Batavia , IL

De Kalb, IL

Search for leptoquarks with the D0 detector

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on behalf of the D0 collaboration

DPF Conference

Honolulu, November 01, 2006

In one step beyond the Standard Model ...

GUT models

$SU(3)_C$ X $SU(2)_L$ X $U(1)_Y$

Quarks	Bosons
Leptons	

SuperSymmetric theories

LEPTOQUARKS

are exotic scalar/vector particles that have color, electric charge and lepton number, predicted by the SM extensions.

LQ interactions

- invariant under SM
- separately conserve lepton and baryon numbers
- no cross-generation coupling

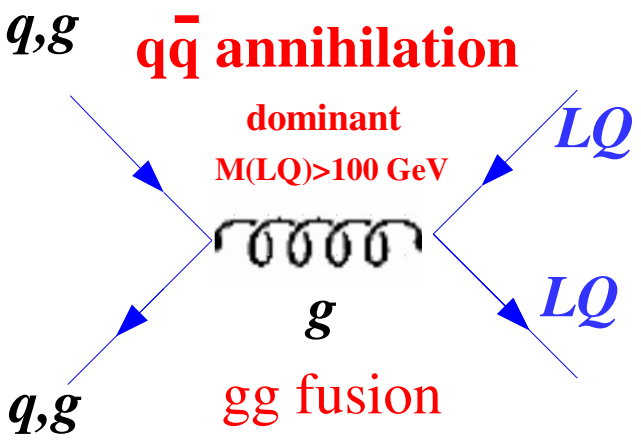
SM fermions		Search
Quarks	Leptons	Leptoquarks ?
u, d	e, ν	LQ1
s, c	μ,ν	LQ2
t, b	τ,ν	LQ3

In this talk

New D0 results (summer 2006) for LQLQ -> $\nu\nu$qq and LQ_3LQ_3->$\nu\nu$bb

Leptoquarks at the Tevatron

Pair Production

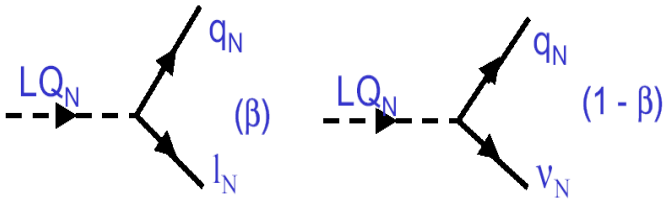


no dependency from unknown LQ – l - q coupling

Scalar LQ : well known (NLO) cross-section

Vector LQ : lager cross-section, model dependent

Decay Signatures



β == branching **LQ->ql$^{\pm}$**

- 2 leptons + 2 jets, no missing energy (MET)
- 1 lepton + 2 jets + MET
- 2 jets + missing energy

Previous strongest limits for MET+2jets final state (CDF collaboration)

