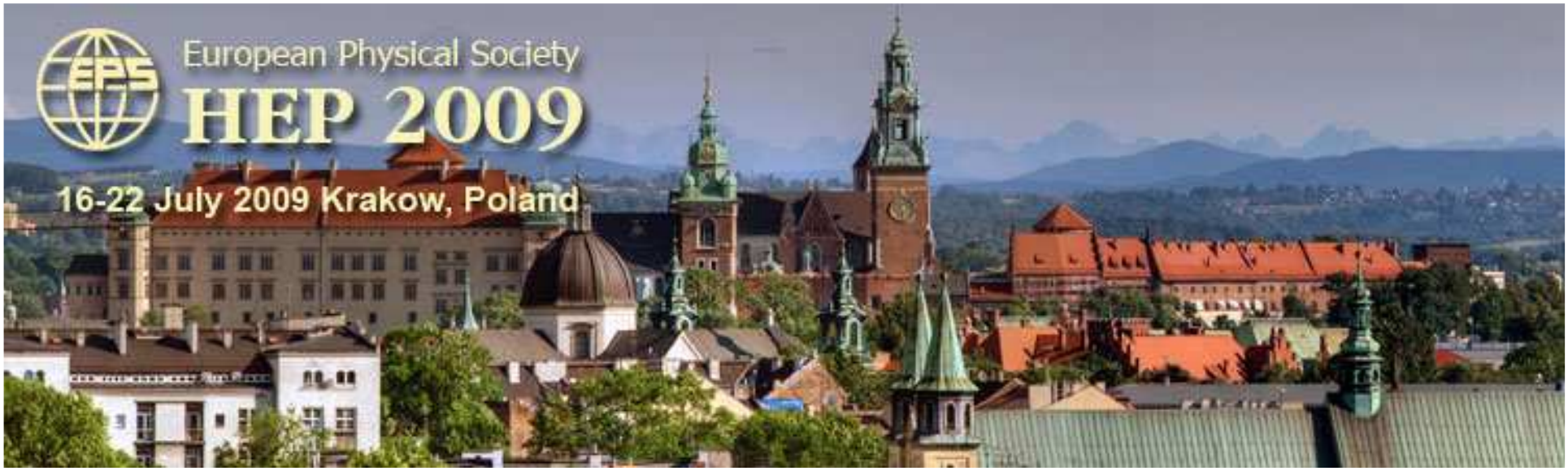


CDF & DØ Searches for Squarks and Gluinos at the Tevatron

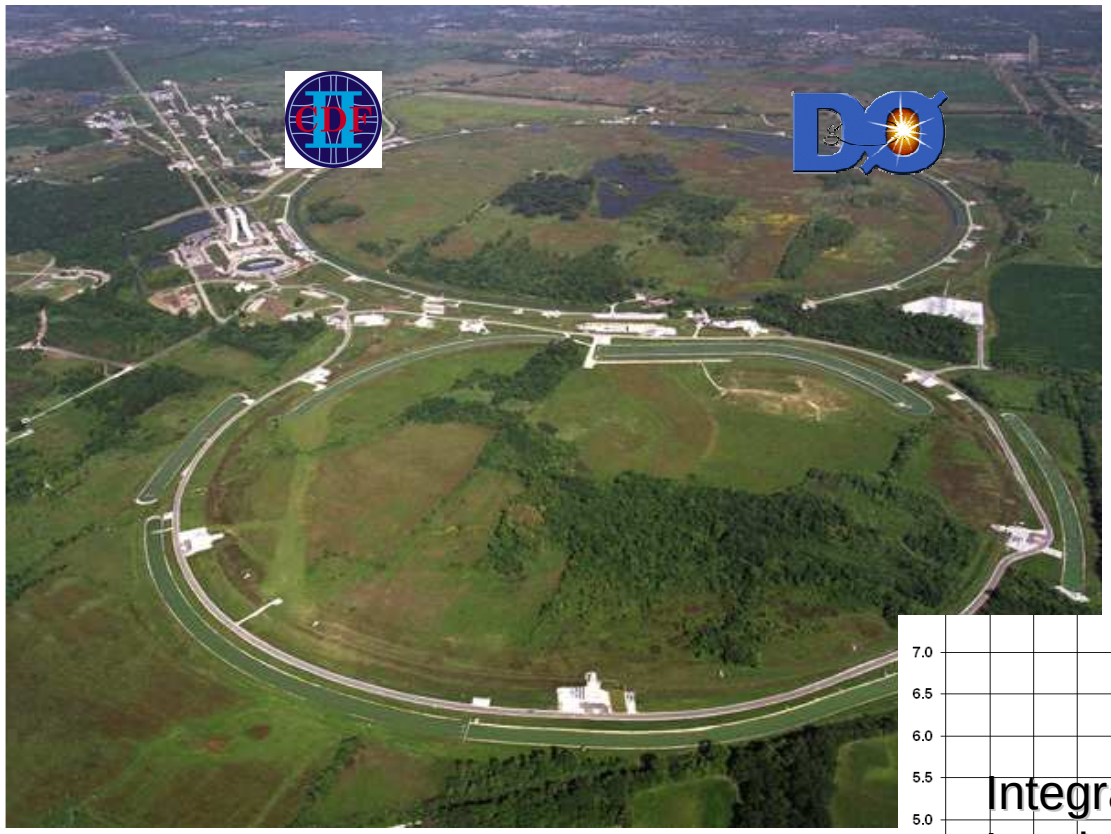
Eric Kajfasz

On behalf of the CDF and D0 Collaborations

Outline

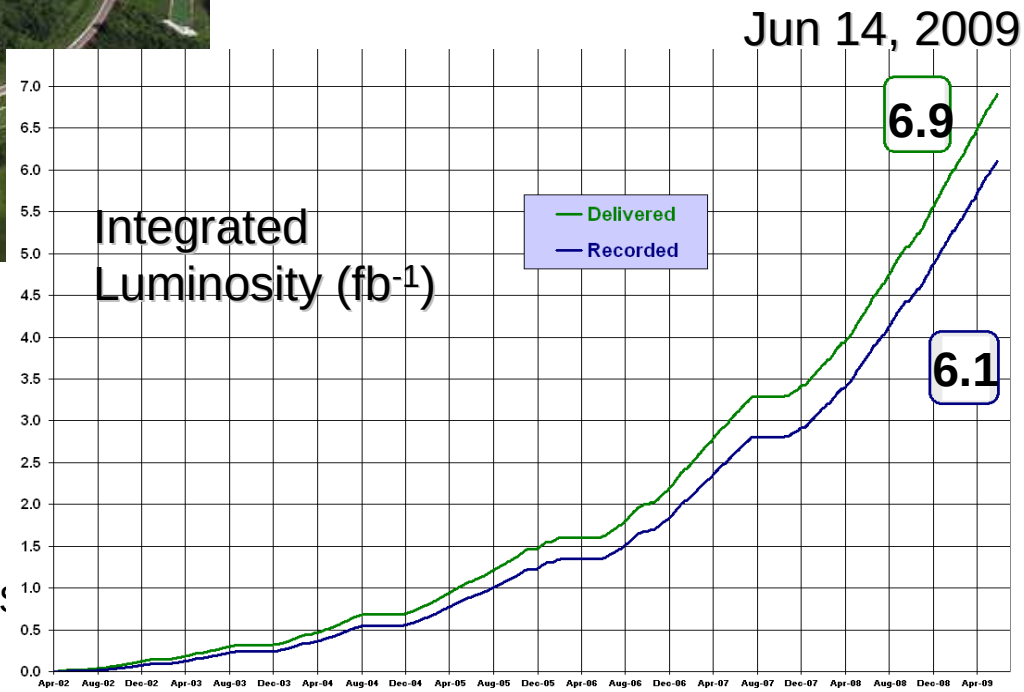
- Tevatron and the collider experiments
- Supersymmetry in a nutshell
- Squarks and gluinos at the Tevatron
- Searches:
  - Inclusive Jets + MET (Missing Transverse Energy)
    CDF, 2 fb^{-1}, PRL 102, 121801 (2009)
    D0, 2.1 fb^{-1}, PLB 660, 449 (2008)
  - Jets + tau(s) + MET
    D0, 1 fb^{-1},
    combined with D0 2.1 fb^{-1} jets+MET,
    submitted to PLB, arXiv:/0905.4086[hep-ex]
  - Exclusive Dijets + MET
    CDF, 2 fb^{-1}, preliminary
- Summary

