Search for GMSB $\gamma\gamma$ events with large missing transverse energy at the Tevatron

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OUTLINE

- GMSB introduction
- D0 detectors and integrated luminosity
- Photon selection
- Missing Transverse Energy (MET) construction
- Backgrounds: instrumental and genuine
- Exclusion limit
- Summary

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GMSB Models

SM production of γγ with large MET is small - so can be sensitive to new physics

In Gauge-Mediated Supersymmetry Breaking (GMSB) models

masses of SUSY partners arise from SM gauge interactions

masses are proportional to effective SUSY breaking scale Λ

SUSY dynamically broken in hidden sector and communicated to

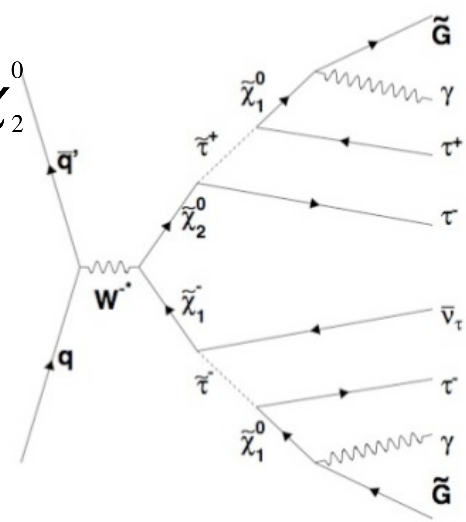
Messenger sector via new gauge interactions

Gravitino has no SM gauge interactions so is LSP. Assume $\tilde{\chi}_1^0$ is the NLSP

Assume prompt decays

Assuming R parity (SUSY pair production) largest σ at

Tevatron is chargino and neutralino production: $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ and $\tilde{\chi}_1^{+}\tilde{\chi}_2^{0}$



Decays to $\tilde{\chi}_1^0$ and eventually $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$

$$p\bar{p} \rightarrow \text{gauginos} \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 \rightarrow \gamma\gamma\tilde{G}\tilde{G} + X$$

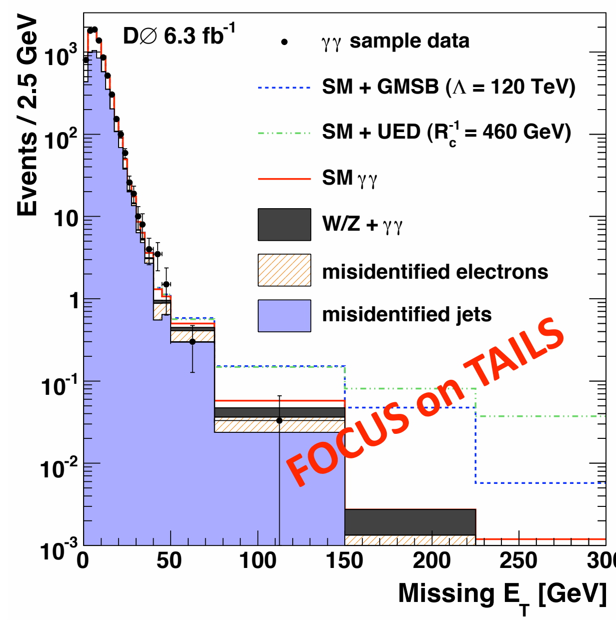
γγ + MET + X final state

GMSB Benchmark

Many SUSY models, choose one GMSB rider (set of parameters SPS8) as representative description of dynamic symmetry breaking

