Astroparticle Physics and the LC

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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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- In 4 dimensions: No connection to collider physics
- In models with extra dimensions: Connections to collider physics may exist (radion–Higgs mixing; spectrum of KK states), but no example is known (to me)

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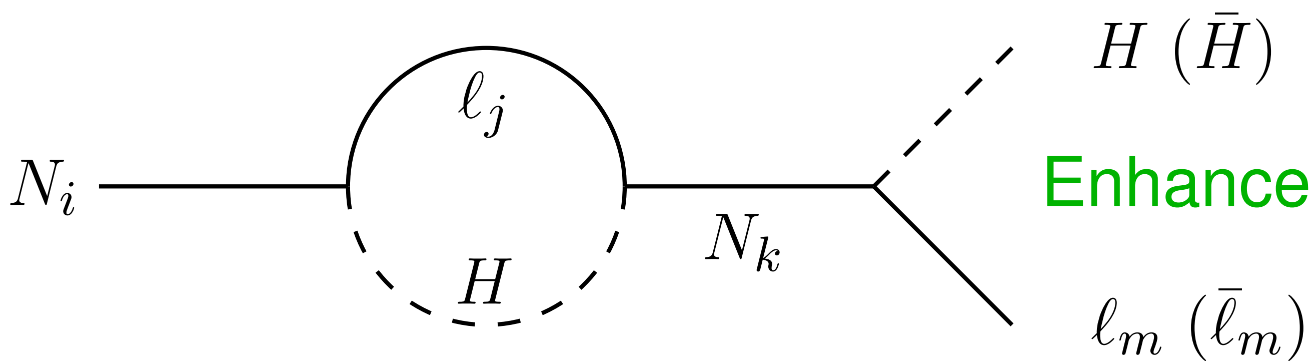
- If $M_2 - M_1 \ll M_1$: effective CP violation enhanced: Can have $M_1 \simeq$ TeV! Pilaftsis 1997/9; Pilaftsis and Underwood 2004

Leptogenesis (cont.d)



Enhanced for $i = 1,\ k = 2$

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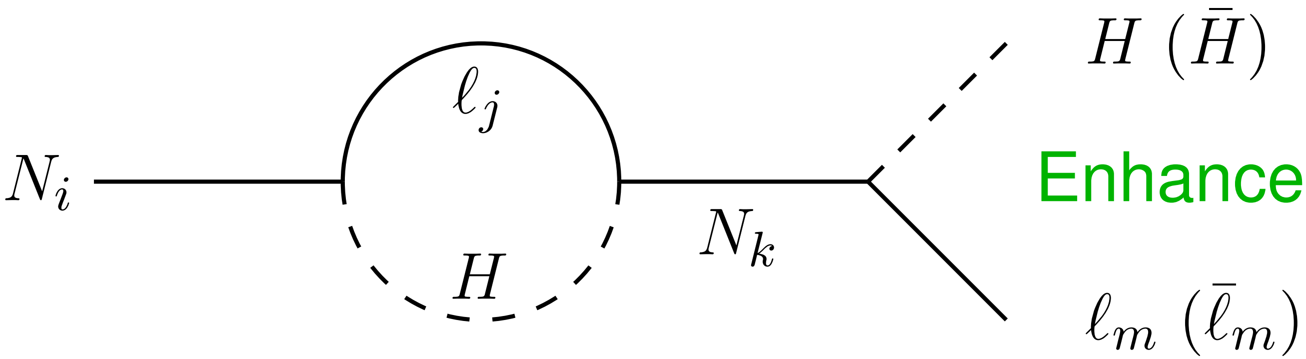

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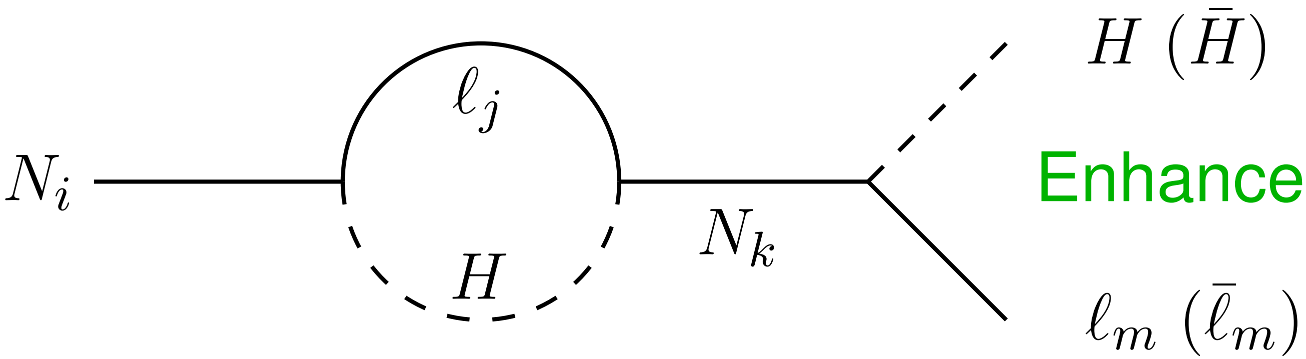

