

Dark matter in left-right symmetric standard model

triplet scalar dark matter portal

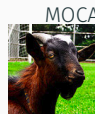


UNIVERSIDAD DE ANTIOQUIA
1803

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June 27, 2017

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Focus on

arXiv:1703.08148 (PRD)

In collaboration with

C. Arbeláez (UFSM) & M. Hirsch (IFIC)

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Dark matter and unification

Unification: $SO(10)$

$$16_{F_i} = \begin{pmatrix} u_R^\dagger \\ u_R^\dagger \\ u_R^\dagger \\ u_L \\ u_L \\ u_L \\ d_L \\ d_L \\ d_L \\ d_R^\dagger \\ d_R^\dagger \\ d_R^\dagger \\ \nu_L \\ e_L \\ e_R^\dagger \\ N \end{pmatrix}_i$$

$$\Rightarrow \mathcal{L}_{SM} \supset h \, 16_F \times 16_F \times 10_S + \text{h.c.}$$



Not-susy $SO(10) \rightarrow SU(5) \rightarrow SU(3)_C \times SU(2)_L \times U(1)_Y \times Z_2$

Standard Model: Z_2 -even

Fermions: 16_F

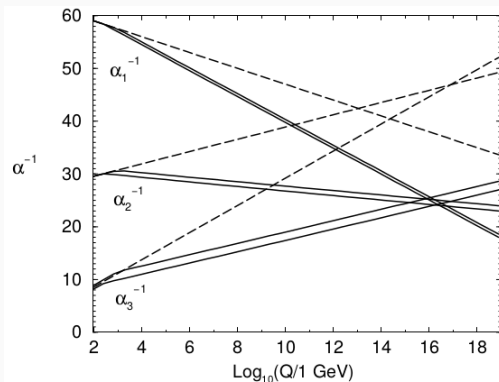
Scalars: $10_H, 45_H \dots$

New Z_2 -odd particles

$10_F, 45_F, \dots$

$16_H, \dots$

Lightest Odd Particle (LOP) may be a suitable dark matter candidate, and can improve gauge coupling unification



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	fermions	scalars
$SU(2)_L \times U(1)_Y$ representation	even $SO(10)$ representations	odd $SO(10)$ representations
1_0	45, 54, 126, 210	16, 144
$2_{\pm 1/2}$	10, 120, 126, 210, 210'	16, 144
3_0	45, 54, 210	144

$SU(3)_C : 3 (T), 6, 8 (\Lambda)$

$$m_{3_0} = 2.7 \text{ TeV}, \quad m_{\Lambda} \sim 10^{10} \text{ TeV}, \quad m_{\text{GUT}} \sim 10^{16} \text{ GeV}.$$

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$SU(3)_C : 3 (T), 6, 8 (\Lambda)$

Split-SUSY like

arXiv:1509.06313 (C. Arbelaez, R. Longas, D.R, O. Zapata)

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$SU(3)_C : 3 (T), 6, 8 (\Lambda)$

Radiative hybrid seesaw (Parida 1106.4137) or 1509.06313

Partial Split-SUSY-like spectrum: bino-higgsino-wino

+

↓

$10'_H$ with fermion DM or, $16_H, \dots$ with scalar DM

Not-susy $SO(10) \rightarrow SU(5) \rightarrow SU(3)_C \times SU(2)_L \times U(1)_Y \times Z_2$

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$SU(3)_C$: 3 (T), 6, 8 (Λ)

1509.06313

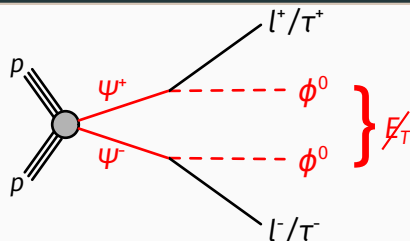
SUSY-like spectrum: bino-higgsino-wino

+

↓

$10'_H$ with fermion DM or, $16_H, \dots$ with scalar DM

Dilepton plus transverse missing energy signal

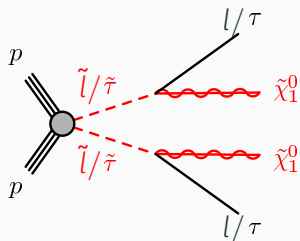


SU(2)_L assignments:

