Searches for Squark and Gluino Production at the Tevatron

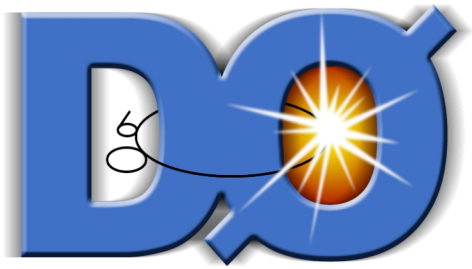
SUSY08

June 2008

Song Ming Wang

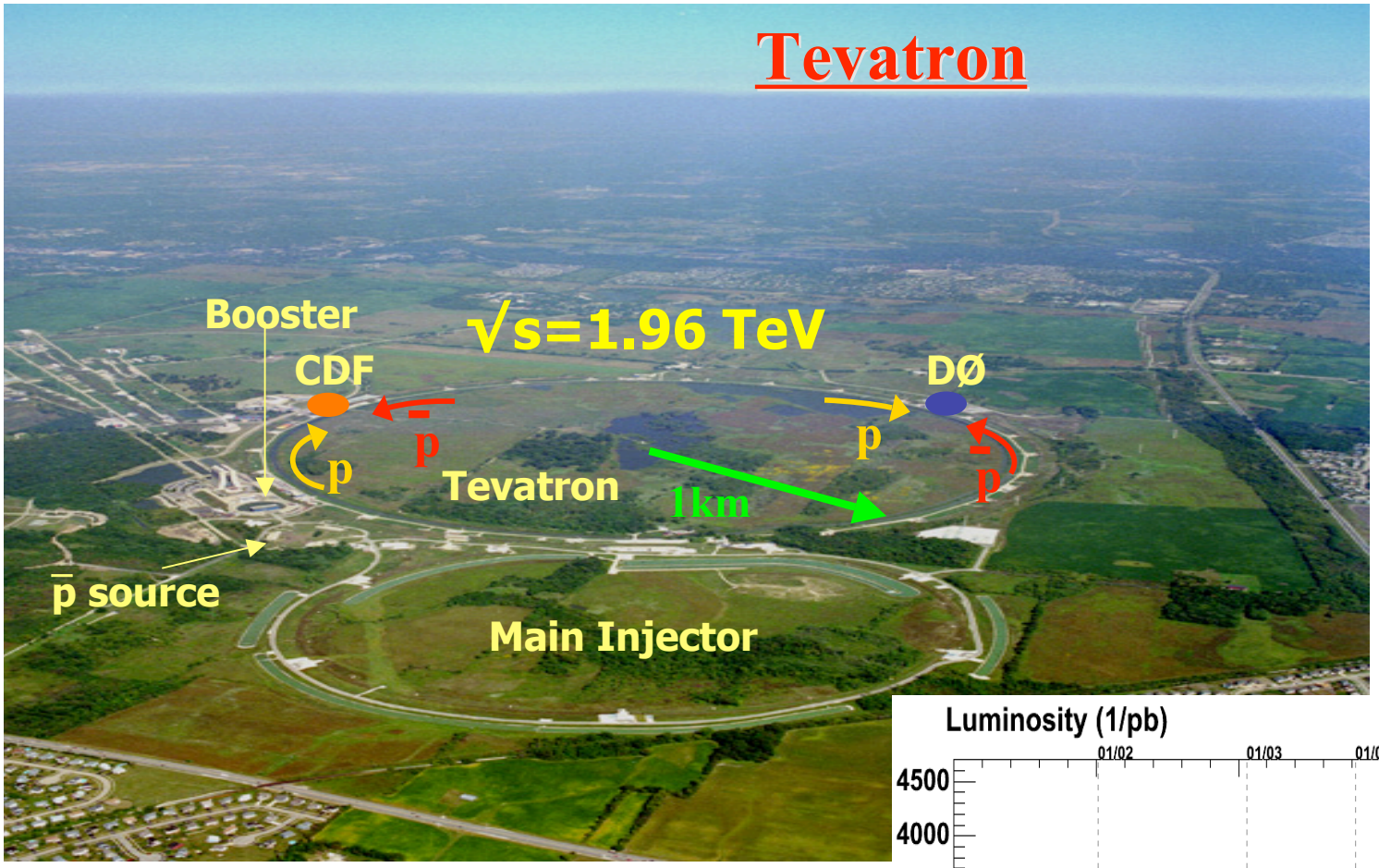
Academia Sinica

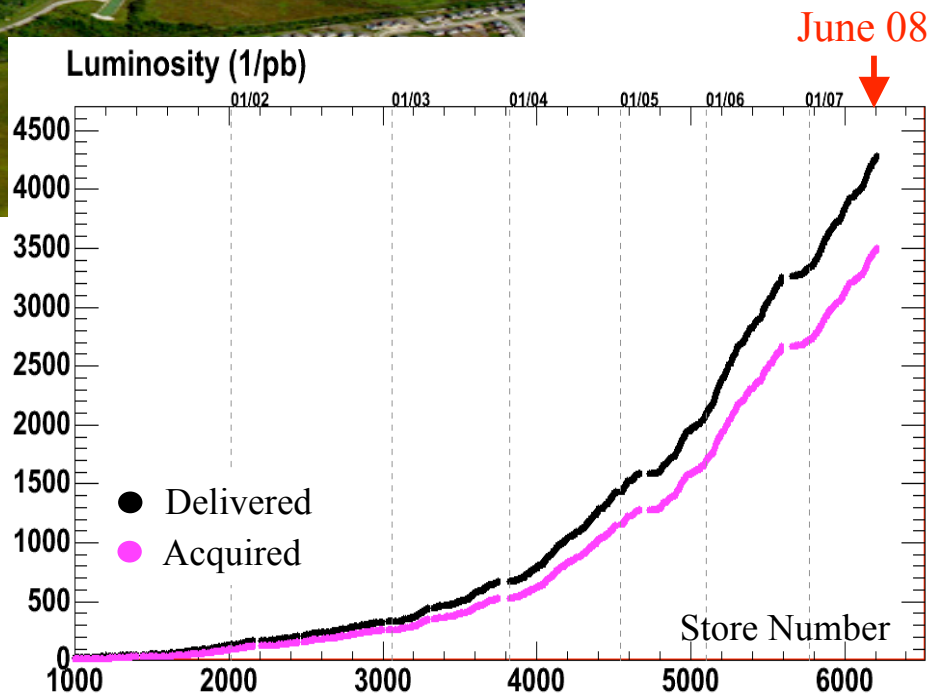
On behalf of the CDF and DØ Collaborations



Outline

- Tevatron and the collider experiments
- SUSY searches at the Tevatron
- Results from squark and gluino searches in
  - Inclusive Missing Transverse Energy (MET) + jets signature
  - MET + jets + tau
  - Model independent MET + di-jet signature
- Summary



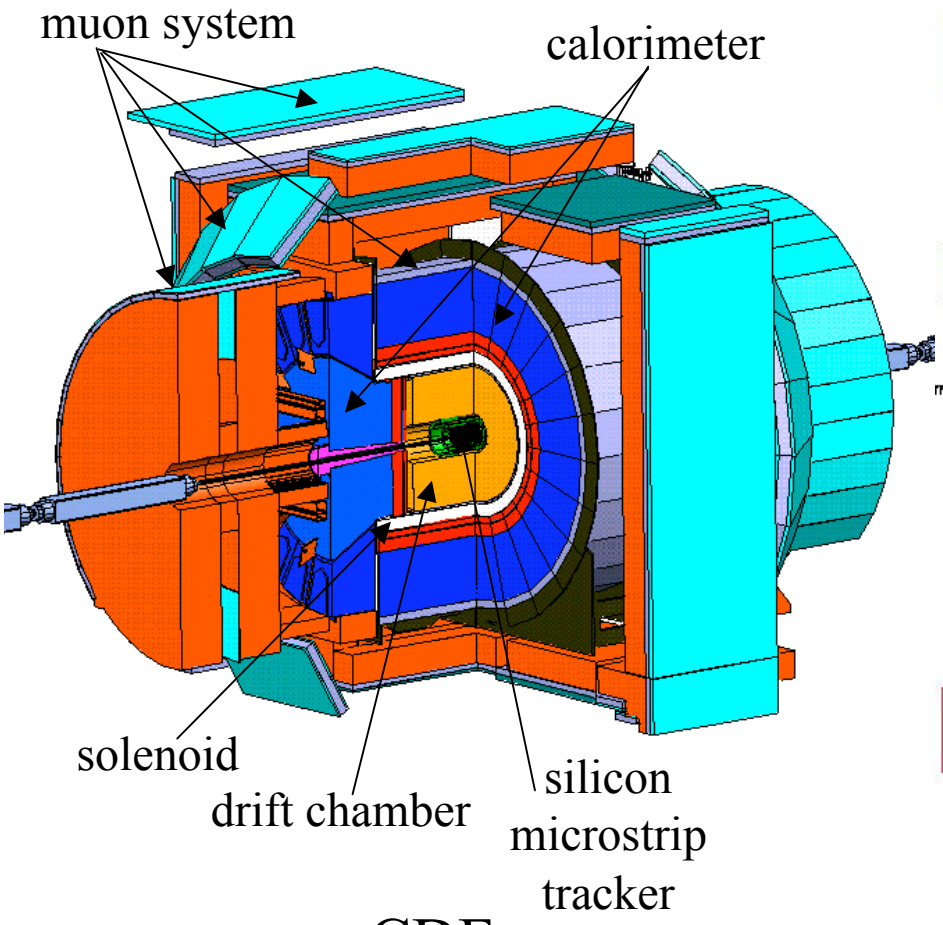


- Tevatron delivered $L = \sim 4.3\ \text{fb}^{-1}$
- CDF and DØ collected $\sim 3.5\ \text{fb}^{-1}$

