Title: Neutrino sector impacts SUSY dark matter

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Abstract: We study effects of the neutrino yukawa coupling on neutralino dark matter observables. We found that presence of the top-like neutrino yukawa coupling does significantly affect neutralino relic density in the regions.

Neutrino Sector Impacts SUSY Dark Matter

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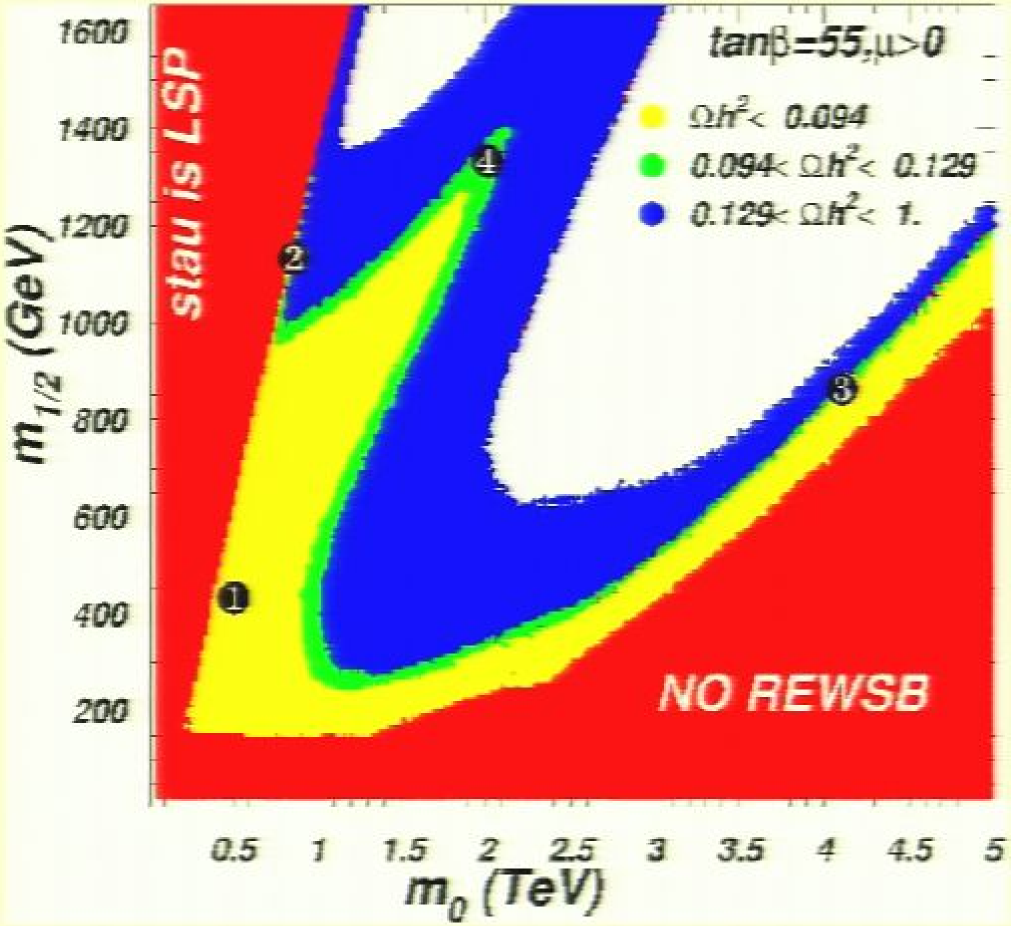
Work in collaboration with Vernon Barger and Danny Marfatia (arXiv:0804.3601)

Neutralino Dark Matter

- WMAP measured relic density:
  $$\Omega_{CDM}h^2 = 0.1120^{+0.0074}_{-0.0076} \qquad (2\sigma)$$
- SUSY with R-parity $\Rightarrow$ stable LSP – DM candidate
- Most of the time LSP = lightest neutralino $\widetilde{Z}_1$
  - RD calculated by solving Boltzmann eq'n – IsaReD, micrOMEGAs, …
  - depends crucially on annihilation/coannihilation cross section
- Direct DM searches via scattering off nucleon:
  - XENON and CDMS probing $\sigma_{SI} \sim (5-10)\times 10^{-8}$ pb for $m_{\widetilde{Z}_1} = 100$ GeV
  - next round – superCDMS and ton-sized noble detectors
- Indirect searches:
  - $\widetilde{Z}_1\widetilde{Z}_1 \to W^+W^-, \tau\bar{\tau}, b\bar{b}, \ldots \to \mu^{\pm}, e^+, \bar{p}, \bar{D}, \gamma$
  - IceCube, PAMELA, GLAST, …

The mSUGRA situation

- Parameter space:
  $m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ sign(\mu)$
- Most of para space ruled out,
  $\Omega_{\tilde{Z}_1} h^2 \gg 1$
- RD-allowed regions:
  1. bulk region (light sfermions)
  2. stau co-annihilation ($m_{\tilde{Z}_1} \simeq m_{\tilde{\tau}_1}$)
  3. HB/FP region (small $|\mu|$)
  4. A-funnel ($2m_{\tilde{Z}_1} \simeq m_A,\ m_H$)
  - ⋆ h corridor ($2m_{\tilde{Z}_1} \simeq m_h$)
  - ⋆ stop co-annihilation ($m_{\tilde{Z}_1} \simeq m_{\tilde{t}_1}$ for particular A_0)



SUSY-seesaw

- Special RD-allowed regions ⇒ implications for collider & DM searches
- How robust are these implications?
- Observed neutrino oscillations ⇒ massive neutrinos
- 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 $SO(10)$ SUSYGUT:
  - $\mathbf{f}_\nu = \mathbf{f}_u$ if higgses $\in \mathbf{10}$
  - $\mathbf{f}_\nu = 3\mathbf{f}_u$ if higgses $\in \mathbf{126}$

mSUGRA+RHN

- Neutrino yukawas appear in RGEs above seesaw scale $\sim M_{N_3}$:

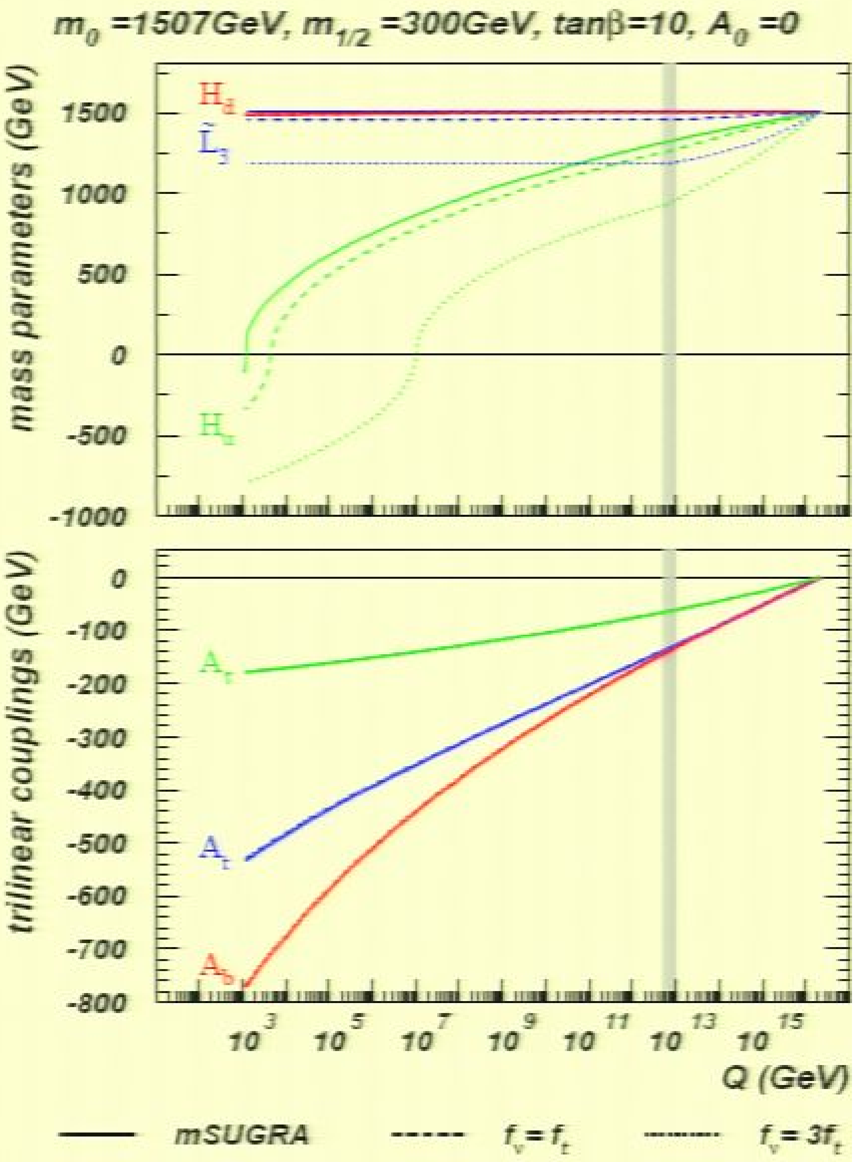
$$\frac{dm^2_{L_3}}{dt} \propto f_\tau^2 X_\tau + f_\nu^2 X_\nu \qquad \frac{dA_\tau}{dt} \propto 3 f_b^2 A_b + f_\nu^2 A_\nu$$

$$\frac{dm^2_{\tilde{\nu}_R}}{dt} \propto f_\nu^2 X_\nu \qquad \frac{dA_t}{dt} \propto 3 f_t^2 A_t + f_\nu^2 A_\nu$$

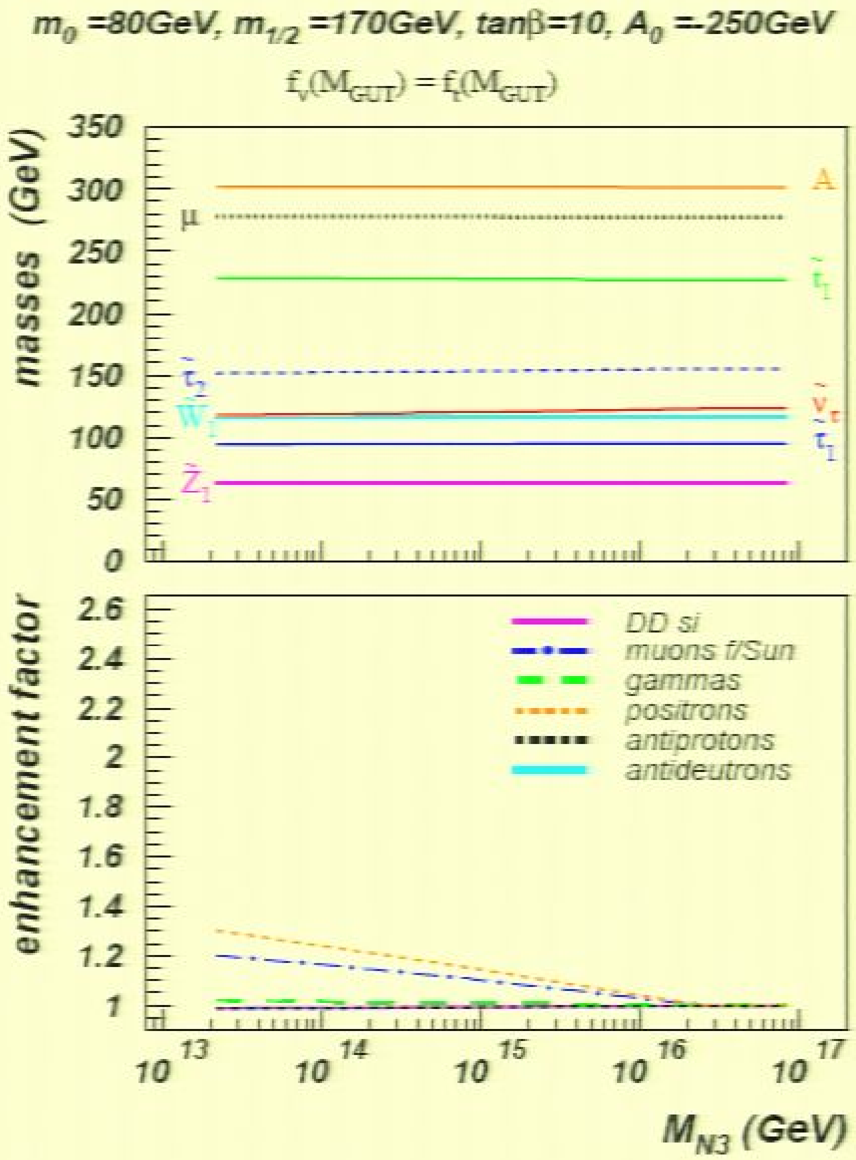
$$\frac{dm^2_{H_u}}{dt} \propto 3 f_t^2 X_t + f_\nu^2 X_\nu$$

