

Search for SUSY at CDF

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Outline

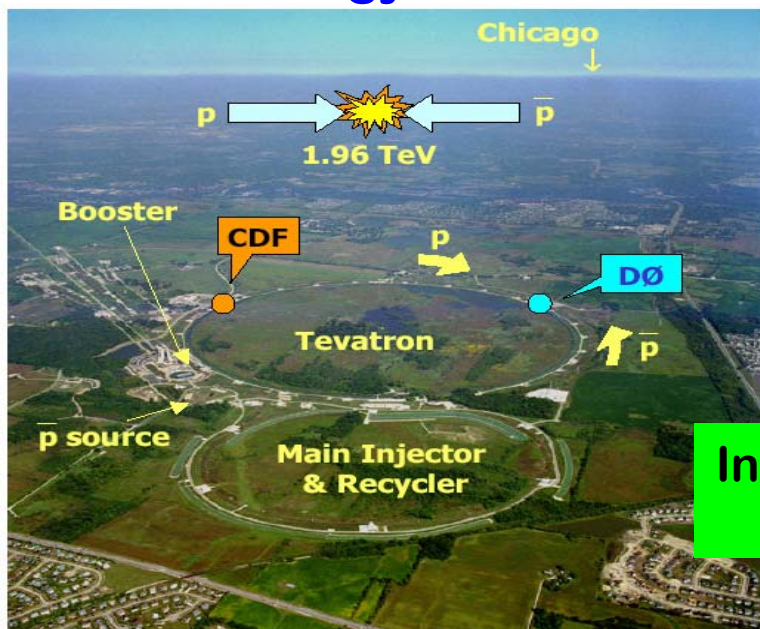
- CDF @ Tevatron
- SUSY Reminder
- Phenomenology
- Searches
- Conclusions





CDF @ Tevatron

The Energy Frontier



Muon system Basic coverage $|\eta| < 1.0$
Extension: $|\eta| < 1.5$

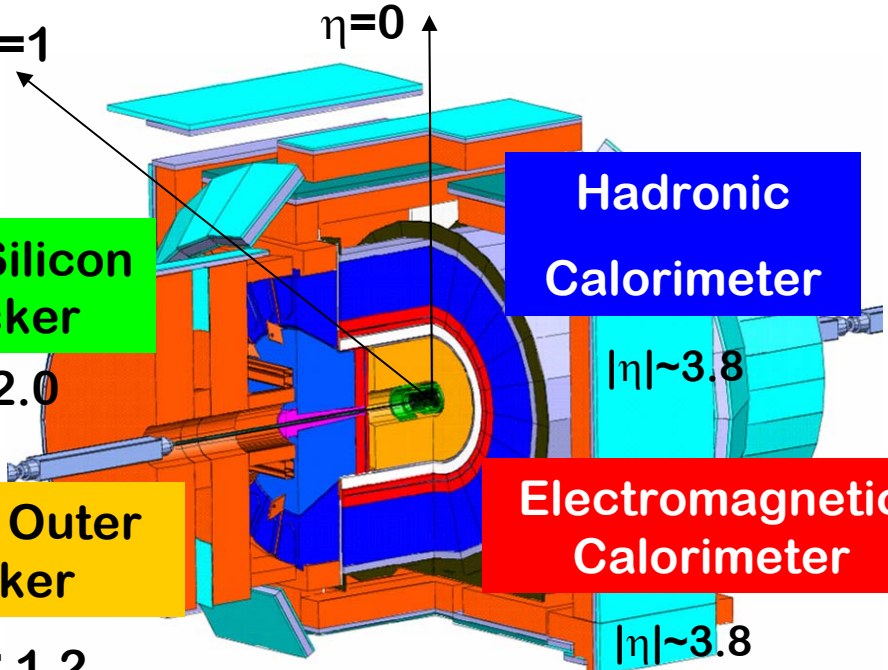
Inner Silicon Tracker
 $|\eta| \sim 2.0$

Central Outer Tracker
 $|\eta| < 1.2$

Hadronic Calorimeter
 $|\eta| \sim 3.8$

Electromagnetic Calorimeter
 $|\eta| \sim 3.8$

Delivered
> 1 fb⁻¹ !!





Supersymmetry

SM fermion (boson) \Leftrightarrow boson (fermion)
Minimal Supersymmetry Standard Model

| | | | |
|--|--|------------------------------|--------------------|
| $[u, d, c, s, t, b]_{L,R}$ | $[e, \mu, \tau]$ | $[\nu_{e,\mu,\tau}]$ | Spin $\frac{1}{2}$ |
| $[\tilde{u}, \tilde{d}, \tilde{c}, \tilde{s}, \tilde{t}, \tilde{b}]_{L,R}$ | $[\tilde{e}, \tilde{\mu}, \tilde{\tau}]$ | $[\tilde{\nu}_{e,\mu,\tau}]$ | Spin 0 |
| g | W^\pm, H^\pm | $\gamma, Z, H_1^0 H_2^0$ | Spin 1/Spin 0 |
| \tilde{g} | $\tilde{\chi}_{1,2}^\pm$ | $\tilde{\chi}_{1,2,3,4}^0$ | Spin $\frac{1}{2}$ |

New parity $R = (-1)^{3(B-L)+2S}$
 If conserved, **Lightest Susy Particle** is stable

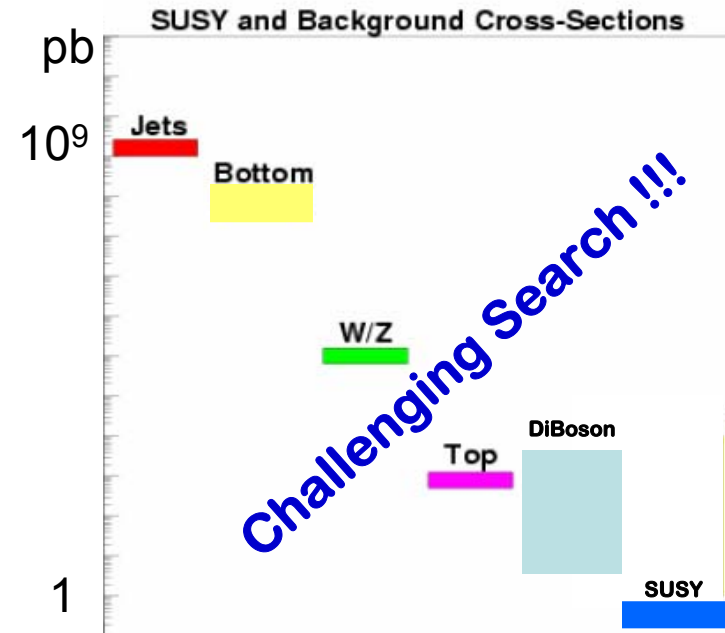
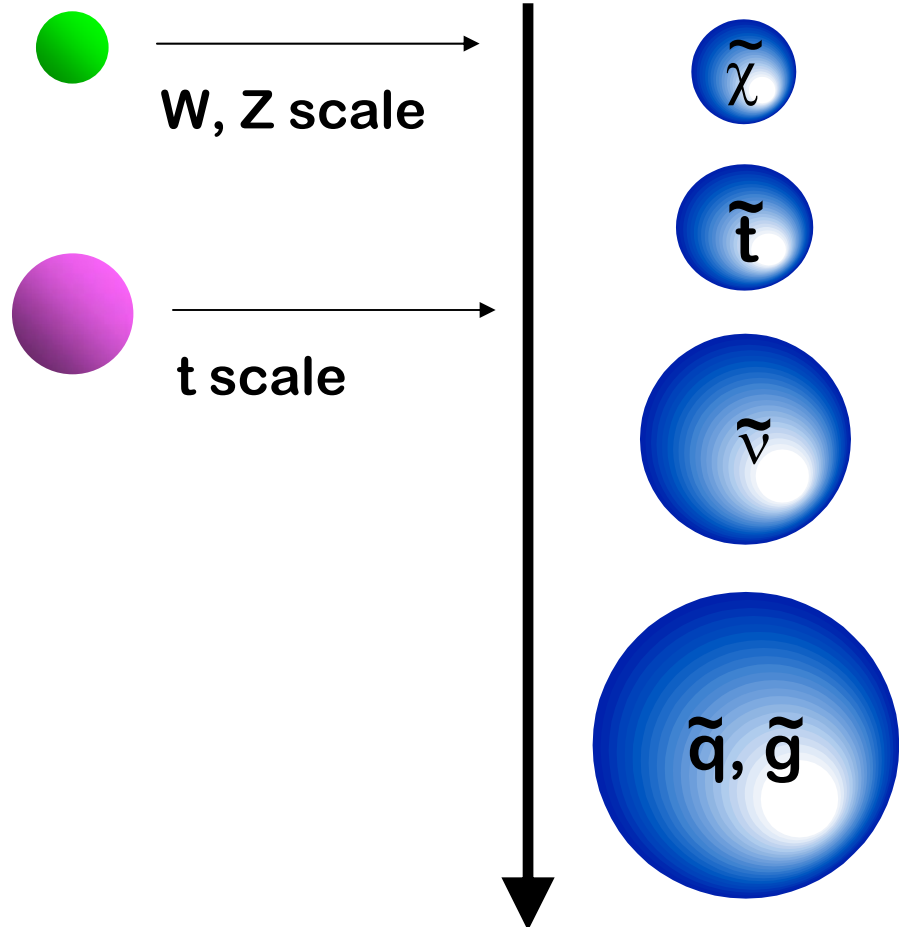
No superparticles yet \Rightarrow broken symmetry !!

