Particle Spectroscopy of SUSY SU(5) in light of Higgs boson mass and g-2 data

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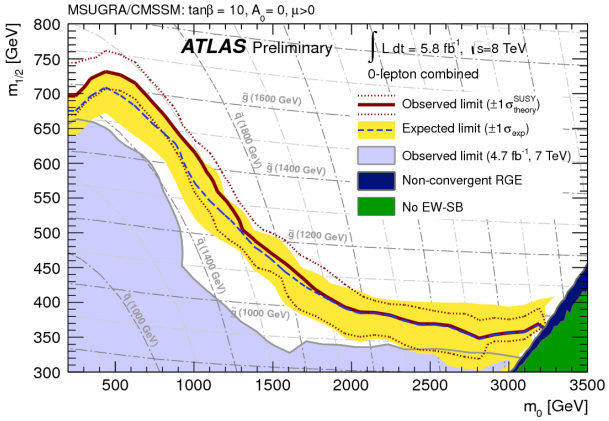
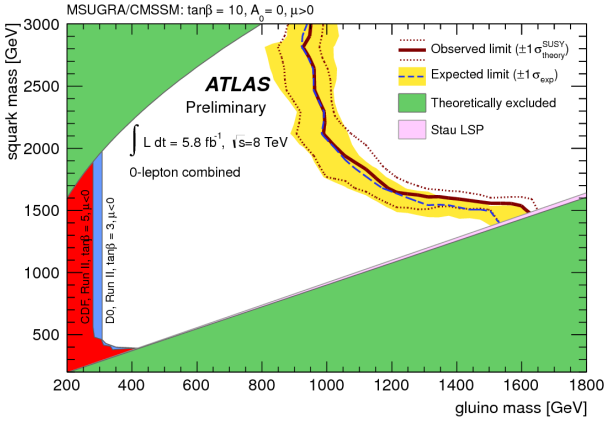
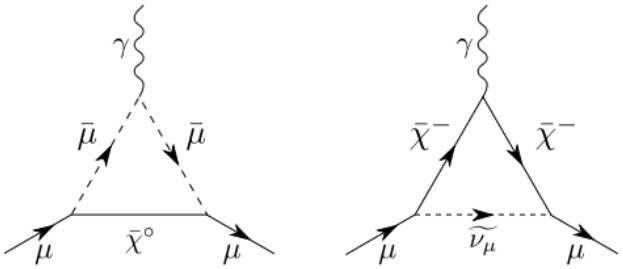
Constraining Supersymmtery (SUSY)





- The LHC has discovered Higgs boson of mass $\sim$ 125 GeV.
- Searches for SUSY at the high energy coliders have constrained SUSY parameter space.
- We can also constrain SUSY models by using precision measurements in low energy experiments
- Precise measurements of the muon anomalous Magnetic Dipole moment (MDM), $a_\mu \equiv (1/2)(g-2)_\mu$, can be used.

SUSY contribution to $g-2$

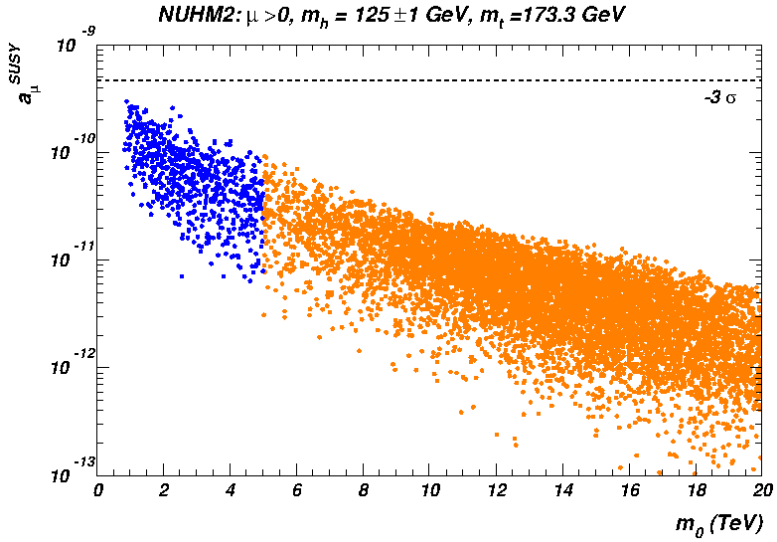


$$\Delta a_\mu^{SUSY} \equiv \frac{(g-2)_\mu}{2} \propto \mu M_2 \tan\beta / \tilde{m}^4,$$

where M_2 is the $SU(2)$ gaugino mass and $\tilde{m}$ is the heaviest mass in the loop.

$$\begin{aligned} a_\mu^{exp} &= 11659208.9(6.3)\times 10^{-10}, \\ a_\mu^{SM} &= 11659182.8(4.9)\times 10^{-10}, \\ \Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} &= (26.1 \pm 8.0) \times 10^{-10}. \end{aligned}$$

Simple models like CMSSM and NUHM2 with $m_h \sim 125$ GeV solutions do not provide sufficient contribution to resolve the (g-2) discrepancy.



