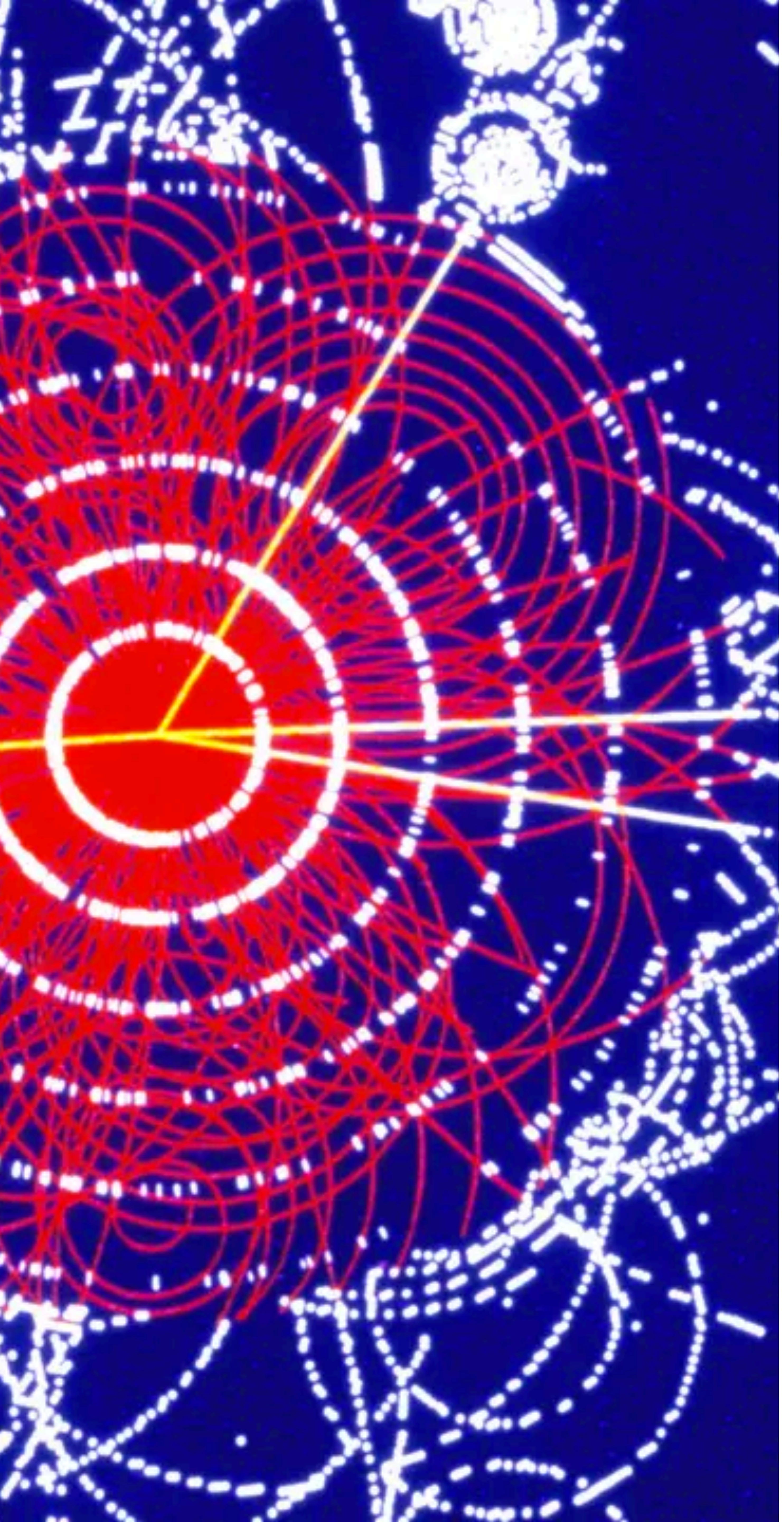


NATIONAL SCIENCE CENTRE
POLAND

FACULTY OF PHYSICS
UNIVERSITY OF WARSAW

Muon g-2 in SUSY with and without stable neutralinos

Rafał Masełek

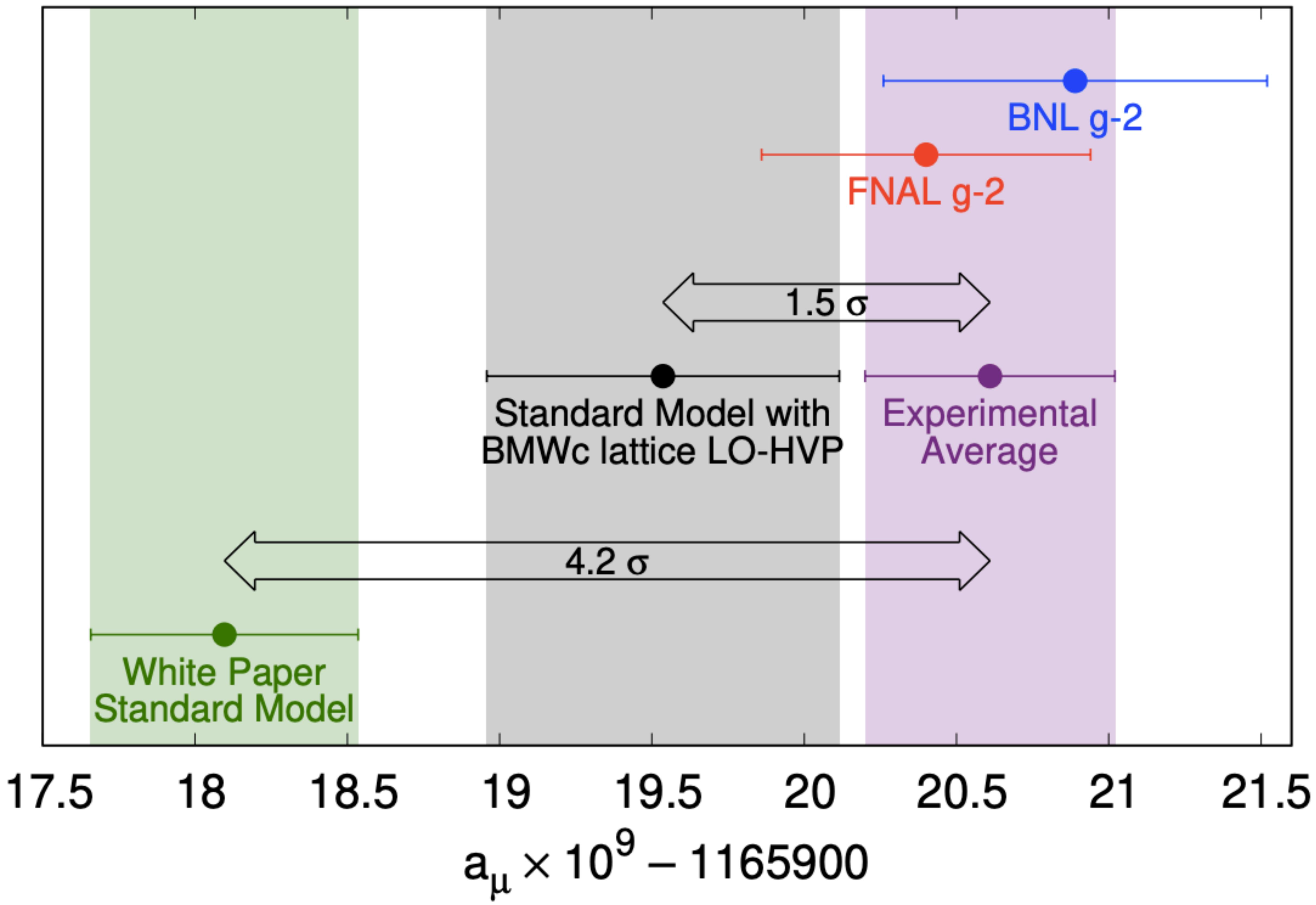
M. Chakraborti, J. S. Kim, S. Iwamoto, K. Sakurai

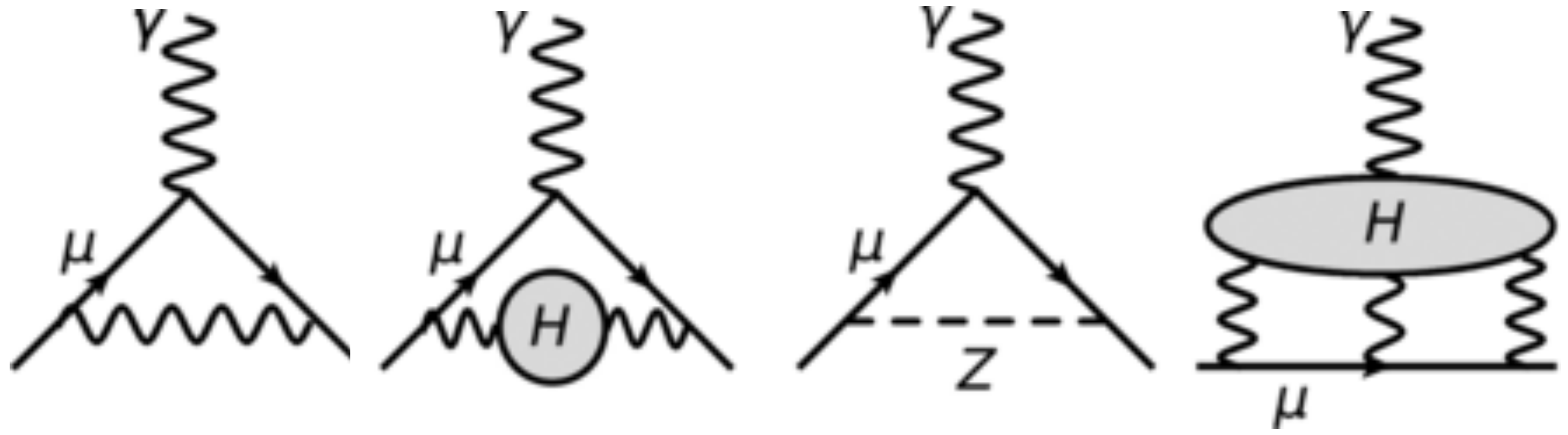
Based on JHEP 08 (2022) 124; https://doi.org/10.1007/JHEP08(2022)124

R. Masełek Corfu Summer Institute 2022/09/05

Work supported by NCN SONATA BIS 7 GRANT (2017/26/E/ST2/00135) and NCN BEETHOVEN GRANT (2016/23/G/ST2/04301) and NCN PRELUDIUM20 (2021/41/N/ST2/00972)

$(g-2)_\mu$ anomaly





			QED	HVP	EW	HLbL
a_μ^{theo}	=	0.00	1165	91	810	(43)
a_μ^{exp}	=	0.00	1165	92	061	(41)

↑ statistical error dominant

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

[Muon g-2, Phys. Rev. Lett. 126, 141801]
[T. Aoyama et al., , Phys. Rep. 887, 1 (2020)]
[L. Lellouch, Moriond 2022 EW]

Motivation

Many BSM scenarios can explain the $(g\text{-}2)_\mu$ 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 $(g\text{-}2)_\mu$?

MSSM

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

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

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 $(g\text{-}2)_\mu$?

RPV DM constraints GMSB

XENON1T/PANDA/LZ/ARGO ...

$(g\text{-}2)_\mu$ viable parameters

Muon g-2 ATLAS/CMS

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

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

RPV DM constraints GMSB

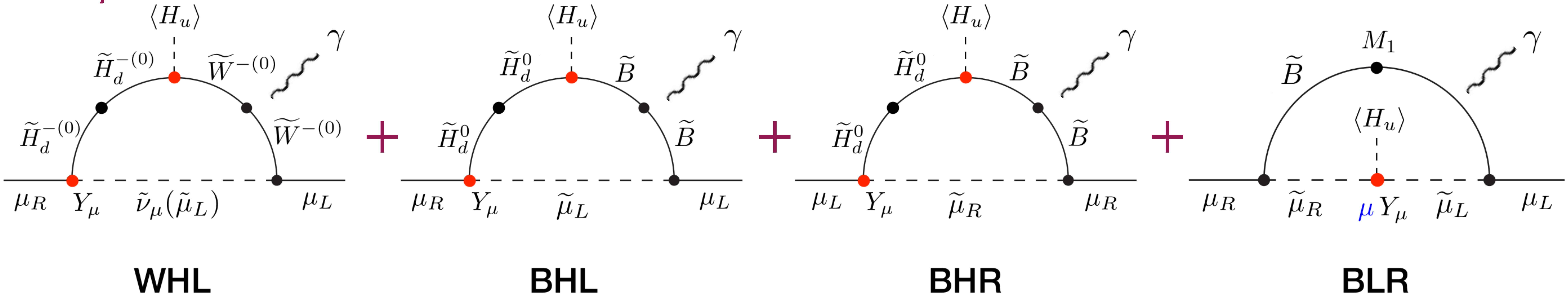
XENON1T/PANDA/LZ/ARGO ...

2D parameter planes

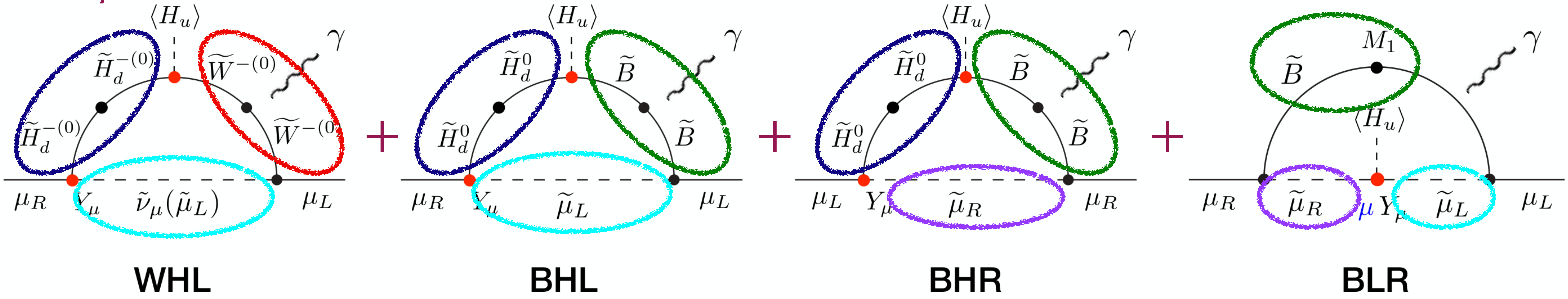
$(g\text{-}2)_\mu$ in SUSY

Malbork Castle, Poland
photo from museum’s FB page

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

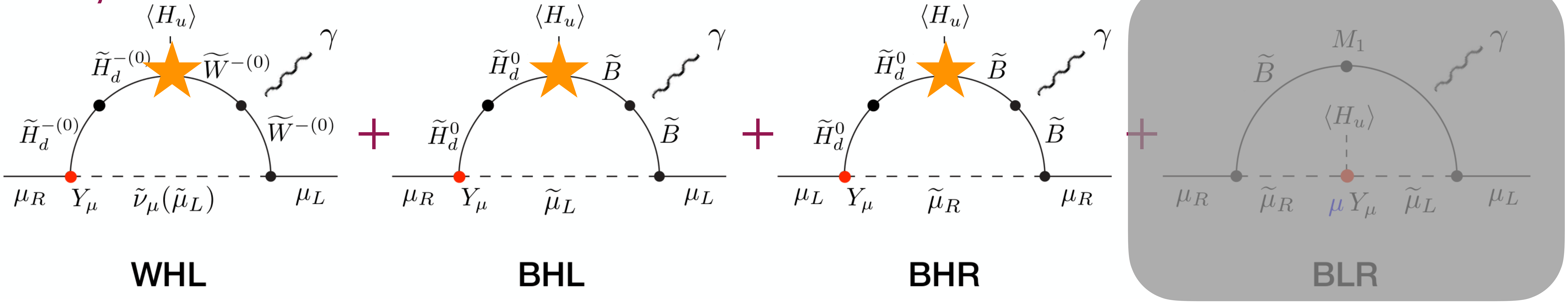


$\Delta a_\mu^{\text{SUSY}} \simeq$



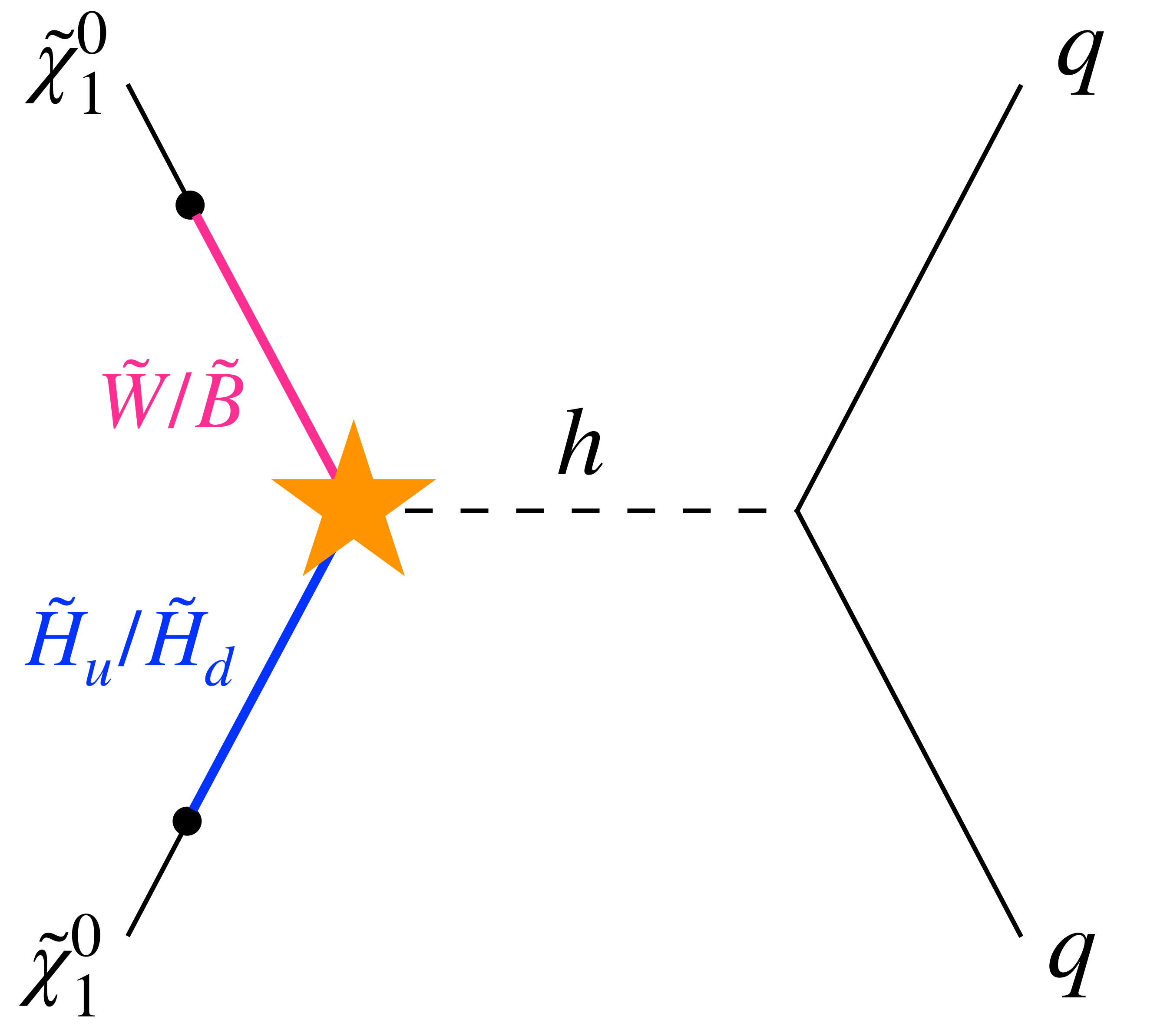
- M_1: Bino mass
- M_2: Wino mass
- μ: Higgsino mass
- $m_{\tilde{l}_R}$: right-handed slepton mass
- $m_{\tilde{l}_L}$: left-handed slepton mass
- $\tan\beta \equiv \langle H_u \rangle / \langle H_d \rangle$

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

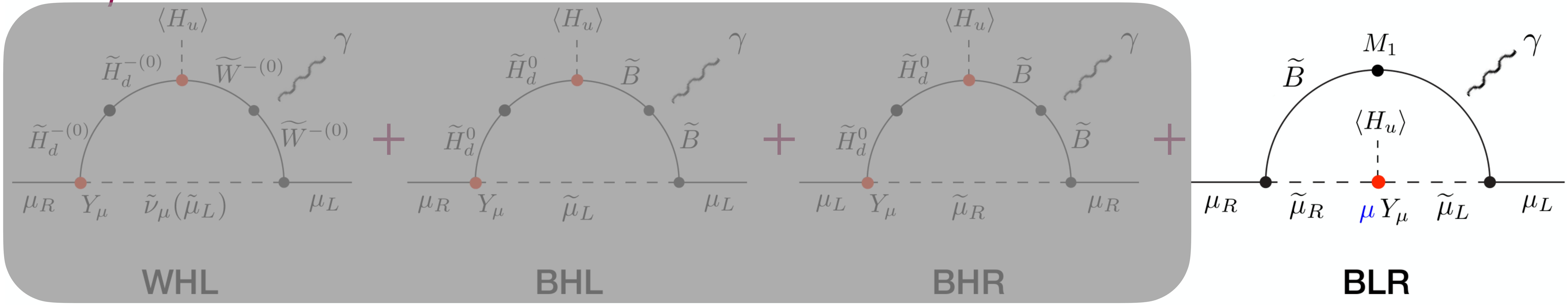


tension

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



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



tension

Bino has very small annihilation cross-section

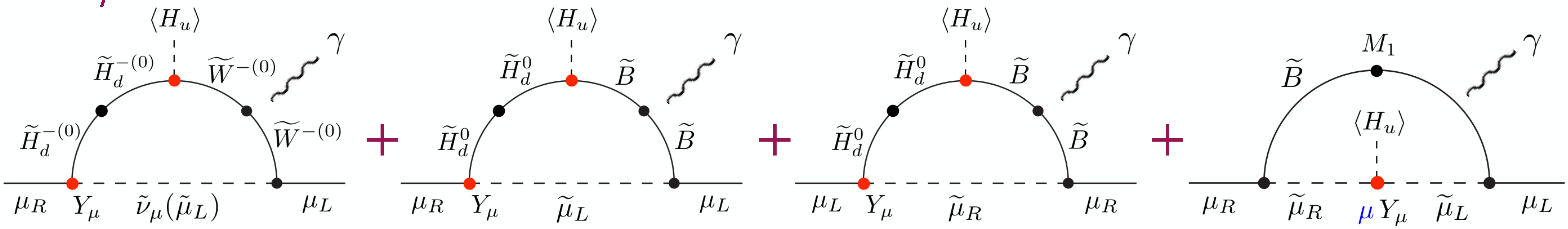
- overproduction of Bino-like neutralinos in the early Universe: $\Omega_{\tilde{\chi}_1^0} < \Omega_{\rm DM}$
- slepton-coannihilation needed: $m_{\tilde{l}} \sim m_{\tilde{B}}$

Large off diagonal term in stau mass matrix:

- charge breaking vacuum: $m^2_{\tilde{\tau}_1} > 0$
- LEP bound: $m_{\tilde{\tau}_1} > 81.9$ GeV
- stau LSP: $m_{\tilde{\tau}_1} > m_{\tilde{\chi}_1^0}$
- vacuum (meta-)stability

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

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



WHL BHL BHR BLR

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

- DM Direct Detection
- (Bino-like) DM overproduction
- lepton + large ETmiss @ LHC

} consequence of stable neutralino

- Vacuum stability (for BLR)

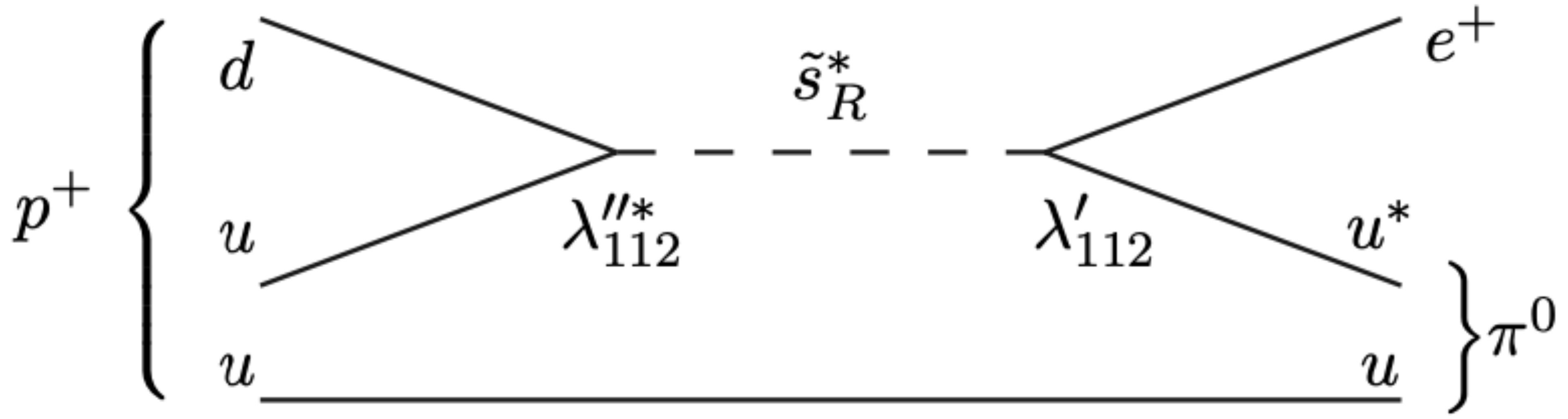
What changes if neutralino is unstable?

