Yukawa Unification, Flavour Symmetry & SUSY GUTs

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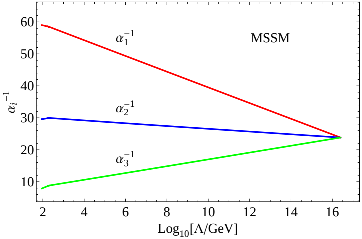
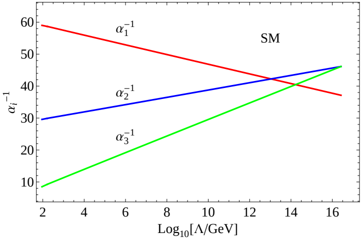
Outline

- Supersymmetric GUTs & Yukawa Unification ($b - \tau$ and $t - b - \tau$)
- Higgs & Sparticle Spectroscopy (including LSP neutralino DM)
- Flavor Symmetry and SUSY GUTs.
- Conclusions

Low Scale (∼ TeV) Supersymmetry (SUSY):

- Arguably the most compelling extension of the Standard Model;
- Resolves the gauge hierarchy problem (more or less);
- Provides cold dark matter candidate (LSP/Neutralino);
- Predicts new particles accessible at the LHC; these enable unification of the SM gauge couplings;

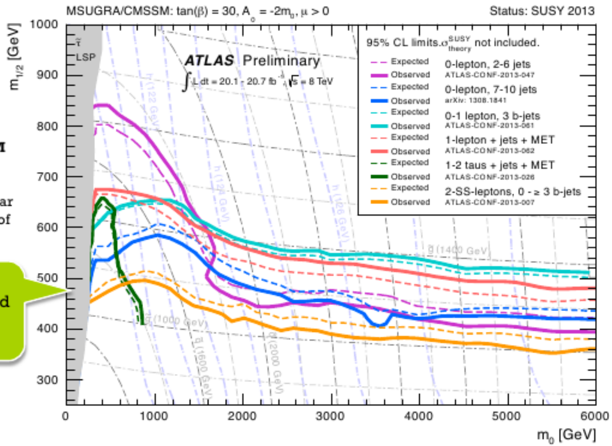




Grand Unified Theories (GUTs)

- Unification of SM / MSSM gauge couplings;
- Unification of matter/quark-lepton multiplets;
- Electric charge quantization; Magnetic monopoles.
- Seesaw physics / neutrino oscillations;
- Quark-Lepton mass relations;
- New source for baryo-leptogenesis;
- Inflation / Observable gravity waves (Planck)

CMSSM: Limits on sparticle masses from ATLAS

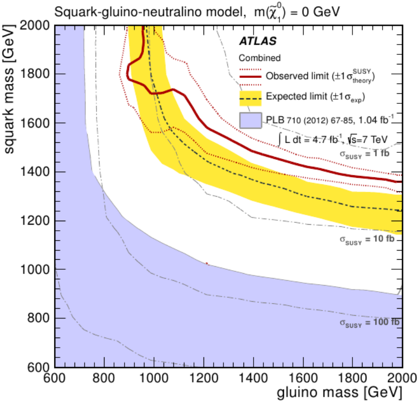


MSUGRA/CMSSM Higgs-aware: accomodates a lightest neutral scalar Higgs boson mass of 125 GeV.

~1.35 TeV gluinos excluded for any squark mass

S.F.Brazzale, ICNFP13

CMSSM: Limits on sparticle masses from ATLAS



- $m_{\tilde{g}} \gtrsim 1.7$ TeV for $m_{\tilde{q}} \simeq m_{\tilde{g}}$
- $m_{\tilde{g}} \gtrsim 1.1$-$1.3$ TeV for $m_{\tilde{q}} >> m_{\tilde{g}}$,

SUSY SO(10)

- Fermion families reside in $\underset{\sim}{16}_i (i=1,2,3)$;
- predicts 'right handed' neutrino $\Rightarrow$ non-zero neutrino masses through seesaw mechanism.
- Automatic Z_2 'matter' parity if $SO(10) \rightarrow$ MSSM using only tensor repsns. Also means stable cosmic strings (in addition to monopoles)
- Yukawa couplings include

$$16_i 16_j 10,\ 16_i 16_j 126, \mathrm{etc.}$$

- $16_3 16_3 10$ yields $t - b - \tau$ unification

$$Y_t = Y_b = Y_\tau = Y_\nu \text{ (not so in non-SUSY SO(10))}$$

- In the 'old days' (B. Ananthanarayan, G. Lazarides and Q. Shafi, 1991) it was used to predict the top quark mass