Tevatron @ Fermilab



- Both CDF and DØ have recorded over 6 fb^{-1} of data, and continue to take data with over 90% efficiency
- I will concentrate on results using up to 2.1 fb^{-1} of data

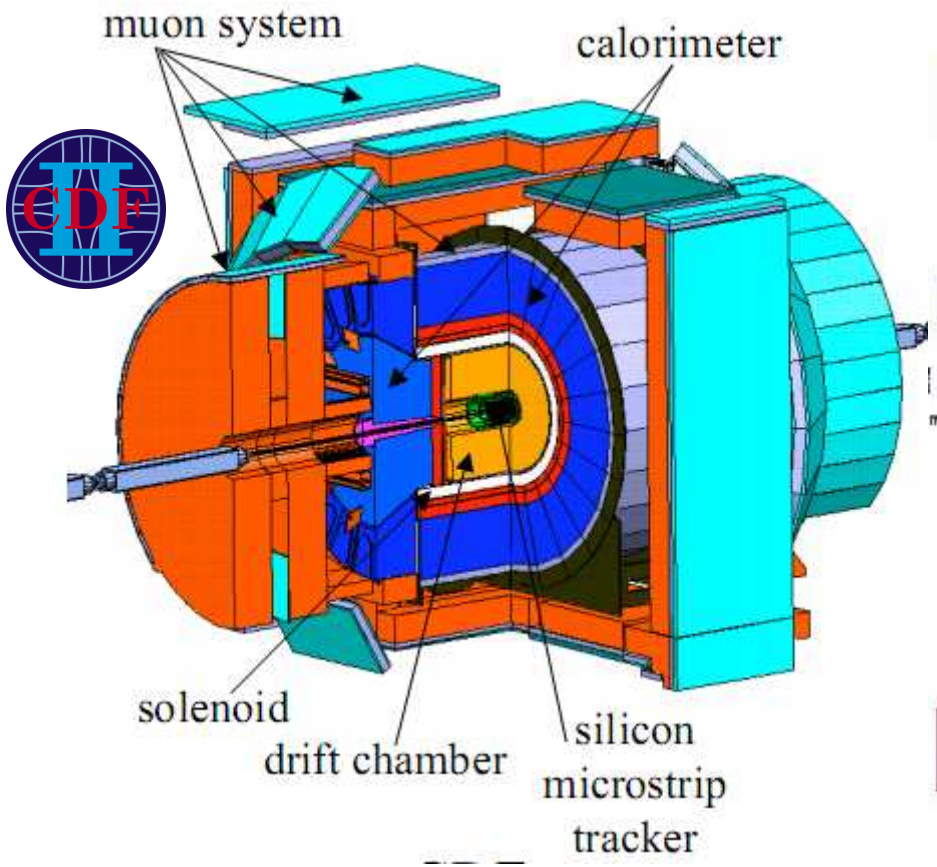
- At 1.96 TeV, theTevatron is still the world's highest energy collider, and an ideal location to search for new physics.

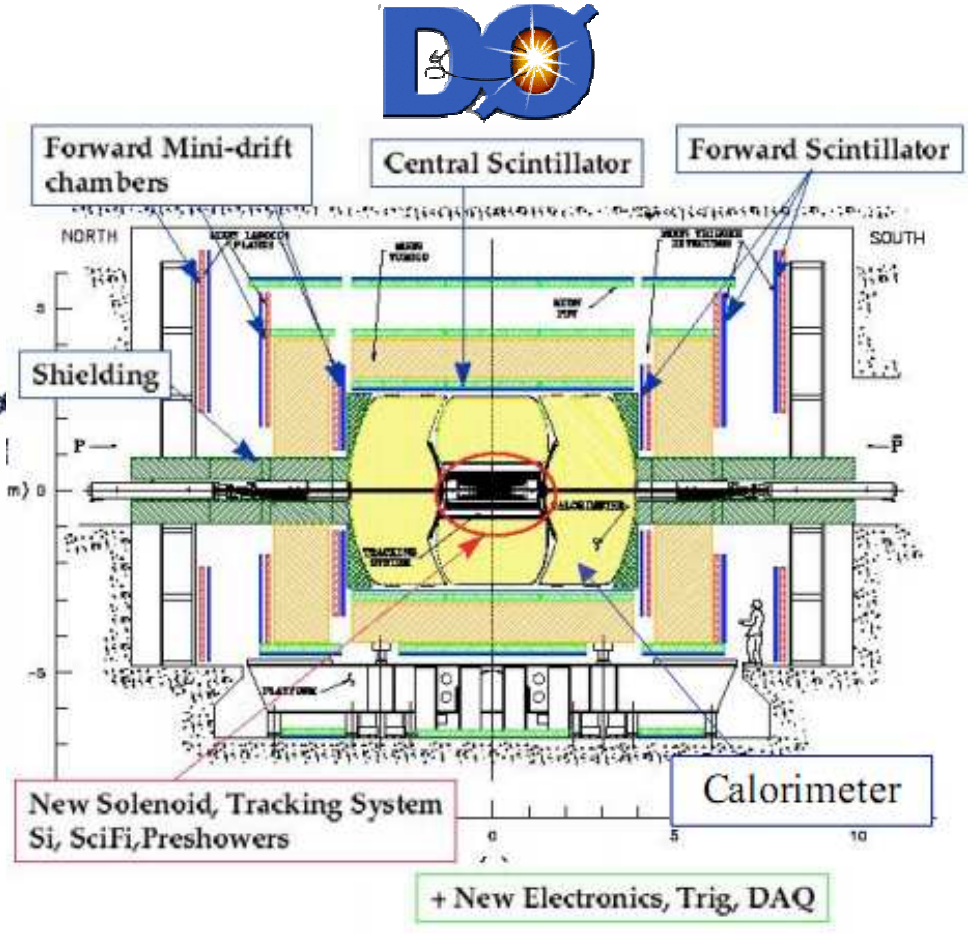


Detectors @ Tevatron

Multipurpose detectors :

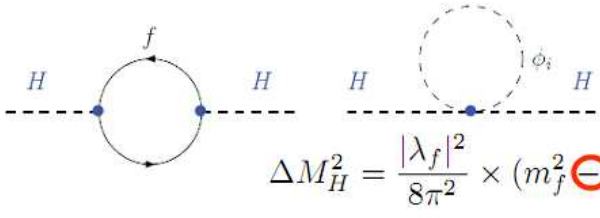
- Electron, muon, tau identification
- Jet and missing energy measurement
- Heavy-flavor tagging through displaced vertices and soft leptons