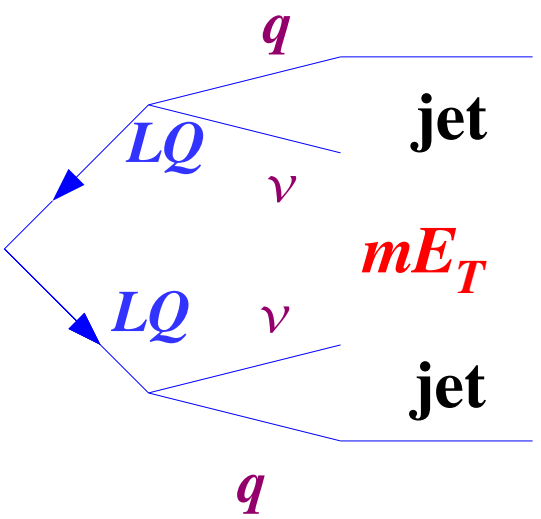
All LQ generations:
M(LQ)>117 GeV

3rd generations :
M(LQ) > 148 GeV

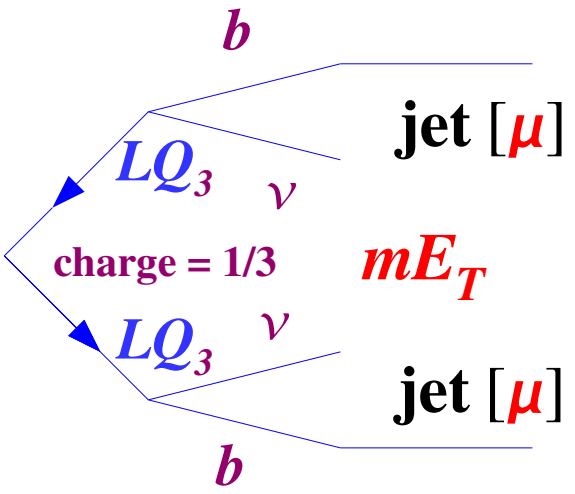
Signal selection

Same topology
Missing energy
and 2 jets,
b-tagging for LQ3

Gen. independent search

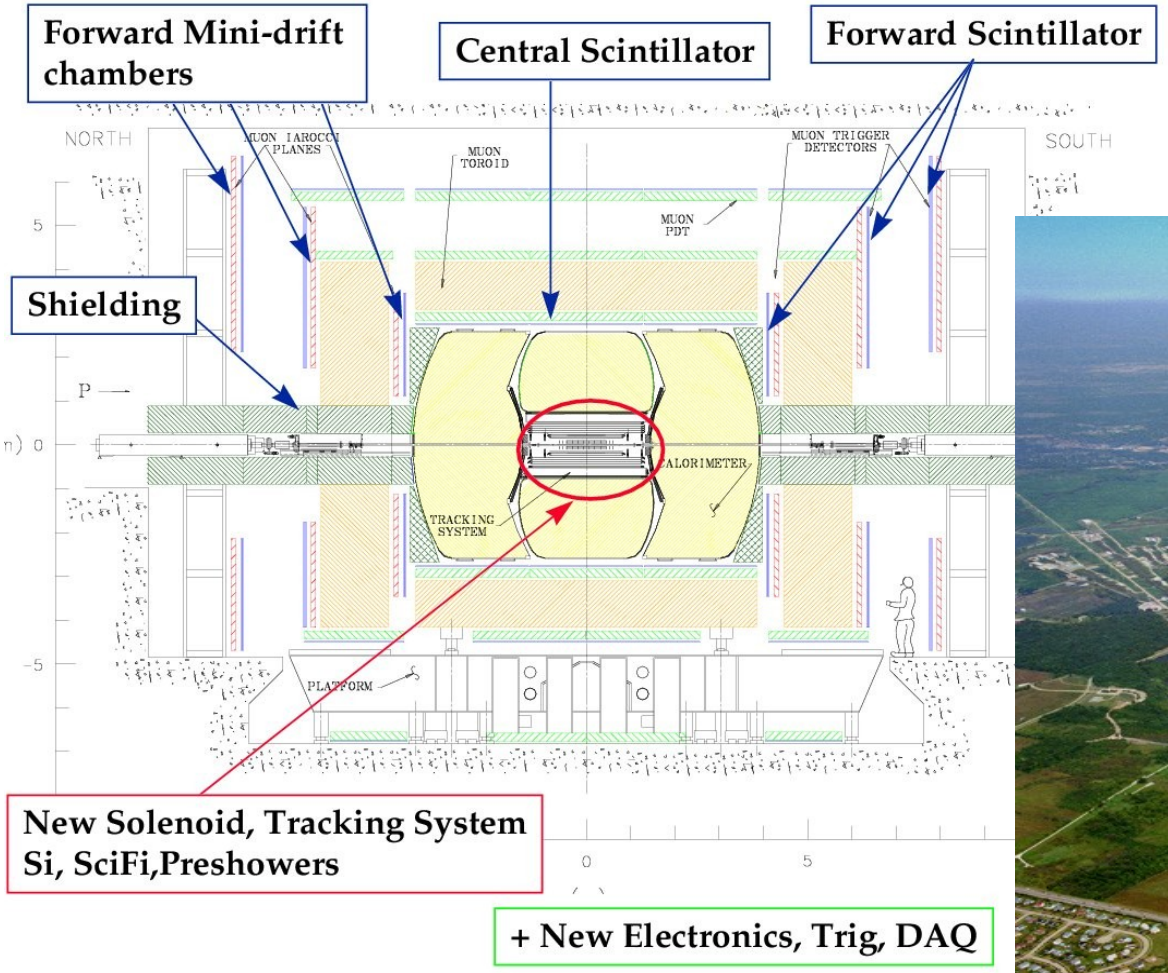


3rd gen. LQ



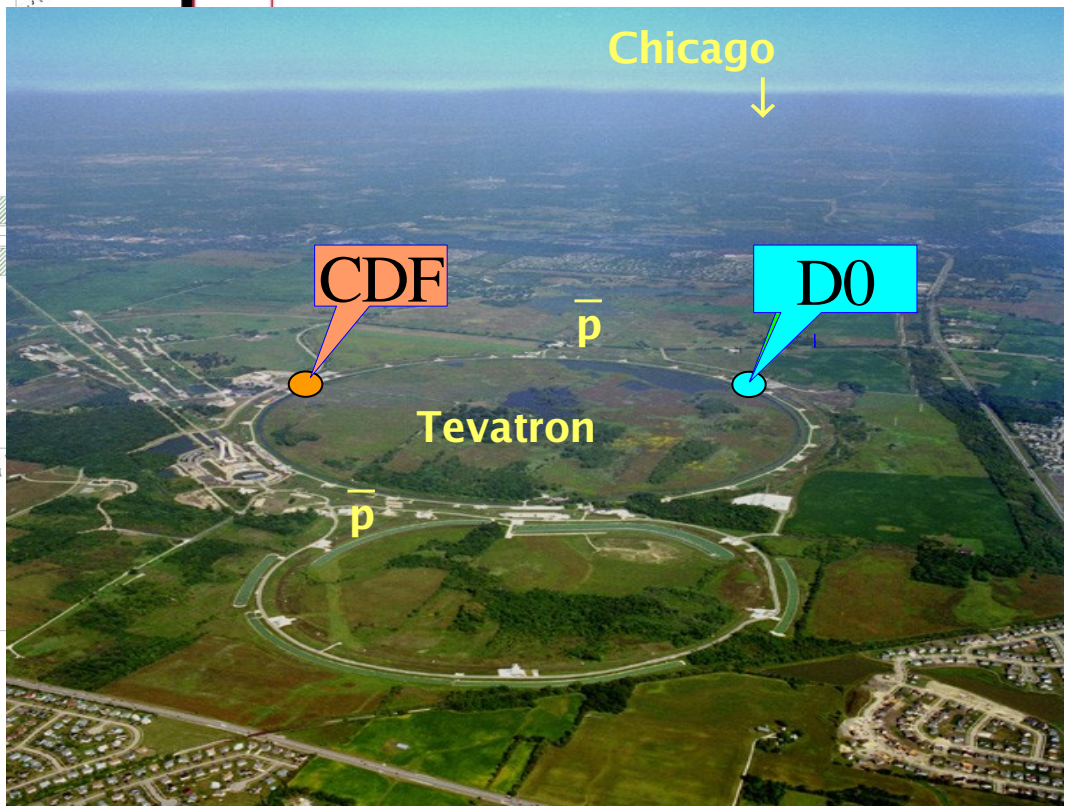
Signal, PYTHIA	LQ (80 to 140 GeV)	LQ3 (150 to 220 GeV)
DATA	Jets + MET trigger (310 pb-1)	Jet + MET(310 pb-1) / MUJET(367pb-1)
SM Backgrounds MC+ Full Det. Sim. QCD(Instrumental)	W->(μ,e,τ)ν+2j (non-nreconstruted lepton), Z->(νν)+2j, WW,WZ, ZZ, top pairs/single production multijet production estimated from data	
LQ Signal selection	Angular correlations between the jet and MET directions	Jet LIfetime Probability (JLIP) b-tag and muon tagging