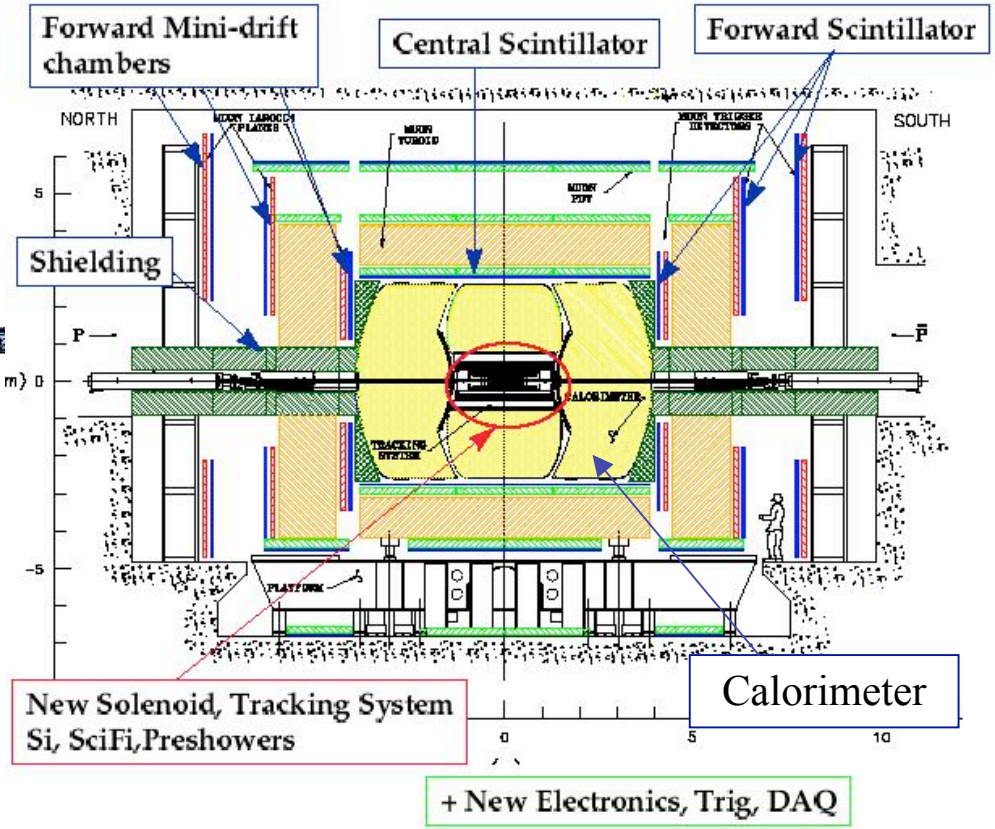
The Tevatron Experiments

Multipurpose detectors :

- Electron, muon, tau identification
- Jet and missing energy measurement
- Heavy-flavor tagging through displaced vertices and soft leptons

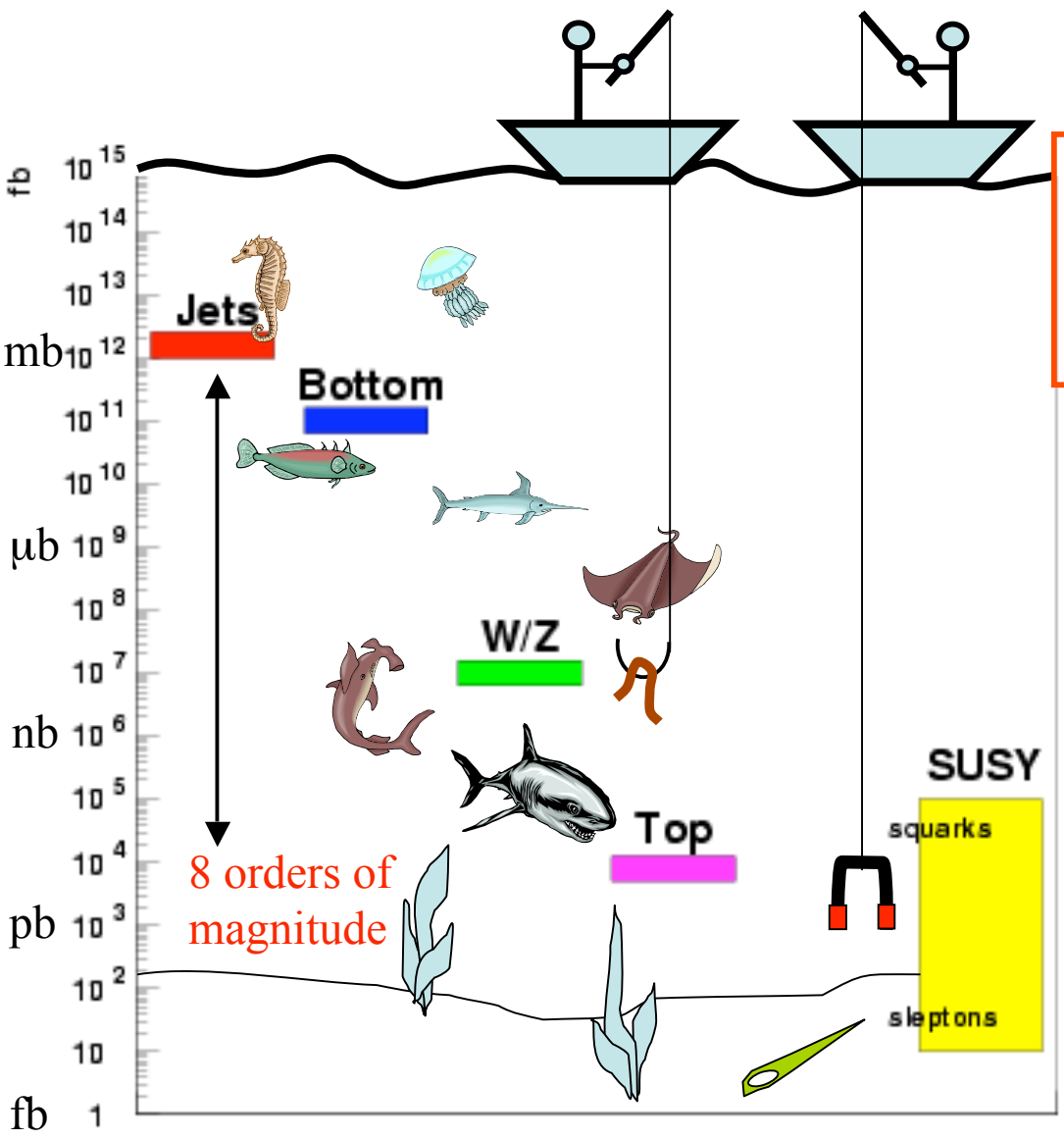


CDF



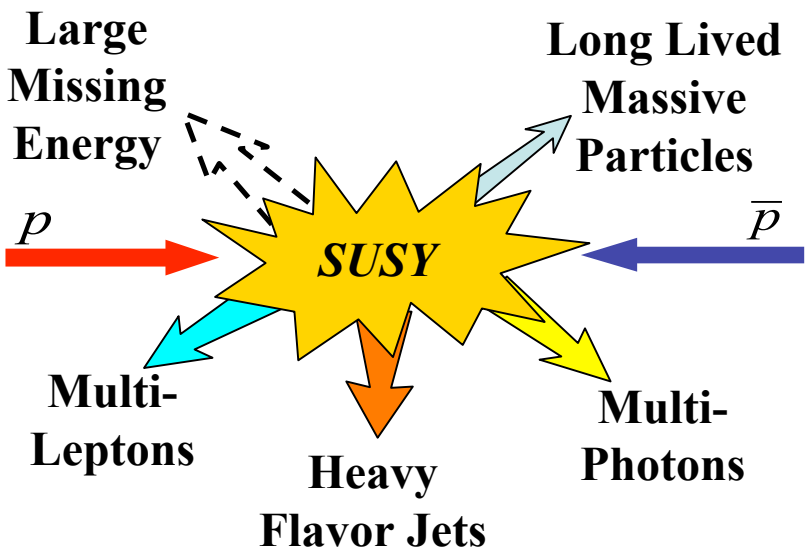
DØ

SUSY at the Tevatron



- Predicted rates for SUSY are LOW !!!

- **Need to look for distinctive signature to distinguish from SM background**



- Present results using data samples : ~1 - 2 fb^{-1}

Searches for Squarks and Gluinos

- Cover on inclusive searches for squarks and gluinos pair production
- Searches for Stop and Sbottom will be covered by Philippe Calfayan
- In these searches, we assume R-parity is conserved

  $\Rightarrow$ Lightest SUSY particle (LSP) is stable

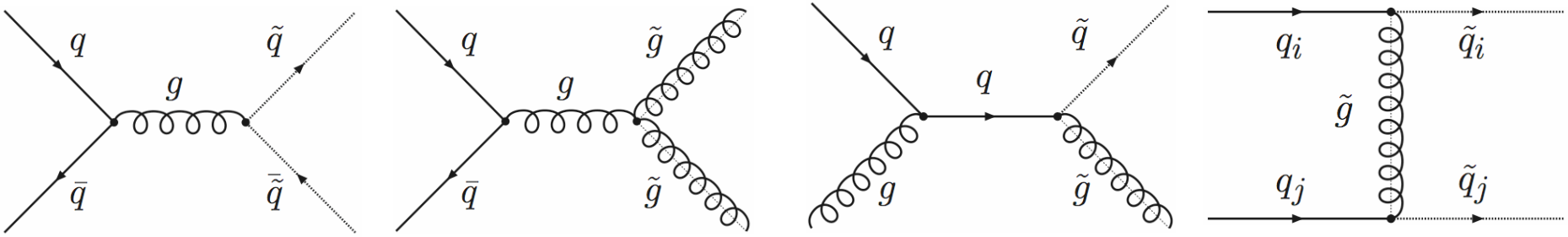
  $\Rightarrow$ SUSY particles are pair produced
- LSP is neutral and interacts weakly

