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Supersymmetric Muon g-2 with/without stable Neutralino

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In collaboration with

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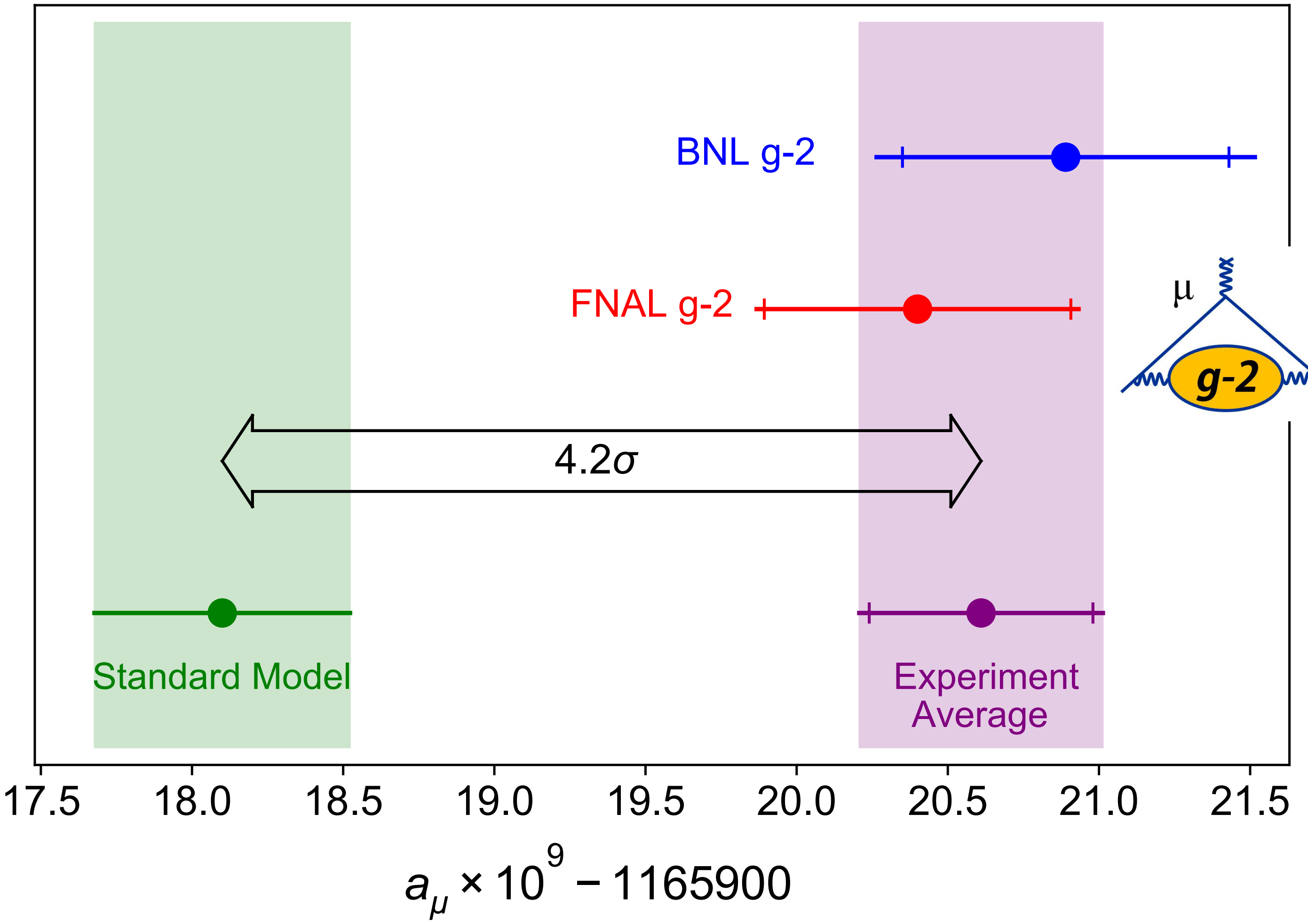
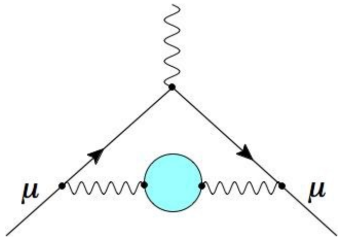
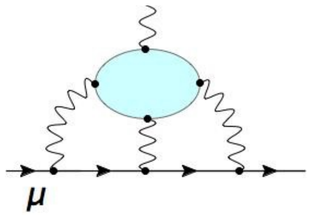
(g - 2)$_\mu$ anomaly

[Phys. Rev. LeS. 126 (2021) 14, 141801]





from HVP, HLbL



$$\begin{array}{lcccccc} & & & \text{QED} & \text{HVP} & \text{EW} & \\ a_\mu^{\text{theo}} & = & 0.00 & 1165 & 91 & 810 & (43) \\ a_\mu^{\text{exp}} & = & 0.00 & 1165 & 92 & 061 & (41) \end{array}$$

stat err dominant

$$a_\mu^{\text{exp}} - a_\mu^{\text{theo}} \simeq (25 \pm 6) \times 10^{-10} \simeq \Delta a_\mu^{\text{BSM}} \,?$$

Motivation

- There are many BSM scenarios that can explain the $(g-2)_\mu$ anomaly:

Leptoquarks, Z’, VLL, 2HDM, axion, ..

- Supersymmetry is particularly motivated since it offers:

Coupling Unification, Radiative EWSB, Baryogenesis, DM, …

- There are many studies on SUSY g-2 already:

[Athrona, Balazsa, Jacoba, Kotlarskic, Stockingerc, Stockinger-Kim]; [Chakraborti, Heinemeyer, Saha]; [Endo,Hamaguchi,Iwamoto,Kitahara]; [Cox, Han, Yanagida]; [Baum, Carena, Shah, Wagner]; [Badziak, KS]; [Hagiwara,Ma,Mukhopadhyay’18], …

- Most studies assume the neutralino is the Lightest SUSY Particle (LSP) and stable.

Q: What happens if neutralino is unstable? (e.g. RPV, Gravitino LSP)

A: DM constraints go away, but LHC constraints change. **How?**

$$\begin{array}{rcccccc} & & & \text{QED} & \text{HVP} & \text{EW} & \\ a_\mu^{\text{theo}} & = & 0.00 & 1165 & 91 & 810 & (43) \\ a_\mu^{\text{exp}} & = & 0.00 & 1165 & 92 & 061 & (41) \end{array}$$

- The deviation is size of the EW correction in SM:

$$a_\mu^{\text{exp}} - a_\mu^{\text{theo}} \simeq (25 \pm 6) \times 10^{-10} \sim \mathcal{O}\left(\Delta a_\mu^{\text{SM,EW}}\right)$$

- We need very light BSM particles **OR** enhancement from couplings

$$\Delta a_\mu^{\text{BSM}} \sim \Delta a^{\text{SM,EW}} \cdot \underbrace{\left(\frac{m_W^2}{m_{\text{BSM}}^2}\right)}_{\mathcal{O}(1)} \cdot \text{coupling}$$

Chiral (tanβ) enhancement in SUSY

- (g-2) operator requires chirality flip:

$$\vec{\mu} = g\left(\frac{e}{2m}\right)\vec{s}$$

$$a_\mu = \frac{(g-2)}{2}$$

$$\boxed{\mathscr{L}_{\text{eff}} \ni i\frac{a_\mu}{m_\mu}\cdot\bar{\psi}_L\sigma^{\mu\nu}\psi_R F_{\mu\nu}}$$

SM: $a_\mu^{\text{SM}} \propto Y_\mu\langle H\rangle = m_\mu$

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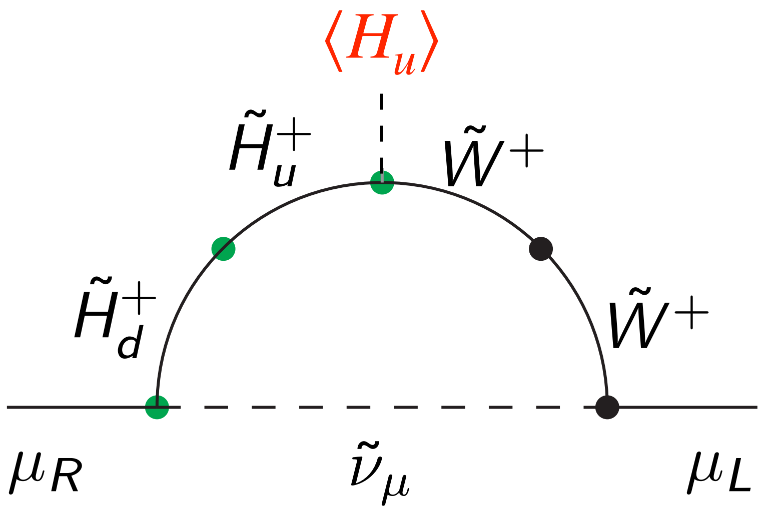
SM: $a_\mu^{\text{SM}} \propto Y_\mu\langle H\rangle = m_\mu$

SUSY: $\Delta a_\mu^{\text{SUSY}} \propto Y_\mu\langle H_u\rangle \underset{\uparrow}{=} m_\mu\cdot\tan\beta$

$$\boxed{m_\mu = Y_\mu\langle H_d\rangle \qquad \tan\beta \equiv \frac{\langle H_u\rangle}{\langle H_d\rangle}}$$



$$\langle H_u\rangle^2 + \langle H_d\rangle^2 = \underset{\substack{\uparrow \\ (246\,\text{GeV})^2}}{\langle H\rangle^2}$$

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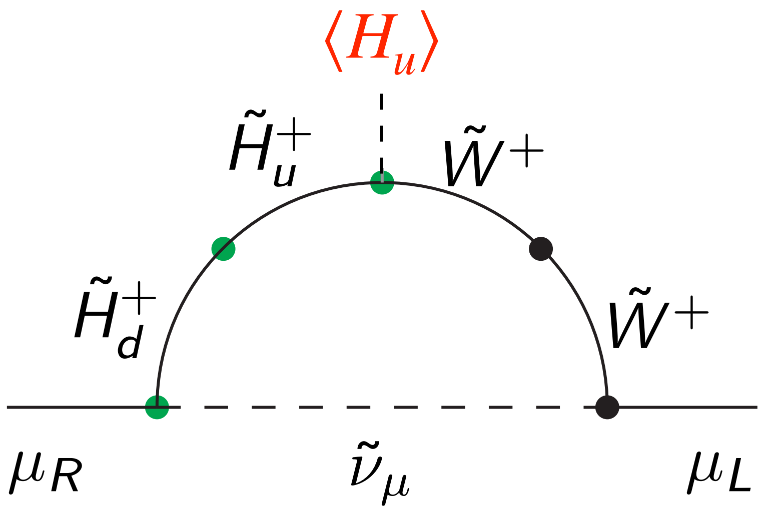

$$\langle H_u\rangle^2 + \langle H_d\rangle^2 = \langle H\rangle^2$$

$$\uparrow$$

$$(246\,\text{GeV})^2$$

$$\Delta a_\mu^{\text{BSM}} \sim \Delta a^{\text{SM,EW}}\cdot\left(\frac{m_W^2}{m_{\text{SUSY}}^2}\right)\cdot\tan\beta$$

$$\tan\beta \in [5-60] \Rightarrow m_{\text{SUSY}} \in [200-600]\,\text{GeV}$$

- Due to strong LHC constraints, we *decouple coloured SUSY particles* (they do not contribute to $(g-2)_\mu$ anyway).

- a_μ^{SUSY} depends on 5 mass parameters and tanβ :

M_1 : Bino mass

M_2 : Wino mass

μ : Higgsino mass

$$m_{\tilde{l}_R} \equiv \widetilde{m}^2_{\tilde{e}_R} = \widetilde{m}^2_{\tilde{\mu}_R} = \widetilde{m}^2_{\tilde{\tau}_R}$$

$$m_{\tilde{l}_L} \equiv \widetilde{m}_{\tilde{\nu}_e} = \widetilde{m}_{\tilde{\nu}_\mu} = \widetilde{m}_{\tilde{\nu}_\tau} = \widetilde{m}_{\tilde{e}_L} = \widetilde{m}_{\tilde{\mu}_L} = \widetilde{m}_{\tilde{\tau}_L}$$

$$\tan\beta \equiv \langle H_u \rangle / \langle H_d \rangle$$

no LFV due to universal soft masses: avoid strong constraint from μ → e γ

$$\boxed{\Delta a_\mu^{\rm SUSY} = \Delta a_\mu^{\rm WHL} + \Delta a_\mu^{\rm BHL} + \Delta a_\mu^{\rm BHR} + \Delta a_\mu^{\rm BLR}}$$

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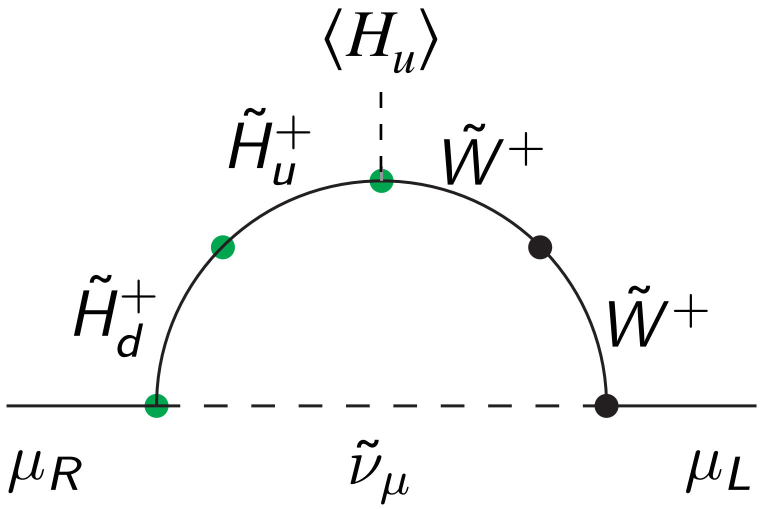


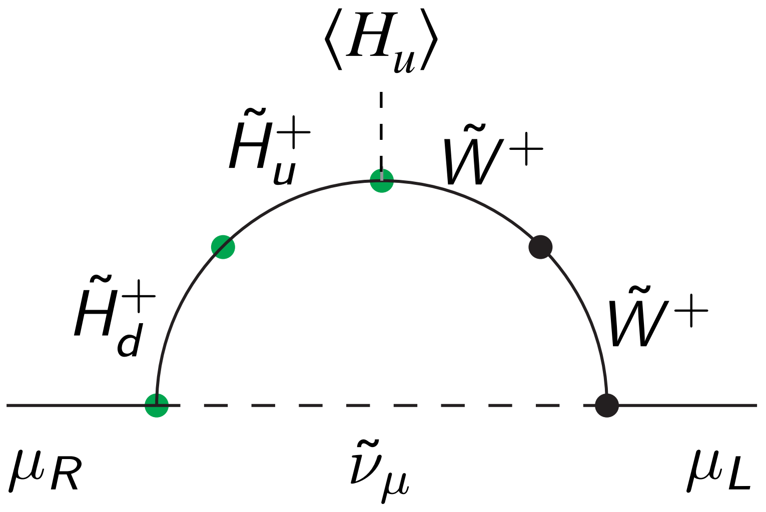
$$\Delta a_\mu^{\rm WHL}(M_2, \mu, m_{\tilde{l}_L}) = \frac{\alpha_W}{8\pi}\frac{m_\mu^2}{M_2\mu}\tan\beta \cdot f_{\rm WHL}(\{\mathbf{m}\})$$

M_1 : Bino ($\tilde{B}$) mass

M_2 : Wino ($\tilde{W}$) mass

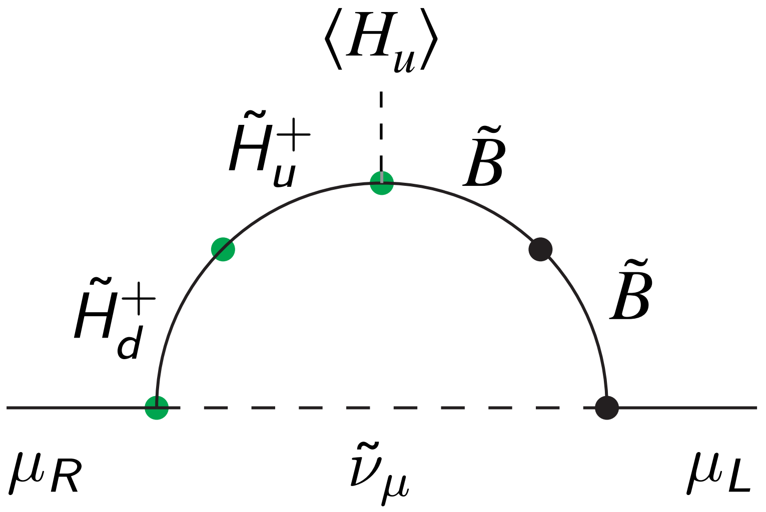
μ : Higgsino ($\tilde{H}_u, \tilde{H}_d$) mass

$$\boxed{\Delta a_\mu^{\mathrm{SUSY}} = \Delta a_\mu^{\mathrm{WHL}} + \Delta a_\mu^{\mathrm{BHL}} + \Delta a_\mu^{\mathrm{BHR}} + \Delta a_\mu^{\mathrm{BLR}}}$$



$$\Delta a_\mu^{\mathrm{WHL}}(M_2, \mu, m_{\tilde{l}_L}) = \frac{\alpha_W}{8\pi} \frac{m_\mu^2}{M_2 \mu} \tan\beta \cdot f_{\mathrm{WHL}}(\{\mathbf{m}\})$$

$$\Delta a_\mu^{\mathrm{BHL}}(M_1, \mu, m_{\tilde{l}_L}) = \frac{\alpha_Y}{8\pi} \frac{m_\mu^2}{M_1 \mu} \tan\beta \cdot f_{\mathrm{BHL}}(\{\mathbf{m}\})$$



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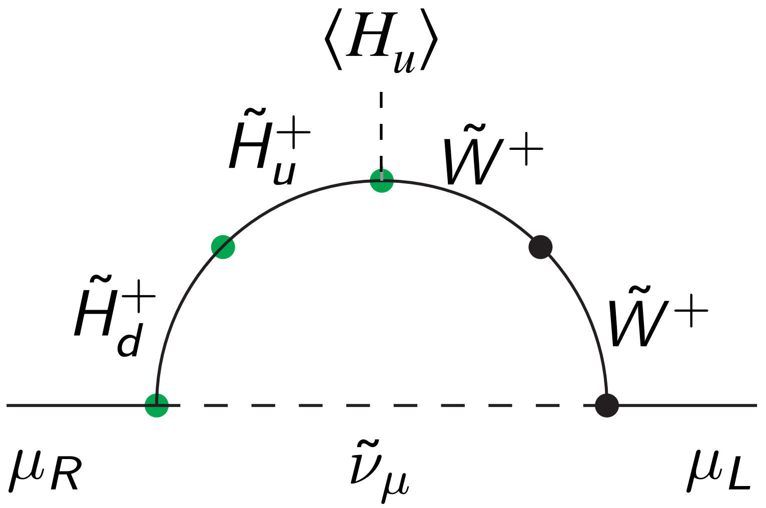
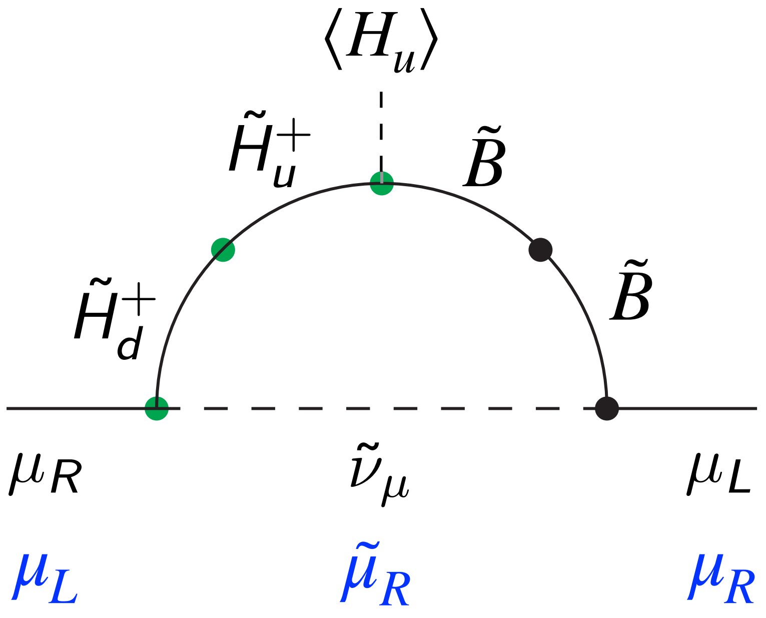


$$\Delta a_\mu^{\mathrm{WHL}}(M_2, \mu, m_{\tilde{l}_L}) = \frac{\alpha_W}{8\pi}\frac{m_\mu^2}{M_2\mu}\tan\beta \cdot f_{\mathrm{WHL}}(\{\mathbf{m}\})$$

$$\Delta a_\mu^{\mathrm{BHL}}(M_1, \mu, m_{\tilde{l}_L}) = \frac{\alpha_Y}{8\pi}\frac{m_\mu^2}{M_1\mu}\tan\beta \cdot f_{\mathrm{BHL}}(\{\mathbf{m}\})$$

$$\Delta a_\mu^{\mathrm{BHR}}(M_1, \mu, m_{\tilde{l}_R}) = -\frac{\alpha_Y}{8\pi}\frac{m_\mu^2}{M_1\mu}\tan\beta \cdot f_{\mathrm{BHR}}(\{\mathbf{m}\})$$