The D0 experiment



Run II started 2001

$p\bar{p}$ @ 1.96 TeV



D0 detector upgrade

extended muon and

new tracking system

Recorded Luminosity (Sep'06) ~ 1.4 fb-1

0.3-0.4 fb-1 Aug '02 -Nov '04

for results in this talk

LQ in the acoplanar jet topology

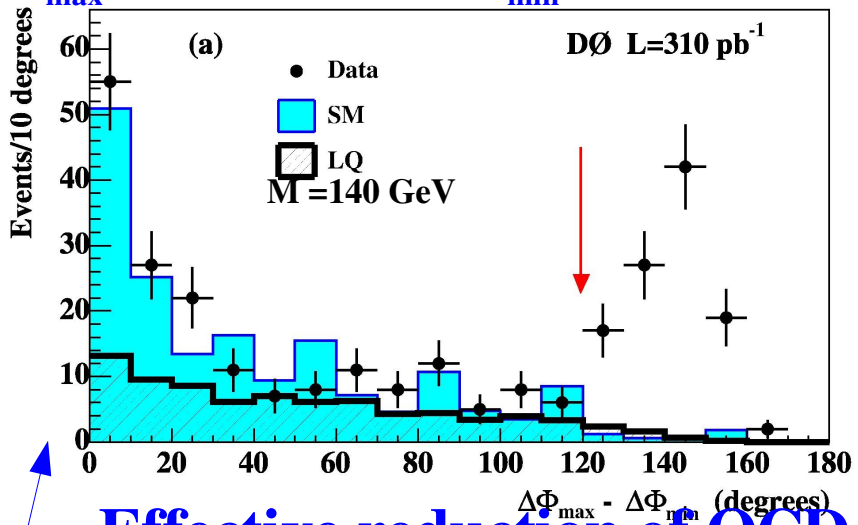
Initial cuts: Data Quality,

MET > 40 GeV, $\Delta\varphi$(jet1,jet2)<165°,

MHT > $|\Sigma_{jets} \vec{P}_T|$ > 40 GeV , | Zpv | < 60 cm

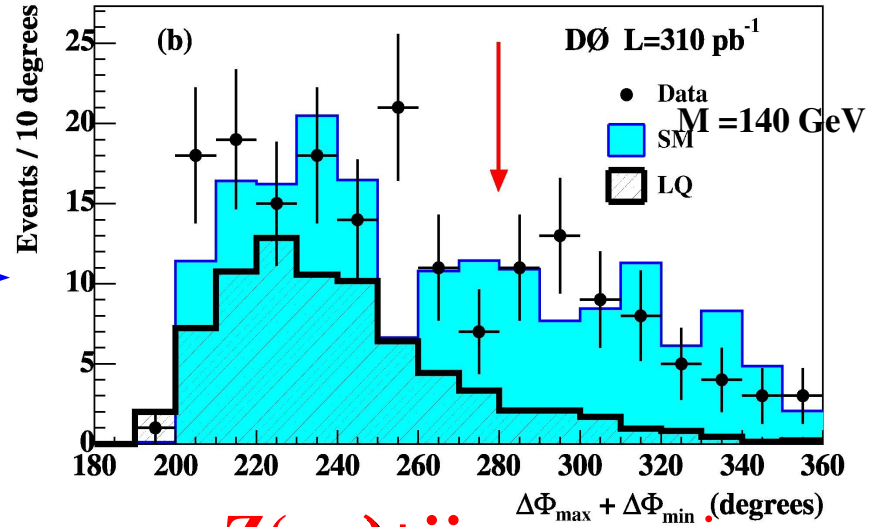
Cut applied		Events left	Efficiency (%)
Initial cuts		306,937	58.8
C1: jet-1 $p_T > 60$ GeV	Inst. bkg.	206,116	48.7
C2: jet-1 $\|\eta_{\rm det}\| < 1.5$		160,323	46.8
C3: jet-2 $p_T > 50$ GeV		48,979	24.8
C4: jet-2 $\|\eta_{\rm det}\| < 1.5$		42,028	22.7
C5: jet-1 jet-2 EMF < 0.95		40,821	22.3
C6: jet-1 jet-2 CPF > 0.05		34,746	22.2
C7: exactly two jets		5,213	15.3
C8: $\not\!\!E_T > 70$ GeV		492	11.8
C9: isolated electron veto	W/Z+ jj	465	11.7
C10: isolated muon veto		399	11.6
C11: isolated track veto		287	10.0
C12: $\Delta\Phi_{\rm max} - \Delta\Phi_{\rm min} < 120°$		180	9.4
C13: $\Delta\Phi_{\rm max} + \Delta\Phi_{\rm min} < 280°$	Z($\nu\nu$)+jj	124	8.4
C14: $\not\!\!E_T > 80$ GeV		86	7.0

$\Delta\varphi_{max}$(mEt,any jet)-$\Delta\varphi_{min}$(mEt, any jet)



Effective reduction of QCD

$\Delta\varphi_{max}$(mEt,any jet)+$\Delta\varphi_{min}$(mEt, any jet



Jet + MET trigger ~ 14 million events.

Down to ~500 events well described by SM

Z($\nu\nu$)+jj suppression

LQ in the acoplanar jet topology

Dominant background : Z(νν)+jj and W(lν) +jj

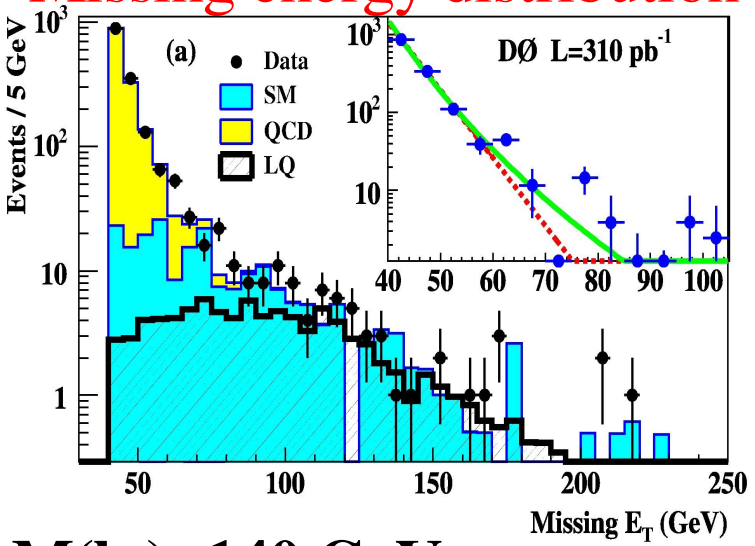
Instrumental background :

