Searches for Squark and Gluino Production at D0

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Search in Jets + MET

Why?

At a hadron collider, squarks and gluinos are copiously produced (strong coupling to partons)

Decay in chains to *pairs* of invisible LSP

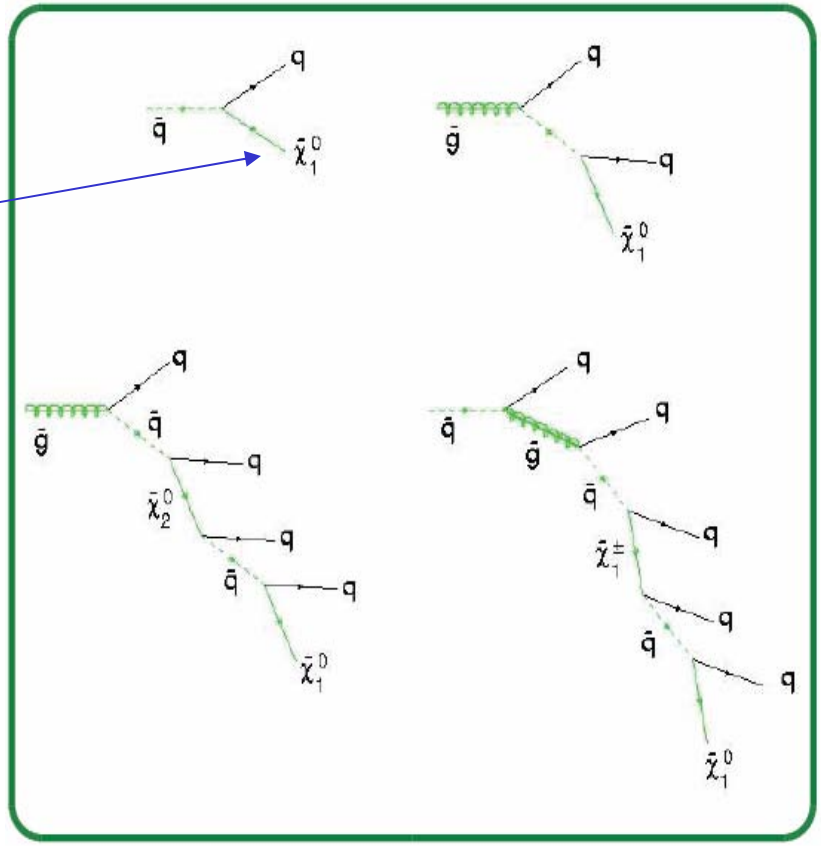
(R Parity conservation)

chains give rise to quark or gluon jets

LSPs (DM candidate) → missing Et

By looking for energetic jets and large MET, push sensitivity to higher squark, gluino masses

larger mass gaps above LSP



D0 Detector for this analysis

Calorimeter:

- triggers: MET + (2 non back to back jets, or 3 j)
- analysis:
  - 2 central jets in $|\eta| < .8$
  - new: additional jets $|\eta| < 2.5$
    - greatly increases efficiency

Tracking confirmation of jets:

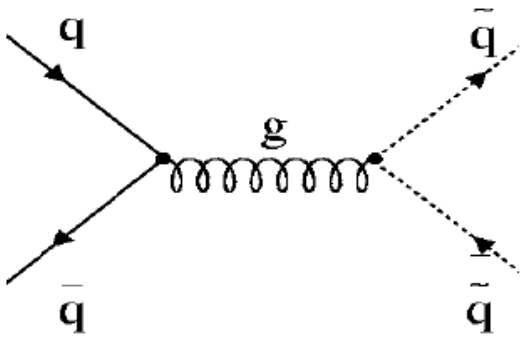
- identify good jets by associating w/ tracks
- verify that using correct primary vertex
  - critical for killing QCD background

Veto on isolated em cluster, mu (kills W, Z + jets)

mSUGRA points for 3 sub-analyses

- Low m_0: $m(\tilde{q})<m(\tilde{g})$
  - $m_0=25$, $m_{1/2}=165$
  - At least 2 jets

→ **"dijet" analysis**

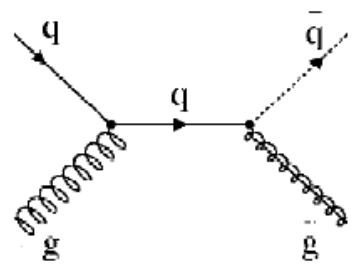


$$\tilde{q}\,\bar{\tilde{q}} \rightarrow q\,\tilde{\chi}_1^0\,\bar{q}\,\tilde{\chi}_1^0$$

- Intermediate m_0:

  $m(\tilde{q}) = m(\tilde{g})$
  - $m_0=188$, $m_{1/2}=145$
  - At least 3 jets

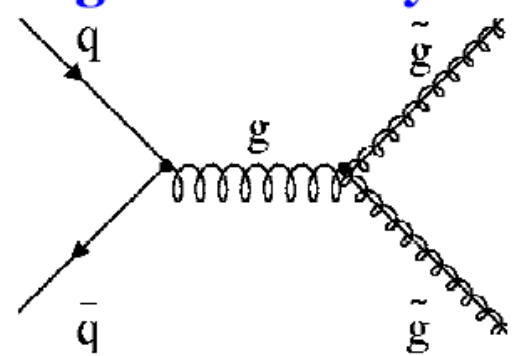
→ **"3-jet" analysis**



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

- High m_0: $m(\tilde{q})>m(\tilde{g})$
  - $m_0=500$, $m_{1/2}=100$
  - At least 4 jets

