Dark Matter, LHC signals and muon (g-2) in some SUSY-GUT's.

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Colaboration with M. Canonni, J. Ellis, S. Lola, Ruiz de Austri JCAP 1603 (2016) and Q. Shafi arXiv:1806.11152 and 1806.06220.

OUTLINE

-GUT's and SUSY.

-NUHM: SO(10) vs NUGM:SU(4)xSU(2)xSU(2)

-SU(4)xSU(2)xSU(2) without L-R symmetry.

- Neutralino relic density and DM detection.

-SUSY Masses and LHC searches.

Conclusions.

SUSY extension of SM

- Divergence cancellations
- Gauge unification
- Particles in the range of coming accelerators.
- DM candidate.
- Small but sizeable contribution to SM processes...

Soft SUSY Breaking Terms

The soft SUSY breaking masses

$$
\begin{aligned}
-\mathcal{L}_{\text{soft}} = & -\frac{1}{2}\left(M_3\,\lambda_{\tilde{g}}^{a}\lambda_{\tilde{g}}^{a} + M_2\,\lambda_{\tilde{W}}^{i}\lambda_{\tilde{W}}^{i} + M_1\,\lambda_{\tilde{B}}\lambda_{\tilde{B}} + \text{h.c.}\right) \\
& + M_L^2\,\tilde{L}^{\dagger}\tilde{L} + M_Q^2\,\tilde{Q}^{\dagger}\tilde{Q} + M_U^2\,\tilde{U}^{*}\tilde{U} + M_D^2\,\tilde{D}^{*}\tilde{D} + M_E^2\,\tilde{E}^{*}\tilde{E} + \\
& m_{H_d}^2\,\tilde{H}_d^{\dagger}\tilde{H}_d + m_{H_u}^2\,H_u^{\dagger}H_u - \left(B\mu\,\tilde{H}_d^{T}H_u + \text{h.c.}\right) \\
& + \left(y_\ell A_\ell\,H_d^{\dagger}\tilde{L}\tilde{E} + y_d A_d\,H_d^{\dagger}\tilde{Q}\tilde{D} - y_u A_u\,H_u^{T}\tilde{Q}\tilde{U} + \text{h.c.}\right),
\end{aligned}
$$

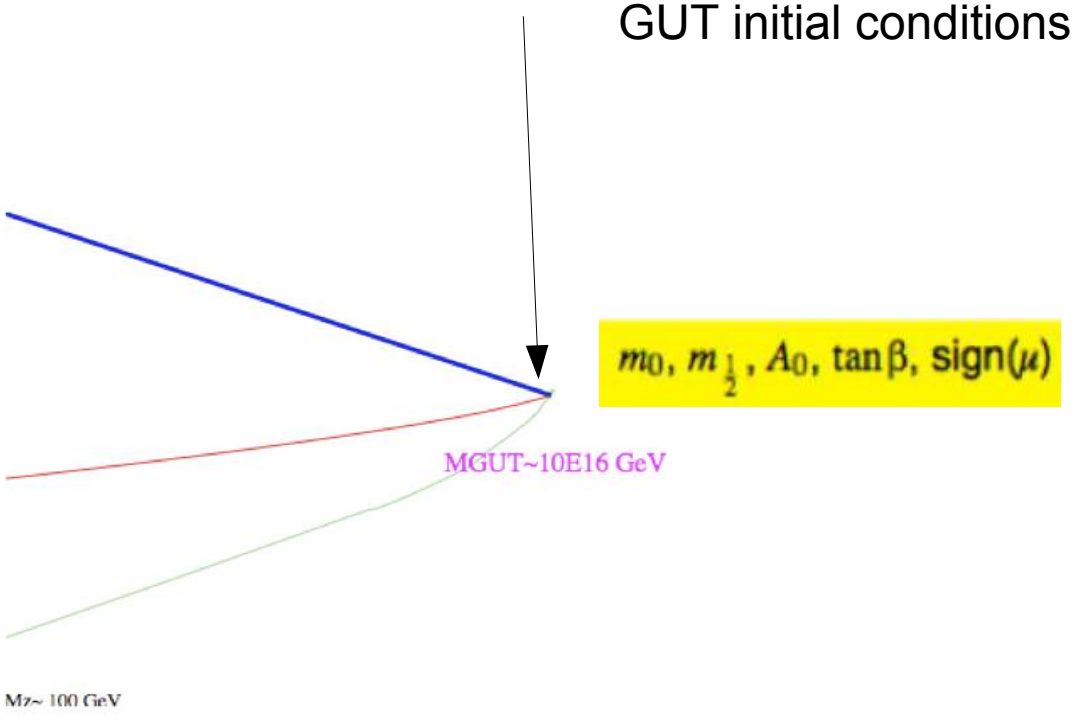
Inspired from supergravity assume universal soft breaking, $\mathcal{L}_{\text{soft}}$:

$$
\sum_{f,H} m_0^2\,\tilde{f}\tilde{f} + \sum_{\lambda} m_{\frac{1}{2}}\,\lambda\lambda + \sum_{f} A_0 Y_f\,\tilde{f}\tilde{F}H_f + B\mu H_u H_d
$$

$$
m_0,\ m_{\frac{1}{2}},\ A_0,\ \tan\beta,\ \text{sign}(\mu)
$$

μ and A_0 can be complex, however their phases contraint to be $< 0{,}2$ rad by the bounds o the fermion EDM.

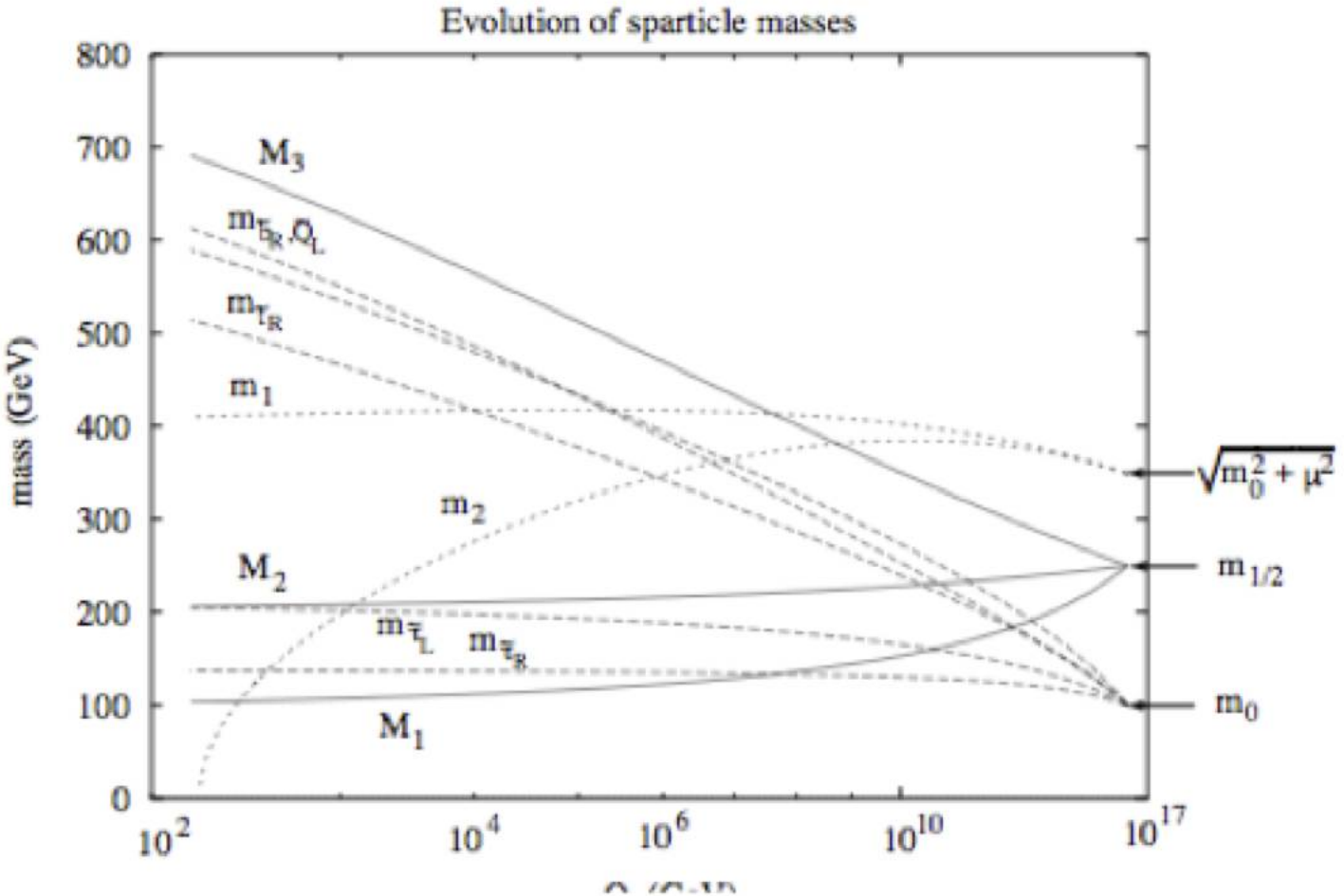
GUT initial conditions



SUSY spectrum

CMSSM, mSUGRA. Parametros de masa universales:

