Leptoquark Searches at DØ

Jose Lazoflores

Florida State University

for

The DØ Collaboration at Fermilab

August 28, 2004

Introduction

- Search for leptoquarks (LQ)
  - First generation (LQ1):
    - 2 electrons and 2 jets
    - 1 electron, 2 jets and missing energy
  - Second generation (LQ2):
    - 2 muons and 2 jets
- Conclusion and outlook

Introduction

- Leptoquarks:
  - Predicted to exist by various extensions of the Standard Model (SM).
  - Could explain observed symmetry between quarks and leptons.
  - Carry color, fractional electric charge, and both lepton and baryon numbers.

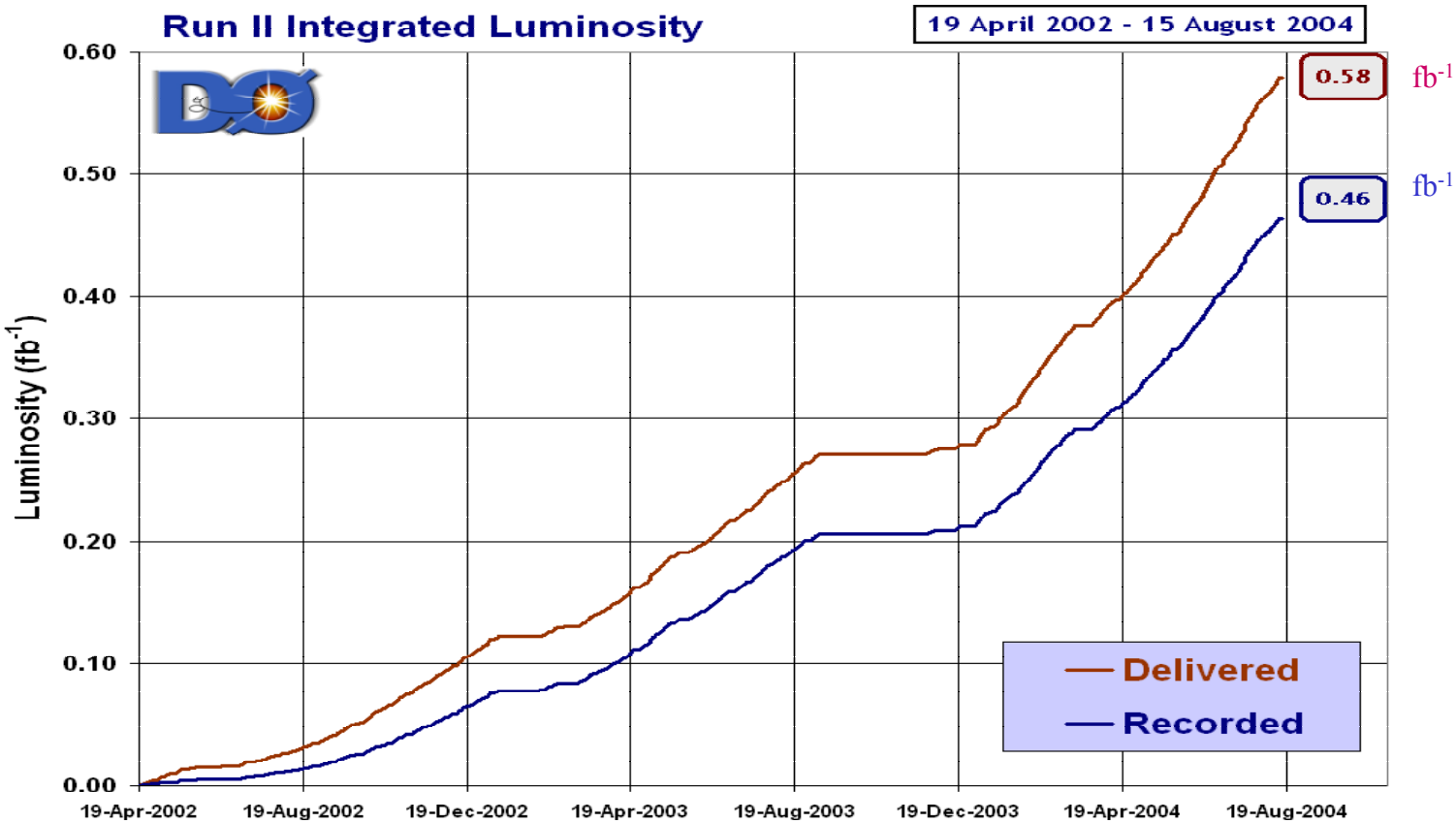
First Generation $\begin{pmatrix} u \\ d \end{pmatrix} \leftrightarrow LQ_1 \leftrightarrow \begin{pmatrix} e \\ \nu_e \end{pmatrix}$

Second Generation $\begin{pmatrix} c \\ s \end{pmatrix} \leftrightarrow LQ_2 \leftrightarrow \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix}$

Third Generation $\begin{pmatrix} t \\ b \end{pmatrix} \leftrightarrow LQ_3 \leftrightarrow \begin{pmatrix} \tau \\ \nu_\tau \end{pmatrix}$

