Adapted from 1974 drawings by K. Dobrowolski illustrating a popular article on particle physics by G. Białkowski

Gravitino dark matter with constraints from Higgs mass and sneutrino decays

Krzysztof Turzyński

(Faculty of Physics, University of Warsaw)

with: L. Roszkowski, S. Trojanowski & K. Jedamzik, 1212.5587, JHEP 1303 (2013) 013;

earlier with: L. Covi, Z. Lalak, M. Olechowski, S. Pokorski, J. Wells 2008-11,
JHEP 0810 (2008) 016, 0912 (2009) 026, 1101 (2011) 033

WIMP

O(100) GeV weakly interacting massive particle

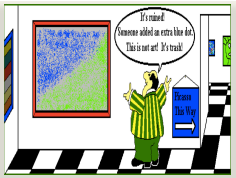
- (the lightest) neutralino: neutral fermionic partner of a gauge/higgs boson in MSSM
- very constraining in (already) constrained models

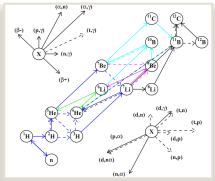
EWIMP

an extremely weakly interacting massive particle

- gravitino: spin 3/2 neutral fermion prese in supergravity embedding of supersymmetric theories

WIMP vs EWIMP dark matter





reheating of the Universe

generation of baryon asymmetry

LHC

nucleosynthesis (BBN)

$10^{9}\ \mathrm{GeV}$

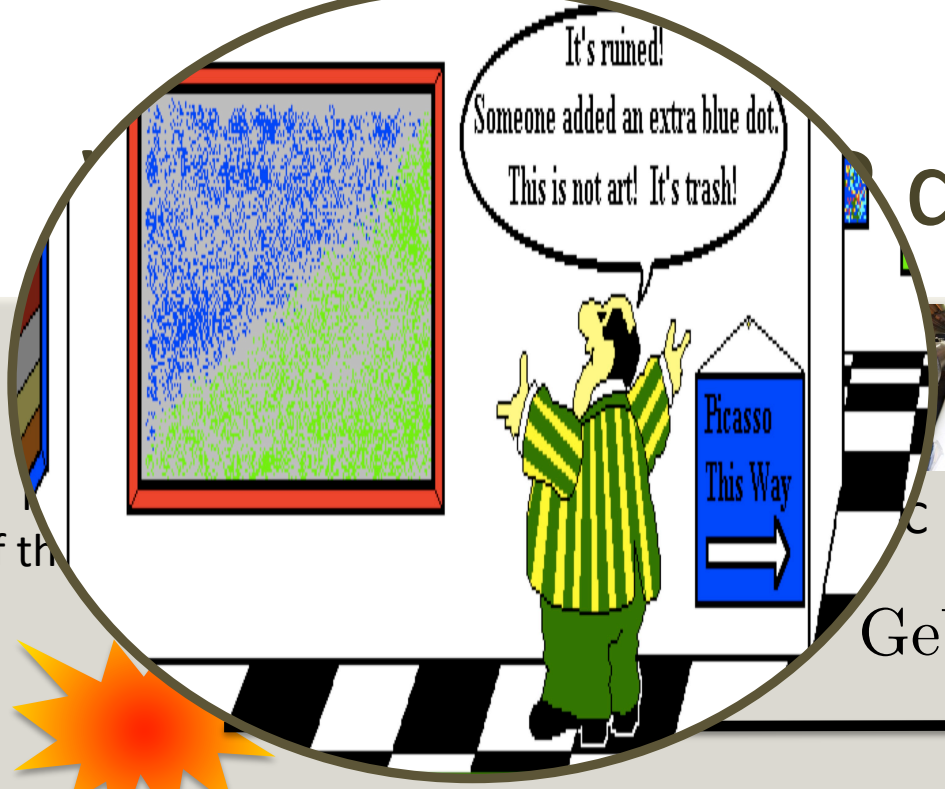
$10^{3}\ \mathrm{GeV}$

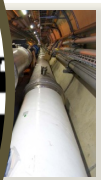
$10^{-5}\ \mathrm{GeV}$

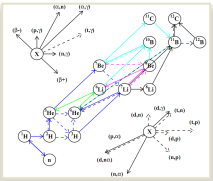
inflation

time

dark matter







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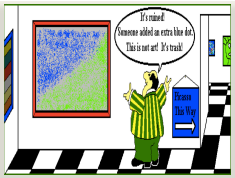
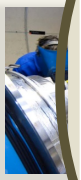
WIMP vs EWIMP





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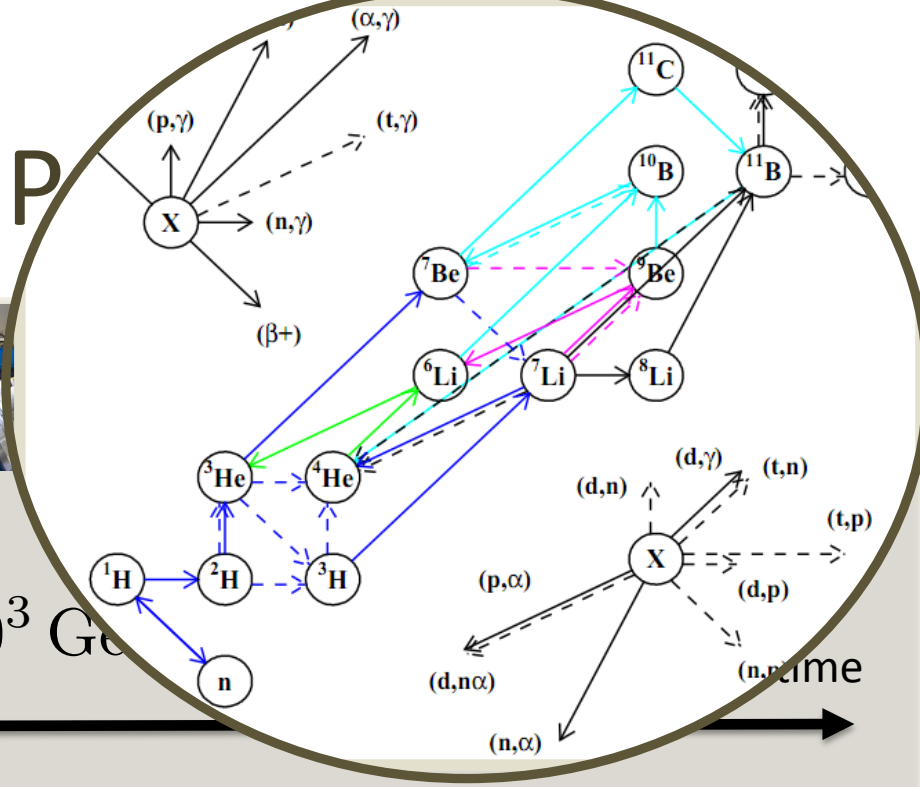

