Recent SUSY results from DØ

Patrice Verdier
Institut de Physique Nucléaire de Lyon

for the DØ collaboration

Supersymmetry

- Beyond the SM ?
  - ➔ radiative corrections to the Higgs mass
  - ➔ Unification of the coupling constants
  - ➔ include gravitation
  - ➔ hierarchy problem
- Supersymmetry: each SM particle has a SUSY partner which differ by ½ in spin :
  - ➔ SM fermion ⇔ SUSY boson
  - ➔ SM boson ⇔ SUSY fermion

$$R-parity=(-1)^{3(B-L)+2S}$$

- No scalar electron with the same mass as the electron:
  - ➔ SUSY must be broken
- R-parity conservation:
  - ➔ SUSY particles are pair produced
  - ➔ the LSP is stable : dark matter candidate
- R-parity violation:
  - ➔ new terms which violate the conservation of the lepton and baryon number can be added in the lagrangian
  - ➔ the LSP is no longer stable

$$W_{RPV}=\lambda_{ijk}L_i L_j \bar{E}_k+\lambda'_{ijk}L_i Q_j \bar{D}_k+\lambda''_{ijk}\bar{U}_i \bar{D}_j \bar{D}_k$$

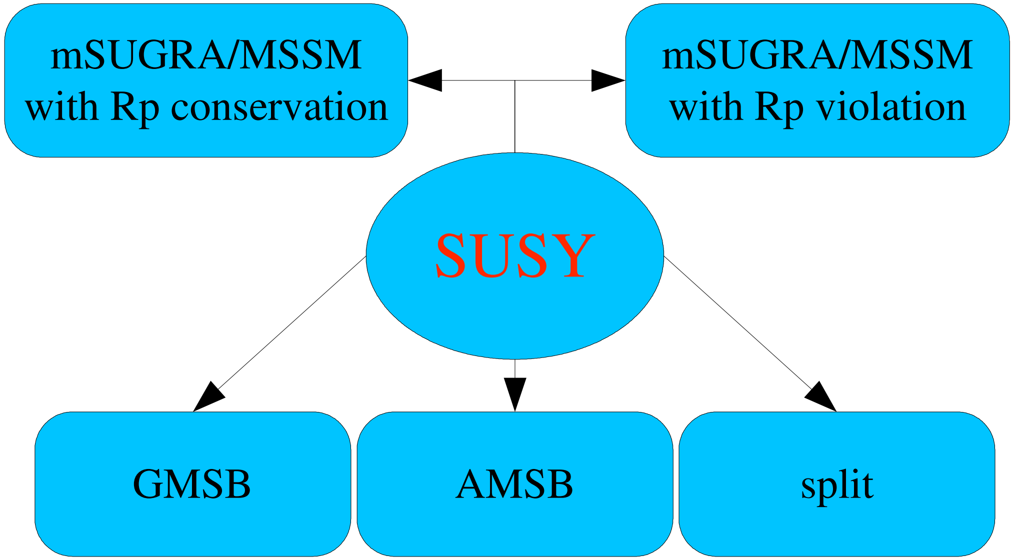
SM	Supersymmetric particles: R-parity = -1			
R-parity=+1	Interaction		Mass	
$q=u,d,c,s,t,b$	$\tilde{q}_L,\tilde{q}_R$	squarks	$\tilde{q}_1,\tilde{q}_2$	squarks
$l=e,\mu,\tau$	$\tilde{l}_L,\tilde{l}_R$	sleptons	$\tilde{l}_1,\tilde{l}_2$	sleptons
$\nu=\nu_e,\nu_\mu,\nu_\tau$	$\tilde{\nu}$	sneutrino	$\tilde{\nu}$	sneutrino
g	$\tilde{g}$	gluino	$\tilde{g}$	gluino
W^{+-}	$\tilde{W}^{+-}$	wino	$\tilde{\chi}^{+-}_{1,2}$	charginos
H_1^-	$\tilde{H}_1^-$	higgsino		
H_2^+	$\tilde{H}_2^+$	higgsino		
γ	$\tilde{\gamma}$	photino	$\tilde{\chi}^0_{1,2,3,4}$	neutralinos
Z	$\tilde{Z}$	zino		
H_1^0	$\tilde{H}_1^0$	higgsino		
H_2^0	$\tilde{H}_2^0$	neutralino		

Supersymmetry

- Why is it so interesting for experimentalists ?
  - ➔ It doubles the particle spectrum: large variety of new particles and of final states
  - ➔ Large number of SUSY models which can be tuned to predict new particles at ~any masses
  - ➔ SUSY can be searched for in all topologies: missing ET, multijets, multileptons, photons, with b quarks or taus, long lived particles...

- Large numbers of new parameter
- mSUGRA: 5 parameters:

  tan(β) : v.e.v. ratio of the 2 Higgs Fields
  m_0 : scalar mass @ GUT scale
  $m_{½}$: gaugino mass @ GUT scale
  sign(μ) : Higgs mixing mass parameter
  A_0 : trilinear coupling @ GUT scale

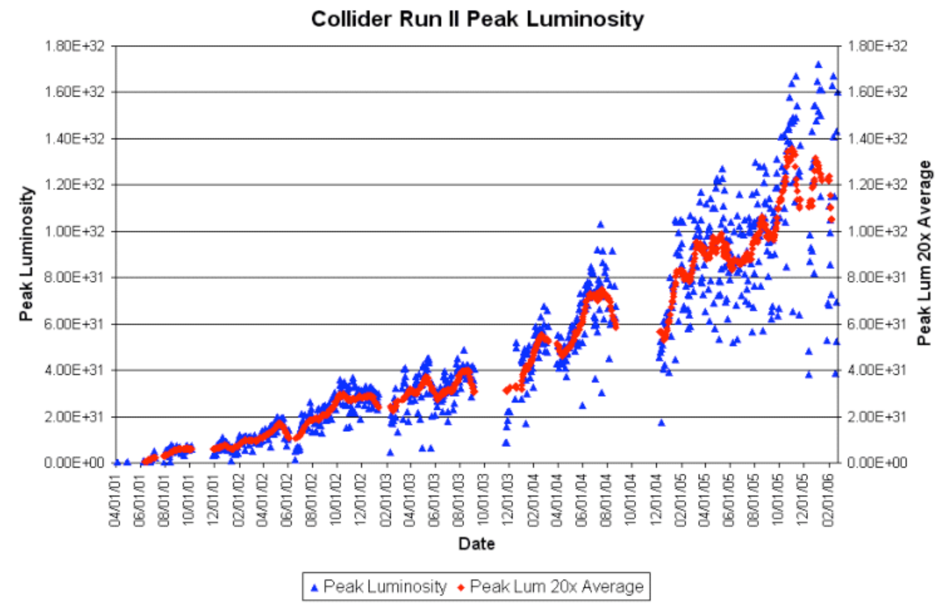


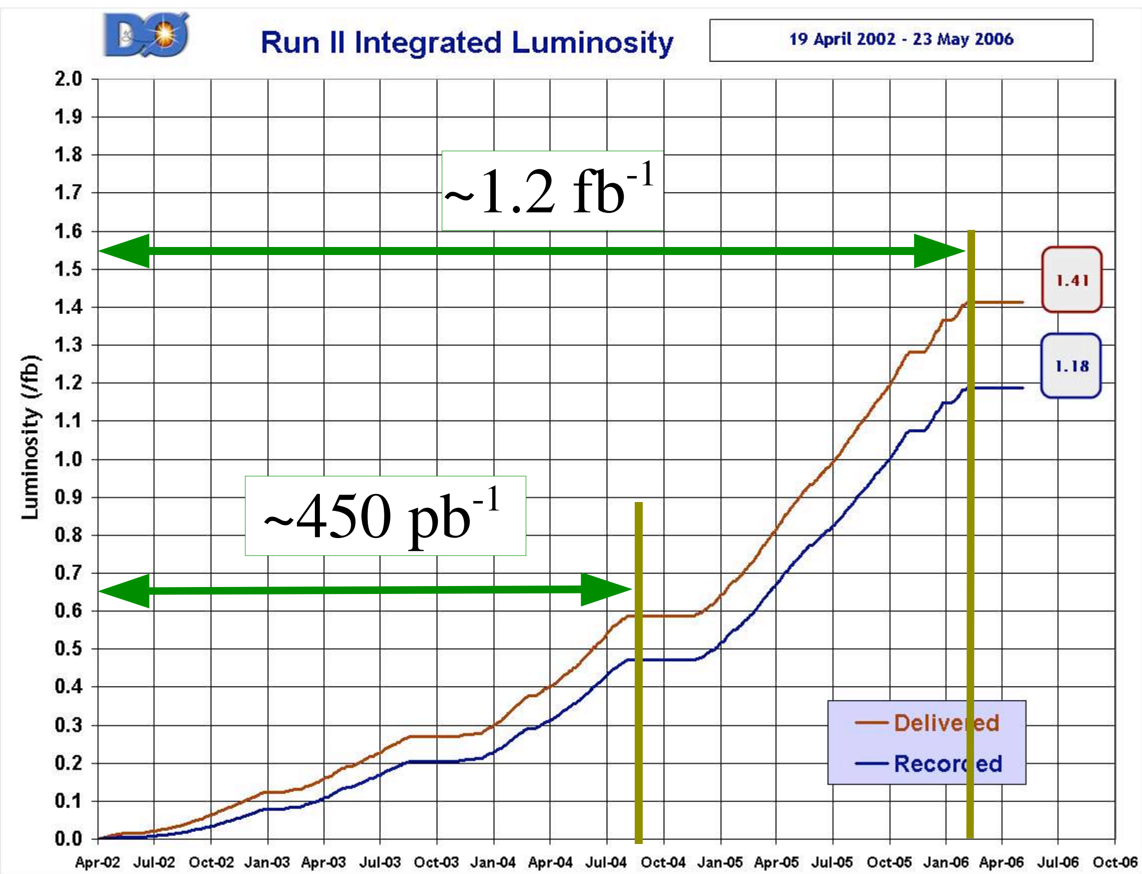
- Only recent results from DØ on SUSY searches are reported
- Much more DØ results on leptoquarks, extra-dimensions, compositeness... available on:
  - ➔ http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

All limits quoted in this talk are at 95% C.L.

Luminosity and data samples

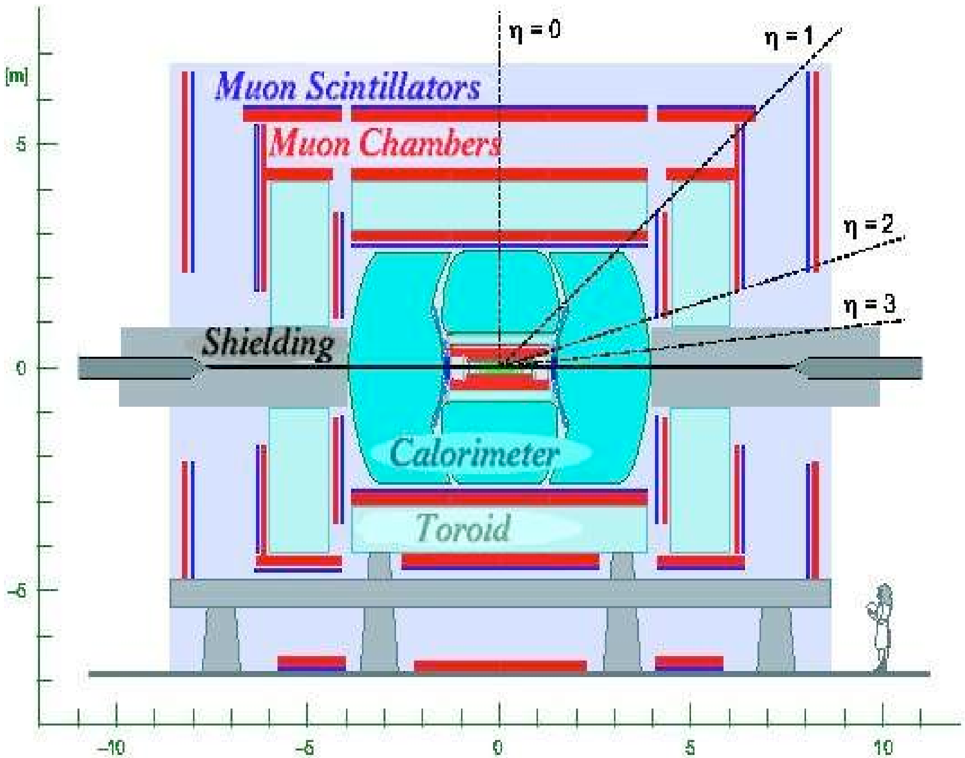
- Excellent performance of the TEVATRON:
  - ➔ 1.2fb^{-1} recorded during RunIIa
  - ➔ Peak luminosity : regularly above 125E30 cm^{2}s^{-1} before the shutdown

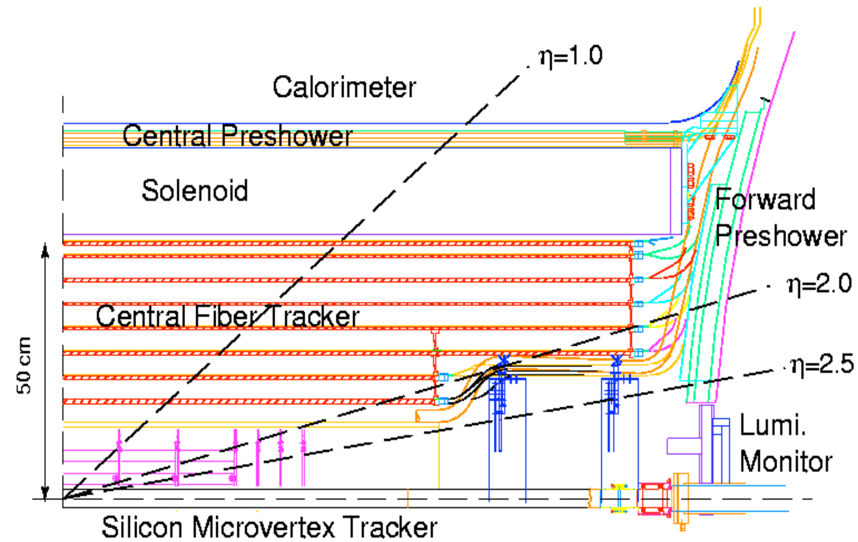




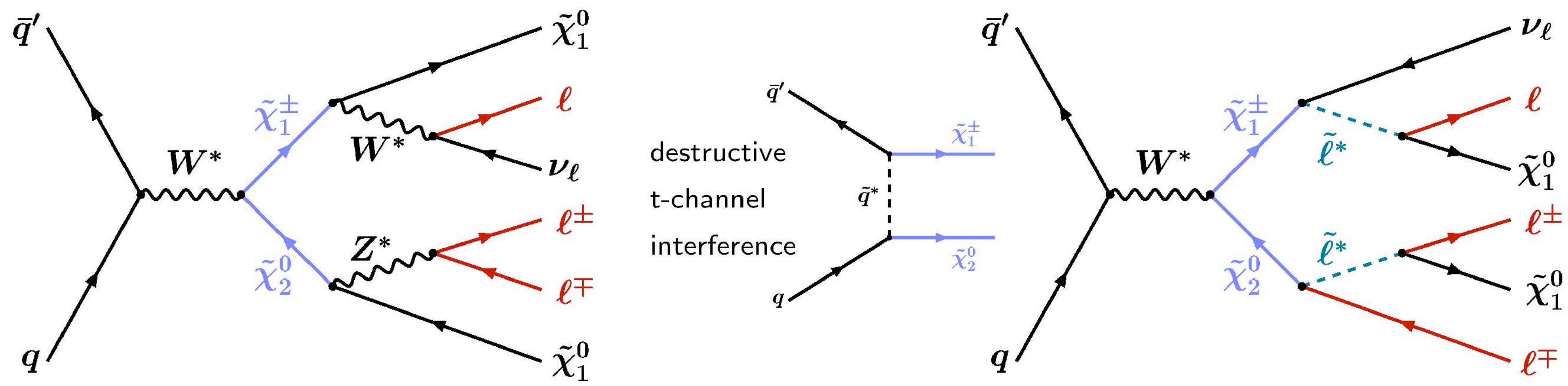
- Most of the results with ~300 to 450 pb^{-1}
- Few results with the entire RunIIa data

