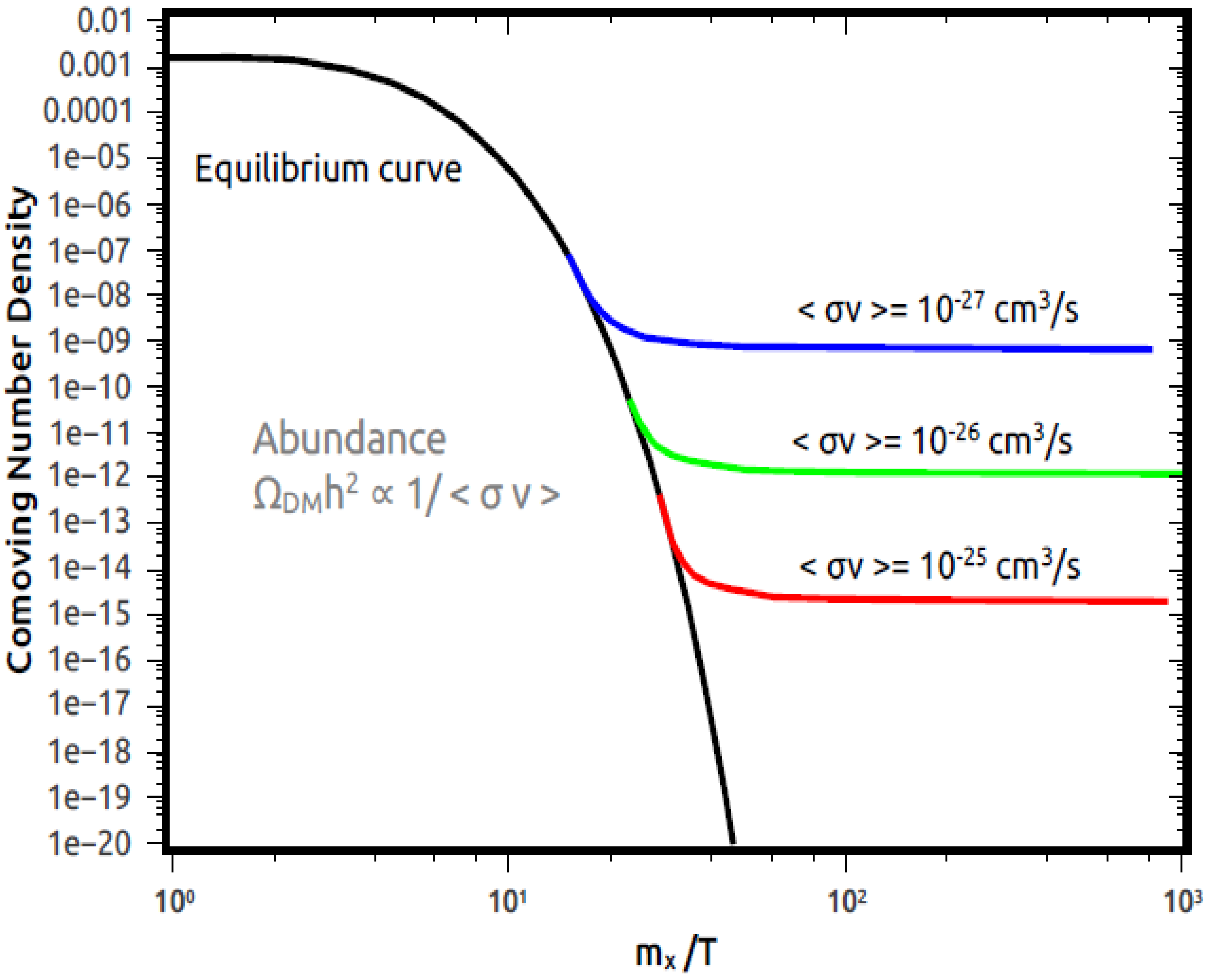
From Simplified to Gauge Invariant Realizations of a Light Pseudoscalar Portal

Giorgio Arcadi
MPIK Heidelberg

MAX-PLANCK-INSTITUT
FÜR KERNPHYSIK
HEIDELBERG

WIMP Paradigm

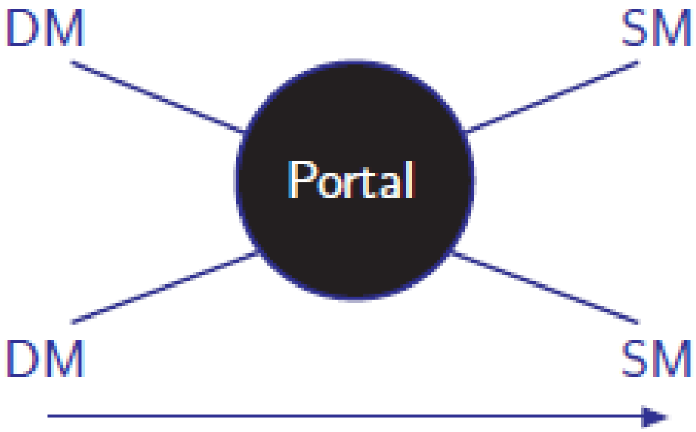


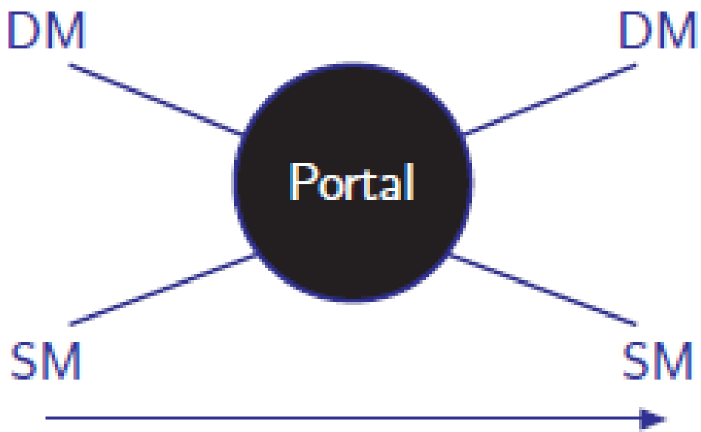
$$\frac{dn}{dt} = -3Hn - \langle \sigma_{\rm ann} v\rangle \left(n^2 - n_{\rm eq}^2\right)$$

$$\frac{dY}{dx} = \frac{1}{3H}\frac{ds}{dx}\langle \sigma v\rangle \left(Y^2 - Y_{eq}^2\right)$$

$$\Omega h^2 \theta^{-3} \approx 8.7661 \times 10^{-11} \mathrm{GeV}^{-2} \left[\overline{g_{\rm eff}}^{1/2} \int_{T_0}^{T_f} \langle \sigma v_{\rm M\o l}\rangle \frac{\mathrm{d}T}{m} \right]^{-1}$$

$$\langle \sigma v\rangle = a + bv^2$$





Relic Density

$$\langle \sigma v \rangle \approx \frac{\lambda_f^2 \lambda_\chi^2 m_\chi^2}{(4m_\chi^2 - m_{\text{med}}^2)^2}(a + b v_{\text{f.o}}^2)$$

$$\sigma_{\chi N} = \frac{\mu_{\chi N}^2 \lambda_\chi^2}{\pi m_{\text{med}}^4} f(\lambda_q)$$

$$v_{\text{f.o}} \sim 0.3$$

s-wave

p-wave

Indirect Detection

$$\langle \sigma v \rangle \approx \frac{\lambda_f^2 \lambda_\chi^2 m_\chi^2}{(4m_\chi^2 - m_{\text{med}}^2)^2}(a + b v_{\text{now}}^2)$$

$$v_{\text{now}} \sim 10^{-3}$$

Dark portal examples

$$\mathcal{L} = \xi \mu_\chi^S \chi\chi S + \xi \lambda_\chi^{S\,2} |\chi|^2 |S|^2 + \frac{c_S}{\sqrt{2}} \frac{m_f}{v_h} \bar{f} f S$$

$$\mathcal{L} = \xi g_\psi \bar{\psi}\psi S + \frac{c_S}{\sqrt{2}} \frac{m_f}{v_h} \bar{f} f S$$

Spin-0 mediator

$$\mathcal{L} = -i \lambda_\psi^a \bar{\psi} \gamma_5 \psi a - i \sum_f \frac{c_a}{\sqrt{2}} \frac{m_f}{v_h} \bar{f} \gamma_5 f a$$

Spin-1 mediator

$$\mathcal{L} = m_V \eta_V^S V^\mu V_\mu S + \frac{1}{2} \eta_S^{V\,2} V^\mu V_\mu S S + \frac{c_S}{\sqrt{2}} \frac{m_f}{v_h} S \bar{f} f$$

$$\mathcal{L} = i g' \lambda_\chi^{Z'} \left(\chi^* \partial_\mu \chi - \chi \partial_\mu \chi^*\right) Z'^\mu + g'^2 \lambda_\chi^{Z'\,2} \chi\chi^* Z'_\mu Z'^\mu + g' \sum_f \bar{f} \gamma^\mu \left(V_f^{Z'} - A_f^{Z'} \gamma_5\right) f Z'_\mu$$

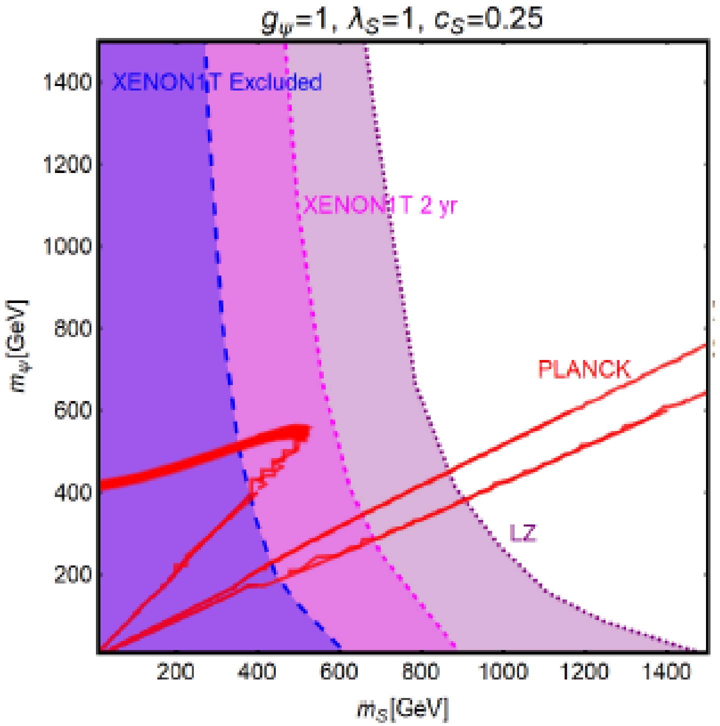
$$\mathcal{L} = g' \xi \bar{\psi} \left(\boxed{V_\psi^{Z'}} - A_\psi^{Z'} \gamma_5\right) \psi Z'^\mu + g' \sum_f \bar{f} \gamma^\mu \left(V_f^{Z'} - A_f^{Z'} \gamma_5\right) f Z'_\mu$$

