What if SUSY breaking unifies beyond the GUT scale?

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in collaboration with K.A.Olive and J.Ellis arXiv:1003.3677, 1004.5399

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*
  - $M_{in} > M_{GUT}$

Minimal SU(5) GUT

- Field content:

$$\phi \in \{D^c, L\},\ \psi \in \{Q, U^c, E^c\},\ \mathcal{H}_1 \in \{H_d, H_d^C\},\ \mathcal{H}_2 \in \{H_u, H_u^C\},\ \Sigma$$

- Superpotential

$$\mathcal{W}_5 = \mu_\Sigma \Sigma^2 + \lambda' \Sigma^3 + \mu_H \mathcal{H}_1 \mathcal{H}_2 + \lambda \mathcal{H}_1 \Sigma \mathcal{H}_2 + h_{10} \psi \psi \mathcal{H}_2 + h_5 \psi \phi \mathcal{H}_1$$

- Parameter space:

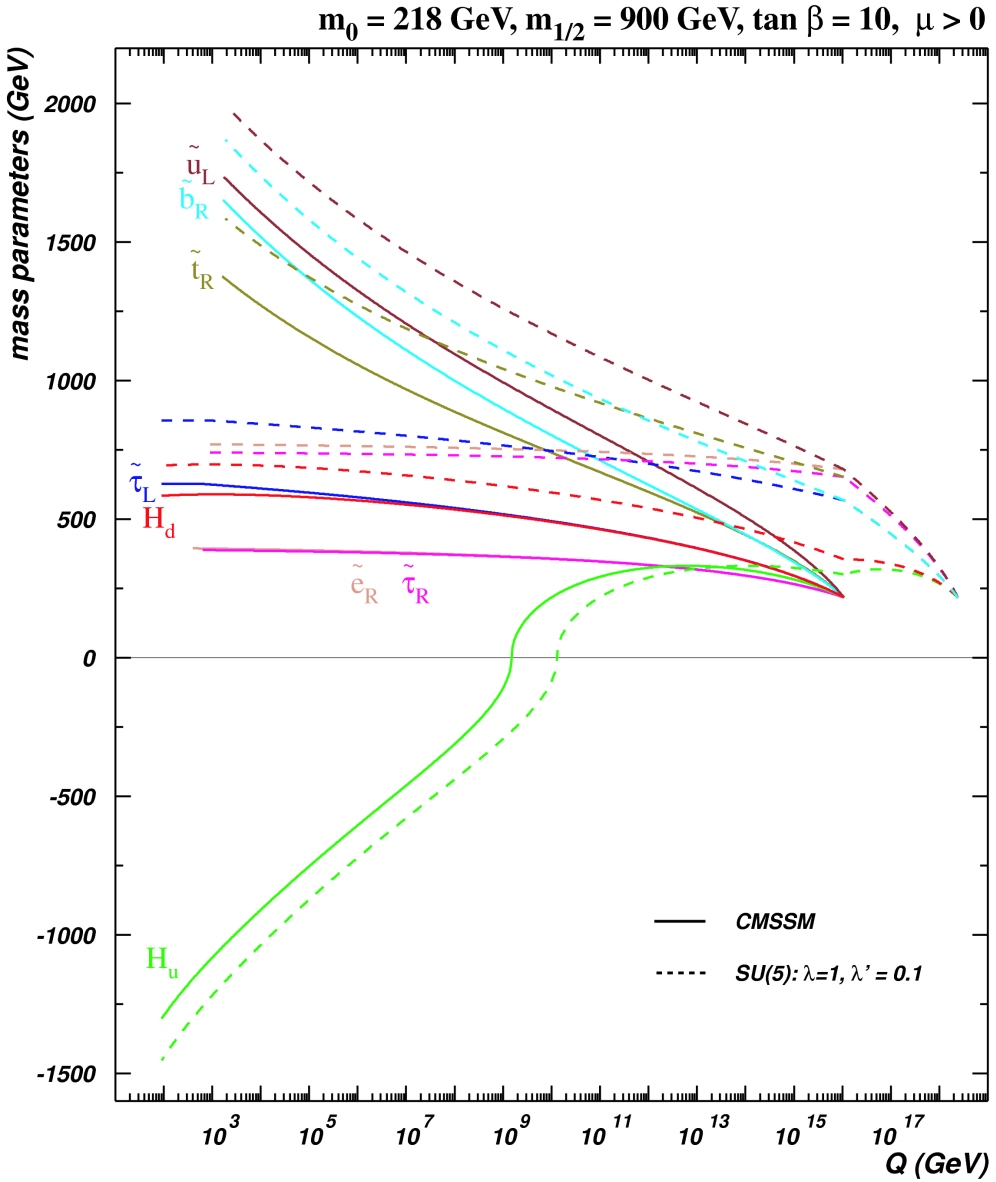
$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ sign(\mu),\ \lambda,\ \lambda',\ M_{in}$$

