Phenomenology of SUSY flipped SU(5) GUT

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in collaboration with K.A.Olive and J.Ellis arXiv: 1103.5140

SUSY breaking

- MSSM: SM fields ⇒ superfields, *two* Higgs doublets
- Add all admissible soft SUSY-breaking terms

$$\mathcal{L}_{soft} = b_{ij} S_i S_j + a_{ijk} S_i S_j S_k - S_i^\dagger m_{ij}^2 S_j - \frac{1}{2} M_{A\alpha} \lambda_{A\alpha} \lambda_{A\alpha}$$

- Assume mechanism to communicate SUSY-breaking from Hidden Sector (Gravity mediation, gauge mediation, anomaly mediation,...)
  ⇨ universality $m_{\tilde{f}} \equiv m_0, \; M_{A\alpha} \equiv m_{1/2}, \; A_i \equiv A_0$ at scale M_{in}
- How large is M_{in} ?
  - $M_{in} = M_{GUT} \simeq 2 \times 10^{16}\, GeV$ ⟶ mSUGRA
  - $M_{in} < M_{GUT}$ ⟶ "GUT-less" models *Ellis,Olive,Sandick '06-'08*
  - $M_{in} > M_{GUT}$
    Choose GUT: SU(5) *[Ellis,Olive,A.M. '10],* flipped SU(5), SO(10),...

Flipped SU(5) GUT

- Gauge group: $SU(5) \times U(1)_X$
- Field content:

$$f(\overline{\mathbf{5}}, -3) = \{U^c, L\},\ F(\mathbf{10}, 1) = \{Q, D^c, N^c\},\ l(\mathbf{1}, 5) = E^c,\ S(\mathbf{1}, 0)$$
$$h_1(\mathbf{5}, -2) = \{T_1, H_d\},\ h_2(\overline{\mathbf{5}}, 2) = \{T_2, H_u\},\ H_1(\mathbf{10}, -1),\ H_2(\overline{\mathbf{10}}, 1)$$

- Advantages over minimal *SU(5)*:
  - Only minimal Higgs representations
  - Neutrinos necessarily massive
  - Successful hybrid inflation
- Superpotential:

$$\mathcal{W} = y_5 F h_2 f - y_{10} F F h_1 - y_1 f l h_1 + \mu_h h_1 h_2 + \lambda_4 H_1 H_1 h_1 + \lambda_5 H_2 H_2 h_2 + y_S F H_2 S + \mu_S S S$$

- Parameter space:

$$\alpha_2 = \alpha_3 = \alpha_5 \qquad 25\alpha_1^{-1} = 24\alpha_X^{-1} + \alpha_5^{-1}$$
$$h_t = h_\nu = y_5/\sqrt{2} \qquad h_b = 4y_{10}$$
$$h_\tau = y_1 \qquad \mu = \mu_h$$