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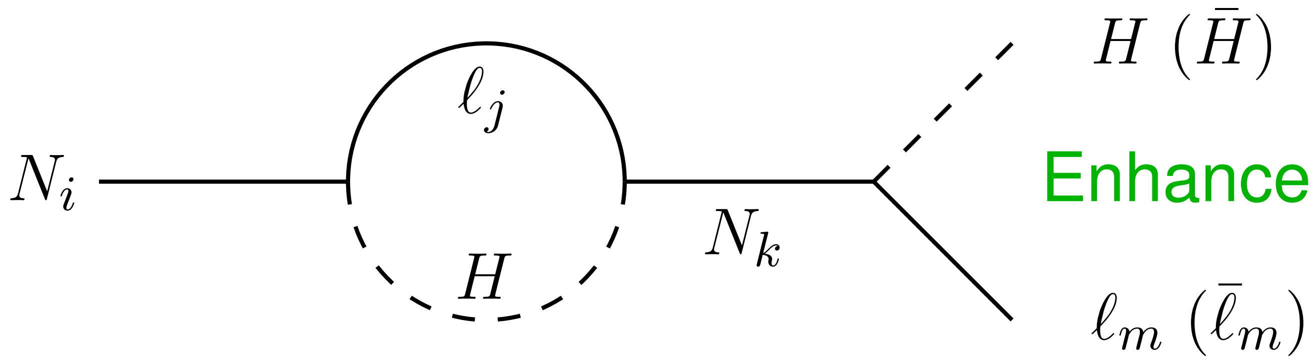

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- Other scenarios with low-scale leptogenesis: Grossman, Kashti, Nir, Roulet 2004; Hambye et al. 2003; Raidal, Strumia, Turzynski 2004

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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 $\Omega_{\rm DM} h^2 = 0.111 \pm 0.009$ **Bennet et al., astro–ph/0302207**

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

$\langle \ldots \rangle$: Thermal average

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

(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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$$\mathcal{M}_0 = \begin{pmatrix} M_1 & 0 & -M_Z \cos\beta \sin\theta_W & M_Z \sin\beta \sin\theta_W \\ 0 & M_2 & M_Z \cos\beta \cos\theta_W & -M_Z \sin\beta \cos\theta_W \\ -M_Z \cos\beta \sin\theta_W & M_Z \cos\beta \cos\theta_W & 0 & -\mu \\ M_Z \sin\beta \sin\theta_W & -M_Z \sin\beta \cos\theta_W & -\mu & 0 \end{pmatrix}$$

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

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$\Longrightarrow$ Can determine decomposition of $\tilde{\chi}_1^0$ by studying $\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0, \tilde{\chi}_3^0$.
Well studied in the MSSM, but not much is known about extensions (e.g. NMSSM)

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

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

Impact on particle physics (mSUGRA)

w./ A. Djouadi, J.-L. Kneur, P. Slavich

Parameter space is constrained by:

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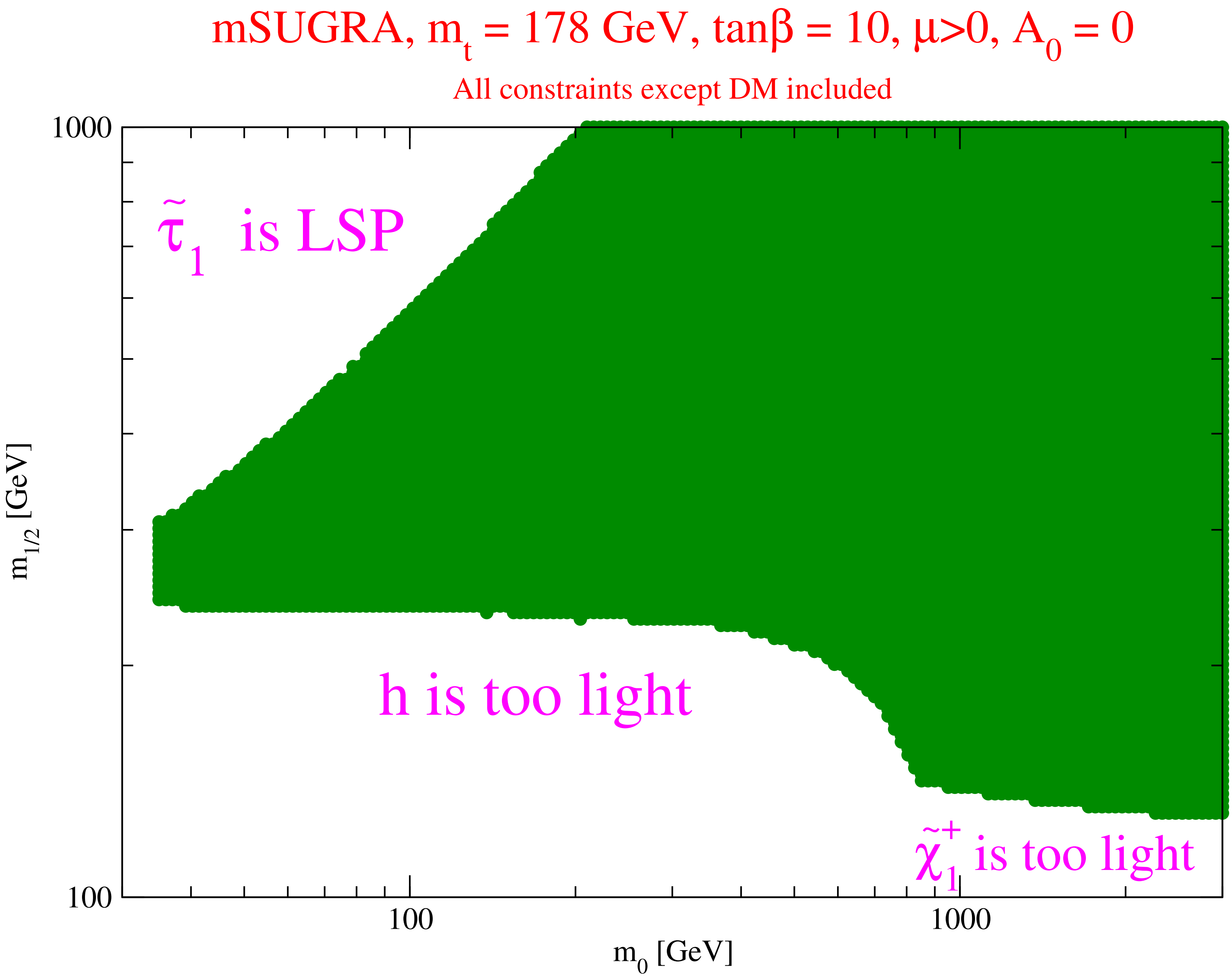

mSUGRA, m_t = 178 GeV, tanβ = 10, μ>0, A_0 = 0
All constraints except DM included
$\tilde{\tau}_1$ is LSP
h is too light
$\tilde{\chi}_1^+$ is too light
1000
100
100
1000
$m_{1/2}$ [GeV]
m_0 [GeV]