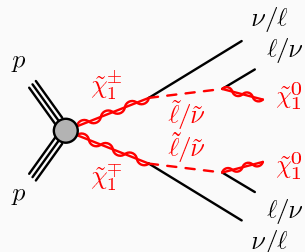
$\Psi = 1, 2(\Psi), 3(\Sigma),$

$\Phi = 1, 2,$ with $m_{DM} \sim m_h/2.$

Simplified SUSY models

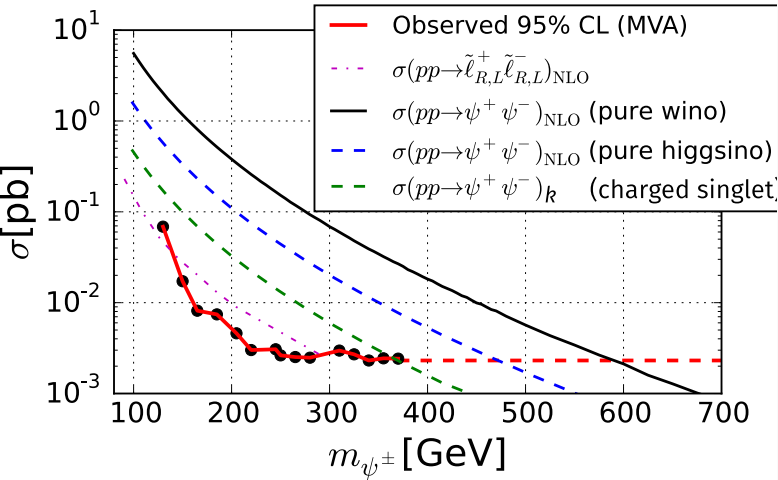


Smaller cross sections.



Intermediate states and smaller lepton p_T

$$m_{\phi^0} = 60 \text{ GeV}$$



Singlet-Doublet-Triplet fermion dark-matter

The most general $SO(10)$ invariant Lagrangian contains the following Yukawa terms

$$-\mathcal{L} \supset Y 10_F 45_F 10_H + M_{45_F} 45_F 45_F + M_{10_F} 10_F 10_F$$

$$\text{Basis } \psi^0 = \left(N, \Sigma^0, \psi_L^0, (\psi_R^0)^\dagger \right)^T$$

$$\mathcal{M}_{\psi^0} = \begin{pmatrix} M_N & 0 & -y c_\beta v / \sqrt{2} & y s_\beta v / \sqrt{2} \\ 0 & M_\Sigma & f c_{\beta'} v / \sqrt{2} & -f s_{\beta'} v / \sqrt{2} \\ -y c_\beta v / \sqrt{2} & f c_{\beta'} v / \sqrt{2} & 0 & -M_D \\ y s_\beta v / \sqrt{2} & -f s_{\beta'} v / \sqrt{2} & -M_D & 0 \end{pmatrix},$$

$$10_F \rightarrow \psi_L, (\psi_R)^\dagger$$

$$45_F \rightarrow \Sigma, \Lambda$$

$$45'_F \rightarrow N$$

arXiv:1511.06495: signals at 100 TeV collider

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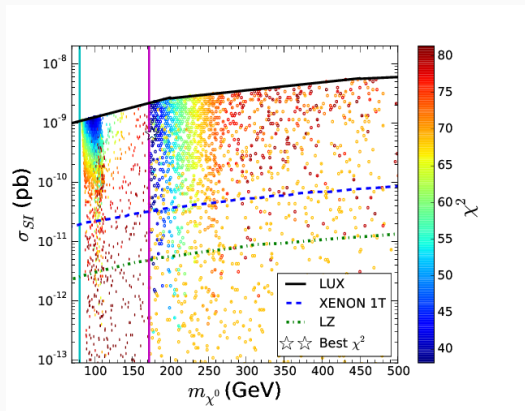
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S. Horiuchi, O. Macias, DR, A. Rivera, O. Zapata, 1602.04788 (JCAP)

