Higgs Boson Mass Limit in GMSB with Messenger-Matter Mixing

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Pheno, 2011

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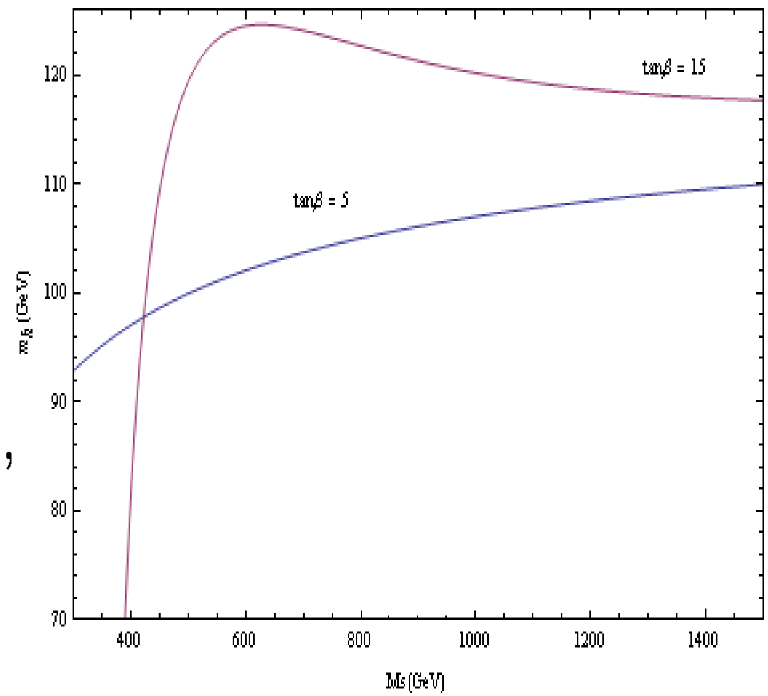
Introduction: Higgs Mass Bounds in MSSM

Tree Level

$m_h < M_z tan(\beta)$ Excluded by LEP2 (114.4 GeV)

1-and 2- loop

$$m_h^2 = M_z^2 cos^2 2\beta (1 - \frac{3}{8\pi^2}\frac{m_t^2}{v^2} t)$$
$$+ \frac{3}{4\pi^2}\frac{m_t^4}{v^2}[\frac{1}{2}\chi_t + t + \frac{1}{16\pi^2}(\frac{3}{2}\frac{m_t^2}{v^2} - 32\pi\alpha_3)(\chi_t t + t^2)],$$



[redacted]

[redacted]

[redacted]

[redacted]

Introduction: GMSB without Messenger-Matter Mixing

$$M_{\lambda_i} = \frac{\alpha_r(M)}{4\pi}\Lambda, \quad \Lambda = \frac{F}{M}$$

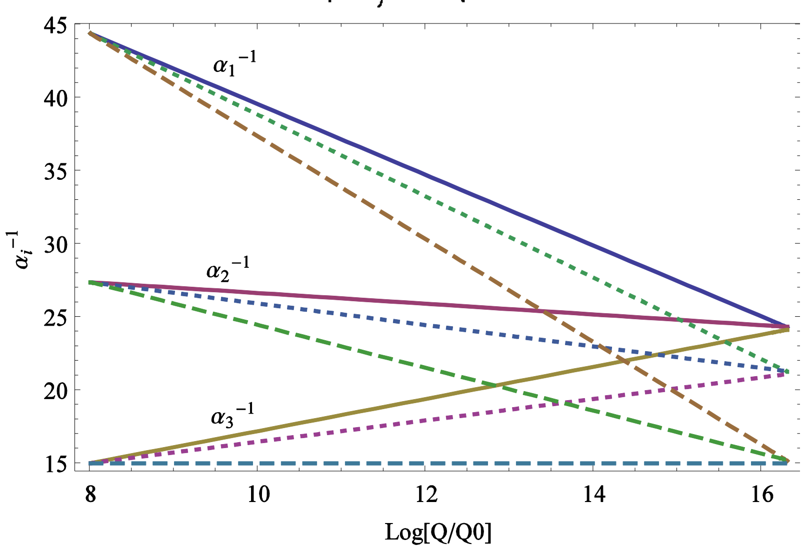
$$\tilde{m}^2 = 2N\sum_{r=1}^{3} c_r\left(\frac{\alpha_r(M)}{4\pi}\right)^2\Lambda^2.$$

