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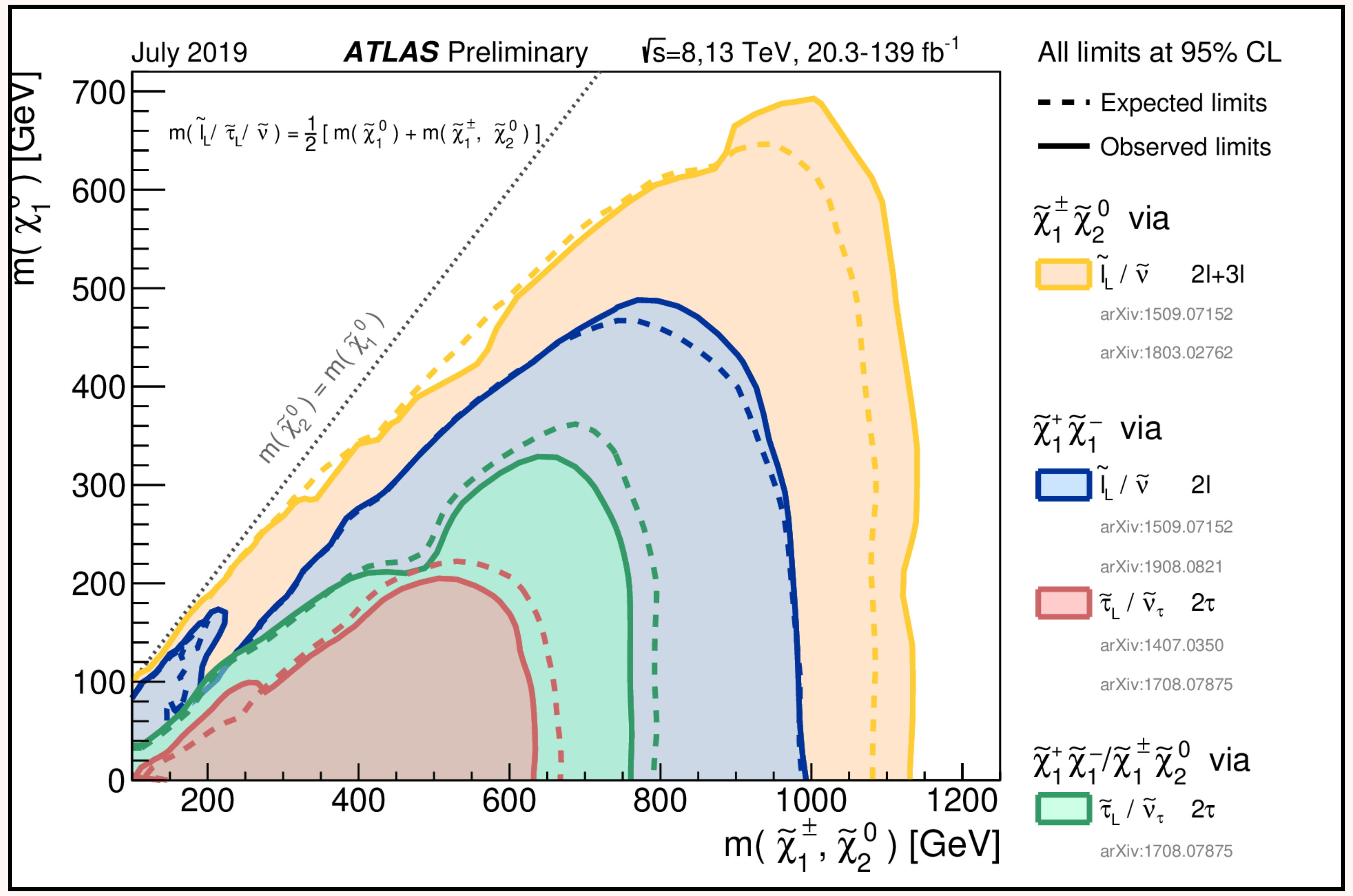
New 'MUON (G-2)' Result and Supersymmetry

