# Searches for SUSY in CDF

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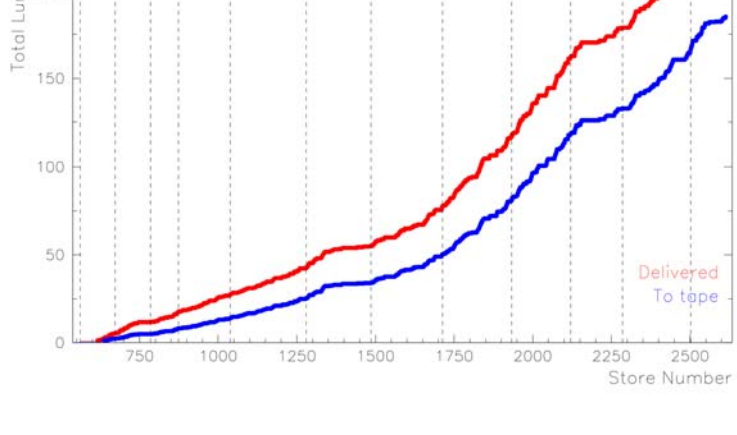
SUSY03, Tucson, Arizona, June 5-10, 2003

# Tevatron and CDF at Run II

Tevatron → $p\bar{p}$ collisions
→ $\sqrt{s}$=1.96 TeV
→ 2 $fb^{-1}$ in Run II

CDF upgraded to cope with
→ high luminosity
→ small bunch spacing (396ns)

- Current luminosity record $4.75 \times 10^{31}\ cm^{-2}s^{-1}$
- ~180 $pb^{-1}$ recorded at CDF
- ~70 $pb^{-1}$ used in analyses




- Extended spatial e, μ coverage
- New plug calorimeter improves also $\not{E}_T$ measurement
- Improved $\not{E}_T$ triggers
- Added triggers to identify $\tau$ leptons at early stage
- No Main Ring, less beam background

# SUSY Search Challenges

- Low cross sections of SUSY processes
  - With available $\int L\, dt \sim 100\ pb^{-1}$ we are limited to $\sigma \geq 1$ pb
- High $Q^2$ SUSY processes often softened by only weakly interacting particles
  - Need topological & kinematical cuts to increase signal sensitivity
- Reach and limits are often driven by systematic uncertainties
  - Need detailed understanding of uncertainties of expected signal and background
  - Signal - mostly theoretical uncertainties
  - Background - mostly experimental uncertainties

# CDF's Run I SUSY Searches

## 1. Traditional searches

$\tilde{\chi}_1^{\pm}$ & $\tilde{\chi}_2^0$ in 3-leptons PRL 80, 5275 (1998)

$$p\bar{p} \to \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to (\nu\tilde{l})(l\tilde{l}) \to (\nu l\tilde{\chi}_1^0)(ll\tilde{\chi}_1^0)$$

Signature: 3 leptons+ MET

$\tilde{q}$ & $\tilde{g}$ with LS leptons PRL 87, 251803 (2001)

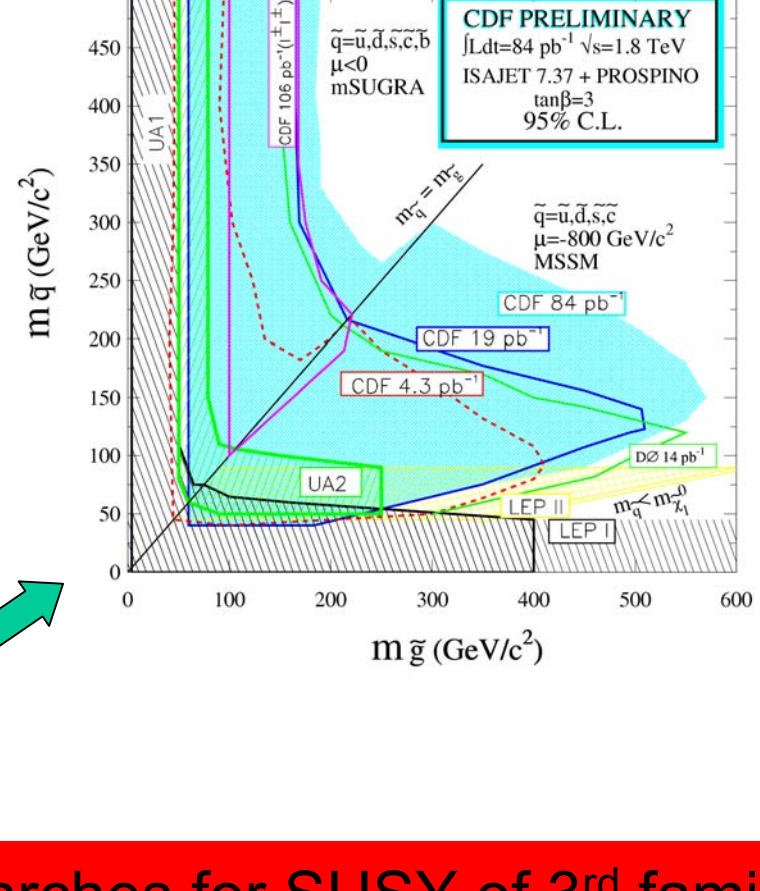
$$p\bar{p} \to \tilde{g}\tilde{g} \to (\bar{q}\tilde{q})(\bar{q}''\tilde{q}'') \to \bar{q}(q'\tilde{\chi}_1^{\pm})\bar{q}''(q'''\tilde{\chi}_1^{\pm})$$

