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Setting Limits on Gauge Mediated Supersymmetry Breaking Models with Photons at CDF

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for the CDF Collaboration

Outline

- Gauge Mediated Supersymmetry Breaking
- Previous Searches
- Analysis
- Optimization and Setting Limits
- Results
- Conclusion and Plan

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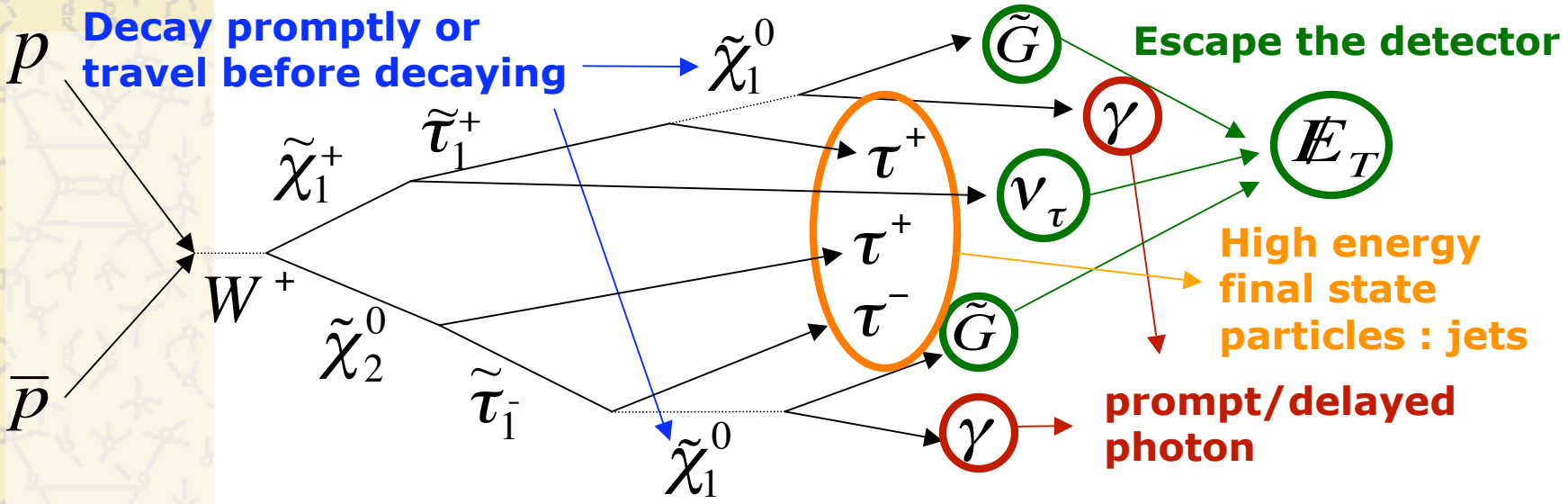
Gauge Mediated Supersymmetry Breaking

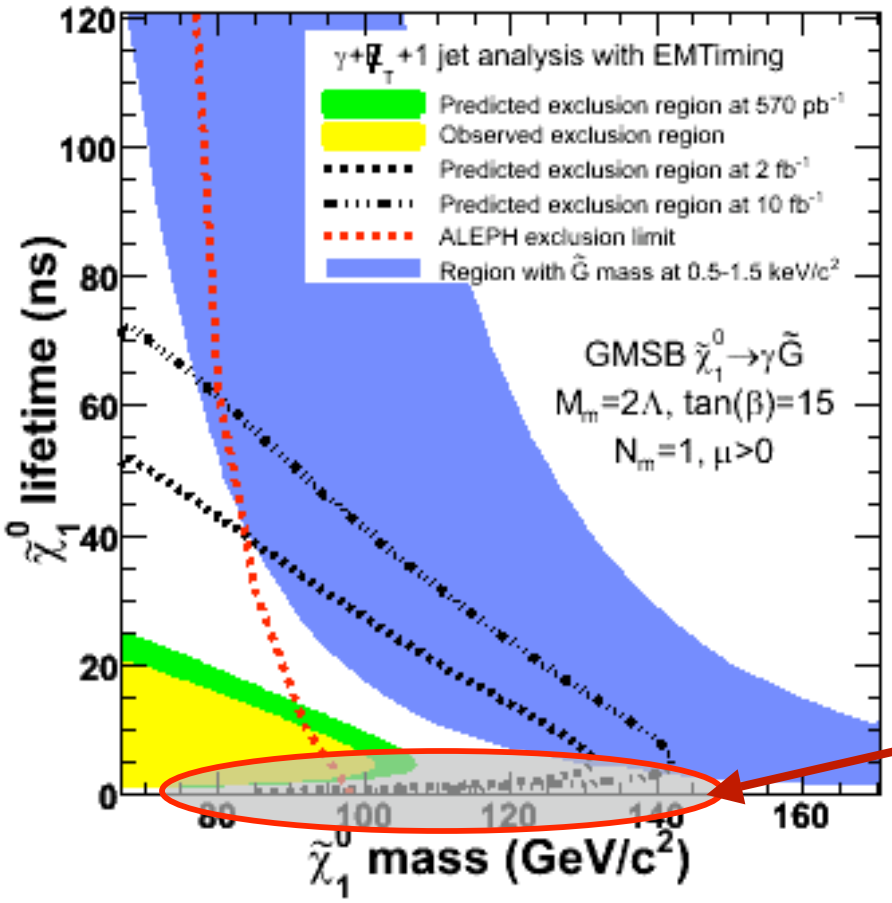
$$\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$$



- Both $\tilde{\chi}_1^0$'s decay in the detector ⇒Two photons
- $\gamma\gamma + \not{E}_T$: Optimal for low neutralino lifetimes ($\tau < 2$ ns)

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

An Important Parameter: $\tilde{\chi}_1^0$ lifetime



- Cosmological constraints relate the mass and lifetime of $\tilde{\chi}_1^0$
- As lifetime goes up, more and more of $\tilde{\chi}_1^0$ leave the detector and lose sensitivity
- Single delayed photon :
  not sensitive to low lifetimes
- Trying to understand our sensitivity here and for larger masses

Delayed Photon at CDF (560 pb^{-1}):
Phys. Rev. Lett 99, 121801 (2007)
Phys. Rev. D 78, 032015 (2008)

Diphoton Searches:
CDF (202 pb^{-1})
Phys.Rev.D71, 031104 (2005)
DØ (1.1 fb^{-1})
Phys.Lett.B659, 856 (2008)