mean of 2 fits of the MET distribution

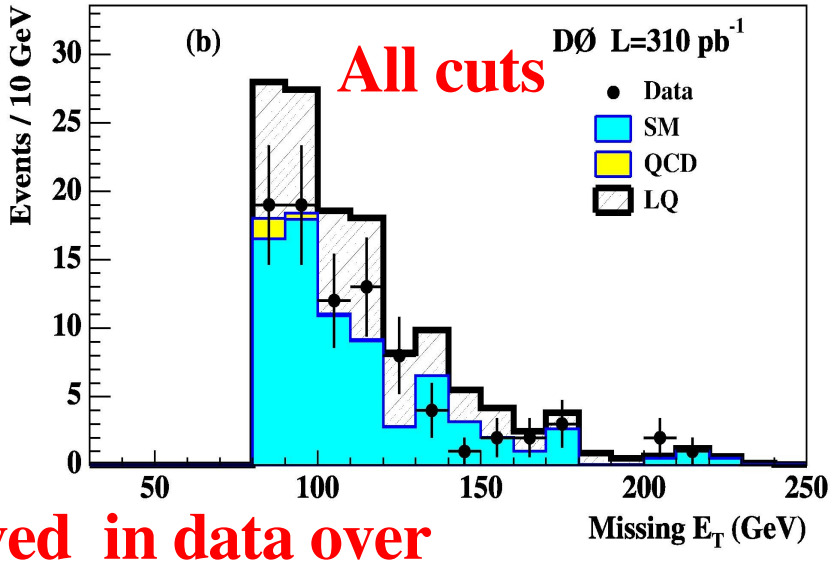
in 40 to 60 GeV region.

$(Z \to \nu\nu)$+2-jets	34.6 ± 4.3
$(W \to \ell\nu)$+jets	$35.0^{+9.1}_{-8.7}$
$(Z \to \ell\ell)$+jets	$0.3^{+0.4}_{-0.2}$
$t\bar{t}$	1.9 ± 0.1
WW, WZ, ZZ	1.2 ± 0.2
Total SM background	$72.9\ ^{+10.1}_{-9.7}\ ^{+10.6}_{-12.1}$
Instrumental background	2.3 ± 1.2
Total background	$75.2\ ^{+10.1}_{-9.7}\ ^{+10.7}_{-12.2}$
Data events selected	86
Signal ($m_{LQ} = 140$ GeV)	$51.8 \pm 1.8^{+5.6}_{-4.6}$

Missing energy distribution

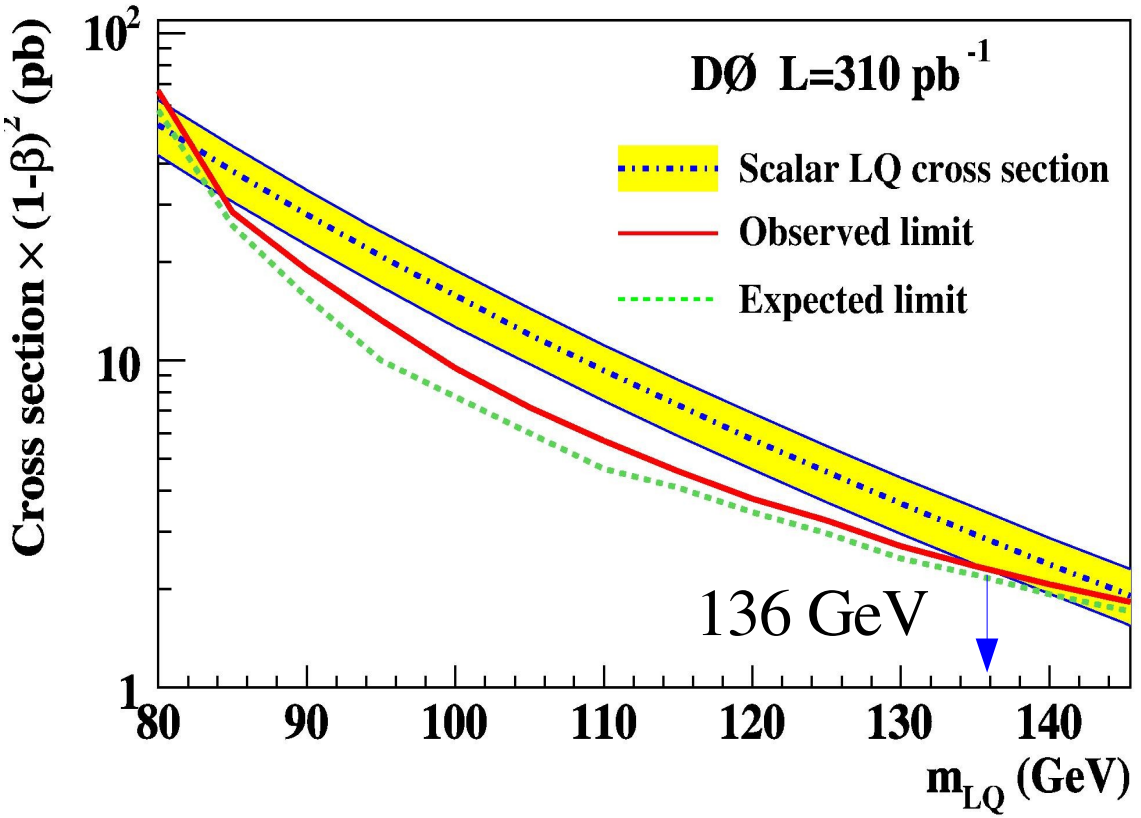


M(lq)=140 GeV



After all cuts : No excess of events observed in data over background expectations.

LQ in the acoplanar jet topology



M(LQ)<136 GeV excluded at 95% CL -

the most stringent limit for 1st and 2nd generation scalar leptoquarks decaying to quark and neutrino

