Testing the WIMP paradigm at Future Experiments

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Based on:
G.A., M. Dutra, P. Ghosh, M. Lindner, Y. Mambrini, M. Pierre, S. Profumo, F. Queiroz, arXiv:1703.07364
G.A., M. Lindner, Y. Mambrini, M. Pierre, F. Queiroz, arXiv:1704.02328 (mostly)

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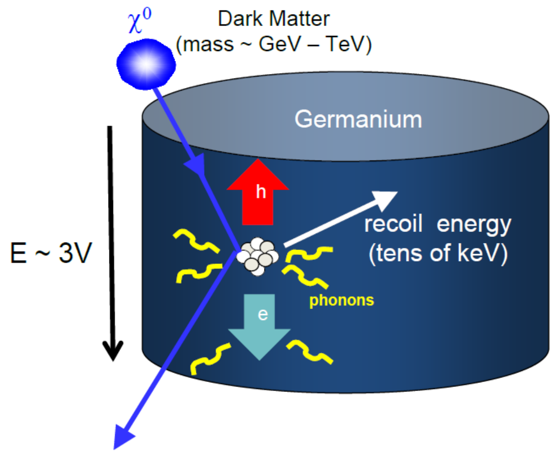
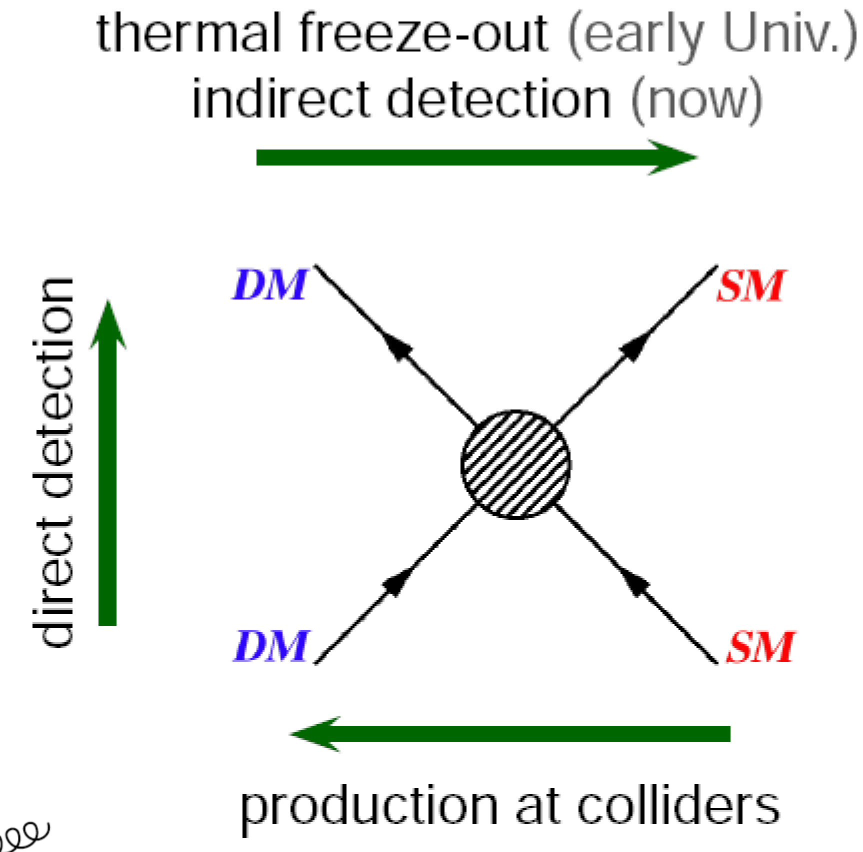
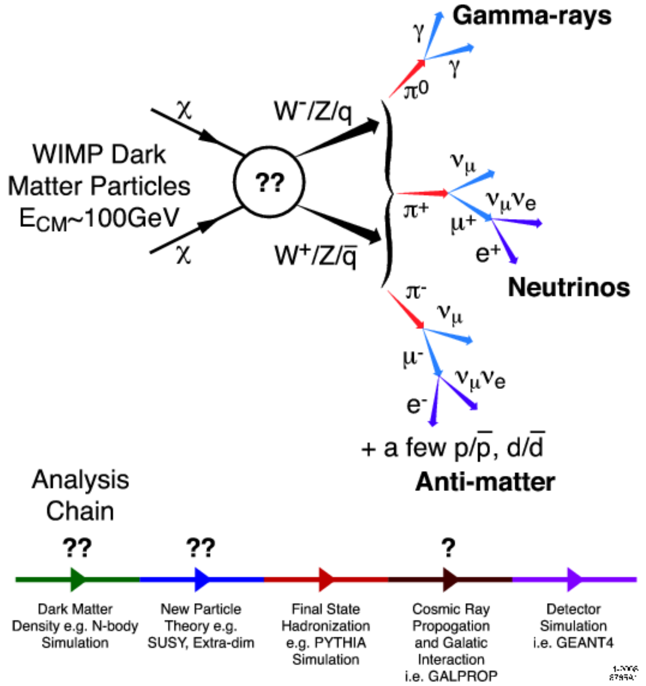
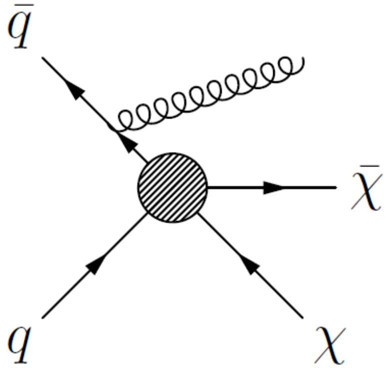
WIMP scenarios feature a strong complementarity between Dark Matter searches.