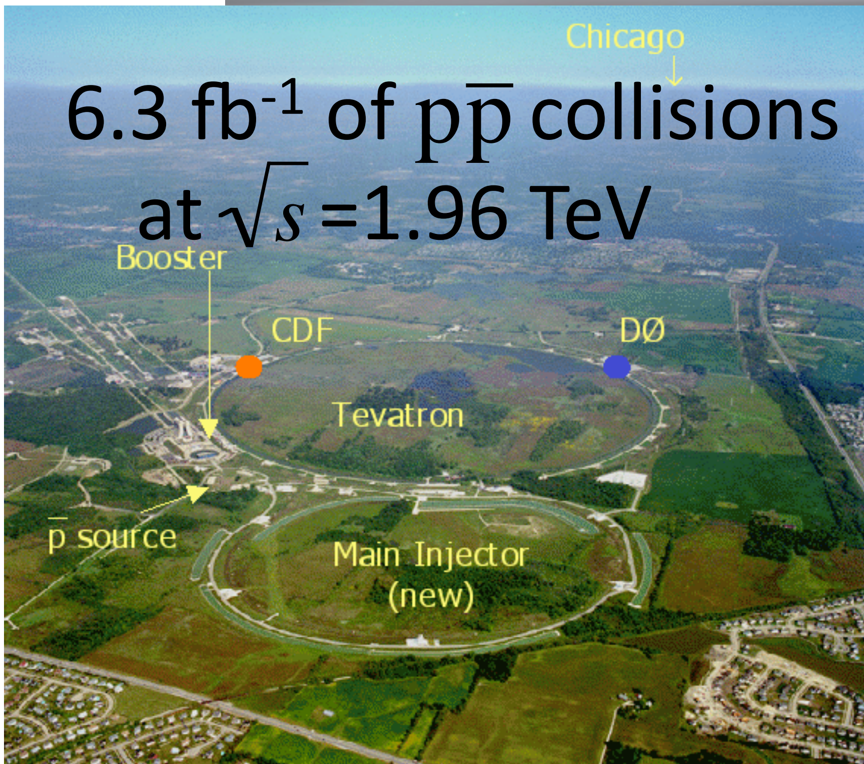
B. C. Allanach et al., Eur. Phys. J. C 25, 113 (2002).
SPS8 =Λ is unconstrained, M_{mes} = 2Λ, tanβ =15, and μ >0
NLO production cross section from Prospino 2.1

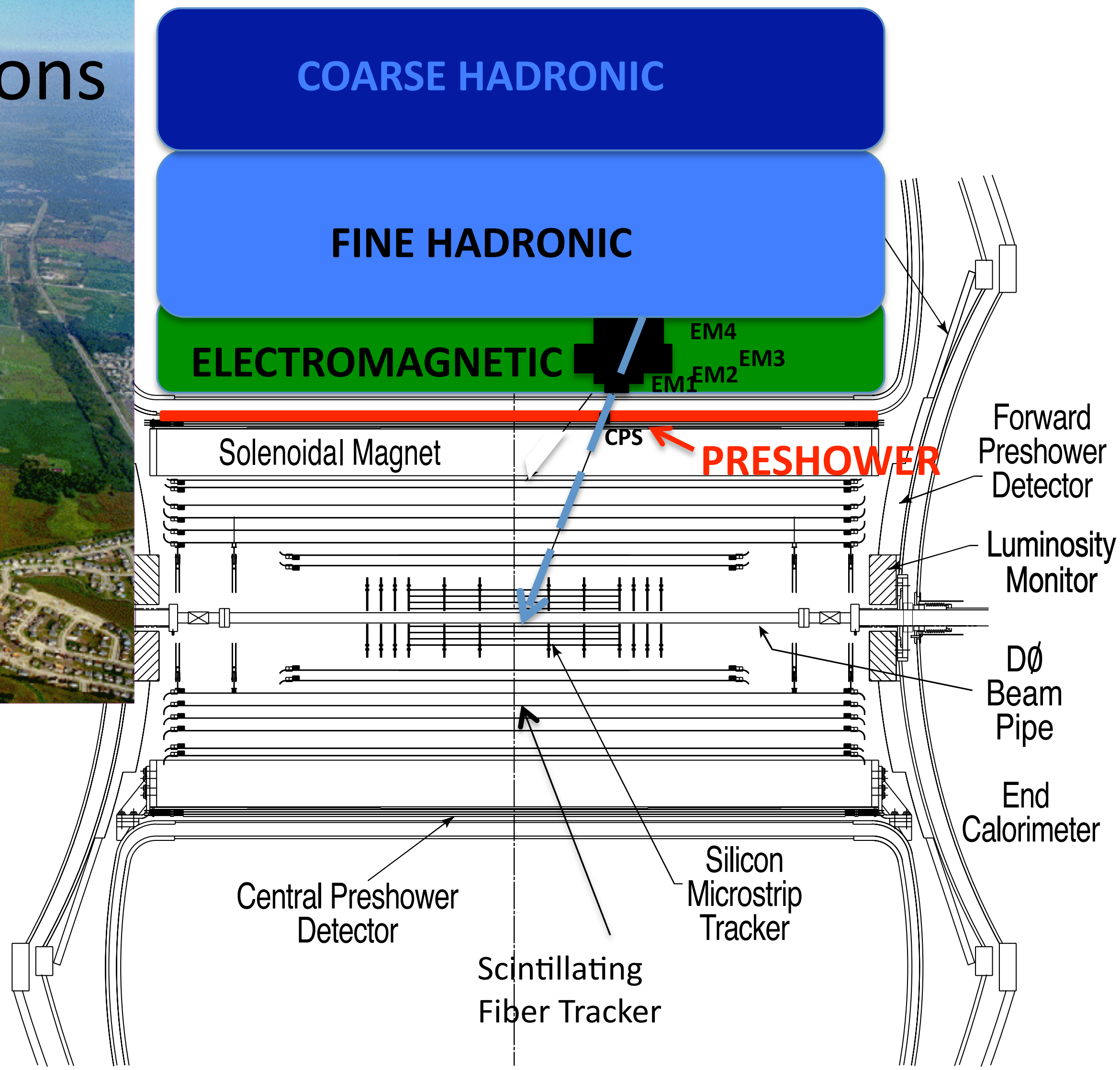
SUSY particle masses, as well as production cross sections, are determined by Λ



