Searches: bilan du TeVatron

Laurent Duflot (LAL)

- SUSY
- Extra dimensions
- (leptoquarks)
- (Other exotica)

Merci à Jean-françois Grivaz à qui j'ai pris beaucoup de transparents

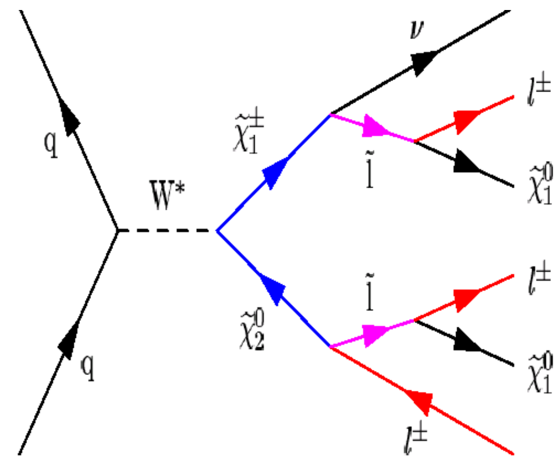
Supersymmetry

Trileptons

- Arise from chargino-neutralino associated production
- “Golden” SUSY signature but:
  - low cross sections ($\times$ BR)
  - soft leptons
  - taus (at large tanβ)

$\Rightarrow$ Needs large integrated luminosity

$\Rightarrow$ Combine various final states



General strategy (similar in CDF and DØ):

Two isolated (rather soft) e or μ

Require some Missing E_T (ν+2χ)

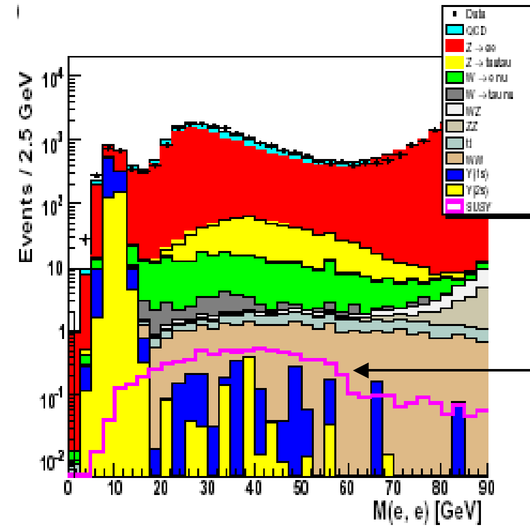
+ channel-dependent cuts (e.g. anti Z, Υ)

- An isolated third lepton or track (sensitive to τ’s), or
- Two same sign leptons

Main backgrounds: DY, WW, WZ, Wγ (+ a bit of bb and mis-ID)

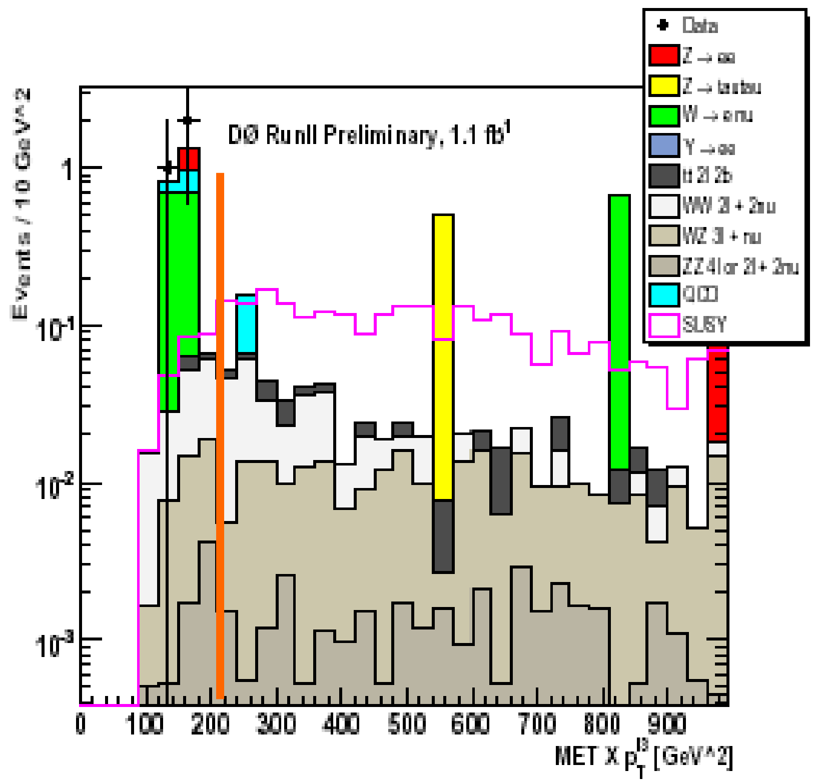
Begin with a background 3 to 4 orders of magnitude larger than the signal

…and in the end…



ee mass below the Z peak

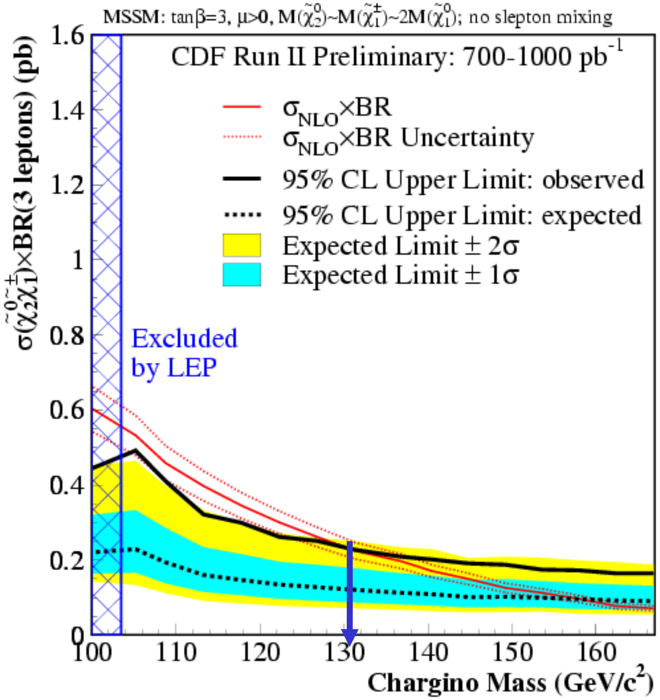
SUSY

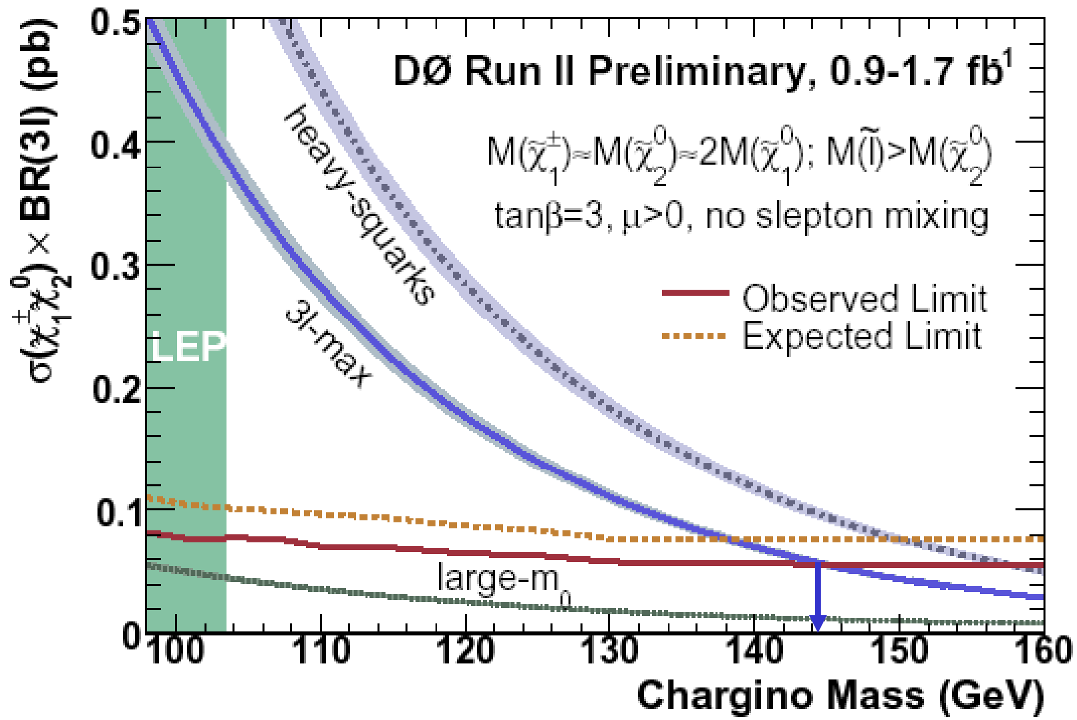


$ME_T \times p_T(3)$ in ee+track

D0 ANALYSIS	BACKGROUND EXPECTED	DATA
e e + track	0.76 ± 0.67	0
LS $\mu^\pm \mu^\pm$	1.1 ± 0.4	1
e μ + track	0.94 ± 0.4	0
$\mu\mu$ + track	0.32 ± 1.34	2

[~ similar results from CDF, with some excesses over SM]





Models = “favorably tweaked” mSUGRA

Both CDF and DØ set $m_{s\tau} = m_{se} = m_{s\mu}$

m_0 = 70 GeV

⇒ 2-body decays enhanced (+)

sτ mixing on (∃ $s\tau_L$ component)

⇒ decays to τ’s slightly enhanced (–)