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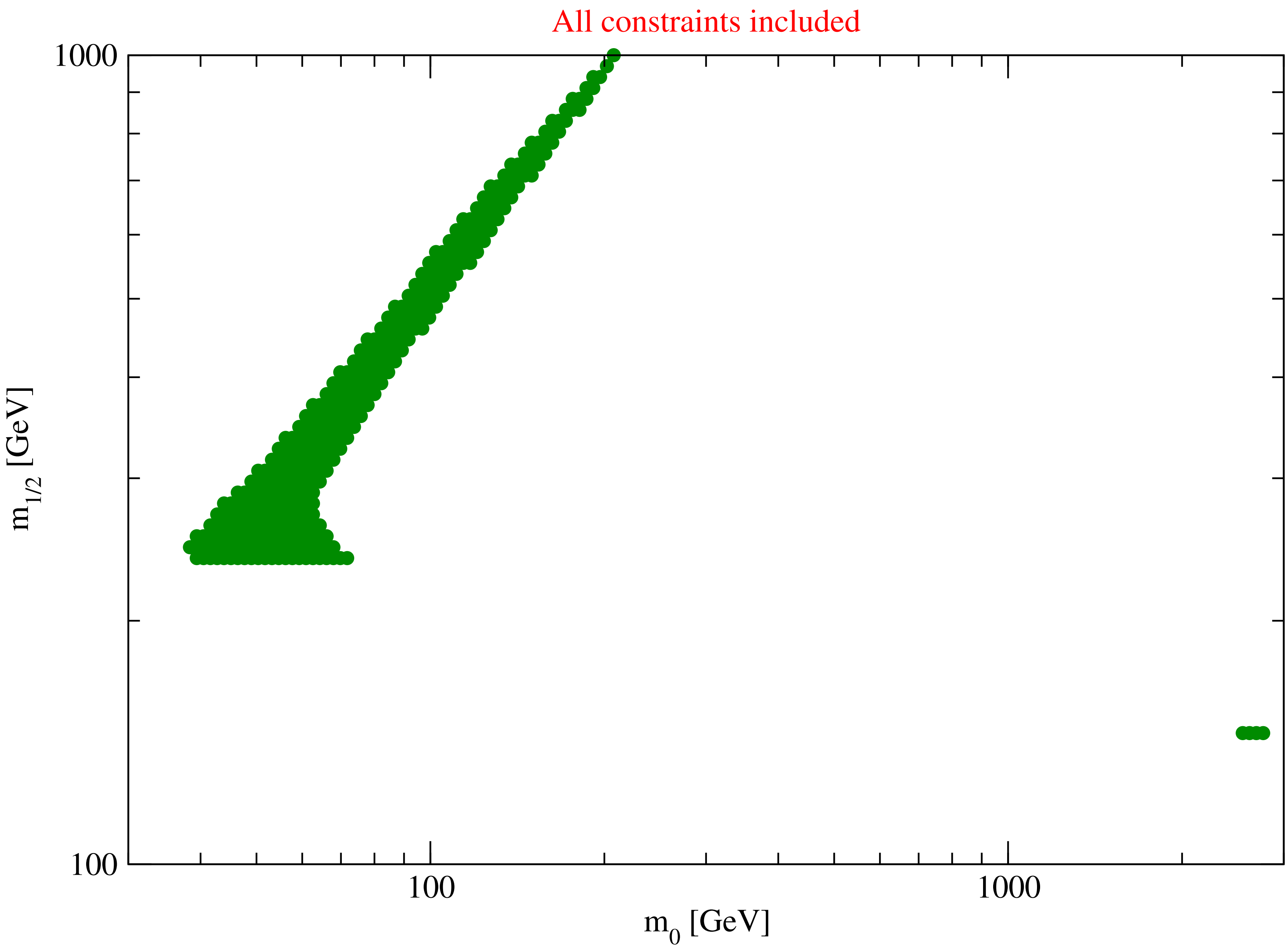

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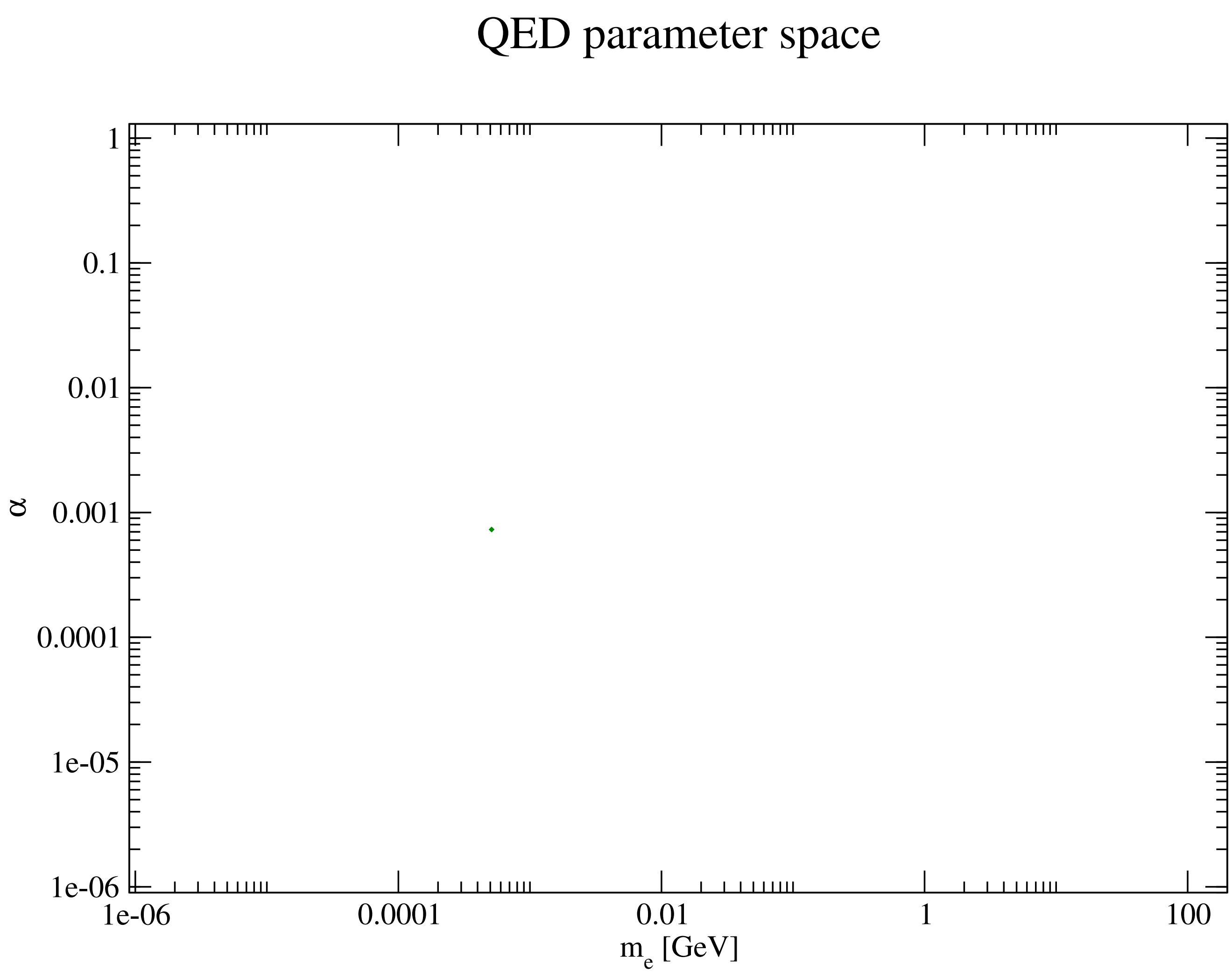

