Neutrino Sector Impacts SUSY Dark Matter

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in collaboration with V.Barger and D.Marfatia PLB 665 (2008)

SUSY seesaw

- Observed neutrino oscillations → massive neutrinos
- Mass scale $\sum m_\nu \lesssim 1\ eV$
- Seesaw mechanism (type-I):

$$\mathcal{M}_\nu = -\mathbf{f}_\nu M_N^{-1} \mathbf{f}_\nu{}^T v_u^2$$

- Right-handed neutrino masses $M_N \sim (10^{10} - 10^{16})\ GeV$

- Neutrino Yukawas from *SO(10)*
  - $\mathbf{f}_\nu = \mathbf{f}_u$ if higgses in **10**
  - $\mathbf{f}_\nu = 3\mathbf{f}_u$ if higgses in **126**

- **Do RHNs affect SUSY Dark Matter?**

RGE analysis

- Neutrino Yukawas appear in RGEs above seesaw scale

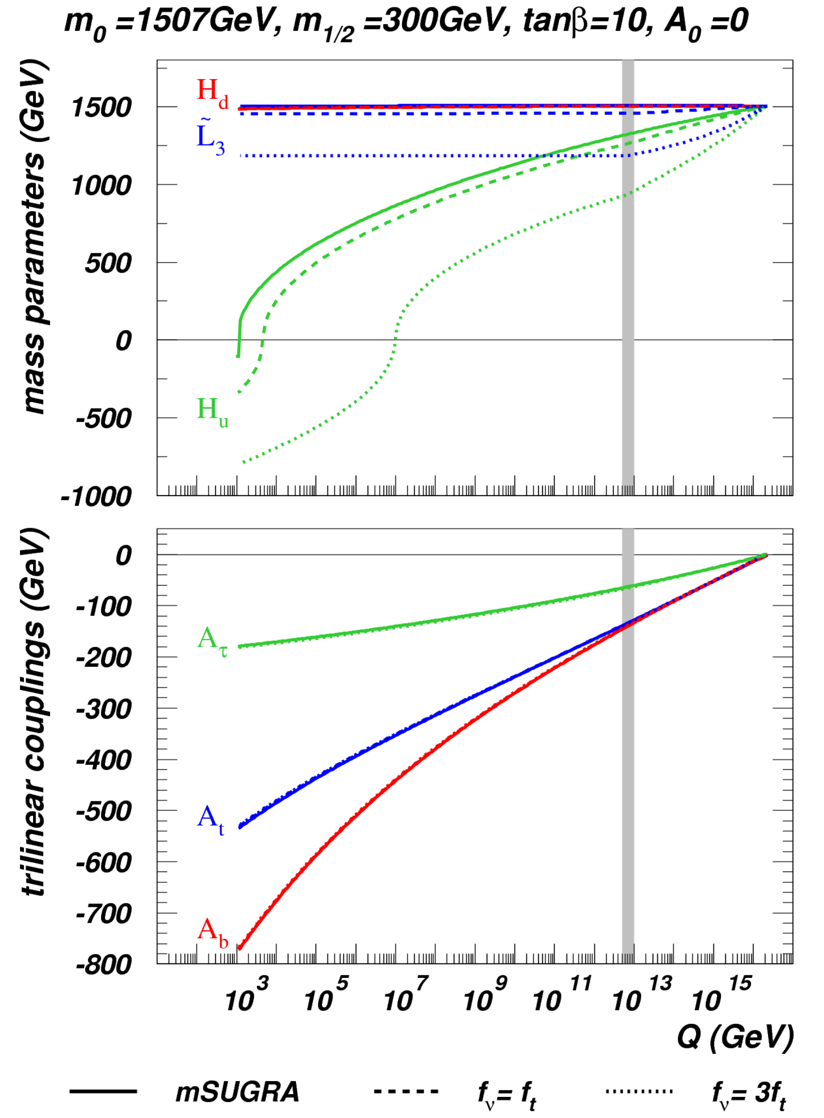
$$\frac{dm^2_{L_3}}{dt} \propto f_\tau^2 X_\tau + f_\nu^2 X_\nu$$

