Search for Second Generation Scalar Leptoquarks at Tevatron

IMPRS Seminar

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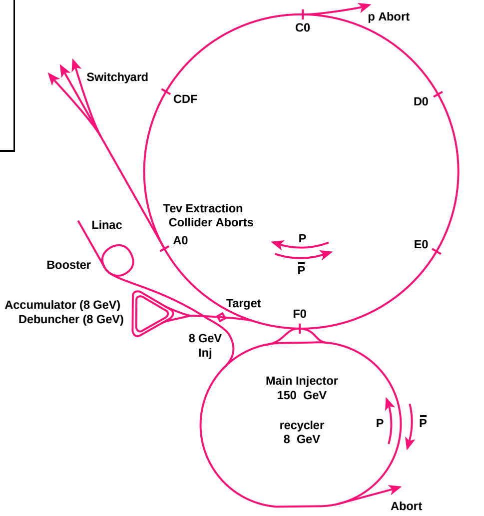
Outline

The Tevatron
The DØ Detector
Leptoquarks at Tevatron
Monte-Carlo Analysis
Conclusion

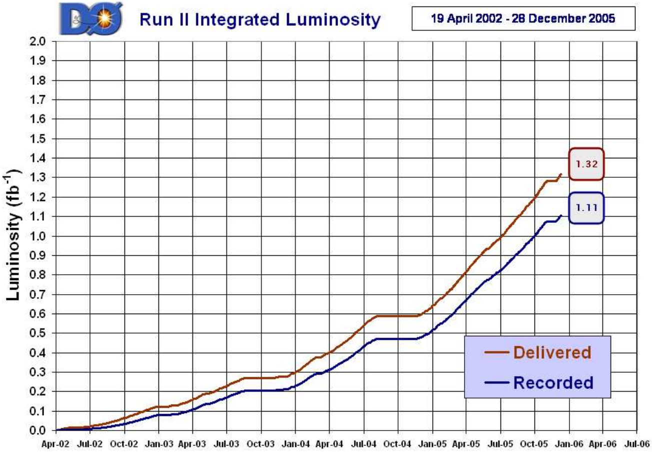
The Accelerator Complex

- $\longrightarrow$ proton-antiproton hadron collider
- $\longrightarrow$ $\sqrt{s} = 1.96$ TeV (Run II)
- $\longrightarrow$ 6 synchrotron rings
- $\longrightarrow$ 2 detectors: DØ and CDF

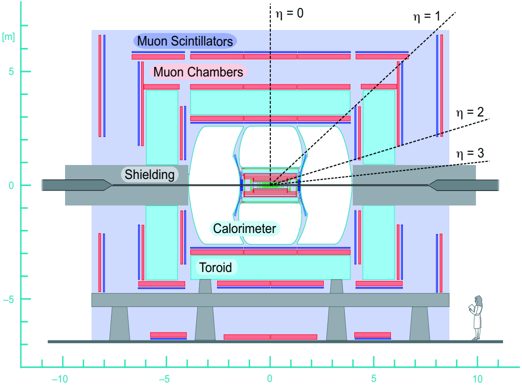
Fermilab Tevatron Accelerator With Main Injector

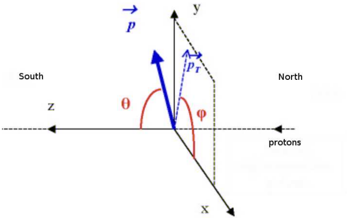


Luminosity


Run II Integrated Luminosity
19 April 2002 - 28 December 2005
Luminosity (fb-1)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Apr-02 Jul-02 Oct-02 Jan-03 Apr-03 Jul-03 Oct-03 Jan-04 Apr-04 Jul-04 Oct-04 Jan-05 Apr-05 Jul-05 Oct-05 Jan-06 Apr-06 Jul-06
1.32
1.11
Delivered
Recorded