R-parity violation scenario

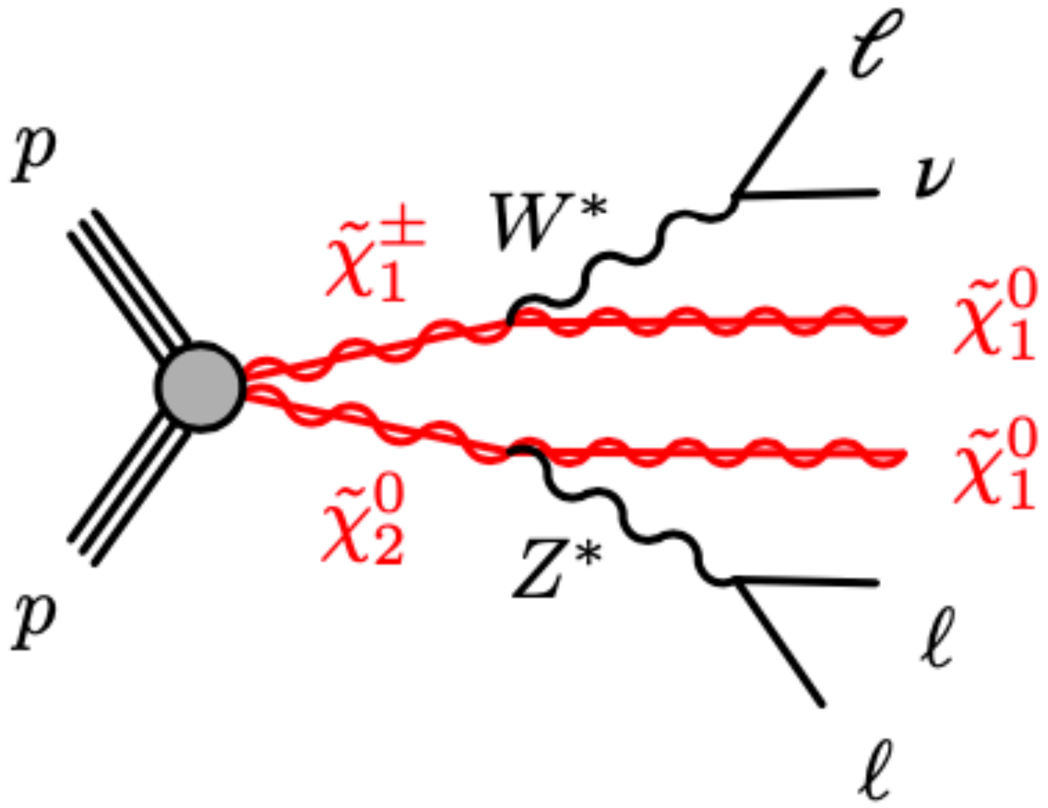
$$W_{\mathrm{RPV}} = \lambda''_{ijk} U_i^c D_j^c D_k^c + \lambda_{ijk} L_i L_j E_k^c + \lambda'_{ijk} L_i Q_j D_k^c + \kappa_i L_i H_u$$

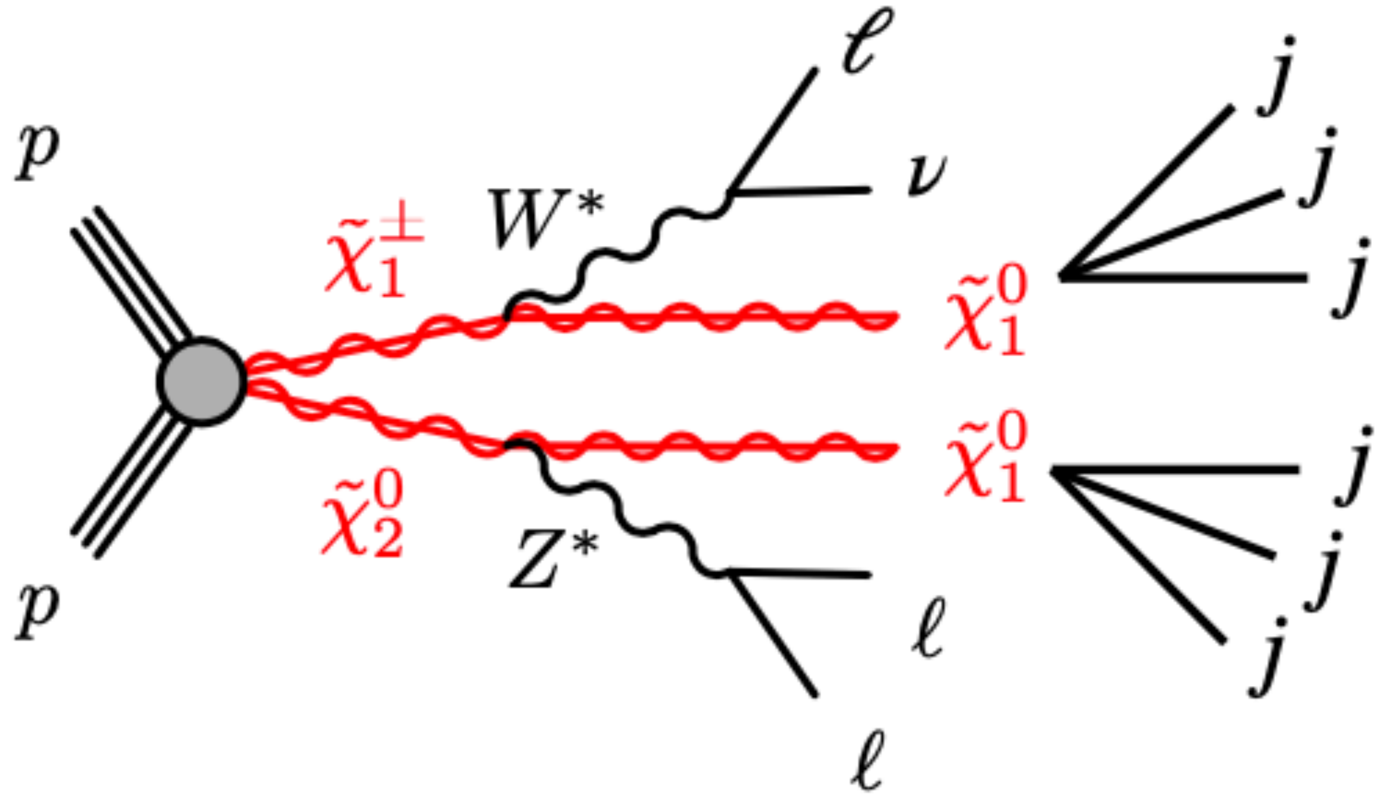
$$\not{B} \qquad \not{L} \qquad \not{L} \qquad \not{L}$$

- 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



neutralino LSP





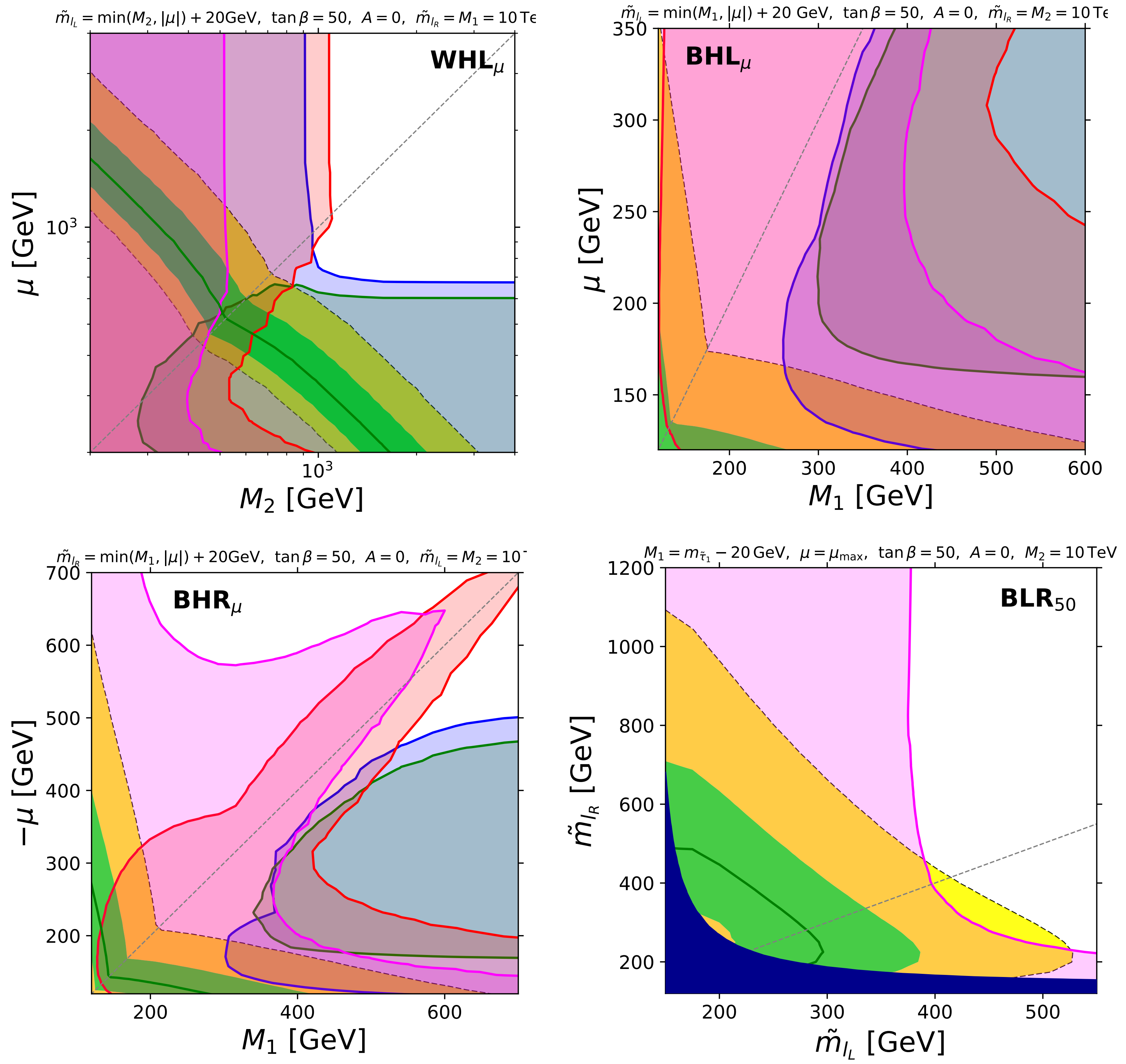
RPV (UDD-type)

No missing energy, but multi-jet

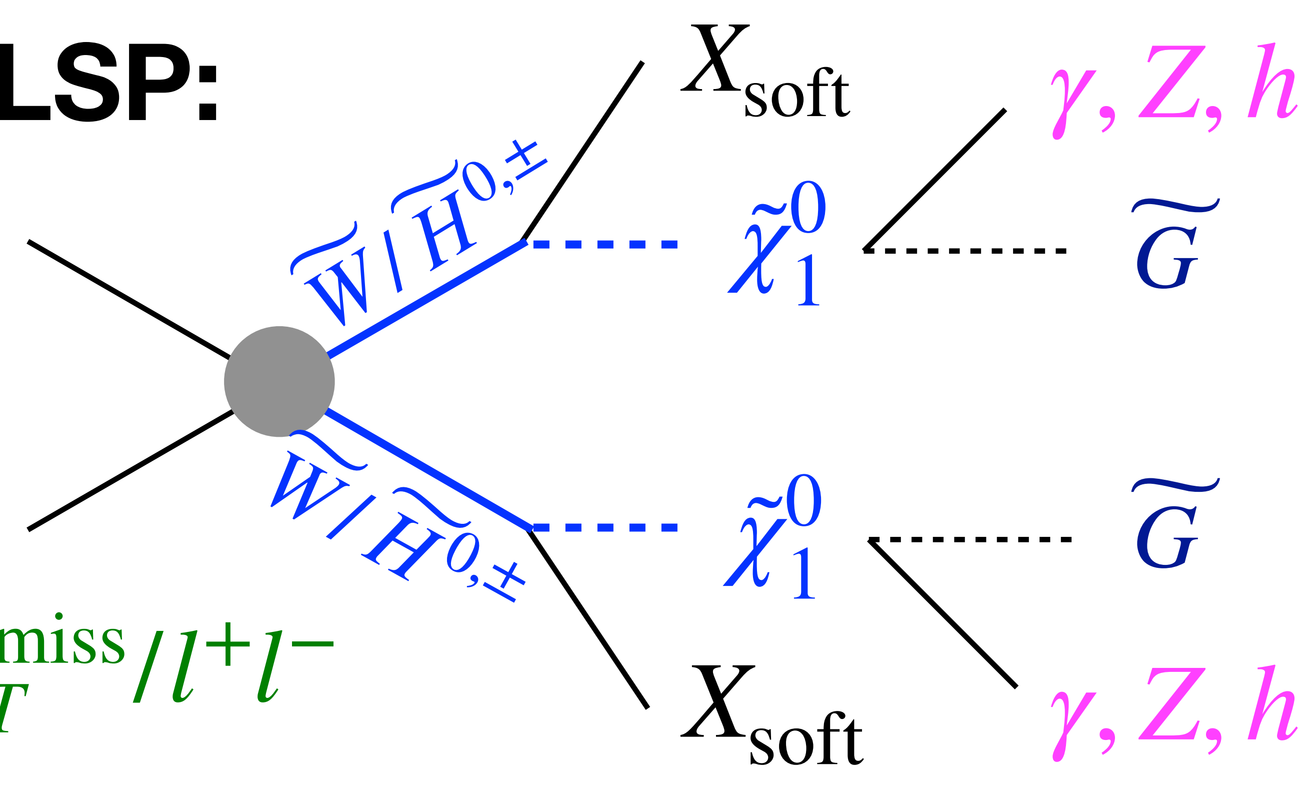
GMSB scenario

In GMSB, light gravitino LSP is motivated by naturallness

- We assume almost massless gravitino LSP ($m_{\tilde{G}} \leq 1$ GeV)
- $(g\text{-}2)_\mu$ doesn't change much wrt. MSSM
- If neutralino is NLSP then totally excluded -> slepton/ sneutrino/stau NLSP

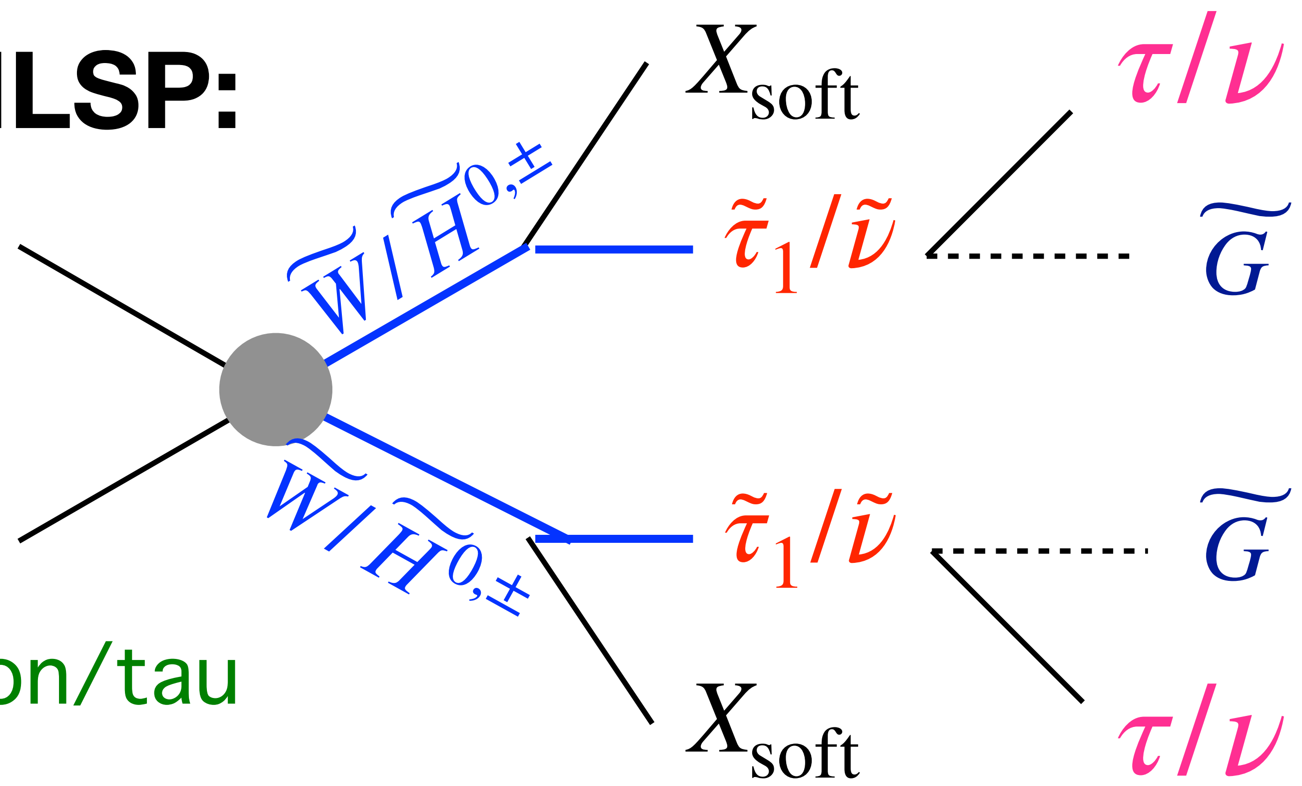


$\tilde{\chi}_1^0$ NLSP:



$\gamma + E_T^{\text{miss}}/l^+l^-$

$\tilde{\tau}_1/\tilde{\nu}$ NLSP:



soft lepton/tau

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(100GeV)* and other 2 very large
3. Then the diagram dominates $\Delta a_\mu^{\mathrm{SUSY}}$
4. Vary 2 masses and relate/fix the third -> 2D plane scan
MC simulations
GM2Calc, CheckMATE2, MicrOmegas ...
constraints
a_μ^{SUSY}
DM abundance
$\sigma_{\mathrm{SI}}^{\tilde{\chi}_1^0}$
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	electrowekinos 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

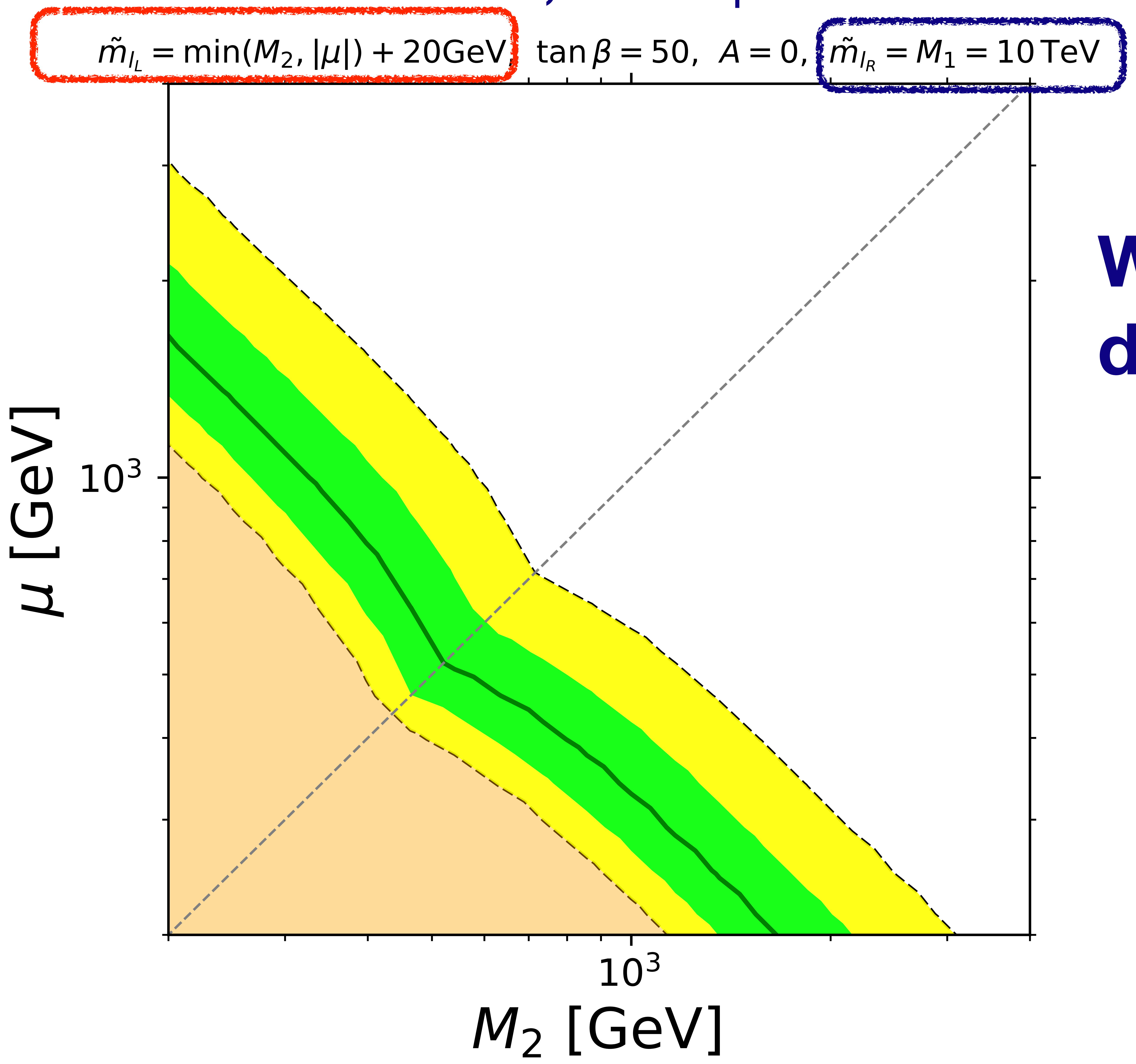
Name	E/TeV	$\mathcal{L}/\text{fb}^{-1}$	Description
atlas_1308_1841	8	20.3	0 lepton + $\geq$ 7 jets + MET
atlas_1308_2631	8	20.1	0 leptons + 2 b-jets + MET
atlas_1402_7029	8	20.3	3 leptons + MET (chargino+neutralino)
atlas_1403_4853	8	20.3	2 leptons + MET (direct stop)
atlas_1403_5222	8	20.3	stop production 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 + $\geq$ 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 + $\geq$ 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, $\geq$ 3 jets, $\geq$ 1 b-jet, MET (DM + 2 top)
cms_sus_13_016	8	19.5	OS lepton 3+ b-tags

