Higgs Decays to Neutralinos in Gauge Mediation

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Davis Seminar

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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

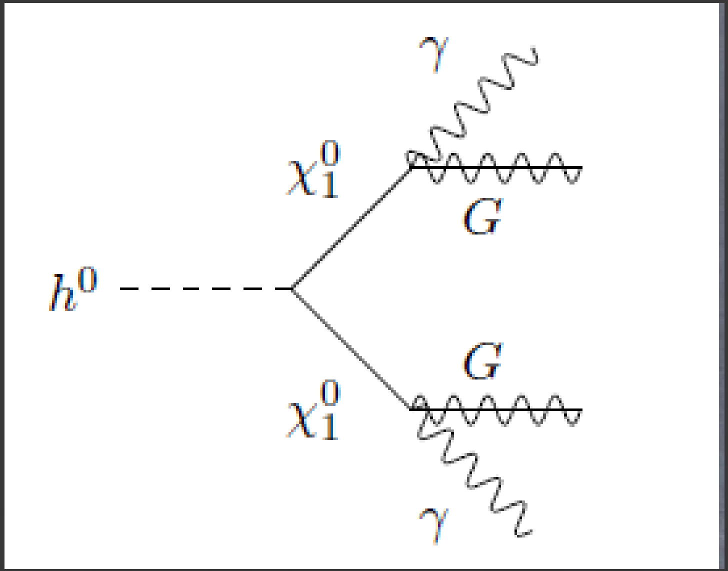
    Dermisek and Gunion (2005)   Chang, Fox, Weiner (2006)

- 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.

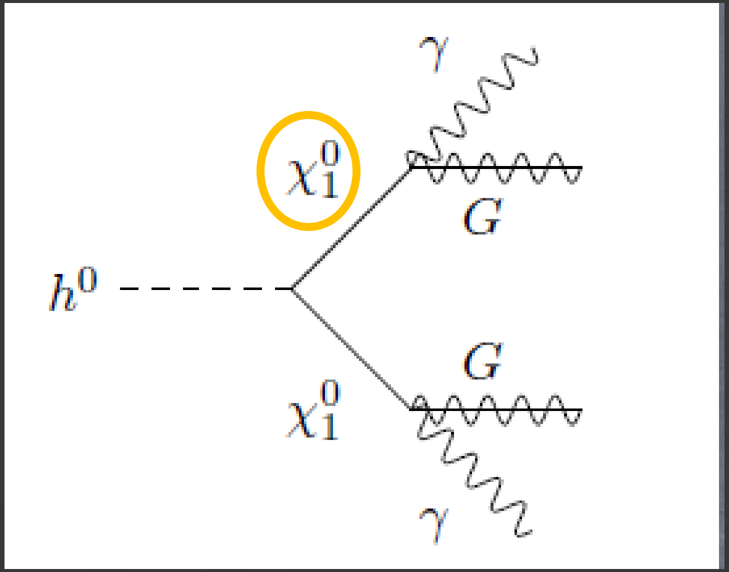
Outline

- 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)

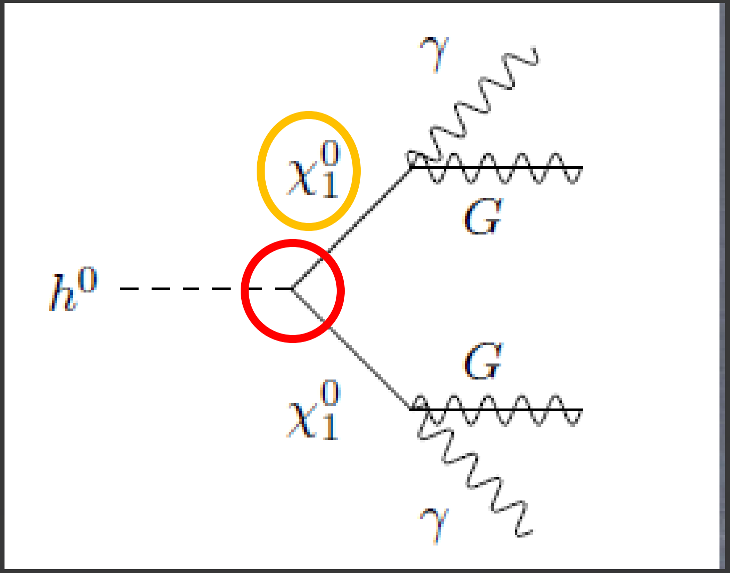


Higgs Decays to Neutralinos in GMSB (theory)



1) $\frac{m_h}{2} > m_\chi$

Higgs Decays to Neutralinos in GMSB (theory)



