The effects of SUSY Seesaw on the Dark Matter and LHC

Kenji Kadota

Michigan Center for Theoretical Physics

Based on the papers in collaboration with
Keith Olive (Minnesota), Jing Shao (Syracuse),
Liliana Vesasco-Sevilla (ICTP)

Summary of today's talk: 3 main results

•Model:CMSSM(Constrained Minimal Supersymmetric Model)+ N_3

Dark Matter:

Features of the thermal relic abundance which don't show up in CMSSM.

1) Emergence of "Sneutrino Coannihilation Regions" (KK,K. Olive and L. Sevilla)

2) Complete disappearance of Focus Point Regions (KK and K. Olive)

Collider Signals:

Enhancement of the tau signals which don't show up in CMSSM.

3) 3 or more taus + jets (with negligible SM backgrounds) at 1/fb for small m_0 and $M_{1/2}$.(KK and J. Shao)

Model

- Toy model: Supersymmetric Seesaw

CMSSM+a right-handed neutrino N_3 (GUT scale mass)

$$\text{(only two additional parameters}: M_N(Q_{GUT}), m_\nu(Q_{Mz}))$$

Q: Does a heavy N affect the thermal dark matter abundance and/or collider signals?
(in this talk, dark matter = neutralino LSP)

$$\text{The coupling of } N \text{ to the other fields}:$$
$$y_N N L H_u$$

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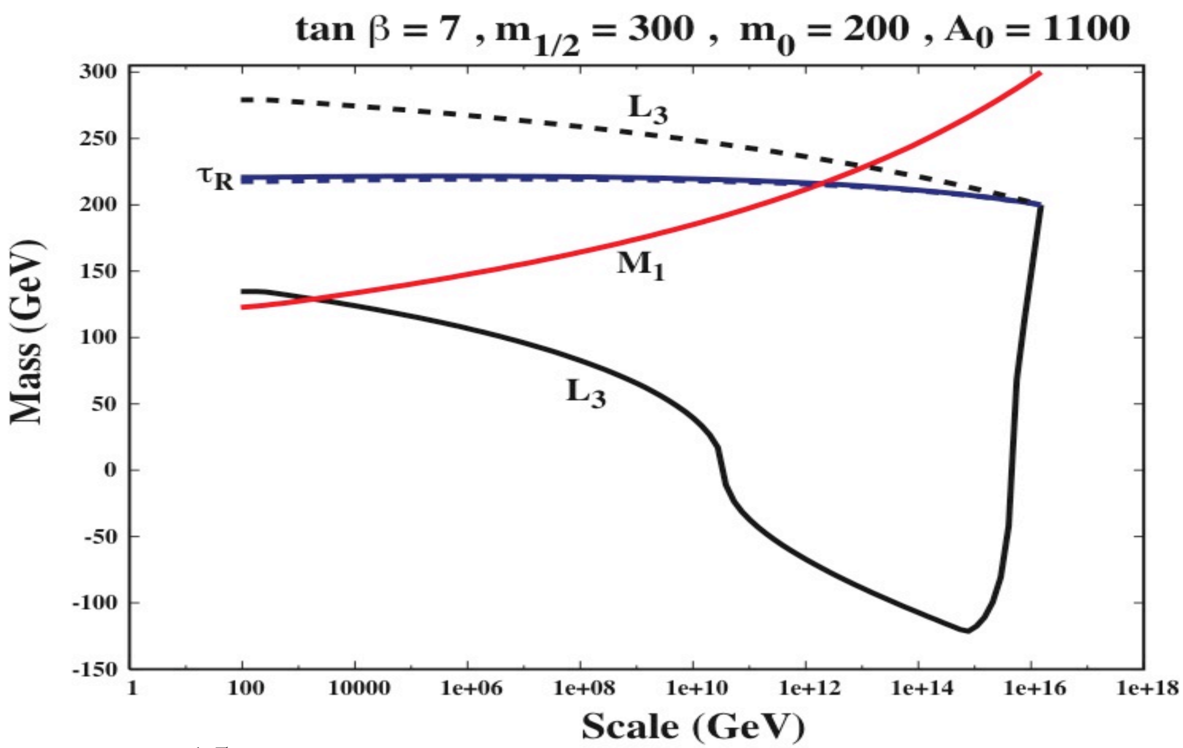
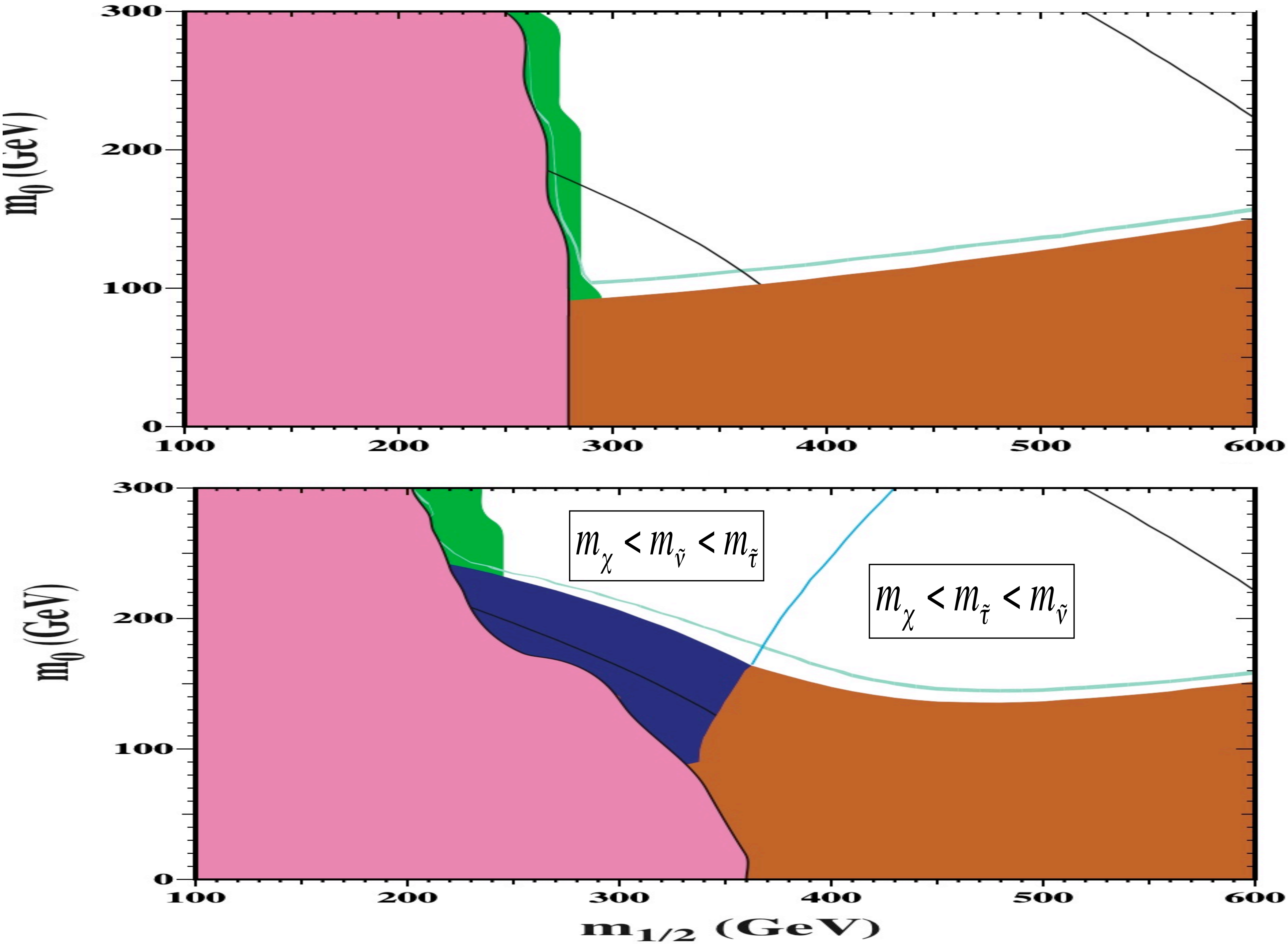