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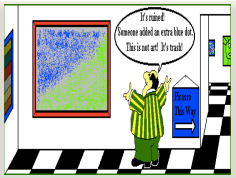
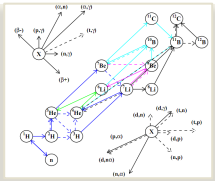
WIMP vs EWIMP dark matter





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production of (MS)SM states (incl. WIMP DM)

DM+DM ↔ SM+SM

~~DM+DM ↔ SM+SM~~

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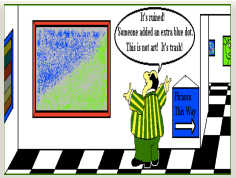

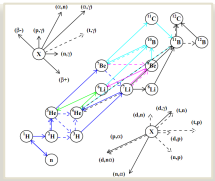

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gravitino EWIMP

production of (MS)SM states (excl. EWIMP DM)

SM+SM → DM+DM

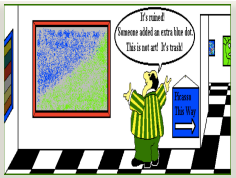
$\widetilde{\mathrm{SM}}$ → SM+DM

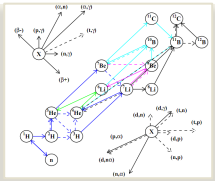
SM+nuclei → !!!

BBN bounds

lightest susy particle (with R-parity)

WIMP vs EWIMP dark matter





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thermal production

$\widetilde{\mathrm{SM}}$ → SM+DM

nonthermal production

$$\Omega^{\mathrm{TP}}h^2 \approx \left(\frac{T_{\mathrm{R}}}{10^8\,\mathrm{GeV}}\right)\left(\frac{1\,\mathrm{GeV}}{m_{3/2}}\right)\sum_r \gamma_r \left(\frac{M_r}{10^3\,\mathrm{GeV}}\right)^2$$

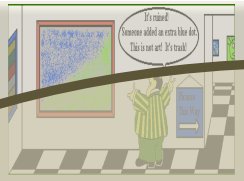
$$\gamma_r \sim \mathcal{O}(1)$$

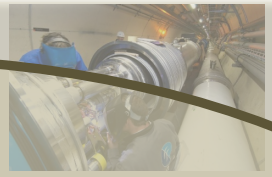
Bolz, Brandenburger, Buchmueller 2001, Pradler, Steffen 2006, Rychkov, Strumia 2007

$$\tau(\tilde{\mathrm{SM}} \to \tilde{G} + \mathrm{SM}) = 5.9 \cdot 10^3\,\mathrm{sec}\left(\frac{m_{3/2}}{100\,\mathrm{GeV}}\right)^2\left(\frac{10^3\,\mathrm{GeV}}{m_{\tilde{\mathrm{SM}}}}\right)^5$$

$$\Omega^{\mathrm{NTP}}h^2 = \frac{m_{3/2}}{m_{\tilde{\mathrm{SM}}}}\Omega_{\tilde{\mathrm{SM}}}h^2$$

WIMP vs EWIMP dark matter





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generation of baryon asymmetry

LHC

nucleosynthesis

10^{9} GeV

10^{3} GeV

10^{-7} GeV

time

inflation

$\widetilde{SM} \rightarrow SM+DM$

$q,\ g,\ \ell^{\pm},\ \nu,\ \gamma$

charged or neutral?

DM+DM ↔ SM+SM

DM+DM ↔ SM+SM

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gravitino EWIMP

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nonthermal production

Ideal candidate for NLSP companion of EWIMP dark matter?

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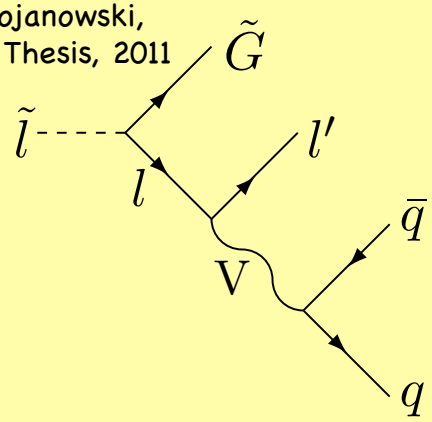
sneutrino!

Ideal candidate for NLSP companion of EWIMP dark matter?

S. Trojanowski, MSc Thesis, 2011



Full computation of this and 3 similar diagrams.

Full computation of sneutrino relic density

Calculations within Non-Universal Higgs Model and General Gauge Mediation

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- **colorless** (little colored particles among decay products suppresses hadrodissociation)
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  Covi, Olechowski, Pokorski, KT, Wells, 2011
- **realistic** (found in known models of supersymmetry breaking)

