Search for First Generation Leptoquarks Decaying into Neutrinos and Jets Using the CDF Detector

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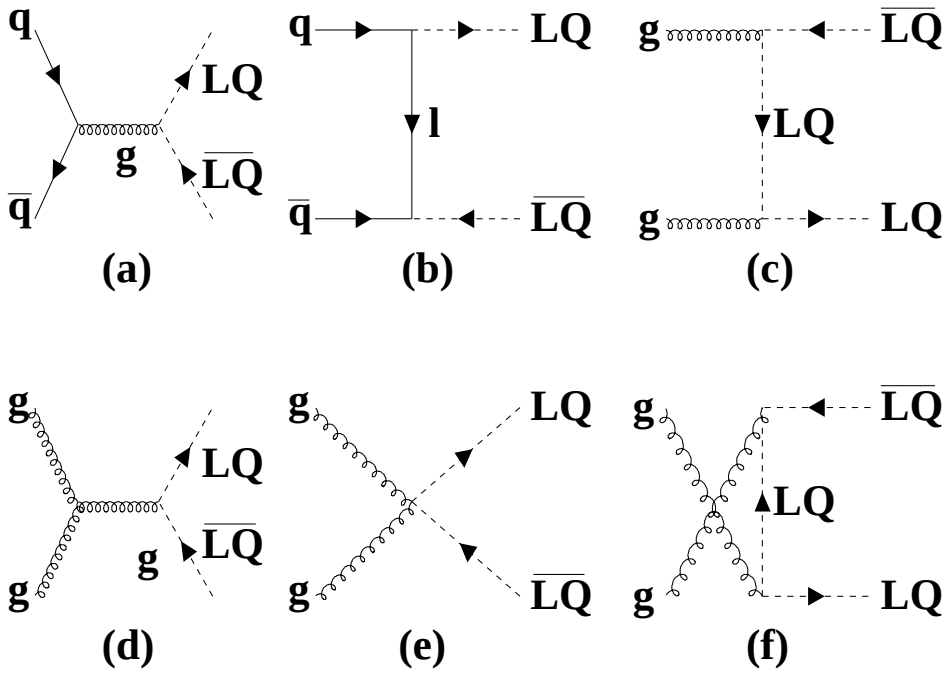
Leptoquarks (LQ)

- Color-triplet bosons, carry lepton and color quantum numbers, couple to both quarks and leptons
- Predicted in several extensions of Standard Model (SM)
  - GUTs
  - Technicolor
  - Compositeness
  - SUSY with R-parity violation
- Could be scalar or vector
- Assume LQ only couples to leptons and quarks of the same generation, to avoid the flavor-changing neutral current (FCNC) constraints

Leptoquarks Production in $p\bar{p}$ collisions

- LQ may be pair produced predominantly by gluon-gluon fusion or $q - \bar{q}$ annihhilation.



