The Primordial Abundance of Stau NLSPs

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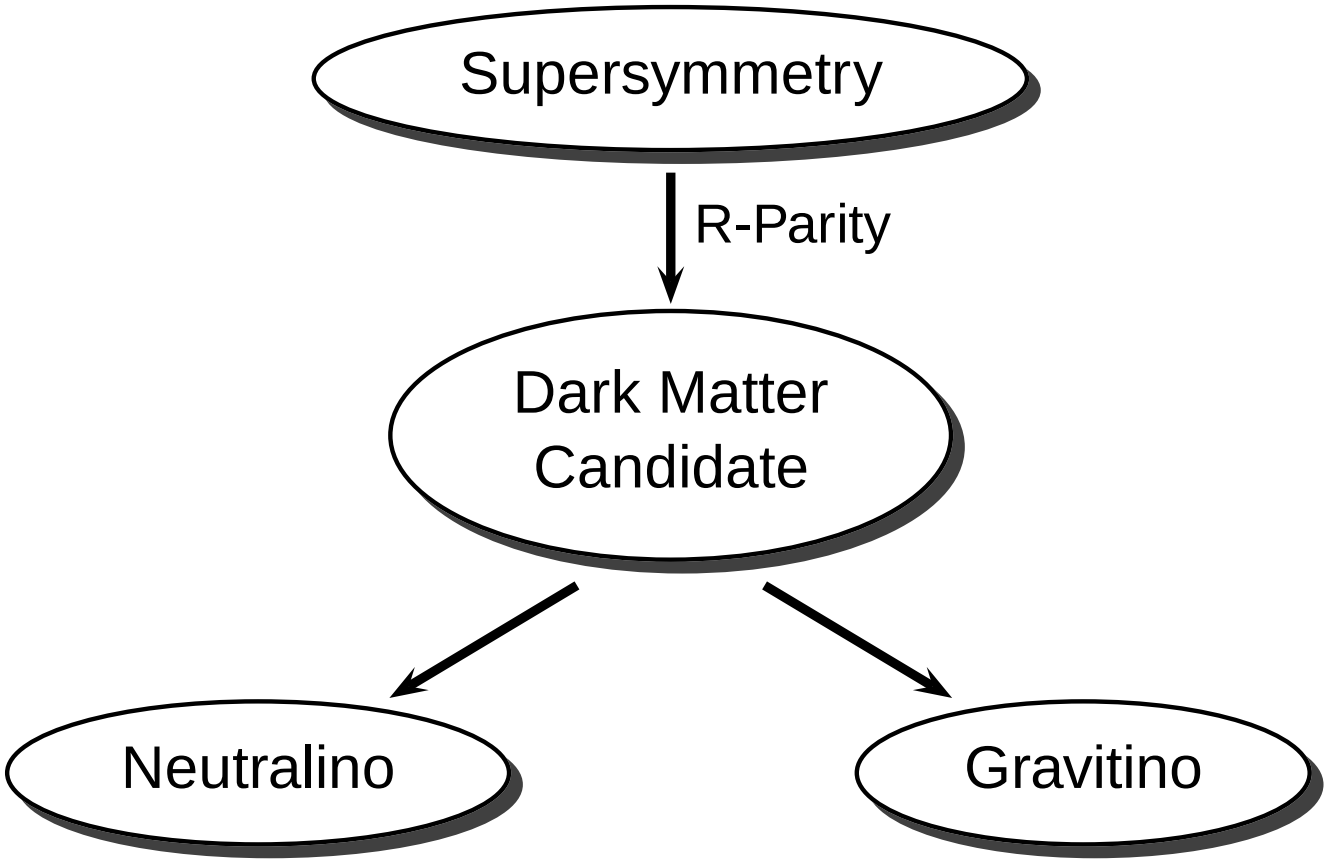
In Collaboration with M. Ratz and K. Schmidt-Hoberg

Journal of Cosmology and Astroparticle Physics (10/2008)

