Searches for Squarks and Gluinos in Jets+Missing Transvere Energy Final States with D0 Detector

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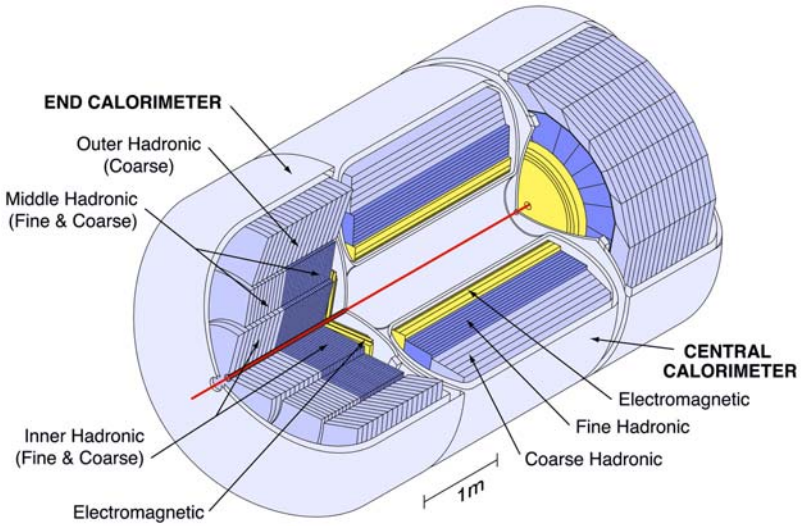
What to talk about

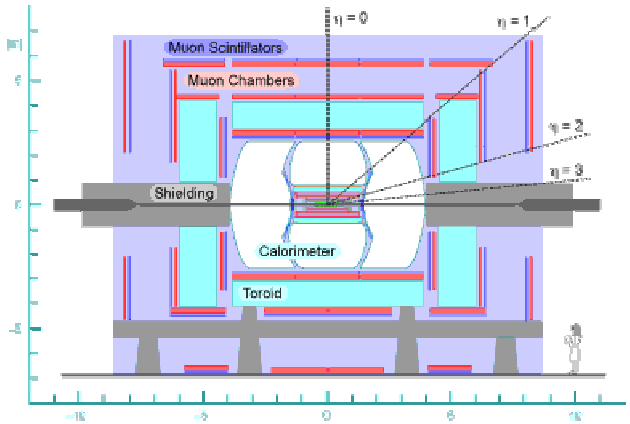
- No need to tell “why we need SUSY”
- Generic search for squarks and gluinos
  - No flavor identification
  - Dependence on squark and gluino masses
  - One new channel with taus in final state
- Search for a light stop
  - Why light?
  - How it decays?
  - Identification of jet flavor
- Results with $1fb^{-1}$
  - Improvement in excluded mass domains over previous searches

This talk assumes :

- Conservation of R-Parity $\Rightarrow$ pair production of SUSY particles
- LSP being the lightest of four neutralinos and stable

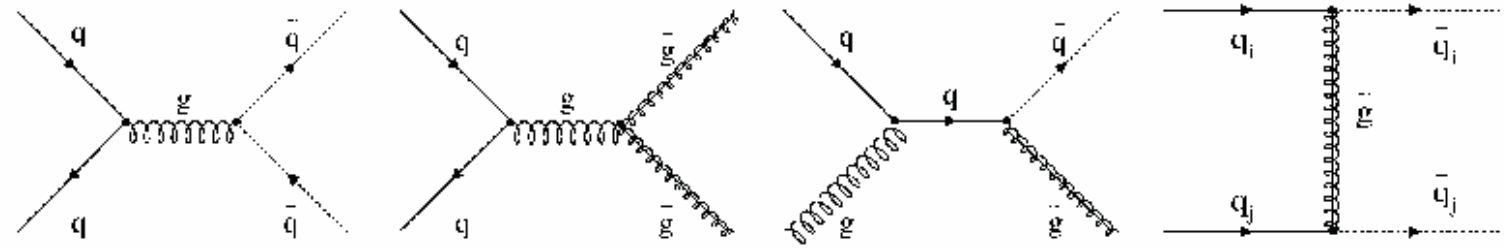
The D0 Detector



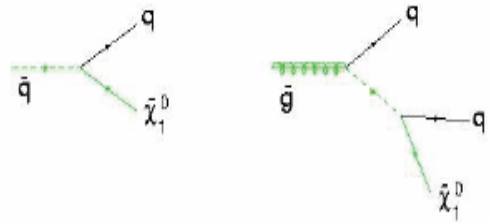


- Silicon microstrip tracker
- Central fiber tracker
- Liquid Argon calorimeter
- Muon detector
  - drift chamber and scintillators

Squarks and Gluinos



- **Produced via strong interaction**
  - Large cross sections
- **Decays**



In final result, cascade decays are taken into account

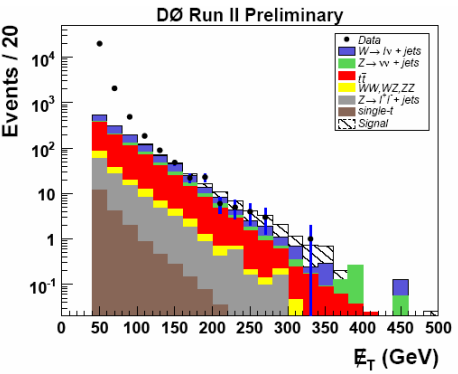
$m_{\tilde{q}} < m_{\tilde{g}} \Rightarrow \tilde{q}\tilde{q} \to q\tilde{\chi}_1^0 q\tilde{\chi}_1^0$ **>=2 jets + Missing transverse energy**

