Naturalness of the Non-Universal MSSM in the light of the recent Higgs results

Martin Spinrath

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Based on collaboration with S. Antusch, L. Calibbi, V. Maurer, M. Monaco, MS: Phys.Rev. D85 (2012) 035025 [arXiv:1111.6547] and arXiv:1207.7236

International School for Advanced Studies

Outline

- Introduction
- Semianalytical approach
- Numerical Results
- Summary and Conclusions

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- **Introduction**
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Is the MSSM still natural?

LHC tells us

- Higgs boson at 125 GeV (presumably)
- SUSY is above 1 TeV (a little simplified)

Measure for fine-tuning (*a* GUT parameter):

$$\Delta = \max_a \left| \frac{\partial \log M_Z}{\partial \log a} \right| = \left| \frac{a}{2M_Z^2} \frac{\partial M_Z^2}{\partial a} \right|$$

[Barbieri, Giudice `88, ...; loop corrected: Horton, Ross `10]

What is the minimal fine-tuning in the MSSM?

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What about the scalar mass parameters?

- Recapitulate (for largish tan β):

$$M_Z^2 \approx -2|\mu|^2 - 2m_{H_u}^2$$

- For the scalar mass parameters:

$$\begin{aligned} m_{H_u}^2(M_{\rm SUSY}) = &-0.0459 m_{\tilde{Q}_1}^2 + 0.0988 m_{\tilde{U}_1}^2 - 0.0469 m_{\tilde{D}_1}^2 + 0.0488 m_{\tilde{L}_1}^2 - 0.0541 m_{\tilde{E}_1}^2 \\ &-0.3347 m_{\tilde{Q}_3}^2 - 0.2500 m_{\tilde{U}_3}^2 - 0.0154 m_{\tilde{D}_3}^2 + 0.0245 m_{\tilde{L}_3}^2 - 0.0236 m_{\tilde{E}_3}^2 \\ &+0.6481 m_{h_u}^2 + 0.0273 m_{h_d}^2 + \dots \end{aligned}$$

[Antusch, Calibbi, Maurer, Monaco, MS `12]

- Universal boundary conditions less tuned

Gaugino masses and trilinears I

- We find: **[Antusch, Calibbi, Maurer, Monaco, MS `12]**

$$\begin{aligned} m^2_{H_u}(M_{\rm SUSY}) = & -M_3^2(1.2865 - 0.0216\eta_1 - 0.0242\eta_1^2) \\ & - M_3^2(0.0230\eta_2 - 0.2177\eta_2^2 + 0.0813\eta_1\eta_2) \\ & + M_3^2\eta_A(0.2904 + 0.0112\eta_1 + 0.0652\eta_2) \\ & - 0.1131 M_3^2\eta_A^2 + \dots \\ \equiv & (f_1(\eta_1,\eta_2) + f_2(\eta_1,\eta_2)\eta_A + f_3\eta_A^2)M_3^2 + \dots \end{aligned}$$

- where we have set ($\eta_{1,2}$ fixed):

$$A_0 = M_3\eta_A \quad , \quad M_{1,2} = M_3\eta_{1,2}$$

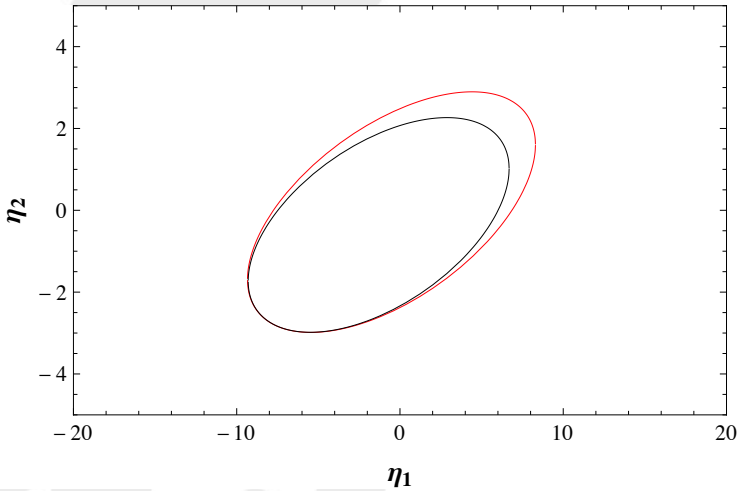
Gaugino masses and trilinears II

- Two solutions with vanishing fine-tuning in this sector

1) $f_1(\eta_1, \eta_2) = 0,$ $\quad \eta_A = 0$

2) $f_1(\eta_1, \eta_2) = \dfrac{f_2(\eta_1, \eta_2)^2}{4 f_3},$ $\quad \eta_A = -\dfrac{f_2(\eta_1, \eta_2)}{2 f_3}$