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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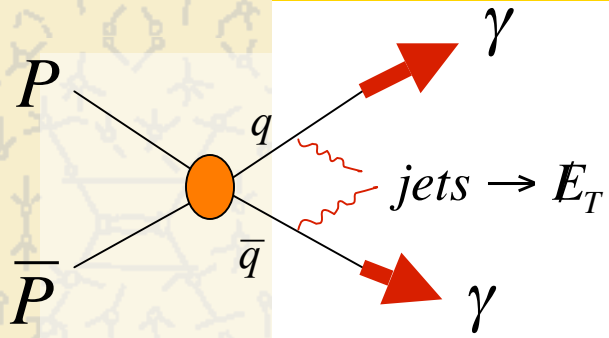
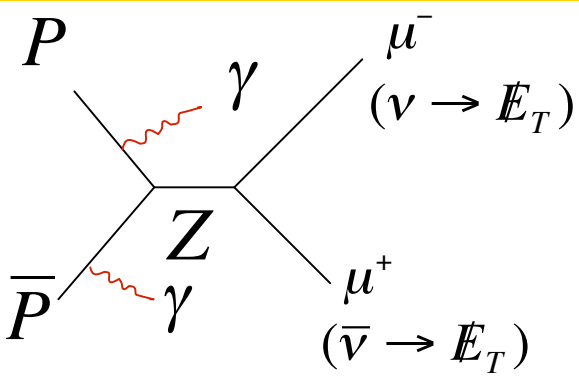
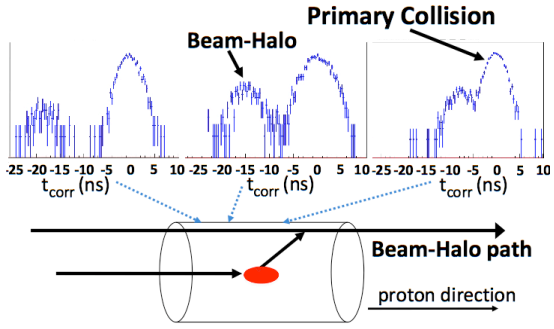
Background Sources and Event Selection



QCD Background



EWK Background



Non-Collision Background
: Cosmic and Beam Halo

- Luminosity = 2.6 fb^{-1}
- Two photons of E_T > 13 GeV, |η| < 1.1
- Backgrounds
  - QCD with fake ME_T (γγ, γj, jj): from data (METMODEL)
  - EWK with true ME_T (W/Z+γ, W/Z+j, $Z \rightarrow \tau\tau \rightarrow \gamma_{fake}\gamma_{fake}$): from MC normalized to data
  - Non-collision (Beam Halo, Cosmics): from data (EMTiming)

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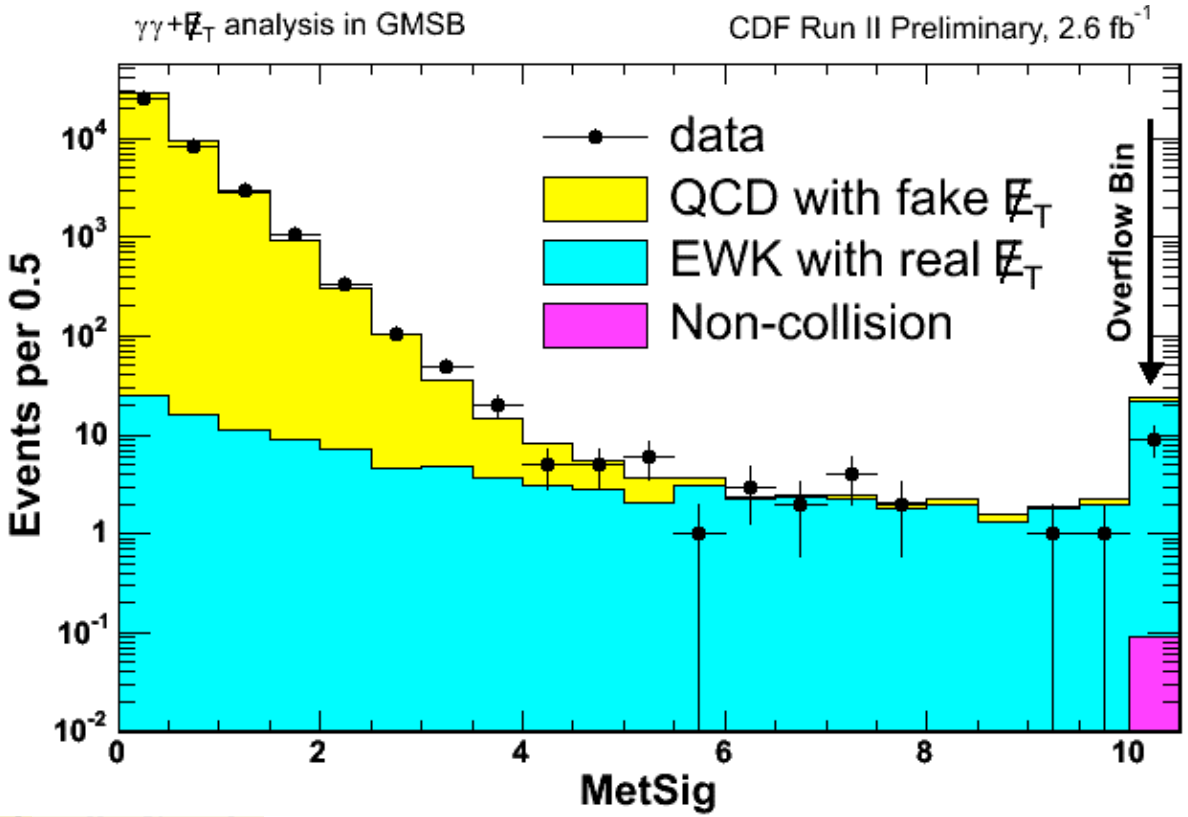
γγ presample and METMODEL

- METMODEL: Use event topology to predict fake MET due to energy measurement fluctuations

⇒Measure how significant the observed MET is



$\not\!\!E_T$-significance (MetSig)

: Probability of Fluctuations in Energy Measurement

$(\not\!\!E_T^{\text{fluctuated}} > \not\!\!E_T^{\text{measured}})$

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The Optimization

- 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 95% C.L. expected cross section limit
- Pick a single set of optimization variable cuts

- MetSig: get rid of QCD with fake Met
- H_T: get cascade decays from heavy particles
- $\Delta\phi(\gamma_1,\gamma_2)$: get rid of back-to-back photons and wrong vertex

- Map it out as a function of neutralino mass and lifetime.

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Optimization Results

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

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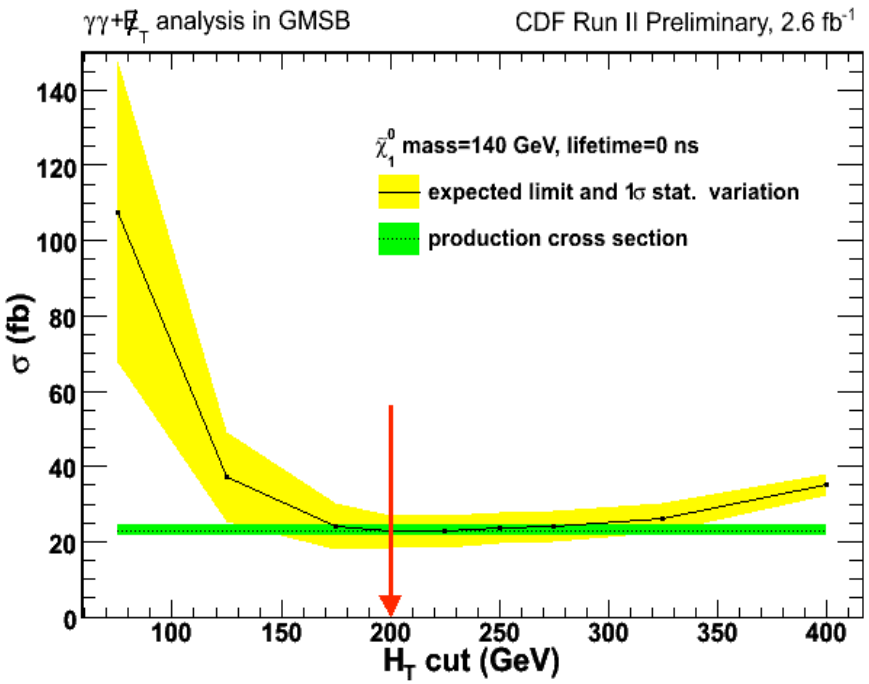
- Example point:
  $m(\chi_1^0)$=140 GeV, $\tau(\chi_1^0)$=0 ns
- Acceptance:
  7.80 ± 0.54 (%)

