

# Supersymmetry Searches at the Tevatron

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# Overview

CDF and DØ detectors + data taking

3rd generation squarks (CDF, DØ)

Gaugino searches:

Charginos & neutralinos  $\rightarrow$  trileptons (CDF, DØ)

GMSB: neutralino  $\rightarrow$  photon  $\gamma\gamma$ +MET (DØ)

'Hidden Valley': dark photon  $\rightarrow$  'leptonic jets'+MET (DØ)

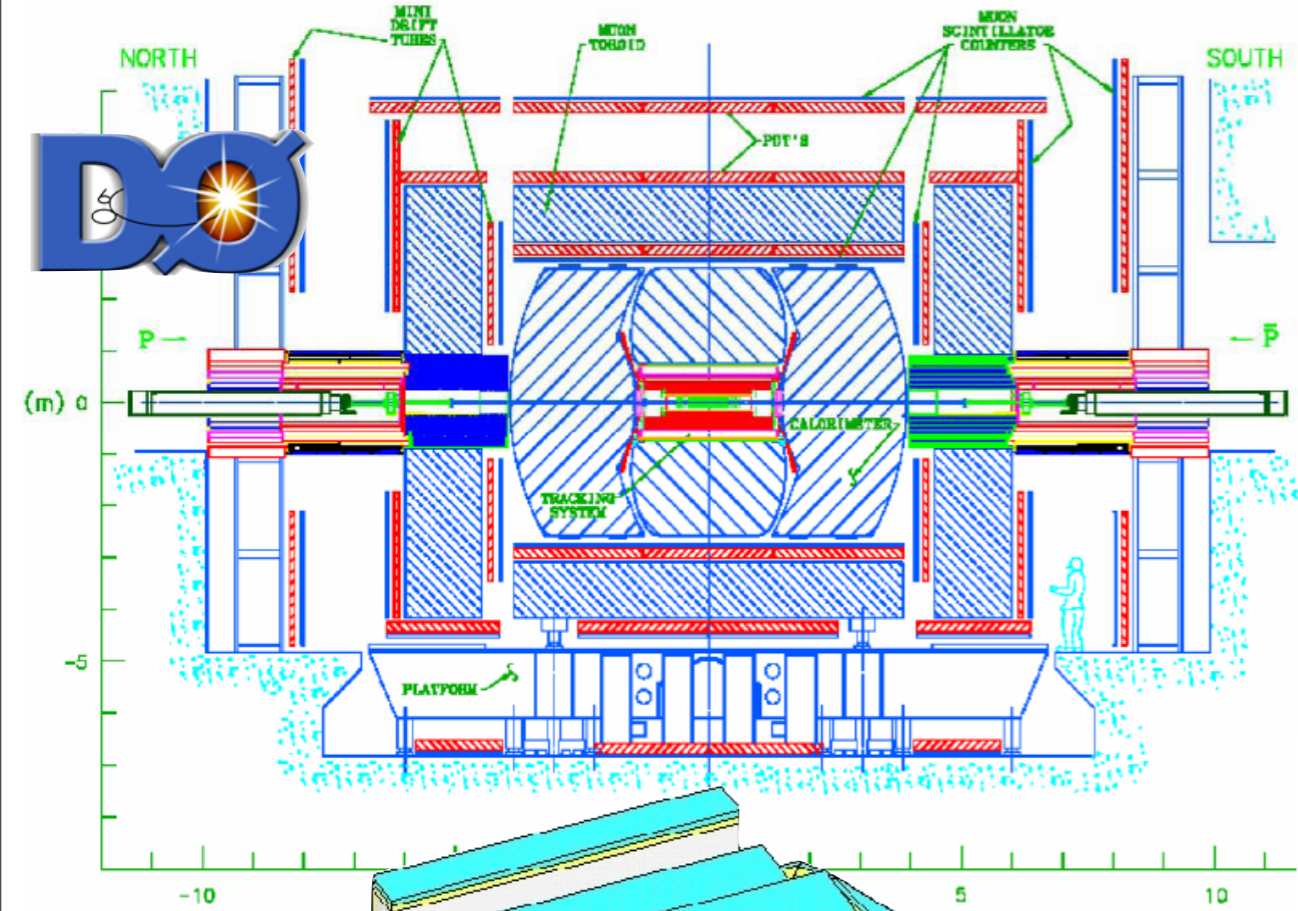
$\tilde{q}/\tilde{g} \rightarrow$  same sign dileptons (CDF)

R-parity violating decays:

$\tilde{\nu}_\tau \rightarrow e+\mu$  (DØ)

$\tilde{g} \rightarrow$  3-jet resonances (CDF)

# Detectors + Data Taking



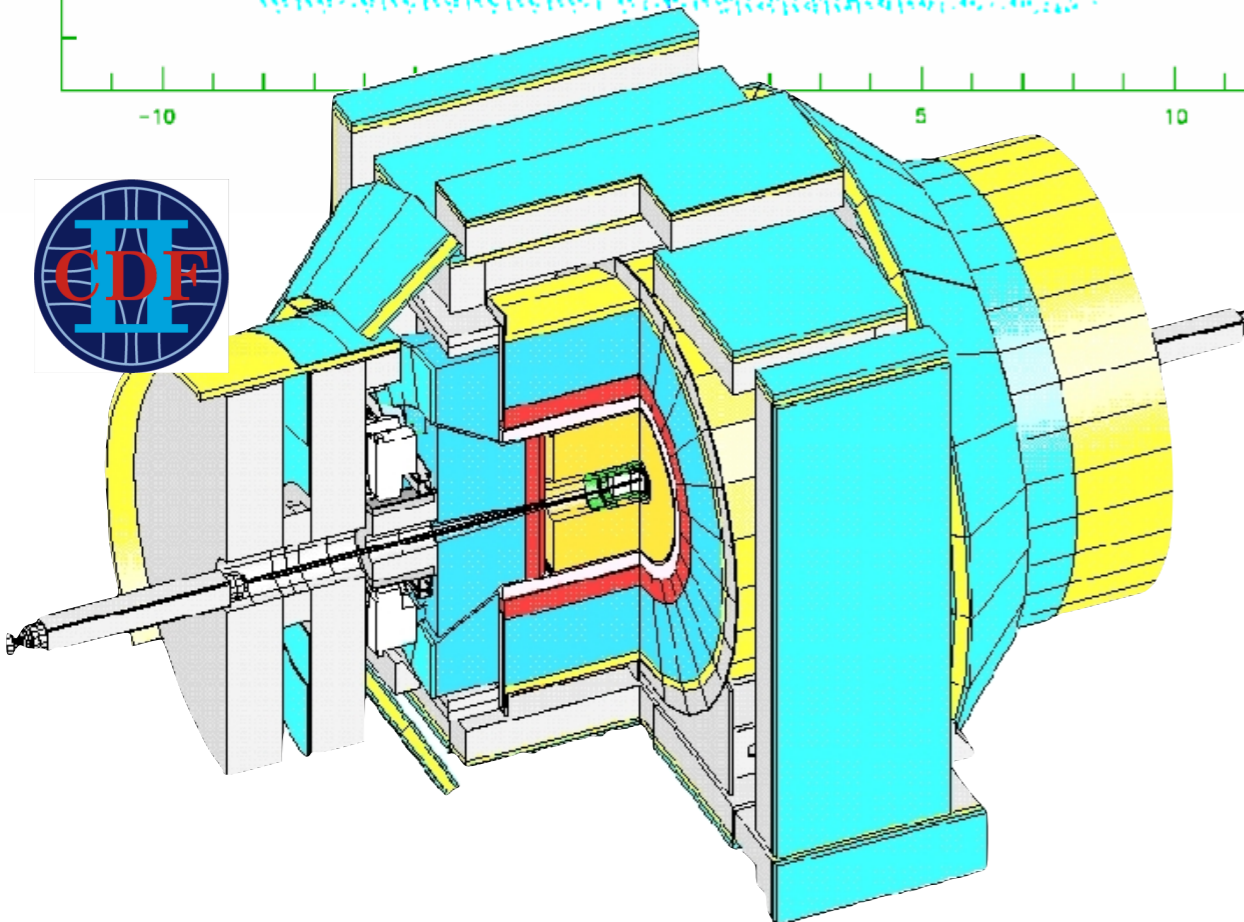
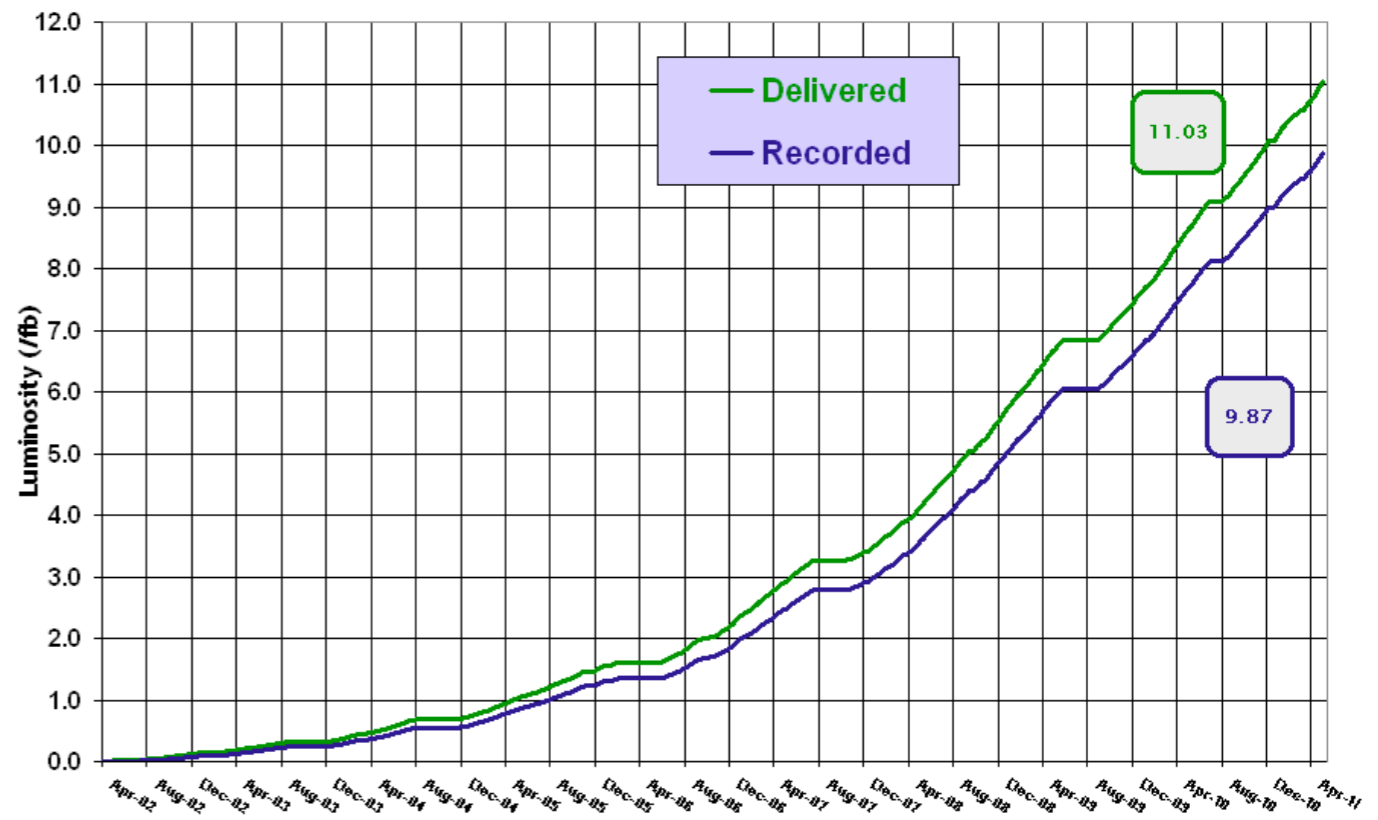
Tevatron Run II: 11/fb delivered, up to 9/fb analyzed

Goal of 12/fb/experiment until Fall 2011 (end of Run II)