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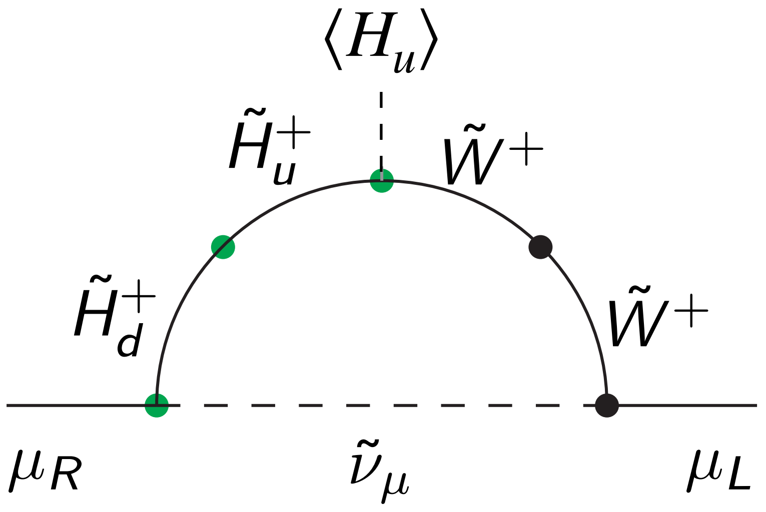
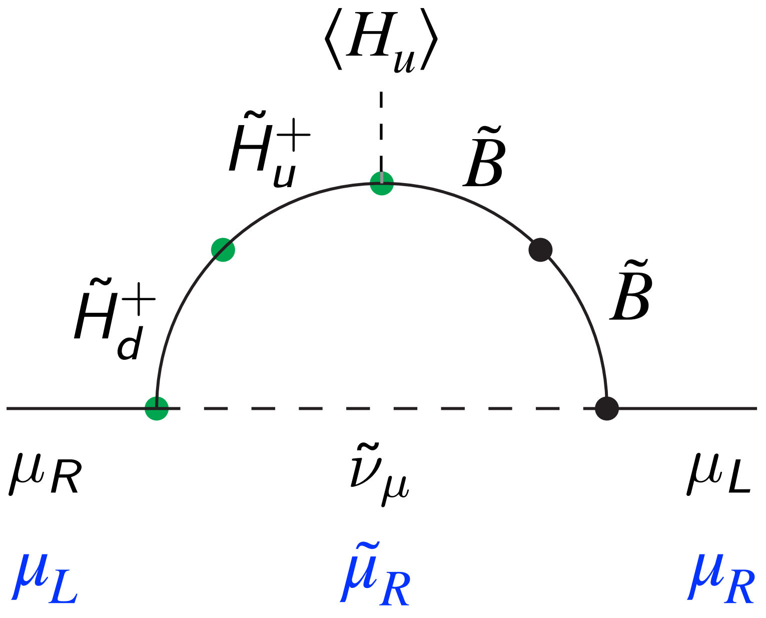
$$\boxed{\Delta a_\mu^{\rm SUSY} = \Delta a_\mu^{\rm WHL} + \Delta a_\mu^{\rm BHL} + \Delta a_\mu^{\rm BHR} + \Delta a_\mu^{\rm BLR}}$$



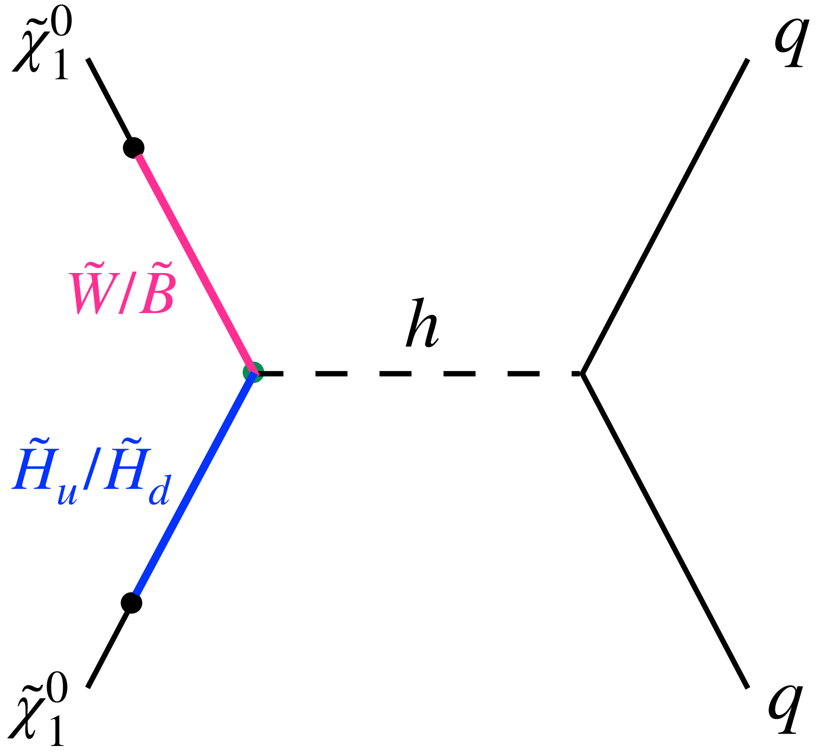
$$\Delta a_\mu^{\rm WHL}(M_2, \mu, m_{\tilde{l}_L}) = \frac{\alpha_W}{8\pi}\frac{m_\mu^2}{M_2\mu}\tan\beta \cdot f_{\rm WHL}(\{\mathbf{m}\})$$

$$\Delta a_\mu^{\rm BHL}(M_1, \mu, m_{\tilde{l}_L}) = \frac{\alpha_Y}{8\pi}\frac{m_\mu^2}{M_1\mu}\tan\beta \cdot f_{\rm BHL}(\{\mathbf{m}\})$$

$$\Delta a_\mu^{\rm BHR}(M_1, \mu, m_{\tilde{l}_R}) = -\frac{\alpha_Y}{8\pi}\frac{m_\mu^2}{M_1\mu}\tan\beta \cdot f_{\rm BHR}(\{\mathbf{m}\})$$



Large gaugino-Higgsino mixing leads to a large cross-section for DM Direct Detection:



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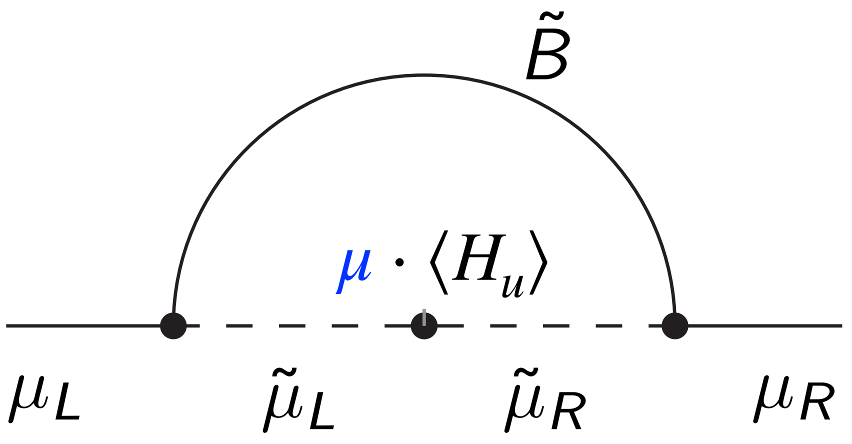

$$\Delta a_\mu^{\mathrm{BLR}}(M_1, m_{\tilde{l}_L}, m_{\tilde{l}_R}; \mu) = \frac{\alpha_Y}{4\pi} \frac{m_\mu^2 M_1 \mu}{m_{\mu_L}^2 m_{\mu_R}^2} \tan\beta \cdot f_{\mathrm{BLR}}(\{\mathbf{m}\})$$

↑

large μ needed

Constraints:

❖ Stau mass² becomes negative or too small!

$$(\tilde{\tau}\ \text{mass matrix}) \sim \begin{pmatrix} m_{\tilde{\tau}_R}^2 & Y_\tau \mu \langle H_u \rangle \\ Y_\tau \mu \langle H_u \rangle & m_{\tilde{\tau}_L}^2 \end{pmatrix}$$

- charge breaking vacuum: $m^2_{\mathrm{stau1}} > 0$
- LEP bound: $m_{\mathrm{stau1}} > 90$ GeV
- stau LSP: $m_{\mathrm{stau1}} > m_{\mathrm{neutralino1}}$
- **Vacuum (meta-)stability:**

$$\left| m_{\tilde{\ell}_{LR}}^2 \right| \leq \left[1.01 \times 10^2\,\mathrm{GeV} \sqrt{m_{\tilde{\ell}_L} m_{\tilde{\ell}_R}} + 1.01 \times 10^2\,\mathrm{GeV} (m_{\tilde{\ell}_L} + 1.03 m_{\tilde{\ell}_R}) - 2.27 \times 10^4\,\mathrm{GeV}^2 + \frac{2.97 \times 10^6\,\mathrm{GeV}^3}{m_{\tilde{\ell}_L} + m_{\tilde{\ell}_R}} - 1.14 \times 10^8\,\mathrm{GeV}^4 \left(\frac{1}{m_{\tilde{\ell}_L}^2} + \frac{0.983}{m_{\tilde{\ell}_R}^2} \right) \right]$$

[Kitahara, Yoshinaga 13]; [Endo, Hamaguchi, Kitahara, Yoshinaga 13]

❖ **Overproduction of Bino-like neutralinos** in the early universe: $\Omega_{\tilde{\chi}_1^0} < \Omega_{\mathrm{DM}}$

slepton-coannihilation needed ⇒ $m_{\mathrm{slepton}} \sim m_{\mathrm{Bino}}$

Summary of g-2 in MSSM

$$\Delta a_\mu^{\rm SUSY} = \Delta a_\mu^{\rm WHL} + \Delta a_\mu^{\rm BHL} + \Delta a_\mu^{\rm BHR} + \Delta a_\mu^{\rm BLR}$$

$$\left.\begin{array}{l} \Delta a_\mu^{\rm WHL}(M_2, \mu, m_{\tilde{l}_L}) \\[2ex] \Delta a_\mu^{\rm BHL}(M_1, \mu, m_{\tilde{l}_L}) \\[2ex] \Delta a_\mu^{\rm BHR}(M_1, \mu, m_{\tilde{l}_R}) \end{array}\right]$$

Higgsino, one gaugino, one slepton all must be light:

⟹ subject to **LHC constraint**

gaugino-Higgsino mixing ⟹ **DM direct detection**

$$\left.\Delta a_\mu^{\rm BLR}(M_1, m_{\tilde{l}_L}, m_{\tilde{l}_R};\ \underset{\substack{\uparrow \\ \text{large}}}{\mu})\right]$$

Bino and both L and R sleptons must be light:

⟹ subject to **LHC constraint**

⟹ **Bino abundance** $\Omega_{\tilde{\chi}_1^0} < \Omega_{\rm DM}$

⟹ **Vacuum stability**

Unstable Neutralino (Gravitino, RPV)

$$\Delta a_\mu^{\rm SUSY} = \Delta a_\mu^{\rm WHL} + \Delta a_\mu^{\rm BHL} + \Delta a_\mu^{\rm BHR} + \Delta a_\mu^{\rm BLR}$$

$$\Delta a_\mu^{\rm WHL}(M_2, \mu, m_{\tilde{l}_L})$$

$$\Delta a_\mu^{\rm BHL}(M_1, \mu, m_{\tilde{l}_L})$$

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Higgsino, one gaugino, one slepton all must be light:

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gaugino-Higgsino mixing ⟹ ~~**DM direct detection**~~

$$\Delta a_\mu^{\rm BLR}(M_1, m_{\tilde{l}_L}, m_{\tilde{l}_R};\ \mu)$$

↑

large

Bino and both L and R sleptons must be light:

⟹ subject to **LHC constraint** ← **Modified**

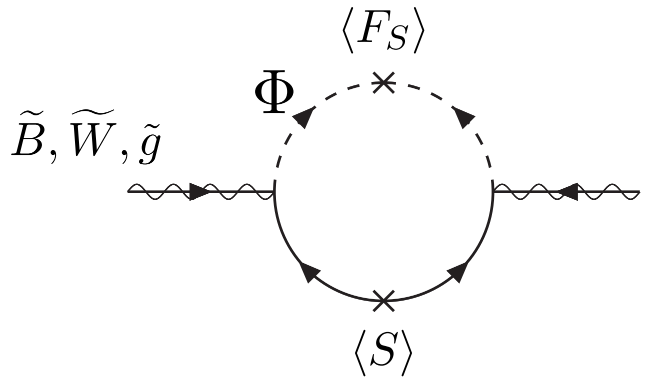
⟹ ~~**Bino abundance** $\Omega_{\chi_1^0} < \Omega_{\rm DM}$~~

⟹ **Vacuum stability**

Gravitino LSP

- In the gauge-mediated SUSY breaking (GMSB) scenario, light gravitino is motivated by naturalness:

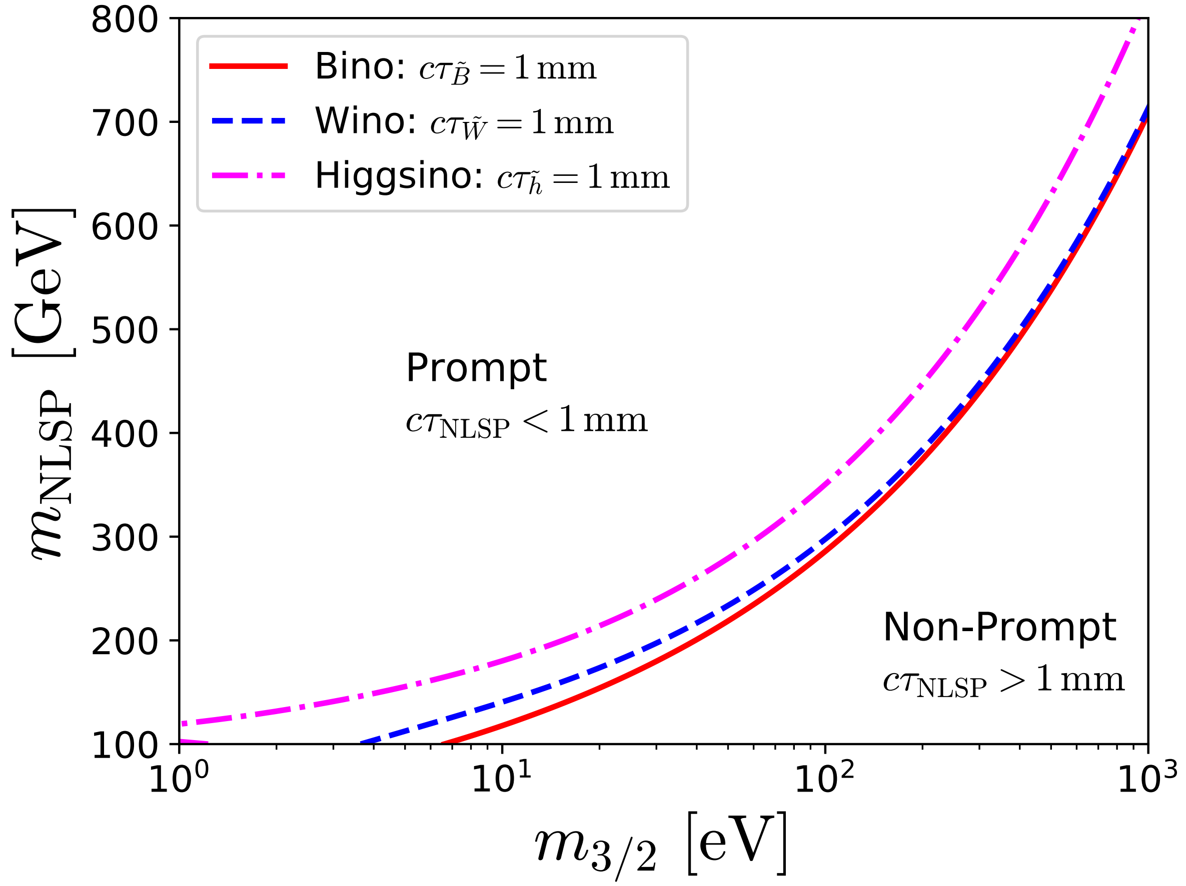
$$\delta m_h^2 \propto m_{SUSY}^2 \ln\left(\frac{\Lambda_{\rm mess}}{M_{\rm PL}}\right) \qquad m_{3/2} = \frac{4\pi}{\sqrt{3}\alpha_W} M_2 \frac{\Lambda_{\rm mess}}{M_{\rm PL}}$$

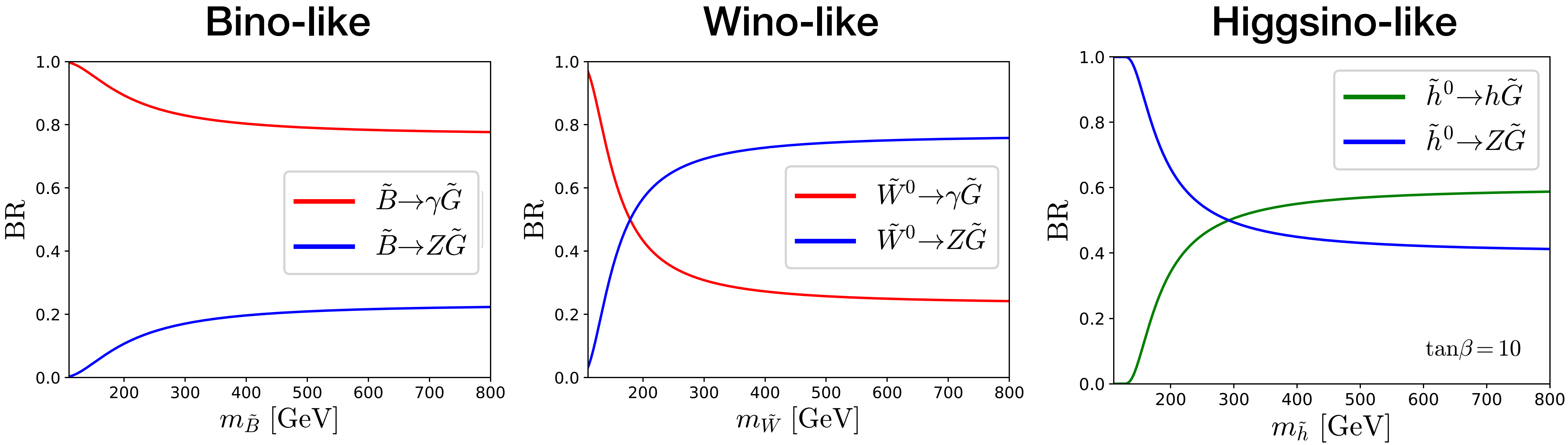


- The decay rate of the NSLP neutralino into the gravitino can be calculated. For light gravitinos (< 10-100 eV), the neutralino decays are prompt.

$$\begin{aligned}
\Gamma(\tilde{\chi}_1^0 \to \tilde{G}\gamma) &= \left|N_{11}c_W + N_{12}s_W\right|^2 \mathcal{A}\,, \\
\Gamma(\tilde{\chi}_1^0 \to \tilde{G}Z) &= \left(\left|N_{12}c_W - N_{11}s_W\right|^2 + \frac{1}{2}\left|N_{13}c_\beta - N_{14}s_\beta\right|^2\right)\left(1 - \frac{m_Z^2}{m_{\tilde{\chi}_1^0}^2}\right)^4 \mathcal{A}\,, \\
\Gamma(\tilde{\chi}_1^0 \to \tilde{G}h) &= \frac{1}{2}\left|N_{13}c_\beta + N_{14}s_\beta\right|^2 \left(1 - \frac{m_h^2}{m_{\tilde{\chi}_1^0}^2}\right)^4 \mathcal{A}\,,
\end{aligned}$$

$$\mathcal{A} = \frac{m_{\tilde{\chi}_1^0}^5}{16\pi m_{3/2}^2 M_{\rm pl}^2} \sim \frac{1}{0.3\,\mathrm{mm}}\left(\frac{m_{\tilde{\chi}_1^0}}{100\,\mathrm{GeV}}\right)^5 \left(\frac{m_{3/2}}{10\,\mathrm{eV}}\right)^{-2}$$




Bino-like

Wino-like

Higgsino-like

$$\Gamma(\tilde{\chi}_1^0 \to \tilde{G}\gamma) = \left|N_{11} c_W + N_{12} s_W\right|^2 \mathcal{A}\,,$$

