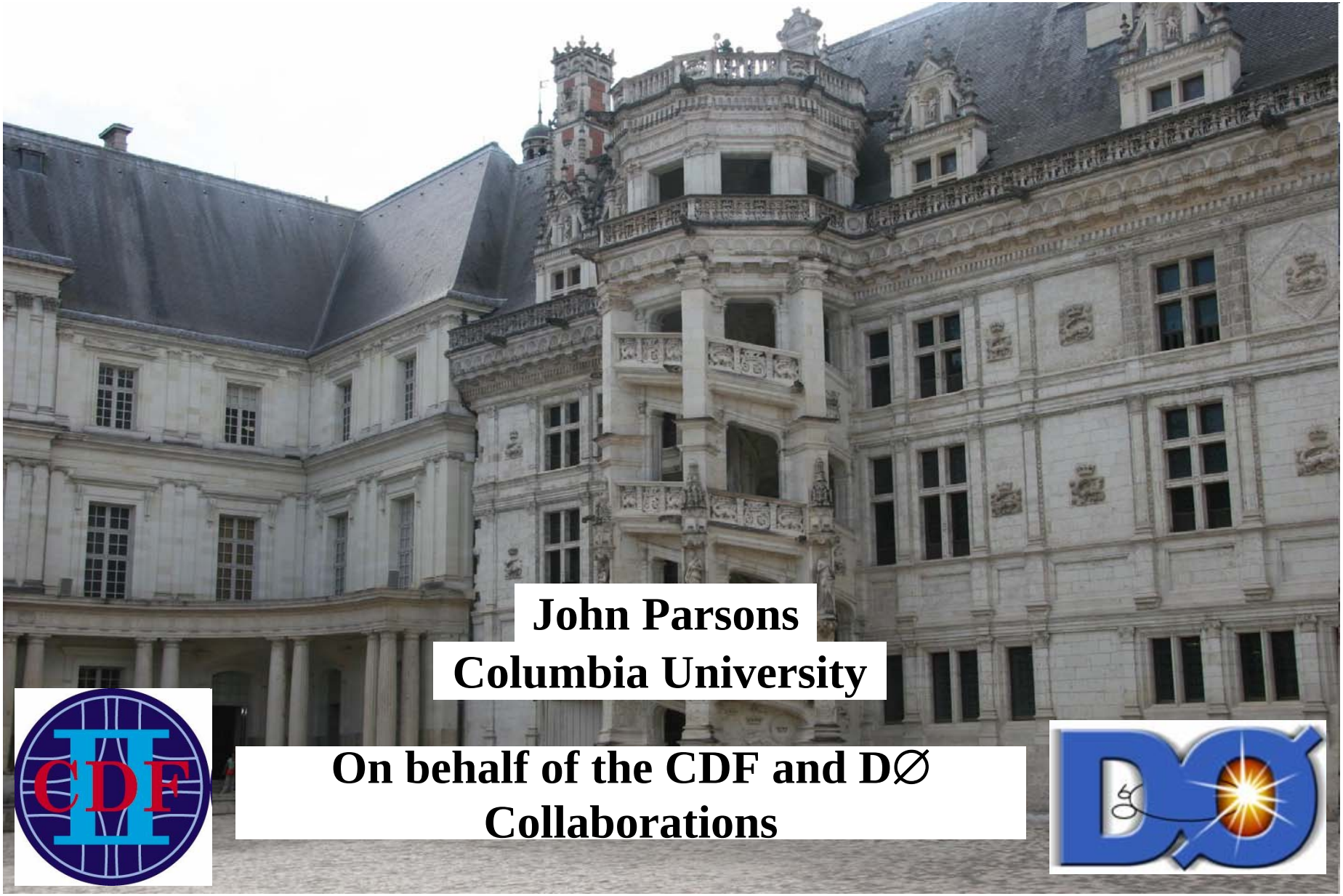
SUSY Searches at the Tevatron



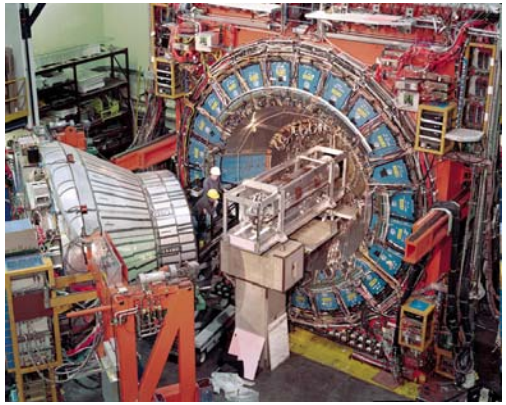
John Parsons

Columbia University

On behalf of the CDF and DØ Collaborations

22nd Rencontres de Blois, July 17/2010

Outline

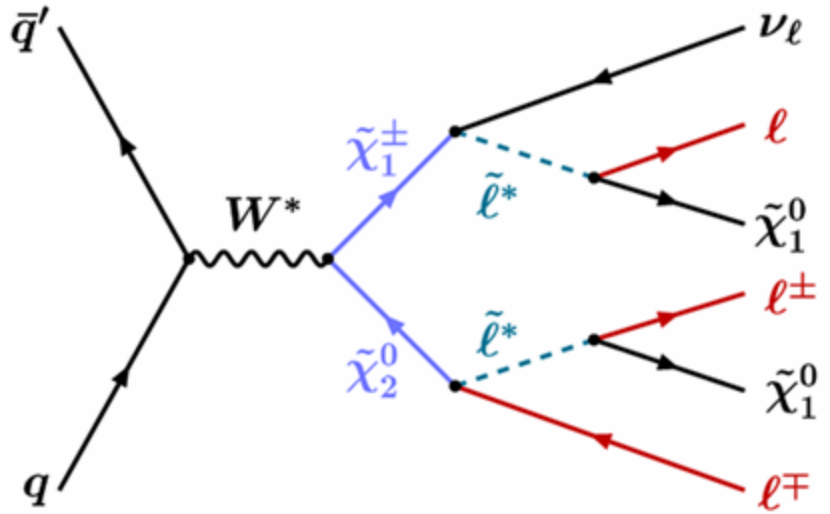


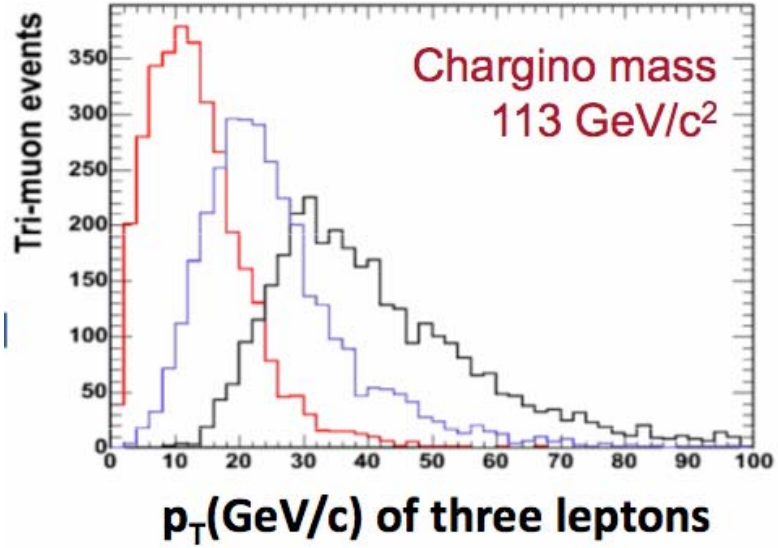
- Searches for gaugino pair production
  - Trileptons
  - GMSB in $\gamma\gamma$ + MET
- Searches for squark/gluino production
- 3rd generation squarks (sbottom, stop)
- RPV sneutrino production
- Hidden Valley SUSY
- Some indirect SUSY constraints
- Summary and outlook

Note: will focus on more recent results

SUSY in Trileptons

- **"Classic" signature of 3 isolated leptons + MET, with very little SM bkgnd**





- **Main experimental challenge is to achieve high efficiency for this low σ×BR process, particularly given the soft p_T spectrum of the third leading lepton**

Search strategies

CDF — 3.2 fb^{-1}
- 3 identified leptons (e,μ)
- 2 identified leptons + track (T)
- "Tight" and "loose" e,μ categories

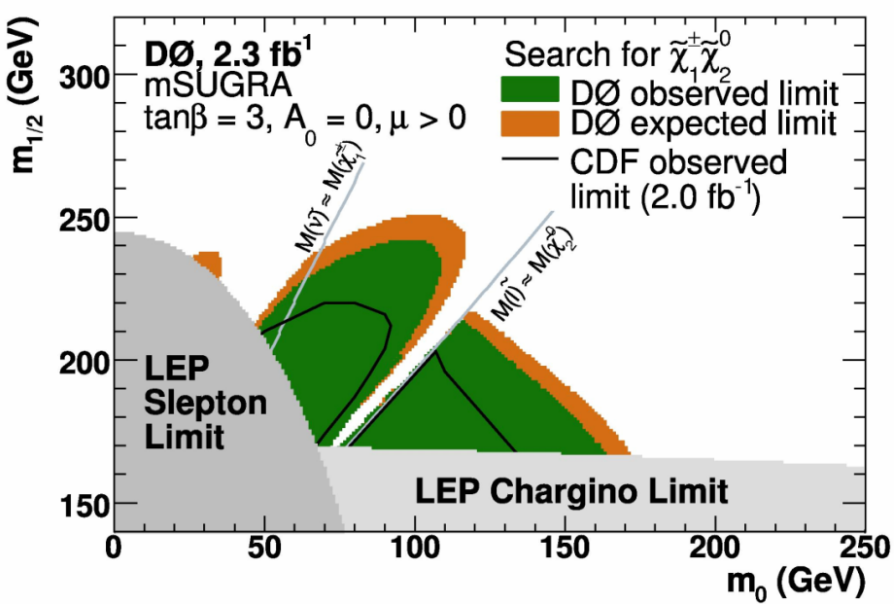
DØ — 2.3 fb^{-1}
- 2 identified leptons + track (T)
- μτ + T and μτ+τ (τ had decay)
- "low-p_T" and "high-p_T" searches