- There are some solutions available

  (Please see M.Ibe et.al. arXiv:1303.6995 [hep-ph] and references there in)

- In order to accomodate above mentioned problems, we have considered $SU(5)$ inspired extention of the CMSSM, where non-universal soft supersymmetry breaking (SSB) masses are assigned for 10 and $\bar{5}$ matter multiplets (assuming flavor blindness) and as well as for two MSSM Higgs doublets.

$SU(5)$ inspired CMSSM

- $m_{10} = (m_{\tilde{Q}} = m_{\tilde{U}^c} = m_{\tilde{E}^c})$ Flavor universal soft SUSY breaking sfermion mass
- $m_{\bar{5}} = (m_{\tilde{D}^c} = m_{\tilde{L}})$ Flavor universal soft SUSY breaking sfermion mass
- $M_{1/2} \equiv$ Universal SSB gaugino mass
- $A_0 \equiv$ Universal SSB trilinear interaction
- $\mu \equiv$ SUSY bilinear Higgs parameter
- $m_A \equiv$ The pseudo scalar Higgs mass
- $\tan\beta \equiv \frac{v_u}{v_d}$
- $sign(\mu) \equiv$ The sign of SUSY bilinear Higgs parameter $sgin\mu > 0$

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

$$
\begin{array}{rcccl}
0 & \leq & m_{10} & \leq & 10\,\mathrm{TeV}, \\
0 & \leq & m_{\bar{5}} & \leq & 5\,\mathrm{TeV}, \\
0 & \leq & M_{1/2} & \leq & 2\,\mathrm{TeV}, \\
0 & \leq & \mu, m_A & \leq & 2\,\mathrm{TeV},
\end{array}
$$

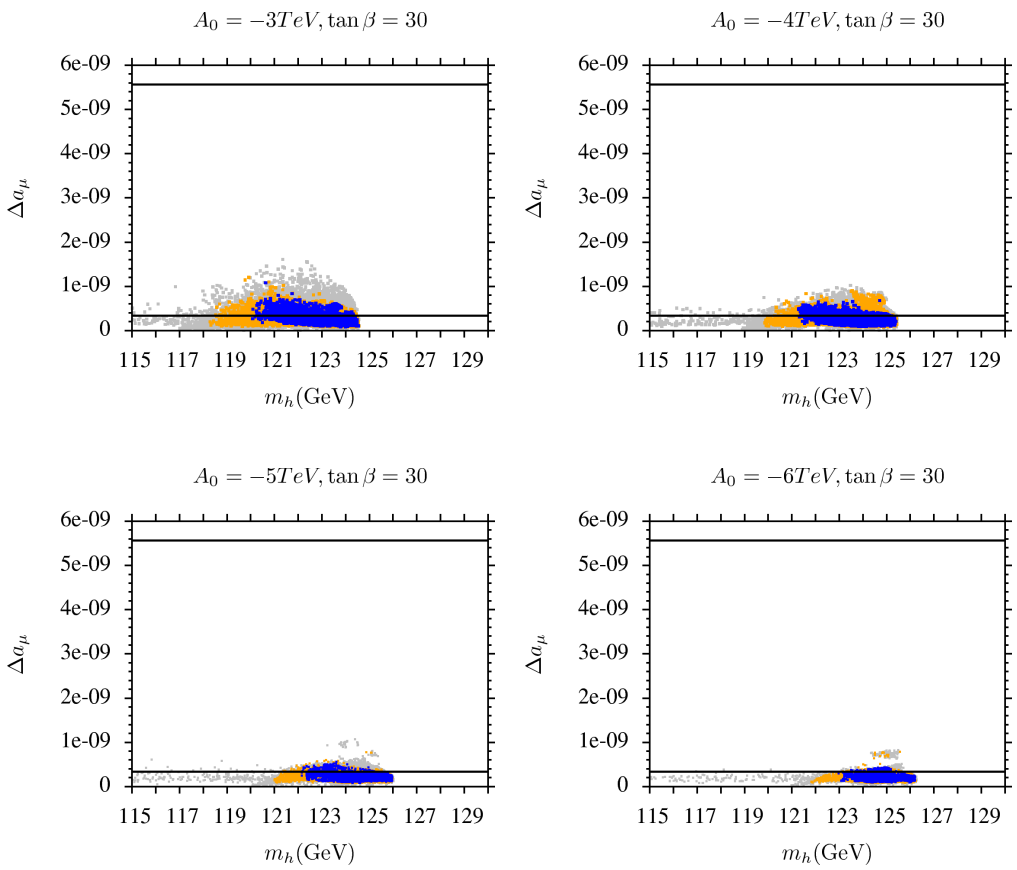
$A_0 = -6, -5, -4, -3, 0, 4\,\mathrm{TeV}$, $\tan\beta = 10, 30, 60$,

