Discovering electroweakinos in (mini)split supersymmetry.

(BASED ON BADZIAK, DELGADO, OLECHOWSKI, SP, SAKURAI, JHEP, 2015)

BEFORE „FORGETTING” SUPERSYMMETRY, LET’S
EXPLORE MORE
IT’S POSSIBLE PARAMETER RANGE:

LIGHT GAUGINOS, HEAVY SFERMIONS - (MINI) SPLIT?

$\Omega h^2 \leq 0.12$ (MULTI - COMPONENT DARK MATTER?)

(MINI)SPLIT SUPERSYMMETRY

SCALAR MASSES AND B_μ (CORRESPONDING TO DIM 2 OPERATORS)

ARE CHARACTERIZED BY $\tilde{m}$ AND GAUGINO/HIGGSINO MASSES

AND A-TERMS (CORRESPONDING TO DIM 3 OPERATORS)
ARE ASSUMMED TO BE $\mathcal{O}(1TeV)$

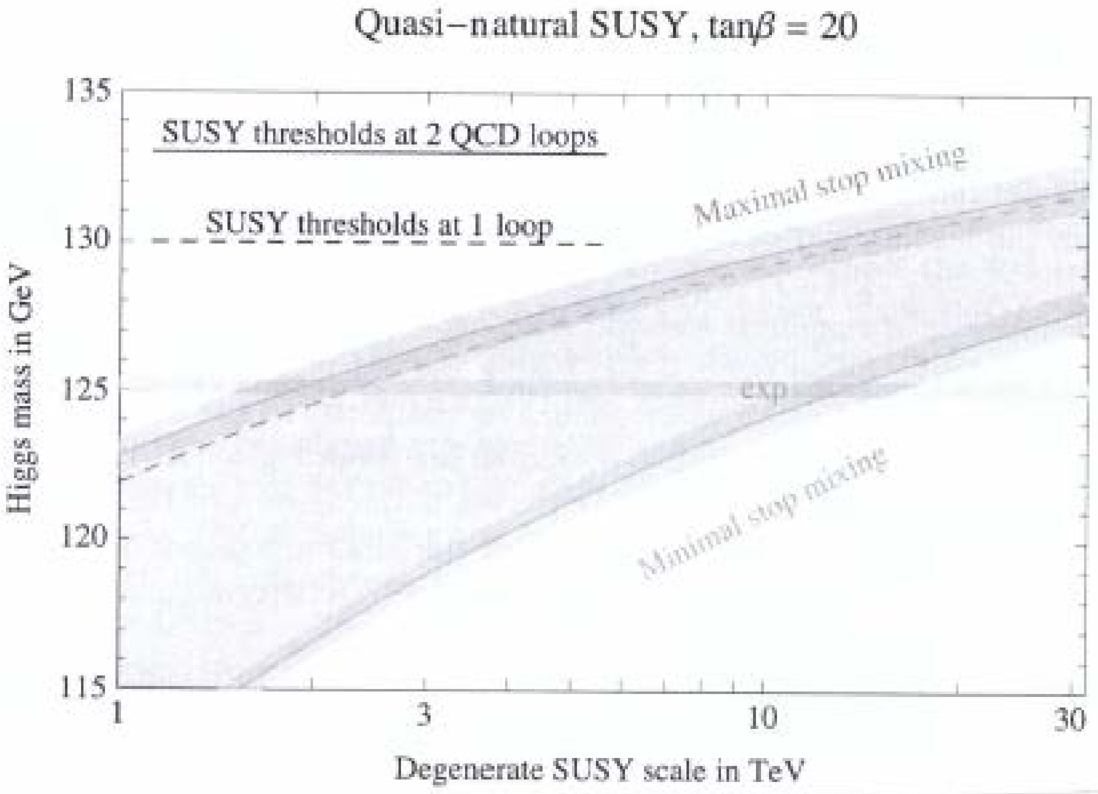
- A VARIETY OF GAUGE MEDIATION MECHANISMS, WITH DIFFERENT PATTERNS OF ELECTROWEAKINO MASSES, ANOMALY MEDIATION, MIRAGE MEDIATION

THE SPLITTING IN SPLIT SUPERSYMMETRY IS CONSTRAINED BY THE HIGGS MASS

($\tan\beta$ DEPENDENT)

Summing $\ln(Msusy/M_Z)$ = MATCHING SM TO MSSM AT Msusy

Bagnaschi, Giudice, Slavich, Strumia (2014)



Superpartner mass mass dependence can be described (in LL approx) by a single effective parameter Tsusy

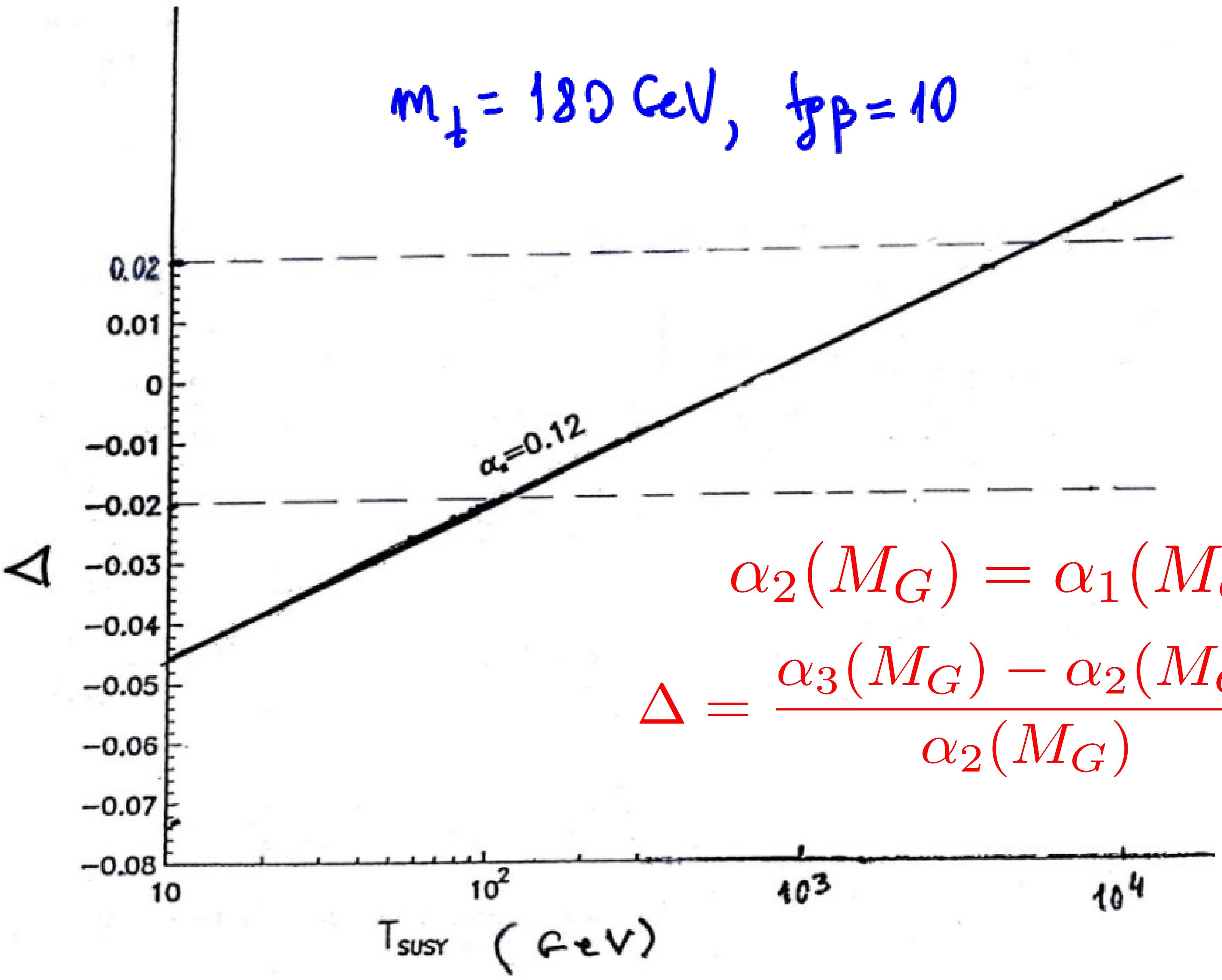
$$T_{susy} = |\mu| \left(\frac{m_{\tilde{w}}}{m_{\tilde{g}}}\right)^{3/2} \left(\frac{M_{\tilde{\ell}}}{M_{\tilde{q}}}\right)^{3/19} \left(\frac{M_{A^0}}{|\mu|}\right)^{3/19} \left(\frac{m_{\tilde{w}}}{|\mu|}\right)^{3/19}$$

$$\approx |\mu| \left[\frac{m_{\tilde{w}}}{m_{\tilde{g}}}\right]^{3/2}$$

CARENA, SP, WAGNER ‘93

A HINT FOR EITHER HEAVY OR COMPRESSED SPECTRUM BECAUSE…

$m_t = 180$ GeV, $tg\beta = 10$



$$\alpha_2(M_G) = \alpha_1(M_G)$$

$$\Delta = \frac{\alpha_3(M_G) - \alpha_2(M_G)}{\alpha_2(M_G)}$$

For instance, for universal gaugino masses at the GUT scale

$$T_{susy} \simeq |\mu| \left[\frac{\alpha_2(M_Z)}{\alpha_3(M_Z)}\right]^{3/2} \sim \frac{1}{7}|\mu|$$

A HINT FOR EITHER HEAVY O(1) TeV OR COMPRESSED SPECTRUM

- ELECTROWEAK SECTOR MAY PLAY LEADING ROLE IN DISCOVERING SUPERSYMMETRY

- ACCEPTING THERMAL HISTORY OF UNIVERSE, IN MODELS WITH STABLE NEUTRALINO (R-PARITY), ITS MASS IS BOUNDED FROM ABOVE BY

$$\Omega h^2 \leq 0.12$$

- **DECOUPLED SFERMIONS (actually, it it's enough to have them 20-30% heavier than gauginos/higgsinos)**

PARAMETERS $M_1, \quad M_2, \quad \mu, \quad \tan\beta$

APPLIES TO MSSM AND ALL MODELS WHERE THE ADMIXTURE OF ADDITIONAL STATES TO LSP AND NLSP IS SMALL

DIRECT DETECTION + LHC -> RELEVANT ELECTROWEAKINO PARAMETR SPACE BEGINS TO BE TESTED

- WHAT IS THE RANGE OF VALUES OF INTEREST FOR Ωh^2
- DIRECT DETECTION
- COLLIDER
- THEIR INTERPLAY

ANALYTICAL QUALITATIVE QUIDE AND NUMERICAL SCANS

It is covenient to organize the discussion according to the LSP composition

BINO-HIGGSINO MIXING $\left(M_2 = m_{sf} = m_A = 7\; TeV\right)$

HIGGSINO-WINO MIXING $\left(M_1 = m_{sf} = m_A = 7\; TeV\right)$

BINO-WINO MiXING WITH $\mu = 1.1\; min(M_1, M_2)$

AND MORE GENERAL BINO-HIGGSINO-WINO MIXING

PURE HIGGSINO

$$\Omega_h h^2 = 0.10(\frac{\mu}{1\ TeV})^2$$

$$\Omega h^2 < 0.12$$ for

$$\mu < 1 TeV$$

PURE WINO

$$\Omega_w h^2 = 0.13(\frac{M_2}{2.5\ TeV})^2$$

$$\Omega h^2 < 0.12$$ for

$$M_2 < 2.2(2.8) TeV$$

LOWER BOUND ON CHARGINO MASS GIVES LOWER BOUND FOR Ω ; ADDING BINO COMPONENT GIVES LARGER Ω (WHEN SFERMIONS ARE HEAVY)

SPIN INDEPENDENT SCATTERING CROSS SECTION

EXCLUSION LIMITS (LUX) AND FUTURE PROSPECTS

REMEMBER: FOR NEUTRALINOS WITH Ω_χ

AND CROSS SECTION σ_{SI}

THE EXCLUSION LIMIT IS $$\frac{\sigma_{SI}^{\chi}}{\sigma_{SI}^{LUX}}\frac{\Omega_\chi}{\Omega_{DM}} > 1$$

$$\sigma_{SI} = 8 \times 10^{-45} cm^2 (\frac{c_{h\chi\chi}}{0.1})^2$$

where

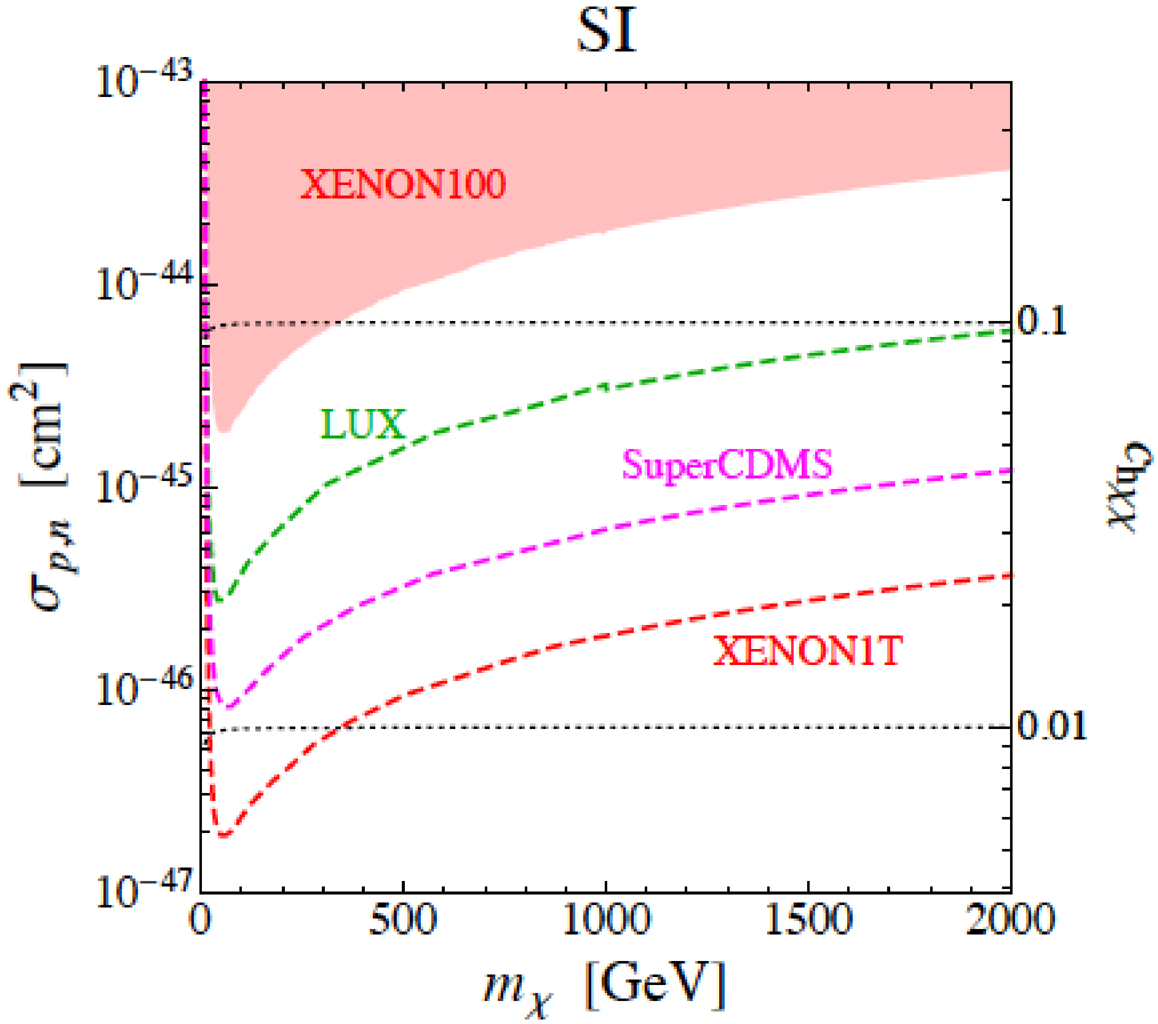
$$L = \frac{c_{h\chi\chi}}{2} h(\chi\chi + \chi^\dagger\chi^\dagger)$$

and (approximately)

$$c_{h\chi\chi} \sim \theta$$ (MIXING)

