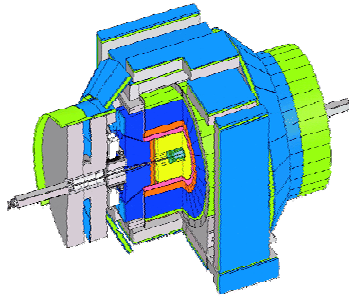
Search for Squark/Gluino Production in CDF



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IFAE-Barcelona

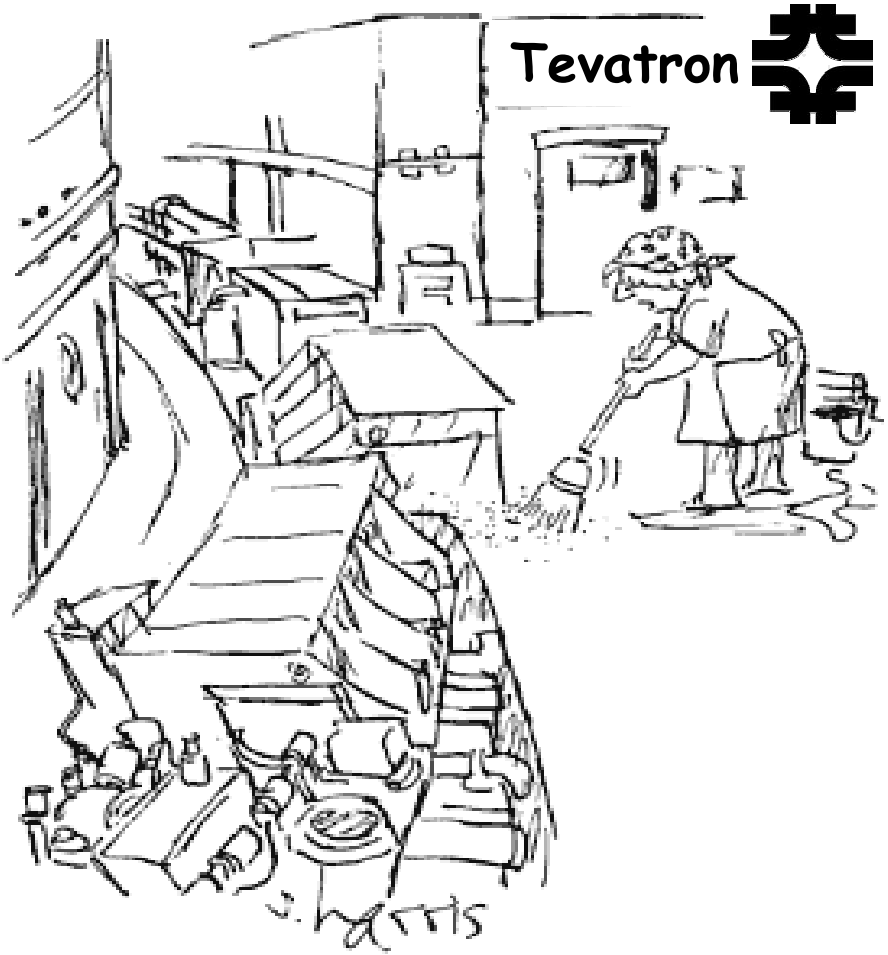
SUSY´06, UC Irvine, June 2006

Outline

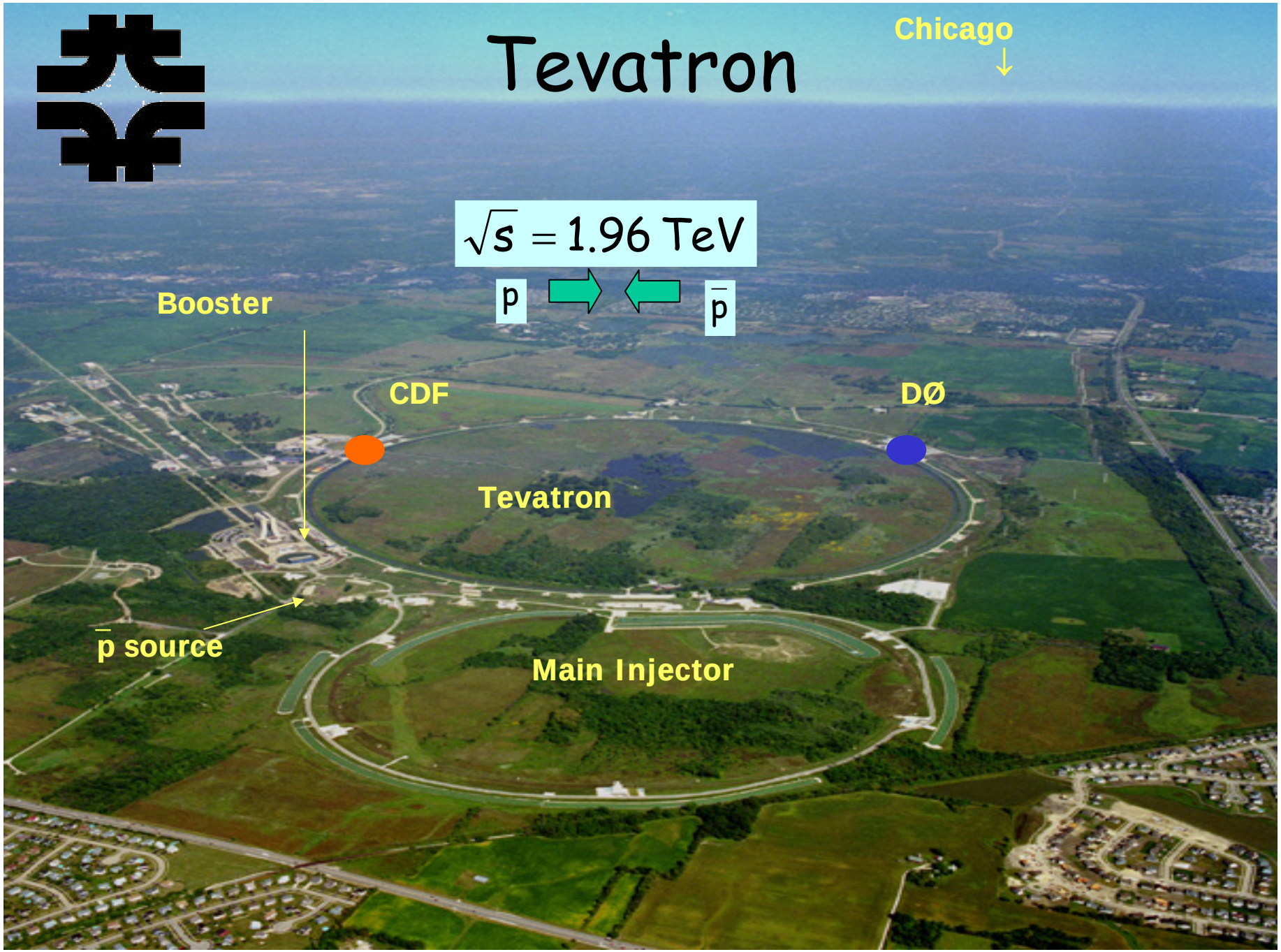
- Tevatron & CDF
- SuperSymmetry

- Inclusive Squark/Gluino Search
- Sbottom from Gluino Decays
- Direct Stop Pair Production
- Stop Production (RPV in decay)

- Final Remarks



"Particles, particles, particles."


Tevatron
Chicago
$\sqrt{s} = 1.96$ TeV
p
$\bar{p}$
Booster
CDF
DØ
Tevatron
$\bar{p}$ source
Main Injector