| | Breaking | Free parameters | LSP |
|-----------------|---------------------|--|--------------------|
| mSUGRA | Gravity like | $m_0, m_{1/2}, \tan\beta, A_0, \text{sgn}(\mu)$ | $\tilde{\chi}_1^0$ |
| R_p violation | Gravity, Gauge, ... | $\lambda_{ijk}, \lambda'_{ijk}, \lambda''_{ijk}$ | ---- |
| GMSB | Gauge mediated | $\Lambda, M_m, N, \tan\beta, \text{sgn}(\mu), C_G$ | \tilde{G} |

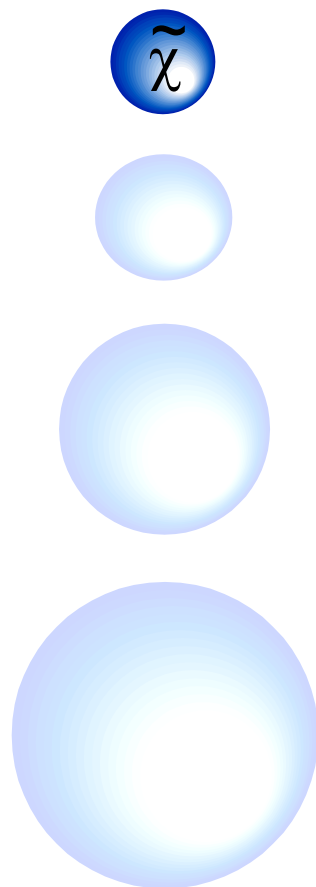


Phenomenology

Mass Spectrum



SUSY in many different signature !



Chargino & Neutralino

mSUGRA & GMSB

Stop

Sneutrino

Squark & Gluino

mSUGRA

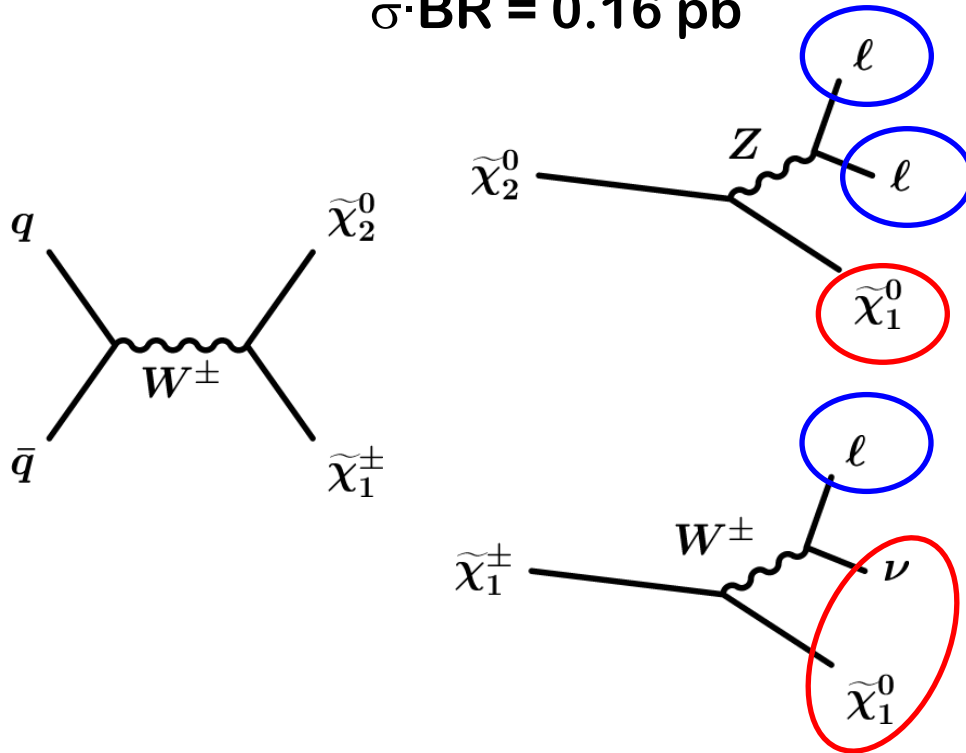


Chargino & Neutralino

mSUGRA SCENARIO

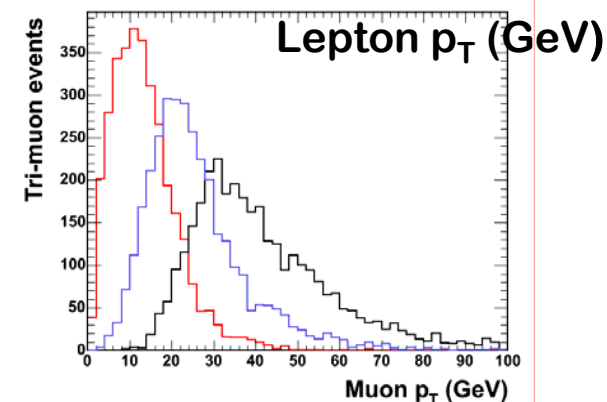
$$M_{1/2}=180, m_0=0, A_0=0, \mu>0, \tan\beta=5$$

$$\sigma \cdot \text{BR} = 0.16 \text{ pb}$$



Limit on Chargino Mass
LEP II 103 GeV/c² (model ind.)
D0 117 GeV/c² (model dep.)