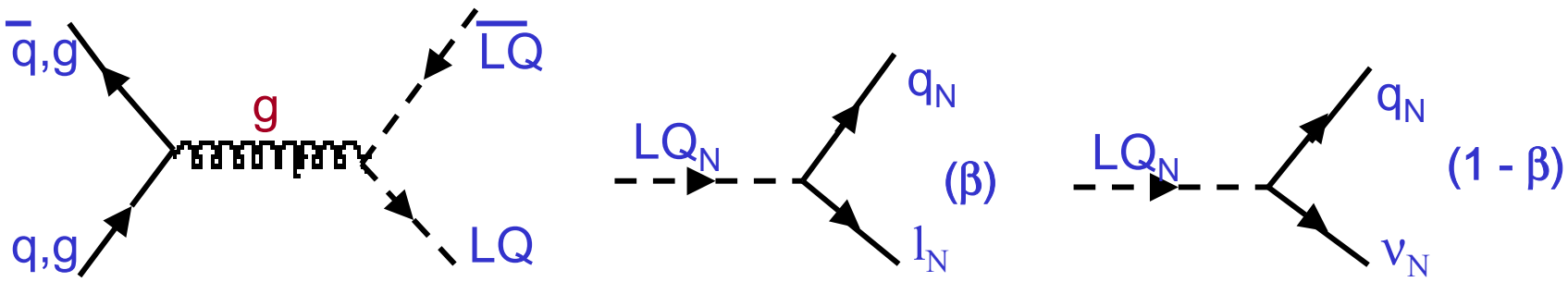
  - Assume no intergenerational mixing.
  - Scalar and vector leptoquarks are possible.
  - Results for scalar LQ are shown here.

Integrated Luminosity



Analyses presented in this talk use a subset of this data.

Signal At the Tevatron



- Pair production modes:
  - Quark anti-quark annihilation.
  - Gluon fusion.
- Decays within the detector.
- Decay parameterized by β.

  β = LQ branching fraction to charged lepton + quark.

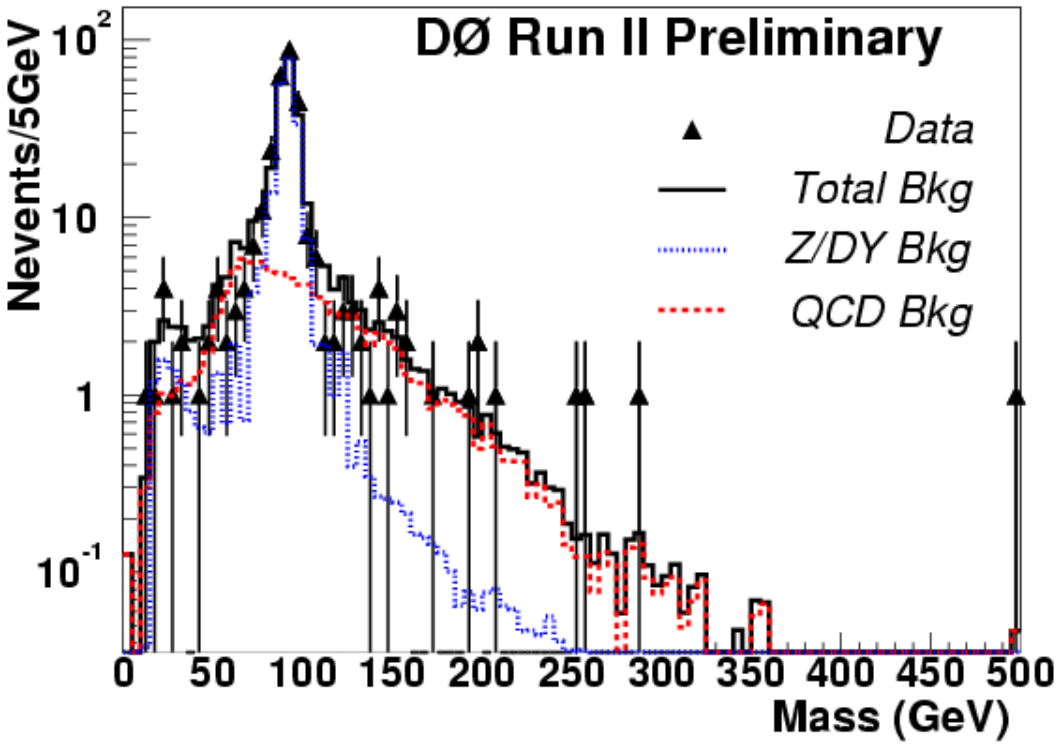
- Possible signatures:
  - 2 leptons (both e or both μ) + 2 jets with no missing energy.
  - 1 lepton + 2 jets + missing energy.
  - 2 jets + missing energy.

- Combined DØ-CDF Run I 1st generation LQ limit:

  $M_{LQ1} > 242$ GeV for $\beta = 1.0$.

2 Electrons and 2 Jets

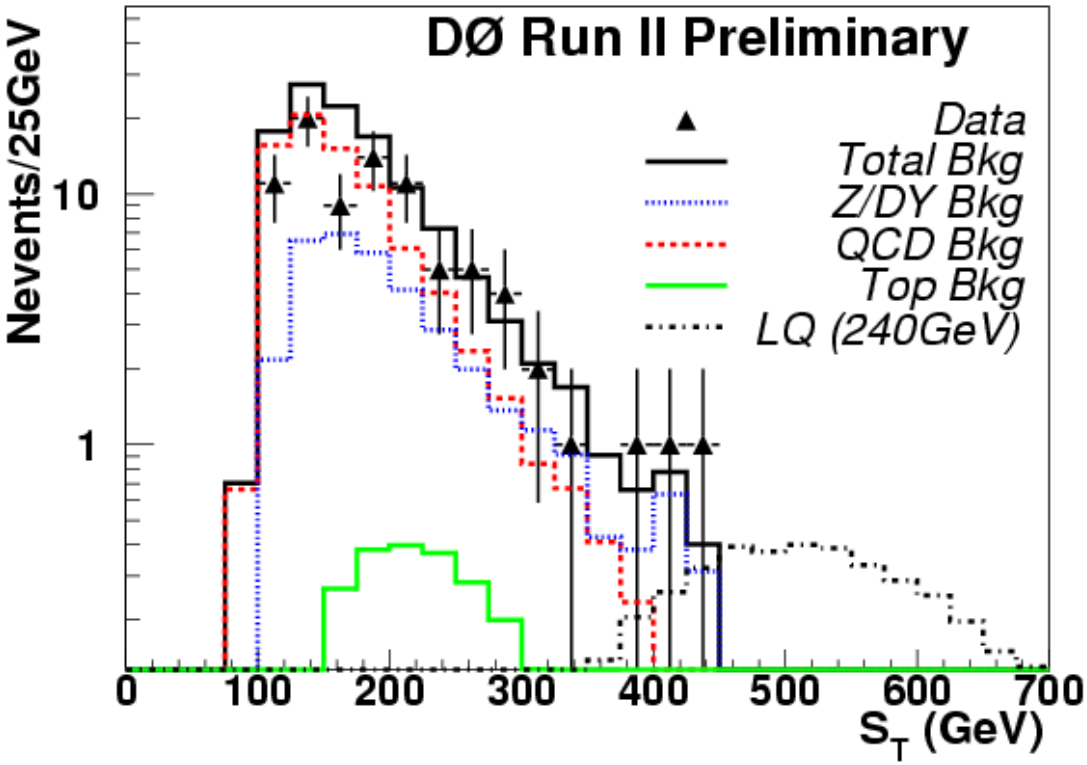
2 Jets with E_T > 20 GeV
2 Electrons with E_T > 25 GeV