$\mathrm{sign}(\mu) > 0$, $m_t = 173.3\,\mathrm{GeV}$.

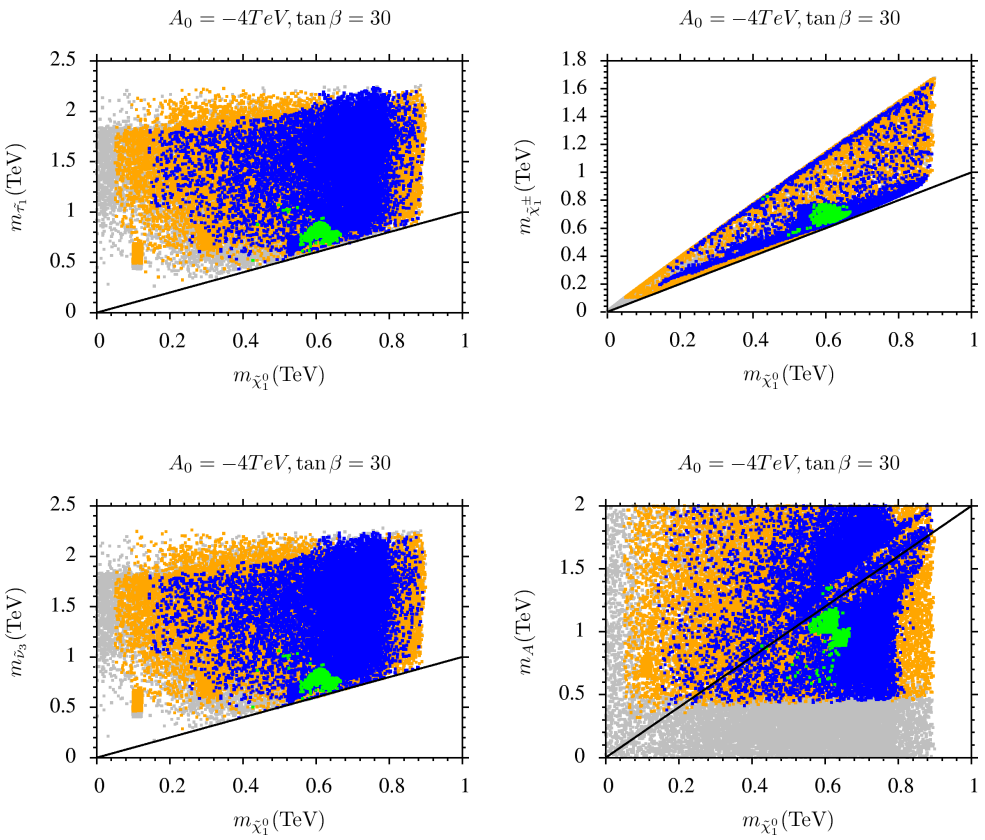
[1] F. E. Paige, S. D. Protopopescu, H. Baer and X. Tata, arXiv:0312045 [hep-ph] .