→ **"gluino" analysis**



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

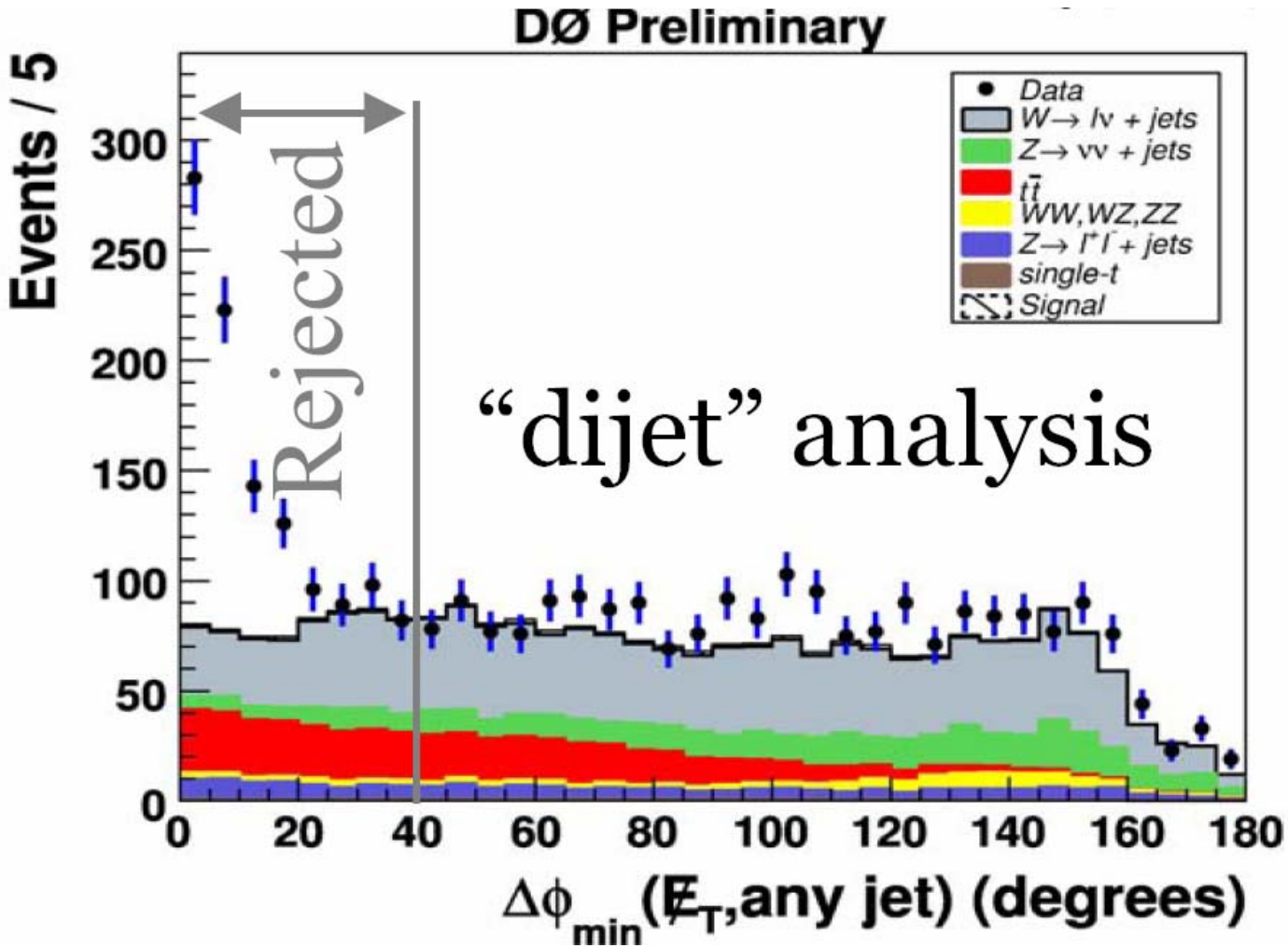
Optimized for these processes, but

efficiency includes all cascade decays

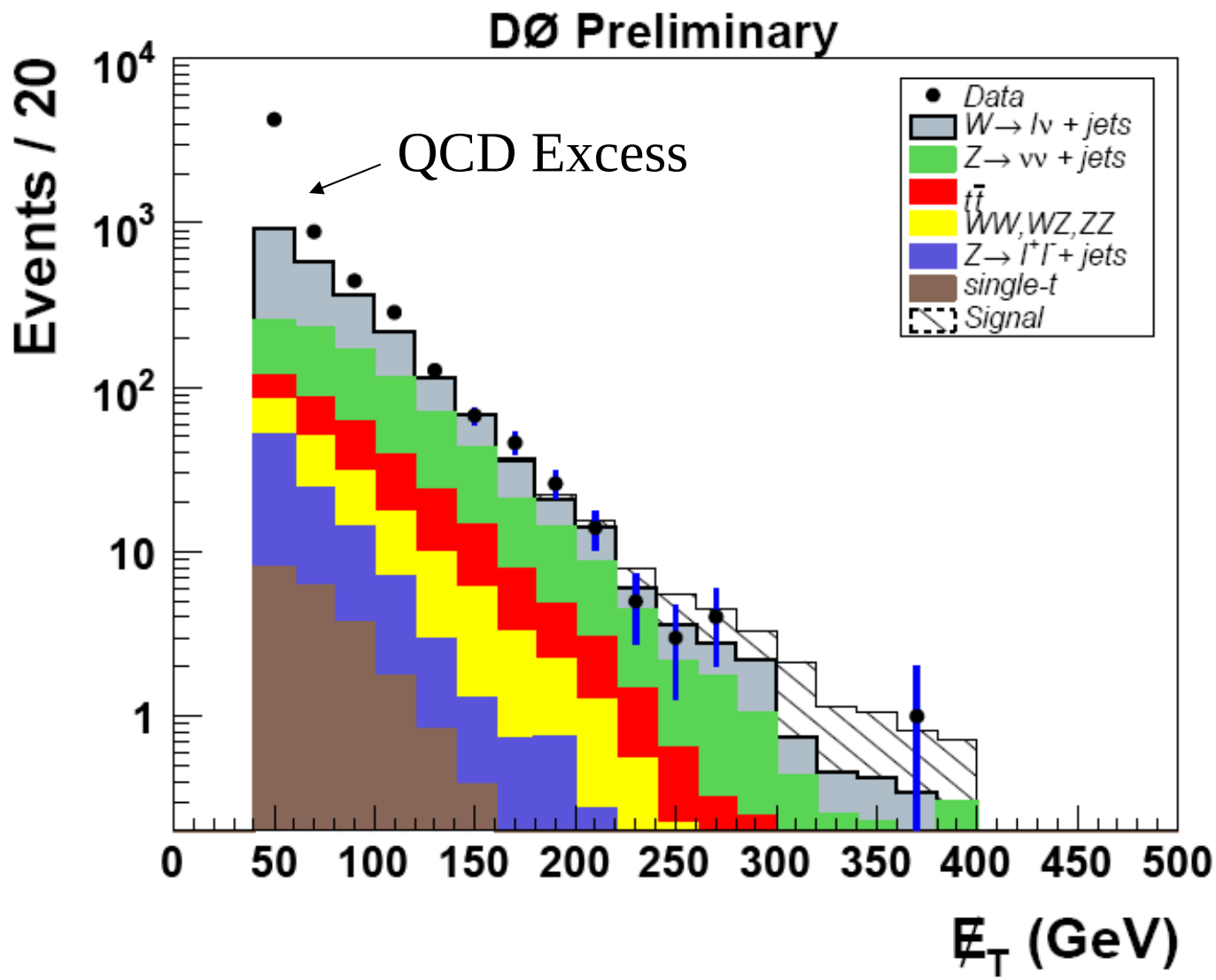
Data sample and Cuts

- All RunIIa data, L=0.96 fb^{-1} ***Update from L=.31***
- Main backgrounds: Z->$\nu\nu$+jets, ttbar, W+jets (ALPGEN)
- QCD negligible at the end of the selections
- Common pre-selection:
  - 2 acoplanar jets with Et >35 GeV and $|\eta|$<0.8 confirmed by the tracks $\Delta\varphi < 165^o$
  - MET>40 GeV
- For the three analyses :
  - MET vs jets isolation cuts $\Delta\varphi > 40\text{-}50^o$
  - electron and muon veto
  - optimization of the 2 final cuts on HT and MET

QCD rejection example



"Dijet" before HT, MET cuts



How the 3 analyses are used:

1) The benchmark mSUGRA point for each

   chosen in region not yet excluded by jets + MET search

   defines efficiency of signal

- R-parity is conserved
- Lightest neutralino χ_1^0 is the LSP
- **$\tan(\beta)=3$, $A=0$, $\mu<0$**

2) Use MC at mSUGRA point to choose Ht, MET cut:

   lowest expected signal cross section limit *if* no signal

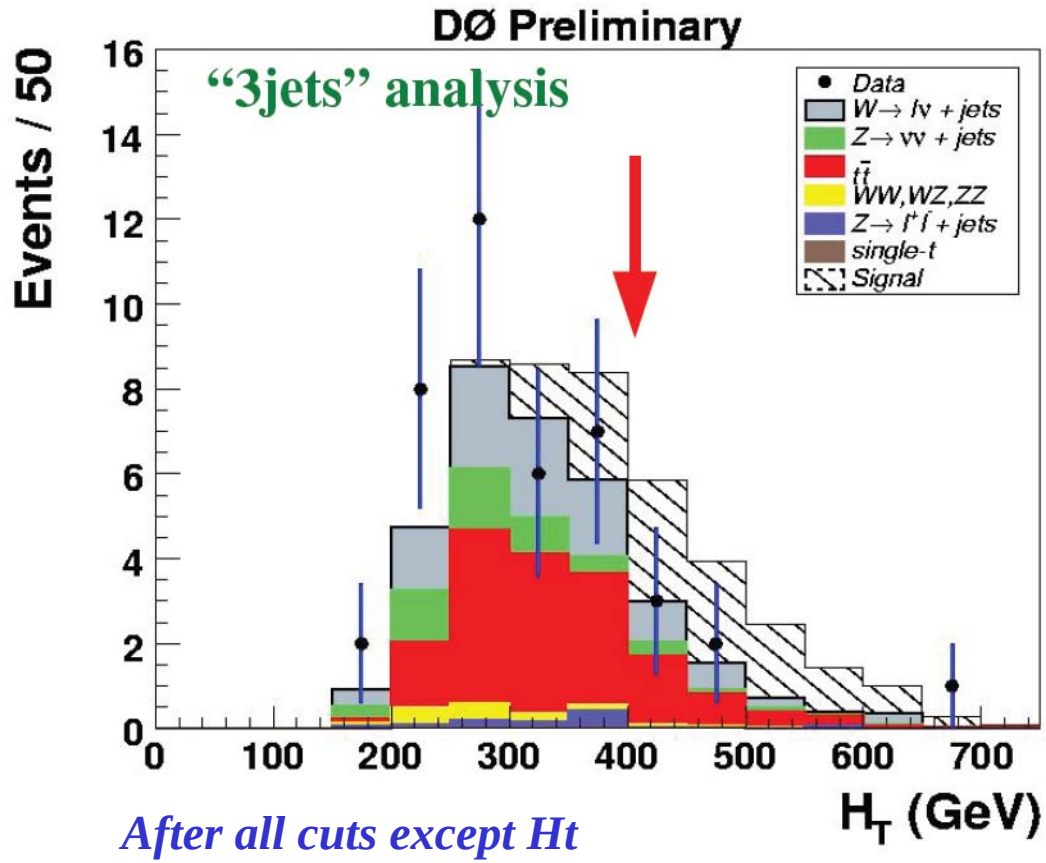
3) Then perform each analysis on data

4) Combine at end

   taking into account overlaps, correlations

Final Cuts

	HT	MET
Dijet	300	225
3j	400	150
Gluino	300	100



After all cuts except Ht

Results: No Excess (Drat!)

	Data	Total background	Smax (CLs @ 95%)
"Dijet"	5	7.5 ±1.1 (stat) +1.3 -1.0 (syst)	7.8
"3 jets"	6	6.1 ±0.4 (stat) +1.3 -1.2 (syst)	8.1
"Gluino"	34	33.4 ±0.8 (stat) +5.6 -4.9 (syst)	21.3