PASCOS
July 6, 2009

SUSY Dark Matter



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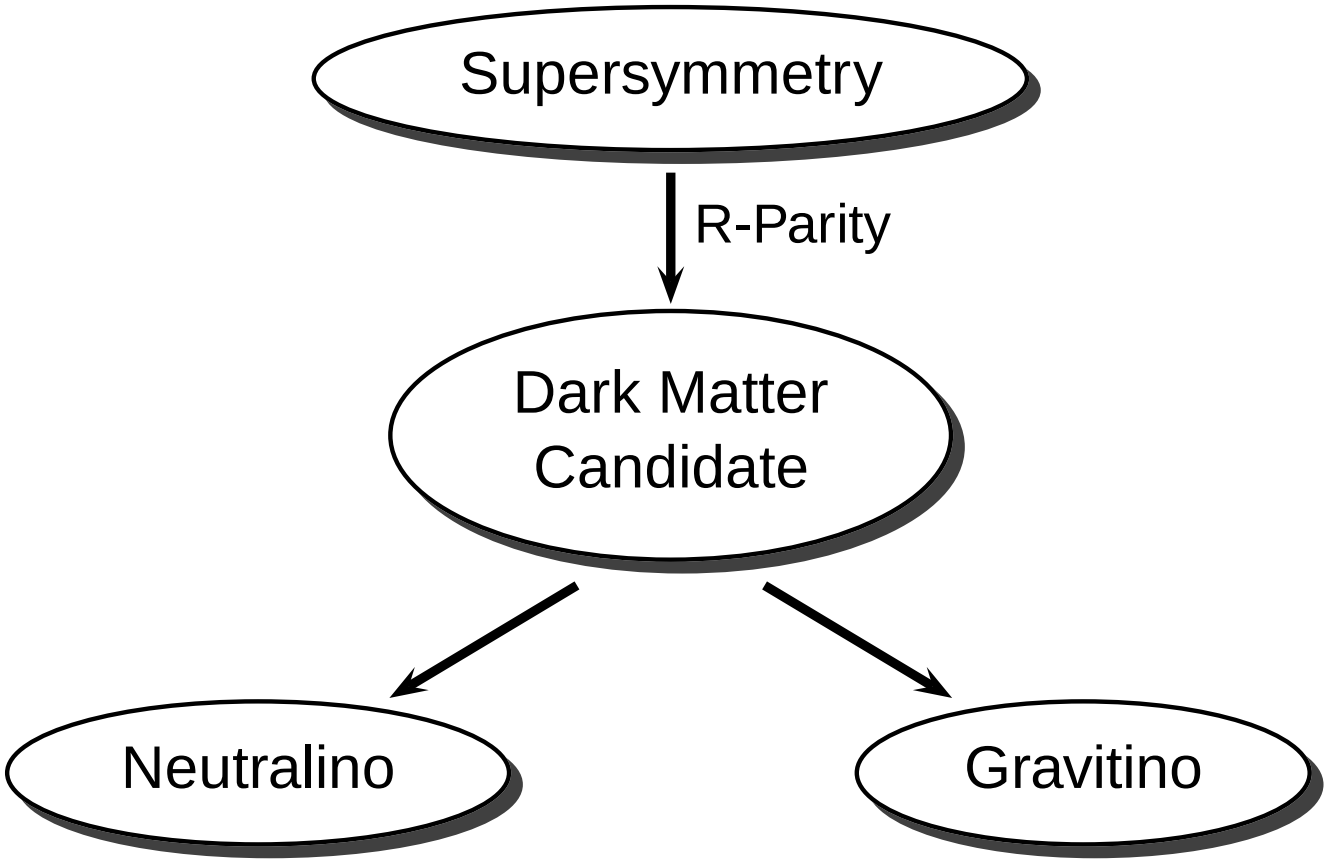


