Searching SUSY at the Tevatron

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Outline

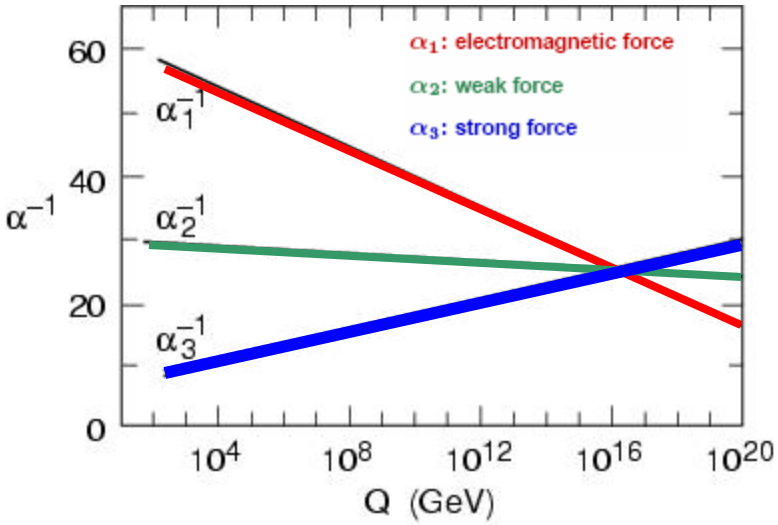
- Focus on searches for squark and gluinos
- Searches for chargino-neutralino and GMSB covered by Tuan Vu Anh
- Results from first ~200 pb^{-1} of the Tevatron run II
  - Tevatron already producing some of the world's best limit
  - Luminosity record in July 2004 of 1×10^{32} $cm^{-2}s^{-1}$
- Topics
  - squark searches in events with $\not{E}_T$ and jets (D0, 85 pb^{-1})
  - sbottom searches in events with $\not{E}_T$ and b-tagged jets (CDF, 156 pb^{-1})
  - light stable stops (CDF, 53 pb^{-1})

CDF Brings the Bubbly Stuff to Main Control Room

CDF delivered a case of champagne to the Main Control Room on Tuesday after losing a bet about the recent luminosity record.

SUSY

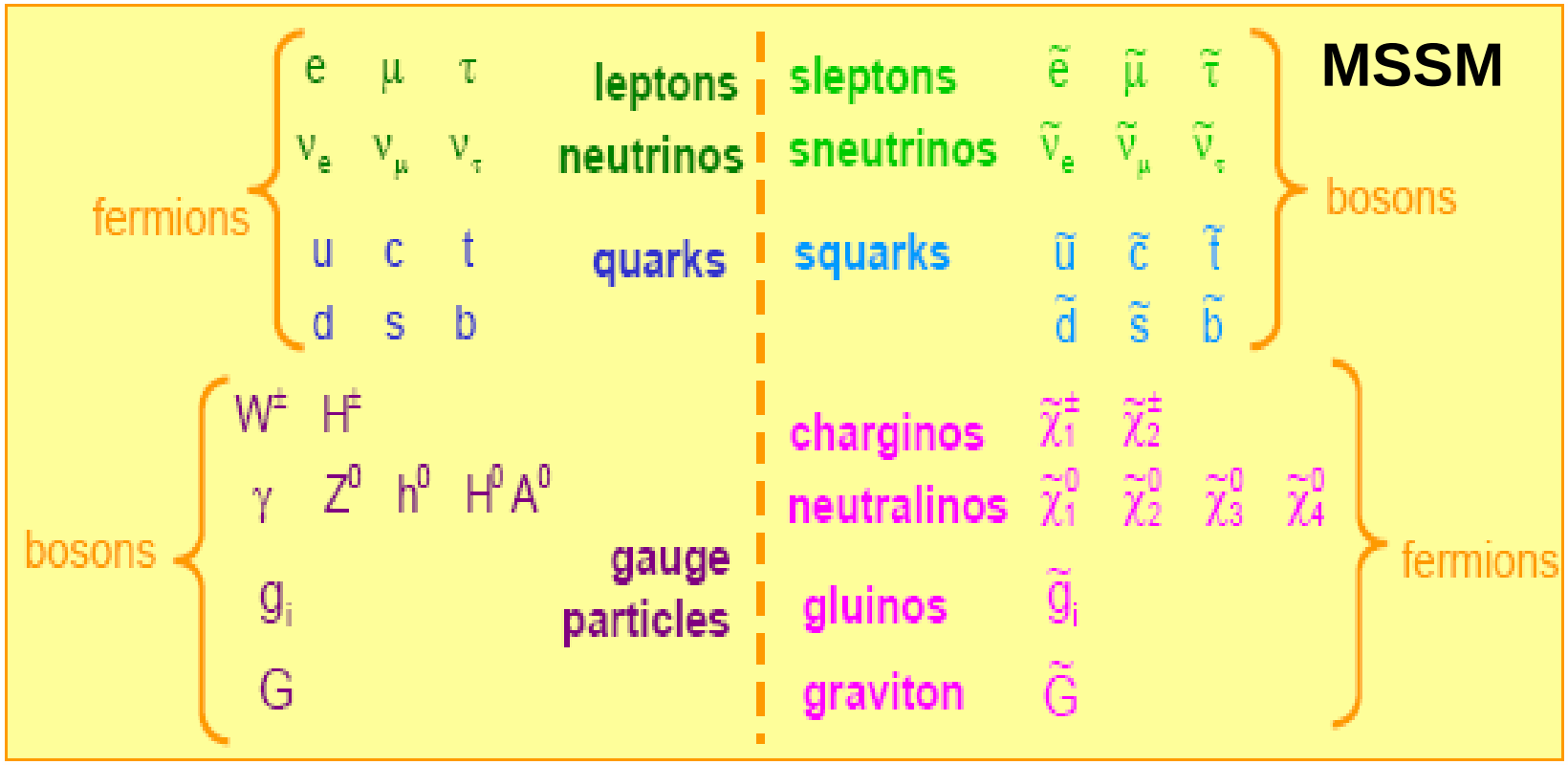
- **SUSY is a natural extension of the SM that unifies particles of different spin:**
  - **Solves "fine-tuning" if M(SUSY)<1TEV**
  - **Predicts unification of the gauge couplings**
  - **Provides dark matter candidate**
  - **Includes quantum gravity**
  - **Predicts a light Higgs**



- **The discovery of SUSY would be a fundamental revolution in physics**

SUSY

Particles R=1 $R = (-1)^{3B+L+2S}$ **SParticles R=-1**



MSSM has 124 parameters:

M_1,M_2, M_3, Gaugino masses, Sfermion masses

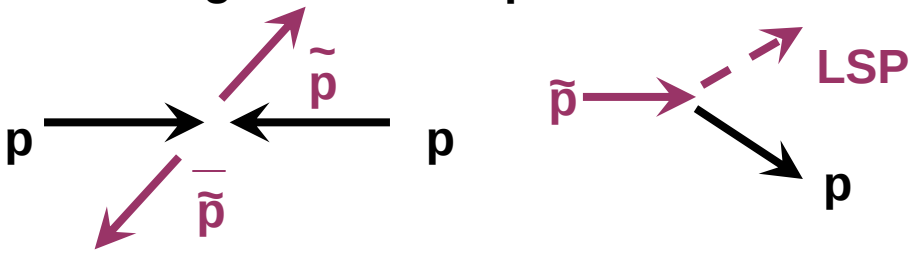
tanβ, μ, m_A Higgs(ino) mass/mixing

A_τ, A_b, A_t (+45 RPV)

- **SUSY is a broken symmetry**

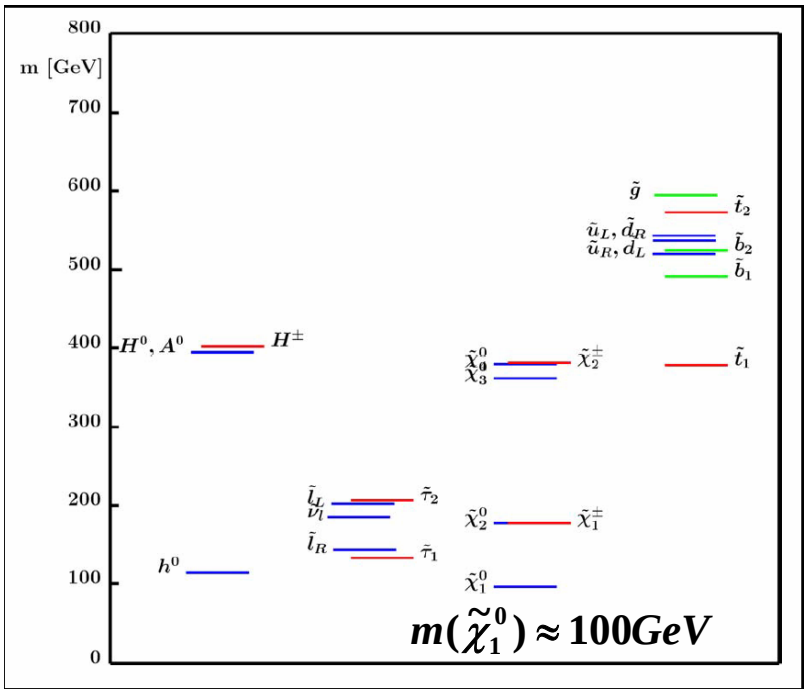
SUSY Breaking

- **If R-parity= $(-1)^{3B+L+2S}$ is conserved:**
  - SUSY particles are pair produced
  - Lightest SUSY particle is stable



