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UNIVERSITY
OF WARSAW

Muon g-2 in SUSY scenarios with unstable neutralinos

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Based on [2202.12928]

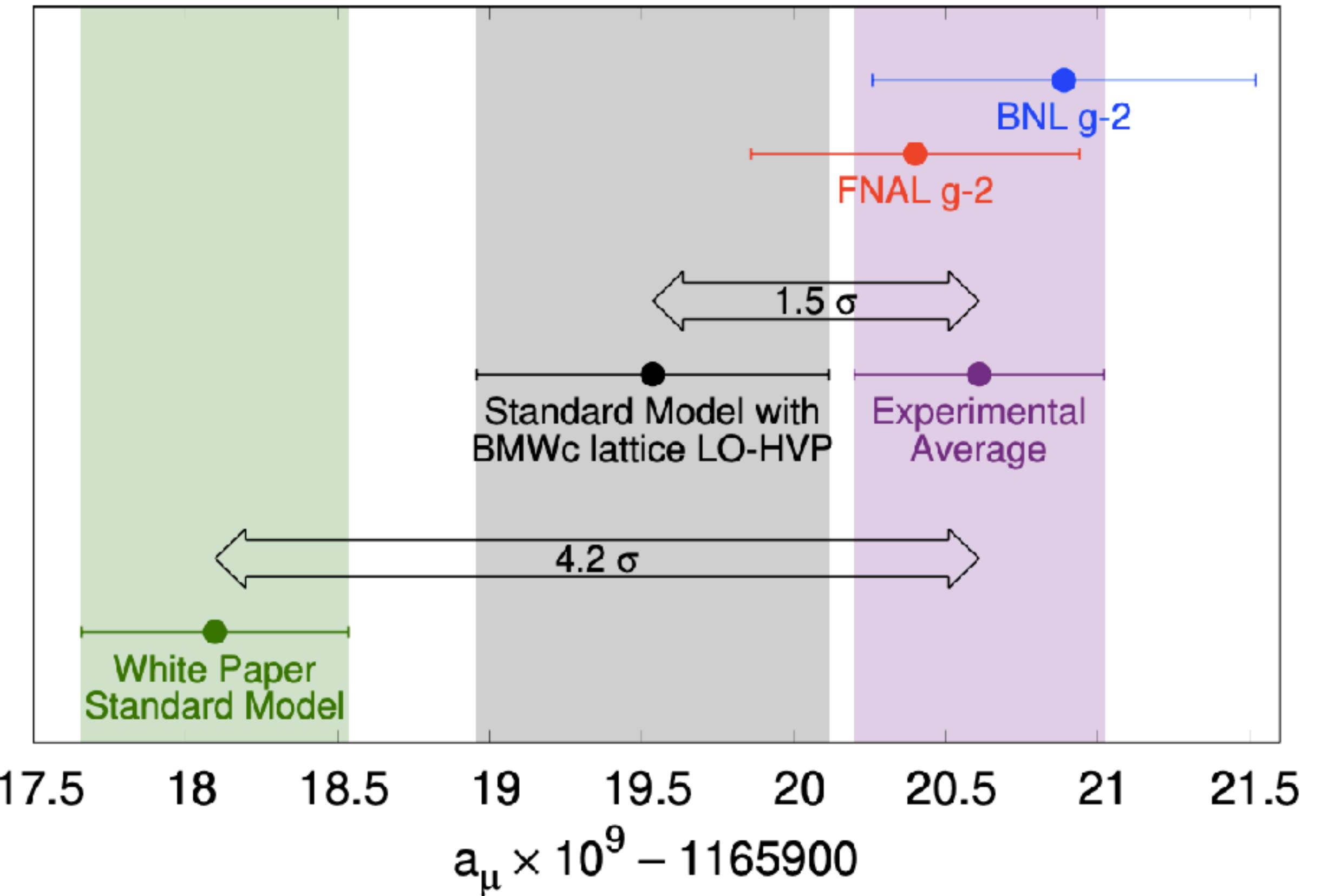
SUSY 2022/06/29

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NCN SONATA BIS 7 GRANT
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$(g-2)_\mu$ anomaly



$$a_\mu^{\text{theo}} = 0.00 \quad 1165 \quad 91 \quad 810 \quad (43)$$

$$a_\mu^{\text{exp}} = 0.00 \quad 1165 \quad 92 \quad 061 \quad (41)$$

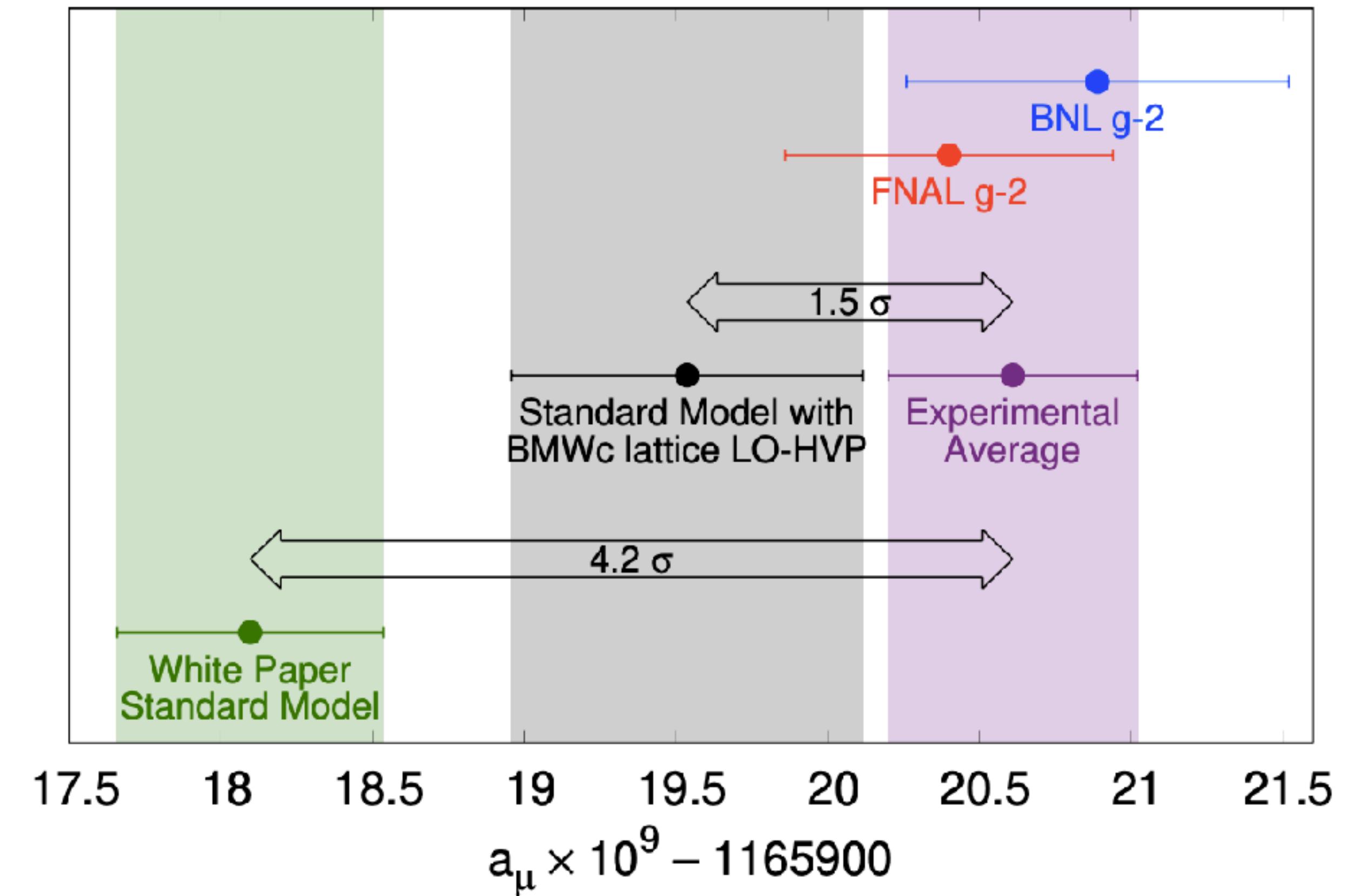
[Muon g-2, Phys. Rev. Lett. 126, 141801]

[T. Aoyama et al., , Phys. Rep. 887, 1 (2020)]

R. Maselek SUSY 2022/06/29

[L. Lellouch, Moriond 2022 EW]

$(g-2)_\mu$ anomaly



$$\begin{aligned} a_\mu^{\text{theo}} &= 0.00 \\ a_\mu^{\text{exp}} &= 0.00 \end{aligned}$$

	QED	HVP	EW	HLbL
a_μ^{theo}	1165	91	810	(43)
a_μ^{exp}	1165	92	061	(41)

↑

statistical
error

dominant

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

[Muon g-2, Phys. Rev. Lett. 126, 141801]

[T. Aoyama et al., , Phys. Rep. 887, 1 (2020)] R. Maselek SUSY 2022/06/29

[L. Lellouch, Moriond 2022 EW]

Motivation

Many BSM scenarios can explain the $(g-2)_\mu$ anomaly

Leptoquarks, Z' , 2HDM, axion, ...

Supersymmetry is particularly motivated, because it offers:

Coupling Unification, Radiative EWSB, Baryogenesis, DM, ...

However, simple SUSY scenarios are heavily constrained by existing experimental results...

Which SUSY scenarios are phenomenologically viable?

Can phenomenologically
viable SUSY explain $(g-2)_\mu$?

MSSM

stable $\tilde{\chi}_1^0$

Can phenomenologically
viable SUSY explain $(g-2)_\mu$?
DM constraints

MSSM unstable $\tilde{\chi}_1^0$ stable $\tilde{\chi}_1^0$

Can phenomenologically
viable SUSY explain $(g-2)_\mu$?

RPV DM constraints GMSB

Muon g-2

ATLAS/CMS

MSSM

unstable $\tilde{\chi}_1^0$

stable $\tilde{\chi}_1^0$

Can phenomenologically
viable SUSY explain $(g-2)_\mu$?

RPV DM constraints GMSB

XENON1T/PANDA/LZ/ARGO ...

$(g-2)_\mu$ viable parameters

Muon g-2

ATLAS/CMS

MSSM

unstable $\tilde{\chi}_1^0$ stable $\tilde{\chi}_1^0$

Can phenomenologically
viable SUSY explain $(g-2)_\mu$?

RPV DM constraints GMSB

XENON1T/PANDA/LZ/ARGO ...

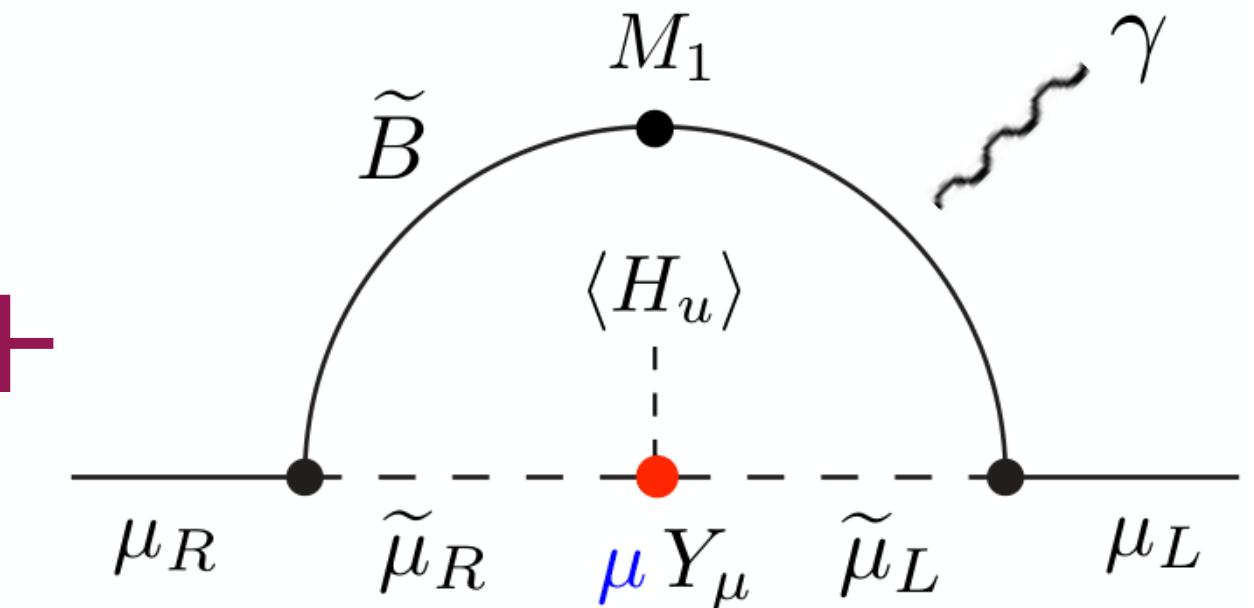
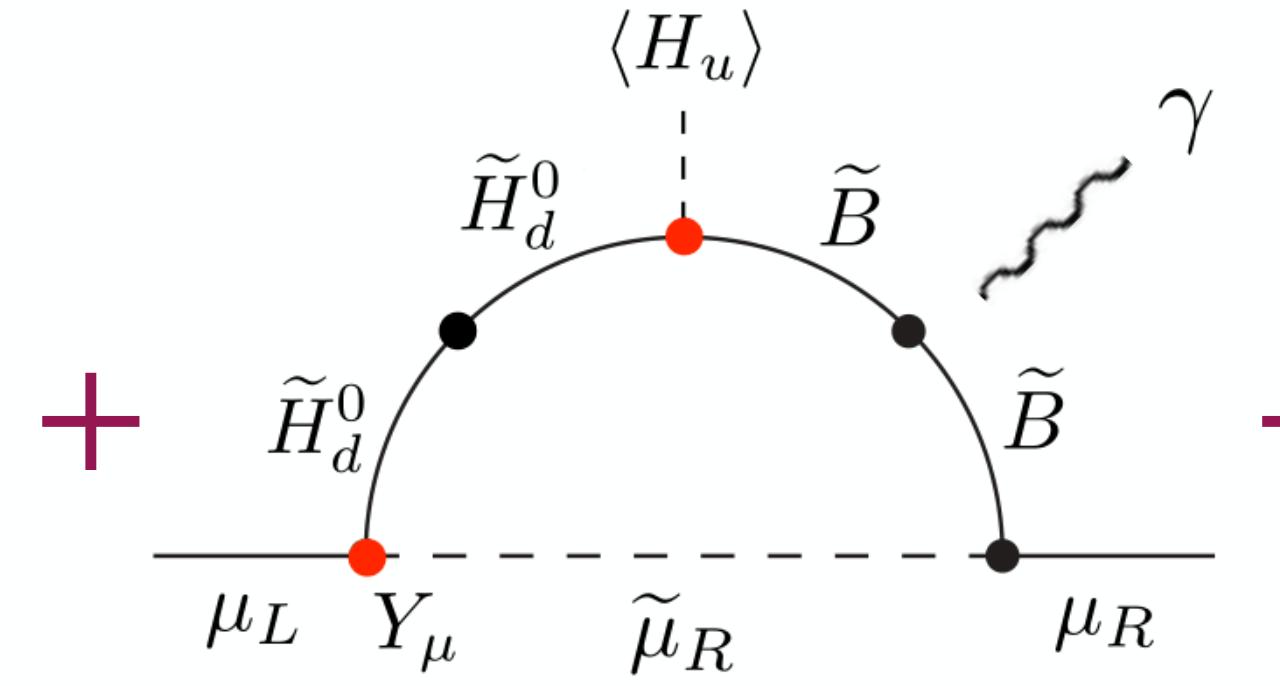
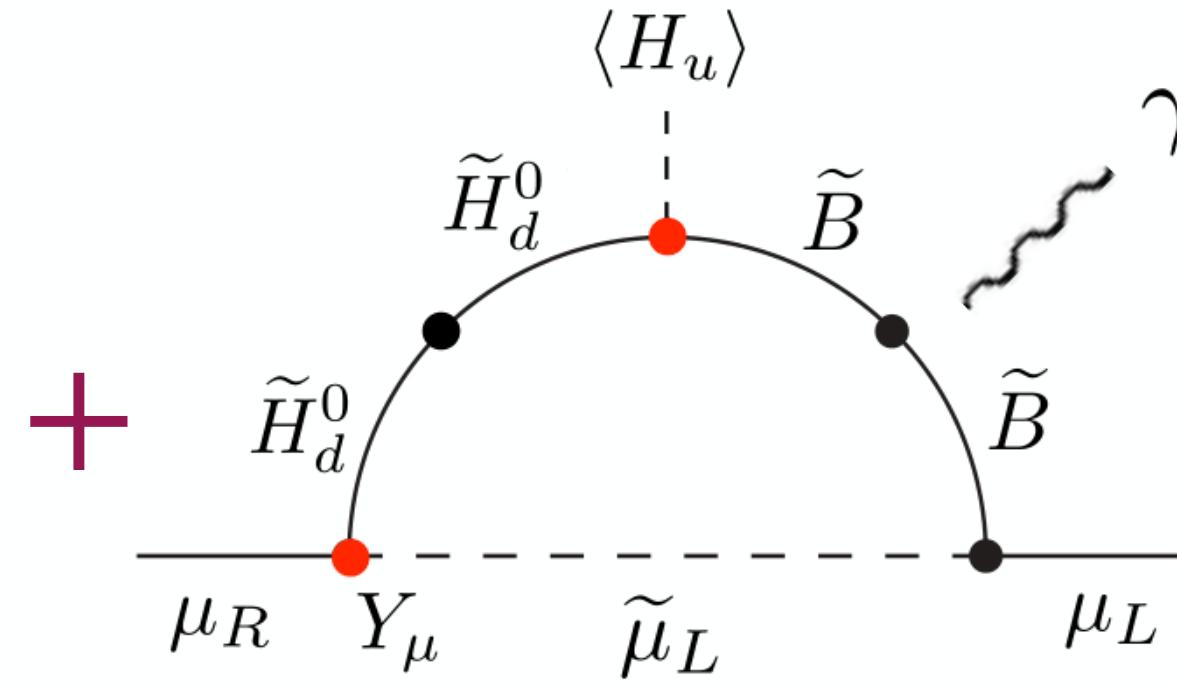
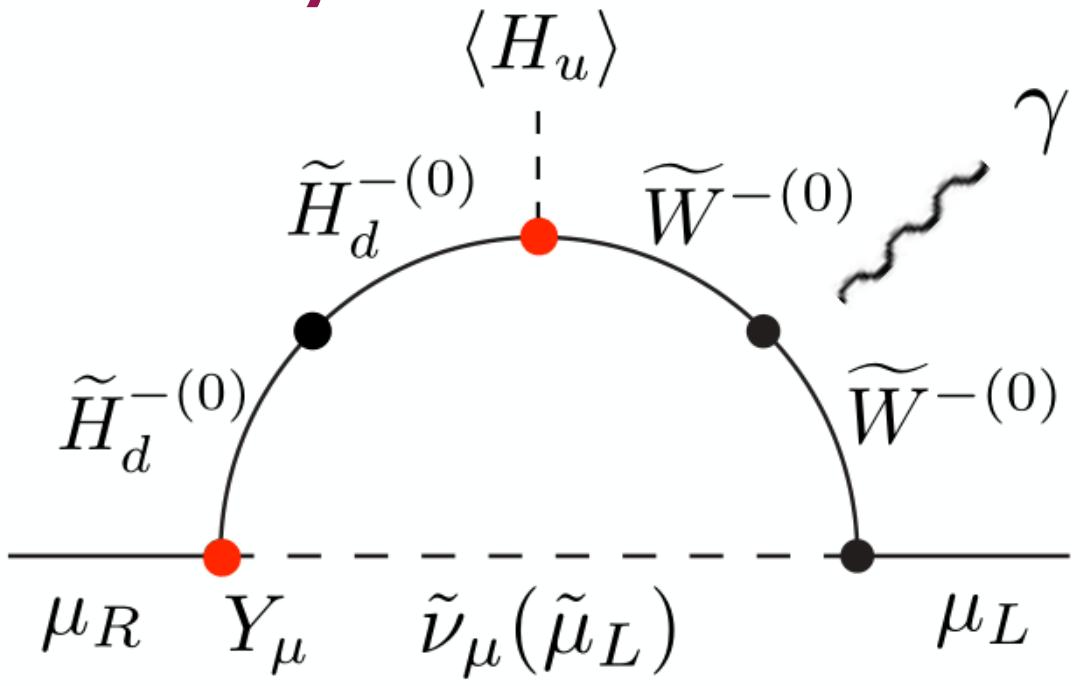
2D parameter planes

A photograph of Malbork Castle in Poland, a large Gothic brick castle with multiple towers and a long wall, set against a sky with orange and blue hues. The castle is reflected in the water in the foreground.

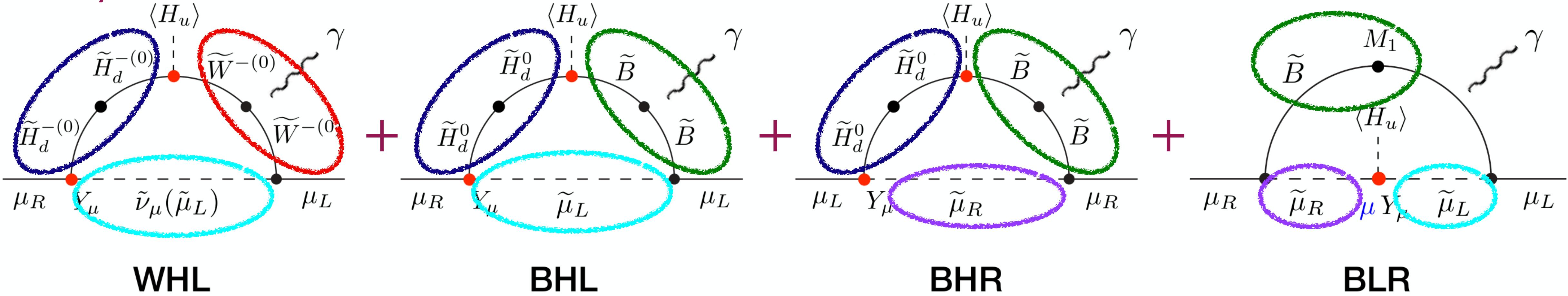
(g-2) $_{\mu}$ in SUSY

Malbork Castle, Poland
photo from museum's FB page

$$\Delta a_\mu^{\text{SUSY}} \simeq$$



$$\Delta a_\mu^{\text{SUSY}} \simeq$$



$\text{⚛ } M_1$: Bino mass

$\text{⚛ } M_2$: Wino mass

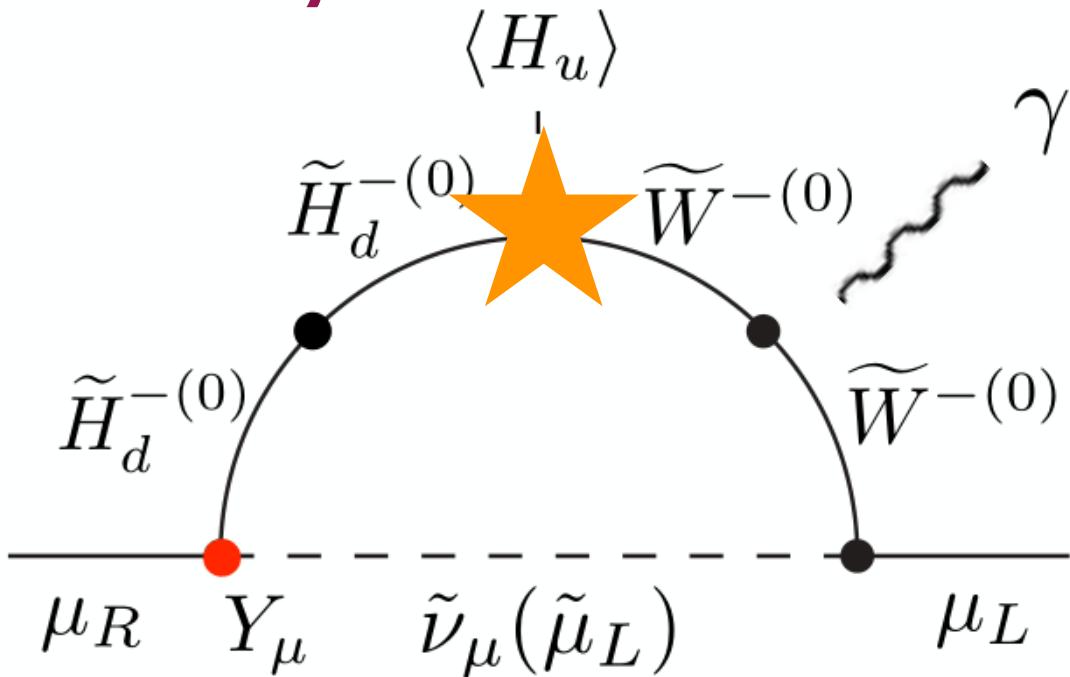
$\text{⚛ } \mu$: Higgsino mass

$\text{⚛ } m_{\tilde{l}_R}$: right-handed slepton mass

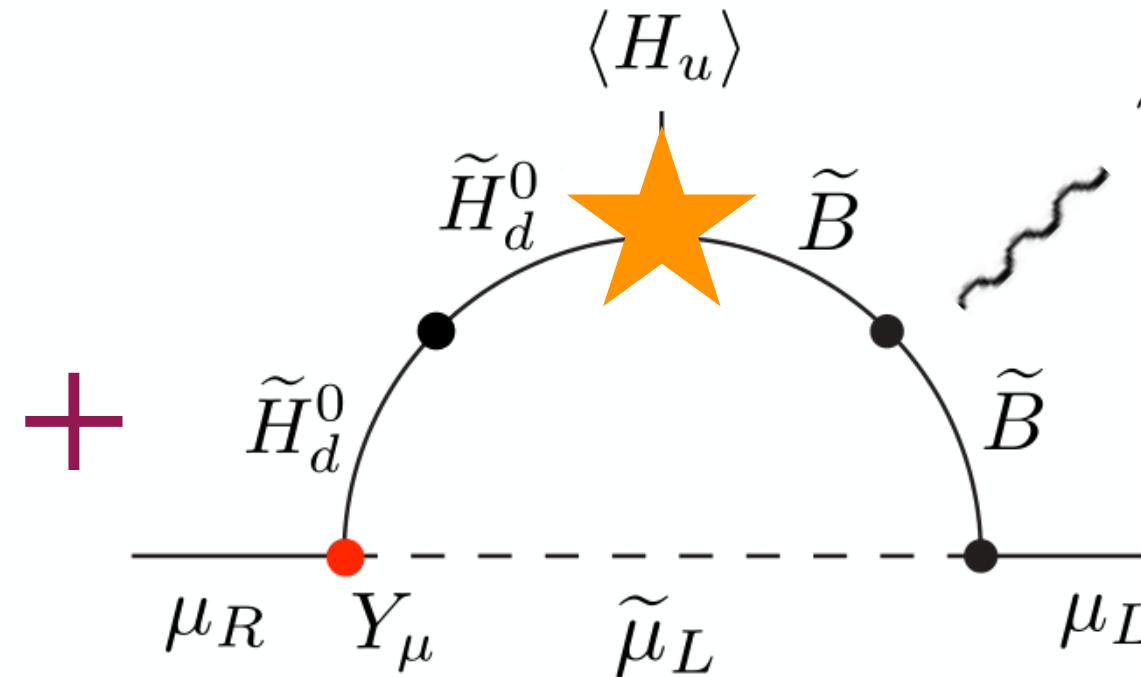
$\text{⚛ } m_{\tilde{l}_L}$: left-handed slepton mass

$\text{⚛ } \tan \beta \equiv \langle H_u \rangle / \langle H_d \rangle$

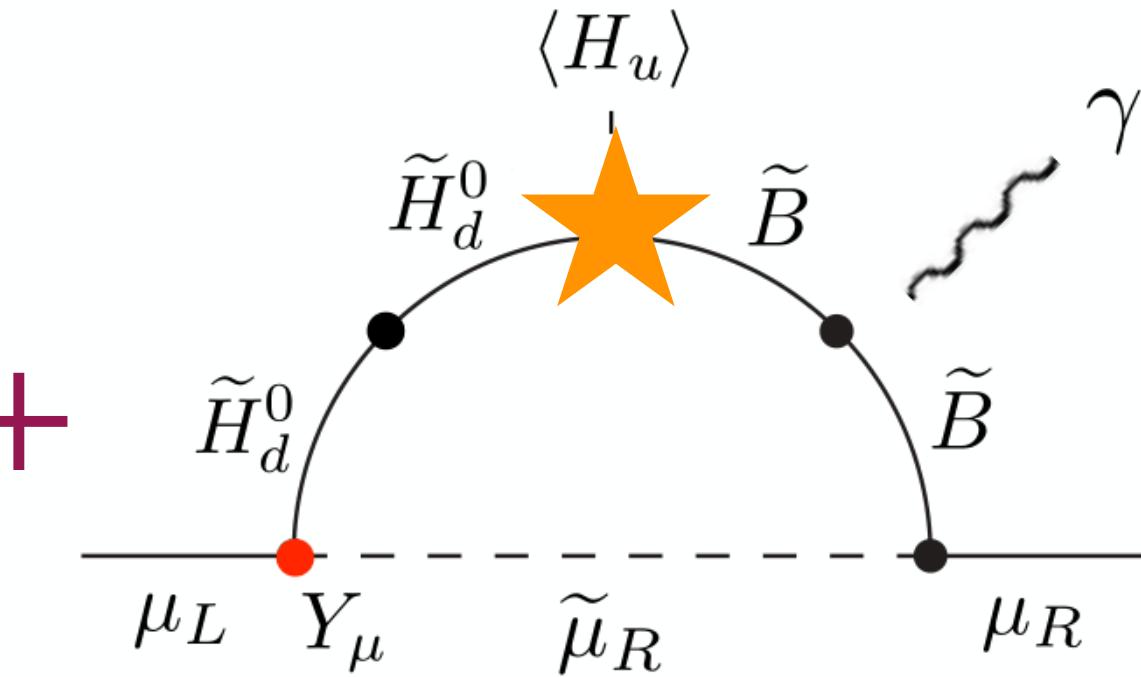
$$\Delta a_\mu^{\text{SUSY}} \simeq$$



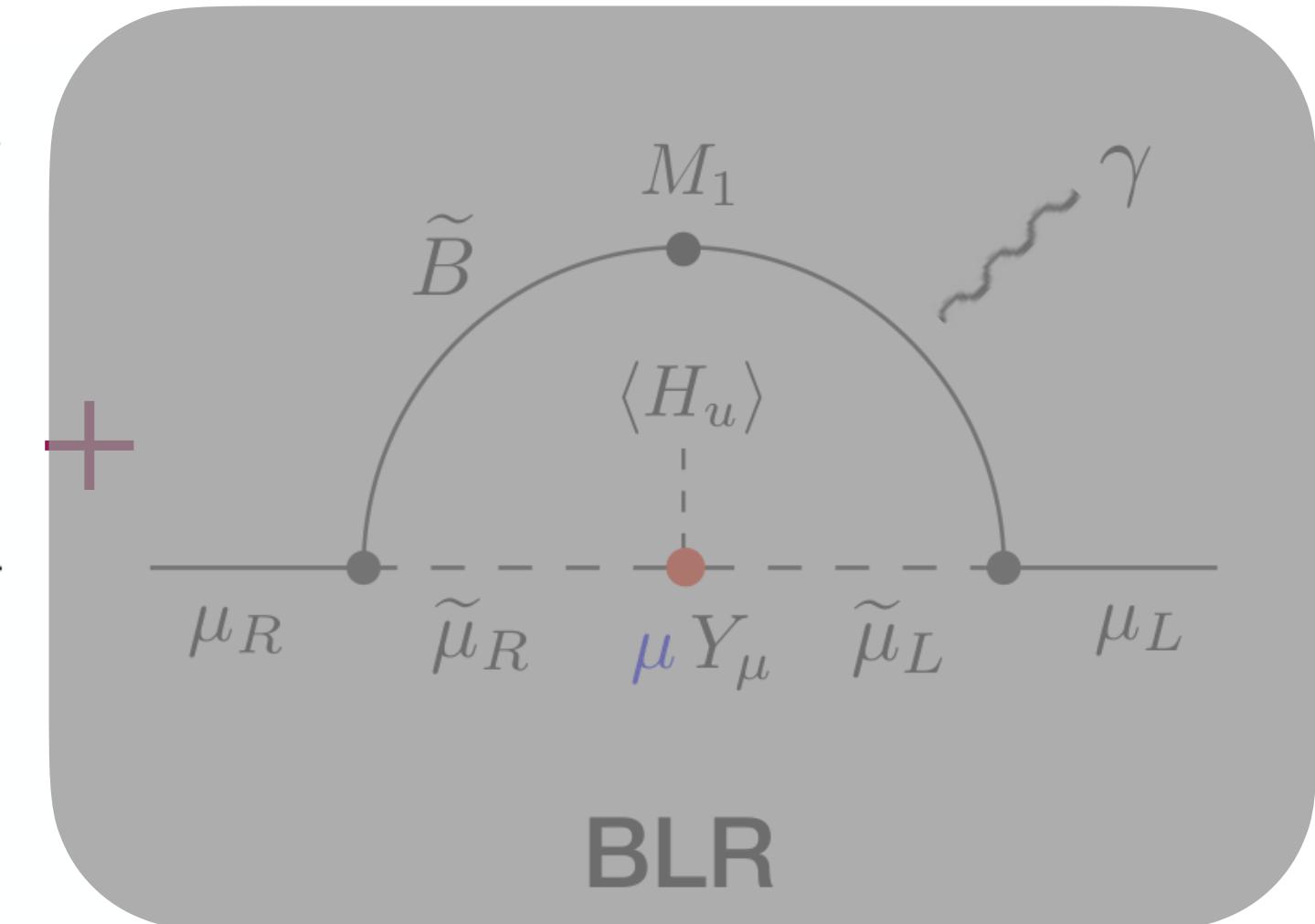
WHL



BHL

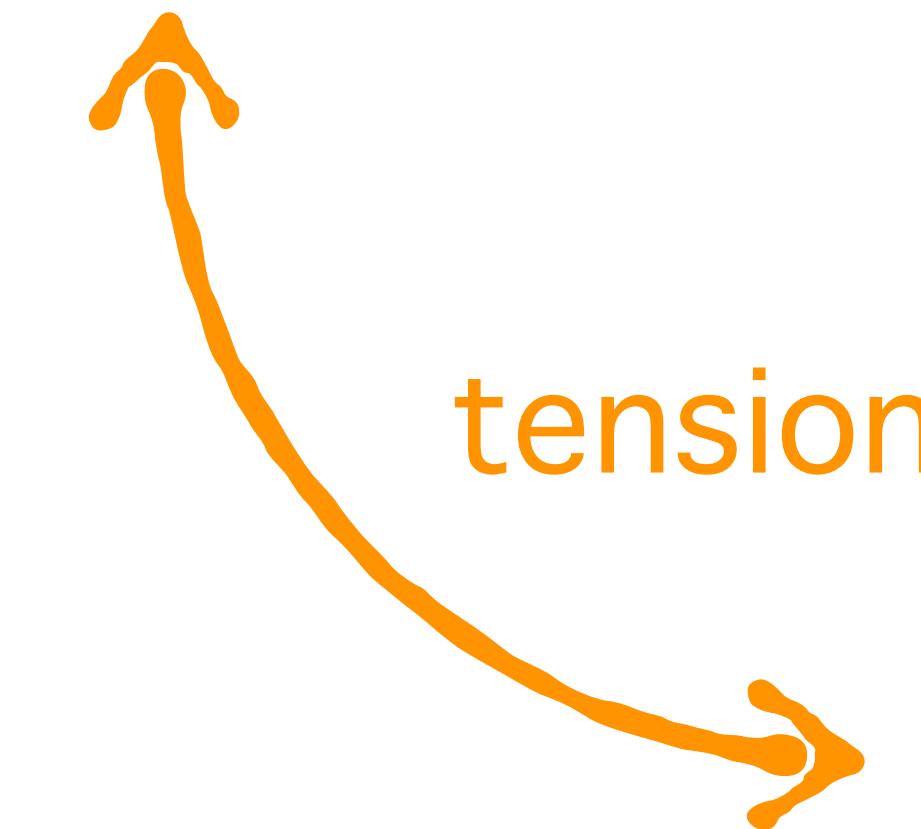


BHR

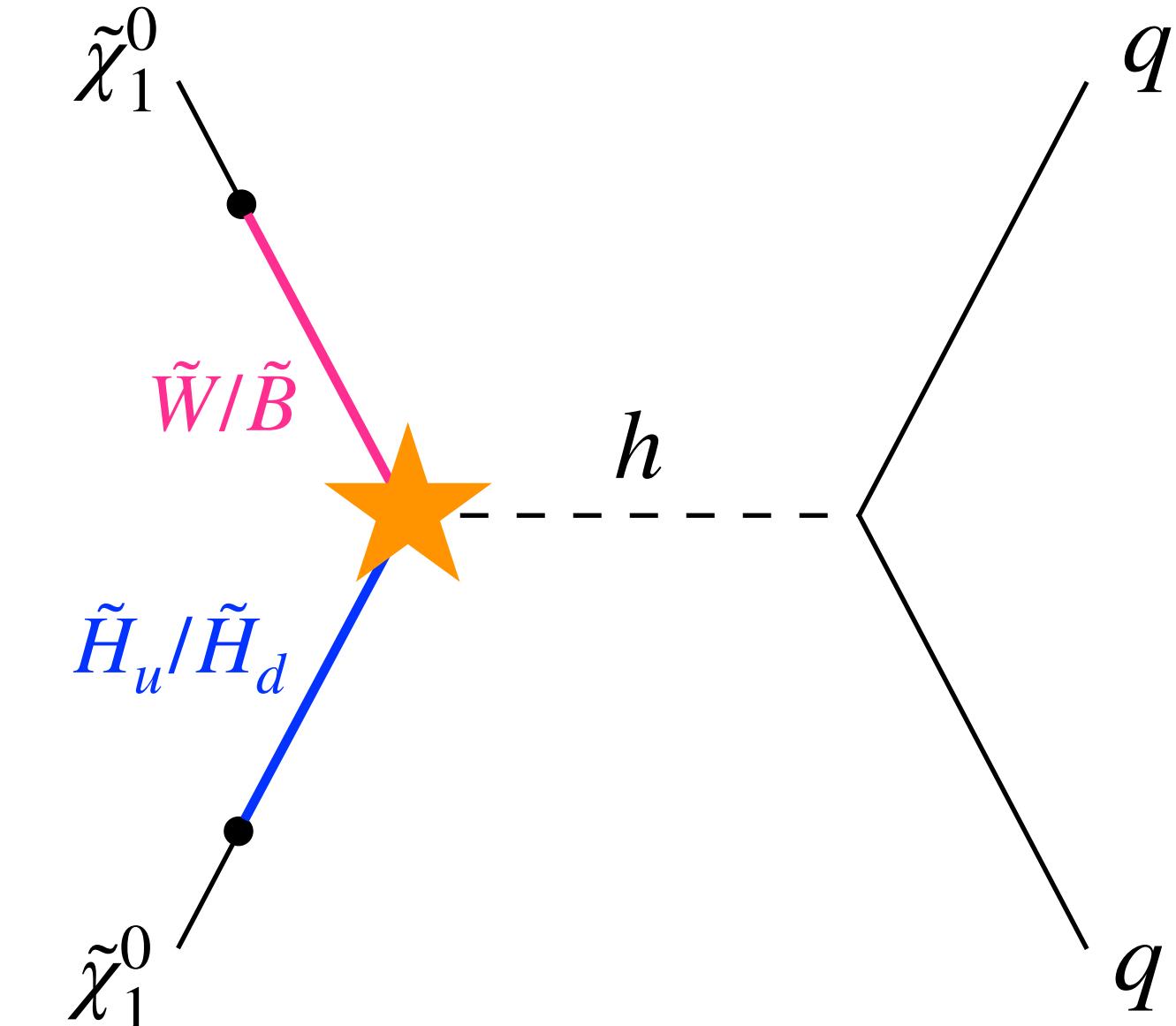


BLR

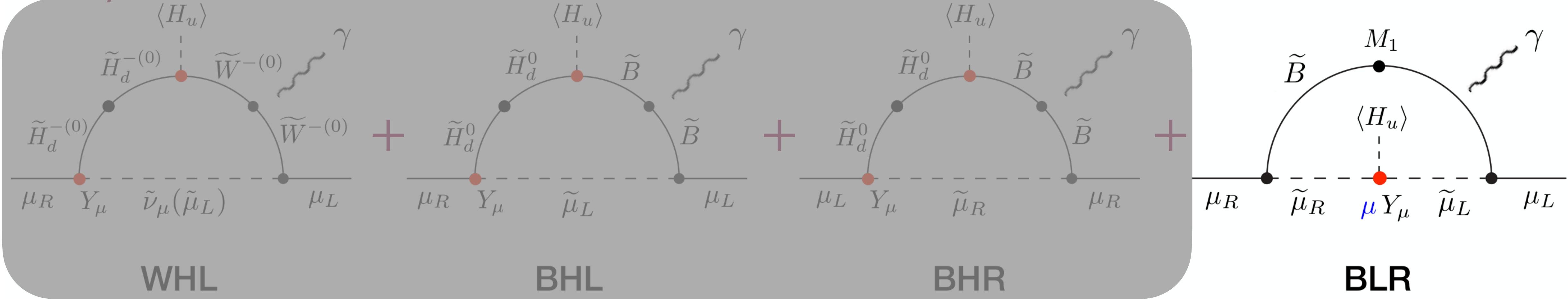
Large gaugino-Higgsino
mixing leads to a large
cross-section for
DM Direct Detection



tension



$$\Delta a_\mu^{\text{SUSY}} \simeq$$



Bino has very small annihilation cross-section

- ⊗ overproduction of Bino-like neutralinos in the early Universe: $\Omega_{\tilde{\chi}_1^0} < \Omega_{\text{DM}}$
- ⊗ slepton-coannihilation needed: $m_{\tilde{l}} \sim m_{\tilde{B}}$

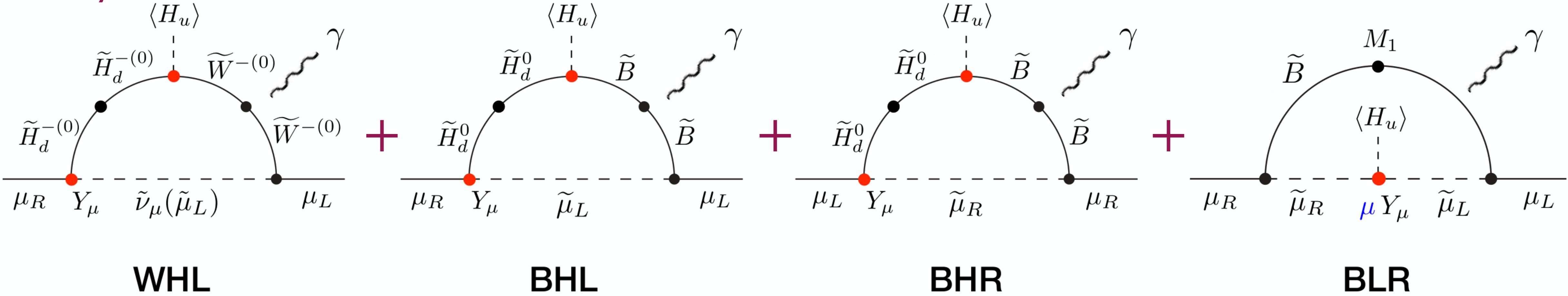
Large off diagonal term in stau mass matrix:

- ⊗ charge breaking vacuum: $m_{\tilde{\tau}_1}^2 > 0$
- ⊗ LEP bound: $m_{\tilde{\tau}_1} > 81.9 \text{ GeV}$
- ⊗ stau LSP: $m_{\tilde{\tau}_1} > m_{\tilde{\chi}_1^0}$
- ⊗ vacuum (meta-)stability (see talk by T. Moroi)

tension

$$M_{\tilde{\tau}}^2 \sim \begin{pmatrix} m_{\tilde{\tau}_R}^2 & Y_{\tau} \mu \langle H_u \rangle \\ Y_{\tau} \mu \langle H_u \rangle & m_{\tilde{\tau}_L}^2 \end{pmatrix}$$

$$\Delta a_\mu^{\text{SUSY}} \simeq$$



$(g-2)_\mu$ in MSSM has a tension with:

- DM Direct Detection
- (Bino-like) DM overproduction
- lepton + large ETmiss @ LHC
- Vacuum stability (for BLR)

}

consequence of **stable neutralino**

What changes if neutralino is unstable?