Beach in Dębki, Poland

MSSM, WHL_μ

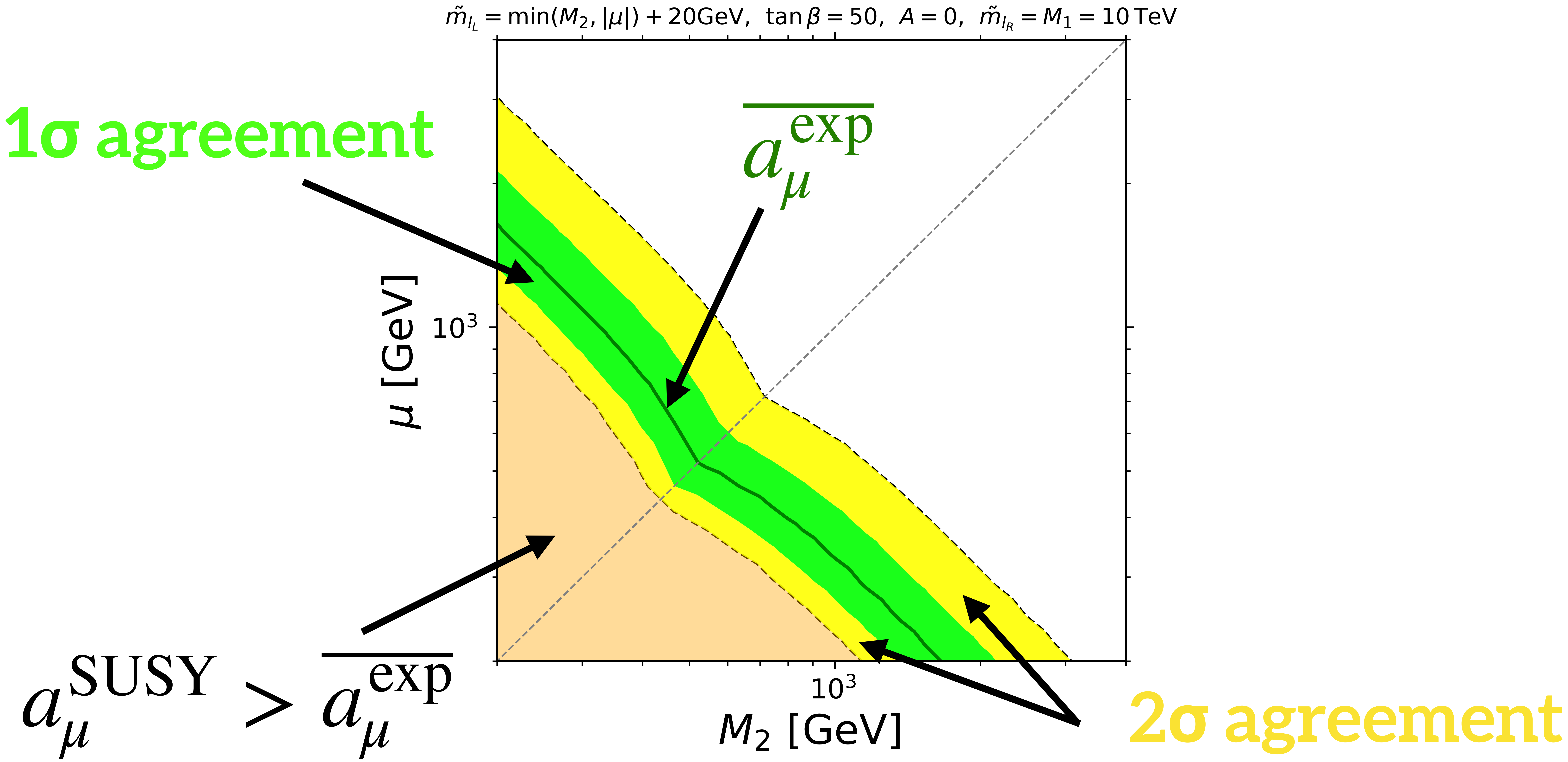
compressed mass spectrum



WHL dominates

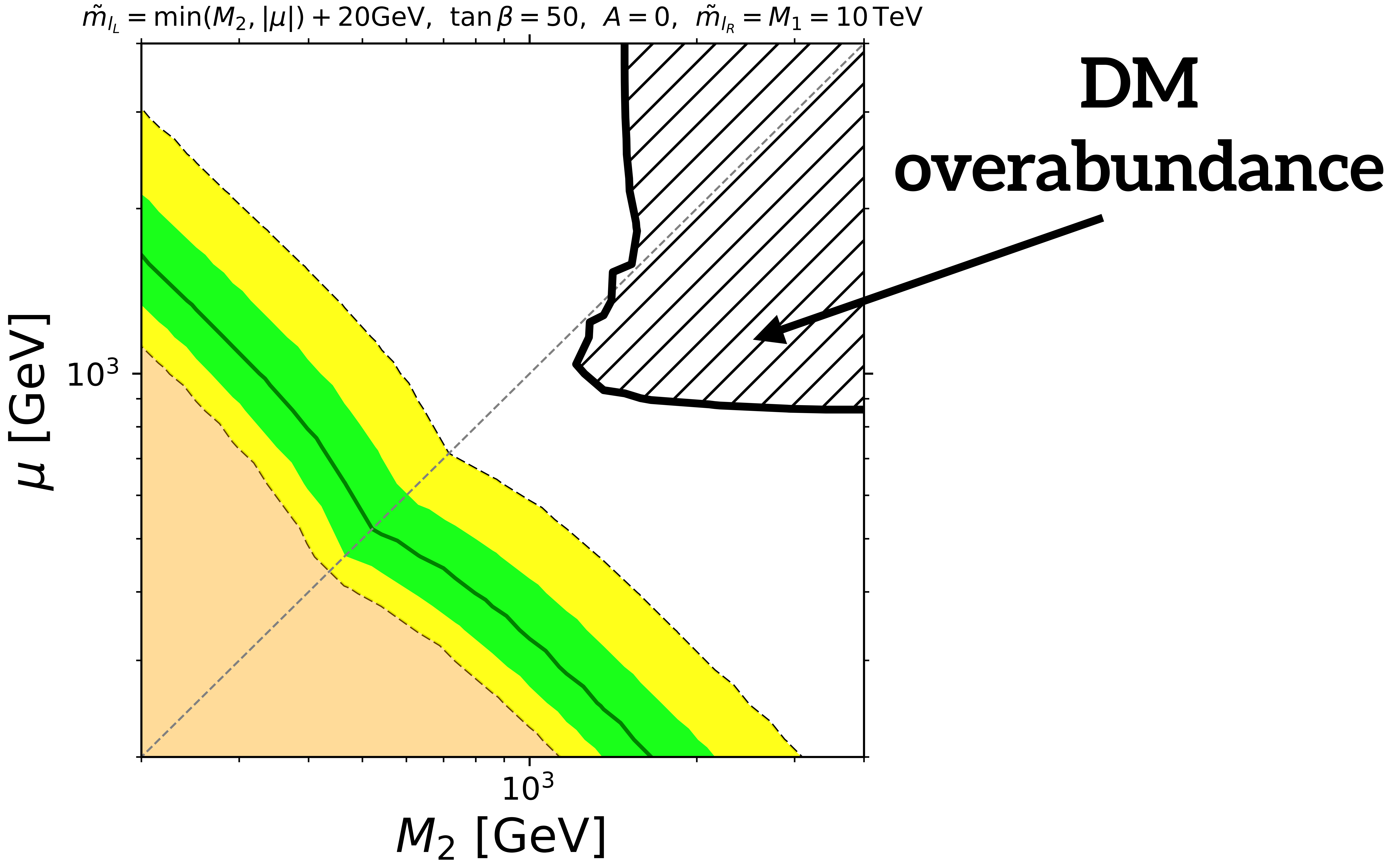
R. Masełek Corfu Summer Institute 2022/09/05

MSSM, WHL$_\mu$



$\tilde{m}_{l_L} = \min(M_2, |\mu|) + 20\text{GeV}$, $\tan\beta = 50$, $A = 0$, $\tilde{m}_{l_R} = M_1 = 10\,\text{TeV}$
1σ agreement
$\overline{a_\mu^{\text{exp}}}$
μ [GeV]
10^3
10^3
M_2 [GeV]
$a_\mu^{\text{SUSY}} > \overline{a_\mu^{\text{exp}}}$
2σ agreement

MSSM, WHL_μ


$\tilde{m}_{l_L} = \min(M_2, |\mu|) + 20\text{GeV}$, $\tan\beta = 50$, $A = 0$, $\tilde{m}_{l_R} = M_1 = 10\,\text{TeV}$
μ [GeV]
10^3
10^3
M_2 [GeV]
DM
overabundance

MSSM, WHL$_\mu$

ATLAS DT

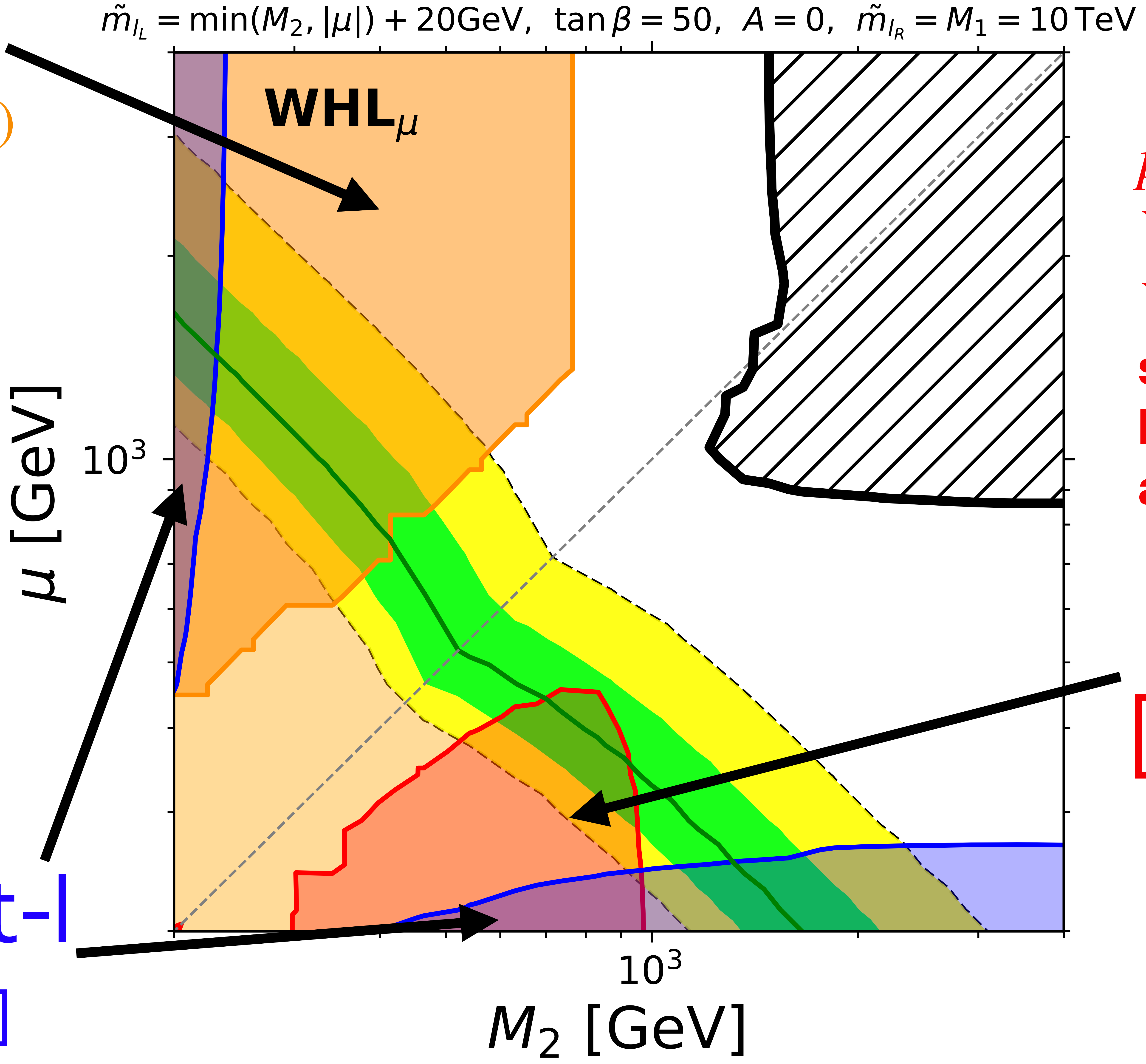
[2201.02472]

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

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

$\chi_1^\pm \to \chi_1^0 + X_{\mathrm{soft}}^\pm$

Wino-like LSP excluded up to $M_2 \sim 760$ GeV



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

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

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

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

CMS l+l-

[2012.08600]

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

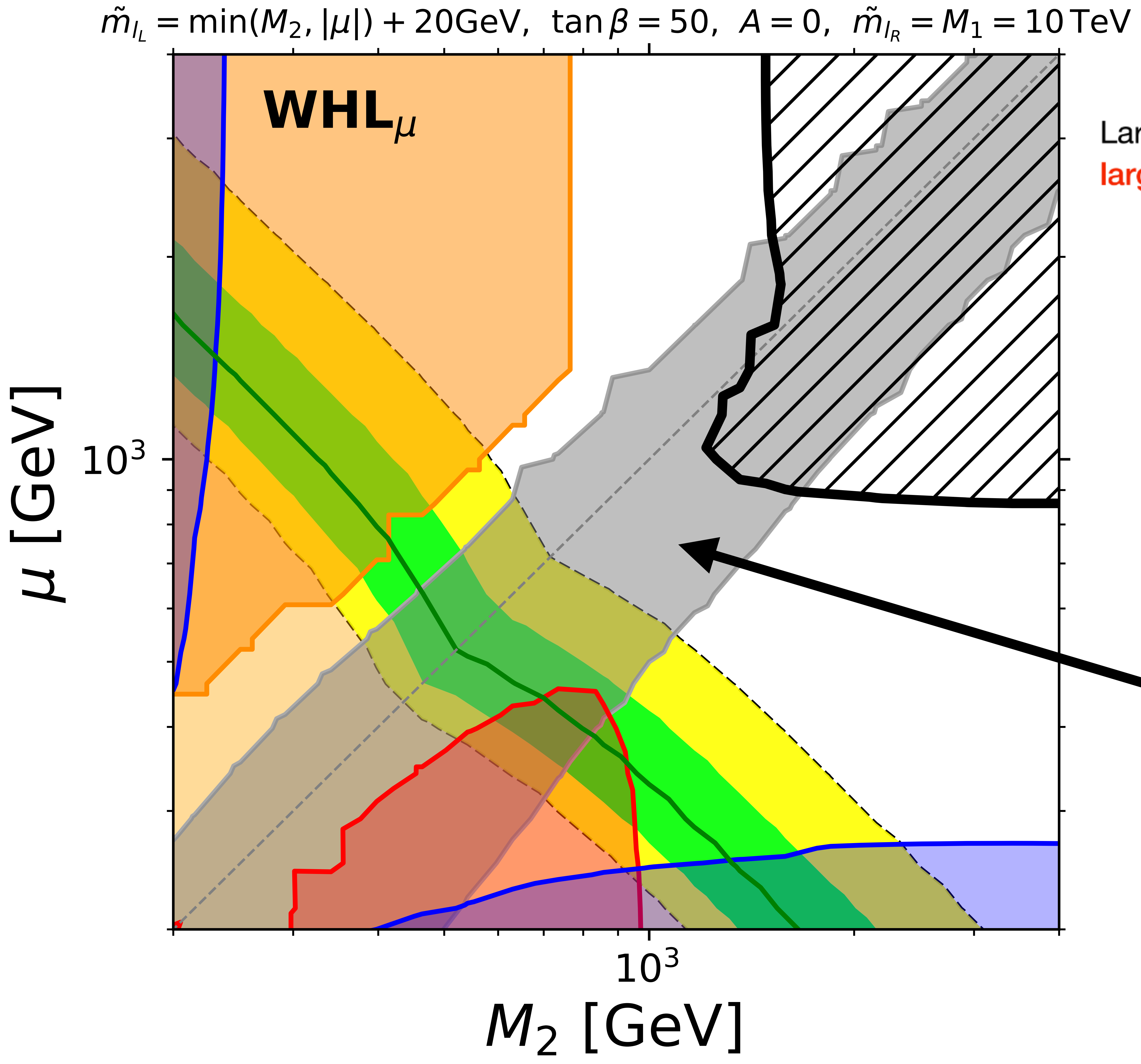
$\tilde{\xi} \equiv \tilde{l}\ /\ \tilde{\nu}$

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

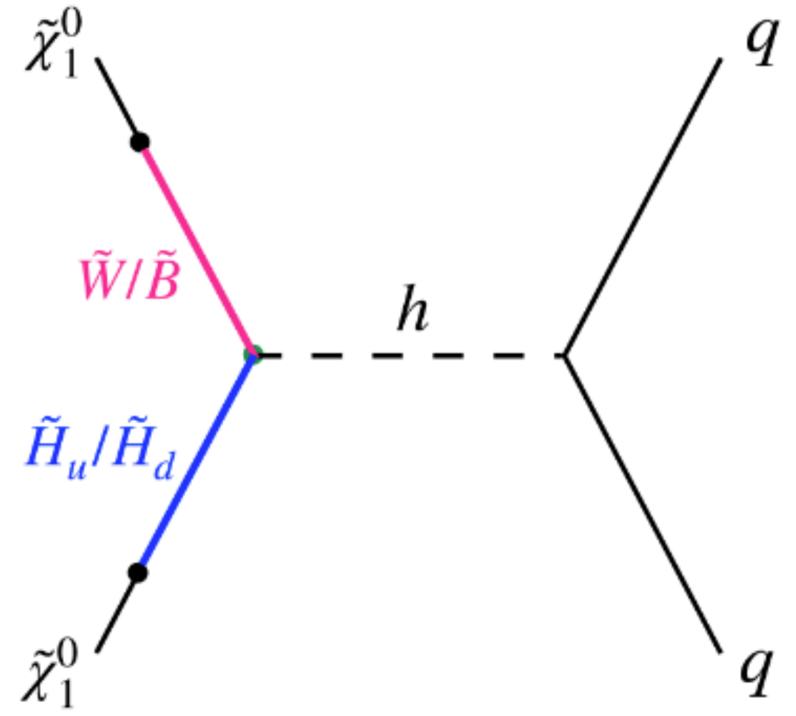
ATLAS soft-l

[1911.12606]

MSSM, WHL_μ



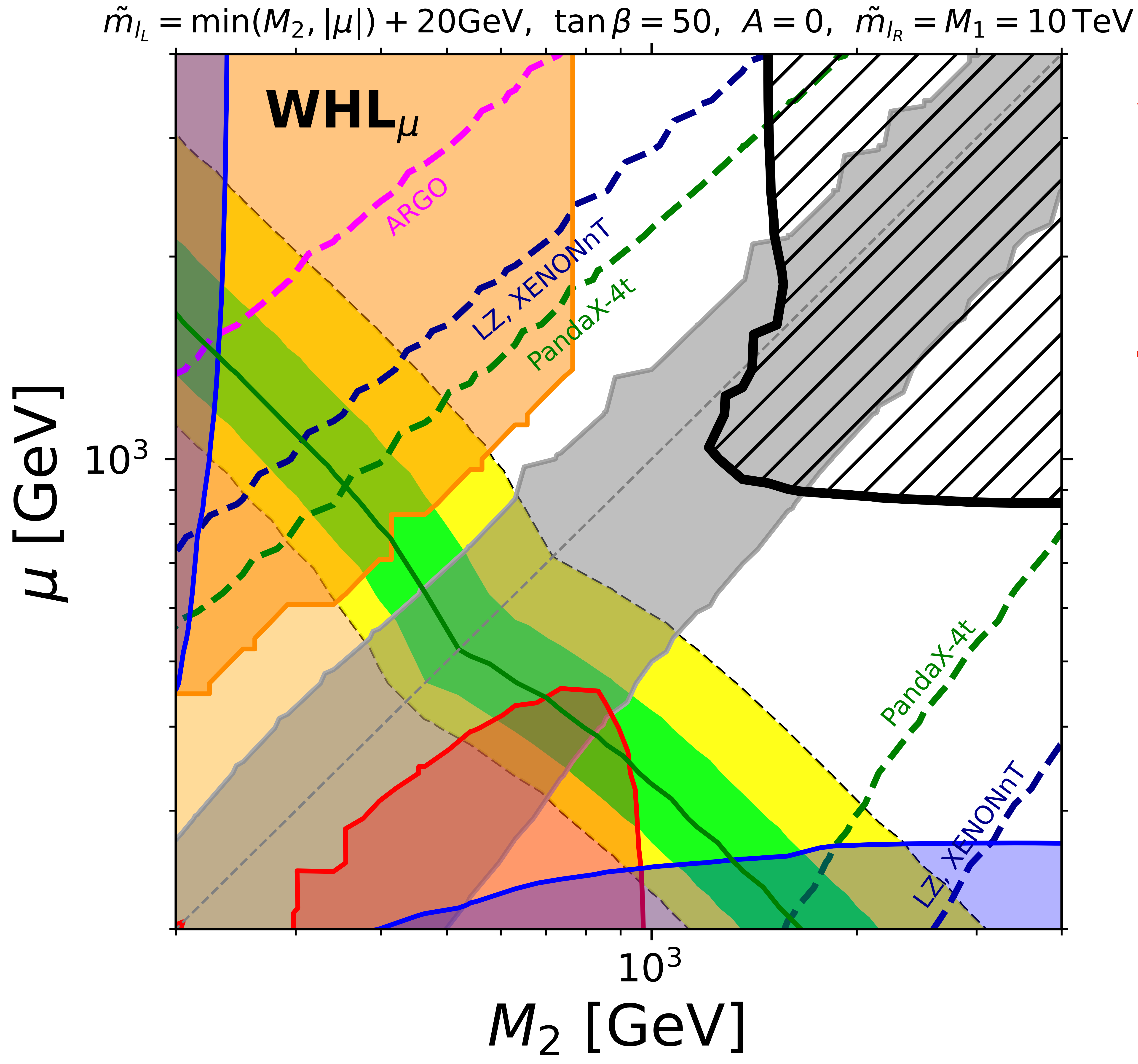
Large gaugino-Higgsino mixing leads to a **large cross-section for DM Direct Detection:**



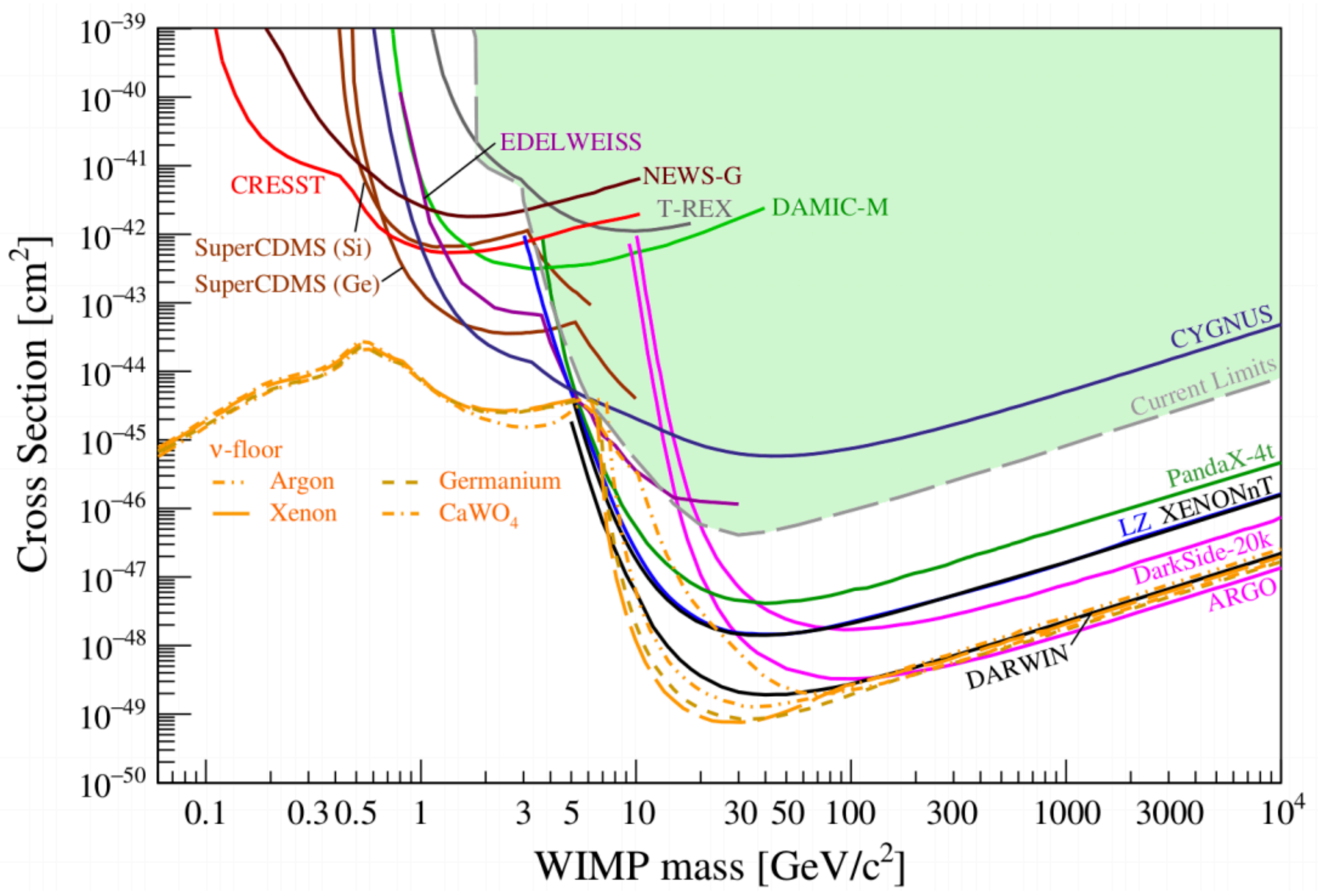
XENON1T

[1805.12562]