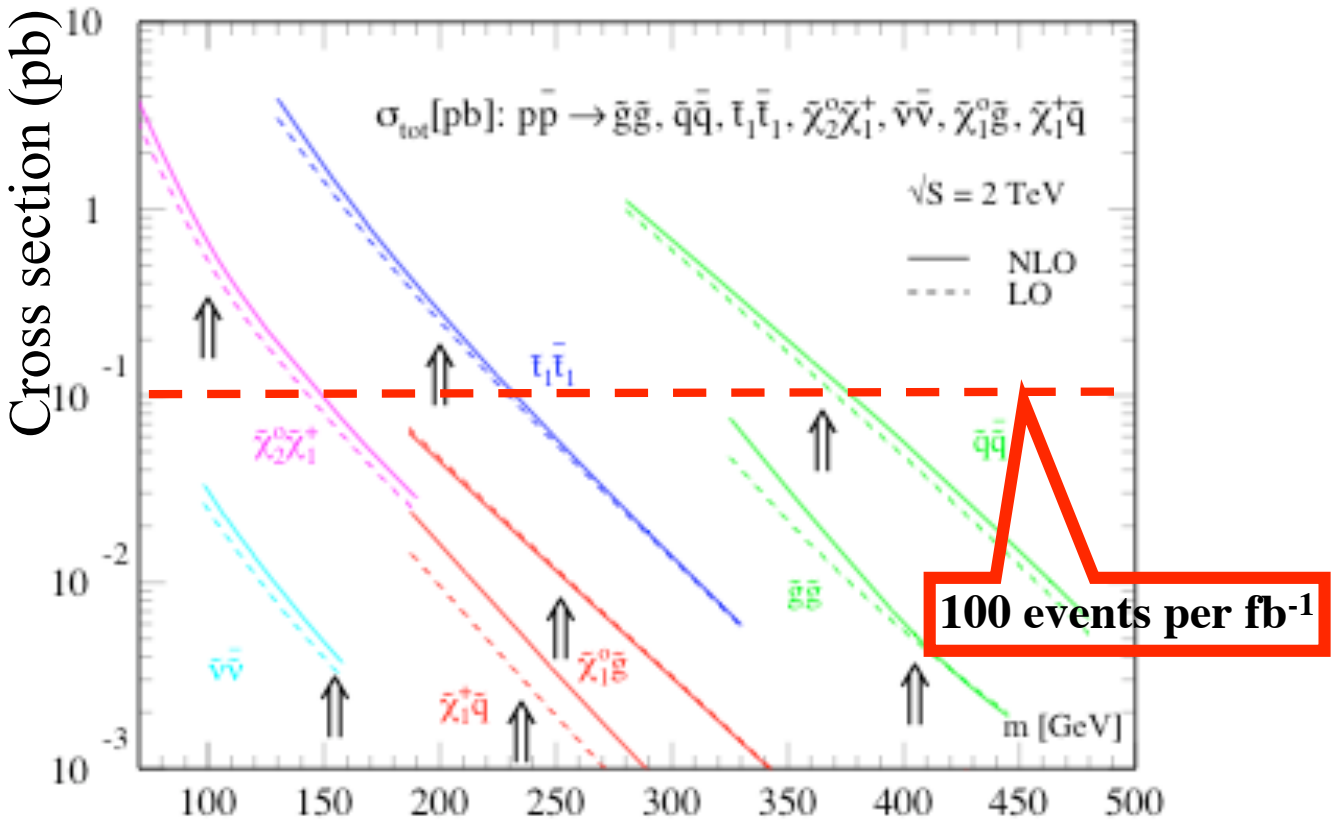
  $\Rightarrow$ escapes detection

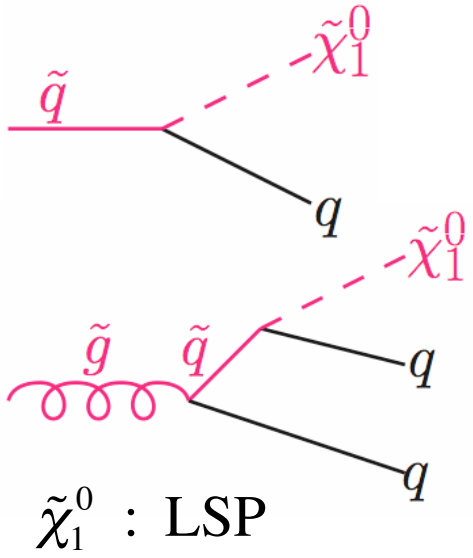
  $\Rightarrow$ missing energy signature

Searches for Squarks/Gluinos in MET+Jets

- $\tilde{q},\tilde{g}$ can be copiously pair produced at Tevatron if sufficiently light







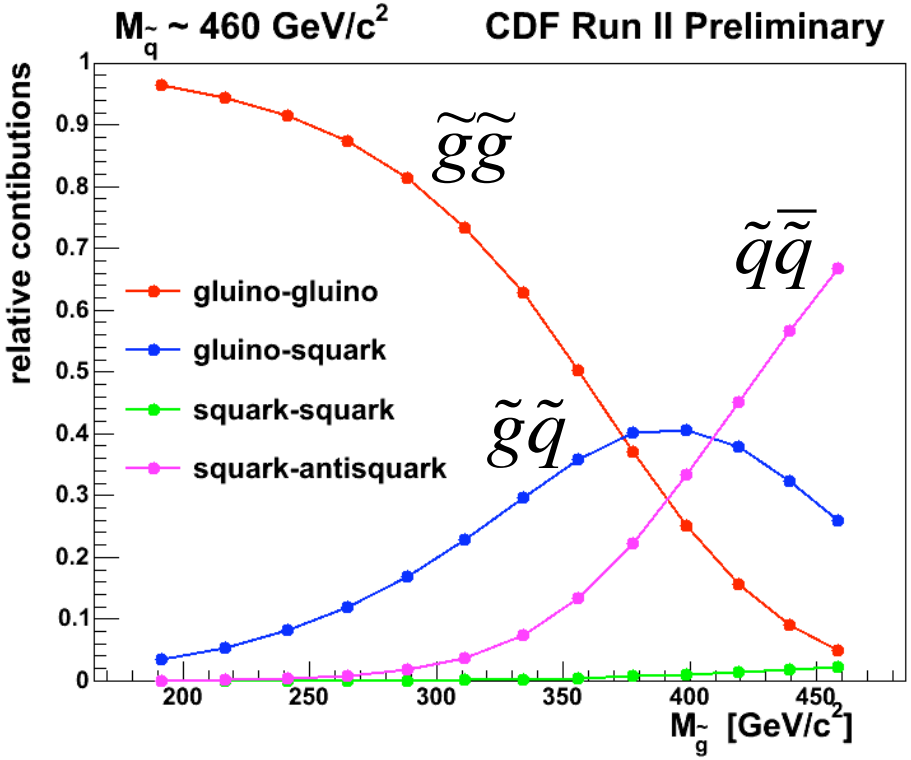
$\tilde{\chi}_1^0$: LSP

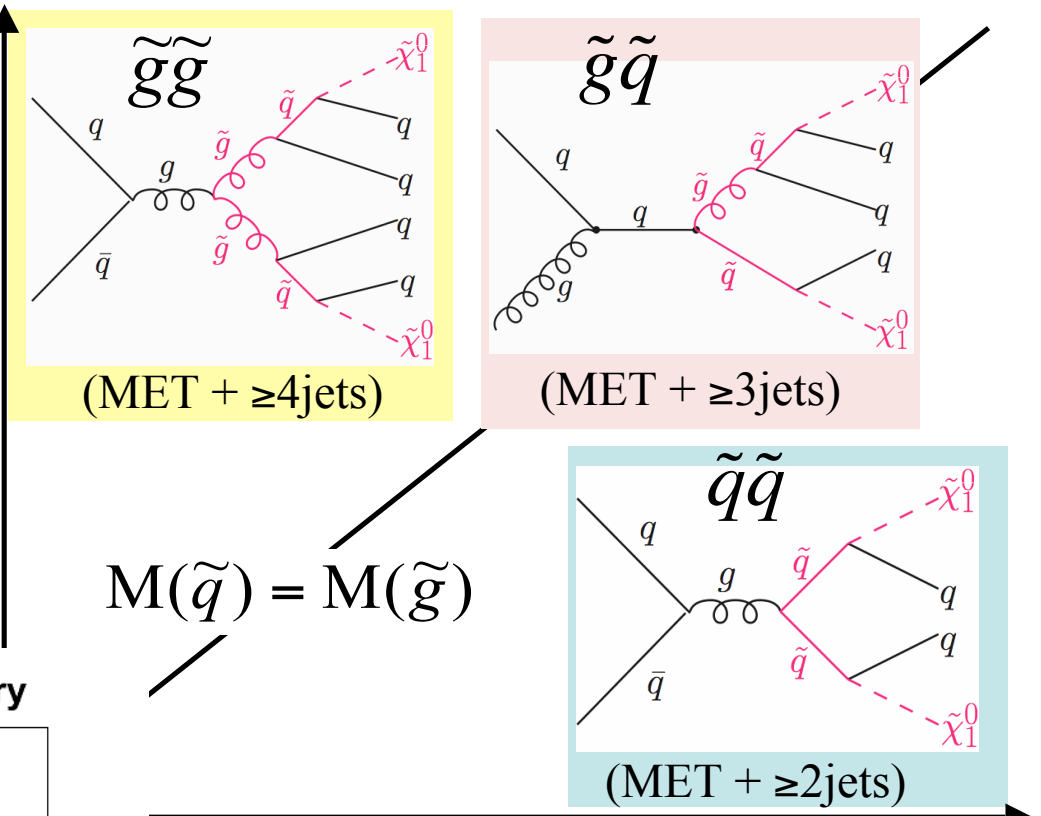
Signature :

- multiple jets and large MET

Search for Squarks/Gluino in Different Topology

Relative Contribution from each Production





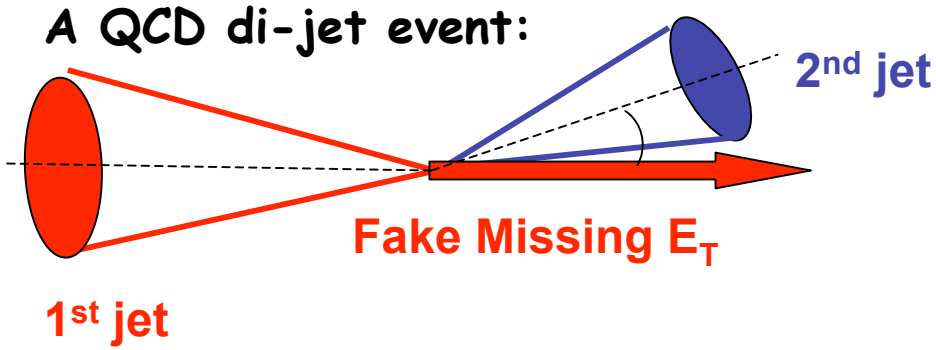
- Contributions from each final state signature depends on the masses of squarks and gluino

Backgrounds in MET+jets Signature

Real MET

- W($\rightarrow l\nu$) + jets
- Z($\rightarrow \nu\nu$) + jets
- tt-bar, single top
  - ($t \rightarrow Wb$, $W \rightarrow l\nu$)
- WW,WZ,ZZ