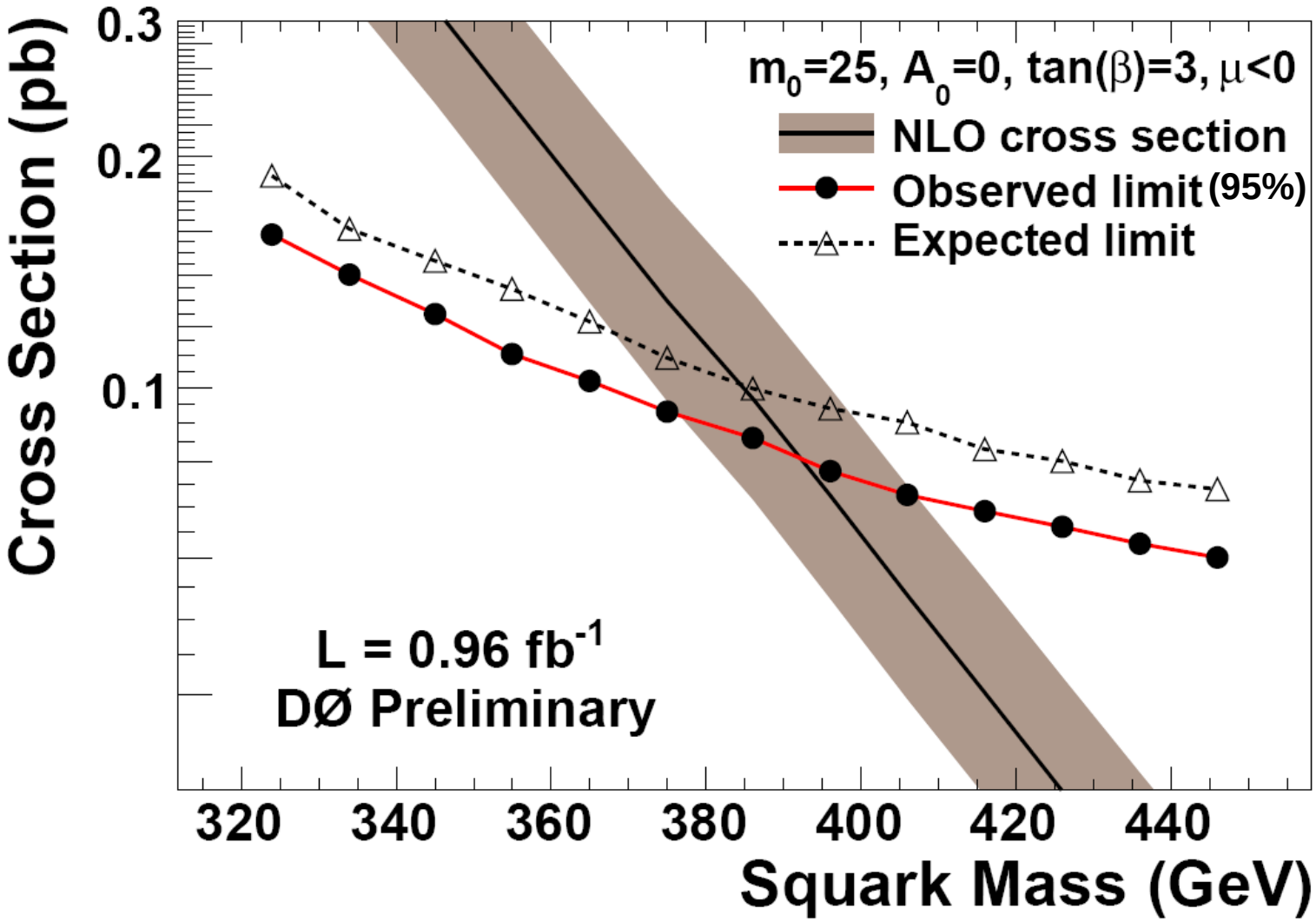
- Systematic uncertainties :
  - mainly JES (6 to 17%) and background cross sections (15%)
  - jet reco*ID, resolution, track confirmation : 5 to 7%
  - luminosity 6.1%
  - PDF on the signal acceptance : 6%
- Signal efficiencies:
  - up to 10%, and higher at large squark-gluino masses