Constraints

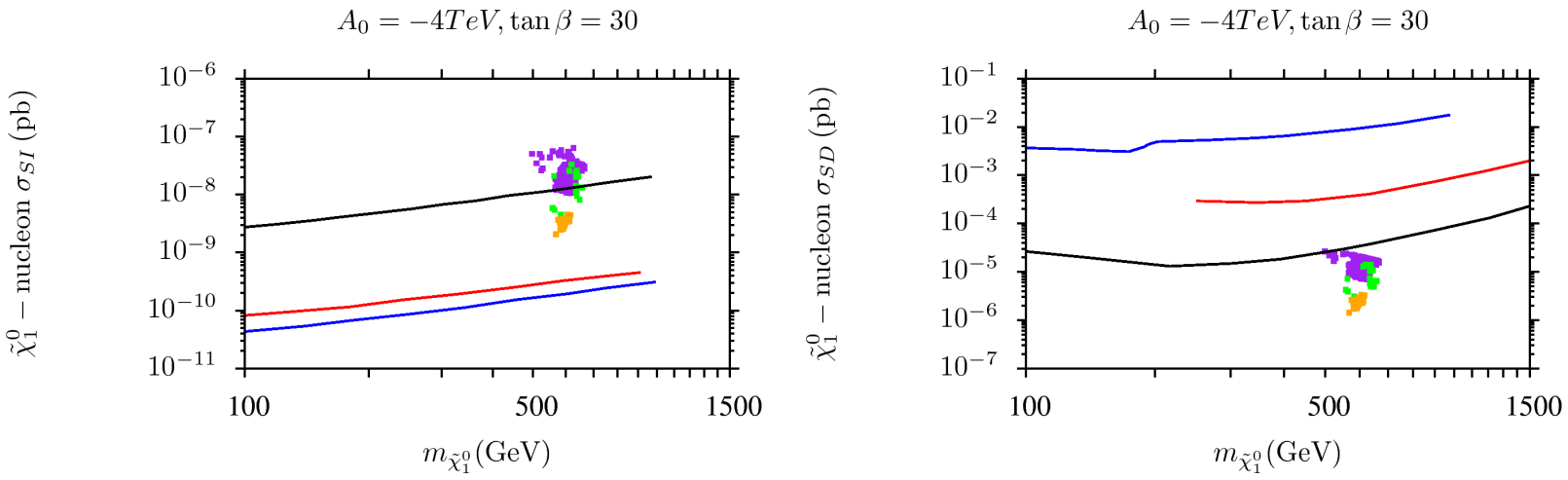
$$124 \lesssim m_h \text{ (lightest Higgs mass)} \lesssim 127 \text{ GeV},$$
$$0.2 \times 10^{-9} \lesssim BR(B_s \to \mu^+\mu^-) \lesssim 6.2 \times 10^{-9} \ (2\sigma),$$
$$0.15 \lesssim \frac{BR(B_u \to \tau\nu_\tau)MSSM}{BR(B_u \to \tau\nu_\tau)SM} \lesssim 2.03 \ (2\sigma),$$
$$2.85 \times 10^{-4} \lesssim BR(b \to s\gamma) \lesssim 4.24 \times 10^{-4} \ (2\sigma),$$
$$\Omega_{\rm CDM} h^2 = 0.111^{+0.028}_{-0.037} \ (5\sigma),$$
$$3.4 \times 10^{-10} \lesssim \Delta a_\mu \lesssim 55.6 \times 10^{-10} \ \ (3\sigma).$$



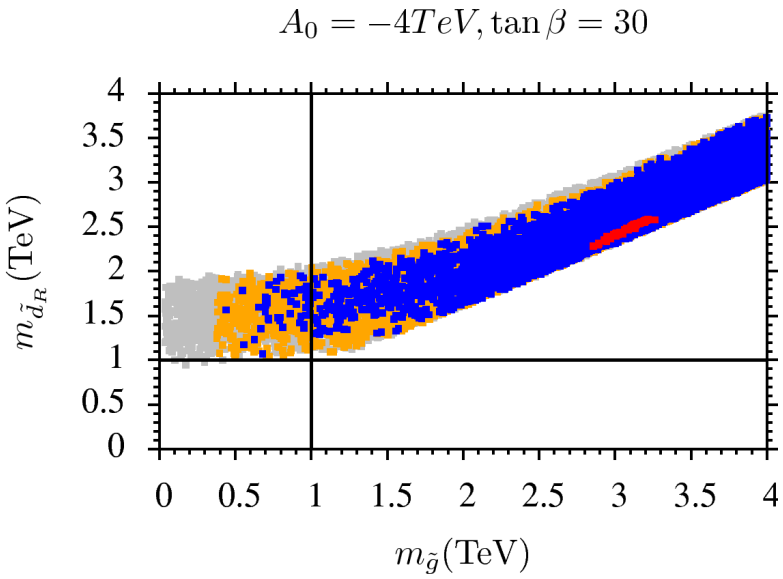
Plots in (Δa_μ, m_h)-plane. Gray points satisfy the requirements of REWSB and neutralino LSP. Orange points satisfy mass bounds and B-physics bounds. Blue points are subset of the orange points and represent solutions satisfying the WMAP bounds at 5σ and $m_{\tilde{g}}$, $m_{\tilde{d}_R} \geq 1$ TeV.