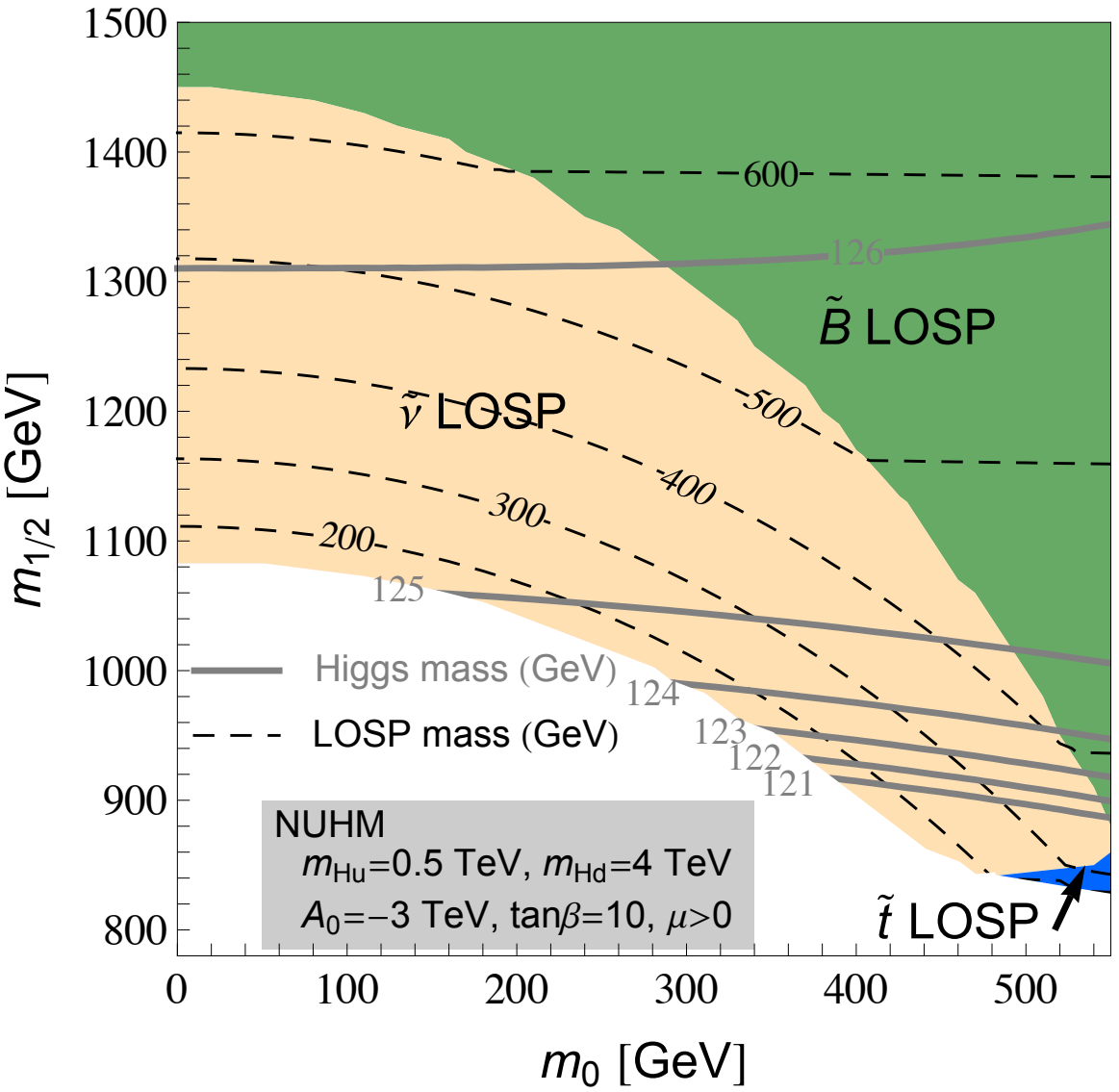
  Jeliński, Pawełczyk, KT, 2012 (F theory)

sneutrino!

~~SUSY~~ masses: NUHM

LOSP: Lightest Supersymmetric Ordinary Particle,
i.e. not gravitino DM

- **gluino heavier than ~2TeV, squarks also heavy, LHC limits**
- low-energy constraints



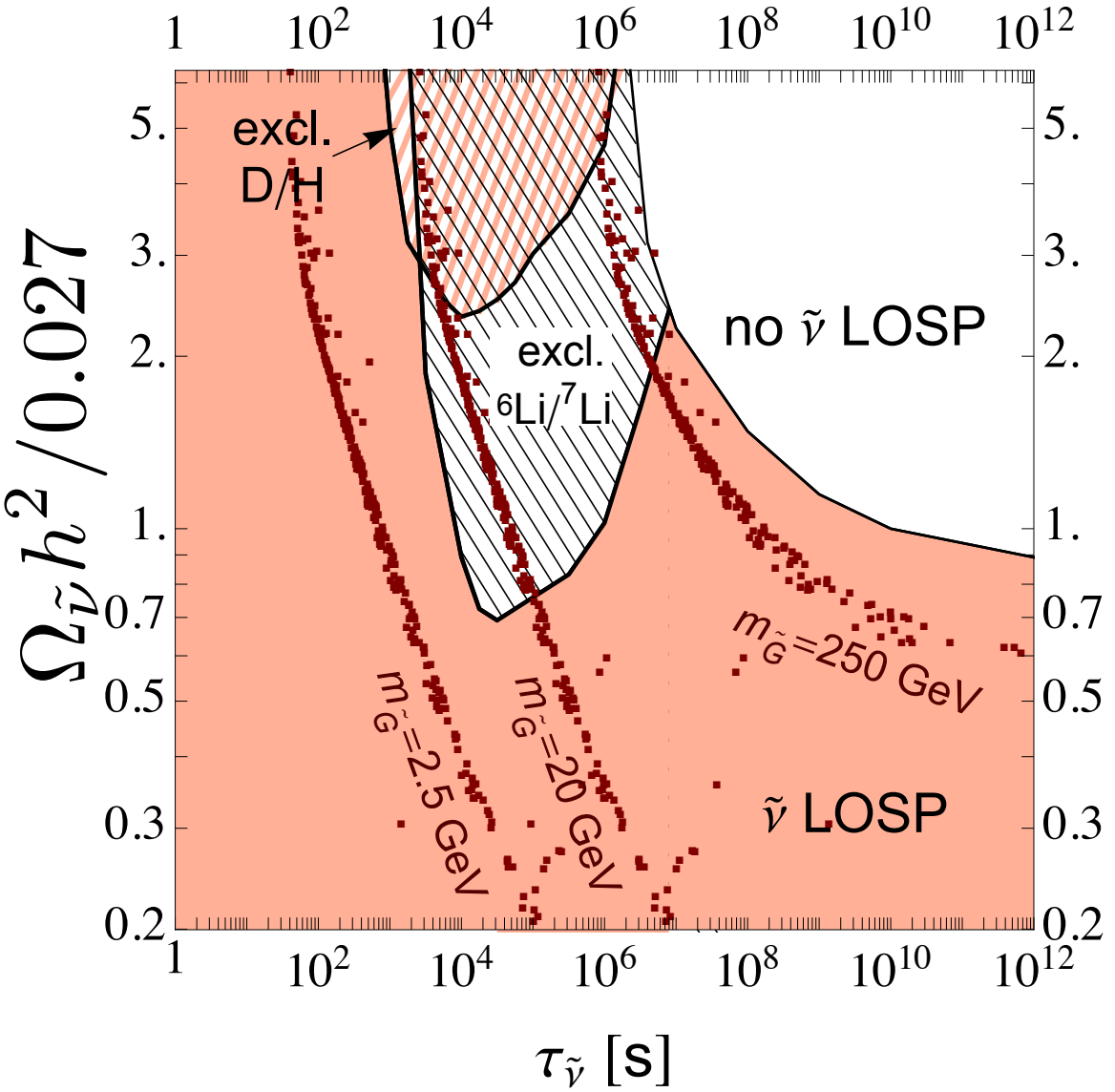
$\tilde{\nu}$ NLSP: BBN bounds

Parameter scaling:

$$\Omega_{\tilde{\nu}} h^2 \propto m_{\tilde{\nu}}^2$$

$$\tau_{\tilde{\nu}} \propto m_{3/2}^2 / m_{\tilde{\nu}}^5$$

$$\Omega_{\rm DM} h^2 \propto T_R m_{\tilde{\nu}}^2 / m_{3/2}$$



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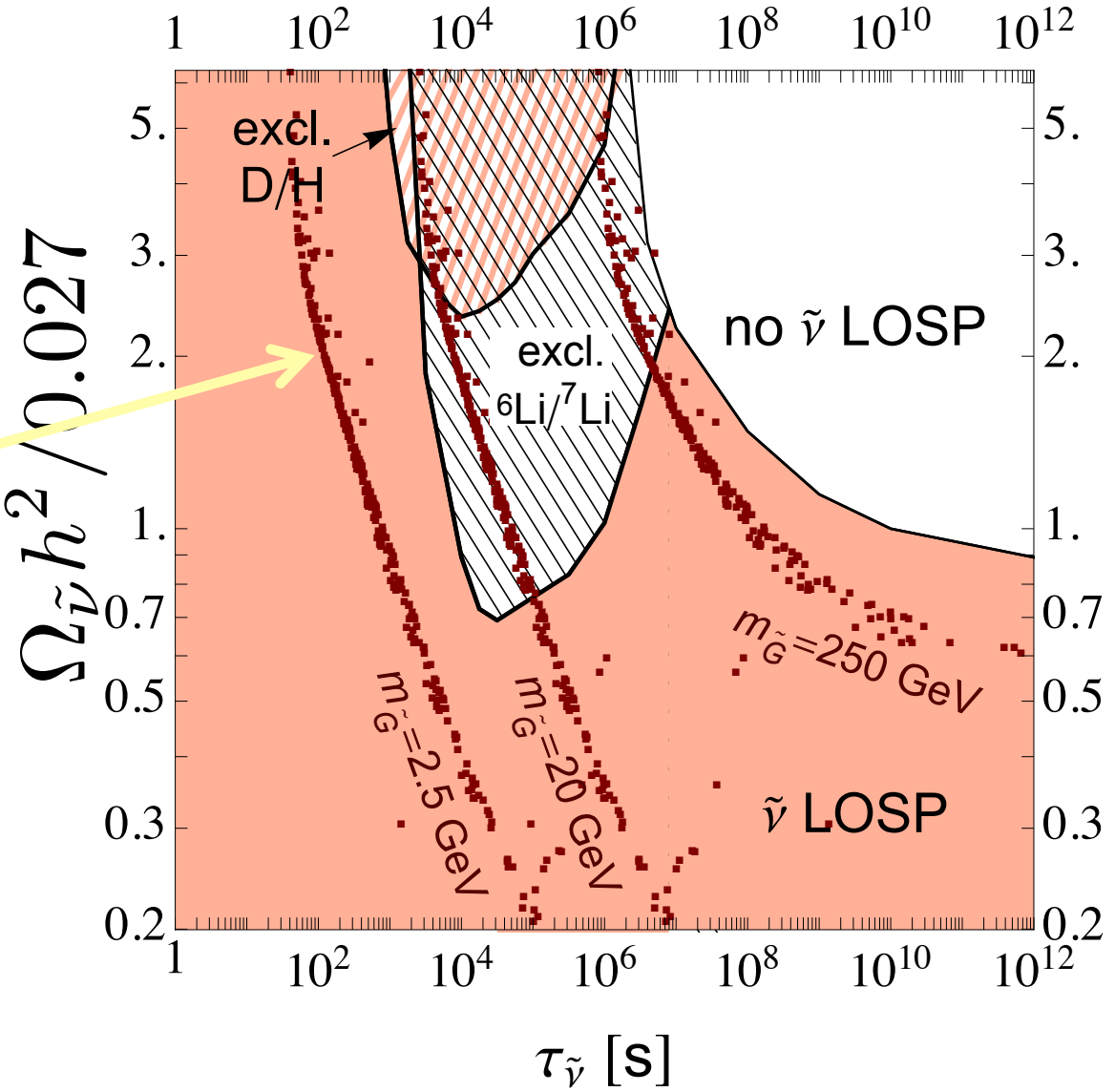
BBN safe, but too low reheating temperature



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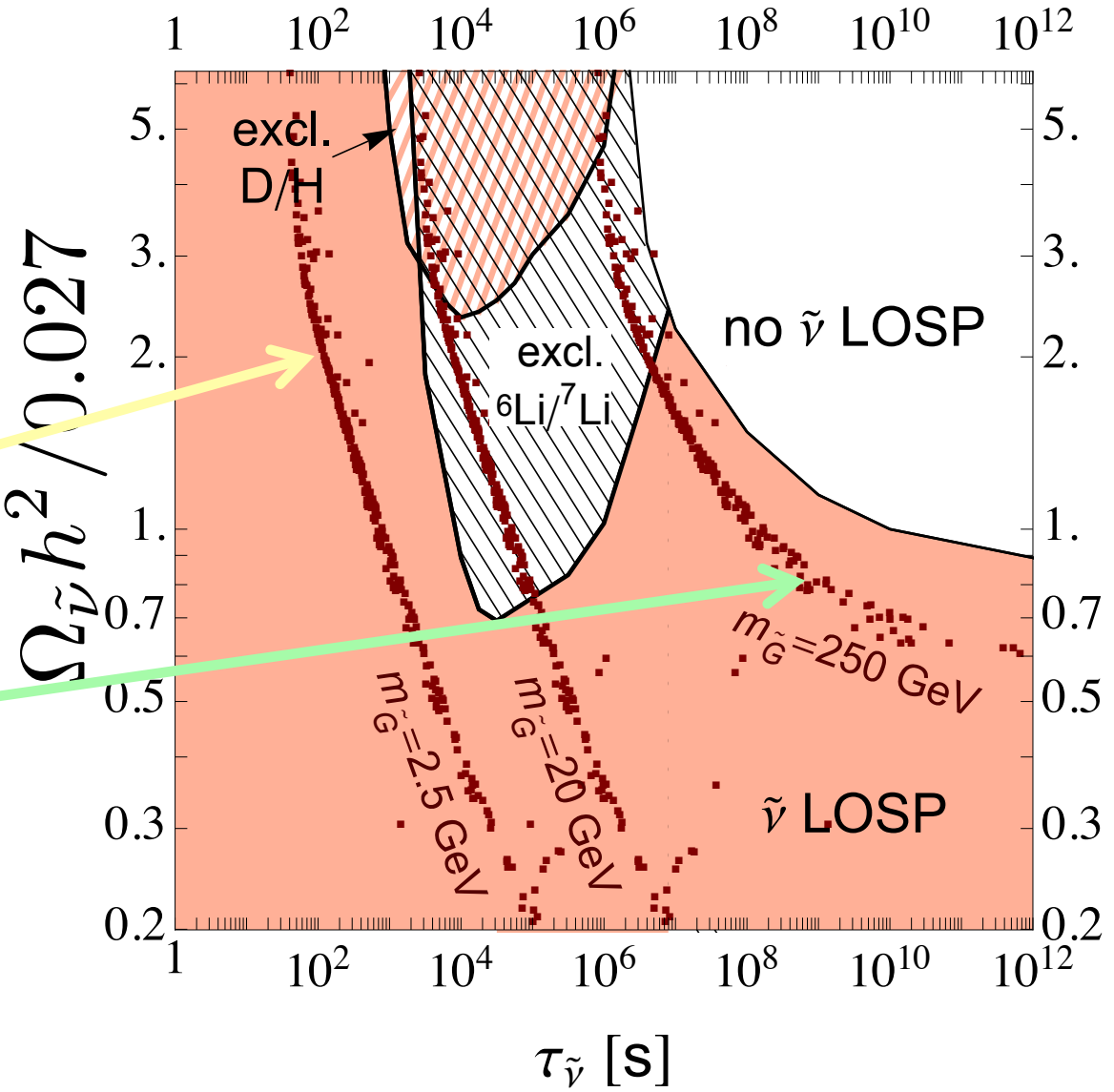
gravitino/sneutrino approx. mass degeneracy, sneutrino lifetime phase-space suppressed, max. reheating temp.