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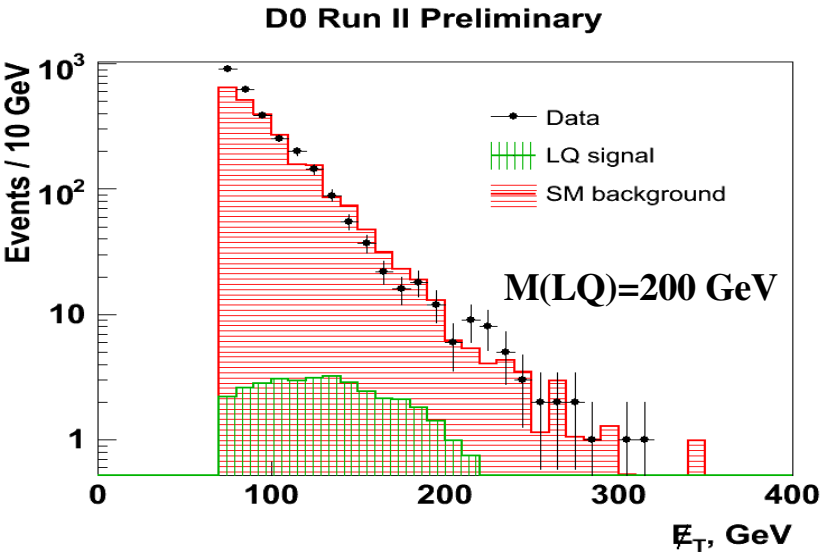
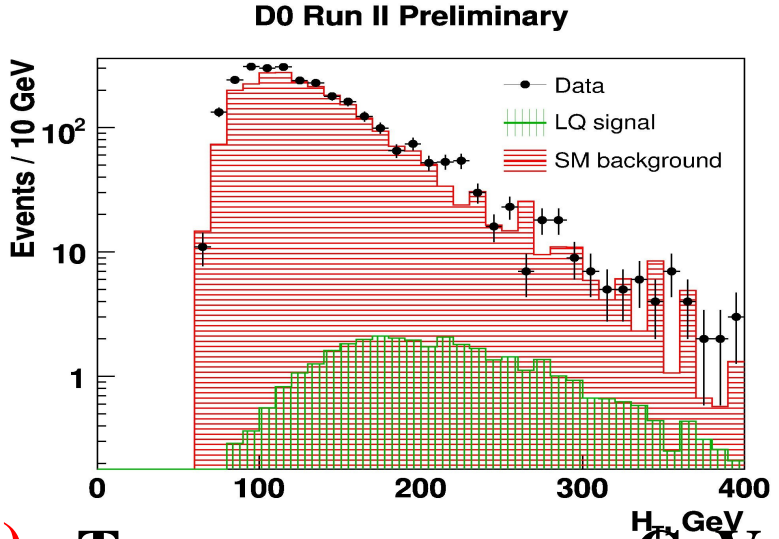
3rd generation leptoquarks. LQ LQ -> bνbν

Suppression of the instrumental background and events with isolated leptons

Cut description	Data	Signal(Accept.) M_{LQ}=200 GeV
trigger, $\not\!\!E_T$ >40 GeV, $\Delta\phi(\not\!\!E_T$,jet) >0.5	482635	59.1 (71.1%)
$\not\!\!H_T$ > 40 GeV	445280	58.6 (70.5%)
leading jet E_T > 40 GeV	419451	58.3 (70.1%)
second jet E_T > 20 GeV	167601	51.7 (62.2%)
no bad jets E_T > 15 GeV	91568	49.7 (59.8%)
the primary vertex $\|z\|$ < 60 cm	87873	49.1 (59.1%)
leading jet $\|\eta\|$ < 1.5	69892	47.9 (57.6%)
jet track confirmation	49494	45.9 (55.3%)
no isolated EM objects p_T > 5 GeV	46569	45.5 (54.8%)
no isolated muons	44198	45.0 (54.2%)
muon p_T^{max} < 200 GeV	44153	44.9 (54.1%)
$\Delta\phi(\not\!\!E_T$,jet) > 0.7	25348	41.6 (50.1%)
acoplanarity < 165°	24661	40.6 (48.8%)
$\not\!\!E_T$ >70 GeV	2804	36.5 (43.9%)
$\Delta R \times p_T$ > 3.5 GeV, H_T > 110 GeV		
$\Delta\phi(\not\!\!E_T$,jet) <3.0	1241	29.9 (35.9%)



Missing energy , GeV



Transverce energy , GeV

Agreement with SM (W/Z events dominated)

Contribution of multijet backgrounds is small

3rd generation leptoquarks (Signal Selection)

Events without muons :

