The NMSSM with Gravitino Dark Matter

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in collaboration with J. Hasenkamp

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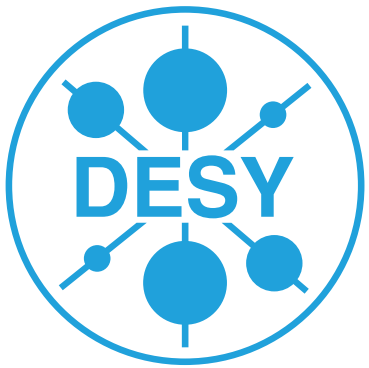
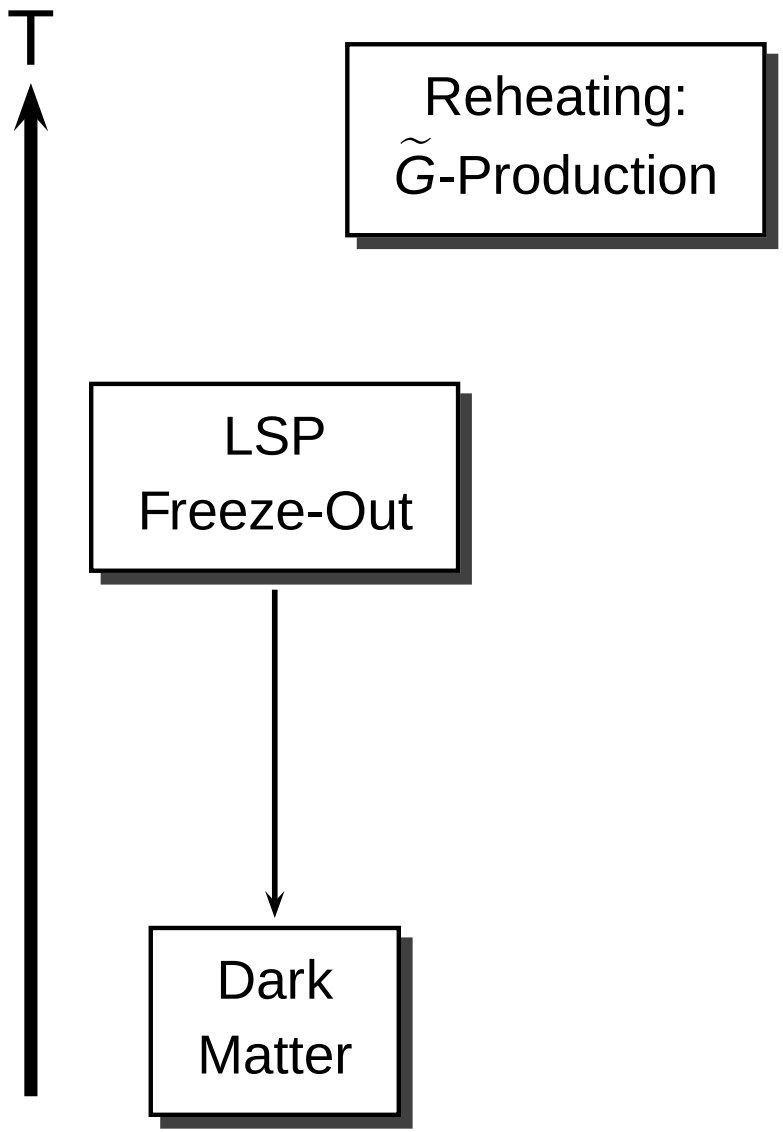


Gravitino Problem

- gravitinos produced at the end of inflation

  Bolz et al. , Nucl. Phys. **B606** (2001)