Striking Signature!
2 or 3 Leptons + MET
Golden Mode at Tevatron

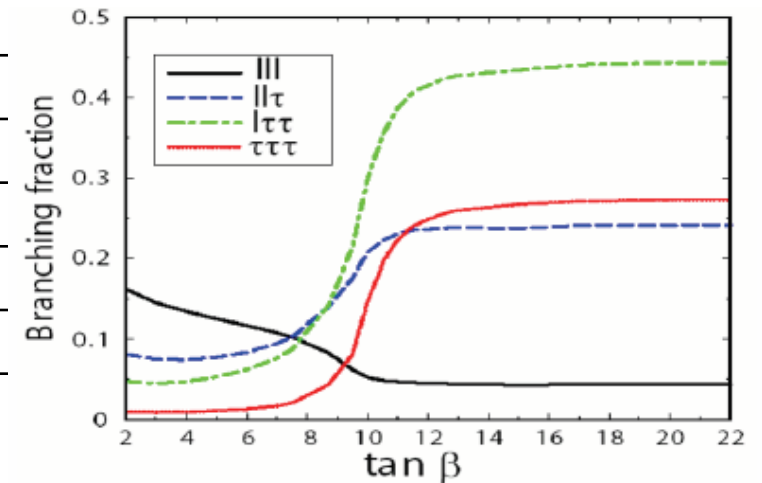




Analysis Strategy

Higher acceptance by combining several analyses

| MODE | TRIGGER PATH | Data(fb ⁻¹) |
|--|-----------------------------------|-------------------------|
| $\mu\mu + e/\mu$ | Single Muon $p_T > 18$ GeV | 0.7 |
| $\mu e + e/\mu$ | Single Muon $p_T > 18$ GeV | 0.7 |
| $ee + e/\mu$ | Single Muon $E_T > 18$ GeV | 0.3 |
| $\mu\mu + e/\mu$ | Dimuon $p_T > 4, 4$ GeV | 0.3 |
| $ee + \text{track}$ | Dielectron $E_T > 4, 4$ GeV | 0.6 |
| $e^\pm e^\pm, \mu^\pm \mu^\pm, e^\pm \mu^\pm$ (LS) | Single Lepton $E_T, p_T > 18$ GeV | 0.7 |



1st and 2nd lepton generation analyses sensitive to low $\tan \beta$ scenarios

ee & Track analysis sensitive to τ modes

LS can detect squark & gluino production



Analysis Overview

SM Backgrounds Drell Yan & DiBoson & QCD

- Veto resonances (J/Ψ, Upsilon, Z)
- Veto jets
- MET > 15 GeV

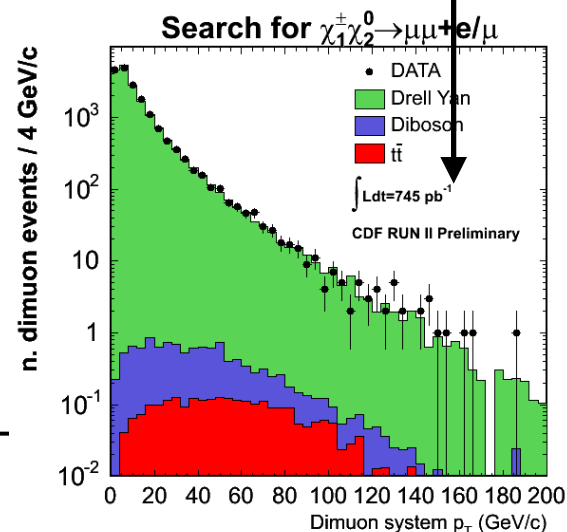
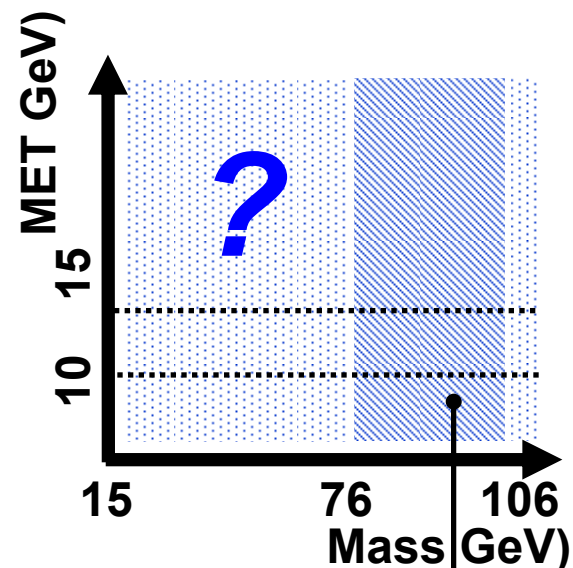
“Blind” counting experiment

Data validated

in up to 17 control regions per channel !!

Challenges

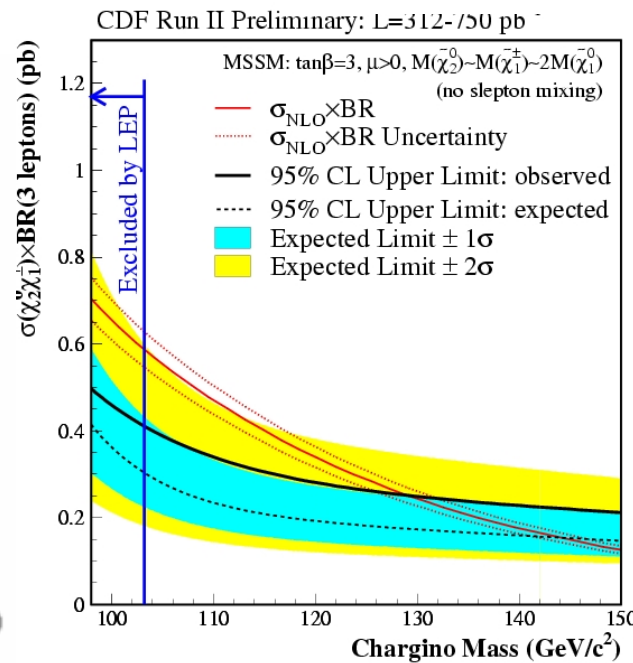
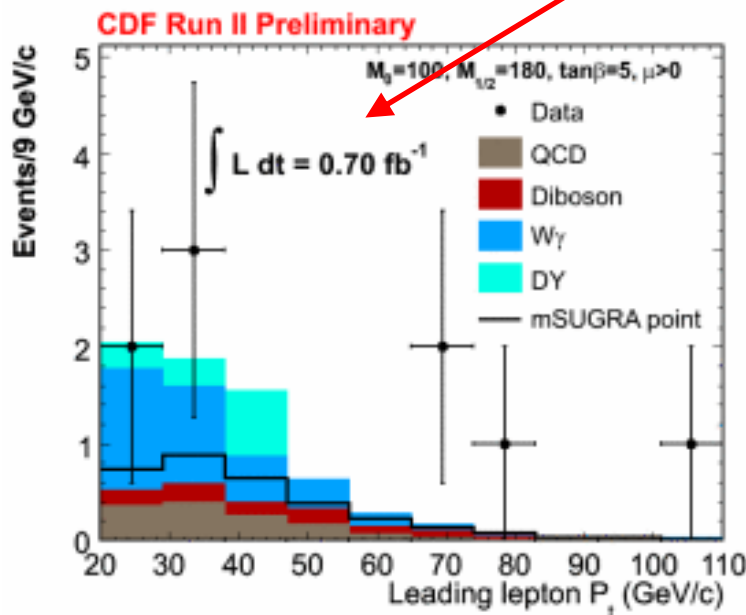
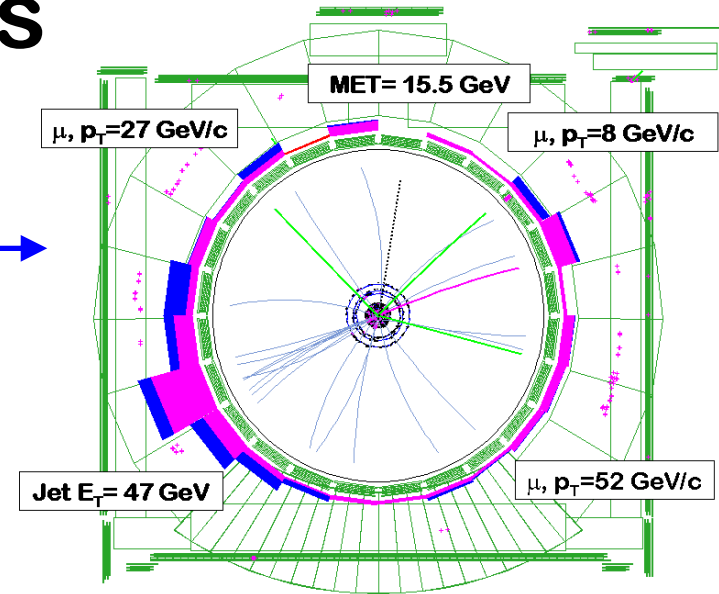
- electrons from photon conversions
- extra interactions in electron channels
- track reconstruction and QCD background in muon channels





