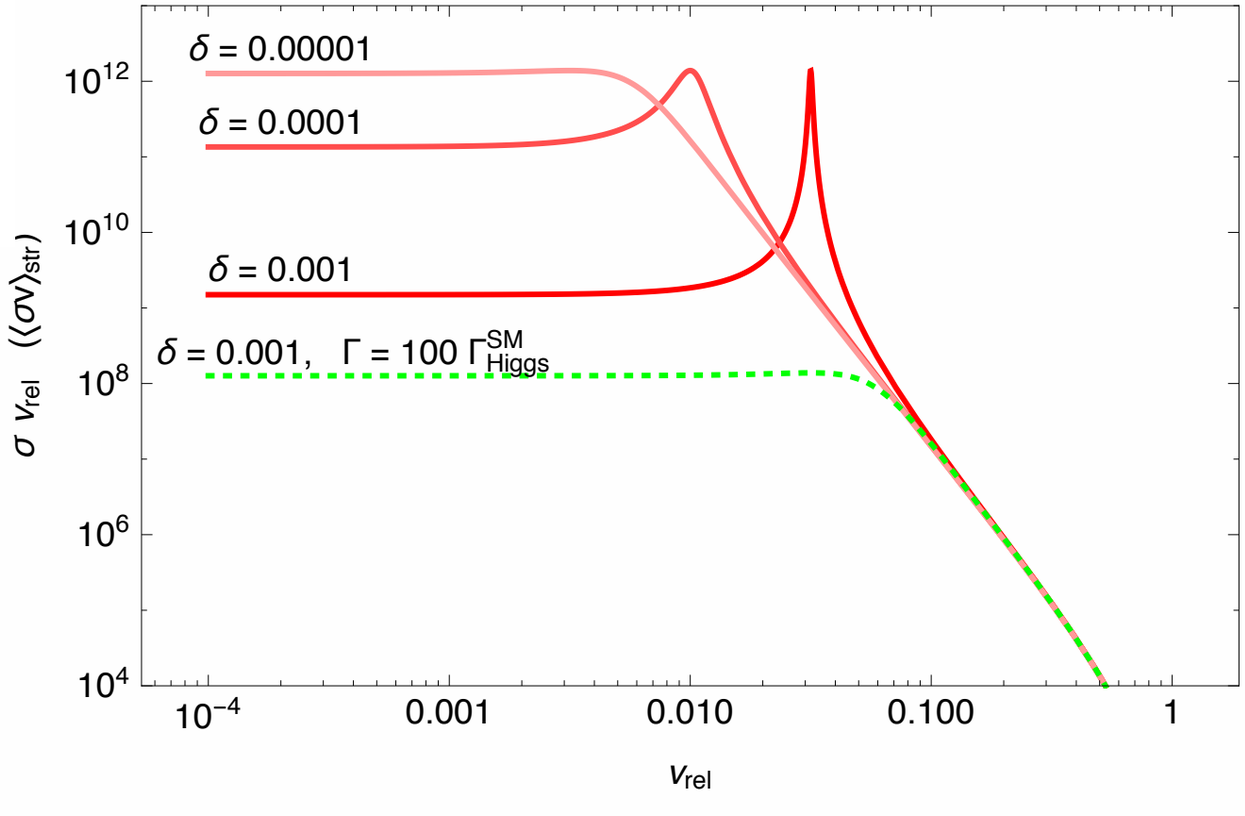
$$m^2 = \frac{M^2}{4\,(1+\delta)},\qquad s\left[m^2,\,v_{rel}\right] = \frac{4\,m^2}{1-v_{rel}^2}$$