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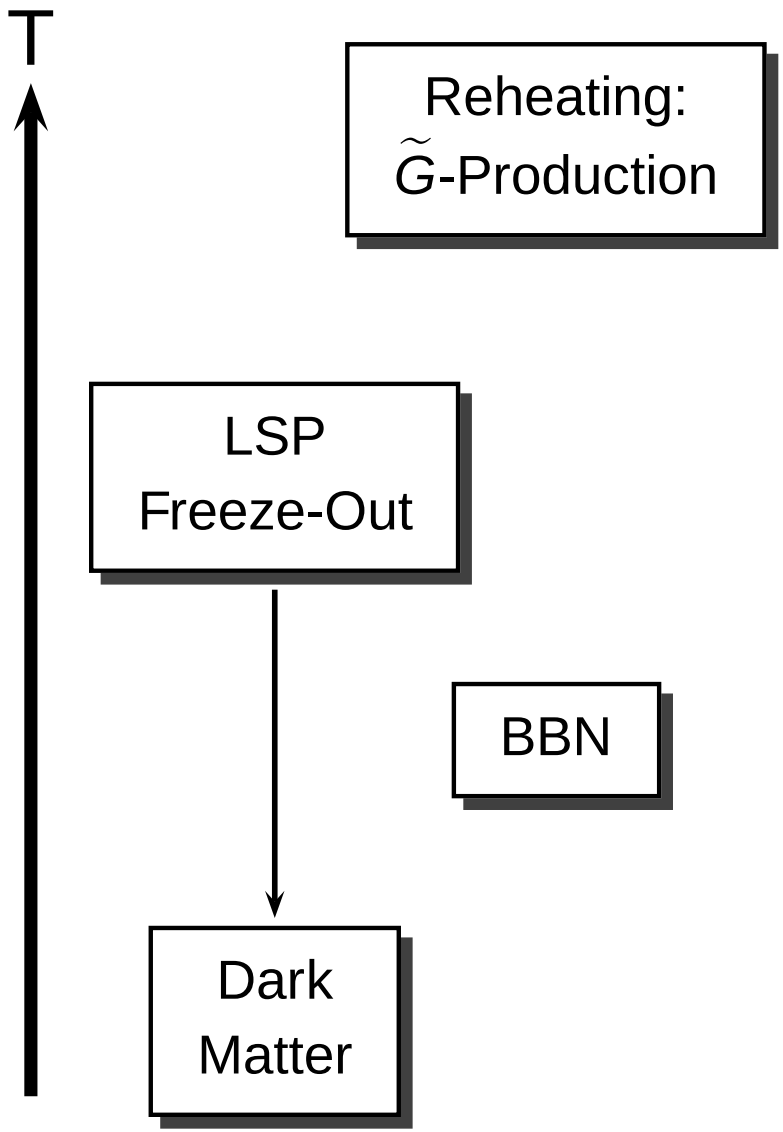

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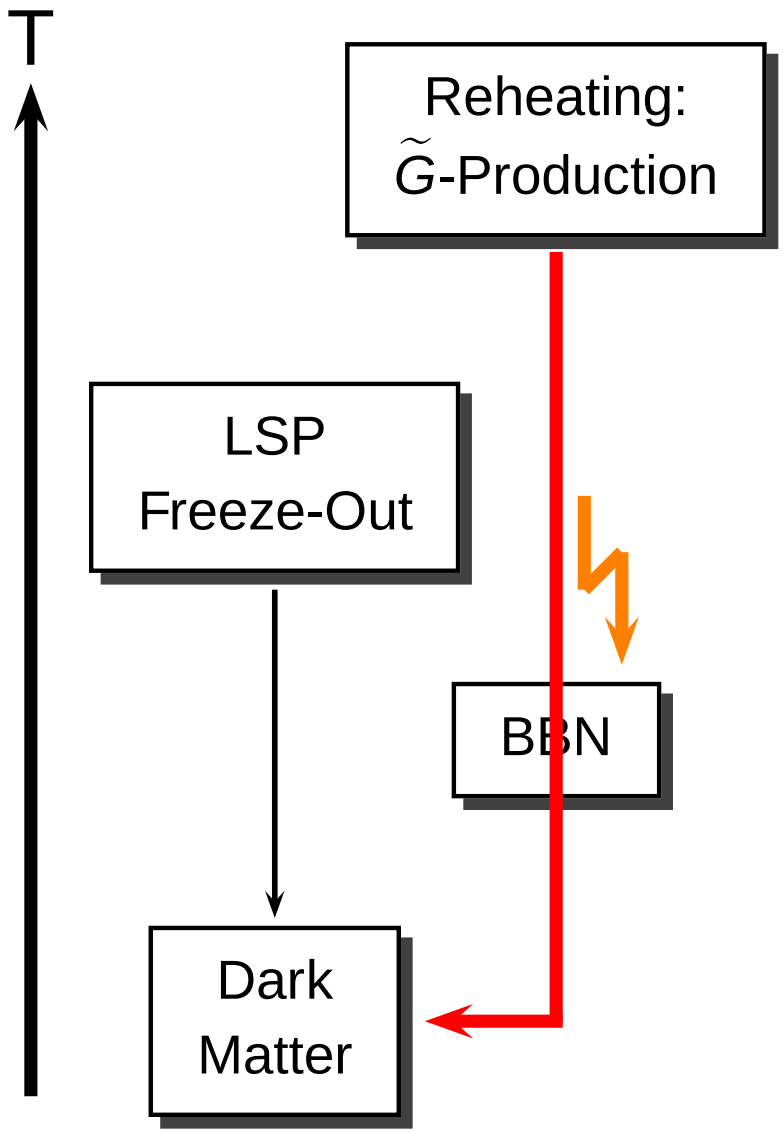
  Weinberg, Phys. Rev. Lett. **48** (1982)



