Dark Portal Scenarios

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Based on
G.A., Y. Mambrini, M. Tytgat and B. Zaldivar
JHEP 1403(2014), 134
arXiv:1401.0221
Francois Richard, G.A. and Yann Mambrini
arXiv:1411.0088
G.A., Yann Mambrini and Francois Richard
arXiv: 1411.2985
Work in progress

invisibles
neutrinos, dark matter & dark energy physics

Outline of the talk

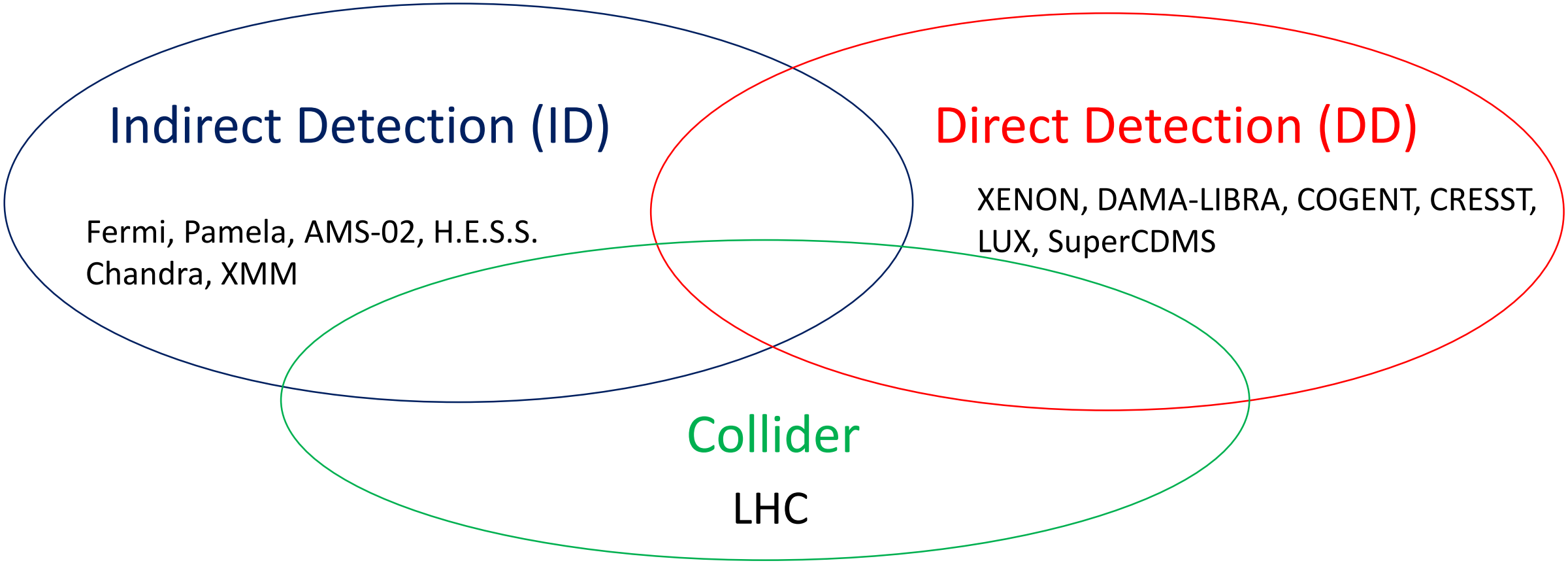
We investigate generic models, featuring a DM fermion and a mediator,which can be embedded in many particle physics frameworks:

-Z portal
-Z‘ portal
-Scalar+pseudo scalar portal

-Complementarity between Direct Detection, Indirect Detection and Planck limits.
-Correlation with GC signal
-Correlation between DM (LUX) constraints and collider searches.

