SUSY Searches at Tevatron

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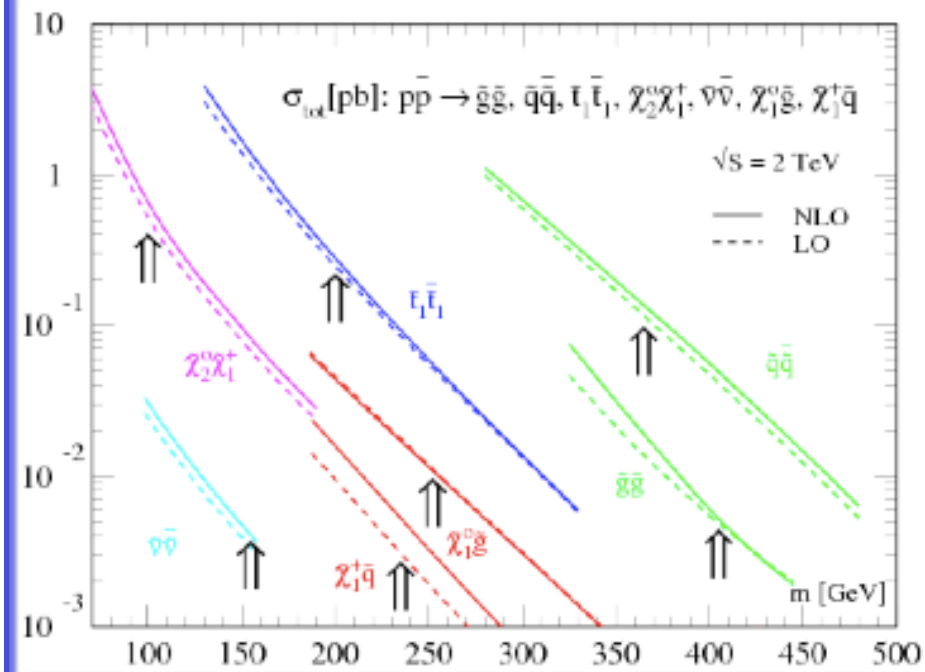
SUSY Breaking Defines Phenomenology & Search Strategy

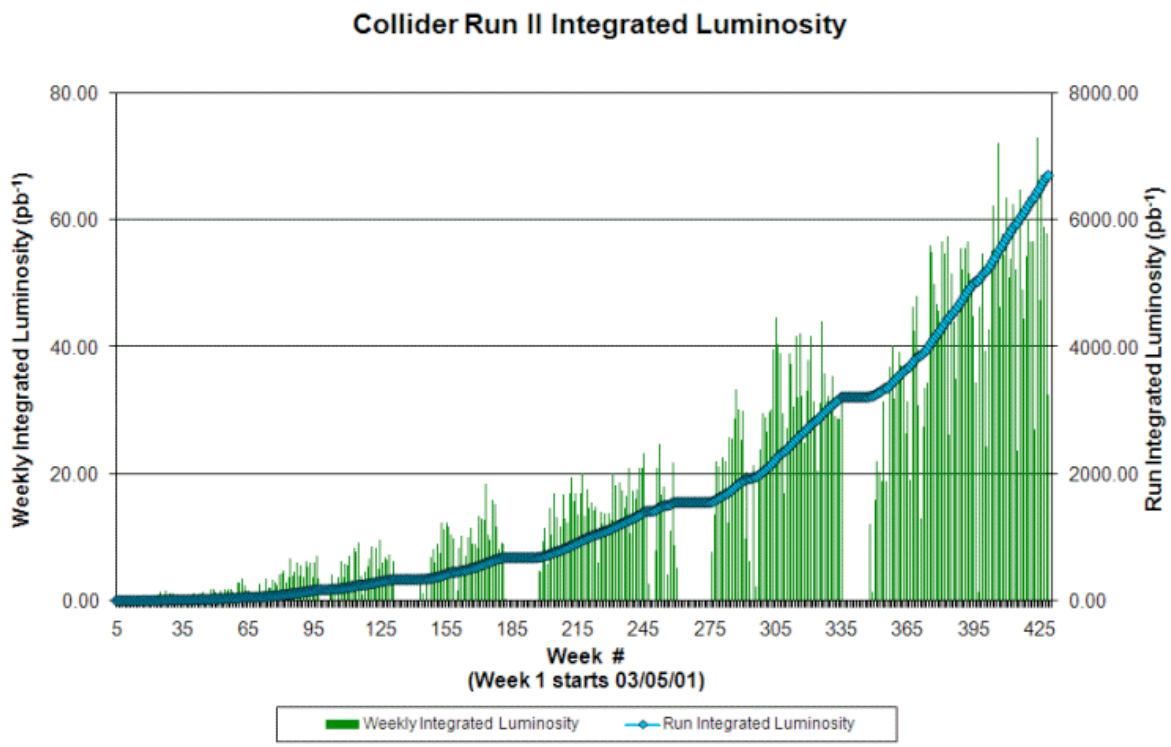
- **mSUGRA is a benchmark model**
  - m_0: common scalar mass at GUT scale
  - $m_{1/2}$: common gaugino mass at GUT scale
  - A_0: common trilinear scalar interaction at GUT scale
    - Higgs-sfermion$_R$-sfermion$_L$
  - tan(β): ratio of Higgs vacuum expectation values
  - Sign(μ): higgsino mass parameter
    - μ^2 Determined by EWSB
  - Lightest sparticle (LSP) is stable
    - missing E_T (MET) signature in detectors
- **Final states depend on sparticle mass hierarchy and mixing**

m_0=100 GeV, $m_{1/2}$=150 GeV, A_0=300, tan(β)=4, μ>0



- **This talk**
  - Chargino-Neutralino
  - Squarks
  - "Exotic" SUSY: GMSB, models with Hidden Valleys and RPV

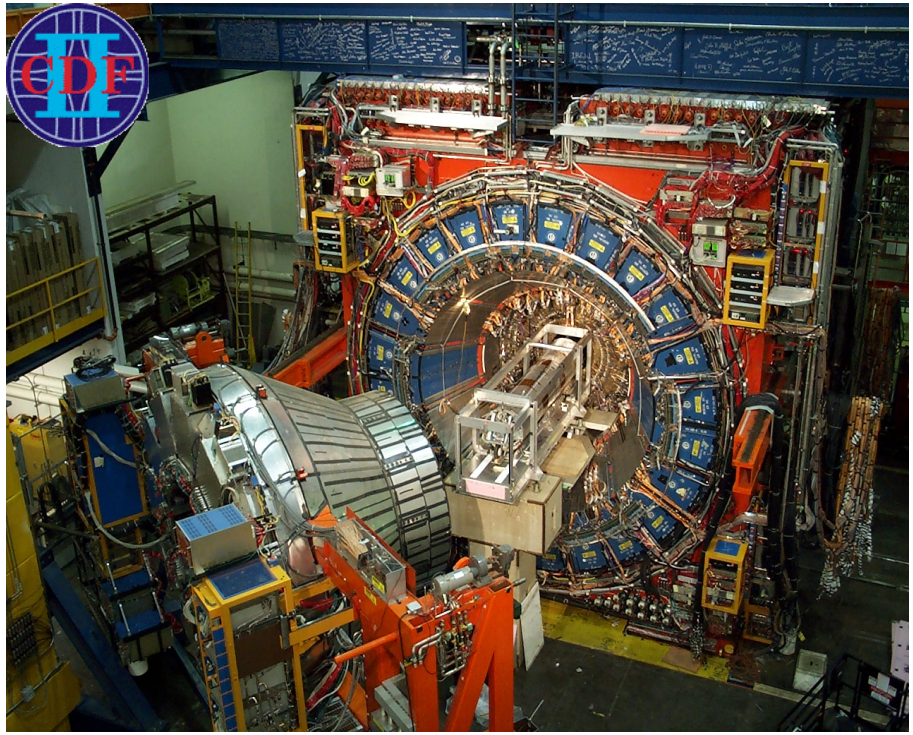
Tevatron is Running Very Well



Results in this talk are based on 1-4 fb^{-1} of data

- ~6.9 fb^{-1} per experiment; ~1.8 fb^{-1} in FY08
- Current rate: 55-60 pb^{-1} per week
- Peak lumi is >300 $\mu b^{-1}/s$
- Running till 2011? Expect 10-12 fb^{-1} per experiment