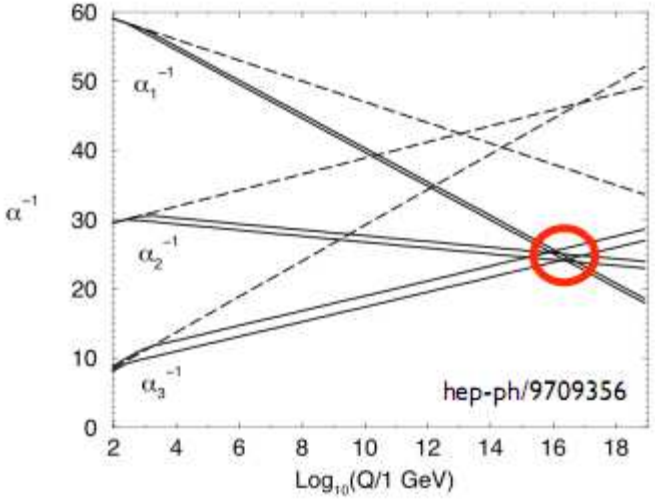


Supersymmetry in a nutshell 1/2

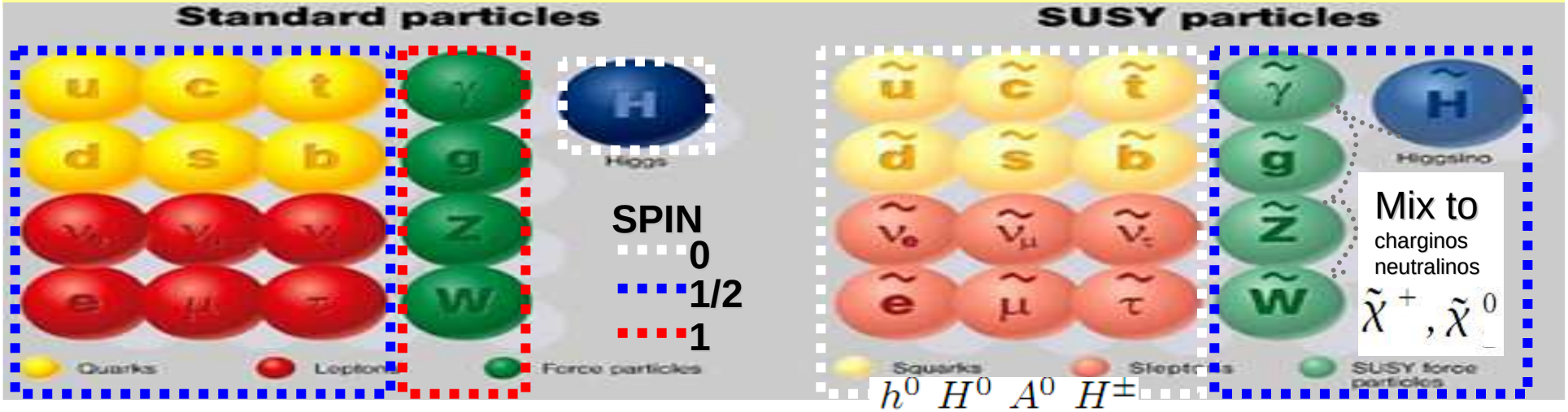
- Standard Model very successful but not complete
- Supersymmetry (SUSY) is a very popular extension
  - extension of Poincaré group: fermions ↔ bosons
  - solves the hierarchy problem
  - Unification of the gauge couplings
  - Lightest Susy Particle (possible Dark matter candidate)
  - ....
- On the other hand:
  - full set of new particles ("s"-particles)
  - broken symmetry
  - sparticles masses must not be too high: TeV scale



$$\Delta M_H^2 = \frac{|\lambda_f|^2}{8\pi^2} \times (m_f^2 - m_S^2) log\left(\frac{\Lambda}{m_S}\right) + ...$$



Supersymmetry in a nutshell 2/2



R-parity:
Symmetry to avoid
B and L number violations.

If conserved, sparticles need to be pair-produced

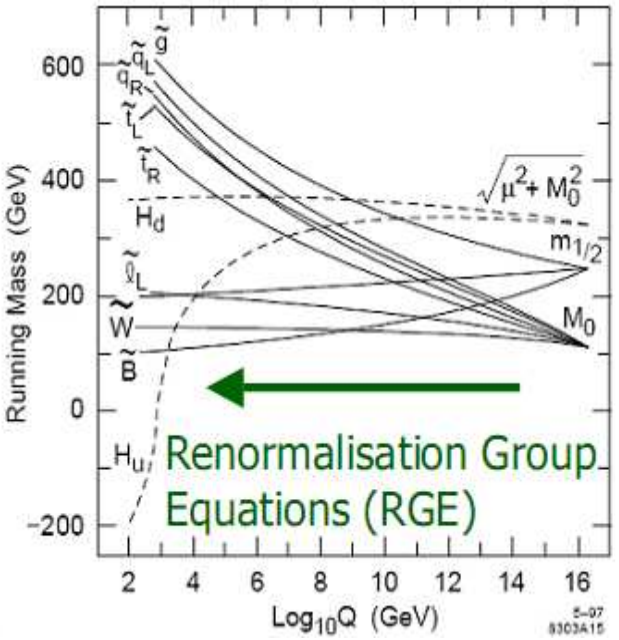
There is a LSP
(dark matter candidate)

MSSM has over hundred new parameters

mSUGRA has only 5

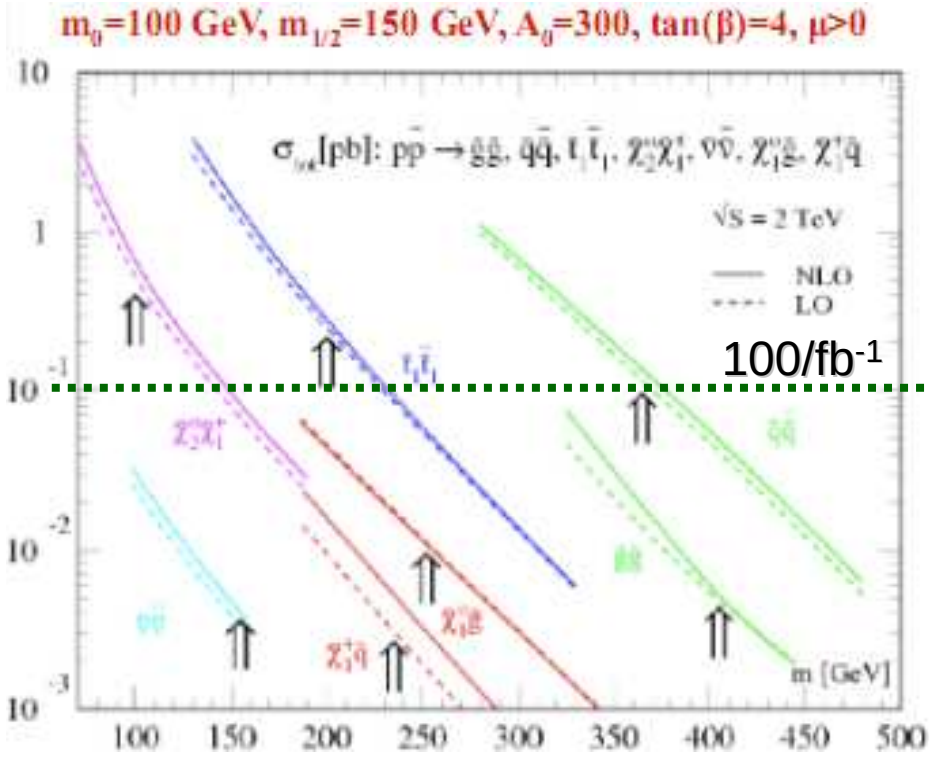
m_0: common scalar mass
$m_{1/2}$: common gaugino mass
A_0: common trilinear coupling
@GUT scale