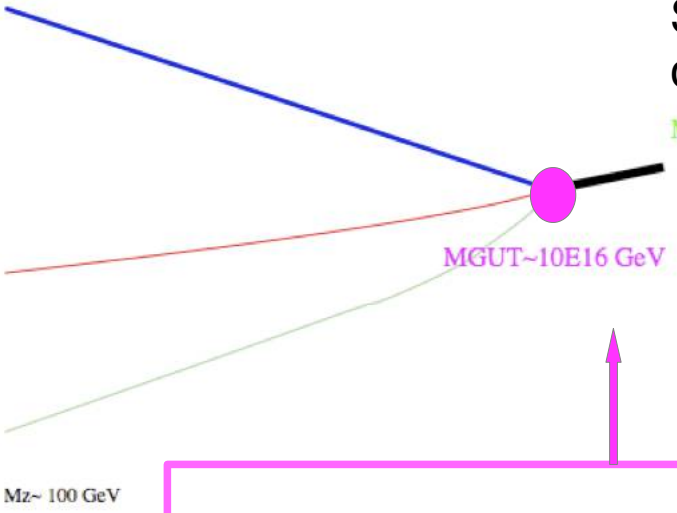
$$m_0,\ M_{1/2},\ A_0,\ \mu_0,\ \alpha_G,\ M_{GUT},\ \tan\beta\ .$$



$$W_{SU(5)} = Y_u^{ij} 10_i 10_j 5^u + Y_d^{ij} 10_i \bar{5}_j \bar{5}^d$$

String scale Initial conditions

Mx>MGUT



m_{10} m_5 m_u , m_d

$(Q_L, U, E) \subseteq 10$ $(D, L) \subseteq \bar{5}$ $H_u \subset 5^u ; H_d \subset \bar{5}^d$

Non Universal scenarios

CMSSM choice:

- *m0 Universal soft masses.*
- m1/2 *Universal gaugino masses.*
- A0 *Universal Trilinear terms.*

Representation-dependent choice

$$m_r = x_r\, m_0$$

$$A_r = Y_r\, A_0, \qquad A_0 = a_0\, m_0$$

Non Universal SO(10)

$$W_{SO(10)} = \lambda^{u}_{ij} 16_i 10^u 16_j + \lambda^{d}_{ij} 16_i 10^d 16_j$$

$$Q_L, D, U, L, E, N \subseteq 16$$

$$H_u \subset 10^u ; H_u \subset 10^u$$

The soft term masses are taken at GUT as:

$$m_{16} = m_0 ; m_u = x_u m_0 ; m_d = x_d m_0 ;$$

Trilinear terms:

$$A_0 = a_0 m_0$$

Non Universal SO(10)

$$W_{SO(10)} = \lambda^{u}_{ij} 16_i 10^u 16_j + \lambda^{d}_{ij} 16_i 10^d 16_j$$

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Equivalent to NUHM

PATI-SALAM Unification

$$G_{PS} \equiv SU(4) \times SU(2)_L \times SU(2)_R$$

$$\mathbf{4_c 2_L 2_R}$$

Matter Fields

F_r	$\begin{pmatrix} d_r & -u_r \\ e_r & -\nu_r \end{pmatrix}$	$(\mathbf{4}, \mathbf{2}, \mathbf{1})$
F_r^c	$\begin{pmatrix} u_r^c \\ d_r^c \end{pmatrix}, \begin{pmatrix} \nu_r^c \\ e_r^c \end{pmatrix}$	$(\bar{\mathbf{4}}, \mathbf{1}, \mathbf{2})$

$$< \tilde{\nu_H^c} > = < \bar{\nu_H^c} > \sim M$$

Higgs Fields

H^c	$\begin{pmatrix} u_H^c \\ d_H^c \end{pmatrix}, \begin{pmatrix} \nu_H^c \\ e_H^c \end{pmatrix}$	$(\bar{\mathbf{4}}, \mathbf{1}, \mathbf{2})$
$\bar{H}^c$	$\begin{pmatrix} \bar{u}_H^c & \bar{d}_H^c \\ \bar{\nu}_H^c & \bar{e}_H^c \end{pmatrix}$	$(\mathbf{4}, \mathbf{1}, \mathbf{2})$
h	$\begin{pmatrix} h_2^+ & h_1^0 \\ h_2^0 & h_1^- \end{pmatrix}$	$(\mathbf{1}, \mathbf{2}, \mathbf{2})$

$$G_{PS} \to \mathrm{SU}(3)_C \otimes \mathrm{SU}(2)_L \otimes \mathrm{U}(1)_Y$$

Non universal Higgs Mass terms due to D- terms.

$$m^2_{H_{u,d}} = m^2_{10} \mp 2M_D^2$$

$$M_1 = \frac{3}{5} M_2 + \frac{2}{5} M_3.$$

Condition for gaugino masses.

→ SUSY SEARCH: SuperBayeS, MultiNest

→ RGE's: SoftSusy

→ Relic Density: MicroOMEGAs

→ Direct DM detection: DarkSUSY

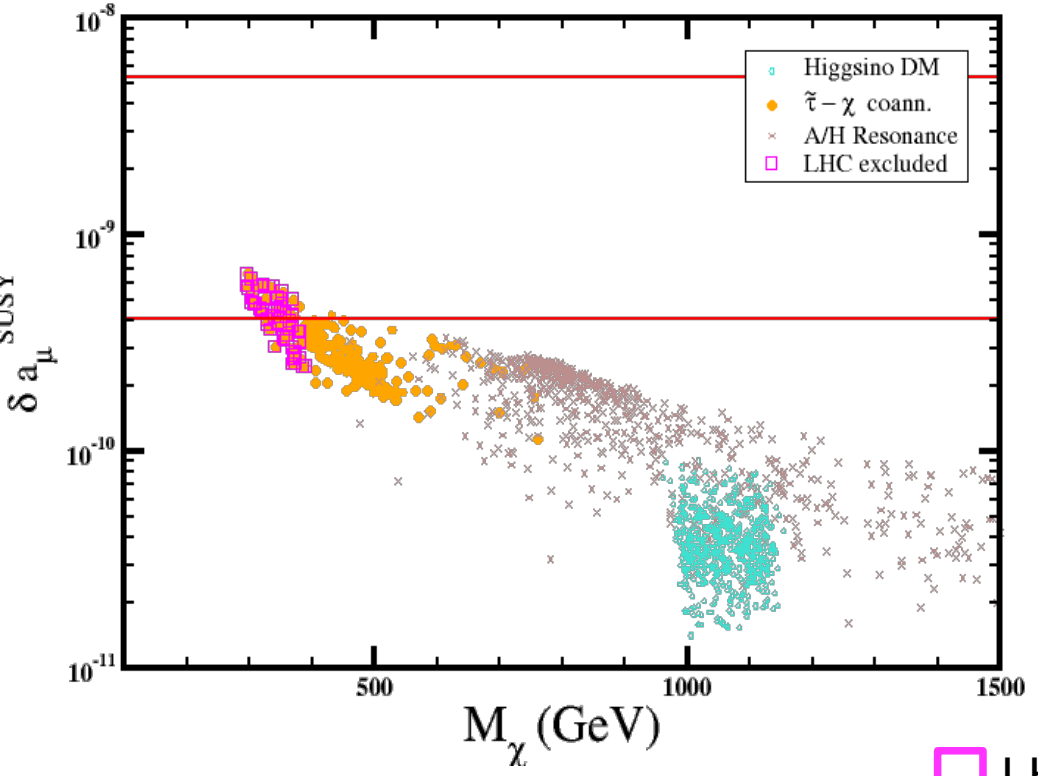
→ Super Iso: $\delta a_\mu^{\rm SUSY}$

→ SusyBSG: B-Physics.

