SUSY Model Building for a 126 GeV Higgs

Moritz McGarrie

The MSSM

3-generations:
stops are typically the lightest coloured superpartners

Names		spin 0	spin 1/2	$SU(3)_C$, $SU(2)_L$, $U(1)_Y$
squarks, quarks	Q	$(\tilde{u}_L \;\; \tilde{d}_L)$	$(u_L \;\; d_L)$	$(\,\mathbf{3},\ \mathbf{2},\ \frac{1}{6})$
($\times 3$ families)	$\overline{u}$	$\tilde{u}^*_R$	$u^\dagger_R$	$(\,\overline{\mathbf{3}},\ \mathbf{1},\ -\frac{2}{3})$
	$\overline{d}$	$\tilde{d}^*_R$	$d^\dagger_R$	$(\,\overline{\mathbf{3}},\ \mathbf{1},\ \frac{1}{3})$
sleptons, leptons	L	$(\tilde{\nu} \;\; \tilde{e}_L)$	$(\nu \;\; e_L)$	$(\,\mathbf{1},\ \mathbf{2},\ -\frac{1}{2})$
($\times 3$ families)	$\overline{e}$	$\tilde{e}^*_R$	$e^\dagger_R$	$(\,\mathbf{1},\ \mathbf{1},\ 1)$
Higgs, higgsinos	H_u	$(H_u^+ \;\; H_u^0)$	$(\tilde{H}_u^+ \;\; \tilde{H}_u^0)$	$(\,\mathbf{1},\ \mathbf{2},\ +\frac{1}{2})$
	H_d	$(H_d^0 \;\; H_d^-)$	$(\tilde{H}_d^0 \;\; \tilde{H}_d^-)$	$(\,\mathbf{1},\ \mathbf{2},\ -\frac{1}{2})$

Table 1.1: Chiral supermultiplets in the Minimal Supersymmetric Standard Model. The spin-0 fields are complex scalars, and the spin-1/2 fields are left-handed two-component Weyl fermions.

Names	spin 1/2	spin 1	$SU(3)_C$, $SU(2)_L$, $U(1)_Y$
gluino, gluon	$\tilde{g}$	g	$(\,\mathbf{8},\ \mathbf{1}\,,\ 0)$
winos, W bosons	$\widetilde{W}^\pm \;\; \widetilde{W}^0$	$W^\pm \;\; W^0$	$(\,\mathbf{1},\ \mathbf{3}\,,\ 0)$
bino, B boson	$\tilde{B}^0$	B^0	$(\,\mathbf{1},\ \mathbf{1}\,,\ 0)$

Table 1.2: Gauge supermultiplets in the Minimal Supersymmetric Standard Model.

Ref: A supersymmetry primer Arxiv:9709356v6

The superpotential for the MSSM is

$$W_{\text{MSSM}} = \overline{u}\mathbf{y_u}QH_u - \overline{d}\mathbf{y_d}QH_d - \overline{e}\mathbf{y_e}LH_d + \mu H_u H_d\,. \tag{6.1.1}$$

$$\mathbf{y_u} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & y_t \end{pmatrix}, \quad \mathbf{y_d} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & y_b \end{pmatrix}, \quad \mathbf{y_e} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & y_\tau \end{pmatrix}. \tag{6.1.2}$$

$$\begin{aligned} \mathcal{L}_{\text{soft}}^{\text{MSSM}} = & -\frac{1}{2}\left(M_3\widetilde{g}\widetilde{g} + M_2\widetilde{W}\widetilde{W} + M_1\widetilde{B}\widetilde{B} + \text{c.c.}\right) \\ & -\left(\widetilde{\overline{u}}\,\mathbf{a_u}\,\widetilde{Q}H_u - \widetilde{\overline{d}}\,\mathbf{a_d}\,\widetilde{Q}H_d - \widetilde{\overline{e}}\,\mathbf{a_e}\,\widetilde{L}H_d + \text{c.c.}\right) \\ & -\widetilde{Q}^\dagger\,\mathbf{m_Q^2}\,\widetilde{Q} - \widetilde{L}^\dagger\,\mathbf{m_L^2}\,\widetilde{L} - \widetilde{\overline{u}}\,\mathbf{m_{\overline{u}}^2}\,\widetilde{\overline{u}}^\dagger - \widetilde{\overline{d}}\,\mathbf{m_{\overline{d}}^2}\,\widetilde{\overline{d}}^\dagger - \widetilde{\overline{e}}\,\mathbf{m_{\overline{e}}^2}\,\widetilde{\overline{e}}^\dagger \\ & - m_{H_u}^2 H_u^* H_u - m_{H_d}^2 H_d^* H_d - (bH_uH_d + \text{c.c.})\,. \end{aligned}$$

A-terms:
Soft terms for each Yukawa

$$\mathbf{a_u} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a_t \end{pmatrix}, \quad \mathbf{a_d} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a_b \end{pmatrix}, \quad \mathbf{a_e} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a_\tau \end{pmatrix}, \tag{6.5.28}$$

1.The Higgs mass 126 GeV

The MSSM at one-loop

top mass

average stop mass

$$m_h^2 \simeq m_z^2 \cos^2(2\beta) + \frac{3}{(4\pi)^2}\frac{m_t^4}{v_{ew}^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2}(1 - \frac{X_t^2}{12 m_{\tilde{t}}^2})\right]$$

$$\boxed{126^2 = 91^2 + 81^2}$$

$$X_t = A_t - \mu\cot\beta$$

stop mixing

- Radiative corrections are same order as tree level piece
- corrections run logarithmically in SUSY
- MSSM case implies either heavy stops or large X_t=A_t +....

Fine tuning: little hierarchy problem

$$m_z^2 = -2(m_{H_u}^2 + |\mu|^2) + \ldots$$

Light Higgsino

For a natural cancellation these should be of the same order

Light stops

$$\delta m_{H_u}^2 \sim -\frac{3y_t^2 m_{\tilde{t}}^2}{4\pi^2}\mathrm{Log}\left(\frac{\Lambda}{m_{\tilde{t}}}\right) - \frac{3g^2}{8\pi^2}(m_{\tilde{W}}^2 + m_{\tilde{h}}^2)\mathrm{Log}(\frac{\Lambda}{m_{\tilde{W}}})$$

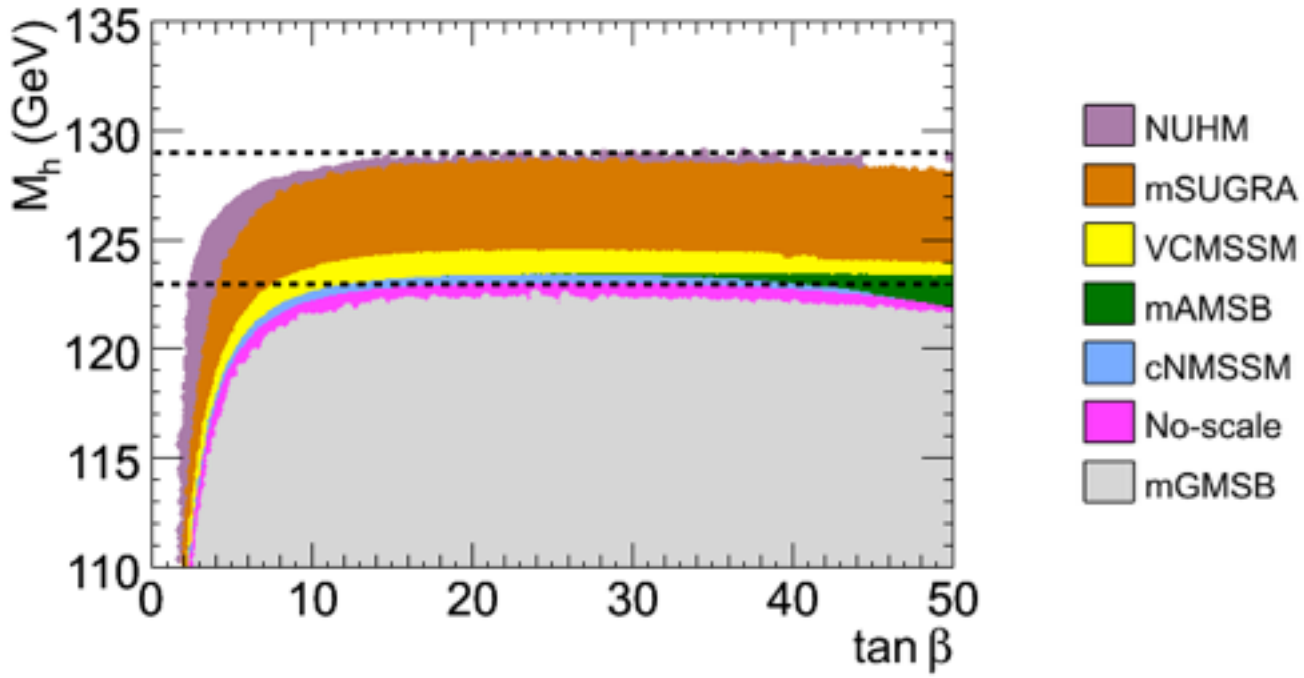
Light(ish) Gluino

Light wino

$$\delta m_{\tilde{t}}^2 = \frac{8\alpha_s M_3^2}{3\pi}\mathrm{Log}\left(\frac{\Lambda}{M_3}\right)$$

Fine tuning (absence of new physics)
appears all models in some way: R-S, composite Higgs, little Higgs, SUSY etc

How do benchmark (minimal) models fair?



1207.1348
Arbey, Battaglia, Djouadi, Mahmoudi

stops less than 2 TeV

The point is that these models all work, but only if the spectrum is very heavy e.g. 5-10 TeV stops: *unnatural and unobservable at LHC14.*

if you give up on naturalness, is there any reason to see anything at the LHC?

Reasons to (still) believe in SUSY

- Solves big hierarchy problem M_{EW}/M_{Pl}
- Improves GUT unification (and so too, stability of Proton)
- necessary for string theory (unification of all forces)
- radiatively induced EWSB in MSSM-like models.
- Believable dark matter candidate(s)
- It is consistent with low energy EW observables
- Improves fit to muon magnetic moment etc.
- MSSM bounds Higgs < 135 GeV

what are our choices?

The trivial *option*

Split SUSY, some landscape (multiverse) gives an explanation for Yu, Λ_{cc}, m_h^2 (maybe more?)

The less *likely option?*

Generate a large At

(vanishing in mGMSB, uncalculable in SUGRA.)

The innovative *option*

non-minimal….get creative....

In this talk I am going to give 2 examples of models that improve naturalness

Non decoupled D-terms

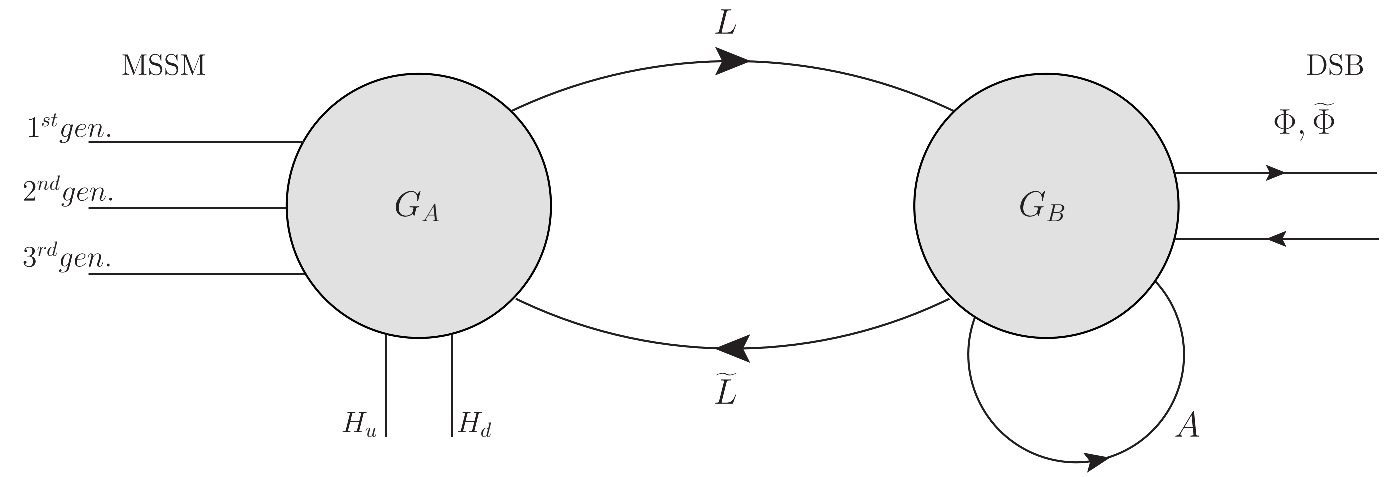
(Aoife Bharucha, Andreas Goudelis & MM) 1310.4500

Large At Without the Desert

(A.Abdalgabar,A.A.Deandrea,A.Cornell, MM) 1405.1038

A quiver model: motivation

- non decoupled D-terms: lifts the Higgs (sometimes substantially) Batra, Delgado, Kaplan, Tait 0309149
- extra adjoints of SU(2),SU(3): lifts the Higgs
- More natural than NMSSM?
- embeds into magnetic SQCD
- Deconstructs an extra dimension



- "Split families": Batra, Kaplan, Tait, Delgado 0404251/0409073

$$m_h^2 \simeq m_z^2 \cos^2(2\beta) + \frac{3}{(4\pi)^2}\frac{m_t^4}{v_{ew}^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{X_t^2}{12 m_{\tilde{t}}^2}\right)\right]$$

$$\Delta = \left(\frac{g_A^2}{g_B^2}\right)\frac{2m_L^2}{m_v^2 + 2m_L^2}$$

Related works:

Csaki, Erlich, Grojean, Kribs 0106044
Medina, Shah, Wagner 0904.1625

"GGM and Deconstruction"
M.M. 1009.0012 and 1101.5158

Auzzi, Giveon, Gudnason, Shacham
1009.1714
1011.1664

+ ...

$$\delta\mathcal{L} = -g_1^2\Delta_1(H_u^\dagger H_u - H_d^\dagger H_d)^2 - g_2^2\Delta_2\sum_a (H_u^\dagger\sigma^a H_u + H_d^\dagger \sigma^a H_d)^2$$

$$m_z^2 \to m_z^2 + \left(\frac{g_1^2\Delta_1 + g_2^2\Delta_2}{2}\right) v_{ew}^2$$