Trilepton Results

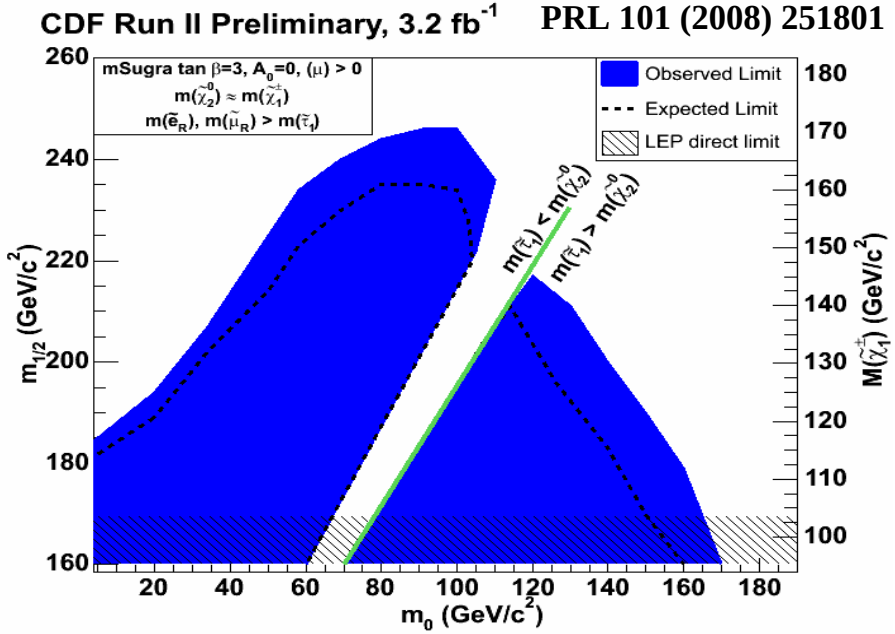
DØ (2.3 fb^{-1})			CDF (3.2 fb^{-1})		
Channel	SM expected	Data	Channel	SM expected	Data
Low p_T	5.4 ± 0.6	9	Trilepton	1.5 ± 0.2	1
High p_T	3.3 ± 0.4	4	Dilepton+trk	9.4 ± 1.4	6

- **Good agreement between data and SM background expectation**
  - **Set limits in common mSUGRA framework with tanβ=3, A0=0, μ>0**

DØ (2.3 fb^{-1}) [PLB 680 (2009) 34]

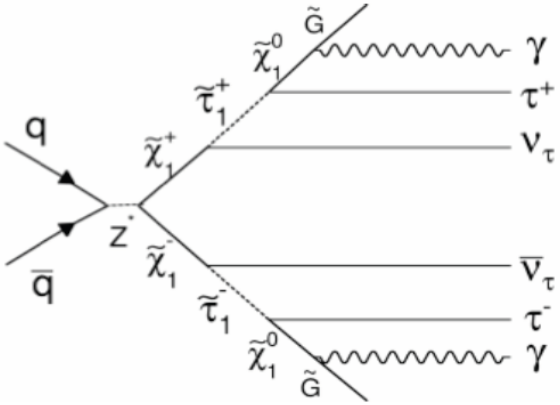


Update of 2.6 fb^{-1} result in PRL 101 (2008) 251801



GMSB in γγ + MET

- In GMSB, Gravitino is LSP and very light (~ keV)
- Gaugino pair (and some slepton pair) production, with cascade decays to NLSP
- If NLSP is neutralino, it decays via $\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$
  - Very small SM bkgnd (W/Z + γγ) in γγ + MET final state

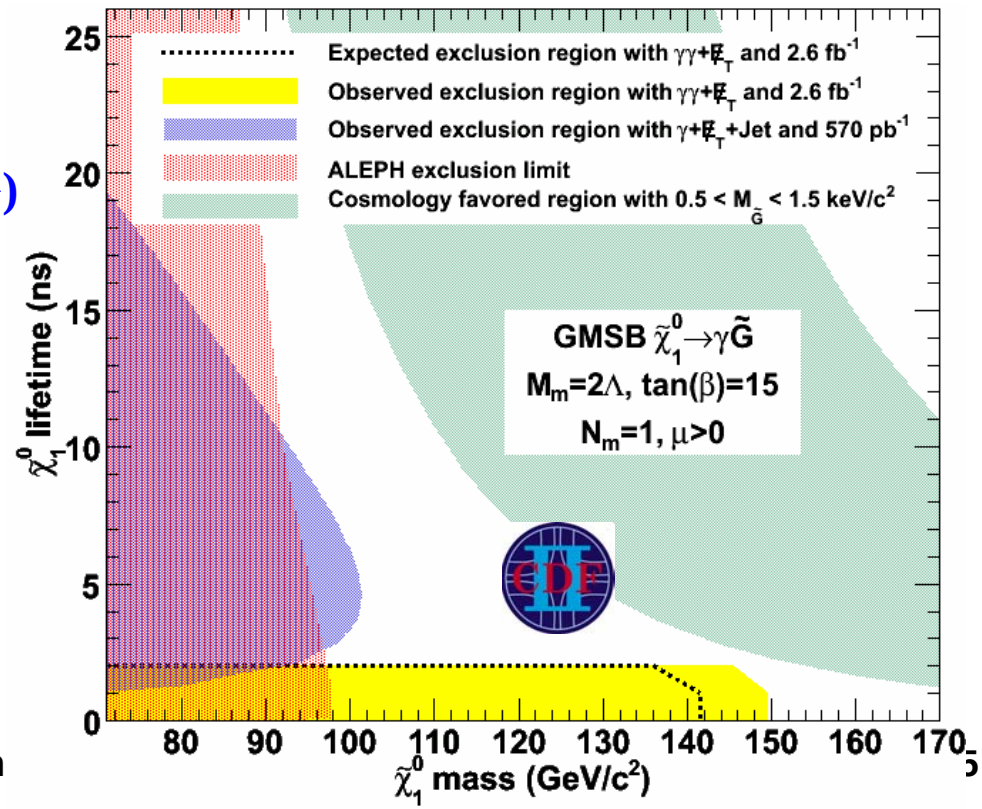


DØ (1.1 fb^{-1})

[PLB 659 (2008) 856]

CDF (2.6 fb^{-1})

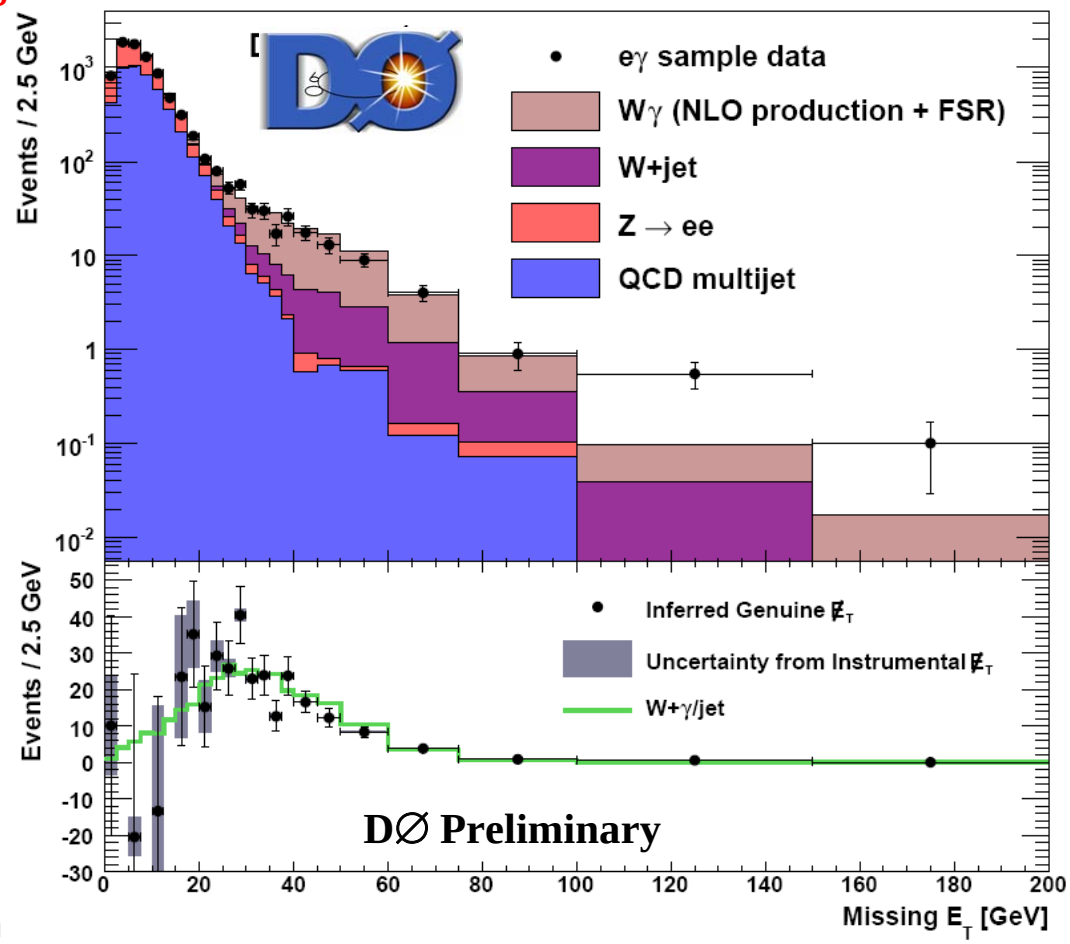
[PRL 104 (2010) 011801]



Brand New!

GMSB in γγ + MET (cont'd)

- **New DØ analysis (6.3 fb^{-1} !)**
  - **Instrumental bkgnds without real MET**
    - **SM γγ (shape modeled in data by ee), γ +jet, multijet (shapes from data)**
    - **Normalized in low MET region**
  - **Instrumental bkgnds with real MET**
    - **W+ γ, W+jet with e→γ misidentification**
    - **Measured in data using an e+γ control set**