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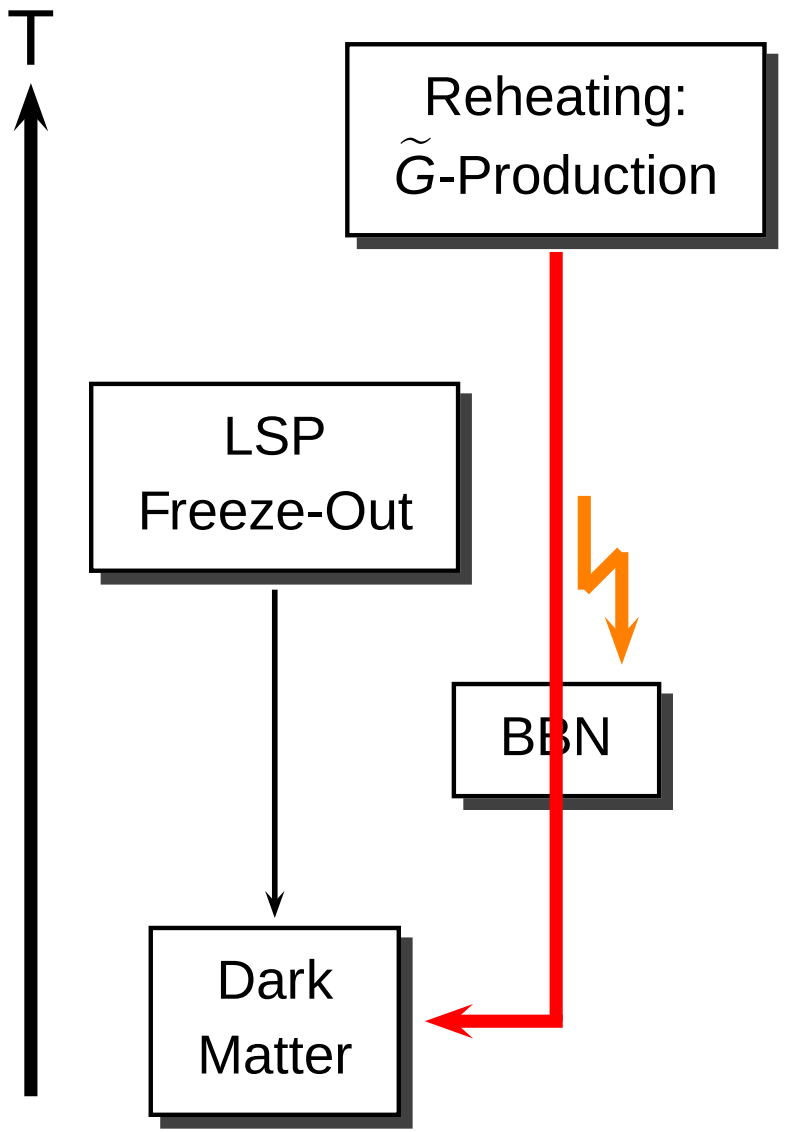
Classes of solutions:

- gravitino decay before BBN
- suppress gravitino abundance
- **stable gravitino**



Gravitino Dark Matter

- gravitino LSP with $m_{3/2} = \mathcal{O}(100\,\text{GeV})$

$$\boldsymbol{\Omega_{3/2} = \Omega_{DM}} \qquad \text{for} \qquad T_R = 10^9 \ldots 10^{10}\,\text{GeV}$$

- consistent with thermal leptogenesis
- problem: late decay of the NLSP

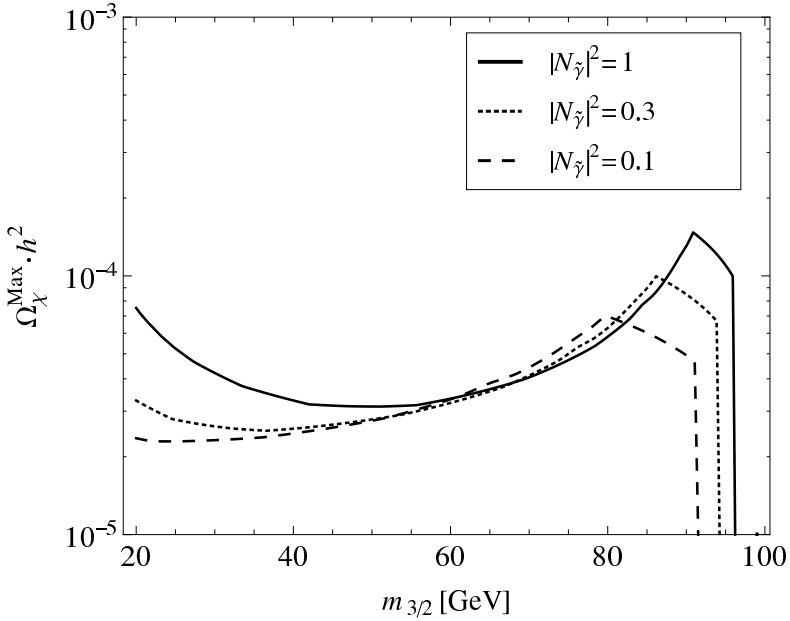
  Cyburt et al., Phys. Rev. **D67** (2003)