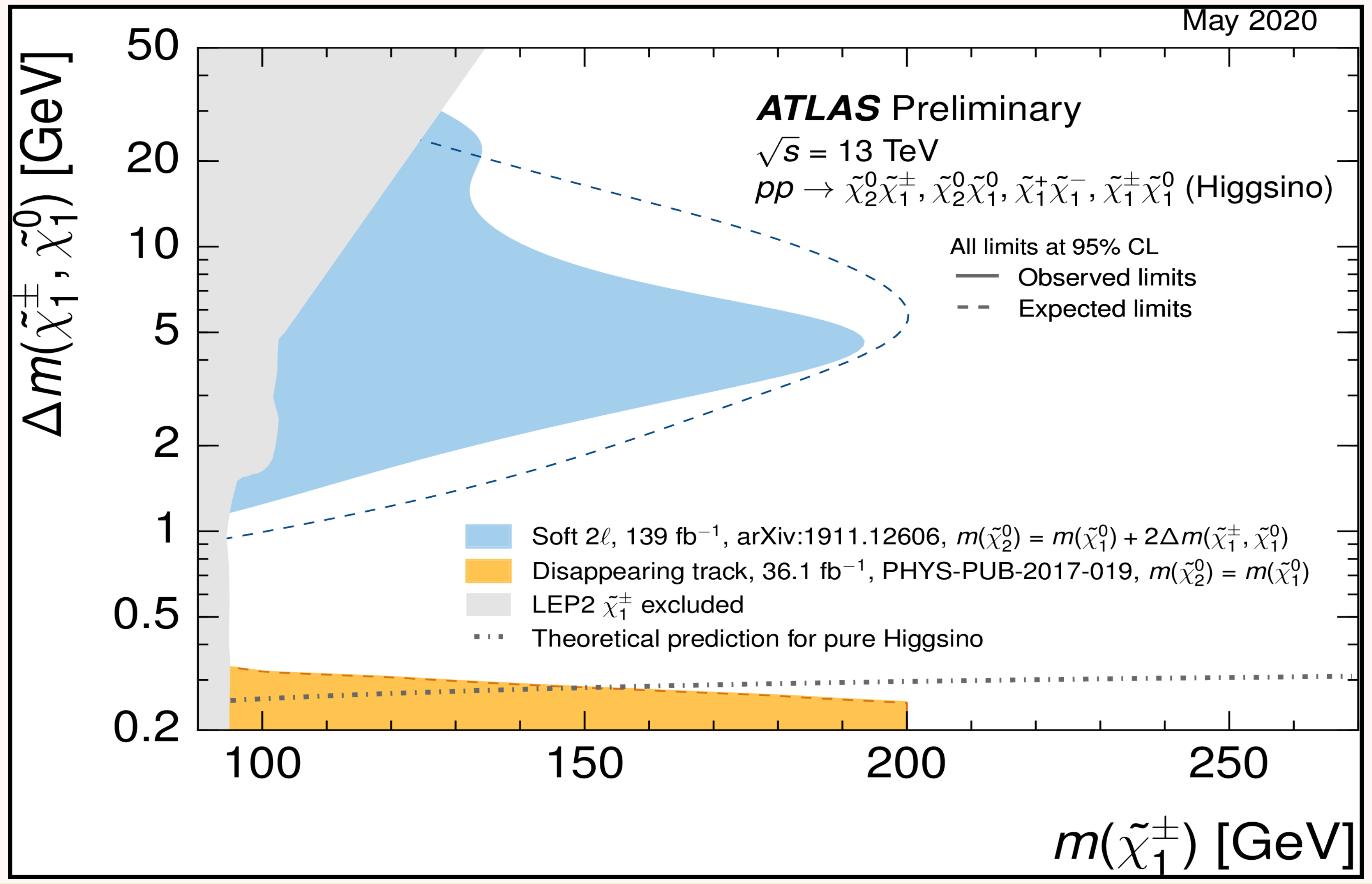
SUSY 2021 – 27/08/2021

BASED ON : 2104.03287 WITH MANIMALA CHAKRABORTI AND SVEN HEINEMEYER

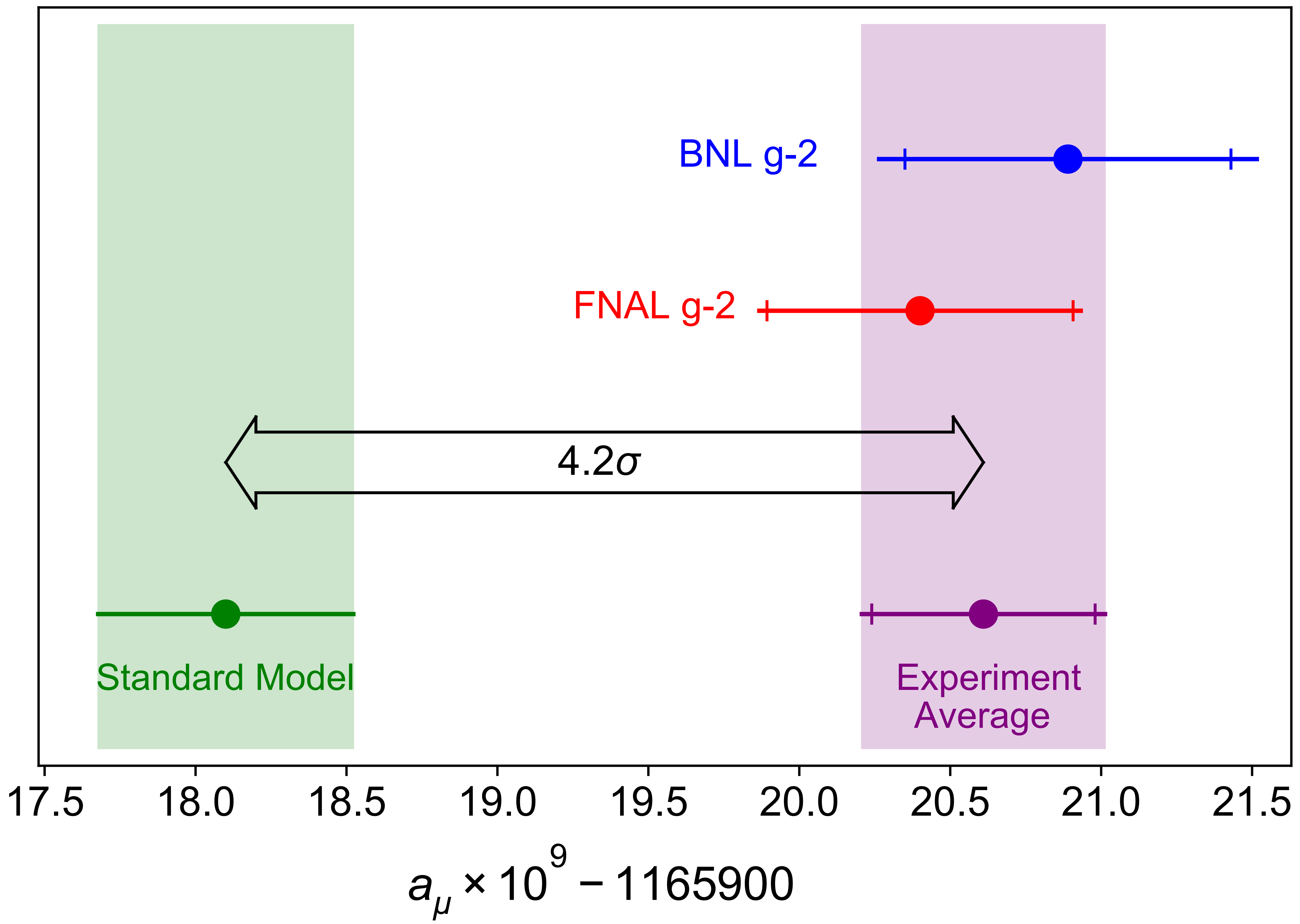
Electroweak MSSM

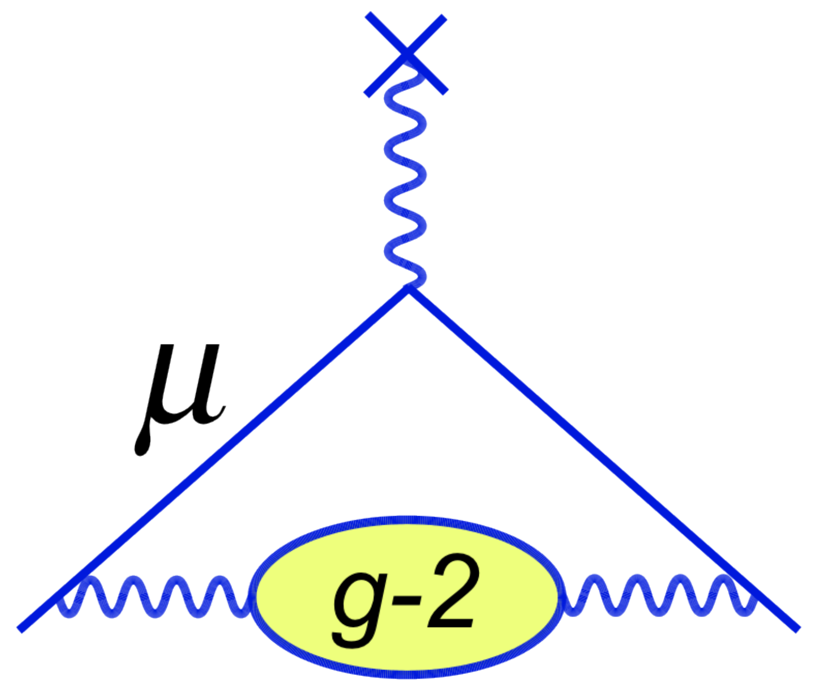
- ★ EW sector may be hiding the key to new physics.
- ★ Modest production cross section, mass bounds from the LHC comparably weak.
- ★ May show up elsewhere : DM experiments, $(g-2)_\mu$ …
- ★ 4.2σ discrepancy in $(g-2)_\mu$
- ★ New results from Fermilab 'MUON (g-2)' !





Muon (g-2)





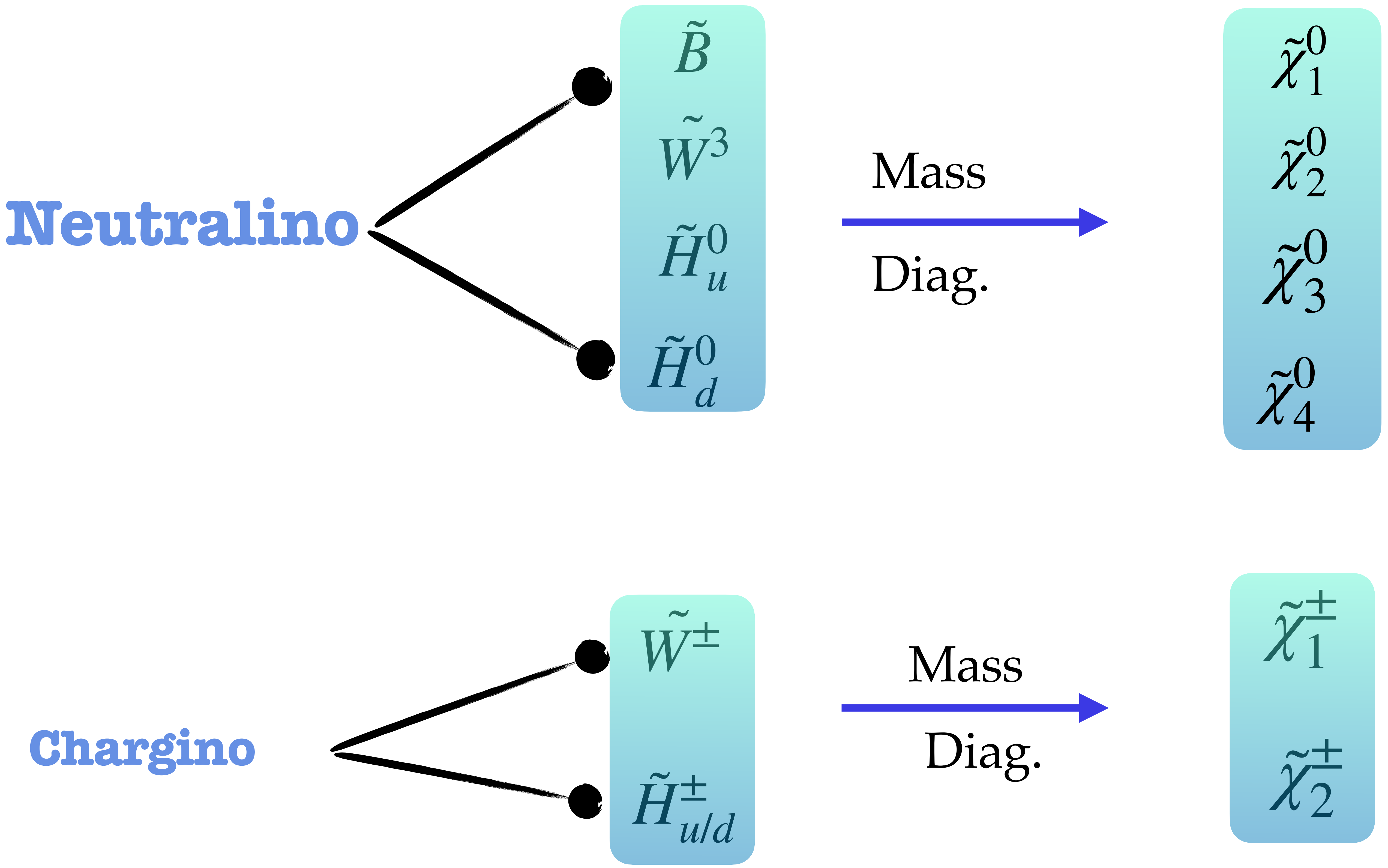
$$a_\mu^{exp} - a_\mu^{theo,SM} = (25.1 \pm 5.9) \times 10^{-10}$$

Muon g-2 experiment at Fermilab aims at 4 x BNL precision

- Abi *et al* PRL '21
- Aoyama *et al* '20

EW Gauginos

Masses and mixing determined by U(1) and SU(2) gaugino masses M_1, M_2 and Higgs mass parameter μ.



FOUR PARAMETERS → $M_1, M_2, \mu, \tan\beta$

Sleptons

Slepton Mass Matrix

$$M_{\tilde{L}}^2 = \begin{pmatrix} m_l^2 + m_{LL}^2 & m_l X_l \\ m_l X_l & m_l^2 + m_{RR}^2 \end{pmatrix}$$