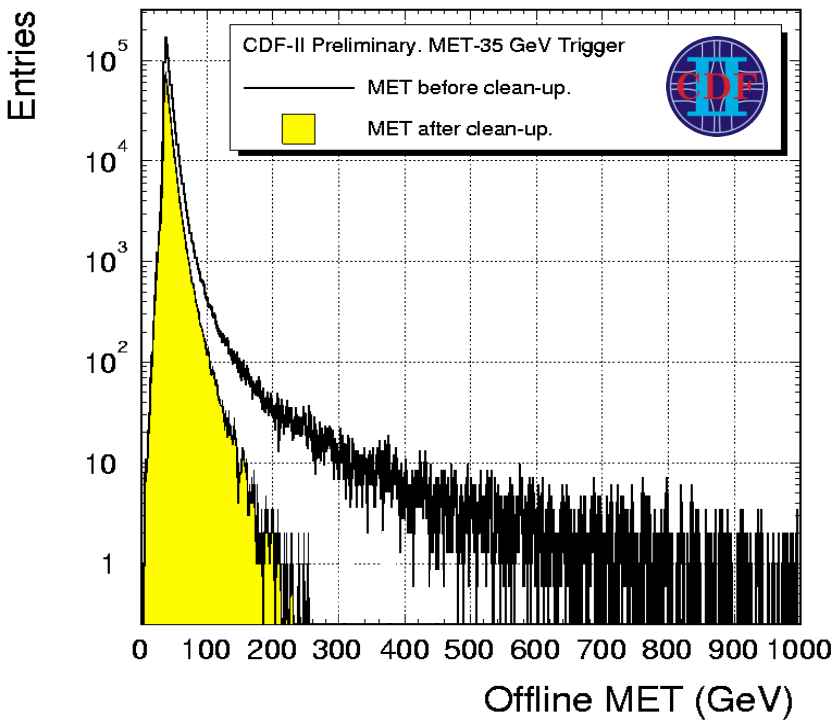
} MET from escaping ν

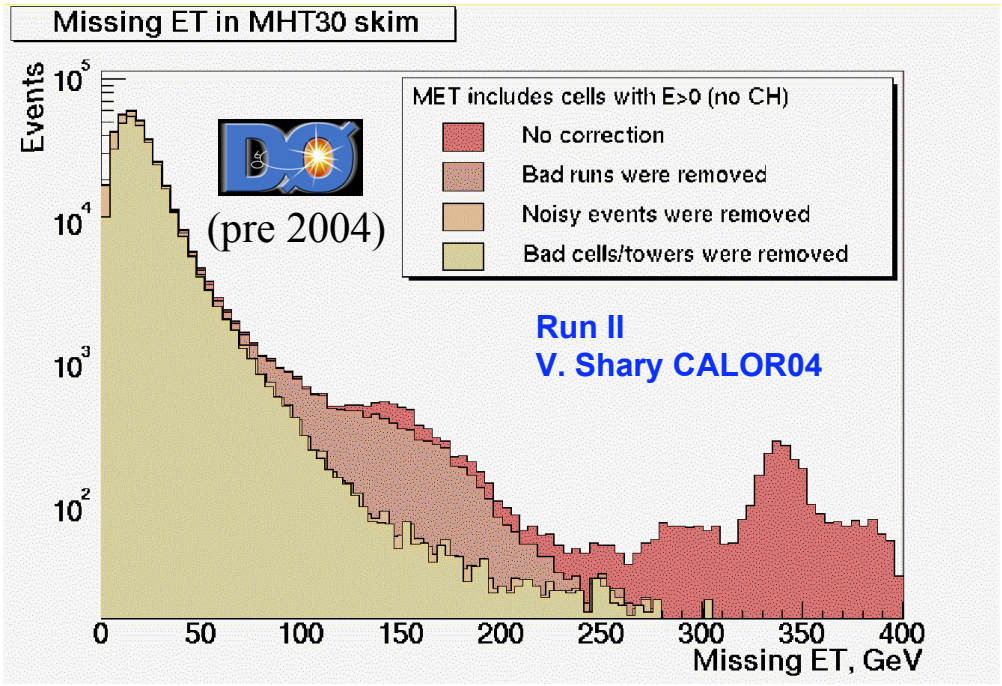


Fake MET

- Mis-measurement of jets' energy
  - energy resolution, particles entering non-instrumented region
  - MET align with mis-measured jet's direction
  - Can have large contribution from QCD multi-jet due to its large cross section
- Non-collision background
  - Beam halo
  - Cosmic muon
  - Noise/dead-channels in detector

Non-Collision MET Background





- **Cleaning up non-collision background**
- Lots of effort from CDF and DØ at the beginning of Run 2 to understand the non-collision background
  - Fix any instrumental issues, or remove runs/events if not fixed
  - Require events with good primary vertex (PV)
  - Sufficient tracks in jets originate from PV
  - …..

Event Selection

- CDF,DØ search in ~2 fb^{-1} data sample
- Separate searches in the MET +2 jets, +3 jets, and +4 jets final states
- Remove non-collision background
- MET direction not align with jets (reduce QCD)
- Lepton veto (reduce W/Z+jets, top, diboson)
- Optimize cuts on leading jets' E_T, MET and H_T (scalar sum of jets' E_T)

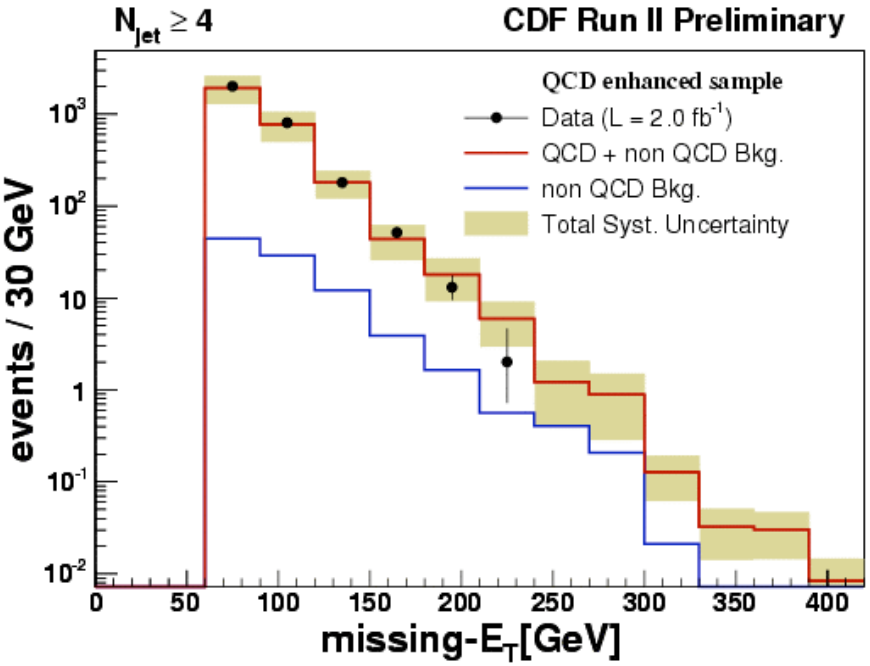
	CDF			DØ		
Analysis	H_T (GeV)	MET (GeV)	Jet E_T (GeV)	H_T (GeV)	MET (GeV)	Jet E_T (GeV)
2-jets	330	180	165,100	325	225	35,35
3-jets	330	120	140,100,25	375	175	35,35,35
4-jets	280	90	95,55,55,25	400	100	35,35,35,20

Events in Control Regions

- Test background prediction in kinematic control regions :