The DØ detector

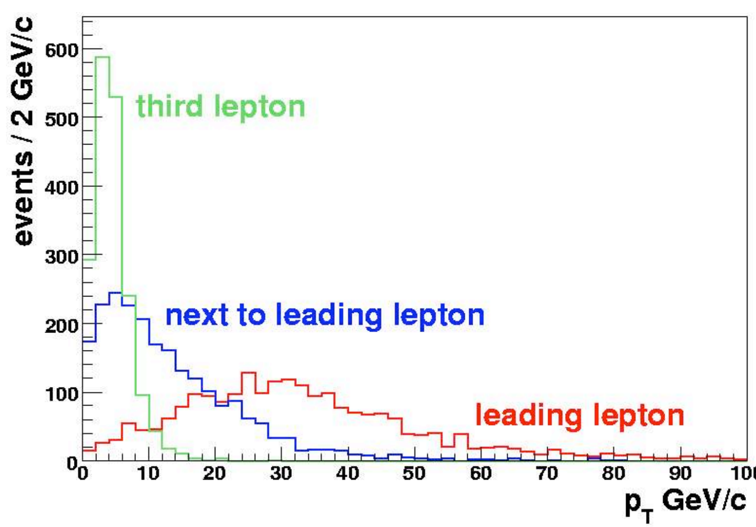




Trileptons (I)



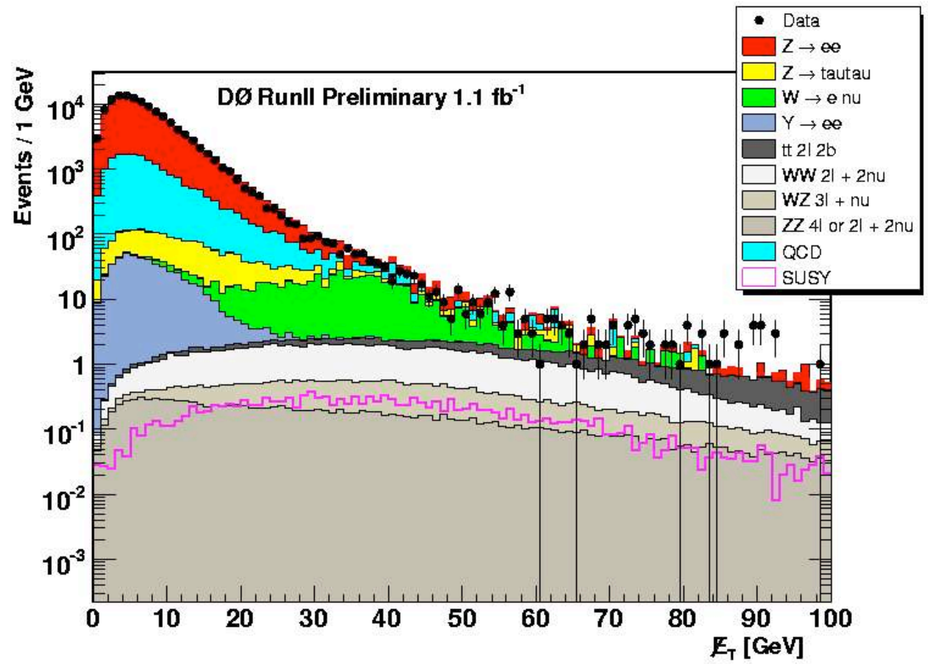
- Gaugino pair production via EW interaction:
  - small cross-section (~0.1-0.5pb)
  - but very low background, thanks to the tri-lepton + MET signature
- However:
  - need to trigger and to reconstruct low pT leptons
  - “identify” the third lepton as an isolated track
  - need to have one analysis per topology:
    - ee+l
    - like-sign di-muon
    - μμ+l, eμ+l, eτ+l, μτ+l
- Analysis with ~320 pb^{-1} is published
  - Phys. Rev. Lett. 95, 151805 (2005)
  - New results for the ee+l and like-sign di-muon channels with ~1fb^{-1}

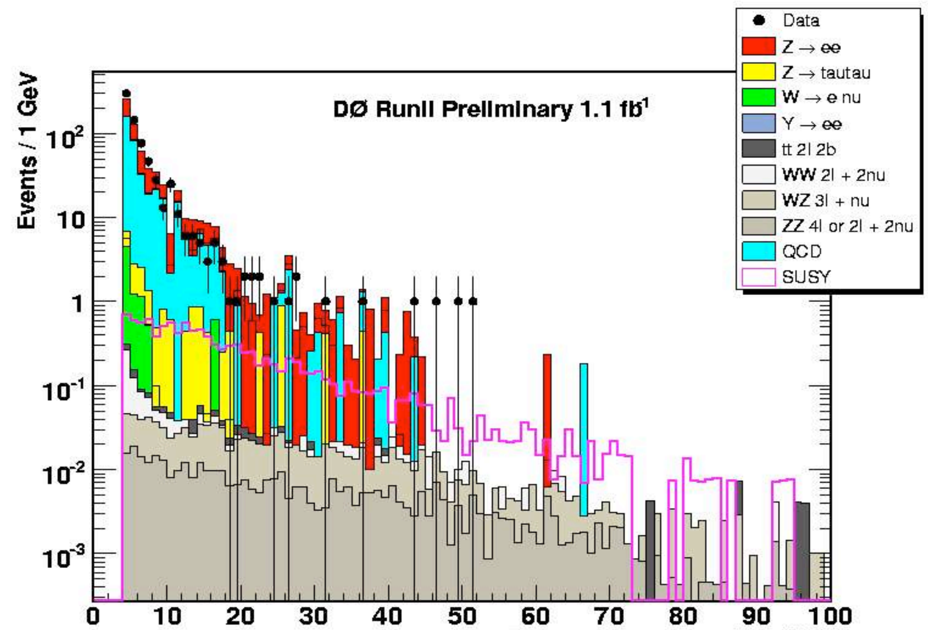


Trileptons (II)

- ee+l analysis : L=1.1 fb^{-1}
- Preselection cuts:
  - 2 electrons with pT>12 and 8 GeV
  - Anti Z->ee cut :
    - 18 < Mee < 60 GeV
    - $\Delta\Phi$(e,e) <2.9
  - anti ttbar H_T<80 GeV
  - require a 3^{rd} isolated track with pT>4 GeV
  - MET related cuts:
    - MET > 22 GeV
    - transverse mass (e,MET)>20 GeV
    - significance of MET > 8 GeV
  - MET*pT(3^{rd} track) > 220 GeV^2
- Backgrounds:
  - using PYTHIA
  - Final background is mainly di-boson
- Systematic uncertainties small compared to the statistical error:
  - JES : <4% signal, 7-20% back.
  - PDF < 4%
  - modeling of the multijet background (4%)

	Data	Total background
ee+l	0	0.76 ±0.67 (stat)



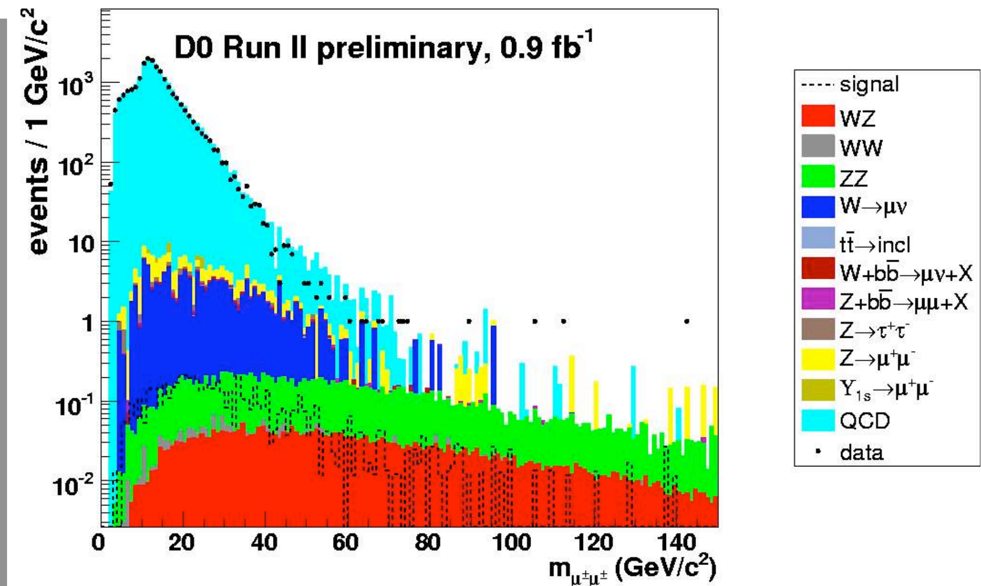


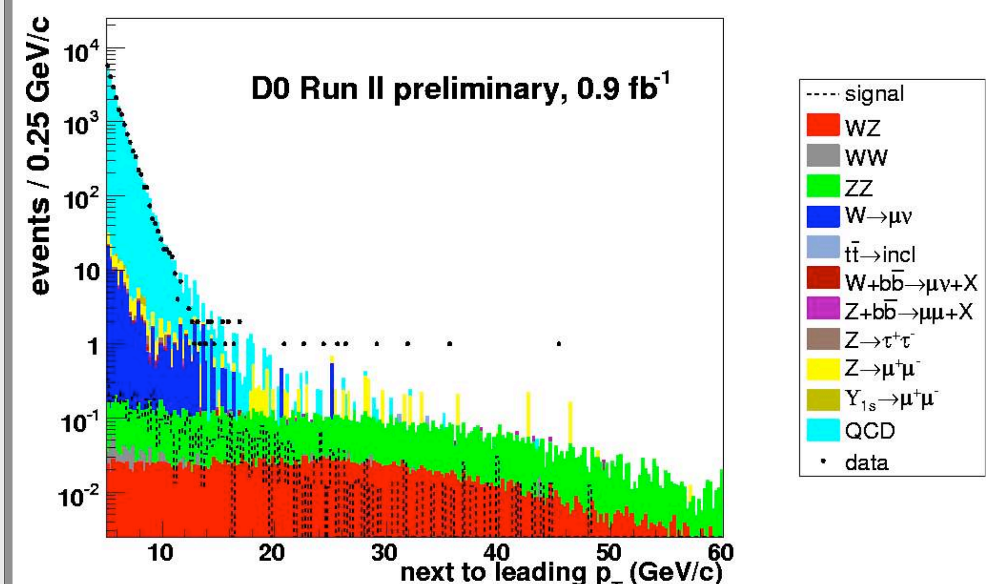
3^{rd} track

Trileptons (III)

- like sign di-muon analysis : L=0.9 fb^{-1}
- Preselection cuts:
  - 2 muons with pT>5 GeV :
    - matched to a central track
    - and with same sign
  - muon isolation wrt calo and tracks
- Optimization of the final event selection:
  - require invariant dimuon mass below the Z
  - pT(μ1)>13 and pT(μ2)>8 GeV
  - pT(μ2)<35 GeV
  - transverse mass (μ2,MET)>20 GeV
  - MET > 10 GeV
  - MET significance > 12
  - MET*pT(μ2) > 160 GeV^2
- Backgrounds:
  - di-boson, W->μν, Z->μμ, Z->bb (PYTHIA)
  - instrumental QCD back. using loosely isolated muons
- Systematic uncertainties small compared to the statistical error:
  - JES : <4% signal, 7-20% back.
  - PDF < 4%
  - modeling of the multijet background (4%)

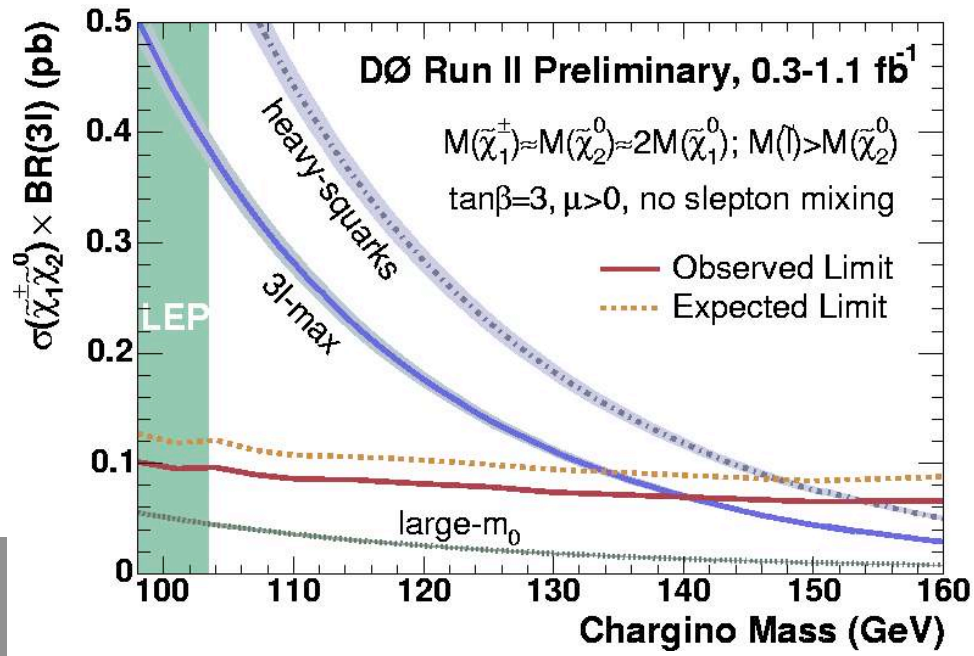
	Data	Total background
like sign di-muon	1	1.1 ±0.4 (stat)





Trileptons (IV)

	Lum. (fb^{-1})	Data	Total background
ee+l	1.2	0	0.76 ±0.67 (stat)
μμ+l	0.3	2	1.75 ±0.57 (stat)
eμ+l	0.3	0	0.31 ±0.13 (stat)
SS μμ	0.9	1	1.10 ±0.40 (stat)
eτ+l	0.3	0	1.58 ±0.14 (stat)
μτ+l	0.3	1	0.36 ±0.13 (stat)



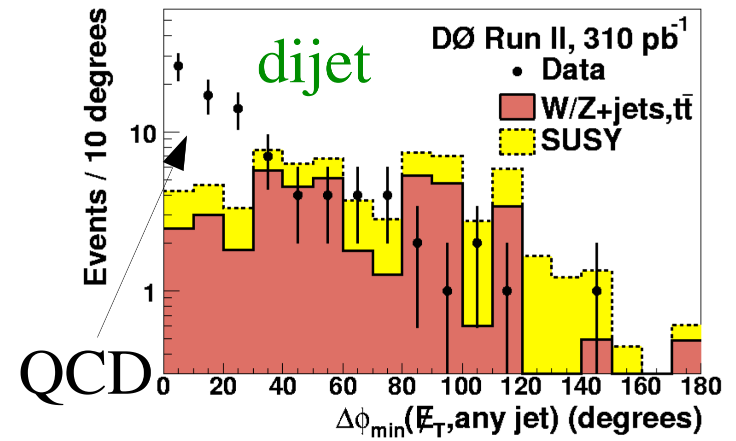
- tan(β)=3, μ>0, no slepton mixing :
  - Heavy-squarks scenario :
    - squarks are heavy
    - sleptons are light
    - No destructive interferences
  - "3l-max" scenario :
    - mSUGRA
    - sleptons are light, but above chi02
  - "large-m0" scenario :
    - mSUGRA at high m0
    - chargino decays only via virtual gauge bosons