- requires highly suppressed NLSP abundance
- very difficult to achieve in MSSM

Cosmological Bounds on a Neutralino NLSP

- consider $\widetilde{\chi} \to \widetilde{G} + \gamma$
- CMB + BBN bounds on e.m. energy injection

  Jedamzik, Phys. Rev. **D74** (2006)
  Hu et al., Phys. Rev. Lett. **70** (1993)



$$\Omega_\chi h^2 \lesssim 10^{-4}$$

- NLSP relic density

$$\Omega_\chi h^2 \simeq \frac{3 \cdot 10^{-10}\,\mathrm{GeV}^{-2}}{\langle \sigma v \rangle}$$

- write $\langle \sigma v \rangle$ as

$$\langle \sigma v \rangle = \frac{g_{\rm eff}^2\,\mathcal{F}}{16\pi\, m_\chi^2}$$

- cosmological bound implies

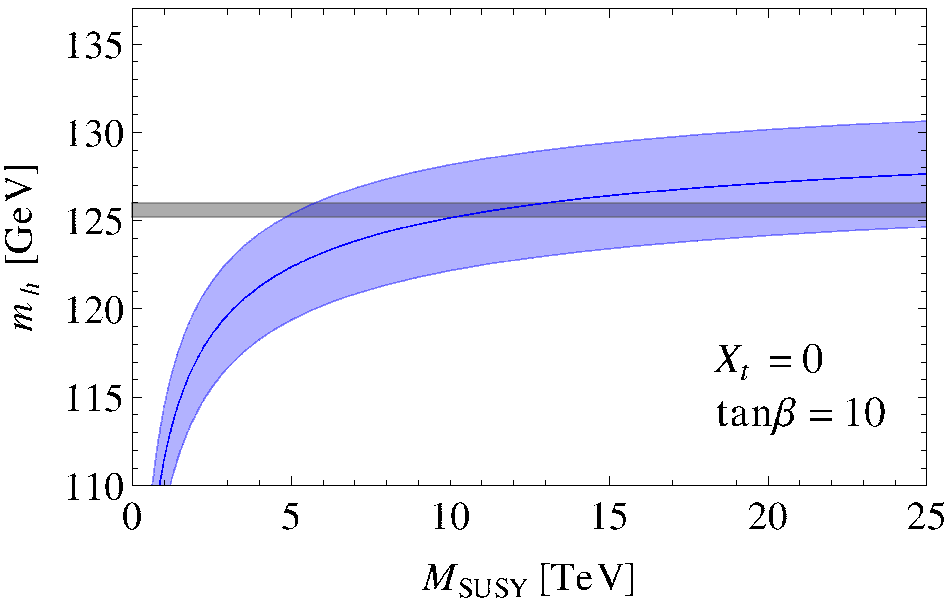
$$g_{\rm eff}^2\,\mathcal{F} > 1$$

$\hookrightarrow$ huge coupling, resonance

Higgs in the MSSM

- discovery of the Higgs boson with $m_h = 126$ GeV

  ATLAS, CMS, Phys. Lett. **B716** (2012)



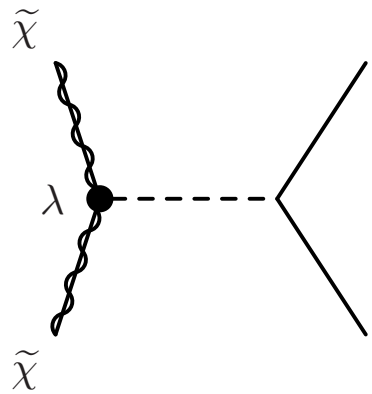
- requires $M_{\rm SUSY} \gg$ TeV in the MSSM

The NMSSM

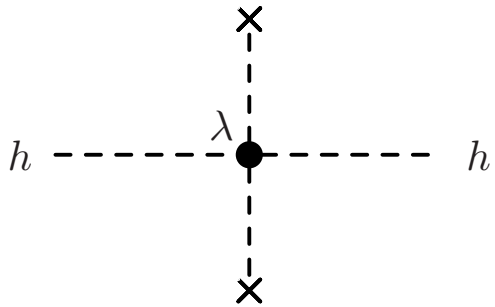
- extend MSSM by singlet superfield $S = (\widetilde{s}, h_s, a_s)$, impose Z_3

