Connection between Flavor and Dark Matter

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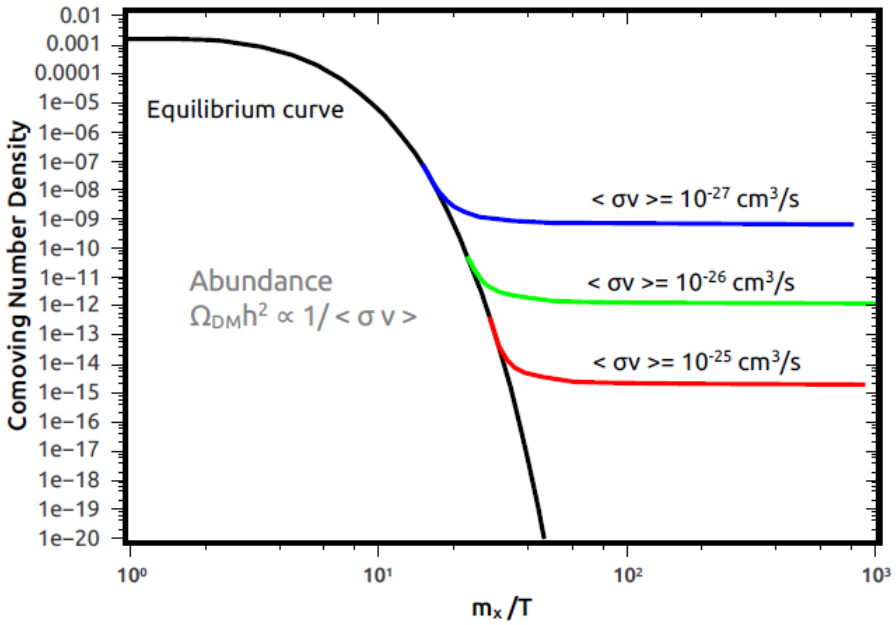
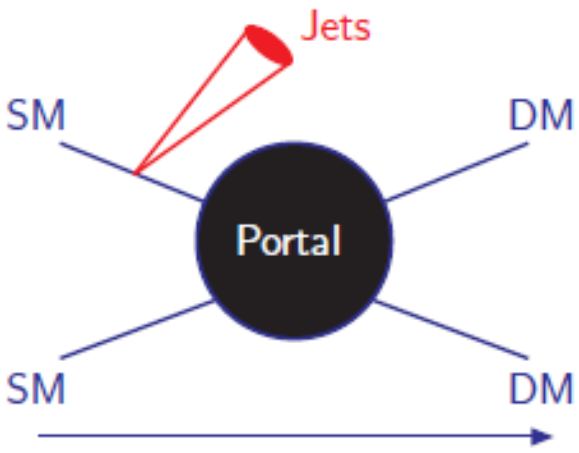
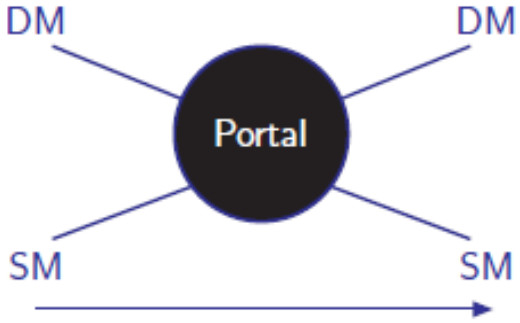
“Portals“

Case of study WIMP DM:





(c) Collider Detection



(a) Direct Detection

$$\langle \sigma v \rangle \approx \frac{\lambda_{DM}^2 \lambda_{SM}^2 m_{DM}^2}{(4\, m_{DM}^2 - m_{Portal}^2)^2} \left(a + \frac{b}{x} \right)$$

$$\approx \frac{\lambda_{DM}^2 \lambda_{SM}^2 m_{DM}^2}{(4\, m_{DM}^2 - m_{Portal}^2)^2} \left(a + \frac{1}{2} b v^2 \right)$$

Interplay with flavor observables

?

Connection between Portals and Flavour Physics

Only through the mediator

(Useful complementarity of flavor constraints especially for light dark sectors)

DM directly involved in flavour processes

DM stability related to flavor (flavored DM)

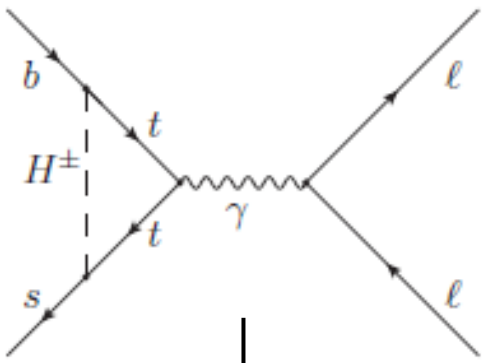
Singlet-doublet DM+ 2HDM

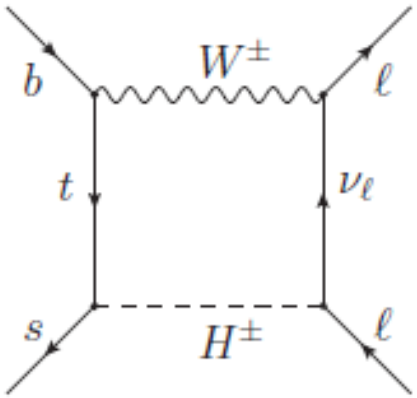
G.A. Eur. Phys. J. C78 (2018) 10, 864

$$-\mathcal{L}_{yuk}^{SM} = \sum_{f=u,d,l} \frac{m_f}{v}\left[\xi_h^f \overline{f} f h + \xi_H^f \overline{f} f H - i\xi_A^f \overline{f}\gamma_5 f A\right]$$
$$-\left[\frac{\sqrt{2}}{v}\overline{u}\left(m_u \xi_A^u P_L + m_d \xi_A^d P_R\right) d H^+ + \frac{\sqrt{2}}{v} m_l \xi_A^l \overline{\nu_L} l_R H^+ + \text{h.c.}\right],$$

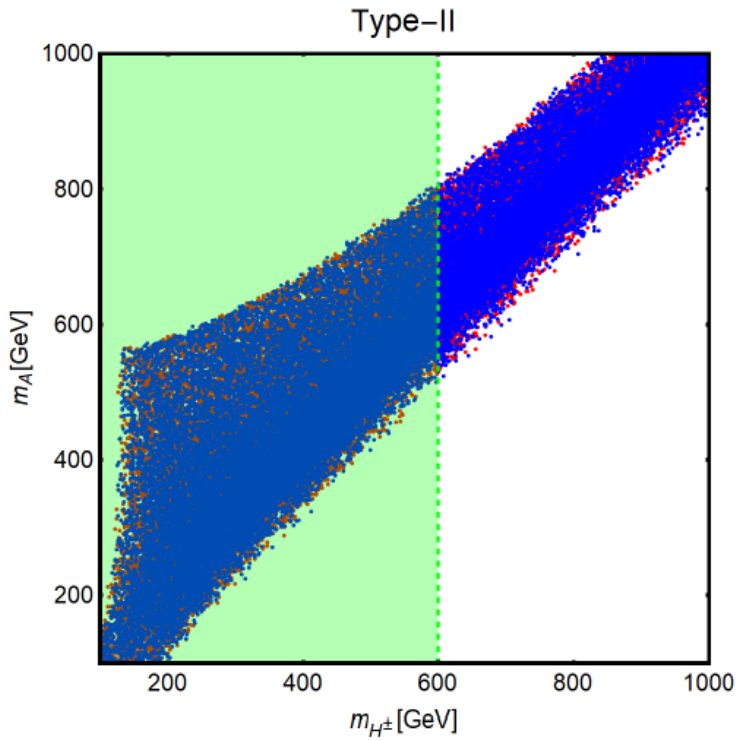
	Type I	Type II	Lepton-specific	Flipped
ξ_h^u	c_α/s_β	$c_\alpha/s_\beta \to 1$	$c_\alpha/s_\beta \to 1$	$c_\alpha/s_\beta \to 1$
ξ_h^d	$c_\alpha/s_\beta \to 1$	$-s_\alpha/c_\beta \to 1$	$c_\alpha/s_\beta \to 1$	$-s_\alpha/c_\beta \to 1$
ξ_h^l	$c_\alpha/s_\beta \to 1$	$-s_\alpha/c_\beta \to 1$	$-s_\alpha/c_\beta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