- Corresponding to two ellipses in the η_1-η_2 plane



[Antusch, Calibbi, Maurer, Monaco, MS `12]

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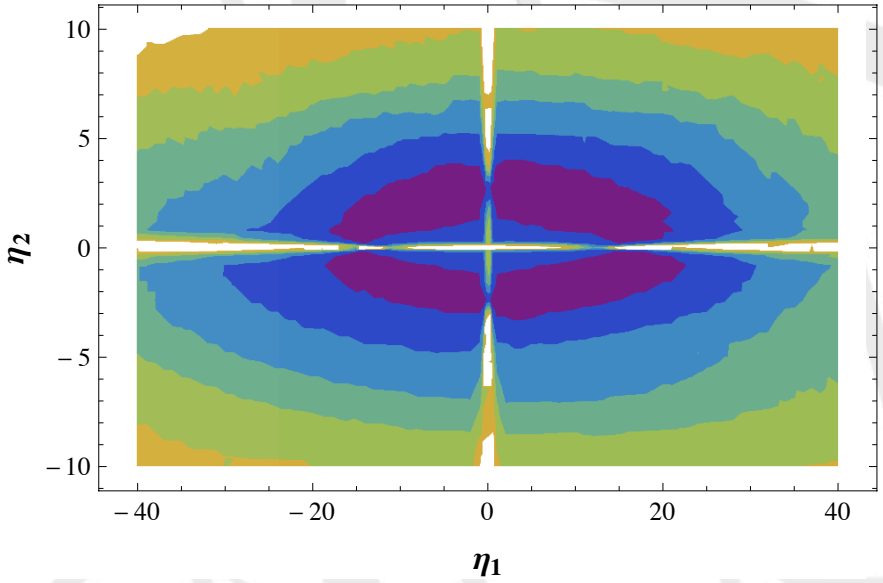
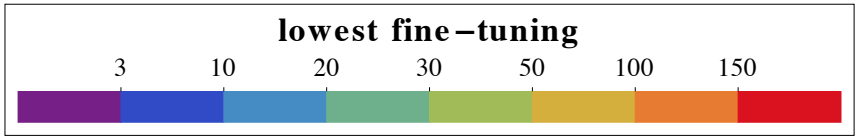
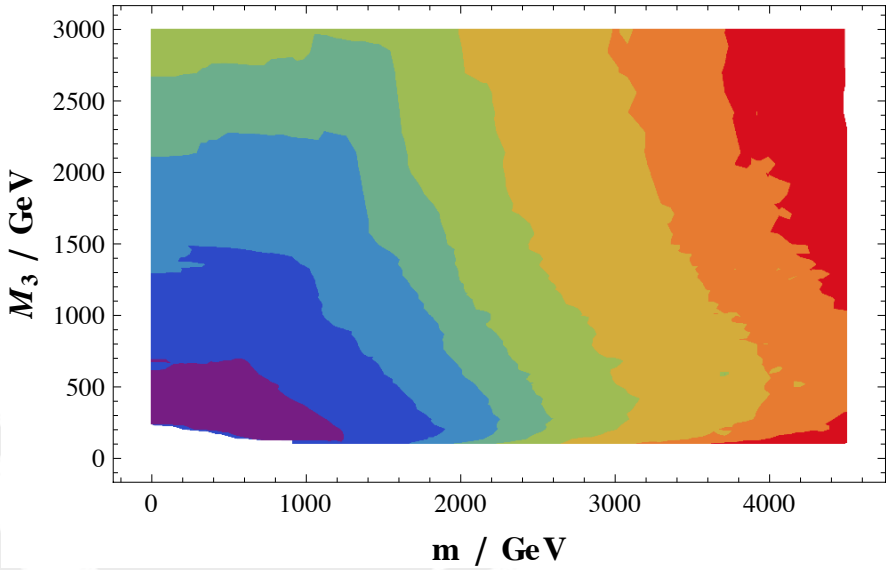
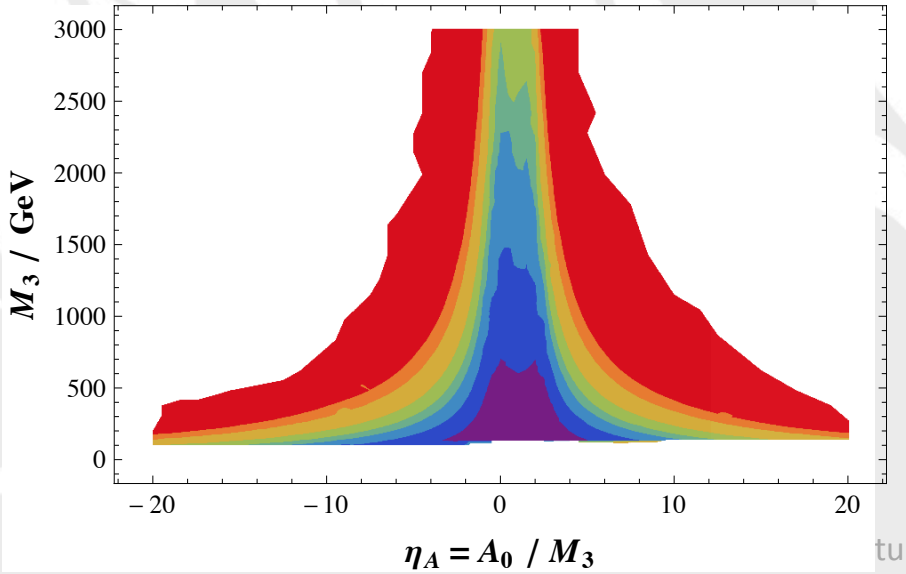
Before the Higgs bound