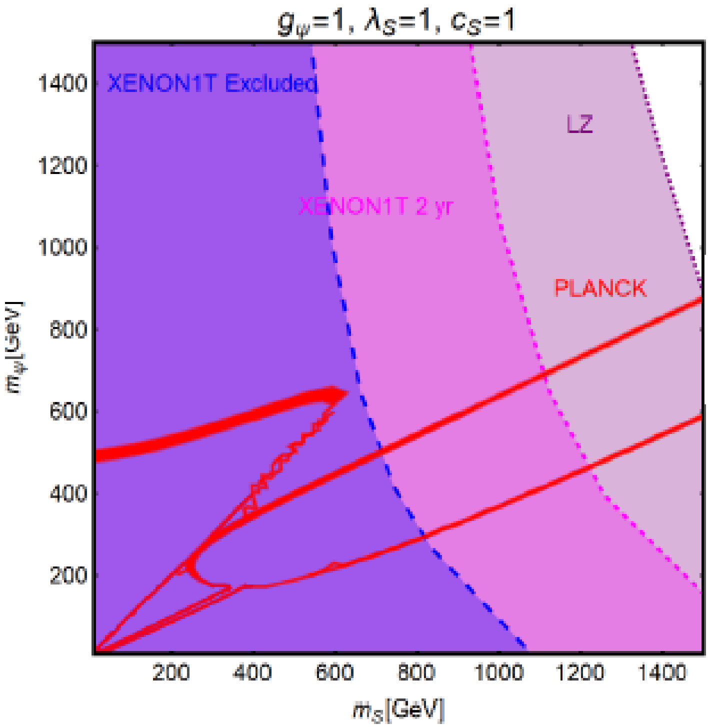
Not present for Majorana fermions

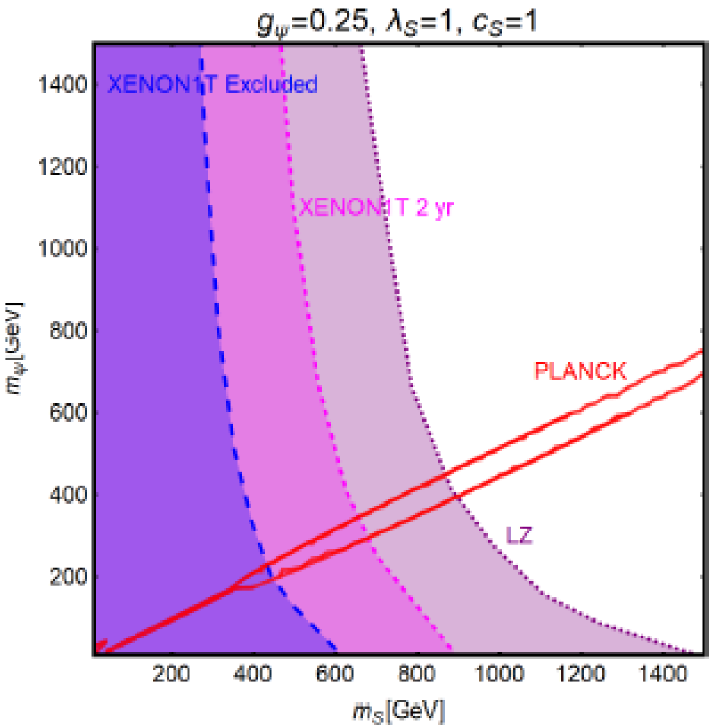
$$\mathcal{L} = g \eta_V^{Z'} [[V V Z]] + \bar{f} \gamma^\mu \left(V_f^{Z'} - A_f^{Z'} \gamma^5\right) f Z'_\mu$$

(Real) Scalar mediator

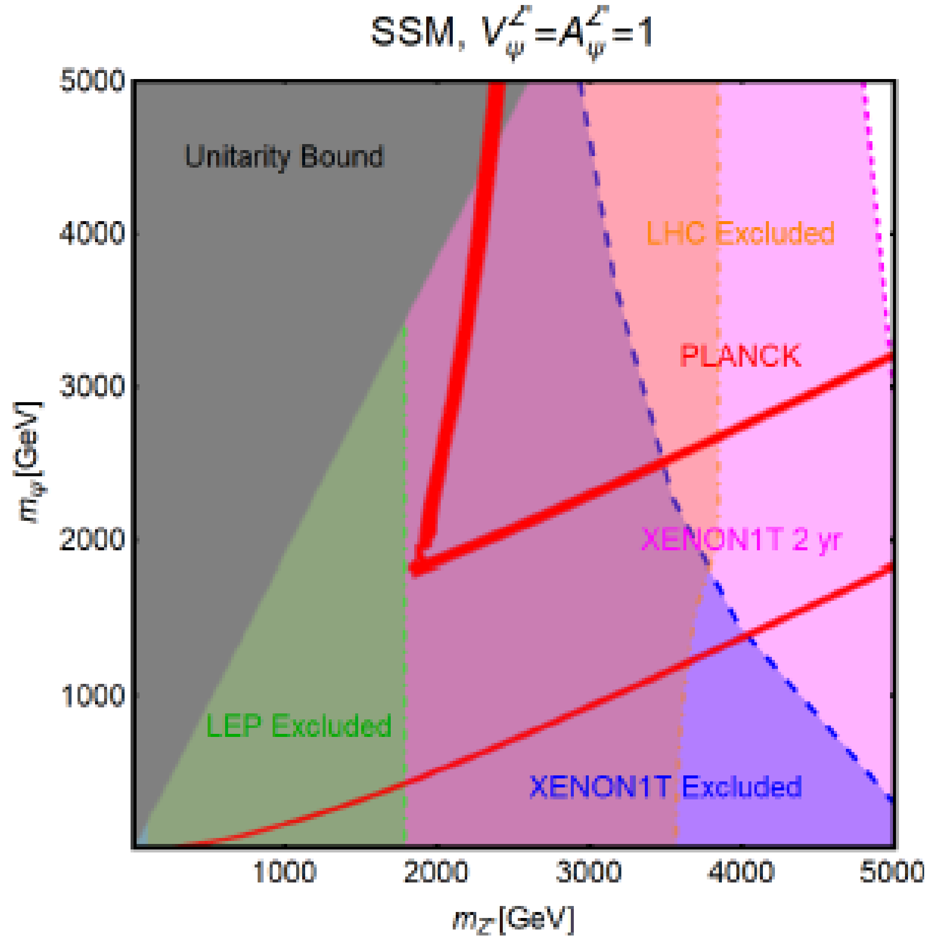
Arcadi et al. 1703.07364

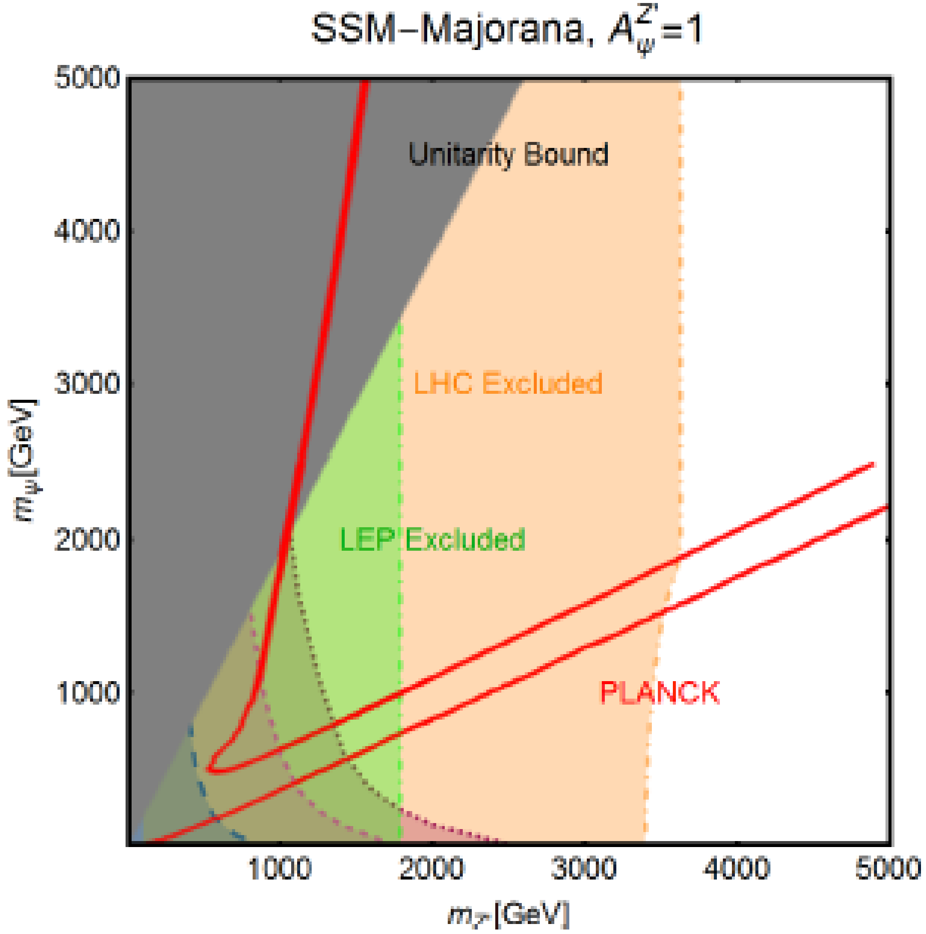






Vector mediator





Achieve sizable DM annihilation cross-section with suppressed scattering cross-section on nuclei (not exhaustive list):

- Accidental cancellations (“Blind Spots“)
- “Natural “ suppression of the scattering cross-section, e.g. dependence on the momentum transfer (radiative corrections can be relevant though)
- Break of the correlation between Direct Detection and relic density, i.e. presence of additional annihilation channels do not influencing Direct Detection.