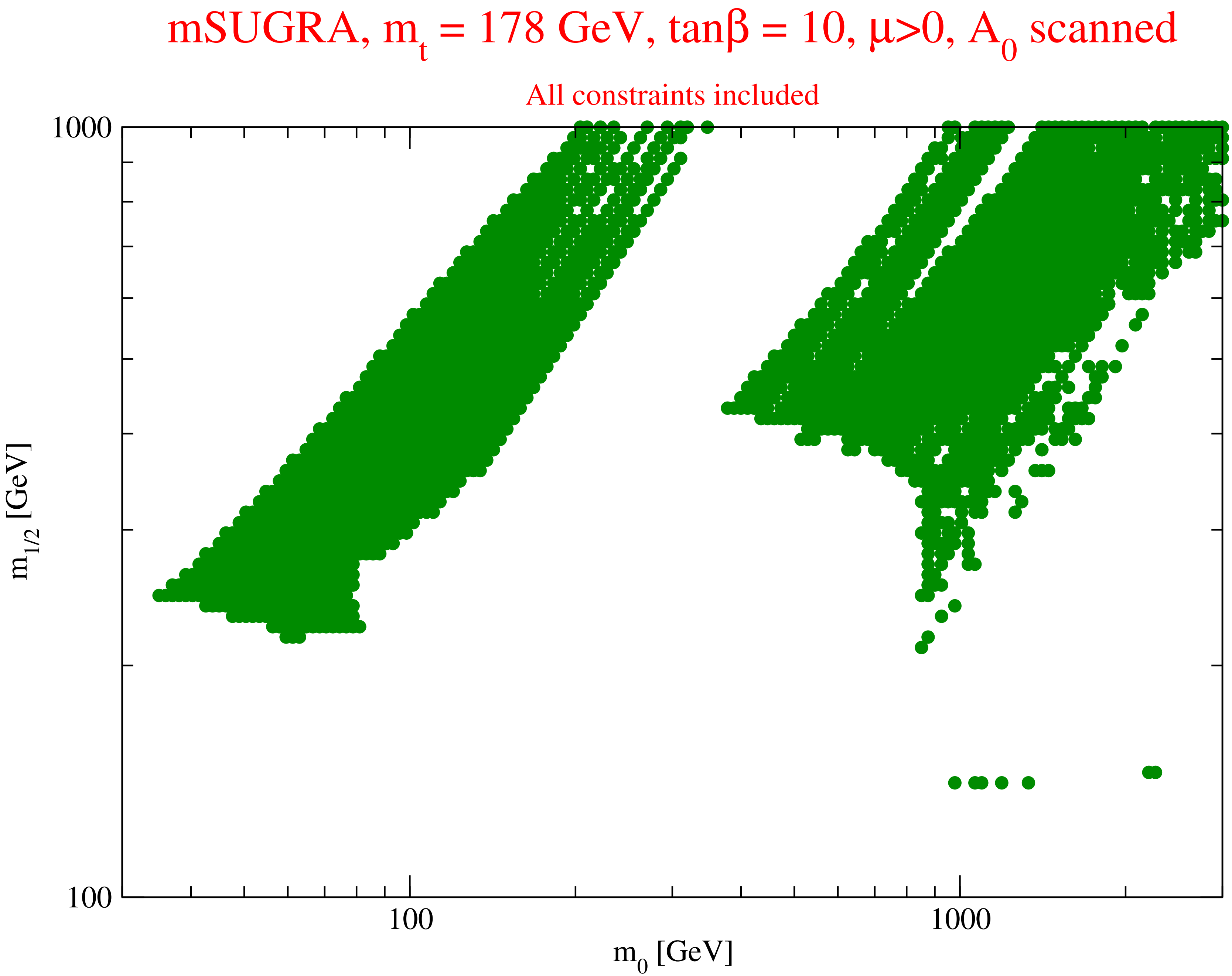
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100
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Beyond mSUGRA

