Search for New Physics in Jets + MET Topology at DØ

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DPF 2004
University of California, Riverside / August 31st, 2004

Introduction

- Tevatron and DØ :
  - Tevatron upgrade and luminosity
  - DØ upgrade
- Jet+MET analysis tools :
  - Trigger description
  - Calorimeter data quality
  - Jet Energy Scale
  - Misvertexing and cosmics
- Jet+MET analyses :
  - LED : Search for Large Extra Dimensions (~monojet topology)
  - SUSY : Search for Squarks and Gluino (essentially dijet topology)
  - LQ : Search for Scalar Leptoquarks (dijet topology)
- Conclusion

Winter 2004 results

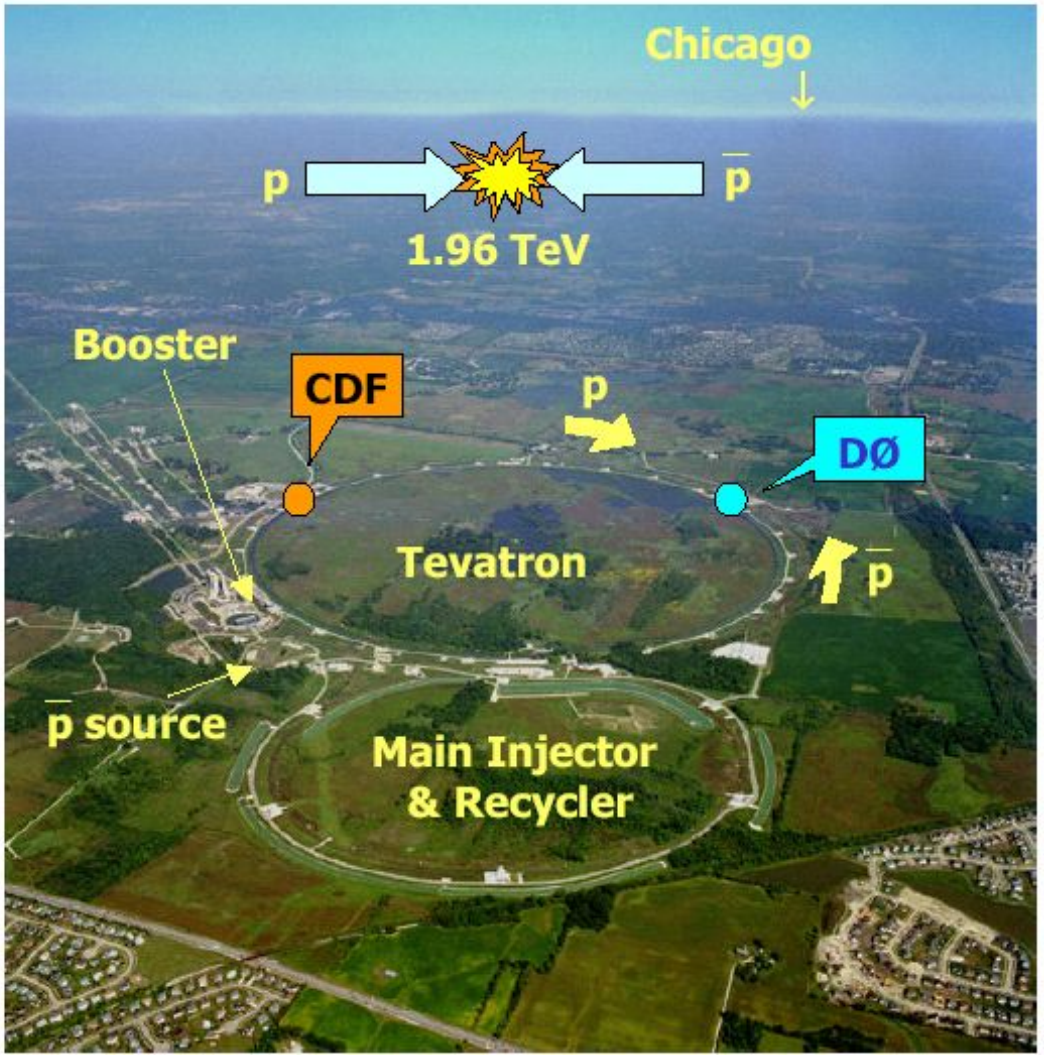
Summer 2004 result

Tevatron RUN II Upgrade

- **New Main Injector:**
  - **Storage ring up to 150 GeV**
- **New Recycler:**
  - **Storage ring for pbar cooling and e-cooling (commissioning)**
- **Higher energy:**
  - **1.96 TeV vs 1.8 TeV @ RUNI**
  - **Higher cross-sections**

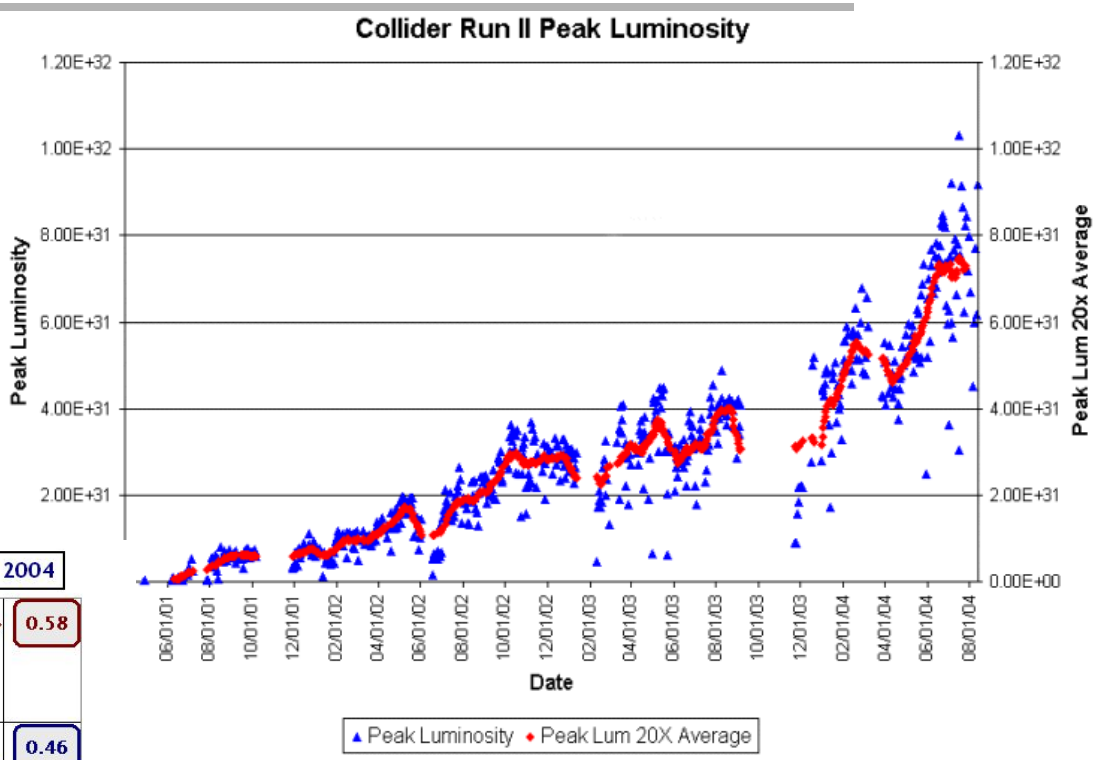
    (30 % for SUSY)
- **Higher anti-proton intensity:**
  - **6x6 ⇒ 36x36 bunches**

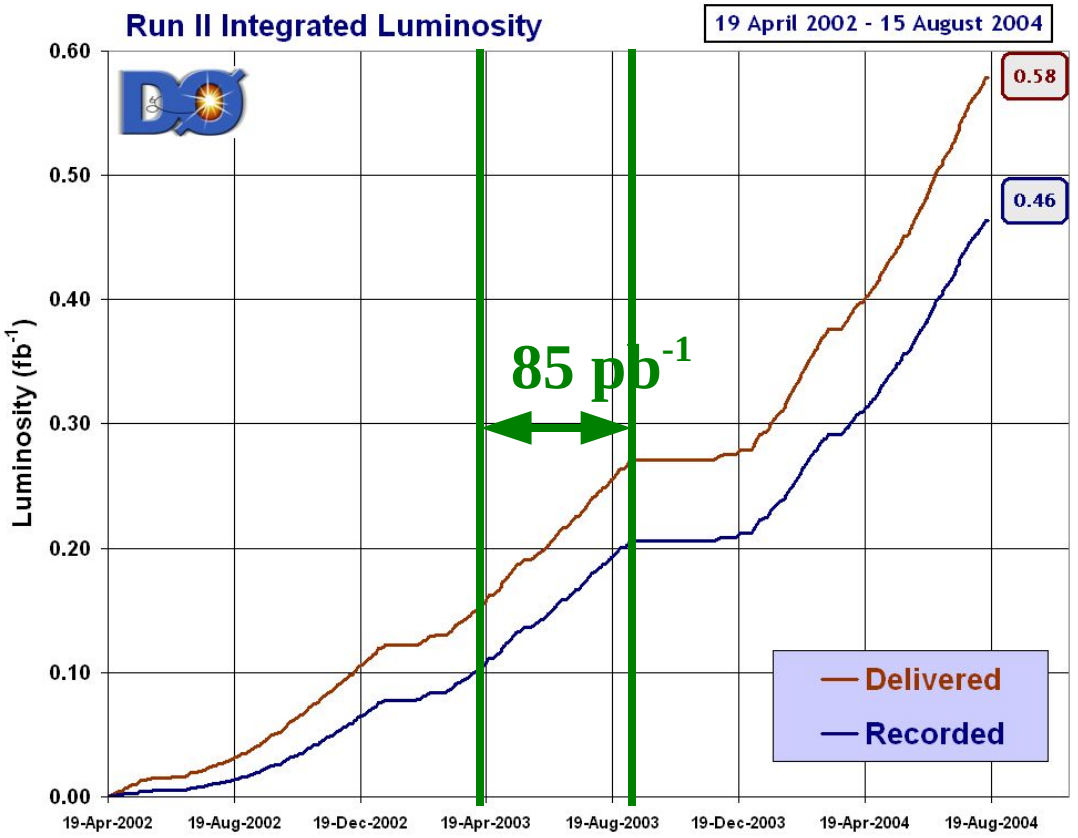
    (3.5 μs ⇒ 396 ns)
- **Higher luminosity:**
  - **Design :**
    - **"Run IIa" : 0.8x10^{32} cm^{-2}s^{-1}**
    - **"Run IIb" : 2-4x10^{32} cm^{-2}s^{-1}**