Flipped SU(5) GUT

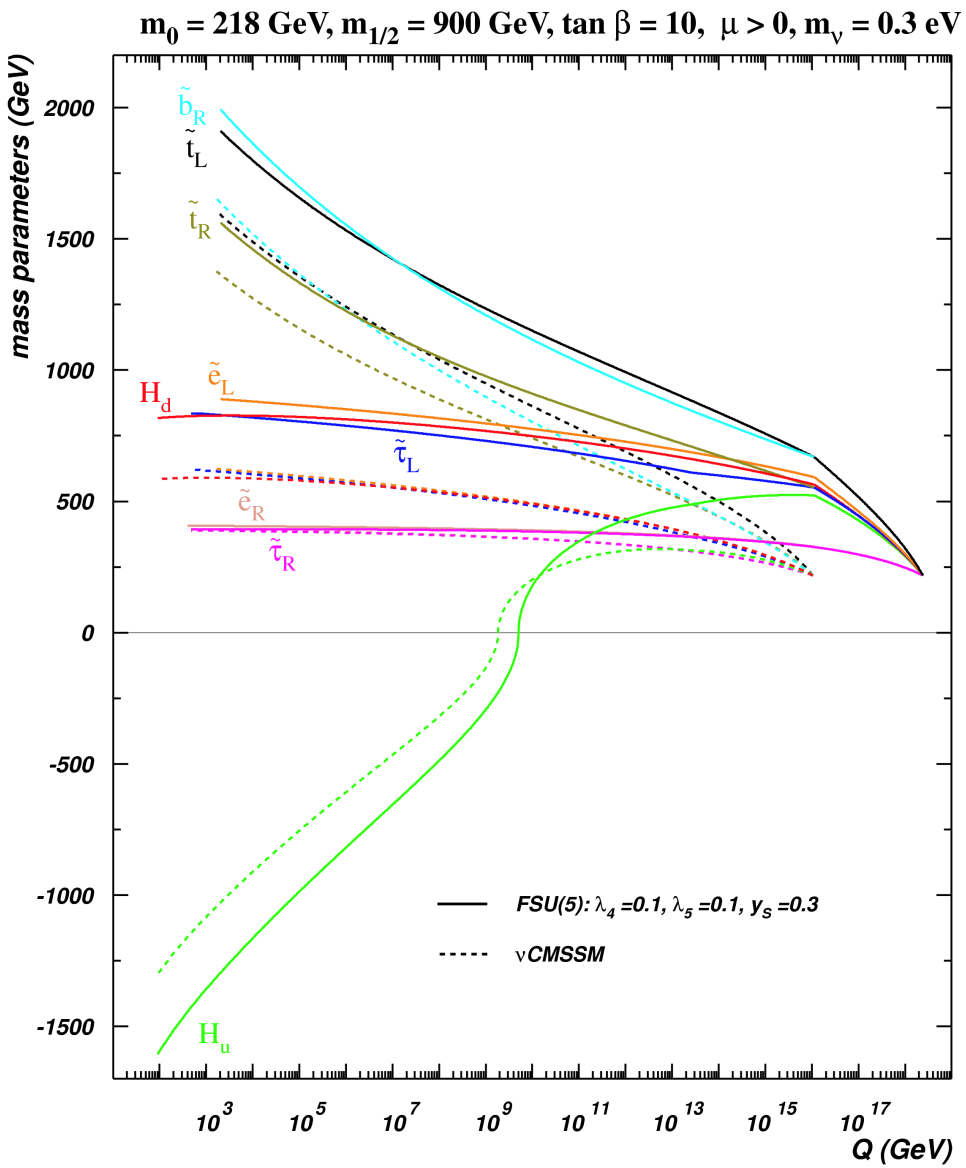
- Parameter space:

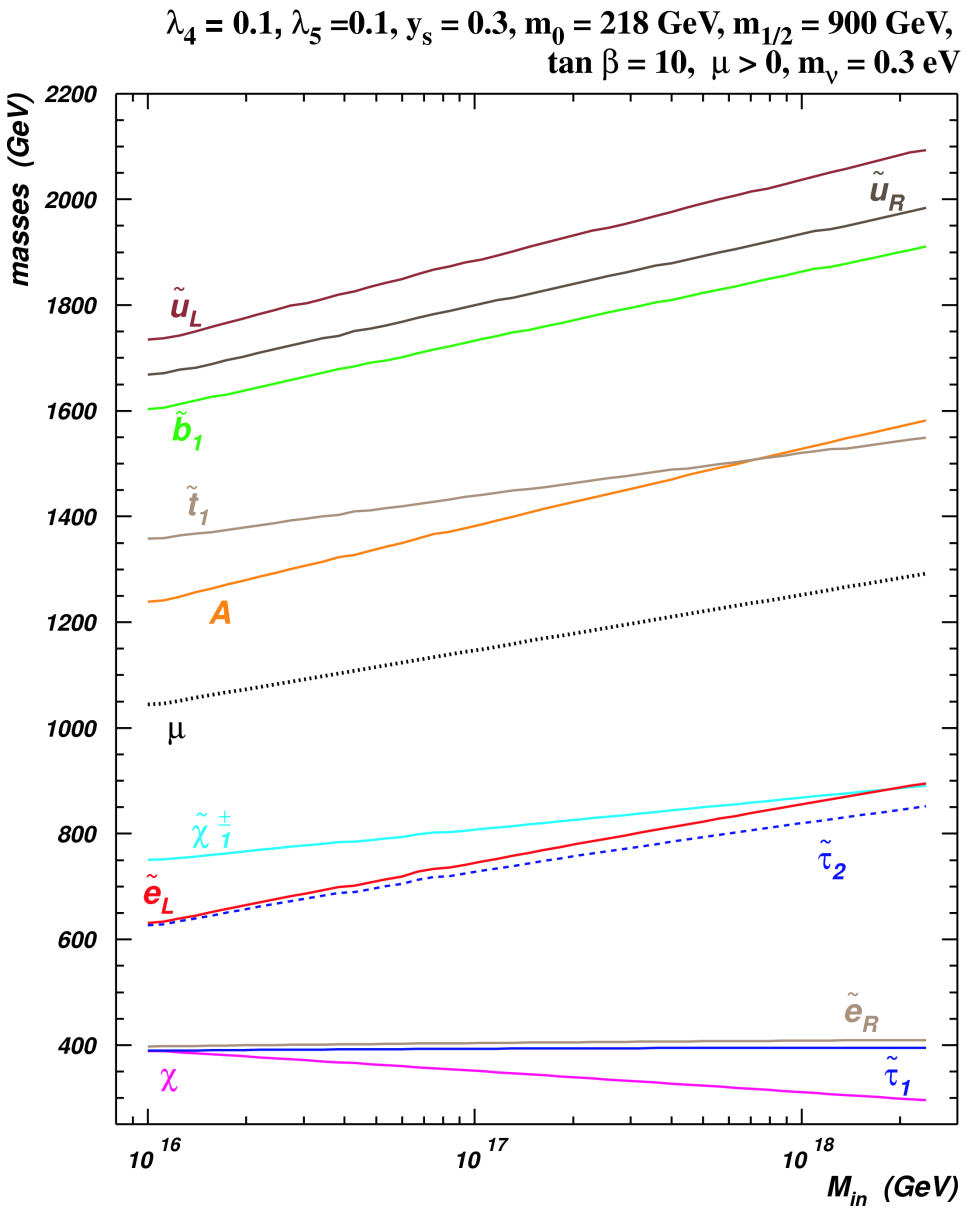
$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ sgn(\mu),\ \lambda_4,\ \lambda_5,\ y_S,\ M_{in}$$