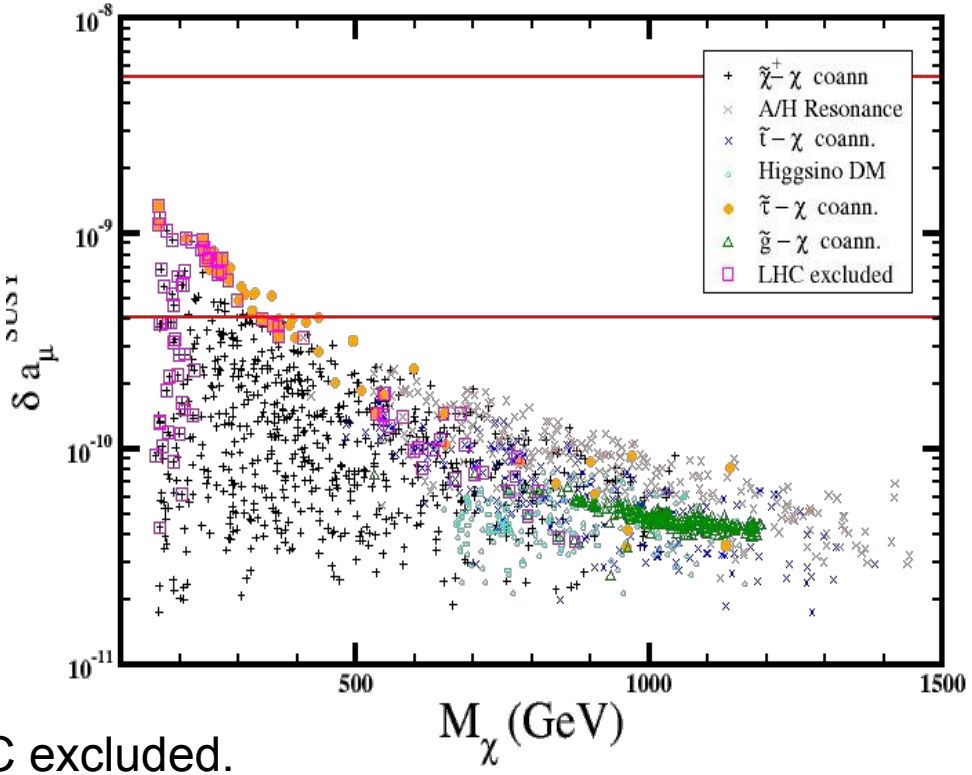
Likelyhood function:

$$\ln \mathcal{L}_{\rm Joint} = \ln \mathcal{L}_{\rm EW} + \ln \mathcal{L}_{\rm B} + \ln \mathcal{L}_{\Omega_\chi h^2} + \ln \mathcal{L}_{\rm LUX} + \ln \mathcal{L}_{\rm Higgs} + \ln \mathcal{L}_{\rm SUSY} + \ln \mathcal{L}_{\rm g-2},$$

SO(10)



PS(4-2-2)



LHC excluded.