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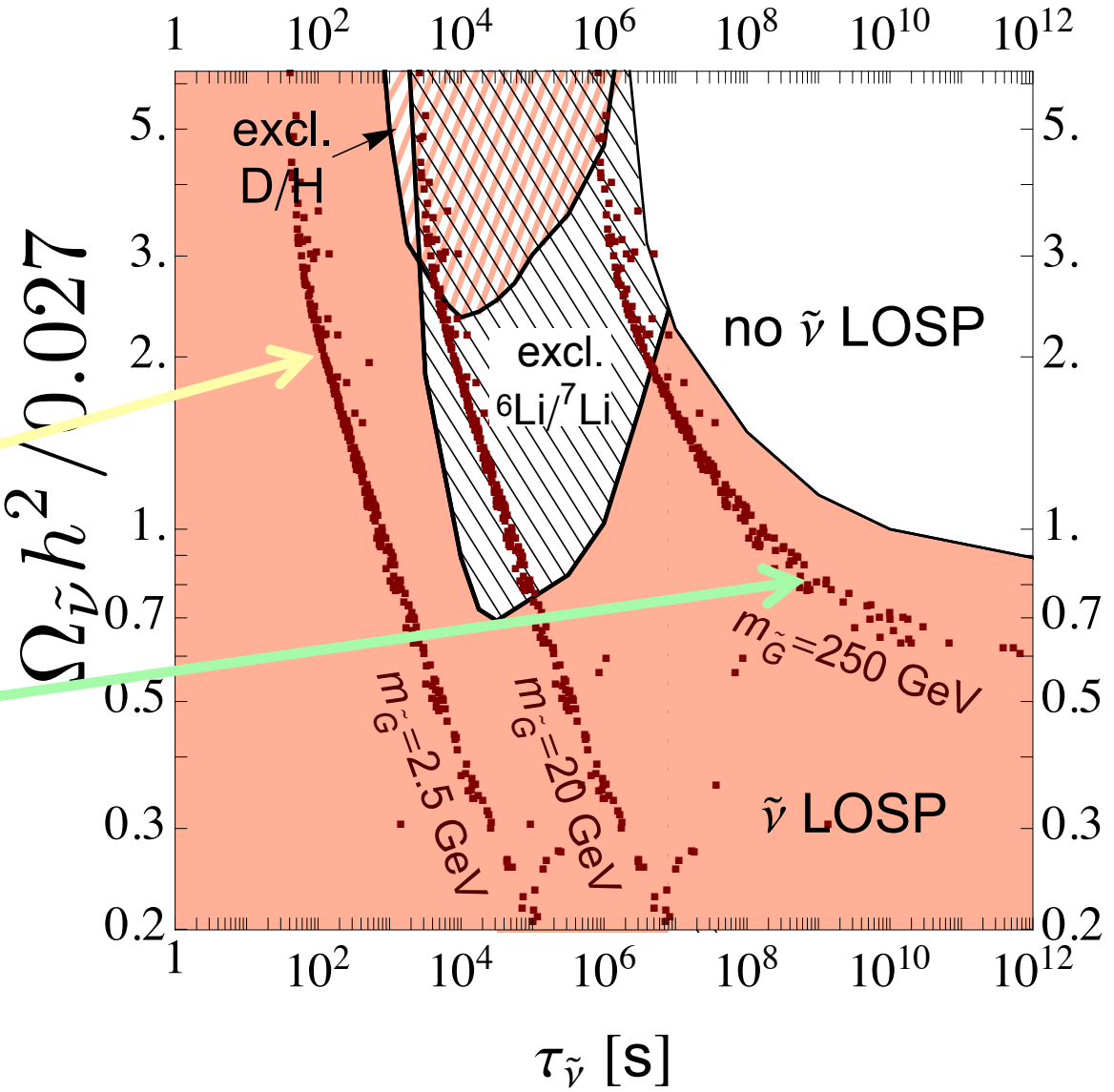
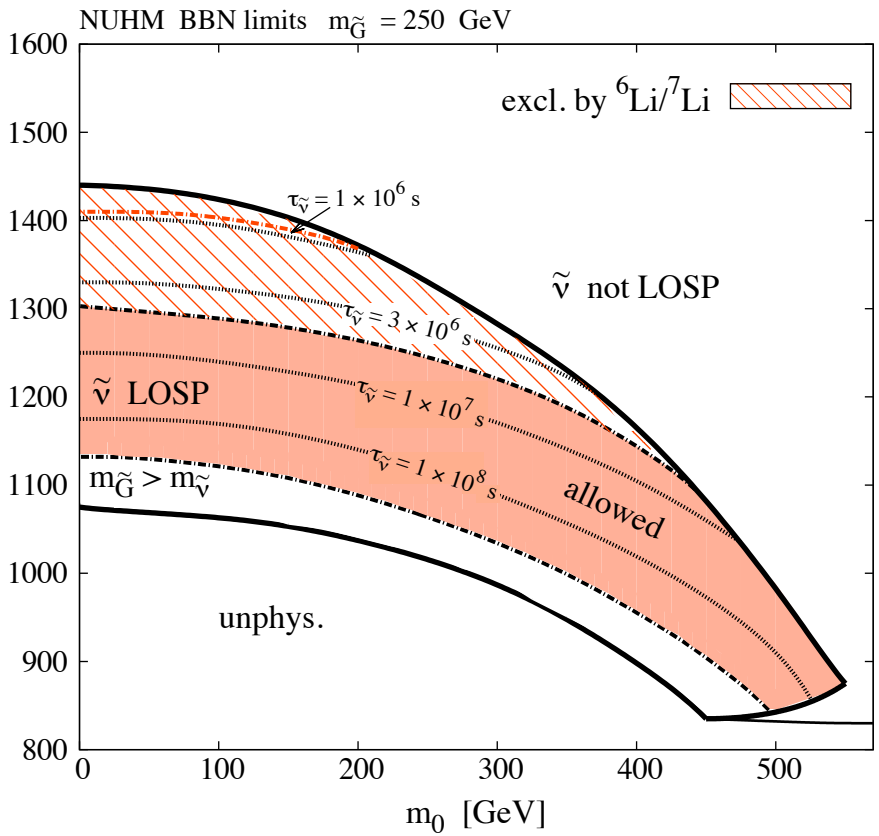
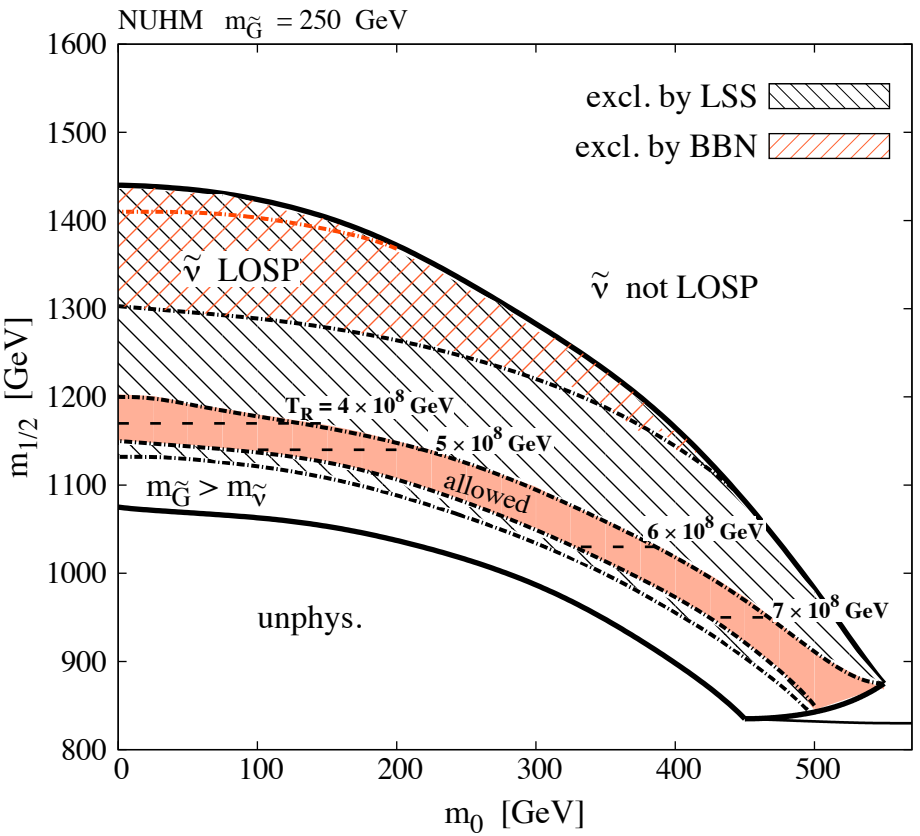
but late-time injection of **warm dark matter**
(Jedamzik, Lemoine, Moultaka '05)