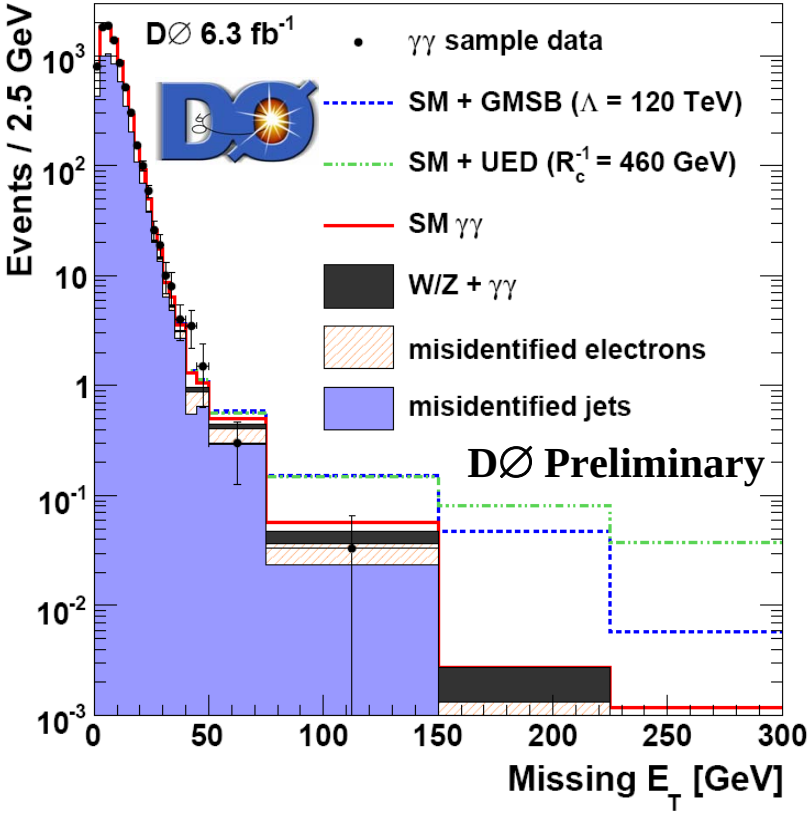


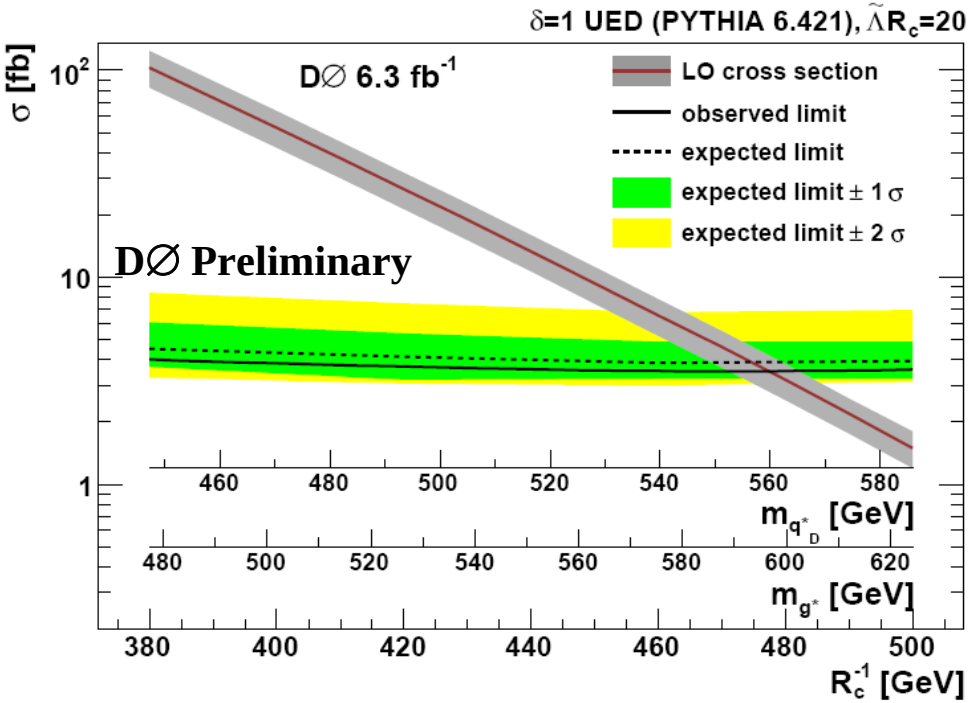
Brand New!

GMSB in γγ + MET (cont'd)

- **New DØ analysis (6.3 fb^{-1} !)**
  - **Use MC to model (small) SM bkgnd (W/Z + γγ)**
  - **No excess seen at high MET ⇒ limits on GMSB**

$M(\chi_1^0)$ > 175 GeV (DØ) [6.3 fb-1]
> 149 GeV (CDF) [2.6 fb-1]

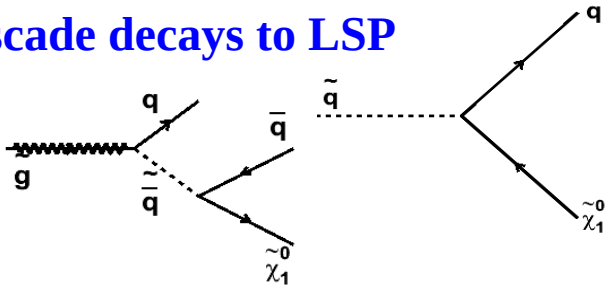




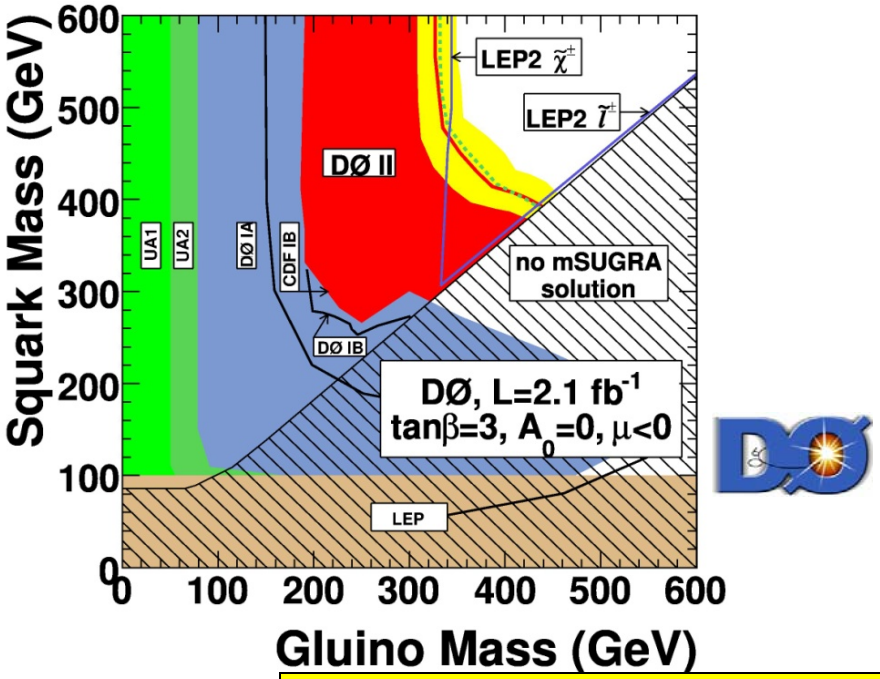
- **DØ result also interpreted to set first limits on UED model with gravity-mediated KK-parity violating decay γ* → γ G**
  - **R_c^{-1} > 477 GeV**

Squark/gluino production

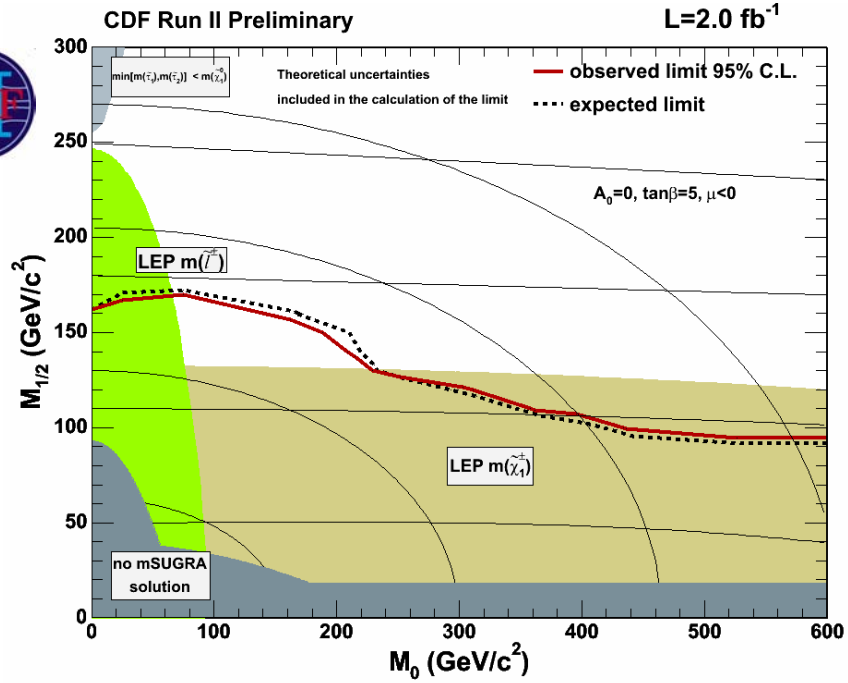
- **Pair production via strong interaction, followed by cascade decays to LSP**
  - **Final state is multijets + MET**
  - **Searches performed separately in 2j ($\tilde{q}\tilde{q}$), ≥3j ($\tilde{q}\tilde{g}$), ≥4j ($\tilde{g}\tilde{g}$) final states**



DØ (2.1 fb^{-1}) [PLB 660 (2008) 449]



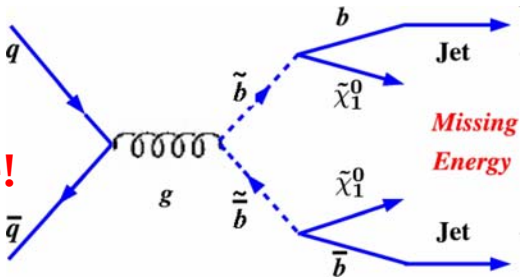
CDF (2.0 fb^{-1}) [PRL 102 (2009) 121801]



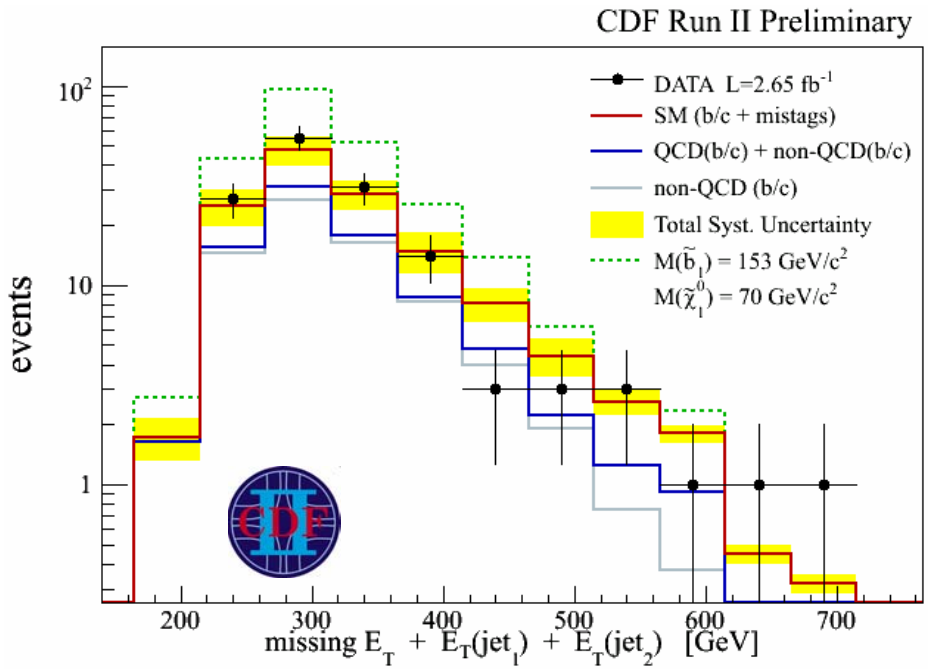
M(squark)	> 379 GeV (DØ)	> 392 GeV (CDF)
M(gluino)	> 308 GeV (DØ)	> 280 GeV (CDF)

