Yukawa Unification and Neutralino Dark Matter in Pati-Salam Model

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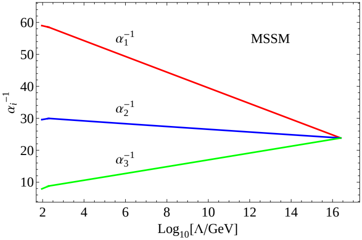
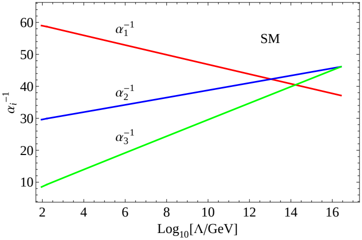
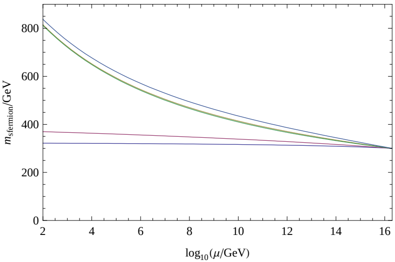
Low Energy Supersymmetry (SUSY)

- Resolution of the gauge hierarchy problem;
- Cold dark matter candidate (LSP);
- Radiative electroweak symmetry breaking;
- Predicts new particles accessible at the LHC;
- Unification of the SM gauge couplings.





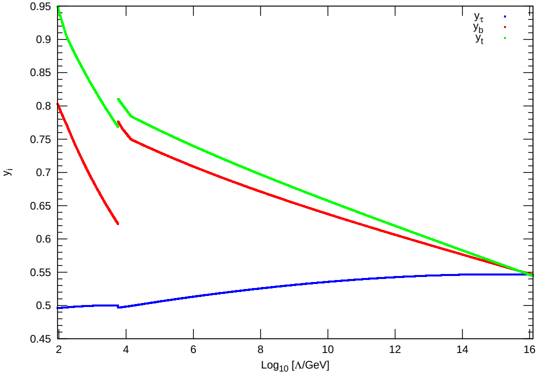
- Low scale SUSY loves unification.
- SUSY has to be broken. One of the most popular scenarios is gravity mediated SUSY breaking and its simplest realization is CMSSM.
- $m_0,\ M_{1/2},\ A_0,\ \tan\beta,\ sign(\mu)$



Evolution of the first two family sfermion masses ($m_{\tilde{Q}}$, $m_{\tilde{U}^c}$, $m_{\tilde{D}^c}$, $m_{\tilde{E}^c}$ and $m_{\tilde{L}}$) from top to bottom.

- SUSY and $t - b - \tau$ Yukawa coupling unification

I.G, R. Khalid and Q. Shafi, arXiv:0903.5204 [hep-ph].



SO(10) GUT

- The SM fermions: 16
- The MSSM Higgs boson: **10**
- Third family Yukawa coupling **16 16 10** yields

$$Y_t = Y_b = Y_\tau = Y_\nu$$

- It turns out to be difficult in the SO(10) model to reconcile the lightest neutralino primordial abundance with the observed dark matter densities.

H. Baer, S. Kraml, S. Sekmen and H. Summy, JHEP 0803, 056 (2008); Phys. Lett. B 666, 5 (2008)

$SU(4)_c \times SU(2)_L \times SU(2)_R$ **(4-2-2)**

I.G, R. Khalid and Q. Shafi, arXiv:0903.5204 [hep-ph].

- The SM fermions: $\psi_{\mathbf{i}} = (\mathbf{4}, \mathbf{2}, \mathbf{1})$ and $\psi_{\mathbf{i}}^{\mathbf{c}} = (\bar{\mathbf{4}}, \mathbf{1}, \mathbf{2})$
- The MSSM Higgs boson: $\mathbf{H} = (\mathbf{1}, \mathbf{2}, \mathbf{2})$
- Third family Yukawa coupling $\psi \, \psi^{\mathbf{c}} \; \mathbf{H}$ yields

$$Y_t = Y_b = Y_\tau = Y_\nu$$

- Left-right symmetric 4-2-2 model, (C-parity)

$\psi_{\mathbf{i}} \leftrightarrow \psi_{\mathbf{i}}^{\mathbf{c}} \Rightarrow$ all sfermion masses are the same

- From C-parity, $SU(2)_L$ and $SU(2)_R$ gaugino masses are the same

- Hypercharge generator $Y = \sqrt{\frac{2}{5}}(B-L) + \sqrt{\frac{3}{5}} I_{3R}$