→ Universal Scalar Masses

Features of GMSB

- Highly predictive
- FCNC are naturally suppressed

$5+\overline{5},\ 10+\overline{10}$



Is it possible to obtain maximal mixing in the ordinary GMSB?

No, because $A_t \approx 0$ at M_{mess}

Messenger- matter mixing with messenger fields belong to $10+\overline{10}$

can reproduce [redacted]

Introduction: The Objectives

To construct GMSB model with messenger-matter mixing that

1- leads to a significant enhancement to the lightest Higgs mass compared to the ordinary GMSB.

2- leads to scalar mass spectra below 1 TeV.

The above objectives should be consistent with

1- FV processes are suppressed in agreement with experiment .

2- Messenger scale below $3 \times 10^8\ \mathrm{GeV}$ is preferred by Cosmology.

GMSB with Messenger-Matter Mixing

[redacted]

[redacted] → [redacted]

[redacted]

[redacted] → [redacted]

$$\delta A_t = -\frac{\lambda_b'^2 \Lambda}{16\pi^2}$$

⟷

[redacted]

The expressions for soft terms induced by messenger –matter mixing can be found in [Giudice and Rattazi, 1998; Chacko and ponton, 2002]

Higgs Mass Bounds in the [redacted] Model

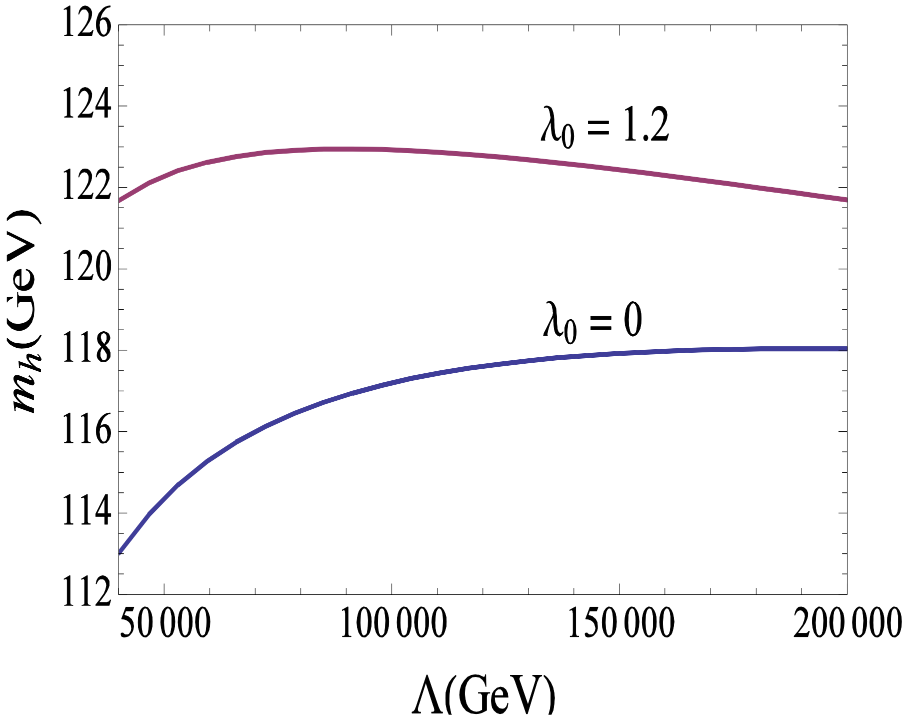
[redacted] → [redacted] There are three parameters:

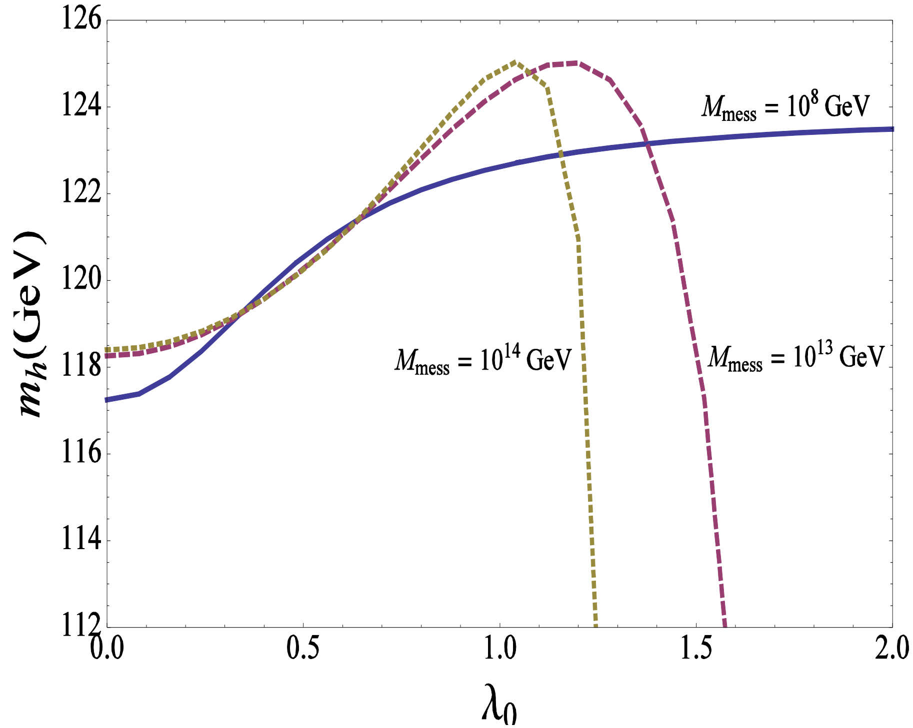
[redacted] [redacted] [redacted]

λ_0	m_h(GeV)	$\Lambda(10^5\text{GeV})$	$M_{mess}(10^8\text{GeV})$	$\tilde{m}_{t_1}$(GeV)	$\tilde{m}_{t_2}$(GeV)	A_t/M_s
0	119	1.6	3.16×10^5	3590	4145	-0.86
0.4	120	1.36	1	2756	3289	-1.1
0.8	123	0.912	10^5	1553	2143	-1.55
1.2	125	0.784	17782	1088	1751	-1.95
1.6	125	0.784	1778	1066	1743	-2
2	125	0.784	177	1138	1762	-1.93

Table 1: We show the values of the GMSB input parameters, Λ, λ_0 and M_{mess} that lead to the highest m_h values. These values correspond to $\lambda_{m0} = 0$ and $\tan\beta = 10$.

Higgs Mass Bounds in the [redacted] Model





Higgs Mass Bounds in the [redacted] Model

Name		$10+\overline{10}$	$10+\overline{10}$	$5+\overline{5}$
Inputs	M_{mess}	10^8	4×10^5	10^8
	N_{mess}	3	3	1
	Λ	0.3×10^5	0.3×10^5	0.95×10^5
	$\tan\beta$	10	5.6	11.6
	λ_0	1.2	1.2	1.2
Higgs:	m_h	121	117.7	114.6
	m_H^0	675	675	1107
	m_A	675	674	1107
	$m_{H^\pm}$	679	678	1110
Gluino:	$m_{\tilde{g}}$	852	852	899
Neutralinos:	m_{χ_1}	121	127	128
	m_{χ_2}	234	245	248
	m_{χ_3}	667	658	706
	m_{χ_4}	675	668	713
Charginos:	χ_1^+	236	233	250
	χ_2^+	676	667	738
Squarks:	$m_{\tilde{u}_L,\tilde{c}_L}$	810	787	1120
	$m_{\tilde{u}_R,\tilde{c}_R}$	786	765	1071
	$m_{\tilde{d}_L,\tilde{s}_L}$	810	787	1121
	$m_{\tilde{d}_R,\tilde{s}_R}$	782	763	1064
	$m_{\tilde{b}_L}$	692	682	997
	$m_{\tilde{b}_R}$	780	763	1045
	$m_{\tilde{t}_L}$	692	682	997
	$m_{\tilde{t}_R}$	518	531	890
Sleptons:	$m_{\tilde{e}_L,\tilde{\mu}_L}$	224	201	371
	$m_{\tilde{\nu}_{eL},\tilde{\nu}_{\mu L}}$	224	201	371
	$m_{\tilde{e}_R,\tilde{\mu}_R}$	168	150	182
	$m_{\tilde{\tau}_L}$	224	201	352
	$m_{\tilde{\tau}_R}$	167	150	1014