$\tilde{\nu}$ NLSP: BBN vs LSS bounds





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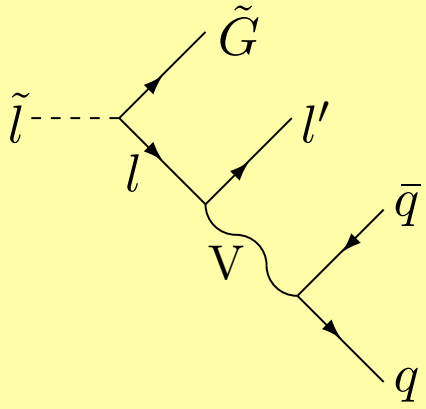
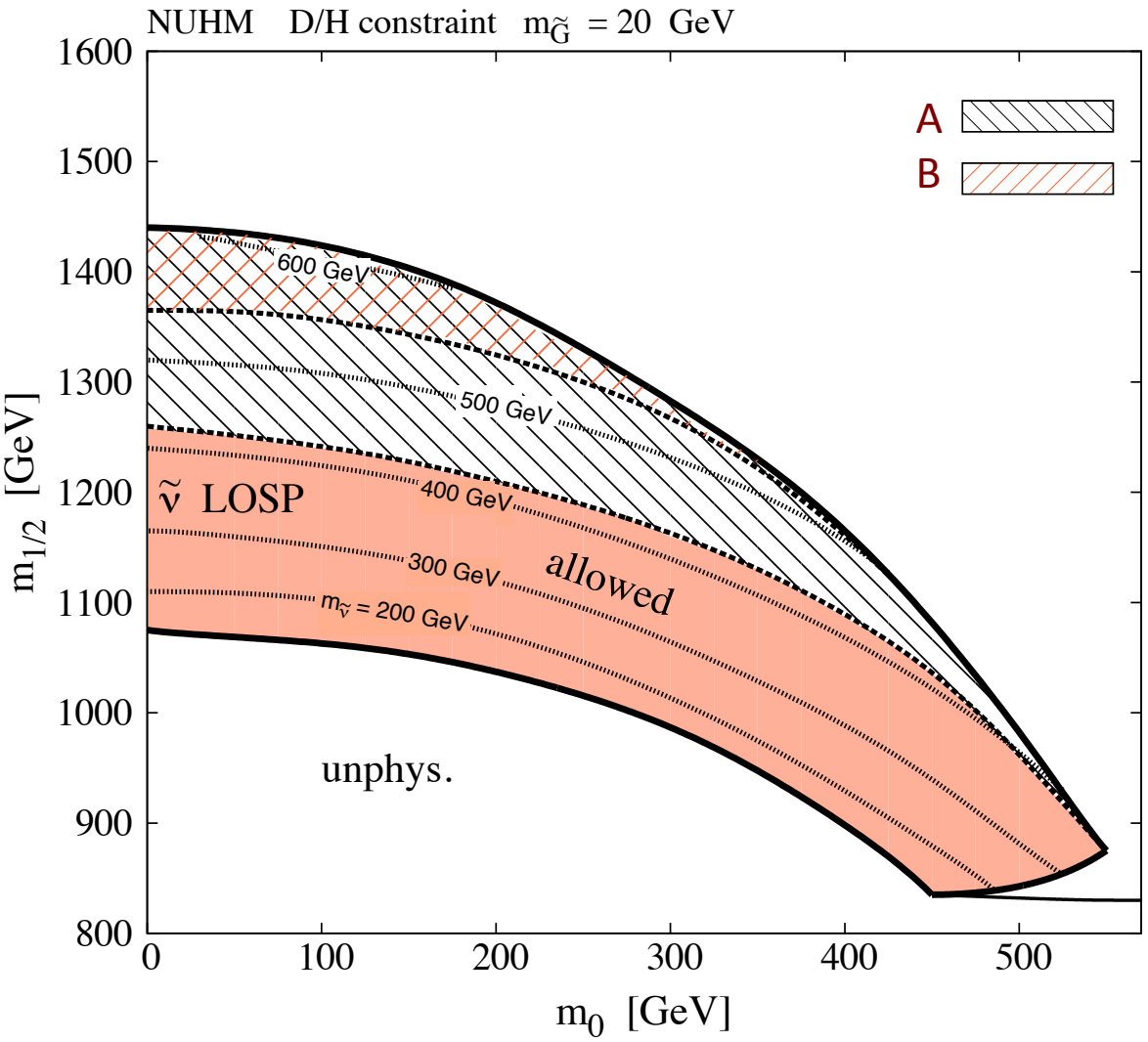
$\tilde{\nu}$ NLSP: BBN and 4-body phase space