$$\frac{dm^2_{H_u}}{dt} \propto 3f_t^2 X_t + f_\nu^2 X_\nu$$

$$\frac{dA_\tau}{dt} \propto 3f_b^2 A_b + f_\nu^2 A_\nu$$

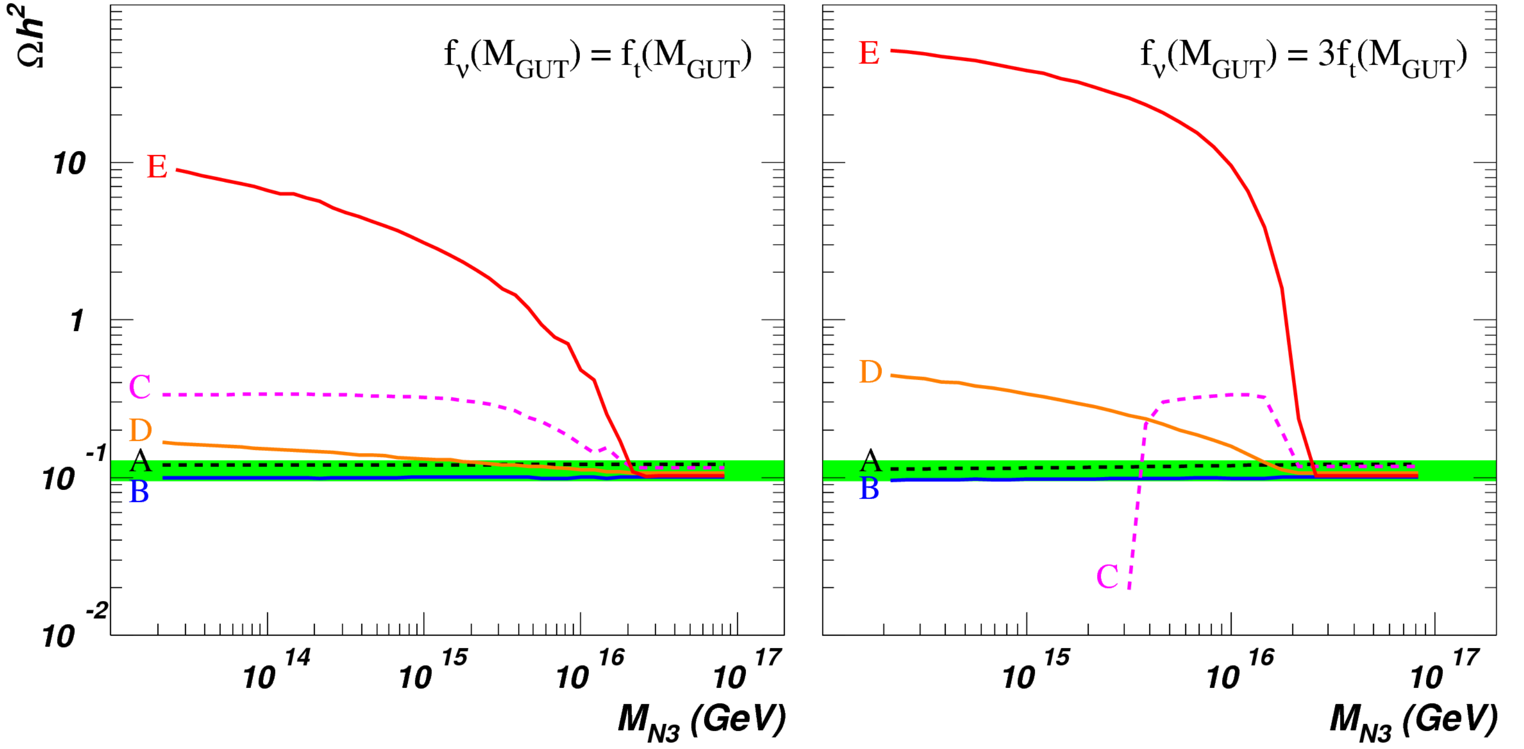
$$\frac{dA_t}{dt} \propto 3f_t^2 A_t + f_\nu^2 A_\nu$$

- EWSB: $\mu^2 \simeq -m^2_{H_u}$
- *CP*-odd Higgs mass $m^2_A \simeq m^2_{H_d} - m^2_{H_u}$
- $m^2_{L_3}$ → stau masses
- *A*-terms → L-R sfermion mixing



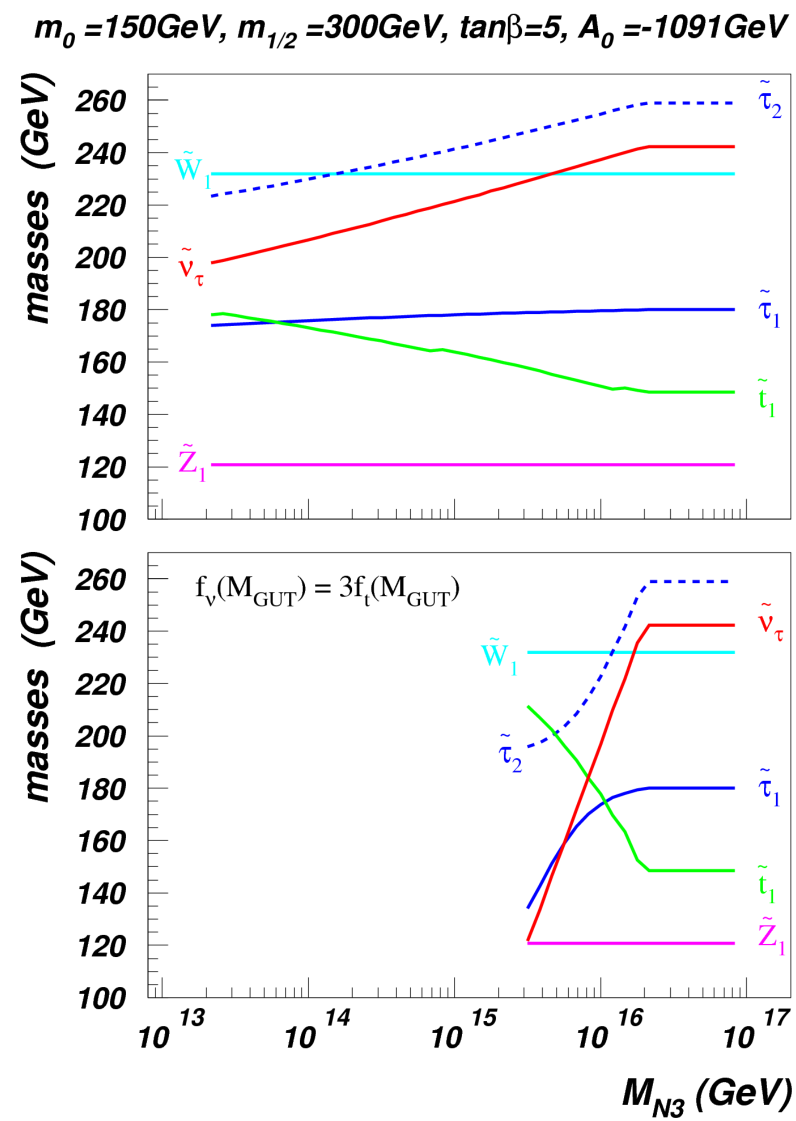
Results

- mSUGRA+RHN model parameters: $m_0, \ m_{1/2}, \ A_0, \ \tan\beta, \ sign(\mu), \ M_{N_3}$
- Benchmark points:
  A=bulk, B=stau co-annih., C=stop co-annih., D=Higgs funnel, E=HB/FP
- Co-annihilation with $\tilde{\nu}_\tau$ in case C