CDF and DØ Experiments

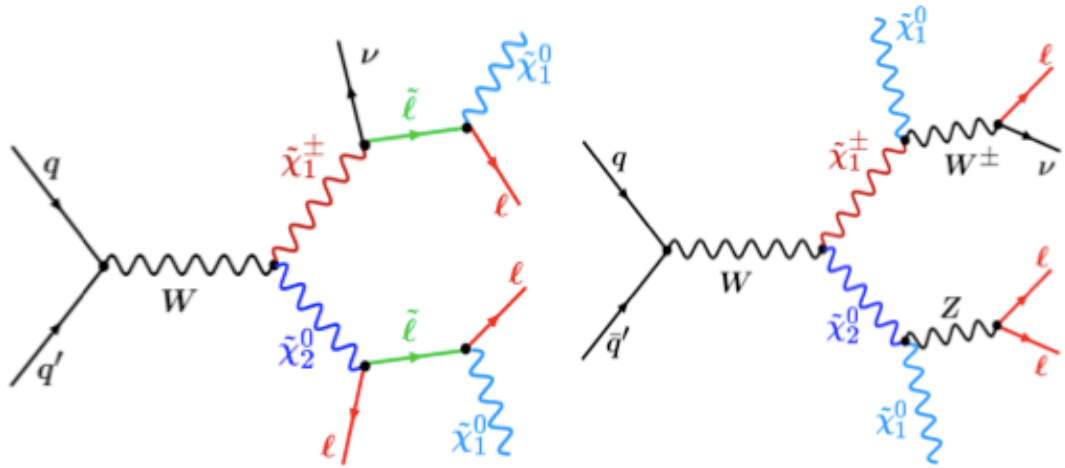


- Multipurpose detectors — classic design
  - "silicon", central tracker, solenoid, calorimeter, muon chambers
- Operating well: 80-90% efficiency
- Broad physics program
  - QCD, EWK, top, B-physics, Higgs searches, searches for new physics

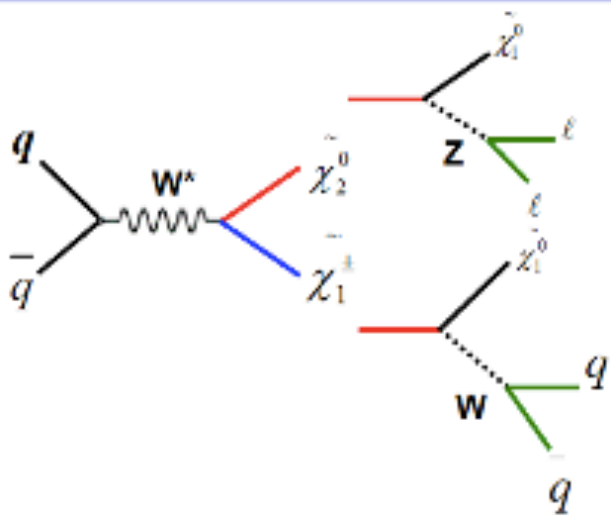
Charginos & Neutralinos at Tevatron

- **Clean signature**
  - 3 isolated leptons
  - Large MET
  - Small SM background
- **Experimental challenge**
  - Small X-section ($\sigma \times Br < 0.5$ pb)
  - Low E_T leptons

Trileptons: golden mode for SUSY at Tevatron



Decays to W/Z if sleptons are heavy; low BR to leptons

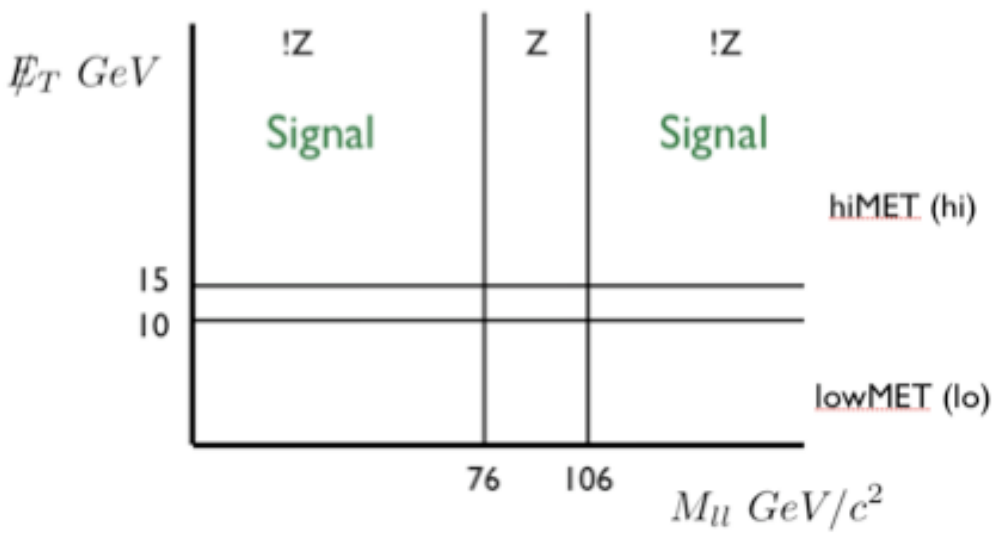


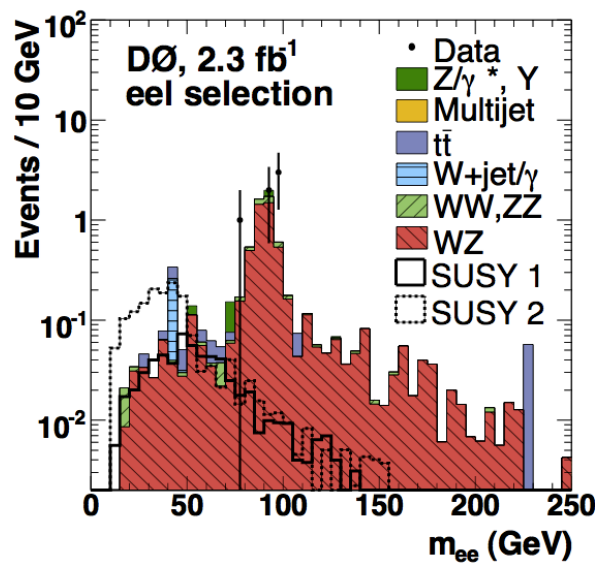
- **Heavy Gauginos**
  - If $M(\chi_2^0)-M(\chi_1^0)>M_Z$ & $M(\chi_1^\pm)-M(\chi_1^0)>M_W$
  - Final state with Z, W and large MET

Charginos and Neutralinos with $l^+l^-l^+$

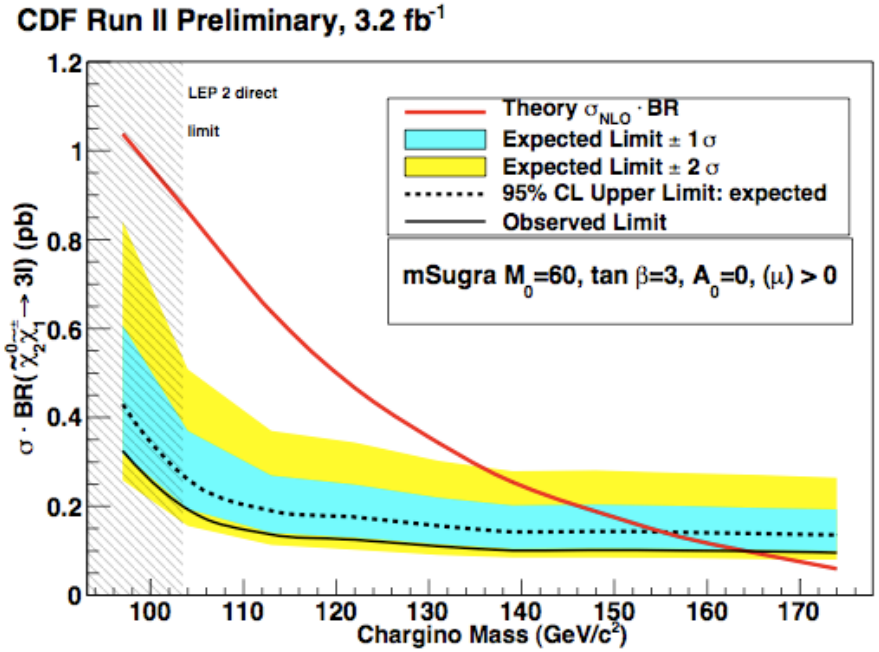
- $l^+l^-l^+$ (l=e,μ), l^+l^- + Track
  - "tight" & "loose" leptons
  - 1st lepton: E_T=15-20 GeV
  - 2nd & 3rd leptons: E_T=5-10 GeV
- Kinematic cuts
  - M_{l+l}, N_{jet}, missing E_T, $\Delta\phi$….