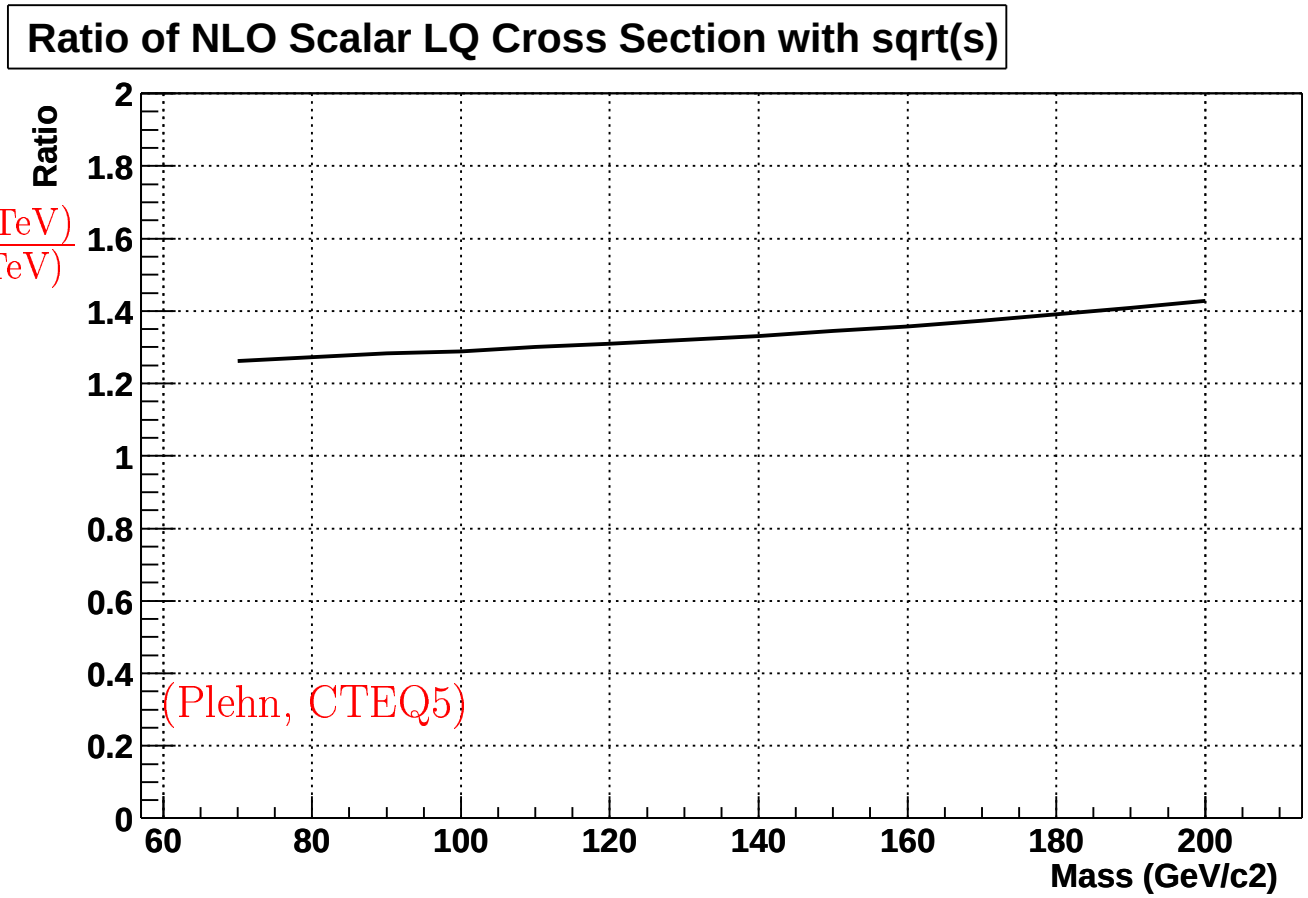
- Contributions from direct leptoquark-quark-lepton coupling is small (λ assumed to be of order electromagnetic strength)
- Coupling of gluon to scalar LQ only determine by the color charge of the particle $\Rightarrow$ model independent
- LQ decays :
  - $LQ \to lq$ $(l = e, \mu, \tau) \Rightarrow \beta = 1$
  - $LQ \to \nu q \Rightarrow \beta = 0$

    (β branching ratio of LQ decaying to charged lepton and quark)

Scalar LQ searches by CDF

- In Run 1, CDF had published search results for LQ in different generations and decay modes, but not for first generation LQ in the $\nu\nu qq$ channel
- We present preliminary results on the search for first generation LQ in the channel $LQ\bar{LQ} \to \nu\nu qq$ using Run 2 data

$\sigma(\sqrt{s} = 1.96\text{TeV})/\sigma(\sqrt{s} = 1.8\text{TeV})$



- Cross section of scalar LQ pair production increase by $\sim$ 30% from $\sqrt{s} = 1.8$ TeV to $\sqrt{s} = 1.96$ TeV (M(LQ)= 100GeV/c^2)