1) $\frac{m_h}{2} > m_\chi$

2) Significant BR

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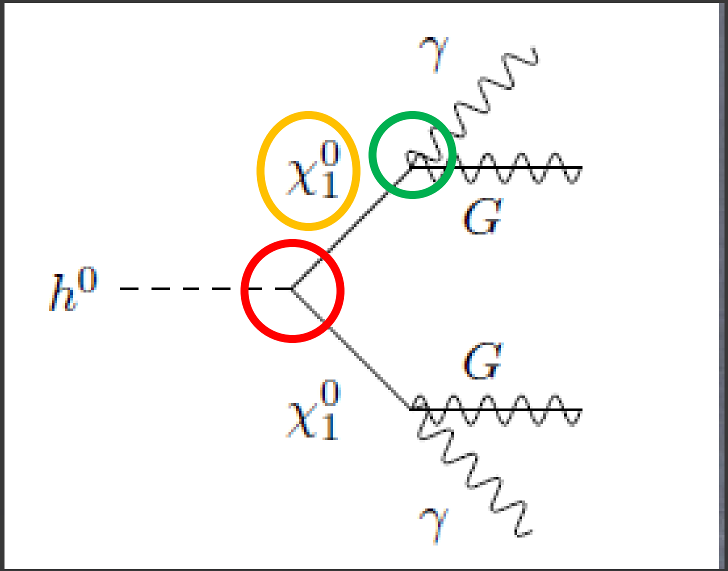
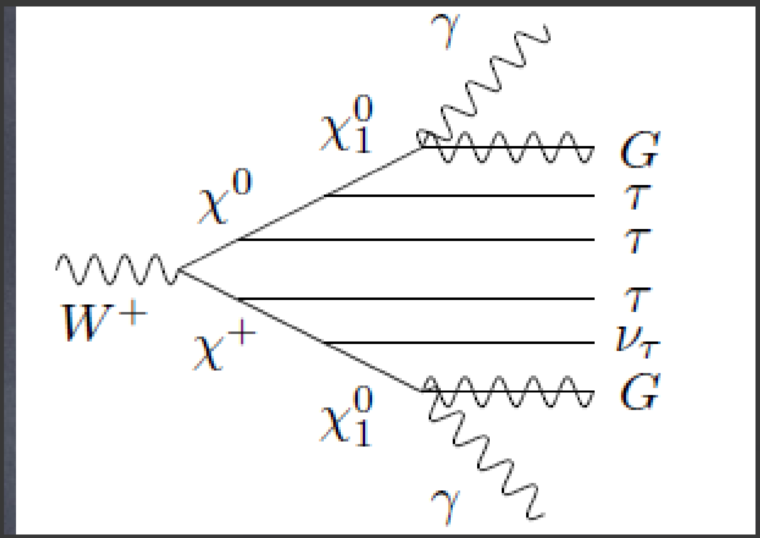


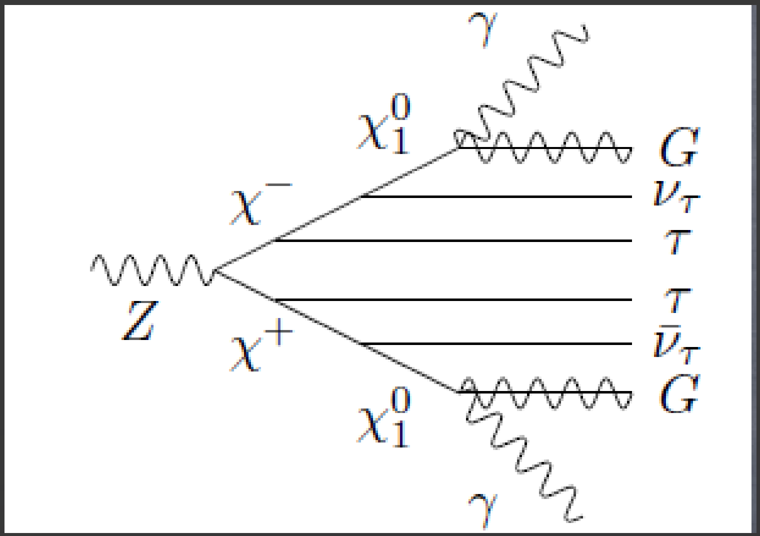
1) $\frac{m_h}{2} > m_\chi$

2) Significant BR

3) Low-Scale Gauge Mediaton

$$1)\ \frac{m_h}{2} > m_\chi$$





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

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

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

Recall the Neutralino Mass matrix

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

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

$$M_2,\ \mu \gg M_1$$

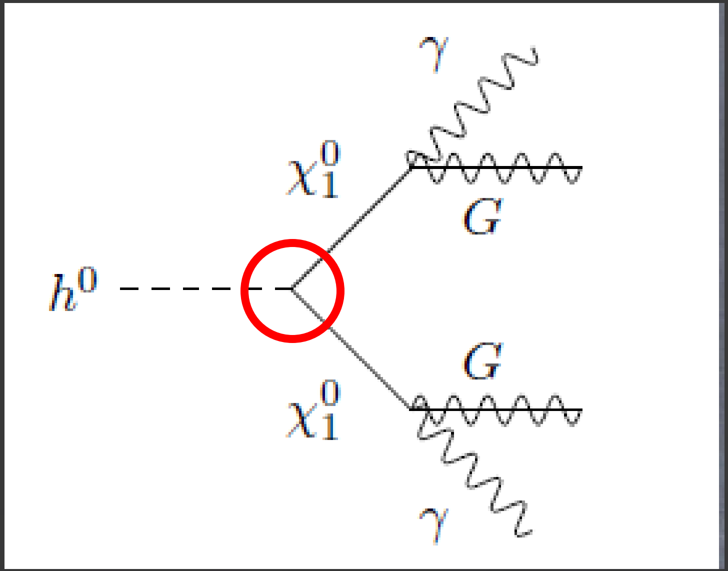
$$g_{Z^0 \chi^0_1 \chi^0_1} \sim \epsilon^2$$

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

Light $\chi 1$

Evades Detection

Higgs Decays to Neutralinos in GMSB (theory)



2) Significant BR

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$$\mathcal{L} \supset \frac{g}{\sqrt{2}} \lambda' \psi_{H_u} H_u^*$$