MSSM, WHL$_\mu$



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



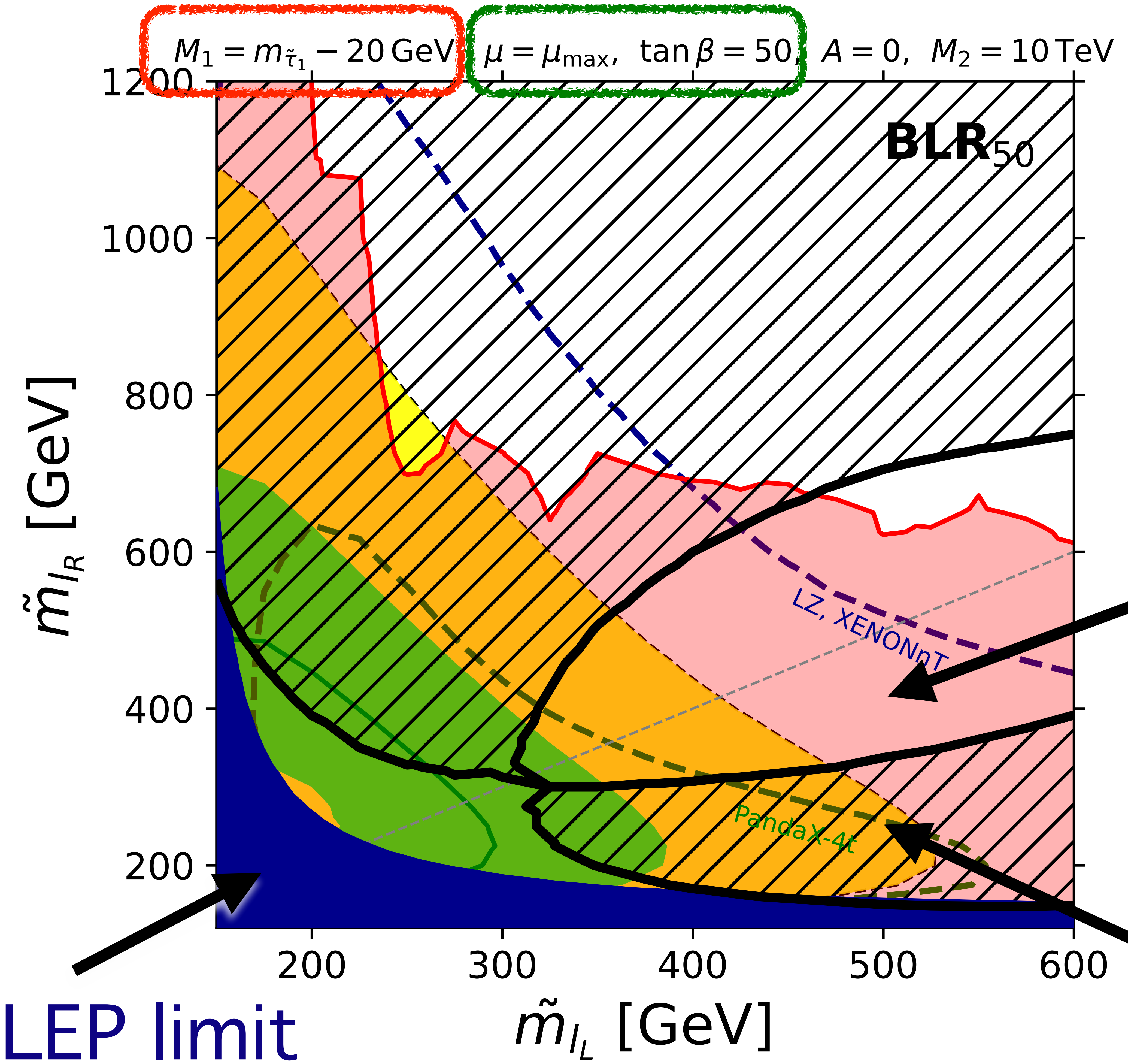
MSSM, BLR

compressed
mass spectrum
(stau coannihilation)

vacuum stability condition

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

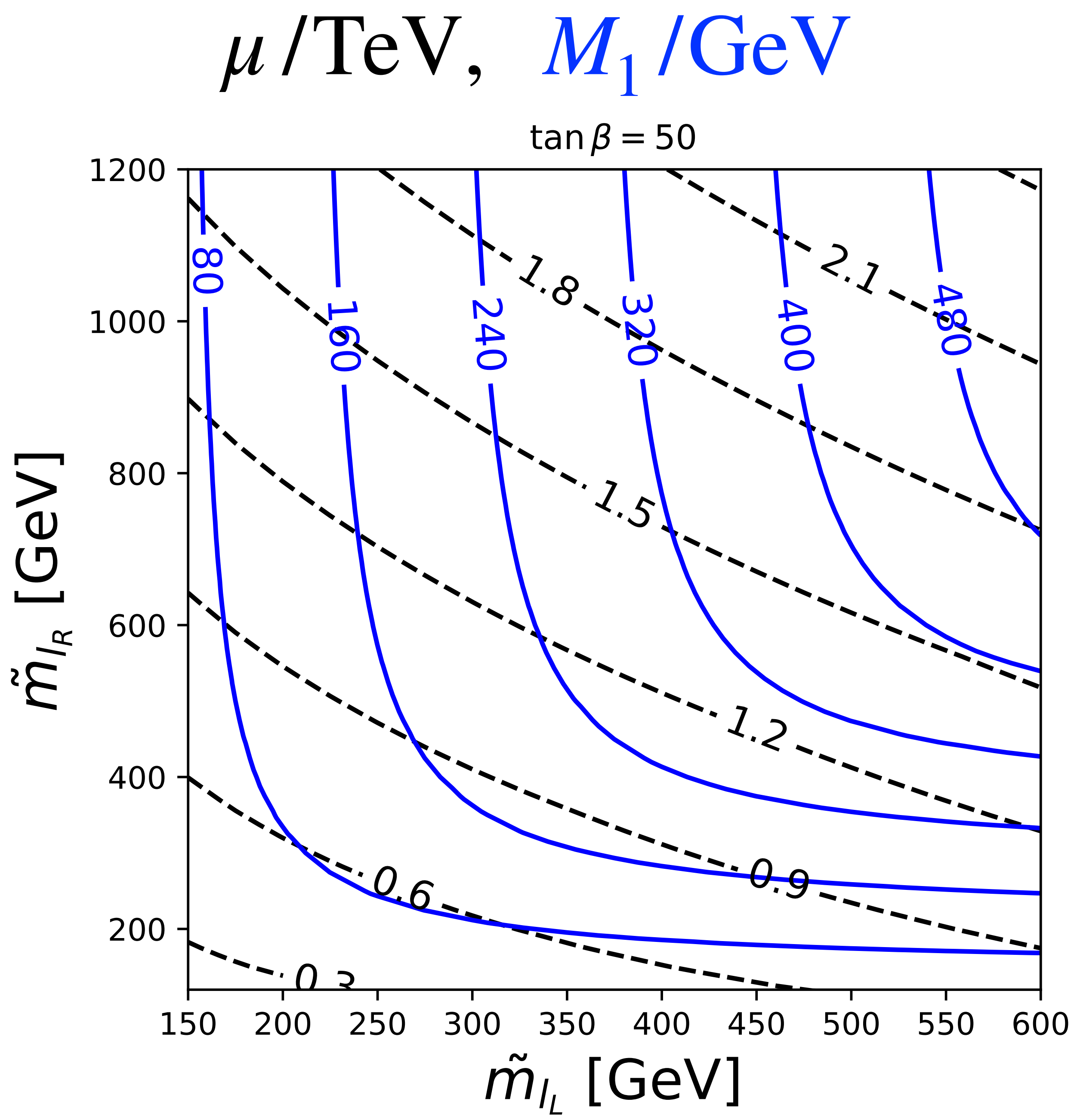
[Kitahara, Yoshinaga 13]; [Endo, Hamaguchi, Kitahara, Yoshinaga 13]



CMS l+l-
[2012.08600]

DM overproduction
due to Bino-like LSP

LEP limit

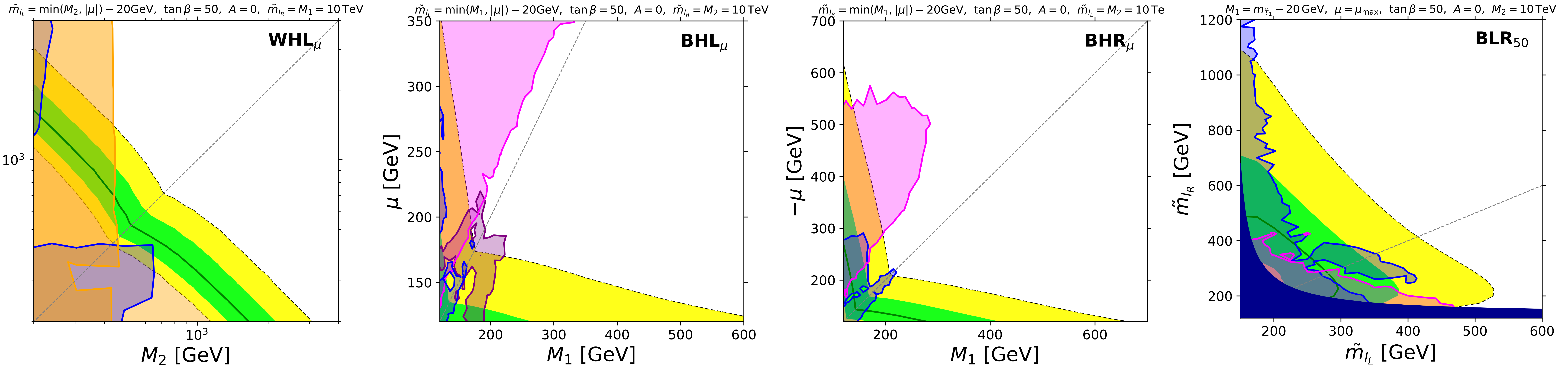


MSSM with stable neutralino

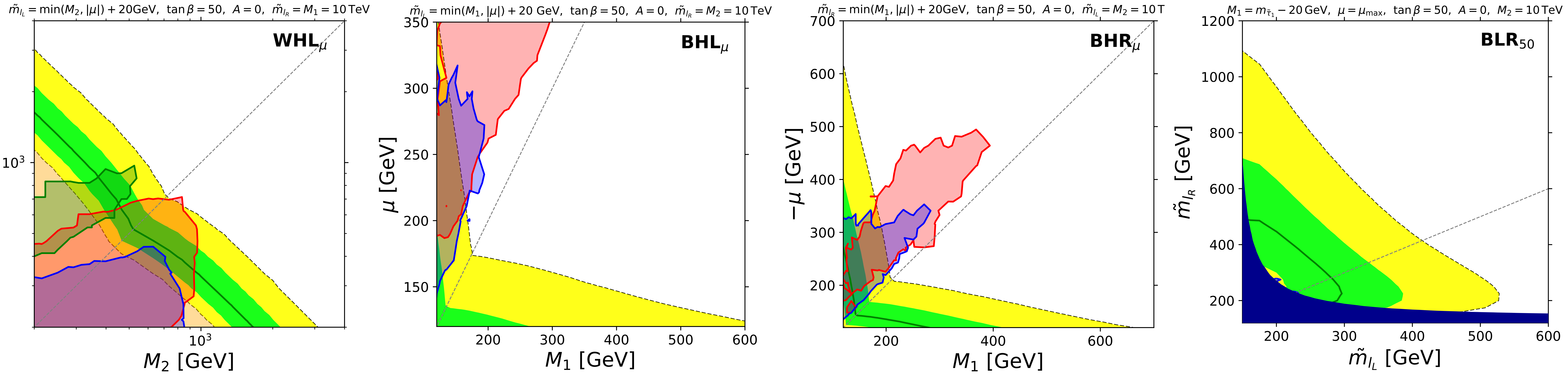
MSSM with stable neutralino

UDD RPV

GMSB with slepton/sneutrino/stau NLPS



UDD RPV



Summary

- There is a 4.2σ discrepancy for $(g\text{-}2)_\mu$ between experiment and SM prediction
- SUSY can explain $(g\text{-}2)_\mu$, but:
  - $\tilde{\chi}_1^0$ is LSP and stable $\Longrightarrow$ constraint from large E_T^{miss}
  - $|\mu| \approx \mathrm{M}_1\ (\mathrm{M}_2) \Longrightarrow$ constraint from DM-DD experiments
  - slepton and Bino are light $\Longrightarrow$ DM overproduction
- If $\tilde{\chi}_1^0$ is not stable LSP, DM constraints go away, and LHC signature changes:
  - RPV with UDD $\Longrightarrow$ LHC constraints from multijet + lepton
  - Gravitino LSP with $\tilde{\chi}_1^0$ NLSP $\Longrightarrow$ $(g\text{-}2)_\mu$ region excluded by $\gamma + E_T^{\text{miss}}$ channel
  - Gravitino LSP with $\tilde{l}/\tilde{\nu}/\tilde{\tau}$ NLSP $\Longrightarrow$ LHC constraints from soft lepton/tau

Thank you for attention!

r.maselek@uw.edu.pl

Dolina Chochołowska, Poland
photo by Piotr Kałuża

Backup slides

Tension between experiment and white paper SM calculations

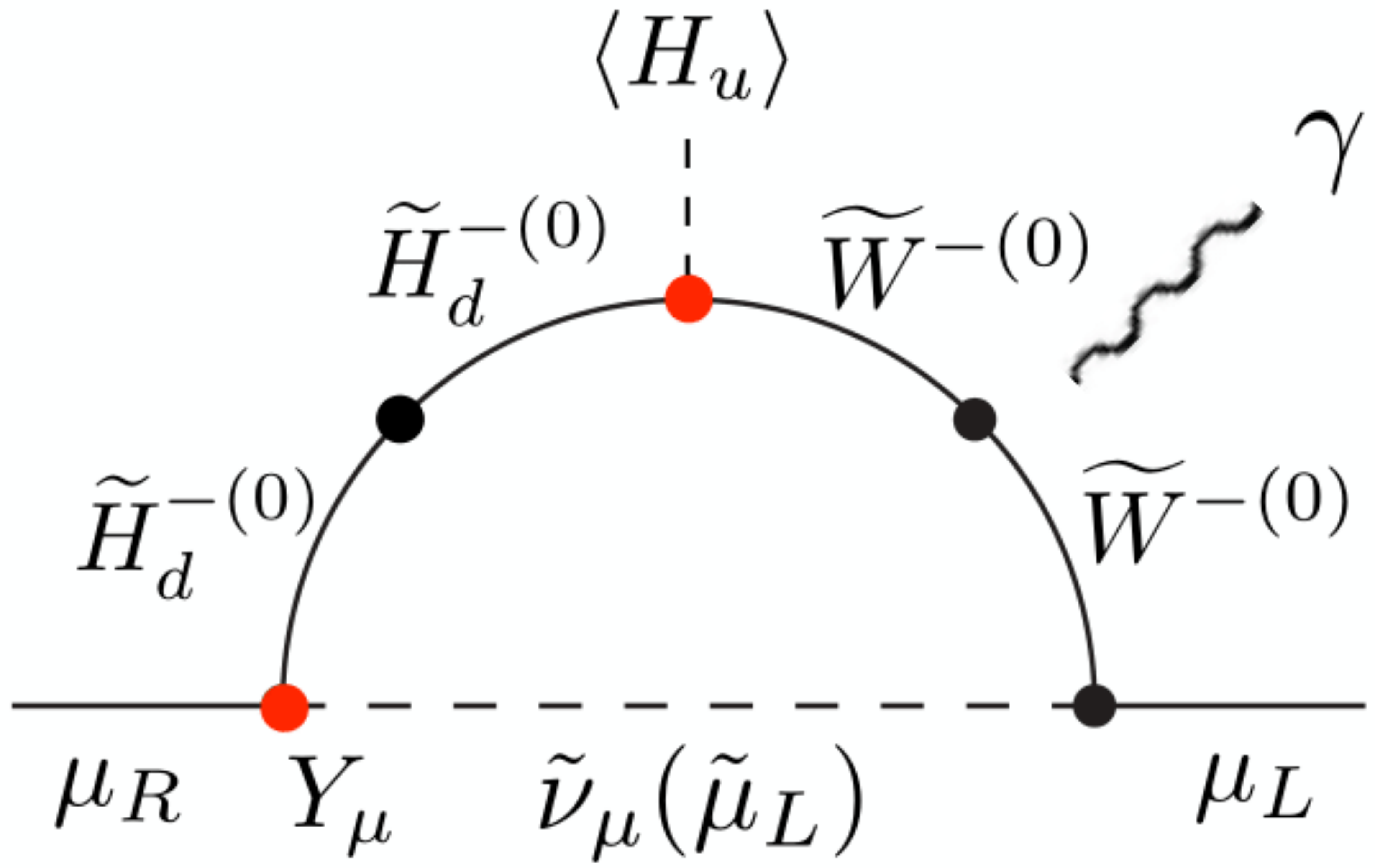
$$a_\mu^{exp} - a_\mu^{SM} = (25 \pm 6) \times 10^{-10} \sim \mathcal{O}\left(\Delta a_\mu^{\text{SM,EW}}\right)$$

We need very light BSM particles OR enhancement from coupling

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

[K.Sakurai, Corfu 2021]

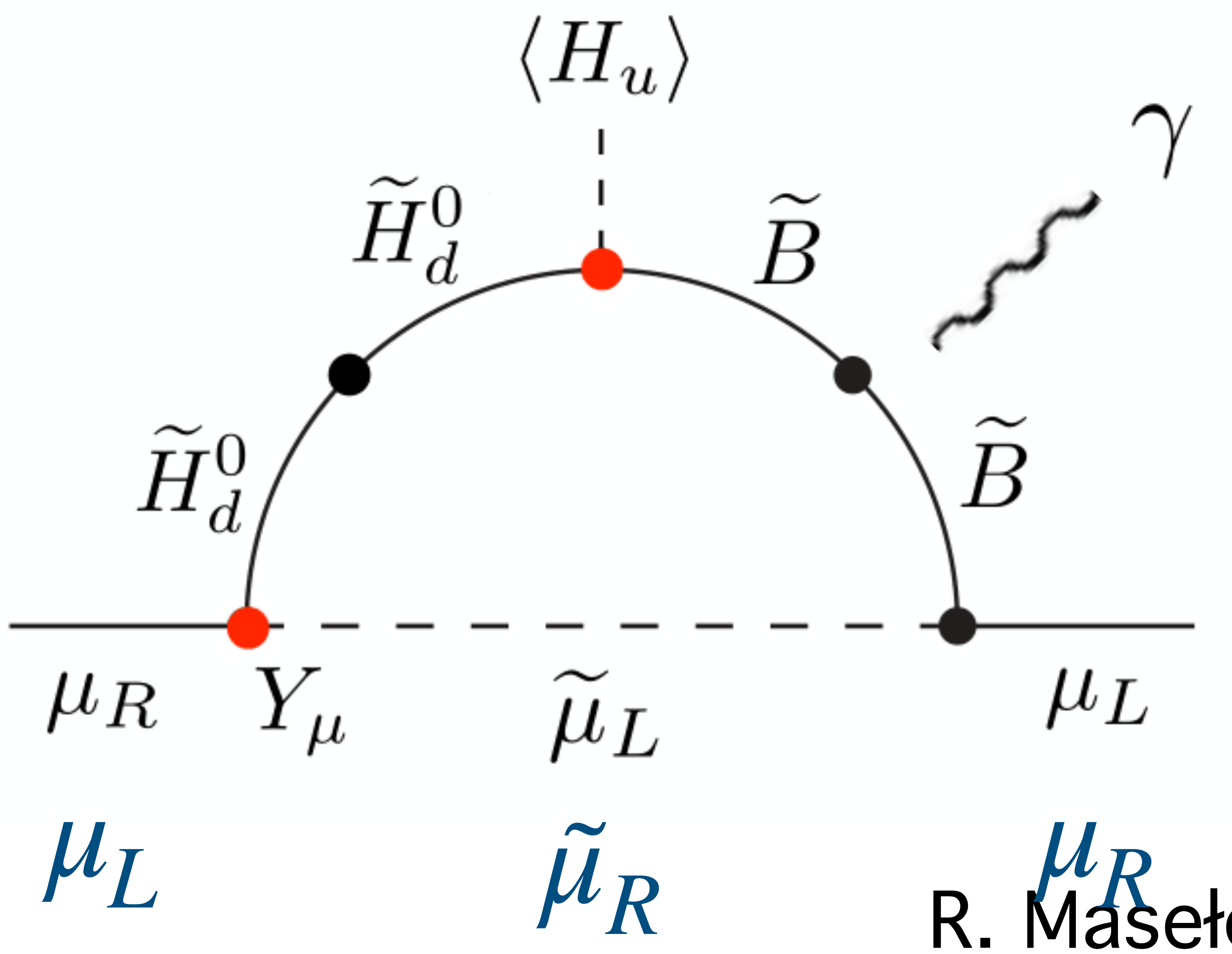
$$\Delta a_\mu^{\mathrm{SUSY}} = \Delta a_\mu^{\mathrm{WHL}} + \Delta a_\mu^{\mathrm{BHL}} + \Delta a_\mu^{\mathrm{BHR}} + \Delta a_\mu^{\mathrm{BLR}}$$



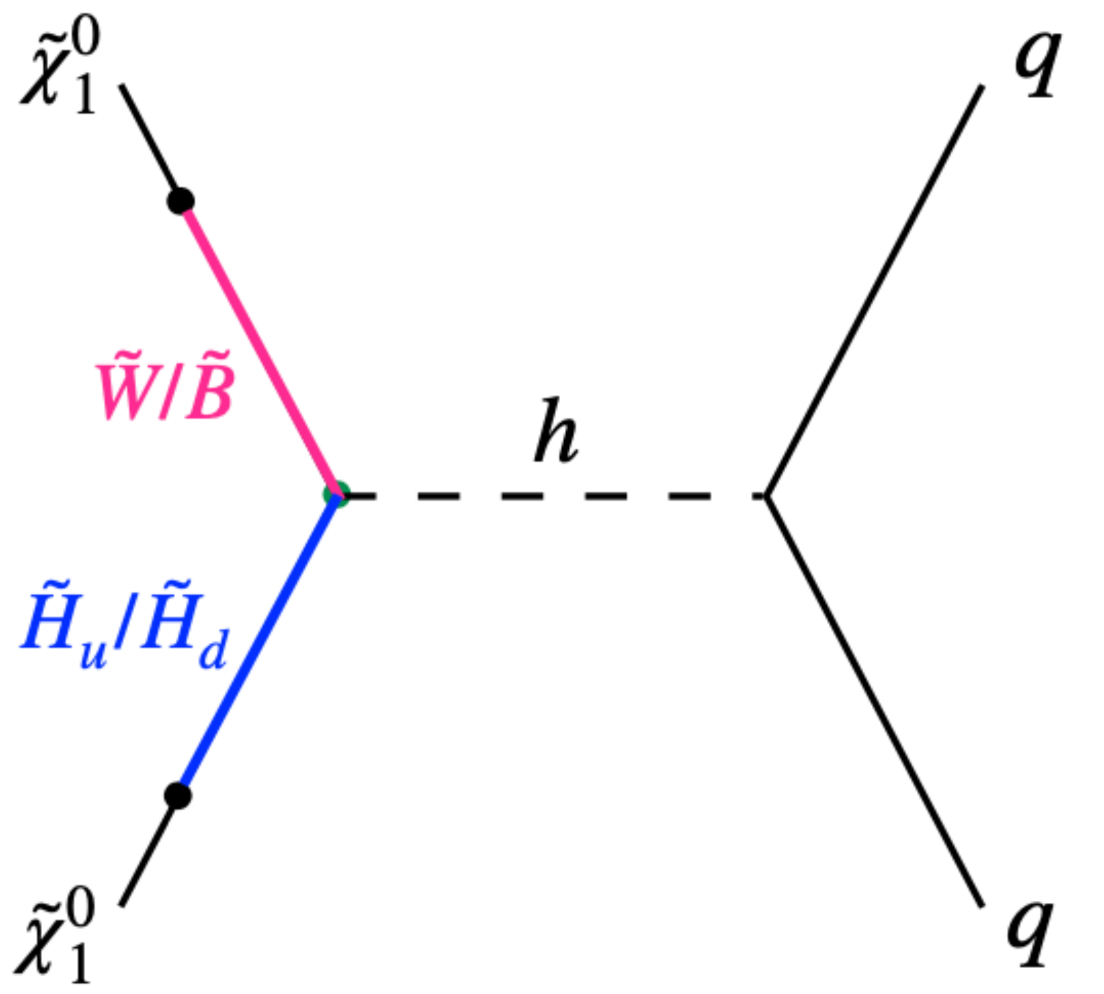
$$\Delta a_\mu^{\mathrm{WHL}}(M_2, \mu, m_{\tilde{l}_L}) = +\frac{\alpha_W}{8\pi}\frac{m_\mu^2}{\mu M_2}\tan\beta \cdot f_{\mathrm{WHL}}(\mathbf{m})$$