tan(β): ratio of Higgs VEV
sign(μ): sign of higgsino mass parameter

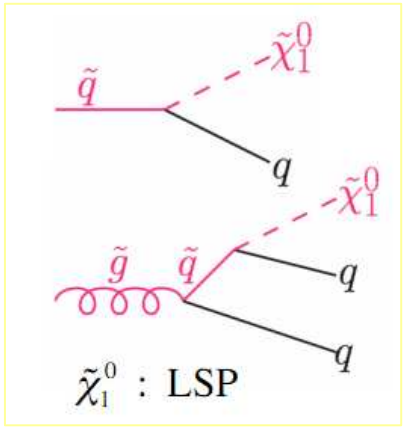


Squarks/gluinos at the Tevatron 1/2

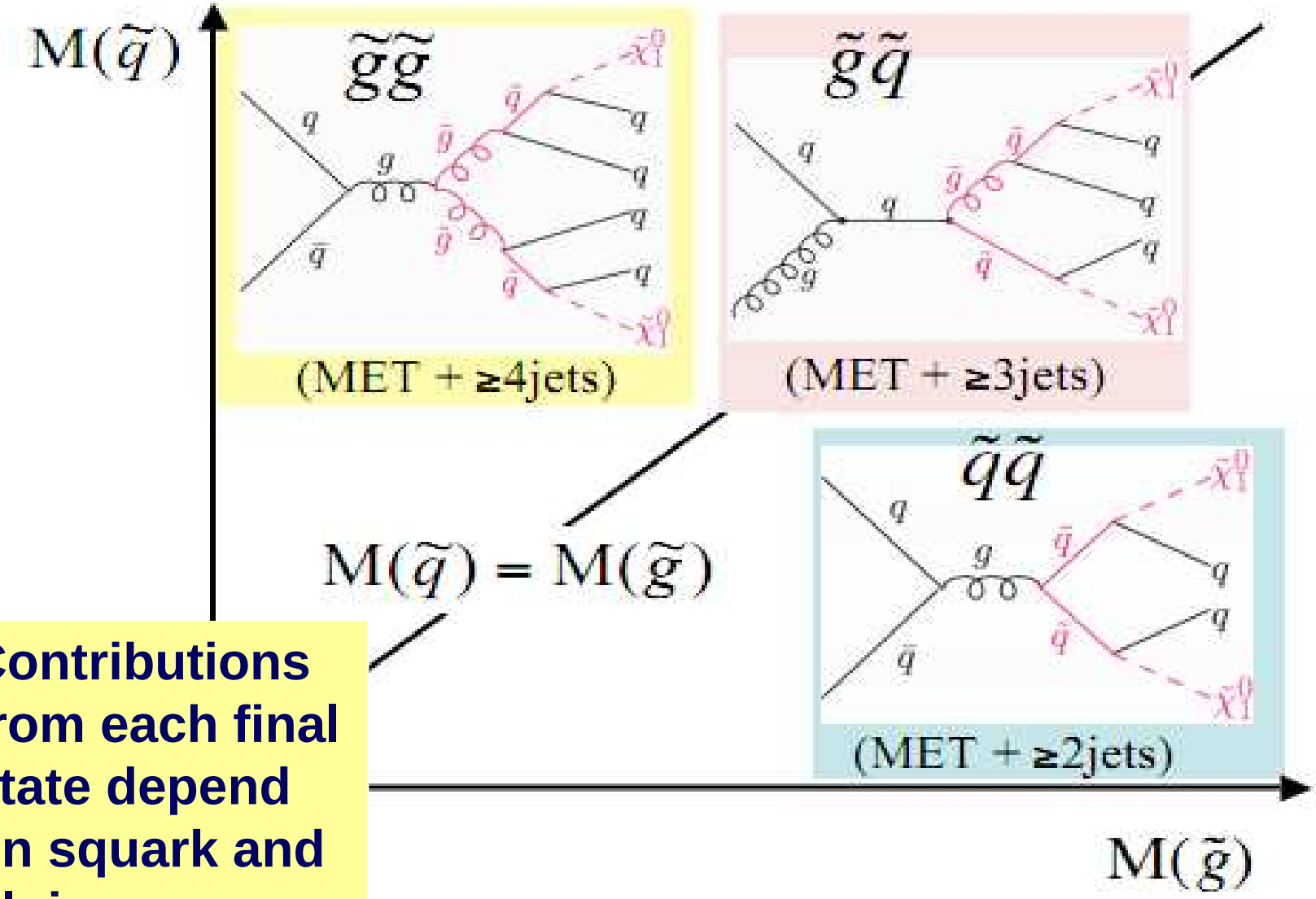
- **mSUGRA as a benchmark model**
- **Squarks/gluinos can be copiously produced by strong interaction if sufficiently light**



- **LSP is stable**
  seen as missing ET (MET)
  in detectors

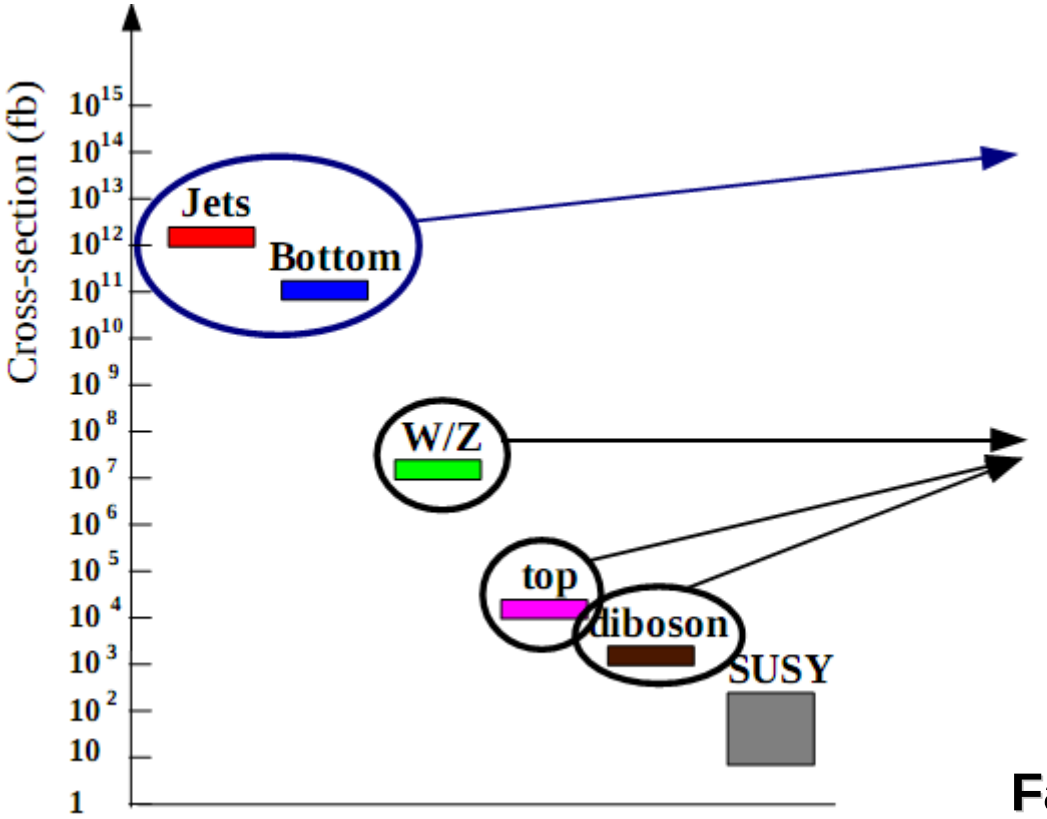


Squarks/gluinos at the Tevatron 2/2



Contributions from each final state depend on squark and gluino masses

Backgrounds in MET + jets



Fake MET

- Mis-measurement of jet energy
- MET aligned with mis-measured jet

Real MET

Neutrinos escaping detection

Signatures similar to SUSY

Fake MET: Non-collision background

- Beam halo
- Cosmic muons
- Noise/dead-channels in detector

…

Jets + MET: selection

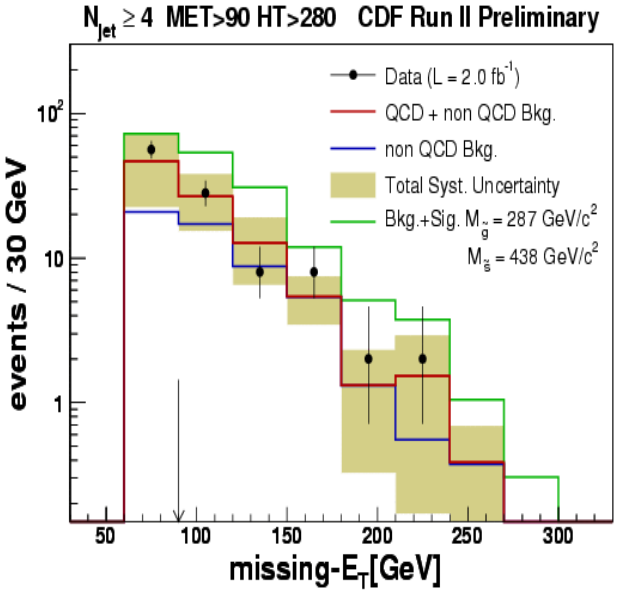
- Search in ~2 fb^{-1} data samples
- Separate searches in the MET + 2 jets, + 3 jets, and + 4 jets final states
- Remove non-collision background
- MET direction not aligned with jets (reduce QCD)
- Lepton veto (reduce W/Z+jets, top, diboson)
- Optimize cuts on leading jets ET, MET and HT (scalar sum of jets ET)

	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

Jets + MET: signal region

	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

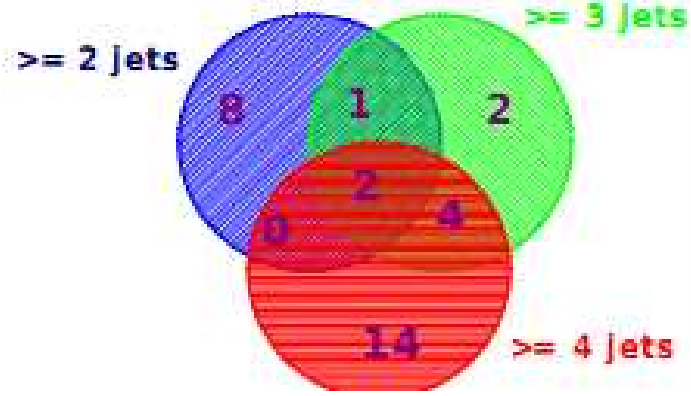
main systematics is JES: 10-15 (6-11)% for Bkg (Sig)