- SSB matching of *FSU(5)* to MSSM

$$\begin{aligned}
M_2 = M_3 = M_5 \qquad & 25 M_1 \alpha_1^{-1} = 24 M_X \alpha_X^{-1} + M_5 \alpha_5^{-1} \\
m_{Q_1}^2 = m_{D_1}^2 = m_{N_1}^2 = m_{F_1}^2 \qquad & m_{Q_3}^2 = m_{D_3}^2 = m_{N_3}^2 = m_F^2 \\
m_{U_1}^2 = m_{L_1}^2 = m_{f_1}^2 \qquad & m_{U_3}^2 = m_{L_3}^2 = m_f^2 \\
m_{E_1}^2 = m_{l_1}^2 \qquad & m_{E_3}^2 = m_l^2 \\
m_{H_u}^2 = m_{h_2}^2 \qquad & m_{H_d}^2 = m_{h_1}^2 \\
A_t = A_\nu = A_5 \qquad & A_b = A_{10} \\
A_\tau = A_1 \qquad & B = B_h
\end{aligned}$$

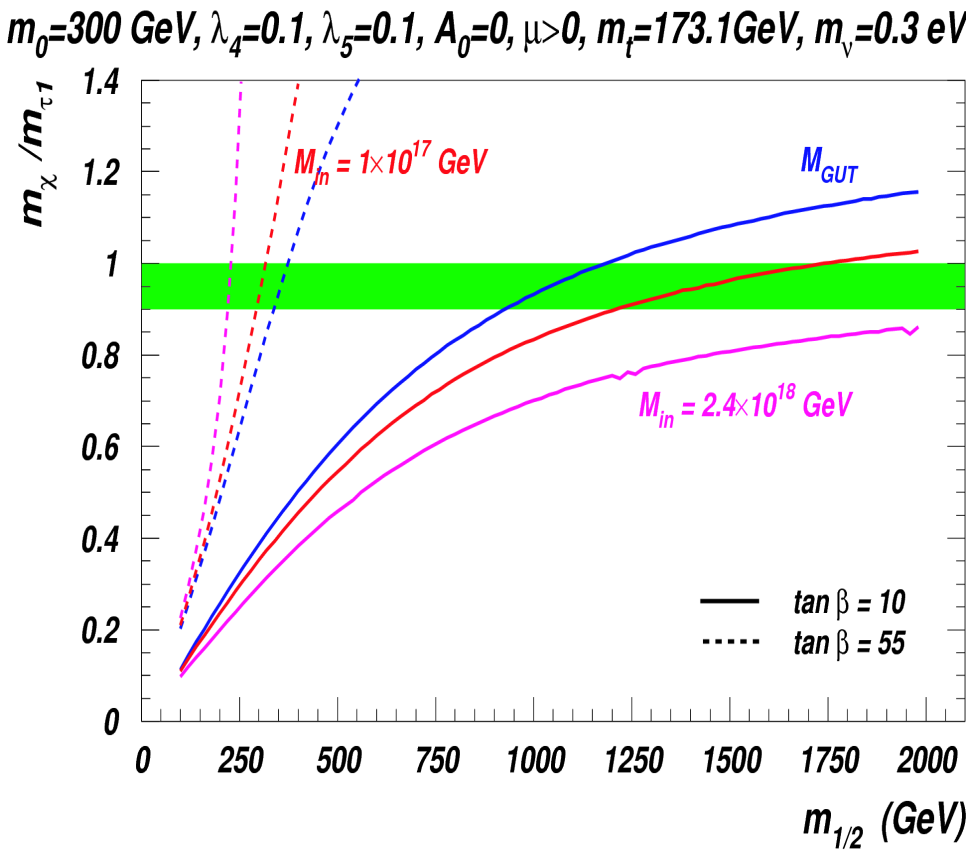