Higgsino DM

$$h_f > 0.1, \quad |m_A - 2m_\chi| > 0.1\, m_\chi.$$

$$h_f \equiv |N_{13}|^2 + |N_{14}|^2,$$

A/H Resonances

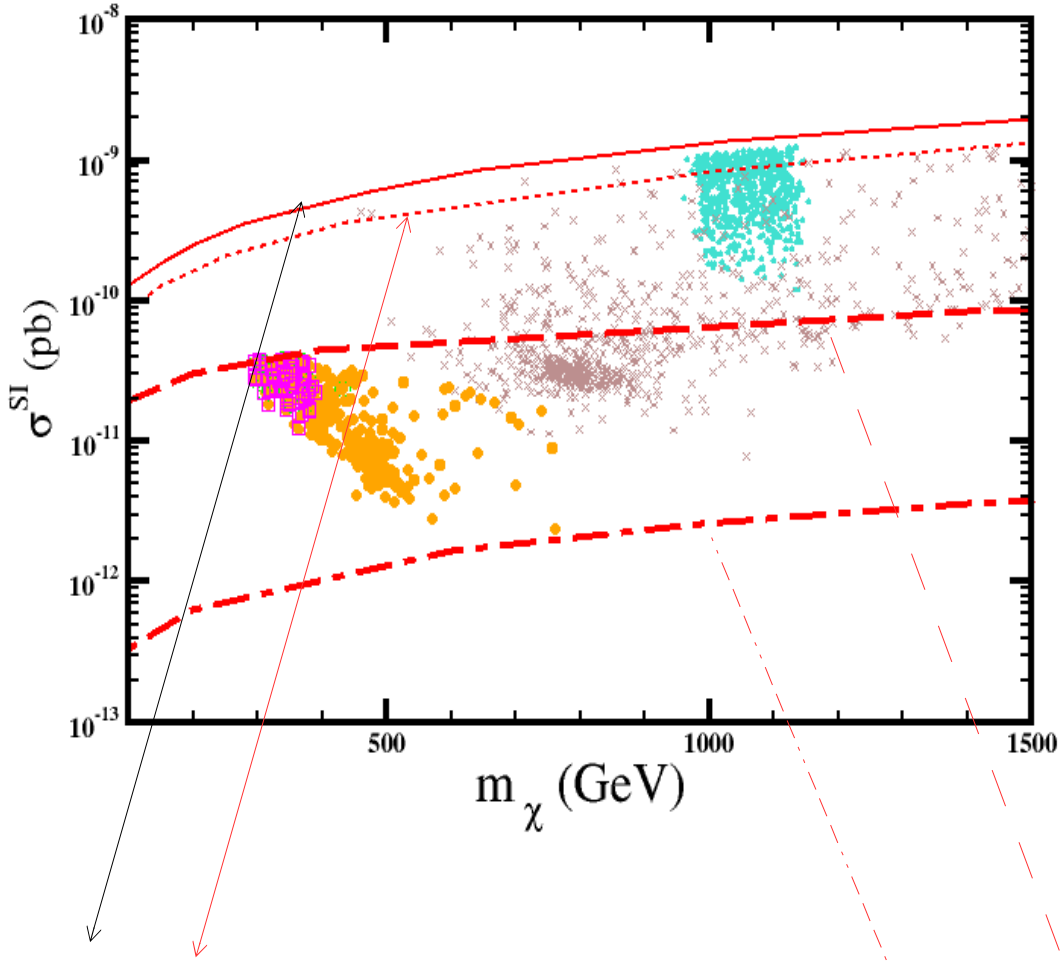
$$|m_A - 2m_\chi| \leq 0.1\, m_\chi$$

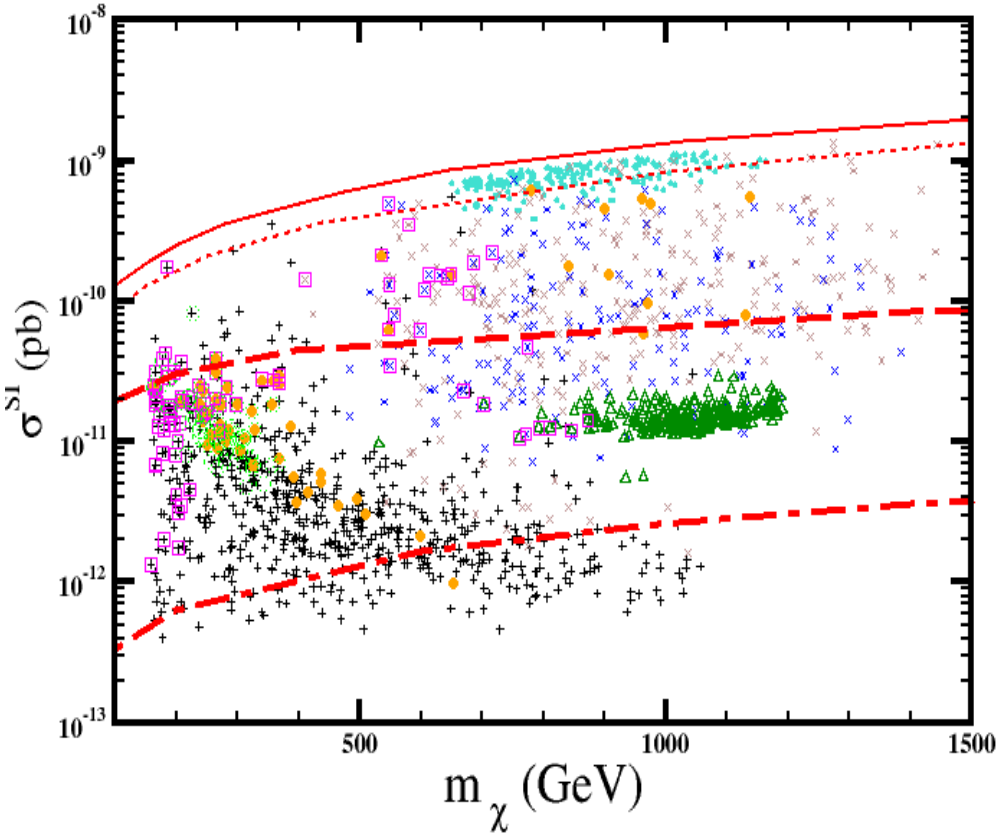
Coanihilations: $\left(m_z - m_{LSP}\right) < 0.1\, m_{LSP}$

$\tilde{\tau}$ $\tilde{\chi}^+$ Stop gluino

SO(10)

PS(4-2-1)



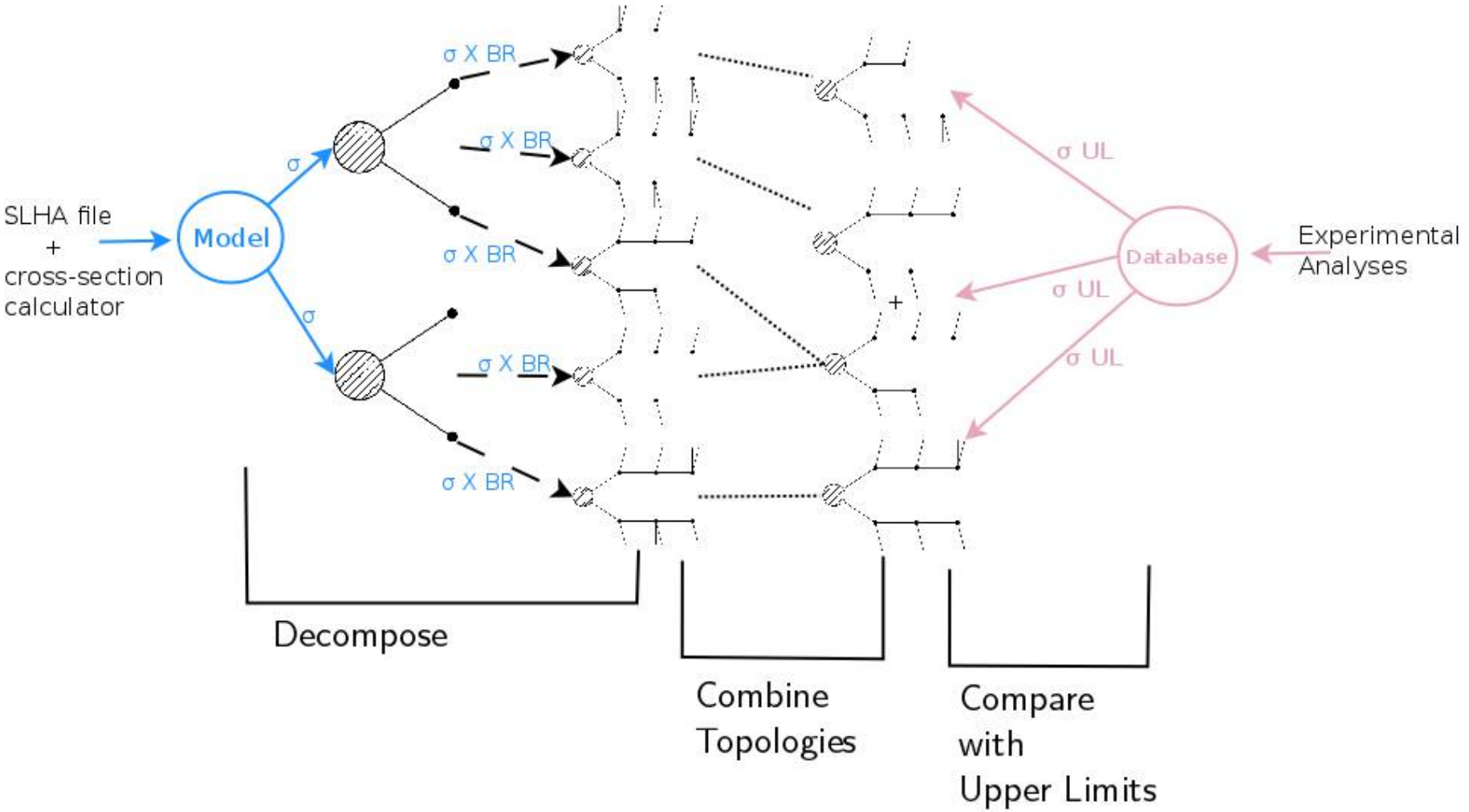


Xenon 1T

Darwin

LZ

LHC analysis with Smodels, *http://smodels.hephy.at/wiki*



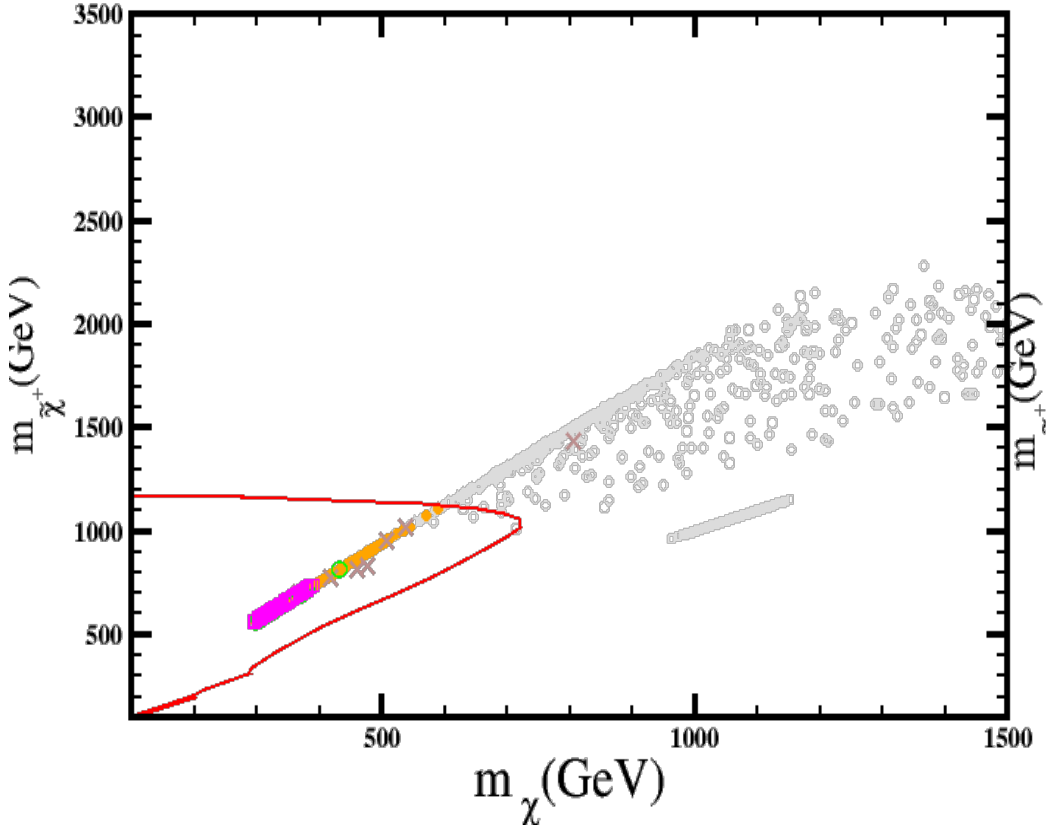
Analyzed points:

Excluded

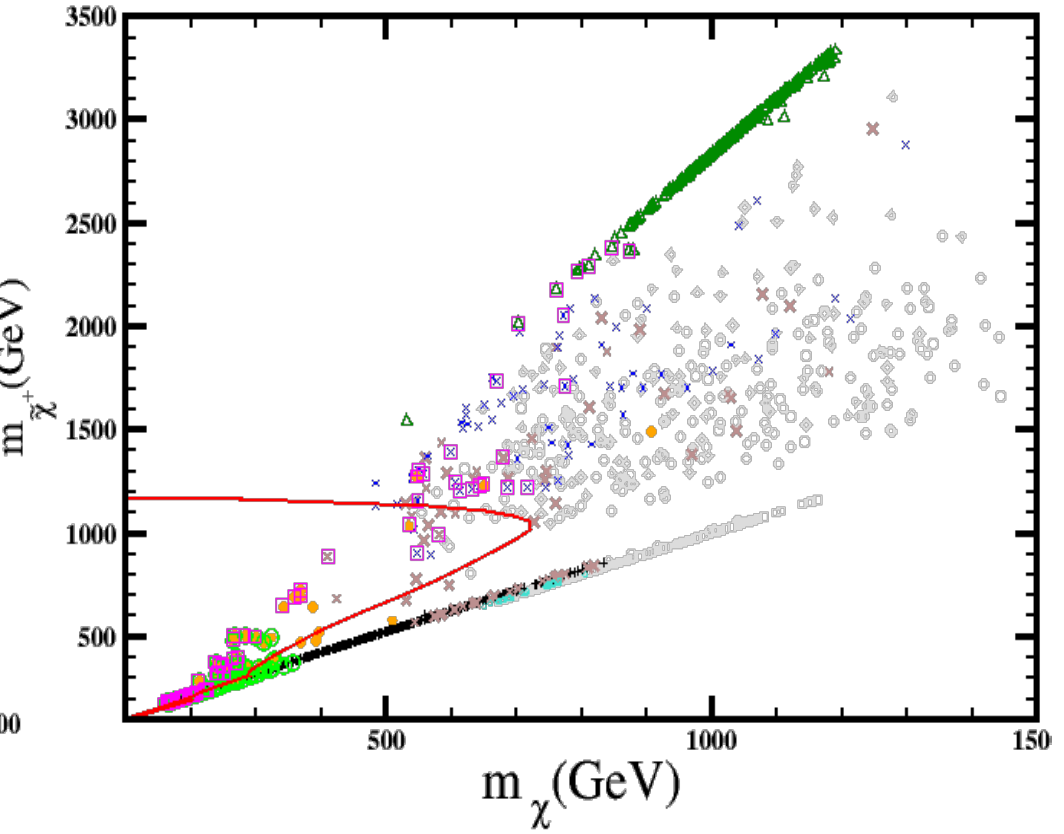
Allowed

Not analyzed.

SO(10)



PS(4-2-2)



Higgsino DM

A/H Resonances

Coanihilations:

$\tilde{\tau}$ + $\tilde{\chi}^+_i$

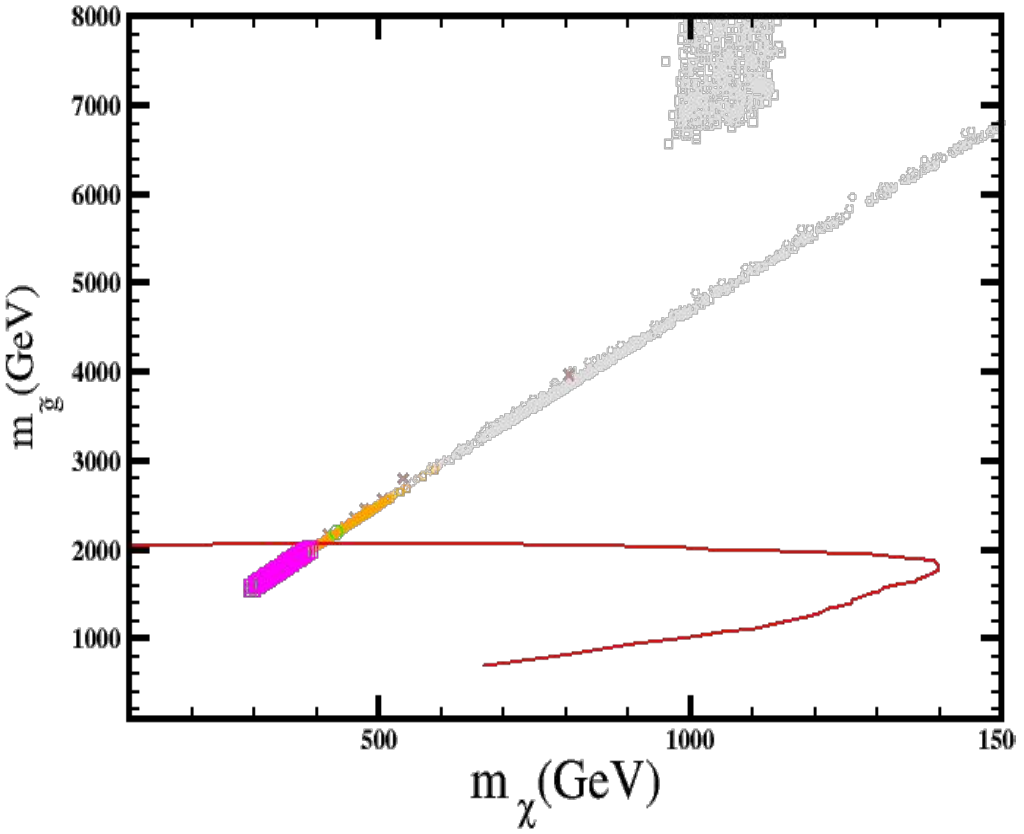
LHC excluded.

good (g-2)

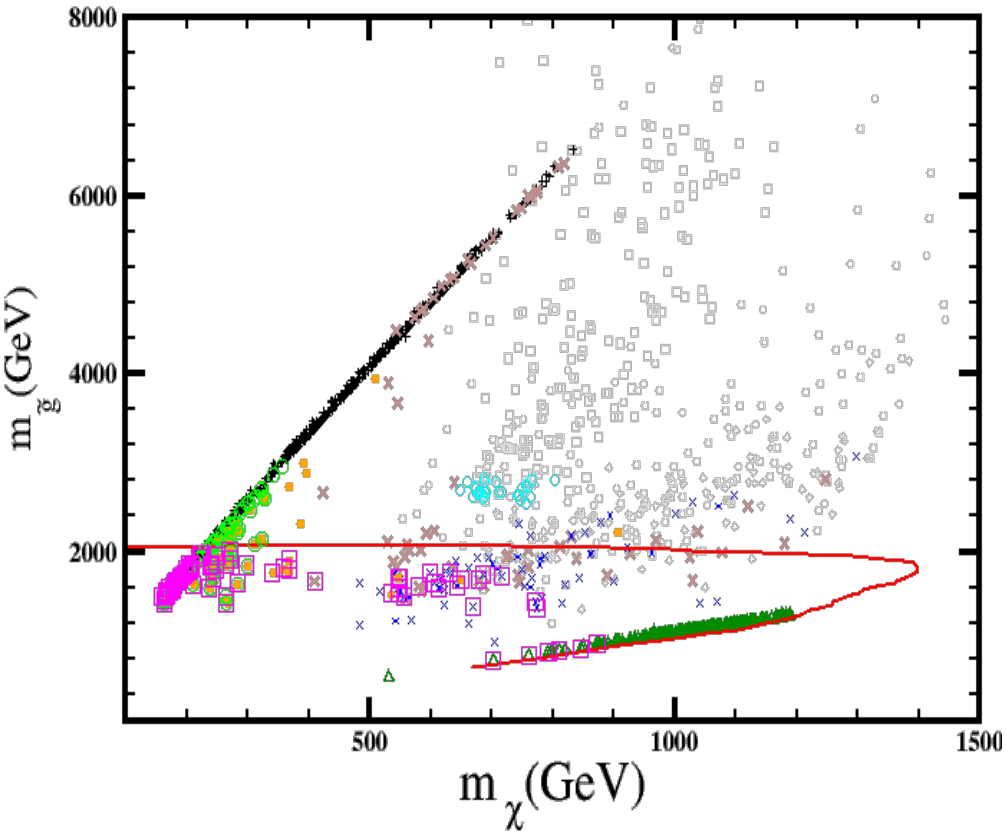
$\tilde{t}$

$\tilde{g}$

SO(10)