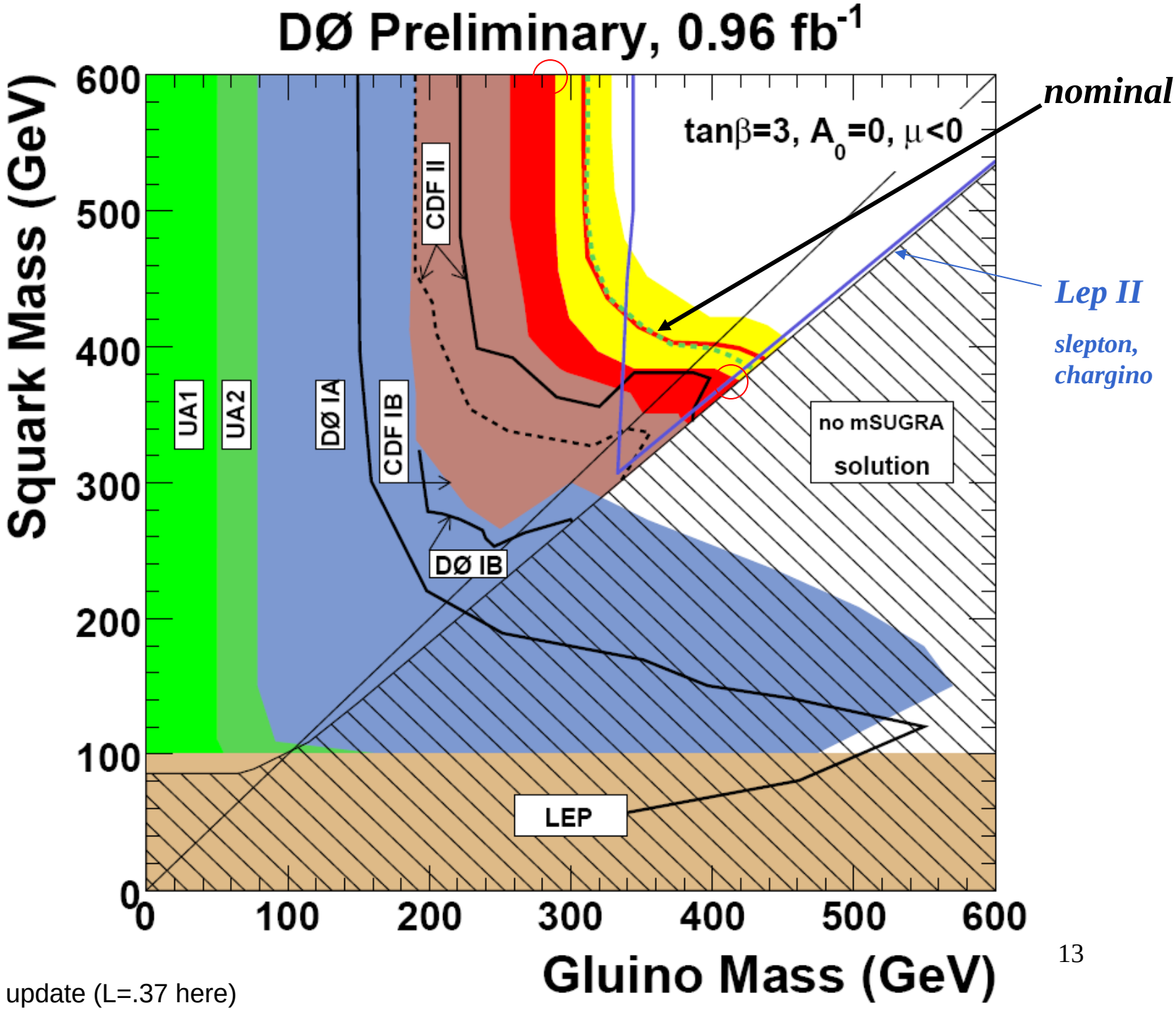
Uncertainties in Signal

- Signal cross sections:
  - using the 40 CTEQ6.1M PDF sets
  - large PDF uncertainty comes from the very poor knowledge of the gluon at high-x
  - Combine quadratically with the effect of the renormalization/factorization scale (μ=Q,Q/2,2Q) => 3 cross section hypotheses: Q = Mq or Mg
    - nominal : CTEQ6.1M and μ=Q
    - minimal
    - maximal
  - Very large effect: +75 -45% for intermediate m0
- Cross section and mass limits :
  - for the 3 cross section hypotheses
  - Combine the 3 analyses in the limit computation (removing the small overlap between them)

We Treat Conservatively: min, max signal as band

From "dijet" Cross Section to Mass Limits





CDF has an update (L=.37 here)

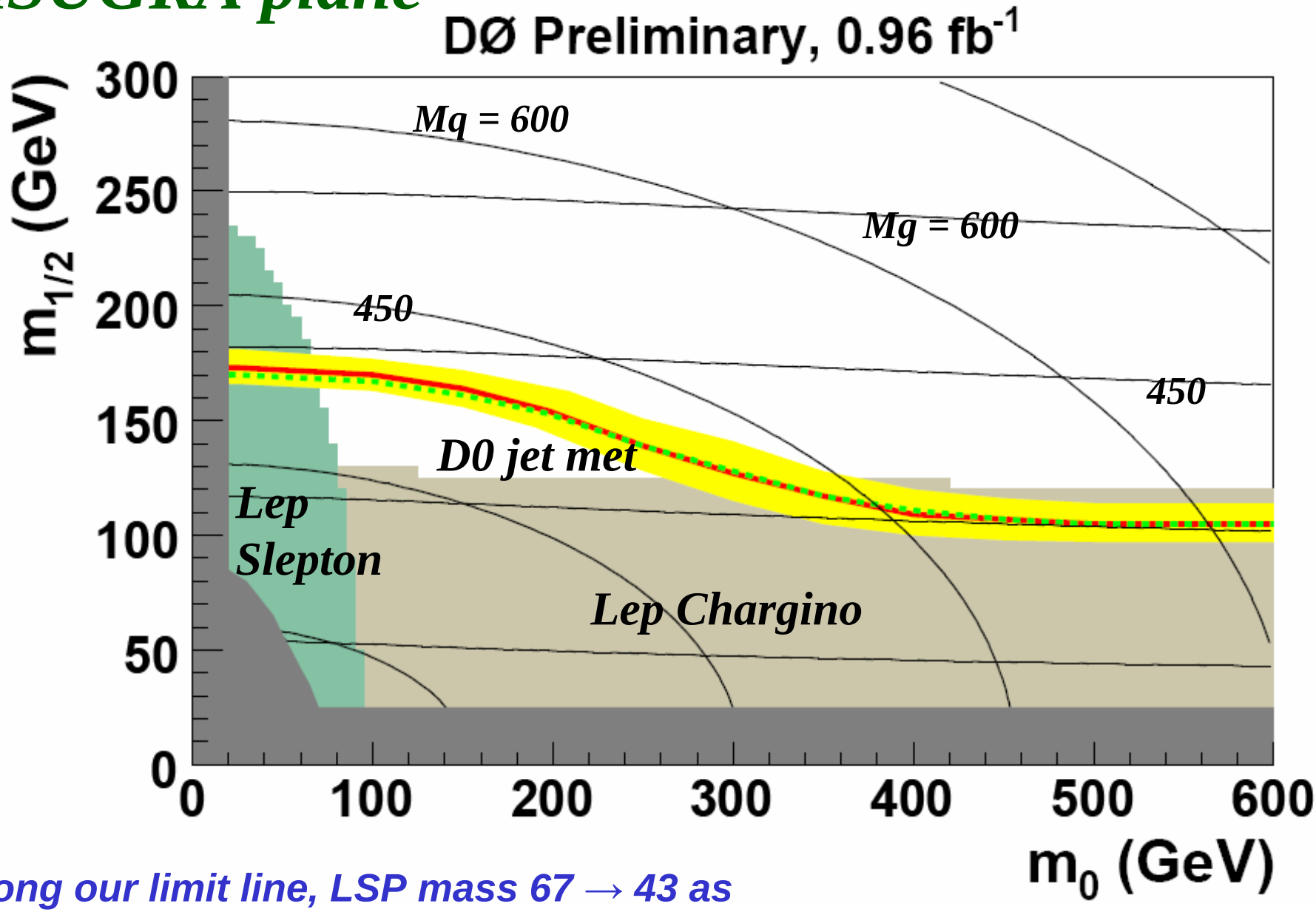
Mass Limits

	Gluino Mass		Squark Mass	
	obs.	exp.	obs.	exp.
sig(min)	289	290	375	366
sig(nom)	309	311	391	384
sig(max)	329	332	405	397