Stau NLSP

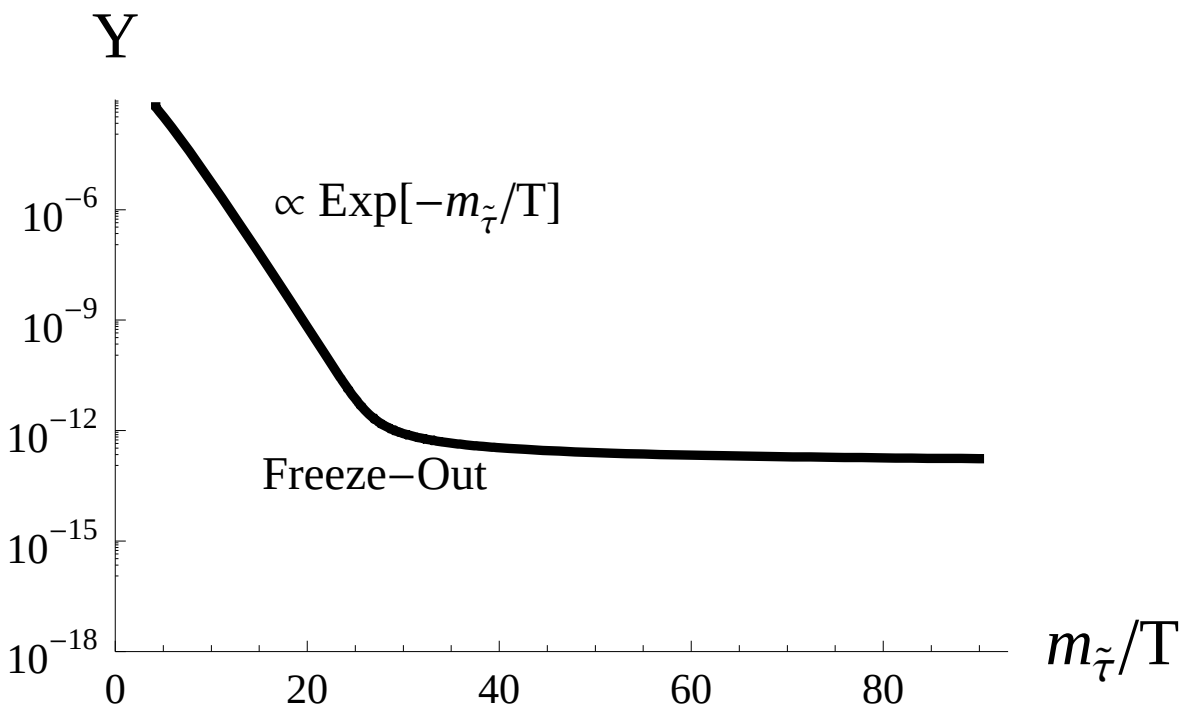
Neutralino NLSP

Sneutrino NLSP

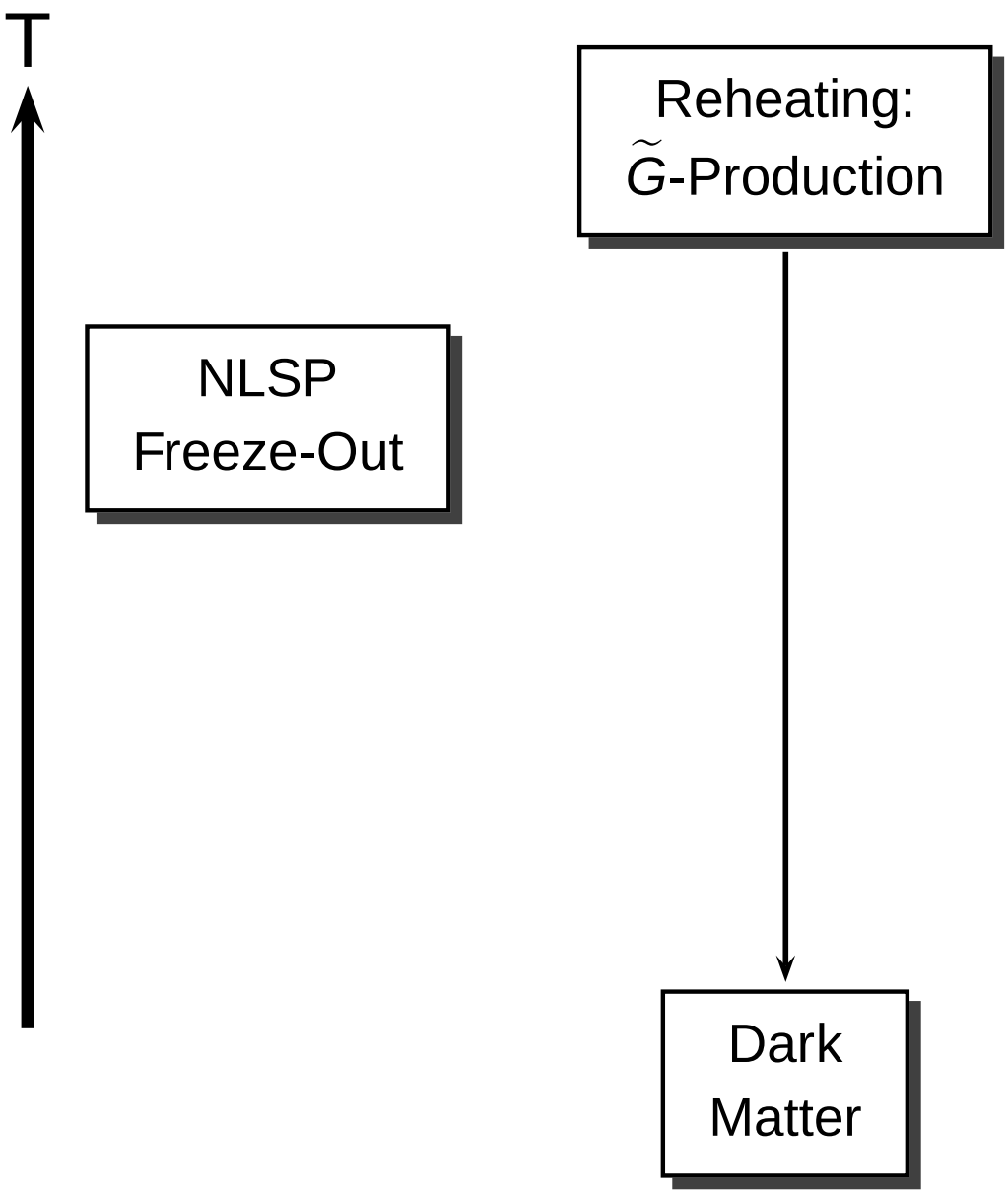
Outline

Early Universe

- Gravitinos produced at the end of inflation $\Rightarrow$ Dark Matter
  Bolz, Brandenburg, Buchmüller, Nucl. Phys. **B606** (2001)
- SM superpartners cascade into stau NLSPs
- Stau abundance decreases till freeze-out