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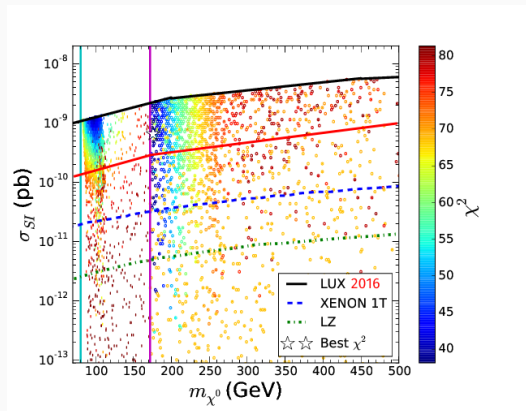
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Singlet-Doublet-Triplet fermion dark-matter

The most general SO(10) invariant Lagrangian contains the following Yukawa terms

$$-\mathcal{L} \supset Y 10_F 45_F 10_H + M_{45_F} 45_F 45_F + M_{10_F} 10_F 10_F + \mathcal{L}(10_\phi).$$

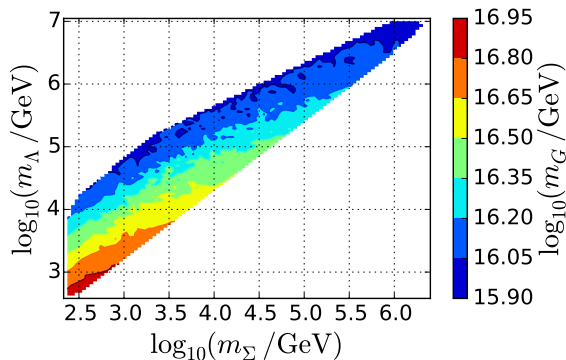
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$$10_F \rightarrow \psi_L, (\psi_R)^\dagger$$

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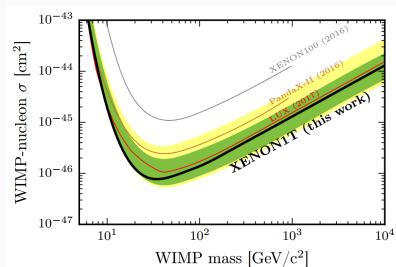


Split-SUSY: like $M_\phi = 2 \text{ TeV}$

Is the glass half empty or half full?

Tree-level SM-portal could be fully excluded in the near future

- Singlet scalar dark matter
- Inert doublet model
- Tree-level SM-portal dark matter ...

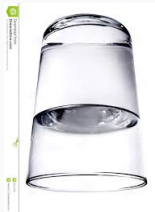


In this talk we explore

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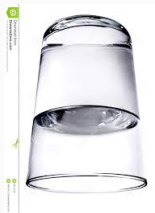
In this talk we explore

- Recover SM-portals in LR models

Is the glass half empty or half full?

Tree-level SM-portal could be fully excluded in the near future

- Singlet scalar dark matter
- Inert doublet model
- Tree-level SM-portal dark matter ...