Schematic View of DØ

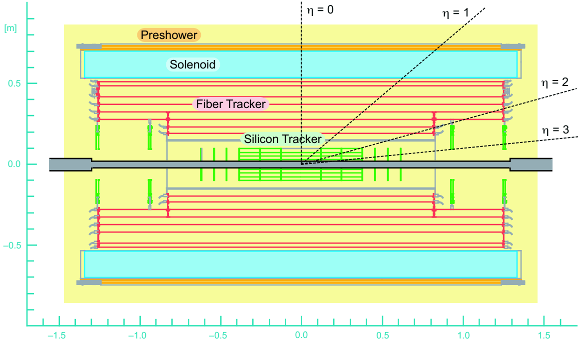


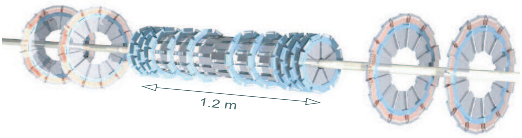


pseudo-rapidity: $\eta = -ln(tan\frac{\theta}{2})$

transverse momentum: $\overrightarrow{P_T}$

The Tracking System

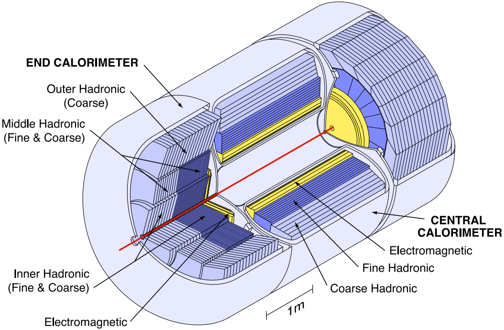




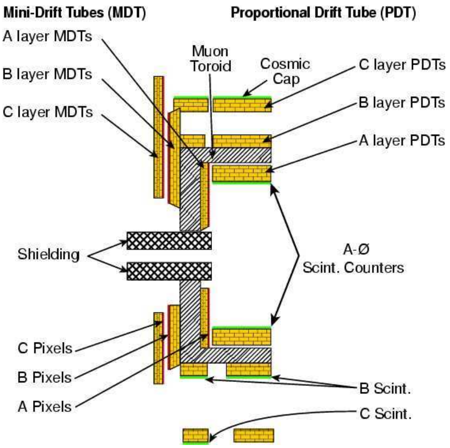
Silicon Microstrip Tracker

The Calorimeter

Liquid-Argon/Uranium



The Muon Detection System



Leptoquarks (LQ)

Leptoquarks are new bosons allowing lepton-quark transitions.

Theoretical Motivation:

Grand Unified Theories gather leptons and quarks within the same multiplets. Leptoquarks, which couple to both leptons and quarks, are predicted as new gauge bosons.

For instance, R-Parity violated SUSY theories allow leptoquark-like couplings, since a squark could couple to a lepton and a quark.

The Effective Leptoquark Model

The *Minimum Buchmüller-Rückl-Wyler model* (mBRW) allows relative small leptoquark masses in reach of hadron colliders like Tevatron.

It assumes that leptoquarks fulfill these conditions:

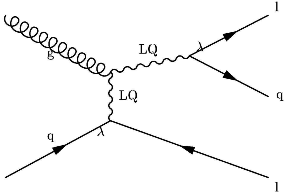
- $\longrightarrow$ have renormalizable interactions
- $\longrightarrow$ have interactions invariant under SM gauge groups SU(3)$\otimes$SU(2)$\otimes$U(1)
- $\longrightarrow$ couple to SM fermions and gauge bosons (usually, by contrast to squarks)
- $\longrightarrow$ conserve the leptonic and baryonic numbers separately
- $\longrightarrow$ each couple only to a single lepton-quark generation (to prevent FCNC)
- $\longrightarrow$ each have pure chiral couplings to SM fermions

This model leads to seven *scalar* and seven *vector* leptoquarks carrying the fermionic number:

$$\boxed{\mathrm{F} = 3\ \mathrm{B} + \mathrm{L}}$$

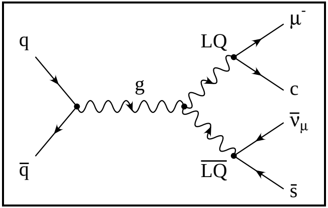
Production and Decay

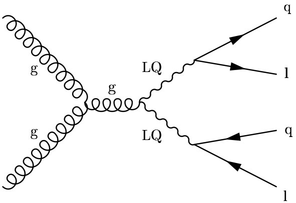
Single LQ production:



The cross-section depends on the unknown λ coupling between a leptoquark, a lepton and a quark.