BBN and the Gravitino



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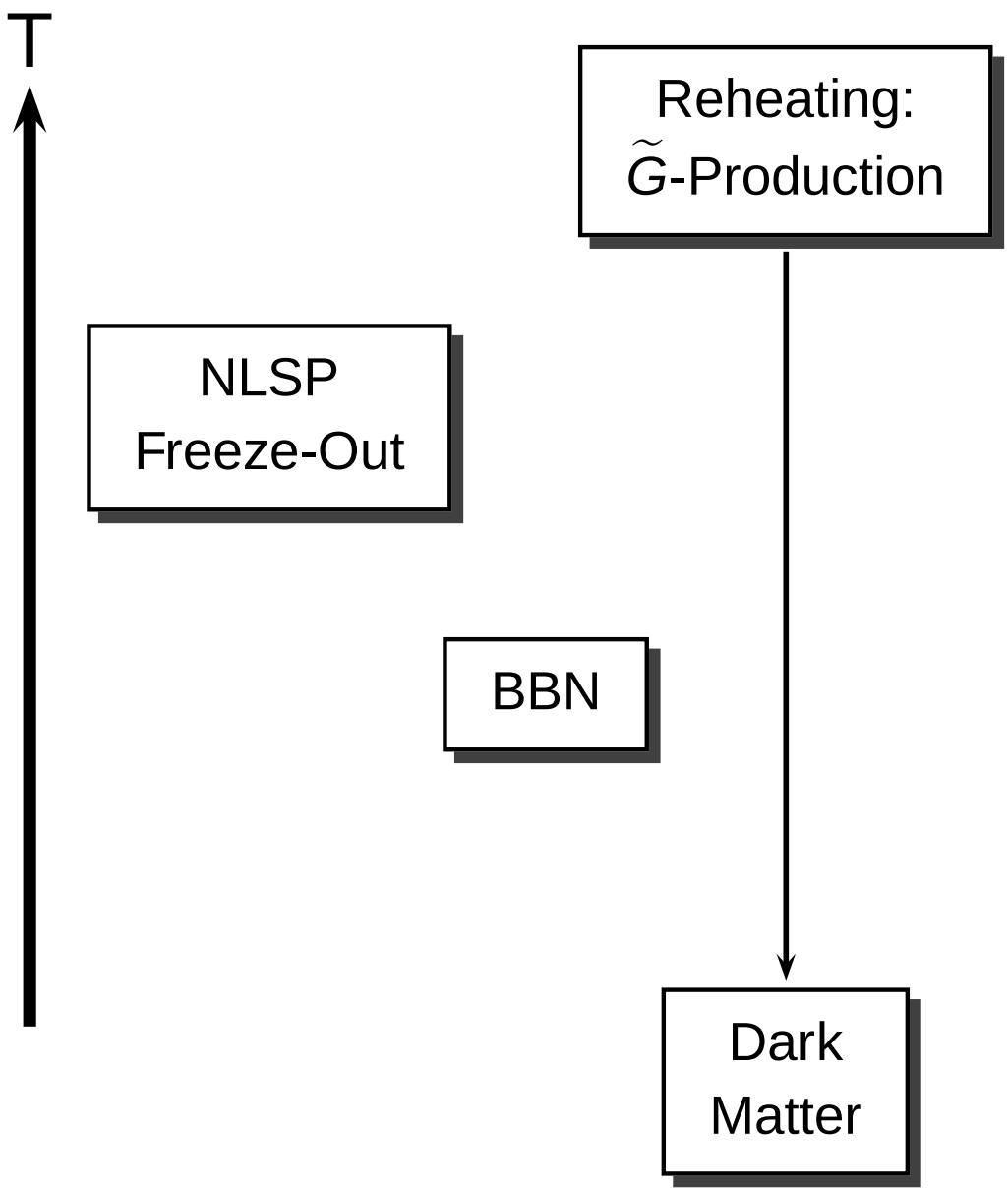
- BBN
  $\Rightarrow$ Light elements