Plots in ($m_{\tilde{\chi}_1^0}$, $m_{\tilde{\tau}_1}$)-plane, ($m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_1^\pm}$)-plane, ($m_{\tilde{\chi}_1^0}$, $m_{\tilde{\nu}_3}$)-plane and ($m_{\tilde{\chi}_1^0}$, m_A)-plane. Gray points satisfy the requirements of REWSB and neutralino LSP. Orange points satisfy mass bounds and B-physics bounds. Blue points are subset of the orange points and represent solutions satisfying WMAP(5σ) bounds, $124\ \mathrm{GeV} \leq m_h \leq 127$ GeV, $m_{\tilde{g}}$, $m_{\tilde{d}_R} \gtrsim 1$ TeV. Green points are subset of the blue points and satisfy the 3σ bounds on Δa_μ.



The SI and SD cross sections of neutralino elastic scattering with nucleon, along with the current and future bounds of direct and indirect dark matter detection experiments. All points satisfy all the requirements of REWSB, neutralino LSP, mass bounds, B-physics bounds, the WMAP bounds, Higgs boson mass and Δa_μ bound. Purple, green and orange points represent the results, respectively, in the bino-Higgsino mixed dark matter region, the neutralino-sneutrino coannihilation region, and the A-resonance region. In the left panel, the black line represents the current upper bound by XENON100, while the blue (red) line represents a future reach by XENON 1T (SuperCDMS). In the right panel, the current upper bounds by Super-K (blue line) and IceCube DeepCore (red line) are shown. A future IceCube DeepCore bound is depicted by the black line.



Plots in ($m_{\tilde{g}}$, $m_{\tilde{d}_R}$)-plane. Gray points satisfy the requirements of REWSB and neutralino LSP. Orange points satisfy mass bounds and B-physics bounds. Blue points are subset of the orange points and represent solutions satisfying WMAP(5σ) bounds, 124 $\mathrm{GeV} \leq m_h \leq$ 127 GeV, $m_{\tilde{g}}$, $m_{\tilde{d}_R} \gtrsim$ 1 TeV. Red points are subset of the blue points and satisfy the 3σ bounds on Δa_μ and current upper bounds by XENON100.

	Point 1	Point 2	Point 3
m_{10}	2382	2945	3788
$m_{\bar{5}}$	542.7	598.8	1131
$M_{1/2}$	1471	1418	912.2
A_0	-4000	-5000	-6000
$\tan\beta$	30	30	30
μ	697.8	688.9	586.4
m_A	1127	917.5	882.4
m_h	124.5	125	125
m_H	1134	924	888
$m_{H^\pm}$	1138	927	892
$m_{\tilde{g}}$	3200	3119	2145
$m_{\tilde{\chi}^0_{1,2}}$	632,711	612,701	397,582
$m_{\tilde{\chi}^0_{3,4}}$	716,1218	704,1180	597,788
$m_{\tilde{\chi}^\pm_{1,2}}$	719,1201	709,1163	591,776
$m_{\tilde{u}_{L,R}}$	3701,3677	4007,4012	4161,4229
$m_{\tilde{t}_{1,2}}$	1766,2779	1663,2891	1404,2839
$m_{\tilde{d}_{L,R}}$	3702,2717	4008, 2612	4162,1931
$m_{\tilde{b}_{1,2}}$	2286,2781	2028,2892	921,2848
$m_{\tilde{\nu}_1}$	1206	1236	1409
$m_{\tilde{\nu}_3}$	822	638	690
$m_{\tilde{e}_{L,R}}$	1217,2331	1249,2867	1419,3682
$m_{\tilde{\tau}_{1,2}}$	839,1963	668,2441	721,3241
$\sigma_{SI}(\mathrm{pb})$	1.17×10^{-8}	1.12×10^{-8}	2.45×10^{-9}
$\sigma_{SD}(\mathrm{pb})$	1.25×10^{-5}	1.06×10^{-5}	4.11×10^{-6}
$\Omega_{CDM}h^2$	0.11	0.11	0.11
Δa_μ	3.40×10^{-10}	3.40×10^{-10}	3.86×10^{-10}

Summary

Higgs boson with mass at around $125 - 126$ GeV has been discovered a the LHC:

- If low energy SUSY is realized in nature in MSSM form, this Higgs boson mass implies at least the masses of the whole sfermions are in multi-TeV range or above.
- In order to address muon anomalous magnetic dipole moment (g-2) problem, we need to have light sparticle masses.
- These problems can be addressed simultaneously in SUSY $SU(5)$ model in gravity mediation framework.
- Neutralino-Higgsino mixed, neutralino-sneutrino and A-resonance solutions are found consistent with all constraints described above. In our case, these solutions will also be tested in near future by experiments like XENON100.