2 JLIP (P(light quark) < 2%) tags

(HT>110 GeV, mET> 70 GeV for M(LQ)<200

increased for higher LQ masses

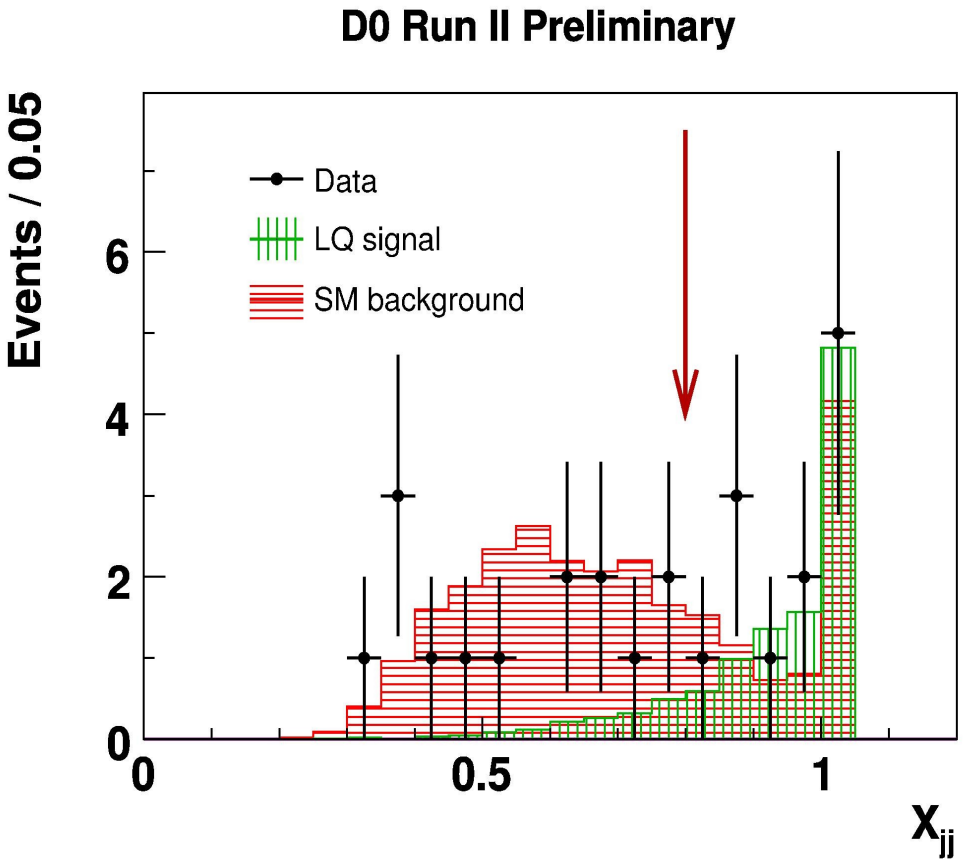
Events with muons

1 muon tag (pT> 4 GeV muon within $\Delta R(\mu,jet) < 0.5$) and/or 1 JLIP tag

Et fraction of tagged jets is large in LQ signal

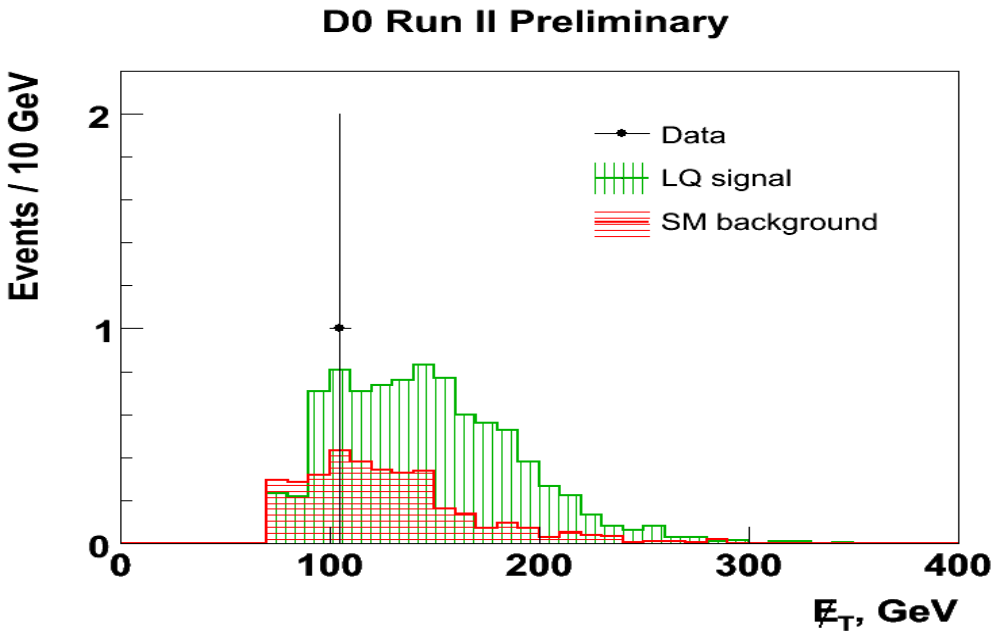
$$Xjj == (Et(tag1)+Et(tag2)+pT\mu)/(\Sigma Et(all\ jets)+pT\mu) > 0.8$$

