Reblessing Talk at Exotics Meeting

Limits on Gauge Mediated Supersymmetry Breaking Models in Diphoton Events with Missing Transverse Energy at CDF II

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Outline

- Analysis Introduction and Overview
- Background Sources and Data Sets
- Background Estimations
- GMSB MC Simulation
- Optimization and Setting Limits
- Figures for PRL
- Conclusion and Plan

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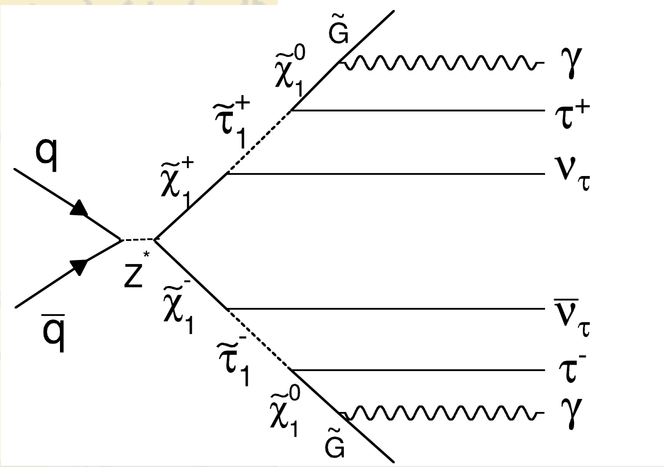
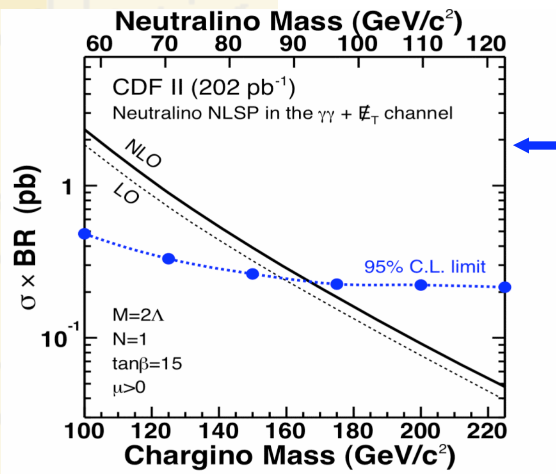
Analysis Introduction and Overview

Dominant Signal Process and Previous Searches



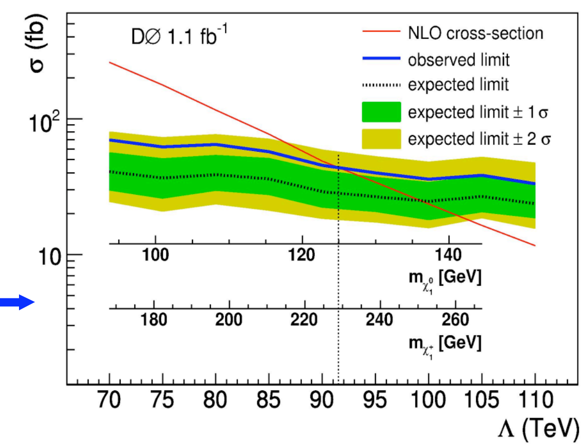
- Looking for $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$
- Both neutralinos decay in the detector $\Rightarrow$ Two photons
- $\gamma\gamma + \not{E}_T$: Optimal for low lifetimes (τ=0 and 1 ns)

D.Toback and P.Wagner, Phys.Rev.D70, 114032 (2004)



Previous Search at CDF (202 pb^{-1})
Phys.Rev.D71, 031104 (2005)

Recent Search at DØ (1.1 fb^{-1})
Phys.Lett.B659, 856 (2008)



Exclusion Region from the Delayed Photon Search

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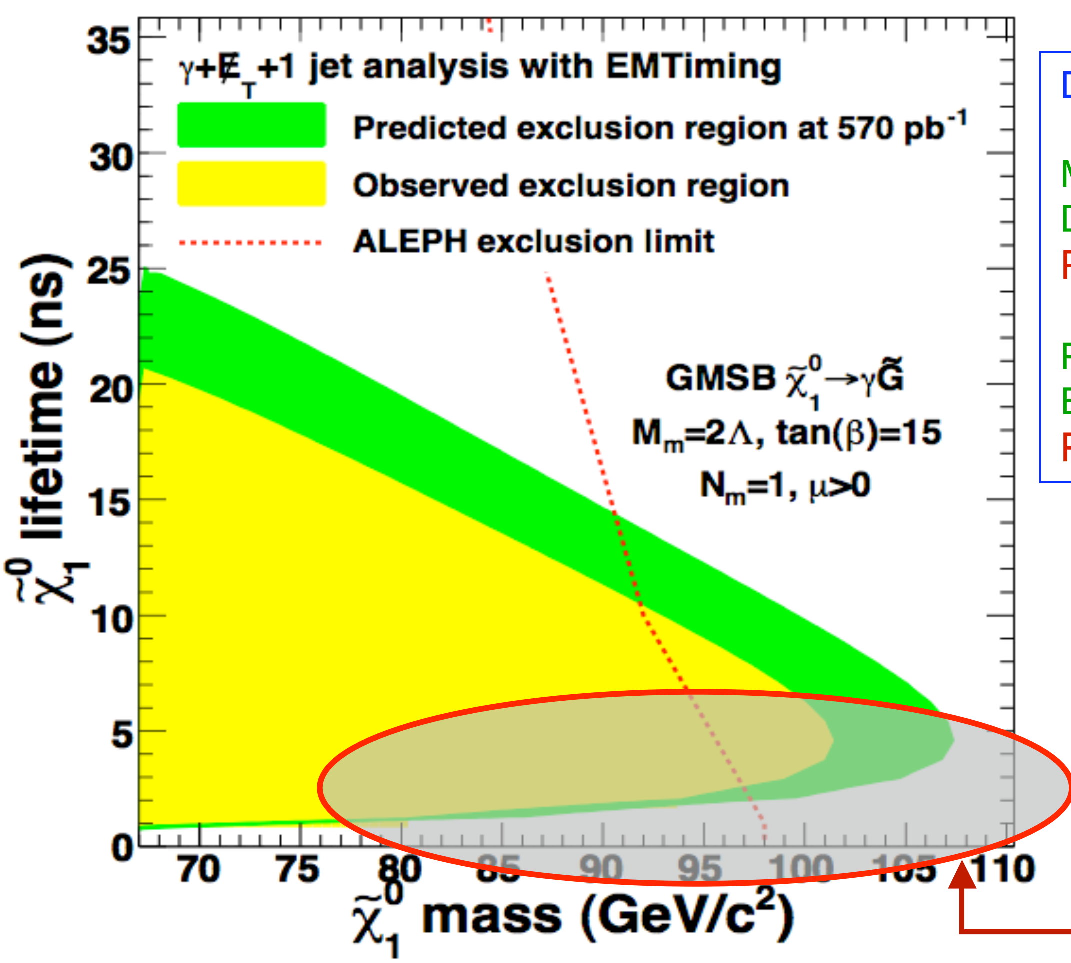

Delayed Photon Analysis

M.Goncharov, V.Krutelyov, E.Lee, D.Toback and P.Wagner
Phys. Rev. Lett 99, 121801 (2007)

P. Geffert, M.Goncharov, V.Krutelyov, E.Lee, D.Toback and P.Wagner
Phys. Rev. D 78, 032015 (2008)

- Single Delayed Photon : Not sensitive to low lifetimes
- Trying to understand our sensitivity here and for larger masses

Quick Analysis Overview

New Features since 202 pb^{-1} analysis
Phys.Rev.D71, 031104 (2005)

- New Met Resolution Model to improve QCD rejection
- The EMTiming system to reject cosmics and beam halo
- Simplify and Re-optimize the analysis due to more direct ways of rejecting backgrounds
- Use 13 times more data
- Estimate the sensitivity to non-zero lifetime
  (EMTiming Simulation in GMSB signal MC)

Documentation:

CDF Notes 9184 and 9575

Analysis Overview

- An *a priori* analysis where we create a presample.
- Estimate the backgrounds for the presample as a function of various cuts
- Optimize with background predictions and signal acceptance
- Open the box

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Background Sources and Data Sets

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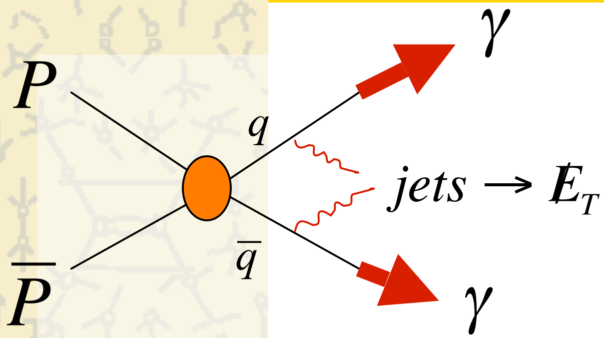
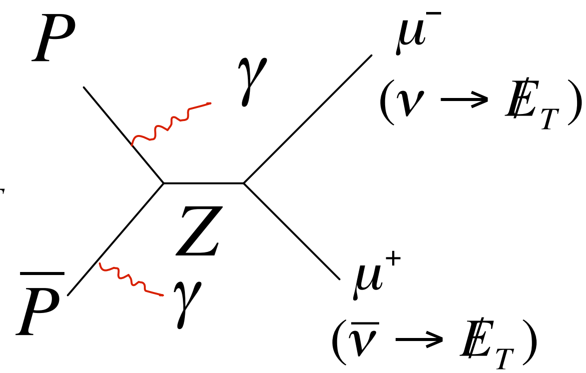
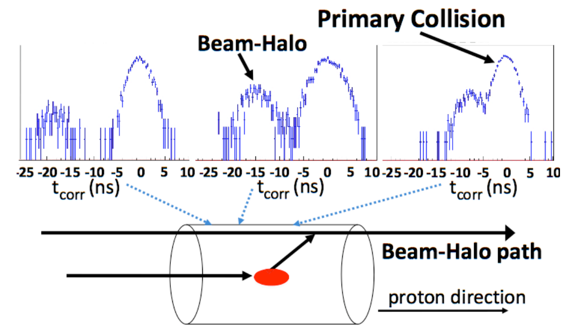
Background Sources



QCD Background



EWK Background



Non-Collision Background : Cosmic and Beam Halo

- QCD Events ($\gamma\gamma, \gamma - jet \rightarrow \gamma\gamma_{fake}$ and $jet - jet \rightarrow \gamma_{fake}\gamma_{fake}$) with fake $\not{E}_T$ due to energy mis-mearsurement and event reconstruction pathologies such as wrong vertex and tri-photon events
- EWK Events with real $\not{E}_T$
- Non-Collision Backgrounds (PMT spikes, cosmic rays, beam halo)

Preselection Requirements, Vertex-Swap Procedure and Met Cleanup Cuts

- Preselection Requirements

  ⇒ Require diphoton events to pass the global event selection, photon ID, non-collision background removal cuts

- Vertex Swap Procedure

  - Remove events where an interaction producing two photon candidates overlapped with more energetic Min-Bias interaction

- Met Cleanup Cuts

  - Remove events with energy lost in calorimeter cracks, or when a photon is lost in the cracks

(More details are CDF Note 9184 and 9575)

Diphoton Events after Pre-selection

Requirements	Events passed
Trigger, Goodrun, and Standard Photon ID with E_T>13 GeV	45,275
Phoenix Rejection	41,418
PMT Spikes Rejection	41,412
Vertex requirements	41,402
E_T(swap)>13 GeV after vertex swap	39,719
Beam Halo Rejection	39,713
Cosmic Rejection	39,663
Met Cleanup Cuts	38,053

- 38,053 events pass these pre-selection cuts
- Next we will talk about the backgrounds and the signal
- Then we will talk about the 3 variables and methods we will use to optimize our analysis for GMSB

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Background Estimations - Sources and methods

QCD Backgrounds with Fake $\not{E}_T$

$$N_{signal}^{QCD} = N_{signal}^{MetModel} + N_{signal}^{PATH}$$

1) QCD due to energy mismeasurements
   (Met Model Prediction-CDF Note 9184)

2) Large fake Met from event reconstruction Pathologies such as Wrong Vertex and Tri-photon events

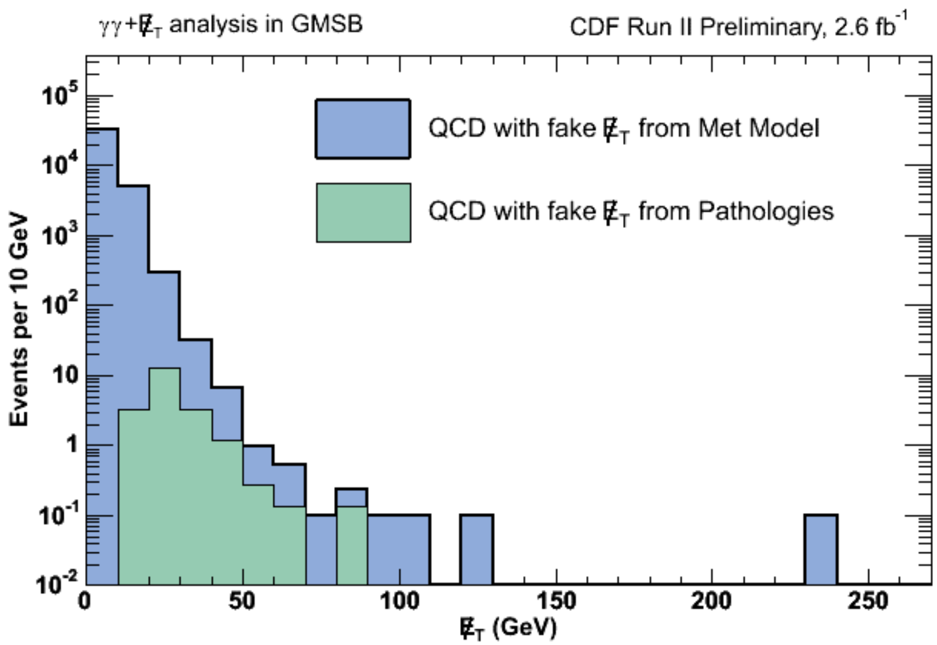
QCD Backgrounds

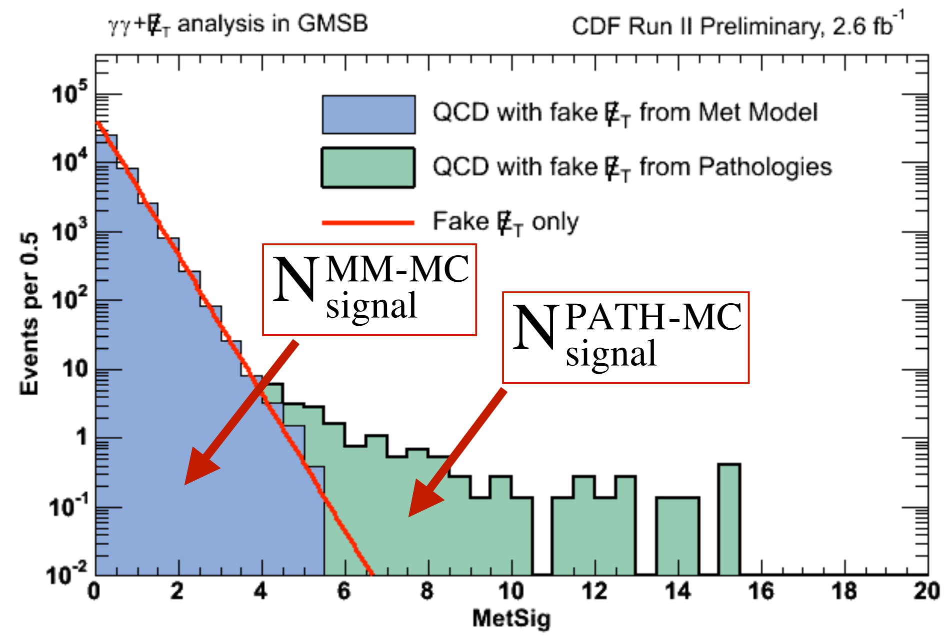
- QCD due to Energy Measurement Fluctuations
  - Predict a shape of fake $\not{E}_T$ by means of Met Resolution Model (CDF note 9184)

- QCD due to Event Reconstruction Pathologies
  - Normalize Pythia diphoton sample (cdfpstn:gx0s1g) to presample to take into account jet backgrounds. Subtract off the Met Model to avoid double counting

$$N^{PATH}_{signal} = (N^{PATH\text{-}MC}_{signal} - N^{MM\text{-}MC}_{signal}) \cdot SF_{QCD}$$

Total QCD Backgrounds for Met and MetSig





EWK Background with Real $\not{E}_T$: Charged Leptons

- W's and Z's with real Met in Charged Leptonic Channels :
  1) $W\gamma\gamma$ and $Z\gamma\gamma$; 2) $W\gamma+\gamma_{fake}$ and $Z\gamma+\gamma_{fake}$; 3) $W+\gamma_{fake}\gamma_{fake}$, $Z+\gamma_{fake}\gamma_{fake}$

  ⇒ $Z\gamma\to\mu\mu\gamma$ events are dominant electroweak background in our analysis