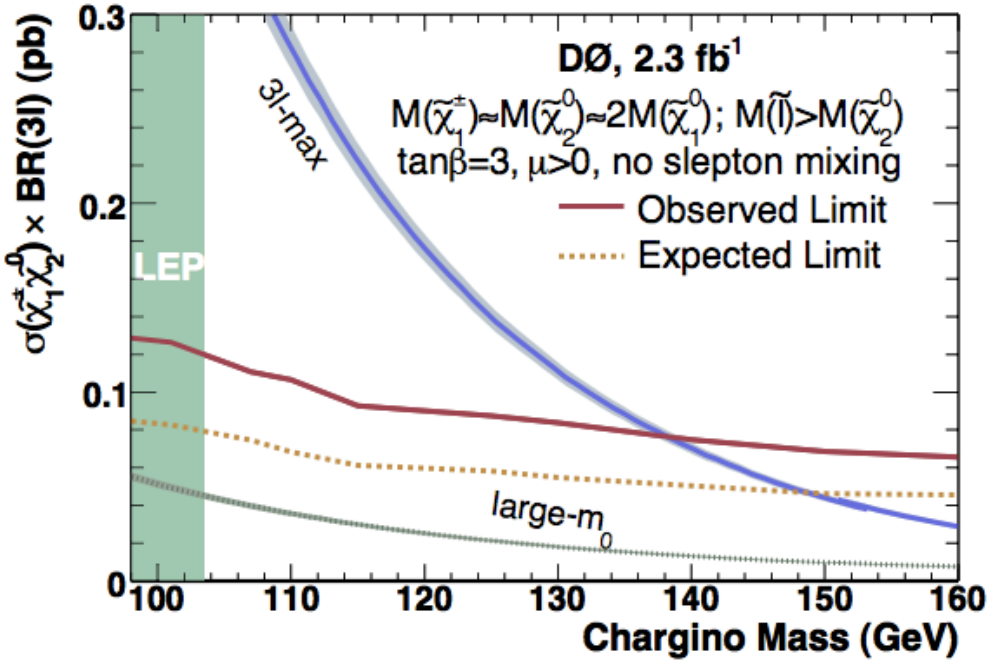
- l^+l^- + Track, $\mu\tau$+Track, $\mu\tau\tau$ ($\tau\rightarrow$hadrons)
  - 1st lepton: E_T=12-20 GeV
  - 2nd & 3rd leptons: E_T=4-16 GeV
- Backgrounds
  - WW, WZ
  - Drell-Yan, W+γ/jets, ttbar





Charginos and Neutralinos with $l^+l^-l^+$

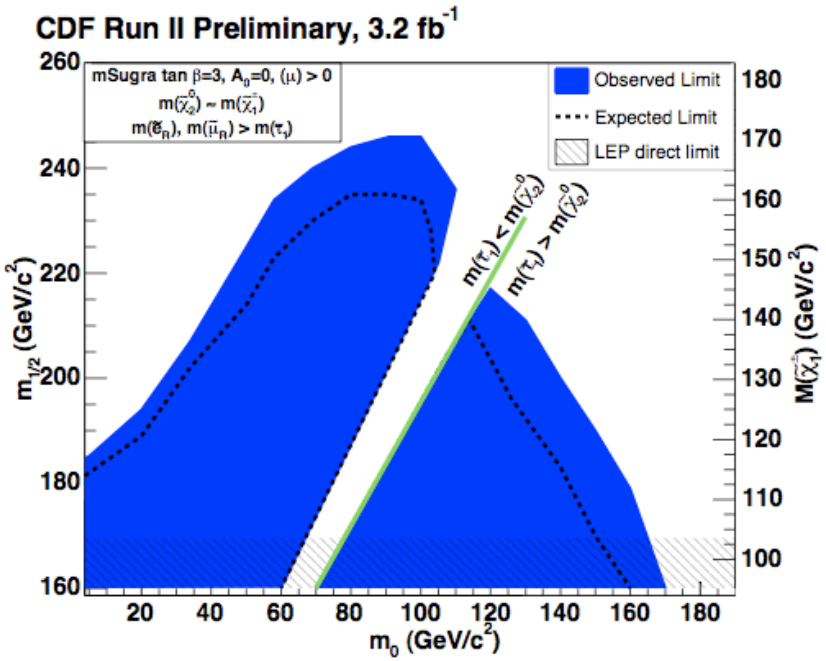


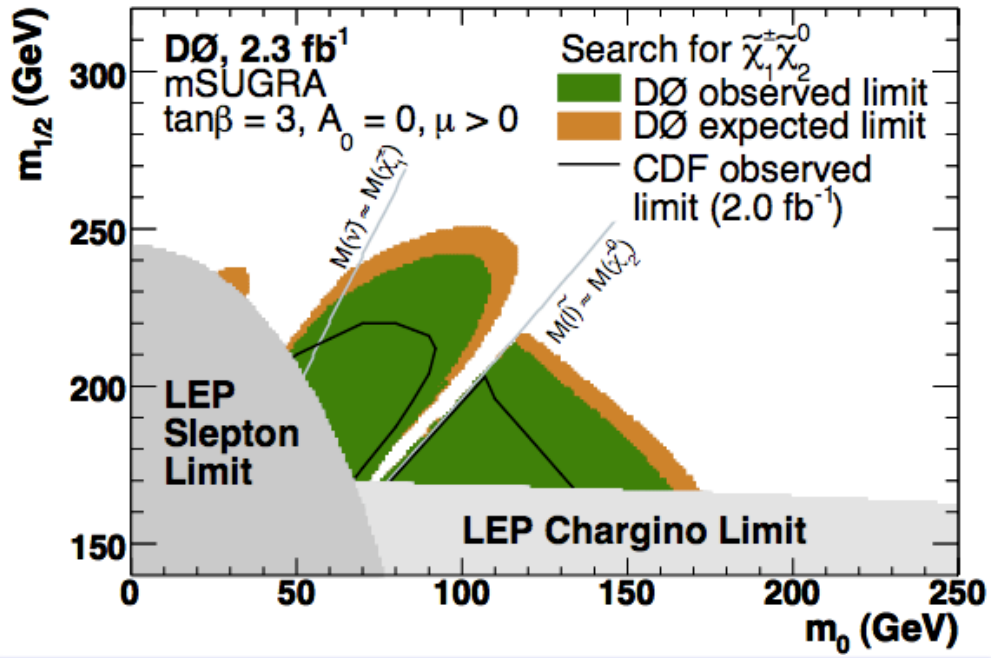


D0 (1.0-2.3 fb^{-1})			CDF (3.2 fb^{-1})		
Channel	SM	Data	Channel	SM	Data
Low p_T	5.4±0.6	9	$l^+l^-l^+$	1.5±0.2	1
High p_T	3.3±0.4	4	l^+l^-+trk	9.4±1.4	6

- **CDF (3.2 fb^{-1})**
  - **$M(\chi^\pm)$>164 GeV/c^2**
- **D0 (2.3 fb^{-1})**
  - **$M(\chi^\pm)$>138 GeV/c^2**
  - **Submitted to PLB**
    - **Hep-ex/0901.0646**