- Nowadays, one employs $t - b - \tau$ unification to make predictions, such as sparticle masses, which can be tested at the LHC (Baer et al.,Raby et al., ...);

- $t - b - \tau$ Yukawa unification can also be realized in $SU(4)_c \times SU(2)_L \times SU(2)_R$, a maximal subgroup of SO(10);

b-τ Yukawa Unification in CMSSM

Ilia Gogoladze, S. Raza and Q. Shafi, Phys.Lett. B706 (2012) 345-349 .

- SUSY $SU(5)$: $\bar{5}_3 \times 10_3 \times \bar{5}_{H_d}$

$$\uparrow \qquad \uparrow$$

$$(L, b^c), (Q, \tau^c) \Longrightarrow y_b = y_\tau$$

- SUSY $SO(10)$: $16_3 \times 16_3 \times 10_{u,d}$

Suppose $10_u \equiv H_u$

while $10_d \equiv H_d \cos\delta + \ldots$

$$\Longrightarrow y_b = y_\tau$$

- Quantify b-τ Yukawa unification(YU) by

$$R_{b\tau} = \frac{\max(y_b, y_\tau)}{\min(y_b, y_\tau)}$$

b-τ YU in CMSSM/mSUGRA

- $m_0, \; M_{1/2}, \; A_0, \; \tan\beta, \; sign(\mu)$
- $m_0 \equiv$ Universal soft SUSY breaking sfermion mass
- $M_{1/2} \equiv$ Universal SSB gaugino mass
- $A_0 \equiv$ Universal SSB trilinear interaction
- $\tan\beta = \frac{v_u}{v_d}$
- $\mu \equiv$ SUSY bilinear Higgs parameter > 0

Constraints

$$
\begin{aligned}
123 \leq m_h \text{ (lightest Higgs mass)} &\leq 127 \text{ GeV}, \\
0.8 \times 10^{-9} < BR(B_s \to \mu^+\mu^-) &< 6.2 \times 10^{-9}, \\
0.15 < \frac{BR(B_u \to \tau\nu_\tau)MSSM}{BR(B_u \to \tau\nu_\tau)SM} &< 2.03 \ (2\sigma), \\
2.99 \times 10^{-4} \leq BR(b \to s\gamma) \leq 3.87 \times 10^{-4} &\ (2\sigma), \\
0.091 < \Omega_{\rm CDM} h^2 < 0.1363 &\ (5\sigma), \\
3.4 \times 10^{-10} \leq \Delta a_\mu \leq 55.6 \times 10^{-10} &\ \ (3\sigma).
\end{aligned}
$$

We performed random scans using ISAJET7.84 [1] for the following parameter range

$$
\begin{aligned}
0 \leq & \quad m_0 \quad \leq 20\,\mathrm{TeV}, \\
0 \leq & \quad M_{1/2} \quad \leq 5\,\mathrm{TeV}, \\
-3 \leq & \quad A_0/m_0 \quad \leq 3, \\
2 \leq & \quad \tan\beta \quad \leq 60, \\
\mu > 0, & \qquad m_t = 173.3\,\mathrm{GeV}.
\end{aligned}
$$

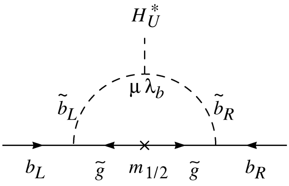
[1] F. E. Paige, S. D. Protopopescu, H. Baer and X. Tata, arXiv:0312045 [hep-ph]

b-τ YU and finite threshold corrections [1]

Dominant contributions to the bottom quark mass from the gluino and chargino loop

$$\delta y_b \approx \frac{g_3^2}{12\pi^2}\frac{\mu m_{\tilde{g}} \tan\beta}{m_1^2} + \frac{y_t^2}{32\pi^2}\frac{\mu A_t \tan\beta}{m_2^2} + \ldots$$

