Higgs Boson Mass In GMSB with Messenger-Matter Mixing

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Based on:

Higgs boson of mass 125 GeV in GMSB models with messenger–matter mixing

A. Albaid and K.S. Babu, arXiv: 1207.1014 [hep-ph]

Outline

- Higgs Boson in Standard Model
- Interesting Features of SUSY
- Shortcomings of SUSY
- Features of GMSB
- Higgs Mass Bounds in minimal GMSB
- The Objectives

Outline

- GMSB with Messenger-Matter Mixing
  - $5+\overline{5}$ Model
  - $10+\overline{10}$ Model
- Improved Higgs Boson mass in $10+\overline{10}$ Model
- Froggatt-Nielsen Mechanism
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- Summary

Higgs Boson in the Standard Model

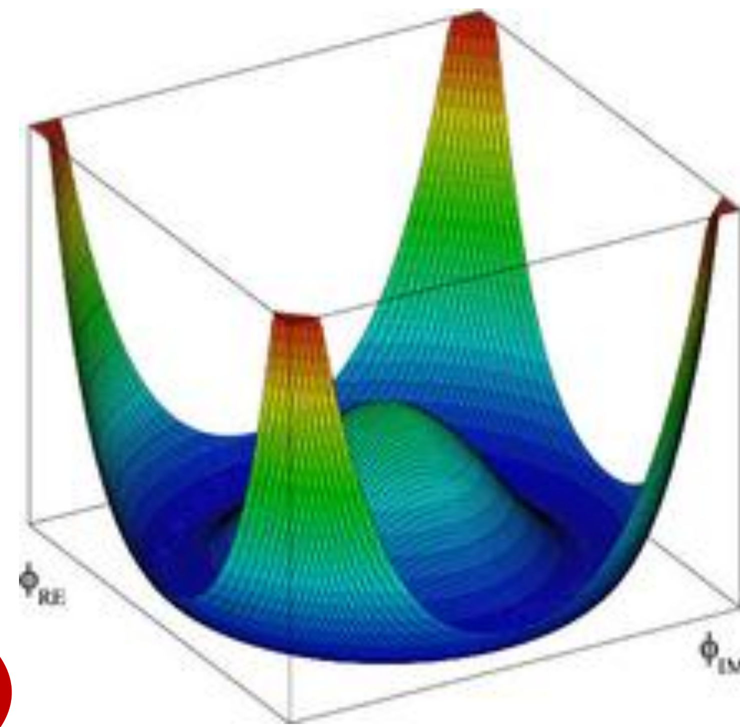
$$V(\phi) = -\mu^2 \phi^\dagger \phi + \lambda(\phi^\dagger \phi)^2, \qquad \mu^2 > 0.$$

$$\langle \phi \rangle = \langle 0|\phi|0\rangle = \frac{v}{\sqrt{2}} \begin{pmatrix} 0 \\ 1 \end{pmatrix},$$

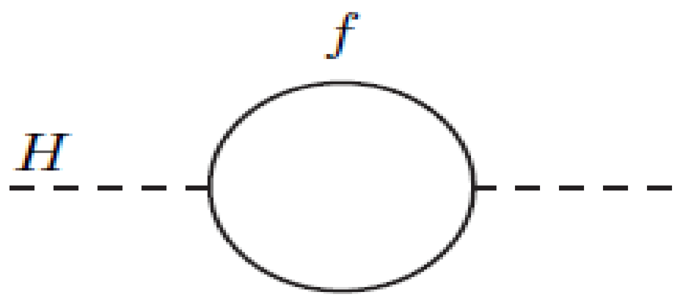
$$m_{\phi_0}^2 = 2\lambda v^2$$

$$\lambda^2 / 4\pi \leq 1$$

$$\Rightarrow \quad m_{\phi_0}^2 \leq 1 \text{ TeV}$$



Higgs Boson in the Standard Model



$$\Delta m_H^2 = -\frac{|\lambda_f|^2}{8\pi^2}\Lambda^2 + \ldots.$$

With $\Lambda \sim M_P$ ⇨ $\Delta m_H^2 \sim 10^{30} m_H^2$

- Supersymmetry (SUSY) is a promising scenario to solve the gauge hierarchy problem

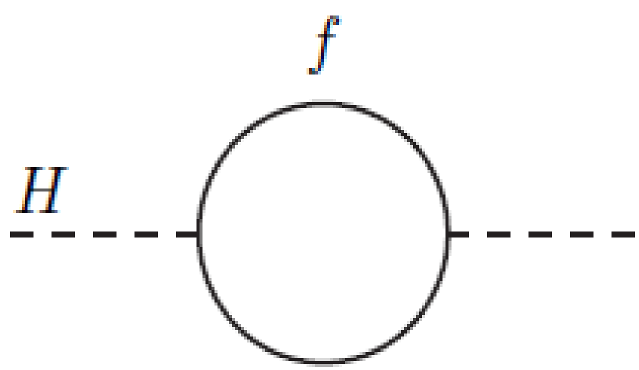
SUSY Spectrum

- The minimal version of supersymmetry is MSSM

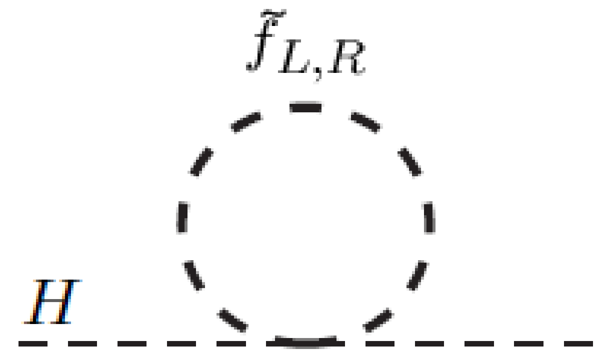
	SM Particles	SUSY Partners	
Spin = 1/2	Q	$\tilde{Q}$	Spin = 0
	u^c	$\tilde{u}^c$	
	d^c	$\tilde{d}^c$	
	L	$\tilde{L}$	
	e^c	$\tilde{e}^c$	
Spin = 0	H_u	$\tilde{H}_u$	Spin = 1/2
	H_d	$\tilde{H}_d$	
Spin = 1	g	$\tilde{g}$	Spin = 1/2
	W	$\tilde{W}$	
	B	$\tilde{B}$	

