So, is this "dark matter" in the room with us right now?

New Results for the DD/LHC Complementarity in the MSSM

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La Cristalera, 05/2022

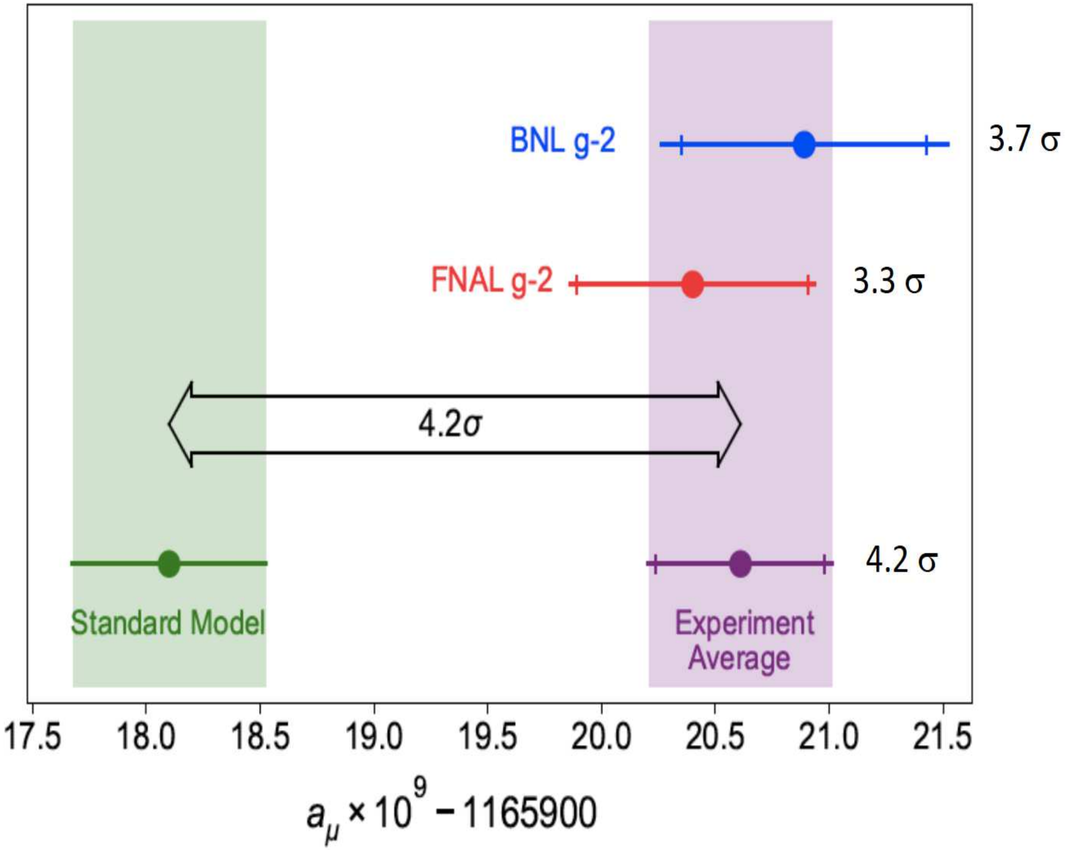
In collaboration with: *M. Chakraborti, I. Saha*

1. The main idea
2. New Results for (nearly) all SUSY scenarios: Direct Detection prospects
3. The missing scenario
4. Conclusions

1. The main idea

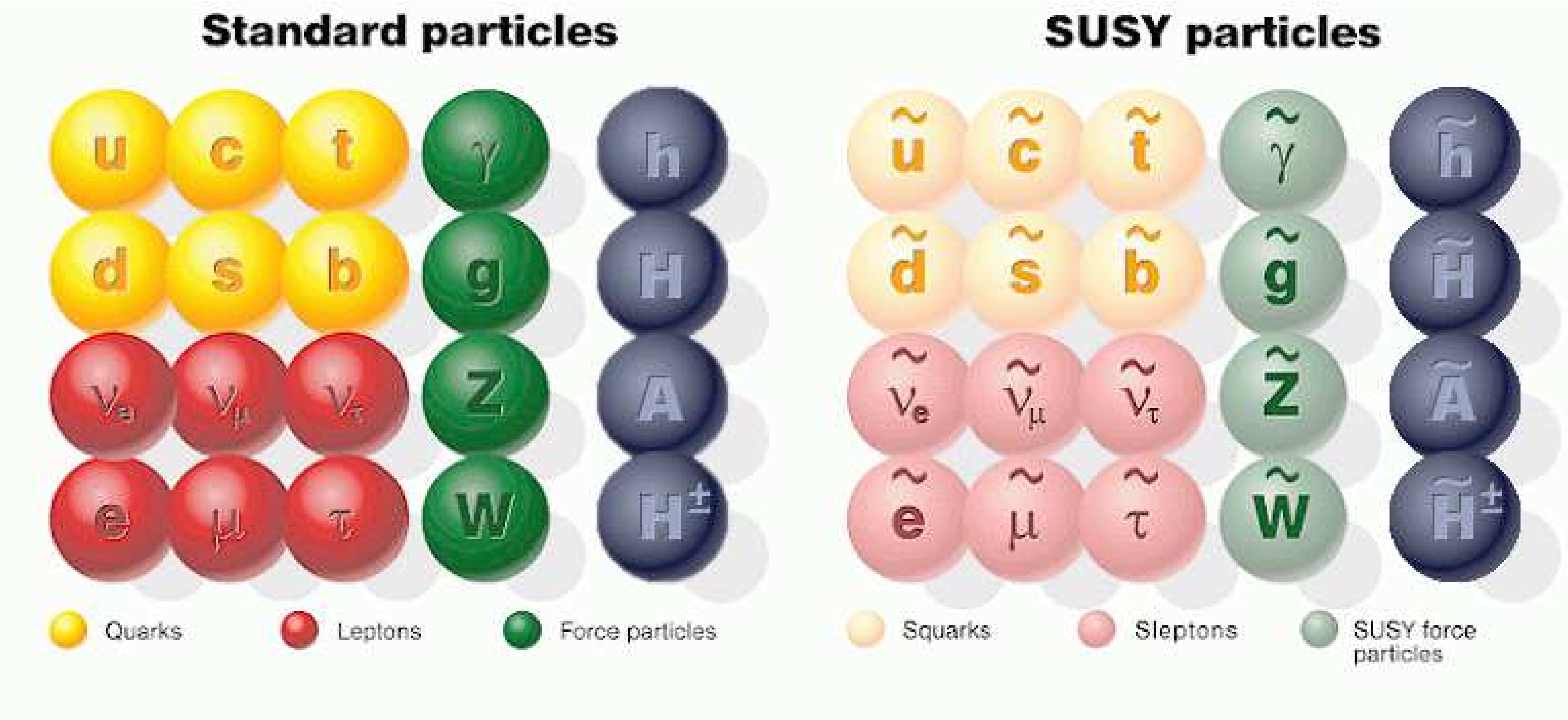
The anomalous magnetic moment of the muon: $a_\mu \equiv (g-2)_\mu/2$

Overview about the current experimental and SM (theory) result:



$$a_\mu^{\rm exp} - a_\mu^{\rm theo,SM} \approx (25.1 \pm 5.9) \times 10^{-10} \quad : 4.2\,\sigma$$

The MSSM



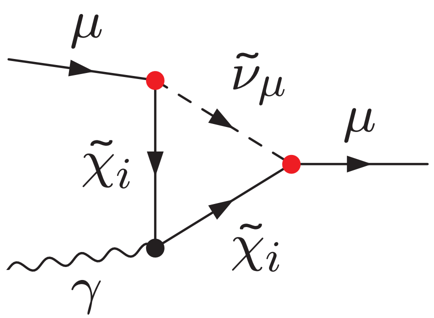
$\Rightarrow$ large uncolored / EW sector

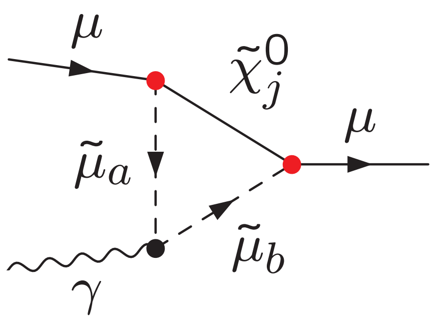
charginos/neutralinos: M_1, M_2, μ, $\tan\beta$

Sleptons: $M_{\tilde{l}_L}$, $M_{\tilde{l}_R}$ (for now equal for all 3 generations)

SUSY can easily explain the deviation in a_μ:

Feynman diagrams for MSSM 1L corrections:





– Diagrams with chargino/sneutrino exchange

– Diagrams with neutralino/smuon exchange

Enhancement factor as compared to SM:

$$\mu - \tilde{\chi}_i^\pm - \tilde{\nu}_\mu \quad : \quad \sim m_\mu \tan\beta$$
$$\mu - \tilde{\chi}_j^0 - \tilde{\mu}_a \quad : \quad \sim m_\mu \tan\beta$$

SM, EW 1L: $\frac{\alpha}{\pi} \frac{m_\mu^2}{M_W^2}$

MSSM, 1L: $\frac{\alpha}{\pi} \frac{m_\mu^2}{M_{\text{SUSY}}^2} \times \tan\beta$

The main idea:

- scan the relevant EW SUSY parameter space

- impose all relevant experimental constraints:
  - $(g-2)_\mu$
  - Dark Matter relic density
  - Dark Matter direct detection
  - LHC searches for EW particles

- Dark Matter relic density requires a mechanism to reduce the density in the early universe
  - bino/wino DM with chargino co-annihilation
  - bino DM with slepton co-annihilation
  - higgsino DM
  - wino DM

- obtain lower and upper limits on the various EW particle masses

- evaluate the prospects for future searches: DD and (HL-)LHC

$(g-2)_\mu$ constraint: (GM2Calc)

$$\text{old: } \Delta a_\mu^{\text{old}} = (28.0 \pm 7.4) \times 10^{-10}$$
$$\text{new: } \Delta a_\mu^{\text{new}} = (25.1 \pm 5.9) \times 10^{-10}$$

$\Rightarrow$ all results for $\Delta a_\mu^{\text{new}} (\equiv \Delta a_\mu)$

Dark Matter relic density: MicrOmegas

$$\Omega_{\text{CDM}} h^2 = 0.120 \pm 0.001$$
$$\text{or} \quad \Omega_{\text{CDM}} h^2 \leq 0.122$$

(as taken from [*Planck '18*])

Dark Matter direct detection: MicrOmegas

limit on spin independent scattering cross section (Xenon1T)
[*Xenon collab. '18*]

LHC limits: CheckMate

many searches newly included [*M. Chakraborti, I. Saha '20,'21*]

Results for (nearly) all SUSY scenarios

A) bino/wino DM with chargino co-annihilation ($M_1 \sim M_2 \lesssim \mu$)
relic DM density 100% fulfilled
$\Rightarrow m_{\text{(N)LSP}} \lesssim$ 650(700) GeV

B/C) bino DM with slepton co-annihilation ($M_1 \lesssim M_2, \mu$)
relic DM density 100% fulfilled
$\Rightarrow m_{\text{(N)LSP}} \lesssim$ 650(700) GeV

D) higgsino DM: $m_{\tilde{\chi}_1^0} \sim m_{\tilde{\chi}_2^0} \sim m_{\tilde{\chi}_1^\pm} \sim \mu$ ($\mu \lesssim M_1, M_2$)
relic DM density as upper limit (otherwise $m_{\tilde{\chi}_1^0} \sim 1$ TeV)
$\Rightarrow m_{\text{(N)LSP}} \lesssim$ 500 GeV

E) wino DM: $m_{\tilde{\chi}_1^0} \sim m_{\tilde{\chi}_1^\pm} \sim M_2$ ($M_2 \lesssim M_1, \mu$)
relic DM density as upper limit (otherwise $m_{\tilde{\chi}_1^0} \sim 3$ TeV)
$\Rightarrow m_{\text{(N)LSP}} \lesssim$ 600 GeV

$\Rightarrow$ predictions for future experiments?!

2. Prospects for Direct Detection Experiments

A) Bino/wino DM with chargino co-annihilation

Parameter scan:

$$100 \text{ GeV} \le M_1 \le 1 \text{ TeV} ,$$

$$M_1 \le M_2 \le 1.1 M_1 ,$$

$$1.1 M_1 \le \mu \le 10 M_1,$$

$$5 \le \tan\beta \le 60,$$

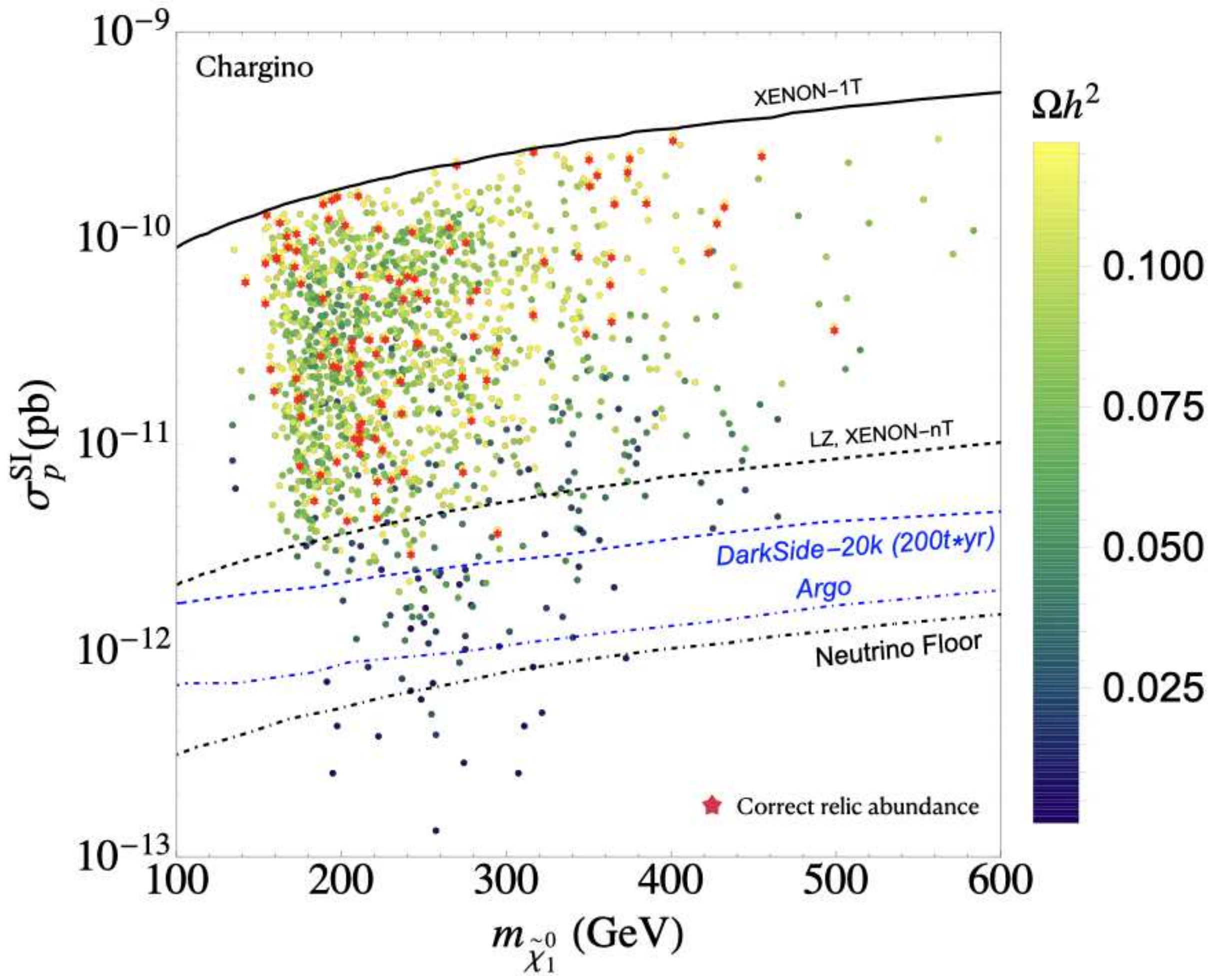
$$100 \text{ GeV} \le m_{\tilde{L}} \le 1 \text{ TeV},$$

$$m_{\tilde{R}} = m_{\tilde{L}} .$$

(latter condition only to make the analysis simpler, no relevant effect)

relic DM density can be 100% fulfilled
$\Rightarrow m_{\text{(N)LSP}} \lesssim 600(650)$ GeV

Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SI}$ plane:

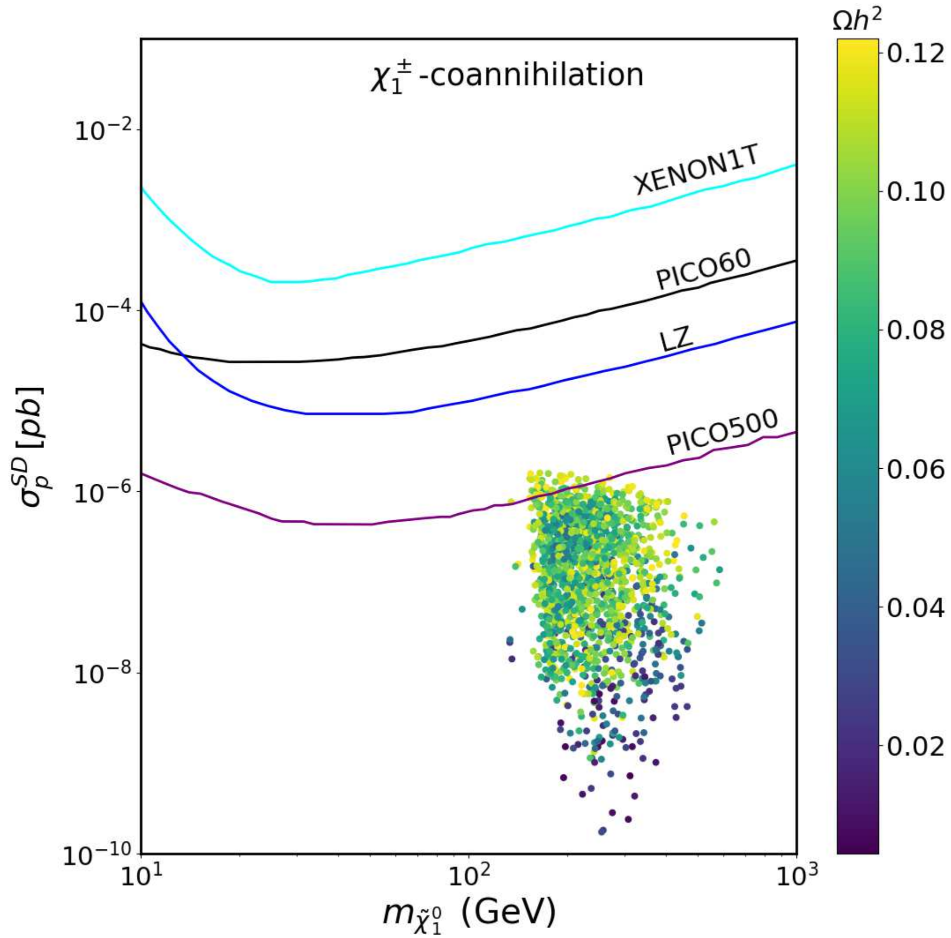


⇒ large part covered by XENON-nT/LZ

⇒ but can go below even the neutrino floor

Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SD}$ plane:

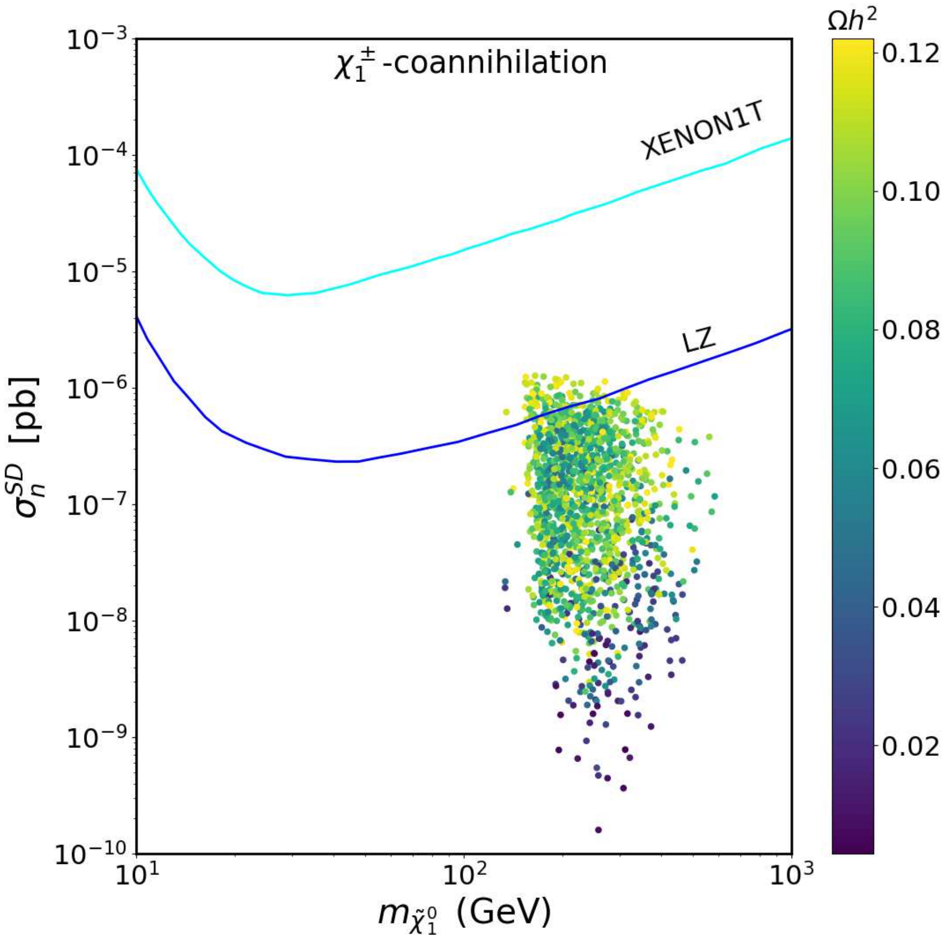
[PRELIMINARY]



⇒ SD DD experiments have to do better . . .

⇒ no indirect detection limits . . .

Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_n^{\rm SD}$ plane:



⇒ SD DD experiments have to do better . . .

⇒ only LZ limits . . .

B/C) Bino DM with slepton co-annihilation

Parameter scan:

$$100\ \text{GeV} \leq M_1 \leq 1\ \text{TeV}\ ,$$

$$M_1 \leq M_2 \leq 10 M_1\ ,$$

$$1.1 M_1 \leq \mu \leq 10 M_1,$$

$$5 \leq \tan\beta \leq 60,$$

Case-L: $M_1 \leq m_{\tilde{L}} \leq 1.2 M_1, \quad M_1 \leq m_{\tilde{R}} \leq 10 M_1.$

Case-R: $M_1 \leq m_{\tilde{R}} \leq 1.2 M_1, \quad M_1 \leq m_{\tilde{L}} \leq 10 M_1.$

relic DM density can be 100% fulfilled
$\Rightarrow m_{\text{(N)LSP}} \lesssim 550(600)$ GeV

B/C) Bino DM with slepton co-annihilation

Parameter scan:

$$100 \text{ GeV} \leq M_1 \leq 1 \text{ TeV} ,$$

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$$1.1 M_1 \leq \mu \leq 10 M_1,$$

$$5 \leq \tan\beta \leq 60,$$

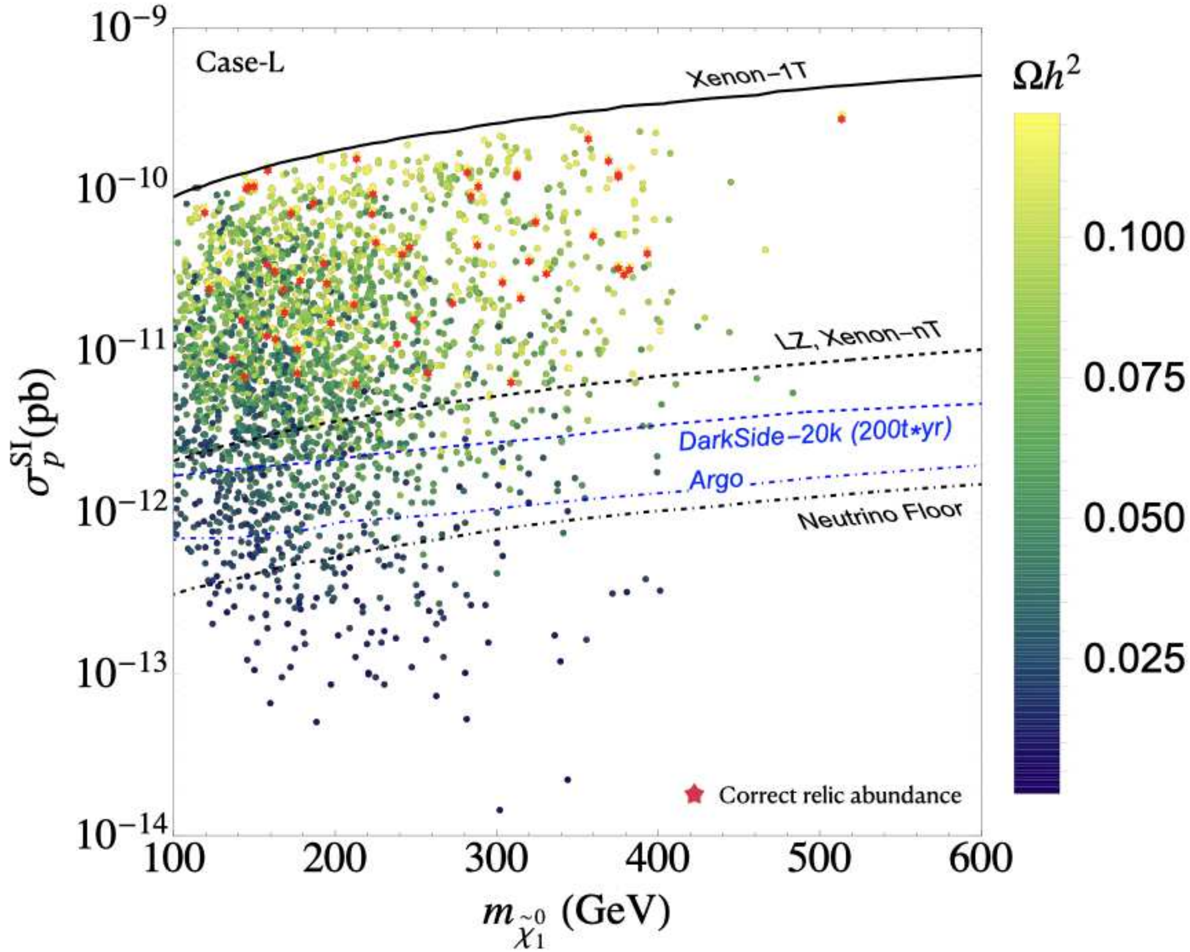
$$\text{Case-L:} \quad M_1 \leq m_{\tilde{L}} \leq 1.2 M_1, \quad M_1 \leq m_{\tilde{R}} \leq 10 M_1.$$

$$\text{Case-R:} \quad M_1 \leq m_{\tilde{R}} \leq 1.2 M_1, \quad M_1 \leq m_{\tilde{L}} \leq 10 M_1.$$

relic DM density can be 100% fulfilled
$\Rightarrow m_{\text{(N)LSP}} \lesssim 550(600)$ GeV

$\Rightarrow$ funny that nobody ever complained here . . .

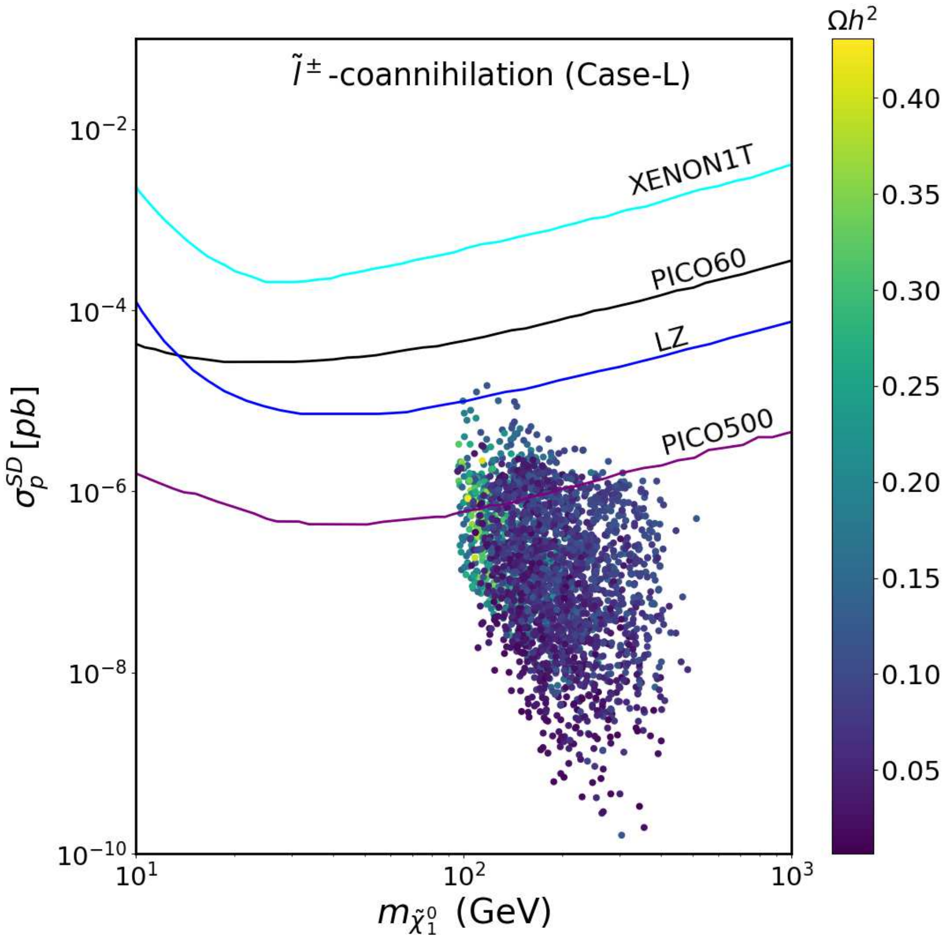
Case-L: results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SI}$ plane:



⇒ large part covered by XENON-nT/LZ

⇒ but can go below even the neutrino floor

Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SD}$ plane: [PRELIMINARY]

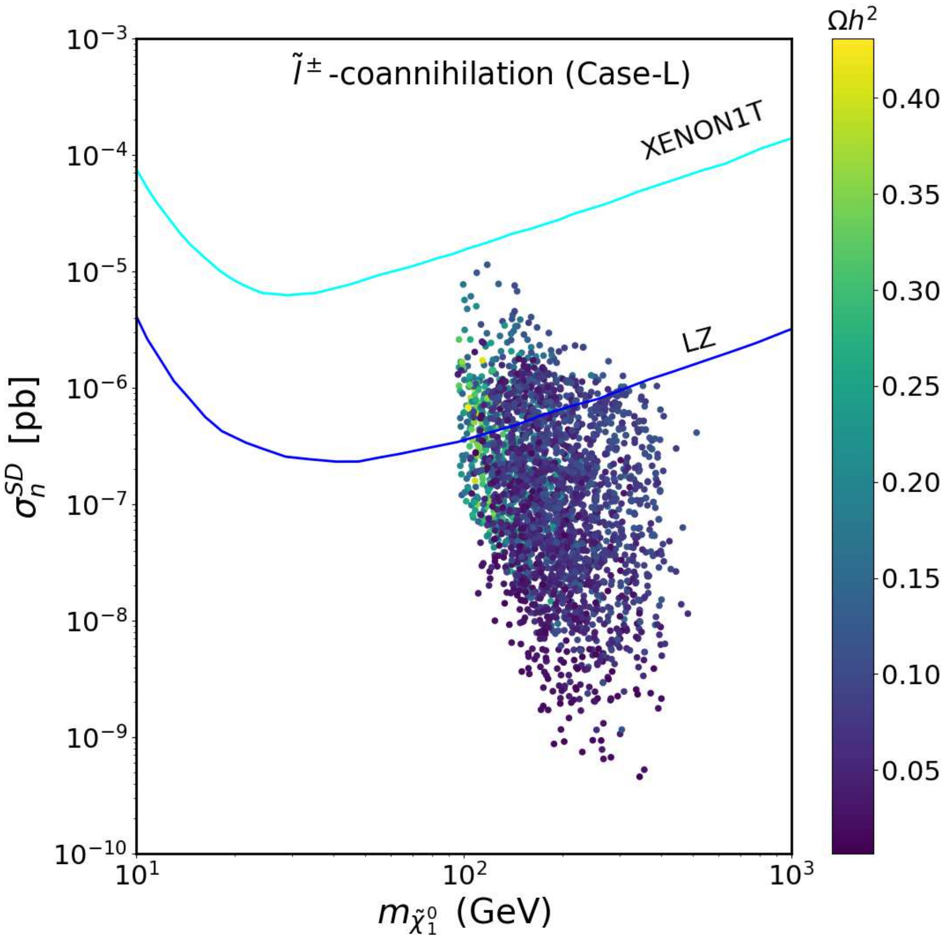


⇒ SD DD experiments have to do better . . .

⇒ no indirect detection limits . . .

Results in the $m_{\tilde{\chi}_1^0}$-σ_n^{SD} plane:

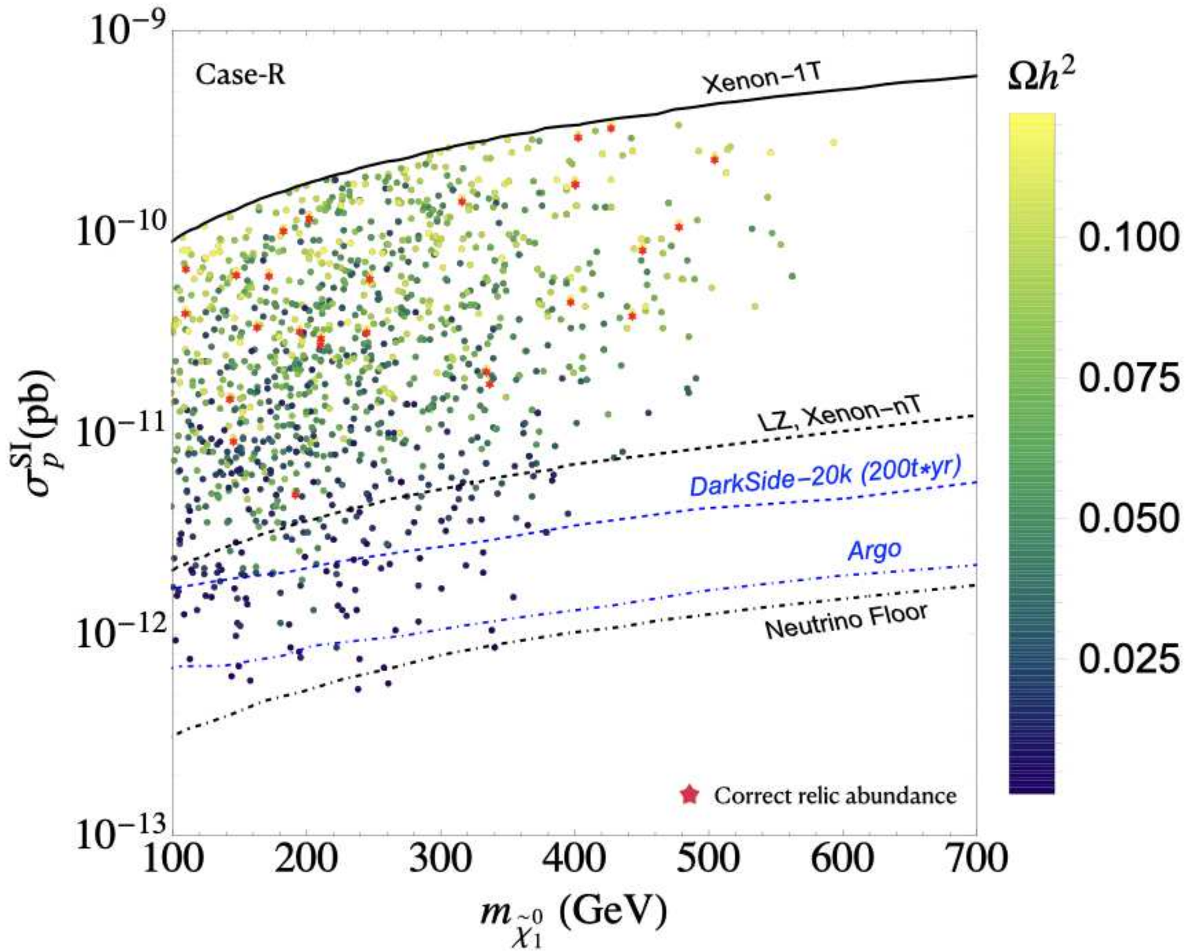
[*PRELIMINARY*]



⇒ SD DD experiments have to do better . . .

⇒ only LZ limits . . .