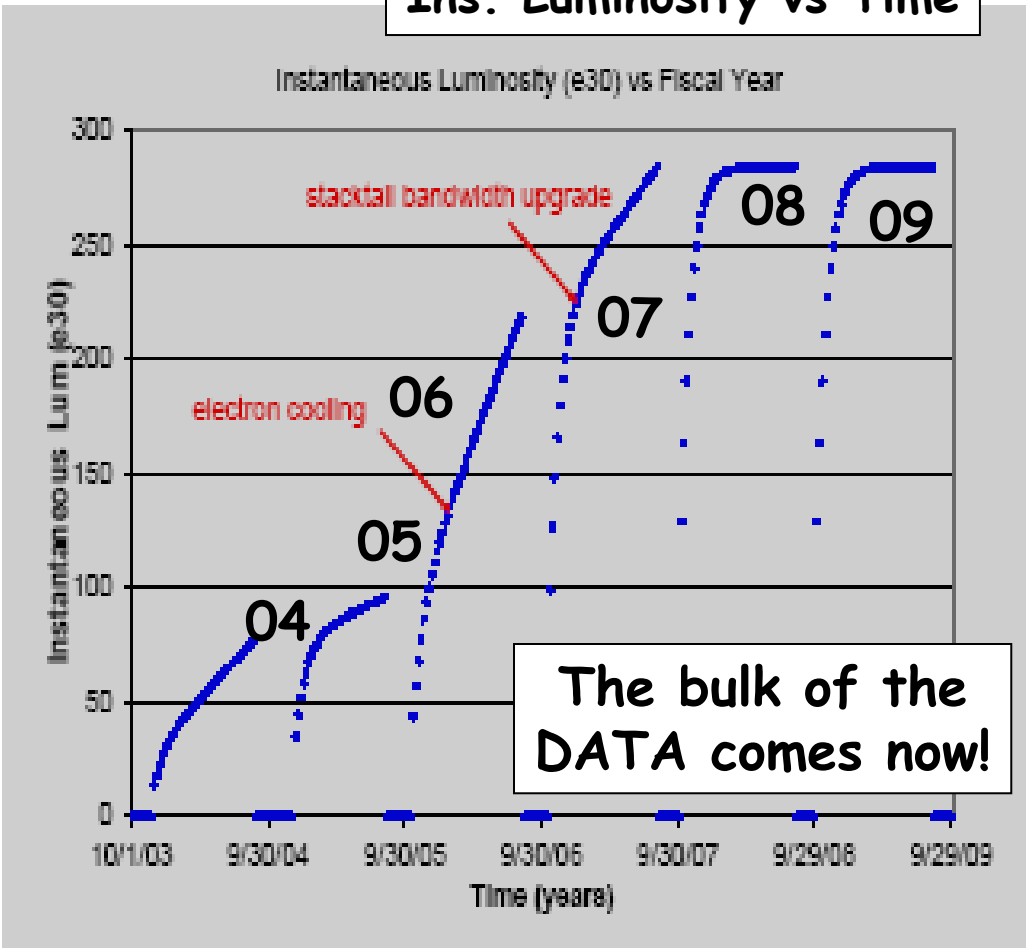
Tevatron

- proton-antiproton collisions
  $\sqrt{s} = 1.96$ TeV (Run I $\rightarrow$ 1.8 TeV)

- Main injector
  (150 GeV proton storage ring)

- antiproton recycler (accumulator)
  - Electron cooling this year
  - Operational on Fall 2005
  - 40% increase in Luminosity

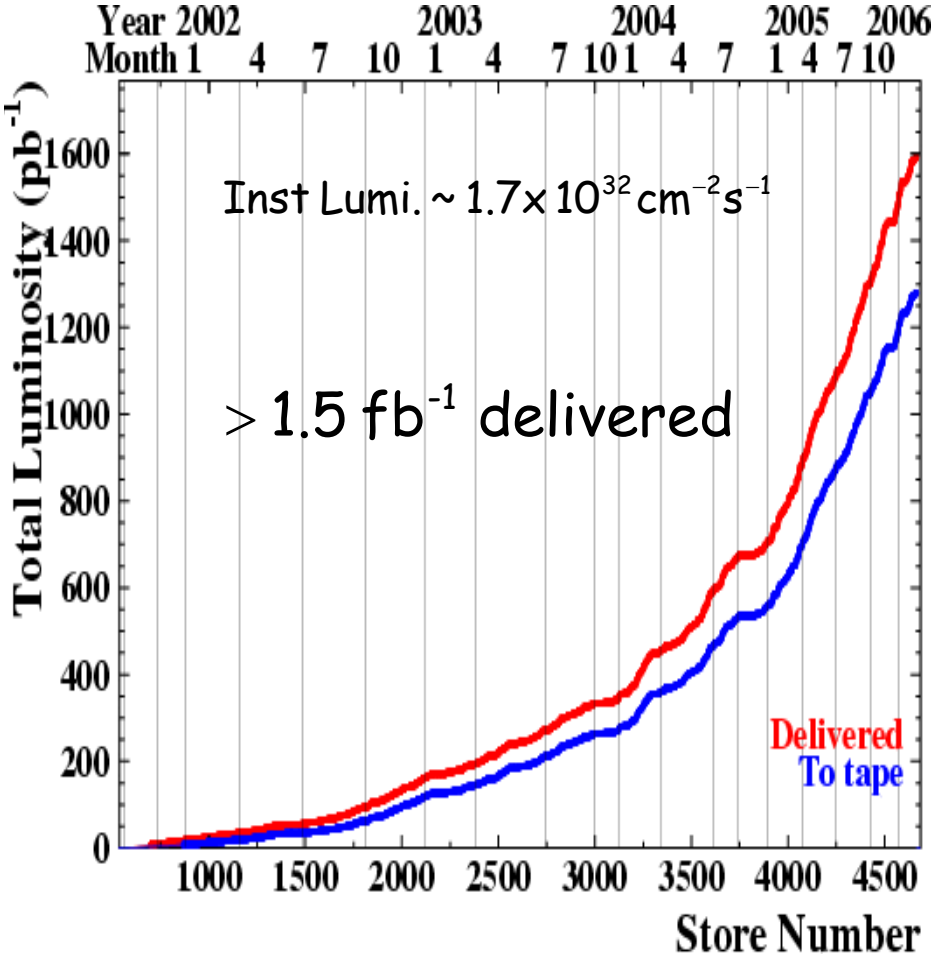
Ins. Luminosity vs Time



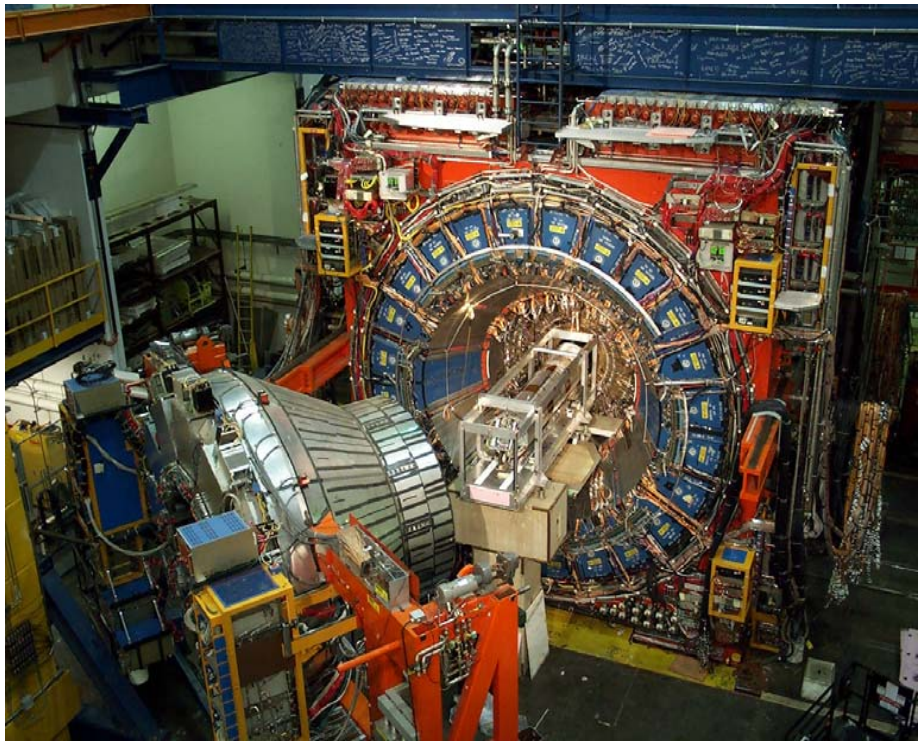
Long Term Luminosity Projection (by end FY2009)

- **Base Goal -> 4.4 fb-1**
- **Design -> 8.5 fb-1**

Tevatron & CDF Performance



Tevatron is now coming back from a long shutdown…



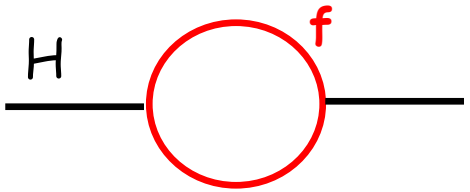
CDF collects high-quality data with high efficiency

collected > 1.2 fb-1 on tape

Hierarchy Problem

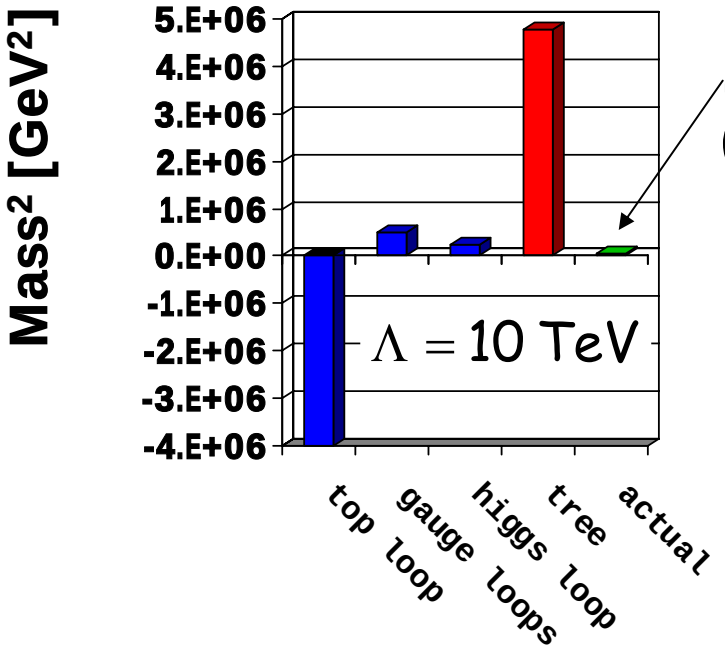
From EWK to Planck scale ?

$$< H > = 174\ GeV \rightarrow m_H^2 \approx O(-100\ GeV^2)$$



$$\Delta m_H^2 = \frac{|\lambda_f|^2}{16\pi^2}[-2\Lambda_{UV}^2 + 6m_f^2 \ln(\Lambda_{UV}/m_f) + ...]$$

if $\Lambda_{UV} \approx M_{planck} \rightarrow$ fine tuning in 10^{30} !!



