Search for First Generation Leptoquarks at DØ

Bjoern Penning
Fermilab

Motivation

- Standard model is believed to be low energy effective theory
- Hints of physics beyond SM
- DØ performed search program for new particles and models
  - Leptoquark (LQ) is predicted by many extensions of the Standard Model (GUT, technicolor, SUSY, etc.)
  - Leptons and quarks don't interact directly in SM
  - LQ carries both, lepton and baryon numbers → mediating boson between each
- Can be scalar or vector field, three generations
- Short-lived and decays to a lepton and a quark

The Tevatron

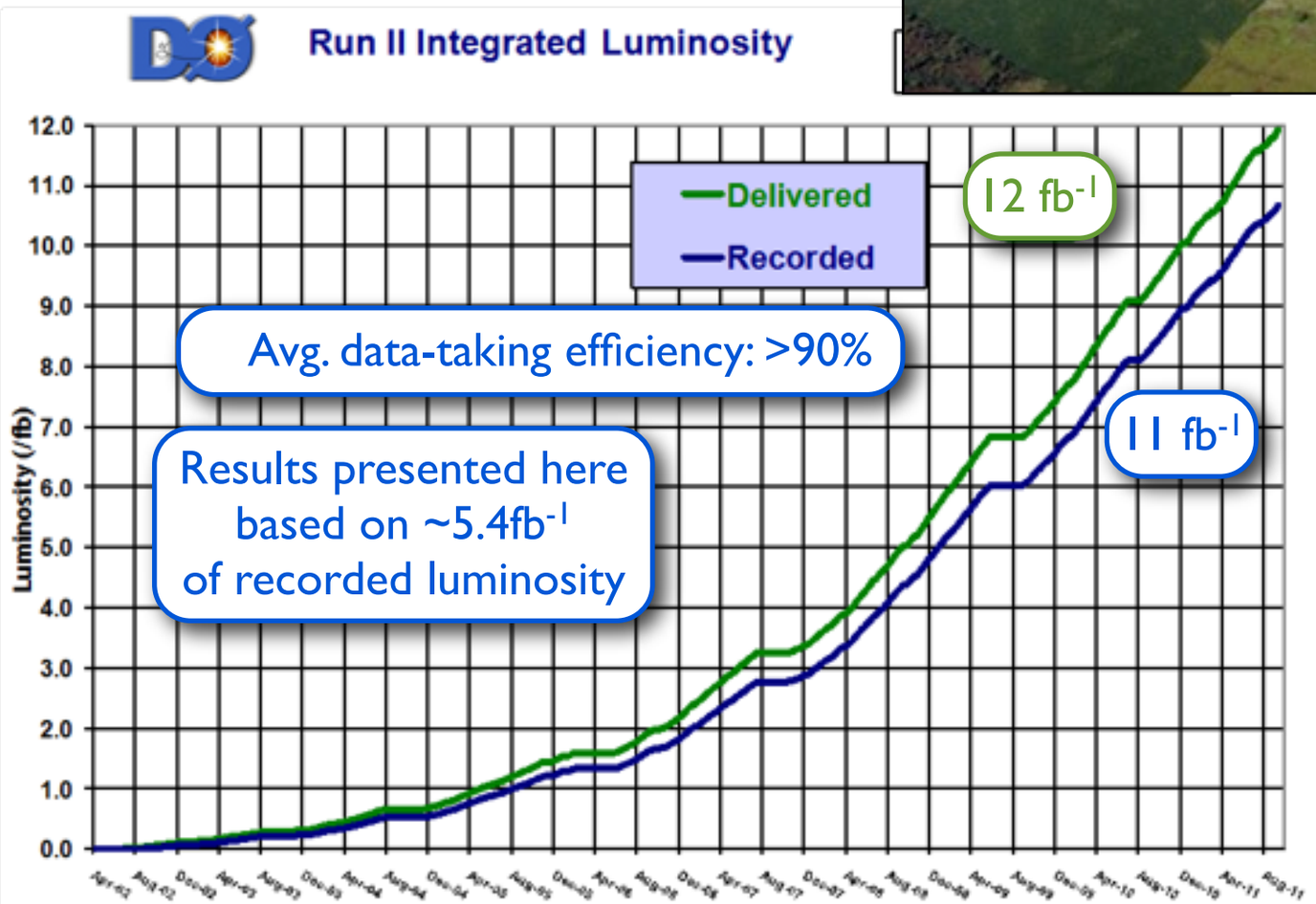
p $\bar{p}$

$\sqrt{s}$ =1.96 TeV

Δt = 396 ns

Run I 1987 (92)-95
Run II 2001-11: 75x larger dataset increased energy

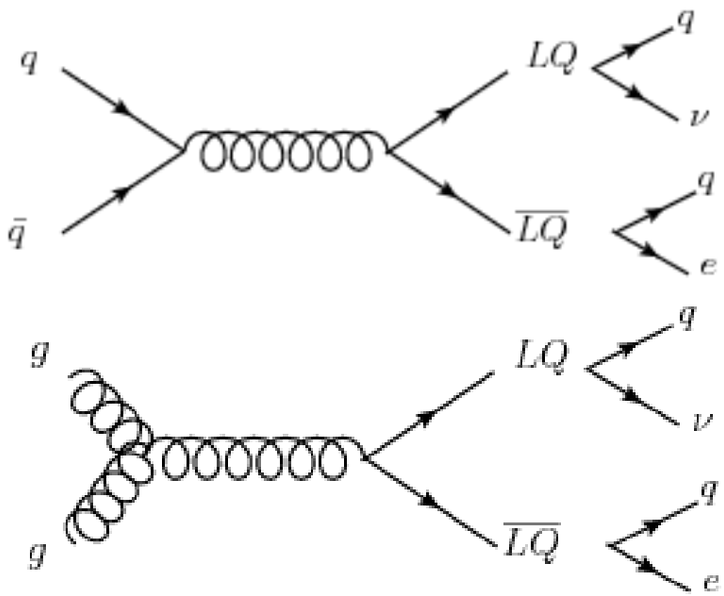
Typical average Luminosity:
>300 x 10^{30} cm^{-2} sec^{-1}
~50pb^{-1} per week



- **Central tracking:**
  silicon vertex detector and fiber tracker in 2T field