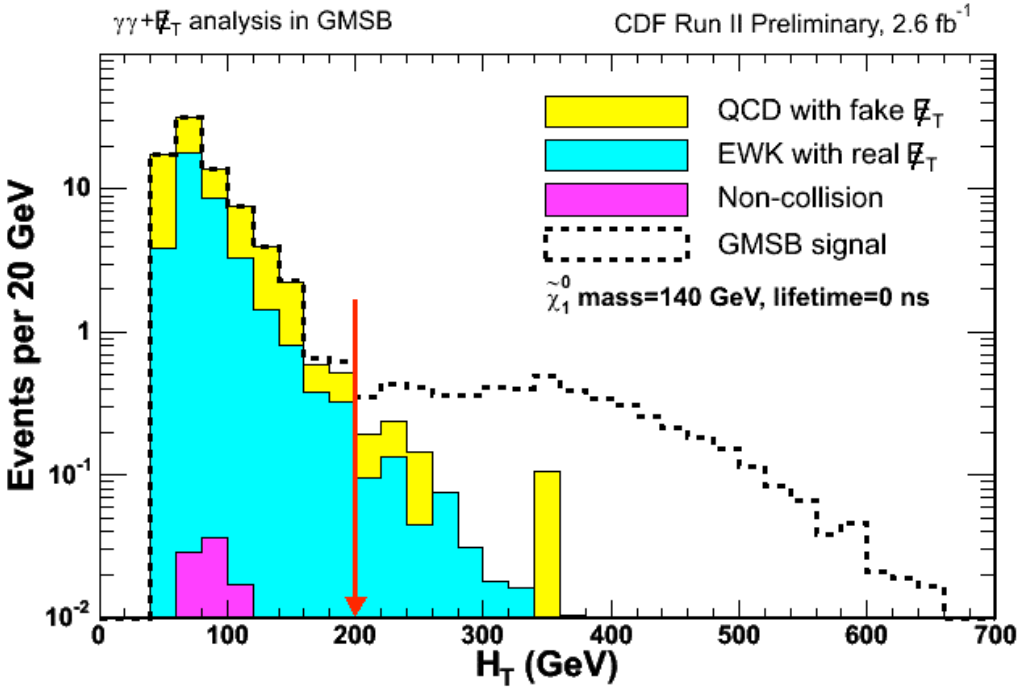
σ^{exp} = 22.62 fb

σ^{prd} = 22.97 fb

Background Estimations	
EWK	0.92 ± 0.21 ± 0.30
QCD	0.46 ± 0.22 ± 0.10
Non-Collision	0.001 + 0.008 - 0.001
Total	1.38 ± 0.30 ± 0.32

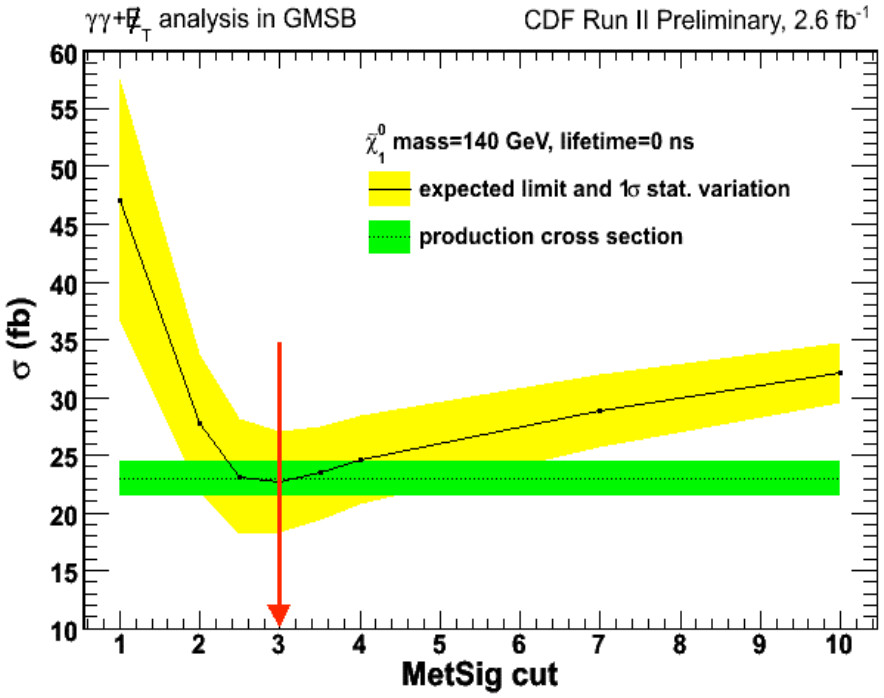
95% C.L. Expected Cross Section Limit and N-1 Plot: H_T