$$m_{LL}^2 = m_{\tilde{L}}^2 + (I_l^{3L} - Q_f s_w^2) M_z^2 c_{2\beta}$$

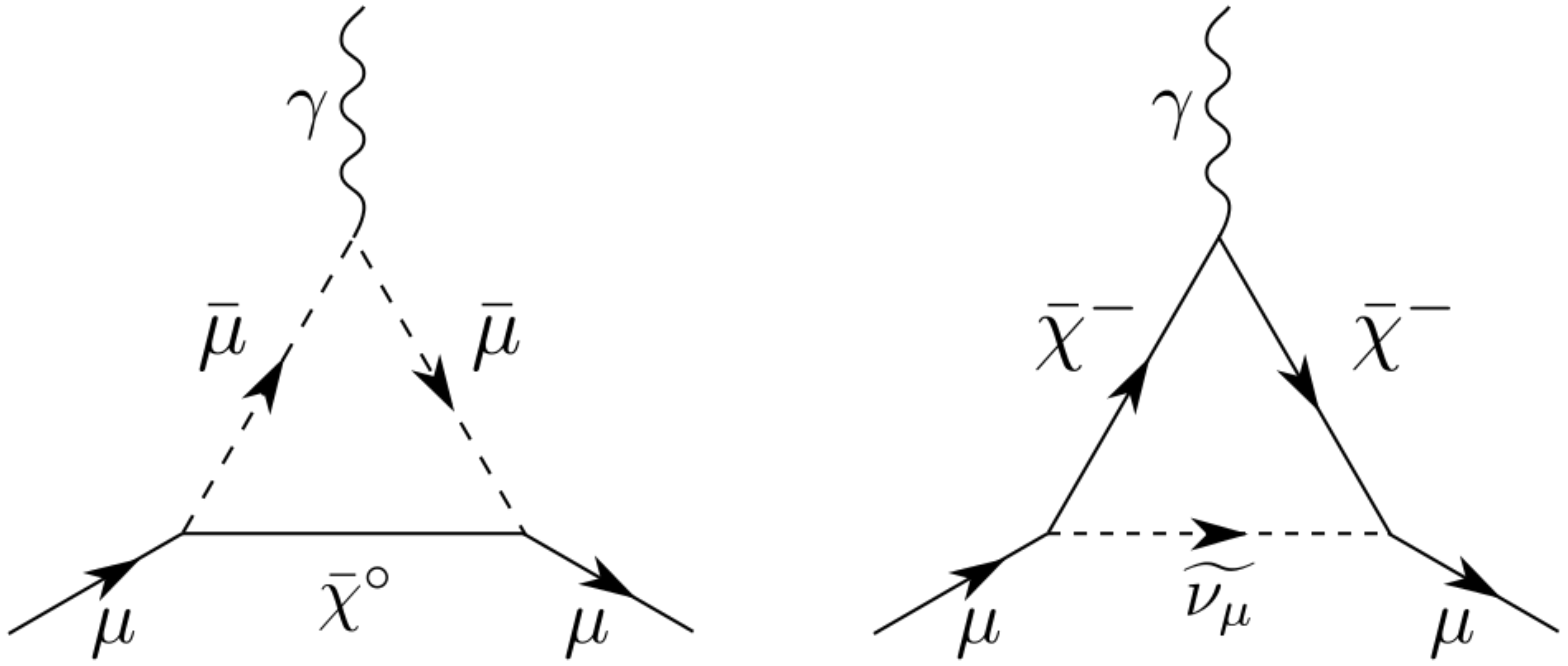
$$m_{RR}^2 = m_{\tilde{R}}^2 + Q_f s_w^2 M_z^2 c_{2\beta}$$

$$X_l = A_l - \mu (\tan\beta)^{2 I_l^{3L}}$$

PARAMETERS → $M_1, M_2, \mu, \tan\beta, m_{\tilde{L}}, m_{\tilde{R}}$

First two gens. $m_{\tilde{l}_1} \sim m_{LL}$ $\quad m_{\tilde{l}_2} \sim m_{RR}$

Muon (g-2)



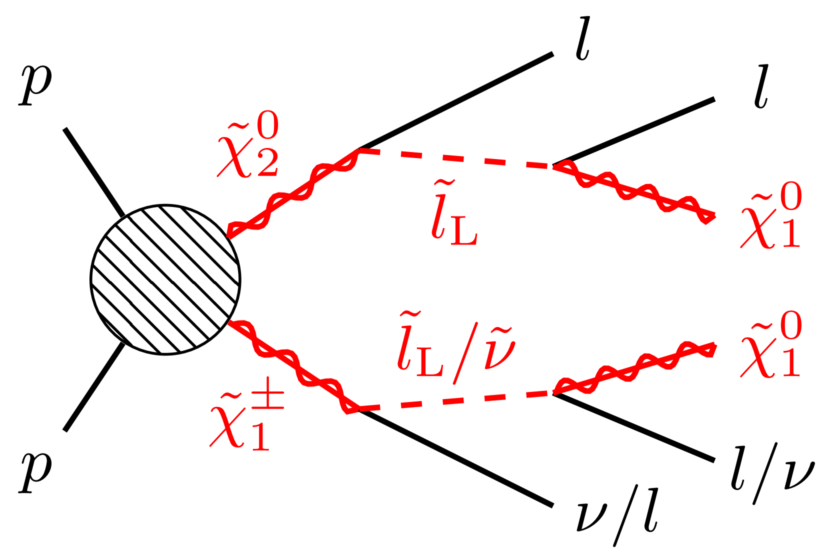
- SUSY contributions from Chargino-Sneutrino and Smuon-Neutralino loop
- SM EW 1 loop : $\frac{\alpha}{\pi}\frac{m_\mu^2}{M_W^2}$. MSSM , 1 loop : $\frac{\alpha}{\pi}\frac{m_\mu^2}{M_{SUSY}^2} \times \tan\beta$
- SUSY can easily explain anomaly : upper limits on EW super partner masses