CP-violation is required

DM bilinear	SM fermion bilinear			
fermion DM	$\bar{f}f$	$\bar{f}\gamma^5 f$	$\bar{f}\gamma^\mu f$	$\bar{f}\gamma^\mu\gamma^5 f$
$\bar{\chi}\chi$	$\sigma v \sim v^2,\ \sigma_{SI} \sim 1$	$\sigma v \sim v^2,\ \sigma_{SD} \sim q^2$	—	—
$\bar{\chi}\gamma^5\chi$	$\sigma v \sim 1,\ \sigma_{SI} \sim q^2$	$\sigma v \sim 1,\ \sigma_{SD} \sim q^4$	—	—
$\bar{\chi}\gamma^\mu\chi$ (Dirac only)	—	—	$\sigma v \sim 1,\ \sigma_{SI} \sim 1$	$\sigma v \sim 1,\ \sigma_{SD} \sim v_\perp^2$
$\bar{\chi}\gamma^\mu\gamma^5\chi$	—	—	$\sigma v \sim v^2,\ \sigma_{SI} \sim v_\perp^2$	$\sigma v \sim 1,\ \sigma_{SD} \sim 1$

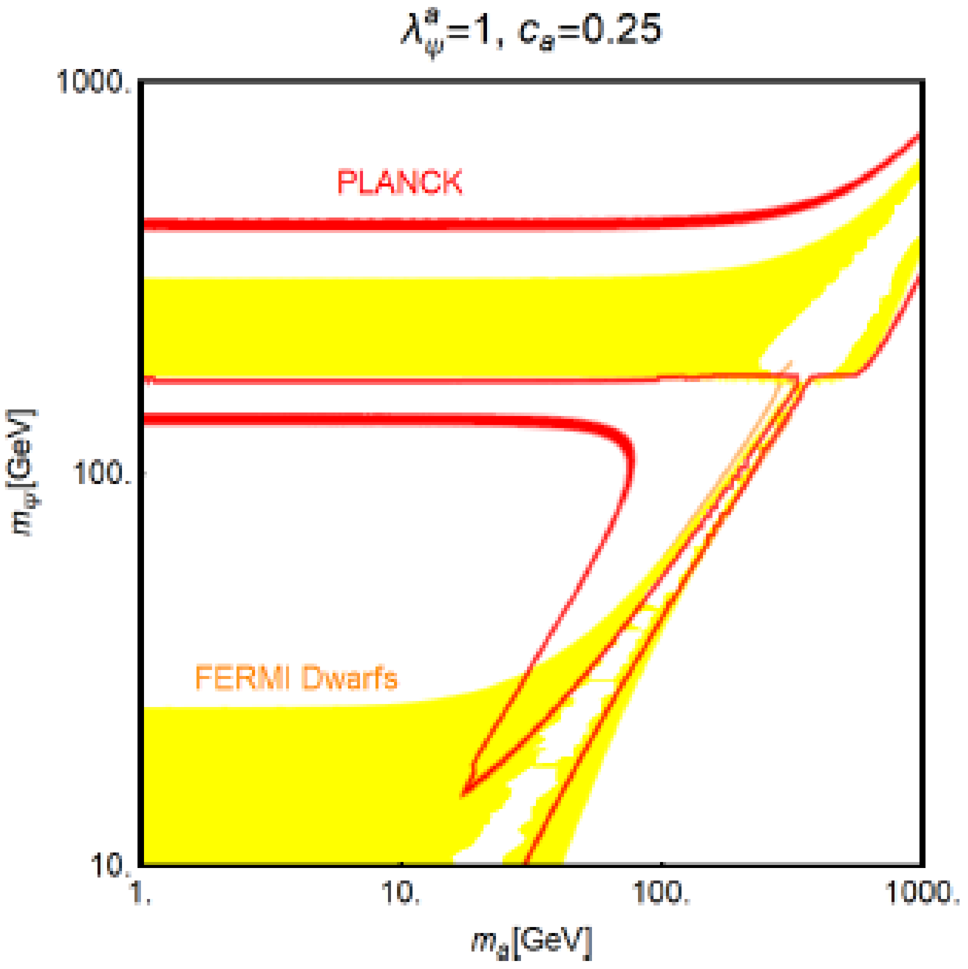
Radiative corrections relevant

DM bilinear	SM fermion bilinear			
scalar DM	$\bar{f}f$	$\bar{f}\gamma^5 f$	$\bar{f}\gamma^\mu f$	$\bar{f}\gamma^\mu\gamma^5 f$
$\phi^\dagger\phi$	$\sigma v \sim 1,\ \sigma_{SI} \sim 1$	$\sigma v \sim 1,\ \sigma_{SD} \sim q^2$	—	—
$\phi^\dagger\overleftrightarrow{\partial_\mu}\phi$ (complex only)	—	—	$\sigma v \sim v^2,\ \sigma_{SI} \sim 1$	$\sigma v \sim v^2,\ \sigma_{SD} \sim v_\perp^2$
vector DM	$\bar{f}f$	$\bar{f}\gamma^5 f$	$\bar{f}\gamma^\mu f$	$\bar{f}\gamma^\mu\gamma^5 f$
$X^\mu X_\mu^\dagger$	$\sigma v \sim 1,\ \sigma_{SI} \sim 1$	$\sigma v \sim 1,\ \sigma_{SD} \sim q^2$	—	—
$X^\nu\partial_\nu X_\mu^\dagger$	—	—	$\sigma v \sim v^2,\ \sigma_{SI} \sim q^2 \cdot v_\perp^2$	$\sigma v \sim v^2,\ \sigma_{SD} \sim q^2$

(Berlin et al 1404.0022)

(Light) Pseudoscalar mediator

$$\mathscr{L} = -i\lambda_\psi^a \overline{\psi}\gamma_5\psi a - i\sum_f \frac{c_a}{\sqrt{2}}\frac{m_f}{v_h}\overline{f}\gamma_5 f a.$$



(see also Arina et al 1406.5542, Bauer et al. 1701.07427,1712.06597)

s-wave cross-section into SM fermions

$$\langle\sigma v\rangle(\overline{\psi}\psi \to \overline{f}f) \approx \sum_f \frac{n_c^f c_a^2 (\lambda_\psi^a)^2}{2\pi}\frac{m_f^2}{v_h^2} \times \begin{cases} \frac{m_\psi^2}{m_a^4} \text{ for } m_\psi < m_a \\ \frac{1}{16 m_\psi^2} \text{ for } m_\psi > m_a \end{cases}$$

$$\langle\sigma v\rangle(\overline{\psi}\psi \to aa) \approx \frac{(\lambda_\psi^a)^2}{192\pi m_\psi^2} v^2$$

Scattering cross-section on nuclei suppressed (at tree level) by the fourth power of momentum transfer.

Tree level DM scattering cross-section suppressed

For a review Cirelli et al arXiv:1307.5955

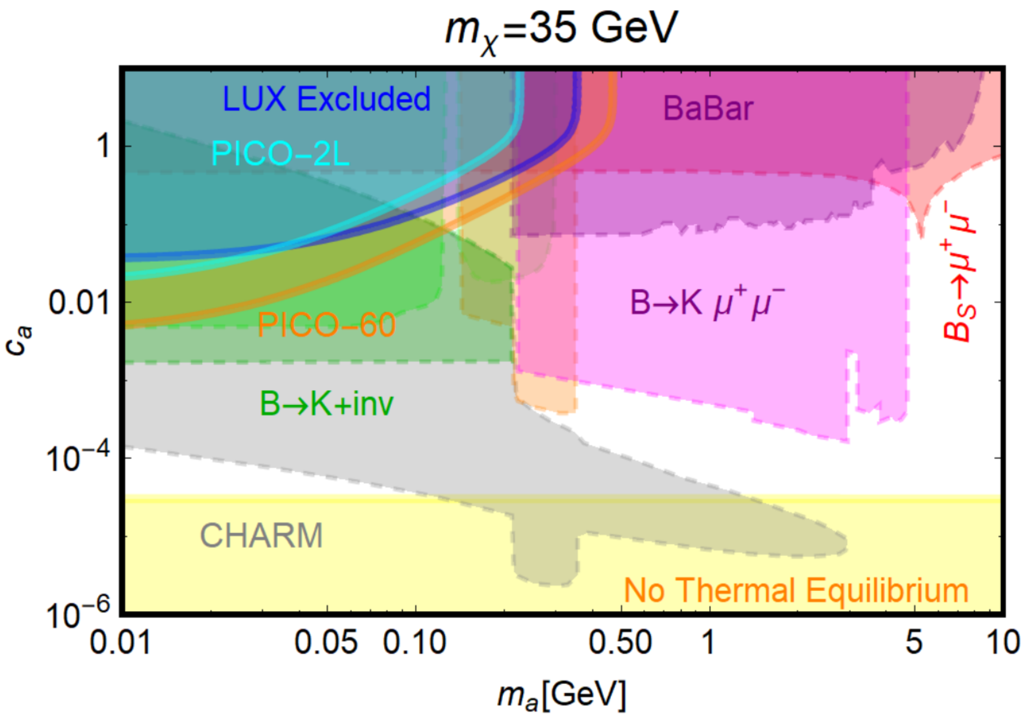
$$\mathcal{L} = g_\chi \bar{\chi}\gamma_5 \chi a + c_a \frac{m_q}{v_h}\bar{q}\gamma_5 q a \longrightarrow \frac{4 g_\chi c_a g_N}{m_a^2}\mathcal{O}_6^{\rm NR}$$

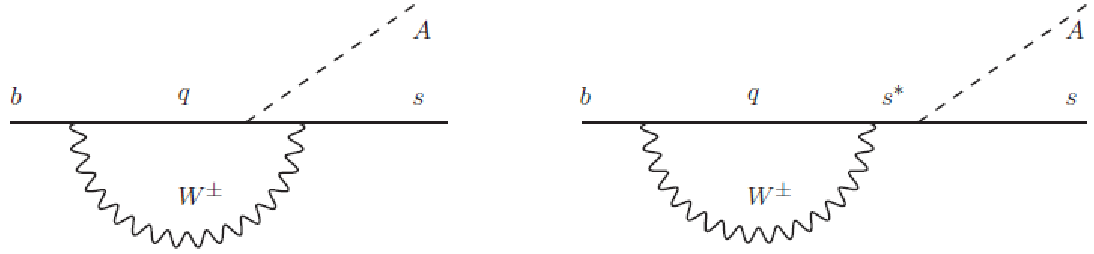
$$\mathcal{O}_6^{\rm NR} = (\vec{s_\chi}\cdot\vec{q})(\vec{s_N}\cdot\vec{q})$$

$$\frac{d\sigma}{dE_T} = \frac{g_\chi^2 c_a^2}{128\pi}\frac{q^2}{m_a^2}\frac{m_T^2}{m_\chi m_N}\frac{1}{v_E^2}\sum_{N,N'} F_{\Sigma''}^{NN'}(q^2)$$

$$g_N = \sum_{q=u,d,s}\frac{m_N}{v_h}\left(1-\frac{\overline{m}}{m_q}\right)\Delta_q^N$$