[Antusch, Calibbi, Maurer, Monaco, MS `12]



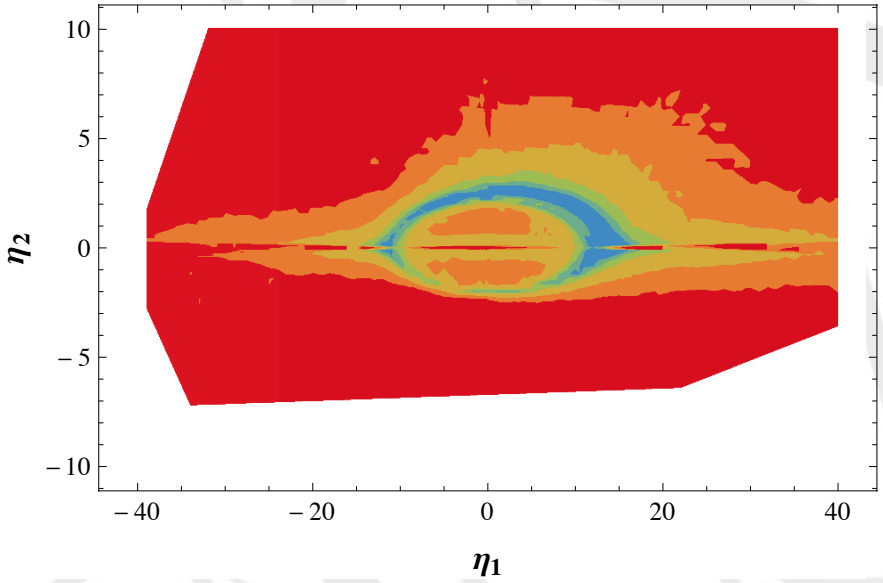


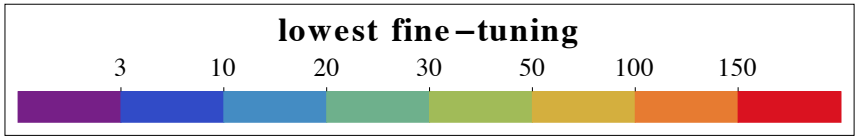


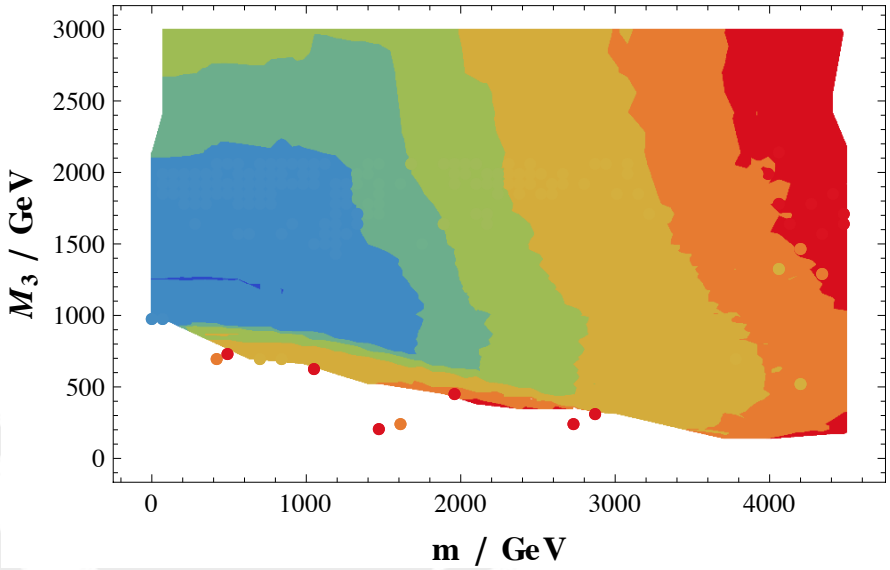


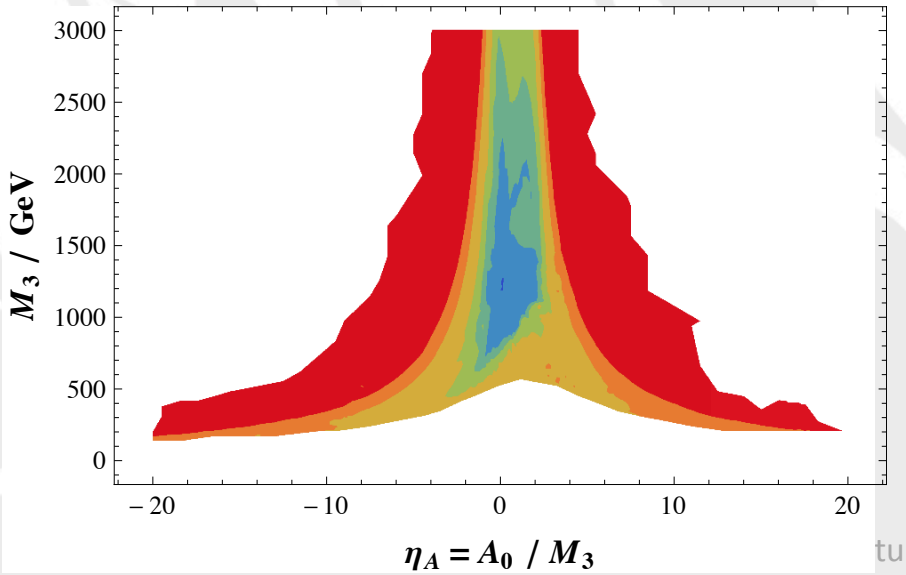
After the Higgs bound

[Antusch, Calibbi, Maurer, Monaco, MS `12]