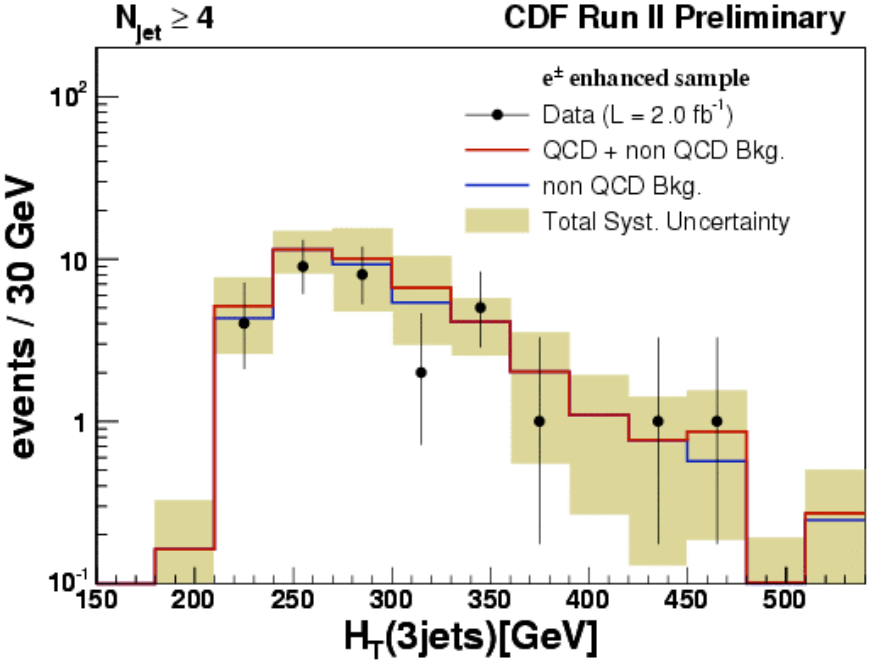
QCD multijet Control Region

- Require at least one jet align with MET

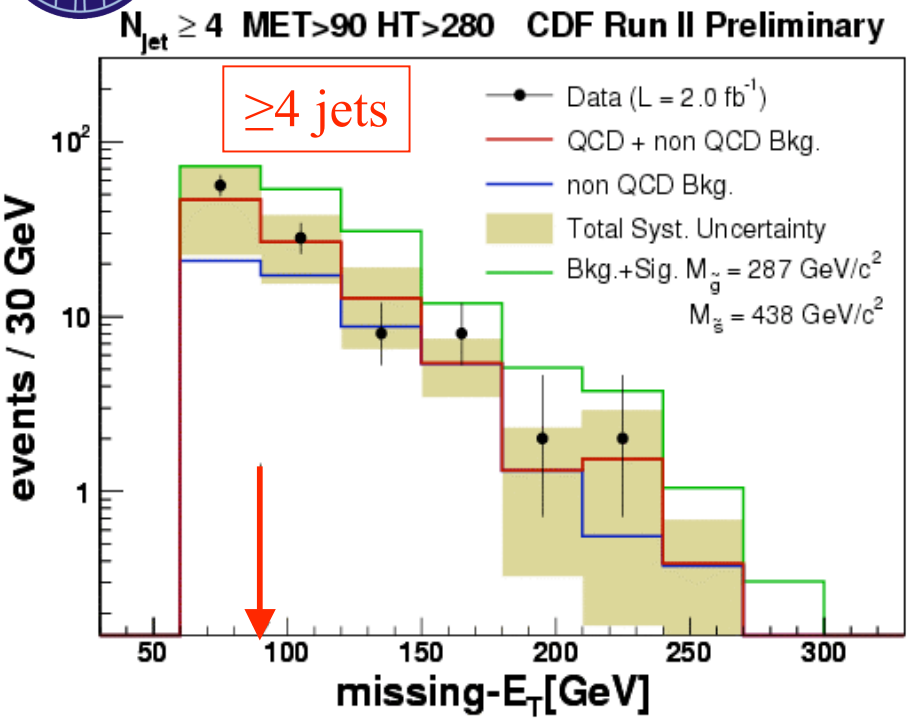


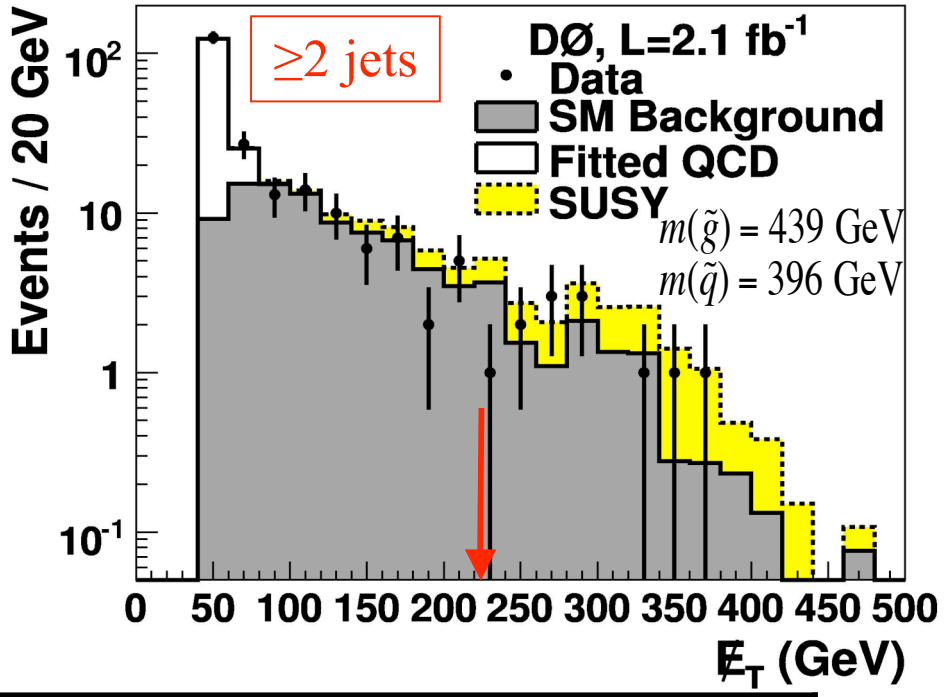
W/Z+jets,top Control Region

- At least one electron candidate



Events in Signal Regions



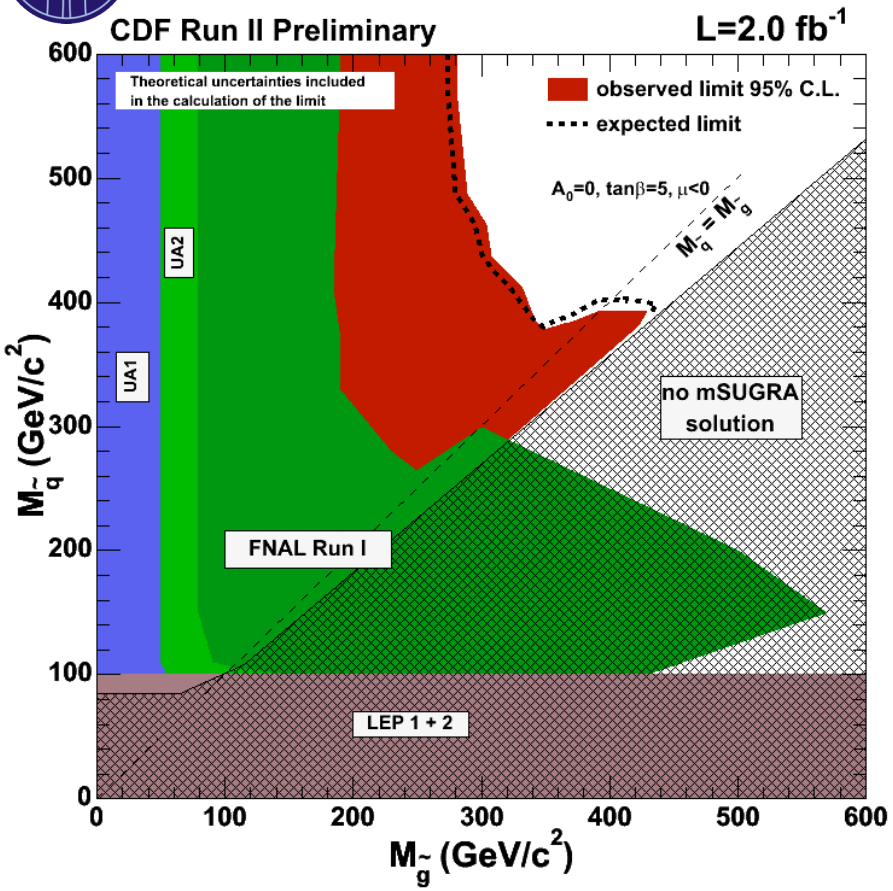


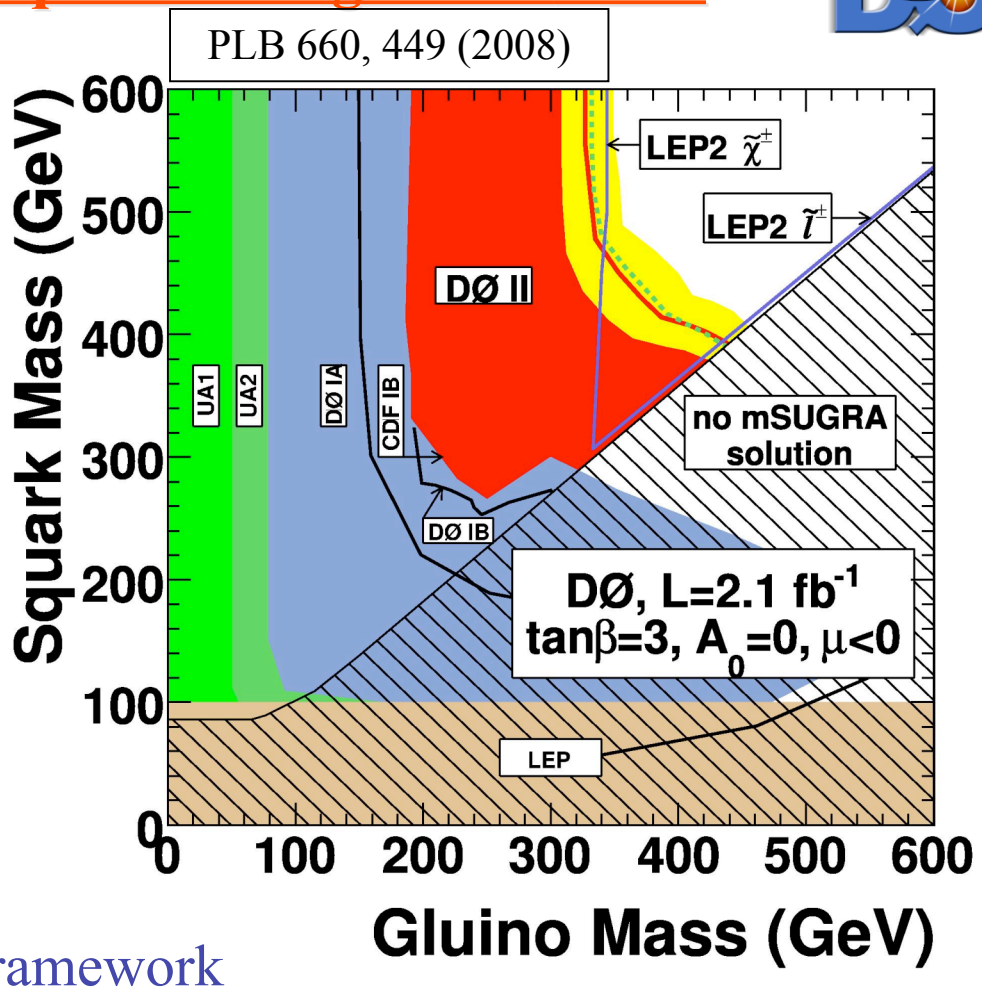
	CDF (2 fb^{-1})		DØ (2.1 fb^{-1})	
Analyses	# Expected	# Observed	# Expected	# Observed
2-jets	16 ± 5	18	$11 \pm 1\,^{+3}_{-2}$	11
3-jets	37 ± 12	38	$11 \pm 1\,^{+3}_{-2}$	9
4-jets	48 ± 17	45	$18 \pm 1\,^{+6}_{-3}$	20

Preliminary

PLB 660, 449 (2008)

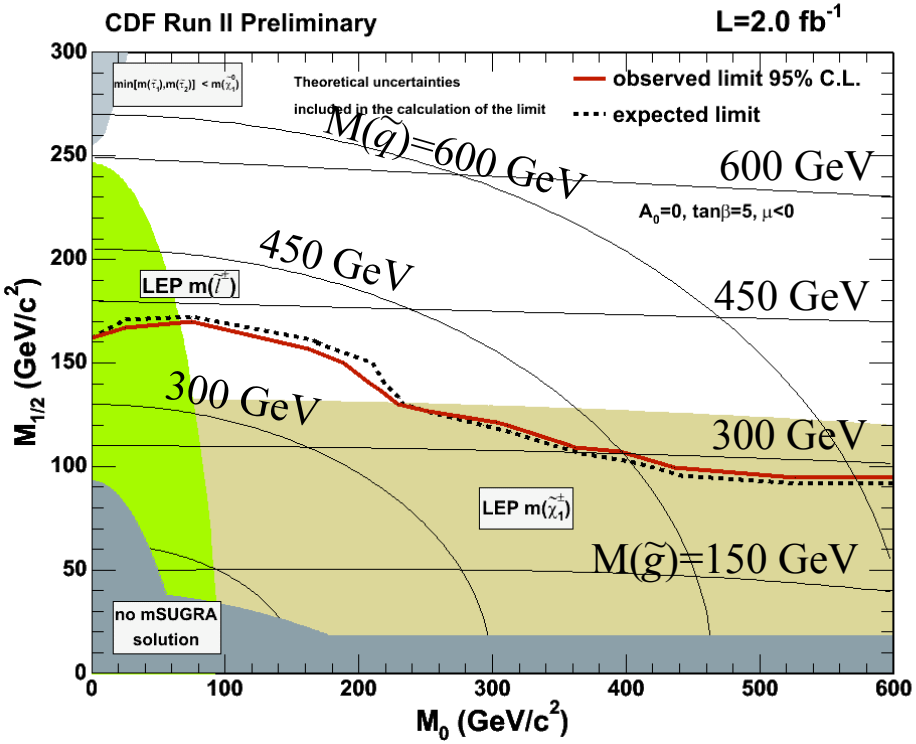
Exclusion Limit in Msquark vs Mglunino Plane