$$\overline{m} = (1/m_u + 1/m_d + 1/m_s)^{-1}$$



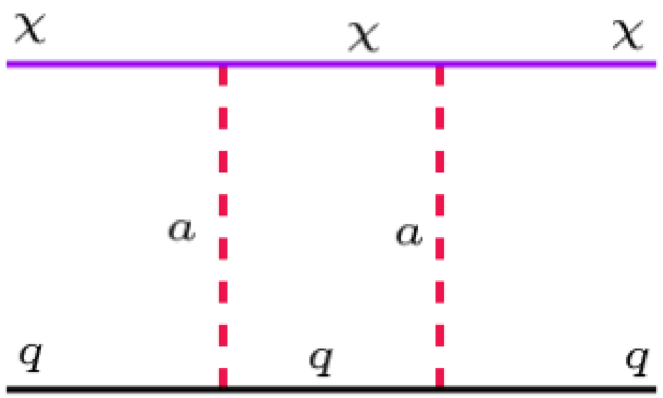


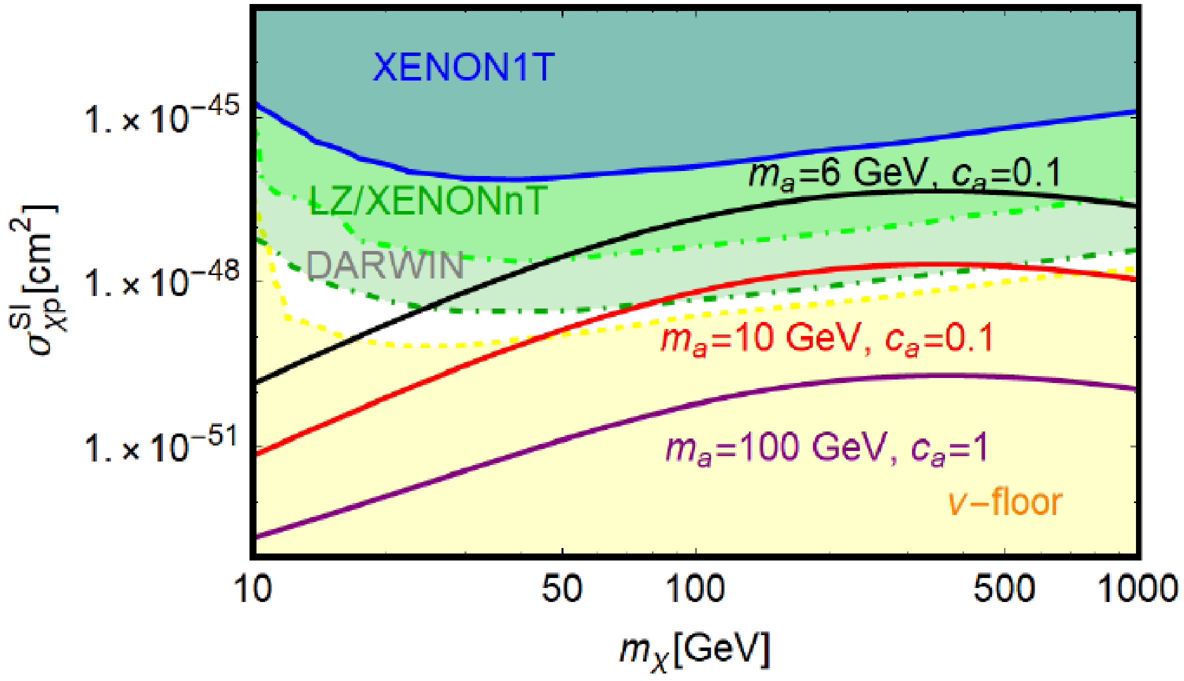
Dolan et al. arXiv:1412.5174
Döbrich et al. arXiv:1810.11336

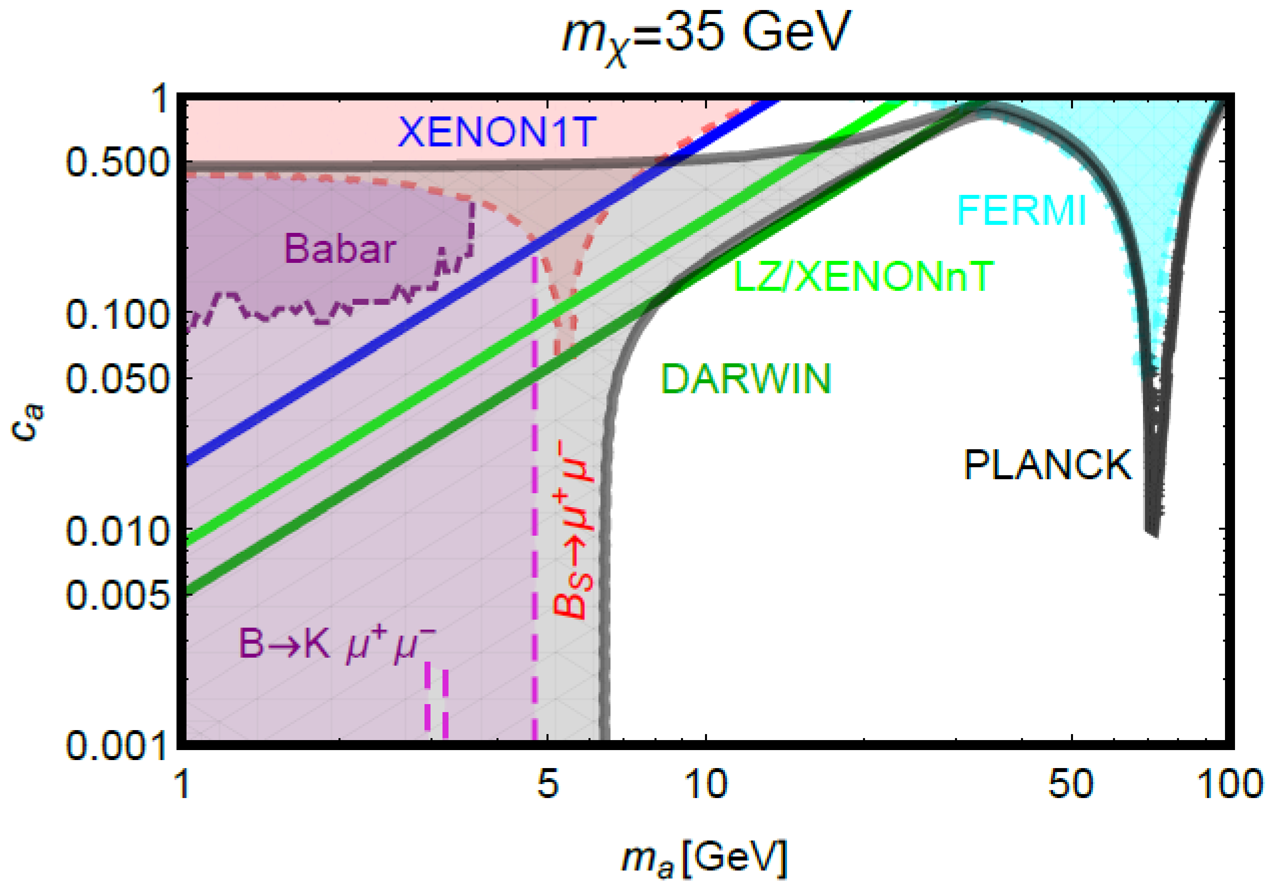
Table from Dolan et al. arXiv:1412.5174

Channel	Experiment	Mass range [MeV]	Ref.	Relevant for
$K^+ \to \pi^+ + \text{inv}$	E949	0–110	[70]	Long lifetime*
		150–260	[71]	Long lifetime*
	E787	0–110 & 150–260	[72]	Long lifetime
$K^+ \to \pi^+\pi^0 \to \pi^+\nu\bar{\nu}$	E949	130–140	[73]	Long lifetime*
$K^+ \to \pi^+ e^+e^-$	NA48/2	140–350	[74]	Leptonic decays
$K_L \to \pi^0 e^+e^-$	KTeV/E799	140–350	[75]	Leptonic decays*
$K^+ \to \pi^+ \mu^+\mu^-$	NA48/2	210–350	[76]	Leptonic decays
$K_L \to \pi^0 \mu^+\mu^-$	KTeV/E799	210–350	[77]	Leptonic decays*
$K_L \to \pi^0 \gamma\gamma$	KTeV	40–100 & 160–350	[78]	Photonic decays*
$K_L \to \pi^0\pi^0 \to 4\gamma$	KTeV	130–140	[79]	Photonic decays*
$K^+ \to \pi^+ A$	$K_{\mu 2}$	10–130 & 140–300	[80]	All decay modes*
$B^0 \to K_S^0 + \text{inv}$	CLEO	0–1100	[81]	Long lifetime*
$B \to K\,\ell^+\ell^-$	BaBar	30–3000	[82]	Leptonic decays
	BELLE	140–3000	[83]	Leptonic decays
	LHCb	220–4690	[84]	Leptonic decays*
$B \to X_s\,\mu^+\mu^-$	BELLE	210–3000	[85]	Leptonic decays
$b \to s\,g$	CLEO	$m_A < m_B - m_K$	[86]	Hadronic decays*
$B_s \to \mu^+\mu^-$	LHCb/CMS	all masses	[87, 88]	Lepton couplings*
$\Upsilon \to \gamma\,\tau^+\tau^-$	BaBar	3500–9200	[89]	Leptonic decays*
$\Upsilon \to \gamma\,\mu^+\mu^-$	BaBar	212–9200	[90]	Leptonic decays*
$\Upsilon \to \gamma + \text{hadrons}$	BaBar	300–7000	[91]	Hadronic decays*
$K,\,B \to A + X$	CHARM	0–4000	[92]	Leptonic and photonic decays*

SI cross-section induced at the loop level







m_χ=35 GeV
XENON1T
Babar
FERMI
LZ/XENONnT
DARWIN
PLANCK
$B_S \to \mu^+\mu^-$
$B \to K\ \mu^+\mu^-$
1
0.500
0.100
0.050
0.010
0.005
0.001
c_a
1
5
10
50
100
m_a [GeV]

2HDM

Can a light pseudoscalar be accommodated in the 2HDM ?

$$V(H_1,H_2) = m_{11}^2 H_1^\dagger H_1 + m_{22}^2 H_2^\dagger H_2 - m_{12}^2\left(H_1^\dagger H_2 + \text{h.c.}\right) + \frac{\lambda_1}{2}\left(H_1^\dagger H_1\right)^2 + \frac{\lambda_2}{2}\left(H_2^\dagger H_2\right)^2 + \lambda_3\left(H_1^\dagger H_1\right)\left(H_2^\dagger H_2\right) + \lambda_4\left(H_1^\dagger H_2\right)\left(H_2^\dagger H_1\right) + \frac{\lambda_5}{2}\left[\left(H_1^\dagger H_2\right)^2 + \text{h.c.}\right]$$

$$H_i = \begin{pmatrix} \phi_i^+ \\ (v_i + \rho_i + i\eta_i)/\sqrt{2} \end{pmatrix}$$