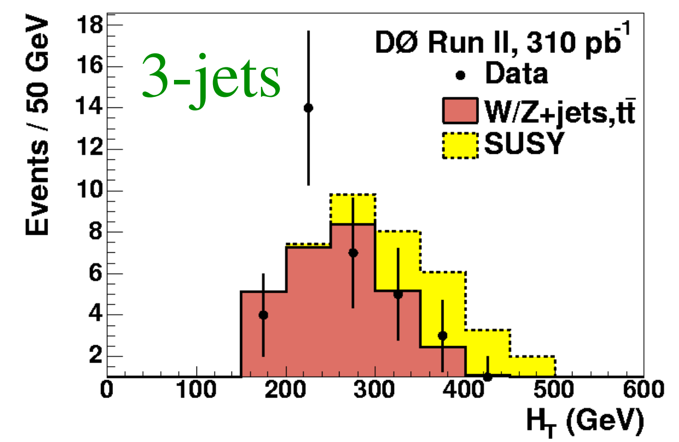
- The new eel (1.1 fb^{-1}) and like-sign di-muon (0.9fb^{-1}) analyses are combined with the published μμ+l, eμ+l analyses (320 pb^{-1})
- Mass limit :
  - Chargino1 mass limit of 140 GeV in the 3l-max scenario
  - previous limit with 320pb^{-1} was 116 GeV

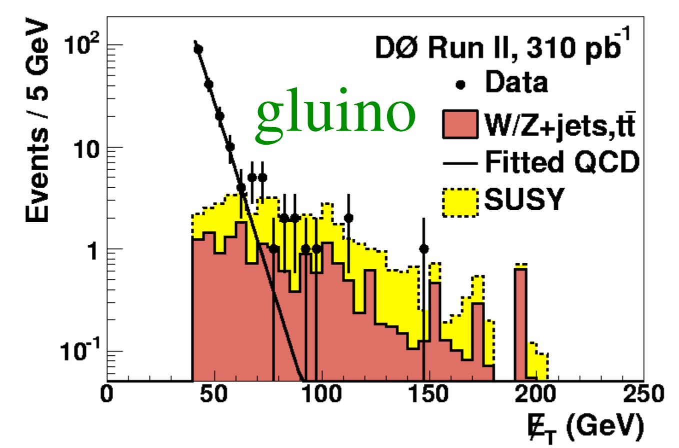
Large improvement with increased statistics

Squarks/gluinos (I)

- Large squark-gluino cross sections at hadron colliders
- Jets+MET topology : largest branching ratio
- mSUGRA with conserved R-parity:
  - ➔ lightest neutralino LSP
  - ➔ for direct comparisons with CDF/D0 Run I results:
    - ➢ tan(β)=3, A=0, μ<0
- 3 analyses for different signal benchmarks: L=310 pb^{-1}
  - ➔ Low m0 : m(squark) < m(gluino) => "dijet" analysis $\tilde{q}\bar{\tilde{q}} \to q\tilde{\chi}_1^0\bar{q}\tilde{\chi}_1^0$
    - ➢ m0=25
    - ➢ at least 2 jets
  - ➔ Intermediate m0 : m(squark) = m(gluino) => "3-jets" analysis $\tilde{q}\tilde{g} \to q\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$
    - ➢ at least 3 jets
  - ➔ High m0: m(squark) > m(gluino) => gluino analysis $\tilde{g}\tilde{g} \to q\bar{q}\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$
    - ➢ m0=500
    - ➢ at least 4 jets





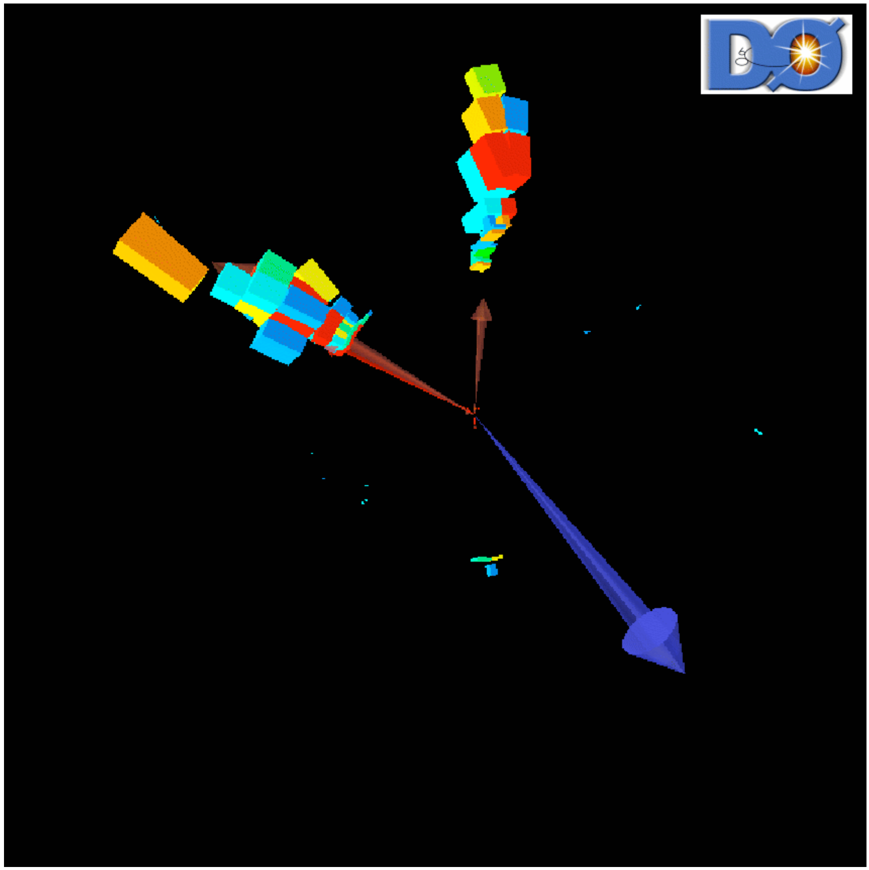


- Main backgrounds: Z->νν+jets, ttbar, W+jets
- Common pre-selection: 2 jets Pt1>60, Pt2>40 GeV and |η|<0.8
  - ➔ require at least 2/3/4 jets (pT>60/40/30/20 GeV)
  - ➔ confirm the jets by their associated tracks : reduce the QCD back.
  - ➔ veto on isolated electrons and muons
  - ➔ isolation between MET and jets
  - ➔ Optimization of the final MET and HT cuts

Squarks/gluinos (II)

- <u>Final MET/HT cuts :</u>
  - ➔ “dijet” : MET > 175 GeV, HT > 250 GeV
  - ➔ “3-jets” : MET > 100 GeV, HT > 325 GeV
  - ➔ “gluino” : MET > 75 GeV, HT > 250 GeV

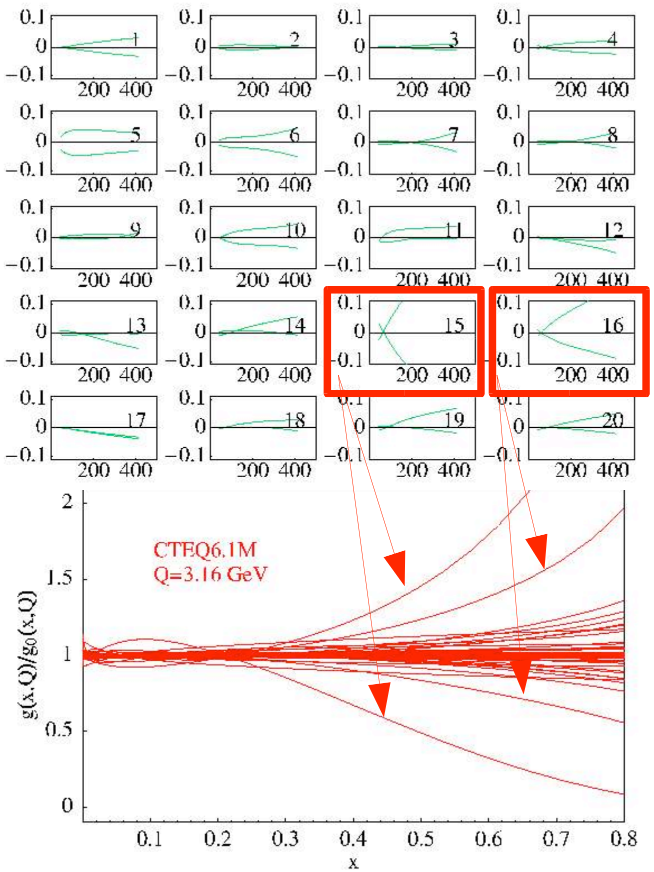
	Data	Total background
“Dijet”	**6**	**4.8 +4.4 -2.0 (stat) +1.1 -0.8 (sys)**
“3 jets”	**4**	**3.9 +1.3 -1.0 (stat) +0.7 -0.8 (sys)**
“Gluino”	**10**	**10.3 +1.5 -1.4 (stat) +1.9 -2.5 (sys)**



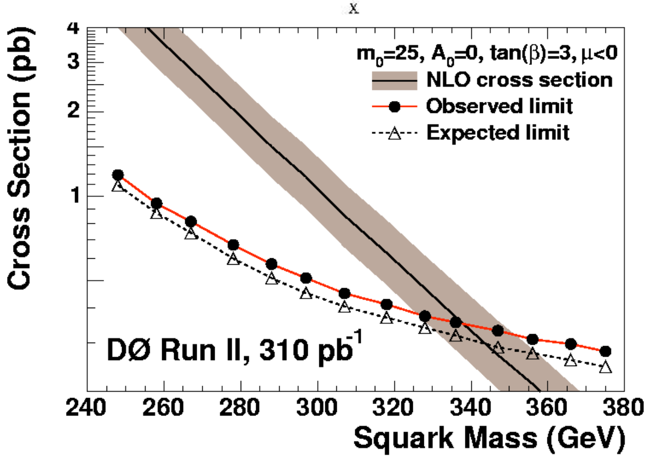
- <u>Systematic Uncertainties :</u>
  - ➔ JES (10-20%)
  - ➔ luminosity (6.5%)
  - ➔ PDF on the acceptance (6%)
  - ➔ jet-ID (5%)
  - ➔ 15% on back. cross sections (W/Z+jets, ttbar)
  - ➔ correct treatment of error correlations between back. and signal
  - ➔ Effect of renormalization/factorization scale on the signal cross section : next slide

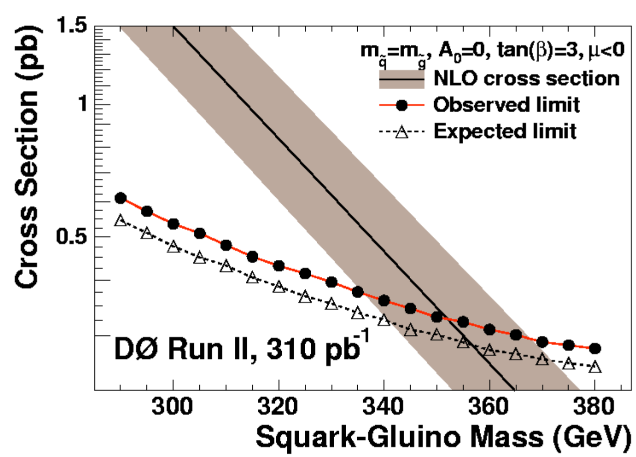
- Candidate with the largest MET:
  - ➔ MET = 349 GeV
  - ➔ HT = 389 GeV
  - ➔ pT (jet1) = 266 GeV
  - ➔ pT (jet2) = 100 GeV

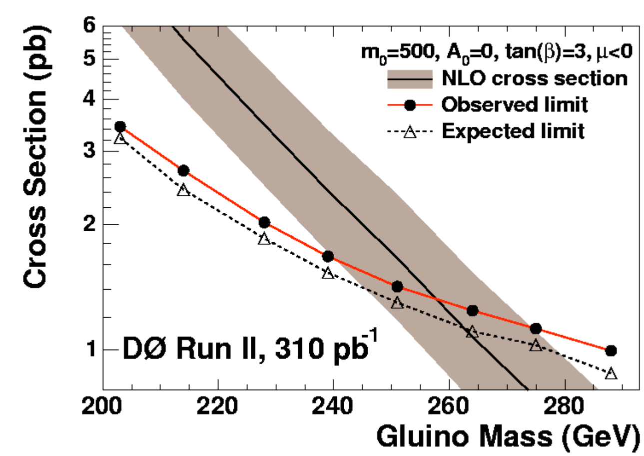
Squarks/gluinos (III)



- <u>Signal cross sections:</u>
  - Signal cross sections using the 40 CTEQ6.1M PDF sets
  - The large uncertainty using eigenvector 15 (PDF sets 29 and 30) comes from the very poor knowledge of the gluon at high-x
  - Combine quadratically the effect of the 20 eigenvectors
  - Combine quadratically with the effect of the renormalization/factorization scale (μ=Q,Q/2,2Q) => 3 cross section hypotheses:
    - nominal : CTEQ6.1M and μ=Q
    - minimal
    - maximal
  - Very large effect: +60 -40% for intermediate m0
- <u>Cross section and mass limits :</u>
  - They are therefore obtained for the 3 cross section hypotheses
  - Combine the 3 analyses in the limit computation (removing the small overlap between them)