Bharucha, Goudelis, M.M. 1310.4500

D-terms Vs NMSSM

$$m_h^2 \simeq m_z^2 \cos^2(2\beta) + \frac{3}{(4\pi)^2}\frac{m_t^4}{v_{ew}^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{X_t^2}{12 m_{\tilde{t}}^2}\right)\right]$$

$$\Delta = \left(\frac{g_A^2}{g_B^2}\right)\frac{2m_L^2}{m_v^2 + 2m_L^2}$$

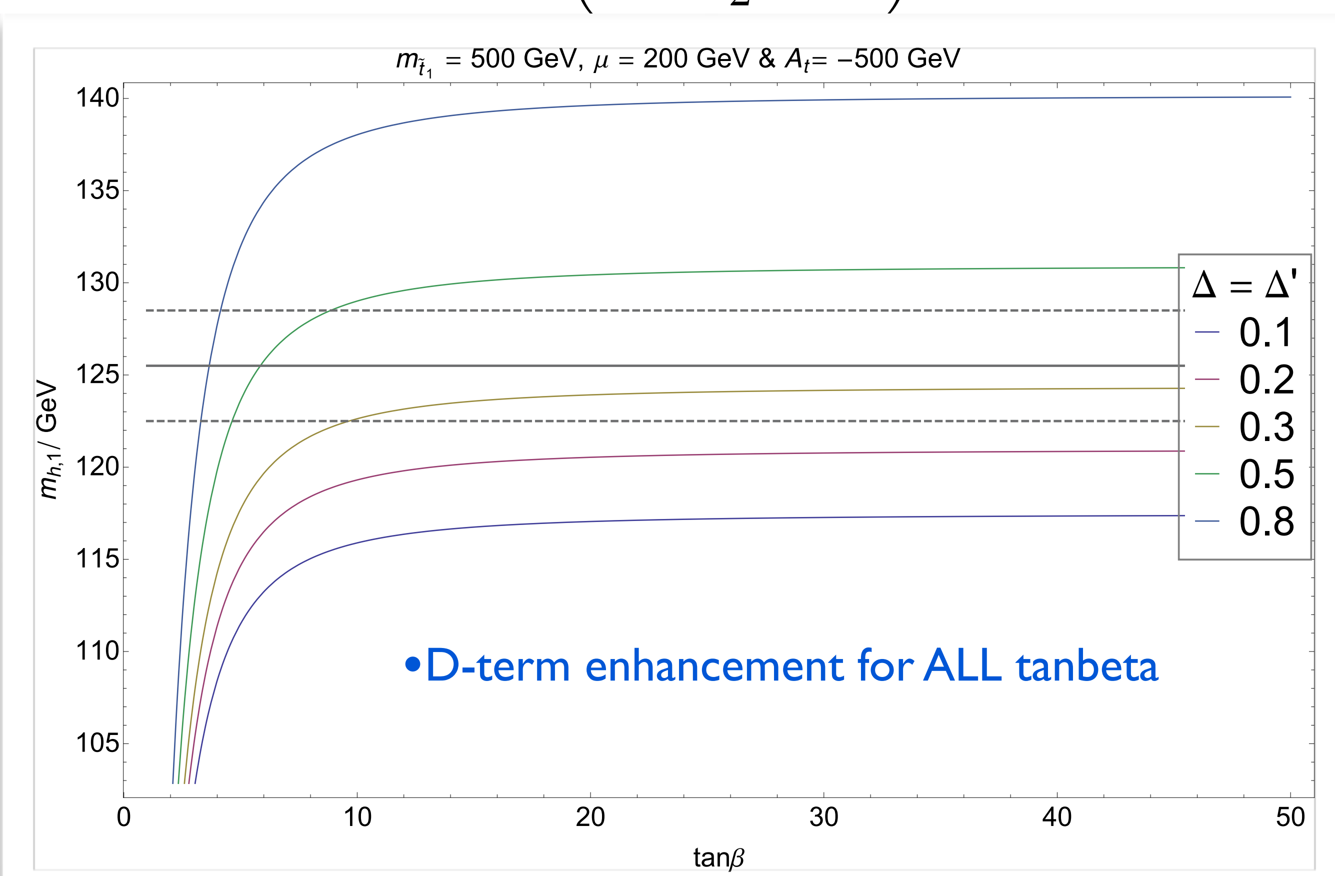
$$\delta\mathcal{L} = -g_1^2\Delta_1(H_u^\dagger H_u - H_d^\dagger H_d)^2 - g_2^2\Delta_2\sum_a(H_u^\dagger\sigma^a H_u + H_d^\dagger\sigma^a H_d)^2$$

$$m_z^2 \to m_z^2 + \left(\frac{g_1^2\Delta_1 + g_2^2\Delta_2}{2}\right)v_{ew}^2$$

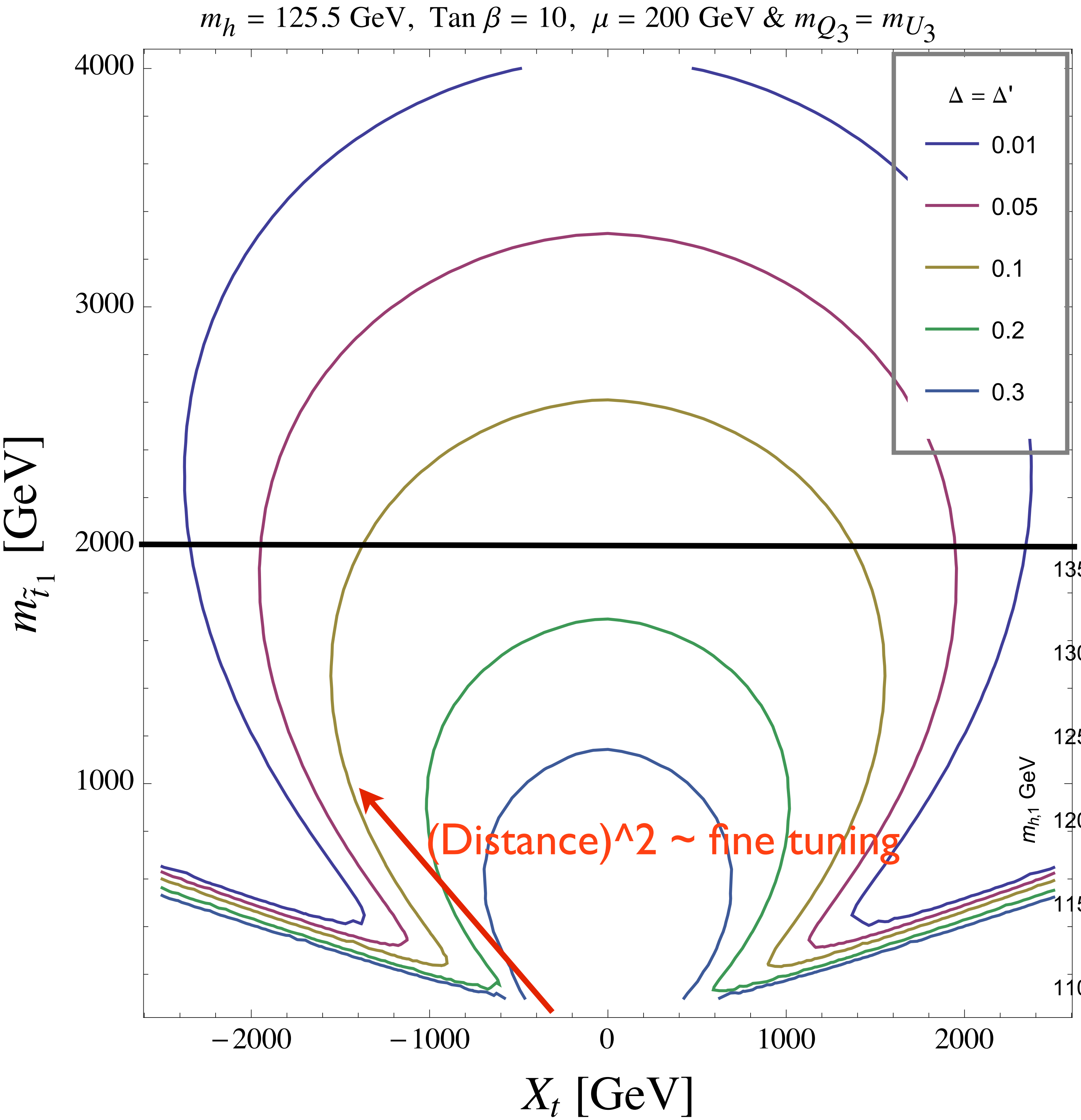
$$W_{NMSSM} \supset \lambda S H_u H_d$$

$$V(\phi's) \supset \lambda^2|H_u H_d|^2$$

$$m_{h_0}^2 = m_z^2\cos(2\beta) + \lambda^2 v_{ew}^2\sin(2\beta)$$

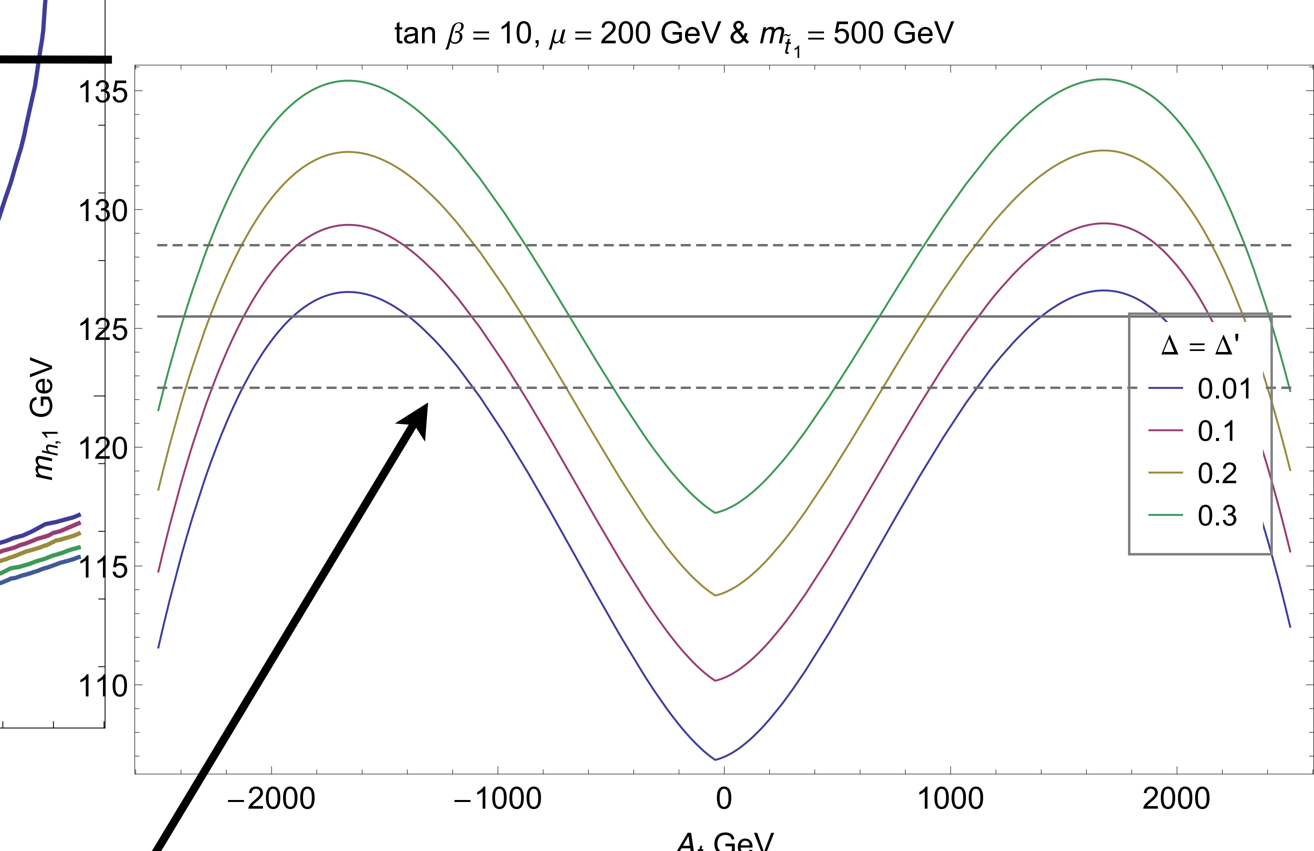


•F-term enhancement only for small tanbeta



M.M. Moortgat-Pick & S.Porto, G.

Sub 2 TeV stops for $\Delta \geq 0.1$



Combination of medium size At and Deltas can do the trick! (GMSB back in the game?)

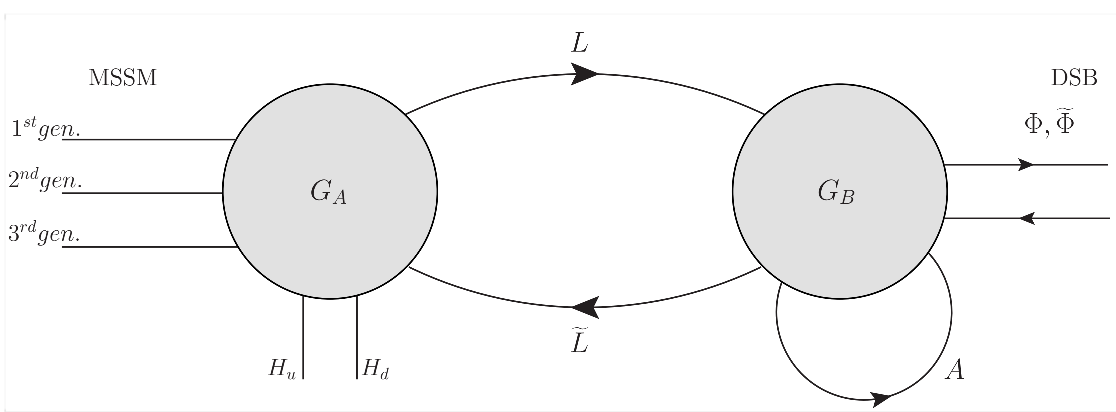
So far most studies of D-terms have been at tree-level and bottom-up ....