But already a serious problem at 10 TeV scale (cancellation among top, gauge and Higgs loops)

This kind of conspiracy has name in Physics…

Hidden Symmetry

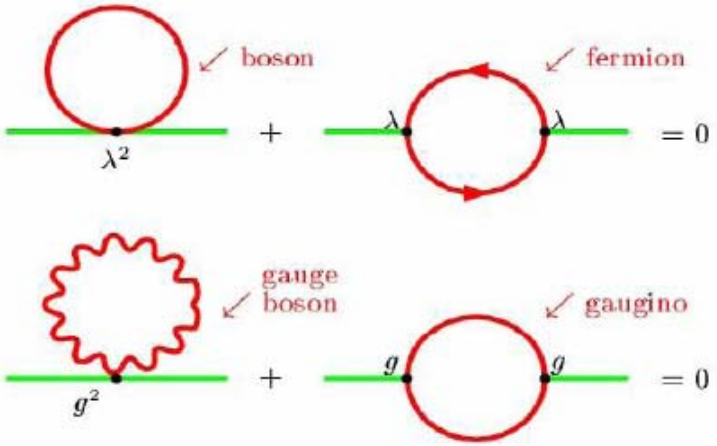
SuperSymmetry in 30"

- Fermion/Boson symmetry

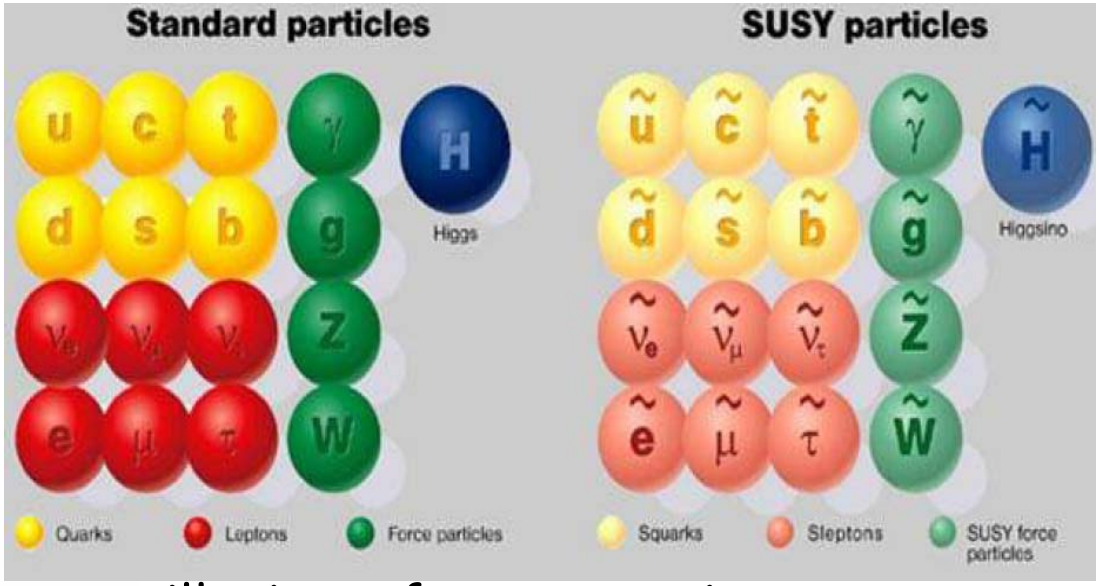
$$Q\,|\,\text{fermion}\,> = |\,\text{boson}\,>$$

$$Q\,|\,\text{boson}\,> = |\,\text{fermion}\,>$$

- Exact cancellation between fermion & boson loops for Higgs



Double Spectra of Particles



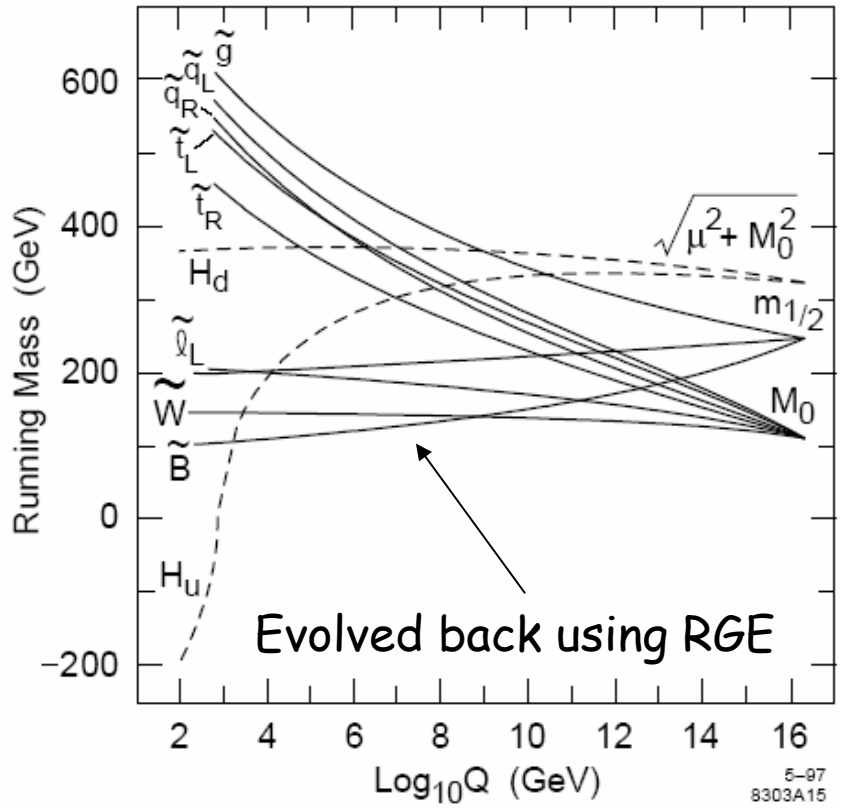
..will mix to form mass eigenstates..

..SUSY must be broken….. model-dependent phenomenology

mSUGRA
(gravity mediated SUSY breaking)

SUSY breaking (hidden sector) → gravity → MSSM (visible sector)

L_{soft} terms introduce huge number (up to 105) of new parameters



Assuming unification of masses at GUT scale allows to reduce it to 5

m_0: common scalar mass at GUT

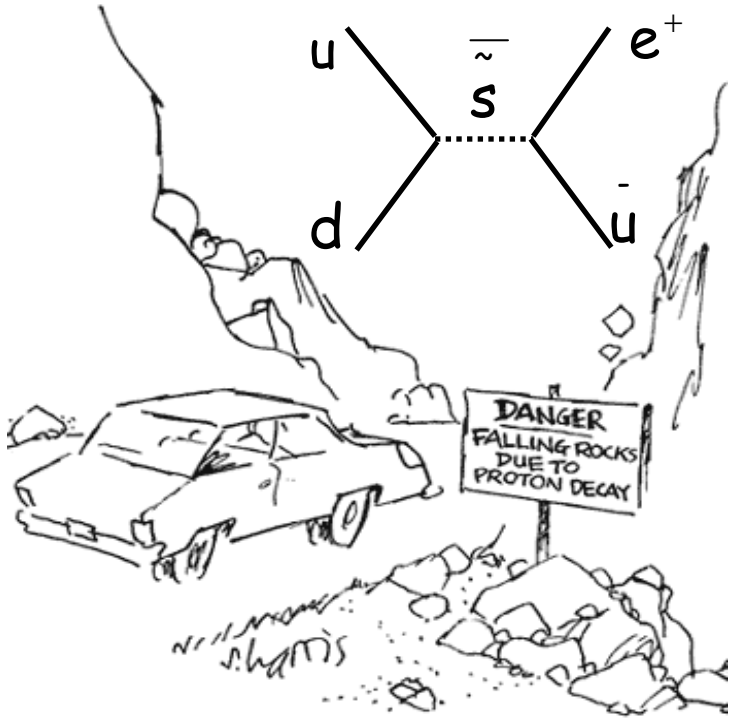
$m_{1/2}$: the common gaugino mass at GUT

tanβ: Ratio of Higgs VEVs

A_0: common (scalar)^3 coupling

Sign(μ): Higgs mass term

R-Parity



Most general superpotential includes terms Violating Baryon number and Lepton number

$$W_{\Delta L=1} = \frac{1}{2}\lambda^{ijk} L_i L_j \bar{e}_k + \lambda'^{ijk} L_i Q_j \bar{d}_k + \mu'^{i} L_i H_u$$