- **~~SUSY~~ has implications on phenomenology :**
  - Gravity LSP: often $\tilde{\chi}_1^0$
  - Gauge LSP: $\tilde{G}$
  - Anomaly LSP: $\tilde{\chi}_1^0, \tilde{\nu}, \tilde{G}$

- **mSUGRA scenarios**

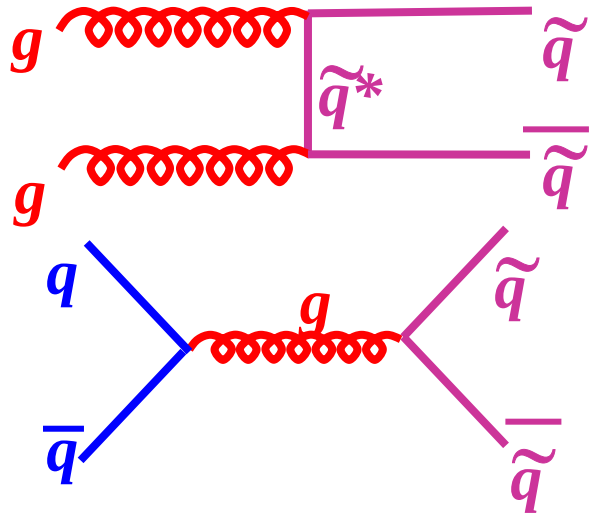


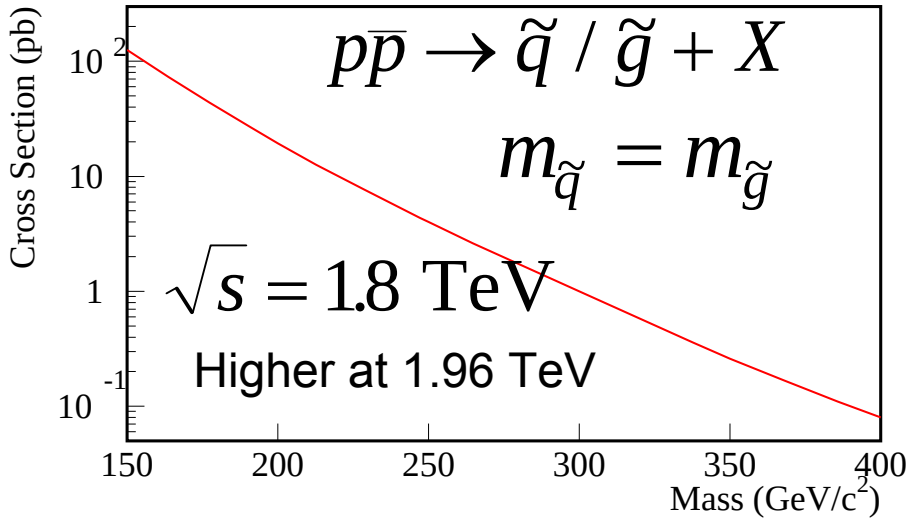
mSUGRA parameters:

- $m_{1/2}$: gaugino mass
- sgnμ : higgsino mass term
- tanβ : Higgs fields vev ratio
- m_0 : sfermions and Higgs mass
- A_0 : trilinear coupling

Cross sections

- **Colored sparticles such as squarks and gluinos should be copiously produced at the Tevatron, if light**





- Third generation squarks could be light, due to large mixing

$$\tilde{q} = \tilde{q}_L \cos\Theta_{\tilde{q}} + \tilde{q}_R \sin\Theta_{\tilde{q}}$$

Light **Sbottom: large tanβ**

Light **Stop: large m_t**

Mass matrix mixing term

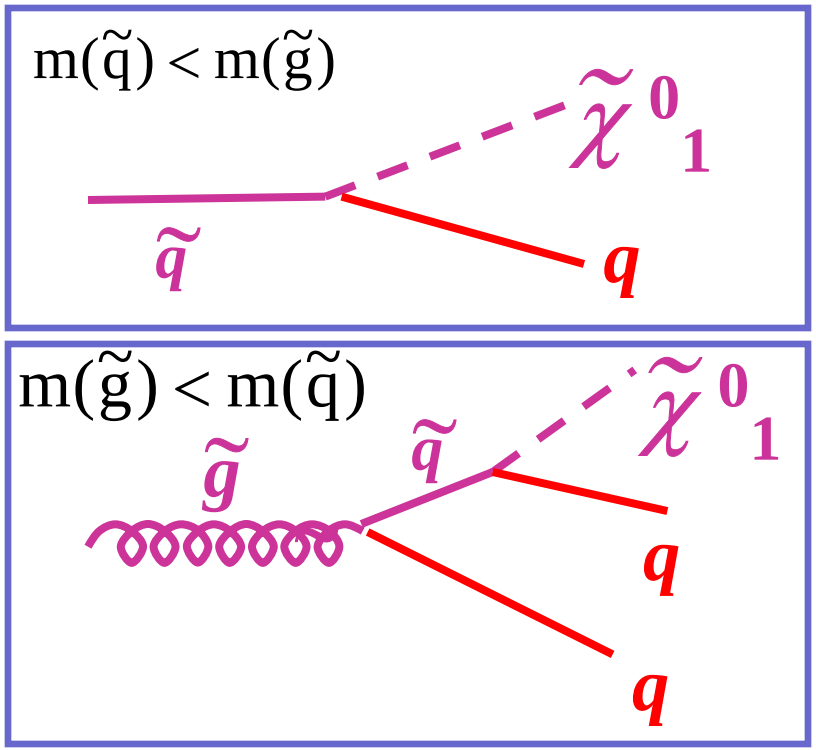
$$m_q (A_q - \mu\kappa)$$

$\kappa = \tan\beta$ down type quarks

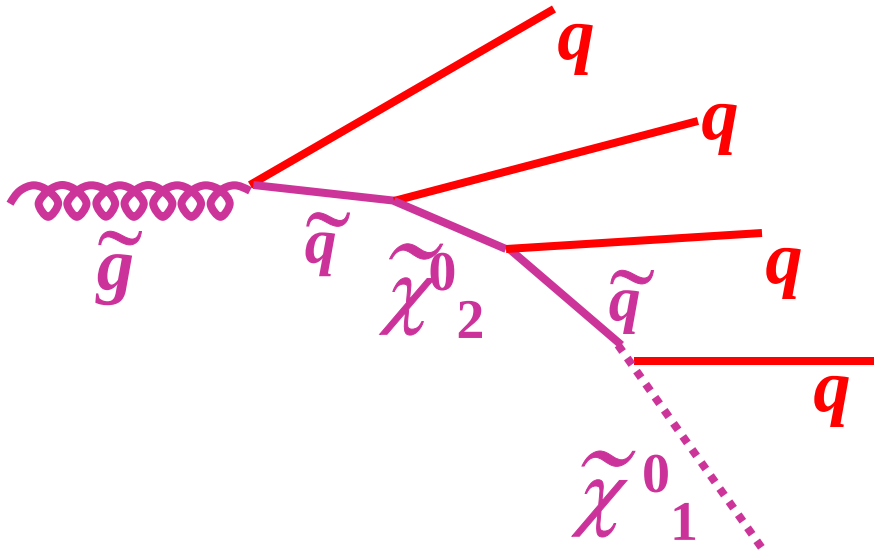
$\kappa = 1/\tan\beta$ up type quarks

Decays

If R-parity is conserved, squarks and gluinos can decay:
directly into the LSP (χ^0_1)