In this talk we explore

- Recover SM-portals in LR models
- New portals in LR models

Left-Right symmetric realization

Field	Multiplicity	$3_c 2_L 2_R 1_{B-L}$	Spin	SO(10) origin
Φ	1	(1, 2, 2, 0)	0	10
χ, χ^c	1	(1, 2, 2, 0)	1/2	10
N	1	(1, 1, 1, 0)	1/2	45

Table 1: The relevant part of the field content. Note that, the two fermion doublets χ and χ^c come from an only fermionic LR bidoublet. In the third column the relevant fields are characterized by their $SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ quantum numbers while their SO(10) origin is specified in the fourth column.

m_{LR} (GeV)	$3_c 2_L 2_R 1_{B-L}$	m_G (GeV)
2×10^3	$\Phi_{1,2,2,0} + 2\Phi_{1,1,3,-2} + \Psi_{1,1,3,0} + \Phi_{1,1,3,0} + \Phi_{8,1,1,0}$	1.65×10^{16}
\vdots	\vdots	\vdots

Table 2: $\Delta_{L,R} = 2\Phi_{1,1,3,-2}$. m_{LR} and m_G are given in GeV.

Triplets

Minimal Left-Right Symmetric Standard Model

Field	Multiplicity	$3_C 2_L 2_R 1_{B-L}$	Spin	SO(10) origin
Q	3	$(3, 2, 1, +\frac{1}{3})$	$1/2$	16
Q^c	3	$(\bar{3}, 1, 2, -\frac{1}{3})$	$1/2$	16
L	3	$(1, 2, 1, -1)$	$1/2$	16
L^c	3	$(1, 1, 2, +1)$	$1/2$	16
Φ	1	$(1, 2, 2, 0)$	0	10
Δ_R	1	$(1, 1, 3, -2)$	0	126

Left-singlet right-triplet DM

Field	Multiplicity	$3_C 2_L 2_R 1_{B-L}$	Spin	SO(10) origin
Q	3	$(3, 2, 1, +\frac{1}{3})$	1/2	16
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Φ	1	$(1, 2, 2, 0)$	0	10
Δ_R	1	$(1, 1, 3, -2)$	0	126
Ψ_{1130}	1	$(1, 1, 3, 0)$	1/2	45

$$\Omega h^2 = 0.1199 \pm 0.0027 \text{ at } 3\sigma$$

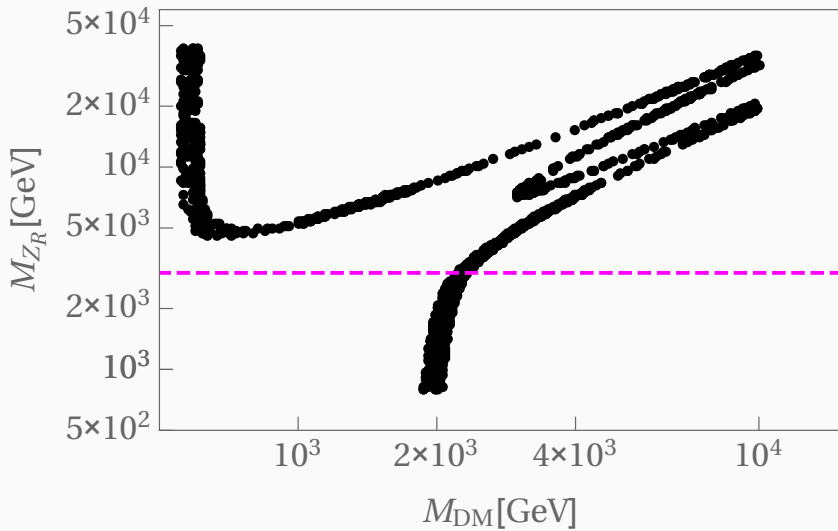


Figure 1: Proper relic density scan: $0.5 < v_R/\text{TeV} < 50$

Mixed Left-singlet right-triplet DM

Field	Multiplicity	$3_C 2_L 2_R 1_{B-L}$	Spin	SO(10) origin
Q	3	$(3, 2, 1, +\frac{1}{3})$	1/2	16
Q^c	3	$(\bar{3}, 1, 2, -\frac{1}{3})$	1/2	16
L	3	$(1, 2, 1, -1)$	1/2	16
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Ψ_{1130}	1	$(1, 1, 3, 0)$	1/2	45
Ψ_{1132}	1	$(1, 1, 3, 2)$	1/2	126
Ψ_{113-2}	1	$(1, 1, 3, -2)$	1/2	$\overline{126}$