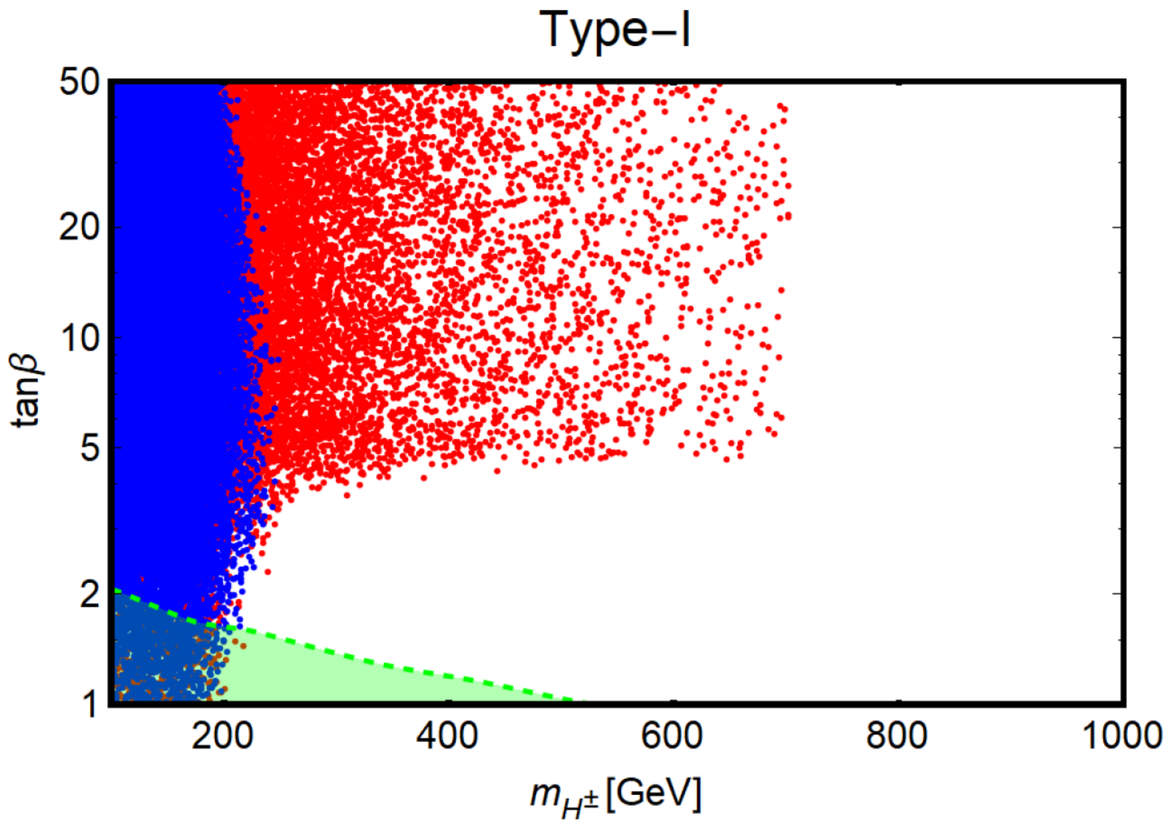
$$\lambda_1 = \frac{1}{v^2}\left[-\tan^2\beta M^2 + \frac{\sin^2\alpha}{\cos^2\beta}m_h^2 + \frac{\cos^2\alpha}{\cos^2\beta}m_H^2\right],$$
$$\lambda_2 = \frac{1}{v^2}\left[-\frac{1}{\tan^2\beta}M^2 + \frac{\cos^2\alpha}{\sin^2\beta}m_h^2 + \frac{\sin^2\alpha}{\sin^2\beta}m_H^2\right],$$
$$\lambda_3 = \frac{1}{v^2}\left[-M^2 + 2m_{H^\pm}^2 + \frac{\sin 2\alpha}{\sin 2\beta}(m_H^2 - m_h^2)\right],$$
$$\lambda_4 = \frac{1}{v^2}\left[M^2 + m_A^2 - 2m_{H^\pm}^2\right],$$
$$\lambda_5 = \frac{1}{v^2}\left[M^2 - m_A^2\right],$$

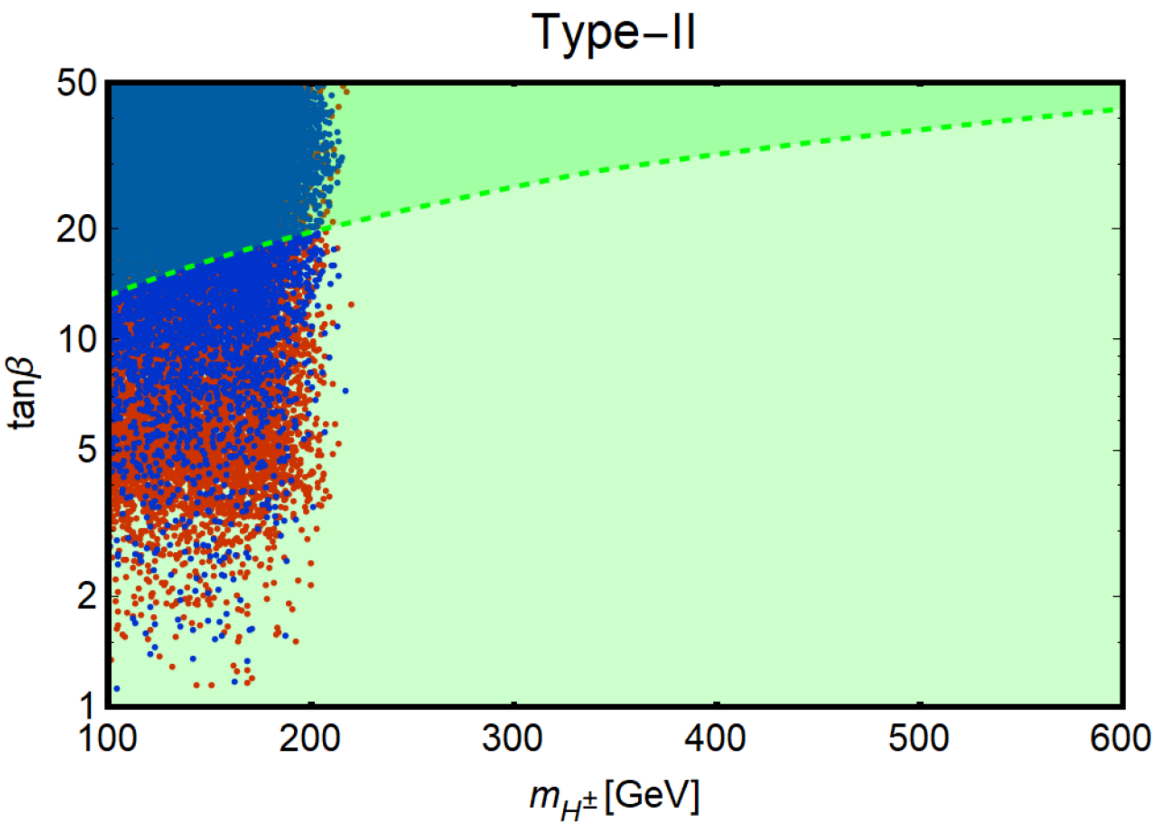
$$\begin{pmatrix} \phi_1^+ \\ \phi_2^+ \end{pmatrix} = \begin{pmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{pmatrix}\begin{pmatrix} G^+ \\ H^+ \end{pmatrix}$$
$$\begin{pmatrix} \eta_1 \\ \eta_2 \end{pmatrix} = \begin{pmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{pmatrix}\begin{pmatrix} G^0 \\ A \end{pmatrix}$$
$$\begin{pmatrix} \rho_1 \\ \rho_2 \end{pmatrix} = \begin{pmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{pmatrix}\begin{pmatrix} H \\ h \end{pmatrix}$$

$$-\mathcal{L}_{yuk}^{SM} = \sum_{f=u,d,l} \frac{m_f}{v} \left[\xi_h^f \overline{f} f h + \xi_H^f \overline{f} f H - i \xi_A^f \overline{f} \gamma_5 f A \right]$$

$$- \left[\frac{\sqrt{2}}{v} \overline{u} \left(m_u \xi_A^u P_L + m_d \xi_A^d P_R \right) d H^+ + \frac{\sqrt{2}}{v} m_l \xi_A^l \overline{\nu_L} l_R H^+ + \text{h.c.} \right],$$

	Type I	Type II	Lepton-specific	Flipped
ξ_h^u	c_α/s_β	$c_\alpha/s_\beta \to 1$	$c_\alpha/s_\beta \to 1$	$c_\alpha/s_\beta \to 1$
ξ_h^d	$c_\alpha/s_\beta \to 1$	$-s_\alpha/c_\beta \to 1$	$c_\alpha/s_\beta \to 1$	$-s_\alpha/c_\beta \to 1$
ξ_h^l	$c_\alpha/s_\beta \to 1$	$-s_\alpha/c_\beta \to 1$	$-s_\alpha/c_\beta \to 1$	$c_\alpha/s_\beta \to 1$
ξ_H^u	$s_\alpha/s_\beta \to -t_\beta^{-1}$	$s_\alpha/s_\beta \to -t_\beta^{-1}$	$s_\alpha/s_\beta \to -t_\beta^{-1}$	$s_\alpha/s_\beta \to -t_\beta^{-1}$
ξ_H^d	$s_\alpha/s_\beta \to -t_\beta^{-1}$	$c_\alpha/c_\beta \to t_\beta$	$s_\alpha/s_\beta \to -t_\beta^{-1}$	$c_\alpha/c_\beta \to t_\beta$
ξ_H^l	$s_\alpha/s_\beta \to -t_\beta^{-1}$	$c_\alpha/c_\beta \to t_\beta$	$c_\alpha/c_\beta \to t_\beta$	$s_\alpha/s_\beta \to -t_\beta^{-1}$
ξ_A^u	t_β^{-1}	t_β^{-1}	t_β^{-1}	t_β^{-1}
ξ_A^d	$-t_\beta^{-1}$	t_β	$-t_\beta^{-1}$	t_β
ξ_A^l	$-t_\beta^{-1}$	t_β	t_β	$-t_\beta^{-1}$


Type–I
50
20
10
5
2
1
tanβ
200
400
600
800
1000
$m_{H^\pm}$ [GeV]


Type–II
50
20
10
5
2
1
tanβ
100
200
300
400
500
600
$m_{H^\pm}$ [GeV]

60 GeV $<m_A<m_h$

The Dark Matter is a mixture of a SM singlet and two (Weyl) fermions doublets under SU(2)

$$\mathcal{L} = -\frac{1}{2} M_N N'^2 - M_L L_L L_R - y_i^L L_L H_i N' - y_i^R \bar{N}' \tilde{H}_i^\dagger L_R + \text{h.c.}, \quad i = 1, 2$$