Stop coannihilation

- Small $m_0, m_{1/2}$ and large A_0
- Light $\tilde{t}_1 \implies$ rapid $\widetilde{Z}_1\tilde{t}_1 \to X_{SM}$
- RHN effects:
  - lighter $\tilde{\nu}_\tau,\ \tilde{\tau}_2 \simeq \tilde{\tau}_L$
  - smaller L-R mixing → heavier $\tilde{t}_1$
  - $\tilde{\tau}_1$ becomes $\tilde{\tau}_L$



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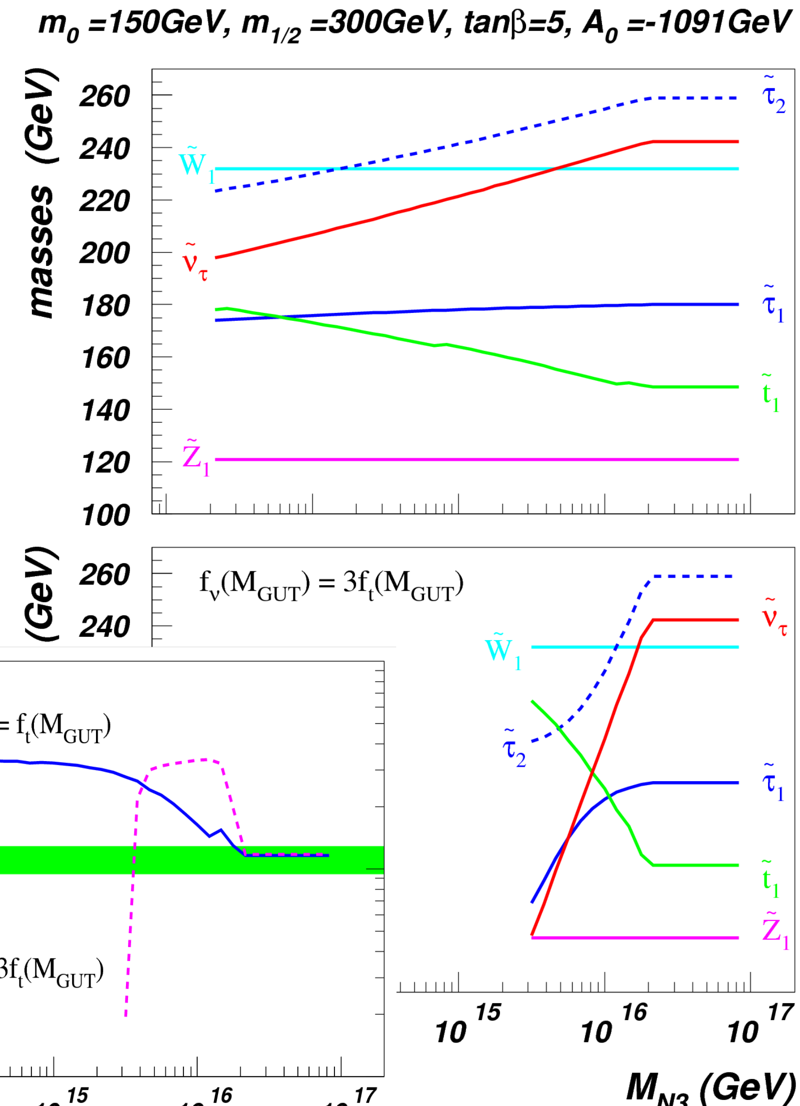
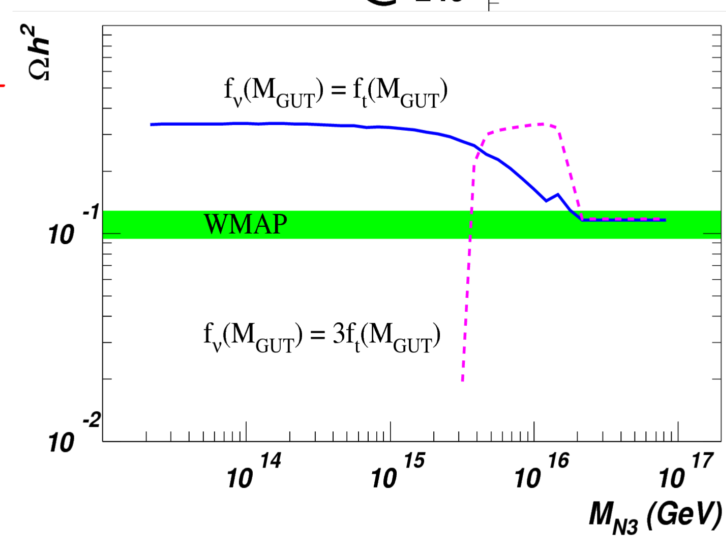
- Coannih. with $\tilde{t}_1$ closes
- New coannih. channel with $\tilde{\nu}_\tau$