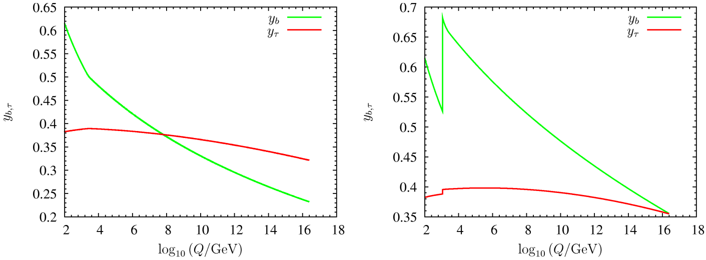
where $m_1 \approx (m_{\tilde{b}_1} + m_{\tilde{b}_2})/2$ and $m_2 \approx (m_{\tilde{t}_2} + \mu)/2$

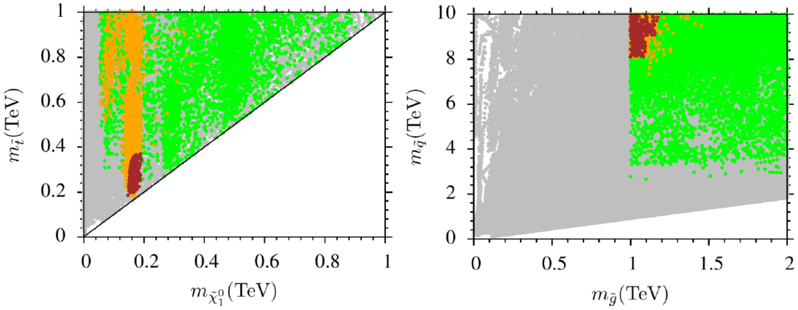


where $\lambda_b = y_b$ and $\lambda_t = y_t$

[1] L. J. Hall, R. Rattazzi and U. Sarid, Phys. Rev.D 50, 7048 (1994)

Importance of finite SUSY threshold corrections





Gray points are consistent with REWSB and $\tilde{\chi}_1^0$ LSP. Green points satisfy collider bounds and orange points are for $R \leq 1.2$. The brown points are subset of orange points that satisfy $\tilde{\chi}_1^0$ DM abundance $\Omega h^2 \leq 1$.

	Point 1	Point 2
m_{16}	17910	8975
M_1	263	329
$\tan\beta$	43.2	33.1
A_0/m_0	-2.35	-2.23
m_t	173.3	173.3
μ	12053	6008
$\Delta(g-2)_\mu$	0.81×10^{-12}	0.54×10^{-11}
m_h	123	124.9
m_H	5138	7049
m_A	5105	7004
$m_{H^\pm}$	5140	7050
$m_{\tilde{\chi}^0_{1,2}}$	174,374	170, 346
$m_{\tilde{\chi}^0_{3,4}}$	12009, 12009	6032, 6032
$m_{\tilde{\chi}^\pm_{1,2}}$	3768, 12026	349, 6047
$m_{\tilde{g}}$	1078	1053
$m_{\tilde{u}_{L,R}}$	17865, 17915	8953, 8980
$m_{\tilde{t}_{1,2}}$	1462, 6738	205, 4705
$m_{\tilde{d}_{L,R}}$	17865, 17924	8953, 8985
$m_{\tilde{b}_{1,2}}$	6853, 9328	4813, 6660
$m_{\tilde{\nu}_1}$	17916	8977
$m_{\tilde{\nu}_3}$	14786	7925
$m_{\tilde{e}_{L,R}}$	17904, 17896	8967, 8969
$m_{\tilde{\tau}_{1,2}}$	10983, 14797	6819, 7956
σ_{SI}(pb)	0.10×10^{-12}	0.11×10^{-13}
σ_{SD}(pb)	0.21×10^{-11}	0.40×10^{-10}
$\Omega_{CDM}h^2$	156	0.104
R	1.00	1.15

The first point displays a solution for a perfect unification while the second point represents a solution for stop-NLSP.

b-τ Yukawa Unification in SU(5)

- Random scans were performed over the parameter space

$$
\begin{array}{lrcl}
m_{10}: & 0 & \rightarrow & 20\ \mathrm{TeV} \\
m_{\bar{5}}: & 0 & \rightarrow & 20\ \mathrm{TeV} \\
M_{1/2}: & 0 & \rightarrow & 2\ \mathrm{TeV} \\
A_t: & -60 & \rightarrow & 60\ \mathrm{TeV} \\
A_b = A_\tau: & -60 & \rightarrow & 60\ \mathrm{TeV} \\
m_{H_u}: & 0 & \rightarrow & 20\ \mathrm{TeV} \\
m_{H_d}: & 0 & \rightarrow & 20\ \mathrm{TeV} \\
\tan\beta: & 1.1 & \rightarrow & 60 \\
\mu > 0, & m_t = 173.3(GeV) & &
\end{array}
$$