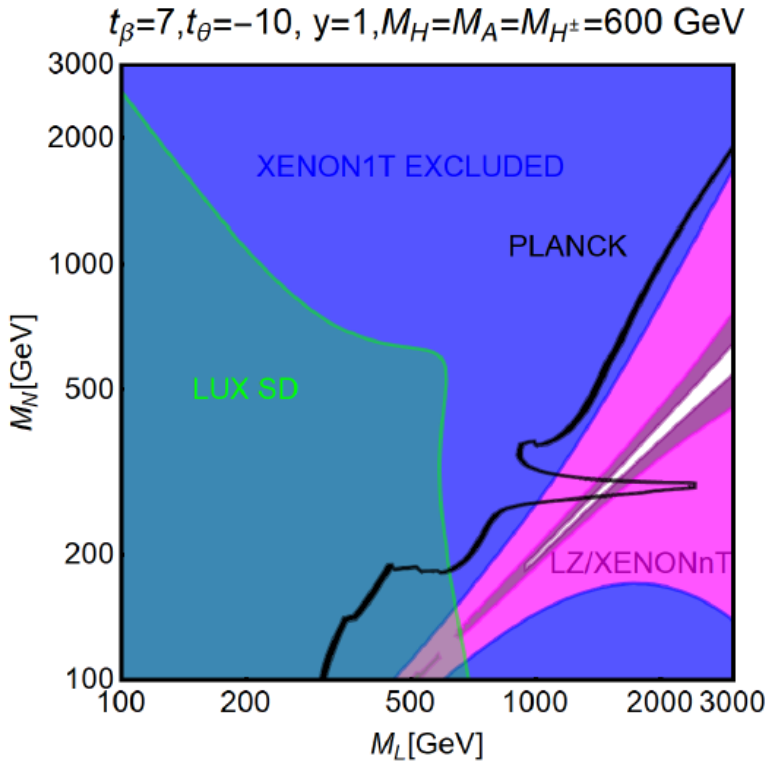
$$\mathcal{L} = \overline{\psi^-}\gamma^\mu\left(g^V_{W\chi_i} - g^A_{W\chi_i}\gamma_5\right)\psi_i W^-_\mu + \text{h.c.}$$
$$+\frac{1}{2}\sum_{i,j=1}^{3}\overline{\psi_i}\gamma^\mu\left(g^V_{Z\psi_i\psi_j} - g^A_{Z\psi_i\psi_j}\gamma_5\right)Z_\mu\psi_j$$
$$+\frac{1}{2}\sum_{i,j=1}^{3}\overline{\psi_i}\left(y_{h\psi_i\psi_j}h + y_{H\psi_i\psi_j}H + y_{A\psi_i\psi_j}\gamma_5 A\right)\psi_j + \text{h.c}$$
$$+\overline{\psi^-}\left(g^S_{H^\pm\psi_i} - g^P_{H^\pm\psi_i}\gamma_5\right)\psi_i H^- + \text{h.c.}$$
$$-eA_\mu\overline{\psi^-}\gamma^\mu\psi^- - \frac{g}{2\cos\theta_W}(1-2\sin^2\theta_W)Z_\mu\overline{\psi^-}\gamma^\mu\psi^- + \text{h.c.}$$

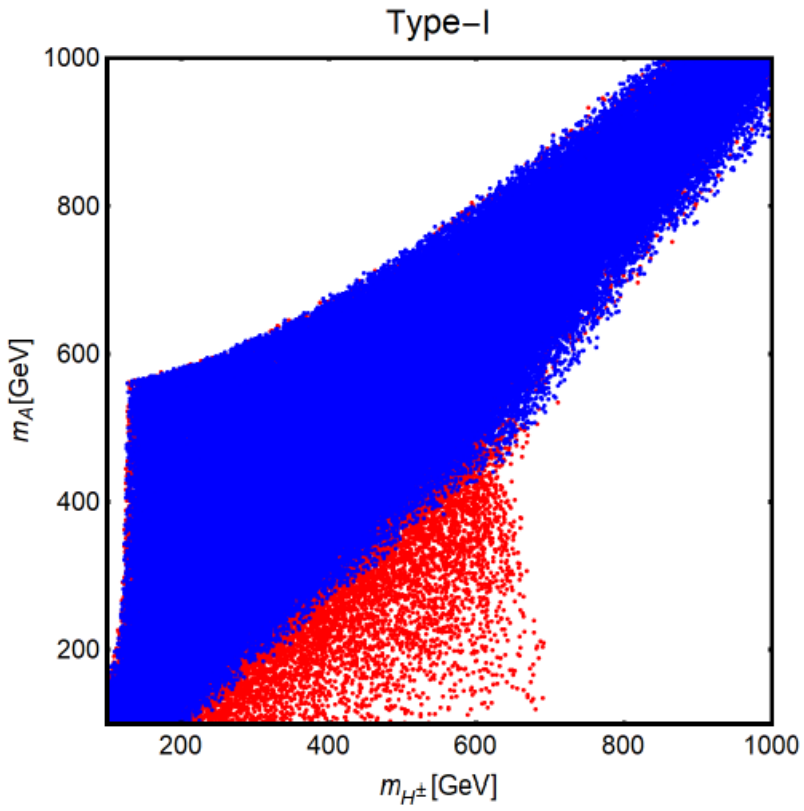


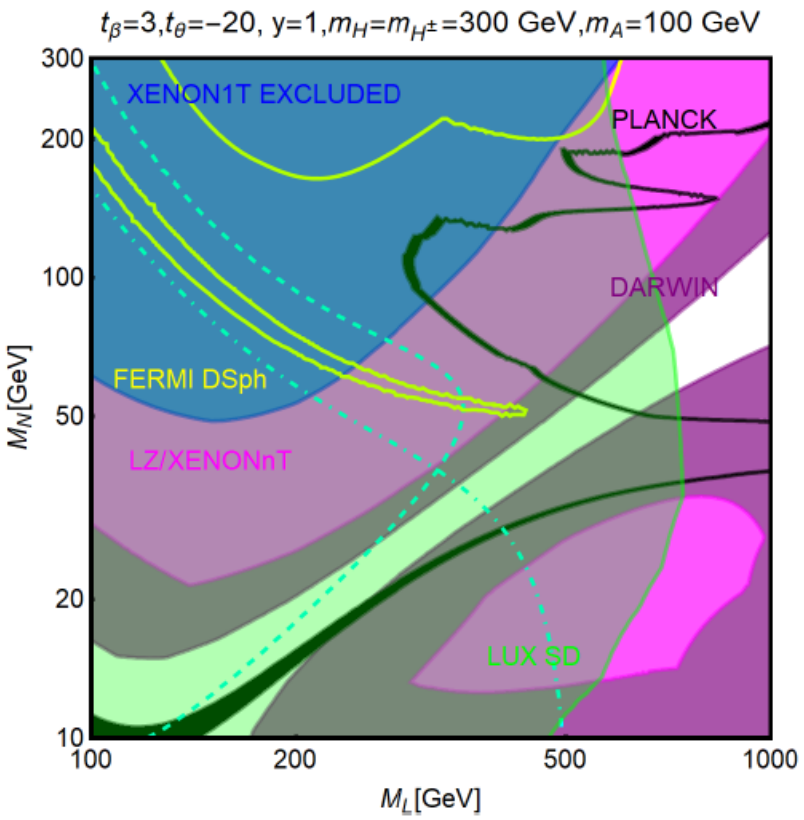


(Sample diagrams. For more complete references see e.g. in P. Arnan, D. Becirevic, F. Mescia, O. Sumensari Eur. Phys. J. C77 (2017) 11, 796
See also:
W. Altmannshofer, P. Paradisi, D. M. Straub JHEP 04 (2012) 008