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

Case of study: fermionic DM interacting with spin-1 (Z') mediator

High invisible branching fraction:

monojet searches

Correlation

Low Invisible branching fraction

Resonance searches

$$\sigma_{\chi p}^{\rm SI} = \frac{\mu_{\chi p}^2}{\pi m_{Z'}^4} |V_\chi^{Z'}|^2 \frac{\left[Z f_p + (A-Z) f_n\right]^2}{A}$$

$$f_p = 2V_u^{Z'} + V_d^{Z'} \qquad f_n = V_u^{Z'} + 2V_d^{Z'}$$

$$\sigma_{\chi p}^{\rm SD} = \frac{3\mu_{\chi p}^2}{\pi m_{Z'}^4} |A_\chi^{Z'}|^2 \left[A_u^{Z'} \Delta_p^u + A_d^{Z'} \left(\Delta_p^d + \Delta_p^s\right)\right]^2$$

$$\langle \sigma v \rangle = \frac{m_\chi^2}{\pi m_{Z'}^4} |V_\chi|^2 \left[\left(a_V + b_V v^2\right) + \alpha^2 \left(a_A + b_A v^2\right)\right]$$

$$\langle \sigma v \rangle = f_1 \sigma_{\chi N}^{\rm SI} + f_2 \sigma_{\chi N}^{\rm SD} \qquad \alpha = \frac{A_\chi}{V_\chi}$$

Spin-1 mediator as new gauge bosons

Spin-1 BSM mediators can be interpreted as gauge bosons of extra symmetry groups

$$E_6 \rightarrow SO(10) \times U(1)_\psi$$ → Extra U(1) from Grand Unified theories

$$SO(10) \rightarrow SU(5) \times U(1)_\chi$$

$$SU(2)_L \times SU(2)_R \times U(1)_{B-L} \rightarrow SU(2) \times U(1)_Y \times U(1)_{LR}$$

General implementation:

$$\mathcal{L} = \sum_f g_f^{'} \bar{f}\gamma^\mu \left(\epsilon_L^f P_L + \epsilon_R^f P_R\right) f Z_\mu^{'} + g_\chi^{'} \bar{\chi}\gamma^\mu \left(\epsilon_L^\chi P_L + \epsilon_R^\chi P_R\right) \chi Z_\mu^{'}$$

$$\epsilon_{L,R}^f = \hat{\epsilon}_{L,R}^f / D$$

	χ	ψ	η	LR	B-L	SSM
D	$2\sqrt{10}$	$2\sqrt{6}$	$2\sqrt{15}$	$\sqrt{5/3}$	1	1
$\hat{\epsilon}_L^u$	-1	1	-2	-0.109	1/6	$\frac{1}{2} - \frac{2}{3}\sin^2\theta_W$
$\hat{\epsilon}_L^d$	-1	1	-2	-0.109	1/6	$-\frac{1}{2} + \frac{1}{3}\sin^2\theta_W$
$\hat{\epsilon}_R^u$	1	-1	2	0.656	1/6	$-\frac{2}{3}\sin^2\theta_W$
$\hat{\epsilon}_R^d$	-3	-1	-1	-0.874	1/6	$\frac{1}{3}\sin^2\theta_W$
$\hat{\epsilon}_L^\nu$	3	1	1	0.327	-1/2	$\frac{1}{2}$
$\hat{\epsilon}_L^l$	3	1	1	0.327	-1/2	$-\frac{1}{2} + \sin^2\theta_W$
$\hat{\epsilon}_R^e$	1	-1	2	-0.438	-1/2	$\sin^2\theta_W$