	Point 1	Point 2	Point 3	Point 4
m_{10}	2604	3849	18380	16800
$m_{\overline{5}}$	3443	900.1	16450	18960
$m_{1/2}$	1049	1056	292.6	358.6
$\tan\beta$	8.3	4.77	42.4	45
A_t	-5140	-7455	-44840	-39510
$A_b = A_\tau$	41070	40830	-8170	23640
m_{H_d}	3424	905	18500	17340
m_{H_u}	1380	4700	14150	10410
$sign(\mu)$	$+$	$+$	$+$	$+$
m_h	120.9	119.6	125.1	125.2
m_A	929	797	18781	13544
μ	2934	2345	17562	17394
$m_{\tilde{\chi}^0_{1,2}}$	461, 882	467, 887	179, 362	179, 354
$m_{\tilde{\chi}^0_{3,4}}$	2857, 2859	2291, 2295	16905, 16905	16406, 16406
$m_{\tilde{\chi}^\pm_{1,2}}$	881, 2857	887, 2311	368, 17075	357, 16429
$m_{\tilde{g}}$	2385	2431	1089	1165
$m_{\tilde{u}_{L,R}}$	3314, 3211	4336, 4405	18374, 18265	16788, 16608
$m_{\tilde{t}_{1,2}}$	1211, 1798	1007, 2825	215, 10165	3289, 7153
$m_{\tilde{d}_{L,R}}$	3315, 3984	4337, 2033	18374, 16488	16788, 19095
$m_{\tilde{b}_{1,2}}$	1375, 2082	489, 2841	10198, 11734	7139, 12709
$m_{\tilde{e}_{L,R}}$	3479, 2719	1321, 3731	16319, 18556	18850, 17052
$m_{\tilde{\tau}_{1,2}}$	876, 2939	803, 341	14263, 14864	11256, 16464
Ωh^2	0.113	0.074	0.11	$2269 \gg 1$
$\langle\sigma v\rangle(v \to 0)$ $[cm^3/s]$	3.886×10^{-27}	9.512×10^{-29}	1.684×10^{-26}	4.385×10^{-31}
$\sigma^{SI}(p)\times10^{12}$ [pb]	5.639	9.689	1.640	0.127
R	1.02	1.02	1.02	1.0

b-τ YU in $SU(5)$ or $SO(10)$ with NUGM

- $m_{16}, \ m_{10}, \ M_i, \ A_0, \ \tan\beta, \ sign(\mu)$
- $m_{16} \equiv$ Universal soft SUSY breaking (SSB) sfermion mass
- $m_{10} \equiv$ Universal SSB MSSM Higgs mass. $m^2_{H_u} = m^2_{H_d}$ at M_{GUT}
- $M_1 : M_2 : M_3 = 1 : 3 : -2$ at M_{GUT}
- $A_0 \equiv$ Universal SSB trilinear interaction
- $\tan\beta = \frac{v_u}{v_d}$
- $\mu \equiv$ SUSY bilinear Higgs parameter $\mu > 0$

	Point 1	Point 2
m_{16}	2405	3672
$m_{1/2}$	2000	1091
$\tan\beta$	46.3	43.1
A_0/m_{16}	2.81	2.26
m_{10}	1414	4309
$sign(\mu)$	$+$	$+$
m_h	124.6	125
m_A	1179	1023
μ	4298	2754
$m_{\tilde{\chi}^0_{1,2}}$	946, 4057	504, 2607
$m_{\tilde{\chi}^0_{3,4}}$	4060, 5102	2623, 2806
$m_{\tilde{\chi}^{\pm}_{1,2}}$	4109, 5052	2632, 2779
$m_{\tilde{g}}$	8108	4714
$m_{\tilde{u}_{L,R}}$	8123, 7238	5723, 5371
$m_{\tilde{t}_{1,2}}$	5505, 6854	2970, 3928
$m_{\tilde{d}_{L,R}}$	8123, 7228	5723, 5369
$m_{\tilde{b}_{1,2}}$	5814, 6821	3575, 3921
$m_{\tilde{e}_{L,R}}$	4462, 2505	4210, 3690
$m_{\tilde{\tau}_{1,2}}$	949, 4147	2064, 3611
Ωh^2	0.64	0.29
$\sigma^{SI}(p) \times 10^{12}$ [pb]	3.86	10.91
$\sigma^{SDI}(p) \times 10^{12}$ [pb]	326.3	2229.9
R	1.04	1.00