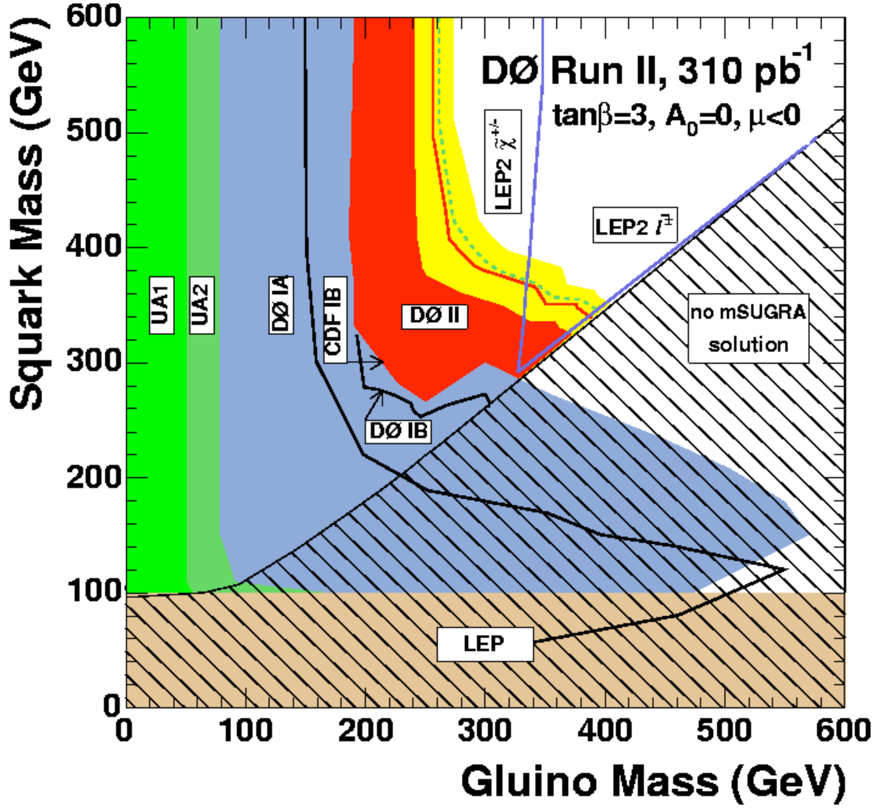


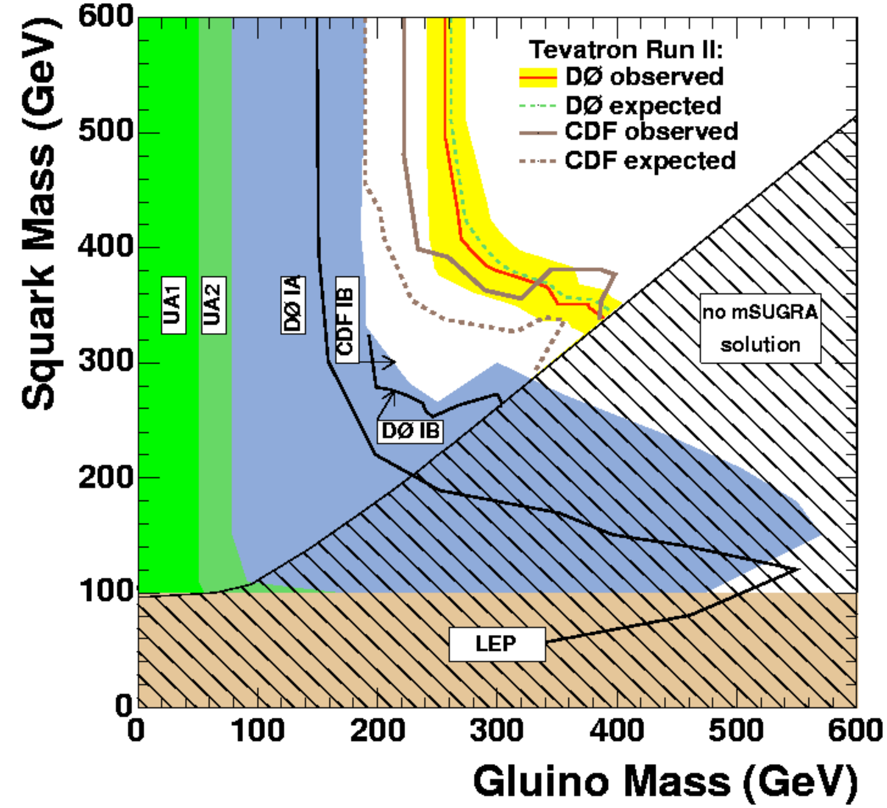




Squarks/gluinos (IV)

DØ Run II 310 pb^{-1}: Accepted by PLB





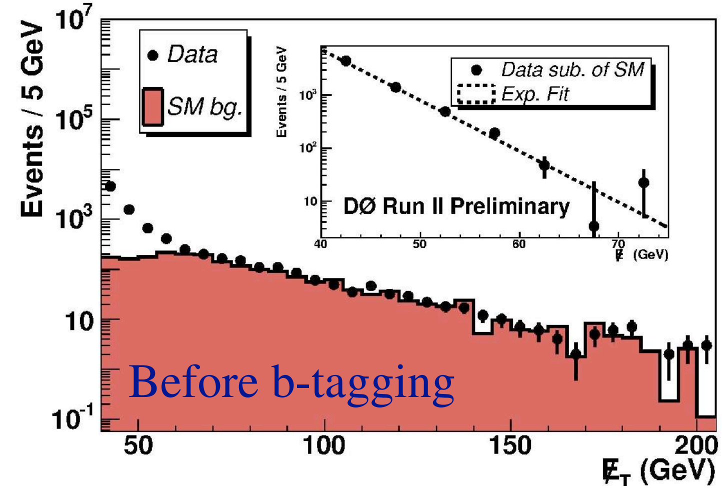
$(M\tilde{g}, M\tilde{q})$	observed	expected
σ min	(241,325)	(246,330)
σ nom	(257,339)	(261,344)
σ max	(274,352)	(280,358)

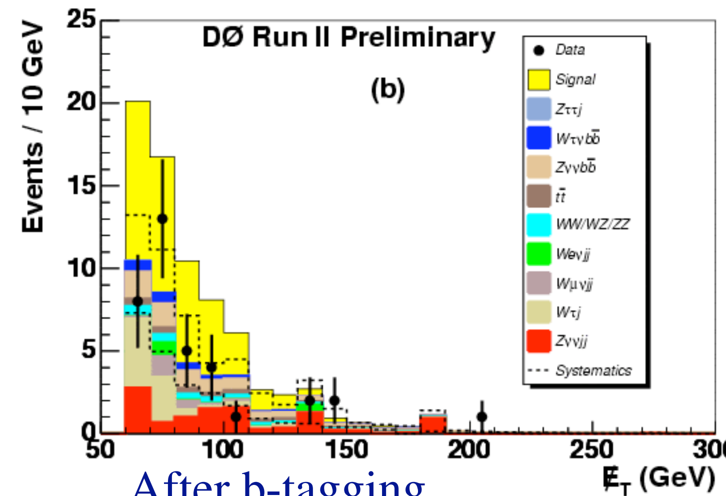
- CDF released a preliminary analysis with 378pb^{-1} optimized for M(squark)=M(gluino): no excess
  - tan(b)=5 (=3 for DØ) : small effect
  - only 1st and 2nd gen. squarks (+sbottom for DØ) : small effect
  - CDF treats the effect of the PDF/Scale on the signal cross section as a systematic uncertainty on the number of signal events expected, in the limit computation : DØ result for the minimal cross section is much more conservative

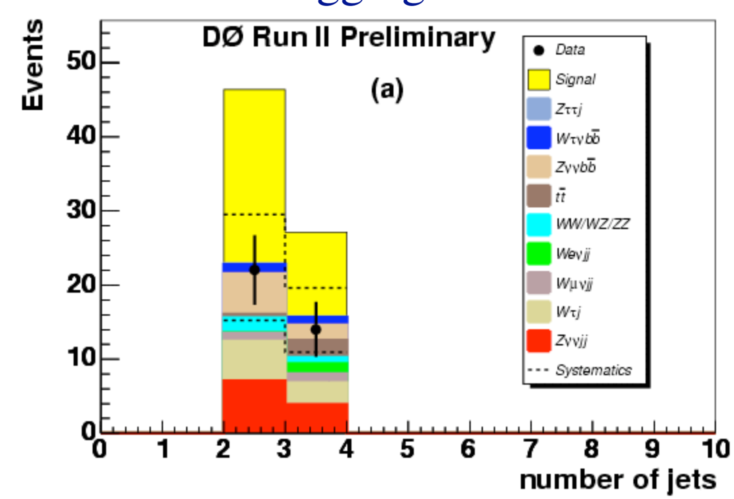
Sbottom (I)

- Lightest sbottom are pair produced and decay: $\tilde{b}_1 \rightarrow b\,\tilde{\chi}_1^0$
  - ➔ R-parity is conserved
  - ➔ 100% BR for this decay channel
- Acoplanar di-jet events + MET + b-tagging
  - ➔ softer jets and MET for low mass difference between the sbottom and the lighest neutralino1

- L=310 pb^{-1}
- Event selection:
  - ➔ at least 2 jets with |η|<0.9 and Pt1>40 and Pt2>15 GeV confirmed by the tracks
  - ➔ acoplanarity between the 2 jets < 165 degrees
  - ➔ MET > 40 GeV
  - ➔ Minimum azimuthal angle between any jet and MET < 35^0
  - ➔ veto on isolated electrons, muons and tracks with Pt > 5 GeV
  - ➔ b-tagging using a Jet Lifetime Probaility (JLIP)
    - ➢ working point with the lowest mistag rate (0.1%)
    - ➢ at least on jet tagged
  - ➔ Final optimization of the following cuts in the (Mstop,Mneutralino1) plane : isolation between jets and MET, MET and jets pT







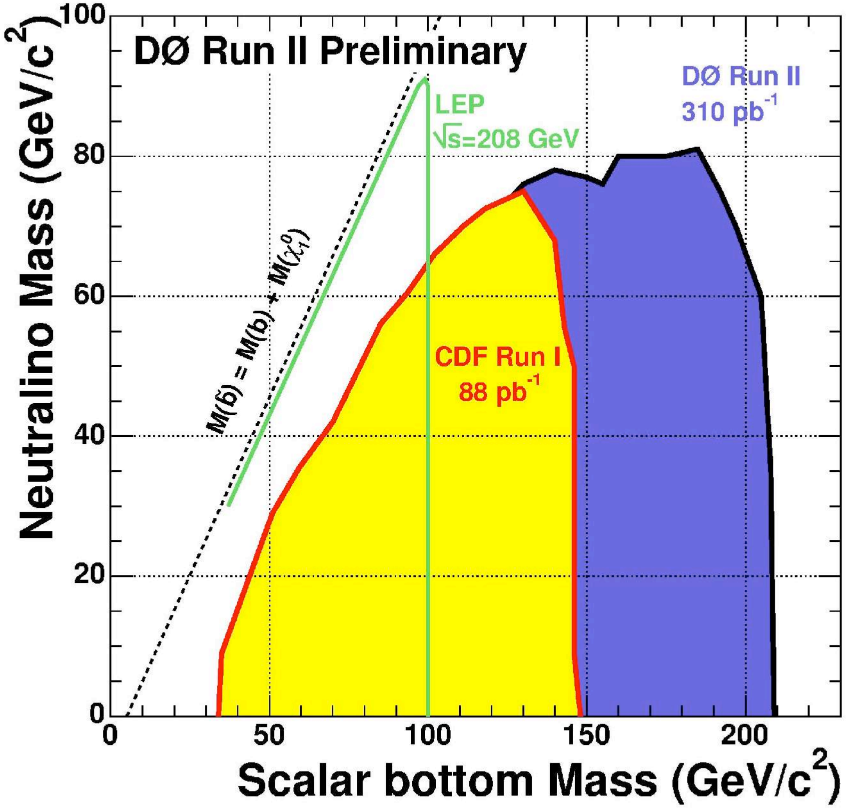
Sbottom (II)

- Optimization of the final cuts for different (sbottom1,neutralino1) mass combinations :
  - (140,80) : Pt(jet1)>40, Pt(jet2)>15 and MET> 60 GeV
  - (160,75) : Pt(jet1)>40, Pt(jet2)>15 and MET> 80 GeV
  - (205,60) : Pt(jet1)>70, Pt(jet2)>40 and MET>100 GeV

	(140,80) GeV	(160,75) GeV	(205,60) GeV
Data	**36**	**15**	**2**
Back.	**38.6 ± 2.8**	**19.6 ± 1.7**	**4.40 ± 0.44**
Signal	**35.0 ± 1.2**	**21.6 ± 0.7**	**6.10 ± 0.17**

statistical error only

- Dominant backgrounds are W/Z+jets
- No excess is observed
- Main systematic uncertainties:
  - JES (12 to 22%)
  - b-tagging (8%)
- Mass limits in the (sbottom1,neutralino1) mass plane
- NLO signal cross sections computed with PROSPINO for the renormalization and factorization scale mu=2Q (Q=Msbottom)
- Previous limits are largely improved

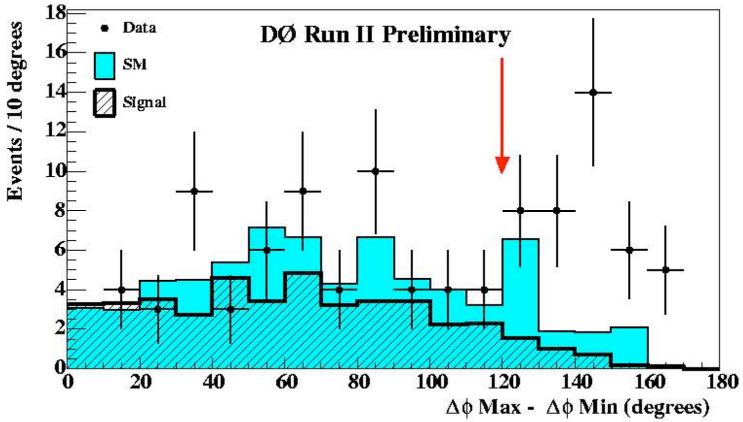


Stop in acoplanar dijet (I)

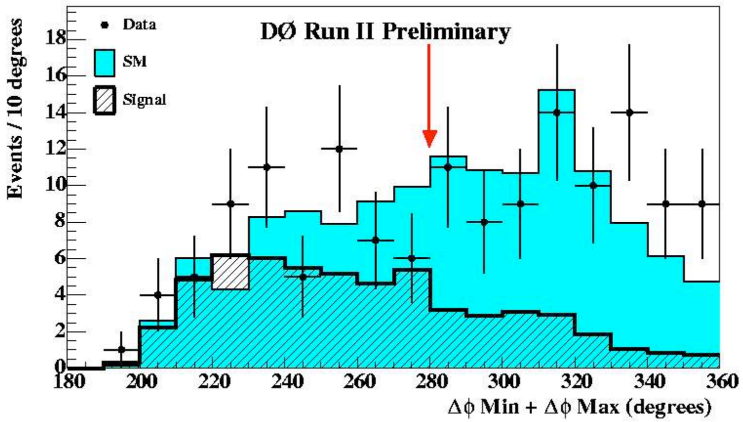
- Search for the flavor changing decay of the lightest stop:
  - ➔ stop are pair produced
  - ➔ R-parity is conserved
  - ➔ 100% BR for this decay channel

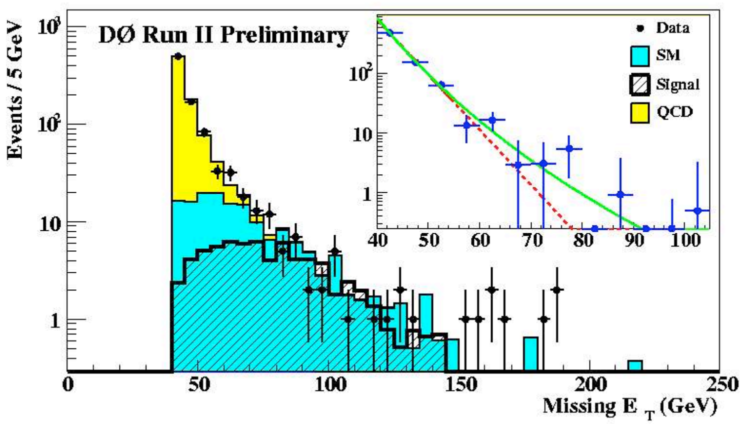
$$\tilde{t}_1 \rightarrow c\,\tilde{\chi}_1^0$$

- Acoplanar di-jet events + MET:
  - ➔ low stop1/anti-stop1cross section
  - ➔ softer jets and MET for low mass difference between the stop and the lighest neutralino1
  - ➔ use c quark tagging



- L=310 pb^{-1}
- Event selection:
  - ➔ exactly 2 jets with |η|<1.5 and Pt1>40 and Pt2>20 GeV confirmed by the tracks
  - ➔ acoplanarity between the 2 jets < 165 degrees
  - ➔ MET > 40 GeV
  - ➔ veto on isolated electrons and muons
  - ➔ Heavy flavor tagging (JLIP):
    - ➢ at least on jet tagged
  - ➔ Optimization of the following cuts in the (Mstop,Mneutralino1) plane : isolation between jets and MET, MET and jets pT