A *meta* model

Bharucha, Goudelis, M.M. 1310.4500

SF	Spin 0	Spin $\frac{1}{2}$	Generations	$(U(1)_A, \mathrm{SU}(2)_B, \mathrm{SU}(3)_c, U(1)_B, \mathrm{SU}(2)_A)$	R-Parity
$\hat{q}$	$\tilde{q}$	q	3	$(\frac{1}{6}, \mathbf{1}, \mathbf{3}, 0, \mathbf{2})$	-1
$\hat{l}$	$\tilde{l}$	l	3	$(-\frac{1}{2}, \mathbf{1}, \mathbf{1}, 0, \mathbf{2})$	-1
$\hat{H}_d$	H_d	$\tilde{H}_d$	1	$(-\frac{1}{2}, \mathbf{1}, \mathbf{1}, 0, \mathbf{2})$	$+1$
$\hat{H}_u$	H_u	$\tilde{H}_u$	1	$(\frac{1}{2}, \mathbf{1}, \mathbf{1}, 0, \mathbf{2})$	$+1$
$\hat{d}$	$\tilde{d}_R^*$	d_R^*	3	$(\frac{1}{3}, \mathbf{1}, \overline{\mathbf{3}}, 0, \mathbf{1})$	-1
$\hat{u}$	$\tilde{u}_R^*$	u_R^*	3	$(-\frac{2}{3}, \mathbf{1}, \overline{\mathbf{3}}, 0, \mathbf{1})$	-1
$\hat{e}$	$\tilde{e}_R^*$	e_R^*	3	$(1, \mathbf{1}, \mathbf{1}, 0, \mathbf{1})$	-1
$\hat{L}$	L	ψ_L	1	$(-\frac{1}{2}, \overline{\mathbf{2}}, \mathbf{1}, \frac{1}{2}, \mathbf{2})$	$+1$
$\hat{\tilde{L}}$	$\tilde{L}$	$\psi_{\tilde{L}}$	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1}, -\frac{1}{2}, \overline{\mathbf{2}})$	$+1$
$\hat{K}$	K	ψ_K	1	$(0, \mathbf{1}, \mathbf{1}, 0, \mathbf{1})$	$+1$
$\hat{A}$	A	ψ_A	1	$(0, \mathbf{3}, \mathbf{1}, 0, \mathbf{1})$	$+1$

Table 2. Matter fields of the model.



$$W_{\text{SSM}} = Y_u\, \hat{u}\, \hat{q}\, \hat{H}_u - Y_d\, \hat{d}\, \hat{q}\, \hat{H}_d - Y_e\, \hat{e}\, \hat{l}\, \hat{H}_d + \mu\, \hat{H}_u\, \hat{H}_d$$

$$W_{\text{Quiver}} = \frac{Y_K}{2} \hat{K} (\hat{L}\, \hat{\tilde{L}} - V^2) + Y_A\, \hat{L}\, \hat{A}\, \hat{\tilde{L}}$$

The most sophisticated model so far implemented into a spectrum generator (SARAH/SPHENO)
A *meta*-model i.e. *independent* of the type of supersymmetry breaking:
AMSB, mSUGRA, GMSB, phenomenological, other?

Building a taylor made spectrum generator!

- We used SARAH (written by Florian Staub) mathematica package: "a spectrum generator *generator*" to write our own spectrum generator.
- We implemented 5 gauge groups with full 2-loop RGE's and one loop self energies (soon 6 and 9 gauge groups!).
- Higgsing, and breaking to the diagonal 4 gauge groups, including all mixing matrices and assignment of Goldstones, Ghosts, RGEs of *vevs*, and Bmu at 2 loop.
- All 3 and 4 vertices of all fields computed, and self energies.
- All anomalous dimensions, tadpoles and running of all *additional soft terms and additional Yukawas, at 2 loop level.*
- finite shifts and threshold corrections also accounted for
- Can talk to FeynArts, FormCalc, CalcHep, Higgsignals, HiggsBounds, WHIZARD. micrOMEGAS, Vevacious and more.

Quiver @ M messenger

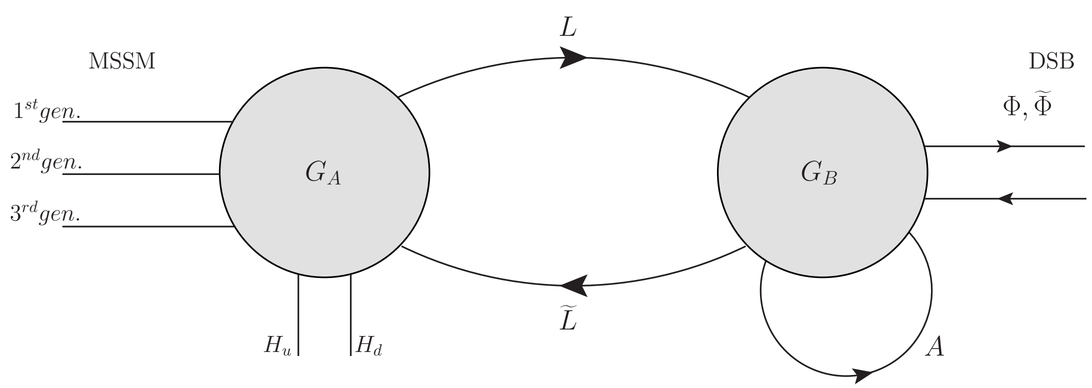
Threshold scale: MSSM

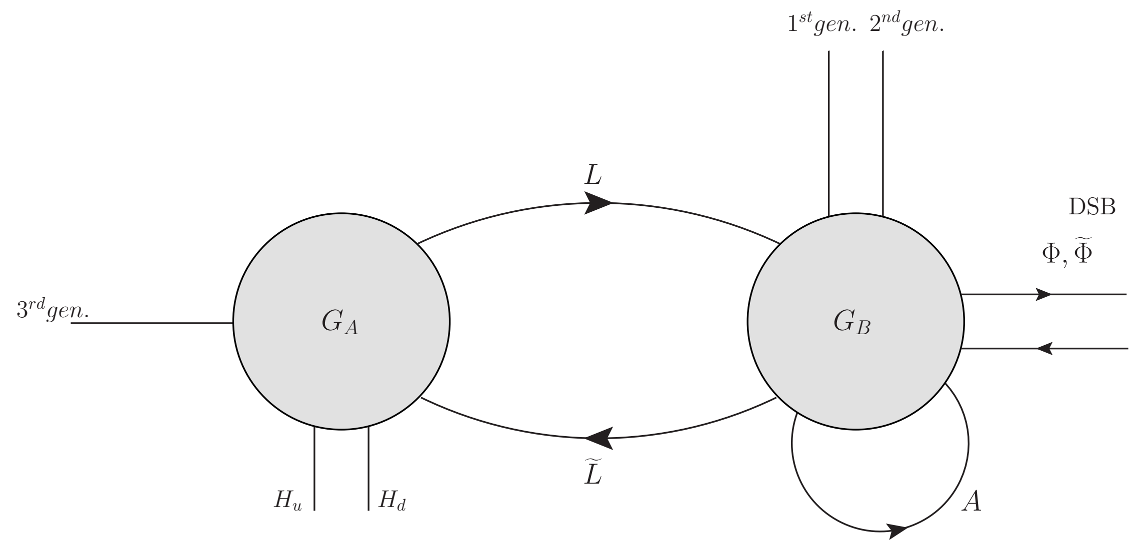
LHC

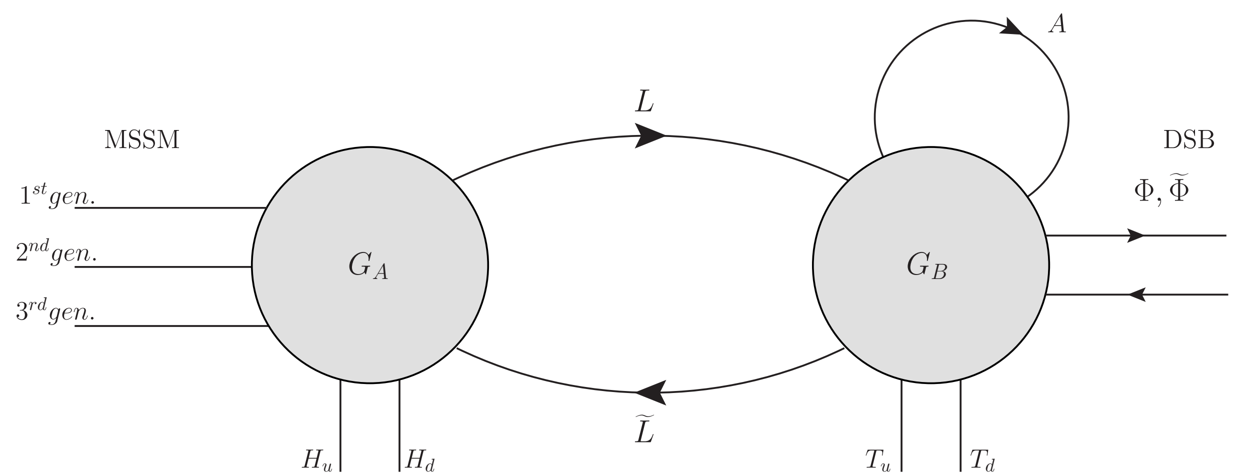
Same precision as SOFTSUSY, SPheno, SUSPECT

Bharucha, Goudelis, M.M. 1310.4500

The Quiver Variations





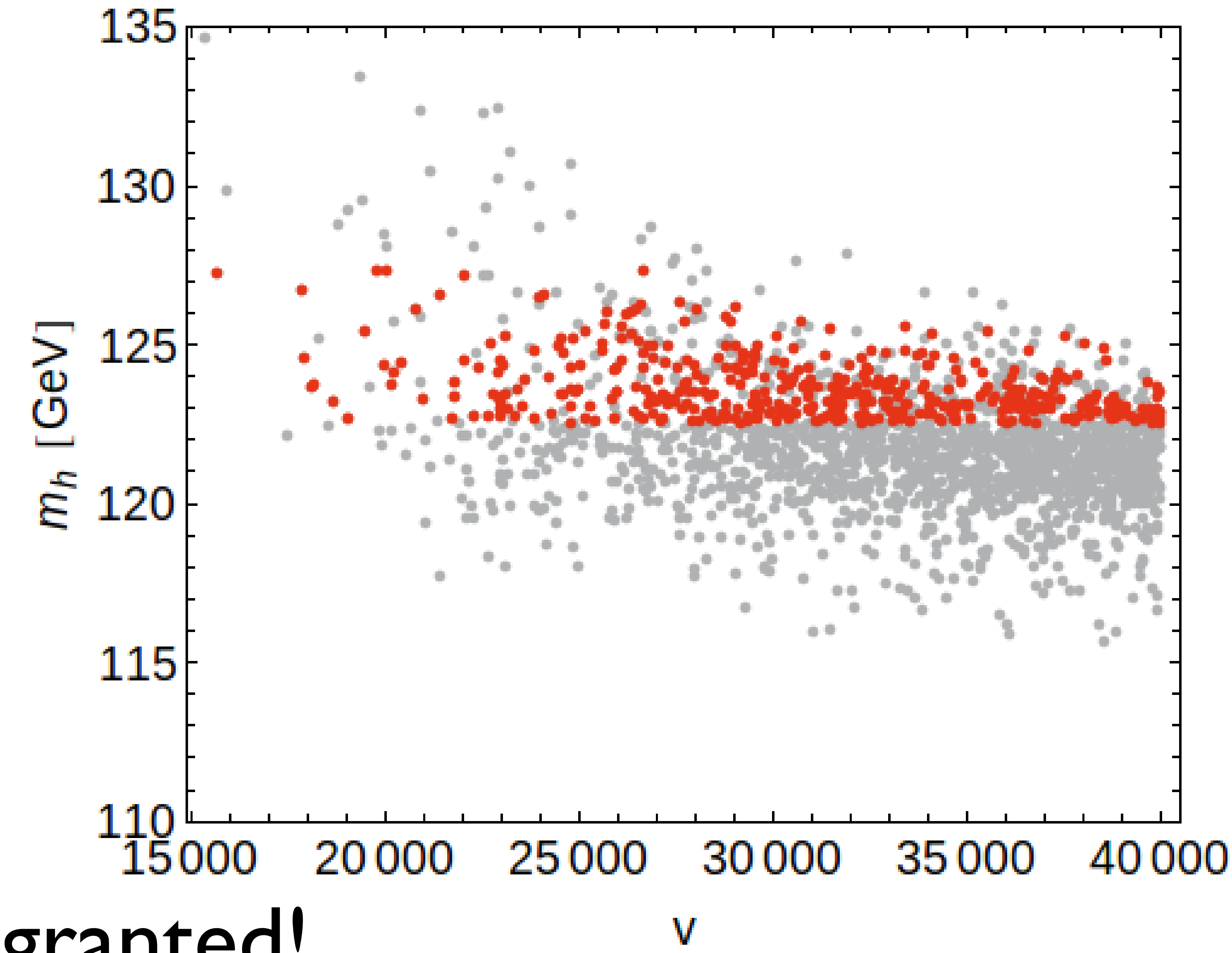


Wish list

- $v < 10\text{TeV}$

  $m_L^2 > m_v^2$

We assumed GMSB for soft terms!



Our wishes were not granted!