*

** from red circles on previous plots*

mSUGRA plane



Along our limit line, LSP mass 67 → 43 as mo 25 → 500; low mass disfavored

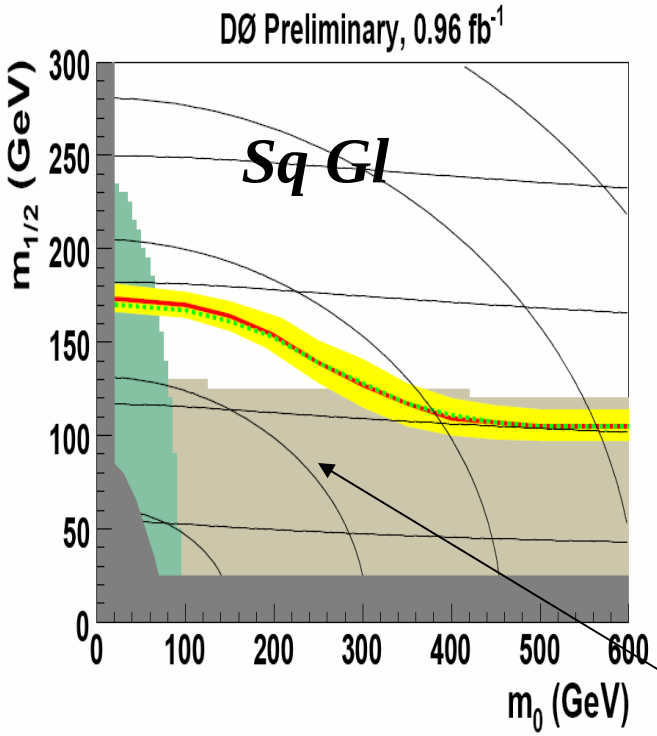
IF you take mSUGRA completely seriously…

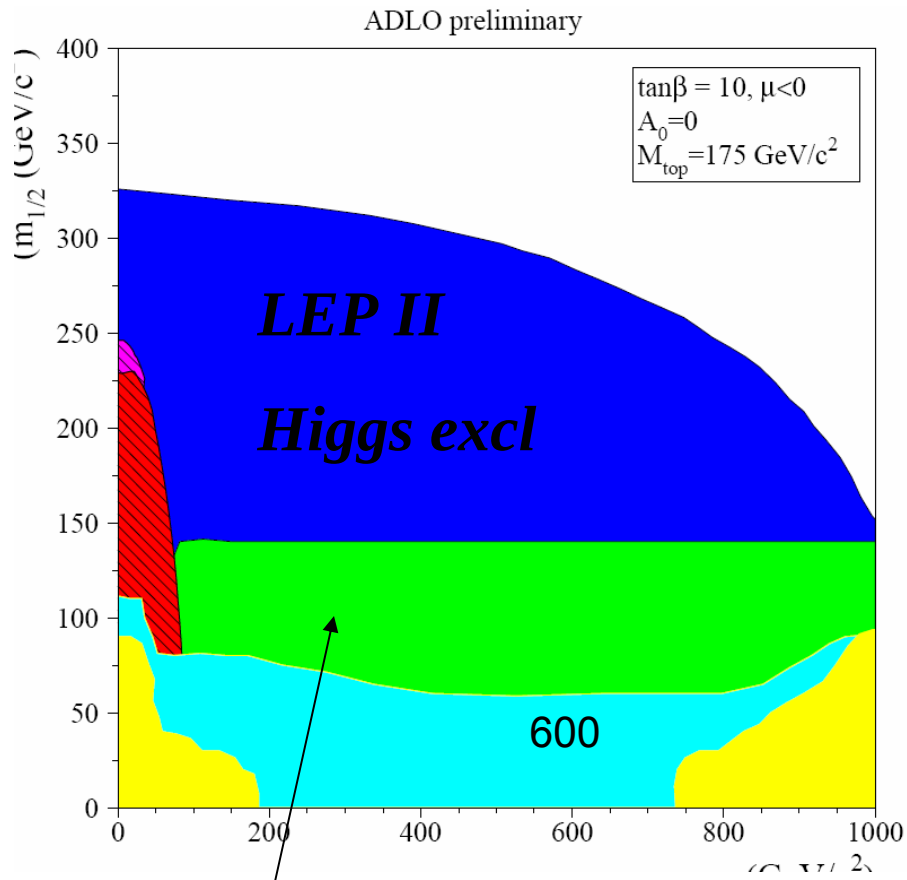
But: LEP insensitive to direct gluino production

No direct squark search beyond 100 GeV

Higgs exclusion most sensitive to model details

And: do you really believe only 2 masses define the model?





chargino

Summary

Most sensitive search for jets + MET

$\sqrt{s}$ = 1.96 TeV, L = .96/fb

No excess. Limits move ~ 50 GeV

better than L= .3 →.96 : jet acceptance

For mSUGRA tan β = 3

Ao = 0, μ < 0

- Using minimal cross-section:
  - $M(\tilde{g}) > 289$ GeV
  - $M(\tilde{q}) > 375$ GeV
  - If $M(\tilde{g}) = M(\tilde{q})$
    then $M(\tilde{g}), M(\tilde{q}) > 383$ GeV

For details see

http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N50/N50.pdf

Backup

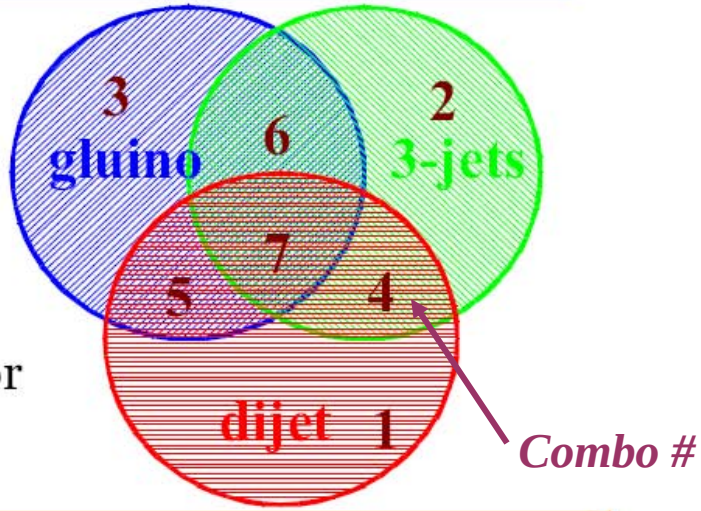
- Overview of the pre-selection and analysis cuts in the 3 analyses
  - common preselection: 2 central jets pT>35 GeV, in the central region (|ieta|<0.8) confirmed by the tracks (CPF0>0.85), acoplanar, and MET>40 GeV