Data Analysis

- Data Sample :
  - Collected with trigger that selects $p\bar{p}$ collision events with large missing transverse energy (MET)
  - Data collected from Feb 2002 to Jan 2003, with integrated luminosity of 76 pb^{-1}
- Selection cuts :
  - MET > 55 GeV
  - 2 or 3 jets
    - $E_{\text{T}}(\text{J1}) > 40$ GeV, $E_{\text{T}}(\text{J2}) > 25$ GeV, $E_{\text{T}}(\text{J3}) > 7$ GeV
    - $\mid \eta_{\text{J1,J2}} \mid < 1$, $\mid \eta_{\text{J3}} \mid < 2.5$
  - No other jet with $E_{\text{T}} > 7$ GeV
  - $100^\circ < \Delta\phi(\text{J1}, \text{MET}) < 165^\circ$
  - $80^\circ < \Delta\phi(\text{J1}, \text{J2}) < 165^\circ$

  } Reject QCD Multi-jet

  - $30^\circ < \min\Delta\phi(\text{J}, \text{MET}) < 135^\circ$ (J: any of the 2 or 3 selected jets)
  - Lepton veto
  - 0.1 < jet electromagnetic fraction < 0.9
  - Min. # of tracks in jet ≥ 4 ($\mid \eta_{\text{jet}} \mid < 1$)

  } Reject W/Z+ jets

- Primary SM backgrounds in selected data events
  - QCD multi-jet production
  - $W + 2\text{jets}$ ($W \to l\nu, \quad l = e, \mu, \tau$)
  - $Z + 2\text{jets}$ ($Z \to ll, \quad l = \mu, \tau, \nu$)
  - $t\bar{t}$
- SM background contributions are estimated with Monte Carlo (MC) simulations
- Normalization of QCD MC sample is obtained from the QCD multi-jet data samples
- For $W/Z + 2\text{jets}$, and $t\bar{t}$, use NLO cross section values