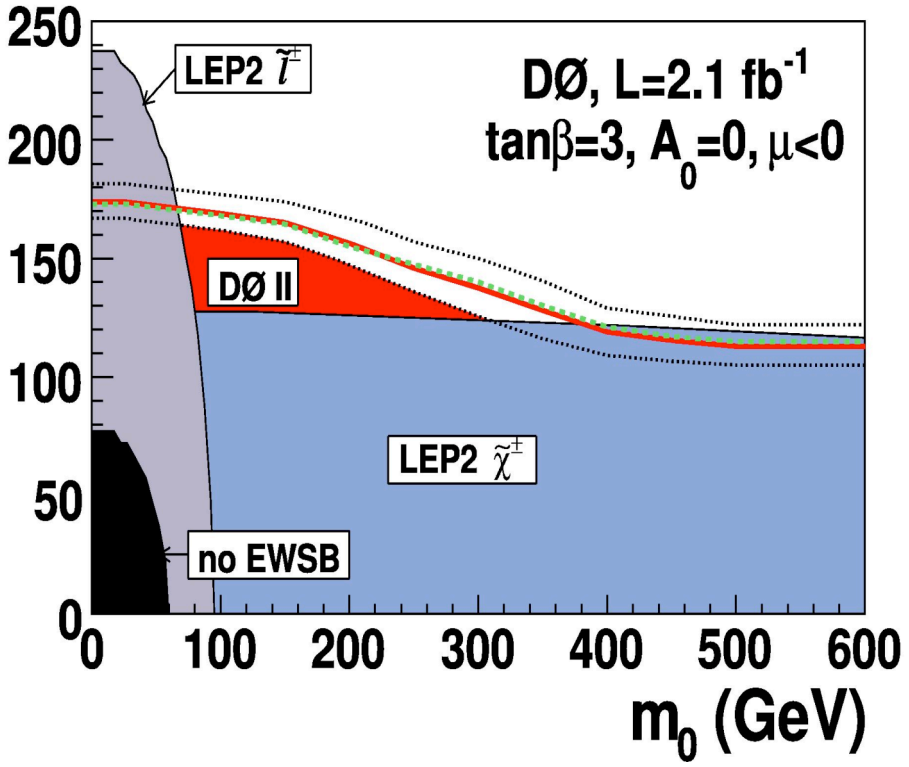




- Determine limits in mSUGRA framework
- Mass limit (taking into account theory uncertainties from PDF, renormalization and factorization scale)
  - $M(\tilde{g})$ <280 GeV (CDF), <308 GeV (DØ), for all squark mass
  - $M(\tilde{q})$ <380 GeV (CDF, DØ), for all gluino mass

Exclusion Limit in m0 vs m1/2 Plane

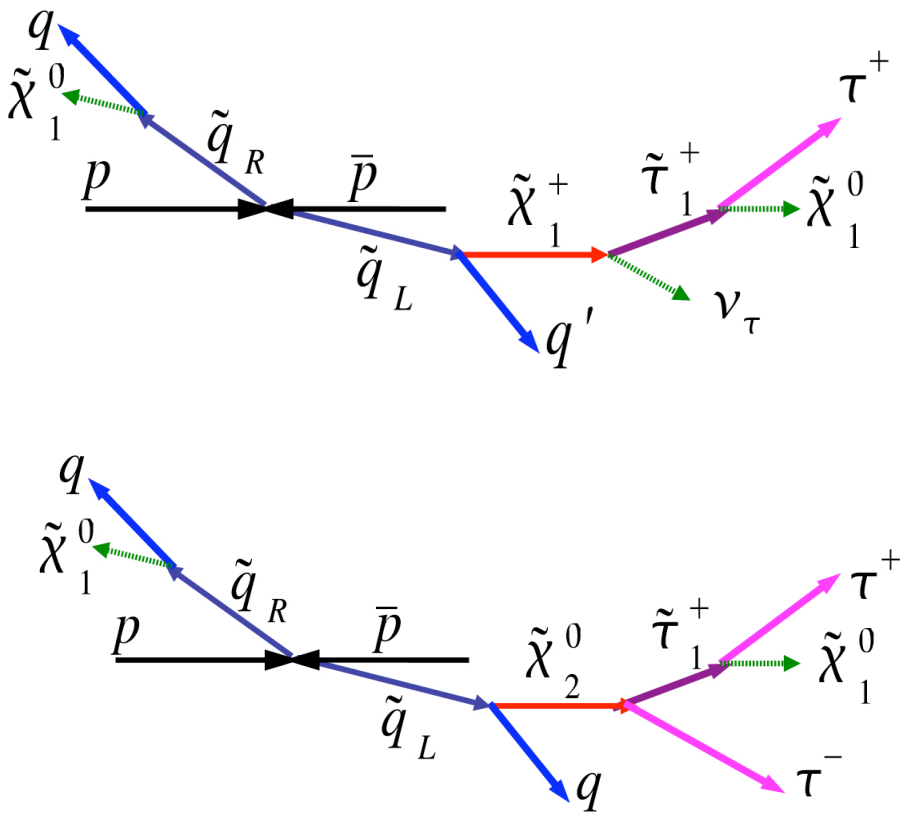




- Results from both experiments also constrain the mSUGRA parameters (m0: univsersal scalar mass, m1/2: universal gaugino mass)
- Extend limits beyond LEP

Squarks in MET+Jets+Tau Channel

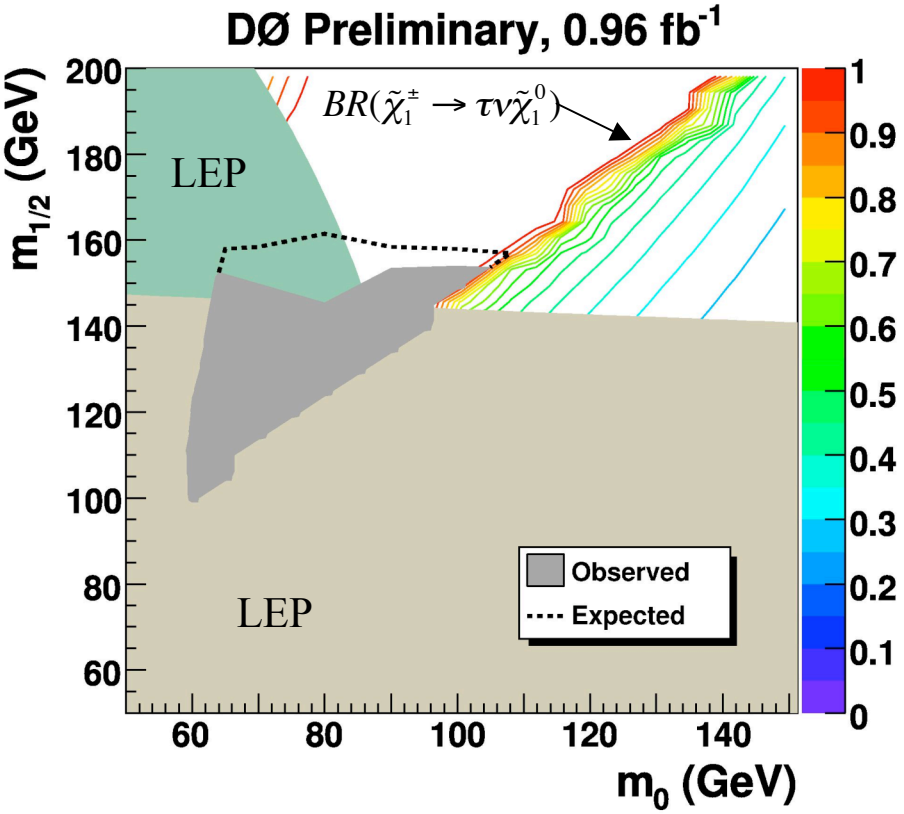
- Large mixing between L- and R-handed superpartners of 3rd generation fermions
- For stau ($\tilde{\tau}$), large mixing may occur at high tanβ
  - ⇒lightest stau ($\tilde{\tau}_1$) might be the lightest slepton
  - ⇒can be produced in cascade decays of squark pair production
  - stau decays directly: $\tilde{\tau}_1 \rightarrow \tau\tilde{\chi}_1^0$

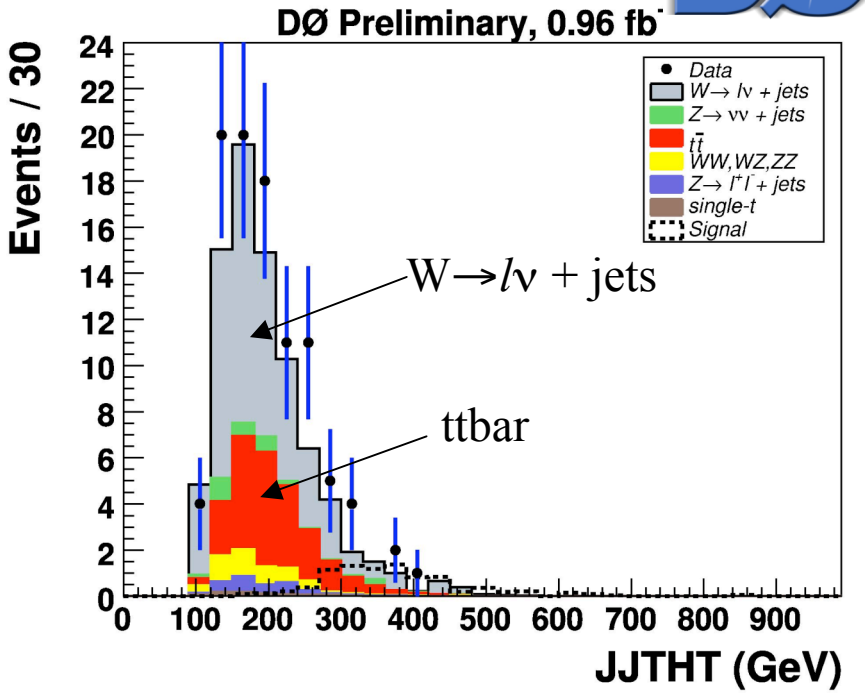


- Final state signature : ≥2 jets + large MET + tau lepton

Squarks in MET+Jets+Tau Channel

- Selection cuts are similar to the inclusive MET+jets channel
- ≥1 hadronic tau (E_T > 15 GeV)
  - Hadronic tau : narrow isolated jet with low track multiplicity
- Optimize the MET and JJTHT($E_T^{jet1} + E_T^{jet2} + E_T^{\tau}$) cut



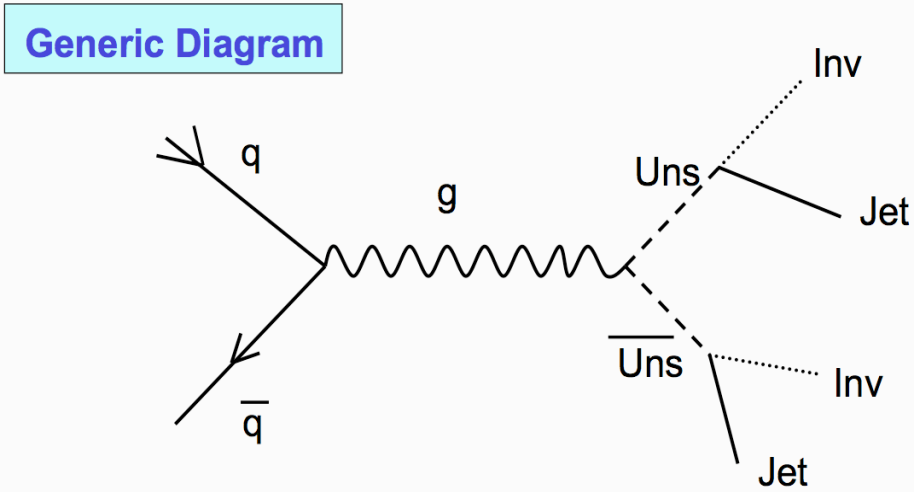


(before final JJTHT and MET cuts)