Gaugino/higgsino $\theta = \frac{(\sin\beta \pm \cos\beta)}{\sqrt{2}}(\frac{M_Z}{(\mu \mp M_i)}$

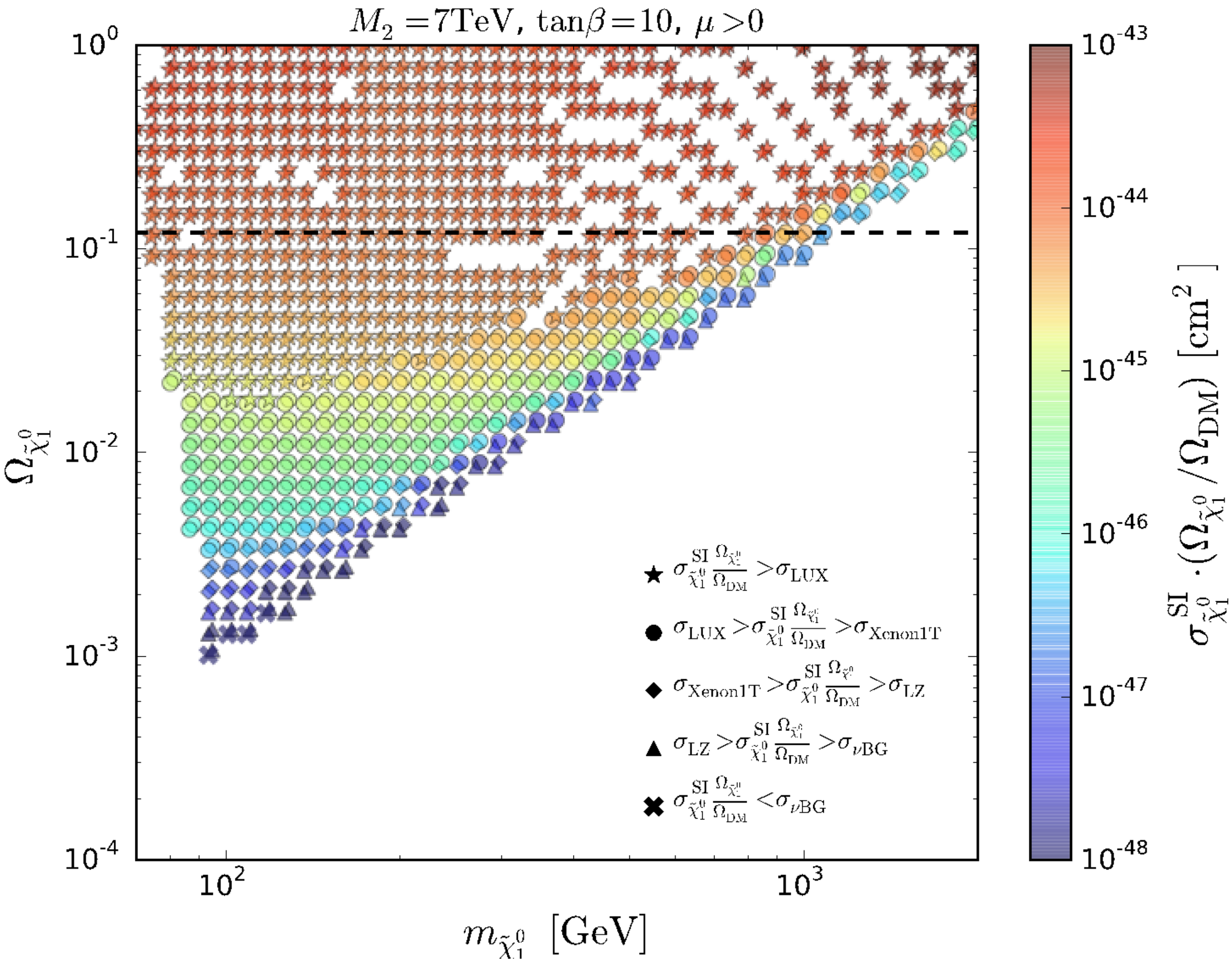
Bino/wino $\theta = \frac{(\sin 2\beta \sin 2\theta_W)}{2}(\frac{M_Z^2}{(M_2 - M_1)\mu})$


SI
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
$\sigma_{p,n}$ [cm^2]
XENON100
LUX
SuperCDMS
XENON1T
0.1
0.01
$c_{h\chi\chi}$
0
500
1000
1500
2000
m_χ [GeV]

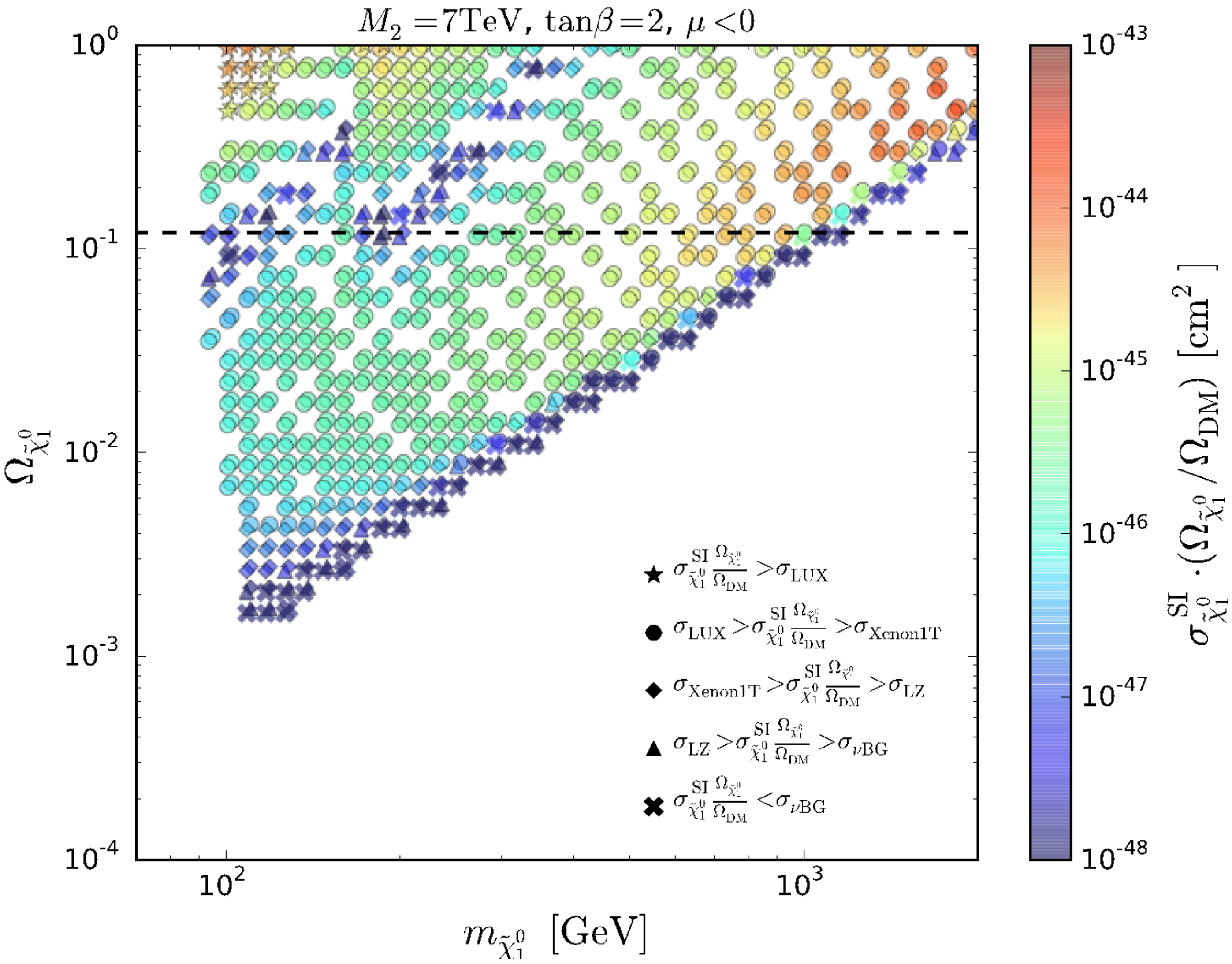
FIRST IMPORTANT CONCLUSION:

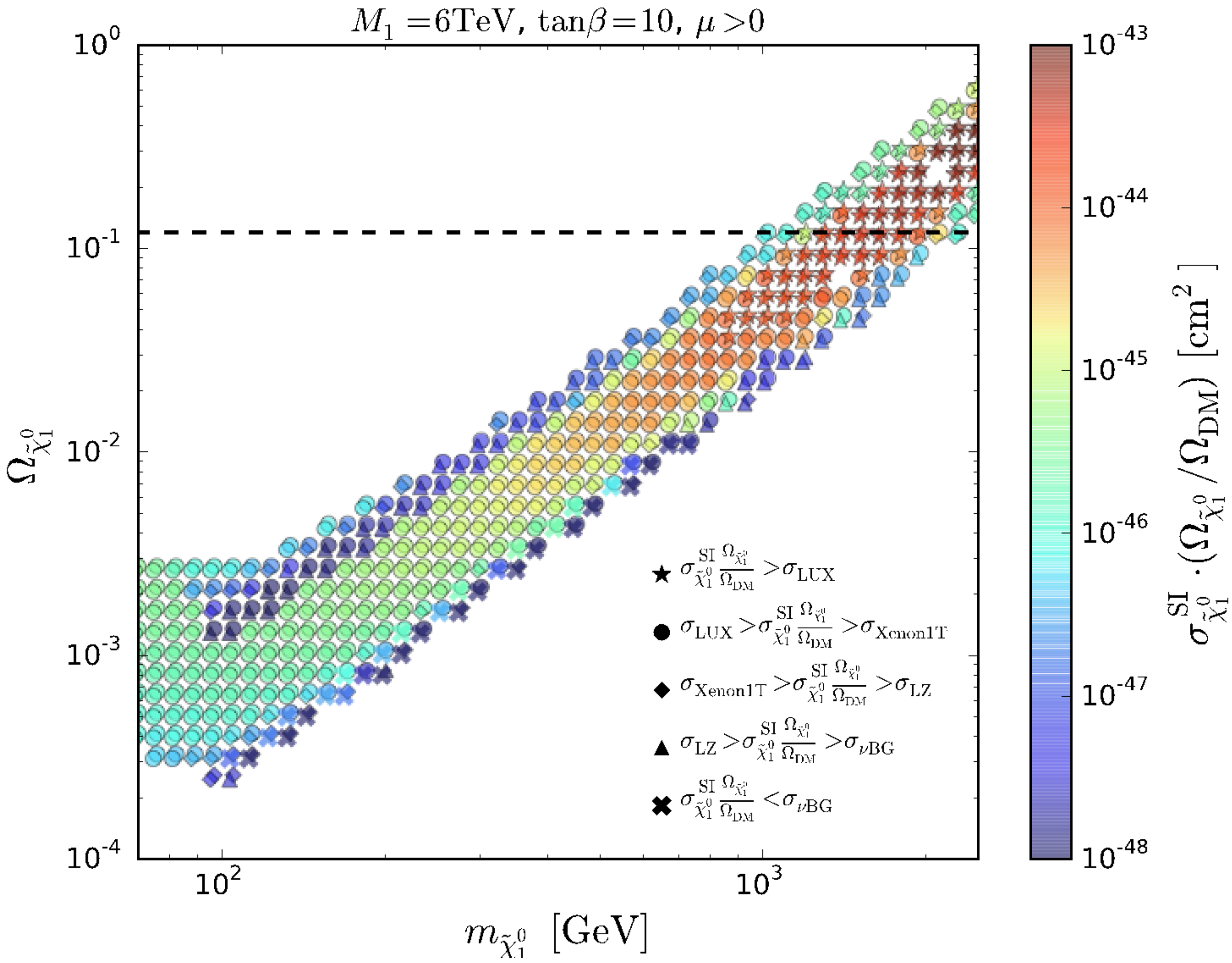
IN SPITE OF THE (SMALL) FLUX FACTOR, LUX AND FUTURE DD EXPERIMENTS ARE/WILL BE SENSITIVE TO NEUTRALINOS EVEN WITH VERY SMALL Ω_χ

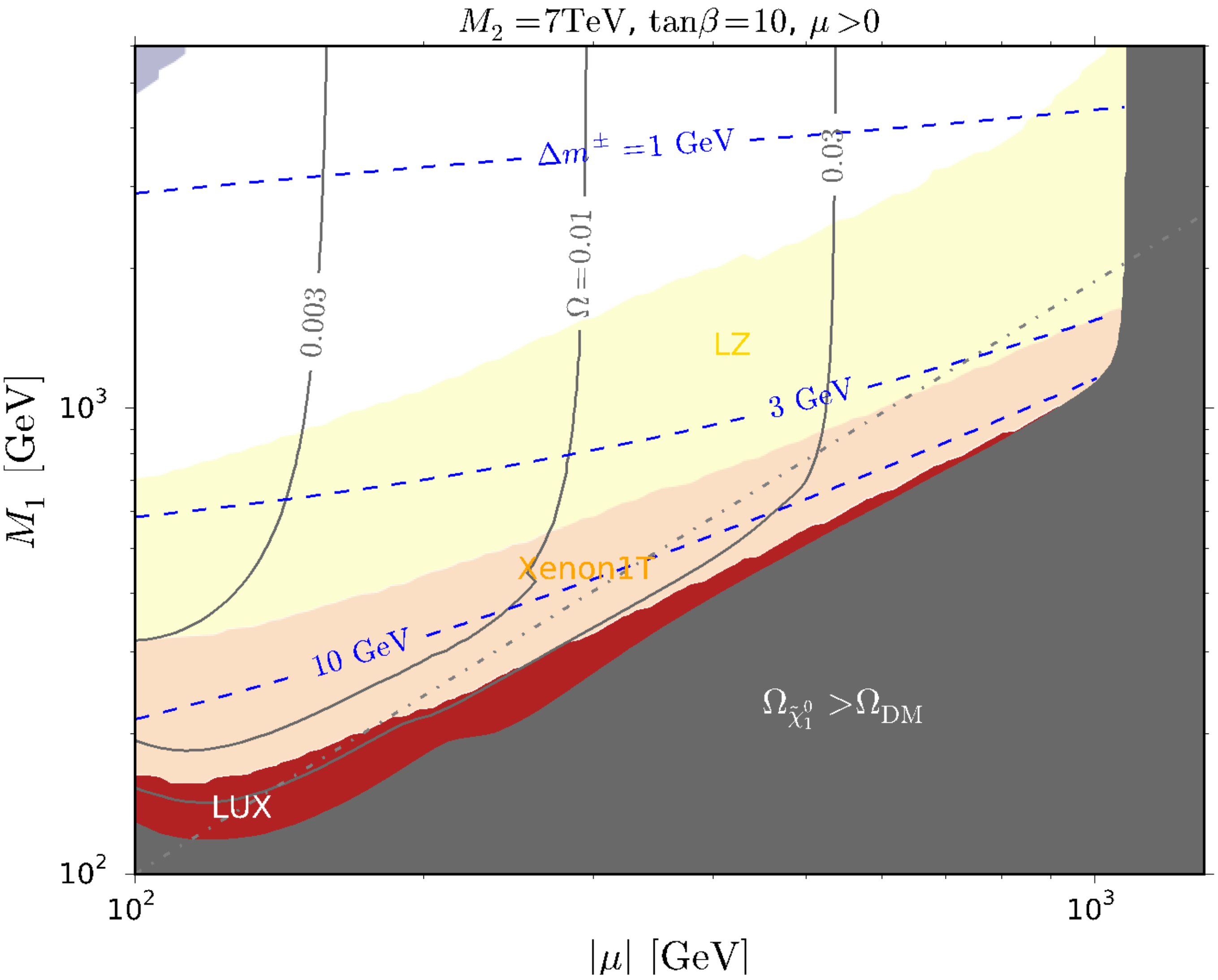
(A SIGNAL WOULD NOT NECESSARILY MEAN THE DISCOVERY OF THE MAIN DM COMPONENT)



