Relatively Heavy Higgs Boson From More Generic Gauge Mediation

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JLE, Ibe, Yanagida, arXiv:1108.3437

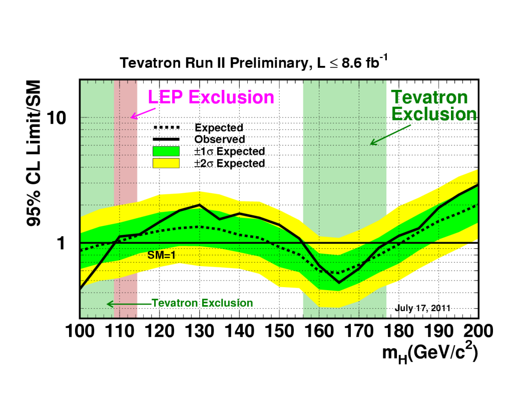
Outline

Should We Still Study SUSY

- Tuning arguments have worked in the past
- Tuning not yet to severe
- Gauge coupling unification is quite suggestive
- SUSY still has viable dark matter candidates
- True killer of the MSSM (Heavy Higgs) seems unlike

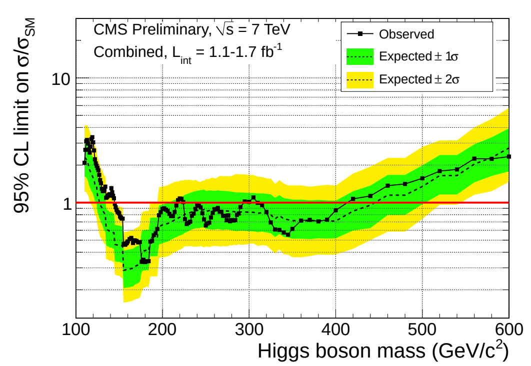
Higgs Searches: Pre LHC

- Pre LHC Higgs: Roughly $m_H > 114\text{GeV}$, $m_H \lesssim 600$ GeV
- Pre LHC Supersymmetric Higgs: $m_H \lesssim 130$ GeV



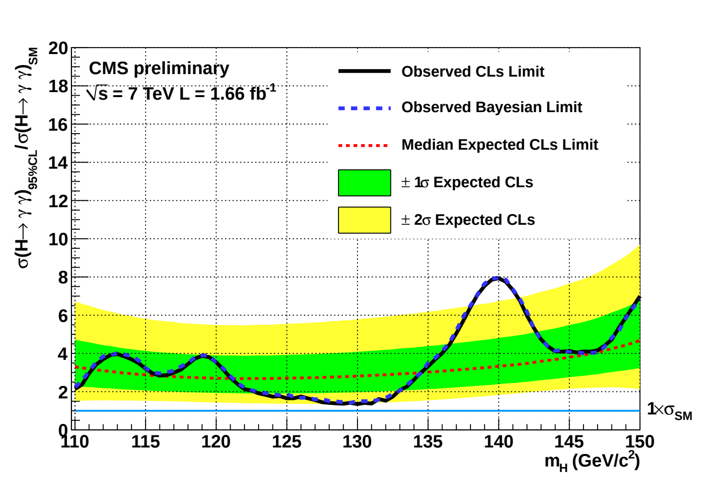
Higgs Searches at LHC

- LHC is making significant progress
- The Higgs is either Very Heavy or close to LEP bound
- CMS exclusion plot (Atlas similar except 140GeV)