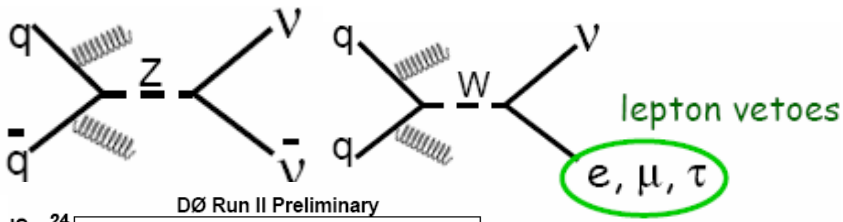
$m_{\tilde{q}} \approx m_{\tilde{g}} \Rightarrow \tilde{q}\tilde{g} \to q\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$ **>=3 jets + Missing transverse energy**

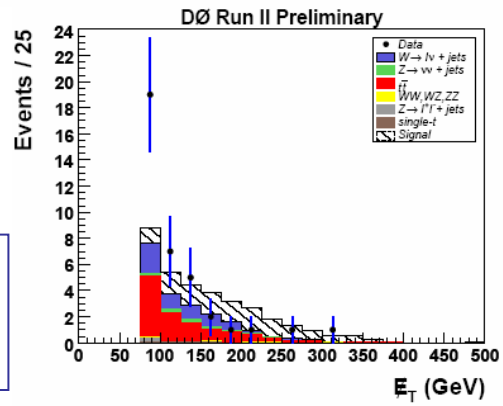
$m_{\tilde{q}} > m_{\tilde{g}} \Rightarrow \tilde{g}\tilde{g} \to q\bar{q}\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$ **>=4 jets ; softer jets and less missing transverse energy**

Selection and Background for squarks gluinos search

- **Basic Selection:**
  - **Clean up events**
  - **High pT jets**
  - **HT (scalar sum of jet pTs)**
  - **MET**
  - **Angular cuts (jet,jet && jet,MET)**







After optimizing on HT and just before cutting on MET

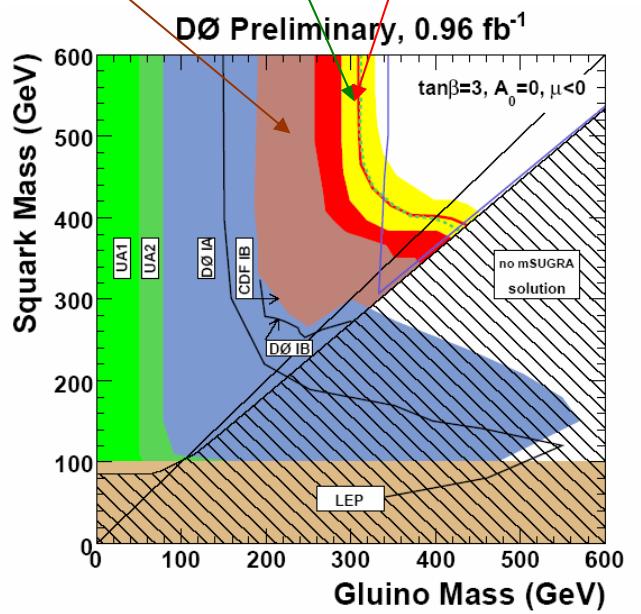
MET > 150 GeV removes any remaining QCD

- Backgrounds
  - QCD
    - Mismeasured jet ⇒ increase in MET
    - Small angular separation between jet and MET
  - SM Processes
    - Vector boson production in association with jets
    - top pair production
    - Diboson

Results for squarks gulinos search with 1fb^{-1}

Expected (observed) with nominal cross section

D0 310 pb^{-1}



Analysis	Background expected	Observed events
"dijet" m(squark) < m(gluino)	7.47 ± 1.06	5
"3 jets" M(squark)≈m(gluino)	6.10 ± 0.37	6
"gluino" M(squark) > m(gluino)	33.35 ± 0.81	34

Taking into account the overlap between three analyses properly and using lower theoretical cross section, excluded masses are

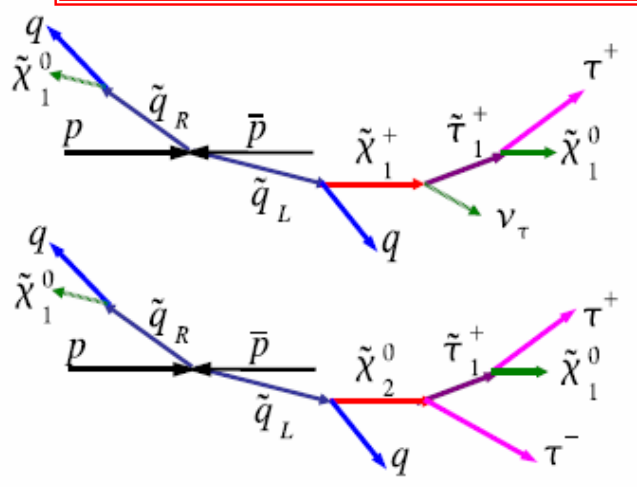
m(squark) < 375 GeV
m(gluino) < 289 GeV
For m(squark) = m(gluino) 383 GeV