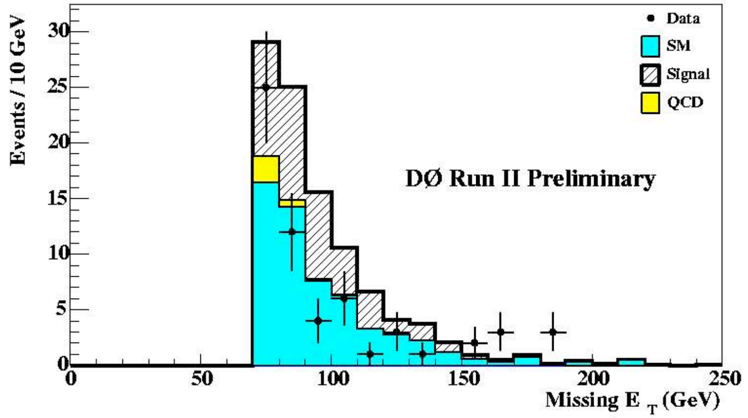


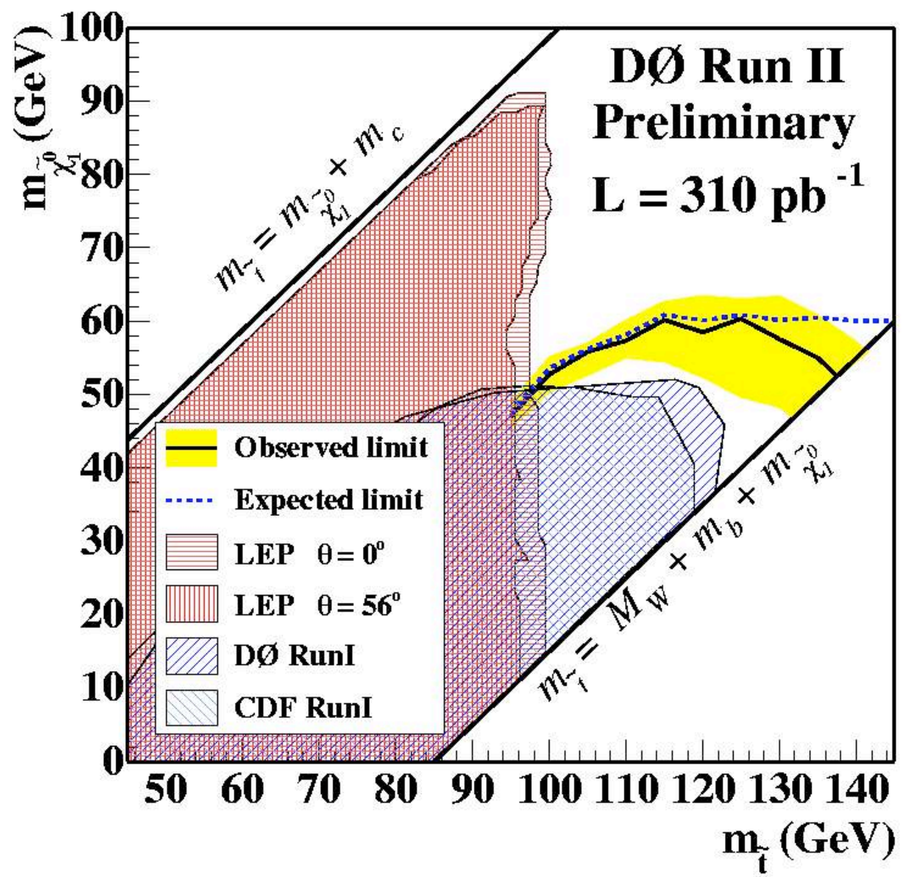
Stop in acoplanar dijet (II)

- For M(stop)=130, M(neutralino1)=50
  - ➔ Pt1>40 GeV, Pt2>20 GeV
  - ➔ MET > 70 GeV
  - ➔ ΔΦ max+ΔΦ min < 280 degrees

	Data	Total background
"Dijet"	**60**	**59.4 ±8.3 (stat) ±9.8 (sys)**

- ➔ Dominant backgrounds are W/Z+jets
- ➔ QCD background is 5.6% of the total back.
- ➔ Signal efficiency = 3.7% => 39.5 signal events
- Small excess of events at very large MET:
  - ➔ 8 events for 3.0 ±1.2 for MET>150 GeV
  - ➔ not in the stop signal signal region
- Main systematic uncertainties:
  - ➔ JES (5-10%)
  - ➔ heavy flavor tagging : 7%
  - ➔ back. cross sections : 13%
- As for the squark-gluino analysis, 3 signal cross section hypotheses (PDF/Scale)
  - ➔ Excluded contour is extended
  - ➔ The largest stop mass excluded is 131 GeV

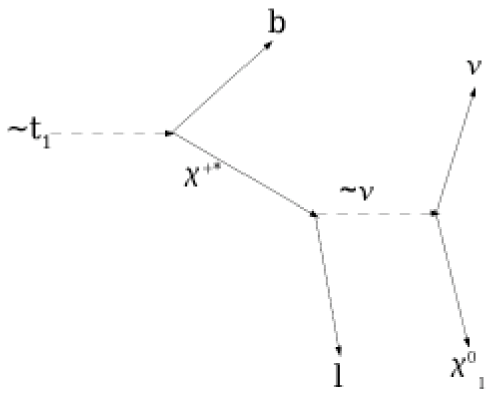




Stop in bl sneutrino (I)

- Search for the three body decay of the lightest stop:
  - stop are pair produced
  - R-parity is conserved
  - two channels:
    - di-muon channel
    - e-mu channel

$$\tilde{t}_1 \rightarrow b\, l\, \tilde{\nu}$$



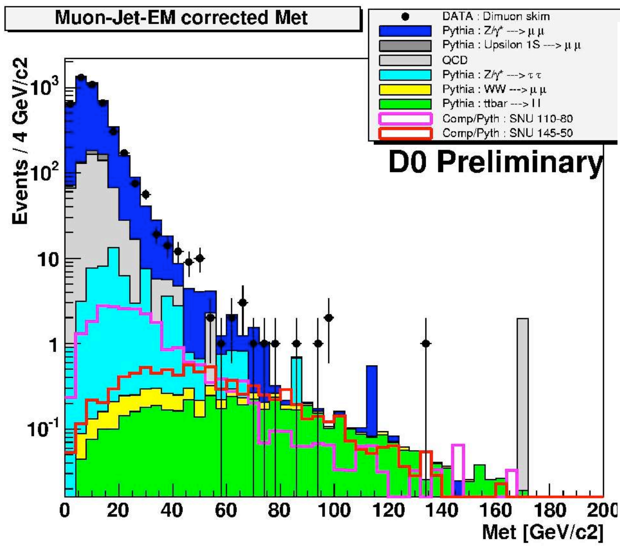
- Di-muon channel : L=339 pb^{-1}
  - 2 opposite sign muons pT > 8 and 6 GeV
  - at least 1 jet with pT > 15 GeV and |η|<2.5
  - 1 loose jet b-tagged (JLIP)
  - ΔΦ (leading mu,MET) vs MET
  - Anti-Z->mumu cut
- Main backgrounds:
  - QCD
  - Z->μμ
  - top pair
- Systematic uncertainties:
  - JES : 4 to 22%
  - b-tagging : until ~11%

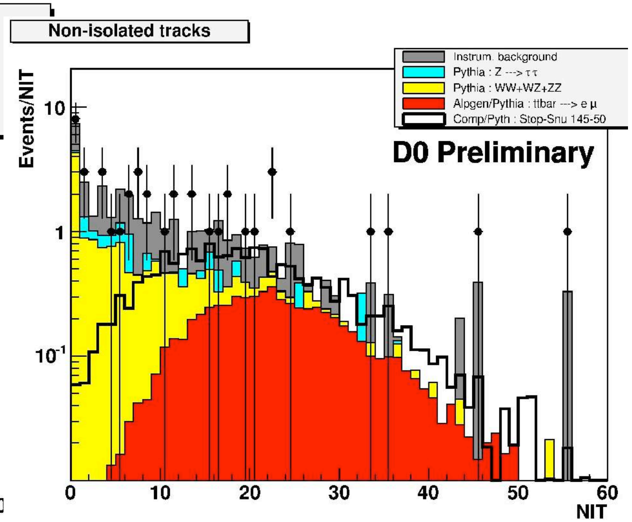
- e-mu channel : L=350 pb^{-1}
  - 1 isolated muon with pT>8 GeV
  - 1 isolated electron with pT > 12 GeV
  - opposite sign
  - Optimization of the final cuts:
    - MET
    - ΔΦ (e,MET) vs ΔΦ (μ,MET)
    - Transverse mass (e,MET)
    - Number of non isolated tracks (NIT) instead of requiring reconstructed jets
- Main backgrounds:
  - Instrumental back.
  - di-boson
  - top pair
  - Z->ττ
- Systematic uncertainties:
  - NIT cut (4%)

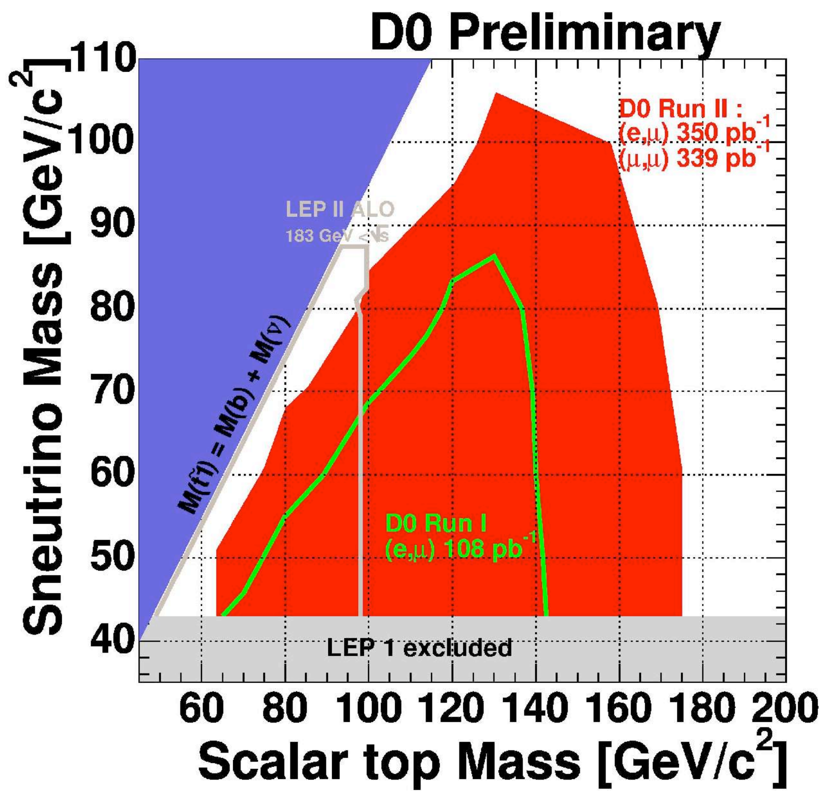
Stop in bl sneutrino (II)

dimuon channel

e-mu channel





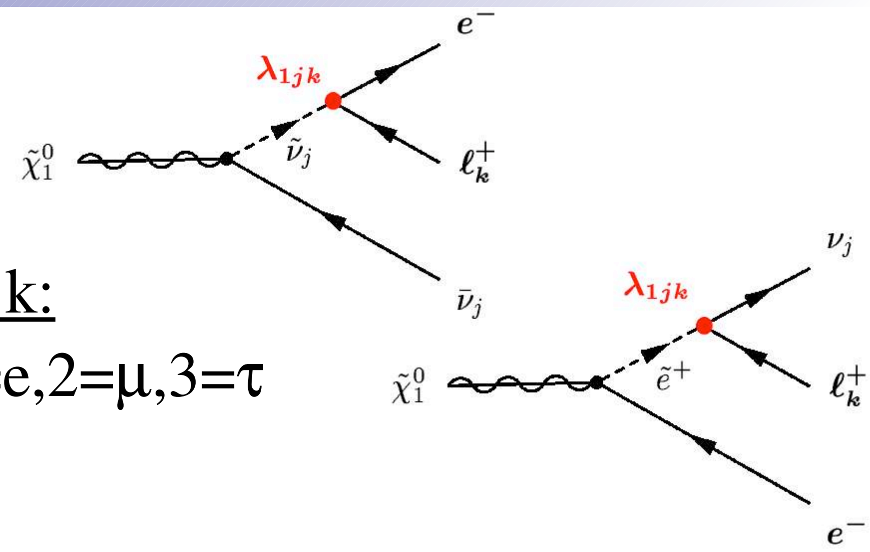


	Data	Total background
emu low Dm	21	23.0 ± 3.1
emu high Dm	42	40.7 ± 4.4
mumu	1	2.88 ± 0.43 (stat) +0.10 -0.04 (sys)

- Combination of the results :
  - with 100% BR for $\tilde{t}_1 \rightarrow b1\tilde{\nu}$
  - MSSM with tan(β)=20, μ=225 GeV, M(gluino)=500 GeV, M(A)=800 GeV
    - slepton parameters tuned to obtain equal BR of chargino1 in all lepton flavors
    - Vary At => stop mass, M(1st/2nd gen. sleptons) => M(sneutrino), M1 => neutralino1 lower than the sneutrino mass, M2 => chargino1 mass virtual
- $M(\tilde{t}_1) > 175$ GeV for $M(\tilde{\nu})$=60 GeV

RPV : trilepton λ121, λ122, λ133

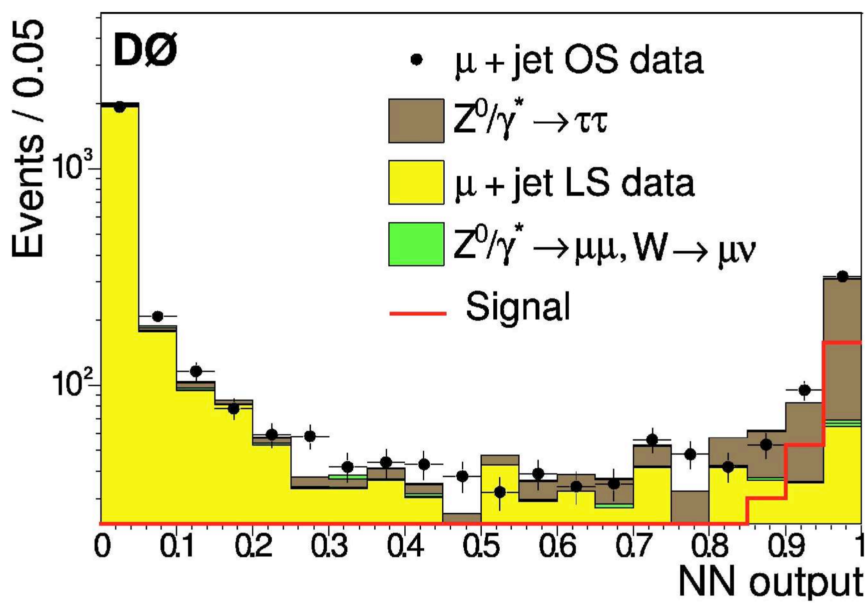
- L=360 pb^{-1}
- Pair production of gaugino $(\tilde{\chi}_1^{+-}\tilde{\chi}_1^{-+} \text{ or } \tilde{\chi}_2^0\tilde{\chi}_1^{-+})$
- R-parity violation: LLE couplings
  - SUSY particles are pair produced (RPC)
  - R-parity violation in the LSP decay $(\tilde{\chi}_1^0)$
- LLE couplings: below current limits, $\tilde{\chi}_1^0$ decay length < 1cm
  - λ121 = λ122 =0.01
  - λ133 = 0.03
- Models :
  - mSUGRA
  - MSSM
- Three analyses :
  - eel : l=e or μ
  - μμl : l=e or μ
  - eeτ
- Event selection:
  - low pT leptons
  - isolated electrons and muons
  - tau ID using NN
  - neutrino in the final state => missing ET cuts



λijk:

1=e,2=μ,3=τ

Z->ττ -> $\tau_{had.}\mu$

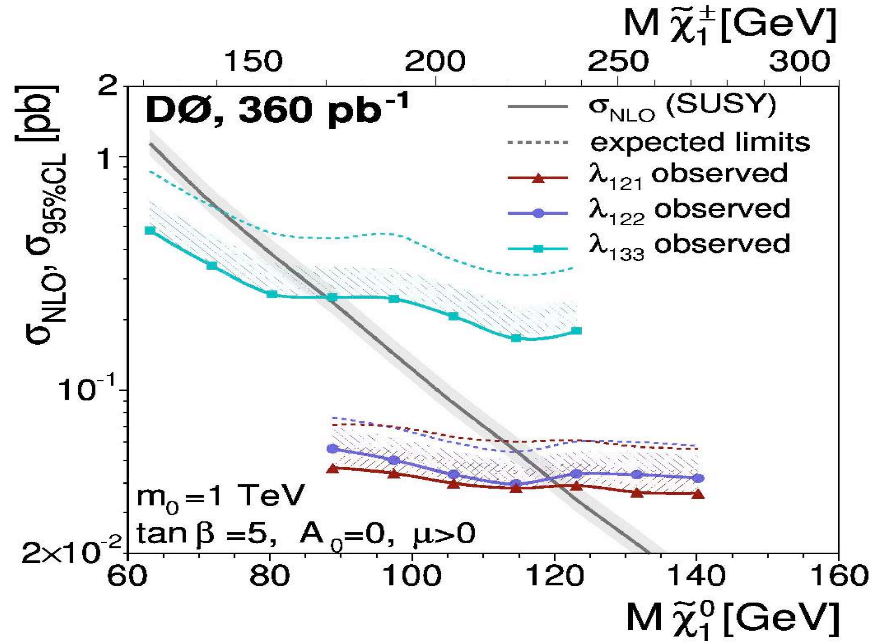


RPV : trilepton λ121, λ122, λ133

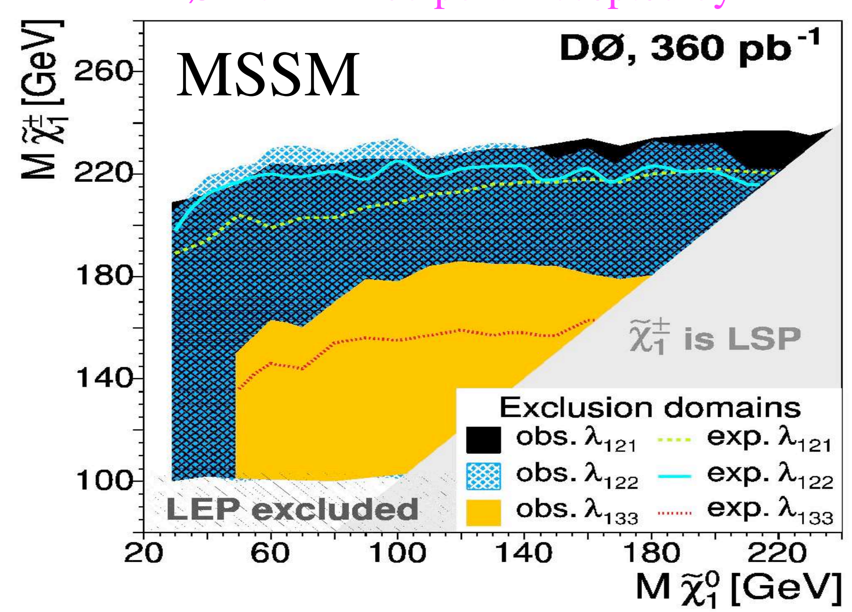
- Signal simulation:
  - SUSYGEN/SUSPECT
  - NLO cross sections with GAUGINOS
- mSUGRA with :
  - tan(β)=5/20, A=0, μ>0 / <0, m0=100 GeV or 1 TeV
- MSSM with :
  - heavy squarks and sleptons
  - no GUT relation between M1 and M2

	Data	Total background
eel	0	0.9 +0.4-0.1 (stat) ± 0.1 (sys)
μμl	0	0.4 ±0.1 (stat) ± 0.1 (sys)
eeτ	0	1.3 ±1.7 (stat) ± 0.5 (sys)

- Some mass limits in mSUGRA:
- tan(β)=5, A=0, μ>0, m0=1 TeV
  - $\lambda 121 : M(\tilde{\chi}^0_1)>119, M(\tilde{\chi}^{+-}_1)>231$ GeV
- tan(β)=5, A=0, μ<0, m0=1 TeV
  - $\lambda 122 : M(\tilde{\chi}^0_1)>117, M(\tilde{\chi}^{+-}_1)>234$ GeV
- tan(β)=20, A=0, μ>0, m0=100 GeV
  - $\lambda 133 : M(\tilde{\chi}^0_1)>115, M(\tilde{\chi}^{+-}_1)>217$ GeV



DØ Run II 360 pb-1: Accepted by PLB

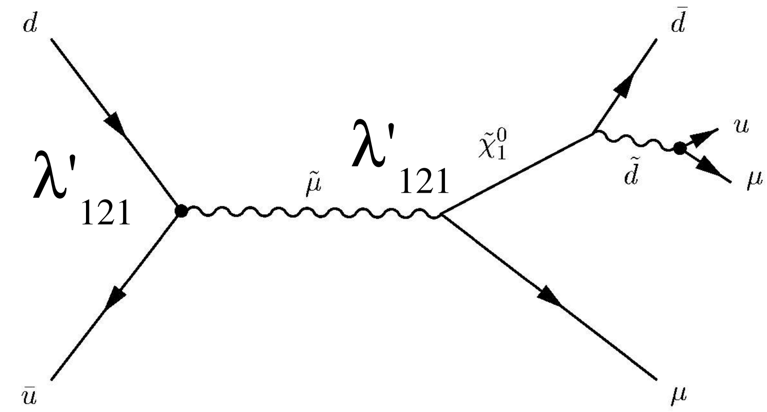


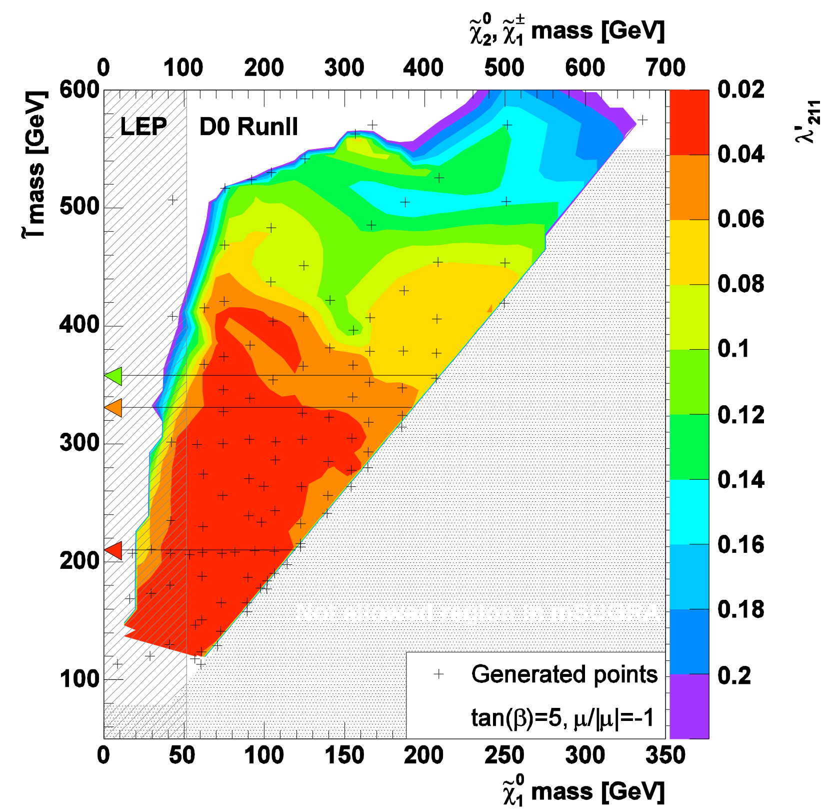
Resonant Slepton

- L=380 pb^{-1}
- Only LQD λ'121coupling can be non zero:
  - Resonant slepton production via RPV λ'121
  - RPC decay into lepton/gaugino
  - decay of the gaugino via λ'121 coupling
- 3 Channels:
  - $\tilde{\mu} \rightarrow \tilde{\chi}^0 \mu$: 2muons + 2 jets
  - $\tilde{\mu} \rightarrow \tilde{\chi}^0_{2,3,4} \mu$: 1 muon + MET + ≥ 2 jet
  - $\tilde{\nu}_\mu \rightarrow \tilde{\chi}^{+-}_{1,2} \mu$: 2 muons + 4 jets
- Event selection:
  - at least 2 isolated muons: Pt1>15 and Pt2>8 GeV
  - 2 jets with Pt>15 GeV and |η|<2.0
  - Final selection optimized for 117 combinations of smuon and neutralino1 mass using the reconstructed masses, the muon and jet momenta. Example for M(slep)=260, and M(neut1)=100 GeV:

	Data	Total background
$\tilde{\mu} \rightarrow \tilde{\chi}^0 \mu$	14	11.9 +2.1 (stat) +1.5-1.6 (sys)
$\tilde{\mu} \rightarrow \tilde{\chi}^0_{2,3,4} \mu$	28	25.4 ±3.2 (stat) +6.7-4.2 (sys)
$\tilde{\nu}_\mu \rightarrow \tilde{\chi}^{+-}_{1,2} \mu$	8	6.5 ±1.6 (stat) +2.0-1.2 (sys)

- Syst. uncertainties: largely dominated by JES (14-26%)
- mSUGRA : tan(β)=5, A=0, μ<0
  - M(smuon)>210 GeV for λ'121>=0.04





GMSB SUSY in diphoton events (I)

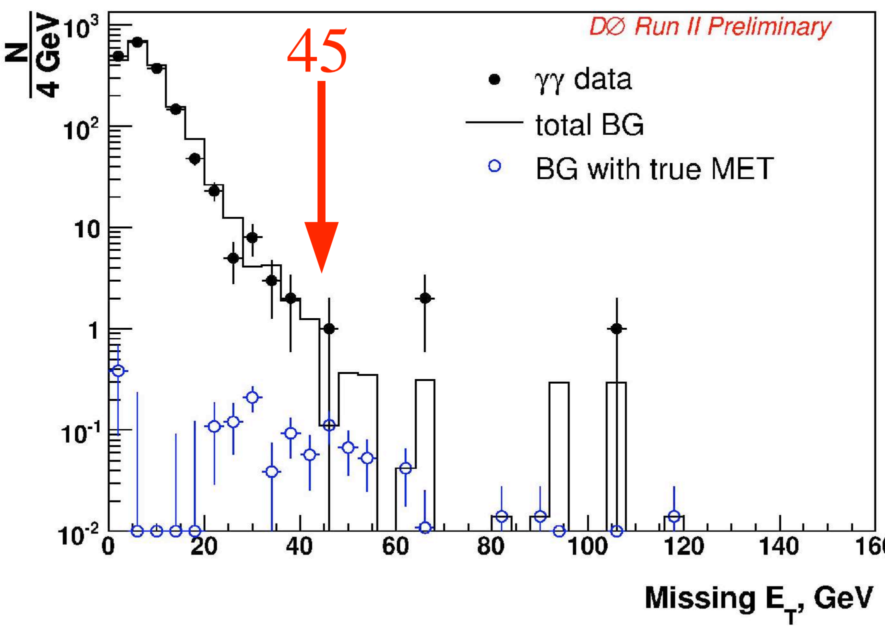
- In this analysis :

$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$$

  - Rp is conserved
  - lightest neutralino NLSP (prompt decay)
  - gravitino LSP (M< few keV)

- Clear signature: 2 photons + MET
- Remember CDF Run I event

- L=760 pb^{-1}
- 100% trigger efficiency at the final stage
- improved photon ID compared to the DØ Run II analysis published with 263pb^{-1} [Phys. Rev. Lett. 94, 041801 (2005)]
- Physics background negligible
- Instrumental backgrounds (EM misidentification) estimated using real data:
  - without true MET : QCD
    - use diEM data sample with loosened photon ID
    - Normalization at MET<12 GeV
  - with true MET : $W(\rightarrow e\nu)+\gamma\ or\ jet$
    - use eγ events with true MET
- Final cut on MET at 45 GeV => 4 events

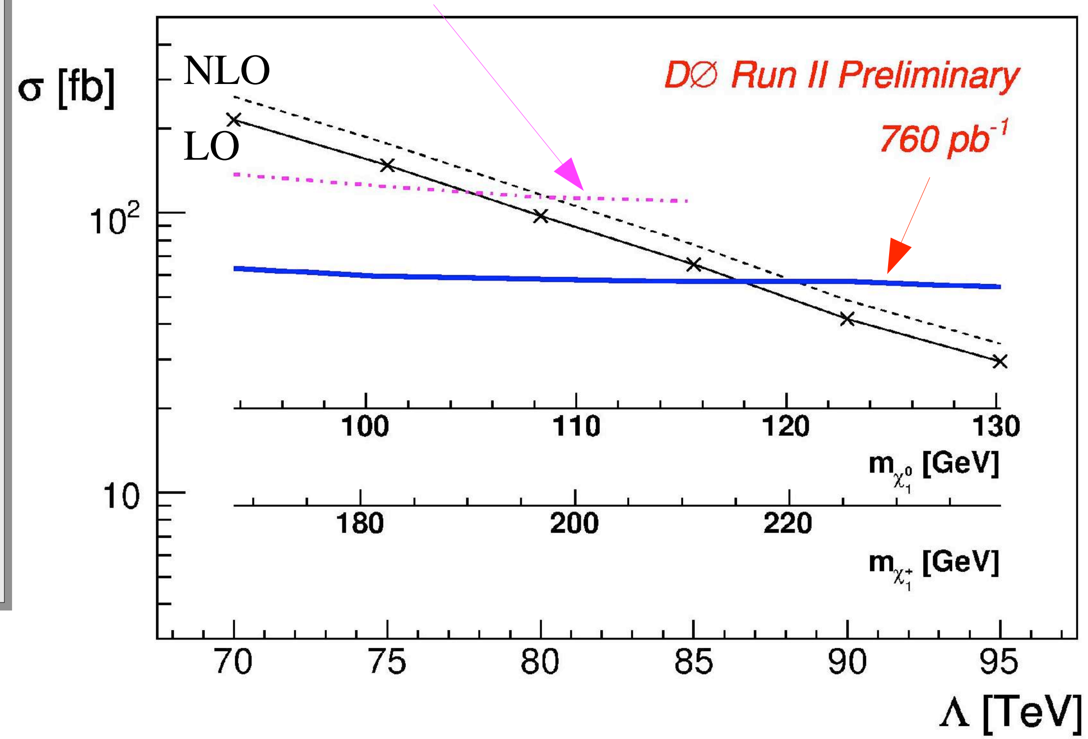


GMSB SUSY in diphoton events (II)

- Good agreement between data and background predictions
- GMSB SUSY signals:
  - GMSB Snowmass slope
- Signal efficiencies : ~18%
- Relative systematic uncertainties :
  - 15% in total (photon ID, lumi, PDF, trigger, track match veto)
  - dominated by photon ID (10%)
- NLO K-factor from PROSPINO
- Limits on the chargino and neutralino1 masses:
  - $m(\tilde{\chi}_1^0) > 120\,\text{GeV}$
  - $m(\tilde{\chi}_1^{+-}) > 220\,\text{GeV}$
  - $\Lambda > 88.5$ TeV (Effective scale of SUSY breaking)

back. with MET	0.28± 0.06
back. without MET	1.8 ± 0.7
Total background	2.1 ± 0.7
data	4

DØ Run II 263pb^{-1}: Phys. Rev. Lett. 94, 041801 (2005)