$$\Psi_{1132} = \begin{pmatrix} \Psi^+/\sqrt{2} & \Psi^{++} \\ \Psi^0 & -\Psi^+/\sqrt{2} \end{pmatrix}, \quad \bar{\Psi}_{113-2} = \begin{pmatrix} \Psi^-/\sqrt{2} & \bar{\Psi}^0 \\ \Psi^{--} & -\Psi^-/\sqrt{2} \end{pmatrix}. \quad (1)$$

$$\begin{aligned} L \supset & M_{11} \text{Tr}(\Psi_{1130} \Psi_{1130}) + M_{23} \text{Tr}(\Psi_{1132} \bar{\Psi}_{113-2}) \\ & + \lambda_{13} \text{Tr}(\Delta_R \bar{\Psi}_{113-2} \Psi_{1130}) + \lambda_{12} \text{Tr}(\Delta_R^\dagger \Psi_{1132} \Psi_{1130}), \end{aligned} \quad (2)$$

$$\tan \gamma = \frac{\lambda_{13}}{\lambda_{12}}, \quad \lambda = \sqrt{\lambda_{12}^2 + \lambda_{13}^2}. \quad (3)$$

Blind spot at

$$M_{23} \sin 2\gamma - M_{\text{DM}} = 0 \quad (4)$$

Proper relic density scan

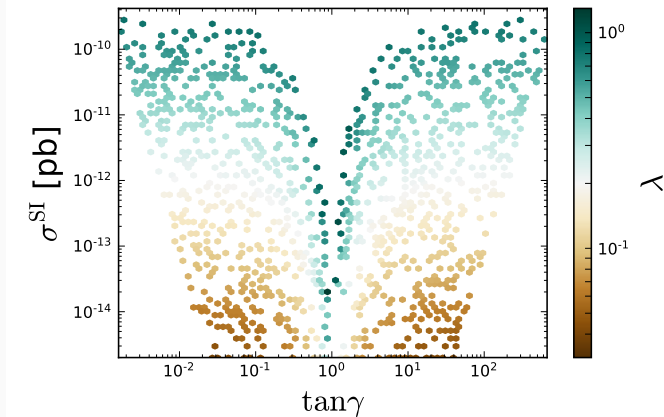
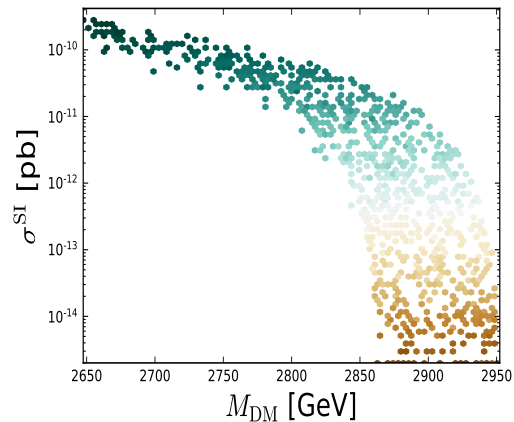


Figure 2: $M_{11} = 50$ TeV $2.7 < M_{23}/\text{TeV} < 3.1$



(Right: $\tan\gamma > 5$)

