Muon $g-2$, Neutralino Dark Matter and Stau NLSP

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Outline

- SUSY and MSSM
- Muon $g-2$ in MSSM
- Fundamental parameter space
- Experimental Constraints
- Mass Spectrum
- Dark Matter Implications
- Conclusion

SUSY and MSSM

- Resolution of the gauge hierarchy problem.
- Presence of non-baryonic dark matter (DM) candidates.
- Unification of the SM gauge couplings assuming TeV scale SUSY.
- Addresses muon $g-2$ anomaly $\rightarrow \Delta \mathrm{a}_{\mu} = (25.1 \pm 5.9) \times 10^{-10}$

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

- First example of quark-lepton unification.
- Electric charge quantization.
- Matter fields reside in $(4, 2, 1)$ and $(\bar{4}, 1, 2)$ representations.
- Absence of gauge boson mediated proton decay.
- If $4 - 2 - 2$ is broken to the SM using tensor representations a Z_2 gauge symmetry is left unbroken.

  In a supersymmetric setting this is precisely "matter" parity $\Longrightarrow$ stable

  LSP dark matter candidate.

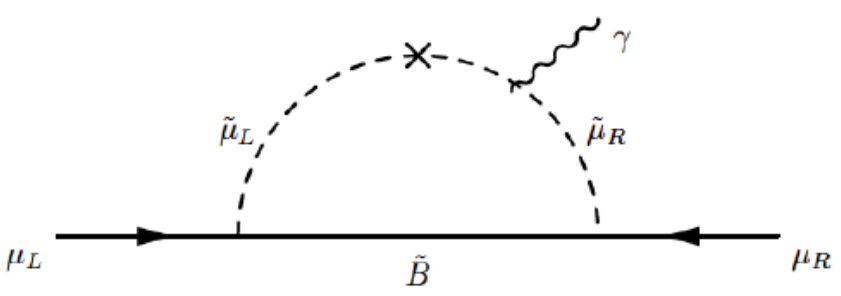
SUSY 4-2-2

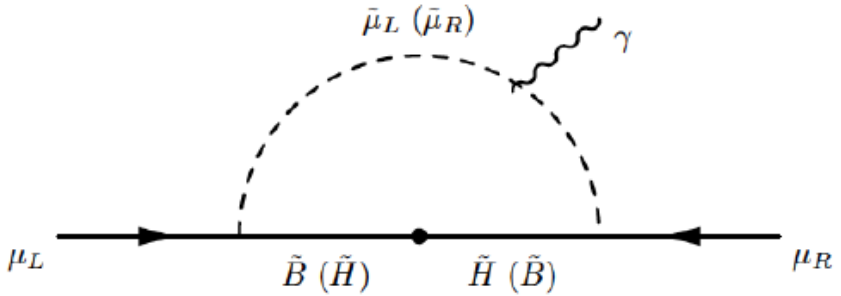
- In this talk, based on SUSY 4-2-2 I will assume that the soft SUSY breaking scalar and gaugino masses do not respect left-right symmetry but are flavor universal.
- Non-universal gaugino masses at the GUT scale:

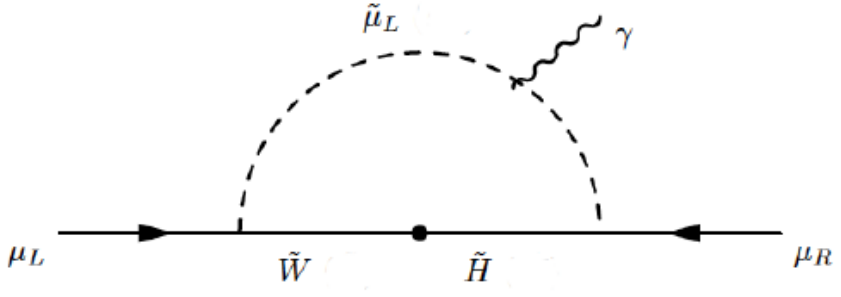
$$M_1 = \frac{3}{5} M_{2R} + \frac{2}{5} M_4 \ ,$$