Interesting Features of Supersymmetry

SUSY Solves the instability in the Higgs mass



$$\Delta m_H^2 = -\frac{|\lambda_f|^2}{8\pi^2}\Lambda^2 + \ldots.$$



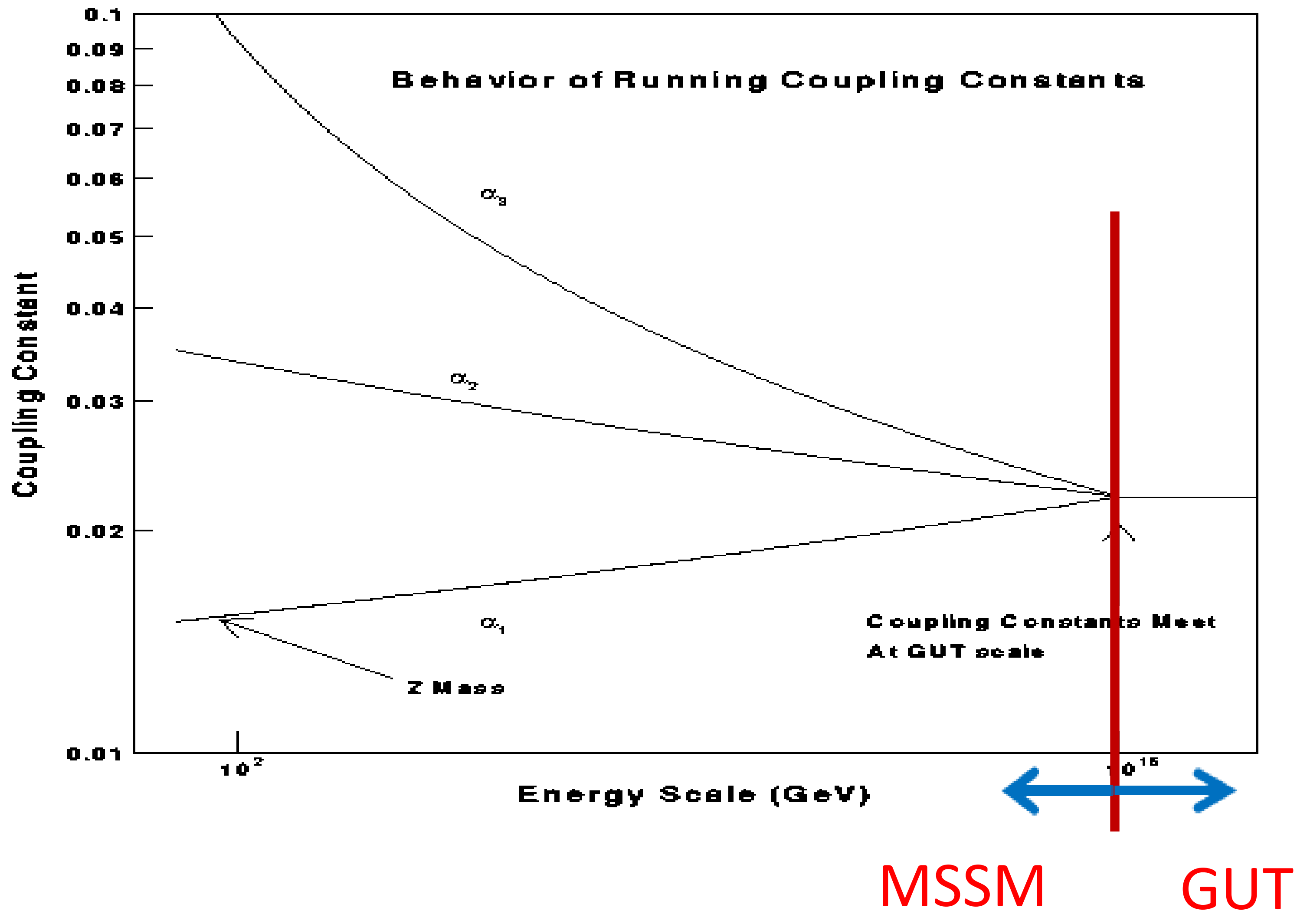
$$\Delta m_H^2 = \frac{2\lambda_{\tilde{f}}}{16\pi^2}\Lambda^2 + \ldots.$$

As a consequence of supersymmetry

$$\lambda_{\tilde{f}} = |\lambda_f|^2$$ ⇒ Quadratic divergence will cancel

Interesting Features of Supersymmetry

- Gauge coupling unification



Interesting Features of Supersymmetry

❖ SU(5) GUT Model

$$\bar{5} = \begin{pmatrix} d^{c1} \\ d^{c2} \\ d^{c3} \\ e^- \\ \nu \end{pmatrix}, \qquad 10 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & u_3^c & u_2^c & u_1 & d_1 \\ -u_3^c & 0 & u_1^c & u_2 & d_2 \\ -u_2^c & -u_1^c & 0 & u_3 & d_3 \\ -u_1 & -u_2 & -u_3 & 0 & e^+ \\ -d_1 & -d_2 & -d_3 & -e^+ & 0 \end{pmatrix}$$

$$\bar{5}_i \rightarrow (d_i^{c\alpha}, L_i)$$

$$10_i \rightarrow (Q_i^{\alpha}, u_i^{c\alpha}, e_i^c)$$

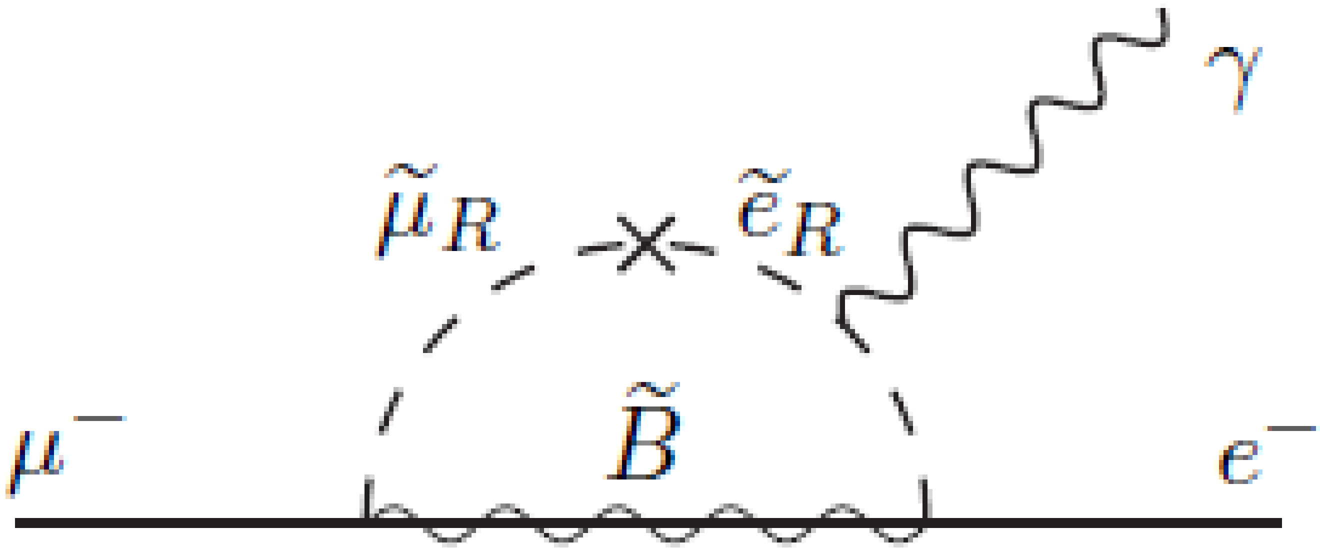
Interesting Features of Supersymmetry

- sets upper bound on the lightest Higgs mass < 130 GeV
- has dark matter candidate
- provides a natural mechanism for EWSB

Shortcomings of MSSM

- **Many new free parameters: about 105 free parameters**
- **New source of flavor violation (FV)**

Experimental upper bound $Br(\mu \to e\gamma) \leq 10^{-12}$



- The degeneracy of the scalar fermion mass solves SUSY flavor problem

Features of GMSB

* Messenger fields, $\Phi_i + \overline{\Phi}_i$

* $W = \lambda \Phi_i \overline{\Phi}_i \hat{Z}$, $\qquad \langle \hat{Z} \rangle = \langle Z \rangle + \theta^2 \langle F_Z \rangle$

$$M_a = \frac{\alpha_a}{4\pi} \Lambda \, n_a(i) \, g(x_i) \qquad (a = 1-3),$$

$$\tilde{m}^2 = 2\Lambda^2 \sum_{a=1}^{3} \left(\frac{\alpha_a}{4\pi} \right)^2 C_a n_a(i) f(x_i) \; .$$

