Higgs Decays to Neutralinos in GMSB

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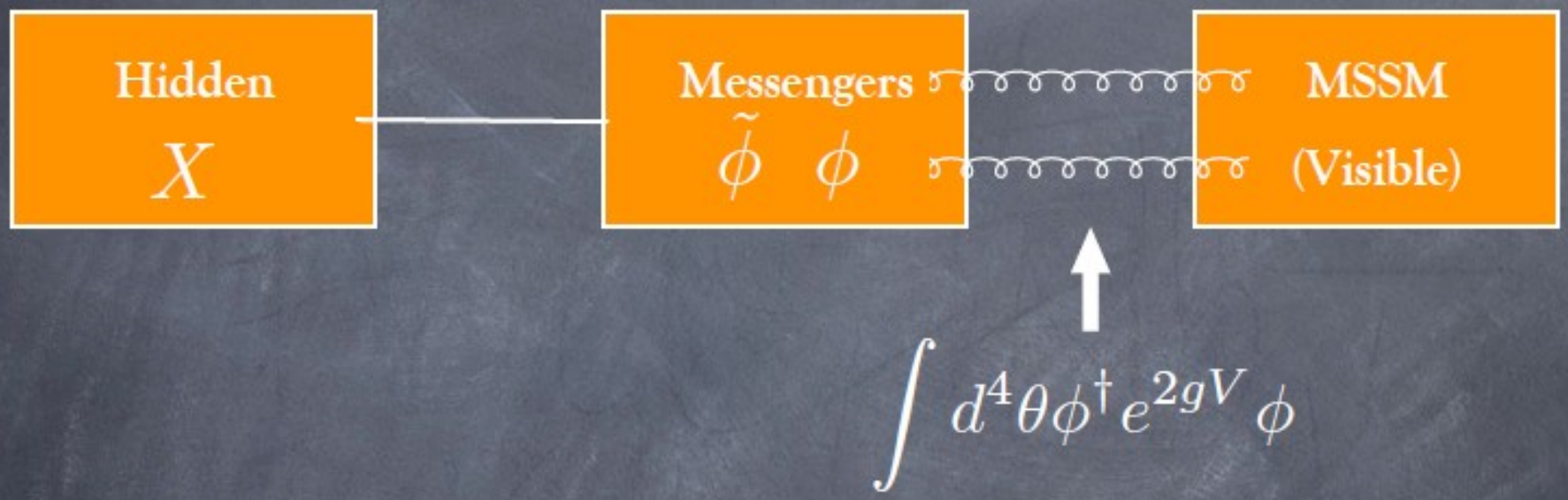
David Morrissey, David Poland, JM arXiv:0909.3523 [hep-ph]

OUTLINE

- Minimal GMSB review
- Non-minimal GMSB motivation
- Higgs Decays to Neutralinos (bounds)
- Higgs Decays to Neutralinos (search)
- Conclusions

Minimal Gauge Mediation



Predictive: Typically a Small number of free parameters

Communicates SUSY breaking with Minimal Flavor Violation

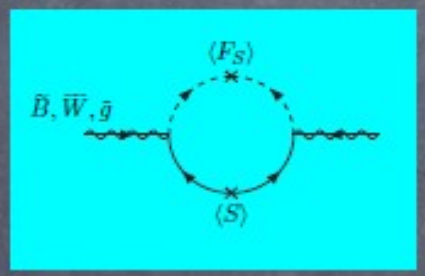
Minimal Gauge Mediation

$$W = \lambda' X \tilde{\phi} \phi$$

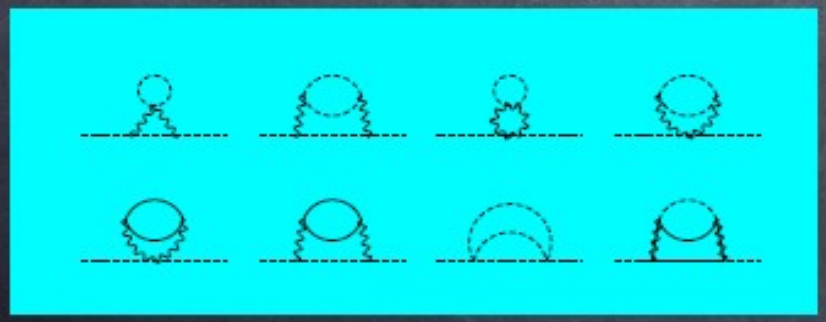
$$X = \langle X \rangle - \theta^2 F$$

$$m^2_{\psi_\phi} = \lambda'^2 \langle X \rangle^2$$

$$m^2_\phi = \begin{pmatrix} \lambda'^2 \langle X \rangle^2 & \lambda' F \\ \lambda' F & \lambda'^2 \langle X \rangle^2 \end{pmatrix}$$



$$M^{(r)}_\lambda = \frac{\alpha^{(r)}}{4\pi} \frac{F}{X}$$



$$m^2_f = 2 \sum_{r=1}^{3} C^r_f \left(\frac{\alpha^{(r)}}{4\pi} \right)^2 \frac{|F|^2}{|X|^2}$$