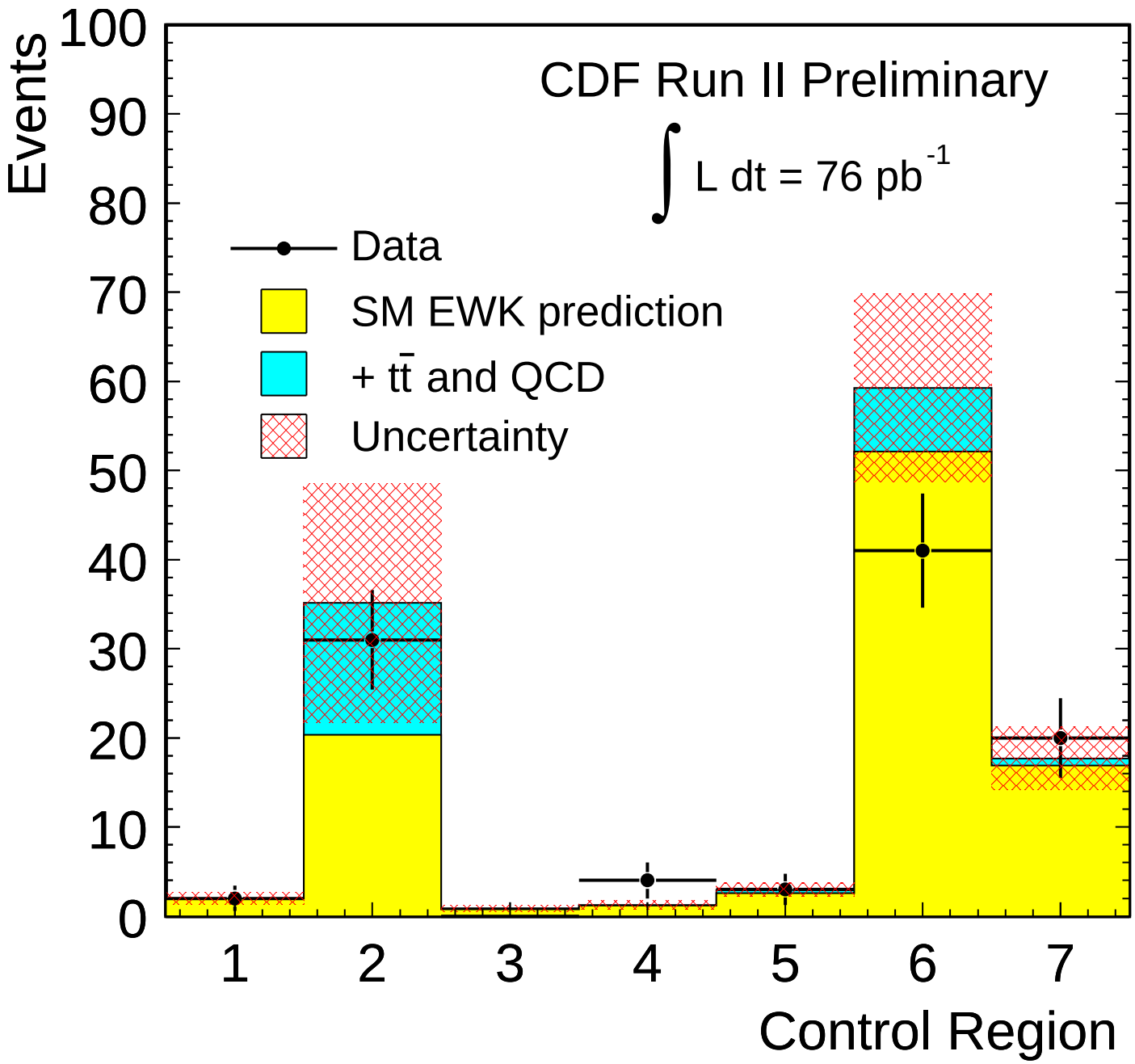
Control Regions

- Define control regions around the signal region to check SM background predictions before looking at the data events in the signal region
- The control regions are selected by relaxing or inverting some of the cuts used to enhance the LQ signal
  - $\Delta\phi(\mathrm{J1}, \mathrm{MET}) < 160°$
  - $0° < \Delta\phi(\mathrm{J1}, \mathrm{J2}) < 165°$
  - $20° < \min\Delta\phi(\mathrm{J}, \mathrm{MET})$ (J: any of the 2 or 3 selected jets)
  - The minimum number of tracks required per jet is removed

Control regions definition				
1)	$45 < \not\!\!E_{\mathrm{T}} < 55$ GeV,	$\Delta\phi(j_1, j_2) > 165°$,	$N_l = 0$	$\Rightarrow$ QCD like
2)	$45 < \not\!\!E_{\mathrm{T}} < 55$ GeV,	$\Delta\phi(j_1, j_2) < 165°$,	$N_l = 0$	
3)	$45 < \not\!\!E_{\mathrm{T}} < 55$ GeV,	$\Delta\phi(j_1, j_2) > 165°$,	$N_l > 0$	
4)	$\not\!\!E_{\mathrm{T}} > 55$ GeV,	$\Delta\phi(j_1, j_2) > 165°$,	$N_l = 0$	
5)	$\not\!\!E_{\mathrm{T}} > 55$ GeV,	$\Delta\phi(j_1, j_2) > 165°$,	$N_l > 0$	
6)	$\not\!\!E_{\mathrm{T}} > 55$ GeV,	$\Delta\phi(j_1, j_2) < 165°$,	$N_l > 0$	$\Rightarrow W/Z+$ jets like
7)	$45 < \not\!\!E_{\mathrm{T}} < 55$ GeV,	$\Delta\phi(j_1, j_2) < 165°$,	$N_l > 0$	

(N_l : # of leptons (e, μ))
(Trigger selection requires $\not\!\!E_{\mathrm{T}} > 45$ GeV)

Background Predictions and Data Around The Signal Region



Signal Region

- In the signal region we expect 42.5±7.6(stat)±7.5(syst) events from SM contributions
- Observe 42 events in signal region

CDF Run II Preliminary

	Events
QCD	7.3
$W \to e\nu + 2$ jets	1.7
$W \to \mu\nu + 2$ jets	8.3
$W \to \tau\nu + 2$ jets	10.3
$Z \to \mu\mu + 2$ jets	0.5
$Z \to \tau\tau + 2$ jets	0.2
$Z \to \nu\nu + 2$ jets	13.4
$t\bar{t}$	0.7
All	$42.5 \pm 7.6(\text{stat}) \pm 7.5(\text{syst})$
Data	42

- Background systematics
  - Luminosity : 6%
  - PDF : 5%
  - Calorimeter Energy Scale : 10%
  - k factor (for $W/Z + 2$ jets) : 12%
  - QCD normalization : 41%