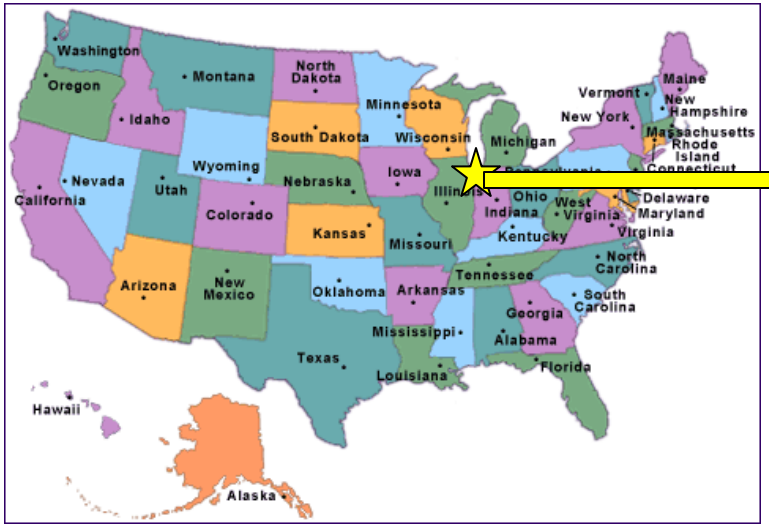


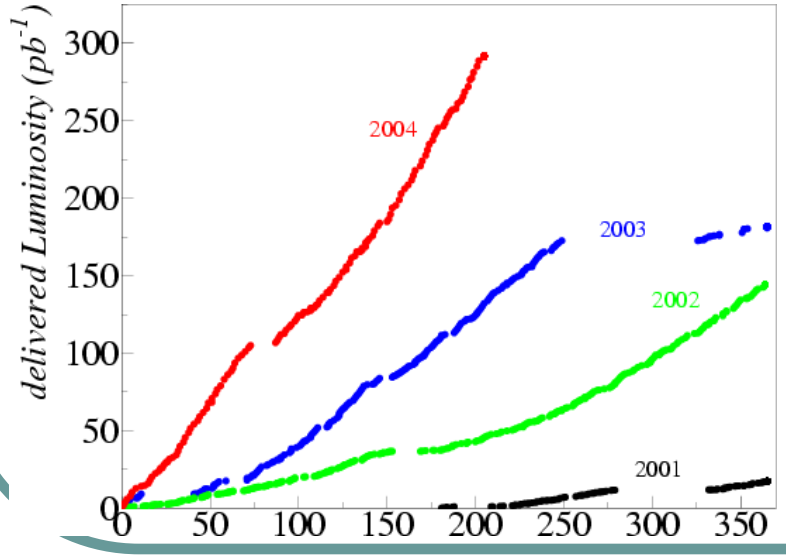
Or cascade down to the LSP

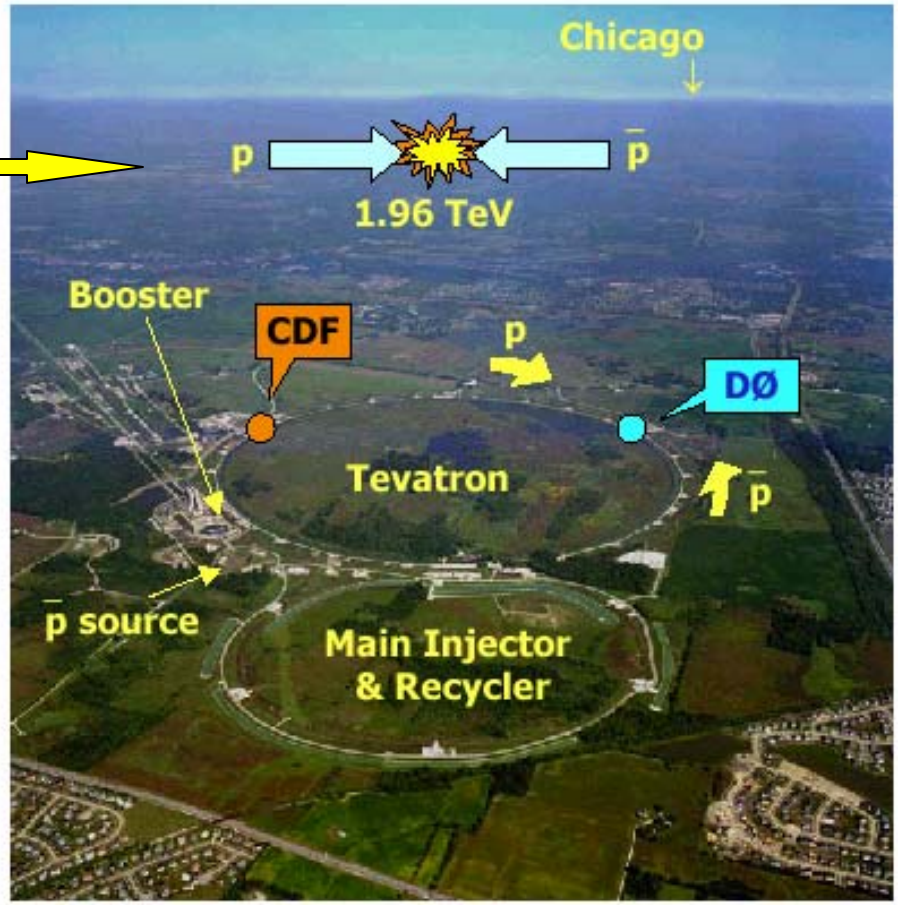


Dominant signature is jets+$\not{E}_T$

The Tevatron at Fermilab



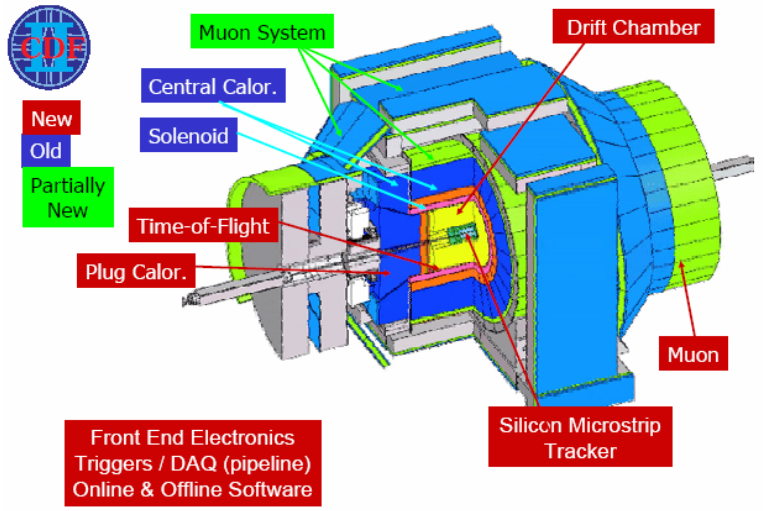


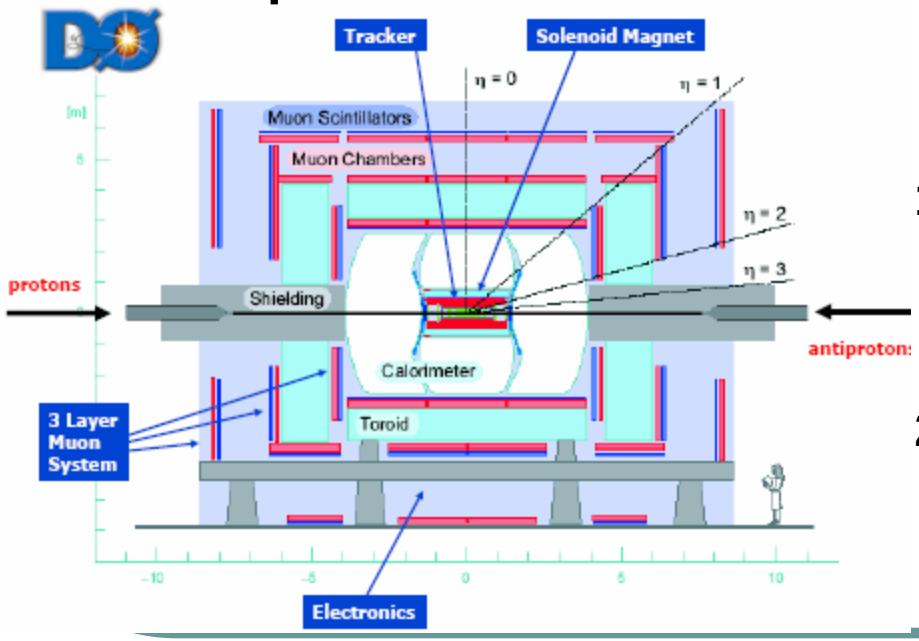


Run II: about 600 pb^{-1} delivered to the experiments

The Detectors

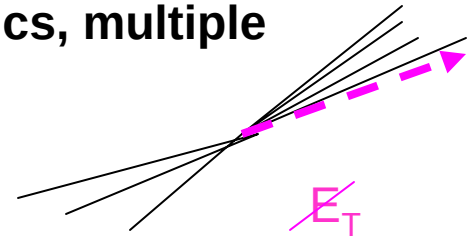
- Multipurpose detectors:
  - **Electron, muon, tau identification**
  - **Jets and missing energy**
  - **b-tagging through displaced vertices and leptons**





$$\vec{\not{E}}_T = -\sum_i \left(E_i \sin\theta_i \right) \hat{n}_i$$

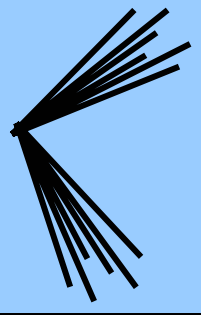
1. Fake $\not{E}_T$ can be caused by detector mis-measurements, limited detector coverage, cosmics, multiple interactions…
2. Often along or opposite to a jet



D0: squarks and gluinos

- Search along the "minimum squark mass line" of mSUGRA: low m_0 (25 GeV), $\tan\beta = 3$, $A_0 = 0$, $\mu < 0$, and scan over $m_{1/2}$
  m(squark)<m(gluinos)
- Signature:

$$p\bar{p} \rightarrow \tilde{q}\bar{\tilde{q}} \rightarrow q\tilde{\chi}_1^0 q\tilde{\chi}_1^0$$



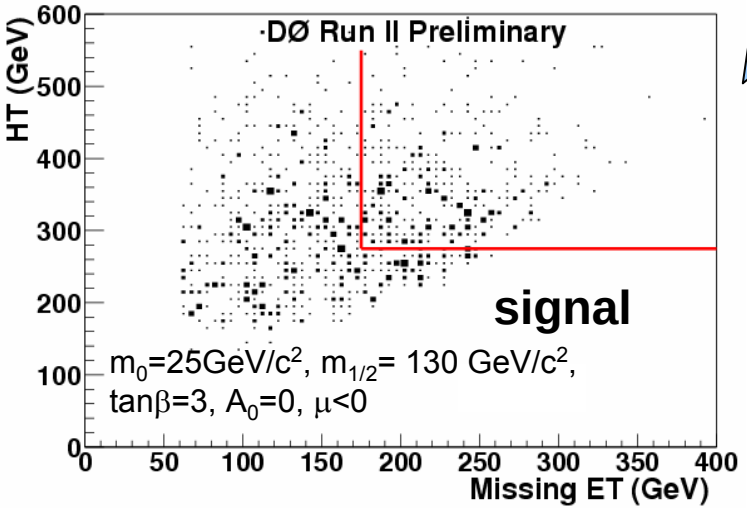
Topology:

2 acoplanar jets + $\not{E}_T$

- Large background from multijets production, Z + jets with ($Z \rightarrow \nu\bar{\nu}$)

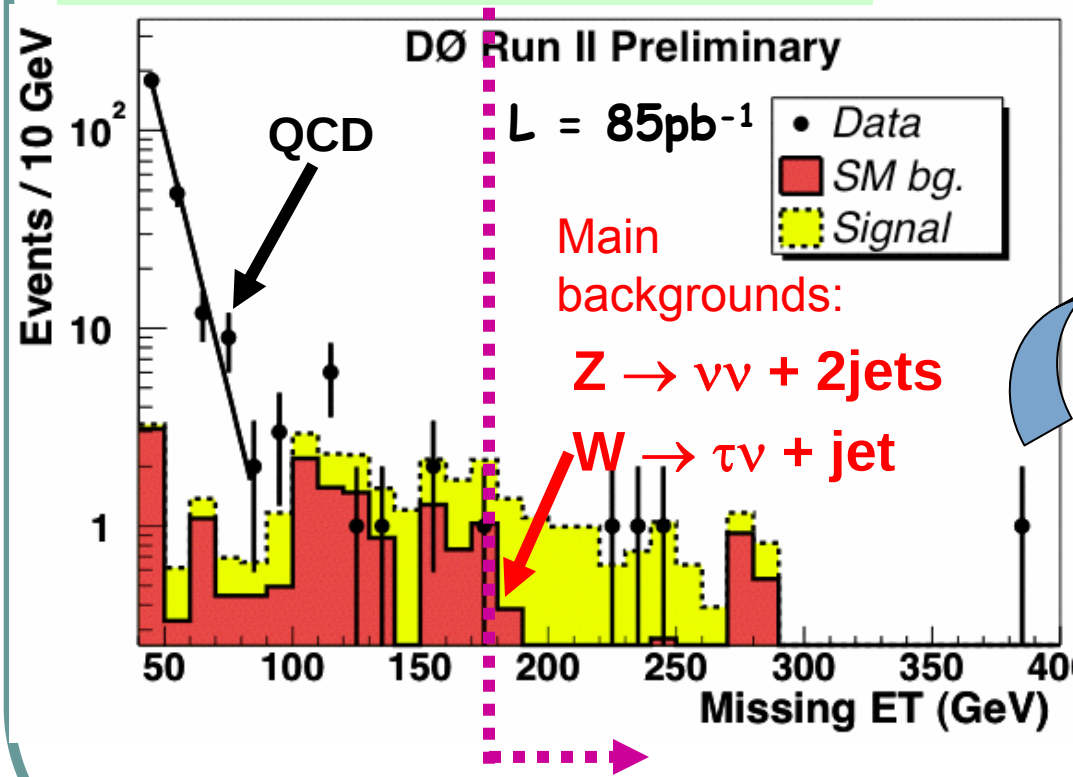
- Tight cuts are required:
  - At least two large jets
  - No isolated leptons
  - Angular cuts between $\not{E}_T$ and jet direction
  - $\not{E}_T > 175\,GeV$