$$W = \lambda S H_u H_d + \frac{\kappa}{3} S^3$$

- large coupling λ



drives
$\widetilde{\chi}$ - annihilation



enhances
Higgs mass

Neutralino Annihilation

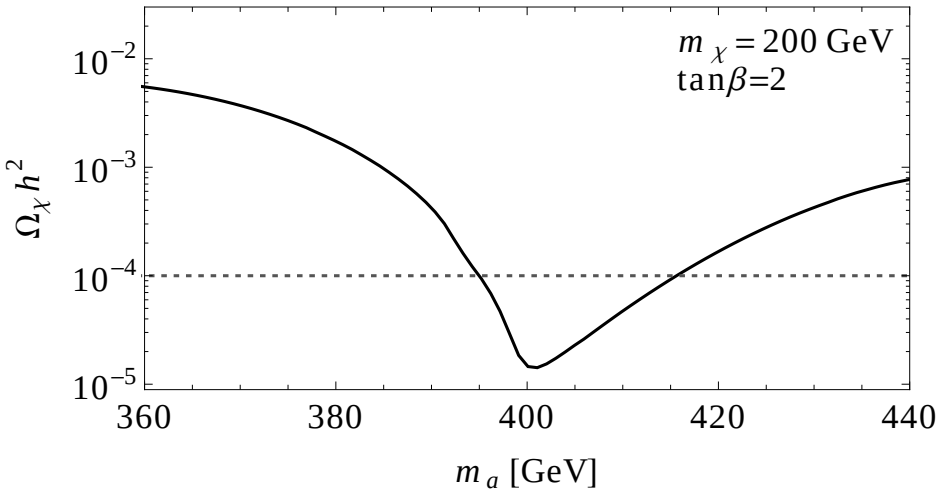
- promising annihilation channel $\widetilde{\chi}\widetilde{\chi} \to a^* \to \bar{t}t$

$$\sigma v \propto \frac{g_{a\chi\chi}^2 \, y_t^2 \, \cot\beta^2}{(s - m_a^2)^2} \qquad \text{with} \qquad g_{a\chi\chi} \sim \lambda \, \mathrm{N}_{14}\mathrm{N}_{15}$$

- perturbativity constraint on λ

  Haber et al., Phys. Rev. **D35** (1987), Espinosa et al., Phys. Lett. **B279** (1992)

  $\hookrightarrow$ mild resonant enhancement for $\Omega_\chi h^2 \sim 10^{-4}$



- $\mathcal{O}(10\%)$ tuning of m_a required, less than in MSSM

Higgs Mass

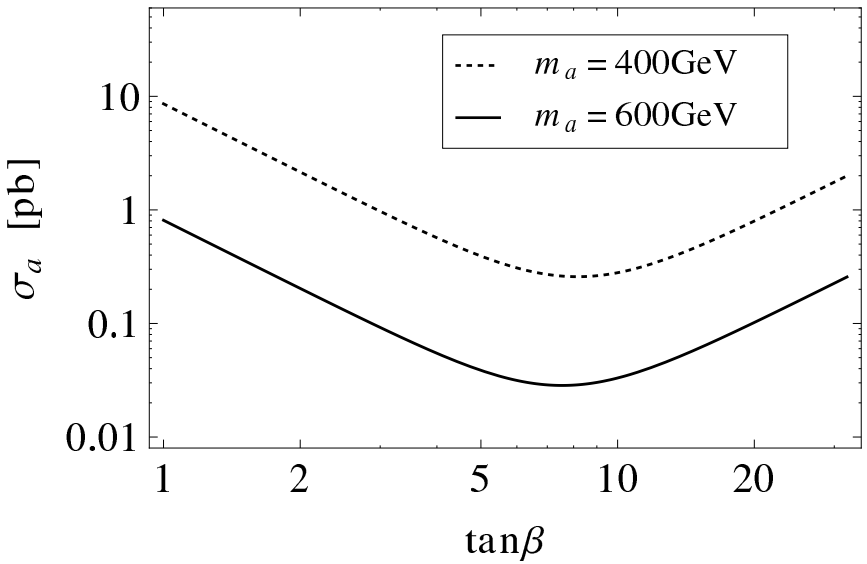
- tree-level Higgs mass

$$m_{h_1}^2 \simeq M_Z^2 \cos^2 2\beta + \lambda^2 v^2 \sin^2 2\beta - \frac{\lambda^4 v^2}{\kappa^2}\left(1 - \frac{m_a^2 \sin^2 2\beta}{4\,\mu^2}\right)^2$$

- $m_{h_1} > M_Z$ and $\mu \gtrsim 2\,m_a$ predicts

$$\tan\beta = 1.4 - 2$$

- production cross section of the doublet pseudoscalar at LHC-8:

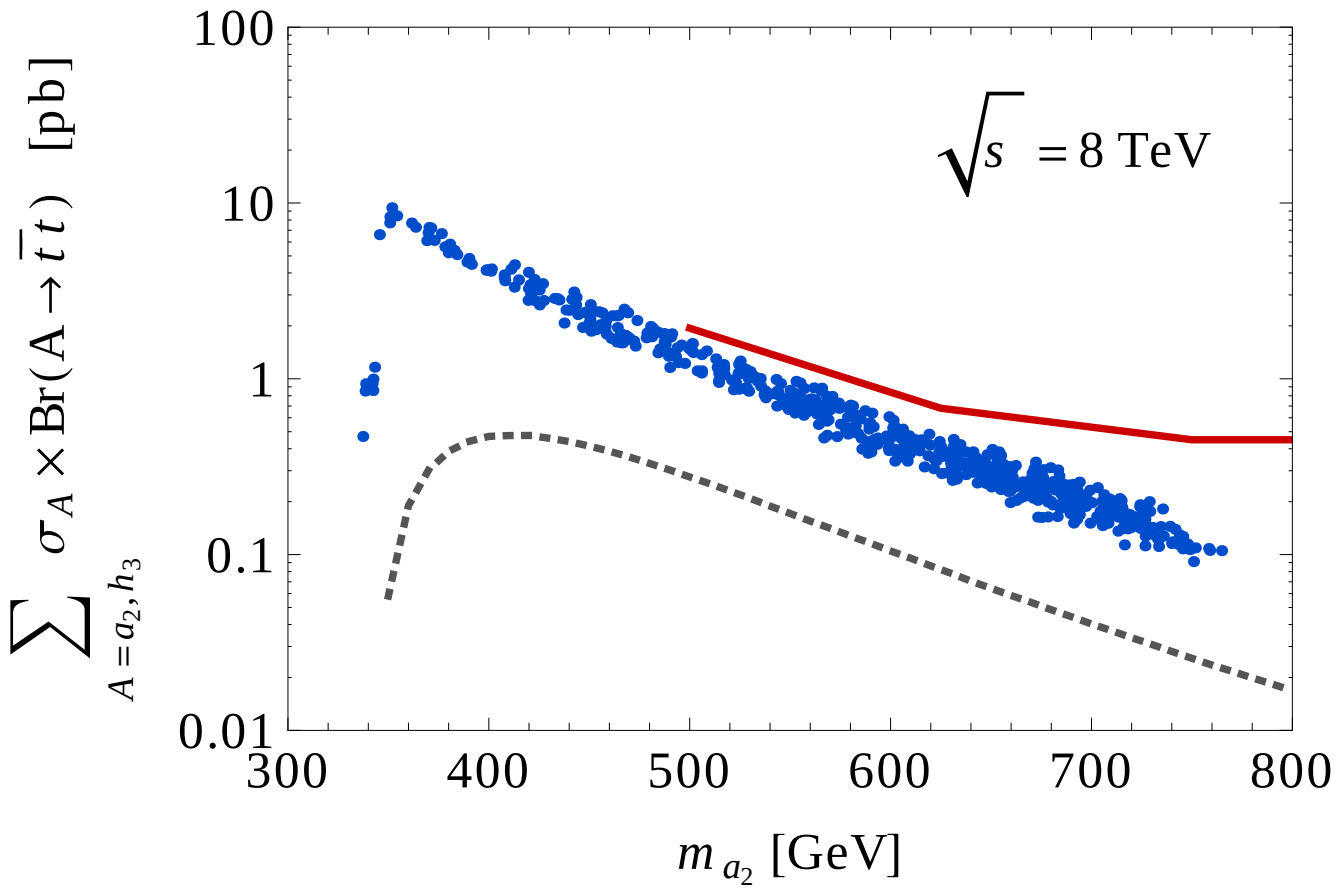


large σ_a

Heavy Higgs Searches

- search channels $a \to \bar{t}t, H \to \bar{t}t$ very promising
- not covered in Higgs searches, but by EXOTICS (Z', KK gluon)