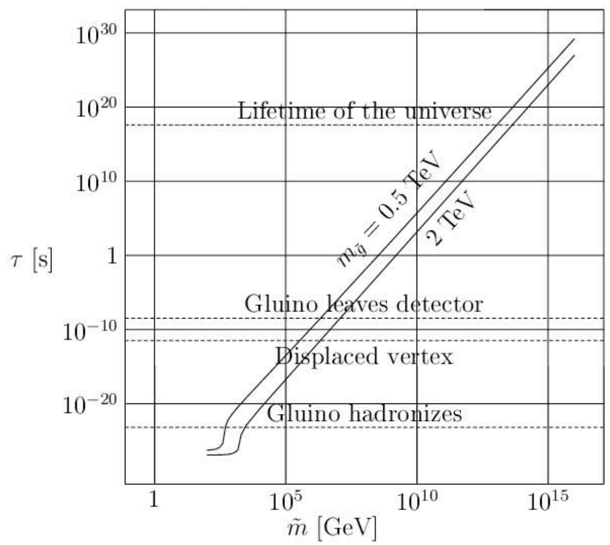


Large improvement with increased statistics

Stopped Gluino (I)

- If the gluino lifetime is long enough, it will hadronize into colorless hadrons i.e. R-hadrons
  - The idea is not new: Fayet and Farrar introduced those R-hadrons in the early years of SUSY models [Phys. Lett. B 76 (1978) 575; Phys. Lett. B 79 (1978) 442; Phys Lett. B 78 (1978) 417]
  - A light gluino (M ~=1.5 GeV) was then considered in the 90's.
    - It was finally excluded in 2001 at LEP
    - At that time also, studies on the R-hadron spectroscopy (some funny names like the glueballino=gluino-gluon state), and on R-hadron interactions with matter
  - New models at the end of the 90's with a gluino LSP, or NLSP but stable, and with a higher gluino mass (~10 to 150 GeV): that's the "heavy stable gluino" scenario
    - Gunion/Rabi : [Phys.Rev.D59:075002,1999; Phys.Rev.D62:035003,2000]
  - And more recently : split SUSY
    - N. Arkani-Hamed, S. Dimopoulos, G.F. Giudice, A. Romanino [Nucl.Phys.B709:3-46,2005]
    - W. Kilian, T. Plehn, P. Richardson, E. Schmidt [Eur.Phys.J.C39:229-243,2005]

- split SUSY very quickly:
  - all scalars are very heavy
  - the fermions (higgsino, gaugino, gluino) are light
  - as the squark are very heavy, the gluino is stable, hadronizes into R-hadrons and reach the calorimeter



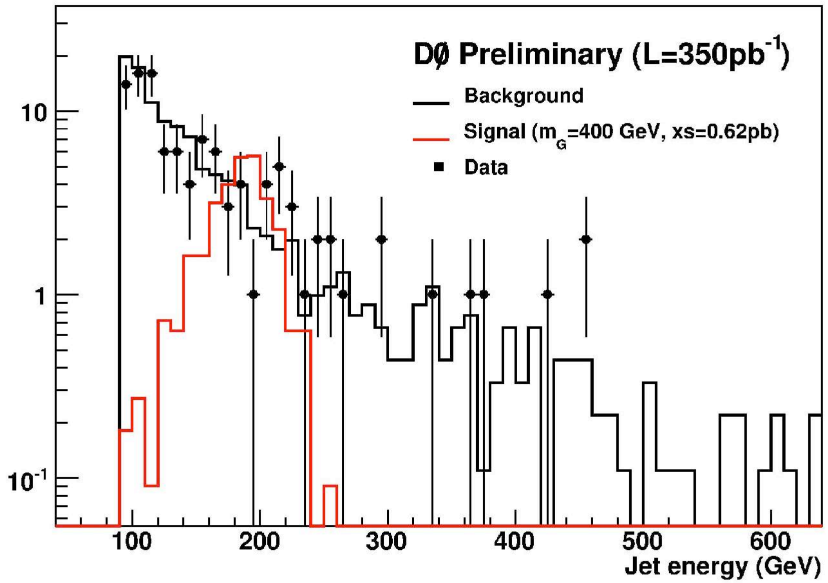
Stopped Gluino (II)

- R-hadron interactions: A. Kraan [Eur.Phys.J.C37:91-104,2004], A. Arvanitaki et al. [hep-ph/0506242]
  - ➔ Fraction of charged R-hadrons ~= ½
  - ➔ via electromagnetic interactions, a R-hadron can stop into the calorimeter, and decay later (10 µs to few hours) into gluon-neutralino
  - ➔ that's a completely new strategy :
    - ➢ jet production not coming from the interaction point, and not synchronized with beam crossing

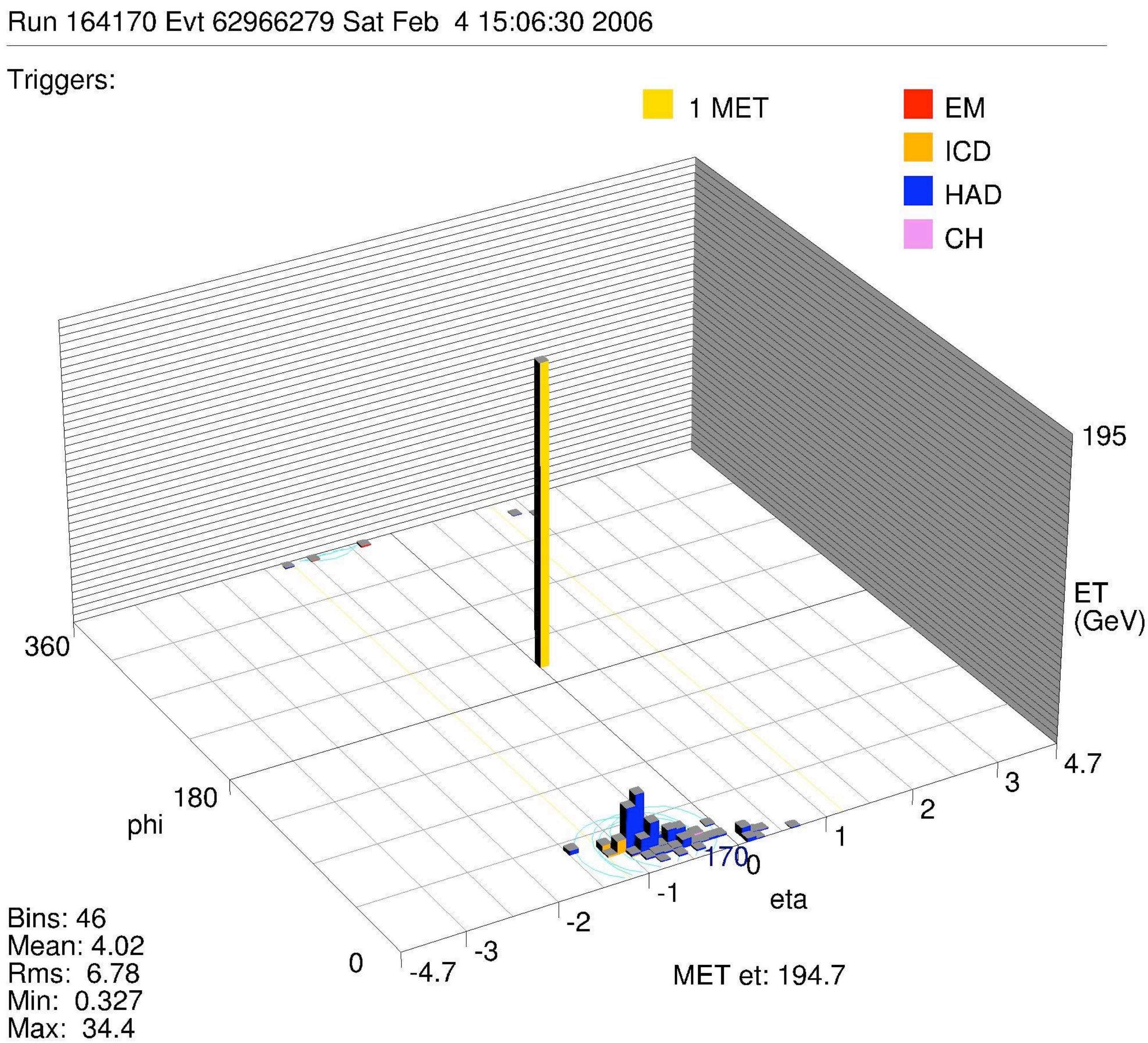
- $L=350\ pb^{-1}$
- Gluino are pair produced
- Gluino Lifetime:
  - ➔ greater than 10 µs
  - ➔ lower than few hours
- Topology:
  - ➔ empty event with a single jet of energy
- Use the triggers requiring:
  - ➔ a jet in the calorimeter
  - ➔ veto on luminosity counters
- Backgrounds:
  - ➔ cosmic muons
  - ➔ beam halo muons

$$E_{jet} = \frac{M_{\tilde{g}}^2 - M_{LSP}^2}{2\,M_{\tilde{g}}}$$

- Event selection:
  - ➔ only one jet with E>90 GeV and |η|<0.9
  - ➔ the jet is a wide shower
  - ➔ no primary vertex
  - ➔ cosmic muon veto
- Background estimation from the data



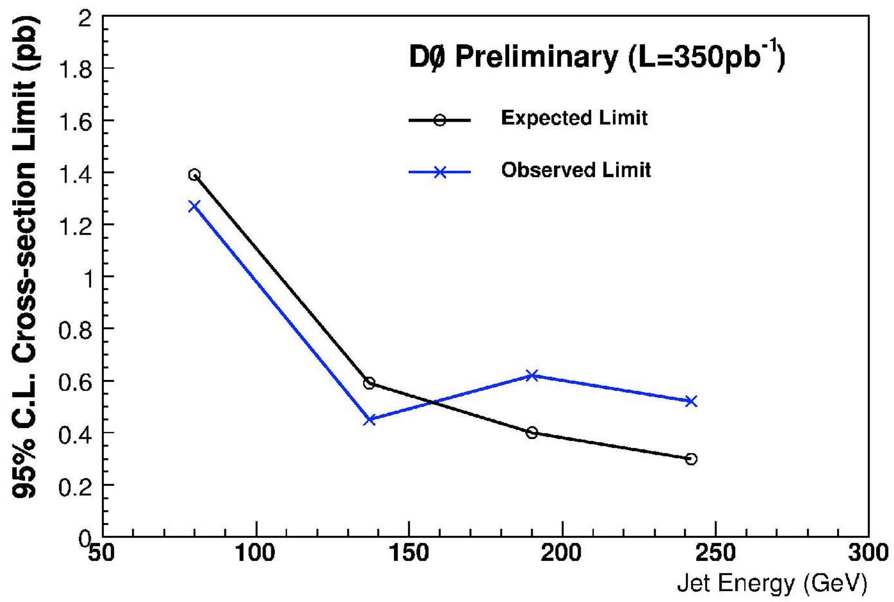
Stopped Gluino (III)



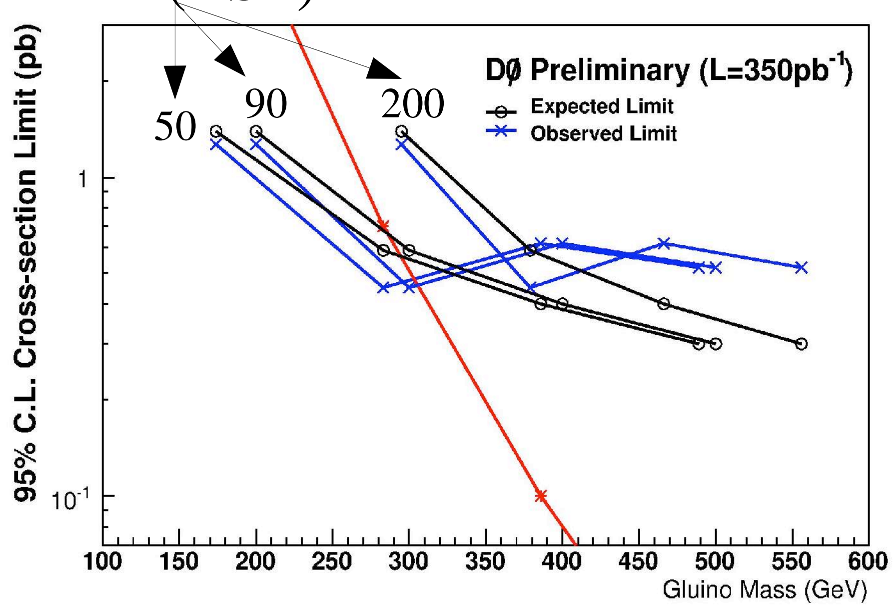
Stopped Gluino (IV)

- The previous jet energy spectrum is divided into windows corresponding to the jet energy resolution:

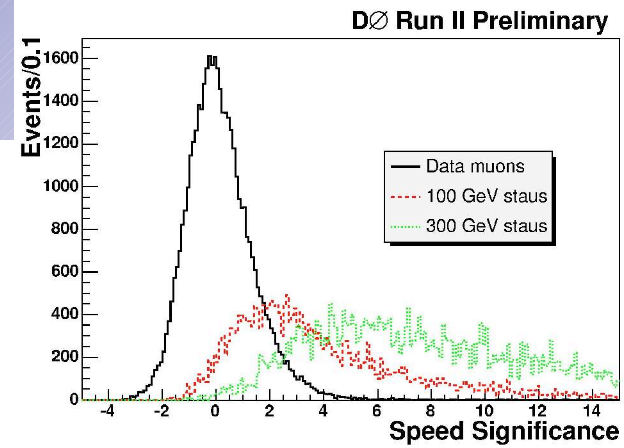
	Data	Back.	Signal Eff.
[94.6,111.6]	46	48.2	0.05
[126.8,171.8]	32	37.8	0.10
[169.3,233.8]	27	21.6	0.11
[214.2,286.6]	14	9.6	0.10



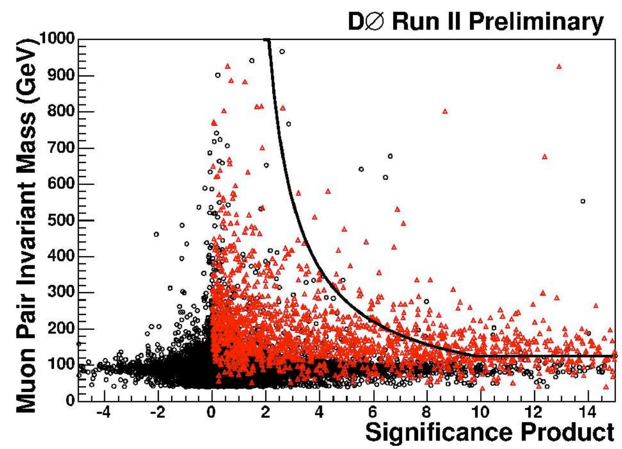
- Cross section limits:
  - 100% BR to monojet
  - the cross section is the gluino pair production cross section multiplied by the probability that the R-hadron stopped into the calorimeter
  - Compute cross section limits vs jet energy
  - Using the formula on previous slide, obtain a limit for a given LSP mass
- Mass limits :
  - Mgluino>270 for M($\tilde{\chi}_1^0$)=50 GeV