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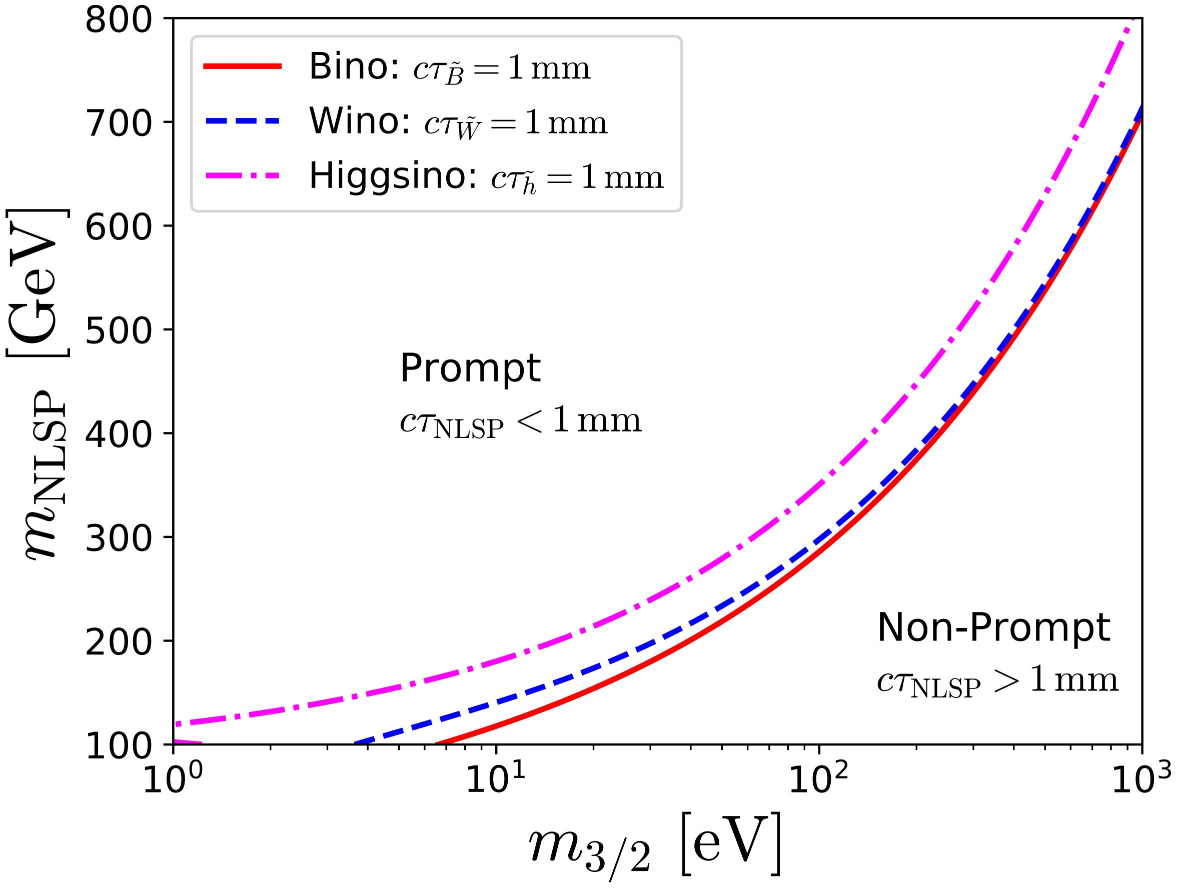
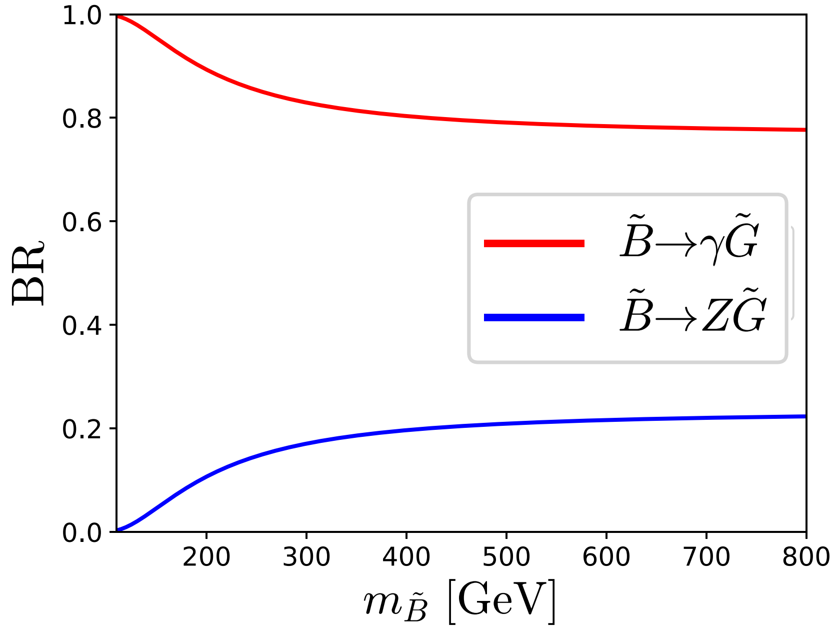
$$\Gamma(\tilde{\chi}_1^0 \to \tilde{G}h) = \frac{1}{2}\left|N_{13} c_\beta + N_{14} s_\beta\right|^2 \left(1 - \frac{m_h^2}{m_{\tilde{\chi}_1^0}^2}\right)^4 \mathcal{A}\,,$$

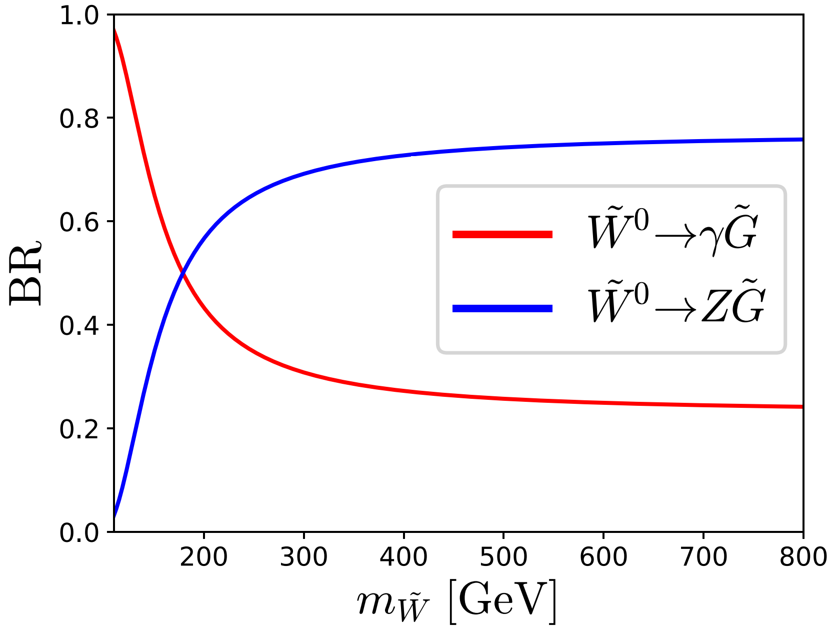
$$\mathcal{A} = \frac{m_{\tilde{\chi}_1^0}^5}{16\pi m_{3/2}^2 M_{\rm pl}^2} \sim \frac{1}{0.3\,{\rm mm}}\left(\frac{m_{\tilde{\chi}_1^0}}{100\,{\rm GeV}}\right)^5\left(\frac{m_{3/2}}{10\,{\rm eV}}\right)^{-2}$$



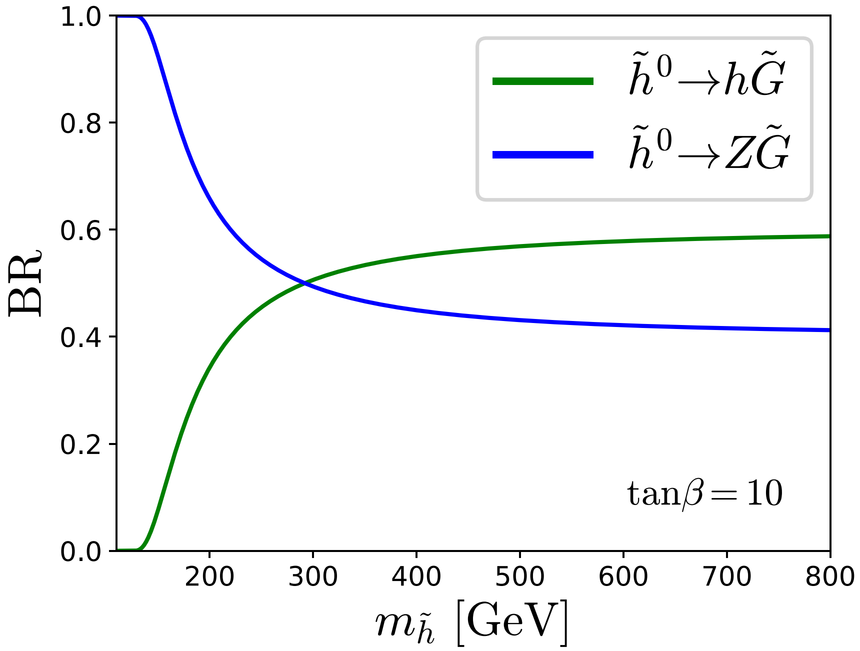
Bino-like



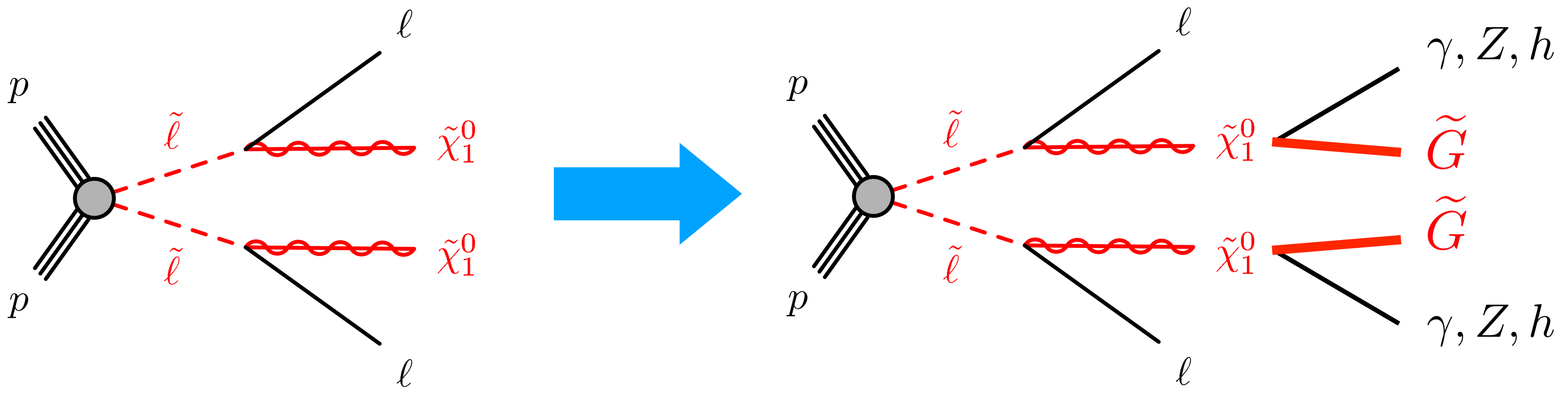
Wino-like



Higgsino-like

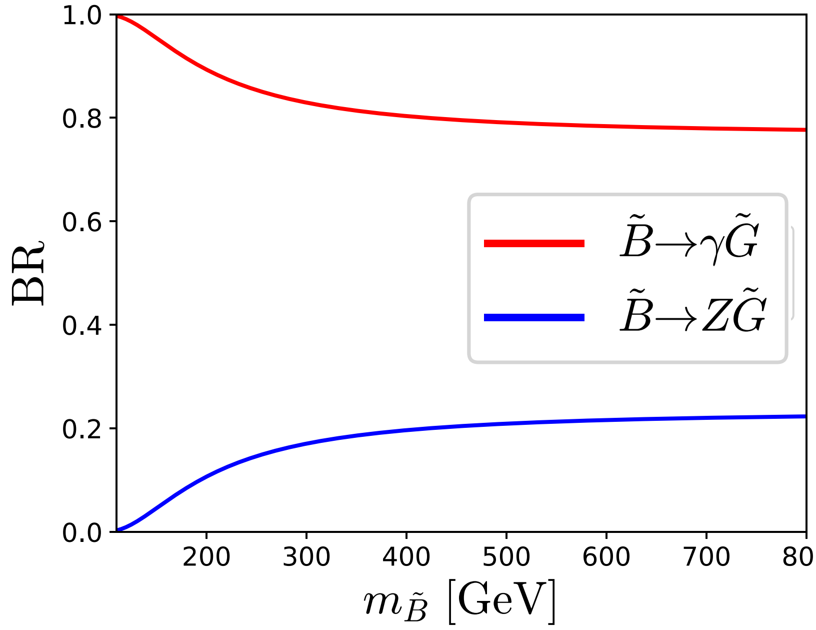


neutralino LSP

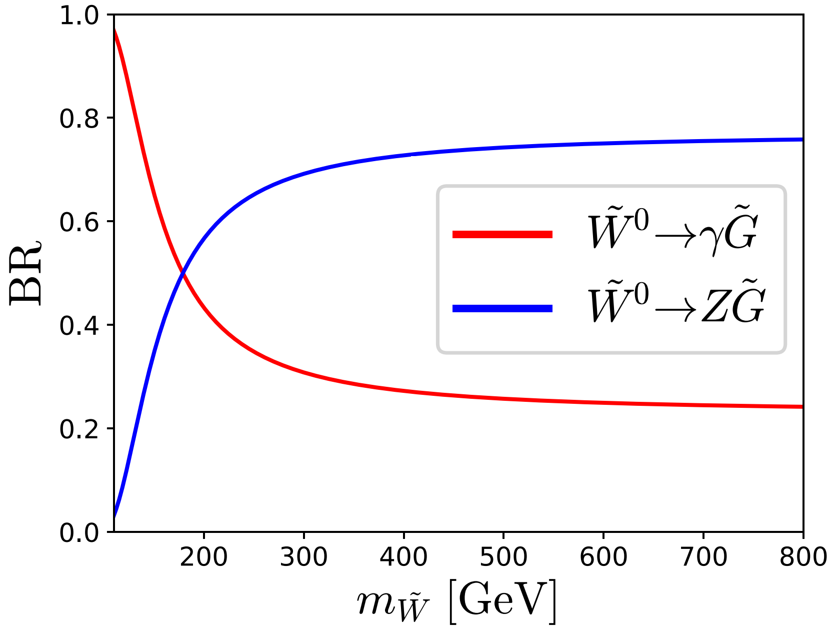


gravitino LSP

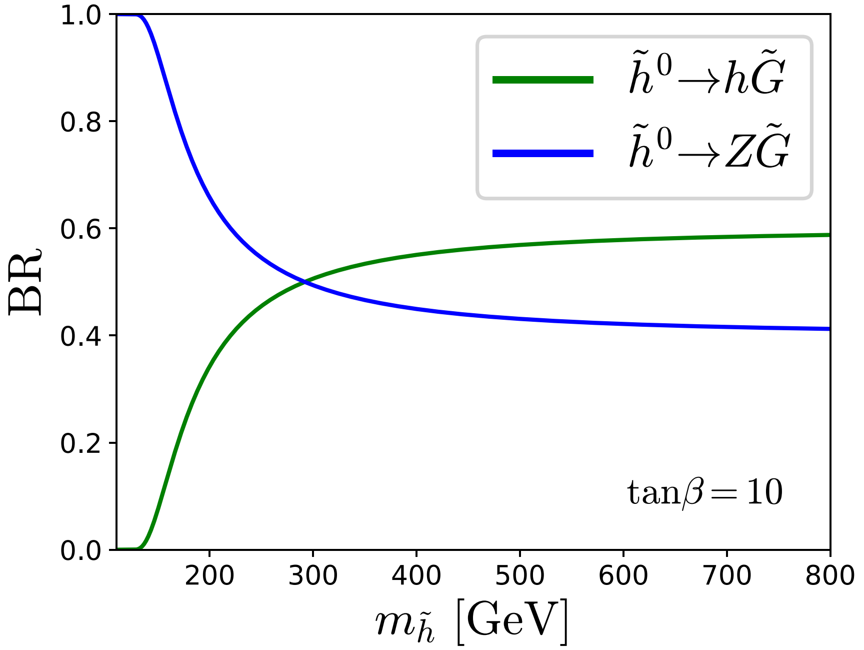
Bino-like



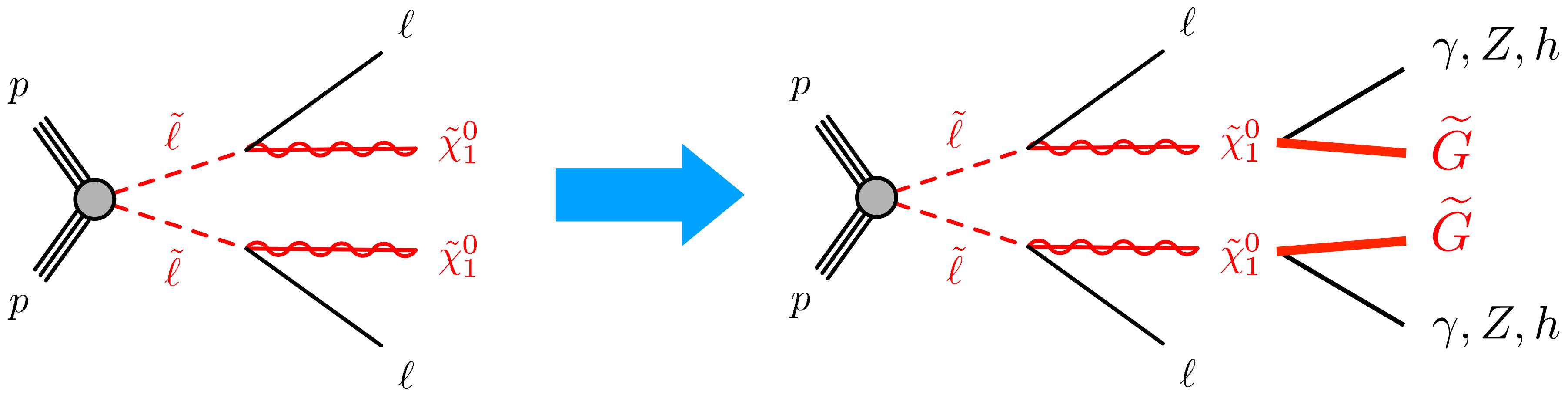
Wino-like



Higgsino-like

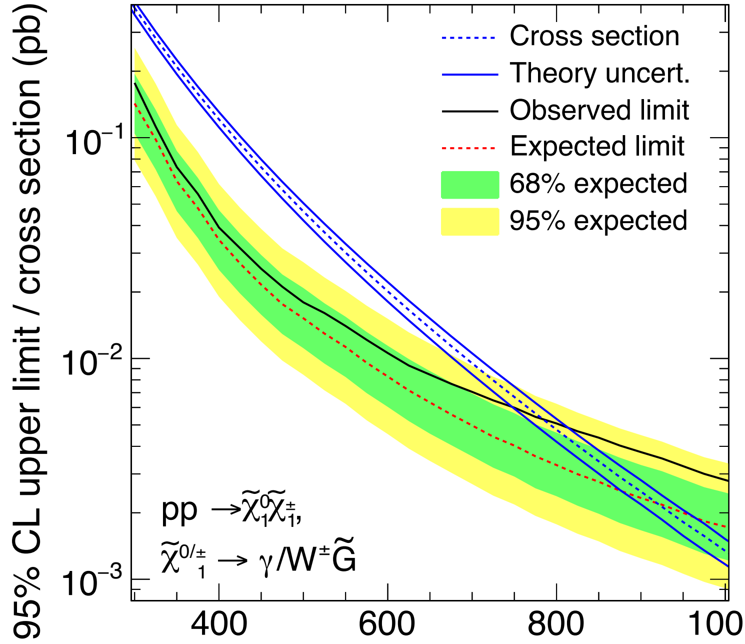


neutralino LSP

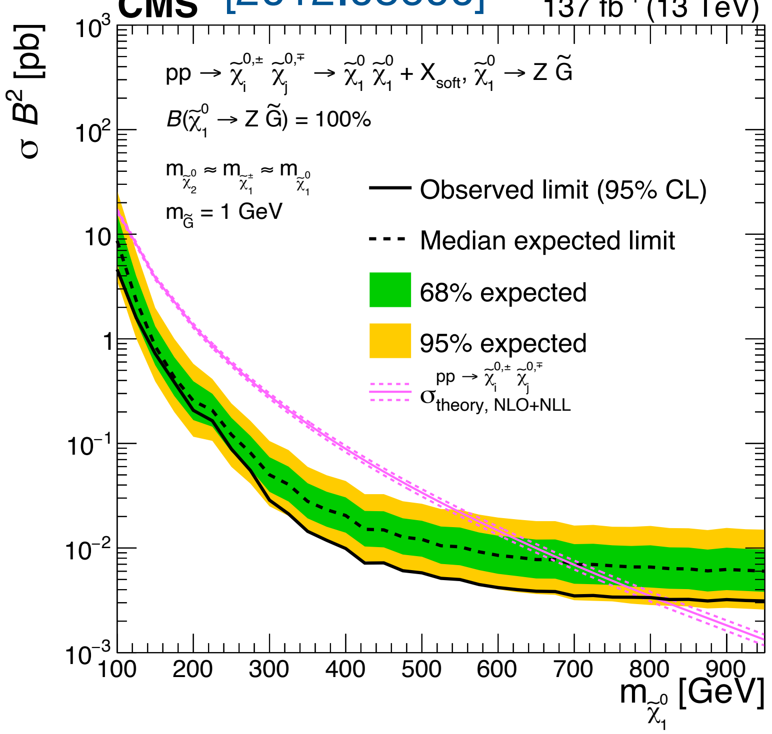


gravitino LSP

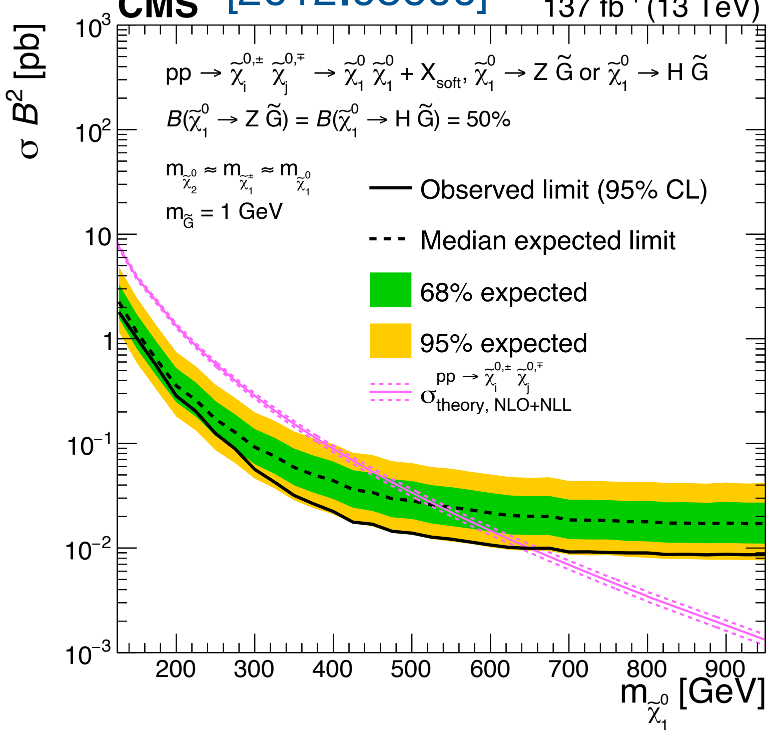
[1711.08008]