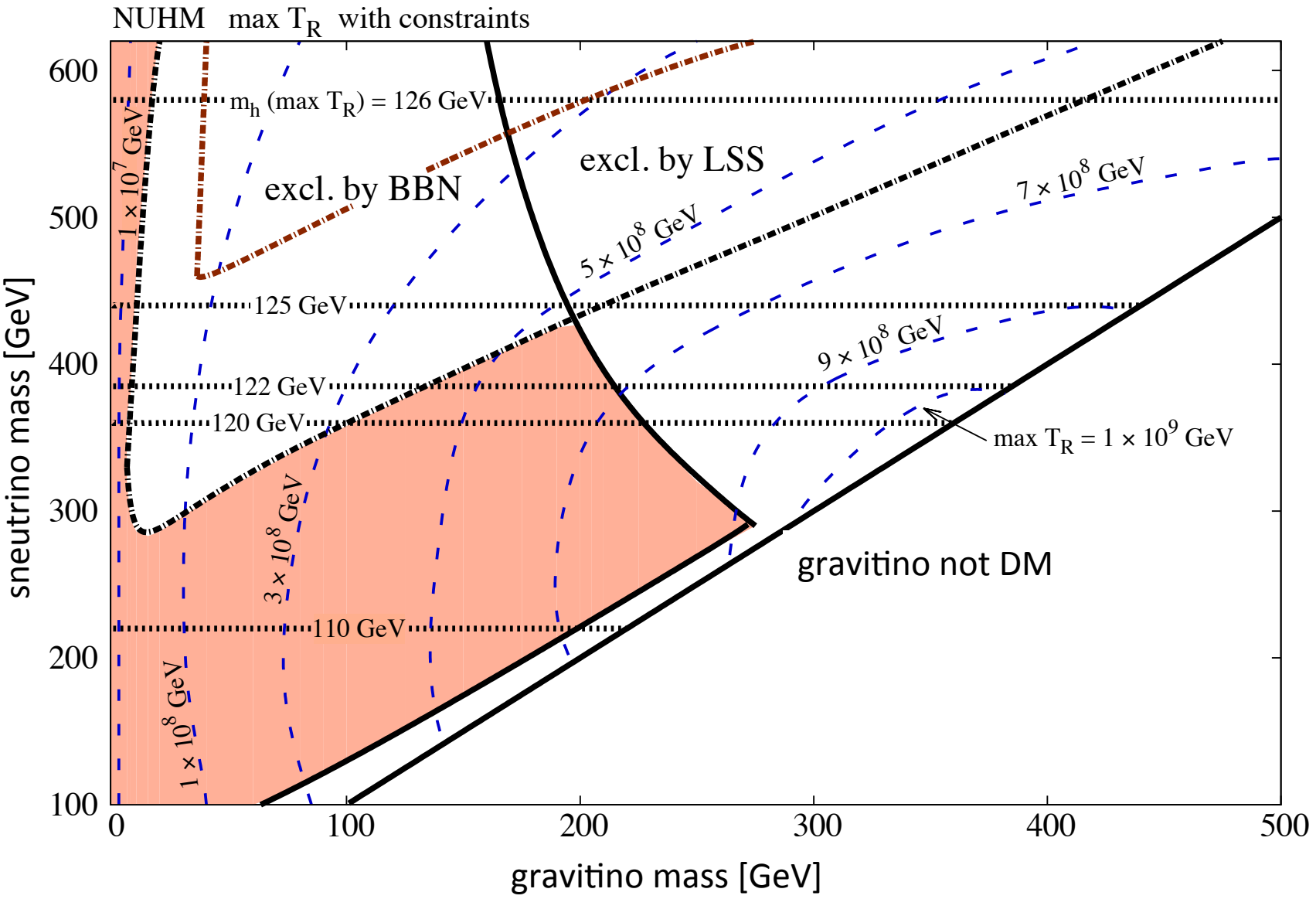


(A) $q\bar{q}$ pair carries 1/3 of available energy

(B) Full computation of this and 3 similar diagrams.



