Astroparticle Physics at Colliders

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  - Scalar fields can get large vevs due to these fluctuations
  - At least one model maybe testable at the LHC!

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- Reheating: (Re-)populates Universe with particles.
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  - May have some connection to collider physics (sphalerons)

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  - Energy density of the Universe begins to be dominated by (dark) matter

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  - In models with dynamical Dark Energy ("quintessence"): Can affect dynamics of BBN, creation of Dark Matter, ...

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- Establishes link between inflationary potential and sparticle masses!
- SUSY can also play crucial role in re–heating Allahverdi et al., hep–ph/0505050, 0512227, 0603244

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- In 4 dimensions: No connection to collider physics
- In models with small extra dimensions: Connections to collider physics may exist (radion–Higgs mixing; spectrum of KK states), but no example is known (to me)
- In models with large extra dimension: LHC may be black hole factory; “cosmon” should be produced in bh decay

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- Some models work at rather low temperature: can be tested at colliders! Will discuss two such models.

Leptogenesis with degenerate neutrinos

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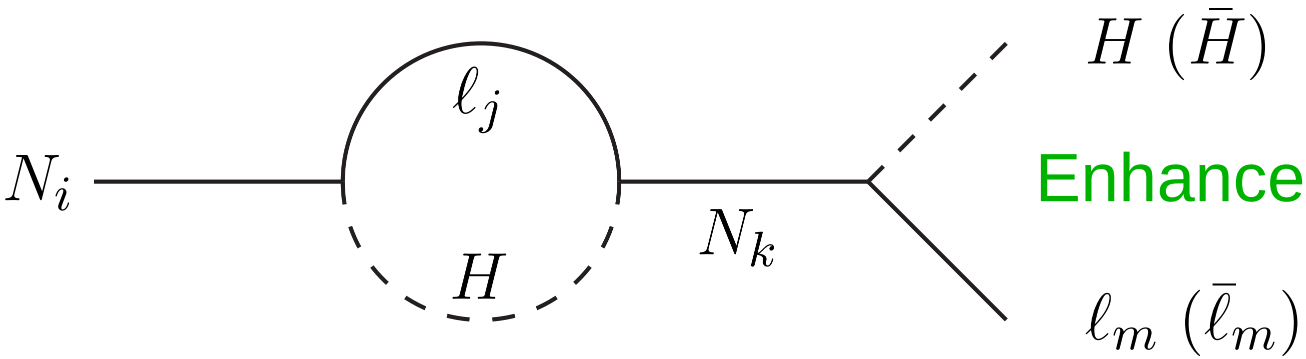
- If $M_2 - M_1 \ll M_1$: effective CP violation enhanced: Can have $M_1 \simeq$ TeV! Pilaftsis 1997/9; Pilaftsis & Underwood 2004

Leptogenesis (cont.d)



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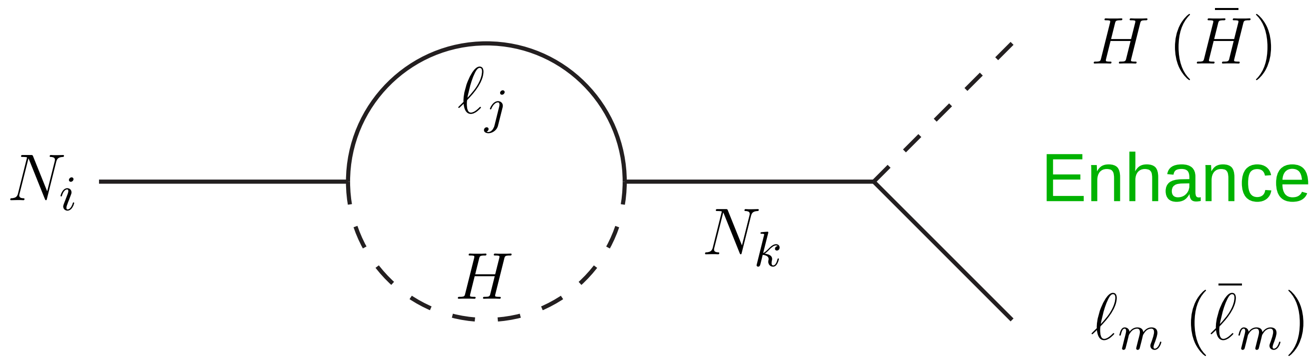