$M_2 = 7\mathrm{TeV},\ \tan\beta = 10,\ \mu > 0$
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\Omega_{\tilde{\chi}_1^0}$
10^{2}
10^{3}
$m_{\tilde{\chi}_1^0}\ [\mathrm{GeV}]$
$\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{LUX}}$
$\sigma_{\mathrm{LUX}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{Xenon1T}}$
$\sigma_{\mathrm{Xenon1T}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{LZ}}$
$\sigma_{\mathrm{LZ}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\nu\mathrm{BG}}$
$\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} < \sigma_{\nu\mathrm{BG}}$
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
$\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \cdot (\Omega_{\tilde{\chi}_1^0}/\Omega_{\mathrm{DM}})\ [\mathrm{cm}^2]$


$M_2 = 7\mathrm{TeV},\ \tan\beta = 2,\ \mu < 0$
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\Omega_{\tilde{\chi}_1^0}$
10^2
10^3
$m_{\tilde{\chi}_1^0}$ [GeV]
★ $\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{LUX}}$
● $\sigma_{\mathrm{LUX}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{Xenon1T}}$
◆ $\sigma_{\mathrm{Xenon1T}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{LZ}}$
▲ $\sigma_{\mathrm{LZ}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\nu\mathrm{BG}}$
✖ $\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} < \sigma_{\nu\mathrm{BG}}$
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
$\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \cdot (\Omega_{\tilde{\chi}_1^0}/\Omega_{\mathrm{DM}})$ [cm^2]


M_1 =6TeV, tanβ=10, μ>0
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\Omega_{\tilde{\chi}_1^0}$
10^{2}
10^{3}
$m_{\tilde{\chi}_1^0}$ [GeV]
$\sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\rm LUX}$
$\sigma_{\rm LUX} > \sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\rm Xenon1T}$
$\sigma_{\rm Xenon1T} > \sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\rm LZ}$
$\sigma_{\rm LZ} > \sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\nu \rm BG}$
$\sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} < \sigma_{\nu \rm BG}$
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
$\sigma^{\rm SI}_{\tilde{\chi}_1^0} \cdot (\Omega_{\tilde{\chi}_1^0}/\Omega_{\rm DM})$ [cm^2]

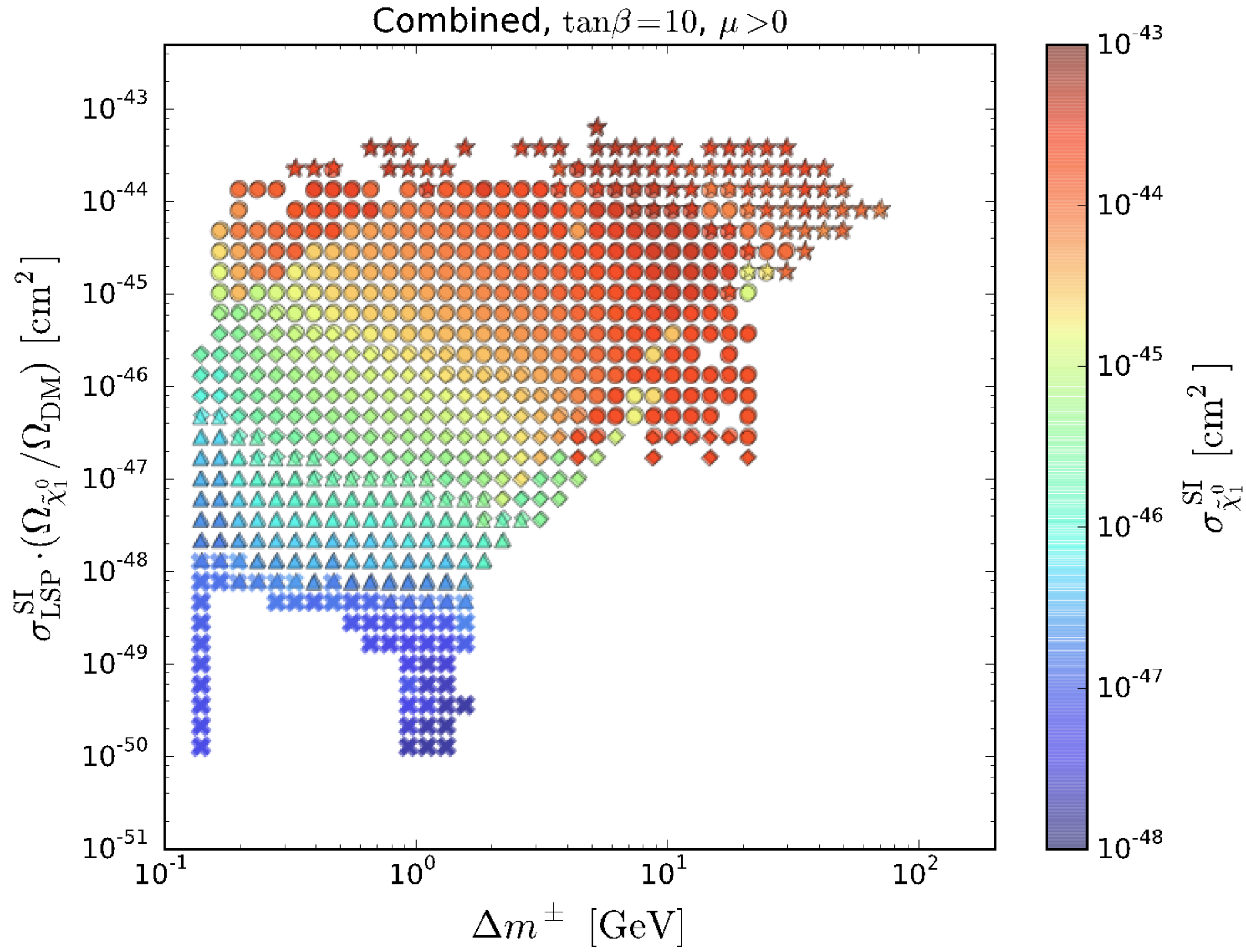

M_2 =7TeV, tanβ=10, μ>0
M_1 [GeV]
$|\mu|$ [GeV]
10^2
10^3
10^2
10^3
$\Delta m^{\pm}$ =1 GeV
3 GeV
10 GeV
0.003
Ω=0.01
0.03
LZ
Xenon1T
LUX
$\Omega_{\tilde{\chi}_1^0}$ >$\Omega_{\rm DM}$

ANOTHER IMPORTANT GENERAL CONCLUSION, WITH STRONG IMPACT ON THE COLLIDER SEARCHES:

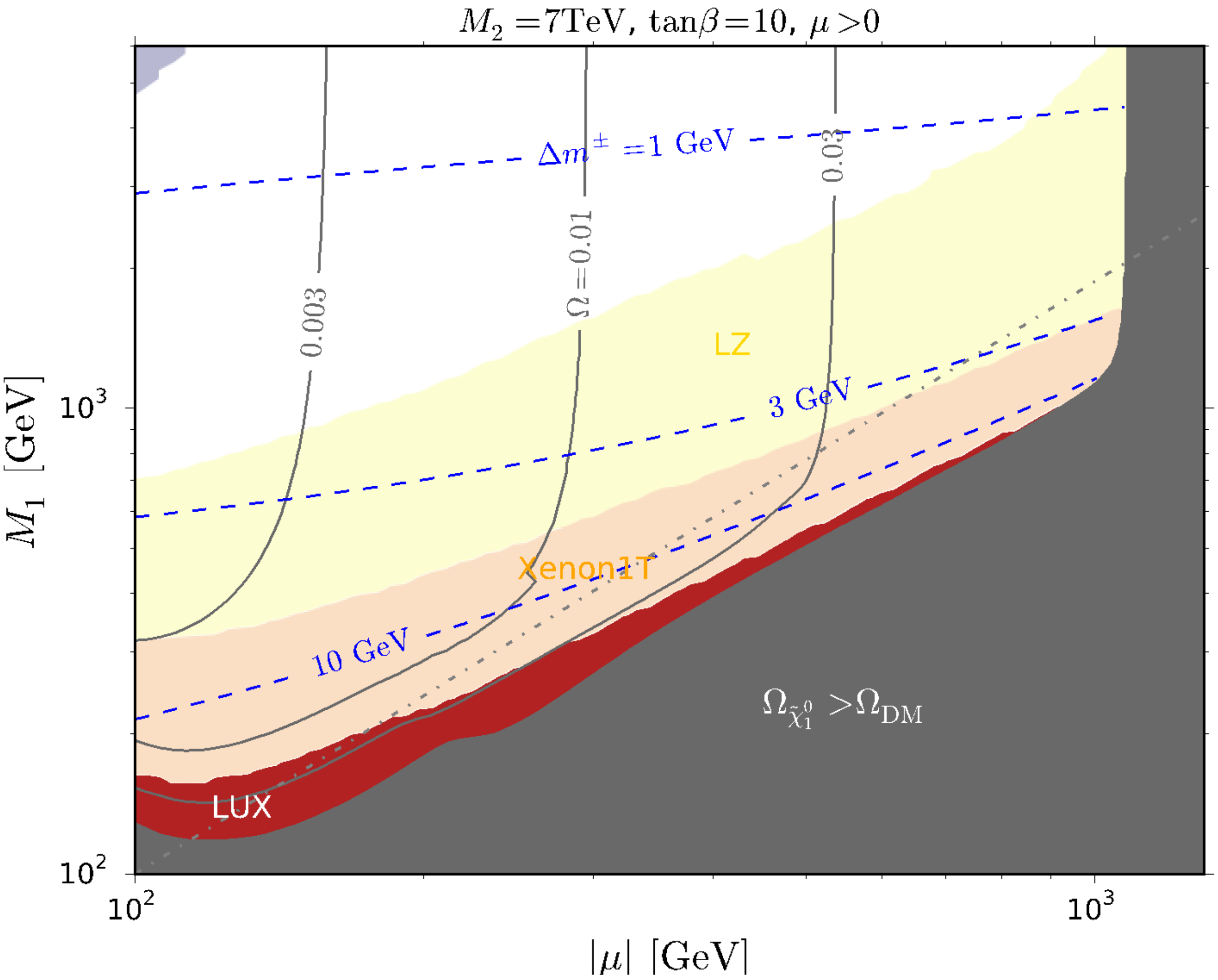
DD LIMITS IMPLY SMALL NLSP-LSP MASS SPLITTINGS

LUX-→ <50 GeV, XENON1T-→ <10GeV

FOLLOWS FROM THE STRONGLY CONSTRAINED FROM ABOVE BINO COMPONENT IN THE LSP BY THE DD LIMITS


Combined, $\tan\beta = 10$, $\mu > 0$
$\sigma^{\rm SI}_{\rm LSP} \cdot (\Omega_{\tilde{\chi}^0_1}/\Omega_{\rm DM})$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-51}
10^{-1}
10^{0}
10^{1}
10^{2}
$\Delta m^{\pm}$ [GeV]
$\sigma^{\rm SI}_{\tilde{\chi}^0_1}$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}

General correlation: the smaller the spin independent cross section the smaller the mass differences and longer life times of the NLPS


M_2 =7TeV, tanβ=10, μ>0
M_1 [GeV]
$|\mu|$ [GeV]
10^2
10^3
10^2
10^3
$\Delta m^{\pm}$ =1 GeV
3 GeV
10 GeV
0.003
Ω=0.01
0.03
LZ
Xenon1T
LUX
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$

