Fine-tuning in GGM and the 126 GeV Higgs particle

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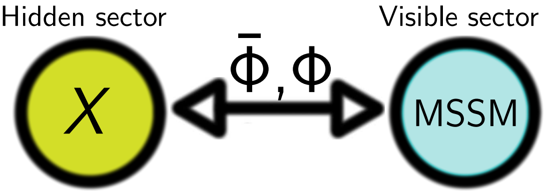
SUSY 2013, 27 Aug 2013, Trieste

based on: Z. Lalak and ML, arXiv:1302.6546 (JHEP 1305)

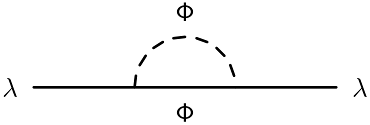
The project "International PhD Studies in Fundamental Problems of Quantum Gravity and Quantum Field Theory" is realized within the MPD programme of Foundation for Polish Science, cofinanced from European Union, Regional Development Fund

SUSY breaking mediation

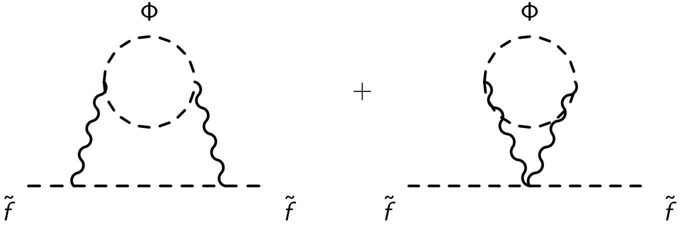
- Supergravity
  - No control over mixing between families $\longrightarrow$ lagre FCNC
- Gauge mediation
  - SUSY is spontaneously broken$\longrightarrow$ singlet $\langle X \rangle = X + \theta^2 F$
  - breaking is transmitted through messengers $W = \lambda \bar{\Phi} X \Phi$
  - messengers $\bar{\Phi}$,Φ interact with MSSM fields only via gauge interactions



Gauge mediated soft terms



$$\Longrightarrow M_i = \frac{\alpha_i}{4\pi}\frac{F}{X}$$



$+ \ldots$

$$\Longrightarrow m_{\tilde{f}}^2 = 2\sum_i C_i(f)\left(\frac{\alpha_i}{4\pi}\right)^2\left|\frac{F}{X}\right|^2$$

GGM soft terms

Meade, Shih and Seiberg 0801.3278

Gauge mediated soft terms can be expressed by just six parameters

- Three gaugino masses

$$M_1 = \frac{\alpha_1}{4\pi} m_Y, \quad M_2 = \frac{\alpha_2}{4\pi} m_w, \quad M_3 = \frac{\alpha_3}{4\pi} m_c,$$

- Three parameters determining scalar masses Λ_c^2 , Λ_w^2 , Λ_Y^2 which give

$$m_f^2 = 2\left[C_3(f)\left(\frac{\alpha_3}{4\pi}\right)^2 \Lambda_c^2 + C_2(f)\left(\frac{\alpha_2}{4\pi}\right)^2 \Lambda_w^2 + C_1(f)\left(\frac{\alpha_1}{4\pi}\right)^2 \Lambda_Y^2\right],$$

- Only negligible A-terms are generated.

Implementations

Two specific models Carpenter et al. 0805.2944

- GGM1

$$W_{GGM1} = X_i(y^i \bar{Q}Q + r^i \bar{U}U + s^i \bar{E}E),$$

with three independent parameters Λ_Q,Λ_U,Λ_E

- GGM2

$$W_{GGM2} = X_i(y^i \bar{Q}Q + r^i \bar{U}U + s^i \bar{E}E + \lambda^i_q \tilde{q}q + \lambda^i_l \tilde{l}l),$$