$$M = m_{higgs},\ g\chi = 1$$

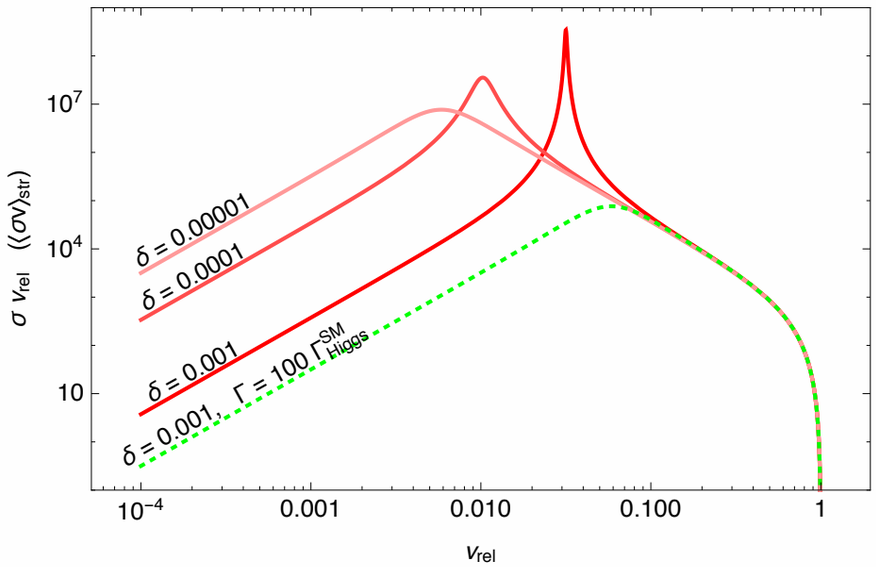
$$A = 1,\ y_f = 1$$

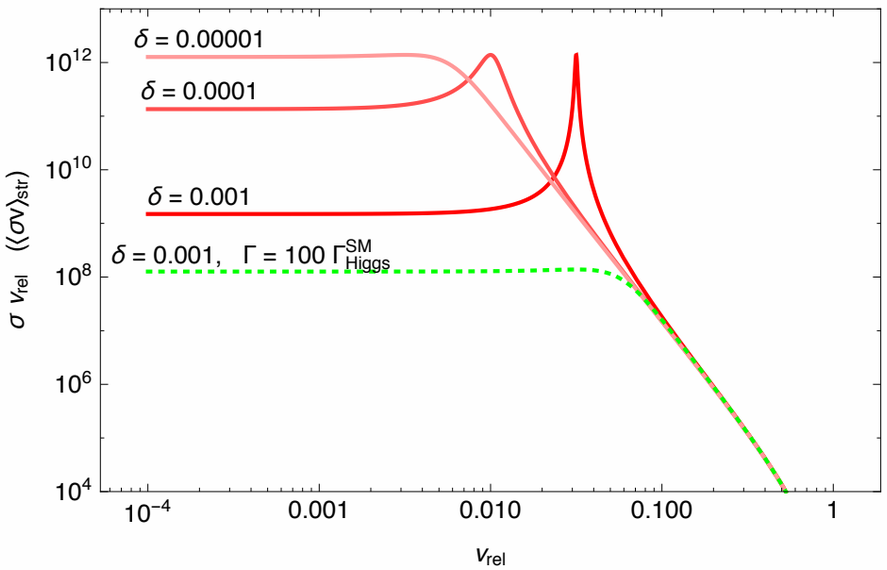
$$\Gamma = \Gamma_{higgs}$$

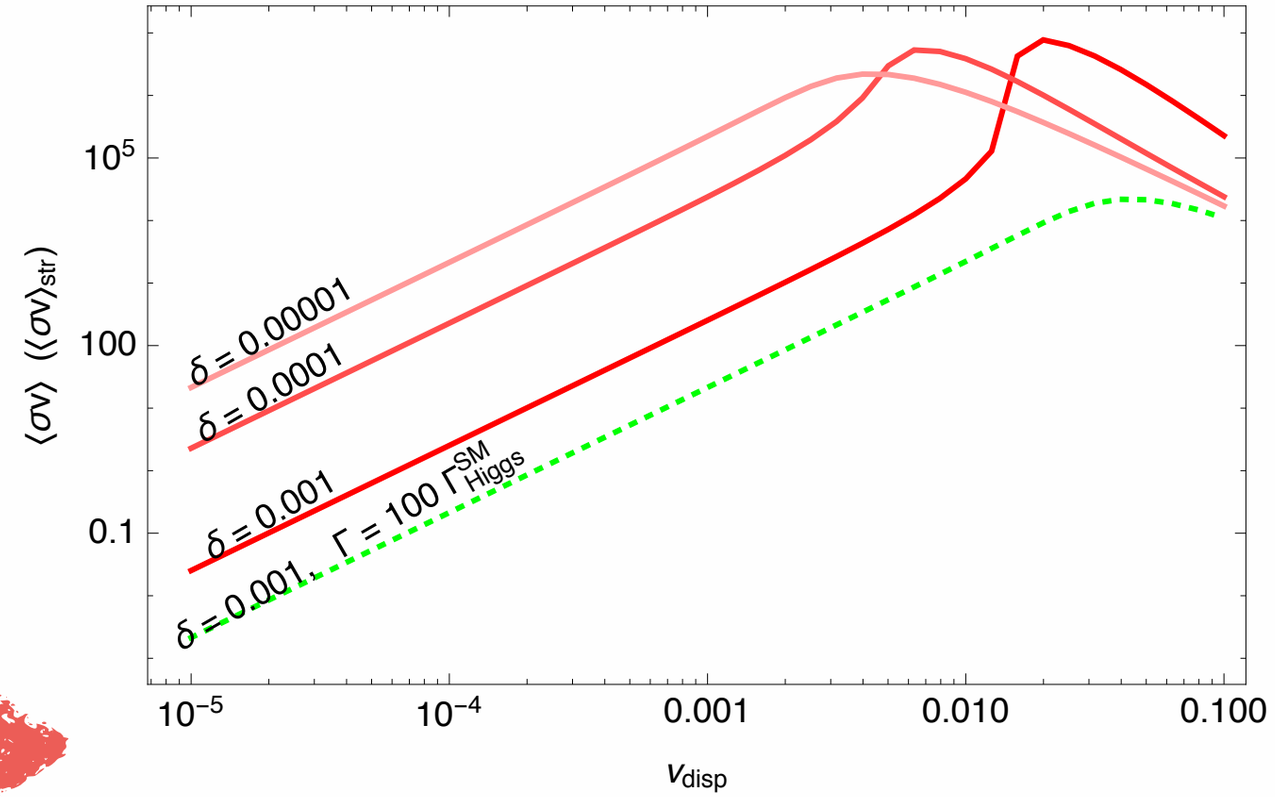


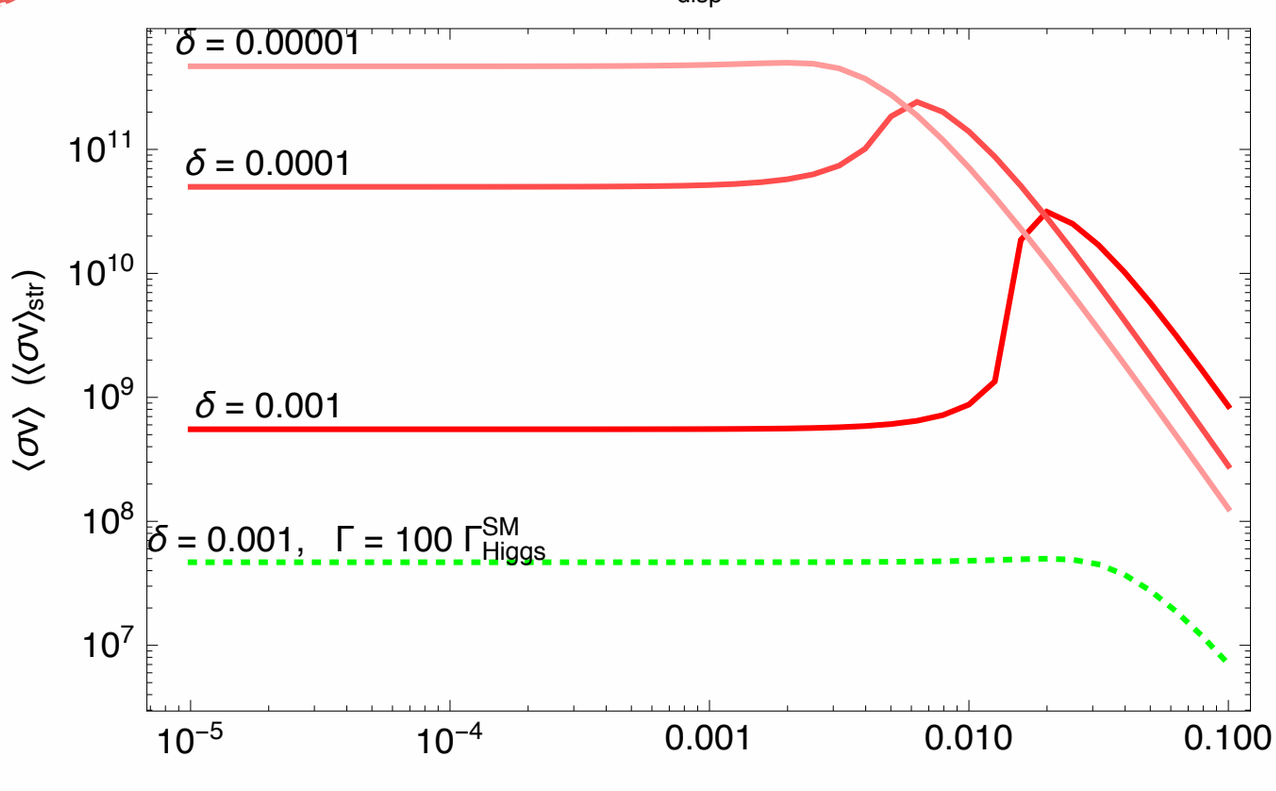