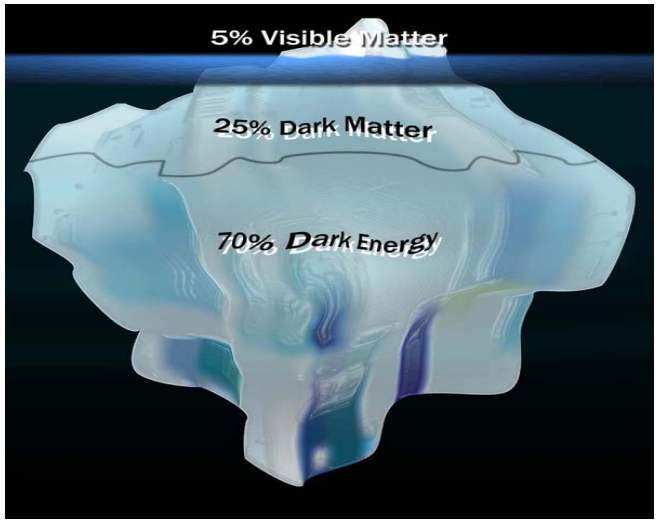
$$W_{\Delta B=1} = \frac{1}{2}\lambda''^{ijk} \bar{u}_i \bar{d}_j \bar{d}_k$$

New symmetry is postulated…

$$R_p = (-1)^{3(B-L)+2s}$$

$R_p = +1$ (particles)

$R_p = -1$ (sparticles)

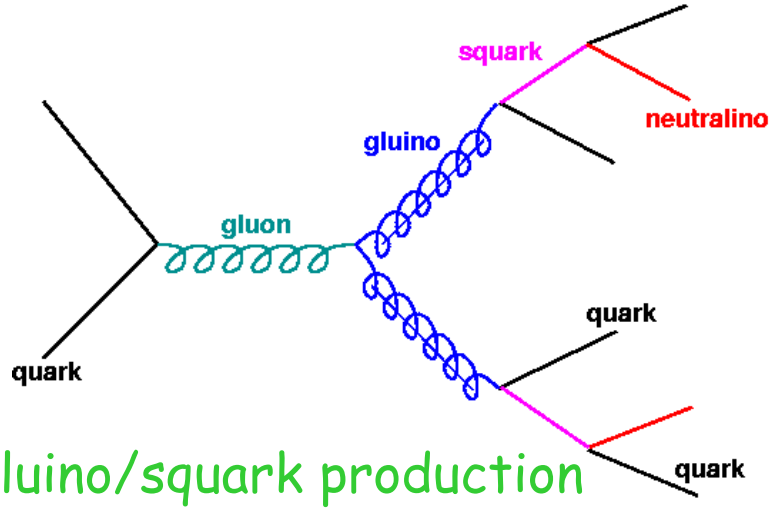


- SUSY particles produced in pairs
- The lightest SUSY particle stable (χ_1^0)
- Valid candidate for Dark Matter