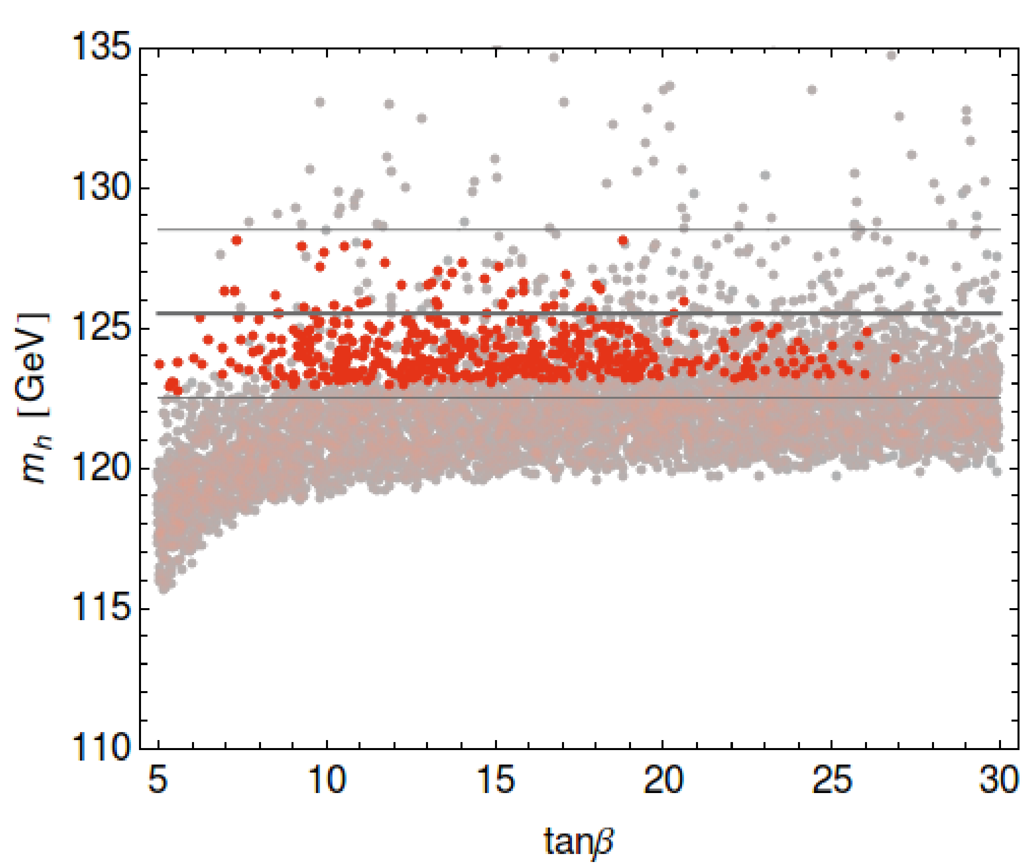
we had to enlarge m_L^2 to make it work

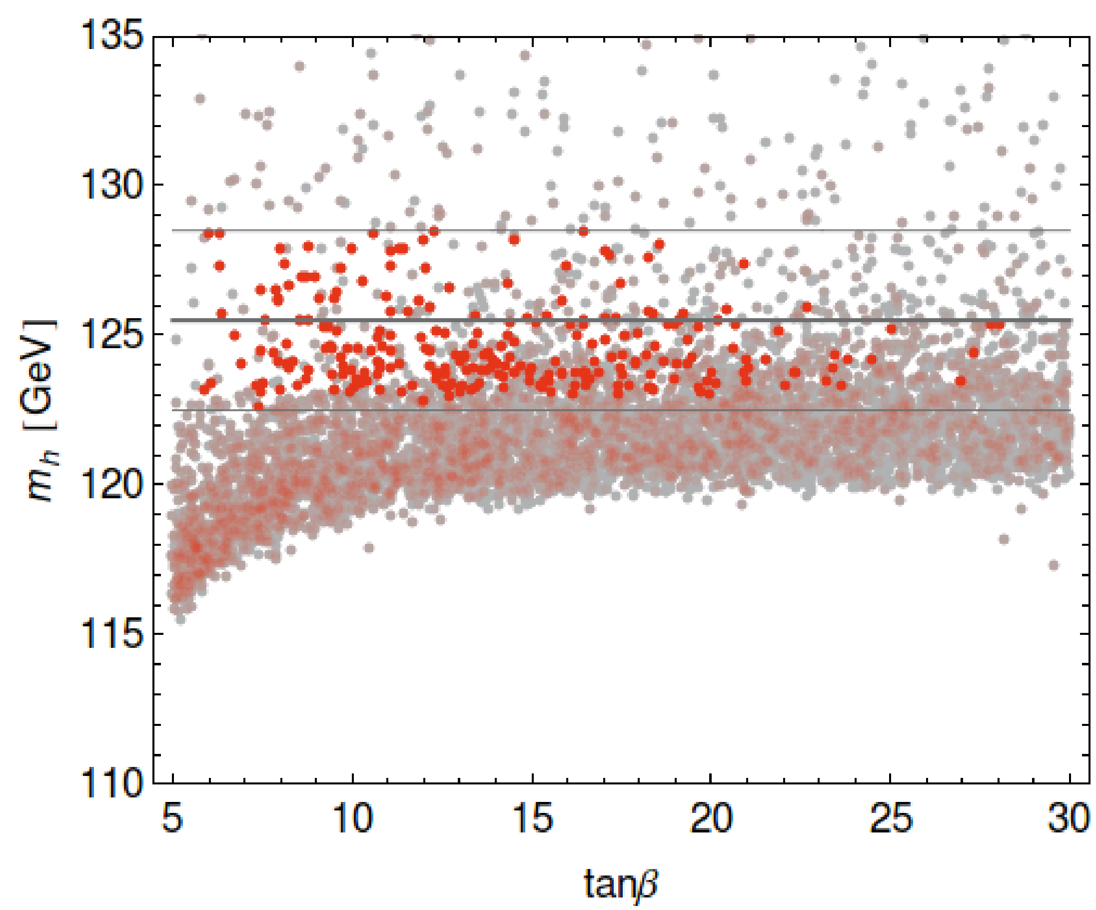
But perhaps this can be improved by considering different SUSY breaking scenarios