DO at the Tevatron

6.3 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s}$ =1.96 TeV





Uranium-Liquid Argon Calorimeter
Pb-scintillator Preshower
Tracking (fiber and silicon)

Selection and Backgrounds

- Sample Selection:
- Two photons are required in the (central calorimeter cryostat)
- Both photons $E_T > 25$ GeV
- no explicit requirements for jets and leptons

- Study signal and background contributions to MET
- Signal populates MET> 50GeV

- SM Backgrounds dominate – use data driven SM background estimates except for small contribution from W/Z+$\gamma\gamma$ events (MC)

- **Instrumental MET** sources (SM $\gamma\gamma$, γ+jets, MultiJet) (mismeasurements create E_T imbalanced event)

- **Genuine MET** source (Wγ, W+jets, W/Z+$\gamma\gamma$)
  (SM events containing real MET(from W) + mis-ID $e \rightarrow \gamma$ fakes)

Electromagnetic Objects

- Electron/Photon reconstruction:
- Localized energy deposits (clusters) in central calorimeter : EM fraction>0.95, $|\eta| < 1.1$, cone radius $R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.2$
- Isolated cluster in calorimeter and tracking
- Shower width in EM3 consistent with EM energy deposit (EM3 has 0.05x0.05 $\eta-\phi$ segmentation)
- Photons are not spatially matched to scintillator or silicon track
- Neural Net trained on track CPS and calorimeter information used to reject 50% of remaining jets, with γ efficiency of 98%
- Energy resolution: $\sigma(E)/E \approx (15/\sqrt{E}+4)\%$

Require 2 photons, each with E_T > 25 GeV in the central calorimeter $|\eta| < 1.1$