$$M_N = 10^{15} GeV, m_\nu = 0.05 eV$$

Light left-handed sneutrino $\Rightarrow$
Emergence of sneutrino coannihilation regions



300
200
100
0
m_0 (GeV)
100
200
300
400
500
600
$m_\chi < m_{\tilde{\nu}} < m_{\tilde{\tau}}$
$m_\chi < m_{\tilde{\tau}} < m_{\tilde{\nu}}$
$m_{1/2}$ (GeV)

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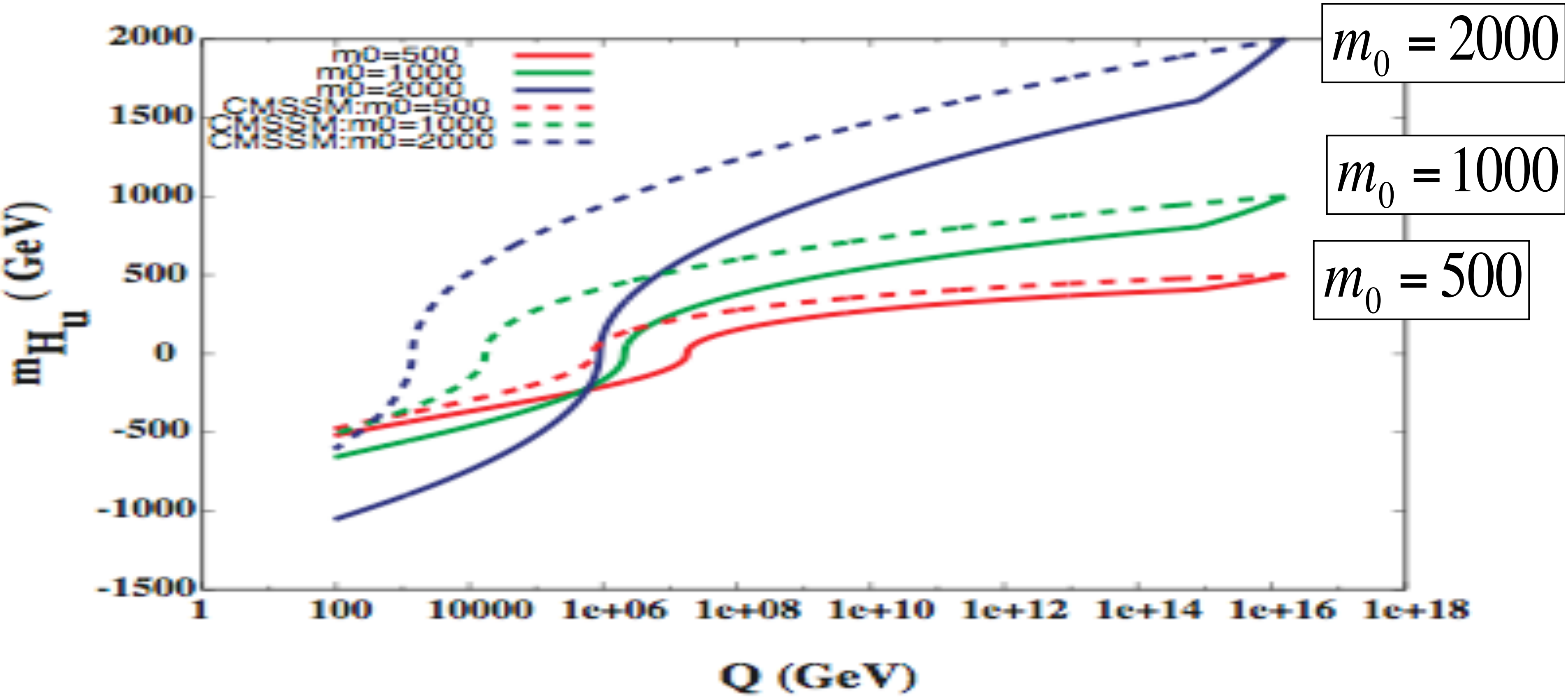
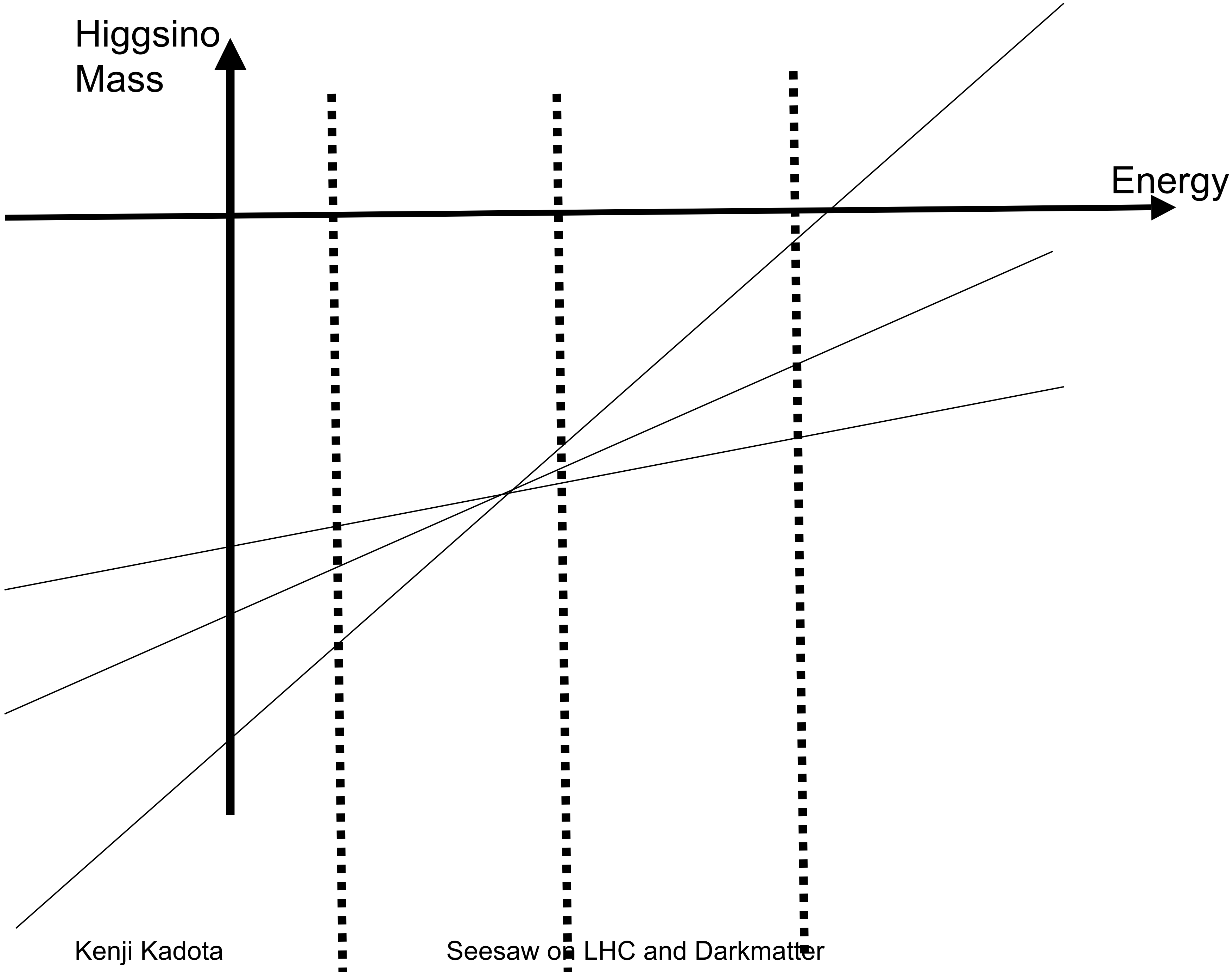
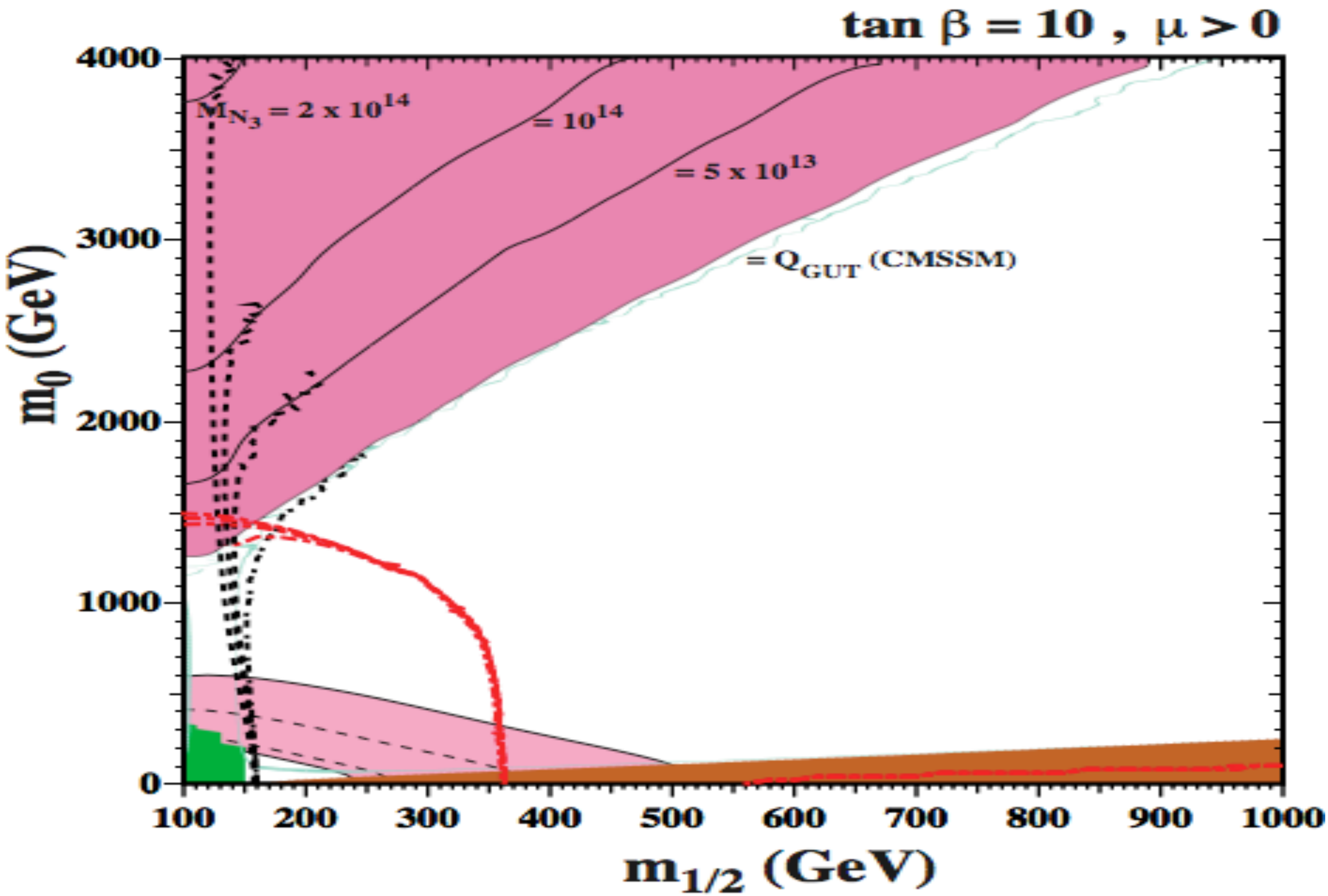
The coupling of N to the other fields : $y_N N L H_u$