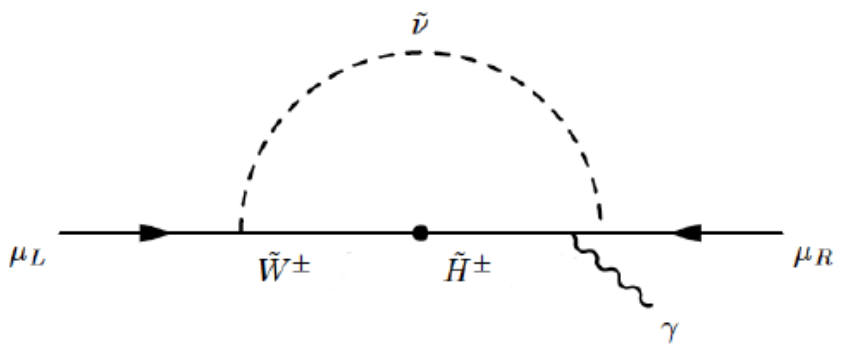
where M_{2R} and M_4 denote the gaugino mass terms for $SU(2)_R$ and $SU(4)_c$, respectively, and $M_3 = M_4$ at M_{GUT}.

Muon $g-2$ in MSSM









$$\Delta a_\mu \approx C_\mu \,\mathrm{sign}(\mu M_i) \left(\frac{500\ \mathrm{GeV}}{M_{\mathrm{SUSY}}}\right) \frac{\tan\beta}{40}\,, \quad C_\mu = \begin{cases} \dfrac{2.4\mu}{500\ \mathrm{GeV}} \times 10^{-10} & \text{for BLR}\,, \\ 1.2 \times 10^{-10} & \text{for BHL}\,, \\ -2.4 \times 10^{-10} & \text{for BHR}\,, \\ 21 \times 10^{-10} & \text{for WHL}\,. \end{cases}$$

Fundamental parameter space

Low Scale	GUT Scale
$m_{\tilde{\mu}_L}, m_{\tilde{\nu}}$	m_L
$m_{\tilde{\mu}_R}$	m_R
$M_{\tilde{B}}$	M_1
$M_{\tilde{W}}$	M_2
μ	m_{H_u}, m_{H_d}
A_μ	A_0
$\tan\beta$	$\tan\beta$

$$
\begin{array}{lll}
0 \leq & m_L & \leq 5 \text{ TeV} \\
0 \leq & M_{2L} & \leq 5 \text{ TeV} \\
-3 \leq & M_3 & \leq 5 \text{ TeV} \\
-3 \leq & A_0/m_L & \leq 3 \\
1.2 \leq & \tan\beta & \leq 60 \\
0 \leq & \mathrm{x_{LR}} & \leq 3 \\
-3 \leq & \mathrm{y_{LR}} & \leq 3 \\
0 \leq & \mathrm{x_d} & \leq 3 \\
-1 \leq & \mathrm{x_u} & \leq 2
\end{array}
$$

where,

$$
\begin{aligned}
m_R &= x_{LR} m_L \\
M_{2R} &= y_{LR} M_{2L} \\
m^2_{H_d} &= x_d m^2_L \\
m^2_{H_u} &= x_u m^2_L
\end{aligned}
$$

Experimental Constraints

$$m_h = 123 - 127 \text{ GeV}$$

$$m_{\tilde{g}} \geq 2.1 \text{ TeV } (800 \text{ GeV if it is NLSP})$$

$$0.8 \times 10^{-9} \leq \text{BR}(B_s \to \mu^+\mu^-) \leq 6.2 \times 10^{-9} \ (2\sigma)$$