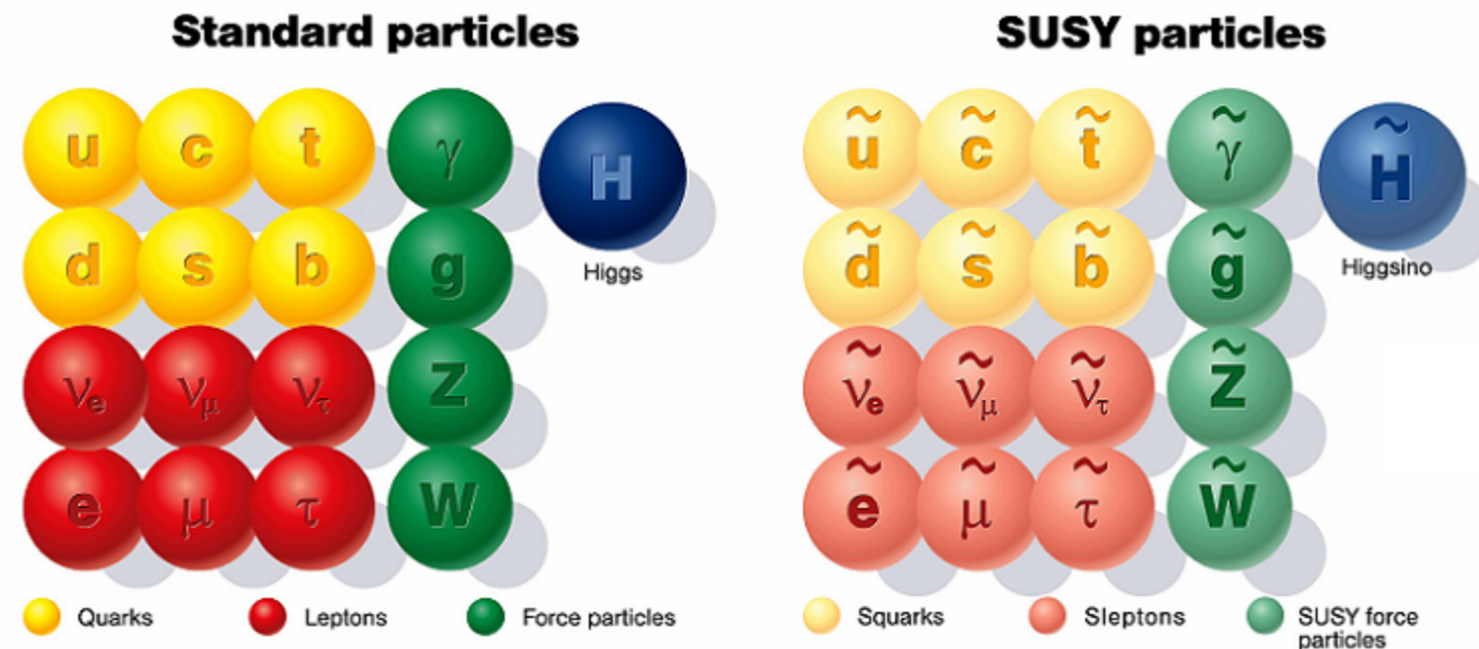
Run II Integrated Luminosity

19 April 2002 - 22 May 2011



# Supersymmetry

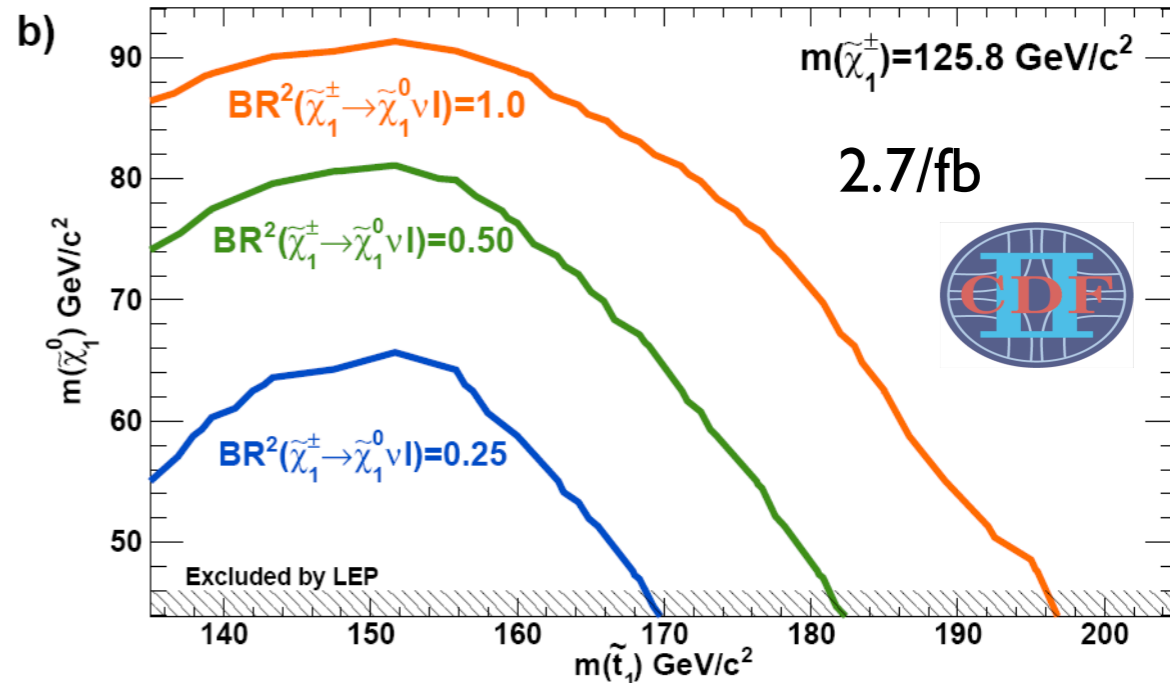
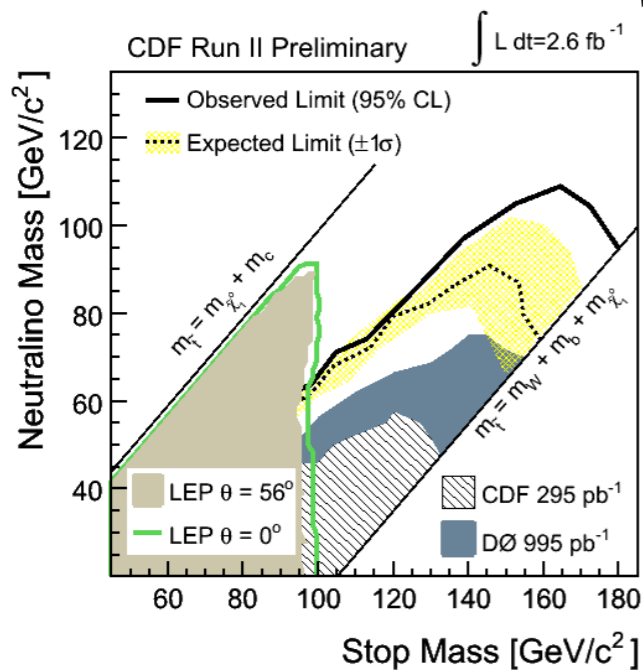
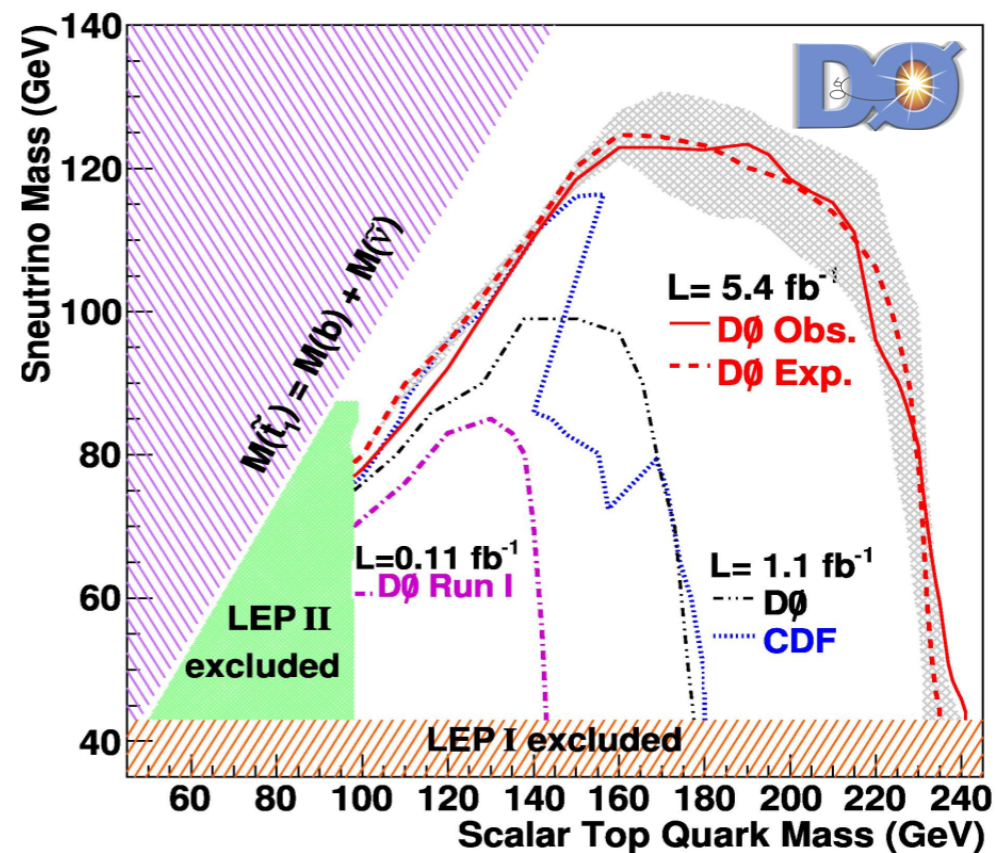
- New boson - fermion symmetry (conserved quantity R-parity  $e^{-(3B+L+S)}$ )
  - Protects Higgs mass if superpartner masses not too different
  - Lots of yet to be discovered particles
  - → Theoretically & experimentally appealing
- ‘Right around the corner’ for the last 30 years





# Stop

- Potentially lightest squark; three decay paths studied:
  - $\tilde{t}_1 \rightarrow bl\tilde{\nu}$  e+ $\mu$ +2b+MET
  - $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm \rightarrow b\tilde{\chi}_1^0 l\nu$  2 leptons (1 isolated), 2 jets (1 btag), MET
  - $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$  2 c jets + MET



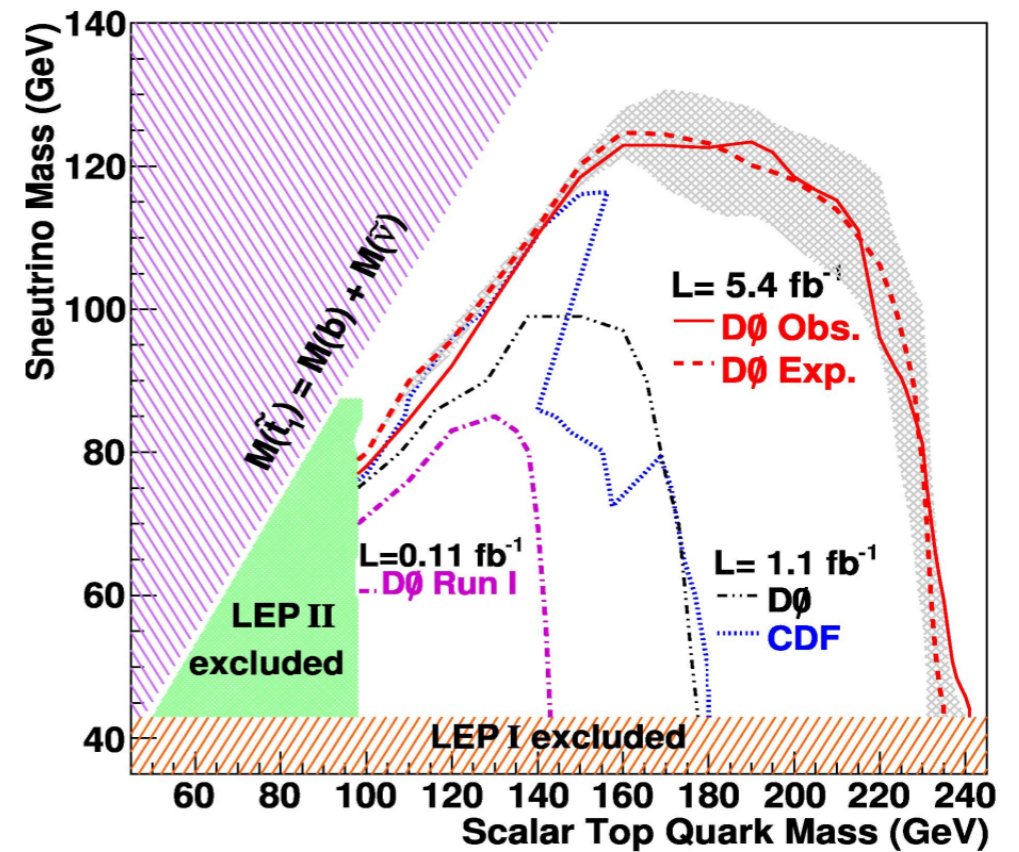


# Stop pair $\rightarrow e + \mu + 2b + \text{MET}$

- Three separate multivariate discriminants for the three main backgrounds  $Z \rightarrow \tau\tau$ ,  $WW$  production, and  $t\bar{t}$
- Selection strategy depends on  $\Delta m = m(\text{stop}) - m(\text{sneutrino})$

events for selection/sample	$\Delta m$ small	$\Delta m$ large
background	$785 \pm 57$	$513 \pm 37$
data	776	472
signal benchmark	$23.8 \pm 3.9$	$51.8 \pm 8.7$