Collider

Drell-Yan production of a pair of gauginos + a hard jet

$\chi_1^+\chi_1^-$, $\chi_2^0\chi_1^0$,

$\chi_1^+\chi_1^0$, $\chi_2^0\chi_1^+$ etc

$pp \to \text{jet}\ \not{E}_T + X$

↑

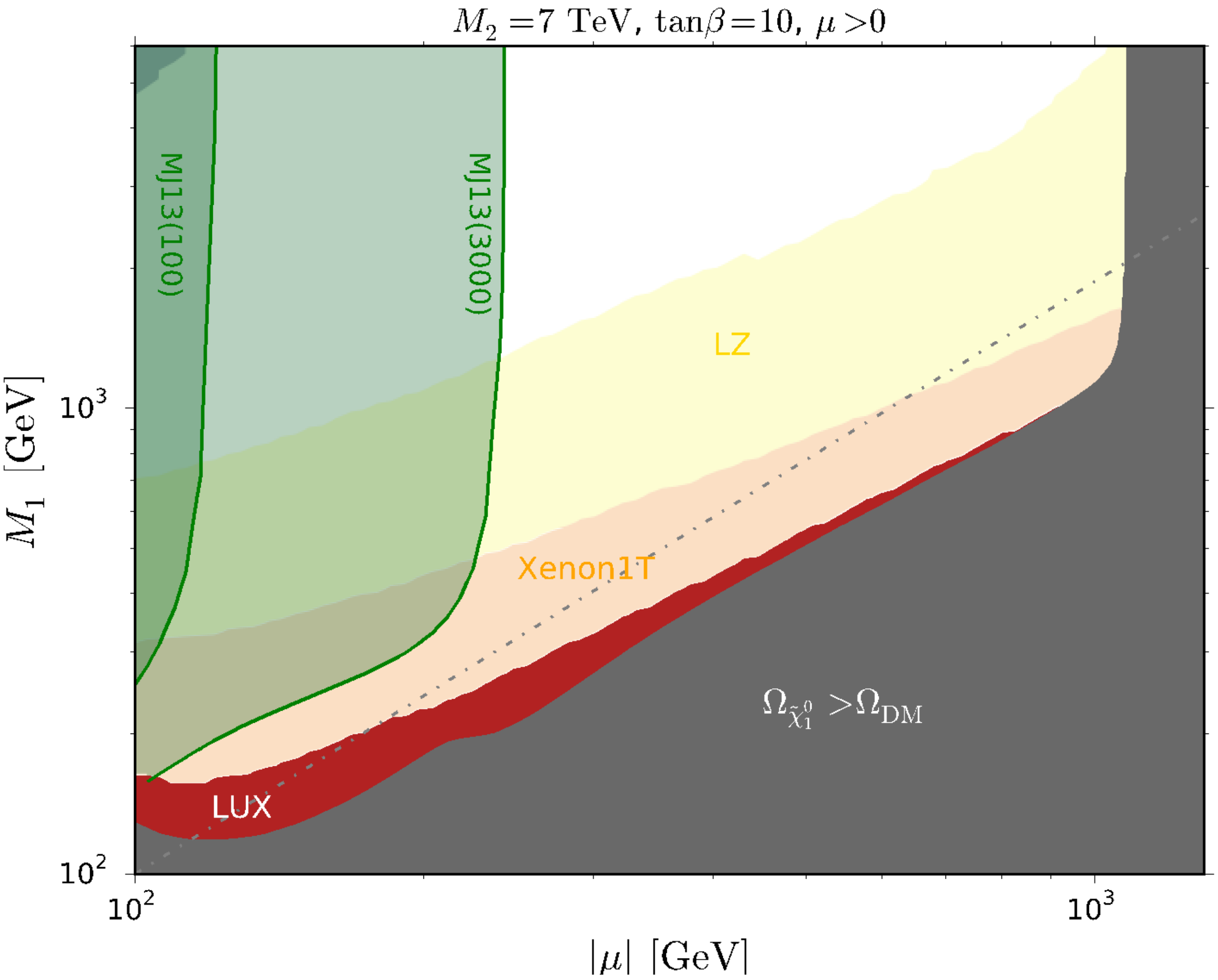
depends on mass differences

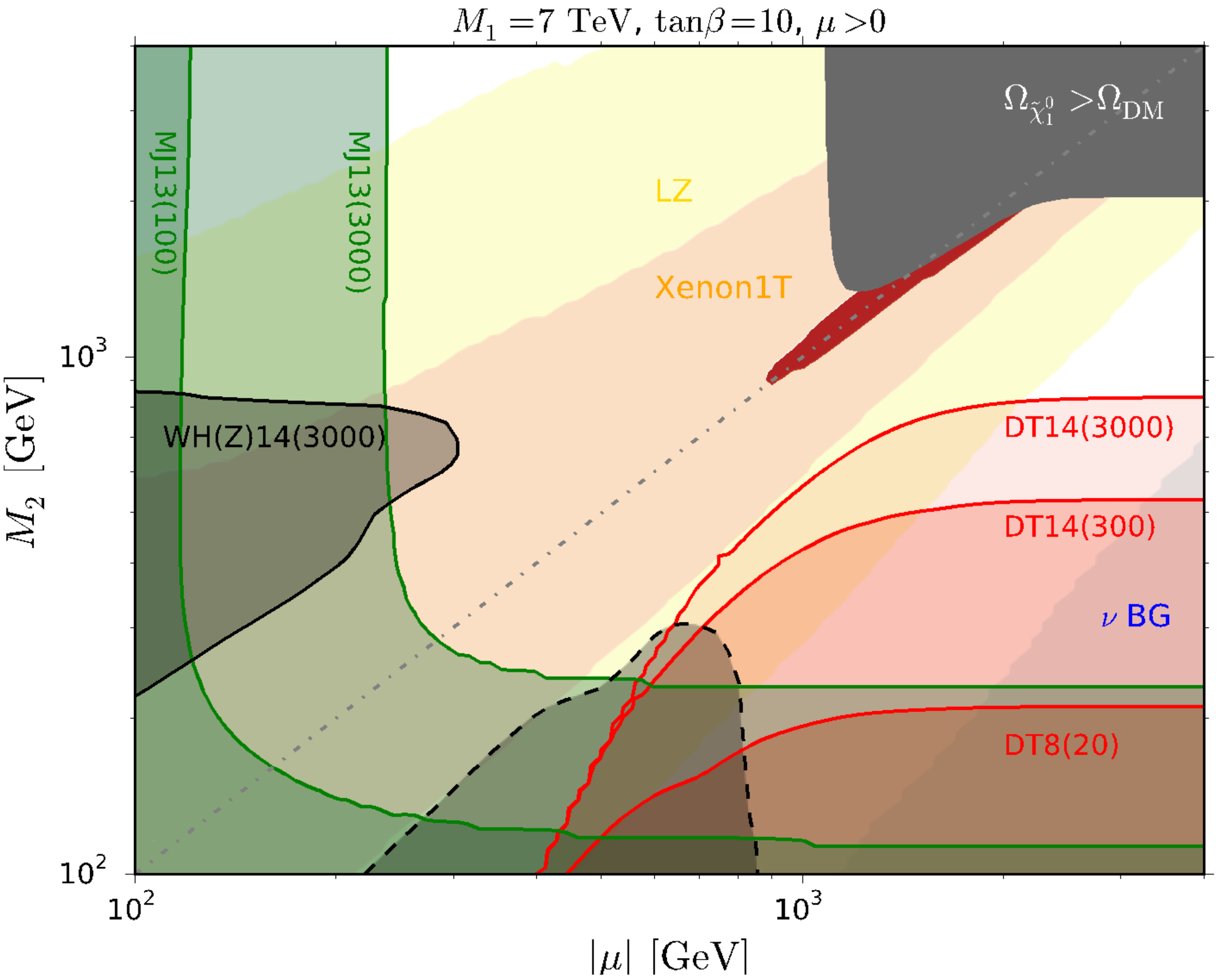
Mass differences for $\Omega h^2 \leq 0.12$

$\Delta m = 20-40$ GeV (rare) soft leptons

$\Delta m \sim O(1$ GeV$)$ (most frequent, monojets, mono-Z, mono-gamma)

$\Delta m \sim O(200-300$ MeV$)$ (disappearing tracks)


M_2 =7 TeV, tanβ=10, μ>0
MJ13(100)
MJ13(3000)
LZ
Xenon1T
LUX
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$
M_1 [GeV]
$|\mu|$ [GeV]
10^3
10^2
10^2
10^3


$M_1 = 7$ TeV, $\tan\beta = 10$, $\mu > 0$
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$
LZ
Xenon1T
MJ13(100)
MJ13(3000)
WH(Z)14(3000)
DT14(3000)
DT14(300)
DT8(20)
ν BG
M_2 [GeV]
$|\mu|$ [GeV]
10^2
10^3
10^2
10^3

CONCLUSIONS (WITH HEAVY SFERMIONS)

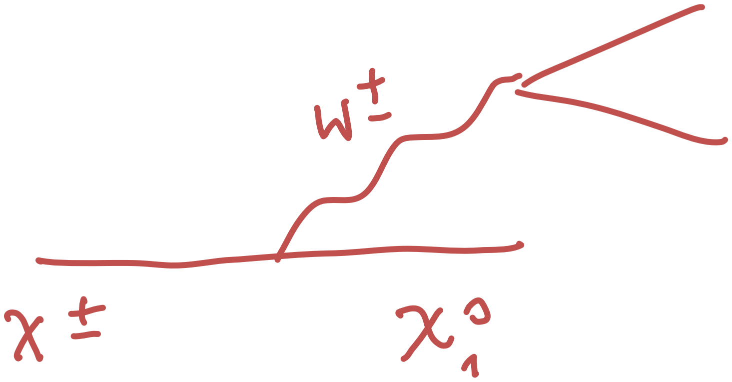
DD EXPERIMENTS ARE SENSITIVE TO NEUTRALINOS WITH

$$\Omega h^2 \approx (10^{-4} - 0.12)$$

THE BOUNDS FROM DD EXPERIMENTS PUSH TOWARDS SQUEZEED ELECTROWEAKINO SPECRTRUM, WITH STRONG IMPACT ON THE COLLIDER SIGNATURES

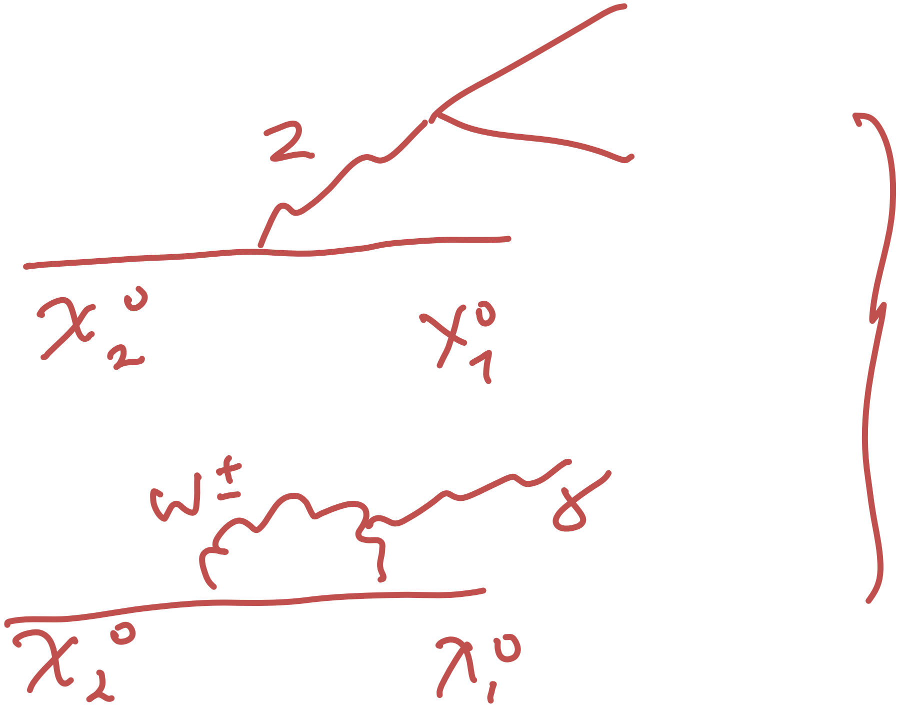
DD EXPERIMENTS + LHC WILL SIGNIFICANTLY EXPLORE THE ELECTROWEAKINO PARAMETER SPACE
(SOME DEGREE OF COMPLEMENTARITY AND SOME OVERLAP IN THE PARAMETER SPACE)

BACKUP

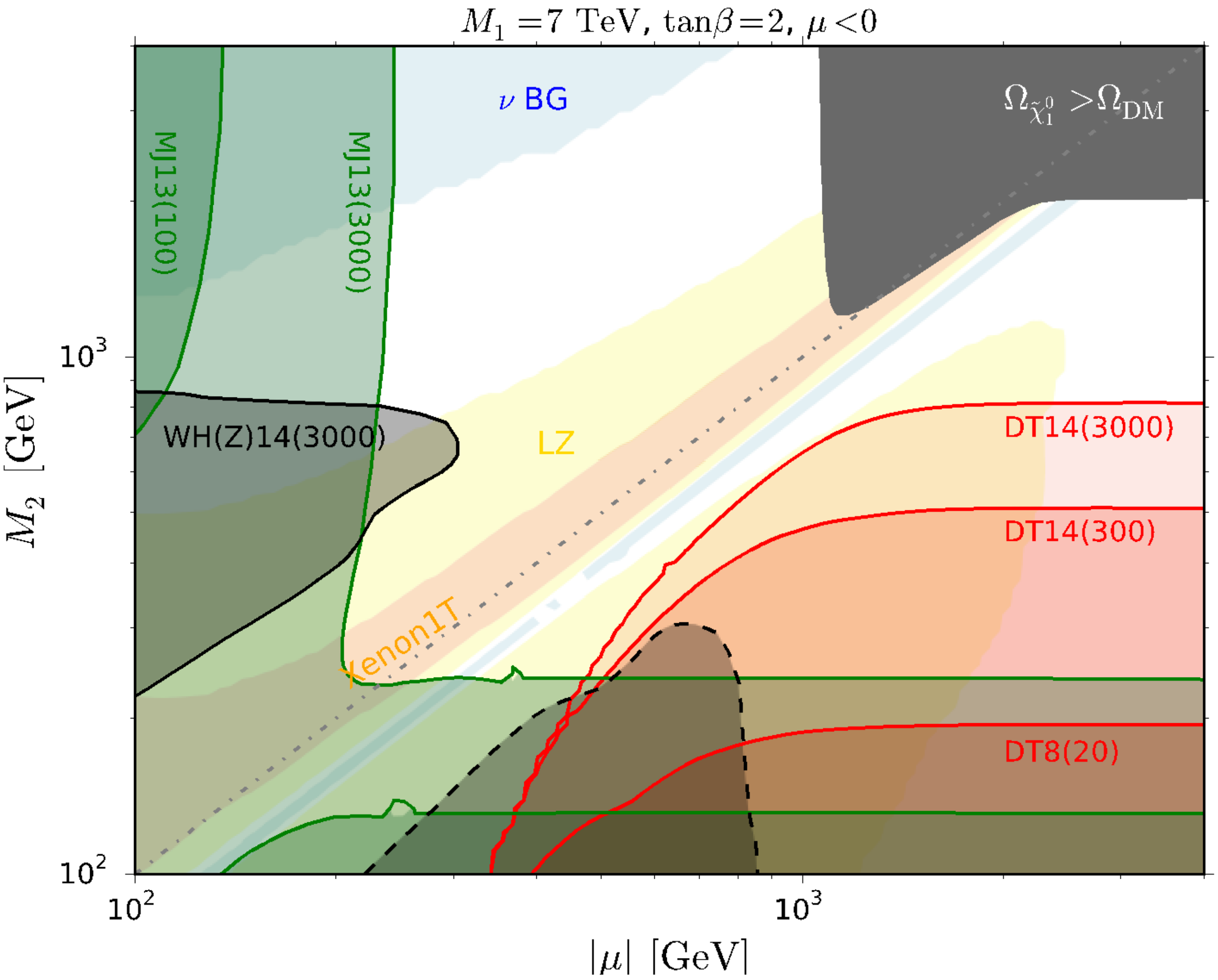


$$\Delta m = \chi_1^\pm - \chi_1^0$$

$(+ \text{Boost})$



$$\Delta m = \chi_2^0 - \chi_1^0$$


$M_1 = 7$ TeV, $\tan\beta = 2$, $\mu < 0$
ν BG
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$
MJ13(100)
MJ13(3000)
WH(Z)14(3000)
LZ
Xenon1T
DT14(3000)
DT14(300)
DT8(20)
10^3
10^2
M_2 [GeV]
$|\mu|$ [GeV]

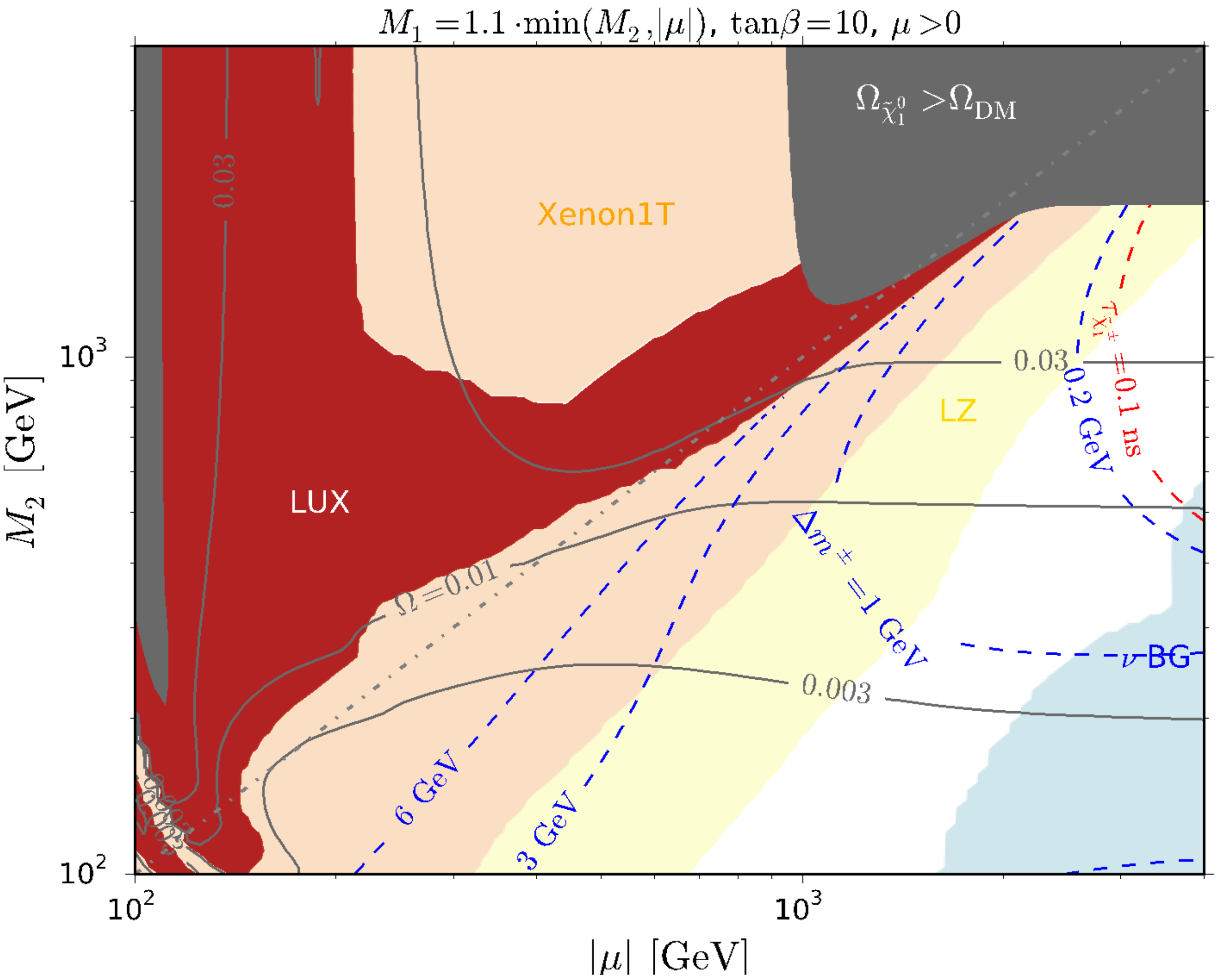
MASS DIFFERENCES (E.G.)