Charginos and Neutralinos with $l^+l^-l^+$

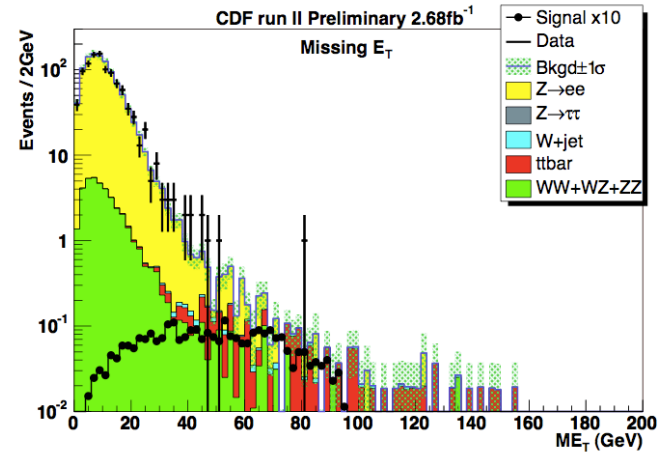


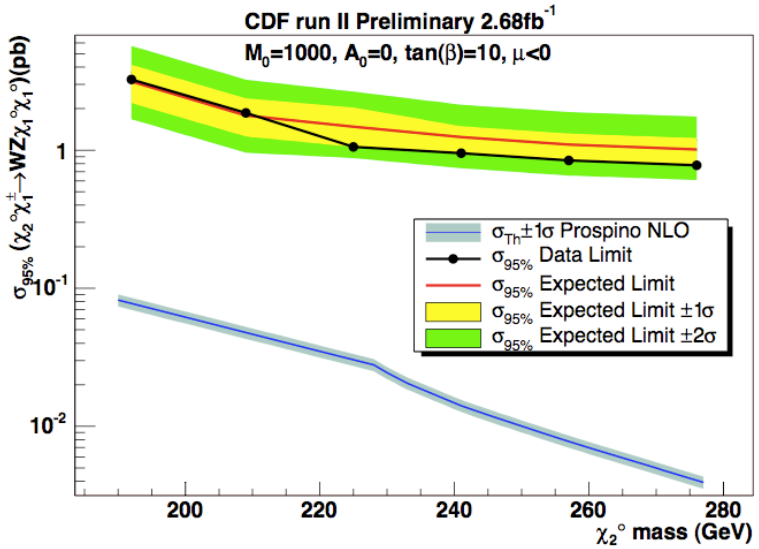


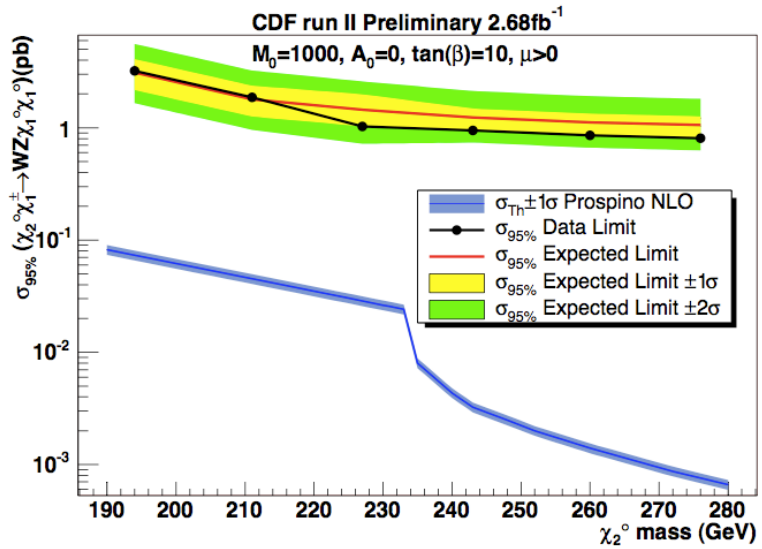
- Benchmark scenario: tan(β)=3,A_0=0, μ>0
- Exclude region in mSUGRA $m_{1/2}$-m_0 space
- Limits depend on neutralino-slepton mass difference

Heavy Chargino & Neutralino in Z+W+MET

- Final state: $Z \rightarrow e^+e^-$, 2 jets ($W \rightarrow qq'$), and MET>40, 50, 60 GeV
  - Final state not explored before
- Main backgrounds: Z+jets & ttbar
- Results for MET>40 GeV
  - Data: 7; SM Bckg: 6.41±0.92



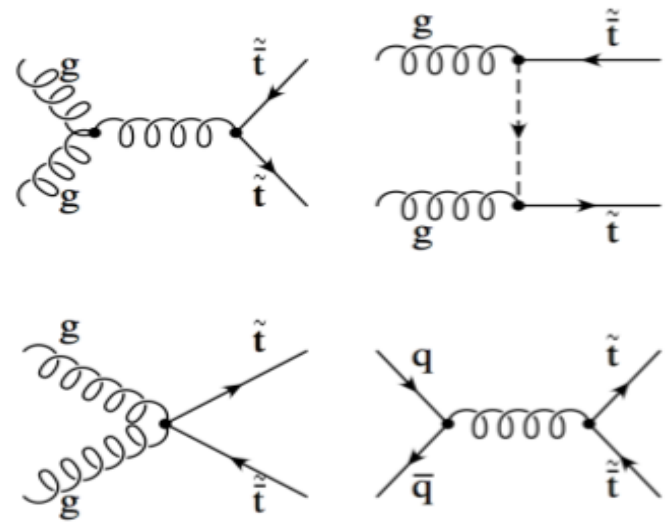


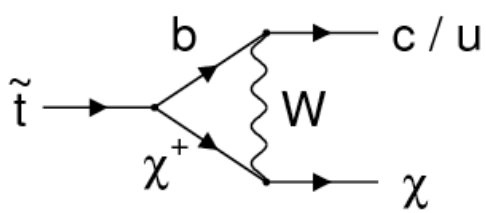


Stop Searches at Tevatron

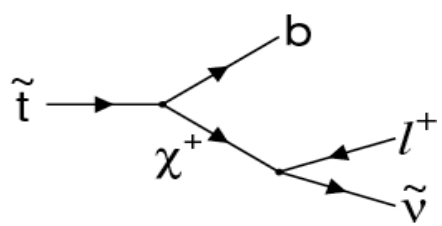
- Lightest of squarks
- Stop searches at Tevatron
  - R_p conservation: $M_{stop}<M_{top}$
  - Decays
    - A) D0: *PLB 665, 1 (2008) – not in this talk*
      if $m_{\tilde{t}_1} < m_b + m_{\tilde{\chi}_1^\pm}$ and $m_{\tilde{t}_1} < m_W + m_b + m_{\tilde{\chi}_0^1}$
    - B) $\tilde{t}_1 \to bl\tilde{\nu}$
    - C) if $m(\tilde{\chi}_1^\pm) - m(\tilde{\chi}_1^0) > m(W)$

$$\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm \to bW^\pm\,\tilde{\chi}_0$$