$\Lambda \equiv \langle F_Z \rangle / \langle Z \rangle$, $n_a(i) = 1$ for $N + \overline{N}$, $C_a(N) = (N^2 - 1)/(2N)$

$$A_f = 0 \quad \text{for all } f$$
$$B = 0$$

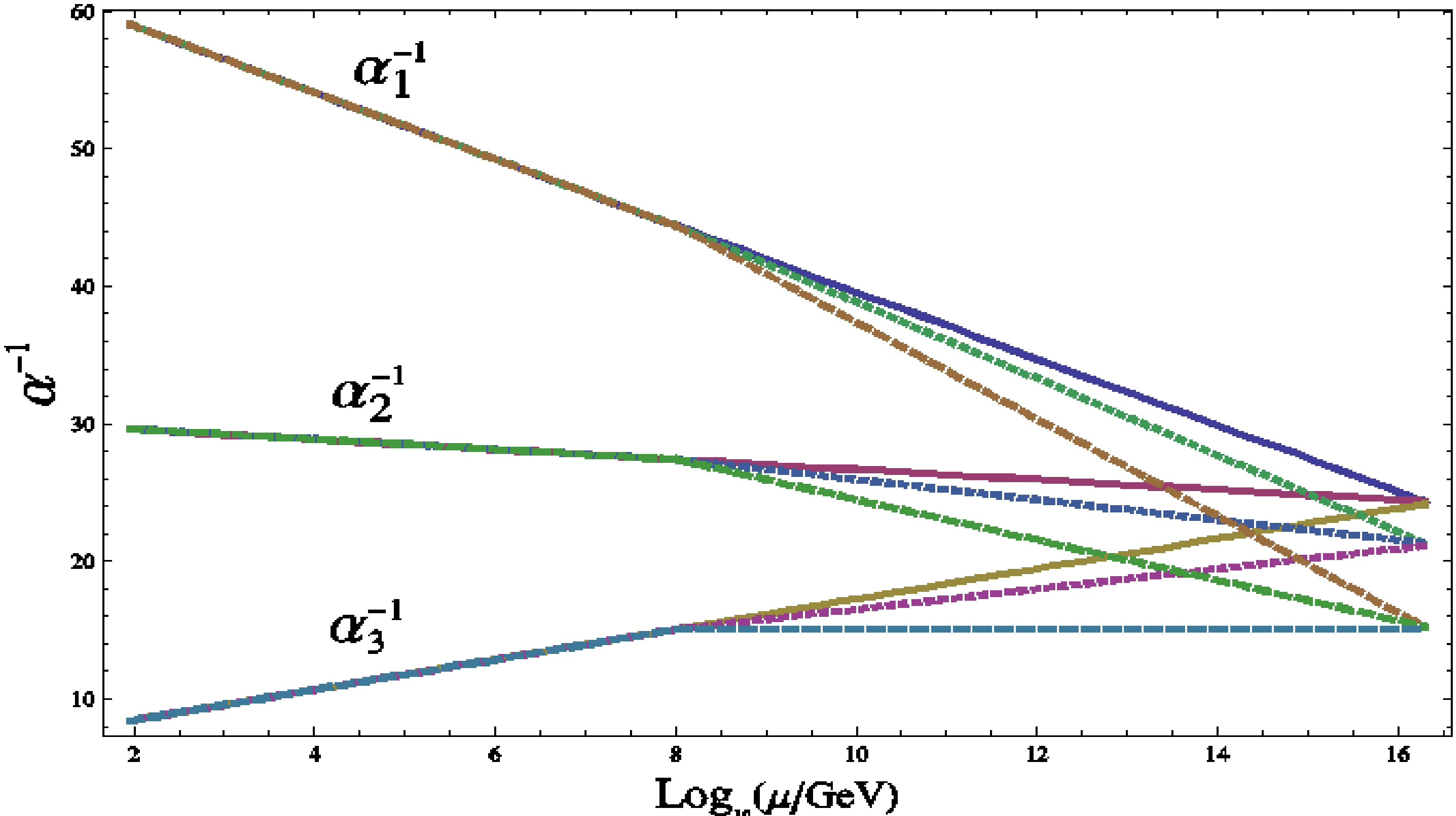
* Highly predictive $\quad$ Λ, M_{mess}, N, $tan\beta$, sign(μ)

* SUSY flavor problem is solved

Features of GMSB

$*$ gauge coupling unification is preserved

$\Phi + \overline{\Phi} \equiv 5 + \overline{5}$ and $10 + \overline{10}$



Higgs Mass Bounds in minimal GMSB

Observation of SM-like Higgs particle severely constrains minimal gauge mediation models

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

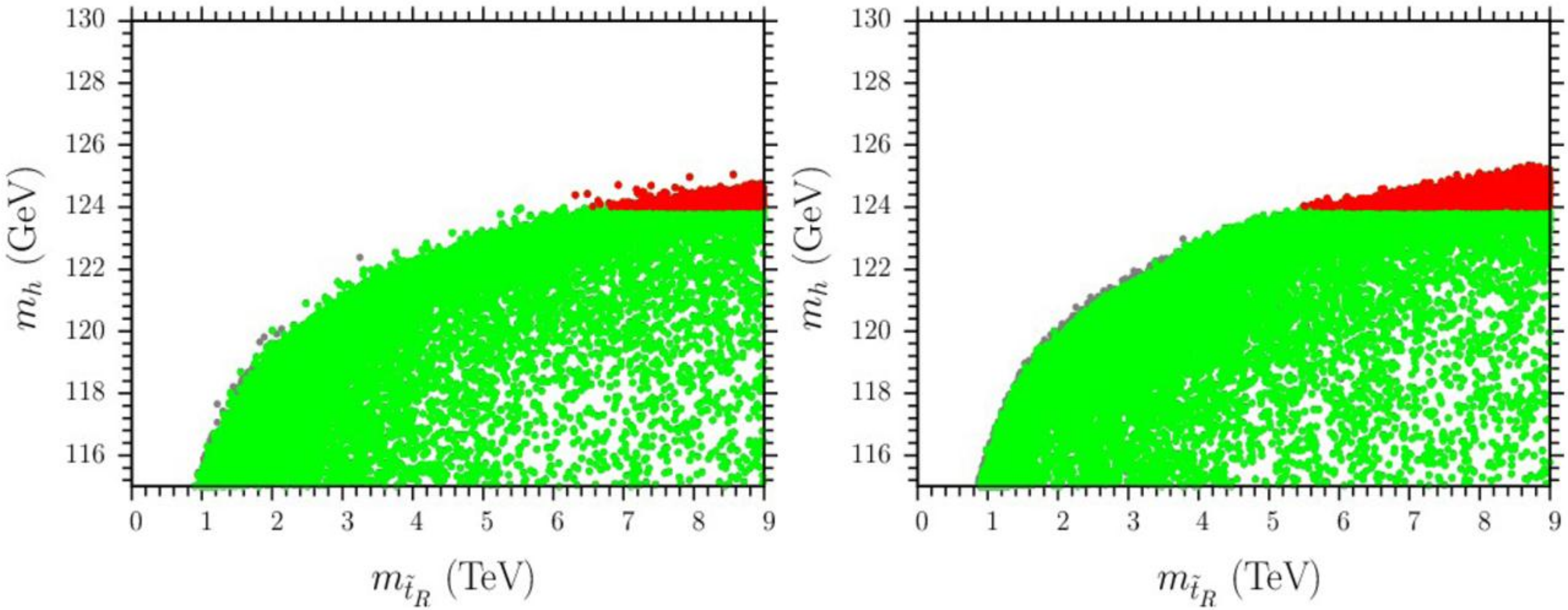
$$v^2 = v_d^2 + v_u^2, \quad t = \log\left(\frac{M_s^2}{M_t^2}\right), \quad X_t = \frac{2\tilde{A}_t^2}{M_s^2}\left(1 - \frac{\tilde{A}_t^2}{12M_s^2}\right), \quad \tilde{A}_t = A_t - \mu\cot\beta$$

Maximal Mixing Condition: $\frac{\tilde{A}_t}{M_s} = \sqrt{6}$ ⇨ $m_h \approx 125\mathrm{GeV}$

In GMSB $\frac{\tilde{A}_t}{M_s} \ll \sqrt{6}$ because $A_t = 0$ at the M_{mess}

$m_h = 125$ GeV requires stop mass larger than 6 TeV!

Higgs Mass Bounds in minimal GMSB



Stop mass versus Higgs mass in GMSB with $n = 1(5)$

Ajaib, Gogoladze, Nasir, Shafi (2012)

If stop masses < 2 TeV, $m_h < 118$ GeV

The Objectives

To construct GMSB model with messenger-matter mixing

- that raises the lightest Higgs mass to about 125 GeV
- that leads to supersymmetric particles of around sub-TeV .