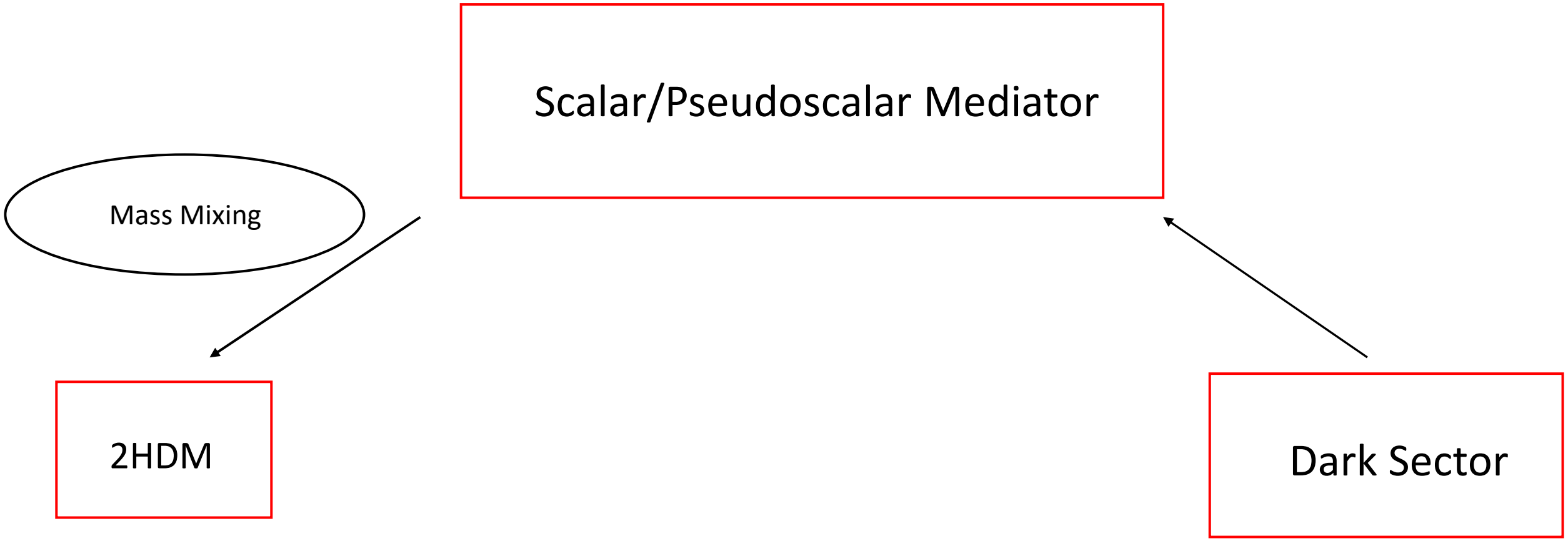


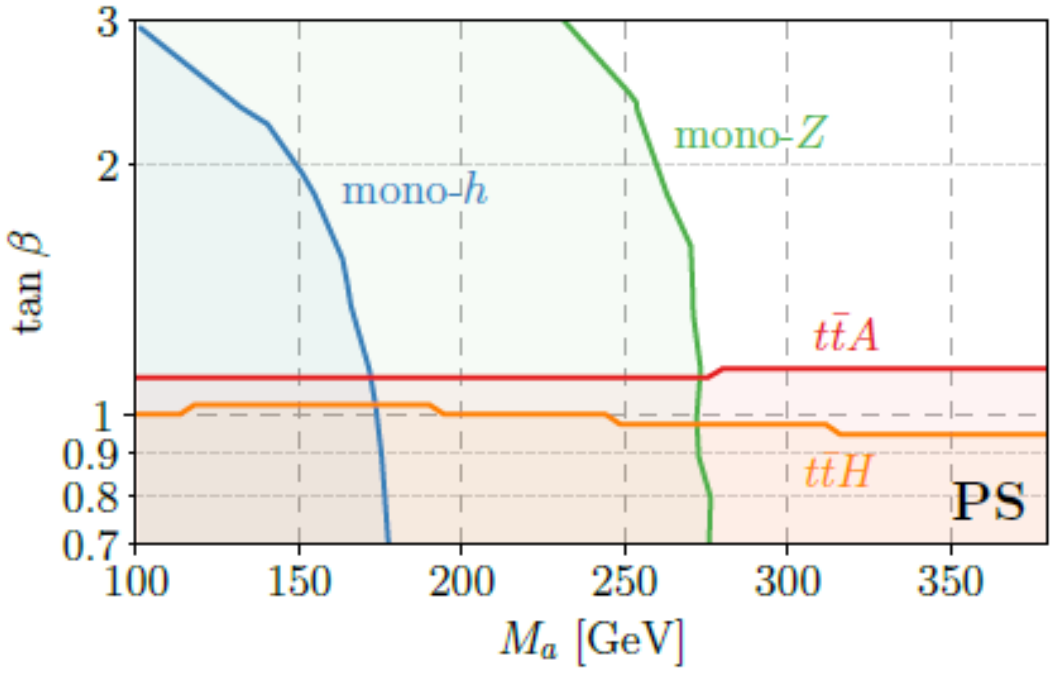


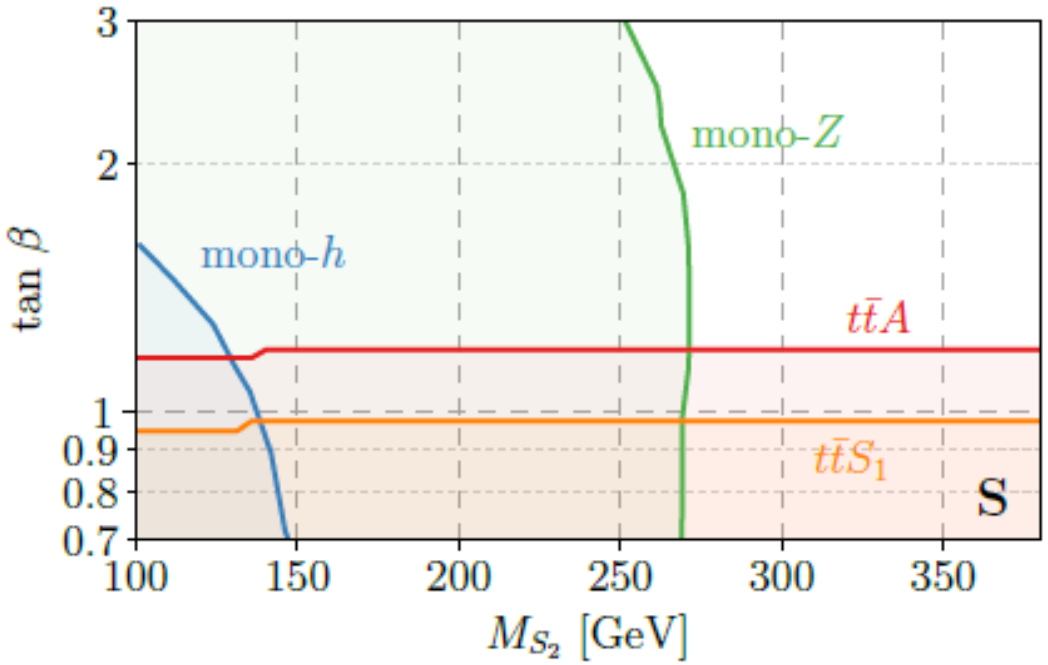

Type−I
1000
800
600
400
200
200
400
600
800
1000
m_A[GeV]
$m_{H^\pm}$[GeV]


t_β=3,t_θ=−20, y=1,m_H=$m_{H^\pm}$=300 GeV,m_A=100 GeV
XENON1T EXCLUDED
PLANCK
DARWIN
FERMI DSph
LZ/XENONnT
LUX SD
300
200
100
50
20
10
100
200
500
1000
M_N[GeV]
M_L[GeV]