- Main backgrounds
  - 2 jets + 2 real electrons from Z^0/Drell-Yan events.
    - Estimated using MC
  - 2 jets and 2 misidentified electrons.
    - Estimated using data with 4 jets and misid probability.
- Z mass cut:
  - Reject events with 80 GeV < mass < 102 GeV

Integrated luminosity = 175 pb^{-1}.

2 Electrons and 2 Jets



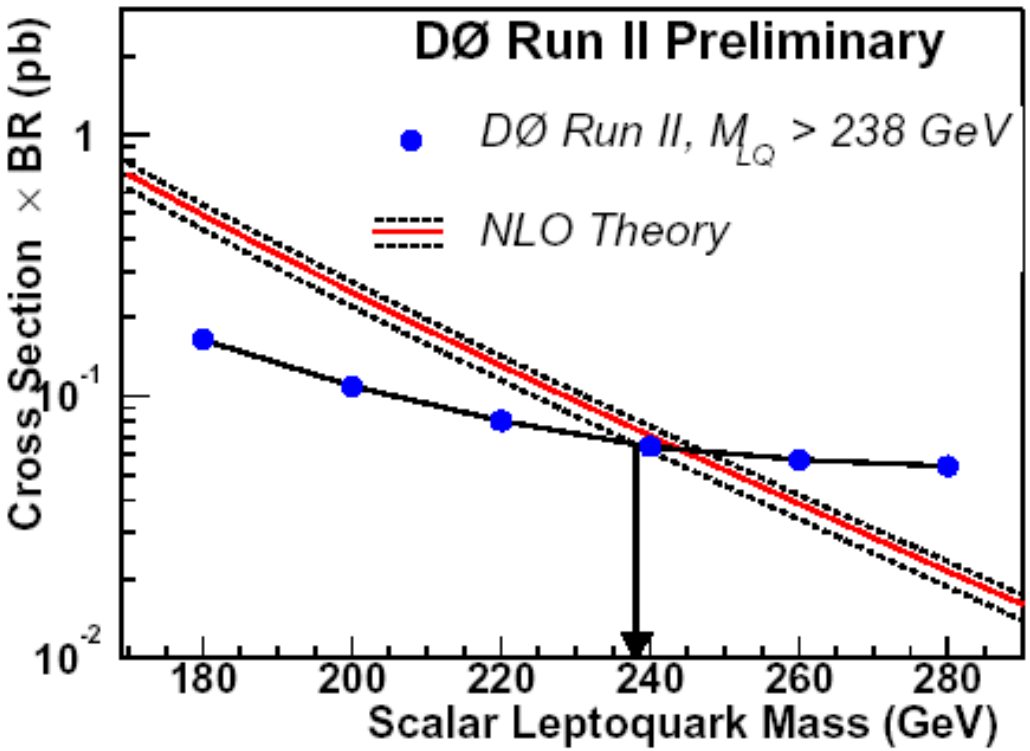
$$S_T = E_T^{e1} + E_T^{e2} + E_T^{Jet1} + E_T^{Jet2}$$

Use Monte Carlo events and QCD events from data to select cuts that optimizes expected limit, assuming no signal.

Require $S_T > 450$ GeV

2 Electrons and 2 Jets

95% confidence level experimental cross-section and NLO theory cross-section.



The mass limit is determined by the point where the experimental cross-section limit crosses the line of the theory prediction