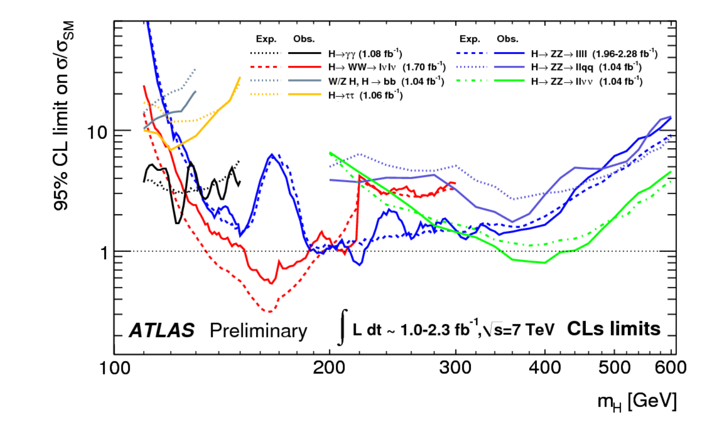
CMS $H \to \gamma\gamma$

- CMS sees prominent peek at 140 GeV, mostly in H$\to \gamma\gamma$



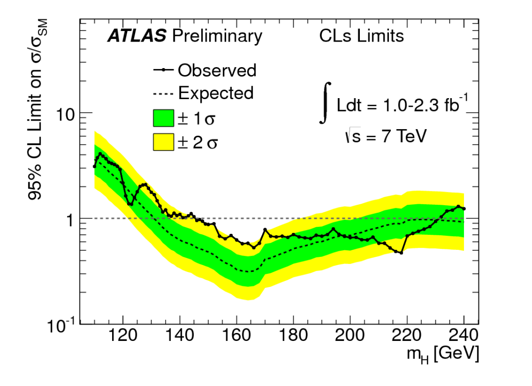
Atlas $H \rightarrow \gamma\gamma$

- Atlas sees no 140 GeV peek in H$\rightarrow \gamma\gamma$



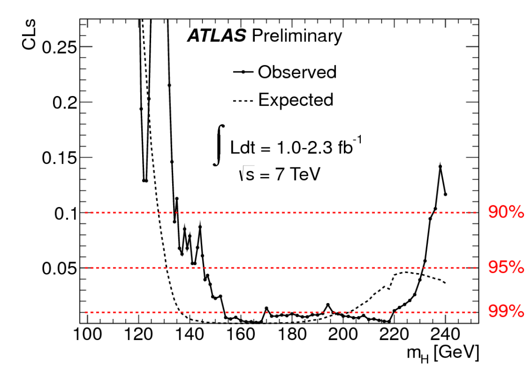
Higgs Searches at LHC: Continued

- Atlas Low Mass exclusion plot
- Atlas believes $m_H = 128$ GeV (Private Conversation)



Higgs Searches at LHC: Continued

- Exclusion confidence levels of SM Higgs

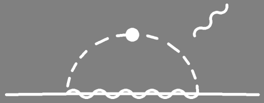


Why Gauge Mediation?

- Softly broken MSSM has many parameters(105 Martin)

$$m^2_{\tilde{f}}, M_i, A_{ij}, B_{ij}$$

- Generic Soft Masses and A terms give FV



- Phenomenology requires

$$m^2_{\tilde{f}_{ij}} \simeq M_{f_i}\delta_{ij} \text{ etc.}$$

- Need a well motivated model with no FV
- Minimal gauge mediation also has no CP problem

Conventional Gauge Mediated SUSY Breaking

- Messengers are in GUT consistent representations
- Simplest representation, $5 + \bar{5}$

$$\Phi = (\Phi_L \;\; \Phi_C) \qquad \bar{\Phi} = (\bar{\Phi}_L \;\; \bar{\Phi}_C)$$

- Messenger parity sequesters the messenger sector

$$\Phi \to -\Phi \qquad \bar{\Phi} \to -\bar{\Phi}$$

- Messenger sector couples to a gauge singlet spurion

$$W_M = Z\bar{\Phi}\Phi \qquad Z = M + \theta^2 F$$

Without Messenger Parity

- Messengers quantum numbers identical to SM fields
- Flavor violating interactions not forbidden

$$W = \rho_1 \Phi_{\bar{L}} Q_L \bar{U}_R + \rho_2 \bar{\Phi}_{\bar{L}} Q_L \bar{D}_R + \rho_3 \bar{\Phi}_{\bar{L}} L_L \bar{E}_R \ ,$$