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

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

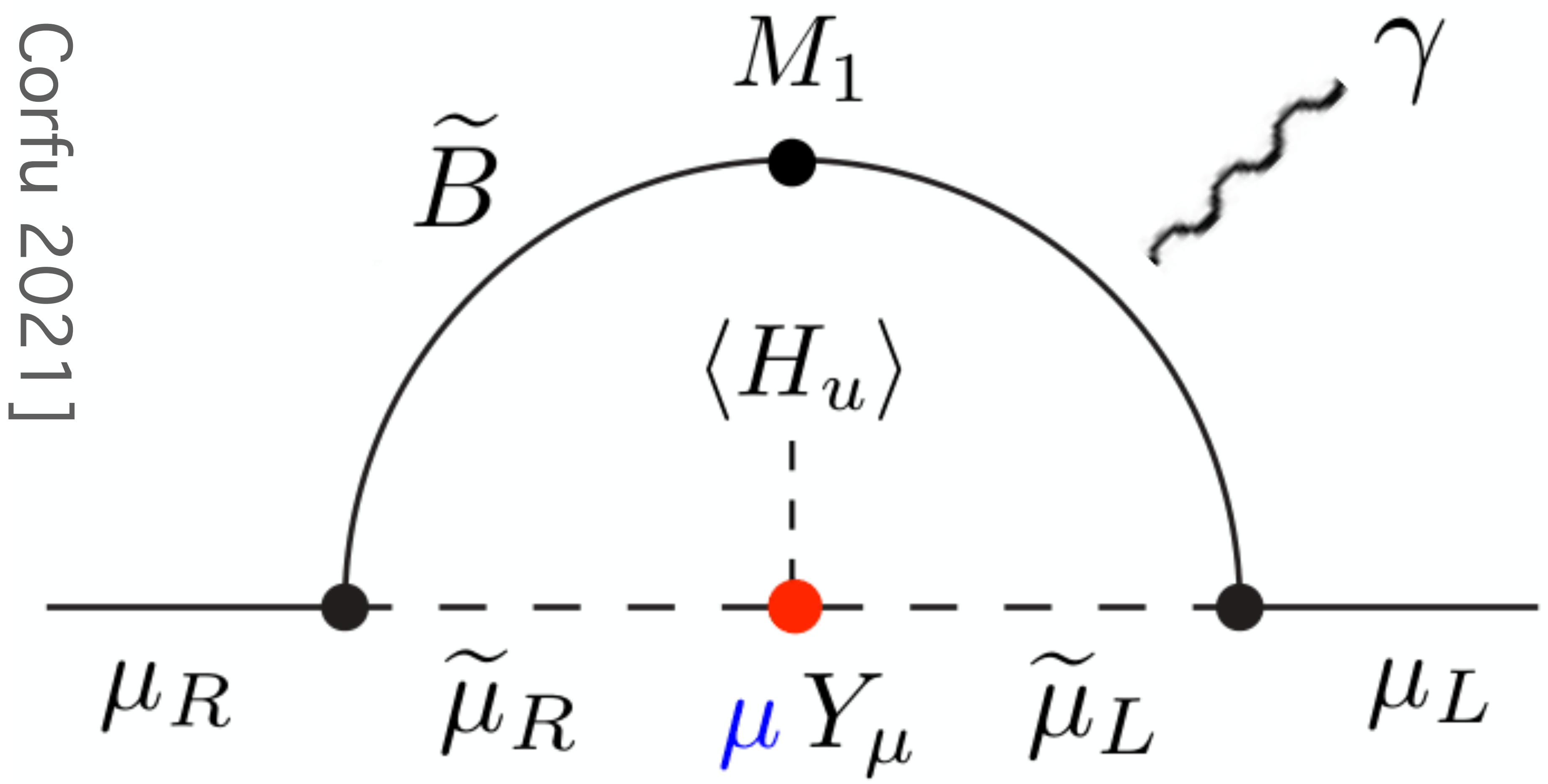


Large gaugino-Higgsino mixing leads to a
large cross-section for DM Direct detection



[K.Sakurai, Corfu 2021]

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



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

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: $m_{\tilde{\tau}_1} > 81.9$ GeV
- stau LSP: $m_{\tilde{\tau}_1} > m_{\tilde{\chi}_1^0}$
- vacuum (meta-)stability

[Kitahara, Yoshinga 13]

Parameter planes definition

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

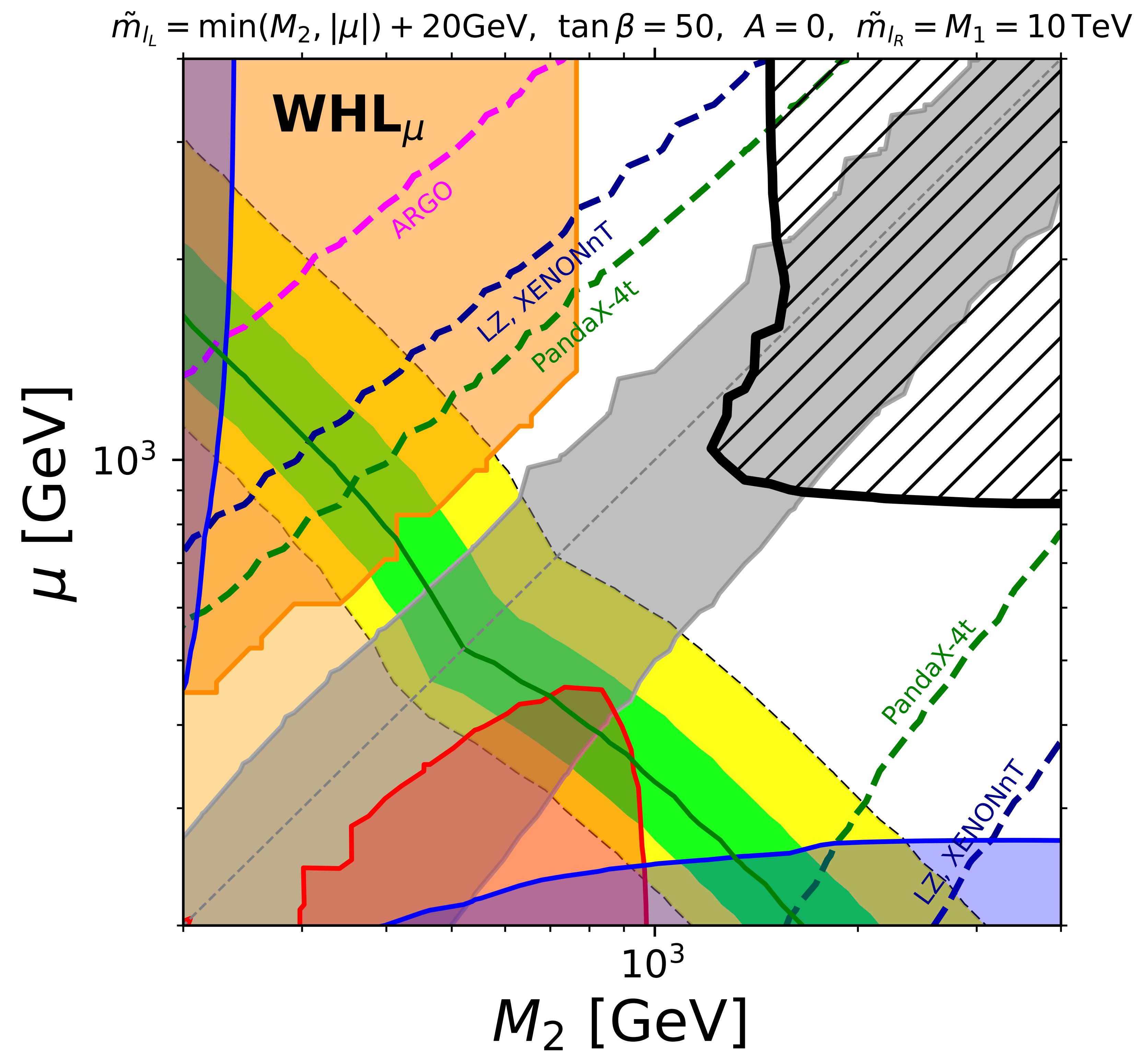
Table 1: The parameter planes and choices of the other parameters. $\mu_{\max}$ is defined as the maximum value allowed by the vacuum stability constraint.

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

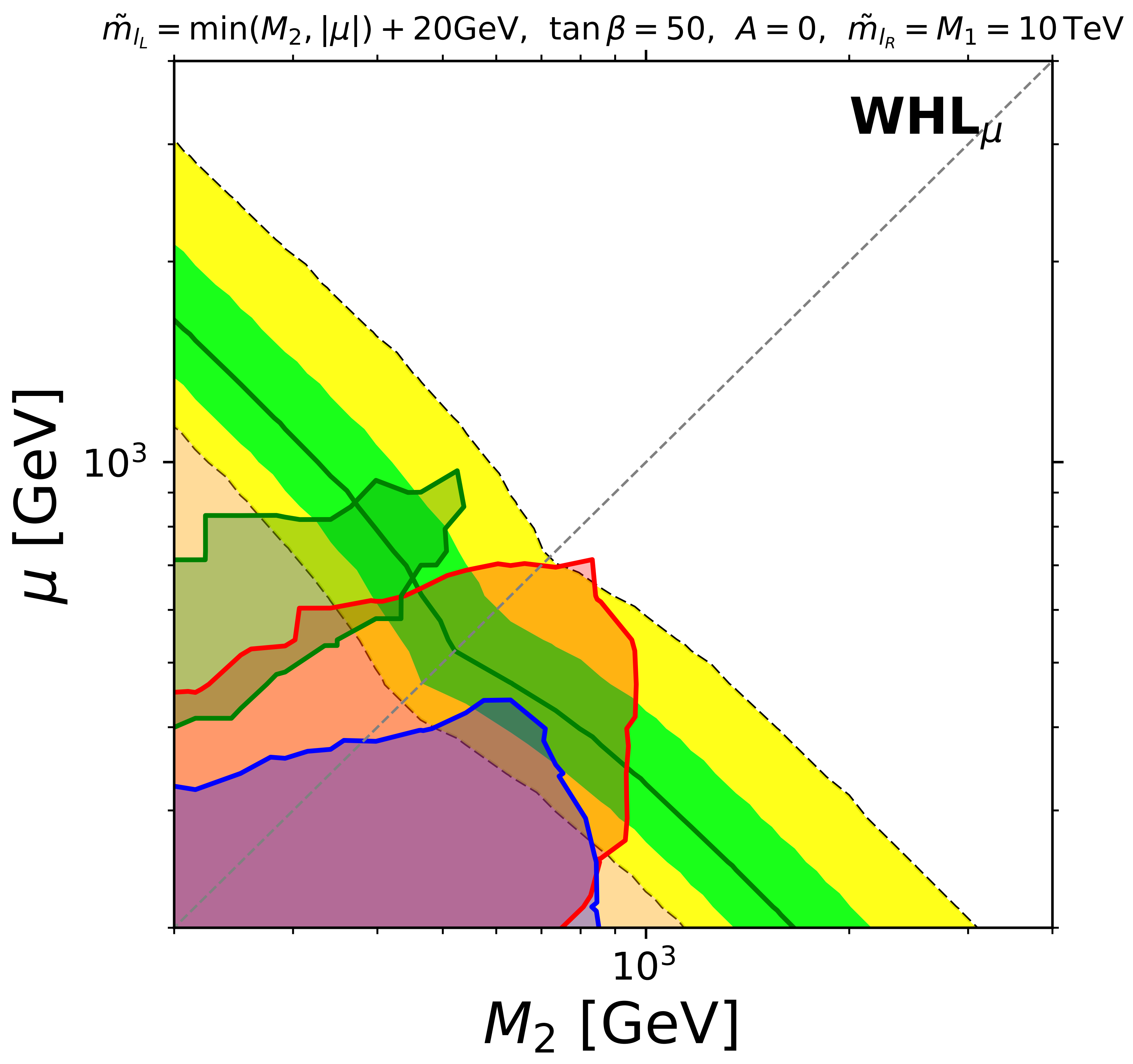
ATLAS DT [2201.02472]
ATLAS soft-l [1911.12606]
CMS l+l- [2004.05153]
XENON1T [1805.12562]

ATLAS jets +E_T^{miss}
[ATLAS-CONF-2019-040]
CMS multilepton [1709.05406]
ATLAS multijet+l [2106.09609]

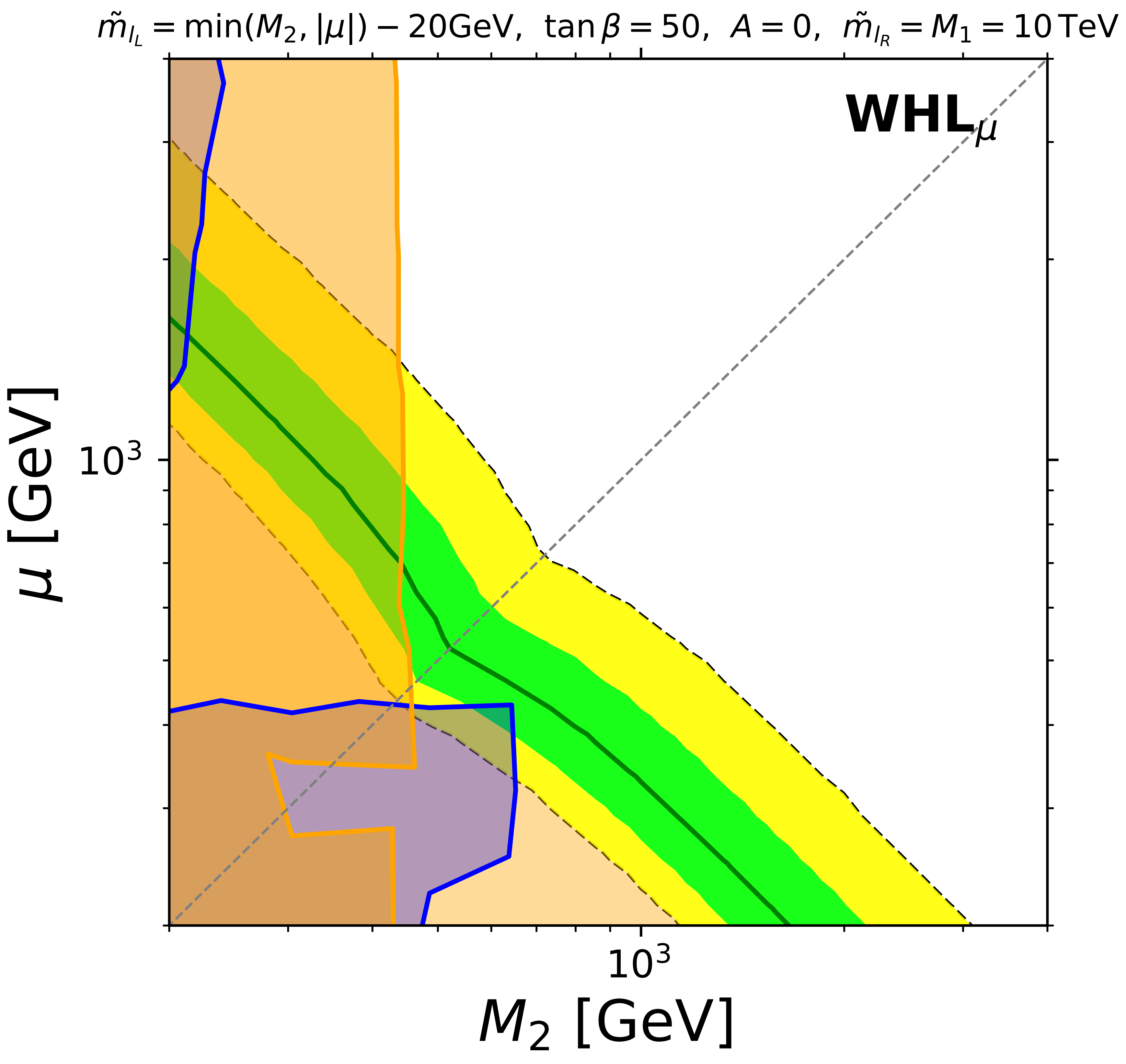
CMS soft l+l-
[1801.01846]
CMS multilepton
[1709.05406]



MSSM



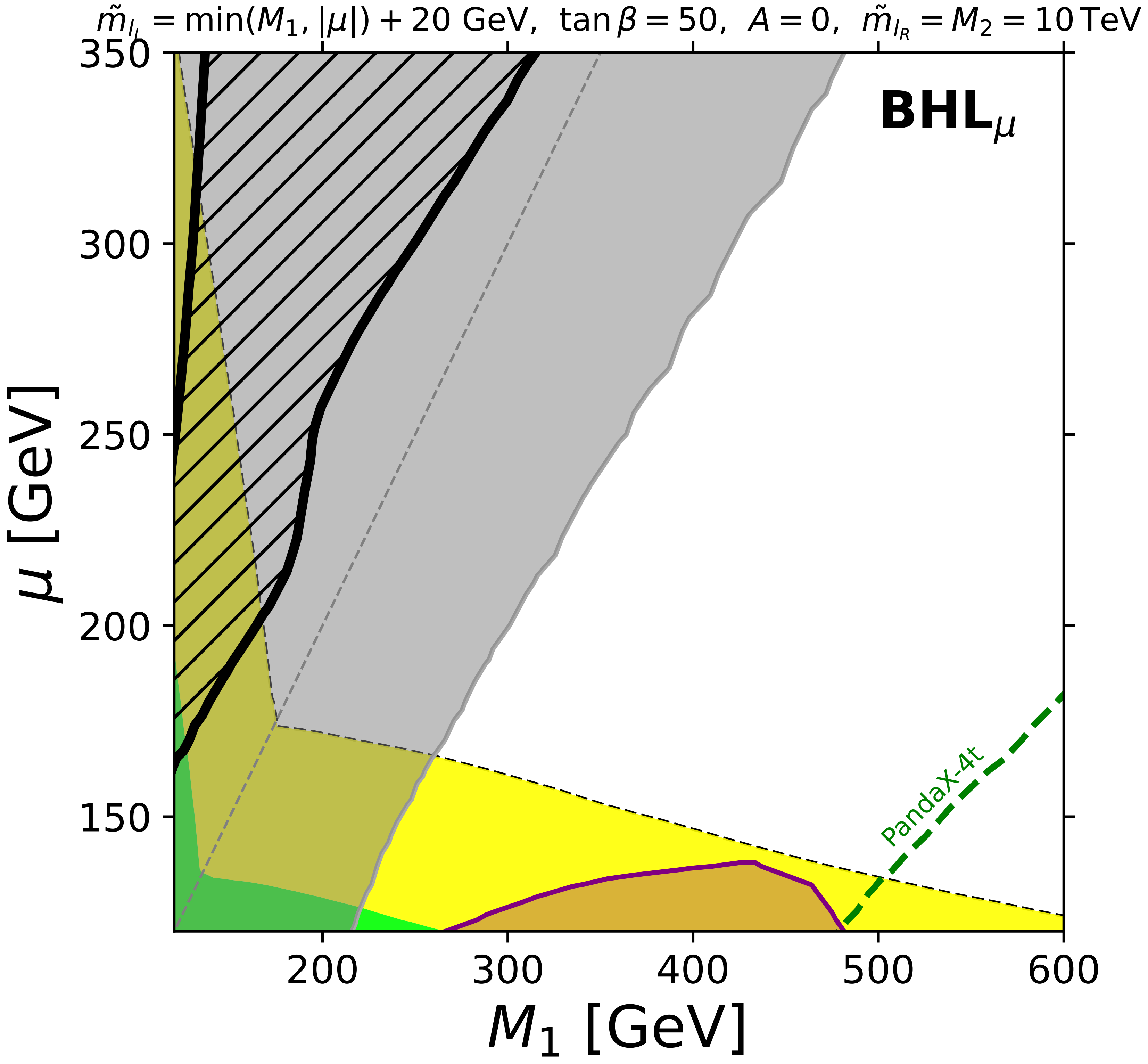
RPV



GMSB

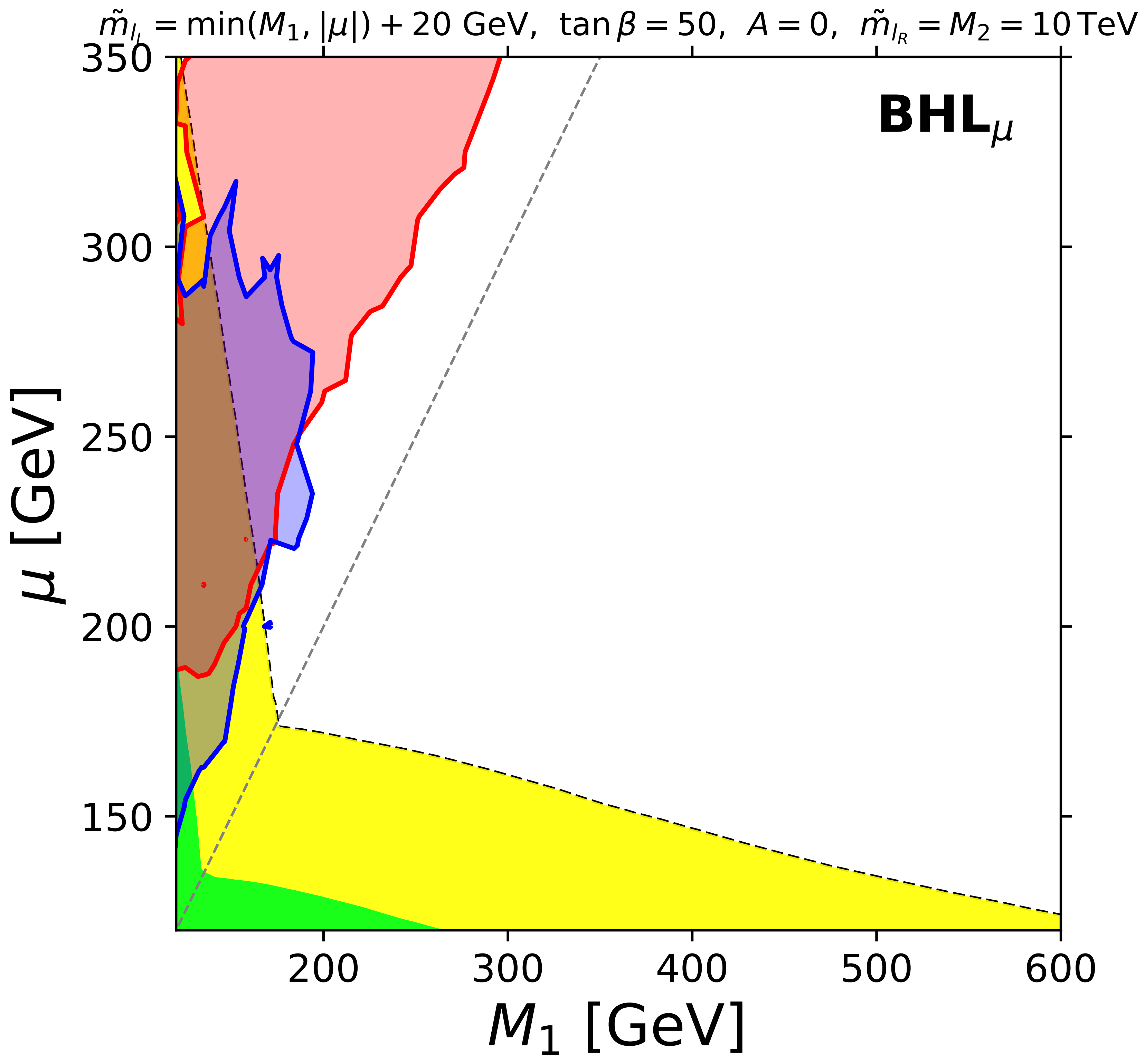
WHLμ

ATLAS soft-l [1911.12606]
CMS l+l- [2004.05153]
XENON1T [1805.12562]



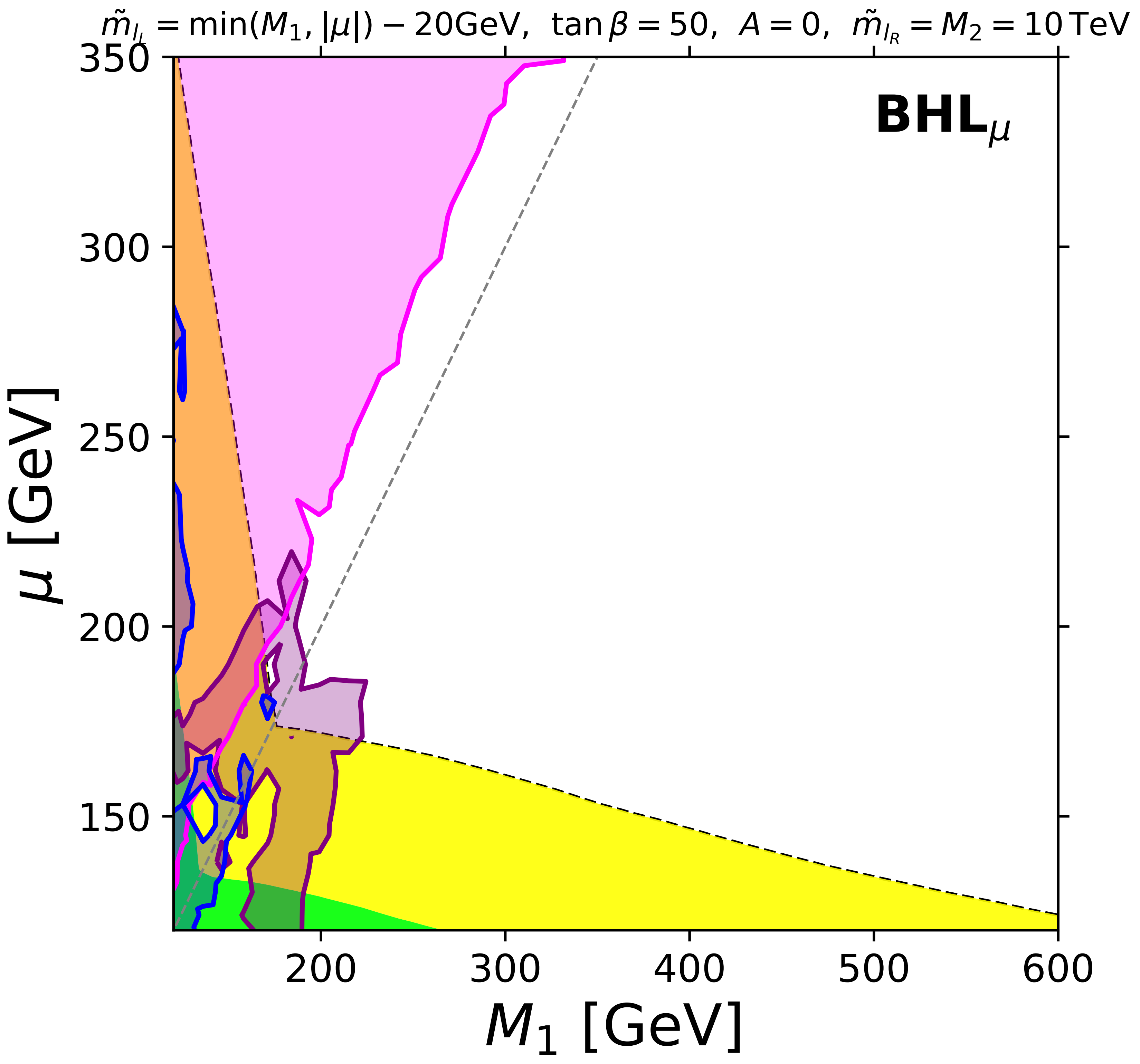
MSSM

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



RPV

ATLAS soft-l [1712.08119]
ATLAS $\tau^+\tau^-$ [1911.06660]