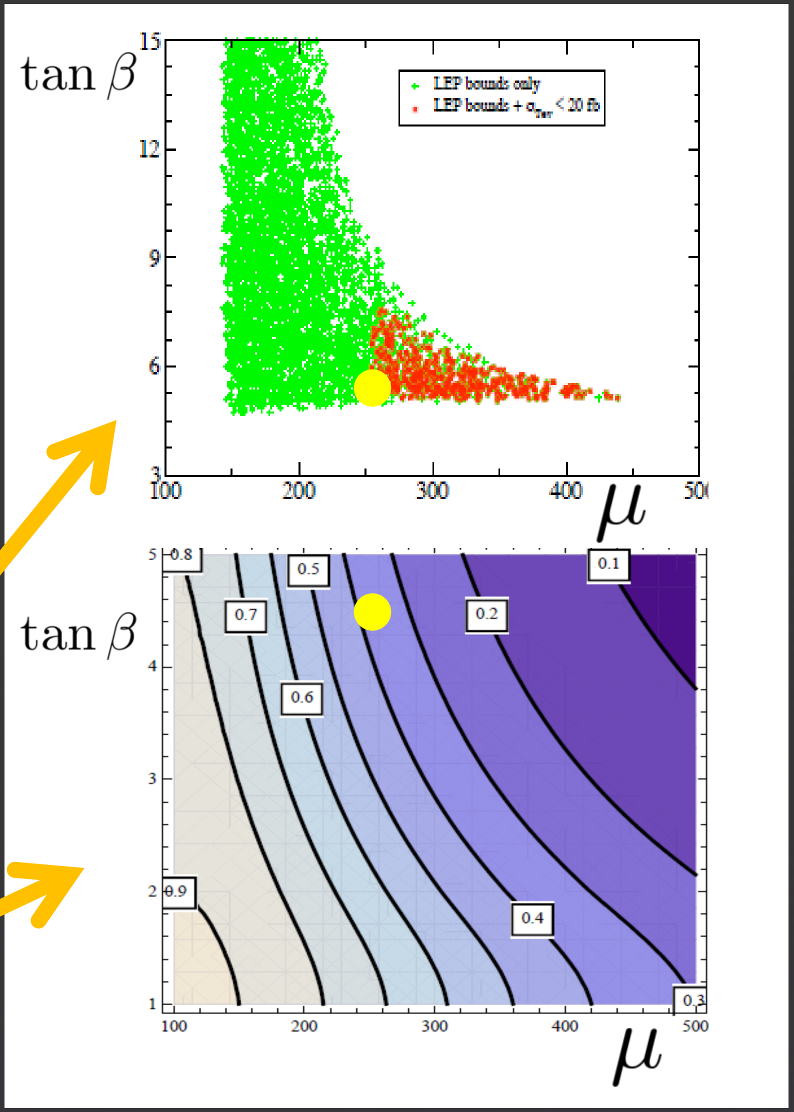
$$g_{h^0 \chi_1 \chi_1} \sim \epsilon$$

NMSSM Tools:

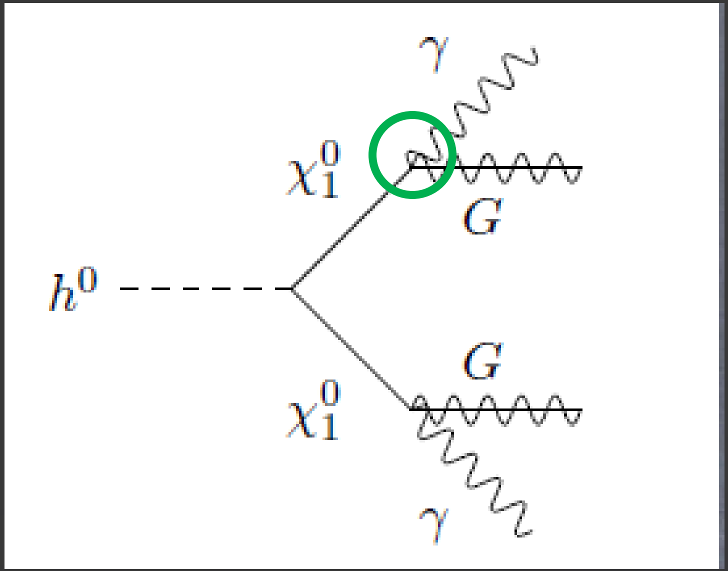
U. Ellwanger, J.F. Gunion, C. Hugonie, C. C. Jean-Louis

Branching Ratio

$$h^0 \to \chi_1 \chi_1$$



Higgs Decays to Neutralinos in GMSB (theory)