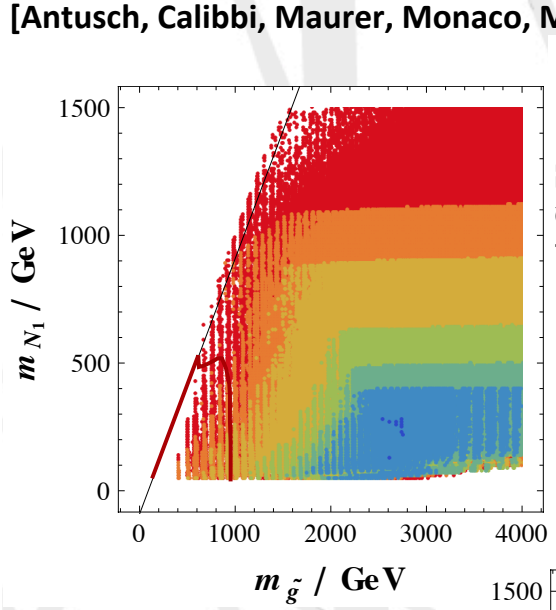


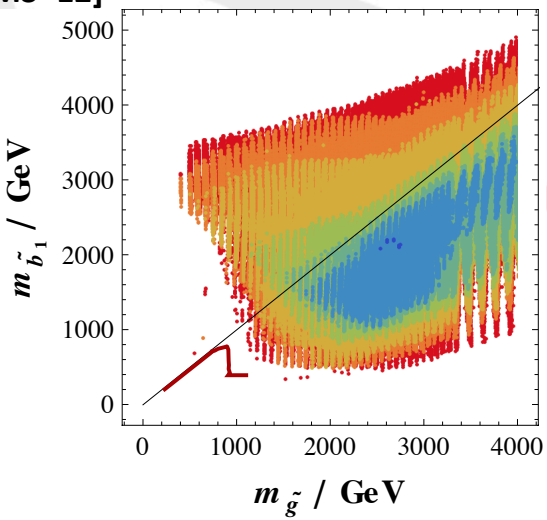
$m_h = 125.3 \pm 0.6 \pm 3$ GeV

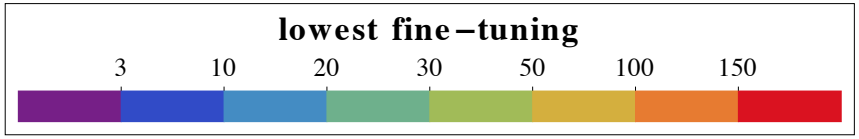
[ATLAS, CMS `12]

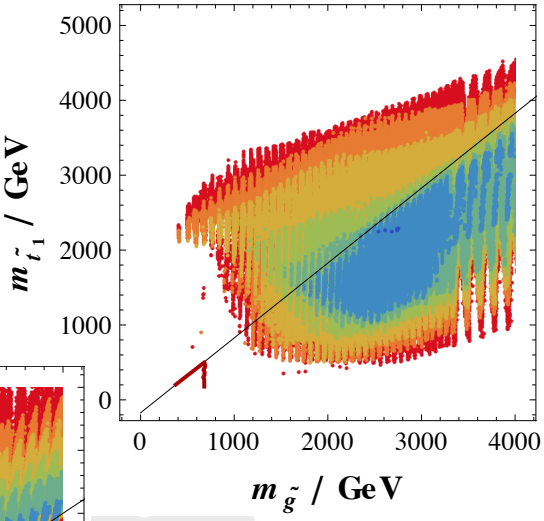
LHC bounds

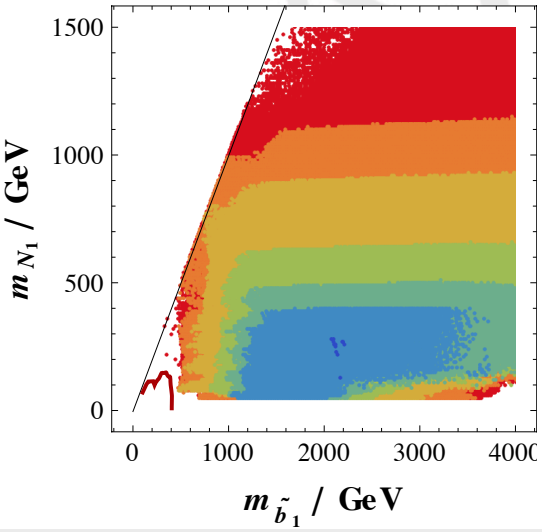
[Antusch, Calibbi, Maurer, Monaco, MS `12]