Sbottom production

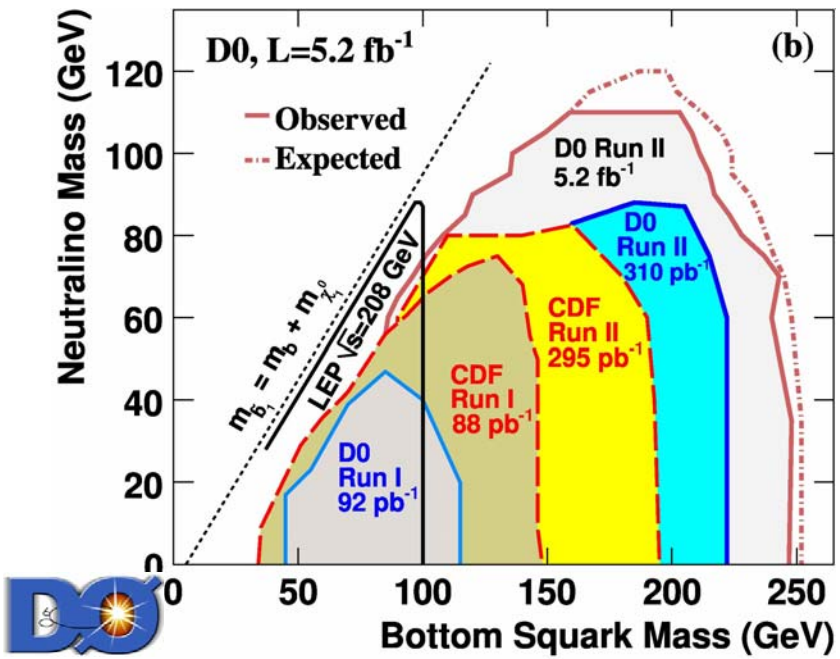
- **Due to mixing in 3rd generation, $\tilde{b}_1$ could be light**
  - **Consider parameter space with decay $\tilde{b}_1 \rightarrow b\chi_1^0$**
  - **Signal yields 2 bjets + MET ⇒ challenging final state!**



CDF (2.65 fb^{-1}) [arXiv: 1005.3600]



DØ (5.2 fb^{-1}) [arXiv: 1005:2222]



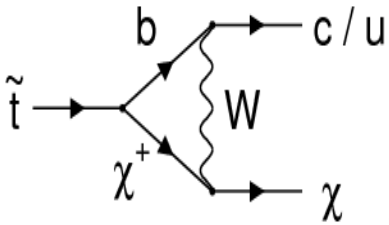
M(sbottom) > 247 GeV for massless neutralino (DØ)
M(sbottom) > 230 GeV for m(neutralino) in [40,80] (CDF)

Reinterpretation as 3rd LQ search – see Eva's talk next

Stop searches

- **Due to mixing in 3rd generation, $\tilde{t}_1$ could be light**
  - **Stop decay (ie. final state) depends on mass hierarchies**

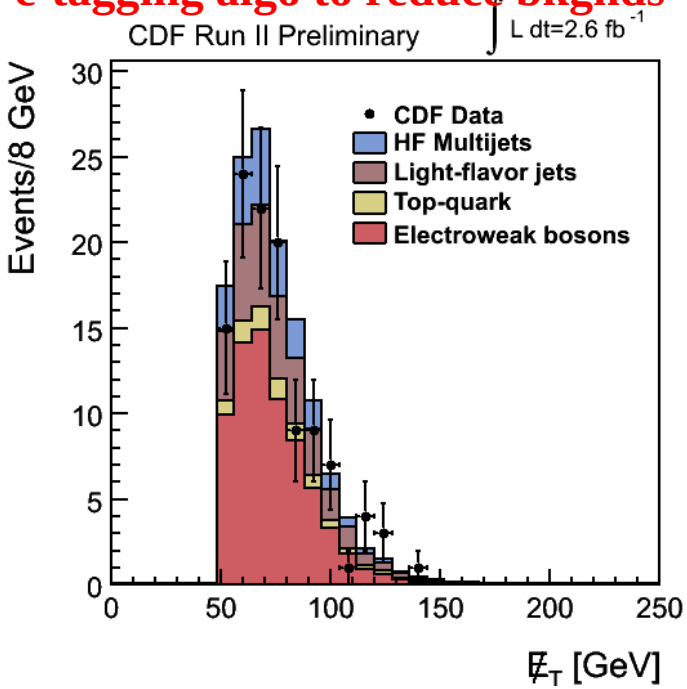
(1) $\tilde{t}_1 \rightarrow c\,\tilde{\chi}_1^0$

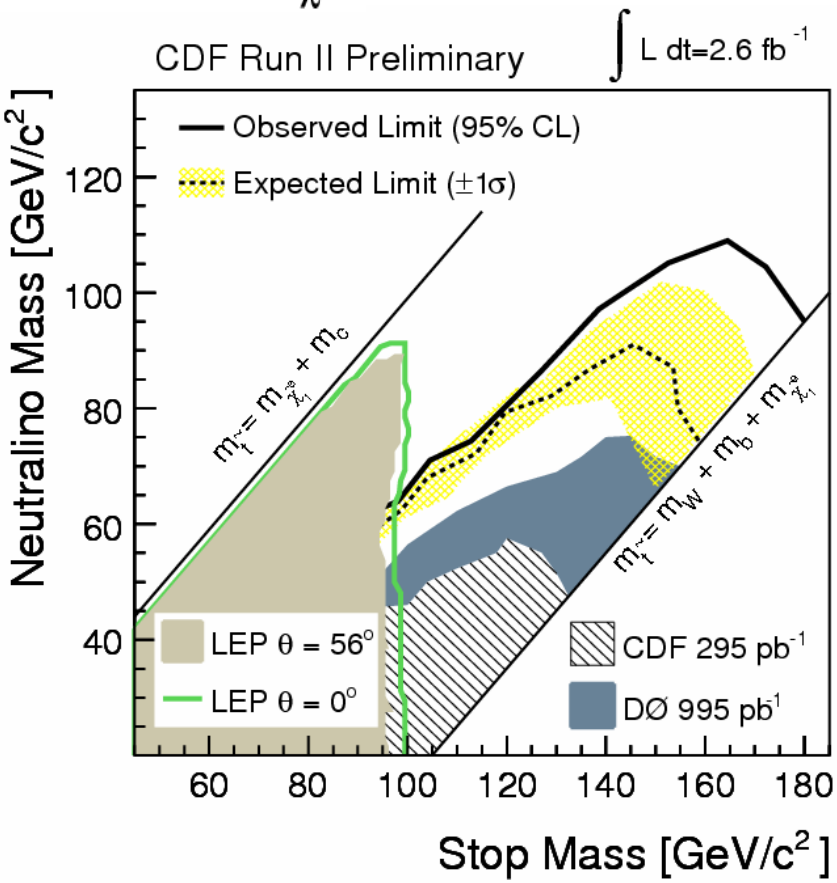


  - **Final state is 2 charm jets + MET**

DØ (1 fb^{-1}) **[PLB 665 (2008) 1]**
CDF (2.6 fb^{-1})

- **c-tagging algo to reduce bkgnds**





J. Parsons, SUSY Searches at the Tevatron, BLOIS'10,

Stop searches (cont'd)

(2) 2-body $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm} \to b\tilde{\chi}_1^0 W^{\pm(*)} \to b\tilde{\chi}_1^0 l\nu$ **or (3) 3-body decay** $\tilde{t}_1 \to bl\tilde{\nu}$

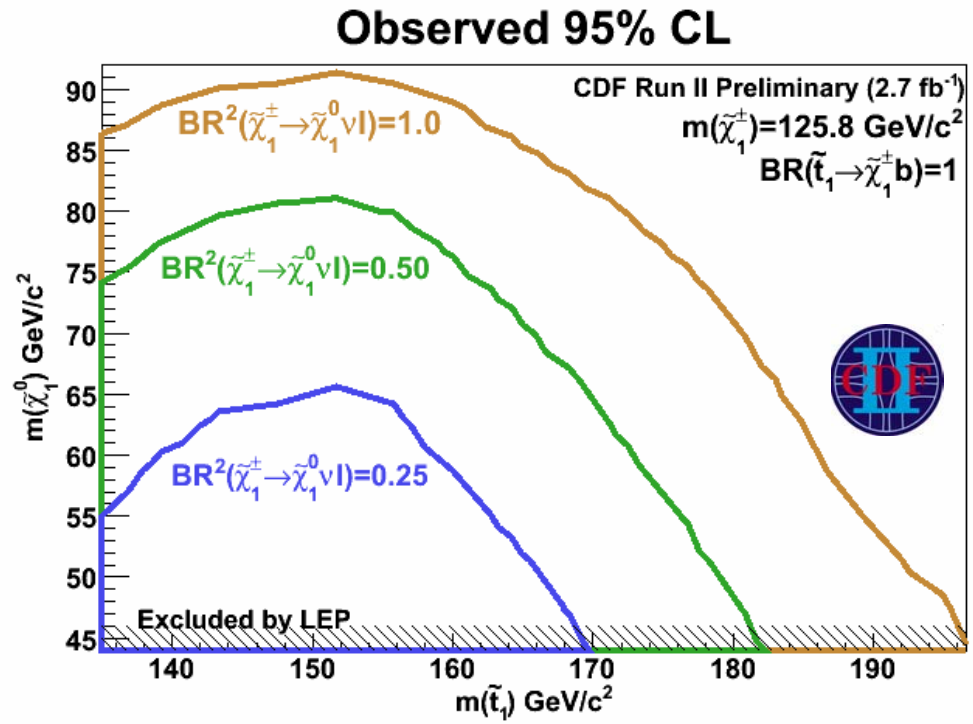
- **Final state dilepton + bjets + MET (ie. very similar to t tbar)**

DØ (0.9 fb^{-1}) **[PLB 674 (2009) 4]**

CDF (1 fb^{-1})

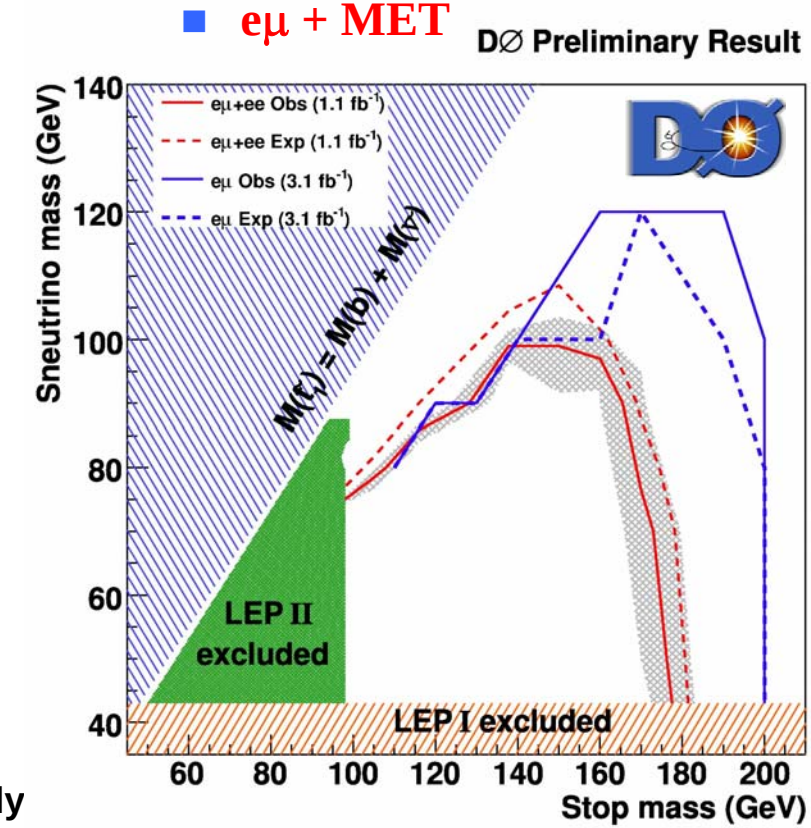
CDF (2.7 fb^{-1}) **[PRL 104 (2010) 251801]**