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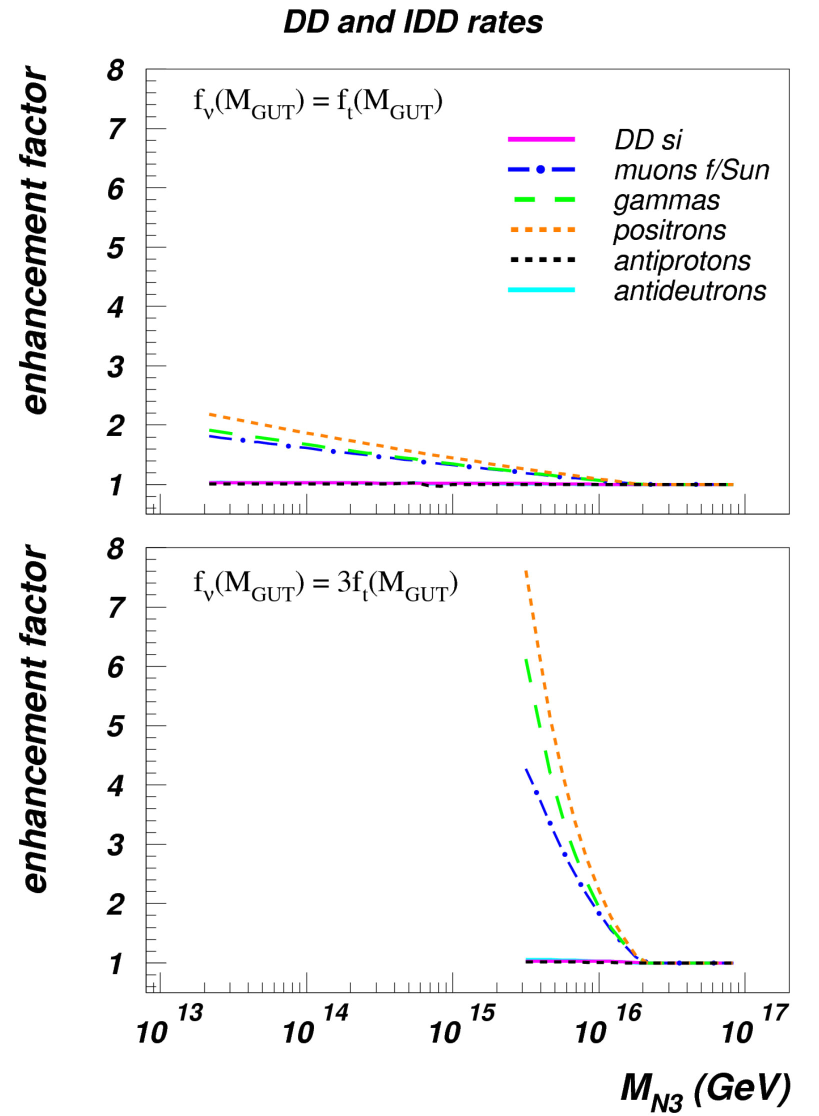
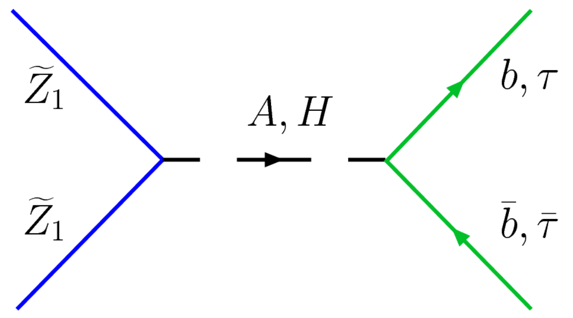
- Positron, muon and gamma rates are up by 100-150% (300-700%)