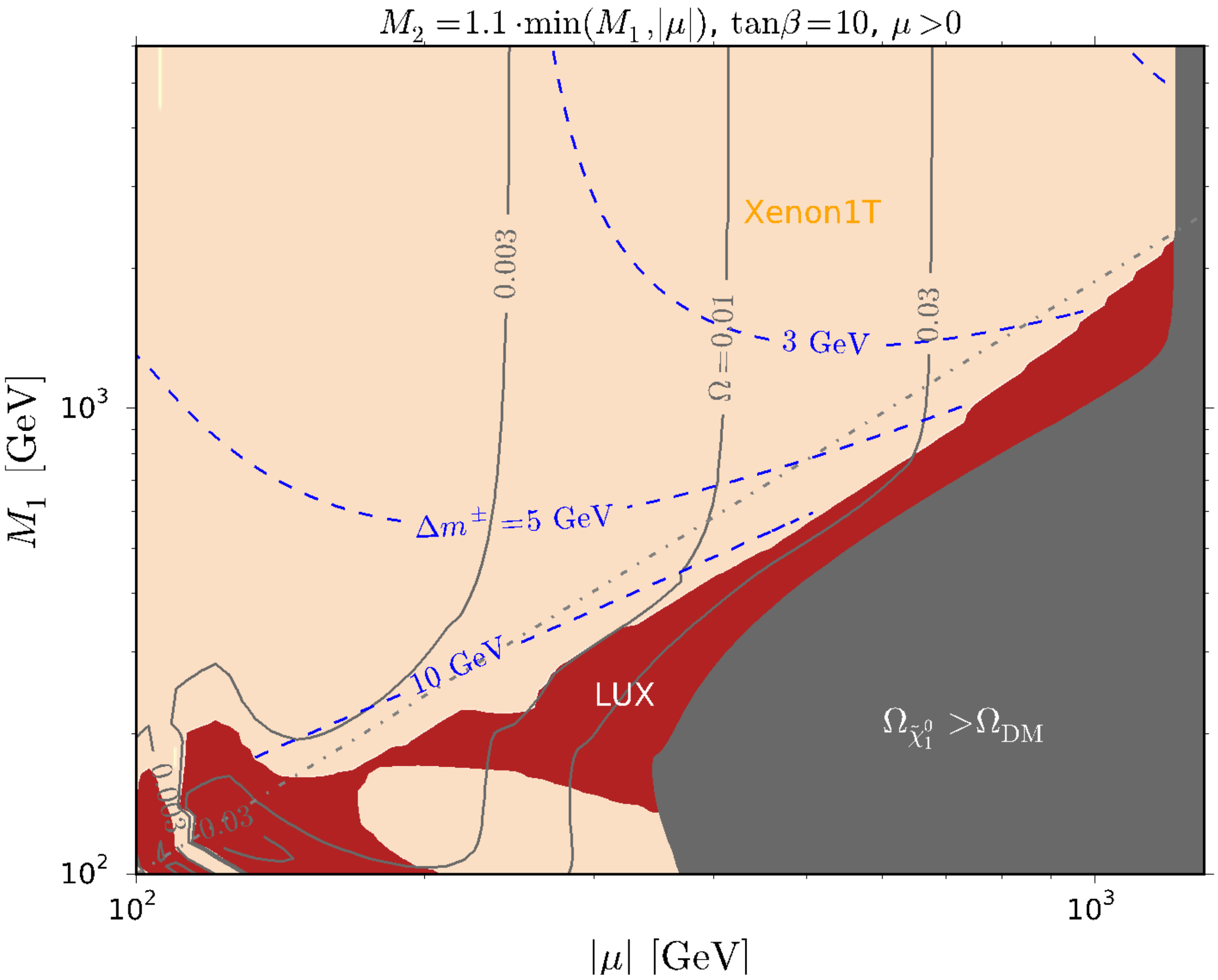
$$|\mu| < |M_1| << |M_2|$$ HIGGSINO-BINO

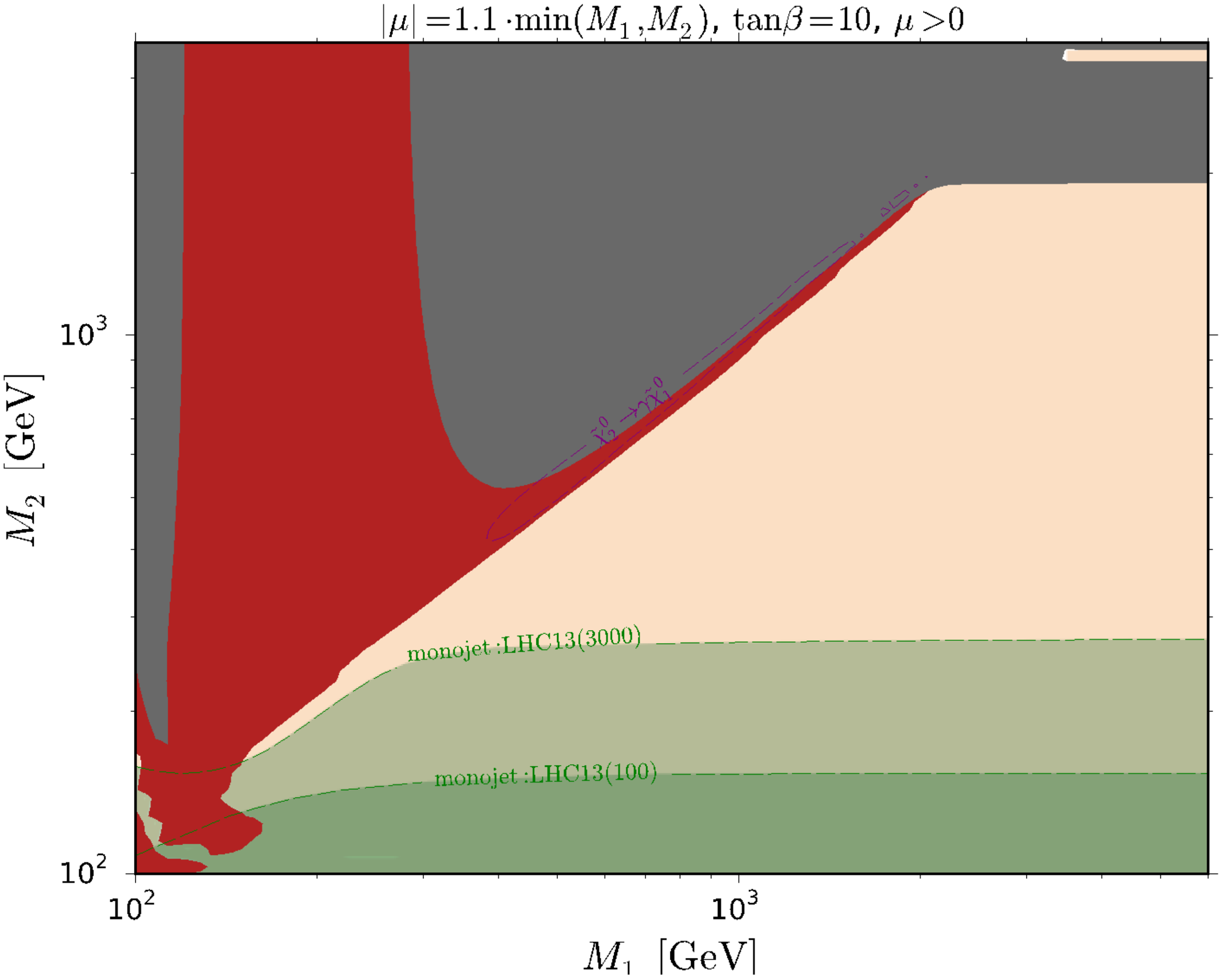
$$m_{\chi_2^0} - m_{\chi_1^0} \approx 2(m_{\chi_1^+} - m_{\chi_1^0}) \approx \frac{1}{2} M_Z^2 (\frac{cos^2\theta_W}{M_2} + \frac{sin^2\theta_W}{M_1})$$

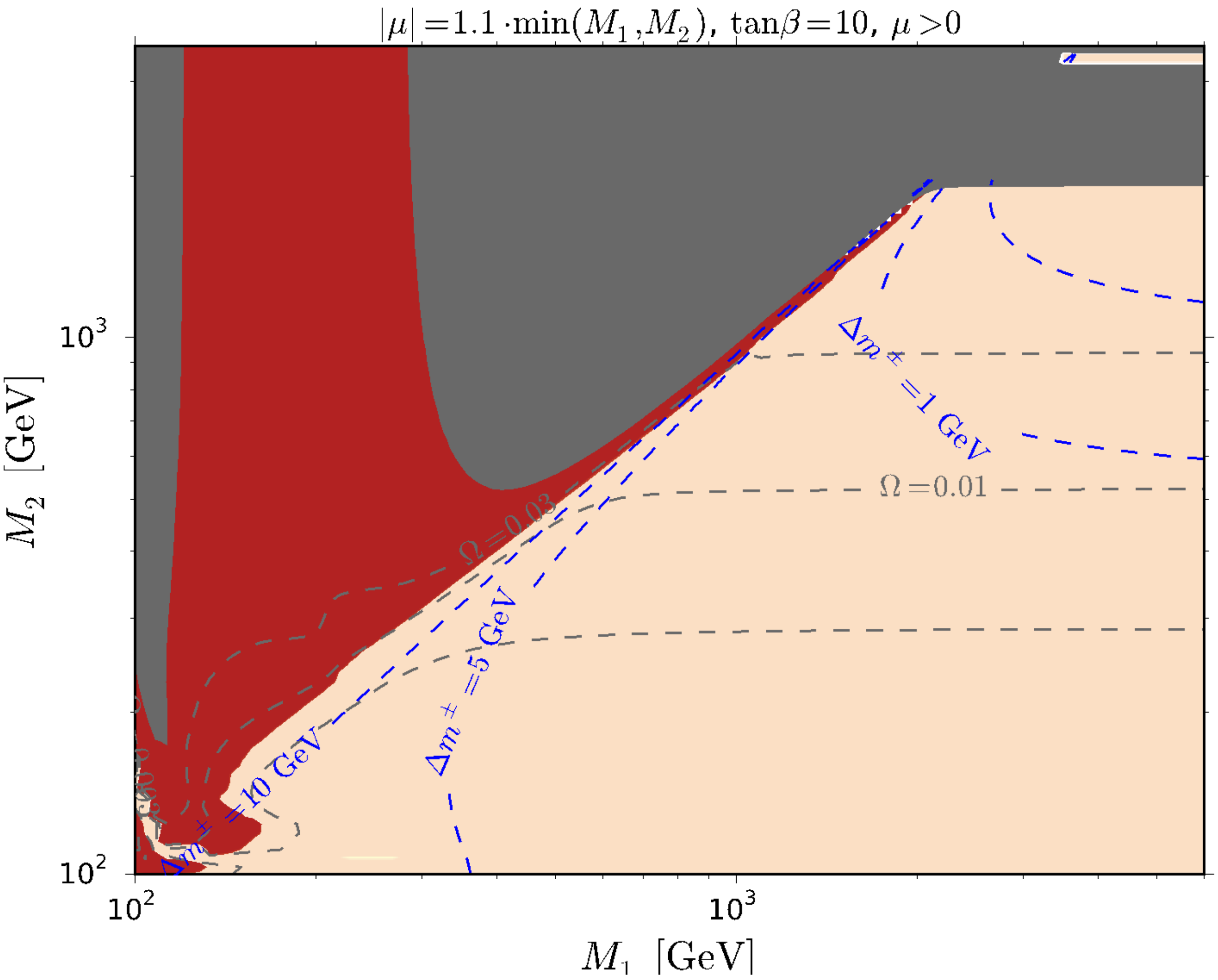
$$|M_2| < |\mu| << M_1$$ HIGGSINO-WINO

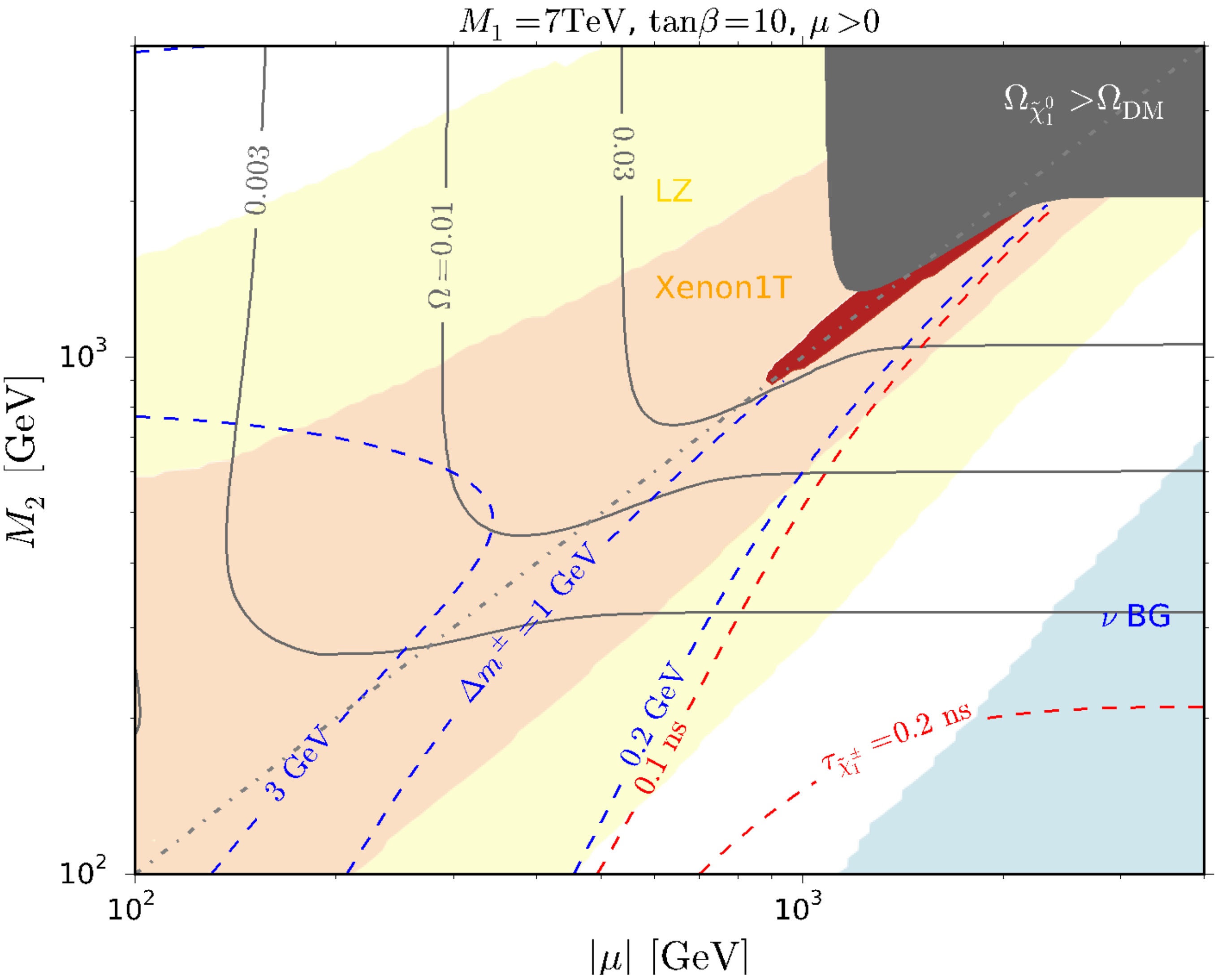
$$m_{\chi_1^+} - m_{\chi_1^0} = \frac{1}{2} \frac{|M_2| M_Z^2}{\mu^4} \cos^4\theta_W cos^2(2\beta)$$