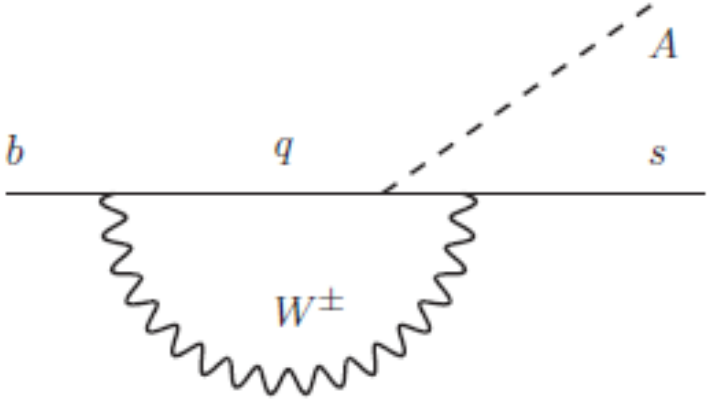
2HDM+Light Scalar/Pseudoscalar

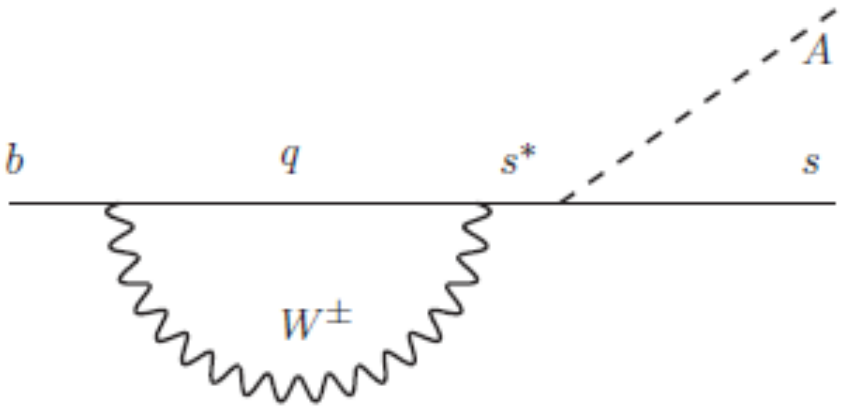


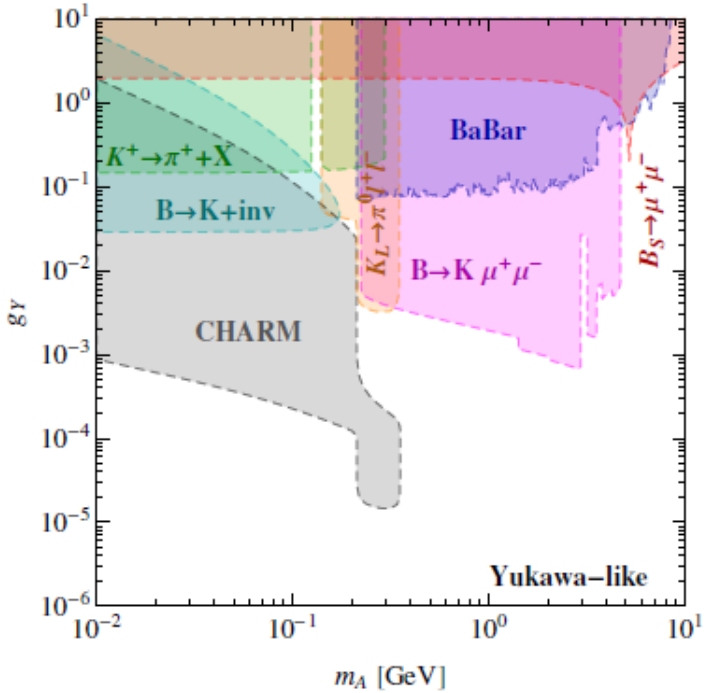


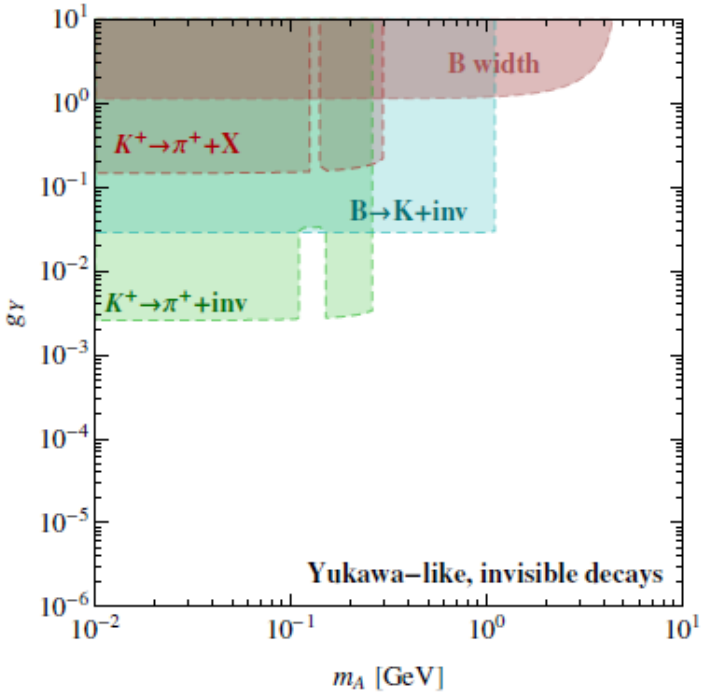


G.A., G. Busoni, T. Hugle, V. Tenorth 2001.10540

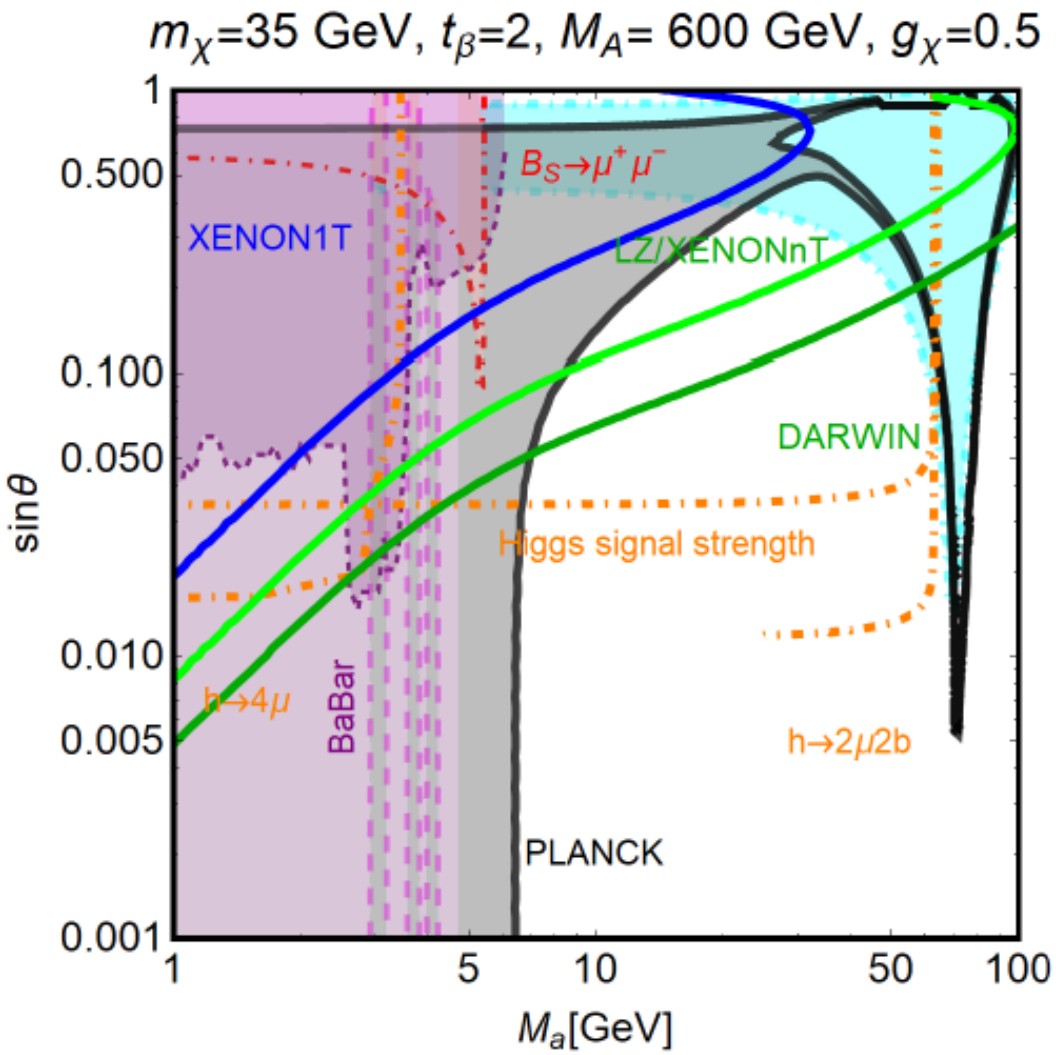