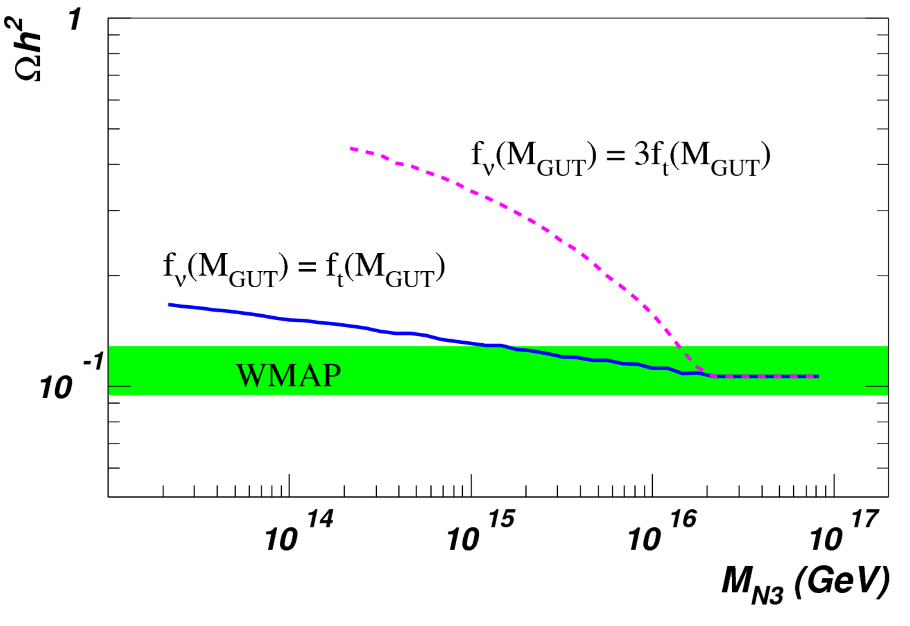


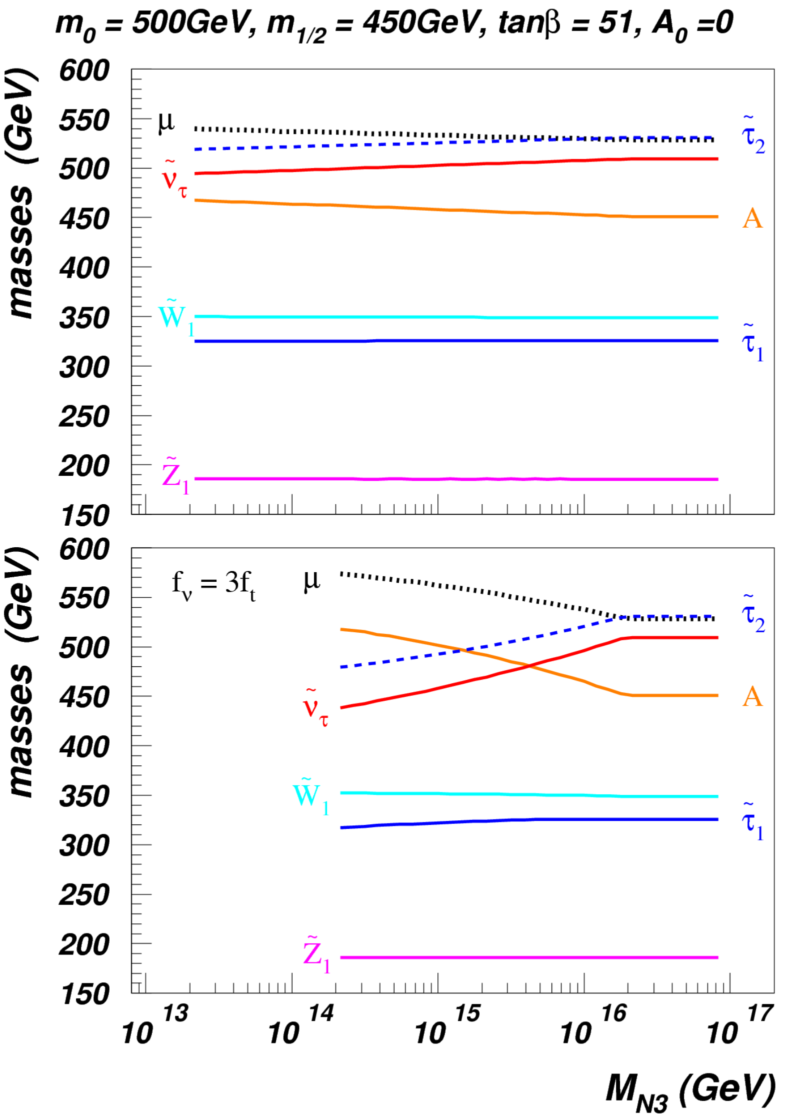
Higgs funnel

- Medium m_0 and large $\tan\beta$



- Lighter RHN ⟶ heavier *CP*-odd Higgs





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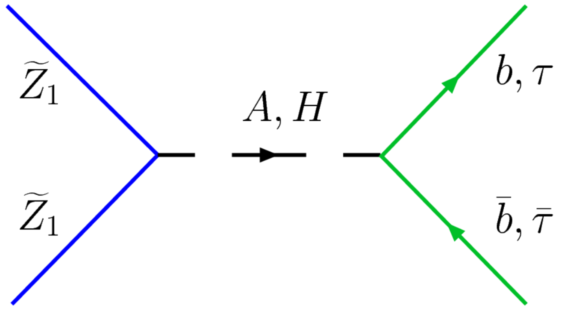
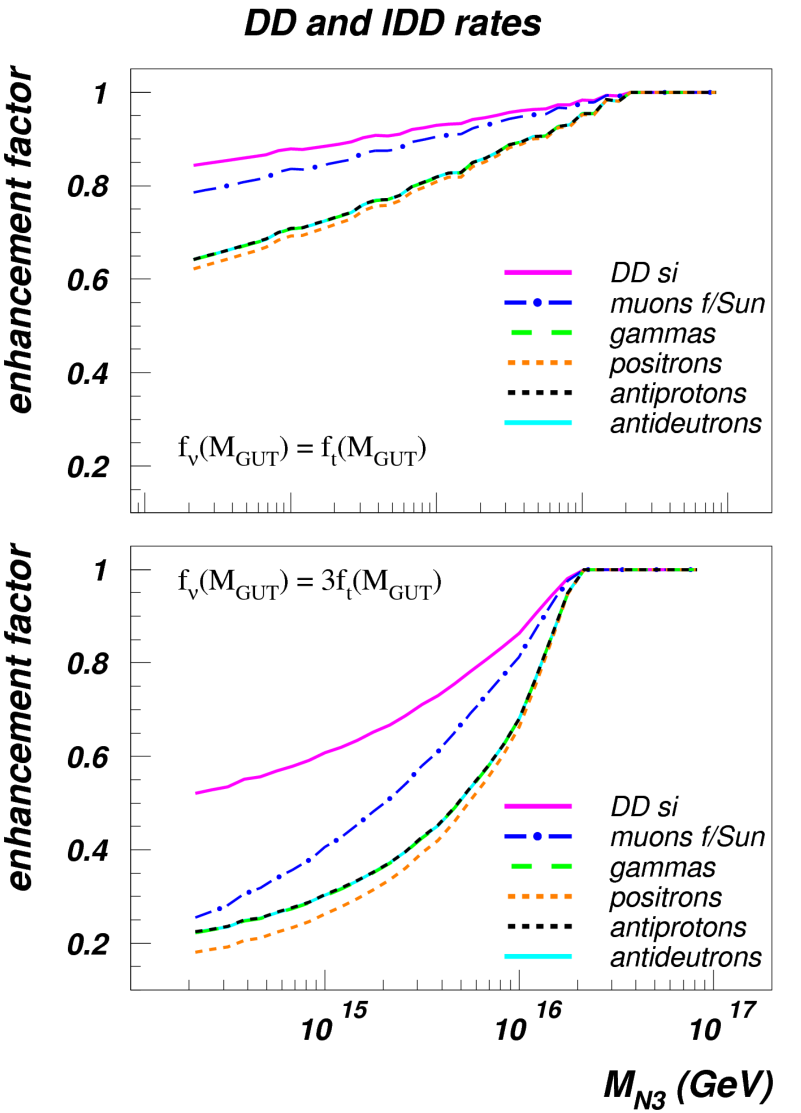
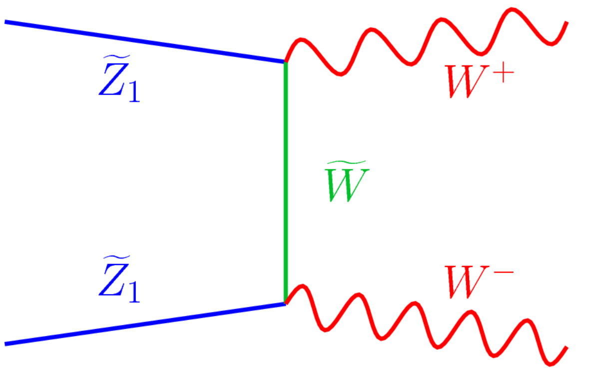