- **Calorimeter:**
  hermetic coverage $|\eta|<4.2$, Liquid Argon Calorimeter
- **Muon System:**
  excellent purity and coverage: $|\eta| < 2$

LQ production

- Produced via quark-antiquark annihilation or gluon-gluon fusion:
  - $q + q \rightarrow LQ + LQ$
  - $g + g \rightarrow LQ + LQ$
- Assume no intergenerational mixing
  - Search for 1st Generation scalar LQ
- LQ can decay to lq or νq'
- Pair production: eqeq, eqνq, and νqνq.
  - Define branching ratio $\beta = Br(LQ \rightarrow e + q)$, then probability of LQ pair decaying to eqνq is $2\beta(1 - \beta)$
- $\sigma \times BR$ maximal for $\beta = 0.5$



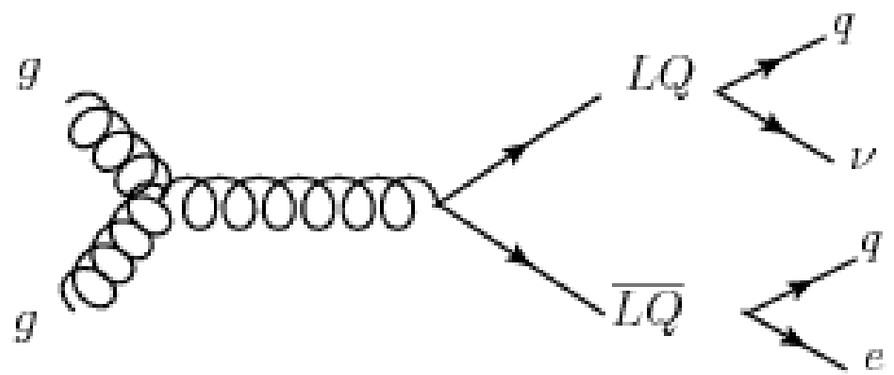
Data and Background Samples

- 5.4 fb^{-1} of Data collected at DØ between 2002 and 2009
- SM backgrounds:
  - Multijet (MJ) background estimated from data
  - W/Z+jets, tt, single top, diboson (WW, WZ and ZZ) Normalized to the (N)NLO
- Leptoquark signal normalized to NLO