- Phys.Lett. B 696 (2011) 321



$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm \rightarrow b\tilde{\chi}_1^0 l\nu$$

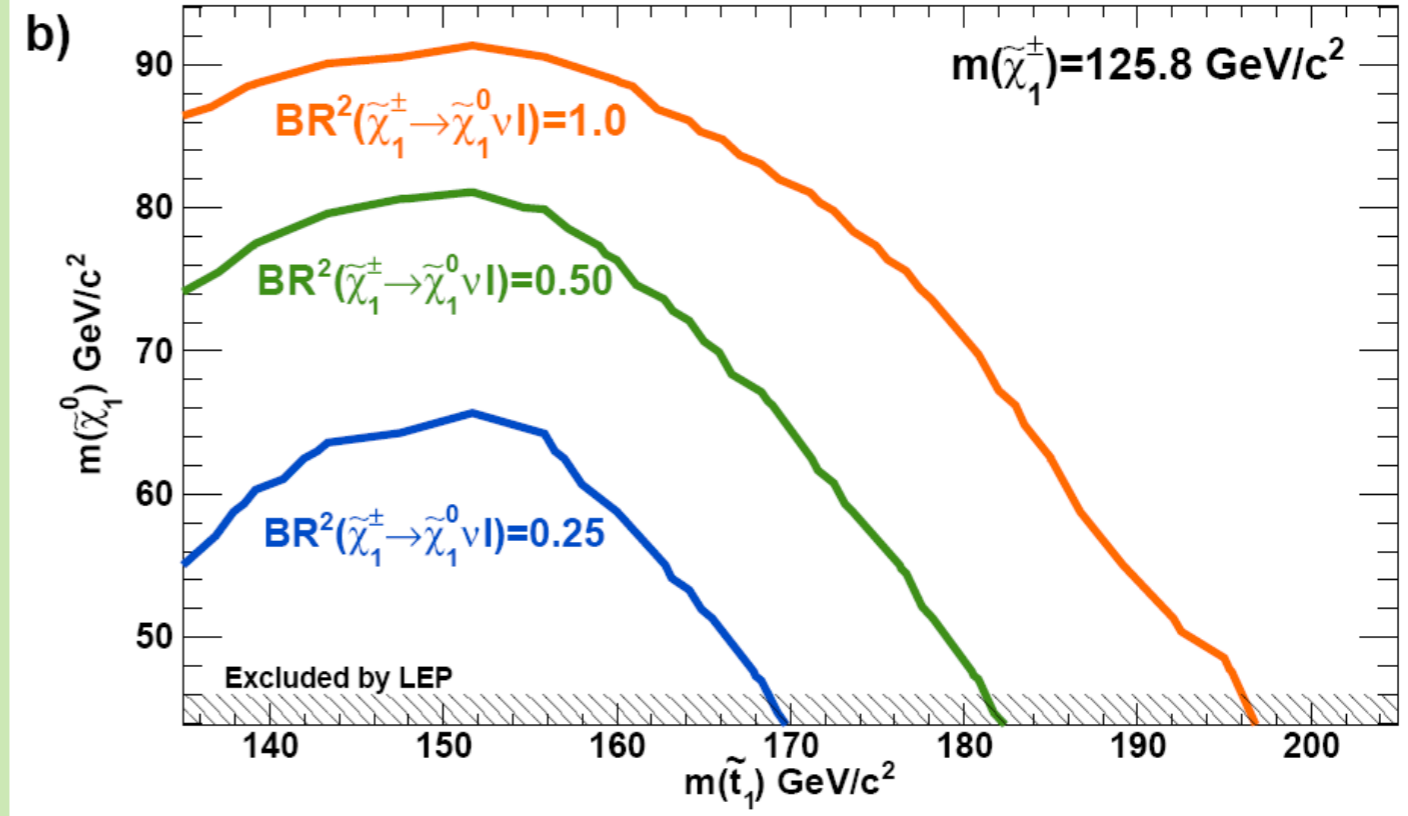
Selection:

2 leptons (e or  $\mu$ ), at least two jets,

MET > 20 GeV

2 samples (btagging)

PRL 104 (2010) 251801



$$\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$$

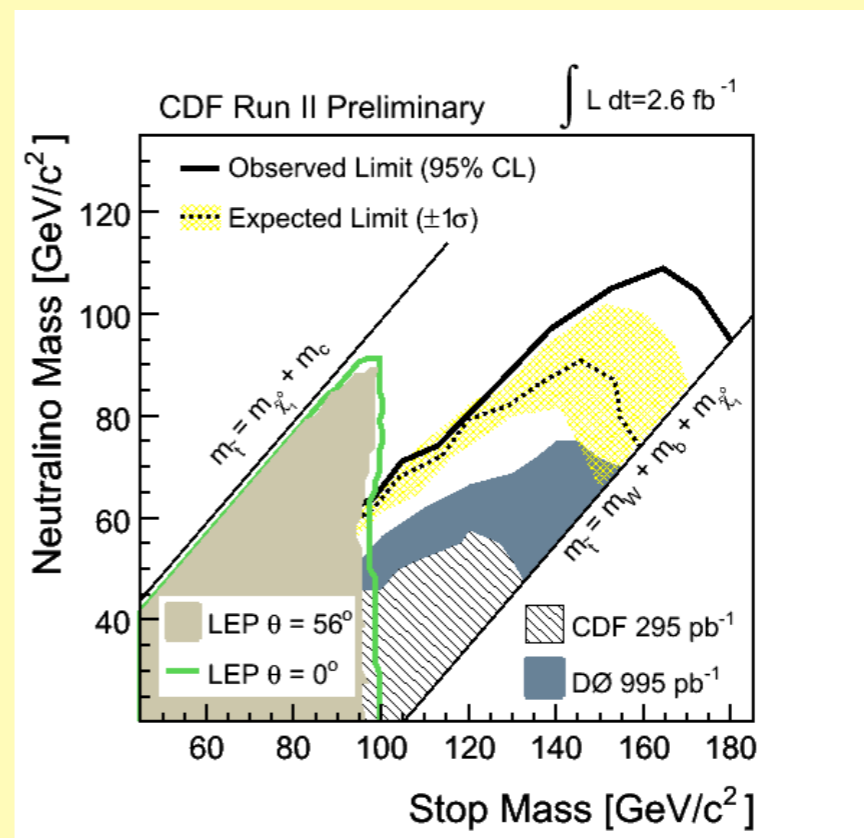
Selection:

2 jets (one b/c-tagged via secondary vertex)

MET > 50 GeV

Neural net to reduce heavy flavour multijet bg

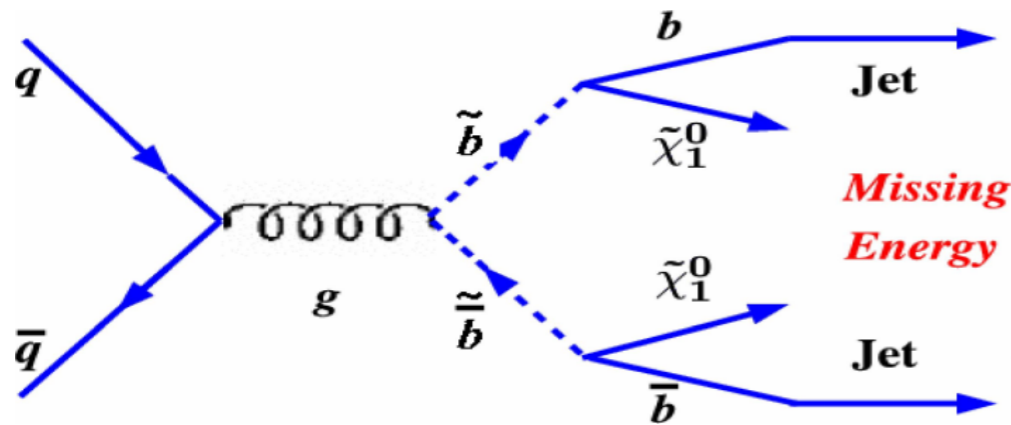
7/2009, CDF public note 9834



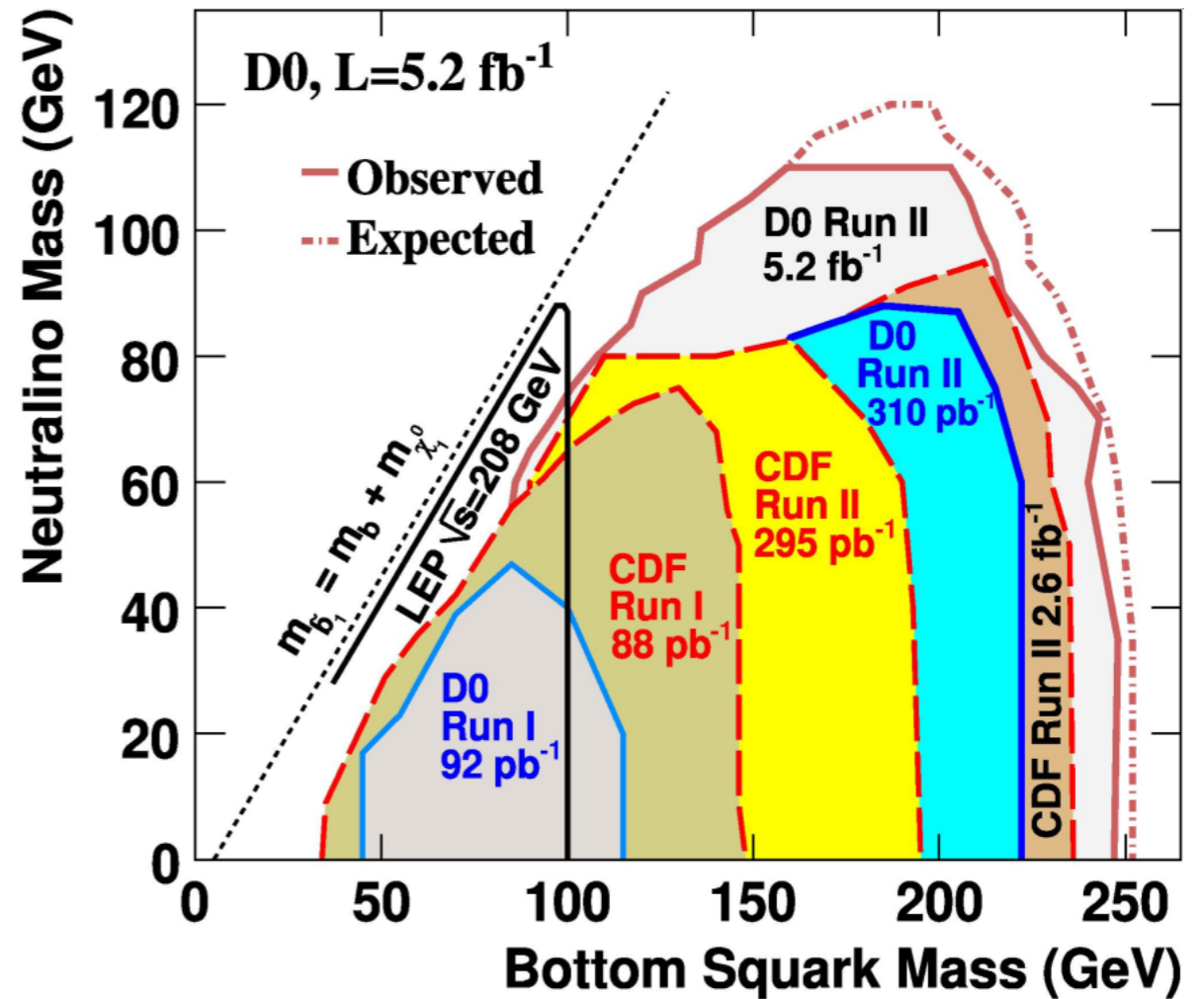
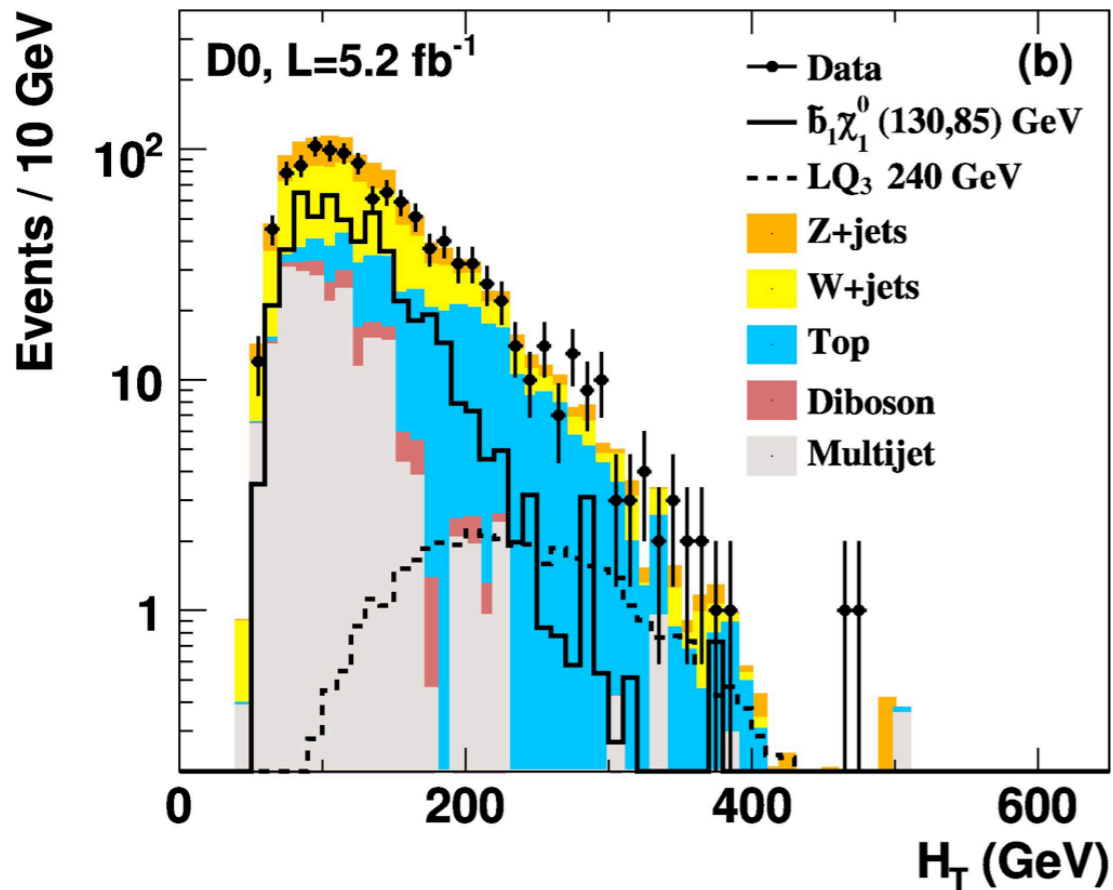