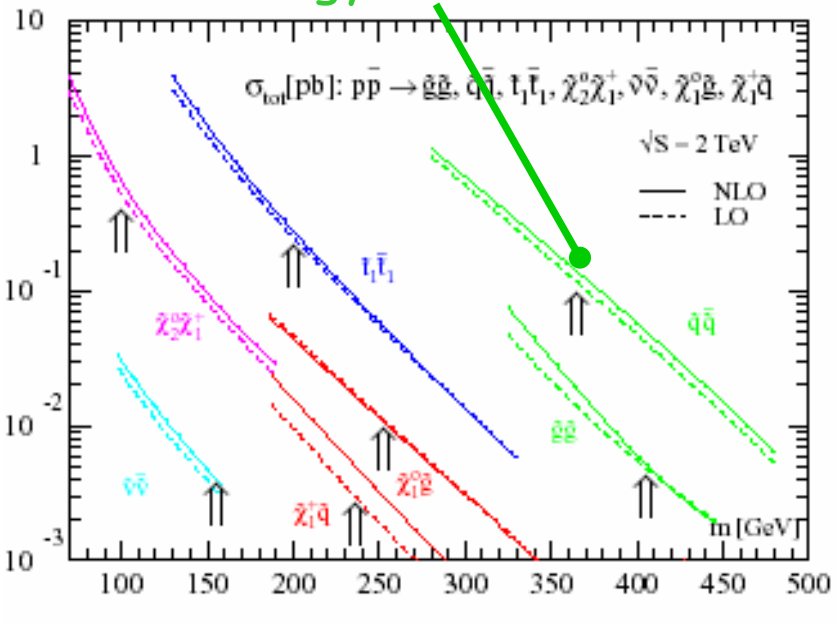
- Distinctive Signature at Colliders

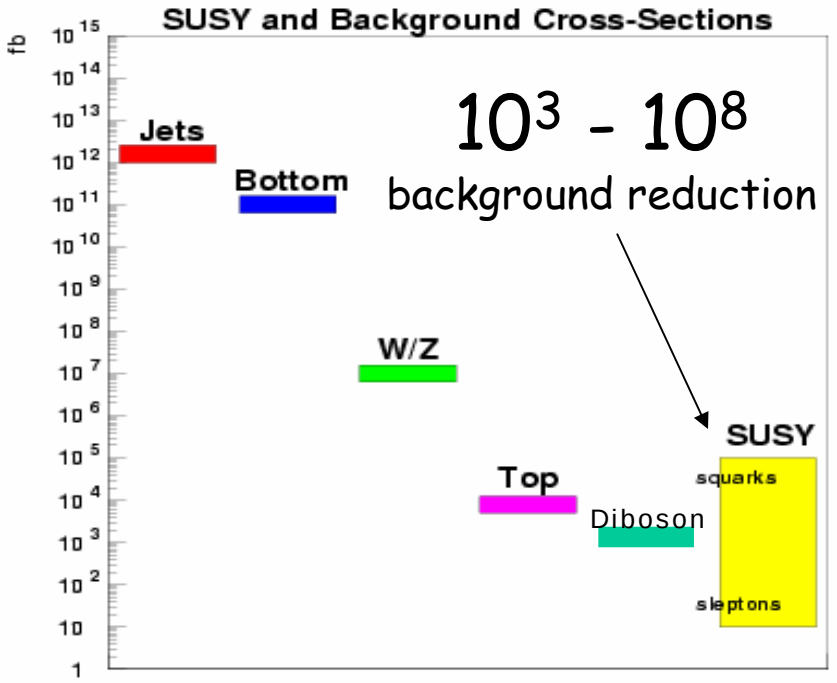
Large Missing E_T

Inclusive Gluino/Squark Search



gluino/squark production
at the energy frontier





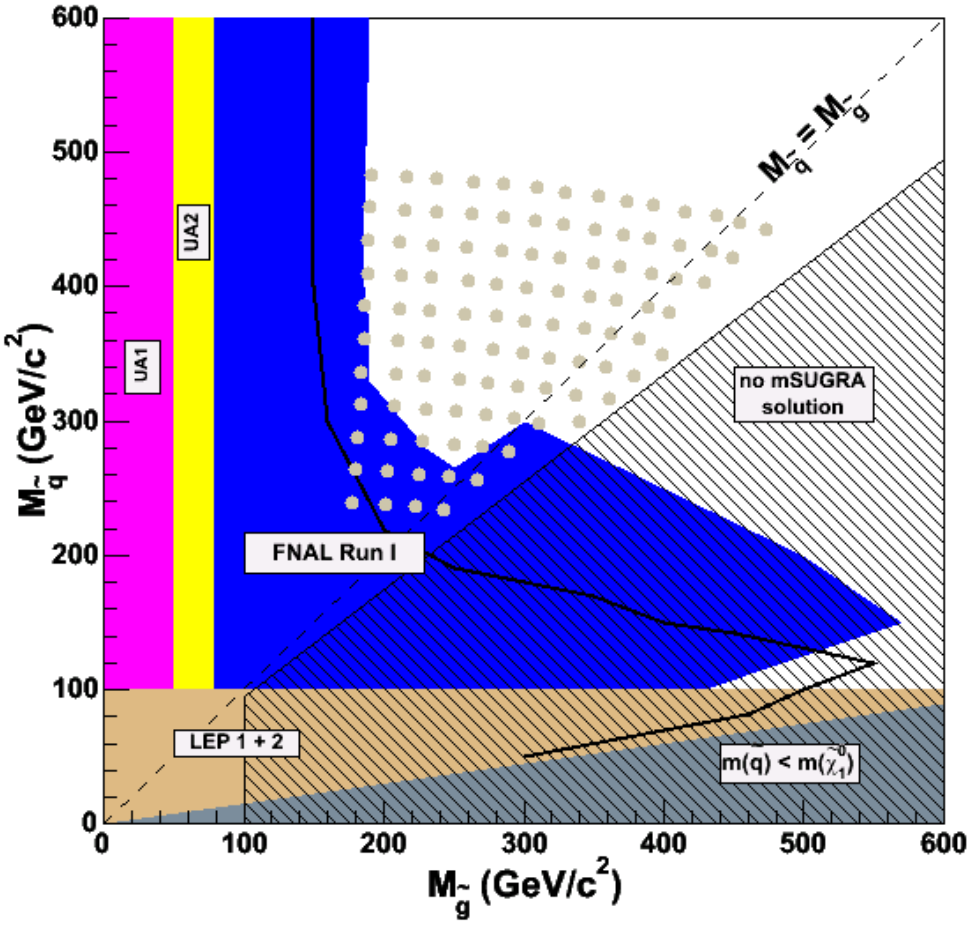
- Signature: $\not{E}_T$ + jets
- Channel with largest cross section
- Difficult…multiple SM backgrounds
  - Detector effects
  - top and Z->νν+jets irreducible
  - understanding of QCD & W/Z+jets

Inclusive Squark/Gluino Search
(mSUGRA Scenario)

- Grid in M_0 - $M_{1/2}$
- $\mu < 0$
- $\tan\beta = 5$
- $A_0 = 0$

- 4 flavors considered
  (no sbottom or stop in 2->2 process)
- Samples generated using
  ISASUGRA in PYTHIA 6.216
- Parton-Shower and Underlying Event
  modeled using Pythia-TuneA
- Different sub-processes normalized
  to NLO according to PROSPINO

$$Q \rightarrow M_{gluino} \text{ or } M_{squark} \text{ or } \frac{1}{2}(M_{gluino} + M_{squark})$$



Inclusive Squark/Gluino Search
(Analysis Strategy)

- Clean-up cuts against cosmics & beam-halo
- $\not\!\!E_T > 70$ GeV
- At least three jets

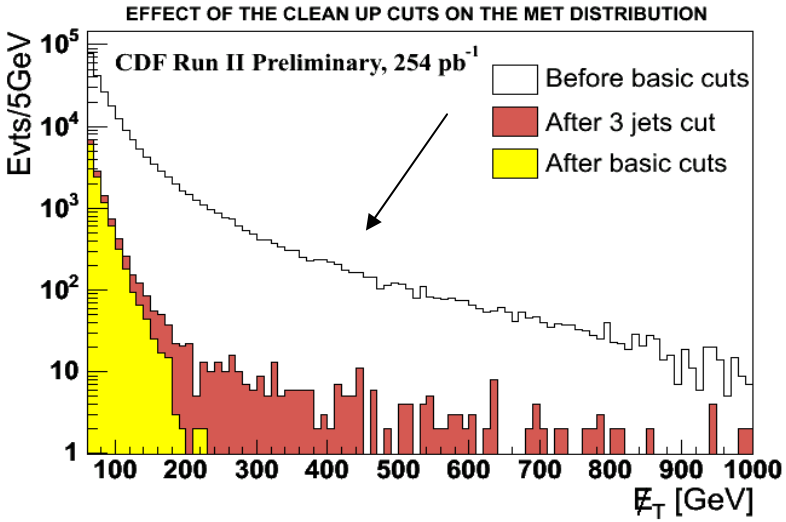
  $E_T^{jet} > 25$ GeV

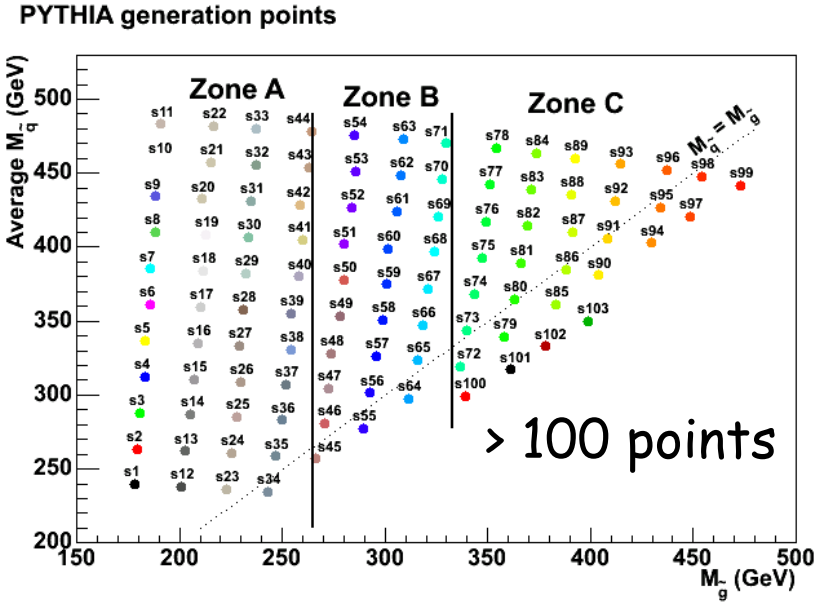
  $|\eta^{jet}| < 2.0$ (one jet central $|\eta^{jet}| < 1.1$)

  EM fraction < 0.9
- $\Delta\phi(\not\!\!E_T, \text{jets}) > 0.7$
- $\Delta\phi(\not\!\!E_T, \text{track}) > 0.7$
- No pairs of tracks in Z-mass window

Set of optimized cuts as a function of gluino/squark masses

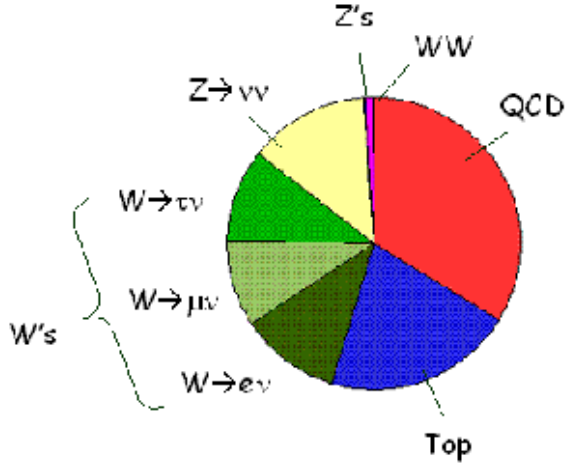
GeV	$\not\!\!E_T$	$H_T = \sum E_T^{jets}$	E_T^{jet1}	E_T^{jet2}
A	75	230	95	55
B	90	280	120	70
C	120	330	140	100