Run II Luminosity

- **Design luminosity without recycler achieved:**
  - **10^{32} $cm^{-2}s^{-1}$ at the Peak**
- **~0.5 fb^{-1} recorded so far at RUN II by DØ**



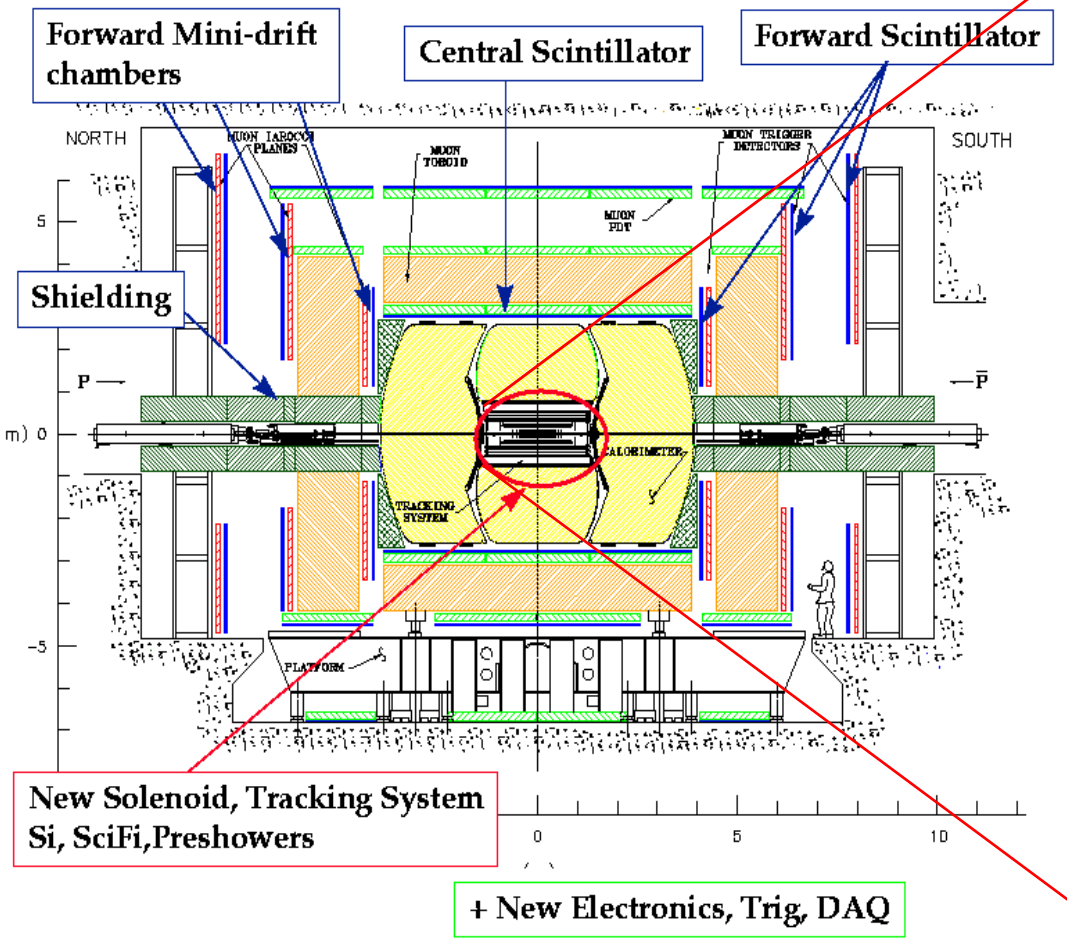


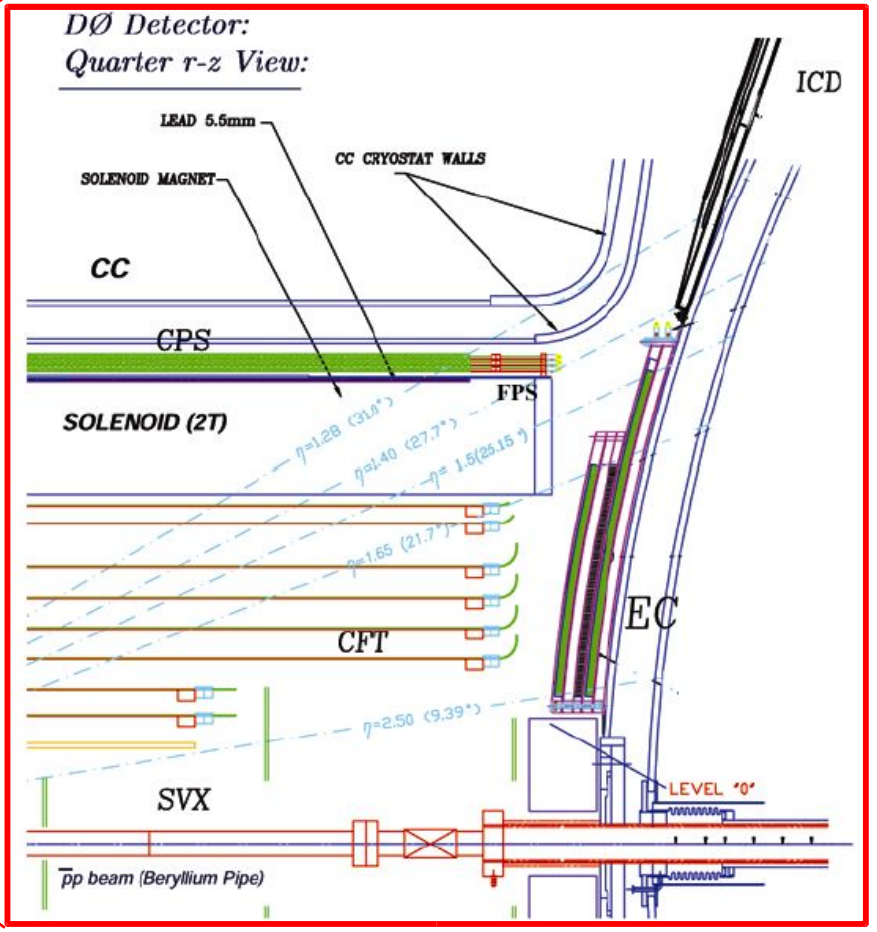
- **All analyses presented here :**
  - **used MHT trigger**
  - **L=85 pb^{-1} recorded from :**

    April 2003 ⇒August 2003
  - **no MHT trigger available before**

$$MHT = \left| \sum \vec{P}_t^{jet} \right|$$

DØ Upgrade



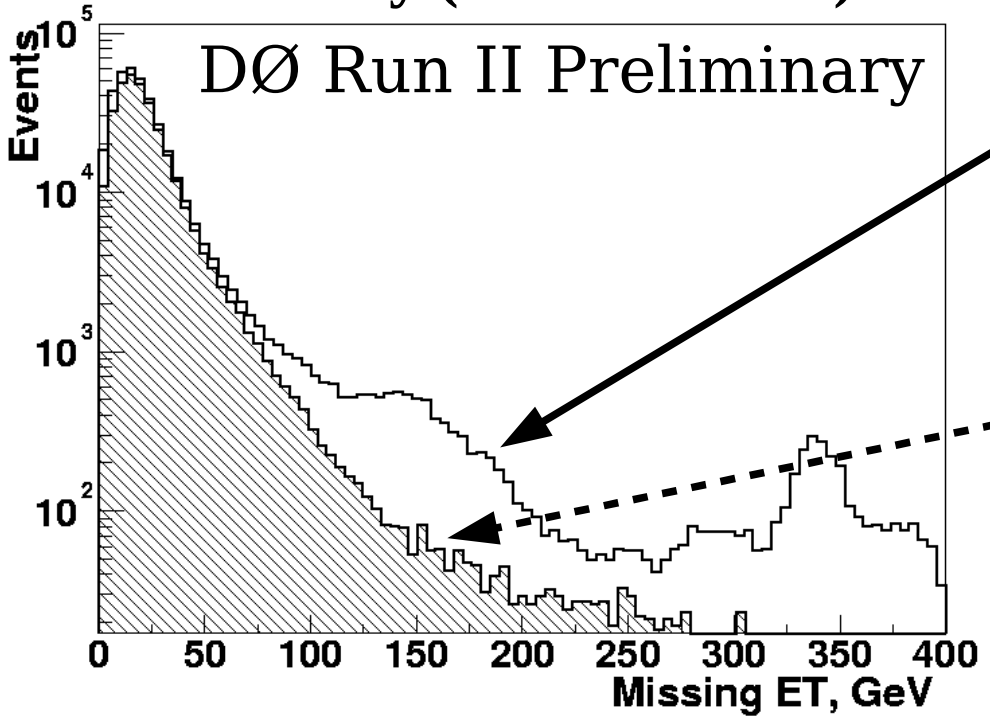


- Solenoid (2T)
- Central tracker
- Silicon Vertex Detector
- Preshower
- Muon forward chamber
- Calorimeter electronic
- Trigger system
- DAQ system

Calorimeter Data Quality

- **Calorimeter Data Quality is very important for Jet+Met analyses, since most calorimeter problems (hot cells, noise...) will increase the MET tail distribution:**
  - **Calorimeter Monitoring programs allow to identify bad runs which are removed from the data sample**
  - **Events well understood as noise patterns are rejected**