Signature: 2 LS leptons, ≥2 jets, MET

$\tilde{q}$ & $\tilde{g}$ with Jets+MET PRL 88, 041801 (2002)

$$p\bar{p} \to \tilde{g}\tilde{g} \to (\bar{q}\tilde{q})(\bar{q}''\tilde{q}'') \to \bar{q}(q'\tilde{\chi}_1^{\pm})\bar{q}''(q'''\tilde{\chi}_1^{\pm})$$

Signature: ≥3 jets,MET




## 2. Searches for SUSY of 3rd family

$\gamma$ final state searches
(See Sung Won Lee's talk)

## 3. Searches for RPV SUSY

# Searches for SUSY of 3rd family

Top to Stop PRD 63, 091101(R) (2001)

$$p\bar{p} \to t\bar{t} \to (\tilde{t}\tilde{\chi}_1^0)(\tilde{\bar{t}}\tilde{\chi}_1^0) \to (b\tilde{\chi}_1^{\pm})\tilde{\chi}_1^0(\bar{b}\tilde{\chi}_1^{\mp})\tilde{\chi}_1^0$$

Signature: ≥1 lepton, ≥2 jets, MET

Stop/Sbottom in c/b+LSP PRL 84, 5704 (2000)

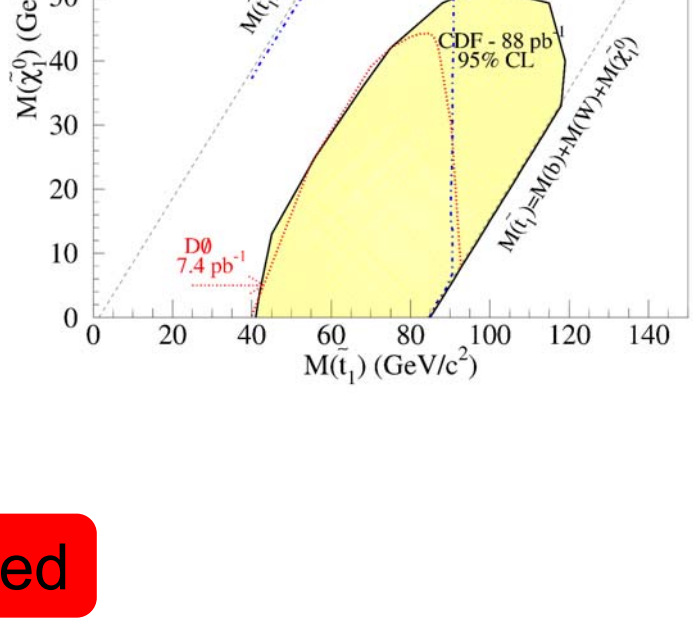
$$p\bar{p} \to \tilde{t}\tilde{\bar{t}} \to (c\tilde{\chi}_1^0)(\bar{c}\tilde{\chi}_1^0)$$

Signature: ≥2 HF jets, MET

Stop in lepton + b-jets PRL 84, 5273 (2000)

$$p\bar{p} \to \tilde{t}\tilde{\bar{t}} \to (b\tilde{\chi}_1^{+})(\bar{b}\tilde{\chi}_1^{-}) \to (bl^{+}\tilde{\chi}_1^0)(\bar{b}l^{-}\tilde{\chi}_1^0)$$

Signature: ≥1 lepton, b-jet (tagged), MET




And the latest Published

Stop in Opposite Sign Dileptons

# Search for Stop with OS Dileptons

$$p\bar{p} \to \tilde{t}\bar{\tilde{t}} \to (bl\tilde{\nu})(\bar{b}\bar{l}\bar{\tilde{\nu}})$$ $(l = e, \mu, \tau$ with Br = 33% for each$)$

Run I, 107 $pb^{-1}$ PRL accepted, hep-ex 0302009

Signature:

≥2 OS leptons, ≥1 jet, MET

Background:

Drell-Yan + Jets

Heavy Flavor Production

$t\bar{t}$, Dibosons, Fake Leptons

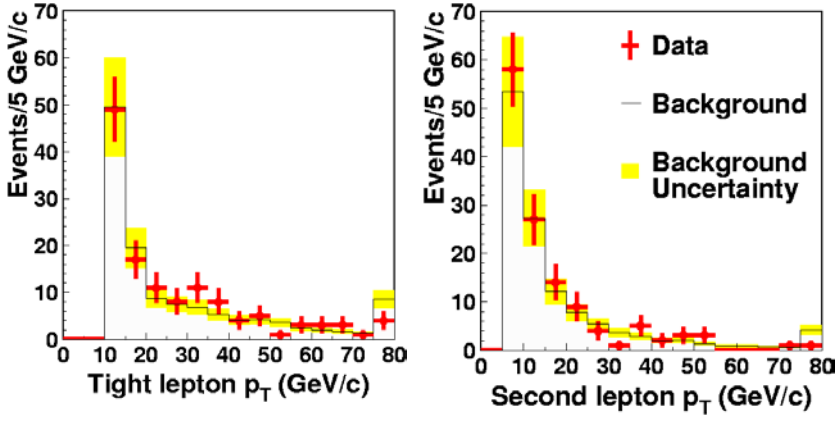
Preselection stage:

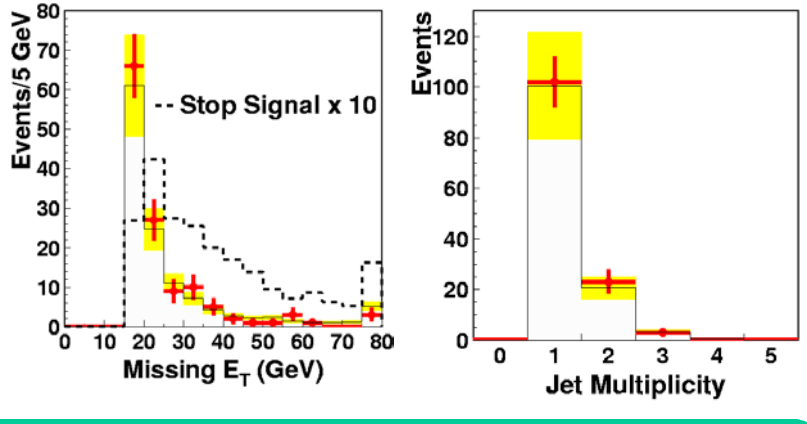
2 isolated leptons (e,μ)

$p_T(l_1) \geq 10$ GeV, $p_T(l_2) \geq 6$ GeV

MET ≥ 15 GeV

Jet $E_T \geq 15$ GeV




- Data agree w/SM expectations
- Sensitivity too low at this stage

# Search for Stop with OS Dileptons

$$\Delta m(\tilde{t},\tilde{\nu}) = m(\tilde{t}) - m(\tilde{\nu})$$

Performed two "blind" analyses:

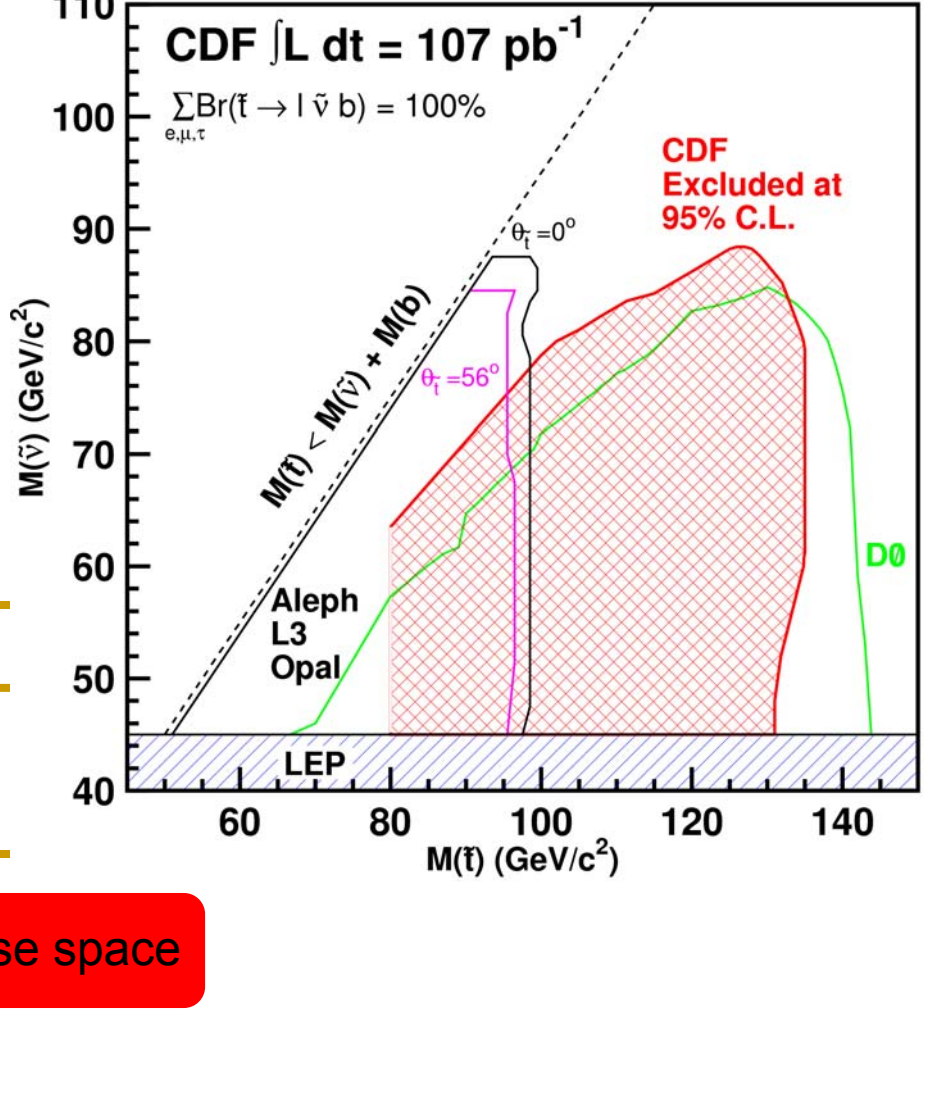
MET ≥ 35 GeV & Angle Cuts

& for small $\Delta m$, $pT(l_2) \geq 6$ GeV

& for large $\Delta m$, $pT(l_2) \geq 10$ GeV

Results

| $\Delta m$ | Data | Background | Signal |
|---|---|---|---|
| small | 0 | 1.5±0.5 | 5.7±2.1 |
| large | 0 | 2.1±0.5 | 8.2±3.1 |




Excluded new regions of phase space

Increased stop sensitivity 4x

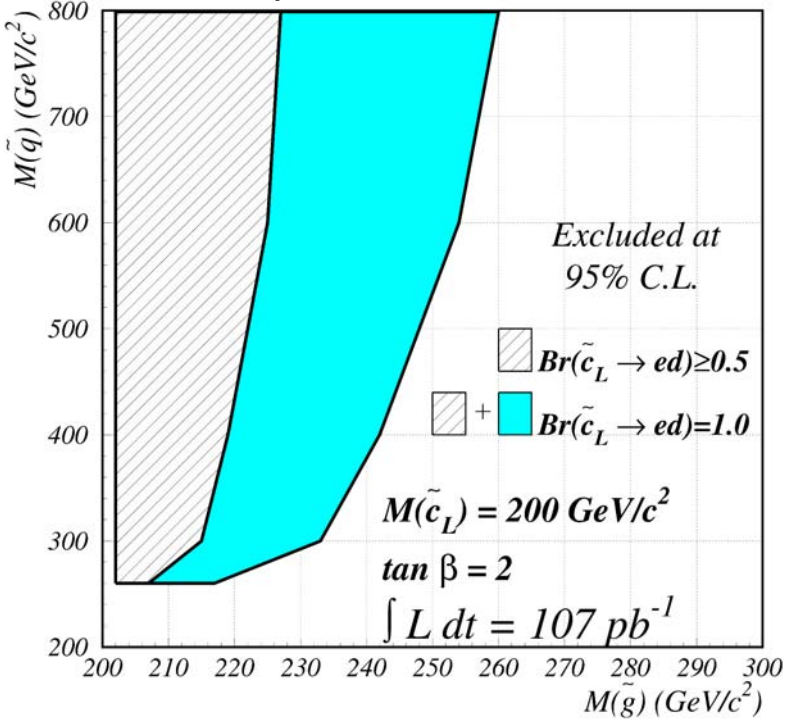
# Search for RPV SUSY

Squarks in LS ele.+Jets PRL 83, 2133 (1999)

$$p\bar{p} \rightarrow \tilde{g}\tilde{g} \rightarrow (c\tilde{c})(c\tilde{c}) \rightarrow c(de^{\pm})c(de^{\pm})$$

Signature: 2 LS electrons, ≥2 Jets

Squarks in RPV, Run I




And the latest

Stop into $\tau$ +b Jet via RPV

and

Single $\tilde{\nu}$ production and RPV decay into two leptons

# Search for Stop with RPV Decay

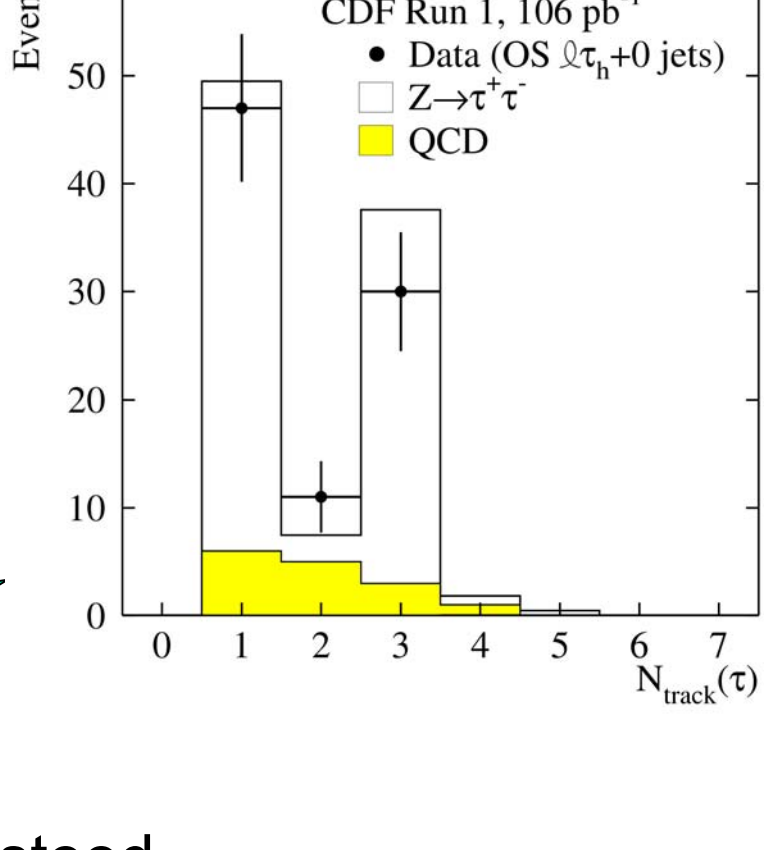
$$p\bar{p} \rightarrow \tilde{t}\bar{\tilde{t}} \rightarrow (b\tau)(\bar{b}\,\bar{\tau}) \rightarrow b(l\nu_l\bar{\nu}_\tau)\bar{b}(\tau_{\mathrm{h}}) \;\; (l = e, \mu)$$