R-parity violation scenario

$$W_{\text{RPV}} = \lambda''_{ijk} U_i^c D_j^c D_k^c + \lambda_{ijk} L_i L_j E_k^c + \lambda'_{ijk} L_i Q_j D_k^c + \kappa_i L_i H_u$$

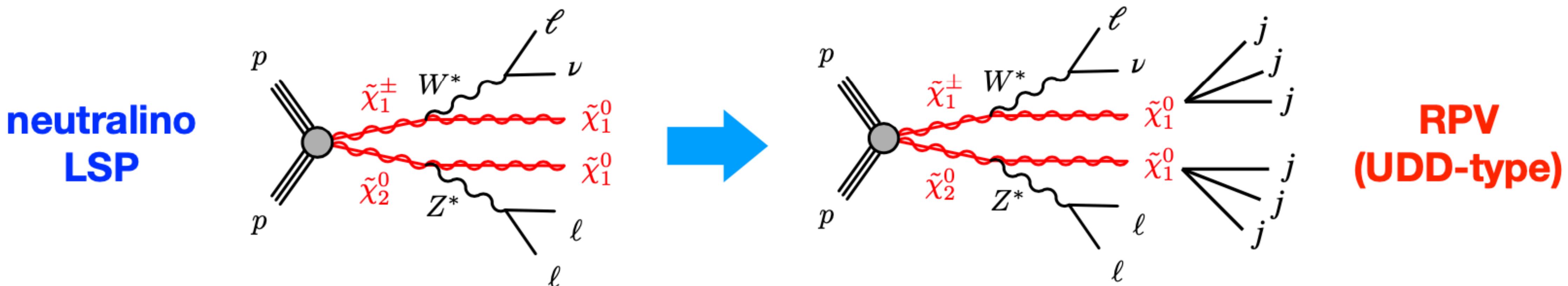
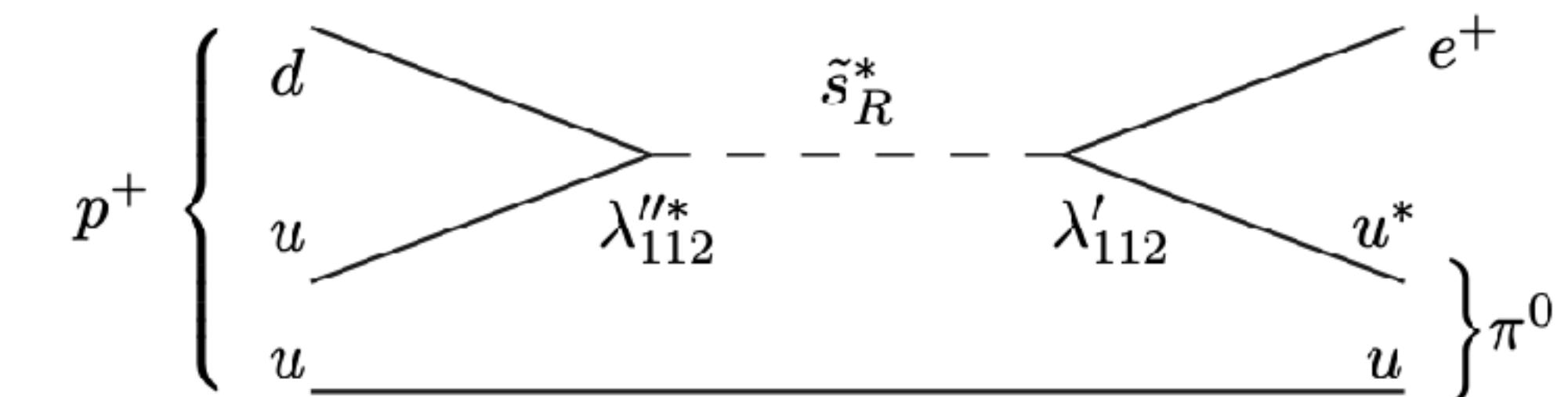
B $\cancel{\text{L}}$ $\cancel{\text{L}}$ $\cancel{\text{L}}$

- Simultaneous violation of both **B** and **L** leads to a rapid proton decay

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

- $(g-2)_\mu$ doesn't change wrt. MSSM

- Neutralino LSP decays to 3 (anti)quarks



No missing energy, but multi-jet

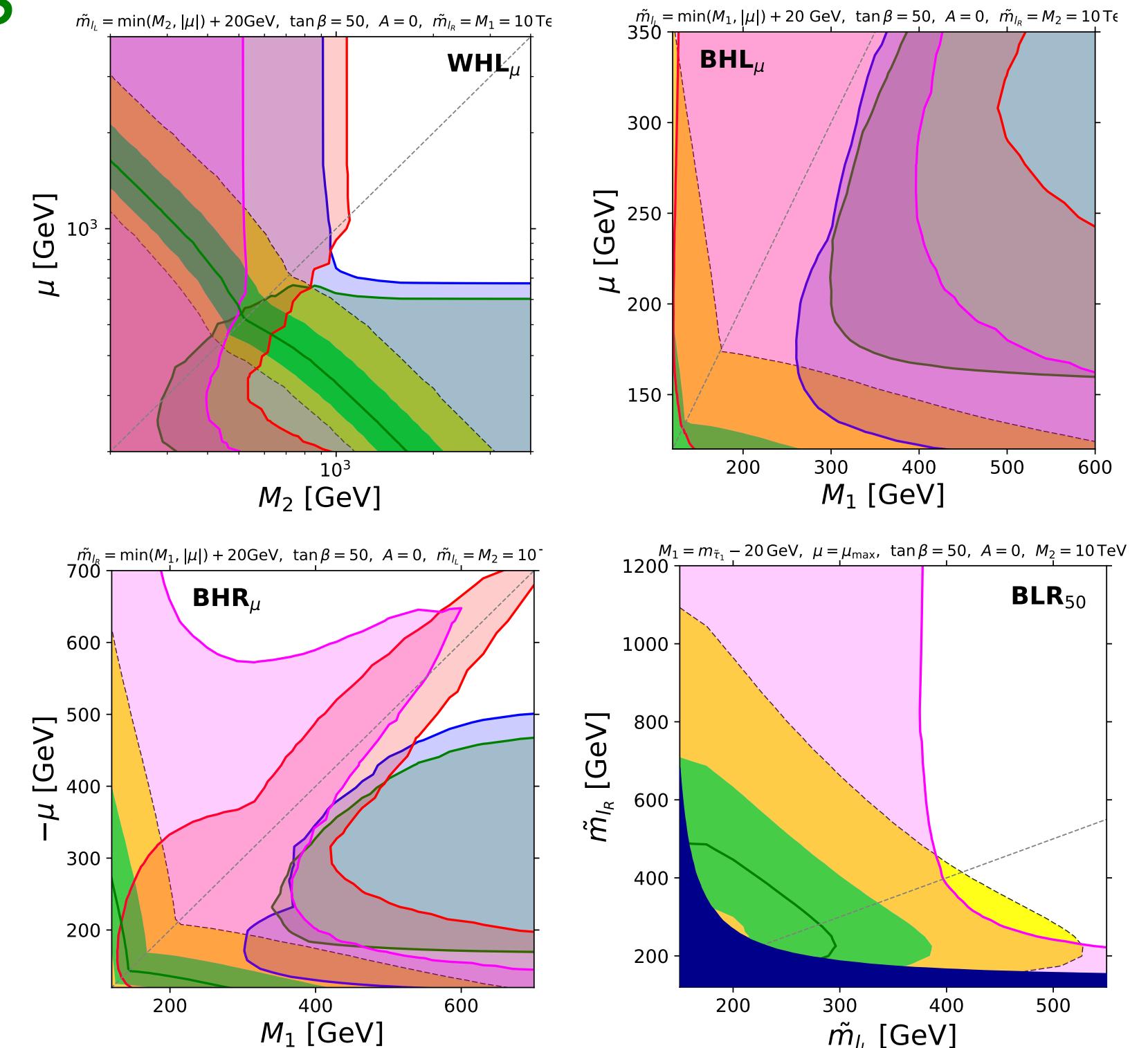
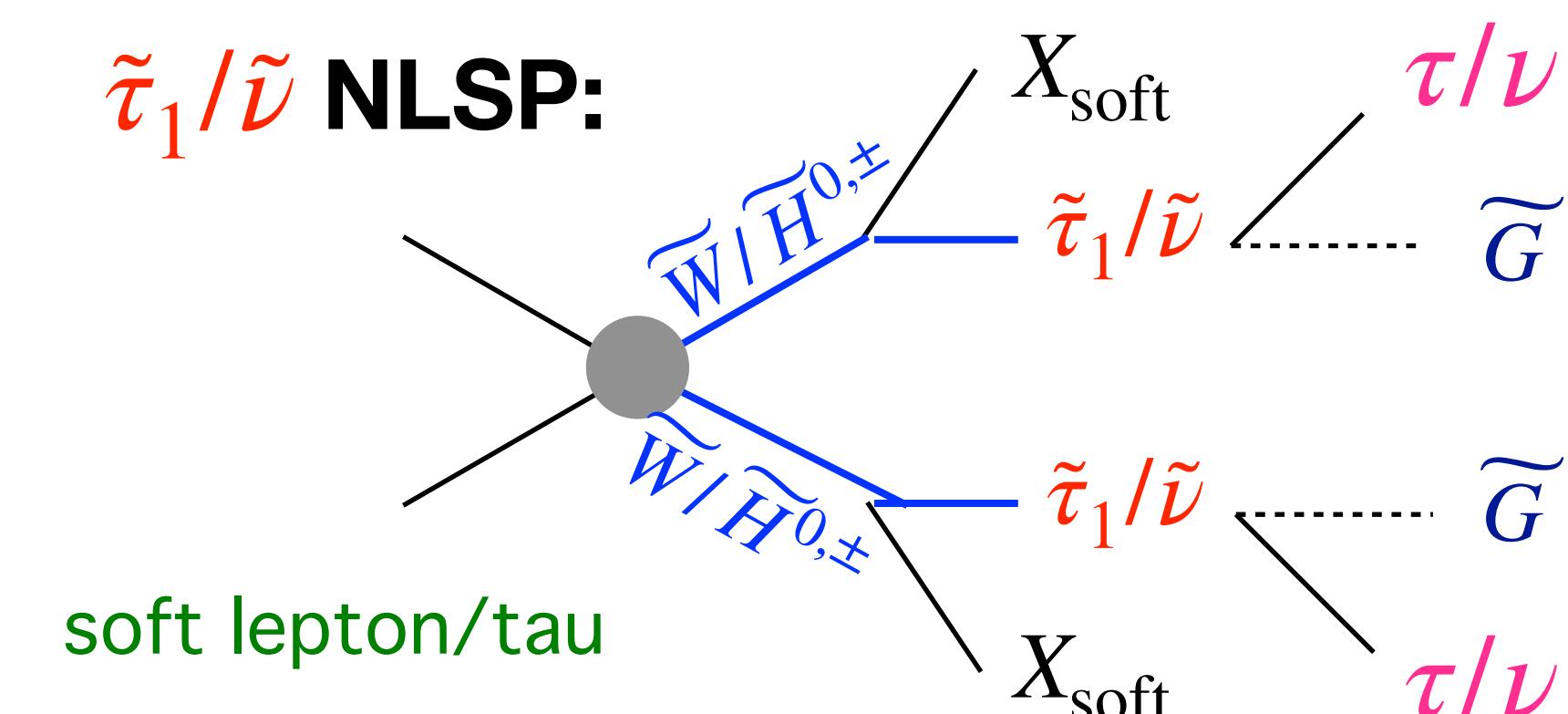
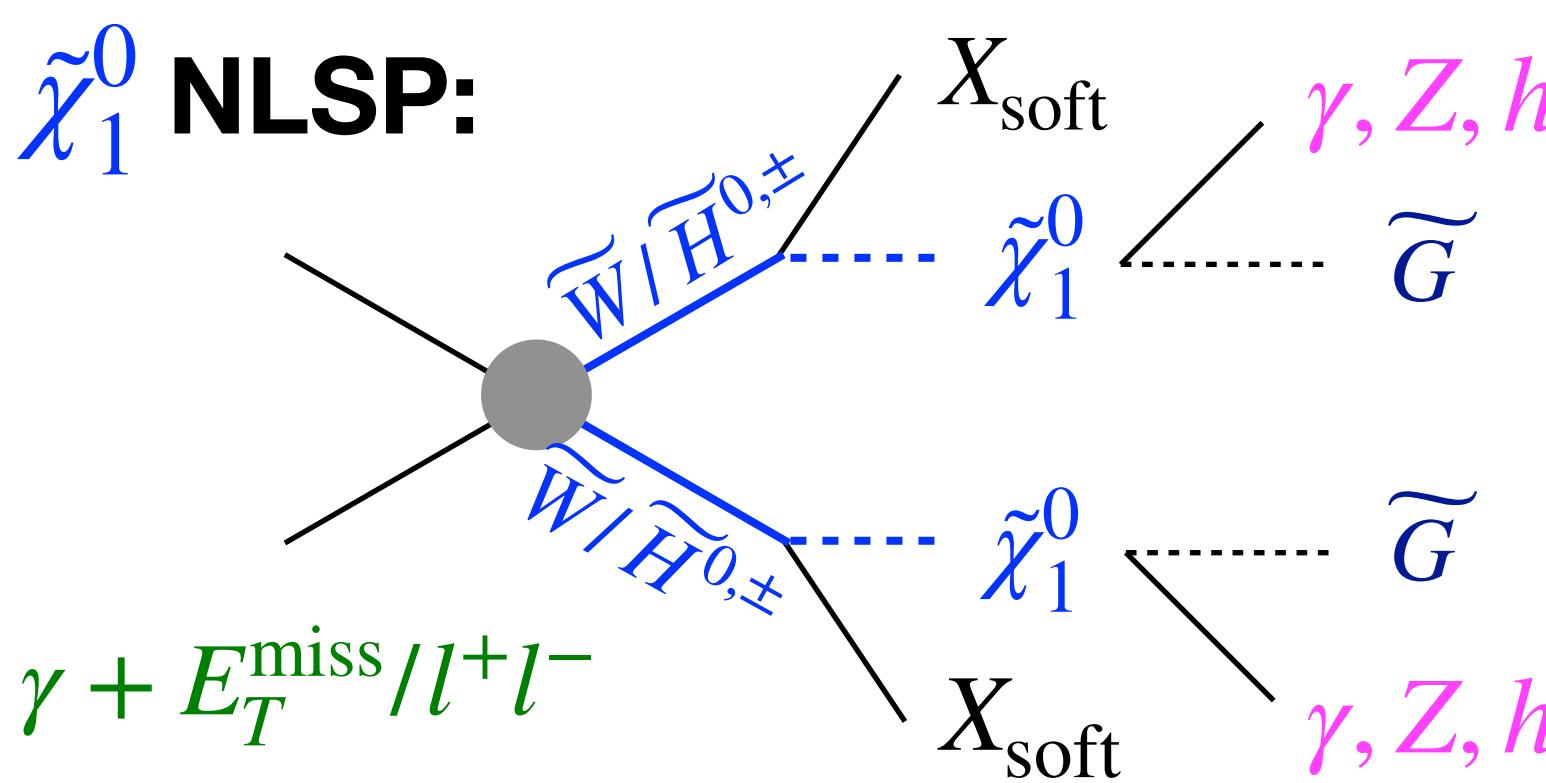
GMSB scenario

In GMSB, light gravitino LSP is motivated by naturalness

- We assume almost massless gravitino LSP ($m_{\tilde{G}} \leq 1$ GeV)

- $(g-2)_\mu$ doesn't change much wrt. MSSM

- If neutralino is NLSP then totally excluded \rightarrow slepton/
sneutrino/stau NLSP



methodology

Morskie Oko, Tatra,
Poland

Analysis

$$M_1, M_2, \mu, m_{\tilde{l}_L}, m_{\tilde{l}_R}, \tan \beta$$

1. Select one of the 4 loop diagrams (WHL, BHL, BHR, BLR)
2. Take 3 relevant masses to be $O(100\text{GeV})$ and other 2 very large
3. Then the diagram dominates $\Delta a_\mu^{\text{SUSY}}$
4. Vary 2 masses and relate/fix the third \rightarrow 2D plane scan



MC
simulations

GM2Calc, CheckMATE2, MicrOmegas ...

constraints

$$a_\mu^{\text{SUSY}}$$

DM abundance

$$\sigma_{\text{SI}}^{\tilde{\chi}_1^0}$$

LHC constraints

List of all recasted LHC analyses

Name	E/TeV	$\mathcal{L}/\text{fb}^{-1}$	Description
atlas_1604_01306	13	3.2	Monophoton
atlas_1605_09318	13	3.3	3 b-jets + 0-1 lepton + MET
atlas_1609_01599	13	36	Monophoton
atlas_1704_03848	13	36	Monophoton
atlas_conf_2015_082	13	3.2	2 leptons (Z) + jets + MET
atlas_conf_2016_013	13	3.2	1 lepton + jets (4 tops, VVL quarks)
atlas_conf_2016_050	13	13.3	1 lepton + (b) jets + MET
atlas_conf_2016_054	13	13.3	1 lepton + (b) jets + MET
atlas_conf_2016_076	13	13.3	2 lepton + jets + MET
atlas_conf_2016_096	13	13.3	Multi-lepton + MET
atlas_conf_2017_060	13	36	Monojet
atlas_conf_2016_066	13	13.3	Photons, jets and MET
atlas_1712_08119	13	36	soft leptons (compressed EWKinos)
atlas_1712_02332	13	36	squarks and gluinos, 0 lepton, 2-6 jets
atlas_1709_04183	13	36	Jets + MET (stops)
atlas_1802_03158	13	36	search for GMSB with photons
atlas_1708_07875	13	36	EWKino search with taus and MET
atlas_1706_03731	13	36	Multilepton + Jets + MET (RPC and RPV)
atlas_1908_08215	13	36	2 leptons + MET (EWKinos)
atlas_1909_08457	13	139	SS lepton + MET (squark, gluino)
atlas_conf_2019_040	13	139	Jets + MET (squark, gluino)
atlas_conf_2019_020	13	139	3 leptons (EWKino)
atlas_1803_02762	13	36	2 or 3 leptons (EWKino)
atlas_conf_2018_041	13	80	Multi- b -jets (stops, sbottoms)
atlas_2101_01629	13	139	1 lepton + jets + MET
atlas_conf_2020_048	13	139	Monojet
atlas_2004_14060	13	139	$t\bar{t}$ + MET
atlas_1908_03122	13	139	Higgs bosons + b -jets + MET
atlas_2103_11684	13	139	4 or more leptons (RPV, GMSB)
atlas_2106_09609	13	139	Multijets + leptons (RPV)
atlas_1911_06660	13	139	Search for Direct Stau Production

Name	E/TeV	$\mathcal{L}/\text{fb}^{-1}$	Description
cms_pas_sus_15_011	13	2.2	2 leptons + jets + MET
cms_sus_16_039	13	35.9	electroweekinos in multilepton final state
cms_sus_16_025	13	12.9	electroweakino and stop compressed spectra
cms_sus_16_048	13	35.9	two soft opposite sign leptons

Name	E/TeV	$\mathcal{L}/\text{fb}^{-1}$	Description
atlas_1308_1841	8	20.3	0 lepton + ≥ 7 jets + MET
atlas_1308_2631	8	20.1	0 leptons + 2 b-jets + MET
atlas_1402_7029	8	20.3	3 leptons + MET (chargino+neutralino)
atlas_1403_4853	8	20.3	2 leptons + MET (direct stop)
atlas_1403_5222	8	20.3	stop production with Z boson and b-jets
atlas_1404_2500	8	20.3	Same sign dilepton or 3 lepton
atlas_1405_7875	8	20.3	0 lepton + 2-6 jets + MET
atlas_1407_0583	8	20.3	ATLAS, 1 lepton + (b-)jets + MET (stop)
atlas_1407_0608	8	20.3	Monojet or charm jet (stop)
atlas_1411_1559	8	20.3	monophoton plus MET
atlas_1501_07110	8	20.3	1 lepton + 125GeV Higgs + MET
atlas_1502_01518	8	20.3	Monojet + MET
atlas_1503_03290	8	20.3	2 leptons + jets + MET
atlas_1506_08616	8	20.3	di-lepton and 2b-jets + lepton
atlas_1507_05493	8	20.3	photonic signatures of gauge-mediated SUSY
atlas_conf_2012_104	8	20.3	1 lepton + ≥ 4 jets + MET
atlas_conf_2013_024	8	20.3	0 leptons + 6 (2 b-)jets + MET
atlas_conf_2013_049	8	20.3	2 leptons + MET
atlas_conf_2013_061	8	20.3	0-1 leptons + ≥ 3 b-jets + MET
atlas_conf_2013_089	8	20.3	2 leptons (razor)
atlas_conf_2015_004	8	20.3	invisible Higgs decay in VBF
atlas_1403_5294	8	20.3	2 leptons + MET, (SUSY electroweak)
atlas_higg_2013_03	8	20.3	2 leptons + MET, (invisible Higgs)
atlas_1502_05686	8	20.3	search for massive sparticles decaying to many jets

Name	E/TeV	$\mathcal{L}/\text{fb}^{-1}$	Description
cms_1303_2985	8	11.7	α_T + b-jets
cms_1408_3583	8	19.7	monojet + MET
cms_1502_06031	8	19.4	2 leptons, jets, MET (only on-Z)
cms_1504_03198	8	19.7	1 lepton, ≥ 3 jets, ≥ 1 b-jet, MET (DM + 2 top)
cms_sus_13_016	8	19.5	OS lepton 3+ b-tags



results

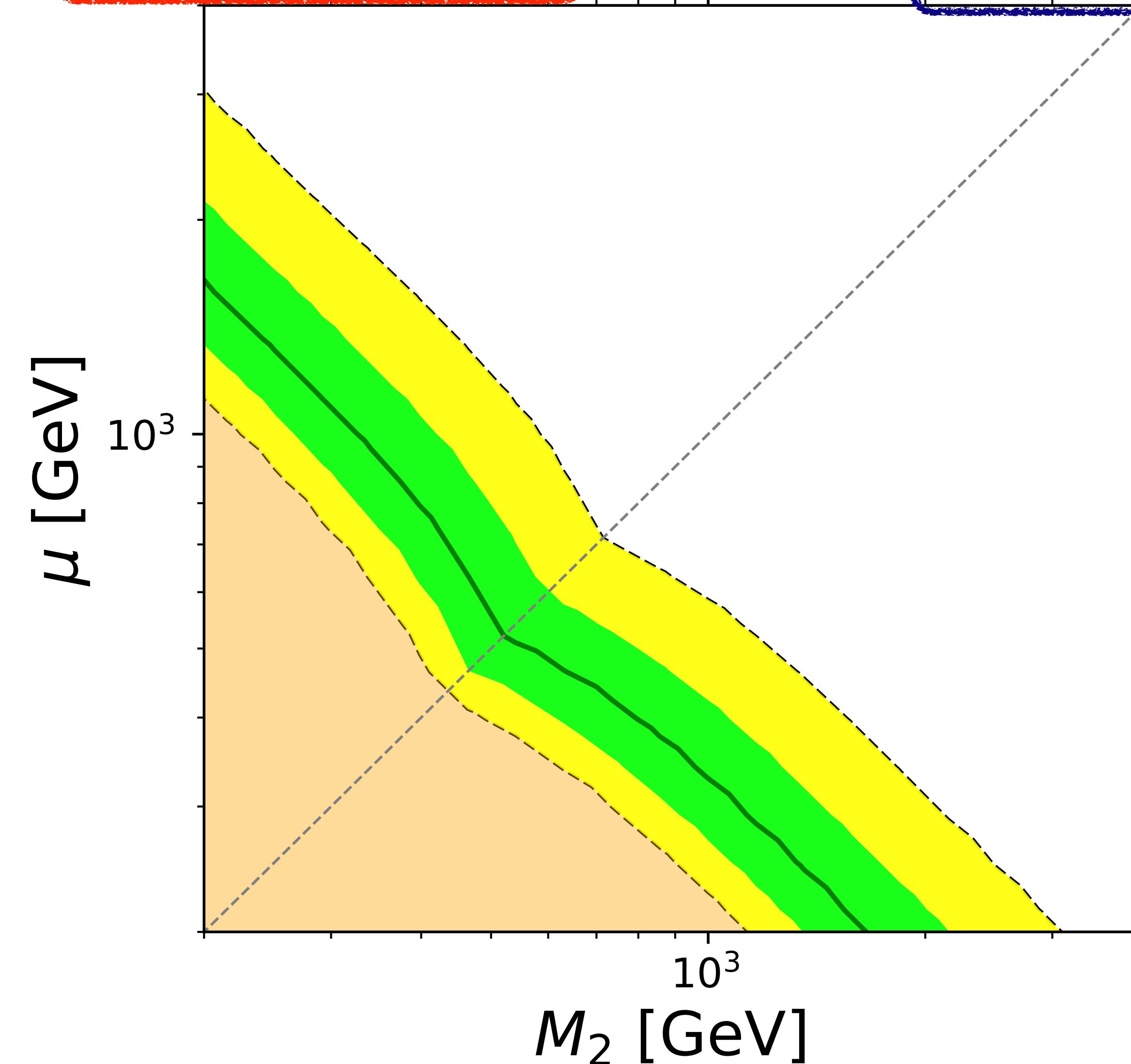
Beach in Dębki, Poland

MSSM, WHL_μ

$\tilde{m}_{I_L} = \min(M_2, |\mu|) + 20\text{GeV}$, $\tan\beta = 50$, $A = 0$, $\tilde{m}_{I_R} = M_1 = 10\text{TeV}$

compressed
mass spectrum

WHL
dominates



MSSM, WHL_μ

$\tilde{m}_{I_L} = \min(M_2, |\mu|) + 20\text{GeV}$, $\tan\beta = 50$, $A = 0$, $\tilde{m}_{I_R} = M_1 = 10\text{TeV}$

1σ agreement

$a_\mu^{\text{SUSY}} > \overline{a}_\mu^{\text{exp}}$

$\overline{a}_\mu^{\text{exp}}$

$\mu [\text{GeV}]$

10^3

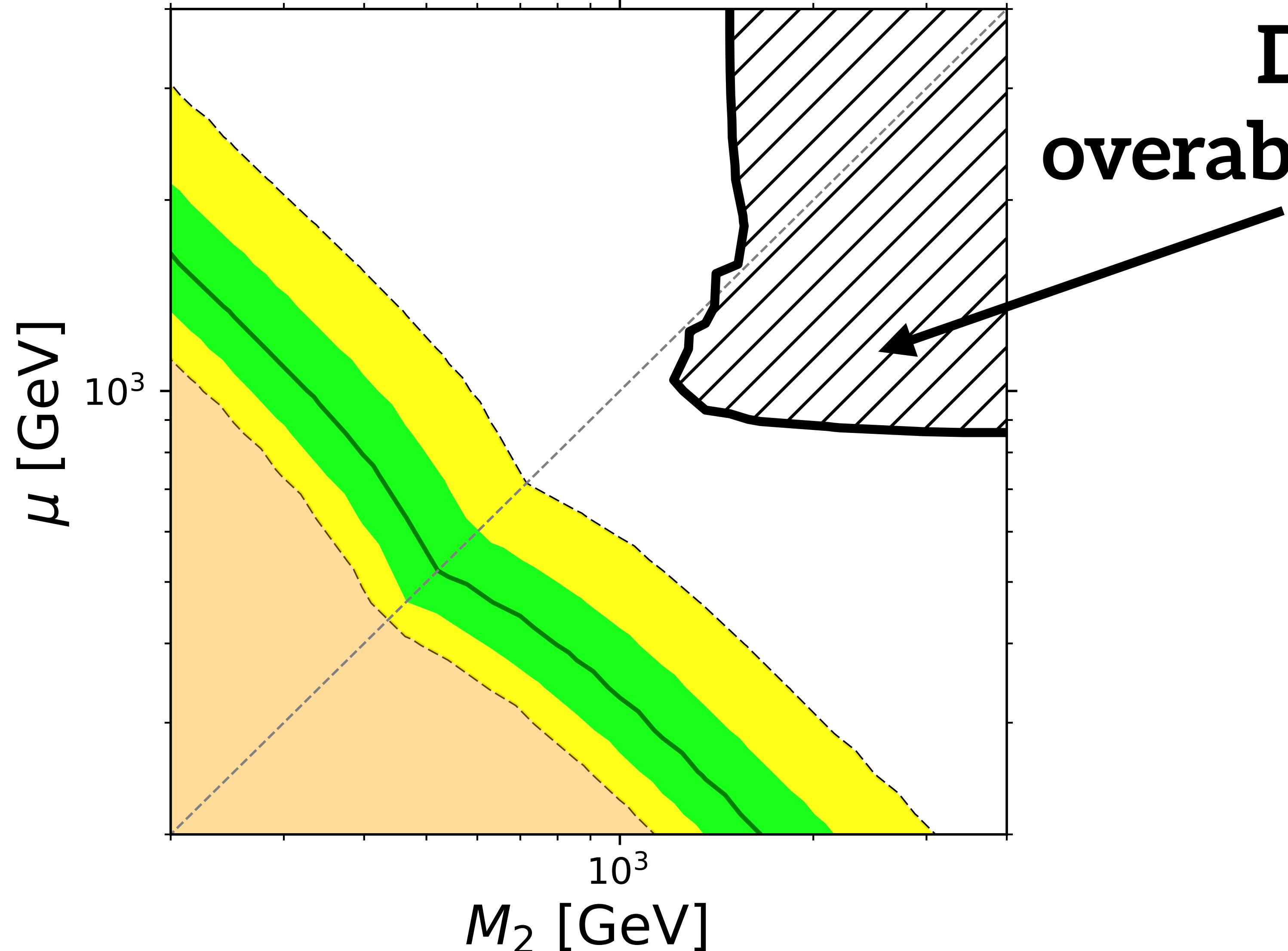
$M_2 [\text{GeV}]$

10^3

2σ agreement

MSSM, WHL_μ

$\tilde{m}_{I_L} = \min(M_2, |\mu|) + 20\text{GeV}$, $\tan\beta = 50$, $A = 0$, $\tilde{m}_{I_R} = M_1 = 10\text{TeV}$



DM
overabundance

ATLAS DT

[2201.02472]

$$m_{\chi_1^\pm} - m_{\chi_1^0} \sim \mathcal{O}(100 \text{ MeV})$$

$$c\tau_{\tilde{\chi}_1^\pm} \sim \mathcal{O}(1 \text{ cm})$$

$$\chi_1^\pm \rightarrow \chi_1^0 + X_{\text{soft}}^\pm$$

**Wino-like LSP excluded
up to $M_2 \sim 760 \text{ GeV}$**

$$\tilde{\xi}\tilde{\xi}' \rightarrow (l^+\tilde{\eta})(l^-\tilde{\eta}')$$

$$\tilde{\xi} \equiv \tilde{l} / \tilde{\nu}$$

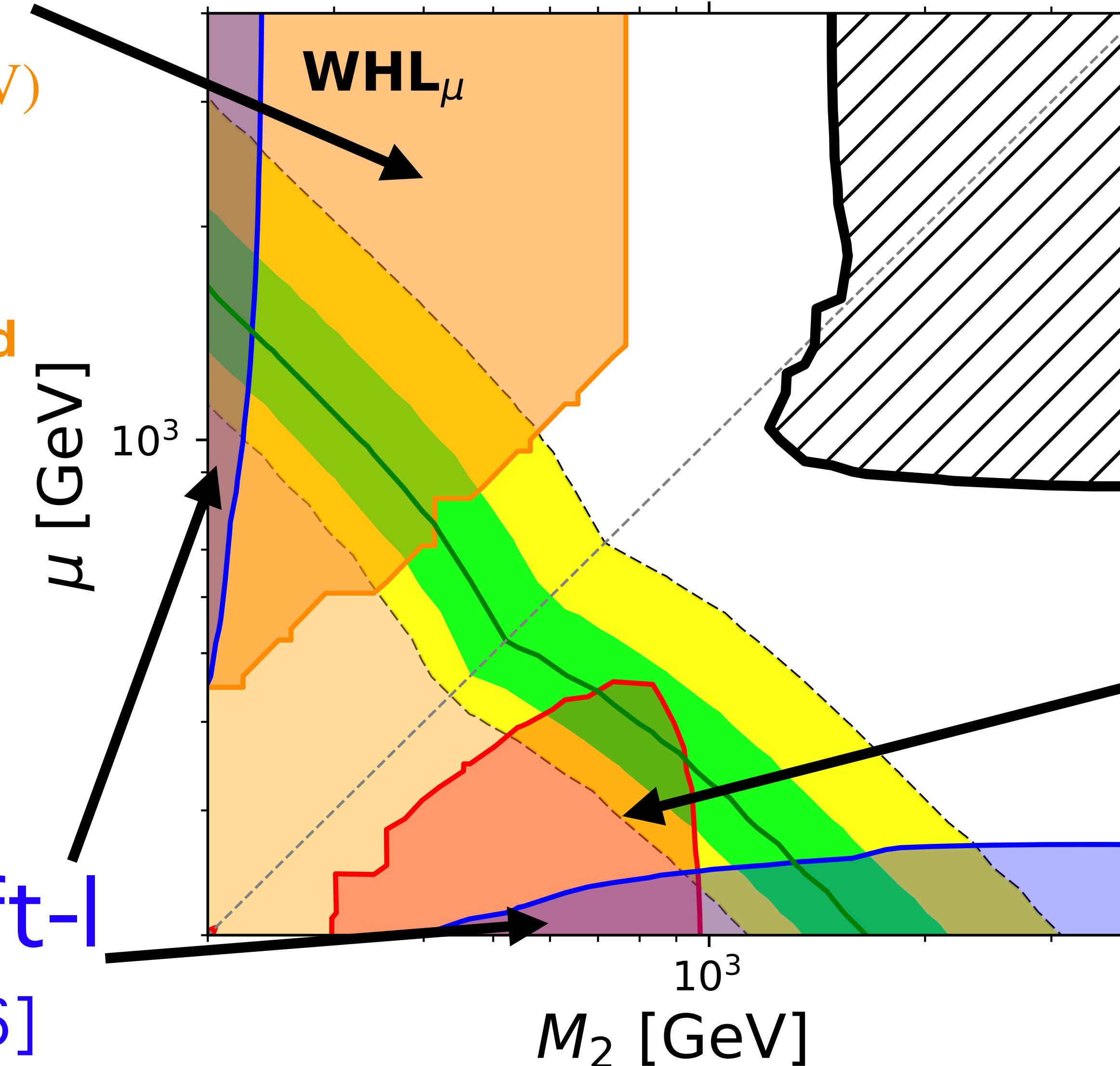
$$\tilde{\eta} \equiv \tilde{\chi}_1^\pm / \tilde{\chi}_1^0$$

ATLAS soft-l

[1911.12606]