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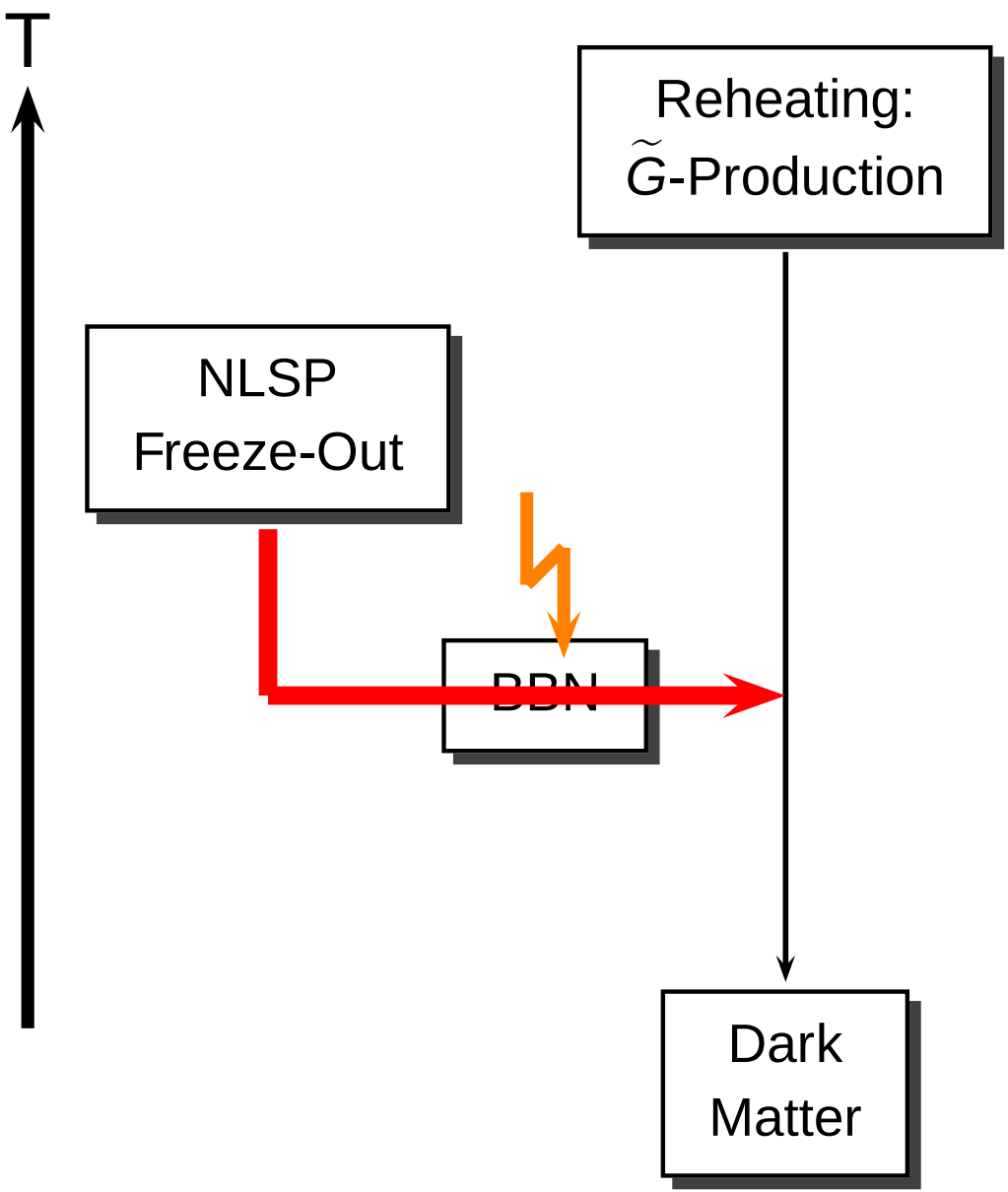