M_{LQ} (GeV)	200	210	220	230	240	250	260	270
σ (fb)	268	193	141	103	76	56	42	31
M_{LQ} (GeV)	280	290	300	310	320	340	360	
σ (fb)	23	17	13	10	7.4	4.2	2.4	

Event Selection

- Channel LQLQ → eqνq;
- A priori don't know assignment of jet to e, ν
- Choose best pairing:



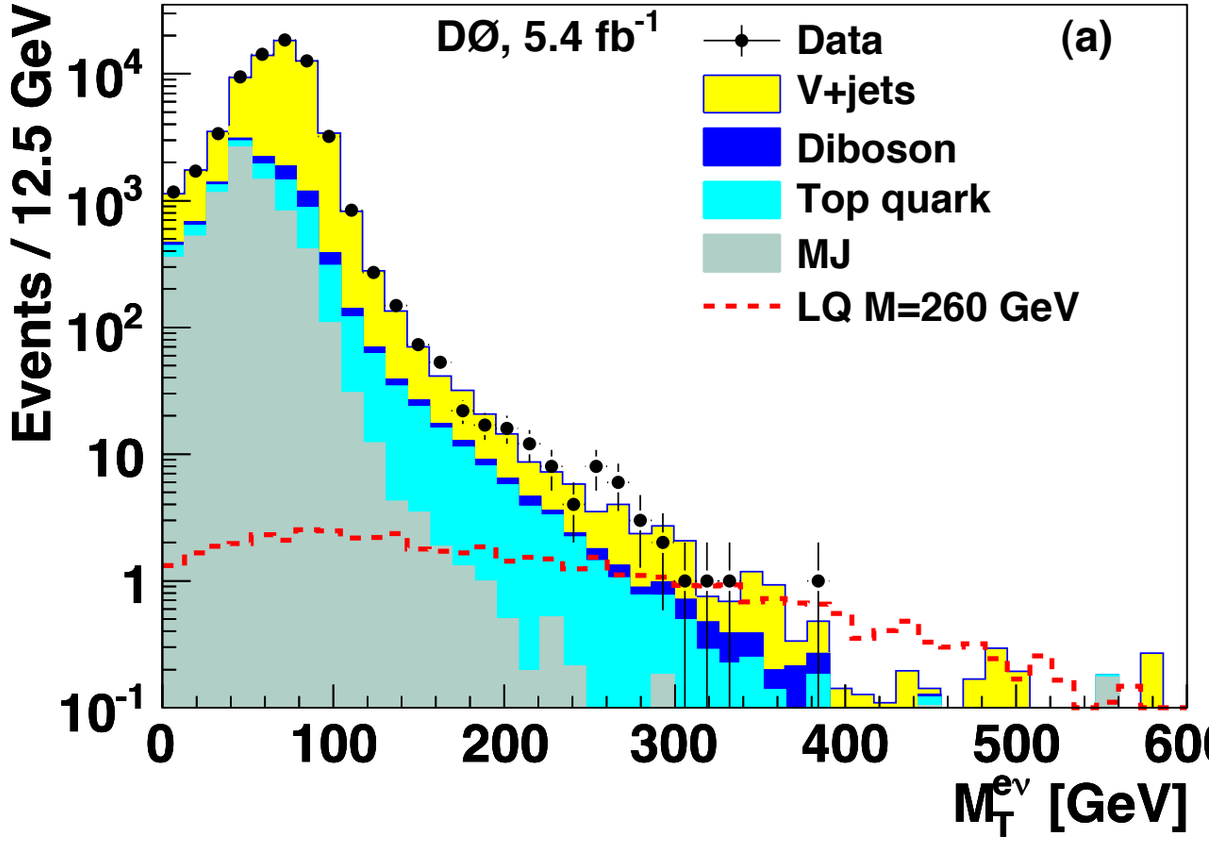
  - matching by minimizing differences in p_T from the combination of (jet,e) and (jet,ν)
  - reconstruct LQ from the both combinations, and pick the combination such that Δϕ(LQ1,LQ2) is closest to π (back to back)
  - matching by minimizing Δϕ between the decay products of LQs
  - matching by minimizing the differences in m_T reconstructed from (jet,e) and (jet,ν), since the LQs are produced with same mass