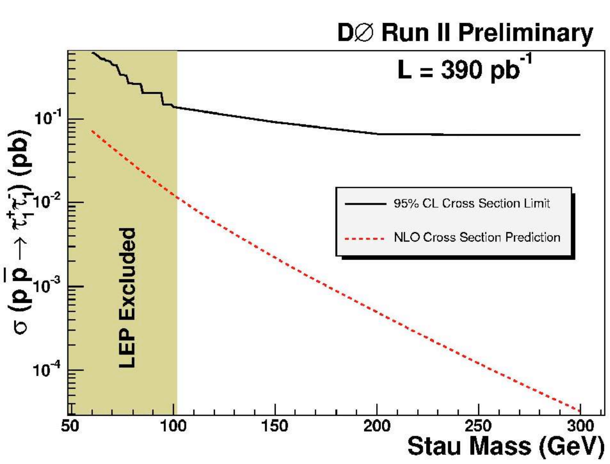


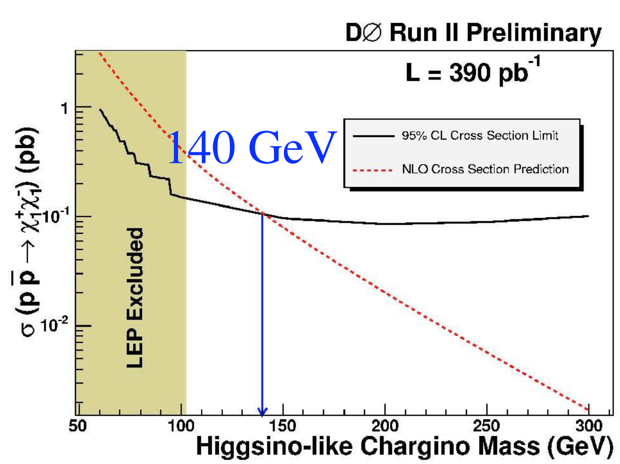
Charged Massive Stable Particles

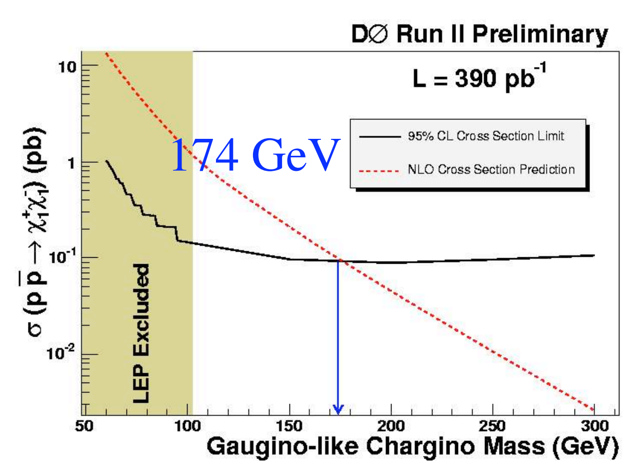


- L=390 pb^{-1}
- Charged particles with lifetime long enough to escape the detector
  - ➔ GMSB with stau NLSP
  - ➔ AMSB with a mass difference between the chargino1 and the neutralino1 below 150 MeV
- CMSP can be detected as a slow moving muon
  - ➔ use the muon timing information
- Pair production of stau and chargino1pair production
- Event selection:
  - ➔ 2 muons with Pt>15 GeV, $\Delta\Phi > 1.0$
  - ➔ construct a speed significance using the information of each layer of scintillator in the muon detector
  - ➔ use the correlation between invariant mass and the product of the speed significance of the 2 muons
- No excess



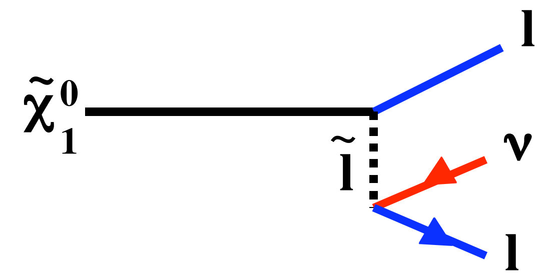


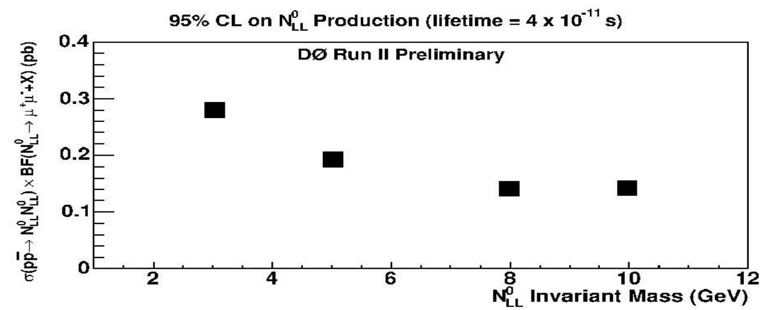


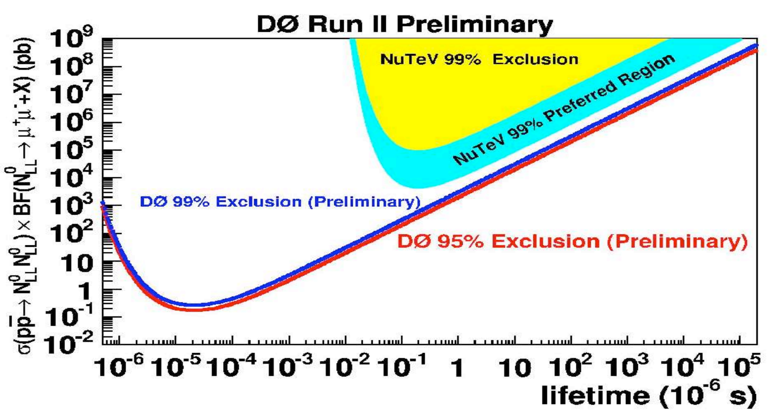


Neutral long-lived particles

- $L=383\ pb^{-1}$
- Search for neutral long-lived particles decaying to 2 muons with a displaced vertex R= 5 to 20 cm
- Motivation:
  - NuTeV observed 3 dimuon events for a background prediction of 0.07
  - This excess is compatible with a neutral long-lived particle with mass ~5 GeV
- Final interpretation in MSSM with RPV:
  - M1=3,5,8,10 GeV, M2=200 GeV, M3=400 GeV
  - tan(β)=10, mu=-5000
  - λ122<1.0, Msbot,stop=1500 GeV, Msquark=300 GeV
  - pair production of neutralino1: x-sec ~= 0.02 pb
- Event selection:
  - 2 isolated muons with pT>10 GeV
  - displaced vertex : r=5-20 cm in the transverse plane
- Background estimation from the data relaxing cuts
- Results:
  - Ndata = 0
  - Nbck. = 0.75 +/- 1.1 +- 1.1
- Not enough to exclude those SUSY points, but SUSY interpretation of NuTeV excess is excluded







Summary

Analysis	Model	Lumi. (pb^{-1})	Mass Limits (GeV)	Conditions
tri-leptons	mSUGRA RPC	900/1100	Mchargino>140	"3l-max" scenario
squark-gluino (Jets+MET)	mSUGRA RPC	310	Msquark>325, Mgluino>241	tan(β)=3, A=0,mu<0.
sbottom->b-chi01	MSSM RPC	310	Msbot1>205 GeV	BR(b chi01)=100% M(chi01)=60
stop->c-chi01	MSSM RPC	310	Mstop1>131 GeV	BR(c chi01)=100% M(chi01)=47
stop->blsnu	MSSM RPC	350	Mstop1>175 GeV	BR(blsnu)=100% M(snu)=60
RPV LEE couplings	MSSM RPV	360	Mchargino1>220	M(chi10)>=40
Resonant sleptons	mSUGRA RPV	380	Msmuon1>210	tan(β)=5, A=0,mu<0. & λ'121>=0.04
diphoton	GMSB	760	Mchi01>120, Mchargino1>220	Snowmass slope
stopped gluino	split-SUSY	350	Mgluino>270	Mchi10=50
CMSP	mSUGRA/AMSB	390	Mchargino1>140	chargino1 higgsino
NNLP	MSSM RPV	383	exclude this SUSY interpretation of NuTeV di-muon excess	

- The DØ New Phenomena group is very active (only SUSY results were shown today)
- A large variety of SUSY models are considered
- Already 1.2 fb-1 recorded during RunIIa:
  - ➔ data fully reprocessed
  - ➔ More results expected in the following months

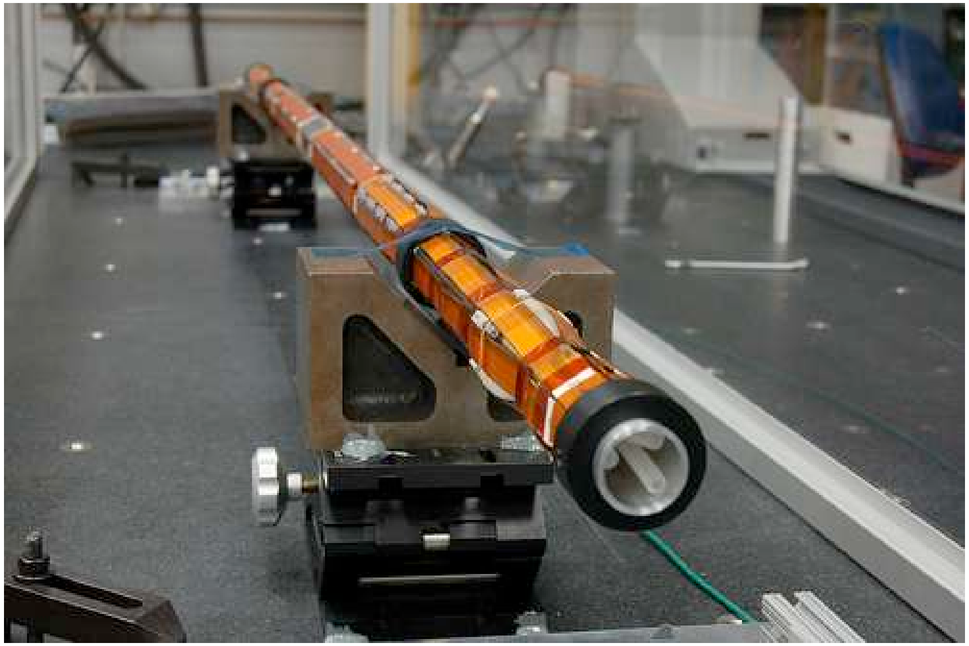
This week is very important for the Fermilab community(ies), because...

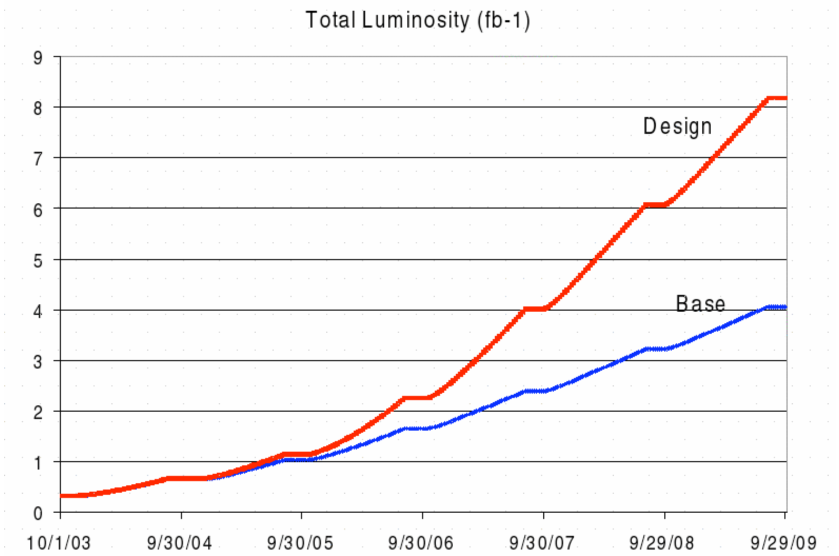
2006 Soccer World cup started in Germany!

DØ : 13 countries in the final tournament

RunIIb is starting

- DØ upgrade for RunIIb:
  - ➔ Layer 0 installed
  - ➔ Upgraded L1Cal and L1CTT (central track) triggers
  - ➔ Commissioning in progress
- Trigger menu for data taking until 300E30 cm^2s^{-1}
  - ➔ physics commissioning will start with the first RunIIb collisions

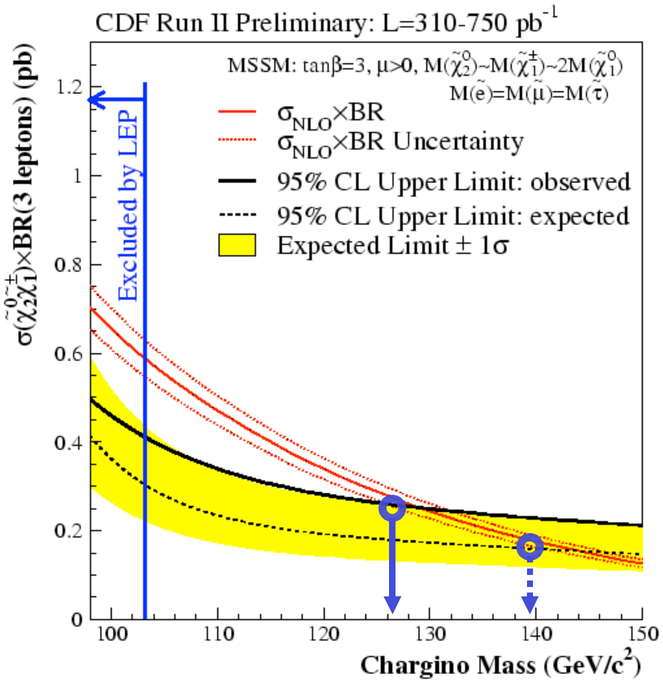


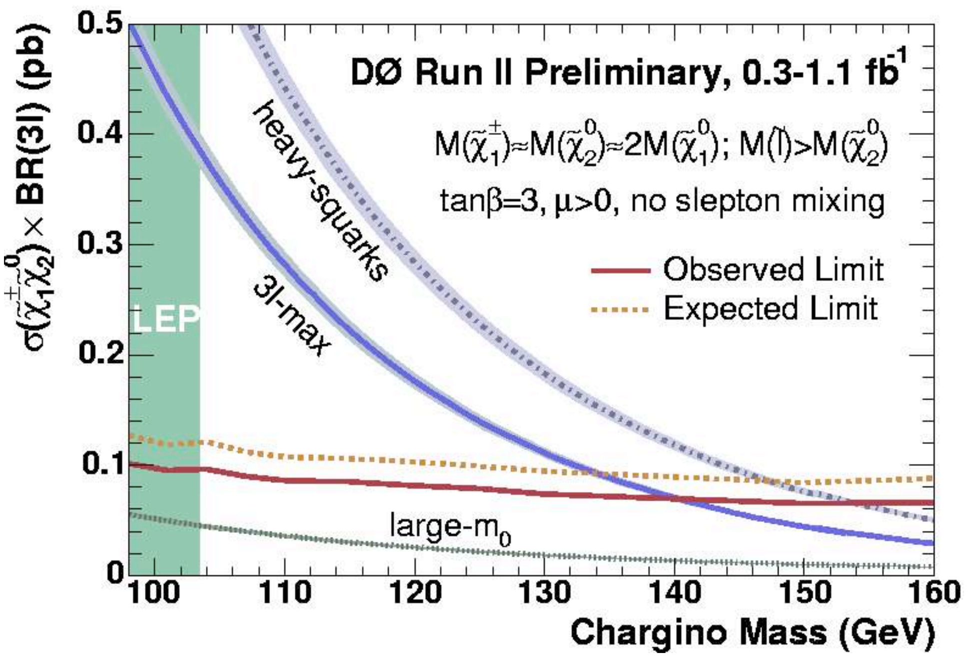


- Running the TEVATRON at high instantaneous luminosity is very challenging
- find SUSY with 4-8 fb^{-1} between now in 2009 ?

Backup

Trileptons : CDF vs DØ





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

m_0=60 GeV
⇒ 2-body decays enhanced (+)
sτ mixing on (∃ $s\tau_L$ component)
⇒ decays to τ's 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 (+)