3) Low-Scale Gauge Mediaton

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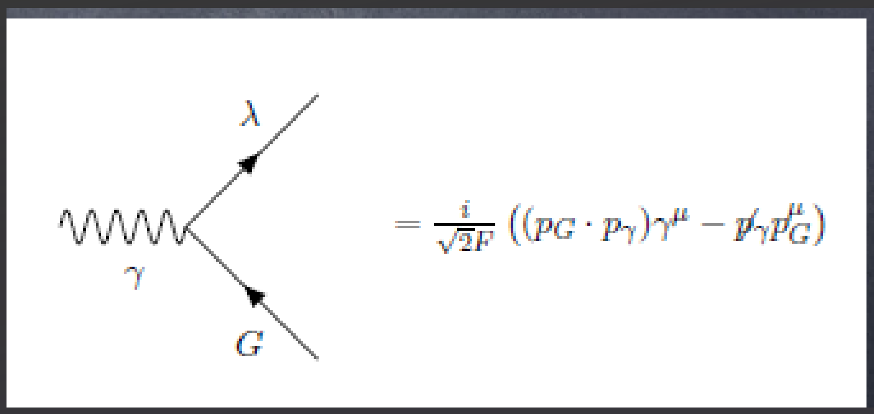
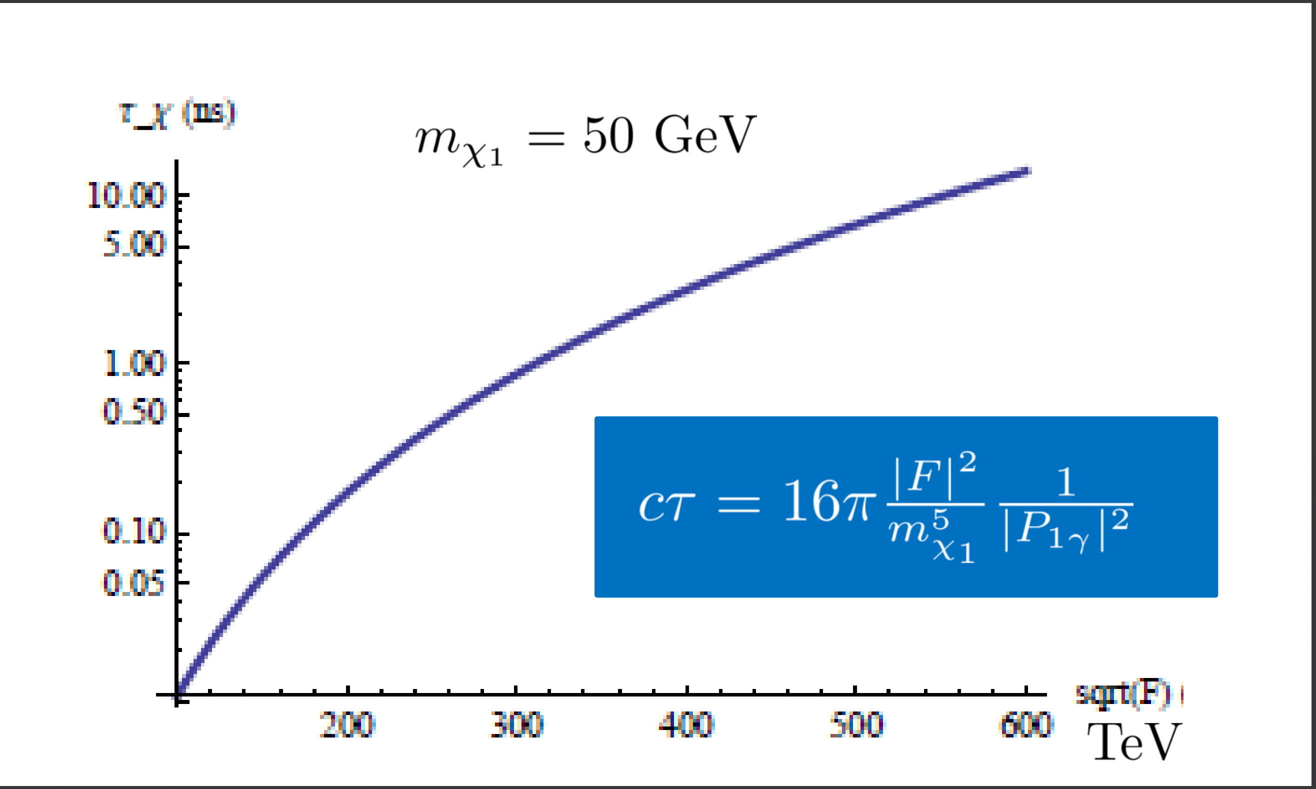
Spontaneously Broken Global SUSY has a Goldstone Fermion: G

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

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

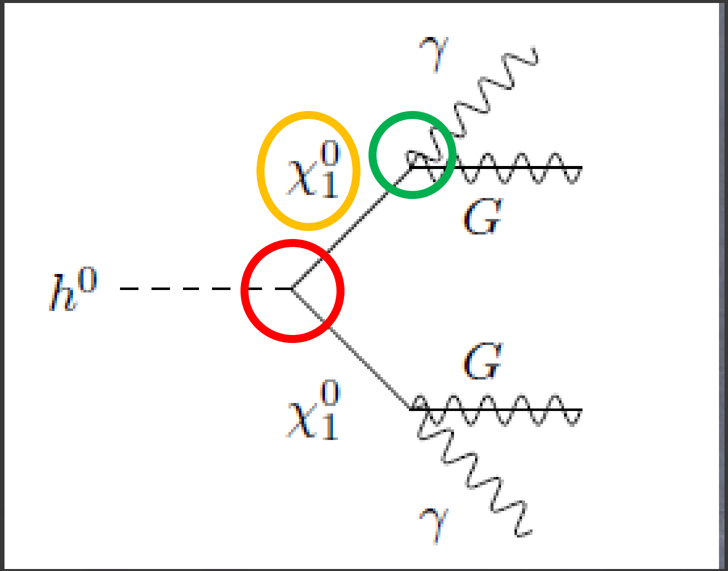


Decays may be prompt or non-prompt



Can have ns lifetimes and displaced decays

Higgs Decays to Neutralinos in GMSB (theory)



1) $\frac{m_h}{2} > m_\chi$

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Prompt Decays to Neutralinos in GMSB (phenomenology)

Study a parameter point:

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

↓

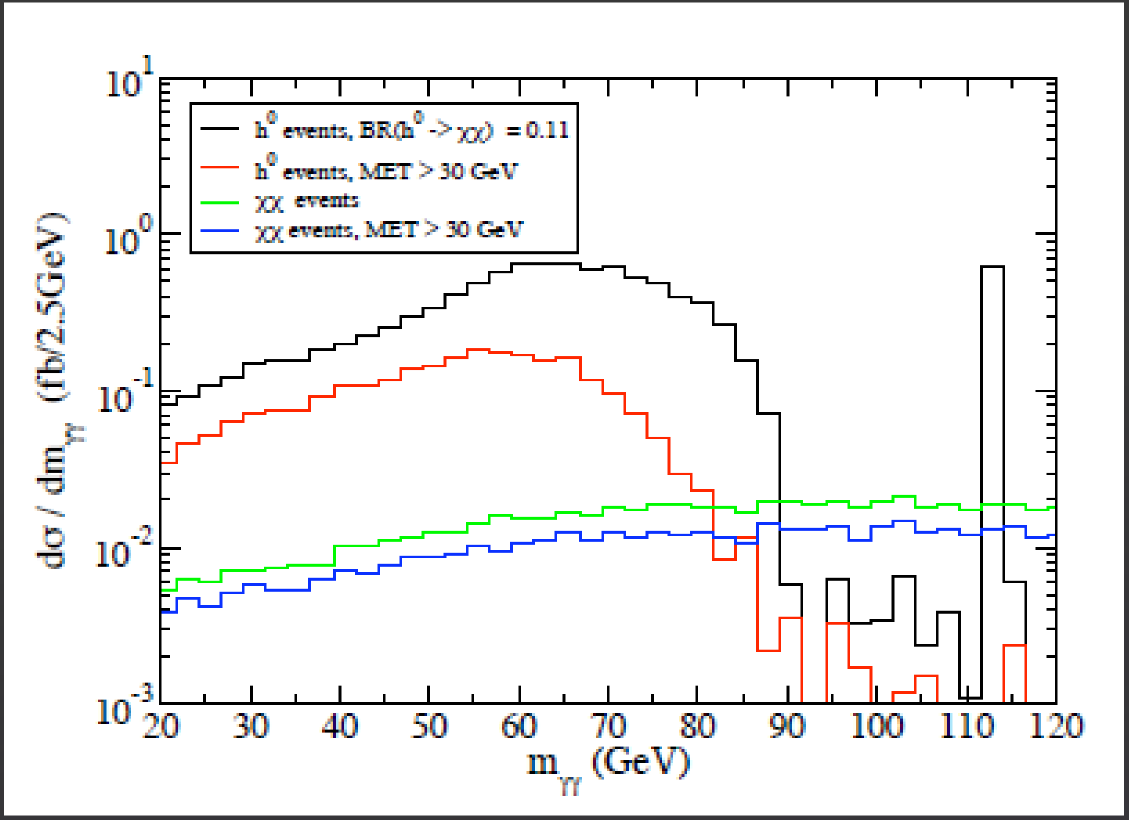
$$BR(h^0 \to \chi_1\chi_1) = 0.1,\ m_h = 115\ \text{GeV},\ m_{\chi_1} = 47\ \text{GeV}$$