m_{LQ} (GeV)	200	240	280
p_T	0.46	0.47	0.47
$\Delta\phi(LQ_1, LQ_2)$	0.61	0.59	0.58
$\Delta\phi$(dec. prod)	0.48	0.47	0.45
$m_{T1}=m_{T2}$	0.77	0.75	0.74

Signal Selection

- Cut based analysis
- Preselection:
  - 1 electron, p_T > 15 GeV,
  - MET > 15 GeV
  - ≥2 jets, p_T > 20 GeV,
  - Multijet removal: MET/50 + m_T(e, MET)/70 ≥ 1

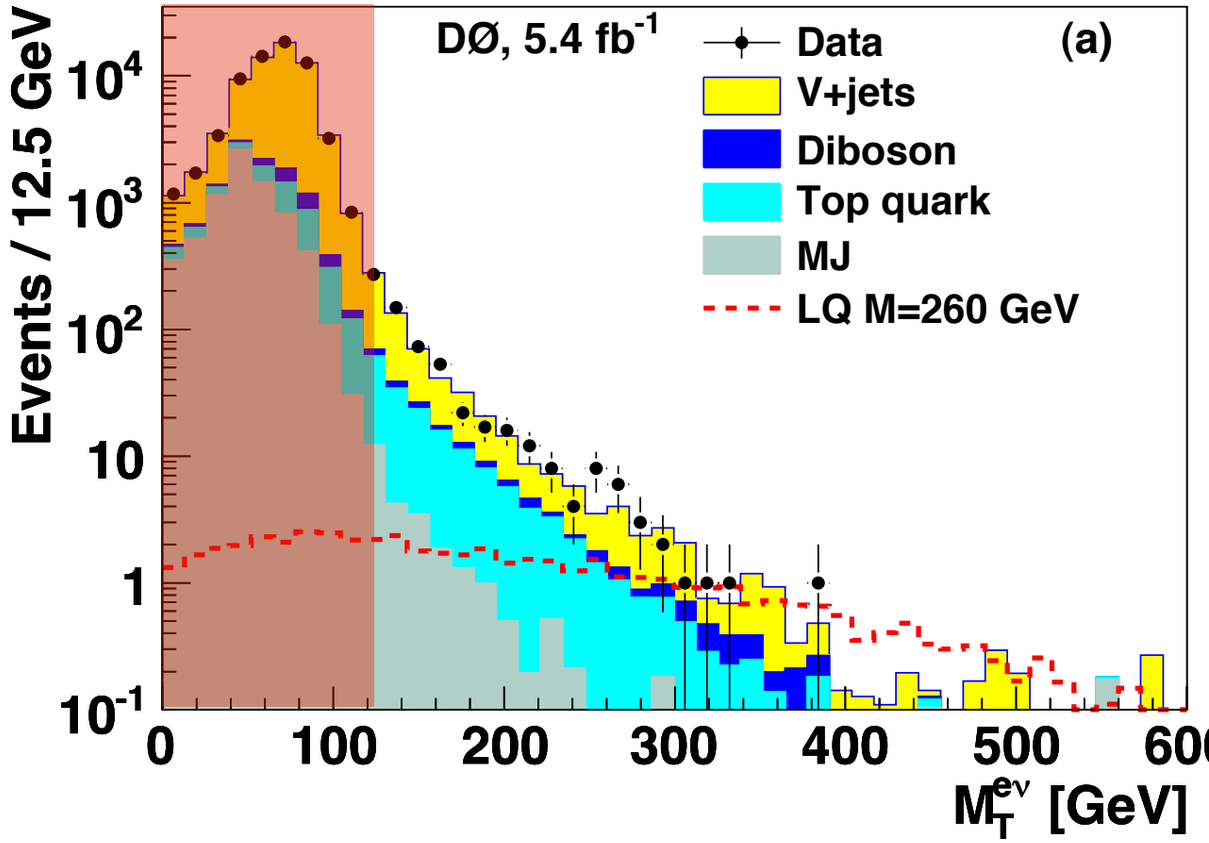
m_{LQ}=240 GeV	Data	Total Bkgd.	Signal
Preselection	65992	65703 ± 5958	50 ± 7