MSSM, WHL_μ

$$\tilde{m}_{I_L} = \min(M_2, |\mu|) + 20 \text{ GeV}, \tan\beta = 50, A = 0, \tilde{m}_{I_R} = M_1 = 10 \text{ TeV}$$



$$pp \rightarrow \tilde{W}^{+,0}\tilde{W}^{-,0}$$

$$W^\pm \rightarrow l^\pm \tilde{\nu}$$

$$W^0 \rightarrow l^\pm \tilde{l}^\mp$$

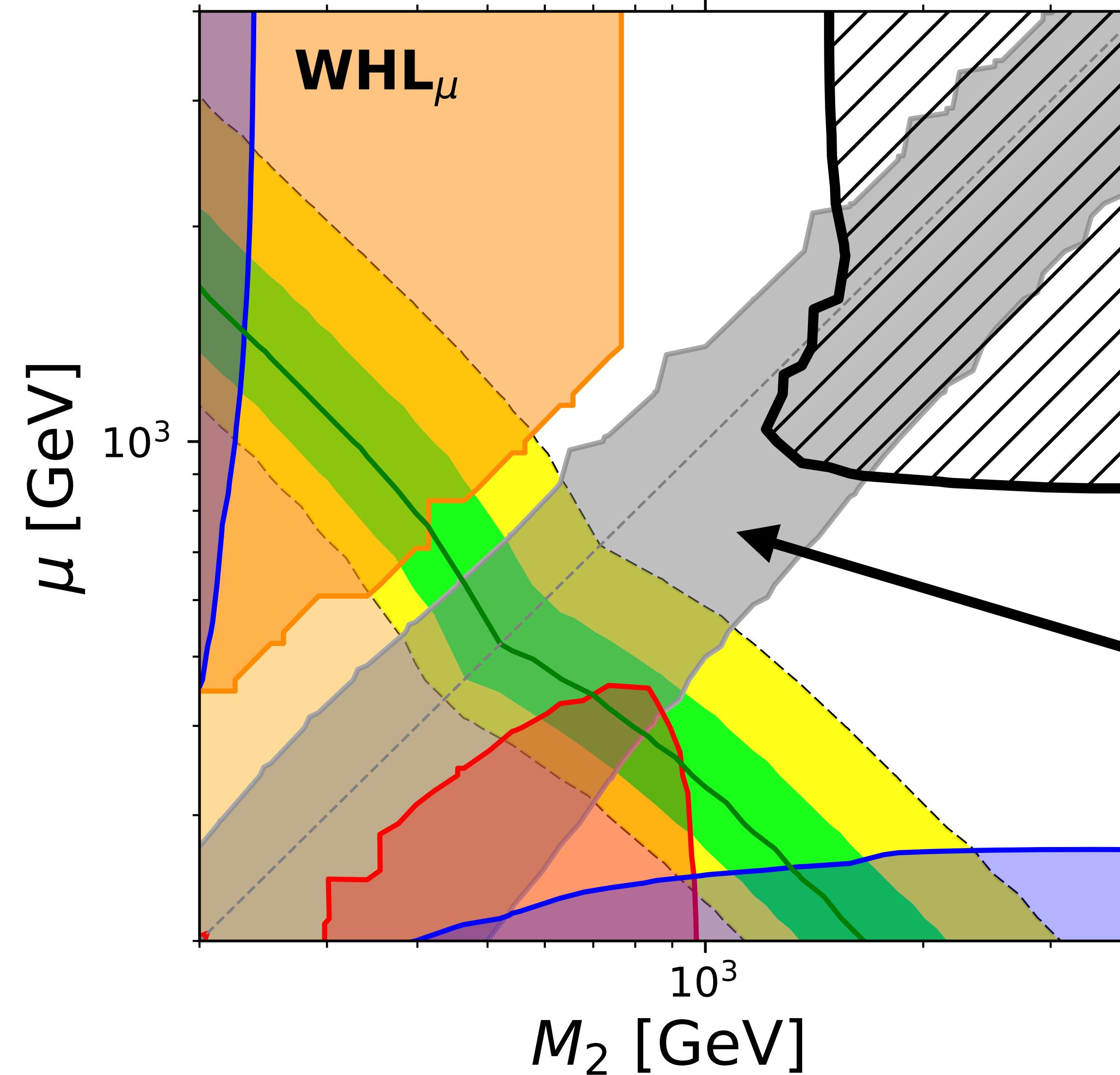
**slepton decays to
higgsino LSP
are very soft (20 GeV)**

CMS |+|-

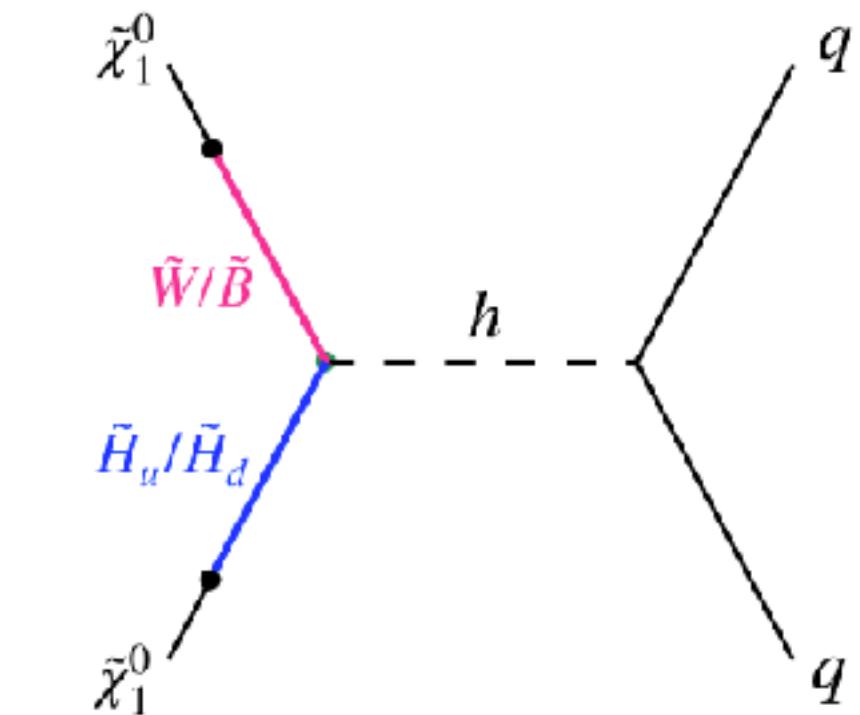
[2012.08600]

MSSM, WHL _{μ}

$\tilde{m}_{I_L} = \min(M_2, |\mu|) + 20\text{GeV}$, $\tan\beta = 50$, $A = 0$, $\tilde{m}_{I_R} = M_1 = 10\text{TeV}$



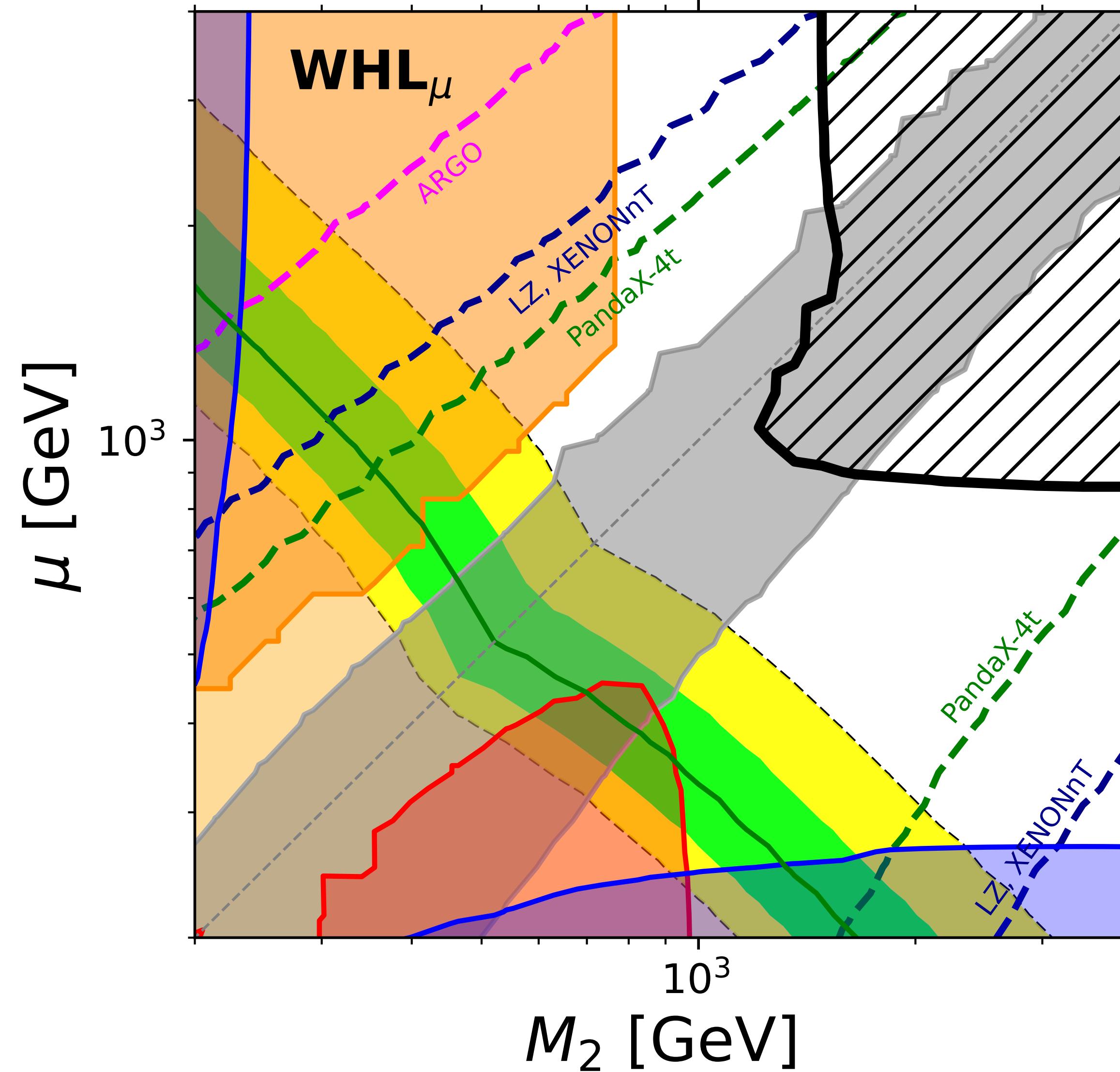
Large gaugino-Higgsino mixing leads to a
large cross-section for DM Direct Detection:



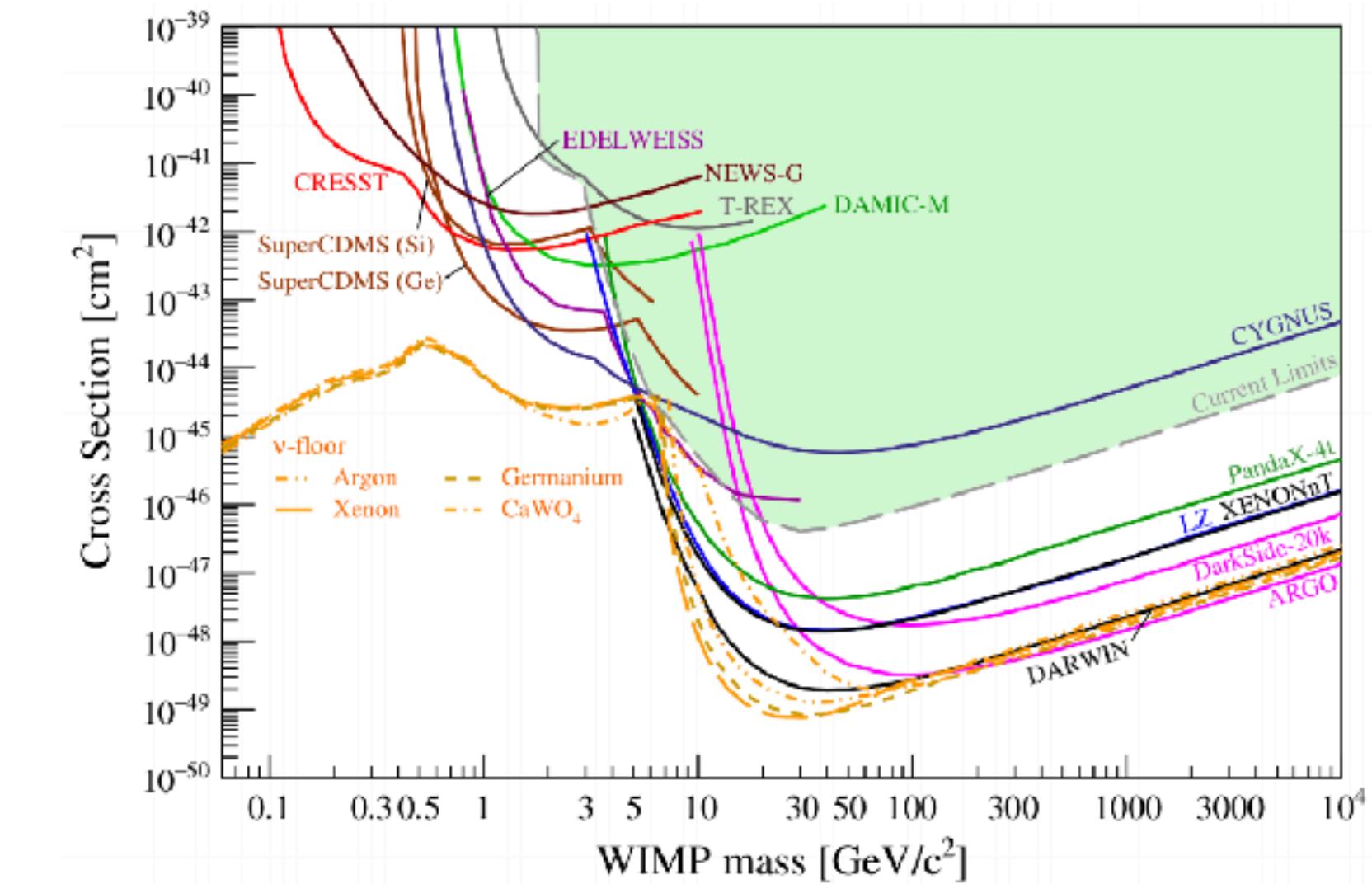
XENON1T
[1805.12562]

MSSM, WHL _{μ}

$$\tilde{m}_{I_L} = \min(M_2, |\mu|) + 20\text{GeV}, \tan\beta = 50, A = 0, \tilde{m}_{I_R} = M_1 = 10\text{TeV}$$



Whole $(g-2)_\mu$ relevant region will be probed in the near future!



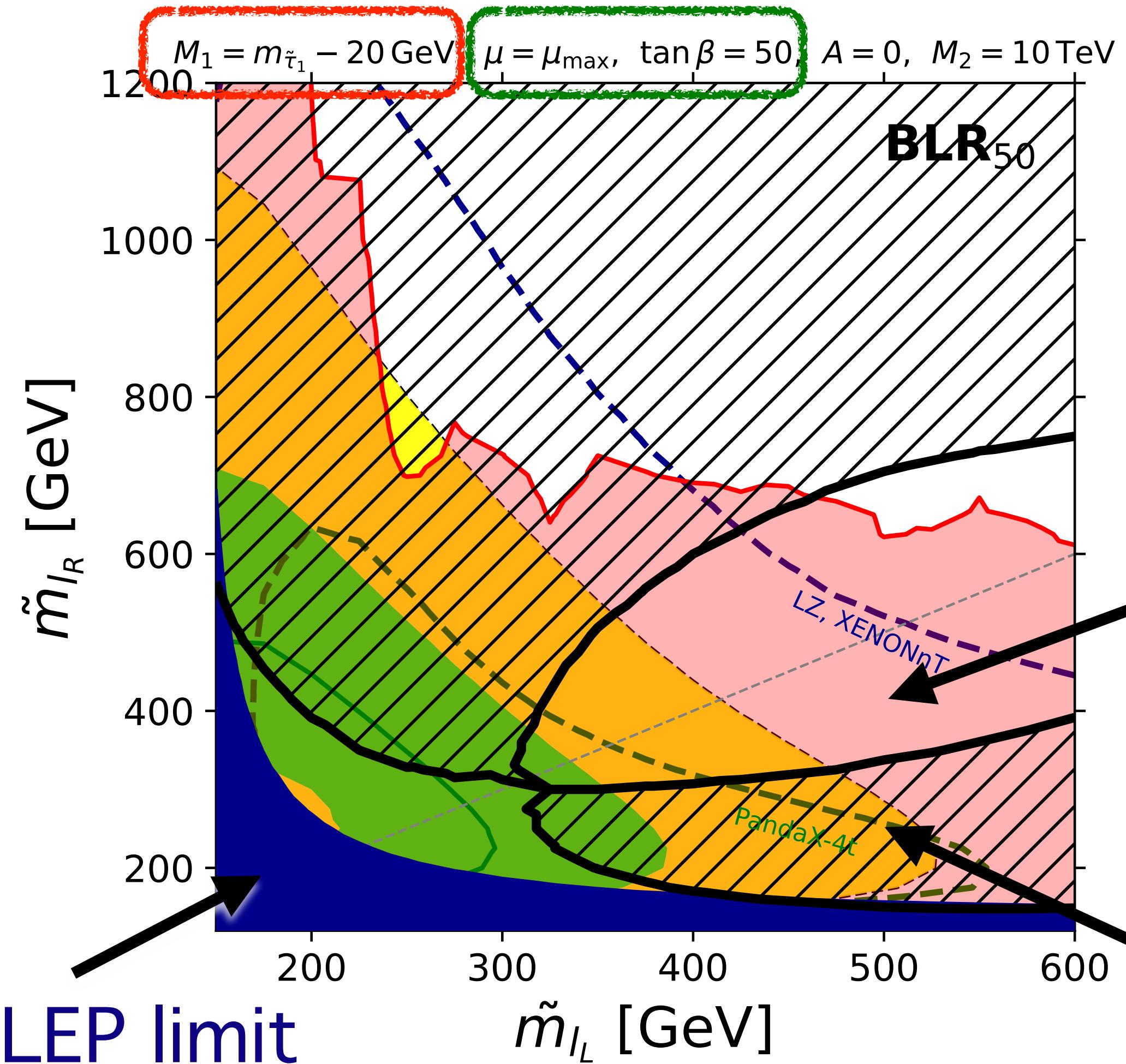
MSSM, BLR

compressed
mass spectrum
(stau coannihilation)

vacuum stability condition

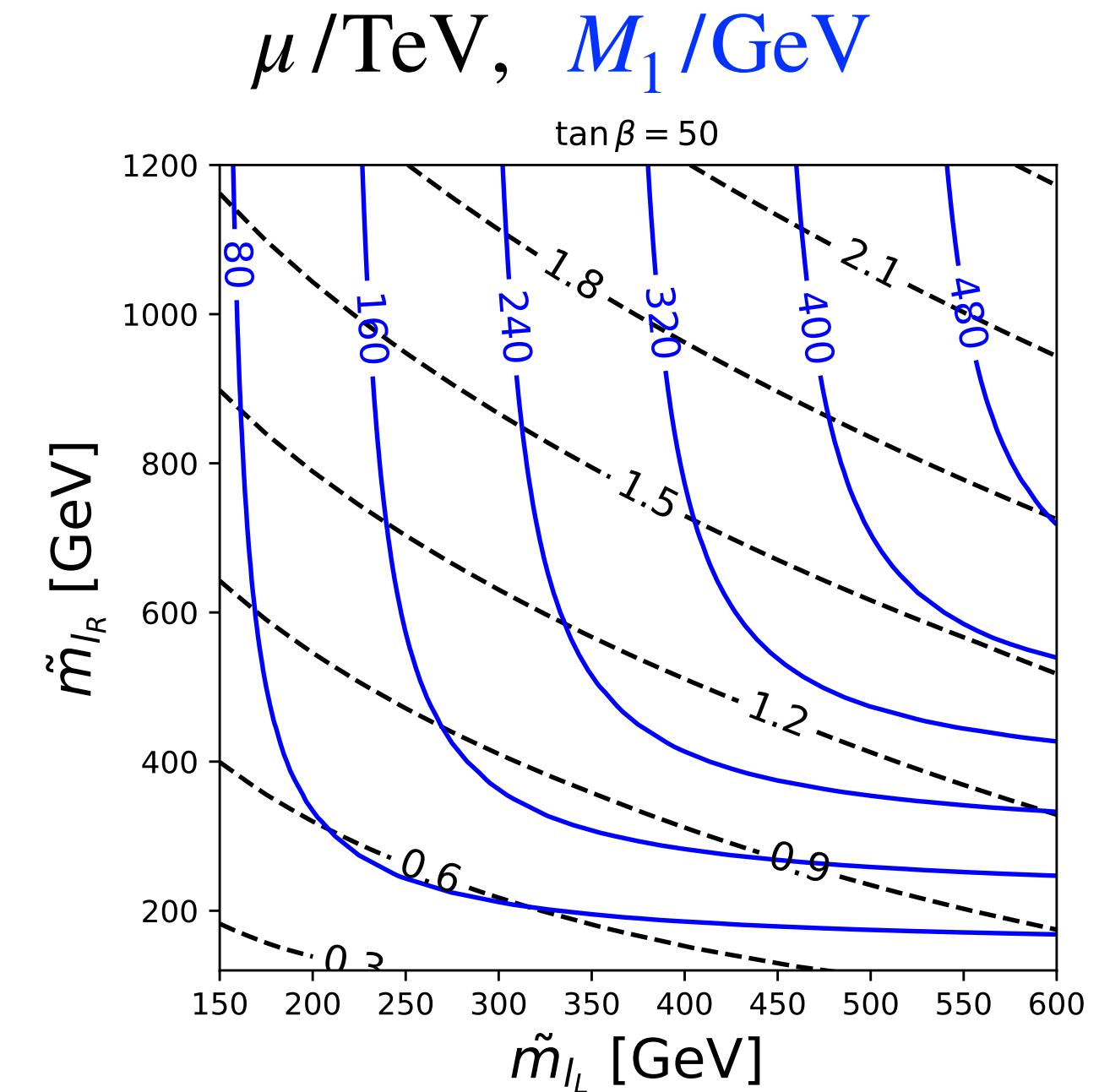
$$\left| m_{\tilde{\ell}_{LR}}^2 \right| \leq \left[1.01 \times 10^2 \text{ GeV} \sqrt{m_{\tilde{\ell}_L} m_{\tilde{\ell}_R}} + 1.01 \times 10^2 \text{ GeV} (m_{\tilde{\ell}_L} + 1.03 m_{\tilde{\ell}_R}) - 2.27 \times 10^4 \text{ GeV}^2 + \frac{2.97 \times 10^6 \text{ GeV}^3}{m_{\tilde{\ell}_L} + m_{\tilde{\ell}_R}}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

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

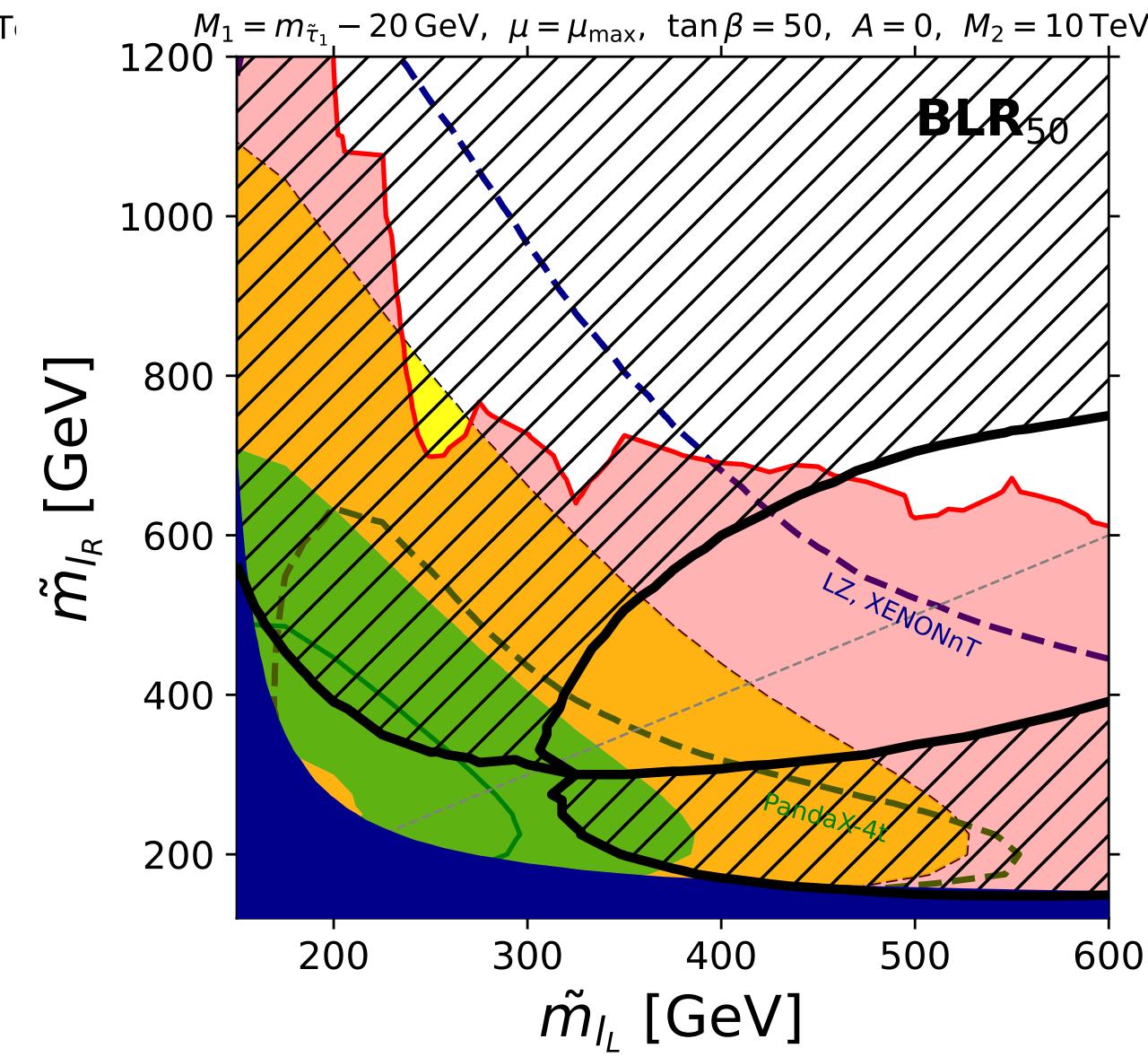
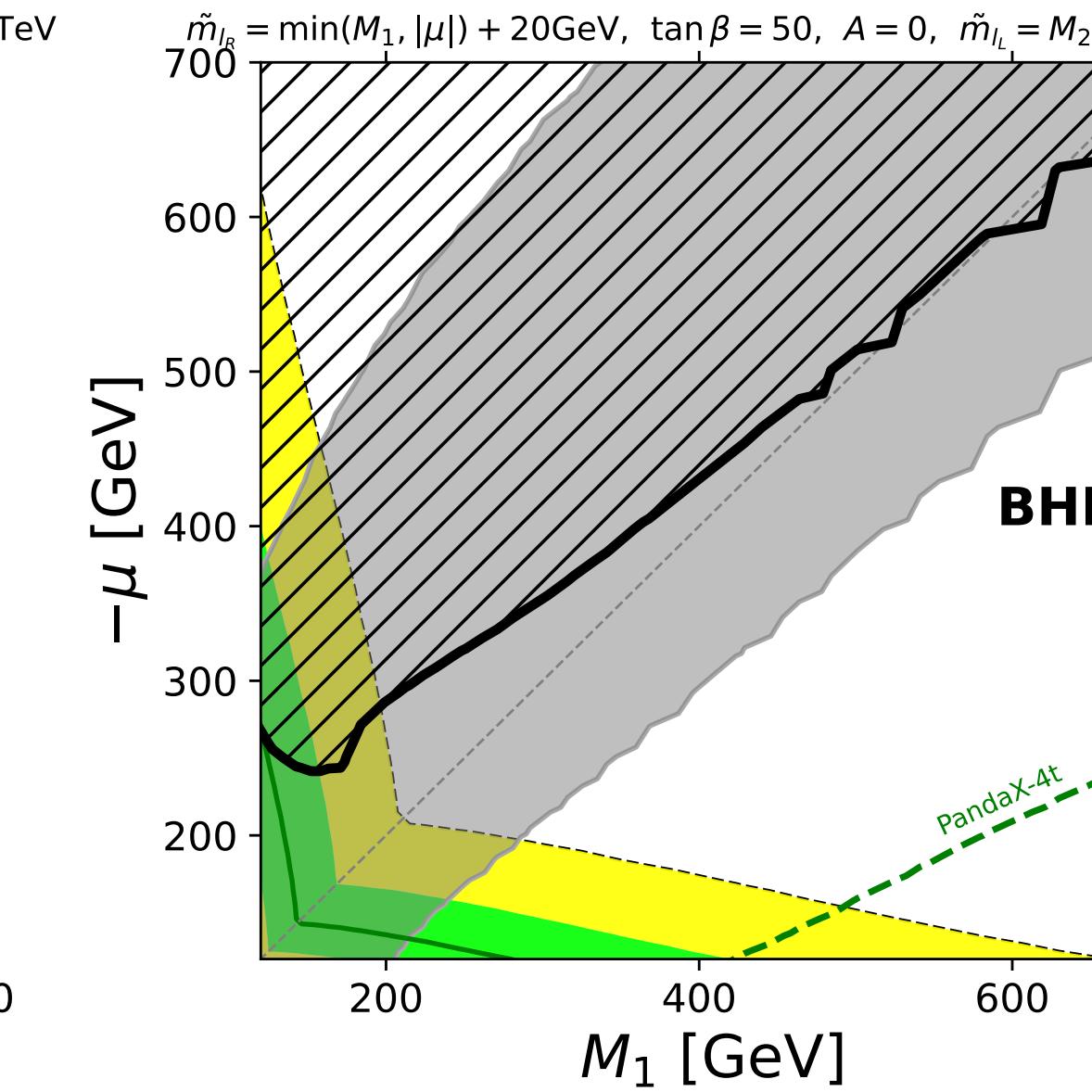
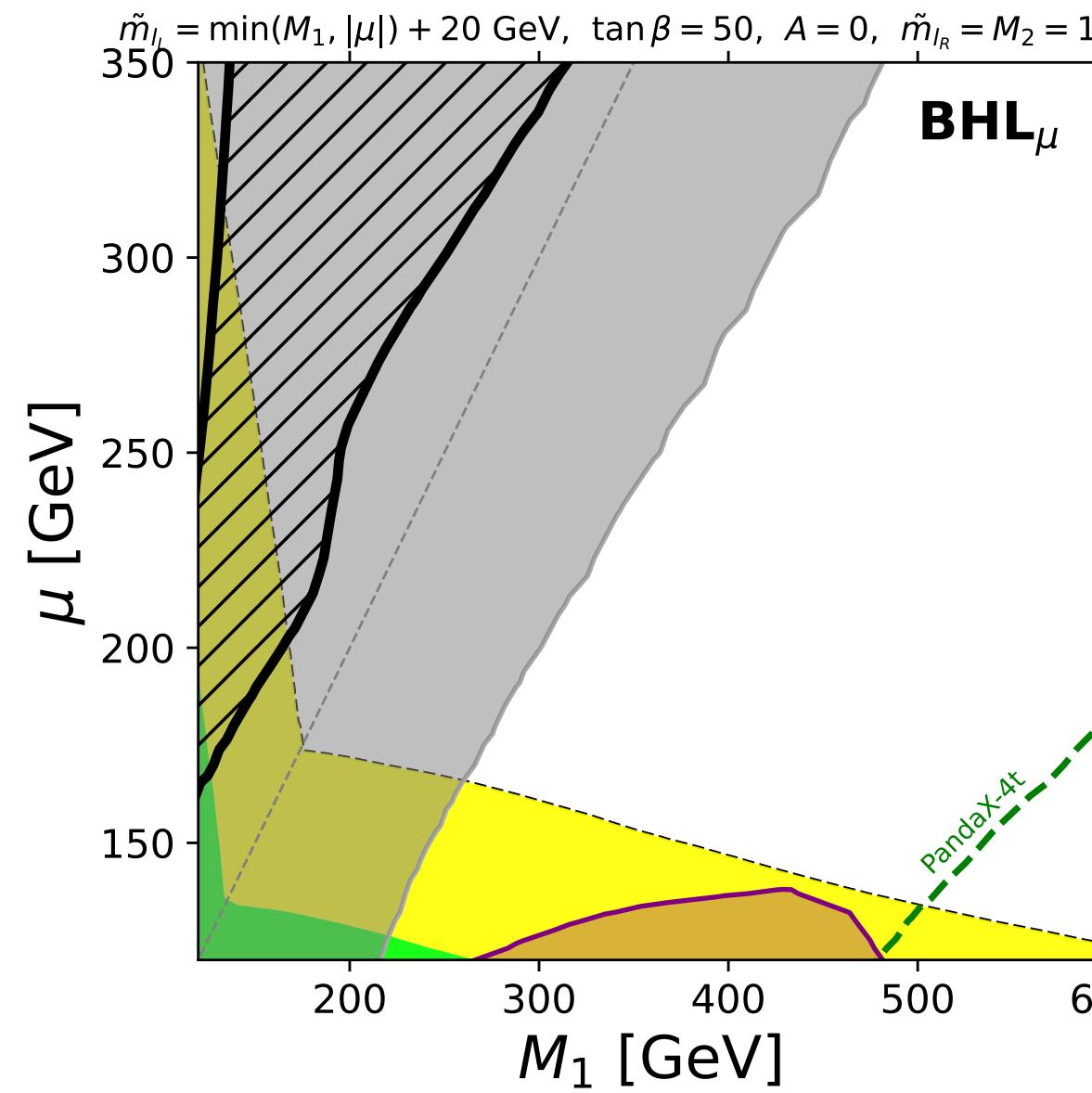
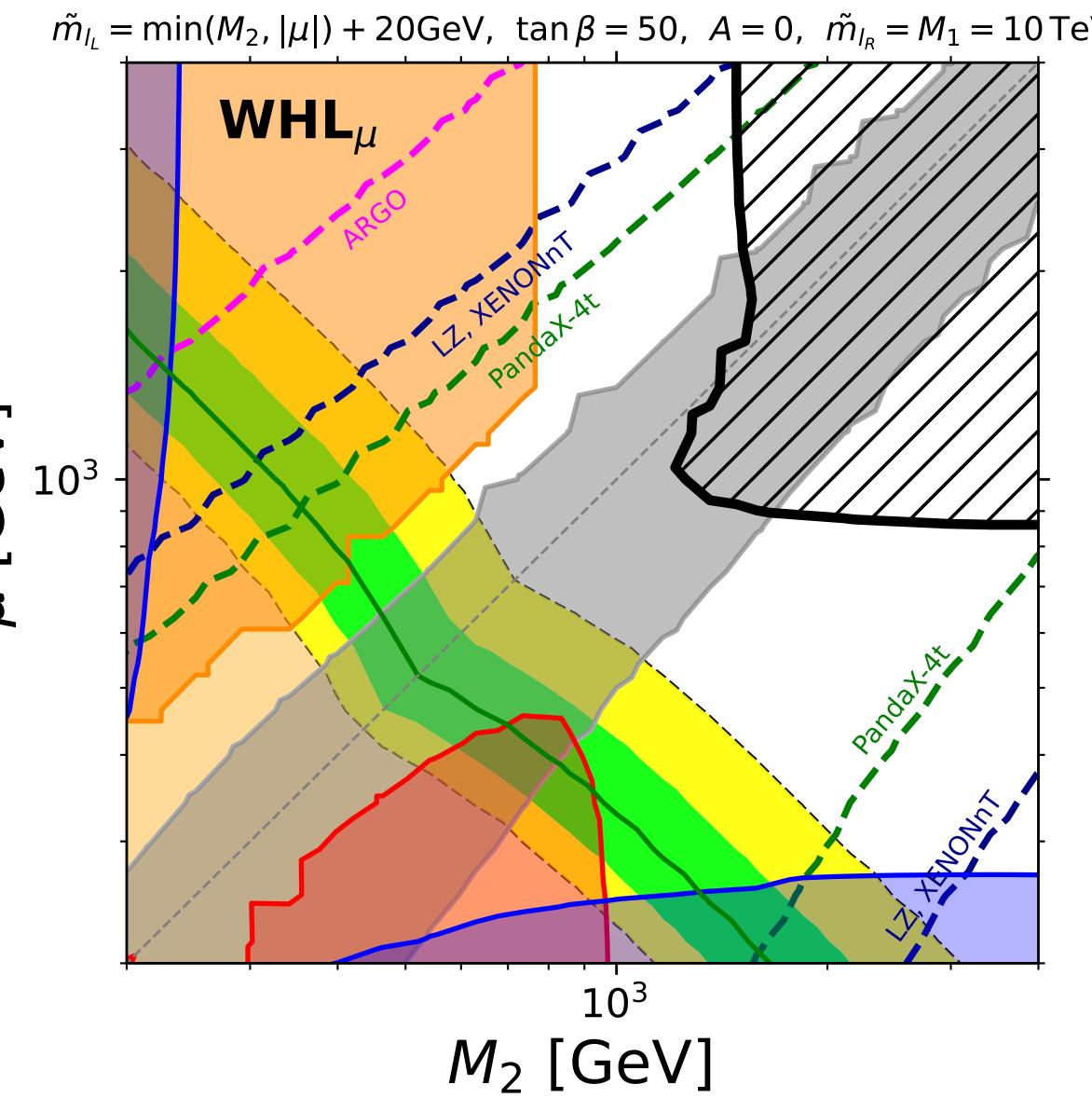


CMS I⁺-
[2012.08600]