The above objectives should be consistent with

- flavor violation processes are suppressed in agreement with experiment .
- the gravitino has a cosmological preferred sub-keV mass.

GMSB with Messenger-Matter Mixing, $5+\overline{5}$ Model

* Messenger fields belong to $5+\overline{5}$

$$5 = (\overline{d^c}_m + \overline{L}_m) \text{ and } \overline{5} = (d^c_m + L_m)$$

* Messenger fields mix with MSSM fields
  (normally, they dont mix with MSSM fields)

$$\text{In } SU(5),\, W = f_0 5_m \overline{5}_m Z + \lambda'_0 \overline{5}_m 10_3 \overline{5}_H$$

$(f_0,\ \lambda'_0)$ at GUT scale

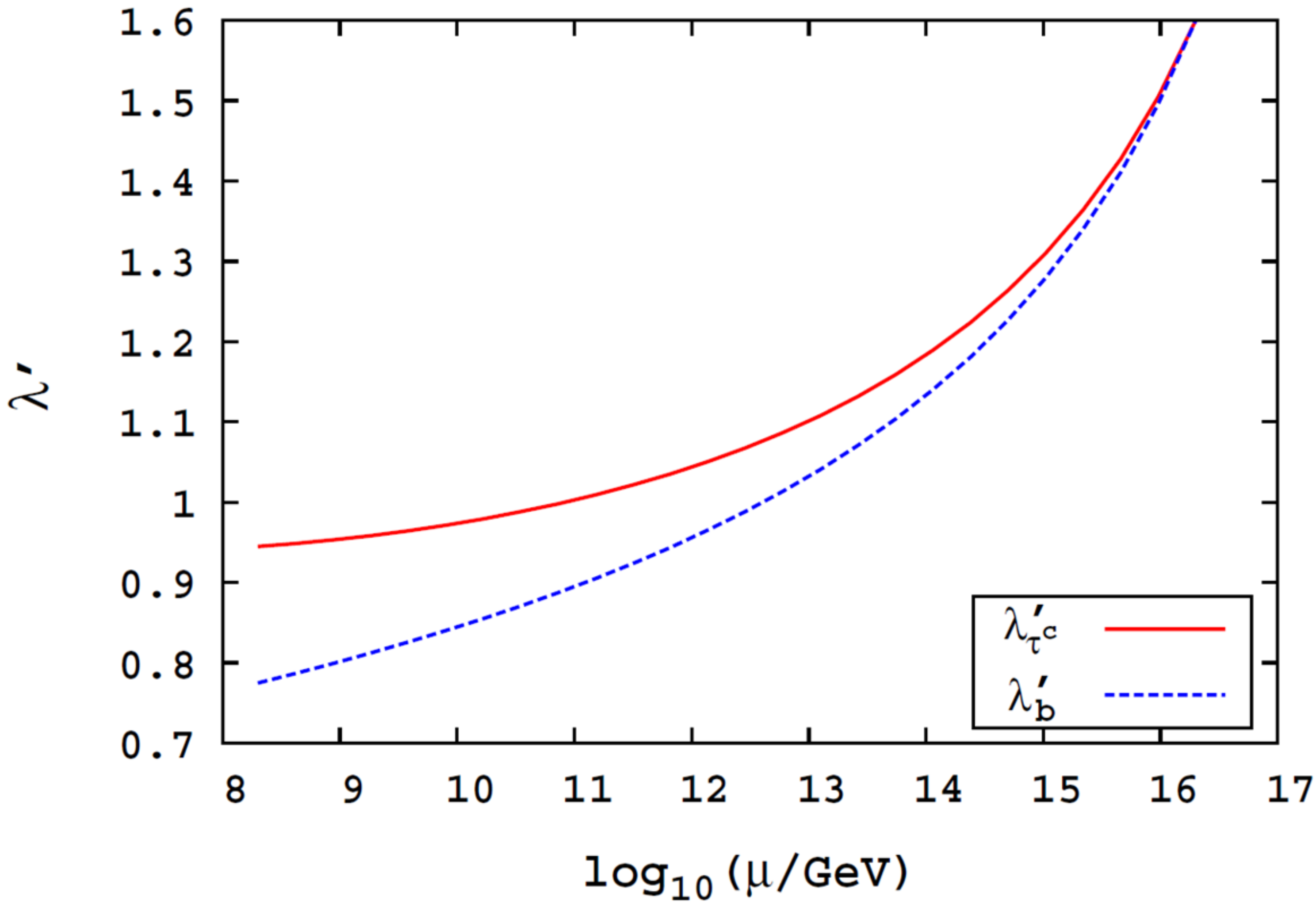
$$W_{5+\overline{5}} \;=\; f_d \overline{d^c}_m d^c_m + f_e \overline{L}_m L_m + \lambda'_b Q_3 d^c_m H_d + \lambda'_{\tau^c} L_m e^c_3 H_d.$$

Messenger scale

$$(\lambda'_b, \lambda'_{\tau^c}) \Rightarrow \delta\tilde{m}^2_{Q_3},\, \delta\tilde{m}^2_{e^c_3} \text{ and } A \text{ terms}$$

GMSB with Messenger-Matter Mixing, $5+\bar{5}$ Model

$*$ Evolution of mixed Yukawa couplings



GMSB with Messenger-Matter Mixing, $5+\bar{5}$ Model

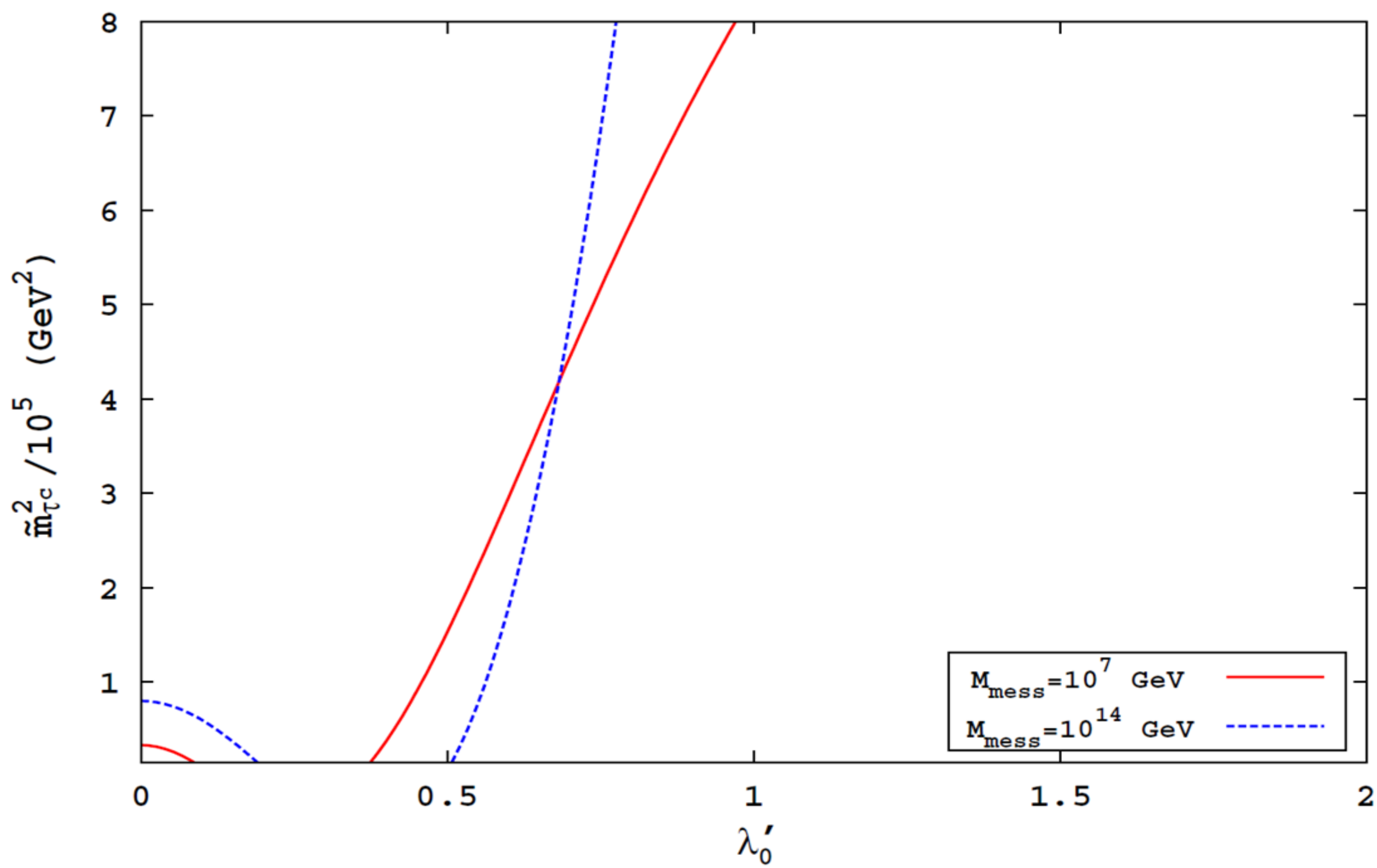
New contributions to soft SUSY breaking parameters:

$$\begin{aligned}
\delta\tilde{m}^2_{Q_3} &= \frac{\alpha'_b\Lambda^2}{8\pi^2}\left(3\alpha'_b + \frac{1}{2}\alpha'_{\tau^c} - \frac{8}{3}\alpha_3 - \frac{3}{2}\alpha_2 - \frac{7}{30}\alpha_1\right), \\
\delta\tilde{m}^2_{\tau^c} &= \frac{2\alpha'_{\tau^c}\Lambda^2}{8\pi^2}\left(2\alpha'_{\tau^c} + \frac{3}{2}\alpha'_b - \frac{3}{2}\alpha_2 - \frac{9}{10}\alpha_1\right), \\
\delta\tilde{m}^2_{H_d} &= \frac{\delta\tilde{m}^2_{\tau^c}}{2} + 3\delta\tilde{m}^2_{Q_3} + \frac{3\Lambda^2\alpha'_b\alpha_t}{16\pi^2} \\
\delta A_t &= -\frac{1}{4\pi}\alpha'_b\Lambda, \\
\delta A_b &= -\left(\frac{4\alpha'_b + \alpha'_{\tau^c}}{4\pi}\right)\Lambda, \\
\delta A_\tau &= -\left(\frac{3\alpha'_b + 3\alpha'_{\tau^c}}{4\pi}\right)\Lambda,
\end{aligned}$$

$$\alpha'_b = \frac{\lambda'^2_b}{4\pi},\ \alpha'_{\tau^c} = \frac{\lambda'^2_{\tau^c}}{4\pi}$$

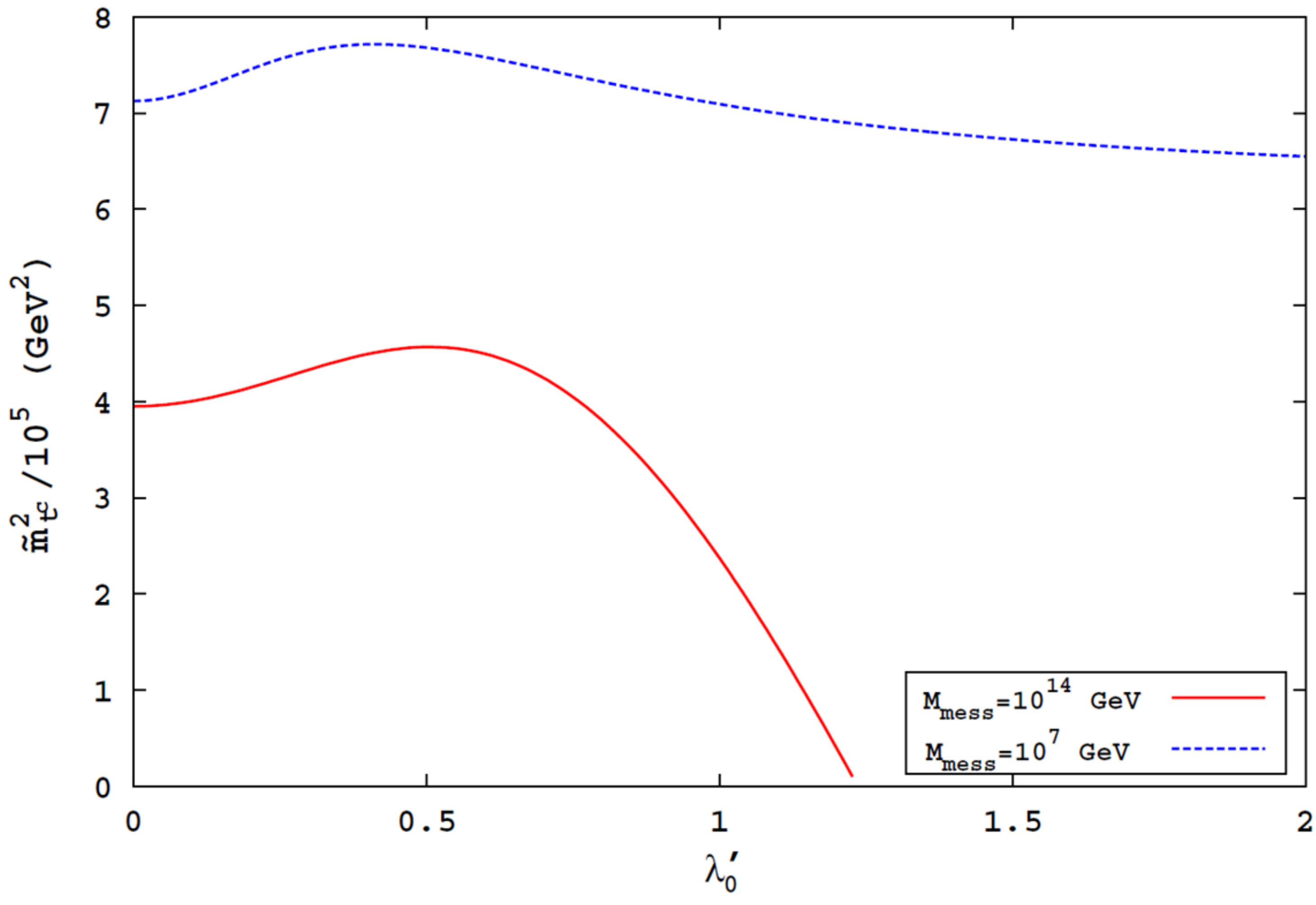
GMSB with Messenger-Matter Mixing, $5+\bar{5}$ Model

$*$ Constraints on Yukawa from positivity of stau mass-squared



GMSB with Messenger-Matter Mixing, $5 + \overline{5}$ Model

$*$ Constraints on Yukawa from positivity of stop mass-squared



GMSB with Messenger-Matter Mixing, $5 + \overline{5}$ Model

$*$ Improved Higgs boson mass

λ'_0	m_h(GeV)	$\Lambda(10^5\text{GeV})$	$M(10^{13}\,\text{GeV})$	$\tilde{m}_{t_1}$(GeV)	$\tilde{m}_{t_2}$(GeV)
0	114	2	1.78	1249	1695
0.8	116	2	10	1212	1583
1.2	119	2	10	384	2613

Messenger–matter mixing increases m_h by 5 GeV

$m_h \simeq$ 121 GeV can be realized with light SUSY spectrum

GMSB with Messenger-Matter Mixing, $10 + \overline{10}$ Model

Consider $10 + \overline{10}$ messenger fields

$$10 + \overline{10} = (Q_m + \overline{Q}_m) + (u^c_m + \overline{u^c}_m) + (e^c_m + \overline{e^c}_m)$$

In $SU(5)$, $W \supset \lambda'_0 10_3 10_m 5_H + \lambda'_{m0} 10_m 10_m 5_H + f_0 10_m \overline{10}_m Z$