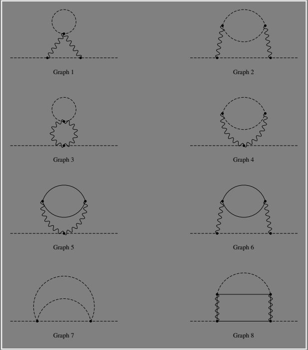
- Generic soft masses are generated
- Operators contributing to Proton decay

$$W = \lambda_1 \Phi_D Q_L Q_L + \lambda_2 \bar{\Phi}_D Q_L L_L \ ,$$

- Messenger parity seems quite necessary

Mass Generation in Gauge Mediation

- Scalar masses generated at two loops



$$m_{\tilde{f}}^2 \simeq \left(\frac{g^2}{16\pi^2}\right)^2 \frac{F^2}{M^2}$$

Mass Generation in Gauge Mediation

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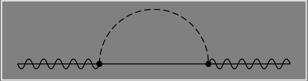
$$m_{\tilde{f}}^2 \simeq \left(\frac{g^2}{16\pi^2}\right)^2 \frac{F^2}{M^2}$$

- Gaugino masses generated at one loops



$$m_{\tilde{\chi}} \simeq \left(\frac{g^2}{16\pi^2}\right) \frac{F}{M}$$

Mass Generation in Gauge Mediation

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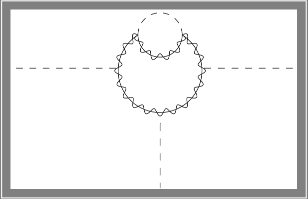
$$m_{\tilde{f}}^2 \simeq \left(\frac{g^2}{16\pi^2}\right)^2 \frac{F^2}{M^2}$$

- Gaugino masses generated at two loops

$$m_{\tilde{\chi}} \simeq \left(\frac{g^2}{16\pi^2}\right) \frac{F}{M}$$

- Trilinears at two loops



$$\frac{A_t^2}{m_{\tilde{f}}^2} \sim \frac{g^2}{16\pi^2} \ll 1$$

Higgs Boson of mGMSB

- $A \simeq 0$ minimal gauge mediation
- One-loop Higgs mass

$$m_{h^0}^2 \lesssim m_Z^2 \cos^2 2\beta + \frac{3}{4\pi^2} y_t^2 m_t^2 \sin^2\beta \left(\log \frac{m_{\tilde{t}}^2}{m_t^2} + \frac{A_t^2}{m_{\tilde{t}}^2} - \frac{A_t^4}{12 m_{\tilde{t}}^4} \right) .$$

- Larger log enhance term still present
- A_t contribute very little
- $m_H < 120$ GeV even for $m_{\tilde{g}} = 2.5$ TeV

More Generic Gauge Mediation

- Are large *A*-terms possible in gauge mediation?
  - Messenger parity$\rightarrow$ the Yukawa and messegner sector interact only at the loop level
  - SUSY breaking only communicated through gauge fields
  - A_t not possible at one-loop

- Wish list for more generic gauge mediation
  - Messenger Yukawa sector mixing allowed
  - No flavor violation
  - No proton decay problems

SUSY-Zero and Messenger Higgs Mixing

- Gauge mediation without messenger parity

	ϕ_+	H_u	H_d	**10**	**5***	$\bar{N}_R$	Φ	$\bar{\Phi}$	Z
$U(1)$	$+1$	-2	-3	$+1$	$+2$	0	0	0	0

$$W = gZ\bar{\Phi}\Phi + \frac{\langle \phi_+^2 \rangle}{\Lambda^2} Z\bar{\Phi}H_u \ ,$$