S. Shary (CALOR 2004)



Before Calorimeter data cleaning procedure

After Calorimeter data cleaning procedure

Jet Energy Scale (JES)

- All Jet+MET analyses cut on a MET distribution which decreases exponentially
- The main systematic uncertainty comes from the error on the JES
- JES relative error (%) : winter 2004 in red, summer 2004 in green

All analyses here use 0.5 cone jets

$$E_{jet} = \frac{(E_{jet}^{det} - O)}{(R_{jet} S)}$$

raw jet E(GeV)		50	100	150	200
data	old	4.5	4.7	4.8	4.9
	new	2.0	2.1	2.5	3.0
MC	old	6.1	6.4	6.6	6.7
	new	0.8	0.4	0.3	0.4
Combined	old	6.3	8.0	8.2	8.3
	new	2.1	2.1	2.6	3.0

LED and SUSY analyses used winter 2004 JES
LQ analysis used summer 2004 JES

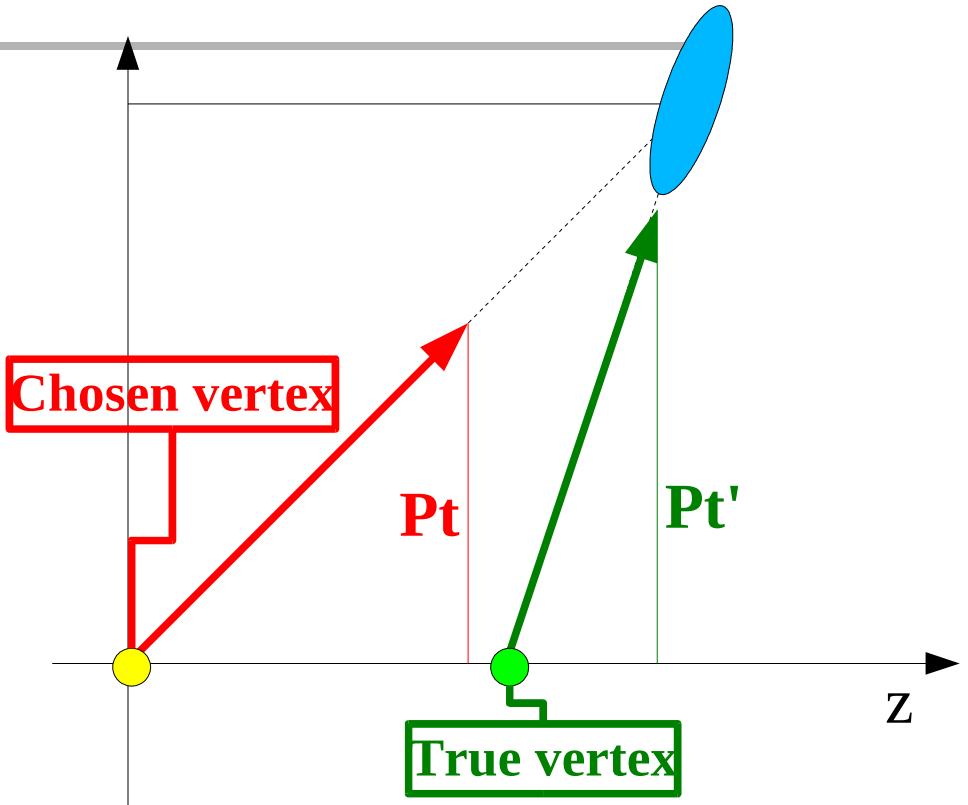
- DATA and MC errors are quadratically added
- 8% relative error on the jet energy => [20%,50%] JES systematic uncertainties at the end of the analyses
- Between winter and summer 2004, JES errors have been reduced by a factor 2-3

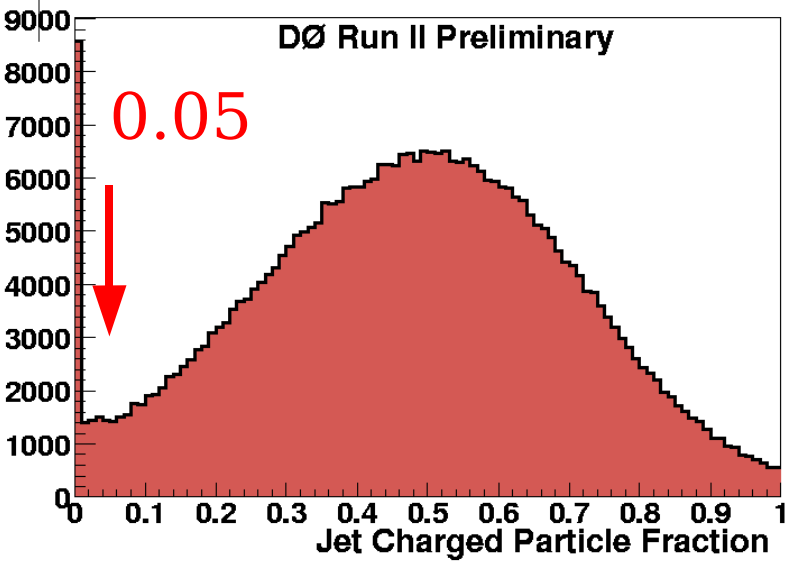
Mis-vertexing and Cosmics

- At RUN I, mis-vertexing creating fake MET was one of the most important source of background in the squark-gluino search
- At RUN II, the improved tracker capabilities is used to reject those events
- Charged Particle Fraction computed per jet with good tracks coming from the chosen vertex:

$$\mathrm{CPF} = \frac{\left(\sum \mathrm{Pt\,good\,associated\,tracks}\right)}{\left(\mathrm{Pt\,jet}\right)}$$

- In case of mis-vertexing, and also of fake jet, CPF is expected to be ~0
- It is a vertex confirmation because of the quality requirements on the tracks entering in the computation of CPF

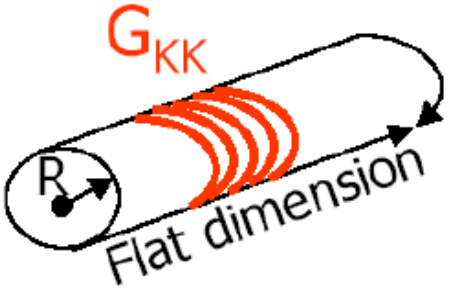




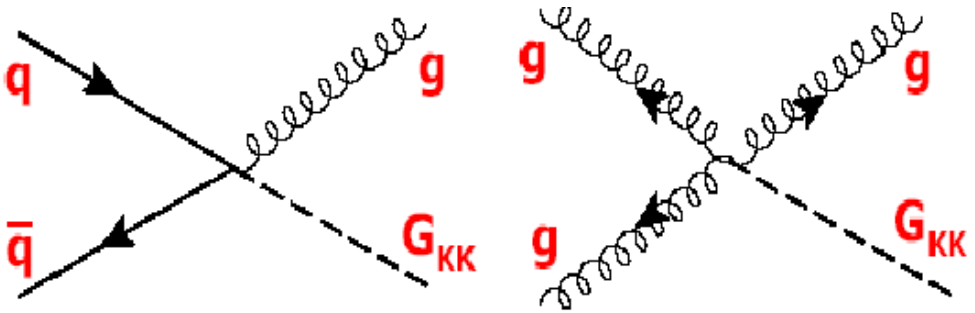
Large ED: Monojet

Large Extra Dimensions

- Theories of large extra dimensions have been proposed as a possible solution of the hierarchy problem
- In a large class of models: series of graviton (G) states called “Kaluza Klein tower”
- Two parameters :
  - The fundamental Planck mass M_D
  - n=number of extra dimensions

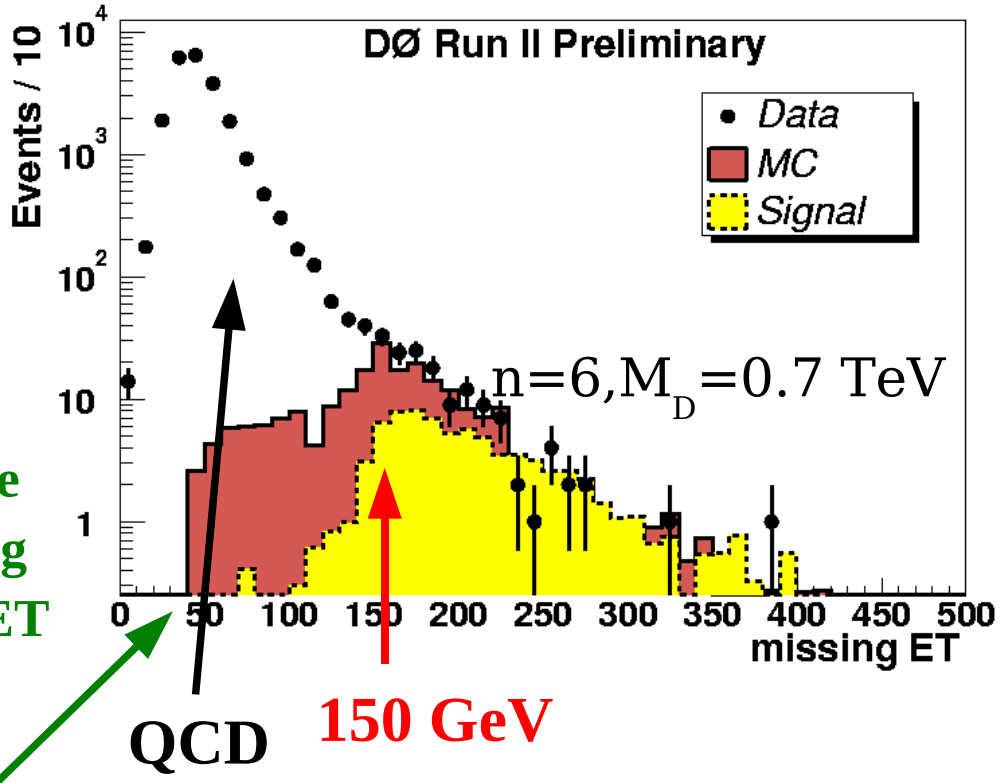


- At the Tevatron:
  - gravitons can be produced recoiling against a quark or a gluon
  - Gravitons escape in the bulk and create MET
  - small gravitational coupling is compensated by the large number of kinematically accessible states