- Using Pythia and Baur MC samples with production cross section, normalize to $e\gamma$ data

$$N^{EWK}_{signal} = \sum_{i=\text{sources}} N^{EWK-MC}_{signal,i} \cdot SF_i \frac{\text{Data}(e\gamma)}{\text{MC}(e\gamma)}$$

where $SF_i = \frac{\sigma_i \cdot k_i \cdot \mathcal{L}}{N^{EWK}_{sample,i}}$ is scale factors to get proper ration of each EWK background for $\gamma\gamma + \not{E}_T$

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EWK Background with Real $\not{E}_T$: Neutral Leptons

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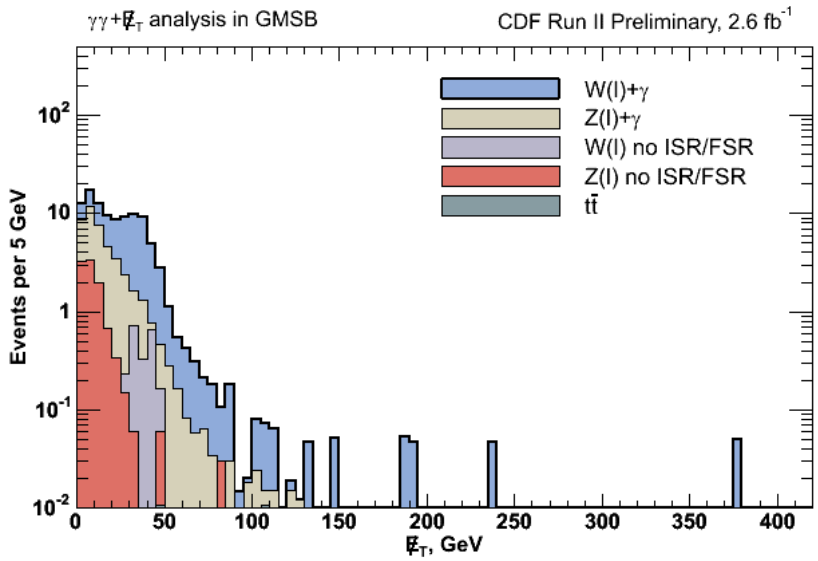
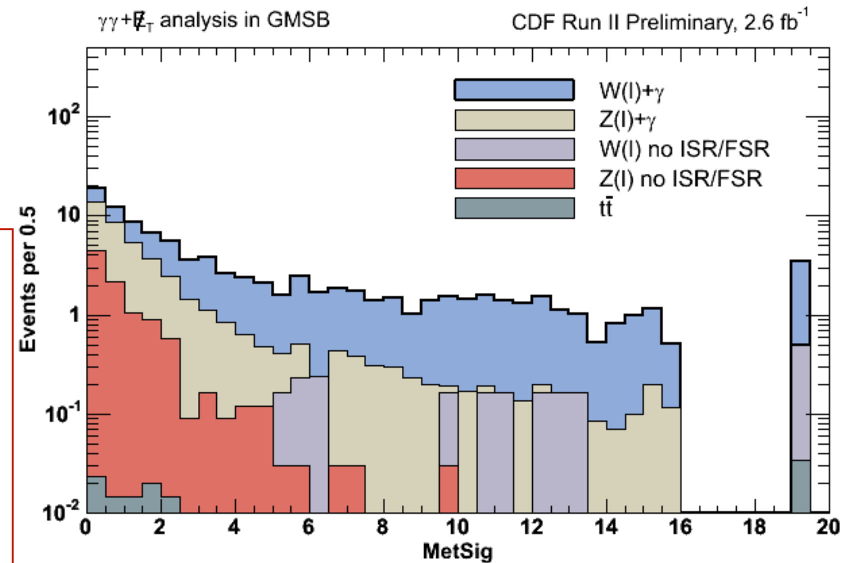
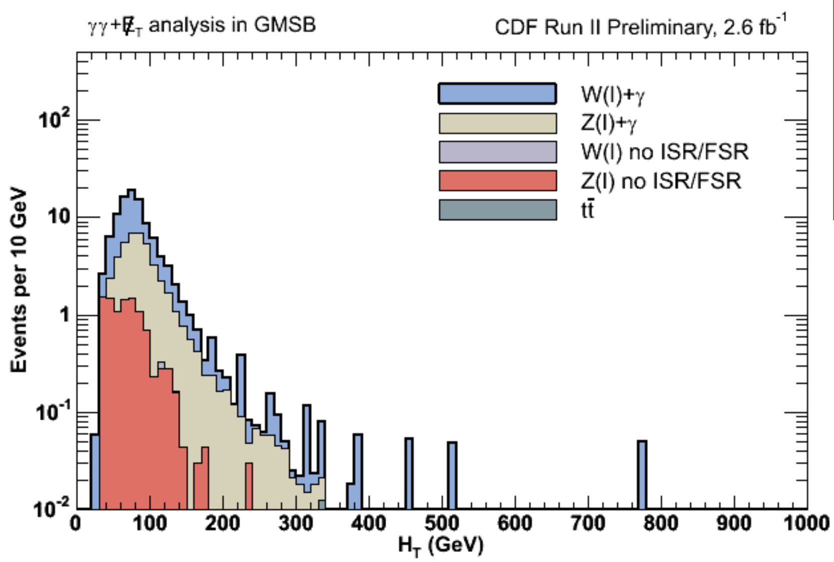
- Neutral Leptonic Channels: $Z\gamma\gamma \rightarrow \nu\nu\gamma\gamma$, $Z\gamma \rightarrow \nu\nu\gamma + \gamma_{fake}$ $Z \rightarrow \nu\nu + \gamma_{fake}\gamma_{fake}$
- Use MadGraph $Z(\mu\mu)+\gamma\gamma$ to estimate $Z(\nu\nu)+\gamma\gamma$ rate indirectly since no such sample is available now.
- Remove photons from FSR by selecting diphoton events by looking at Z mass window [86, 96] GeV at HEPG level
- We are producing Pythia $Z(\nu\nu)+\gamma$ sample now for direct estimation (Still in progress)

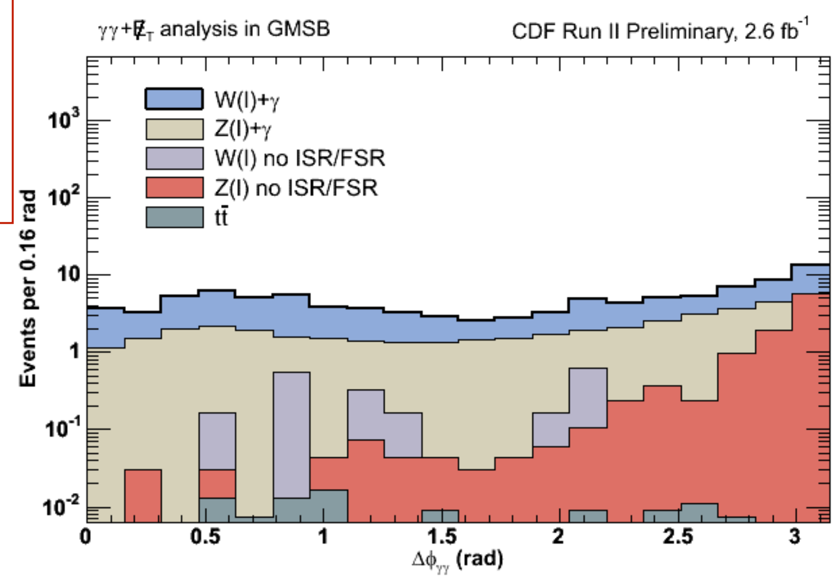
EWK Backgrounds Distributions





Note: Z→νν not included here





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Non-Collision Background

- PMT Spikes:

  Very rare and a distinctive signature - Negligible

- Beam Halo:

  Estimate how many B.H. remain based on rejection power F_{BH}(~90%)

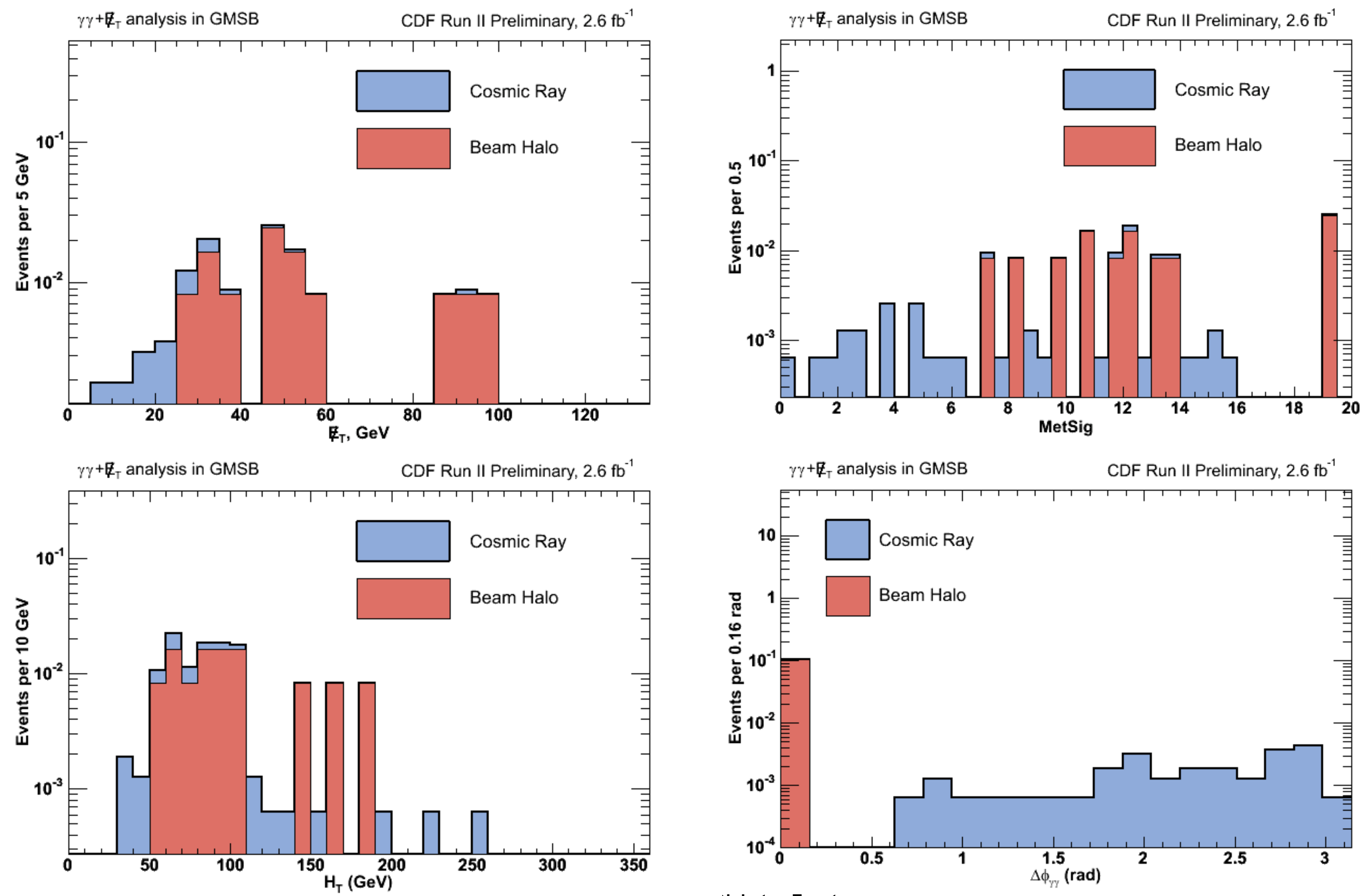
- Cosmic Rays:

  Use the EMTiming system

  These non-collision backgrounds are almost negligible compared to QCD and EWK backgrounds

⇒ **More details in CDF note 9184 and 9575**

Non-Collision Background Distributions



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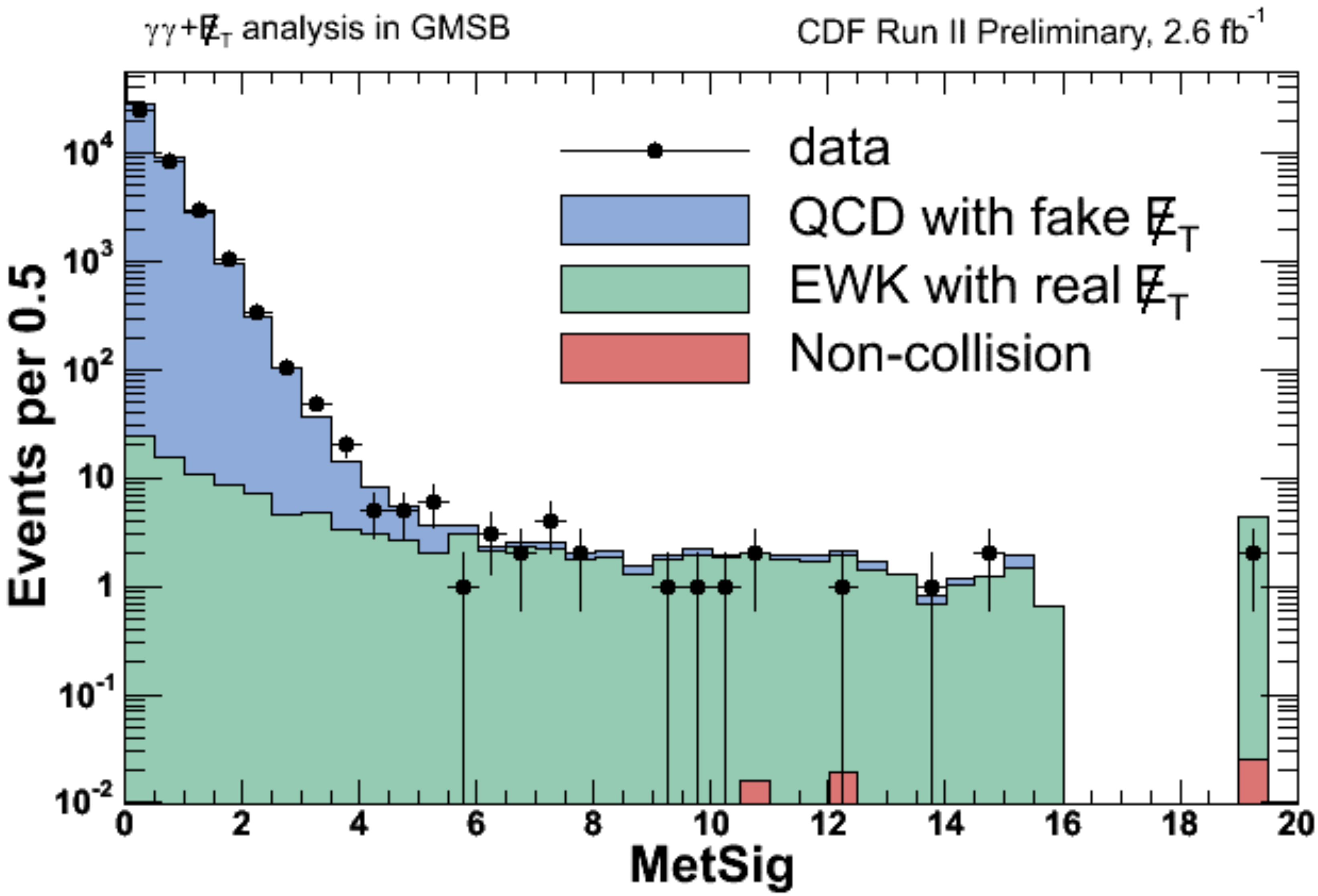
Full Background Comparisons for the Presample



To be pre-blessed

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GMSB MC Simulation and Systematic Uncertainties

GMSB MC Simulation

- Use Pythia Tune-A plus Min-Bias to generate the GMSB signal and cdfSim(Gen6) to simulate the detector.
- The EMTiming system is simulated. (CDF note 7982)

  http://hepr8.physics.tamu.edu/elee/EmtimeSimul.html
- Generate Neutralino MC samples with the following parameters fixed on the minimal GMSB Snowmass Slope SPS 8 with a neutralino NLSP

$$N = 1, \quad \frac{M_m}{\Lambda} = 2, \quad \tan\beta = 15, \quad \mu > 0$$

- Generate 133K events for different mass (70 GeV - 150 GeV) and lifetime (0 ns - 2 ns) points.

Systematic Uncertainties

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- Acceptance
  - Diphoton ID and Isolation: 5.4%
  - ISR/FSR: 4.0%
  - JES: 1.5%
  - MetSig parameterization: 0.7%
  - PDFs: 0.6%
- Cross Section
  - PDFs: 7.5%
  - Q^2: 2.6%
- **Total (combined in quadrature): 10.6%**

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Optimization and Setting Limits

Optimization Strategy and Expected Limits

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- Take the pre-sample and then do an optimization
- Pick a GMSB parameter point (mass=140 GeV, lifetime=0 ns) and find the optimal cuts by calculating the lowest 95% C.L. expected cross section limit.
- Use the standard cross section limit calculator taking into account the expected no. of background events, acceptance, luminosity and their errors
- Pick a single set of optimization variable cuts (next slide)
- Map it out as a function of neutralino mass and lifetime.