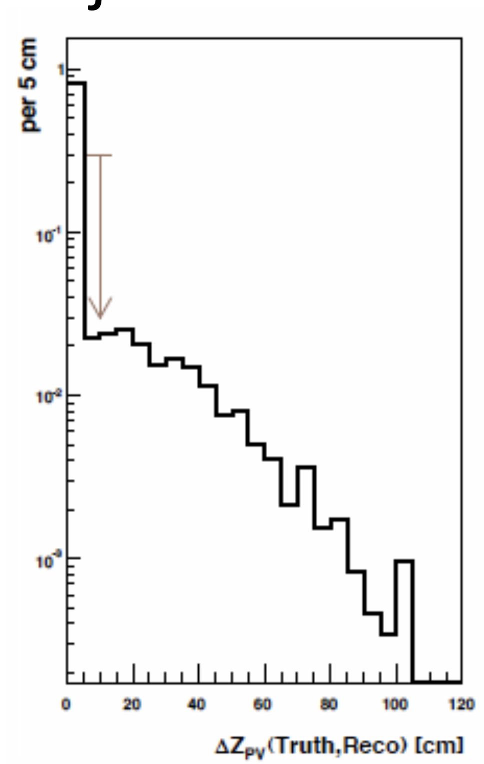
MET

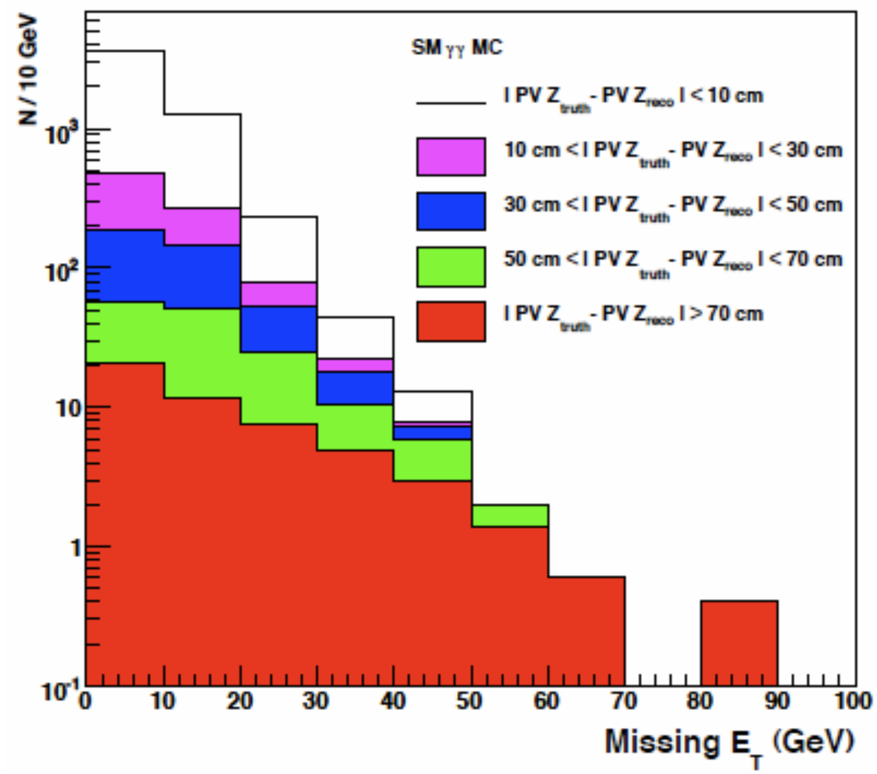
- **Missing Transverse Energy definition**
- Vector sum of transverse energy of the EM and Fine Hadronic calorimeter cells surviving noise algorithms - (cells $|\eta| < 4.2$ with segmentation 0.1x0.1 in η-ϕ)
- Includes corrections for:
  - energy scale of EM objects
  - energy scale of jets (adding any coarse hadronic cells contained in the jets)
  - p_T of muons subtracted and then dE/dx added back
- 3 Topological $\Delta\phi$ requirements to reduce MET mismeasurement:
  - $\Delta\phi(EM_1, EM_2) > 0.1$ [removes beam halo]
  - $\Delta\phi(EM_i, MET) > 0.2$ [mismeasured jets aligned; signal anti-aligned]
  - $\Delta\phi$(Leading Jet, MET) < 2.5 (If jets exists: $\mathbf{p_T}$>15GeV; $|\eta_{det}| < 2.5$)