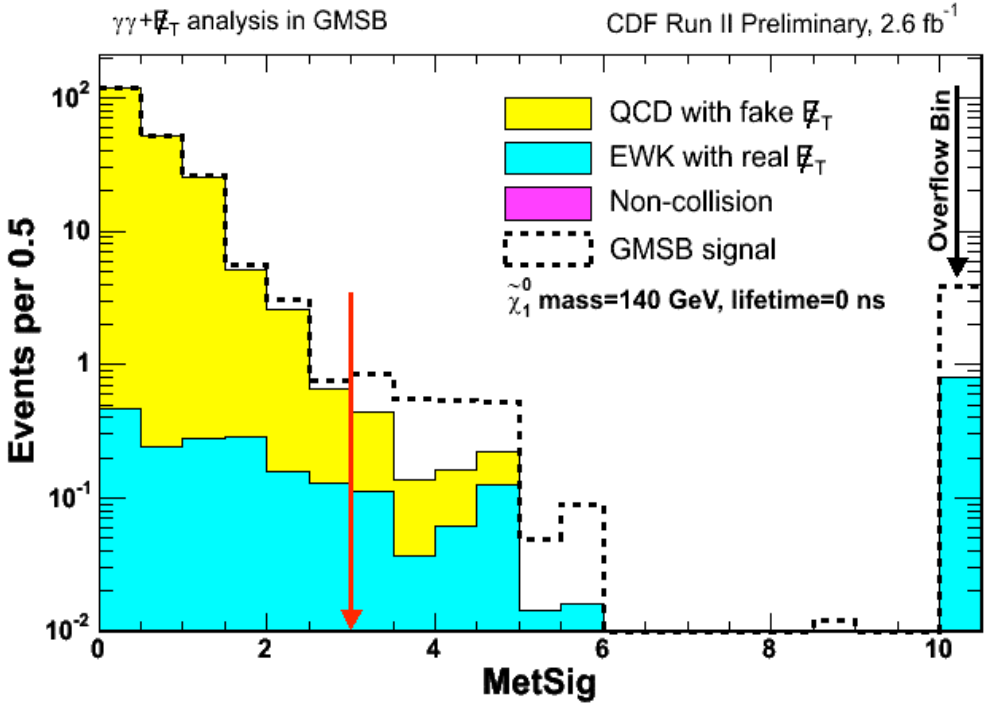




- **While varying H_T cut other variables held at optimal cuts**
- **N-1 plot for background distributions along with GMSB MC signal shows good separation**

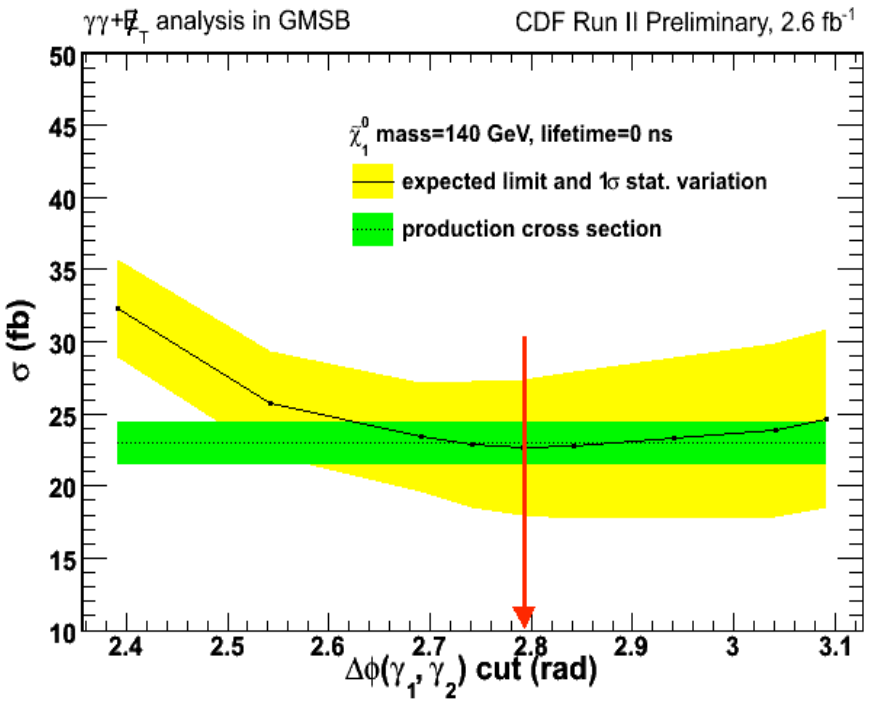
95% C.L. Expected Cross Section Limit and N-1 Plot: MetSig

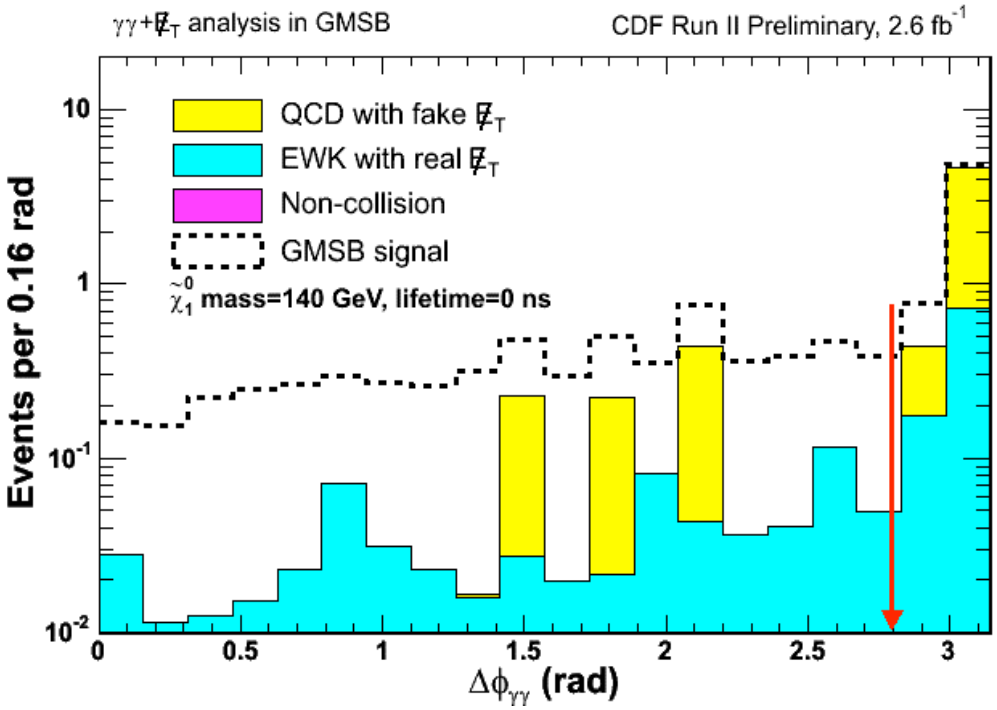




- **While varying a cut other variables held at optimal cuts**
- **N-1 plot for background distributions along with GMSB MC signal shows good separation**