The Optimization Cuts

- MetSig : get rid of QCD with fake Met
  - GMSB prodcution has mostly real Met
- H_T : get cascade decays from heavy particles
  - GMSB has lots of H_T, compared to SM backgrounds, from the gaugino pair's cascade decays
- $\Delta\phi(\gamma_1,\gamma_2)$: get rid of back-to-back photons and wrong vertex
  - EWK backgrounds with large H_T are typically a high E_T photon recoiling against W boson, which is highly boosted $\Rightarrow$ The two photons in the final state are mostly back-to-back.
  - The high E_T diphoton with large H_T from QCD are mostly back-to-back with fake Met

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Optimization Results

H_T > 200 GeV
$\Delta\phi(\gamma_1,\gamma_2) < \pi - 0.35$ rad
MetSig > 3

- Example point

$m(\chi^0_1)$=140 GeV, $\tau(\chi^0_1)$=0 ns

- Acceptance : 7.80 ± 0.54 (%)
- Luminosity : 2.6 ± 0.2

Background Estimations	
EWK	0.77 ± 0.21 ± 0.22
QCD	0.46 ± 0.22 ± 0.10
Non-Collision	0.001 + 0.008 - 0.001
Total	1.23 ± 0.30 ± 0.24

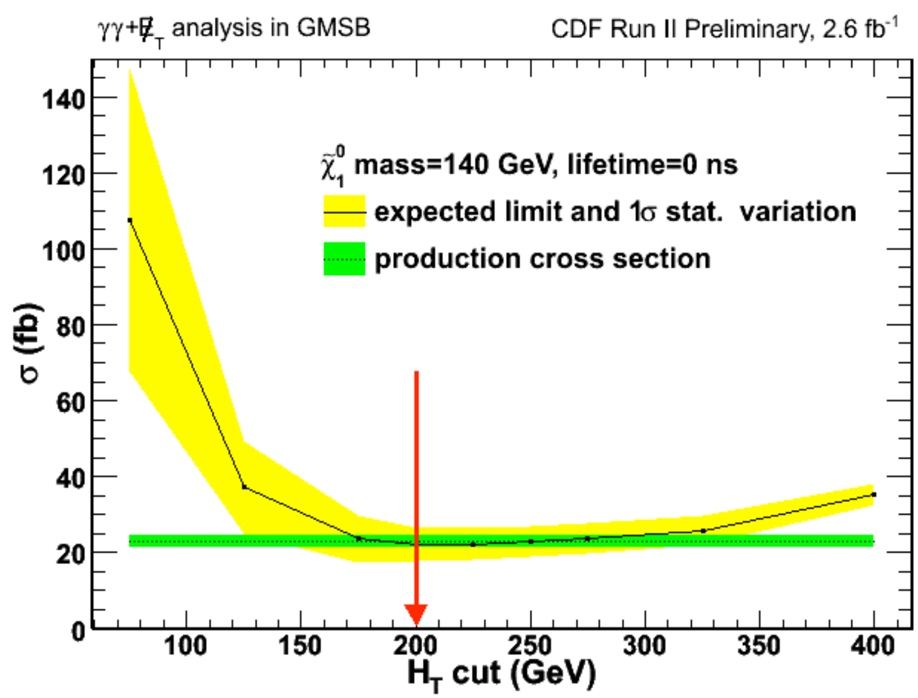
σ_{exp} = 22.08 fb

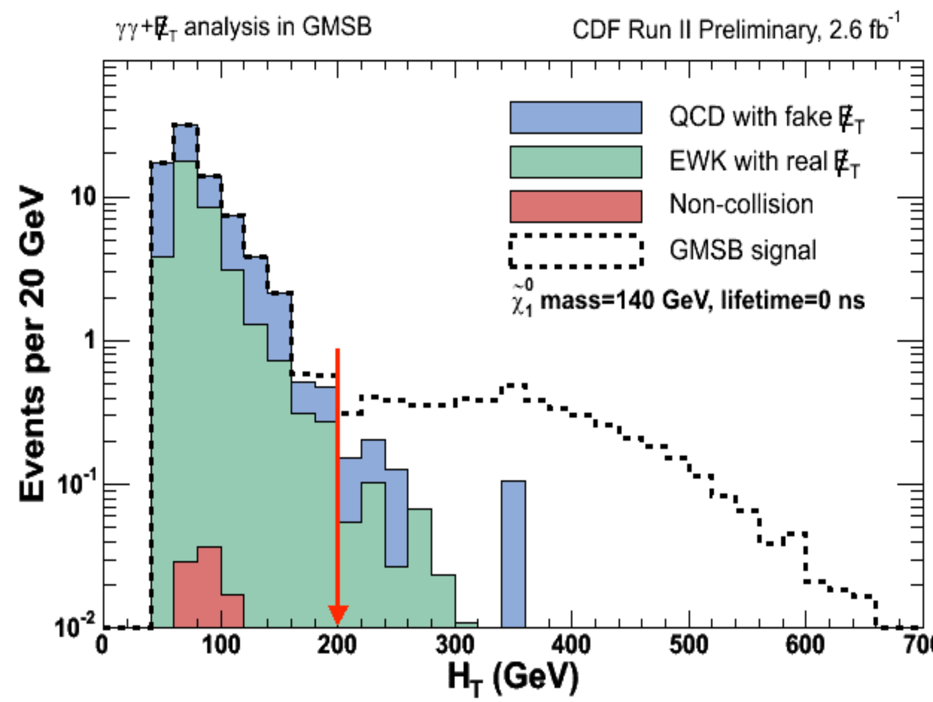
σ_{prod} = 22.97 fb

The Plots to be Pre-Blessed

All Plots from here on out to be reblessed

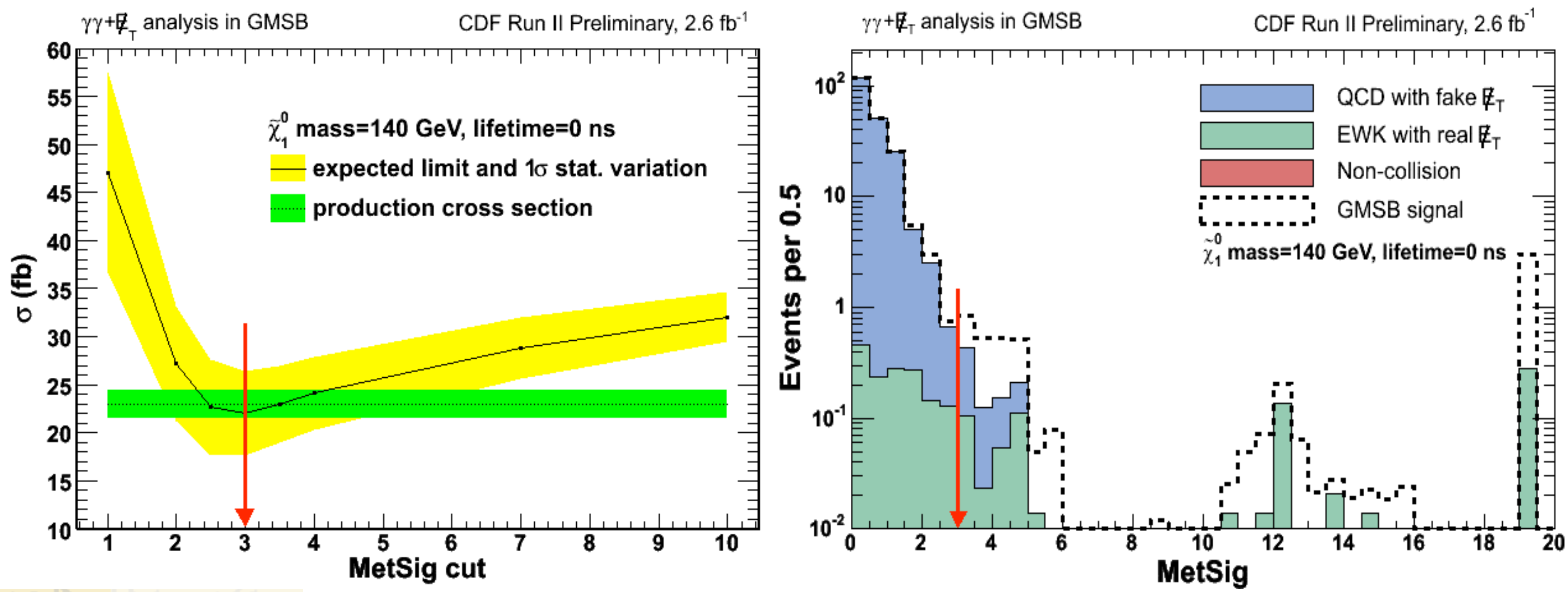
95% C.L. Expected Cross Section Limit and N-1 Plot: H_T





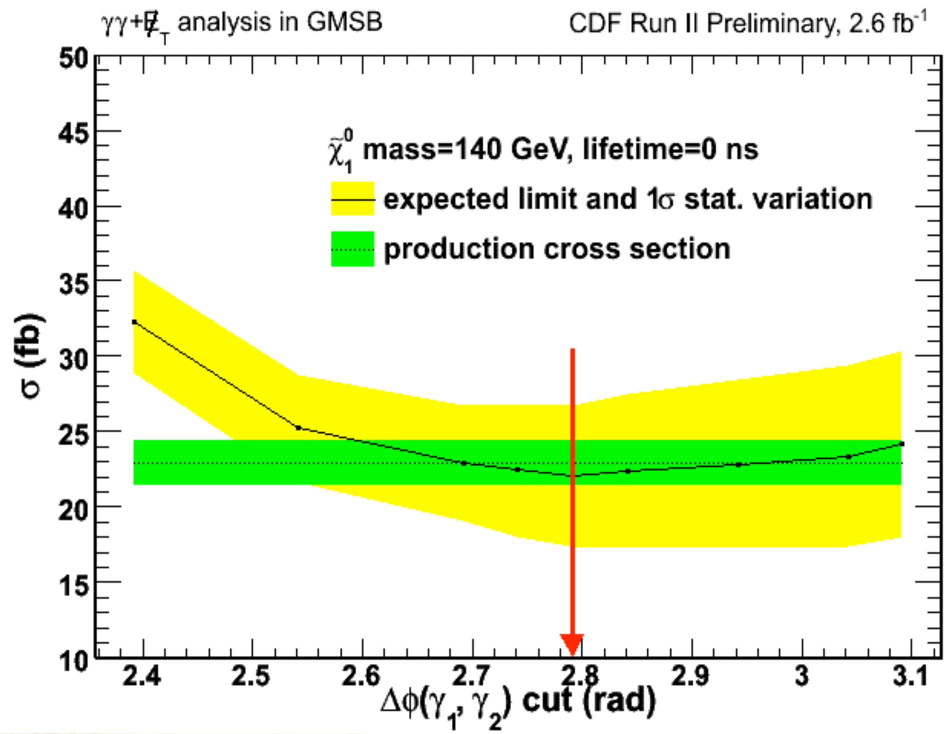
- **While varying a cut all other variables held at optimal cuts**
- **N-1 plot for background distributions along with GMSB MC signal shows good separation**

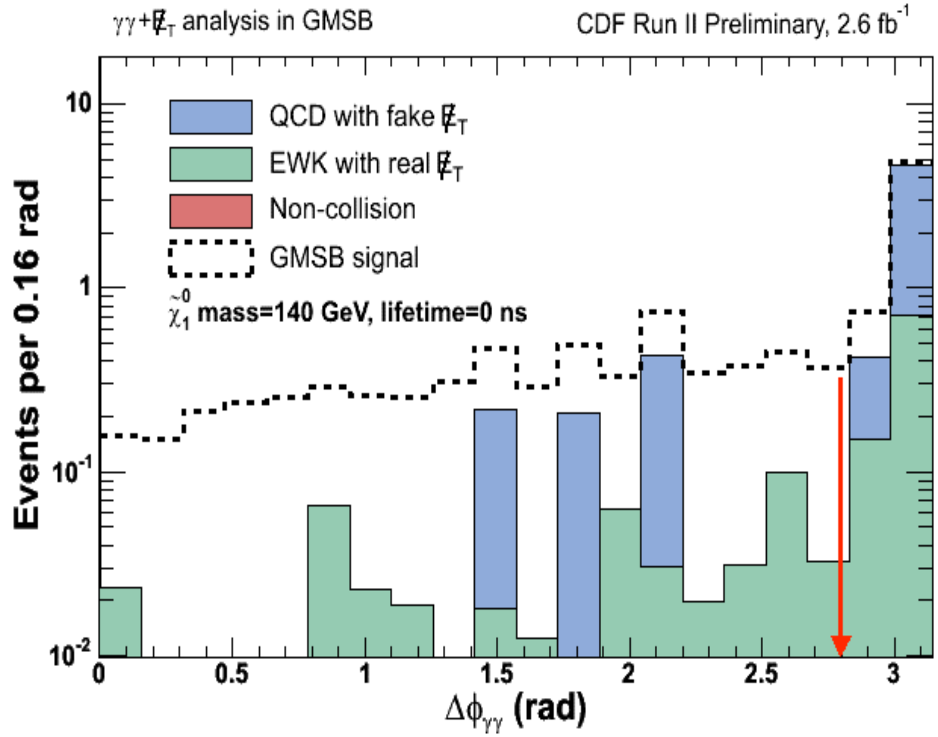
95% C.L. Expected Cross Section Limit and N-1 Plot: MetSig



- While varying a cut all other variables held at optimal cuts
- N-1 plot for background distributions along with GMSB MC signal shows good separation

95% C.L. Expected Cross Section Limit and N-1 Plot: $\Delta\phi(\gamma_1,\gamma_2)$

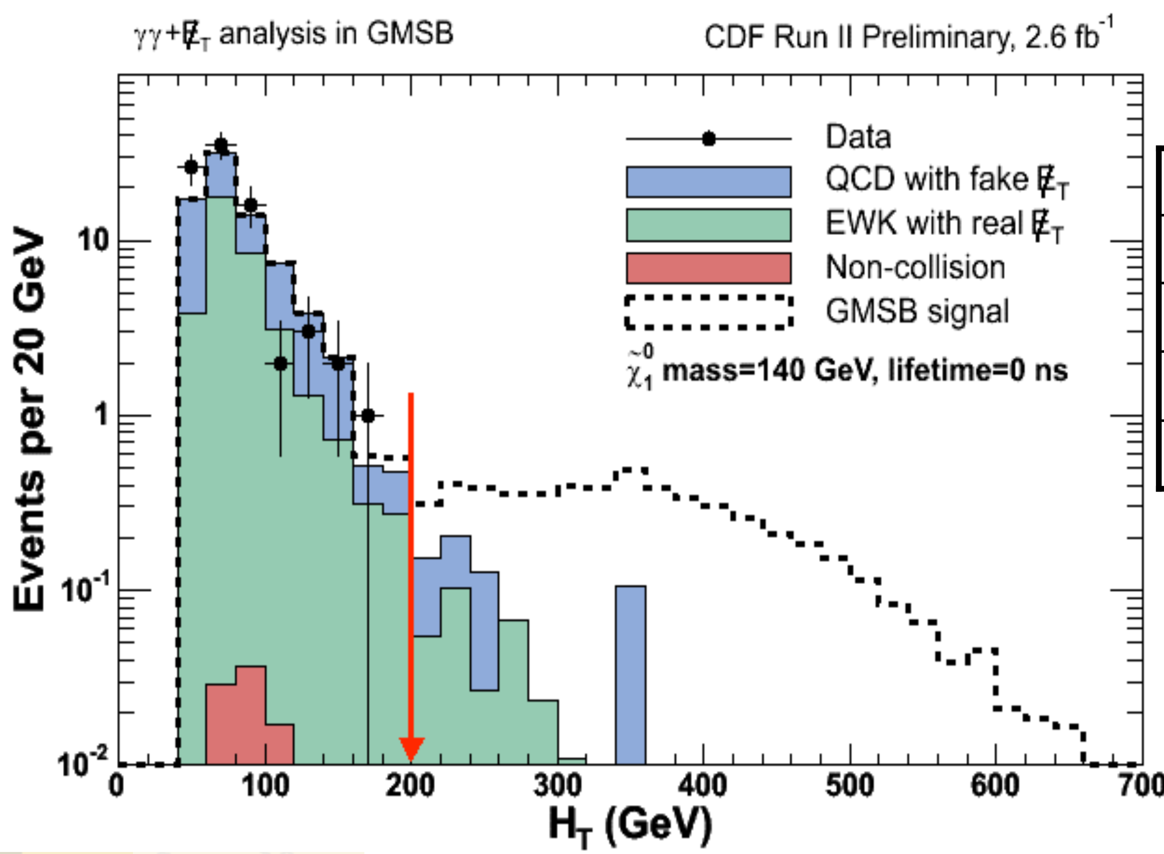




- While varying a cut all other variables held at optimal cuts
- N-1 plot for background distributions along with GMSB MC signal shows good separation