- **Reconstruct m(stop) via kinematic fit**



DØ (3.1 fb^{-1})

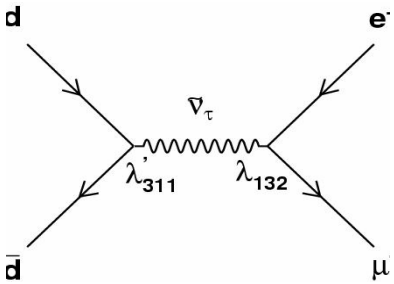
- **eμ + MET**



J. Parsons, SUSY Searches at the Tevatron, BLOIS'10, July

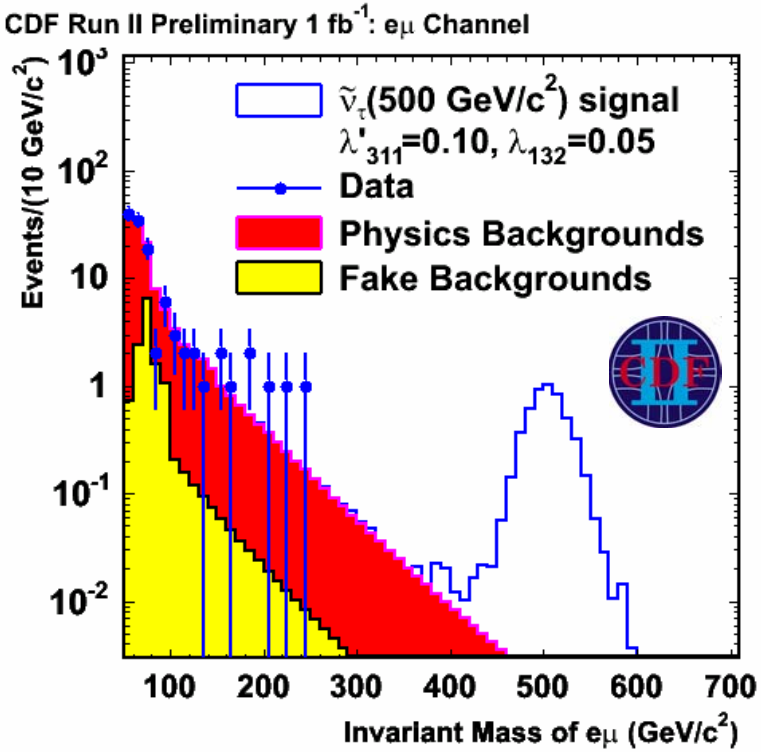
Sneutrino Search (with R-Parity Violation)

- In case of RPV, can produce single sparticles
- Consider resonant tau sneutrino production, with dilepton decay
  - Search for peak in dilepton invariant mass distribution



CDF (1.1 fb^{-1}) [arXiv: 1004.3043]

- e+mu, e+tau, mu+tau

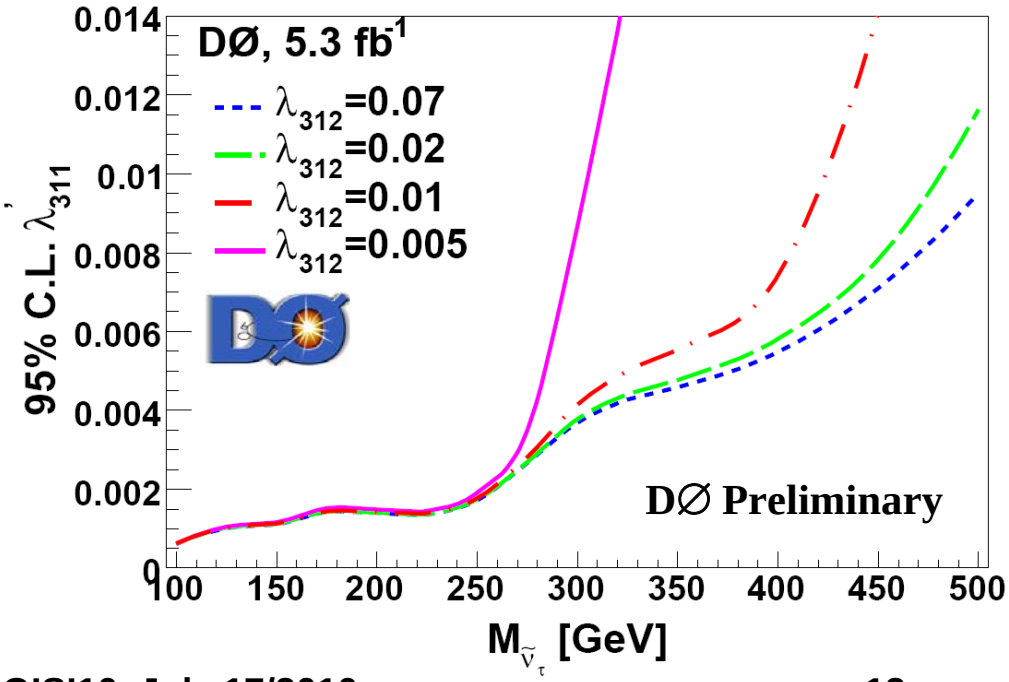


New!

DØ (5.3 fb^{-1})

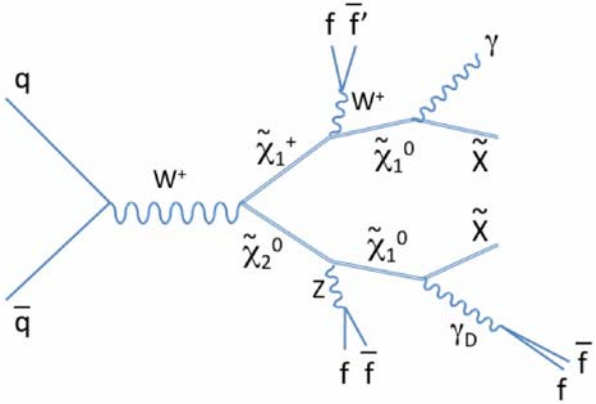
[update of PRL 100 (2008) 241803]

- e+mu



Hidden Valley SUSY

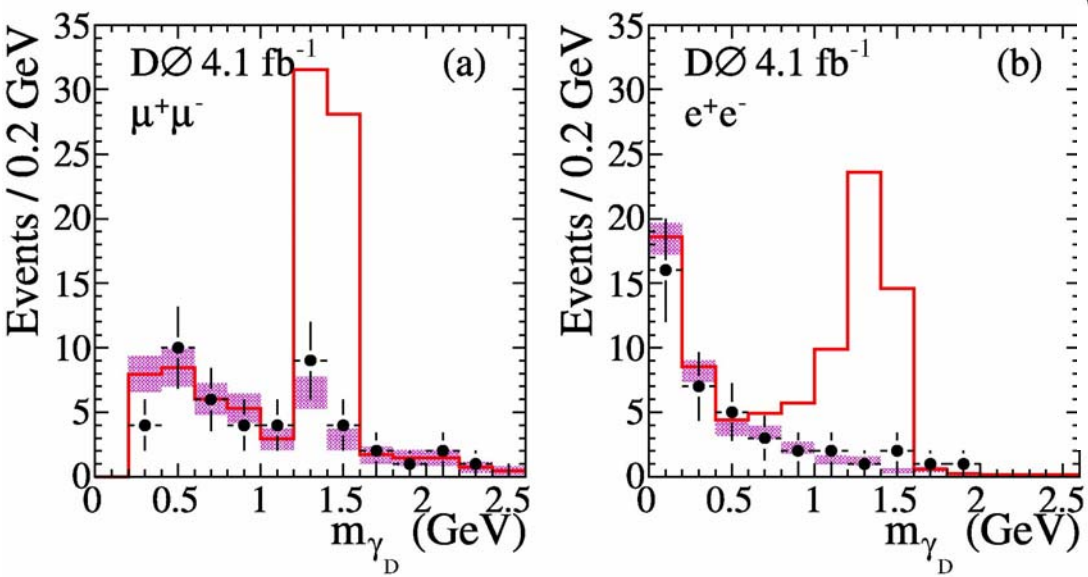
- Gaugino pair production, with cascade decays to SUSY LSP (neutralino)
- LSP decays to hidden sector
  - photon + dark LSP ($\tilde{X}$)
  - dark photon (γ_D) + dark LSP ($\tilde{X}$)
- γ_D decays to SM fermion pair, while $\tilde{X}$ escapes

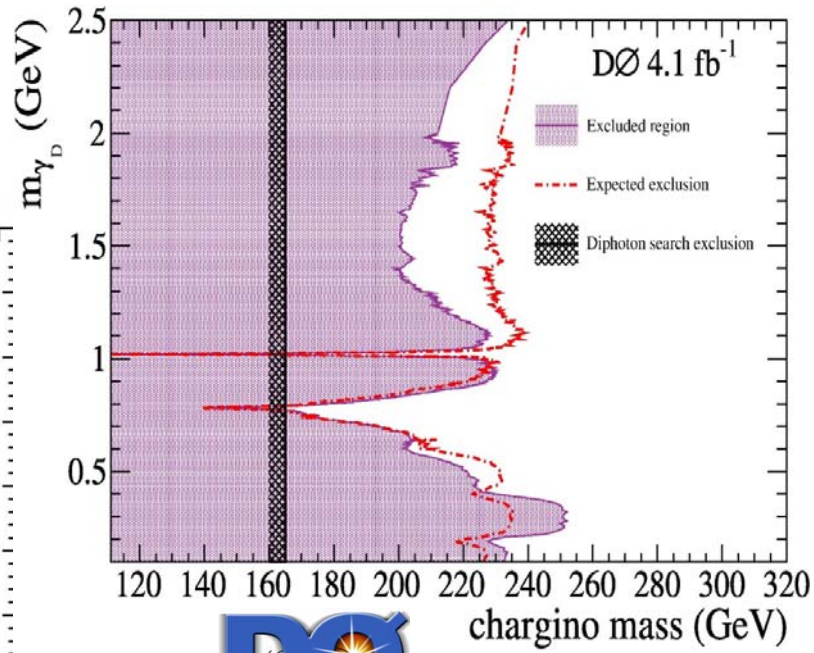


DØ (4.1 fb^{-1})

[PRL 103 (2009) 081802]