Flavor Violation

Mass Insertion Parameters:

The messenger-matter couplings reintroduce the flavor violation

[redacted] $\delta\tilde{m}^2$ [redacted] δA [redacted]

$\delta\tilde{m}^2$, δA are generated by the exotic Yukawa couplings.

Froggatt-Nielsen Mechanism:

- U(1) flavor symmetry is assumed.
- U(1) is broken at high scale M^* by $\langle S \rangle$
- The hierarchy of the masses and mixing can be explained as power expansion of

[redacted]

Flavor Violation

SU(5)	10_1	10_2	10_3	$\bar{5}_1$	$\bar{5}_2$,$\bar{5}_3$	5_u,$\bar{5}_d$	S	5_m	$\bar{5}_m$	10_m	$\overline{10}_m$	Z
$U(1)$	4	2	0	p+1	p	0	-1	-α	0	0	-α	α

Table 1: The $U(1)$ charge assignments to the messenger, MSSM, Z and S fields.

[redacted]

[redacted] $\lambda'_{u^c}\epsilon^4$ $\lambda'_{c^c}\epsilon^2$ $\lambda'_u\epsilon^4$ $\lambda'_c\epsilon^2$ $\lambda'_b\epsilon^p$ $\lambda'_\tau\epsilon^p$

$$M_d \sim M_e^T \sim \epsilon^p \begin{pmatrix} \epsilon^5 & \epsilon^3 & \epsilon \\ \epsilon^4 & \epsilon^2 & 1 \\ \epsilon^4 & \epsilon^2 & 1 \end{pmatrix},$$

→ Lopsided Structure

$$U_L^e \sim U_R^d \sim \begin{pmatrix} 1 & \epsilon & \epsilon \\ \epsilon & \omega & \omega \\ \epsilon & \omega & \omega \end{pmatrix}, \quad U_R^e \sim U_L^d \sim \begin{pmatrix} 1 & \epsilon^2 & \epsilon^4 \\ \epsilon^2 & 1 & -\epsilon^2 \\ \epsilon^4 & \epsilon^2 & 1 \end{pmatrix}.$$