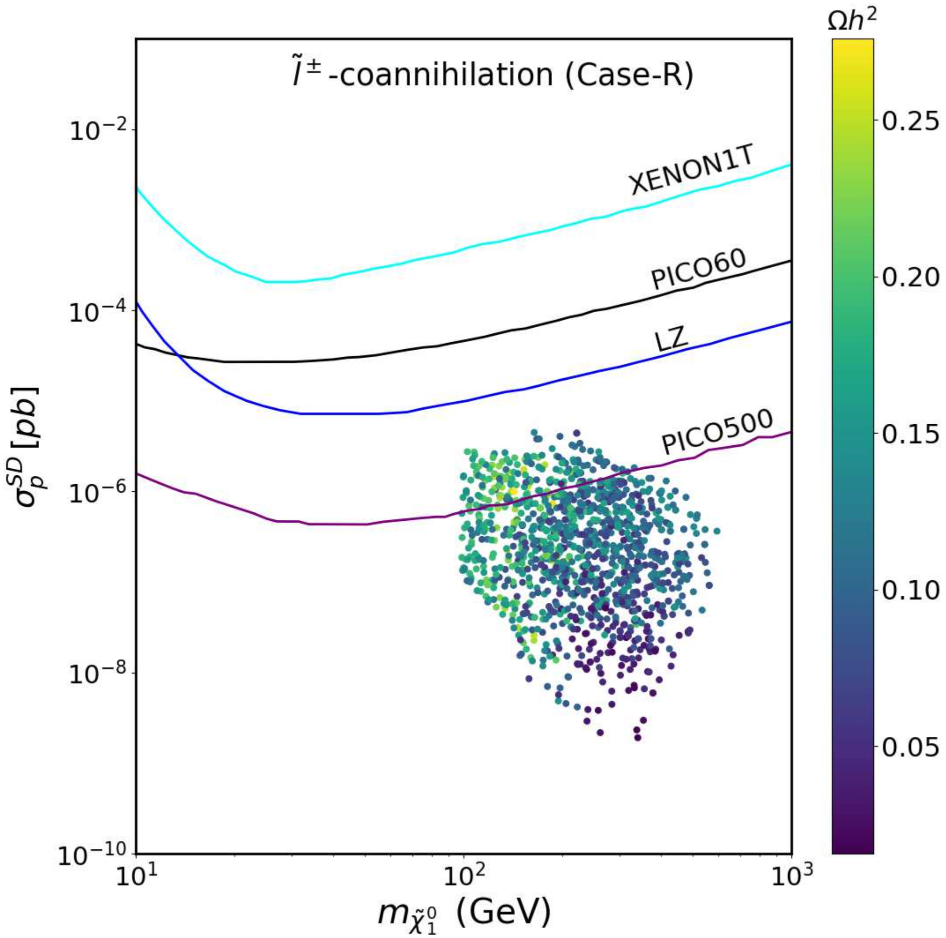
Case-R: results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SI}$ plane:



⇒ large part covered by XENON-nT/LZ

⇒ but can go below even the neutrino floor

Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SD}$ plane: [PRELIMINARY]

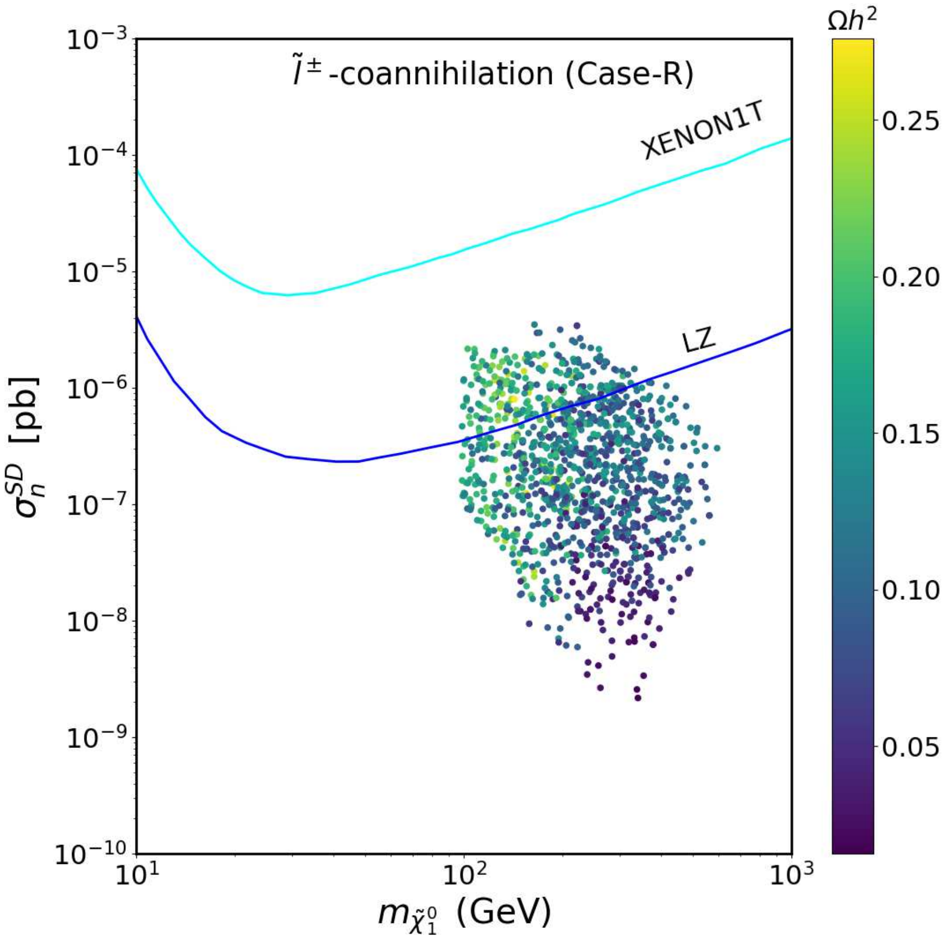


⇒ SD DD experiments have to do better . . .

⇒ no indirect detection limits . . .

Results in the $m_{\tilde{\chi}_1^0}$-σ_n^{SD} plane:

[PRELIMINARY]



⇒ SD DD experiments have to do better . . .

⇒ only LZ limits . . .

D) Higgsino DM

Parameter scan:

$$100 \text{ GeV} \leq \mu \leq 1.2 \text{ TeV} ,$$

$$1.1\mu \leq M_1 \leq 10\mu ,$$

$$1.1M_2 \leq \mu \leq 10\mu ,$$

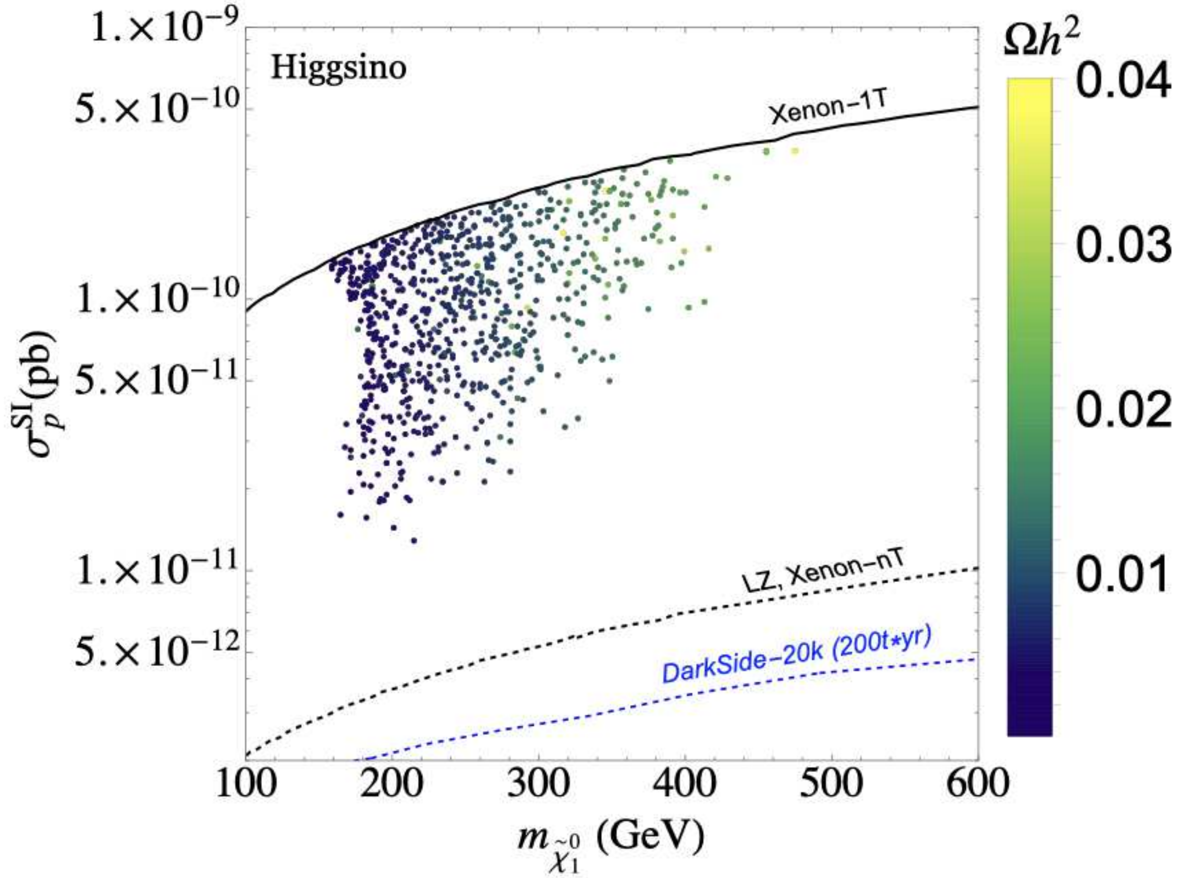
$$5 \leq \tan\beta \leq 60,$$

$$100 \text{ GeV} \leq m_{\tilde{L}}, m_{\tilde{R}} \leq 2 \text{ TeV},$$

$\Rightarrow m_{\tilde{\chi}_1^0} \sim m_{\tilde{\chi}_2^0} \sim m_{\tilde{\chi}_1^\pm} \sim \mu$

Full DM relic density reached only for $m_{\tilde{\chi}_1^0} \sim 1$ TeV
$\Rightarrow$ incompatible with $(g-2)_\mu$
$\Rightarrow m_{\text{(N)LSP}} \lesssim 500$ GeV

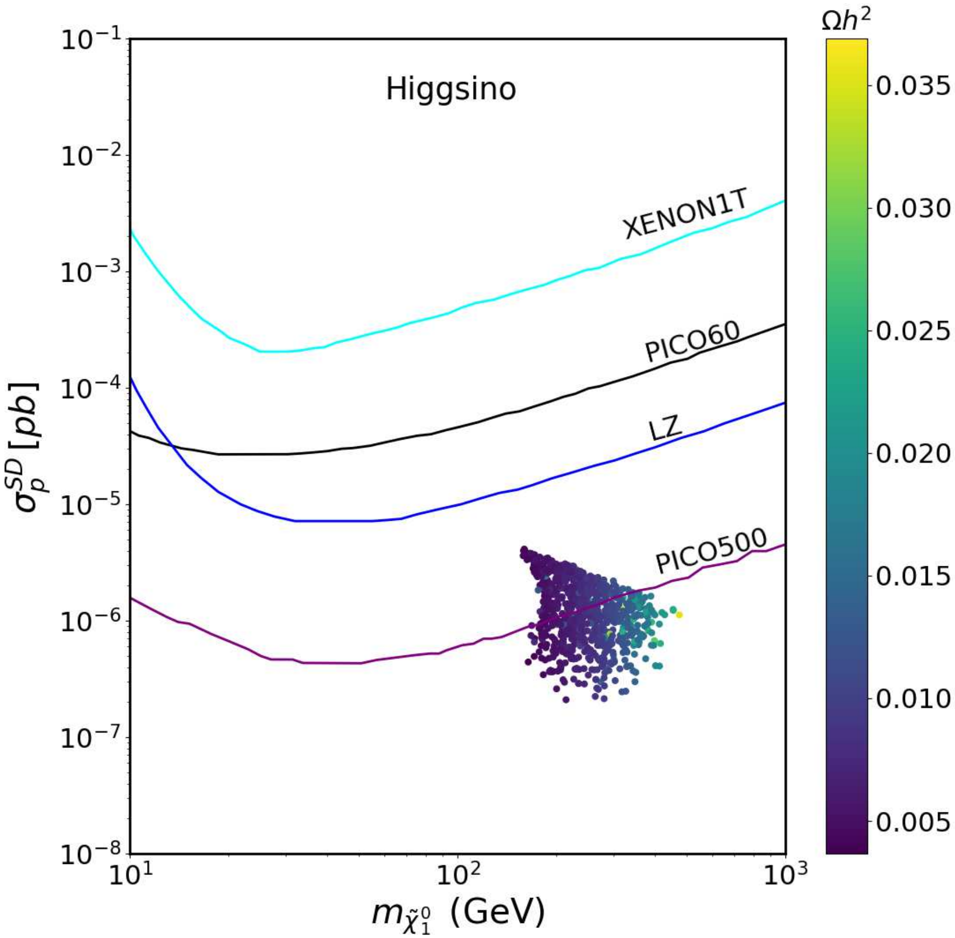
Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SI}$ plane:



⇒ everything covered by XENON-nT/LZ

⇒ Direct Detection experiments cover the full parameter space

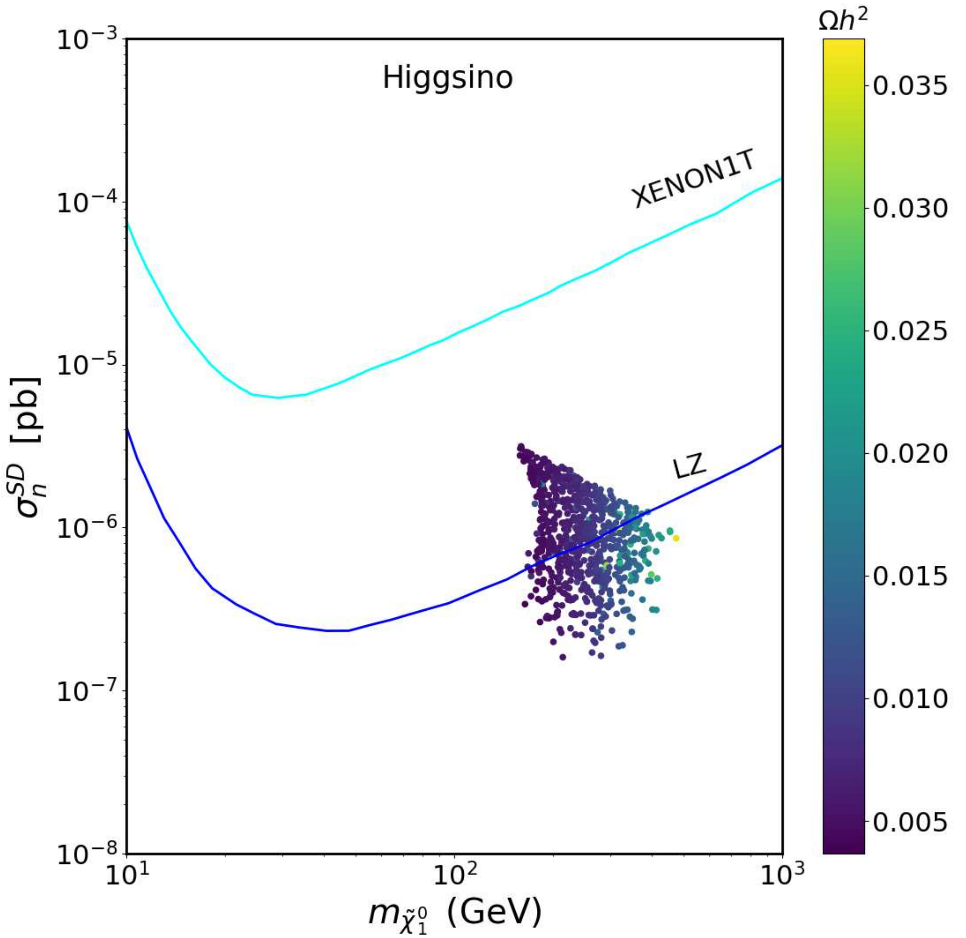
Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SD}$ plane: [*PRELIMINARY*]



$\Rightarrow$ looks better, but SI experiments clearly win . . .

$\Rightarrow$ no indirect detection limits . . .

Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_n^{\rm SD}$ plane: [PRELIMINARY]



⇒ looks better, but SI experiments clearly win . . . ??

⇒ only LZ limits . . . maybe tehre are chances?