Preselection Cut		All Analyses	
1st jet E_T [a]		≥ 35	
2nd jet E_T [a]		≥ 35	
$\not\!\!E_T$		≥ 40	
Acoplanarity		$< 165°$	
|Vertex z pos.|		< 60 cm	
Selection Cut	"dijet"	"3-jets"	"gluino"
Trigger	acoplanar dijet	multijet	multijet
3rd jet E_T [b]	–	≥ 35	≥ 35
4th jet E_T [b]	–	–	≥ 20
$\not\!\!E_T$	≥ 75	≥ 75	≥ 75
Electron veto	yes	yes	yes
Muon veto	yes	yes	yes
$\Delta\phi(\not\!\!E_T, \text{jet}_1)$	$\geq 90°$	$\geq 90°$	$\geq 90°$
$\Delta\phi(\not\!\!E_T, \text{jet}_2)$	$\geq 50°$	$\geq 50°$	$\geq 50°$
$\Delta\phi_{\min}(\not\!\!E_T, \text{any jet})$	$\geq 40°$	–	–
H_T	≥ 300	≥ 400	≥ 300
$\not\!\!E_T$	≥ 225	≥ 150	≥ 100

- 1st and 2nd jets are central and track confirmed
- 3rd and 4th jets acceptance extended to |ieta|<2.5, and no cut on CPF0

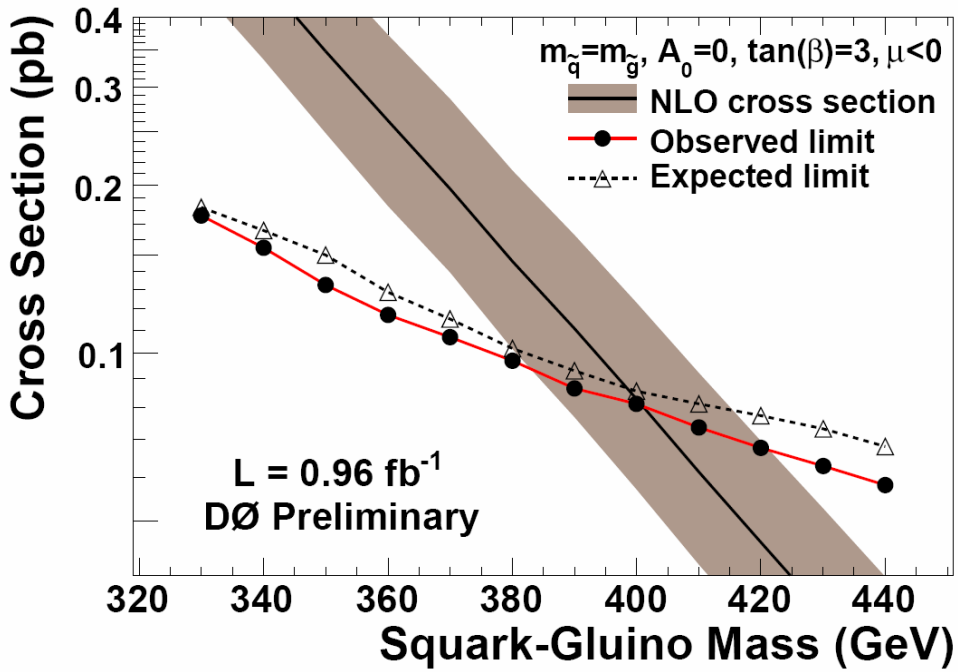
Combining the analyses

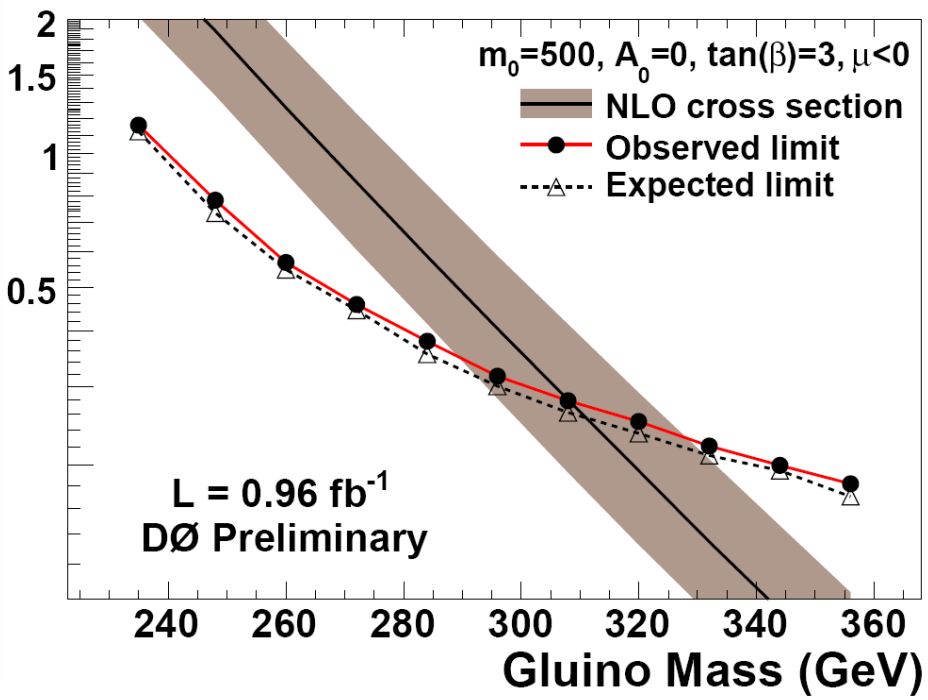
- The 3 analyses are combined
  - 7 independent event selections
  - Good agreement between data and Standard Model expectations
  - Systematic uncertainties are re-computed for each combinations