The mu-Problem in MGM

$$W = \mu H_D H_U$$

1) Gives mass to Charginos $m_{\chi_1^\pm} > 105\mathrm{GeV}$

2) EWSB in MGM demands: $\mu \sim \mathrm{TeV}$

Therefore it is natural to expect a Dynamical origin to the mu-term connected to SUSY Breaking

Gauge Mediation requires some extension to explain this. Simplest models create a "B-term" that is too large.

"Little Hierarchy" in MGM

Automatic Hierarchy

$$\frac{\tilde{m}_{squark}}{\tilde{m}_{slepton}} \sim \left(\frac{4}{5}\right)^{\frac{1}{2}} \frac{g_3^2}{g_1^2} \sim 10.2$$

Experimental Bounds

$$m_{\tilde{e}_R} > 73\text{GeV} \rightarrow m_{sq} > 750\text{GeV}$$

Radiative Corrections

$$\delta m_{H_U}^2 = -\frac{3y_t^2}{4\pi^2} m_{\tilde{t}}^2 \ln(\lambda' \langle X \rangle / m_{\tilde{t}}) < -(600\text{GeV})^2$$

EWSB

$$\frac{m_Z^2}{2} = \frac{m_{H_D}^2 - m_{H_U}^2 \tan\beta^2}{\tan\beta^2 - 1} - \mu^2$$

$$\mu^2 > (600\text{GeV})^2$$

$$T = \frac{\mu^2}{\frac{m_Z^2}{2}} \sim 89 \rightarrow 1\%$$

Non-Minimal Gauge Mediation

"Squashing" the sparticle spectrum is needed for lighter stops

$$m_{sq} \sim \frac{g_3^2}{16\pi^2}\Lambda_q$$

$$m_{sl} \sim \frac{g_1^2}{16\pi^2}\Lambda_\ell$$

$$\Rightarrow \quad \boxed{\frac{m_{sq}}{m_{sl}} \sim \frac{g_3^2}{g_1^2}\left(\frac{\Lambda_q}{\Lambda_\ell}\right) \sim 3}$$

"two-parameter Model" with Non-Minimal Messengers

S. Martin 98

$$W = (\lambda_1 X_1 + \lambda_2 X_2)\tilde{\phi}\phi$$

This fits into the broader framework of "General Gauge Mediation"

Meade, Seiberg, and Shih 08

- Mu and little hierarchy problems exist in Minimal GMSB.
- GMSB can still be flavor blind and have a non-minimal spectrum.
- Non-minimal spectra can help ease the “little hierarchy.”

The Gravitino is the LSP in GMSB

Spontaneously Broken global SUSY has a Goldstino: G_α

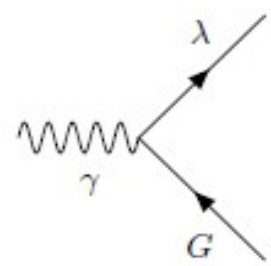
Combines with the Graviton multiplet and becomes the "gravitino."

$$m_G = \frac{|F|}{\sqrt{3}M_p} \qquad \sqrt{|F|} = 100 \text{ TeV} \rightarrow m_G = 1 \text{ eV}$$

$$\mathcal{L} = \frac{1}{8M_p}\bar{\lambda}\gamma^\rho\sigma^{\mu\nu}\tilde{G}_\rho F_{\mu\nu} + \text{h.c.}$$

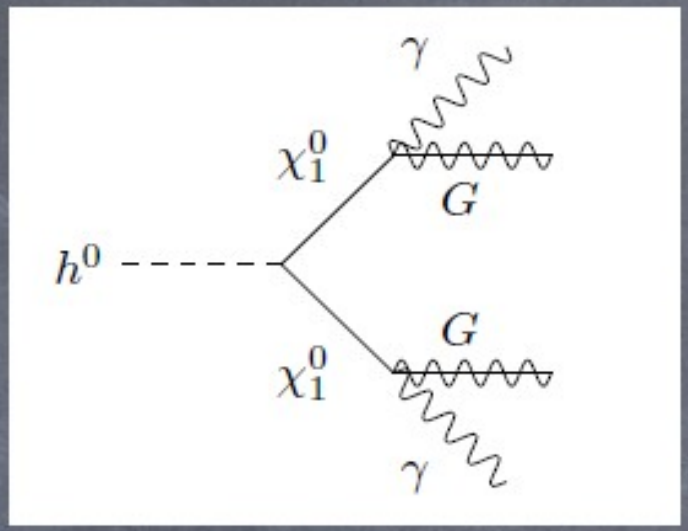
$E \gg m_G \rightarrow$ only the longitudinal mode remains coupled