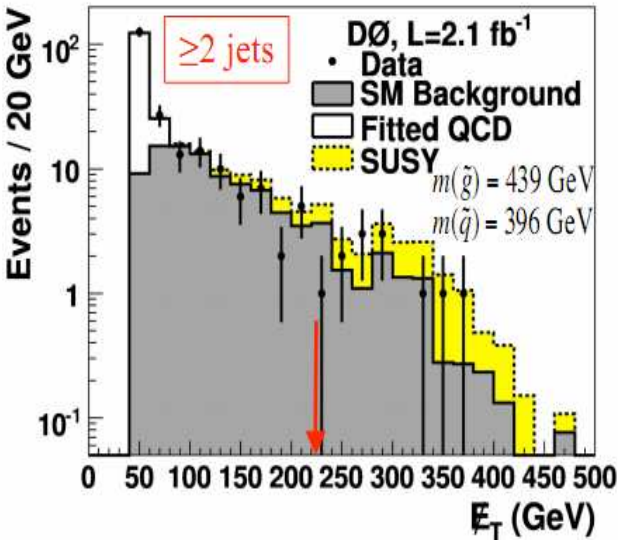


combination

For each squark-gluino mass, **CDF** considers the selection which gives the best expected limit

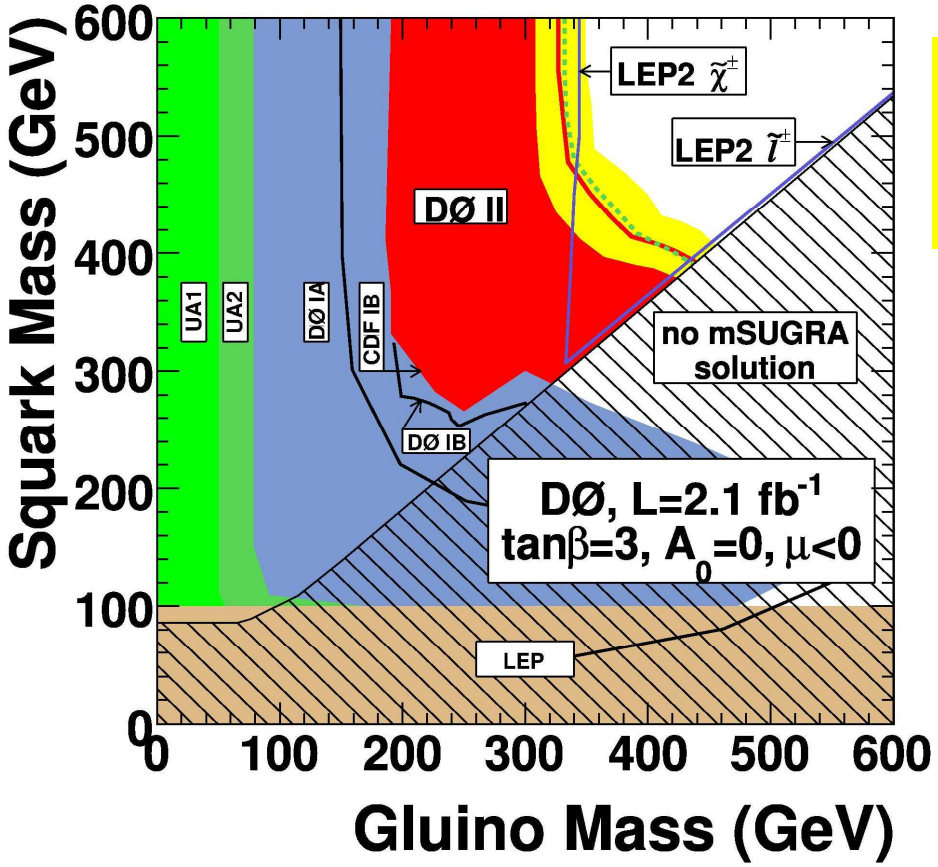
D0 combines the 3 analyses in 7independent selections





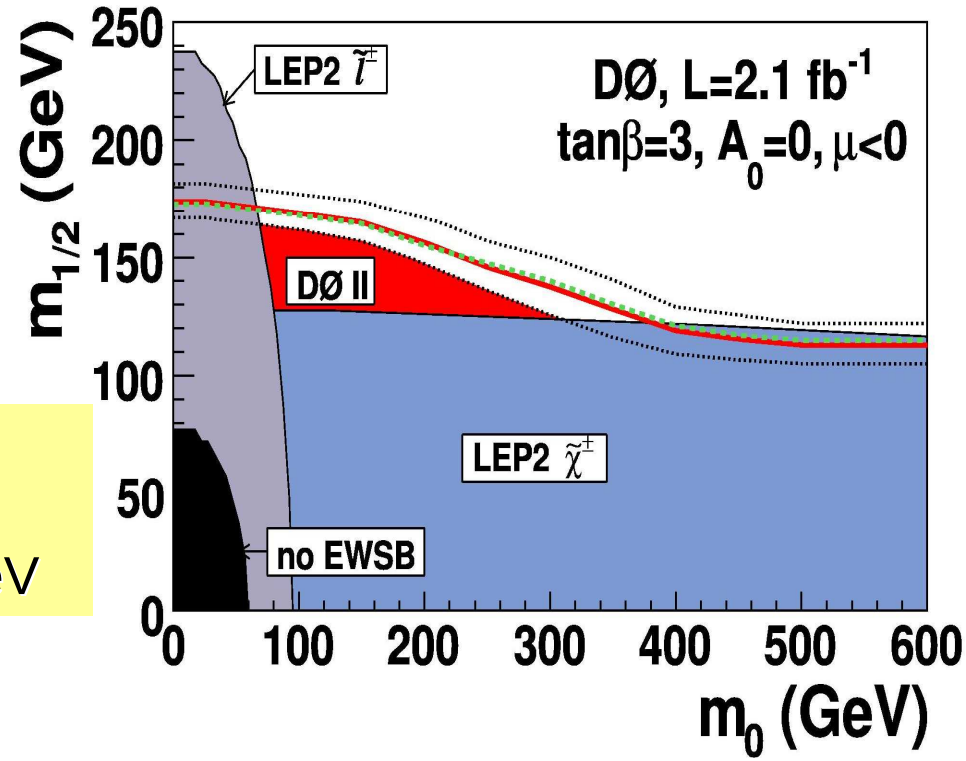
Jets + MET: limits

2.1fb^{-1}



Yellow band:
PDF and R&F scale uncertainty on the signal NLO cross-section (25-75%)

PLB 660, 449 (2008)