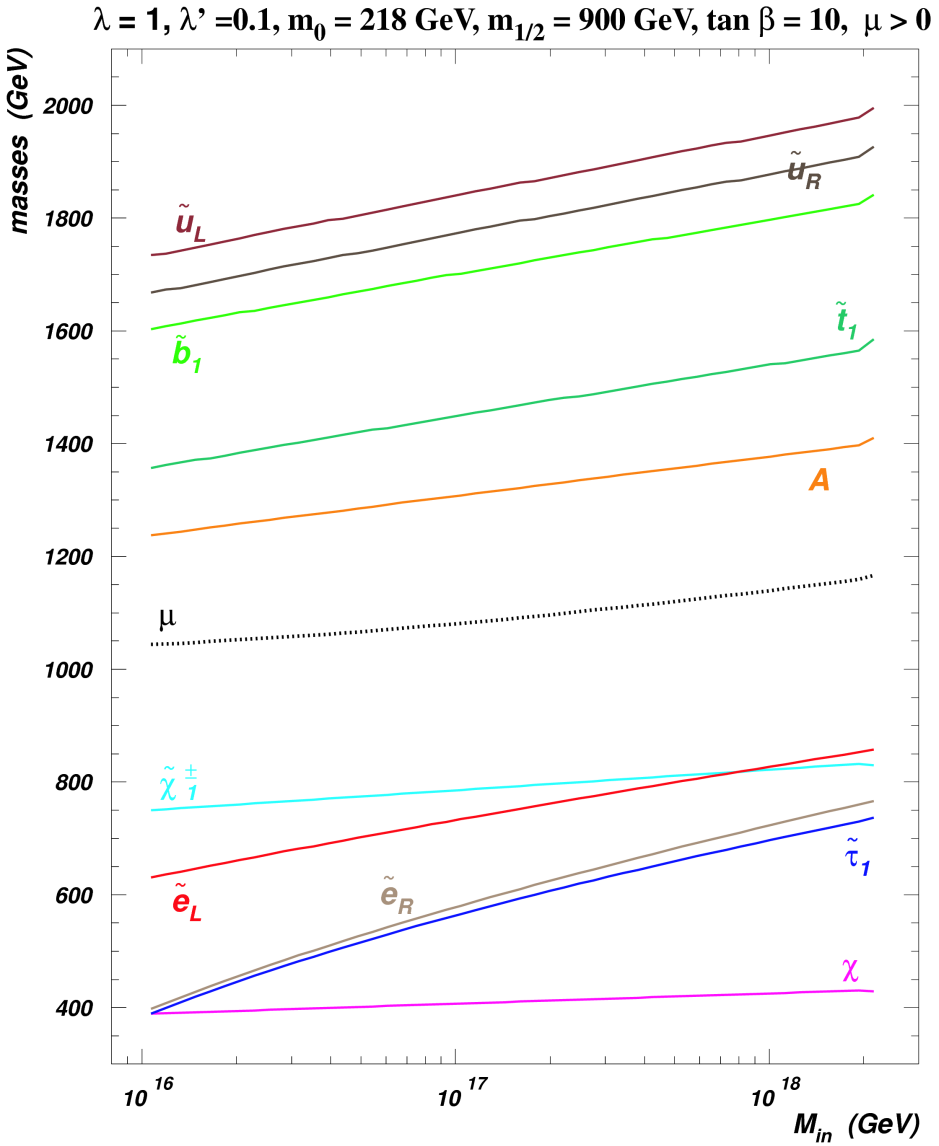
- SSB matching of SU(5) to MSSM

$$A_t = A_{10}\,, \qquad A_b = A_\tau = A_5\,,$$
$$m^2_{D_3} = m^2_{L_3} = m^2_5\,, \qquad m^2_{Q_3} = m^2_{U_3} = m^2_{E_3} = m^2_{10}\,,$$
$$m^2_{H_d} = m^2_{\mathcal{H}_1}\,, \qquad m^2_{H_u} = m^2_{\mathcal{H}_2}$$

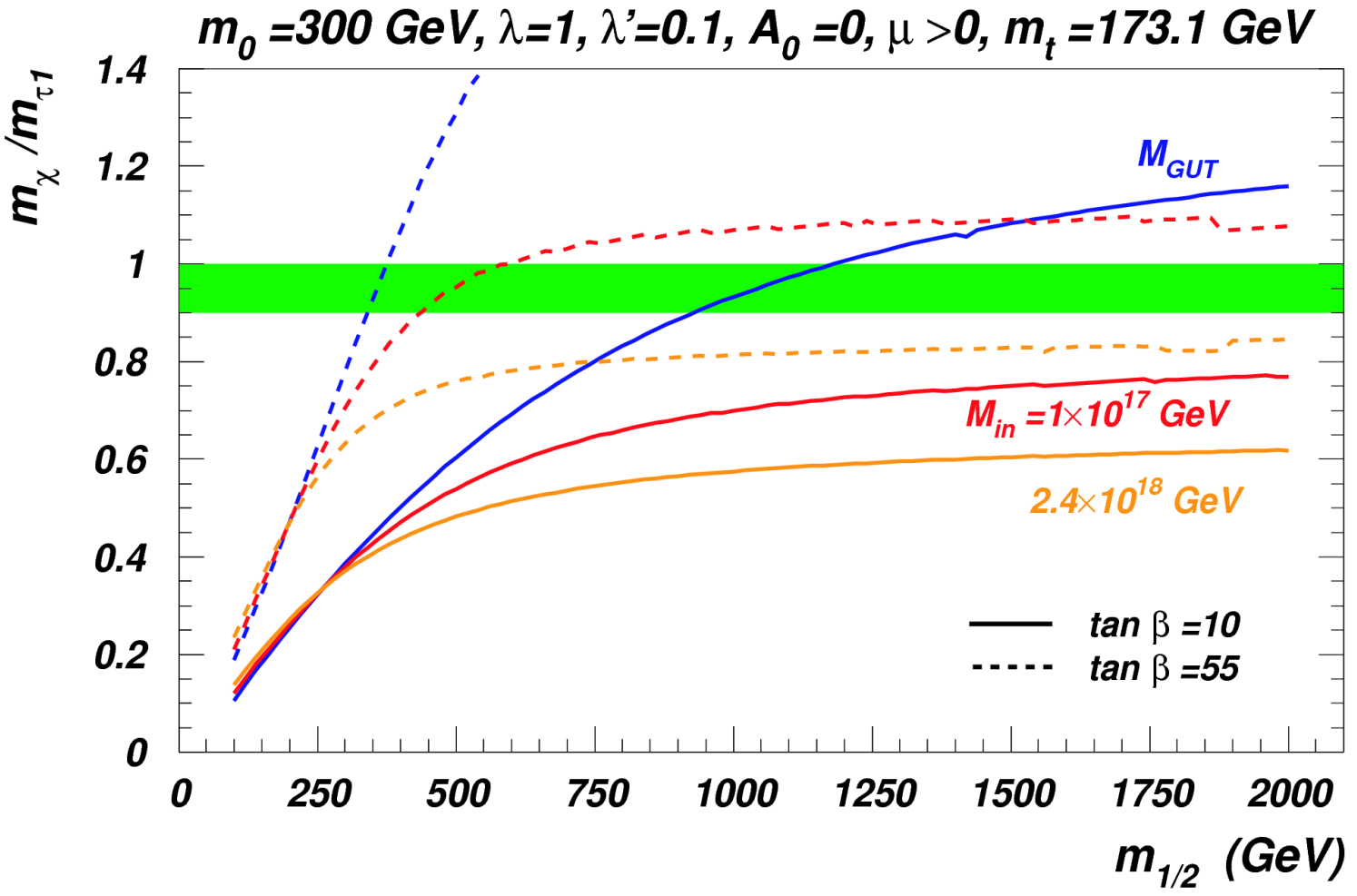
- Previous works: Polonski and Pomarol '94, Baer et al '00, Blair, Porod and Zerwas '03, ...

