Low-energy predictions of yukawa-deflected gauge mediations models

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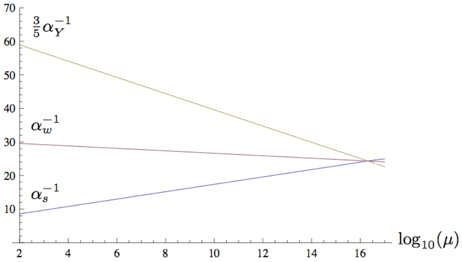
1. MSSM

Still the best candidate for BSM is softly broken MSSM:

- solves problem of quadratic corrections to m_{h^0}
- dark matter candidate → LSP
- better unification of gauge couplings at 10^{16} GeV→ hint for GUT model

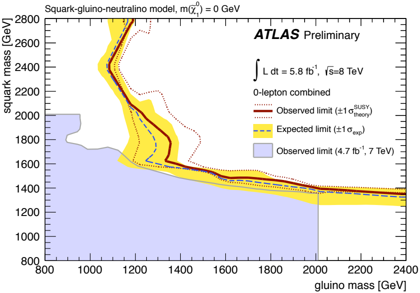


Problems:

- one needs additional sector which breaks SUSY communicate with MSSM
- fine-tuning
- a lot of parameters (soft terms) → explain them using RGE and some simple set of initial conditions at high scale (← GUT model)

What do the LHC searches tell us about MSSM?

- no SUSY signal so far
- relevant exclusions only for 1st and 2nd family
- still $\widetilde{Q}_3, \ldots$ can be as light as 400 GeV



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BUT important information comes from Higgs mass measurement:

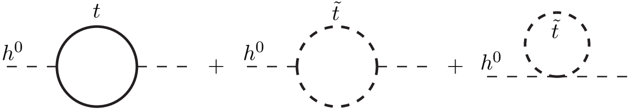
- $m \sim 125$ GeV $\rightarrow$ need for large loop corrections

ASSUME other MSSM Higgses are much heavier and masses of $\widetilde{Q}_{1,2}$ and $\widetilde{g}$ are bigger than 1.5 TeV.

3. 1-loop corrections to m_{h^0}

- dominant contribution from top quarks and stops (due to $y_t \sim 1$):

$\Delta(m_{h^0}^2) =$

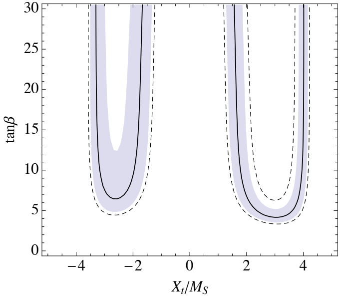


$$m_{h^0}^2 = m_Z^2 \cos^2 2\beta + \frac{3m_t^4}{4\pi^2 v^2}\left[\ln\frac{M_S^2}{m_t^2} + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right] \approx (125\,\mathrm{GeV})^2,$$

$$M_S = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$$
$$X_t = A_t - \mu \cot\beta$$

A-terms:

$$V_{\text{soft}} \supset y_t A_t H_u \widetilde{Q}_3 \widetilde{U}_3^c \longrightarrow y_t A_t h_0 \tilde{t}_1 \tilde{t}_2$$



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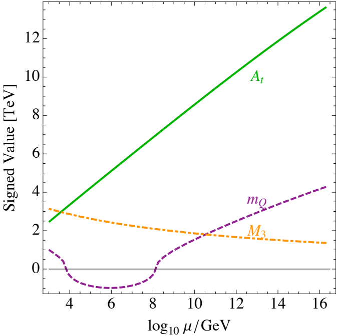
4. How to generate large A-terms?

- value of A-term gives initial condition for RGE evolution



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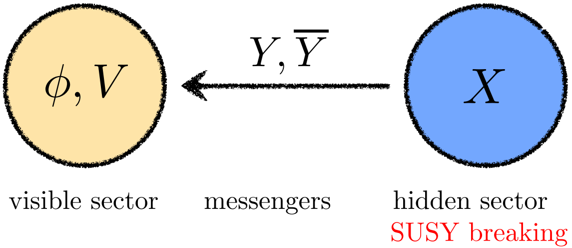
$$\mu \frac{dA_t}{d\mu} \sim y_t^2 A_t + g_3^2 M_3$$

- how to get A-terms in GUT model?