The predicted Dark Matter density can be altered by modifying the SUSY model and/or by modifying the cosmological model.

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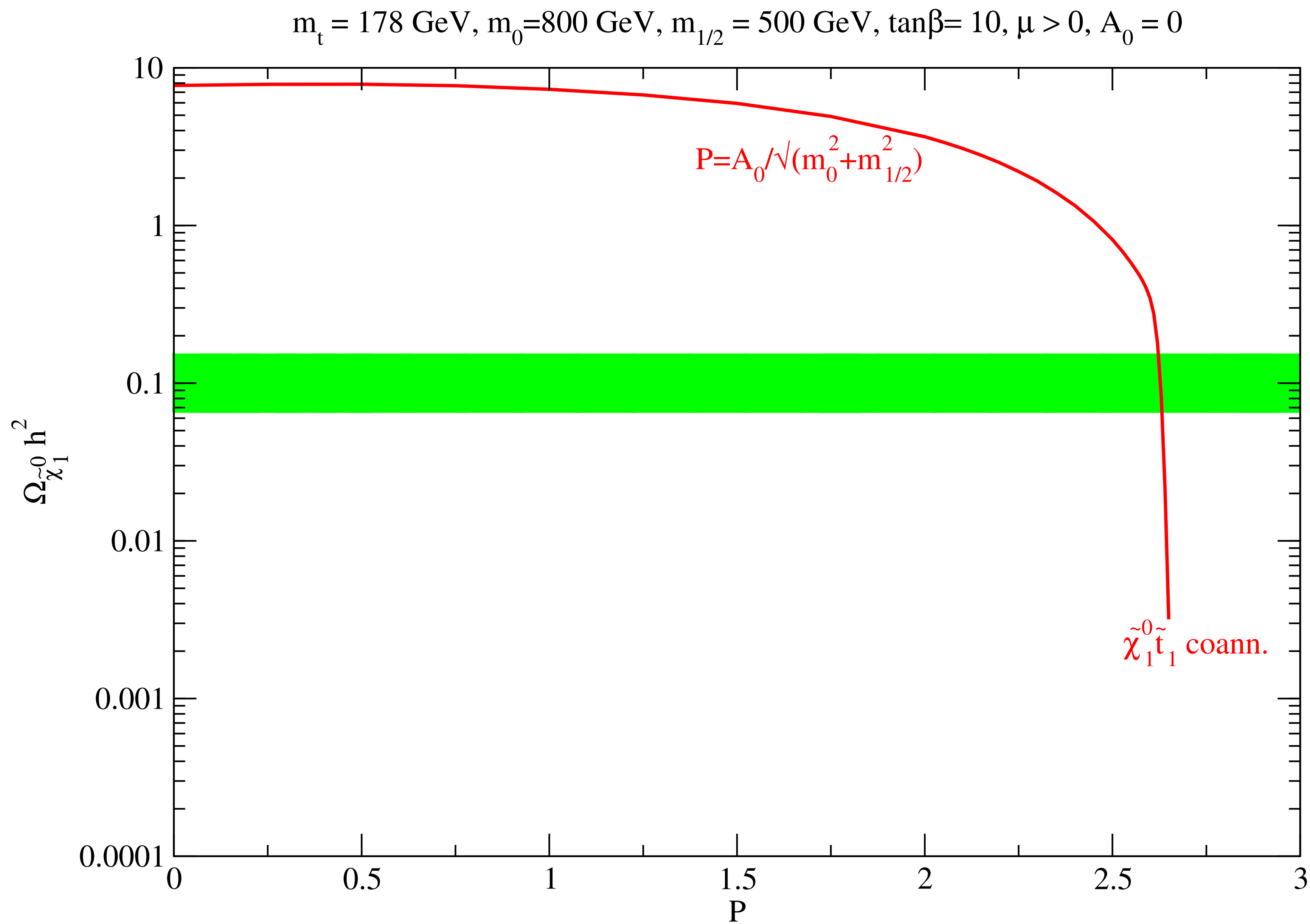
These modifications lead to greatly altered collider phenomenology!