1) At Tevatron

2) At LHC

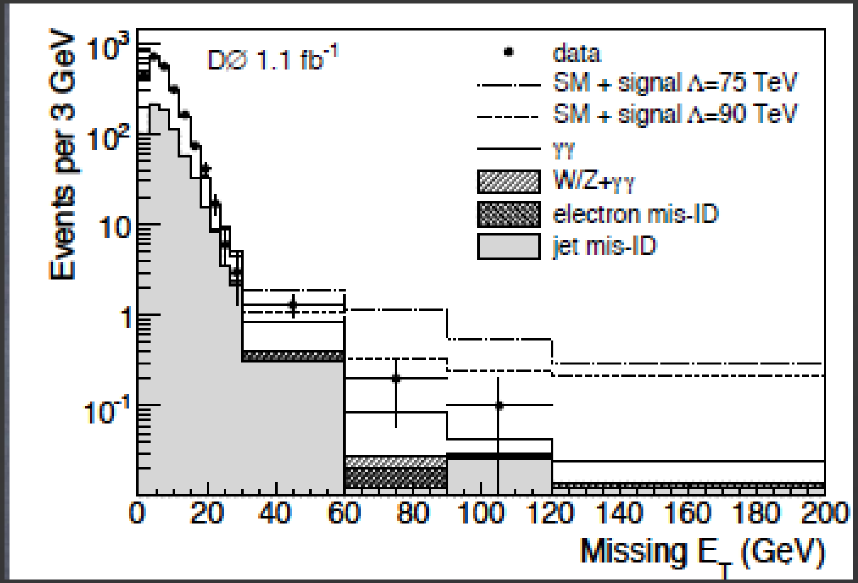
1) At Tevatron

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



D0 GMSB Search

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



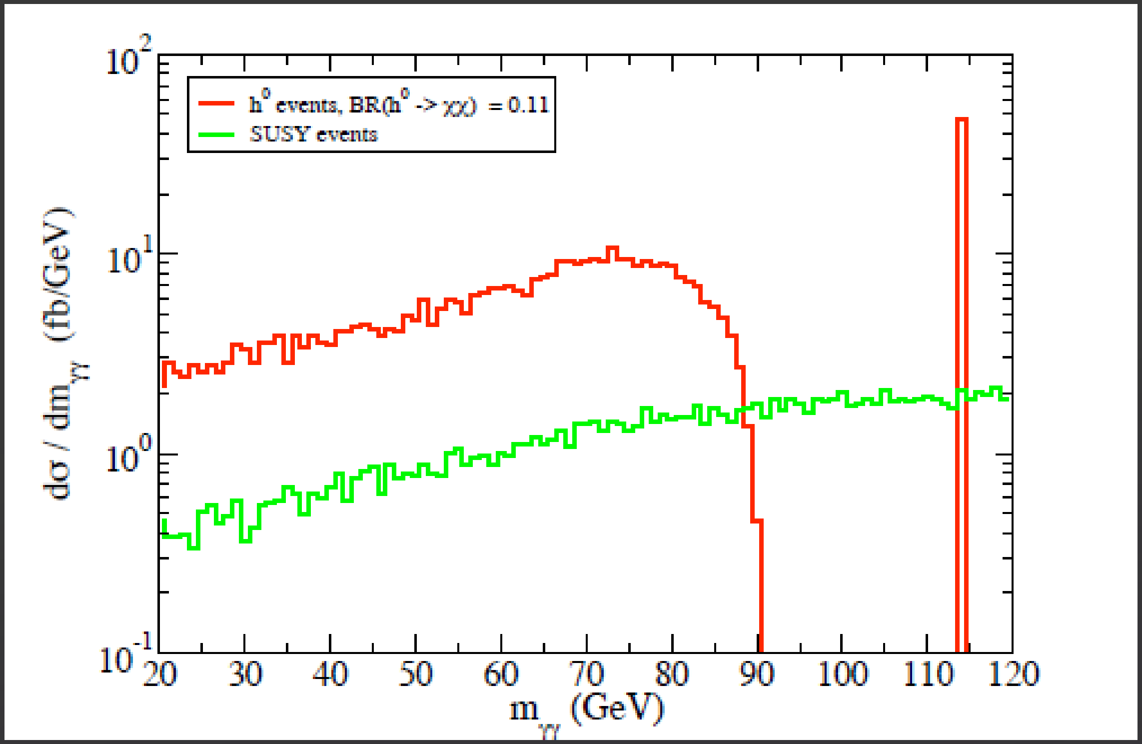
Abazov et. al. (2007): 0710.3946 [hep-ex]