Benchmark points: The first point displays a solution for stau-neutralino coannihilation, while the second point depicts a solution with A-resonance.

b-τ YU in $SU(4) \times SU(2)_L \times SU(2)_R$ (422)

- $m_{16}, \; m_{H_i}, \; M_i, \; A_0, \; \tan\beta, \; sign(\mu)$
- $m_{16} \equiv$ Universal soft SUSY breaking (SSB) sfermion mass
- $m_{H_d,H_u} \equiv$ Universal SSB MSSM Higgs masses.
- $M_i \equiv$ SSB gaugino masses.

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

- $A_0 \equiv$ Universal SSB trilinear interaction
- $\tan\beta = \frac{v_u}{v_d}$
- $\mu \equiv$ SUSY bilinear Higgs parameter $\mu > 0$

We performed random scans for the following parameter range (NUHM2):

$$\begin{aligned}
0 &\leq & m_{16} &\leq & 20\,\mathrm{TeV}, \\
0 &\leq & M_2 &\leq & 5\,\mathrm{TeV}, \\
0 &\leq & M_3 &\leq & 5\,\mathrm{TeV}, \\
-3 &\leq & A_0/m_{16} &\leq & 3, \\
0 &\leq & m_{H_d} &\leq & 20\,\mathrm{TeV}, \\
0 &\leq & m_{H_u} &\leq & 20\,\mathrm{TeV} \\
2 &\leq & \tan\beta &\leq & 60, \\
\mu > 0, & & & & m_t = 173.3\,\mathrm{GeV}.
\end{aligned}$$

	Point 1	Point 2	Point 3	Point 4	Point 5
m_{16}	12730	9839	17640	7477	11940
M_1	1172	1903	1462	1496	1700
M_2	1820	2881	2327	2335	2660
M_3	550	435.3	165	237	260
m_{H_d}, m_{H_u}	11720, 14690	5967, 7279	12890, 5640	6624, 1513	3111, 5478
$\tan\beta$	36.3	41.3	52.9	32.4	39.0
A_0/m_0	-2.07	-2.41	-2.62	-2.56	-2.63
m_t	173.3	173.3	173.3	173.3	173.3
μ	4957	9186	19086	8552	13149
$\Delta(g-2)_\mu$	0.82×10^{-11}	0.72×10^{-11}	0.28×10^{-11}	0.97×10^{-11}	0.45×10^{-11}
m_h	126.4	125.9	123.9	125	123.3
m_H	2262	2157	1799	7900	3058
m_A	2247	2144	1788	7849	3039
$m_{H^\pm}$	2264	2160	1802	7901	3061
$m_{\tilde{\chi}^0_{1,2}}$	641,1682	918, 2585	770,2276	715, 2087	837, 2441
$m_{\tilde{\chi}^0_{3,4}}$	4973, 4974	9137, 9137	18924, 18924	8537, 8537	13101, 13101
$m_{\tilde{\chi}^\pm_{1,2}}$	1697, 4979	2604, 9133	2281, 18927	2104, 8534	2457, 13090
$m_{\tilde{g}}$	1625	1314	879	790	943
$m_{\tilde{u}_{L,R}}$	12743, 12860	9988, 9900	17708, 17538	7616, 7393	12019, 11977
$m_{\tilde{t}_{1,2}}$	689, 6131	1042, 4668	5577, 7056	781, 4077	901, 5263
$m_{\tilde{d}_{L,R}}$	12743, 12715	9988, 9853	17708, 17721	7617, 7525	12019, 11933
$m_{\tilde{b}_{1,2}}$	6234, 8566	4706, 5997	6884, 7646	4125, 5259	5293, 7047
$m_{\tilde{\nu}_1}$	12859	10035	17634	7562	12091
$m_{\tilde{\nu}_3}$	11262	8267	12950	6496	10076
$m_{\tilde{e}_{L,R}}$	12846, 12581	10027, 9814	17630, 17854	7554, 7623	12081, 11906
$m_{\tilde{\tau}_{1,2}}$	9129, 11263	5711, 8239	5525, 12875	5399, 6519	7366, 10045
$\sigma_{SI}(\mathrm{pb})$	0.71×10^{-13}	0.16×10^{-13}	0.70×10^{-14}	0.62×10^{-14}	0.27×10^{-13}
$\sigma_{SD}(\mathrm{pb})$	0.18×10^{-9}	0.19×10^{-11}	0.14×10^{-14}	0.41×10^{-12}	0.59×10^{-16}
$\Omega_{CDM}h^2$	0.13	0.86	0.45	0.09	0.123
R	1.06	1.18	1.04	1.10	[illegible]