RGEs and sparticle spectrum

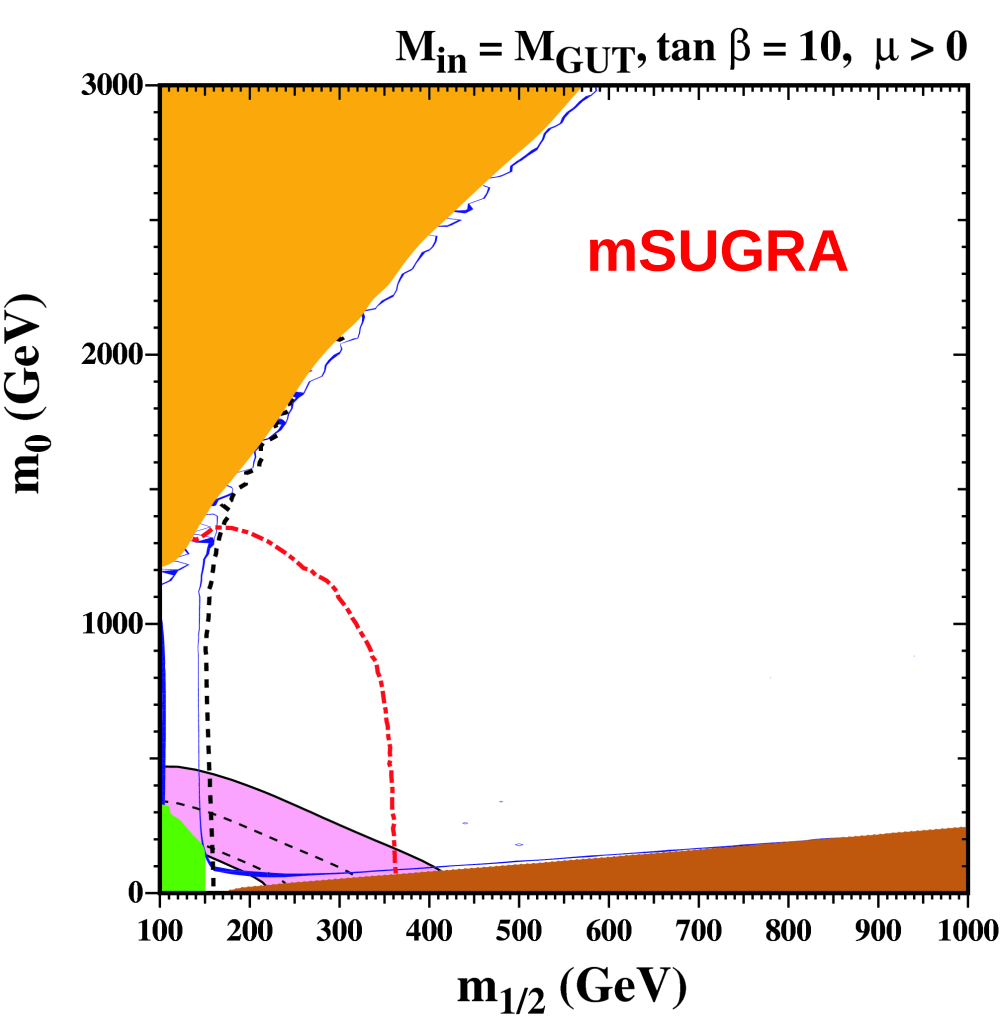


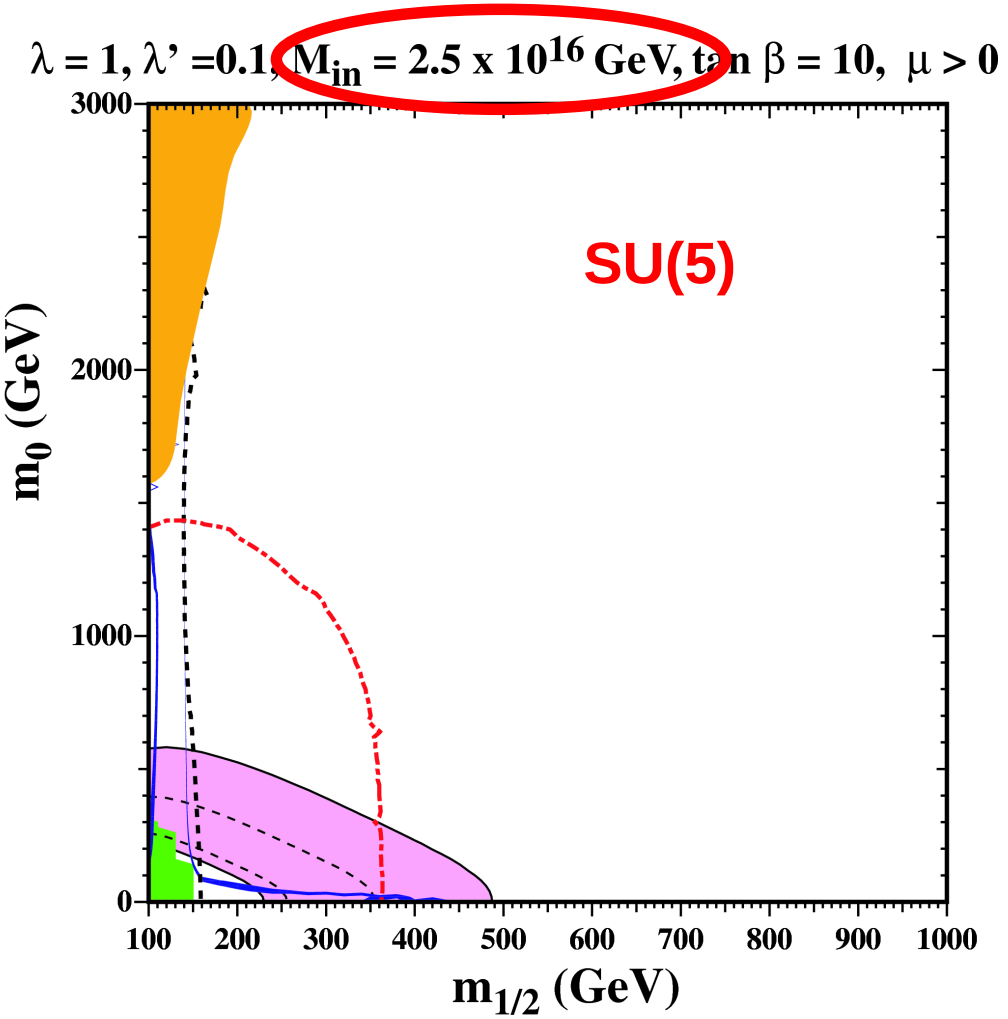


RD mechanisms in SU(5)