with five independent parameters Λ_Q,Λ_U,Λ_E,Λ_q,Λ_l

fine-tuning definition

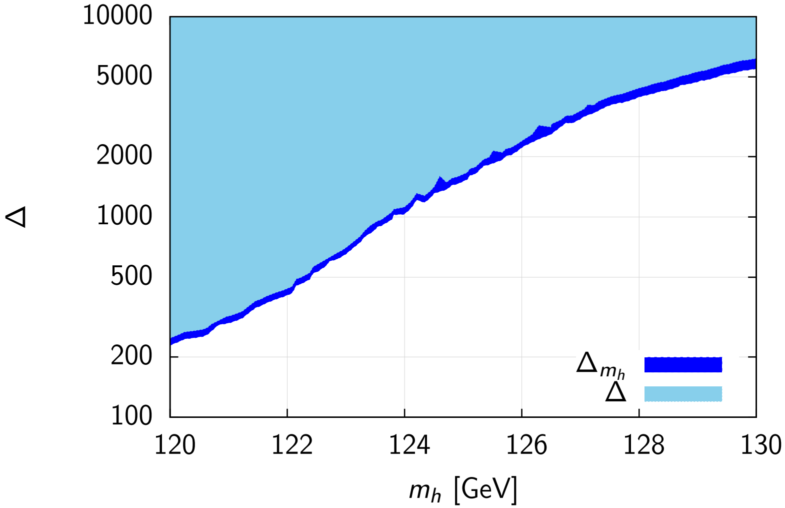
- fine-tuning from parameter a

$$\Delta_a = \left| \frac{\partial \ln m_Z^2}{\partial \ln a} \right| .$$

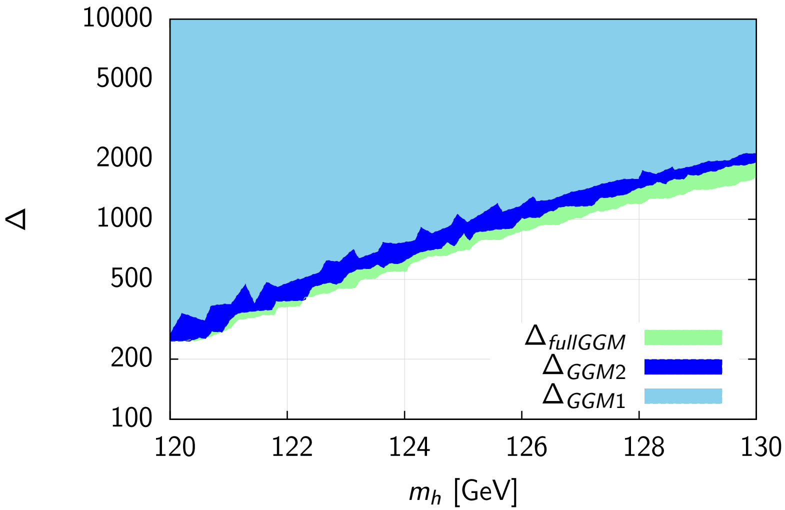
- fine-tuning coming from a whole set of parameters a_i

$$\Delta = \max_{a_i} \Delta_{a_i} .$$

FT in mSUGRA


10000
5000
2000
1000
500
200
100
Δ
120
122
124
126
128
130
m_h [GeV]
Δ_{m_h}
Δ

FT in GGM



10000
5000
2000
1000
500
200
100
Δ
120
122
124
126
128
130
m_h [GeV]
$\Delta_{fullGGM}$
Δ_{GGM2}
Δ_{GGM1}

reducing fine-tuning

Assuming that parameters are not independent of each other, but instead are functions of some fundamental parameters. For example, if gaugino masses M_i are given functions of parameter $M_{\frac{1}{2}}$ we obtain

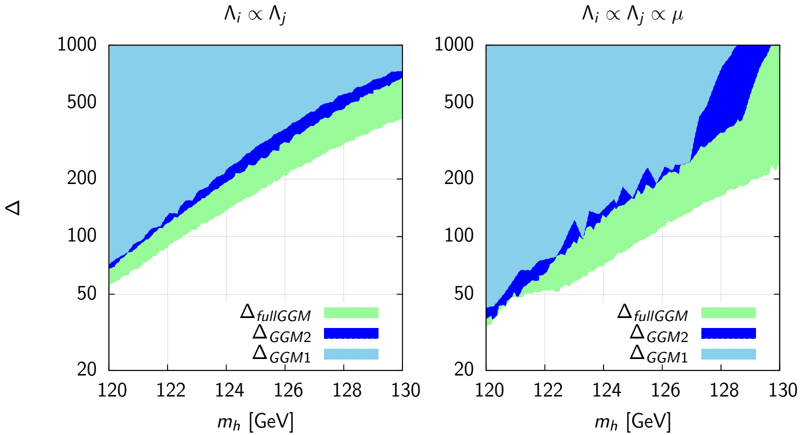
$$\begin{aligned} M_i &= f_i(M_{\frac{1}{2}}), \\ \Delta_{M_{\frac{1}{2}}} &= \left| \frac{\partial \ln M_Z^2}{\partial \ln M_{\frac{1}{2}}} \right| = \left| M_{\frac{1}{2}} \frac{f_i'(M_{\frac{1}{2}})}{f_i(M_{\frac{1}{2}})} \frac{\partial \ln M_Z^2}{\partial \ln M_i} \right|. \end{aligned}$$

If f_i are simply proportional to $M_{\frac{1}{2}}$ one finds

$$\Delta_{M_{\frac{1}{2}}} = \left| \sum_{i=1}^{3} \frac{\partial \ln M_Z^2}{\partial \ln M_i} \right|.$$