-Prospects for next generation Direct Detection experiments

Three, possibly complementary, kinds of DM searches:



Complementary information from DM relic density. Case of study WIMP mechanism:

$$\Omega h^2 \simeq 0.12 \longrightarrow \langle \sigma v \rangle \simeq 3 \times 10^{-26} \mathrm{cm}^3 \mathrm{s}^{-1}$$

Dark Portals

Z-portal

$$\mathcal{L} = \frac{g}{4\cos\theta_W}\left(\overline{\chi}\gamma^\mu\left(V_\chi - A_\chi\gamma^5\right)\chi Z_\mu + \overline{f}\gamma^\mu\left(V_f - A_f\gamma^5\right)f Z_\mu\right)$$

Z´ portal

$$\mathcal{L} = g_D\overline{\chi}\gamma^\mu\left(V_\chi - A_\chi\gamma^5\right)\chi Z'_\mu + g_D\overline{f}\gamma^\mu\left(V_f - A_f\gamma^5\right)f Z'_\mu$$

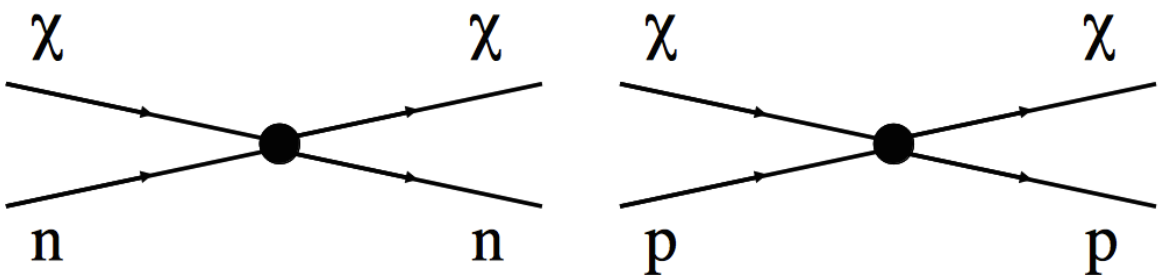
Scalar/pseudoscalar portal

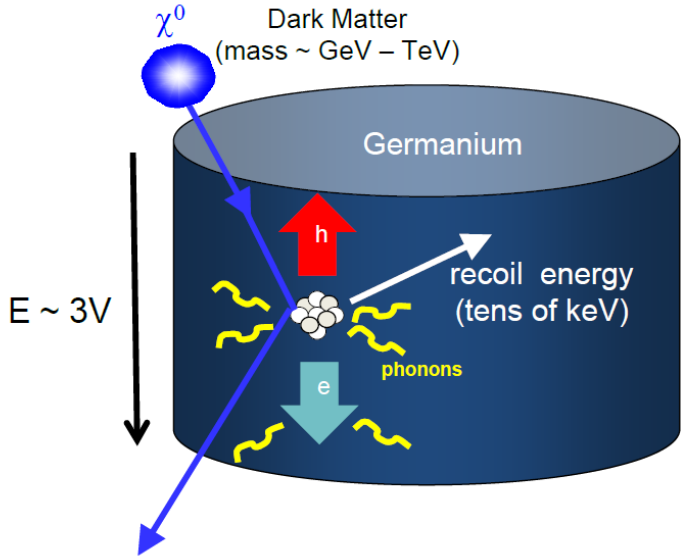
$$\mathcal{L} = s\left[\lambda_s^\chi\bar{\chi}\chi + \lambda_s^f\bar{f}f\right] + a\left[i\lambda_a^\chi\bar{\chi}\gamma_5\chi + i\lambda_a^f\bar{f}\gamma_5 f\right]$$

DM Direct Detection

Microscopic description through interactions of DM with quarks (or gluons)

Translated as effective interaction with nucleons.





Two kinds of interactions customarily distinguished

Spin Indipendent (SI) interactions: Sum coherently among nucleons of the target

Spin Dependent (SD) interactions: Sensitive to the contributions from protons and nucleons to the nuclear spin.

The pair annihilation cross-section can expressed in terms of observable quantities, i.e. DM scattering cross-sections.

s-wave or p-wave dominated according the nature of the DM coupling

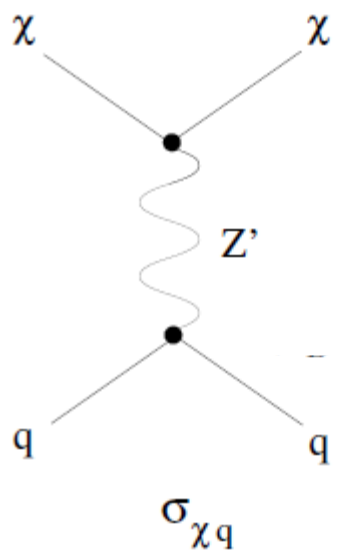
$$\langle \sigma v \rangle = f_1 \sigma^{\mathrm{SI}}_{\chi N} + f_2 \sigma^{\mathrm{SD}}_{\chi N}$$

Possible constraints from ID

DD constraints the relic abundance of DM.