$$X_\nu = m^2_{L_3} + m^2_{\tilde{\nu}_R} + m^2_{H_u} + A_\nu^2$$

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



Bulk region



- Low $m_0, m_{1/2}, A_0 \Rightarrow$ light sparticles
- $\widetilde{Z}_1\widetilde{Z}_1 \to \tau\bar{\tau}$ via t-channel $\tilde{\tau}_1$
- Smaller M_{N_3} $\to$ smaller $m^2_{L_3}$
  - lighter $\tilde{\nu}_\tau$, $\tilde{\tau}_2 \simeq \tilde{\tau}_L$ – up to 3%
- No effect on RD ($\tilde{\tau}_1 \simeq \tilde{\tau}_R$)
- Increased IDD rates:
  - positrons – 30%
  - muons – 20%
  - γ-rays – 2%

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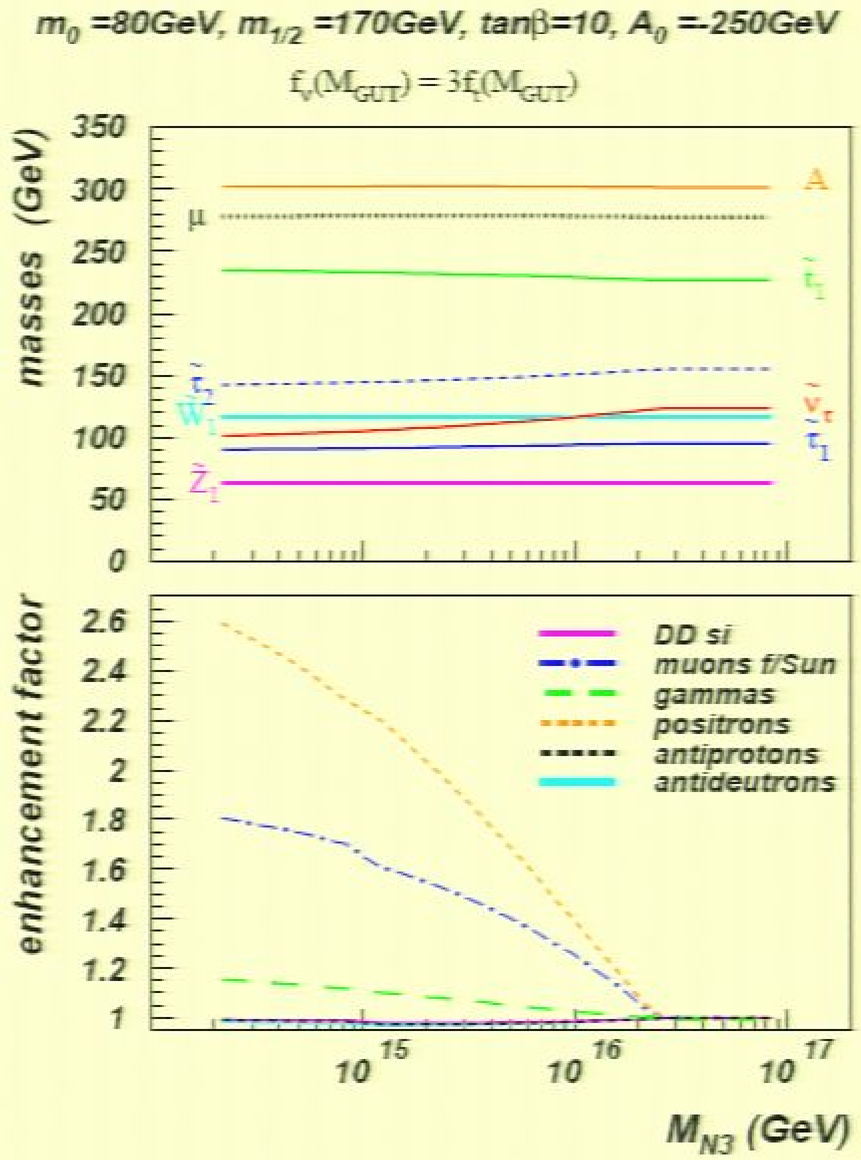
- Smaller $M_{N_3} \to$ smaller $m^2_{L_3}$
  - lighter $\tilde{\nu}_\tau, \tilde{\tau}_2 \simeq \tilde{\tau}_L$
    – up to 3% (15% for larger f_ν)
- No effect on RD ($\tilde{\tau}_1 \simeq \tilde{\tau}_R$)
- Increased IDD rates:
  - positrons – 30% (160%)
  - muons – 20% (80%)
  - γ-rays – 2% (20%)