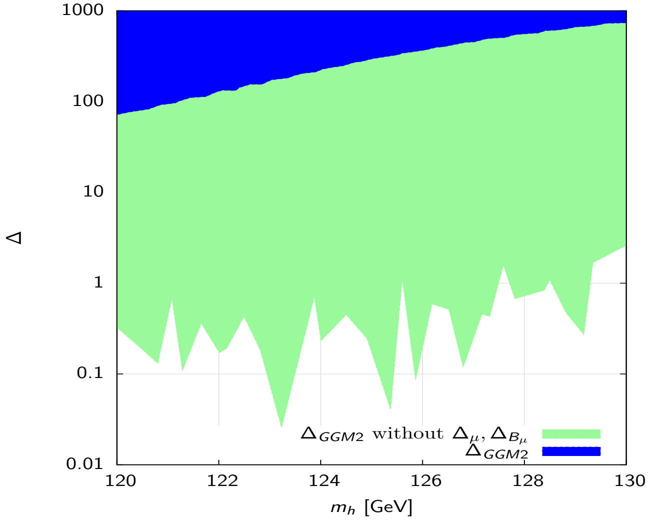
If these functions were logarithms

$$M_i(M_{\frac{1}{2}}) = \tilde{m} \ln \frac{M_{\frac{1}{2}}}{Q} \quad , \quad \Delta_{M_{\frac{1}{2}}} = \left| \sum_{i=1}^{3} \frac{\tilde{m}}{M_i} \frac{\partial \ln M_Z^2}{\partial \ln M_i} \right|.$$



$\Lambda_i \propto \Lambda_j$
$\Lambda_i \propto \Lambda_j \propto \mu$
Δ
1000
500
200
100
50
20
120
122
124
126
128
130
m_h [GeV]
$\Delta_{fullGGM}$
Δ_{GGM2}
Δ_{GGM1}

fine-tuning from only gauge mediated soft terms



Brummer and Buchmuller 1201.4338

Constraints from $g_\mu - 2$

- discrepancy between measurement and SM prediction:

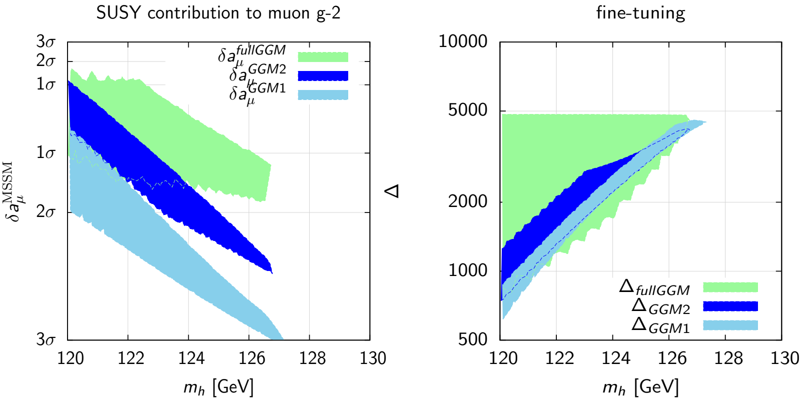
$$\delta a_\mu = a_\mu^{\mathrm{EXP}} - a_\mu^{\mathrm{SM}} = (2.8 \pm 0.8)10^{-9}.$$

- The simplest approximation of SUSY contribution

$$\delta a_\mu^{\mathrm{SUSY}} \approx \left(\frac{g_1^2 - g_2^2}{192\pi^2} + \frac{g_2^2}{32\pi^2} \right) \frac{m_\mu^2}{M_{\mathrm{SUSY}}^2} \operatorname{tg}\beta,$$

Problem:We need heavy superpartners (M_{SUSY})

$g_\mu - 2$ and FT



SUSY contribution to muon g-2
$\delta a_\mu^{fullGGM}$
δa_μ^{GGM2}
δa_μ^{GGM1}
3σ
2σ
1σ
1σ
2σ
3σ
$\delta a_\mu^{\rm MSSM}$
120
122
124
126
128
130
m_h [GeV]
fine-tuning
10000
5000
2000
1000
500
Δ
$\Delta_{fullGGM}$
Δ_{GGM2}
Δ_{GGM1}
120
122
124
126
128
130
m_h [GeV]

Conclusions

1. GGM predicts smaller fine-tuning than mSUGRA
2. for $m_h = 126$GeV fine-tuning always larger than 100 unless one includes only gauge mediated soft terms
3. including $g_\mu - 2$ raises fine-tuning about four times, but its still possible to obtain $g_\mu - 2$ within 1σ bound
4. decrease of the Higgs mass down to 123 GeV reduces the fine-tuning by a factor of 2.