- Search for evts with γ +MET plus $\gamma_D \rightarrow ee/\mu\mu$

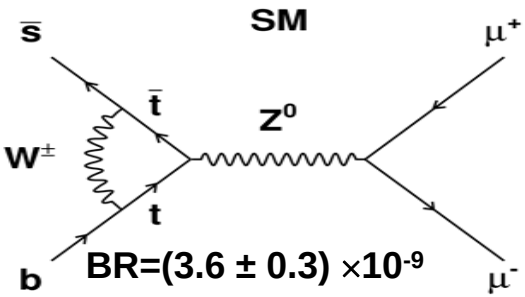




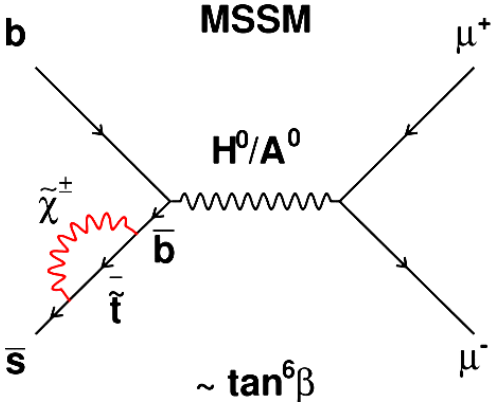
Examples of Indirect SUSY Constraints

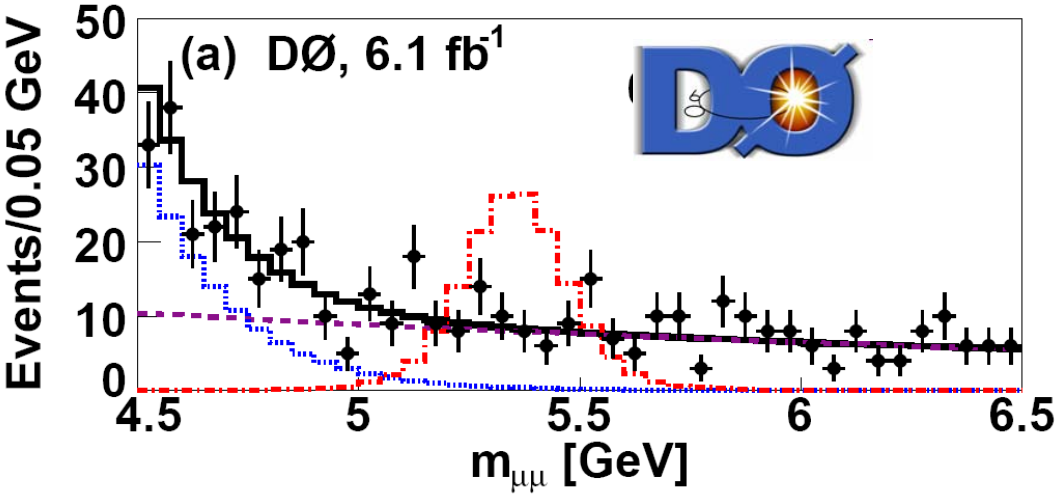
1. **Anomalous like-sign dimuon charge asymmetry**
   - **DØ (6.1 fb^{-1}): 3.2σ deviation from SM prediction**
     [arXiv: 1005.2757; accepted by PRD]
   - **For details, see earlier talks in Heavy Flavour session**

2. **$B_s \rightarrow \mu\mu$**
   - **CDF (Prelim, 3.7 fb^{-1})**
     - **BR < 4.3 X 10^{-8}**
   - **DØ (6.1 fb^{-1}) [arXiv: 1006.3469]**
     - **BR < 5.1 X 10^{-8}**



Prog. Theor. Phys. 122 (2009) 145





Summary and Outlook

- **CDF and D∅ have searched for SUSY in a variety of final states and signatures**
  - **Most recent analyses utilize > 3 fb^{-1} (even up to 6.3 fb^{-1} !)**
  - **So far, no evidence for SUSY observed, and limits set on a variety of SUSY models**

- **Tevatron has (as of last week) delivered 9 fb^{-1}/experiment in Run II, and is going strong!**
  - **Has achieved instantaneous luminosities as high as 4E32**
  - **It took only 119 days to deliver the last 1 fb^{-1} !!**

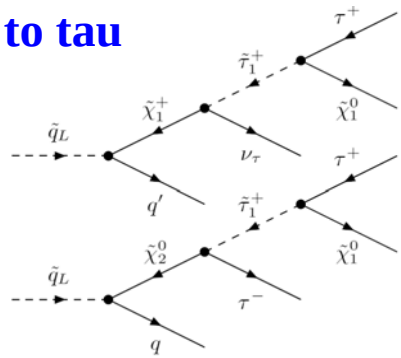
- **Tevatron is currently approved to run through fall 2011**
  - **Expect ~12 fb^{-1} delivered/experiment through 2011**
  - **Detectors are very well understood**

- **Analyses are being updated (and new ones thought of!) as data continues to be accumulated**
  - **Should expect continued significant expansion in Tevatron potential to discover (and/or limit) SUSY**

Backup Slides

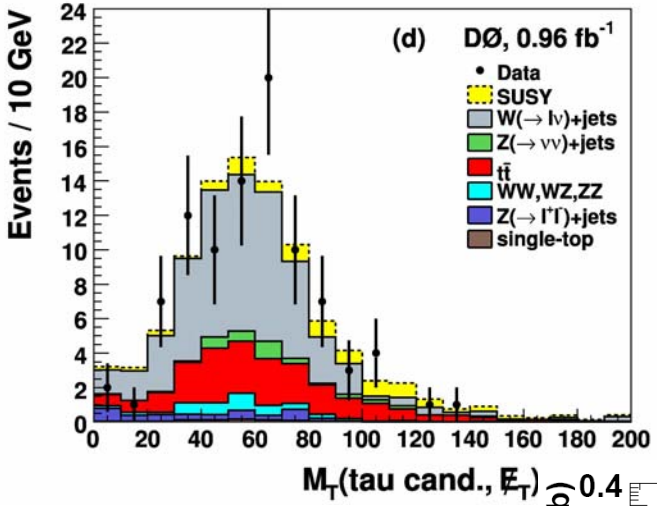
Squarks in jets+tau+MET

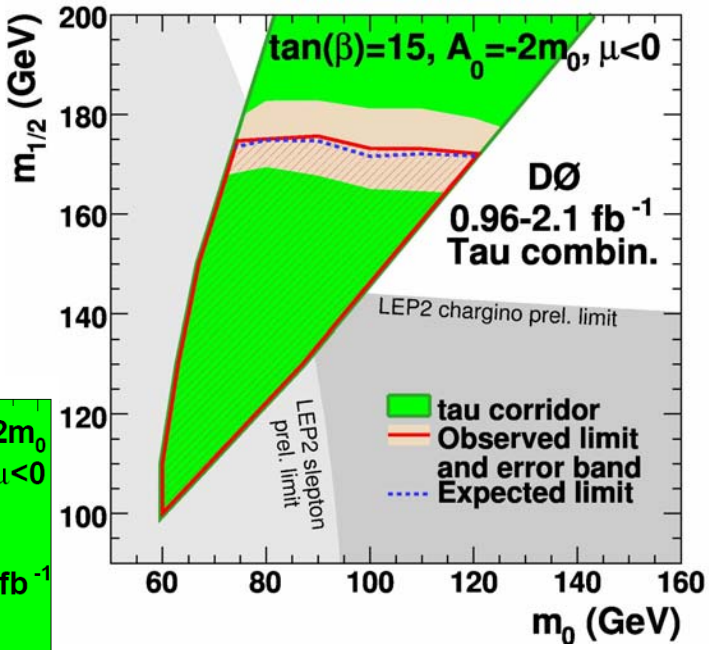
- In "tau corridor", chargino/neutralino decays through stau to tau
  - Final state is jets + tau + MET

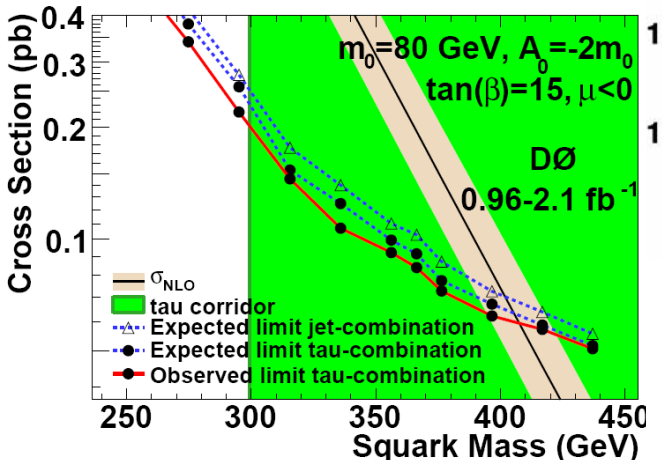


DØ (2.1 fb^{-1}) [PLB 680 (2009) 24]

- Search with hadronic tau decay



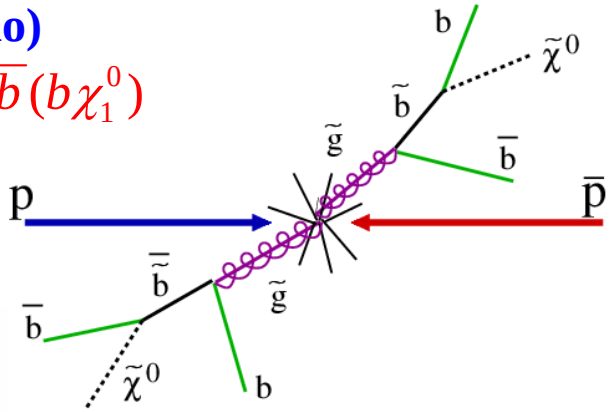




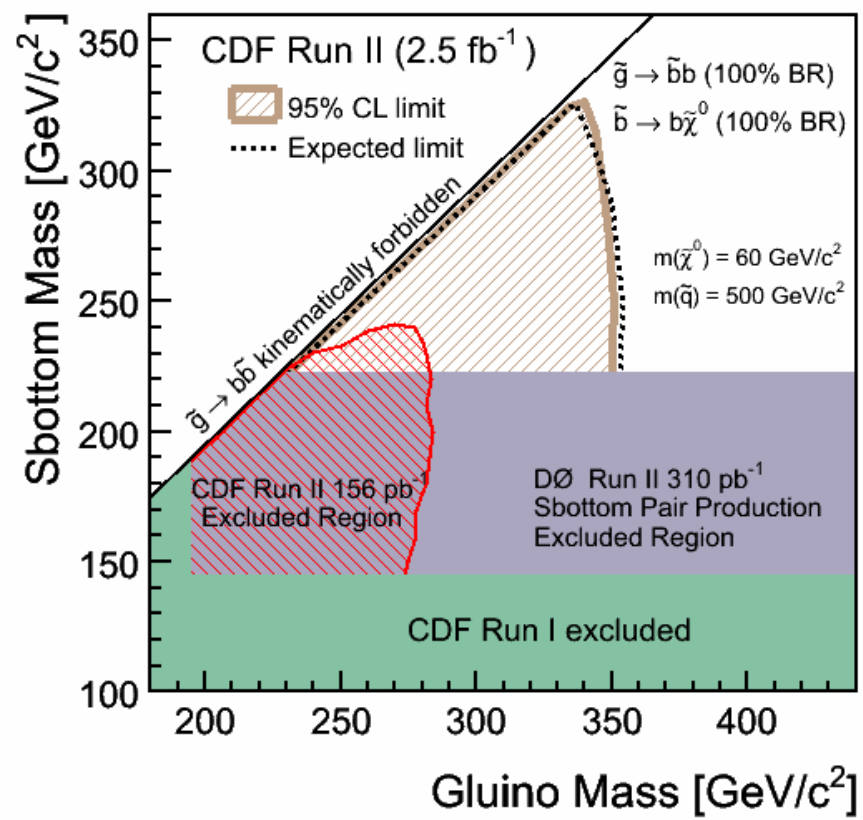
Can combine with jet+MET to improve its sensitivity