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

1) At LHC

Atlas cuts:

$$p_T^{\gamma_1} > 40\ \mathrm{GeV},\ p_T^{\gamma_2} > 25\ \mathrm{GeV},\quad |\eta| < 1.37,\ 1.52 < |\eta| < 2.37$$



Sensitivity:

$$\frac{S}{\sqrt{B}} = 5,\ 20\ \mathrm{fb}^{-1}$$

CMS h/Z and h/W search

CMS cuts:

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

Additional cuts:

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

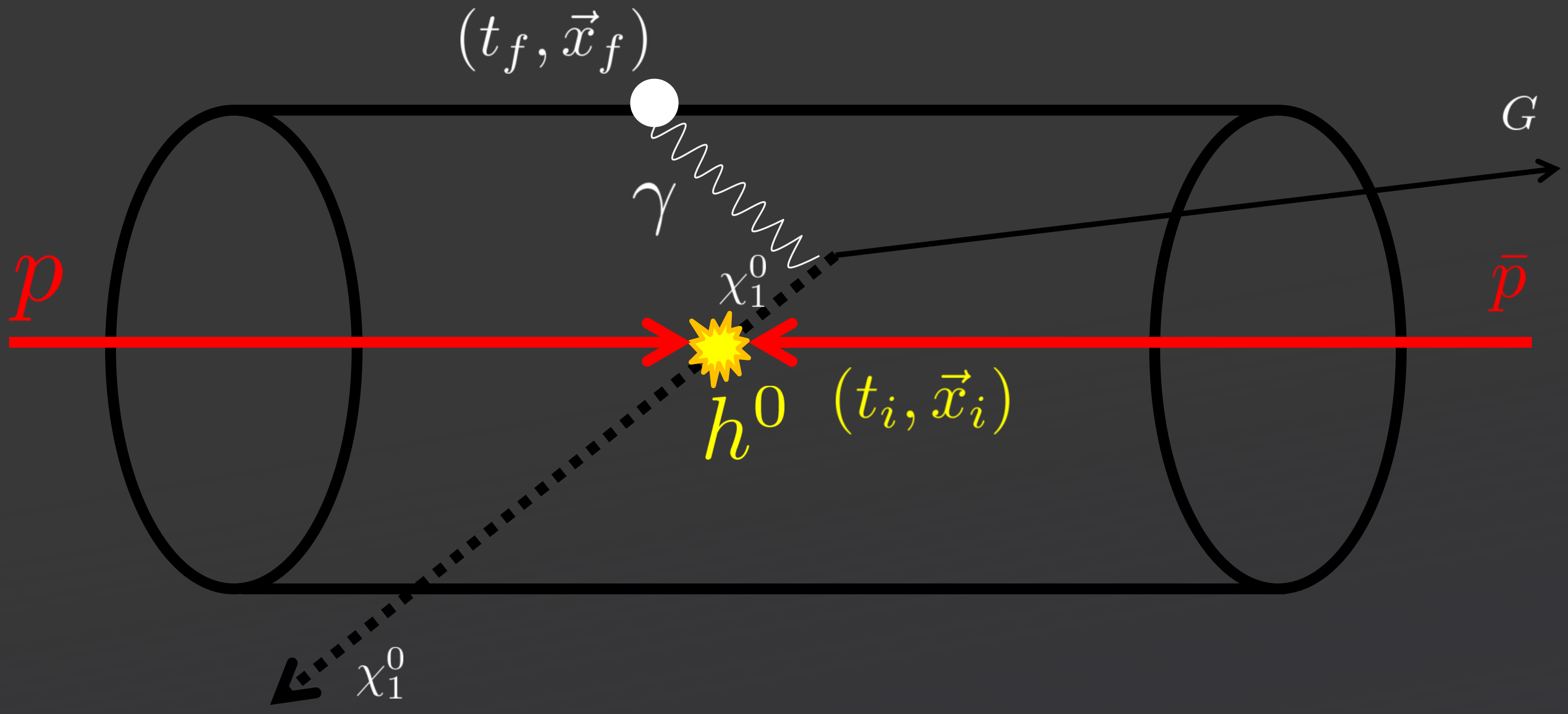
Sensitivity:

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

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)