E) Wino DM

Parameter scan:

$$100 \text{ GeV} \le M_2 \le 1.5 \text{ TeV} ,$$

$$1.1 M_2 \le M_1 \le 10 M_2 ,$$

$$1.1 M_2 \le \mu \le 10 M_2 ,$$

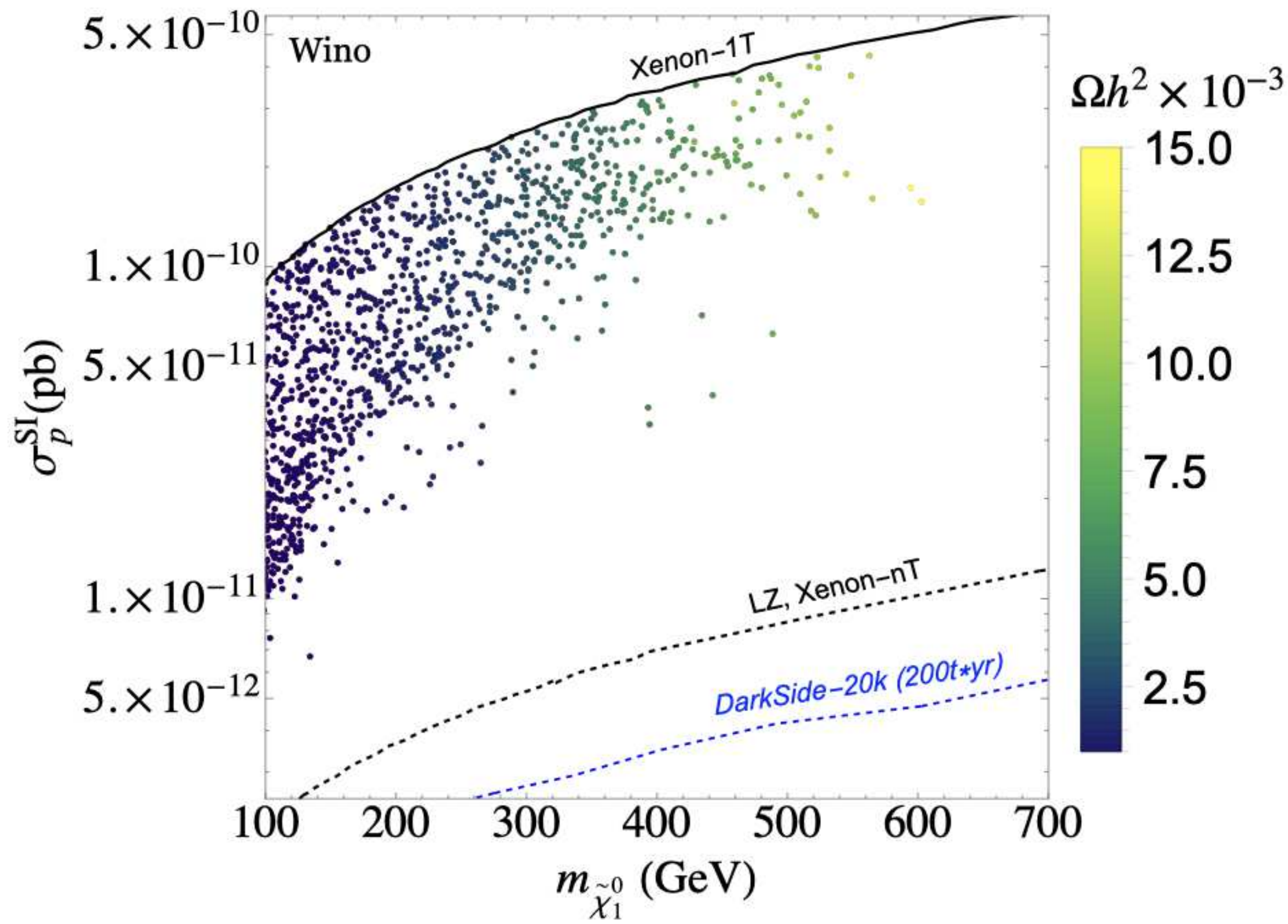
$$5 \le \tan\beta \le 60,$$

$$100 \text{ GeV} \le m_{\tilde{L}}, m_{\tilde{R}} \le 2 \text{ TeV},$$

$\Rightarrow m_{\tilde{\chi}_1^0} \sim m_{\tilde{\chi}_1^\pm} \sim M_2$

Full DM relic density reached only for $m_{\tilde{\chi}_1^0} \sim 3$ TeV
$\Rightarrow$ incompatible with $(g-2)_\mu$
$\Rightarrow m_{\text{(N)LSP}} \lesssim 600$ GeV

Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_p^{\rm SI}$ plane:



⇒ everything covered by XENON-nT/LZ

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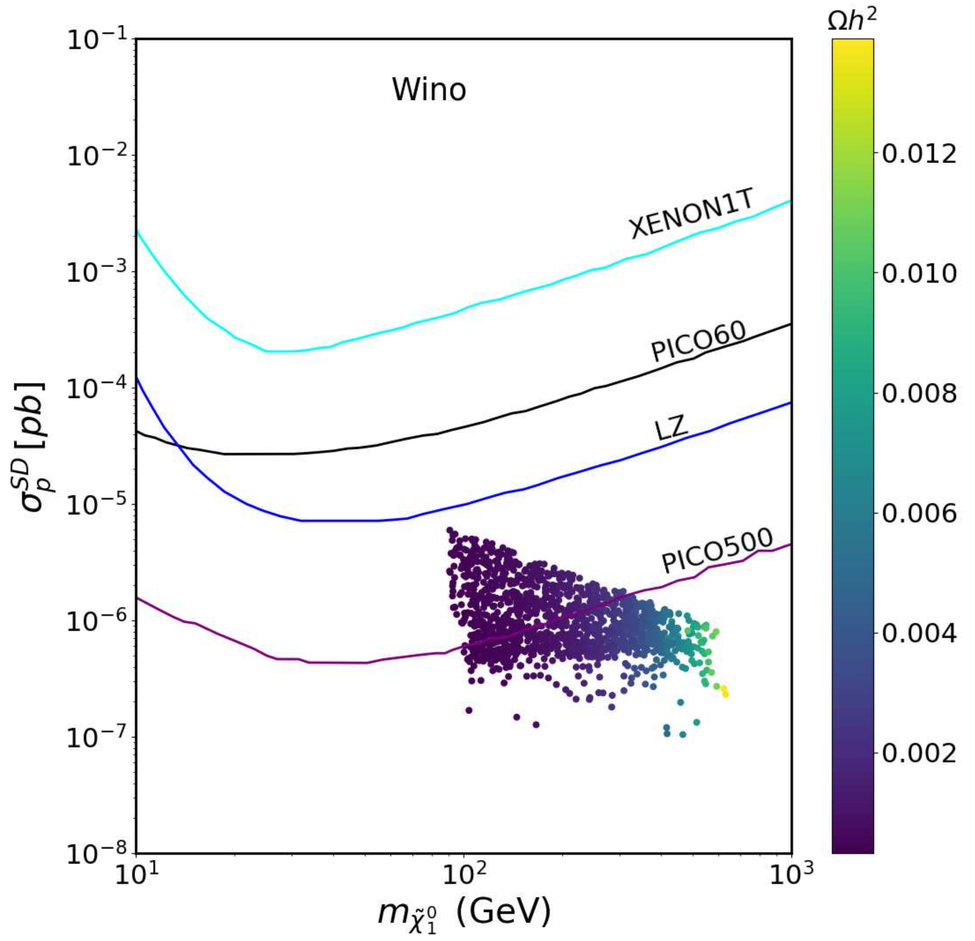
Results in the $m_{\tilde{\chi}_1^0}$-σ_p^{SD} plane:

[*PRELIMINARY*]



⇒ looks better, but SI experiments clearly win . . .

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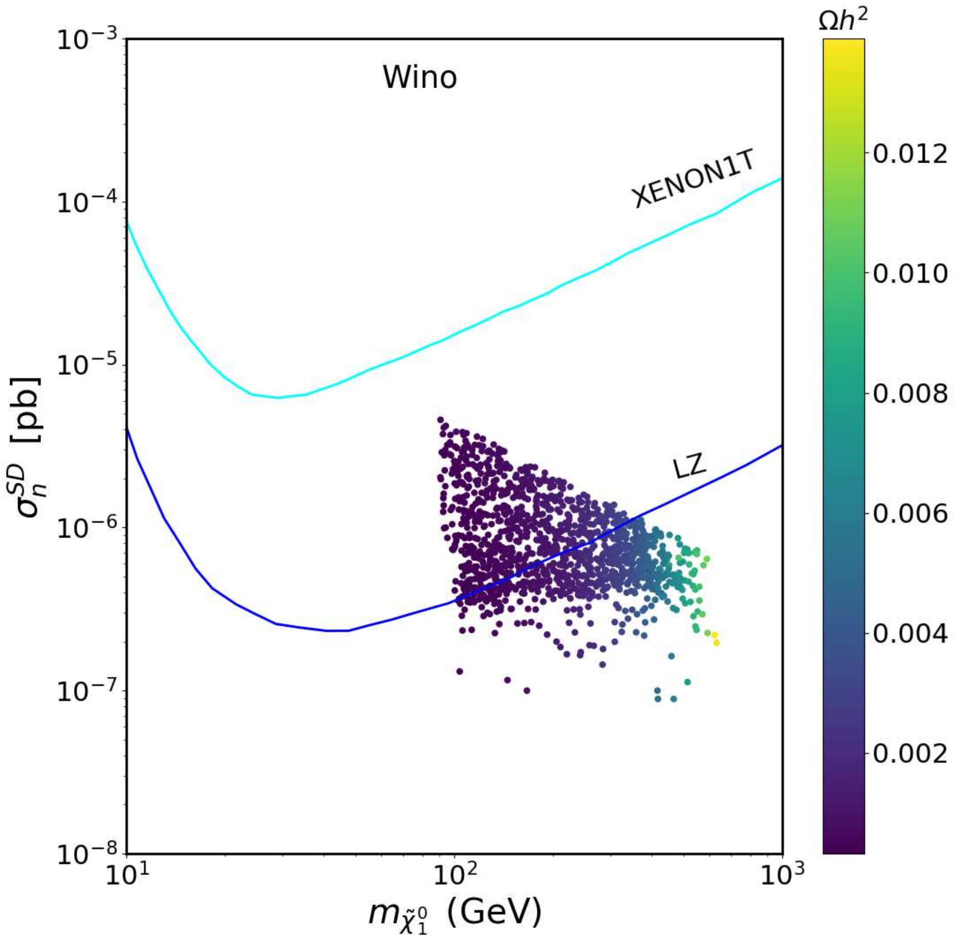
Results in the $m_{\tilde{\chi}_1^0}$-$\sigma_n^{\rm SD}$ plane: [PRELIMINARY]



⇒ looks better, but SI experiments clearly win . . . ??

⇒ only LZ limits . . . maybe tehre are chances?

3. The missing channel

B/C) Bino DM with slepton co-annihilation

Parameter scan:

$$100 \text{ GeV} \le M_1 \le 1 \text{ TeV} ,$$

$$M_1 \le M_2 \le 10 M_1 ,$$

$$1.1 M_1 \le \mu \le 10 M_1,$$

$$5 \le \tan\beta \le 60,$$

Case-L: $M_1 \le m_{\tilde{L}} \le 1.2 M_1,$ $M_1 \le m_{\tilde{R}} \le 10 M_1.$

Case-R: $M_1 \le m_{\tilde{R}} \le 1.2 M_1,$ $M_1 \le m_{\tilde{L}} \le 10 M_1.$

relic DM density can be 100% fulfilled
$\Rightarrow m_{\text{(N)LSP}} \lesssim 550(600)$ GeV

$\Rightarrow$ funny that nobody ever complained here . . .

Potential problem:

Slepton co-annihilation directly linked to $(g-2)_\mu$

$\Rightarrow$ slepton mass parameters chosen identical for all three generations

$\Rightarrow$ what happens if stau co-annihilation is chosen,
and no directly link to smuons contributing to $(g-2)_\mu$ is made ??

Parameter scan for stau co-annihilation:

$$100 \text{ GeV} \le M_1 \le 1 \text{ TeV} \,,$$

$$1.1 M_1 \le M_2 \le 10 M_1 \,,$$

$$1.1 M_1 \le \mu \le 10 M_1,$$

$$5 \le \tan\beta \le 60,$$

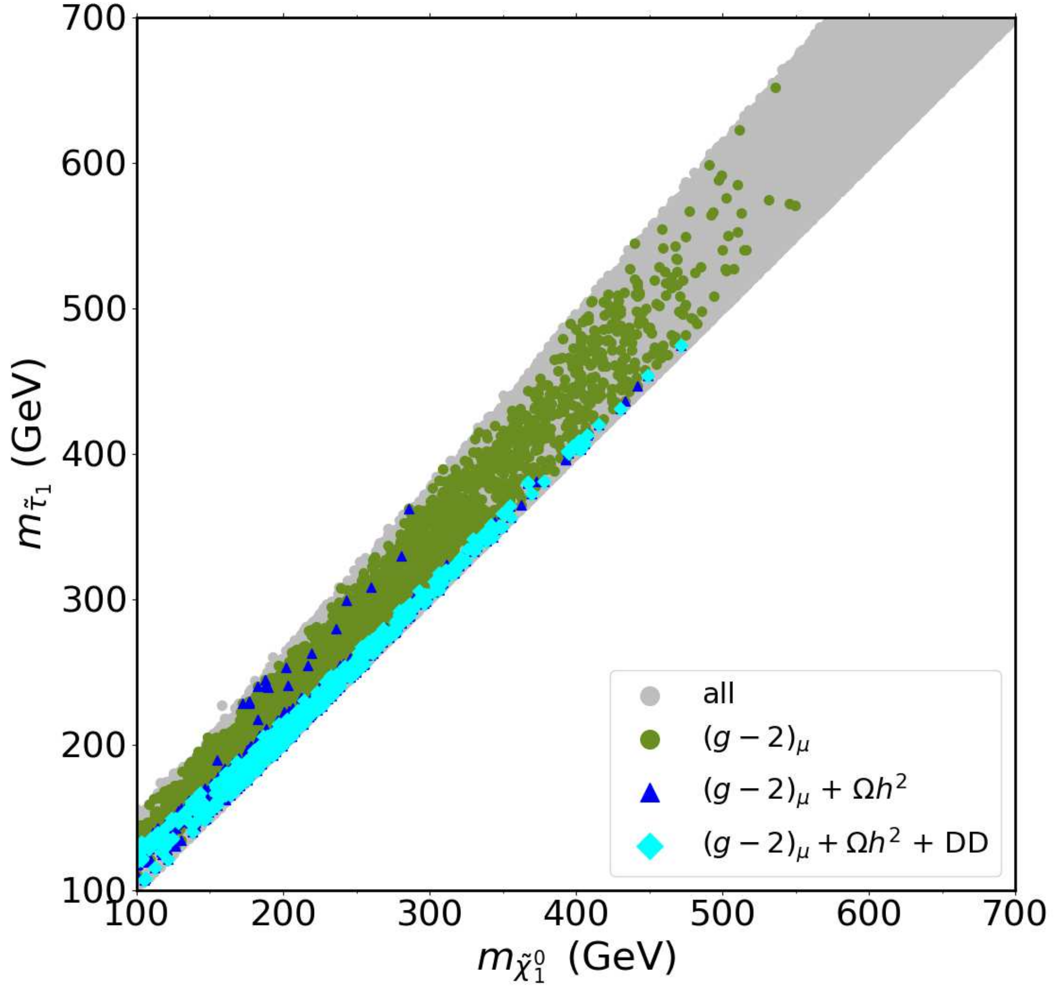
$$1.1 M_1 \le m_{\tilde{L}}, m_{\tilde{R}} \le 10 M_1,$$

$$\text{Case-L:} \quad M_1 \le m_{\tilde{\tau}_L} \le 1.2 M_1, \quad M_1 \le m_{\tilde{\tau}_R} \le 10 M_1,$$

$$[\text{Case-R:} \quad M_1 \le m_{\tilde{\tau}_R} \le 1.2 M_1, \quad M_1 \le m_{\tilde{\tau}_L} \le 10 M_1].$$

Stau co-annihilation case-L: [PRELIMINARY]

(no LHC limits applied yet)

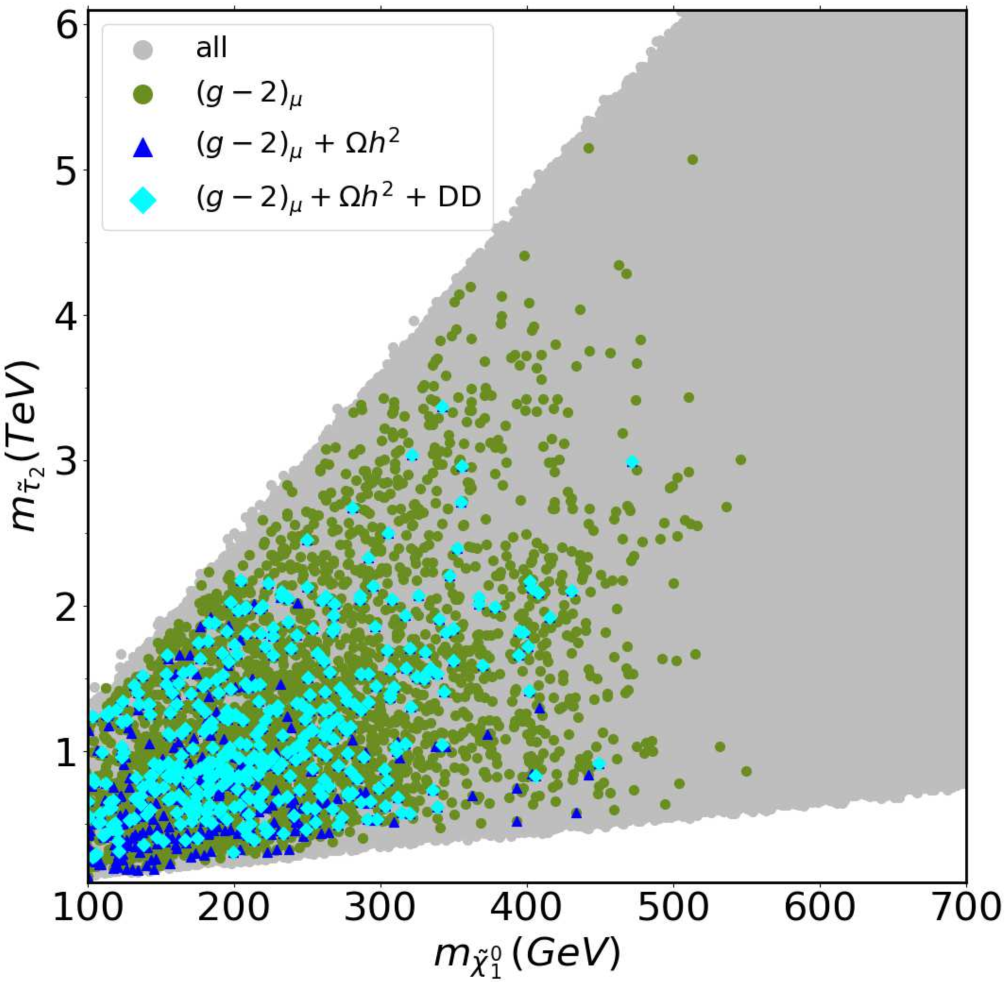


$\Rightarrow m_{\text{(N)LSP}} \lesssim 500$ GeV

Stau co-annihilation case-L:

[PRELIMINARY]

(no LHC limits applied yet)