Yellow band: Effect of PDF and scale uncertainties

Squarks and Gluinos in tau+jets+MET channel

- Large Yukawa couplings for third generation
  - Negative contribution while running masses from unification to physical mass scale
- Significant mixing between left and right superpartners of third generation fermions
- stau could be lighter than all other sleptons
- Leptonic final state
- Signature
  - Pair of tau leptons accompanied by jets and MET

Explored for the first time at Tevatron



$$\tau^{\pm} \to \pi^{\pm} \nu_\tau$$

$$\tau^{\pm} \to \pi^{\pm} \pi^{\circ} \nu_\tau$$

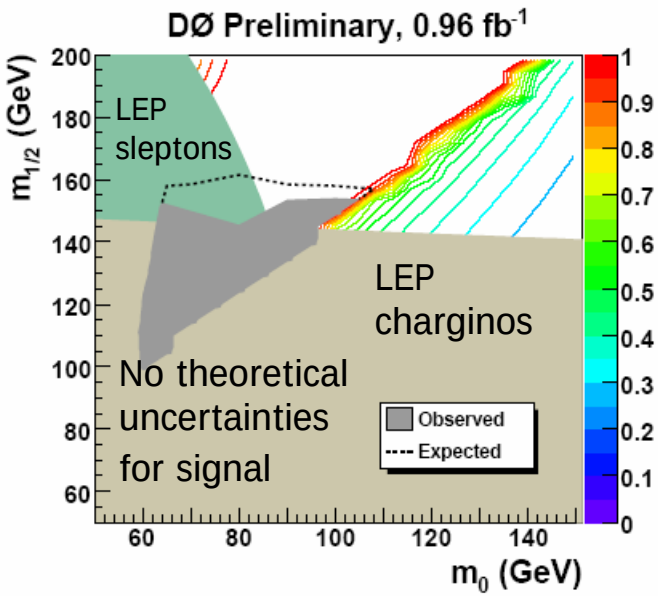
$$\tau^{\pm} \to \pi^{\pm} \pi^{\mp} \pi^{\pm} (\pi^{\circ}) \nu_\tau$$

Hadronic decay mode of τ
$\Rightarrow$ Jets with low track multiplicity

Selection and Background for tau+jets+MET channel

- Similar variables as used in generic search: jet pT, HT, MHT, MET
- At least one tau with E_T> 15 GeV
  - taus are identified with NNs using information from calorimeter and tracking system
- tt bar largest background

mSUGRA framework
tanβ = 15, A_o=-2m_o, μ<0
Favored => light sleptons and large stau mixing



Colored lines represent branching ratio $\tilde{\chi}_1^{\pm} \to \tau^{\pm} \nu_{\tau} \tilde{\chi}_1^{\circ}$

Excluded mass
m(squark) < 366 GeV

Important channel to compliment Generic squark and gluino search in jets+MET

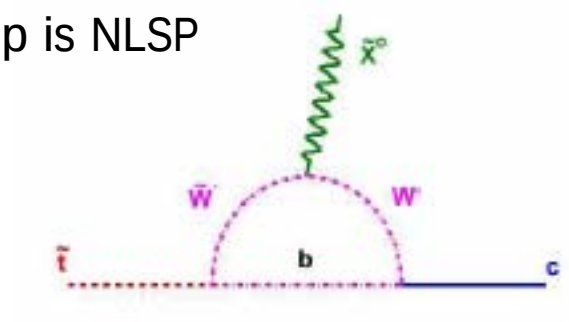
Third Generation Squark (stop)

- Light stop
  - In addition to large Yukawa coupling and enhanced mixing
  - Light stop to Higgs coupling
    - Large enough complex phase to generate electroweak baryogenesis

- stop lighter than top quark
  - Two kinematically allowed decay channels

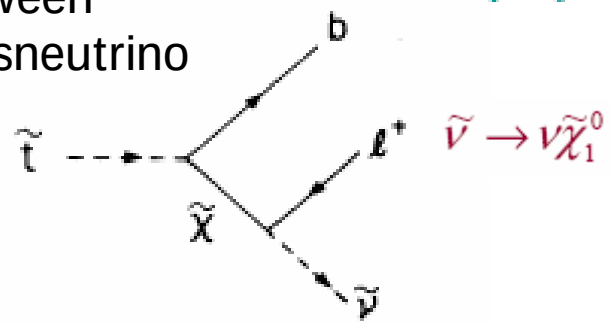
$$\tilde{t} \rightarrow c\tilde{X}^{o}$$