- Negatively charged couplings forbidden by holomorphy

$$W =\subset \underset{0\ +1\ +1}{\rho_1 \Phi_{\bar{L}} Q_L \bar{U}_R} + \underset{0+1+2}{\rho_2 \bar{\Phi}_{\bar{L}} Q_L \bar{D}_R} + \underset{0\ +2\ +1}{\rho_3 \bar{\Phi}_{\bar{L}} L_L \bar{E}_R} \ ,$$

$$W = \underset{0\ +1+1}{\lambda_1 \Phi_D Q_L Q_L} + \underset{0\ +1+2}{\lambda_2 \bar{\Phi}_D Q_L L_L} \ ,$$

Type-II Gauge Mediation

- Type-II gauge mediation, H_u mixes with messengers

$$W = gZ\bar{\Phi}\tilde{\Phi} + g' Z\bar{\Phi}_{\bar{L}}\tilde{H}_u + \tilde{\mu}\tilde{H}_u H_d + \tilde{y}_{Uij}\tilde{H}_u Q_{Li}\bar{U}_{Rj} \ ,$$

- Rotating, a messenger Yukawa interaction emerges

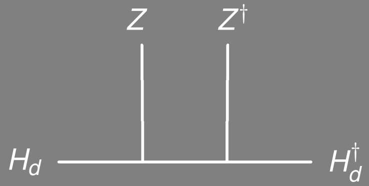
$$W = \bar{g}Z\bar{\Phi}\Phi + \mu H_u H_d + \mu' \Phi_{\bar{L}} H_d + y_{Uij} H_u Q_{Li}\bar{U}_{Rj} + y'_{Uij}\Phi_{\bar{L}} Q_{Li}\bar{U}_{Rj} \ ,$$

$$y_{Uij} = \frac{g}{\sqrt{g^2 + g'^2}}\tilde{y}_{Uij} \ , \quad y'_{Uij} = \frac{g'}{\sqrt{g^2 + g'^2}}\tilde{y}_{Uij} \ .$$

- Type-II has minimal flavor violation (MFV)
- Messenger Higgs mixing suppressed by μ'/M

Tree Level Effects

- Higgs messenger mixing gives tree level Higgs mass

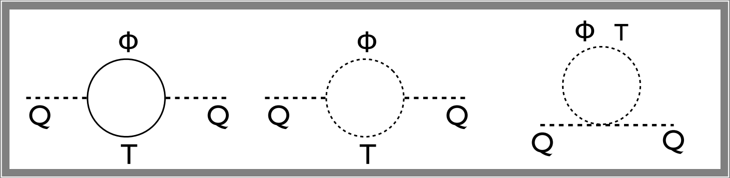


- Tree level effects suppressed by messenger scale

$$m_{H_d}^2 = -\mu'^2 \frac{F^2}{M^4 - F^2} .$$

One-Loop Scalar Masses

- One-loop squark and slepton masses



- One-loop contribution is negative

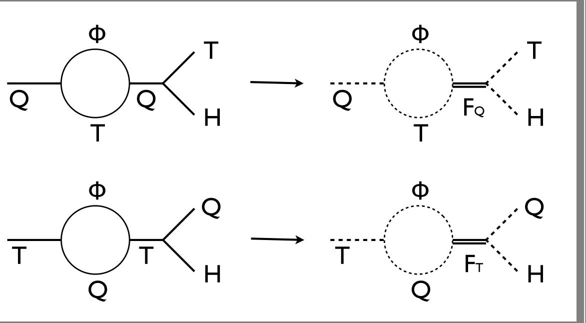
$$\delta m_{Q_3}^2 = \frac{1}{2}\delta m_T^2 \quad = \quad \simeq \frac{8}{3}\left(\frac{\alpha_3}{4\pi}\right)^2 \frac{F^2}{M^2} - \frac{y_t'^2}{48\pi^2}\frac{F^2}{M^2}\frac{F^2}{M^4}\,, \qquad (x \ll 1)$$