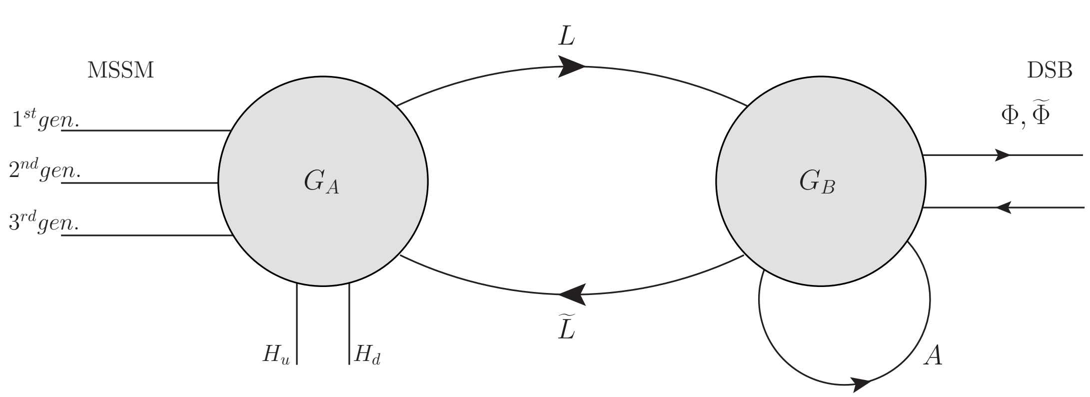
Ex. Applying mSUGRA here may get v down

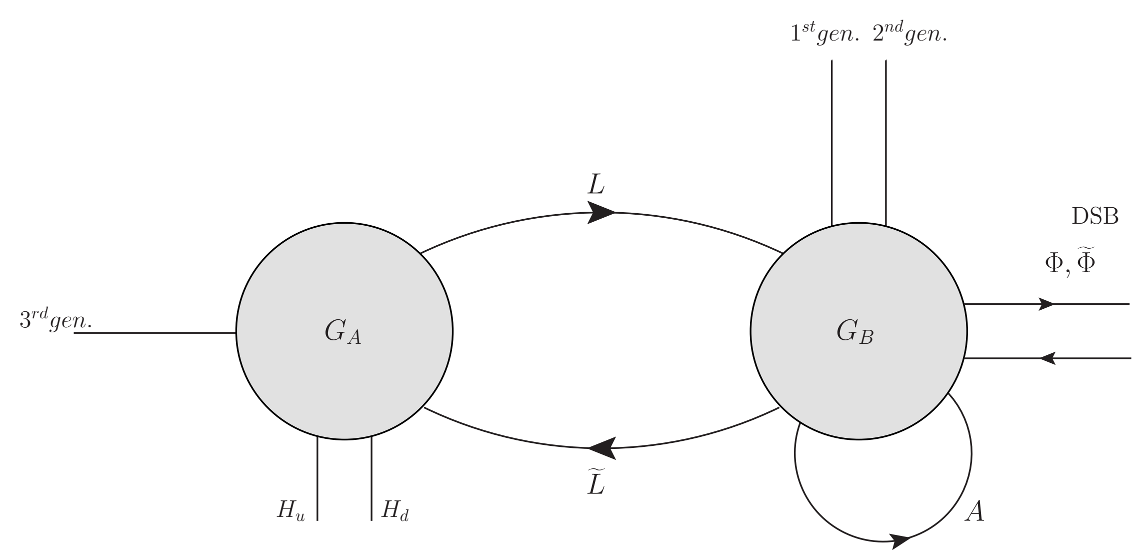
Bharucha, Goudelis, M.M. 1310.4500

Bharucha,Goudelis, M.M. 1310.4500

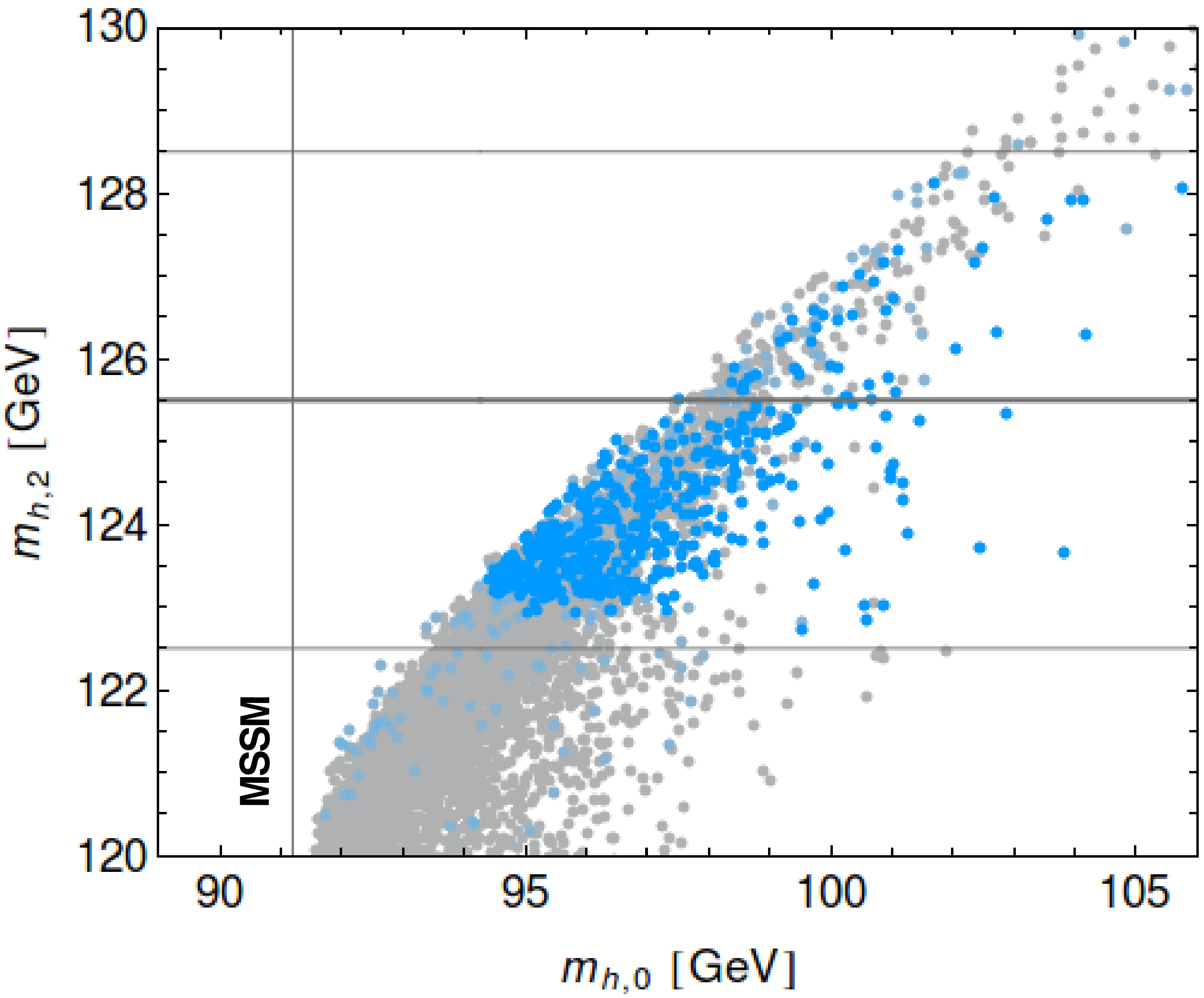


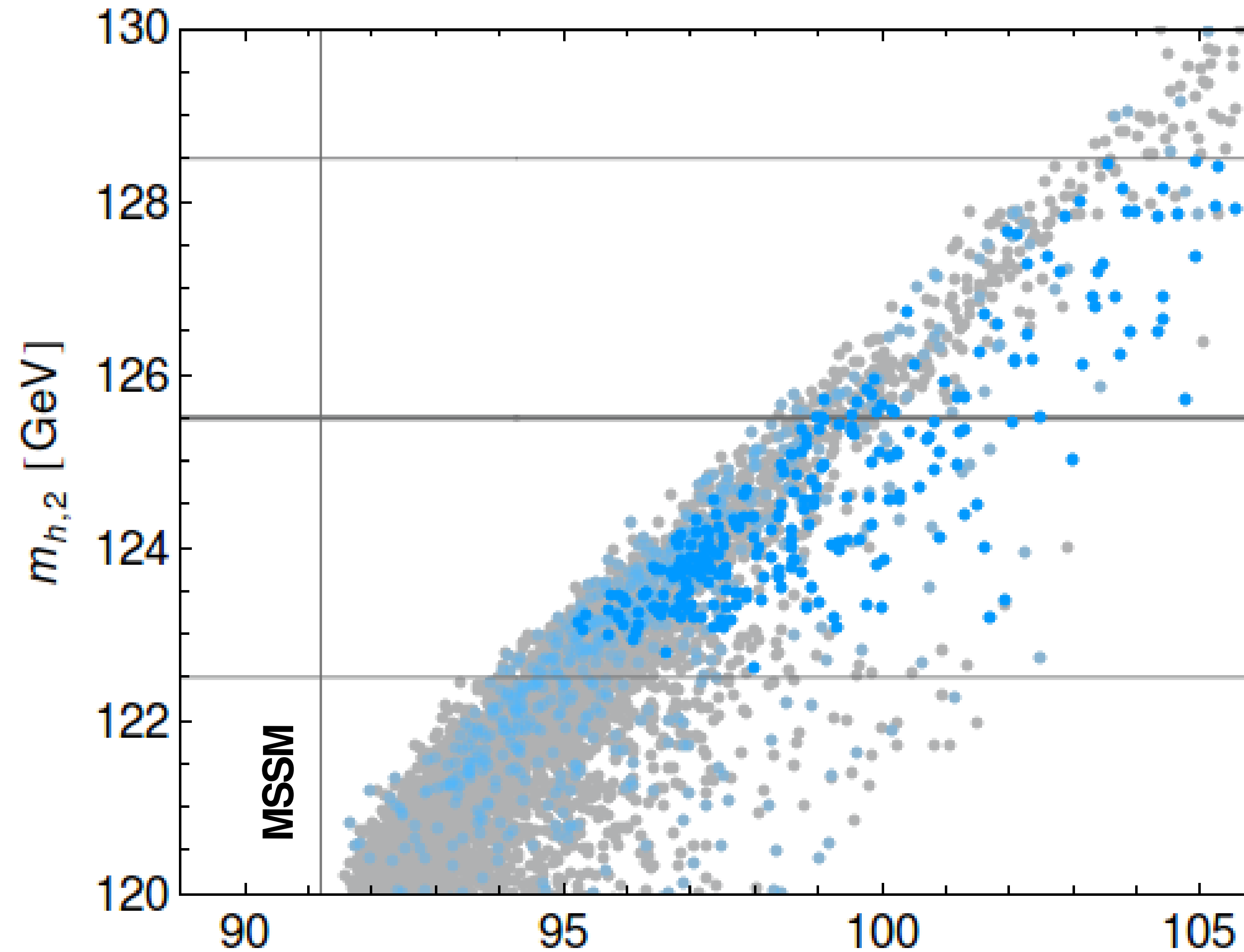


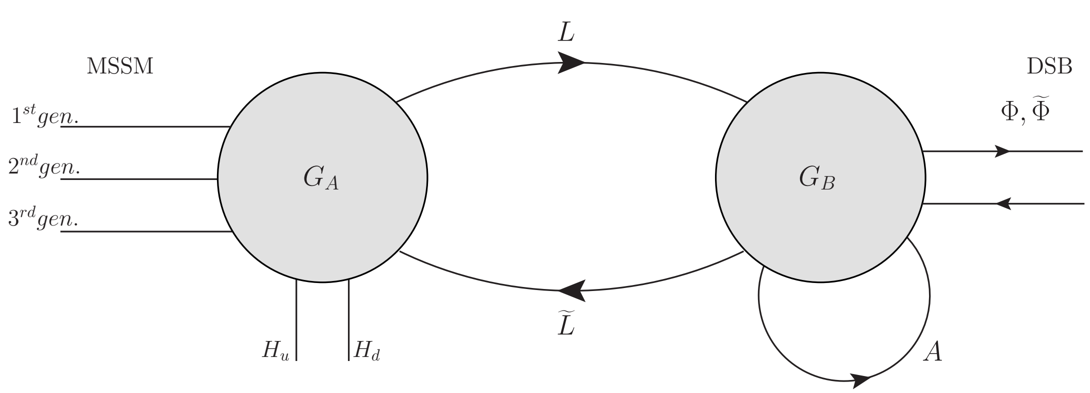


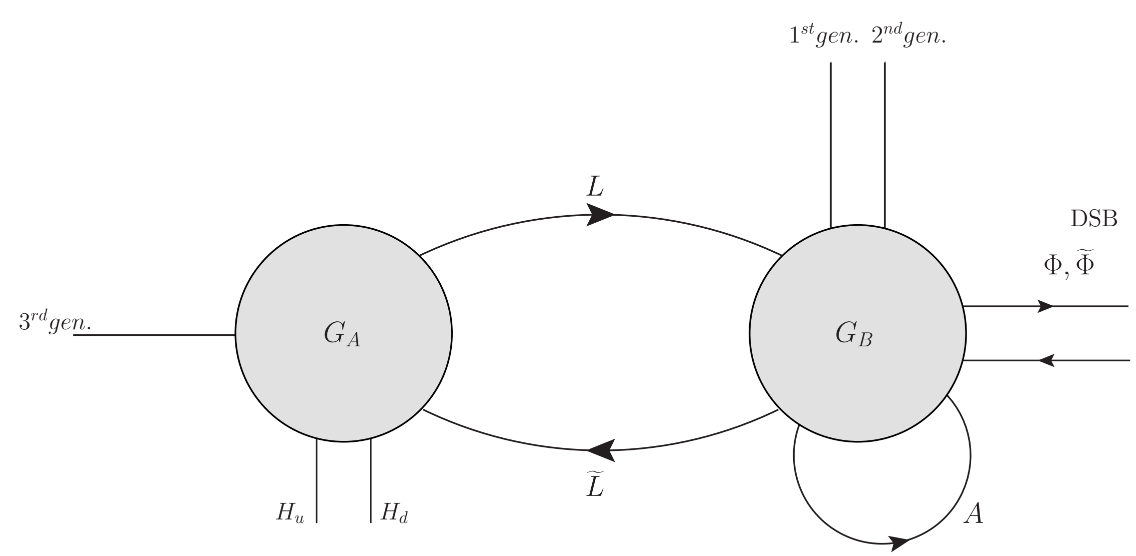


Bharucha,Goudelis, M.M. 1310.4500

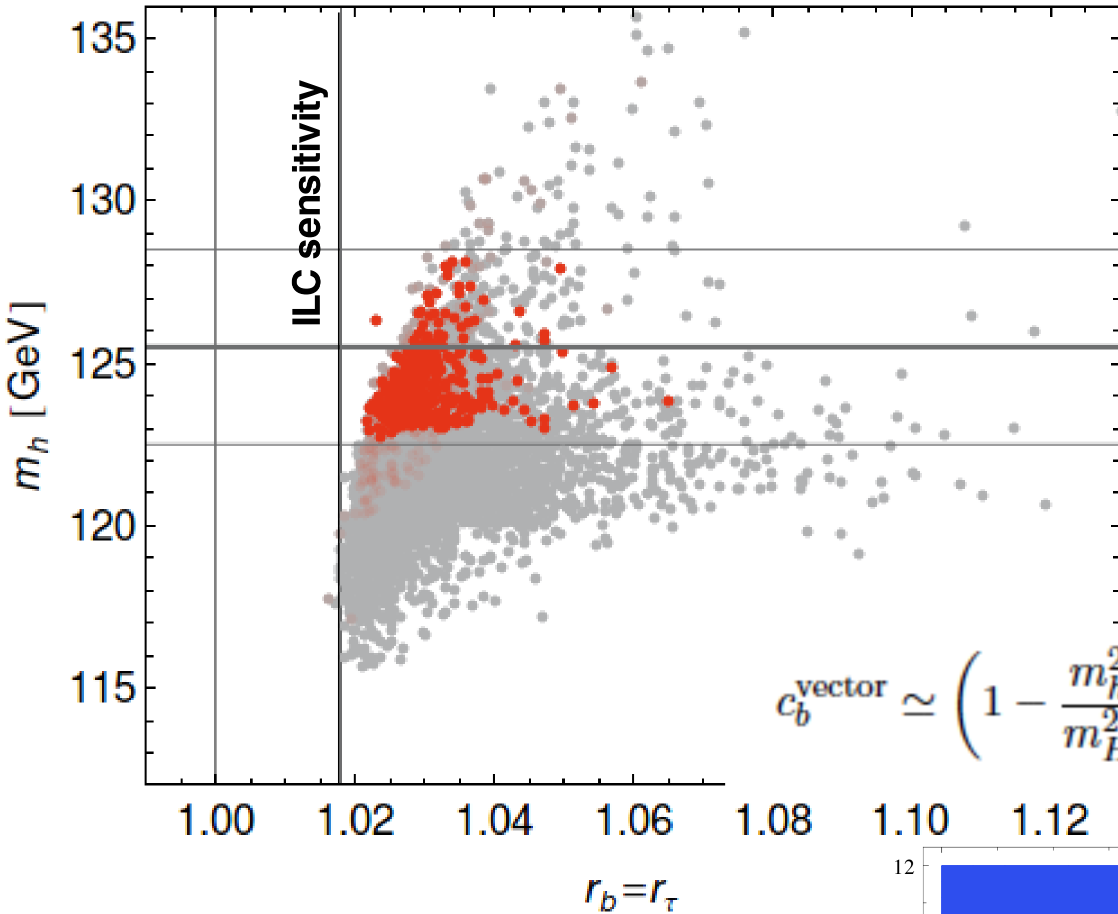


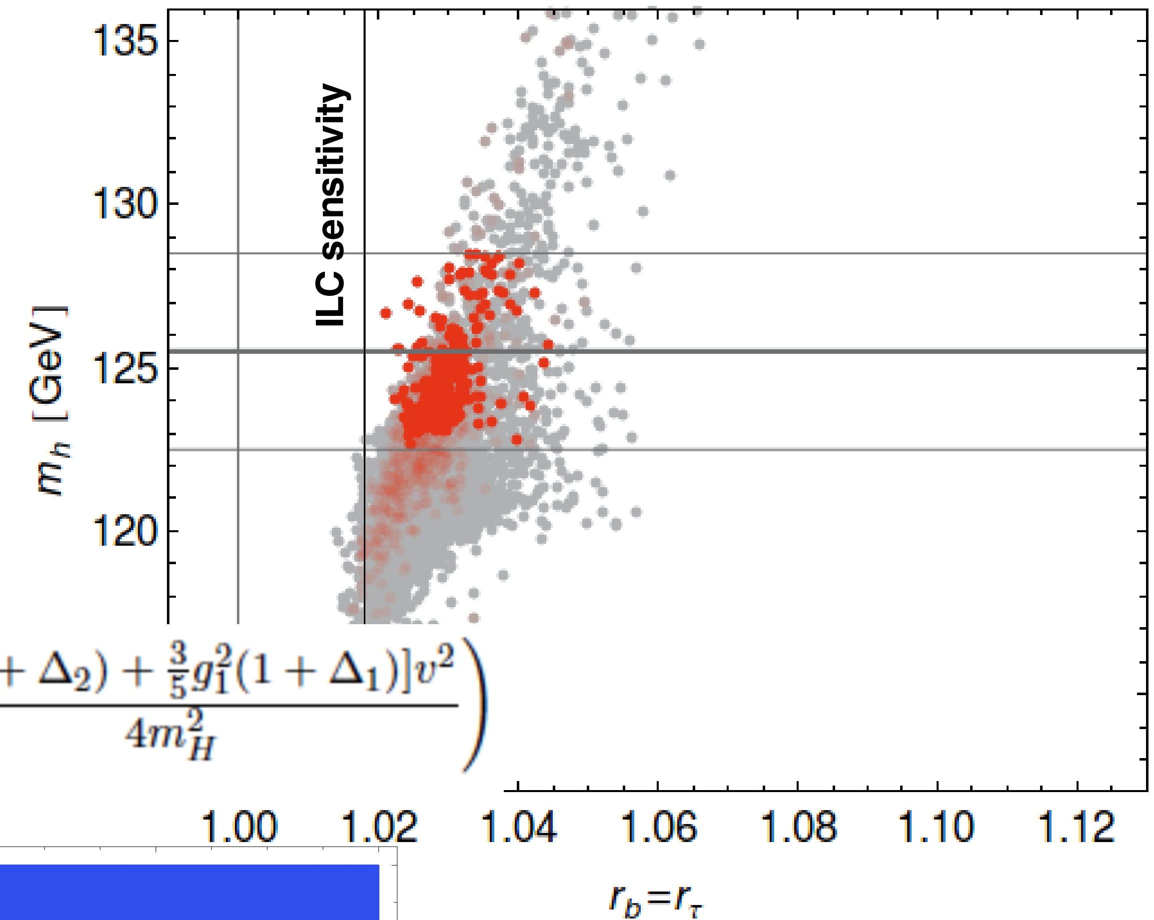




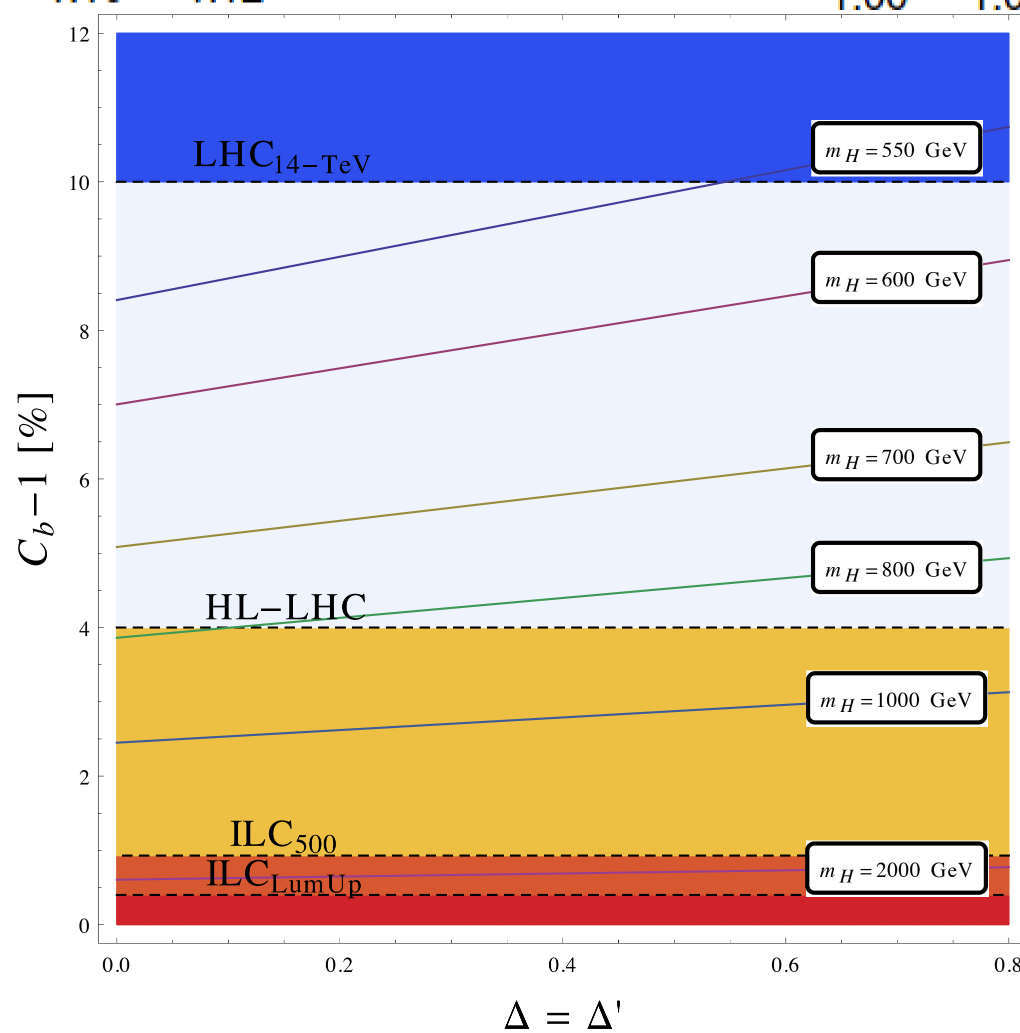


Testable at ILC!