$$H_T = \sum_i p_T^{i,jet} > 275\,GeV$$



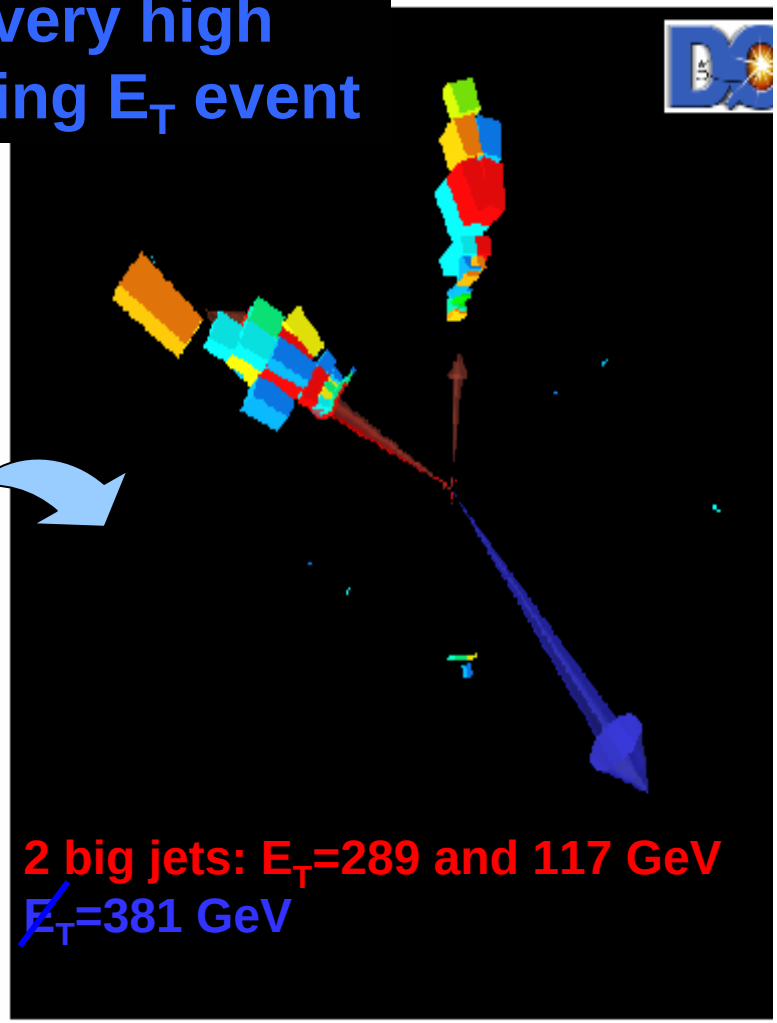
D0: squark and gluino

- Results based on 85 pb^{-1}
- Observed 4 events
- Expected 2.7±1.0



Final missing E_T cut here

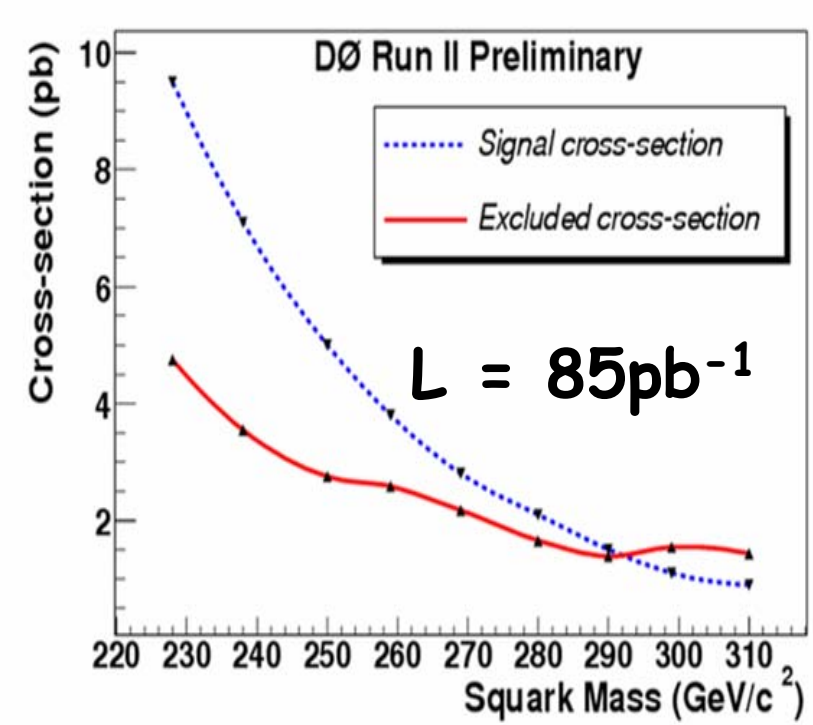
One very high missing E_T event

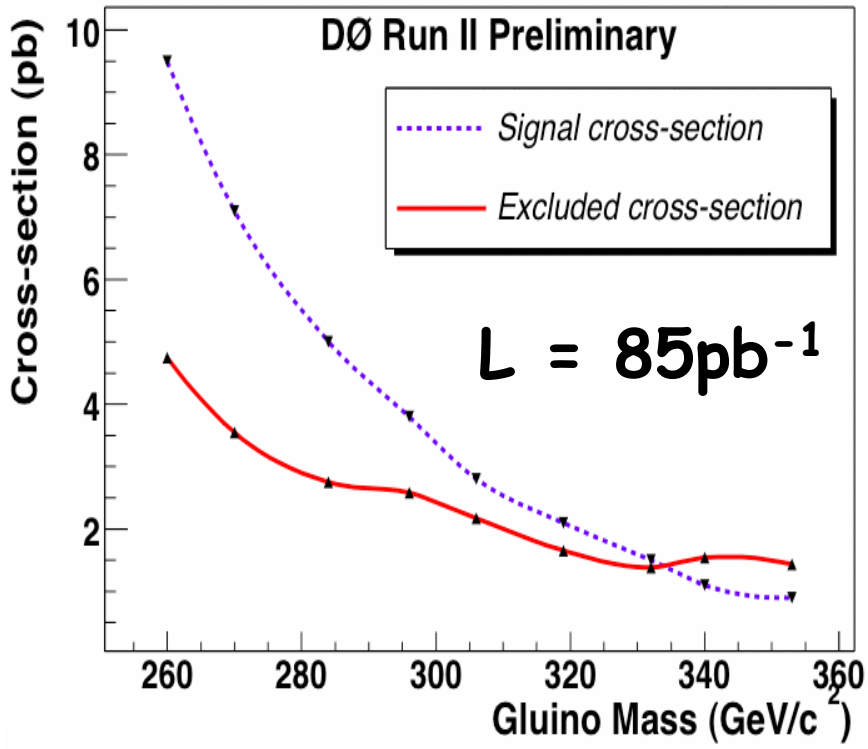


Limits on Squarks & Gluinos

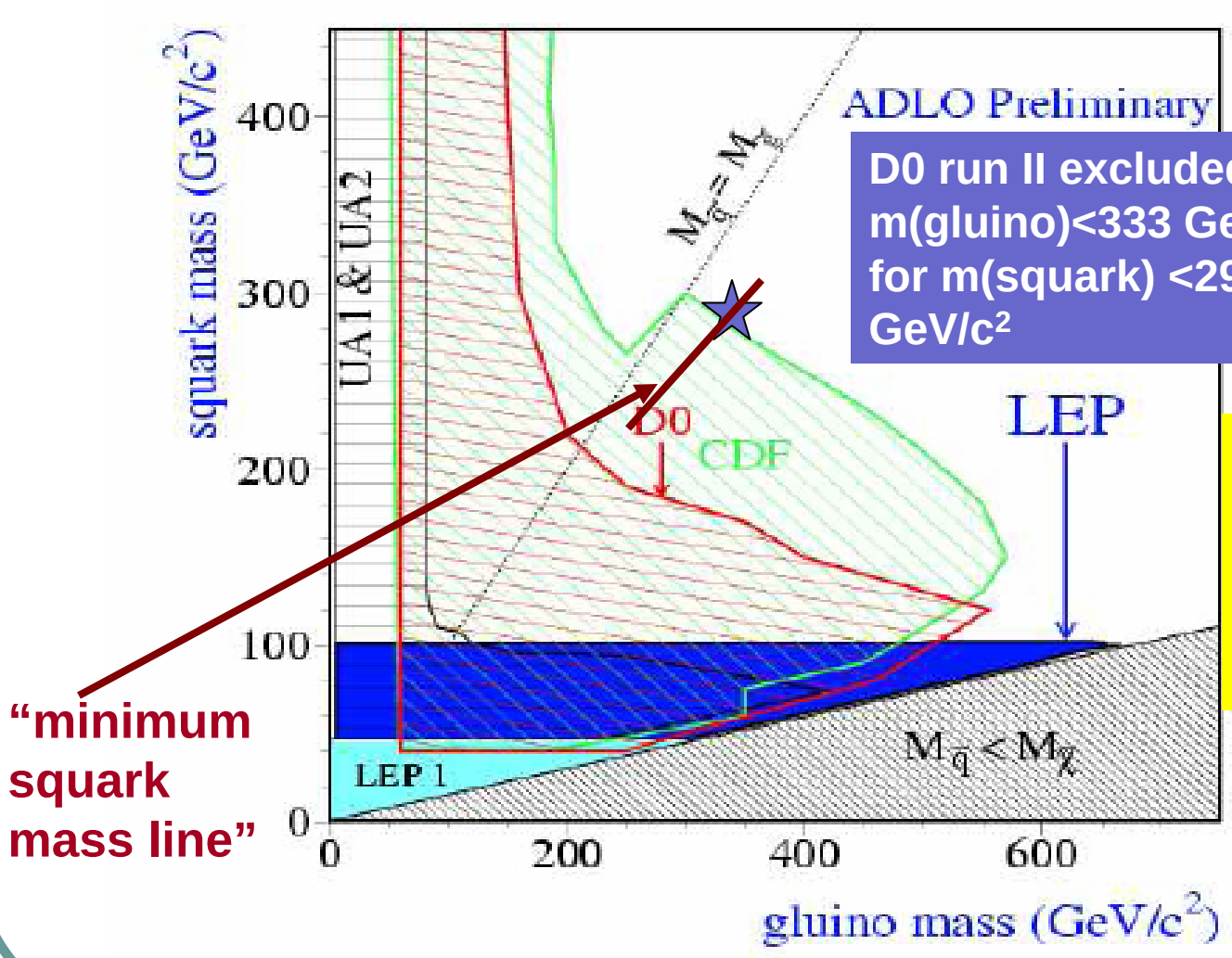
- Efficiency 2-7%
- New limits at 333 GeV/c^2 (for a squark mass of 292 GeV/c^2)

mSUGRA model with M_0 = 25 GeV/c^2, A_0=0, tan β = 3, μ<0, varying $M_{\frac{1}{2}}$





Limits on squarks and gluino

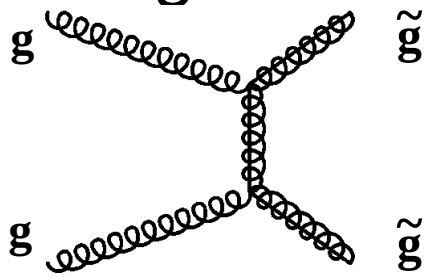


"minimum squark mass line"

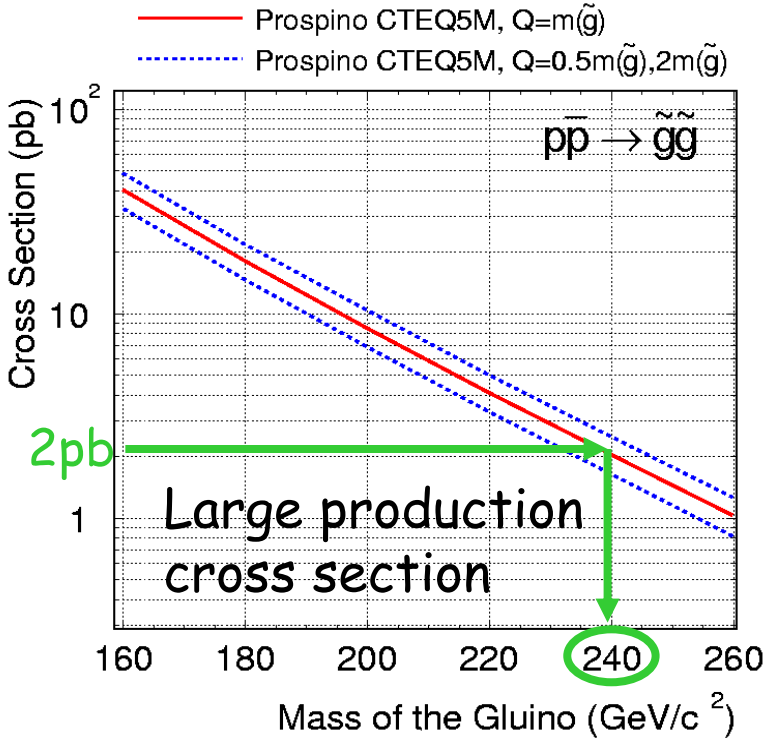
- **Extends previous CDF limit**

CDF: sbottom from gluino decays

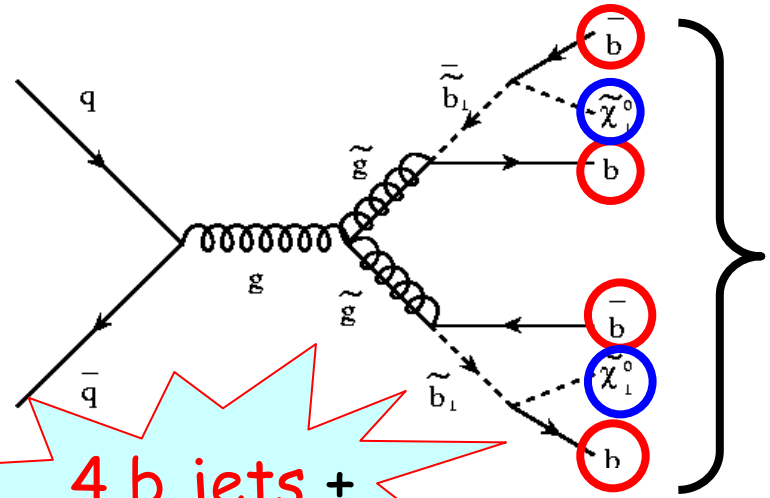
- Large cross section



Gluino-pair production



- Spectacular signature



4 b jets + $\not{E}_T$

$$\tilde{g}\tilde{g} \to (b\tilde{b}_1)(b\tilde{b}_1) \to (b\tilde{\chi}_1^0)(b\tilde{\chi}_1^0)$$