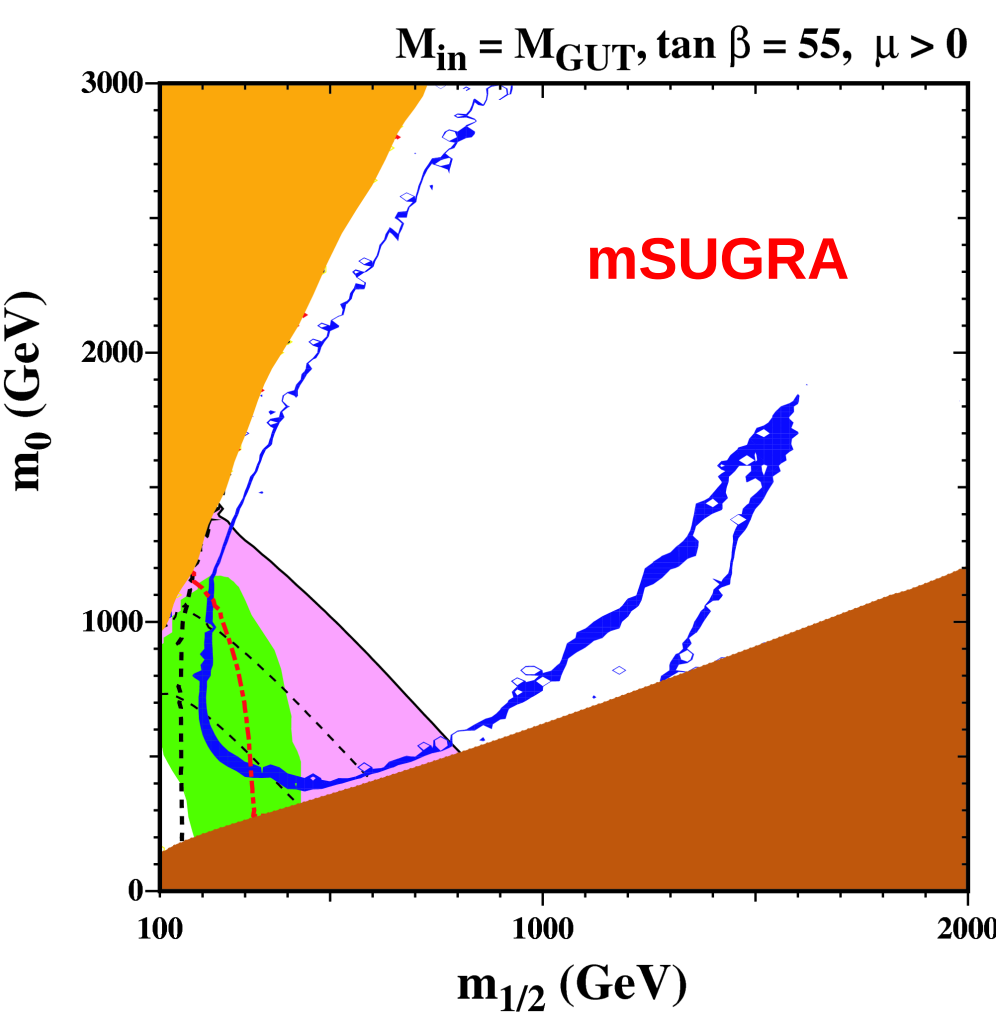


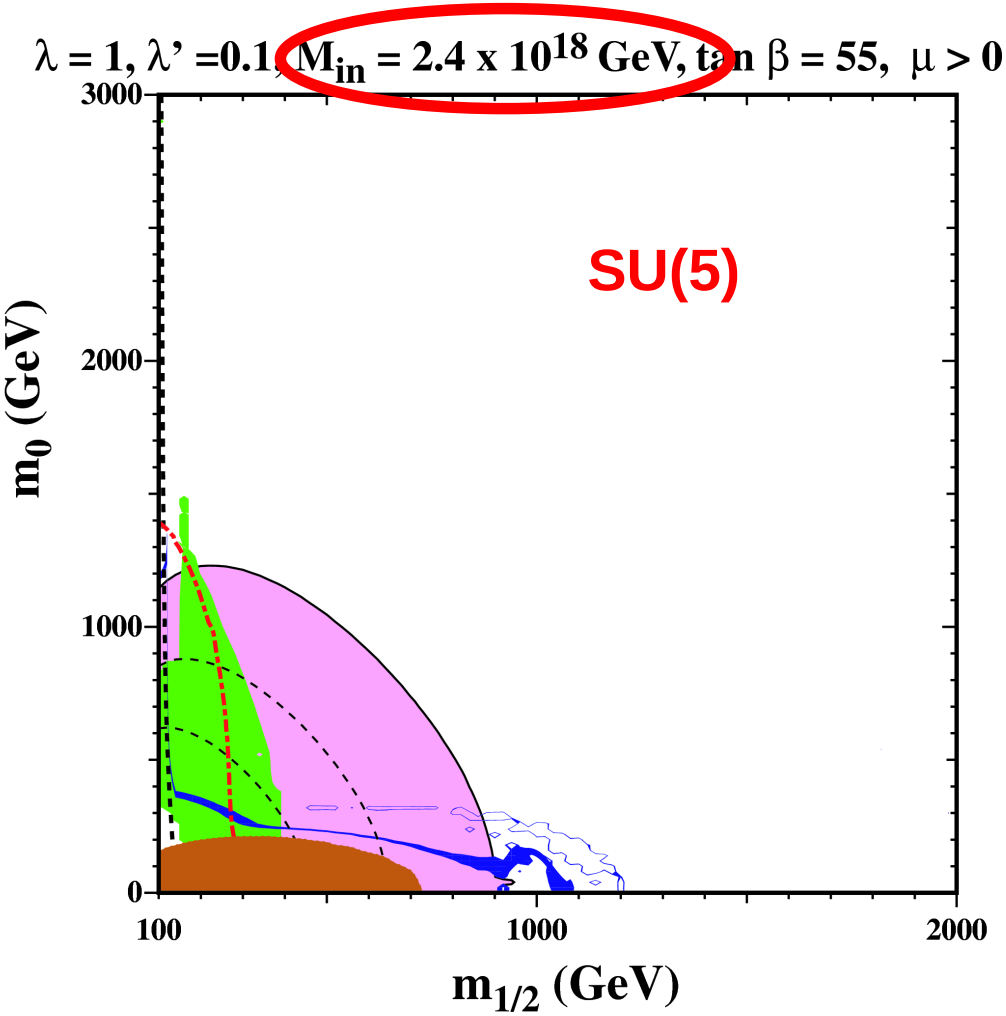
$(m_0,\ m_{1/2})$ plane


$M_{in} = M_{GUT}$, tan β = 10, μ > 0
mSUGRA
m_0 (GeV)
$m_{1/2}$ (GeV)
3000
2000
1000
0
100
200
300
400
500
600