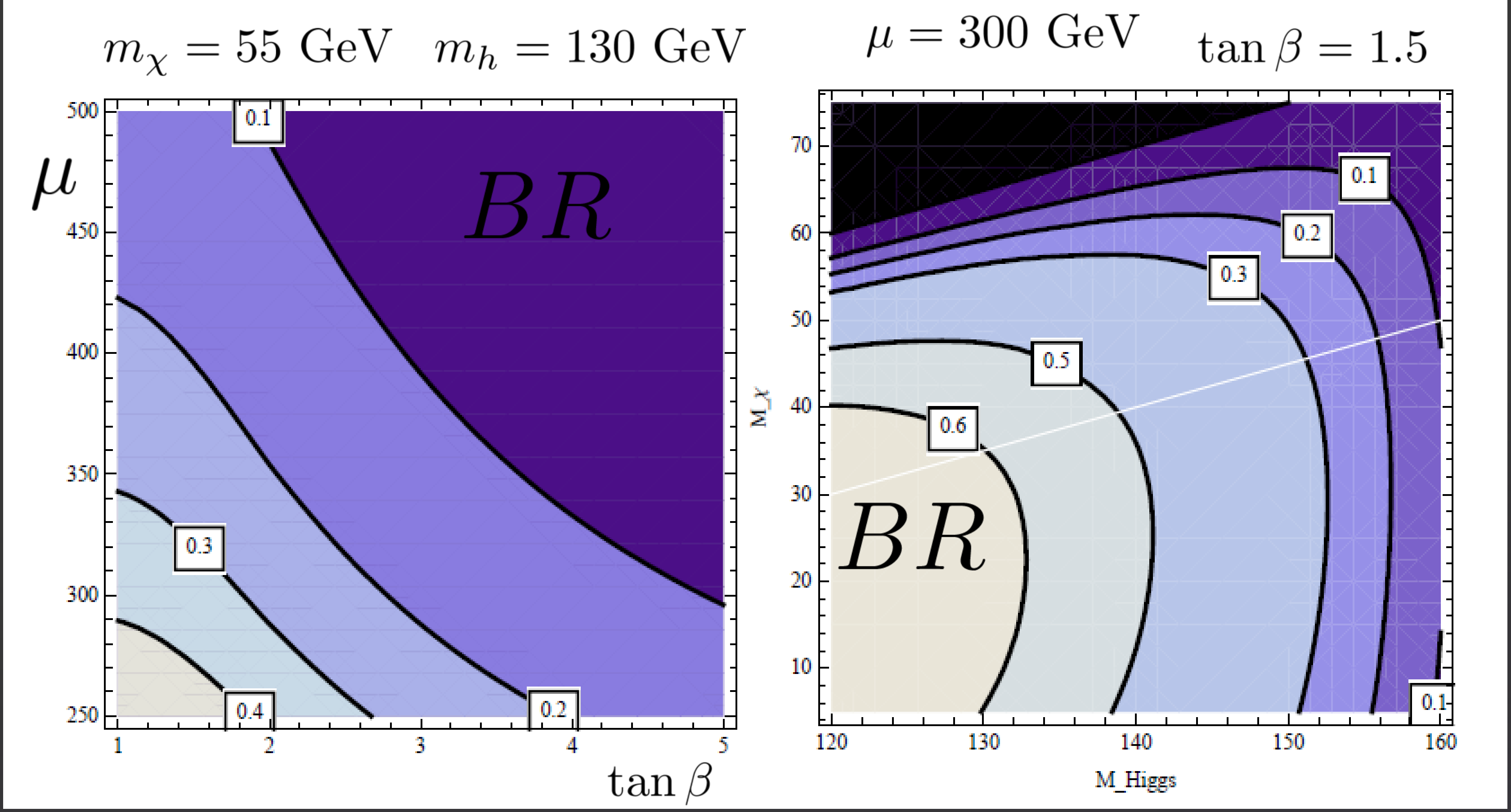


$$t_{corr} = (t_f - t_i) - \frac{|\vec{x}_f - \vec{x}_i|}{c}$$

Pick parameters

$$(\tau_{\chi_1},\ \ \mu,\ \ \tan\beta,\ \ m_{\chi_1}, m_h)$$

Pick parameters



Pick parameters

$$BR = [0 - 0.7]$$

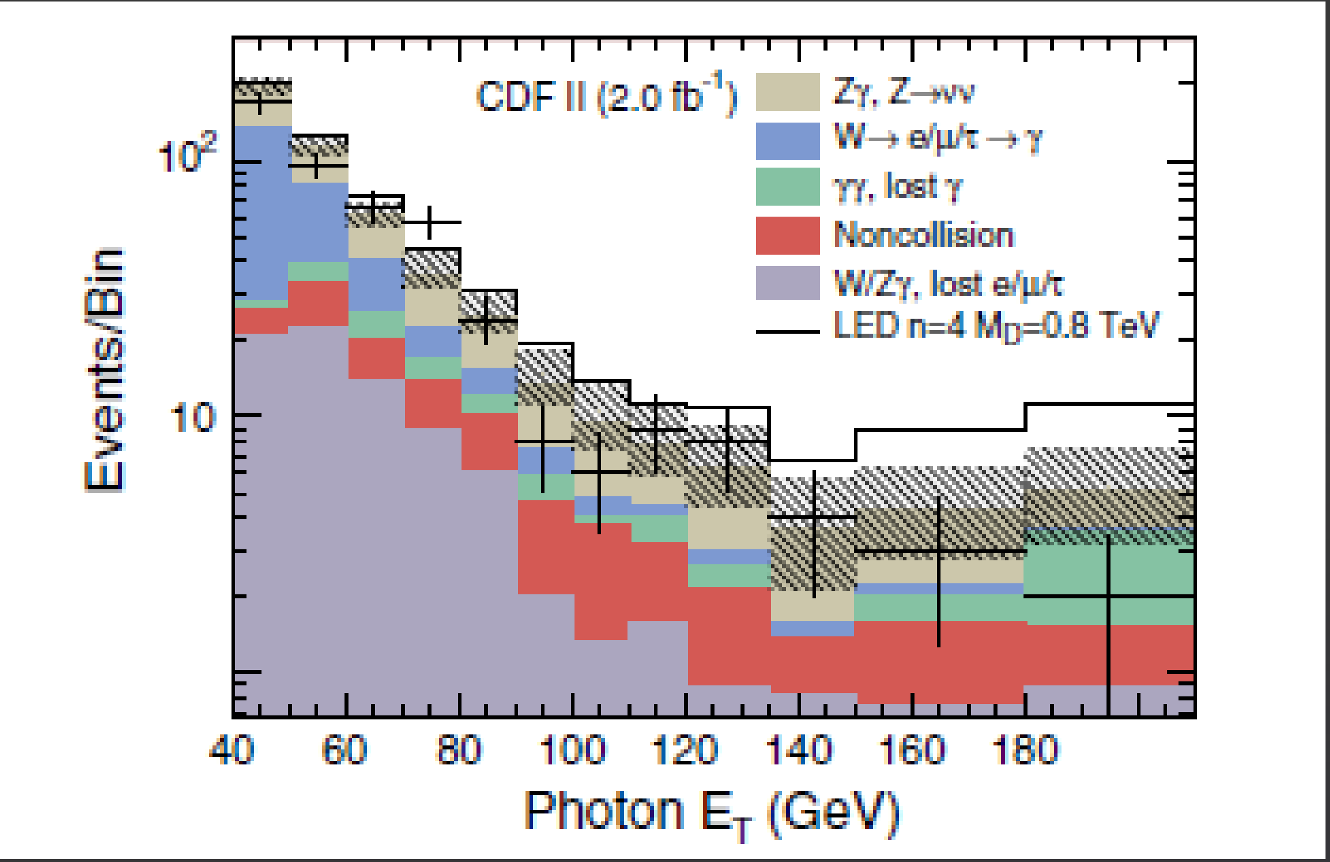
$$(\tau_{\chi_1}, \mu, \tan\beta, m_{\chi_1}, m_h)$$

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

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

Higgs mass will be the main parameter.