Han et al. 1308.2738

Vectorial and axial couplings are actually combinations of left-handed and right-handed currents

$$g^{'} V_f = \frac{g_f^{'}}{2}\left(\epsilon_L^f + \epsilon_R^f\right) \qquad g^{'} A_f = \frac{g_f^{'}}{2}\left(\epsilon_L^f - \epsilon_R^f\right)$$

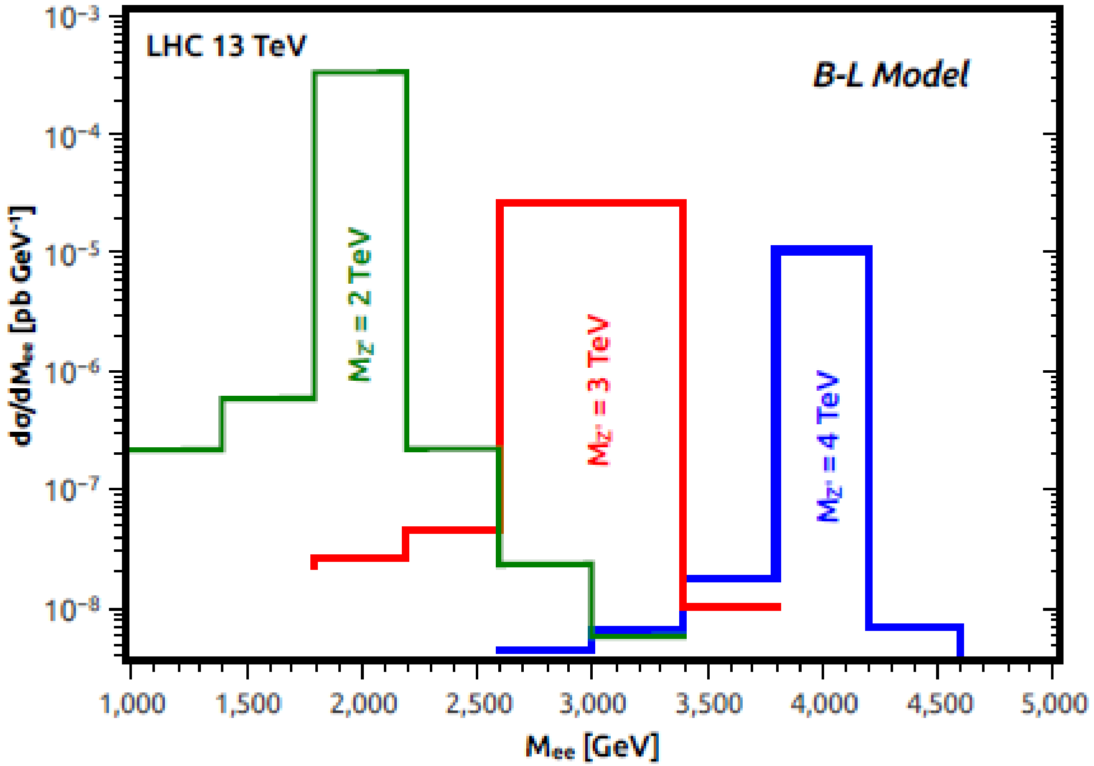
$$g^{'} V_\chi = \frac{g_\chi^{'}}{2}\left(\epsilon_L^\chi + \epsilon_R^\chi\right) \qquad g^{'} A_\chi = \frac{g_\chi^{'}}{2}\left(\epsilon_L^\chi - \epsilon_R^\chi\right)$$

