Higgs Decays to Neutralinos in Gauge Mediation

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David Morrissey, David Poland, JM arXiv:0909.3523 [hep-ph]
JM and David Toback, to appear
Introduction

• Will the Higgs be the Standard Model Higgs?
• Crucial to measure its mass and decay modes.
  – SM decay modes
  – New decay modes to non-SM particles

• The Supersymmetric Neutralino can be light.
• If the Supersymmetry Breaking scale is low the Neutralinos decay on short time scales.
• We will consider the phenomenology of a Higgs that decays to Neutralinos in Gauge Mediaton.
Outline

• Higgs Decays to Neutralinos in GMSB (theory)
• Prompt Higgs Decays to Neutralinos in GMSB
  – Tevatron
  – LHC (full power)
• Non-Prompt Higgs Decays to Neutralinos in GMSB
  – CDF timing
• Conclusions/Outlook
Higgs Decays to Neutralinos in GMSB (theory)
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1) \( \frac{m_h}{2} > m_\chi \)
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3) Low-Scale Gauge Mediation
1) \( \frac{m_h}{2} > m_\chi \)

**LEP 1:** \( BR(Z^0 \rightarrow \gamma\gamma + \not{E}_T) < 3 \times 10^{-6} \)

**LEP 2:** \( \sigma(e^+ e^- \rightarrow \gamma\gamma + \not{E}_T) < 10^{-2} \text{ pb} \)

**Tevatron:** \( \sigma(p\bar{p} \rightarrow \chi\chi) < 20 \text{ fb} \)
Recall the Neutralino Mass matrix

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

\[ M_2, \mu \gg M_1 \]

\[ g Z^0 X_1^0 X_1^0 \sim \epsilon^2 \]

\[ \mu > 250 \text{ GeV} \]

Light $X_1$ Evades Detection
Higgs Decays to Neutralinos in GMSB (theory)

2) Significant BR
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\[ \mathcal{L} \supset \frac{g}{\sqrt{2}} \lambda' \psi_{H_u} H_u^* \]

\[ g h^0 \chi_1 \chi_1 \sim \epsilon \]

NMSSM Tools:
U. Ellwanger, J.F. Gunion, C. Hugonie, C. C. Jean-Louis

Branching Ratio
\[ h^0 \rightarrow \chi_1 \chi_1 \]
Higgs Decays to Neutralinos in GMSB (theory)

3) Low-Scale Gauge Mediation
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Spontaneously Broken Global SUSY has a Goldstone Fermion: $G$

$$m_G = \frac{|F|}{\sqrt{3} M_p}$$

$$\sqrt{|F|} = 100 \text{ TeV} \rightarrow m_G = 1 \text{ eV}$$

$$\mathcal{L} \supset \frac{i \sqrt{2}}{8 |F|} [\bar{\lambda} \gamma^\rho \sigma^{\mu \nu} (\partial_\rho G)] F_{\mu \nu} + \text{h.c}$$
Decays may be prompt or non-prompt

\[ m_{\chi_1} = 50 \text{ GeV} \]

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

Can have ns lifetimes and displaced decays
Higgs Decays to Neutralinos in GMSB (theory)

1) $\frac{m_h}{2} > m_{\chi}$
2) Significant BR
3) Low-Scale Gauge Mediation
Prompt Decays to Neutralinos in GMSB (phenomenology)

Study a parameter point:

\[ M_1 = 50 \text{ GeV}, \ \mu = 300 \text{ GeV}, \ \tan \beta = 5.5, \ m_A = 1000 \text{ GeV} \]

\[ BR(h^0 \rightarrow \chi_1 \chi_1) = 0.1, \ m_h = 115 \text{ GeV}, \ m_{\chi_1} = 47 \text{ GeV} \]

1) At Tevatron  
2) At LHC
1) At Tevatron

$p_T^\gamma > 25 \text{ GeV} \quad \text{and} \quad |\eta| < 1.1$
D0 GMSB Search

$p_T^\gamma > 25 \text{ GeV}, \quad |\eta| < 1.1, \quad \slashed{E}_T > 30 \text{ GeV}

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

Sensitivity: $\frac{S}{\sqrt{B}} = 3, \quad 10 \text{ fb}^{-1}$
1) **At LHC**

**Atlas cuts:**

\[ p_T^{\gamma_1} > 40 \text{ GeV}, \quad p_T^{\gamma_2} > 25 \text{ GeV}, \quad |\eta| < 1.37, \quad 1.52 < |\eta| < 2.37 \]

**Sensitivity:**

\[ \frac{S}{\sqrt{B}} = 5, \quad 20 \text{ fb}^{-1} \]
CMS h/Z and h/W search

CMS cuts:

\[ p_T^\gamma > 35 \text{ GeV}, \ 20 \text{ GeV}; \quad |\eta| < 2.5 \]

Additional cuts:

\[ 20 \text{ GeV} < m_{\gamma\gamma} < 90 \text{ GeV} \]

Sensitivity:

\[ \frac{S}{\sqrt{B}} = 5, \ 16 \text{ fb}^{-1} \]
Prompt Photon Summary

- CMS W/Z associated higgs search is sensitive to this higgs decay.
- D0 GMSB search is somewhat sensitive to this higgs Decay.
- These searches are not optimized for this Signal, and are still sensitive.
Non-Prompt Decays to Neutralinos in GMSB (phenomenology)

\[ t_{corr} = (t_f - t_i) - \frac{|\vec{x}_f - \vec{x}_i|}{c} \]
Pick parameters

\[(\tau_{\chi_1}, \mu, \tan \beta, m_{\chi_1}, m_h)\]
Pick parameters

$m_\chi = 55$ GeV  $m_h = 130$ GeV  

$\mu = 300$ GeV  $\tan \beta = 1.5$

$BR$
Pick parameters

$$BR = [0 - 0.7]$$

$$\tau_{\chi_1} = 5 \text{ ns}$$

$$m_h = 2m_{\chi_1} + (20 \text{ GeV})$$

Higgs mass will be the main parameter.
Exclusive single photon at CDF

single photon $|\eta| < 1.1$, MET $> 50$ GeV, jet veto

PRL101.181602
Use the CDF timing system to select events with delayed photons.

\[ t_{\text{corr}} = (t_f - t_i) - \frac{|\vec{x}_f - \vec{x}_i|}{c} \]

Background smeared with 0.65 ns resolution

\[ m_h = 130 \text{ GeV} \]

\[ t_{\text{corr}} > 0 \text{ ns} \]

\[ t_{\text{corr}} > 2 \text{ ns} \]
Count events to get 95% CL exclusion curve

Close to bounding some parameter space of the MSSM
Higgs decays to this final state
Summary

• Higgs can decay to two Neutralinos in GMSB.
• Future D0 GMSB and CMS exclusive higgs searches are sensitive to h -> gg + MET decay mode, if prompt.
• CDF’s timing system with standard MET cuts will bound single h -> photon + MET final states close to some MSSM parameter space.
Outlook

• Large MET cuts remove much of the Signal. Softer cuts will increase both Background and Signal, but perhaps allow one to win in the timing cut.
• Interesting to see how ATLAS and CMS can do with the delayed photon scenario.
• Different models may accommodate this decay mode with larger BR: ex. NMSSM.
Thank You !