Stop is NLSP



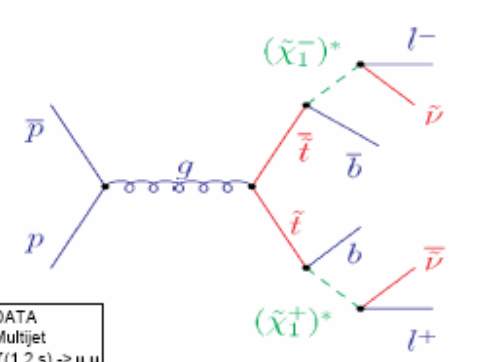
Mass hierarchy between chargino, stop and sneutrino

$$\tilde{t}_1 \rightarrow bl\tilde{\nu}$$

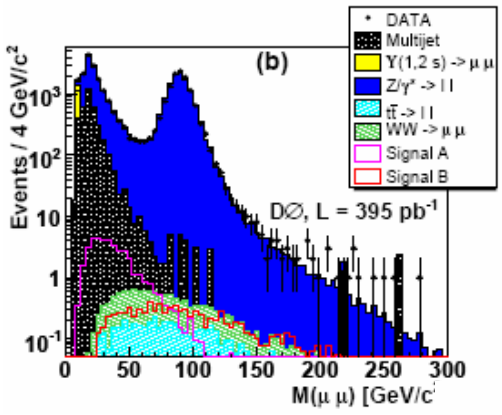


Stop : b l snu channel

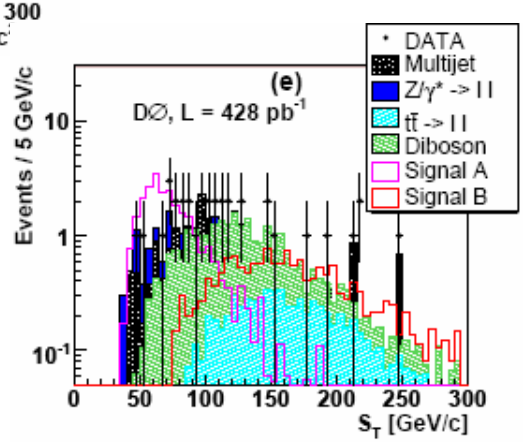
- Signature
  - Two leptons, jets and missing transverse energy
- Explored dimuon and electron muon channel



- $\mu\mu$ channel
  - Two muons
  - M($\mu\mu$) not between 75 and 120 GeV
  - Angular separation between muon and MET
  - At least one jet above 15 GeV and identified as b-jet



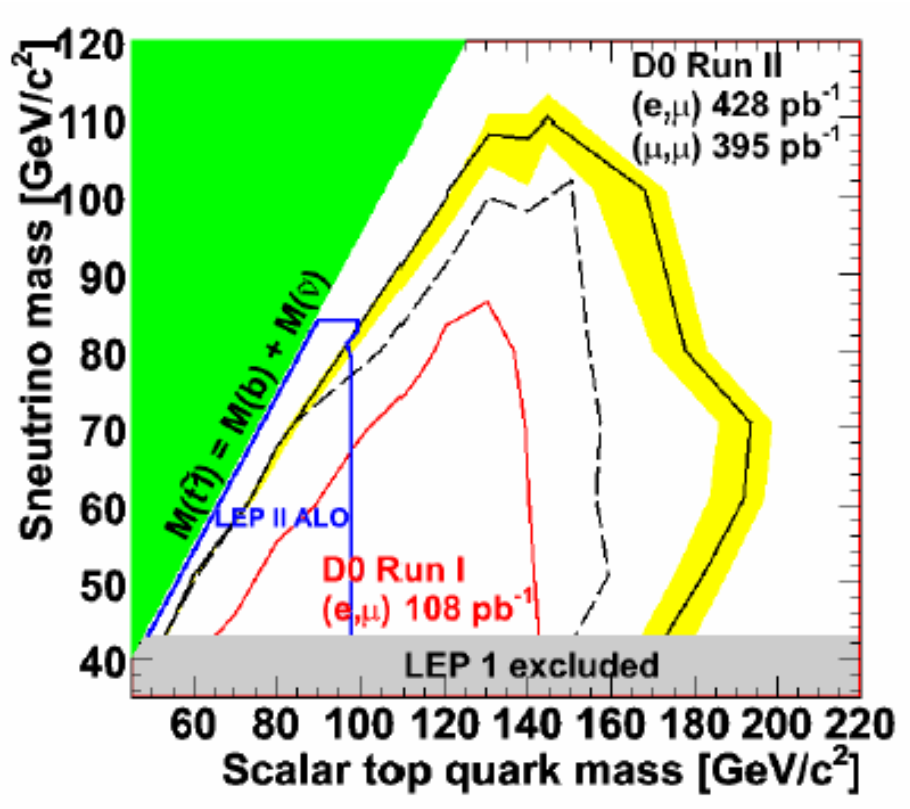
- eμ channel
  - One electron, one muon, MET,HT
  - Angular separation (e, MET) and (μ, MET)
  - ST=pt(e)+pt(μ) +MET



Backgrounds:
QCD, Diboson, Z($\tau\tau$),Top pair

Stop (bl snu) Results

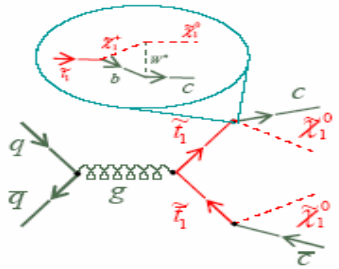
- Combined channels optimized for different $\Delta m = m(\text{stop}) - m(\text{sneutrino})$
- Excluded masses
  - m(stop) < 186 GeV for m(sneutrino) = 71 GeV
  - M(sneutrino) < 107 GeV for m(stop) = 145 GeV