700
800
900
1000

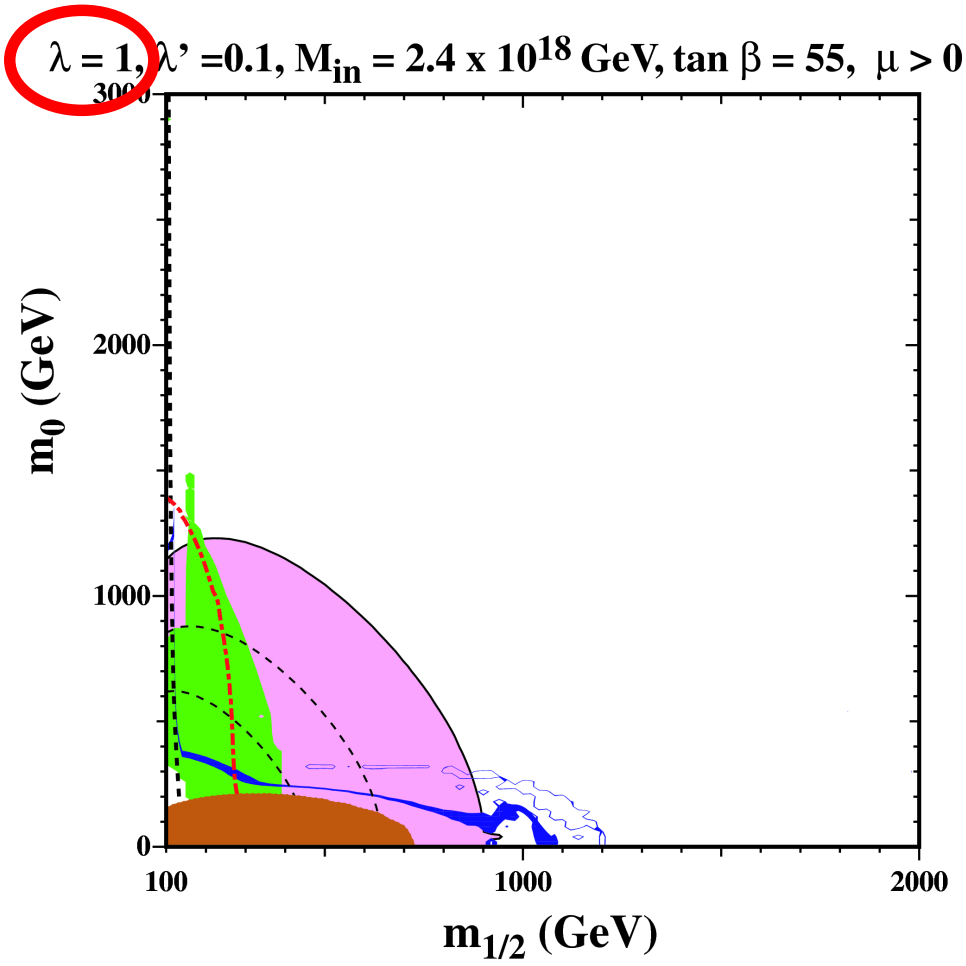

λ = 1, λ' =0.1, $M_{in} = 2.5 \times 10^{16}$ GeV, tan β = 10, μ > 0
SU(5)
m_0 (GeV)
$m_{1/2}$ (GeV)
3000
2000
1000
0
100
200
300
400
500
600
700
800
900
1000