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

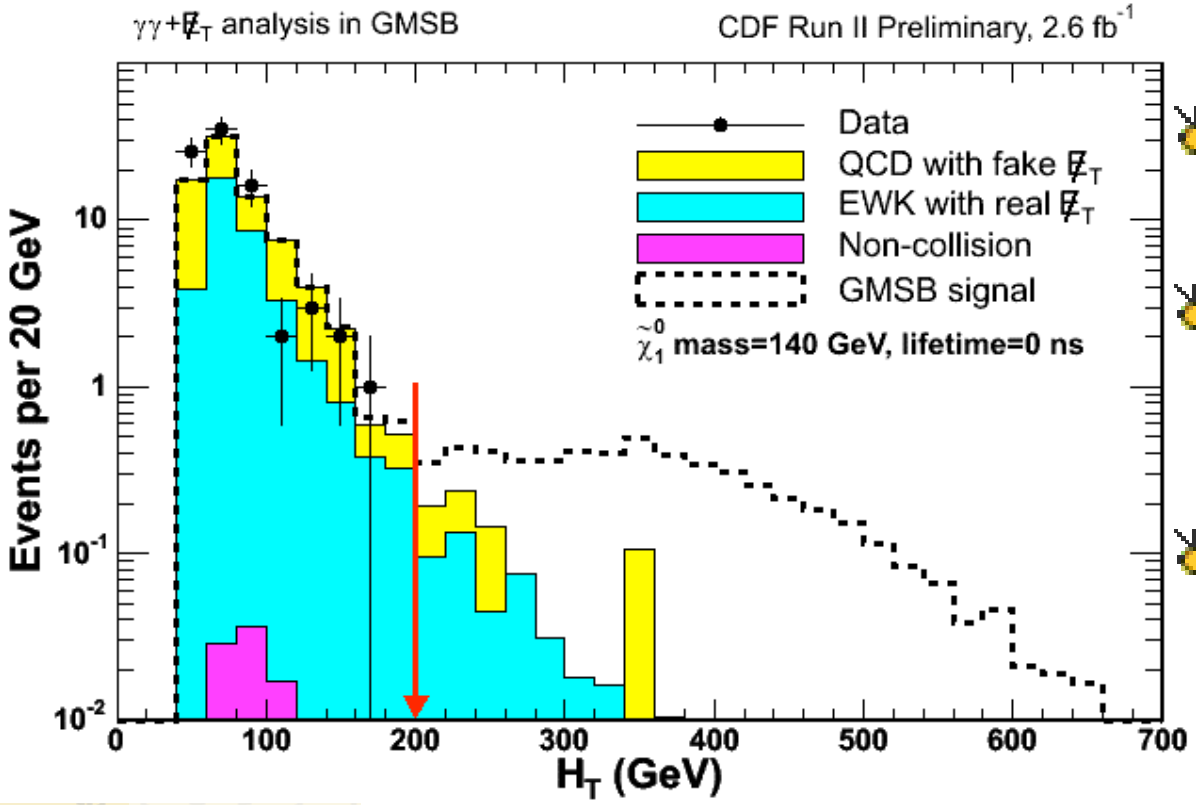




- **While varying a cut other variables held at optimal cuts**
- **N-1 plot for background distributions along with GMSB MC signal shows good separation**

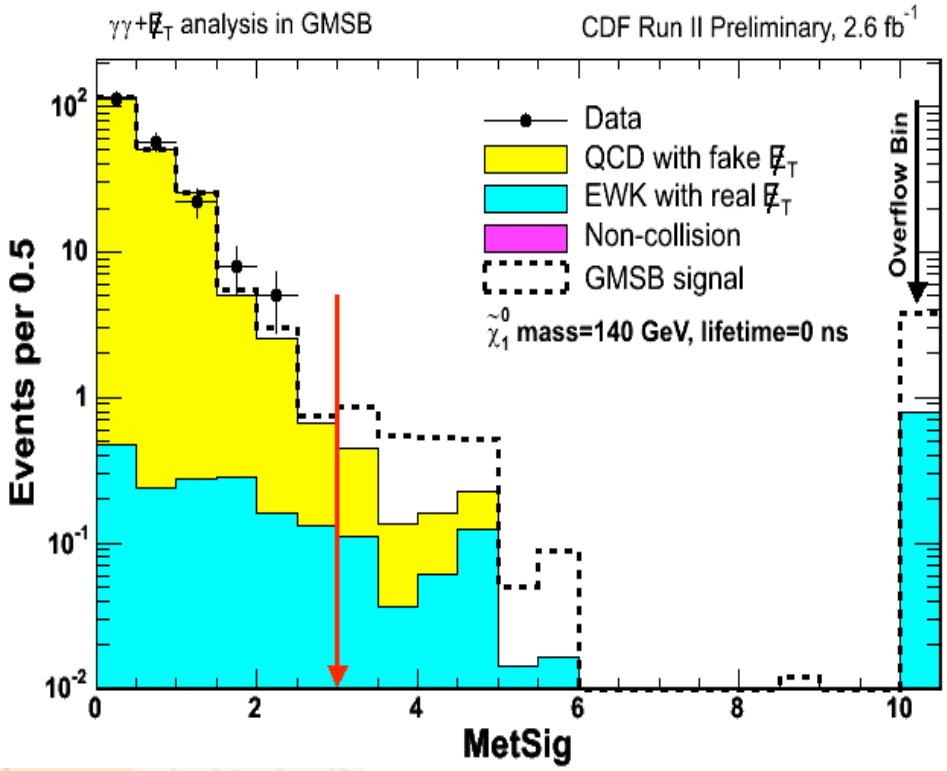
Data distribution and N-1 Plots

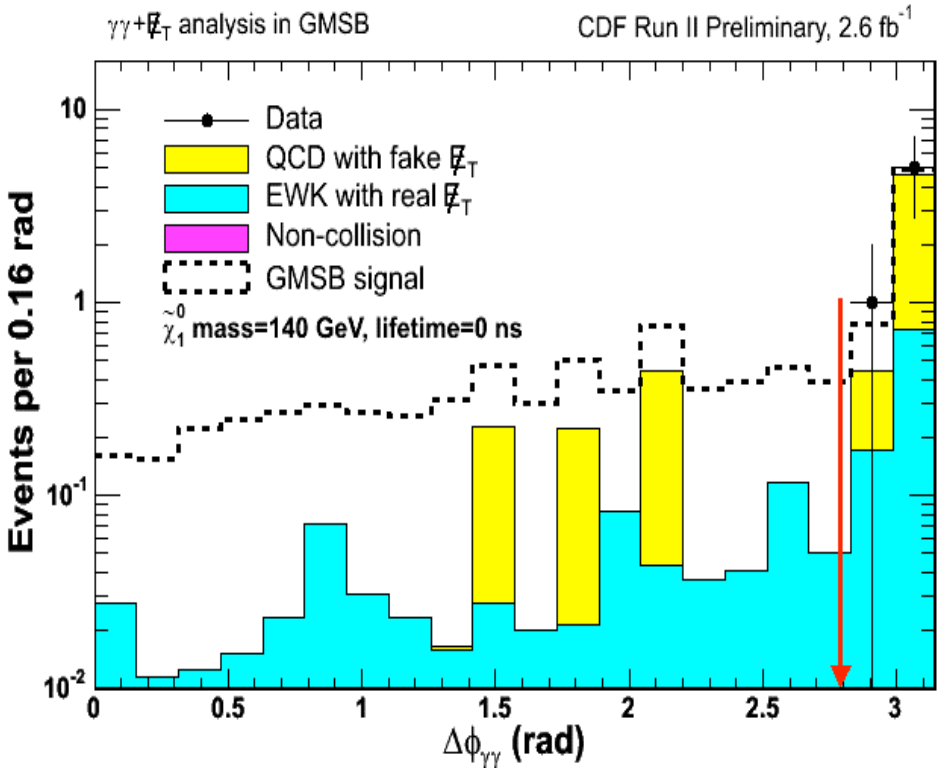
We open the box: 0 events observed



- **No Evidence for GMSB**
- For H_T distribution all other variables held at optimal cuts
- Everything is well modeled