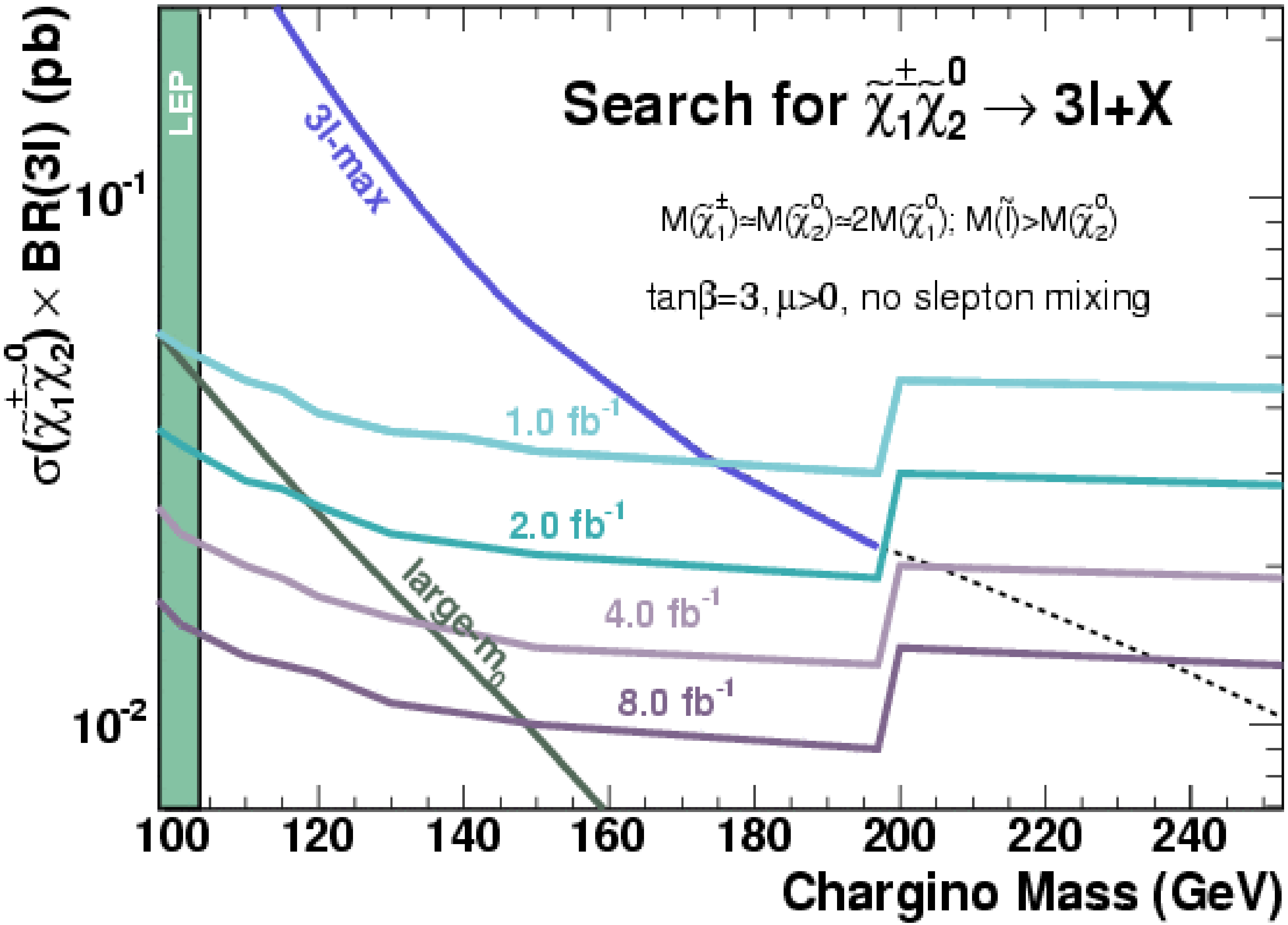
$m(sl) = m(\chi_2^0) + \varepsilon$

⇒ only 3-body decays (–)

sτ mixing off (no $s\tau_L$ component)

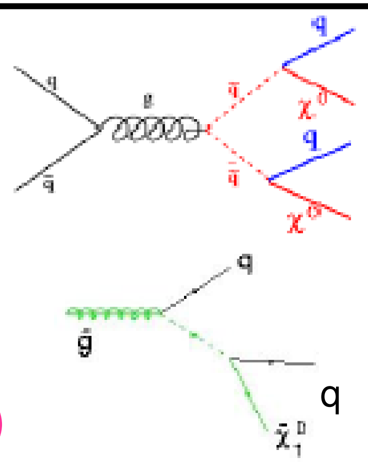
⇒ decays to τ’s = to e/μ (+)

Projections



Squarks & gluinos: generic search

Strong production (⇒ Large cross sections) of:



- sq-sqbar and sq-sq ⇒ at least 2 jets + missing E_T (sq → qχ)
- gl-gl ⇒ at least 4 jets + missing E_T (gl → qqχ)
- sq-gl ⇒ at least 3 jets

Cascade decays complicate the picture ⇒ model needed (mSUGRA)

Main backgrounds:

- Instrumental (QCD multijets with fake missing E_T)
- (W→(missed lepton)+ν) +jets (also from ttbar)
- (Z → νν) +jets (irreducible)

Three analyses optimized for each of these processes

DØ reduces QCD to a negligible level

CDF larger QCD background, estimated from control regions

Example of a cut flow: 2-jet analysis in DØ

- Jets+MHT trigger (MHT = MET from jets only)
- Bad runs and noisy events removal

- 2 jets with pT > 35 GeV
- $|\eta| < 0.8$ for both jets
- Both jets “confirmed” by charged tracks
- ∀ $\Delta\varphi(jet1,jet2) < 165^o$
- MET > 75 GeV

- No isolated electron or muon

- ∀ $\Delta\varphi(MET,jet1) > 90^o$
- ∀ $\Delta\varphi(MET,jet2) > 50^o$
- ∀ $\Delta\varphi_{min}(MET,any\ jet) > 40^o$

- Optimize the final cuts on MET and HT, based on the **expected** CLs

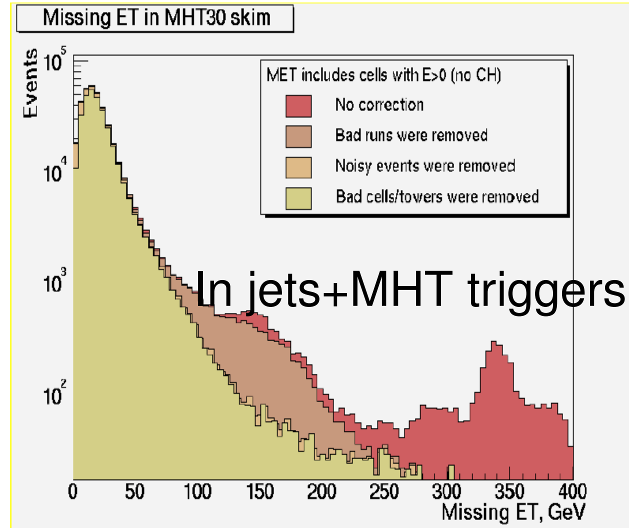
In the signal, the two leading jets are central, energetic, acoplanar and there is a lot of MET

Background from $W \to l\nu$ (including tt) is suppressed by the lepton vetoes

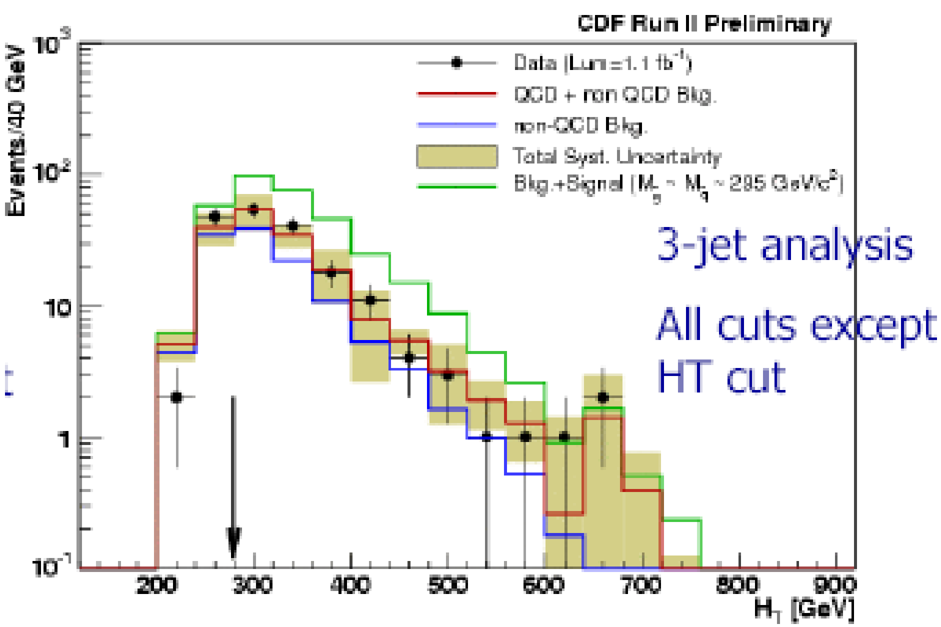
In the QCD background, due to mismeasured jets, the MET falls exponentially, and tends to be aligned with a jet.

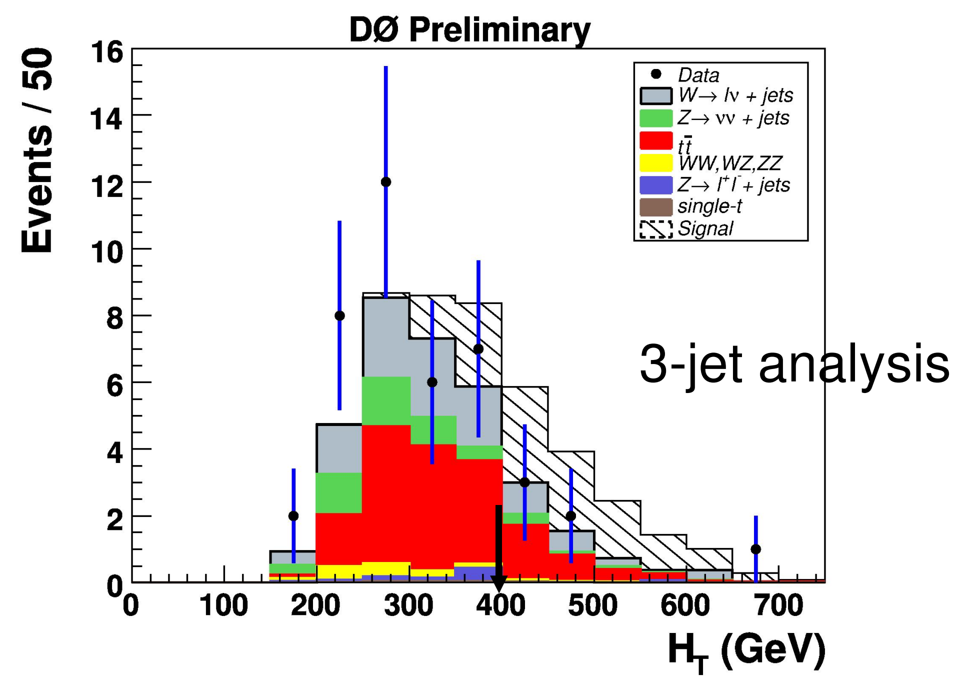
Main analysis cuts:

- Data cleaning
- Jet1,2(,3(,4)) p_T
- Missing E_T
- H_T = sum of jets p_T's
- Lepton veto
- Angles (jet,missing E_T)