# Sbottom

$$\tilde{b}_1 \tilde{b}_1 \rightarrow b \tilde{\chi}_1^0 \bar{b} \tilde{\chi}_1^0$$

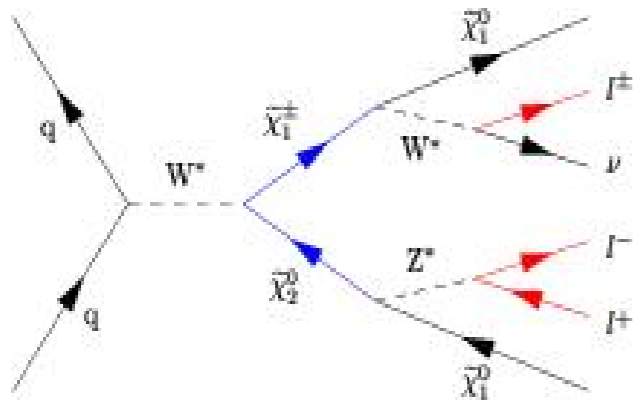


- 2 or 3 jets (b-tagged) + MET
- Phys.Lett. B 693 (2010) 95





# Gauginos: trilepton searches



- Chargino + neutralino pair production  $\rightarrow$  trileptons
- Limits set in mSUGRA (5 free parameters)

Experiments have slightly different approach to maximize efficiency for 3 relatively low  $p_T$  leptons:

CDF - trilepton & dilepton+track channels

Trilepton: 1 ( $1.5 \pm 0.2$ ) events observed (expected)

Dilepton+Track: 6 ( $9.4 \pm 1.4$ ) events observed (expected)

6/25/2009, public note 9817

DØ - 3 channels ( $l =$  loose lepton):

$eel, \mu\mu l$  &  $e\mu l$  ; different selection depending on expected  $p_T$  of final state particles

Low- $p_T$ : 9 ( $5.4 \pm 0.4 \pm 0.4$ ) events observed (expected)

High- $p_T$ : 4 ( $3.3 \pm 0.3 \pm 0.3$ ) events observed (expected)

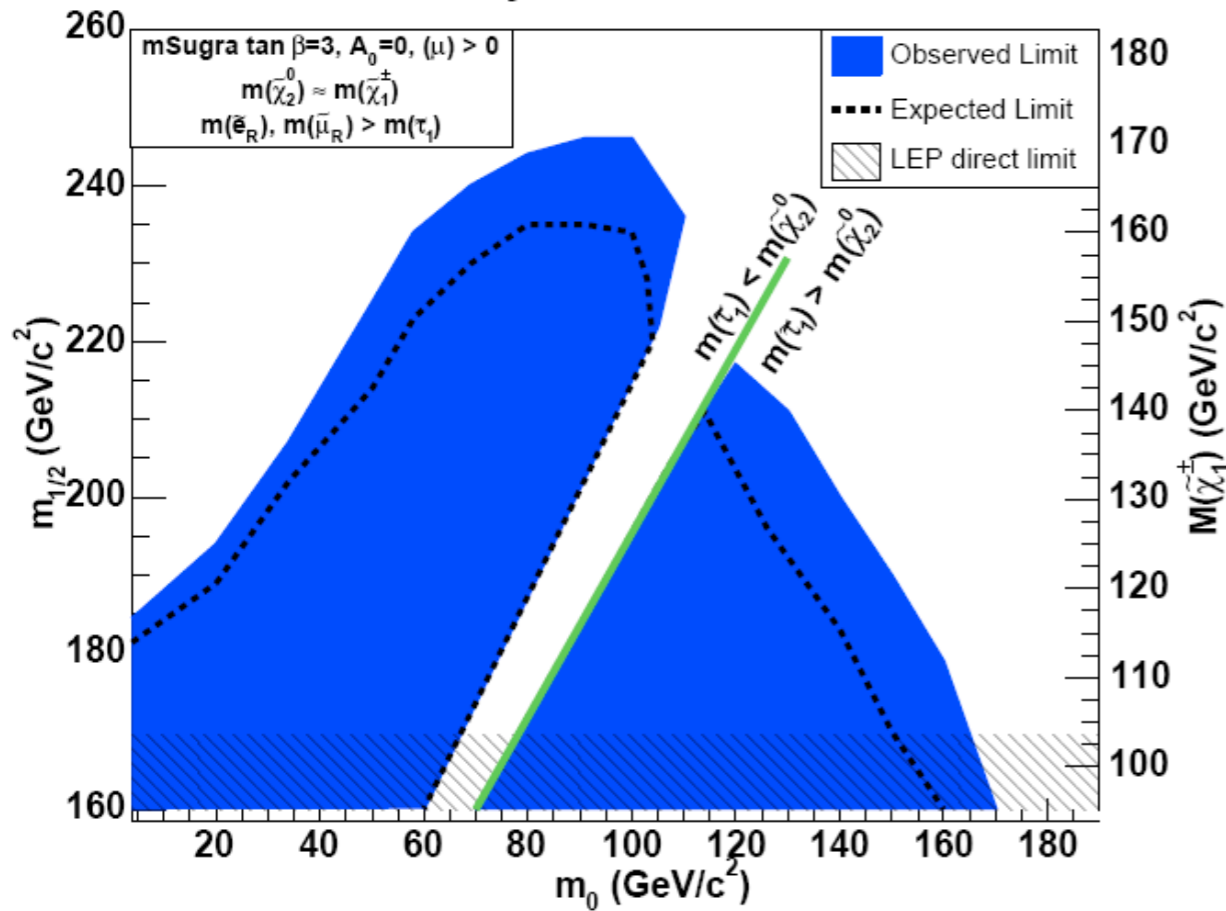
Phys.Lett. B 680 (2009) 34



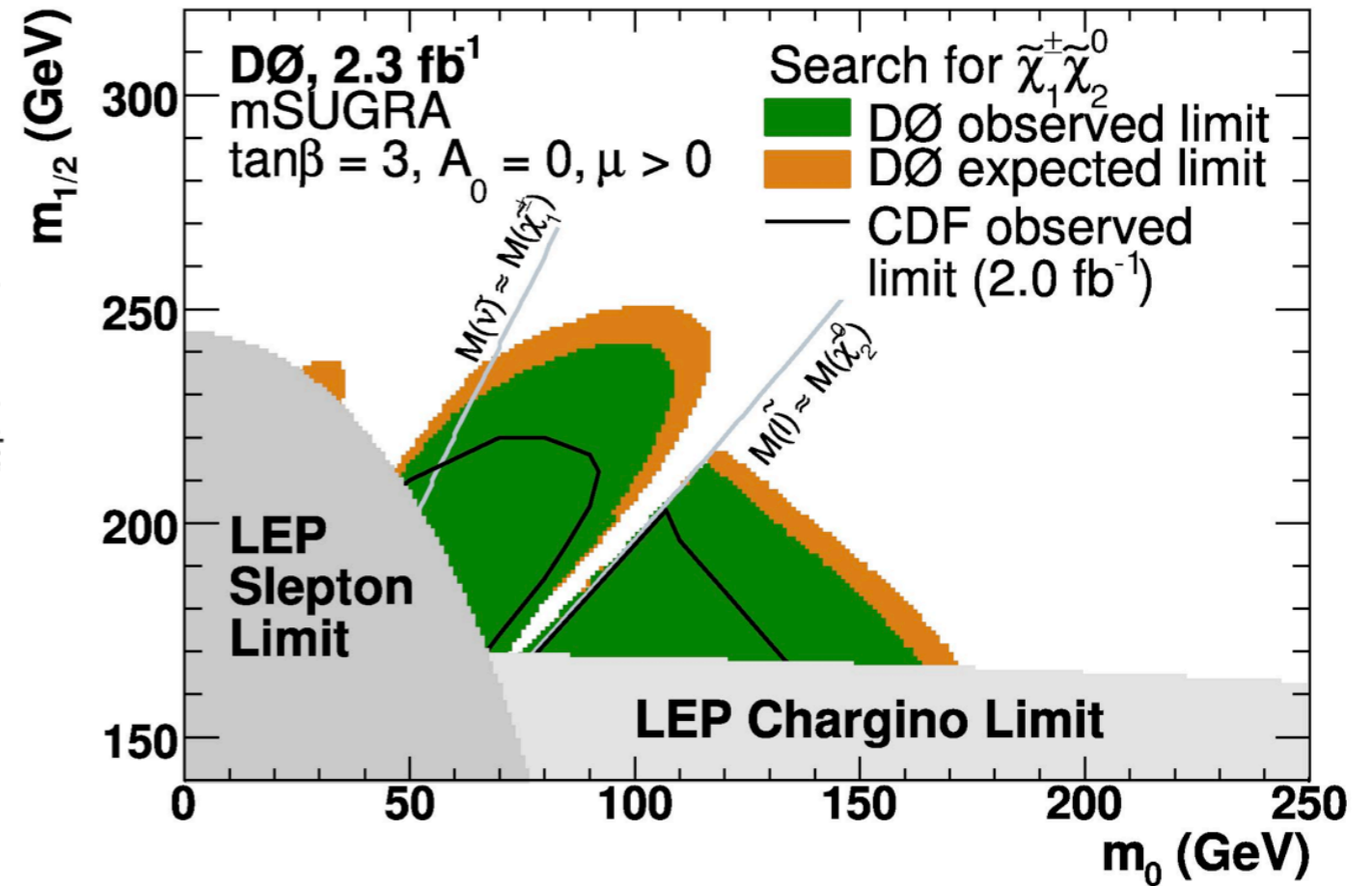
# Trileptons II

results:

CDF Run II Preliminary, 3.2 fb<sup>-1</sup>



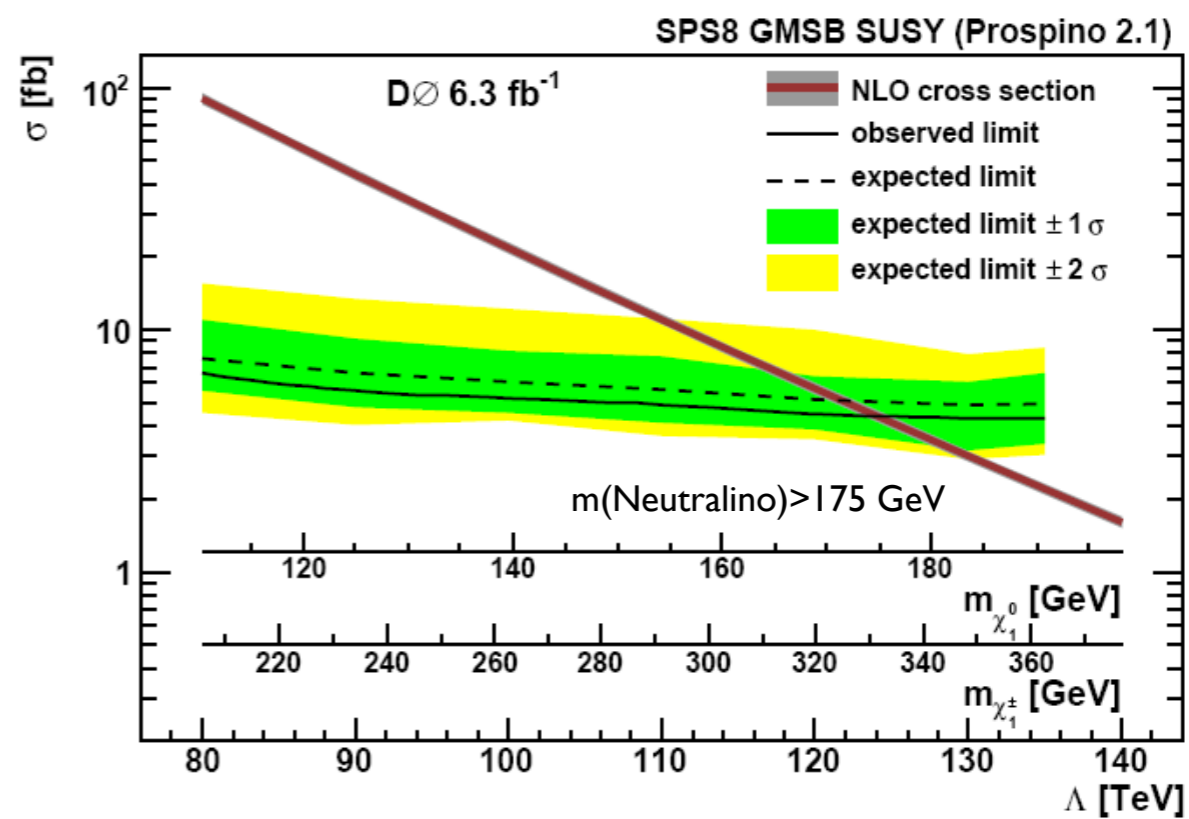
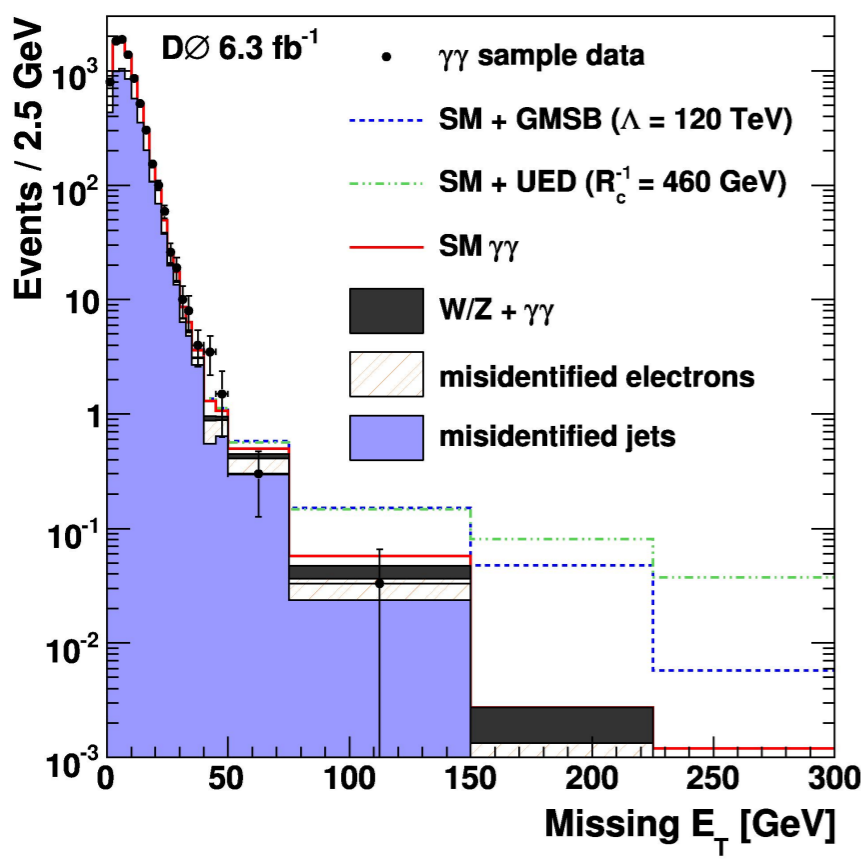
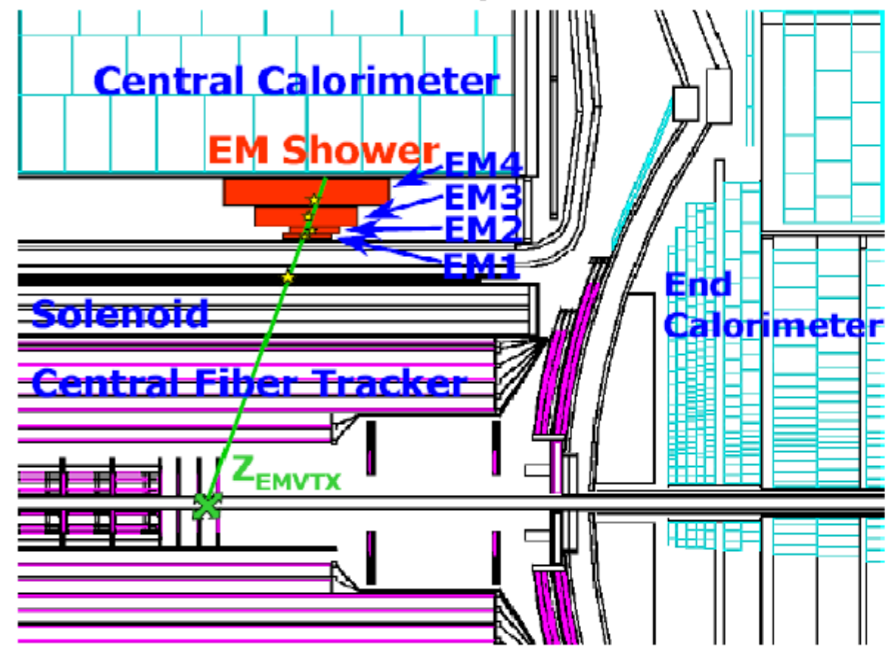
$m_{\text{chargino}} > 164$  GeV (mSUGRA,  $m_0=60, \tan\beta=3, A_0=0, \mu>0$ )





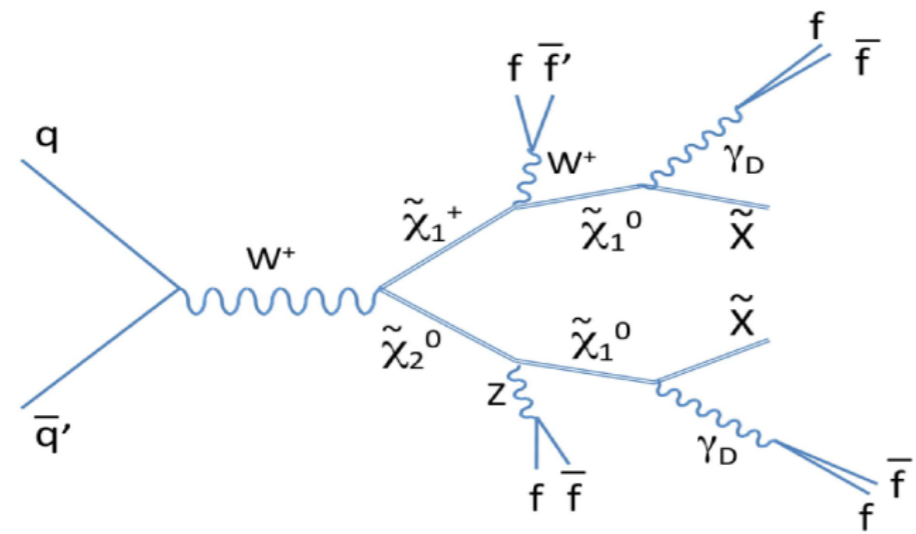
# GMSB: diphotons

- LSP = gravitino
- $\bar{p}p(\rightarrow \text{gauginos}) \rightarrow \text{neutralino pairs}$
- $\rightarrow \text{photons} + \text{MET}$
- Photon pointing  $\rightarrow$  primary vertex
- PRL 105 (2010) 221802



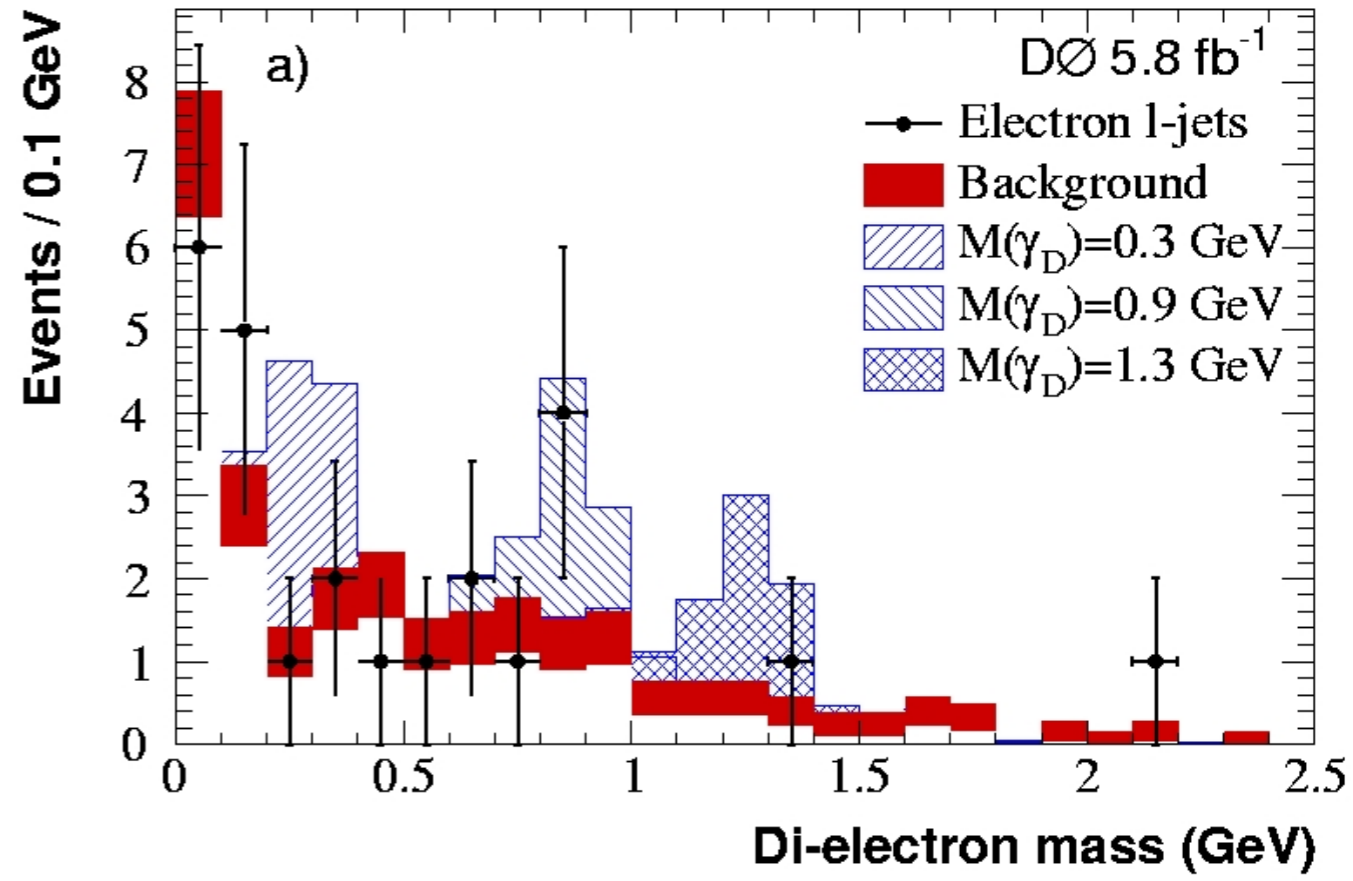


# 'Hidden Valley': leptonic jets



- Hidden sector with dark photons, weakly coupled to SM
- Dark photon decays to tightly collimated jets of fermions
- Needs modified lepton ID (isolation criteria)