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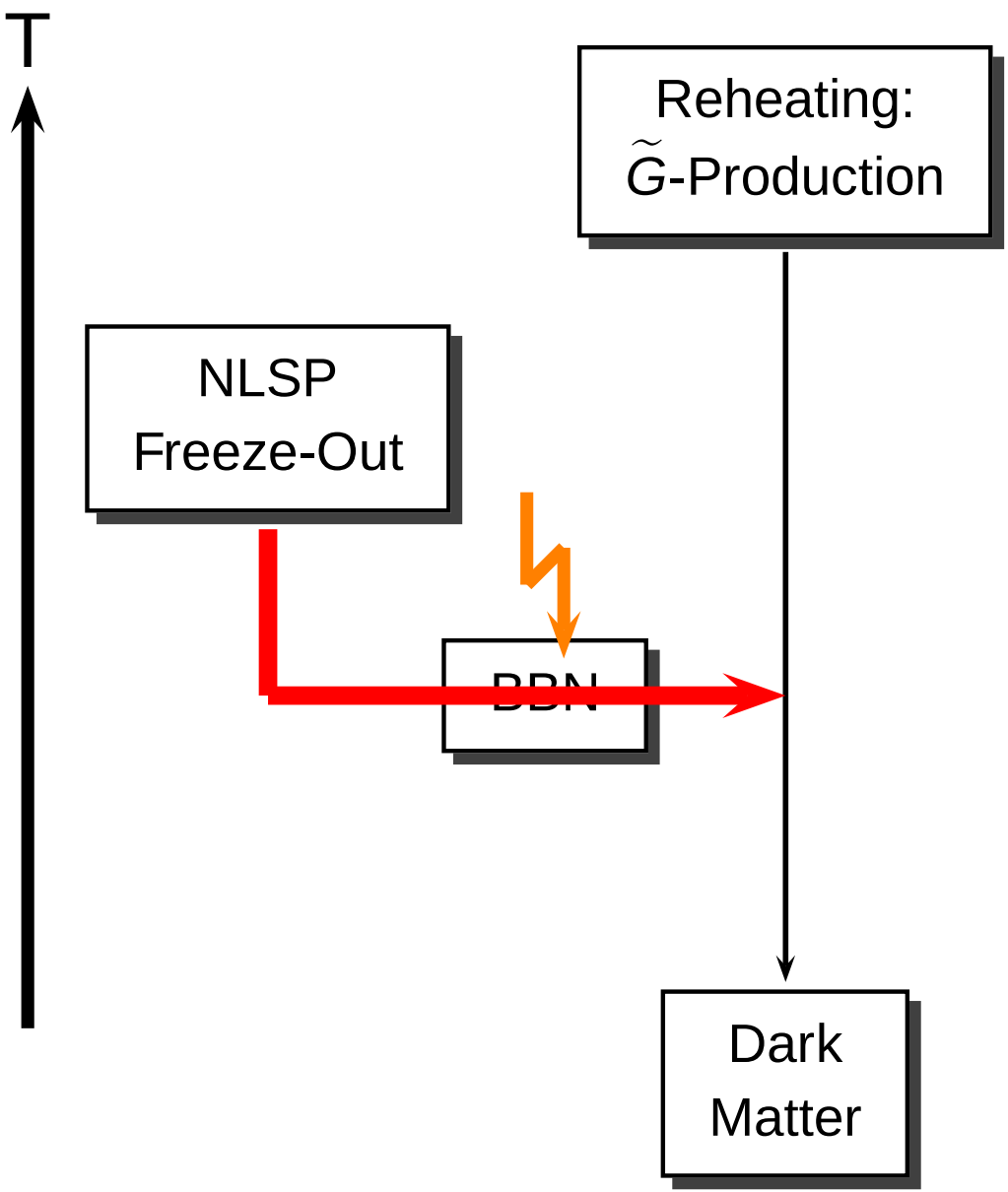
  Steffen, JCAP **09** (2006),
  Jedamzik, Phys. Rev. **D74** (2006)
- Staus form bound states

  Pospelov, Phys. Rev. Lett. **98** (2007)

  $$({}^4He - \widetilde{\tau}) + D \rightarrow {}^6Li + \widetilde{\tau}$$



The BBN-Problem

- Cosmological bound (for $\tau_{\tilde{\tau}} \gtrsim 10^4 s$):

  Kawasaki, Kohri, Moroi, Phys. Lett. **B649** (2007),
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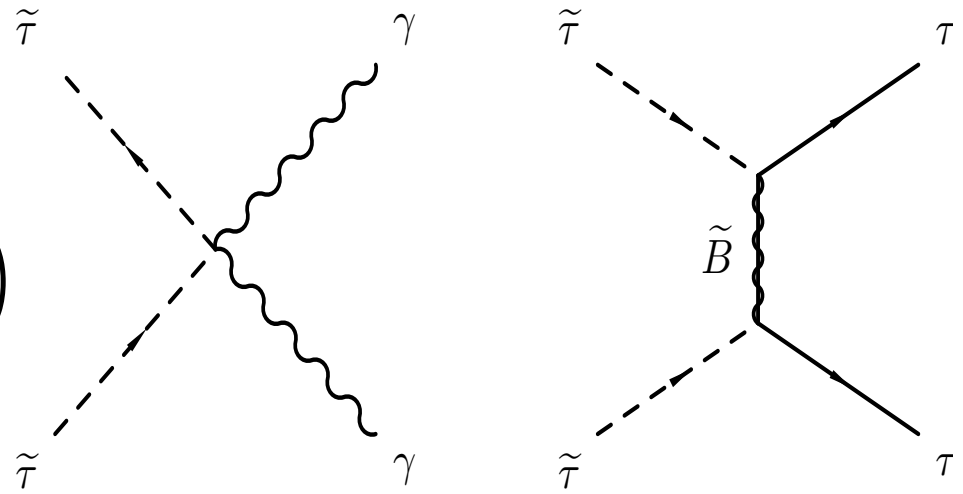
- Problem:
  Right-handed $\tilde{\tau}$
  $\Rightarrow$ Small couplings

$$Y_{\tilde{\tau}} \sim 10^{-13} \times \left(\frac{m_{\tilde{\tau}}}{140\,\text{GeV}} \right)$$

Asaka, Hamaguchi, Suzuki,
Phys. Lett. **B490** (2000)



Solutions to the BBN-problem

Previous solutions:

- Short $\tau_{\tilde{\tau}}$:
  - $\tau_{\tilde{\tau}} \sim 10^7\,\mathrm{s} \left(\frac{250\,\mathrm{GeV}}{m_{\tilde{\tau}}}\right)^5 \left(\frac{m_{\tilde{G}}}{100\,\mathrm{GeV}}\right)^2$

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  - R-Parity violation

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    Buchmüller, Covi, Hamaguchi, Ibarra, Yanagida, JHEP **03** (2007)

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- Late time entropy production

  Buchmüller, Hamaguchi, Ibe, Yanagida, Phys. Lett. **B643** (2006)

Enhanced Coupling - The Higgs Channel

Can the $\widetilde{\tau}$ have stronger couplings?