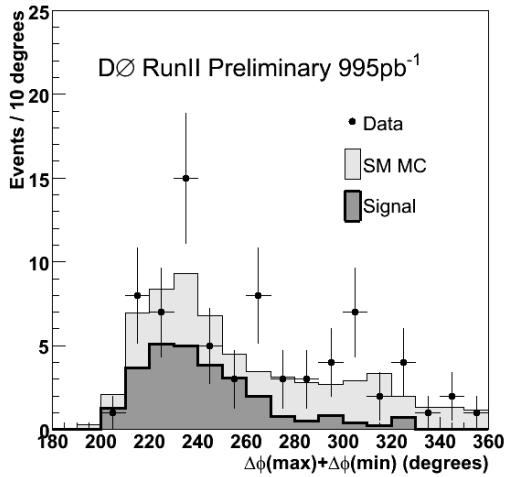
Search for stop (charm neutralino mode)

Event signature

- Two charm jets and missing transverse energy
- Topological selection using
  - Jet pt, HT, MET, angular cuts, isolated leptons and track vetoes
- Identify at least one heavy flavor jet using combined information from
  - impact parameter
  - displaced vertices
  - life time probability
- Optimized for various stop and neutralino masses

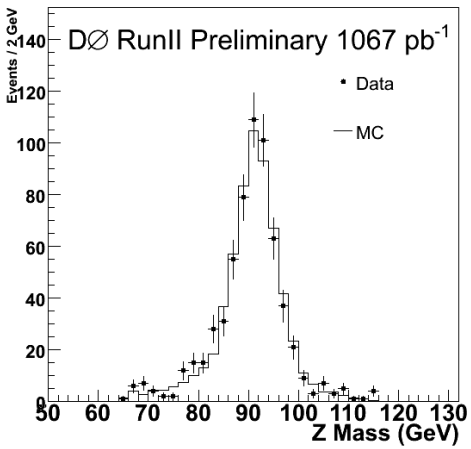


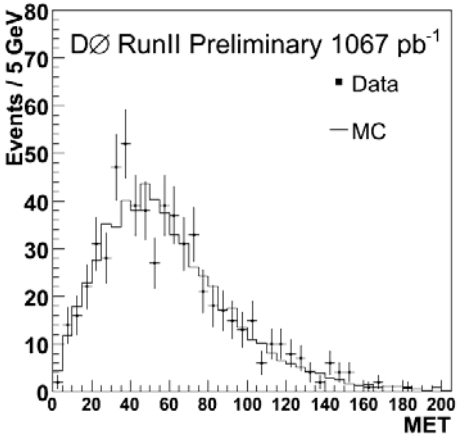
Largest background W+jets followed by $Z \rightarrow \nu\nu$+ jets

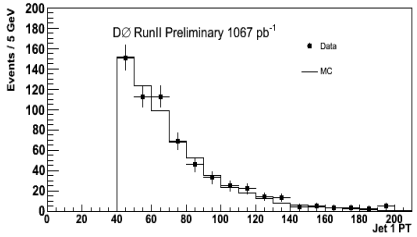


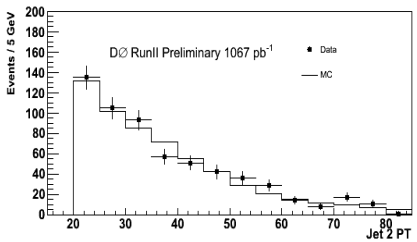
Using the Power of Z(ee) Events (I)

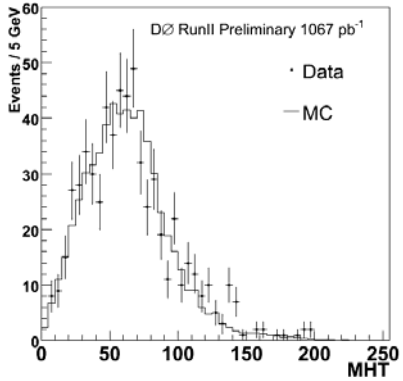
- In order to calibrate Z(νν) + jets background, used Z(ee) + jets events
- How well simulation describes the data after reweighting the the ratio of Z pT in data to that in MC
  - All kinematical variables used in stop search are well described

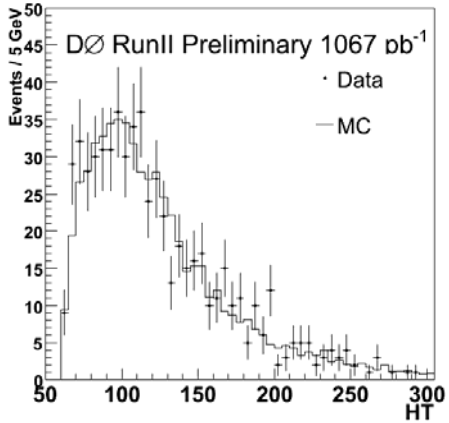








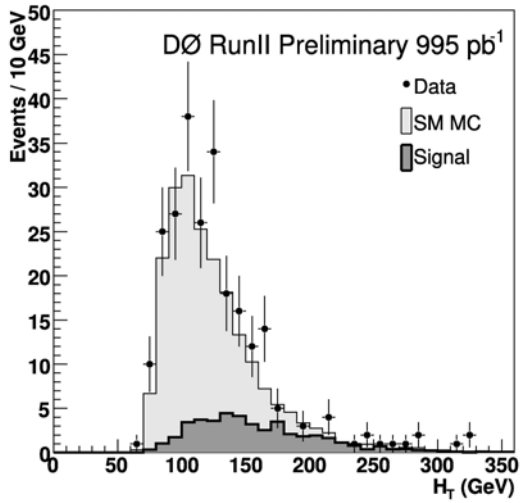




Using the Power of Z(ee) Events (II)