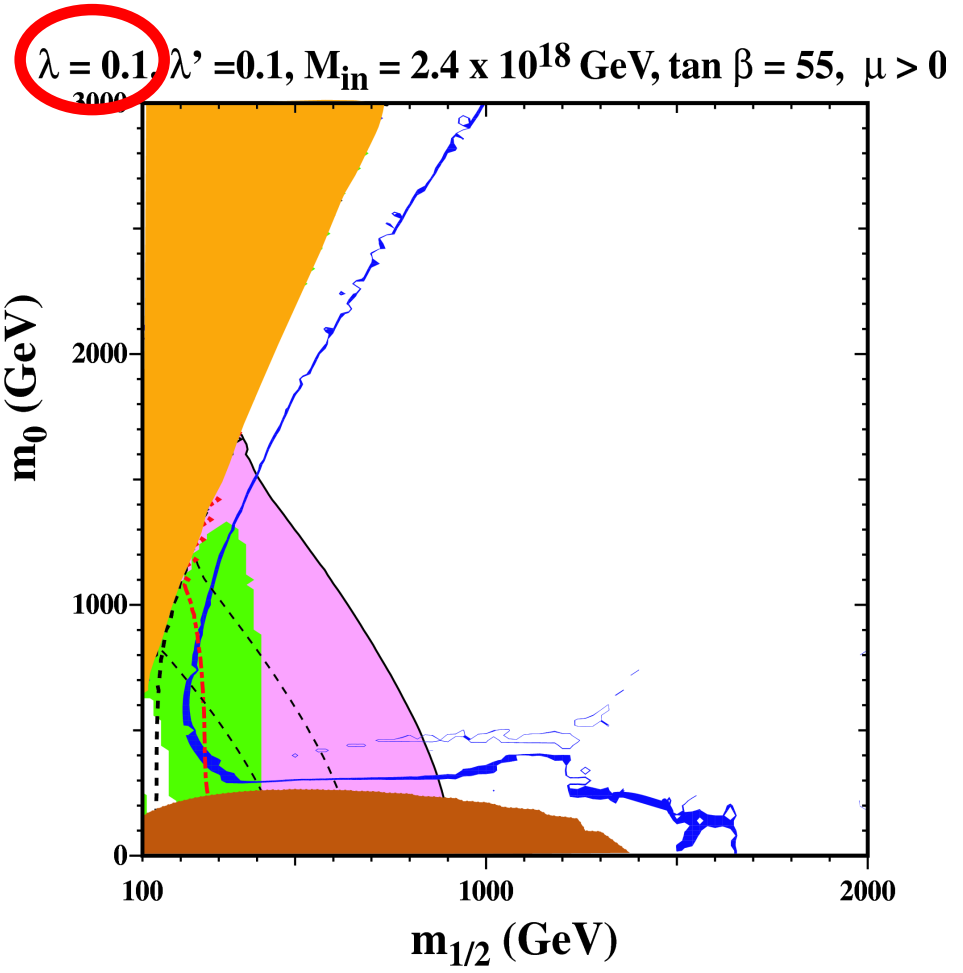
$(m_0,\ m_{1/2})$ plane at large $\tan\beta$





Effect of coupling λ





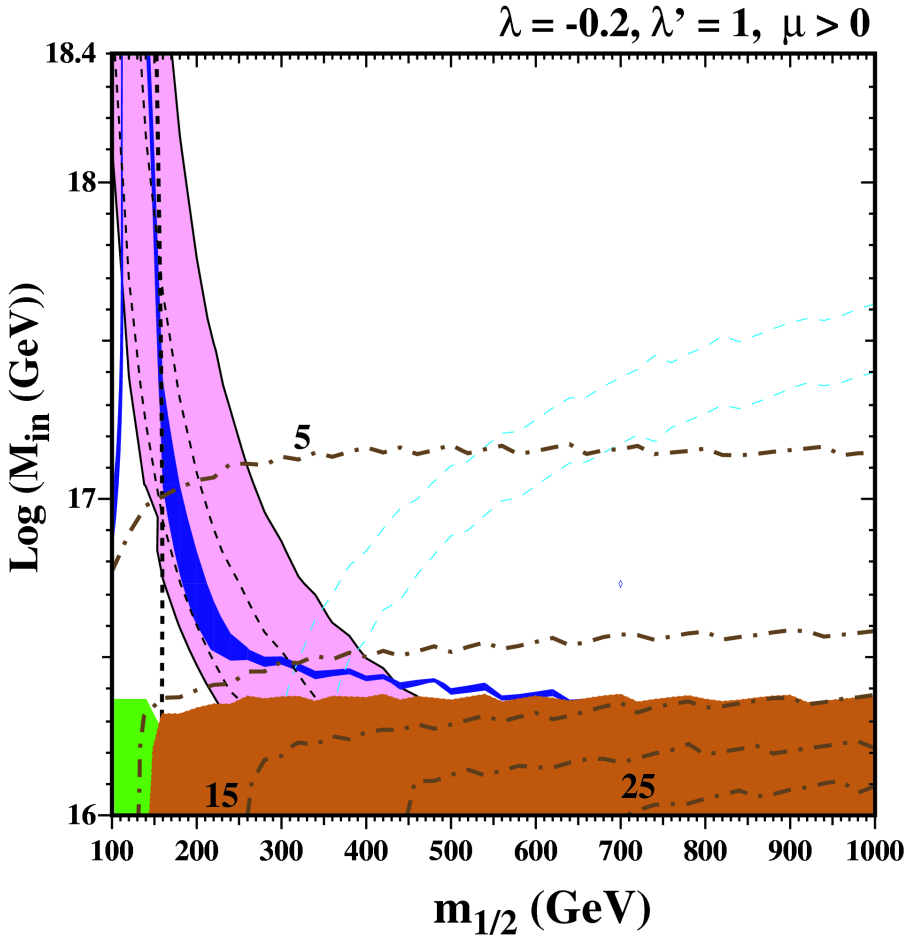
No-scale SU(5)