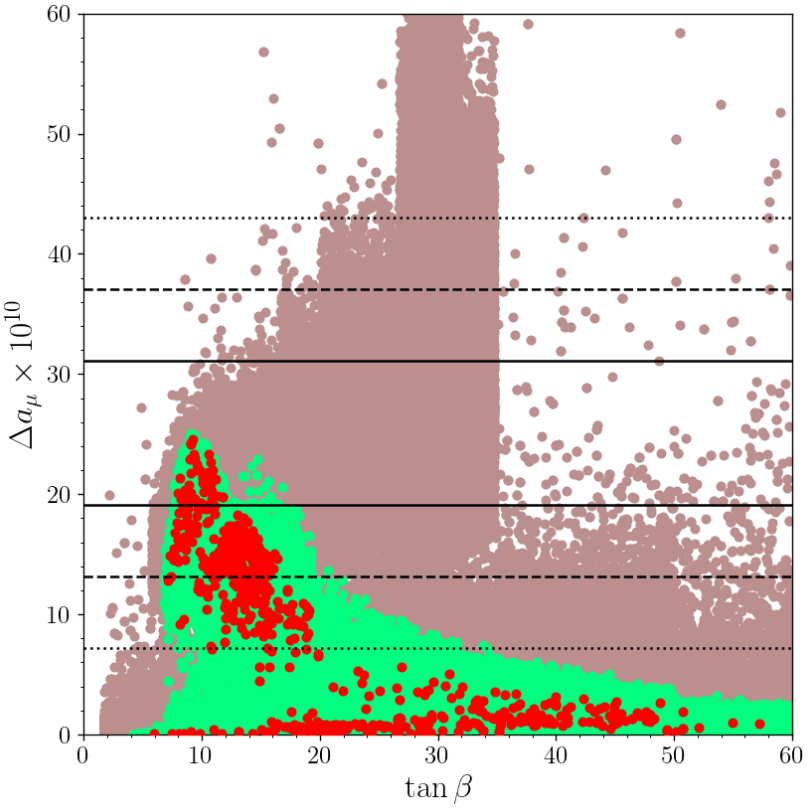
$$2.99 \times 10^{-4} \leq \text{BR}(B \to X_s\gamma) \leq 3.87 \times 10^{-4} \ (2\sigma)$$

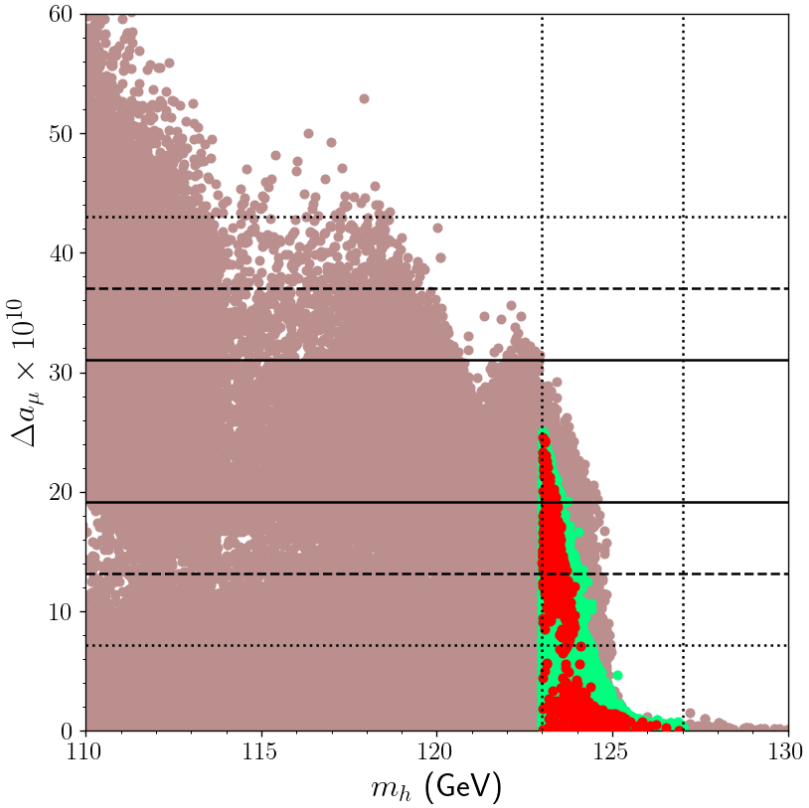
$$0.114 \leq \Omega_{\text{CDM}}h^2 \leq 0.126$$