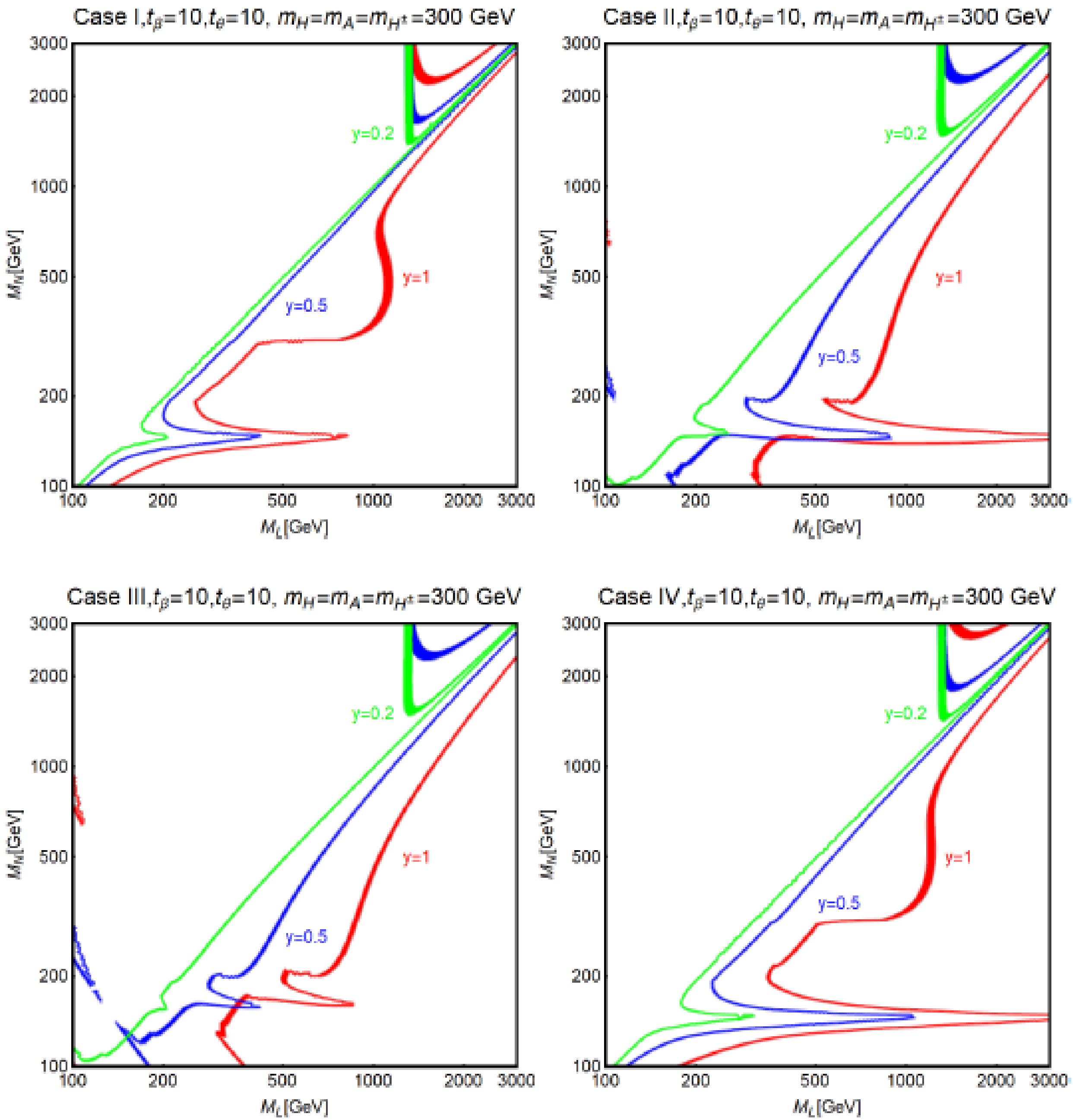
$$y_1 = y \cos\theta \quad y_2 = y \sin\theta$$

$$M = \begin{pmatrix} M_N & \frac{y_1 v_1}{\sqrt{2}} & \frac{y_2 v_2}{\sqrt{2}} \\ \frac{y_1 v_1}{\sqrt{2}} & 0 & M_L \\ \frac{y_2 v_2}{\sqrt{2}} & M_L & 0 \end{pmatrix} \longrightarrow \psi_i = N' U_{i1} + N_L U_{i2} + N_R U_{i3}$$

$$\mathcal{L} = \overline{\psi^-} \gamma^\mu \left(g^V_{W\chi_i} - g^A_{W\chi_i} \gamma_5\right) \psi_i W^-_\mu + \text{h.c.} \quad + \frac{1}{2} \sum_{i,j=1}^{3} \overline{\psi_i} \gamma^\mu \left(g^V_{Z\psi_i\psi_j} - g^A_{Z\psi_i\psi_j} \gamma_5\right) Z_\mu \psi_j$$

$$+ \frac{1}{2} \sum_{i,j=1}^{3} \overline{\psi_i} \left(y_{h\psi_i\psi_j} h + y_{H\psi_i\psi_j} H + y_{A\psi_i\psi_j} \gamma_5 A\right) \psi_j + \text{h.c} \quad + \overline{\psi^-} \left(g^S_{H^\pm\psi_i} - g^P_{H^\pm\psi_i} \gamma_5\right) \psi_i H^- + \text{h.c.}$$

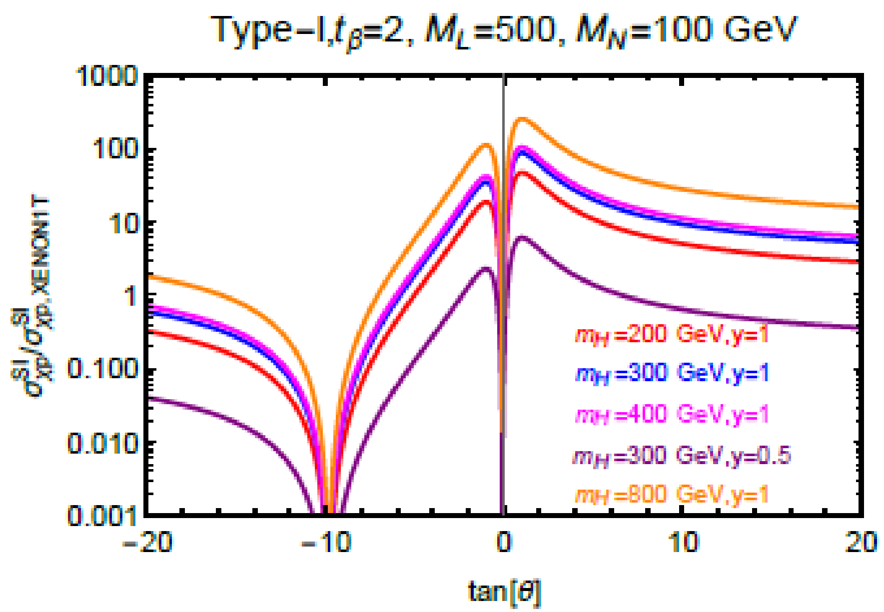
$$- e A_\mu \overline{\psi^-} \gamma^\mu \psi^- - \frac{g}{2\cos\theta_W} (1 - 2\sin^2\theta_W) Z_\mu \overline{\psi^-} \gamma^\mu \psi^- + \text{h.c.}$$


Case I, t_β=10, t_θ=10, m_H=m_A=$m_{H^\pm}$=300 GeV
Case II, t_β=10, t_θ=10, m_H=m_A=$m_{H^\pm}$=300 GeV
Case III, t_β=10, t_θ=10, m_H=m_A=$m_{H^\pm}$=300 GeV
Case IV, t_β=10, t_θ=10, m_H=m_A=$m_{H^\pm}$=300 GeV
M_N[GeV]
M_L[GeV]
y=0.2
y=0.5
y=1
100
200
500
1000
2000
3000

Exchange of CP-even Higgses induces SI cross-section.

Limits can be avoided in presence of the so called Blind Spots.

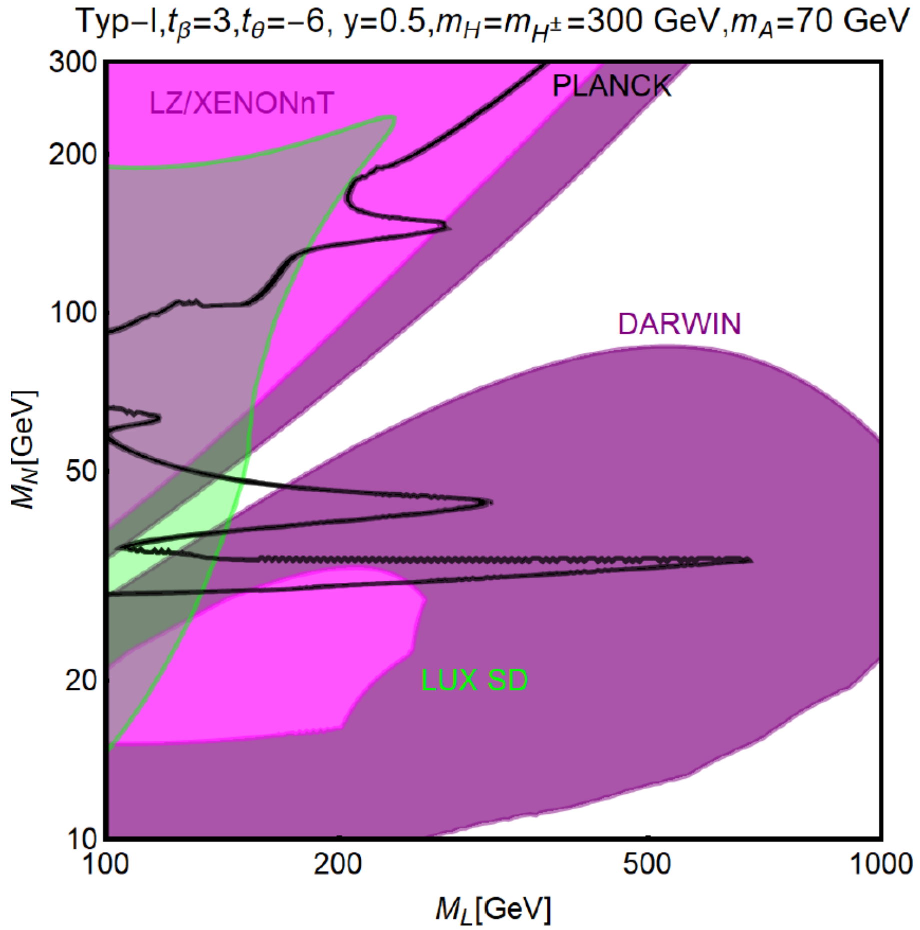
$$\sigma_{\chi p}^{\rm SI} = \frac{\mu_\chi^2}{\pi}\frac{m_p^2}{v^2}\left|\sum_q f_q \left(\frac{g_{h\psi_1\psi_1}\xi_h^q}{m_h^2} + \frac{g_{H\psi_1\psi_1}\xi_H^q}{m_H^2}\right)\right|^2$$