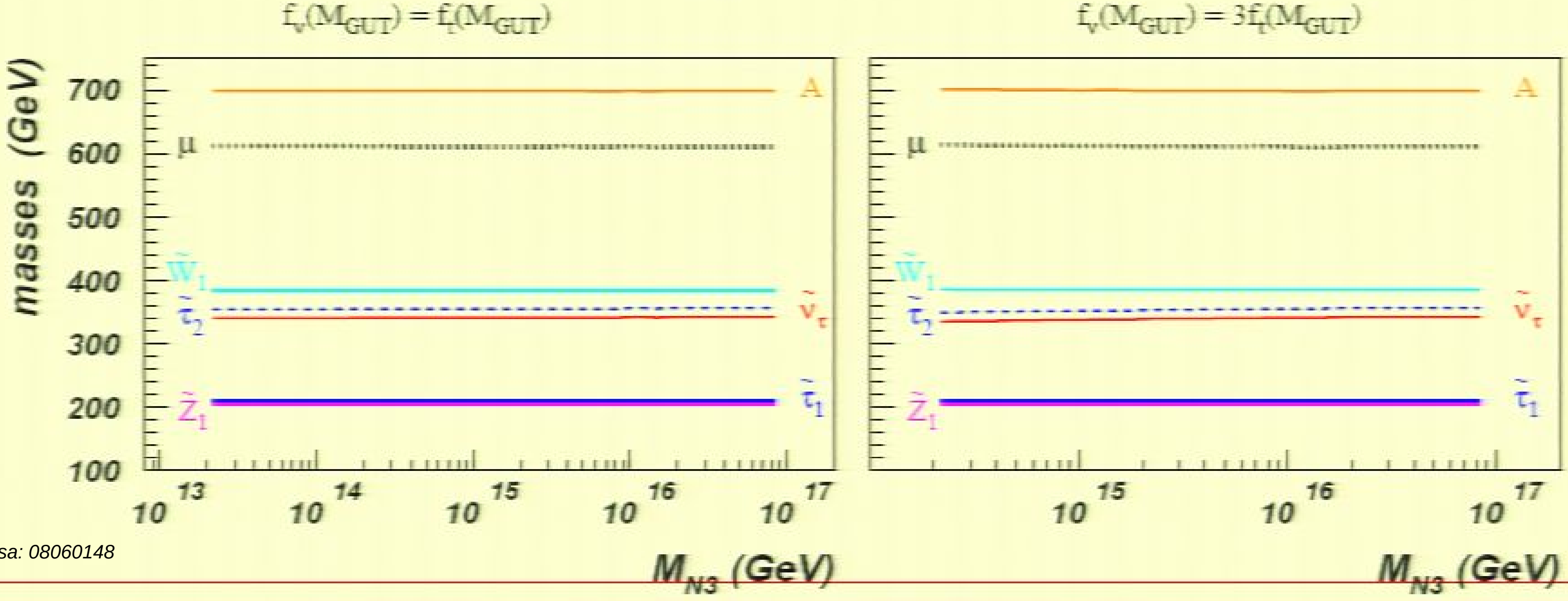
m_0 =80GeV, $m_{1/2}$ =170GeV, tanβ=10, A_0 =-250GeV

$f_\nu(M_{GUT}) = 3f_t(M_{GUT})$

Stau coannihilation

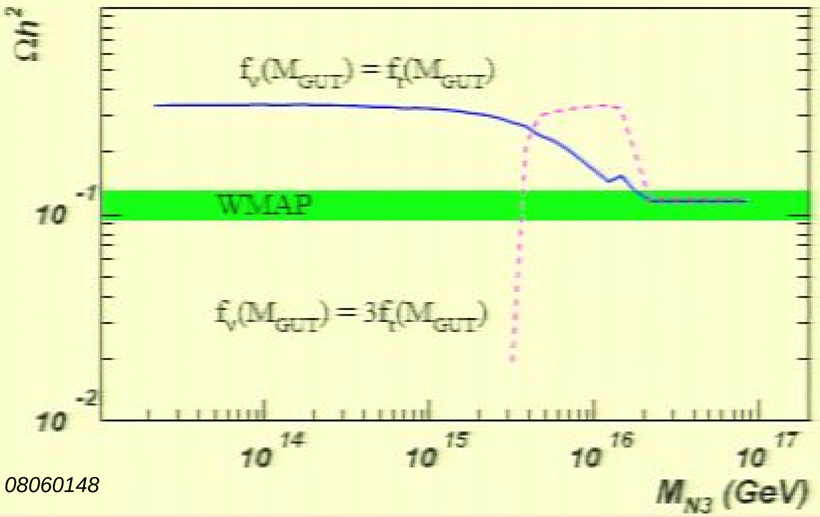
- Low m_0 and medium $m_{1/2}$ region
- $\tilde{\tau}_1$ close to $\widetilde{Z}_1 \Rightarrow$ rapid $\widetilde{Z}_1 \tilde{\tau}_1 \to X_{SM} \Rightarrow$ low $\Omega_{\widetilde{Z}_1} h^2$
- Lighter RHN $\Rightarrow$ lighter $\tilde{\nu}_\tau$, $\tilde{\tau}_2 \simeq \tilde{\tau}_L$
- No effect on RD ($\tilde{\tau}_1 \simeq \tilde{\tau}_R$)
- Smaller increases of positron and muon rates (up to 2% and 12%)