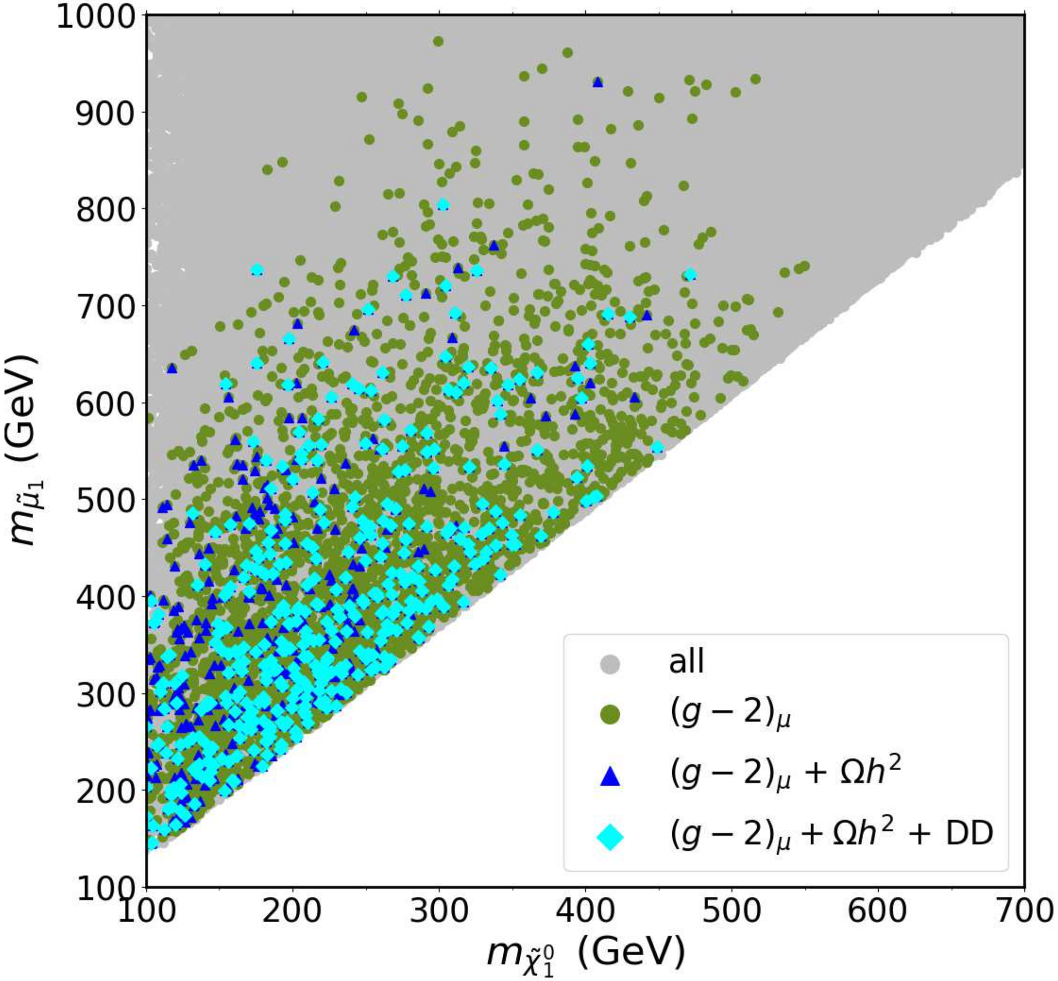


$\Rightarrow m_{\tilde{\tau}_2}$ nearly unconstrainted

Stau co-annihilation case-L:

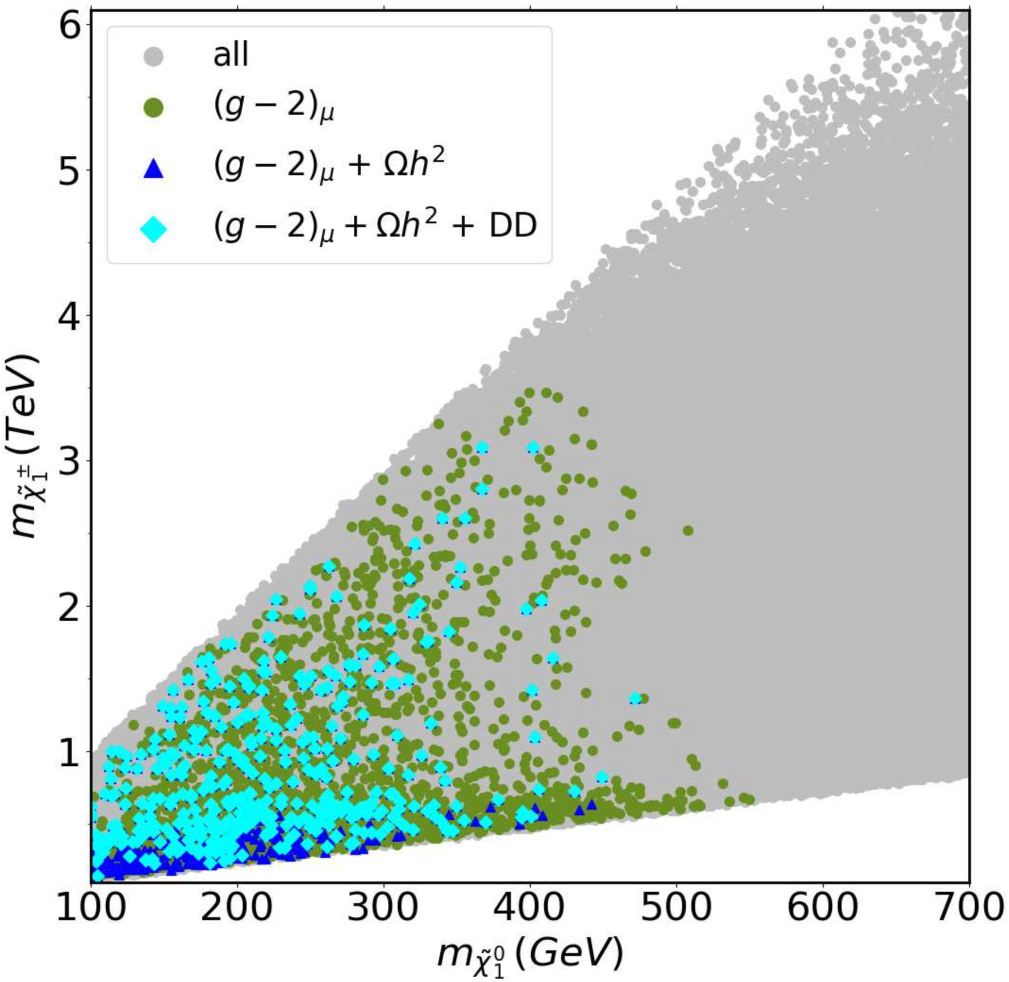
[PRELIMINARY]

(no LHC limits applied yet)



$\Rightarrow m_{\tilde{\mu}_1} \lesssim 800$ GeV

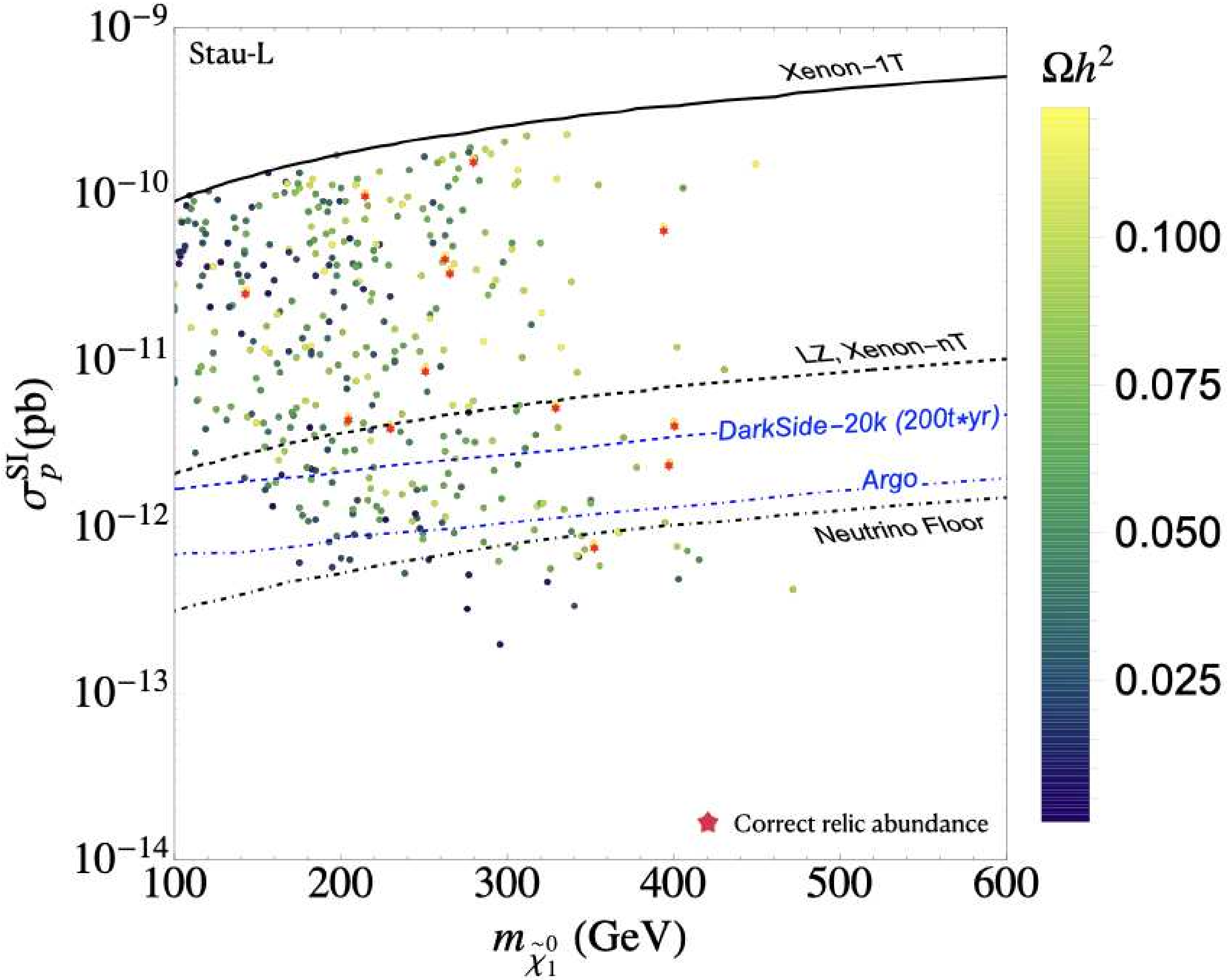
(no LHC limits applied yet)



$\Rightarrow m_{\tilde{\chi}_1^\pm}$ nearly unconstrainted

Stau co-annihilation case-L:

(no LHC limits applied yet)

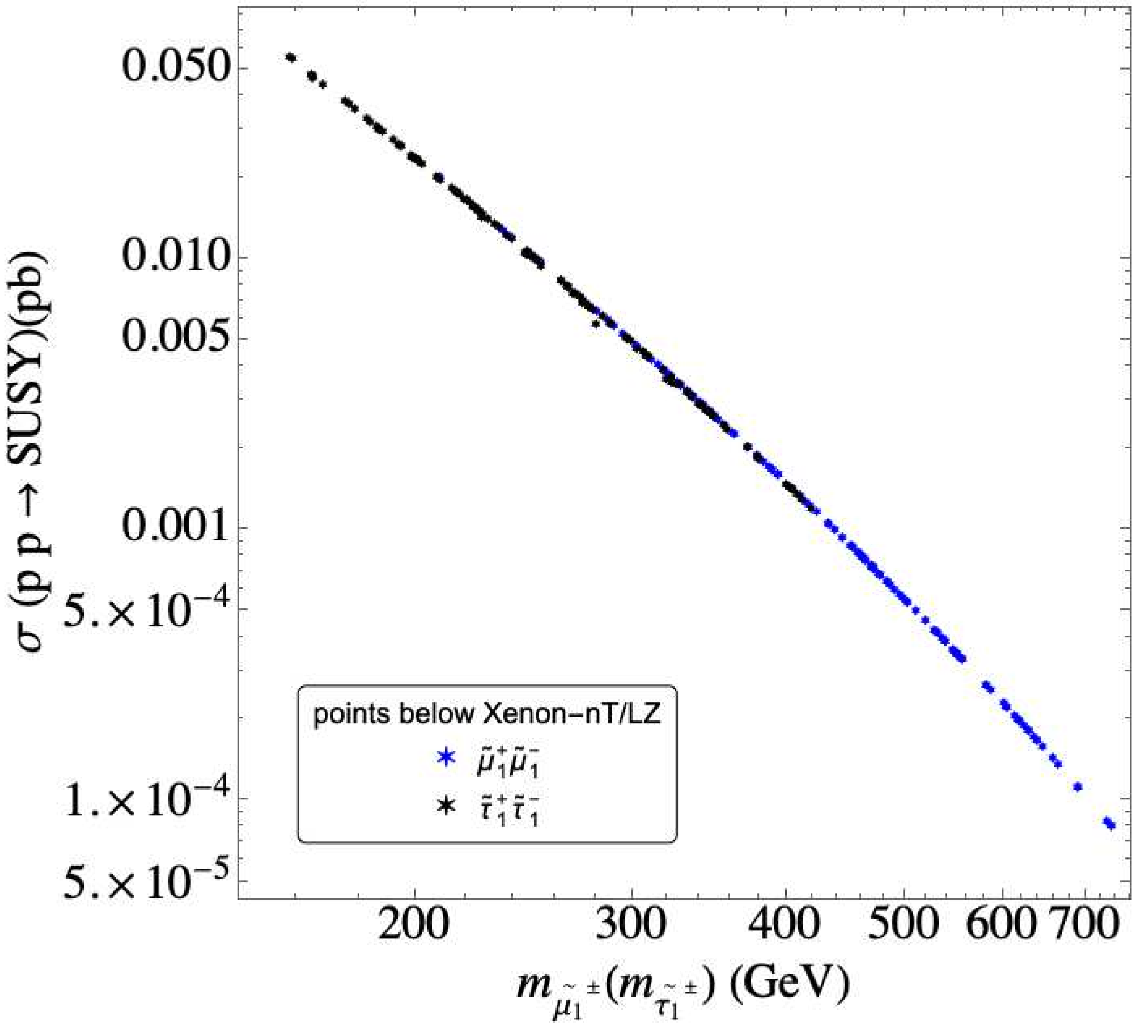


⇒ large part covered by XENON-nT/LZ

⇒ but can go below even the neutrino floor

Stau co-annihilation case-L: DD/HL-LHC complementarity: [*PRELIMINARY*]

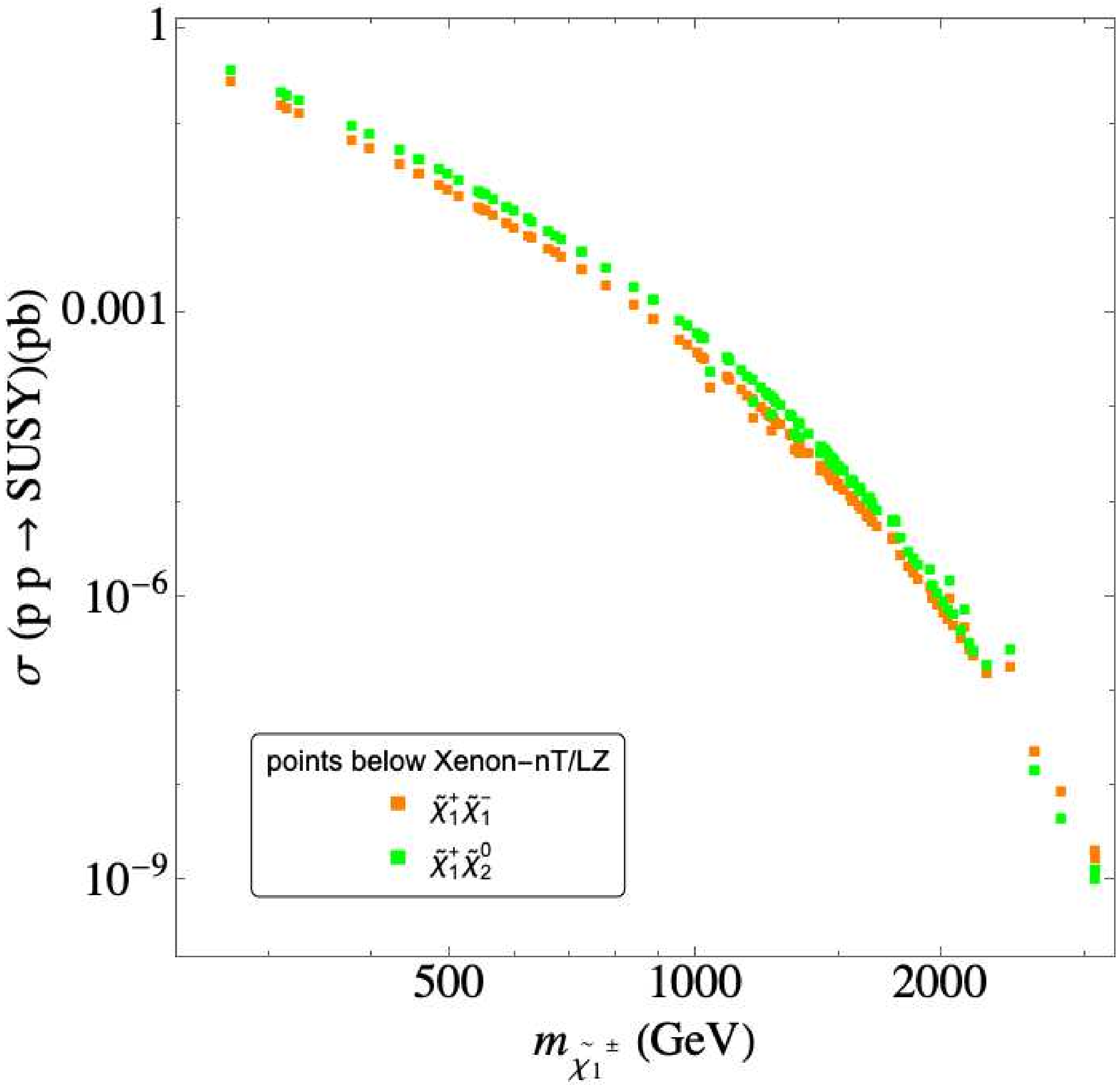
points below LZ limit: (no LHC limits applied yet)



⇒ in the kinematic reach, but compressed spectra! ⇒ ILC/CLIC?