[2012.08600]

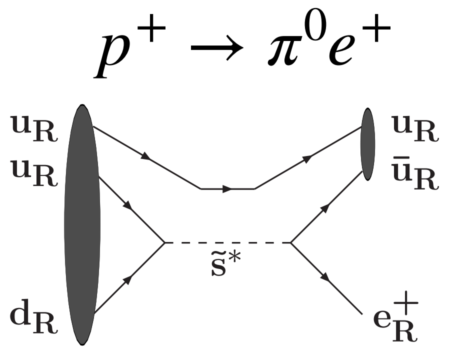


[2012.08600]



R-Parity Violation; UDD

$$W_{\mathrm{RPV}} = \underbrace{\lambda''_{ijk} U^c_i D^c_j D^c_k}_{\cancel{B}} + \underbrace{\lambda_{ijk} L_i L_j E^c_k + \lambda'_{ijk} L_i Q_j D^c_k + \kappa_i L_i H_u}_{\cancel{L}}$$



- Allowing both **B** and **L** violation leads to a rapid proton decay:

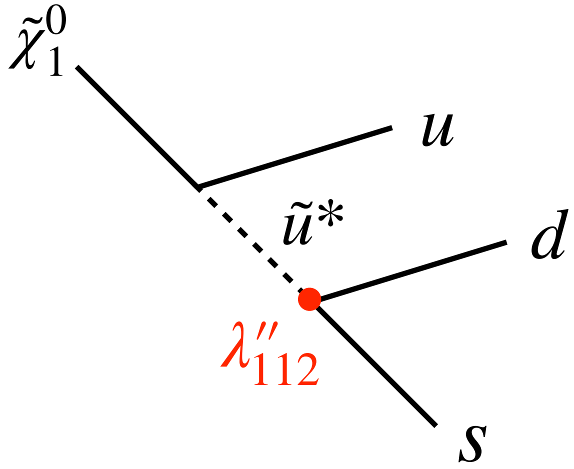
- We introduce only the **UDD** operator with: $\lambda''_{112} \neq 0$

  - Constraint from K0-K0bar mixing can easily be satisfied:

$$|\lambda''_{112}\lambda''_{123}| \lesssim 2.8 \times 10^{-2} \left(\frac{m_{\tilde{s}_R,\tilde{u}_R}}{1\,\mathrm{TeV}}\right)$$
$$|\lambda''_{112}\lambda''_{113}| \lesssim 1.2 \times 10^{-1} \left(\frac{m_{\tilde{d}_R,\tilde{u}_R}}{1\,\mathrm{TeV}}\right)$$

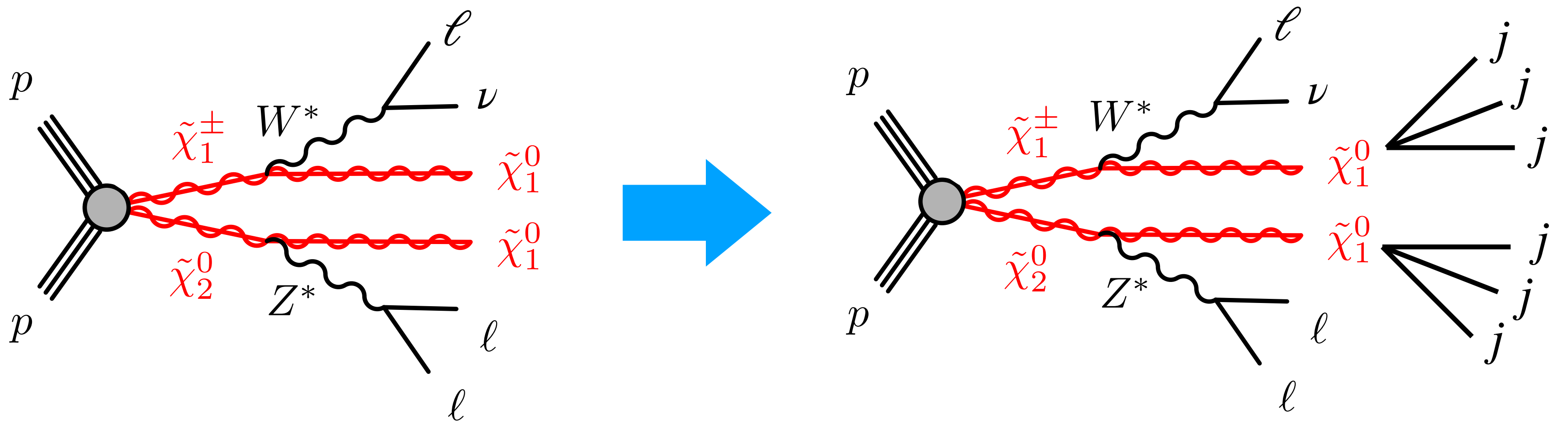
[1810.08228]

  - **LHC signature is the most challenging:**
    no leptons, no b-jets in the neutralino decay



R-Parity Violation; UDD

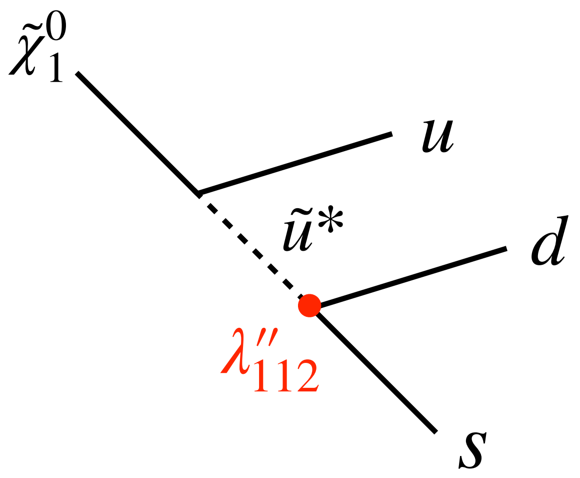
neutralino LSP



RPV (UDD-type)

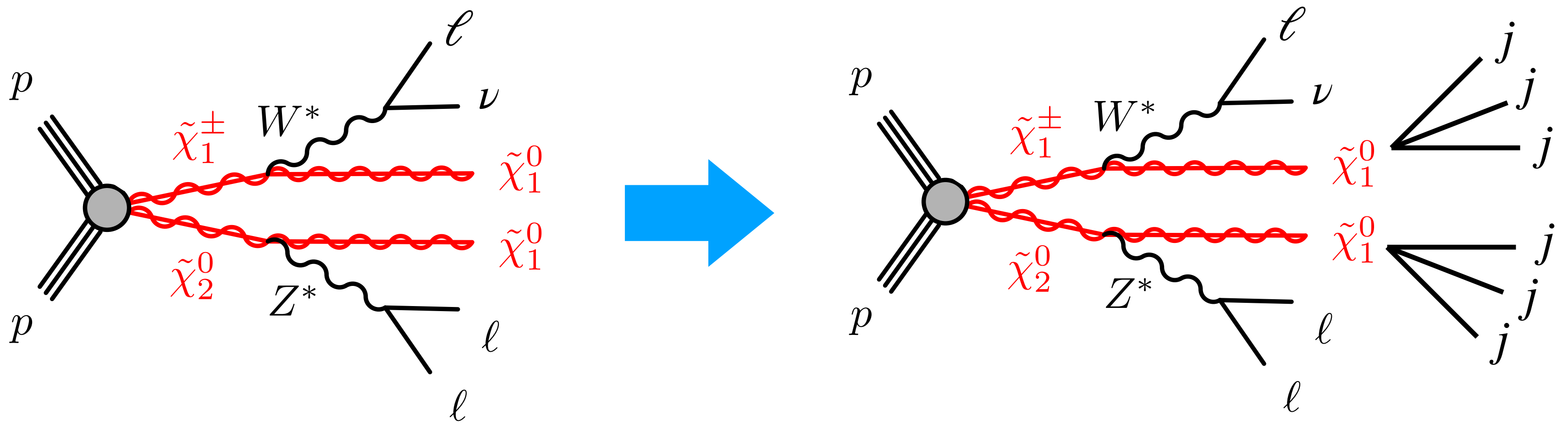
No missing energy, but multi-jet

- LHC signature is the most challenging:
  no leptons, no b-jets in the neutralino decay



R-Parity Violation; UDD

neutralino LSP

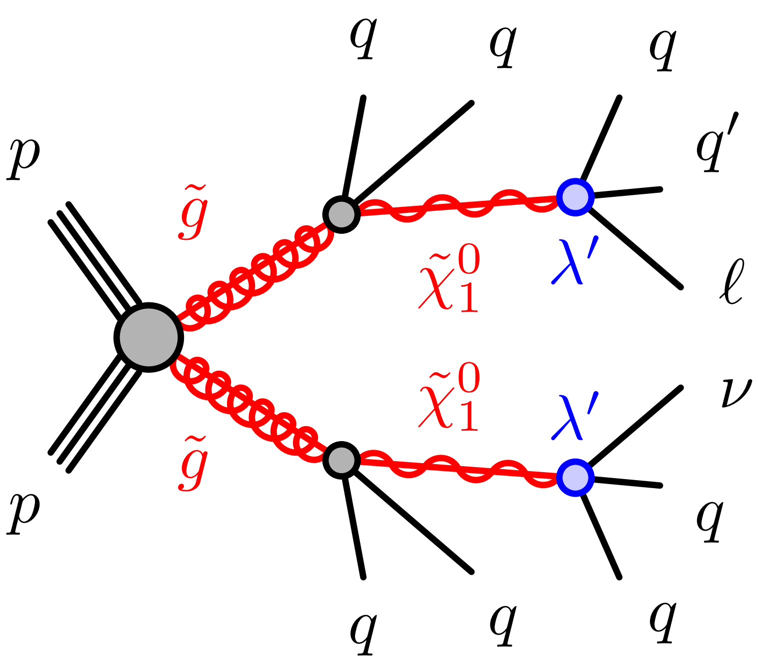


RPV (UDD-type)

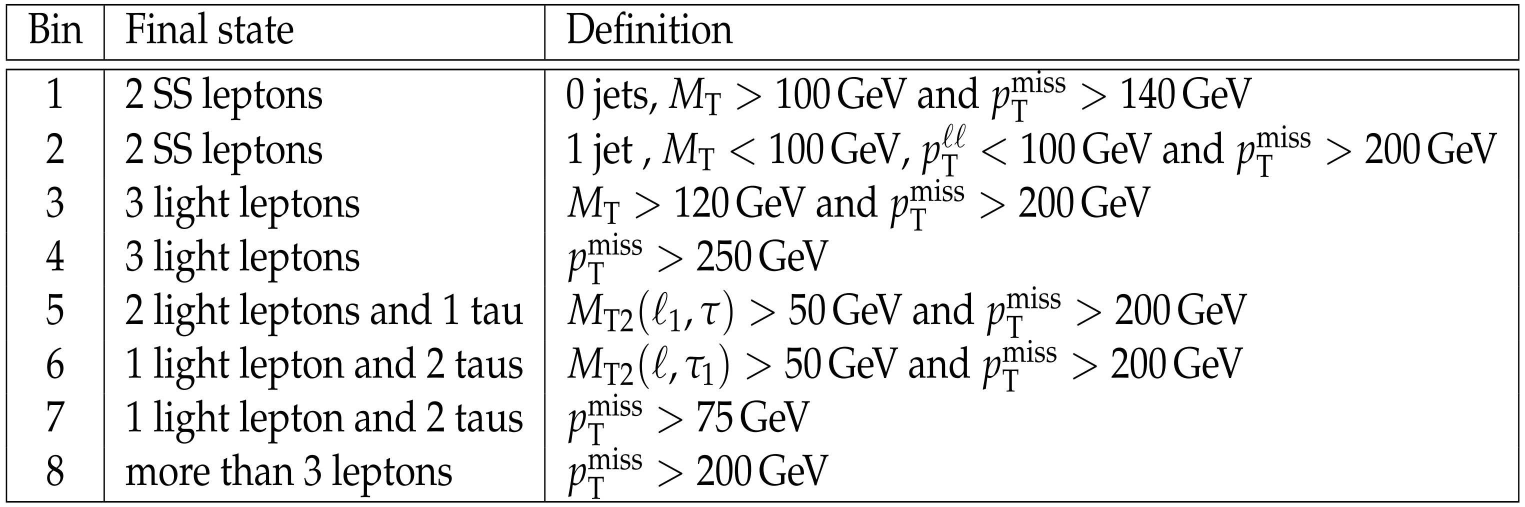
No missing energy, but multi-jet

- There exist ATLAS and CMS analyses sensitive to such final states:

ATLAS [2106.09609]



CMS [1709.05406]



Bin	Final state	Definition
1	2 SS leptons	0 jets, $M_T > 100$ GeV and $p_T^{miss} > 140$ GeV
2	2 SS leptons	1 jet , $M_T < 100$ GeV, $p_T^{\ell\ell} < 100$ GeV and $p_T^{miss} > 200$ GeV
3	3 light leptons	$M_T > 120$ GeV and $p_T^{miss} > 200$ GeV
4	3 light leptons	$p_T^{miss} > 250$ GeV
5	2 light leptons and 1 tau	$M_{T2}(\ell_1, \tau) > 50$ GeV and $p_T^{miss} > 200$ GeV
6	1 light lepton and 2 taus	$M_{T2}(\ell, \tau_1) > 50$ GeV and $p_T^{miss} > 200$ GeV
7	1 light lepton and 2 taus	$p_T^{miss} > 75$ GeV
8	more than 3 leptons	$p_T^{miss} > 200$ GeV

Analysis Framework

SUSY g-2: 1-loop + leading 2-loop GM2Calc [Eur.Phys.J. C76 (2016) no.2, 62]

Neutralino abundance, Direct Detection: MicrOMEGAs [2003.08621]

Decay of SUSY particles: SUSY-HIT [hep-ph/0609292]

LHC constraints:

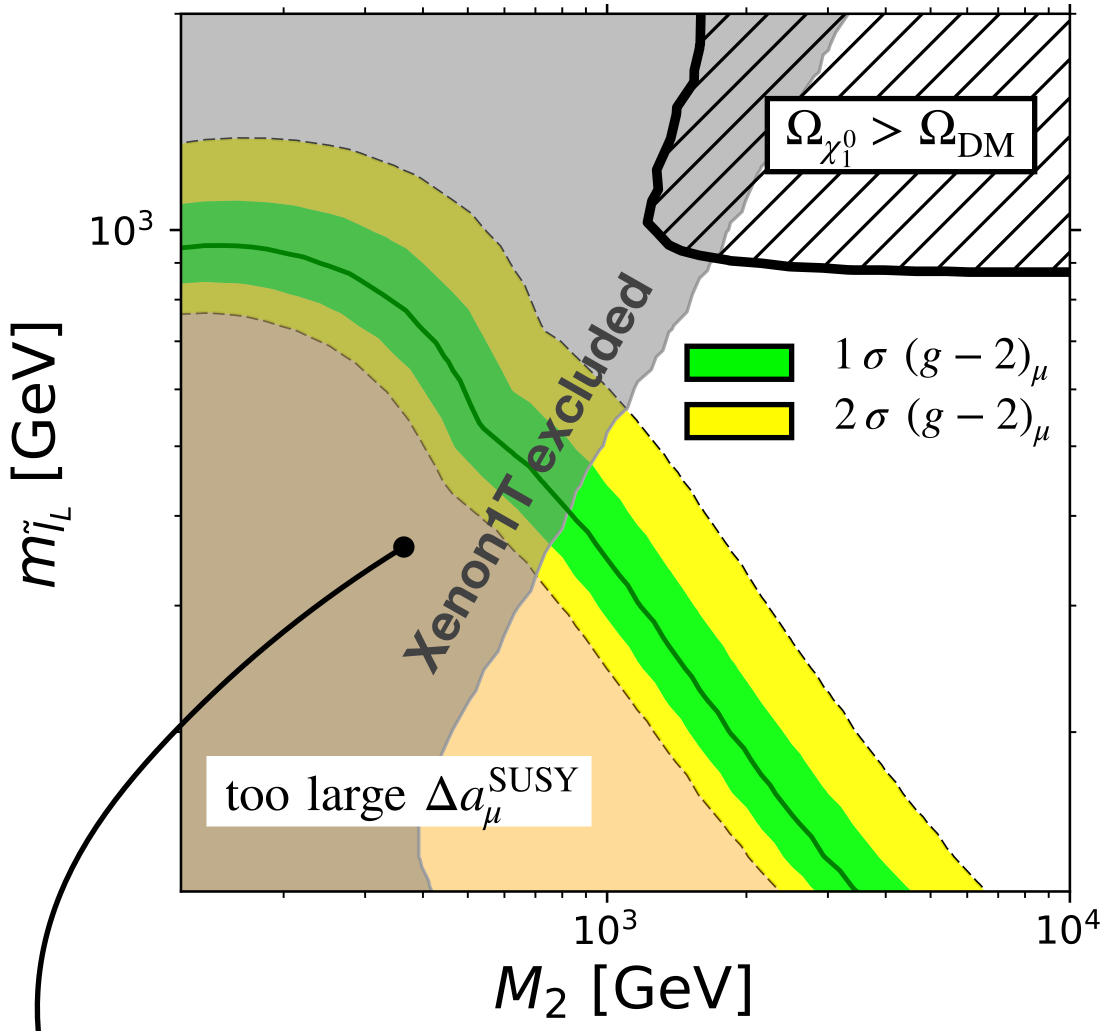
- **MSSM:** Fastlim/SModelS-like approach with HEP-DATA info
- **Gravitino LSP:** Fastlim/SModelS-like approach with HEP-DATA info
- **RPV (UDD-type):** Pythia 8 + CheckMATE 2 [1907.09874], [1611.09856]

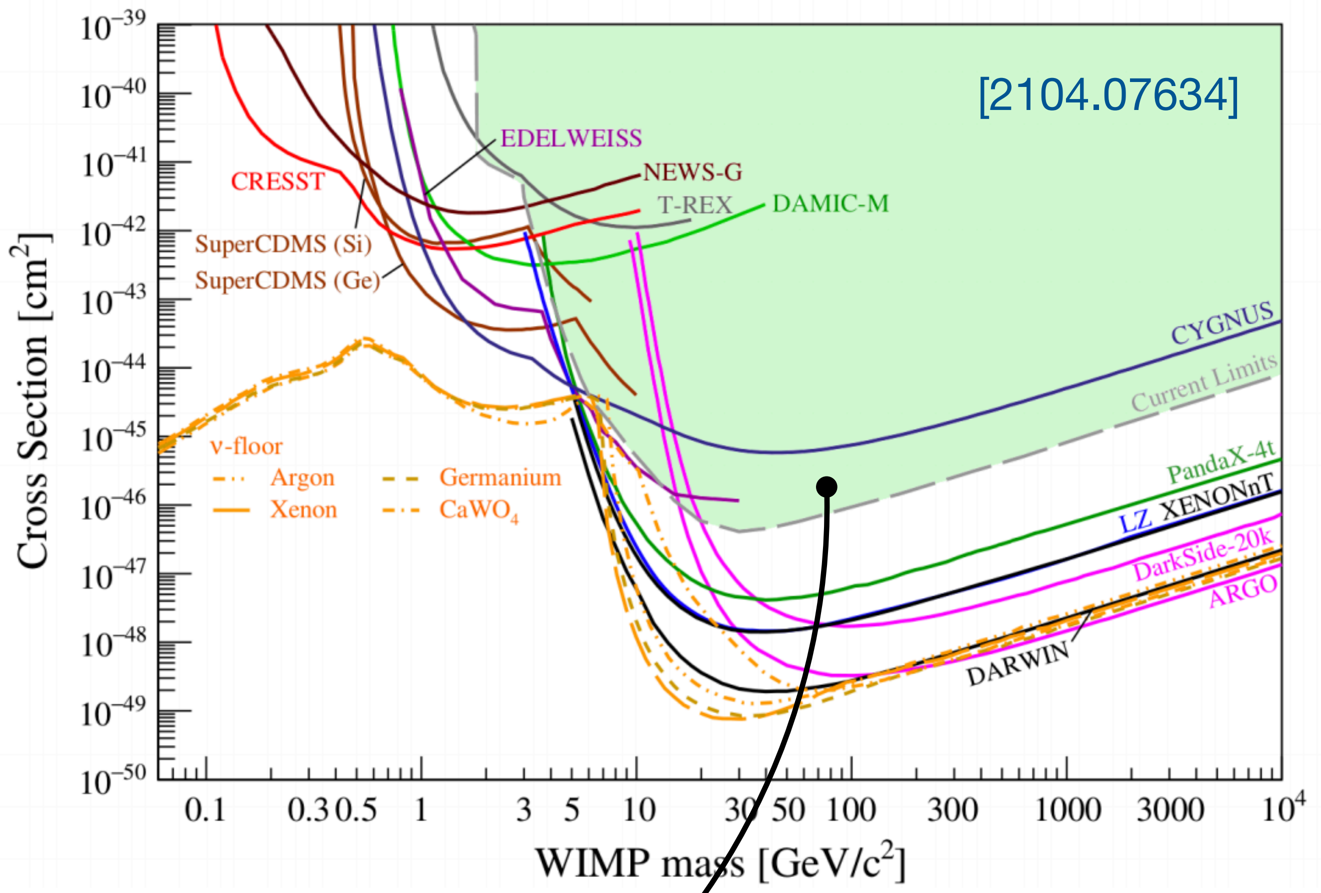
All results below are preliminary

WHL (MSSM)