$$m_t = 173.3 \text{ GeV}$$

$$\mu > 0$$

tan β and Higgs mass

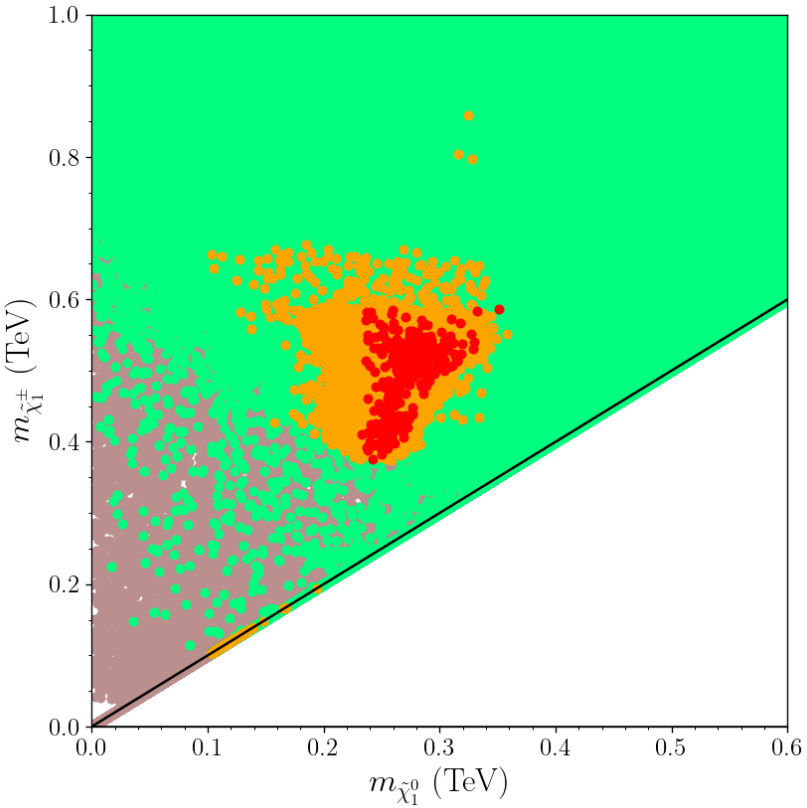


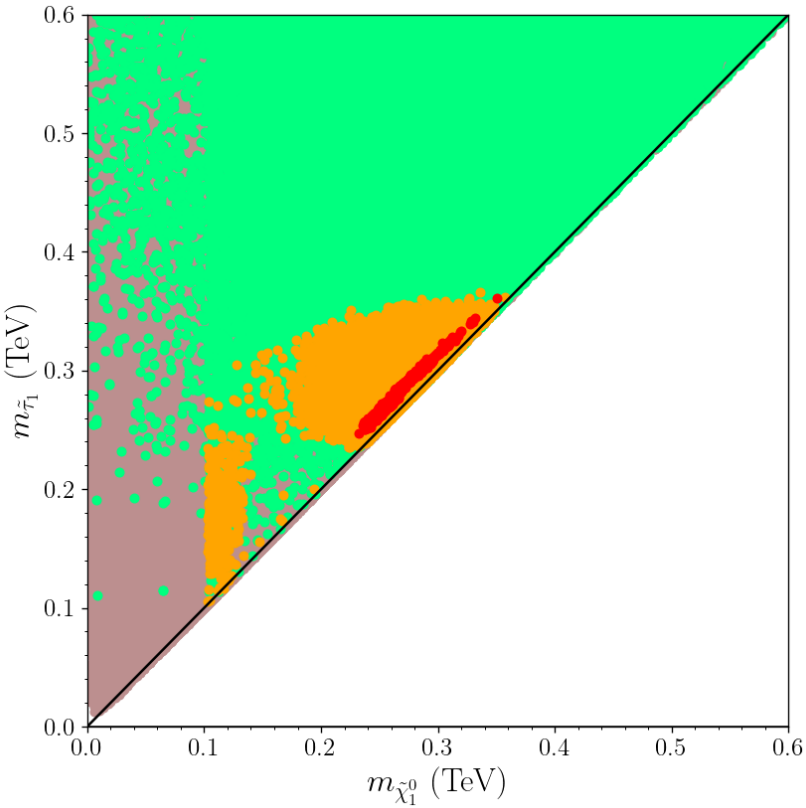


$$\Delta m_h^2 \simeq \frac{m_t^4}{16\pi^2 v^2 \sin^2\beta}\frac{\mu A_t}{M_{\rm SUSY}^2}\left[\frac{A_t^2}{M_{\rm SUSY}^2} - 6\right] +$$