Signal Selection

- Cut based analysis
- Preselection:
  - 1 electron, p_T > 15 GeV,
  - MET > 15 GeV
  - ≥2 jets, p_T > 20 GeV,
  - Multijet removal: MET/50 + m_T(e, MET)/70 ≥ 1

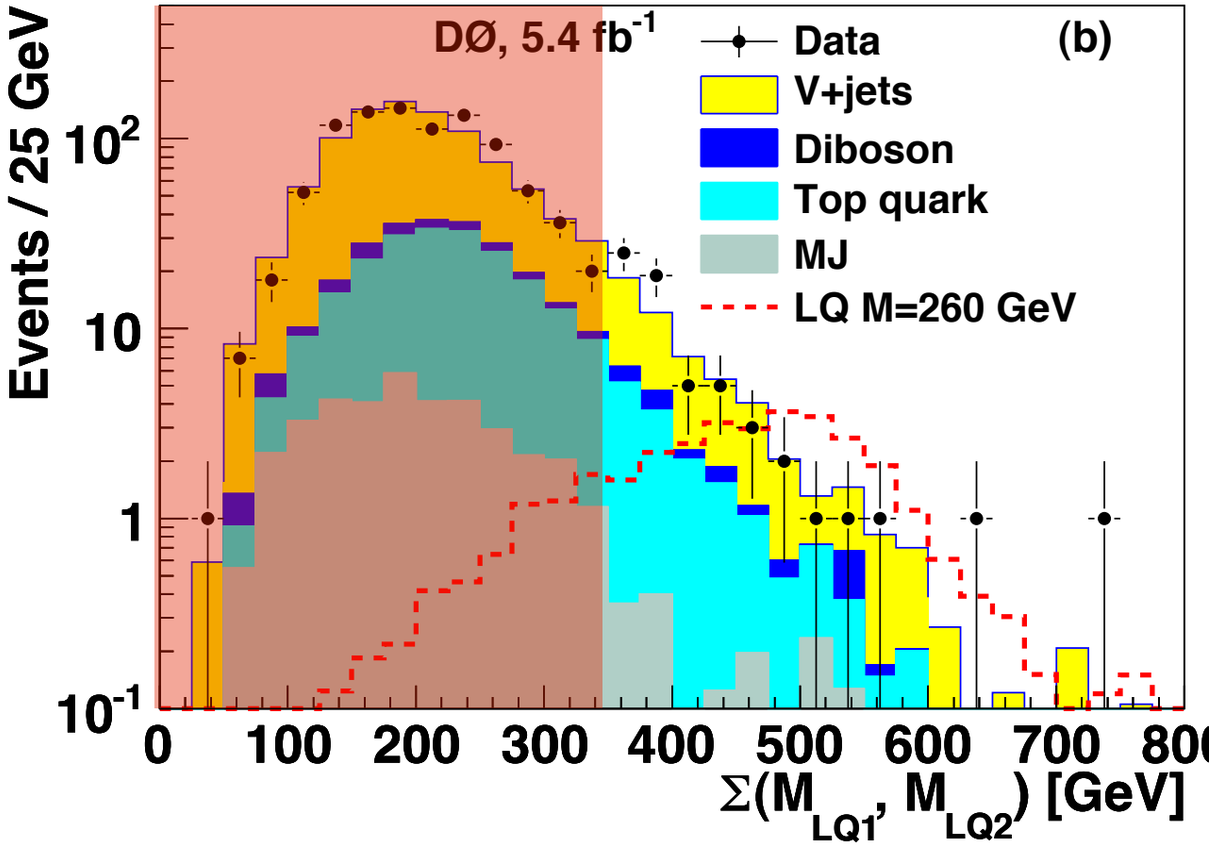
m_{LQ}=240 GeV	Data	Total Bkgd.	Signal
Preselection	65992	65703 ± 5958	50 ± 7
$M_T^{e\nu}$>110 GeV	990	986 ± 82	34 ± 5