PS(4-2-2)



Higgsino DM

A/H Resonances

Coanihilations:

$\tilde{\tau}$ + $\tilde{\chi}^{+}_{i}$

LHC excluded.

good (g-2)

$\tilde{t}$

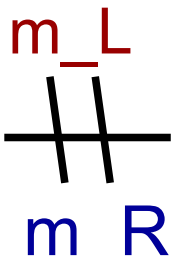
$\tilde{g}$

PS(4-2-1) ***LR Asymmetry***

MATTER FIELDS

$$F_r \quad \begin{pmatrix} d_r & -u_r \\ e_r & -\nu_r \end{pmatrix} \quad (\mathbf{4}, \mathbf{2}, \mathbf{1})$$

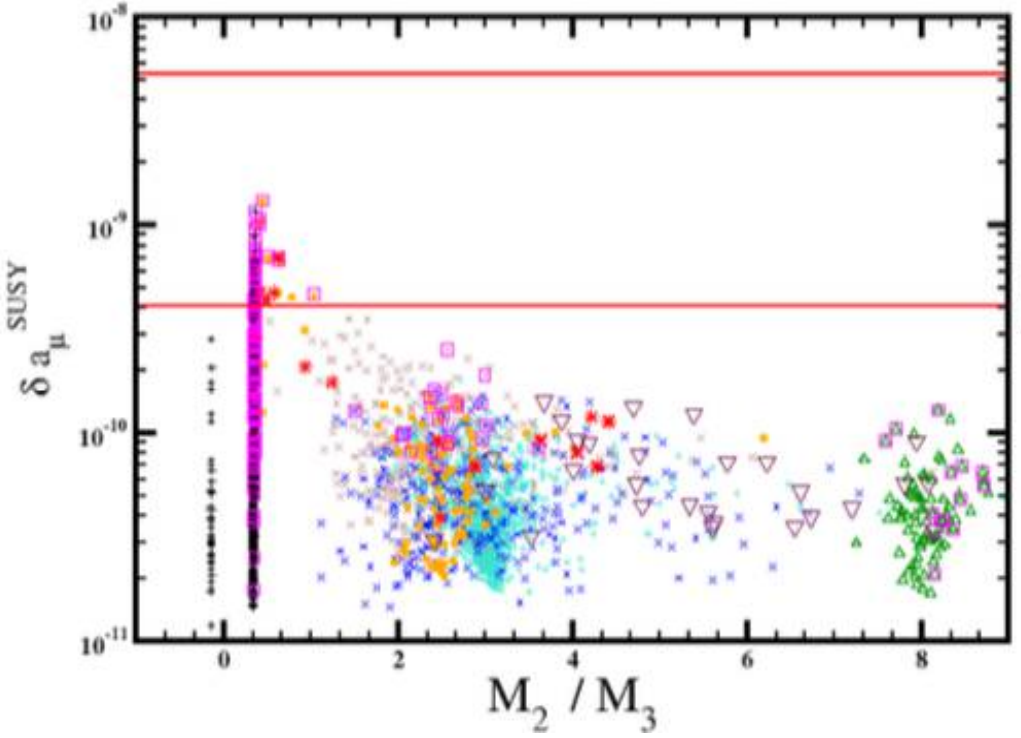
$$F_r^c \quad \begin{pmatrix} u_r^c \\ d_r^c \end{pmatrix}, \begin{pmatrix} \nu_r^c \\ e_r^c \end{pmatrix} \quad (\bar{\mathbf{4}}, \mathbf{1}, \mathbf{2})$$

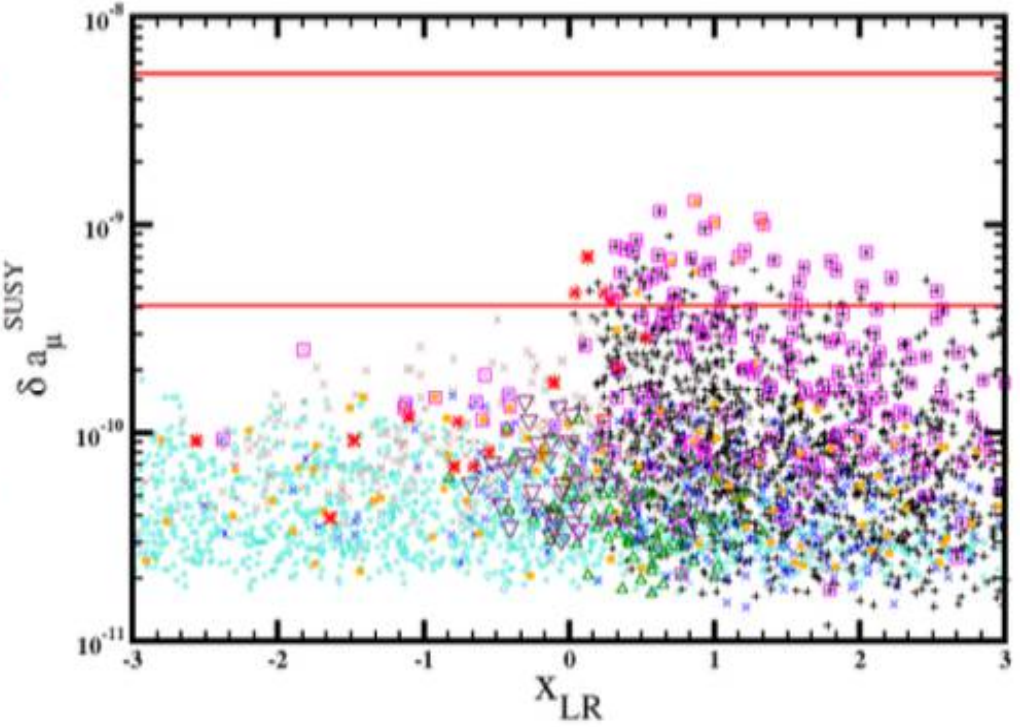


New Parameter $x_{LR} = \dfrac{m_L}{m_R}$,

PS(4-2-2)