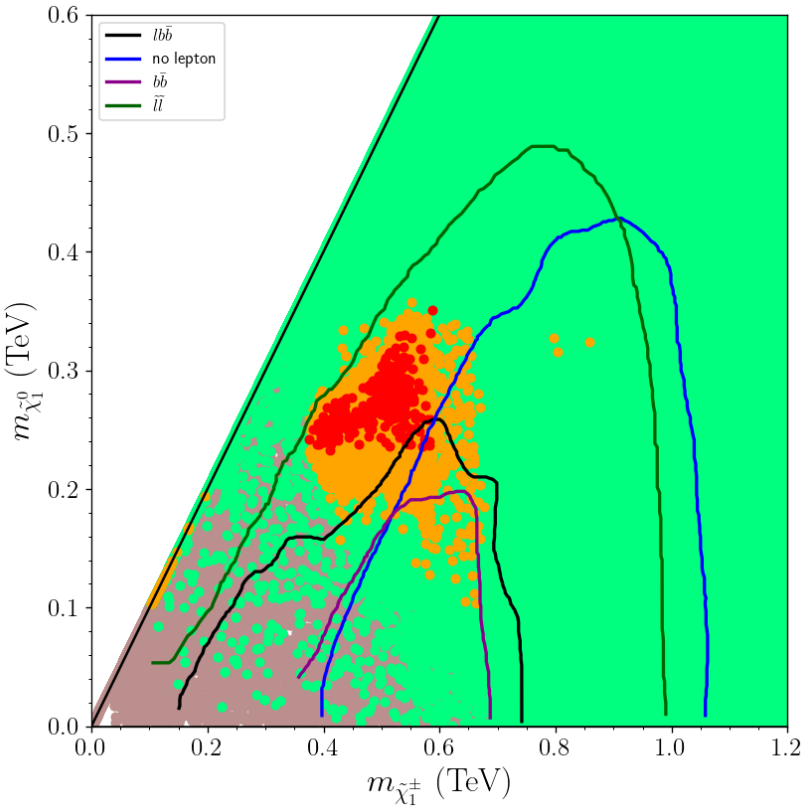
$$\frac{y_b^4 v^2}{16\pi^2}\sin^2\beta\frac{\mu^3 A_b}{M_{\rm SUSY}^4} + \frac{y_\tau^4 v^2}{48\pi^2}\sin^2\beta\frac{\mu^3 A_\tau}{m_{\tilde\tau}^4}$$