Prediction of the value of the scattering cross-section from the requirement the DM is thermal.

Example: Vector mediator



$\sigma_{\chi q}$

$$\sigma^{\rm SI}_{\chi N} = \frac{4 g_D^4 \mu^2_{\chi N} |V_\chi|^2}{\pi M^4_{Z'}} \alpha_{\rm SI}$$

$$\sigma^{\rm SD}_{\chi N} = \frac{16 g_D^4 \mu^2_{\chi N} |A_\chi|^2}{\pi M^4_{Z'}} \alpha_{SD}$$

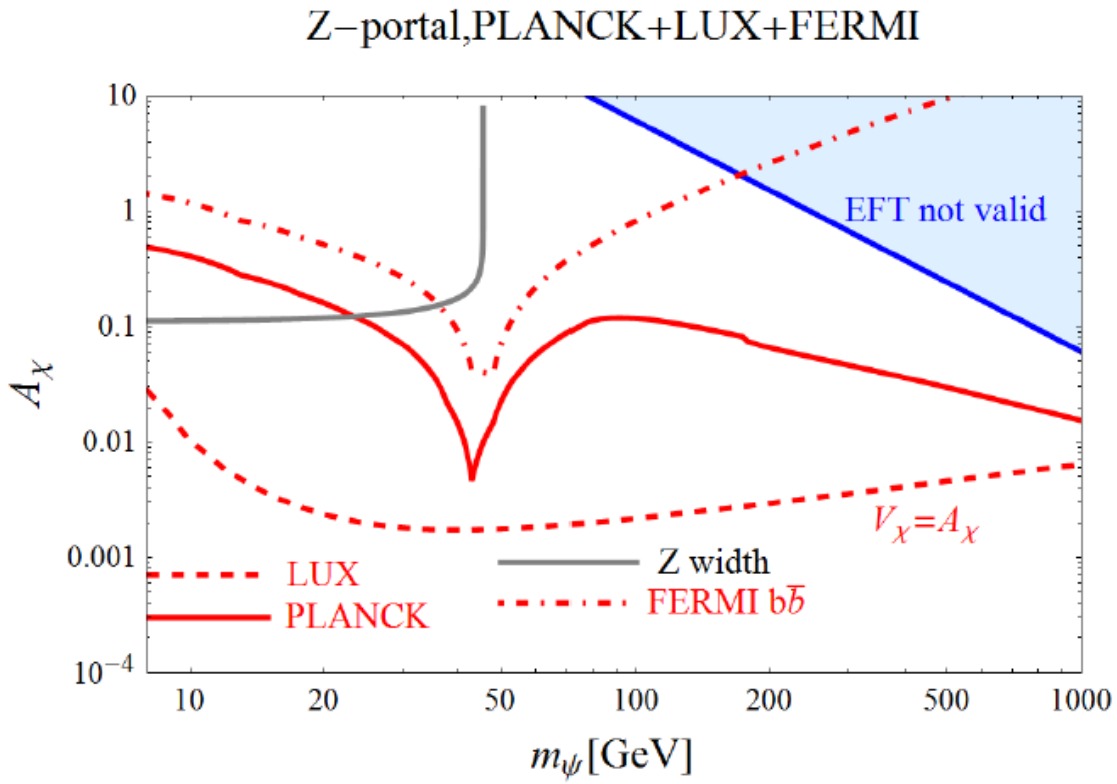
Account for different interactions with proton and neutrons.