L/R Asymetry





Higgsino DM

A/H Resonances

Coanihilations: $\tilde{\tau} + \tilde{\chi}^{+}_{i}$

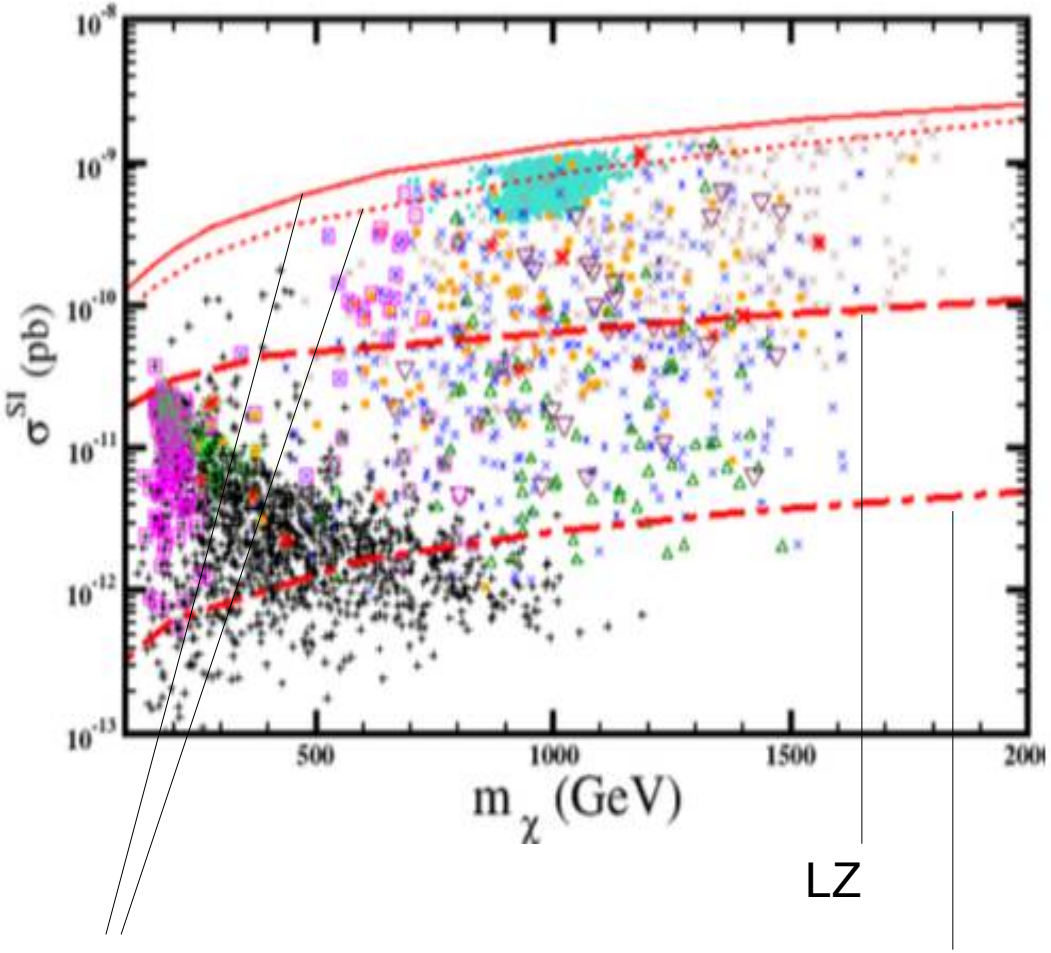
$\tilde{\tau} - \tilde{\nu}$

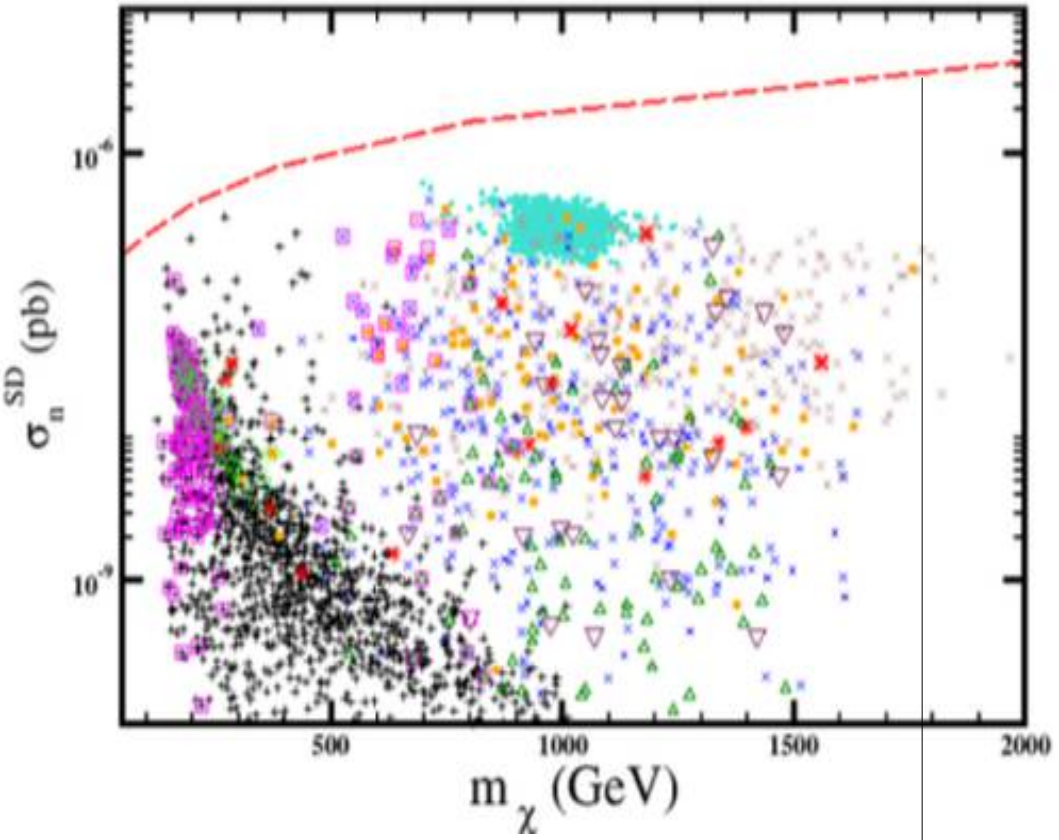
LHC excluded.

good (g-2)