Focus point scale can change dramatically $\Rightarrow$
Disappearance of the focus point regions


Higgsino
Mass
Energy


tan β = 10 , μ > 0
4000
3000
2000
1000
0
100
200
300
400
500
600
700
800
900
1000
m0 (GeV)
m1/2 (GeV)
MN3 = 2 x 10^14
= 10^14
= 5 x 10^13
= QGUT (CMSSM)

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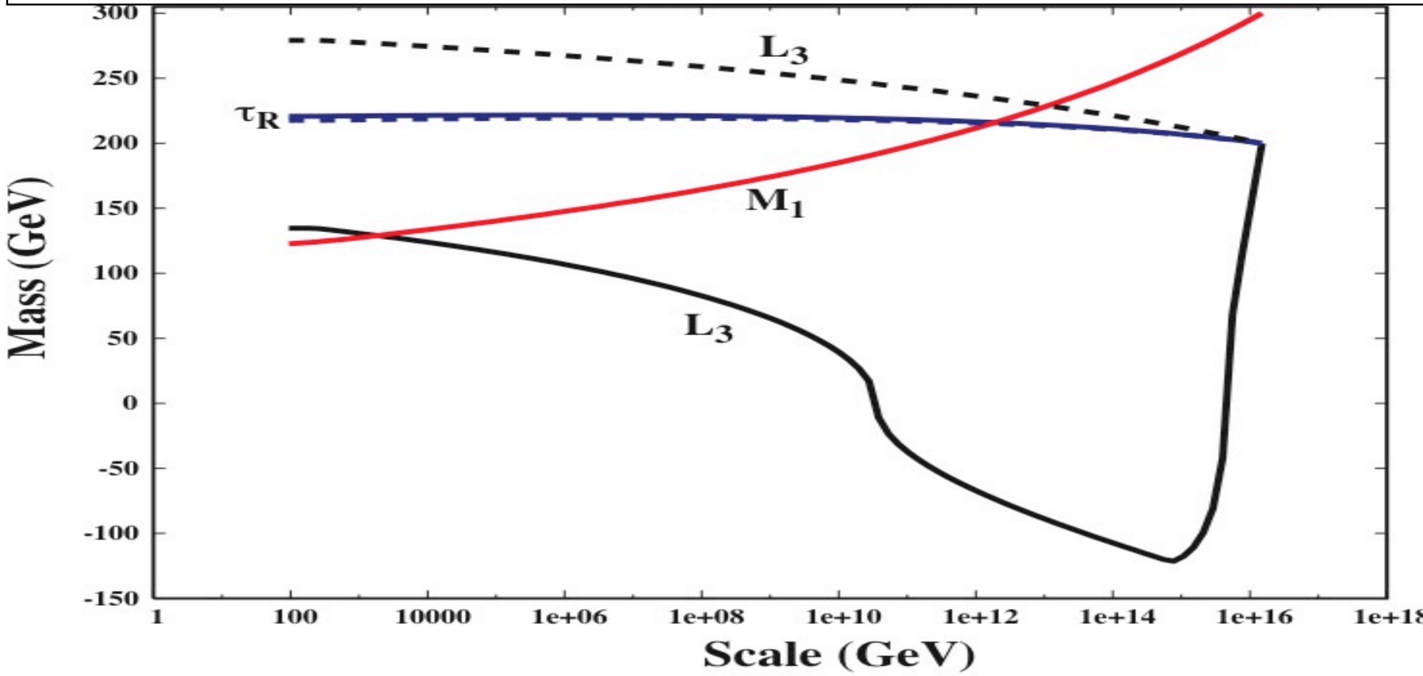
Model: Light left-handed stau doublet



$\tilde{\chi}_1^0$: Bino - like. $\tilde{\chi}_2^0$ & $\tilde{\chi}_1^{\pm}$: Wino - like.

CMSSM : $\tilde{\tau}_1$ is RH

Drees&Nojiri ‘92, Baer et al ‘98, Barger&Kao ‘99, Lykken&Matchev ‘00, Hinchliffe&Paige ‘00, Wells ‘98, Arnowitt et al ‘06, Chattopadhyay et al ‘07, Katz&Tweedie ‘10 …