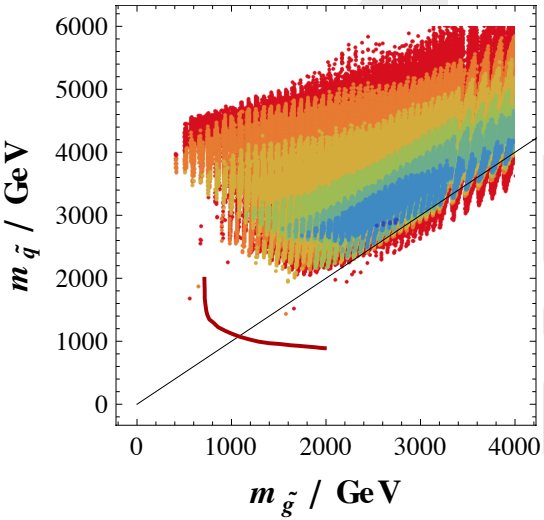






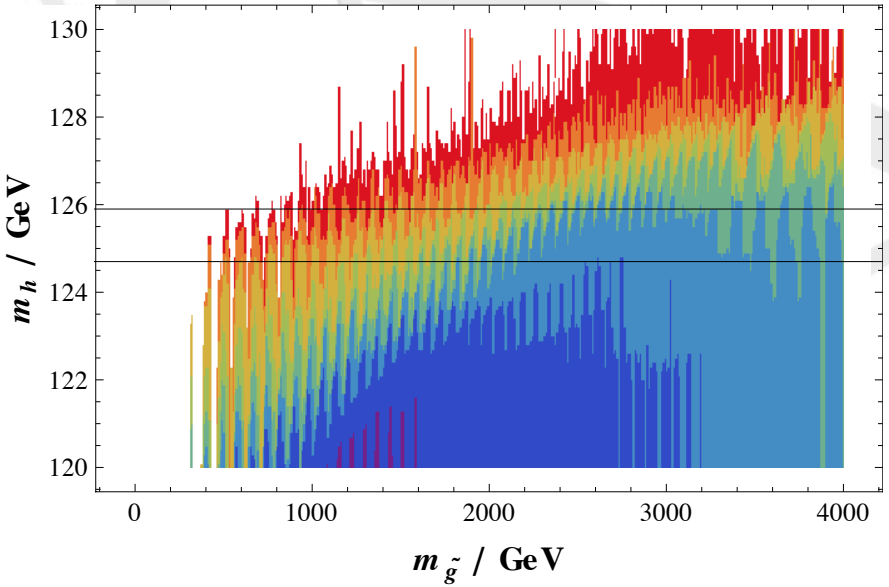