Data distribution and N-1 Plots

We open the box: 0 events observed

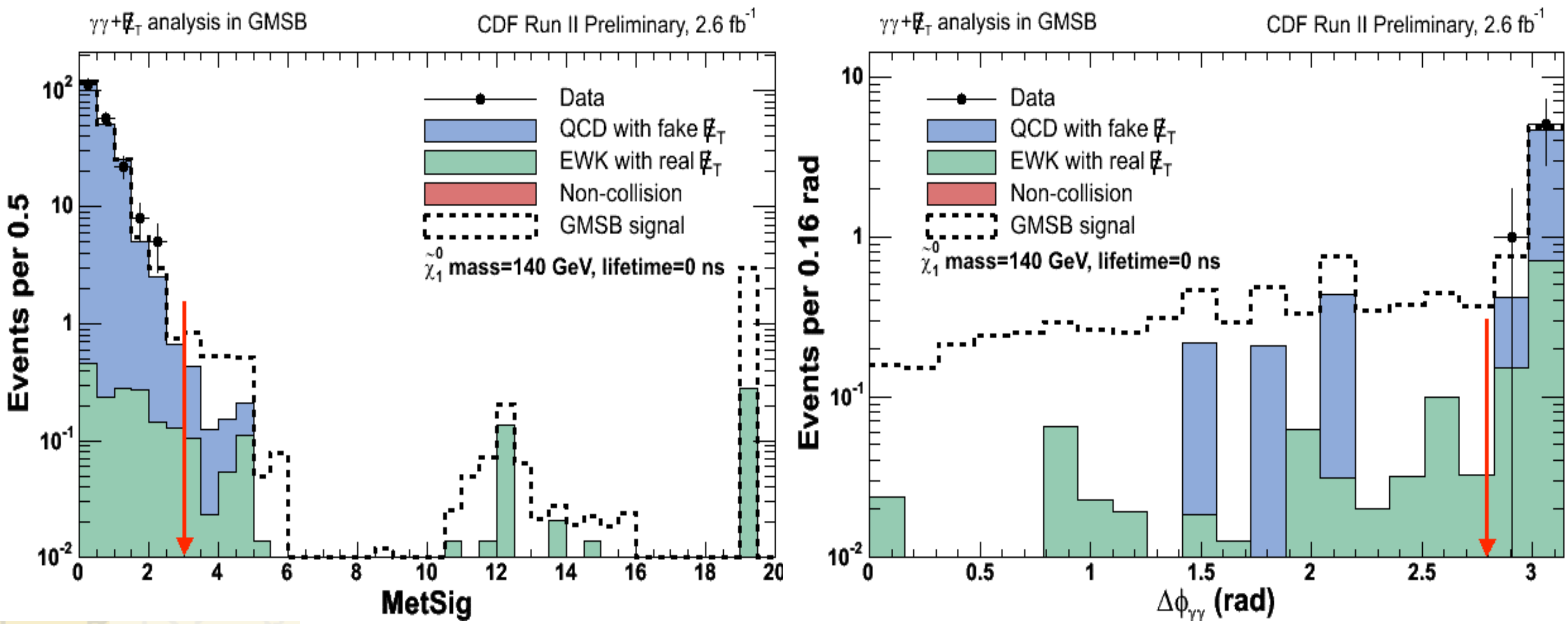


The table to be reblessed

Background Estimations	
EWK	0.77 ± 0.21 ± 0.22
QCD	0.46 ± 0.22 ± 0.10
Non-Collision	0.001 + 0.008 - 0.001
Total	1.23 ± 0.30 ± 0.24

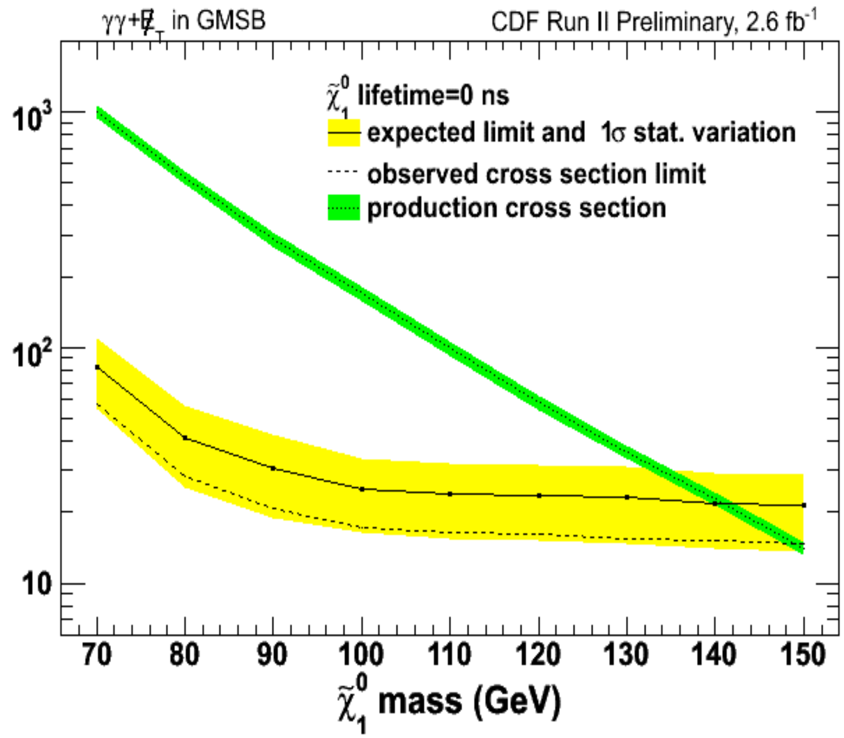
- For a distribution all other variables held at optimal cuts
- Everything is well modeled

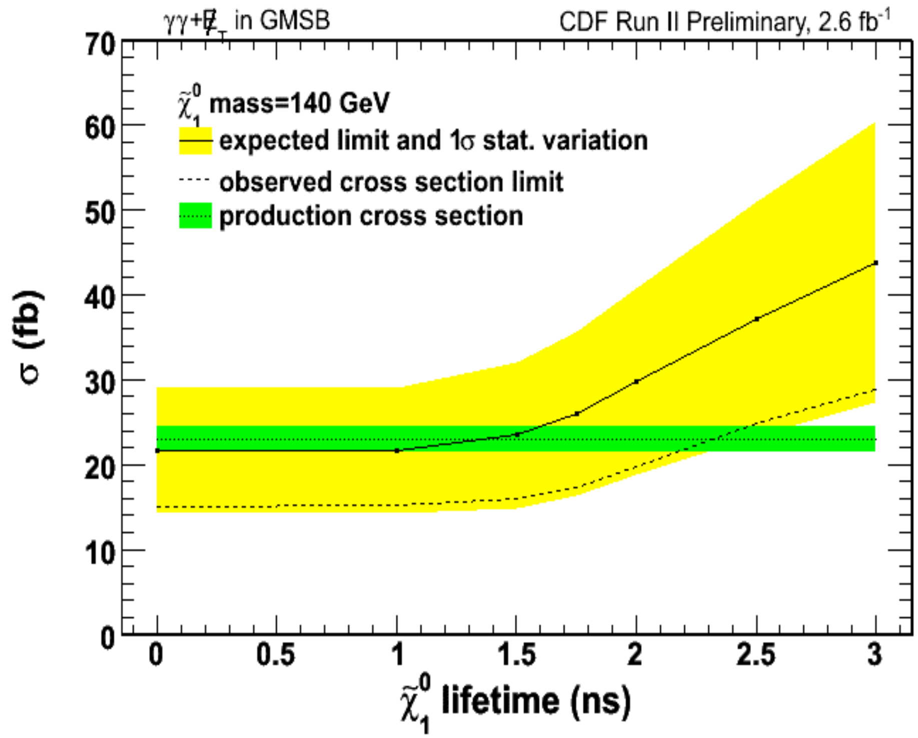
More N-1 Plots



- For a distribution all other variables held at optimal cuts

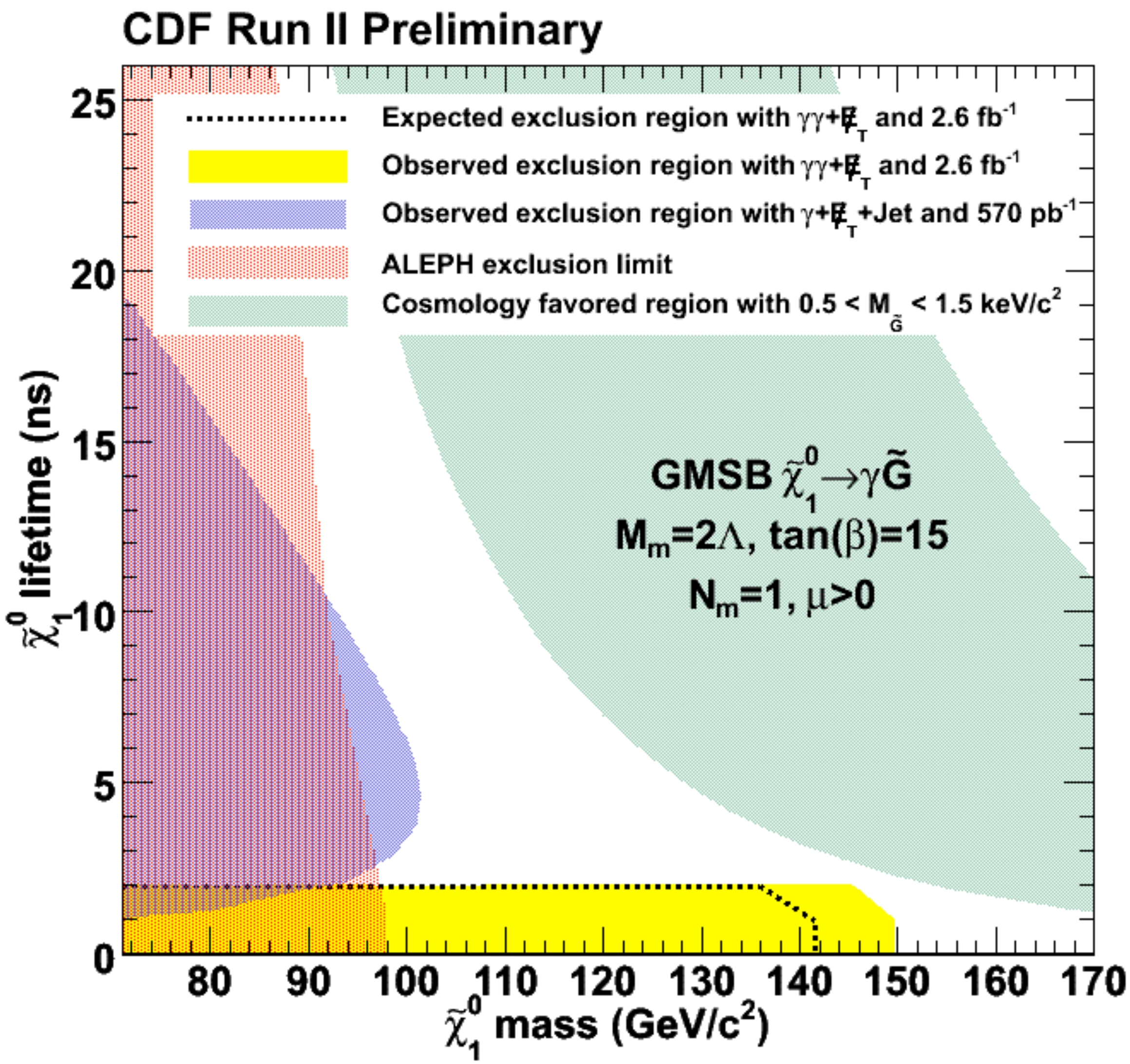
Cross Section Limits vs. Neutralino mass (for τ = 0 ns) and lifetime (for m=140 GeV)





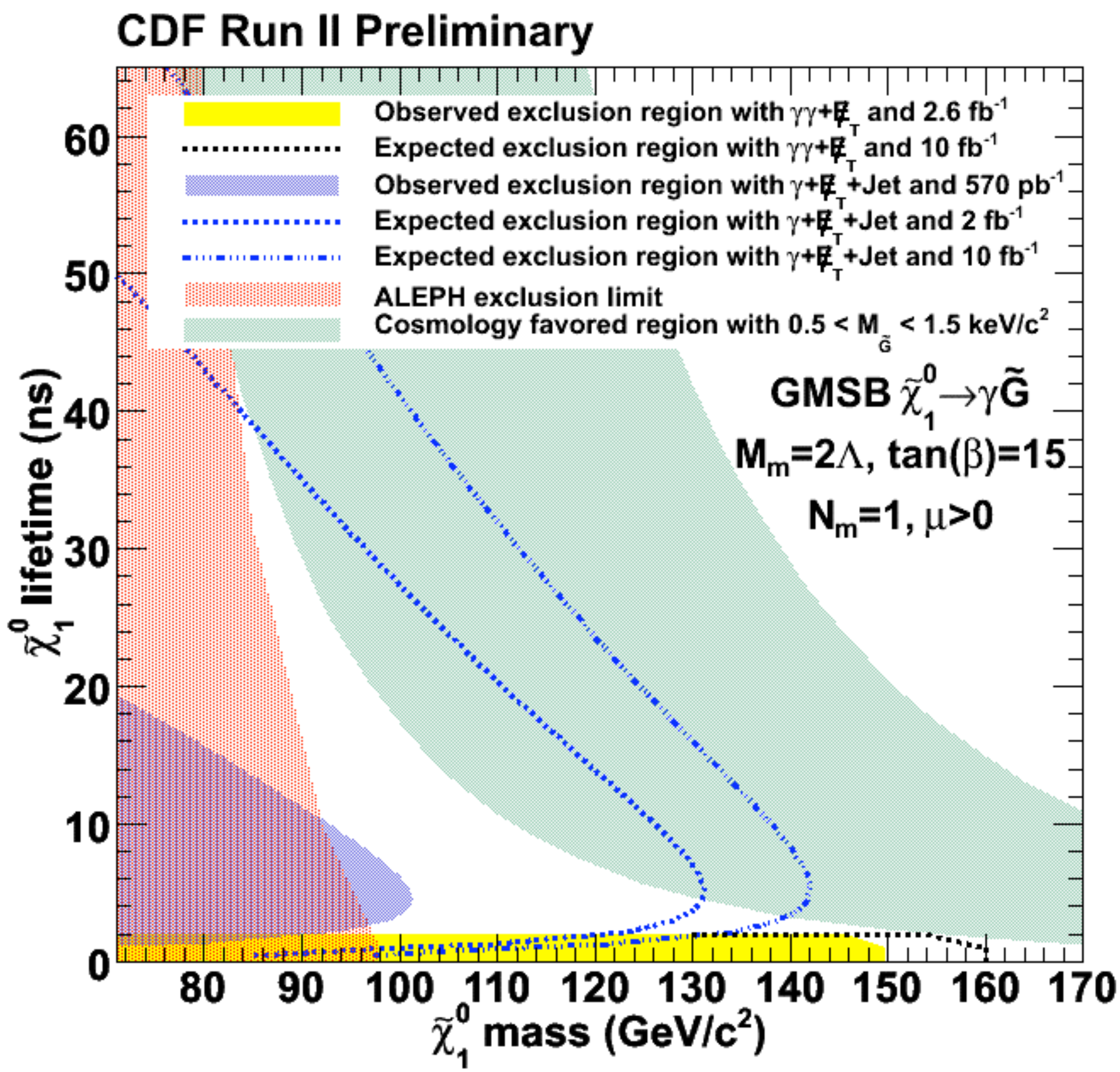
- Using the optimal cuts: Ht > 200 GeV $\Delta\phi(\gamma_1,\gamma_2) < \pi - 0.35$ rad MetSig >3
- Expected (Observed) neutralino mass limit 141 GeV (149 GeV) for τ=0 ns
- Exclude neutralino lifetime up to ~2.3 ns for m=140 GeV

Exclusion Region



- Exclude up to ~ 149 GeV at 0 and 1 ns. (Beyond DØ Limit = 125 GeV)
- New Limits extend the sensitivity in both mass and lifetime. (goes above the Delayed Photon Analysis)
- We are nearing the cosmology favored region (green band)
- We stop artificially at 2 ns

Prospects for the future



- For high luminosity we calculate the cross section limits assuming:
  - all backgrounds scale linearly with luminosity
  - their uncertainty fractions remain constant
- $\gamma\gamma+\not\!\!E_T$: will extend mass limits up to 160 GeV with 10 fb^{-1}
- The next generation delayed photon analysis will cover up high lifetime region

Conclusion and Plan

- All changes discussed last time and documented in the CDF note
- Optimization:
  Ht > 200 GeV, $\Delta\phi(\gamma_1, \gamma_2) < \pi - 0.35$, Metsig > 3
- Exclude neuralino mass 149 GeV for lifetime=0, 1 ns.
- World BEST Limit
- Finish $Z(\nu\nu)+\gamma\gamma$
- Publish in PRL

Back Up Slides

Blessed Analysis 11/06/08 - cont.