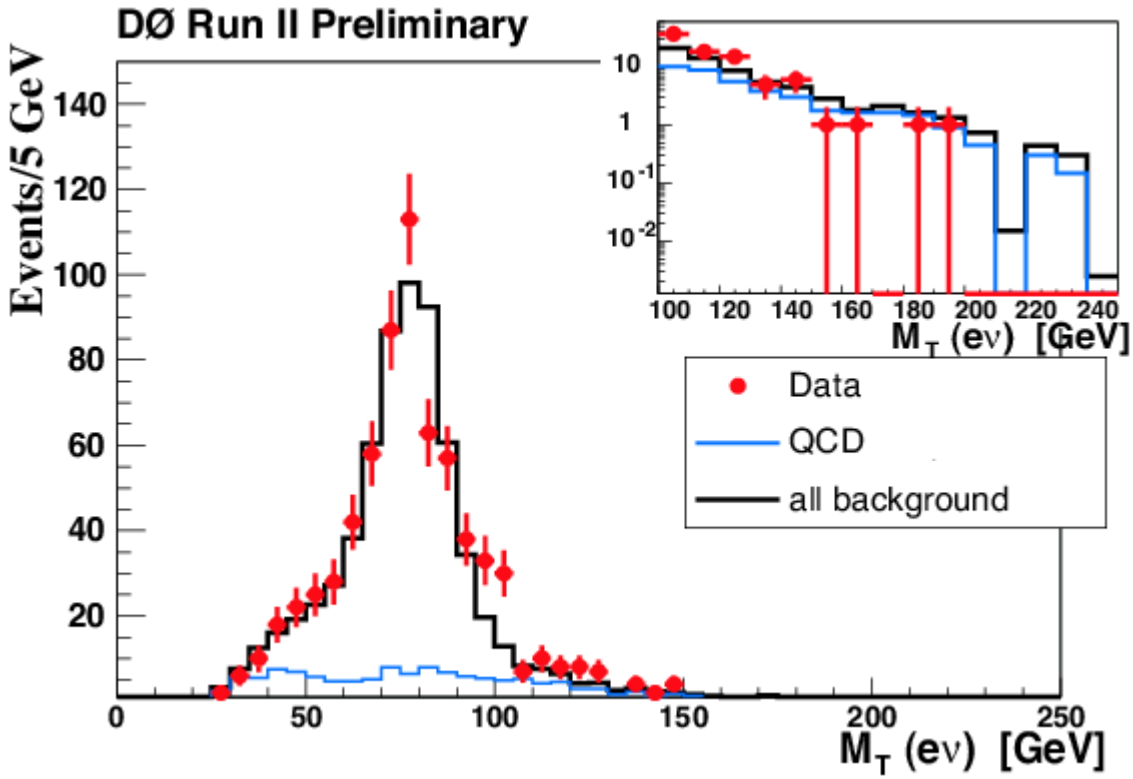
1 Electron, 2 Jets and Missing E_T

1 electron with E_T > 35 GeV
2 jets with E_T > 25 GeV
Missing E_T > 30 GeV

Main Background:

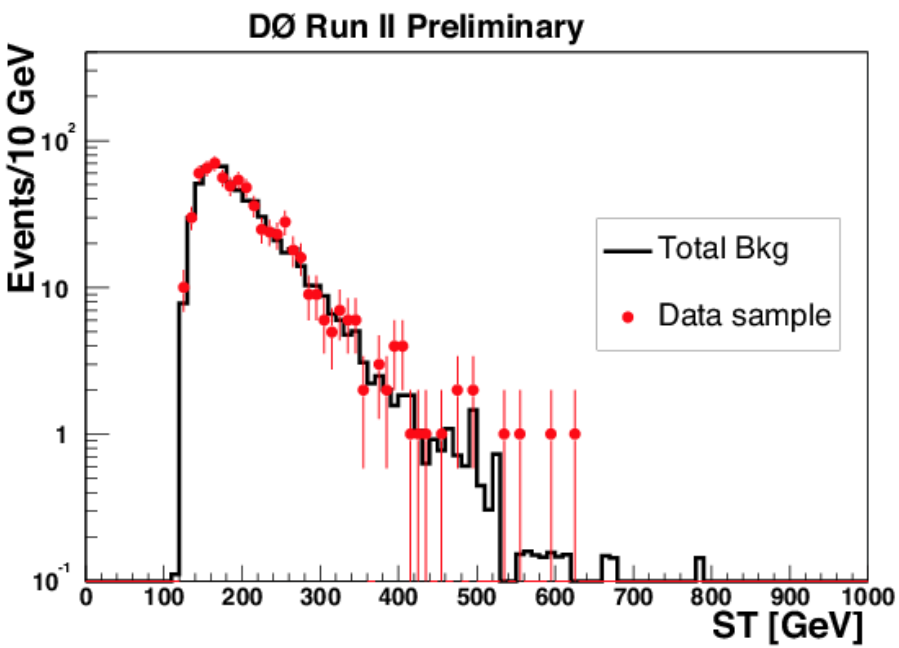
- W + jets
- Misidentified electron + 2 jets
  - Determined from data.
  - Missing E_T shape from QCD events with "almost identified" electrons.
  - Normalize to electron + jets data at low missing E_T

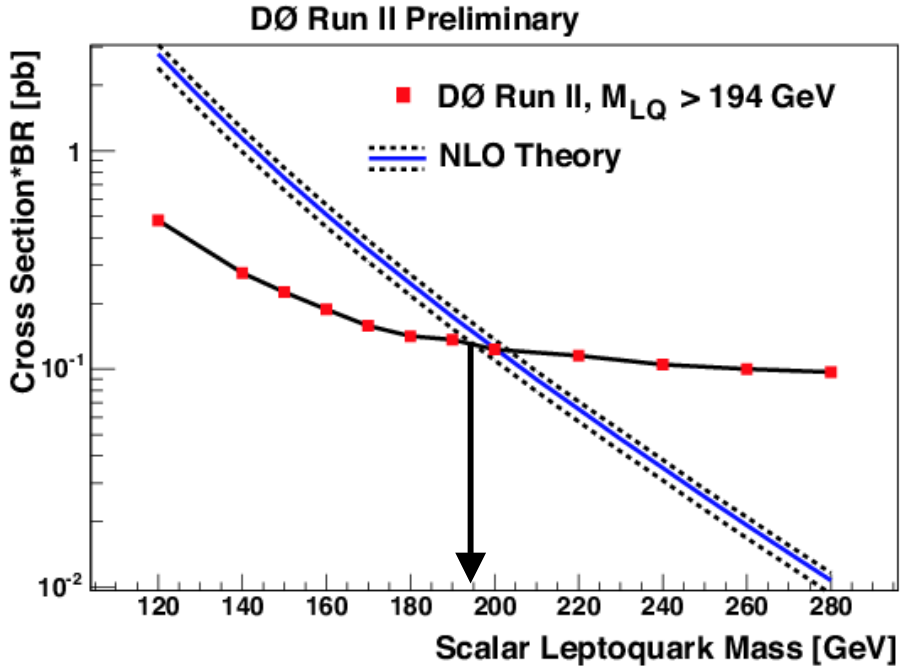
L_{int} = 175 pb^{-1}.



Require M_T > 130 GeV (to veto W).