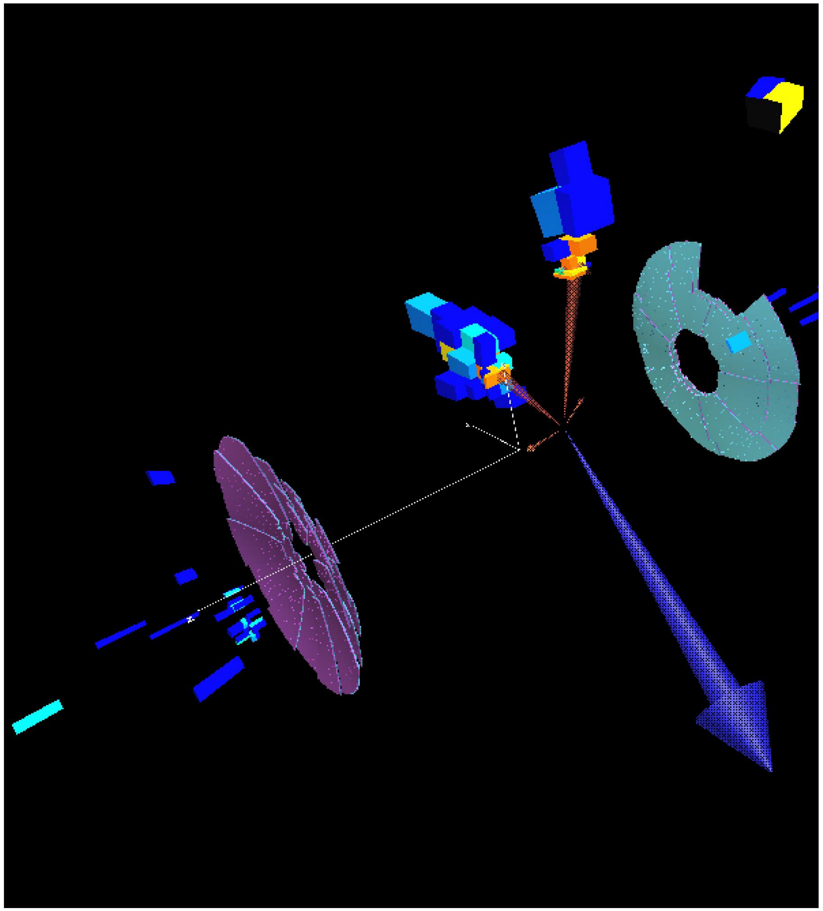


Important to clean up sample: data quality, detector malfunction, machine background, cosmics, etc



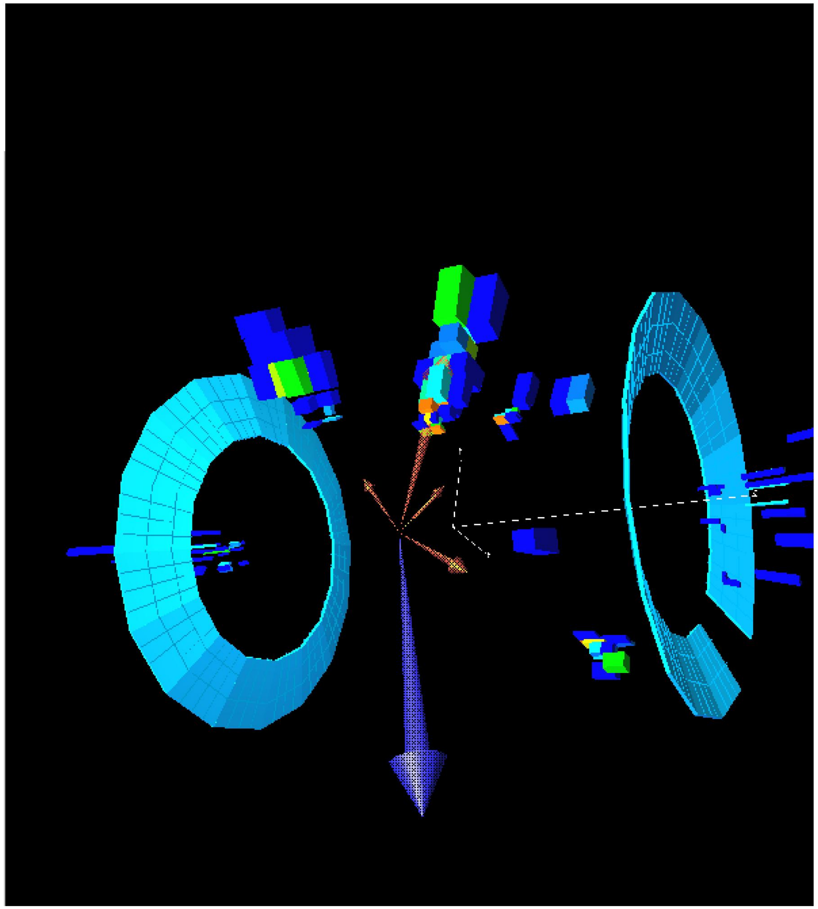


2-jet event



MET = 368 GeV , HT= 489 GeV

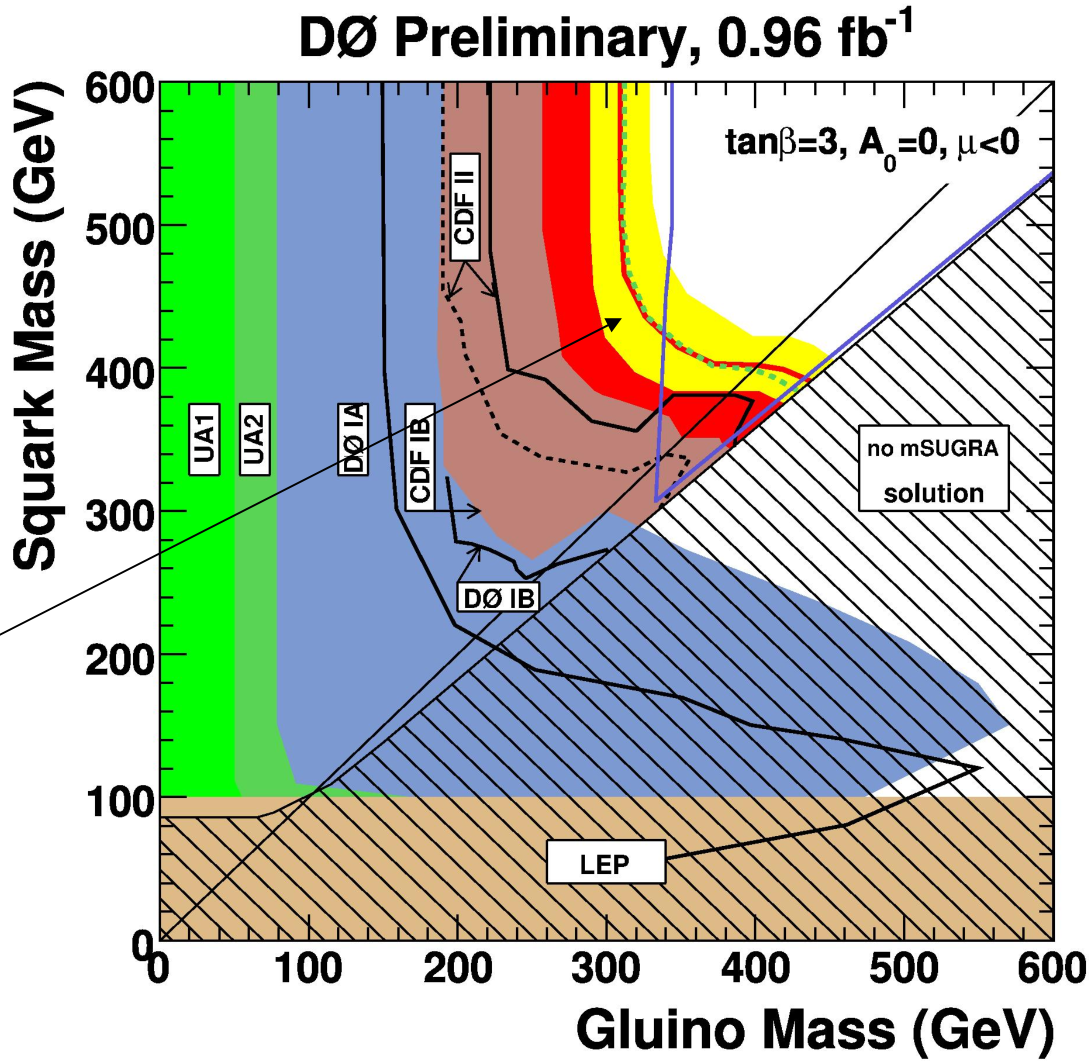
4-jet event



MET = 321 GeV , HT = 464 GeV

DØ Analysis	Background expected	Events observed
2-jets	7.5±1.6	5
3-jets	6.1±1.3	6
4-jets	33.4±5.3	34

Recent CDF update with similar results



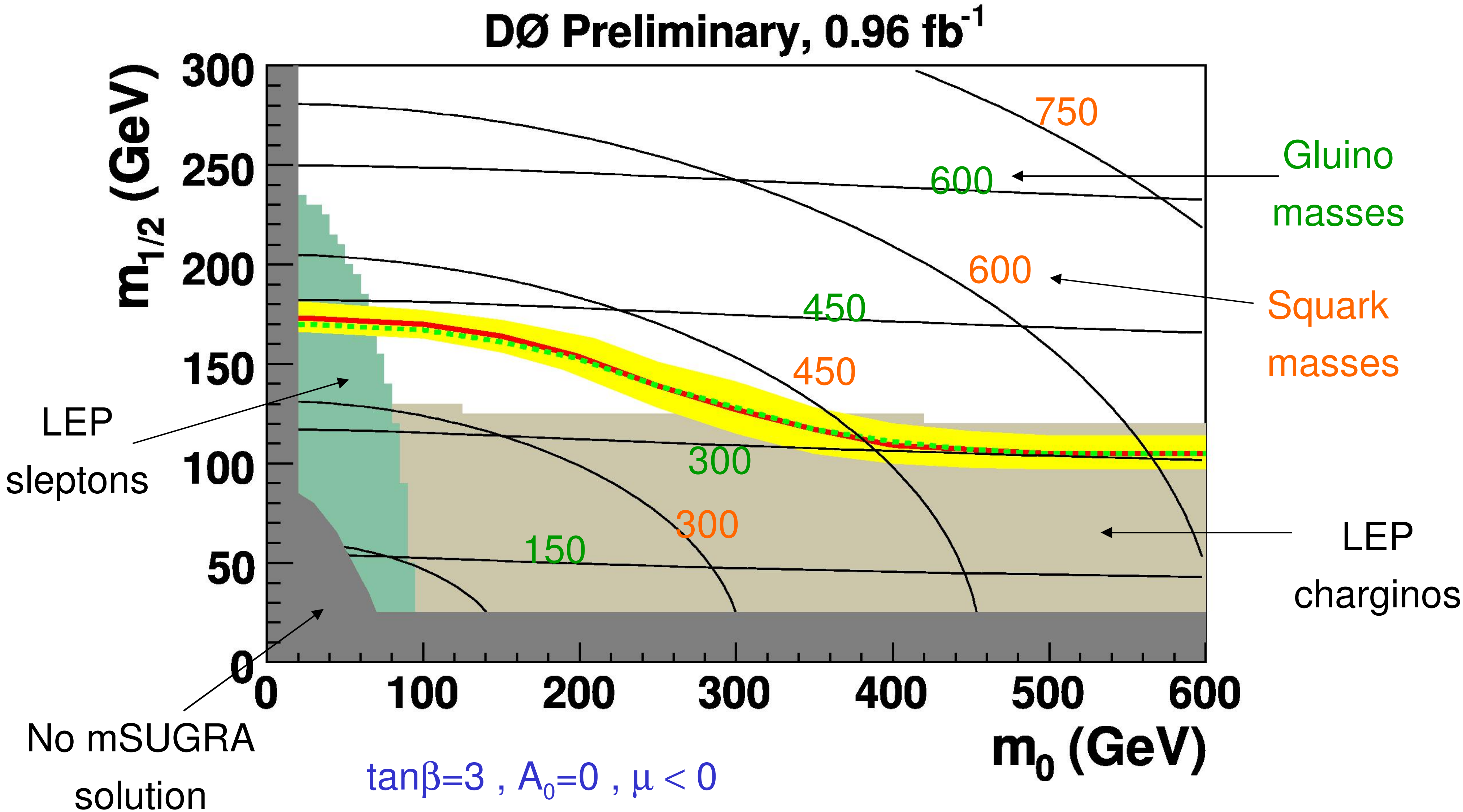
The yellow band represents the theoretical uncertainty (renormalization scale and PDFs)