Gluino-mediated sbottom production

- **Consider parameter space with m(sbottom) < m(gluino)**
  - **Gluino-pair production, followed by** $\tilde{g} \to \bar{b}\tilde{b}_1 \to \bar{b}(b\chi_1^0)$
  - **Final state is 4 bjets + MET**

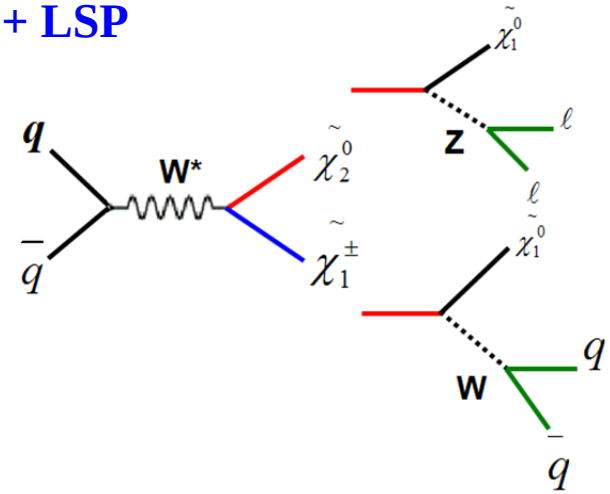


CDF (2.5 fb^{-1}) **[PRL 102 (2009) 221801]**



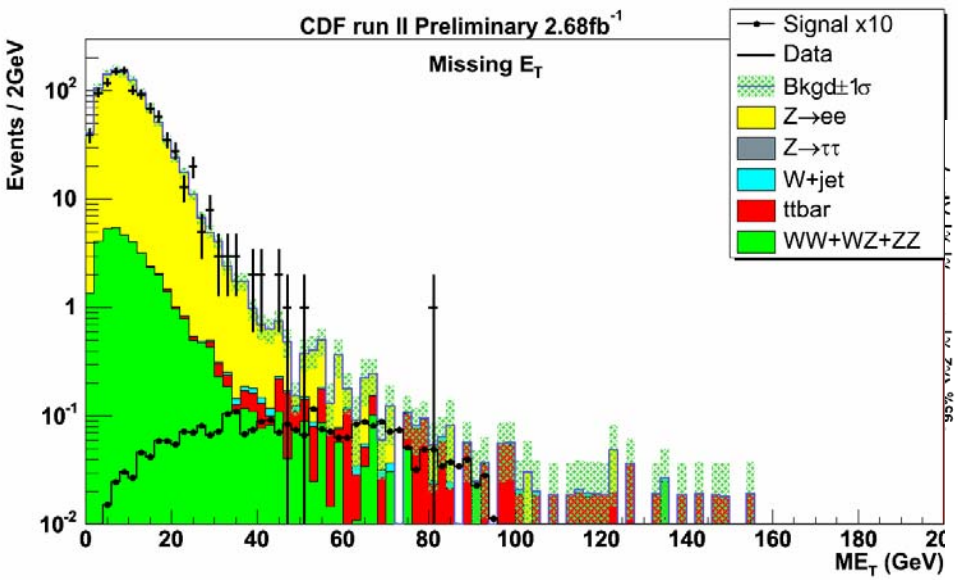
Search for heavy chargino/neutralino

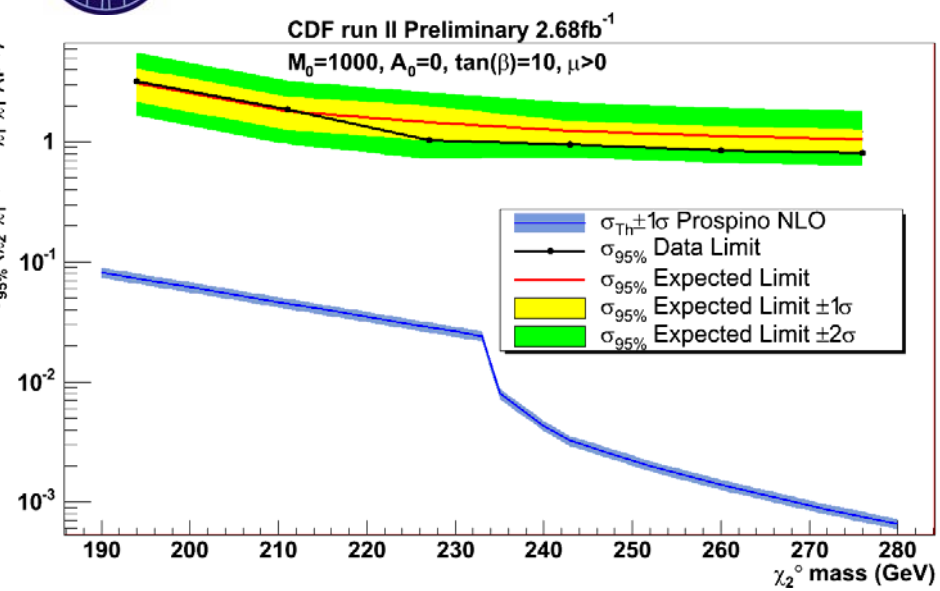
- **Consider heavy chargino/neutralino decays to W/Z + LSP**
  - **Final state is WZ + MET [(jj)(ll) + MET]**



CDF (2.68 fb^{-1})

- **jj + ee + MET**
- **make W, Z mass cuts**



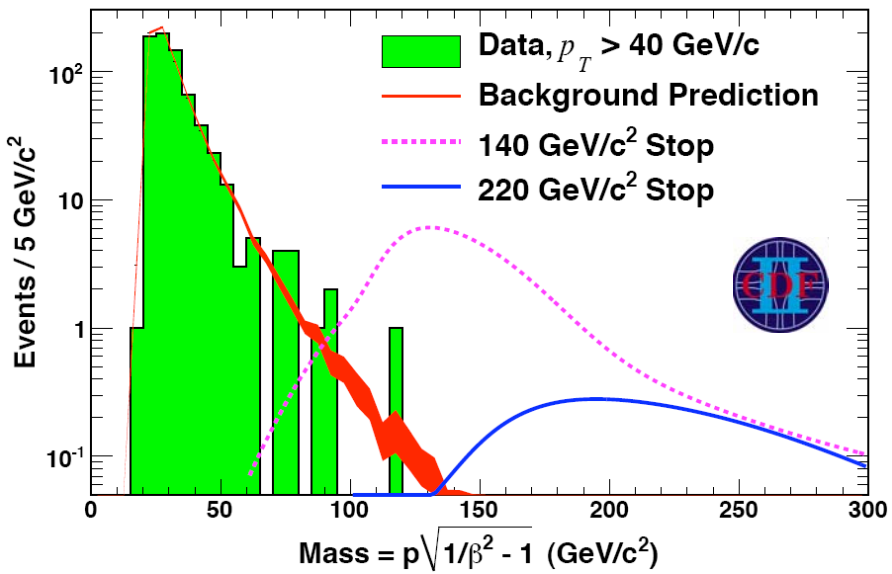


Charged massive long-lived particles

- **Various SUSY variants predict the existence of long-lived charged particles**
  - **Look like highly-ionizing "slow muons" in the detectors**
  - **Use time-of-flight information to determine mass**

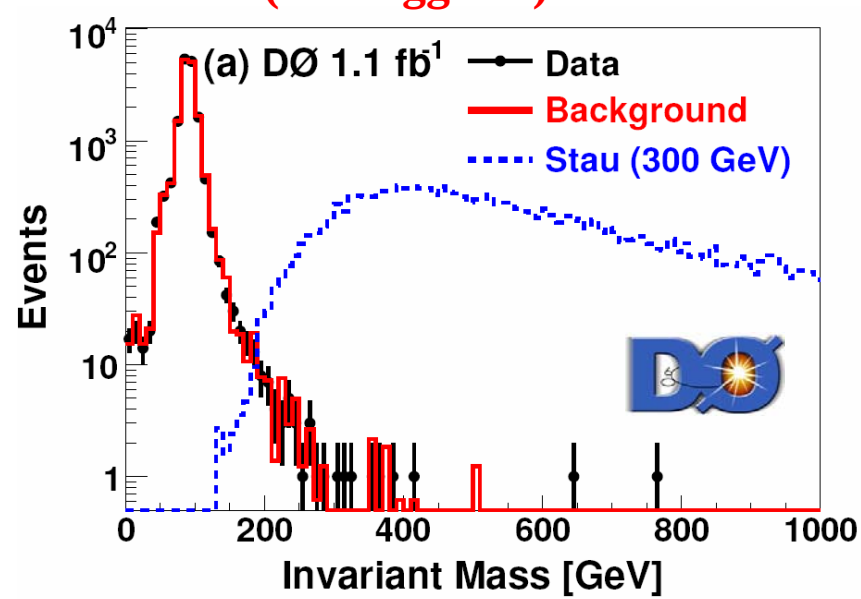
CDF (1.0 fb^{-1}) **[PRL 103 (2009) 021802]**

- **1 trk with m>100 GeV, consistent with bkgnd estimate of 1.9 ± 0.2**
- **Interpret as limit of m(stop)>249 GeV**