  ATLAS-CONF-2013-052, CMS-PAS-B2G-12-006



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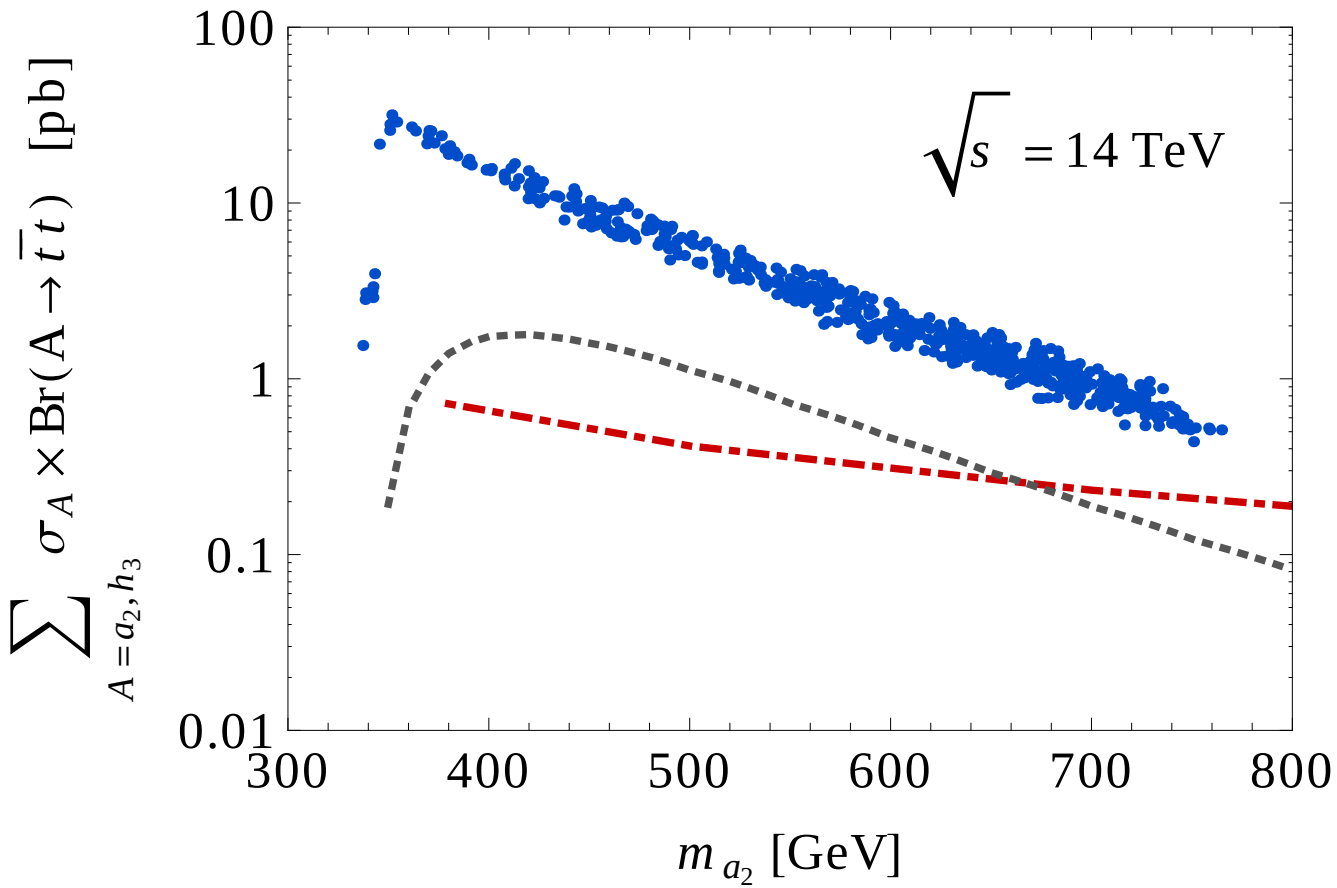
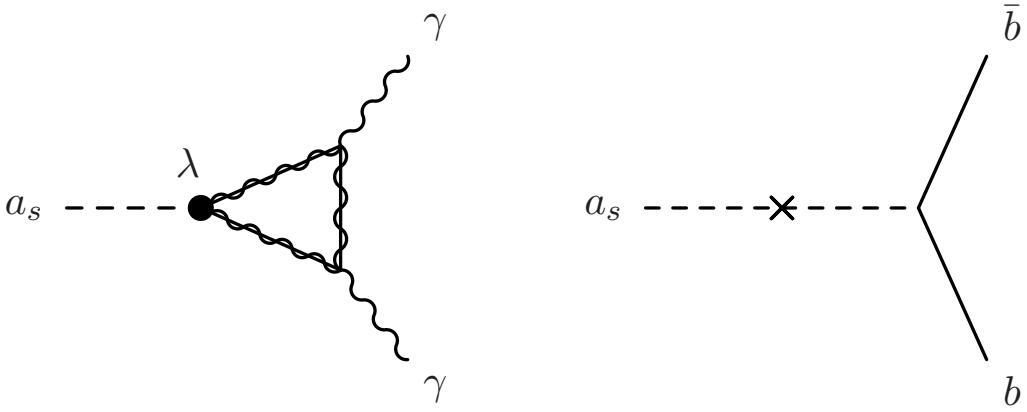
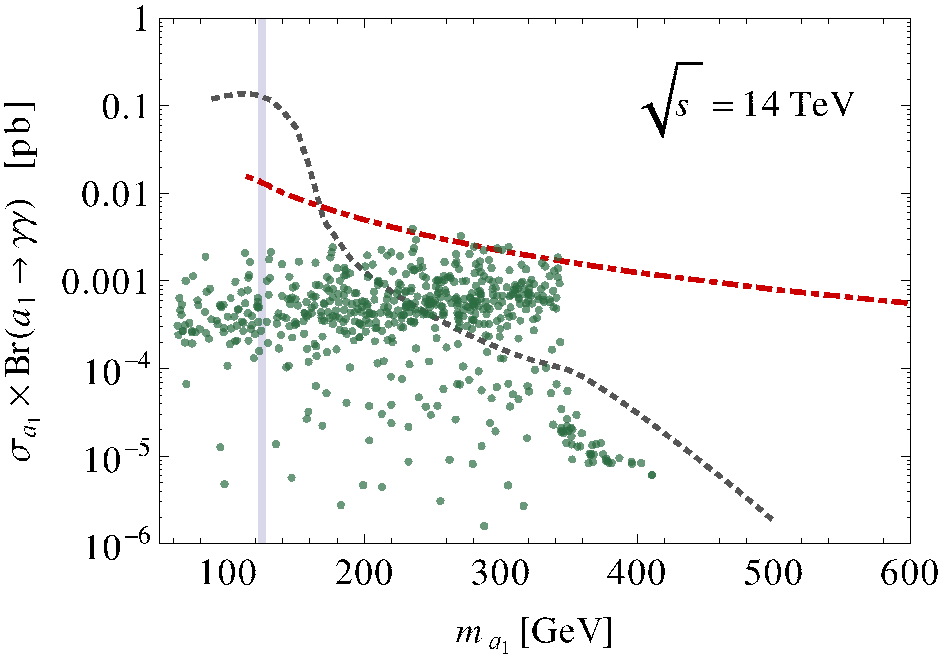