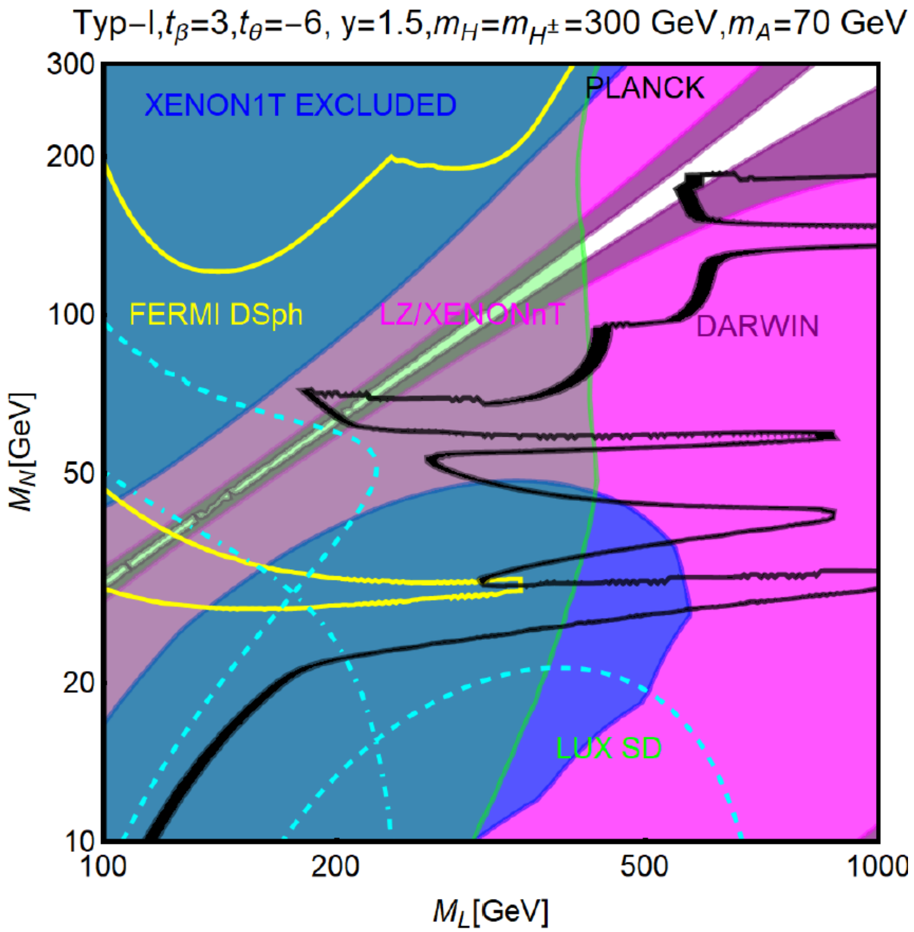


In case the new fermions couple with only one doublet

$$g_{h\psi_1\psi_1} = y^2 v \cos^2\beta \frac{m_{\psi_1} + M_L \sin 2\theta}{2M_L^2 + 4M_N m_{\psi_1} - 6m_{\psi_1}^2 + y^2 v^2 \cos^2\beta}$$

$$g_{H\psi_1\psi_1} = \frac{1}{2} y^2 v \sin 2\beta \frac{m_{\psi_1} + M_L \sin 2\theta}{2M_L^2 + 4M_N m_{\psi_1} - 6m_{\psi_1}^2 + y^2 v^2 \cos^2\beta}$$


Typ–I,t_β=3,t_θ=–6, y=0.5,m_H=$m_{H^\pm}$=300 GeV,m_A=70 GeV
LZ/XENONnT
PLANCK
DARWIN
LUX SD
M_N[GeV]
M_L[GeV]


Typ–I,t_β=3,t_θ=–6, y=1.5,m_H=$m_{H^\pm}$=300 GeV,m_A=70 GeV
XENON1T EXCLUDED
PLANCK
FERMI DSph
LZ/XENONnT
DARWIN
LUX SD
M_N[GeV]
M_L[GeV]

2HDM+Light Pseudoscalar

- DM can be a pure SM singlet.
- Higher hierarchy between the lighter pseudoscalar and the other new boson (not arbitrary because of unitarity bound).

$$V = V_{\rm 2HDM} + \frac{1}{2} m_{a_0} a_0^2 + \frac{\lambda_a}{4} a_0^4 + \left(i \kappa a_0 H_1^\dagger H_2 + \text{h.c.} \right)$$

$$\mathcal{L} = i g_\chi a_0 \bar{\chi} i \gamma^5 \chi$$

$$\begin{pmatrix} A_0 \\ a_0 \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} A \\ a \end{pmatrix}$$

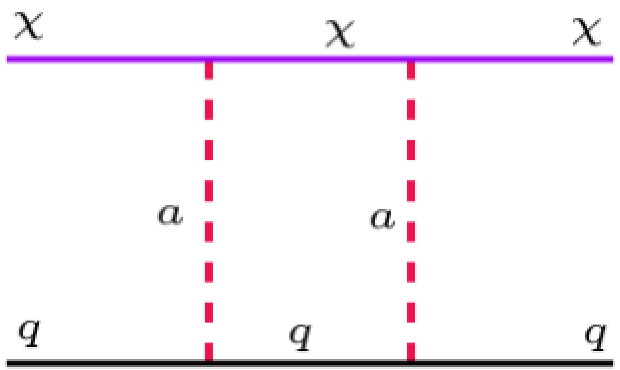
$$\tan 2\theta = \frac{2 \kappa v_h}{m_{A_0}^2 - m_{a_0}^2}$$

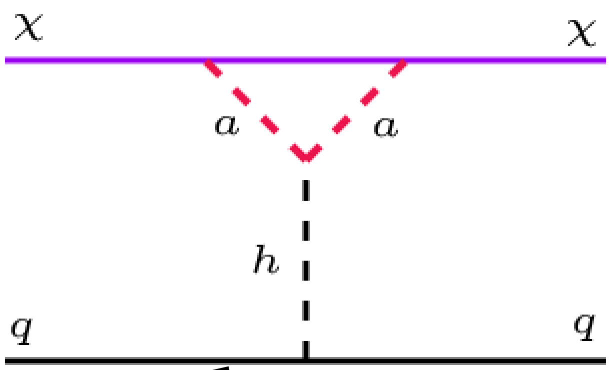
$$\mathcal{L}_{\rm DM} = g_\chi \left(\cos\theta a + \sin\theta A\right)\bar{\chi} i\gamma_5 \chi$$

$$\mathcal{L}_{\rm scalar} = \frac{1}{2 v_h}\left(m_A^2 - m_a^2\right)\left[\sin 4\theta a A + \sin^2 2\theta \left(A^2 - a^2\right)\right]\left(\sin(\beta-\alpha) h + \cos(\beta-\alpha) H\right)$$

$$\mathcal{L}_{\rm Yuk} = \sum_f \frac{m_f}{v_h}\left(\xi_f^h h \bar{f} f + \xi_f^H H \bar{f} f - i\xi_f^A A \bar{f}\gamma_5 f - i\xi_f^a a \bar{f}\gamma_5 a\right)$$

SI cross-section induced at the loop level





(see also 1803.01574)

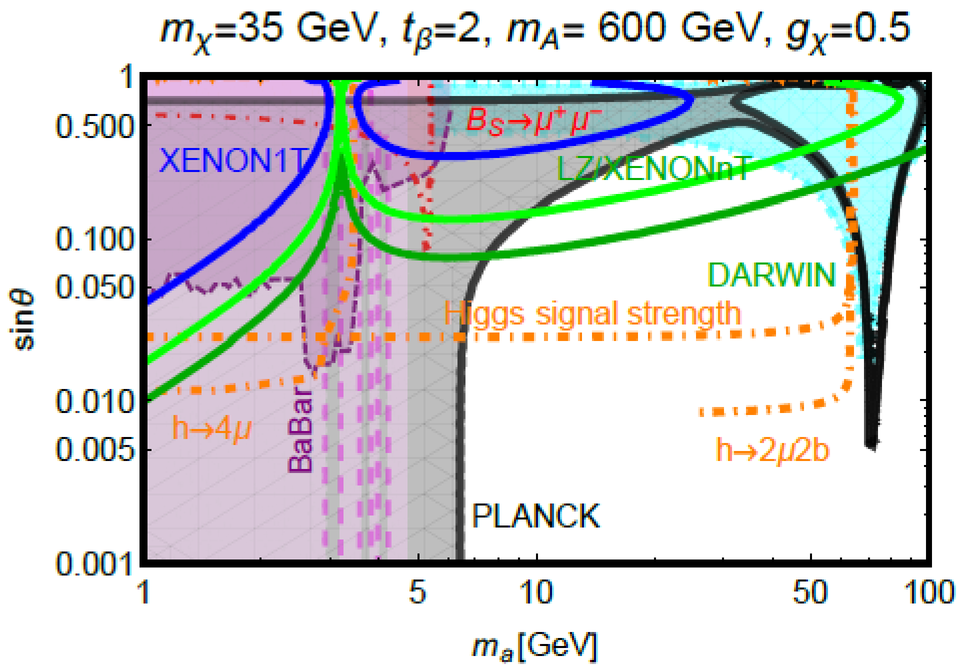
Computation recently superseded by Abe et al arXiv:1810.01039

$$\mathcal{L} = g_\chi^2 \sum_q C_{V,q} \bar{\chi}\gamma^\mu \chi \bar{q}\gamma_\mu q + C_{S,q}\bar{\chi}\chi\bar{q}q$$