Mass and velocity suppressed

$$m_\chi \ll m_{Z'}$$

$$\langle \sigma v \rangle_{f\bar{f}} \simeq \frac{g_D^4 m_\chi^2}{2\pi m^4_{Z'}} \sum_f n_c^f \left(|V_f|^2 + |A_f|^2\right) \left[2|V_\chi|^2 + |A_\chi|^2 \left(\frac{m_b^2}{m_\chi^2} \frac{|A_b|^2}{\sum_f (|V_f|^2 + |A_f|^2)} + \frac{v^2}{6}\right)\right]$$

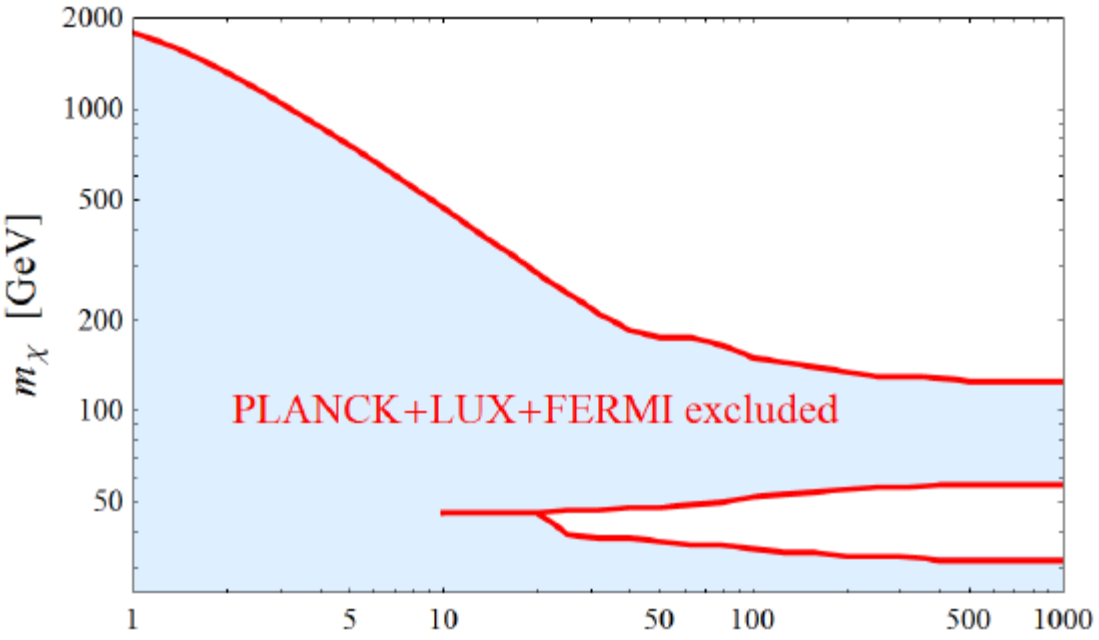
$$= \frac{2 m_\chi^2}{\mu^2_{\chi p}} \sum_f n_c^f \left(|V_f|^2 + |A_f|^2\right) \left[2\frac{\sigma^{\rm SI}_{\chi p}}{\alpha_{\rm SI}} + \frac{\sigma^{\rm SD}_{\chi p}}{3\alpha_{\rm SD}} \left(\frac{m_b^2}{m_\chi^2} \frac{|A_b|^2}{\sum_f (|V_f|^2 + |A_f|^2)} + \frac{v^2}{6}\right)\right]$$



Z-portal viable for almost pure axial couplings except for Z-pole and multi TeV regions.

The case of comparable axial and vector couplings is excluded by limits from LUX (SI) and Z-width.