For the “nominal cross section →

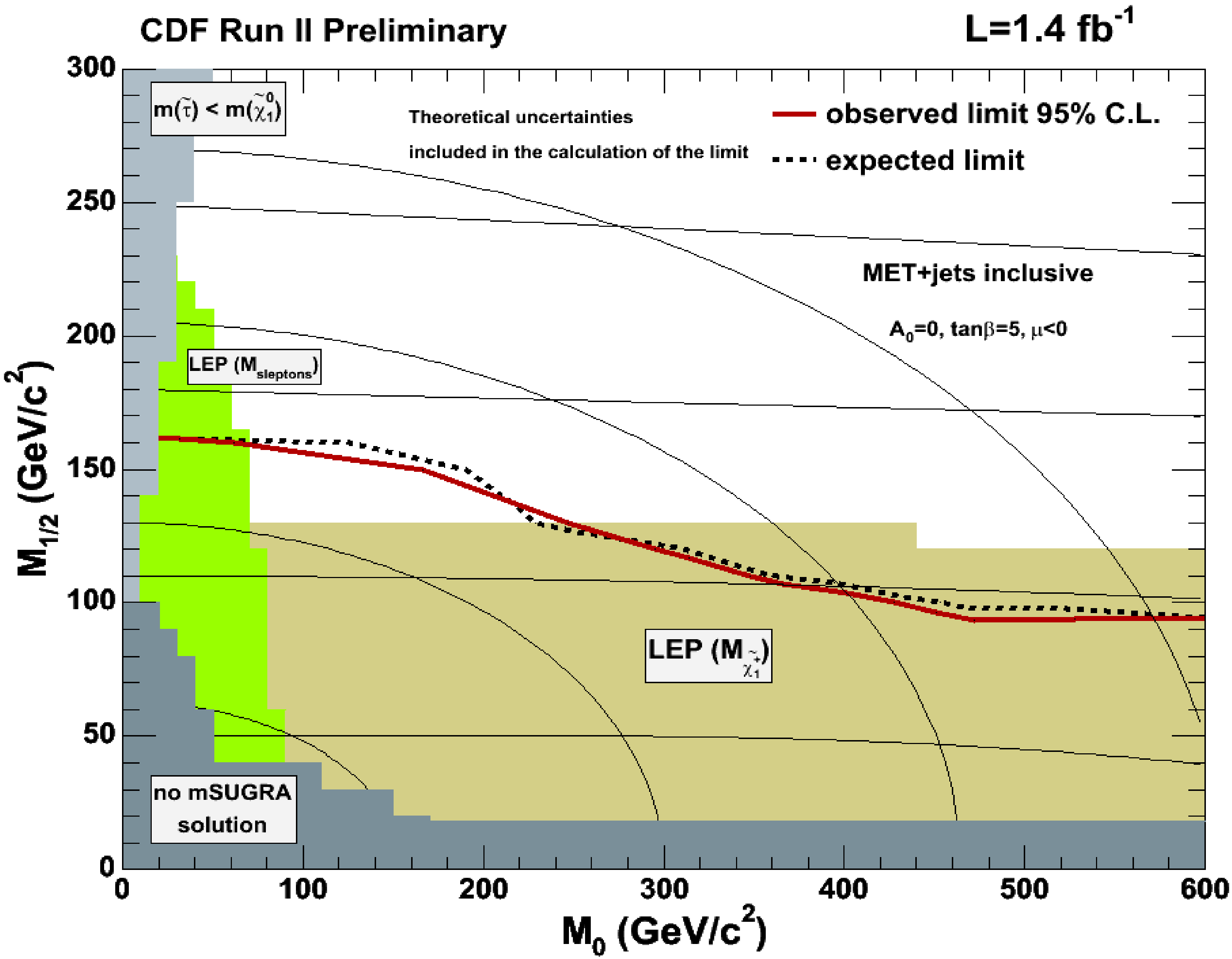
M_{gl} > 402 GeV (when $M_{gl} \sim M_{sq}$)

M_{gl} > 309GeV & M_{sq} > 391 GeV

Alternative presentation



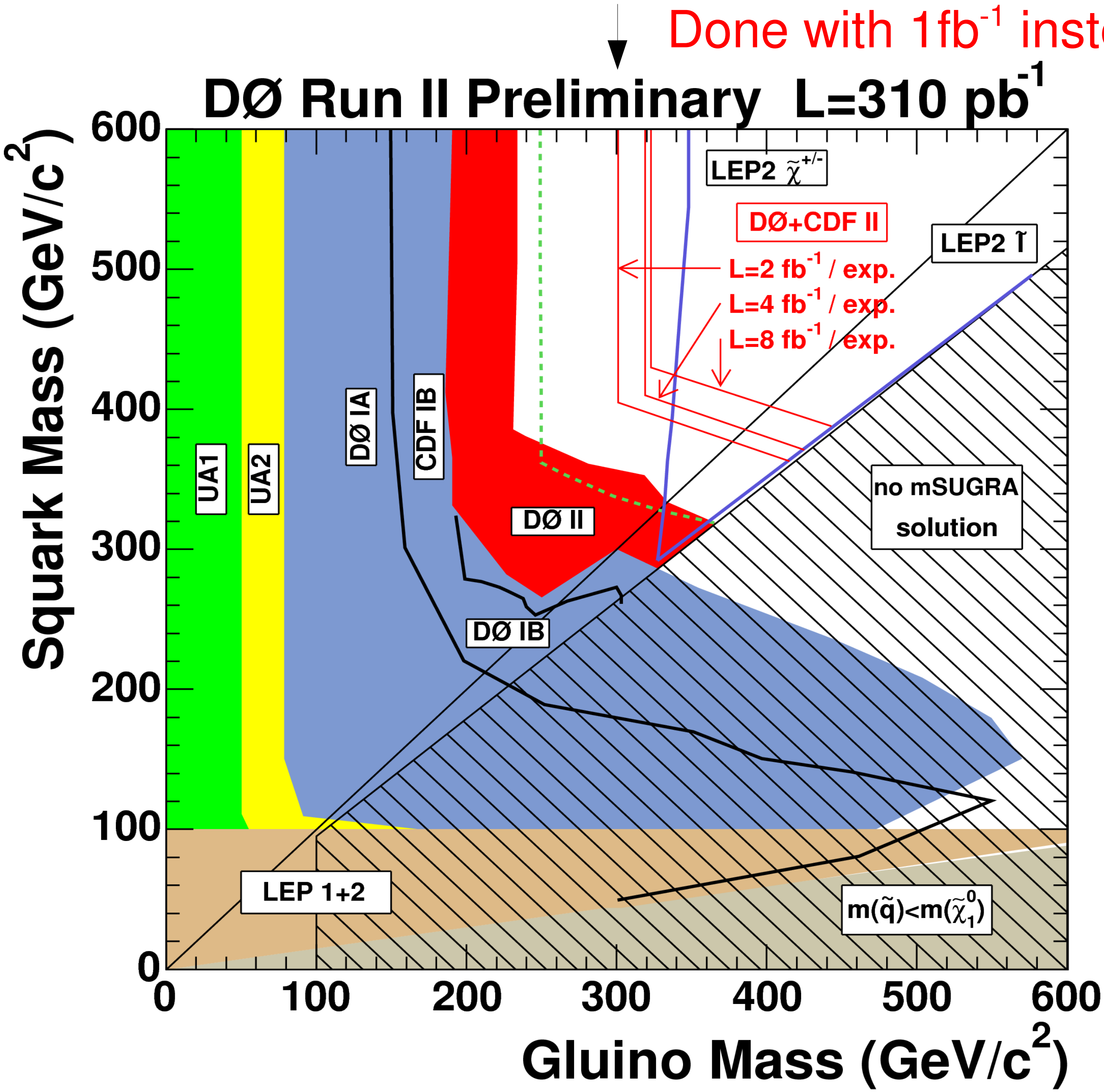
tanβ=3 , A_0=0 , μ < 0



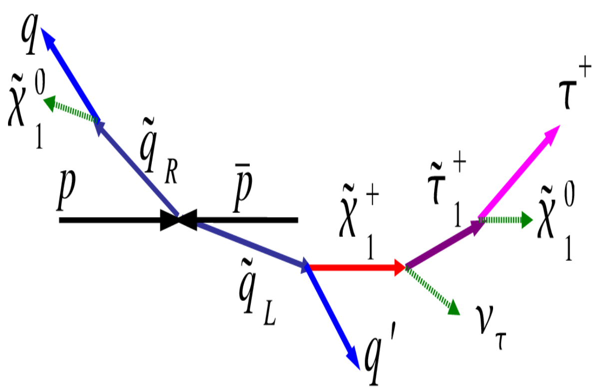
CDF Run II Preliminary
L=1.4 fb-1
m(τ̃) < m(χ̃⁰₁)
Theoretical uncertainties
included in the calculation of the limit
observed limit 95% C.L.
expected limit
MET+jets inclusive
A0=0, tanβ=5, μ<0
LEP (M sleptons)
LEP (M χ̃±₁)
no mSUGRA
solution
M1/2 (GeV/c2)
M0 (GeV/c2)
0
50
100
150
200
250
300
0
100
200
300
400
500
600

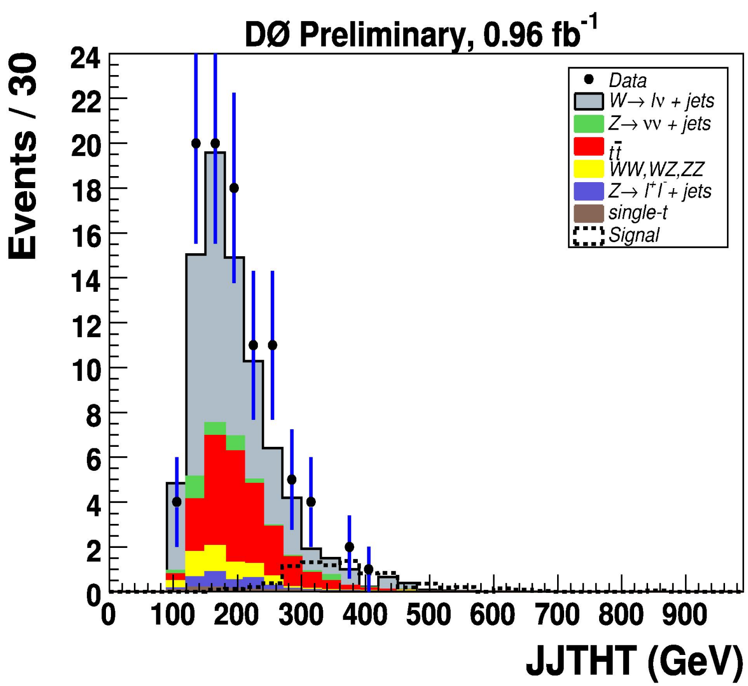
Projections

Done with 1fb^{-1} instead of 2fb^{-1} !