LED : Event Selection

- **Trigger "offline" confirmation:**
  - **MHT > 40 GeV**
- **Cleaning procedure:**
  - **Calorimeter data quality**
  - **|z| vertex < 60 cm**
- **Select events with 1 high Pt jet:**
  - **Pt leading jet > 150 GeV**
  - **|η| leading jet < 1.**
  - **leading jet hadronic**
  - **leading jet track confirmation**
  - **electron and muon veto against W/Z**
- **Topological cuts:**
  - **MET > 150 GeV**
  - **Pt 2nd leading jet < 50 GeV**
  - **min. ΔΦ(MET, jet) > 30°**



before cutting on MET

2nd jet with low Pt is allowed

cut on the phi angle between any jet and MET to reject events where one of the jet energy fluctuates and creates fake MET

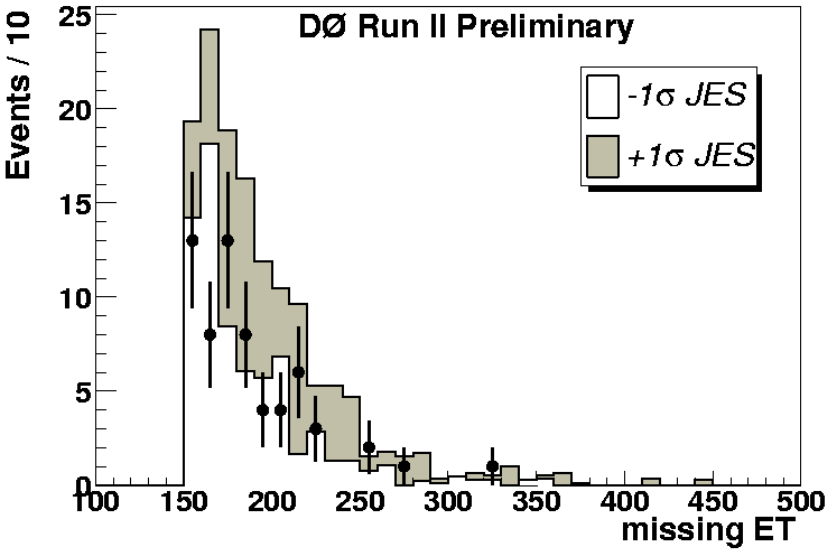
LED : Event Selection

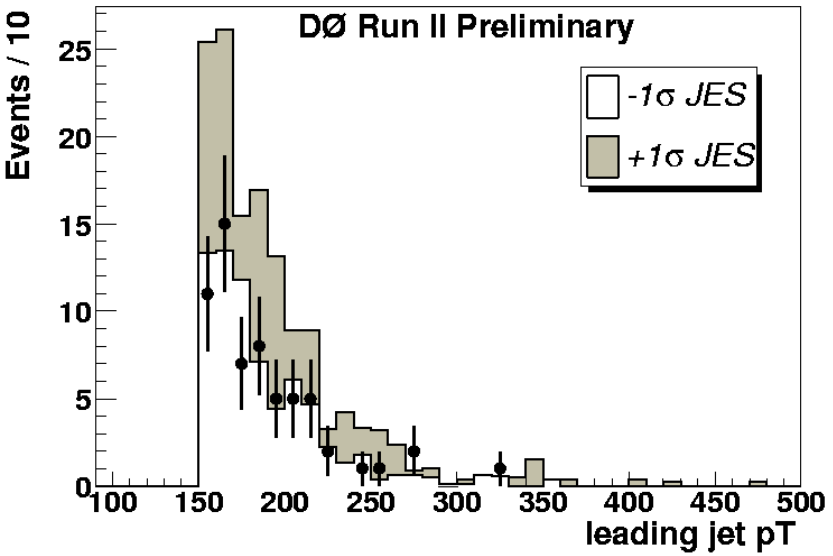
- No QCD background remaining
- main background:
  - $Z \rightarrow \nu\nu$ + jets
- Signal :
  - Scanning :
    - n = 4,5,6,7
    - M_D = 0.6, 0.7, 0.8 TeV
  - Efficiencies : 4.7%to 5.4%
- Excess of SM but within systematic uncertainty (next slide)

	N events
W -> enu + jets	5.3 ± 1.6 (stat)+2.7 -1.6 (JES)
W -> munu + jets	12.0 ± 1.9 (stat)+6.0 -3.6 (JES)
W -> taunu + jets	22.2 ± 3.5(stat)+11.1 -6.7 (JES)
Z ->nunu + jets	60.5 ± 4.5(stat)+30.2 – 18.1(JES)
SM back.	100.2 ± 6.2 (stat)+50.1 -30.1 (JES)
Data	63
M=700, Nd=6	57.3 ± 2.2 (stat) ± 11.5 (JES)

LED : Systematic Uncertainties

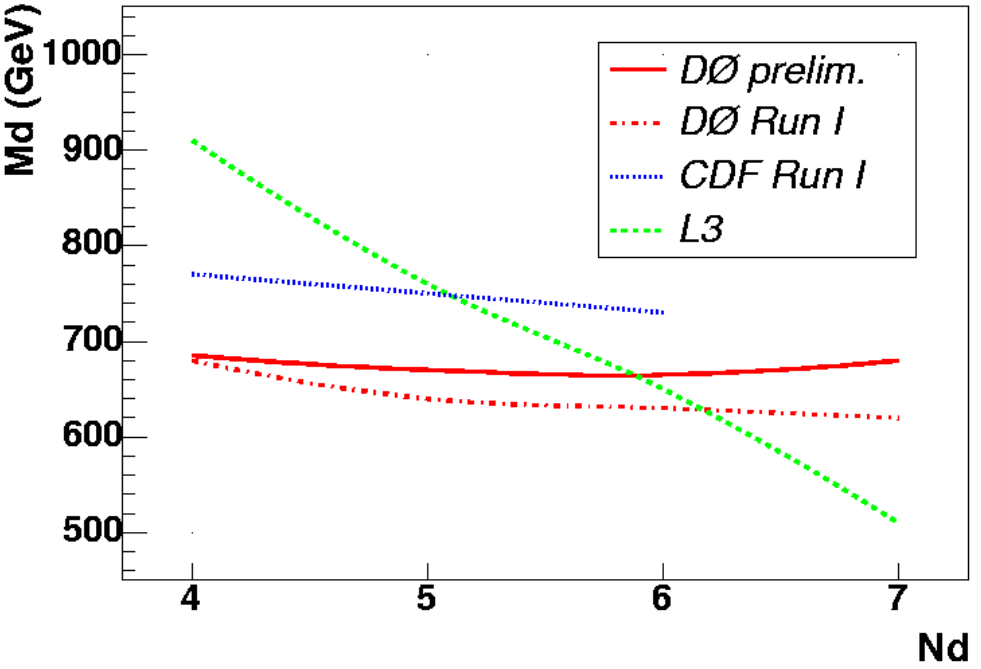
- **Systematic uncertainties:**
  - **Integrated luminosity: 6.5%**
  - **In the data and MC Jet Energy Scales:**
    - **SM backgrounds : +50% -30%**
    - **Signal : +20% -20%**
    - **JES errors are fully correlated between SM backgrounds and signal**
  - **Cross-section and PDF:**
    - **CTEQ5L has been used for the signal cross-section in the analysis**
    - **Other PDF have been used for systematics which increase by ~10% the signal cross-section**
    - **Conservatively: no systematics from PDF**
- **Excess of SM background is within systematic errors**





LED: Results

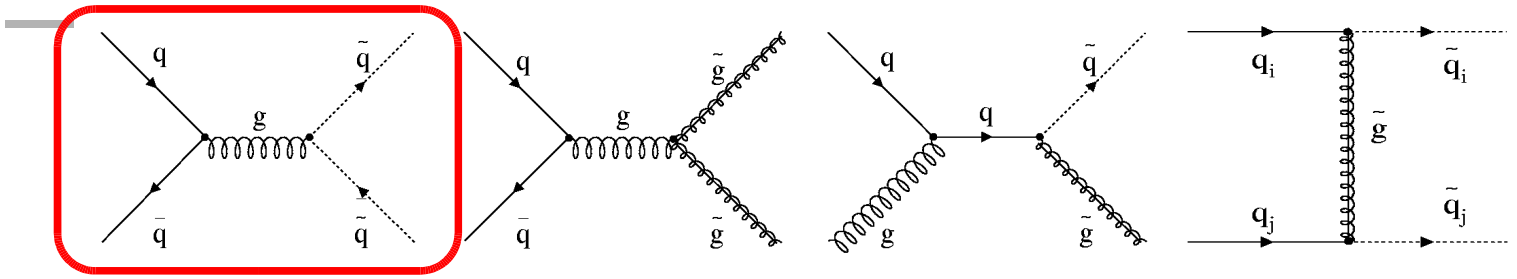
- 95 % CL level cross-section limits are derived using the CLs approach taking correctly into account correlations between errors:
  - JES systematic error is fully correlated between SM back. and signal
  - Without proper error correlation treatment, obtained limits would be increased
- Results still below CDF RUN I result
- This analysis will greatly benefit from the new JES we have with lower errors