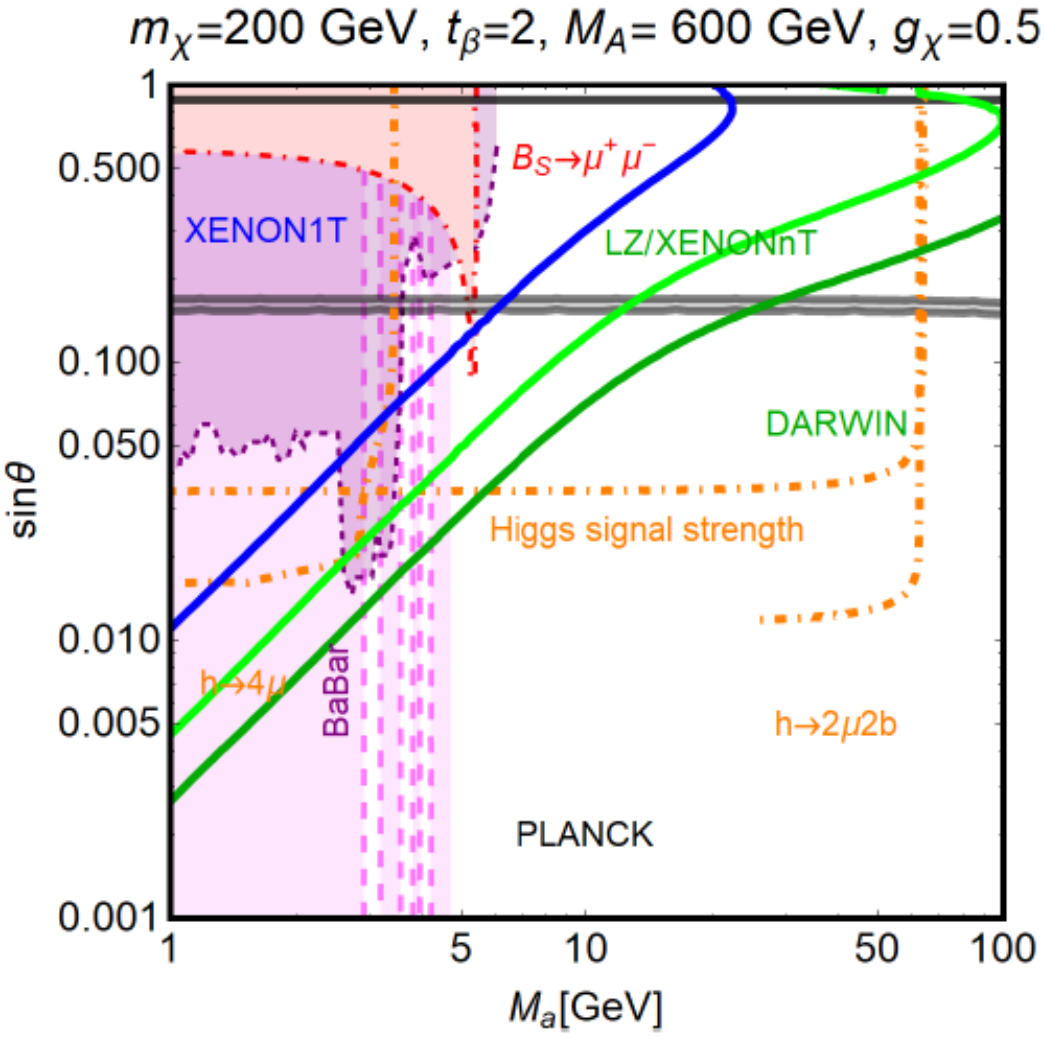




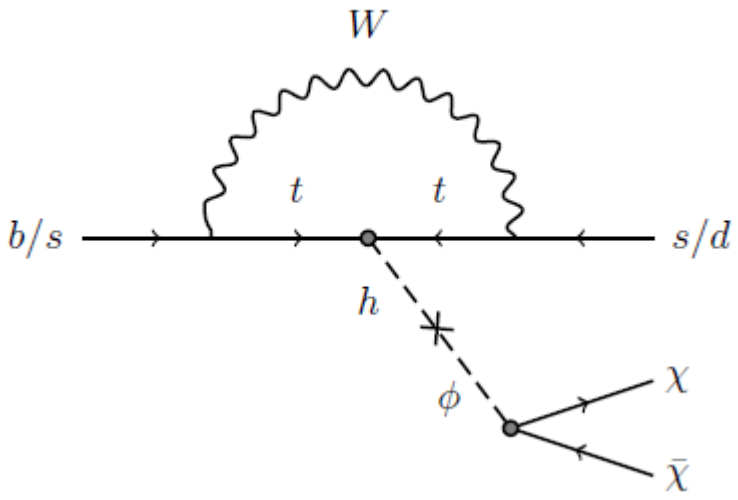


M. J. Dolan, F. Kahlhoefer, C. McCabe, K. Schmidt-Hoberg JHEP 03 (2015) 171

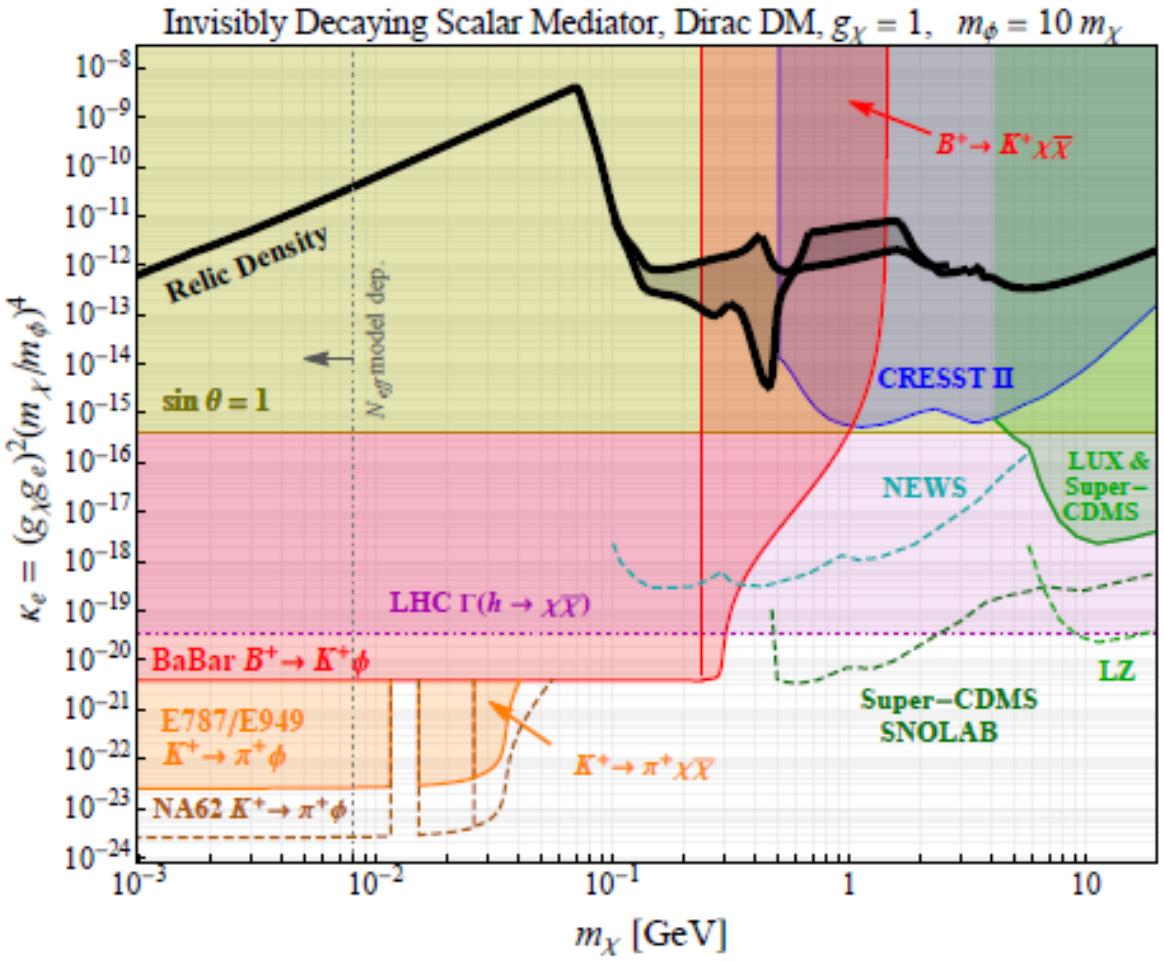




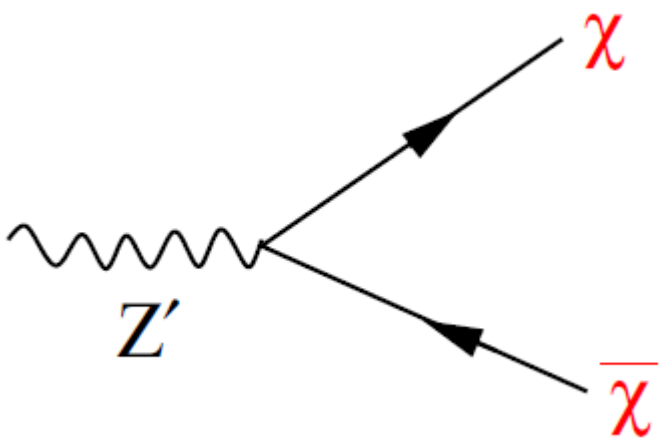
G.A., M. Lindner, F.S. Queiroz, W. Rodejohann, S. Vogl JCAP 03 (2018) 042