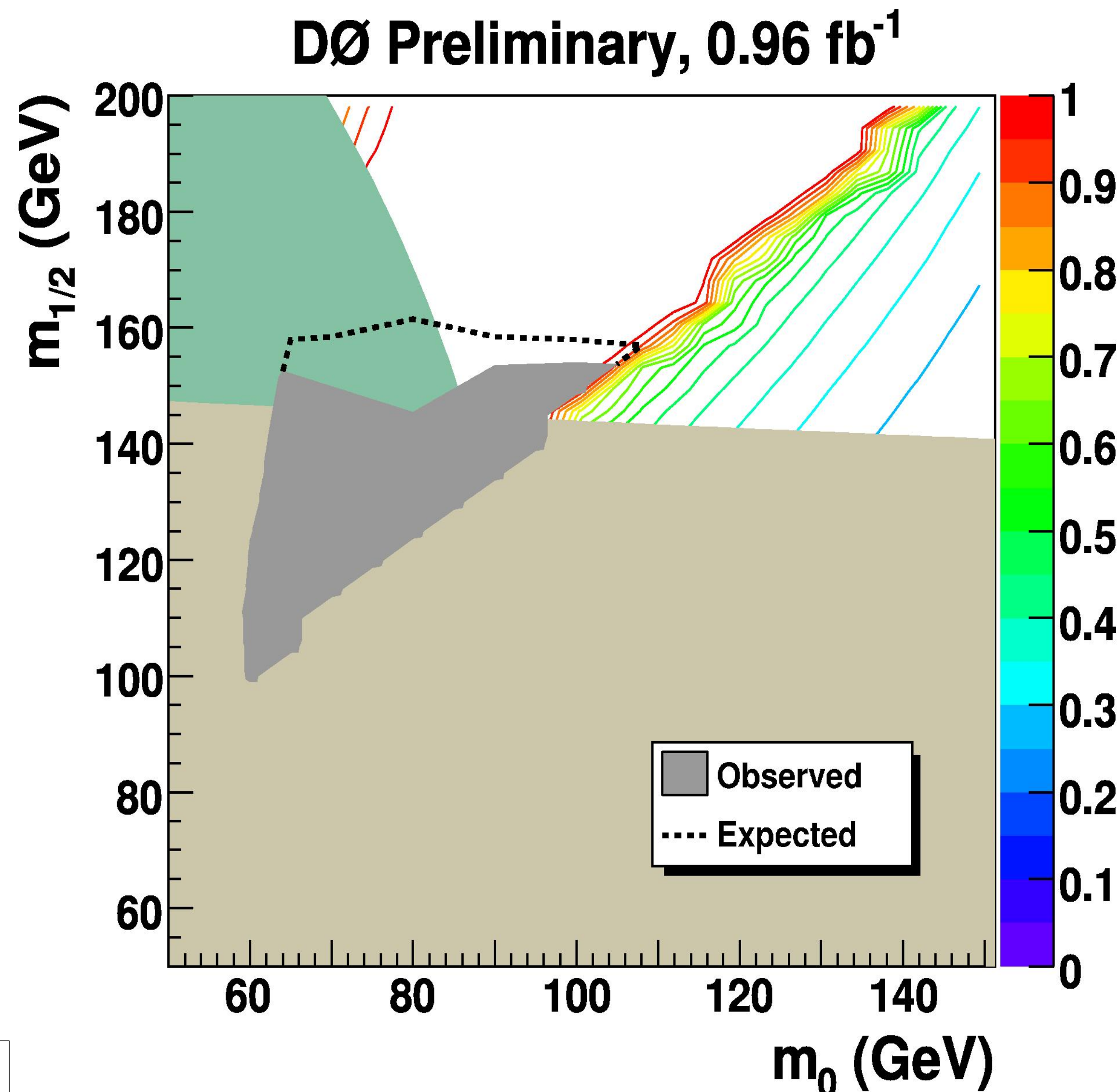


Squarks & gluinos with taus

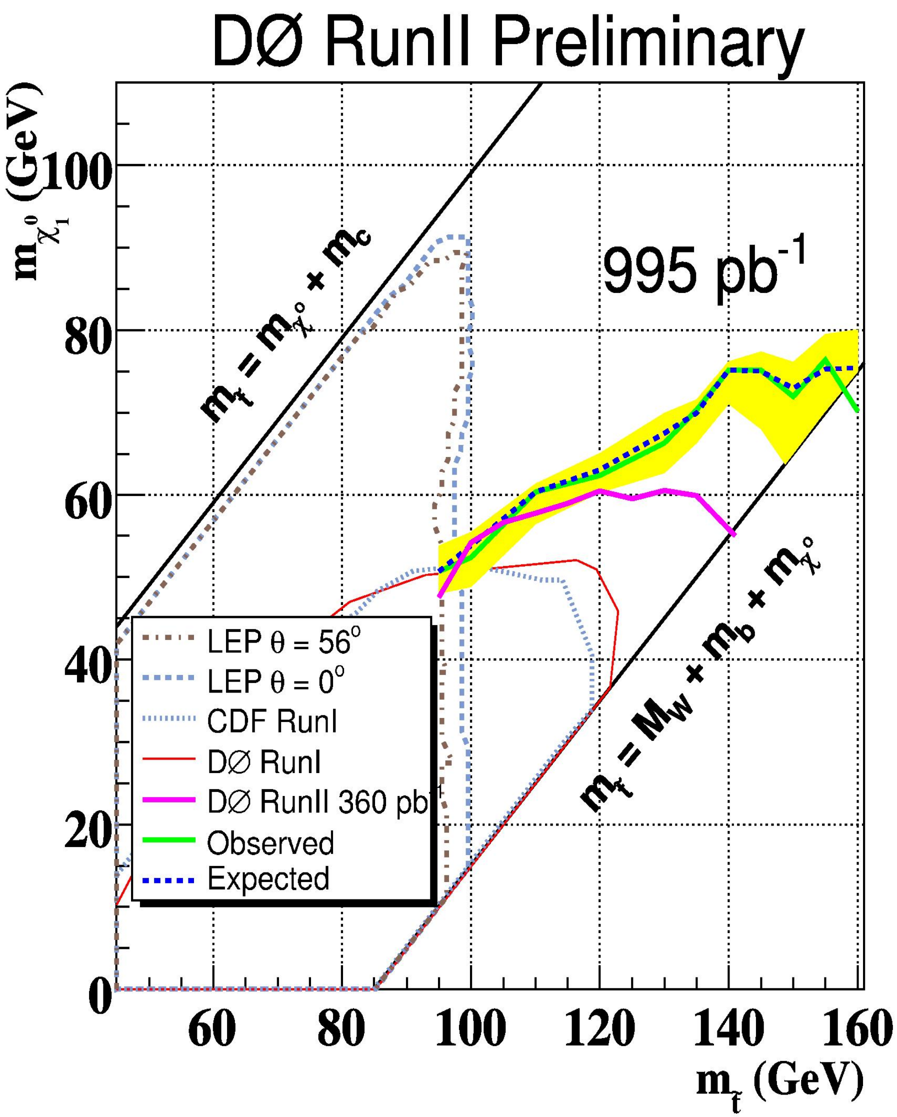


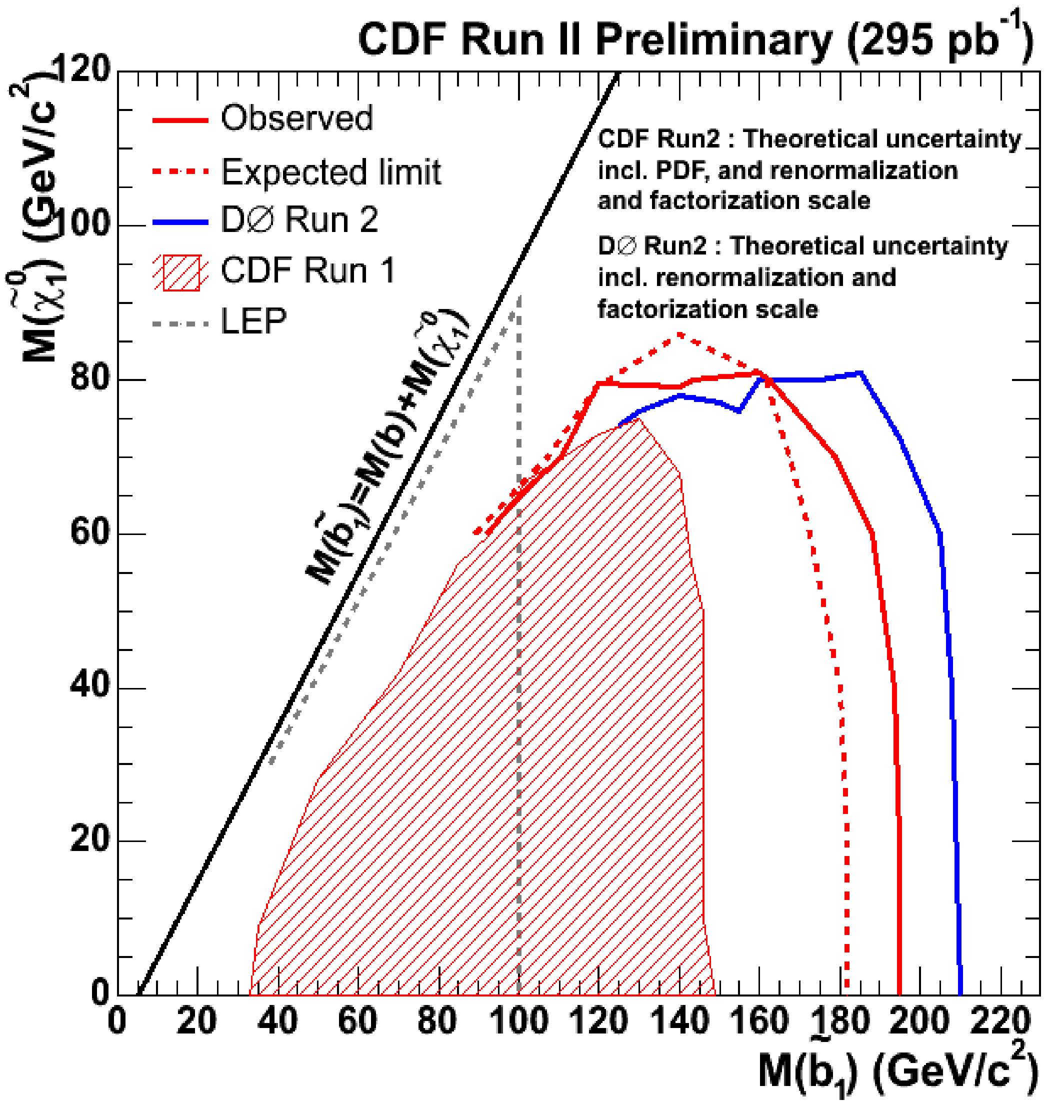


Sum ET of first two jets and first tau before final kinematic cuts

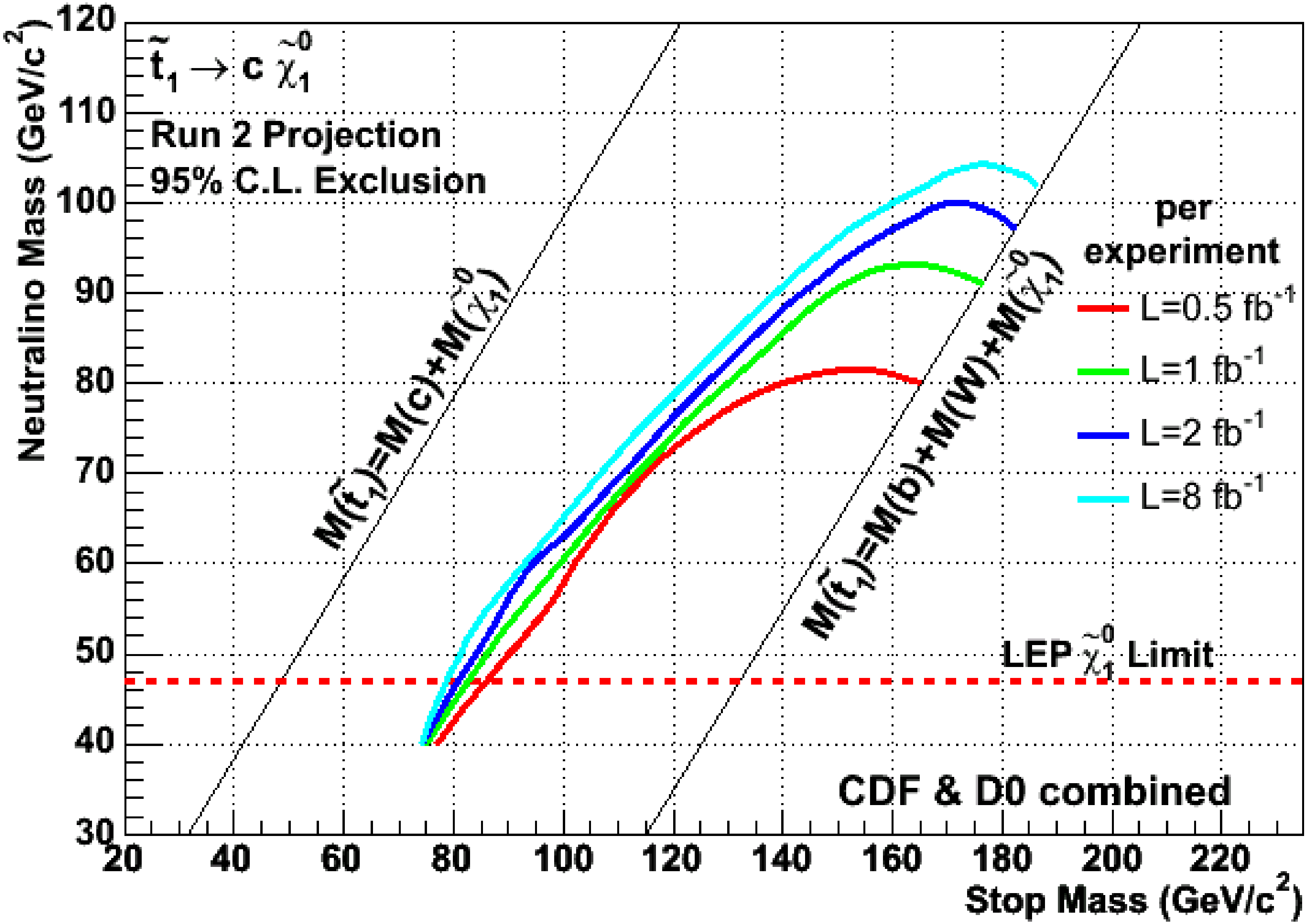


Stop & sbottom





Projections

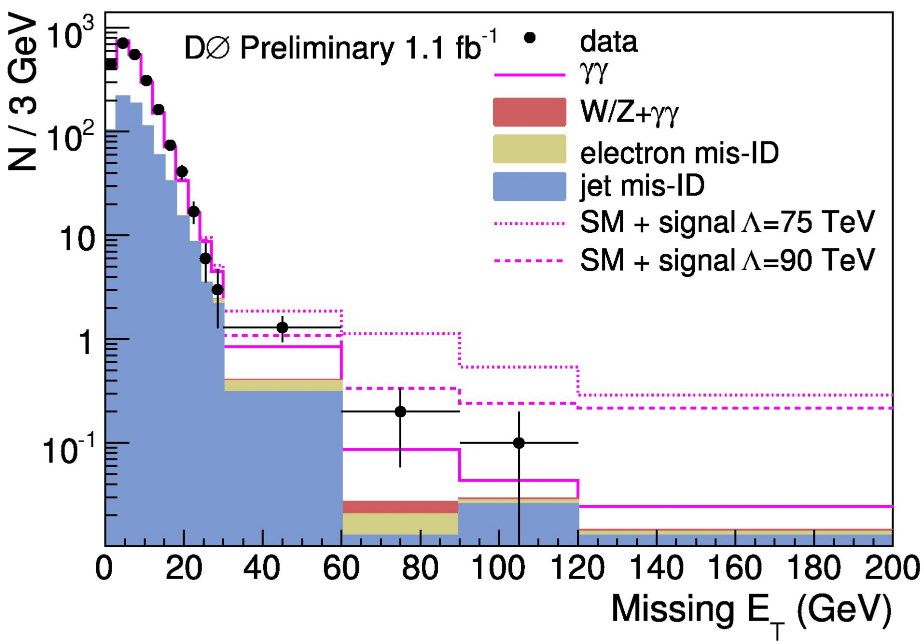


GMSB

Pair production of SUSY particles

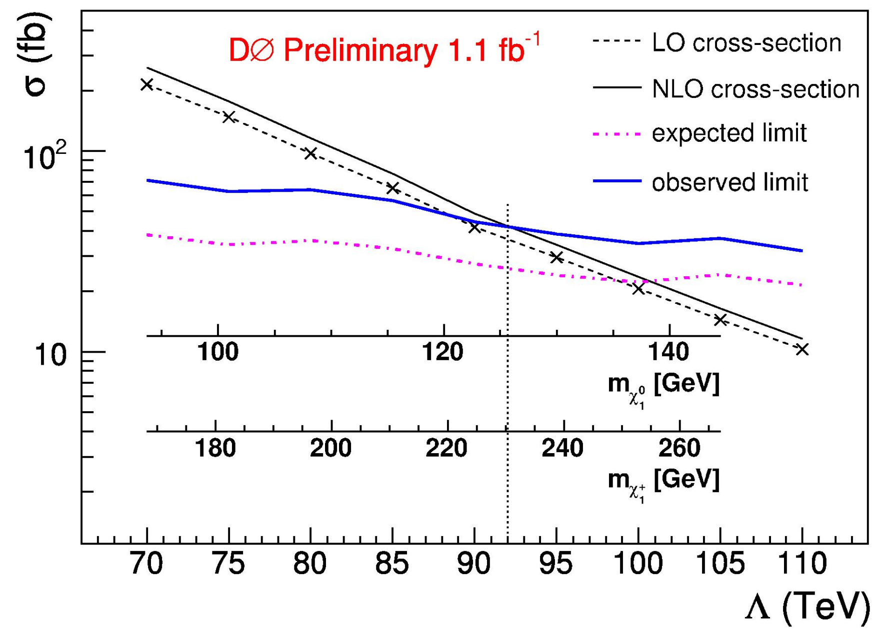
⇒ Inclusive search

for $\gamma\gamma$ + missing E_T



All backgrounds determined from data

(fake photons from dijet events, W→eν+γ/jet)



"mGMSB Snowmass slope"

($N=1$, $M_m = 2\Lambda$, $\mu > 0$, $\tan\beta = 15$)