1 Electron, 2 Jets and Missing E_T

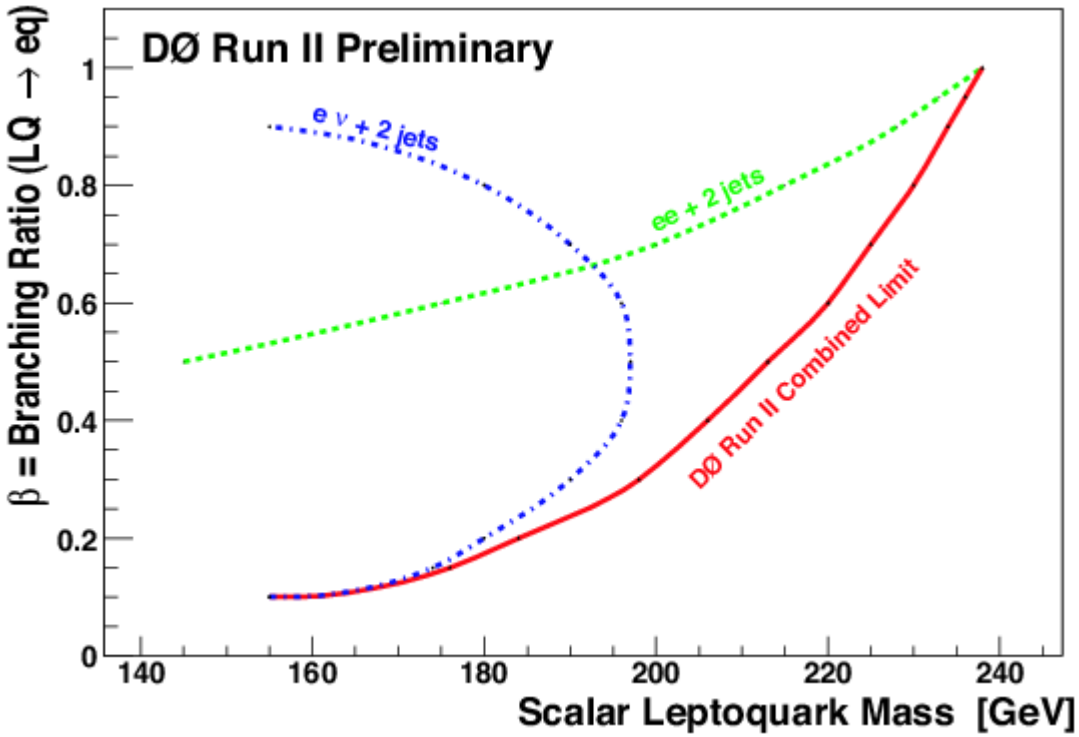




Require S_T > 330 GeV.

For β = 0.5: M_{LQ} > 194 GeV @ 95% CL

DØ Run II combined LQ Limits



Lower limits at 95% CL for 1st generation LQ as function of β.

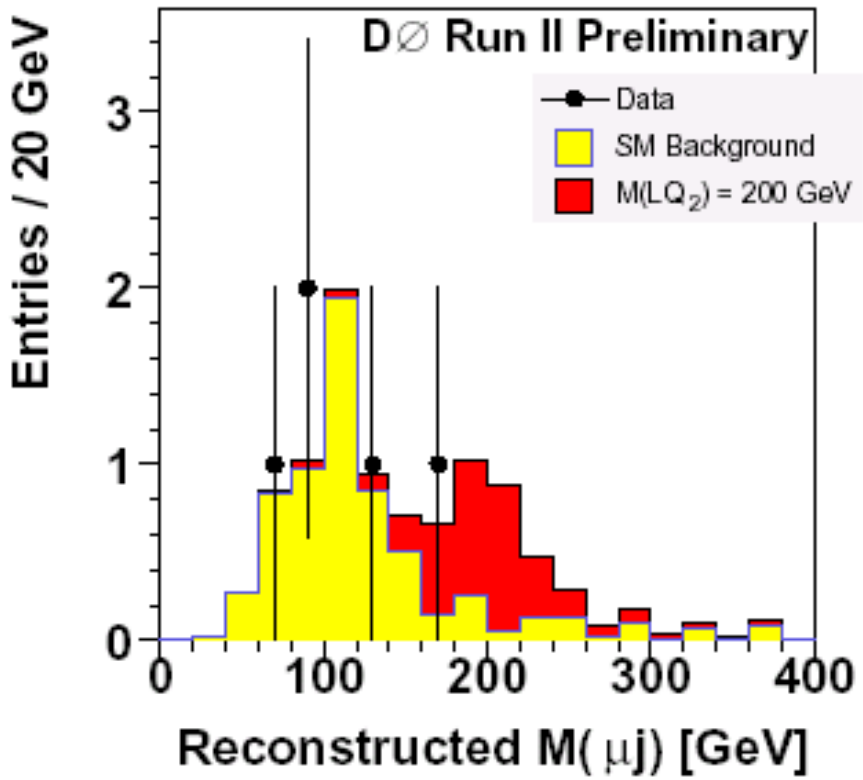
- M_{LQ} > 219 GeV combined eejj and evjj limit for β = 0.5
- M_{LQ} > 238 GeV for β = 1.
- M_{LQ} > 109 GeV for β = 0 (see Patrice Verdier's talk).

- Region to left of red curve excluded.