n_D	DØ RII	CDF RI	LEP
4	0,68	0,77	0,91
5	0,67		0,76
6	0,66	0,73	0,65
7	0,68		0,51

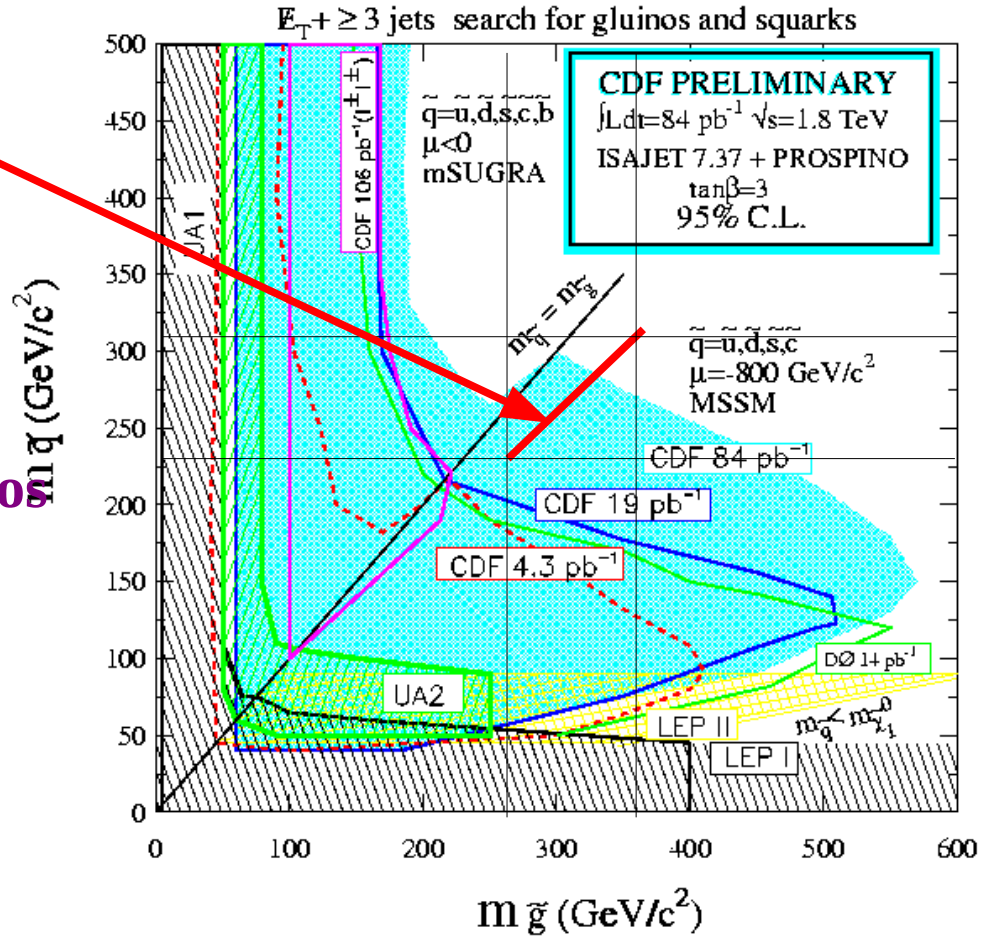
SUSY:
Squarks & Gluinos

SUSY: Squarks & Gluinos



dominant

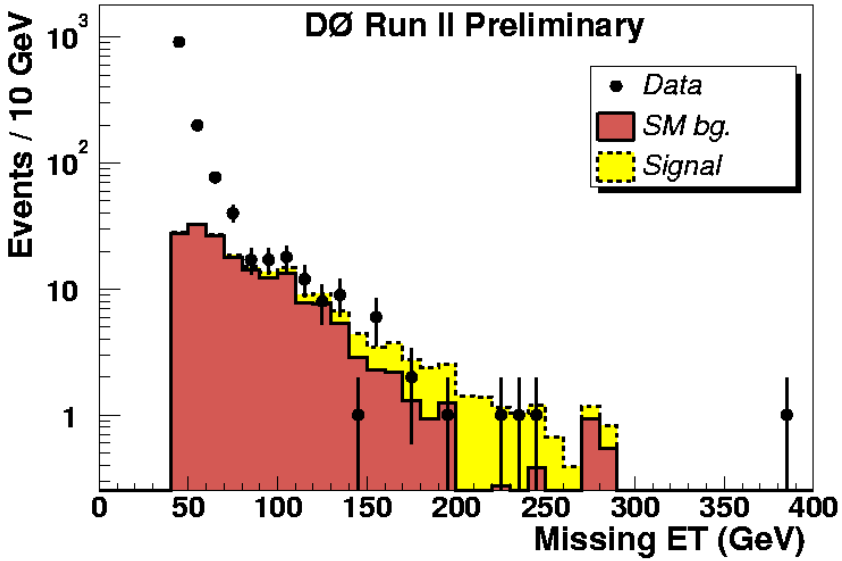
- **mSUGRA model :**
  - **m0 = 25, tan(beta)=3, A0 = 0, mu<0**
  - **m1/2 = [100-140]**
- **R-parity is conserved : Lightest neutralino is the LSP**
- **Squarks are always lighter than gluinos**
- **Only 1st and 2nd squark generations**
- **sq-sqbar production is dominant**
- **All cascade decay implemented**
- **Analysis is optimized to search for acoplanar dijet event**



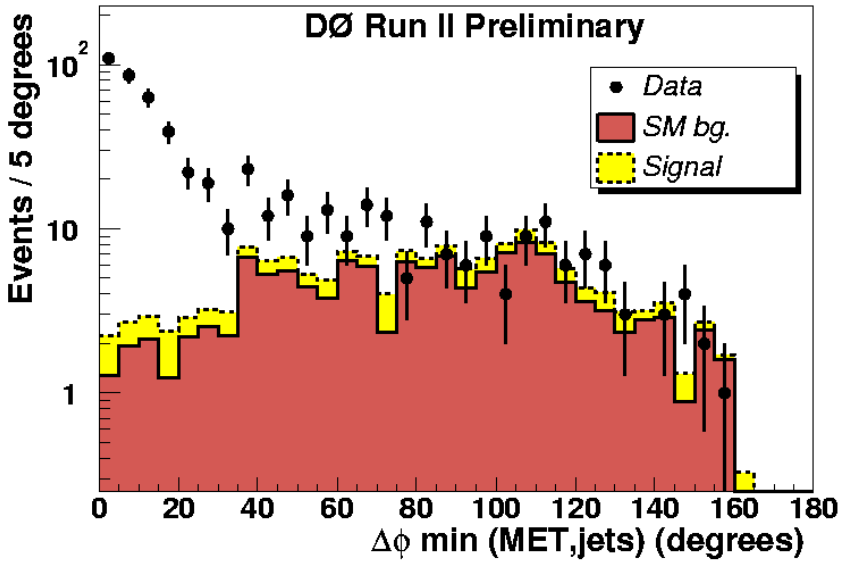
SUSY: pre-selection

- **Trigger "offline" confirmation:**
  - **MHT > 40 GeV**
- **Cleaning procedure:**
  - **Calorimeter data quality**
  - **|z| vertex < 60 cm**
  - **Jet track confirmation (1st or 2nd)**
  - **2 leading jets hadronics**
- **Select acoplanar dijet events:**
  - **acoplanarity < 165°**
  - **Pt 1st leading jet > 60 GeV**
  - **|η| 1st leading jet < 0.8**
  - **Pt 2nd leading jet > 50 GeV**
  - **EM and muon veto**
- **Topological cuts:**
  - **MET > 60 GeV**
  - **min. ΔΦ(MET, jet) > 30°**
  - **max. ΔΦ(MET, jet) < 165°**
- **Final optimization (next slide)**