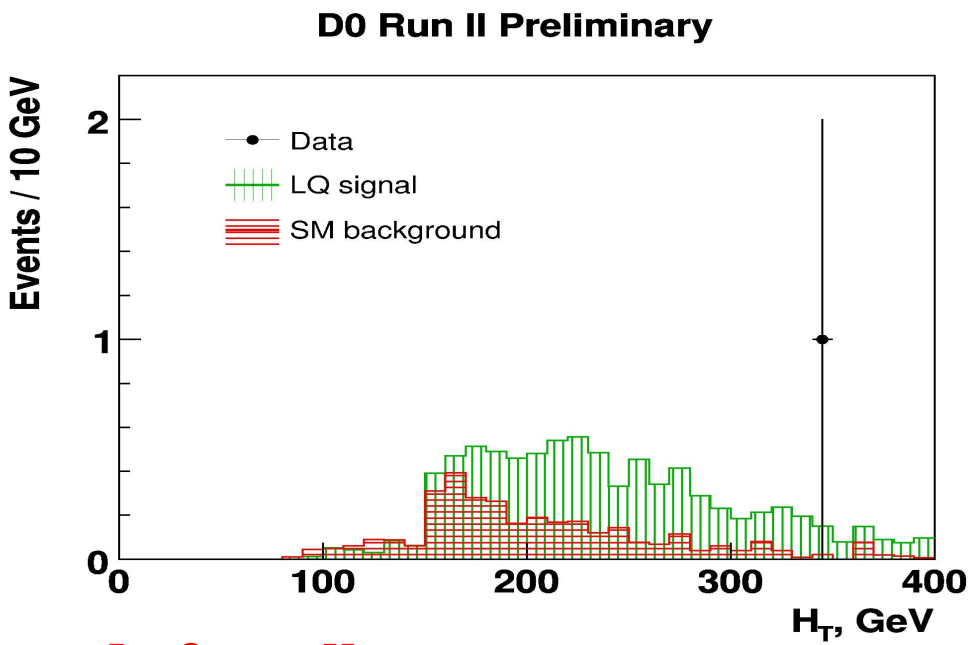
Effectively reduces top backround



3rd generation leptoquarks

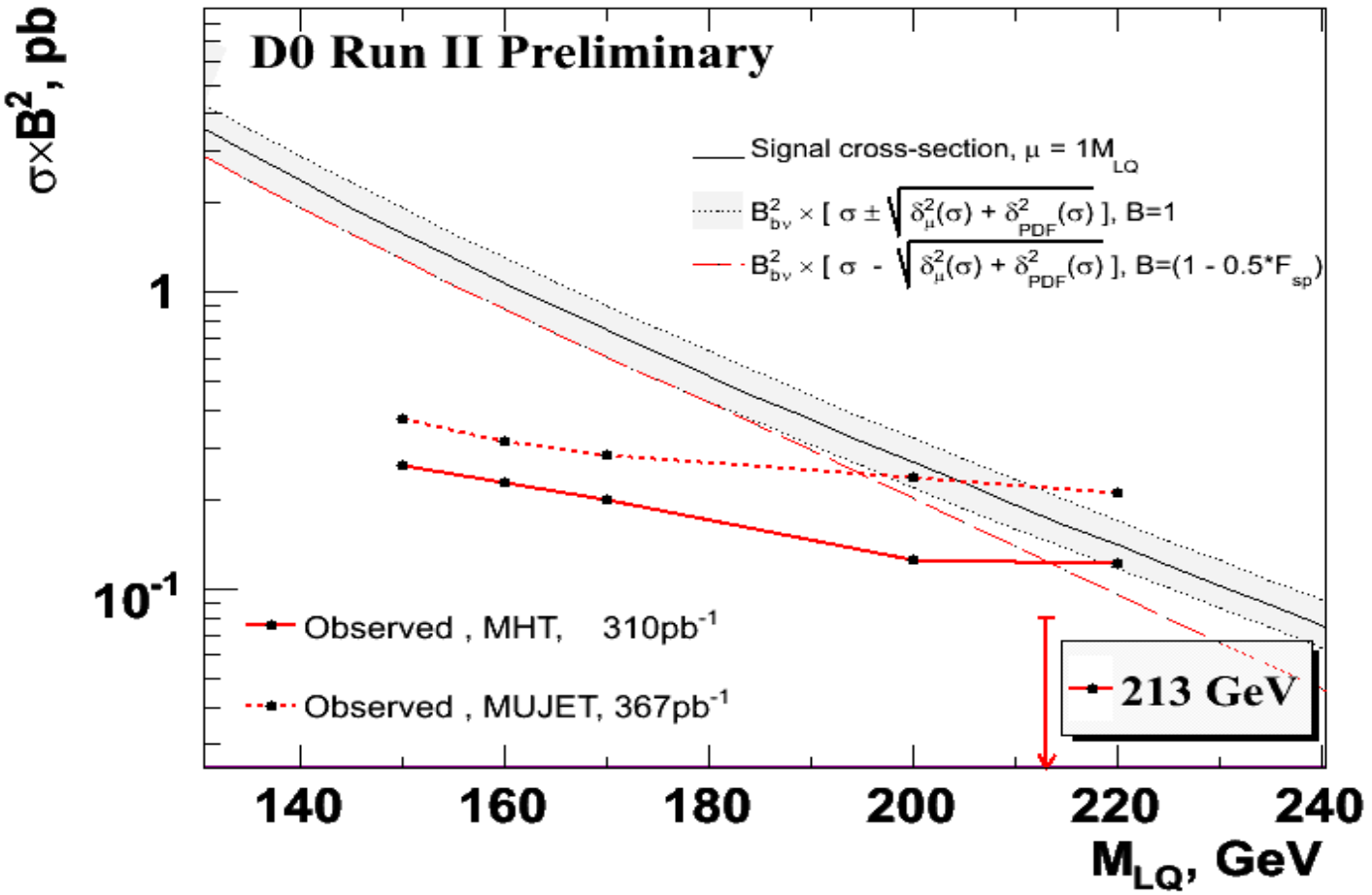
Process	Pretag	Double JLIP	Muon+ Single JLIP	Total
W(μν)+jj	287±9	0.02±0.01	**0.15±0.07**	0.17±0.07
W(eν)+jj	320±18	0.02±0.01	0±0	0.02±0.01
W(τν)+jj	698±44	**0.15±0.01**	0±0	0.15±0.04
Z(νν)+jj	1062±21	**0.38±0.14**	0.03±0.03	0.41±0.14
Top	**60±1**	**0.71±0.06**	**0.80±0.09**	**1.51±0.11**
W/Z + bb	**28±1**	**0.66±0.07**	**0.53±0.11**	**1.19±0.13**
SM expected	2456 ± 53	1.95±0.17	1.52±0.16	**3.47±0.24**
Data (**310 pb^{-1}**)	2804	1	0	**1**
Signal **M(LQ)=200 GeV**	37±1 (43.9%)	5.8±0.2 (**6.9%**)	3.1±0.2 (**3.7%**)	**8.8±0.2** (**10.6%**)





No excess observed after all cuts

3rd generation leptoquarks LQ LQ -> bνbν



Excluded LQ3 mass @ 95 % CL :

BF(*bν*)=1	BF=1 – 0.5*F(*bν*)$_{sp}$
219 GeV	**213 GeV**

Analysis note http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

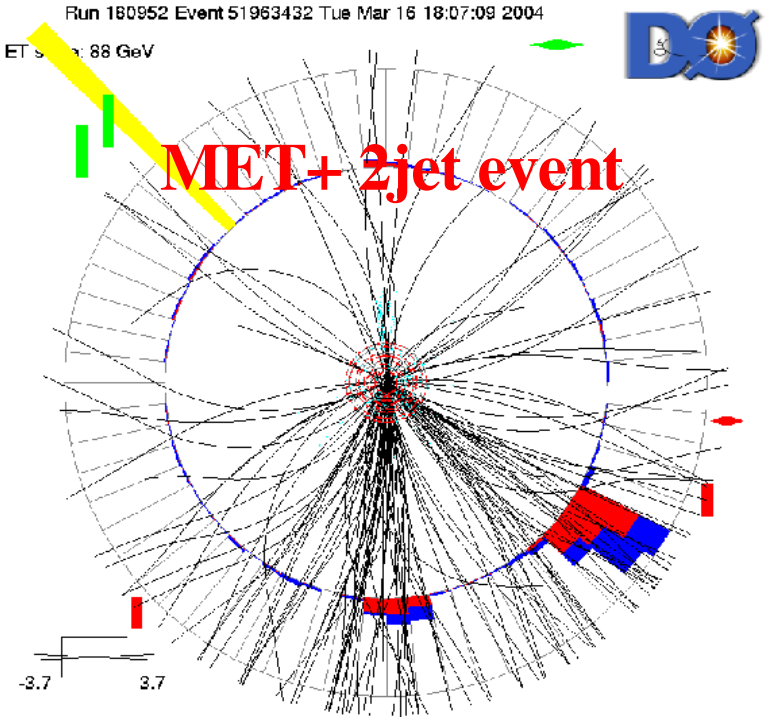
Summary

- No evidence of LQ observed in LQLQ -> $\nu\nu$qq and LQ_3LQ_3->$\nu\nu$bb

- new 95% CL limits on LQ mass:

  136 GeV and 213 (219) GeV for these channels

- With new data arriving (up to 8 pb-1 in '09) still possibility for discovery and search for new physics



Backup Slides

Resent Fermilab Results

LQ in acoplanar jets : CDF, 2005, M<117 GeV, 191 pb^{-1}

Fermilab results 3rd generation

	Run I D0 limits (GeV)	(RunII 310 pb^{1})	Run I CDF limits (GeV),	(RunII 322 pb^{1})
Scalar LQ3	94 ($\nu\nu bb$)	213(219)	148 ($\nu\nu bb$), 99 ($\tau\tau bb$)	---
Vector (min coupling)	148 ($\nu\nu bb$)	------	199($\nu\nu bb$)	251 ($\tau\tau bb$, B=1)
Vector (Yang-Mills)	216 ($\nu\nu bb$)	------	250($\nu\nu bb$)	317 ($\tau\tau bb$, B=1)