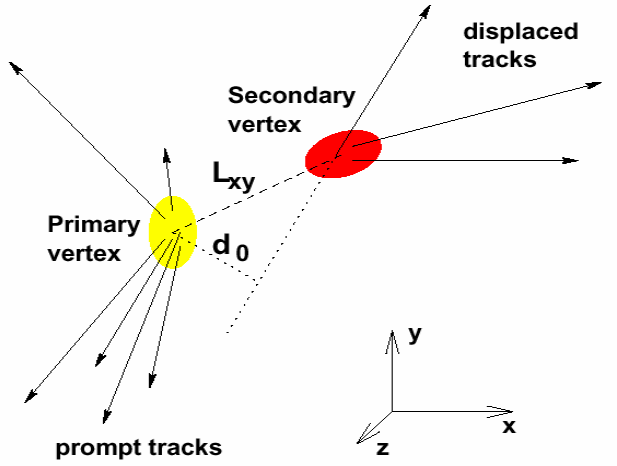
$$m_{\tilde{g}} > m_{\tilde{b}} > m_{\tilde{\chi}_1^0}$$

$$BR\left(\tilde{b}_1 \to b\tilde{\chi}_1^0\right) = 100\%$$

Backgrounds

- QCD: $b\bar{b}, c\bar{c}, q\bar{q}$
  - Determined using fake b-jets rate from data (negative L_{xy}) + MC
  - Reduced by requiring:
    - Large $\not\!\!E_T$
    - angular cuts between $\not\!\!E_T$ and jet direction
- EWK:W/Z+jets and Diboson events
  $W \to \ell\nu$ *and* $Z \to \ell\ell, \nu\bar{\nu}, b\bar{b}$
  - Determined using MC
  - Reduced by requiring isolated lepton veto and b-tag
- tt events : $t \to Wb$
  - Determined using MC
  - Reduced by isolated lepton veto