    [Leading jet in background is anti-aligned due to energy resolution and falling pt spectrum]

Photon Pointing

- D0 photons contain 4 EM longitudinal layers and CPS
- Restrict sample to photons that point to within 10cm of primary vertex; non-collision high MET events are rejected





Instrumental MET shapes

- Events with no intrinsic MET
- Real γ and misID-Jet difference in energy resolution leads to different MET shapes
- SM γγ – MET > 35 GeV shape modeled in Z-> ee
  - sys err estimated by data-MC difference
  - Shape agrees with Z-> ee for MET< 35 GeV
- γ+jets and multi-jets – same requirements as γγ sample, except 'γ' fails the NN EM ID cut.
  - γγ/γ+jets determined from fit to MET<20 GeV
- Total instrumental MET background for MET< 10 GeV normalized to γγ data
- 41% of the sample over full MET range is SM γγ

Genuine MET background

- SM $\gamma\gamma$ + MET+ X – determined via MC (MADGRAPH)

- eγ sources: have real MET but at least 1 γ is due to electron fake. Excess over instrumental sources in MET> 30 GeV well described by W+γ, W+jets
  - Expected W transverse mass distribution observed
  - W+j normalization from NN shape comparison of real γ and fake γ in MET> 30 GeV
  - Remainder consistent with W+γ after accounting for final state radiation

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SM events in 3 MET bins

Observed events, SM backgrounds and 2 GMSB benchmarks presented for three MET bins

Instrumental MET sources: SM $\gamma\gamma$, γ+jets, MultiJet

Genuine MET sources: Wγ, W+jets, W/Z+$\gamma\gamma$)

MET interval	Observed events	SM Backgrounds			Expected Signal	
(GeV)		Instr. MET	Genuine MET	Total	GMSB Λ=100 TeV	GMSB Λ=120 TeV
35-50	18	9.6+-1.9	2.3+-0.5	11.9+-2.0	1.8+-0.1	0.3+-0.1
50-75	3	3.5+-0.8	1.5+-0.3	5.0+-0.9	4.1+-0.3	0.8+-0.1
>75	1	1.1+-0.4	0.8+-0.1	1.9+-0.4	14.3+-1.1	4.4+-0.4