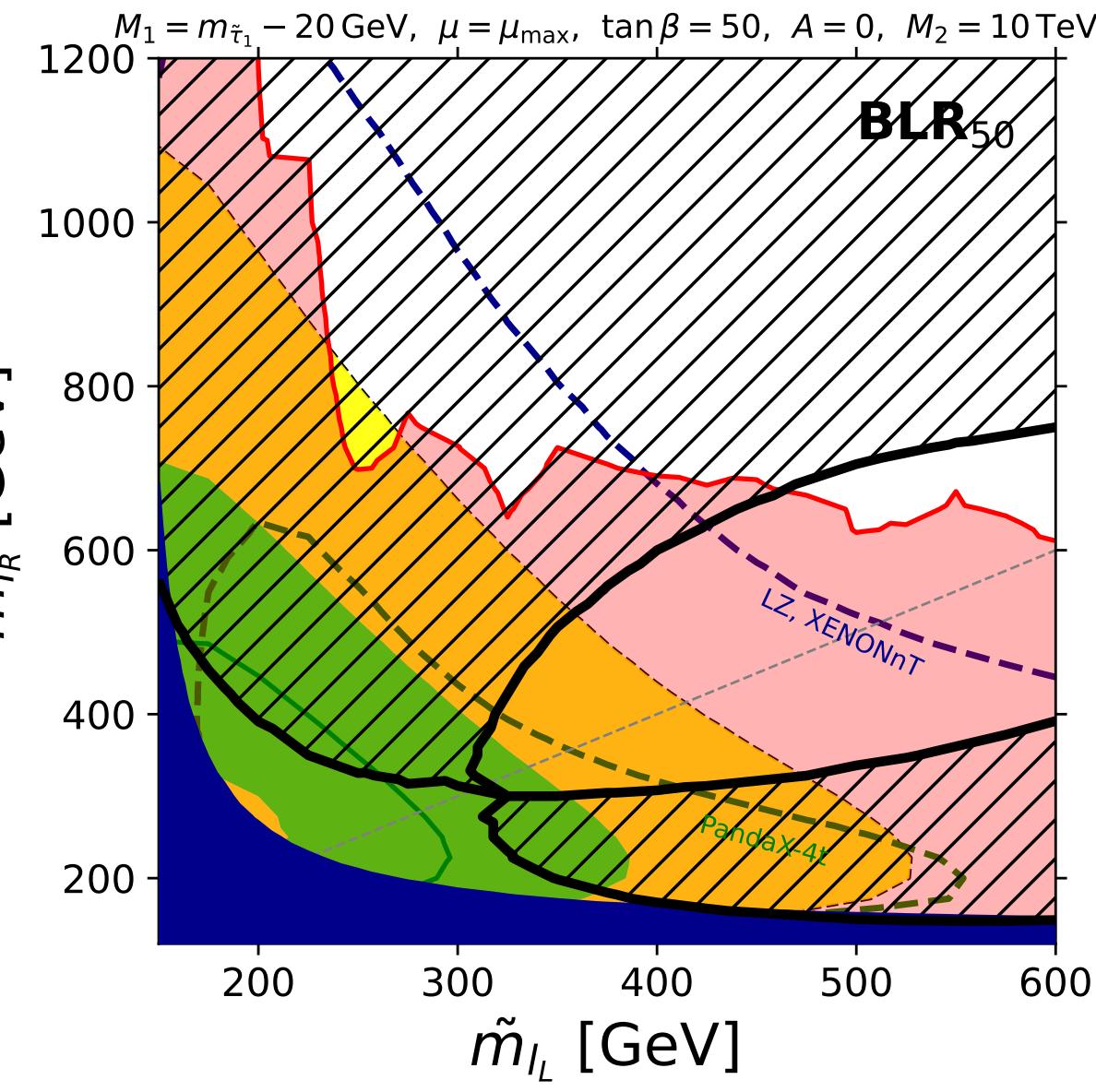
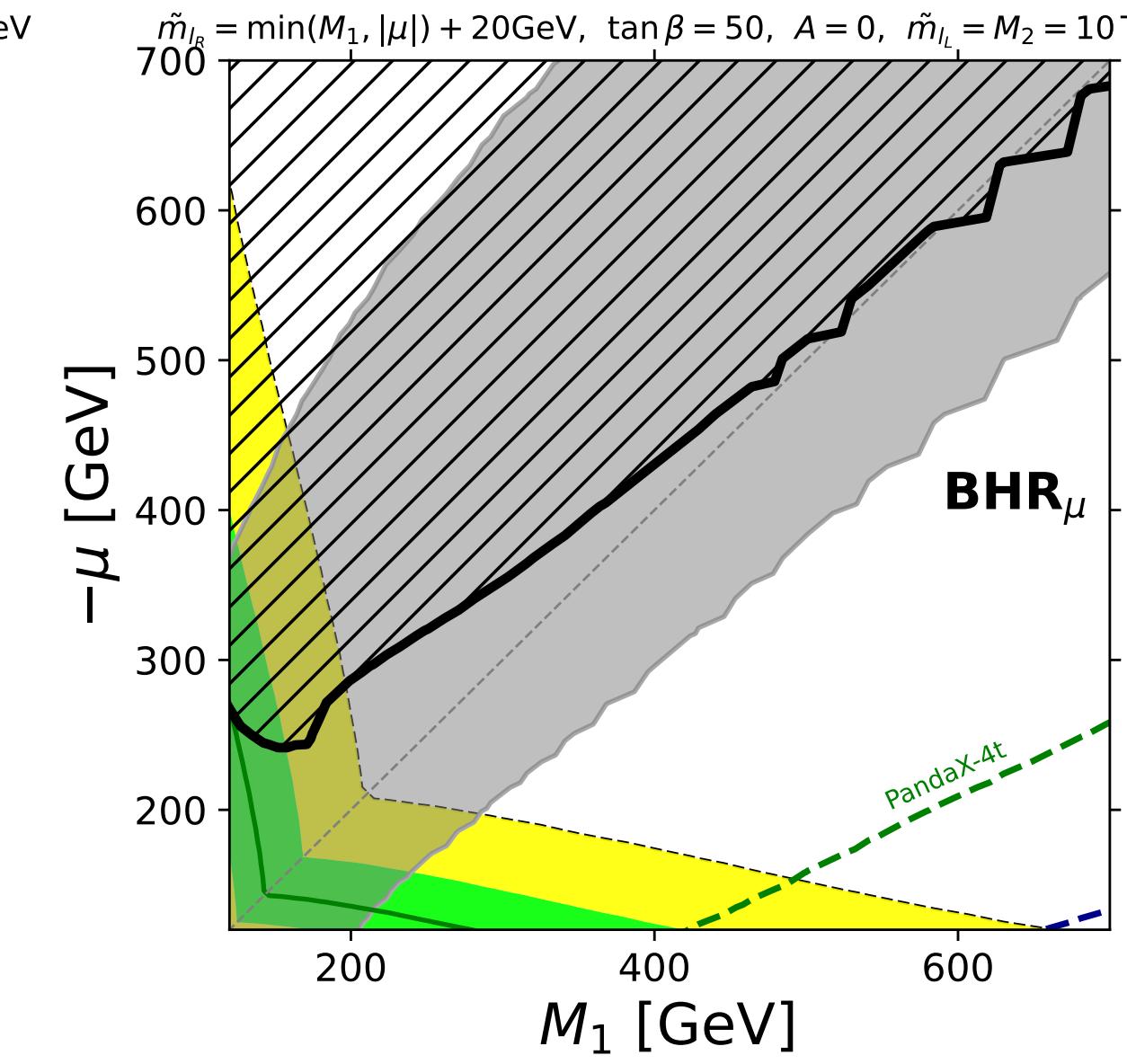
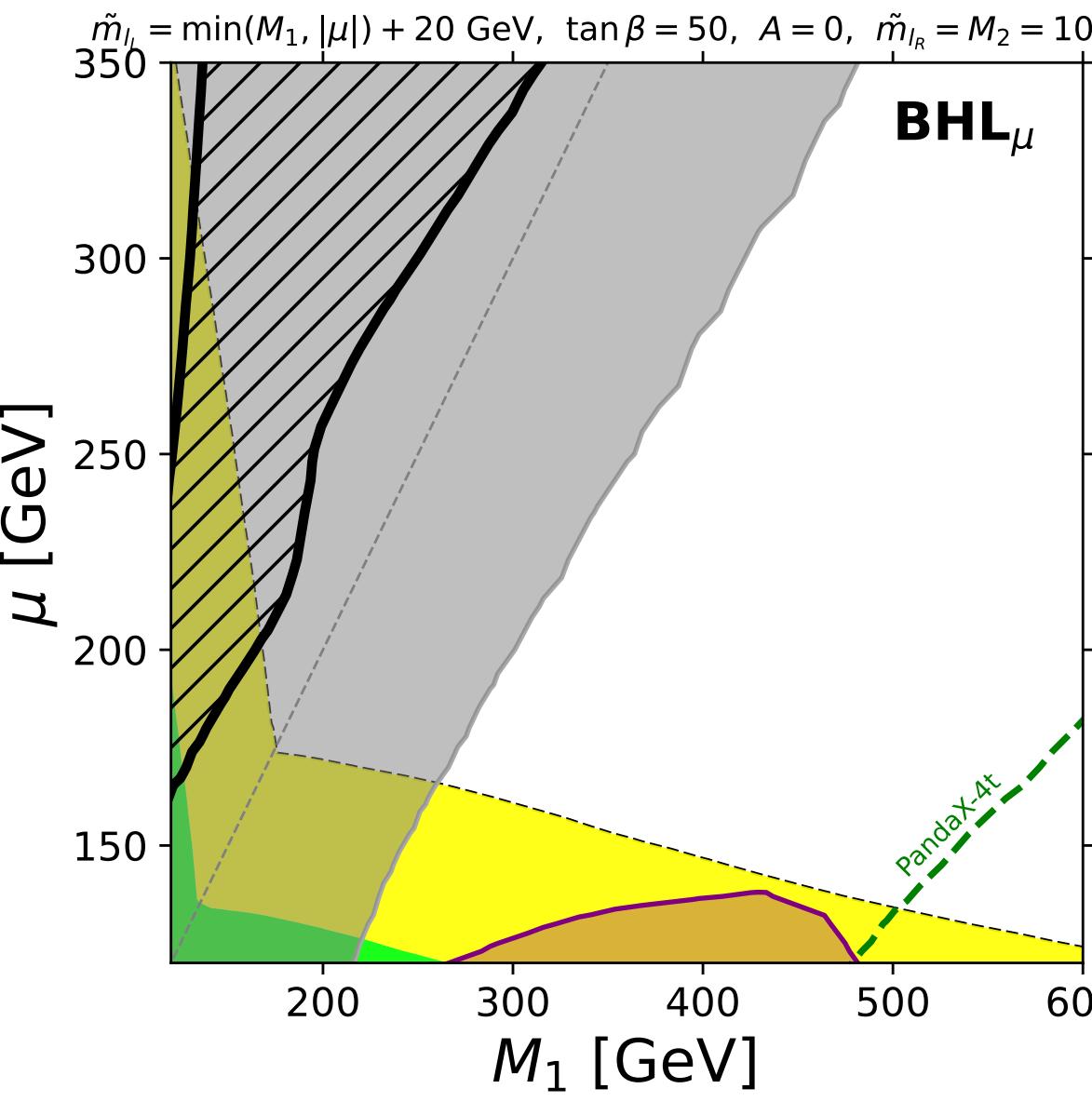
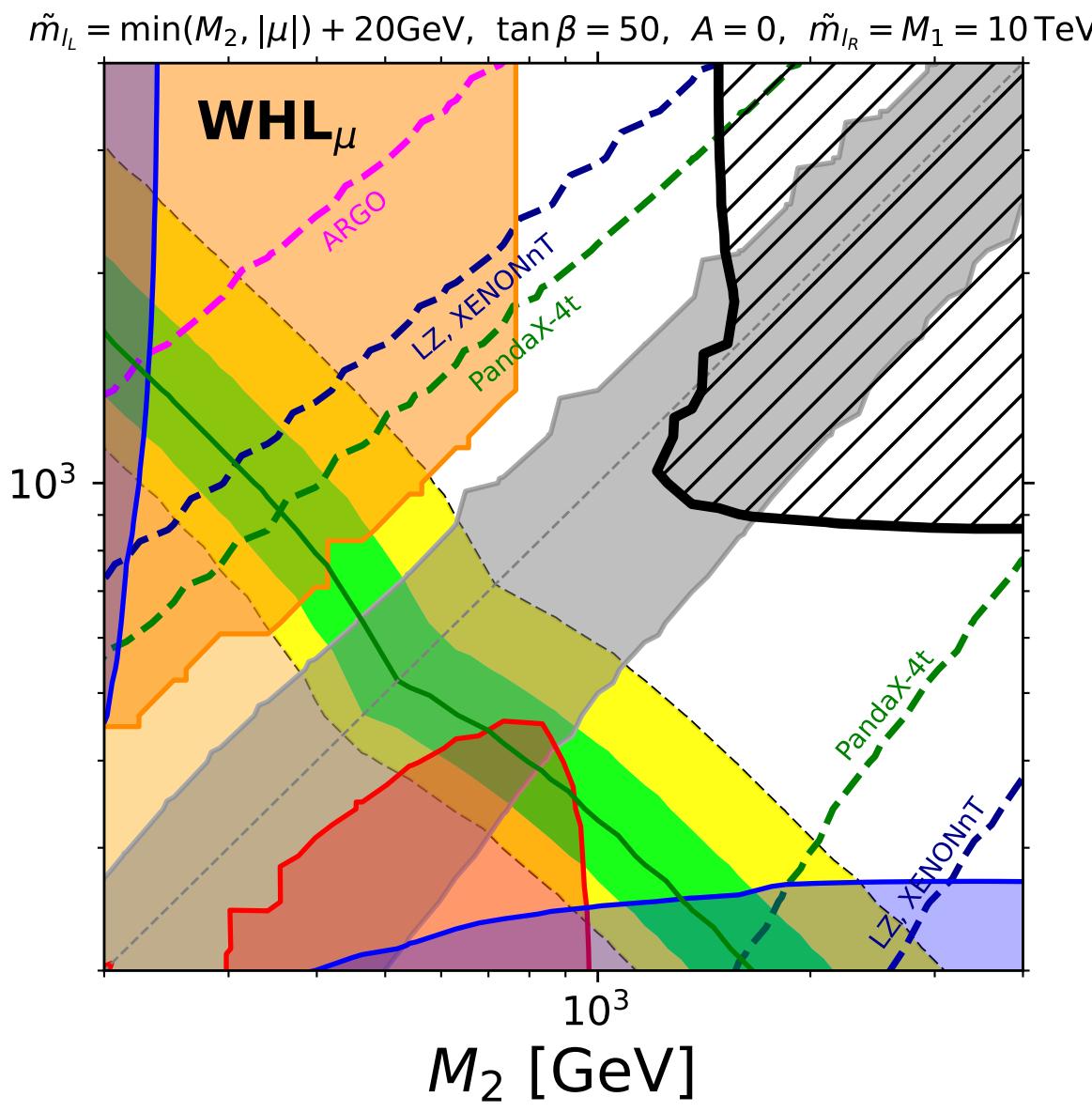
DM overproduction
due to Bino-like LSP



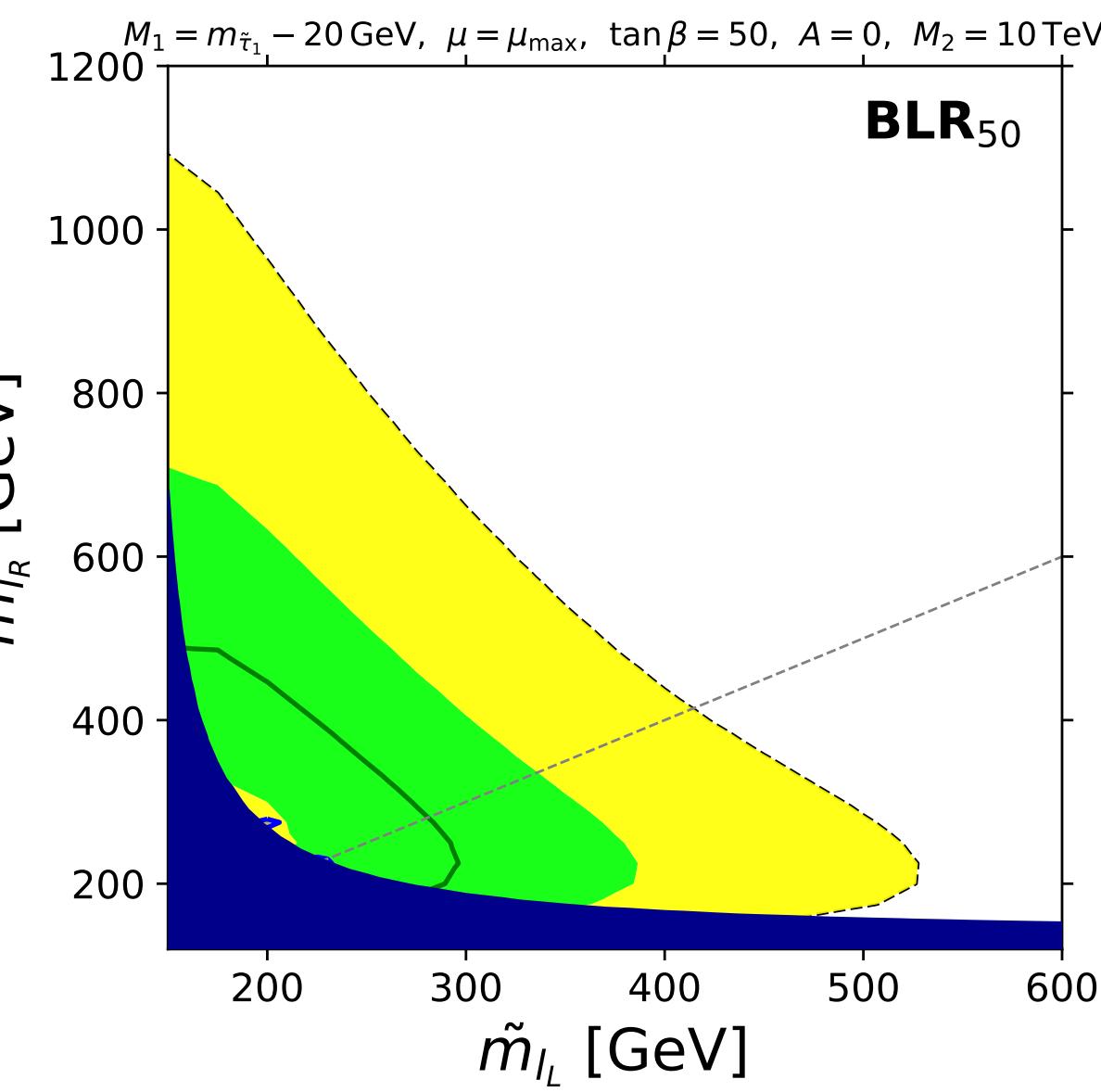
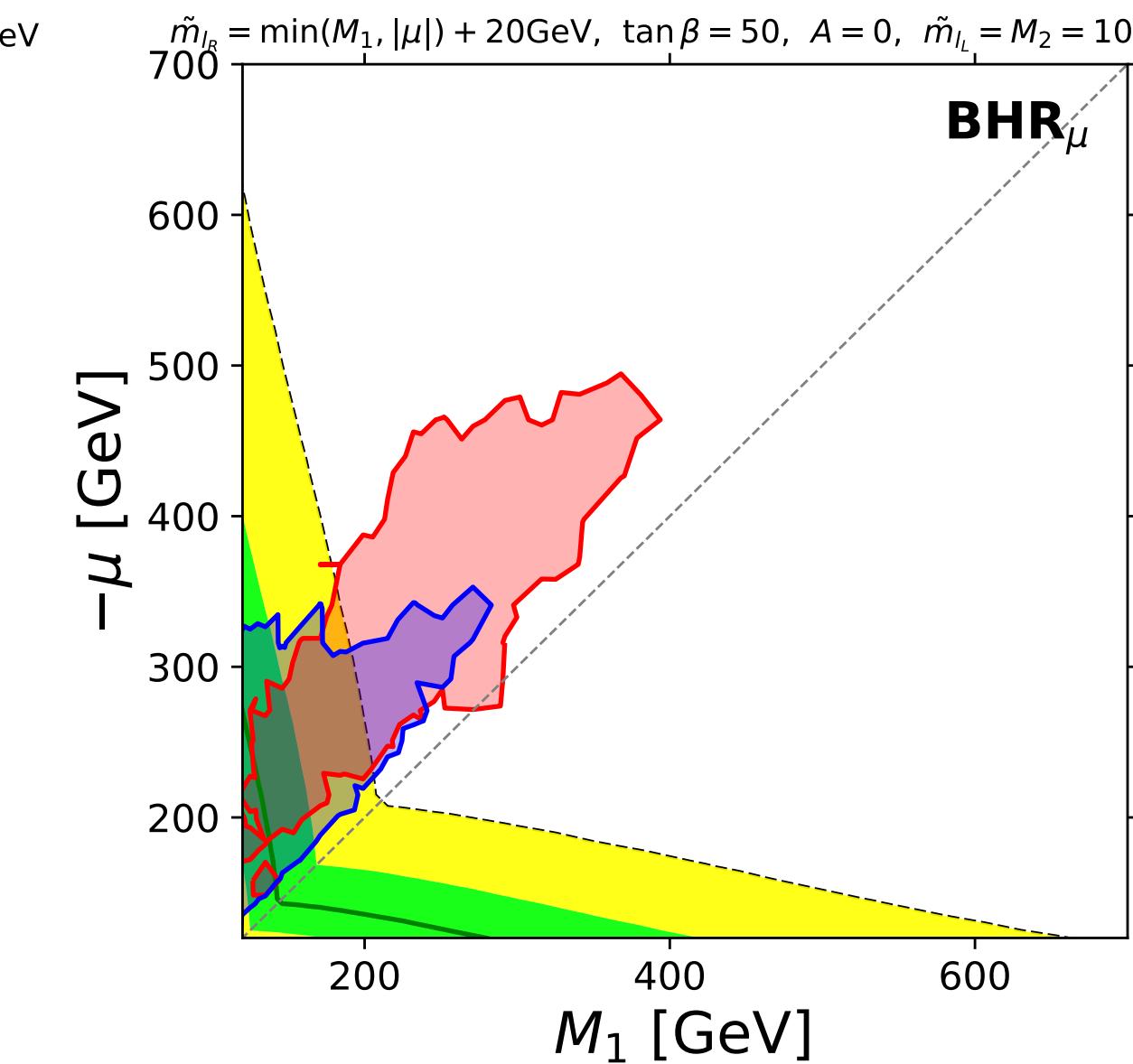
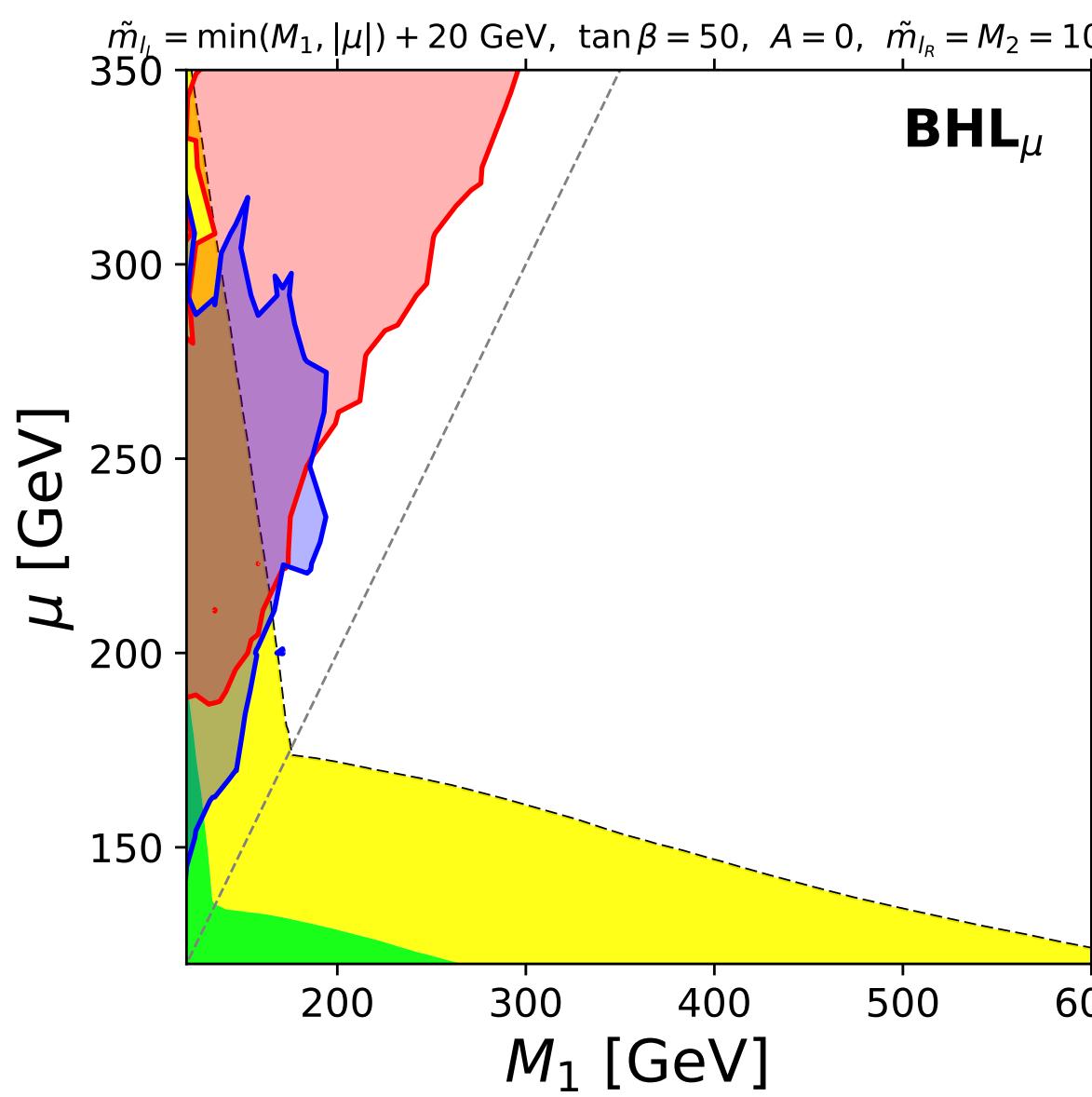
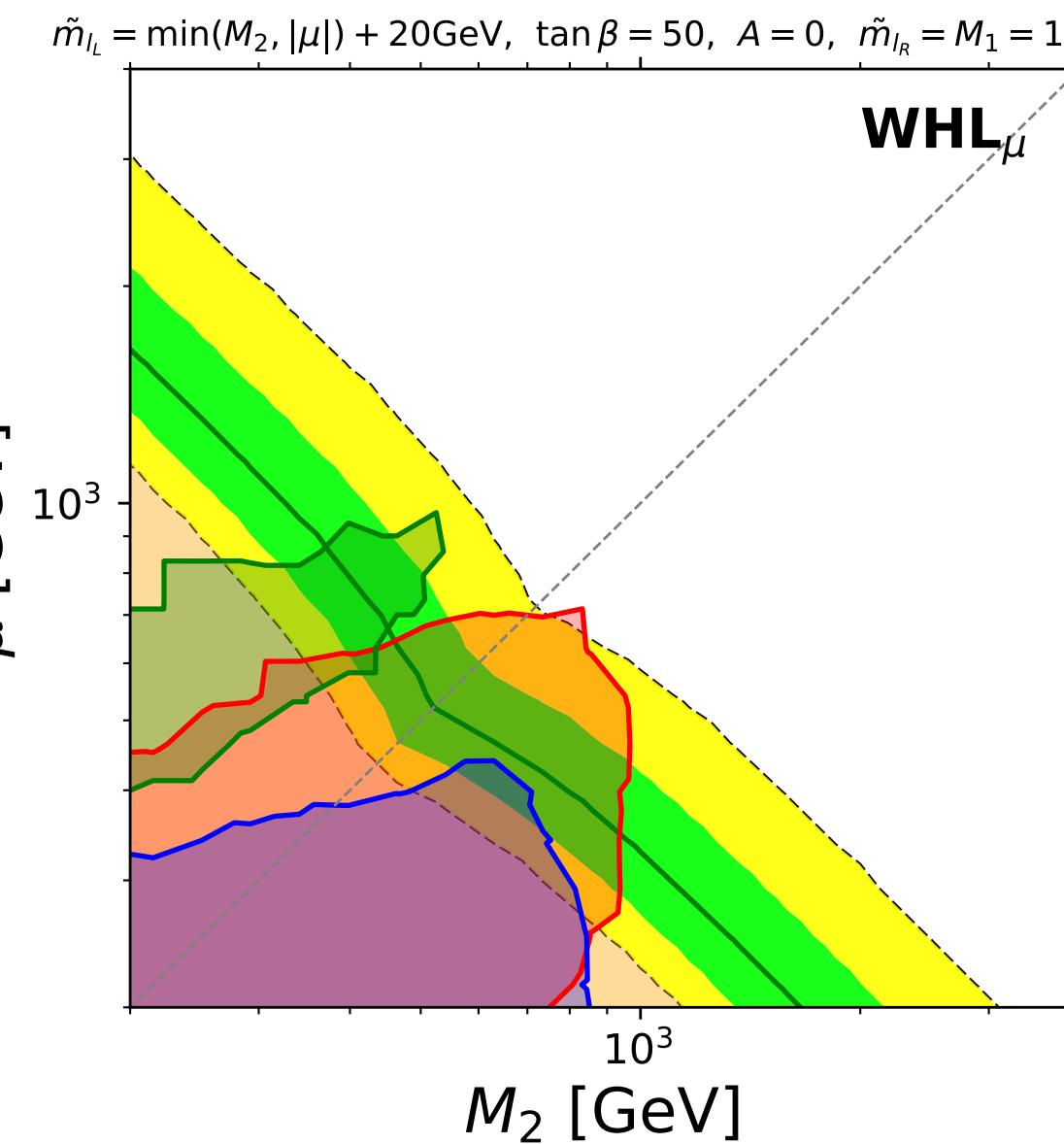
MSSM with stable neutralino



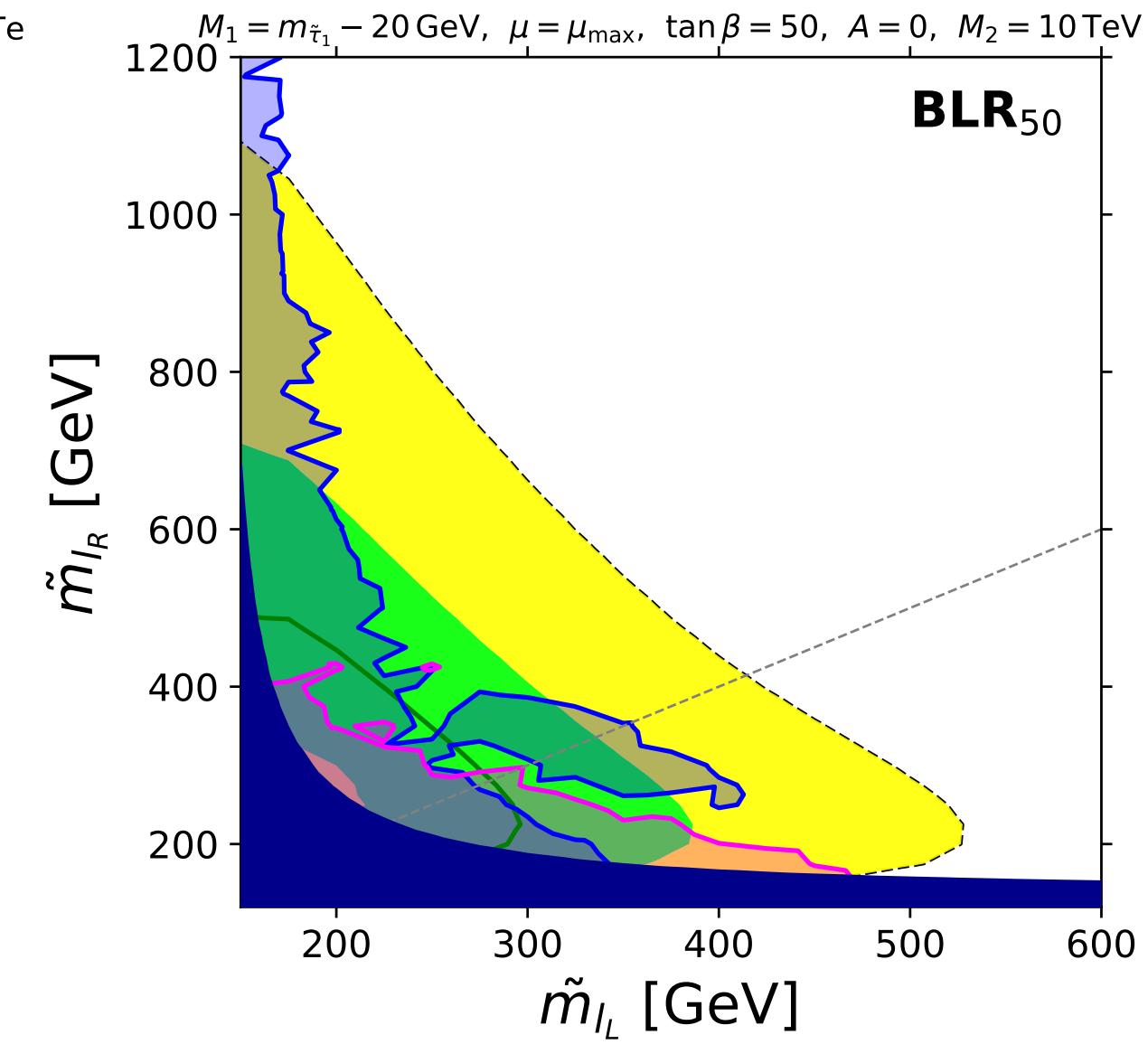
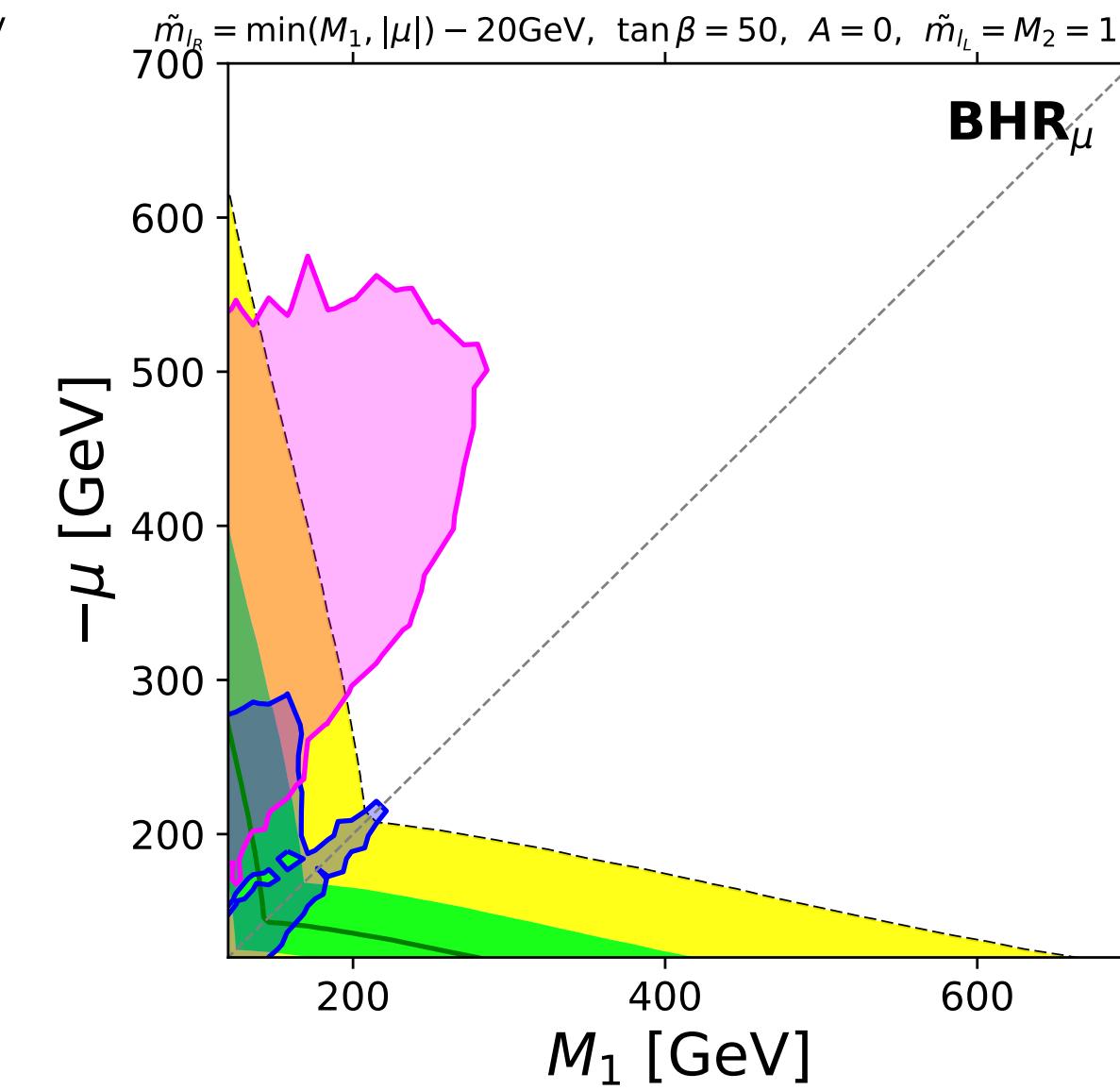
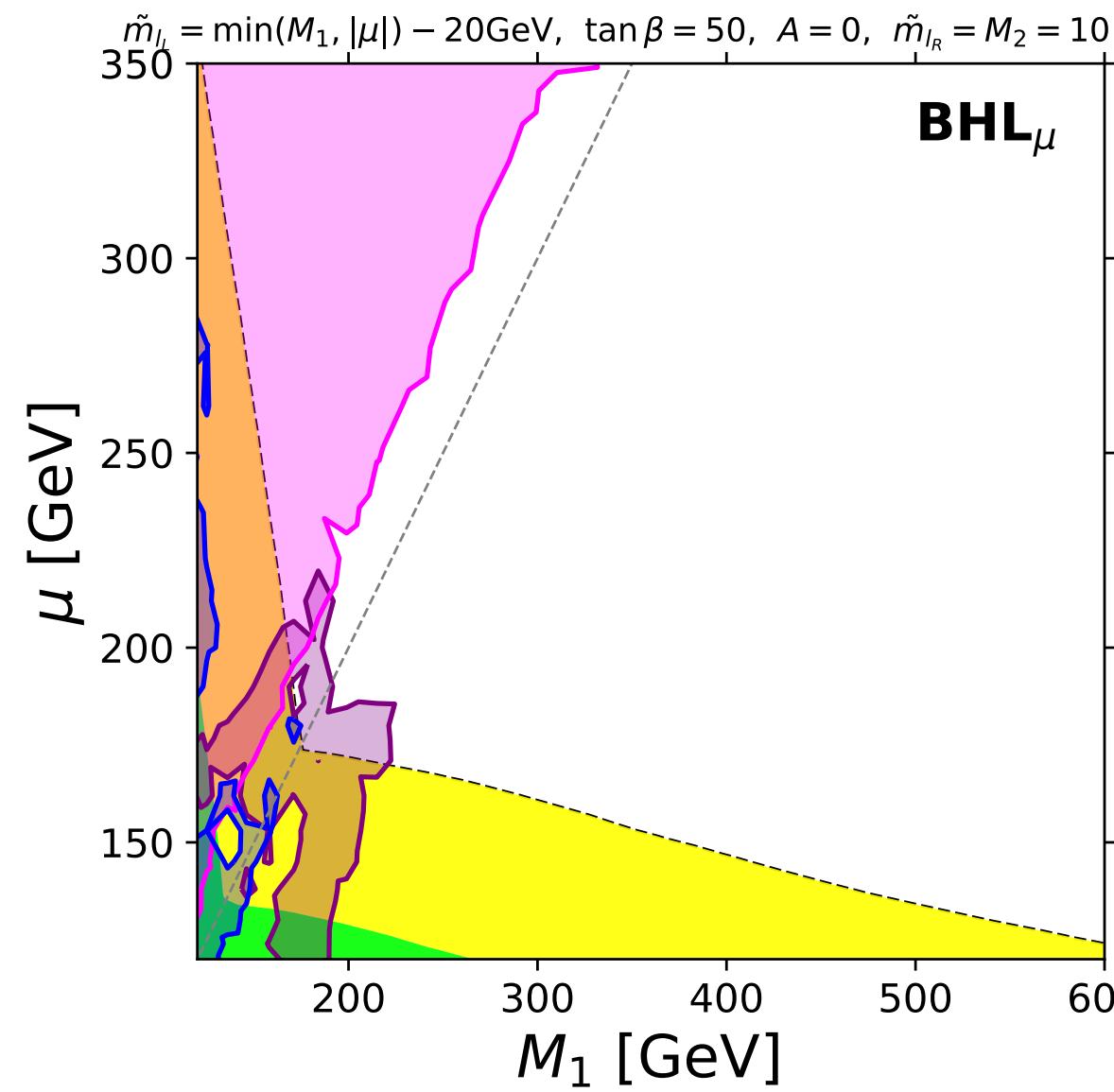
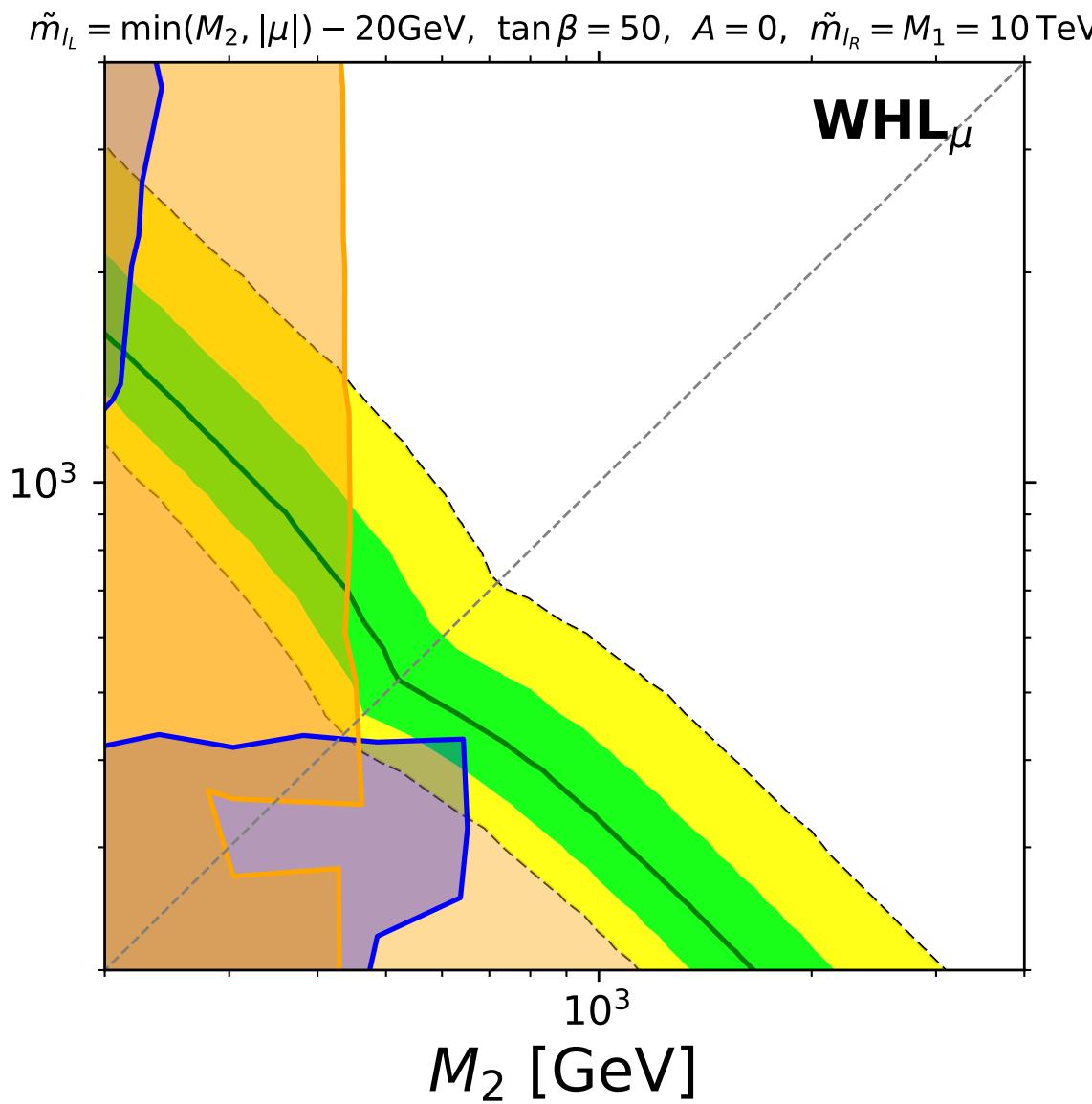
MSSM with stable neutralino