Signal dominated by $\chi^{\pm}\chi_2^0$ production

$m(\chi^{\pm}) > 231$ GeV

Extra dimensions

Large extra dimension: monojets

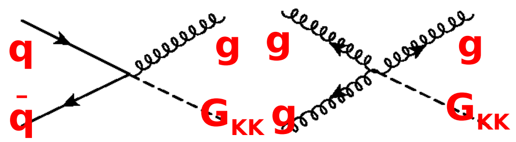
CDF search in 1.1 fb^{-1}:

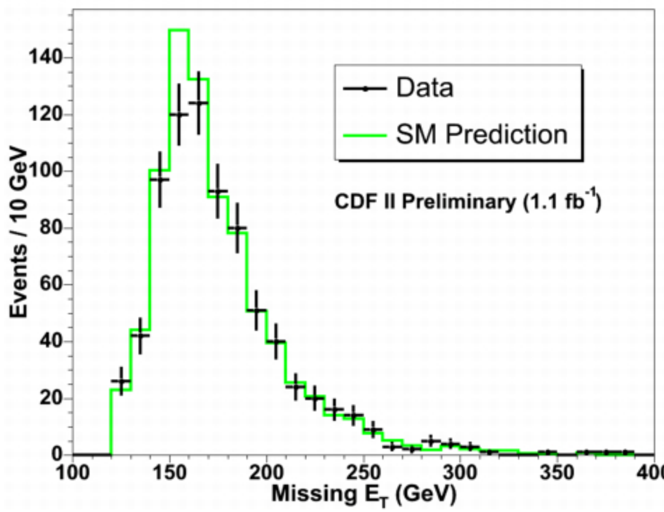
Main selection cuts:

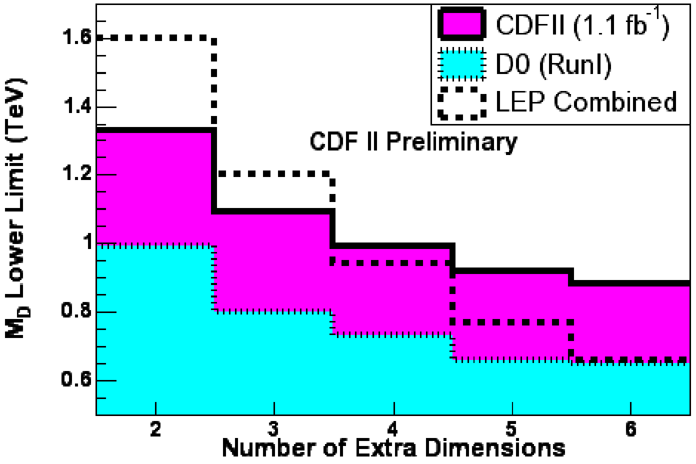
- one high pT jet (> 150 GeV)
  (soft jets from ISR are allowed)
- isolated lepton veto
- Missing E_T away from jets
- Missing E_T > 120 GeV

Main background: $(Z \rightarrow \nu\nu)$ +jet
in region where MC not demonstrated to fit data
Calibrated with ($Z \rightarrow ll$ and $W \rightarrow l\nu$) + jet
QCD is negligible