$$\mathrm{Br} = 100\%$$

Run I, 106 pb$^{-1}$

Signature:

≥1 lepton (e, μ)
hadronic τ , OS with
≥2 b-jets (no tag)




Background:

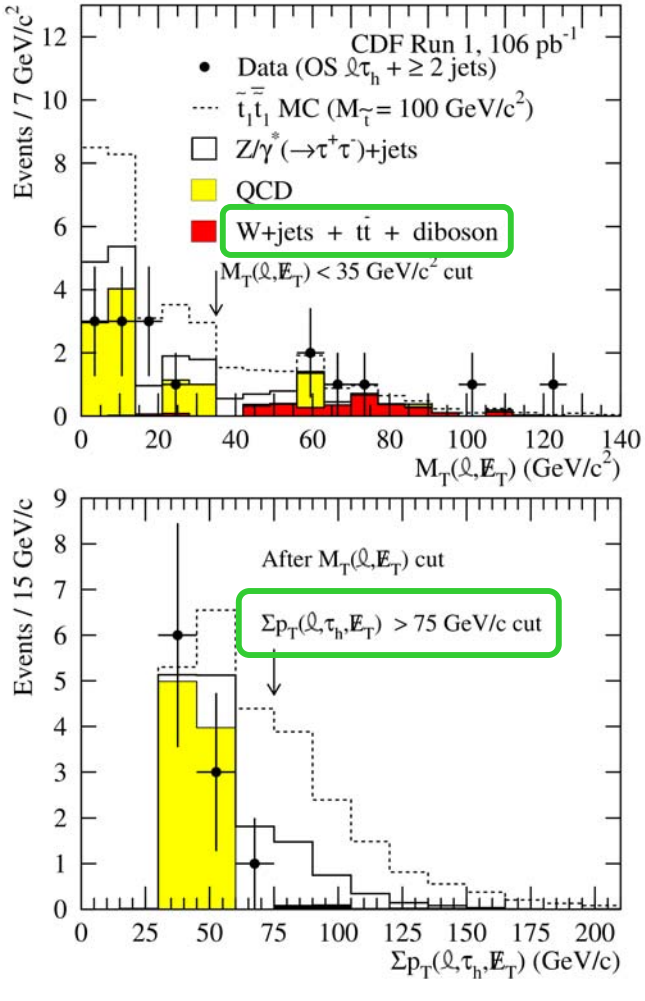
Drell-Yan → τ τ +Jets
Fake τ leptons (QCD)
$t\bar{t}$, Dibosons

Control Sample:

OS lepton & τ +0 Jets well understood

# Search for Stop with RPV decay

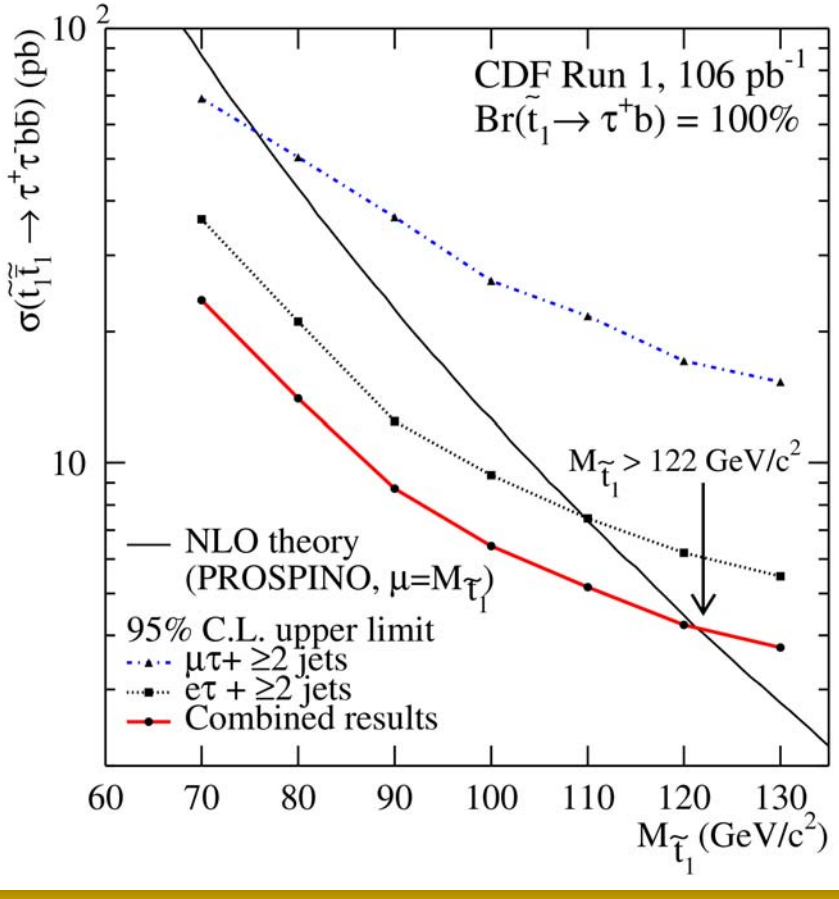
Selection:




Result:

Observed 0

Expected $3.2^{+1.4}_{-0.3}$



# Search for Sneutrino with RPV

$p\bar{p} \rightarrow \tilde{\nu} \rightarrow ll'$ $(l = e, \mu, \tau)$ RPV production & decays

Run I, 110 $pb^{-1}$

**Signature:**

OS different flavor leptons (e, μ)
(e τ, μ τ, if leptonic τ decays)

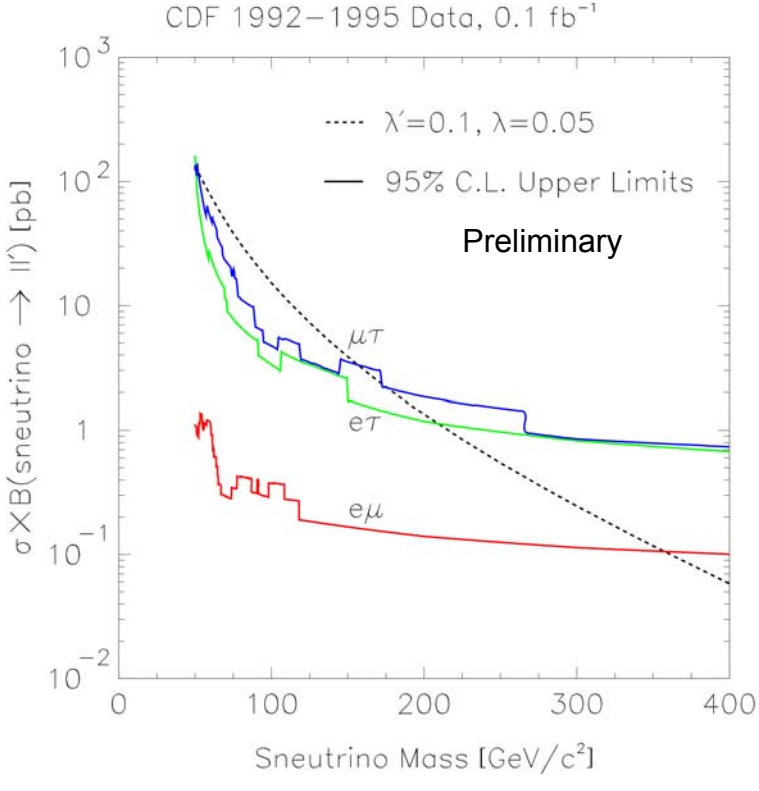
**Background:**

Drell-Yan → τ τ
Fake leptons (QCD)
$t\bar{t}$, Dibosons

**Selection:**

OS, high $p_T$ e or μ
angle cuts

Results




| | e, μ | e,τ | μ,τ |
|---|---|---|---|
| Data | 19 | 1.5±0.5 | 5.7±2.1 |
| Backgd. | 20±1 | 2.1±0.5 | 8.2±3.1 |

# First SUSY Searches in Run II

- High MET+Jets signature

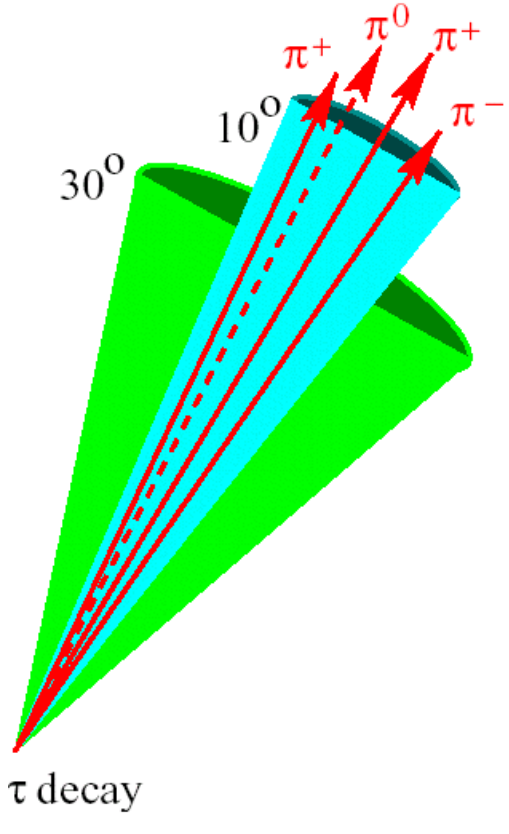
  Sensitivity tested on 1st generation LQ model