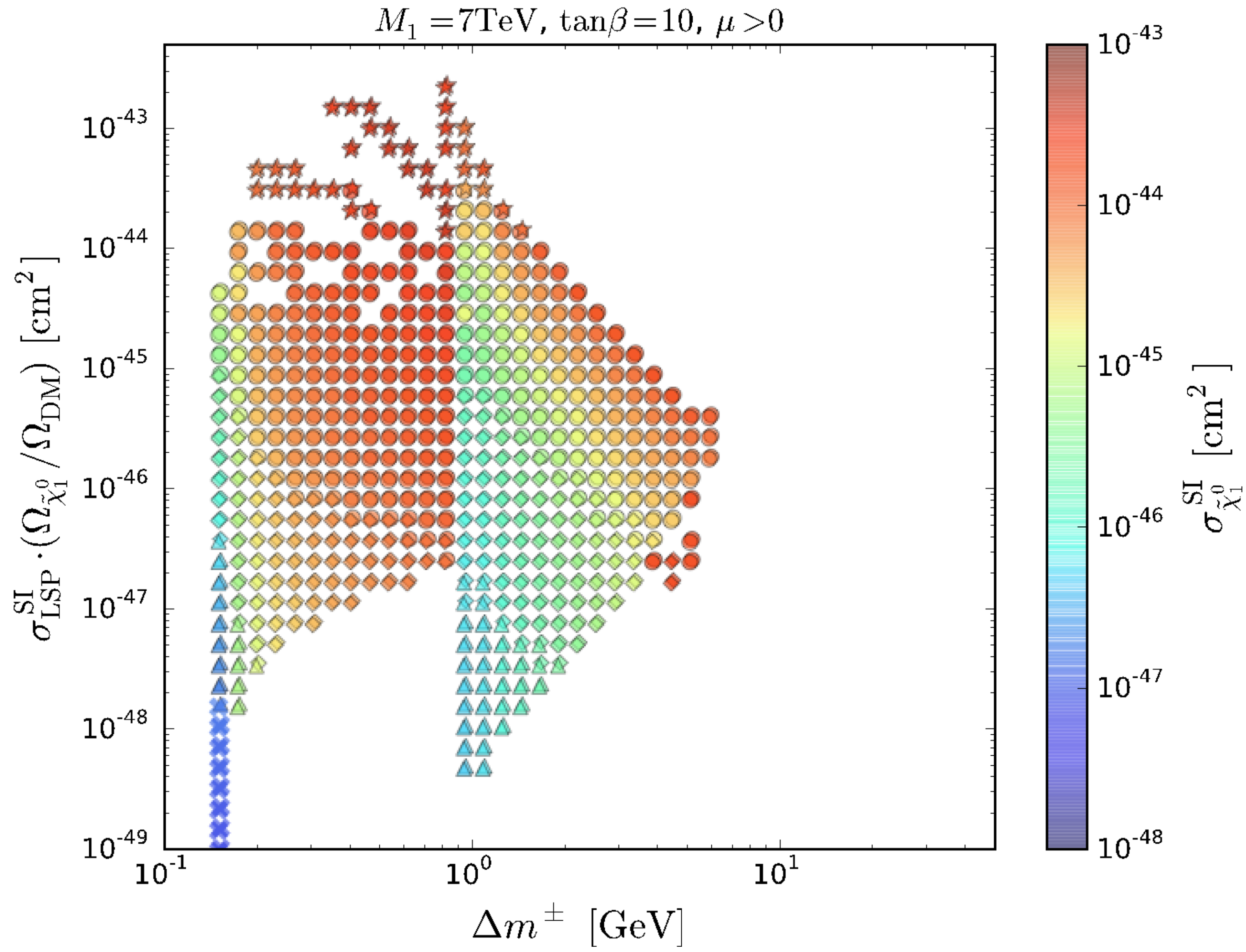

$M_1 = 1.1 \cdot \min(M_2, |\mu|)$, $\tan\beta = 10$, $\mu > 0$
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$
Xenon1T
LUX
LZ
0.03
0.03
$\Omega = 0.01$
0.003
6 GeV
3 GeV
$\Delta m_\pm = 1$ GeV
0.2 GeV
$\tau_{\tilde{\chi}_1^\pm} = 0.1$ ns
ν-BG
10^3
10^2
M_2 [GeV]
10^2
10^3
$|\mu|$ [GeV]

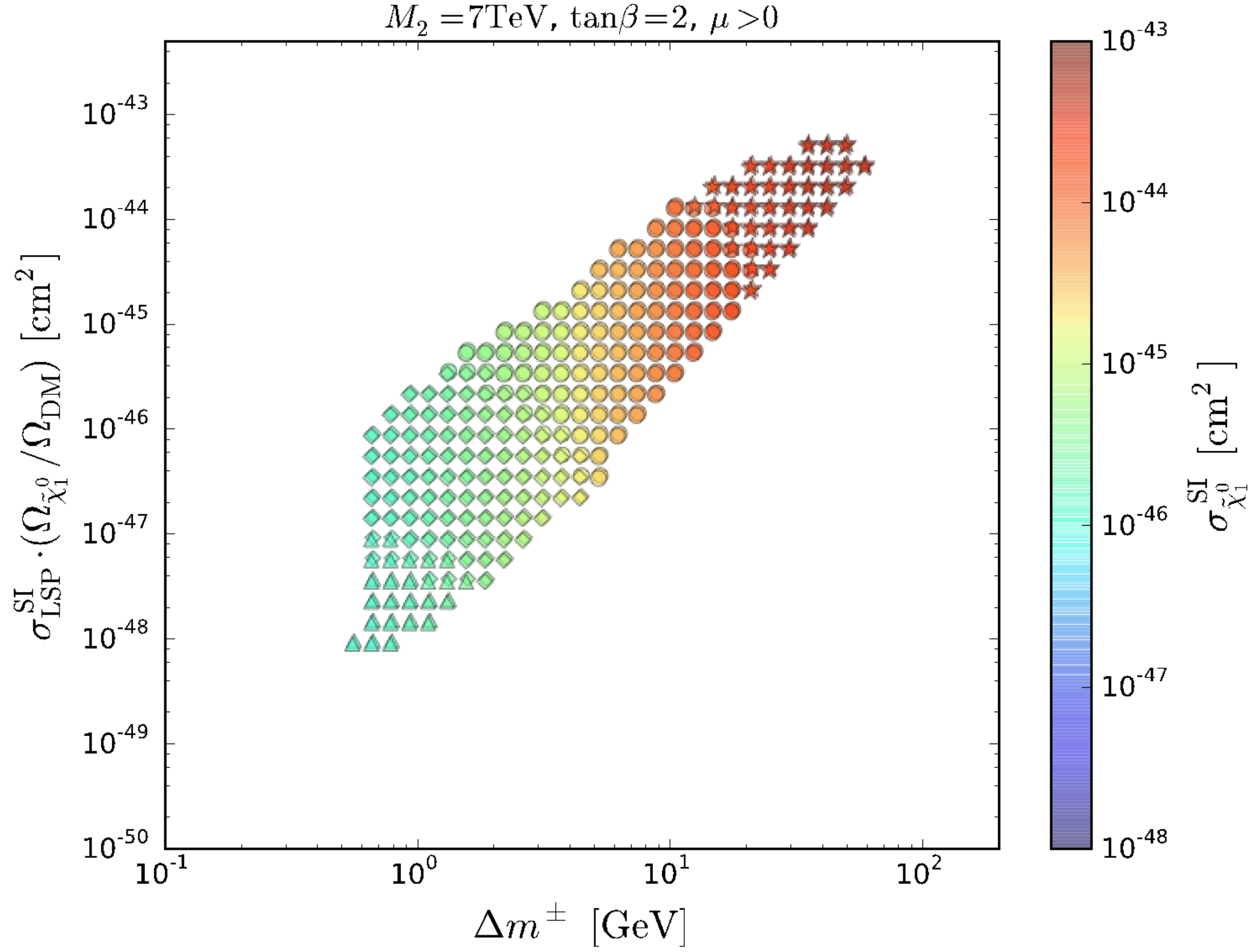

$M_2 = 1.1 \cdot \min(M_1, |\mu|)$, $\tan\beta = 10$, $\mu > 0$
Xenon1T
0.003
$\Omega = 0.01$
0.03
3 GeV
$\Delta m^{\pm} = 5$ GeV
10 GeV
LUX
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$
0.003
0.03
10^3
10^2
M_1 [GeV]
10^2
10^3
$|\mu|$ [GeV]

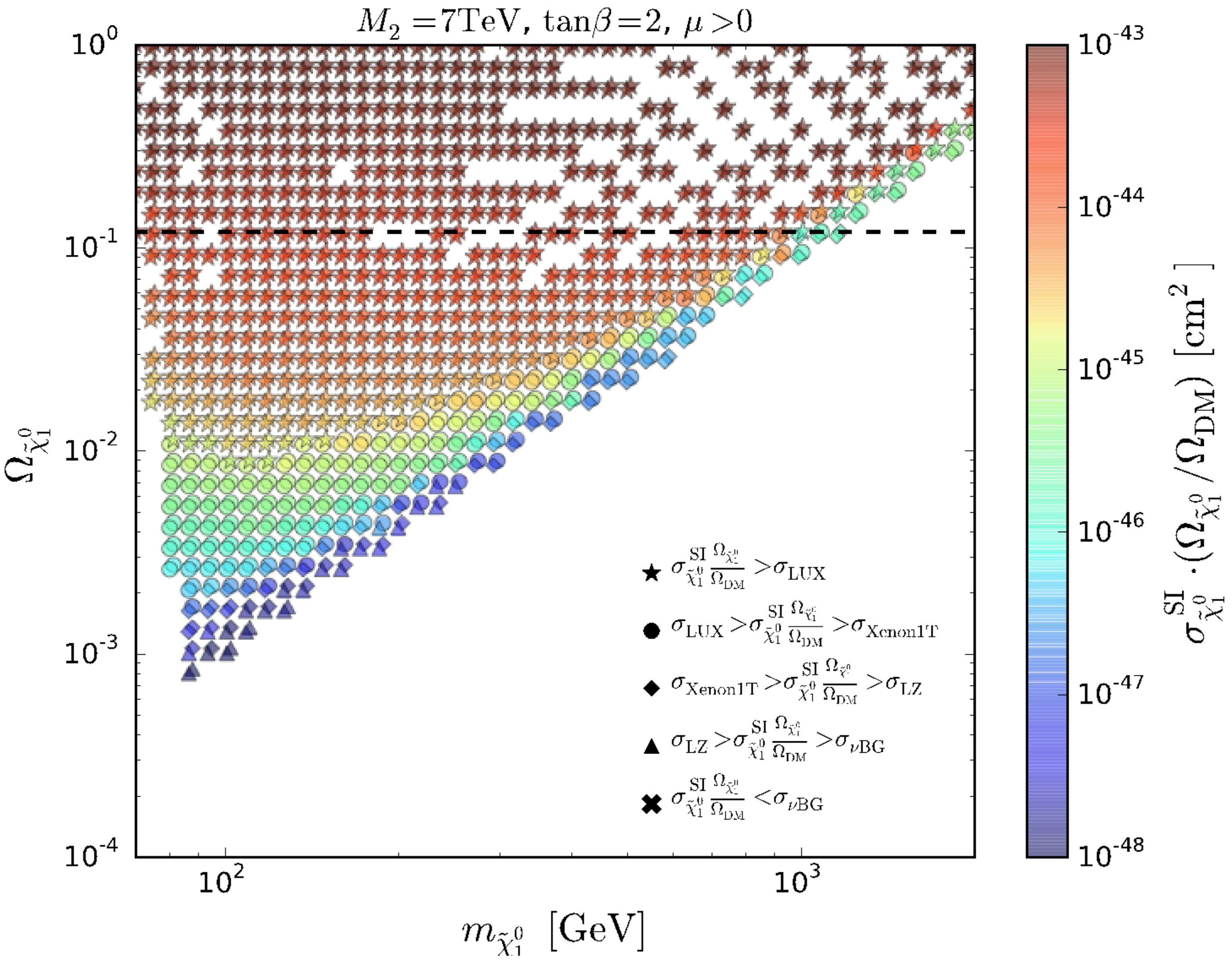

$|\mu|=1.1\cdot\min(M_1,M_2)$, $\tan\beta=10$, $\mu>0$
M_2 [GeV]
M_1 [GeV]
10^2
10^3
10^2
10^3
$\tilde{\chi}_2^0\to\gamma\tilde{\chi}_1^0$
monojet :LHC13(3000)
monojet :LHC13(100)