Only 3rd family mixing is assumed

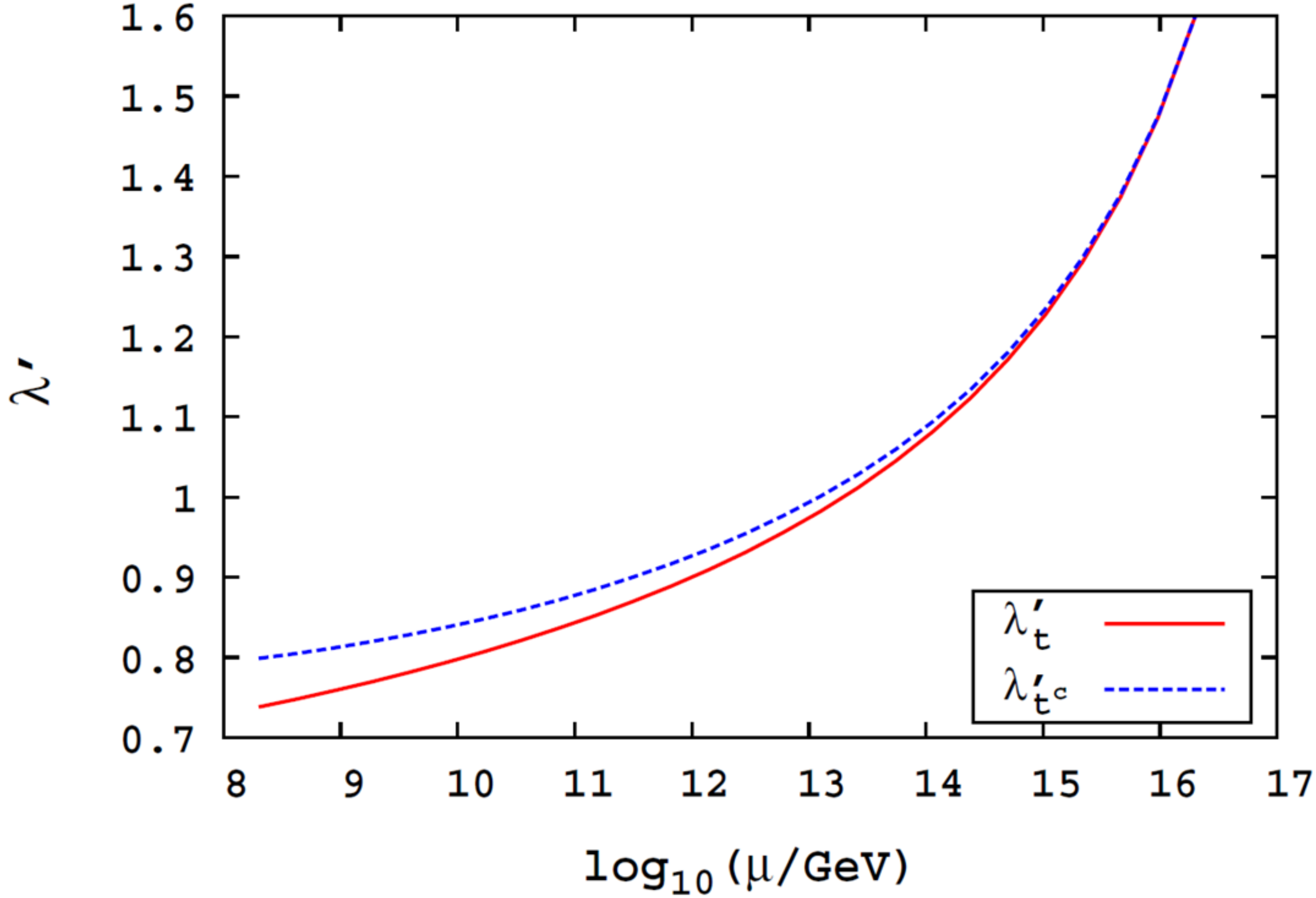
$$\begin{aligned} W_{10+\overline{10}} &= \lambda'_{t^c} Q_3 u^c_m H_u + \lambda'_t Q_m u^c_3 H_u + \lambda'_m Q_m u^c_m H_u \\ &+ f_{e^c} \overline{e^c}_m e^c_m Z + f_{u^c} \overline{u^c}_m u^c_m Z + f_Q \overline{Q}_m Q_m Z. \end{aligned}$$

λ'_{t^c}, λ'_t and λ'_m are exotic Yukawa couplings

⇨ $\delta\tilde{m}^2_{Q_3}$, $\delta\tilde{m}^2_{u^c_3}$ and A terms

GMSB with Messenger-Matter Mixing, $10 + \overline{10}$ Model

$*$ Evolution of mixed Yukawa couplings



GMSB with Messenger-Matter Mixing, $10 + \overline{10}$ Model

New contributions to soft SUSY breaking parameters:

$$\delta\tilde{m}^2_{Q_3} = \frac{\Lambda^2}{8\pi^2}\left[\alpha'_{t^c}\left(3\alpha'_{t^c} + \frac{3}{2}\alpha'_t + \frac{5}{2}\alpha'_m - \frac{8}{3}\alpha_3 - \frac{3}{2}\alpha_2 - \frac{13}{30}\alpha_1\right) - \alpha_t\left(\frac{5}{2}\alpha'_t + \frac{3}{2}\alpha'_m\right)\right],$$

$$\delta\tilde{m}^2_{t^c} = \frac{2\Lambda^2}{8\pi^2}\left[\alpha'_t\left(3\alpha'_t + \frac{3}{2}\alpha'_{t^c} + 2\alpha'_m - \frac{8}{3}\alpha_3 - \frac{3}{2}\alpha_2 - \frac{13}{30}\alpha_1\right) - \alpha_t\left(2\alpha'_{t^c} + \frac{3}{2}\alpha'_m\right)\right],$$

$$\delta\tilde{m}^2_{H_u} = \frac{3\Lambda^2}{8\pi^2}\left[\alpha'_{t^c}\left(3\alpha'_{t^c} + \frac{3}{2}\alpha'_t + \frac{5}{2}\alpha'_m - \frac{8}{3}\alpha_3 - \frac{3}{2}\alpha_2 - \frac{13}{30}\alpha_1\right) + \alpha'_t\left(3\alpha'_t + \frac{3}{2}\alpha'_{t^c} + 2\alpha'_m - \frac{8}{3}\alpha_3 - \frac{3}{2}\alpha_2 - \frac{13}{30}\alpha_1\right) + \alpha'_m\left(3\alpha'_m + 2\alpha'_t + \frac{5}{2}\alpha'_{t^c} - \frac{8}{3}\alpha_3 - \frac{3}{2}\alpha_2 - \frac{13}{30}\alpha_1\right)\right]$$

$$\delta A_t = -\left[\frac{5\alpha'_t + 4\alpha'_{t^c} + 3\alpha'_m}{4\pi}\right]\Lambda, \quad \Leftrightarrow \quad \delta A_t = -\frac{1}{4\pi}\alpha'_b$$

$$\delta A_b = -\frac{\alpha'_{t^c}}{4\pi}\Lambda$$

$$\alpha'_{t^c} = \frac{\lambda'^2_{t^c}}{4\pi},\ \alpha'_t = \frac{\lambda'^2_t}{4\pi},\ \alpha'_m = \frac{\lambda'^2_m}{4\pi}$$