$$\mu = \min(M_2, m_{\tilde{l}_L}) - 20\,\mathrm{GeV}$$

$$\tan\beta = 50, \quad M_1 = m_{\tilde{l}_R} = 10\,\mathrm{TeV}$$



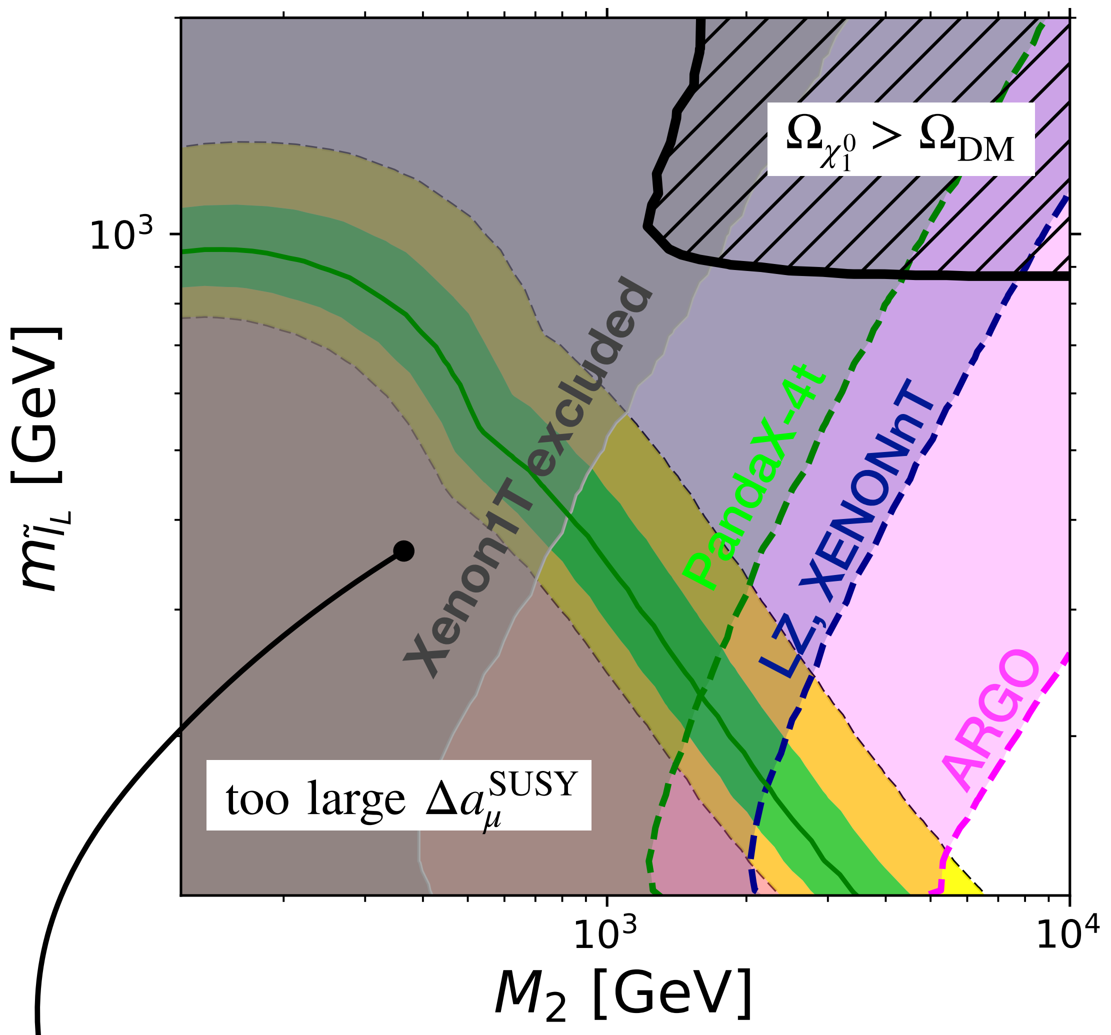


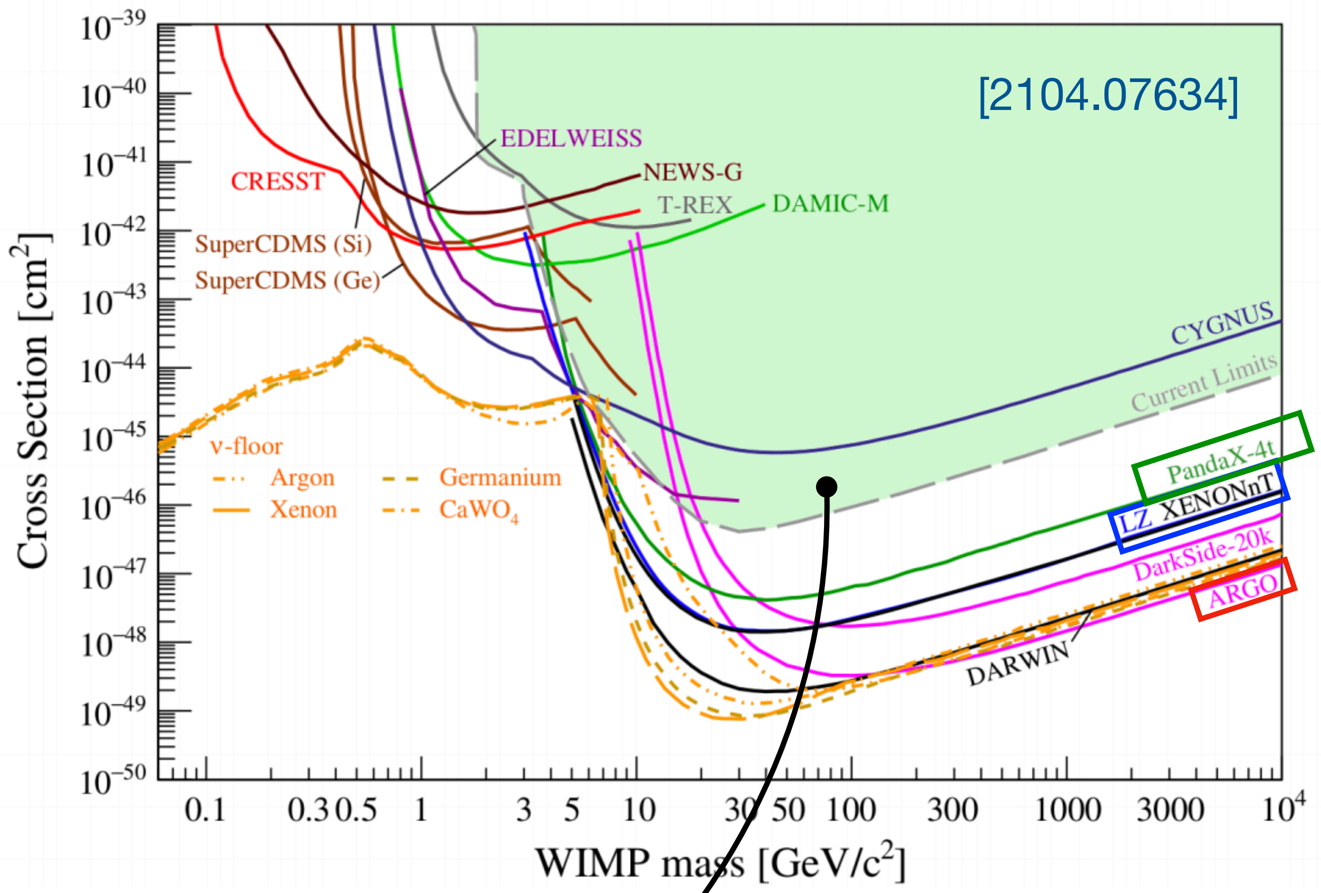
$$\sigma^{\mathrm{SI}}_{\chi N\to\chi N}(m_{\tilde{\chi}^0_1}) \cdot \frac{\Omega_{\tilde{\chi}^0_1}}{\Omega_{\mathrm{DM}}} > \sigma^{\mathrm{SI}}_{\mathrm{Xenon1T}}(m_{\mathrm{DM}})$$

WHL (MSSM, DD prospect)

$$\mu = \min(M_2, m_{\tilde{l}_L}) - 20\,\mathrm{GeV}$$

$$\tan\beta = 50, \quad M_1 = m_{\tilde{l}_R} = 10\,\mathrm{TeV}$$



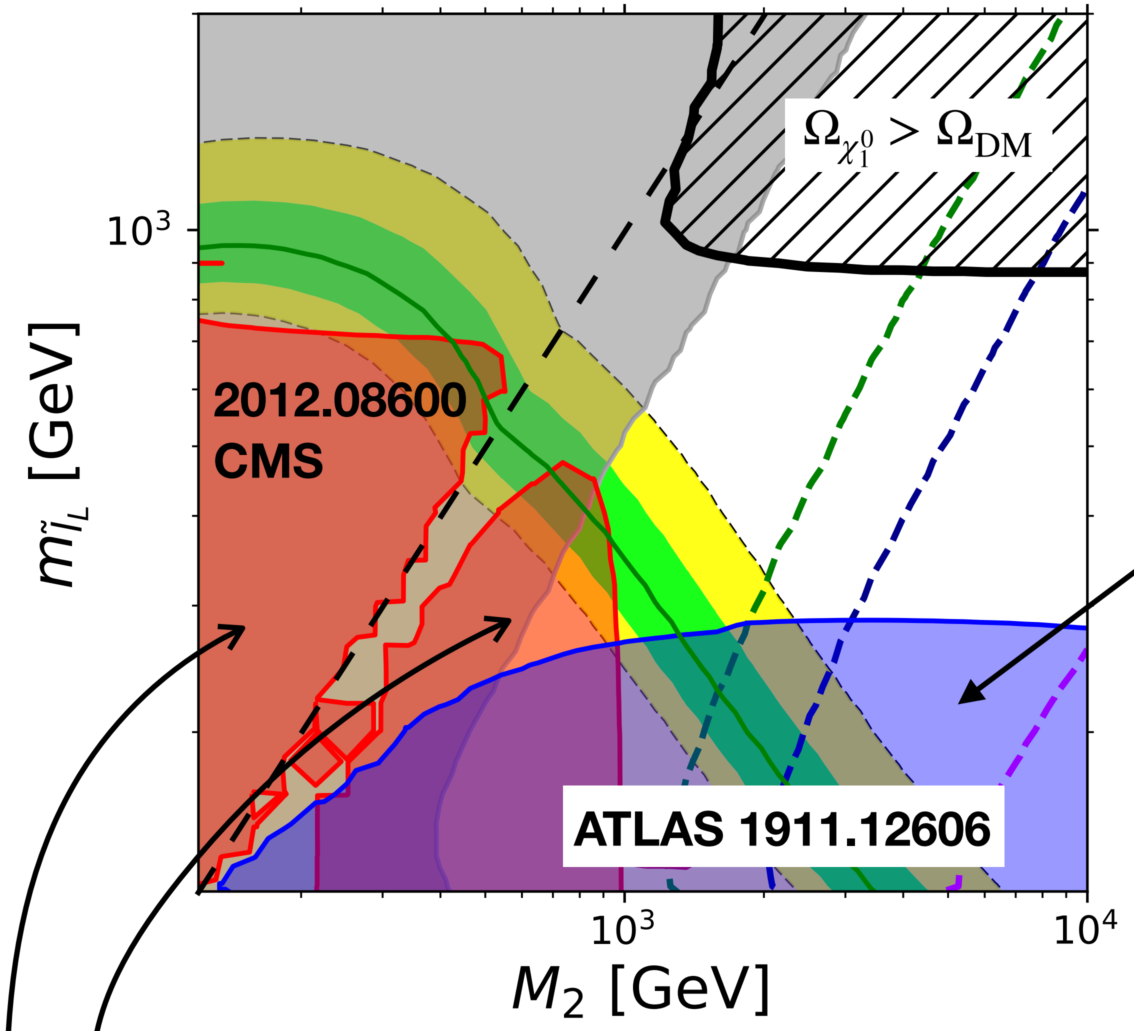


$$\sigma^{\mathrm{SI}}_{\chi N \to \chi N}(m_{\tilde{\chi}^0_1}) \cdot \frac{\Omega_{\tilde{\chi}^0_1}}{\Omega_{\mathrm{DM}}} > \sigma^{\mathrm{SI}}_{\mathrm{Xenon1T}}(m_{\mathrm{DM}})$$

WHL (MSSM, LHC)

$$\mu = \min(M_2, m_{\tilde{l}_L}) - 20\,\mathrm{GeV}$$

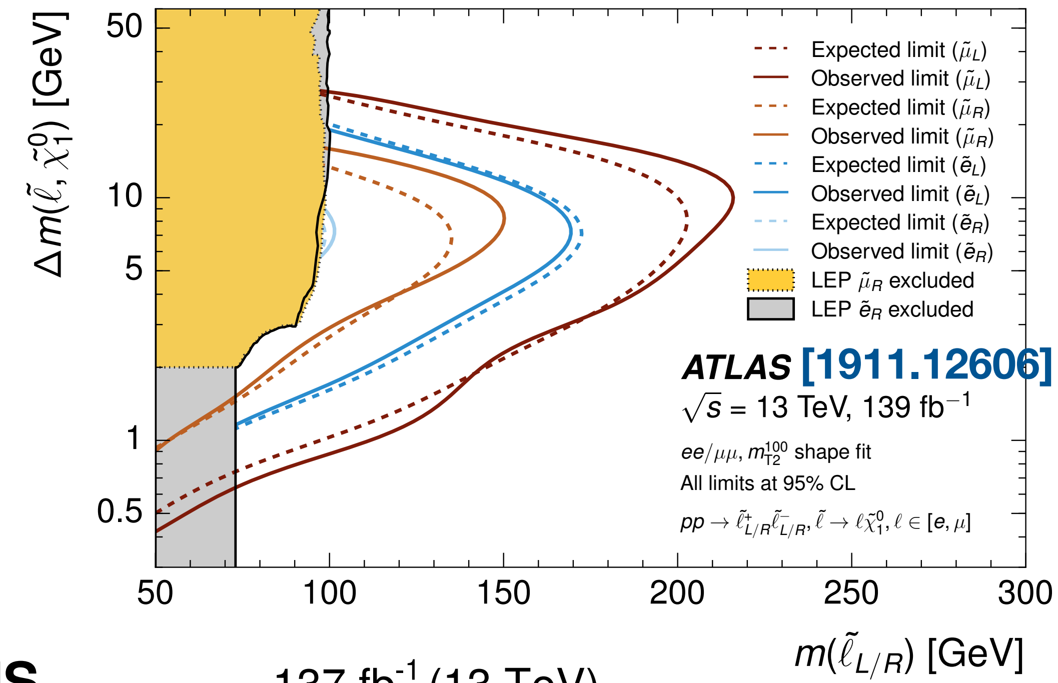
$$\tan\beta = 50, \quad M_1 = m_{\tilde{l}_R} = 10\,\mathrm{TeV}$$

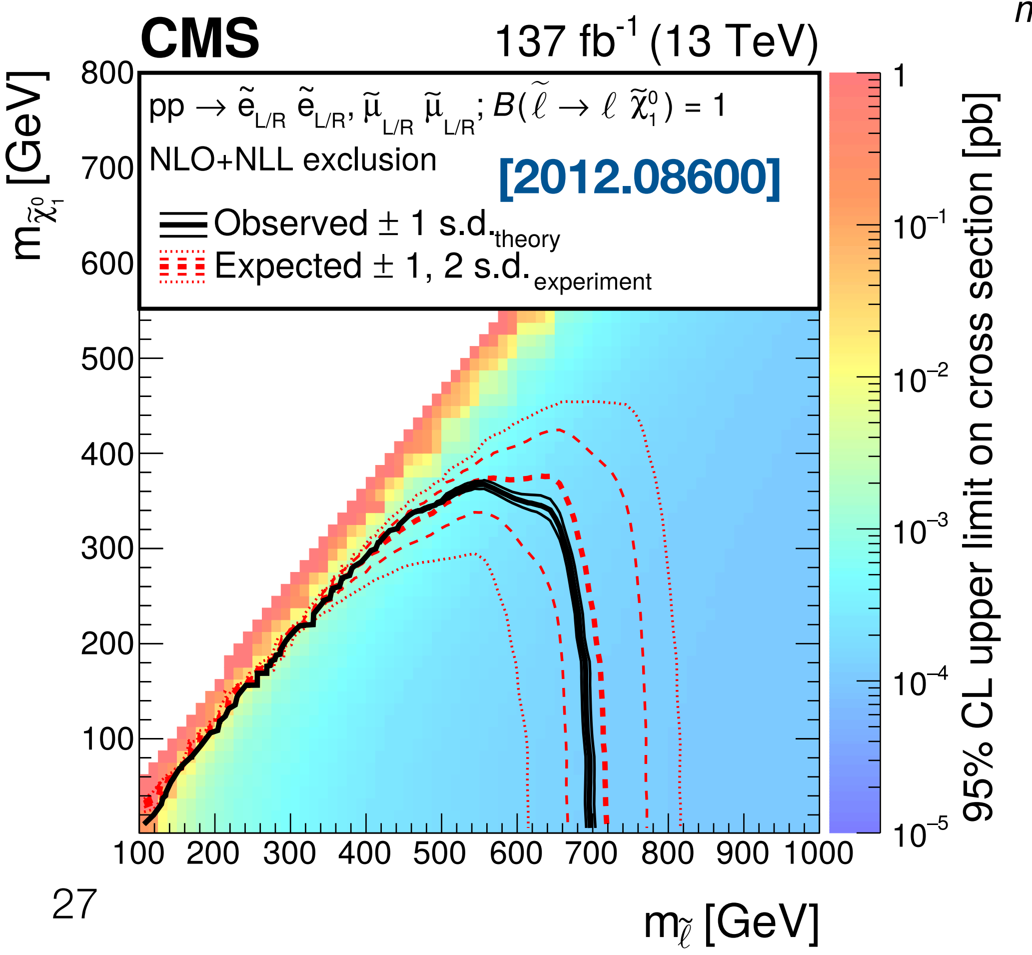


$$pp \to \widetilde{W}\widetilde{W}, \ \widetilde{W}^{0,\pm} \to \ell + (\tilde{\ell}, \tilde{\nu})$$

$$pp \to \tilde{\ell}\tilde{\ell}, \ \tilde{\ell} \to \ell + \tilde{\chi}_1^0$$

$$pp \to \tilde{\ell}\tilde{\ell}, \ \tilde{\ell} \to \ell + \tilde{\chi}_1^0$$

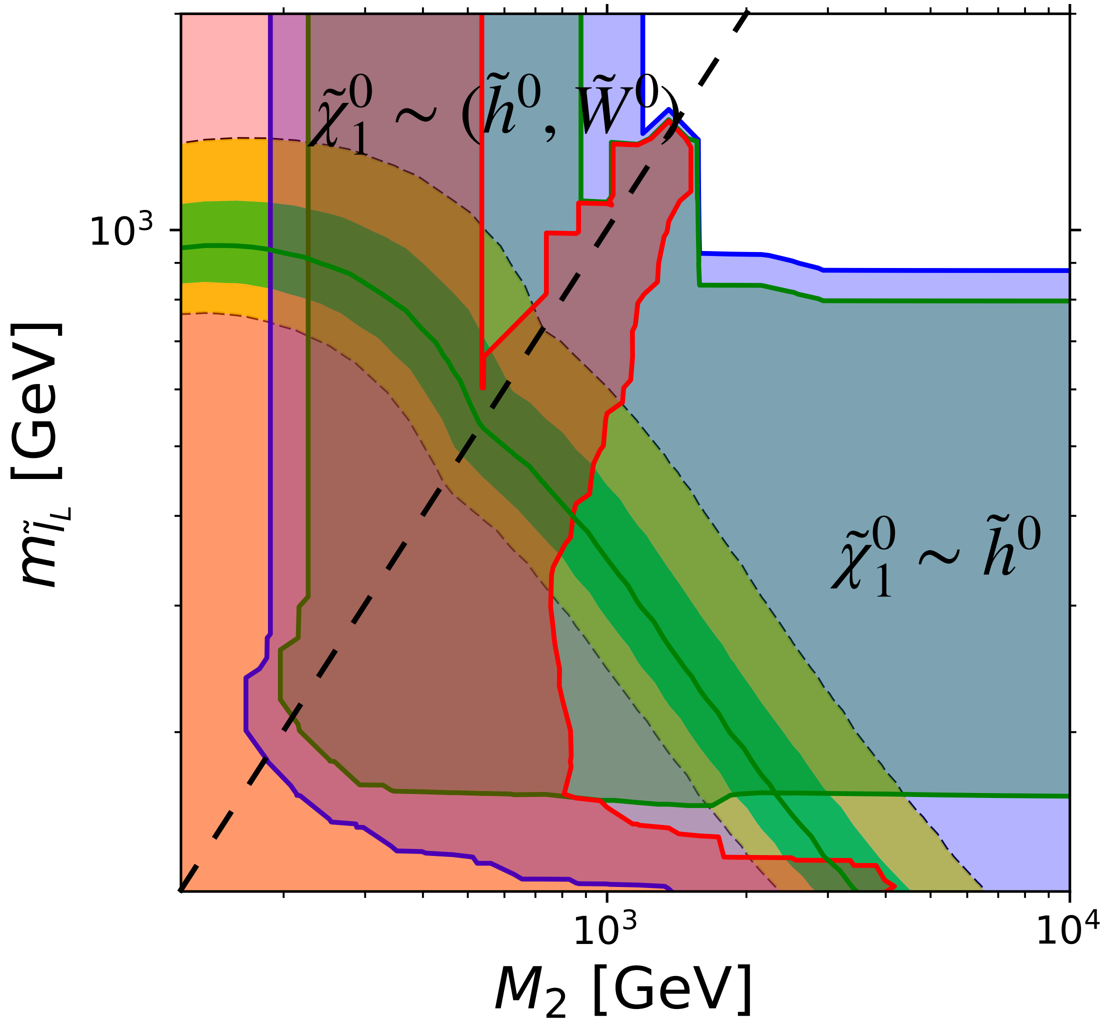




WHL (Gravitino LSP)

$$\mu = \min(M_2, m_{\tilde{l}_L}) - 20\,\mathrm{GeV}$$

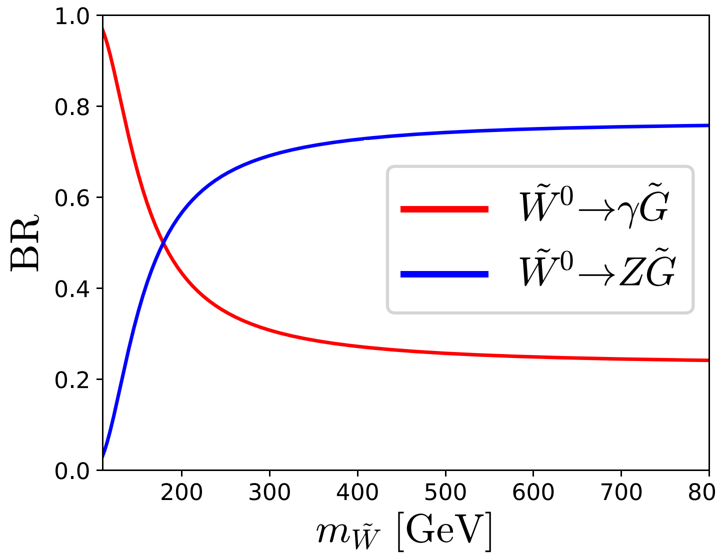
$$\tan\beta = 50, \quad M_1 = m_{\tilde{l}_R} = 10\,\mathrm{TeV}$$