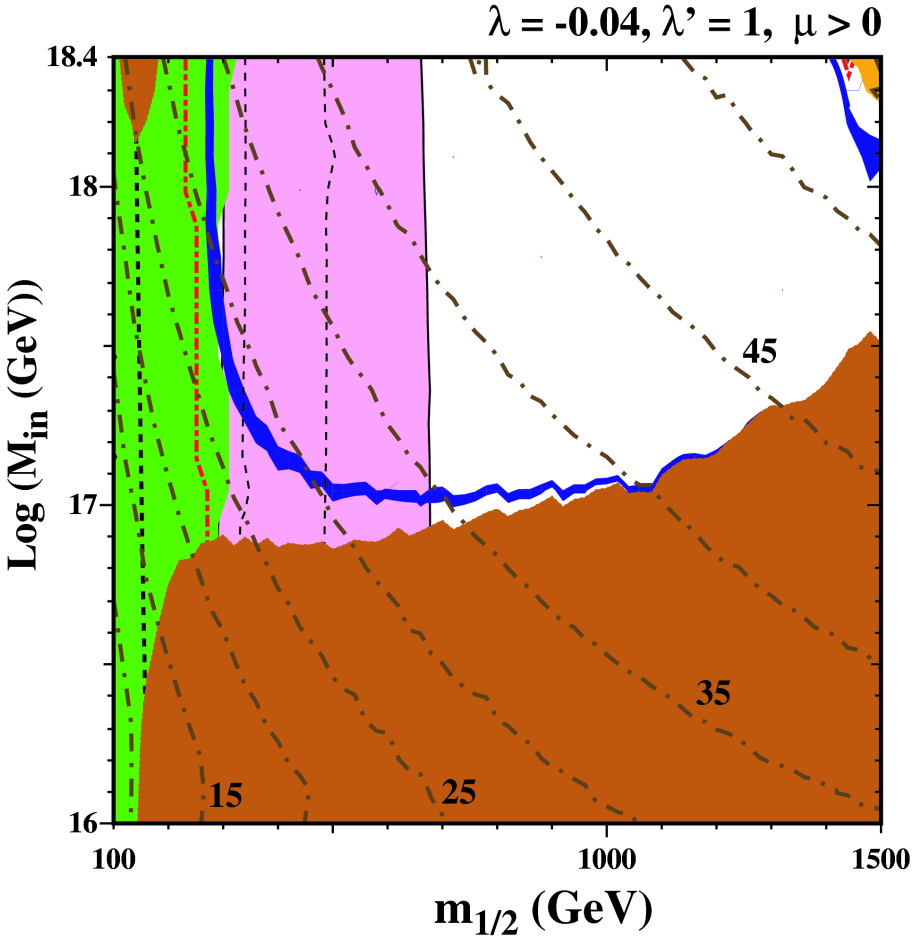
- No-scale $m_0 = A_0 = B_0 = 0$ provides solution to SUSY flavor problem
- Appears in supergravity and gaugino mediation
- Ruled out for $M_{in} = M_{GUT}$ ← stau LSP
- No-scale SU(5) para space: $m_{1/2}, \lambda, \lambda', M_{in}$
- Additional matching condition

$$B = B_H - \frac{6\lambda}{\mu\lambda'}\left[(B_\Sigma - A_{\lambda'})(2B_\Sigma - A_{\lambda'}) + m_\Sigma^2\right]$$

$(m_{1/2}, M_{in})$ plane of no-scale SU(5)

- Case $\lambda > 0$ (also Schmaltz and Skiba '00): $\tan\beta \lesssim 30$
- Case $\lambda < 0$ ⟶ large $\tan\beta$