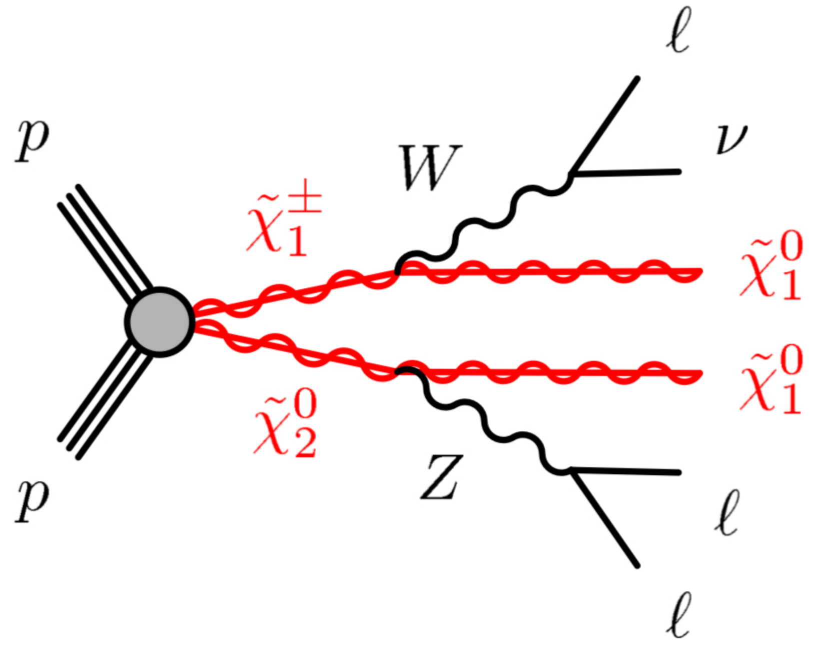
Searches at the LHC

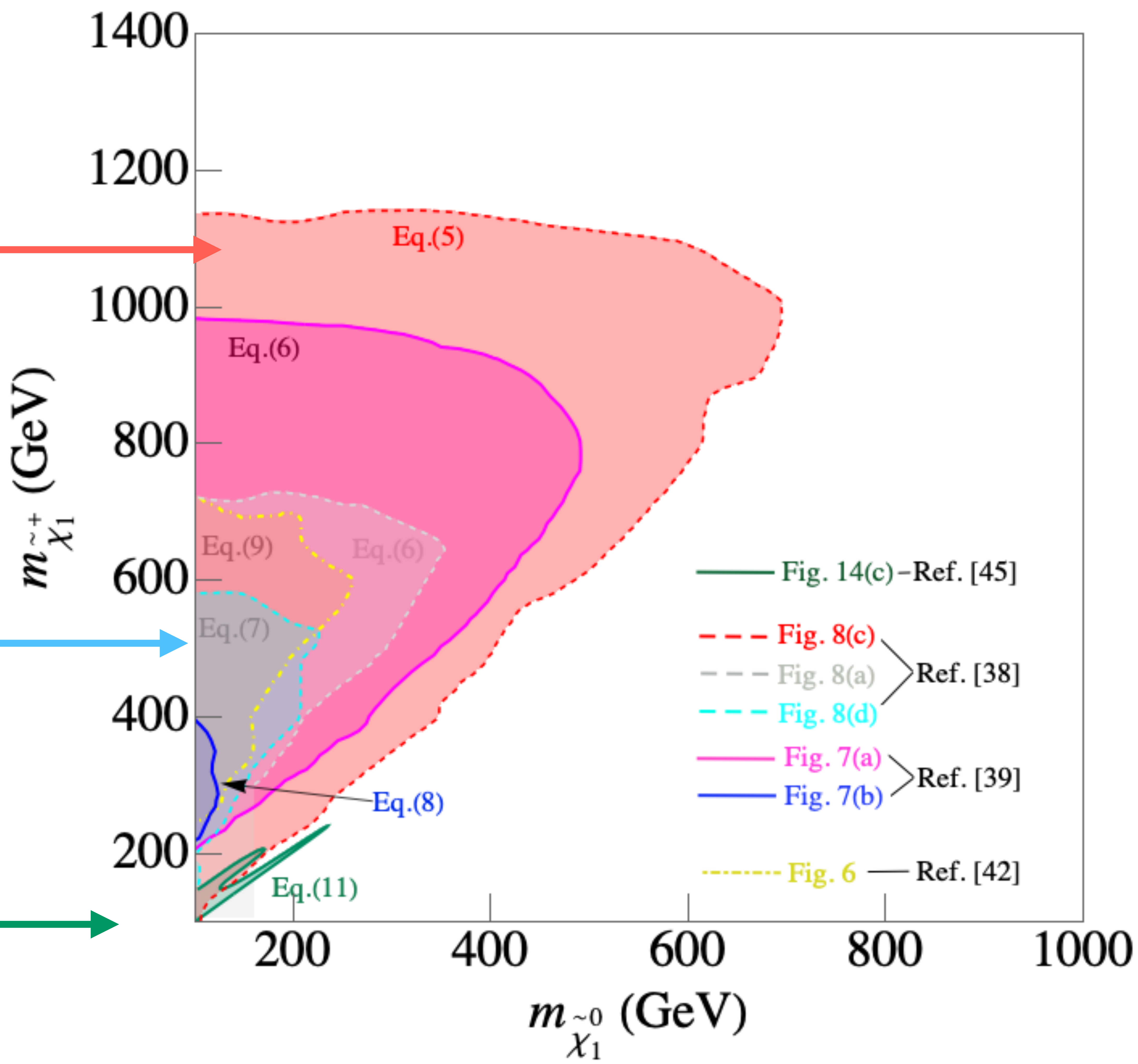
- Trilepton searches

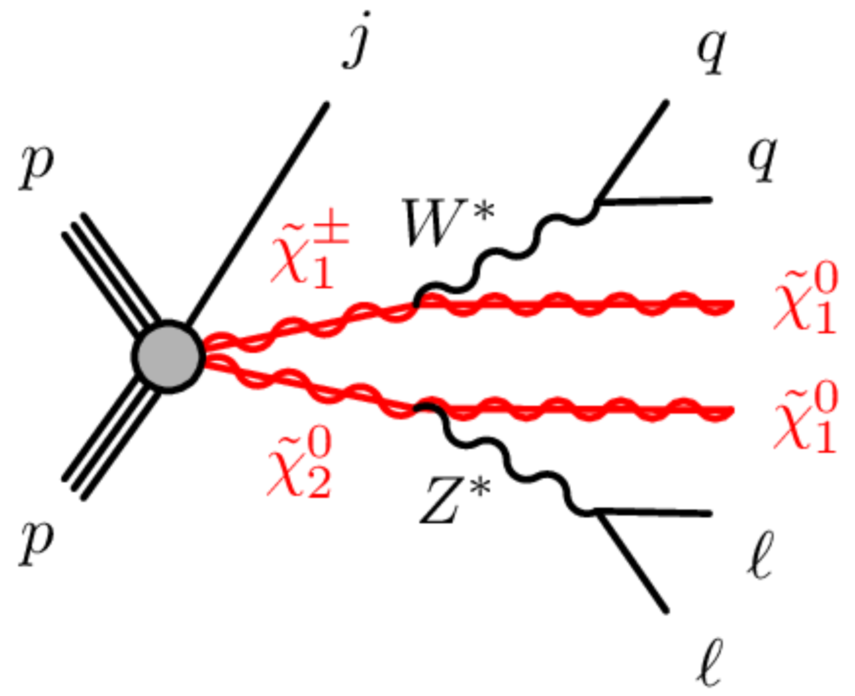
  ATLAS [1803.02762]

  13 TeV, 36 fb^{-1}









- Compressed spectra searches

  ATLAS 1911.12606

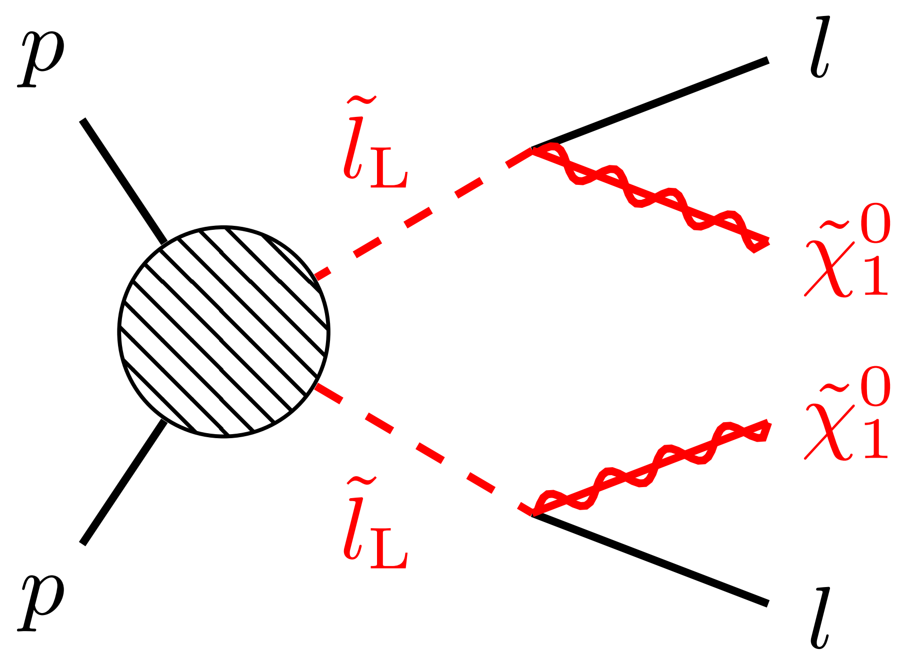
Proper recasting is important → **checkMATE**

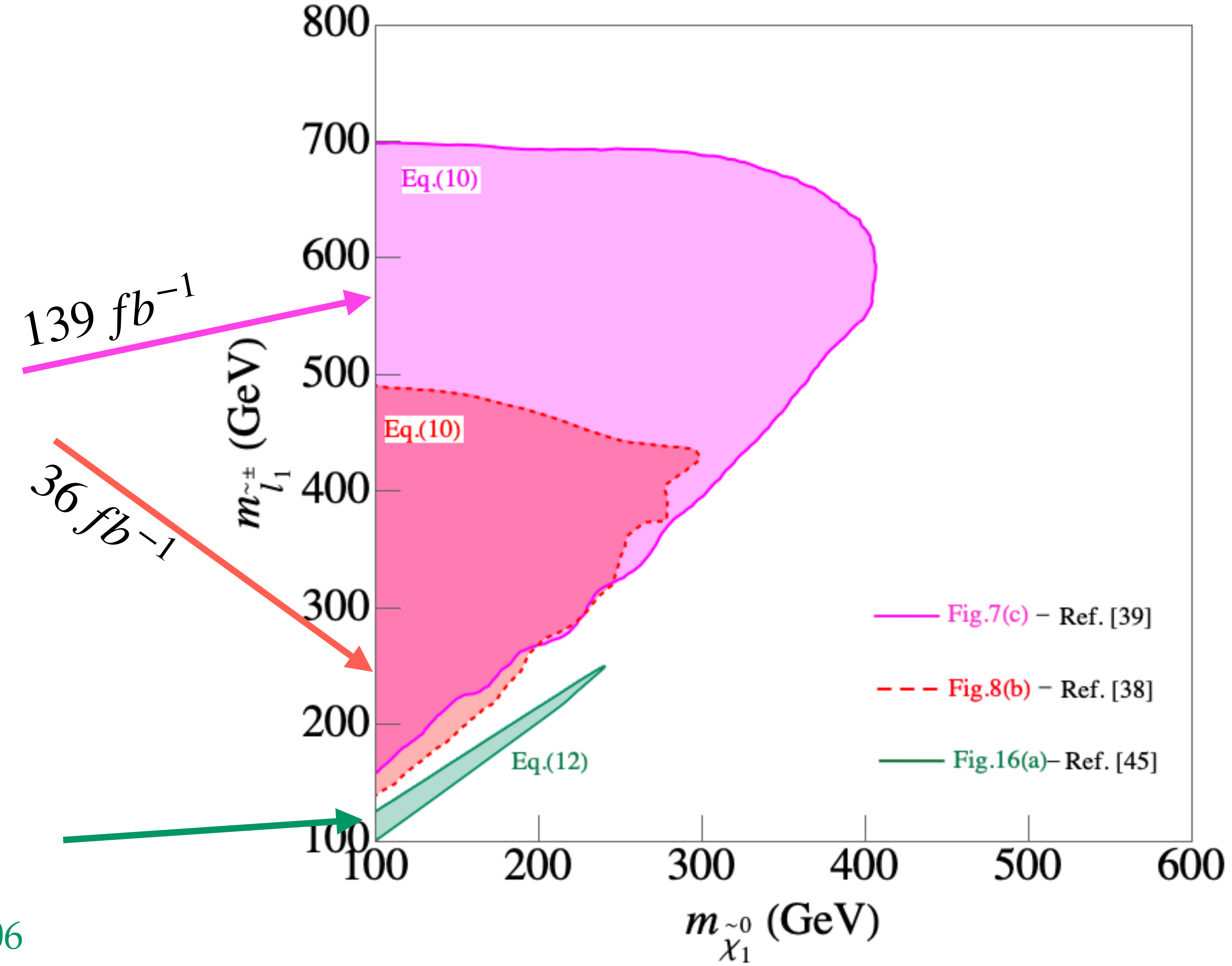
Searches at the LHC

- Slepton pair production

ATLAS [1908.08215]

13 TeV, 139 fb^{-1}





COMPRESSED

ATLAS 1911.12606

Proper recasting is important → checkMATE

Recasting with CM

Drees, Dreiner, Schmeier, Tattersall, Kim '13
Kim, Schmeier, Tattersall, Rolbiecki '15
Dercks, Desai, Kim, Rolbiecki, Tattersall '16

Event generation → MG5_aMC@NLO

↓

Showering and hadronization → Pythia8

↓

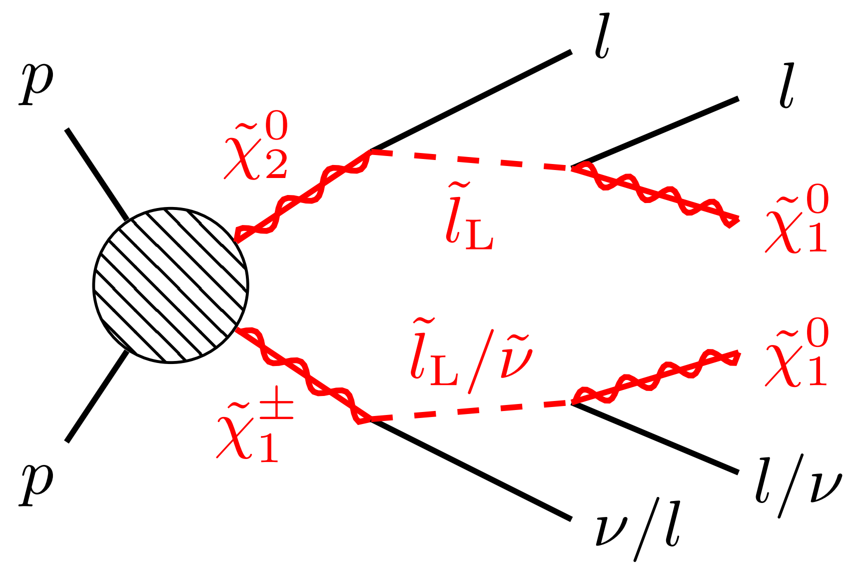
Detector effect → Delphes

↓

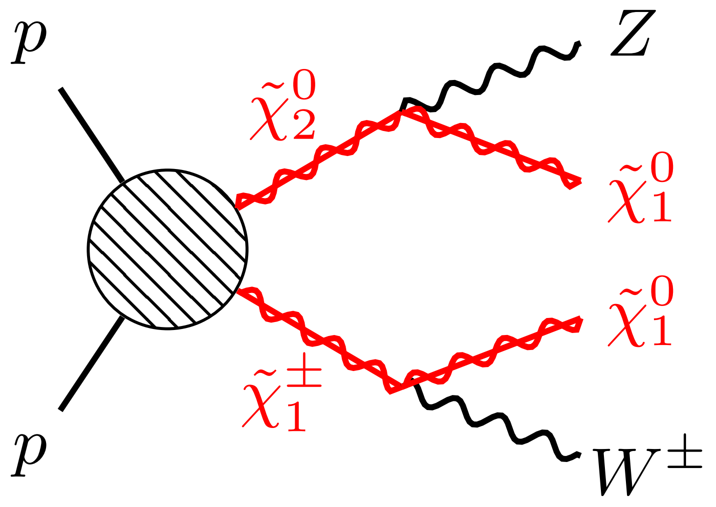
SR definition and statistical evaluation