Results

| MODE | SM Backg. | SUSY | Data |
|---------------------|-----------------|------|------|
| $\mu\mu + e/\mu$ | 0.64 ± 0.18 | 1.6 | 1 |
| $\mu e + e/\mu$ | 0.78 ± 0.17 | 1.0 | 0 |
| $ee + e/\mu$ | 0.17 ± 0.05 | 0.5 | 0 |
| $\mu\mu + e/\mu$ | 0.13 ± 0.03 | 0.2 | 0 |
| $ee + \text{track}$ | 0.49 ± 0.14 | 1.2 | 1 |
| LS leptons | 6.8 ± 1.0 | 3.2 | 9 |

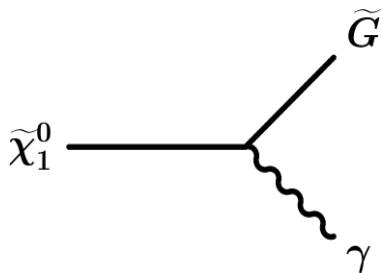


Chargino Mass Excluded up to $127 \text{ GeV}/c^2$

Sensitivity up to $140 \text{ GeV}/c^2$

Chargino & Neutralino

GMSB SCENARIO



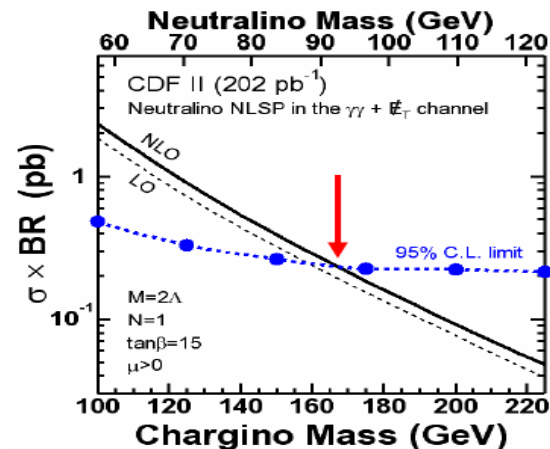
Backgrounds

cosmics and misID γ

- $p_T(\gamma) > 20, 13 \text{ GeV}$
- $\text{MET} > 45 \text{ GeV}$

0 observed vs. SM 0.27 ± 0.12

Signature $\gamma\gamma + \text{MET}$

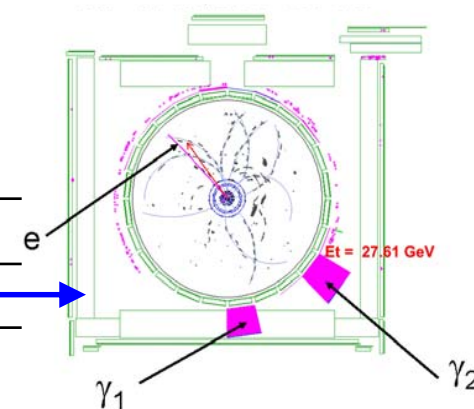


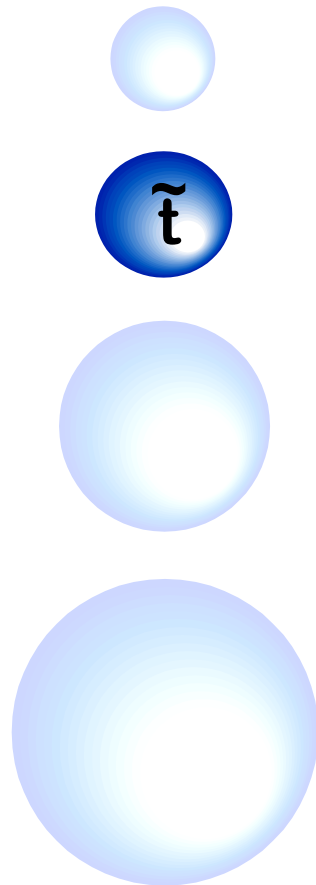
Keep hunting for the Run1 event! in up to 1fb^{-1}

Signature $\gamma\gamma + X (e, \mu, \gamma)$

- $p_T(\gamma) > 13 \text{ GeV}$
- $p_T(e/\mu) > 20 \text{ GeV}$

| MODE | Lum (fb^{-1}) | SM Backg. | Data |
|-------------------------|--------------------------|---------------|------|
| $\gamma\gamma + \gamma$ | 1.0 | 1.9 ± 0.6 | 4 |
| $\gamma\gamma + e$ | 0.7 | 4.5 ± 0.8 | 2 |
| $\gamma\gamma + \mu$ | 0.7 | 0.5 ± 0.1 | 0 |





Chargino & Neutralino
mSUGRA & GMSB

Stop

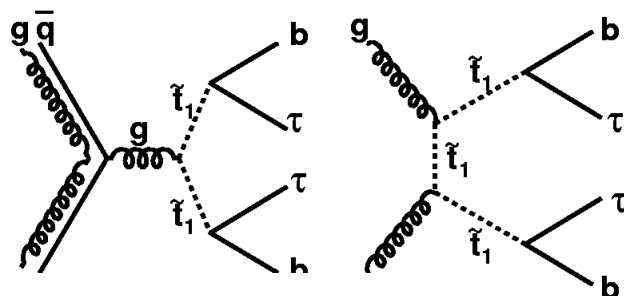
Sneutrino

Squark & Gluino
mSUGRA

Stop

mSUGRA SCENARIO $\tilde{t}_1 \rightarrow \chi_1^0 c$ and $\tilde{t}_1 \rightarrow \chi_1^\pm b$