m_0 = 100GeV, $m_{1/2}$ = 500GeV, tanβ=10, A_0 =0

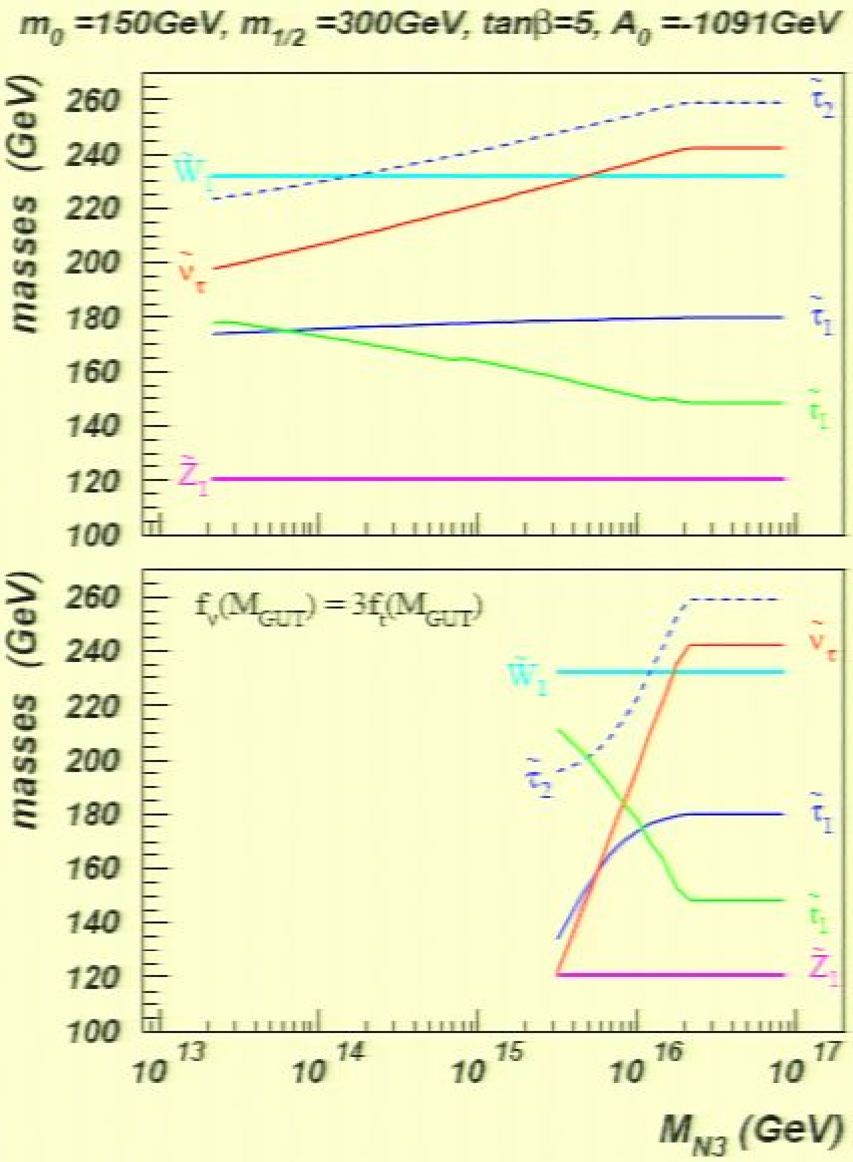


Stop coannihilation

- Small $m_0, m_{1/2}$ and large A_0
- Light $\tilde{t}_1 \Rightarrow$ rapid $\widetilde{Z}_1 \tilde{t}_1 \to X_{SM}$
- RHN effects:
  - lighter $\tilde{\nu}_\tau$, $\tilde{\tau}_2 \simeq \tilde{\tau}_L$
  - smaller mixing $\to$ heavier $\tilde{t}_1$
  - $\tilde{\tau}_1$ becomes $\tilde{\tau}_L$