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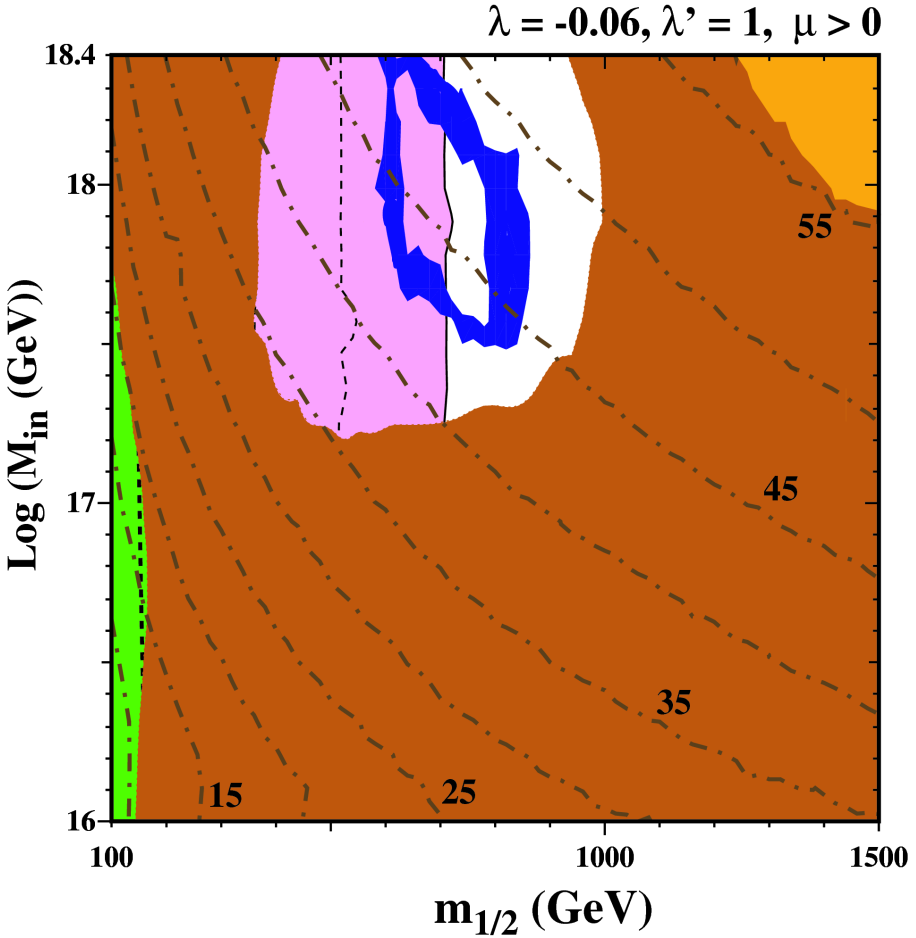
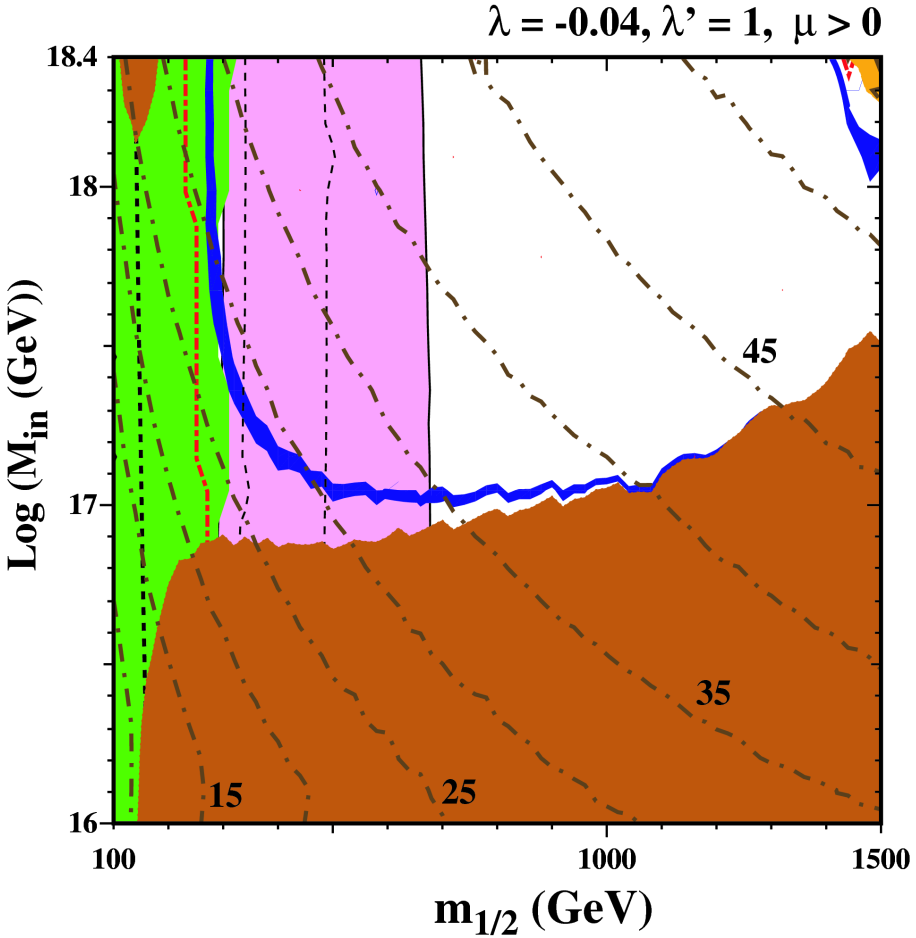
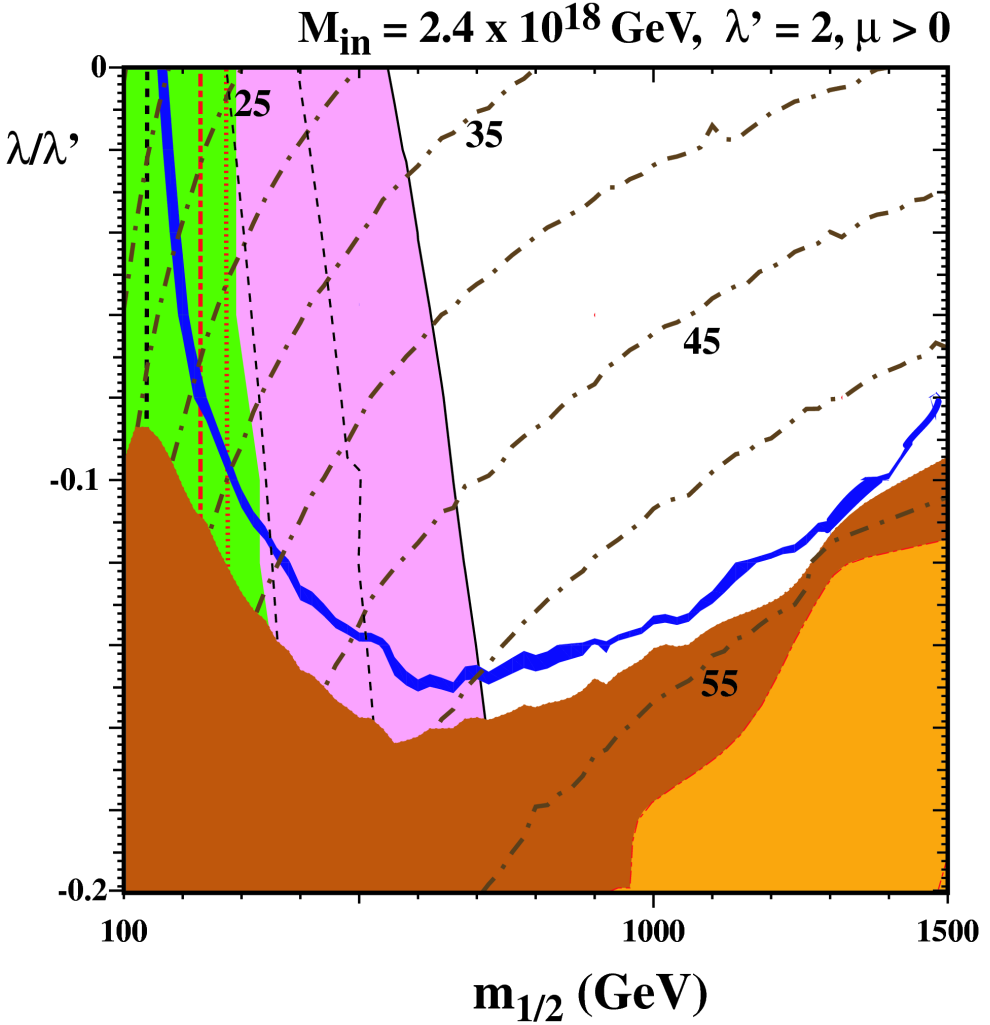




$(m_{1/2}, M_{in})$ plane of no-scale SU(5)

- Case $\lambda > 0$ (also Schmaltz and Skiba '00): $\tan\beta \lesssim 30$
- Case $\lambda < 0$ $\longrightarrow$ large $\tan\beta$
- How large $\lambda, \lambda', M_{in}$ can be?



Summary

- SU(5) higgs couplings $\lambda,\ \lambda'$ are important for pheno
- Increasing M_{in} increases splitting between sparticle masses
- RD-allowed regions move: stau coannihilation and A-funnel squeezed to smaller $m_{1/2}$; HB/FP migrates to larger m_0
- No-scale survives in SU(5) and is constrained to $m_{1/2} \lesssim 1\,TeV\,(1.5\,TeV)$

  $\longrightarrow$ light sparticle spectrum fully testable at LHC with $10\,(100)\,fb^{-1}$

HB/FP in minimal SU(5)