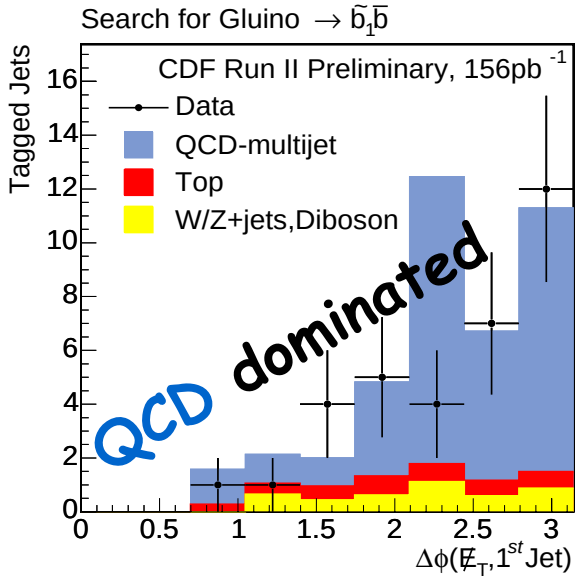
B-tagging

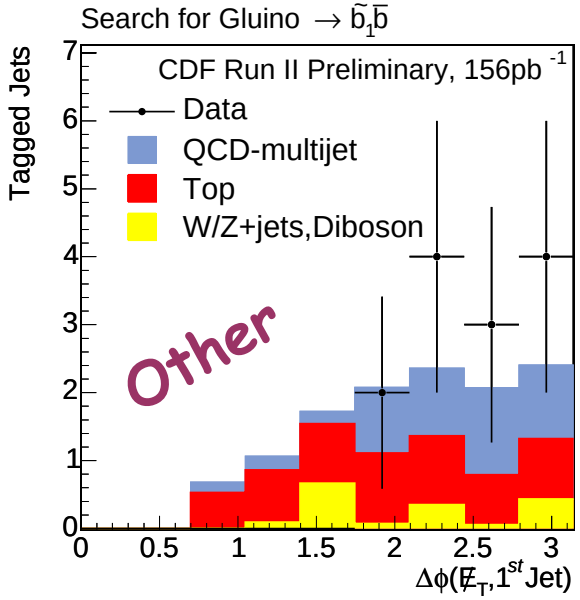


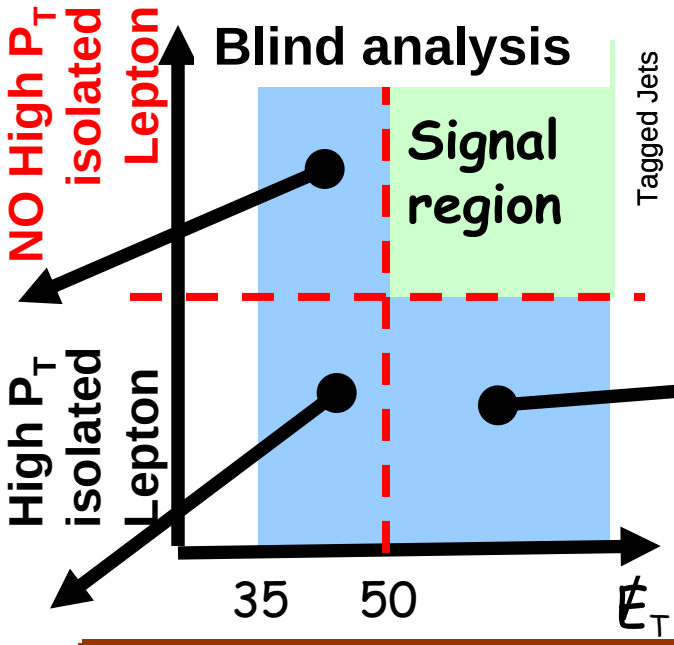
Fake rate/jet ~0.3%

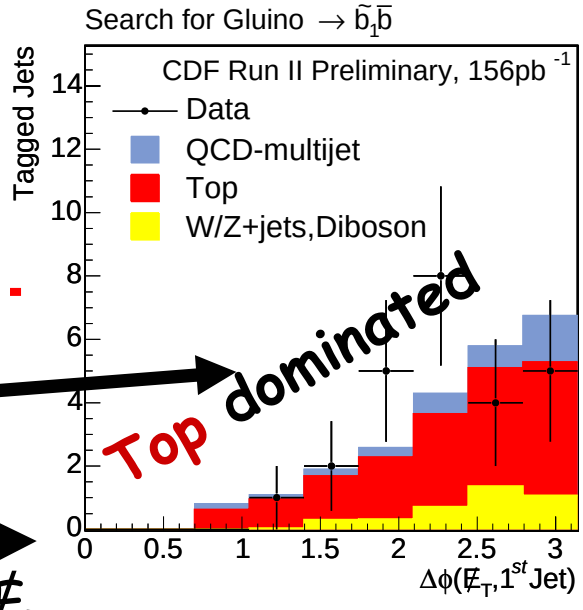
Efficiency/b-jet 25-40 %

Control regions





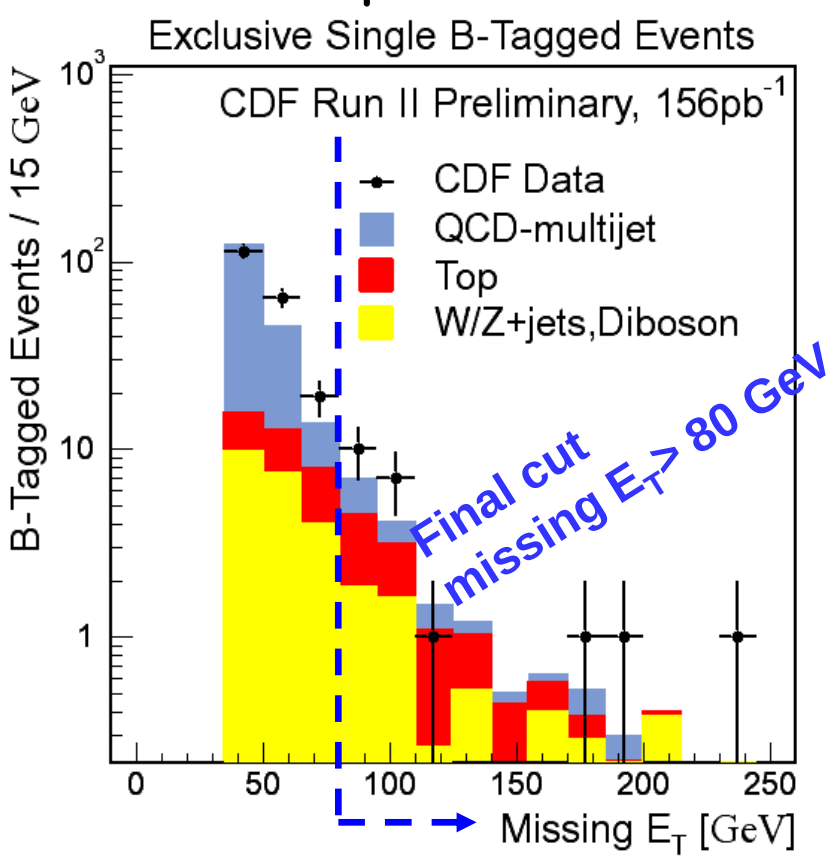


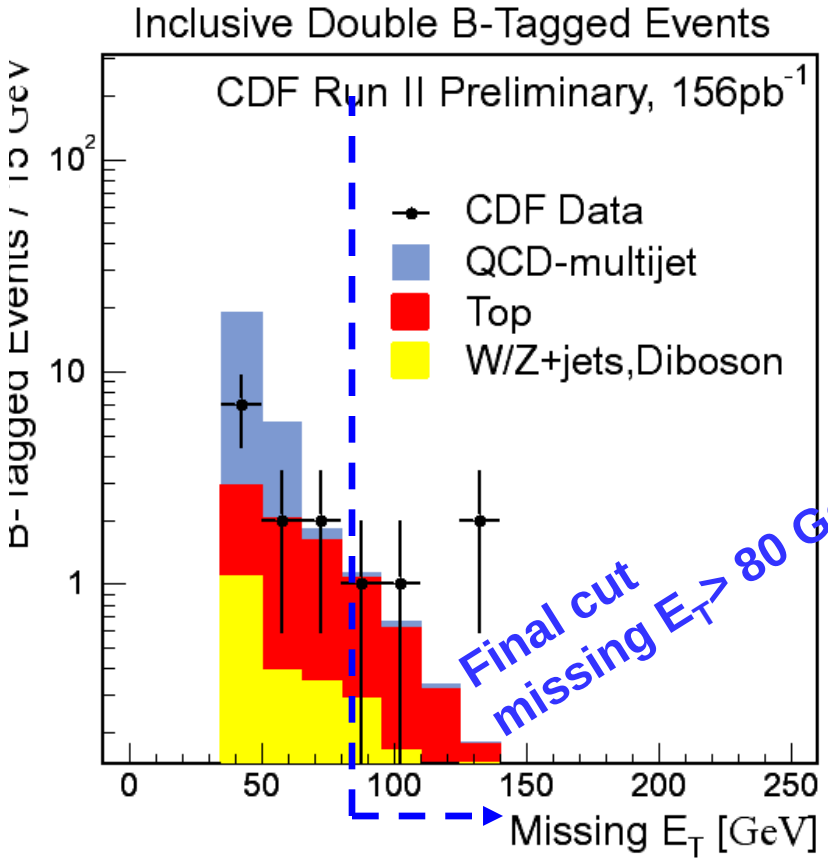


	Other	QCD dominated	Top dominated
EW	3.9±0.8	11.0±1.2	9.6±1.2
Top	11.7±0.2	8.2±0.1	35.2±0.3
QCD	19.2±4.1	129.6±17.3	10.9±4.5
BCK	34.8±4.2	148.8±17.3	55.7±4.7
OBS	36	121	63

Signal region

Based on 156pb^{-1} of data taken 2002-2003





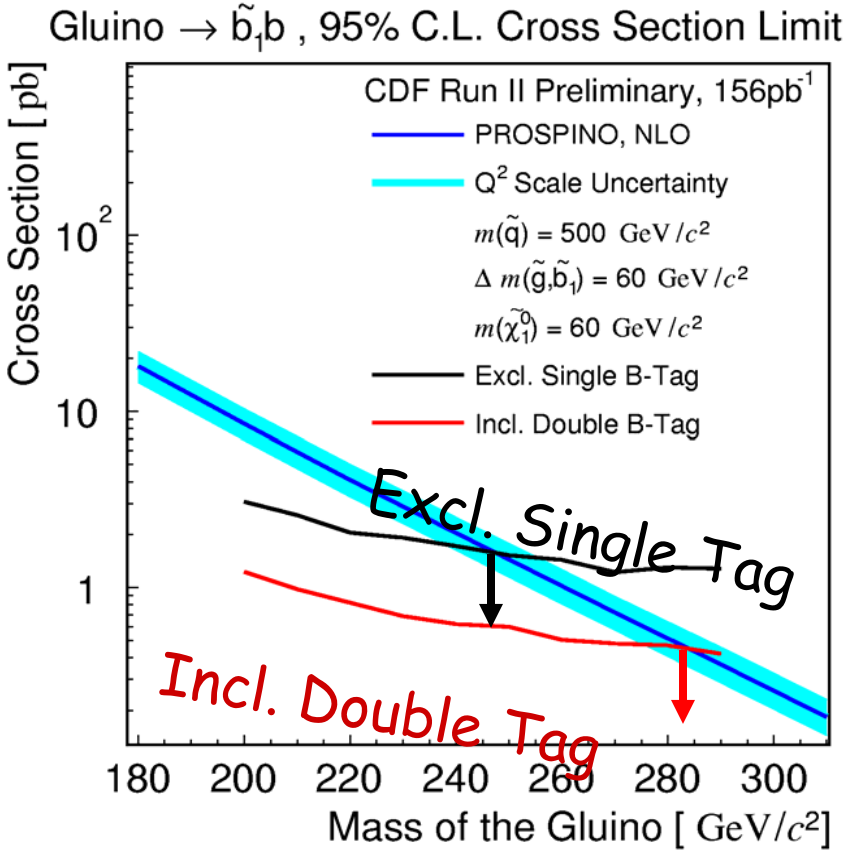
Expected
Excl. single tag 16.4±3.7
Observed 21

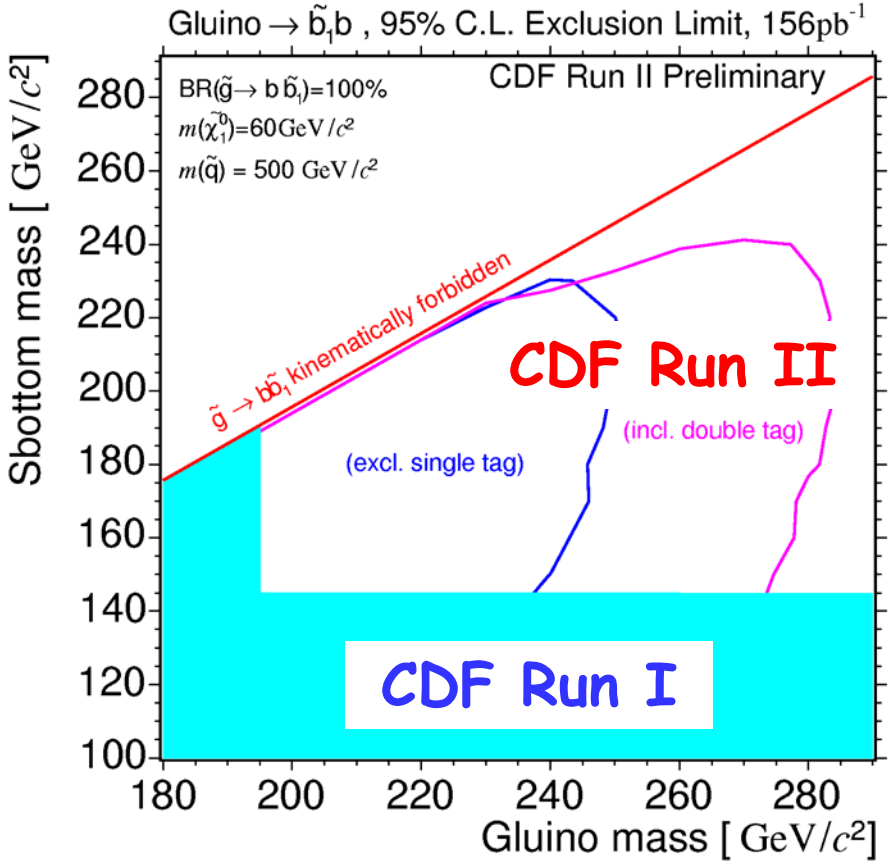
Expected
incl. double tag 2.6±0.7
Observed 4

Cross Section Limits

M(gluino)=240 GeV/c^2, m(sbottom)=180 GeV/c^2

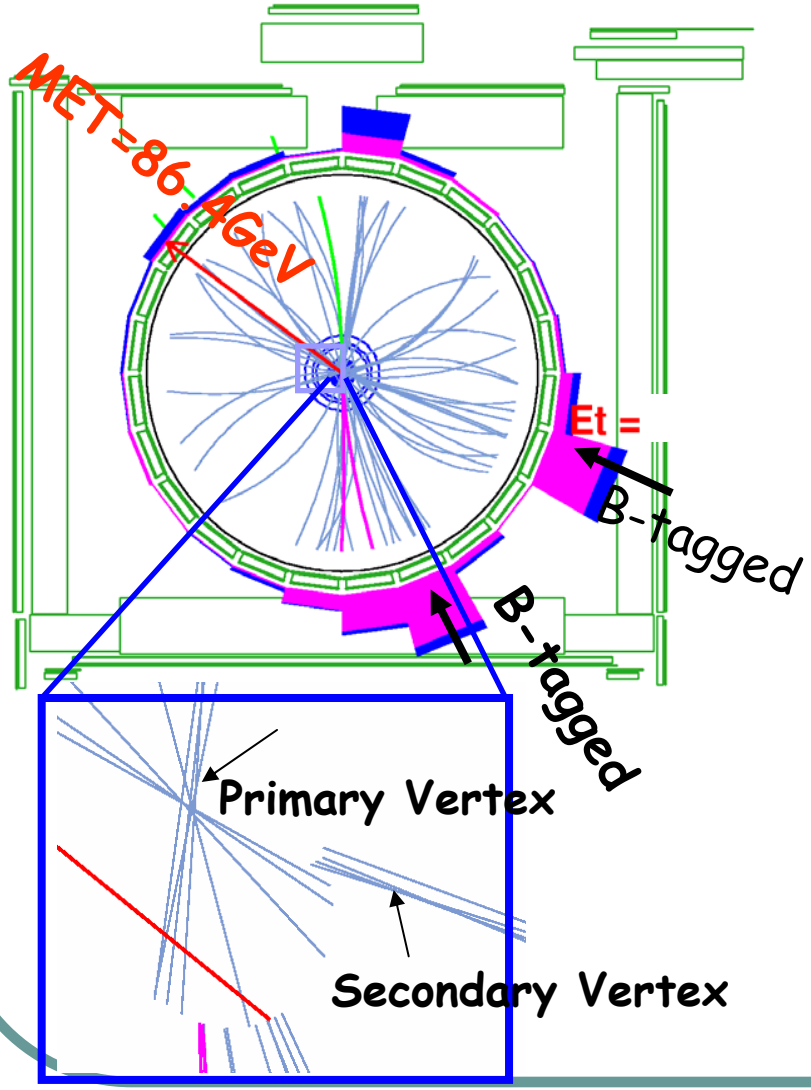
Acceptance: Exclusive SingleTag=7.7% Inclusive DoubleTag= 9.0%