$$\tilde{G}_\rho \rightarrow \frac{i}{m_G}\sqrt{\frac{2}{3}}\partial_\rho G$$



$$= \frac{i}{\sqrt{2}F}\left((p_G \cdot p_\gamma)\gamma^\mu - \not{p}_\gamma p_G^\mu\right)$$

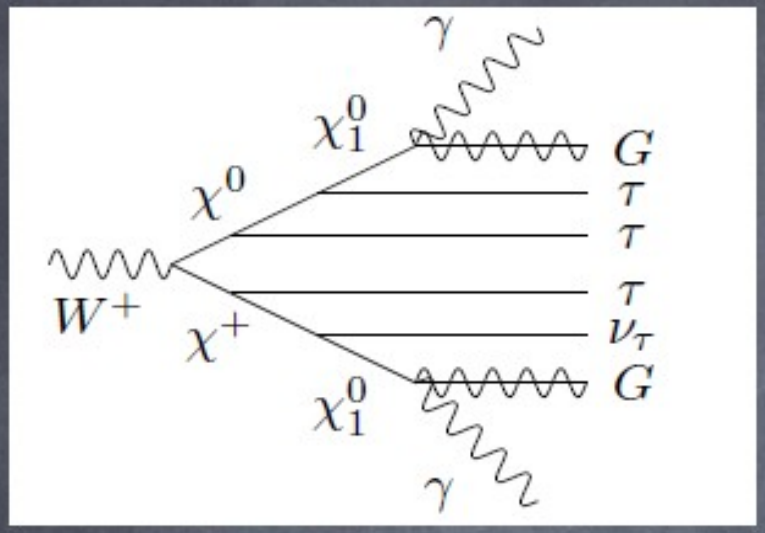
Higgs Decays to Neutralinos

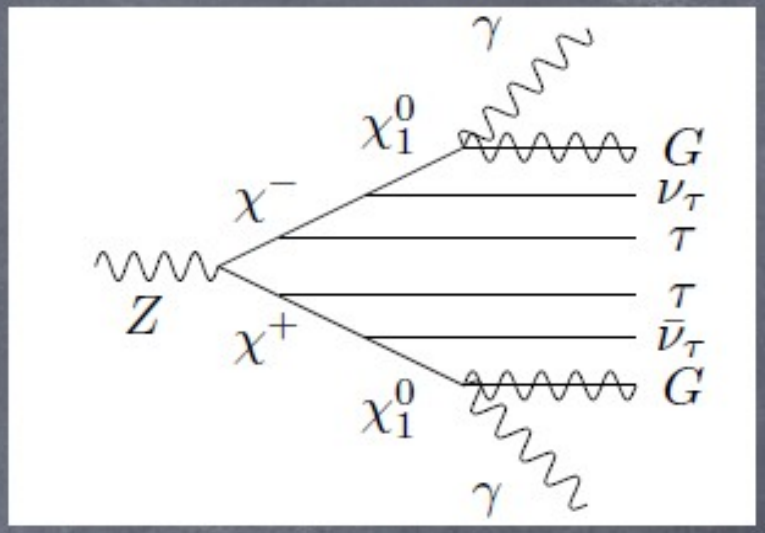


"Prompt" Decays : $c\tau < 2 \text{ cm}$ $\qquad c\tau = 16\pi \frac{|F|^2}{m_{\chi_1^0}^5} \frac{1}{|P_{1\gamma}|^2}$