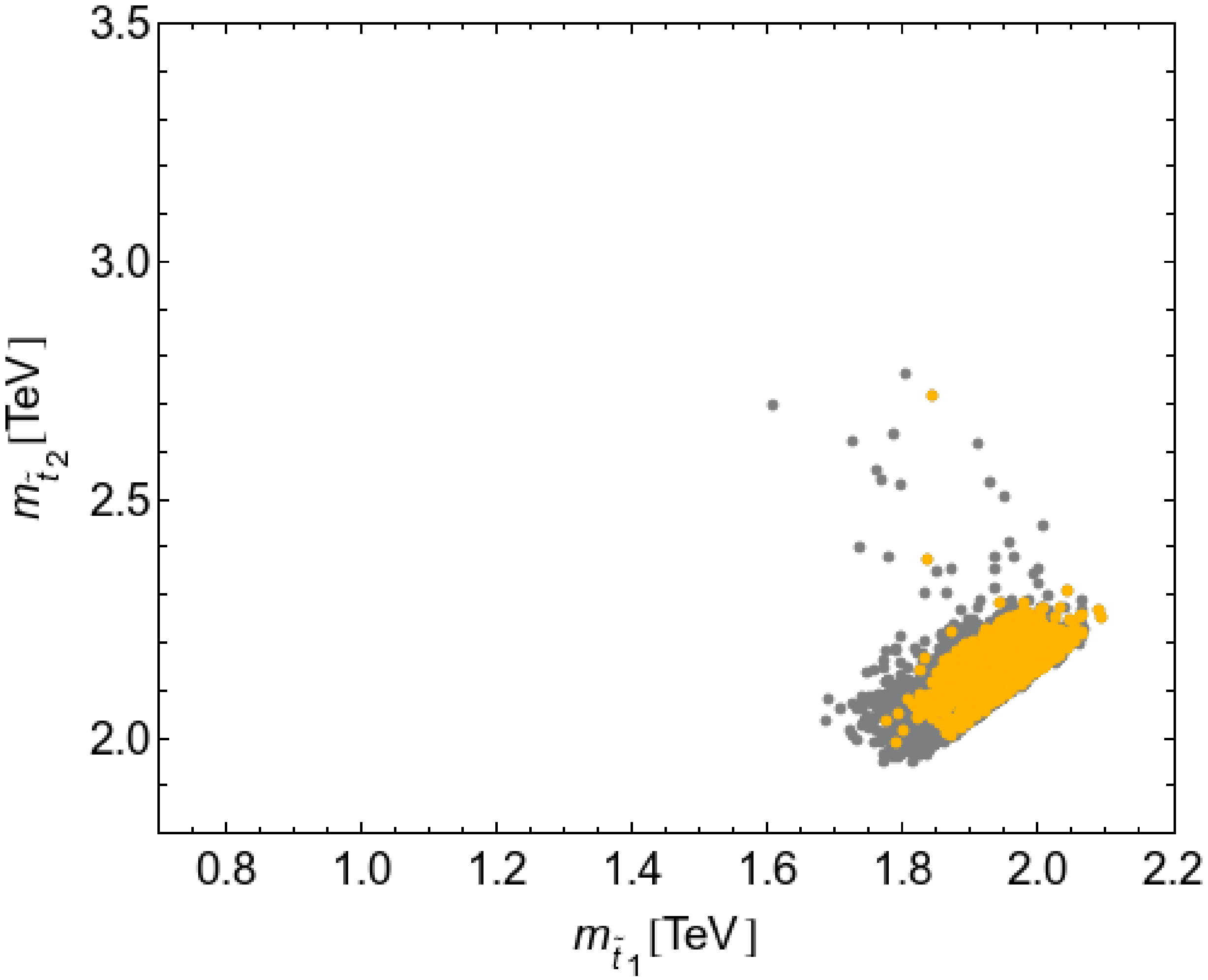
$$c_b^{\text{vector}} \simeq \left(1 - \frac{m_h^2}{m_H^2}\right)^{-1} \left(1 + \frac{[g_2^2(1+\Delta_2) + \frac{3}{5}g_1^2(1+\Delta_1)]v^2}{4m_H^2}\right)$$

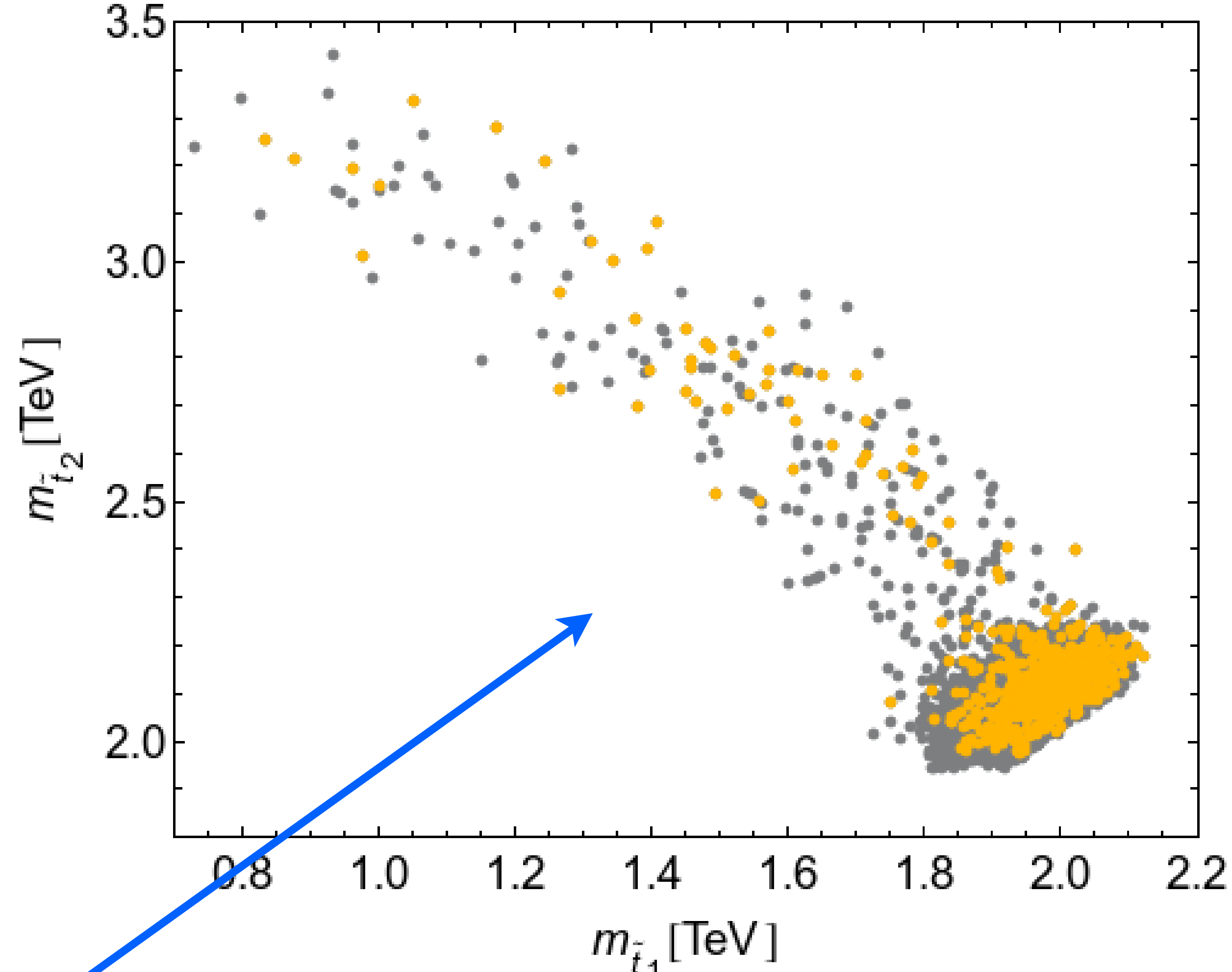


Testing D-terms
@ILC
with S.Porto, G. Moortgat-Pick (DESY)

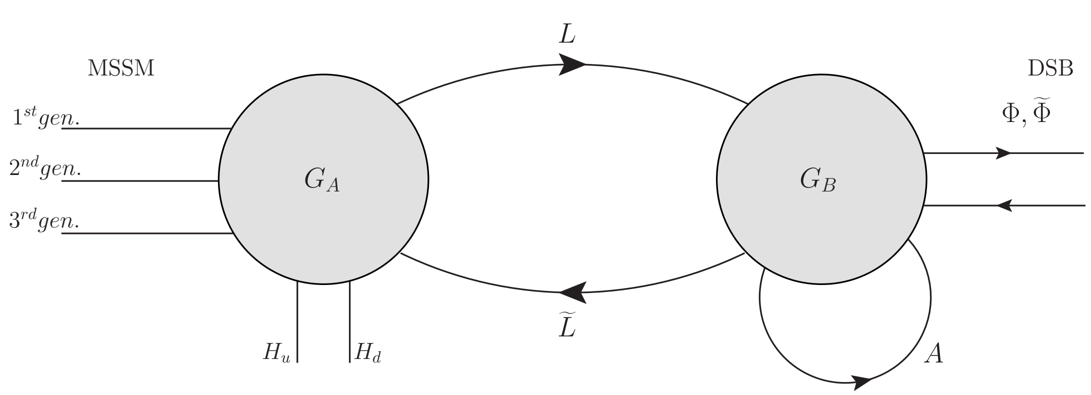
Bharucha, Goudelis, M.M. 1310.4500

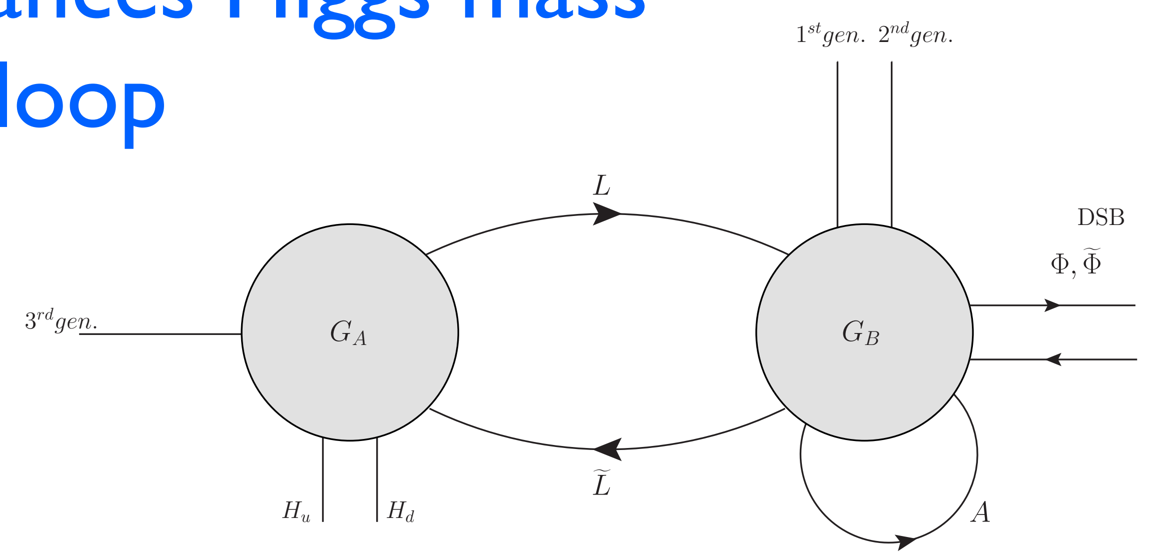
$$m_h^2 \simeq m_z^2\cos^2(2\beta) + \frac{3}{(4\pi)^2}\frac{m_t^4}{v_{ew}^2}\left[\log\frac{m_{\tilde t}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde t}^2}\left(1-\frac{X_t^2}{12 m_{\tilde t}^2}\right)\right] + \Delta m_{h,1}^2 = \frac{3m_Z^2}{16\pi^2 v_{ew}^2}\left(1-\frac{8}{3}\sin\theta_W^2\right)\cos 2\beta\, m_t^2\, \ln\left(\frac{m_{\tilde q_L^3}^2}{m_{\tilde u_R^3}}\right)$$





Stop splitting enhances Higgs mass @ 1-loop





Bharucha, Goudelis, M.M. 1310.4500

	MI	MIIa	MIIb
Input values			
M	233 TeV	288 TeV	260 TeV
$\Lambda_{1,2}$	44.9 TeV	85.6 TeV	111 TeV
Λ_3	190 TeV	206 TeV	208 TeV
m_L^2	47.3 TeV^2	83.3 TeV^2	86.2 TeV^2
v	26.2 TeV	26.5 TeV	25.4 TeV
θ_1, θ_2	1.18, 1.13	1.09,1.33	1.05,1.04
$\tan\beta$	16	12	28
Squark sector			
$m_{\tilde{t}_1}$	1.84 TeV	1.99 TeV	409 GeV
$m_{\tilde{t}_2}$	1.98 TeV	2.06 TeV	3.49 TeV
A_t	-442 GeV	-146 GeV	-141 GeV
$m_{\tilde{b}_R}$	1.95 TeV	2.05 TeV	2.56 TeV
$m_{\tilde{q}_{12,L}}$	2.05 TeV	2.12 TeV	2.19 TeV
$m_{\tilde{q}_{12,R}}$	1.97 TeV	2.10 TeV	2.14 TeV
Slepton sector			
$m_{\tilde{l}_{12,L}}$	738 GeV	314 GeV	515 GeV
$m_{\tilde{l}_{3,L}}$	736 GeV	315 GeV	440 GeV
$m_{\tilde{l}_{12,R}}$	901 GeV	183 GeV	262 GeV
$m_{\tilde{l}_{3,R}}$	899 GeV	110 GeV	4.31 TeV
Gaugino sector			
$m_{\tilde{\chi}_1^0}$	53.2 GeV	116 GeV	154 GeV
$m_{\tilde{\chi}_2^0}$	99.3 GeV	242 GeV	306 GeV
$m_{\tilde{\chi}_3^0}$	187 GeV	750 GeV	818 GeV
$m_{\tilde{\chi}_4^0}$	222 GeV	755 GeV	823 GeV
$m_{\tilde{\chi}_1^\pm}$	96.8 GeV	242 GeV	306 GeV
$m_{\tilde{\chi}_2^\pm}$	225 GeV	756 GeV	823 GeV
$m_{\tilde{g}}$	1.62 TeV	1.66 TeV	1.75 TeV
Higgs sector			
m_{h_0}	125 GeV	127 GeV	125 GeV
m_{H_0}	720 GeV	792 GeV	885 GeV
m_{A_0}	721 GeV	796 GeV	894 GeV
$m_{H^\pm}$	726 GeV	799 GeV	893 GeV

Extensions:

- 6 gauge groups
- resolve issue of MHu^2 and V
- Other SUSY breaking parameterisations?
- Single regime spectrum generator
- Add the states to PDG etc….