Flavor Violation

Process	Mass Insertion (δ)	$5+\overline{5}$	$10+\overline{10}$	Exp. Bounds*
$\mu \to e\gamma$	$(\delta^l_{12})_{LL}$	-	ϵ^{4p+1}	0.02
	$(\delta^l_{12})_{RR}$	ϵ^6	-	0.0087
	$(\delta^l_{12})_{RL,LR}$	$\kappa^l_5(\epsilon^{p+4},\ \epsilon^{p+3})$	$\kappa^l_{10}\ \epsilon^{3p+1}$	7×10^{-6}
$\tau \to e\gamma$	$(\delta^l_{13})_{LL}$	-	ϵ^{4p+1}	75
	$(\delta^l_{13})_{RR}$	ϵ^4	-	22
	$(\delta^l_{13})_{RL,LR}$	$\kappa^l_5(\epsilon^{p+4},\ \epsilon^{p+1})$	$\kappa^l_{10}\ \epsilon^{3p+1}$	0.44
$\tau \to \mu\gamma$	$(\delta^l_{23})_{LL}$	-	ϵ^{4p}	14
	$(\delta^l_{23})_{RR}$	ϵ^2	-	4
	$(\delta^l_{23})_{RL,LR}$	$\kappa^d_5(\epsilon^{p+2},\ \epsilon^{p})$	$\kappa^l_{10}\ \epsilon^{3p}$	0.08
$K-\overline{K}$	$\left(\sqrt{\mathrm{Re}(\delta^d_{12})^2_{LL}}, \sqrt{\mathrm{Im}(\delta^d_{12})^2_{LL}}\right)$	ϵ^6	ϵ^6	(0.065, 0.0052)
	$\left(\sqrt{(\mathrm{Re}(\delta^d_{12})^2_{RR})}, \sqrt{(\mathrm{Im}(\delta^d_{12})^2_{RR})}\right)$	-	ϵ^{1+4p}	(0.065, 0.0052)
	$\left(\sqrt{\mathrm{Re}(\delta^d_{12})^2_{LR}}, \sqrt{(\mathrm{Im}(\delta^d_{12})^2)_{LR}}\right)$	$\kappa^d_5\epsilon^{4+p}$	$\kappa^d_{10}\epsilon^{1+3p}$	$(0.007,\ 5.2 \times 10^{-5})$
	$\left(\sqrt{\mathrm{Re}(\delta^d_{12})^2_{LR}}, \sqrt{(\mathrm{Im}(\delta^d_{12})^2)_{LR}}\right)$	$\kappa^d_5\epsilon^{3+p}$	$\kappa^d_{10}\epsilon^{1+3p}$	$(0.007,\ 5.2 \times 10^{-5})$
	$\sqrt{\mathrm{Re}(\delta^d_{12})_{LL}(\delta^d_{12})_{RR}}$	-	$\epsilon^{3.5+2p}$	0.00453
	$\sqrt{\mathrm{Im}(\delta^d_{12})_{LL}(\delta^d_{12})_{RR}}$	-	$\epsilon^{3.5+2p}$	0.00057
$B_d-\overline{B}_d$	$(\mathrm{Re}\delta^d_{13}, \mathrm{Im}\delta^d_{13})_{LL}$	ϵ^4	ϵ^4	(0.238, 0.51)
	$(\mathrm{Re}\delta^d_{13}, \mathrm{Im}\delta^d_{13})_{RR}$	-	ϵ^{1+4p}	(0.238, 0.51)
	$(\mathrm{Re}\delta^d_{13}, \mathrm{Im}\delta^d_{13})_{LR,RL}$	$\kappa^d_5(\epsilon^{4+p},\ \epsilon^{1+p})$	$\kappa^d_{10}\epsilon^{1+3p}$	(0.0557, 0.125)
$B_s-\overline{B}_s$	$(\delta^d_{23})_{LL}$	ϵ^2	ϵ^2	1.19
	$(\delta^d_{23})_{RR}$	-	ϵ^{1+4p}	1.19
$b \to s\gamma$	$(\delta^d_{23})_{LR,RL}$	$\kappa^d_5(\epsilon^{p+2},\ \epsilon^{p})$	$\kappa^d_{10}(\epsilon^2,\ 1)$	0.04

* F. Gabbiani, E. Gabrielli, A. Masiero and L. Silvestrini, Nucl. Phys. B **477**, 321 (1996) [arXiv:hep-ph/9604387]; D. Becirevic *et al.*, Nucl. Phys. B **634**, 105 (2002) [arXiv:hep-ph/0112303]; K. S. Babu and Y. Meng, Phys. Rev. D **80**, 075003 (2009) [arXiv:0907.4231 [hep-ph]];

Conclusion

- The maximal mixing condition that leads to the upper limit of the lightest Higgs mass of MSSM is obtained in the model where the messenger fields belong to [redacted] of SU(5).

- Consistent with cosmology preference $\leq \mathbf{3} \times \mathbf{10^8}$ GeV. This model can lead to the lightest Higgs mass of around 121 GeV with all superparticle masses below 1 TeV.

- These results are consistent with the gauge and exotic Yukawa couplings being perturbative and unified at the GUT scale as well as the FCNC being suppressed in agreement with experimental bounds.