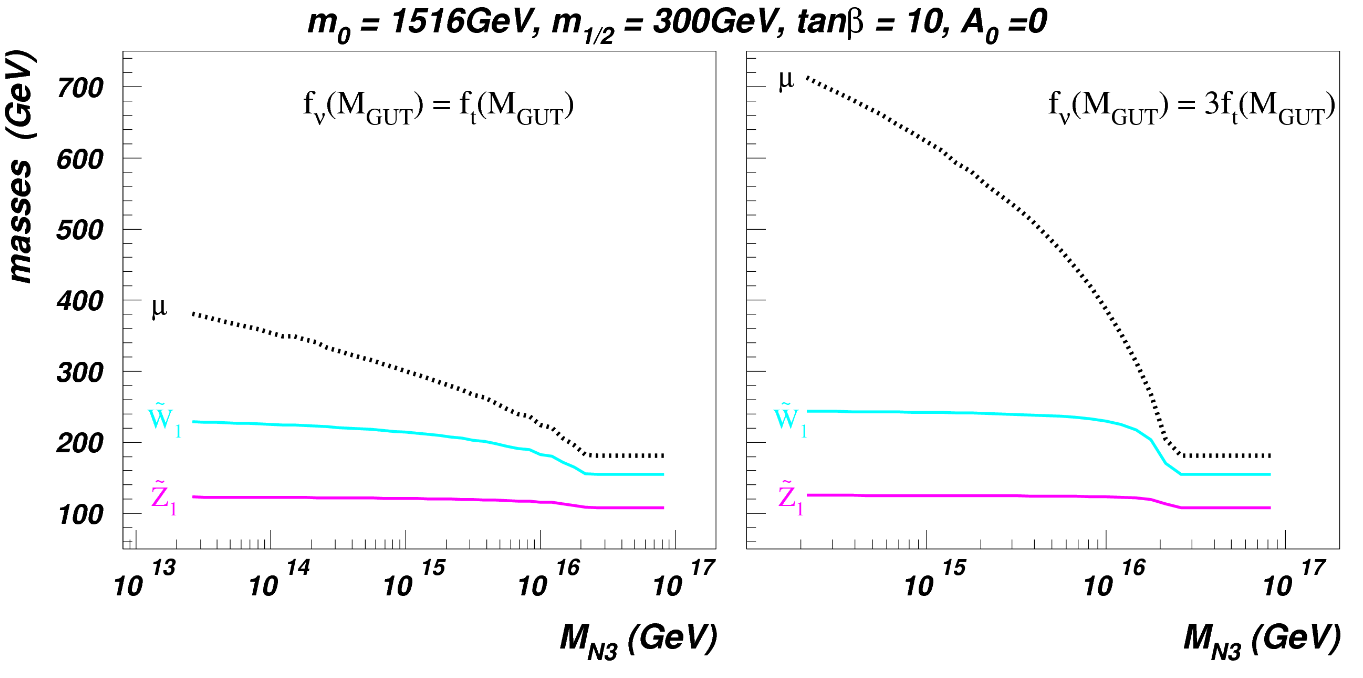
- Lighter RHN ⟶ heavier CP-odd Higgs
- Decreasing DM detection rates:
  - DD – 15% (50%)
  - muons – 20% (75%)
  - antimatter and gammas – 40% (75%)



Focus point

- Large m_0 region
- Small $\mu \Longrightarrow$ mixed bino-higgsino $\widetilde{Z}_1$
- Smaller $M_{N_3} \Longrightarrow$ larger μ
  ⇒ smaller higgsino content of $\widetilde{Z}_1$





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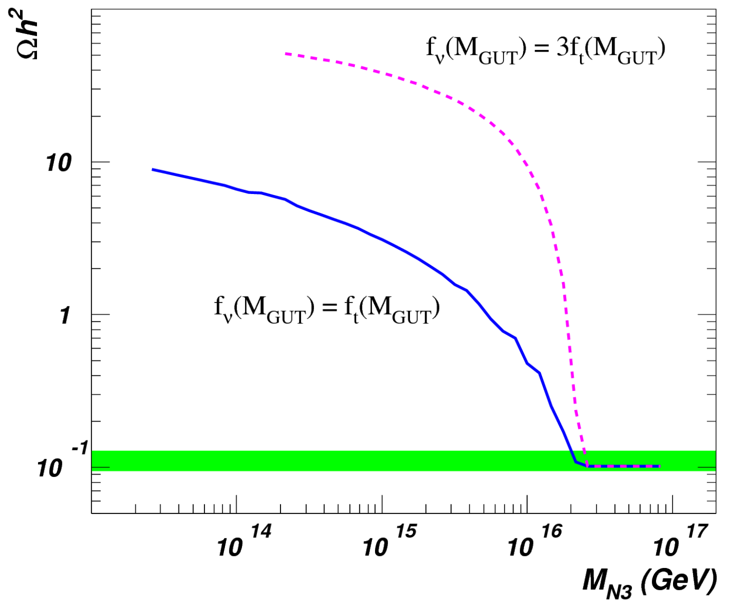