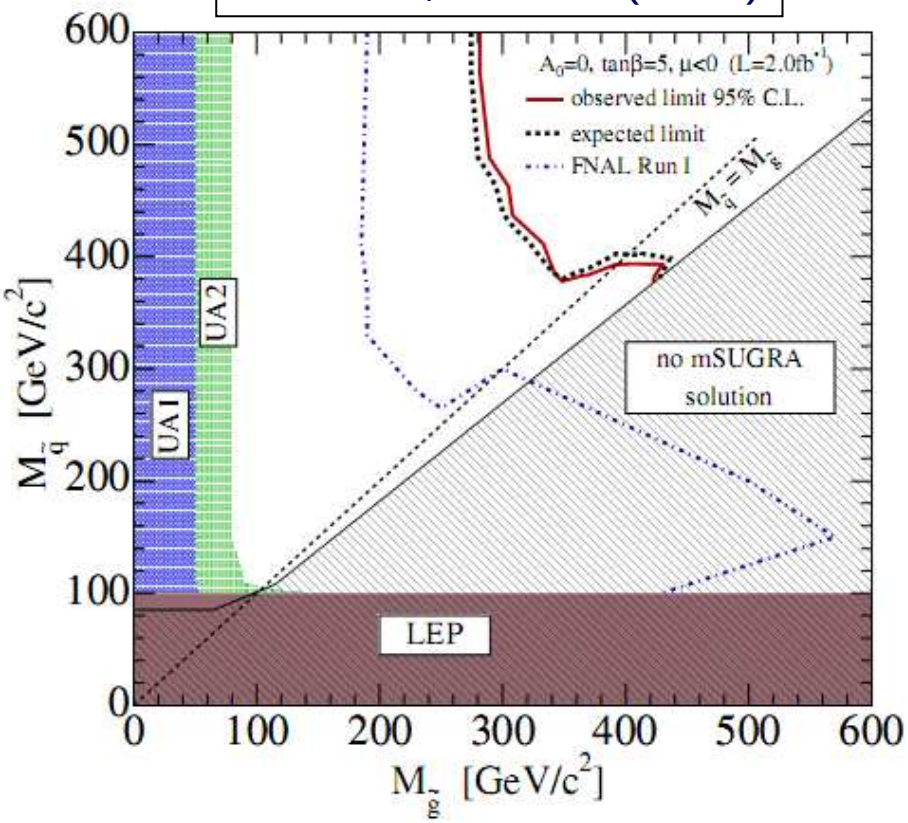


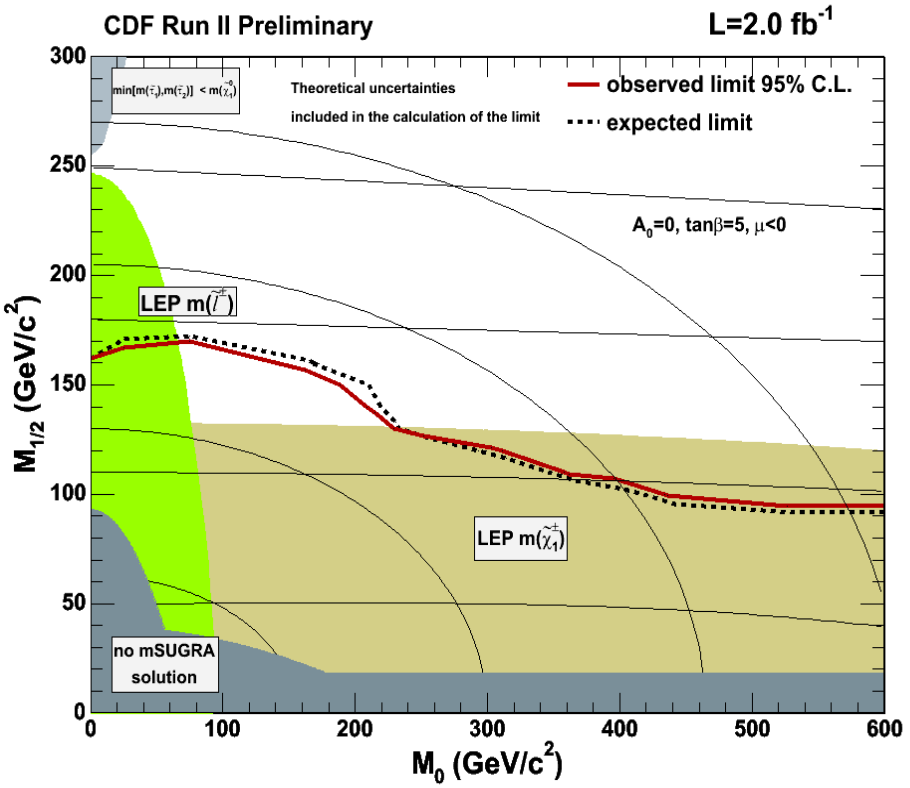
In mSUGRA parameter space:
Improvement over LEP for
m_0=70-300 GeV and $m_{1/2}$=125-165 GeV

Jets + MET: limits

2fb^{-1}

PRL 102, 121801 (2009)





gluinos: m < 280 GeV (CDF), < 308 GeV (DØ), for all squark mass
squarks: m < 380 GeV (CDF, DØ), for all gluino mass

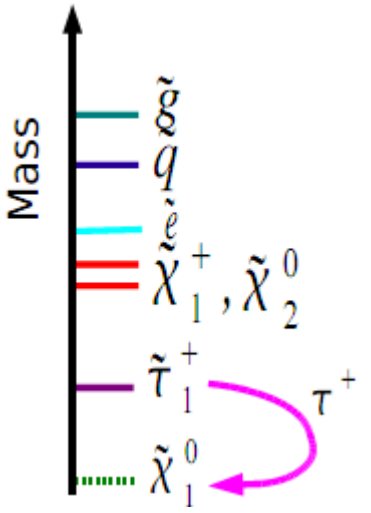
Jets + tau(s) +MET: intro

Mixing:

- In SUSY, the mass difference between the partners of leptons depend on the lepton mass

$$\begin{pmatrix} M^2_{\tilde{\ell}_L} + m^2_\ell & m_\ell \times (A_\ell - \mu \tan\beta) \\ m_\ell \times (A_\ell - \mu \tan\beta) & M^2_{\tilde{\ell}_R} + m^2_\ell \end{pmatrix}$$

- Large mixing -> $\tilde{\tau}^+_1$ is the lightest slepton and could be the NLSP
- Can be produced in cascade decay of squark (and gluinos)
- Enhancement of final states with taus



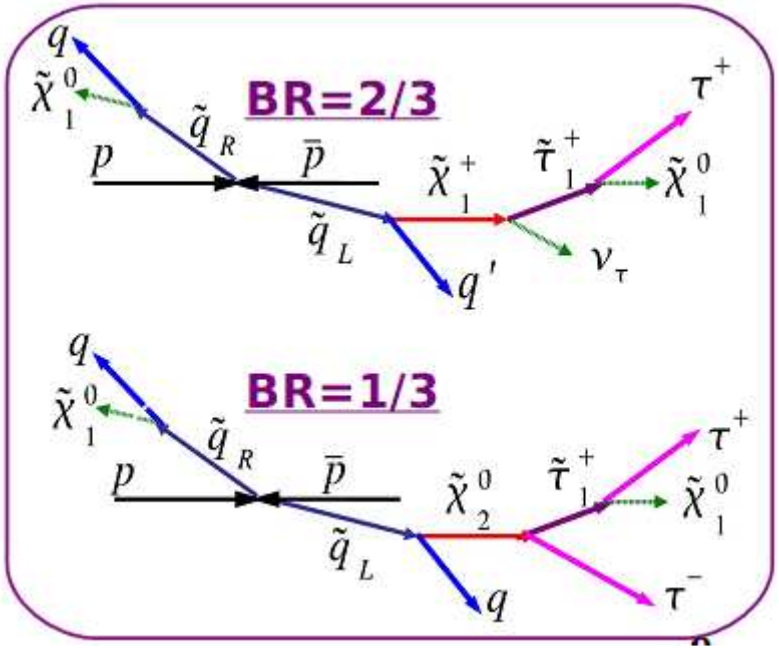
"tau corridor"

Signature:

- $p\bar{p} \to \tilde{q}\bar{\tilde{q}}$ dominates
- >= 2 jets + >= 1 tau(had) + MET

Dataset: 1.0 fb^{-1}, jet+MET trigger

Model: mSUGRA with tanβ=15, A_0=-2m_0, μ<0



Jets + tau(s) +MET

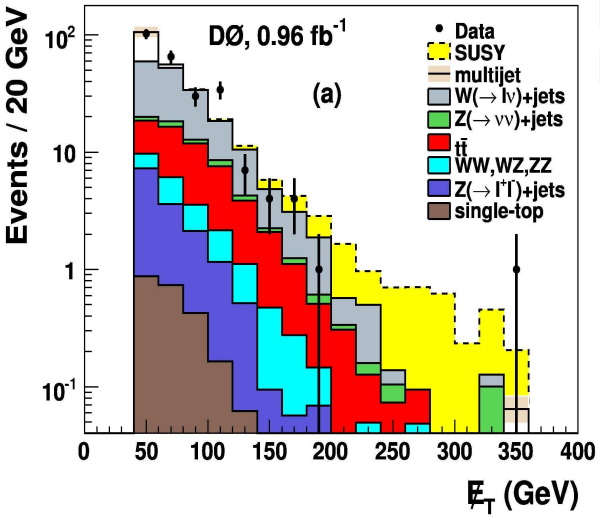
1.0 fb^{-1}

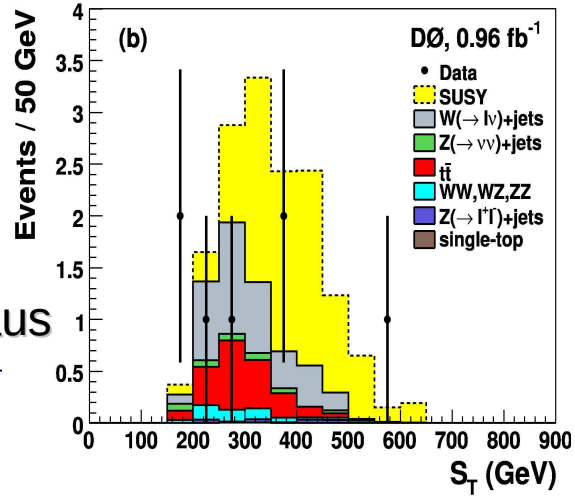
Selection similar to inclusive analyses

- >=2 jets OR >= 3 jets

>= 1 tau(had)