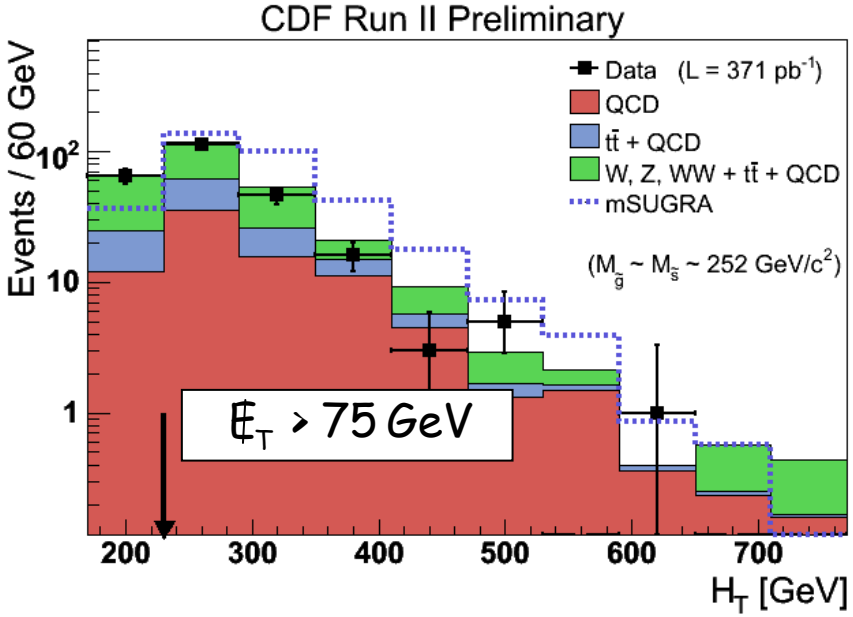


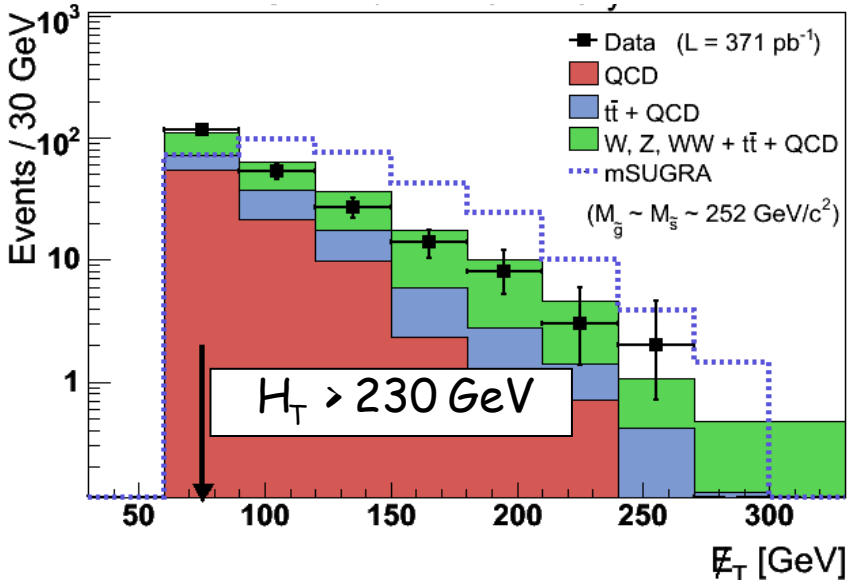
Inclusive Squark/Gluino Search
(Comparison with SM)

- QCD MC (Pythia) normalized using data at low $\not\!\!E_T$
- Z/W+jets generated using ALPGEN+PS and normalized to NLO
- Top & WW normalized to NLO



- Data compatible with SM predictions

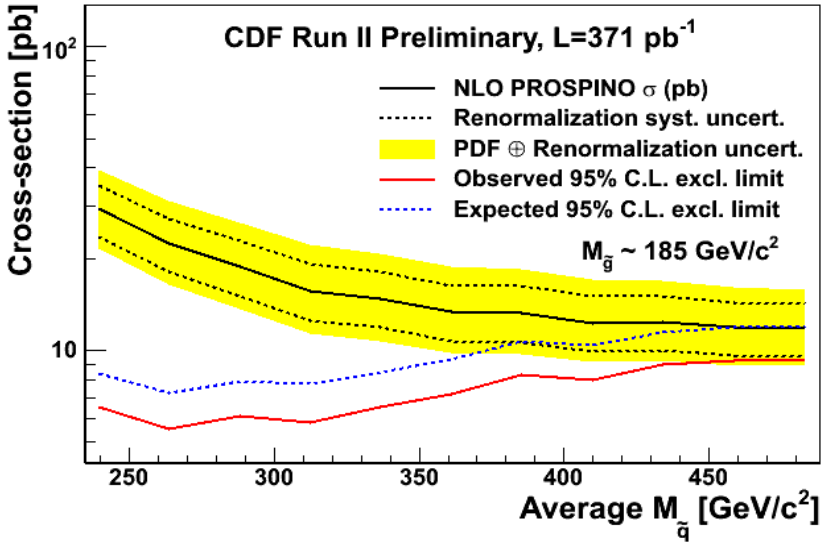


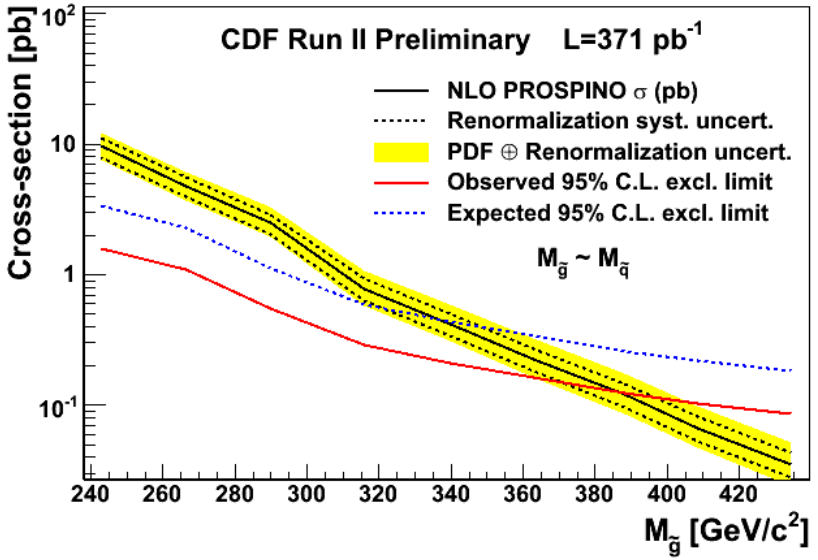


Inclusive Squark/Gluino Search
(Calculation of Gluino/Squark Mass Limits)

- Bayesian approach at 95% CL
- Signal vs Background correlations of systematic uncertainties considered
- Systematic uncertainties
  - CAL energy Scale
  - PDFs (specially gluon at high-x)
  - Renormalization/Factorization scale
  - Initial/Final State Gluon Radiation
  - Luminosity

  (total systematic uncertainty ~20-30%)
- Theoretical Uncertainties included in calculation of limits

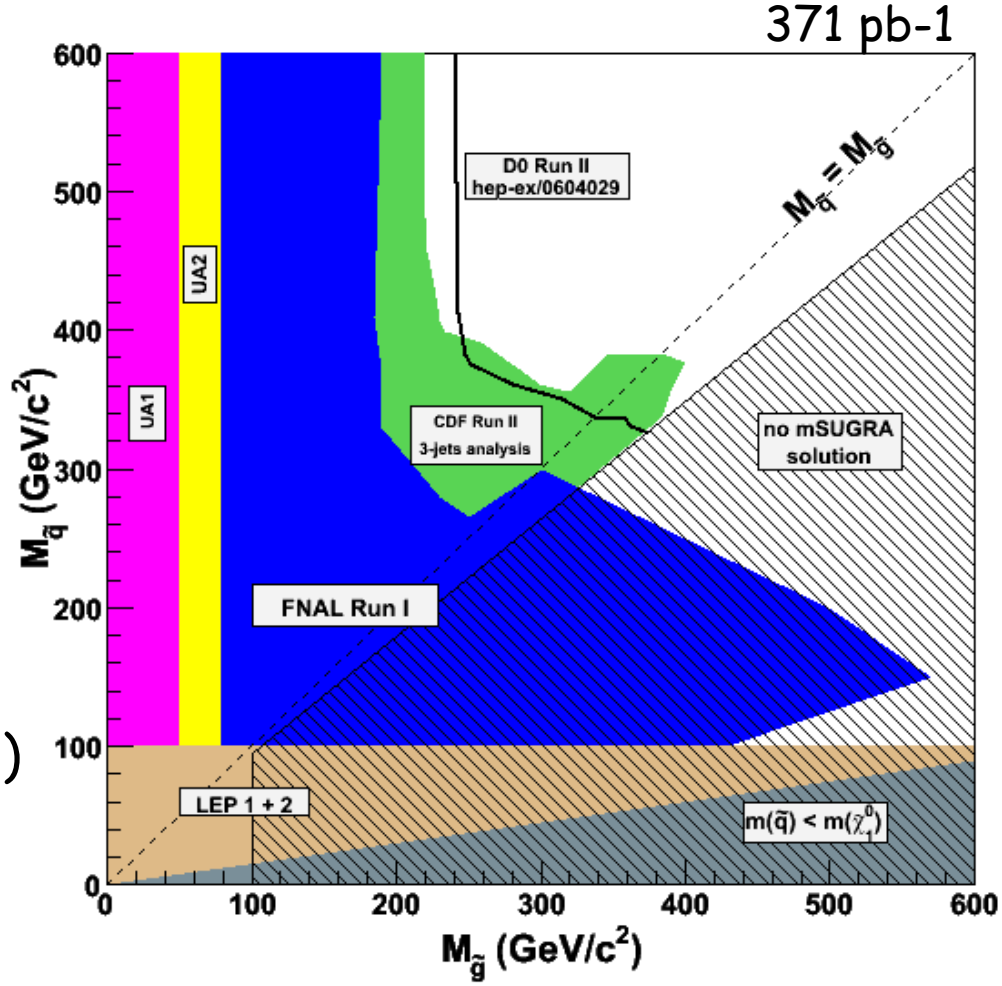




Limits on Gluino/Squark Production

mSUGRA Scenario

- 4 flavors
- $\mu < 0$
- $\tan\beta = 5$
- $A_0 = 0$



CDF Limits (@ 95 CL)