$|F|^{\frac{1}{2}} < 100 \text{ TeV}$ $\Rightarrow$ Low-Scale Gauge Mediation

Bounds





1) Bounds from LEP : $\sqrt{s} = 209 \text{ GeV}$

$$\sigma(e^+e^- \to \gamma\gamma + \not{E}_T) < 10^{-2} \text{ pb}$$

$$BR(Z^0 \to \gamma\gamma + \not{E}_T) < 3 \times 10^{-6}$$

2) Bounds from Tevatron : $\sigma(p\bar{p} \to \chi\chi) < 20 \text{ fb}$

Satisfying Tevatron Bounds

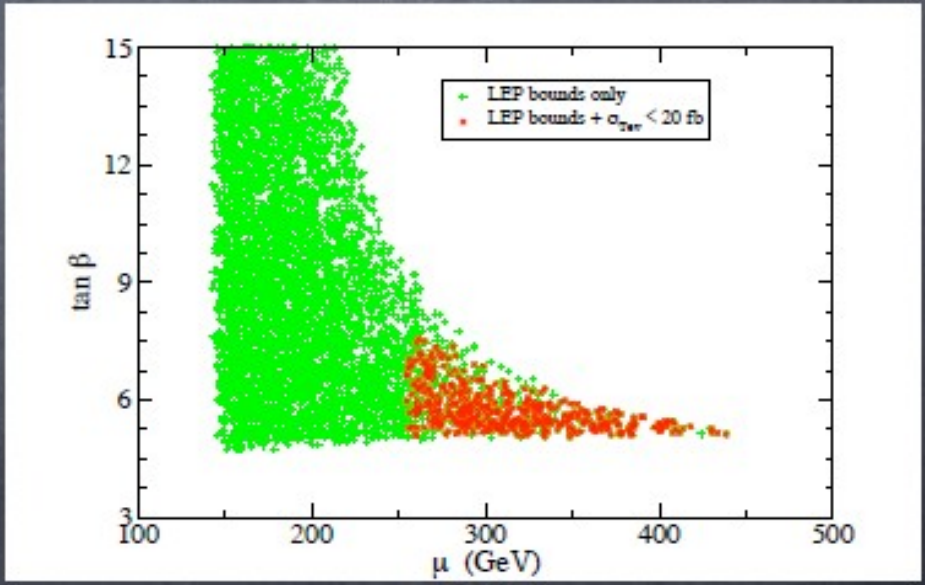
$$M_2,\ \mu >> M_1$$

$$\mathcal{M} = \begin{pmatrix} M_1 & 0 & -m_Z s_\beta s_W & m_Z c_\beta s_W \\ 0 & M_2 & m_Z c_W s_\beta & -m_Z c_\beta c_W \\ -m_Z s_\beta s_W & m_Z c_\beta s_W & 0 & -\mu \\ m_Z c_\beta s_W & -m_Z c_\beta c_W & -\mu & 0 \end{pmatrix}$$

$$\begin{pmatrix} \lambda' \\ \lambda^3 \\ \psi^2_{H_u} \\ \psi^1_{H_d} \end{pmatrix}$$