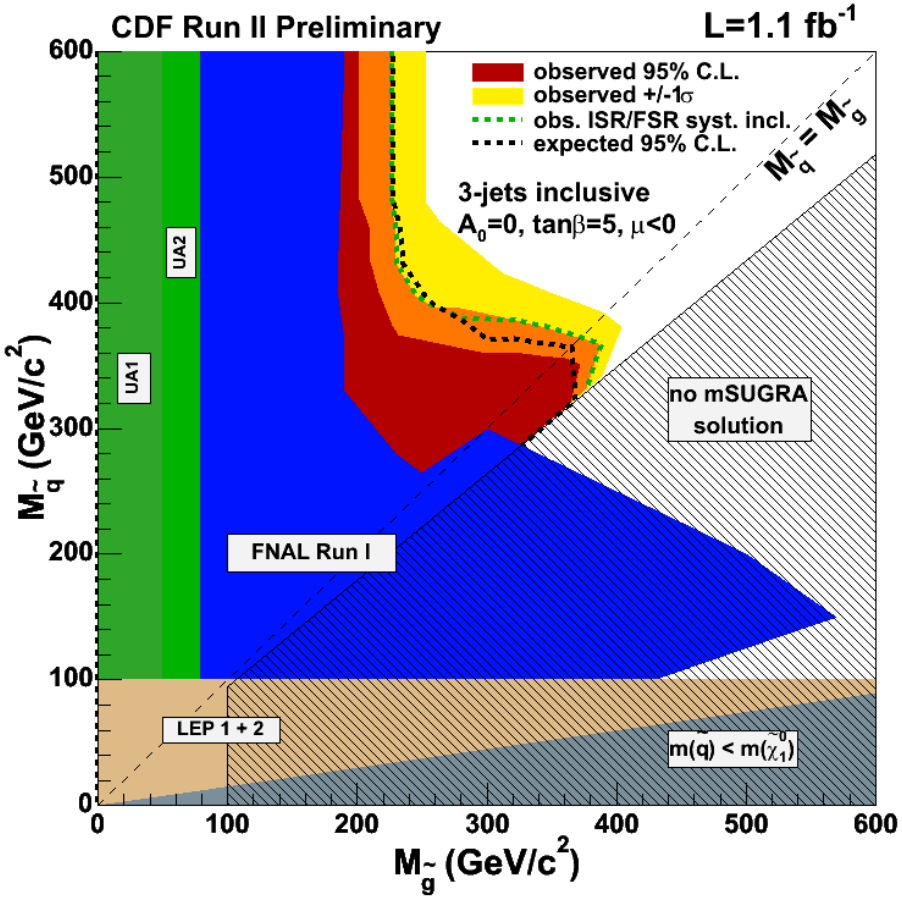
Name	"dijet"	"3-jets"	"gluino"	Data	SM events expected
"dijet"	yes	-	-	5	7.47 ± 1.06 (stat.) $^{+1.32}_{-1.02}$ (syst.)
"3-jets"	-	yes	-	6	6.10 ± 0.37 (stat.) $^{+1.26}_{-1.16}$ (syst.)
"gluino"	-	-	yes	34	33.35 ± 0.81 (stat.) $^{+5.56}_{-4.92}$ (syst.)
combination 1	yes	no	no	5	6.10 ± 1.04 (stat.) $^{+1.17}_{-0.73}$ (syst.)
combination 2	no	yes	yes	1	1.09 ± 0.14 (stat.) $^{+0.17}_{-0.22}$ (syst.)
combination 3	no	no	yes	29	$27.78 + 0.73$ (stat.) $^{+4.39}_{-3.84}$ (syst.)
combination 4	yes	yes	no	0	0.22 ± 0.07 (stat.) $^{+0.02}_{-0.06}$ (syst.)
combination 5	yes	no	yes	0	0.78 ± 0.14 (stat.) $^{+0.12}_{-0.16}$ (syst.)
combination 6	no	yes	yes	5	4.42 ± 0.32 (stat.) $^{+1.01}_{-0.83}$ (syst.)
combination 7	yes	yes	yes	0	0.37 ± 0.11 (stat.) $^{+0.07}_{-0.13}$ (syst.)
global "OR"		-		40	40.76 ± 1.33 (stat.) $^{+6.91}_{-5.88}$ (syst.)

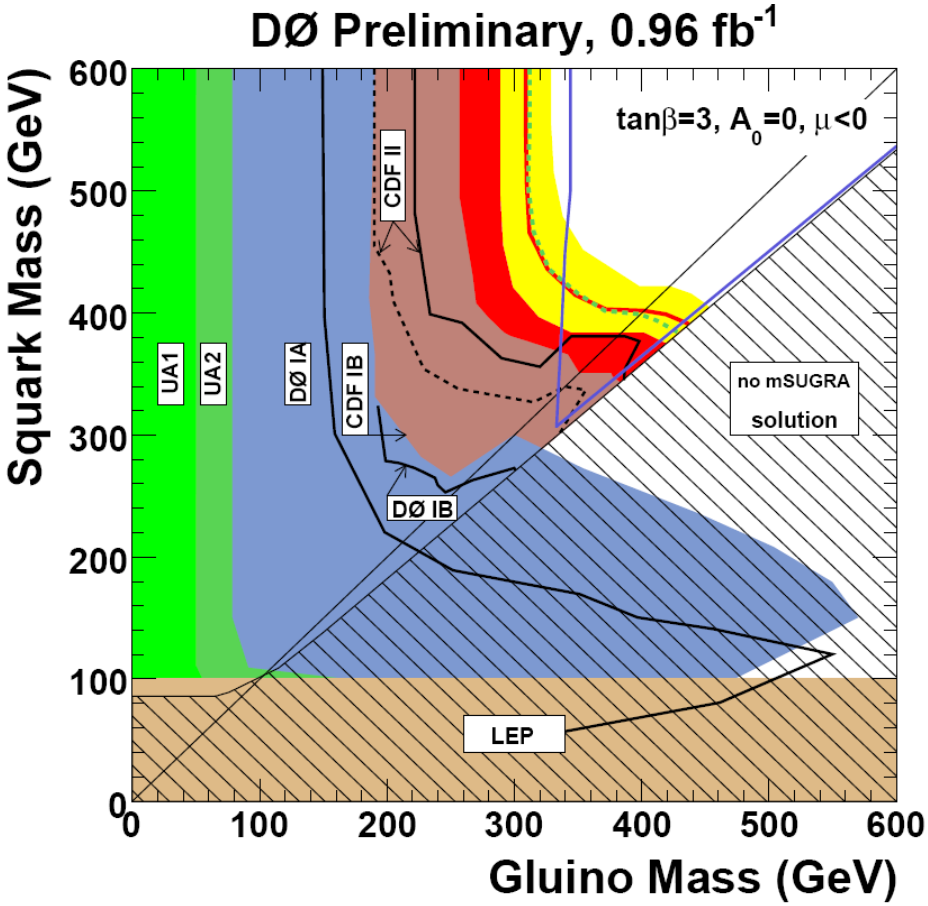
Mass Limits: the other cases





Wider band on signal cross section because gluons essential


CDF Run II Preliminary
L=1.1 fb-1
observed 95% C.L.
observed +/-1σ
obs. ISR/FSR syst. incl.
expected 95% C.L.
3-jets inclusive
A0=0, tanβ=5, μ<0
M~q = M~g
no mSUGRA solution
FNAL Run I
UA1
UA2
LEP 1 + 2
m(q) < m(χ1)
M~q (GeV/c2)
M~g (GeV/c2)


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