Exclusive single photon at CDF



PRL101.181602

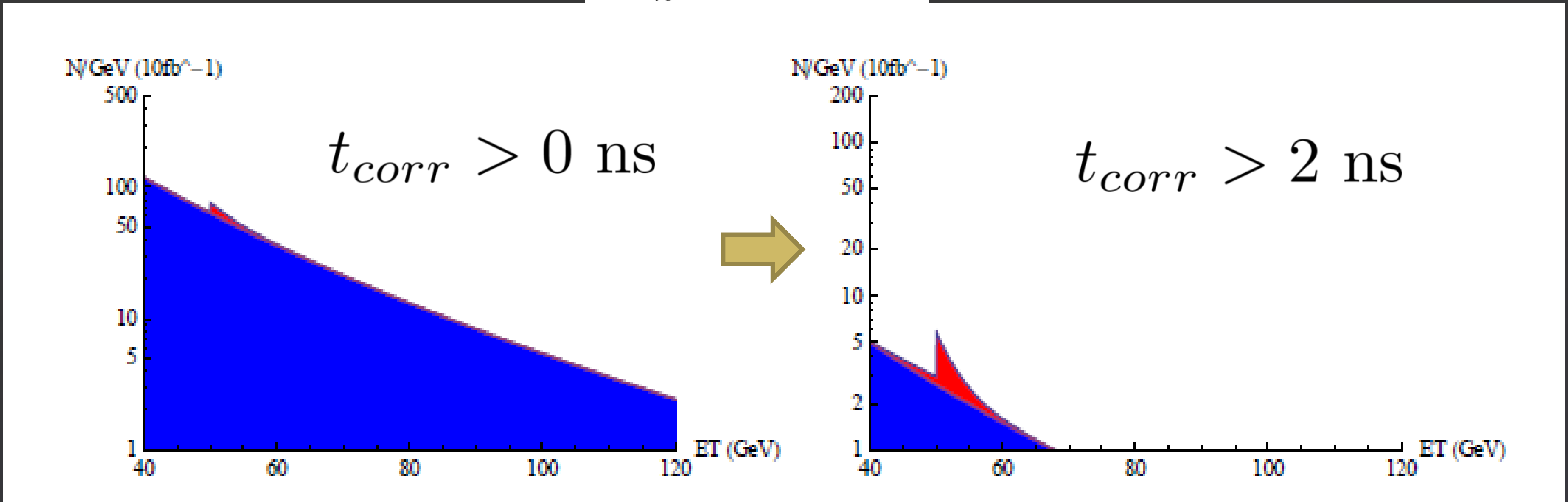
single photon |eta| < 1.1 , MET > 50 GeV , jet veto

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

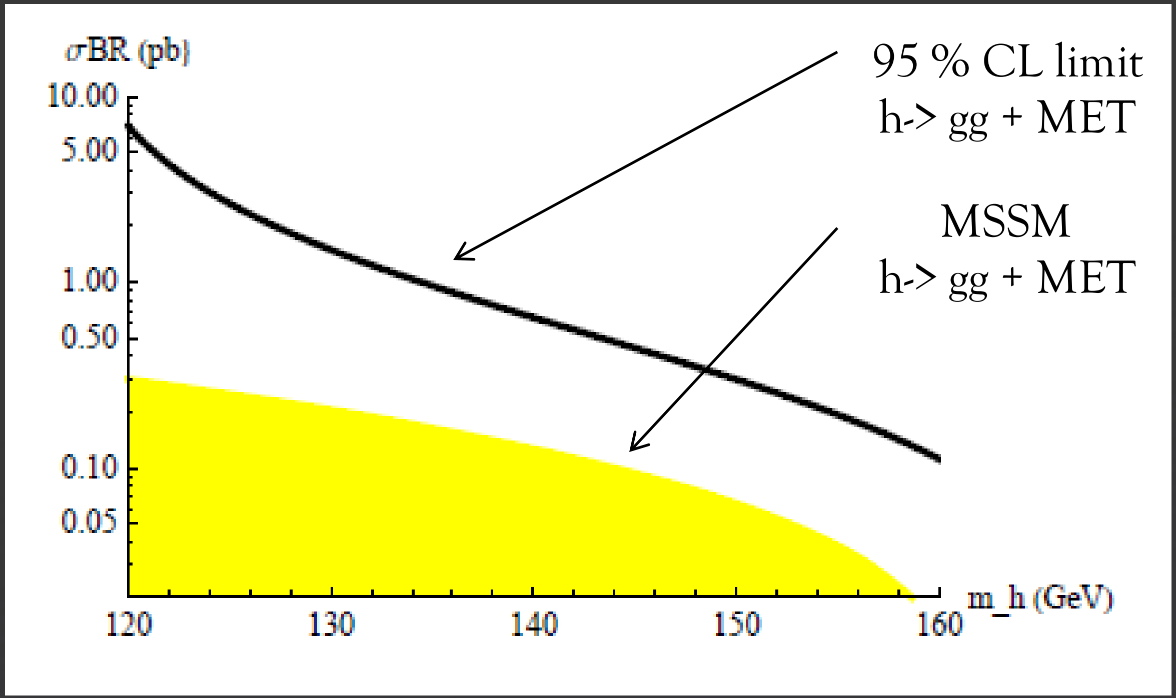
$$t_{corr} = (t_f - t_i) - \frac{|\vec{x}_f - \vec{x}_i|}{c}$$

Background smeared with 0.65 ns resolution

$m_h = 130$ GeV



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 !