R_p VIOLATION SCENARIO

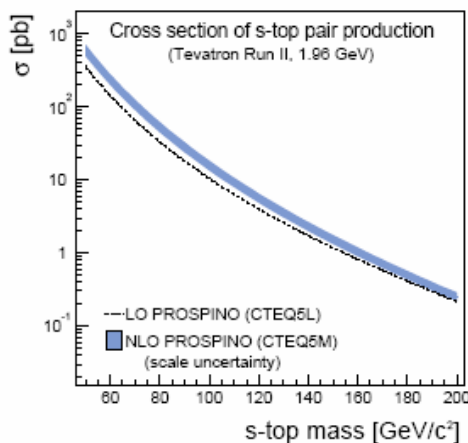


Signature

2 jets

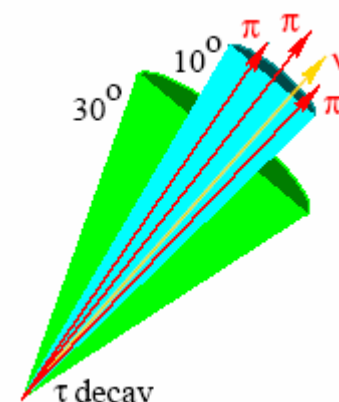
τ_h & $\tau_{e/\mu}$

Limit on Stop Mass
CDF Run II 129 GeV/c²



Challenges

- τ identification
 - high purity and efficiency
 - $Z \rightarrow \tau\tau$ for hadronic τ ID
 - $\epsilon \sim 56\%$



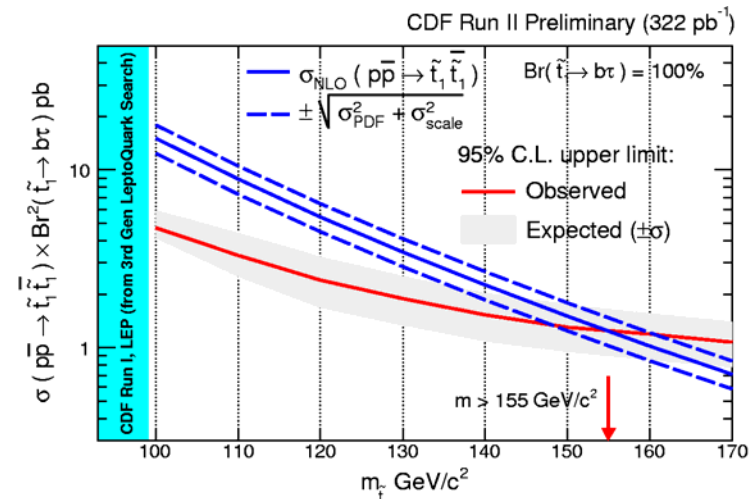
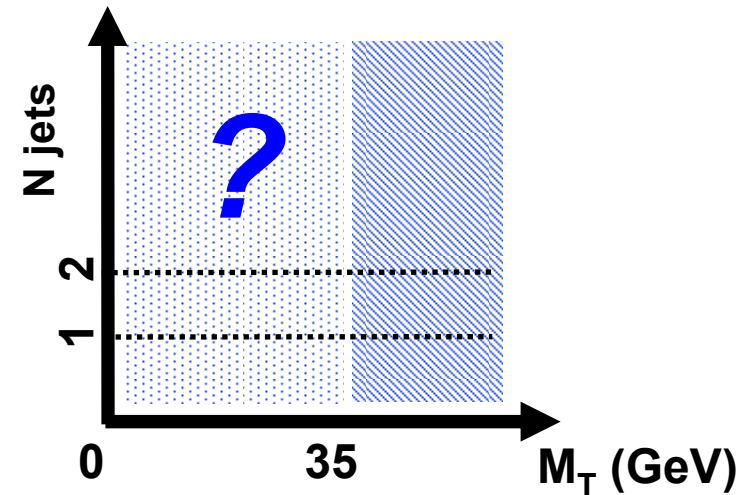
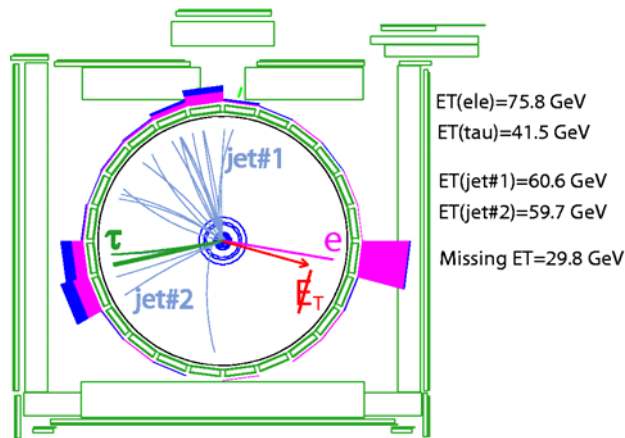
Background & Results

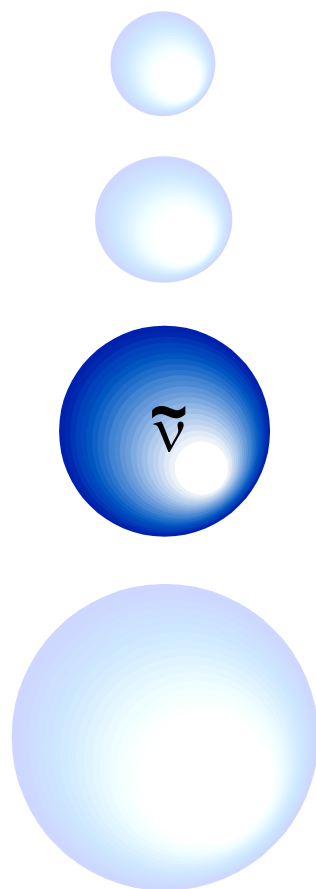
“Blind” counting experiment

SM Backgrounds QCD & W/Z + jets

- $p_T(e/\mu) > 10 \text{ GeV}$ & $p_T(\tau_h) > 15 \text{ GeV}$
- $E_T(\text{jet}) > 20 \text{ GeV}$
- Resonance veto
- $S = p_T^{e/\mu} + p_T^\tau + \text{MET} > 110 \text{ GeV}$