779 events selected
819 ± 71 expected



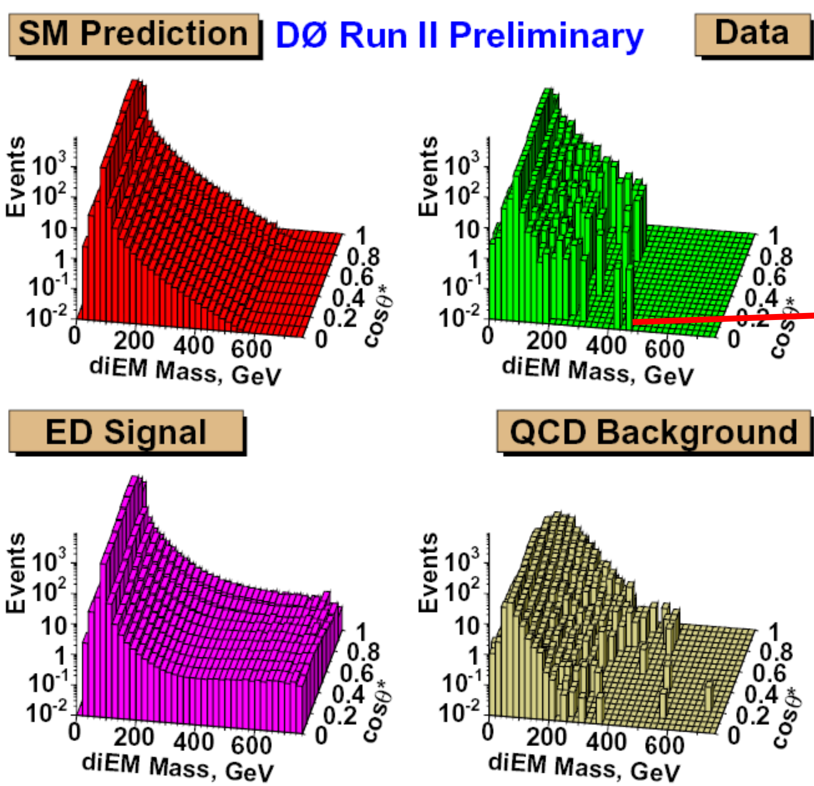




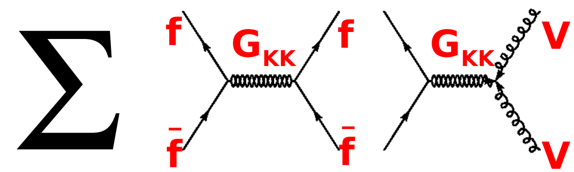
High p_T dileptons & diphotons

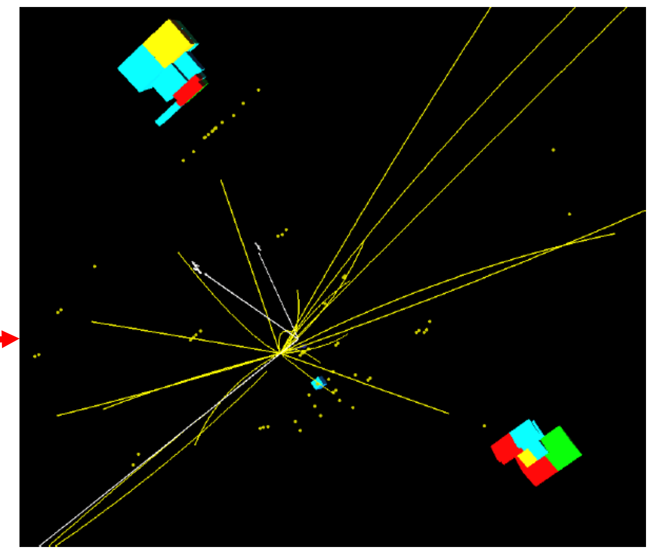
DØ search in 200 pb^{-1} combines ee and $\gamma\gamma$ to maximize the sensitivity

Fit of Data to SM+QCD+LED(M_S)



BR($\gamma\gamma$) = 2 BR(ee)





Still world tightest limits:

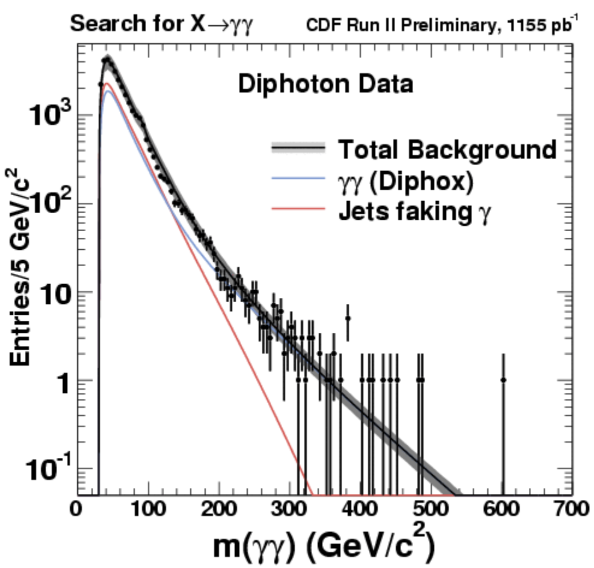
M_S >1.43 TeV

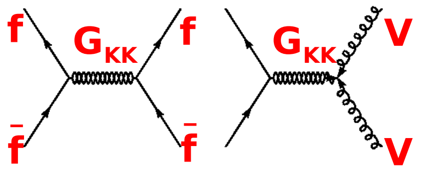
in the GRW formalism

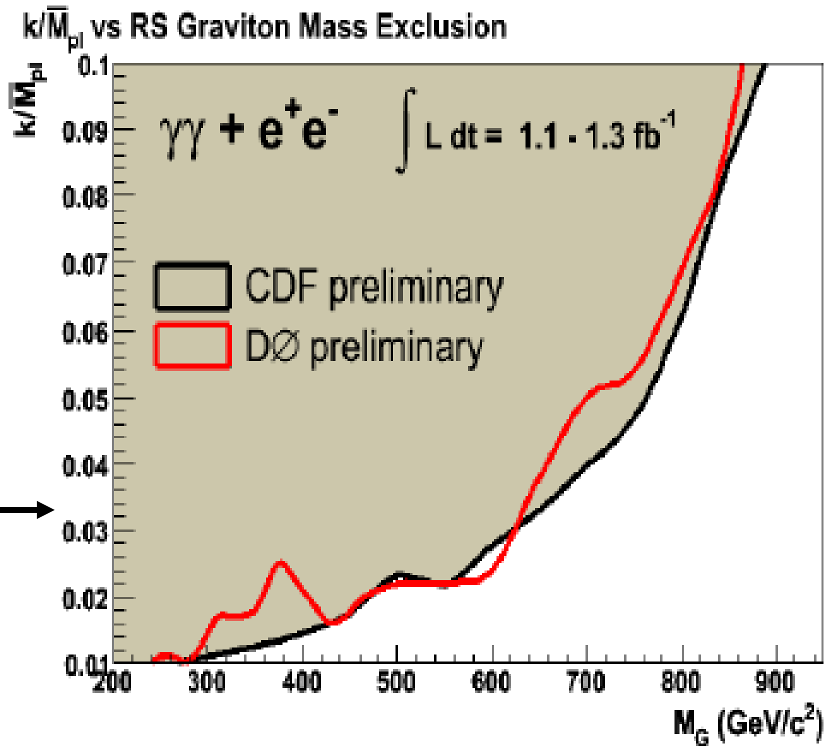
Randall-Sundrum models

Here too, most of the sensitivity is in diphotons (BR = 2∗ee)

But now look for a narrow resonance in the mass spectrum







Two model parameters:
Mass and coupling (κ/M_{Pl})

For $\kappa/M_{Pl} = 0.1$: $M > 890$ GeV

Generic search for anomalies

VISTA

- define many topologies based on physics objects (e, mu, jet, b etc)
- Fit corrections factors
- Compare data to MC prediction

SLEUTH

- Investigate signal, assuming
  - search by exclusive final state
  - excess at high pT

No significant excess in $1 fb^{-1}$ of CDF RunII data

Remarks

- Understanding the data (quality, efficiencies, triggers...) takes time. Searches are sensitive to rare detector malfunctions, to non collision related backgrounds (cosmics, machine background), things that not be detected by standard monitoring
  - e.g. in D0 many of the calorimeter data quality events flags originate from studies performed for SUSY searches in jet + MET
- It is important to define standard physics objects with enough variations (from loose to tight), together with procedures and standard programs to determine trigger and reconstruction efficiencies.
- In many cases, on has to OR a number of triggers which can become tricky for luminosity calculation and/or efficiency determination.

More remarks

- Even SM “physics” backgrounds are not that simple to predict. W/Z + jets is a background for many analyses, yet we are still investigating / calibrating our simulation (Alpgen + pythia). We have started to look at Sherpa (compared to Alpgen at generator level), but it needs tuning. We've not looked at other generators like MC@NLO, MADGRAPH etc... It is very time consuming.
- PDF understanding is important, in particular the gluon at high x. E.g. it gives up to 50% systematic uncertainty on the squark-gluino cross-section.

Extra / backup

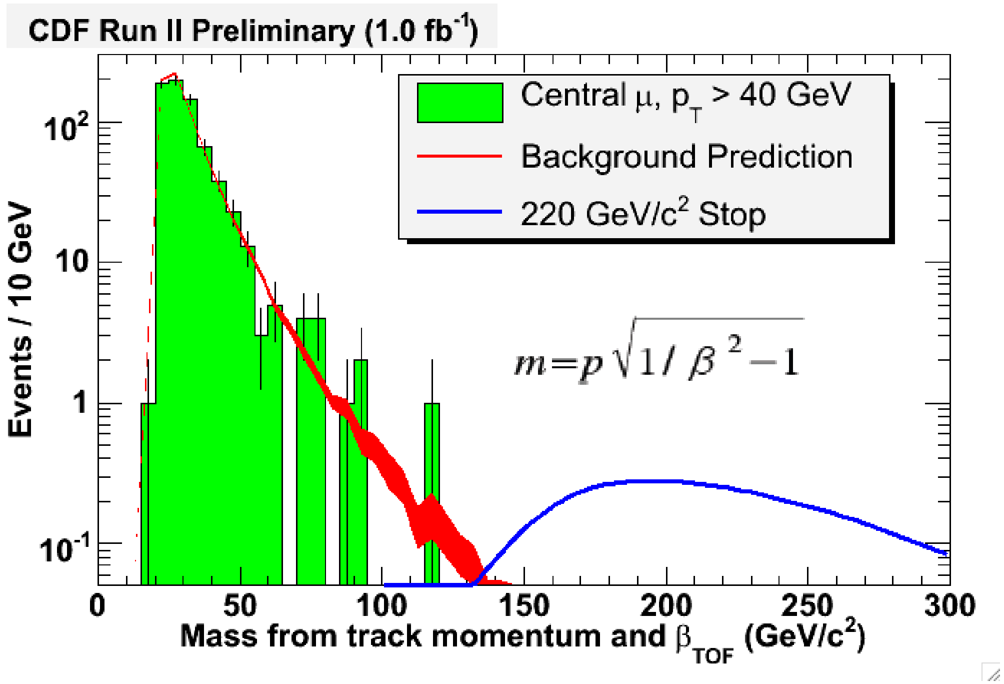
Charged massive stable particles

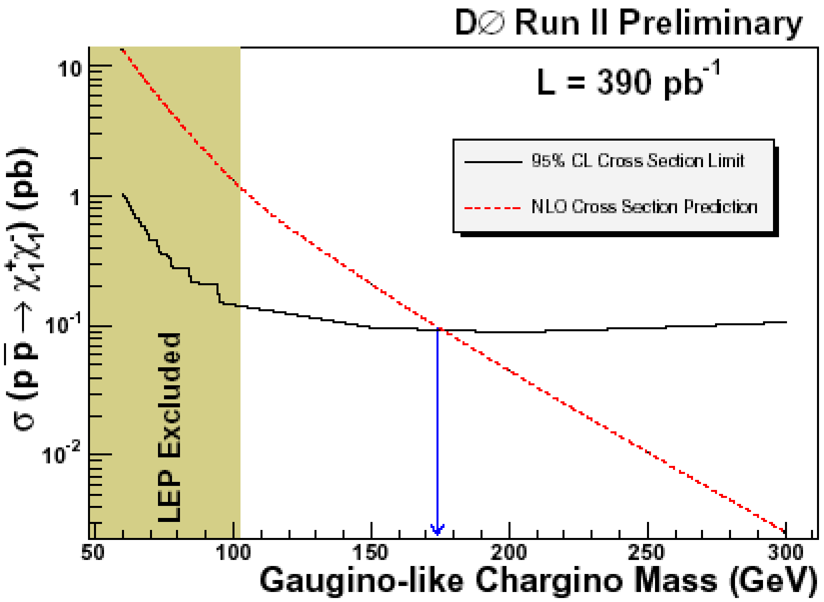
Long-lived charginos are expected in some AMSB models

with a "wino-LSP" (small $\chi^{\pm} - \chi_1^0$ mass difference)