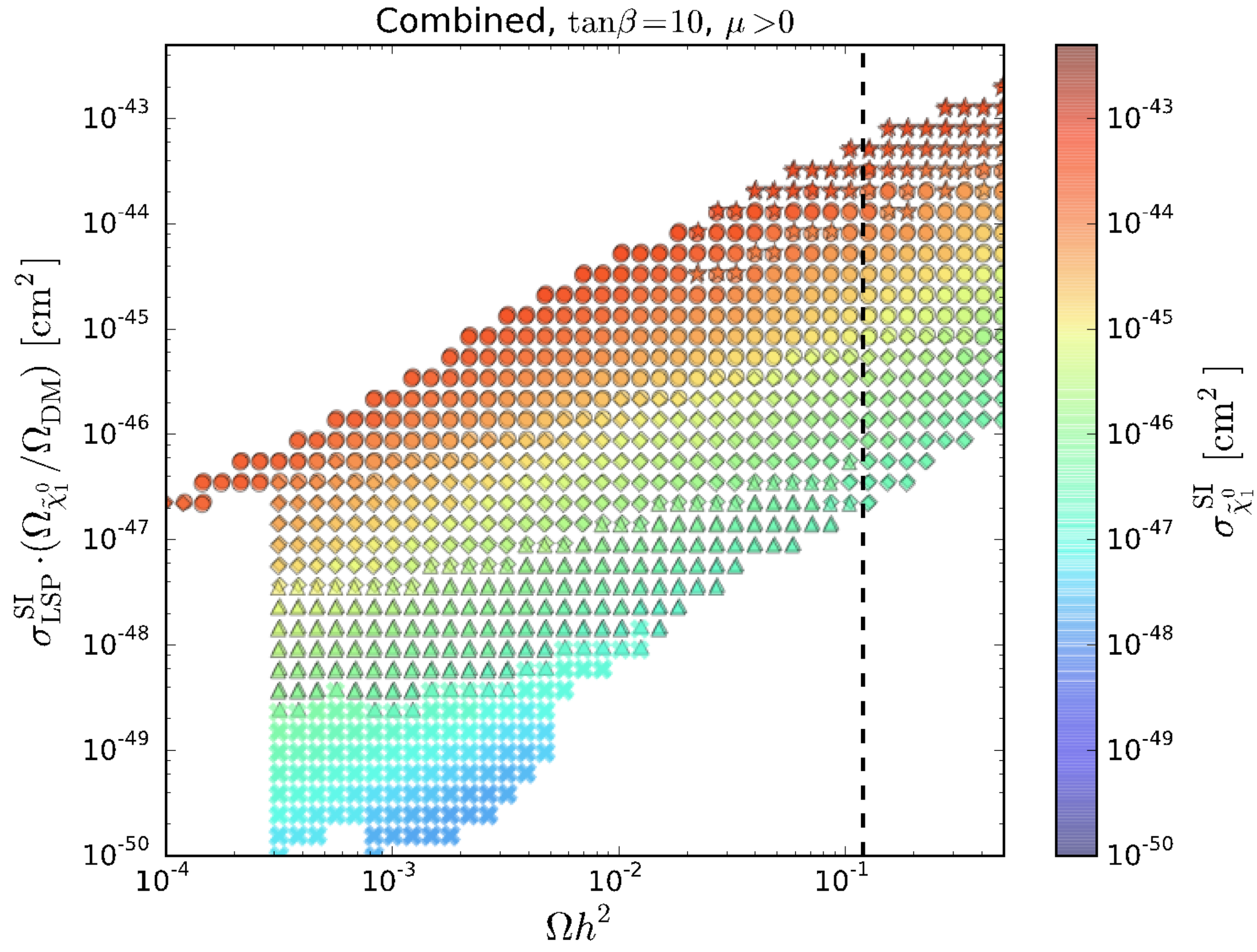

$|\mu| = 1.1 \cdot \min(M_1, M_2)$, $\tan\beta = 10$, $\mu > 0$
M_2 [GeV]
M_1 [GeV]
10^2
10^3
10^2
10^3
$\Omega = 0.03$
$\Omega = 0.01$
$\Delta m^\pm = 10$ GeV
$\Delta m^\pm = 5$ GeV
$\Delta m^\pm = 1$ GeV

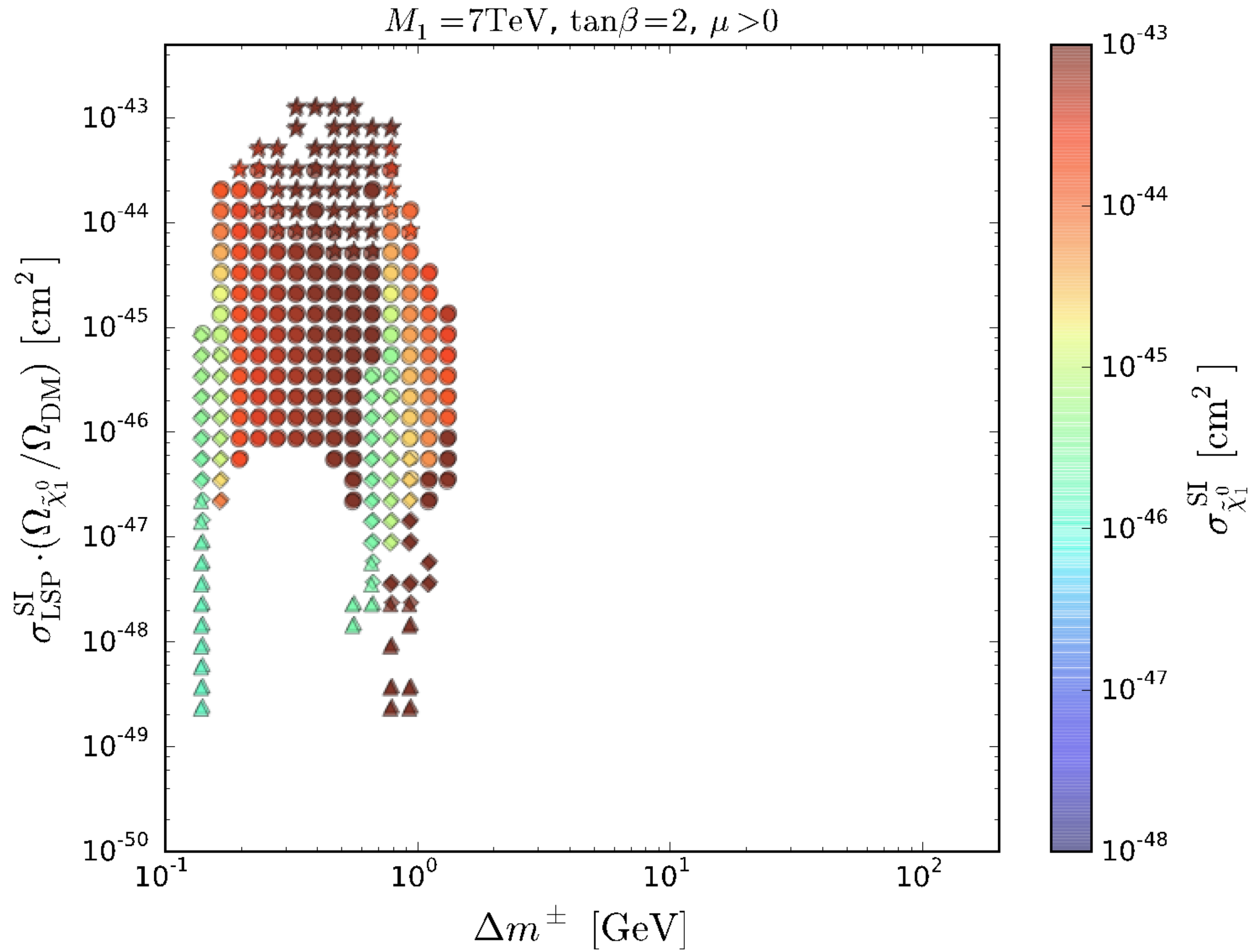

M_1 =7TeV, tanβ=10, μ>0
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$
LZ
Xenon1T
0.003
Ω=0.01
0.03
$\Delta m^\pm$=1 GeV
3 GeV
0.2 GeV
0.1 ns
$\tau_{\tilde{\chi}_1^\pm}$ =0.2 ns
ν BG
M_2 [GeV]
$|\mu|$ [GeV]
10^2
10^3
10^2
10^3

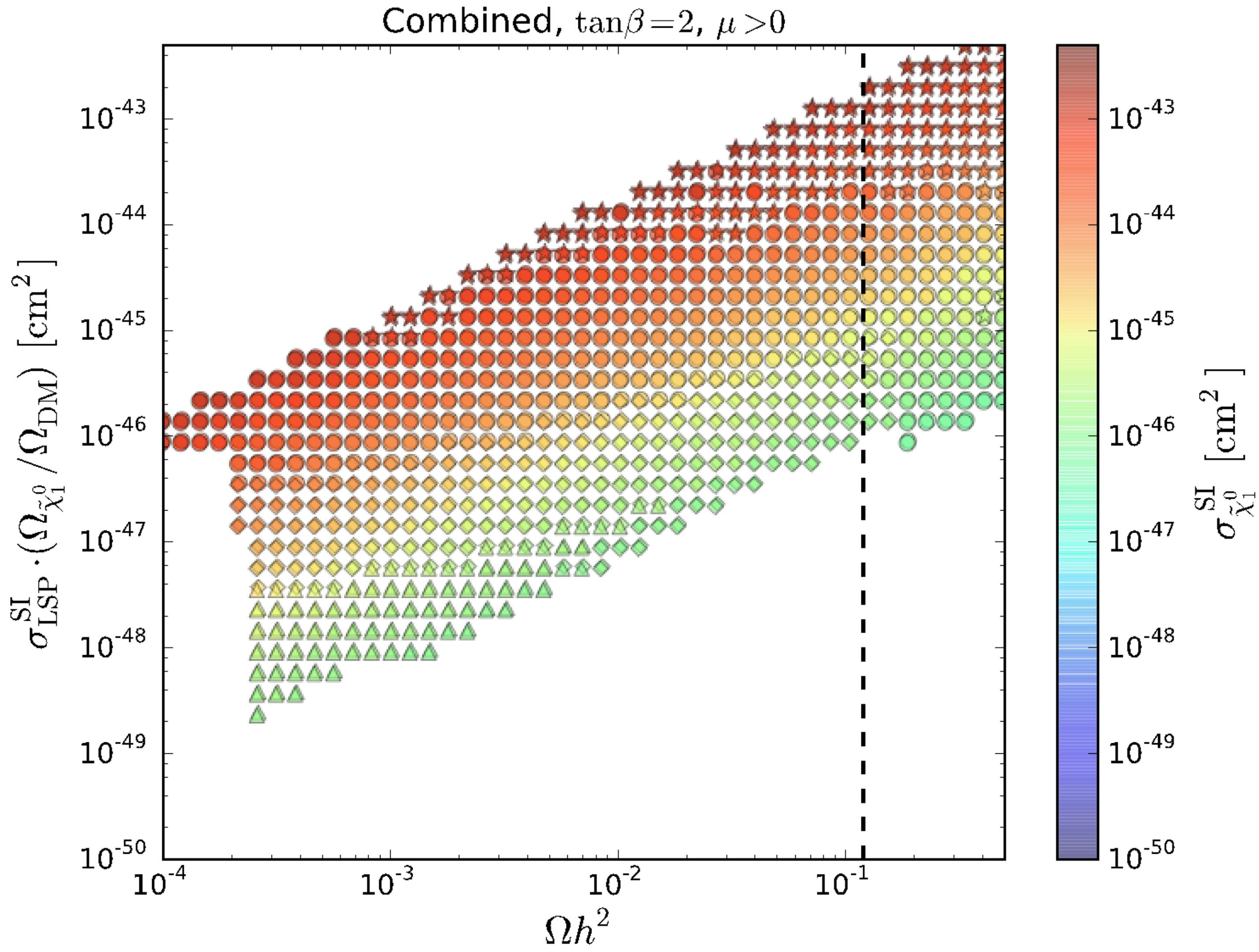

$M_1 = 7\mathrm{TeV}$, $\tan\beta = 10$, $\mu > 0$
$\sigma^{\mathrm{SI}}_{\mathrm{LSP}} \cdot (\Omega_{\tilde{\chi}^0_1} / \Omega_{\mathrm{DM}})$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-1}
10^{0}
10^{1}
$\Delta m^{\pm}$ [GeV]
$\sigma^{\mathrm{SI}}_{\tilde{\chi}^0_1}$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}

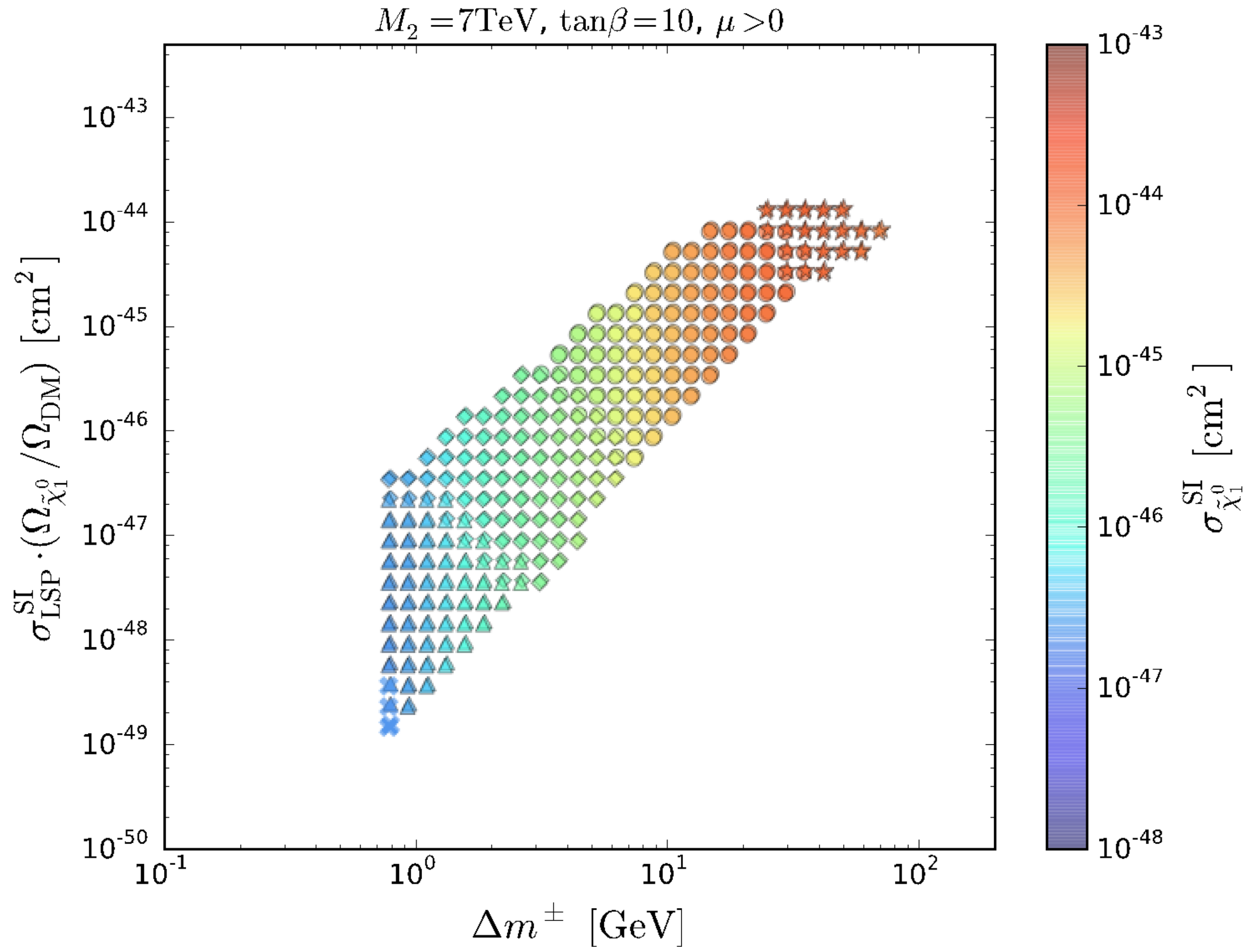

$M_2 = 7\mathrm{TeV}$, $\tan\beta = 2$, $\mu > 0$
$\sigma^{\mathrm{SI}}_{\mathrm{LSP}} \cdot (\Omega_{\tilde{\chi}^0_1} / \Omega_{\mathrm{DM}})$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-1}
10^{0}
10^{1}
10^{2}
$\Delta m^{\pm}$ [GeV]
$\sigma^{\mathrm{SI}}_{\tilde{\chi}^0_1}$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}