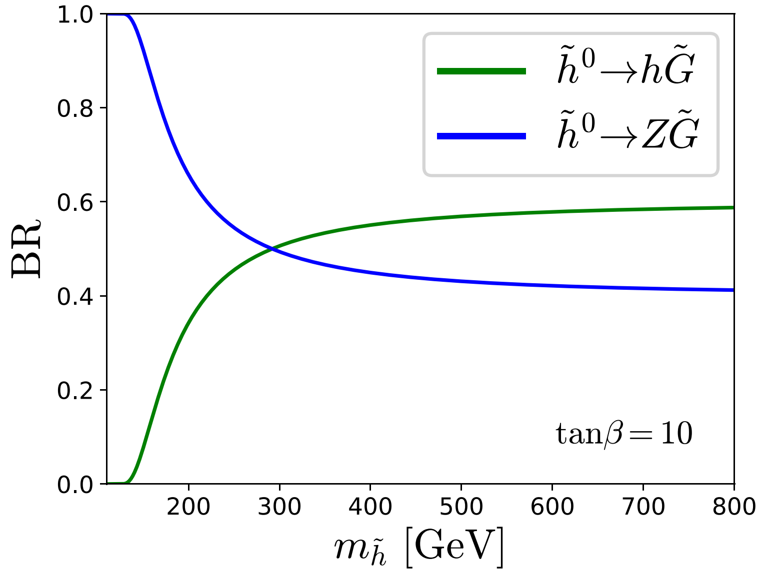


🟦 $\chi_1^0\chi_1^0 \to ZZ\tilde{G}\tilde{G}$ **CMS** [2012.08600]

🟩 $\chi_1^0\chi_1^0 \to hZ\tilde{G}\tilde{G}$ **CMS** [2012.08600]

🟥 $\chi_1^0 \to \gamma\tilde{G}$ **CMS** [1711.08008]





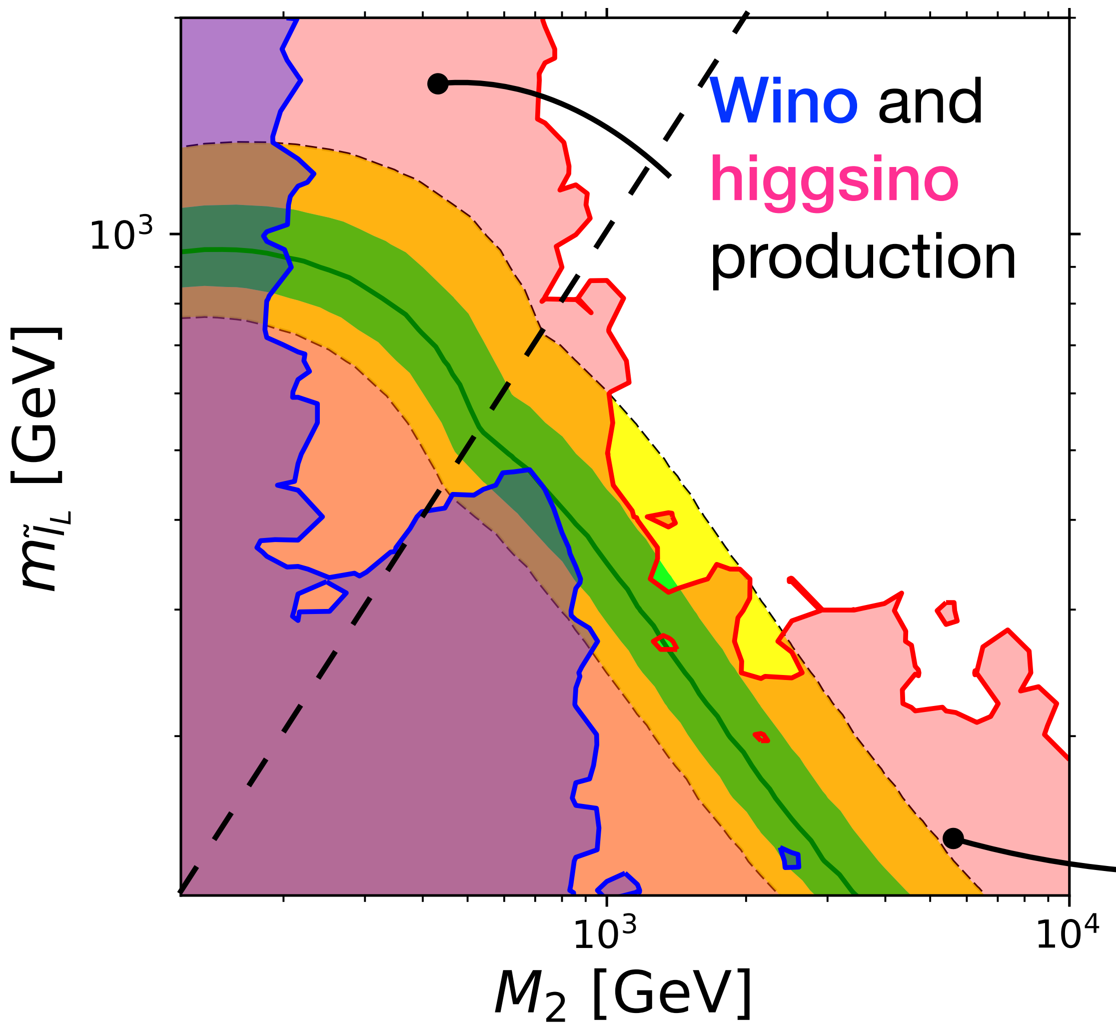
- No DM constraint

- All g-2 region excluded!

WHL (RPV UDD)

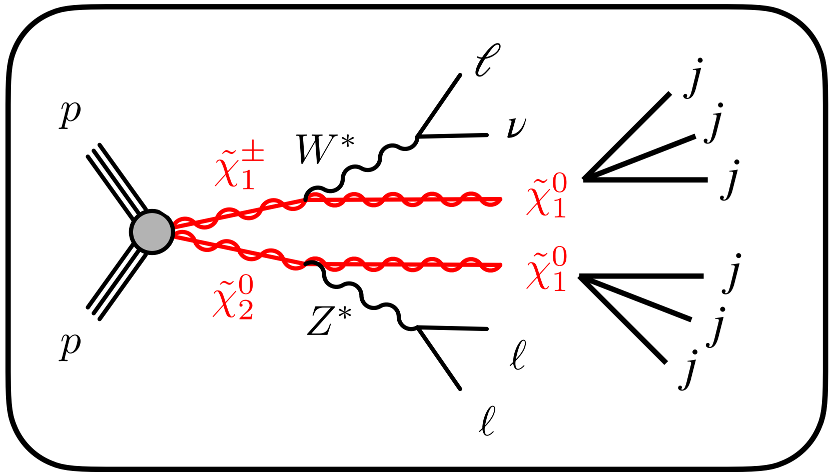
$$\mu = \min(M_2, m_{\tilde{l}_L}) - 20\,\mathrm{GeV}$$

$$\tan\beta = 50, \quad M_1 = m_{\tilde{l}_R} = 10\,\mathrm{TeV}$$



higgsino production

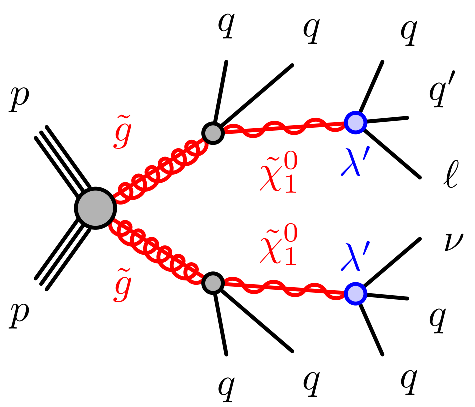
$$pp \to W^{\pm}W^{0,\mp}, \quad \tilde{h}^{0,\pm}\tilde{h}^{0,\mp}$$



soft lepton + multi-jet final state

🟥 **ATLAS** [2106.09609]

🟦 **CMS** [1709.05406]



Bin	Final state	Definition
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2	2 SS leptons	1 jet , $M_T < 100\,\mathrm{GeV}$, $p_T^{\ell\ell} < 100\,\mathrm{GeV}$ and $p_T^{\mathrm{miss}} > 200\,\mathrm{GeV}$
3	3 light leptons	$M_T > 120\,\mathrm{GeV}$ and $p_T^{\mathrm{miss}} > 200\,\mathrm{GeV}$
4	3 light leptons	$p_T^{\mathrm{miss}} > 250\,\mathrm{GeV}$
5	2 light leptons and 1 tau	$M_{T2}(\ell_1, \tau) > 50\,\mathrm{GeV}$ and $p_T^{\mathrm{miss}} > 200\,\mathrm{GeV}$
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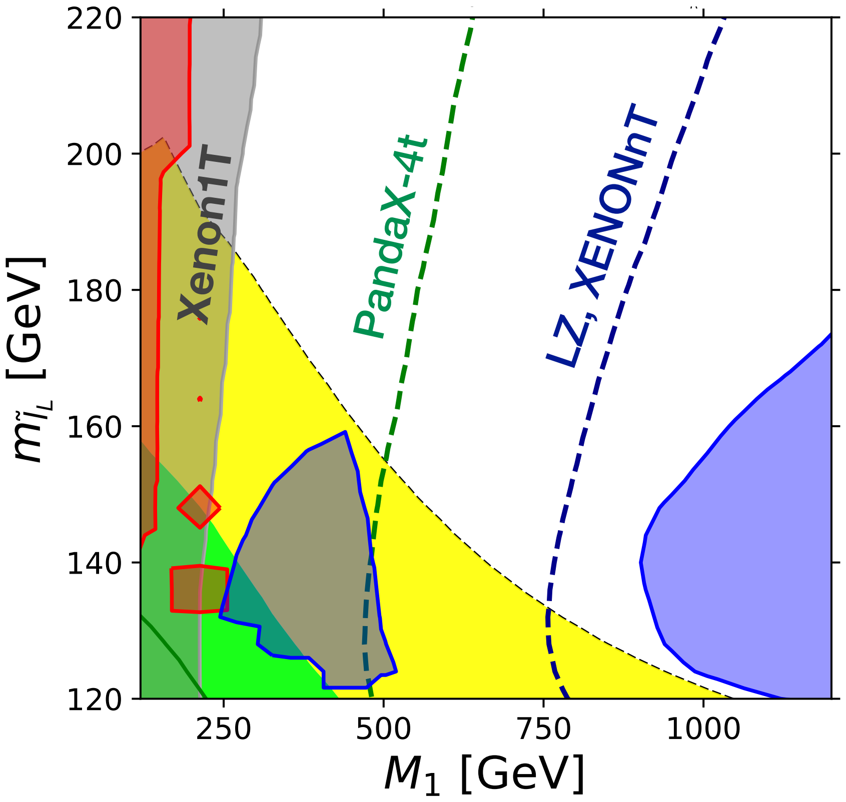
7	1 light lepton and 2 taus	$p_T^{\mathrm{miss}} > 75\,\mathrm{GeV}$
8	more than 3 leptons	$p_T^{\mathrm{miss}} > 200\,\mathrm{GeV}$

BHL

$$\mu = \min(M_1, m_{\tilde{l}_L}) - 20\,\mathrm{GeV}$$

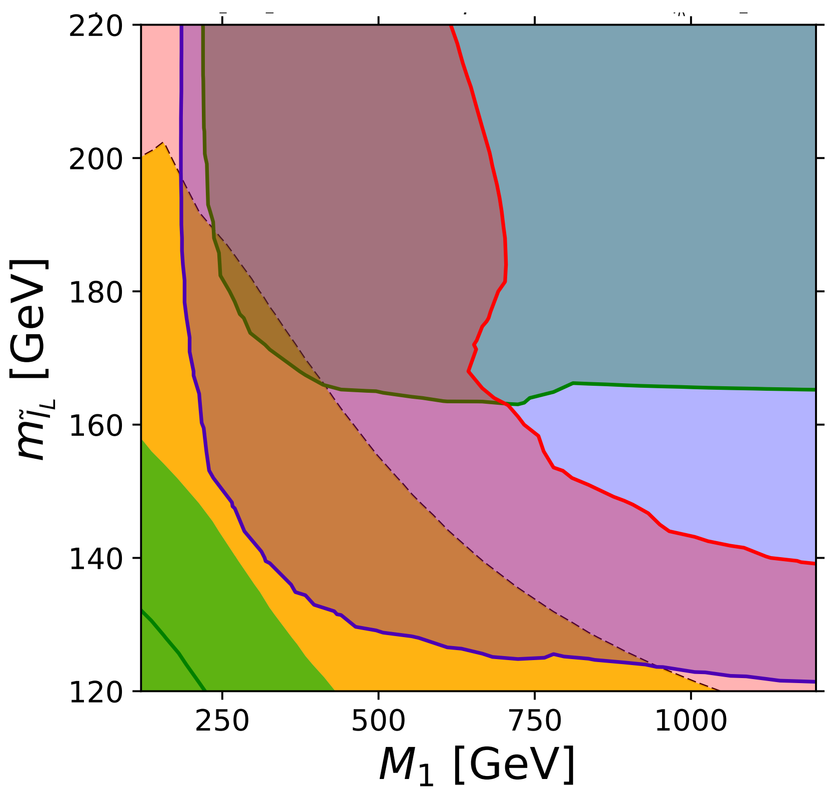
$$\tan\beta = 50, \quad M_2 = m_{\tilde{l}_R} = 10\,\mathrm{TeV}$$

MSSM



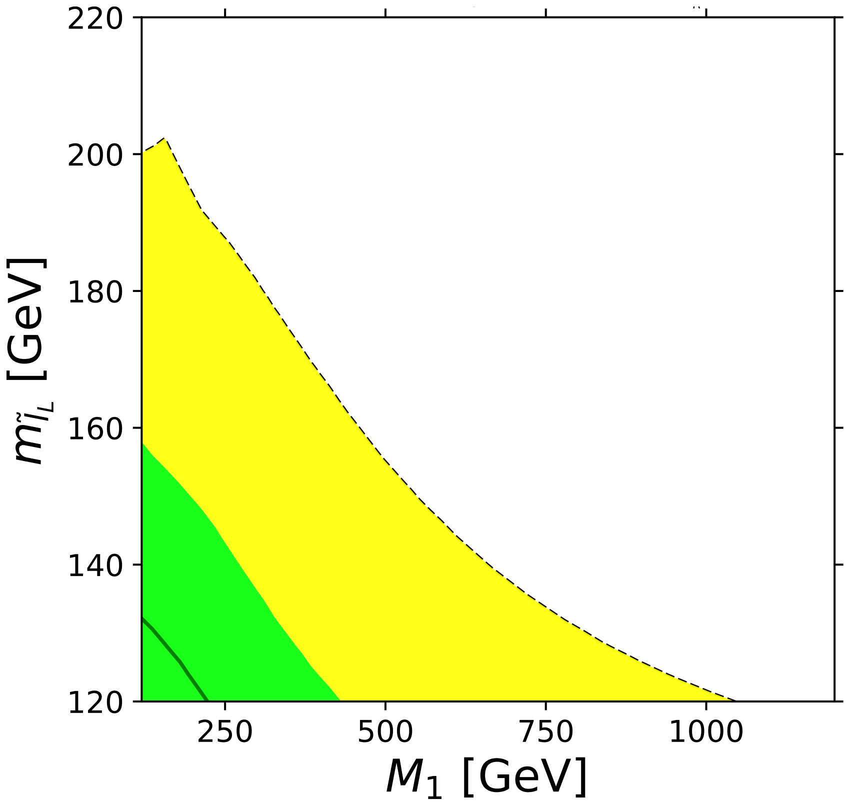
There is a region where $(g\text{-}2)_\mu$ anomaly can be explained. Almost entire region will be probed by the next generation DM DD experiments.

Gravitino LSP



$\mu < m_{lL} < 220$GeV. Such a light higgsino-like NSLP is excluded in gravitino LSP scenario.

UDD RPV



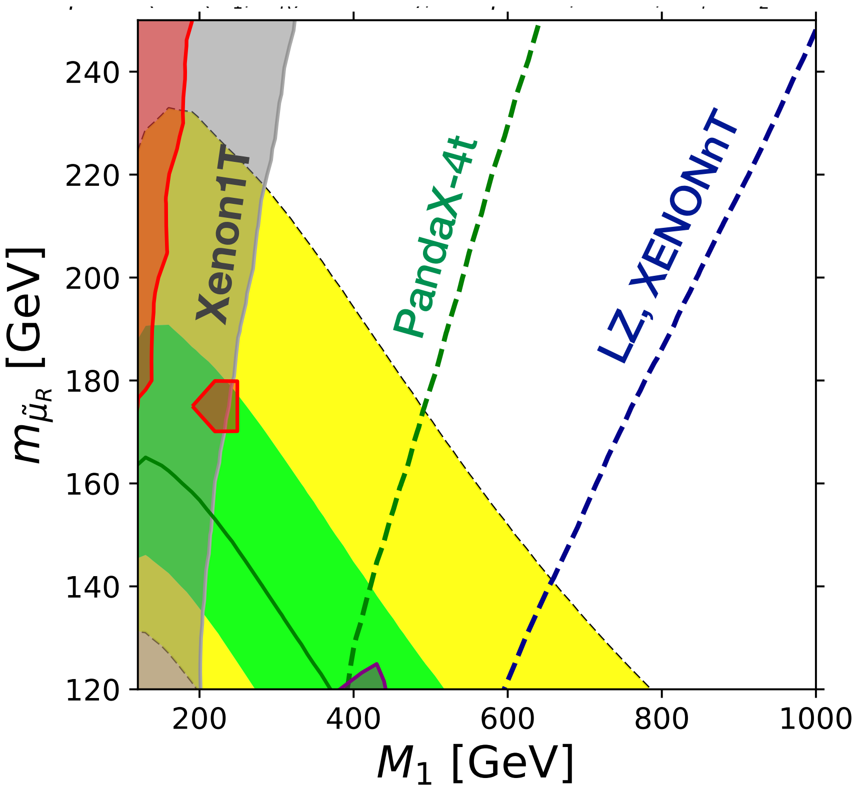
Higgsino production dominates but the mass splitting among higgsino states are tiny (< a few GeV) due to M_2 = 10 TeV. Leptons produced from decays among higgsino states are too soft and not detected.