3 possible final states:  
 Both dark photons decay to photon + LSP (6.3/fb diphoton analysis)  
 Both dark photons decay to fermions (leptonic jets) (this analysis)  
 One photon + one leptonic jet (previous 4.1/fb Hidden Valley analysis)

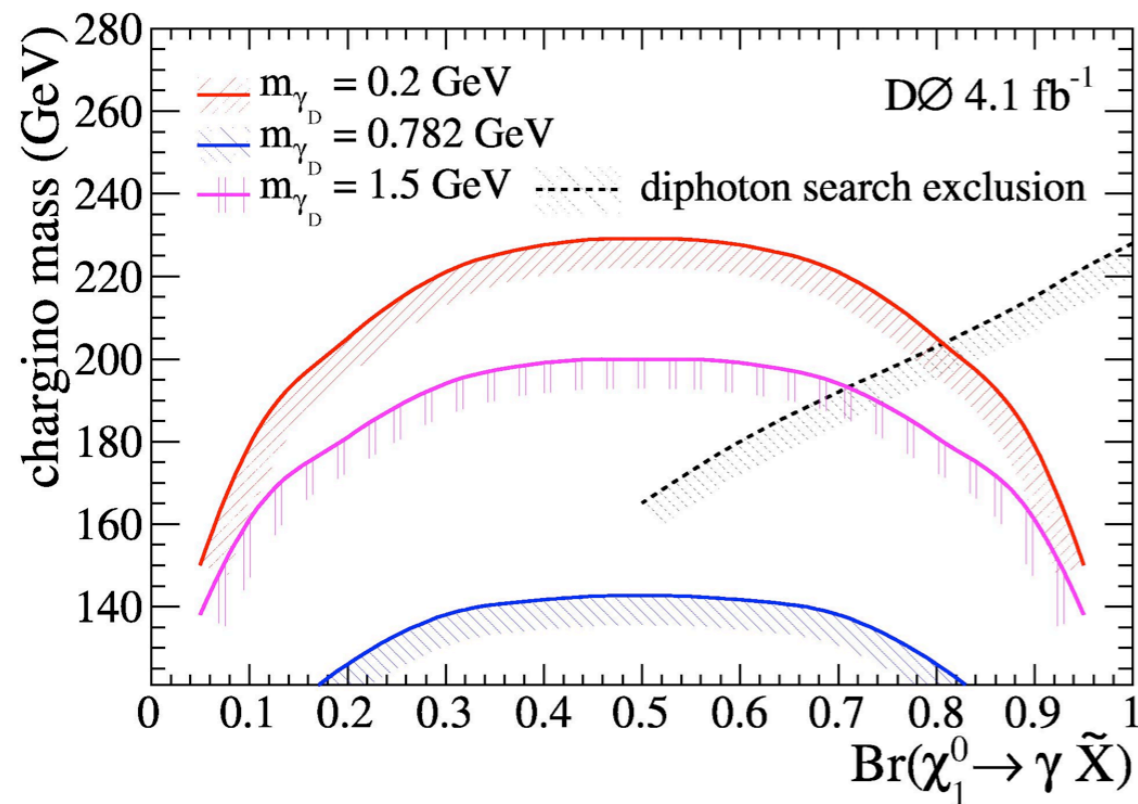


# Hidden Valley II

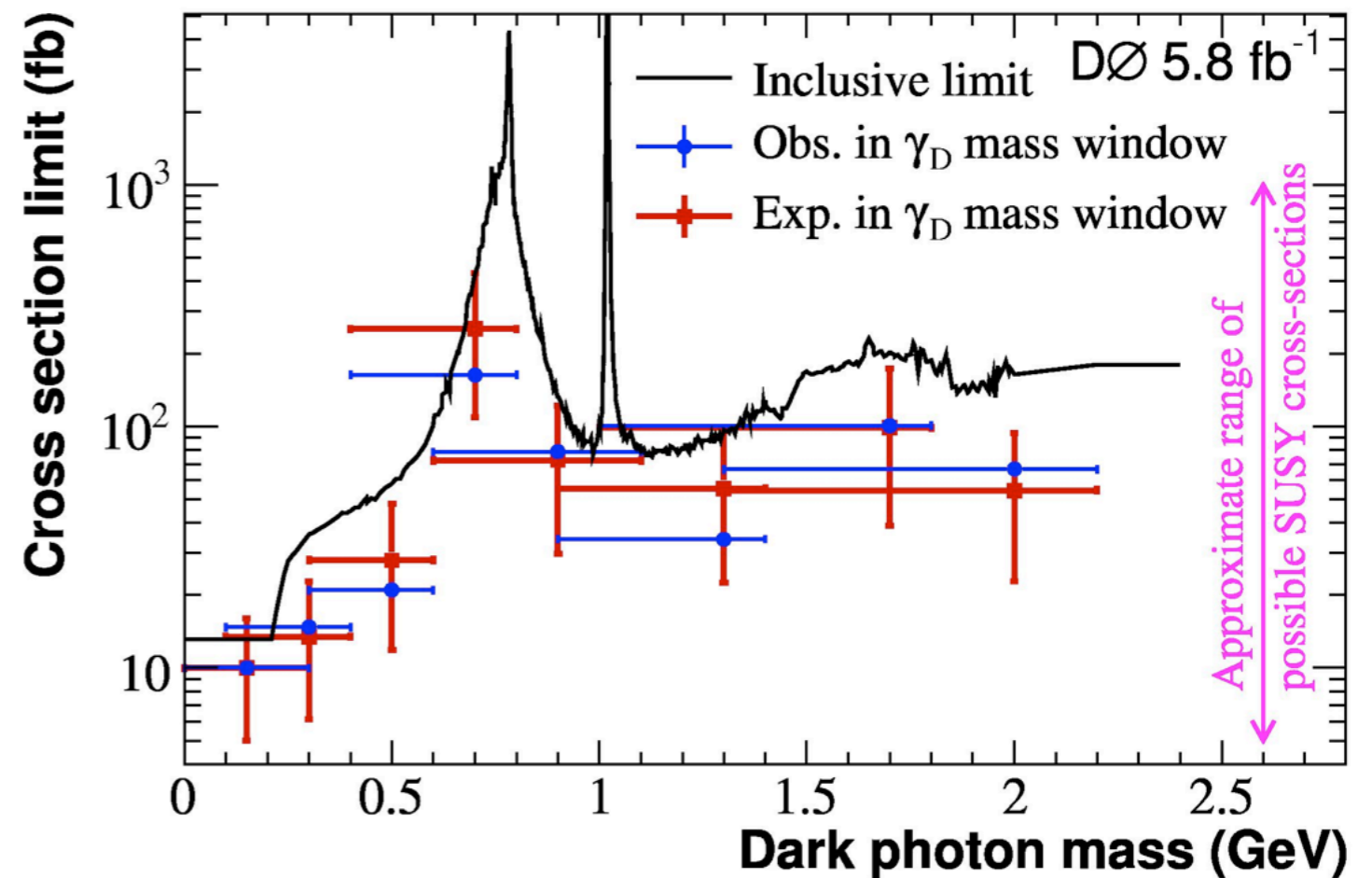
Result: limits on  $\sigma \times \text{BR}$

PRL 105 (2010) 211802

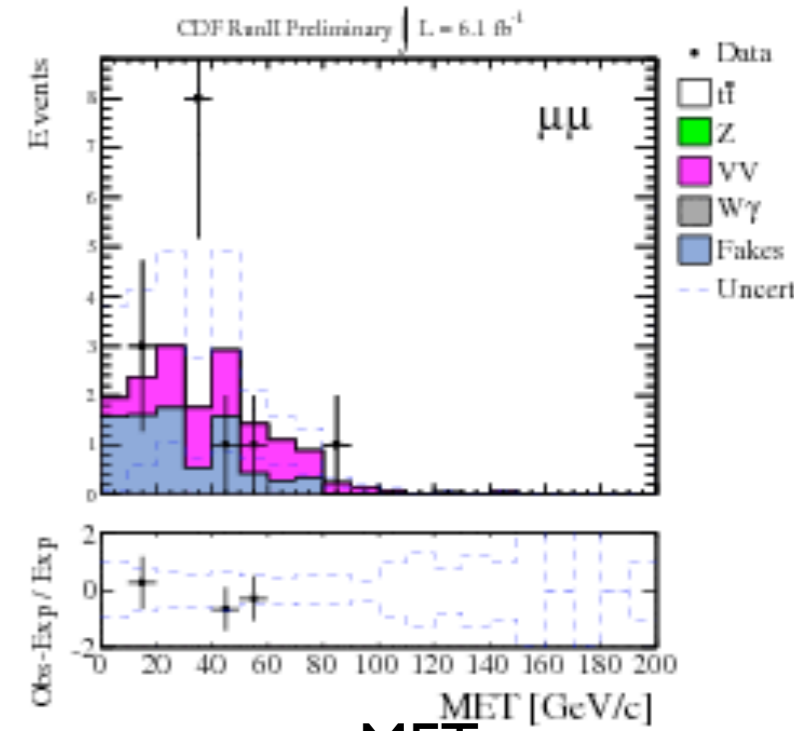
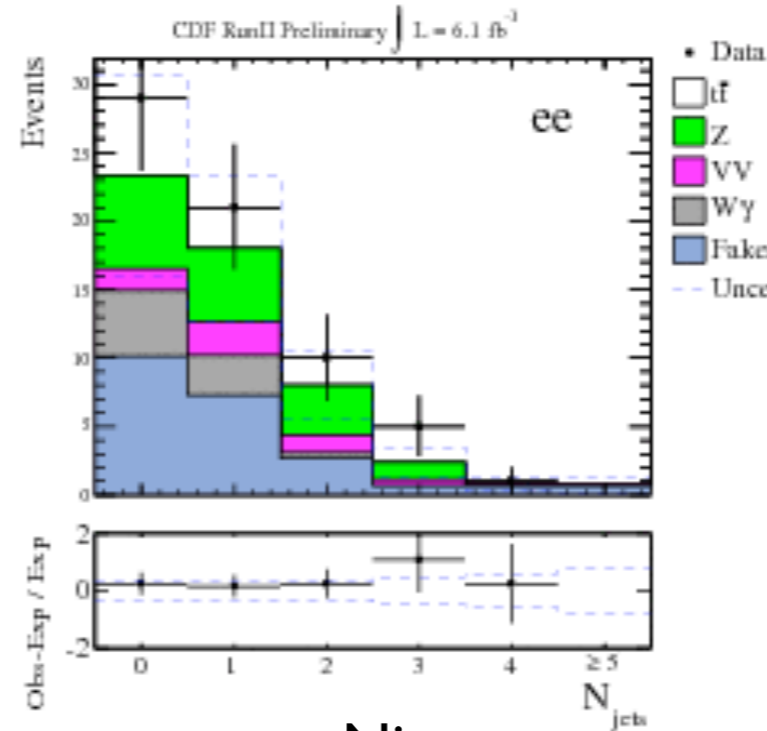
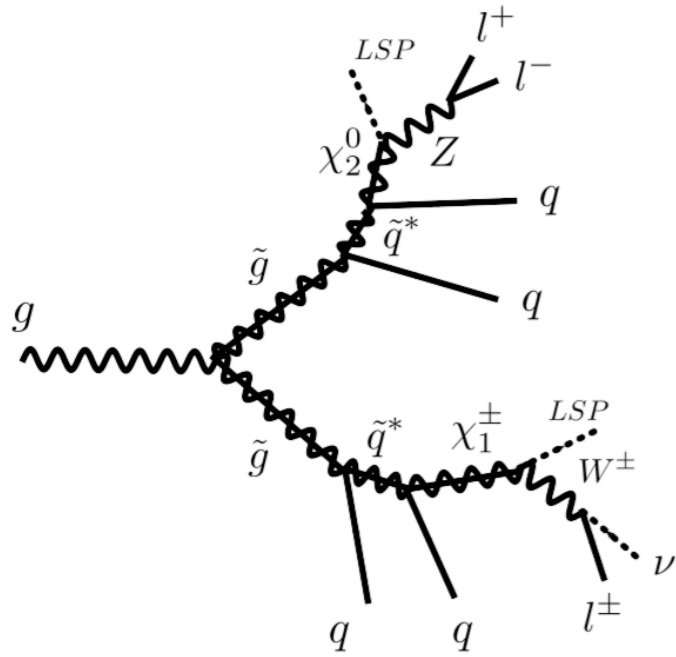
previous limit