Narrow isolated jet with
low multiplicity track (NN)
pT >15 GeV, |η| < 2.5
No overlap w/ 2 leading pT jets
Reject e, mu and jets faking had. taus



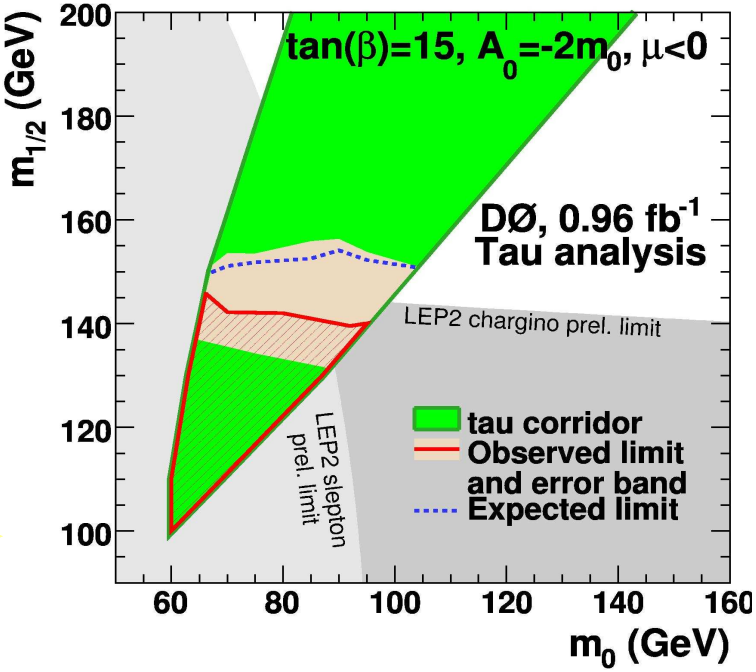


Optimization on:

MET (> 175 GeV)

ST = pT(j1)+pT(j2)+pT(tau) (> 325 GeV)

Data: 3
SM .: 2.3+/-0.4+/-0.7
QCD: negligible



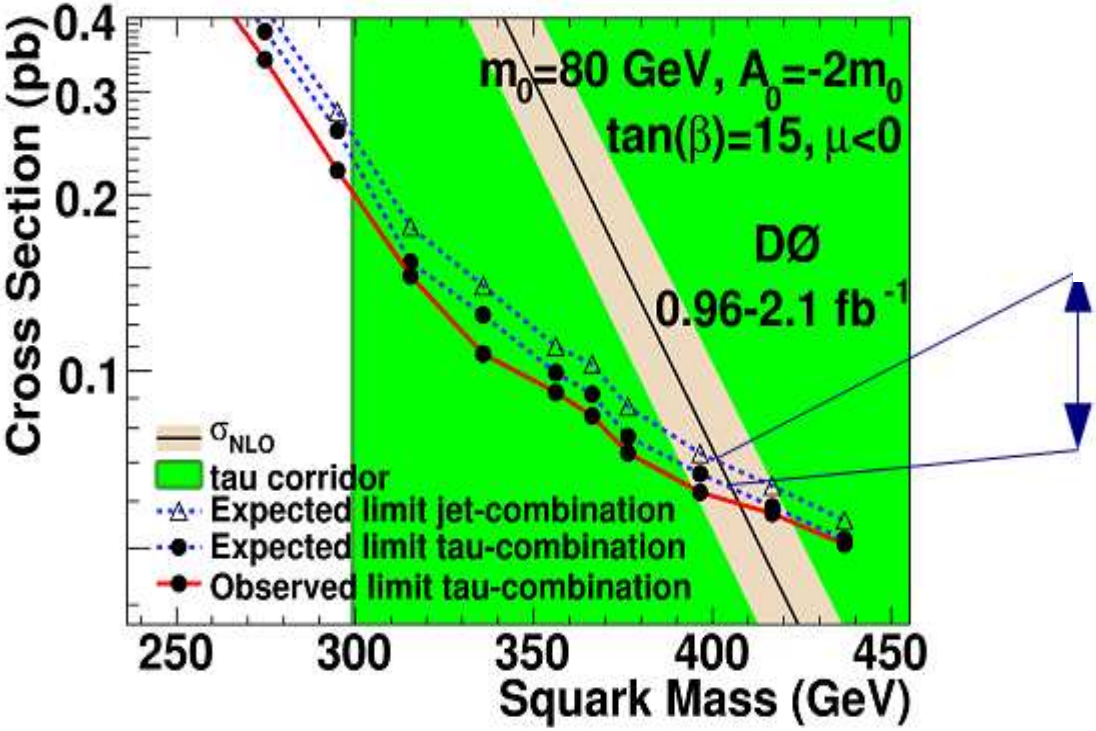
Sensitivity exceeds LEP2 limits

m(squark) excluded up to 340 GeV

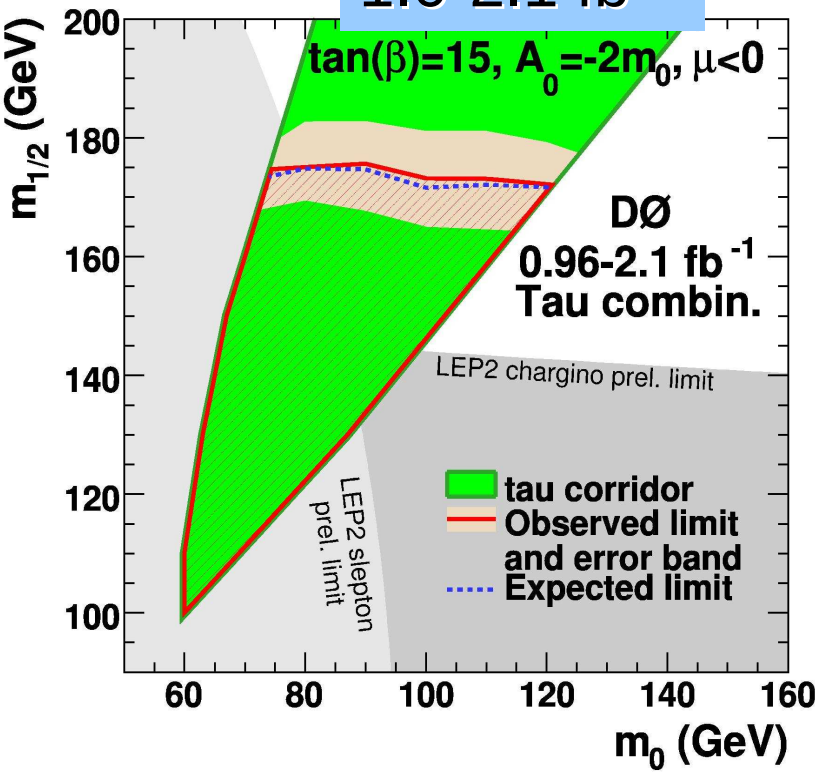
Jets + [tau(s)] +MET: combination

A had. decay. tau is also detected as a jet
Combination with 2.1 fb^{-1} inclusive Jets+MET

10 independent channels
In the "tau corridor":
- Limits exceed the LEP2 ones
- Sensitivity to squark masses up to 408 GeV
- Highest excluded squark mass: 410 GeV