2 events vs. SM $2.3^{+0.5}_{-0.2}$ in 0.3 fb^{-1}





Chargino & Neutralino
mSUGRA & GMSB

Stop

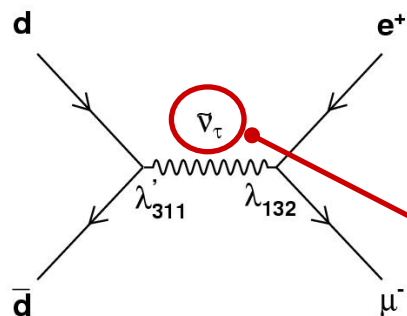
Sneutrino

Squark & Gluino
mSUGRA



Sneutrinos

R_p VIOLATION SCENARIO



Signature

$e \ \& \ \mu$

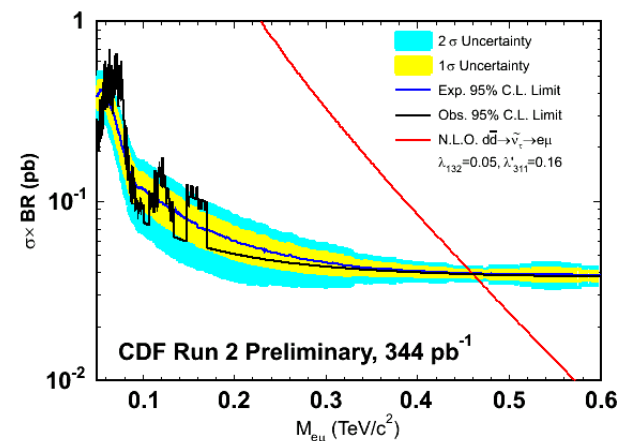
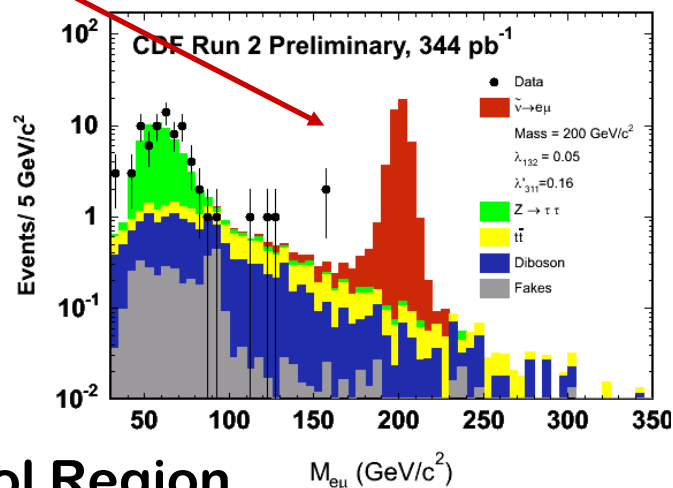
Limit on Sneutrino Mass

CDF Run I 350 GeV/c^2

SM BACKGROUNDS

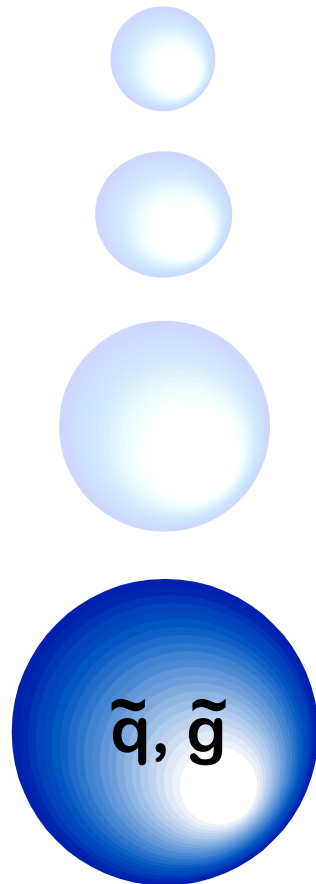
$Z \rightarrow \tau\tau$ & Diboson

▪ $p_T(e, \mu) > 20 \text{ GeV}$



Low mass as Control Region

5 events vs. SM 7.7 ± 0.6 in 0.3 fb^{-1}



Chargino & Neutralino

Stop

Sneutrino

Squark & Gluino
mSUGRA

Squarks and Gluinos

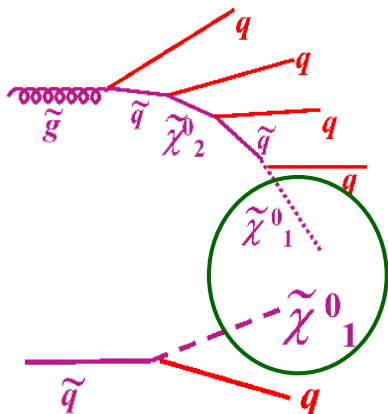
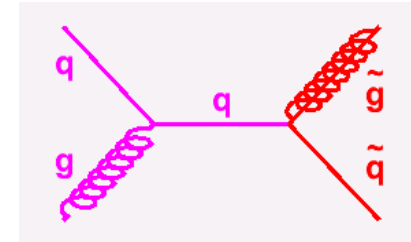
mSUGRA SCENARIO

Glينو mass > squark mass $A_0=0, \mu < 0, \tan\beta=5$

Limit on Mass

D0 RunII Squark $\sim 350 \text{ GeV}/c^2$

D0 RunII Gluino $\sim 250 \text{ GeV}/c^2$



Signature

Multijets

&

MET

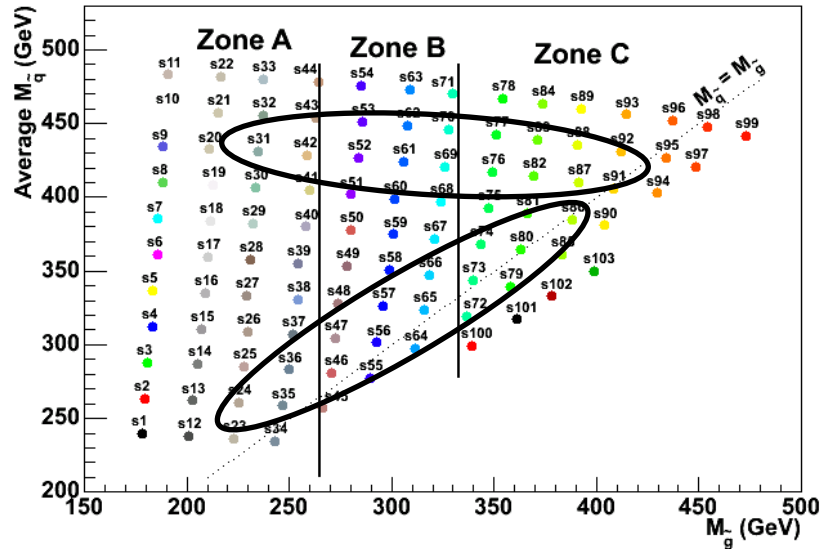
Challenges

- QCD background
 - LO MC simulation
 - jet energy reconstruction
 - energy calibration



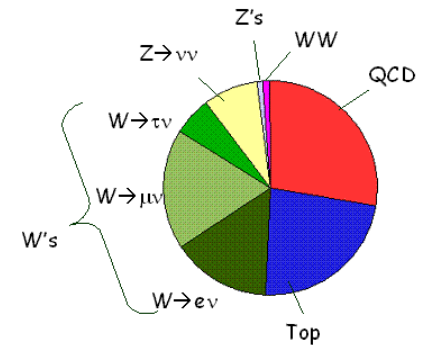
Analysis Overview

PYTHIA generation points



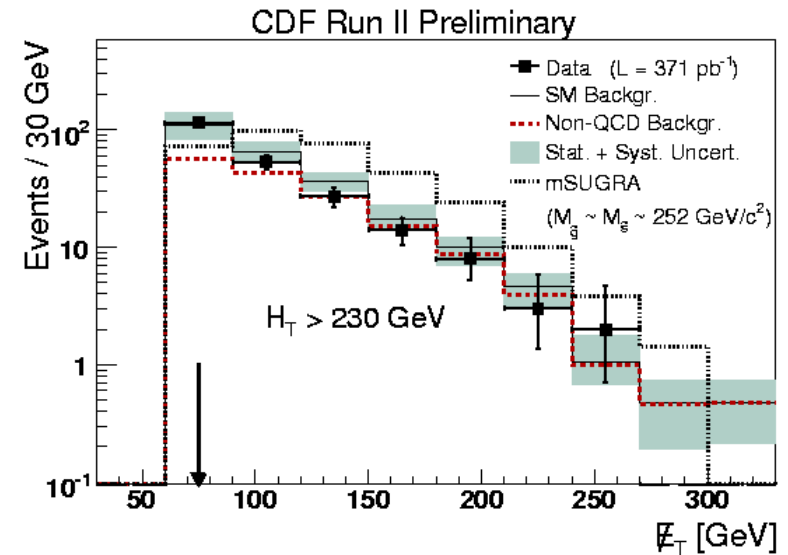
Suppress background

- pre-selection cuts
- E_T of 3 jets
- MET
- $H_T = \sum \text{jet } E_T$



| | ME_T | H_T | E_T^{jet1} | E_T^{jet2} | E_T^{jet3} |
|---|--------|-------|---------------------|---------------------|---------------------|
| A | 75 | 230 | 95 | 55 | 25 |
| B | 90 | 280 | 120 | 70 | 25 |
| C | 120 | 330 | 140 | 100 | 25 |