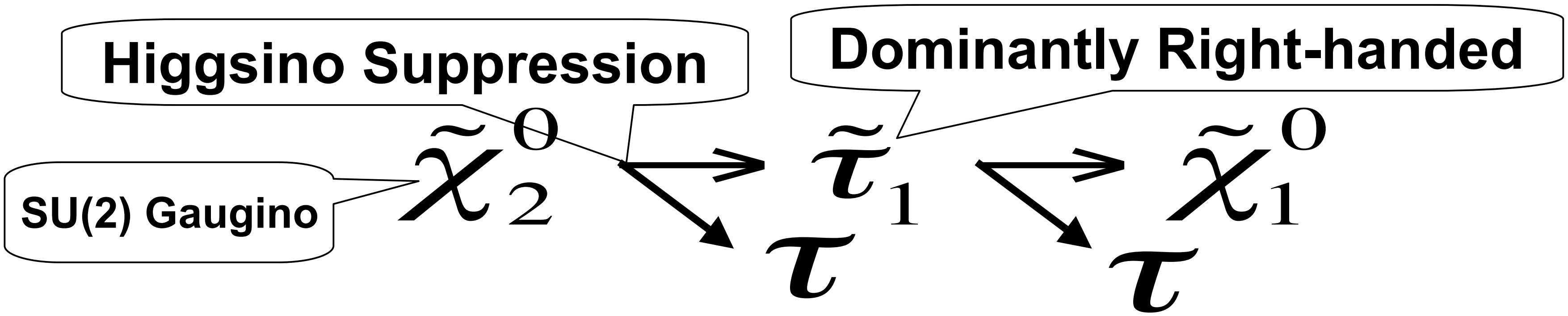
Seesaw : $\tilde{\tau}_1$ is LH

KK&J. Shao ‘09

Enhanced tau events in light stau doublet scenario

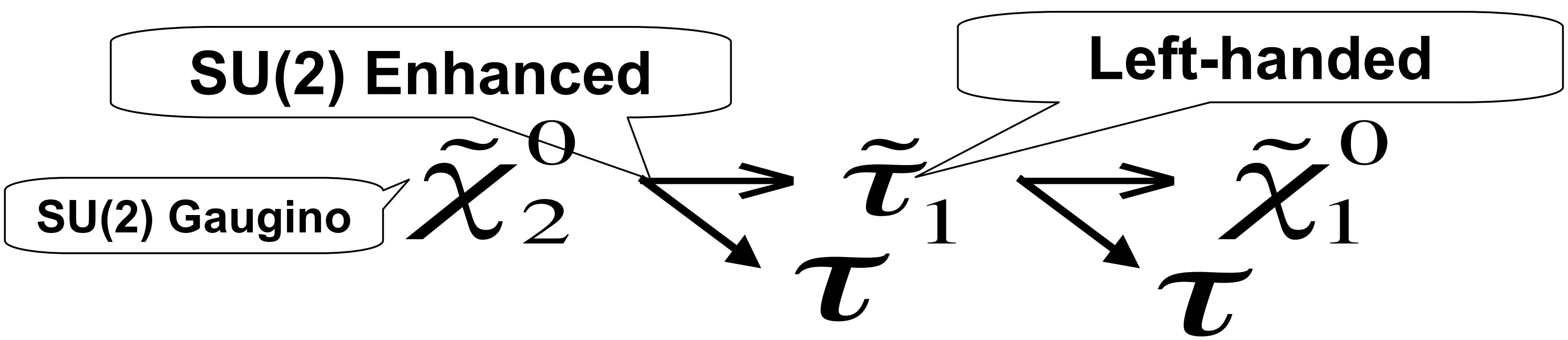
- Previous literature: Light right-handed stau