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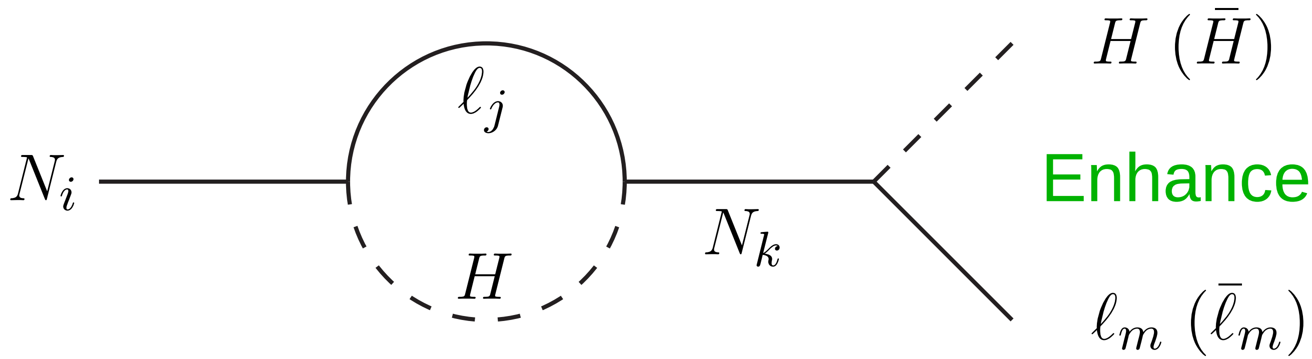

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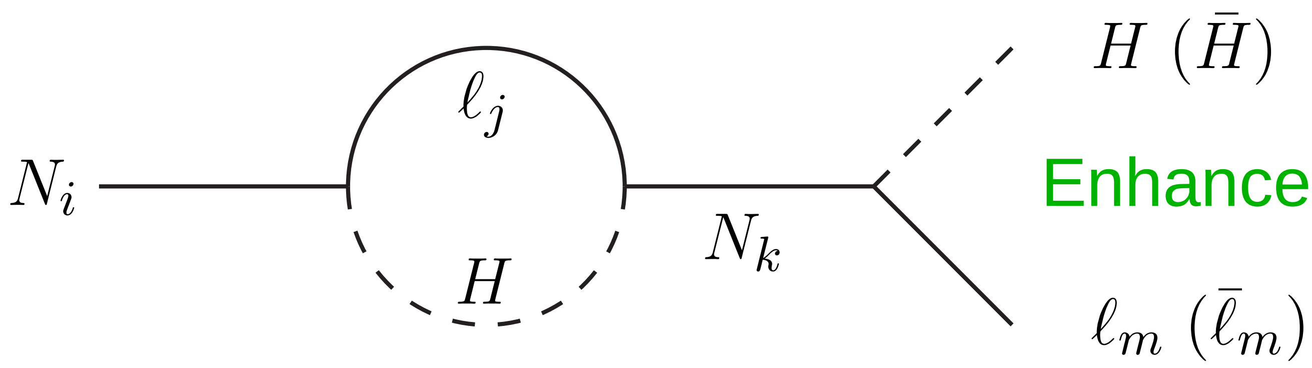

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- Other scenarios with low-scale leptogenesis: Grossman, Kashti, Nir, Roulet 2004; Hambye et al. 2003; Raidal, Strumia, Turzynski 2004

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- Does not work in SM: cross–over (no phase transition) for $m_H \gtrsim 60$ GeV!

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  - Determination of ϕ_μ in relevant region of parameter space

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- Models of structure formation, X ray temperature of clusters of galaxies, ...
- Cosmic Microwave Background anisotropies (WMAP) imply $\Omega_{\rm DM} h^2 = 0.105^{+0.007}_{-0.013}$ **Spergel et al., astro–ph/0603449**

Density of thermal DM

Decoupling of DM particle χ defined by:

$$n_\chi(T_f)\langle v\sigma(\chi\chi \to \mathrm{any})\rangle = H(T_f)$$

n_χ: χ number density $\propto \mathrm{e}^{-m_\chi/T}$

v: Relative velocity

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Gives average relic mass density

$$\Omega_\chi \propto \frac{1}{\langle v\sigma(\chi\chi\to\mathrm{any})\rangle}$$

Gives roughly right result for weak cross section!

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- Such particles exist for best–motivated χ candidates: SUSY, Little Higgs, universal extra dimension

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- Must satisfy DM search limits $\Rightarrow\ \chi \neq \tilde{\nu}$

And the winner is . . .

SUSY Dark Matter

Conditions for successful DM candidate:

- Must be stable $\Rightarrow$ $\chi =$ LSP and $R-$parity is conserved (if LSP in visible sector)
- Exotic isotope searches $\Rightarrow$ χ must be neutral
- Must satisfy DM search limits $\Rightarrow$ $\chi \neq \tilde{\nu}$

And the winner is . . .

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

(or in hidden sector)

$\tilde{\chi}_1^0$ relic density

To predict thermal $\tilde{\chi}_1^0$ relic density: have to know

$$\sigma(\tilde{\chi}_1^0\tilde{\chi}_1^0 \longrightarrow \mathrm{SM\ particles})$$

In general, this requires knowledge of almost all sparticle and Higgs masses and of all couplings of the LSP!