$$\Omega h^2 = 0.1199 \pm 0.0027 \text{ at } 3\sigma$$

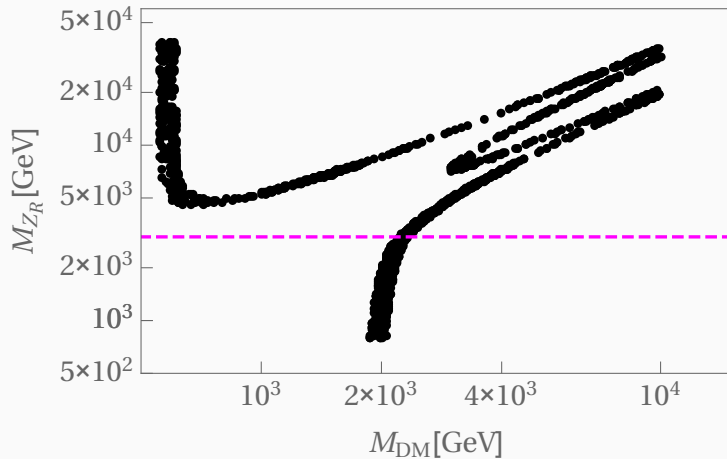


Figure 3:

$$\Omega h^2 = 0.1199 \pm 0.0027 \text{ at } 3\sigma$$

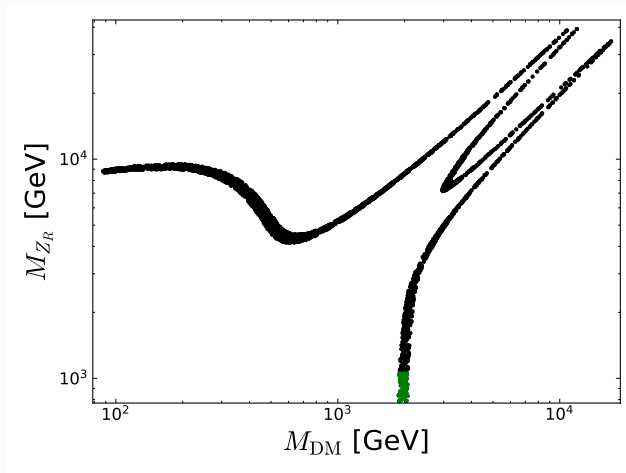


Figure 3: Proper relic density scan: $v_R : [2, 50]$ TeV, $M_{23} : [0.2, 50]$ TeV, $M_{11} : 50$ TeV, $\tan \gamma = -1$ and $\lambda = 0.14$.

Direct detection cross section

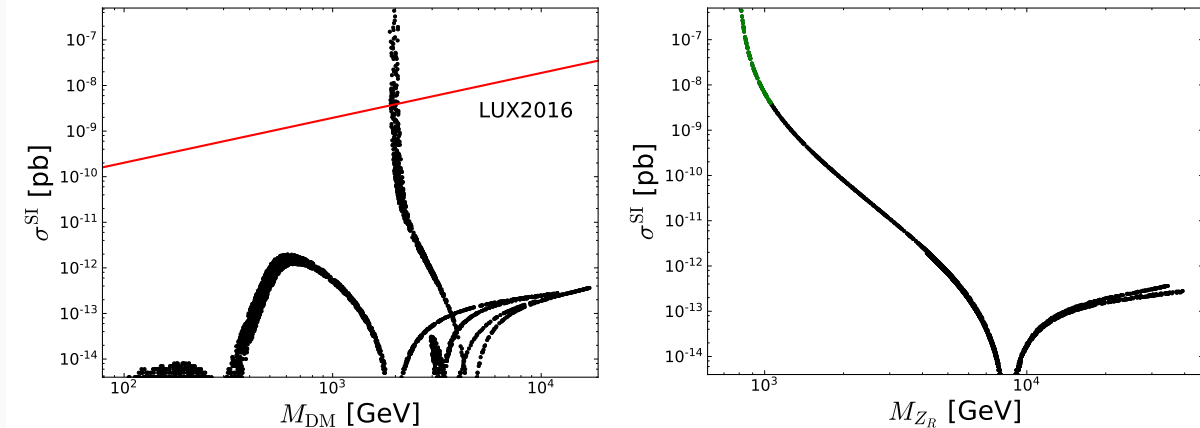


Figure 4: v_R : [2, 50] TeV, M_{23} : [0.2, 50] TeV, M_{11} : 50 TeV, $\tan \gamma = -1$ and $\lambda = 0.14$.