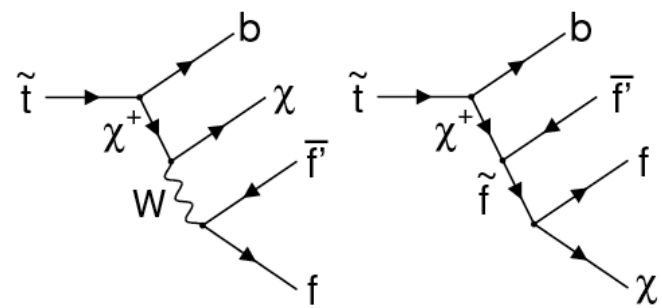




A) Two-body

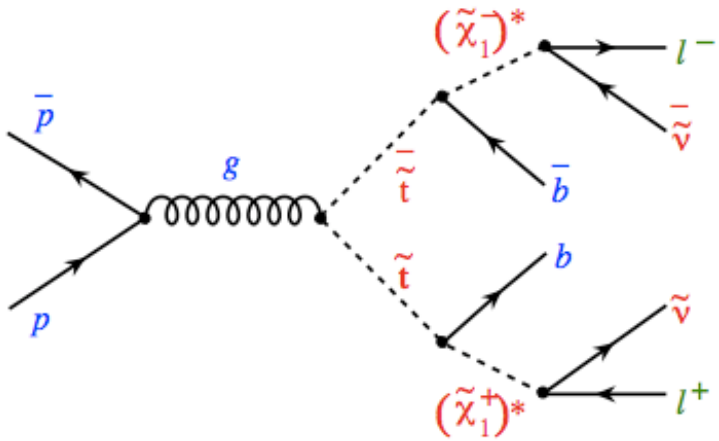


B) Three-body

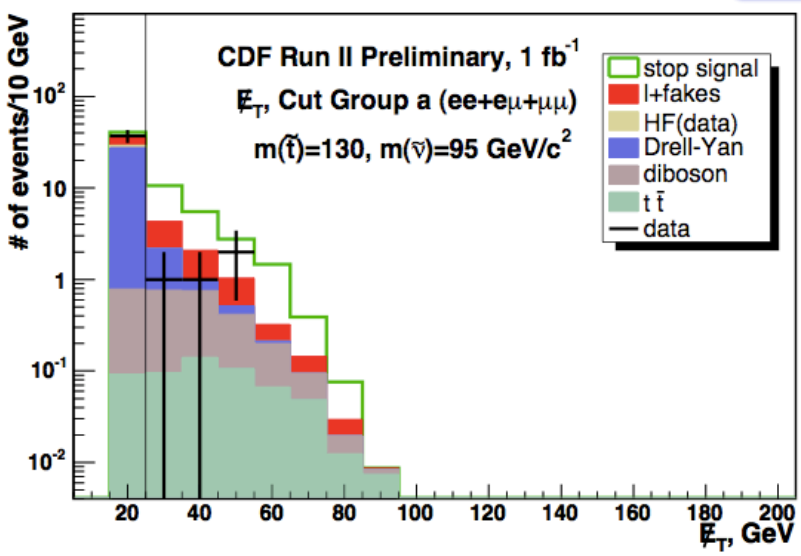


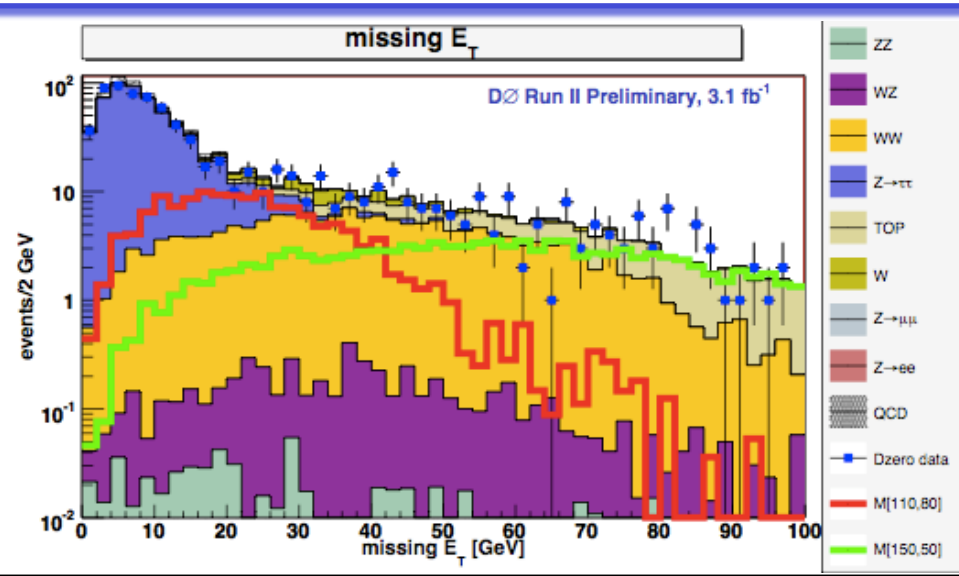
C) Four-body

Stop→$l^{\pm}$+b+sneutrino in l^+l^-+jets+MET



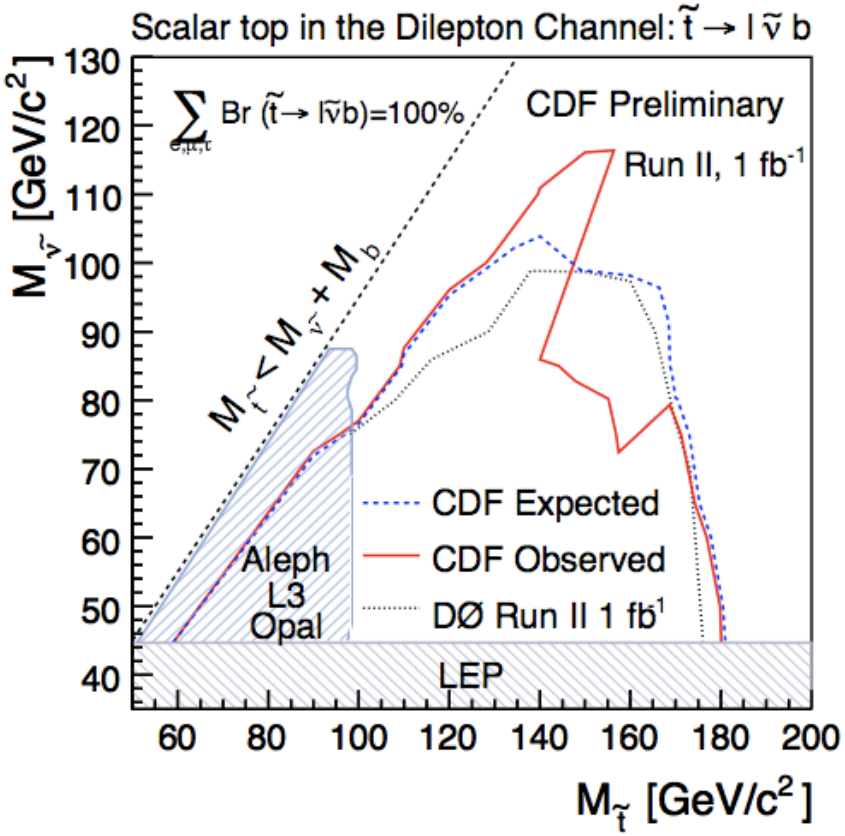
- Assume sneutrino is LSP
- Br=100% for $\tilde{t}_1 \rightarrow bl\tilde{\nu}$
- Signal topology depends on Δm=m(stop)-m(sneutrino)
- Final state:
  - CDF (1 fb^{-1}): l^+l^-+N_{jet}>1+MET (ll=ee, $\mu\mu$, eμ)
  - D0 (3.1 fb^{-1}): e$^+\mu^-$+(jets)+MET

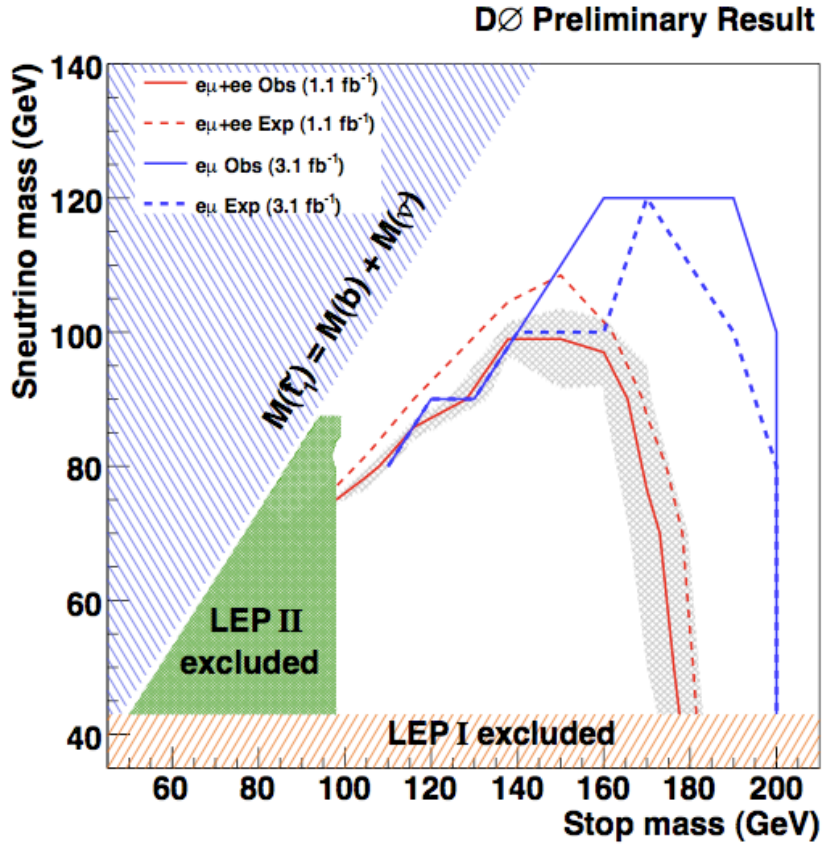




Stop→$l^{\pm}$+b+sneutrino in l^+l^-+jets+MET

- **Results at large Δm=m(stop)-m(sneutrino)**
  - **D0 (3.1 fb^{-1}): m(stop)>200 GeV**
  - **CDF (1 fb^{-1}): m(stop)>180 GeV**





Stop Decays Mimicking Top Signature

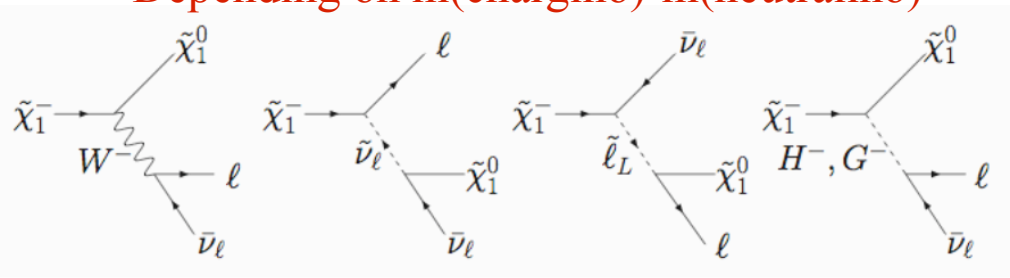
- Assume 100% BR to b-quark and chargino

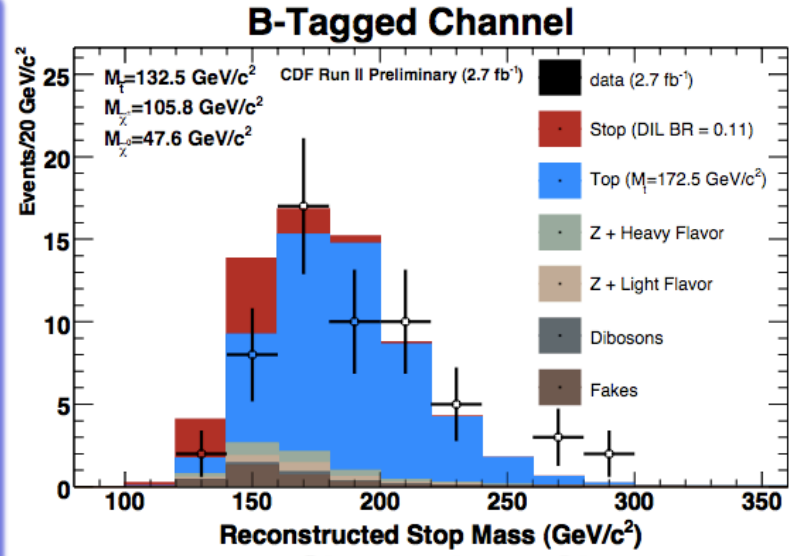
$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm} \rightarrow b\tilde{\chi}_1^0 l\nu$$