- $\mathcal{L} = y^{\tau}\,\mu\,h_2^0\,\widetilde{\tau}_L\,\widetilde{\tau}_R^* + h.c.$ (from F_{h_1})

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- After EWSB: mixing of the chiral states

$$\mathcal{M}_{\widetilde{\tau}} = \begin{pmatrix} m^2_{\widetilde{\tau}_L} & -y^\tau \mu \langle h_2 \rangle \\ -y^\tau \mu \langle h_2 \rangle & m^2_{\widetilde{\tau}_R} \end{pmatrix}, \qquad y^\tau \sim 0.5 \left(\frac{\tan\beta}{50} \right)$$

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$$\widetilde{\tau}_1 = \cos\theta_{\widetilde{\tau}} \, \widetilde{\tau}_L + \sin\theta_{\widetilde{\tau}} \, \widetilde{\tau}_R$$

- Coupling between h and $\widetilde{\tau}_1$ (decoupling limit):

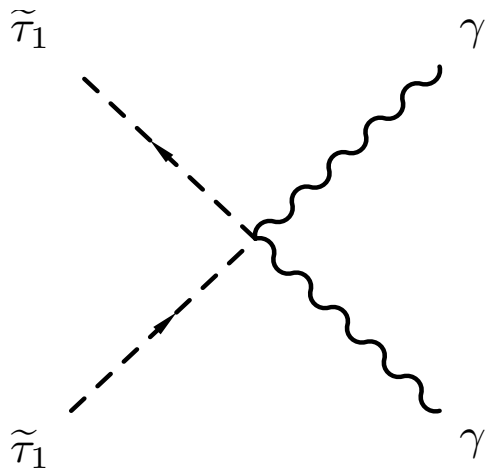
$$\mathcal{L} = \frac{y^\tau \, \mu}{\sqrt{2}} \sin 2\theta_{\widetilde{\tau}} \;\; h \, \widetilde{\tau}_1 \, \widetilde{\tau}_1^*$$

Can be very strong!

A Comparison

- Relic Abundance: $Y_{\widetilde{\tau}} \propto 1/\langle \sigma v \rangle$

Without Mixing



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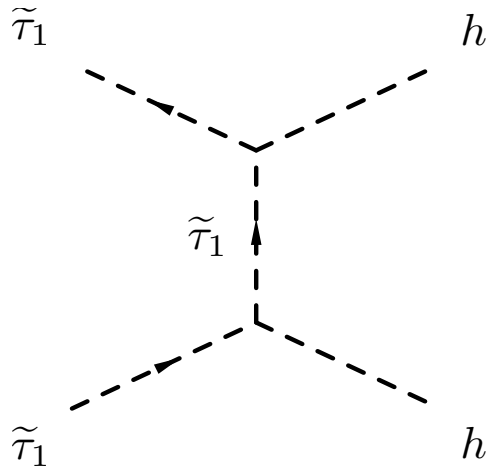

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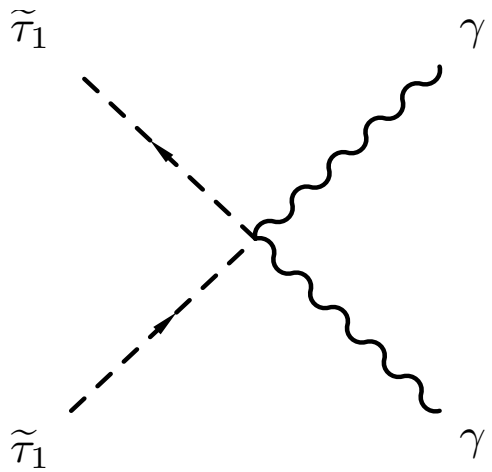