Stau co-annihilation case-L: DD/HL-LHC complementarity: [*PRELIMINARY*]

points below LZ limit: (no LHC limits applied yet)



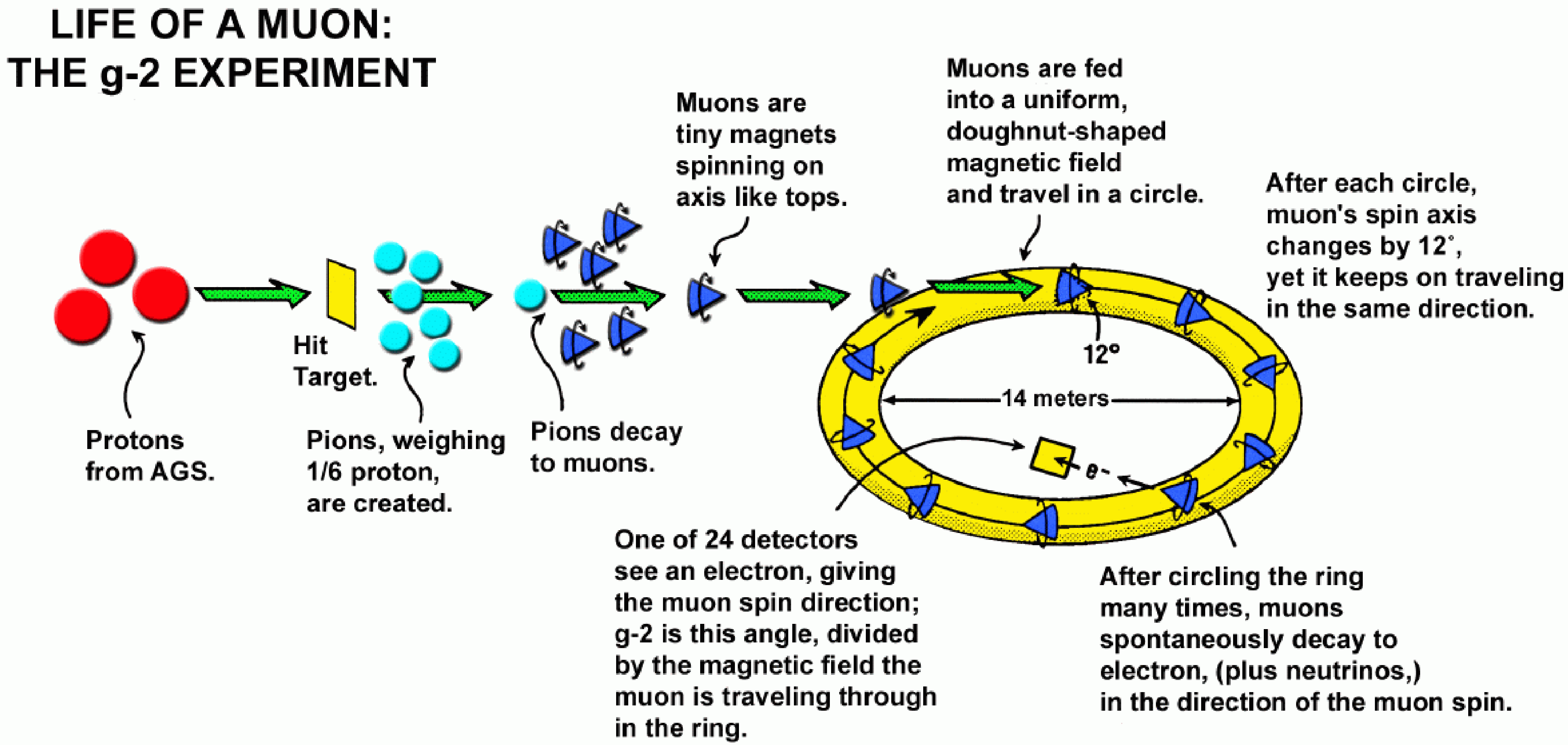
⇒ too low cross sections at the HL-LHC . . .

4. Conclusinos

- new $(g-2)_\mu$ result confirms old result and deviation from the SM
  $(g-2)_\mu$ is real $\Rightarrow$ (relatively) light EW particles $\Rightarrow$ focus on MSSM
- $\Rightarrow$ scan the EW sector of the MSSM with all constraints:
  $(g-2)_\mu$, DM relic density, DM DD, LHC EW searches
  $\Rightarrow$ upper limits on EW masses $\Rightarrow$ evaluate prospects for DD/(HL-)LHC
- A) bino/wino DM with chargino coann. (DM full)
  B/C) bino DM with slepton coann. (DM full)
  D) higgsino DM $m_{\tilde{\chi}_1^0} \sim m_{\tilde{\chi}_2^0} \sim m_{\tilde{\chi}_1^\pm} \sim \mu$ (DM upper limit)
  E) wino DM $m_{\tilde{\chi}_1^0} \sim m_{\tilde{\chi}_1^\pm} \sim M_2$ (DM upper limit)
  $\Rightarrow$ clear upper limits, $m_{\text{(N)LSP}} \lesssim 600$ GeV confirmed
- Direct Detection prospects:
  – bino/wino or bino DM σ_p^{SI} below XENON-nT/LZ and even ν floor
  – NEW: σ_p^{SD}: never competitive with σ_p^{SI} (some data missing)
- The missing scenario: stau co-annihilation: (so far case-L)
  $\Rightarrow m_{\text{(N)LSP}} \lesssim 500$ GeV, $m_{\tilde{\mu}_1} \lesssim 800$ GeV
  $\Rightarrow \sigma_p^{\text{SI}}$ below XENON-nT/LZ and even neutrino floor
  $\Rightarrow$ HL-LHC prospects unclear (compressed spectra) $\Rightarrow$ ILC/CLIC?


Further Questions?

The $(g-2)_\mu$ experiment:

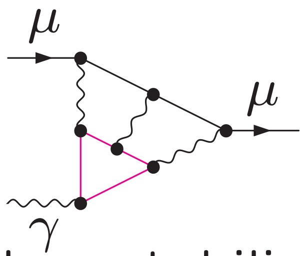


Coupling of muon to magnetic field : $\mu - \mu - \gamma$ coupling

$$\bar{u}(p') \left[\gamma^\mu F_1(q^2) + \frac{i}{2m_\mu} \sigma^{\mu\nu} q_\nu F_2(q^2) \right] u(p) A_\mu \qquad F_2(0) = a_\mu$$

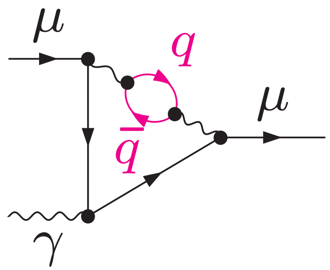
Theory of $(g-2)_\mu$:

– the light-by-light contribution:



2002: sign error discovered; since then stabilized
2021: confirmed by LQCD

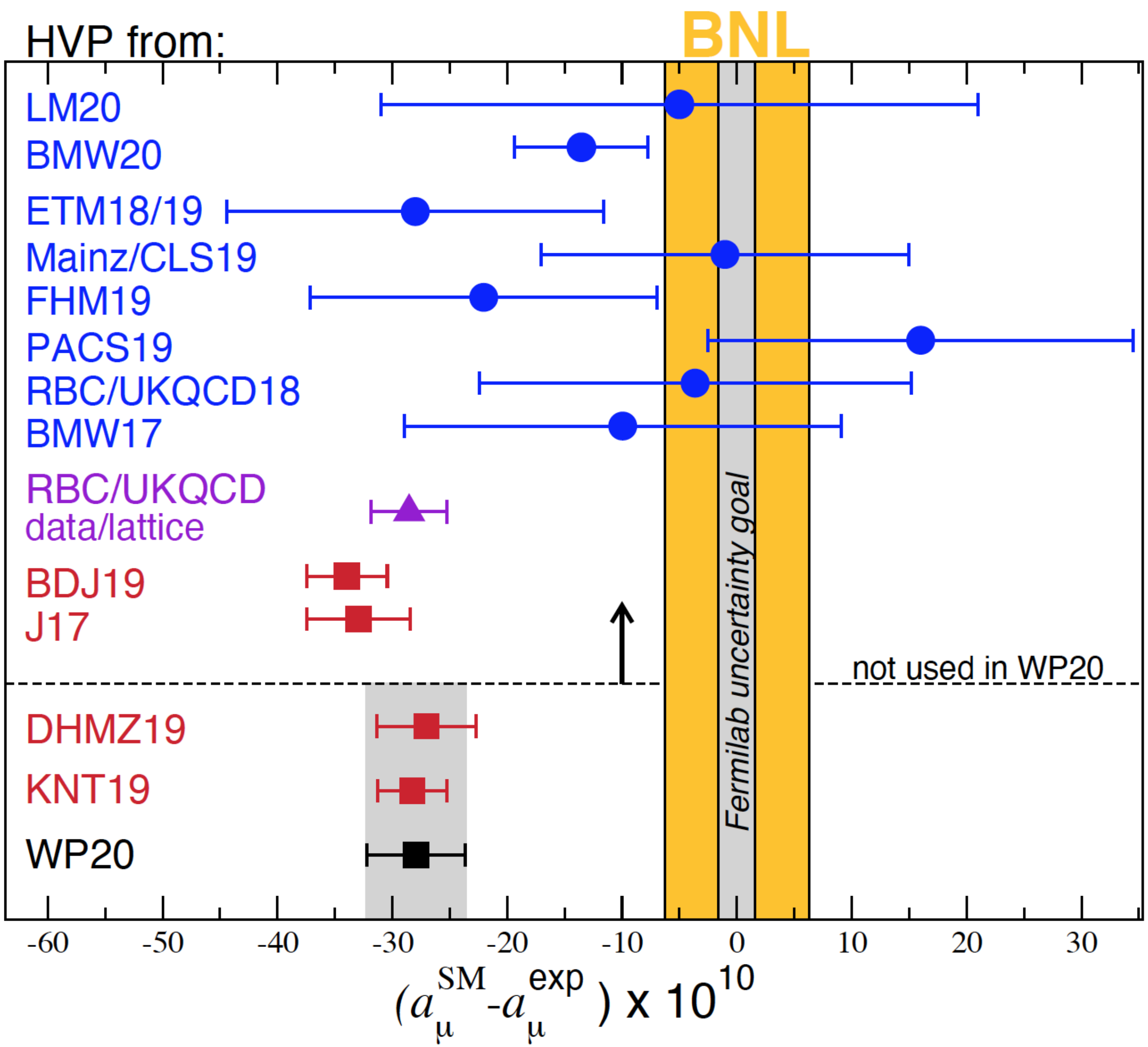
– the hadronic vacuum contribution:



'direct' e^+e^- data:
from CMD-II, SND, KLOE, BaBar (radiative return)
$\Rightarrow$ agree relarively well (also with old e^+e^- data)
$\Rightarrow$ tension with LQCD results

τ data:
tended to be closer to experimental result
inclusion of γ-ρ mixing: agreement with e^+e^- [F. Jegerlehner, R. Szafron '10]
$\Rightarrow$ not used anymore

HVP summary:



⇒ BMW20: difference to experimental data $\sim 1.5\,\sigma$

LHC searches: (as given for Simplified Model Spectra (SMS))

Decay via sleptons (3l)

$$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to (\tilde{l}^\pm \nu)(\tilde{l}^+ l^-) \to 3l + \not{E}_T \ ,$$
$$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to (l^\pm \tilde{\nu})(\tilde{l}^+ l^-) \to 3l + \not{E}_T \qquad (5)$$

Decay via sleptons (2l)

$$\tilde{\chi}_1^+ \tilde{\chi}_1^- \to (\tilde{l}^+ \nu)(\tilde{l}^- \nu) \to 2l + \not{E}_T \ ,$$
$$\tilde{\chi}_1^+ \tilde{\chi}_1^- \to (l^+ \tilde{\nu})(l^- \tilde{\nu}) \to 2l + \not{E}_T \qquad (6)$$

Decay via gauge bosons

$$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to (W \tilde{\chi}_1^0)(Z \tilde{\chi}_1^0) \to 3l + \not{E}_T \ , \qquad (7a)$$
$$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to (W \tilde{\chi}_1^0)(Z \tilde{\chi}_1^0) \to 2l + \text{jets} + \not{E}_T \ , \qquad (7b)$$
$$\tilde{\chi}_1^+ \tilde{\chi}_1^- \to (W^+ \tilde{\chi}_1^0)(W^- \tilde{\chi}_1^0) \to 2l + \not{E}_T \qquad (8)$$

Decay via Higgs bosons

$$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to (W \tilde{\chi}_1^0)(h \tilde{\chi}_1^0) \to l + b\bar{b} + \not{E}_T \qquad (9)$$

$\tilde{l}$-pair production (2l)

$$\tilde{l}^+ \tilde{l}^- \to (l^+ \tilde{\chi}_1^0)(l^- \tilde{\chi}_1^0) \to 2l + \not{E}_T \qquad (10)$$

Compressed spectra

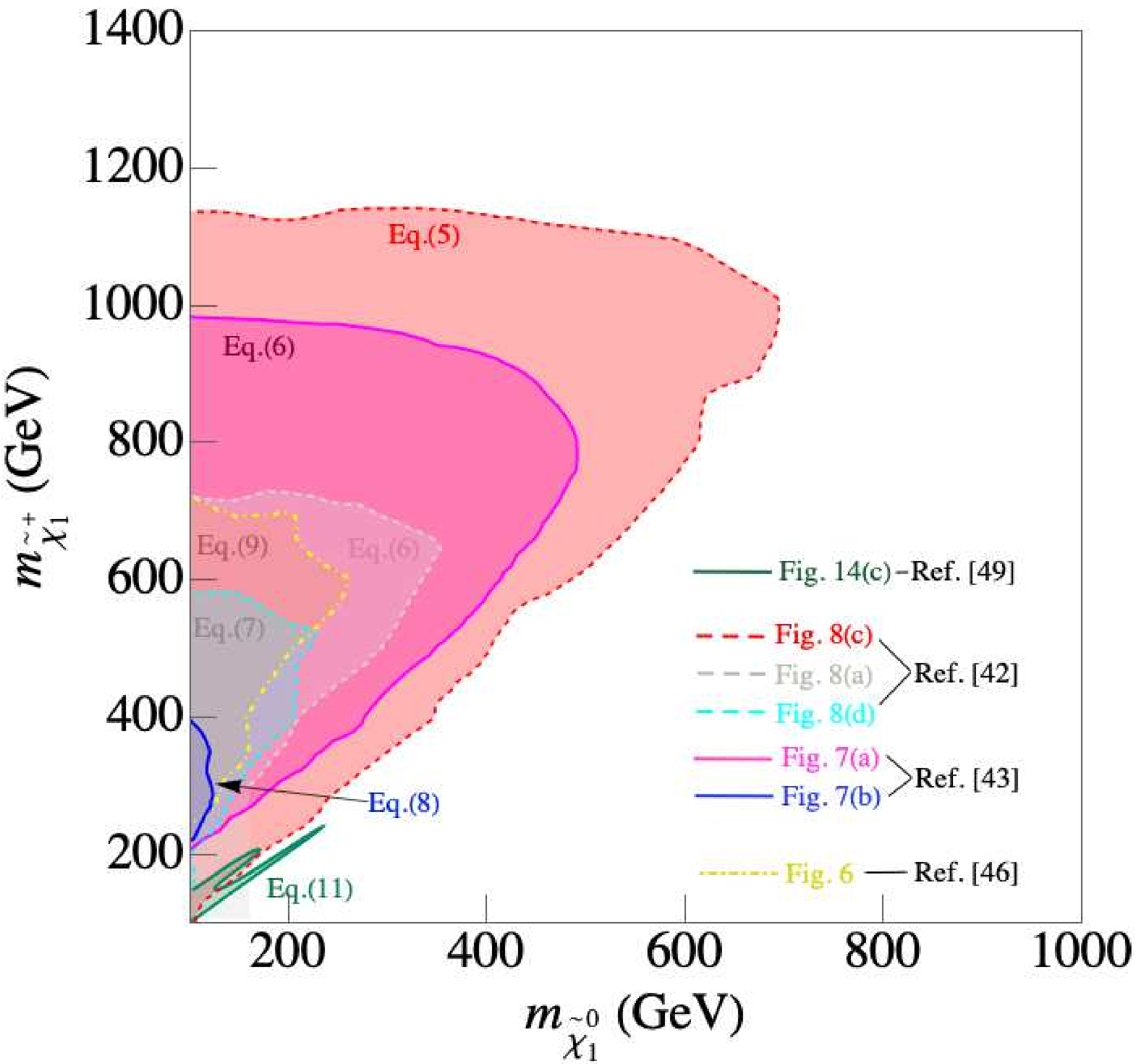
$$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to (W^* \tilde{\chi}_1^0)(Z^* \tilde{\chi}_1^0) \to 2l + \not{E}_T \; + \mathrm{ISR} \,, \qquad (11)$$
$$\tilde{l}^+ \tilde{l}^- \to (l^+ \tilde{\chi}_1^0)(l^- \tilde{\chi}_1^0) \to 2l + \not{E}_T \; + \mathrm{ISR} \qquad (12)$$

Searches involving Staus

⇒ all newly included into CheckMate *[M.C & I.S.]*

Exception: compressed spectra ⇒ direct application

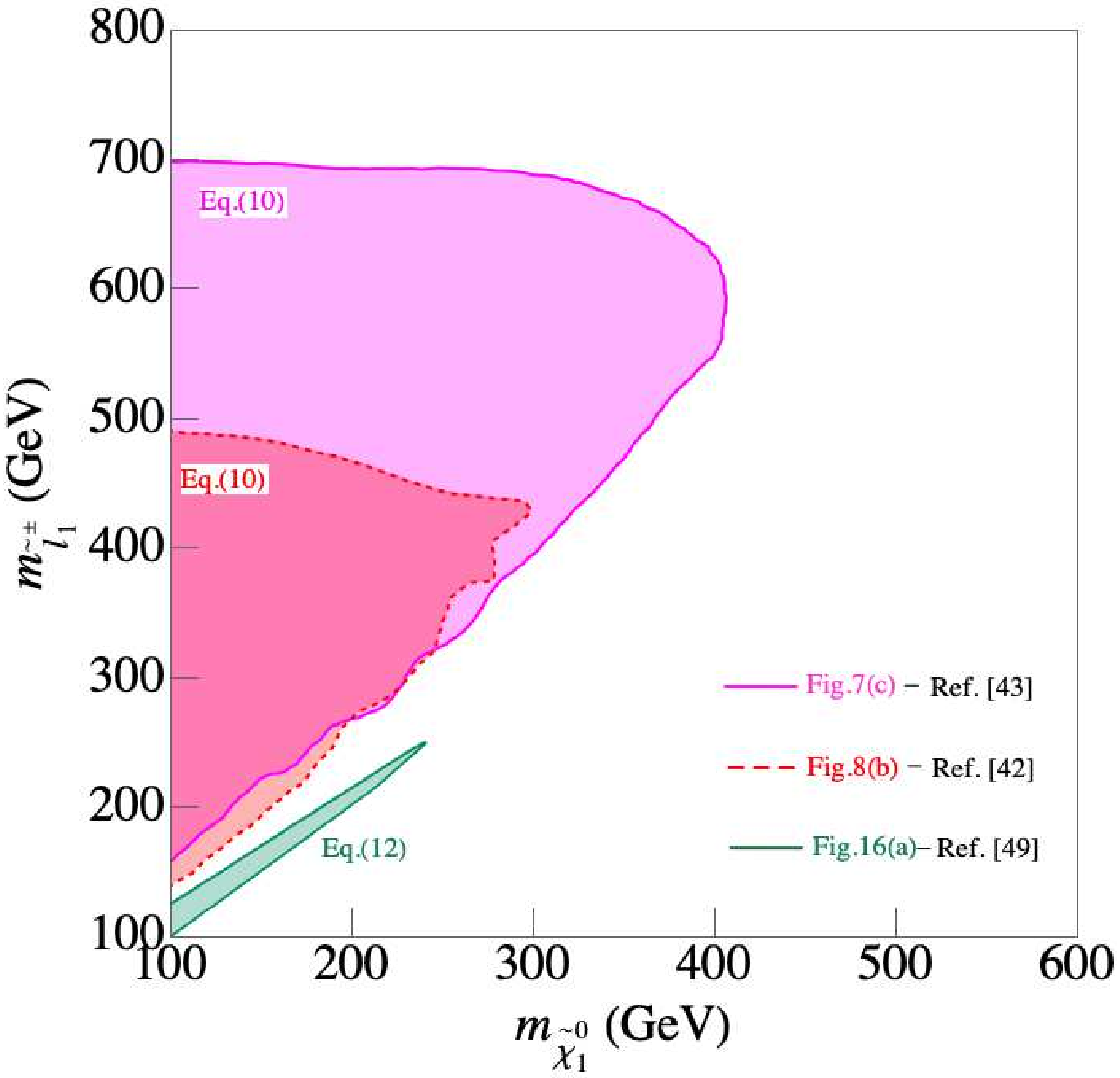
LHC exclusion bounds (I) (as given for Simplified Model Spectra (SMS))