RGEs and sparticle spectrum

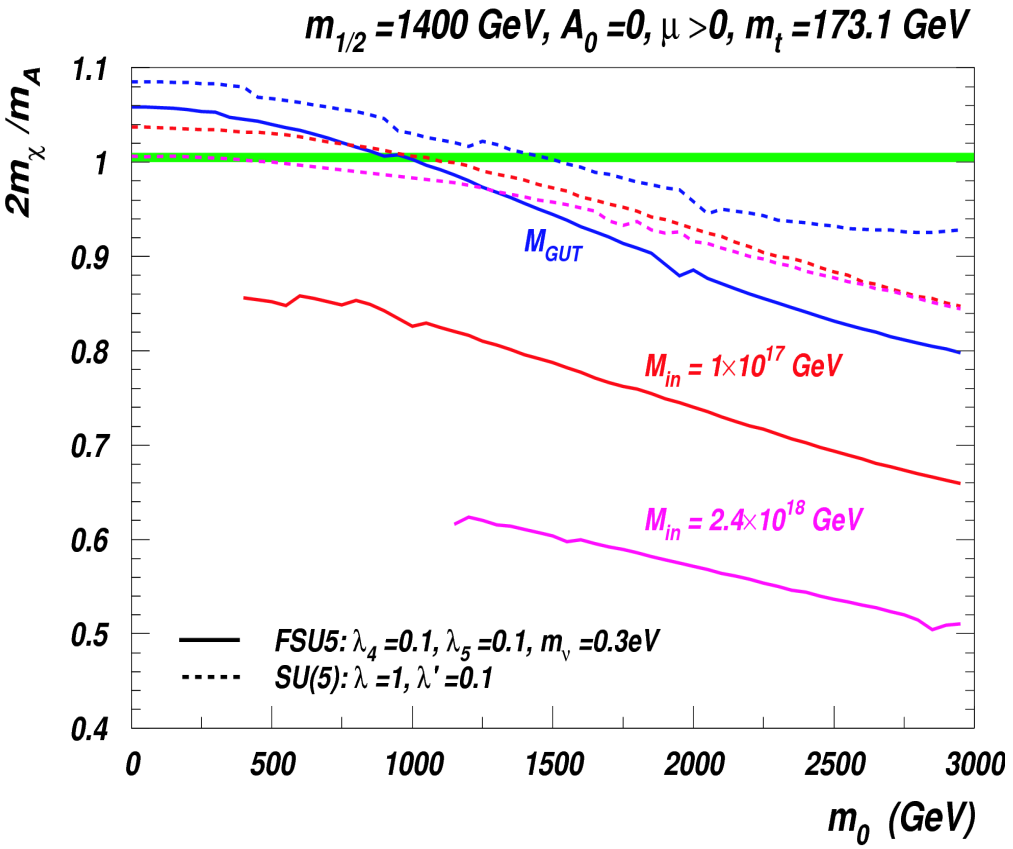




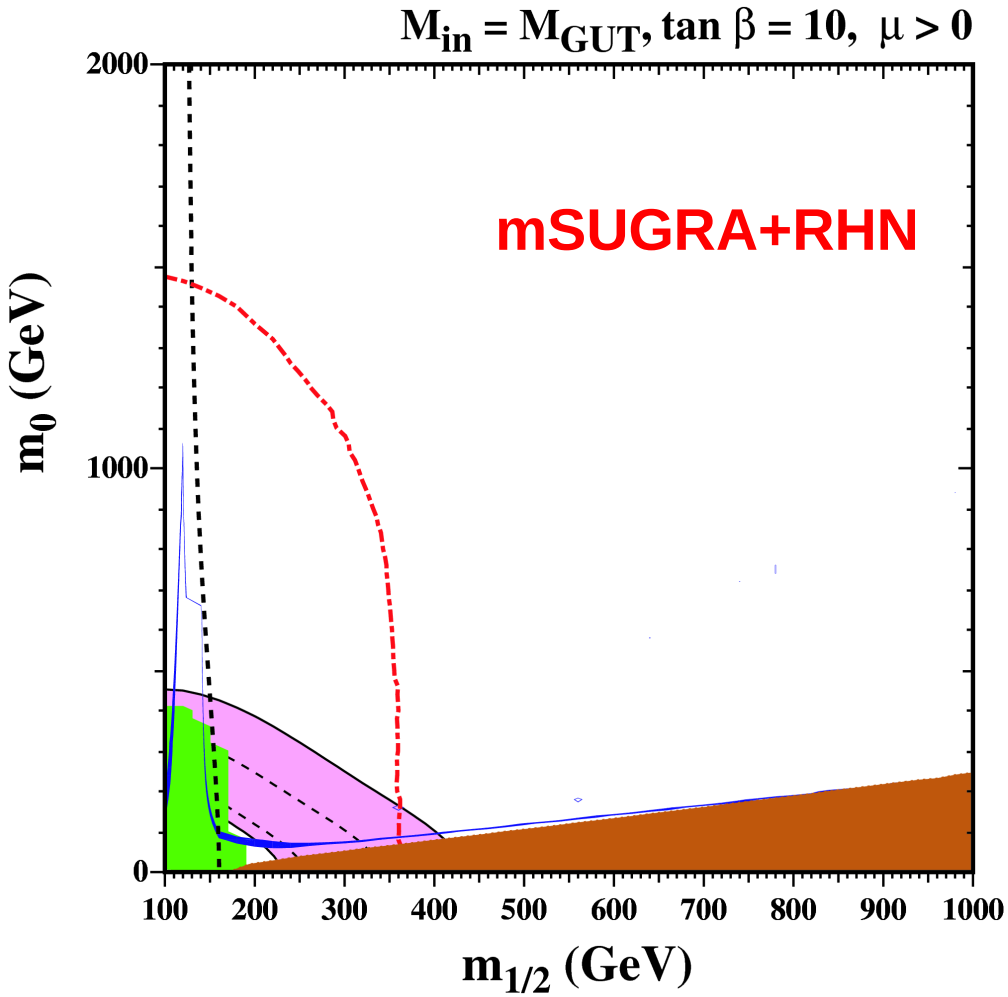
RD mechanisms in FSU(5)

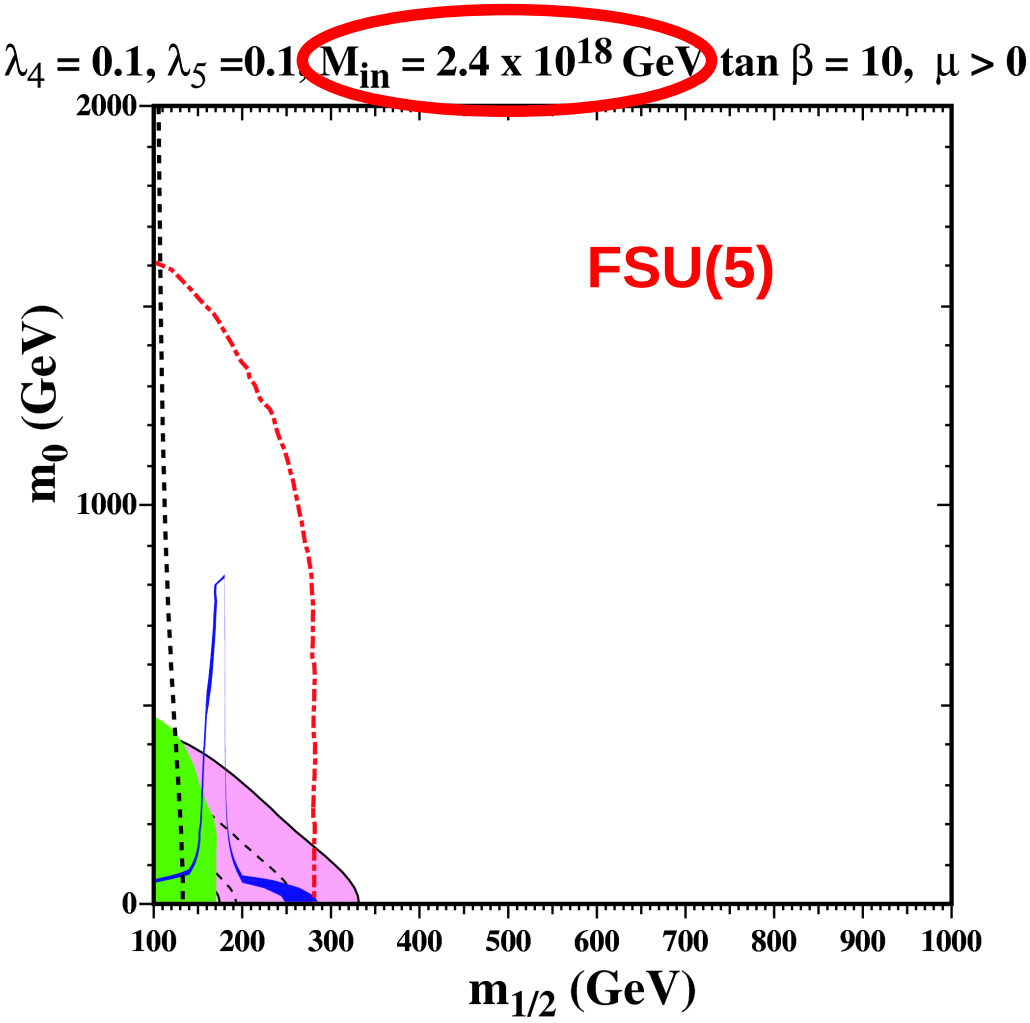
- Stau-coannih. region moves but is always present
- *A*-funnel disappears very rapidly with growing M_{in}