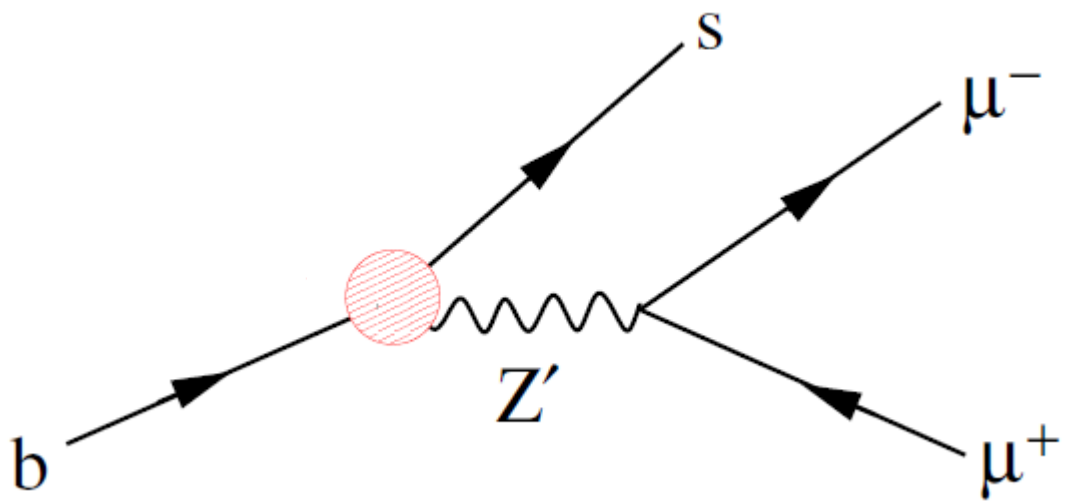


G. Krnjaic, Phys. Rev. D94 (2016) 7, 073009



Z‘ models for B-anomalies

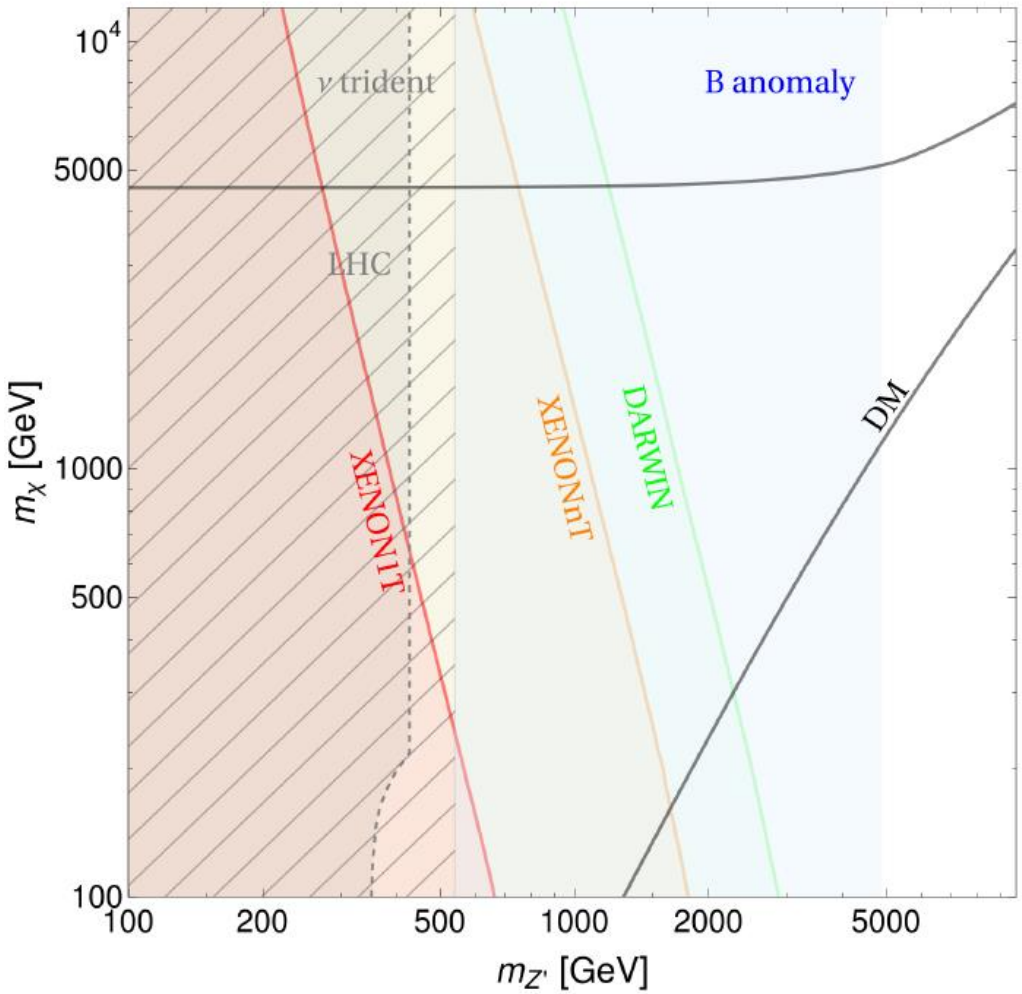




(Incomplete list of possibilities)

J. M. Cline, J. M. Cornell, D. London, R. Watanabe Phy. Rev. D95 (2017) 9, 095015
S. Baek, Phys. Lett. B781 (2018) 376-382
G.A., T. Hugle, F. S. Queiroz Phys. Lett. B784 (2018) 151
L. Darmé, K. Kowalsa, L. Roskowzki, E. M. Sessolo JHEP 10 (2018) 052
S. Singirala, S. Sahoo, R. Mohanta Phys. Rev. D99 (2019) 3, 035042

$L_\mu - L_\tau$ model

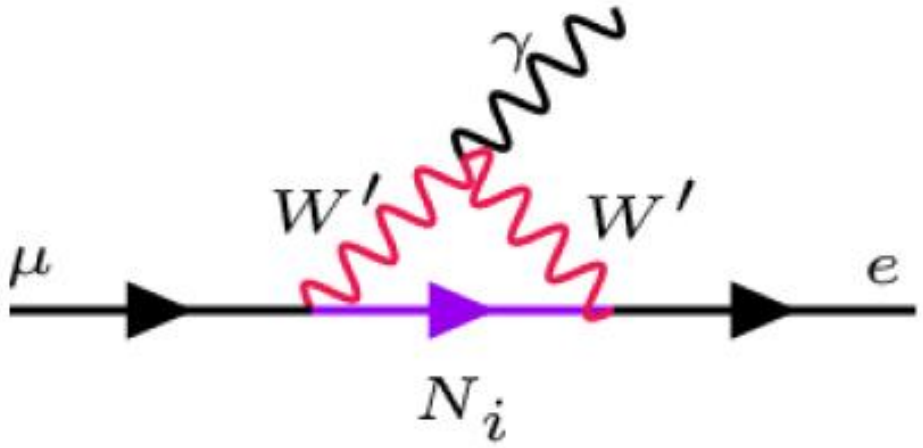


G.A., T. Hugle, F. S. Queiroz Phys. Lett. B784 (2018) 151

LFV induced by DM

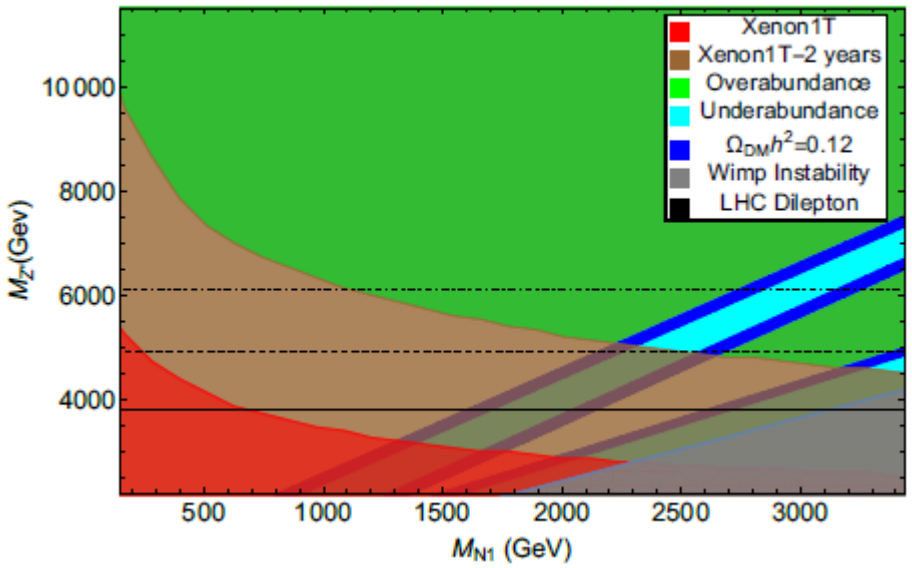
$$\mathcal{L} \supset -\frac{g}{\sqrt{2}}\left[\bar{N}_{aL}\gamma^{\mu}\ell_{aL}W'^{+}_{\mu} + \bar{\nu}_{aL}\gamma^{\mu}N_{aL}U^{0}_{\mu}\right] - \frac{g}{\sqrt{2}}\left[\bar{U}_{3L}\gamma^{\mu}d_{3L}W'^{+}_{\mu} + \bar{u}_{iL}\gamma^{\mu}D_{iL}W'^{+}_{\mu}\right]$$