  Proceeding with search for squarks & gluinos

- Charged Massive Stable Particles

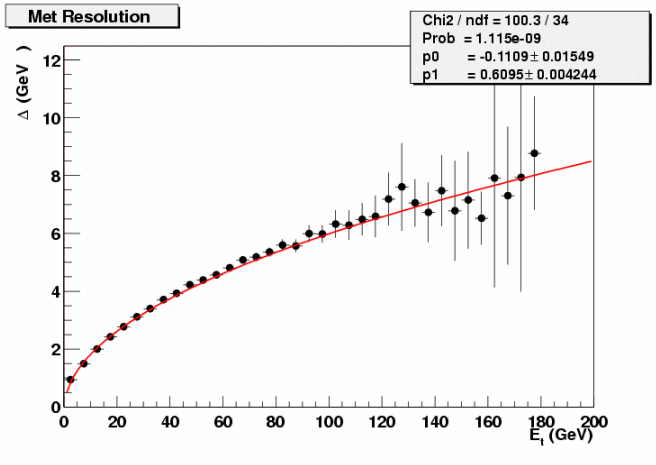
  Searched for long lived Stop

- Prepared ground for tau related analyses

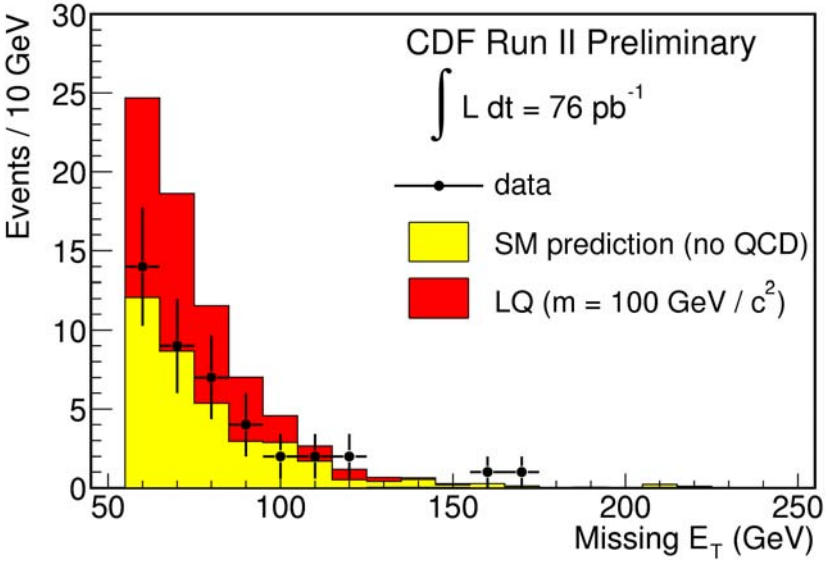


# MET in Run II

- Improved Run II MET due to
  - less beam related background
  - better plug calorimeter
  - lower threshold MET triggers
- MET resolution 0.61 (0.58 in Run I)




- High MET Run II data
  - compared to SM predictions
  - no signs of new physics
- Sensitivity tested on LQ model (see Steve Worm's talk)



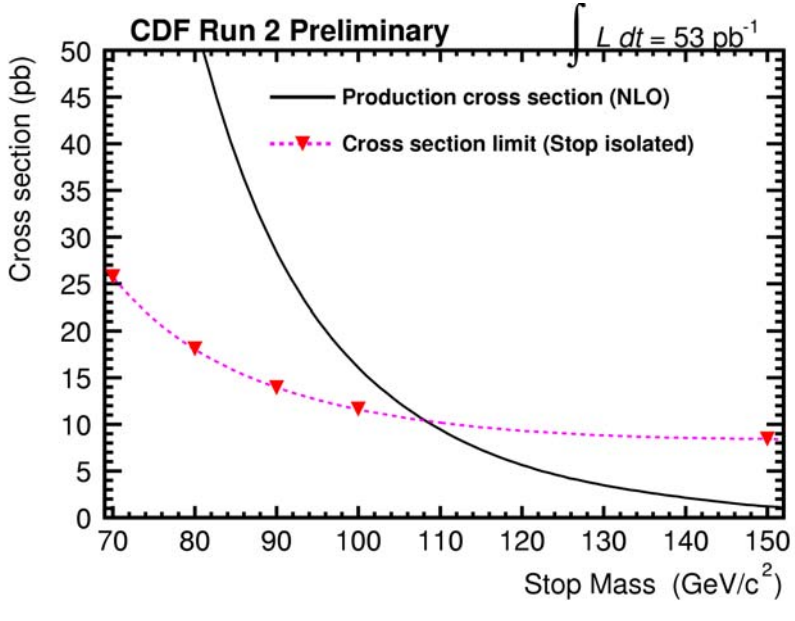

- Will improve after fine tune of calorimeters and beam position corrections

# Search for Long Lived Stop in Run II

- Previously searched for:
  - Stop decaying within detector
- If Stop long lived:
  - acts as Min. Ion. Particle
  - has a large Time Of Flight
- Heavy Stop:
  - high $p_T$ tracks
  - would reach muon system
- Selection:
  - tracks with $p_T \geq 40$ GeV/$c^2$
    $|TOF-t_0| \geq 2.5$ ns