t-b-τ Yukawa Unification in NUHM2

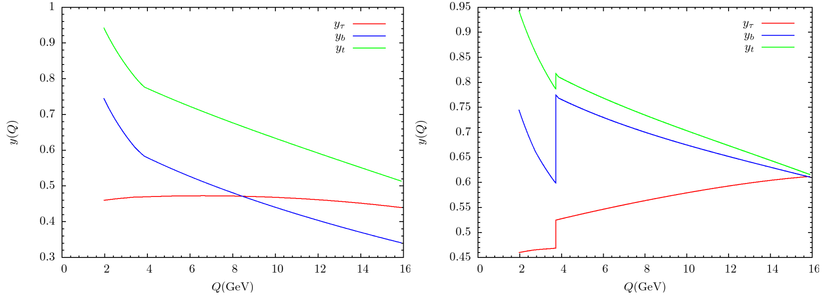
- $m_0, \; M_{1/2}, \; A_0, \; m_{H_u}, \; m_{H_d} \; \tan\beta, \; sign(\mu)$
- $m_0 \equiv$ Universal soft SUSY breaking sfermion mass
- $M_{1/2} \equiv$ Universal SSB gaugino mass
- $A_0 \equiv$ Universal SSB trilinear interaction
- $m_{H_u} \equiv$ SSB Higgs mass term
- $m_{H_d} \equiv$ SSB Higgs mass term
- $\tan\beta = \frac{v_u}{v_d}$
- $\mu \equiv$ SUSY bilinear Higgs parameter $\mu > 0$

	Point 1	Point 2	Point 3	Point 4
m_{16}	29390	25560	17630	25790
$m_{1/2}$	31.49	128	615.9	776
A_0/m_{16}	-2.57	-2.38	-2.06	-2.09
$\tan\beta$	57.3	55.6	51.7	51.2
m_{H_d}	27020	29900	23670	34830
m_{H_u}	13230	22390	20590	30160
m_h	125.2	126.8	125.0	124.9
m_H	12268	9053	4867	8070
m_A	12188	8994	4835	8016
$m_{H^\pm}$	12268	9054	4868	8071
$m_{\tilde{g}}$	750	908	1916	2432
$m_{\tilde{\chi}^0_{1,2}}$	125,308	150,348	337,684	440 ,894
$m_{\tilde{\chi}^0_{3,4}}$	29633, 29633	18942 ,18942	4037 ,4037	5660 ,5660
$m_{\tilde{\chi}^\pm_{1,2}}$	301 ,29651	350,18932	686 ,4009	897 ,5619
$m_{\tilde{u}_{L,R}}$	29423, 29114	25577,25337	17656 ,17549	25828 ,25667
$m_{\tilde{t}_{1,2}}$	9748,10952	6548 ,7958	3134 ,5189	4558 ,7601
$m_{\tilde{d}_{L,R}}$	29423,29578	25577,25716	17655 ,17744	25828 ,25959
$m_{\tilde{b}_{1,2}}$	10595 ,11337	7798 ,8339	5314 ,6168	7837,9098
$m_{\tilde{\nu}_1}$	29187	25387	17541	25657
$m_{\tilde{\nu}_3}$	21962	18765	13042	19092
$m_{\tilde{e}_{L,R}}$	29183,29182	25383,25901	17535,17799	25648,26045
$m_{\tilde{\tau}_{1,2}}$	12486 ,21892	9596 ,18727	6687 ,13047	9892 ,19097
$\Omega_{CDM}h^2$	$12482 \gg 1$	$13160 \gg 1$	$784 \gg 1$	$1807 \gg 1$
$R_{tb\tau}$	1.02	1.00	1.07	1.07

Higgs Boson Mass from t-b-τ YU (NUHM1 and Non-Universal Gauginos)