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- Triggers : DIPHOTON_12 (iso), DIPHOTON_18 (no iso)
- Luminosity = 2.03 fb^{-1} with 6% uncertainty
- Preselection Cuts:
  - $N_{vx12} \geq 1$, Highest ΣP_T Vertex, $|Z_{vx}| < 60$ cm
  - Two Central Photons ($E_T > 13$ GeV)
  - Standard Photon ID cuts with PMT spikes and Phoenix rejection cut
  - Cosmics and Beam Halo removal cuts

Preselection Requirements for the Presample	Events passed
Trigger, Goodrun, and Standard Photon ID with E_T>13 GeV	36,802
Phoenix Rejection	33,899
PMT Spikes Rejection	33,796
Vertex Cuts	32,899
Beam Halo Rejection	32,890
Cosmic Rejection (EMTiming cut for Runs after 190851)	32,865
Cosmic Rejection (Muon Stub Cut for Runs before 190851)	32,720

Good Runs, Triggers, Data Sets and Pre-Selection Cuts

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- Data Stntuples: cdfpstn: cdipa(d,h,i,j) , cdfpstn: bhelb(d,h,i,j)
- Triggers : DIPHOTON_12 (iso), DIPHOTON_18 (no iso),
  PHO_50 (no iso), PHO_70 (no HadEm)
- Goodrun list: The good run list v.23 (up to and including period 17)
- Luminosity = 2.59 fb^{-1} with 6% uncertainty
- Code Release: cdfsoft 6.1.4, Stntuple dev_243
- Data Samples : $\gamma\gamma$ sample, $W\rightarrow e\nu$ sample (study EWK with real $\not\!\!E_T$),
  $Z\rightarrow e^+e^-$ sample (study QCD with fake $\not\!\!E_T$)
- Pre-Selection Cuts:
- $N_{vx12} \geq 1$, Highest ΣP_T Vertex, $|Z_{vx}| < 60$ cm
- Two Central Photons ($E_T > 13$ GeV)
- Standard Photon ID cuts and Phoenix rejection cut
- PMT Spikes, Cosmics and Beam Halo removal cuts
- Vertex Swap Procedure and Met Cleanup cuts

Standard Central Photon ID Cuts

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cuts	Tight cuts
Calorimeter fiduciality	central
Photon E_T	>13 GeV (7 GeV for pre-selection)
CES fiduciality	$\|X_{CES}\|$<21.0 cm; 9.0 cm<$\|Z_{CES}\|$<230.0 cm
Average CES χ^2	<20
Had/Em	<0.055+0.00045*E_T
Corrected CalISO	<2.0+0.02(E_T-20) or <0.1*E_T if E_T<20.0 GeV
TrkISO	<2.0+0.005*E_T
N3D	N3D=0,1
Trk P_T (if N3D=1)	<1.0+0.005*E_T
2^{nd} CES (wire or strip)	<0.14*E_T if E_T<18 GeV or <2.4+0.01*E_T if E_T>18 GeV

Phoenix rejection	No photons matched to phoenix track
PMT spike rejection	|pmt1-pmt2|/(pmt1+pmt2)<0.65

Vertex Swap Procedure and Met Cleanup Cuts

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- Vertex Swap Procedure:
  - A wrong vertex can be picked when a diphoton pair is produced by one interaction and overlaps with a more energetic semi-hard interaction (Min-Bias interaction) giving the highest ΣP_T vertex
  - Usually small, but sometimes can give large fake Met if the two vertices are far apart or if the original photons are sufficiently energetic
  - For every event with multiple vertices we calculate the photon E_T with respect to every vertex with $|Z_{vx}|<60$ cm and select the one that gives the smallest Met
  - As a result, some photons fall below the $E_T > 13$ GeV and are removed.

- Met Cleanup Cuts:
  - Remove events with *tower-9* effects, energy lost in -cracks between CEM towers, or when a photon is lost in the central or forward crack leaving a signature of a small jet if
    1) The second photon is pointing right at the Met
    2) Any jet is pointing right at the Met (More details are CDF Note 9184 and 9575)

Non-Collision Background Removal Cuts

- PMT Spikes (CDF note 7960) removed by requiring:
  i) E_{CEM}>10 GeV and lpmt1-pmt2l/(pmt1+pmt2)<0.65 (removes ~100%)
  ii) E_{HAD}>10 GeV and lpmt1-pmt2l/(pmt1+pmt2)<0.85 (studied by looking on balanced jets)

- Beam Halo(CDF note 7960, 8409) removed by requiring:
  seedWedge>4, NHadPlug>2,
  seedWedgeHadE<0.4+(M.I.*(N_{vx12}-1)+U.E.)*seedWedge

- Cosmics(CDF note 7960) removed by two different category cuts:
  All Data (starting from run 190851) has EMTiming information
  ⇒ $|T_{1,2}| > 4\sigma_T$ where σ_T=1.665 ± 0.007 ns
  ⇒ $|\Delta T=T_1-T_2| > 4\sigma_{\Delta T}$ where $\sigma_{\Delta T}$=1.021 ± 0.007 ns

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QCD Background due to Energy Mismeasurements in the Calorimeter

- Predict a shape of fake $\not{E}_T$ (un-clustered energy and jets) by means of Met Resolution Model (CDF note 9184)
- For un-clustered energy $\not{E}_T$ distributions fitted with double Gaussian parameterized by MC samples (Pythia $\gamma\gamma$, Pythia $Z \rightarrow e^+e^-$) and Data ($\gamma\gamma$ control sample, $Z \rightarrow e^+e^-$)
  - ⇒ Systematics: Difference between $\gamma\gamma$ control sample and $Z \rightarrow ee$ and Uncertainty on evolution of 4 parameters
- For jets obtain jet energy resolution as a function of jet E_T. The jet resolution is parameterized by Gaussian+ Landau fit (Pythia di-jet, Pythia Z/γ^*, Pythia Z+jet and di-jet, Z+jet data)
  - ⇒ Sytematics: Uncertainty on evolution of 5 parameters
- Sum up all of individual $\not{E}_T$ components due to un-clustered energy and each of jets with $E_T^{smear} > 15$ GeV
  - ⇒ Sytematics: 10 individual sources combined in quadrature

QCD Background with Large Met from Pathologies

- Use Pythia diphoton sample (cdfpstn:gx0s1g) and subtract off the expectation for Gaussian fluctuations in MC and normalize to data

$$N_{\text{signal}}^{\text{PATH}} = (N_{\text{signal}}^{\text{PATH-MC}} - N_{\text{signal}}^{\text{MM-MC}}) \cdot SF_{\text{QCD}}$$

$$N_{\text{signal}}^{\text{MM-MC}} = N_{\text{signal}}^{\text{noMetSig cut}} \cdot R_{\text{MetSig}}^{\text{exp}}$$

where $N_{\text{signal}}^{\text{noMetSig cut}}$ = number of events passing all cuts but MetSig cut

$$R_{\text{MetSig}}^{\text{exp}} = \ln(10) \cdot 10^{-\text{MetSig}}$$ = expected rate for MetSig cut

$$SF_{\text{QCD}} = \frac{N_{\text{presample}}^{\text{QCD-Data}}}{N_{\text{presample}}^{\text{QCD-MC}}} = \frac{38{,}053}{283{,}554} = 0.134 \pm 0.007$$

Reblessing Talk

EWK Background with Real $\not{E}_T$ in Charged Leptonic Channels

Reblessing Talk

- W's and Z's with real Met in Charged Leptonic Channels :

  1) $W\gamma\gamma$ and $Z\gamma\gamma$; 2) $W\gamma+\gamma_{fake}$ and $Z\gamma+\gamma_{fake}$; 3) $W+\gamma_{fake}\gamma_{fake}$, $Z+\gamma_{fake}\gamma_{fake}$

  ⇒ $Z\gamma\rightarrow\mu\mu\gamma$ events are dominant electroweak background in our analysis
- Use the standard electroweak MC sample normalized to their prodcution cross section and sum up all sources in all decay channels of W/Z
- To minimize the dependence of prediction on Data-MC differences, normalize $e\gamma$+Met events in MC-to-Data to be global scale factor
- The uncertainty on the EWK backgrounds are dominated by the normalization factor uncertainty, which include data and MC statistical uncertainties and differences in MC modeling of E/p distribution

$$N^{EWK}_{signal} = \sum_{i=\text{sources}} N^{EWK-MC}_{signal,i} \cdot SF_i \frac{\text{Data}(e\gamma + \not{E}_T)}{\text{MC}(e\gamma + \not{E}_T)}$$

where $SF_i = \dfrac{\sigma_i \cdot k_i \cdot \mathcal{L}}{N^{EWK}_{sample,i}}$ is scale factors to get proper ration of each EWK background for $\gamma\gamma + \not{E}_T$

Reblessing Talk

Wrong Vertex

- Wrong Vertex with no vertex

- The vertex swap cannot fix events when diphoton interaction does not produce a reconstructed vertex at all, e.g., with large Z_{vx}

1) First model all QCD background constribution as being from "cdfpstn:gx0s1g" Pythia $\gamma\gamma$ sample with large statistics
2) Select Pythia $\gamma\gamma$ events where the hard interaction does not produce a vertex, and primary vertex is due to overlapping Min-Bias interaction
3) To avoid double counting the events from energy mismeasurements predicted by Met Model, subtract Met Model prediction
4) The systematic uncertaintis from scale factor and the uncertainty due to MC-data difference in unclustered energy parametrization and jet energy scale

$$N^{WVX}_{signal} = (N^{WVX\text{-}MC}_{signal} - N^{WVX\text{-}MC}_{Met\ Model}) \cdot SF_{QCD}$$

where $SF_{QCD} = N^{QCD\text{-}Data}_{presample} / N^{QCD\text{-}MC}_{presample}$ is the QCD scale factor.

Tri-Photon

- Tri-photon with a lost photon
  - Events when we lost a photon in the calorimeter cracks
  1) Use the exactly same strategy as in the wrong vertex
  2) Select reconstructed tri-photon candidate event in Pythia $\gamma\gamma$ sample and apply all of the analysis cuts and multiply by the QCD scale factor
  3) Also subtract Met Model prediction to avoid double counting events from energy mismeasurements predicted by Met Model
  4) The systematic uncertaintis from scale factor and the uncertainty due to MC-data difference in unclustered energy parametrization and jet energy scale

$$N^{\mathrm{TRI}}_{\mathrm{signal}} = (N^{\mathrm{TRI\text{-}MC}}_{\mathrm{signal}} - N^{\mathrm{TRI\text{-}MC}}_{\mathrm{Met\ Model}}) \cdot SF_{\mathrm{QCD}}$$

where $SF_{\mathrm{QCD}} = N^{\mathrm{QCD\text{-}Data}}_{\mathrm{presample}} / N^{\mathrm{QCD\text{-}MC}}_{\mathrm{presample}}$ is the QCD scale factor.

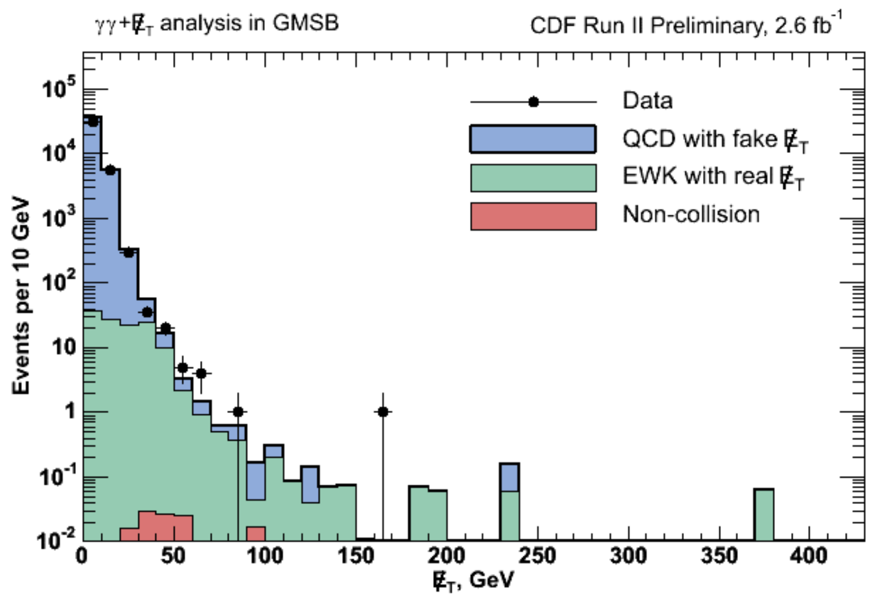
Rebelssing Talk

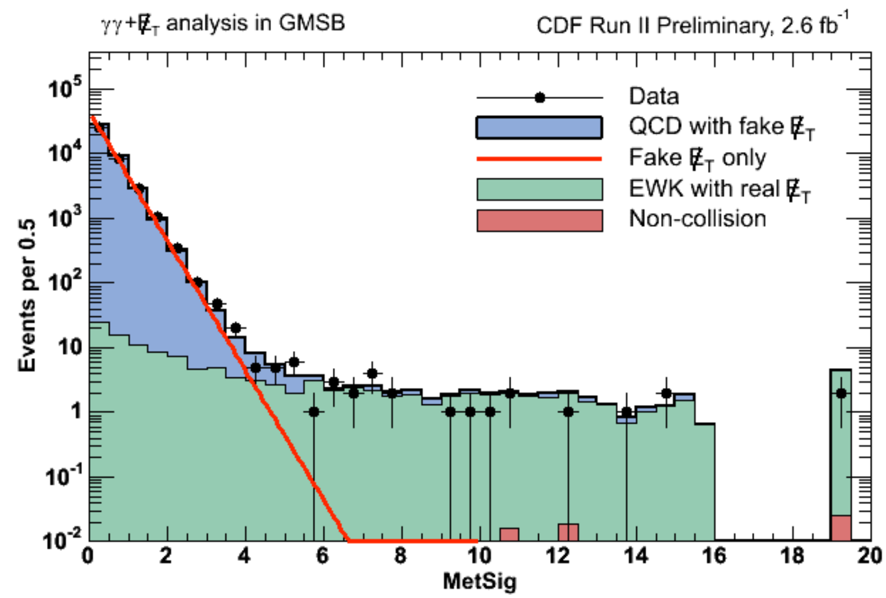
Non-Collision Background

- PMT Spikes:
  Very rare and a distinctive signature (remove very efficiently) : Negligible
- Beam Halo:
  Estimate how many B.H. remain based on rejection power F_{BH}(~90%)
  The uncertainties are dominated by statistical uncertainty on the number of identified cosmic ray events
- Cosmic Rays:
  Determine $\gamma\gamma$ -like cosmic ray event rates in signal timing window ($4\sigma_T$) and $\Delta T(\gamma_1\text{-}\gamma_2) <$ 5 ns, assuming flat timing distribution of cosmic rays
  The uncertainties are dominated by statistical uncertainty on the number of identified beam halo events
  These non-collision backgrounds are almost negligible compared to QCD and EWK backgrounds