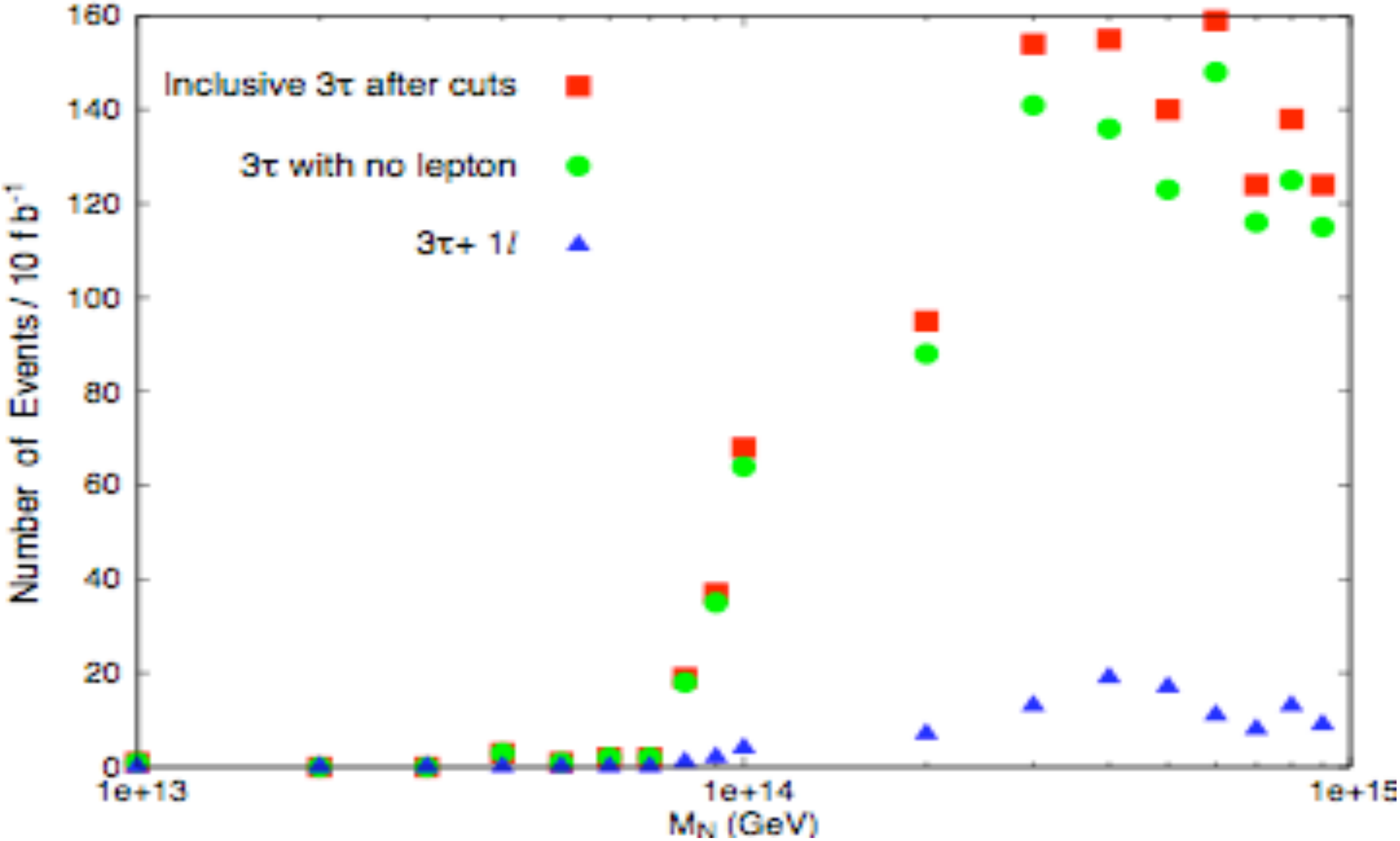
  Large tanβ or/and A_0:Kinematically preferable small m_0,$m_{1/2}$ tightly constrained by Br($b \to s\gamma$), Br($Bs \to \mu^+ \mu^-$) etc.



- This talk: Light left-handed stau

  Kinematically preferable small m_0,$m_{1/2}$ (Sneutrino Co-annihilation region)





138 3-tau events for constrained seesaw @ M_N=8x10^{14}GeV.
1 3-tau event for CMSSM
(tau efficiency factor ε_τ=0.4.)

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Enhanced Tau Lepton Signatures in Constrained Supersymmetric Seesaw Scenarios

- Production and decay of weak gauginos

could signal the deviations from SM

e.g. Enhanced tau events

(could be related to finite neutrino masses)

$$W = W_{MSSM} + y_N N L H_u + \frac{1}{2} M_N N N$$

$$m_0, M_{1/2}, A_0, \tan\beta, sign(\mu)$$

$$M_N(Q_{GUT}), m_\nu(Q_{Mz})$$

- Simple cuts:
  - Four jets with pt>50GeV with the leading jets pt>100GeV
  - MET>max(0.2Meff,100GeV)
  - Hadronically decaying taus pt>20GeV, $|\eta|<2.5$.

Tau efficiency factor $\varepsilon_\tau=0.4$.

Checked these strong cuts sufficiently reduce the backgrounds (ZZ, WZ, Z+Jets,WW,tt, QCD jets) to be negligible for 3 and 4 tau events for our study

- Jet rejection factor(function of ε_τ and jet Et):

300 for 20GeV<Et<30GeV

500 for 30<Et<60GeV

1000 for 60<Et<100GeV

3000 for 100GeV<Et

- Tau reconstruction/identification
- E.g. to be tested by ~100/pb of LHC data for multi jet backgrounds

- Simple cuts:

1) Four jets with pt>50GeV with the leading jets pt>100GeV

2) MET>max(0.2Meff,100GeV)

3) Leptons (e,μ) pt>20GeV and $|\eta|<2.5$

4) Hadronically decaying taus pt>20GeV, $|\eta|<2.5$. Tau efficiency factor $\varepsilon_\tau=0.4$.