Pair LQ production:



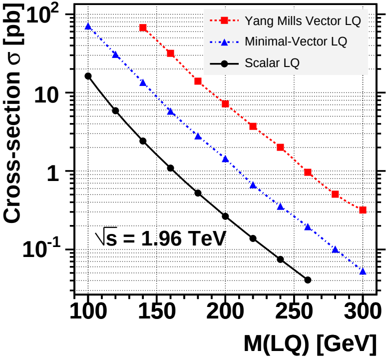


(pure QCD processes)

Pair Production cross-section

→ The pair production cross-section of scalar LQ can be written as a function of the LQ mass only.

→ The pair production cross-section of vector LQ depends on unknown anomalous couplings.



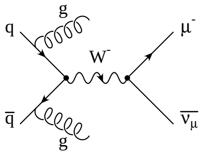
Signal & Background

→ **Signal:**

We consider the pair production of scalar LQ in the case where one of them decays to a *muon* and a *quark*, and the other to a *neutrino* and a *quark*.

PYTHIA has been patched so that the two LQ decay to different final states.

→ **Main Background:**



Final State: μ, $\not{E}_T$, 2 *jets*

→ **Samples:**

Sample	σ_{NLO} (pb)	Number of Events	MC generator
LQ (220 GeV)	0.14	10k	PYTHIA
LQ (240 GeV)	0.08		
LQ (260 GeV)	0.04		
Wjj (Pt>8 GeV, R>0.4)	290	160k	ALPGEN

Quality Cuts

Good Muon:

- → loose quality (number of hits in layers)
- → has a central track
- → > 1 hits in SMT
- → region cut
- → isolated
- → $P_T > 15$ GeV
- → not cosmic

Good Jet:

- → standard quality criteria (EM, CH fractions, ...)
- → region cut
- → $E_T > 25$ GeV

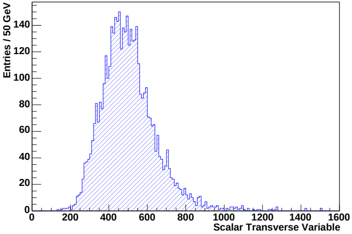
To remove bad reconstructed high energetic muons, we ask for $\Delta\phi(\mu,\nu) > 3$.

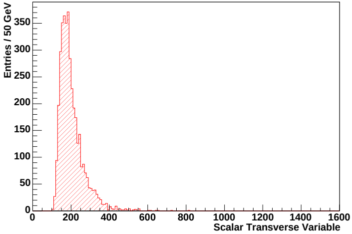
Cumulated efficiencies:

Samples	good μ	2 good jets	$\not{E}_T > 30$ GeV	$\Delta\phi(\mu,\nu) > 3$
LQ (260 GeV)	0.58	0.47	0.46	0.42
Wjj (Pt>8 GeV, R>0.4)	0.50	0.037	0.026	0.024

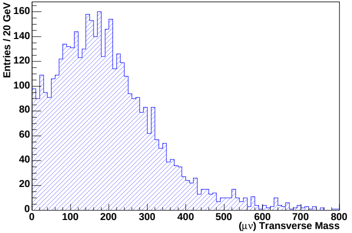
Selection Cuts

→ S_T definition: $S_T = \not{E}_T + P_T^{\mu_1} + E_T^{jet_1} + E_T^{jet_2}$

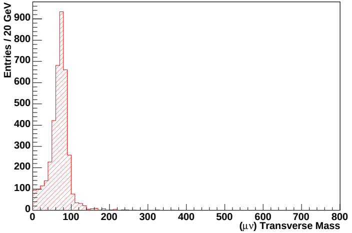




→ Transverse Mass ($\mu\nu$)