Units of GeV



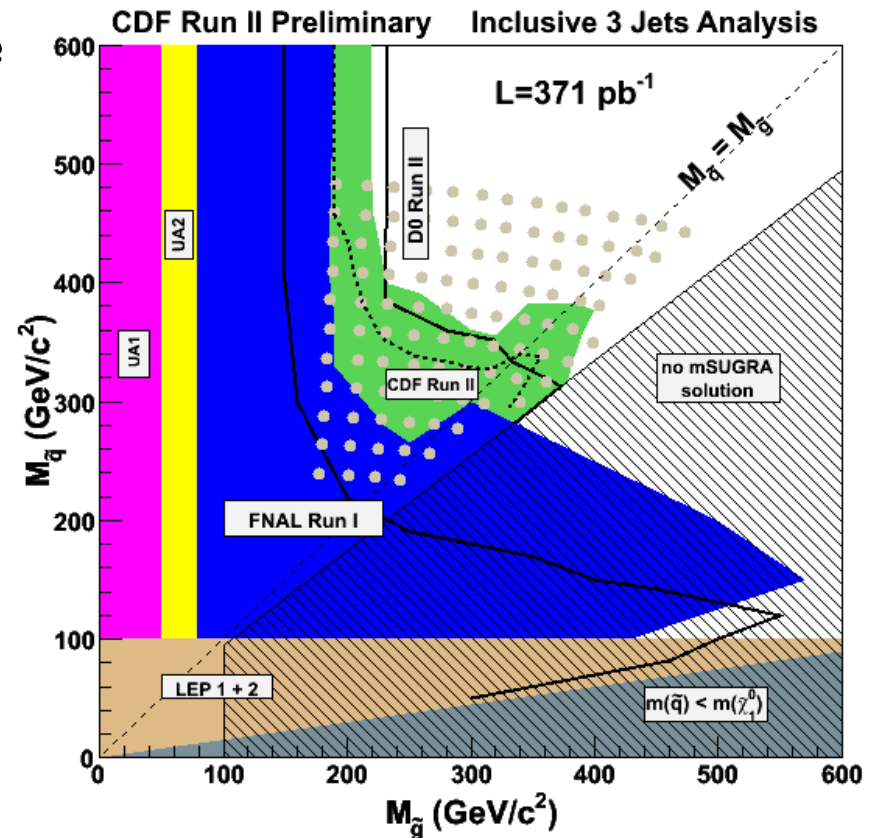
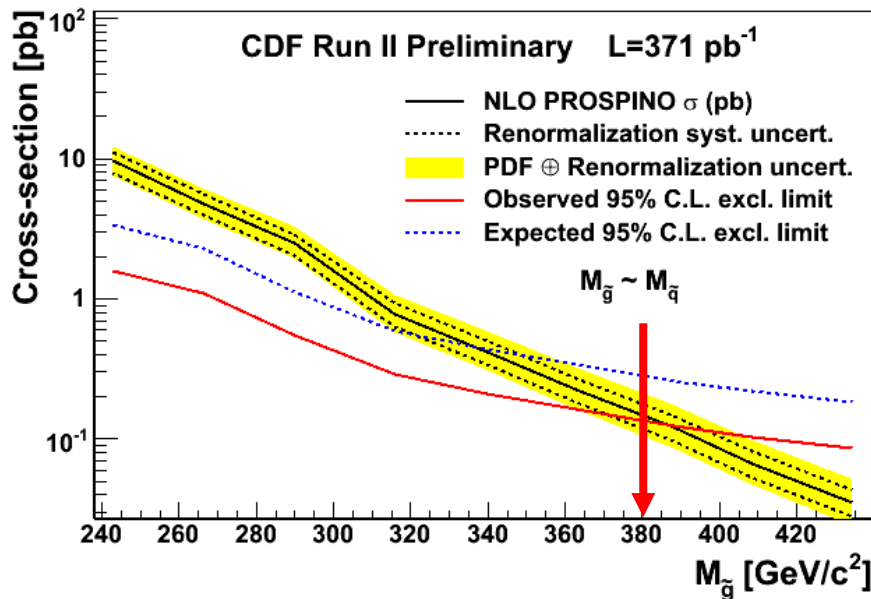


Results

NO evidence for SUSY in $\sim 0.4 \text{ fb}^{-1}$!

Limit on gluino mass in the scenario $m(\text{gluino}) \sim \text{mass}(\text{squark})$

$\text{mass}(\text{gluino}) > 380 \text{ GeV}/c^2$





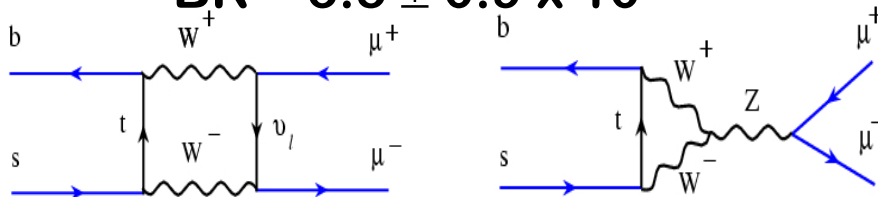
Indirect search for SUSY?



$B_s \rightarrow \mu\mu$

Suppressed in the SM:

$$BR = 3.5 \pm 0.9 \times 10^{-9}$$

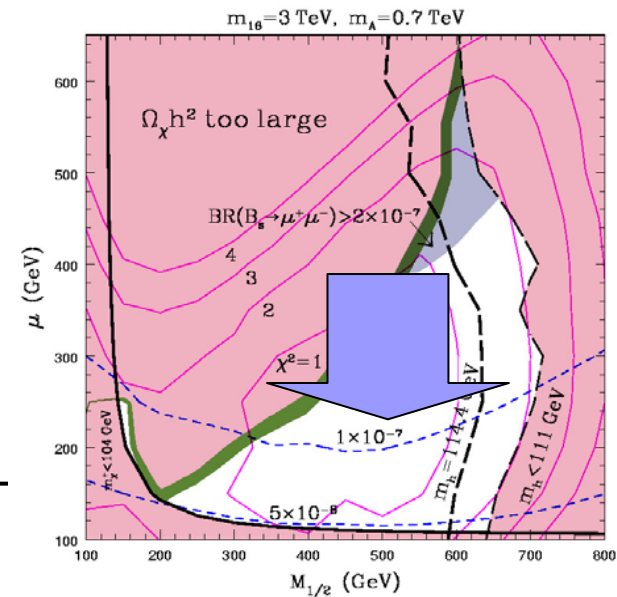
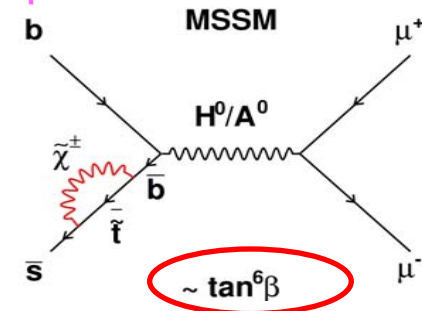