Singlet Higgs Searches

- singlet-like pseudoscalar large Br($a_s \to \gamma\gamma$)





- gluon fusion of a_s suppressed

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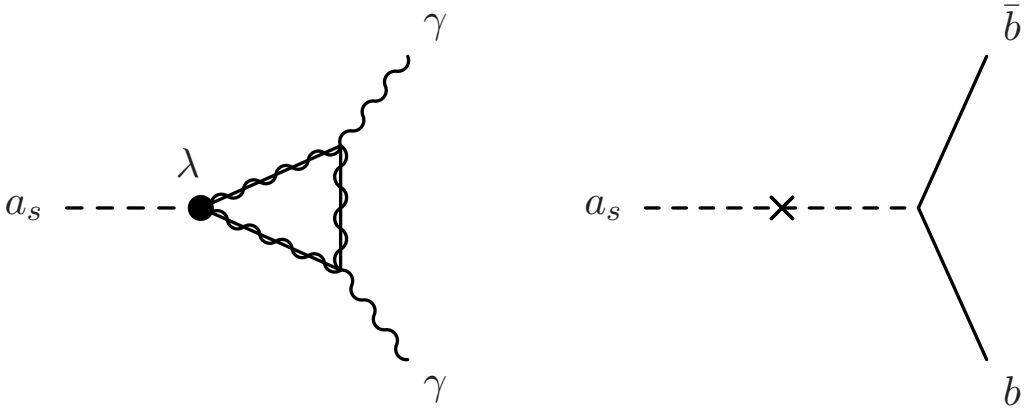

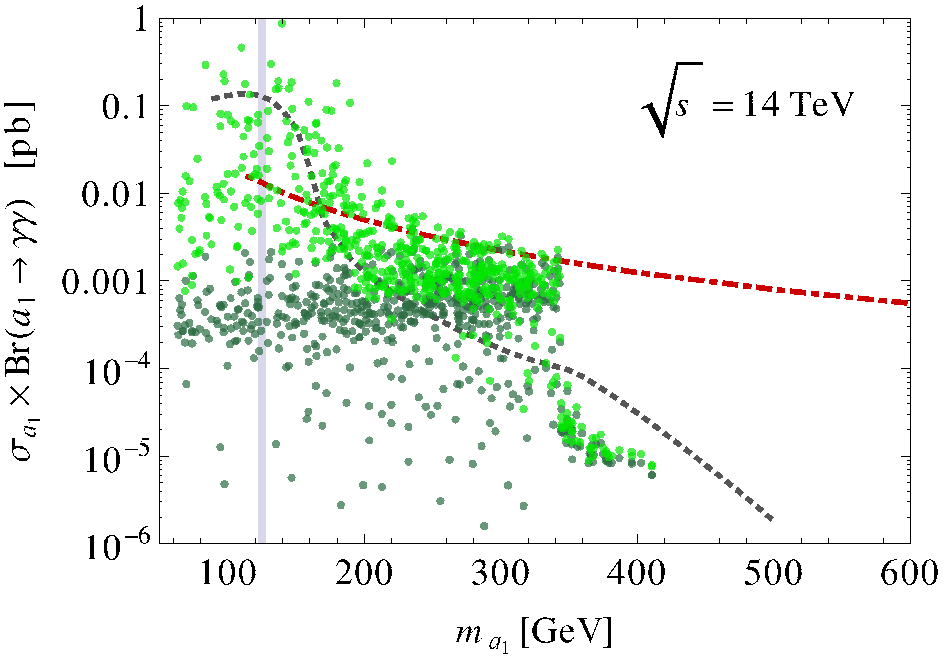

- gluon fusion of a_s suppressed
- **but:** production via a,H-decay

Conclusion

- strong cosmological constraints on long-lived NLSPs
- $\Omega_\chi h^2$ of singlino/higgsino NLSP in NMSSM can be highly suppressed
- cosmological bounds can be satisfied (10% tuning of m_a)
- responsible coupling $\lambda S H_u H_d$ simultaneously enhances m_h
- prediction: detection of pseudoscalar in search for $\bar{t}t$-resonances