Extrapolation of the D0 LQ3 search for VLQ is in progress

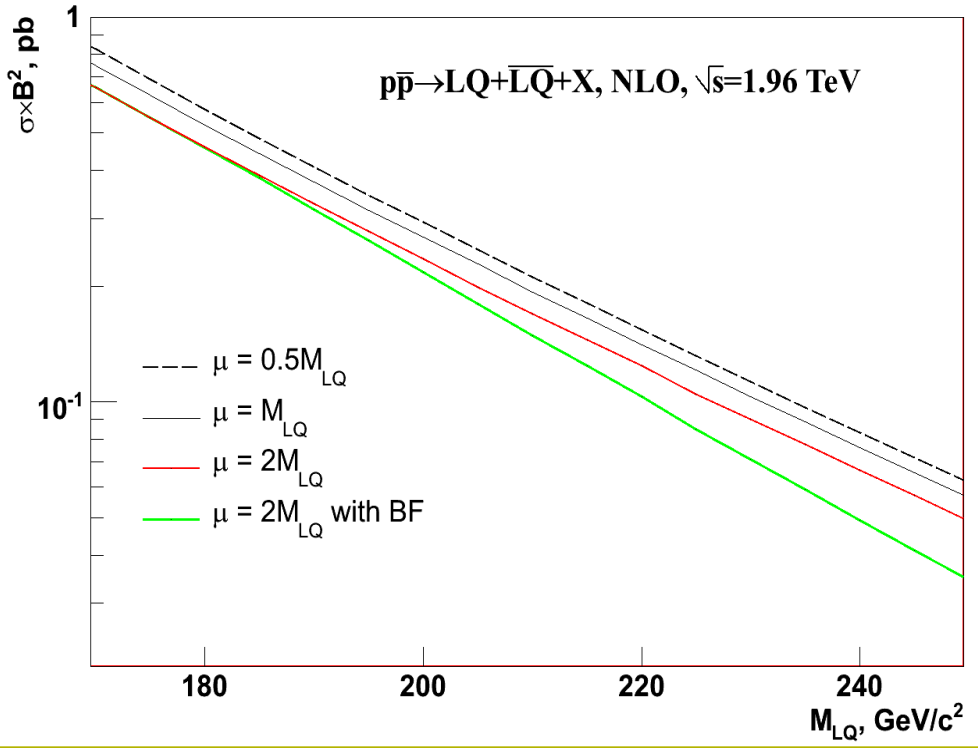
3rd generation leptoquarks (Branching suppression factor)

For the LQ mass >> M(top)

the LQ->bν branching ratio would be Br(LQ->bν) = Br(LQ->tτ) = 0.5

In LQ mass range 180 - 220 GeV the LQ->top+tau channel suppressed but not negligible. Correspondingly decreased Br(LQ->bν) (Table)

The green graph was used in the analysis to find LQ mass limit.



BR (LQ_3-> $b\nu$) = 1 – 0.5*Fs($b\nu$)

M(LQ),GeV	*Br(bν)**2*
185	0.99
200	0.93
220	0.83

3rd generation leptoquarks - Muon tagging (MUJET triggers)

Total events triggered : ~17000000 (367 pb-1)

Cleaning cuts (down to ~190 events - "noQCD" point) :

- **track conf. pT> 4 GeV muon in jet with dR(mu,jet) < 0.5**
- **removal "bad jet" events (not confirmed by d0 correct)**
- **Et_{leading jet} > 40 GeV, Et{second leading jet} > 20 GeV**
- **Delta phi(mEt, nearest jet) > 0.7 rad , mEt>75 GeV, mHt > 50 GeV**

"NoQCD" point, dominant SM
(W-> lν)+jets (~75%)

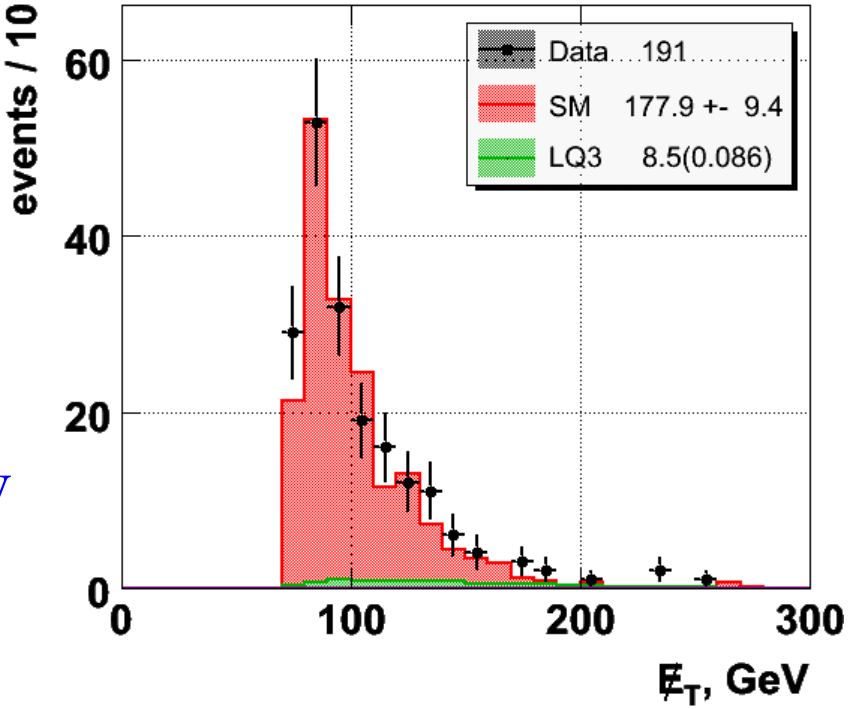
-- **isolation e/mu veto (for pT(e/μ) > 5 GeV)**

-- **pT(μ) > 6 GeV (pi/K decays suppression)**

-- **DR(μ,jet) x pT(μ) < 3.5 GeV**

-- **sum of track's pT**
in cone 0.5 around the muon Σ pT (trk) > 10 GeV

-- **Fμ , fraction of calorimeter energy around muon**
direction in 0.4 cone to 0.6 cone. > 0.7



Systematic uncertainties (3rd generation leptoquarks)

Systematic (%) after all cuts

Error source	Signal (M=200 GeV)	SM background
Integrated luminosity	6.5	
SM cross section	**--**	**15**
Trigger efficiency	5	
Jet selection (MHT only)	1	
Jet energy scale	+2.4, -3.2	**+11.8, -7.9**
b-tagging efficiency	**+13.5, -11.4**	**+12.0, -10.7**
b->mu branching fraction	1.5%	

Other sources of systematic: muon isolation (cuts on **DR(μ,jet) x pT(μ)** and **Σ pT (trk)) , PDF for signal, track isolation DR(track,jet) x pT** were studied: **combined contribution less then 5% - not included in the limits calculations .**