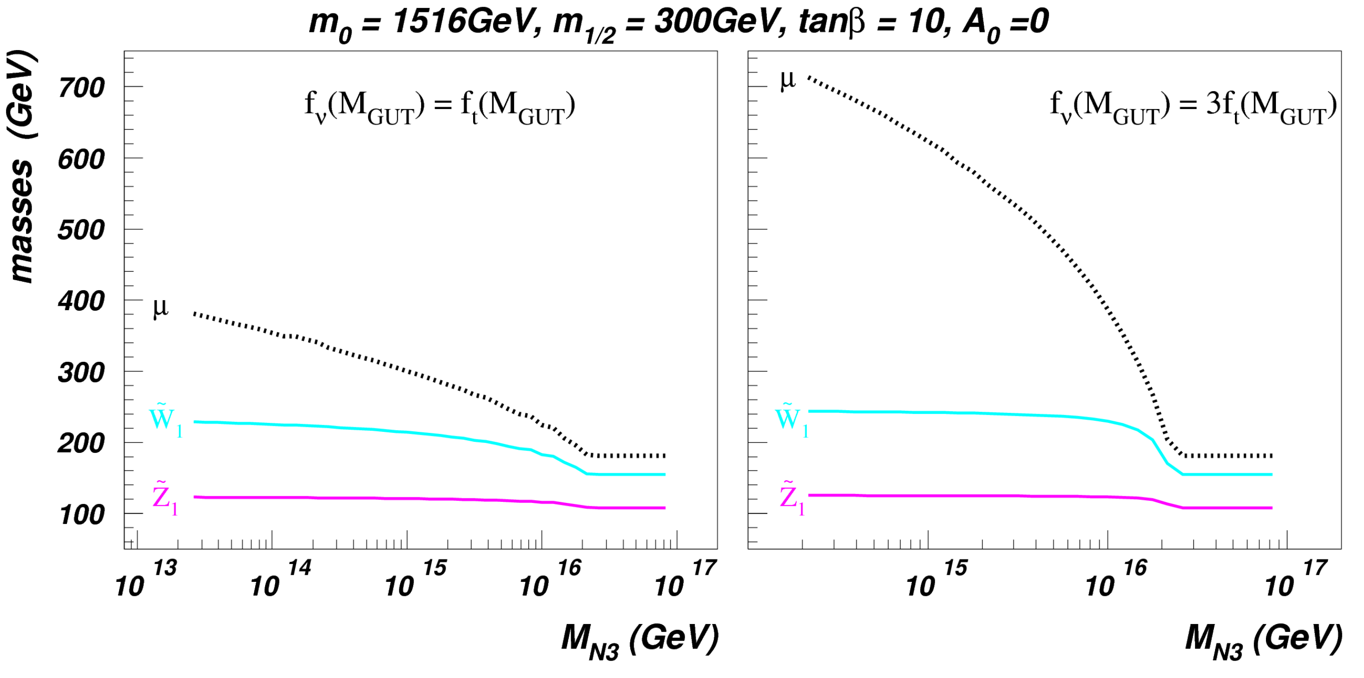

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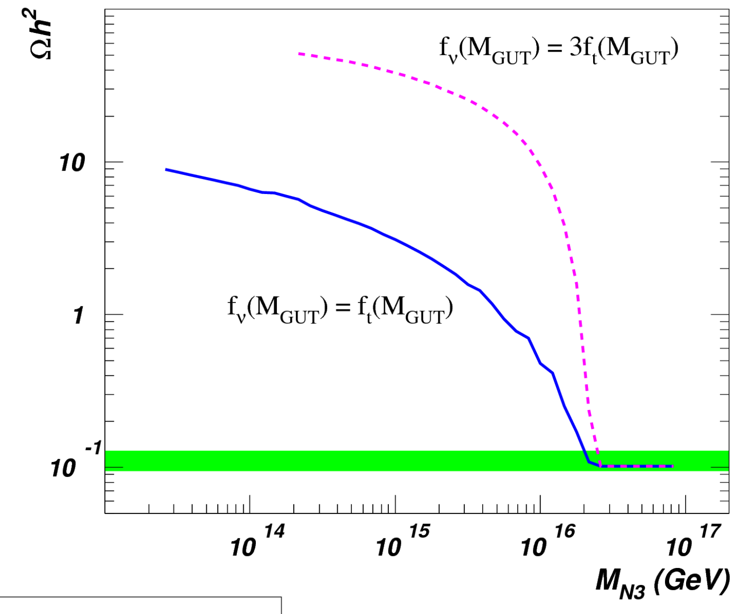
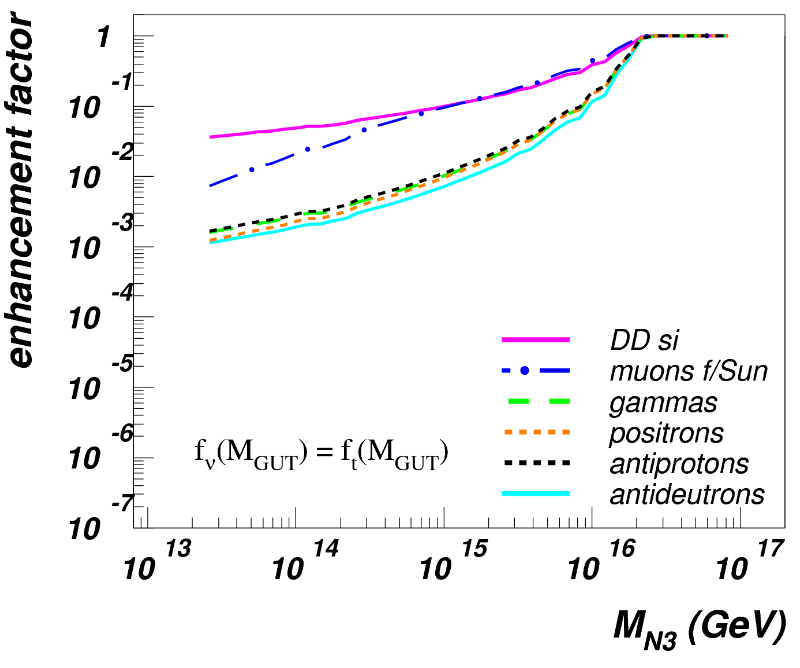
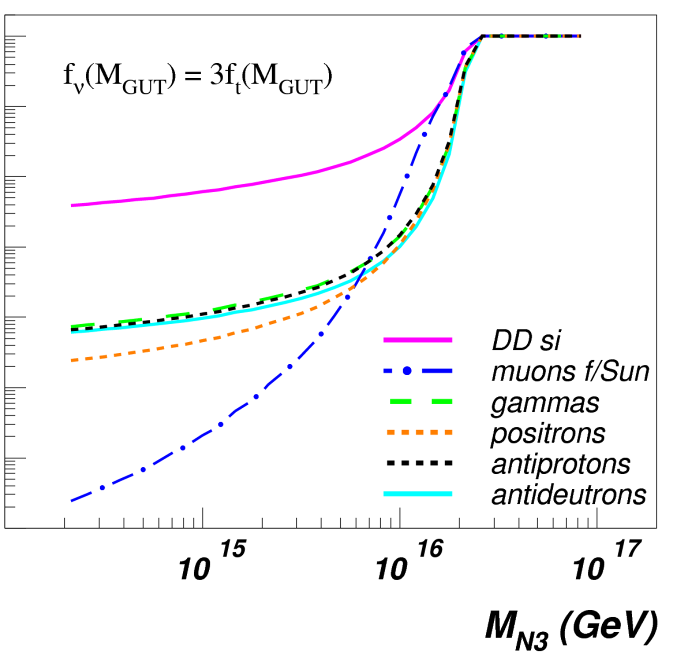
  ⇨ smaller higgsino content of $\widetilde{Z}_1$
- DM rates drop by several orders !