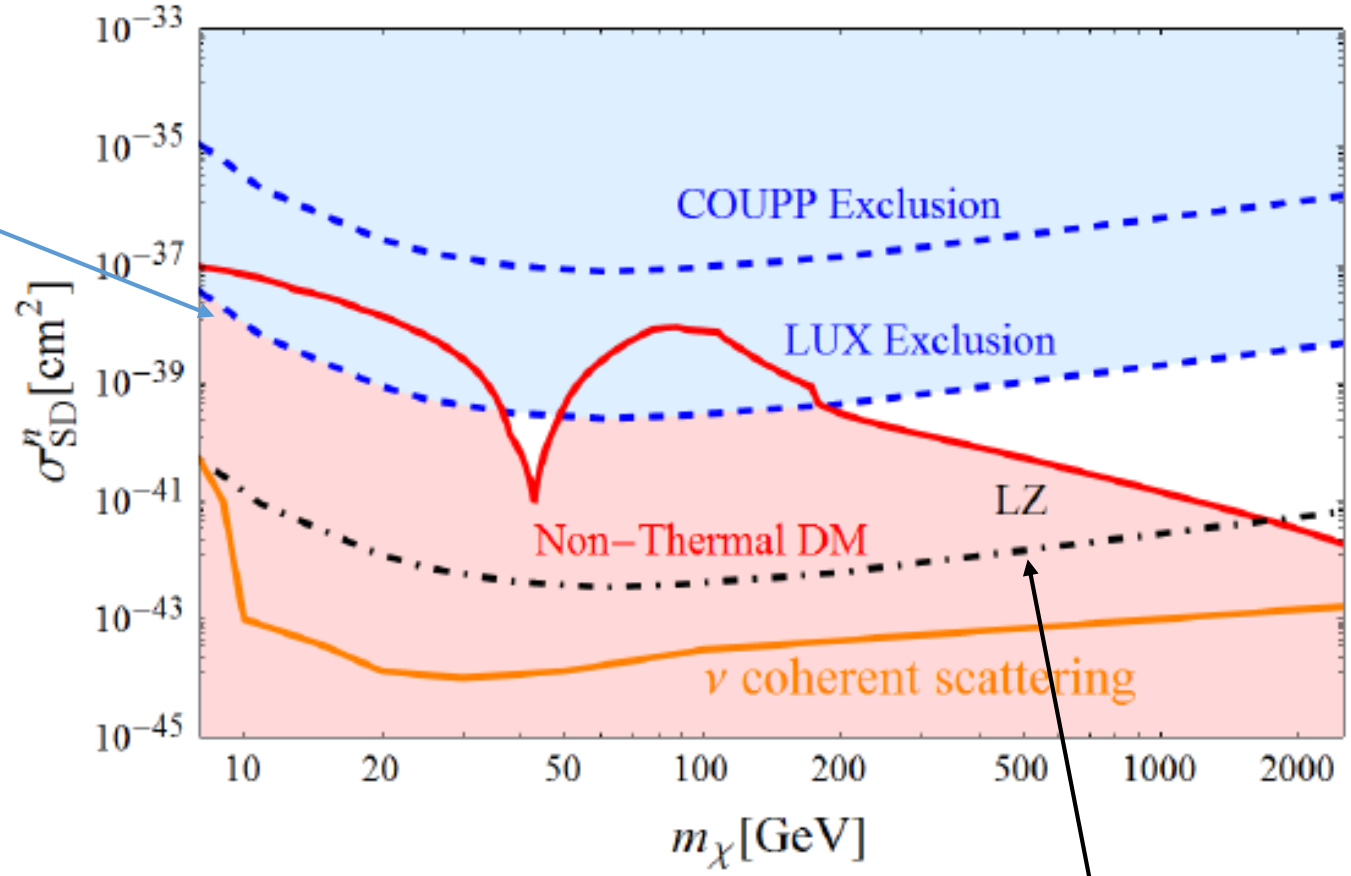
Z-portal viable for pure axial couplings for DM masses below the TeV scale.



$$\alpha = \frac{A_\chi}{V_\chi}$$

Correct relic density (dominant axial interaction) ⟷ Lower bound on SD cross-section

Interaction of DM with neutrons



Next future experiments can completely probe Z portal scenario

GC signal

Recent studies have reported an excess in gamma-rays (Daylan et al. arXiv:1402.6703). The presence of an unknown component in the gamma-ray spectrum is confirmed by FERMI collaboration.