All cuts applied except MET > 60 GeV



All cuts applied except min. ΔΦ(MET, jet) > 30°

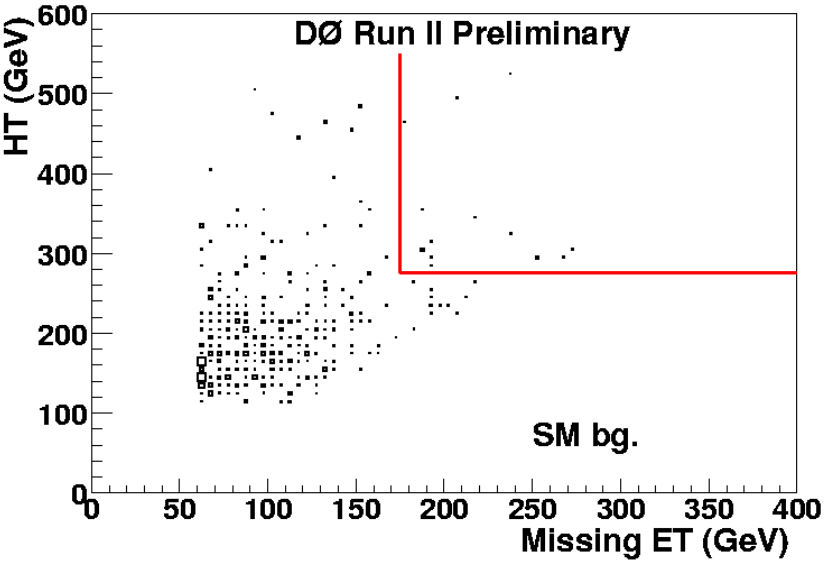


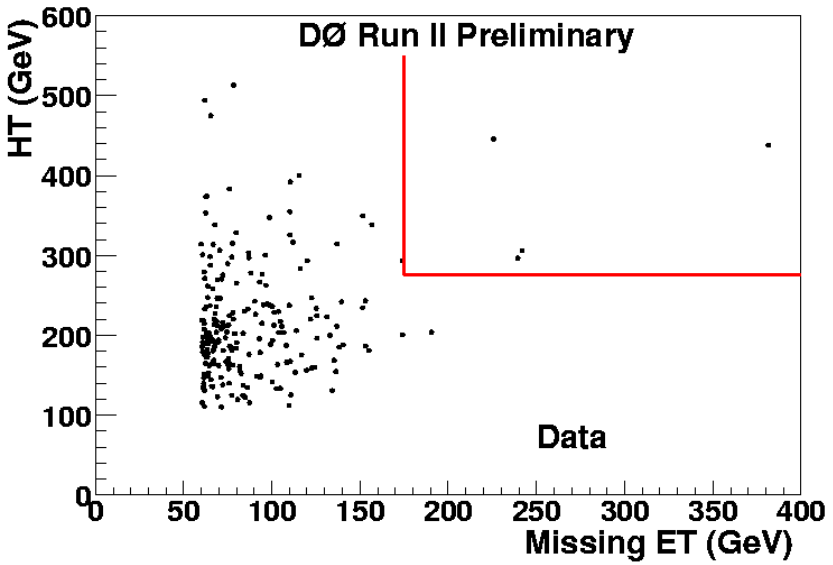
SUSY: Final Optimization

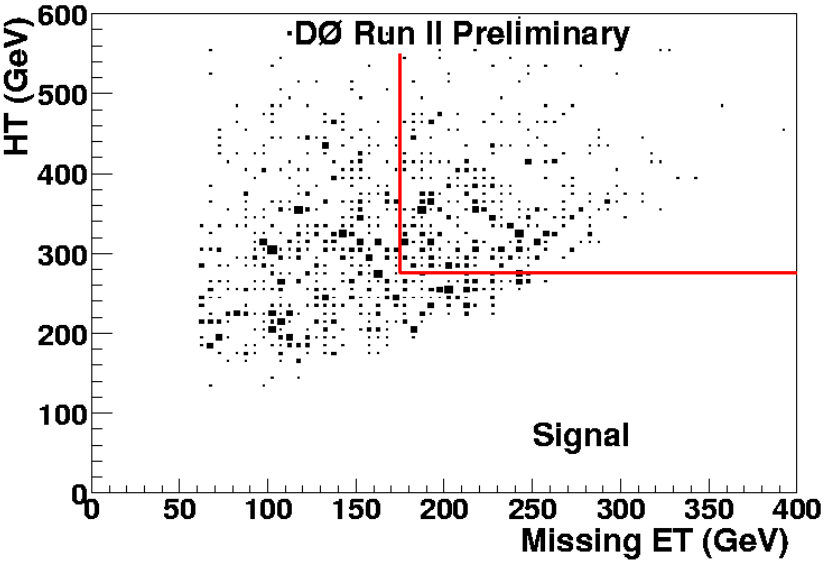
- **Final optimization performed varying the cuts on:**
  - **MET**
  - **HT**

$$HT = \sum |\vec{P}_t^{jet}|$$

- **Expected cross-section limit is computed for all combinations (CLs approach)**
- **Optimal set of cuts is :**
  - **MET > 175 GeV**
  - **HT > 275 GeV**





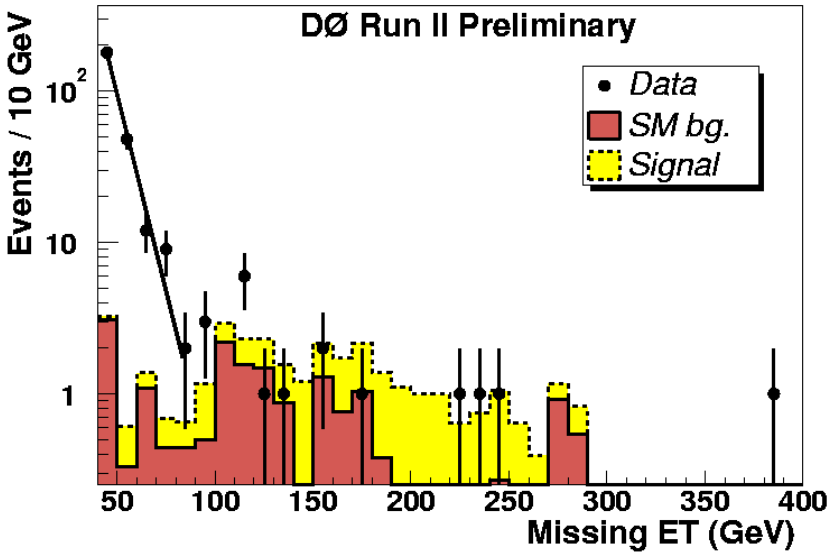


SUSY: Results

- **QCD background:**
  - QCD is fitted in the low MET region (all cuts expect MET cuts)
  - QCD background is found to be negligible for MET > 175 GeV
  - It is conservatively neglected when computed the limits

	N events
W -> enu + jets	0.22 ± 0.16 (stat)+0.17 -0.10 (JES)
W ->munu + jets	0.45 ± 0.23 (stat)+0.35 -0.19 (JES)
W ->taunu + jets	0.65 ± 0.66 (stat)+0.50 -0.28 (JES)
Z ->nunu + jets	1.35 ± 0.62 (stat)+1.04 -0.58(JES)
SM back.	2.67 ± 0.95 (stat)+2.05 -1.15 (JES)
Data	4

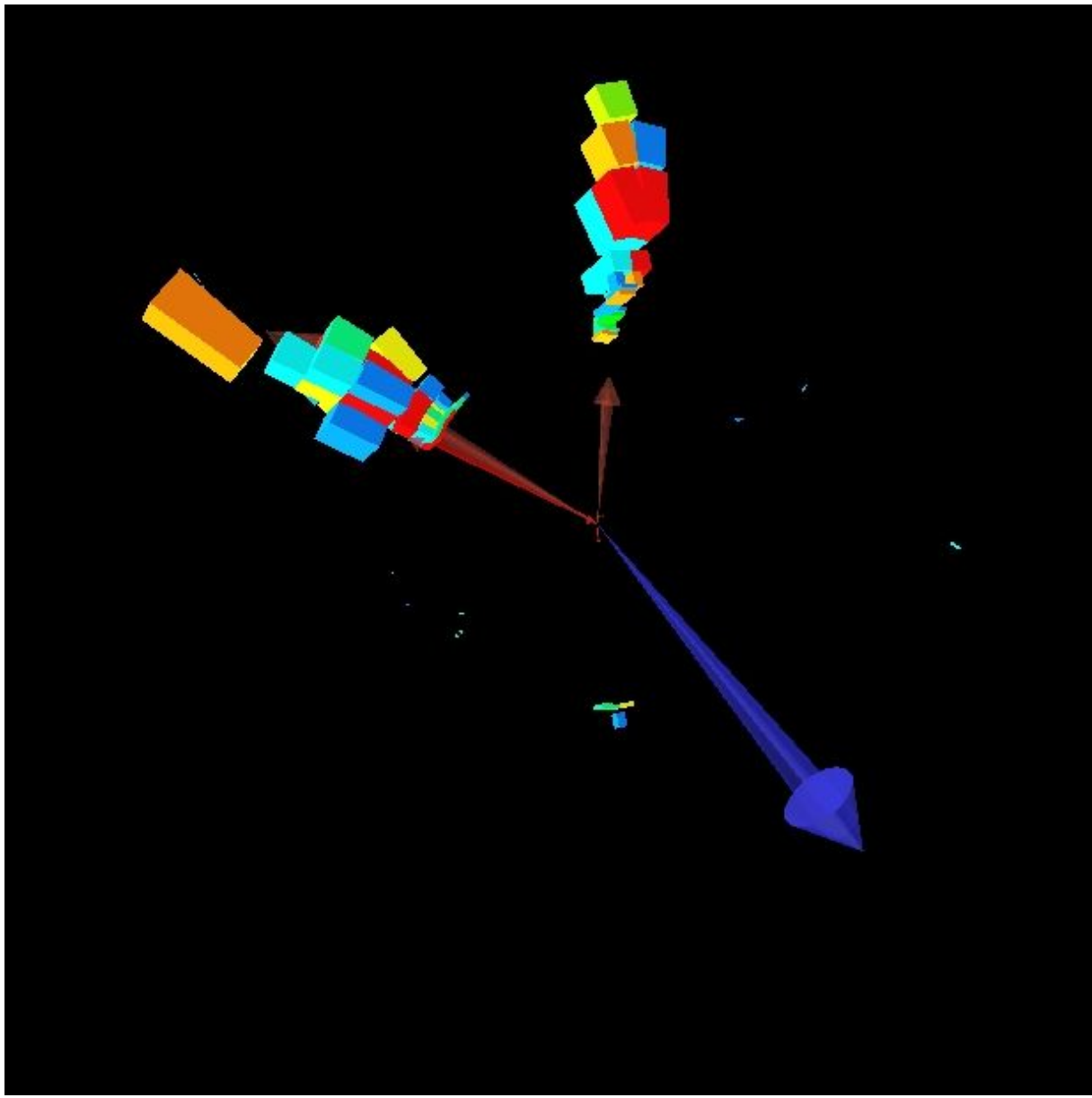
- **Signal:**
  - Efficiencies ranges from 2.1% (m1/2=100) to 7.1%(m1/2=140)



- **Systematic uncertainties:**
  - Integrated luminosity: 6.5%
  - in the data and MC Jet Energy Scales:
    - SM backgrounds : +77% -43%
    - Signal : +20% -15%
  - cross-sections:
    - SM backgrounds : 8%
    - Signal : 10%