- $\tilde{t}$-coan. closes
- New $\tilde{\nu}_\tau$-coan. appears



m_0 =150GeV, $m_{1/2}$ =300GeV, $\tan\beta$=5, A_0 =-1091GeV



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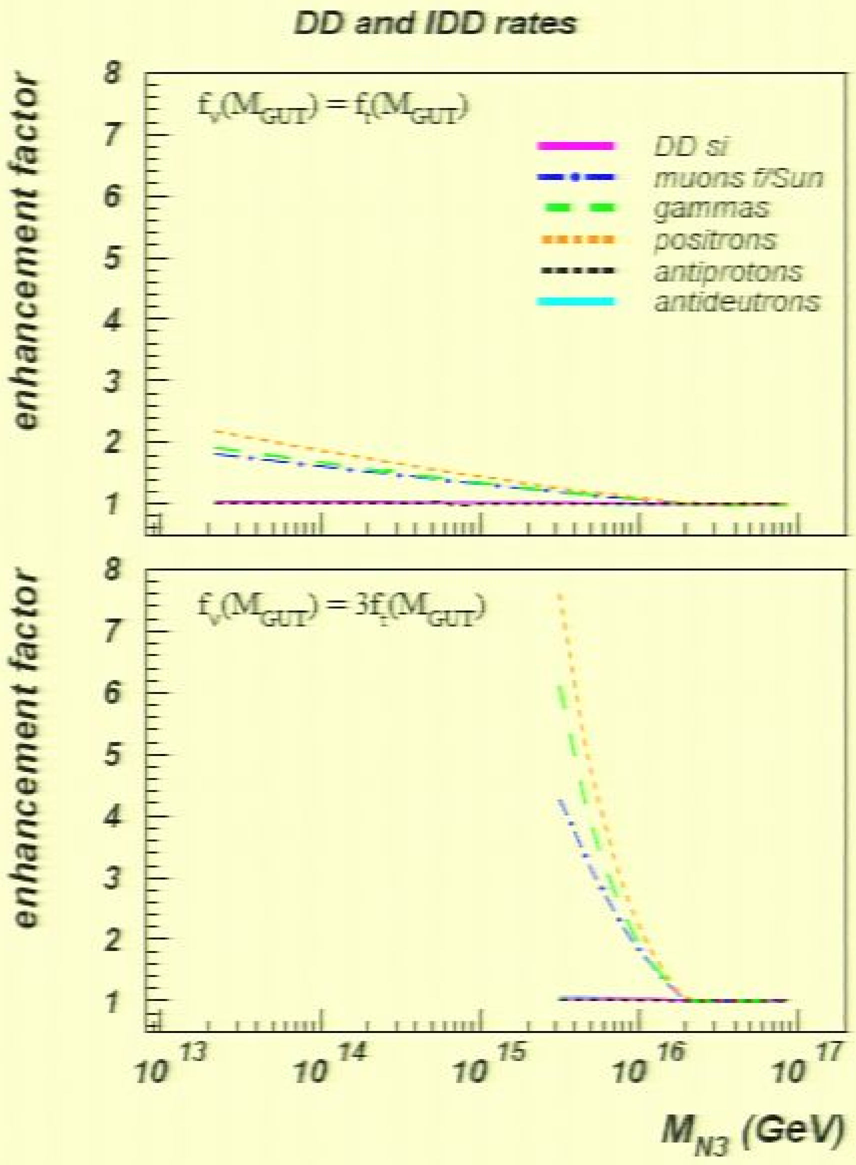
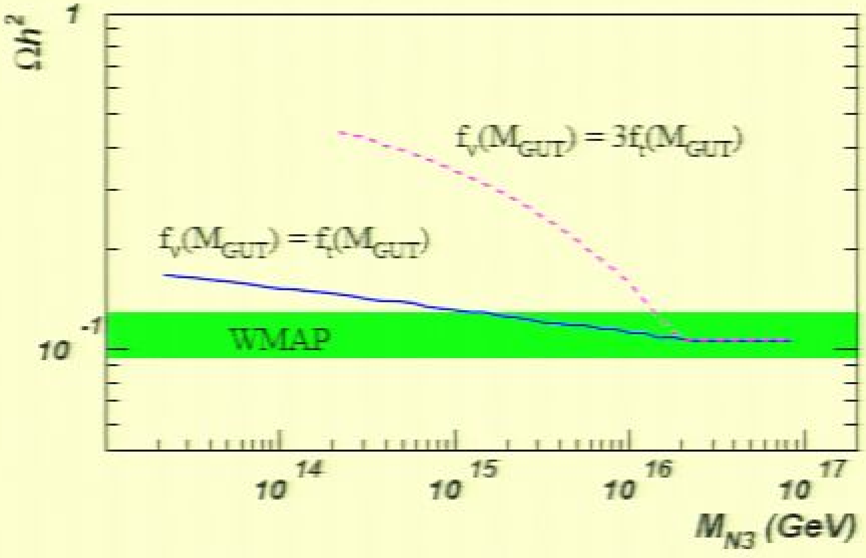
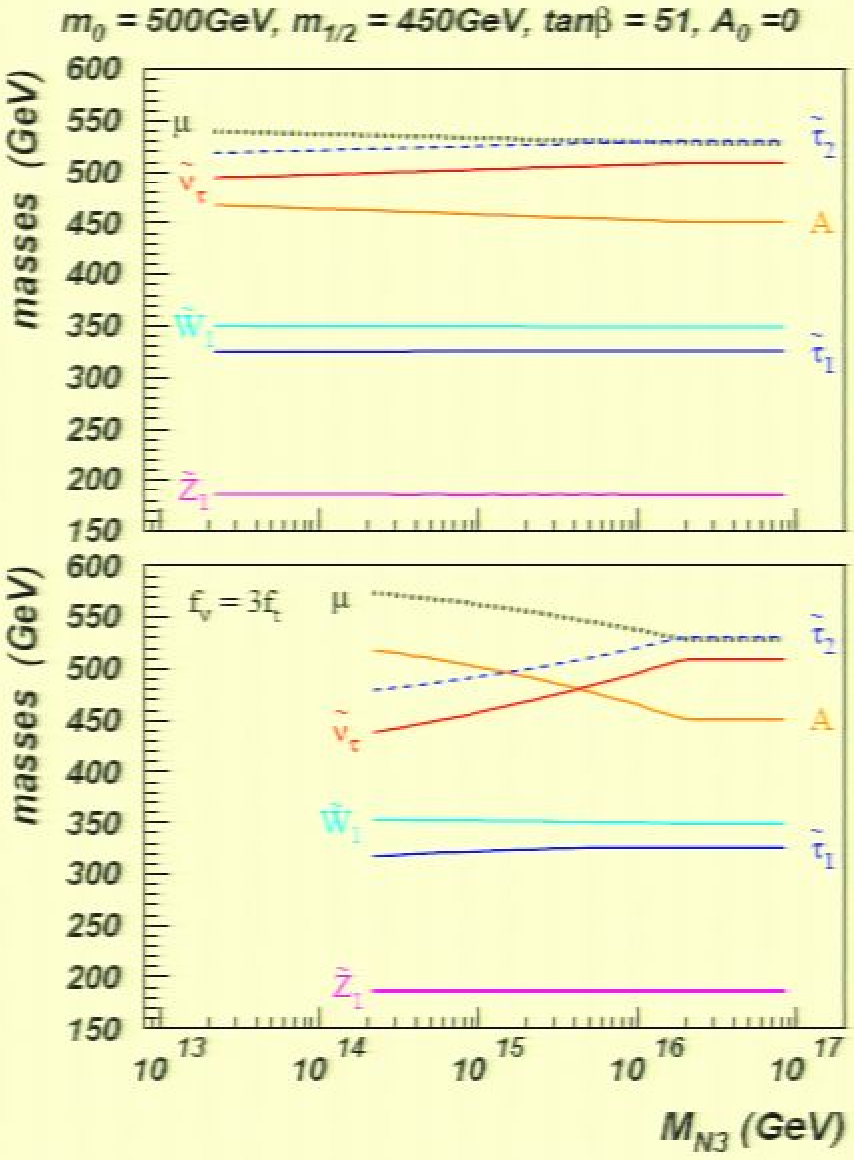
- $\tilde{t}$-coan. closes
- New $\tilde{\nu}_\tau$-coan. appears
- positron, muon and γ-ray rates up by 100-150% (300-700%)