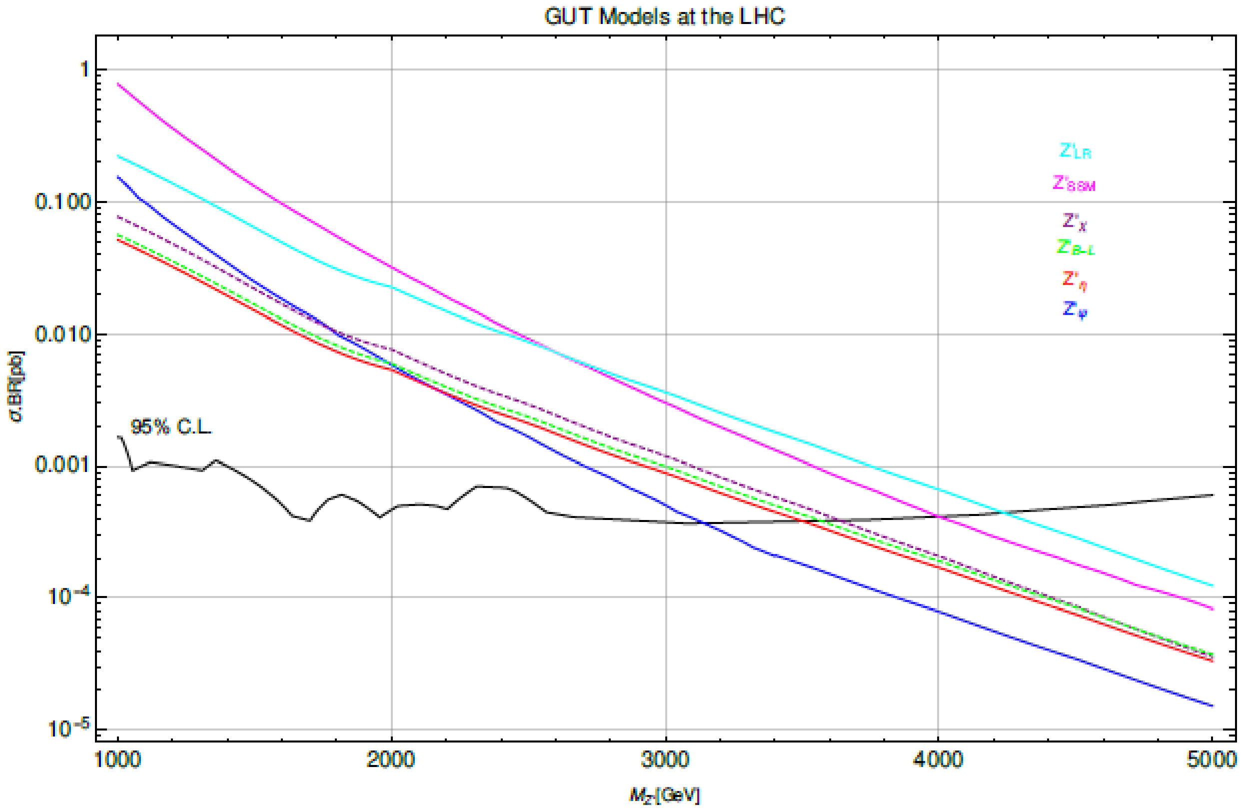
Search of heavy dilepton resonances

- $E_T(e_1) > 30\,\mathrm{GeV}, E_T(e_2) > 30\,\mathrm{GeV}, |\eta_e| < 2.5,$
- $p_T(\mu_1) > 30\,\mathrm{GeV}, p_T(\mu_2) > 30\,\mathrm{GeV}, |\eta_\mu| < 2.5,$
- $80\,\mathrm{GeV} < M_{ll} < 6000\,\mathrm{GeV},$

$$\frac{N_{\text{signal events}}(M^2_{\text{new}}, E_{\text{new}}, \mathcal{L}_{\text{new}})}{N_{\text{signal events}}(M^2, 13\,\text{TeV}, 13.3 fb^{-1})} = 1,$$

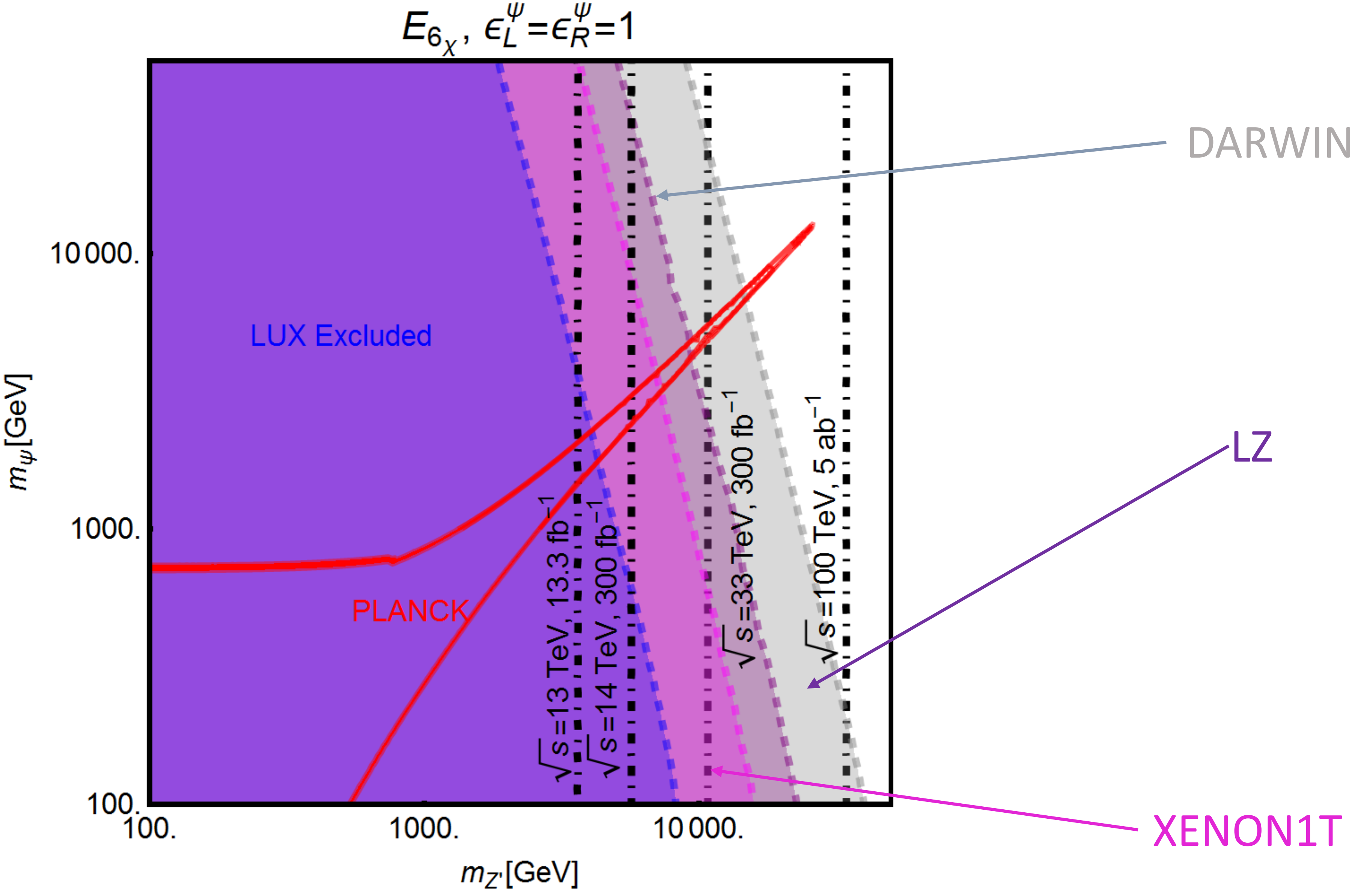
Projected bounds obtained through COLLIDER REACH CODE