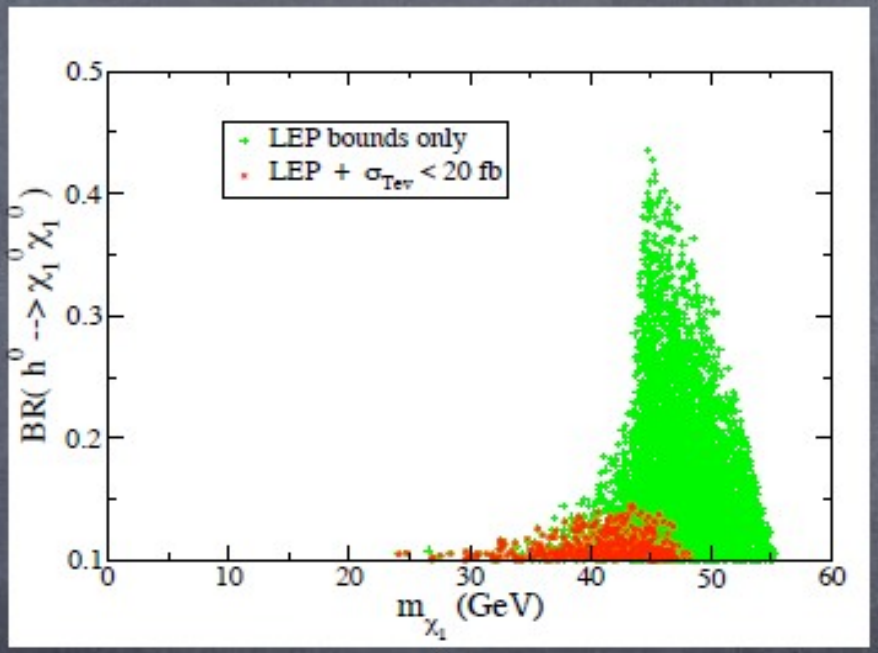
$$g_{Z\chi_1\chi_1} \sim \epsilon^2$$

$$\mu > 250 \text{ GeV}$$



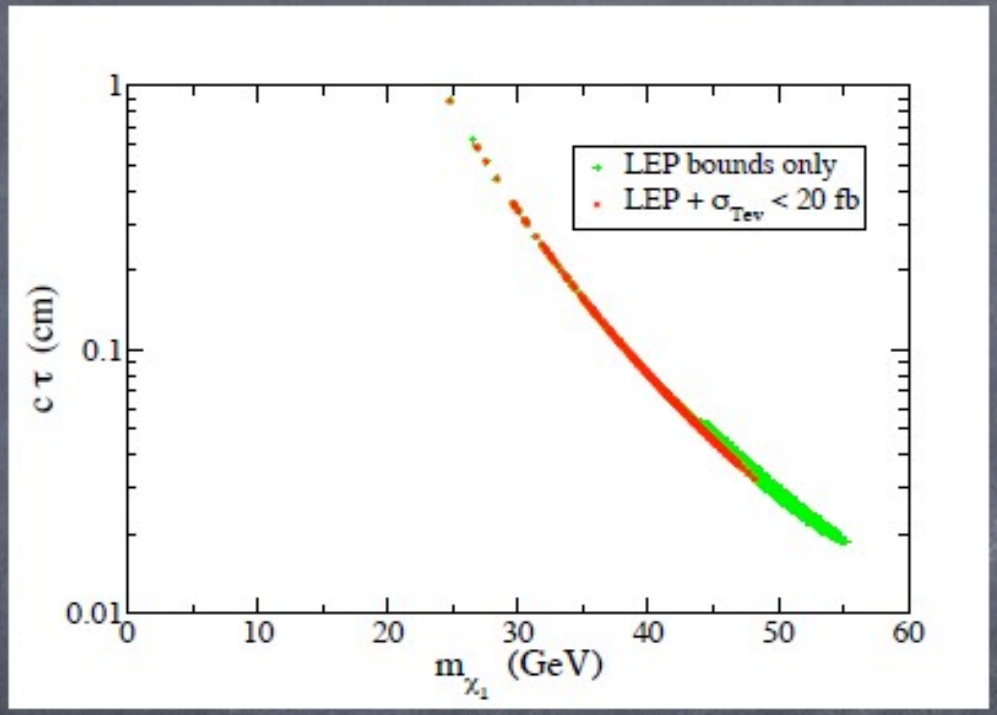
Higgs Branching Ratio

$$\mathcal{L} = \sqrt{2}\lambda' \psi^i_{H_u} H^{i*}_u \Longrightarrow g_{h^0\chi_1\chi_1} \sim \epsilon$$



$$BR(h^0 \to \chi^0_1 \chi^0_1) \sim 0.1$$

Prompt Decays



$$c\tau = 16\pi \frac{|F|^2}{m_{\chi_1^0}^5} \frac{1}{|P_{1\gamma}|^2}$$

$$|F| = (50 \text{ TeV})^2$$

Tevatron Higgs Search

SM : $BR(h^0 \to \gamma\gamma)_{SM} = 2 \times 10^{-3}$

GMSB : $BR(h^0 \to \chi_1\chi_1 \to \gamma\gamma + \not{E}_T) = 0.15$

Tevatron Limits : $\sigma BR < 15(\sigma BR)_{SM}$

Can this give a signal ? ⇨ $(\sigma BR)_{GMSB} = 50(\sigma BR)_{SM}$

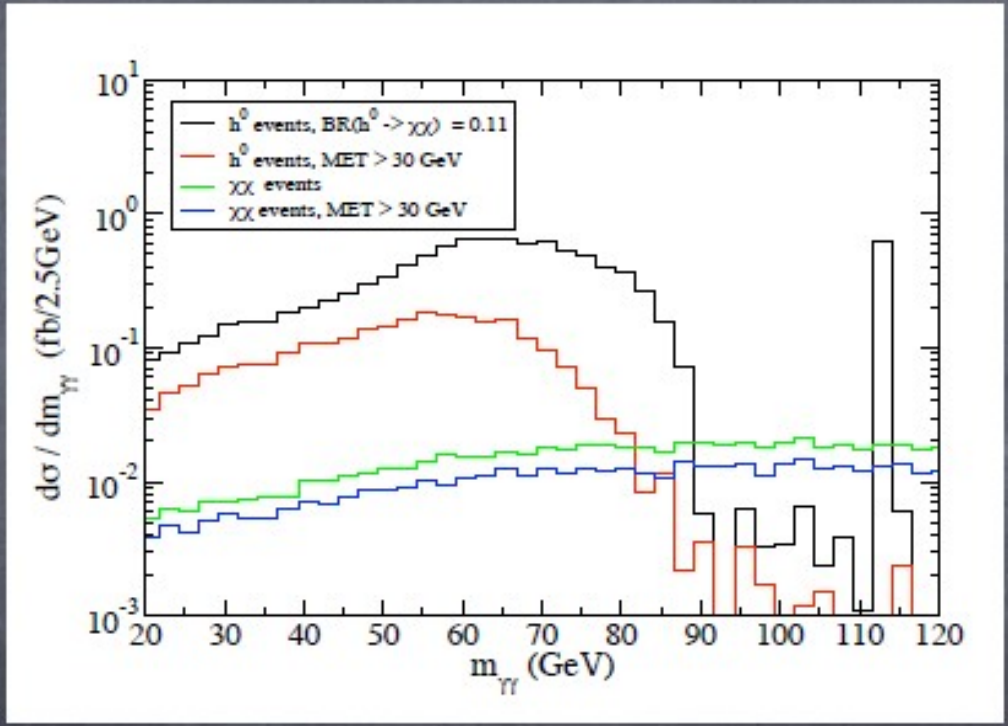
Study a parameter point consistent w/ LEP and Tevatron :