$M > 387\ GeV/c^2$ ($M_{gluino} = M_{squark}$)

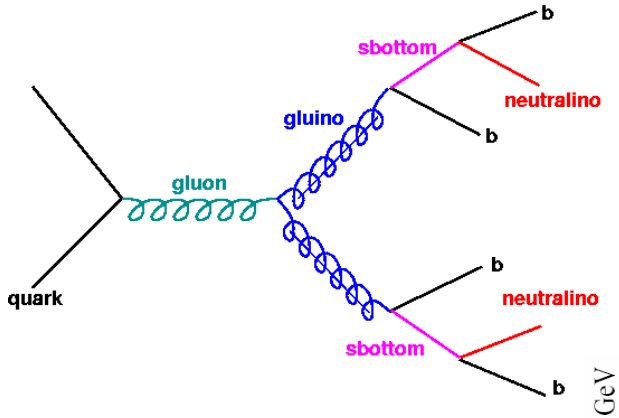
$M_{gluino} > 220\ GeV/c^2$ (all cases)

at low gluino mass a 4-jet analysis is desirable as suggested by the large sensitivity to ISR/FSR modeling

update coming based on ~1 fb-1 data sample

PRL 96 (2006) 171802

Sbottom from Gluino Decays



$\tilde{q}_L\ \tilde{q}_R \xrightarrow{\text{mixing}} \tilde{q}_1\ \tilde{q}_2$

scenario where substantial mixing leads to a sbottom mass eigenstate lighter than gluino

$\tilde{g} \to \tilde{b}_1\, b\ (100\%)$

$\tilde{b}_1 \to b\chi_1^0\ (100\%)$

$M(\chi_1^0) > 60\ \text{GeV}$

$\not\!\!E_T > 35\ \text{GeV}$

At least three jets

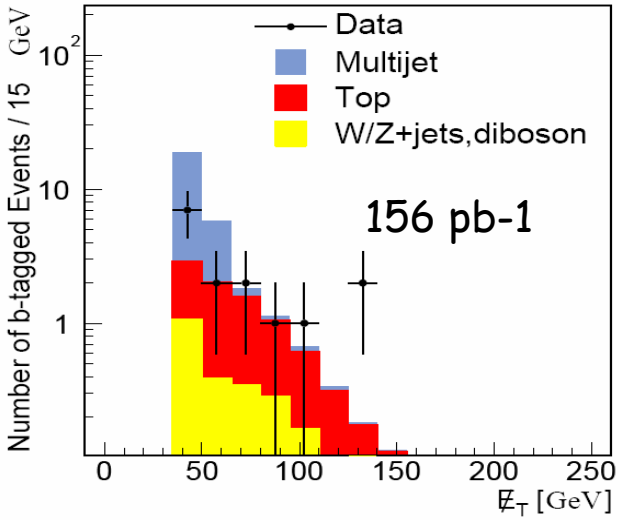
$E_T^{jet} > 15\ \text{GeV}$

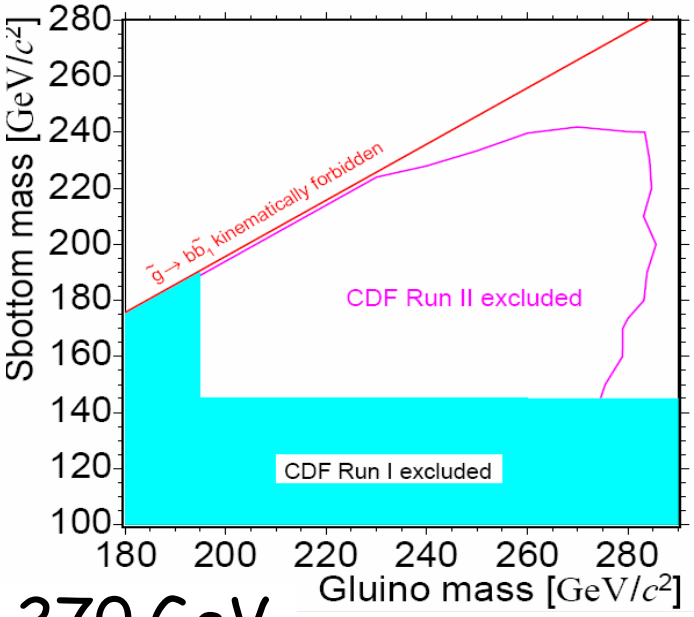
$|\eta^{jet}| < 2$

At least two b-tags

No isolated leptons

Cuts on $\Delta\phi(\not\!\!E_T, \text{jet})$





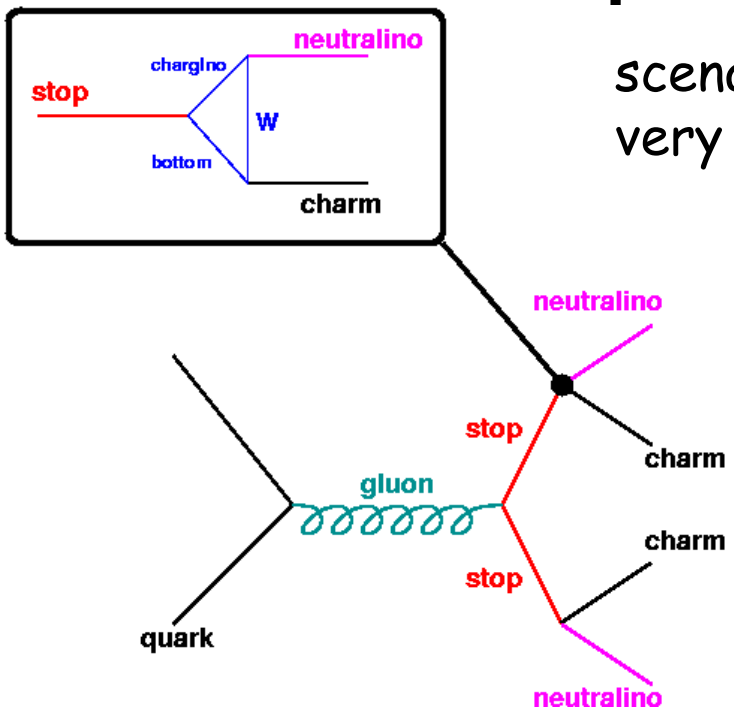
$\not\!\!E_T > 80\ \text{GeV}$ { 4 events (SM : 2.6 ± 0.7)

$M_{\tilde{g}} > 270\ \text{GeV}$

$M_{\tilde{b}_1} > 220\ \text{GeV}$

@95%CL

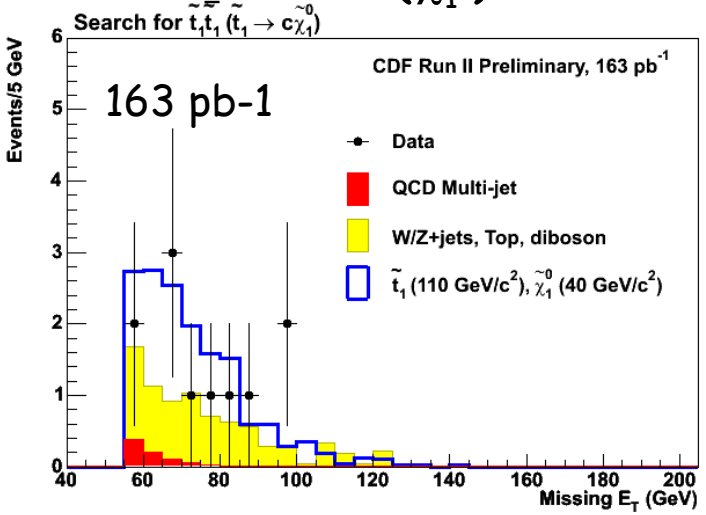
Stop Pair Production



scenario with a very light stop

$\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$ (100%)

$M(\tilde{\chi}_1^0) > 40$ GeV



$\not\!\!E_T > 55$ GeV

At least two jets

$E_T^{jet} > 35(25)$ GeV

$|\eta^{jet}| < 1(1.5)$

At least one c-tag

No isolated leptons

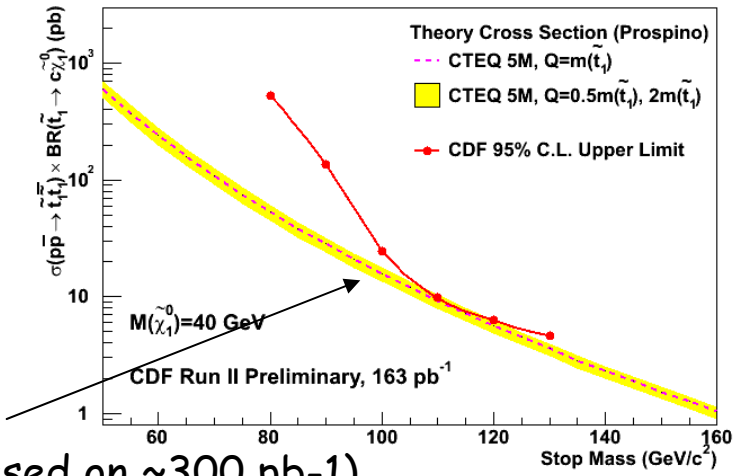
Cuts on $\Delta\phi(\not\!\!E_T, \text{jet})$