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Neutralino mass matrix in the MSSM:

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$\Longrightarrow$ Can determine decomposition of $\tilde{\chi}_1^0$ by studying $\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0, \tilde{\chi}_3^0$.

$\tilde{\chi}_1^0$ annihilation in the MSSM

- $m_{\tilde{f}_L}$, $m_{\tilde{f}_R}$, $\theta_{\tilde{f}}$: Needed for $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to f\bar{f}$

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- Parameters in Higgs and squark sector are also needed to predict $\tilde{\chi}_1^0$ detection rate, i.e. $\sigma(\tilde{\chi}_1^0 N \rightarrow \tilde{\chi}_1^0 N)$

Impact on particle physics (mSUGRA)

w./ A. Djouadi, J.-L. Kneur, hep-ph/0602001

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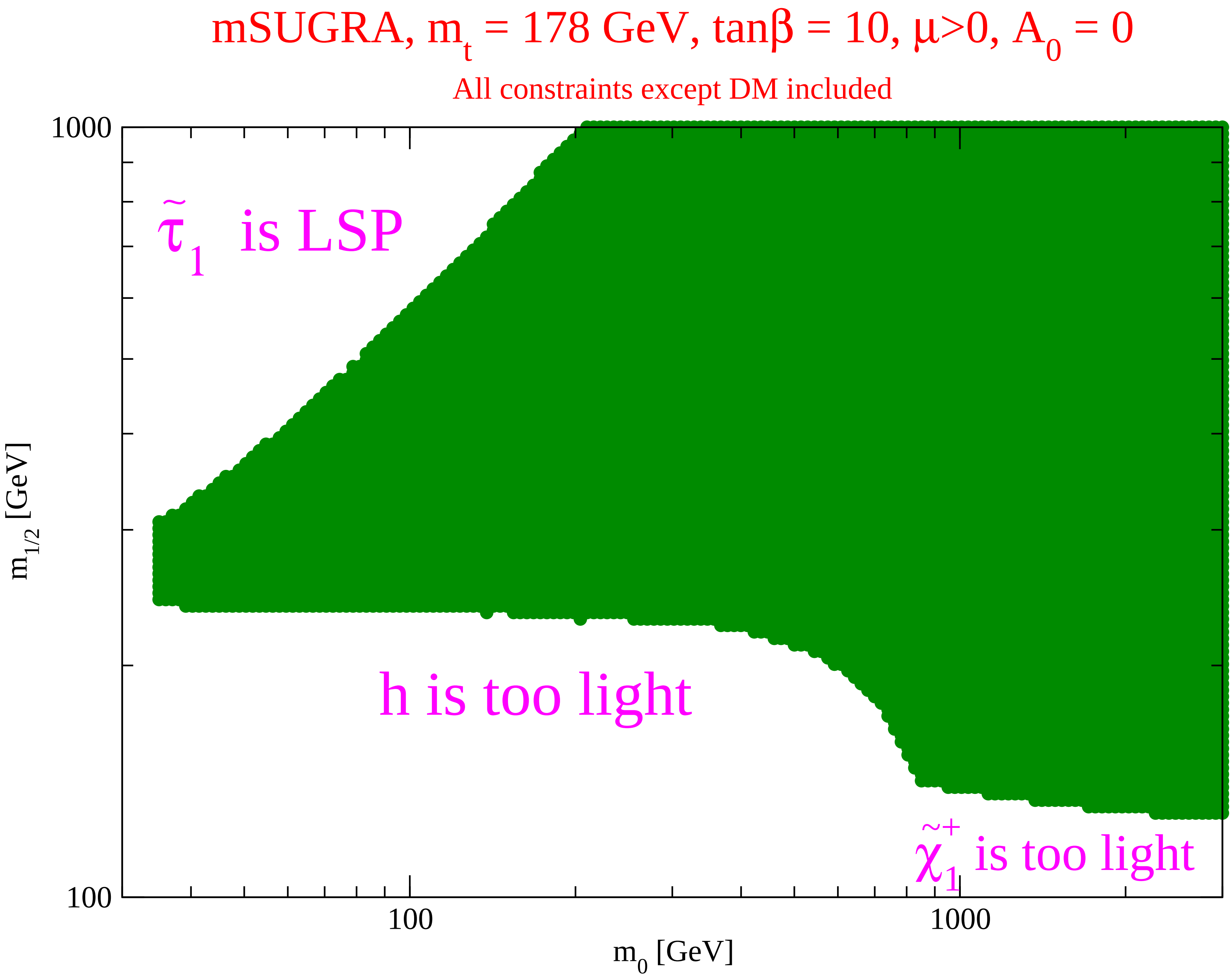
- Simple CCB constraints (at weak scale only)