$$M_1 = 50 \text{ GeV}, \quad \mu = 300 \text{ GeV}, \quad \tan\beta = 5.5, \quad m_{A^0} = 1000 \text{ GeV},$$

$BR(h^0 \to \chi_1\chi_1) = 0.11$ $\quad m_{h^0} = 114.7$ GeV $\quad m_{\chi_1} = 46.6$ GeV

Tevatron Search (D0-Higgs-type)

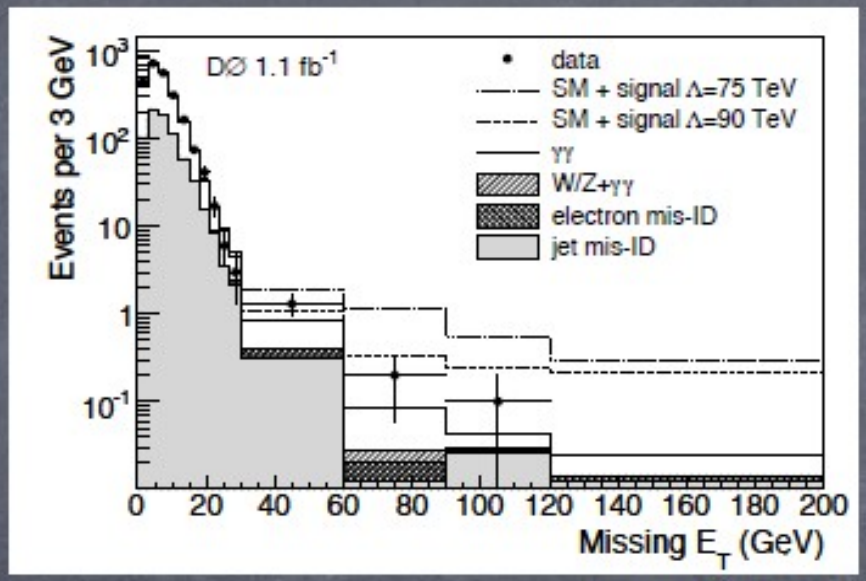
$$p_T^\gamma > 25 \text{ GeV} \qquad |\eta| < 1.1$$



$$50 \text{ GeV} < m_{\gamma\gamma} < 90 \text{ GeV} \Rightarrow \frac{S}{\sqrt{B}} < 0.08$$

Tevatron Search (D0-GMSB-type)

$$p_T^\gamma > 25 \text{ GeV} \qquad |\eta| < 1.1 \qquad \not{E}_T > 30\text{GeV},\ 60 \text{ GeV}$$