Signal Selection

- Cut based analysis
- Preselection:
  - 1 electron, p_T > 15 GeV,
  - MET > 15 GeV
  - ≥2 jets, p_T > 20 GeV,
  - Multijet removal: MET/50 + m_T(e, MET)/70 ≥ 1

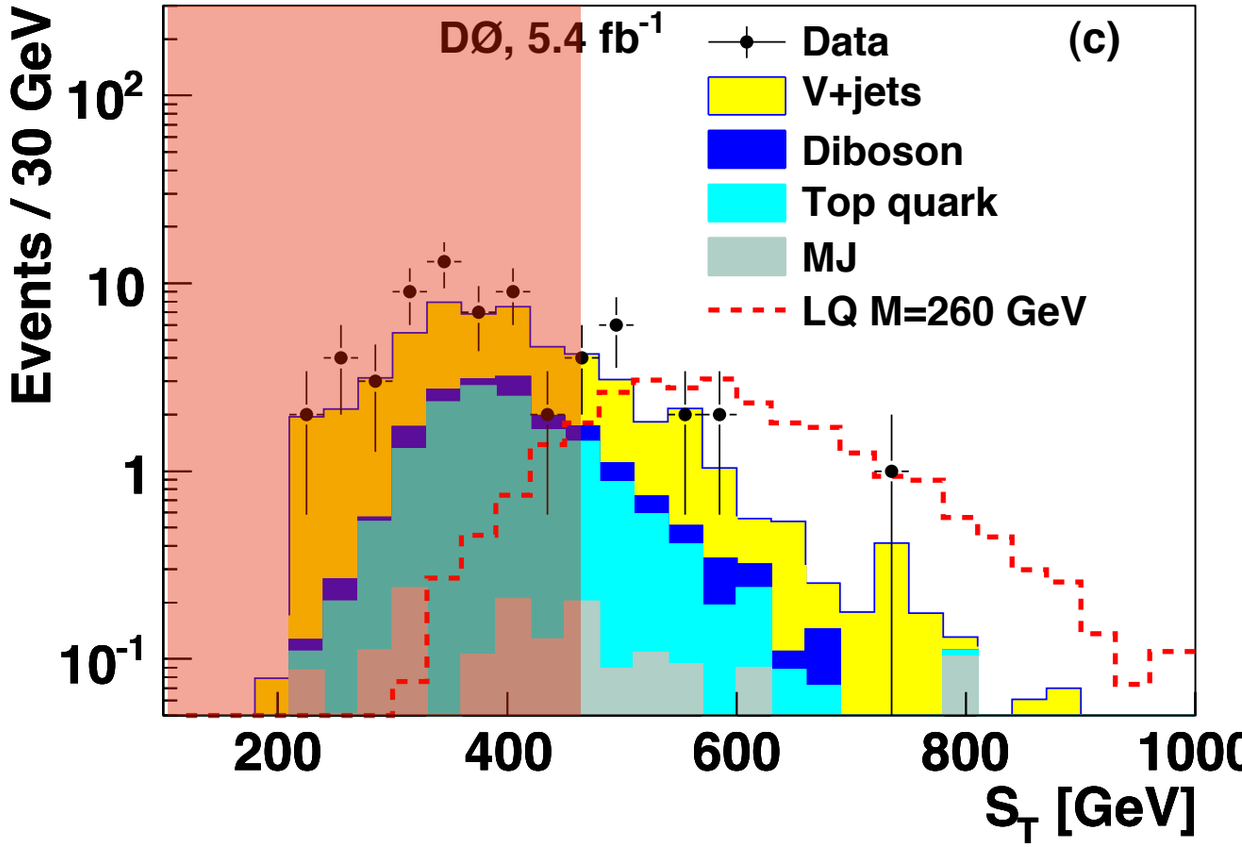
m_{LQ}=240 GeV	Data	Total Bkgd.	Signal
Preselection	65992	65703 ± 5958	50 ± 7
M_T^{ev}>110 GeV	990	986 ± 82	34 ± 5
ΣM_{LQ}>350 GeV	64	55 ± 4	27 ± 4