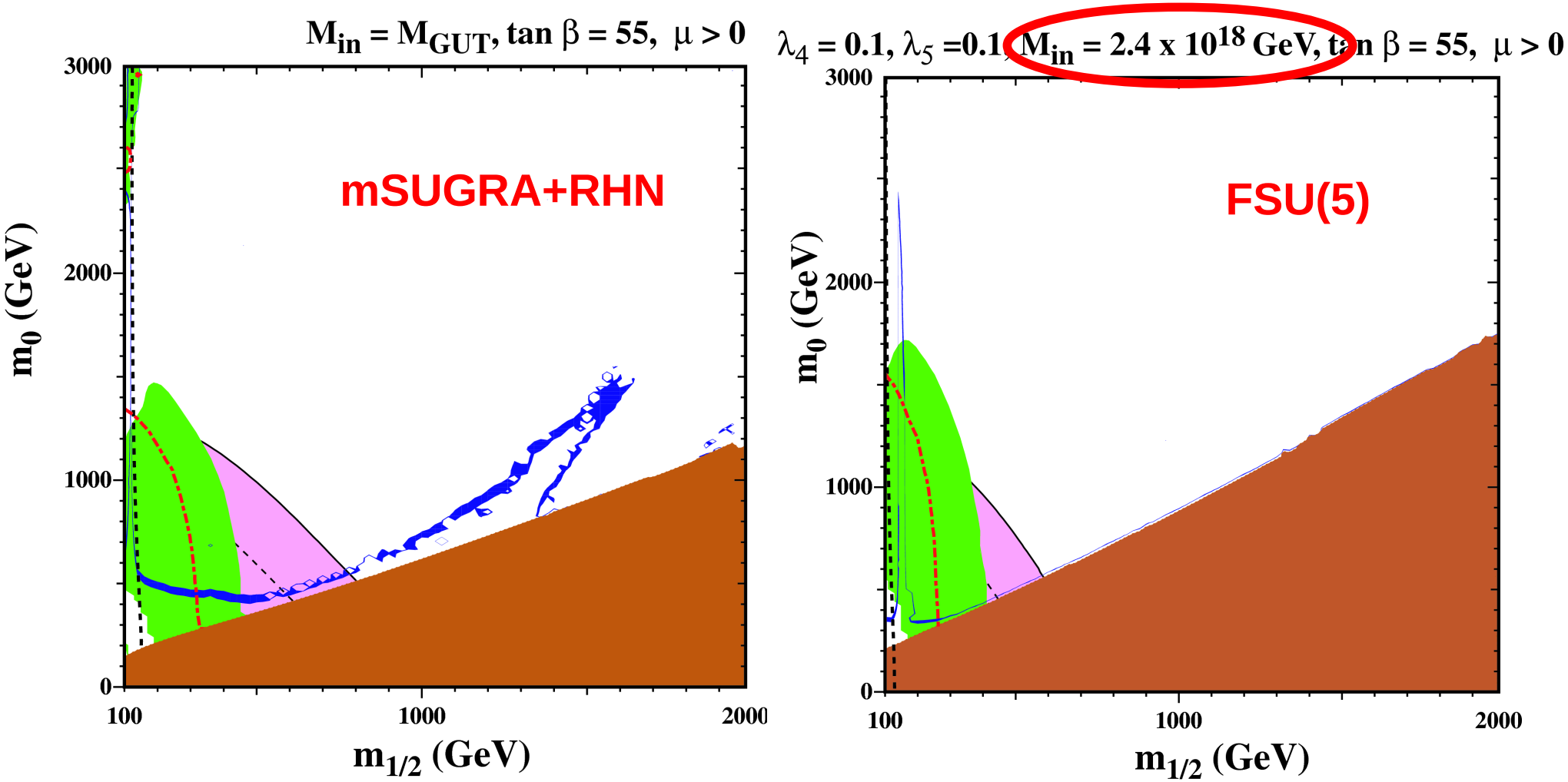


$(m_0,\ m_{1/2})$ plane

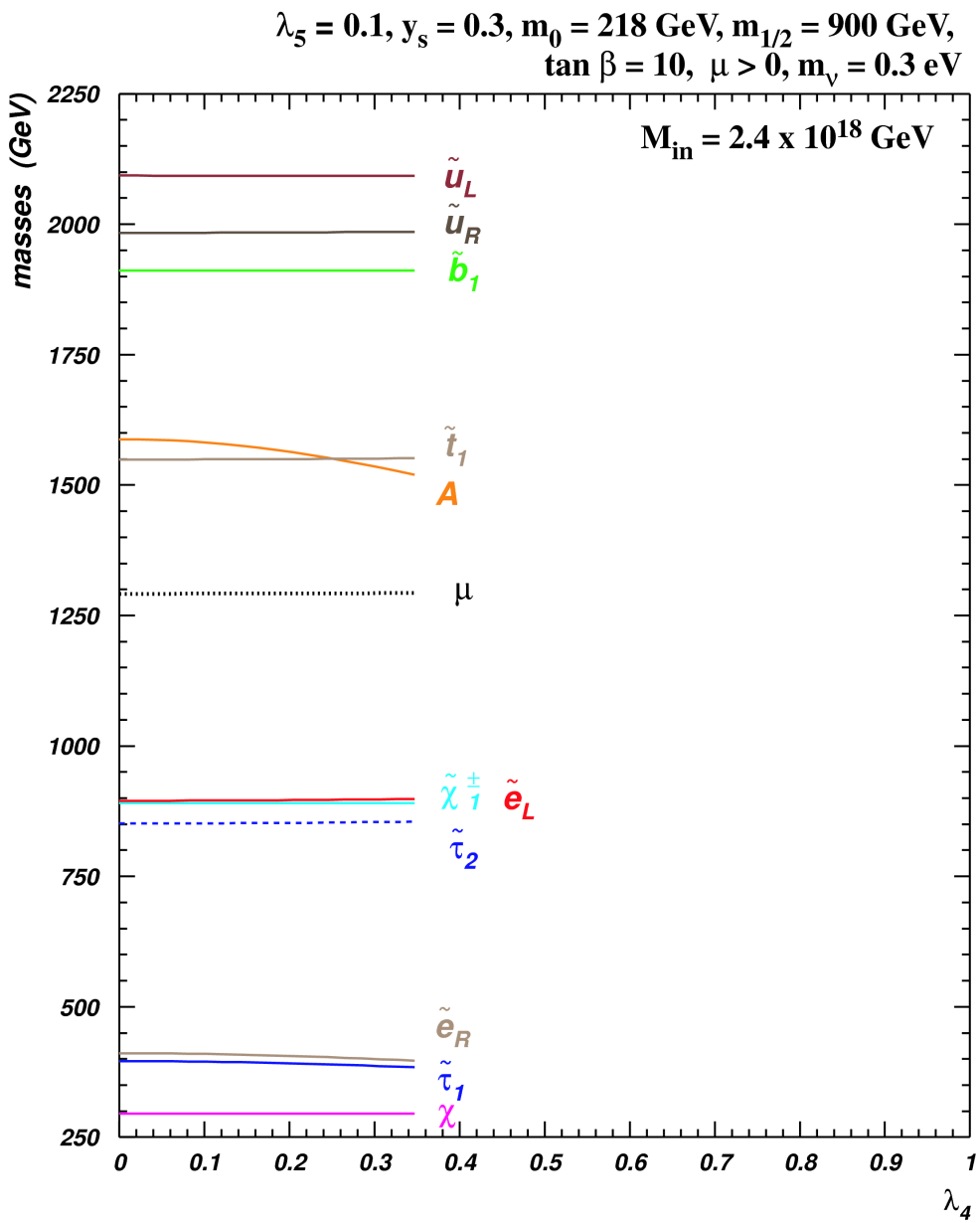

$M_{in} = M_{GUT}$, tan β = 10, μ > 0
mSUGRA+RHN
m_0 (GeV)
$m_{1/2}$ (GeV)
2000
1000
0
100
200
300
400
500
600
700
800
900
1000