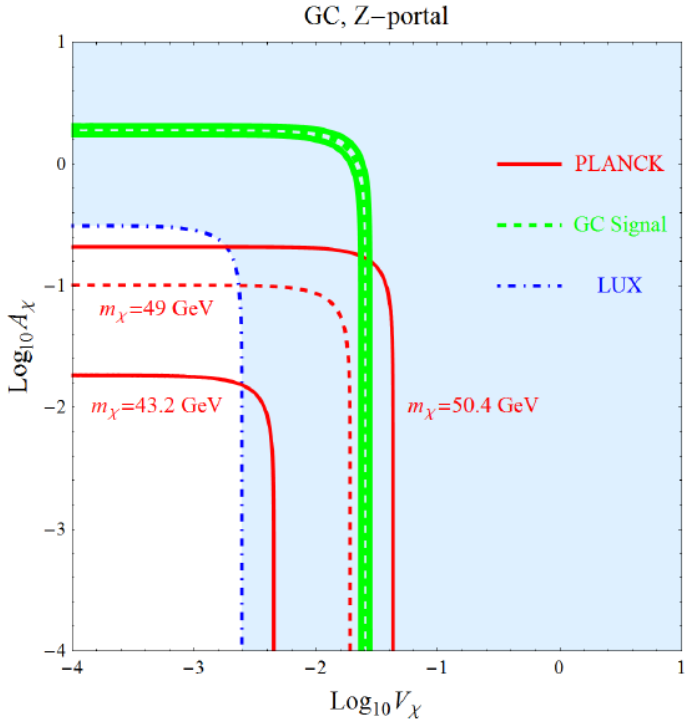
The signal is compatible with a DM annihilating into bb and mass between 30 (Berlin et al. 1404.0022) and 50 GeV (Calore et al. 1409.0042) (Astrophysical interpretation is also feasible)

New analysis have enlarged the range of candidate masses and final states including WW, ZZ, tt and hh. (In these cases the DM mass is close to the kinematical thresold) (Agrawal et al. 1411.2592 and Calore et al 1411.4647).

Annihilation into bb mass and velocity suppressed in the pure axial limit.

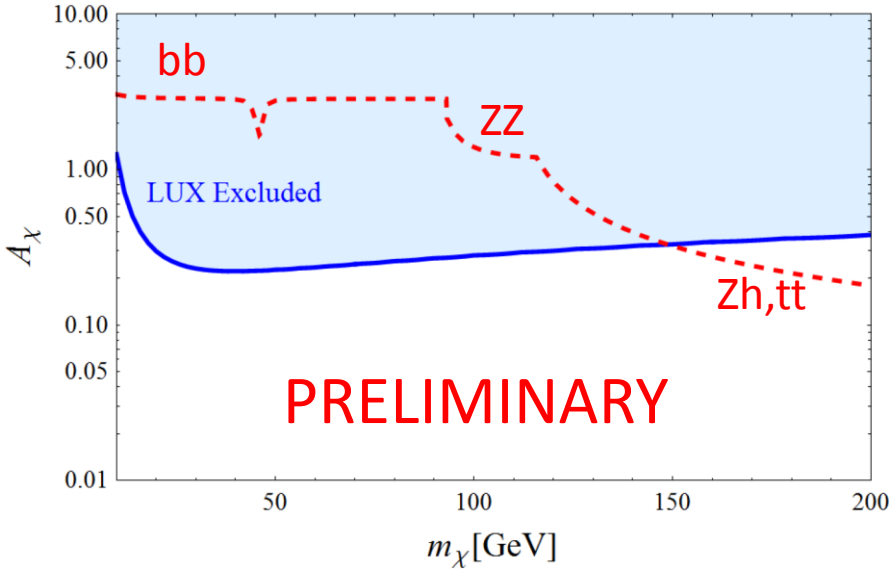
$$\frac{\langle\sigma v\rangle_{v\to 0}}{\langle\sigma v\rangle_{\rm f.o.}} \approx \frac{3}{2v_{\rm f.o.}^2}\frac{m_b^2}{m_\chi^2}\frac{\left(m_Z^2-4m_\chi^2\right)^2}{m_Z^4}$$

$$\frac{|A_b|^2}{\sum_{m_\chi>m_f}\left(|V_f|^2+|A_f|^2\right)} \simeq O\left(10^{-3}\right)$$