They would appear as slowly-moving muons

$\Rightarrow$ Make use of the time of flight information





Strongly interacting: m(stop) > 250 GeV

Weakly interacting

Long lived gluinos

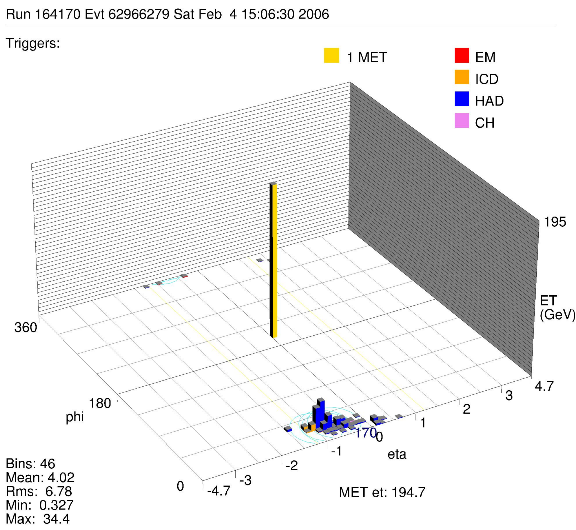
In "Split-SUSY", squarks are ultra-heavy ⇒ long-lived gluinos

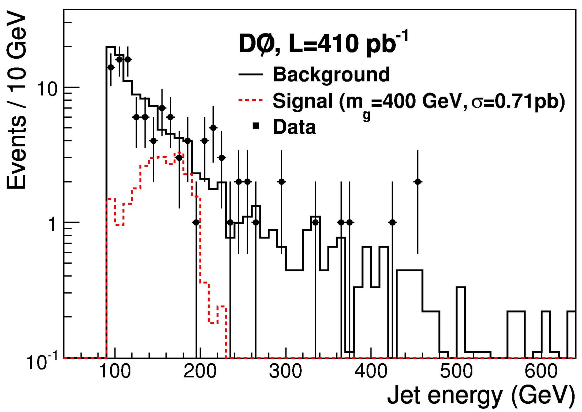
Such gluinos form R-hadrons which may stop in the calorimeter.

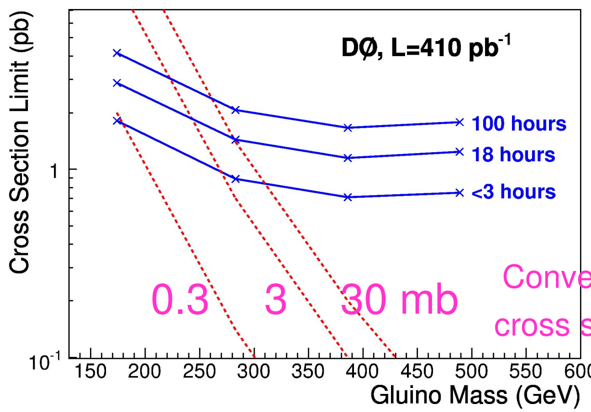
(A. Arvanitaki et al., arXiv:hep-ph/0506242)

After a while, they decay into a gluon + χ_1^0

(q-qbar-χ_1^0 also possible).







Strategy:

look for a randomly oriented monojet in an otherwise empty event (diffractive-gap trigger).

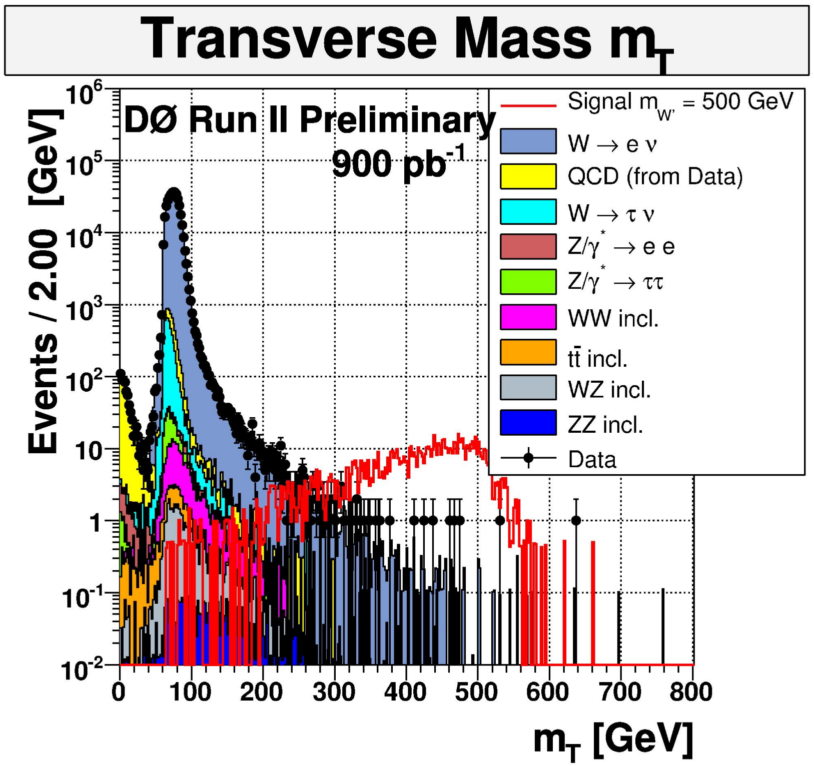
Backgrounds:

beam and cosmic muons, measured in data.

For m_χ < ~100 GeV gluino masses up to ~ 270 GeV are excluded

Extra gauge bosons

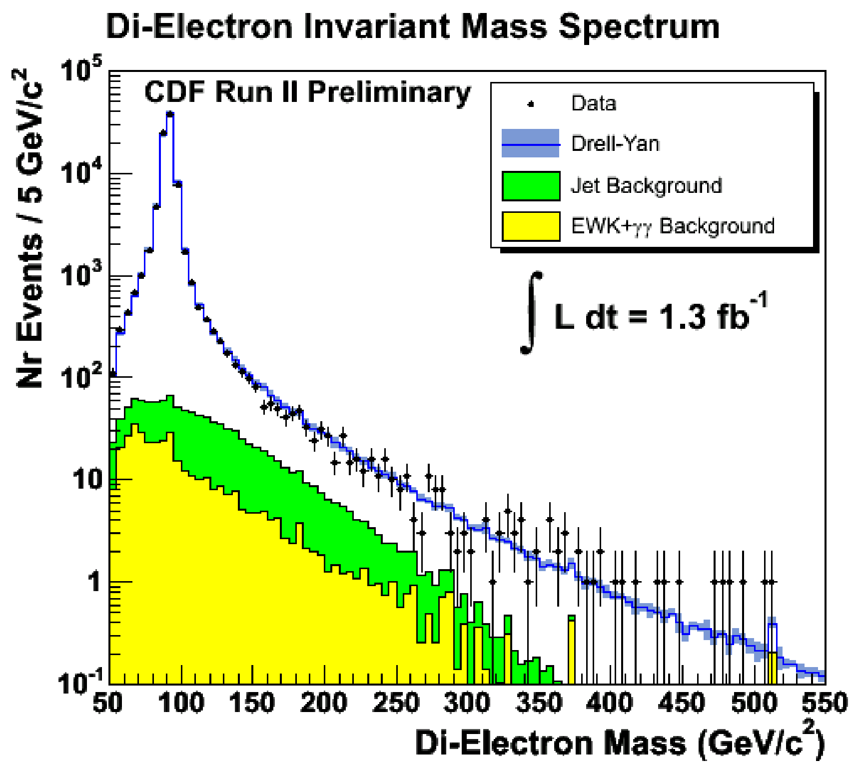
e.g., W' in L-R models



M_T = M(electron-p_T,missing-E_T)

M(W'-seq.) > 1002 GeV

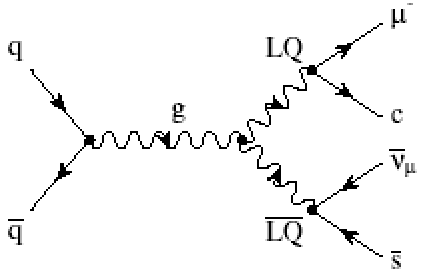
Z', e.g. within E(6) GUTs



M(Z'-seq.) > 923 GeV

(somewhat lower limits in)
(canonical E(6) models)

Scalar leptoquarks



The final states depend on the decay modes

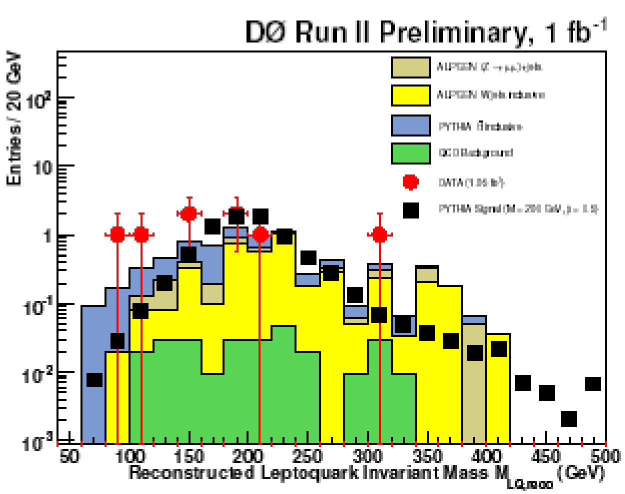
LQ → $l^{\pm}$q (BR = β) or LQ → νq (BR = 1 – β)

and on the lepton flavor (i.e. the LQ generation)

Pair production ⇒ llqq, lνqq or ννqq final states

⇒ Nine different final states to investigate…

The pair production cross section depends only on the scalar LQ mass



Scalar LQ mass limits range from 136 GeV (1st gen., β=0), searched in 2 jets + MET, to 256 Gev (1^{st} gen., β=1), searched in 2 electrons + 2 jets.

e.g. LQ2 in μνqq

- Isolated muon
- Large MET
- two jets
- Reconstruct M(LQ) ⇒M(LQ2) > 214 GeV for β = 0.5