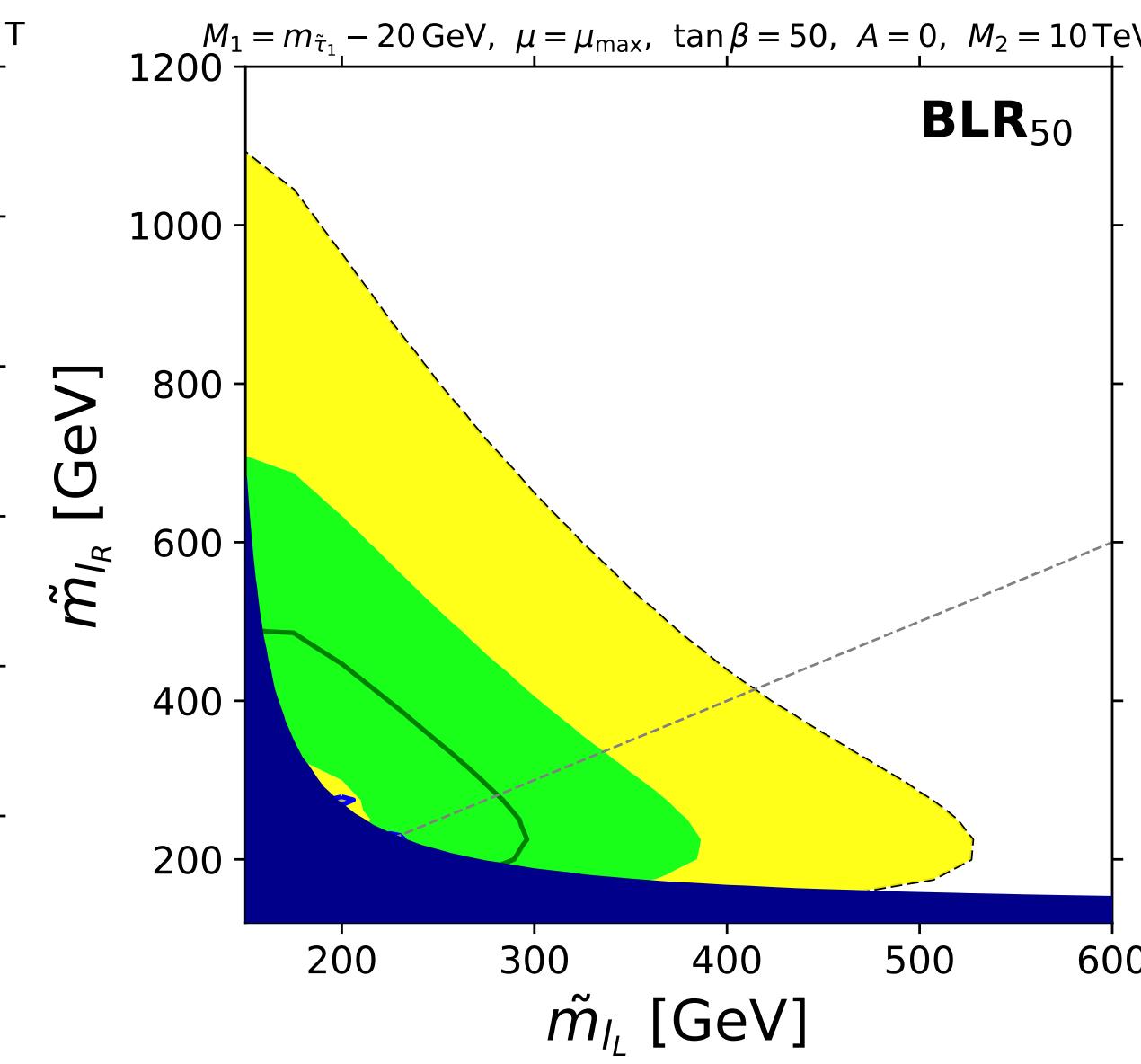
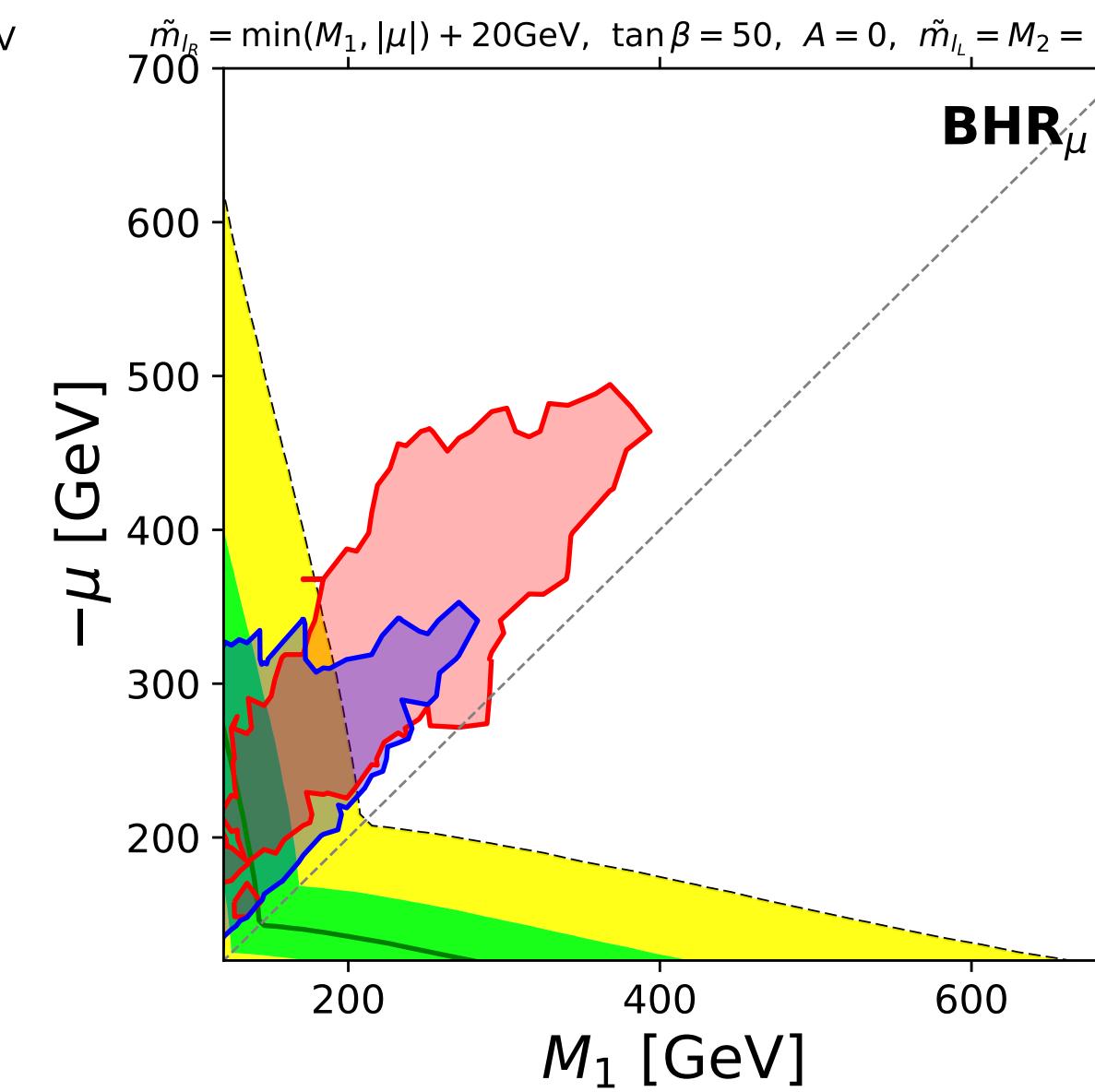
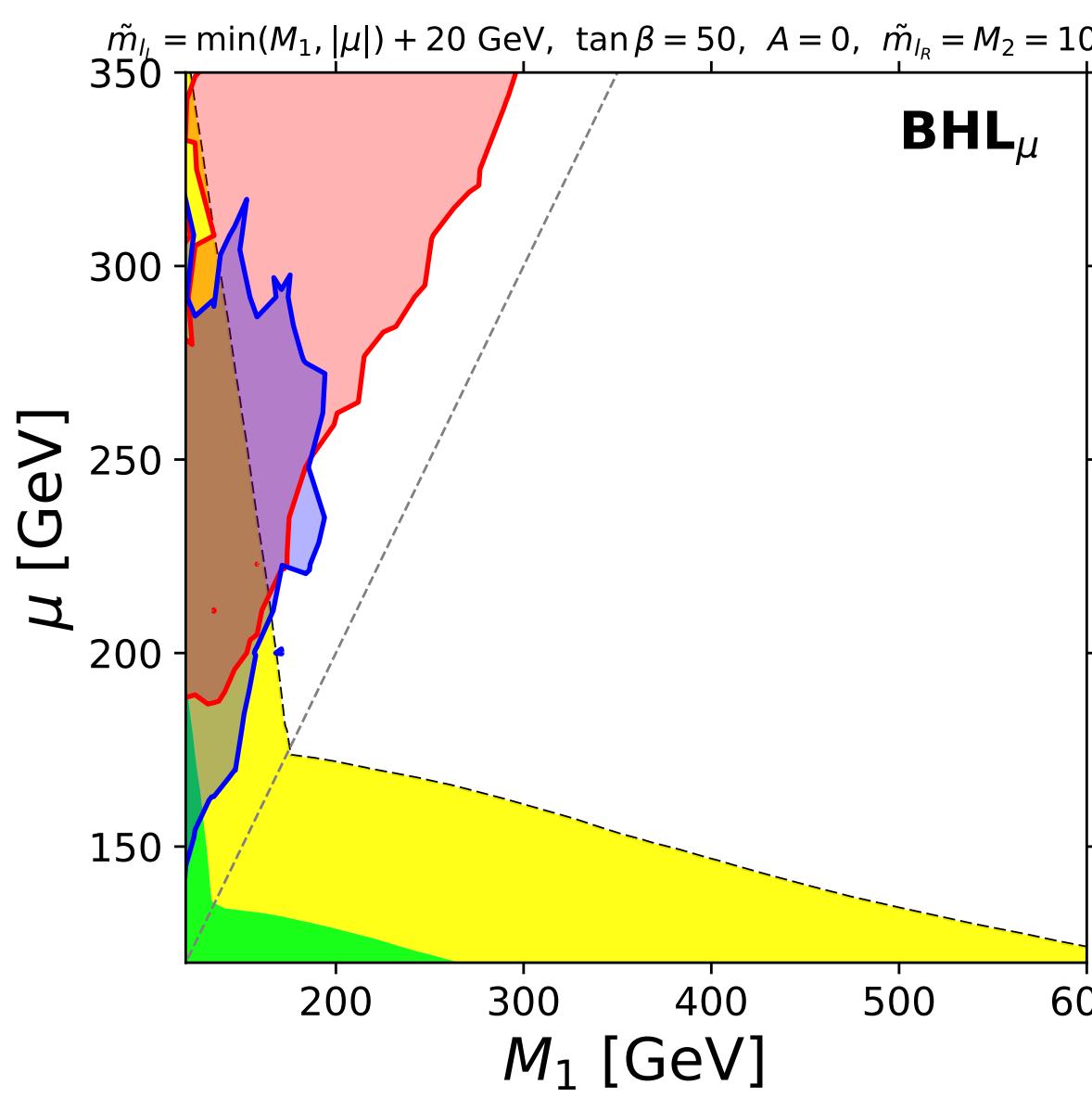
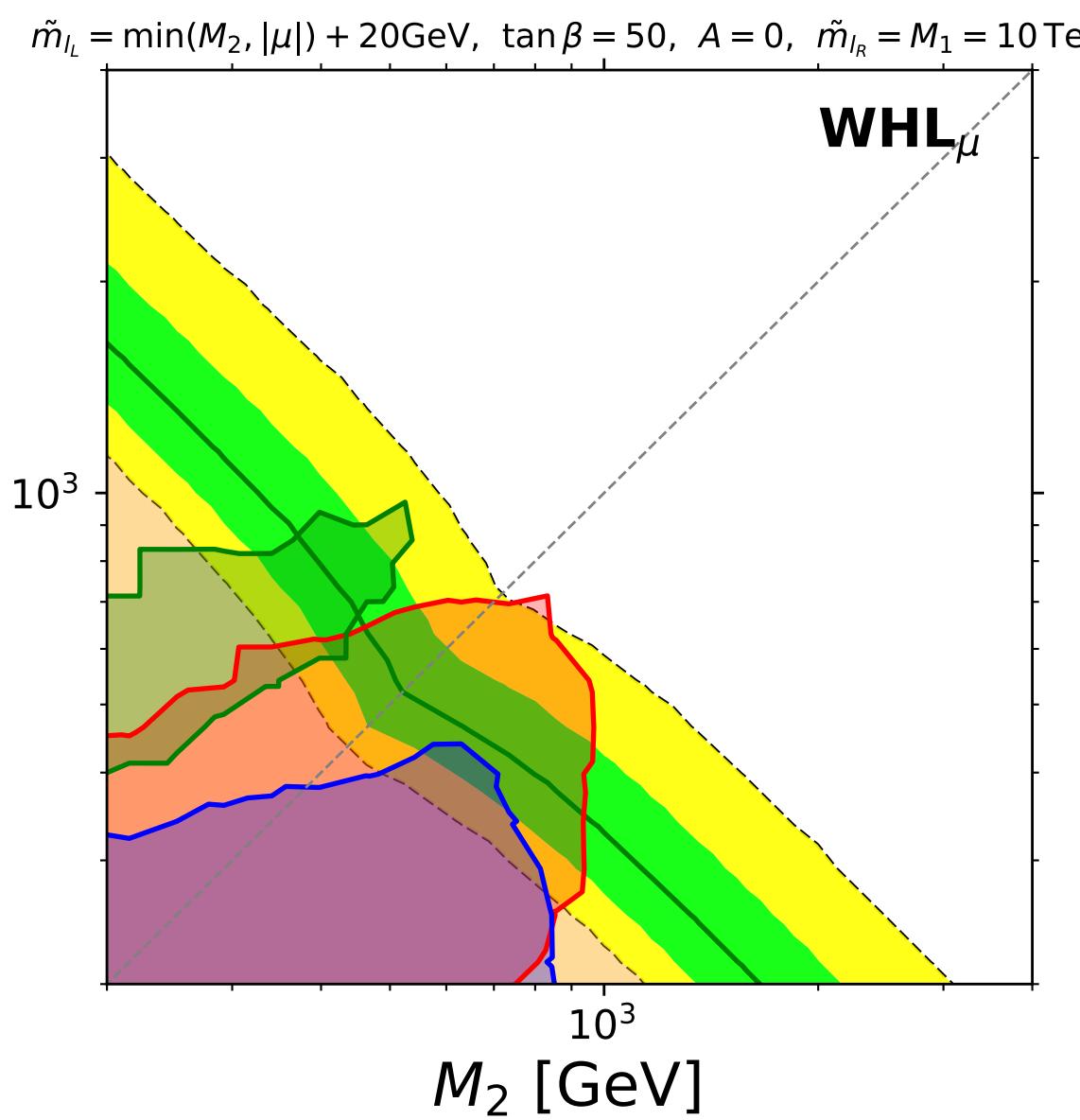
UDD RPV



GMSB with slepton/sneutrino/stau NLPS



UDD RPV



Summary

- ⦿ There is a 4.2σ discrepancy for $(g-2)_\mu$ between experiment and SM prediction
- ⦿ SUSY can explain $(g-2)_\mu$, but:
 - ⦿ $\tilde{\chi}_1^0$ is LSP and stable \Rightarrow constraint from large E_T^{miss}
 - ⦿ $|\mu| \approx M_1 (M_2) \Rightarrow$ constraint from DM-DD experiments
 - ⦿ slepton and Bino are light \Rightarrow DM overproduction
- ⦿ If $\tilde{\chi}_1^0$ is not stable LSP, DM constraints go away, and LHC signature changes:
 - ⦿ RPV with UDD \Rightarrow LHC constraints from multijet + lepton
 - ⦿ Gravitino LSP with $\tilde{\chi}_1^0$ NLSP \Rightarrow $(g-2)_\mu$ region excluded by $\gamma + E_T^{\text{miss}}$ channel
 - ⦿ Gravitino LSP with $\tilde{l}/\tilde{\nu}/\tilde{\tau}$ NLSP \Rightarrow LHC constraints from soft lepton/tau



Thank you for attention!

r.maselek@uw.edu.pl

Backup slides

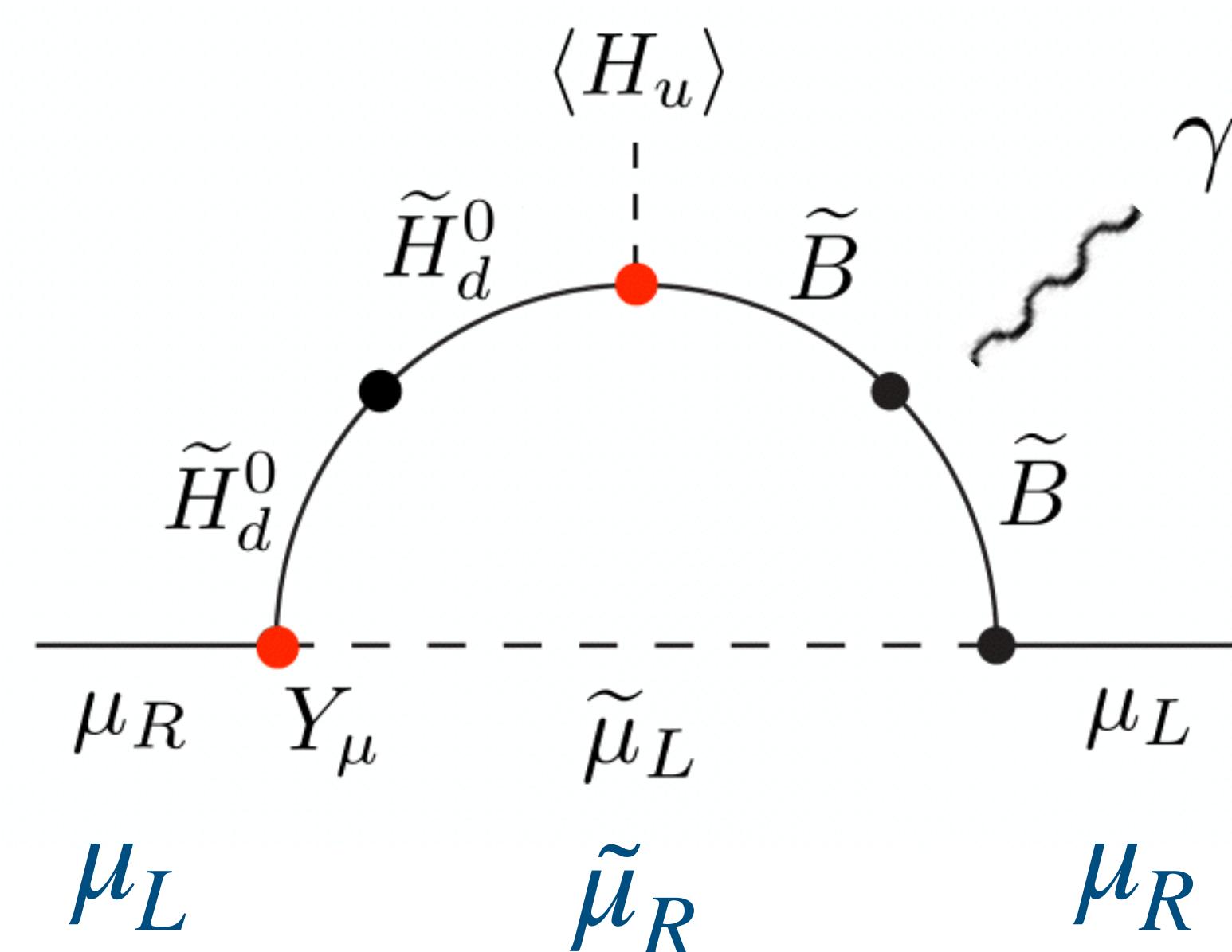
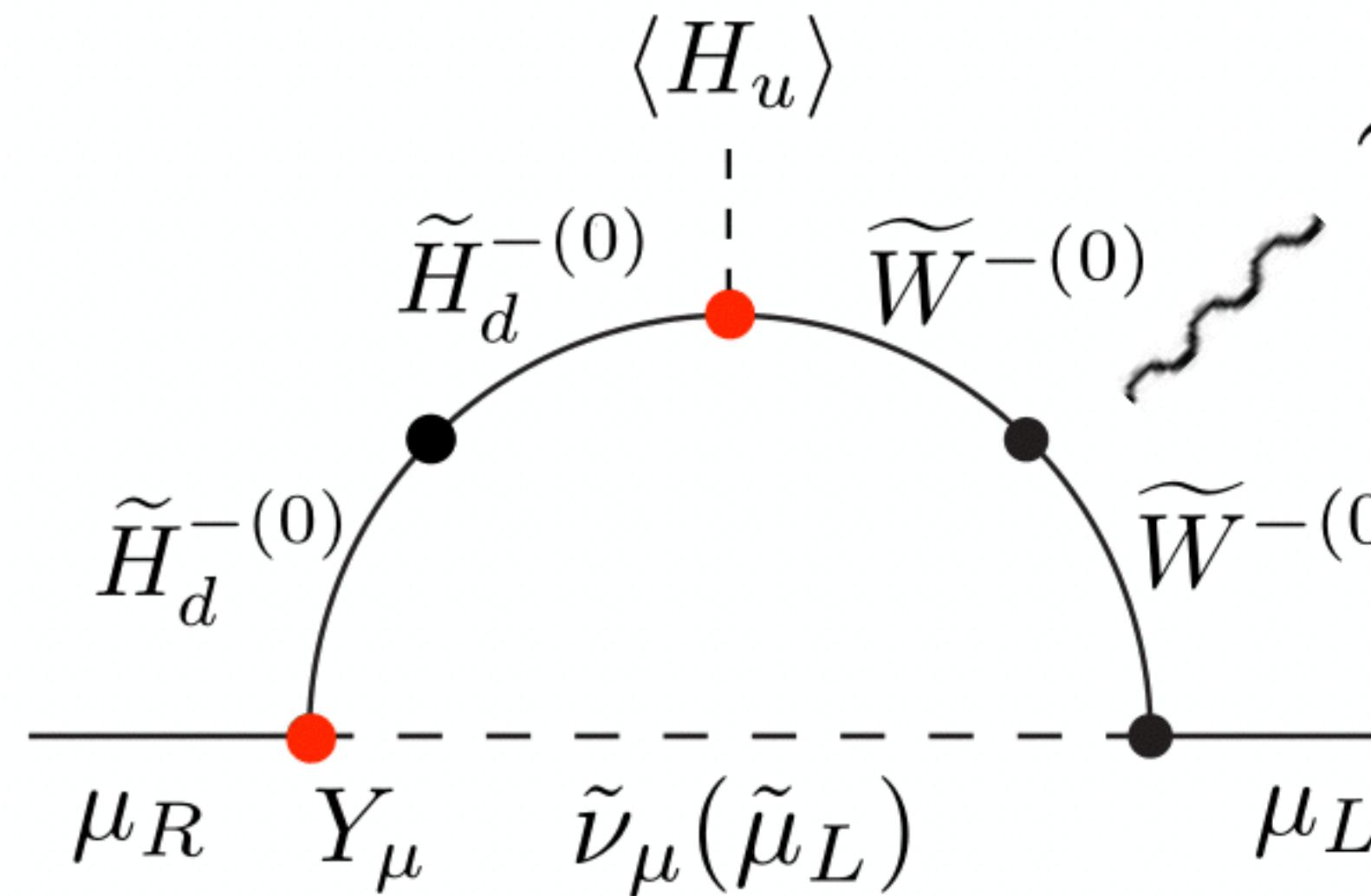
Tension between experiment and white paper SM calculations

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

We need **very light BSM particles** OR **enhancement from coupling**

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

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

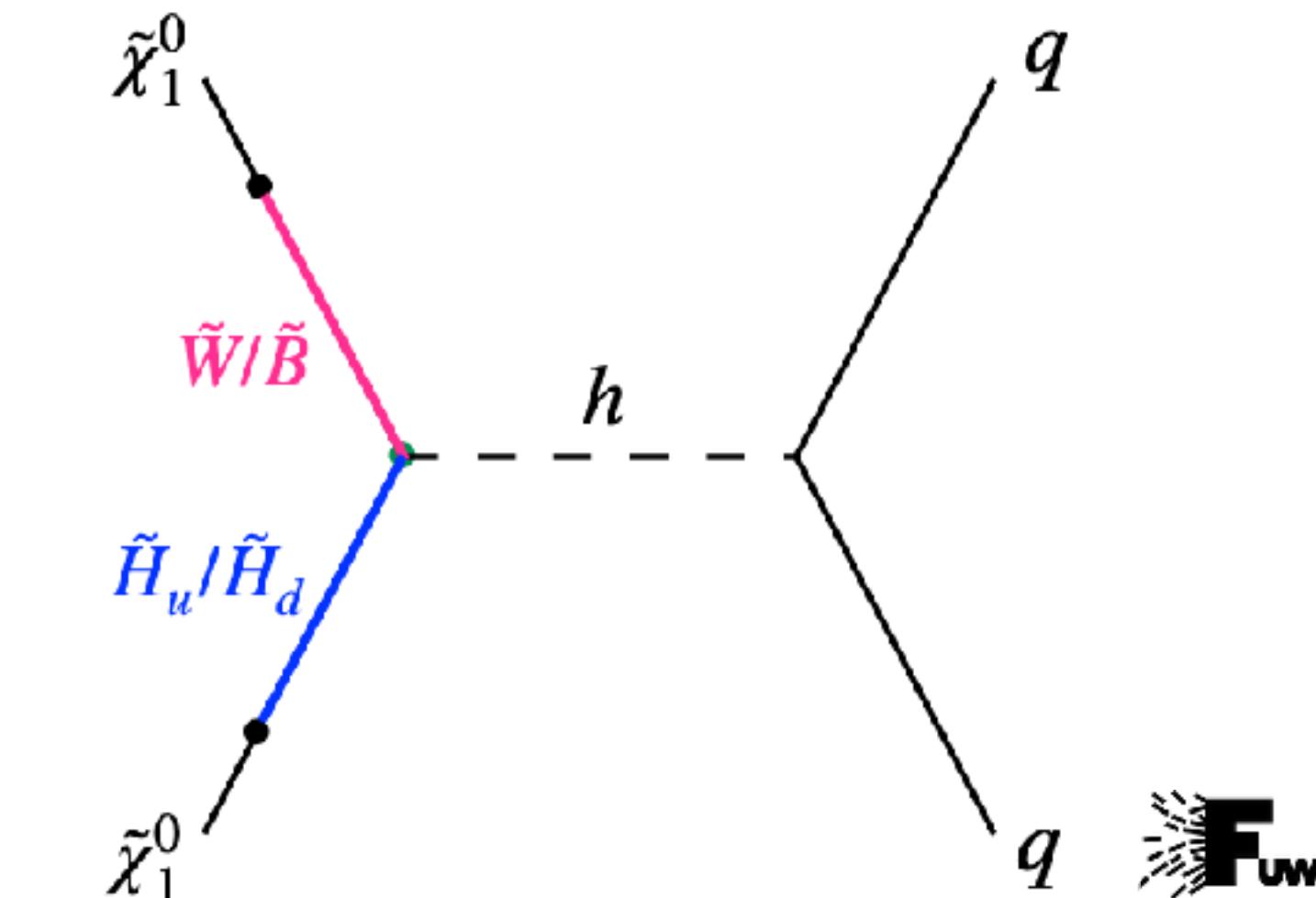


$$\Delta a_\mu^{\text{WHL}}(M_2, \mu, m_{\tilde{l}_L}) = + \frac{\alpha_W}{8\pi} \frac{m_\mu^2}{\mu M_2} \tan \beta \cdot f_{\text{WHL}}(\mathbf{m})$$

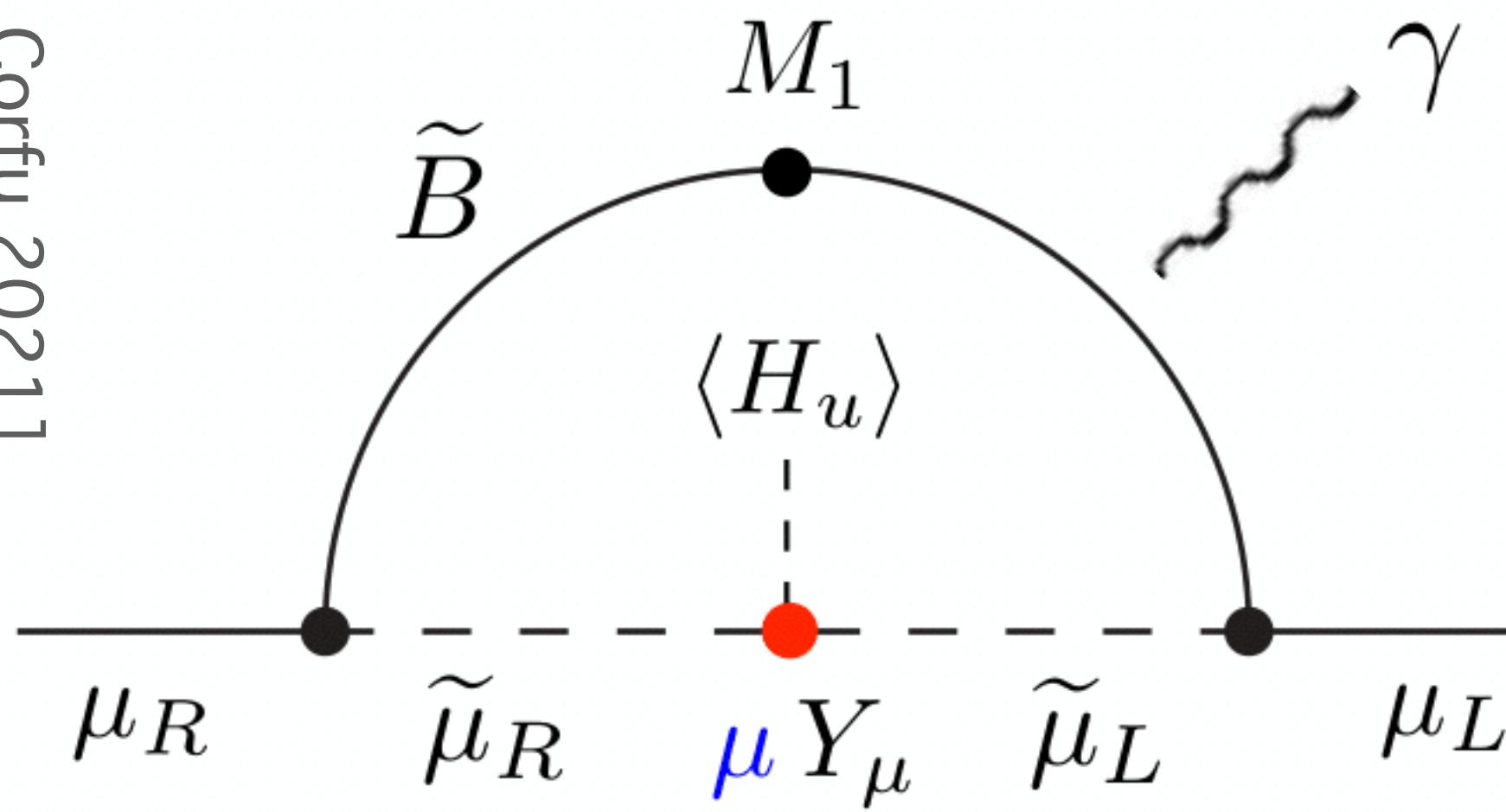
$$\Delta a_\mu^{\text{BHL}}(M_1, \mu, m_{\tilde{l}_L}) = + \frac{\alpha_Y}{8\pi} \frac{m_\mu^2}{\mu M_1} \tan \beta \cdot f_{\text{BHL}}(\mathbf{m})$$

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

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



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



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

large μ needed

Stau mass squared becomes too small or even negative!

$$M_{\tilde{\tau}}^2 \sim \begin{pmatrix} m_{\tilde{\tau}_R}^2 & Y_\tau \mu \langle H_u \rangle \\ Y_\tau \mu \langle H_u \rangle & m_{\tilde{\tau}_L}^2 \end{pmatrix}$$

Constraints on staus:

- charge breaking vacuum: $m_{\tilde{\tau}_1}^2 > 0$

- LEP bound: $m_{\tilde{\tau}_1} > 81.9 \text{ GeV}$

- stau LSP: $m_{\tilde{\tau}_1} > m_{\tilde{\chi}_1^0}$

- vacuum (meta-)stability

Parameter planes definition

name	axes	range [TeV]	other parameters	$\tan \beta$
WHL _{μ}	(M_2, μ)	$([0.2, 4], [0.2, 4])$	$\tilde{m}_{l_L} = \min(M_2, \mu) + 20 \text{ GeV}, M_1 = \tilde{m}_{l_R} = 10 \text{ TeV}$	50
WHL _{L}	(M_2, \tilde{m}_{l_L})	$([0.2, 4], [0.2, 2])$	$\mu = \min(M_2, \tilde{m}_{l_L}) - 20 \text{ GeV}, M_1 = \tilde{m}_{l_R} = 10 \text{ TeV}$	50
BHL _{μ}	(M_1, μ)	$([0.12, 0.6], [0.12, 0.35])$	$\tilde{m}_{l_L} = \min(M_1, \mu) + 20 \text{ GeV}, M_2 = \tilde{m}_{l_R} = 10 \text{ TeV}$	50
BHL _{L}	(M_1, \tilde{m}_{l_L})	$([0.12, 0.8], [0.14, 0.22])$	$\mu = \min(M_1, \tilde{m}_{l_L}) - 20 \text{ GeV}, M_2 = \tilde{m}_{l_R} = 10 \text{ TeV}$	50
BHR _{μ}	(M_1, μ)	$([0.12, 0.7], [0.12, 0.7])$	$\tilde{m}_{l_R} = \min(M_1, \mu) + 20 \text{ GeV}, M_2 = \tilde{m}_{l_L} = 10 \text{ TeV}$	50
BHR _{L}	(M_1, \tilde{m}_{l_R})	$([0.12, 0.8], [0.14, 0.25])$	$-\mu = \min(M_1, \tilde{m}_{l_R}) - 20 \text{ GeV}, M_2 = \tilde{m}_{l_L} = 10 \text{ TeV}$	50
BLR ₅₀	$(\tilde{m}_{l_L}, \tilde{m}_{l_R})$	$([0.15, 0.6], [0.12, 1.2])$	$M_1 = m_{\tilde{\tau}_1} - 20 \text{ GeV}, \mu = \mu_{\max}, M_2 = 10 \text{ TeV}$	50
BLR ₁₀	$(\tilde{m}_{l_L}, \tilde{m}_{l_R})$	$([0.15, 0.6], [0.12, 1.2])$	$M_1 = m_{\tilde{\tau}_1} - 20 \text{ GeV}, \mu = \mu_{\max}, M_2 = 10 \text{ TeV}$	10

Table 1: The parameter planes and choices of the other parameters. μ_{\max} is defined as the maximum value allowed by the vacuum stability constraint.

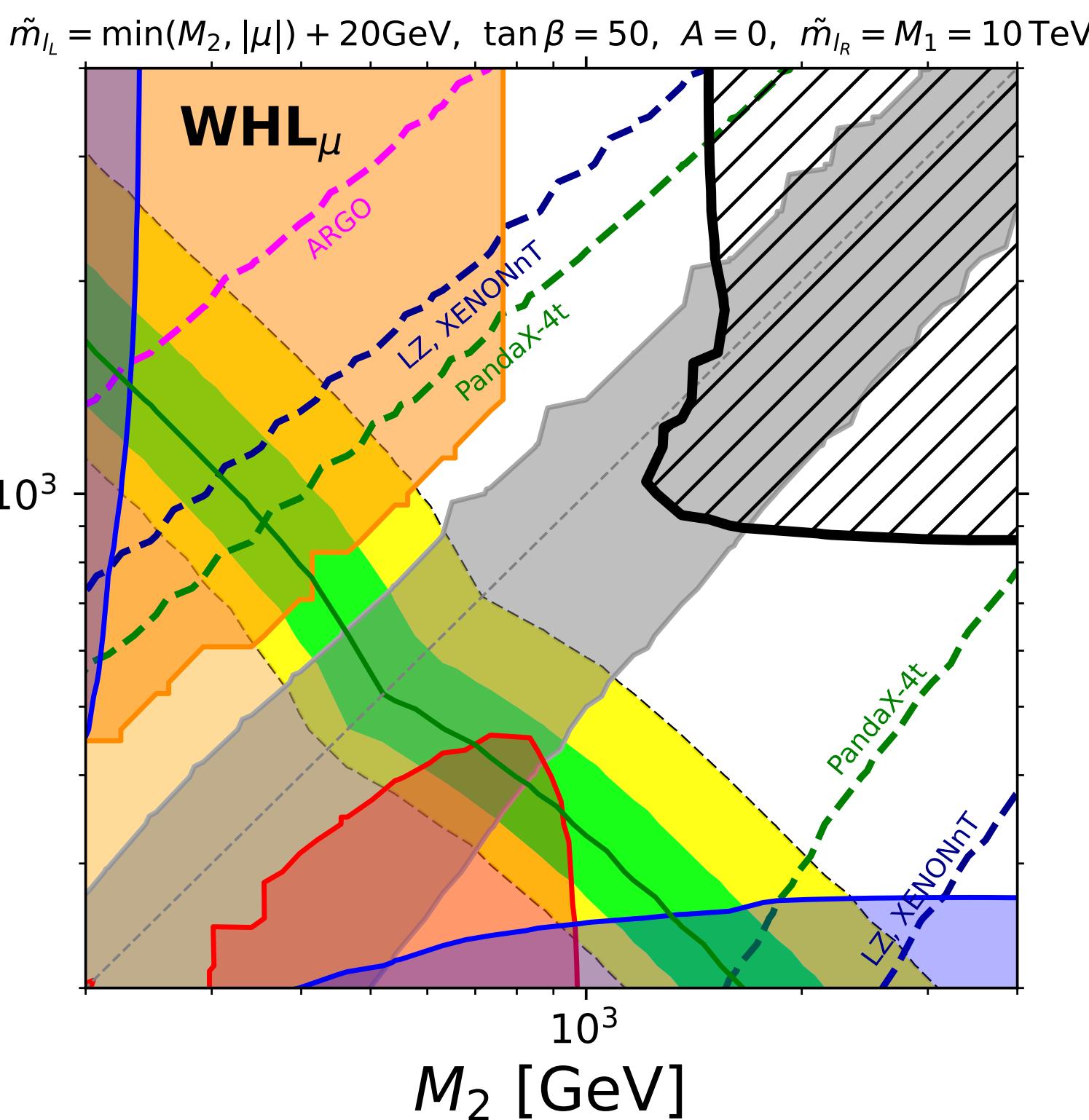
For GMSB we modify the planes to ensure that slepton/stau/sneutrino is the NLSP.