⇒ **More details of these estimations in CDF note 9184 and 9575**

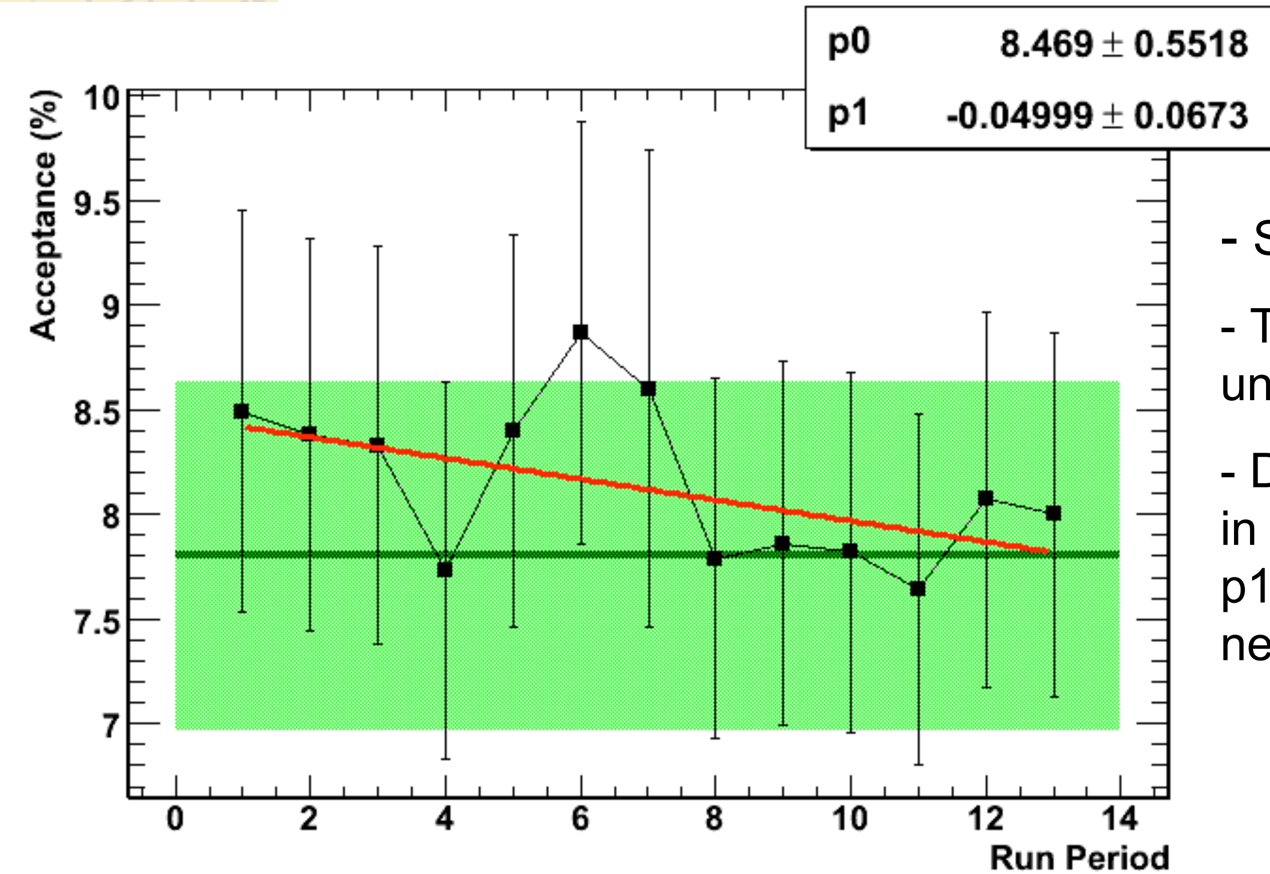
Distributions for Presample I





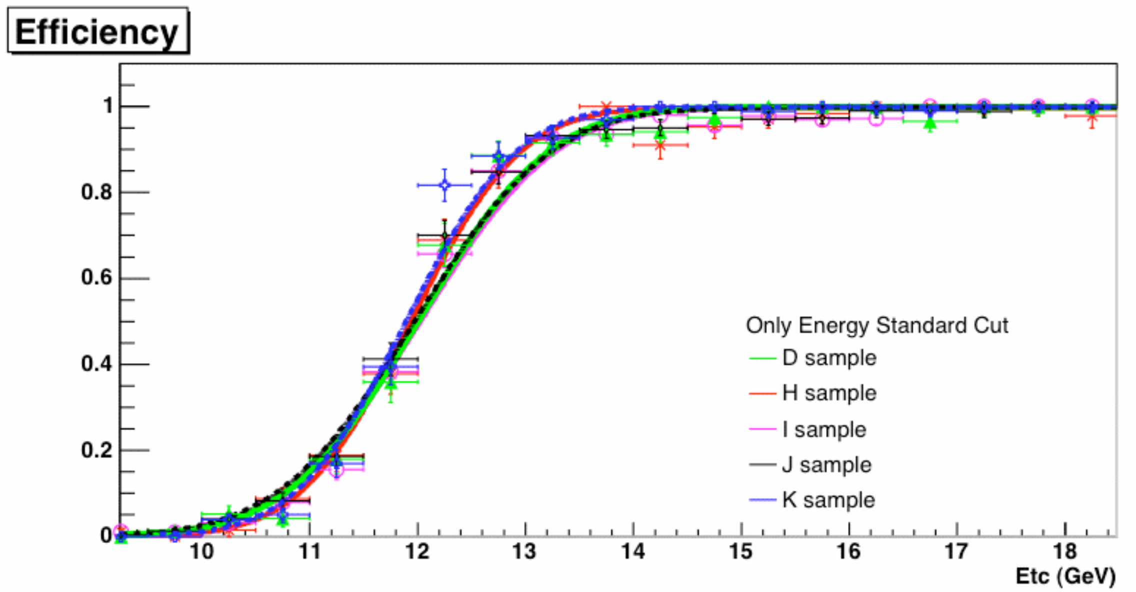
- **All backgrounds are well modeled**
- **MetSig plot shows the clear separation between QCD and EWK backgrounds showing the power of our background estimation technique**

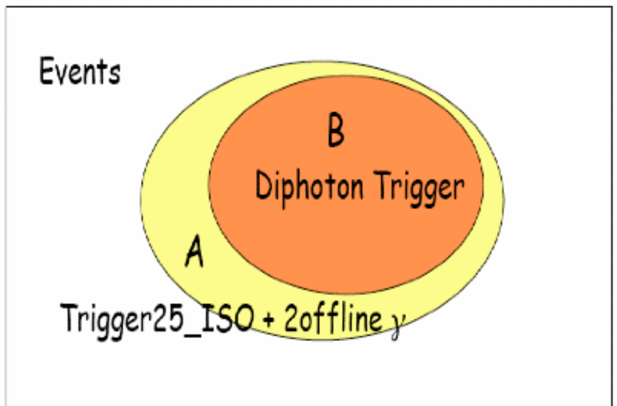
Run-Dependent GMSB MC with Min-Bias and Tune-A Acceptance VS. Luminosity



- Simulate p1 - p13
- The slope is zero within uncertainty
- Difference of acceptance in the run regions (p14 - p17) we didn't simulate is negligible

Diphoton Trigger Efficiency (CDF Note 9533)





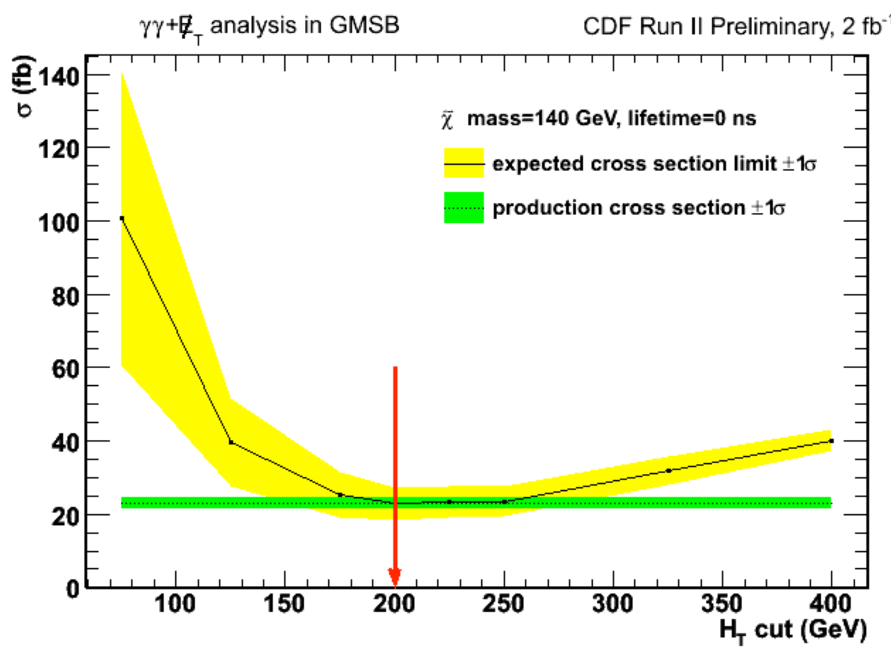
- DIPHOTON_12 used for this study

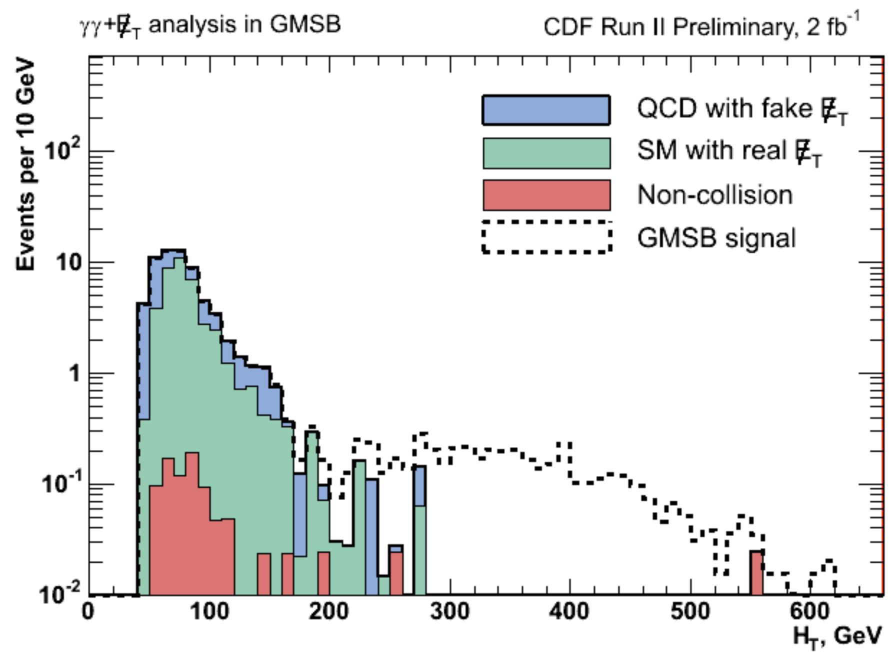
- Our analysis passed one of :

DIPHOTON_12, DIPHOTON_18(no ISO), PHO_50(no ISO), PHO_70(no HadEm)

- So close to 100% trigger efficiency, so changing to 99% wouldn't affect our analysis and thus taking 1% additional syst. error in quadrature with 10.6% makes no difference

Blessed Result (2.0 fb^{-1})
Cross Section Limit and N-1 Plot: H_T

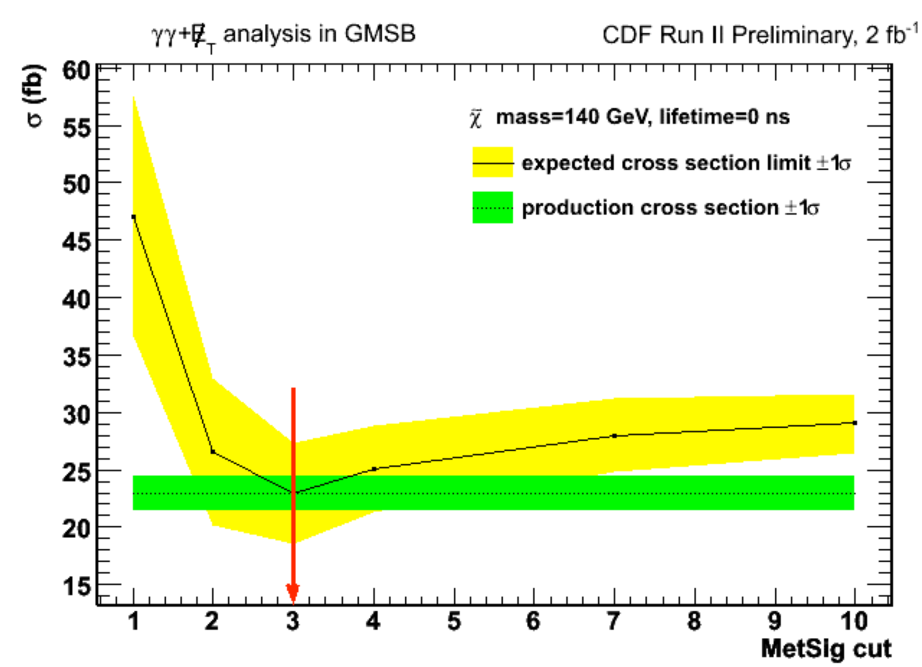


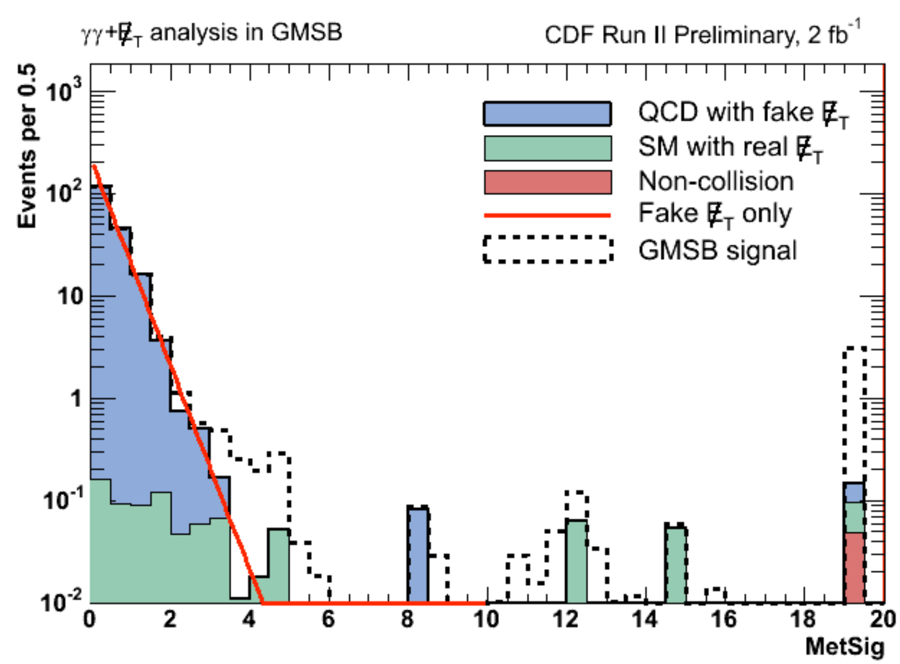


- **While varying a cut all other variables held at optimal cuts**
- **N-1 plot for background distributions along with GMSB MC signal shows good separation**

Reblessing Talk

Blessed Result (2.0 fb^{-1})
Cross Section Limit and N-1 Plot: MetSig



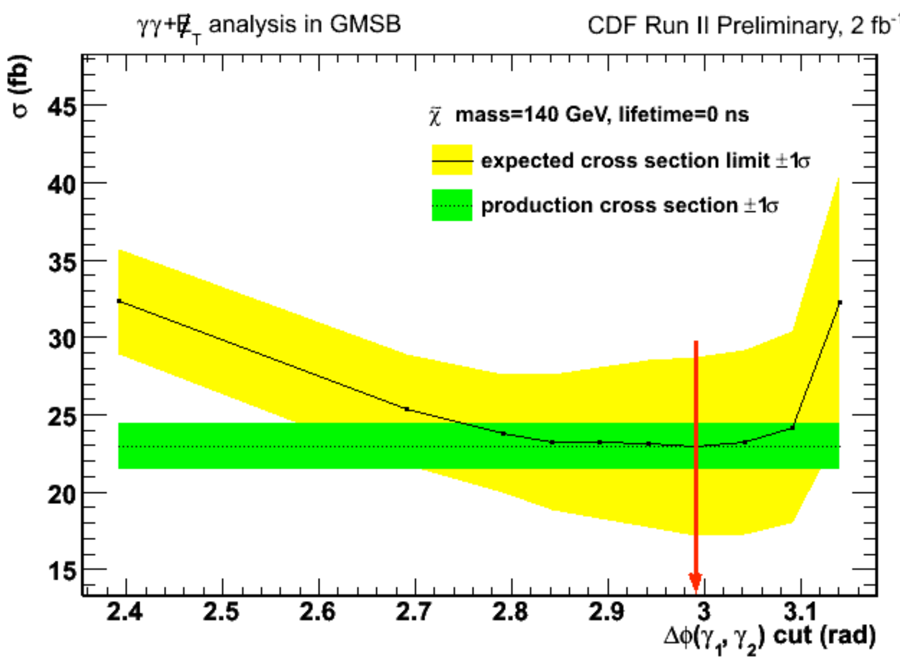


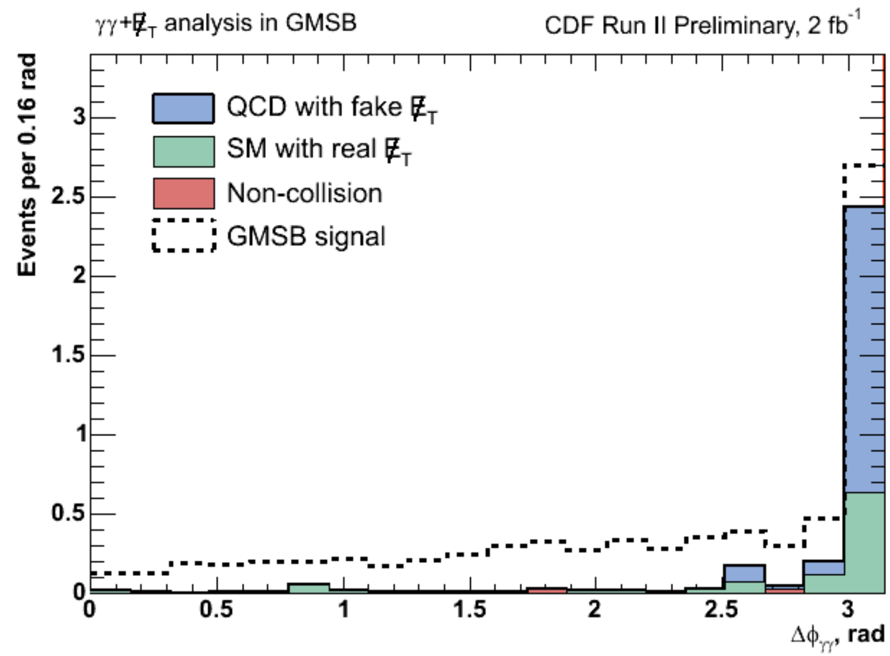
- **While varying a cut all other variables held at optimal cuts**
- **N-1 plot for background distributions along with GMSB MC signal shows good separation**

Reblessing Talk

Blessed Result (2.0 fb^{-1})
Cross Section Limit and N-1 Plot: $\Delta\phi(\gamma_1,\gamma_2)$