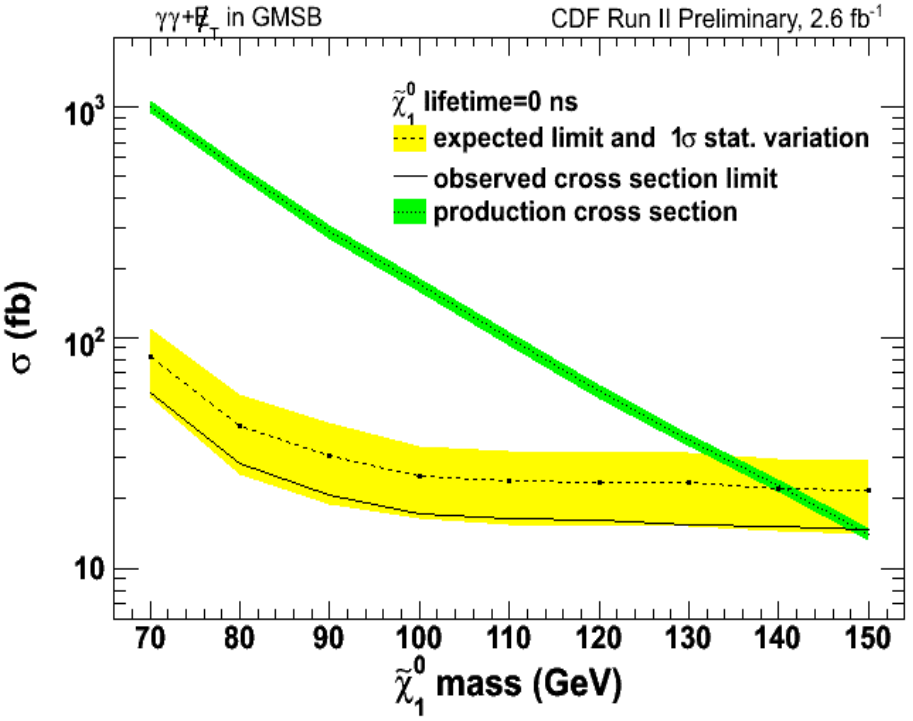
More N-1 Plots

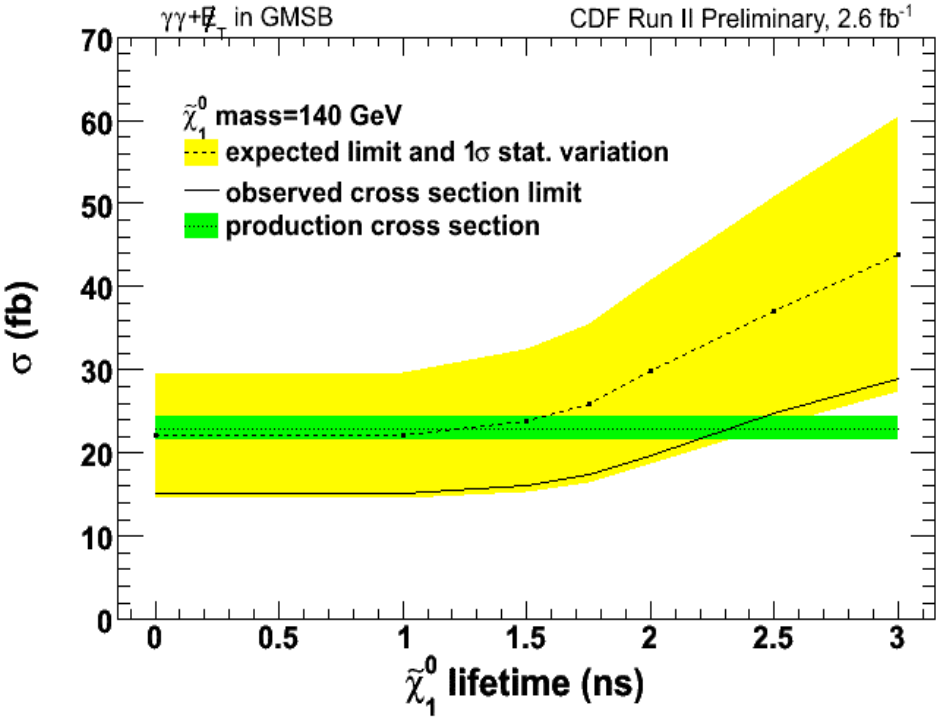




- For a distribution all other variables held at optimal cuts

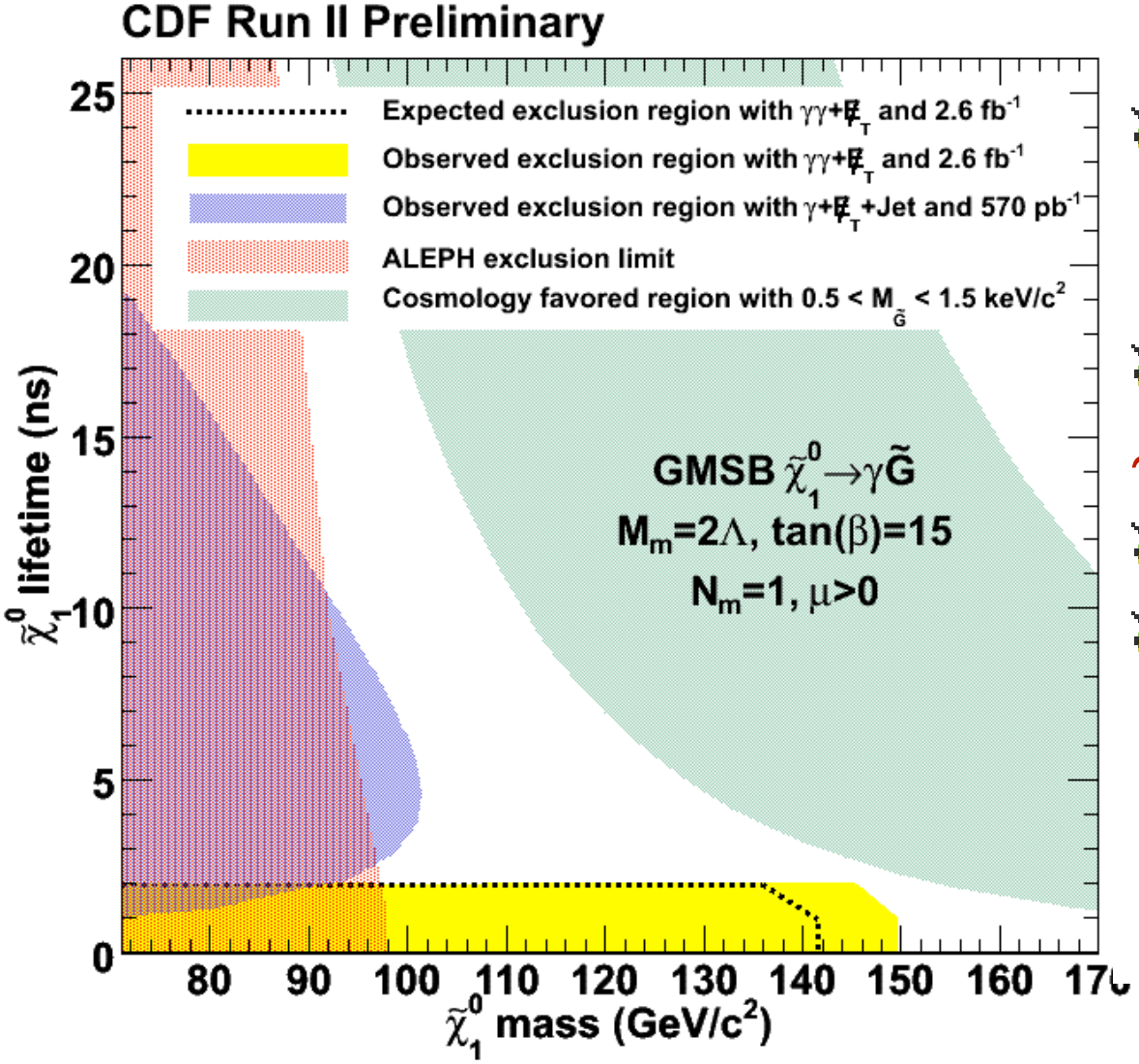
Cross Section Limits vs. Mass and Lifetime