ATLAS DT [2201.02472]

ATLAS soft-I [1911.12606]

CMS I+I- [2004.05153]

XENON1T [1805.12562]



MSSM

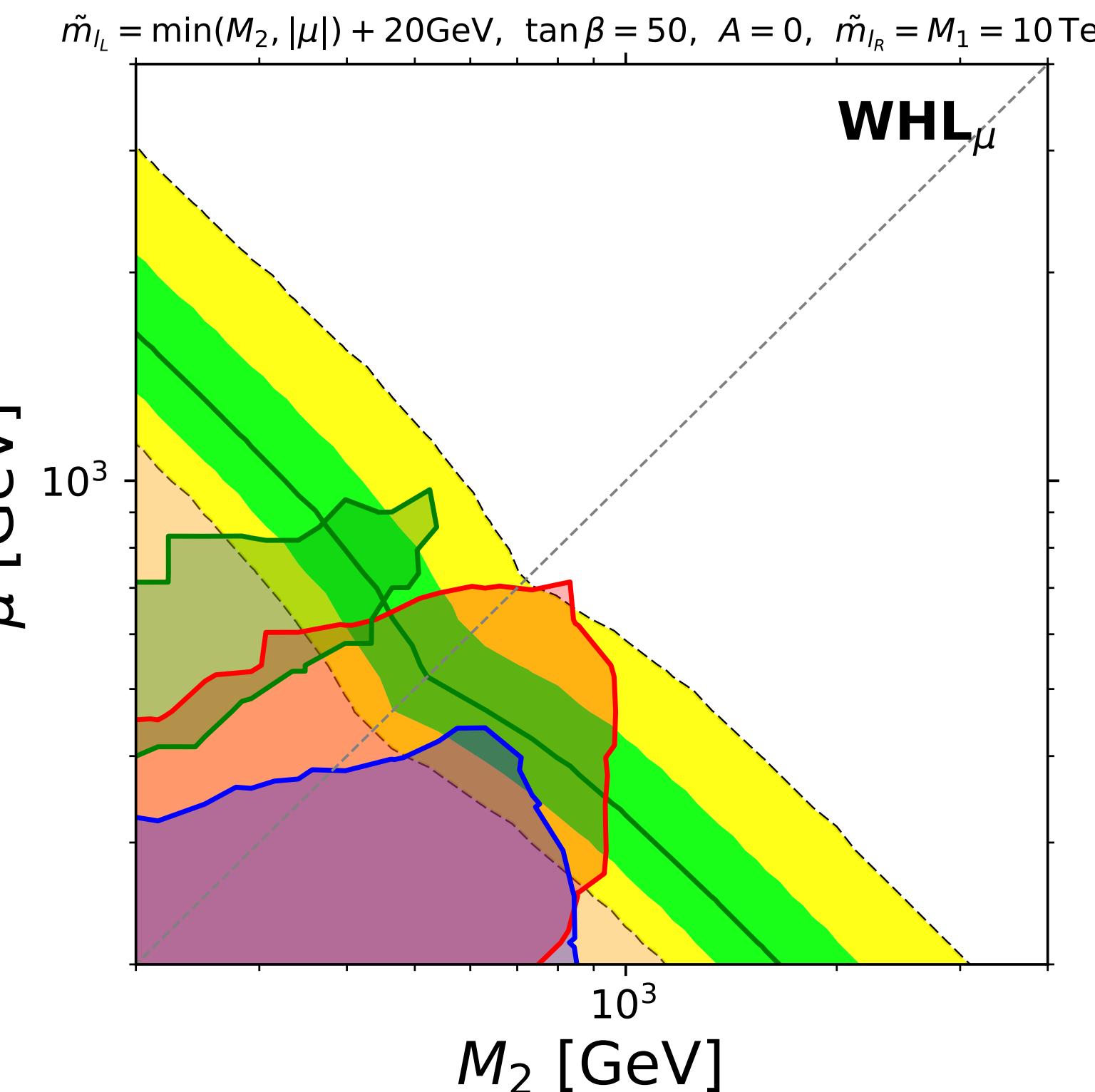
WHL μ

ATLAS jets + E_T^{miss}

[ATLAS-CONF-2019-040]

CMS multilepton [1709.05406]

ATLAS multijet+I [2106.09609]



RPV

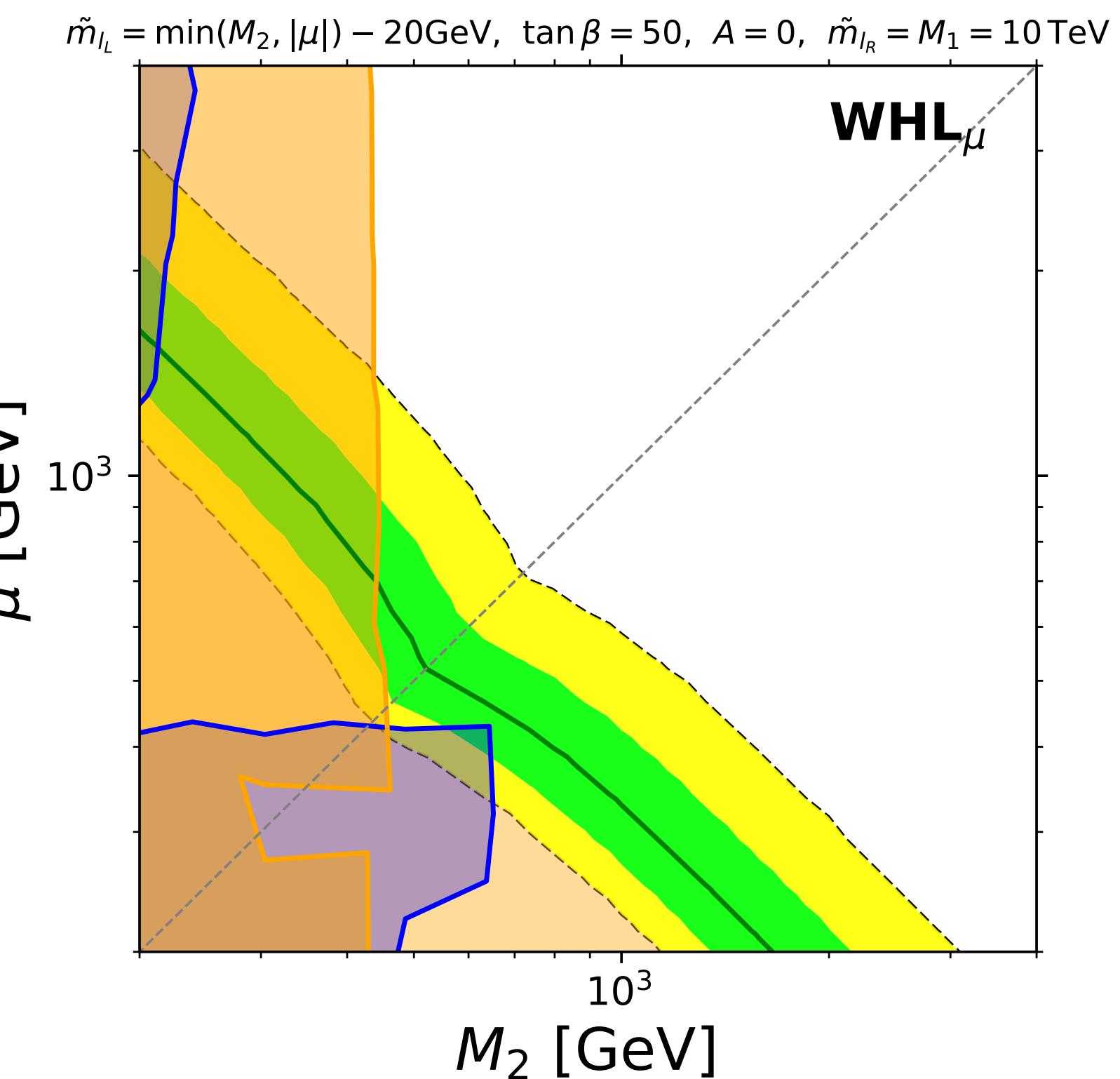
R. Masełek SUSY 2022/06/29

CMS soft I+I-

[1801.01846]

CMS multilepton

[1709.05406]



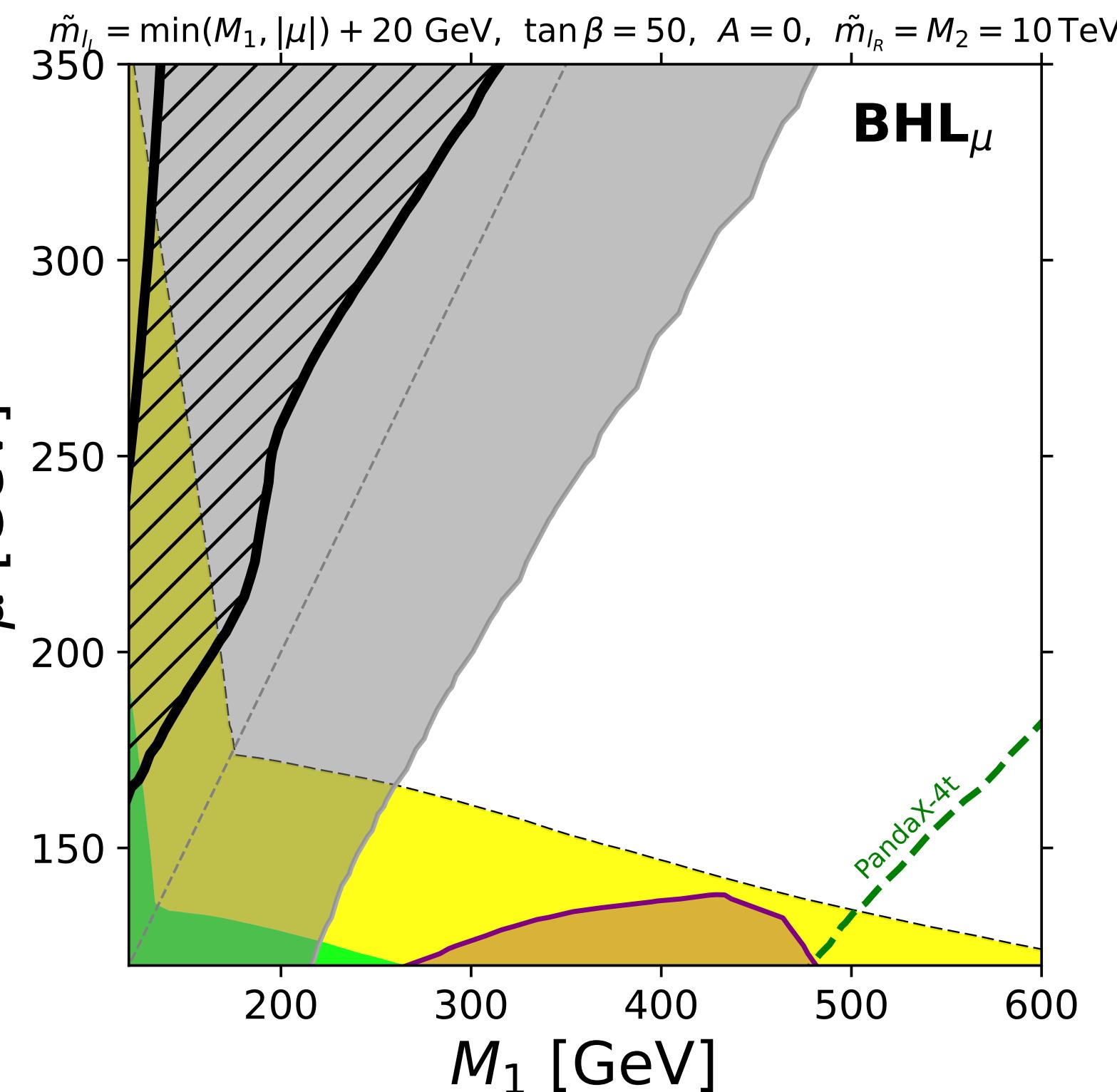
GMSB



ATLAS soft-l [1911.12606]

CMS l+- [2004.05153]

XENON1T [1805.12562]

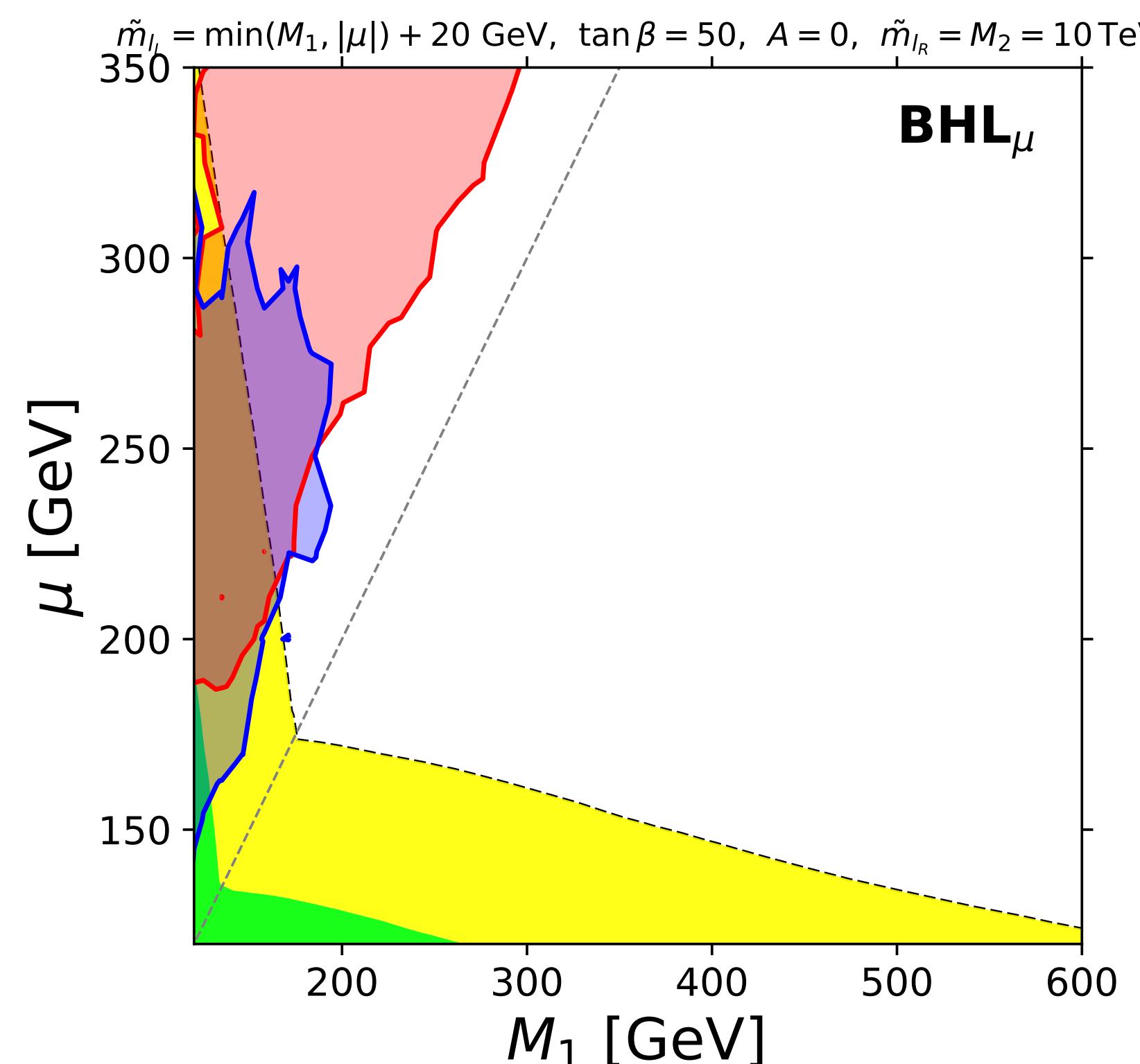


MSSM

BHL μ

CMS multilepton [1709.05406]

ATLAS multijet+l [2106.09609]

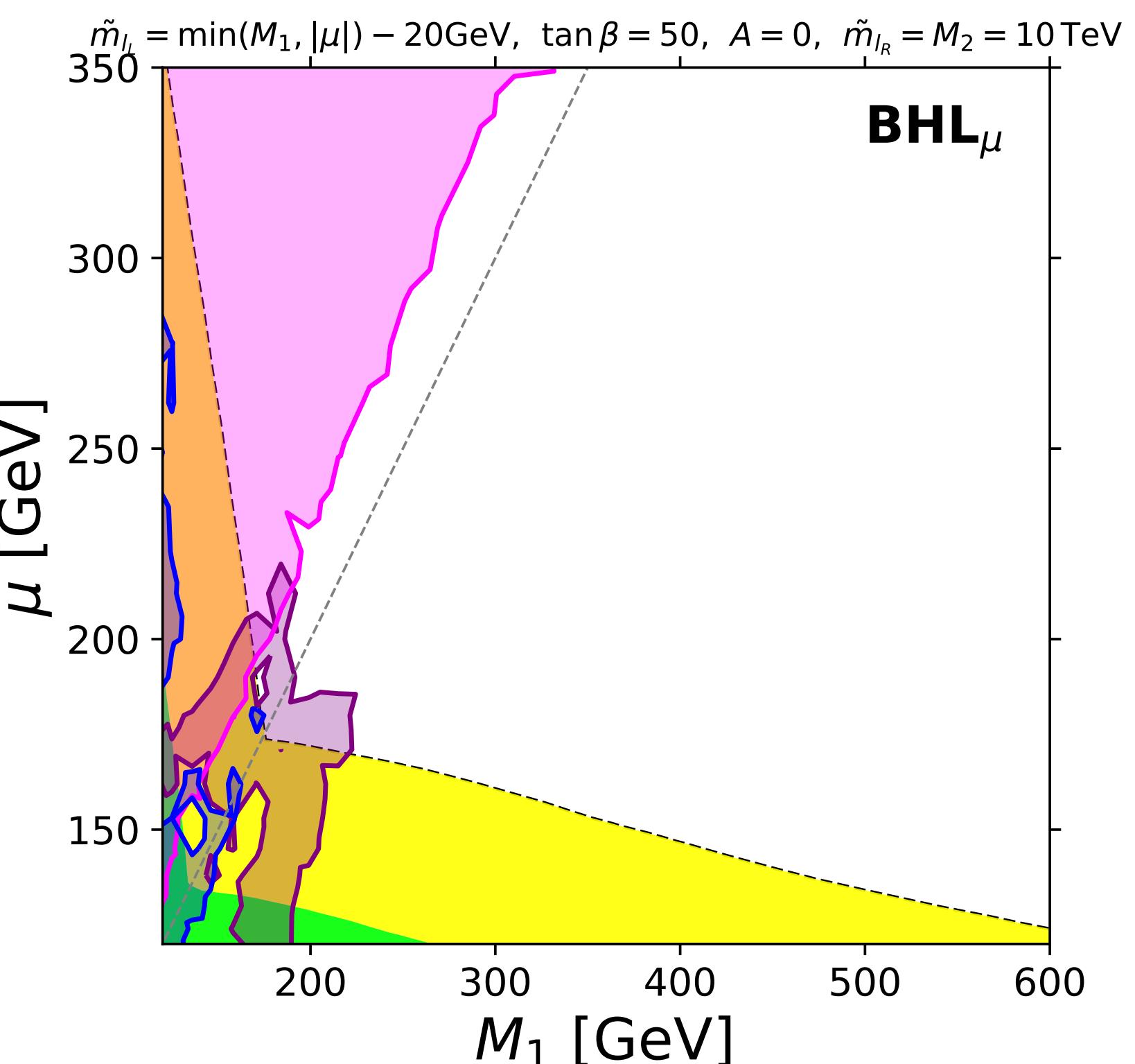


RPV

R. Masełek SUSY 2022/06/29

ATLAS soft-l [1712.08119]

ATLAS $\tau^+\tau^-$
[1911.06660]



GMSB

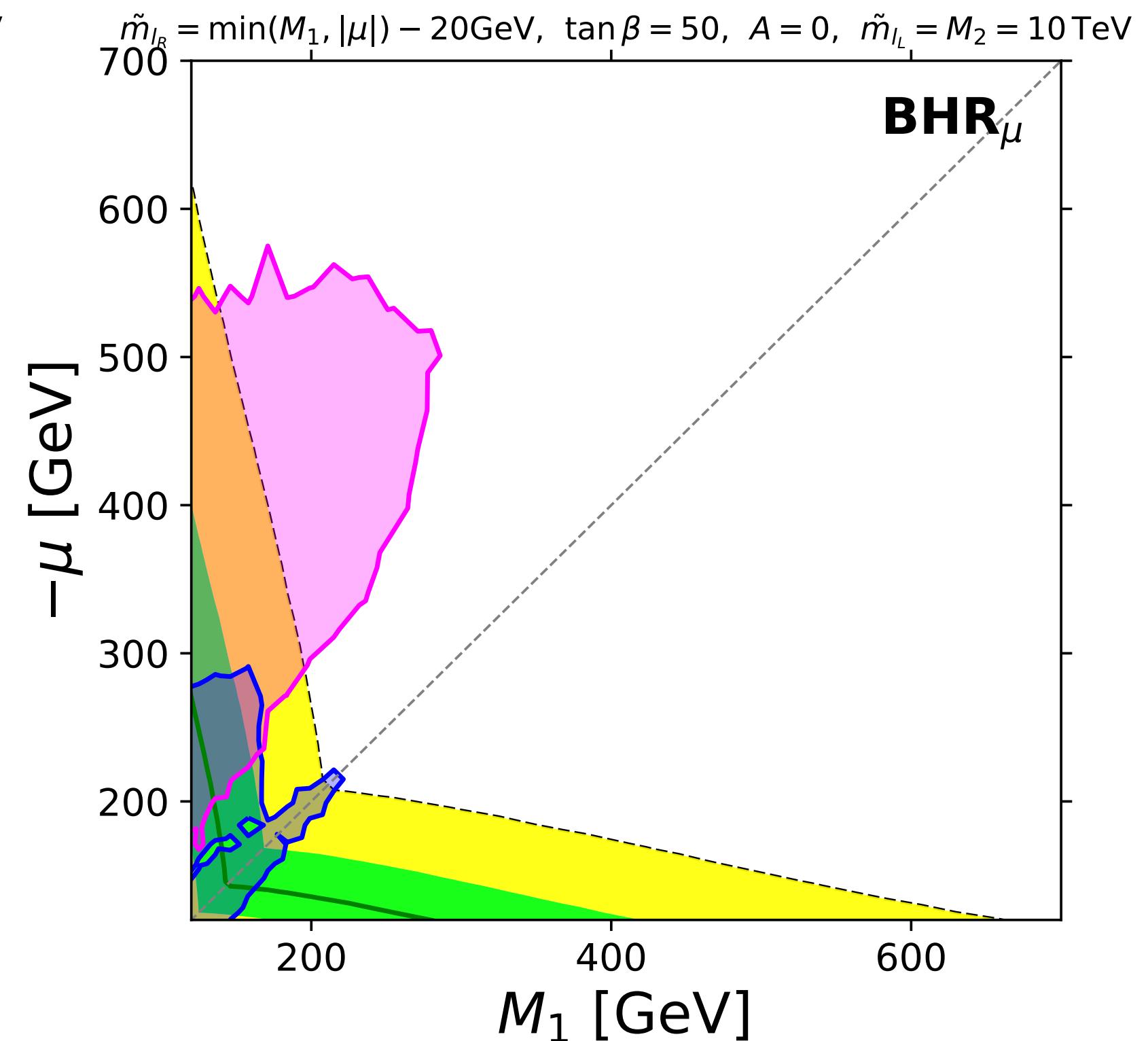
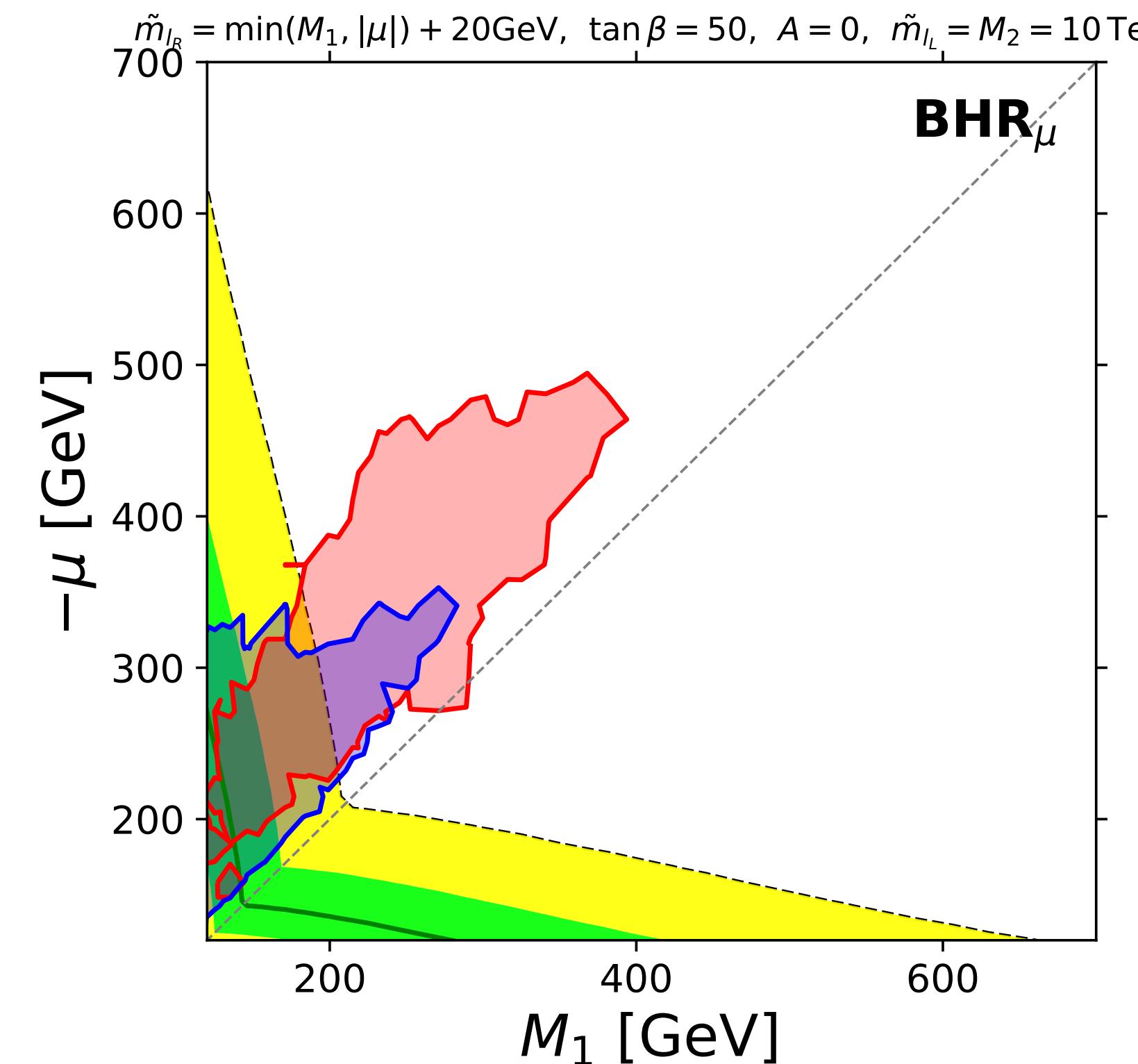
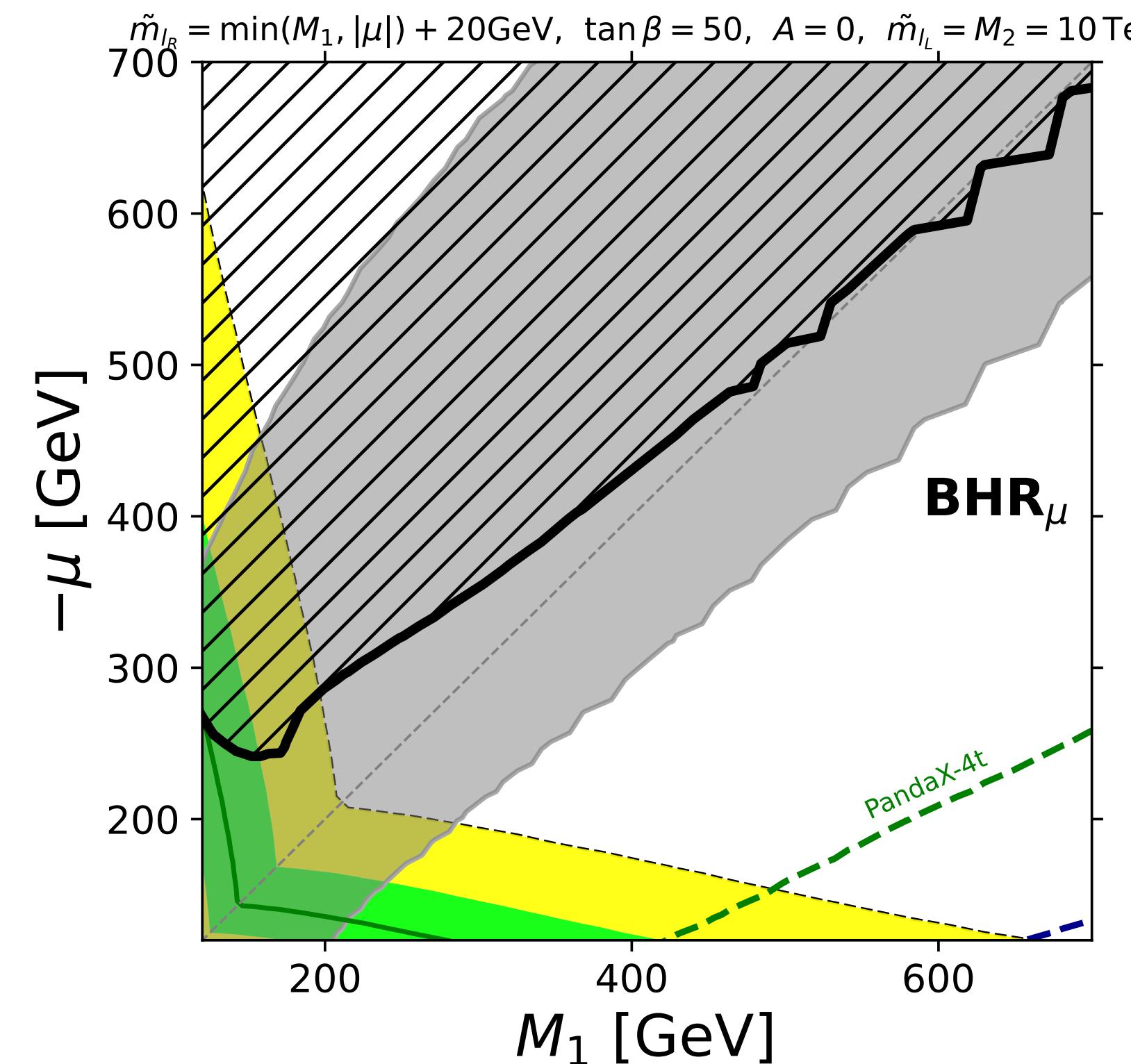


CMS multilepton
[1709.05406]

XENON1T [1805.12562]

CMS multilepton [1709.05406]
ATLAS multijet+l [2106.09609]

ATLAS $\tau^+\tau^-$
[1911.06660]



MSSM

BHR _{μ}

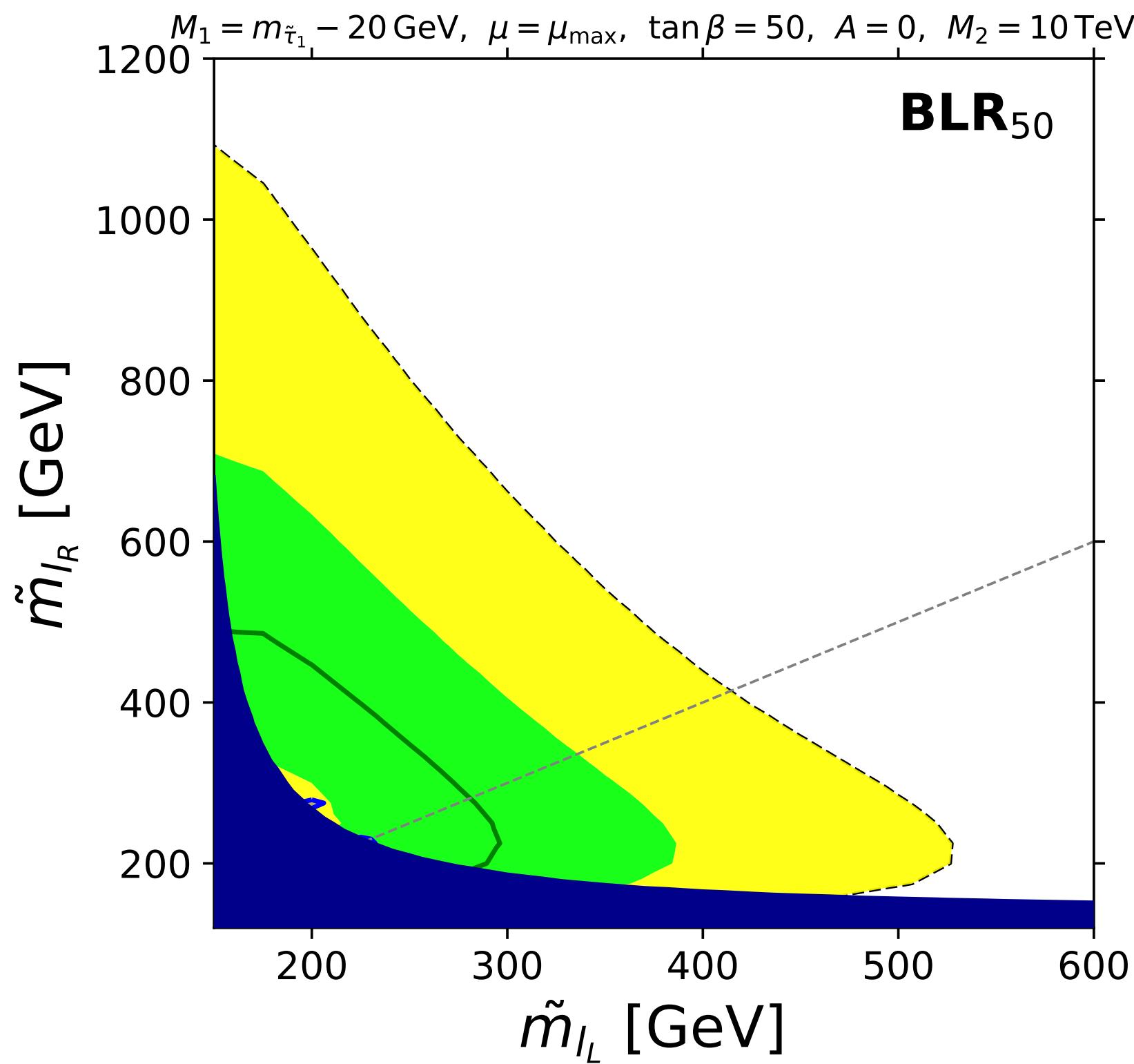
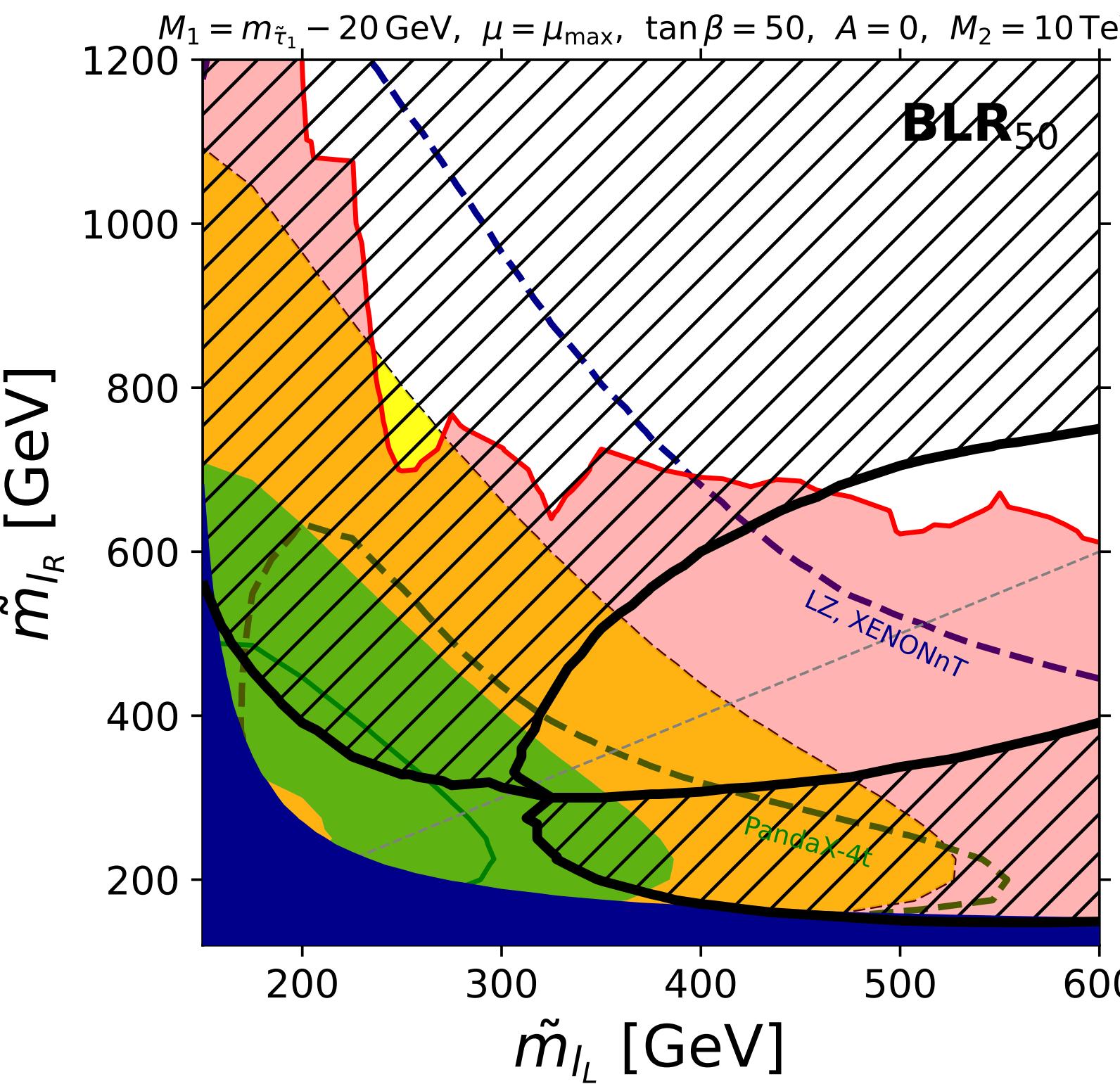
RPV

GMSB

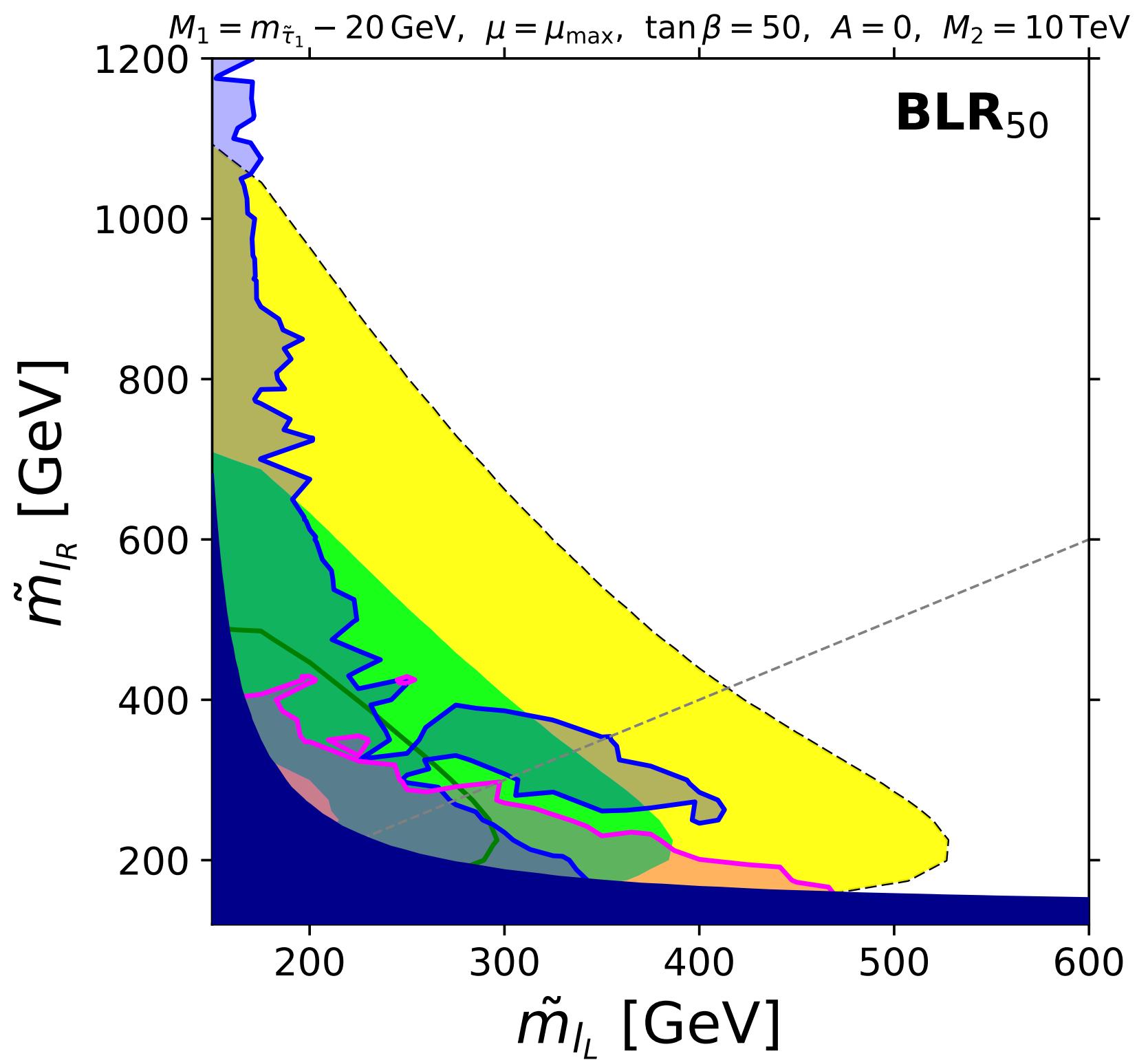
LEP stau mass bond

CMS I+I- [2004.05153]