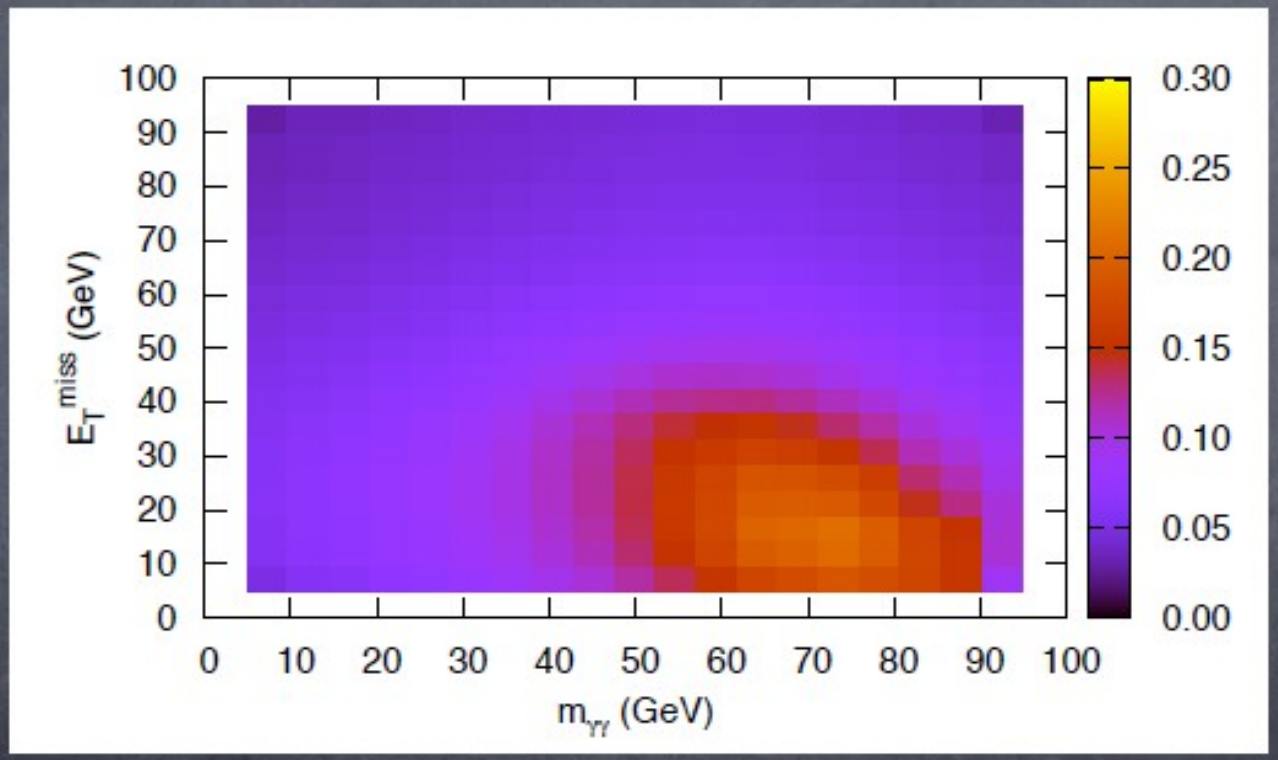
Abazov et. al. (2007) : 0710.3946 [hep-ex]

$$S = 2.7/\text{fb}^{-1}$$

$$B = 9.8/\text{fb}^{-1}$$

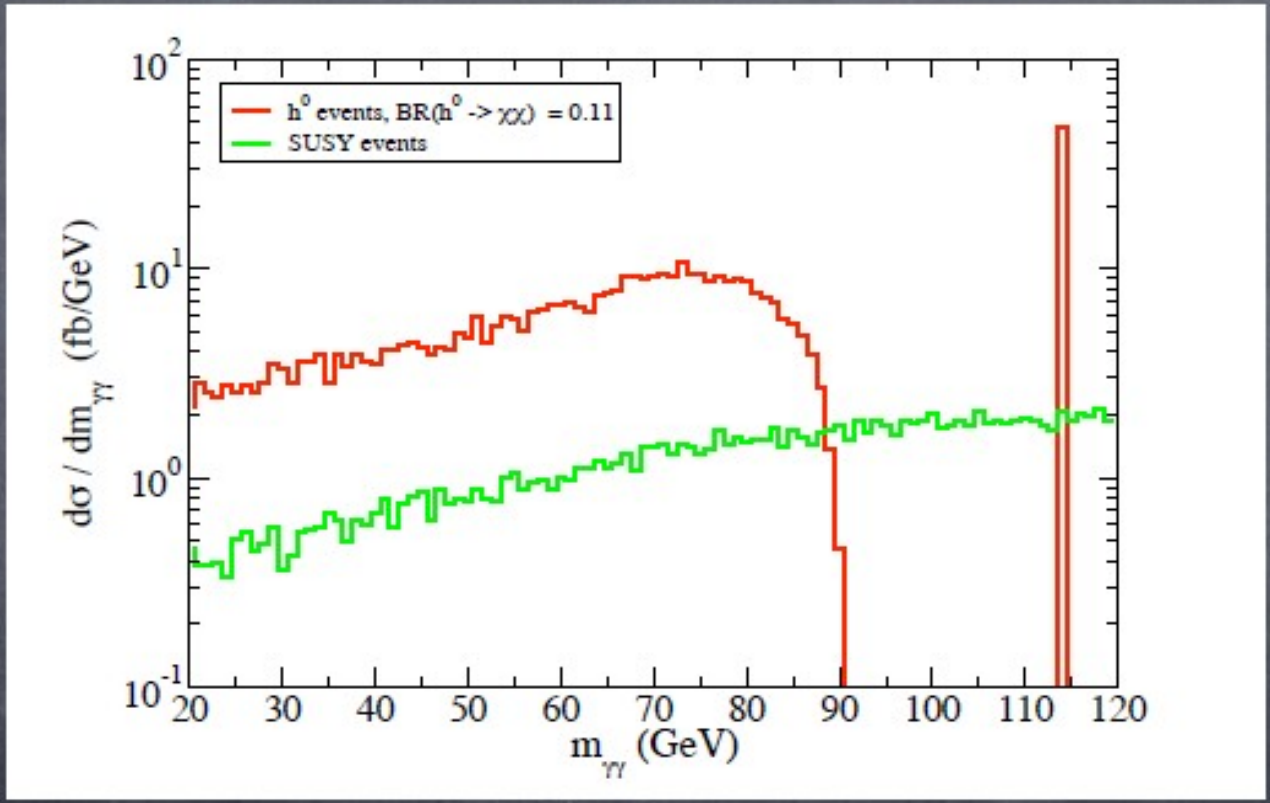
$$\frac{S}{\sqrt{B}} = 3,\ 10 \text{ fb}^{-1}$$