Leptoquark Acceptance

CDF Run II Preliminary

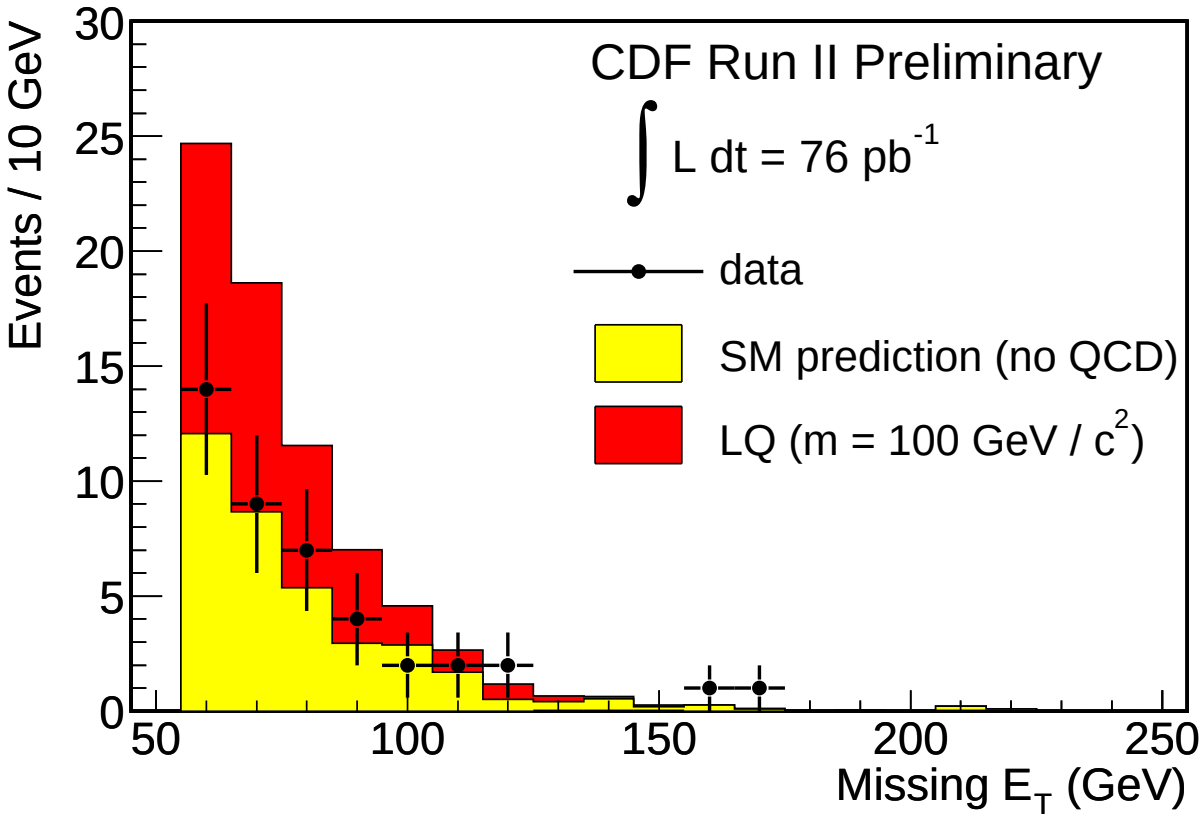
LQ Mass (GeV/c^2)	Acceptance	# Expected ($L = 76\text{pb}^{-1}$)
60	0.0020	33.8
75	0.0085	45.0
90	0.0231	45.7
100	0.0334	37.0
110	0.0464	30.4
125	0.0662	21.0
150	0.0909	10.0
175	0.110	4.74
200	0.124	2.32