RP offers interesting phenomenology for indirect section



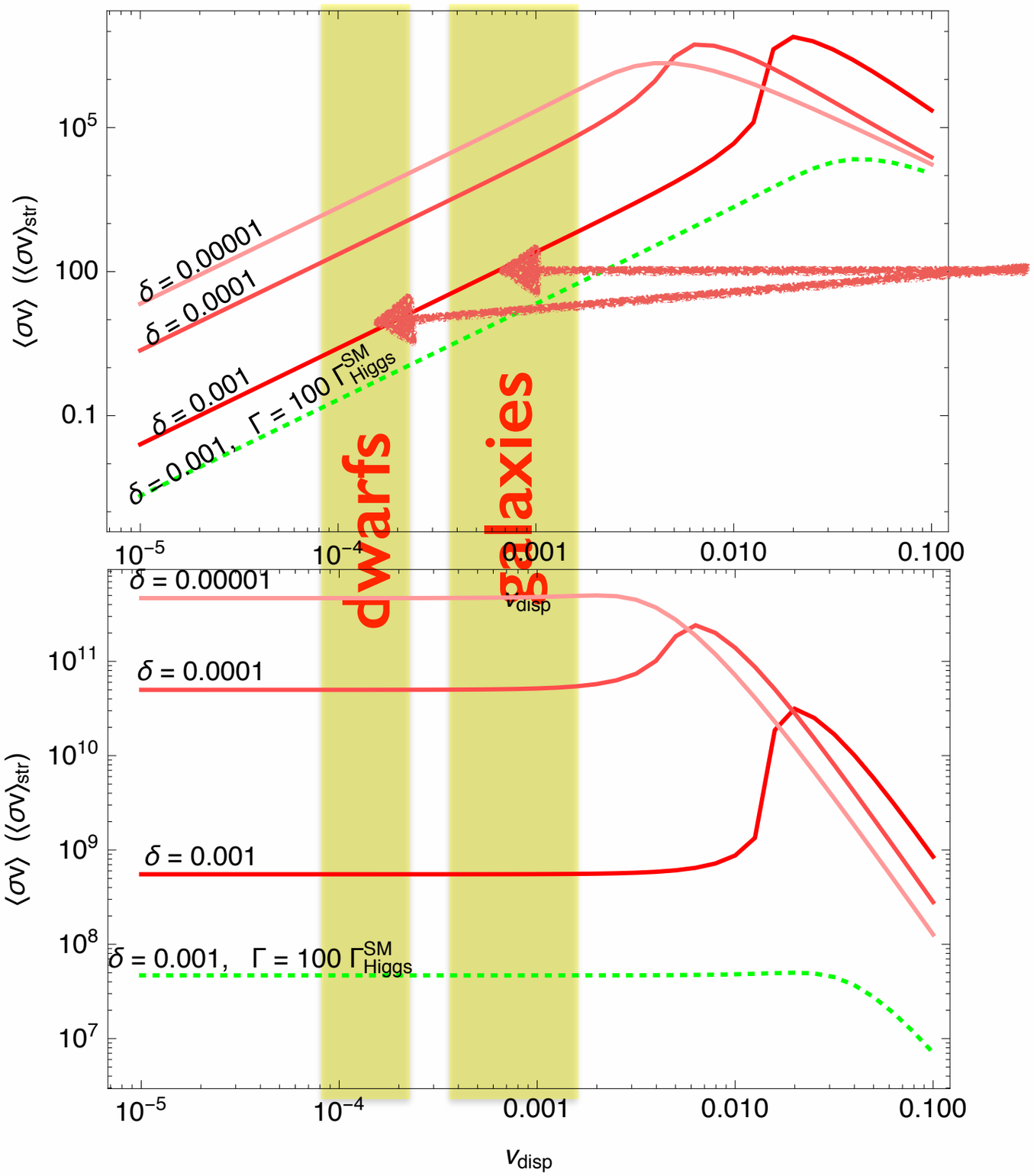






RP offers interesting phenomenology for indirect section

scalar



pseudo-scalar

Difference of two orders magnitude!

However, the real life is more complicated!

Takeaway messages from my talk

- Coy DM offers rich phenomenology — be careful with the γ-ray line!
- 'Resonance Portal' — the annihilation cross-section constraints from galaxy clusters, galaxies, dwarfs etc are different!

Thank you!