1.0-2.1 fb^{-1}



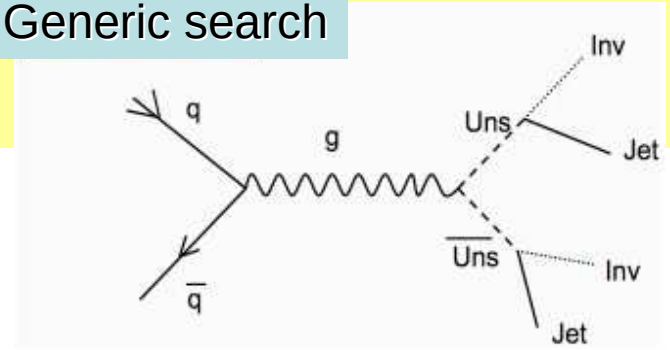
11% gain w.r.t. jets+MET alone

in prod. XSection upper limit
Expect 33% with tau analysis based on 2.1 fb^{-1}

arXiv:/0905.4086 [hep-ex]
Submitted to PLB

Exclusive Dijet + MET

Generic search

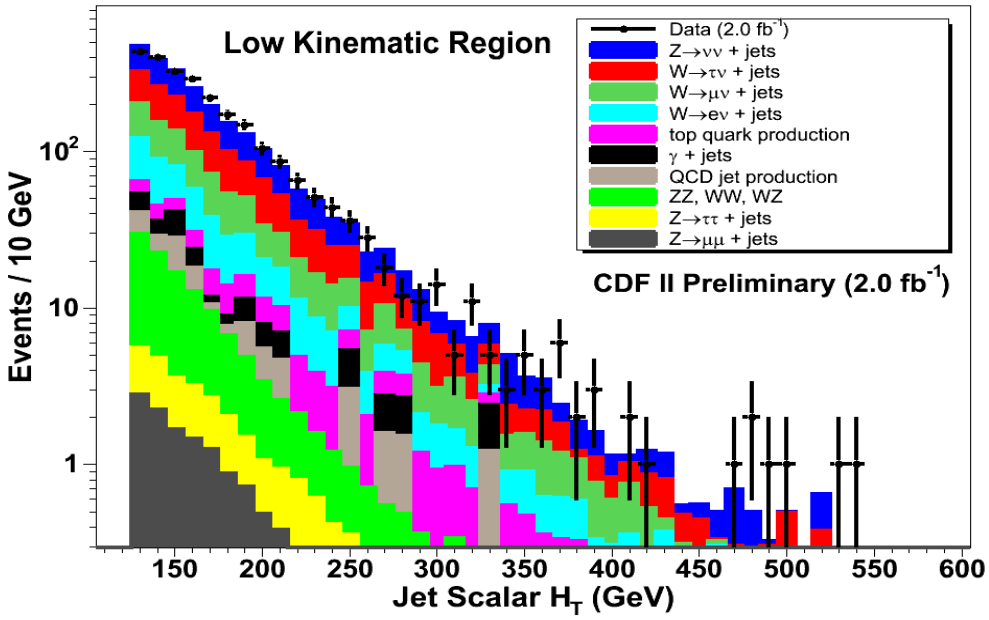


- Similar pre-selection cuts as inclusive squark/gluino search
- Require only 2 jets
- 2 kinematic regions (**LoR** & **HiR**) => sensitivity to wide range of new physics
- **Low Region** : HT(ET(J1)+ET(J2))>125GeV, MET>80 GeV
- **High Region** : HT>225 GeV, MET>100 GeV

•Uns : new unstable particle

•Inv : new invisible particle

2fb^{-1}



Background	125/80 (Low region)	225/100 (High region)
$Z \to \nu\bar{\nu}$	888 ± 54	86 ± 13
$W \to \tau\bar{\nu}$	669 ± 42	50 ± 8
$W \to \mu\bar{\nu}$	399 ± 25	33 ± 5
$W \to e\bar{\nu}$	256 ± 16	14 ± 2
$Z \to l\bar{l}$	29 ± 4	2 ± 0
QCD	49 ± 30	9 ± 9
γ + jets	75 ± 11	5 ± 1
Dibosons	90 ± 7	5 ± 0
top	74 ± 9	11 ± 2
non-collision	4 ± 4	1 ± 1
Total Predicted	2533 ± 151	216 ± 30
Observed	2506	186

Obs. within 0.2σ of SM in LoR, 1σ in HiR

Exclusive Dijet + MET

2fb^{-1}

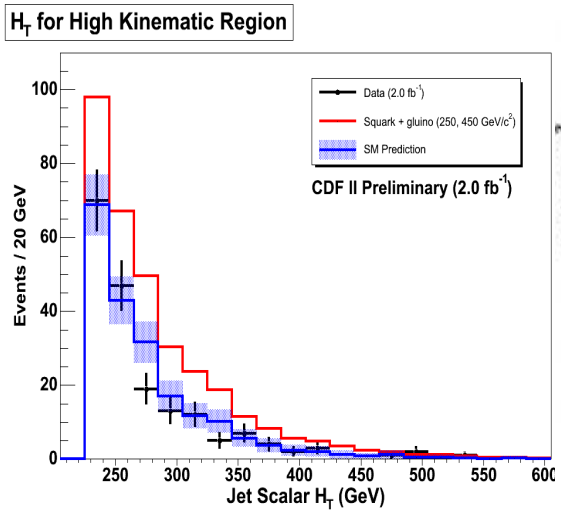
Leptoquark interpretation in Th. Nunnemann's talk on Saturday

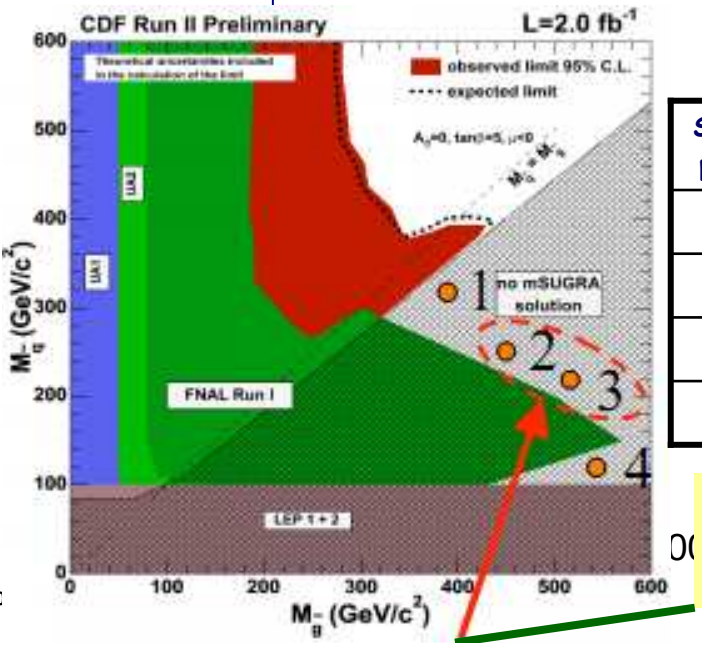
$\tilde{\chi}_1^0$ is the LSP
$\tilde{u},\tilde{d},\tilde{c},\tilde{s}$ are degenerate in mass
$m(\tilde{g})/m(\tilde{q})$ >1.2
No mSUGRA solution
Squark pair prod. dominates
tanβ=3, A_T=-500, μ=-800

Interpretation in MSSM

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

Decide kinematic region cuts to be applied based on best a priori cross section upper limit
Low Reg.: point 4
High Reg.: points 1,2,3





SUSY point	A priori limit (pb)	Observed limit (pb)	Pythia LO XSection (pb)
1	0.53	0.37	0.36
2	0.90	0.62	1.73
3	1.94	1.33	3.21
4	78.9	73.8	57.4

SUSY points 2,3 excluded at LO using Pythia XSection

Summary

- Tevatron experiments have searched for squarks/gluinos in jets+MET final states on up to 2.1 fb^{-1} data samples
- CDF/D0 combined limits are in progress

- No evidence of SUSY yet, but …
- Both experiments have already over 6 fb^{-1} of recorded data and continue to take high quality data …
- Stay tuned for updated results!

- For a complete list of results refer to:
  - http://www-cdf.fnal.gov/physics/exotic/exotic.html
  - http://www-d0.fnal.gov/Run2Physics/WWW/results/np.html

backups

τ-ID

- narrow calorimeter energy clusters matched to tracks
- separate τ's into 3 categories, defined by their decay mode
  - π-like (type 1), ρ-like (type 2), and 3-prongs (type 3)
  - implement neural nets (NN) for each τ-type to discriminate τ signal from QCD jets