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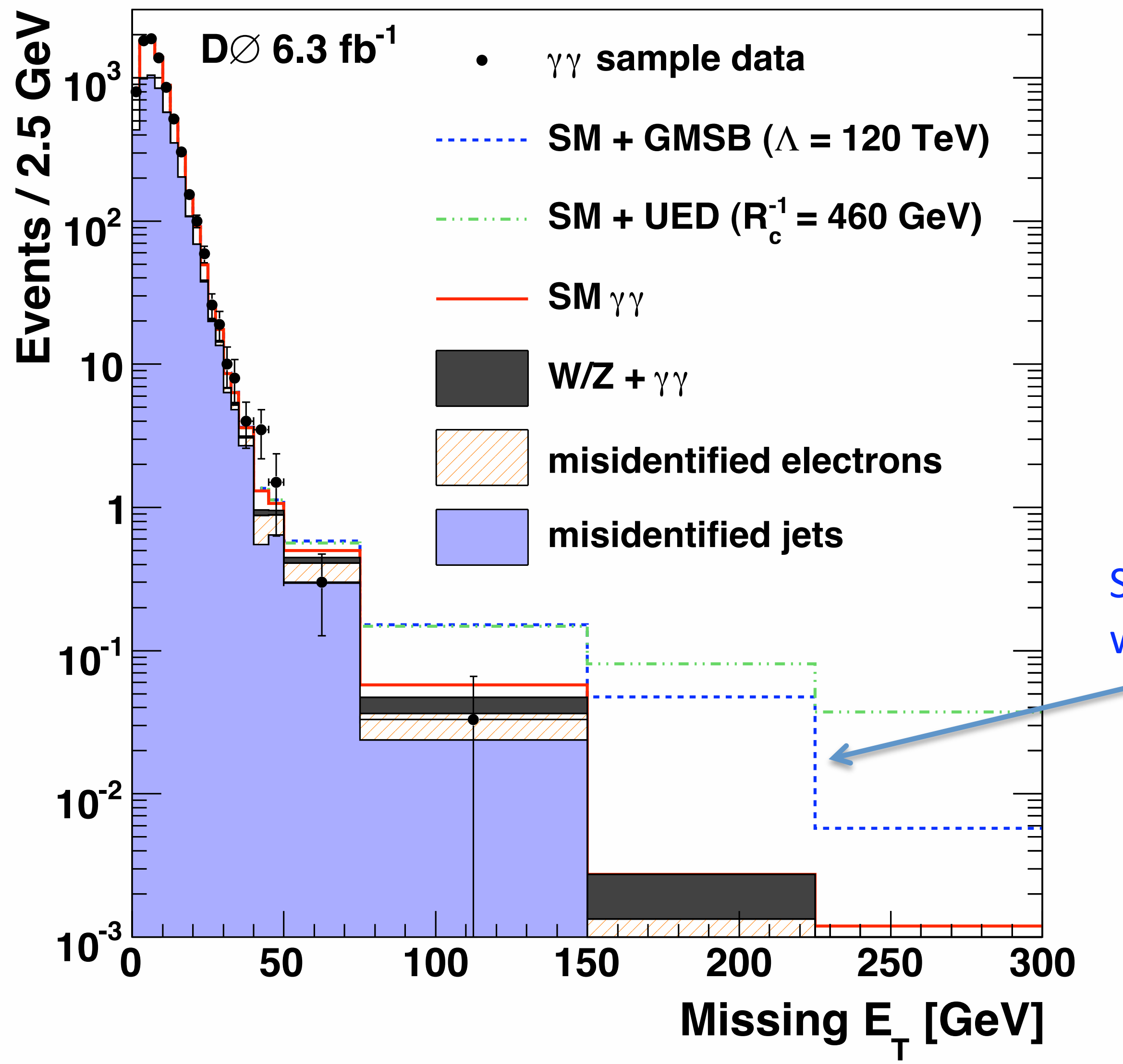
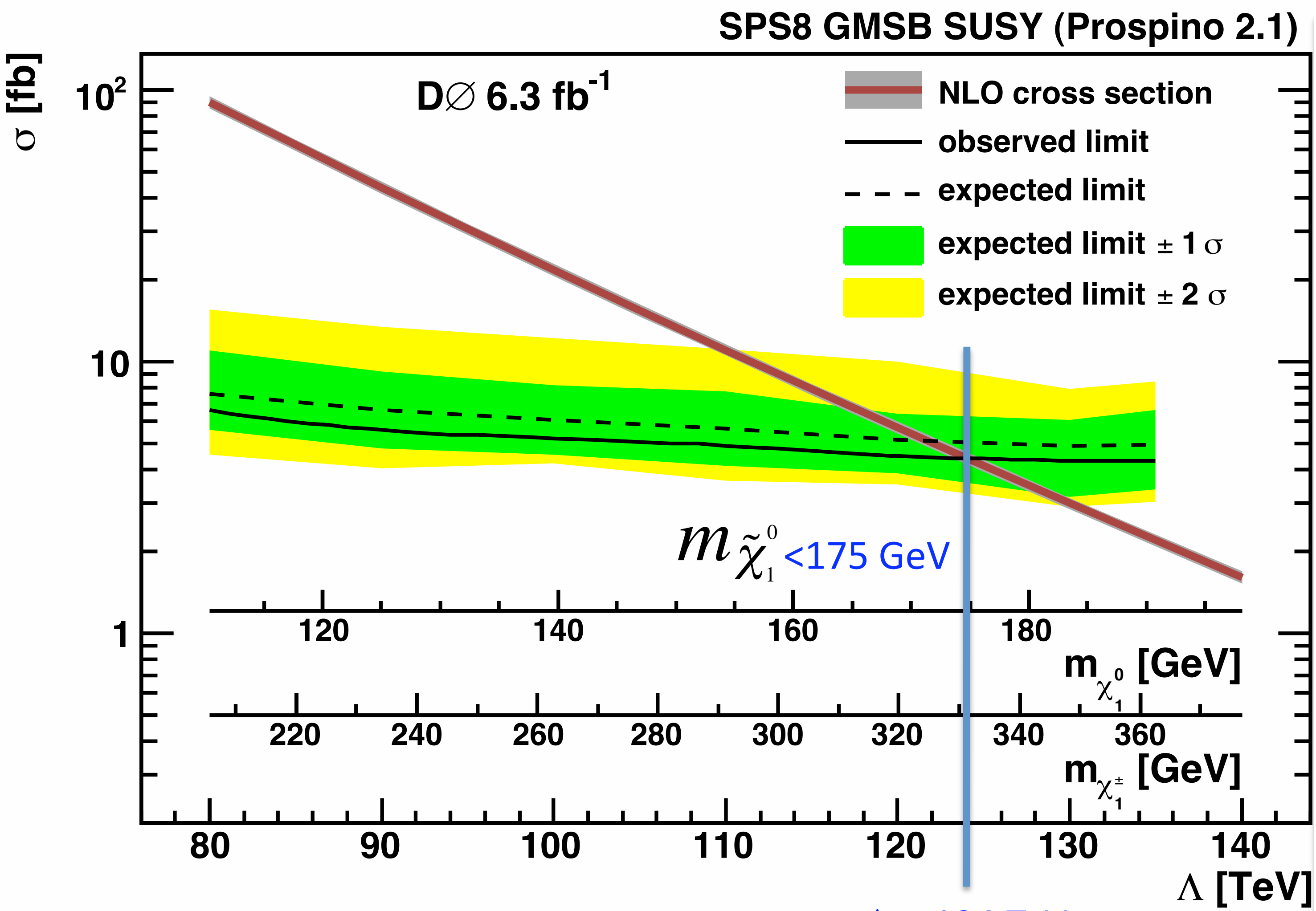
Missing E_T