- Good agreement seen in electron channel
  - same normalization procedure adopted for stop search
- Instead of using luminosity to predict background, used Z events
  - Replace the luminosity X cross section uncertainty (6.1% ⊕ 15%) by the statistical uncertainty of Z+>=2 jets events (4%)

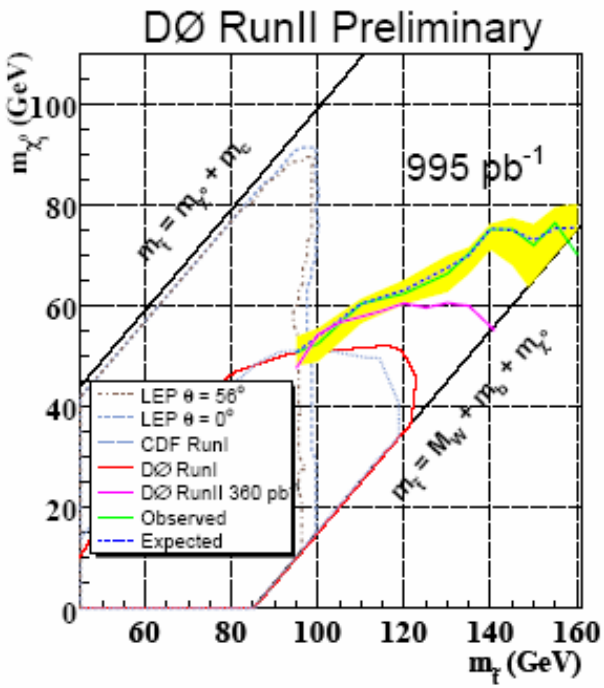
Z normalization and absolute normalization give consistent results



Results: stop(charm neutralino) with 1fb^{-1}

- No excess observed in data
- Excluded regions of mass stop neutralino mass plane
- Previous limits improved
- Yellow band – effect of scale and PDF uncertainties

$m_{\tilde{t}}$	H_T	P	# observed	#Expected
$95-130$	>100	<260	83	$81.9 \pm 4.0^{+13.9}_{-14.1}$
$135-145$	>140	<300	57	$57.1 \pm 3.1^{+8.6}_{-8.6}$
$150-160$	>140	<320	66	$64.2 \pm 3.2^{+9.0}_{-9.1}$



With lower theoretical cross section :
stop mass < 149 GeV
neutralino mass = 63 GeV are excluded