- Look for excess of dimuon events in the B_s mass window in up to $\sim 0.8 \text{ fb}^{-1}$
- Likelihood ratio powerful tool to reject background
- $B^+ \rightarrow J/\Psi K^+$ normalization mode

| MODE | SM Backg. | Data |
|-----------------------|---------------|------|
| Central Central μ | 0.9 ± 0.3 | 1 |
| Central Forward μ | 0.4 ± 0.2 | 0 |

$BR < 1 \times 10^{-7}$
95% C.L

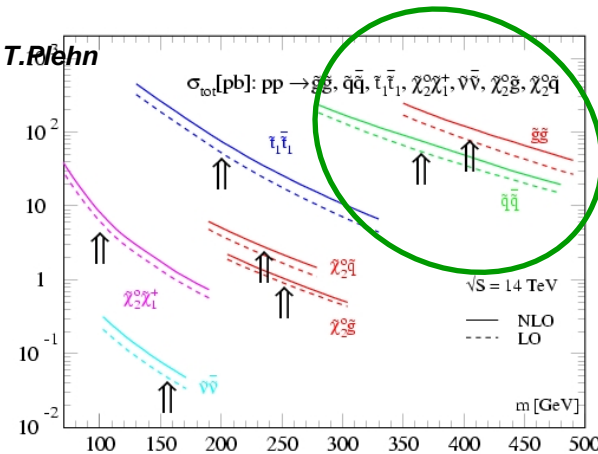
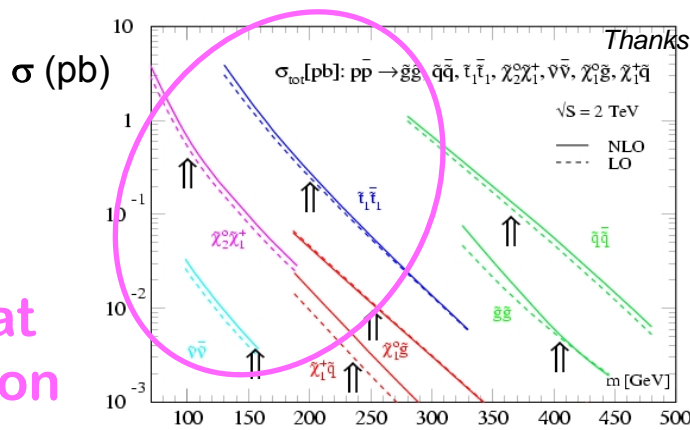
mSUGRA scenario @ large $\tan\beta$
GMSB with low N_m
 R_p violation scenario





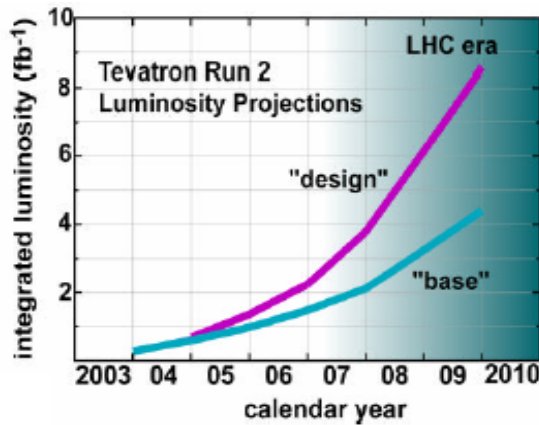
Summary

We searched for SUSY in wide range of signatures!



Best at Tevatron

Getting ready for LHC !



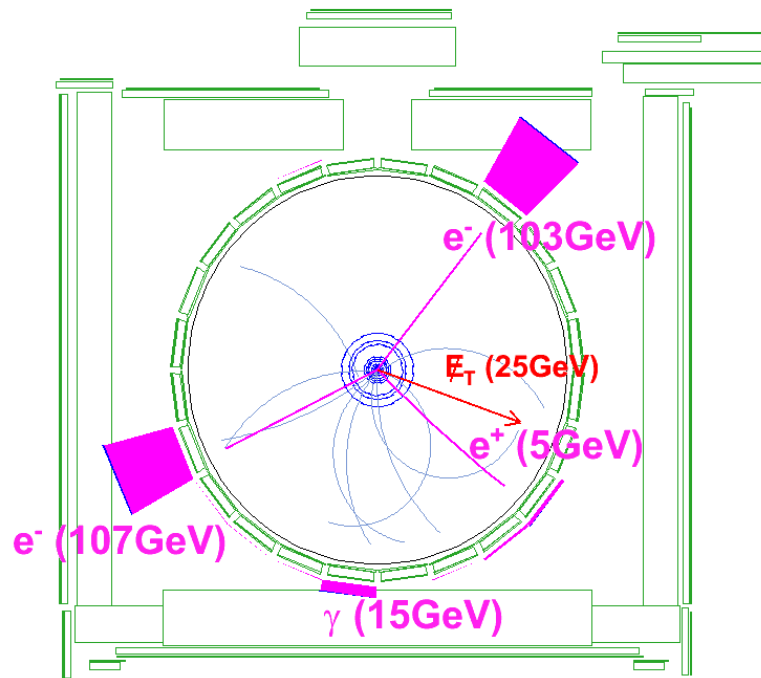
World best limits set with $\sim 1\text{fb}^{-1}$ of CDF data

Expect up to 8fb^{-1} by 2009,

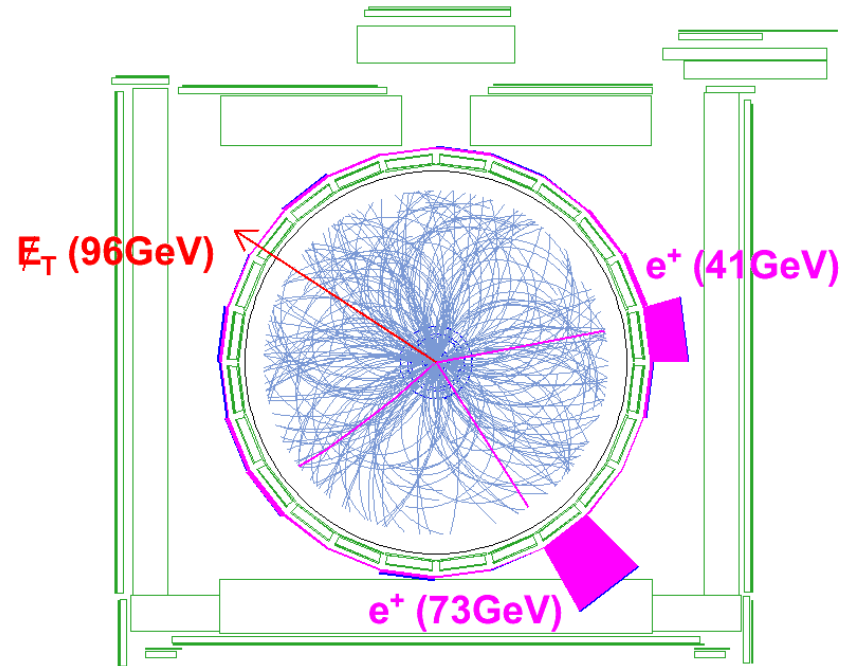
the hunt continues !!



Back up Slides



Two electrons above 100 GeV each. In the same event we have a photon of 15 GeV, Met of 25 GeV and a third electron of 5 GeV that does not pass the calorimeter isolation



This event has more than 100 GeV Met. There are lots of piled-up interactions. As one can see from the next figure, the third electron does not come from the same interaction vertex