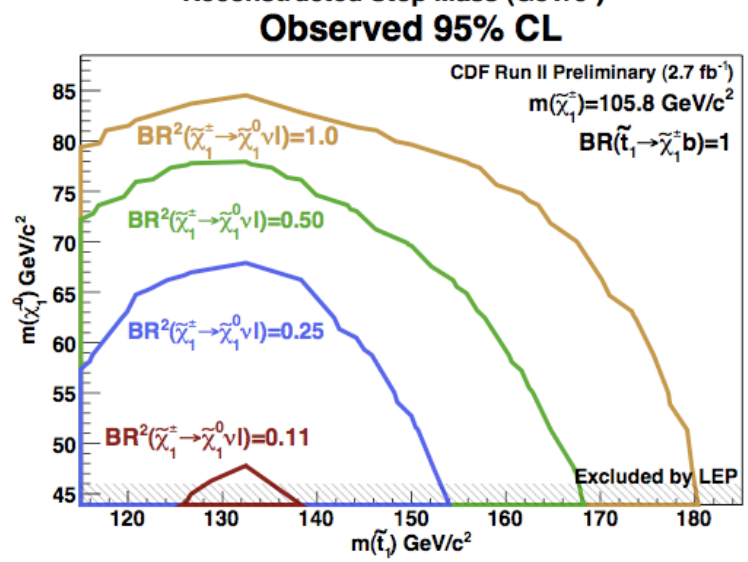
1. $\tilde{\chi}_1^0$ is the LSP
2. $m_{\tilde{t}_1} \lesssim m_t$
3. $m_{\tilde{\chi}_1^+} < m_{\tilde{t}_1} - m_b$

- Same selection as for ttbar analysis
  - l^+l^-+bb+MET (l=e, μ)
- Reconstruct M(stop)

Depending on m(chargino)-m(neutralino)





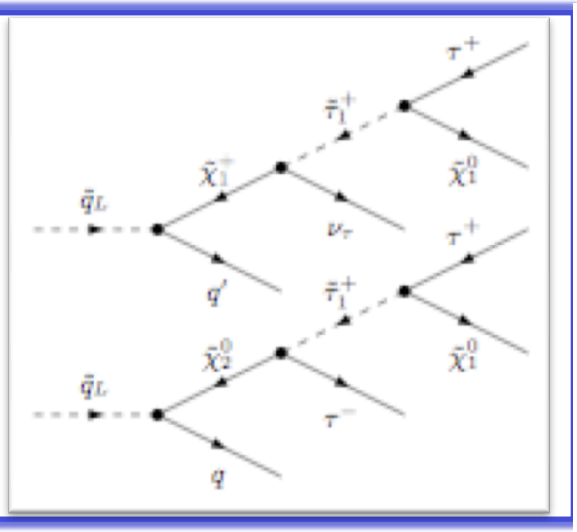


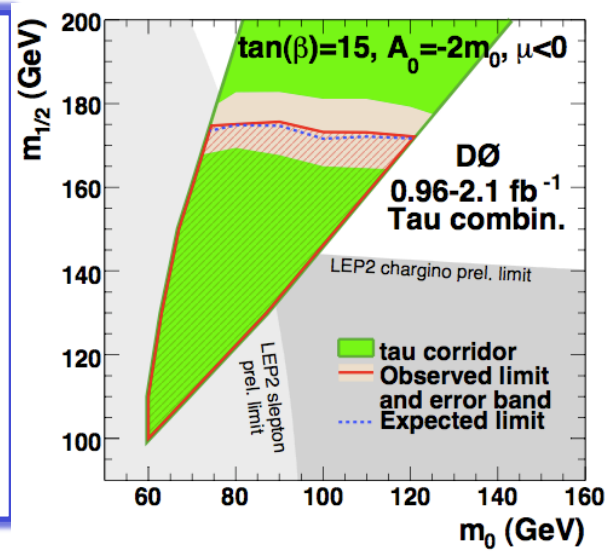
Squark Production in jets+τ_h+MET

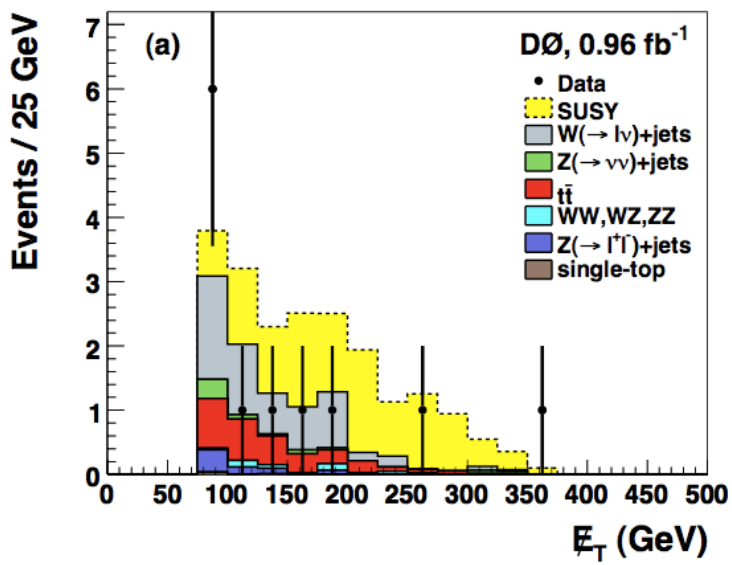
- "Tau corridor"
  - Stau is lightest slepton

    $M(\tilde{\tau}_1) < M(\tilde{\chi}_1^{\pm}), M(\tilde{\chi}_2^0)$
  - M(squark)<M(sgluino)

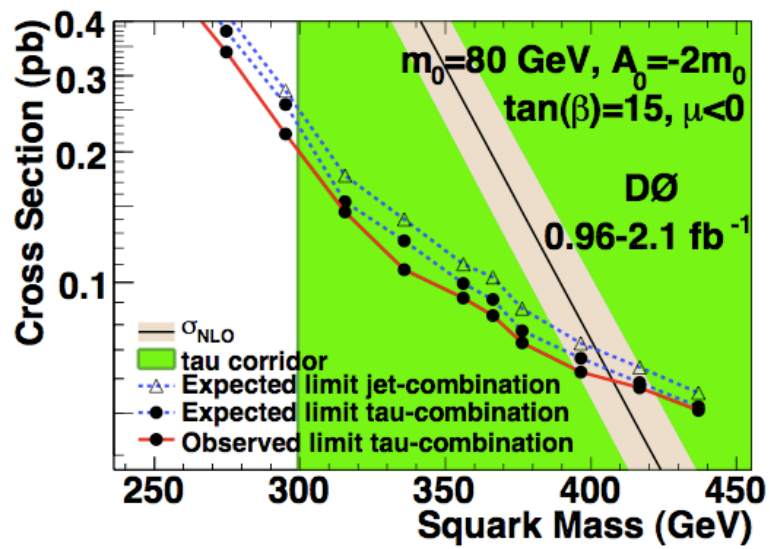
    $p\bar{p} \rightarrow \tilde{q}_R \tilde{q}_L, \ \tilde{q}_R \rightarrow q\tilde{\chi}_1^0$
- Final state: jets+τ_h+MET
  - Not studied before







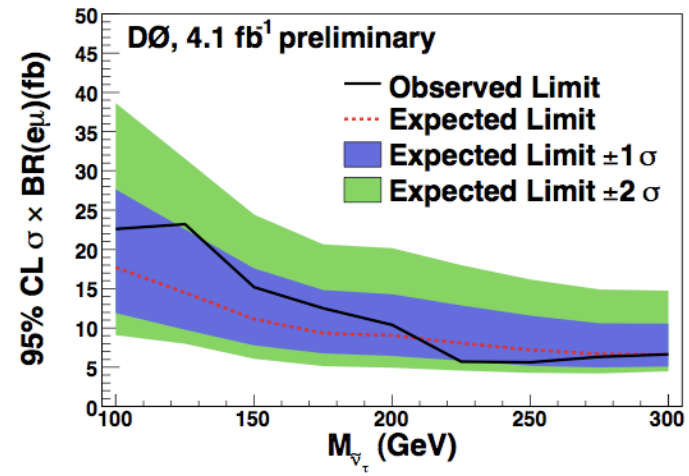
Submitted to PLB
ArXiv:
hep-ex/0905.4086