- Positive stop mass constraints

$$\frac{F}{M^2} \ll 2\sqrt{2} \times \frac{\alpha_3}{y_t'}\,.$$

A-Terms in Gauge Mediation

- A-terms from wave function renormalization



- A-term not suppressed by F/M^2 (can be large)

$$A_t = -\frac{3}{32\pi^2} y_t'^2 \frac{F}{M} \frac{1}{x} \log\left(\frac{1+x}{1-x}\right) \simeq -\frac{3y_t'^2}{16\pi^2} \frac{F}{M} \qquad (1)$$

Two-Loop Scalar Masses

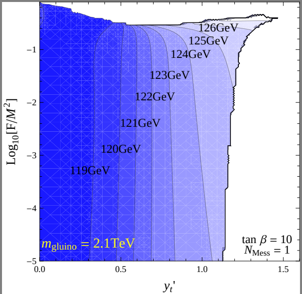
- Two-loop contribution from wave function renormalization

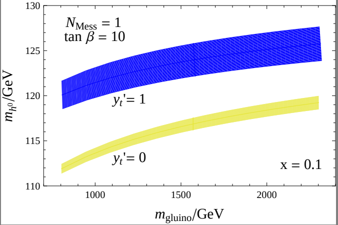
$$\begin{aligned}
\delta m_{Q_3}^2 &= \frac{y_t'^2}{128\pi^4}\left(3y_t'^2 + 3y_t^2 - \frac{8}{3}g_3^2 - \frac{3}{2}g_2^2 - \frac{13}{30}g_1^2\right)\frac{F^2}{M^2}\,, \\
\delta m_{\bar{T}}^2 &= \frac{y_t'^2}{128\pi^4}\left(6y_t'^2 + 6y_t^2 - \frac{16}{3}g_3^2 - 3g_2^2 - \frac{13}{15}g_1^2\right)\frac{F^2}{M^2}\,, \\
\delta m_{H_u}^2 &= -9\frac{y_t^2 y_t'^2}{256\pi^4}\frac{F^2}{M^2}\,.
\end{aligned}$$

- Two loop contribution important, not suppressed by F/M^2.
- Two loop contribution POSITIVE for most y_t'
- Two-loop $>$ One-loop contribution unless $F/M^2 \simeq 1$

Lightest Higgs Boson Mass

- The Lightest Higgs boson mass in Type-II





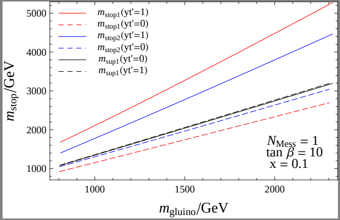
- Upper bound on x from tachyonic stop mas
- Upper bound on y_t' from tachyonic slepton

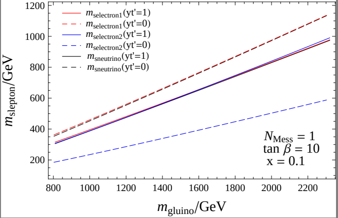
$$\delta\beta_{m_{\tilde{l}}^2} \simeq \frac{1}{8\pi^2}\frac{3}{5} Y g_1^2 \mathcal{S}_{new} \propto m_{Q_3}^2 - 2m_T^2$$

- $\mathcal{S}$ is large and negative because of two-loop contribution

Mass Spectrum of Type-II

- Slepton and squark masses in Tyep-II





- Third generation squark masses significantly increased
- Left-handed slepton masses decreased
- Right-handed slepton masses increased

Conclusion

- LHC excluded Higgs mass in most of 145$\sim$ 400 GeV (95%)
- Some prominent features are emerging
- Vanilla SUSY models have very light Higgs mass
- Using SUSY-zero, Higgs-Messenger mixing possible
- Higgs-Messenger mixing enhances A-terms
- Large A-terms Give larger Higgs masse