GMSB

BHLμ

CMS multilepton [1709.05406]

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

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

XENON1T [1805.12562]

MSSM

RPV

GMSB

BHRμ

R. Masełek Corfu Summer Institute 2022/09/05

LEP stau mass bond

CMS l+l- [2004.05153]

XENON1T [1805.12562]

CMS multilepton [1709.05406]

MSSM RPV GMSB

BLR50

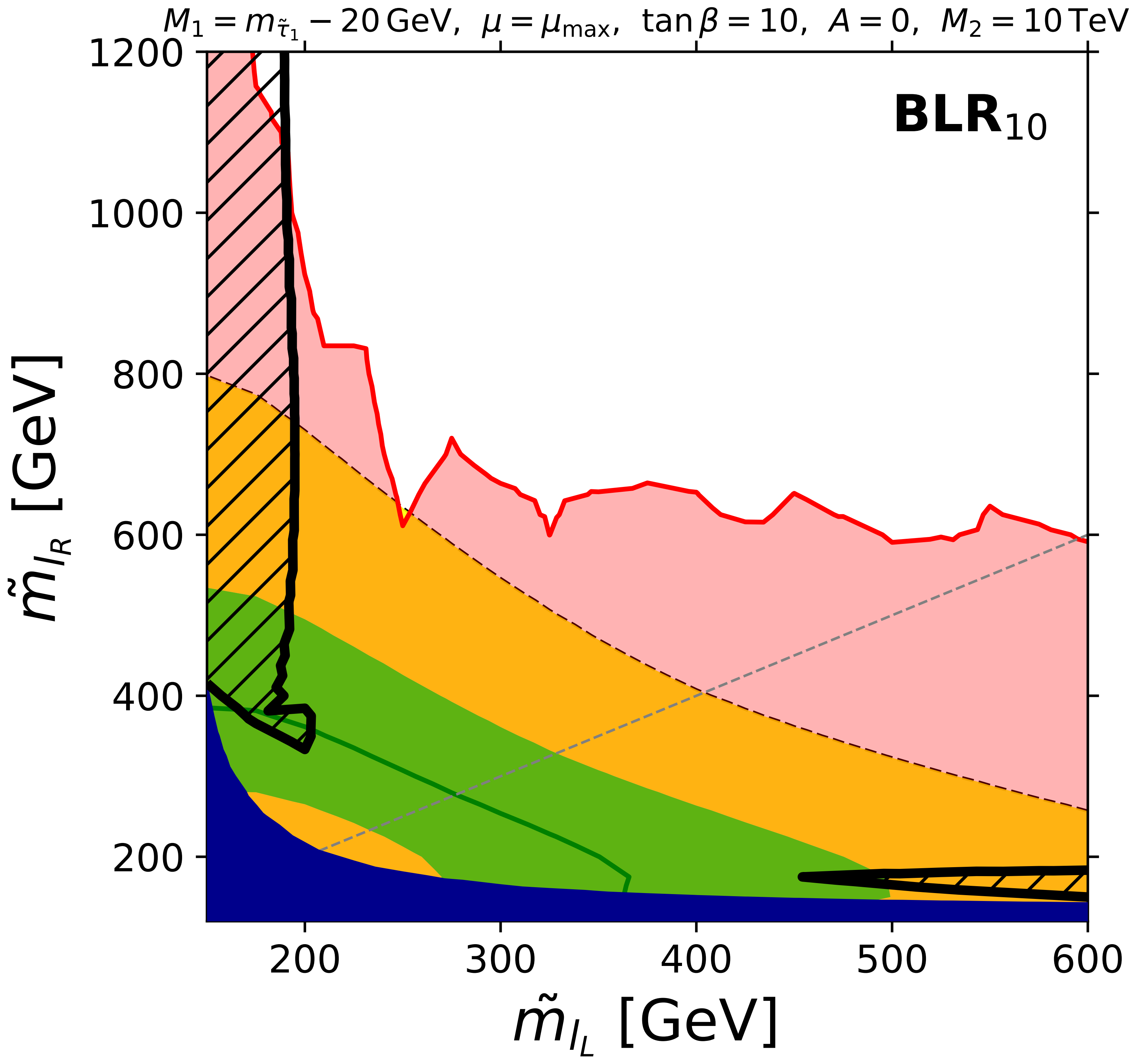
R. Masełek Corfu Summer Institute 2022/09/05

LEP stau mass bond

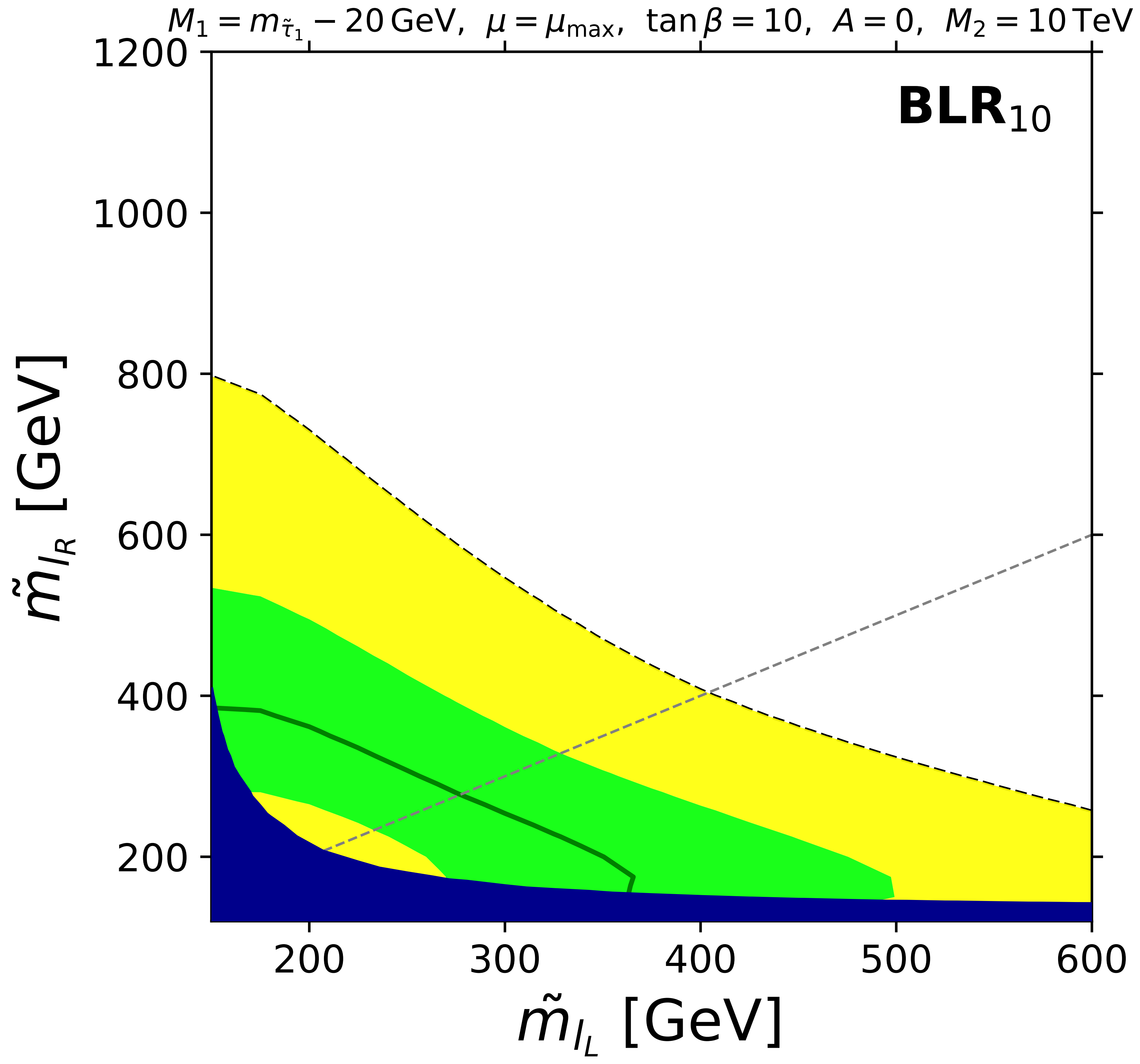
CMS l+l- [2004.05153]

XENON1T [1805.12562]

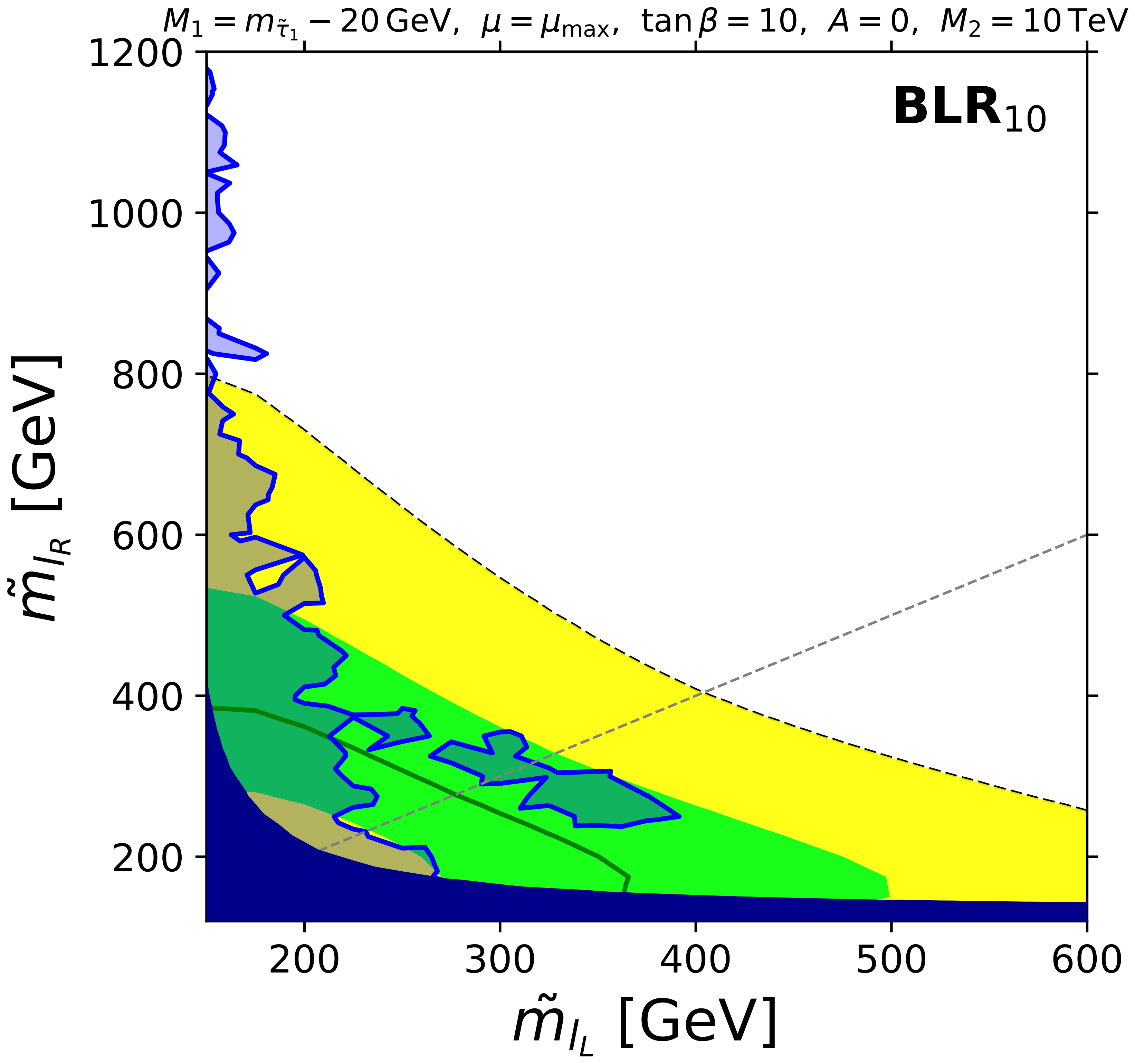
CMS multilepton [1709.05406]



MSSM



RPV

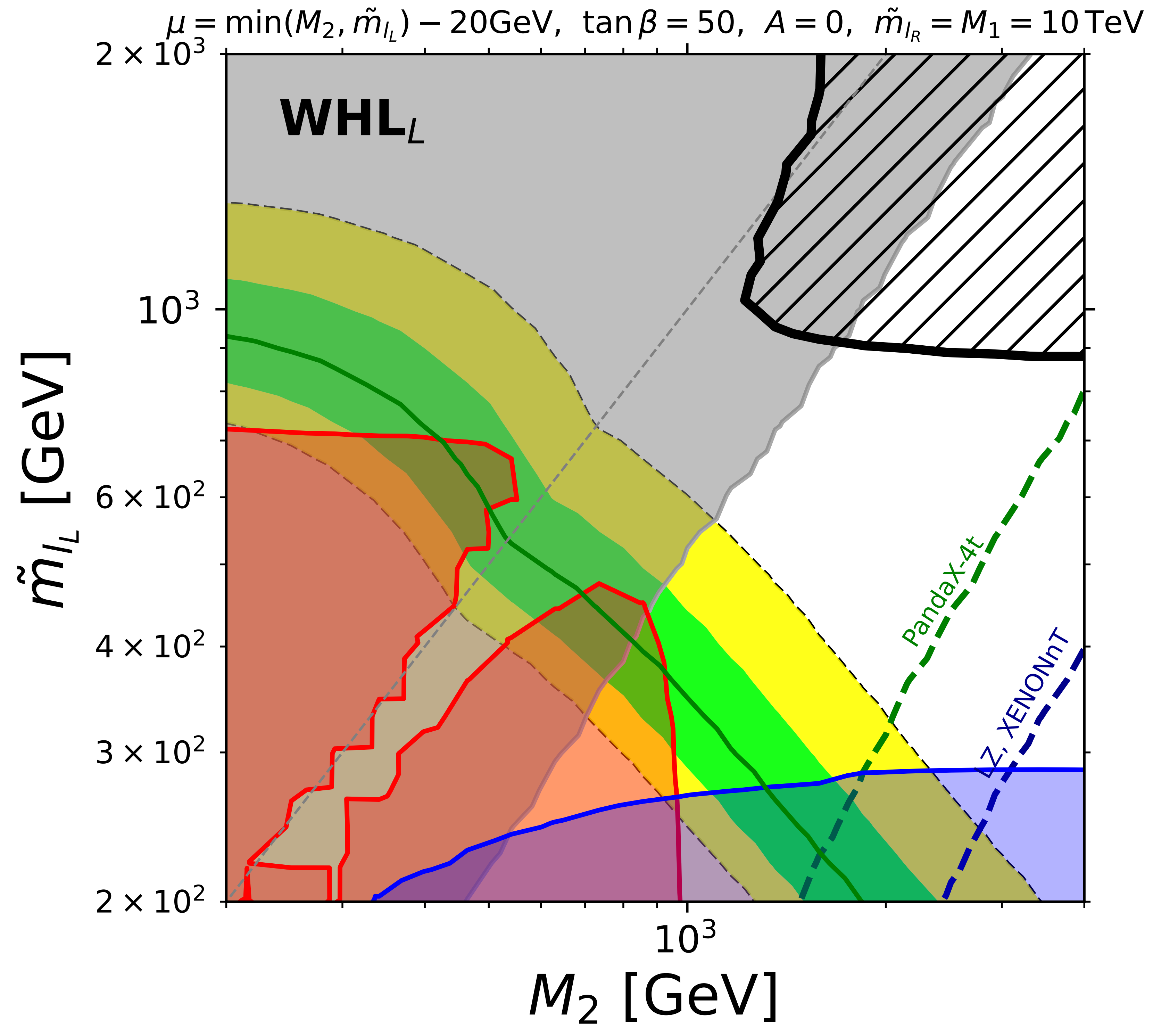


GMSB

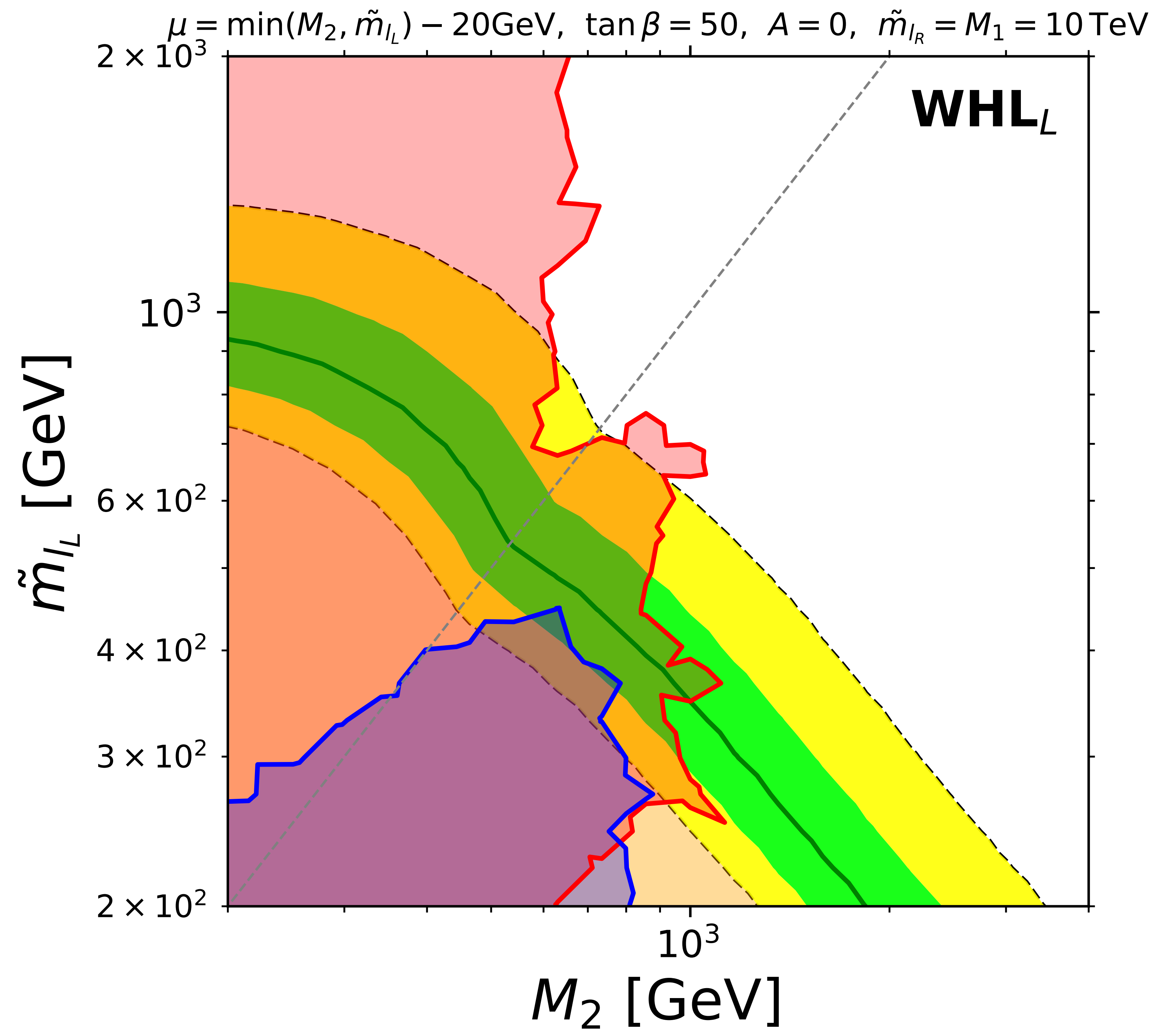
BLR$_{10}$

ATLAS soft-l [1911.12606]
CMS l+l- [2004.05153]
XENON1T [1805.12562]

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



MSSM



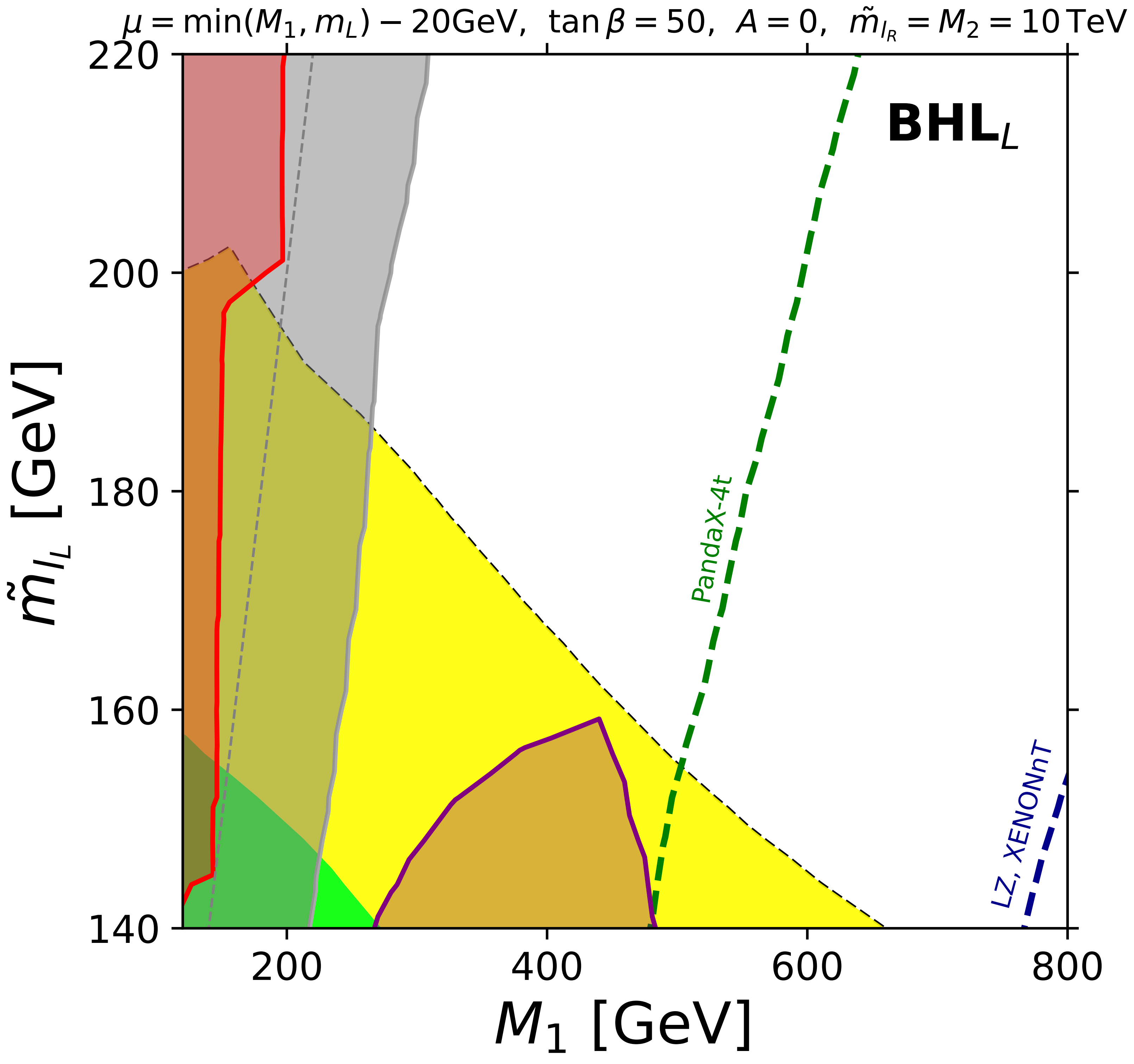
RPV

WHL$_L$

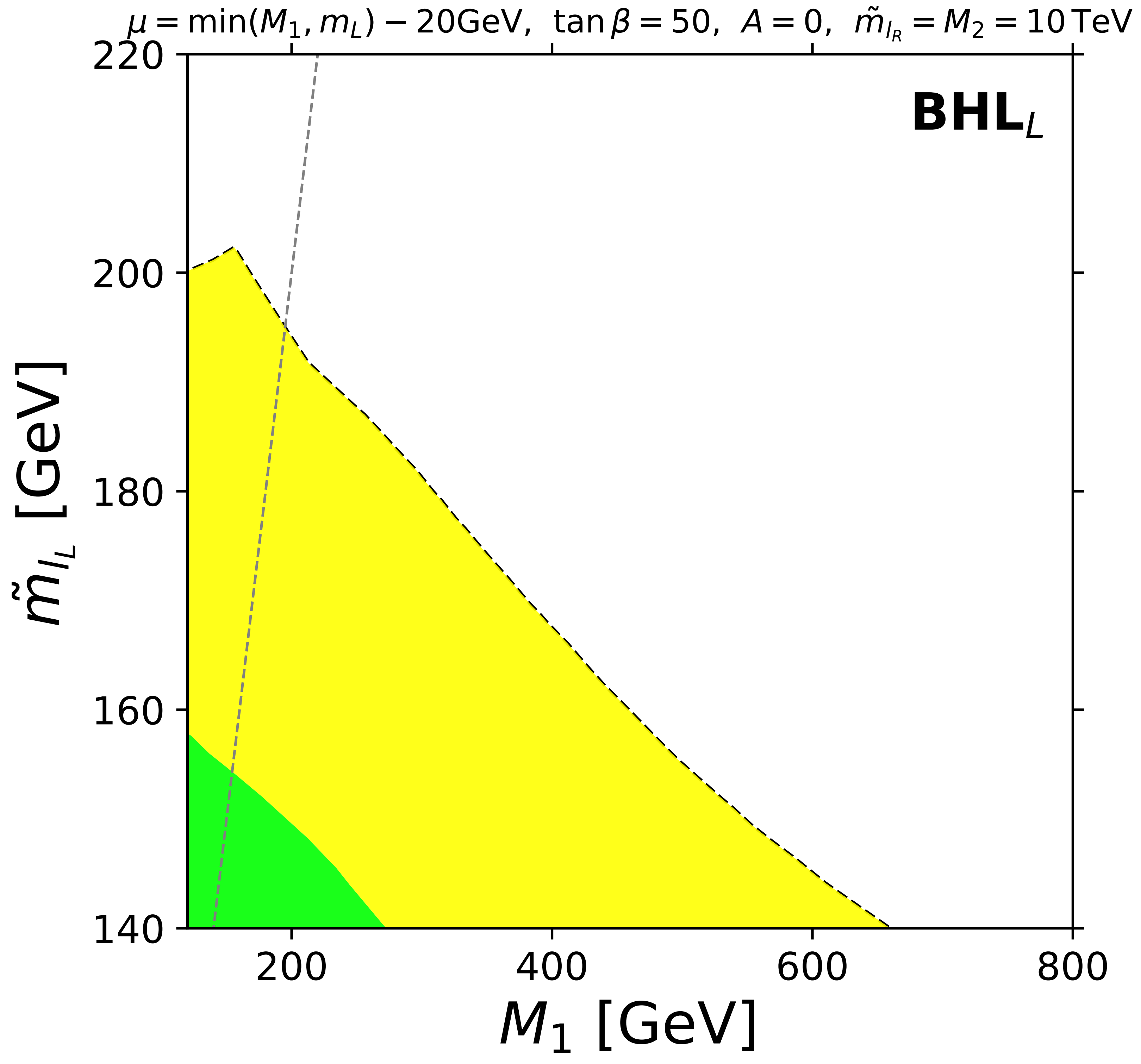
ATLAS soft-l [1911.12606]