Reblessing Talk

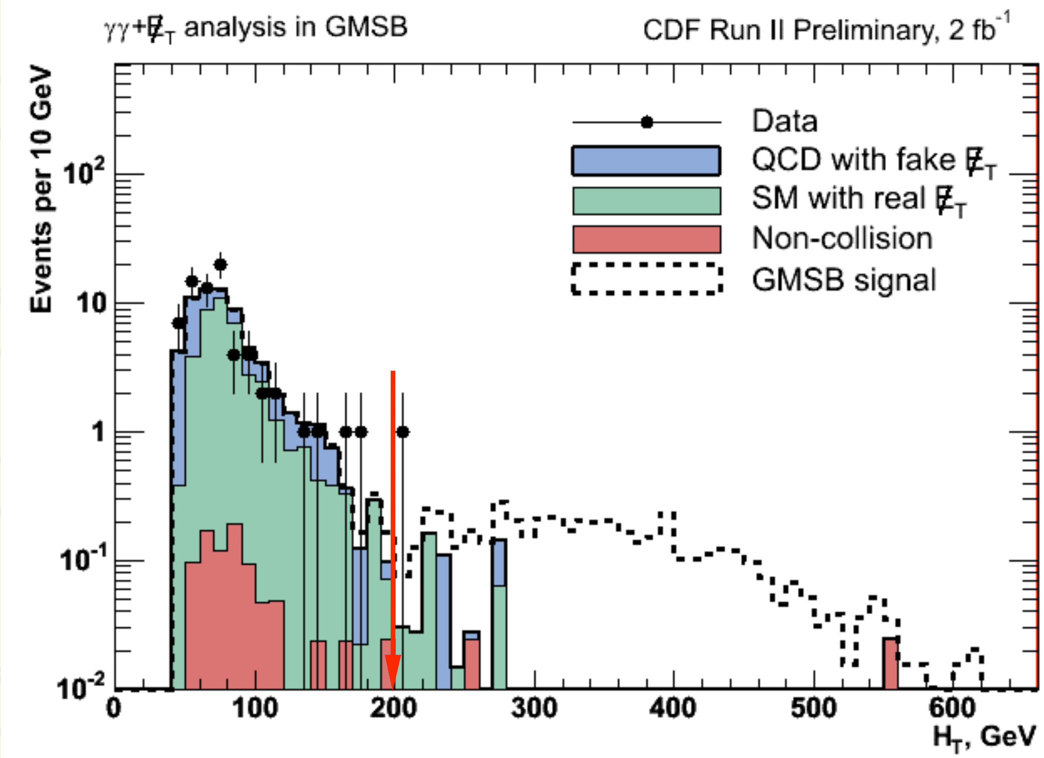




- **While varying a cut all other variables held at optimal cuts**
- **N-1 plot for background distributions along with GMSB MC signal shows good separation**

Blessed Result (2.0 fb^{-1}) N-1 Plots

We open the box: 1 event observed



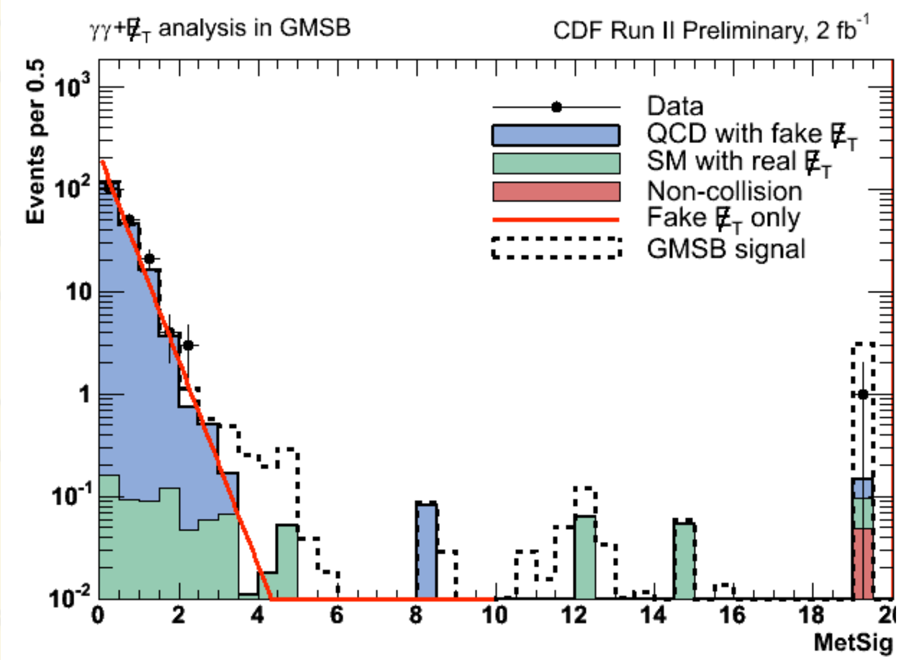
The table to be pre-blessed

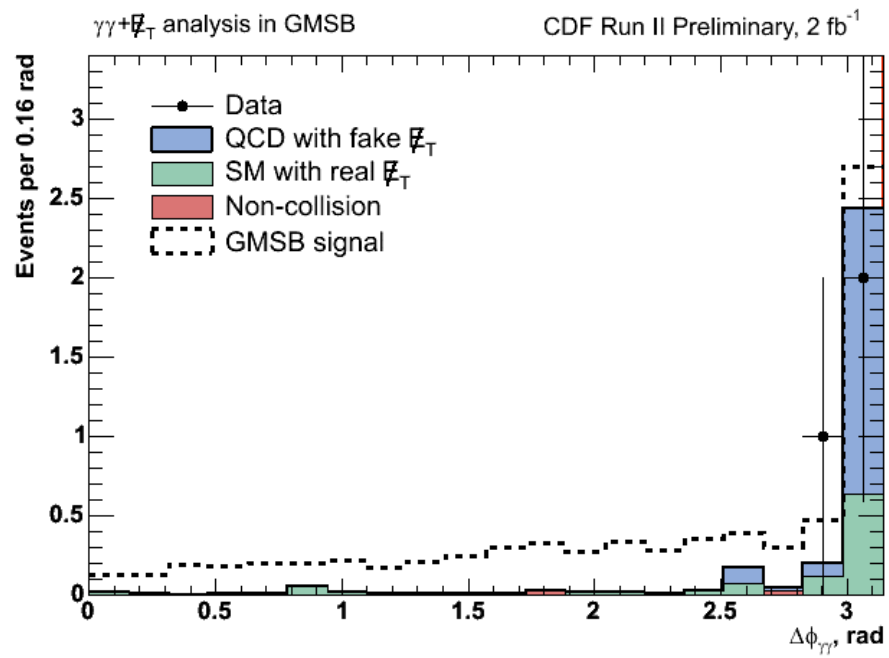
Background Estimations	
EWK	0.39 ± 0.14 ± 0.11
Non-Collision	0.049 ± 0.042 ± 0.028
Tri-Pho	0.00 ± 0.180 ± 0.035
Wrong Vertex	0.081 ± 0.081 ± 0.008
QCD	0.1 ± 0.1 ± 0.0
Total	0.62 ± 0.26 ± 0.12
Data	1

- For a distribution all other variables held at optimal cuts
- Everything is well modeled

We have looked at this event and there is no evidence it is from GMSB

Blessed Result (2.0 fb^{-1})
More N-1 Plots



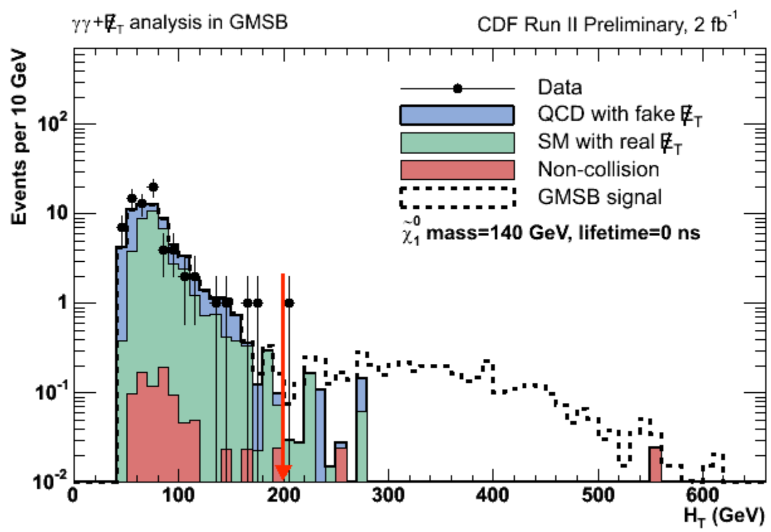


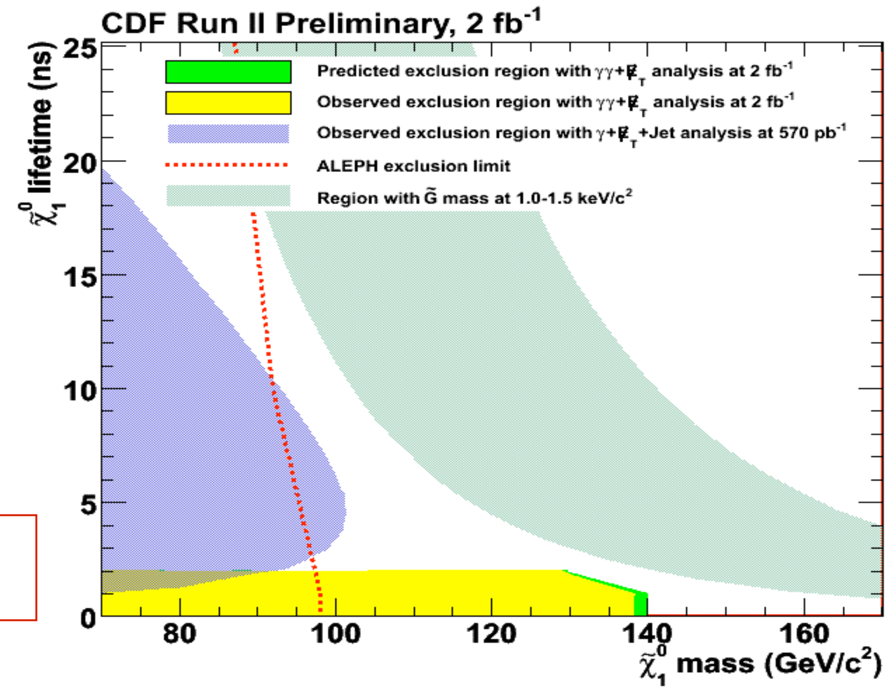
- For a distribution all other variables held at optimal cuts

Changes since the Blessing

Blessed Analysis 11/06/08

Reblessing Talk





Optimal Cuts :
$H_T > 200$ GeV, $\Delta\phi(\gamma_1,\gamma_2) < \pi - 0.15$ rad, MetSig > 3

EWK	0.39 ± 0.14 ± 0.11
Non-Collision	0.049 ± 0.042 ± 0.028
Tri-Pho	0.00 ± 0.180 ± 0.035
Wrong Vertex	0.081 ± 0.081 ± 0.008
QCD	0.1 ± 0.1 ± 0.0
Total	0.62 ± 0.26 ± 0.12
Data observed	1

- Exclude up to ~ 138 GeV at 0 and 1 ns. (Beyond DØ Limit = 125 GeV)
- New Limits extend the sensitivity in both mass and lifetime. (goes above the Delayed Photon Analysis)
- We are nearing the cosmology favored region (gray-green band)

Changes

- Added more data and did lots of small tweaks and minor bug fixes as part of the polishing process

- Added p12 - p17 (1.0 fb^{-1}) with high inst. lumi. and dropped p0 (0.4 fb^{-1}) with low inst. lumi. and no EMTiming.
  - Now all data (2.6 fb^{-1}) has the EMTiming information: Provide a single set of simple and efficient way to remove cosmic rays and beam halo events. Dropped the old inefficient cosmic cuts.
  - Higher inst. lumi. Increases the number of vertices per event, which results in larger contributions due to QCD wrong vertex. This, after optimization, is still negligible.
- Added the PHO_50 and PHO_70 triggers
  - Recover loss in efficiency for χ^2_{CES} at high photon E_T and take the trigger efficiency to be 100% (CDF Note 9533, 9429, 8302)
  - This leads to larger acceptances, but also larger backgrounds, in particular, larger electroweak backgrounds. However, changes are again negligible after optimization

Reblessing Talk

Reblessing Talk

Changes - cont.

- Simulate run-dependant GMSB MC signal sample using Pythia with Tune-A and Min-Bias.
  - We realized we were not simulating GMSB signal with Min-Bias
  - Reduced the acceptance and thus the sensitivity from what was reported previously by a few percent
- Switched back to using the vertex swap procedure and added the Met cleanup cut
  - The vertex swap procedure : remove wrong vertex events
  - The Met cleanup cut : remove tri-photon events with a lost photon
  - This has inadvertently been done for the background estimations, but not for signal: Acceptance had been slightly overestimated relative to the backgrounds
  - Since the cuts are now part of the analysis and we are using them explicitly this requires no changes.

Changes - cont.

- After changes we re-optimize and found :
  - Only the $\Delta\phi(\gamma_1,\gamma_2)$ cut needed to change from π-0.15 (2.99) to π-0.35 (2.79).
  - Confirmed vertex swap procedure and Met cleanup cuts help the sensitivity using the improved simulation of the signal
- Finished Systematics :
  - Used 18% from 202 pb-1 analysis to be conservative for the blessing
  - Now it is 10.6%
- Correct the cosmology favored region band
  - Found that the formulae used to produce the cosmology favored region band is incorrect
  - The correct formula used to produce the band :

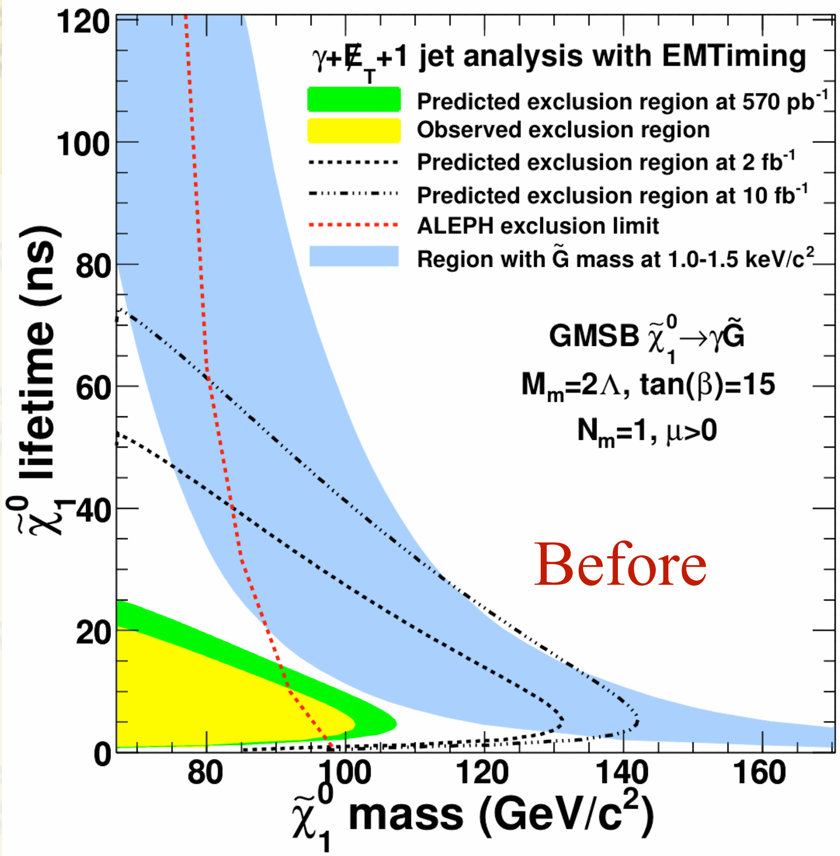
$$\tau_\chi = 69.33 \cdot \left(\frac{100\ \text{GeV}}{m_\chi} \right)^5 \cdot \left(\frac{m_G}{1\ \text{keV}} \right)^2 \ \text{ns}$$

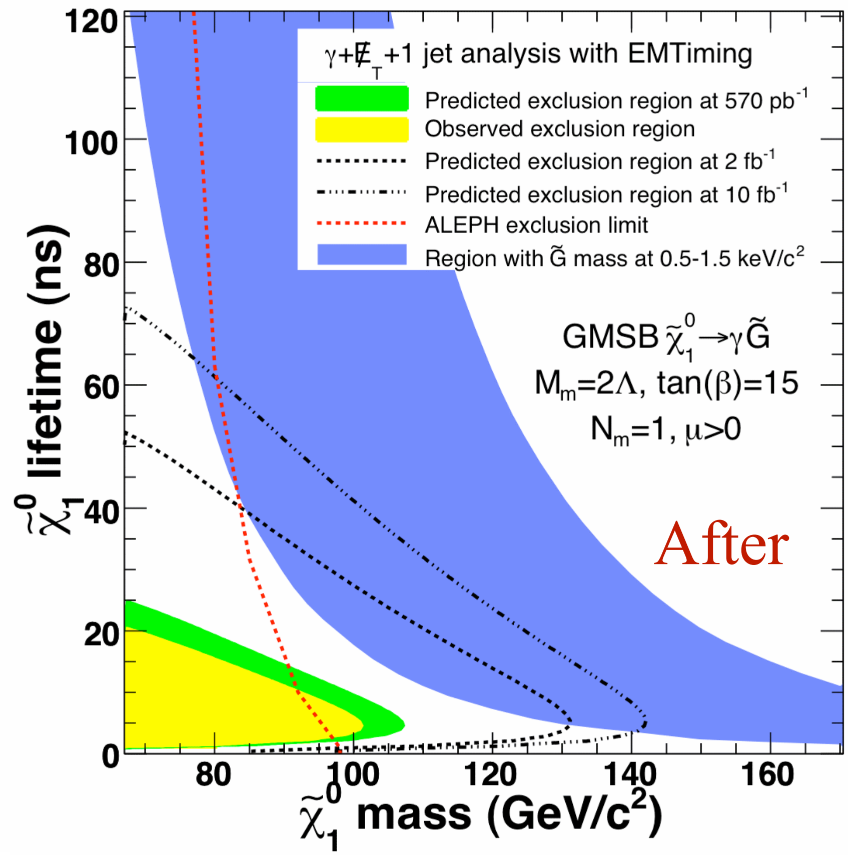
where m_χ is the neutralino mass in 100 GeV and m_G is the gravitino mass in 1 keV

C.H.Chen and J.F.Gunion, Phys.Rev.D58, 075005 (1998)

Reblessing Talk

Changes - cont.