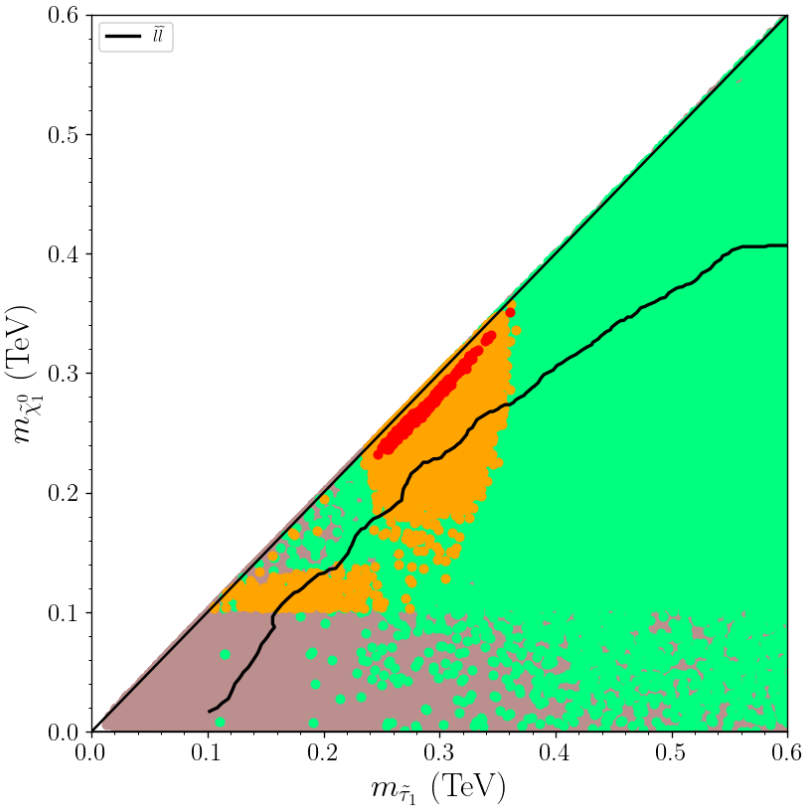
Stau Coannihilation



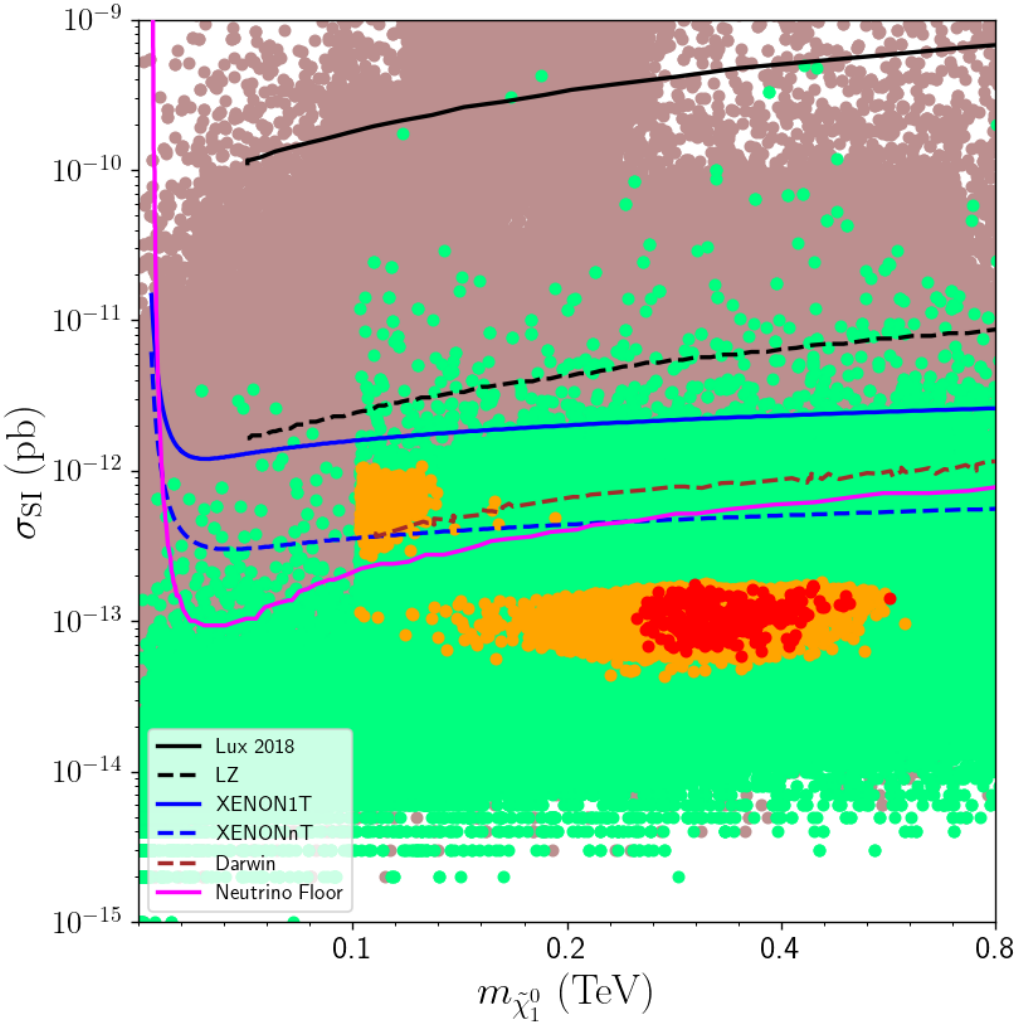


Bounds from the collider searches





Dark Matter Implications



Benchmark table

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
$m_{\widetilde{L}}$	335.319	375.605	311.513	377.107	330.994	361.925
M_1	616.148	672.019	633.965	767.804	787.614	1282.26
M_{2L}	731.027	747.131	603.037	721.392	698.554	327.194
M_3	4819.28	4920.39	4274.83	5067.11	4789.29	4505.82
$A_0/m_{\widetilde{L}}$	-1.87	-1.71	-2.93	-1.52	-1.52	0.73
$\tan\beta$	9.08099	11.7627	16.1768	9.44659	7.63402	18.6131
x_{LR}	0.79	0.88	2.12	0.88	0.86	2.2
y_{LR}	-2.99	-2.89	-2.97	-2.91	-2.69	-2.65
$m_{\widetilde{R}}$	265.065	329.393	660.442	331.076	285.988	795.804
M_{2R}	-2185.94	-2160.23	-1793.28	-2098.4	-1880.17	-866.78
μ	4875.83	4951.28	4402.88	5098.57	4839.6	4493.68
$\Delta a_\mu \times 10^{10}$	**24.28**	19.8	15.05	16.99	14.91	13.92
m_h	123.07	123.142	123.031	**123.541**	123.03	123.215
m_H	4999.35	5061.57	4404.11	5222.41	5062.4	4498.81
m_A	4999.31	5061.55	4404.11	5222.38	5062.35	4498.81
$m_{H^\pm}$	4996.57	5058.82	4401.99	5219.5	5059.58	4496.11
$m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}$	238, 543	263, 557	250, 441	305 , 532	315, 514	194, 530
$m_{\tilde{\chi}_3^0}, m_{\tilde{\chi}_4^0}$	4991,4992	5068, 5069	4504, 4505	5219, 5220	4956, 4957	4607, 4607