New analysis implementation

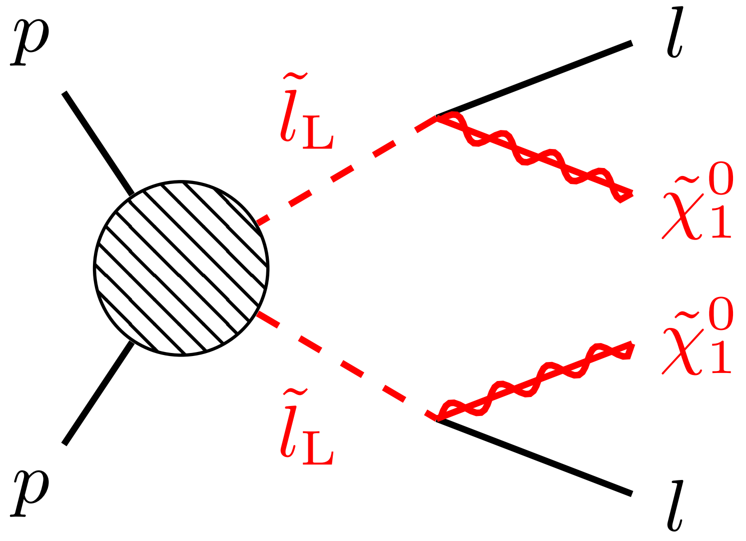
- ATLAS [1803.02762]



- ATLAS [1803.02762]



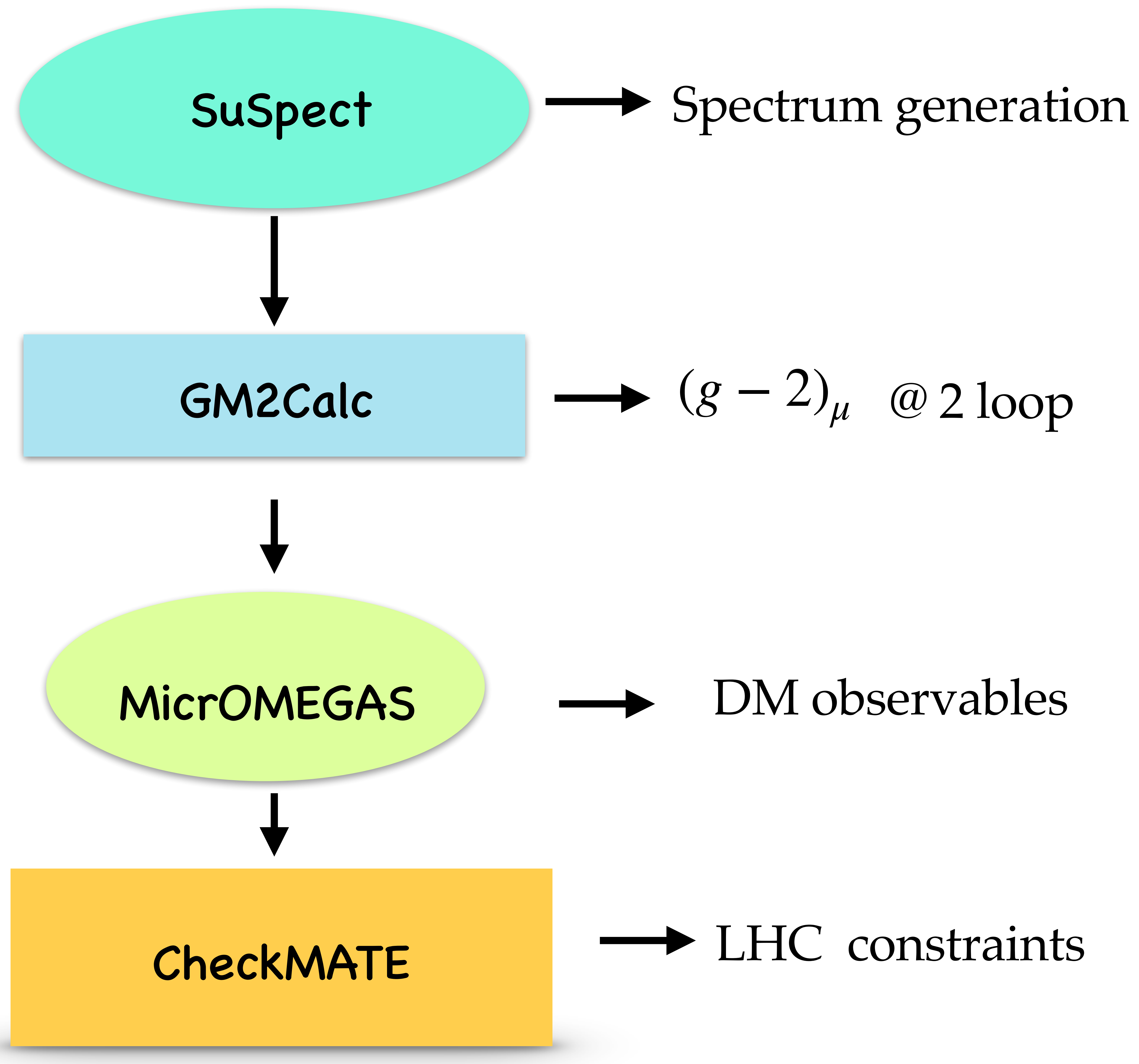
- ATLAS [1908.08215]



Compressed spectra searches applied directly

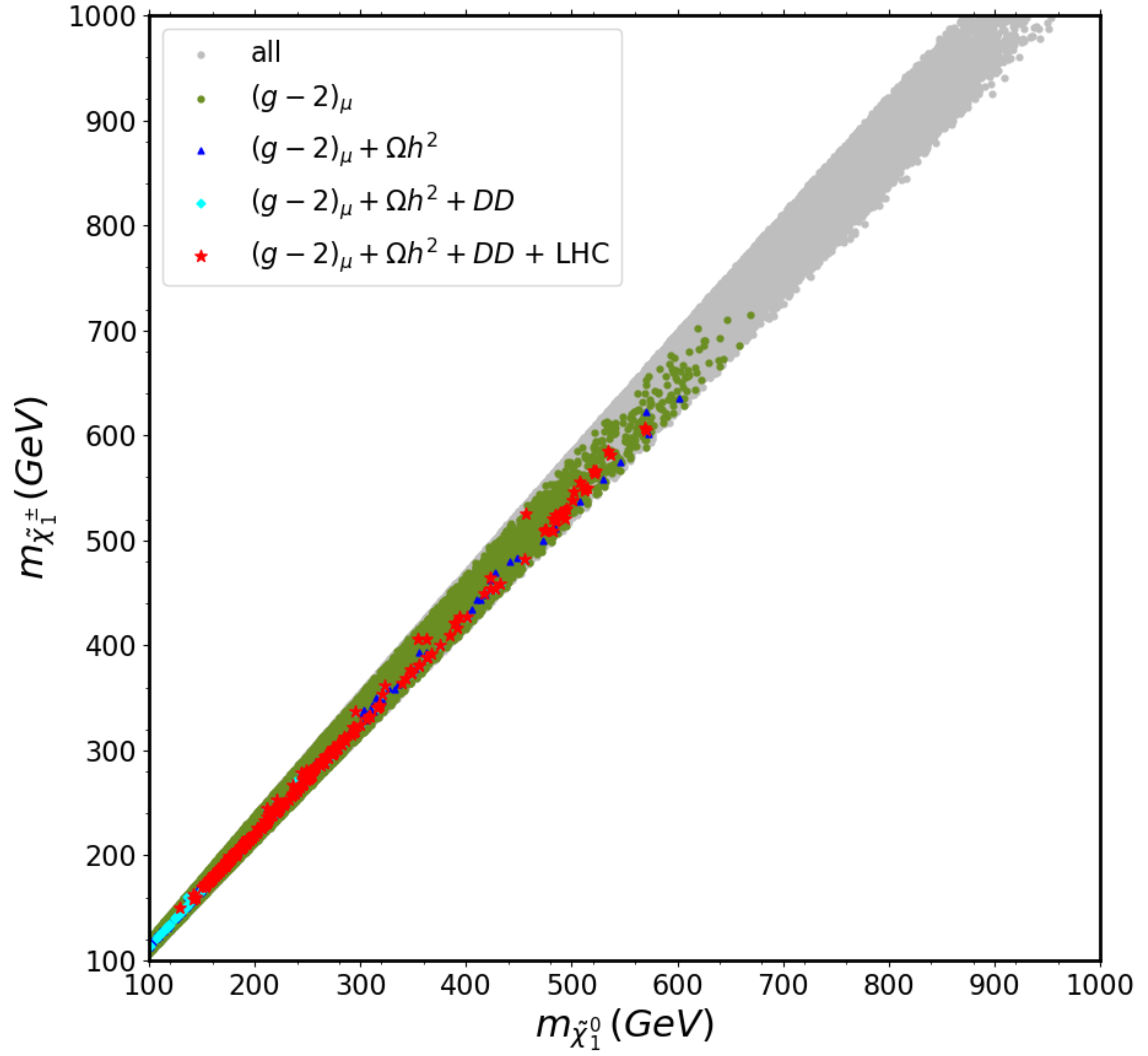
Most relevant in our case

Analysis flow



- $\Delta a_\mu = (25.1 \pm 5.9) \times 10^{-10}$
- $\Omega_{CDM} h^2 = 0.120 \pm 0.001$
- Direct detection SI bounds from XENON1T