mSUGRA, m_t = 178 GeV, tanβ = 10, μ>0, A_0 = 0
All constraints except DM included
$\tilde{\tau}_1$ is LSP
h is too light
$\tilde{\chi}_1^+$ is too light
1000
100
100
1000
m_0 [GeV]
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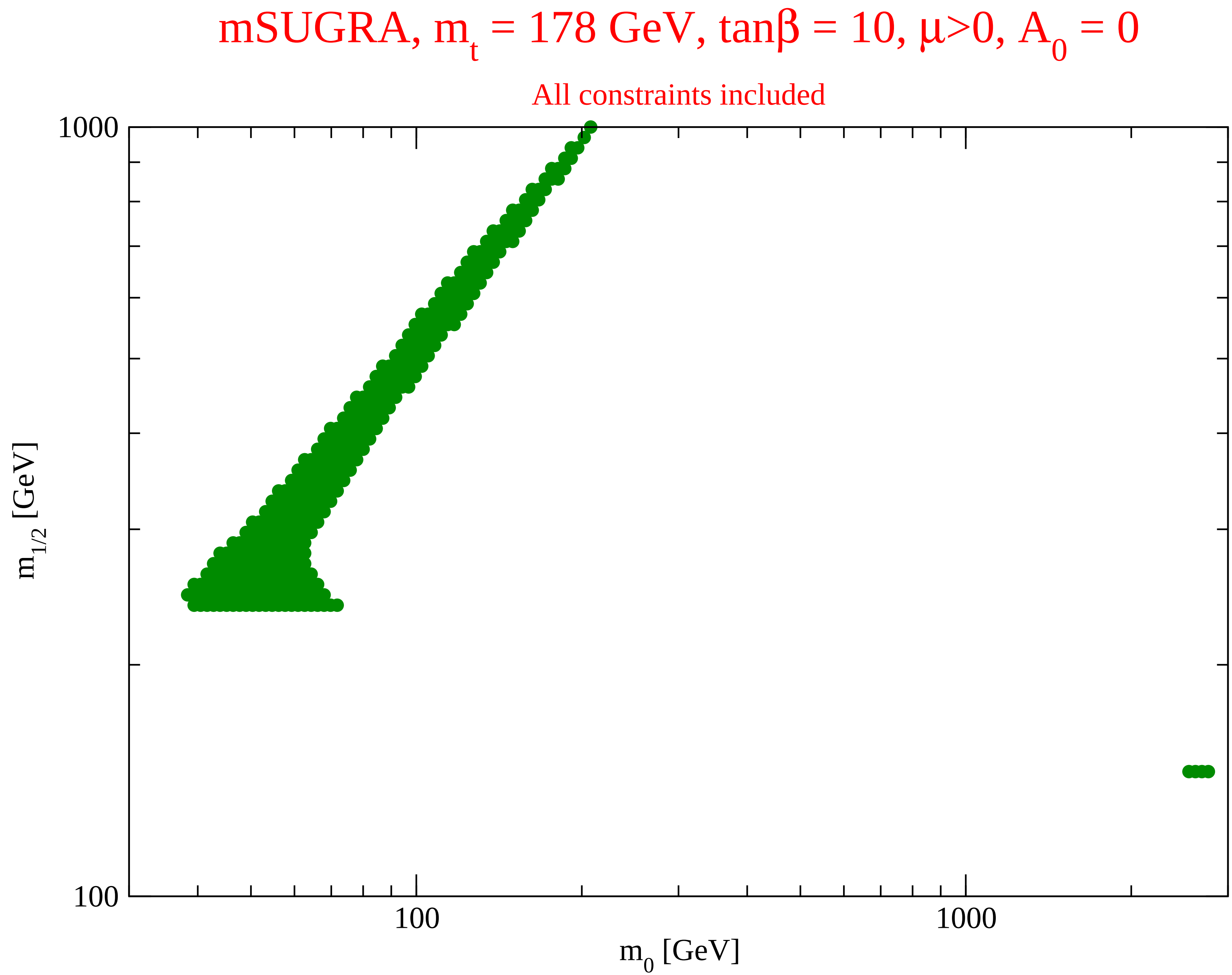
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Based on spectrum information only!

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Any mSUGRA parameter set can have the right DM density if LSP is in hidden or invisible sector. It could be:

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- Detection of hidden sector DM seems impossible: Cross sections are way too small!

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If $\tilde{\chi}_1^0$ makes DM: Can use measurements at colliders to constrain cosmology!

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  - SUSY WIMPs: Relic density often depends very sensitively on parameters: need very accurate measurements in collider experiments!