- $m_{16},\ m_{10},\ M_i,\ A_0,\ \tan\beta,\ sign(\mu)$
- $m_{16} \equiv$ Universal soft SUSY breaking (SSB) sfermion mass
- $m_{10} \equiv$ Universal SSB MSSM Higgs mass. $m_{H_u} = m_{H_d}$ at M_{GUT}
- $M_1 : M_2 : M_3 = 1 : 3 : -2$ at M_{GUT}
- $A_0 \equiv$ Universal SSB trilinear interaction
- $\tan\beta = \frac{v_u}{v_d}$
- $\mu \equiv$ SUSY bilinear Higgs parameter $\mu > 0$

RG-evolution of Yukawa couplings without and with threshold corrections



$$\delta y_b = \frac{g_3^2}{12\pi^2}\frac{\mu m_{\tilde{g}} \tan\beta}{m_1^2} + \frac{y_t^2}{32\pi^2}\frac{\mu A_t \tan\beta}{m_2^2} + \ldots$$

	Point 1	Point 2	Point 3
m_{16}	1022	1153	1964
M_1	1074	1056	1810
M_2	3222	3168	5430
M_3	-2148	-2112	-3620
m_{10}	283	1153	219
$\tan\beta$	46.1	46.8	47
A_0/m_0	1.94	1.68	2.71
m_t	173.1	173.1	173.1
μ	1973	1768	3545
B_μ	16.9	19.5	27.8
m_h	122	122	124
m_H	550	510	589
m_A	547	507	585
$m_{H^\pm}$	559	519	597
$m_{\tilde{\chi}^0_{1,2}}$	499,1980	490, 1777	854, 3554
$m_{\tilde{\chi}^0_{3,4}}$	1984, 2727	1781, 2683	3557, 4611
$m_{\tilde{\chi}^\pm_{1,2}}$	2007, 2699	1803, 2655	3601, 4565
$m_{\tilde{g}}$	4524	4457	7377
$m_{\tilde{u}_{L,R}}$	4462, 3981	4430, 3963	7336, 6527
$m_{\tilde{t}_{1,2}}$	3190, 3880	3127, 3814	5079, 6259
$m_{\tilde{d}_{L,R}}$	4463, 3976	4431, 3958	7337, 6518
$m_{\tilde{b}_{1,2}}$	3309, 3858	3259, 3792	5286, 6226
$m_{\tilde{\nu}_1}$	2290	2323	3933
$m_{\tilde{\nu}_3}$	2177	2179	3689
$m_{\tilde{e}_{L,R}}$	2295, 1089	2327, 1211	3938, 2063
$m_{\tilde{\tau}_{1,2}}$	500, 2188	492, 2188	861, 3705
$\Delta(g-2)_\mu$	0.97×10^{-10}	0.10×10^{-9}	0.34×10^{-10}
σ_{SI}(pb)	0.16×10^{-9}	0.28×10^{-9}	0.37×10^{-10}
σ_{SD}(pb)	0.69×10^{-8}	0.12×10^{-7}	0.58×10^{-9}
$\Omega_{CDM}h^2$	0.15	0.17	0.53
R	1.04	1.04	1.01

sMSSM : (Flavour) Symmetry-based MSSM

K. Babu, I. Gogoladze, S. Rizvi, QS.

- *Motivation*: Realize Supersymmetric Models in which symmetry considerations alone dictate the form of the SUSY breaking Lagrangian.
- Two key Ingredients:
  - GUT symmetry G such as SO(10);
  - Non-Abelian Flavour symmetry H which adequately suppresses SUSY-induced flavour violation.
- H unifies the three 16-plets of SO(10) into either a 2+1 pattern [e.g. SU(2), S_3], or a triplet [SO(3), A_4];
- Soft SUSY breaking squark masses of the first two families would be degenerate in the 2+1 case $\Longrightarrow$ Split families;

sMSSM : (Flavour) Symmetry-based MSSM

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- Discrete non-abelian symmetries may have the advantage that they are automatically free from D-term issues (which can split the masses of superparticles within a given H-multiplet after SUSY breaking).
- Solution of SUSY CP problem based on spontaneous CP violation leading to a complex quark mixing matrix.
- Non-trivial task in constructing such models is to ensure compatibility with the observed fermion masses and mixings.
- Phenomenology of sMSSM controlled by 7 soft SUSY breaking parameters for the 2+1 assignment of matter multiplets:
- 2 scalar masses, universal gaugino mass, A_0, $\tan\beta$, $|\mu|$, m_A.