Tevatron Search (D0-hybrid-type) ??



LHC Search (ATLAS inclusive)

$p_T^\gamma = 40$ GeV, 25 GeV $\qquad |\eta| < 1.37,\ 1.52 < |\eta| < 2.37$



$60 \text{ GeV} < m_{\gamma\gamma} < 90 \text{ GeV}$ ⇨ $\dfrac{S}{\sqrt{B}} = 5,\ 20 \text{ fb}^{-1}$

LHC (CMS) Search (W/h, Z/h)

$$p_T^\gamma = 35 \text{ GeV} \ , \ 20 \text{ GeV} \qquad |\eta| < 2.5$$

$$20 \text{ GeV} < m_{\gamma\gamma} < 90 \text{ GeV}$$

$$\frac{S}{\sqrt{B}} = 5, \ 16 \text{ fb}^{-1}$$

Experimental Summary

- Future D0 GMSB and CMS $(W/Z)h^0 \rightarrow \gamma\gamma$ Searches are sensitive to this decay mode.
- CDF GMSB uses $H_T = \sum_i p_T^i + \not{E}_T > 200 \text{ GeV}$ which eliminates most of the signal
- Larger pT cuts in ATLAS ($p_T^\gamma > 50\ GeV$) (non-inclusive) searches eliminate the signal.

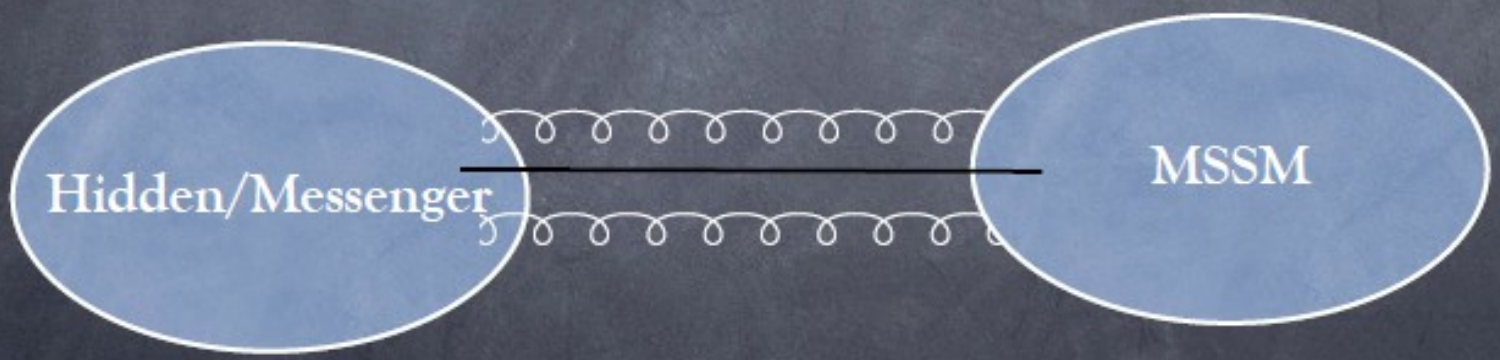
Conclusions

- Higgs may have an interesting Decay Channel to photons and missing energy.
- Realized in Non-Minimal GMSB
- Could be visible at Tevatron and LHC
- NMSSM Scenarios
  1) $BR(h^0 \to \chi_1\chi_1) \sim 1, \text{ small } \tan\beta$
  2) $\chi_1^0 \to a^0 + G \qquad a^0 \to b\bar{b}, \tau\bar{\tau}$

Non-Minimal Gauge Mediation

Carpenter, Dine, Festuccia, JM (08)
JM (09)

OR ...



Meade, Seiberg, Shih (08)
Komargodski, Seiberg (08)

General Soft Masses

Still Communicates SUSY breaking with Minimal Flavor Violation