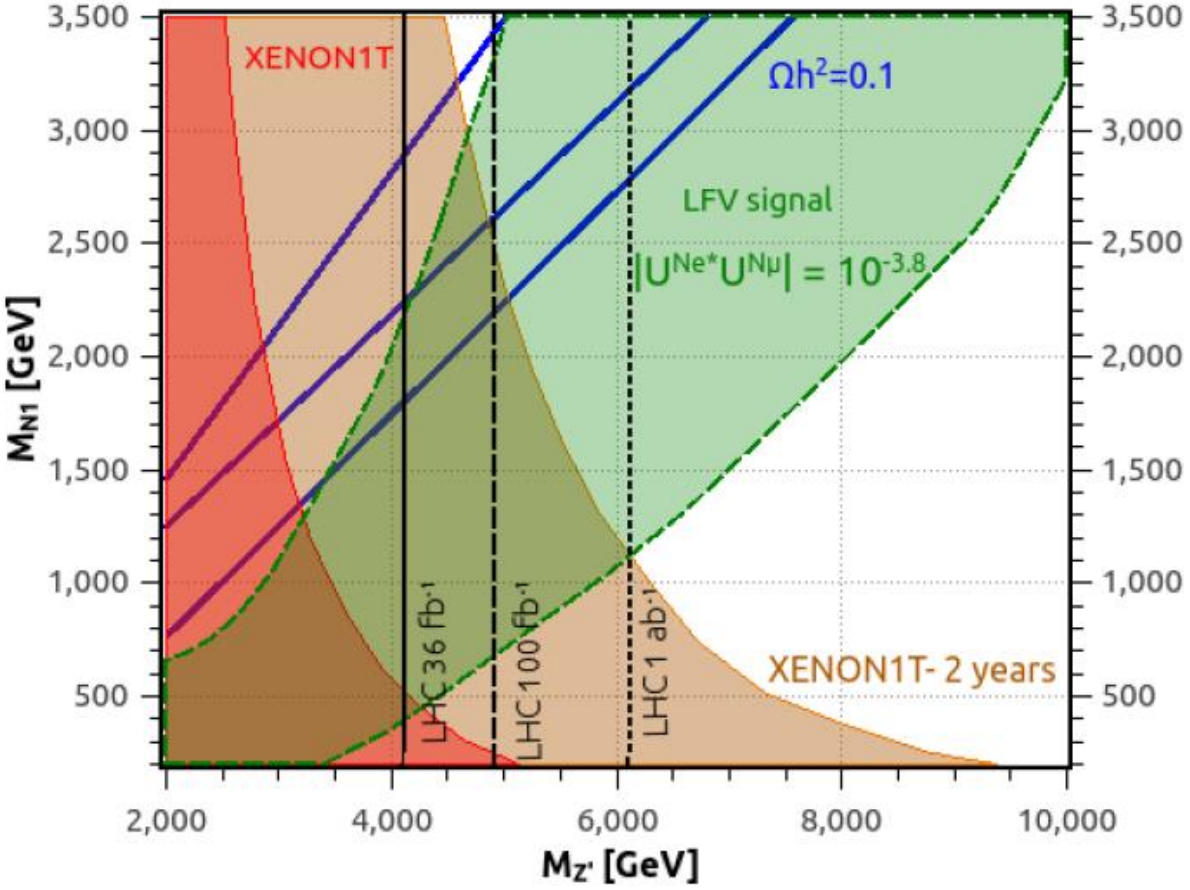
$$-\frac{g}{2\cos\theta_W}\sum_f\left[\bar{f}\,\gamma^{\mu}\left(g'_V + g'_A\gamma^5\right)f\,Z'_{\mu}\right]$$



$$Br(\mu \to e\gamma) = 1.6 \times \left(\frac{1\,\mathrm{TeV}}{M_{W'}}\right)^4 |g^{N_1 e*} g^{N_1 \mu}|^2$$

$$g^{N_1 e,\mu} = \frac{g}{2\sqrt{2}} U^{N_1 e,\mu}$$





G.A., C.P. Ferreira, F. Goertz, M.M. Guzzo, F.S. Queiroz
Phys. Rev. D97 (2018) 7, 075022

Flavored DM

P. Agrawal, M. Blanke, K. Gemmler JHEP 10 (2014) 072

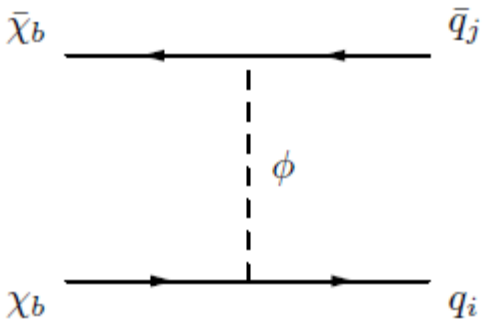
	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$	$U(3)_q$	$U(3)_u$	$U(3)_d$	$U(3)_\chi$
q_L	**3**	**2**	1/6	**3**	**1**	**1**	**1**
u_R	**3**	**1**	2/3	**1**	**3**	**1**	**1**
d_R	**3**	**1**	-1/3	**1**	**1**	**3**	**1**
ℓ_L	**1**	**2**	-1/2	**1**	**1**	**1**	**1**
e_R	**1**	**1**	-1	**1**	**1**	**1**	**1**
H	**1**	**2**	1/2	**1**	**1**	**1**	**1**
ϕ	**3**	**1**	-1/3	**1**	**1**	**1**	**1**
χ_L	**1**	**1**	0	**1**	**1**	**1**	**3**
χ_R	**1**	**1**	0	**1**	**1**	**1**	**3**
Y_u	**1**	**1**	0	**3**	$\bar{\mathbf{3}}$	**1**	**1**
Y_d	**1**	**1**	0	**3**	**1**	$\bar{\mathbf{3}}$	**1**
λ	**1**	**1**	0	**1**	**1**	**3**	$\bar{\mathbf{3}}$

$$\mathcal{L} = \mathcal{L}_{\rm SM} + i\bar{\chi}\partial\!\!\!/\chi - m_\chi\bar{\chi}\chi - (\lambda_{ij}\bar{d}_{Ri}\chi_j\phi + \text{h.c.})$$
$$+(D_\mu\phi)^\dagger(D^\mu\phi) - m_\phi^2\phi^\dagger\phi + \lambda_{H\phi}\,\phi^\dagger\phi\,H^\dagger H + \lambda_{\phi\phi}\,\phi^\dagger\phi\,\phi^\dagger\phi$$

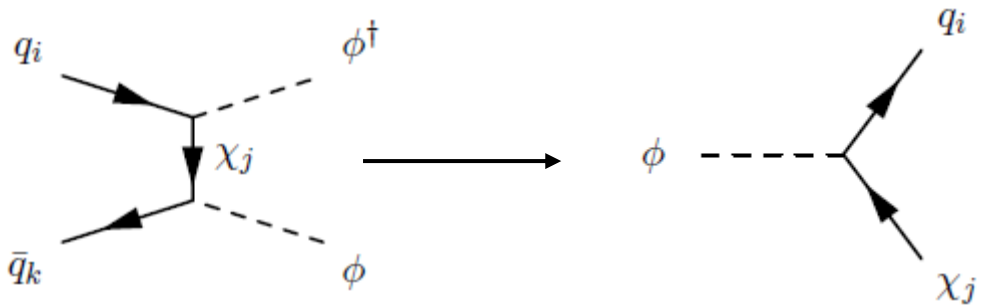
$$\lambda = U_\lambda D_\lambda$$

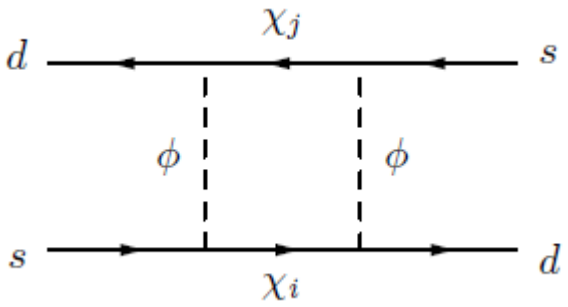
$$U_\lambda = \begin{pmatrix} c^\lambda_{12} c^\lambda_{13} & s^\lambda_{12} c^\lambda_{13} e^{-i\delta^\lambda_{12}} & s^\lambda_{13} e^{-i\delta^\lambda_{13}} \\ -s^\lambda_{12} c^\lambda_{23} e^{i\delta^\lambda_{12}} - c^\lambda_{12} s^\lambda_{23} s^\lambda_{13} e^{i(\delta^\lambda_{13}-\delta^\lambda_{23})} & c^\lambda_{12} c^\lambda_{23} - s^\lambda_{12} s^\lambda_{23} s^\lambda_{13} e^{i(\delta^\lambda_{13}-\delta^\lambda_{12}-\delta^\lambda_{23})} & s^\lambda_{23} c^\lambda_{13} e^{-i\delta^\lambda_{23}} \\ s^\lambda_{12} s^\lambda_{23} e^{i(\delta^\lambda_{12}+\delta^\lambda_{23})} - c^\lambda_{12} c^\lambda_{23} s^\lambda_{13} e^{i\delta^\lambda_{13}} & -c^\lambda_{12} s^\lambda_{23} e^{i\delta^\lambda_{23}} - s^\lambda_{12} c^\lambda_{23} s^\lambda_{13} e^{i(\delta^\lambda_{13}-\delta^\lambda_{12})} & c^\lambda_{23} c^\lambda_{13} \end{pmatrix}$$

$$D_\lambda \equiv \mathrm{diag}(D_{\lambda,11}, D_{\lambda,22}, D_{\lambda,33}) = \lambda_0 \cdot \mathbb{1} + \mathrm{diag}(\lambda_1, \lambda_2, -(\lambda_1 + \lambda_2))$$