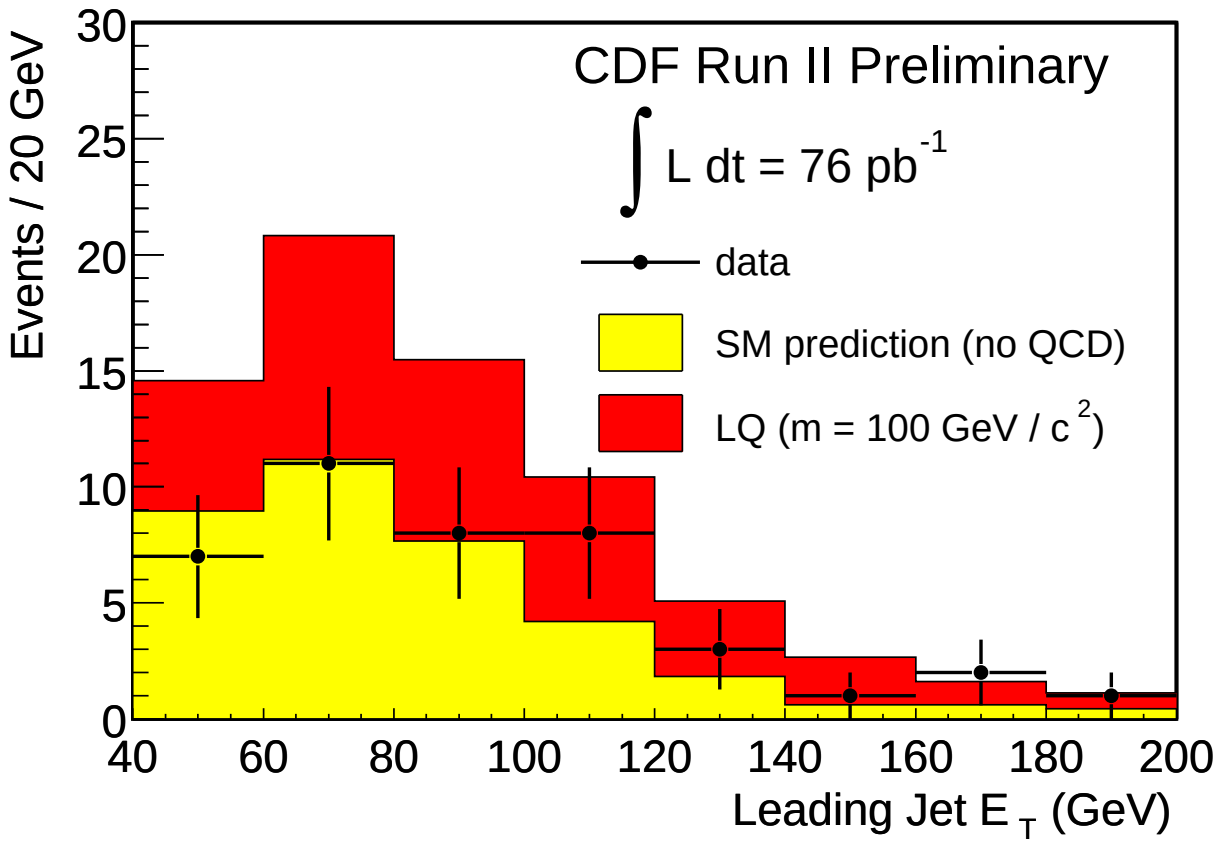
Systematic Uncertainties on Leptoquark Acceptance