Chargino Co-annihilation

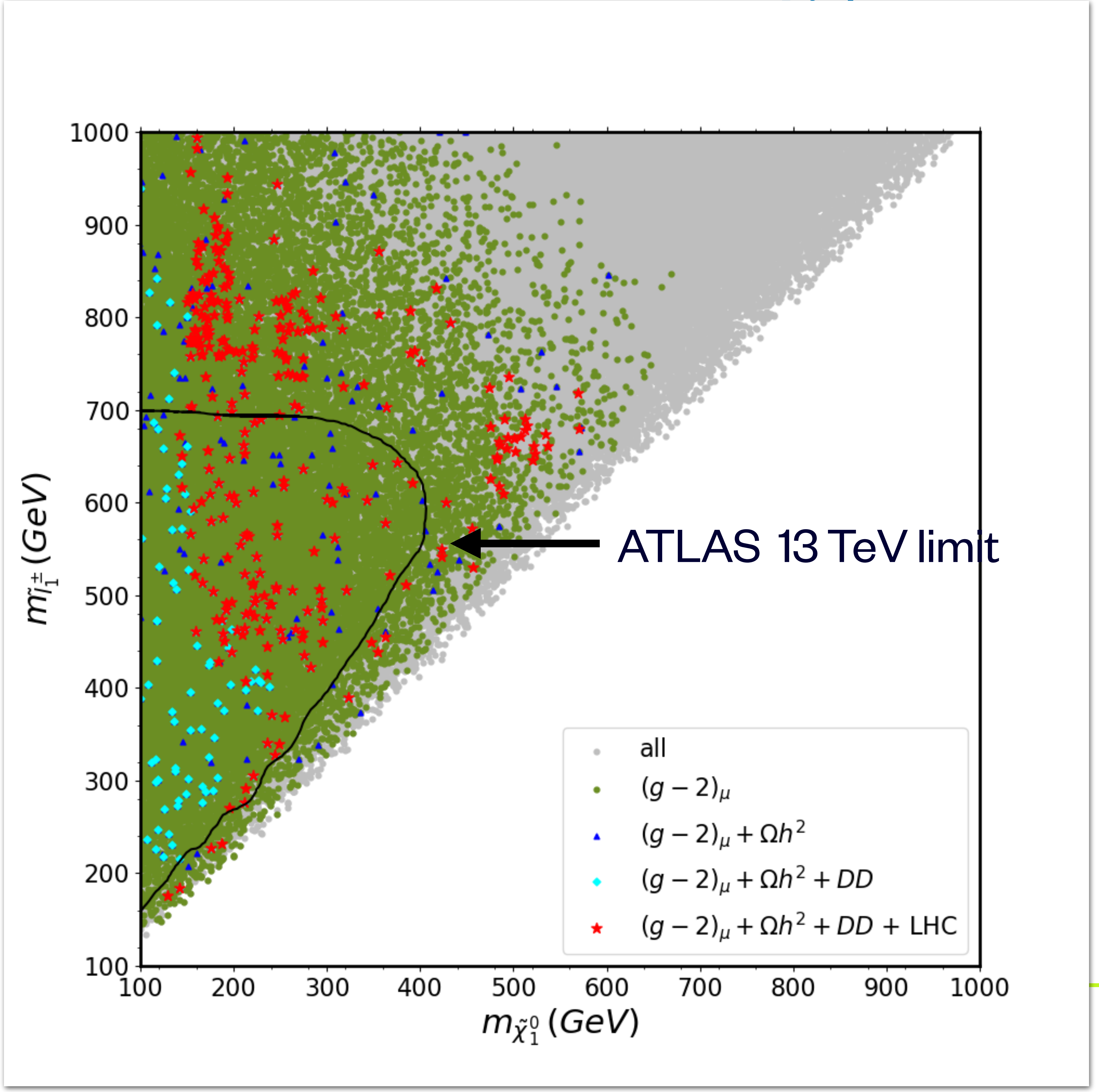


Bino-wino co-annihilation

$$100 \text{ GeV} \leq M_1 \leq 1 \text{ TeV}, \quad M_1 \leq M_2 \leq 1.1 M_1,$$
$$1.1 M_1 \leq \mu \leq 10 M_1, \quad 5 \leq \tan\beta \leq 60,$$
$$100 \text{ GeV} \leq m_{\tilde l_L} \leq 1 \text{ TeV}, \quad m_{\tilde l_R} = m_{\tilde l_L}.$$

Upper and lower bounds from $(g-2)_\mu$ and LHC searches (for compressed spectrum) respectively.

Results in the $m_{\tilde{\chi}_1^0} - m_{\tilde{l}_1}$ plane



- Slepton-pair production →($2l$ + missing E_T) provides important search channel

- Considerable BR for $\tilde{e}_L(\tilde{\mu}_L) \rightarrow \tilde{\chi}_1^\pm \nu_e(\nu_\mu)$

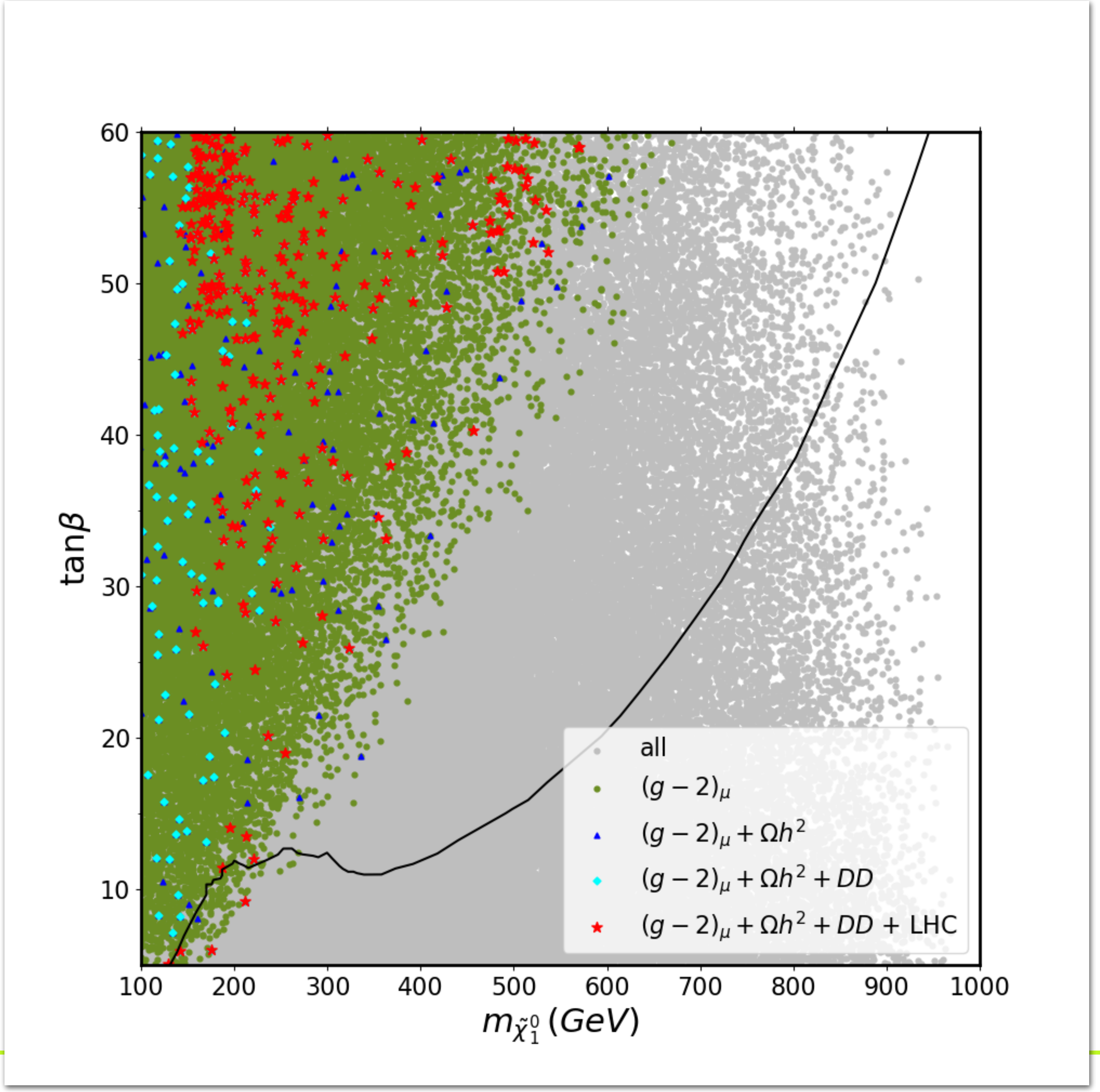
Less no. of signal leptons.