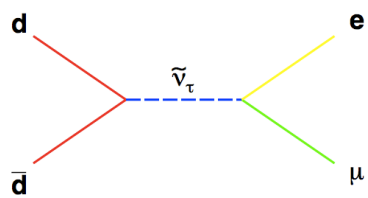


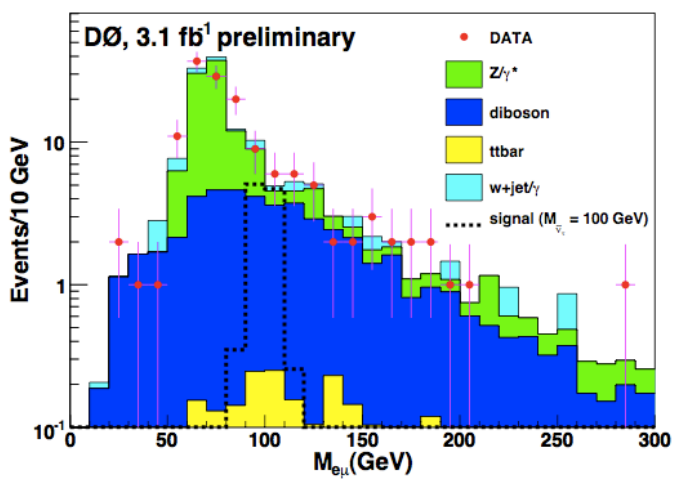
Sneutrino in e+μ+X

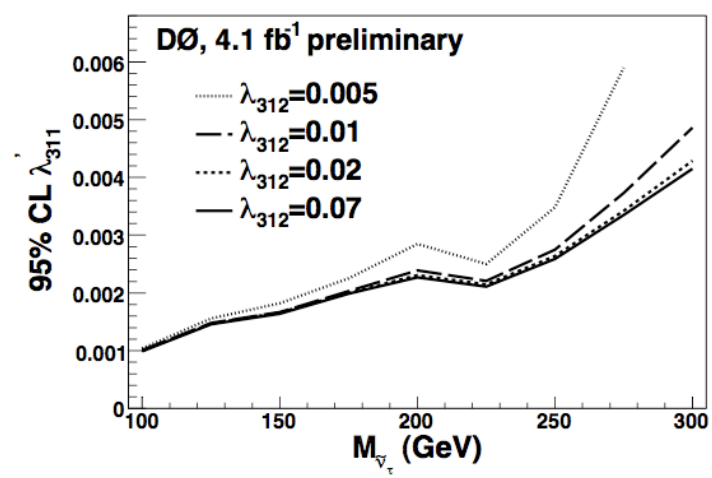
- Assume R_p violation
  - production of single sparticle
- Look for high mass $e^+\mu^-$ resonances in 3.1 fb^{-1}
  - Striking signature
  - Veto events with MET & jets
  - Backgrounds: $Z/\gamma^* \to \tau\tau \to e\mu$, dibosons

$\lambda'_{311}=0.12$ $\lambda_{213}=0.07$

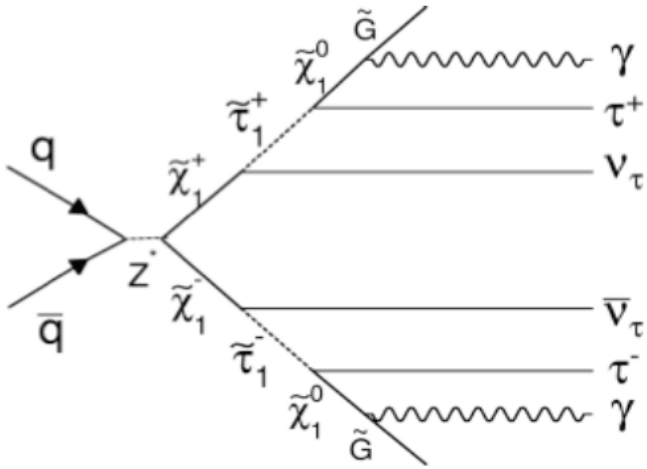


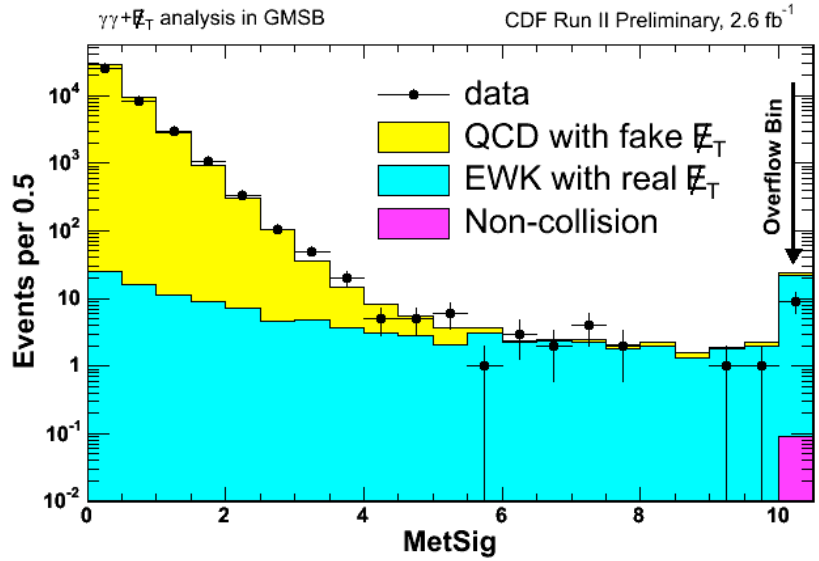






Limits on GMSB in γγ+MET



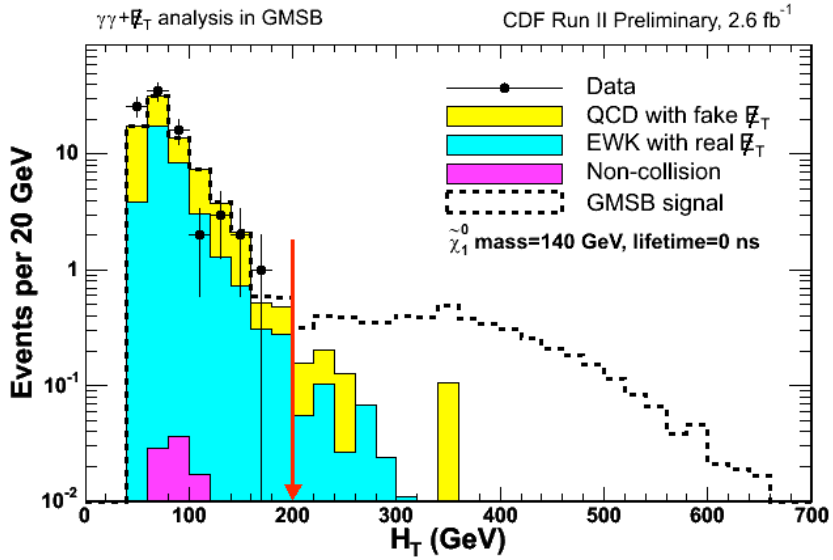


MET-significance based on energy resolution

- **Gauge-Mediated SUSY Breaking**
  - SUSY breaking scale:10-100 TeV
  - Heavy squarks, gluinos, sleptons
  - Gravitino LSP (<<MeV)
  - Neutralino or slepton NLSP
  - If χ^0 NLSP: $\chi^0 \rightarrow \gamma G$ (Br=100%)
  - Snowmass Slope constraint (SPS-8)

- **3D optimization:**
  - MET-significance, H_T, $\Delta\varphi_{\gamma\gamma}$
    - $H_T = E_T(\gamma 1) + E_T(\gamma 2) + MET + \ldots$
- **Backgrounds**
  - $Z\gamma\gamma \rightarrow \nu\nu\gamma\gamma$, $W\gamma \rightarrow \nu\gamma\gamma_{fake}$