5. SUSY breaking mediation



- such structure is dictated by SUSY
- mediation = interactions between $Y, \overline{Y}$ and other fields
- singlet $\langle X \rangle = M + \theta^2 F \rightarrow$ spontaneous SUSY breaking
- X does not interact via superpotential with visible sector
- messengers have large masses e.g. $M \sim 10^{14}$ GeV

6. SUSY breaking mediation

- supergravity
  - no control over FCNC at all $\rightarrow$ arbitrary mixings between families
- gauge interactions
  - no FCNC effects at M scale (small mixing generated via RGE)
  - $A \approx 0$ at M scale
  - $m_{h^0} \sim 125$ GeV $\rightarrow M \gtrsim 10^{14}$ GeV (i.e. here A need long RGE evolution)
- Yukawa (and gauge) interactions
  - mild hierarchy of additional couplings $\longrightarrow$ FCNC effects suppressed
  - A-terms $\neq 0$ at M scale
  - easy to satisfy $m_{h^0} \sim 125$ GeV even for $M \sim 10^5$ GeV
  - rich phenomenology

7. Messenger couplings

Focus on: $SU(5)$ unification model with messengers in $5+\overline{5}$ and $10+\overline{10}$

- matter ϕ_i in $5, \overline{5}$ or 10 (in MSSM only $5\,10\,10$ and $\overline{5}\,\overline{5}\,10$)
- pair of messengers $\mathsf{Y} = (Y, \overline{Y})$

$$W_Y = \eta \mathsf{YYY} + h_I^i \phi_i \mathsf{YY} + h_{II}^{ij} \phi_i \phi_j \mathsf{Y}$$

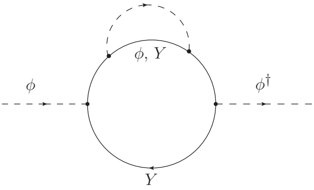
- allowed couplings: $5\,10\,10, \quad \overline{5}\,\overline{5}\,10, \quad \overline{5}\,\overline{10}\,\overline{10}, \quad 5\,5\,\overline{10}$
- $h_{I,II}$ quite well explored (Yukawa-Deflected Gauge Mediation)

  usually some hierarchy in messenger-matter is assumed

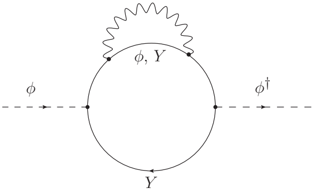
  see talks by: J. Pawełczyk, L. Callibbi
- couplings of three messengers η → additional effects!
  - relevant only if occur together with h_I or h_{II}
  - do not contribute to A-terms (nor to 1-loop masses)

- 2-loop contributions to soft masses

$$W_Y = \eta \mathsf{YYY} + h_I \phi \mathsf{YY} + h_{II} \phi\phi \mathsf{Y}$$



$h_{I,II},\ \eta$



$h_{I,II}$

$$m^2_{\tilde{\phi},\eta} \sim \frac{1}{(4\pi)^4}(\eta^2 h^2 + \eta h^3 + \eta h^2 y)\left(\frac{F}{M}\right)^2$$

NEW CONTRIBUTIONS!

9. Phenomenological constraints

Assumptions:

- no rapid proton decay via

$$\phi_{\bar{5}}\phi_{\bar{5}}\phi_{10}, \quad \frac{1}{M}\phi_{\bar{5}}\phi_{10}\phi_{10}\phi_{10} \quad \frac{1}{M^2}(\phi_{10}^{\dagger}\phi_{10})^2$$