11 events

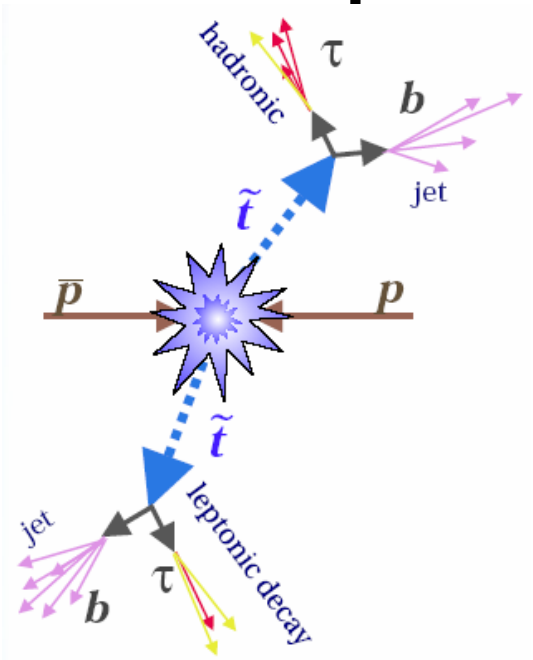
$(SM : 8.3^{+2.3}_{-1.7})$

95% C.L. above NLO

(new result coming based on ~300 pb-1)



Stop Production (RPV in decay)



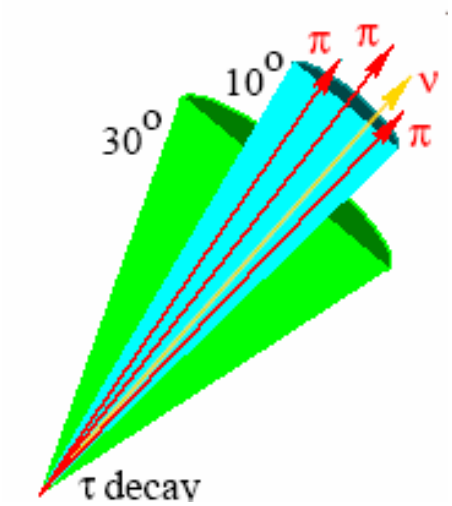
$Br(\tilde{t}_1 \to b\tau) = 100\%$

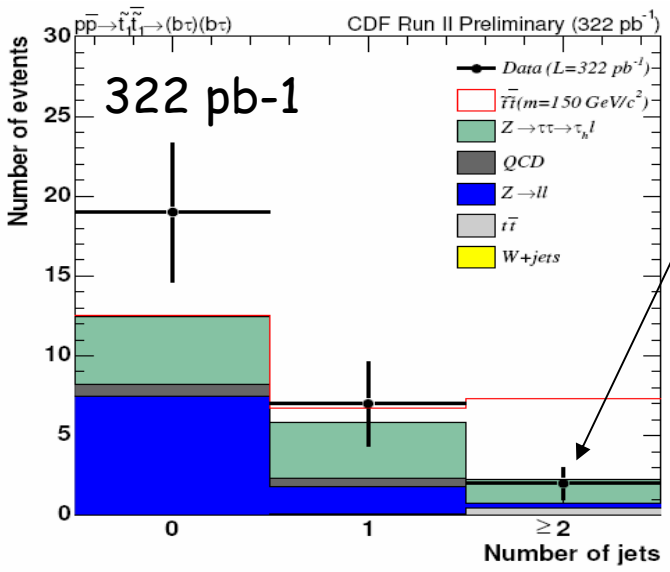
- One high-pt lepton (e or μ)
- One hadronic τ decay
- At least two jets

$E_T^{jet} > 20\ GeV$

$|\eta^{jet}| < 2.4$

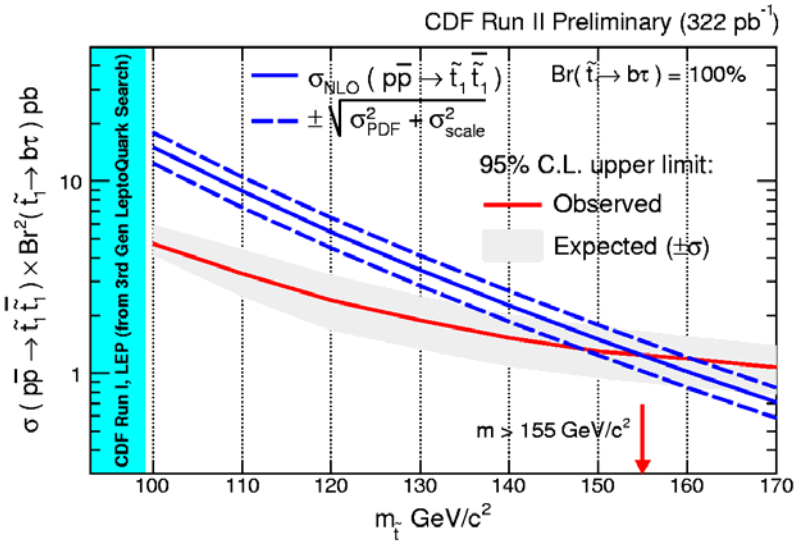
- $M_T(l, \not{E}_T) < 35\ GeV$
- $P_T^{lep} + P_T^{\tau_h} + \not{E}_T > 110\ GeV$





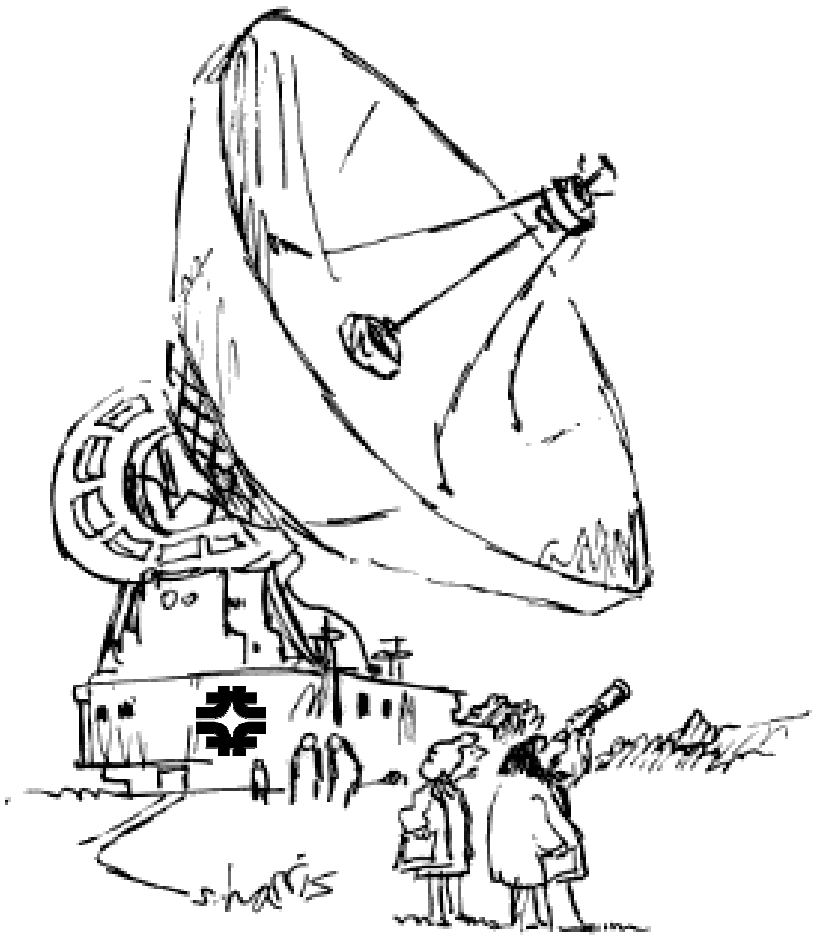
2 events

(SM : $2.3^{+0.5}_{-0.2}$)



$M_{\tilde{t}_1} > 155\ GeV\ (@\ 95\%\ CL)$

Final Notes



- First CDF Run II results on Searches for Gluino/Squark Production
- ~1 fb-1 of data still being analyzed
- Tevatron promises to deliver much more data in the following months
- Aiming for discovery before LHC era