Higgs funnel

- Medium m_0 and large $\tan\beta$
- $\widetilde{Z}_1\widetilde{Z}_1 \to A \to b\bar{b}/\tau\bar{\tau}$
- Lighter $\tilde{\nu}_\tau$, $\tilde{\tau}_2 \simeq \tilde{\tau}_L$
- Heavier A Higgs boson
- $\Omega_{\widetilde{Z}_1} h^2$ grows beyond WMAP





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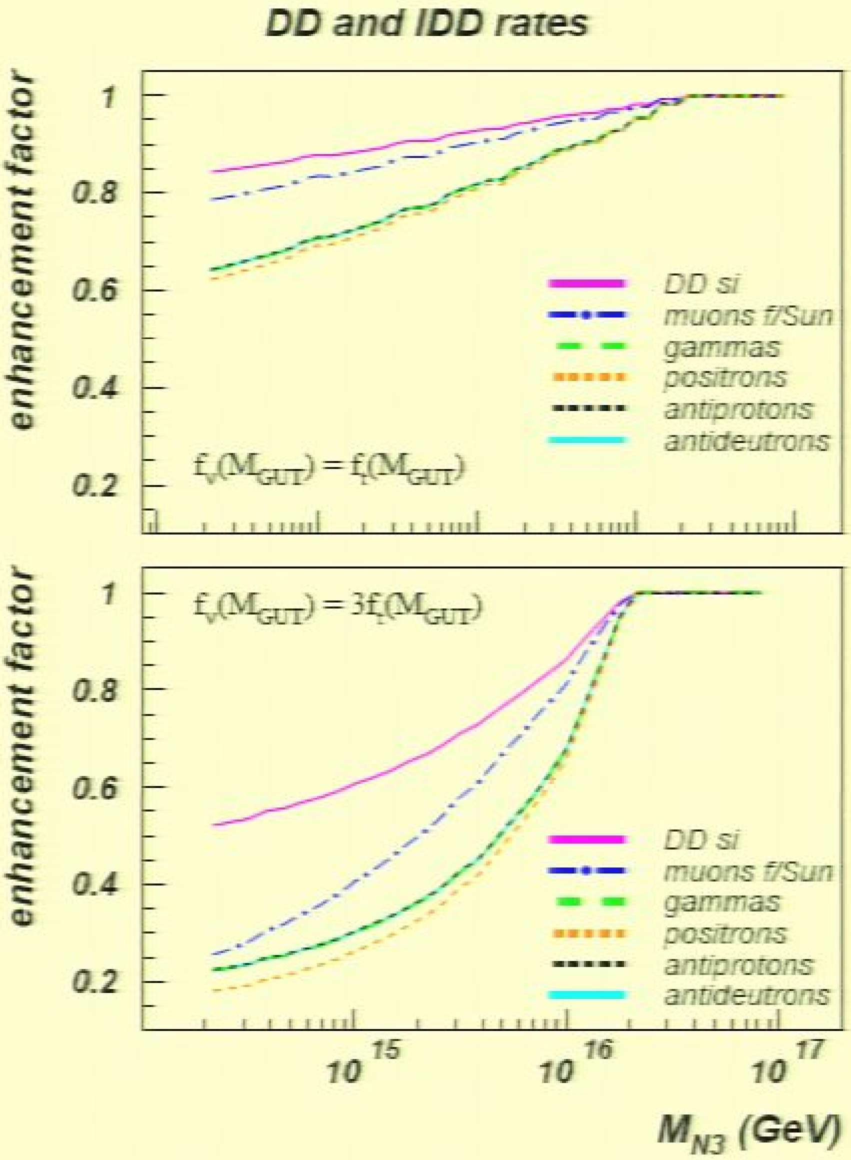
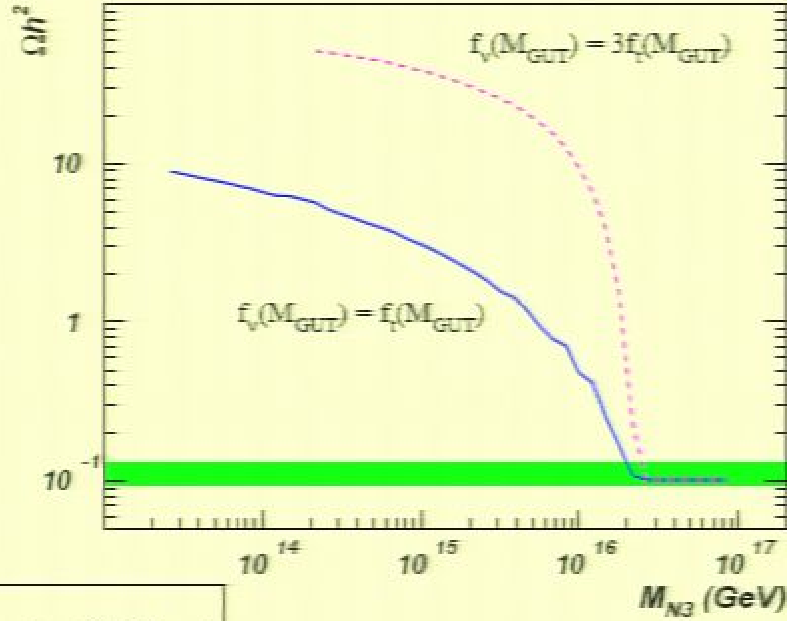
- Lighter $\tilde{\nu}_\tau$, $\tilde{\tau}_2 \simeq \tilde{\tau}_L$
- Heavier A Higgs boson
- $\Omega_{\widetilde{Z}_1}h^2$ grows beyond WMAP
- Decreasing DM rates:
  - DD – 15% (50%)
  - muons – 20% (75%)
  - antimatter and γ-rays – 40% (75%)



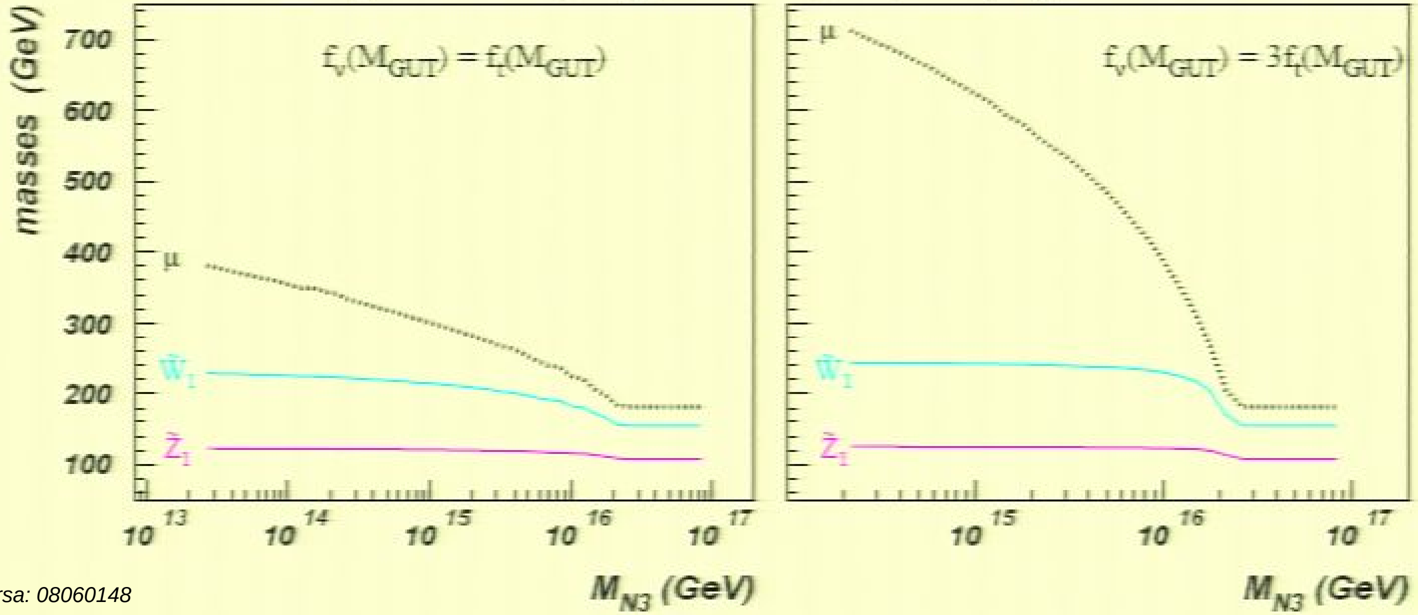
DD and IDD rates

Focus point

- Large m_0 region
- Small μ: mixed bino-higgsino $\widetilde{Z}_1$
- $\widetilde{Z}_1\widetilde{Z}_1 \to WW/ZZ/Zh$
- Larger $\mu \to$ smaller higgsino content of $\widetilde{Z}_1$
- RD increase 100-500 times