Random scans performed for the following parameter range:

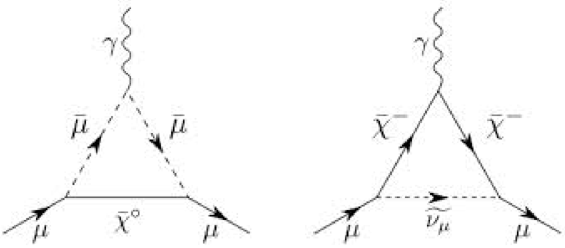
$$0 \leq m_{1,2} \leq 3\,\mathrm{TeV}$$
$$0 \leq m_3 \leq 3\,\mathrm{TeV}$$
$$0 \leq M_{1/2} \leq 3\,\mathrm{TeV}$$
$$-3 \leq A_0/m_3 \leq 3$$
$$2 \leq tan\beta \leq 60$$
$$0 \leq \mu \leq 3\,\mathrm{TeV}$$
$$0 \leq m_A \leq 3\,\mathrm{TeV}$$
$$\mu > 0$$

The anomalous magnetic moment of muon,
$a_\mu = (g-2)_\mu/2$, **(muon $g-2$)**

$$\Delta a_\mu \equiv a_\mu(\mathrm{exp}) - a_\mu(\mathrm{SM}) = (28.6 \pm 8.0) \times 10^{-10}$$

3.6σ discrepancy

The leading contribution from low scale supersymmetry



	Point 1	Point 2	Point 3	Point 4
$m_{1,2}$	222	302	355	55.2
m_3	2862	1760	1623	2610
$M_{1/2}$	545.6	494	645	886.2
$\tan\beta$	35.4	20.9	44.4	49.2
A_0/m_3	-1.54	-2.24	-2.61	-1.94
μ	503.1	2179	2582	2171
m_A	2891	1648	2815	1851
m_t	173.3	173.3	173.3	173.3
Δa_μ	$\mathbf{31.8 \times 10^{-10}}$	$\mathbf{24.3 \times 10^{-10}}$	$\mathbf{23.4 \times 10^{-10}}$	$\mathbf{21.0 \times 10^{-10}}$
m_h	**123.1**	**124.2**	**124.5**	**125**
m_A	2910	1658	2833	1863
$m_{H^\pm}$	2911	1661	2835	1865
$m_{\tilde{\chi}^0_{1,2}}$	232,420.7	211, 410	279, 535	387, 737
$m_{\tilde{\chi}^0_{3,4}}$	514.2, 548	2164, 2164	2565, 2565	2159, 2161
$m_{\tilde{\chi}^\pm_{1,2}}$	423.5, 546.5	411, 2169	536, 2566	739, 2163
$m_{\tilde{g}}$	1290	1171	1485	1987
$m_{\tilde{u}_{L,R}}$	1137, 1041	1066, 1059	1399, 1218	1775, 1694
$m_{\tilde{t}_{1,2}}$	1066, 1960	896, 1553	990, 1537	1364, 2067
$m_{\tilde{d}_{L,R}}$	1140, 1117.5	1069, 1022	1402, 1374	1777, 1703
$m_{\tilde{b}_{1,2}}$	1976, 2466	1532, 1892	1480, 1675	2049, 2352
$m_{\tilde{\nu}_1}$	244	473	328	549
$m_{\tilde{e}_{L,R}}$	319, 474	491, 218	355, 756	571, 387
$m_{\tilde{\tau}_{1,2}}$	2195, 2546	1581, 1731	298, 1092	1029, 2054
$\Omega_{CDM}h^2$	0.11	0.11	0.10	0.12

Conclusions

- Several interesting and distinct scenarios which are being tested at the LHC:
  b-τ YU
  - CMSSM/mSUGRA; NLSP Stop
  - SU(5); NLSP Stop & A-resonance
  - NUGM; NLSP Stau & A-resonance
  - 422; NLSP Gluino, NLSP Stop

  t-*b*-τ YU
  - NUHM2 (SO(10)); Gluino lightest colored particle (can be $\sim$ 2-3 TeV)
  - NUGM
    - SO(10); NLSP Stau, Gluino & Squarks $\gtrsim$ 3TeV
    - 422; NLSP Gluino
- Flavor symmetry & SUSY GUTs
  - 7 parameters $\rightarrow$ rich LHC phenomenology.