- After all selection cuts:
  - Nobs=2, Nexpt=$1.7 \pm 0.2^{+0.6}_{-0.3}$
- Interpret results in mSUGRA model (tanβ=15, $A_0=-2m_0$, μ<0)
- Exclude mass m(squark)<366 GeV

Signature Based Search in the MET+dijet Channel

- In many new physics models their predictions have MET +2 jets signature in the final state:
  - SUSY, Leptoquarks, Universal Extra Dimensions …
- Perform a generic search in MET +2 jets signature w/o optimizing to a specific model



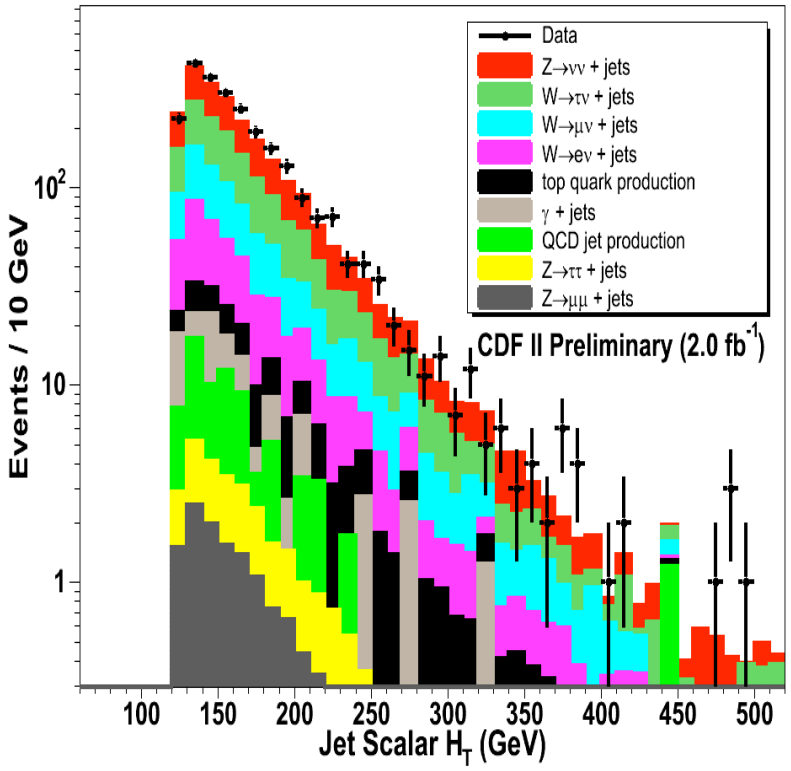
- Uns : new unstable particle
- Inv : new invisible particle

- **Event Selection:**
  - Similar pre-selection cuts as inclusive squark/gluino search
    - But requires only 2 jets in final state
  - Choose two kinematic regions to have sensitivity to a wide range of new physics
    - Low kinematic region : $H_T(E_{T(J1)} + E_{T(J2)})$>125 GeV, MET>80 GeV
    - High kinematic region : H_T>225 GeV, MET>100 GeV

Selected Events in L=2 fb^{-1} Data Sample

CDF Run II Preliminary

Background	(Low) H_T>125, MET>80 (GeV)	(High) H_T>225, MET>100 (GeV)
$Z\rightarrow\nu\nu$	777 ± 49	71 ± 12
$W\rightarrow\tau\nu$	669 ± 42	50 ± 8
$W\rightarrow\mu\nu$	399 ± 25	33 ± 5
$W\rightarrow e\nu$	256 ± 16	14 ± 2
$Z\rightarrow ll$	29 ± 4	2 ± 0
Top Production	74 ± 9	11 ± 2
QCD	49 ± 30	9 ± 9
γ+jets	55 ± 13	5 ± 3
Non-collision	4 ± 4	1 ± 1
Total predicted	2312 ± 140	196 ± 29
Data observed	2506	186

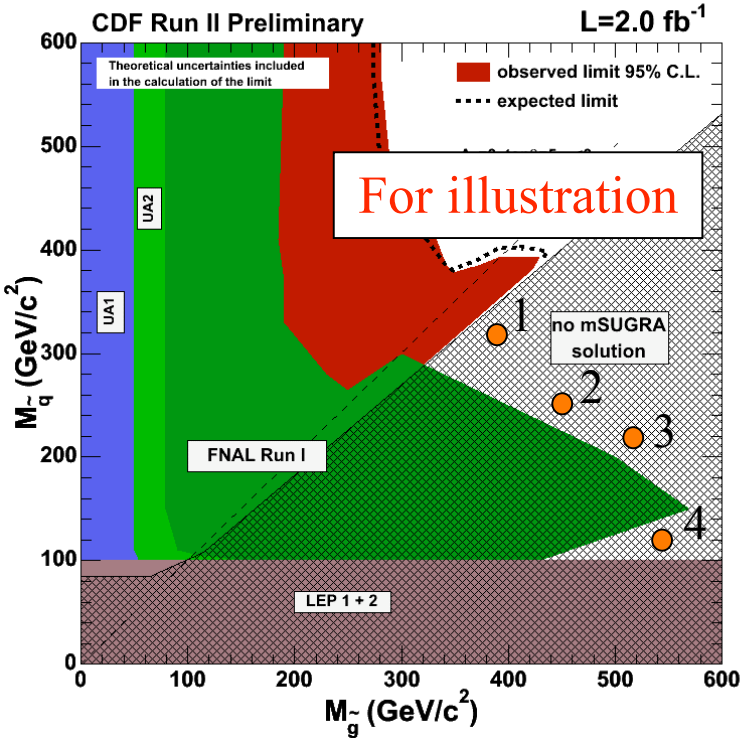


H_T distribution from low kinematic region

Interpretation of Results in MSSM SUSY Model

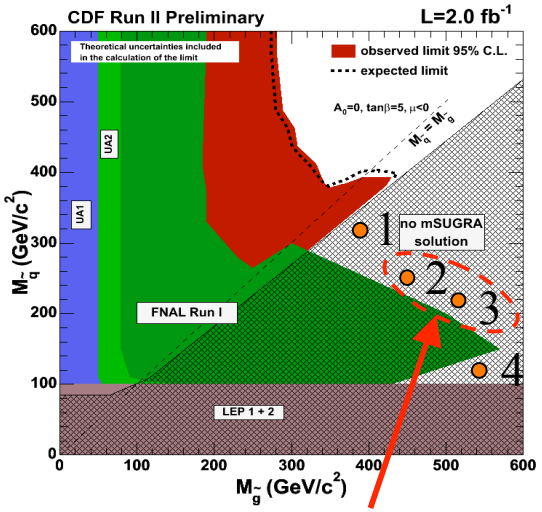
- Choosen MSSM model:
  - $\tilde{\chi}_1^0$ is the LSP
  - $\tilde{u},\tilde{d},\tilde{c},\tilde{s}$ are degenerate in mass
  - $m(\tilde{g})/m(\tilde{q})$ >1.2
    - No mSUGRA solution
    - Squark pair production dominates
  - tanβ=3, A_T=-500, μ=-800
- Decide the kinematic region cuts to be applied on which SUSY points based on lowest (best) a priori cross section upper limit :
  - Low kinematic (125/80): point 4
  - High kinematic (225/100): points 1,2,3

SUSY spectrum	$\tilde{q}$ mass (GeV)	$\tilde{g}$ mass (GeV)	$\tilde{\chi}_1^0$ mass (GeV)
1	320	390	60
2	250	450	72
3	220	520	85
4	120	550	89



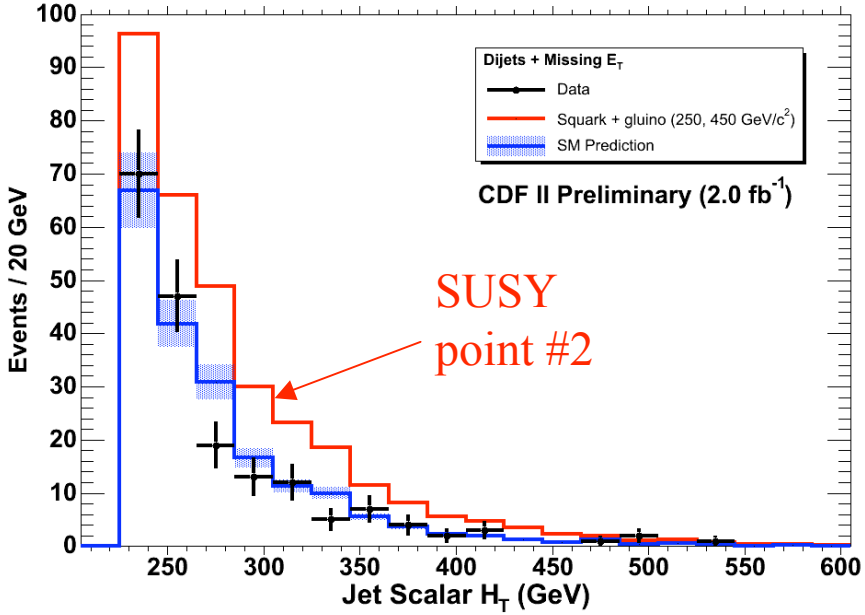
Cross Section Limit

SUSY spectrum	A priori limit (pb)	Observed limit (pb)	Pythia LO cross section (pb)
1	0.52	0.46	0.36
2	0.88	0.77	1.73
3	1.82	1.60	3.21
4	75.9	122.3	57.4