Possibility of A-pole annihilation

$$a_\mu \sim \frac{\tan\beta}{m_{EW}^2}$$

$M_h^{125}(\tilde{\chi})$

Benchmark scenario



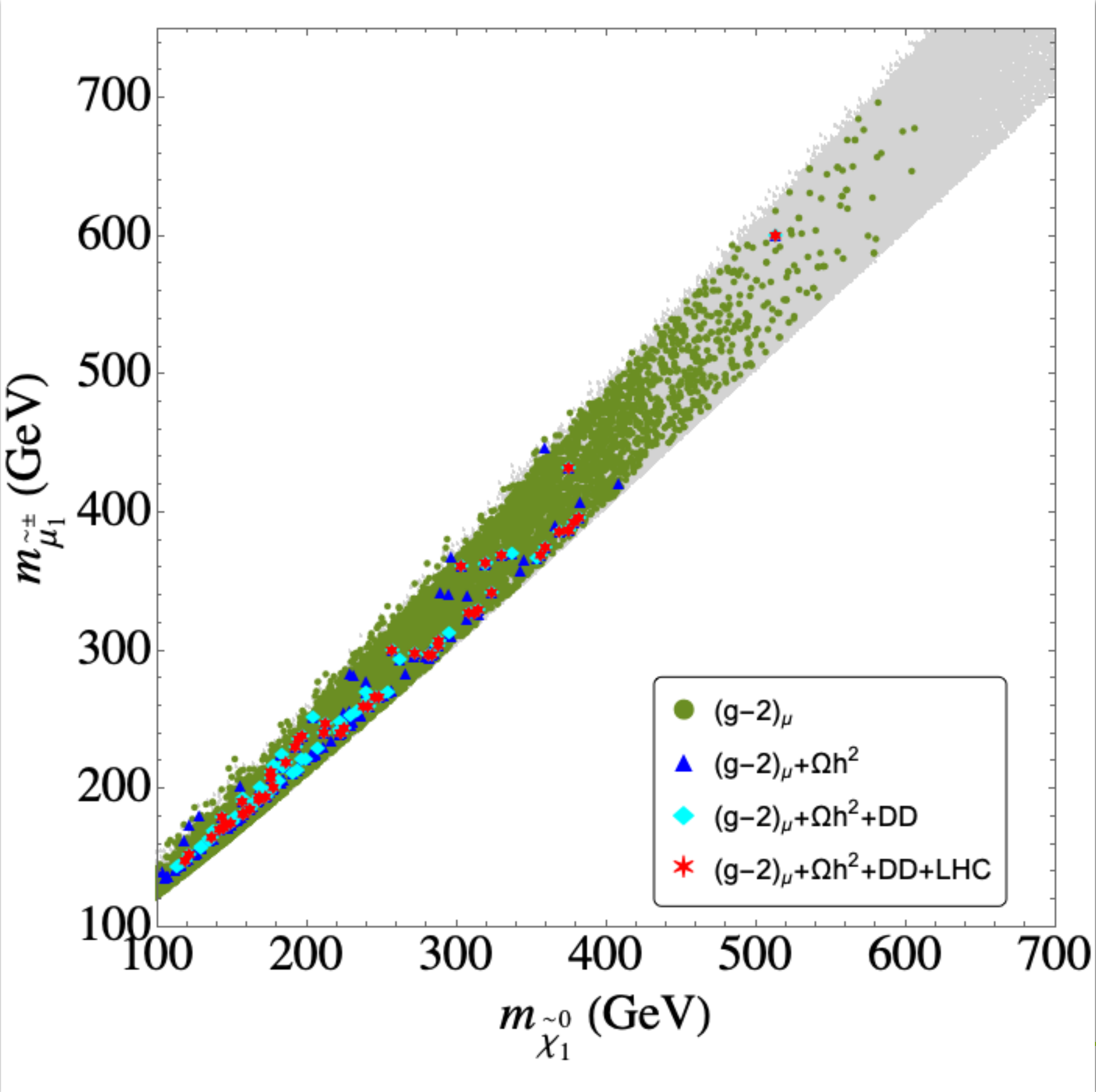
Bagnaschi et al. '18

$$m_{\tilde{\chi}_1^0} = \frac{M_A}{2}$$

Black contour : simplified application of $H/A \to \tau^+\tau^-$

A-pole annihilation strongly constrained

Slepton Co-annihilation: Case-L

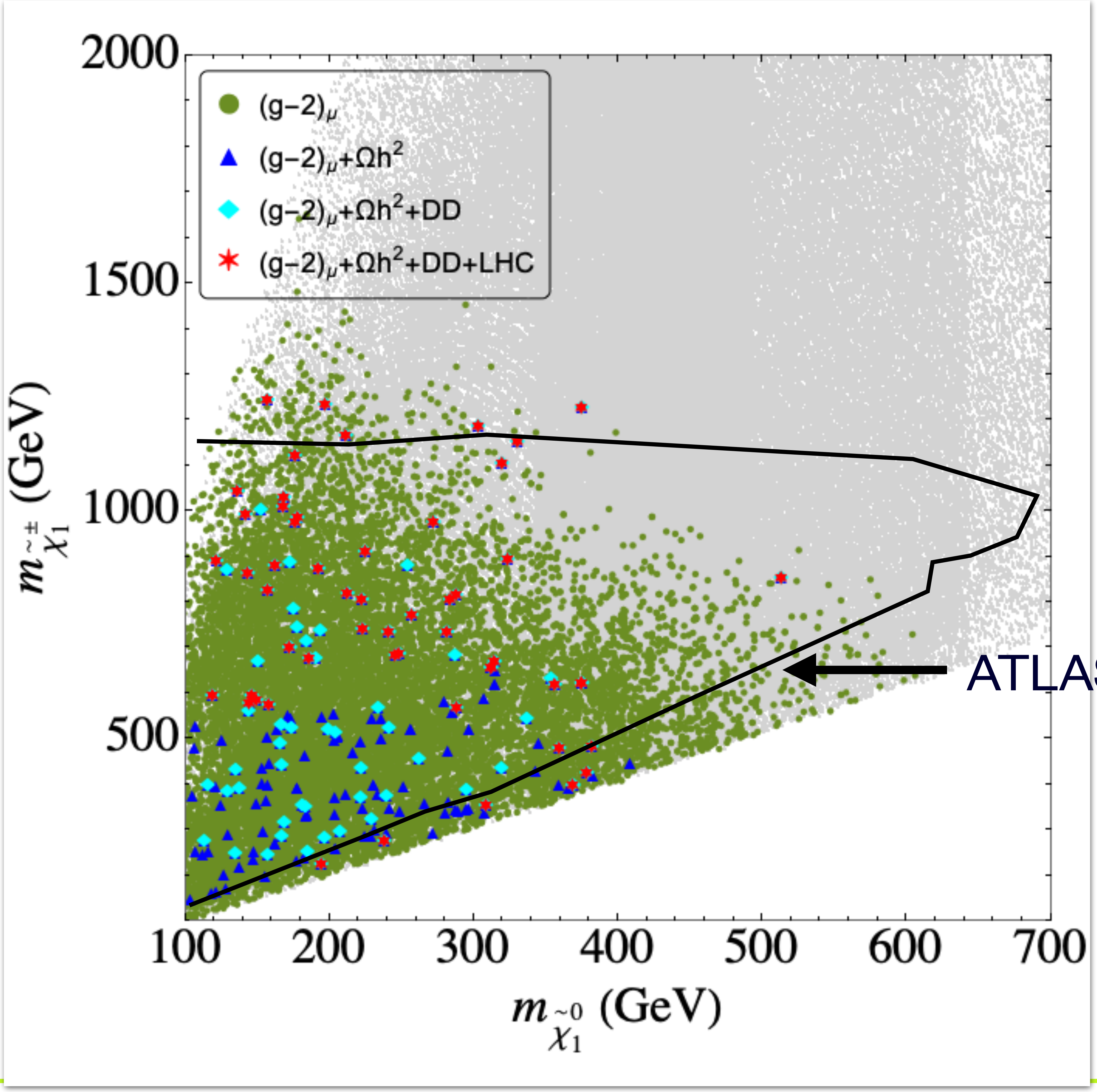


Case-L: SU(2) doublet

$$100 \text{ GeV} \le M_1 \le 1 \text{ TeV} , \quad M_1 \le M_2 \le 10 M_1 ,$$
$$1.1 M_1 \le \mu \le 10 M_1 , \quad 5 \le \tan\beta \le 60,$$
$$M_1 \text{ GeV} \le m_{\tilde{l}_L} \le 1.2 M_1 , \quad M_1 \le m_{\tilde{l}_R} \le 10 M_1 .$$

The left-sleptons and sneutrinos are close in mass to the LSP.

Slepton Co-annihilation: Case-L



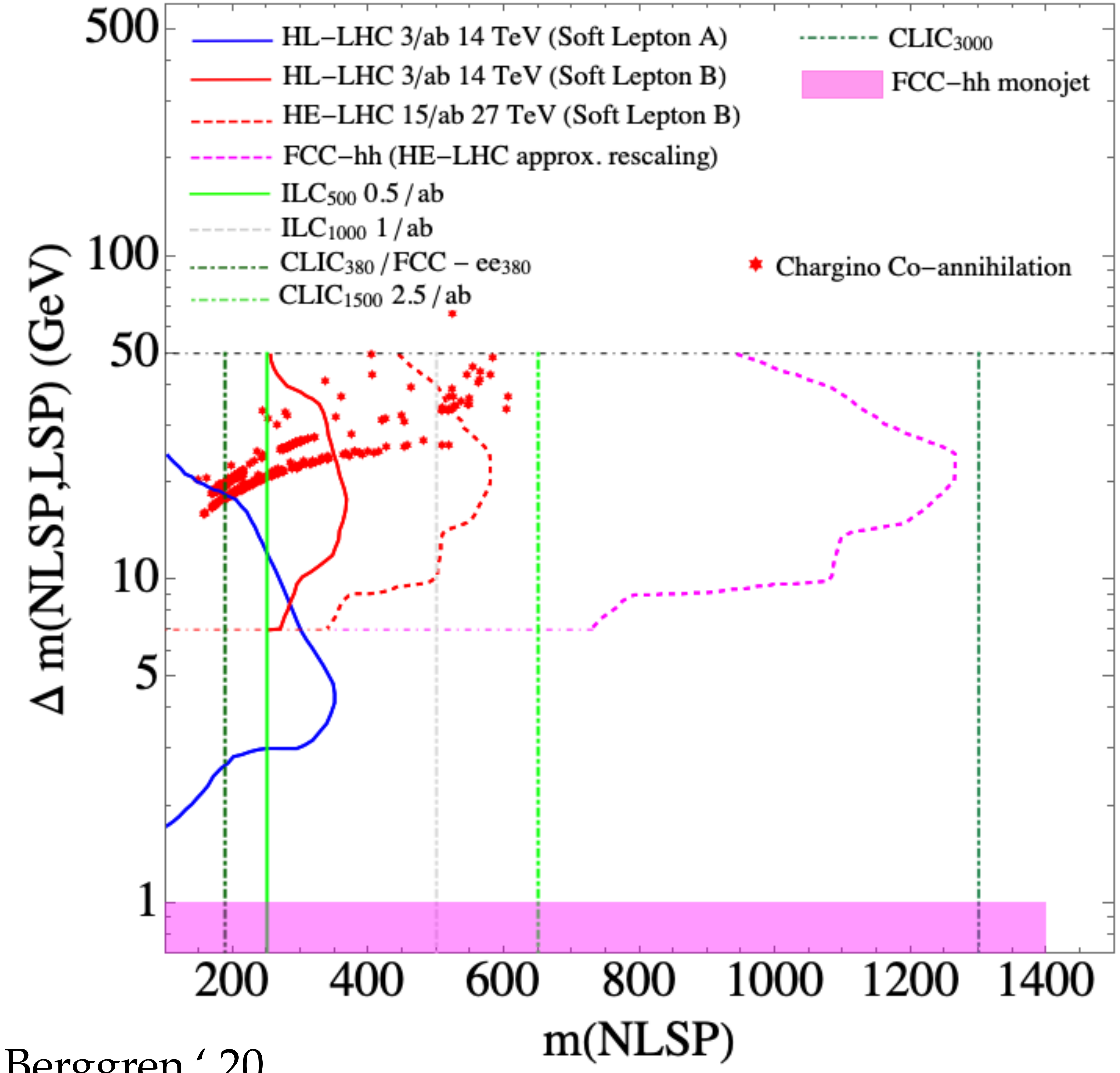
Case-L: SU(2) doublet

$$100 \text{ GeV} \le M_1 \le 1 \text{ TeV}, \quad M_1 \le M_2 \le 10M_1,$$
$$1.1M_1 \le \mu \le 10M_1, \quad 5 \le \tan\beta \le 60,$$
$$M_1 \text{ GeV} \le m_{\tilde{l}_L} \le 1.2M_1, \quad M_1 \le m_{\tilde{l}_R} \le 10M_1 .$$