- Expected (Observed) neutralino mass limit:
  141 GeV (149 GeV) for τ=0 ns
- Expected (Observed) neutralino lifetime limit:
  1.2 ns (2.3 ns) for m=140 GeV

Exclusion Region

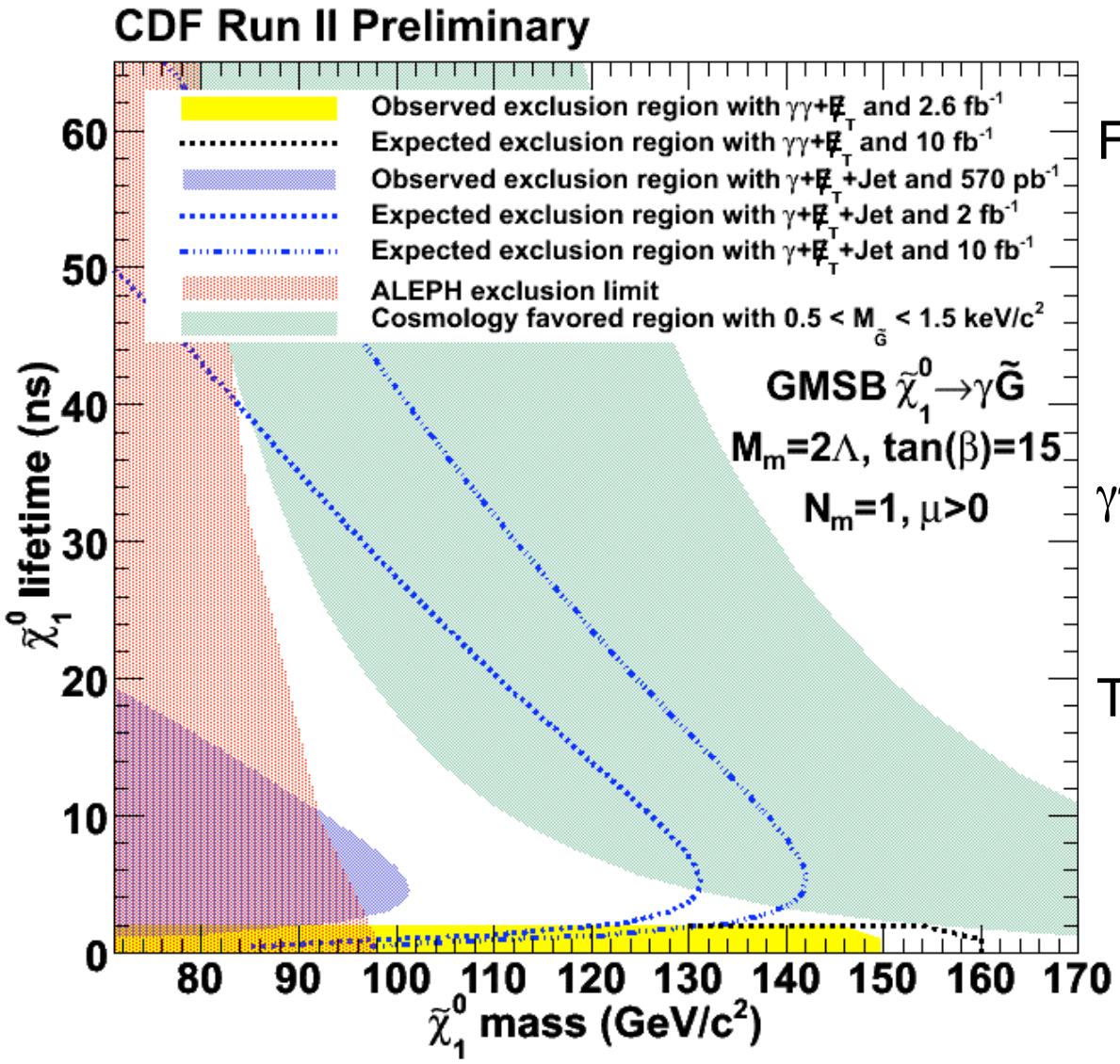


- Set limits on GMSB in neutralino mass and lifetime
- Exclude up to

~ 149 GeV at 0 and 1 ns

- World BEST Limits
- Nearing cosmology favored region (green band) : Gravitino can be warm dark matter candidate

Prospects for the future



For high luminosity :

- 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

- Presented the world's most sensitive search for low-lifetime GMSB in $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$
- Observed 0 events consistent with 1.4±0.4 of background expectation
- Exclude neutralino mass up to 149 GeV for $\tau < 2$ ns, which is the worlds best limits.
- Next generation delayed photon analysis is coming soon - sensitive to higher lifetimes (above ~ 2 ns).
- News of neutralinos will be a hallmark of Supersymmetry