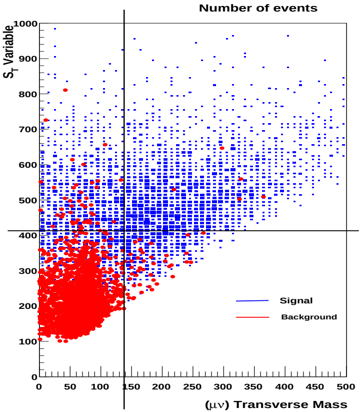
(Signal)

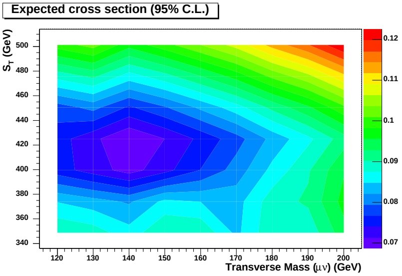


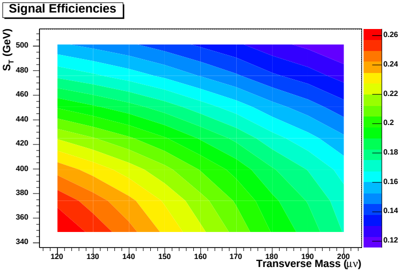
(Background)

Cut Optimisation

The cuts on $M_{\mu\nu}$ and S_T are optimized by cutting in the space ($M_{\mu\nu}$,S_T) so as to minimize the 95% C.L. cross-section limit, which is calculated for a luminosity of 500 pb^{-1}, with 10% of systematics error for the signal and 30% for the background.







Selection Cut Efficiencies

→ Optimized cuts efficiencies (cumulated, after preselection):

Samples	**$M_{\mu\nu} > 140$ GeV**	**$S_T > 410$ GeV**
LQ (260 GeV)	0.26	0.22
Wjj	0.00029	3.1×10^{-5}

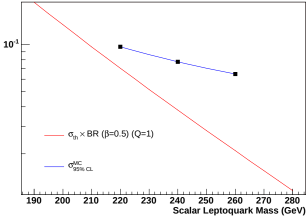
→ We apply these cuts to the other LQ samples (220 and 240 GeV)

Samples	**$\sigma^{mc}_{95\%CL}$ (pb)**	**Signal Efficiency**	**Nb Bgd Evts (L=500 pb^{-1})**
LQ (220 GeV)	0.097	0.15	4.47
LQ (240 GeV)	0.078	0.18	
LQ (260 GeV)	0.065	0.22	

(After all cuts)

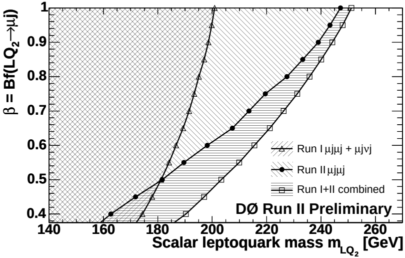
Exclusion Region

→ The masses 220, 240, and 260 GeV cannot be excluded.



$$\begin{cases} BR(LQ \to l^{\pm} q) = \beta \\ BR(l\nu qq) = 2\beta(1-\beta) \end{cases}$$

→ Current Results on Second Generation Scalar Leptoquarks:



Combined results:

- Run I : $L \simeq 94\ pb^{-1}, \sqrt{s} = 1.8$ TeV
- Run II : $L \simeq 294\ pb^{-1}, \sqrt{s} = 1.96$ TeV

Conclusion

- **Promising Analysis:**
  - → More than 1 fb^{-1} of luminosity is available
  - → Good variables to make out the signal from the background
- **Next Steps:**
  - → Process real data
  - → Understand the data-MC comparison
  - → Put a limit on the LQ mass if no evidence of LQ
  - → Combine results with other LQ decay channels