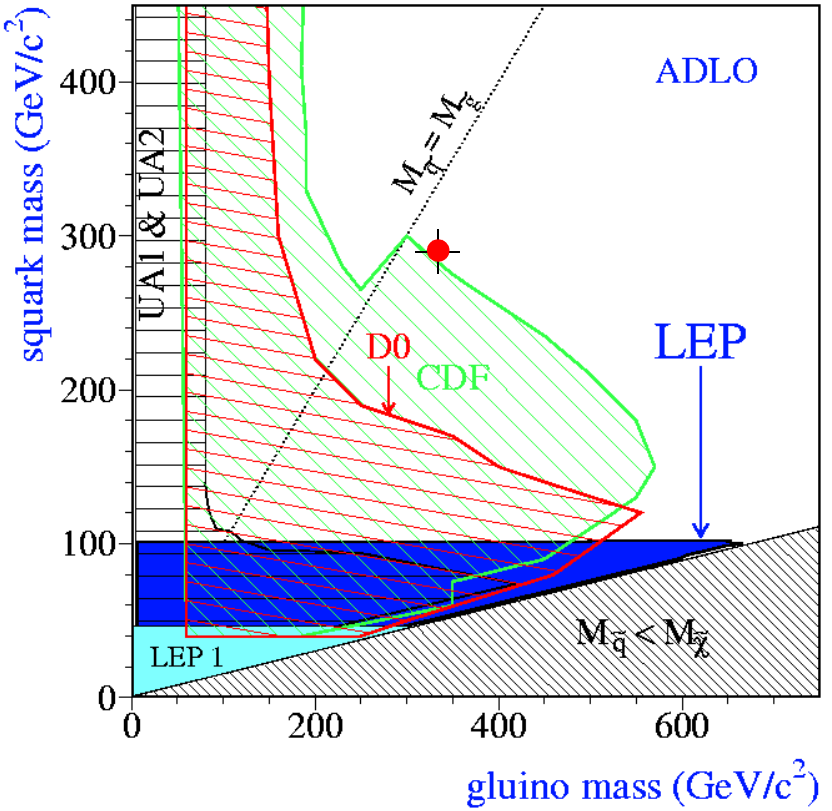
SUSY: Highest MET Candidate

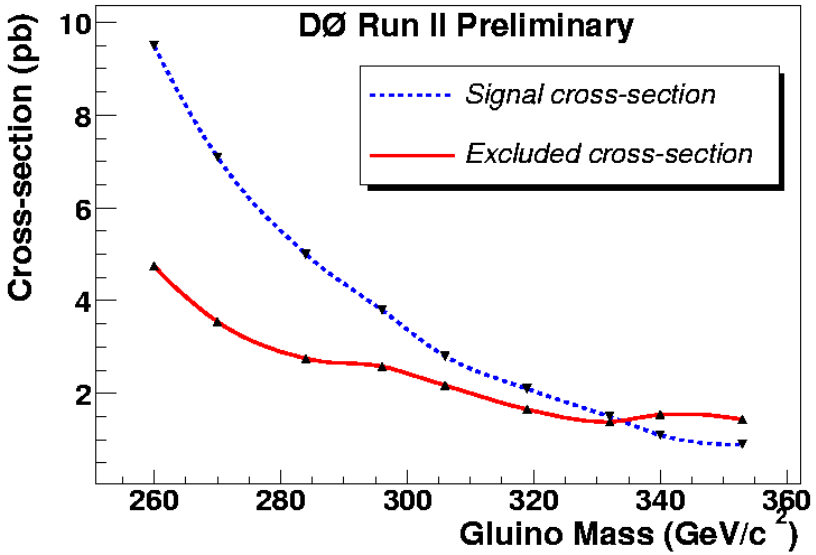
- **Highest MET candidate:**
  - **MET = 381 GeV**
  - **HT = 431 GeV**
  - **2 High Pt jet:**
    - **jet 1 : 289 GeV**
    - **jet 2 : 117 GeV**
  - **+ 2 Low Pt jet (11 and 14 GeV)**

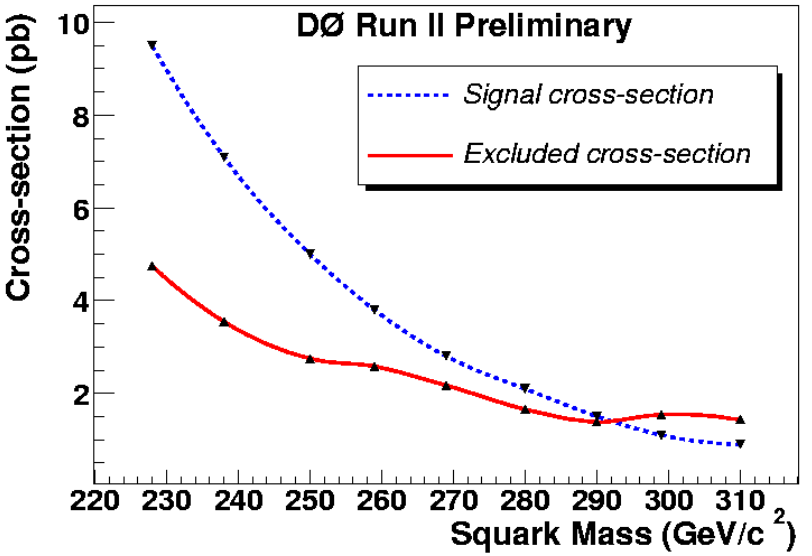


SUSY: Results

- Cross-sections upper limits (@ 95% CL) have been obtained for the set of mSUGRA parameters considered:
  - m0 = 25, tan(beta)=3, A0 = 0, mu<0
  - PYTHIA cross-sections with PROSPINO K-factors
  - Cls approach with correlations between systematic errors properly taken into account
- Msquark > 292 GeV/c^2 - Mgluino > 333 GeV/c^2
- These results slightly improve CDF results obtained at RUN I





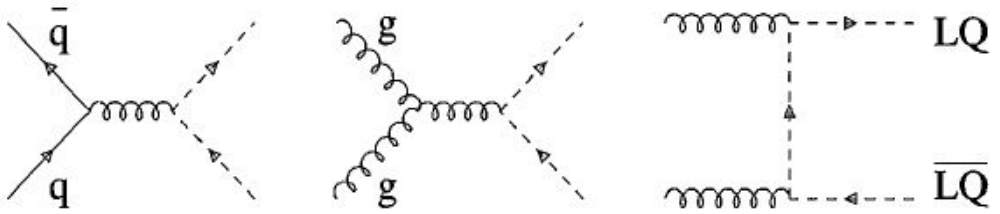


Scalar Leptoquarks: $\nu\nu$qq Channel

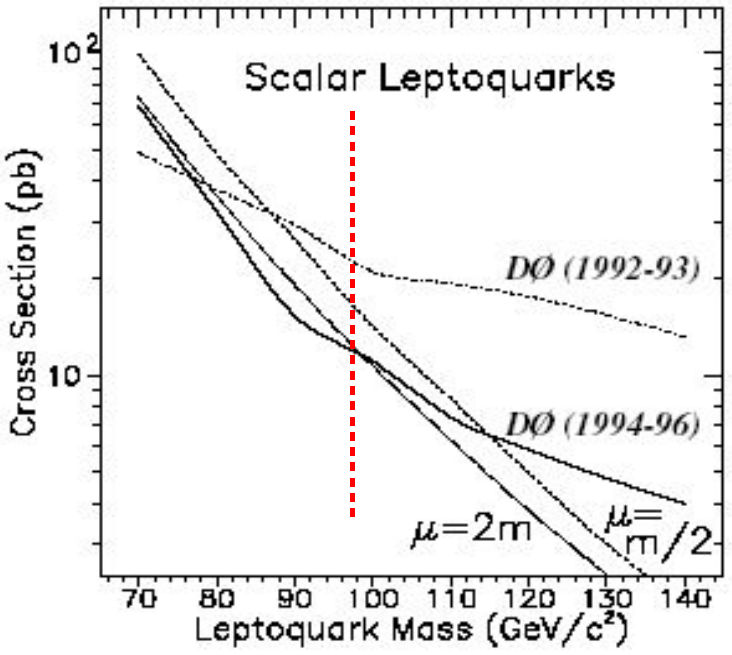
Leptoquarks

- **Leptoquarks: connect the lepton and quark sectors**
- **At the Tevatron, leptoquarks are pair-produced**

$$q + \bar{q} \rightarrow LQ + \overline{LQ},$$
$$g + g \rightarrow LQ + \overline{LQ}.$$



- **Scalar leptoquarks are considered with BR(LQ→qν)=100%**
  - **acoplanar dijet topology**

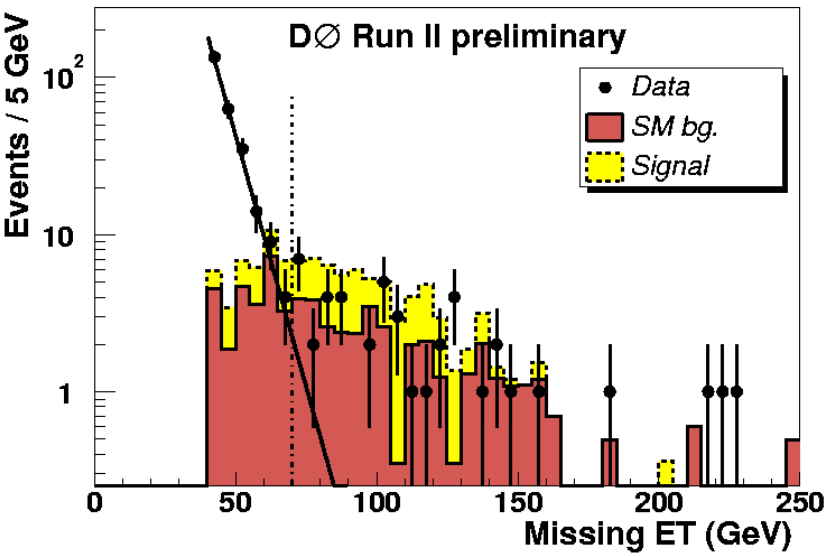


- **DØ RUN I result: 85.2 pb^{-1}**
  - **No excess observed**
  - **95% CL limit on the LQ mass:**
    - **98 GeV/c^2**

LQ : pre-selection

- The LQ analysis pre-selection is very closed to the SUSY analysis:
- Trigger "offline" confirmation:
  - MHT > 40 GeV
- Cleaning procedure:
  - Calorimeter data quality
  - |z| vertex < 60 cm
  - Jet track confirmation (1st or 2nd)
  - 2 leading jets hadronics
- Select acoplanar dijet events:
  - acoplanarity < 165°
  - Pt 1st leading jet > 60 GeV
  - |η| 1st leading jet < 0.8
  - Pt 2nd leading jet > 50 GeV
  - EM and muon veto
- Topological cuts:
  - MET > 60 GeV
  - min. ΔΦ(MET, jet) > 30°
  - max. ΔΦ(MET, jet) < 165°