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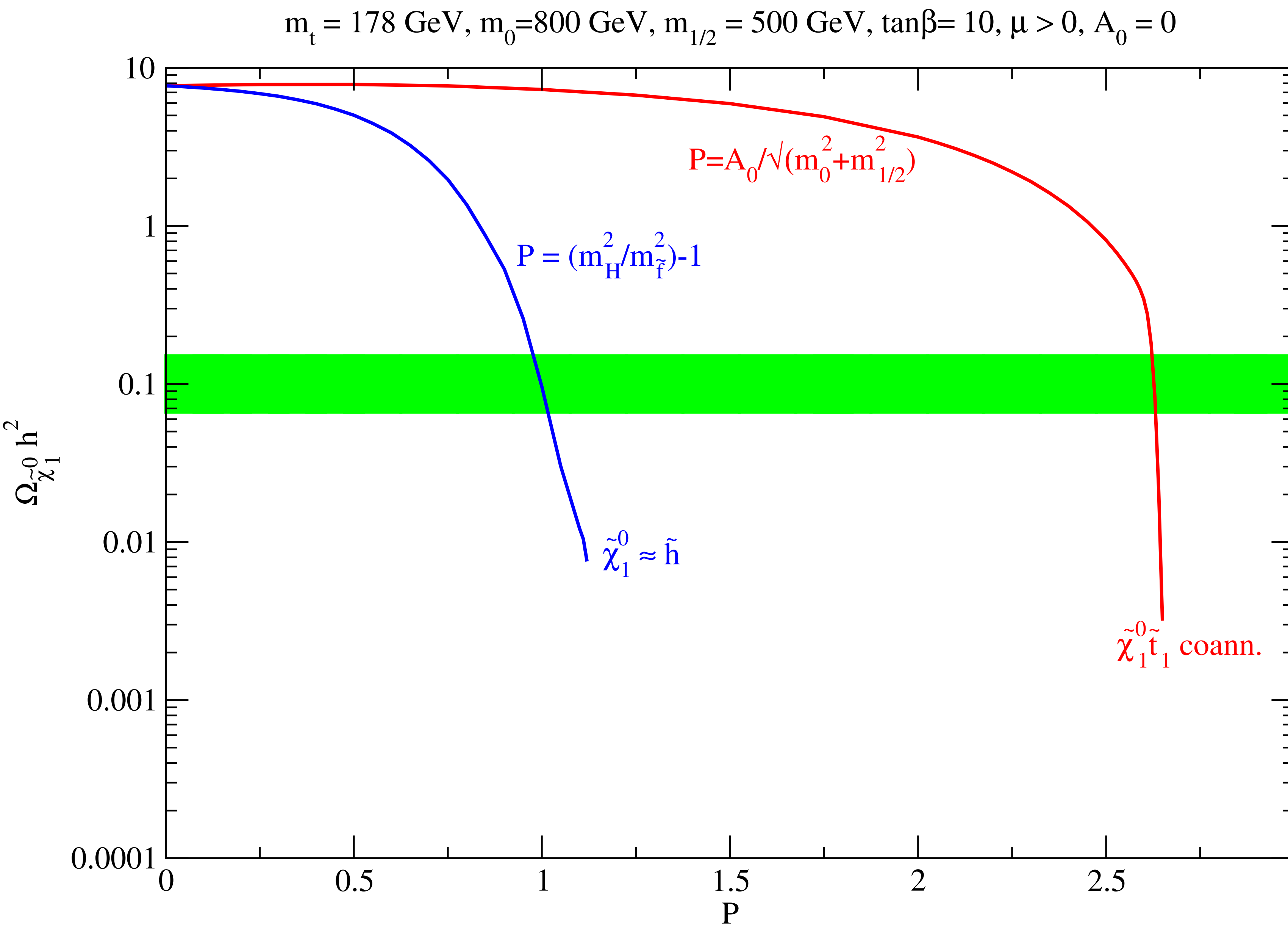
χ̃_1^0 t̃_1 coann.
10
1
0.1
0.01
0.001
0.0001
0
0.5
1
1.5
2
2.5
3
P
Ω_χ̃_1^0 h^2