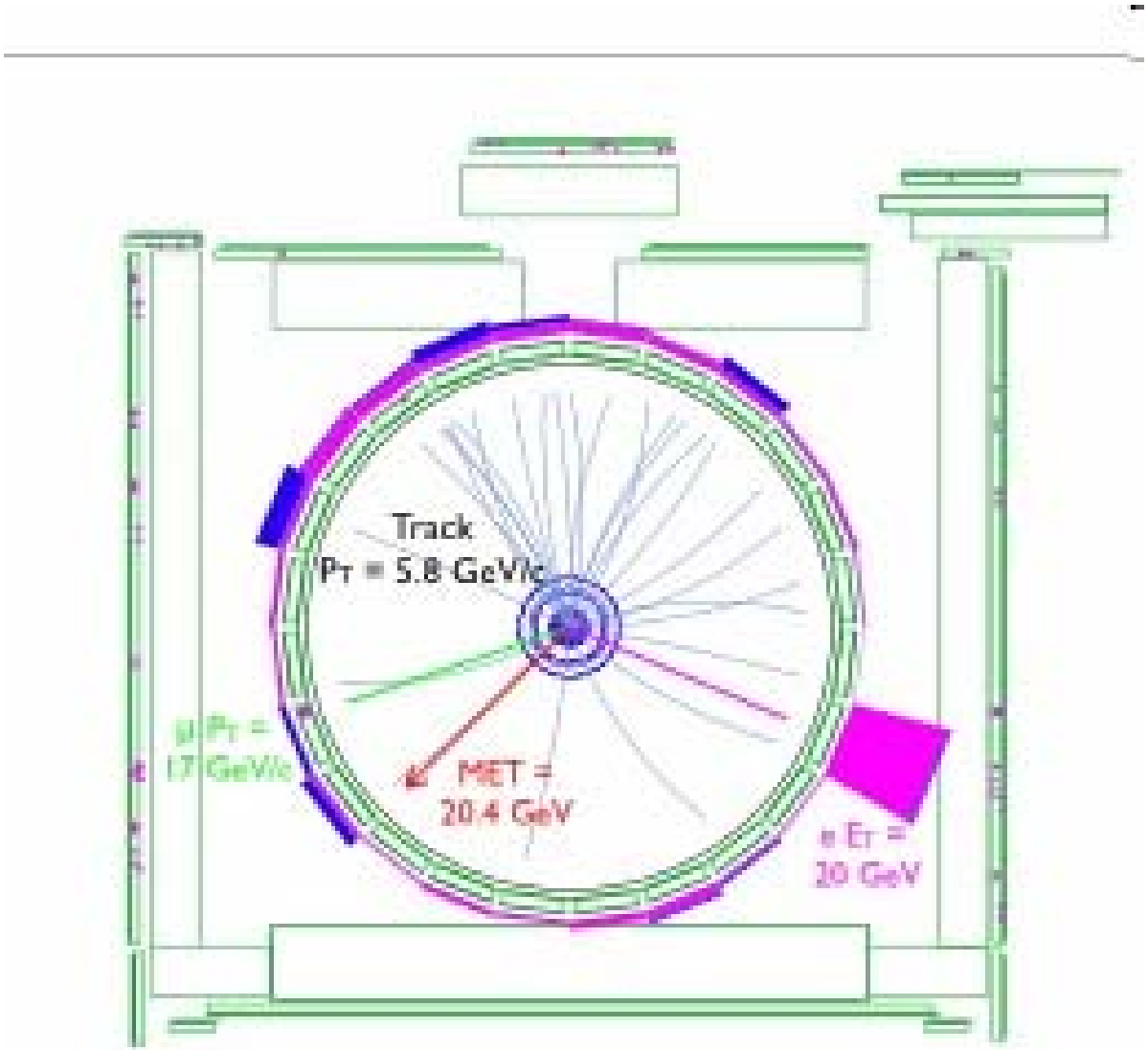


DØ (1.1 fb^{-1}) **[PRL 102 (2009) 161802]**

- **Interpret as limits on stable stau production, or on**
  m(chargino) > 206 GeV
  m(ch. Higgsino) > 171 GeV

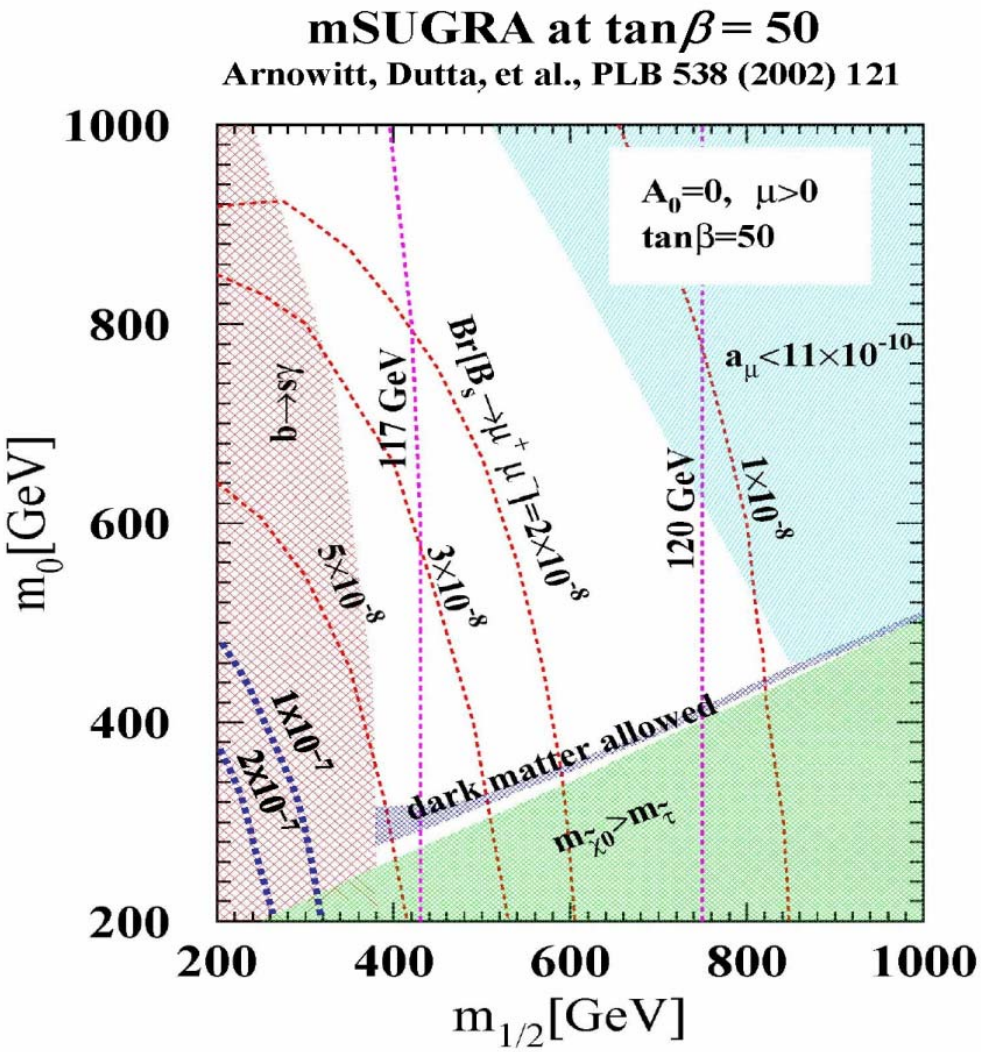


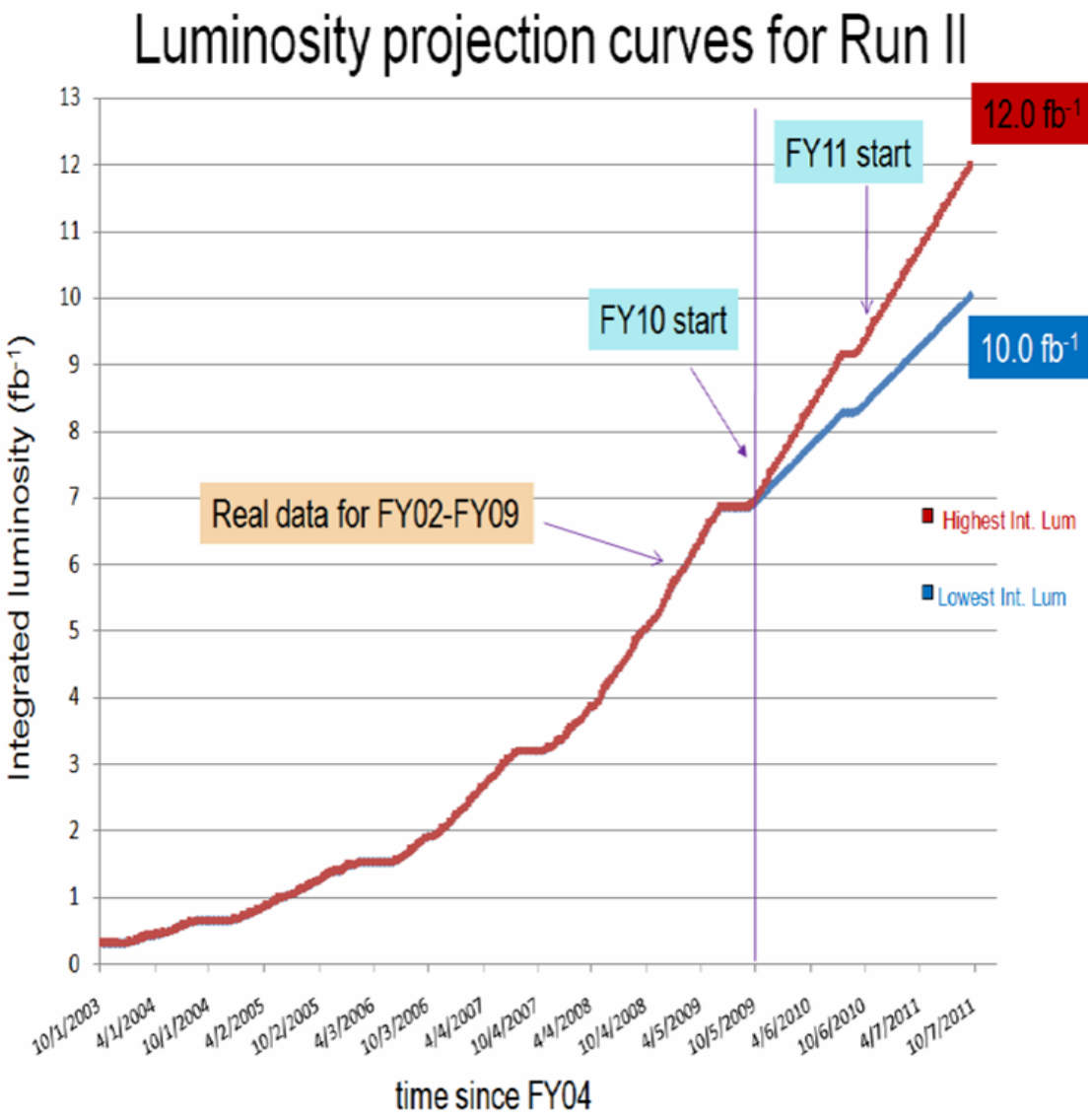
Trilepton (e+μ+trk+MET) event candidate from CDF



$B_s \rightarrow \mu\mu$

1. $B_s \rightarrow \mu\mu$
   - CDF (Prelim, 3.7 fb^{-1})
     - BR < 4.3 X 10^{-8}
   - DØ (6.1 fb^{-1}) [arXiv: 1006.3469]
     - BR < 5.1 X 10^{-8}




Luminosity projection curves for Run II
Integrated luminosity (fb-1)
time since FY04
12.0 fb-1
10.0 fb-1
FY11 start
FY10 start
Real data for FY02-FY09
Highest Int. Lum
Lowest Int. Lum
0
1
2
3
4
5
6
7
8
9
10
11
12
13
10/1/2003
4/1/2004
10/1/2004
4/2/2005
10/2/2005
4/3/2006
10/3/2006
4/4/2007
10/4/2007
4/4/2008
10/4/2008
4/5/2009
10/5/2009
4/6/2010
10/6/2010
4/7/2011
10/7/2011