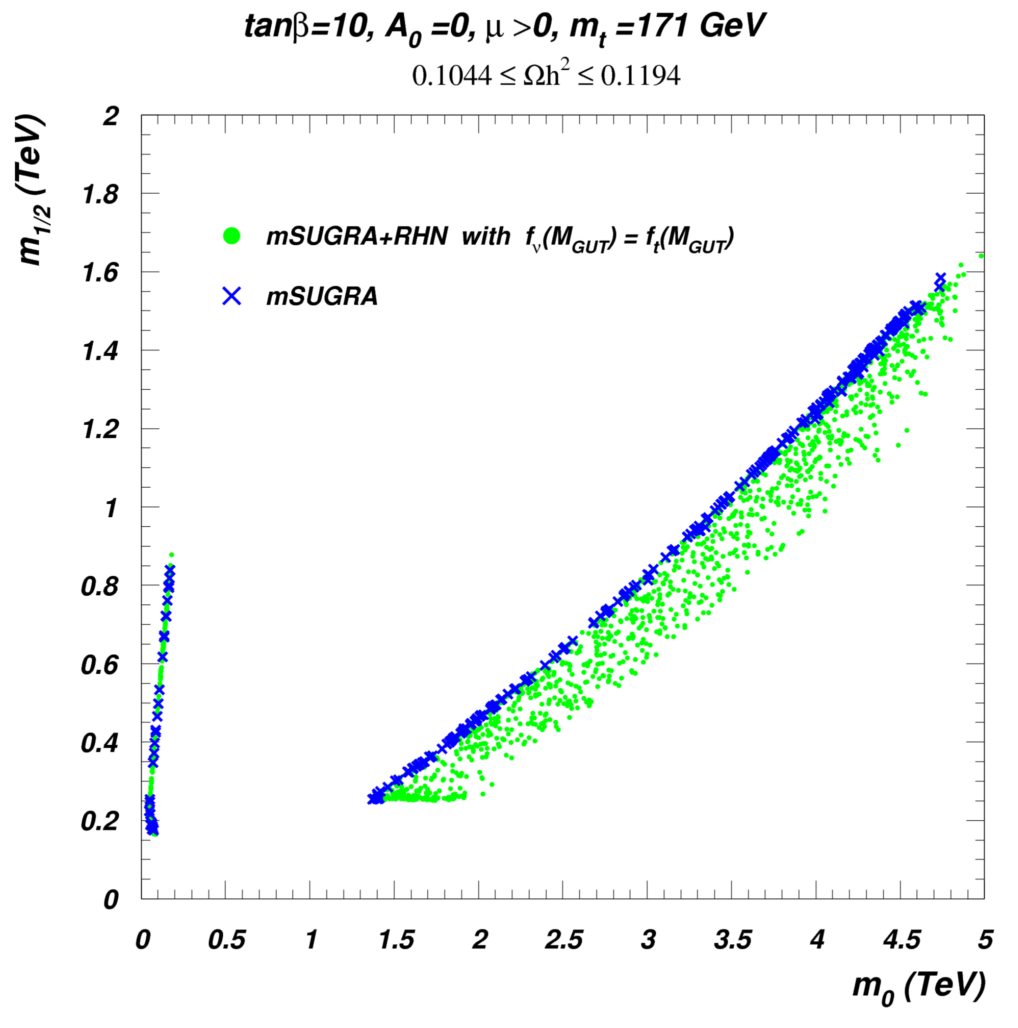






RD in mSUGRA+RHN

- Random scan in $(m_0, m_{1/2})$
- Neutrino Yukawa effects can be compensated by SSB parameters
  ⇨ shifts of RD-allowed regions
- Expect effects on DM rates and/or collider signatures



Conclusions

- Neutrino Yukawa coupling can significantly affect neutralino DM:
  - Sparticle masses and composition can be modified
  - RD-allowed regions shift → collider effects
  - New sneutrino coannihilation mechanism possible
  - DM detection rates may change by up to several orders of magnitude!
- Most prominent when SSB slepton mass and/or trilinears large
  - Stop coannihilation, *A*-funnel and HB/FP regions of mSUGRA
- Effects in stau coannihilation and the bulk are small *only* because in mSUGRA $\tilde{\tau}_1 \simeq \tilde{\tau}_R$
- Other types of seesaw (*e.g.* Double seesaw) can have $M_N \sim 10^8\ GeV$ → even larger effects