$\tilde{t}$ $\tilde{g}$ $\tilde{b}$

PS *L/R Asymetry*





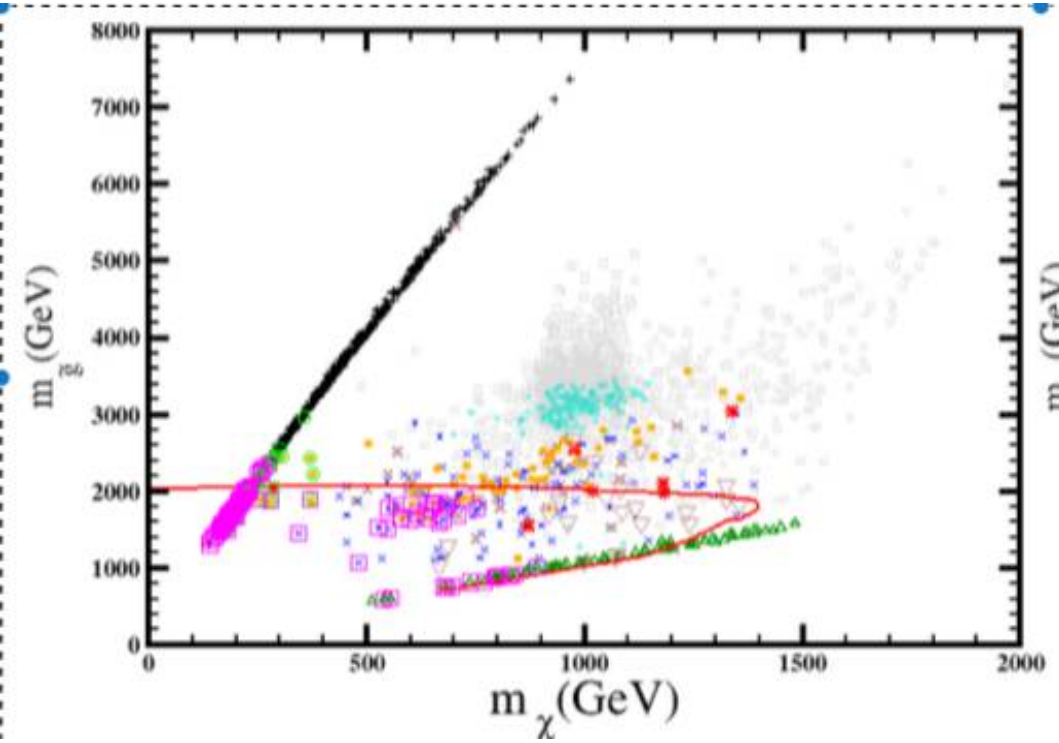
LZ

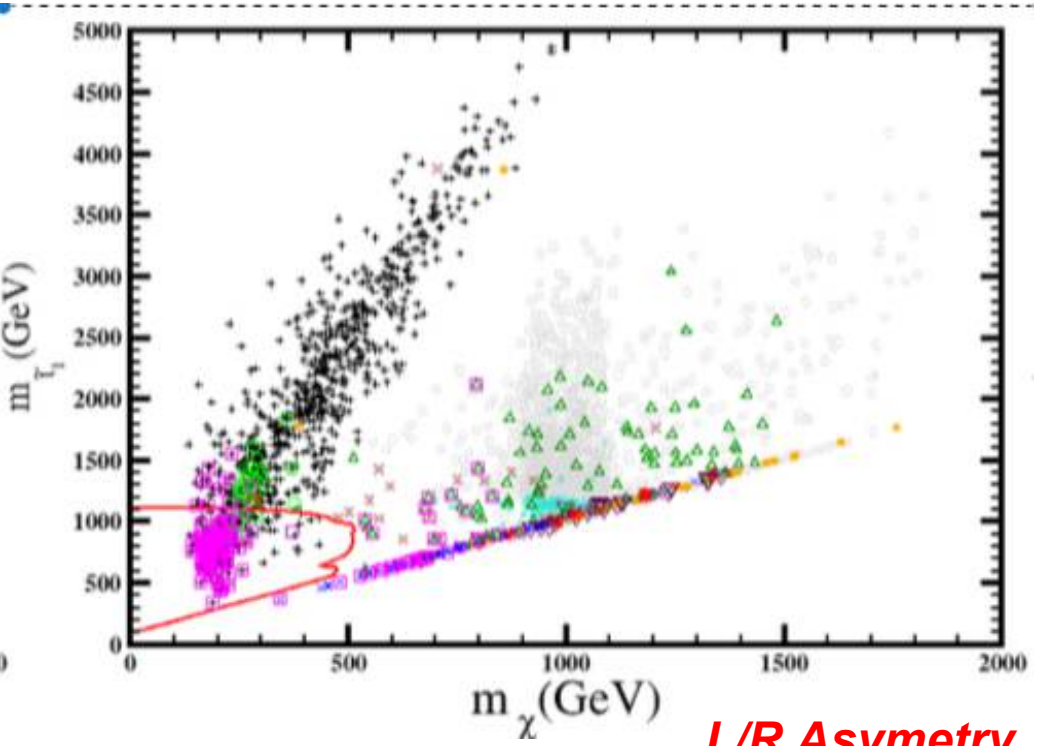
Xenon 1T

Darwin

Proyected LZ

PS(4-2-2) ***L/R Asymetry***





L/R Asymetry

Higgsino DM

A/H Resonances

Coanihilations: $\tilde{\tau} - \tilde{\nu}$

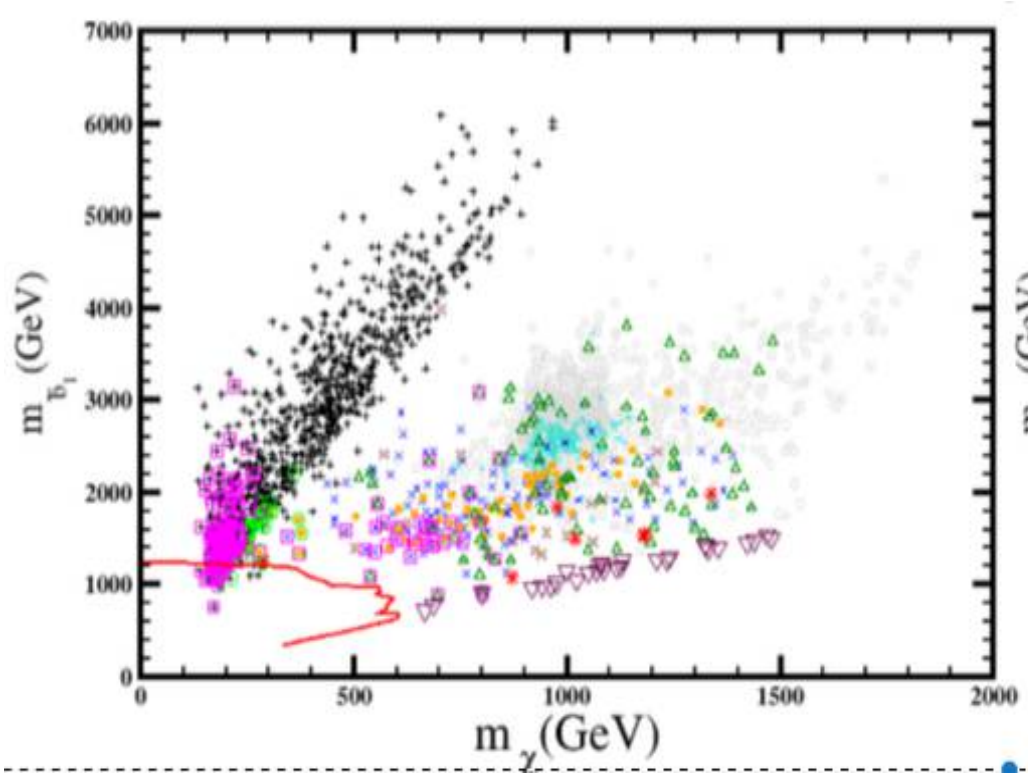
$\tilde{\tau} + \tilde{\chi}^{+}_{i}$

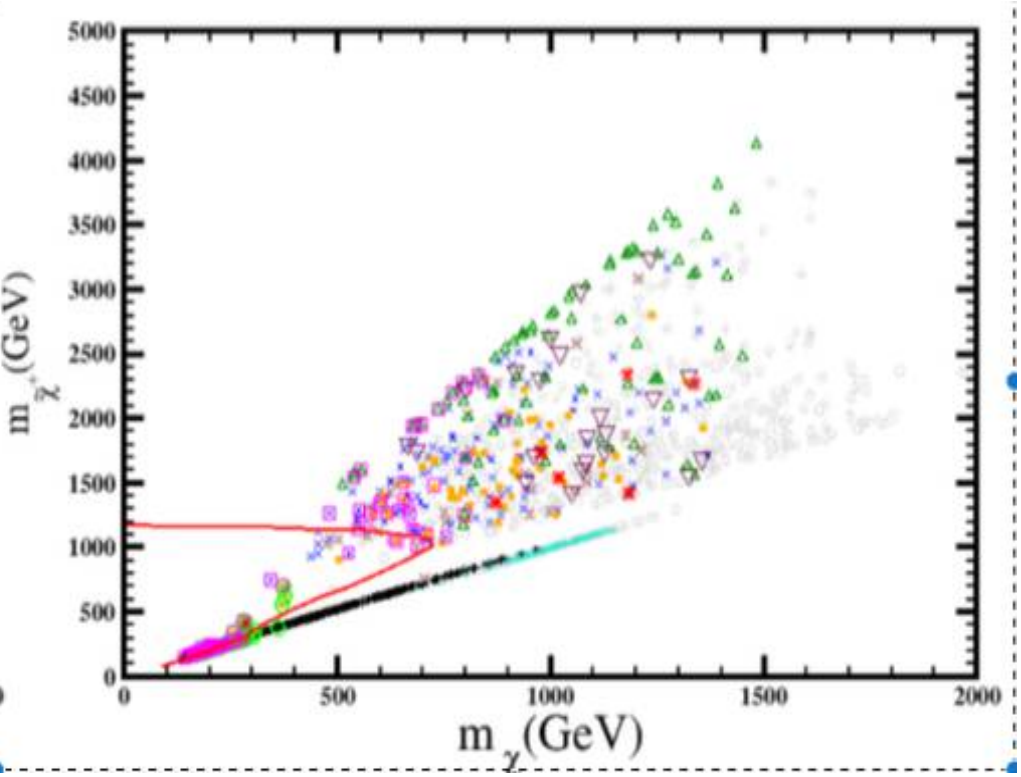
LHC excluded.

good (g-2)

$\tilde{t}$ $\tilde{g}$ $\tilde{b}$

PS(4-2-2) *L/R Asymmetry*





Higgsino DM

A/H Resonances

Coanihilations:

$\tilde{\tau} - \tilde{\nu}$

$\tilde{\tau} + \tilde{\chi}^{+}_{i}$

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$\tilde{t}$ $\tilde{g}$ $\tilde{b}$

CONCLUSIONS

We have identified different patterns of soft SUSY-breaking terms at the GUT scale, with different dark matter predictions and the constraints from LHC searches.

We have calculated the SUSY spectra for the different gauge groups, finding that the models predict different spectra for the same LSP mass, connecting possible future observations with the structure of the underlying unified theory.

None of the GUT models studied offers high prospects for reducing substantially the muon (g-2) discrepancy via a SUSY contribution.

We have found that SO(10) (gaugino universality), PS (gaugino non universality) lead to very different predictions for dark matter and LHC experiments, and thus are distinguishable in future searches. PS predicts stop-LSP, gluino-LSP coannihilations that are absent in the other groups and can be explored by LHC searches.

The LHC searches for generic missing E_T, charginos and stops are quite complementary, and future LHC runs will be able to constrain the models in several different ways.