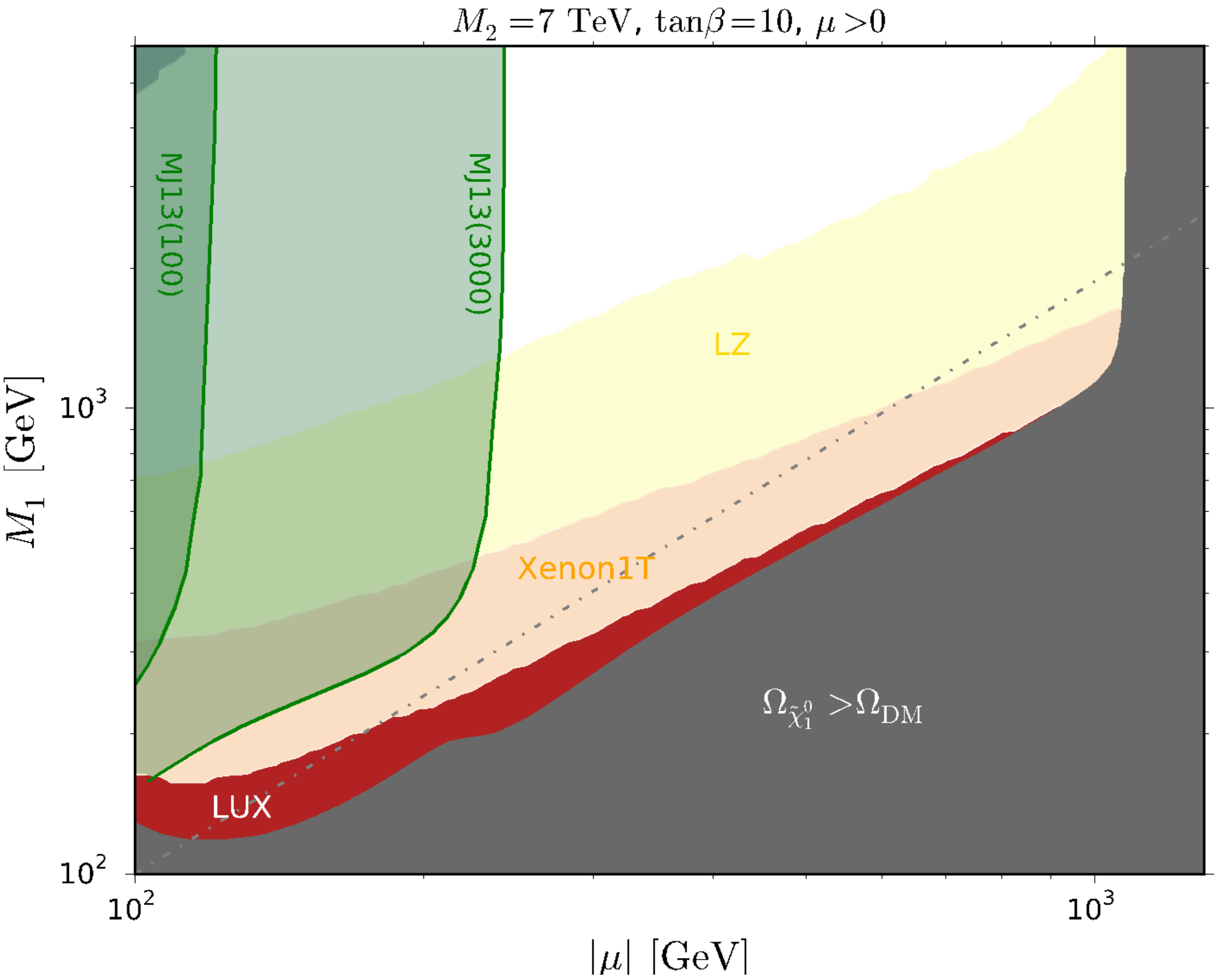

M_2 =7TeV, $\tan\beta$=2, $\mu>0$
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\Omega_{\tilde{\chi}_1^0}$
10^2
10^3
$m_{\tilde{\chi}_1^0}$ [GeV]
★ $\sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\rm LUX}$
● $\sigma_{\rm LUX} > \sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\rm Xenon1T}$
◆ $\sigma_{\rm Xenon1T} > \sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\rm LZ}$
▲ $\sigma_{\rm LZ} > \sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} > \sigma_{\nu \rm BG}$
✖ $\sigma^{\rm SI}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\rm DM}} < \sigma_{\nu \rm BG}$
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
$\sigma^{\rm SI}_{\tilde{\chi}_1^0}\cdot(\Omega_{\tilde{\chi}_1^0}/\Omega_{\rm DM})$ [cm^2]

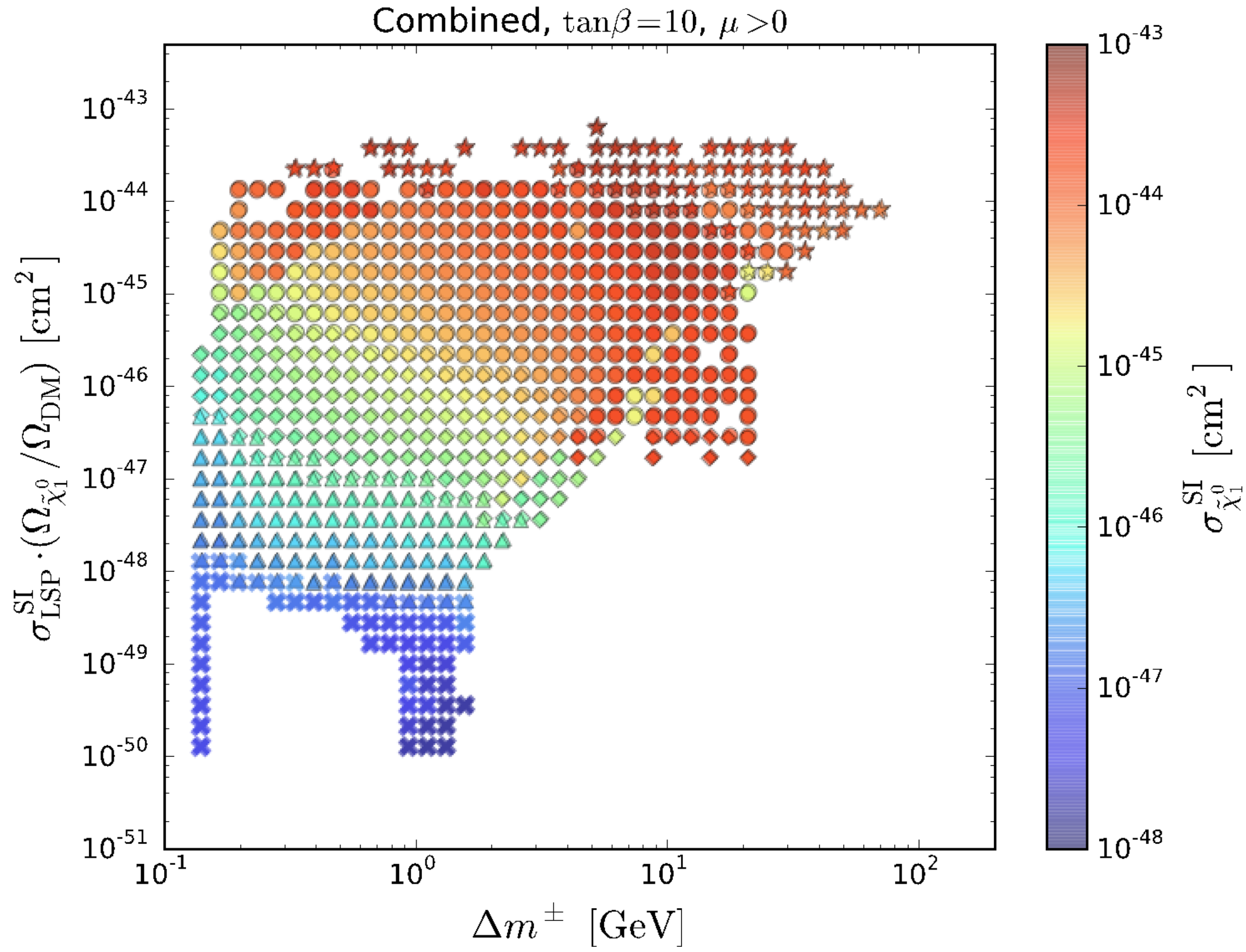

Combined, $\tan\beta = 10$, $\mu > 0$
$\sigma^{\rm SI}_{\rm LSP} \cdot (\Omega_{\tilde\chi^0_1}/\Omega_{\rm DM})$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Ωh^2
$\sigma^{\rm SI}_{\tilde\chi^0_1}$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}

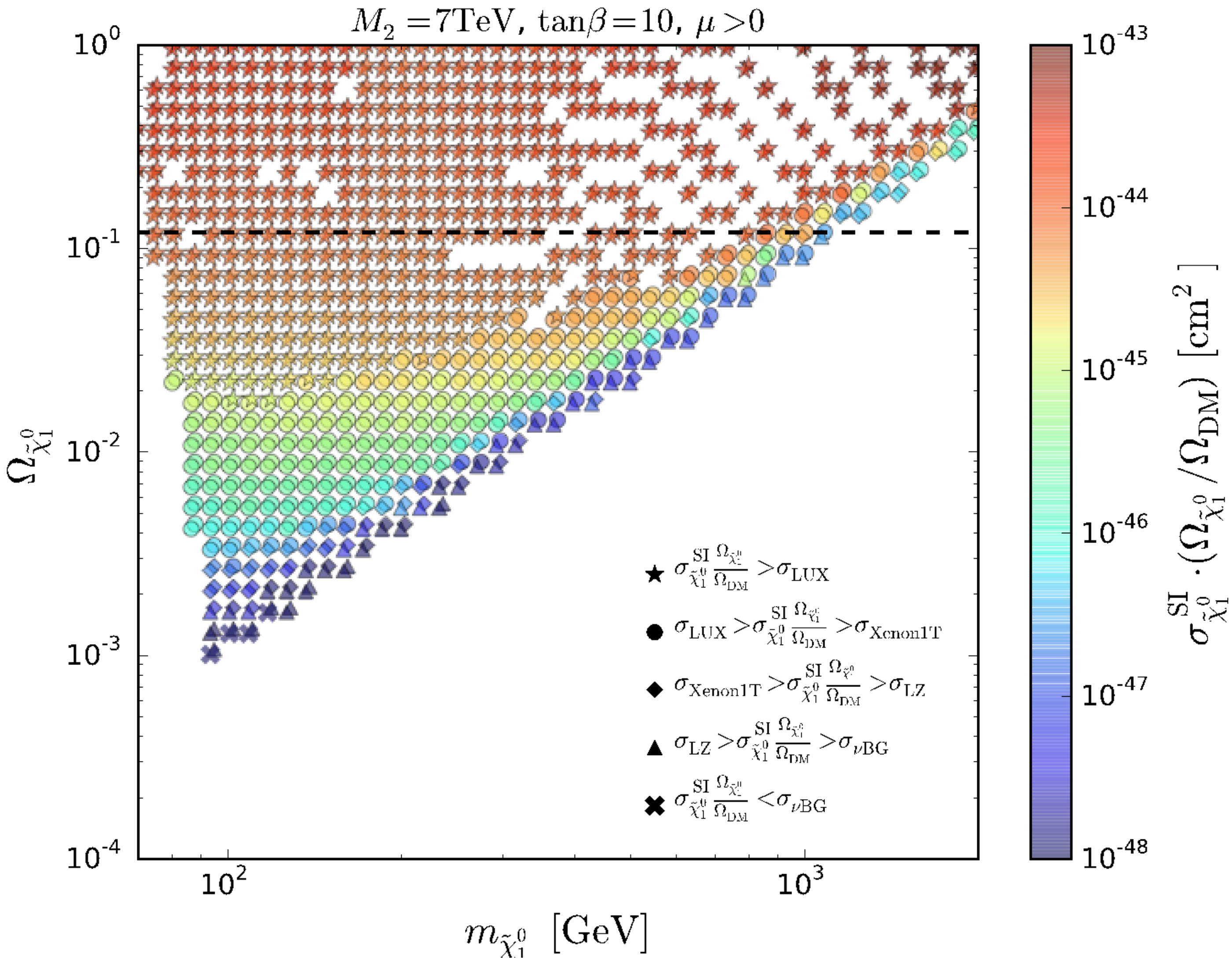

M_1 =7TeV, tanβ=2, μ>0
$\sigma^{\rm SI}_{\rm LSP}\cdot(\Omega_{\tilde\chi^0_1}/\Omega_{\rm DM})$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-1}
10^{0}
10^{1}
10^{2}
$\Delta m^{\pm}$ [GeV]
$\sigma^{\rm SI}_{\tilde\chi^0_1}$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}


Combined, $\tan\beta = 2$, $\mu > 0$
$\sigma^{\rm SI}_{\rm LSP} \cdot (\Omega_{\tilde\chi^0_1}/\Omega_{\rm DM})$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Ωh^2
$\sigma^{\rm SI}_{\tilde\chi^0_1}$ [cm^2]


$M_2 = 7\mathrm{TeV},\ \tan\beta = 10,\ \mu > 0$
$\sigma^{\mathrm{SI}}_{\mathrm{LSP}} \cdot (\Omega_{\tilde{\chi}^0_1}/\Omega_{\mathrm{DM}})\ [\mathrm{cm}^2]$
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-1}
10^{0}
10^{1}
10^{2}
$\Delta m^{\pm}\ [\mathrm{GeV}]$
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
$\sigma^{\mathrm{SI}}_{\tilde{\chi}^0_1}\ [\mathrm{cm}^2]$


M_2 =7 TeV, tanβ=10, $\mu>0$
MJ13(100)
MJ13(3000)
LZ
Xenon1T
LUX
$\Omega_{\tilde{\chi}_1^0} > \Omega_{\rm DM}$
M_1 [GeV]
$|\mu|$ [GeV]
10^2
10^3
10^2
10^3

 Combined, $\tan\beta = 10$, $\mu > 0$
$\sigma^{\rm SI}_{\rm LSP} \cdot (\Omega_{\tilde{\chi}^0_1}/\Omega_{\rm DM})$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-51}
10^{-1}
10^{0}
10^{1}
10^{2}
$\Delta m^{\pm}$ [GeV]
$\sigma^{\rm SI}_{\tilde{\chi}^0_1}$ [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}


$M_2 = 7\mathrm{TeV},\ \tan\beta = 10,\ \mu > 0$
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\Omega_{\tilde{\chi}_1^0}$
10^{2}
10^{3}
$m_{\tilde{\chi}_1^0}$ [GeV]
$\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{LUX}}$
$\sigma_{\mathrm{LUX}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{Xenon1T}}$
$\sigma_{\mathrm{Xenon1T}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\mathrm{LZ}}$
$\sigma_{\mathrm{LZ}} > \sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} > \sigma_{\nu\mathrm{BG}}$
$\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0}\frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}} < \sigma_{\nu\mathrm{BG}}$
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
$\sigma^{\mathrm{SI}}_{\tilde{\chi}_1^0} \cdot (\Omega_{\tilde{\chi}_1^0}/\Omega_{\mathrm{DM}})$ [cm^2]