- absence of μ/B_μ problem
- no $\mu H_u H_d$ term in the superpotential
- Higgs mass term via

$$\frac{1}{M_{GUT}}X^{\dagger}H_u H_d$$

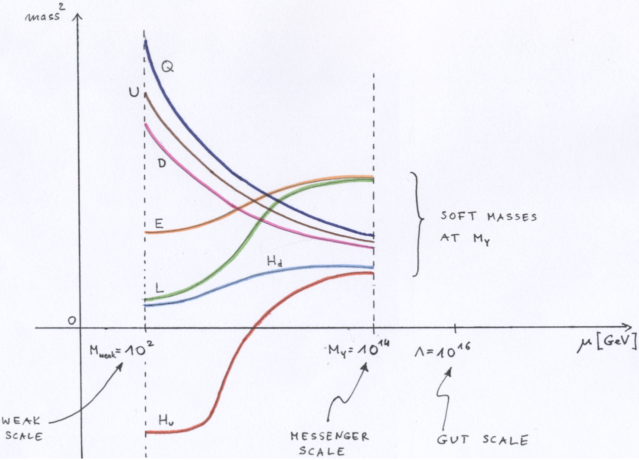
One needs addtional selection rules → e.g. global $U(1)$ symmetry

- the simplest model restricted by $U(1)$

$$W_{\mathsf{Y}} = \frac{1}{2}h_{14}\phi_{10}Y_{\bar{5}}Y_{\bar{5}} + \frac{1}{2}\eta_2 Y_{\bar{5}}Y_{\overline{10}}Y_{\overline{10}}.$$

10. Top-down analysis

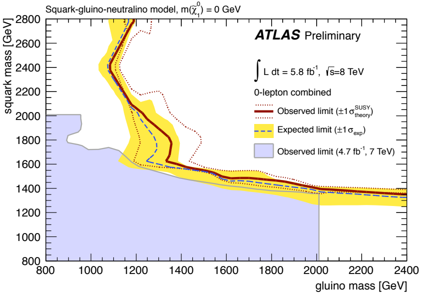
Reverse the initial problem and evolve parameters from M to EWSB scale:



11. Phenomenology

Find spectrum and check if phenomenology is correct i.e.

- $m_{h^0} \approx 125\,\text{GeV}$
- no tachyons
- scalar potential bounded from below, no CCB
- a_μ, $b \to s\gamma$
- ATLAS bounds on gluino and squarks of 1. and 2. generation



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12. The simplest example

$$W_{\mathrm{Y}} = \frac{1}{2}\eta_2 Y_{\overline{5}} Y_{\overline{10}} Y_{\overline{10}} + \frac{1}{2} h_{14}\phi_{10} Y_{\overline{5}} Y_{\overline{5}}$$

$$m^2_{\widetilde{Q},\eta} = 6\alpha_{h_{14}}\alpha_{\eta_2}\frac{\xi^2}{16\pi^2}, \quad m^2_{\widetilde{Q},h} = \alpha_{h_{14}}\left(6\alpha_{h_{14}} - \frac{7}{15}\alpha_1 - 3\alpha_2 - 6\alpha_3\right)\frac{\xi^2}{16\pi^2}$$

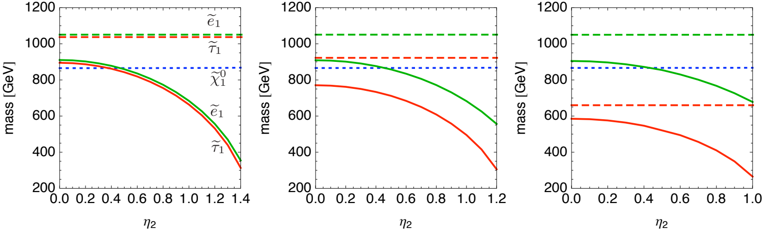

Figure: Plot of the particles masses vs. η_2 coupling for $\tan\beta = 10$ (left plot), $\tan\beta = 30$ (middle plot) and $\tan\beta = 50$ (right plot). h_{14} is set to 1.2, while $\xi = F/M$ scale is 1.6×10^5 GeV. Dashed lines show masses of the particles when $h_{14} = \eta_2 = 0$, which corresponds to the standard GMSB case. $\widetilde{\tau}_1$ and $\widetilde{e}_1$ are mostly right-handed.

$$\mu\frac{dm^2_{\widetilde{E}_3}}{d\mu} = \ldots + \frac{6}{10}g_1^2 m^2_{\widetilde{Q},\eta}$$

13. Conclusions

- Yukawa-Deflected Gauge Mediation models naturally accommodate for left-right top squarks mixing
- in some cases superpotential couplings of three messengers are relevant to mass spectrum
- additional selection rules (e.g. global $U(1)$) are necessary to satisfy phenomenological constraints