XENON1T [1805.12562]



CMS multilepton
[1709.05406]



MSSM

BLR₅₀

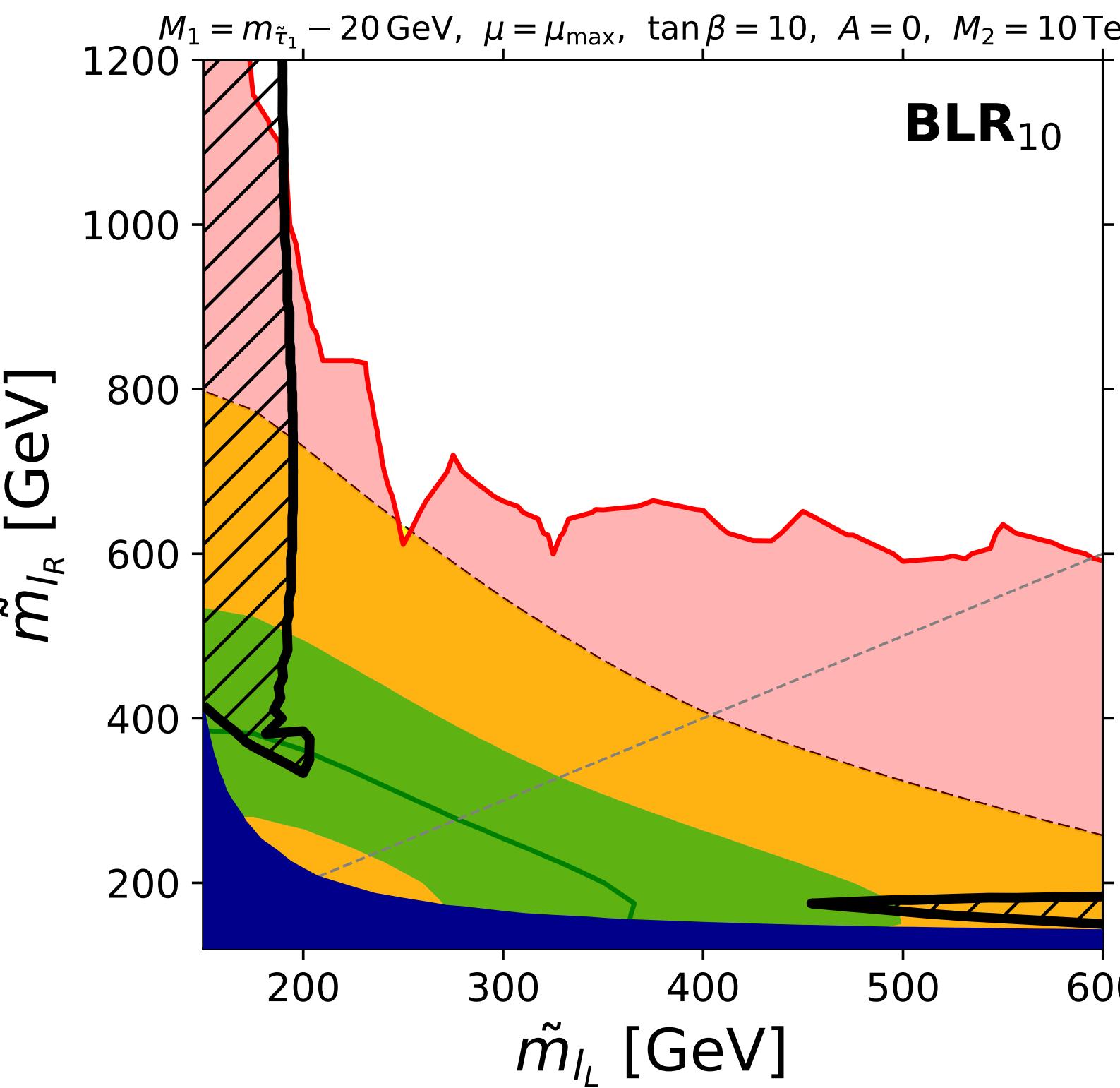
RPV

GMSB

LEP stau mass bond

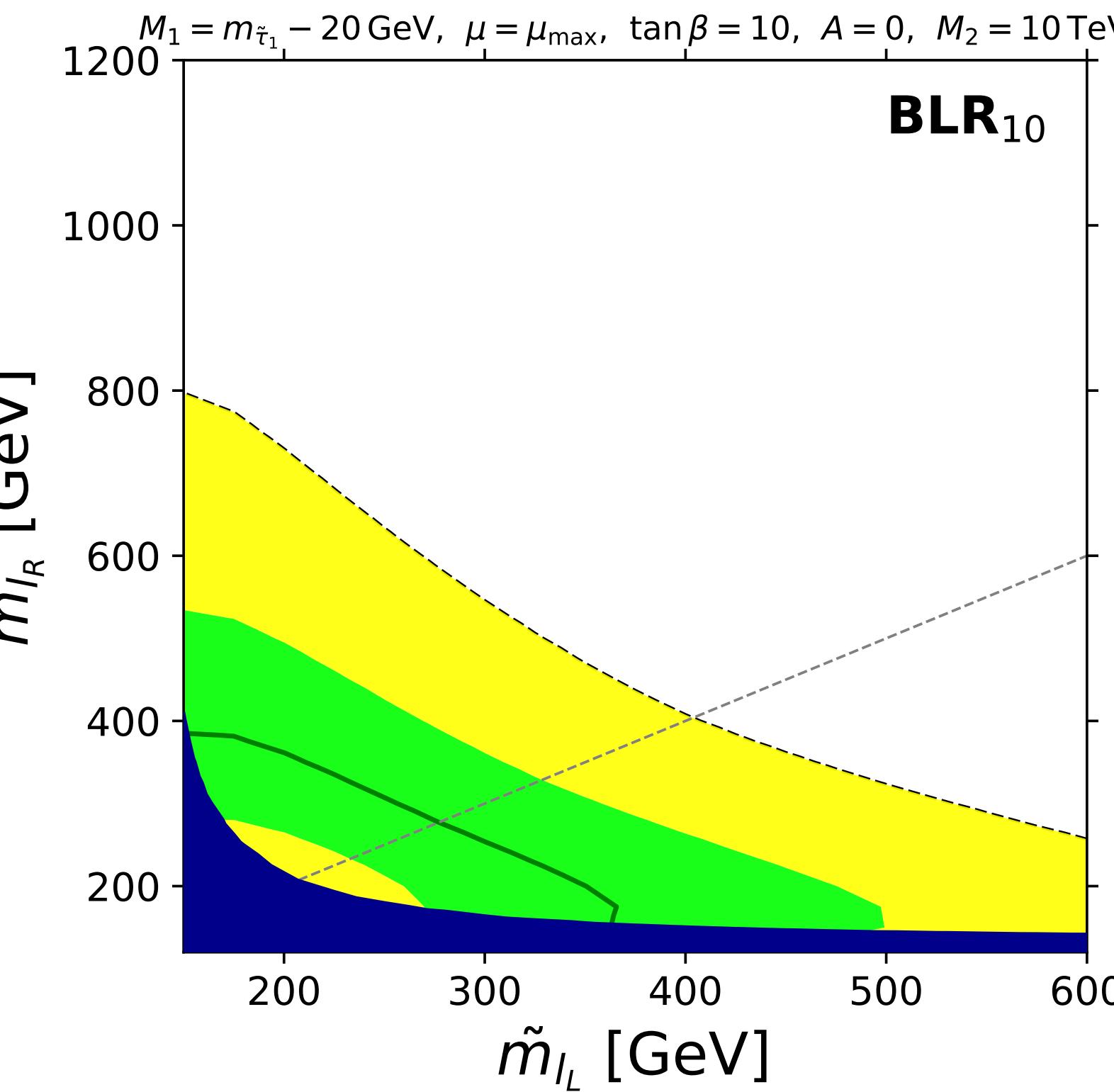
CMS |+| [2004.05153]

XENON1T [1805.12562]



MSSM

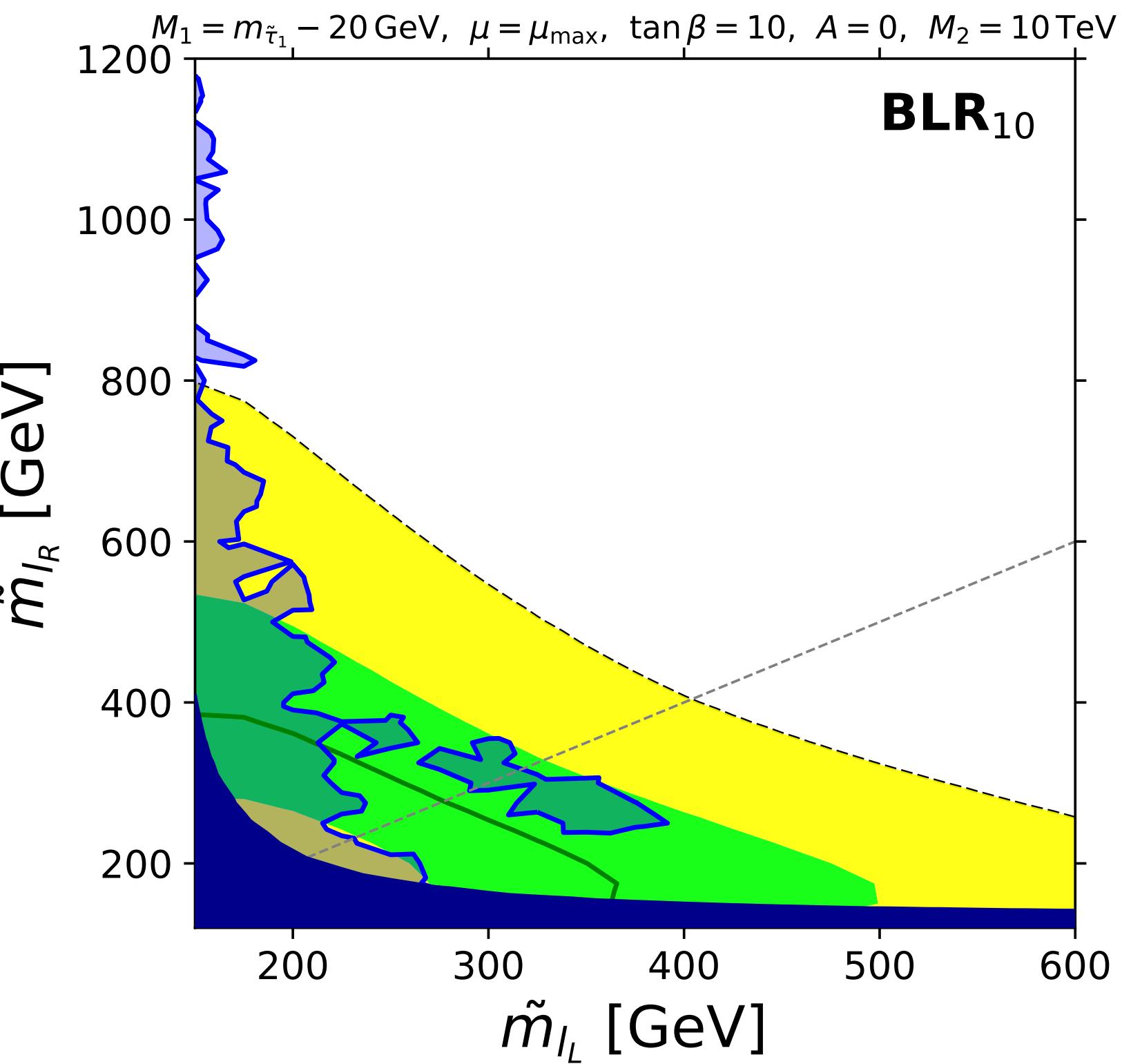
BLR₁₀



RPV

R. Masełek SUSY 2022/06/29

CMS multilepton
[1709.05406]



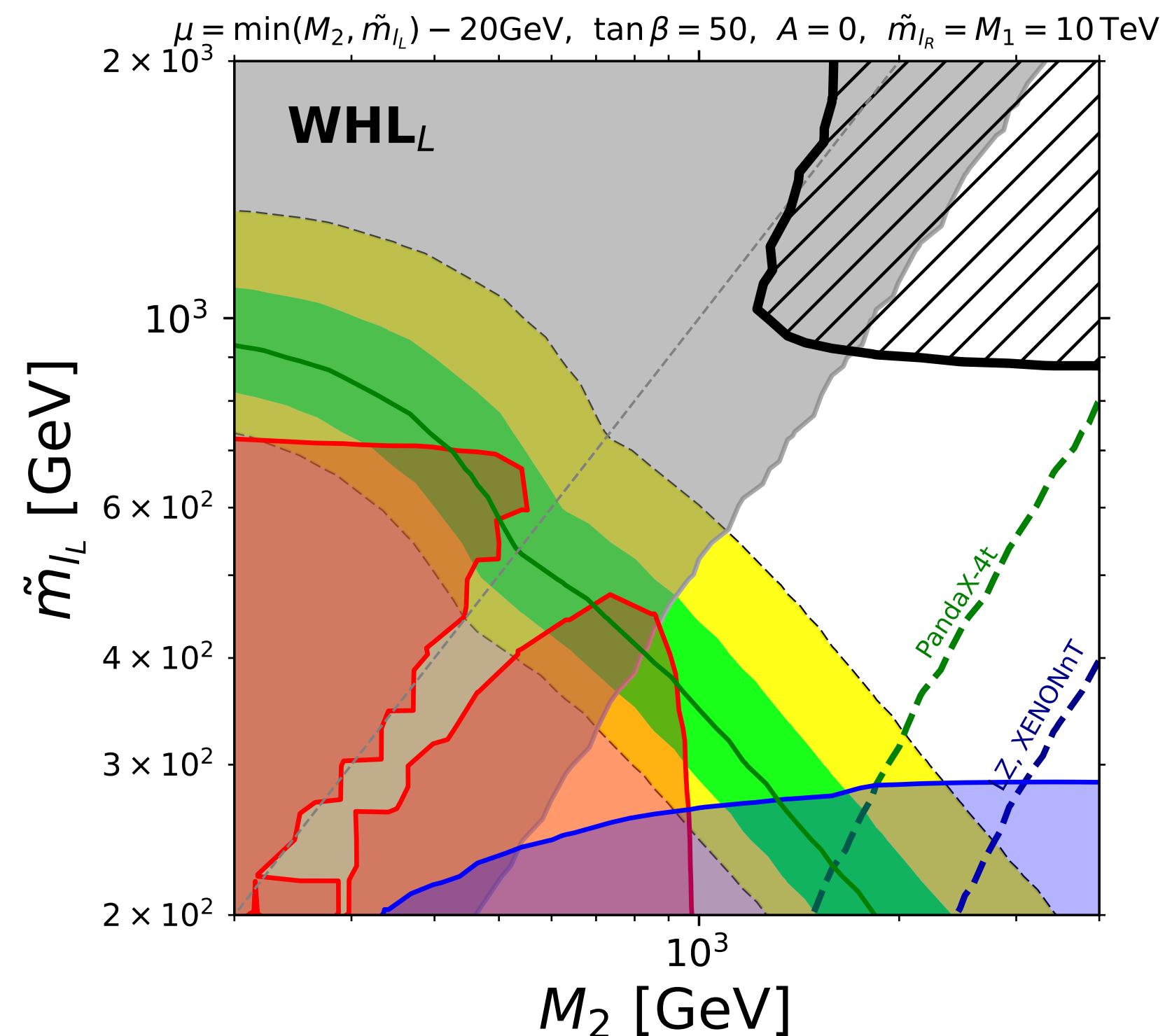
GMSB



ATLAS soft-| [1911.12606]

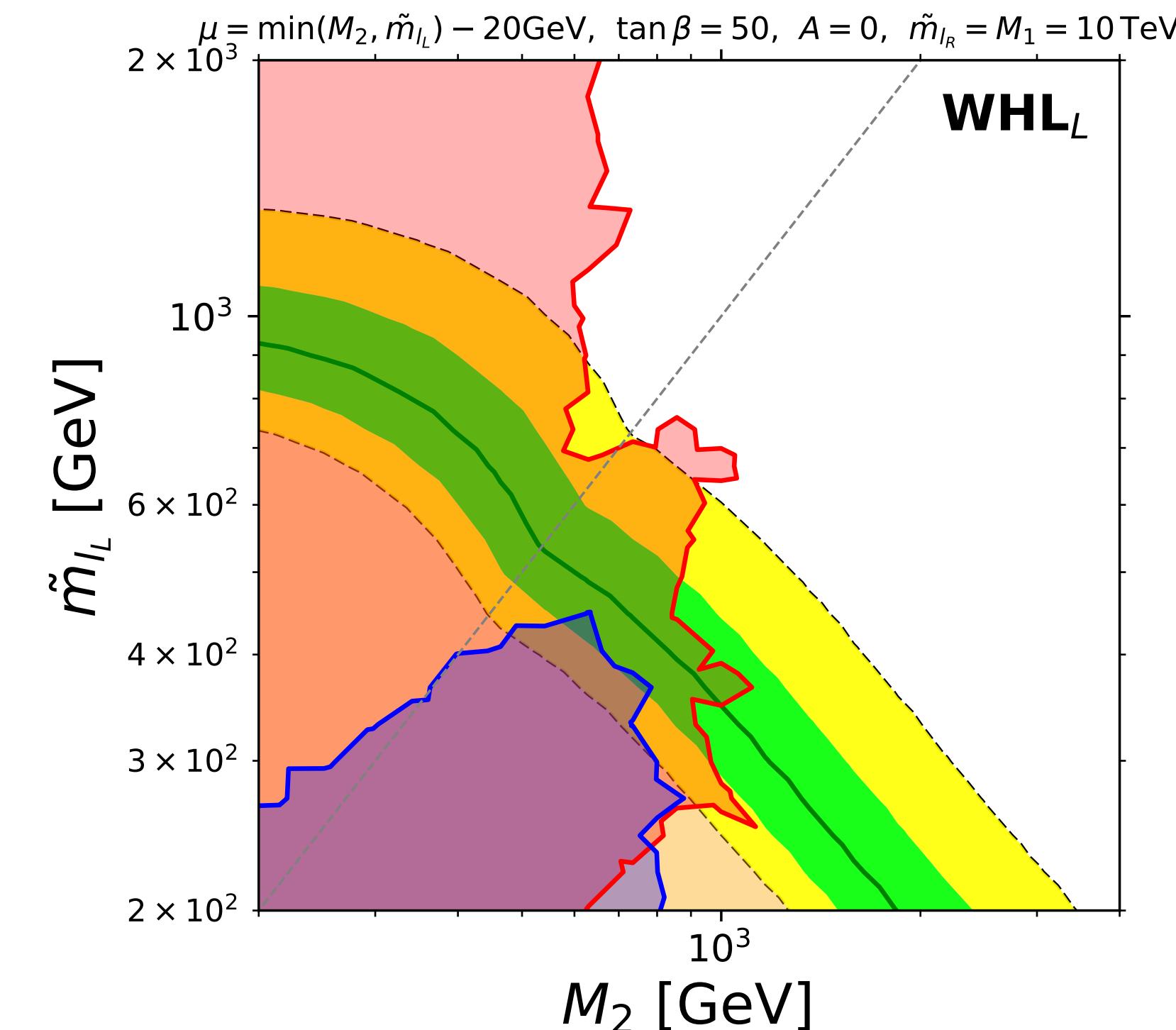
CMS |+|- [2004.05153]

XENON1T [1805.12562]



MSSM

CMS multilepton [1709.05406]
ATLAS multijet+| [2106.09609]



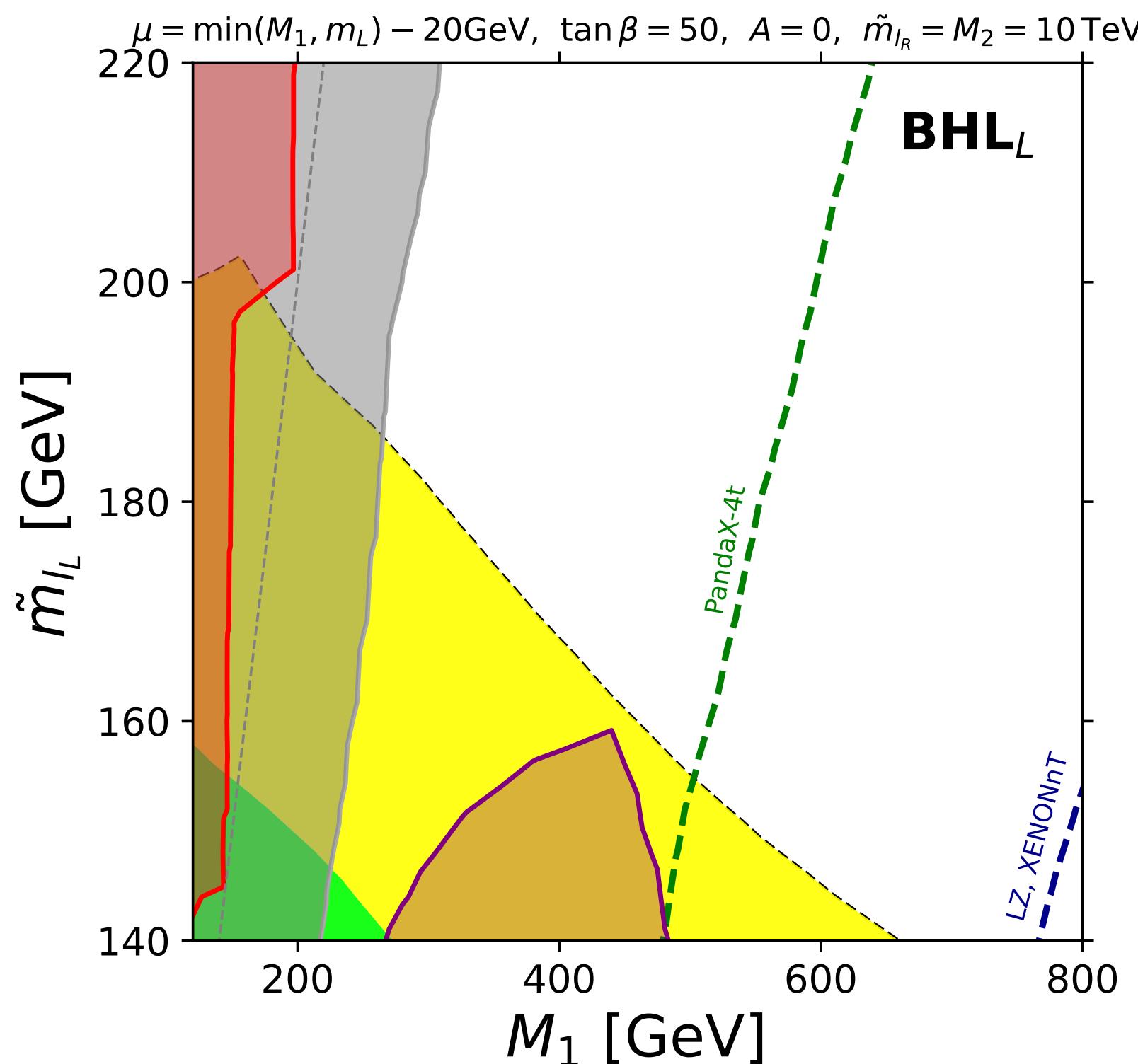
RPV

WHL_L

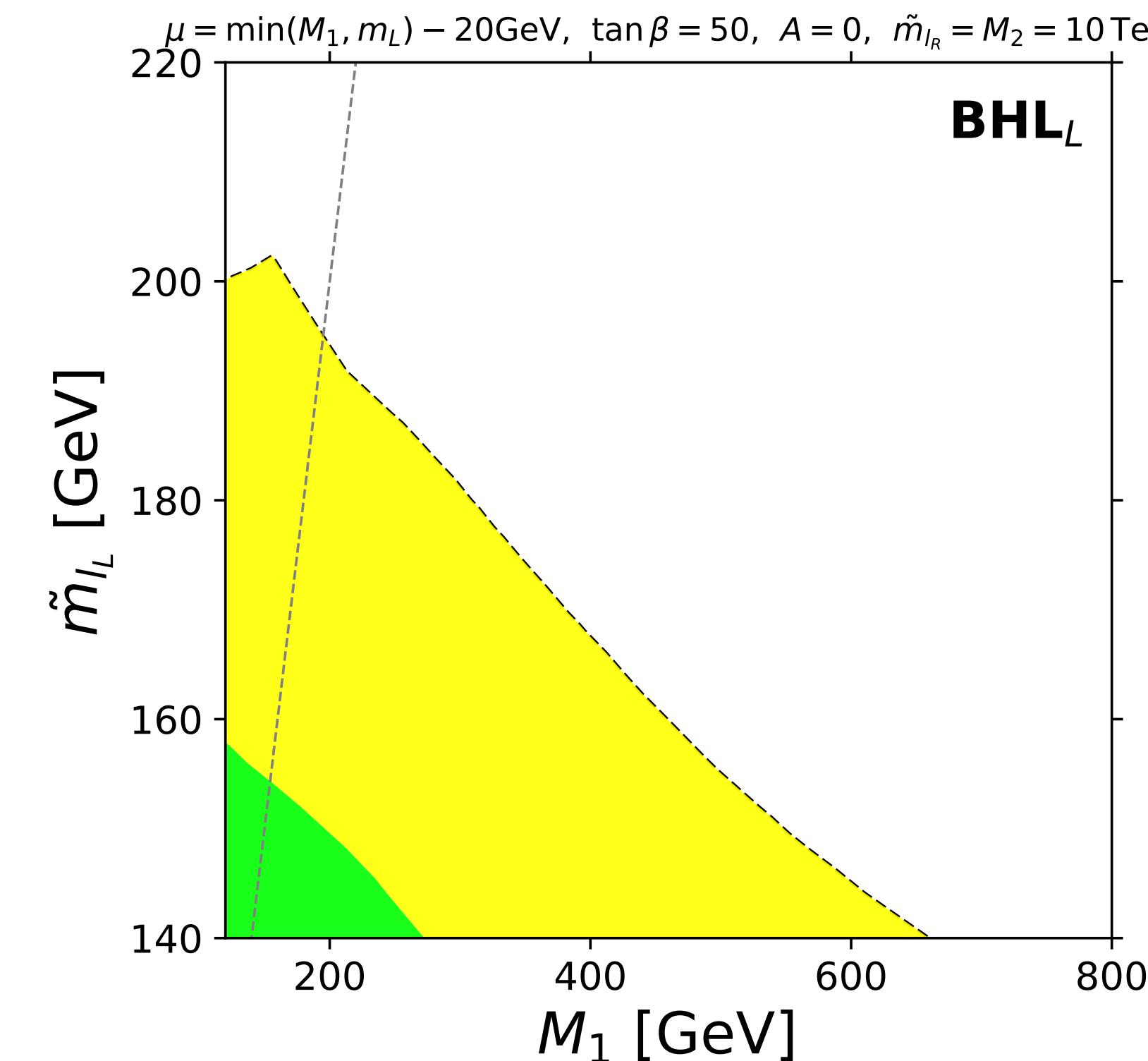
ATLAS soft-| [1911.12606]

CMS |+- [2004.05153]

XENON1T [1805.12562]



MSSM

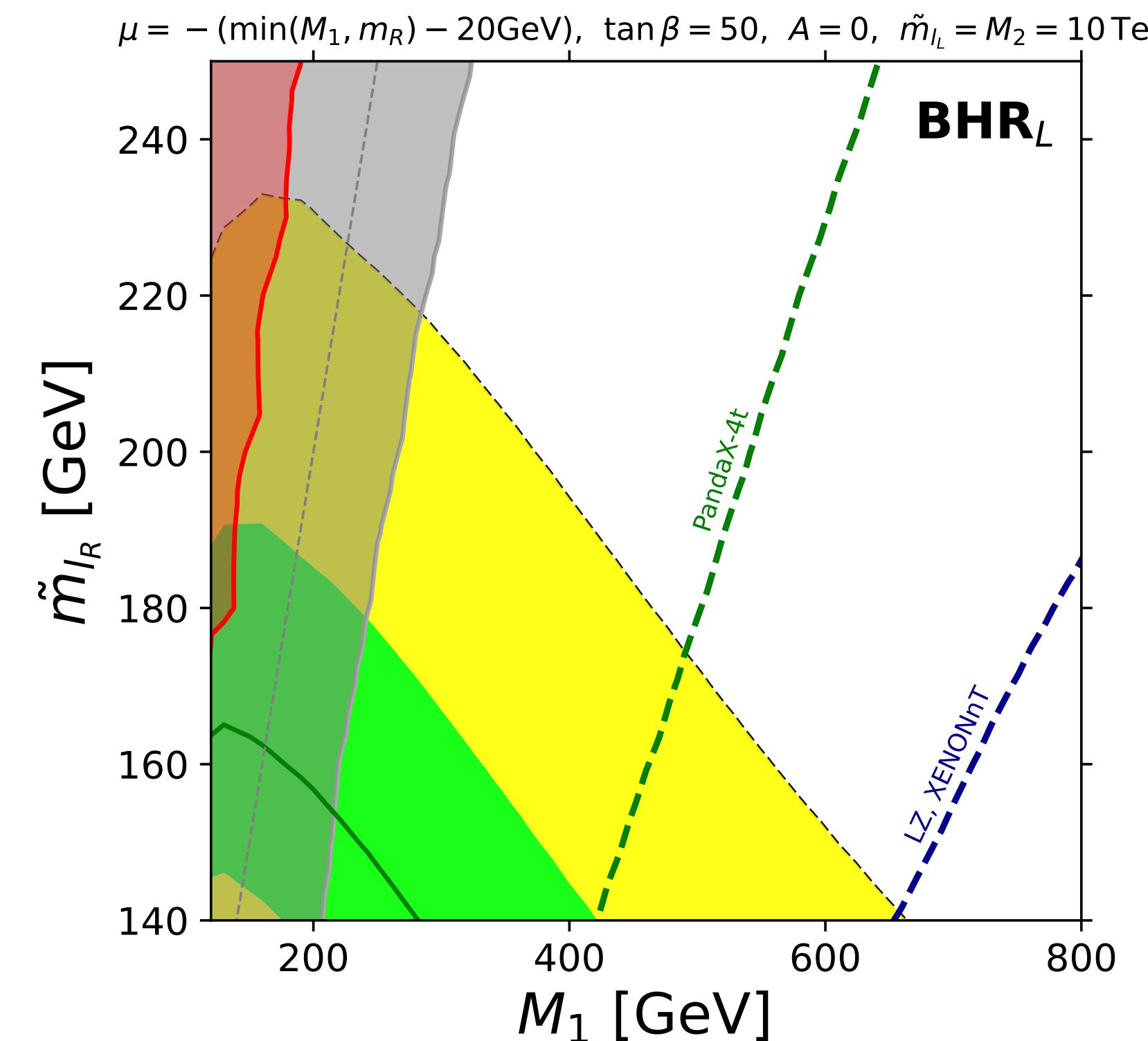


RPV

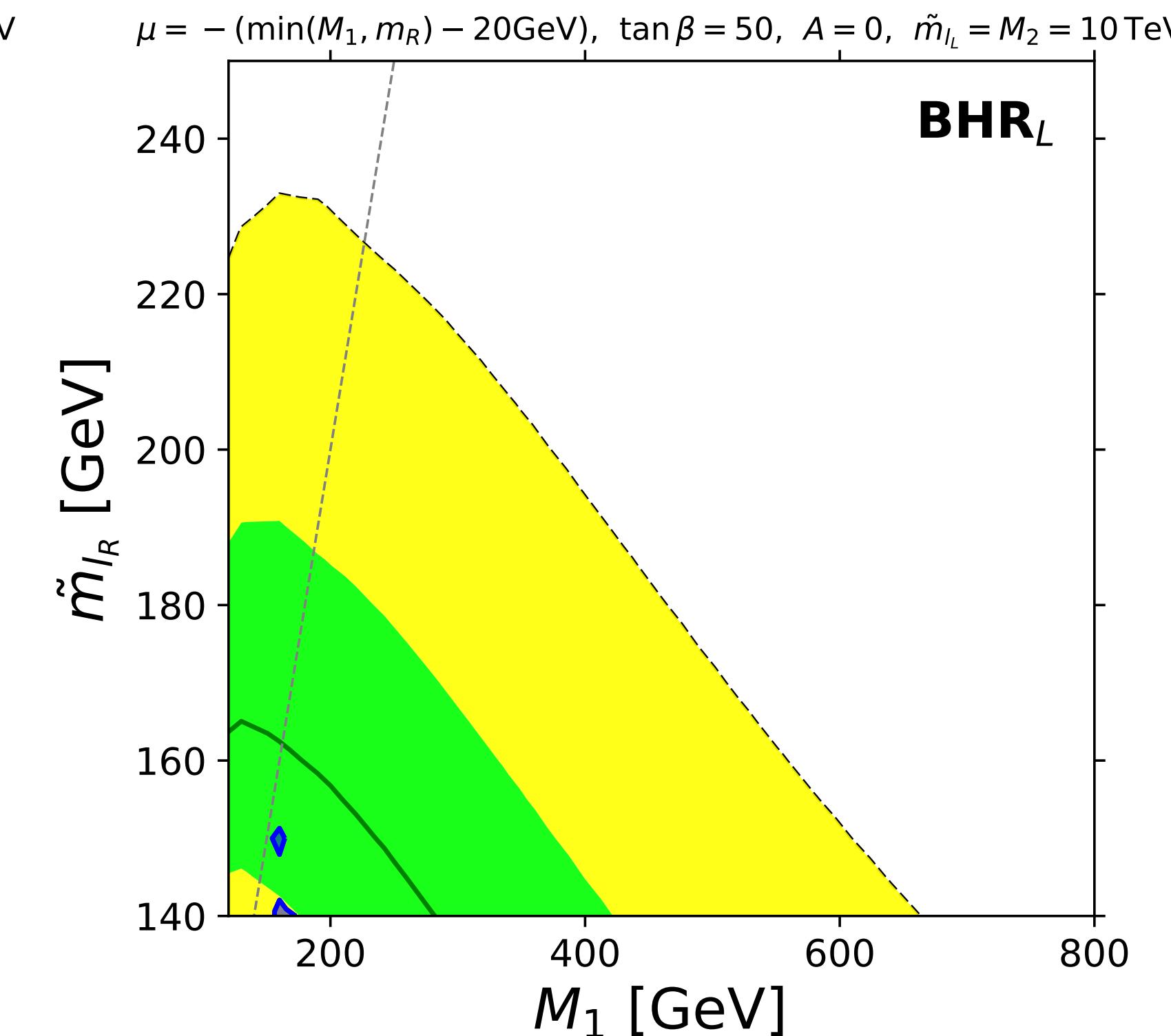
BHL_L

CMS |+|- [2004.05153]

XENON1T [1805.12562]



CMS multilepton [1709.05406]

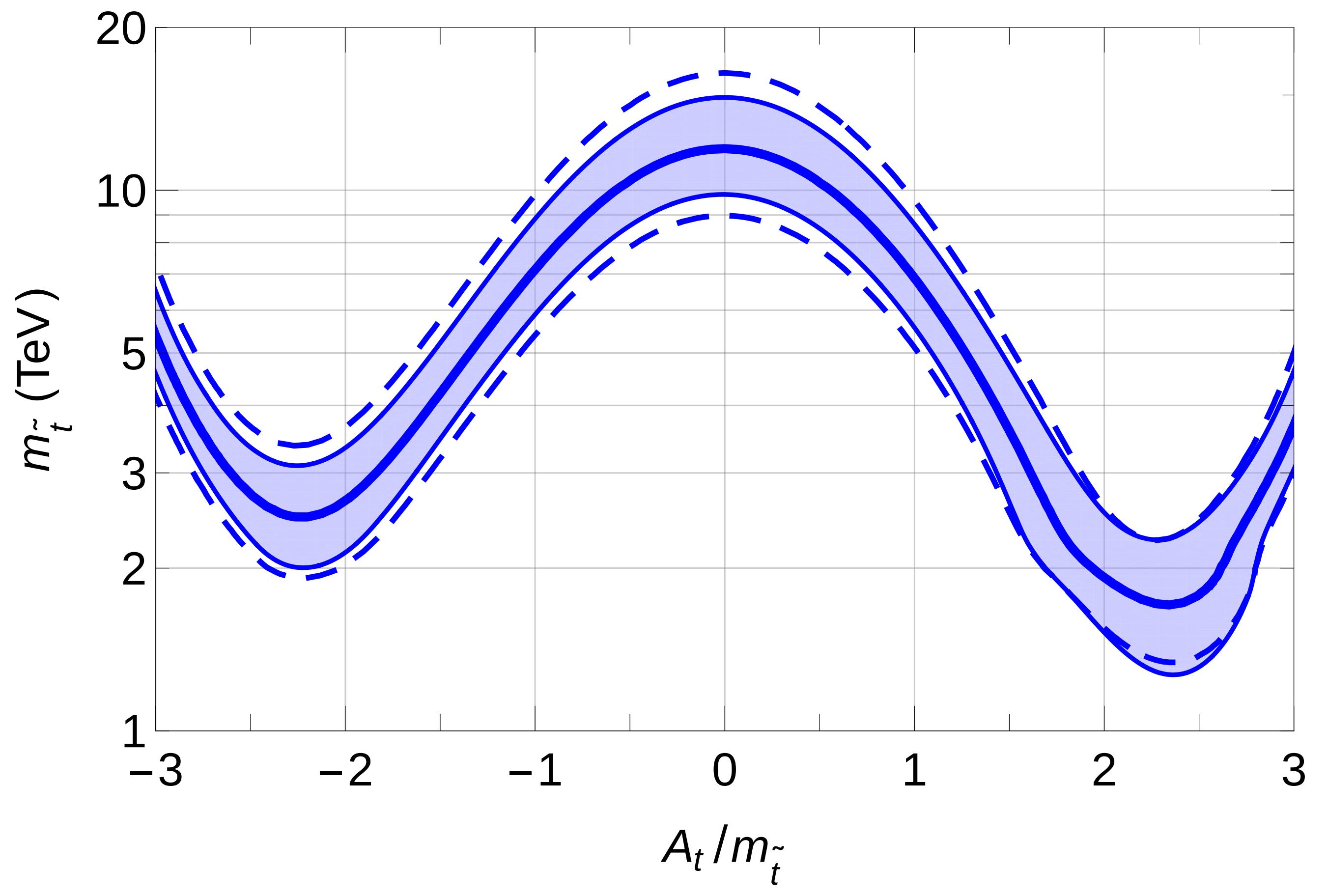


MSSM

RPV

$$m_{\tilde{G}} = \frac{F_X}{\sqrt{3}M_{\text{Pl}}}, \quad M_3 = \frac{\alpha_3}{4\pi} \frac{F_X}{M_{\text{mess}}}$$

$$m_{\tilde{G}} = \sim 10 \text{ eV} \cdot \left(\frac{m_{\tilde{t}}}{10 \text{TeV}} \right) \left(\frac{M_{\text{mess}}}{10 \text{TeV}} \right)$$