CMS l+l- [2004.05153]

XENON1T [1805.12562]



MSSM



RPV

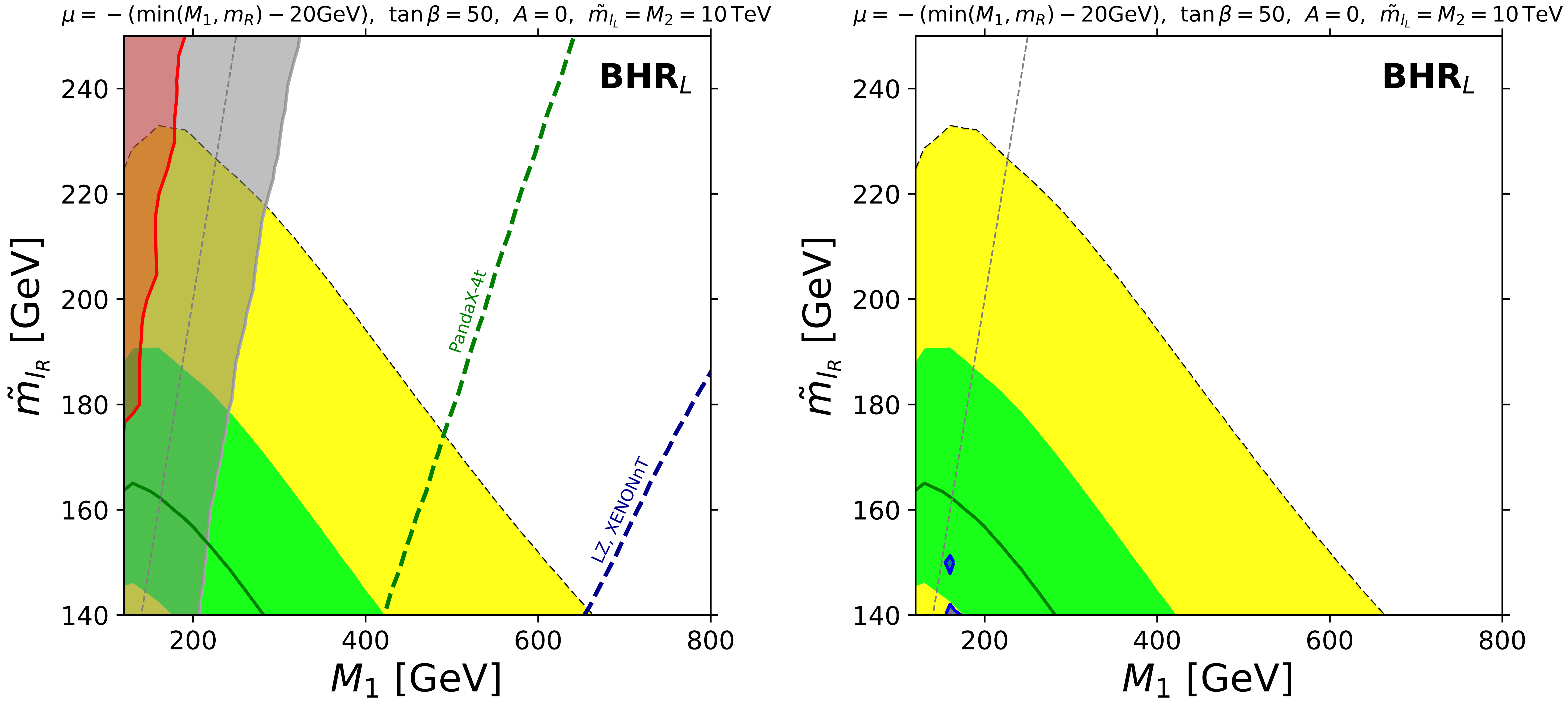
BHL$_L$

R. Masełek Corfu Summer Institute 2022/09/05

CMS l+l- [2004.05153]

XENON1T [1805.12562]

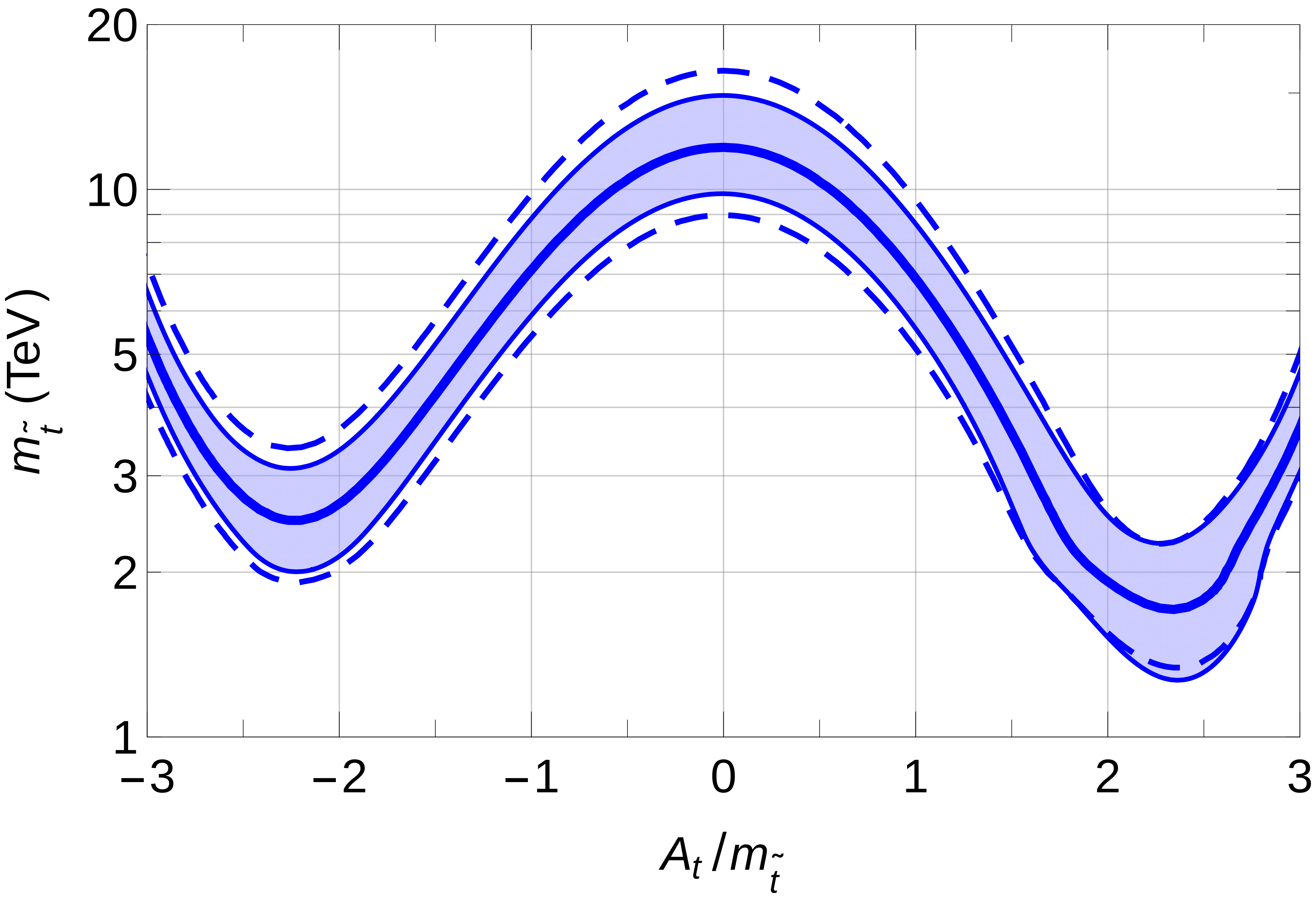
CMS multilepton [1709.05406]



MSSM

RPV

BHR$_L$



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

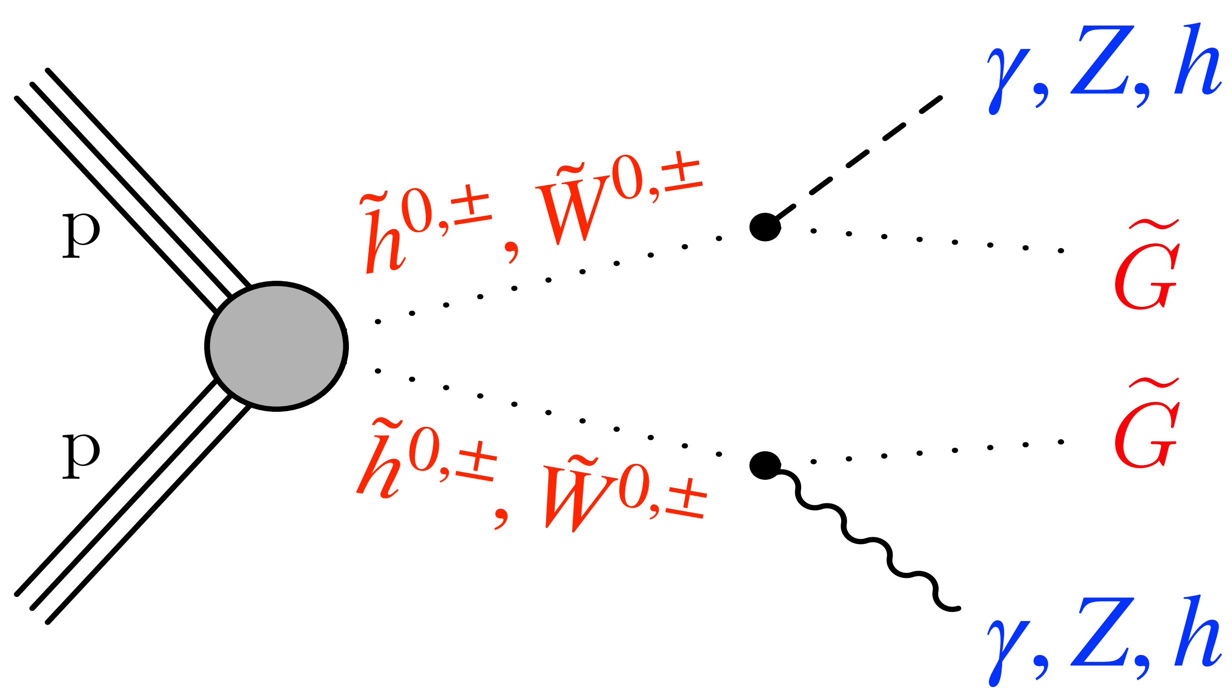
[1504.05200]

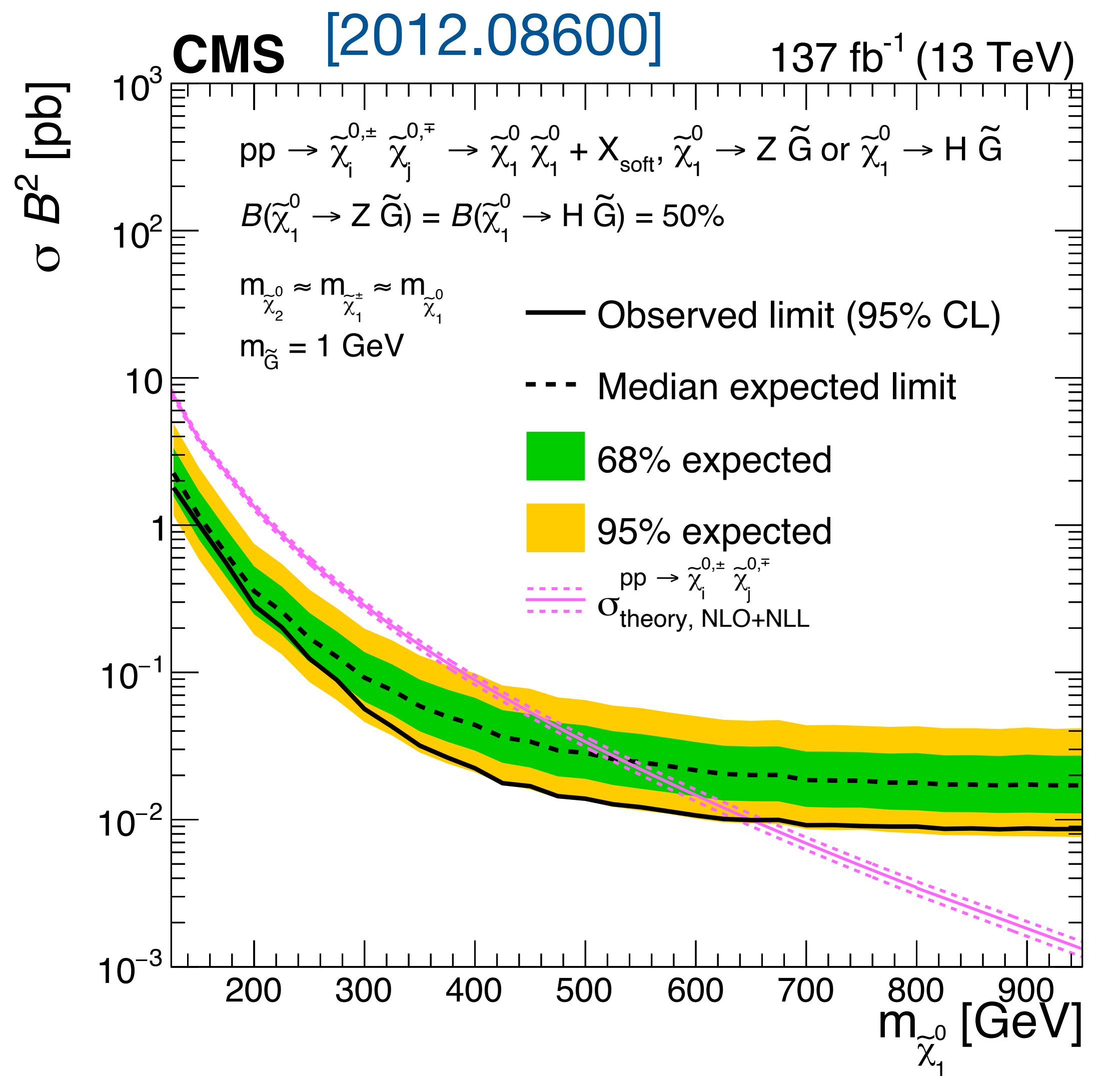
$$m_{\tilde{G}} = \sim 10\,\text{eV} \cdot \left(\frac{m_{\tilde{t}}}{10\text{TeV}}\right)\left(\frac{M_{\rm mess}}{10\text{TeV}}\right)$$

Gravitino LSP

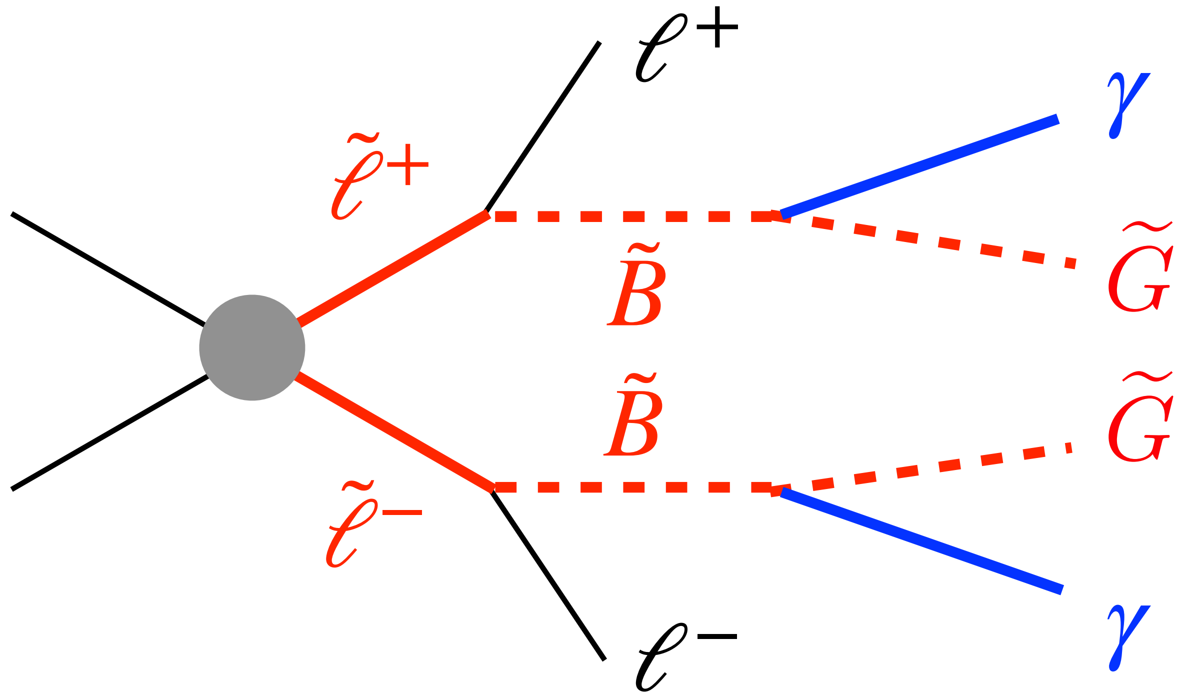
We assume a **massless** gravitino (m < 1GeV) and **prompt** neutralino decay.