G.A., M. Lindner, Y. Mambrini, M. Pierre, F. Queiroz, 1704.023028

Model	13 TeV,13.3 fb^{-1}	13 TeV,37 fb^{-1}	14 TeV,100 fb^{-1}	14 TeV,300 fb^{-1}	33 TeV,100 fb^{-1}	33 TeV,300 fb^{-1}	100 TeV,5 ab^{-1}
Z'_{ψ}	3.13 TeV	3.68 TeV	4.46 TeV	5.13 TeV	7.98 TeV	9.47 TeV	30.54 TeV
Z'_{η}	3.47 TeV	4.04 TeV	4.85 TeV	5.51 TeV	8.85 TeV	10.38 TeV	33.25 TeV
Z'_{B-L}	3.55 TeV	4.11 TeV	5.55 TeV	5.59 TeV	9.03 TeV	10.56 TeV	33.8 TeV
Z'_{χ}	3.63 TeV	4.19 TeV	5.55 TeV	5.68 TeV	9.23 TeV	10.76 TeV	34.41 TeV
Z'_{SSM}	4.02 TeV	4.59 TeV	6.05 TeV	6.09 TeV	10.21 TeV	11.75 TeV	37.36 TeV
Z'_{LR}	4.23 TeV	4.8 TeV	6.27 TeV	6.31 TeV	10.73 TeV	12.28 TeV	38.92 TeV