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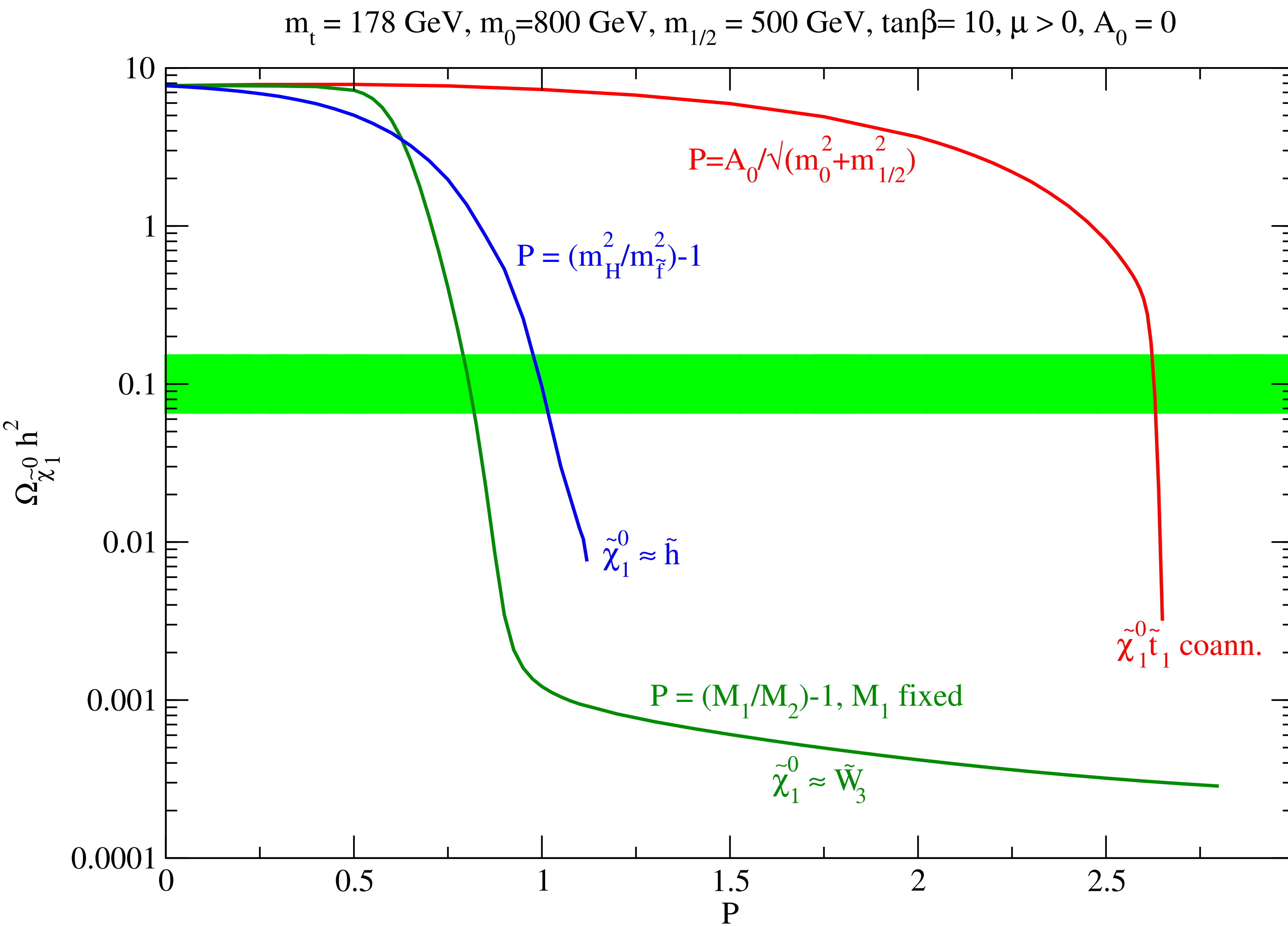

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χ̃_1^0 t̃_1 coann.
P = (M_1/M_2)-1, M_1 fixed
χ̃_1^0 ≈ W̃_3
Ω_χ̃1^0 h^2
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Hidden Sector Dark Matter

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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- Join the new Astro–Particle Working Group! Convenors: A. Djouadi, M. Drees