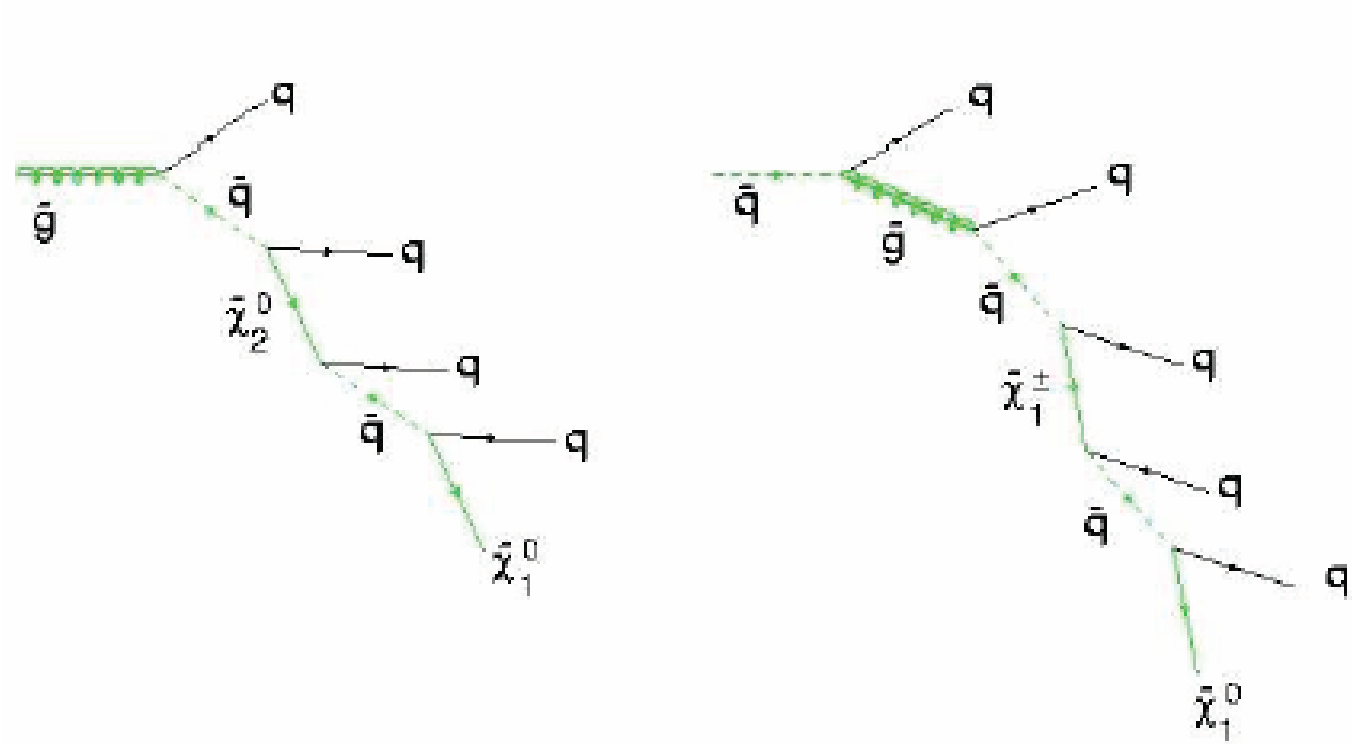
Conclusion

- D0 has searched for squarks and gluinos in jets+MET final states with 1 fb^{-1} of data
- No evidence yet for the existence of SUSY!
- Looking forward to many more interesting results as we analyze 3 fb^{-1} of data

Stay Tuned!!

Backup Slides

Cascade decays of squark and gluinos



$$\tilde{t}_1\bar{\tilde{t}}_1 \rightarrow b\bar{b}\ \tilde{\chi}^{\pm} \qquad \tilde{\chi}^{\pm}$$
$$\hookrightarrow \mu\tilde{\nu} \rightarrow \mu\nu\tilde{\chi}_1^0 \quad \hookrightarrow \mu\tilde{\nu} \rightarrow \mu\nu\tilde{\chi}_1^0$$
$$\hookrightarrow e\tilde{\nu} \rightarrow e\nu\tilde{\chi}_1^0 \quad \hookrightarrow \mu\tilde{\nu} \rightarrow \mu\nu\tilde{\chi}_1^0$$

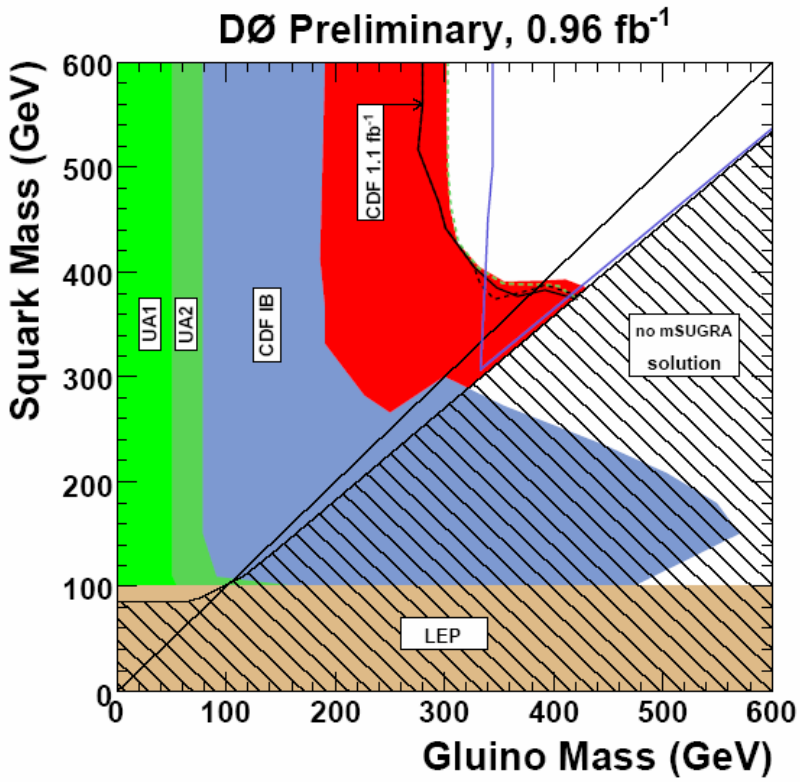
$$m^2_{\tilde{t}_{1,2}} = \frac{m^2_{\tilde{t}_L} + m^2_{\tilde{t}_R}}{2} \mp \sqrt{\left[\frac{m^2_{\tilde{t}_L} - m^2_{\tilde{t}_R}}{2}\right]^2 + \frac{m_t^2 M_t^2}{\sin^2\beta}}$$
$$M_t \equiv A_t \sin\beta + \mu\cos\beta$$

- μμ channel
  - $p_T(\mu 1) > 8$ GeV
  - $p_T(\mu 2) > 6$ GeV
  - M(μμ) not between 75 and 120 GeV
  - Angular separation between muon and MET
  - At least one jet above 15 GeV and identified as b-jet