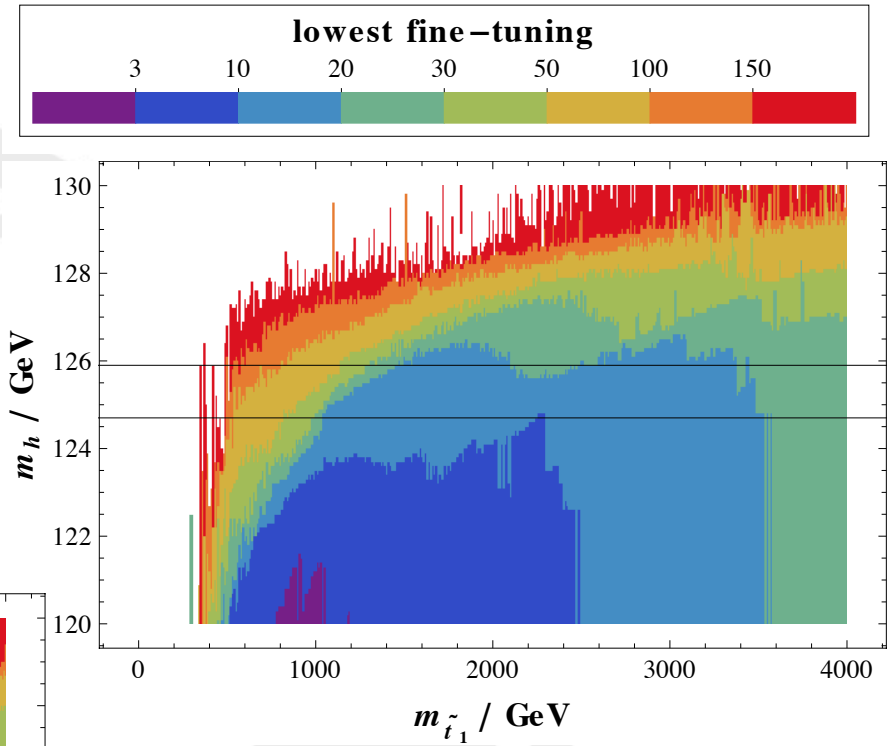


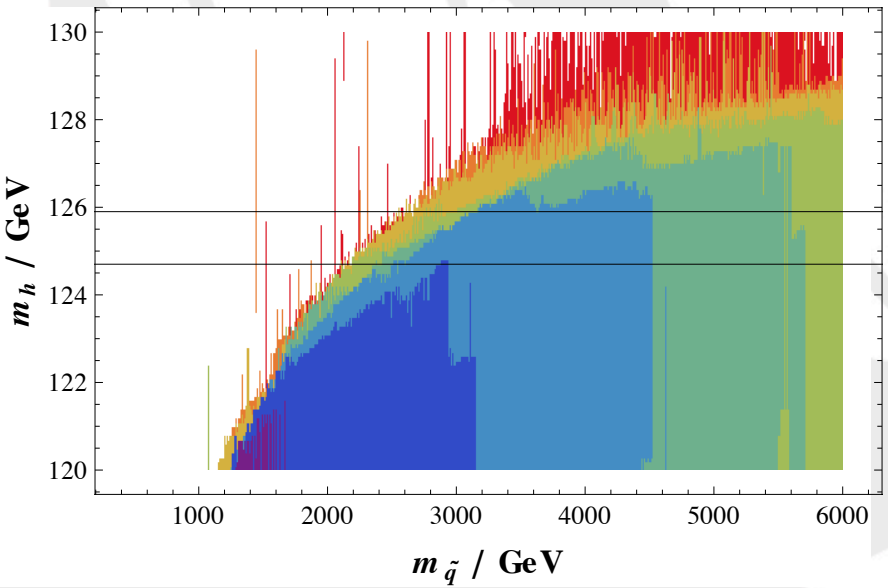


[Based on ATLAS and CMS SUSY searches]