BHR

$$-\mu = \min(M_1, m_{\tilde{l}_R}) - 20\,\mathrm{GeV}$$

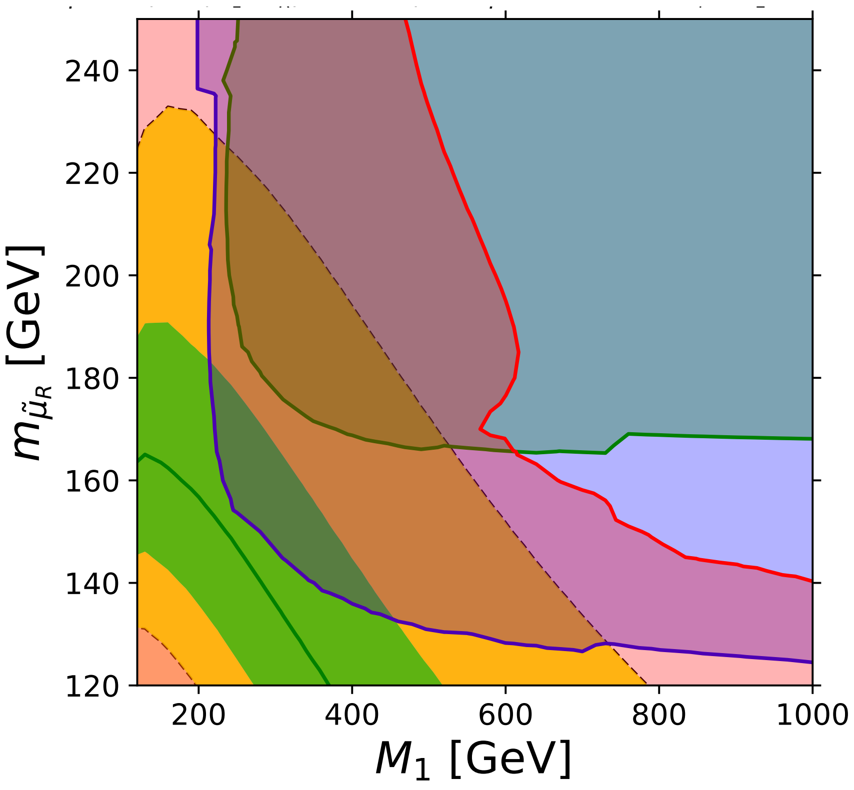
$$\tan\beta = 50, \quad M_2 = m_{\tilde{l}_L} = 10\,\mathrm{TeV}$$

MSSM



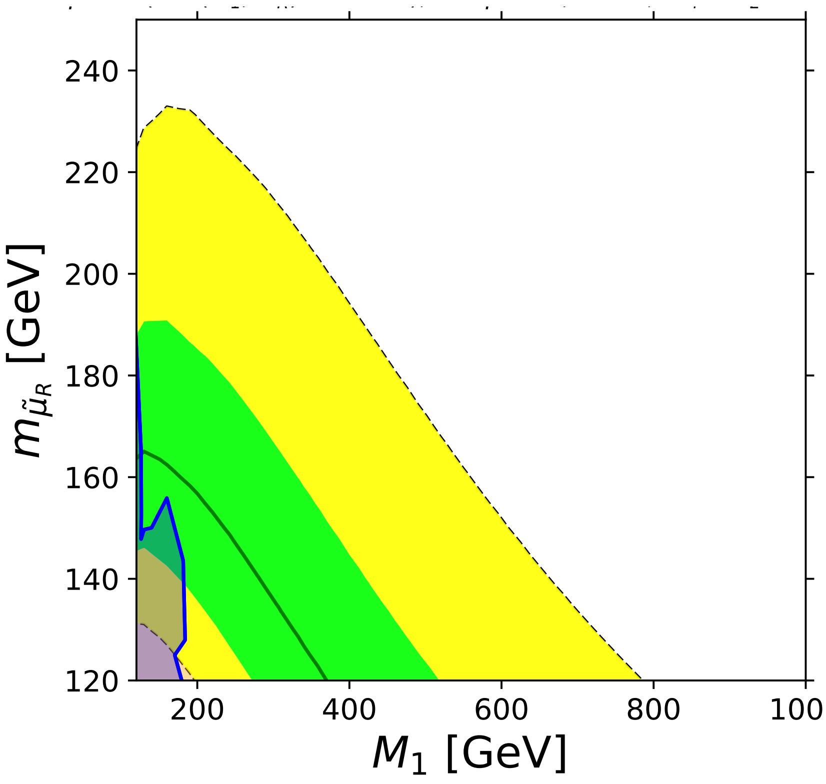
There is a region where $(g-2)_\mu$ anomaly can be explained. Almost entire region will be probed by the next generation DM DD experiments.

Gravitino LSP



$|\mu| < m_{lL} < 250$GeV. Such a light higgsino-like NSLP is excluded in gravitino LSP scenario.

UDD RPV

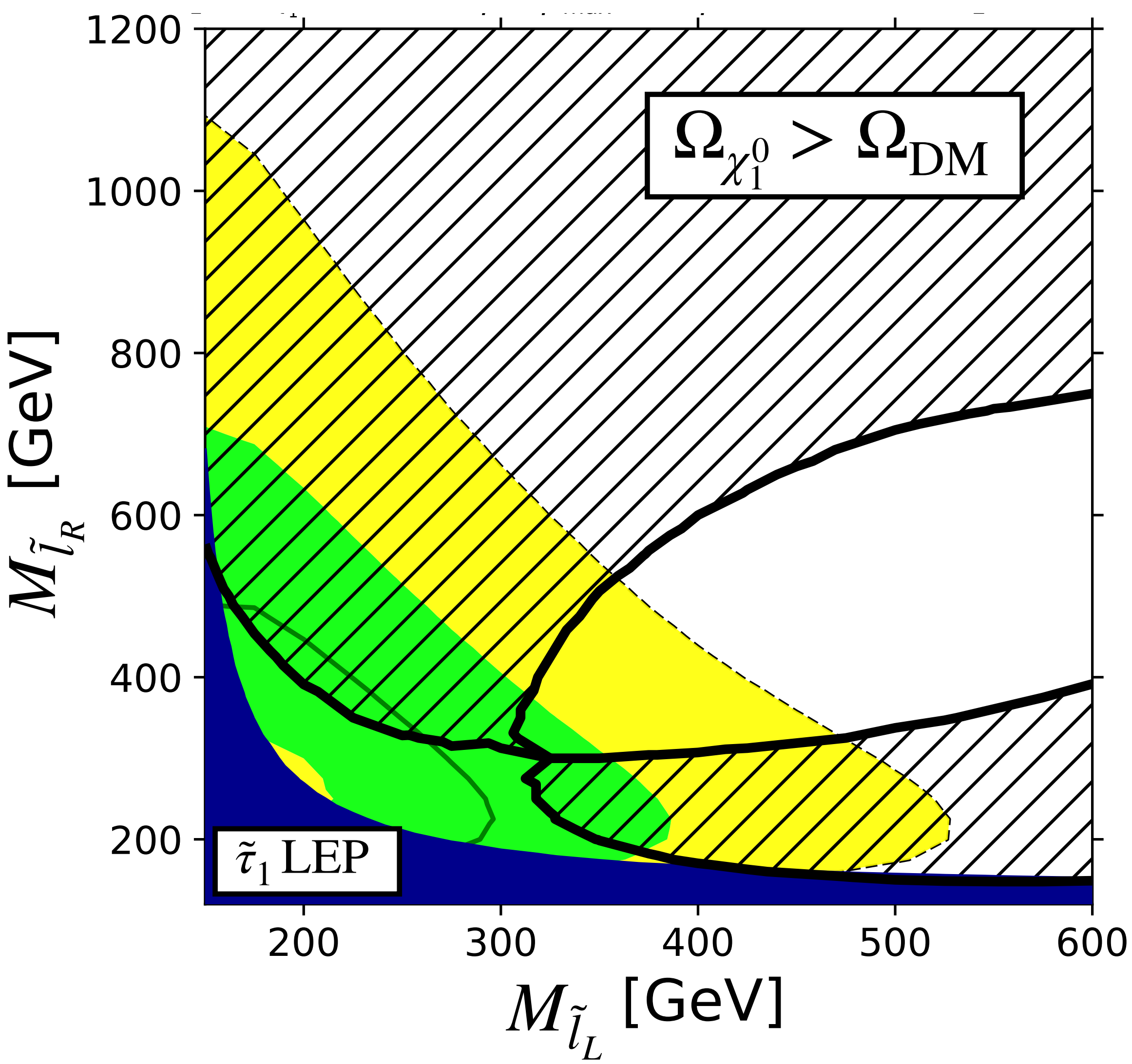


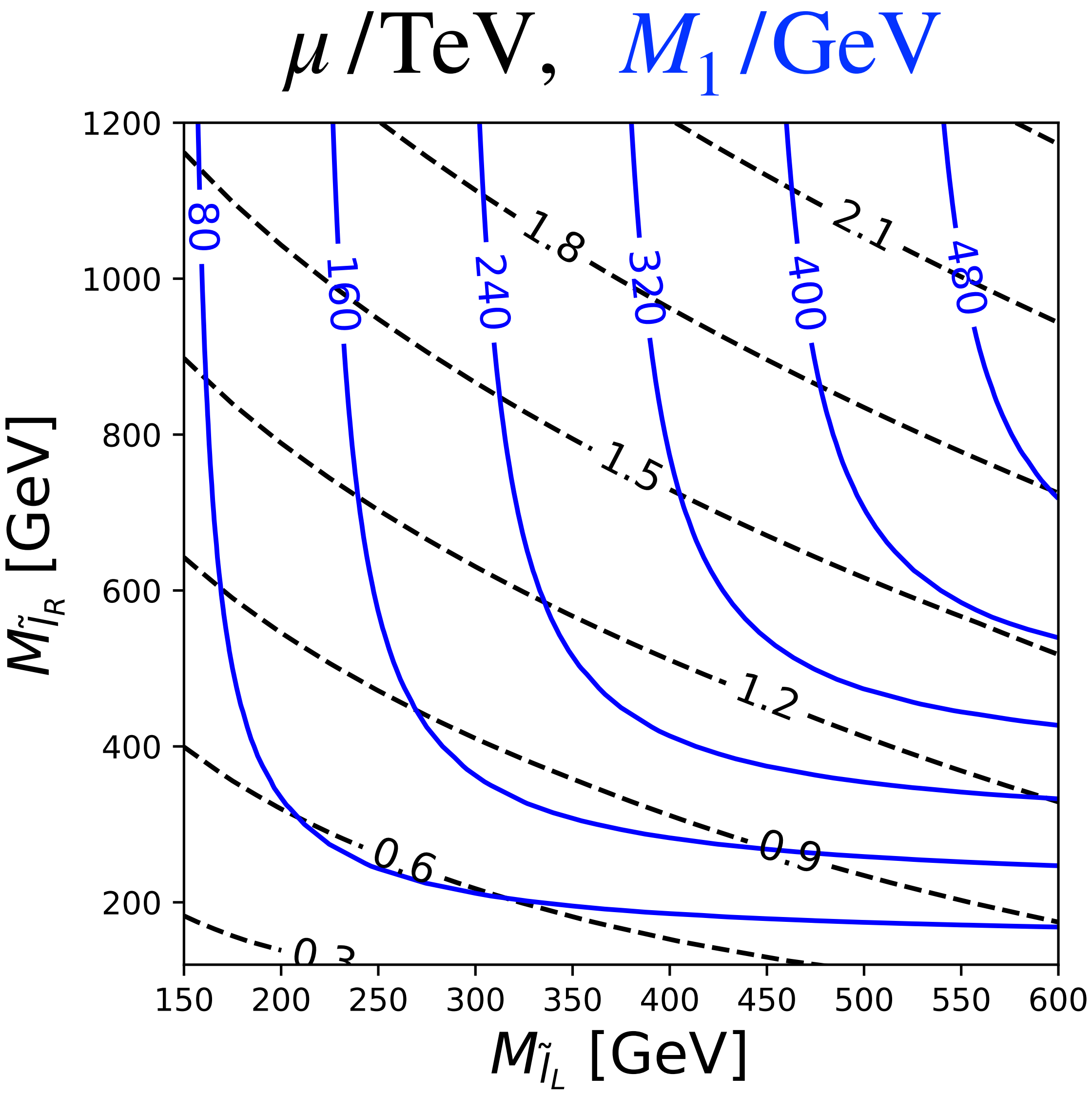
Higgsino production dominates but the mass splitting among higgsino states are tiny (< a few GeV) due to M_2 = 10 TeV. Leptons produced from decays among higgsino states are too soft and not detected.

BLR

$$\Delta a_\mu^{\mathrm{BLR}}(M_1, m_{\tilde{l}_L}, m_{\tilde{l}_R};\ \mu)$$

MSSM





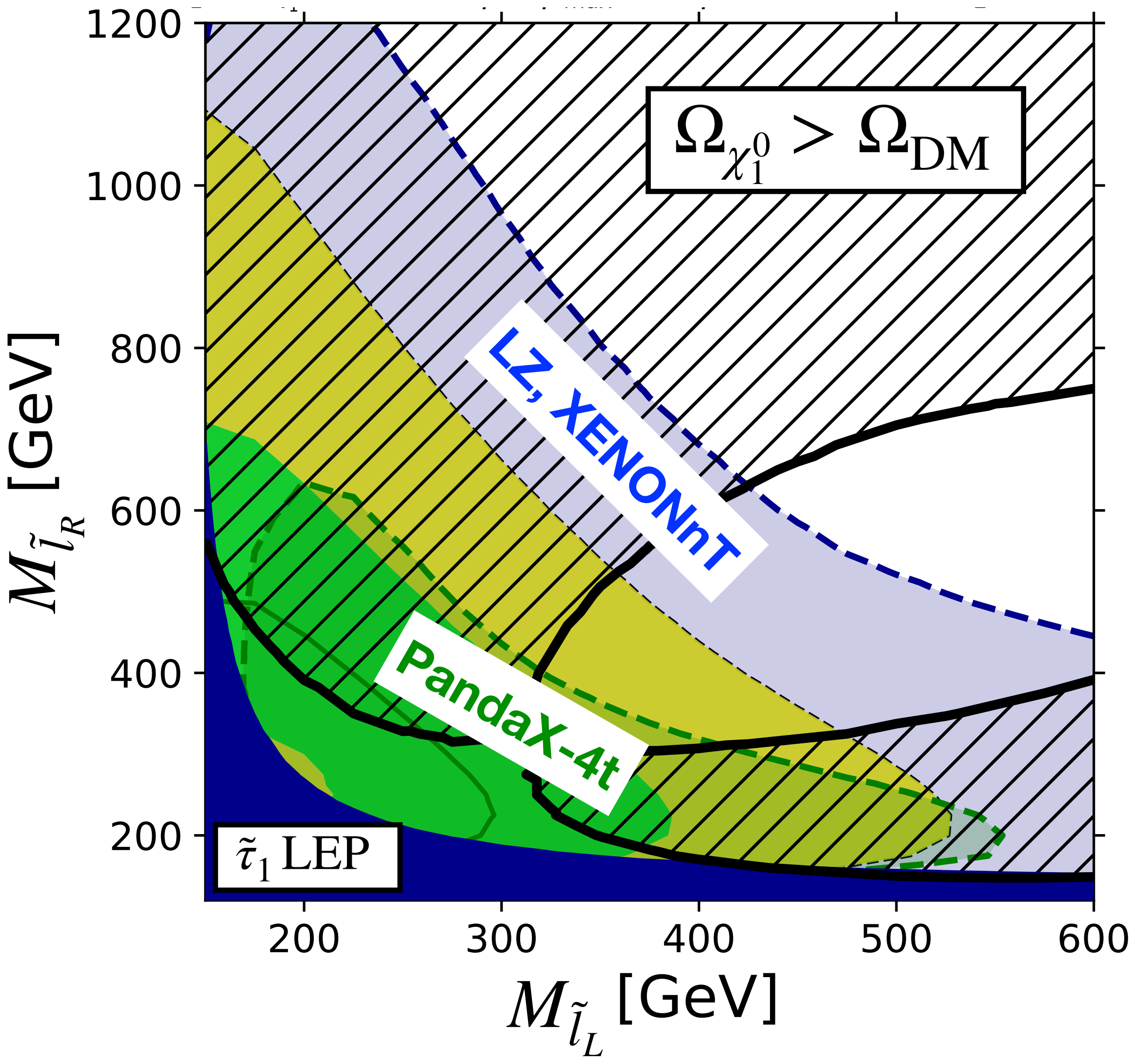
$M_1 = m_{\tilde{\tau}_1} - 20\,\mathrm{GeV}$, $M_2 = 10\,\mathrm{TeV}$

$\mu = \mu_{\max}$, $\tan\beta = 50$

maximum allowed by
vacuum (meta-)stability

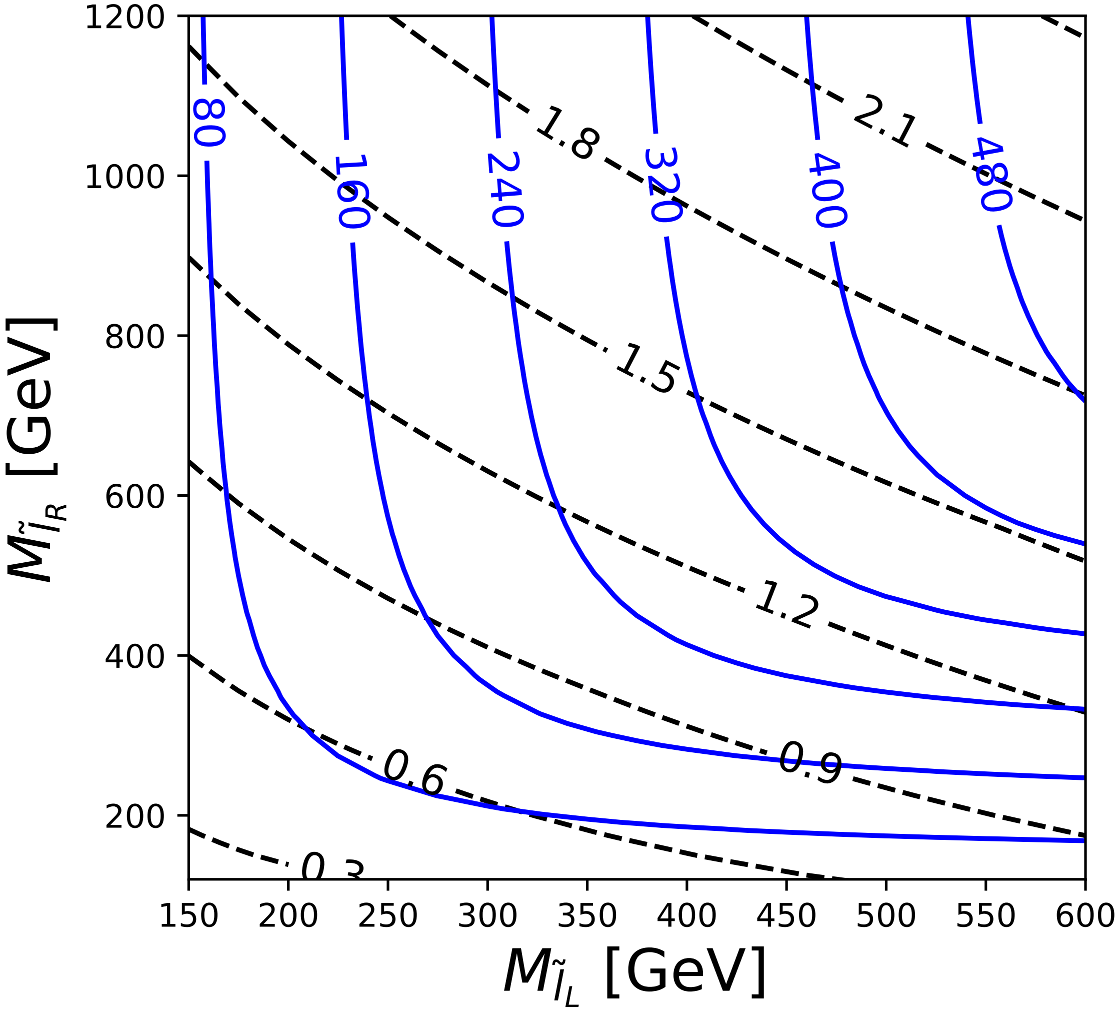
BLR

MSSM



$$\Delta a_\mu^{\rm BLR}(M_1, m_{\tilde l_L}, m_{\tilde l_R}; \mu)$$

μ /TeV, M_1 /GeV



$M_1 = m_{\tilde\tau_1} - 20\,\mathrm{GeV}$, $M_2 = 10\,\mathrm{TeV}$

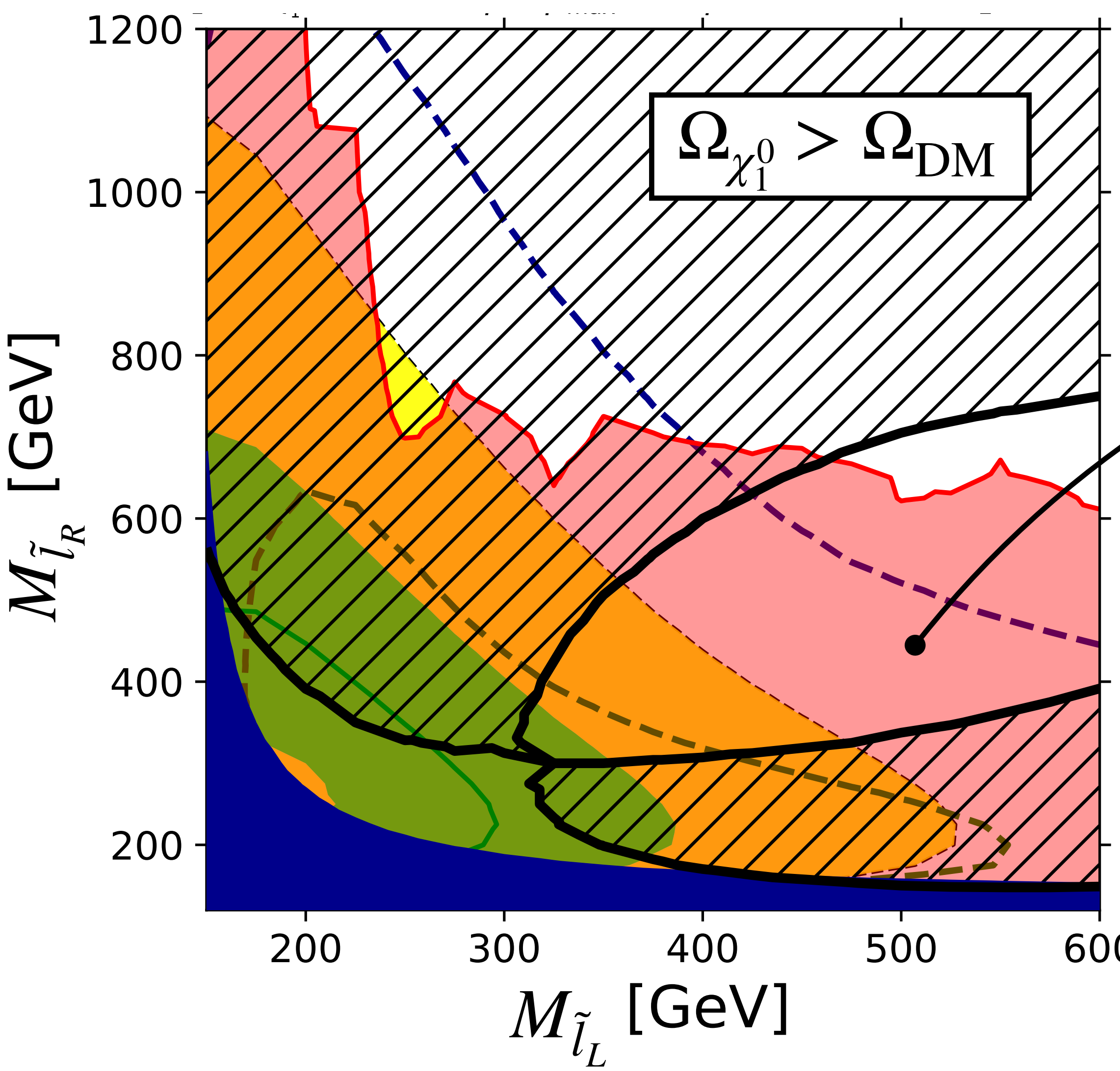
$\mu = \mu_{\rm max}$, $\tan\beta = 50$

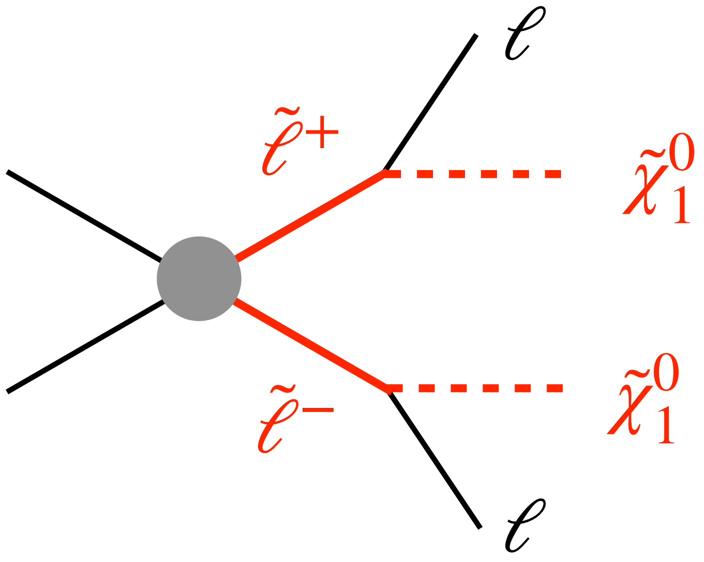
maximum allowed by vacuum (meta-)stability