A renormalisable way to model an extra dimension

Ex. KK gluons, gluinos, Z', KK W's

Can talk to FeynArts, Formcalc,CalcHep, Higgsignals, HiggsBounds, WHIZARD,microOMEGA,Vevacious and more

“Large At Without the Desert”

A.Abdalgabar, A.Cornell, A.Deandrea, MM 1405:1038

$$\mathbf{a_u} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a_t \end{pmatrix}, \quad \mathbf{a_d} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a_b \end{pmatrix}, \quad \mathbf{a_e} \approx \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a_\tau \end{pmatrix},$$

UV — In many models At= 0 in UV

↓ At runs negative

IR — typically ends up negative a few 100 GeV

Not sufficient to the get correct Higgs mass….

Question: Can we accelerate its running?

1.The Higgs mass 126 GeV

The MSSM at one-loop

top mass

average stop mass

$$m_h^2 \simeq m_z^2 \cos^2(2\beta) + \frac{3}{(4\pi)^2}\frac{m_t^4}{v_{ew}^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2}(1 - \frac{X_t^2}{12 m_{\tilde{t}}^2})\right]$$

$$\boxed{126^2 = 91^2 + 81^2}$$

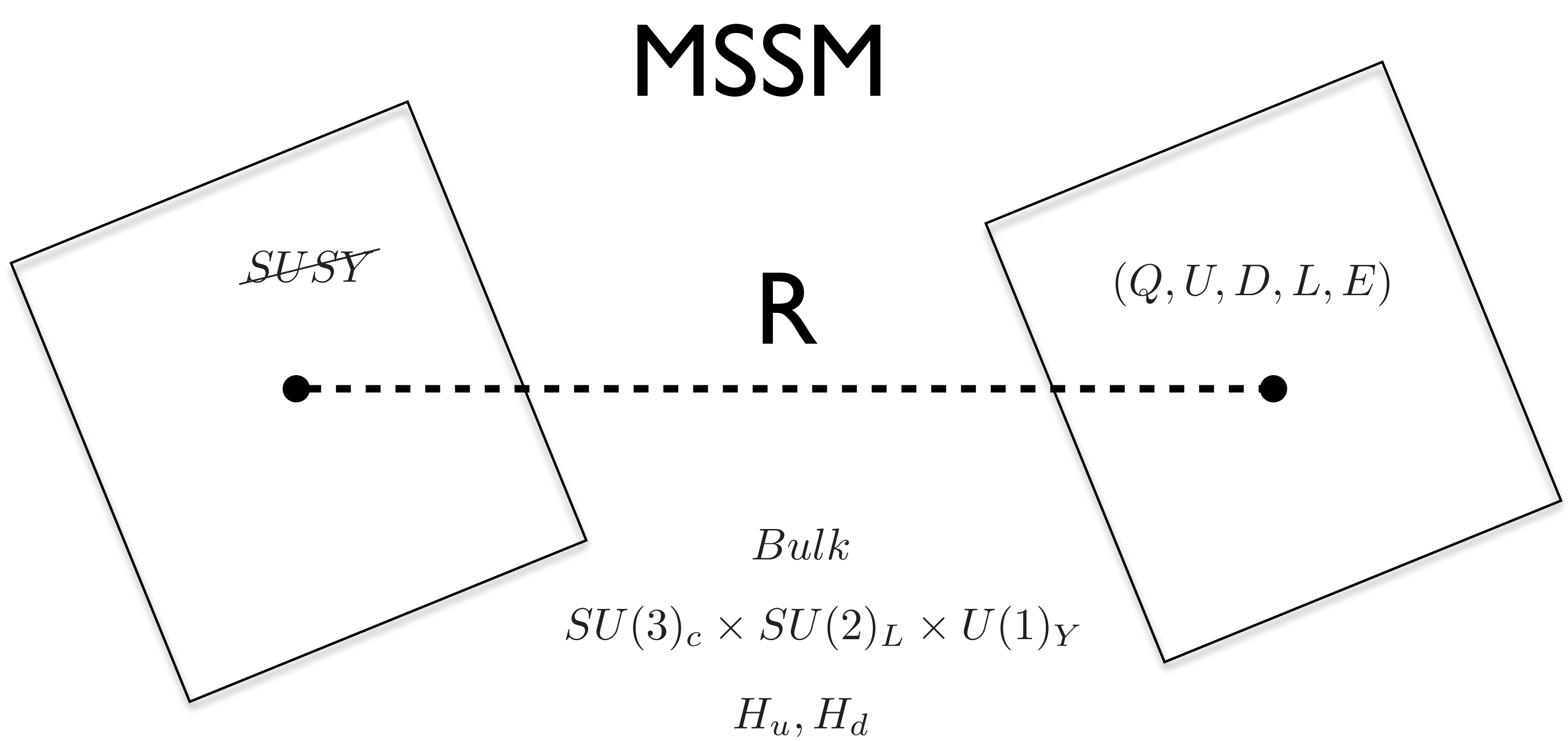
$$X_t = A_t - \mu \cot\beta$$

stop mixing

- Radiative corrections are same order as tree level piece
- corrections run logarithmically in SUSY
- MSSM case implies either heavy stops or large X_t=A_t +....

In 5D you can get large At!

“Power law running”



An extra dimension of radius R.
Additional Kaluza Klein modes enter RGEs @ Q> 1/R

Large At: Independent of the details of SUSY breaking

Split families: Locate different generations in brane or bulk

$$m^2_{(Q,U,D)_3} << m^2_{(Q,U,D)_{1,2}}$$

Power law running

$$\alpha^{-1}(Q) = \alpha^{-1}(m_z) - \frac{b}{2\pi}\log\frac{Q}{m_z} + \frac{\tilde{b}}{2\pi}\log\frac{Q}{m_{KK}} - \frac{\tilde{b}}{2\pi}(\frac{Q^d}{m_{KK}} - 1)c_d$$

(K.Dienes, E.Dudas, T. Gherghetta) 9803466
(K.Dienes, E.Dudas, T. Gherghetta) 9806292

"The finite power-law corrections to the Yukawa couplings have the right sign and magnitude to cancel the tree-level terms. This can help to explain the hierarchical structure of the fermion Yukawa couplings."

(A.Abdalagbar, A.Cornell, A.Deandrea, MM) 1405:1038

"Perhaps we can use this to accelerate the value of At?"

4+d dimensional MSSM

- ✓ Always unify
- ✓ No proton decay
- ✓ Explains flavour
- ✓ Large At

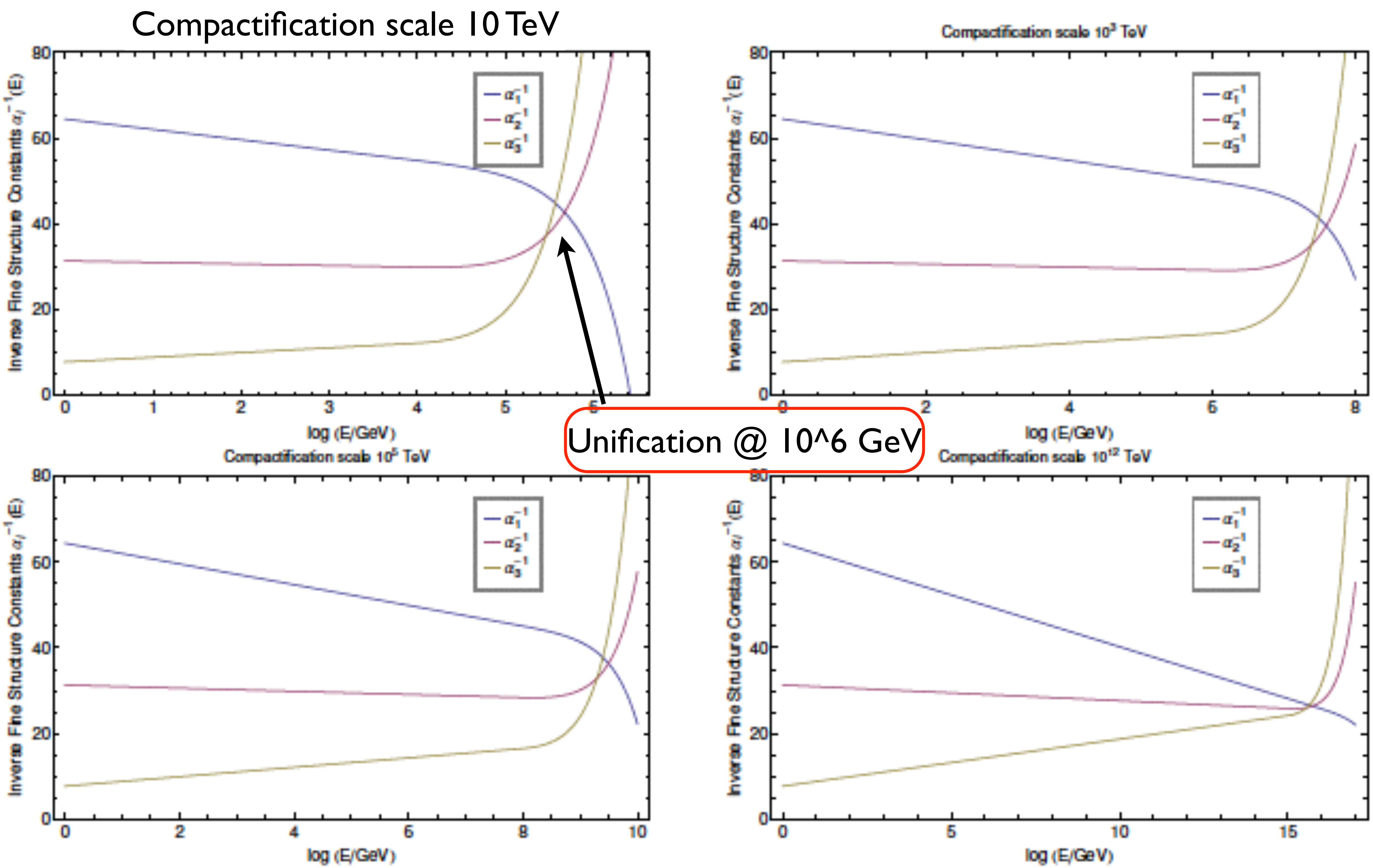


Figure 1. *Running of the inverse fine structure constants $\alpha^{-1}(E)$, for three different values of the compactification scales 10 TeV (top left panel), 10^3 TeV (top right), 10^5 TeV (bottom left) and 10^{12} TeV (bottom right), with M_3 of 1.7 TeV, as a function of log(E/GeV).*

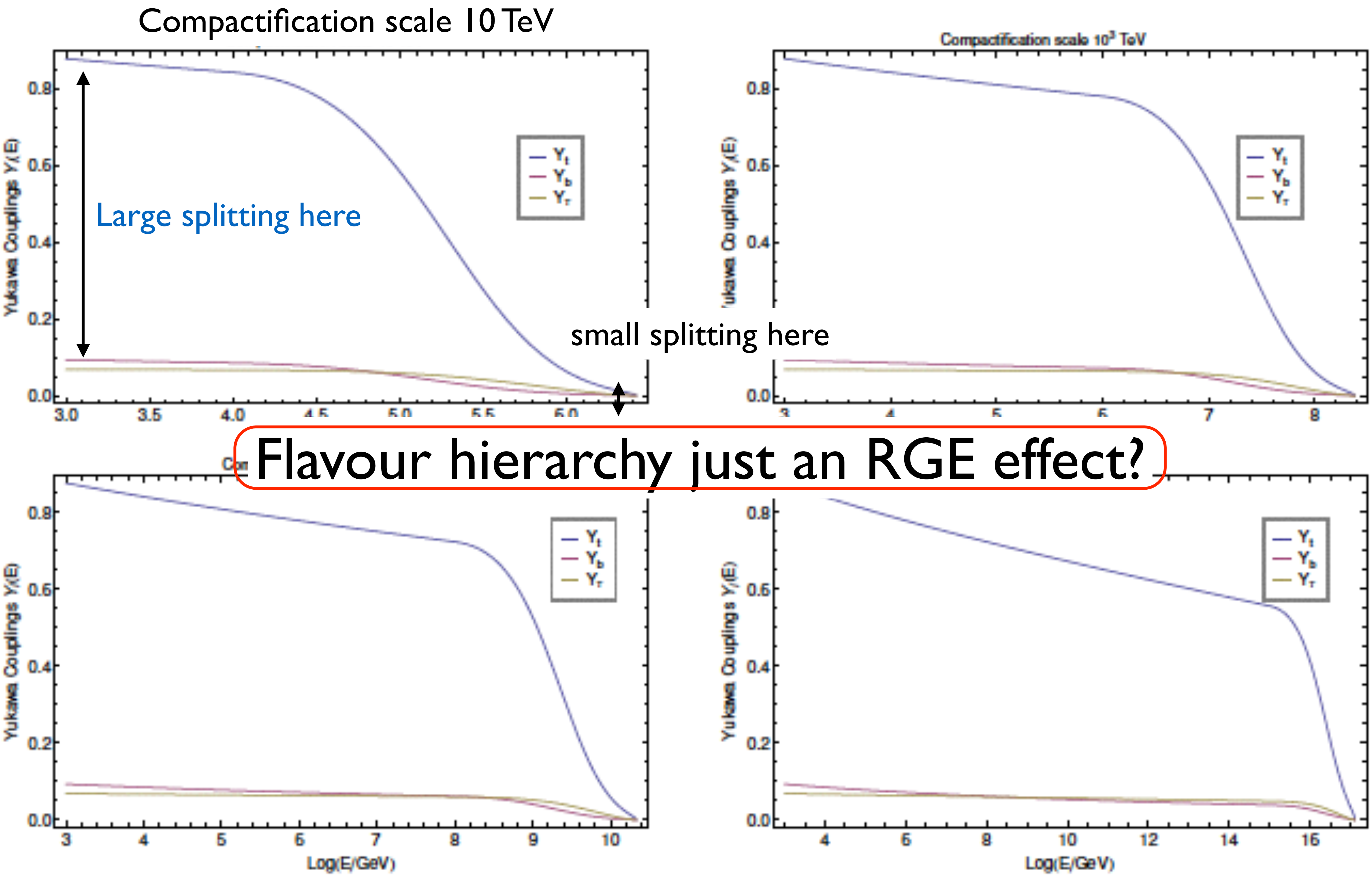


Figure 2. *Running of Yukawa couplings Y_i, for three different values of the compactification scales: 10 TeV (top left panel), 10^3 TeV (top right), 10^5 TeV (bottom left) and 10^{12} TeV (bottom right), with $M_3[10^3]$ of 1.7 TeV, as a function of log(E/GeV).*