$\tilde{\nu}$ NLSP: BBN, LSS and Higgs mass bounds



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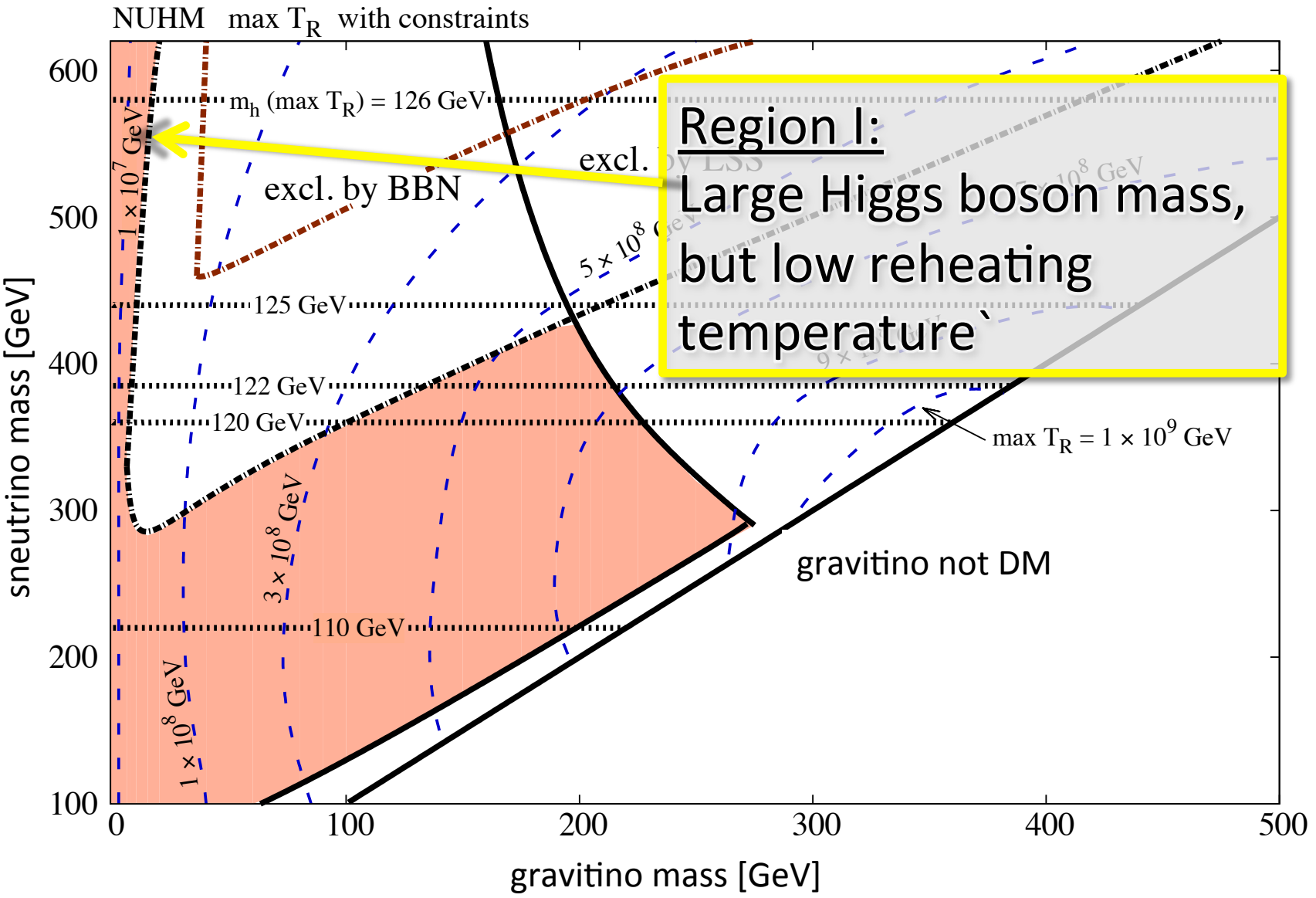
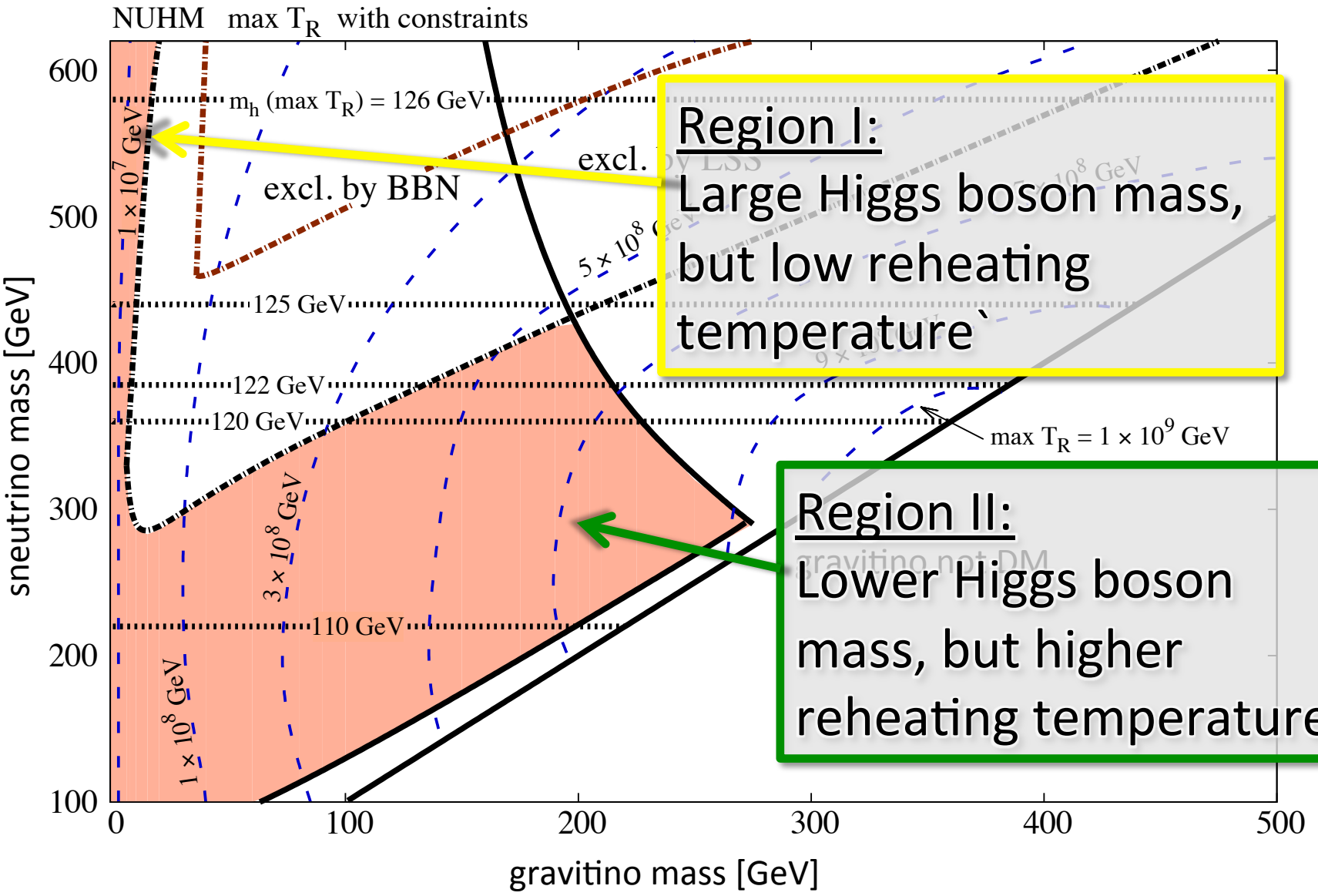


Region I:
Large Higgs boson mass, but low reheating temperature`

$\tilde{\nu}$ NLSP: BBN, LSS and Higgs mass bounds



Region I:
Large Higgs boson mass, but low reheating temperature`

Region II:
Lower Higgs boson mass, but higher reheating temperature`

Conclusions

Gravitino DM with sneutrino LOSP least constrained the gravitino problem:

nucleosythesis:
- ◆ short LOSP lifetimes
- ◆ small gravitino masses
- ◆ low reheating temperatures

leptogenesis:
- ◆ high reheating temperatures
- ◆ large gravitino masses
- ◆ long LOSP lifetimes

but with the 126 GeV Higgs boson discovery, such a scenario looks disfavored.