$m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^\pm}$	544, 4992	557, 5069	442, 4505	532, 5220	515, 4957	195, 4607
$m_{\tilde{g}}$	9549	9741	8555	10017	9501	9032
$m_{\tilde{u}_1}, m_{\tilde{u}_2}$	8049, 8050	8210, 8211	7231, 7259	8437, 8439	8012, 8012	7630, 7677
$m_{\tilde{t}_1}, m_{\tilde{t}_2}$	6979, 7525	7123, 7670	6267, 6724	7319, 7886	6945, 7492	6712, 7126
$m_{\tilde{d}_1}, m_{\tilde{d}_2}$	8051, 8055	8212, 8216	7231, 7262	8438, 8444	8012, 8018	7630, 7678
$m_{\tilde{b}_1}, m_{\tilde{b}_2}$	7518, 8031	7662, 8177	6713, 7196	7878, 8417	7484, 8001	7117, 7598
$m_{\tilde{\nu}_{e,\mu}}, m_{\tilde{\nu}_\tau}$	430, 418	459, 438	369, 331	451, 437	403, 394	293, 246
$m_{\tilde{e}_1,\tilde{\mu}_1}, m_{\tilde{e}_2,\tilde{\mu}_2}$	368, 437	447, 465	377, 703	445, 458	410, 446	303, 937
$m_{\tilde{\tau}_1}, m_{\tilde{\tau}_2}$	255, 484	284, 535	268, 690	320, 523	325, 489	200, 919
$\sigma_{SI}(pb)$	1.15×10^{-13}	7.7×10^{-14}	6.7×10^{-14}	1.05×10^{-13}	1.71×10^{-13}	4.86×10^{-13}
$\sigma_{SD}(pb)$	1.05×10^{-10}	1.04×10^{-10}	1.69×10^{-10}	8.97×10^{-11}	1.06×10^{-10}	2.58×10^{-9}
Ωh^2	0.118	0.119	0.116	0.115	0.115	0.001

Conclusion

- Higgs mass problematic for tan$\beta \gtrsim 17$
- Stau-neutralino Coannihilation
- A Bino-like Dark Matter
- Spin-independent scattering cross-sections on the order of 10^{-13} pb.
- Testable in the near future.