CDF Run II Preliminary

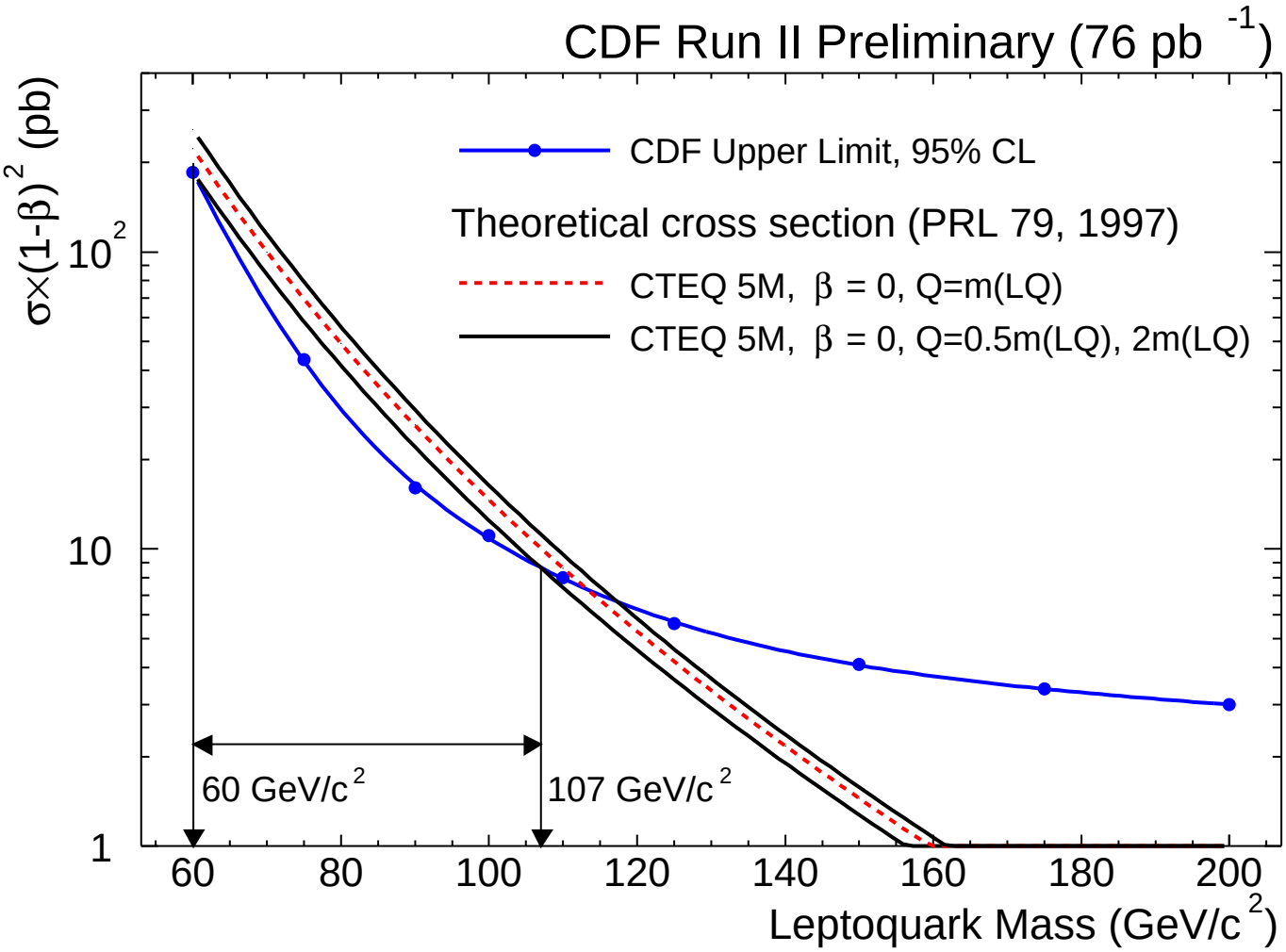
Systematic	Value
PDF	8%
ISR/FSR	10%
MC Statistics	3%
Luminosity	6%
Vertex Cut	0.5%
Trigger Efficiency	2%
Calorimeter Energy Scale	10%
Total	18%