Relic Density

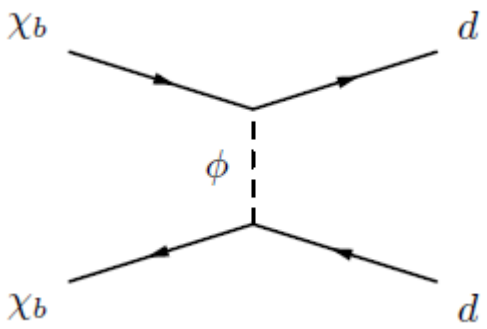


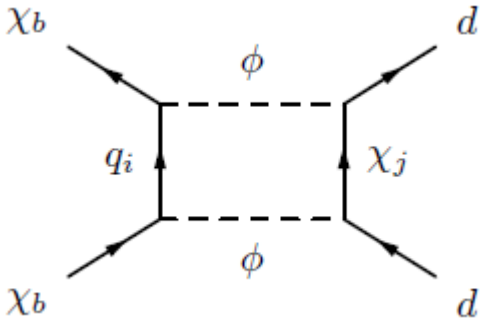


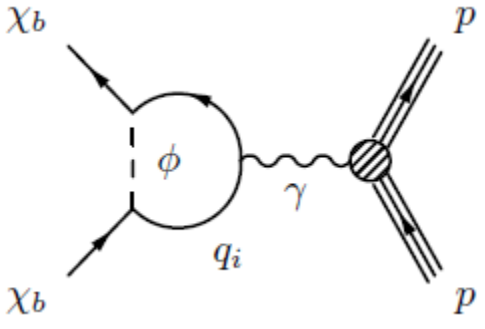
Flavor

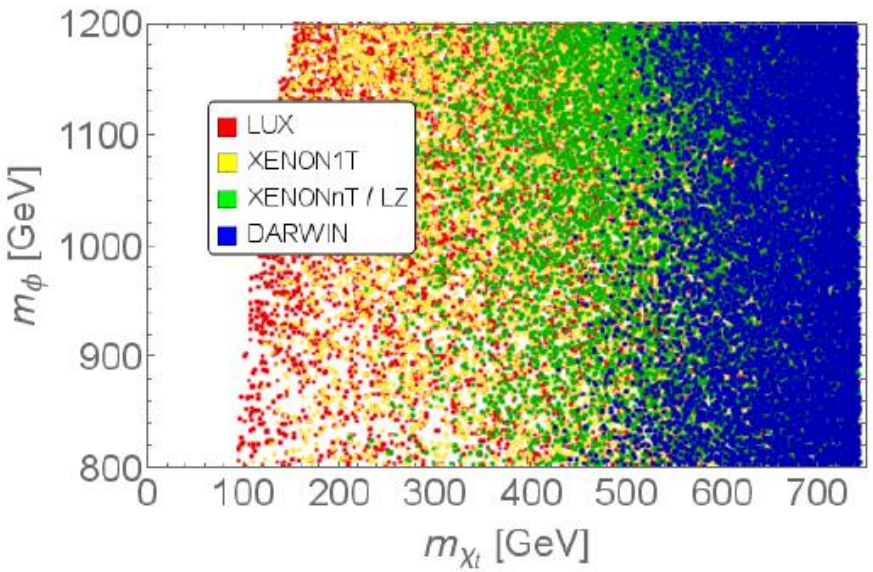
Collider

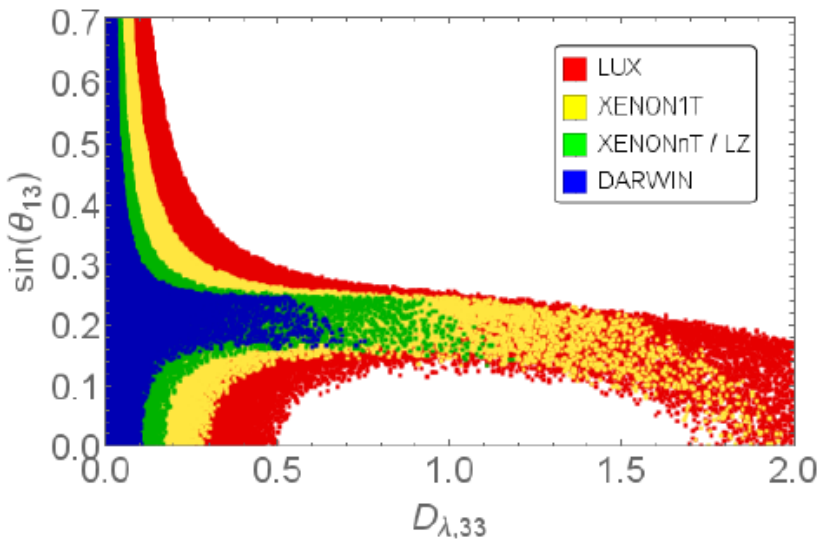
Direct Detection

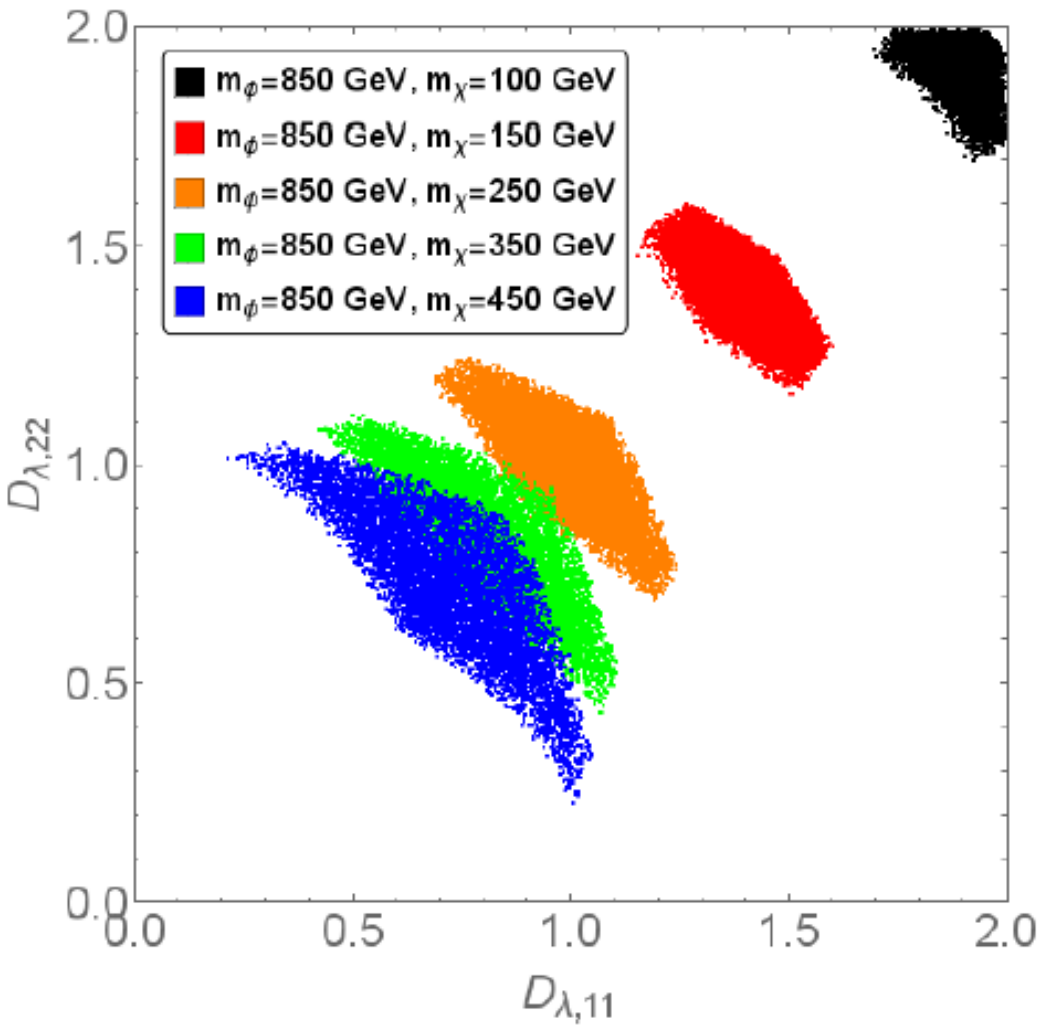












M. Blancke, S. Kast, JHEP 05 (2017) 161

Conclusions

The DM and flavor are among the biggest puzzles in high energy physics.

We have presented a (non complete) list of scenarios in which these two puzzles can be correlated.