⇒ all newly included into CheckMate [*M.C & I.S.*]

Exception: compressed spectra ⇒ direct application

LHC exclusion bounds (II) (as given for Simplified Model Spectra (SMS))

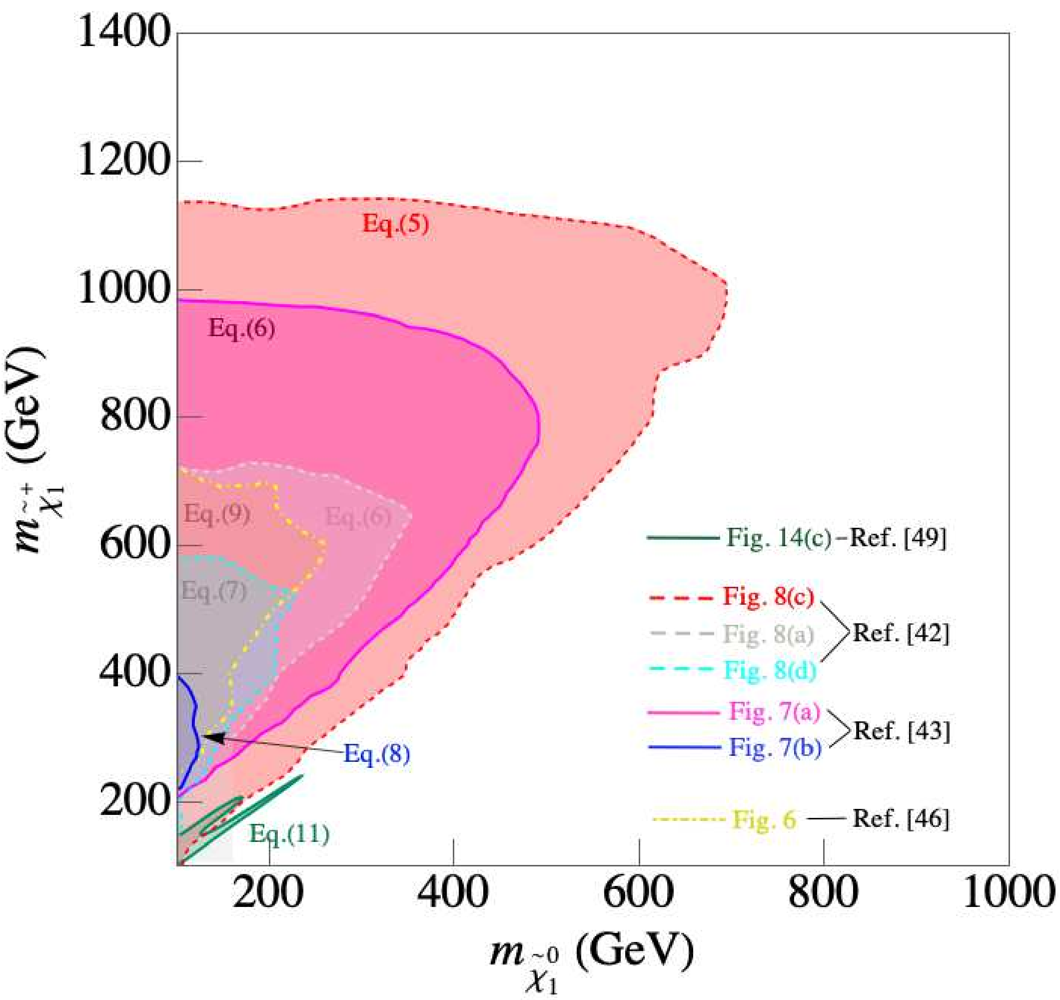


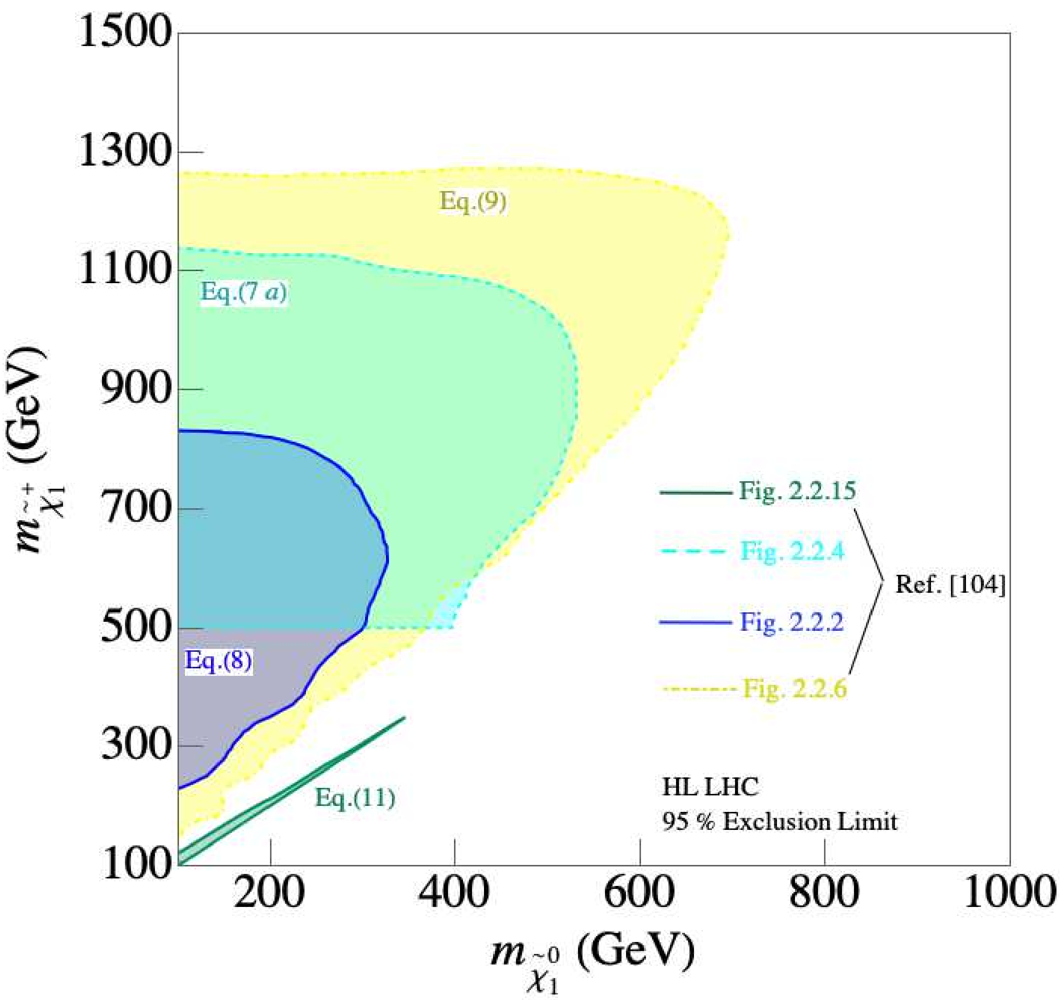
⇒ all newly included into CheckMate *[M.C & I.S.]*

Exception: compressed spectra ⇒ direct application

LHC exclusion bounds vs. HL-LHC exclusion bounds

not all channels available [*YR18*]

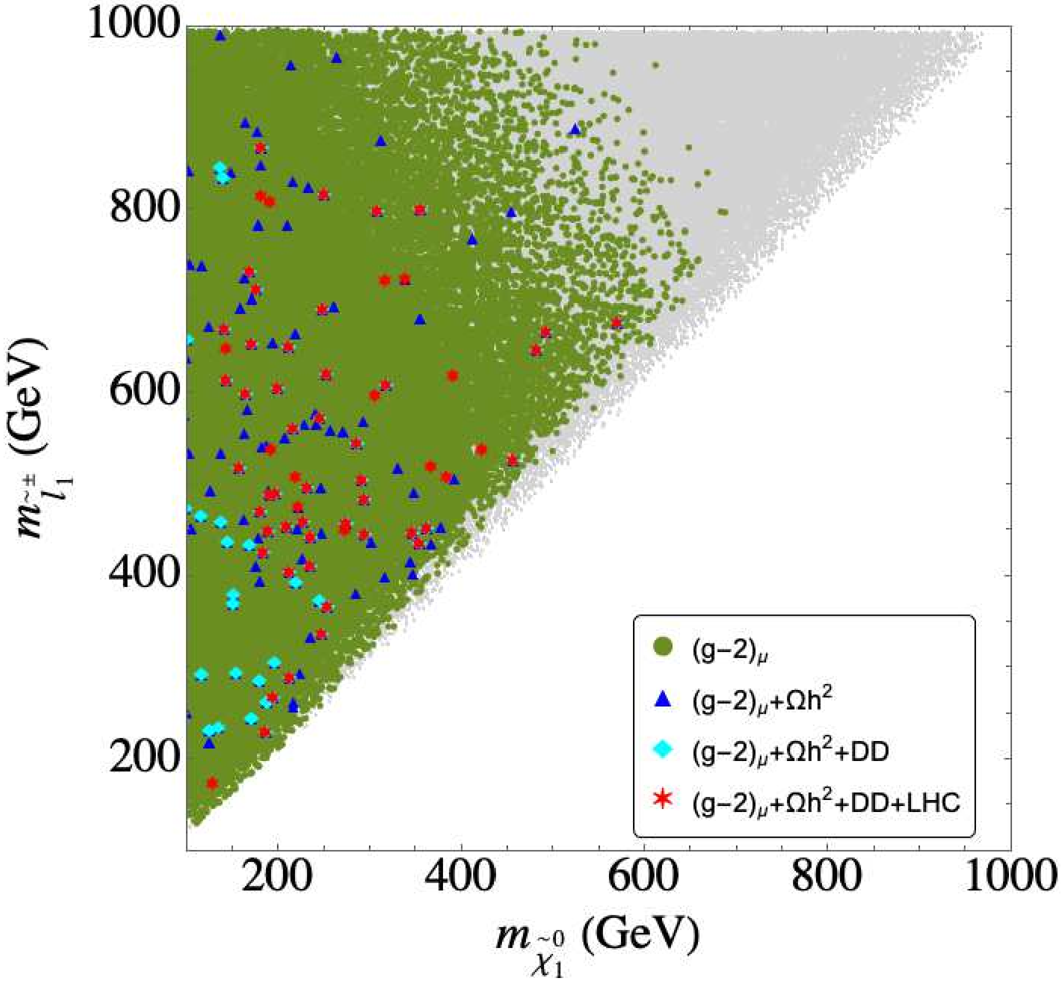




⇒ exclusion reach can be important

⇒ no CheckMate inclusion available . . .

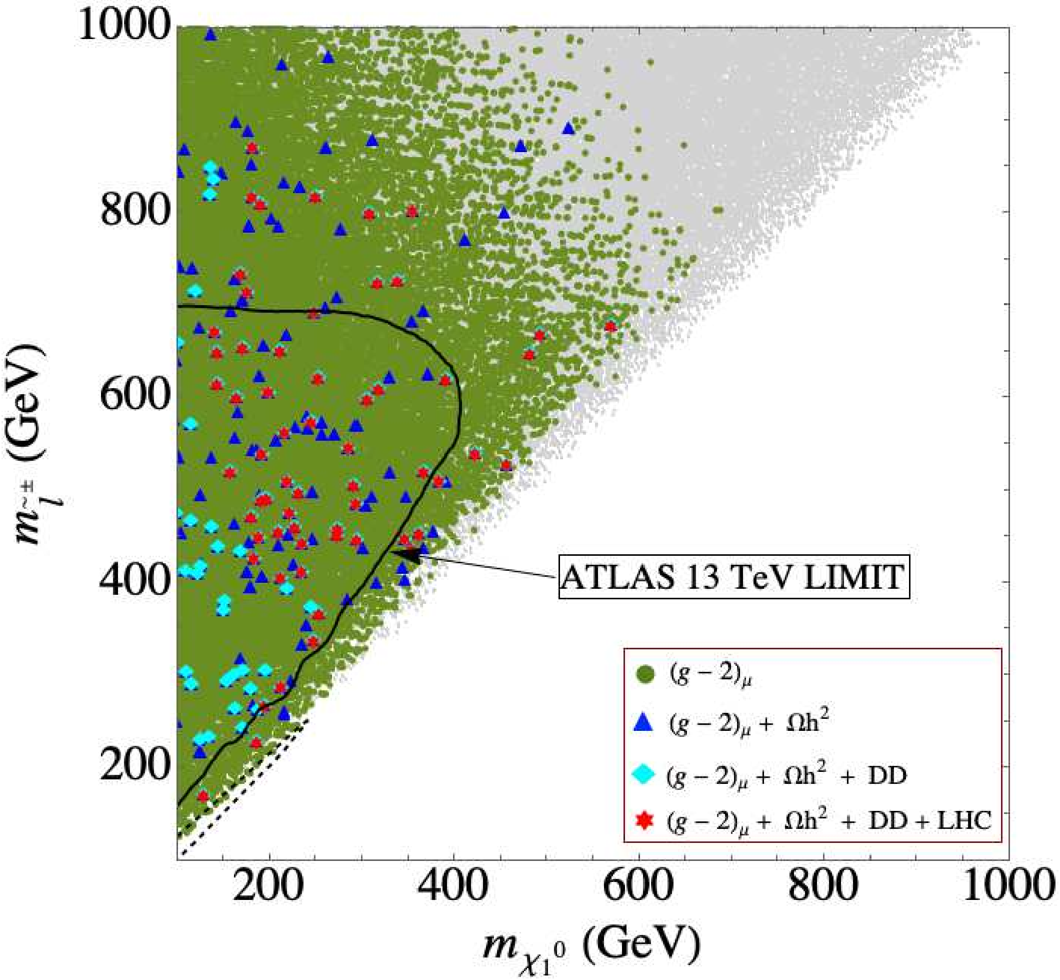
new $(g-2)_\mu$



$\Rightarrow$ important: $\tilde{l}$-pair production searches (10)

Example I: $\tilde{\chi}_1^{\pm}$-coannihilation: $m_{\tilde{\chi}_1^0}$-$m_{\tilde{l}_1}$ plane:

old $(g-2)_\mu$

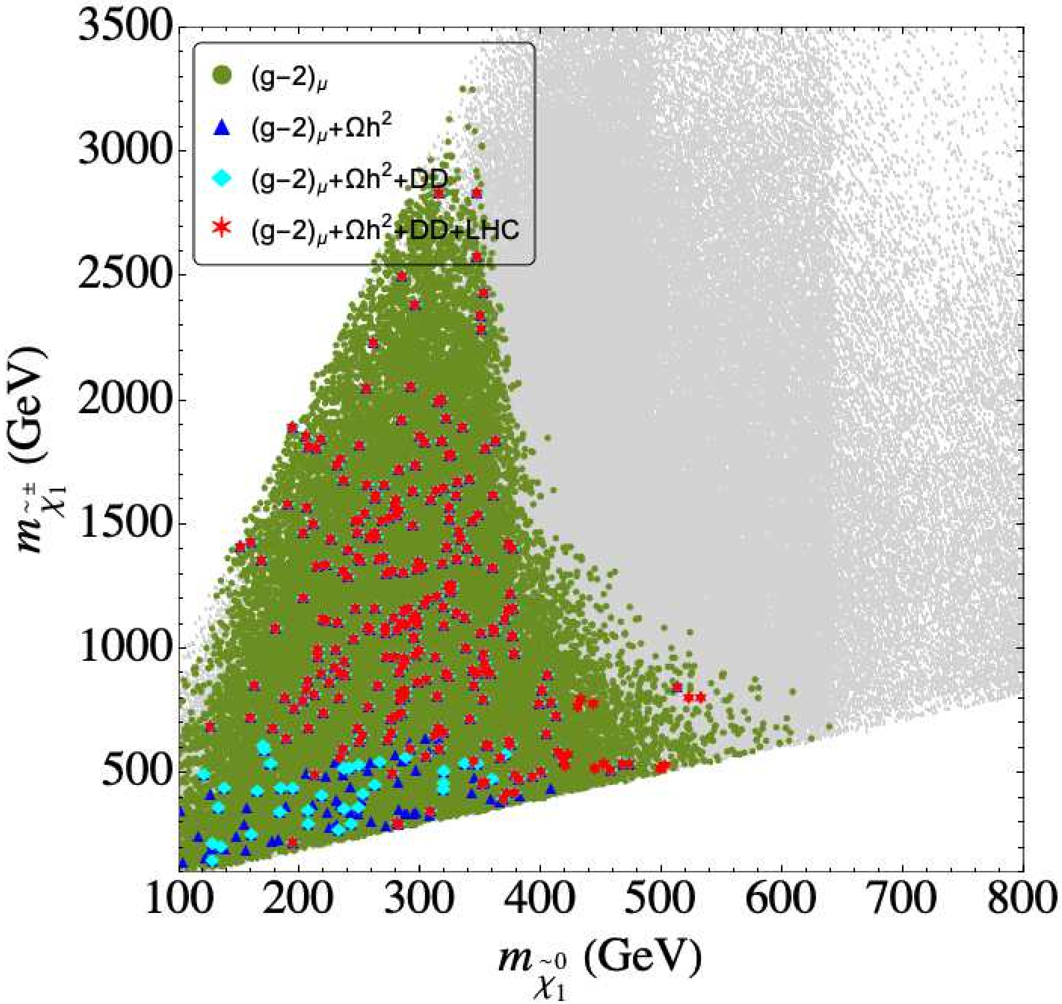


⇒ important: $\tilde{l}$-pair production searches (10)

⇒ naive application of LHC bounds fails

Example II: $\tilde{l}$-coannihilation: $m_{\tilde{\chi}_1^0}$-$m_{\tilde{\chi}_1^\pm}$ plane:

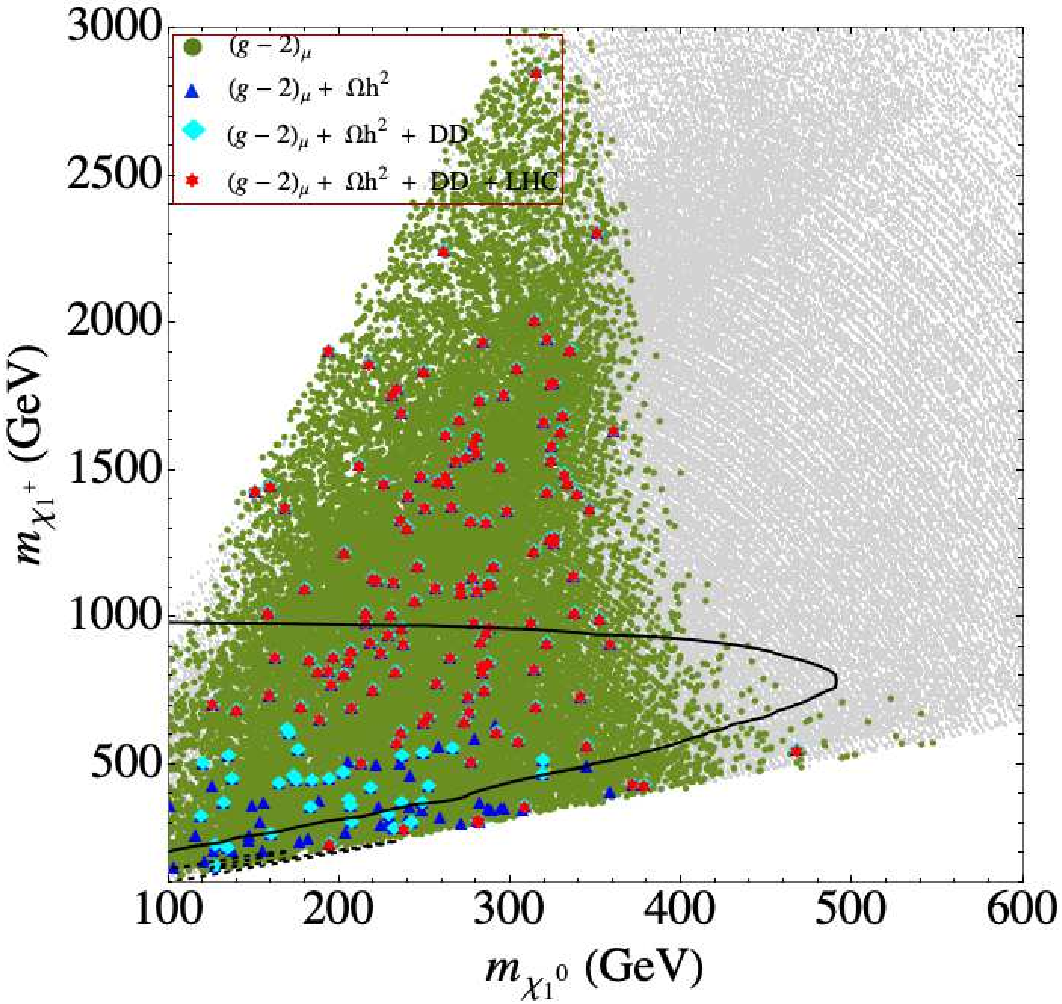
new $(g-2)_\mu$



$\Rightarrow$ important: $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production searches (5)

Example II: $\tilde{l}$-coannihilation: $m_{\tilde{\chi}_1^0}$-$m_{\tilde{\chi}_1^\pm}$ plane:

old $(g-2)_\mu$

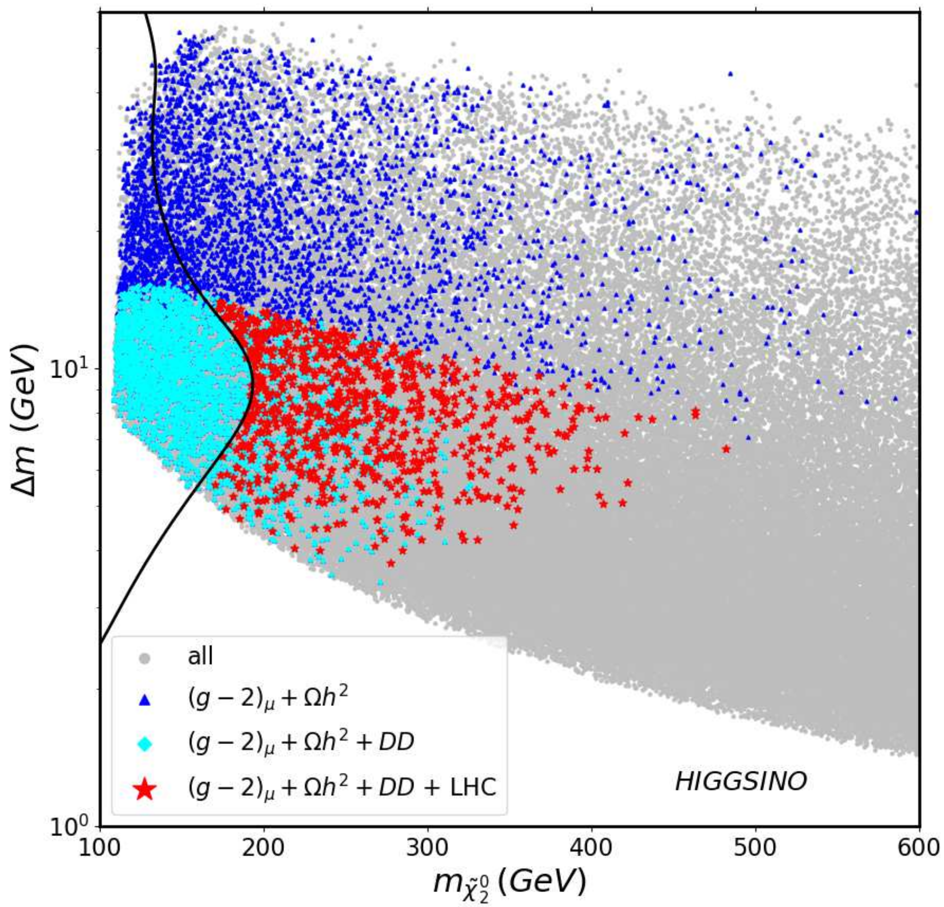


⇒ important: $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production searches (5)

⇒ naive application of LHC bounds fails

Example III: higgsino DM: $m_{\tilde{\chi}_2^0}$-Δm plane:

old $(g-2)_\mu$

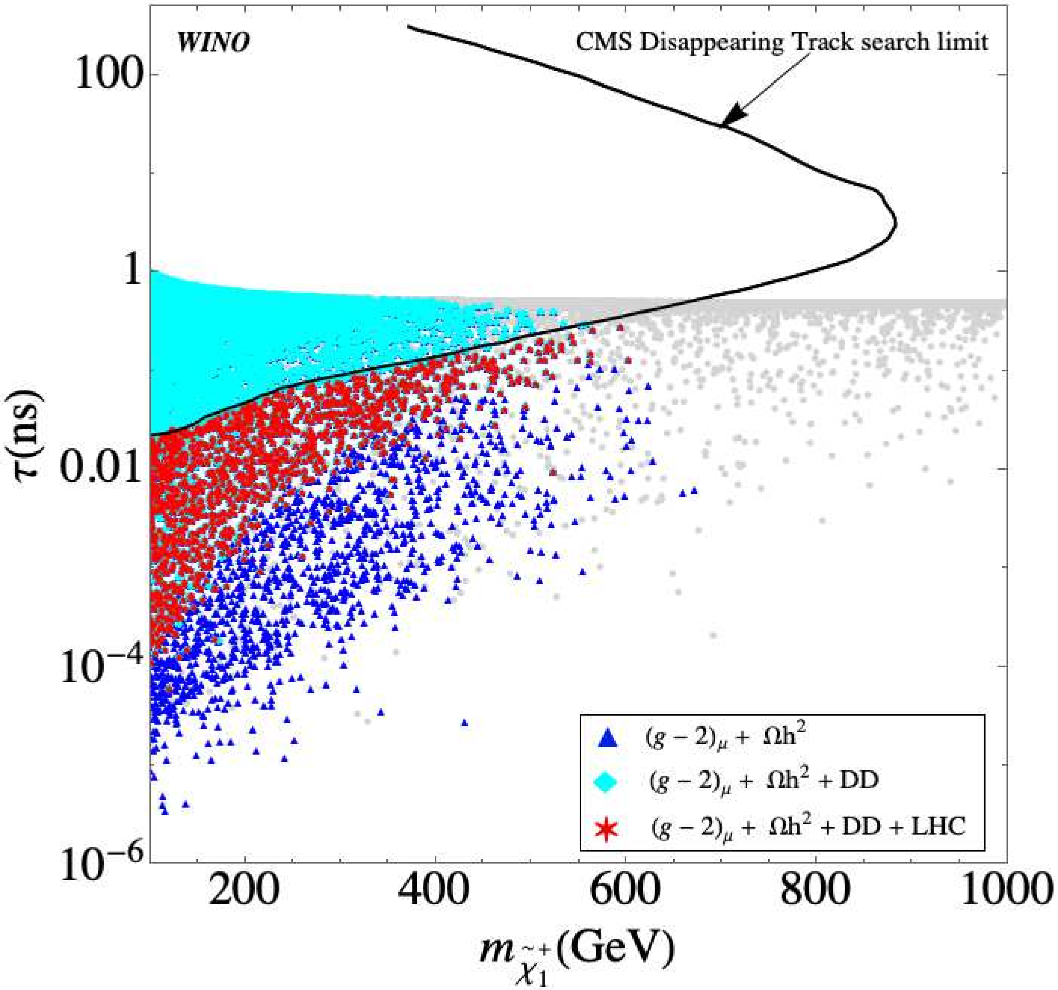


⇒ important: compressed spectra searches (11)

⇒ right where the model prediction sits ⇒ very powerful

Example IV: wino DM: $m_{\tilde{\chi}_1^\pm}$-$\tau_{\tilde{\chi}_1^\pm}$ plane:

old $(g-2)_\mu$



⇒ important: disappearing track limit ⇒ $m_{(N)LSP} \lesssim 600$ GeV

⇒ allowed parameter space squeezed by DD limits and disapp. tracks

5. Interplay with the (HL-)LHC

A) Bino/wino DM with chargino co-annihilation

$\Rightarrow$ large part covered by XENON-nT/LZ

$\Rightarrow$ but can go below even the neutrino floor

$\Rightarrow$ Can the (HL-)LHC cover this scenario?

B/C) Bino DM with slepton co-annihilation

$\Rightarrow$ large part covered by XENON-nT/LZ

$\Rightarrow$ but can go below even the neutrino floor

$\Rightarrow$ Can the (HL-)LHC cover these scenarios?

D) Higgsino DM

$\Rightarrow$ everything covered by XENON-nT/LZ

$\Rightarrow$ Direct Detection experiments cover the full parameter space

$\Rightarrow$ good! (HL-)LHC has problems with compressed spectra

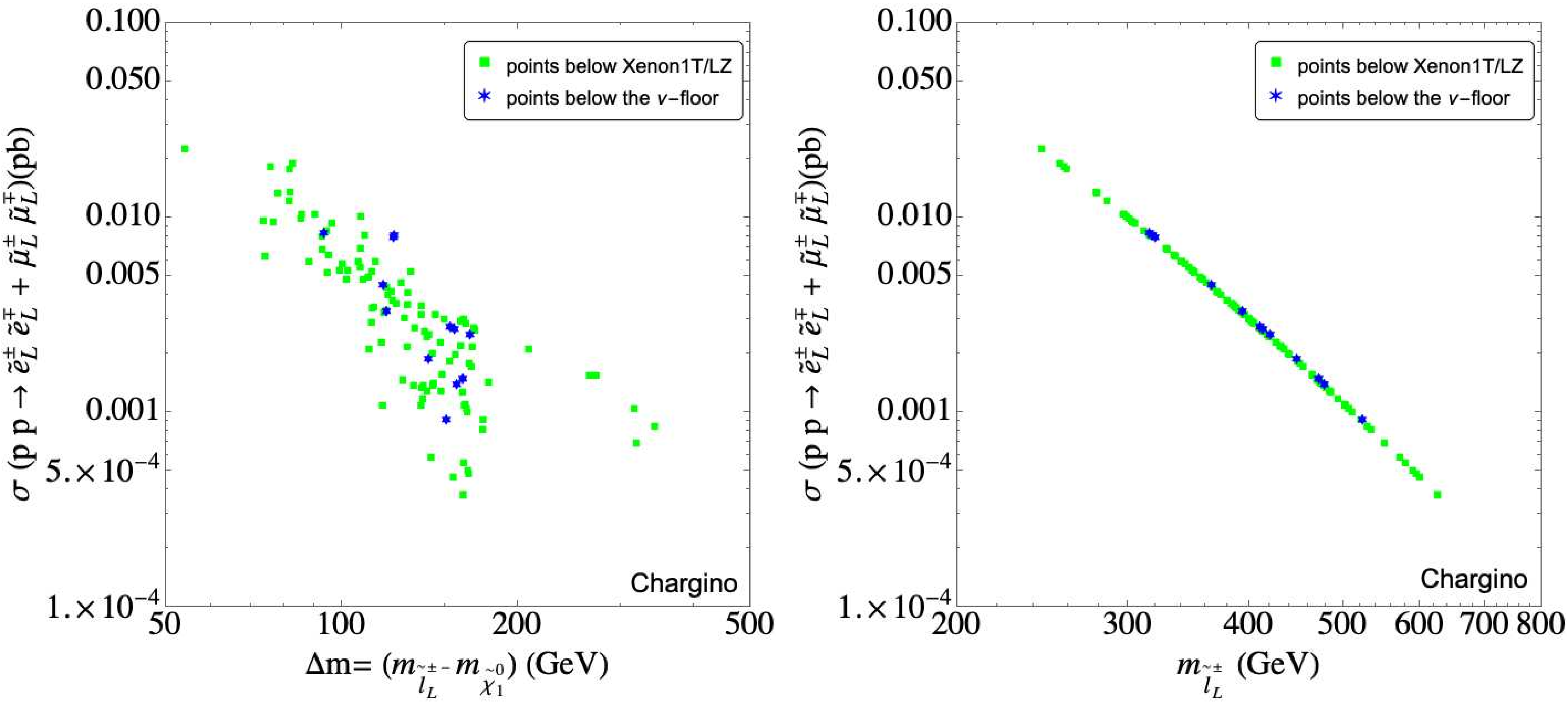
E) Wino DM

$\Rightarrow$ everything covered by XENON-nT/LZ

$\Rightarrow$ Direct Detection experiments cover the full parameter space

$\Rightarrow$ good! (HL-)LHC has problems with compressed spectra

(HL-)LHC cross sections for $\tilde{\chi}_1^{\pm}$-coannihilation: [*PRELIMINARY*]

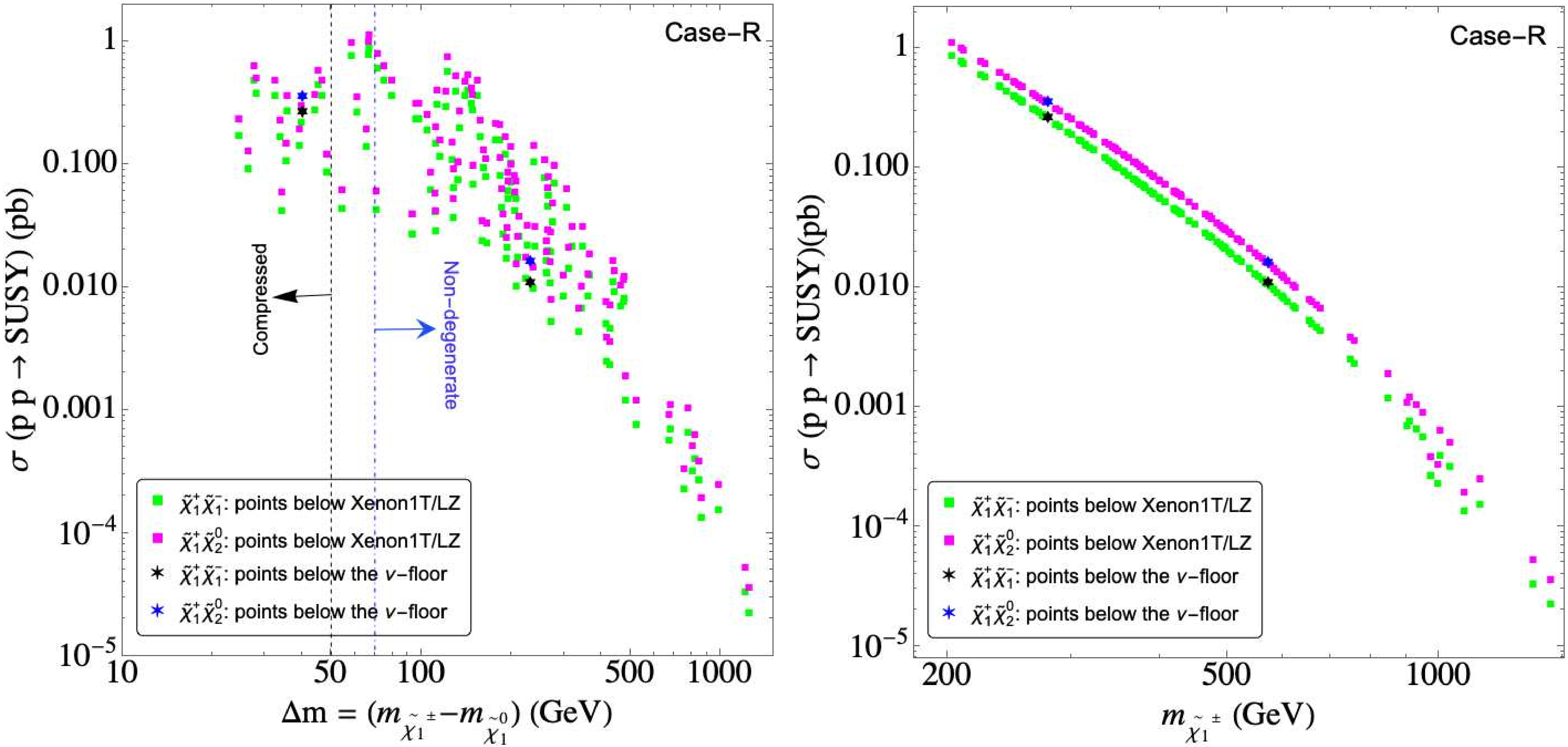


⇒ XS above 0.4 fb ⇒ more than 1200 events

⇒ even better for "BNF" points: XS above 1 fb

But: detailed (HL-)LHC analysis missing! (spectra not too compressed!)

(HL-)LHC cross sections for $\tilde{l}$-coannihilation case-R: [PRELIMINARY]



⇒ XS above 0.04 fb ⇒ more than 120 events

⇒ very good for "BNF" points: XS above 10 fb

But: detailed (HL-)LHC analysis missing! (spectra can be compressed!)