- Comparison the cosmology favored region band before and after fixes
- This doesn't change the analysis and just fixed the cosmology region
- Note that gravitino mass range changed in the new plot :

  $1.0 < m_G < 1.5 \Rightarrow 0.5 < m_G < 1.5$

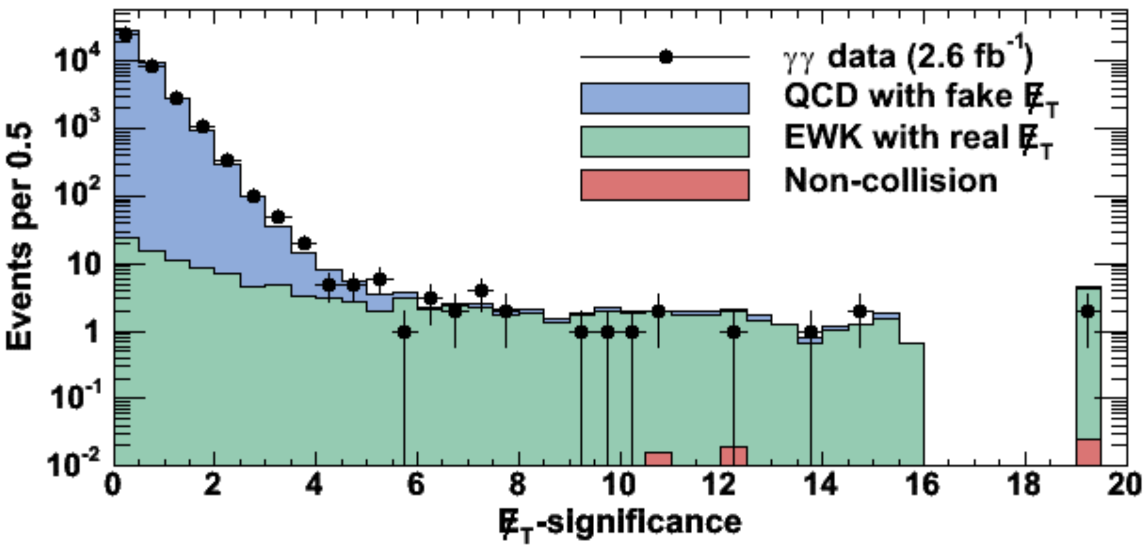
Changes in Results

	Old	New
Luminosity	2.0 fb^{-1}	2.6 fb^{-1}
Acceptance (%) ($m(\chi)$ =140 GeV, $\tau(\chi)$=0 ns)	9.21 ± 1.66	7.80 ± 0.83
EWK	0.39 ± 0.18	0.77 ± 0.30
QCD	$0.10^{+0.22}_{-0.10}$	0.46 ± 0.24
Non-Collision	$0.049^{+0.050}_{-0.049}$	$0.001^{+0.008}_{-0.001}$
Total Backgrounds	0.62 ± 0.29	1.23 ± 0.38
Data observed	1	0
σ^{exp}(fb)	22.24	22.08
σ^{obs} (fb)	22.97	15.11

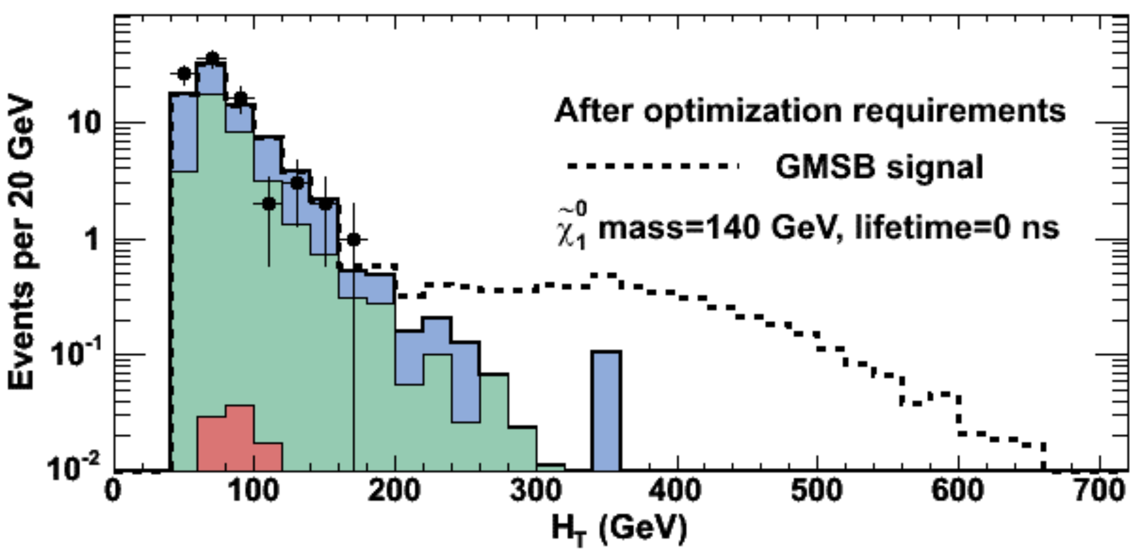
Figures for the PRL

Reblessing Talk at Exotics Meeting

PRL Figure 1

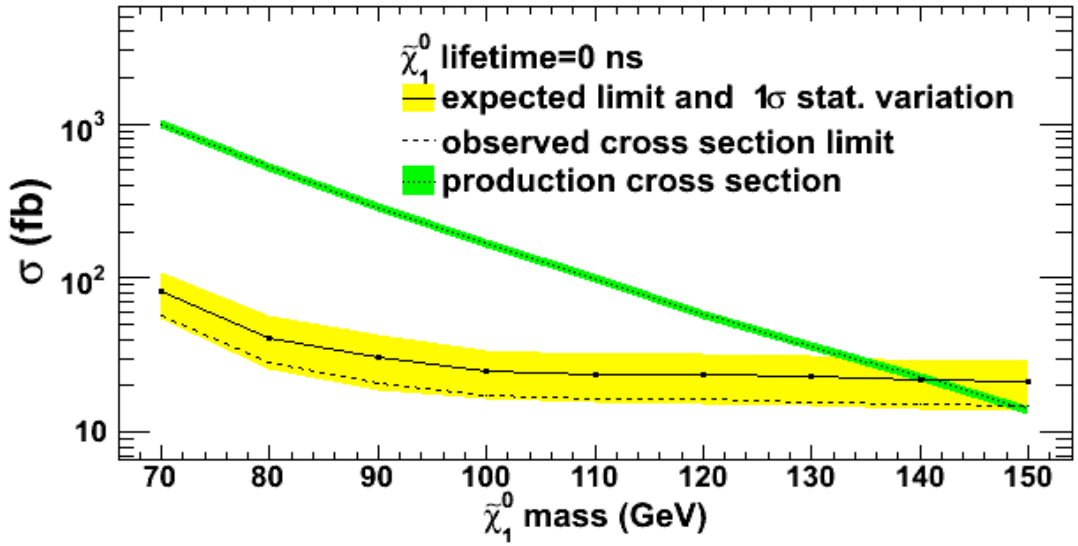


MetSig Distribution for the Presample

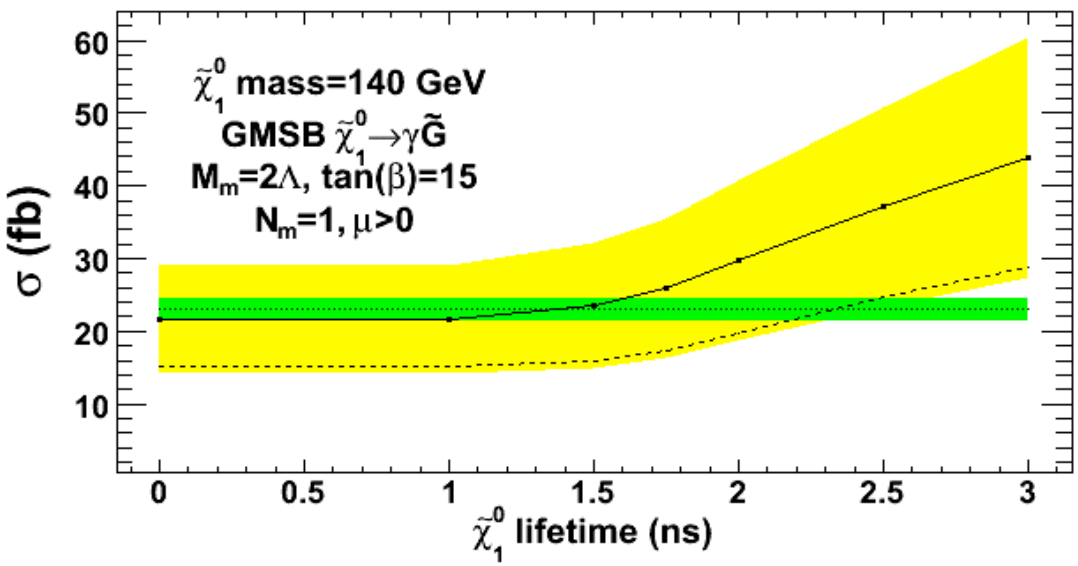


H_T Distribution after optimal cuts but H_T cut

PRL Figure 2

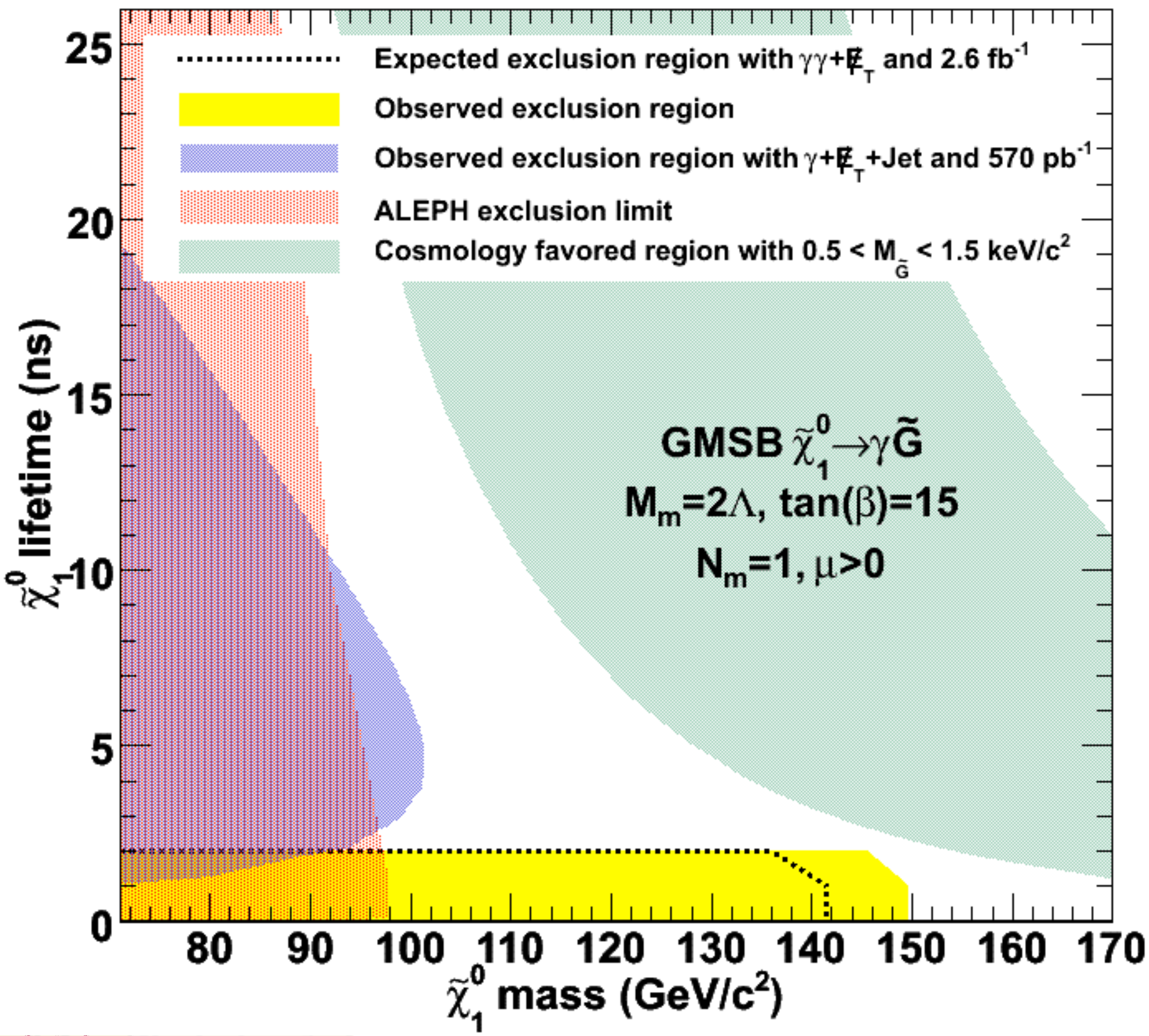


Cross section vs neutralino mass for lifetime = 0 ns



Cross section vs neutralino lifetime for mass = 140 GeV

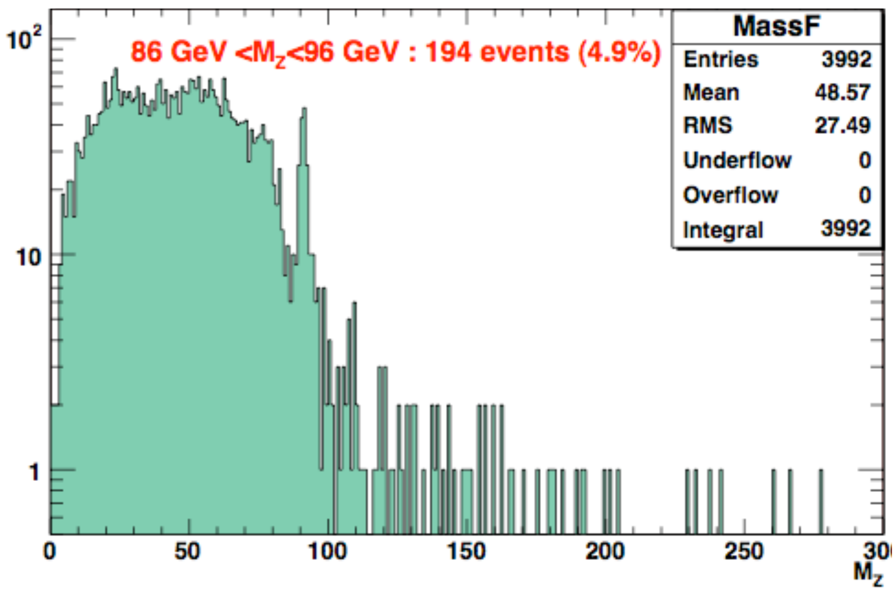
PRL Figure 3



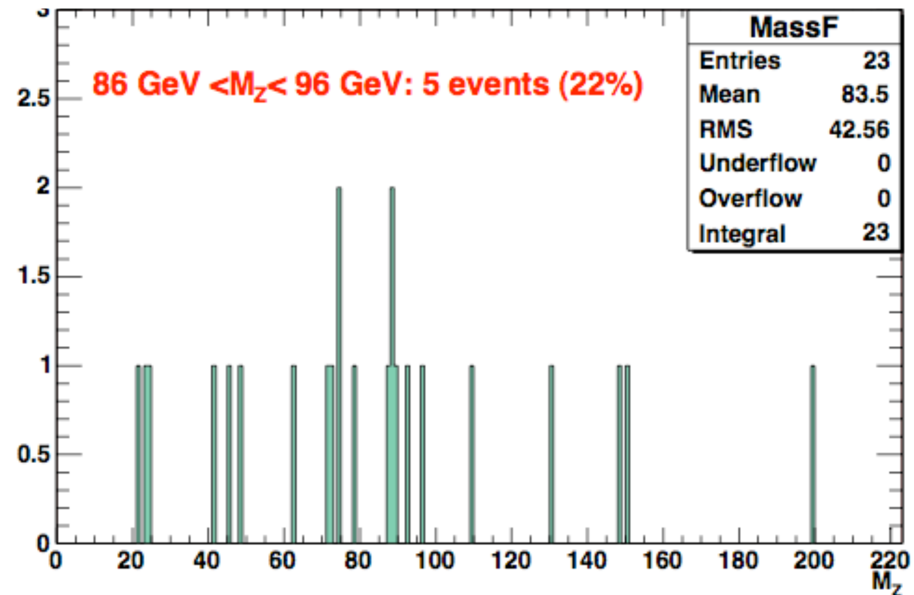
Exclusion Region in neutralino mass and lifetime plane

Z(νν) Estimate

Z boson mass (hepg level) before GMSB cuts



Z boson mass (hepg level) before GMSB cuts



Use Baur+Pythia Z(μμ) γγ : 0.14±0.02

Use MadGraph Z(μμ) γγ : 0.11±0.03

Use MadGraph Z(νν) γγ : 0.22±0.09

They all agree within 1 σ stat.