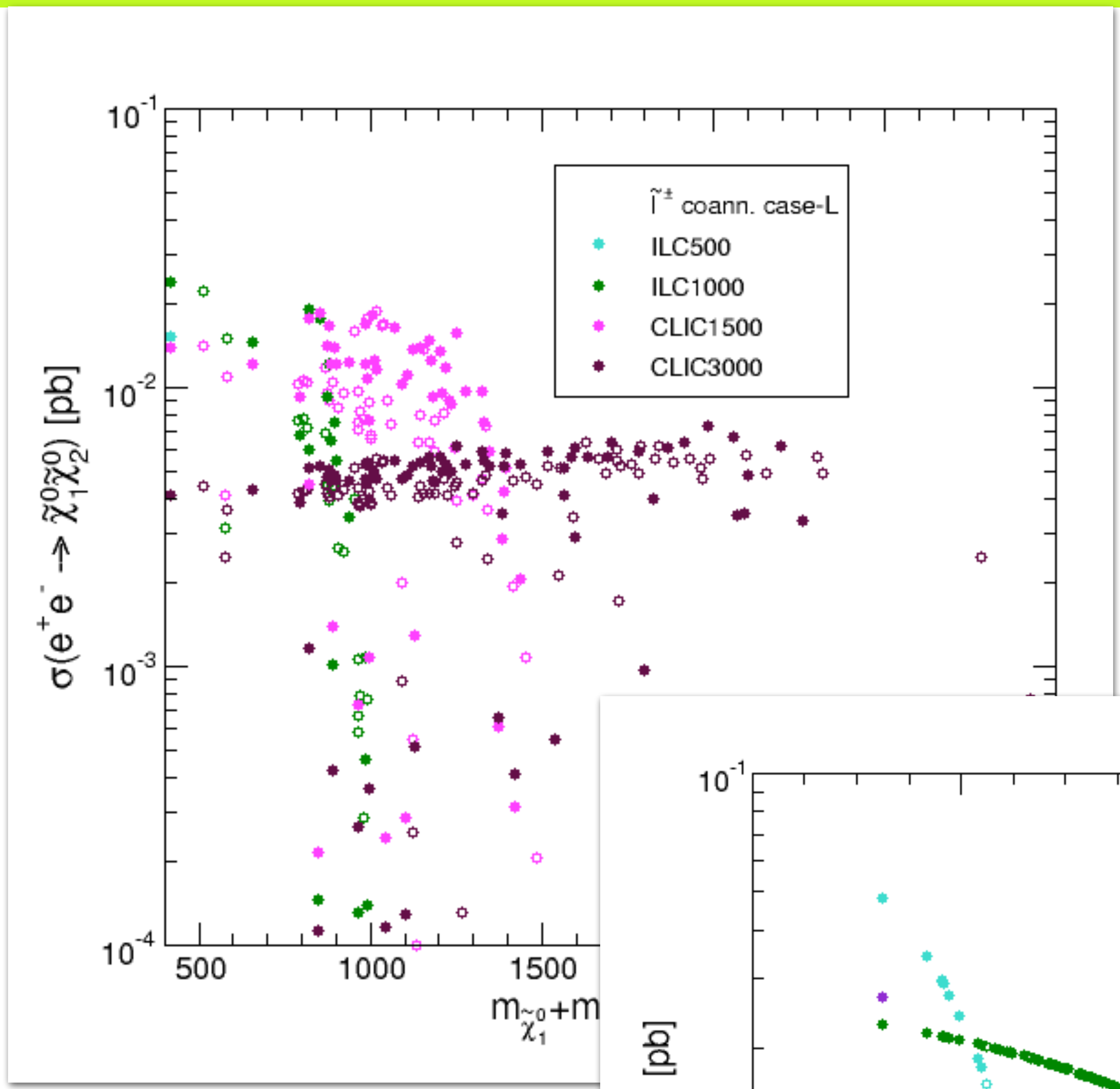
($3l$ + missing E_T) exclusion limit weakens

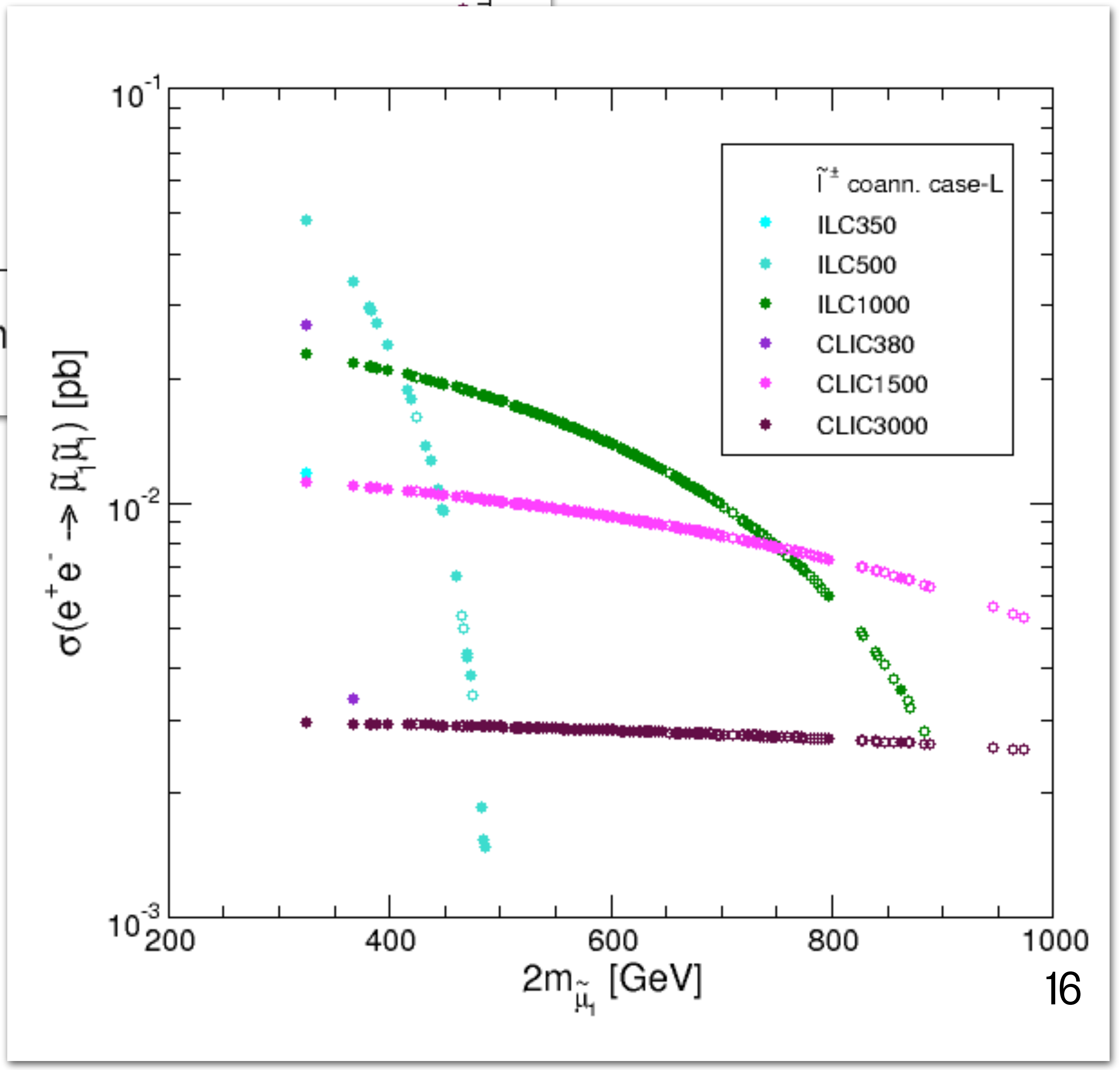
$\text{BR}(\tilde{\chi}_1^\pm \to \tilde{\tau}_1\nu_\tau)$ and $\text{BR}(\tilde{\chi}_2^0 \to \tilde{\tau}_1\tau)$, $\text{BR}(\tilde{\chi}_2^0 \to \tilde{\nu}\nu)$

Future prospects



Berggren ' 20





Slepton Co-annihilation case-L

Conclusions

- It is possible to constrain the EW MSSM with the help of indirect constraints along with the direct collider limits.
- DM and muon (g-2) constraint put effective upper limit on EW SUSY masses while LHC limits restrict the mass ranges from below.
- LHC exclusion bound strongly depends on EW gaugino composition. Proper recasting of ATLAS/CMS analysis relaxes the existing bound.
- Searches at future colliders, HL-LHC, ILC/CLIC will be conclusive.
- We wait for more experimental results on muon (g-2) from Fermilab, J-PARC. STAY TUNED!!!

THANK YOU!