Kinematic Distributions of Events in Signal Region



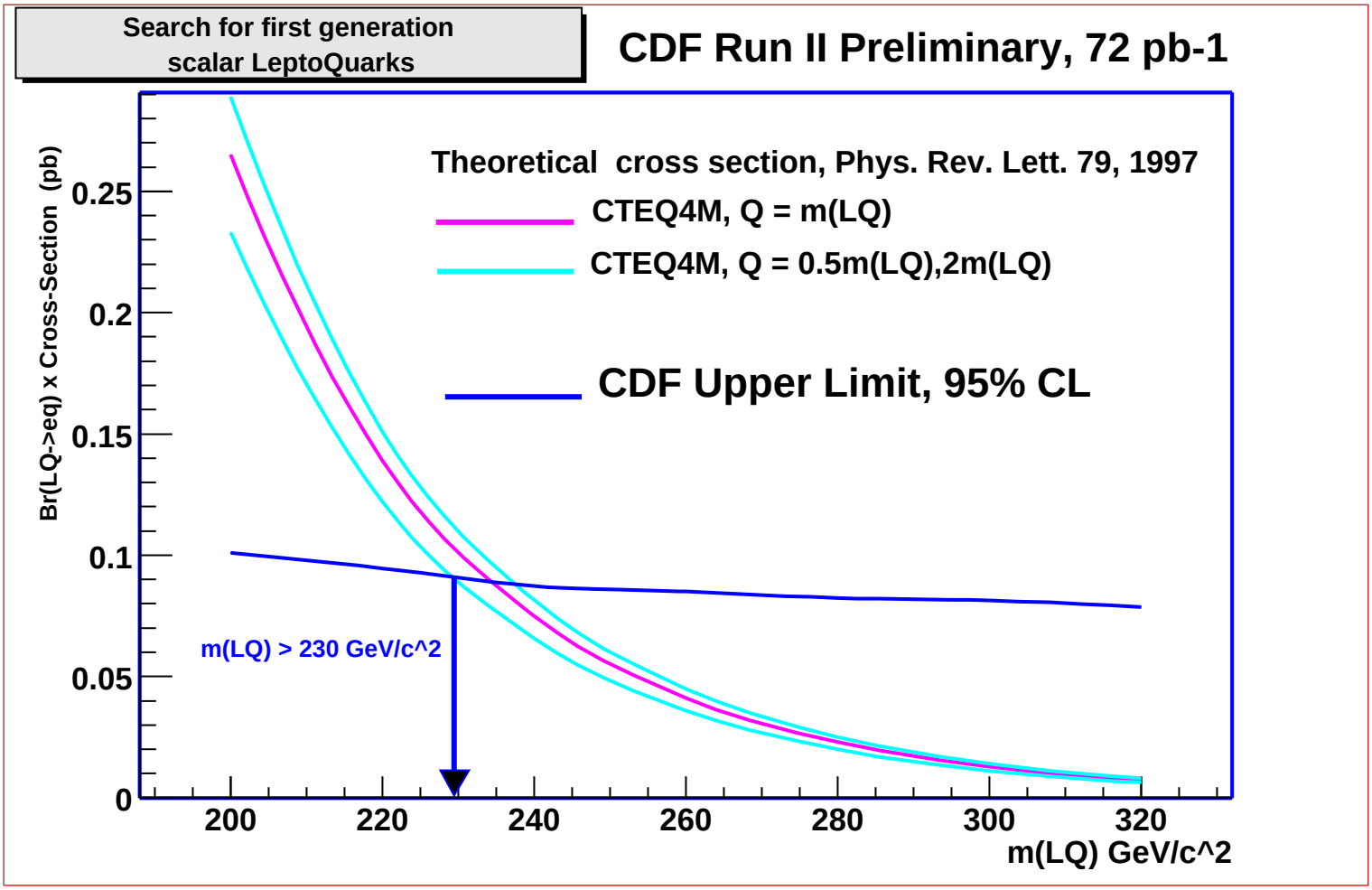


Upper Limit Cross Section vs LQ Mass



- Preliminary results exclude first generation leptoquark with $\beta = 0$ in the mass range $60 < \mathrm{m}(LQ) < 107$ GeV/c^2
- D0's Run I search in the same channel excludes first generation leptoquark in the mass range $\mathrm{m}(LQ) < 98$ GeV/c^2
  (Phys. Rev. Lett. 88, 191801 (2002))

Preliminary Results from First Generation Leptoquark Search in $eejj$ Channel



- Preliminary results exclude first generation leptoquark with $\beta = 1$ in the mass range $\mathrm{m}(LQ) < 230\ \mathrm{GeV/c^2}$

Summary

- Using 76pb^{-1} of Run II data CDF observe no evidence of excess in the events of large missing transverse with two or three jets
- Set 95% C.L. on the mass of the first generation leptoquark ($LQ \rightarrow \nu q$), excluding the mass range $60 < \mathrm{m}(LQ) < 107$ GeV/c^2
- Plan to use larger data sample to extend the search of first generation leptoquark to higher mass range
- Apply Heavy Flavor tagging algorithm on the jets to search for second and third generation leptoquarks