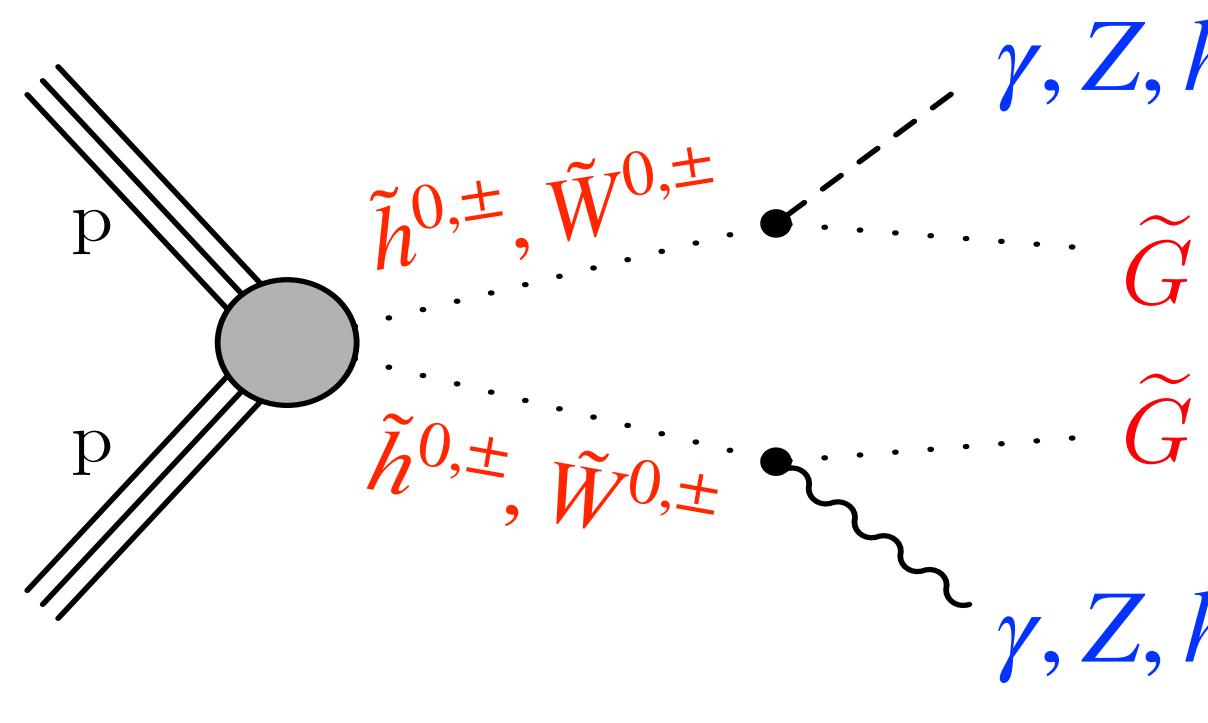


[1504.05200]

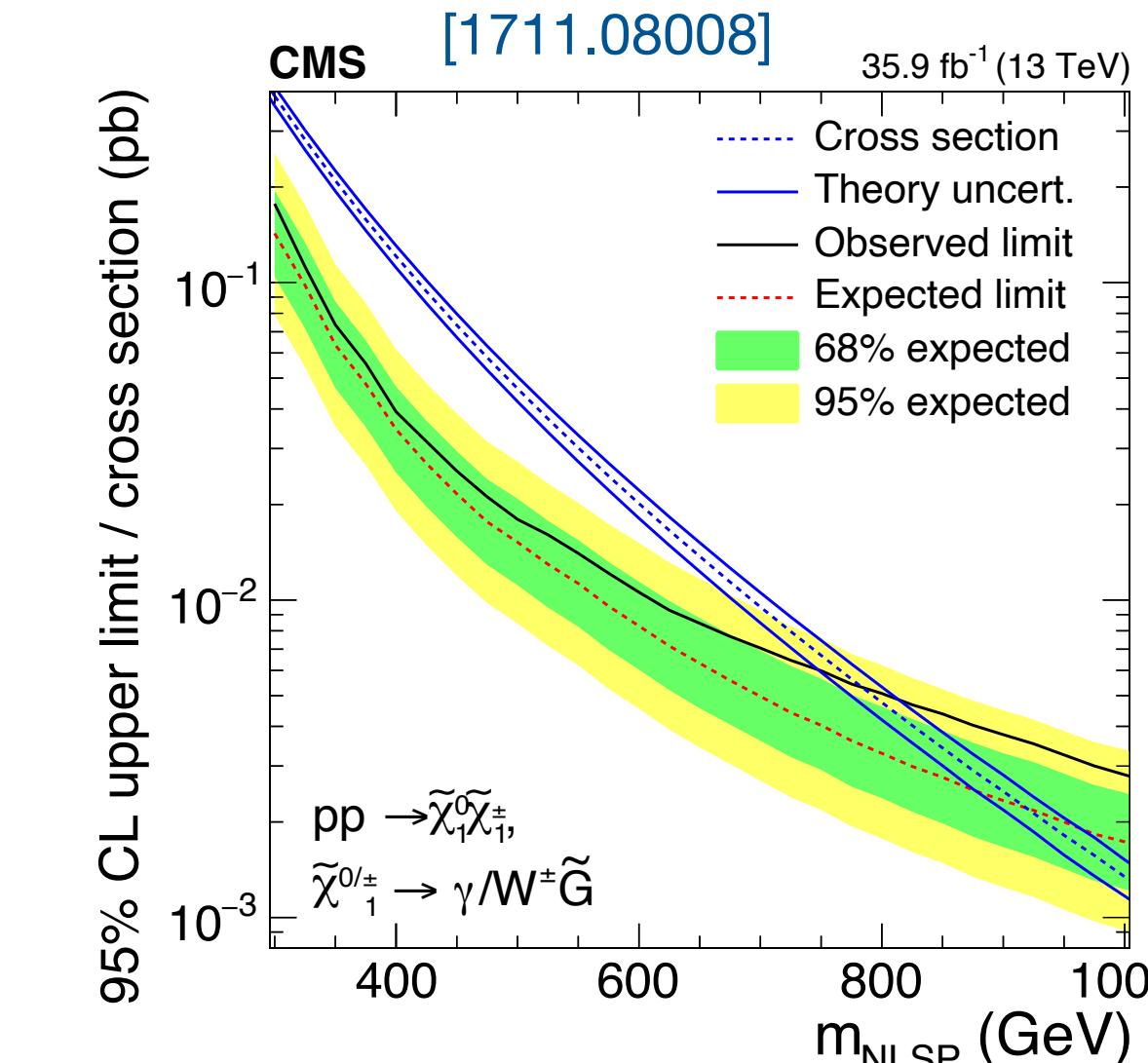
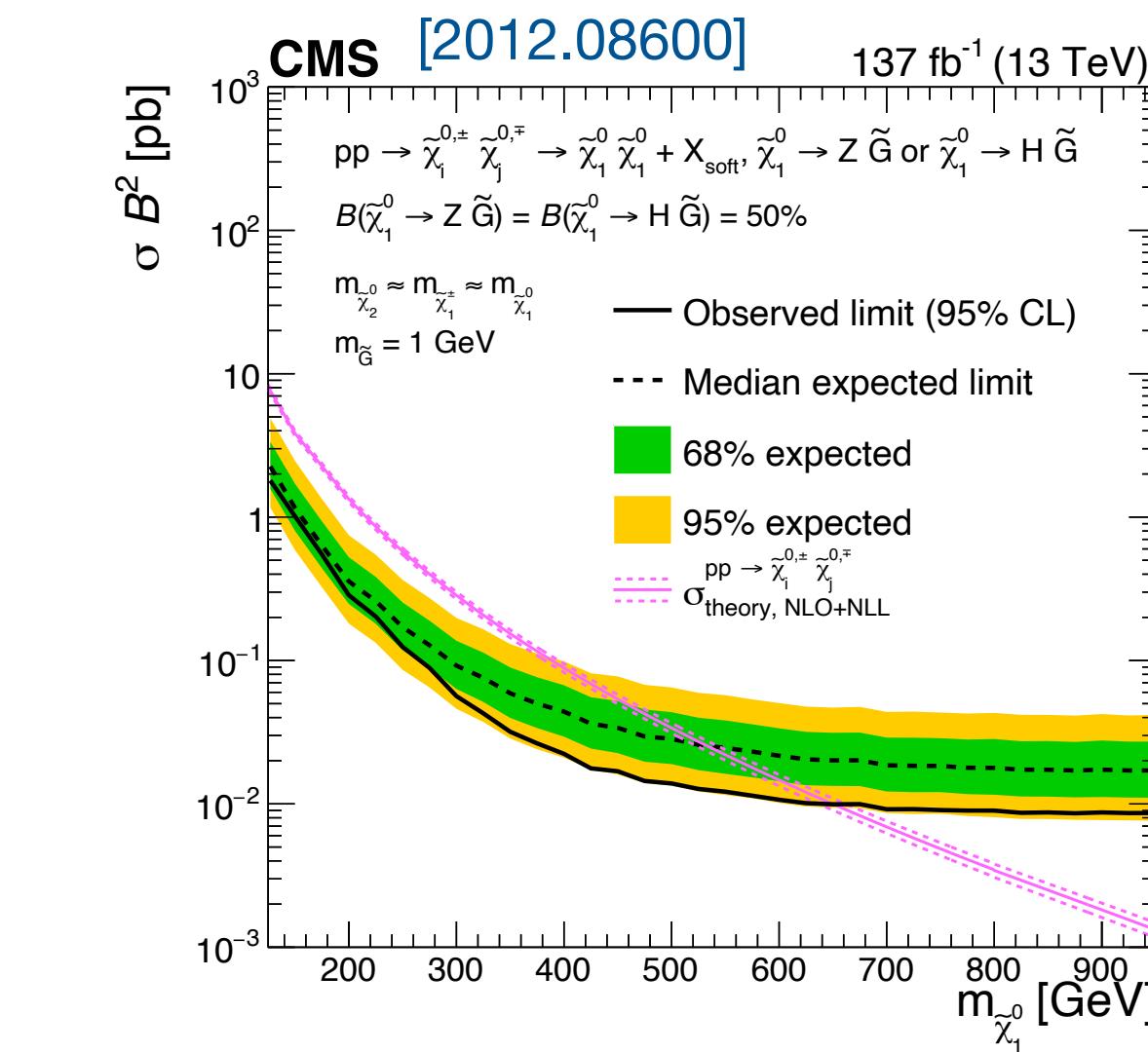
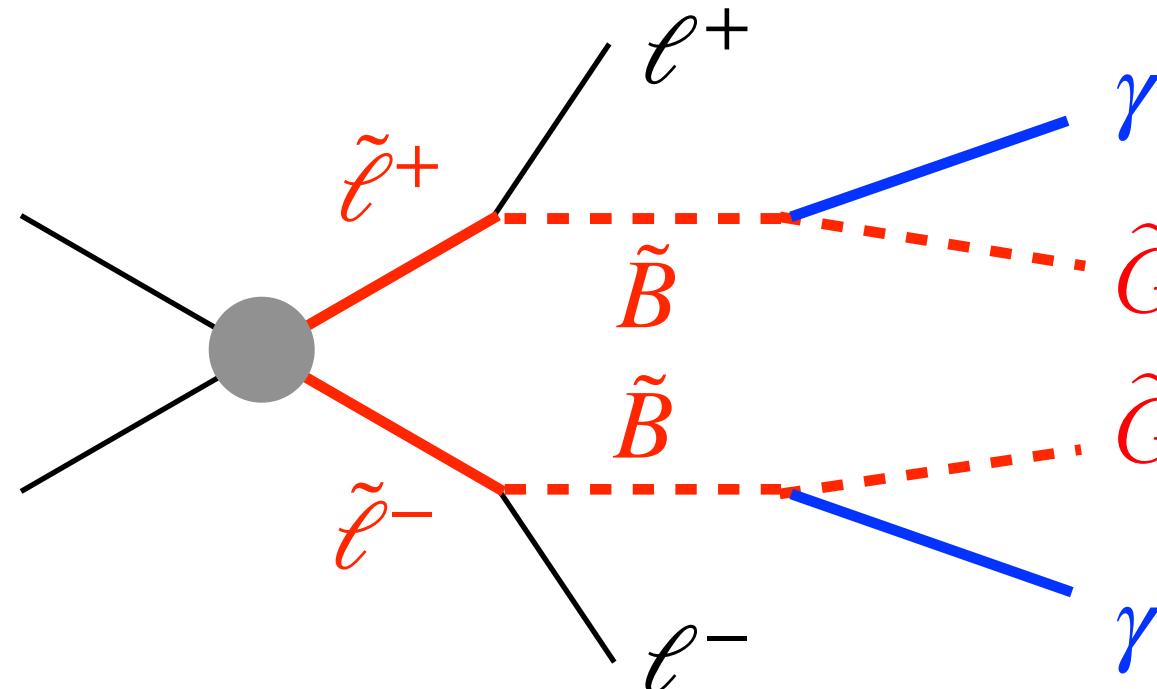
Gravitino LSP

We assume a **massless** gravitino ($m < 1\text{GeV}$) and **prompt** neutralino decay.

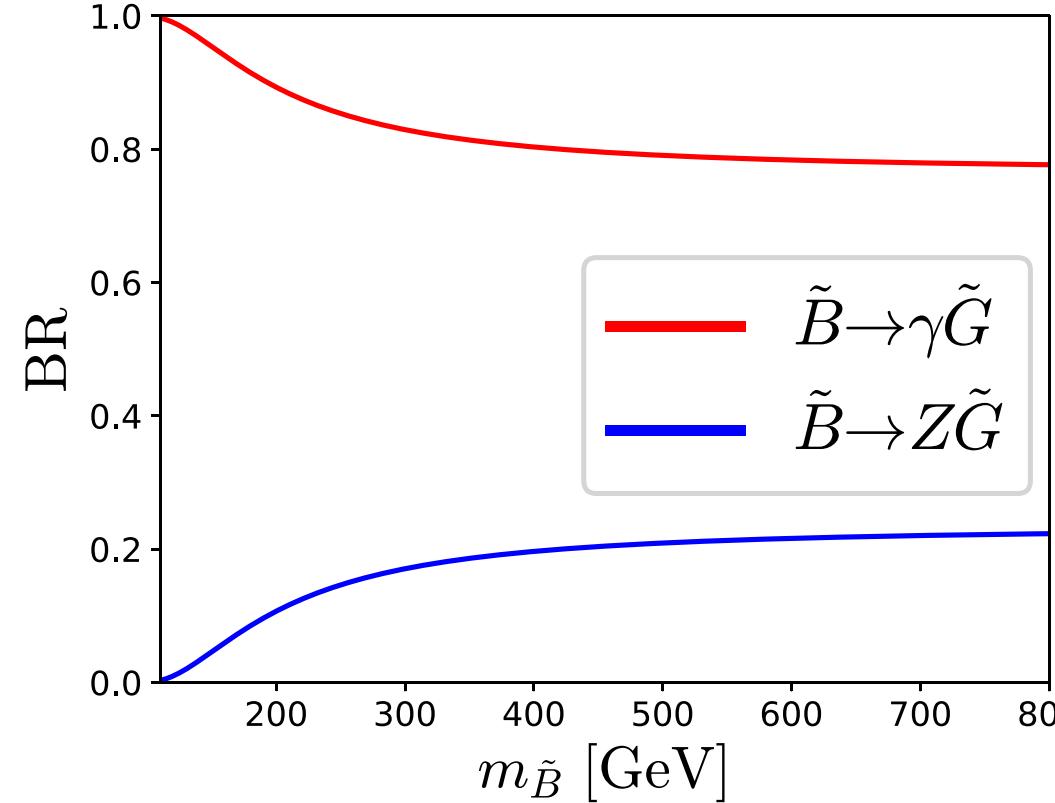
Wino, Higgsino NLSP



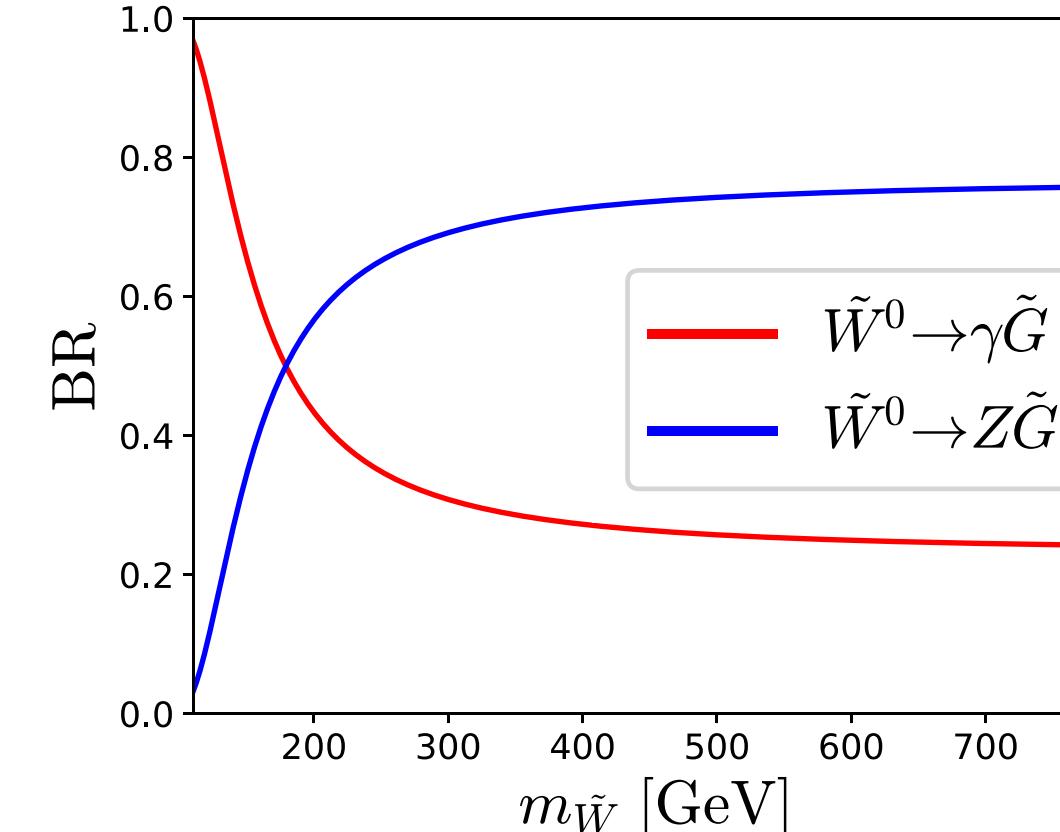
Bino NLSP



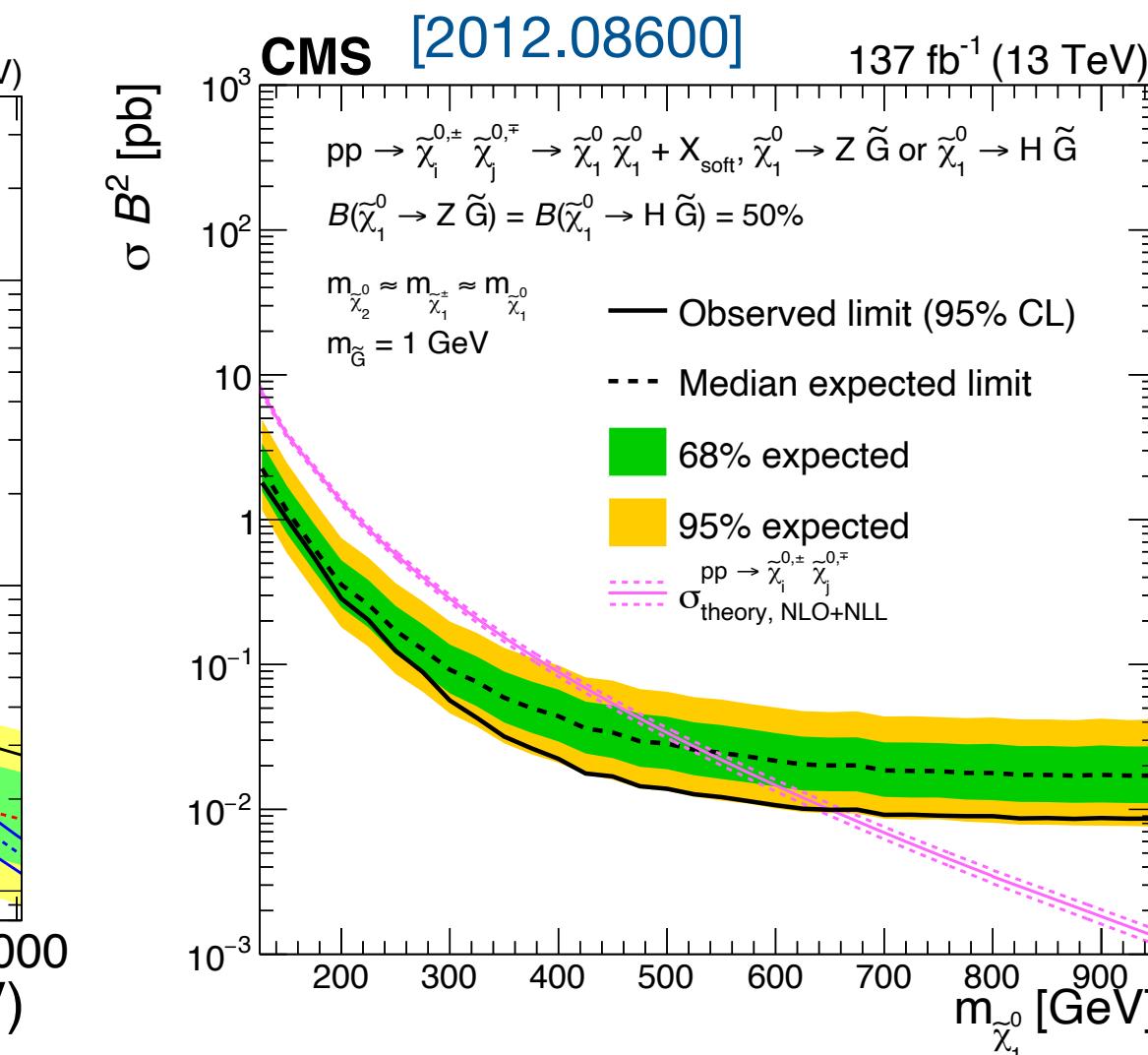
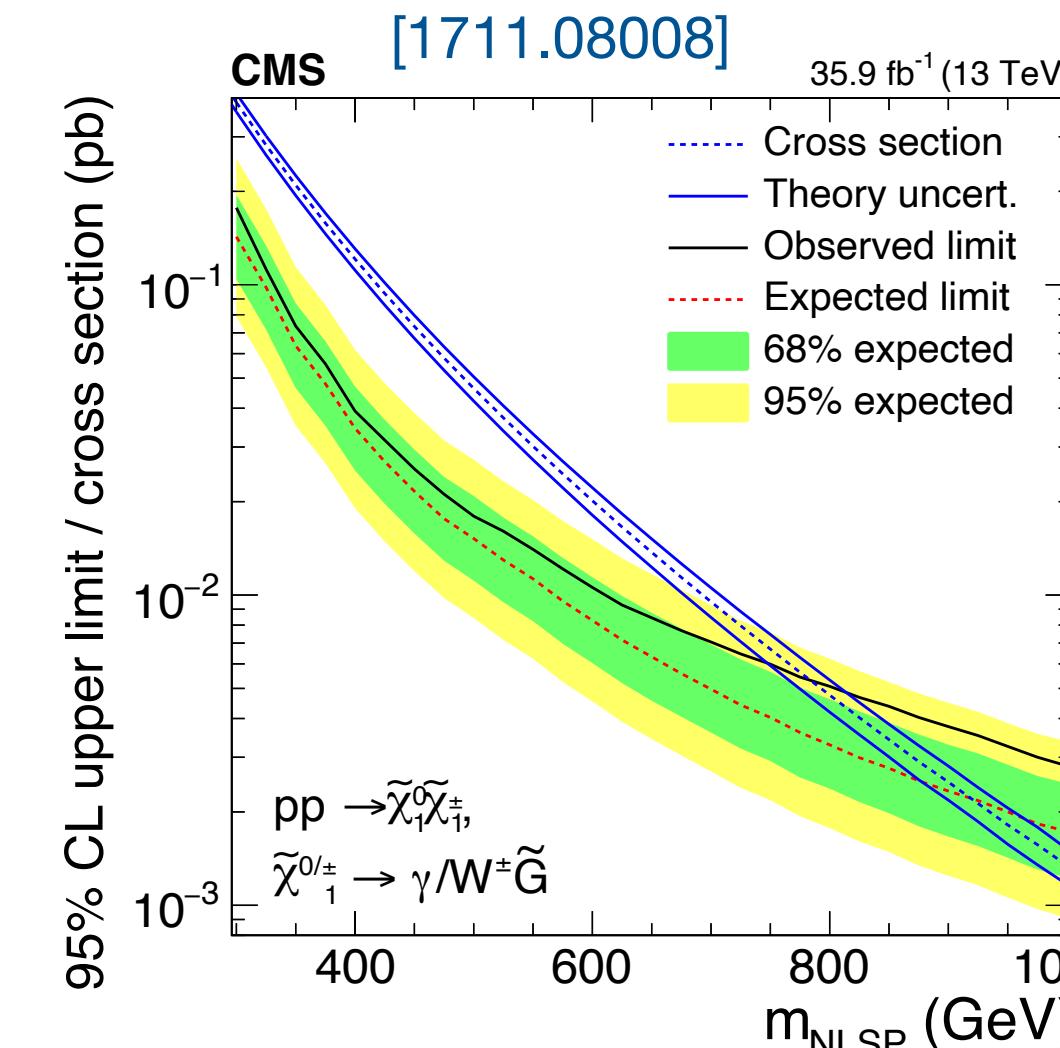
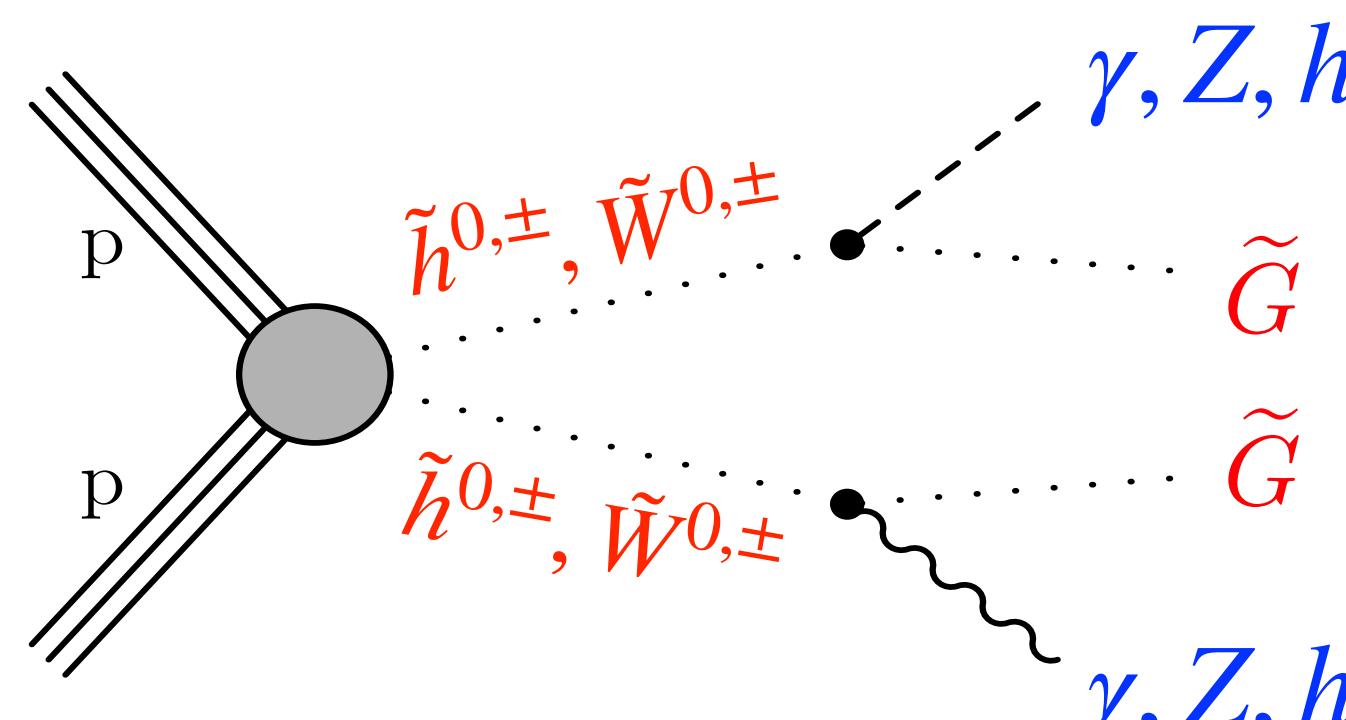
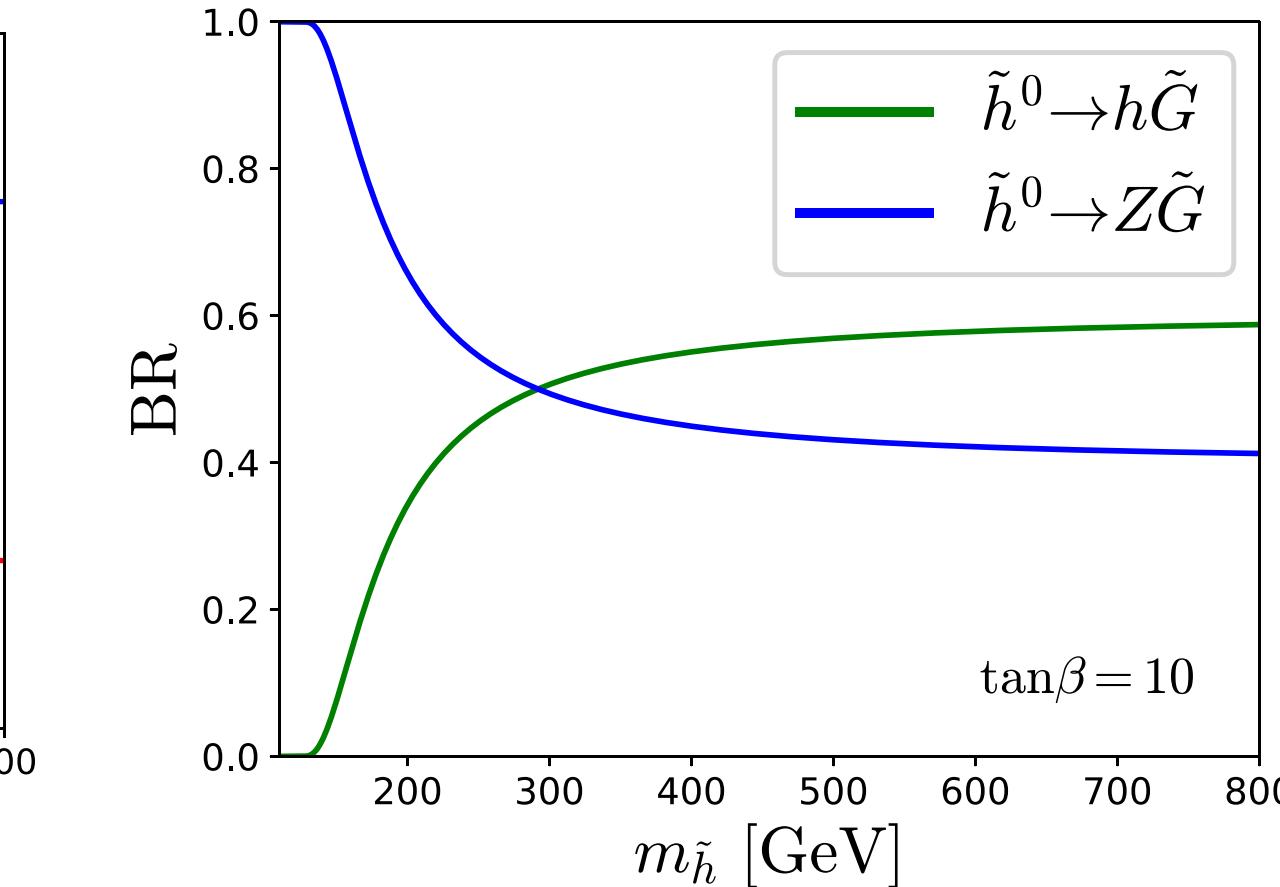
Bino-like



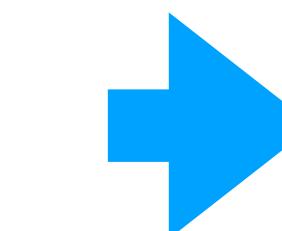
Wino-like



Higgsino-like

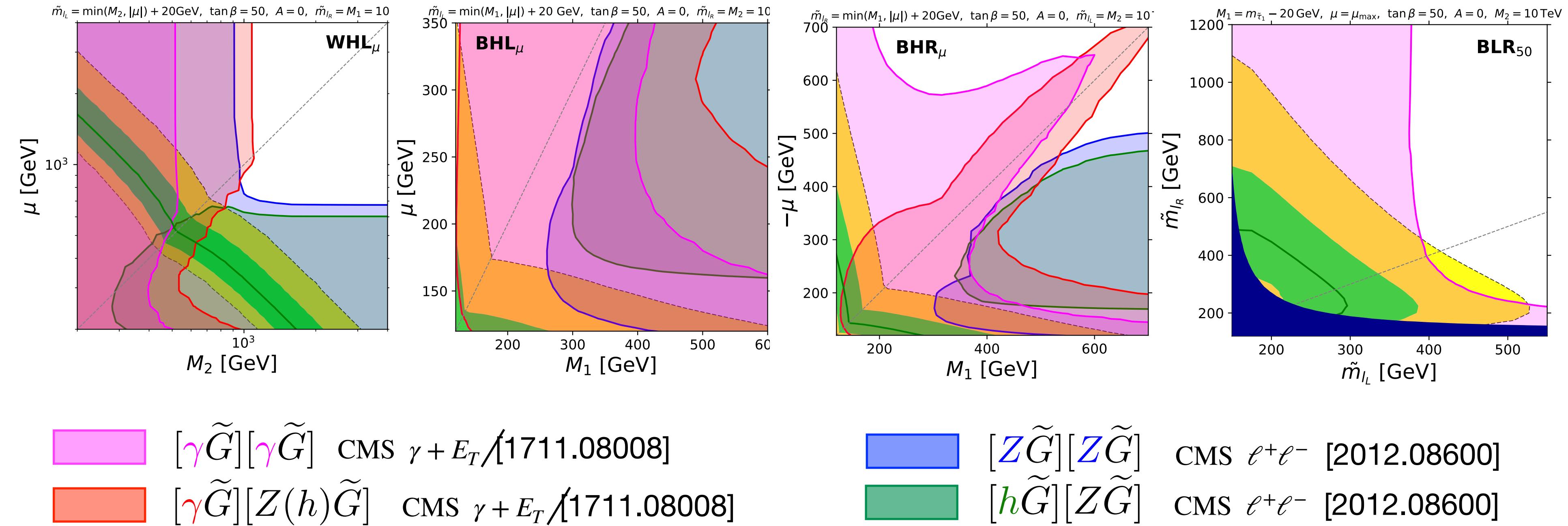


- Higgsino, Wino direct production excluded up to $\sim 700\text{GeV}$
- SUSY g-2 requires Higgsino or Wino with $m < 600\text{ GeV}$



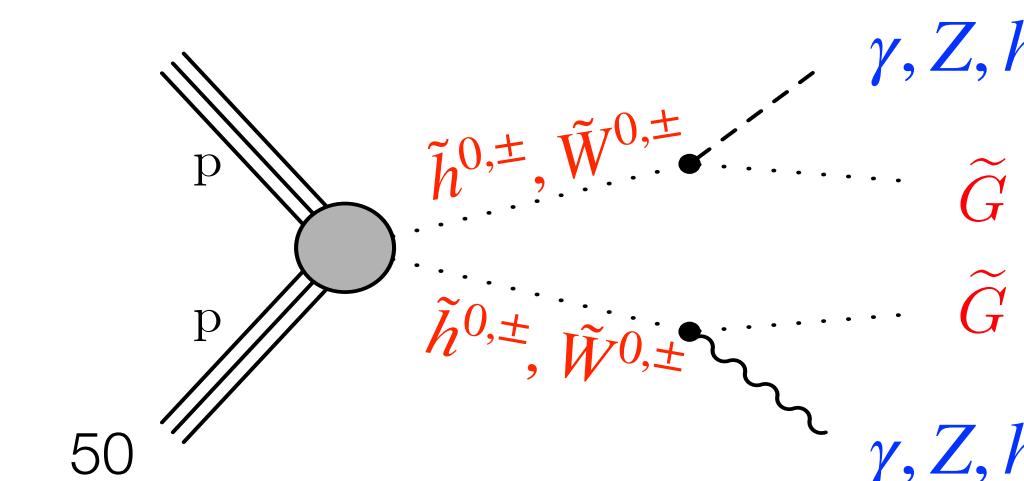
**SUSY $(g-2)_\mu$
incompatible
with LHC**

Gravitino LSP

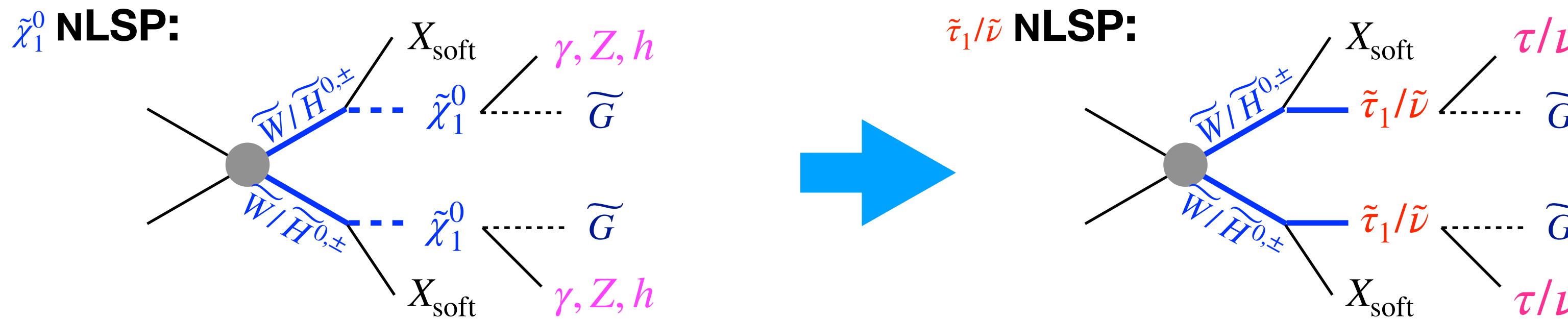


[(massless) gravitino LSP + neutralino NLSP] cannot explain muon g-2

Unlike MSSM, in gravitino LSP, one cannot hide high pT decay products and E_T^{miss} by making mass spectrum compressed.



Gravitino LSP with slepton NLSP



WHL plane:

$$(M_2 \text{ vs } \mu) \text{ with } \tilde{m}_{l_L} = \min(M_2, \mu) + 20 \text{ GeV} \implies m_{l_L} = \min(M_2, \mu) - 20 \text{ GeV} \quad \left. \right\} \tilde{\nu}_L \text{ NLSP}$$

BHL plane:

$$(M_1 \text{ vs } \mu) \text{ with } \tilde{m}_{l_L} = \min(M_1, \mu) + 20 \text{ GeV} \implies m_{l_L} = \min(M_2, \mu) - 20 \text{ GeV} \quad \left. \right\} \tilde{\nu}_L \text{ NLSP}$$

BHR plane:

$$(M_1 \text{ vs } \mu) \text{ with } \tilde{m}_{l_R} = \min(M_1, |\mu|) + 20 \text{ GeV} \implies m_{l_R} = \min(M_1, \mu) - 20 \text{ GeV} \quad \left. \right\} \tilde{e}_R, \tilde{\mu}_R, \tilde{\tau}_R \text{ NLSP}$$

BLR plane:

$$(\tilde{m}_{l_L} \text{ vs } \tilde{m}_{l_R}) \text{ with } M_1 = m_{\tilde{\tau}_1} - 20 \text{ GeV} \implies M_1 = m_{\tilde{\tau}_1} + 20 \text{ GeV} \quad \left. \right\} \tilde{\tau}_1 \text{ NLSP}$$