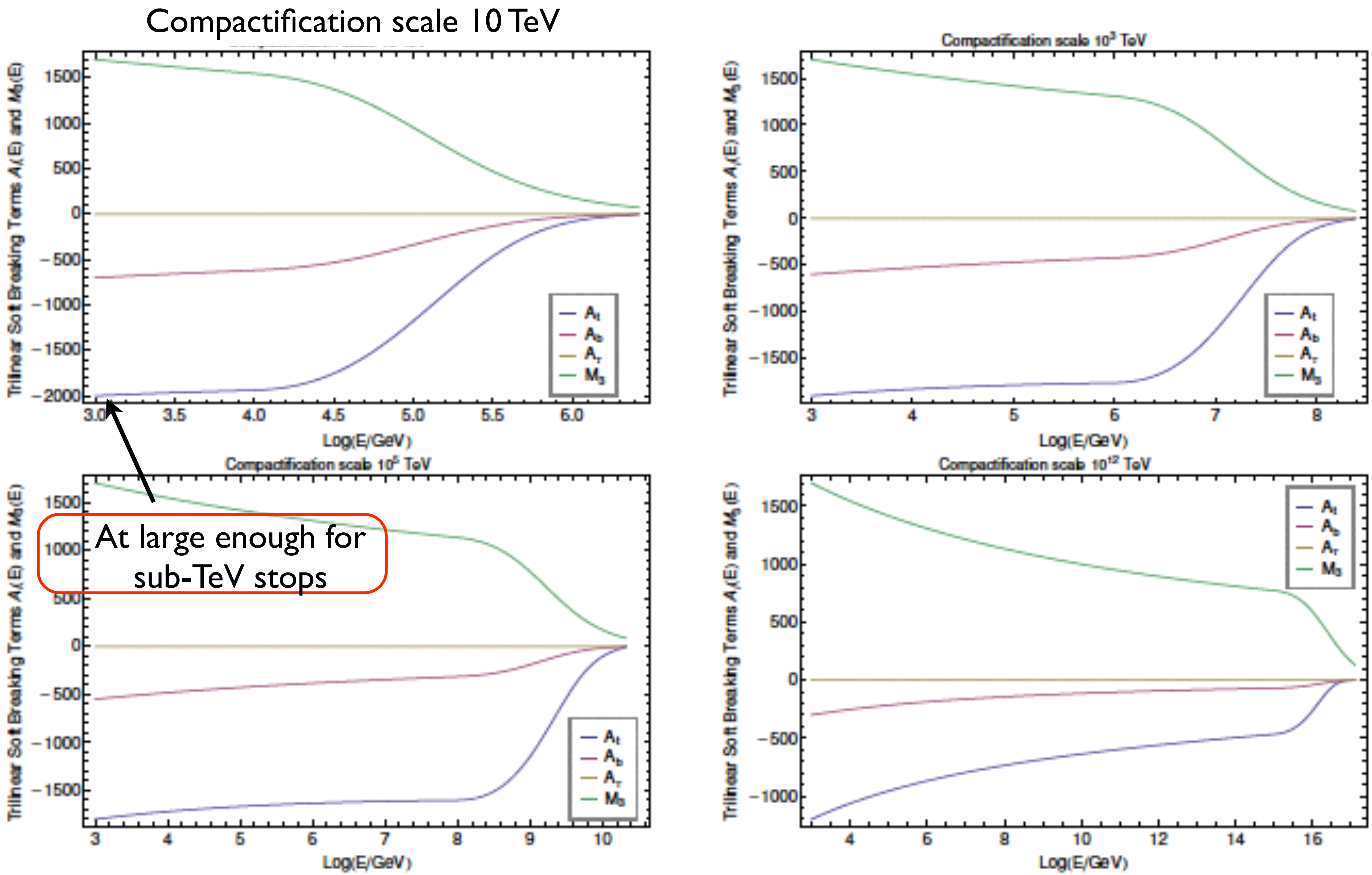
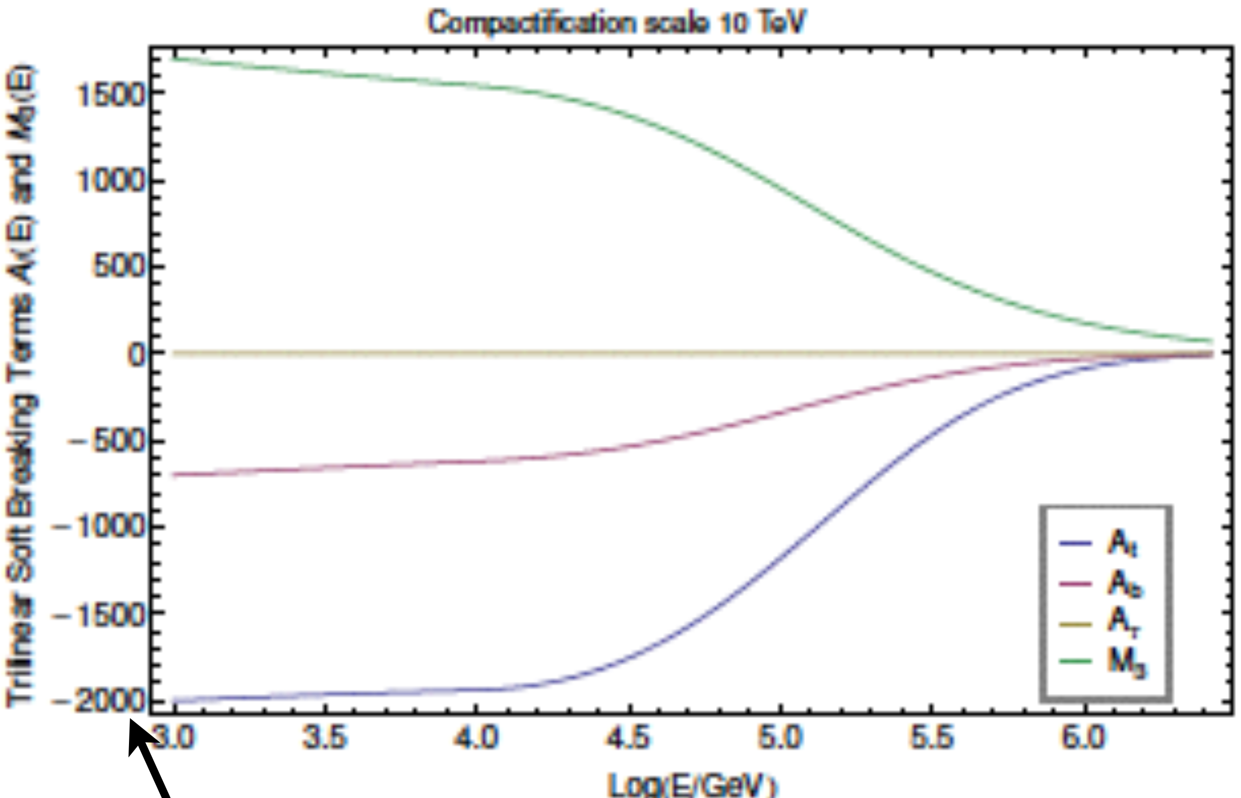
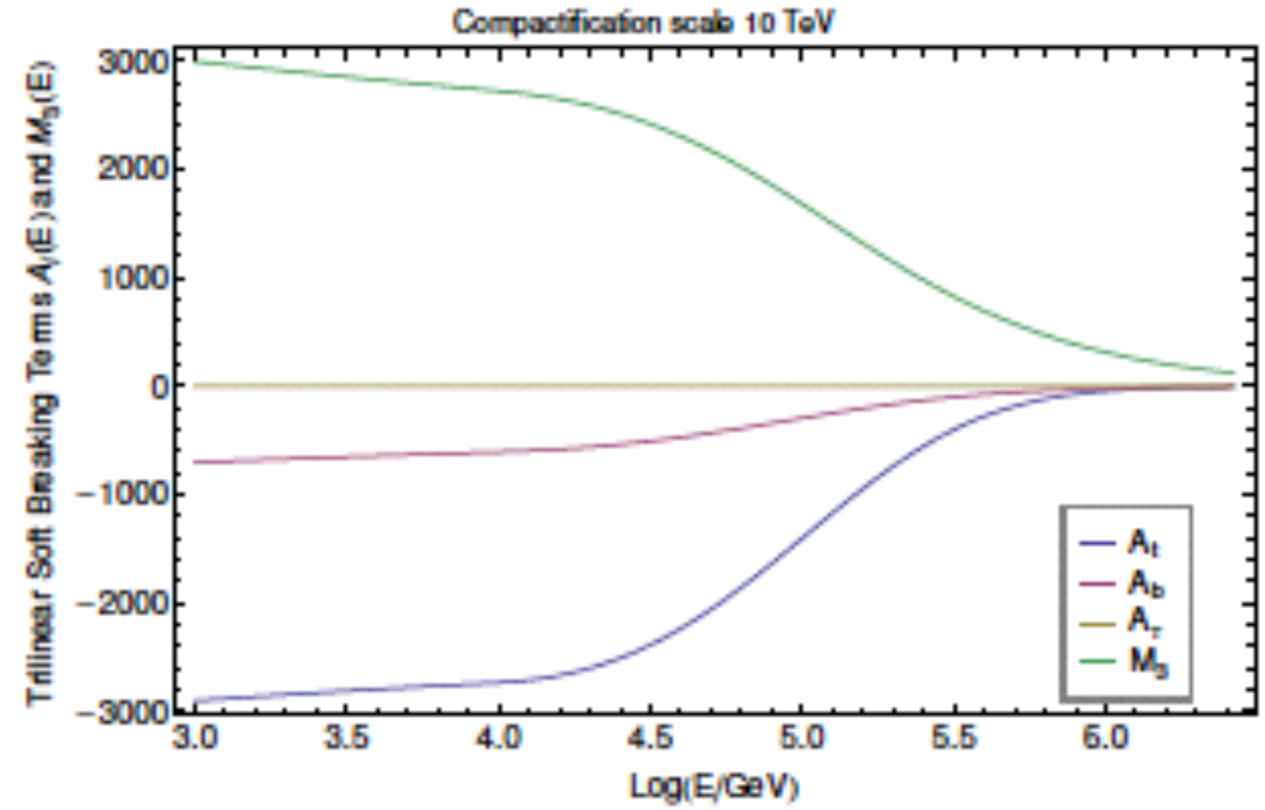
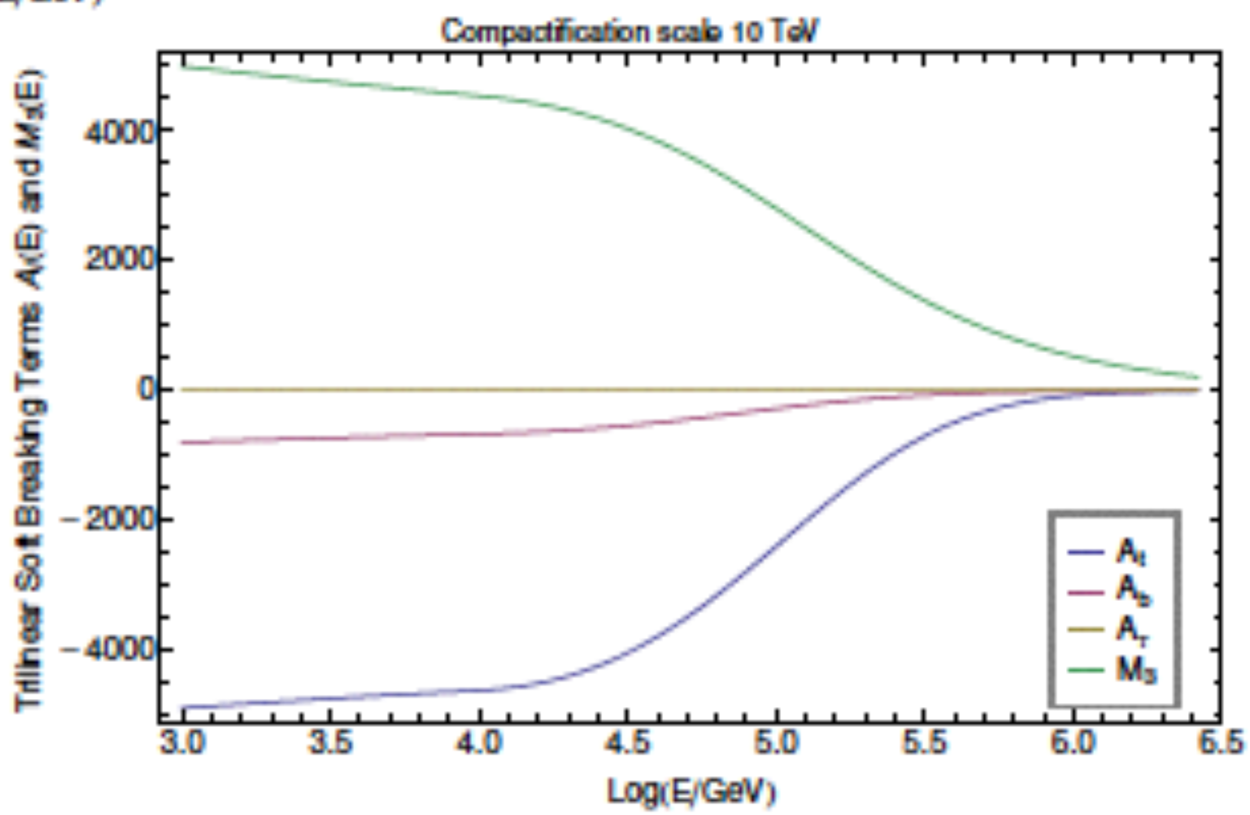


Figure 3. *Running of trilinear soft terms $A_i(3,3)(E)$, for three different values of the compactification scales 10 TeV (top left panel), 10^3 TeV (top right), 10^5 TeV (bottom left) and 10^{12} TeV (bottom right), with $M_3[10^3]$ of 1.7 TeV, as a function of log(E/GeV).*





At large enough for sub-TeV stops



Larger gluino gives larger At

Thanks for listening!

Conclusions

- Traditional models are in bad shape
- Perhaps it is time to panic?
- Natural SUSY is motivated from bottom up
- These can have exciting top-down motivations too
- It does mean sacrificing minimality!