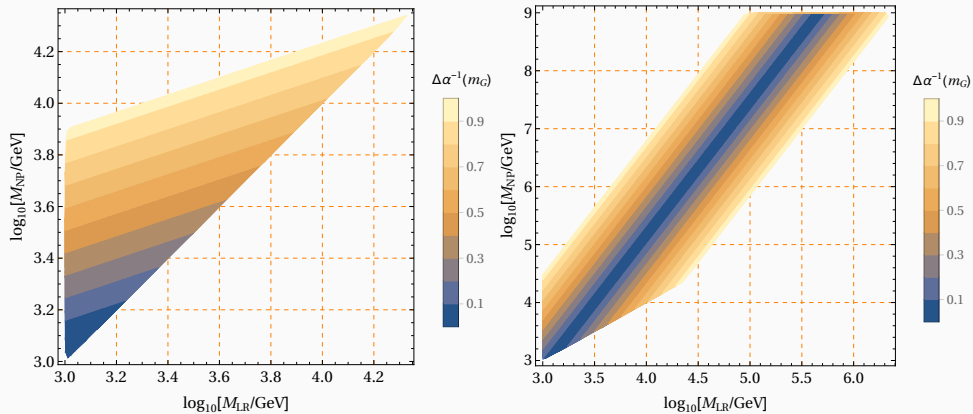
Unification

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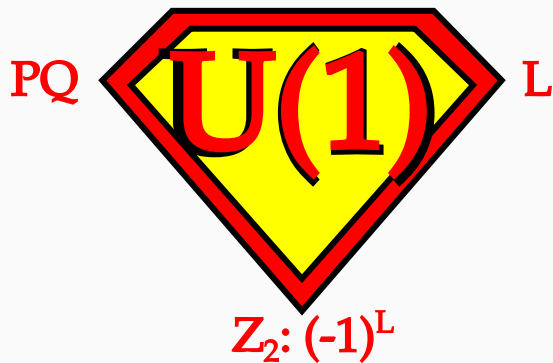
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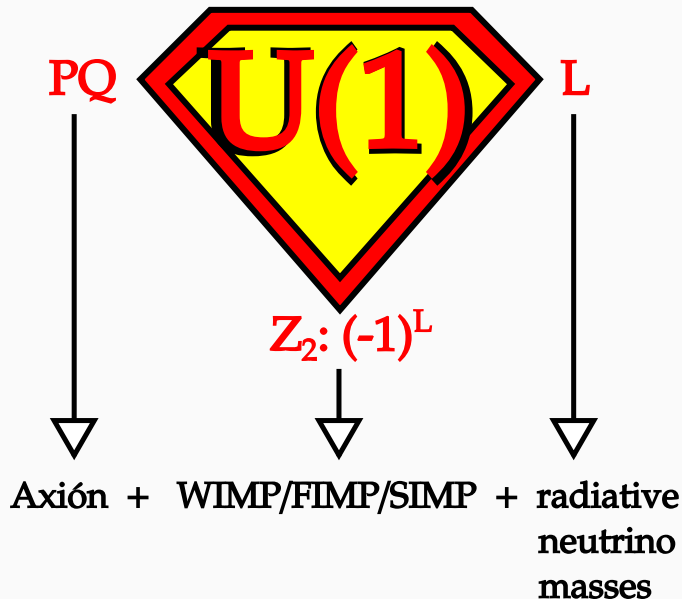
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Ψ_{113-2}	1	$(1, 1, 3, -2)$	1/2	$\overline{126}$
Ψ_{1310}	1	$(1, 3, 1, 0)$	1/2	45
Ψ_{8110}	1	$(1, 1, 8, 0)$	1/2	45
$\Psi_{321\frac{1}{3}}$	1	$(3, 2, 1, 1/3)$	1/2	16
$\Psi_{321-\frac{1}{3}}$	1	$(1, 2, 3, -1/3)$	1/2	$\overline{16}$