PRL 103 (2009) 081802



# Same-sign Dileptons



From decays of squark or gluino pairs

Njets

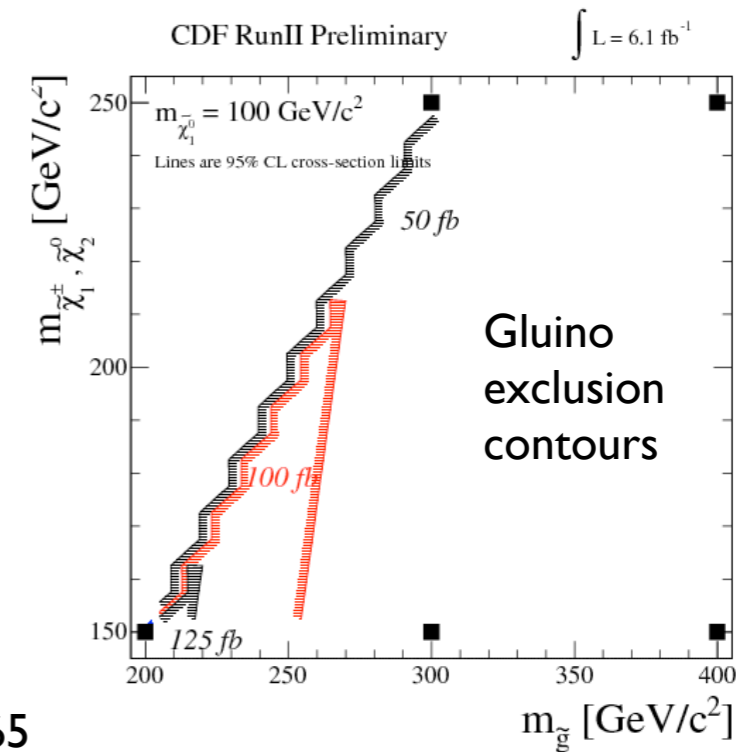
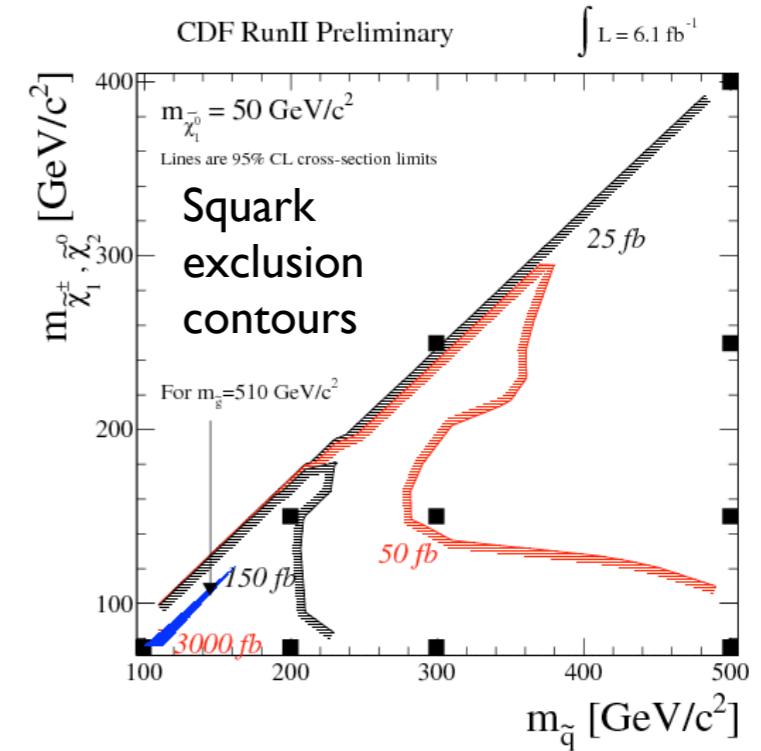
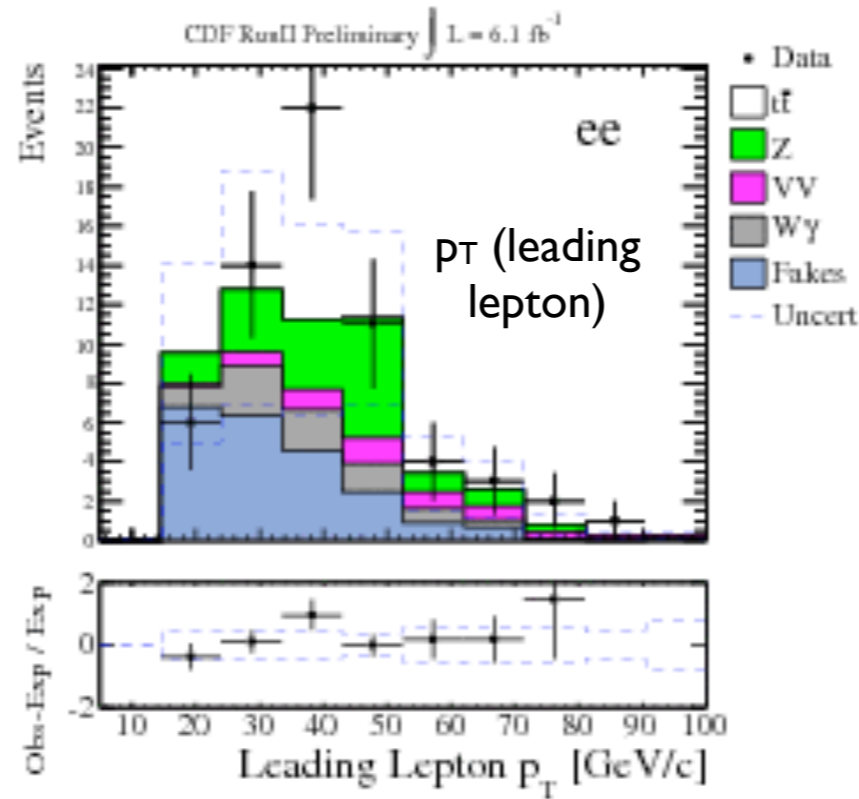
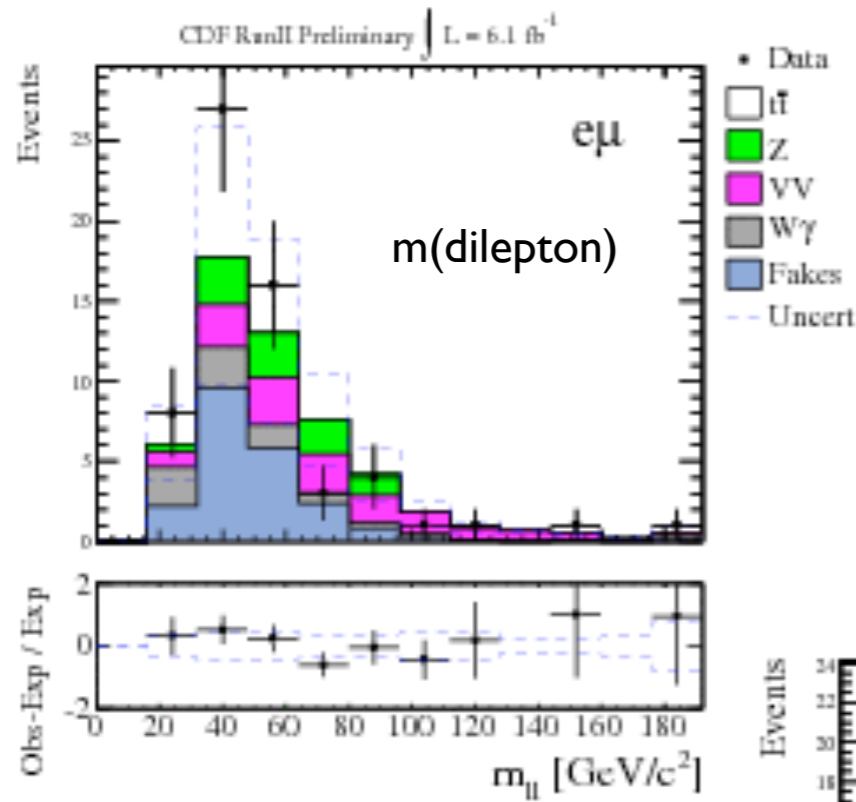
MET

TABLE I: Predicted and observed event yields in same-sign lepton events.

CDF RunII Preliminary $\int \mathcal{L} dt = 6.1 \text{ fb}^{-1}$				
Process	Total $\ell\ell$	$\mu\mu$	$ee$	$e\mu$
$t\bar{t}$	$0.1 \pm 0.0$	$0.0 \pm 0.0$	$0.0 \pm 0.0$	$0.1 \pm 0.0$
$Z \rightarrow ee$	$15.7 \pm 2.7$	$0.0 \pm 0.0$	$15.7 \pm 2.7$	$0.0 \pm 0.0$
$Z \rightarrow \mu\mu$	$8.7 \pm 2.0$	$0.0 \pm 0.0$	$0.0 \pm 0.0$	$8.7 \pm 2.0$
$Z \rightarrow \tau\tau$	$2.2 \pm 0.9$	$0.0 \pm 0.0$	$1.3 \pm 0.6$	$1.0 \pm 0.6$
$WZ$	$24.7 \pm 1.3$	$7.0 \pm 0.4$	$5.1 \pm 0.3$	$12.7 \pm 0.7$
$WW$	$0.2 \pm 0.1$	$0.0 \pm 0.0$	$0.1 \pm 0.1$	$0.1 \pm 0.0$
$ZZ$	$3.5 \pm 0.2$	$0.9 \pm 0.1$	$0.8 \pm 0.1$	$1.7 \pm 0.1$
$W(\rightarrow e\nu)\gamma$	$7.8 \pm 1.7$	$0.0 \pm 0.0$	$7.8 \pm 1.7$	$0.0 \pm 0.0$
$W(\rightarrow \mu\nu)\gamma$	$7.8 \pm 1.7$	$0.0 \pm 0.0$	$0.0 \pm 0.0$	$7.8 \pm 1.7$
$W(\rightarrow \tau\nu)\gamma$	$0.6 \pm 0.4$	$0.0 \pm 0.0$	$0.3 \pm 0.3$	$0.3 \pm 0.3$
Fakes	$51.6 \pm 24.2$	$8.2 \pm 5.3$	$22.1 \pm 8.9$	$21.3 \pm 10.6$
Total	$123.0 \pm 24.6$	$16.1 \pm 5.4$	$53.3 \pm 9.5$	$53.6 \pm 10.9$
Data	145	14	66	65

Event yields:

# Same-sign Dileptons II



5/13/2011, CDF public notes 10464 and 10465



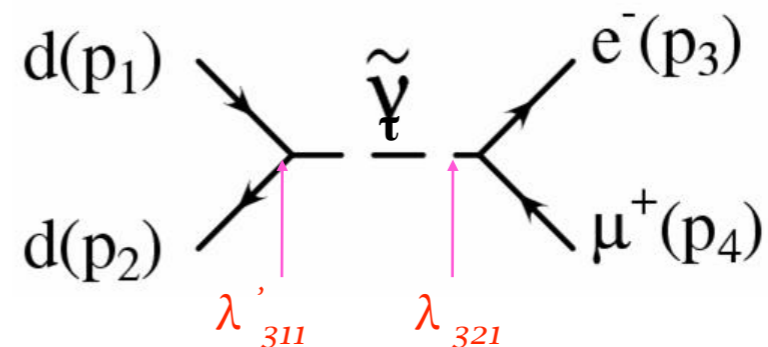
# R-parity violating decays

$\tilde{\nu}_\tau$  search:

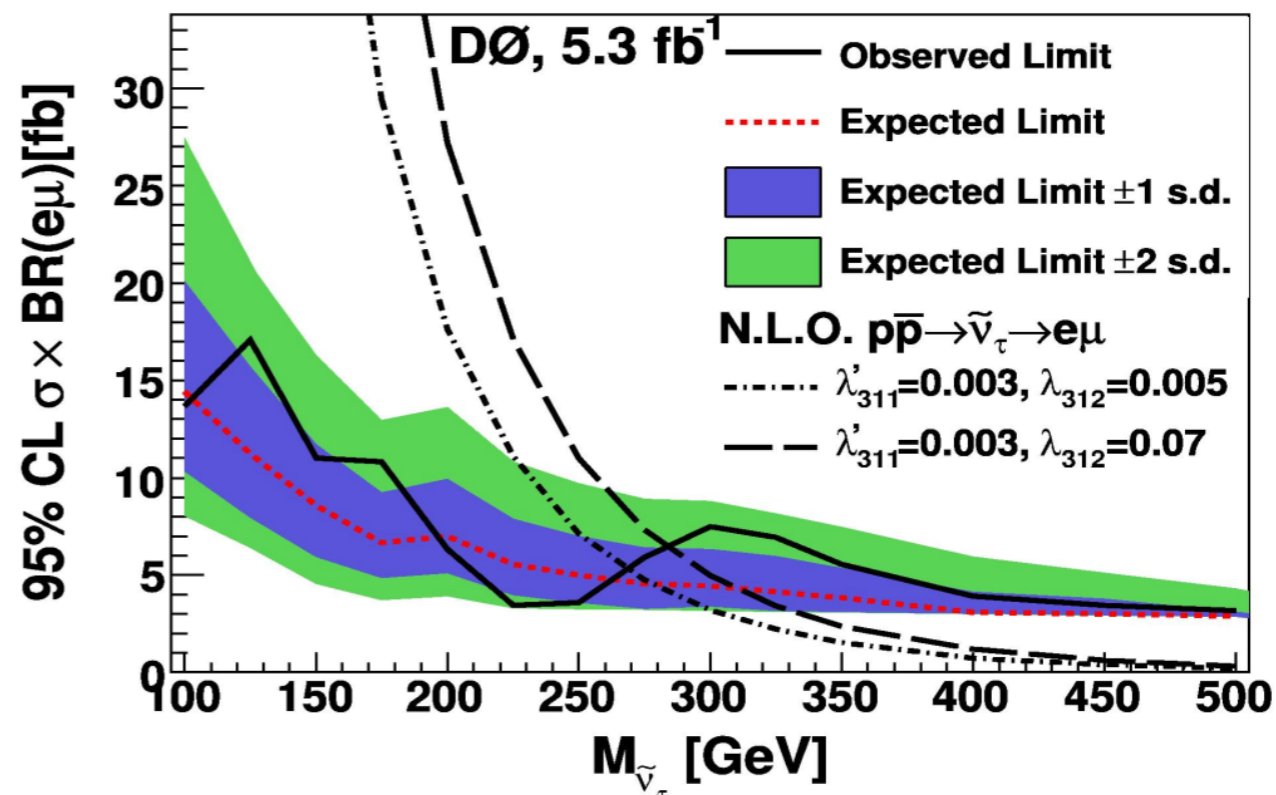
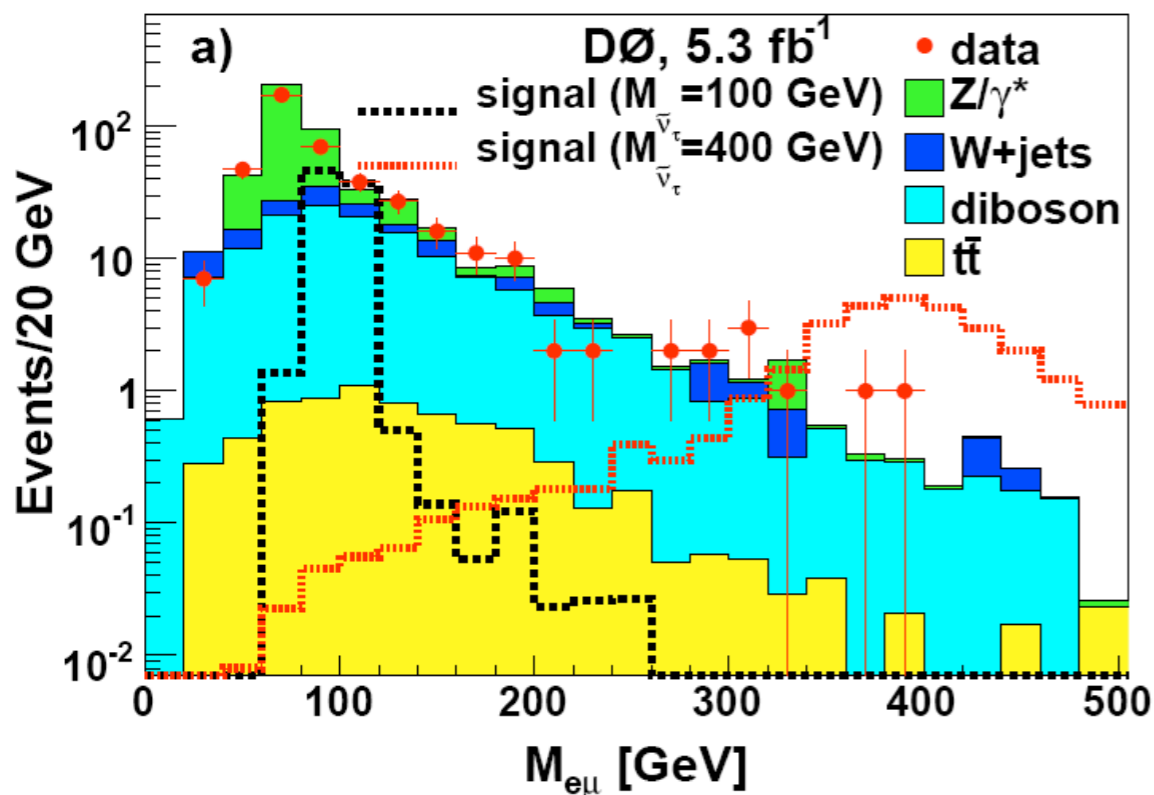
Isolated e and  $\mu$

No jets with  $P_T > 25$  GeV

414 candidate events,  $410 \pm 38$  expected



PRL 105 (2010) 191802





# gluinos: 3-jet resonance

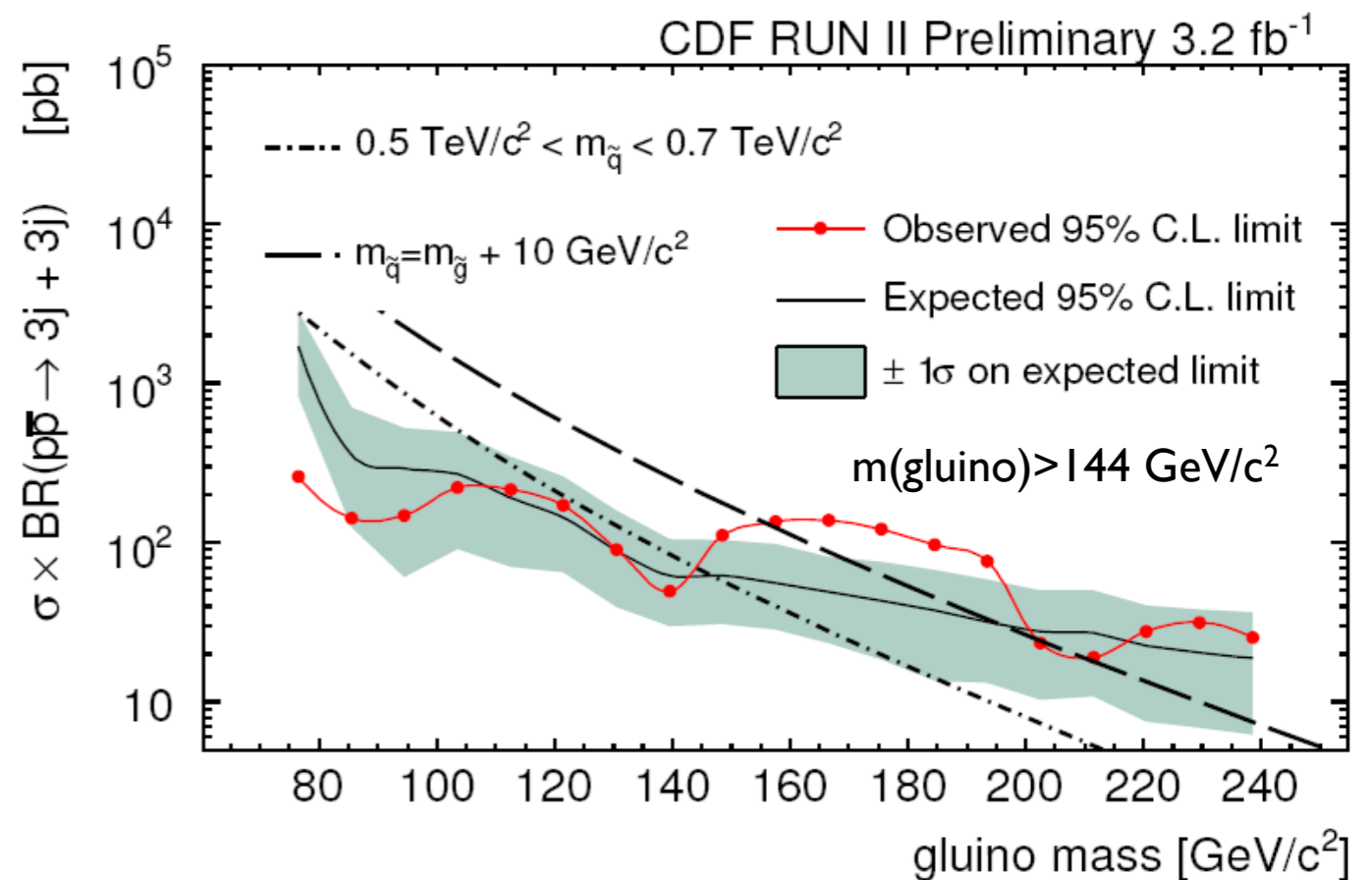
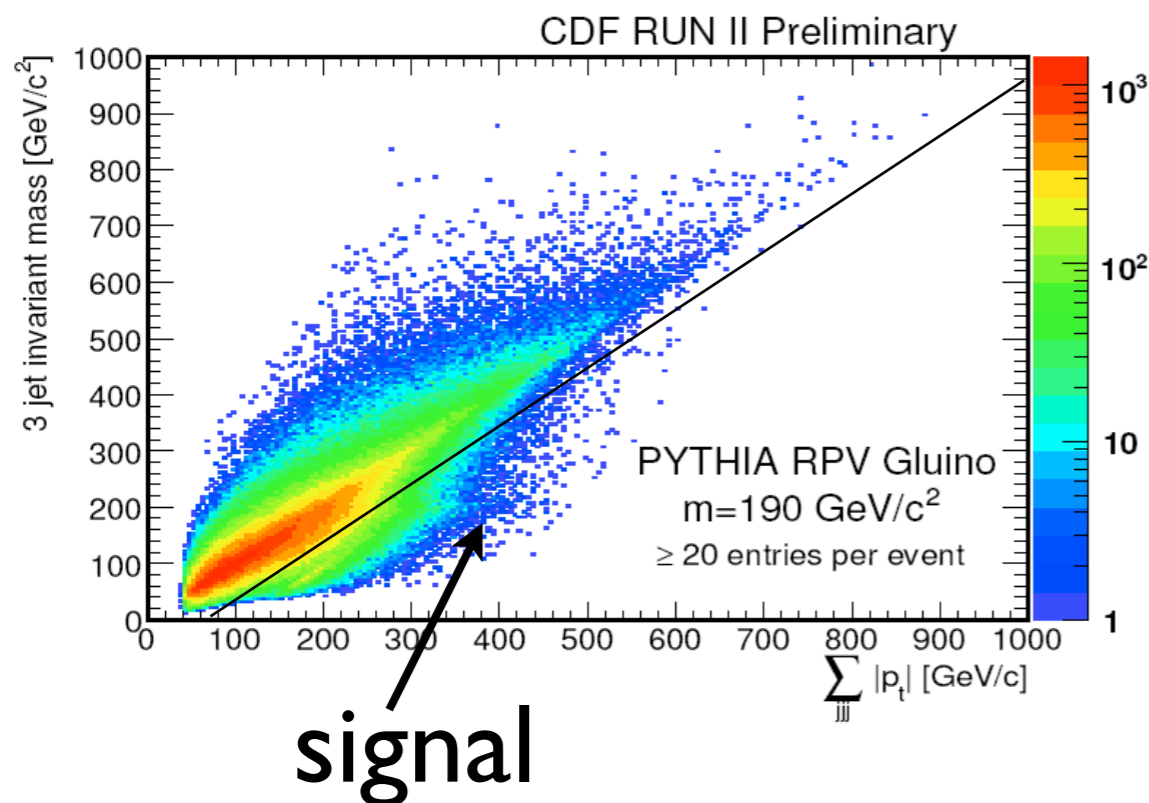
data:  $n(\text{jets}) \geq 6; \sum P_T(\text{jets}) > 250 \text{ GeV}$

Glino pairs  $\rightarrow$  3+3 jets, no MET

Diagonal cut  $\sum p_T > m_{3\text{jet}} + \text{offset}$  on all 3 jet mass combinations

Background shapes from 5-jet data (top mass window excluded)

2/5/2011, CDF public note 10256



# Summary

Improved analysis techniques & increased statistics yield new  $\bar{p}p$  limits for many supersymmetry searches

Updates presented here based on integrated luminosities up to 6.3/fb

11/fb delivered so far, with goal of 12/fb by end of Run II

Analysis web pages:

<http://www-cdf.fnal.gov/physics/exotic/exotic.html>

<http://www-d0.fnal.gov/Run2Physics/np/>

Hopefully it won't take the LHC another 30 years to find it!

# Backup Slides

# Future Plans

- Planned updates:
- CDF:
  - Same sign tau analysis - might add supersymmetry interpretation
- DZero:
  - Z+gamma+GMSB result (interpreted in a modified GMSB model) - currently in review.
  - Update to the massive stable particles (interpreted for stable staus, charginos, and stops) - in review.
  - Planned update for the trilepton search - hopefully this summer.

# Trilepton plots

CDF Run II Preliminary, 3.2 fb<sup>-1</sup>