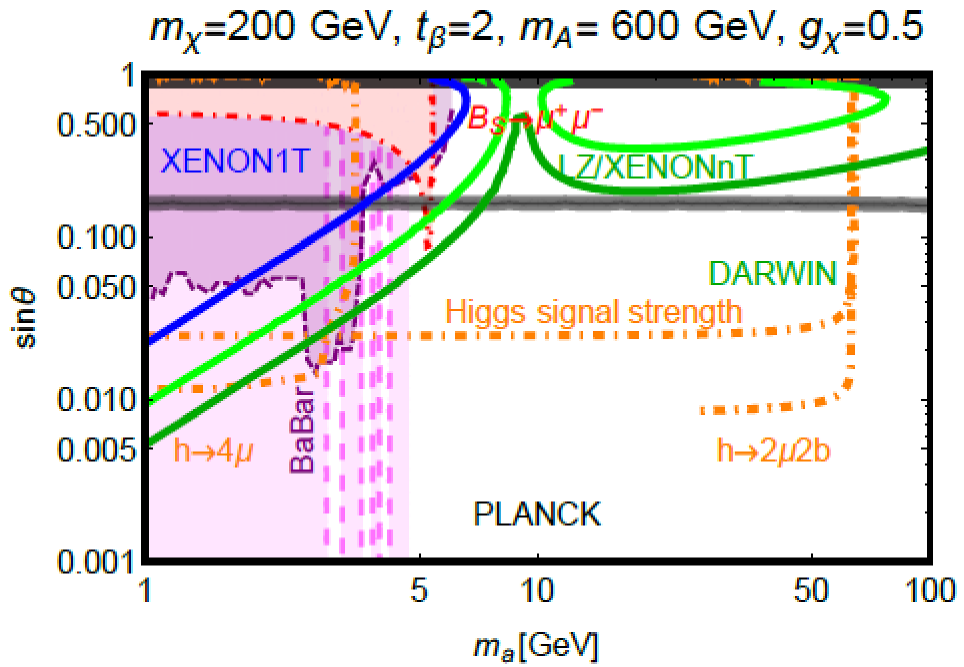
Neglible for yukawa like interactions

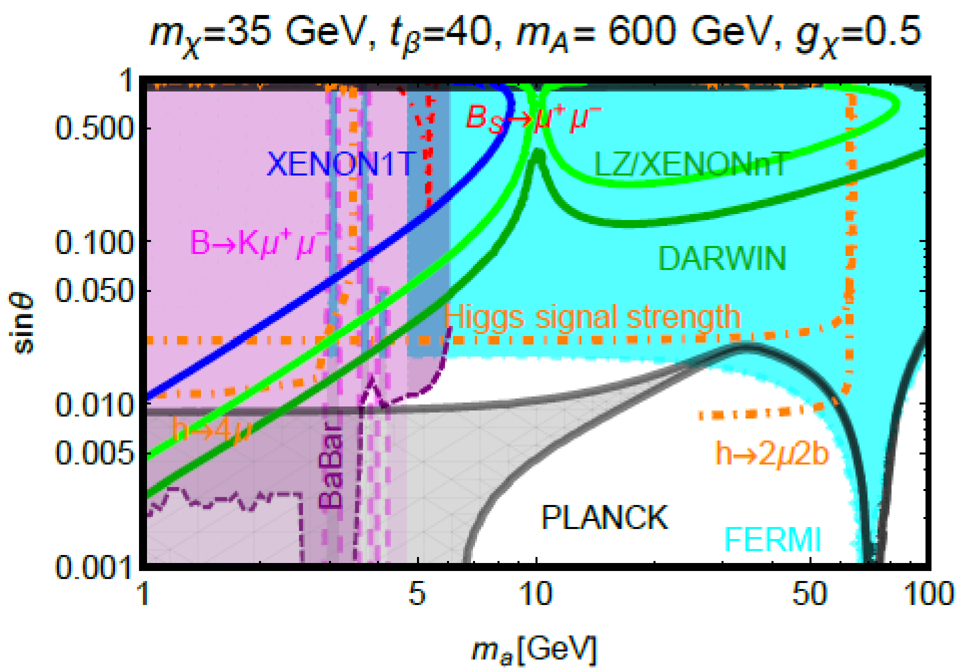
$$\sigma_{\chi p}^{\rm SI} = \frac{\mu_{\chi p}^2}{\pi} g_\chi^4 |F_l(m_\chi, m_a, m_h, m_q)|^2$$

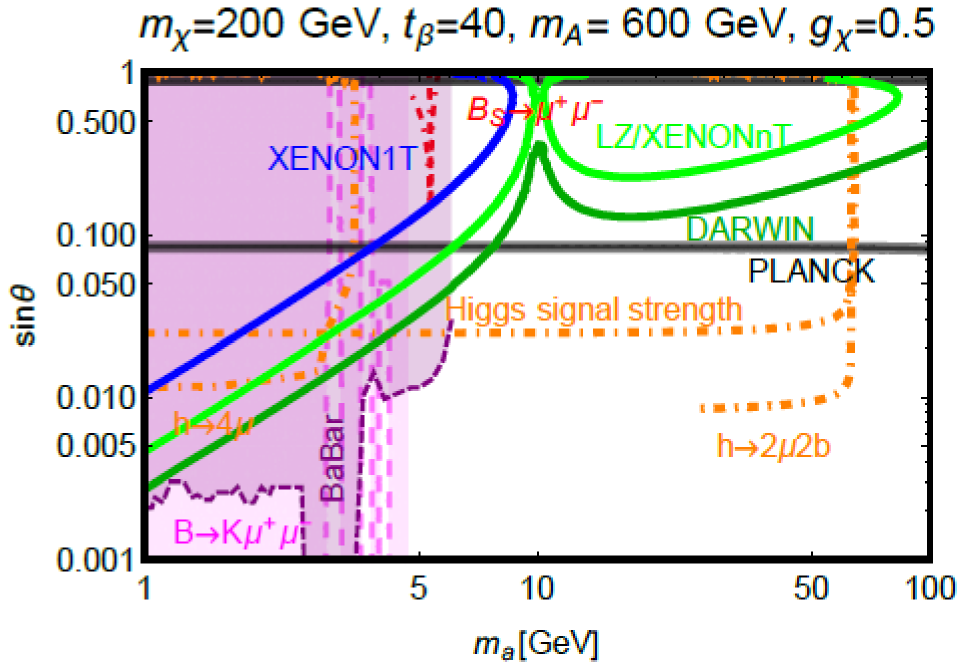
$$F_l(m_\chi, m_a, m_h, m_q) = \frac{2}{27} f_{\rm TG} \sum_{q \in heavy} \frac{m_q m_p}{v_h^2} \left(C_{S,q,\rm triangle} + C_{S,q,\rm box}\right)$$

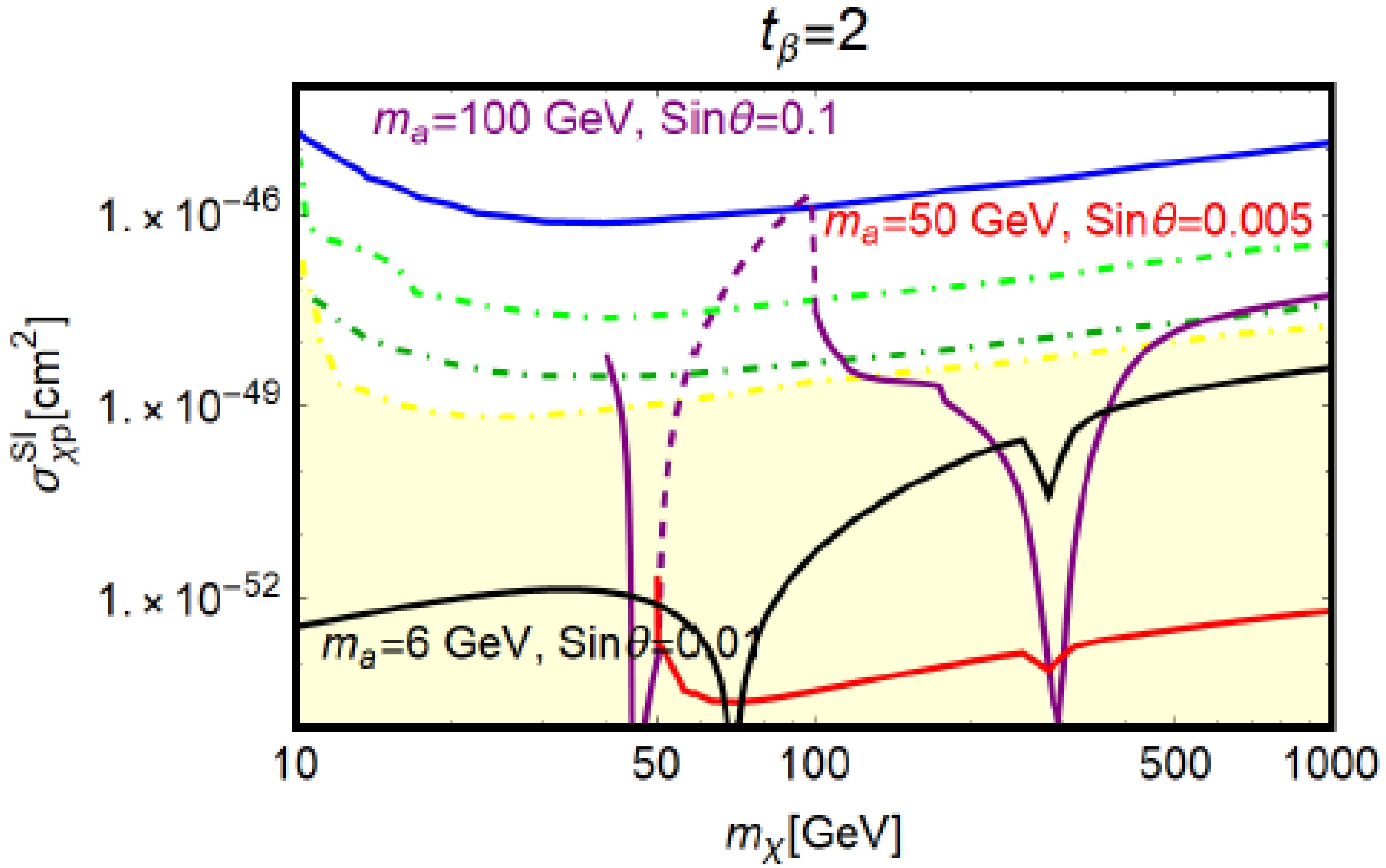


G.A., M. Lindner, F. Queiroz, W. Rodejohann, S. Vogl
arXiv:1711.02110




m_χ=35 GeV, t_β=40, m_A= 600 GeV, g_χ=0.5
$B_s\to\mu^+\mu^-$
XENON1T
LZ/XENONnT
$B\to K\mu^+\mu^-$
DARWIN
Higgs signal strength
$h\to 4\mu$
BaBar
$h\to 2\mu 2b$
PLANCK
FERMI
sinθ
m_a[GeV]


m_χ=200 GeV, t_β=40, m_A= 600 GeV, g_χ=0.5
$B_s\to\mu^+\mu^-$
XENON1T
LZ/XENONnT
DARWIN
PLANCK
Higgs signal strength
$h\to 4\mu$
$h\to 2\mu 2b$
BaBar
$B\to K\mu^+\mu^-$
sinθ
m_a[GeV]



It is possible to have a WIMP model with typical scattering cross-section lying in the so-called 'neutrino floor'

Conclusions

A particularly interesting scenario is the case in which WIMP interactions are mostly mediated by a (possibly light) pseudoscalar field.

We have proposed an overview of possible implementations of this scenario from a simple portal to more refined models.