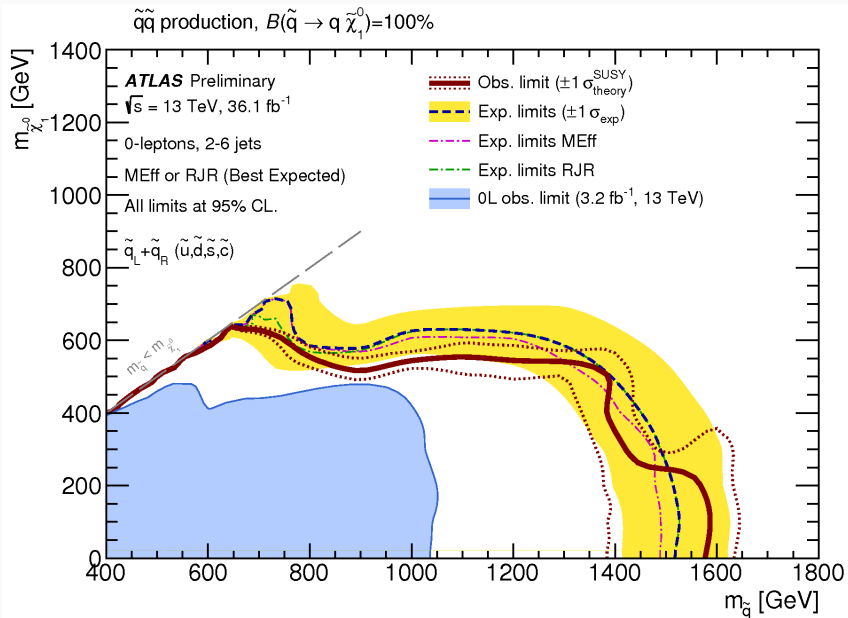
Unification quality

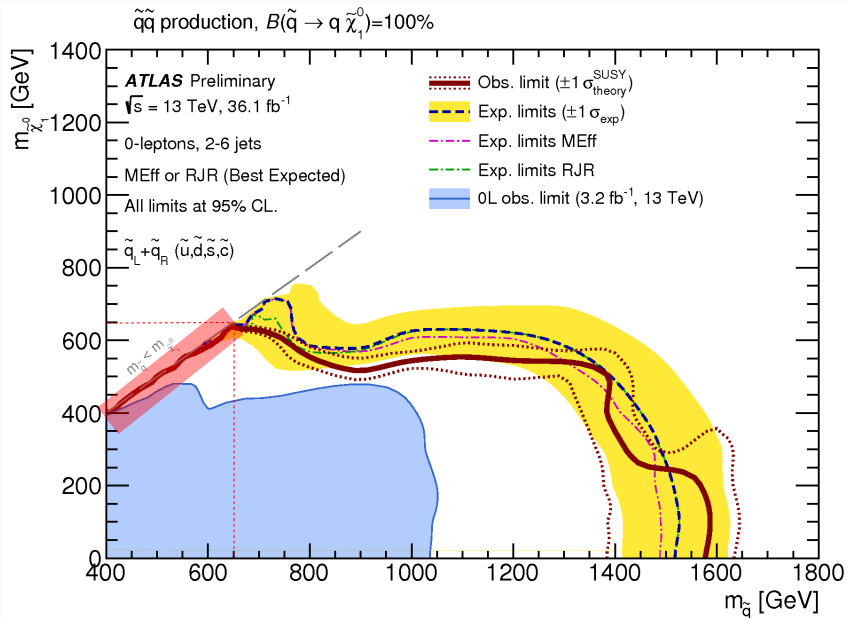












In addition to accommodate usual simplified dark matter models, Left-right symmetric standard models have additional DM portals:

New Δ_R portal for direct detection of left-singlet right-triplet mixed dark matter, in companion with left-singlets charged and doubly charged fermions.

Next: Search for them in compressed spectra scenarios at the LHC

Thanks!