2nd Generation: 2 Muons and 2 Jets

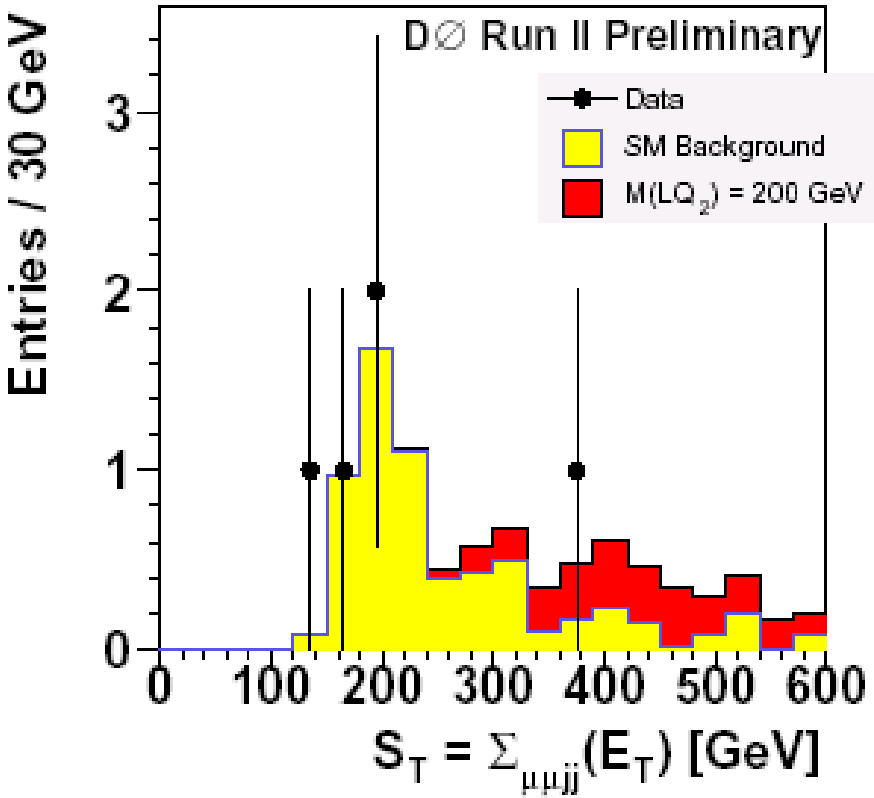
- Require jet E_T > 25 GeV.
- Require muon p_T > 15 GeV and opposite charge.
- Also, require Z veto ($M_{\mu\mu}$ > 110 GeV).

- Integrated luminosity used for this study: L_{int} = 104 pb^{-1}



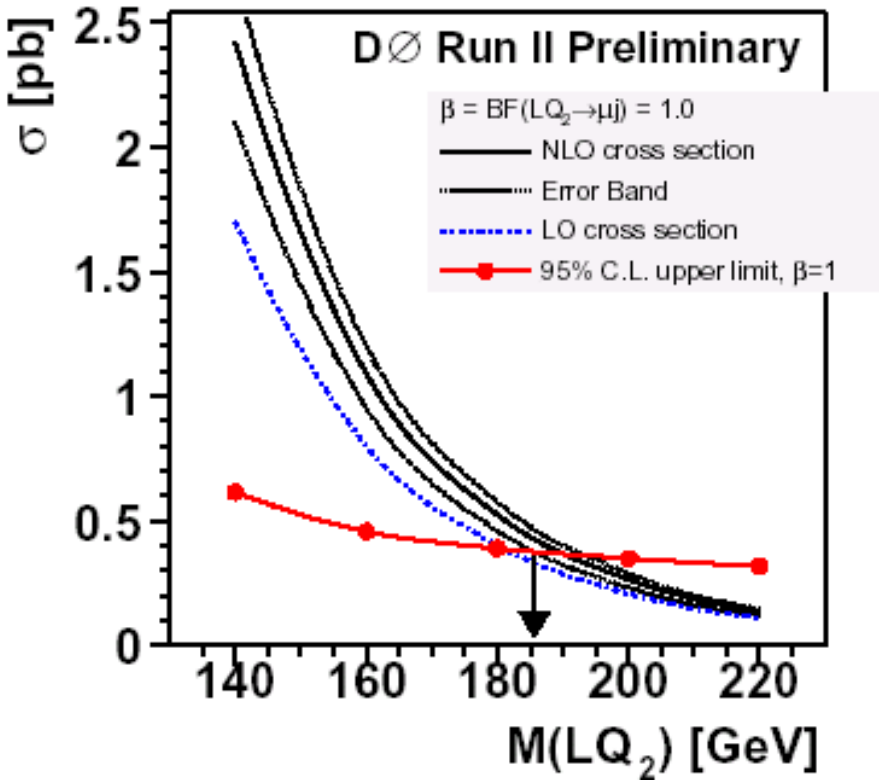
Reconstructed LQ mass ($M_{\mu j}$)
The combination with the smallest mass difference between the two candidates is chosen.

2nd Generation: 2 Muons and 2 Jets



$$S_T = E_T^{\mu 1} + E_T^{\mu 1} + E_T^{Jet1} + E_T^{Jet2}$$

Require S_T > 280 GeV.



M_{LQ} > 186 GeV for β = 1
Integrated luminosity: L = 104 pb^{-1}
Soon results will be available for larger dataset.

Conclusions and Outlook

- No evidence of LQ production so far.
- DØ preliminary limits are:

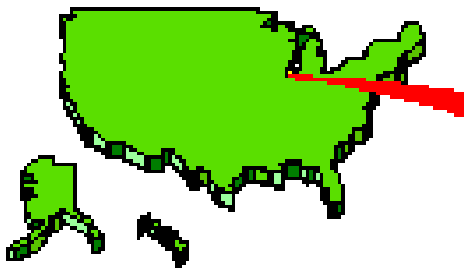
Channel	β	M_{LQ}(GeV)	$L_{int}(pb^{-1})$
DØ First Generation Scalar			
eejj	1	238	175
evjj	0.5	194	175
eejj + evjj (combined)	0.5	213	175
νvjj	0	109	85
DØ Second Generation Scalar			
μμjj	1	186	104

- Best limits from a single experiment for 1st generation LQ with β = 1 and 0.5.
- As integrated luminosity increases, we will continue to look for evidence of leptoquarks and new physics.