Mass relations







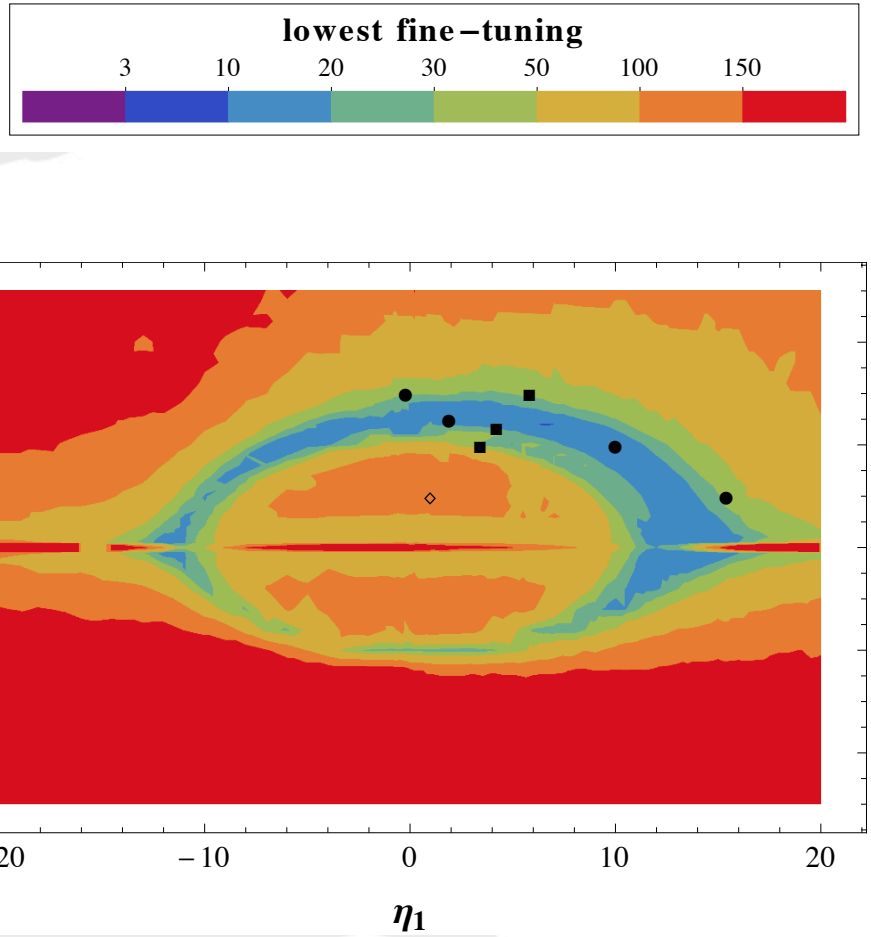
[Antusch, Calibbi, Maurer, Monaco, MS `12]

Comparison to Models

η_1, η_2	$\Delta_{\rm min}$	Origin
1, 1	118	CMSSM (Gaugino Unification)
10, 2	12	200 of SU(5) [1]
$\frac{19}{10}$, $\frac{5}{2}$	18	770 of $SO(10) \to (1,1)$ of $SU(4) \times SU(2)_R$ [1]
$\frac{77}{5}$, 1	36	770 of $SO(10) \to (1,0)$ of $(SU(5)' \times U(1))_{\rm flipped}$ [1]
$-\frac{1}{5}$, 3	46	210 of $SO(10) \to (75,0)$ of $(SU(5)' \times U(1))_{\rm flipped}$ [1]
$\frac{21}{5}$, $\frac{7}{3}$	13	O-II with $\delta_{\rm GS} = -6$ [2]
$\frac{17}{5}$, 2	28	O-II with $\delta_{\rm GS} = -7$ [2]
$\frac{29}{5}$, 3	44	O-II with $\delta_{\rm GS} = -5$ [2]

[1] Chakrabortty, Raychaudhuri '09; Martin '09
[2] Brignole, Ibanez, Munoz '94, '95; Horton, Ross '09