**Results**

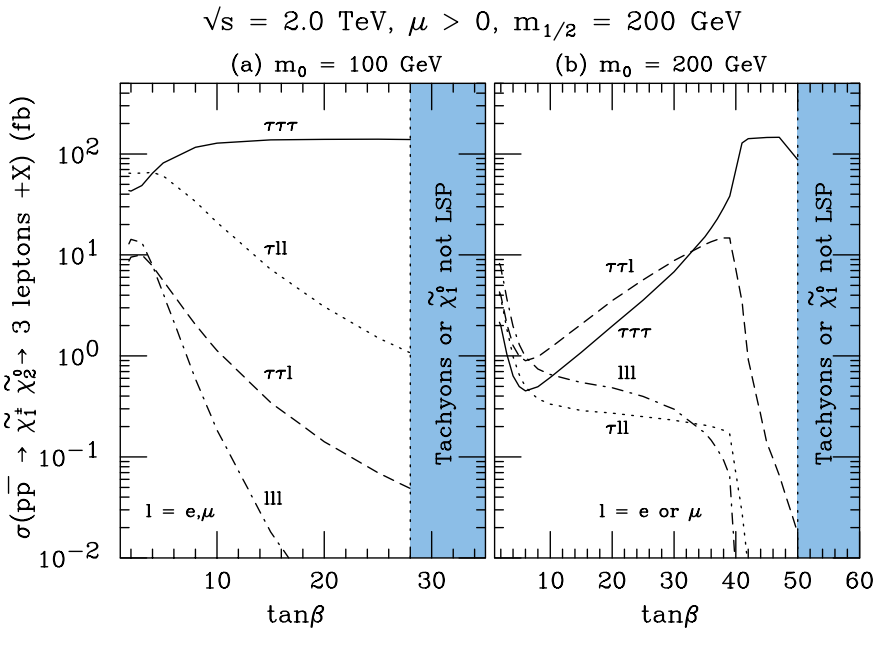
Observed 7 events
Expected 2.9±0.7(stat) ±3.1(syst)




Excluded m(stop)<107 GeV/$c^2$

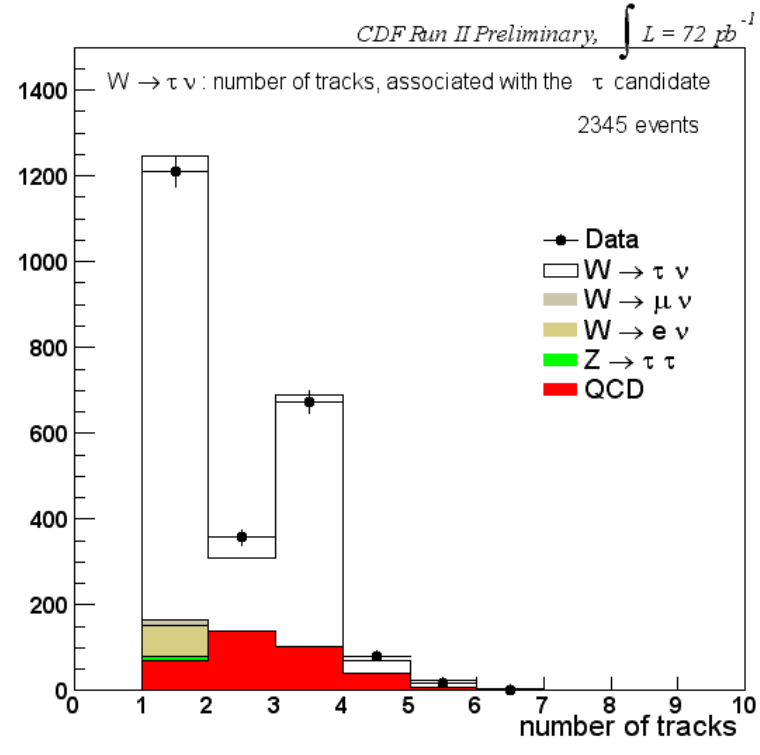
# SUSY with Taus in Run II

- Tau leptons:
  - significant at large tanβ
  - dominate Br in $\tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm$ 3-lepton search




- CDF implemented
  - tau + MET triggers
  - ditau triggers (as low as 5 GeV)

$W \rightarrow \tau \nu$




- Compared data to SM processes
  - $Z \rightarrow \tau\tau$, $W \rightarrow \tau \nu$
  - no new physics indication yet
  - looking forward for more data

# Conclusions

- Upgraded CDF is recording physics quality data @ high efficiency
  - reached more than 9 $pb^{-1}$ recorded/week
- Detector tune-ups in final stage
- First Run II "New Particle" searches completed
  - long lived Stop
  - $1^{st}$ generation Leptoquark
- With current luminosity, soon extending our Run I SUSY limits
- Tevatron has the best SUSY discovery potential before LHC