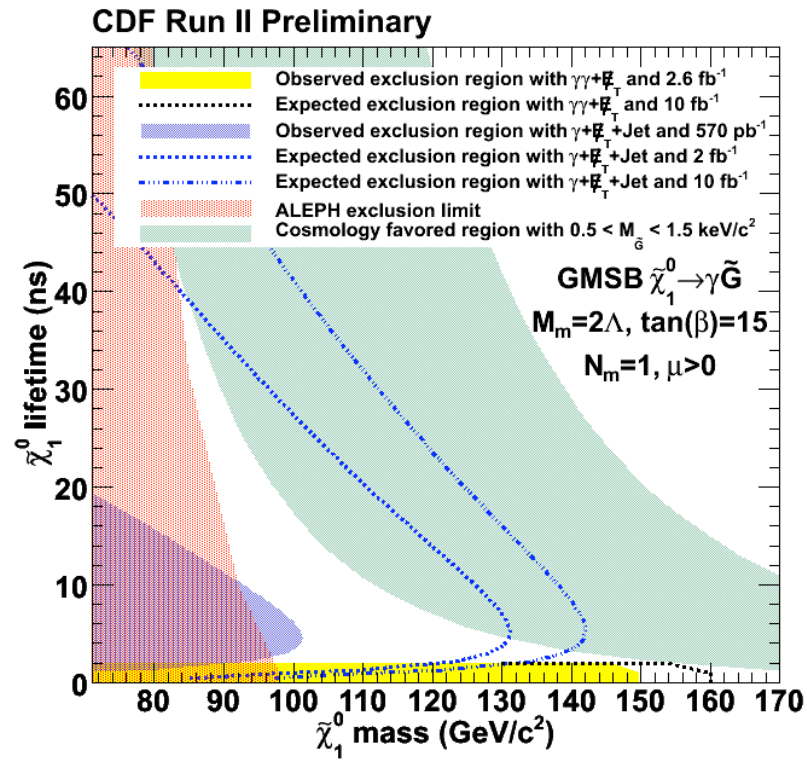
Limits on GMSB in γγ+MET



$H_T=E_T(\gamma1)+E_T(\gamma2)+MET+...$

After MET-sig>3 & $\Delta\varphi_{\gamma\gamma}$<3

Data: no events observed

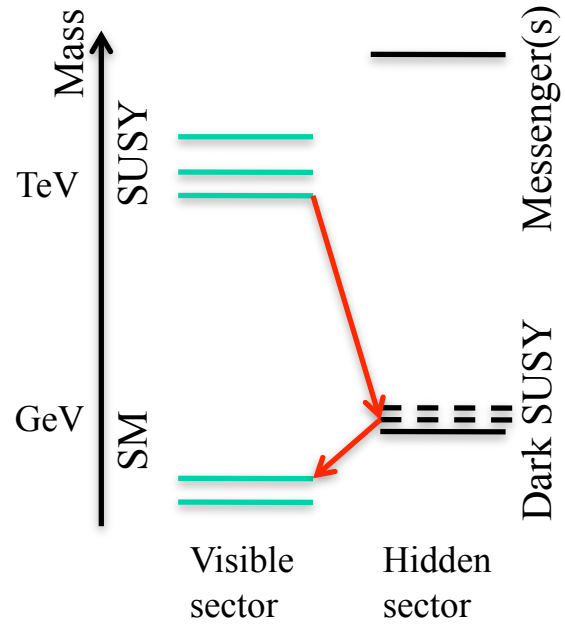


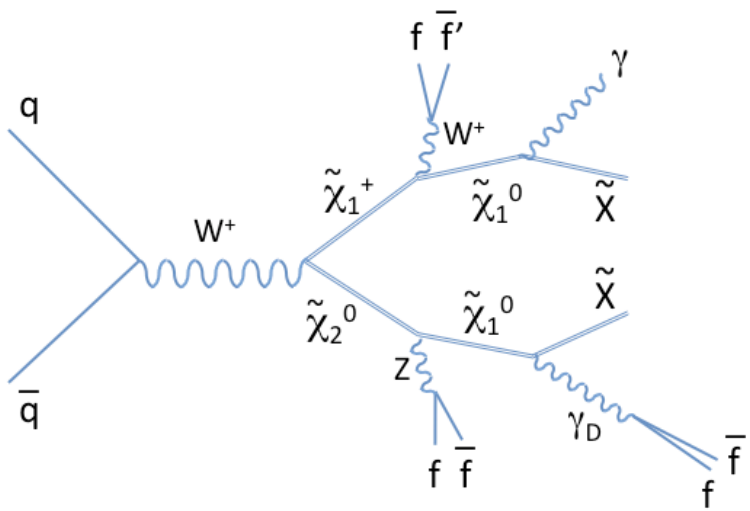
Background Source	Expected Rate±Stat±Sys
Electroweak	0.77±0.21±0.22
QCD	0.46±0.22±0.10
Non-Collision	$0.001^{+0.008}_{-0.001} \pm 0.001$
Total	1.23±0.30±0.24

- **95% CL limits in neutralino mass & lifetime plane**
  - **Neutralino mass>149 GeV/c^2**
  - **Signal acceptance: 9.2%±1.7%**

Dark Photons

- Supersymmetric Hidden Valleys (HV)
- Motivated by recent PAMELA, ATIC results
- SUSY HV phenomenology is similar to GMSB
  - Cascade to LSP; LSP→hidden sector
    - Photon + dark LSP (darkino)
    - Dark photon (γ_D) + darkino (MET)
    - γ_D→fermions

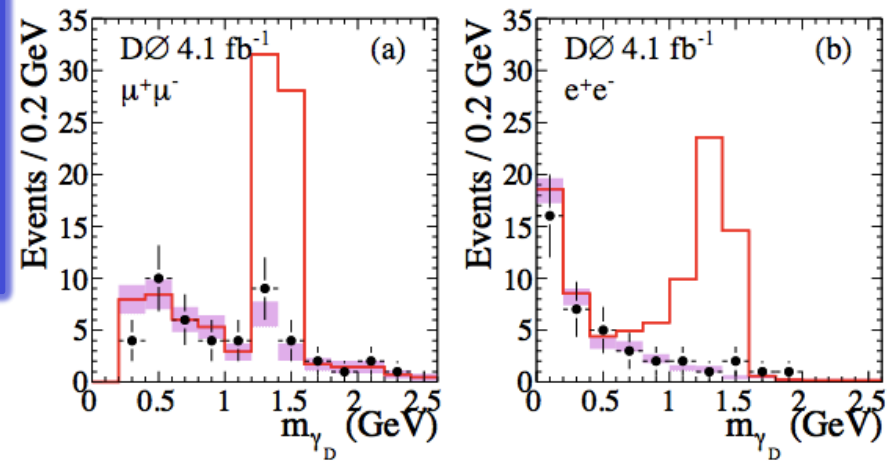


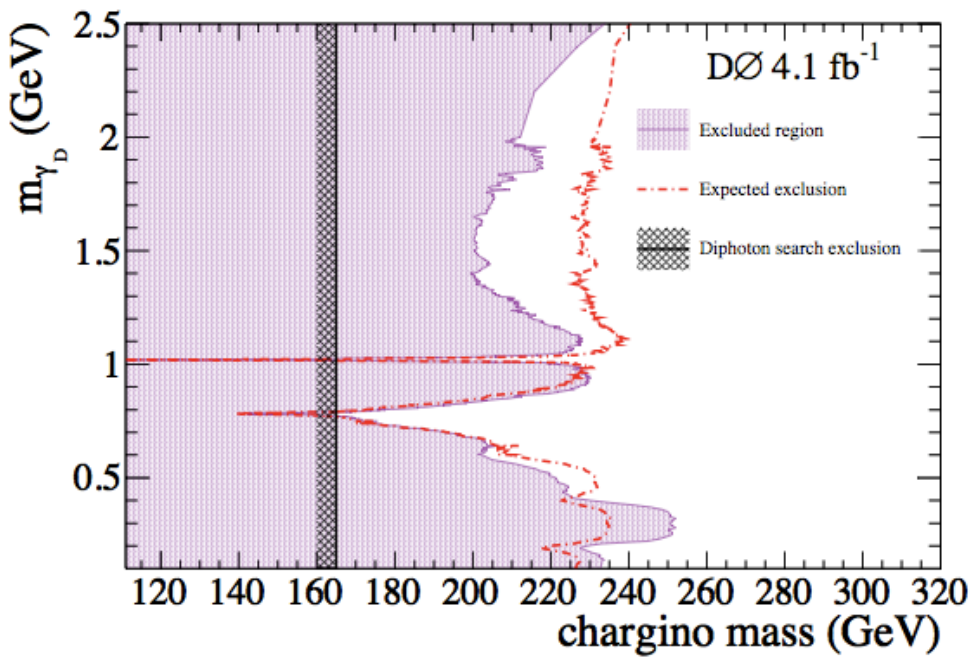


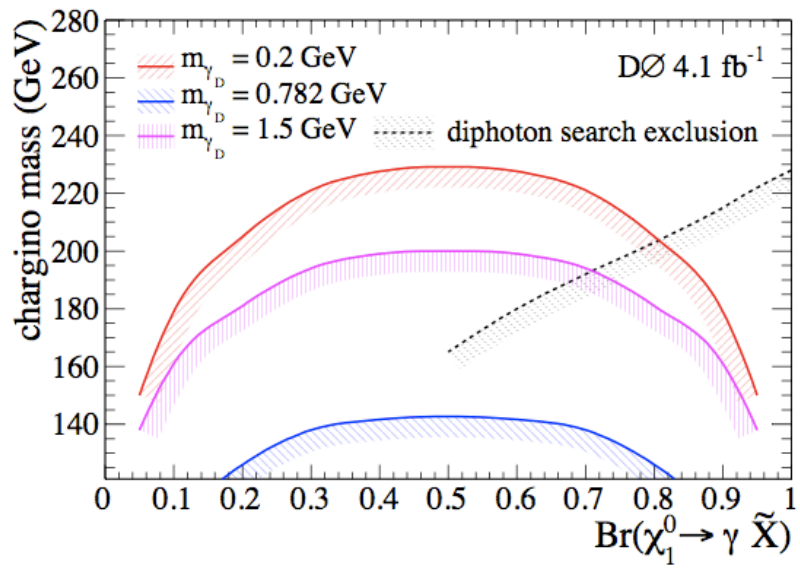
- Look for:
  - γ, MET, two closely spaced leptons
- Main background
  - Multijets, W+γ/jets

Dark Photons

- Optimize for $M(\gamma_D)$=1.4 GeV
- Limit in chargino & γ_D mass plane
- *arXiv:0905.1478 sub. to PRL*







Summary

- CDF and DØ have rigorous SUSY program
  - New results on "classic" analyses: stop, trileptons
  - Both experiments continue exploring new signatures and analysis techniques
  - SM still prevails
- With >5 fb^{-1} on tape and 2-5 fb^{-1} still to come, expect more exciting results
- More CDF and DØ results at

http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

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