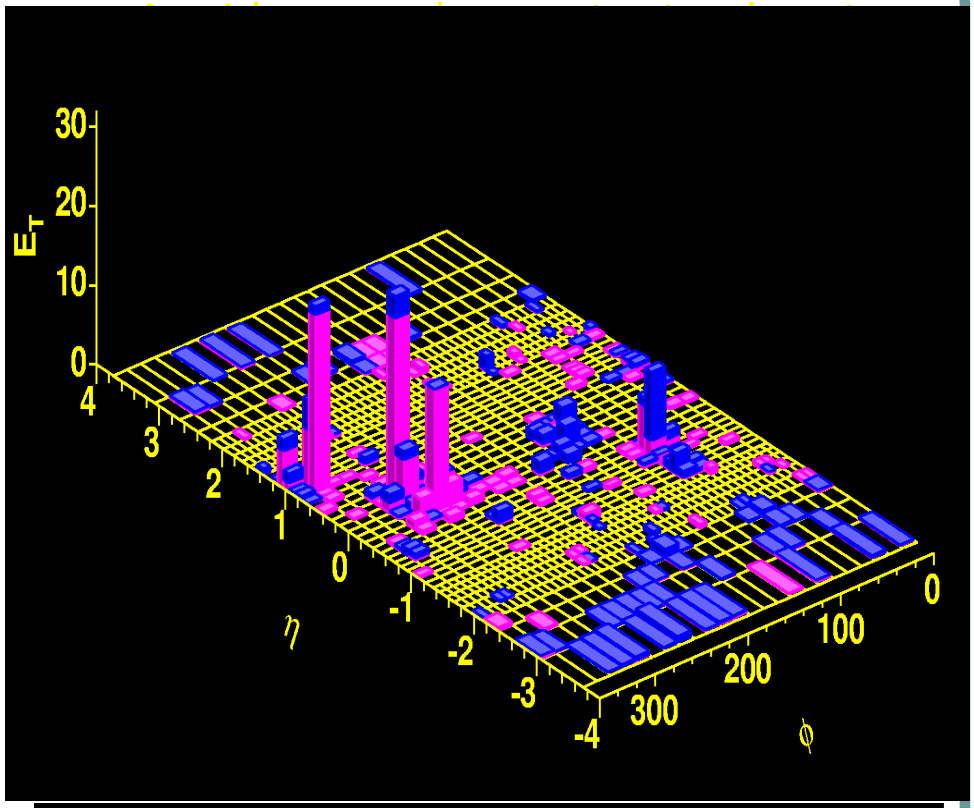




New parameter space excluded

CDF: Event candidate

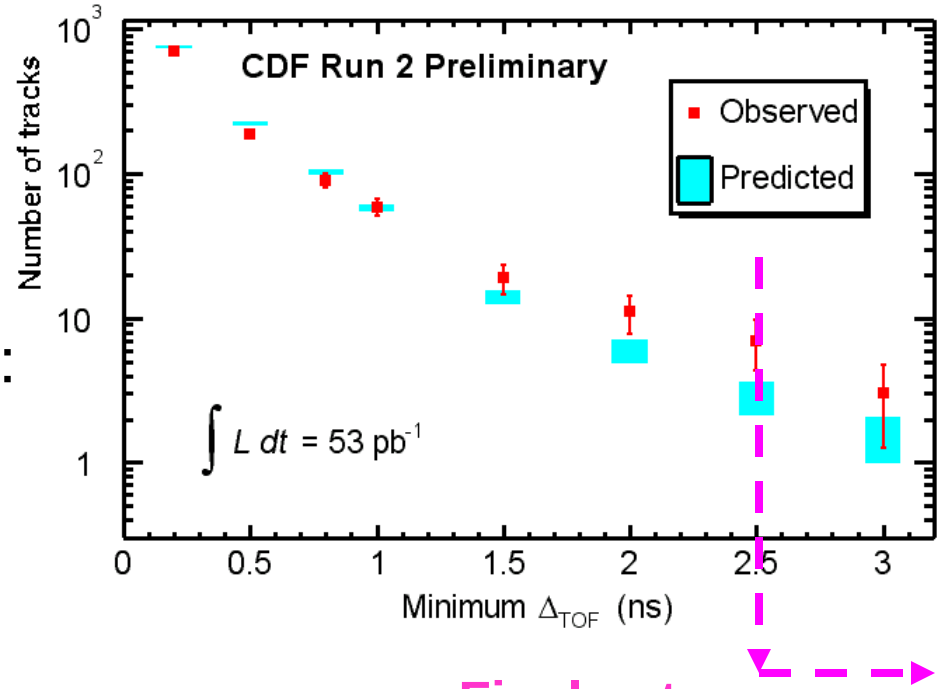




Et	η	φ	Tag
85.3GeV	0.02	286	1
51.6GeV	0.84	342	1
30.0GeV	-0.83	81	0

CDF: stable stop

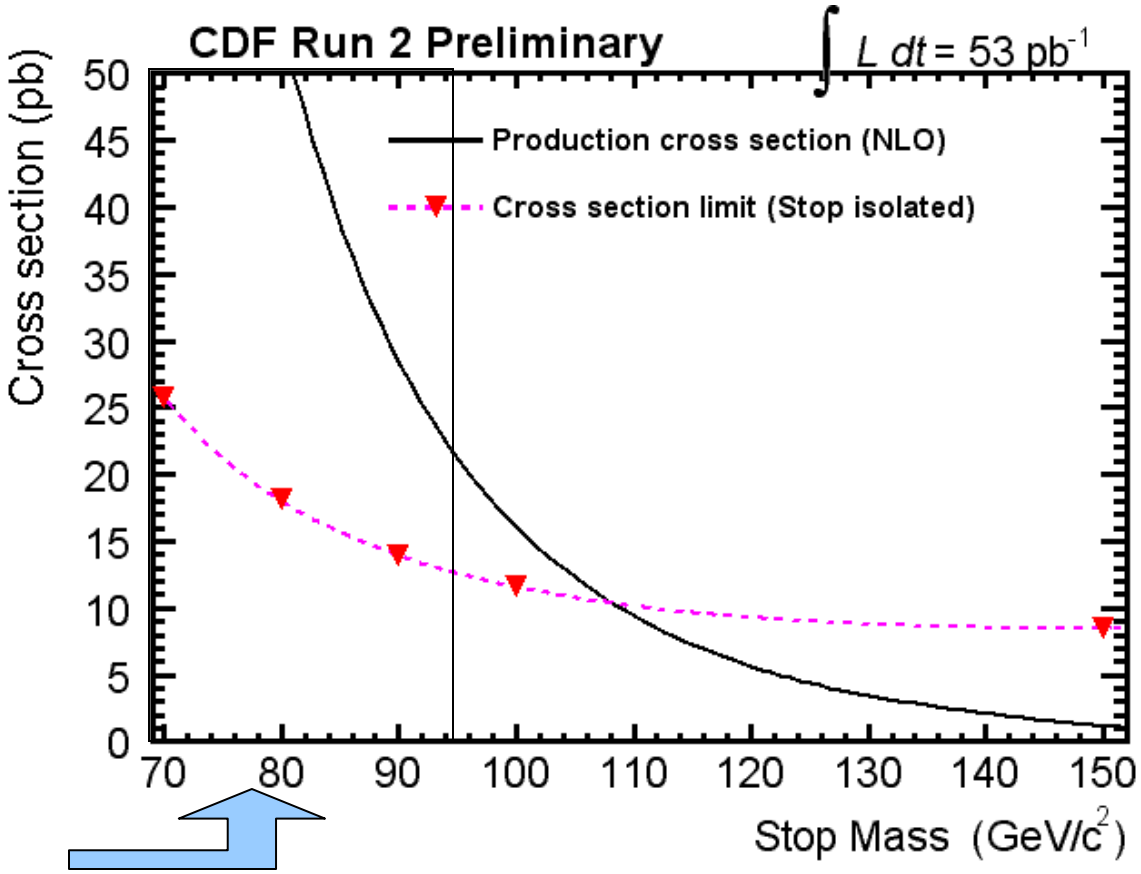
- Stop and stau can be NLSP in models with Gauge Mediated SUSY Breaking, and they can become stable
- In this scenario stop has :
  - Long lifetime
  - Large ionization energy loss
  - Reconstructed as a “muon”
- Experimental signature: out of time, high p_T muons
  - Muon-trigger, p_T>40 GeV
  - Select slow-moving charged particles using TOF
  - Background extrapolated from $20<p_T<40$ GeV:



- 2.9 ± 0.7 (stat.) ±3.1(sys) expected
- 7 events observed in the data

CDF: stable stop search

- Efficiency ~1-4%



Excluded by Aleph

- **CDF Limit on pair production of long lived stop: m(stop)>107 GeV at 95% CL**

Conclusions

- **The Tevatron is the high energy frontier for the next "N" years.**
- **Exciting results are coming out**
- **Some preliminary results on the first 200 pb^{-1} are ready to be published**
- **Many of these results already the world's most sensitive**
- **Sensitivity will increase in the next few years**