- Asymptotic relation between the three MSSM gaugino masses

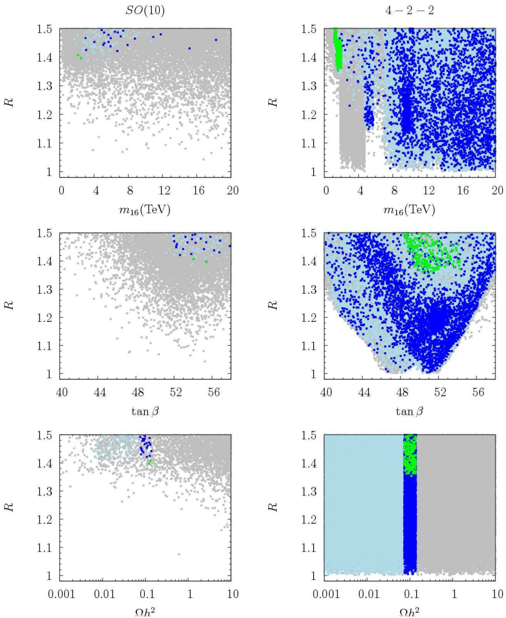
$$M_1 = \frac{3}{5} M_2 + \frac{2}{5} M_3$$

- It has one additional parameter compared to the SO(10) model

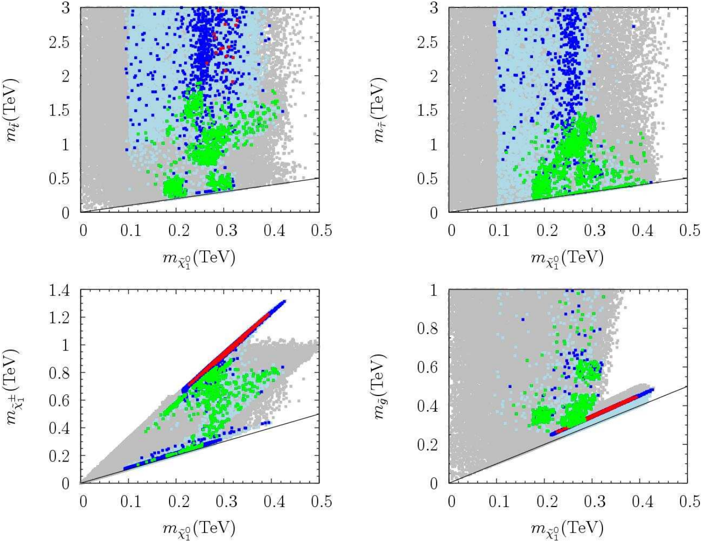
$$M_{1/2} \rightarrow M_2 \text{ and } M_3$$

- Following Baer *et al.* we introduce $R = \frac{\max(y_t, y_b, y_\tau)}{\min(y_t, y_b, y_\tau)}$

- We employ ISAJET 7.78 package to perform random scans over the parameter space



SO(10)
4 − 2 − 2
R
m16(TeV)
tan β
Ωh²



$m_{\tilde{t}}$(TeV)
$m_{\tilde{\tau}}$(TeV)
$m_{\tilde{\chi}_1^\pm}$(TeV)
$m_{\tilde{g}}$(TeV)
$m_{\tilde{\chi}_1^0}$(TeV)

	Point 1	Point 2	Point 3
m_{16}	14110	8429	13124
M_2	832.03	1020.2	689.4
M_3	0.7945	60.542	9.6261
$\tan\beta$	50.82	46.41	51.17
M_D/m_{16}	0.4543	0.5595	0.3323
m_{10}/m_{16}	0.7741	1.1584	1.3048
A_0/m_{16}	-2.4487	-2.1527	-1.8226
m_h	123	126	127
m_H	7569	2163	9882
m_A	7520	2150	9818
$m_{H^\pm}$	7571	2175	9883
$m_{\tilde{\chi}^{\pm}_{1,2}}$	**887**,13869	**975**,4047	**712**,3750
$m_{\tilde{\chi}^{0}_{1,2}}$	**283**, 885	**319**,974	**228**,712
$m_{\tilde{\chi}^{0}_{3,4}}$	13879,13879	4049,4049	3784,3785
$m_{\tilde{g}}$	**325**	**365**	**265**
$m_{\tilde{u}_{L,R}}$	14126,13916	8435,8361	13140,12841
$m_{\tilde{t}_{1,2}}$	5337,5726	**1911**,2640	4931,5310
$m_{\tilde{d}_{L,R}}$	14126,14203	8435,8455	13141,13249
$m_{\tilde{b}_{1,2}}$	5237,5653	2521,2767	4115,5146
$m_{\tilde{\nu}_1}$	13988	8409	12926
$m_{\tilde{\nu}_3}$	10598	6577	9535
$m_{\tilde{e}_{L,R}}$	13988,14376	8408,8514	12926,13500
$m_{\tilde{\tau}_{1,2}}$	6412,10581	4270,6573	5580,9559
μ	14100	4110	3840
$\Omega_{LSP}h^2$	0.095	0.112	0.116
R	**1.00**	1.07	1.09

Summary

- We considered an L-R symmetric $SU(4)_c \times SU(2)_L \times SU(2)_R$ model with gravity mediated supersymmetry breaking. We find that in this case $t - b - \tau$ Yukawa coupling unification is consistent with neutralino dark matter abundance and with constraints from collider experiments (except $(g-2)_\mu$)
- The model predicts a very characteristic sparticle spectrum: very heavy sfermions > 5 TeV but relatively light gluinos (around 300 GeV). Light gluinos can be easily found at LHC.