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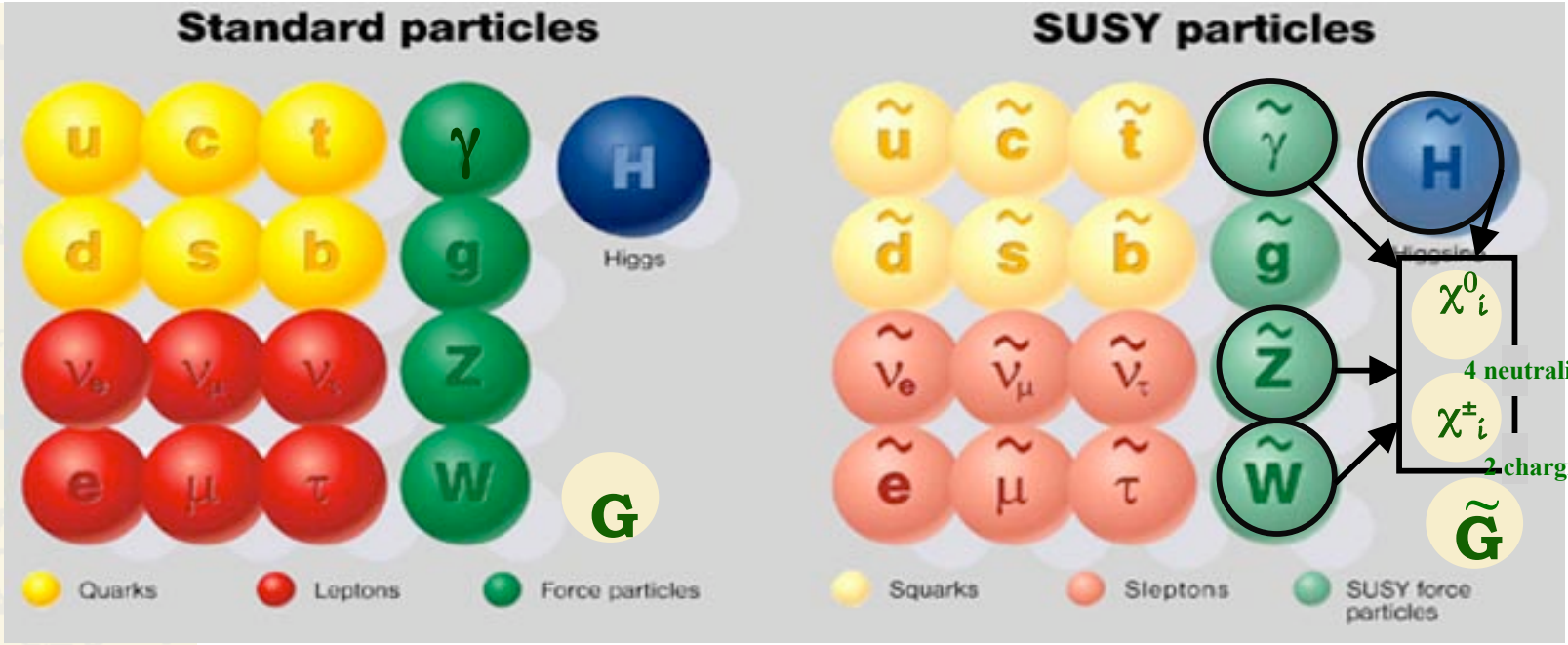
Back Up Slides

Supersymmetry

- Modern particle theories beyond the Standard Model (SM) suggest a symmetry between fermions and bosons, called **Supersymmetry**, at very high energies.
- An important theory, "Gauge Mediated Supersymmetry Breaking" (**GMSB**), predicts heavy, neutral particles with masses that can be produced and studied now at the Fermilab Tevatron.



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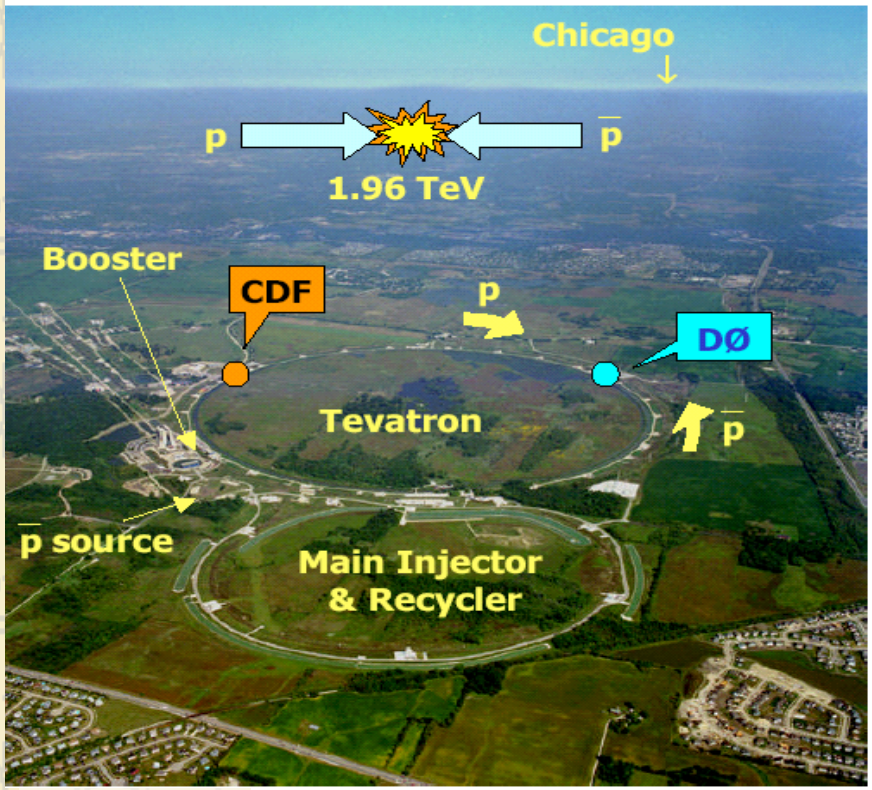
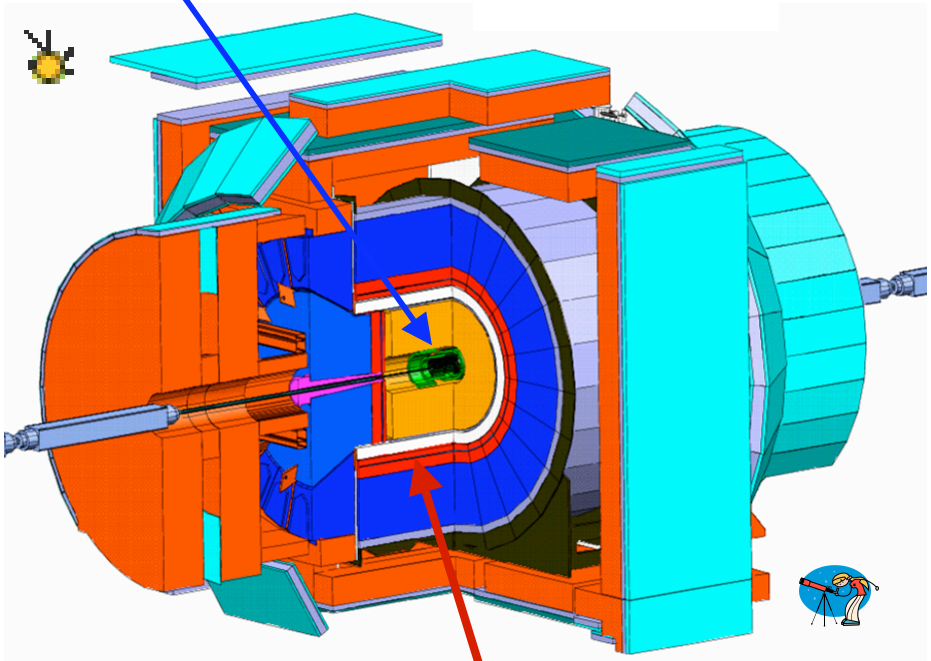
Tevatron at Fermilab: Collider Detector at Fermilab (CDF)

The Tevatron (accelerator) : to produce high energy proton-antiproton collisions

Surround the collision point with a huge detector

CDF : To study the collisions





EM Calorimeter: Photon timing + 4-momentum

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Good Runs, Triggers, Data Sets and Preselection Cuts

- 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

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Standard Central Photon ID Cuts

	Requirements
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
2nd 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

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