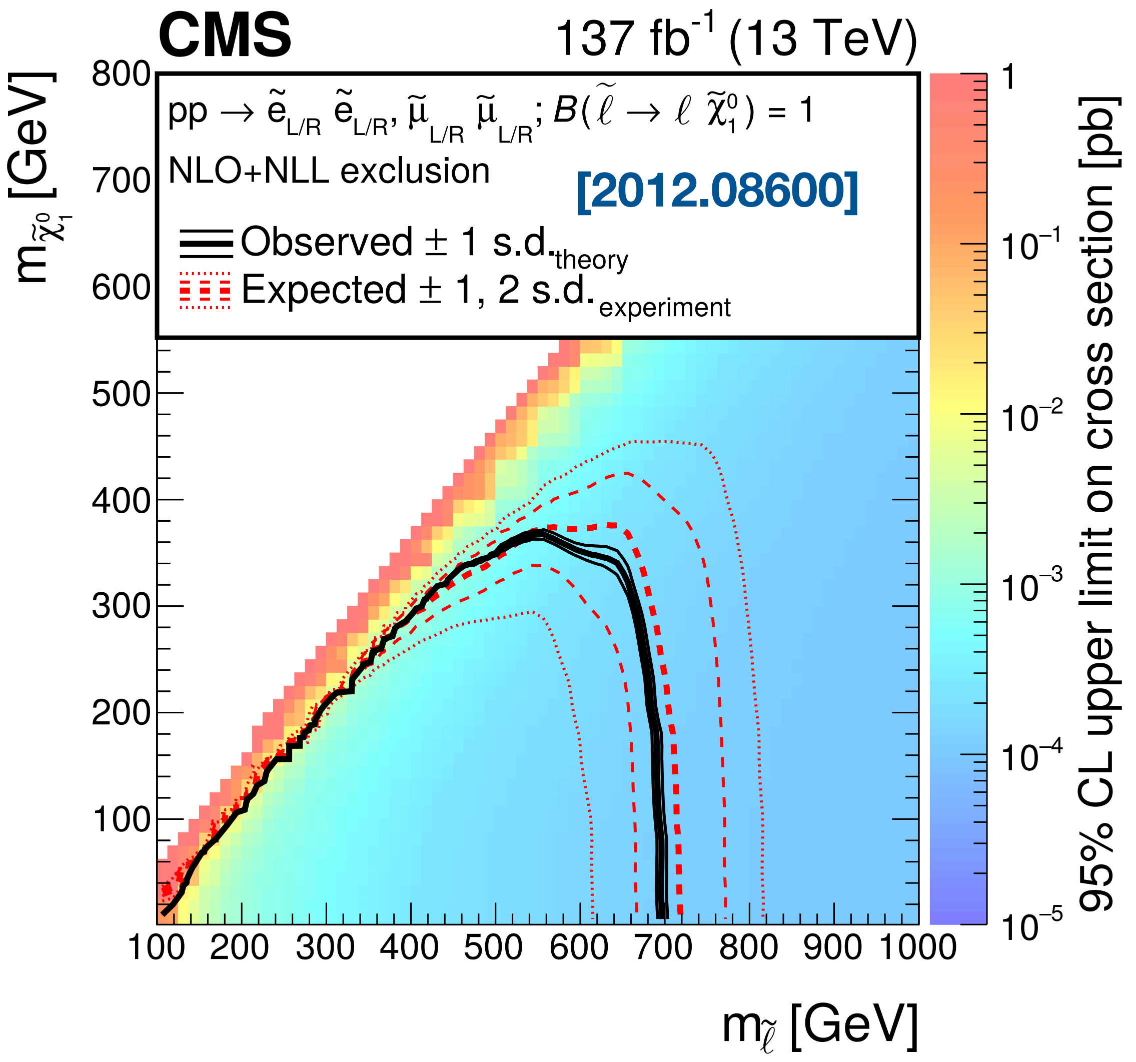
BLR

$$\Delta a_\mu^{\rm BLR}(M_1, m_{\tilde{l}_L}, m_{\tilde{l}_R};\ \mu)$$

MSSM







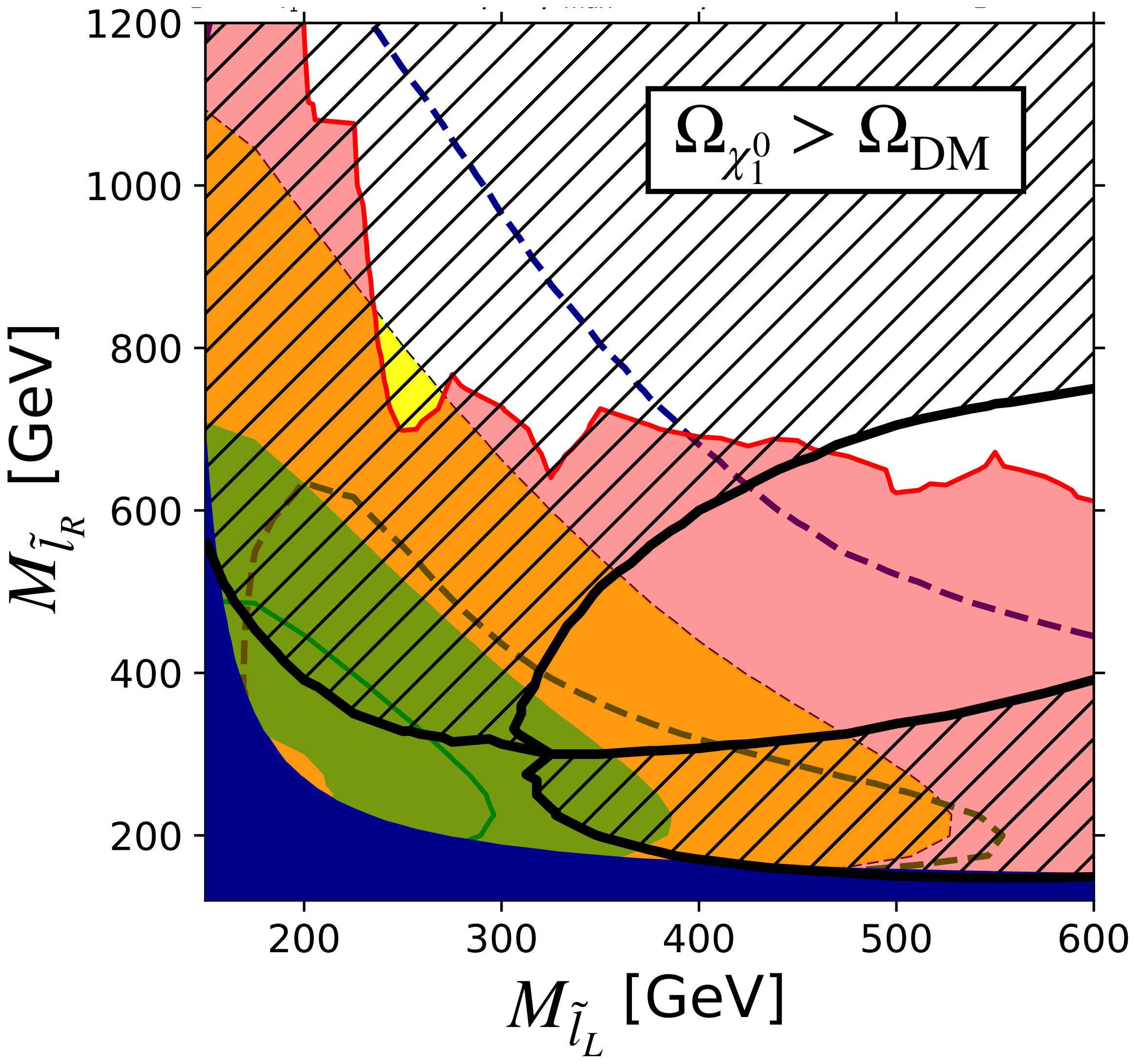
$$\boxed{M_1 = m_{\tilde{\tau}_1} - 20\,\mathrm{GeV},}\quad M_2 = 10\,\mathrm{TeV}$$

$$\boxed{\mu = \mu_{\rm max},}\quad \tan\beta = 50$$

maximum allowed by vacuum (meta-)stability

BLR

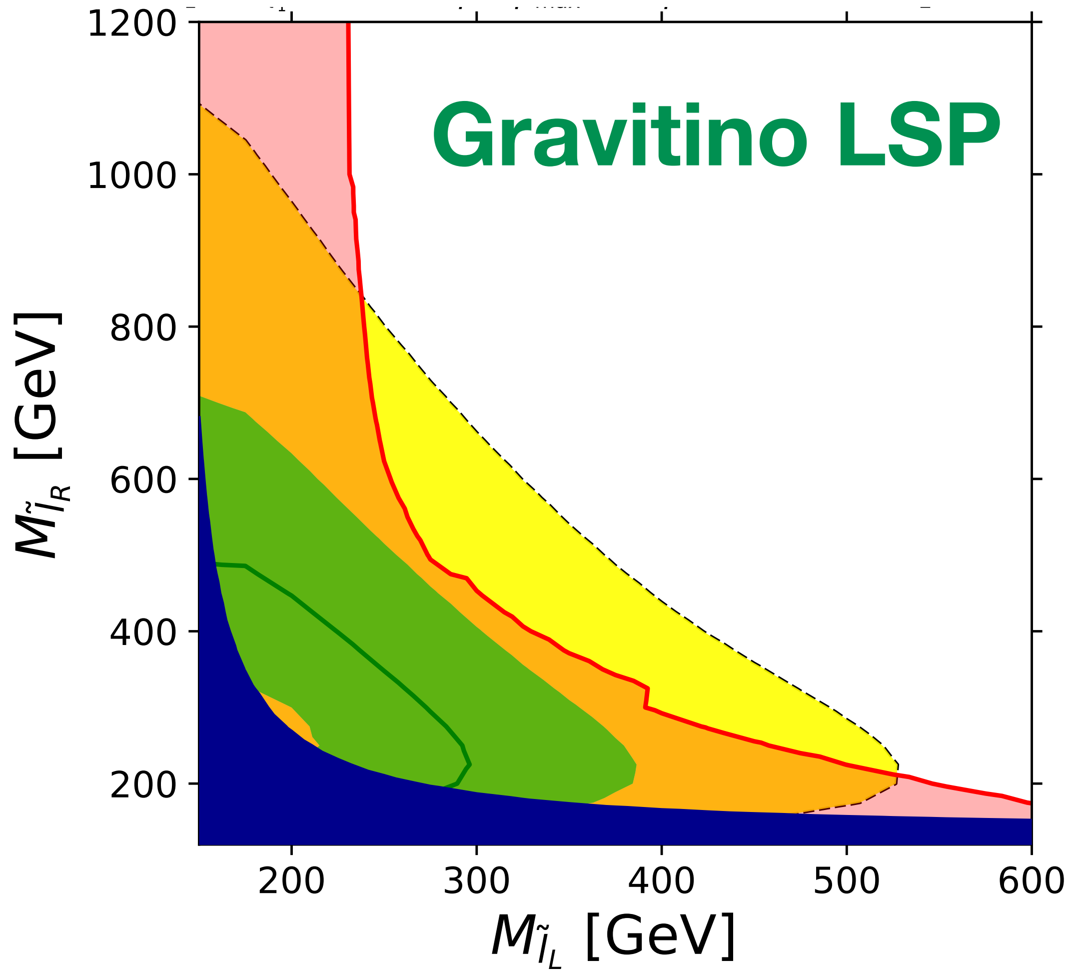
MSSM

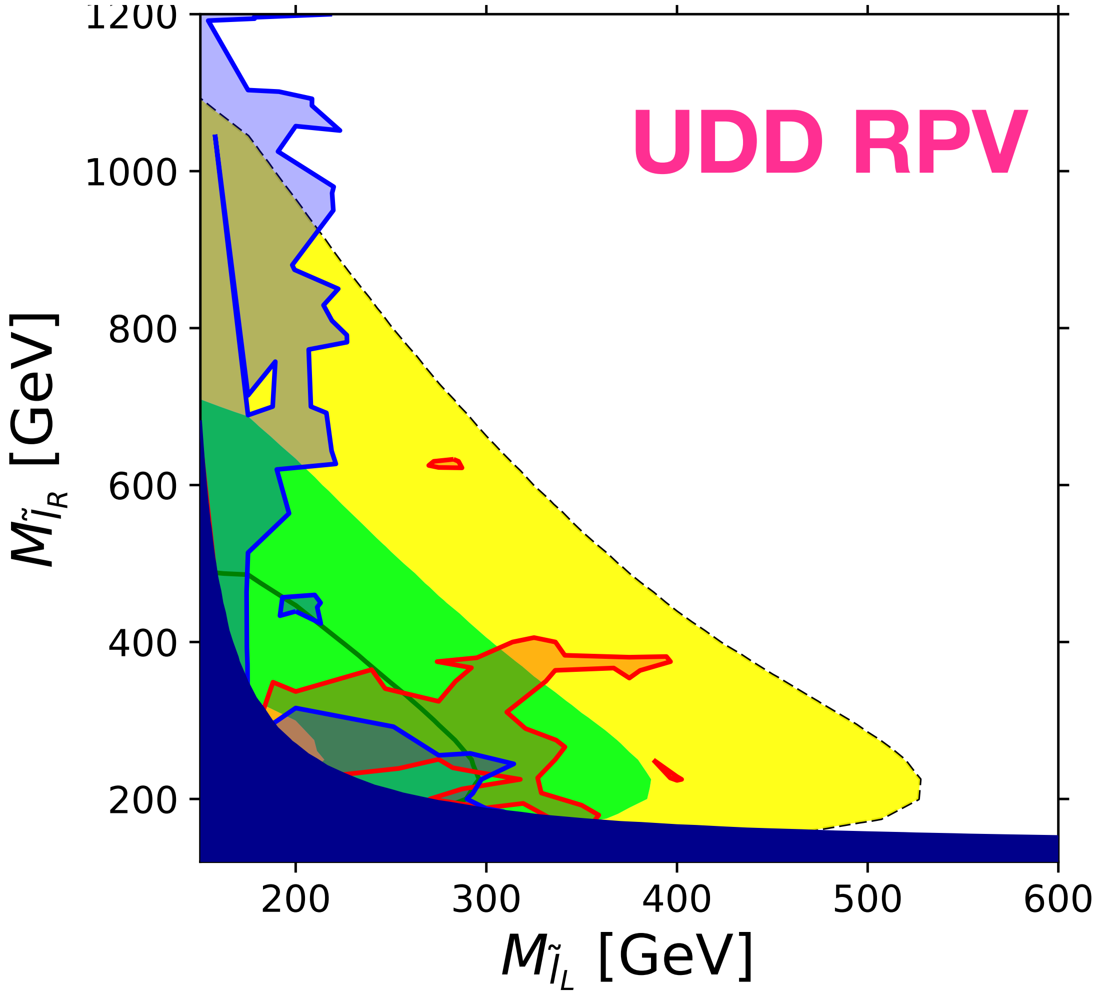


$M_1 = m_{\tilde{\tau}_1} - 20\,\mathrm{GeV},$ $M_2 = 10\,\mathrm{TeV}$

$\mu = \mu_{\mathrm{max}},$ $\tan\beta = 50$

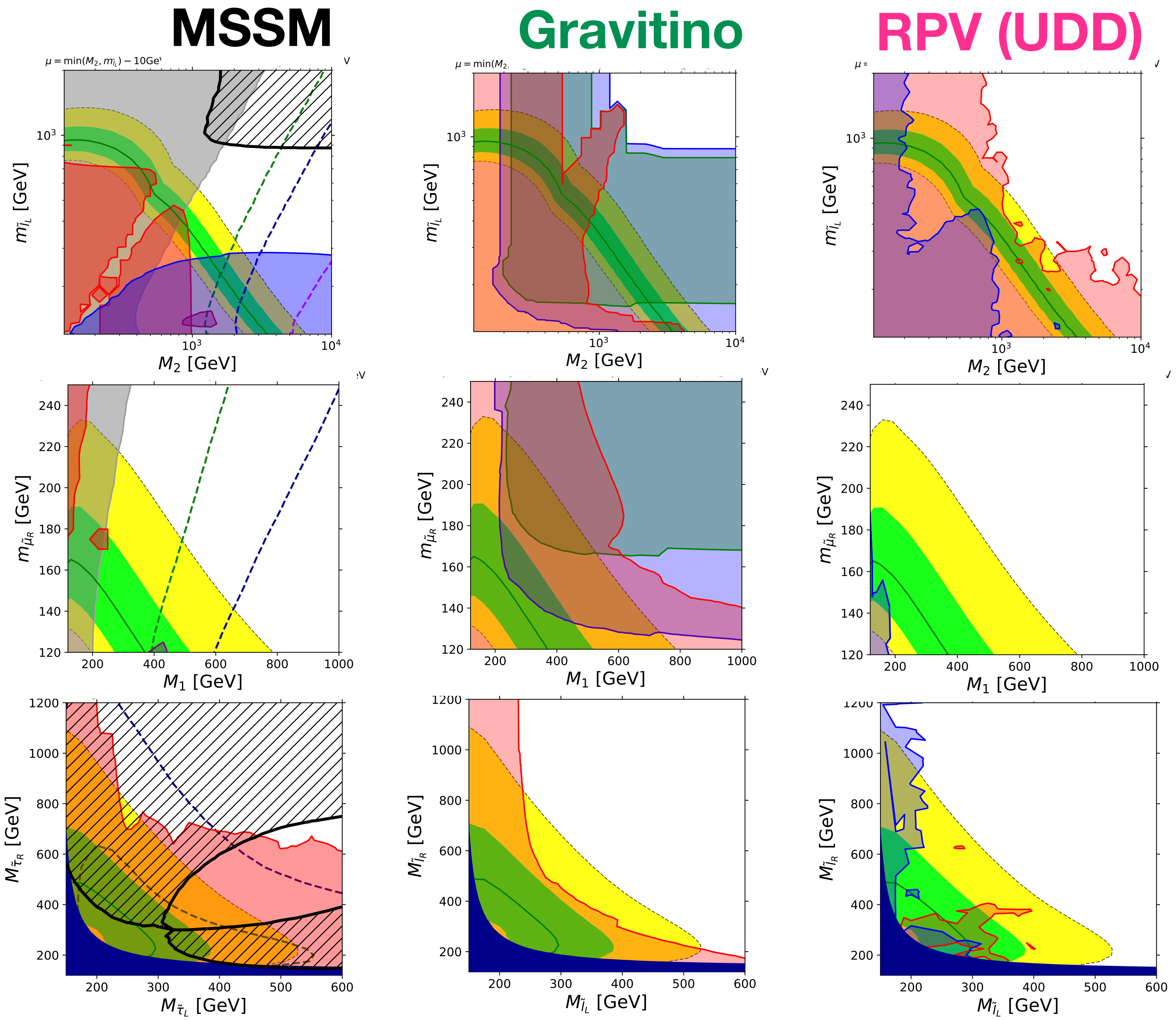
maximum allowed by vacuum (meta-)stability





Conclusion

- Studied the SUSY parameter space that can explain muon g-2 anomaly.
- Phenomenological constraints depend on whether or not neutralino-1 is stable:



Stable (**MSSM**):

- Dark Matter:

  Overproduction, Direct Detection

  → **Next generation DD exps will explore the entire 2-sigma region**

- LHC constraints: **Lepton + MET**

Unstable:

- **No dark matter constraints:**
- LHC constraints:

  Gravitino → **photon + MET**

  RPV (UDD) → **lepton + multi-jet**

Norway
grants

NATIONAL SCIENCE CENTRE
POLAND

The research leading to the results presented in this talk has received funding from the Norwegian Financial Mechanism for years 2014-2021, grant nr 2019/34/H/ST2/00707

Understanding the Early Universe:
interplay of theory and collider experiments

Joint research project between the University of Warsaw & University of Bergen