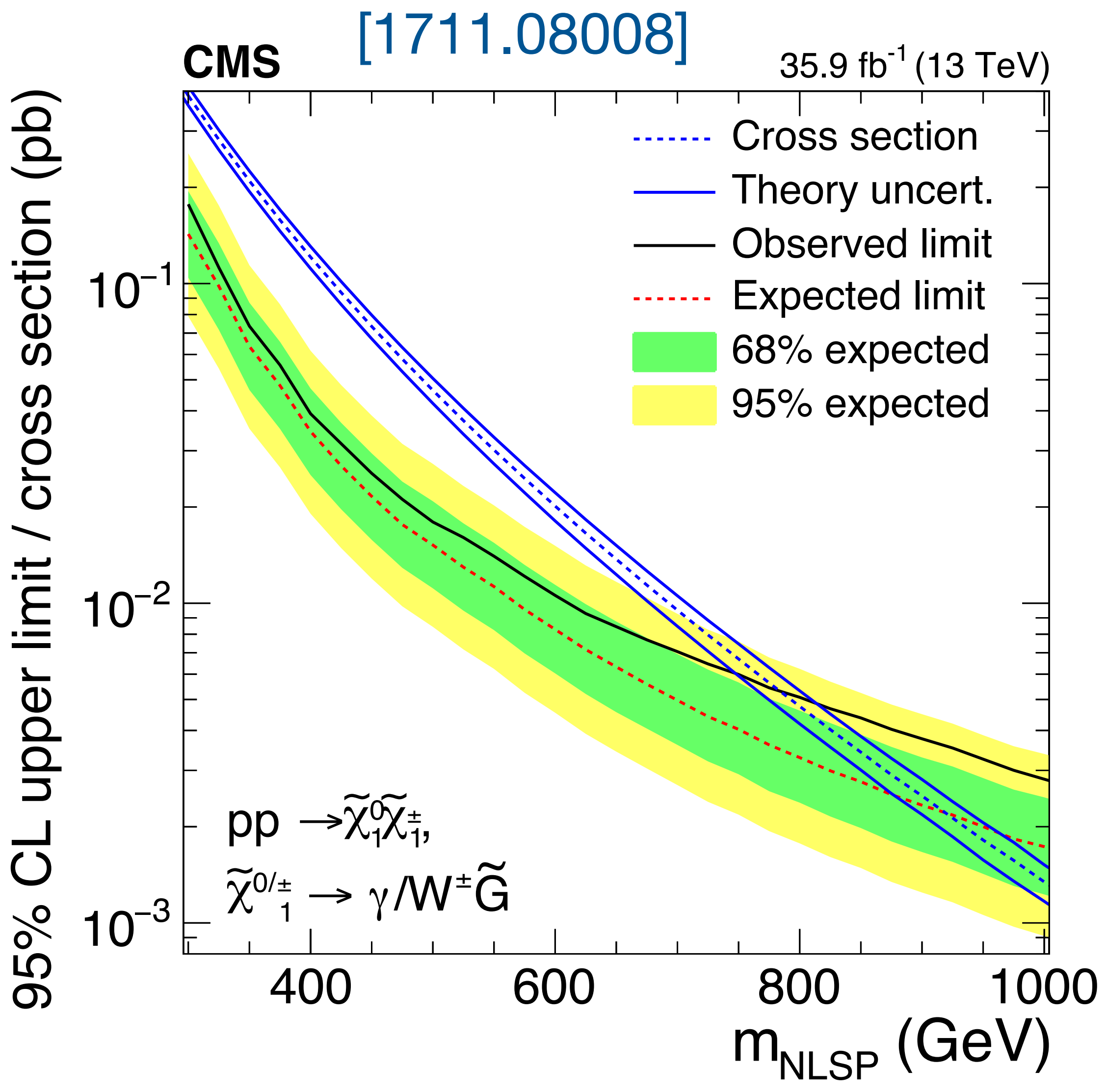
Wino, Higgsino NLSP



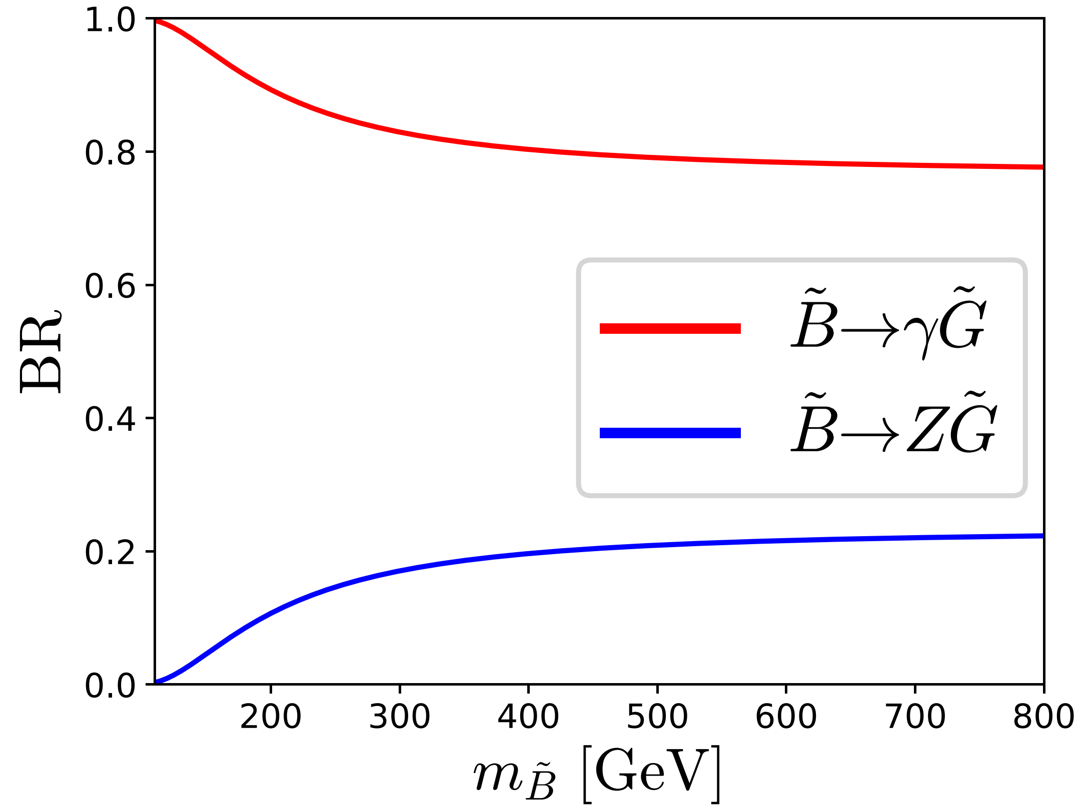


Bino NLSP

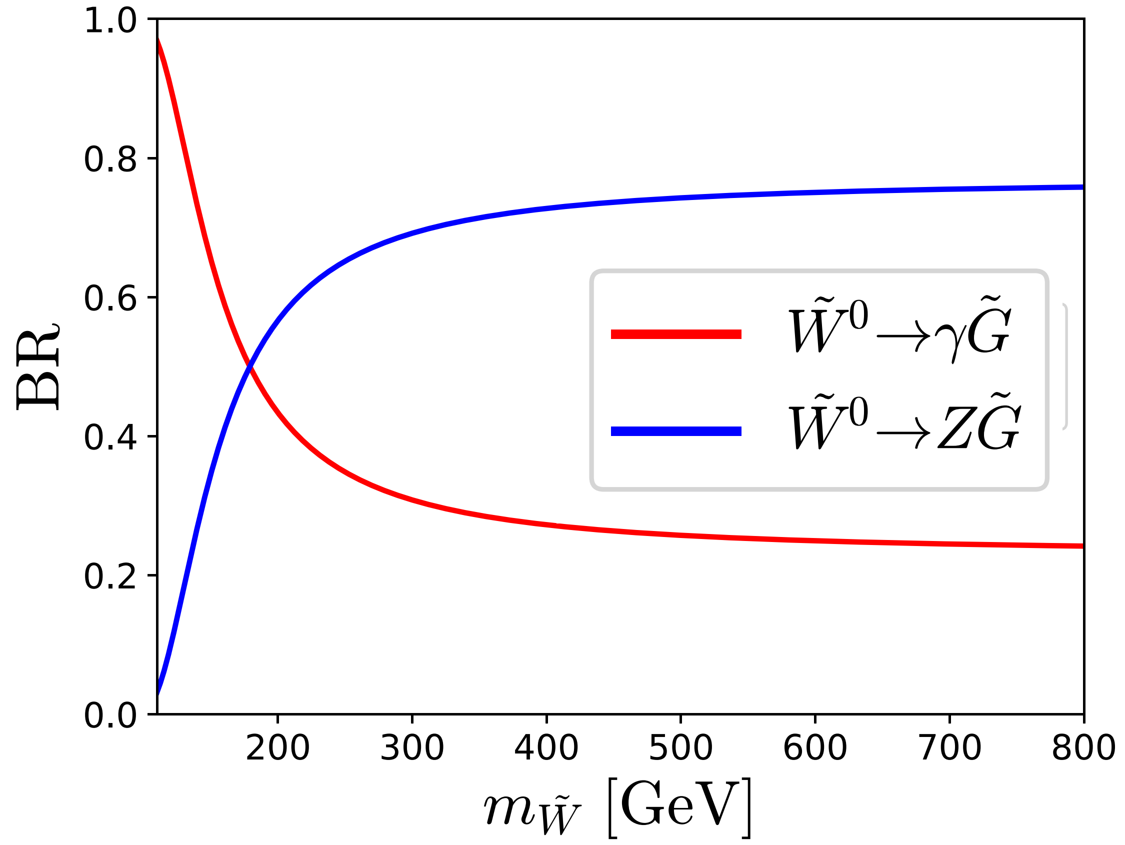




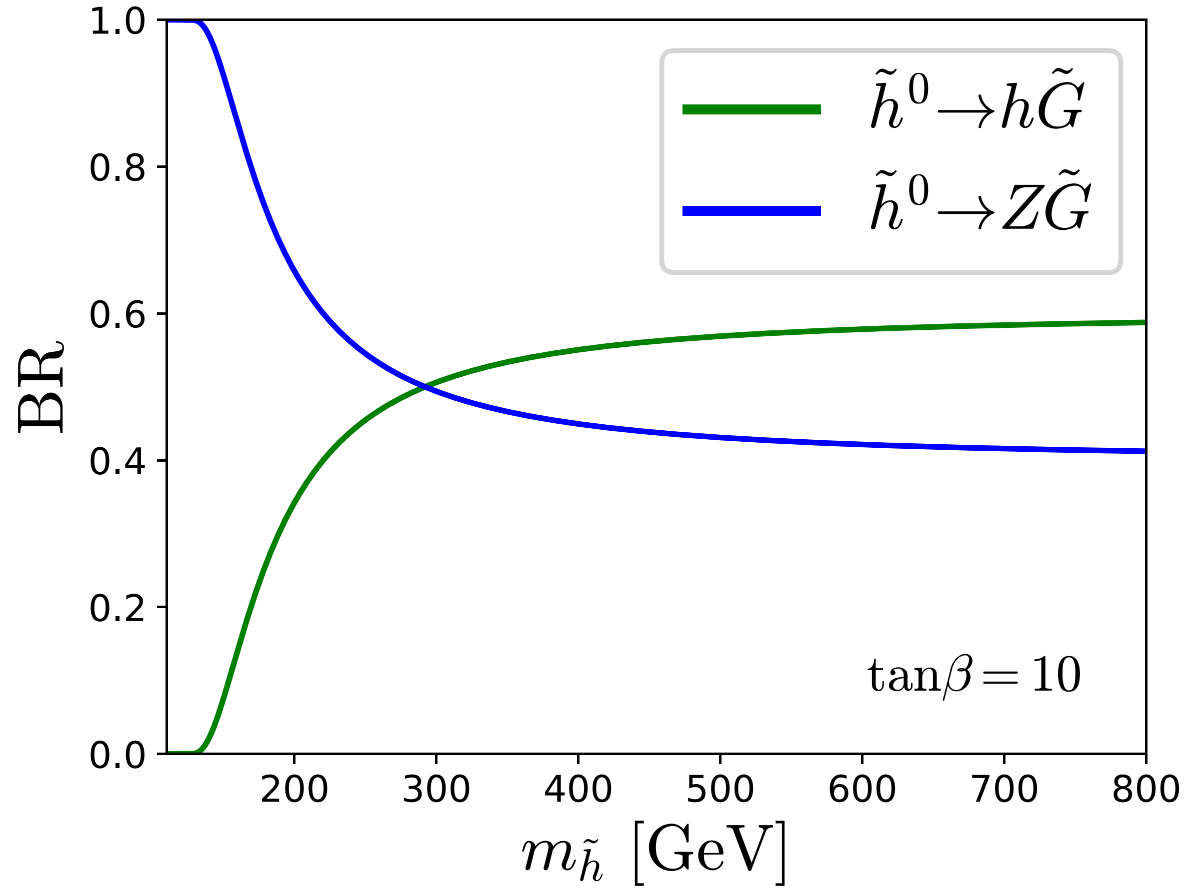
Bino-like

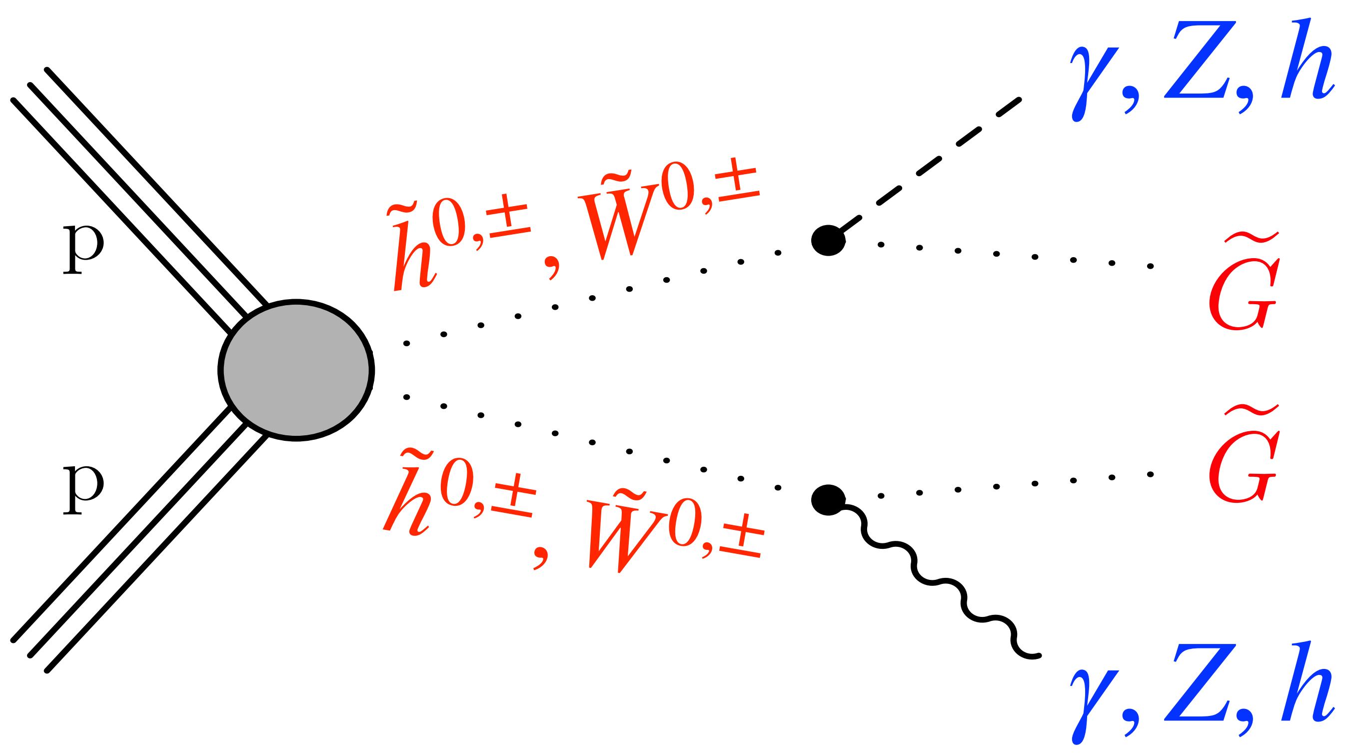


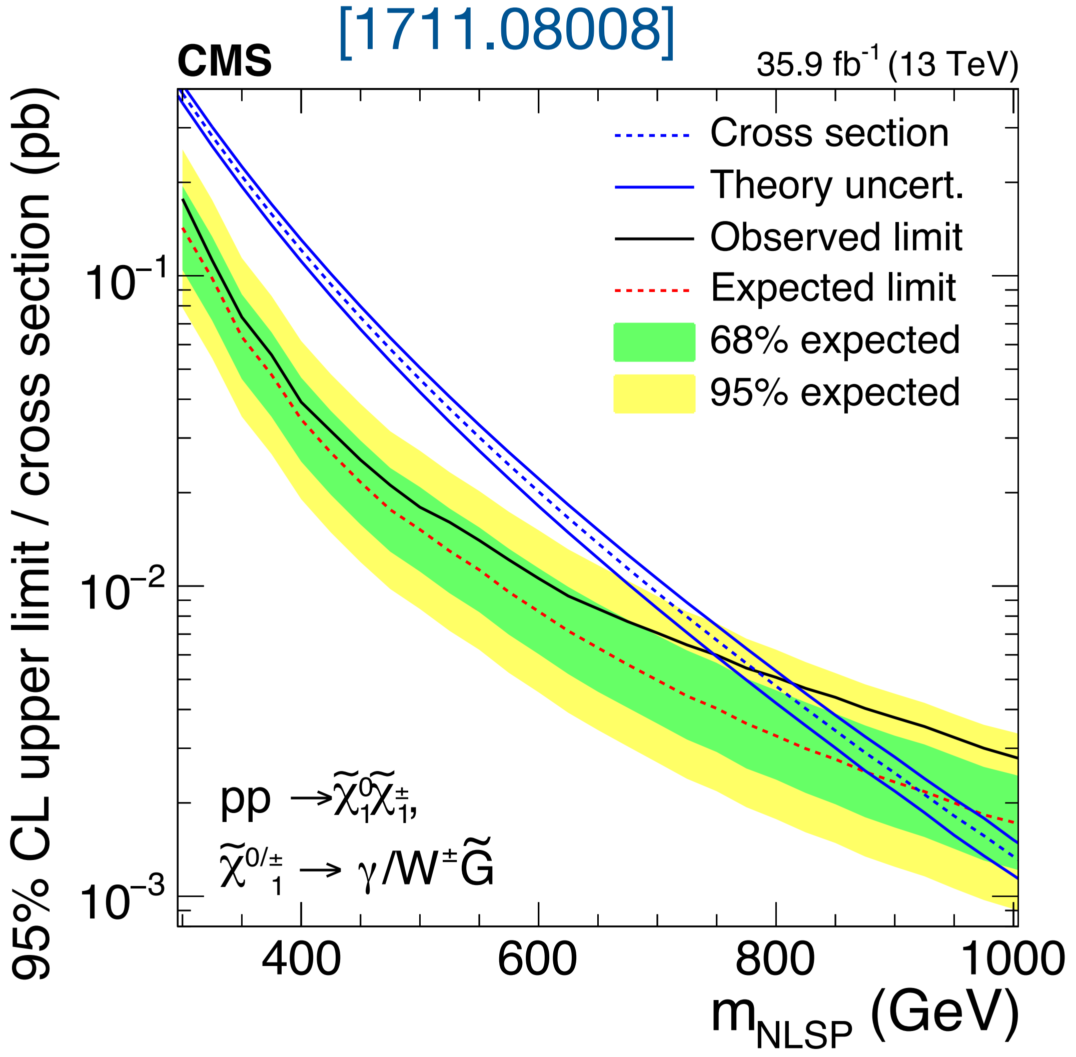
Wino-like

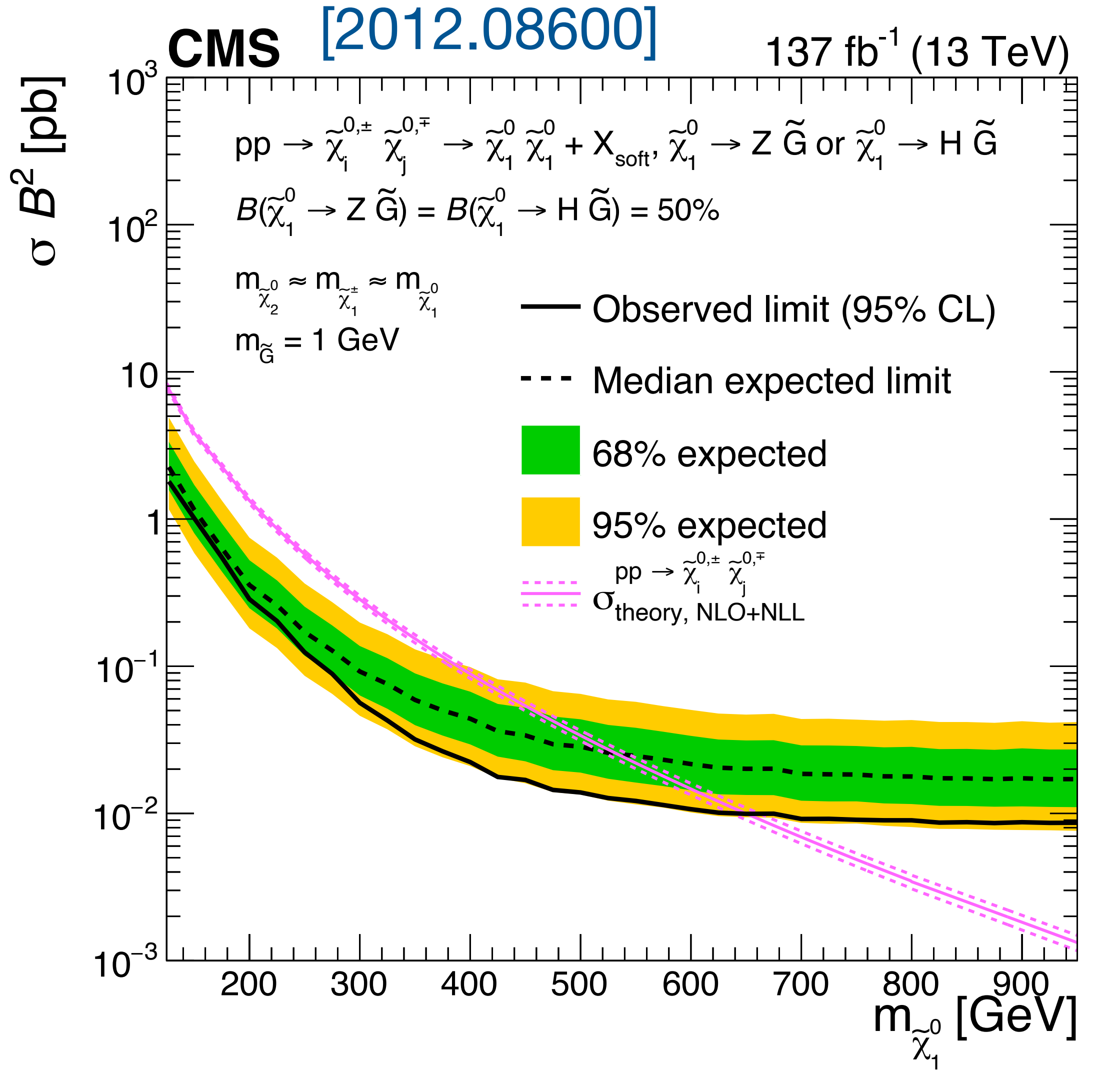


Higgsino-like





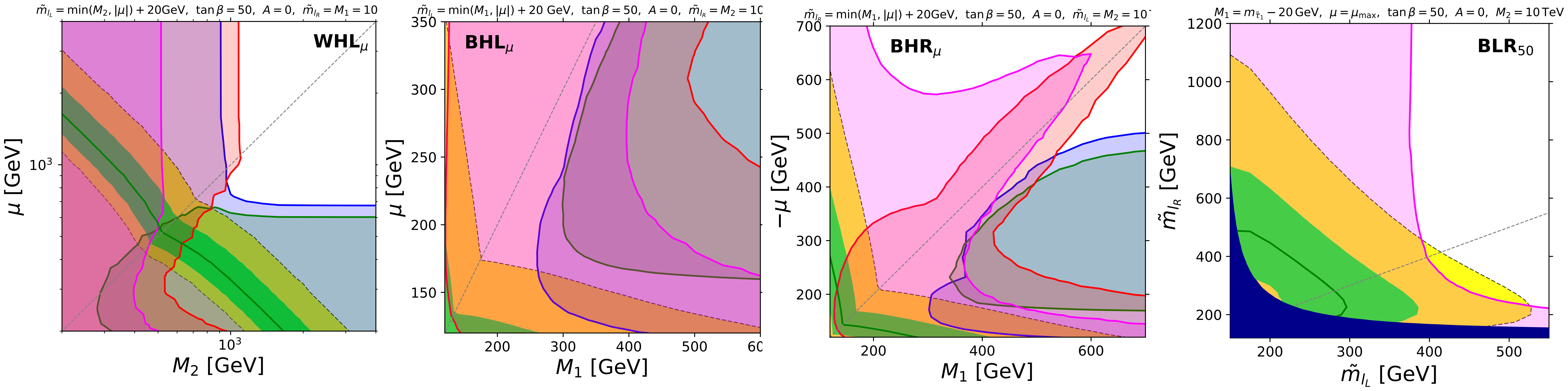




- Higgsino, Wino direct production excluded up to ~ 700GeV
- SUSY g-2 requires Higgsino or Wino with m < 600 GeV

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

Gravitino LSP



$[\gamma\widetilde{G}][\gamma\widetilde{G}]$ CMS $\gamma + E_T\!\!\!/$ [1711.08008]

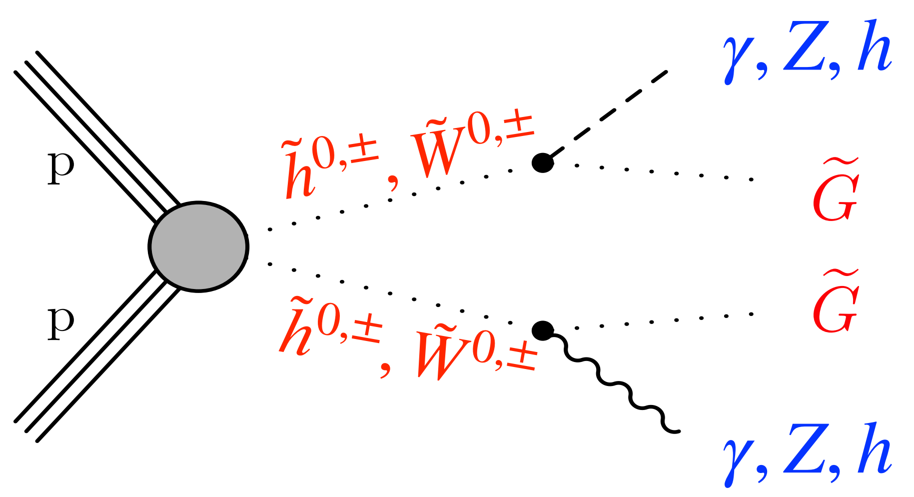
$[\gamma\widetilde{G}][Z(h)\widetilde{G}]$ CMS $\gamma + E_T\!\!\!/$ [1711.08008]

$[Z\widetilde{G}][Z\widetilde{G}]$ CMS $\ell^+\ell^-$ [2012.08600]

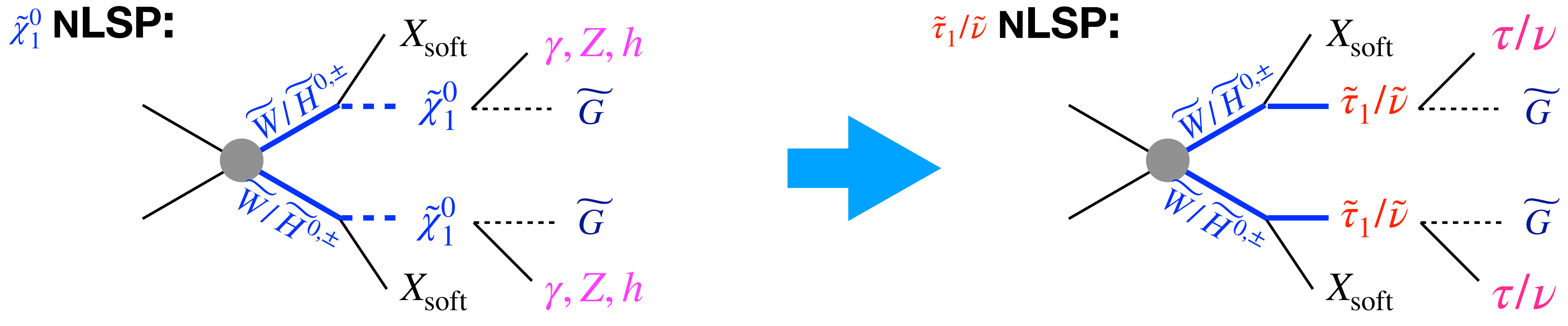
$[h\widetilde{G}][Z\widetilde{G}]$ CMS $\ell^+\ell^-$ [2012.08600]

[(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:

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

BHL plane:

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

} $\tilde{\nu}_L$ **NLSP**

BHR plane:

$$(M_1 \text{ vs } \mu) \quad \text{with} \quad \tilde{m}_{l_R} = \min(M_1, |\mu|) + 20\,\text{GeV} \implies m_{l_R} = \min(M_1, \mu) - 20\,\text{GeV}$$

} $\tilde{e}_R, \tilde{\mu}_R, \tilde{\tau}_R$ **NLSP**

BLR plane:

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

} $\tilde{\tau}_1$ **NLSP**