Improved Higgs Boson mass in $10 + \overline{10}$ Model

$$0 \leq \lambda_0 \leq 2,$$

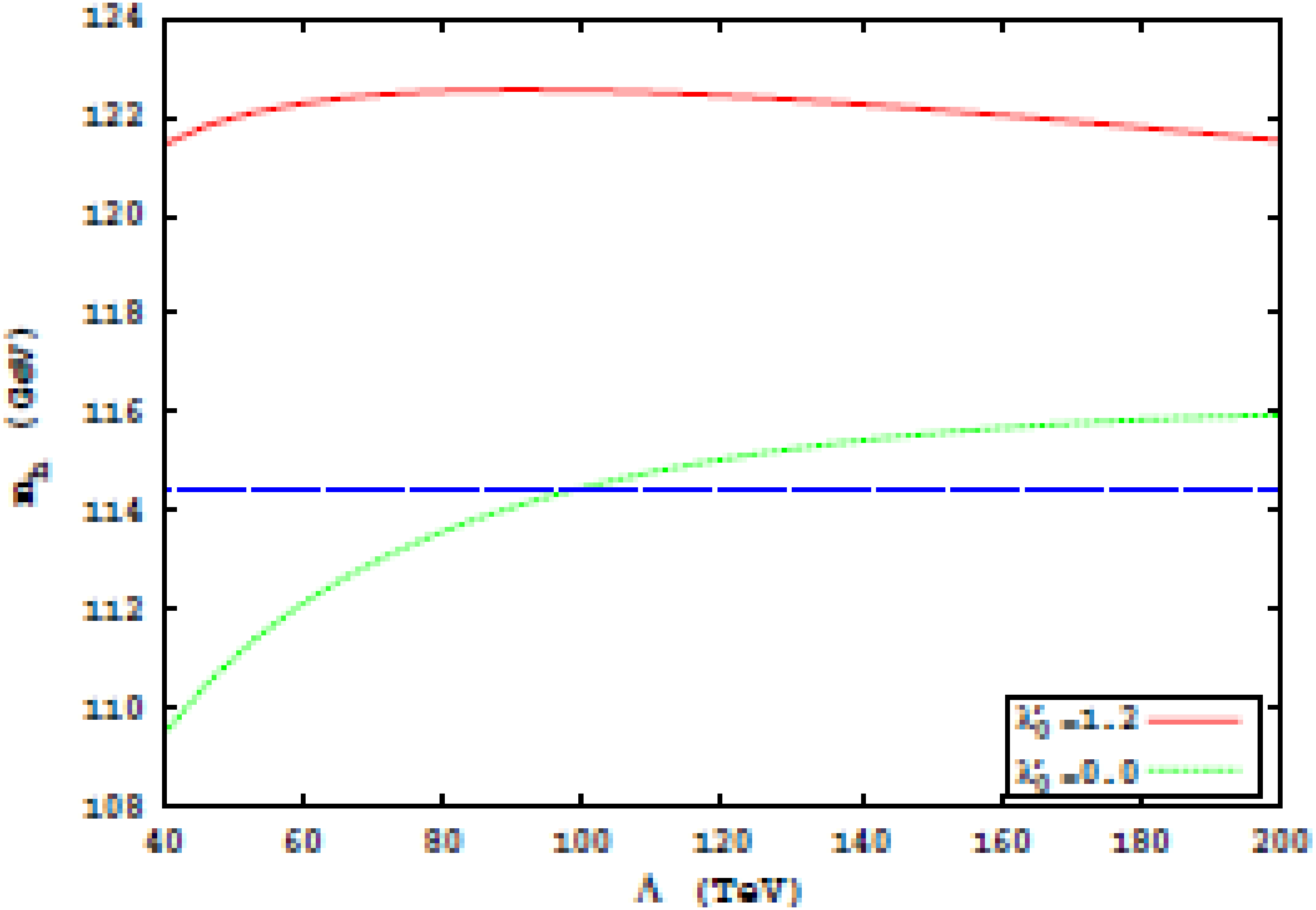
$$10^6\mathrm{GeV} \leq M_{mess} \leq 10^{14}\mathrm{GeV},$$

$$40\mathrm{TeV} \leq \Lambda \leq 200\mathrm{TeV}.$$

λ'_0	m_h(GeV)	$\Lambda(10^5\mathrm{GeV})$	M_{mess}(GeV)	$\tilde{m}_{t_1}$(GeV)	$\tilde{m}_{t_2}$(GeV)	A_t/M_s
0	117	1.6	3.16×10^{13}	2656	3284	-0.86
0.4	118	1.36	10^8	1795	2396	-1.27
0.8	122	0.912	10^{13}	1553	2143	-1.95
1.1	123	0.784	1.8×10^{11}	735	1429	-2
2	123	0.784	10^8	743	1426	-2.26

$m_h \simeq 125$ GeV can be realized with light SUSY spectrum

Improved Higgs Boson mass in $10 + \overline{10}$ Model



Particle		$10+\overline{10}$	$10+\overline{10}$	$5+\overline{5}$
Inputs	$M_{\rm mess}$	10^8	4×10^5	10^8
	$N_{\rm mess}$	3	3	1
	$\Lambda(10^5\,{\rm GeV})$	0.45	0.3	1.5
	$\tan\beta$	10	6.1	15.6
	f_0	0.25	0.25	0.25
	λ_0	1.3	1.2	1.2
Higgs:	m_h	122	118	114.5
	m_H^0	858	592	1690
	m_A	858	591	1690
	$m_{H^\pm}$	862	597	1689
Gluino:	$\tilde{m}_g$	980	667	1041
Neutralinos:	m_{χ_1}	186	124	208
	m_{χ_2}	346	225	408
	m_{χ_3}	800	557	781
	m_{χ_4}	807	569	790
Charginos:	χ_1^+	347	227	409
	χ_2^+	807	569	790
Squarks:	$\tilde{m}_{u_L,c_L}$	972	657	1480
	$\tilde{m}_{u_R,c_R}$	929	632	1377
	$\tilde{m}_{d_L,s_L}$	971	657	1480
	$\tilde{m}_{d_R,s_R}$	922	630	1365
	$\tilde{m}_{b_L}$	800	555	1315
	$\tilde{m}_{b_R}$	919	629	1294
	$\tilde{m}_{t_L}$	853	621	1315
	$\tilde{m}_{t_R}$	412	270	1123
Sleptons:	$\tilde{m}_{e_L,\mu_L}$	323	200	596
	$\tilde{m}_{\nu_{e\,L},\nu_{\mu\,L}}$	323	200	596
	$\tilde{m}_{e_R,\mu_R}$	152	92	290
	$\tilde{m}_{\tau_L}$	322	197	539
	$\tilde{m}_{\tau_R}$	151	92	1543

Froggatt-Nielsen Mechanism

- U(1) flavor symmetry is assumed.
- there is a SM singlet " flavon" field $\mathbf{S}$
- U(1) is broken at high scale by $\langle \mathbf{S} \rangle$
- The hierarchy of fermion masses and mixings can be explained as a power expansion of $\epsilon = \frac{\langle \mathbf{S} \rangle}{\mathbf{M}^*}$

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.

$$\begin{aligned} W_{MSSM} &= y^u_{ij}\,\epsilon^{n^u_{ij}}\,u^c_i Q_j H_u + y^d_{ij}\,\epsilon^{n^d_{ij}}\,d^c_i Q_j H_d + y^e_{ij}\,\epsilon^{n^e_{ij}}\,e^c_i L_j H_d \\ &+ f_d \overline{Q}_m Q_m Z + \lambda'_b Q_3 d^c_m H_d + f_e \overline{L}_m L_m Z + \lambda'_{\tau^c} L_m e^c_3 H_d \end{aligned}$$

Froggatt-Nielsen Mechanism

$$M^u = Y^u v_u = \begin{pmatrix} y^u_{11}\epsilon^8 & y^u_{12}\epsilon^6 & y^u_{13}\epsilon^4 \\ y^u_{21}\epsilon^6 & y^u_{22}\epsilon^4 & y^u_{23}\epsilon^2 \\ y^u_{31}\epsilon^4 & y^u_{32}\epsilon^2 & y^u_{33} \end{pmatrix} v_u \ ,$$

$$M^d = Y^d v_d = \epsilon^p \begin{pmatrix} y^d_{11}\epsilon^5 & y^d_{12}\epsilon^3 & y^d_{13}\epsilon \\ y^d_{21}\epsilon^4 & y^d_{22}\epsilon^2 & y^d_{23} \\ y^d_{31}\epsilon^4 & y^d_{32}\epsilon^2 & y^d_{33} \end{pmatrix} v_d \ , \qquad \epsilon \simeq 0.2.$$

$$M^e = Y^e v_d = \epsilon^p \begin{pmatrix} y^e_{11}\epsilon^5 & y^e_{12}\epsilon^4 & y^e_{13}\epsilon^4 \\ y^e_{21}\epsilon^3 & y^e_{22}\epsilon^2 & y^e_{23}\epsilon^2 \\ y^e_{31}\epsilon & y^e_{32} & y^e_{33} \end{pmatrix} v_d \ .$$

$$\Rightarrow \quad (U_R^{u,d,e})\, M^{u,d,e}\, (U_L^{u,d,e})^\dagger = M^{u,d,e}_{\text{diag}}$$