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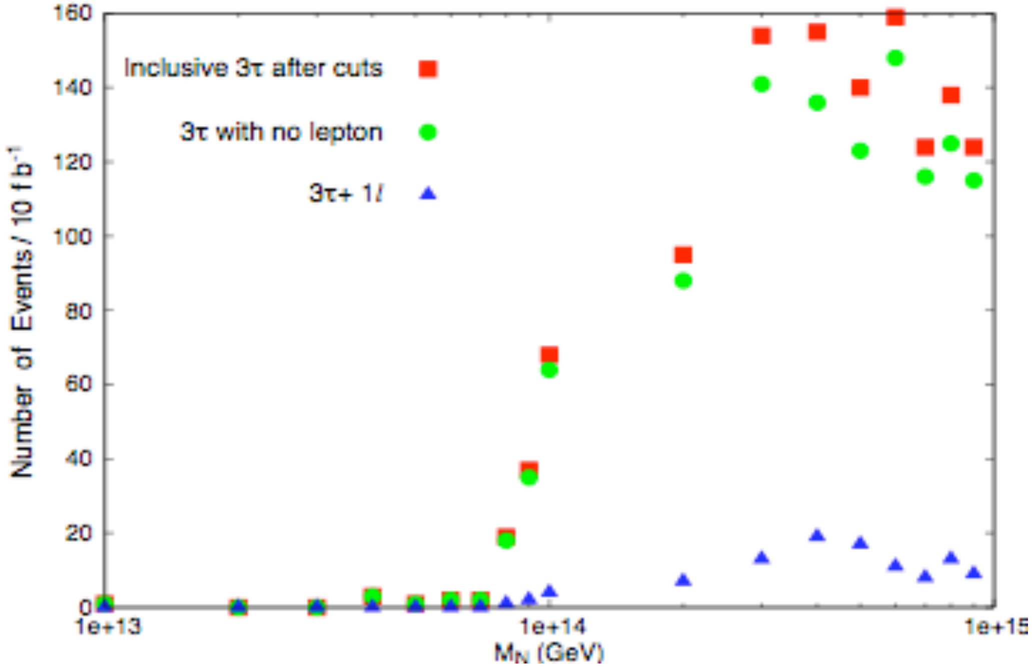
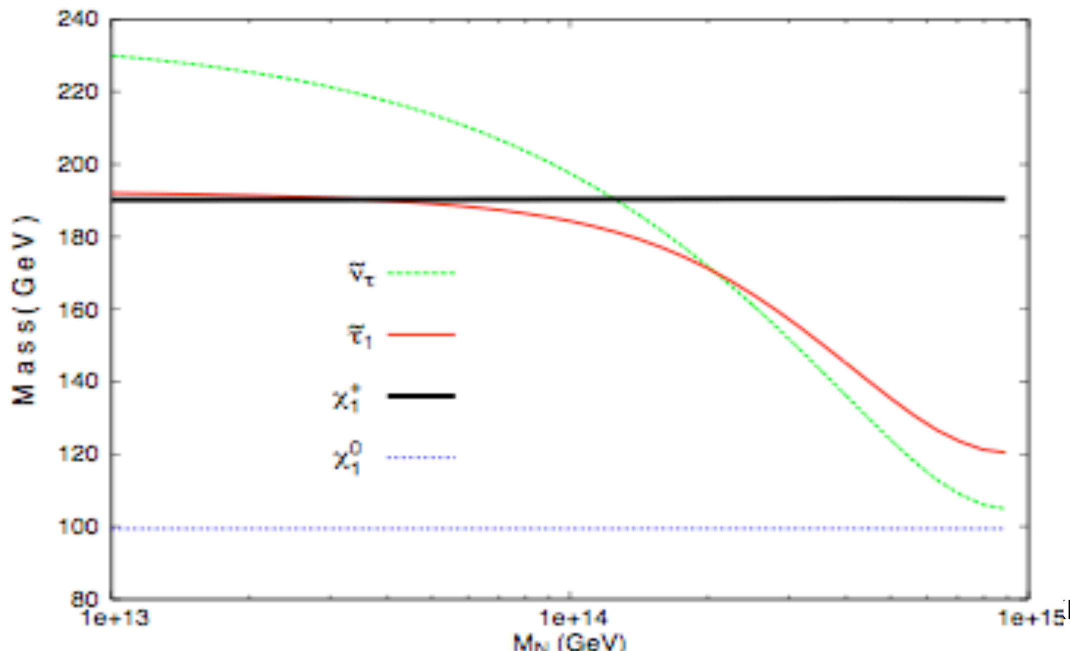
Tau Decay

- 35% leptonically with two neutrinos
- 65% hadronically with one (50%) or three (15%) charged particles

- Low multiplicity and high collimation





138 3-tau events for constrained seesaw @ $M_N=8x10^{14}$GeV.
1 3-tau event for CMSSM for 10/fb

(sigma(tot)=50pb,
m0=180GeV, m12=250GeV,tanb=7)

	Seesaw	CMSSM
3 tau:	138	1
2 tau+1L:	521	5
1 tau+ 2L:	468	14
3L:	109	73

for 10/fb

matter

Model: Constrained Seesaw

CMSSM(Constrained Minimal Supersymmetric Model)+N

$$W = W_{MSSM} + y_N N L H_u + \frac{1}{2} M_N N N$$

$$m_0, M_{1/2}, A_0, \tan\beta, sign(\mu)$$

$$M_N(Q_{GUT}), m_\nu(Q_{Mz})$$

$$Q_{GUT} \sim 2 \times 10^{16} GeV, M_N \sim 10^{15} GeV$$

$$Q < M_N : L \ni -\kappa(LH_u)(LH_u) \Rightarrow m_\nu(Q_{EW}) = \kappa \langle H_u \rangle^2$$

Q: Does a heavy N affect collider signals?