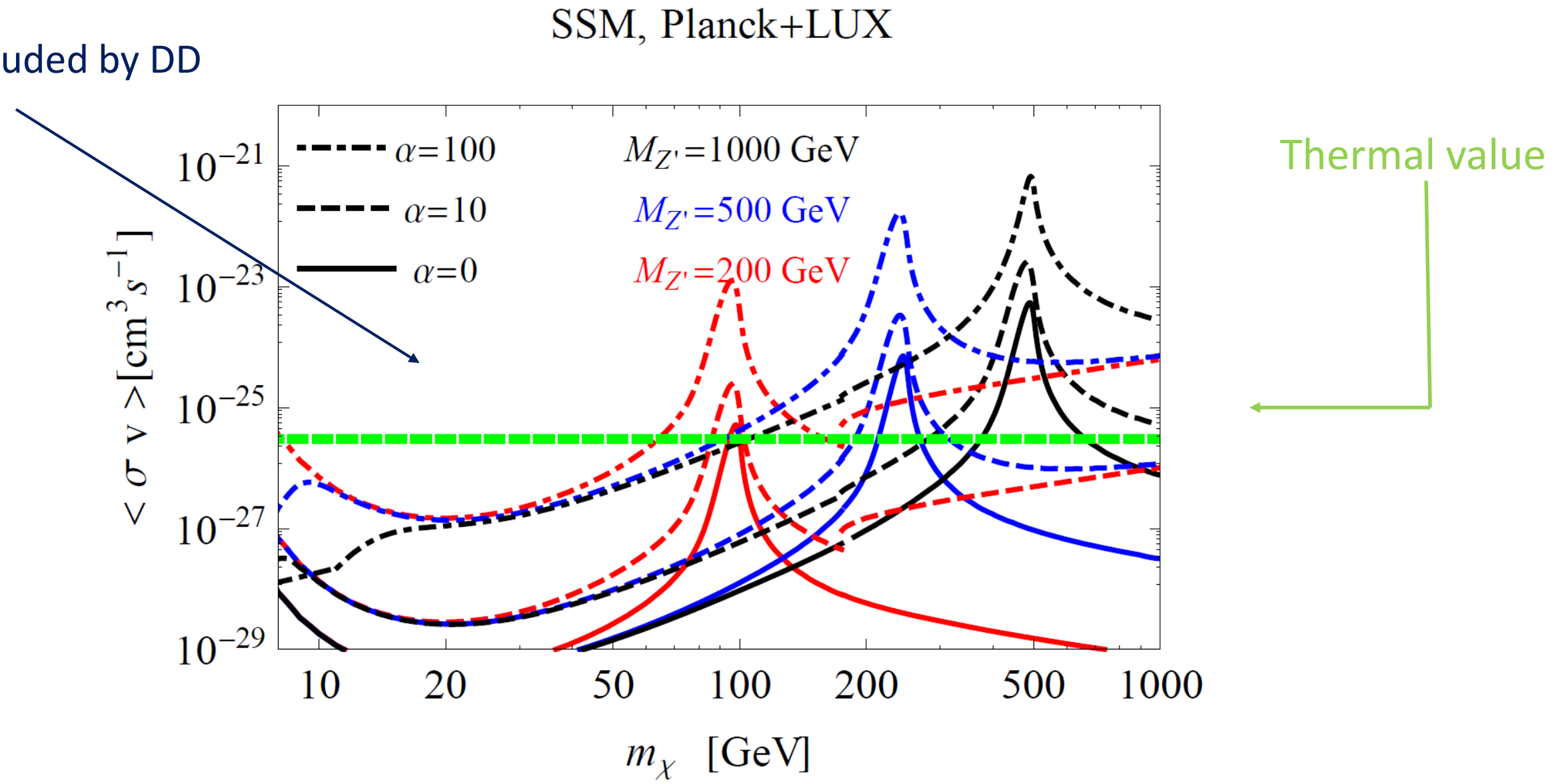
GC signal requires instead:

$$\frac{\langle\sigma v\rangle_{v\to 0}}{\langle\sigma v\rangle_{\rm f.o.}} \simeq 1$$



For axial Z-portal is not possible to reproduce the GC signal with bb annihilation because of the velocity suppression of the cross-section.

In Z´ scenarios one can consider heavier mediators allowing for sizable vector coupling
-> sizable s-wave cross-section



CONCLUSIONS

We have considered the interplay of Dark Matter searches in some dark portal scenarios.
These are simple but encopass several realistic particle frameworks.

Z-portal scenarios are the most minimal and constrained. They will be fully probed by next generation DD experiments.

Z´ portal scenarios offer wider phenomenology. Correct relic density can be achieved through s-channel annihilations even at low DM masses -> good prospects for ID. They offer also good prospects for collider searches.