Y $\sim$ 10^{-13}

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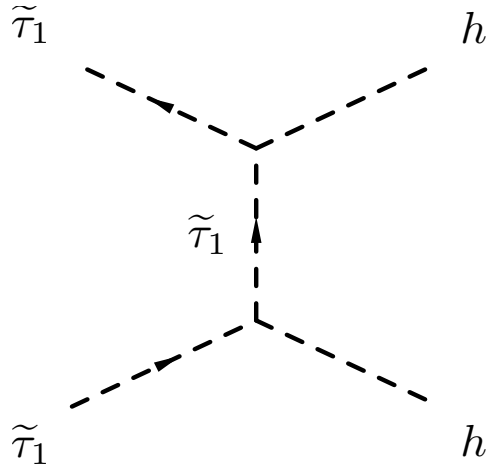
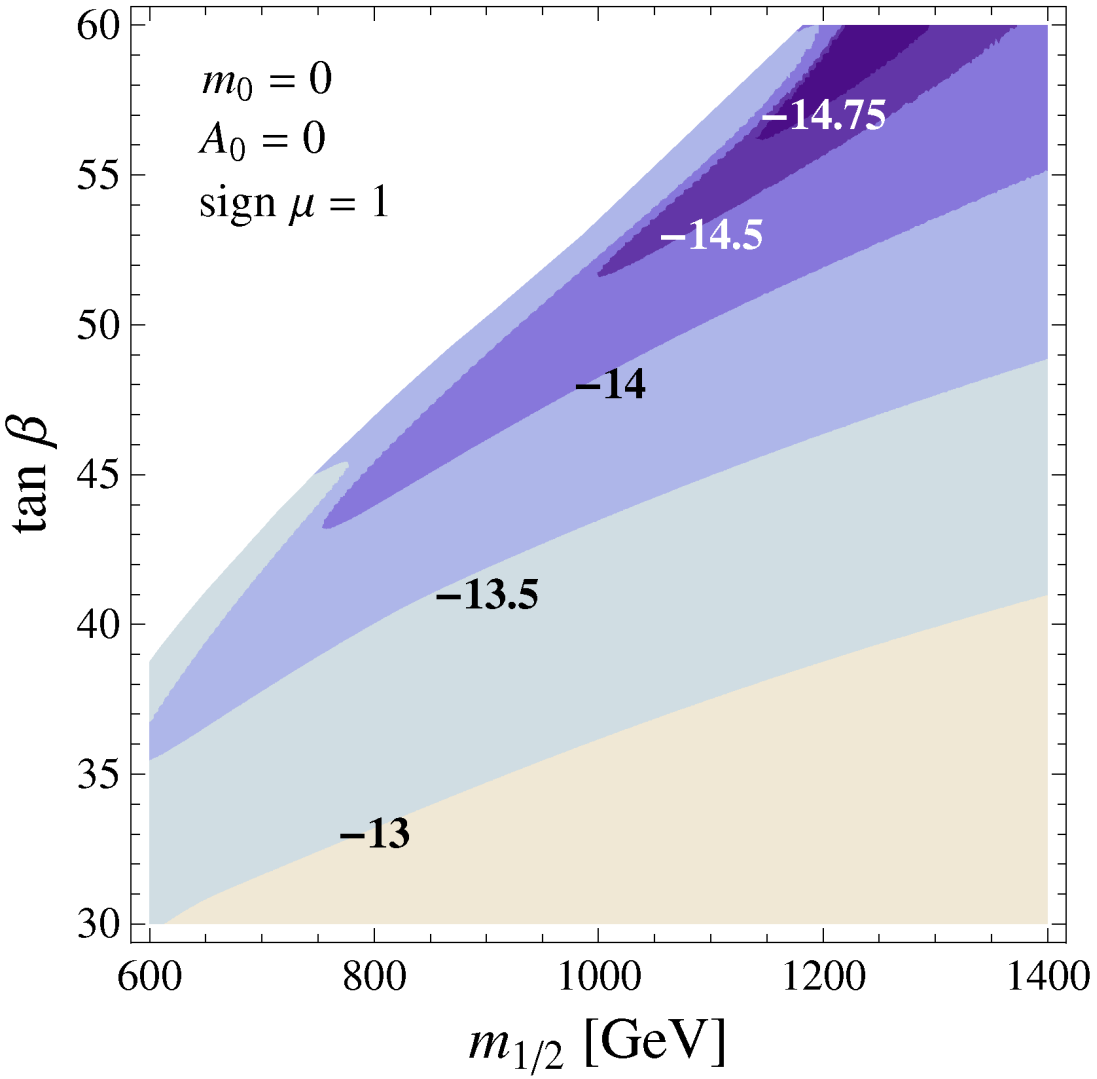


Y $\sim$ 10^{-15}

(Cosmological bound: 2×10^{-15})

Relic Abundance in the CMSSM



- Lower Limit: $Y_{\tilde{\tau}} \sim 10^{-15}$ (Vacuum Stability)

LHC

- Production of long-lived staus
  - $\longrightarrow$ Decay chains of colored superpartners
  - $\longrightarrow$ Drell-Yan production: $q + \bar{q} \longrightarrow \widetilde{\tau} + \widetilde{\tau}^*$
- Measure stau-Higgs-coupling
- Trapping of staus in extra detector

  Hamaguchi, Kuno, Nakaya, Nojiri, Phys. Rev. **D70** (2004)

  - $\longrightarrow$ Decay of staus: gravitino = LSP

    Buchmüller, Hamaguchi, Ratz, Yanagida, Phys. Lett. **B588** (2004)

Conclusion

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- All ingredients of this scenario will be tested at LHC