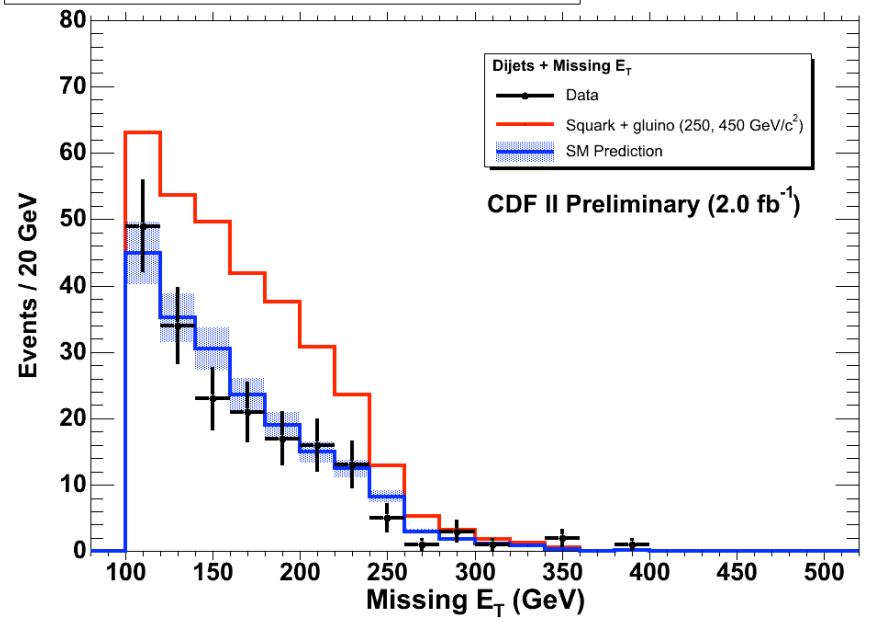


- SUSY points 2,3 excluded at LO using Pythia's cross section

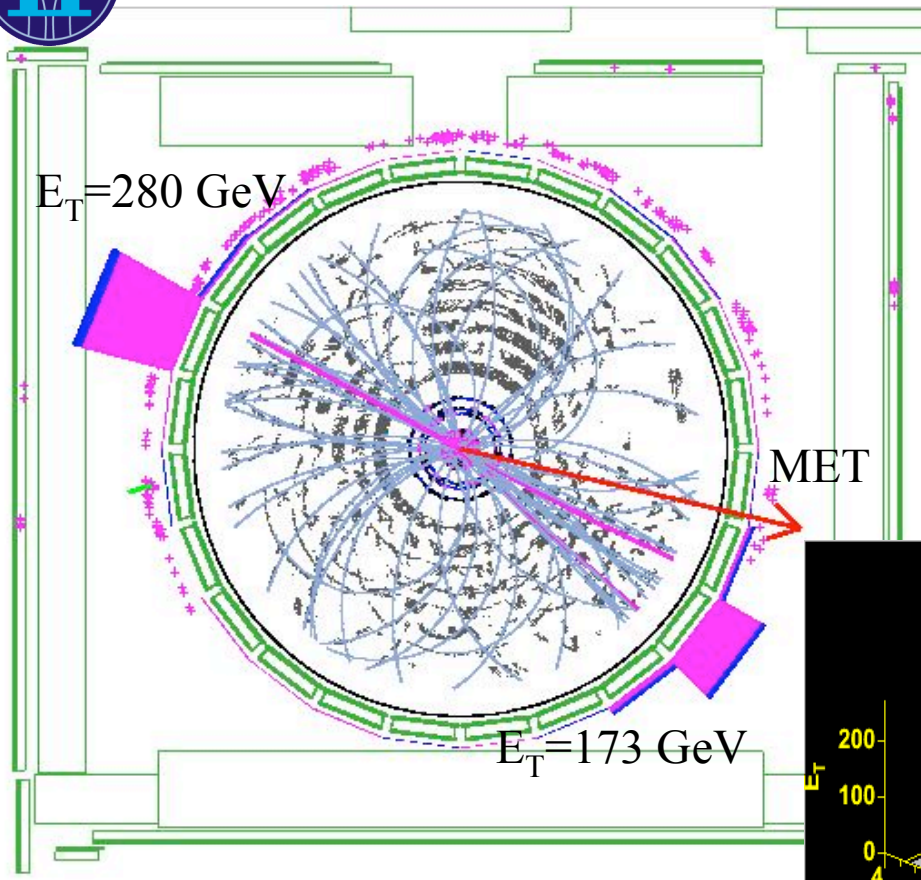
H_T for High Kinematic Region



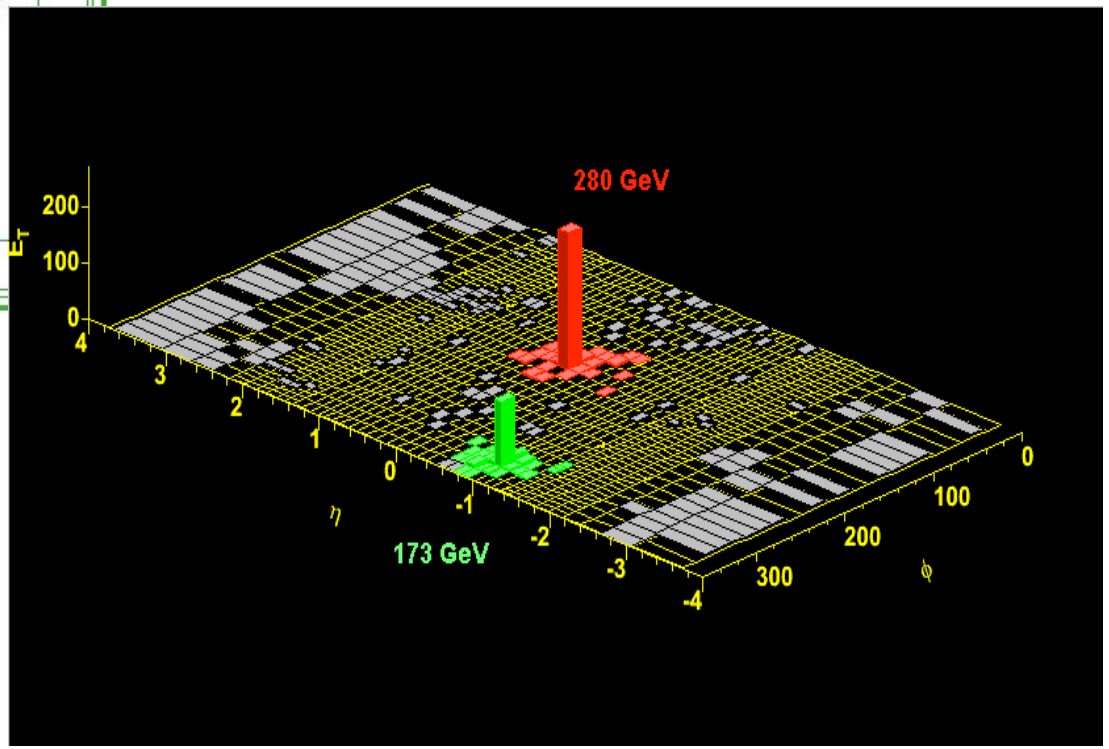
Missing E_T for High Kinematic Region



A MET+dijet Event Candidate



- Highest H_T event
  - H_T = 452 GeV
  - MET = 116 GeV
- Could be a QCD di-jet event with a mis-measured jet



Summary

- Tevatron experiments have searched for squarks and gluinos in MET+jets final states on 2 fb^{-1} data sample
- No evidence of SUSY yet
- Expect ~2-3X more data by end of Run II (& 2X more by combining CDF+DØ)
- Keep our eyes open for any tantalizing hints !!!
- If nothing found, will provide further important constraints !

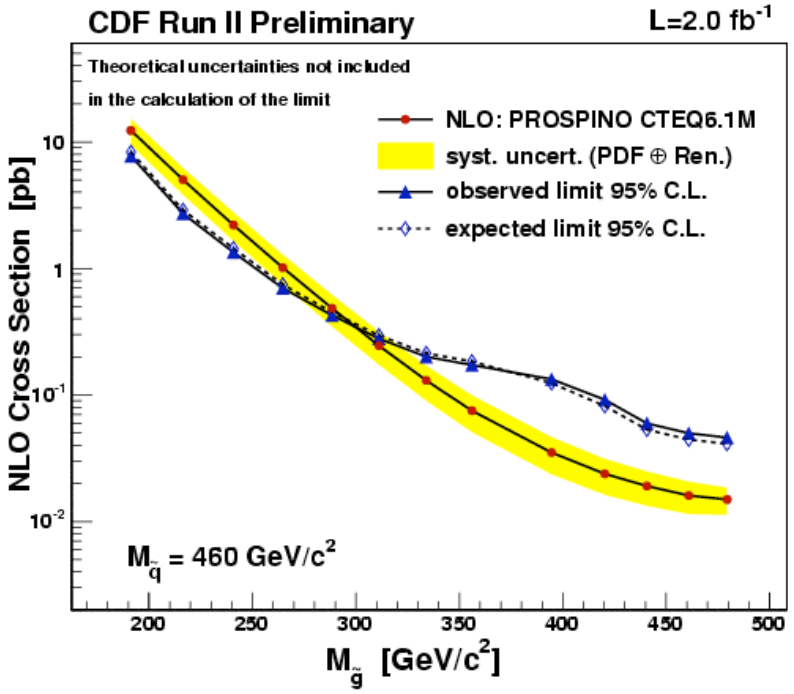
http://www-cdf.fnal.gov/physics/exotic/exotic.html

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

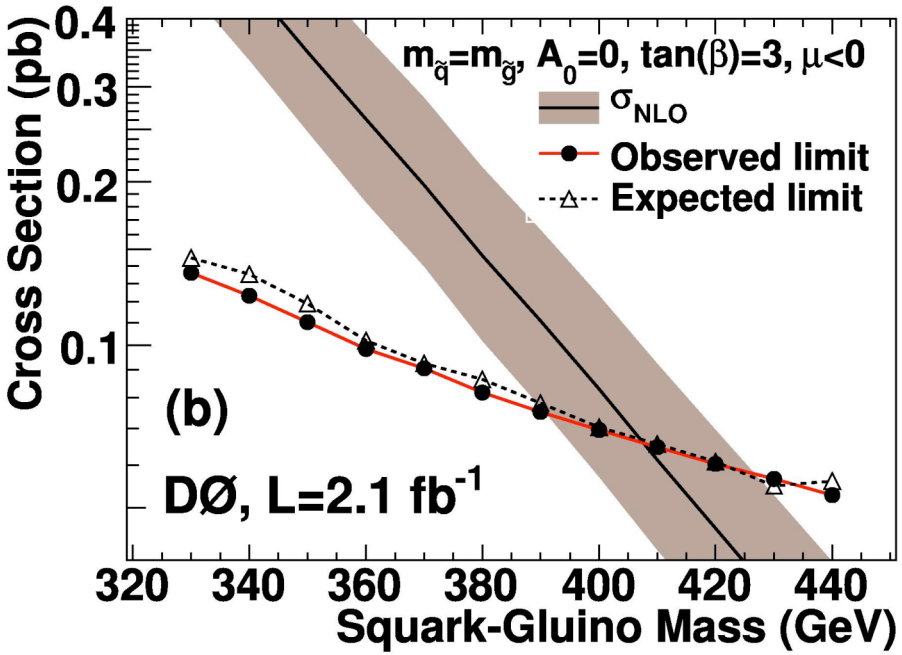
Back Up

Upper Limit Cross Section in MET + Jets Search

•For m(squark)=460 GeV



• m(squark)=m(gluino)



MET + Jets + Tau : After All Section Cuts