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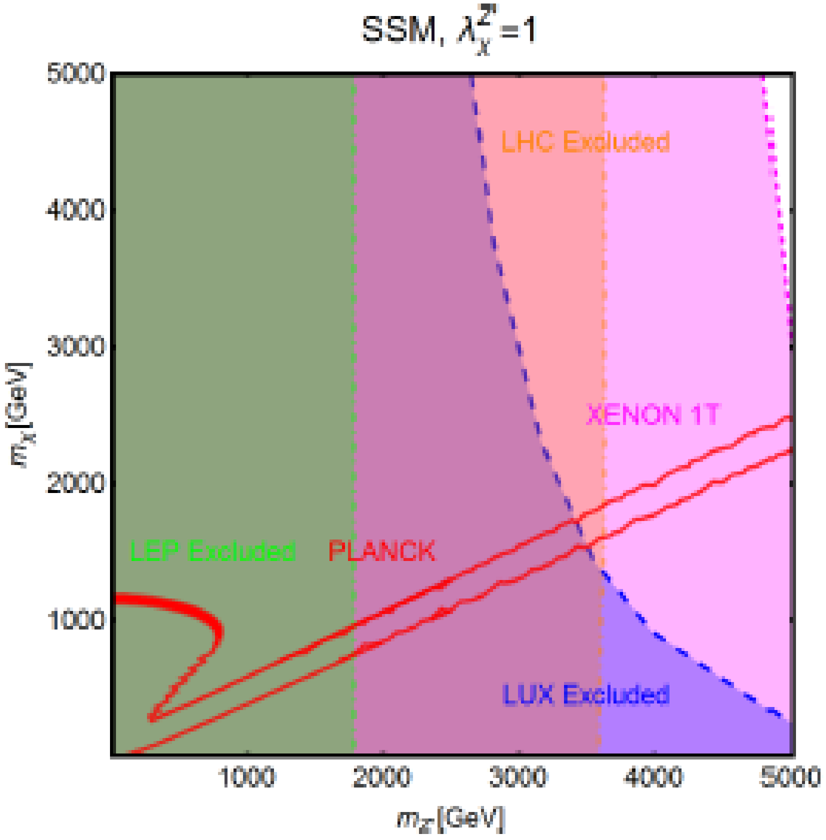
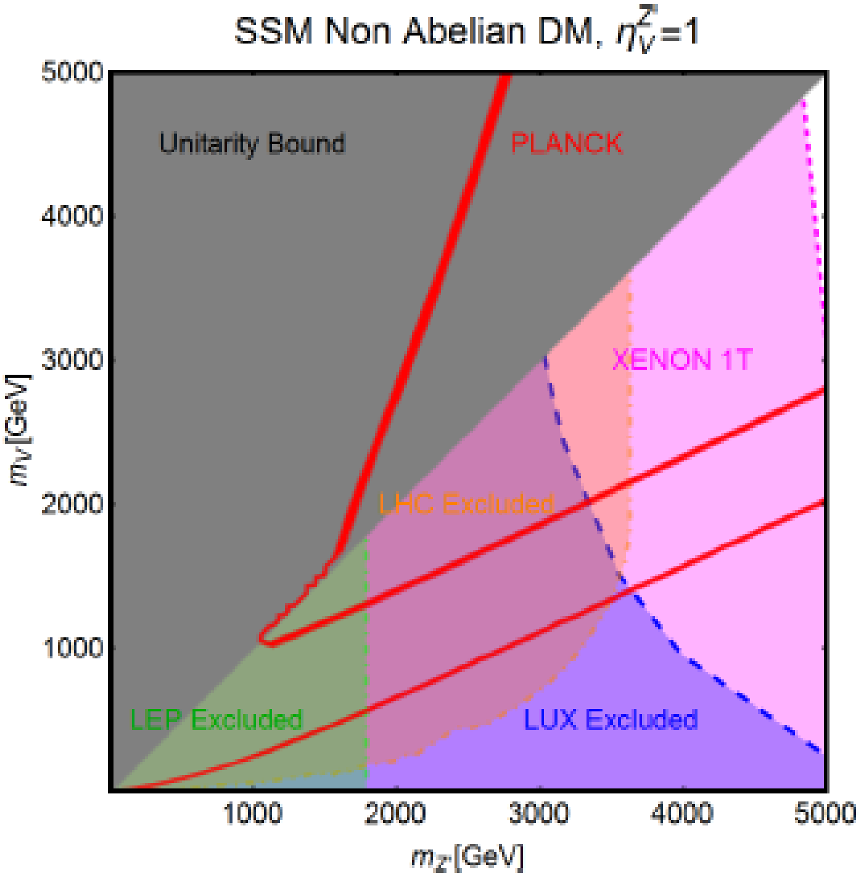
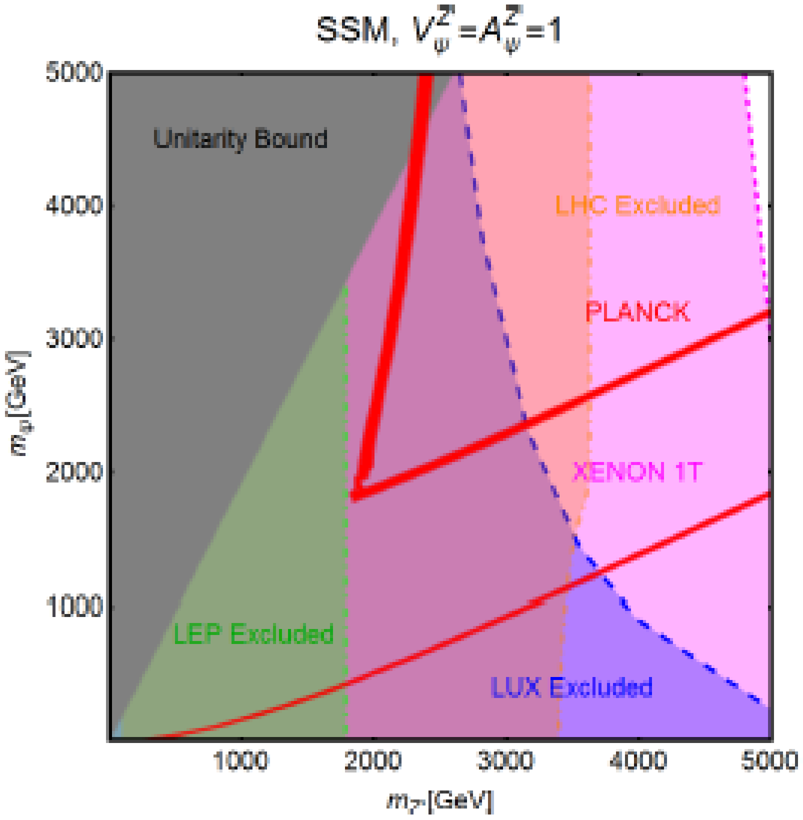