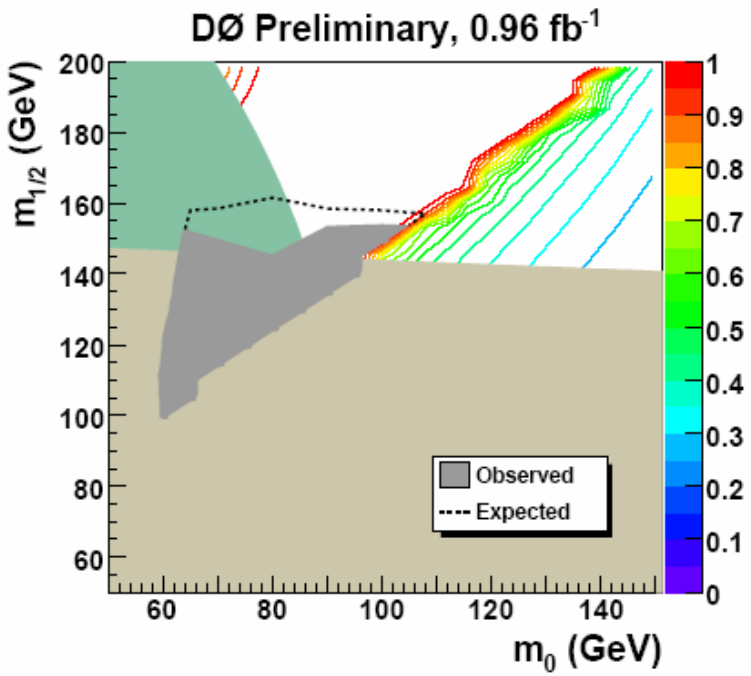
Comparison of CDF and D0 reuslts

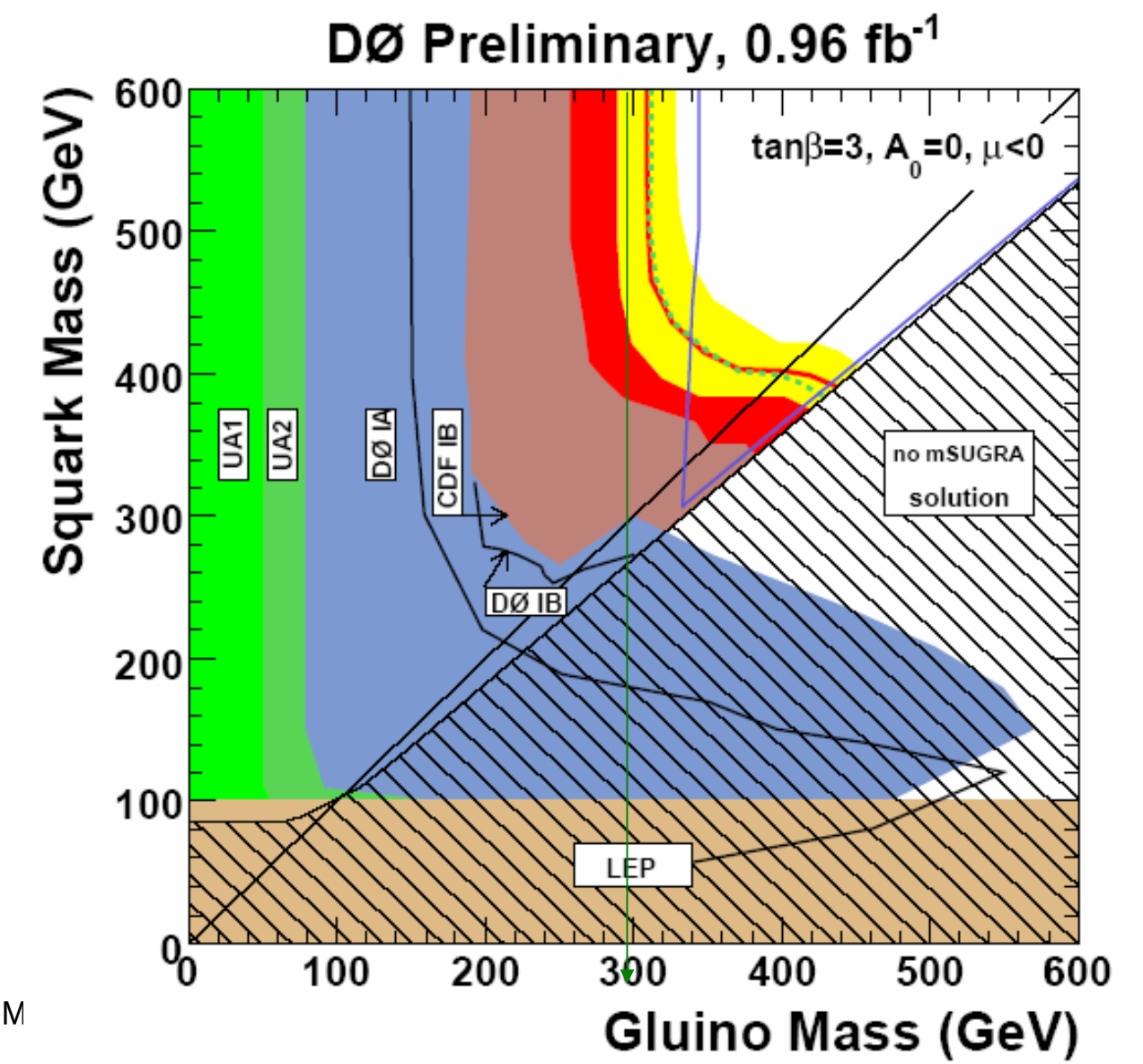
- Limit calculate using same procedure CDF does as

CDF	D0
tanβ=5	tanβ=3
ISASUSY	SUSPECT, SDECAY
	ISR/FSR systeamtic studied by varing Pythia parameters



- Green and beige areas excluded by LEP2 searches m(selectron) > 100 GeV, m(smuon) > 97 GeV, m(stau) > 93 GeV and m(chargino) > 103 GeV




DØ Preliminary, 0.96 fb-1
tanβ=3, A0=0, μ<0
Squark Mass (GeV)
Gluino Mass (GeV)
UA1
UA2
DØ IA
CDF IB
DØ IB
LEP
no mSUGRA solution
0
100
200
300
400
500
600