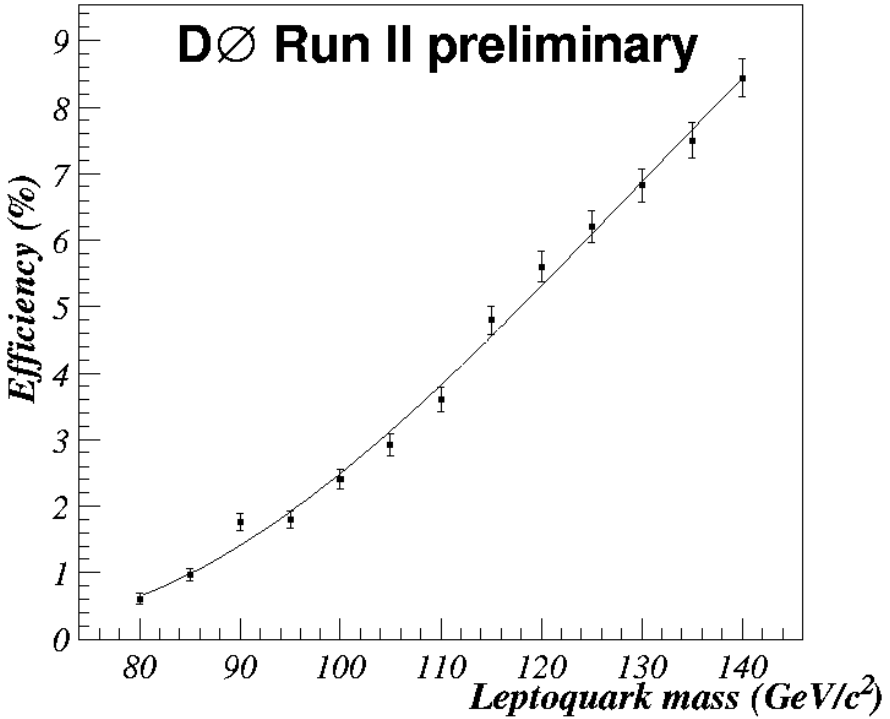
- LQ analysis is using summer 2004 JES with lower errors
- Isolated track veto to remove remaining $W \rightarrow l\nu$ + jets background:
  - no isolated tracks with Pt > 5 GeV
- require exactly 2 or 3 jets
- At the end, a cut is performed on MET to mininize the expected excluded cross-section: MET>70 GeV



LQ : Results

- **QCD background:**
  - **MET distribution (all cuts expect MET cuts) is fitted**
  - **QCD background is found to be small: 3.1 ± 2.0 events**

	N events
W -> enu + jets	2.9 ± 0.6 (stat) ± 0.3 (JES)
W -> munu + jets	4.3 ± 0.7 (stat) ± 0.4 (JES)
W -> taunu + jets	10.6 ± 2.6 (stat) ± 1.1 (JES)
Z -> nunu + jets	20.6 ± 2.4 (stat) ± 2.1 (JES)
QCD back.	3.1 ± 2.0
Total back.	41.5 ± 4.2 (stat) ± 2.9
Data	44

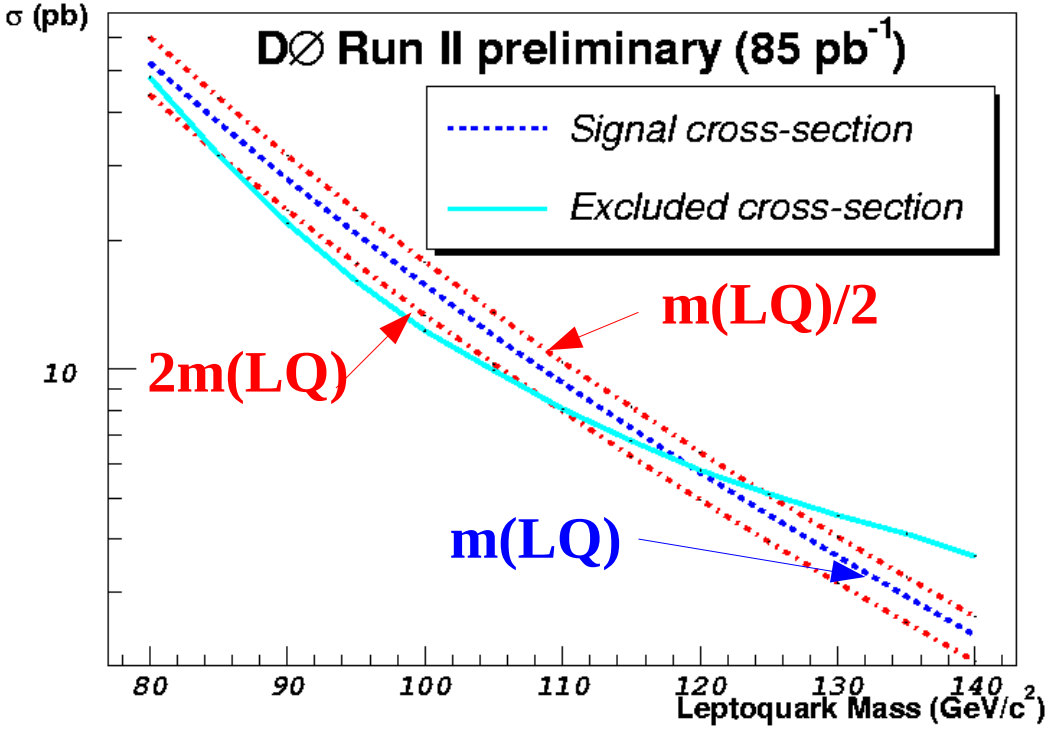


- **Signal efficiencies:**
  - **parametrized as a function of the LQ mass**
  - **0.6 % (m(LQ) = 80 GeV) to 8.4 % (m(LQ) = 140 GeV)**

LQ : systematic Uncertainties & Limits

- **Systematic uncertainties:**
  - **Integrated luminosity: 6.5%**
  - **in the data and MC Jet Energy Scales:**
    - **SM backgrounds : +10% -10%**
    - **Signal : +13% -10%**
  - **PDF for signal generation:**
    - **Signal : 5 %**
- **Signal cross-section:**
  - **with PDF CTEQ6.1**
- **LQ mass range excluded :**
  - **[85-109] GeV/c^2 for renormalization scale = 2m(LQ)**
  - **The mass lower limit is 120 GeV/c^2 for renormalization scale = m(LQ)**
- **This result improves on previous RUN I limits**

- **Cross-sections upper limits (@ 95% CL) have been obtained as a function of the LQ mass:**
  - **Cls approach with correlations between systematic errors properly taken into account**

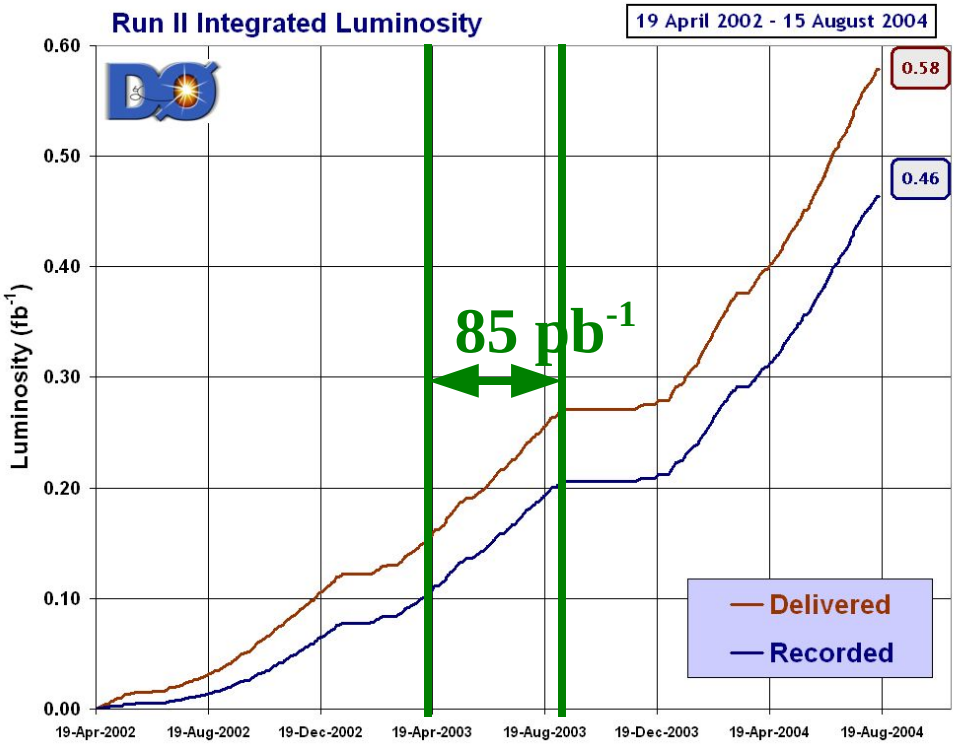


CDF RUN II result: no excess

M(LQ) > 117 GeV/c^2 with 191 pb^{-1}

Conclusion

- With 85 pb^{-1} (~RUN I luminosity), no excess of events has been observed in the Jet+MET topology at DØ RUN II.
- The 3 analyses (LED, SUSY, LQ) set new limits which extend RUN I results
- Improvements are still expected with better control of the Jet Energy Scale (LED and SUSY analyses)
- Data already on tape and which will be recorded in the next few years will allow to continue those searches in unexplored regions



backup slides

MHT30_3CJT5 Trigger

- It is a difficult task to trigger efficiently on Jet+MET events because of the QCD background

$$MHT = |\sum \vec{P}_t^{jet}|$$

- MHT30_3CJT5 trigger has been designed for Jet+MET analyses (HZ→bbνν, stop and sbottom, squarks, leptoquarks, monojets)
- Trigger requirement :
  - L1 : at least 3 trigger towers with 5 GeV - 155 Hz
  - L2 : MHT > 20 GeV - 28 Hz
  - L3 : MHT > 30 GeV - 1.9 Hz

At L1/L2: $|\eta| < 3.2$

- This trigger is available since April 2003
- The trigger efficiencies are calculated using set of parameterized functions tuned on data
- The trigger efficiencies are almost 100 % for the final selections (LED, SUSY, LQ)