m_0 = 1516GeV, $m_{1/2}$ = 300GeV, tanβ = 10, A_0 =0



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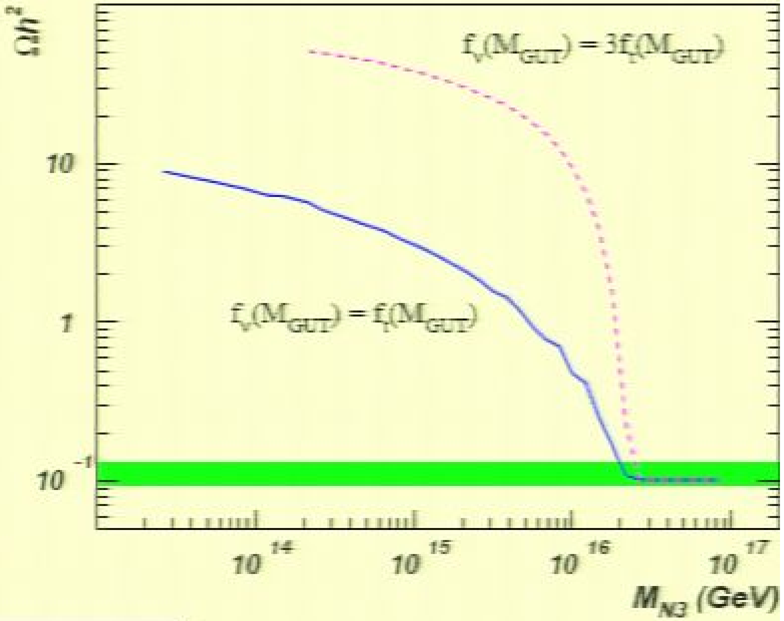
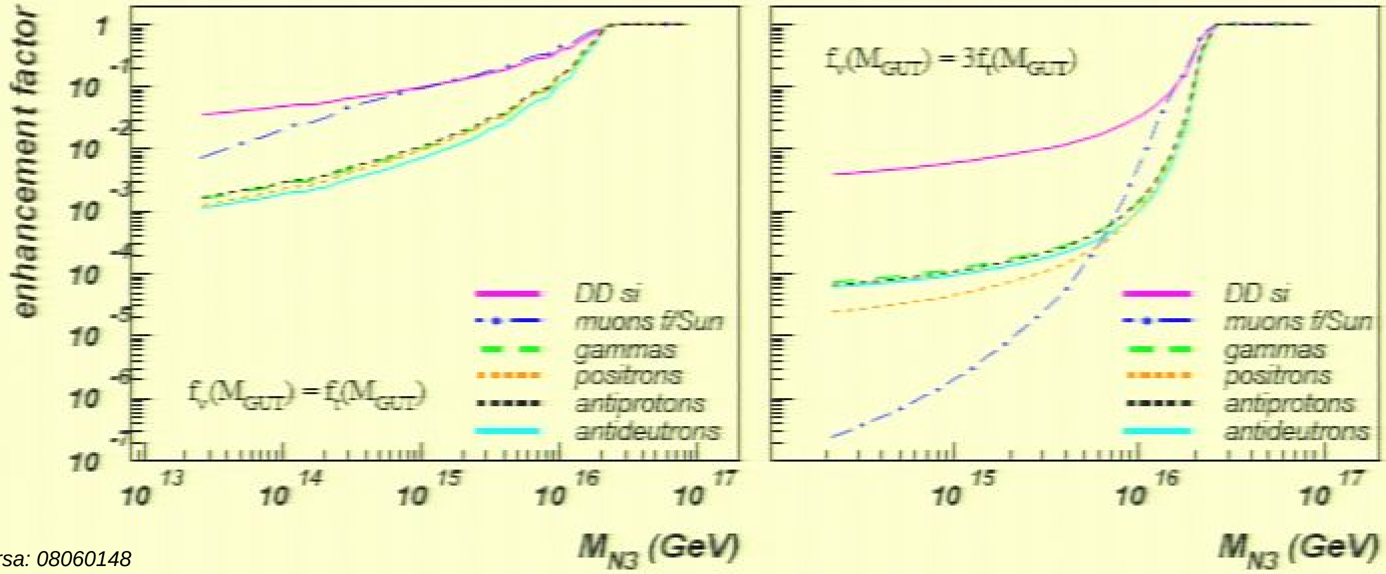
- RD increase 100-500 times
- DM rates drop by several orders of magnitude

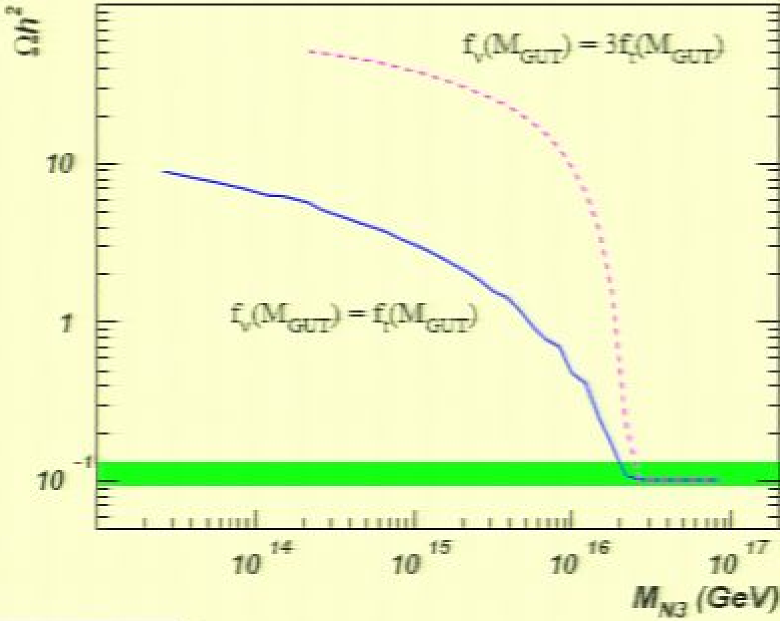




Conclusions

- Neutrino Yukawa couplings can significantly affect the Dark Matter observables
  - Sparticle masses and composition can sufficiently modified
  - RD-allowed regions shift $\Rightarrow$ collider effects
  - New coannihilation mechanisms possible
  - DM-detection rates may change by up to several orders of magnitude!
- Most prominent when SSB slepton masses and/or trilinears large
  - $\tilde{t}$-coannihilation, $A-$funnel and focus point regions in mSUGRA
- Wider changes possible in non-mSUGRA models
- Other types of seesaw ($e.g.$ double seesaw) can have $M_N \sim 10^8$ GeV $\Rightarrow$ even larger effects

Focus point



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