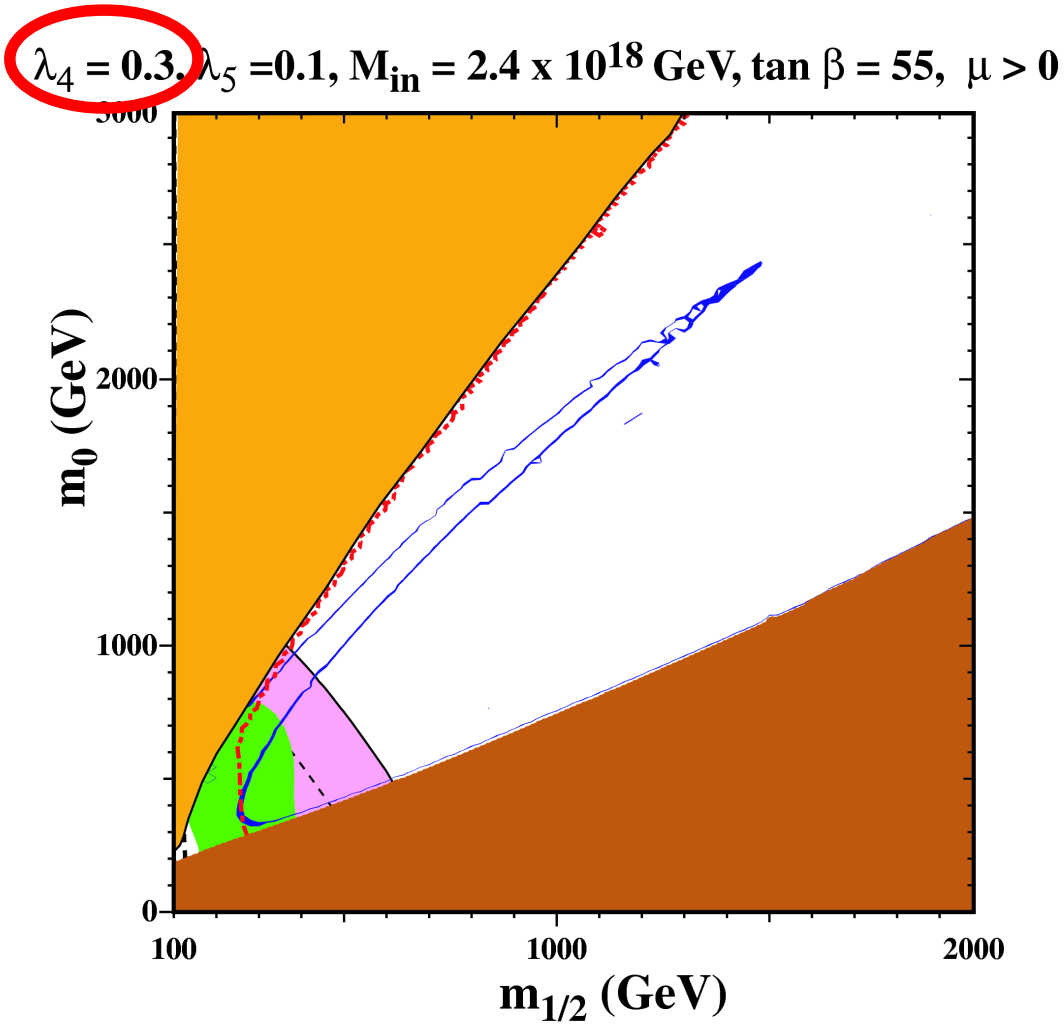

λ_4 = 0.1, λ_5 =0.1, M_{in} = 2.4 x 10^{18} GeV tan β = 10, μ > 0
FSU(5)
m_0 (GeV)
$m_{1/2}$ (GeV)
2000
1000
0
100
200
300
400
500
600
700
800
900
1000

$(m_0,\ m_{1/2})$ plane at large $\tan\beta$



Effect of coupling λ_4





Summary

- Increasing M_{in} increases splitting between sparticle masses
- RD-allowed regions move:
  - stau coannihilation shifts in $m_{1/2}$
  - *A*-funnel rapidly disappears
  - *h*-funnel becomes compatible with chargino bound
  - HB/FP migrates to very large m_0
- *A*-funnel can be restored at large λ_4, but at different location
- *FSU(5)* Direct Detection rates fall fast as neutralino mass increasing similar to mSUGRA
- No-scale solution is possible in *FSU(5)* for larger $\lambda_4,\ \lambda_5$ but has too light Higgs mass and neutralino RD
- *FSU(5)* sparticle pattern different from *SU(5)* and mSUGRA that can be used as discriminator at LHC

Effect of neutrino mass