Backup Slides (just in case)

The Tevatron

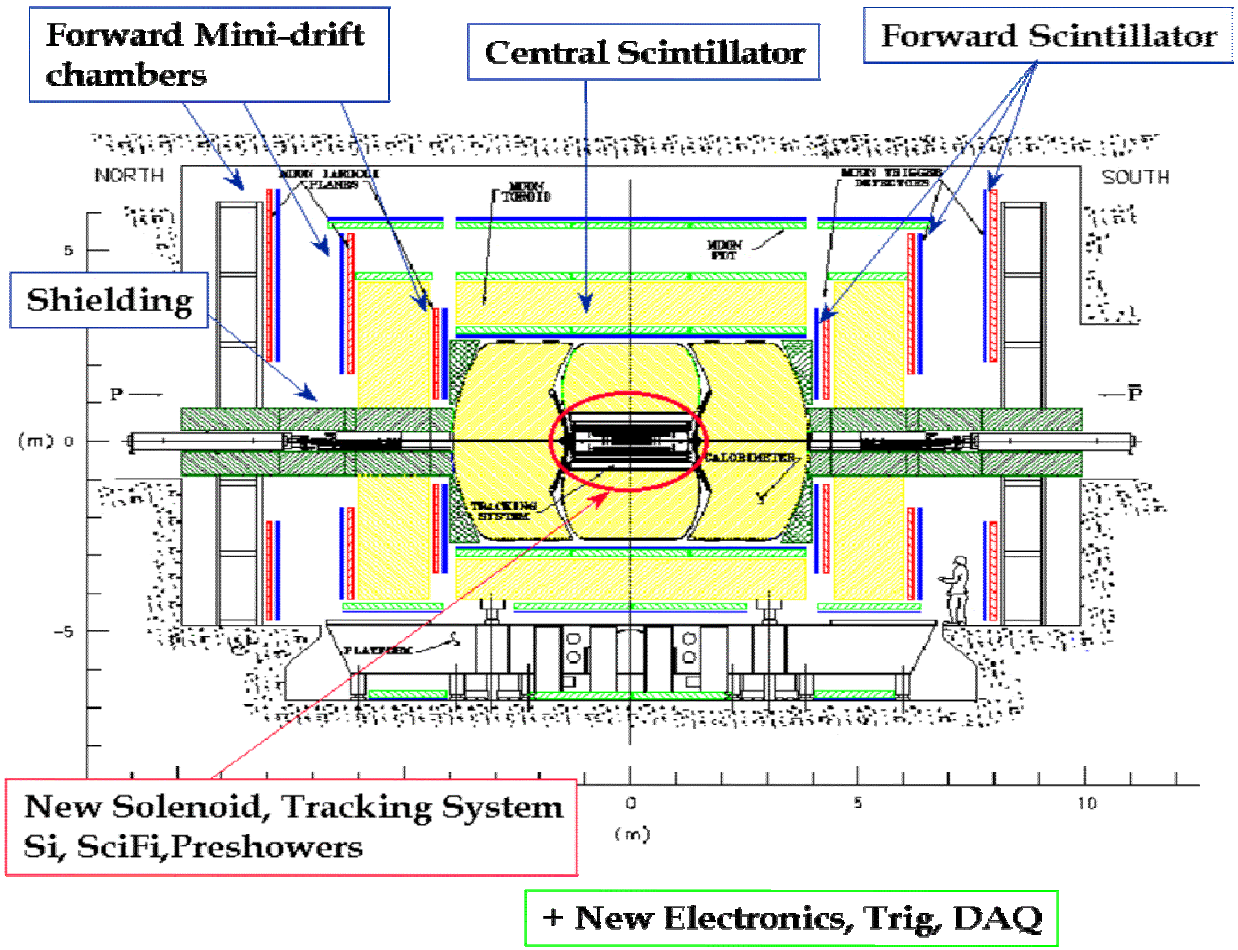
Fermilab is here



Run II: Proton-antiproton collisions started in 2001 at $\sqrt{s} = 1.96$ TeV

In these analysis, the data sets used range from 104 – 175 pb^{-1} of Run II data.