- Fermion mass hierarchy

$$m_u : m_c : m_t \sim \epsilon^8 : \epsilon^4 : 1$$
$$m_d : m_s : m_b \sim \epsilon^5 : \epsilon^2 : 1$$
$$m_e : m_\mu : m_\tau \sim \epsilon^5 : \epsilon^2 : 1$$

- Fermion mass mixing

$$U_L^d \sim \begin{pmatrix} 1 & \epsilon^2 & \epsilon^4 \\ \epsilon^2 & 1 & \epsilon^2 \\ \epsilon^4 & \epsilon^2 & 1 \end{pmatrix}$$

Agree with quark mixing angles

$$U_L^e \sim \begin{pmatrix} 1 & \epsilon & \epsilon \\ \epsilon & \omega & \omega \\ \epsilon & \omega & \omega \end{pmatrix}$$

Agree with neutrino mixing angles

Flavor Violation

- Messenger matter mixing induces flavor violation

- Additional couplings

$$W_{5+\bar{5}} = f_m^d \overline{d^c}_m d_m^c Z + \lambda_b' Q_3 d_m^c H_d + f_m^e \overline{L}_m L_m Z + \lambda_{\tau^c}' L_m e_3^c H_d .$$

$$\begin{aligned} W_{10+\overline{10}} &= \lambda_{t^c}' Q_3 u_m^c H_u + Q_m \lambda_t' u_3^c H_u + \lambda_m' Q_m u_m^c H_u + \lambda_b' \epsilon^p Q_m d_3^c H_d \\ &+ \lambda_\tau' \epsilon^p L_3 e_m^c H_d + f_{e^c} \overline{e^c}_m e_m^c Z + f_{u^c} \overline{u^c}_m u_m^c Z + f_Q \overline{Q}_m Q_m Z \end{aligned}$$

- **Mass Insertion Parameters**:

The messenger-matter couplings reintroduce the flavor violation

$$\tilde{m}^2_{LL,RR} = \tilde{m}_0^2 (I + \delta_{LL,RR}), \quad \delta_{LL,RR} = \frac{U^\dagger_{L,R} \delta\tilde{m}^2 U_{L,R}}{m_0^2}, \quad \delta_{LR} = \frac{U_L^\dagger \delta A U_R}{m_0^2}$$

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

Flavor Violation

Mass Insertion (δ)	$5+\overline{5}$	$10+\overline{10}$	Process	Exp. Bounds
$(\delta^l_{12})_{LL}$	-	ϵ^{1+2p}	$\mu \to e\gamma$	0.00028
$(\delta^l_{12})_{RR}$	$r\ \epsilon^6$	-		0.0004
$(\delta^l_{12})_{RL,LR}$	$r\ \kappa^l_5(\epsilon^4,\ \epsilon^3)$	$\kappa^l_{10}\ (\epsilon^{4+2p},\epsilon^{3+2p})$		1.3×10^{-6}
$(\delta^l_{13})_{LL}$	-	ϵ^{1+2p}	$\tau \to e\gamma$	0.026
$(\delta^l_{13})_{RR}$	$r\ \epsilon^4$	-		0.04
$(\delta^l_{13})_{RL,LR}$	$r\ \kappa^l_5(\epsilon^4,\ \epsilon^1)$	$\kappa^l_{10}(\epsilon^{4+2p},\epsilon^{1+2p})$		0.002
$(\delta^l_{23})_{LL}$	-	ϵ^{2p}	$\tau \to \mu\gamma$	0.02
$(\delta^l_{23})_{RR}$	$r\ \epsilon^2$	-		0.03
$(\delta^l_{23})_{RL,LR}$	$r\ \kappa^l_5(\epsilon^2,\ 1)$	$\kappa^l_{10}(\epsilon^{2+2p},\epsilon^{2p})$		0.0015
$\left(\sqrt{\lvert\mathrm{Re}(\delta^d_{12})^2_{LL}\rvert},\ \sqrt{\lvert\mathrm{Im}(\delta^d_{12})^2_{LL}\rvert}\right)$	ϵ^6	ϵ^6	$K-\overline{K}$	(0.065, 0.0052)
$\left(\sqrt{\lvert\mathrm{Re}(\delta^d_{12})^2_{RR}\rvert},\ \sqrt{\lvert\mathrm{Im}(\delta^d_{12})^2_{RR}\rvert}\right)$	-	ϵ^{1+2p}		(0.065, 0.0052)
$\left(\sqrt{\lvert\mathrm{Re}(\delta^d_{12})^2_{LR}\rvert},\ \sqrt{\lvert\mathrm{Im}(\delta^d_{12})^2_{LR}\rvert}\right)$	$\kappa^d_5\ (\epsilon^3,\epsilon^4)$	$\kappa^d_{10}\epsilon^3$		$(0.007,\ 5.2\times10^{-5})$
$\left(\sqrt{\lvert\mathrm{Re}(\delta^d_{12})^2_{RL}\rvert},\ \sqrt{\lvert\mathrm{Im}(\delta^d_{12})^2_{RL}\rvert}\right)$	$\kappa^d_5\epsilon^{3+p}$	$\kappa^d_{10}\epsilon^4$		$(0.007,\ 5.2\times10^{-5})$
$\sqrt{\lvert\mathrm{Re}(\delta^d_{12})_{LL}(\delta^d_{12})_{RR}\rvert}$	-	$\epsilon^{3.5+p}$		0.00453
$\sqrt{\lvert\mathrm{Im}(\delta^d_{12})_{LL}(\delta^d_{12})_{RR}\rvert}$	-	$\epsilon^{3.5+p}$		0.00057
$(\mathrm{Re}\delta^d_{13},\mathrm{Im}\delta^d_{13})_{LL}$	ϵ^4	ϵ^4	$B_d-\overline{B}_d$	(0.238, 0.51)
$(\mathrm{Re}\delta^d_{13},\mathrm{Im}\delta^d_{13})_{RR}$	-	ϵ^{1+2p}		(0.238, 0.51)
$(\mathrm{Re}\delta^d_{13},\mathrm{Im}\delta^d_{13})_{LR,RL}$	$\kappa^d_5(\epsilon^4,\ \epsilon)$	$\kappa^d_{10}(\epsilon,\epsilon^4)$		(0.0557, 0.125)
$(\delta^d_{23})_{LL}$	ϵ^2	ϵ^2	$B_s-\overline{B}_s$	1.19
$(\delta^d_{23})_{RR}$	-	ϵ^{2p}		1.19
$(\delta^d_{23})_{LR,RL}$	$\kappa^d_5(1,\epsilon^2)$	$\kappa^d_{10}(1,\epsilon^2)$	$b\to s\gamma$	0.04

$\kappa^d_5=0.0045$, $\kappa^l_5=0.019$, $\kappa^d_{10}=0.002$, $\kappa^l_{10}=0.0014$. $r=1$ (unified Yukawa couplings), $r=0$ (non-unified Yukawa couplings)

With $\epsilon \simeq 0.2$, SUSY FCNC suppressed sufficiently

Summary

- Higgs boson mass of order 125 GeV is naturally realized in GMSB with messenger matter mixing

- Relatively light SUSY spectrum is obtained

- FCNC processes are sufficiently suppressed in agreement with experiment