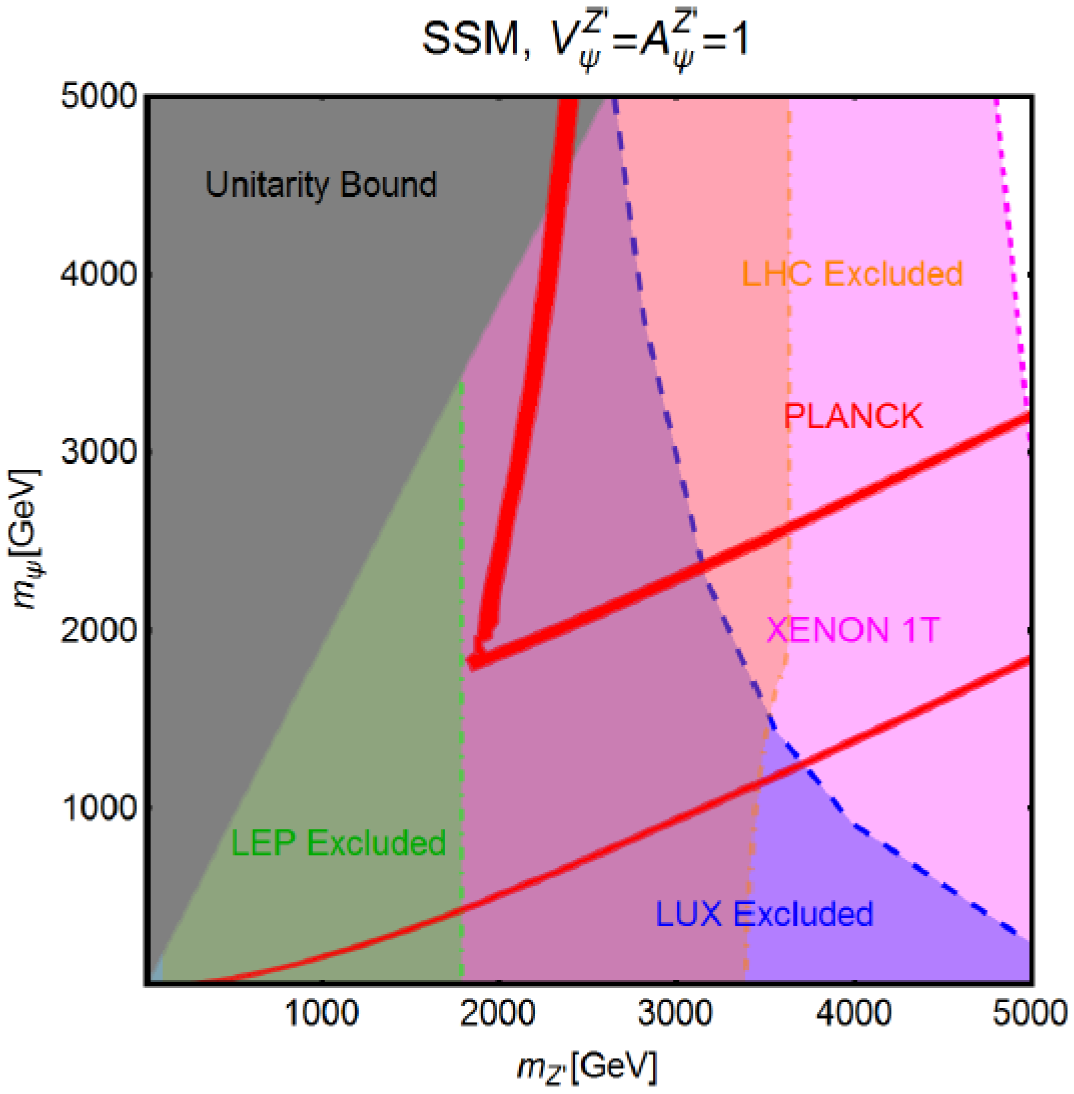
Complex scalar DM

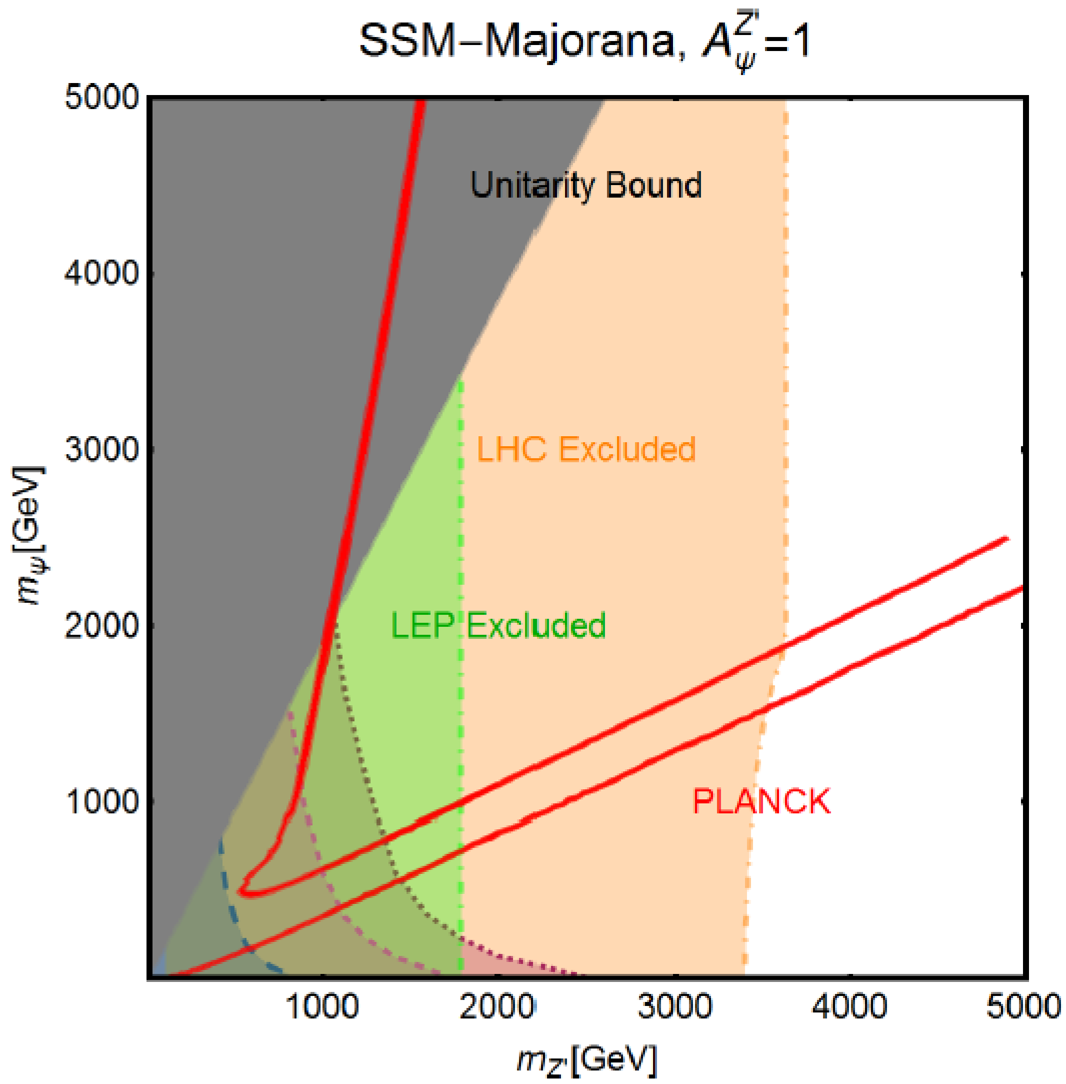
Non abelian vector DM





Dirac fermion DM


SSM, $V_\psi^{Z'}=A_\psi^{Z'}=1$
Unitarity Bound
LHC Excluded
PLANCK
XENON 1T
LEP Excluded
LUX Excluded
m_ψ[GeV]
$m_{Z'}$[GeV]
5000
4000
3000
2000
1000
1000
2000
3000
4000
5000


SSM−Majorana, $A_\psi^{Z'}=1$
Unitarity Bound
LHC Excluded
LEP Excluded
PLANCK
m_ψ[GeV]
$m_{Z'}$[GeV]
5000
4000
3000
2000
1000
1000
2000
3000
4000
5000

Conclusions

Next generation experiments, high energy/luminosity collider and multi-ton DD facilities have the potential capability of fully testing the WIMP paradigm.

This result is achived thanks to complementarity of the different search strategies.

Some theoretically motivated setups will be completely ruled out in absence of signals at next generation experiments.