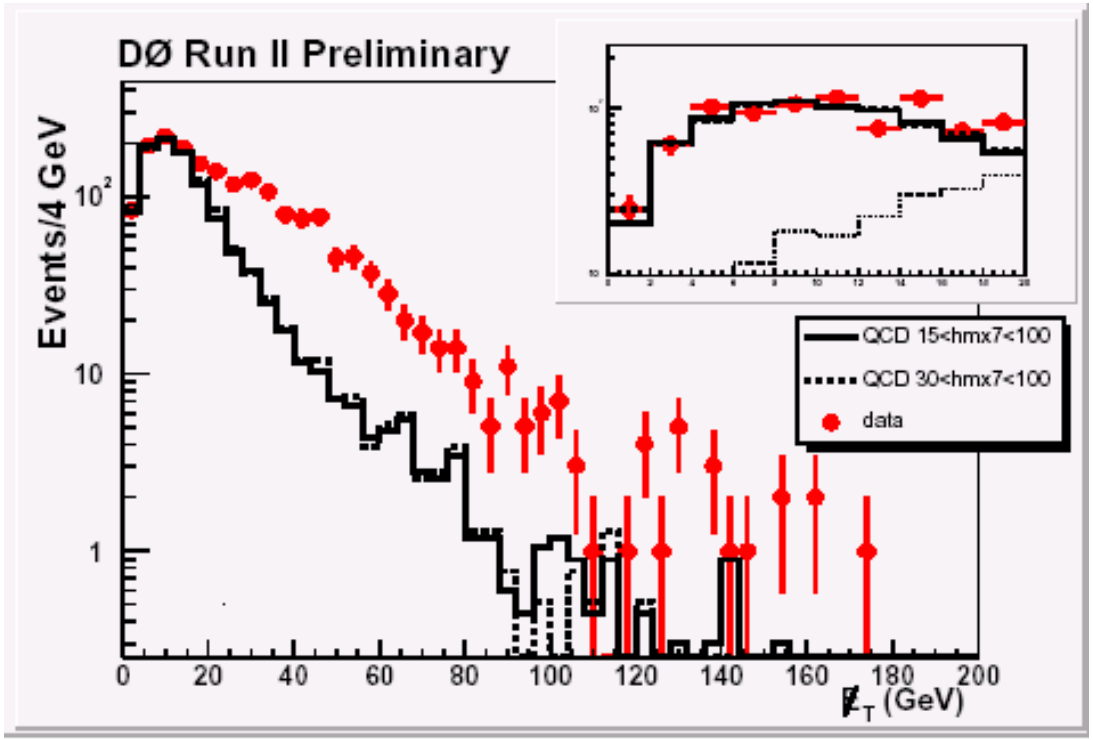
The DØ Detector for Run II



- Electrons
  - **EM calorimeter**
  - **Tracking system**
- Muons
  - **Tracking system**
  - **Muon system**
- Jets
  - **Calorimeter**
- Missing Energy
  - **Calorimeter corrected for muons and electrons**

1 Electron, 2 Jets and Missing E_T

2 Jets with E_T > 25 GeV
1 Electron with E_T > 35 GeV
Missing E_T > 30 GeV

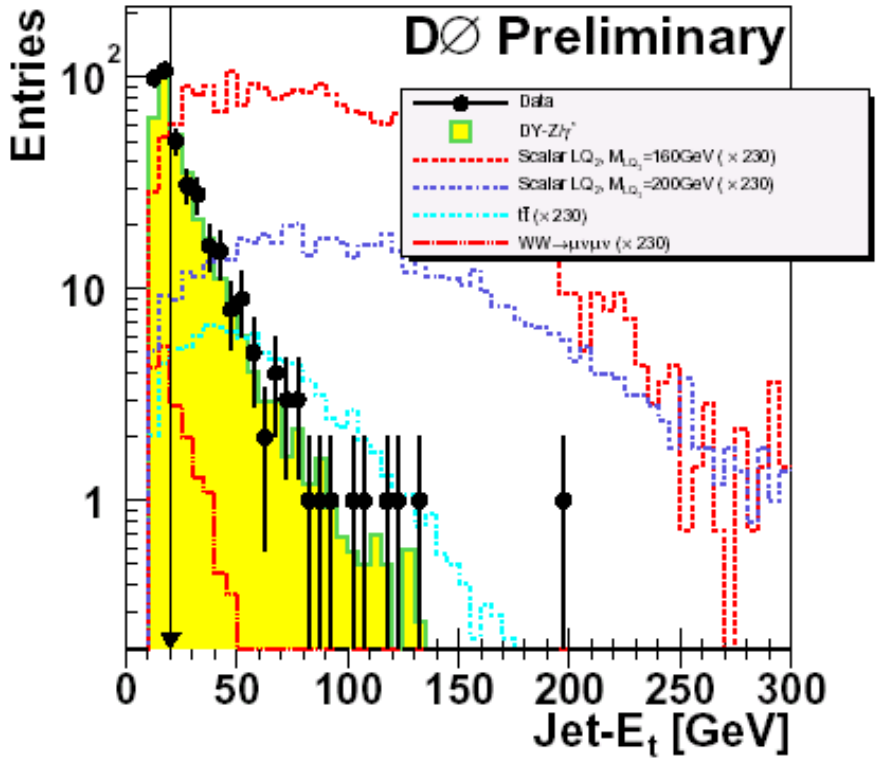


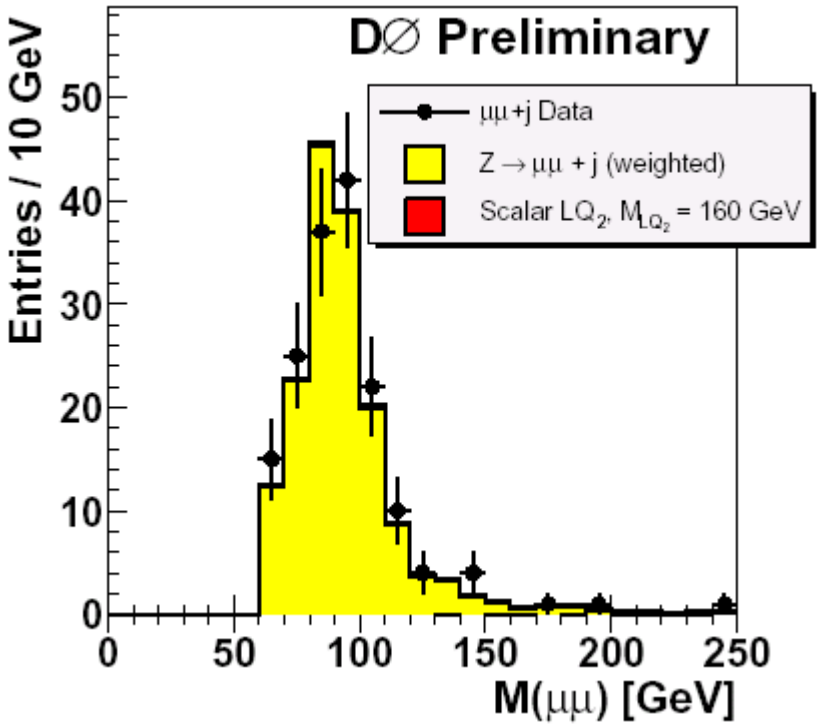
Main Background:

- **W + Jets**
- **Fake electron** + 2Jets
  - **Fake from miss id γ or Jet**
  - **Normalize at low missing E_T**

2nd Generation: 2 Muons and 2 Jets

For $\beta = 1$
Transverse energy of the two most energetic jets.





Invariant di-muon mass of μμ + ≥ 1jet for data, MC, and scalar LQ for with M_{LQ2} = 160 GeV