Simulated GMSB signal with Λ = 120 TeV

Exclusion Limit



$m_{\tilde{\chi}^0_1}$ <175 GeV

Λ < 124 TeV

Phys. Rev. Lett. ***105***, *221802 (2010)*

Summary

- No Evidence for beyond the SM physics in MET distribution in $\gamma\gamma$ + MET events
- Limits on GMSB benchmark model derived using Poisson log-likelihood ratio test (CLs modified Frequentist approach) using the full MET distribution.
  T. Junk, Nucl. Instrum. Methods Phys. Res., Sect. A 434,435 (1999)
  W. Fisher, Report No. FERMILAB-TM-2386-E, 2006.
- Pseudoexperiments generated for background only and background+signal hypotheses include statistical and systematic uncertainties
- In SPS8 GMSB model the effective SUSY **breaking scale Λ < 124 TeV** is excluded at the 95% confidence level; also excludes $m_{\tilde{\chi}_1^0}$ **<175 GeV**

Backup Slides

Detailed γ ID requirements

- EM fraction (EMfrac): EMfrac > 0.95
- Calorimeter Isolation (CaloIso): CaloIso < 0.10
- Track Isolation (TrkIso): TrkIso < 2.0 GeV
- EM3 shower width (EM3w): EM3w $< 14(18)$
- Photon neural net 5 (NN5 or NN): NN5 > 0.10
- Track Veto (TrkVeto): TrkPrb $< 0.0001(0)$ *and* HOR $< 0.5(0.9)$.

- Neural Net variables
  - the number of cluster EM1 cells with $E > 450$ MeV in a $\Delta R < 0.20$ cone about the cluster centroid
  - the number of cluster EM1 cells with $E > 450$ MeV in a $0.20 < \Delta R < 0.40$ hollow cone about the cluster centroid
  - track isolation
  - the number of CPS clusters in a $\Delta R < 0.10$ cone about the cluster centroid
  - the energy weighted CPS RMS in ϕ [26].

GMSB Cross Sections