[Antusch, Calibbi, Maurer, Monaco, MS `12]



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Summary and Conclusions

- CMSSM is fine-tuned ($\Delta > 110$)
- Little fine-tuning with non-universal gaugino masses ($\Delta = O(10)$) for $\Delta < 20$:
  - gluino: 2-3 TeV
  - squarks: 2.5-4.5 TeV
  - light stop: 1.0-3.5 TeV

Final comments

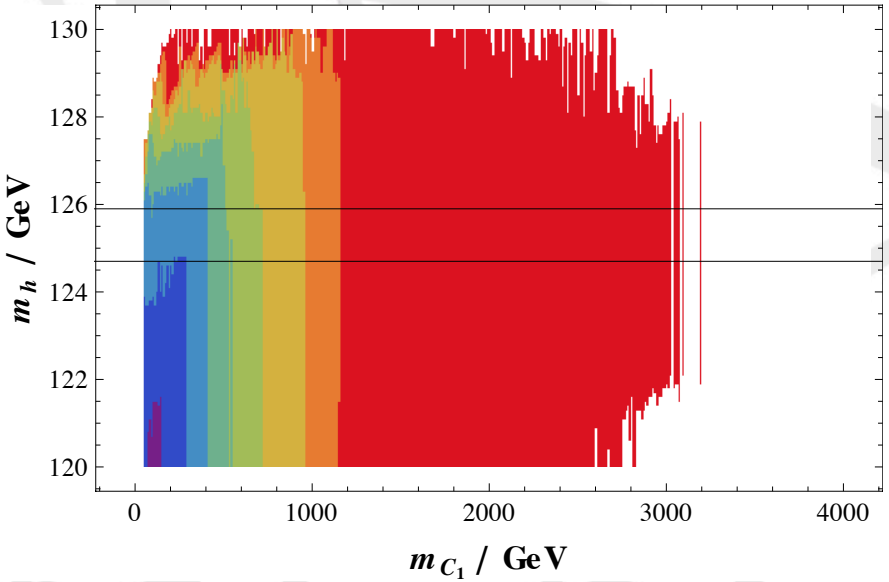
To paraphrase Mark Twain:

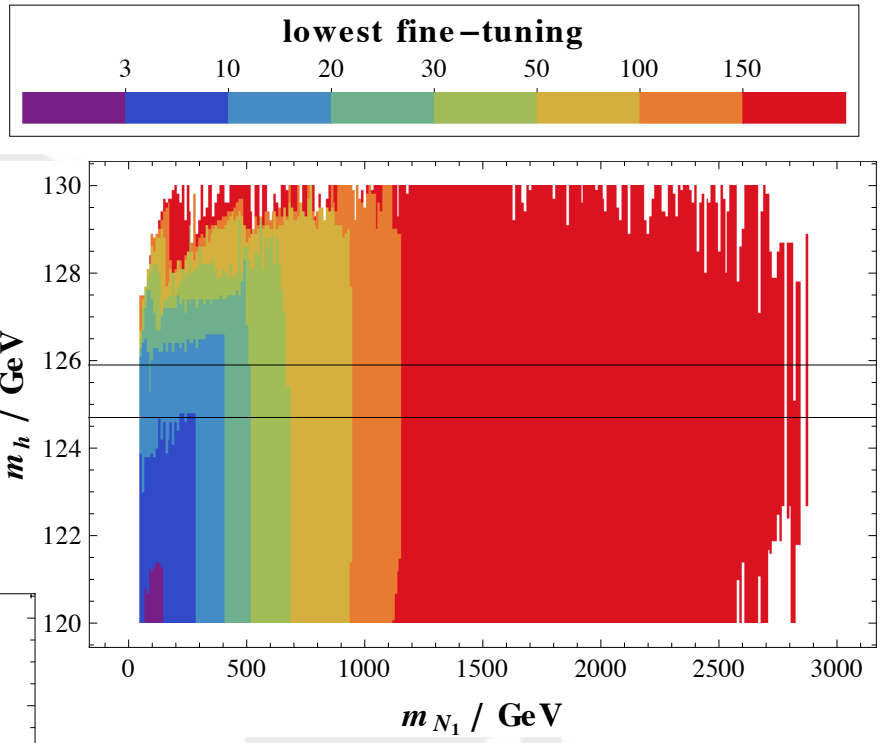
The reports of an disfavoured MSSM are greatly exaggerated.

Thank you for your attention!

Backup

Mass relations II





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