Signal Selection

- Cut based analysis
- Preselection:
  - 1 electron, p_T > 15 GeV,
  - MET > 15 GeV
  - ≥2 jets, p_T > 20 GeV,
  - Multijet removal: MET/50 + m_T(e, MET)/70 ≥ 1

m_{LQ}=240 GeV	Data	Total Bkgd.	Signal
Preselection	65992	65703 ± 5958	50 ± 7
$M_T^{e\nu}$>110 GeV	990	986 ± 82	34 ± 5
ΣM_{LQ}>350 GeV	64	55 ± 4	27 ± 4
S_T>450 GeV	15	15 ± 1	24 ± 3

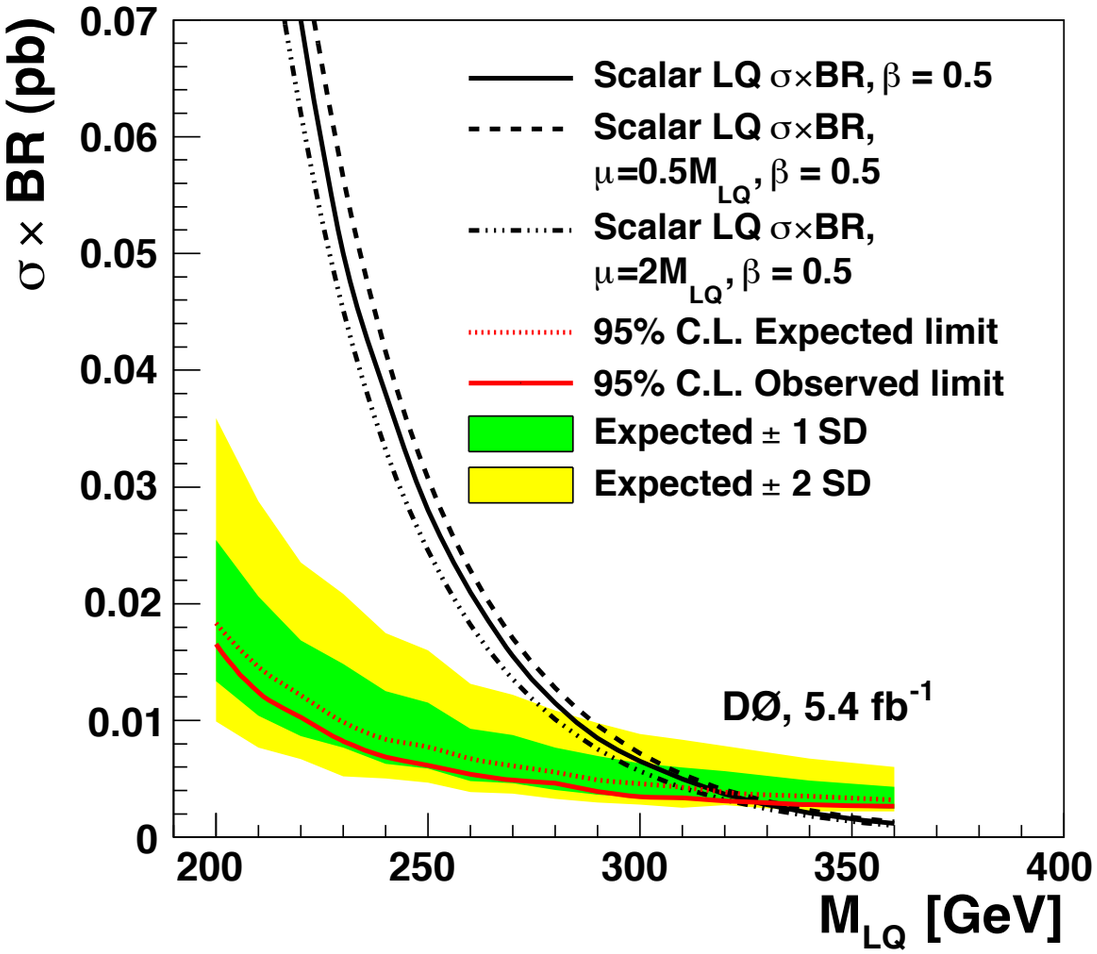


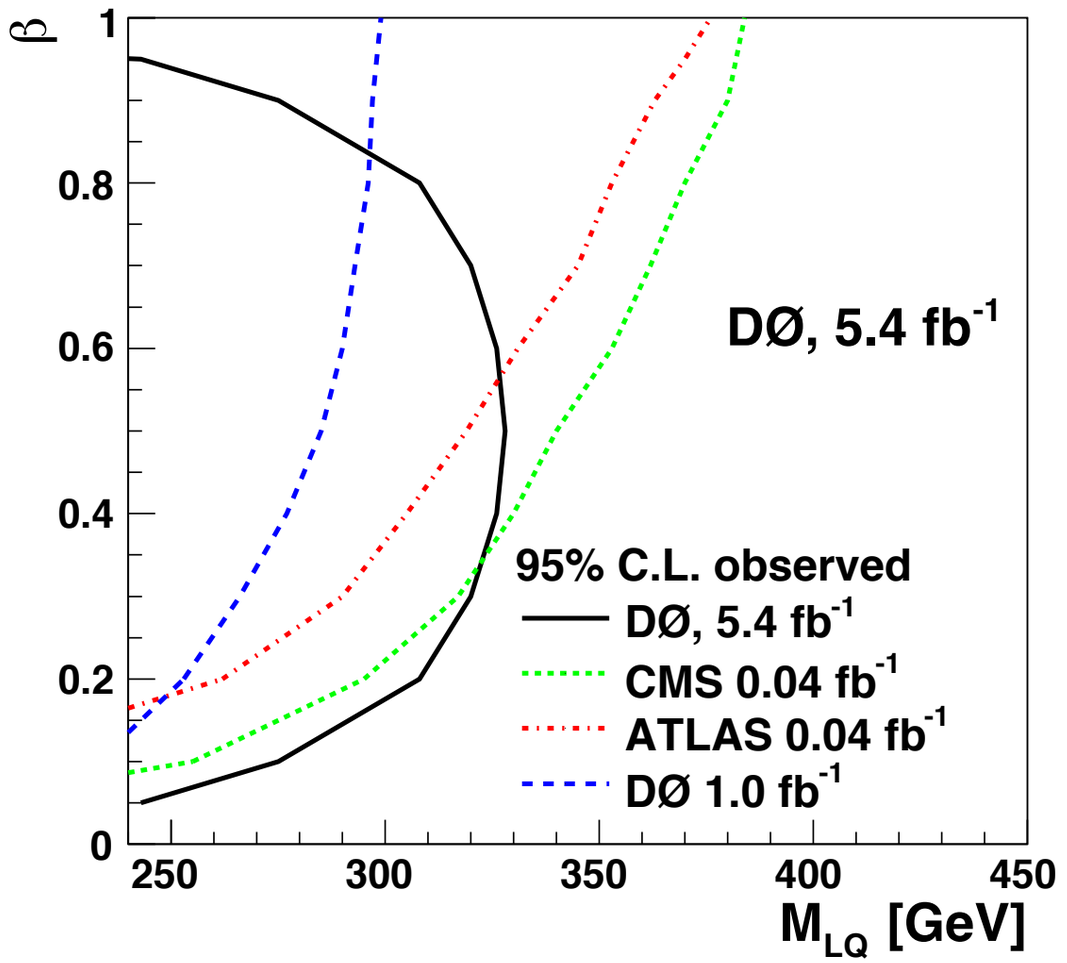
Systematics

- **Normalization of signal and and background (6%-10%) processes,**
- **MJ background (20%),**
- **Integrated luminosity (6.1%),**
- **Lepton trigger and identification (4%)**
- **Jet Energy Scale, Resolution and Identification (4-7%)**

Results

- Using S_T with final selection to search for LQ
- No excess in data ⇒ limits set
  - For β=0.5 LQ with mass below 326 GeV is excluded





Phys. Rev. D 84, 071104 (2011), arXiv:1107.1849

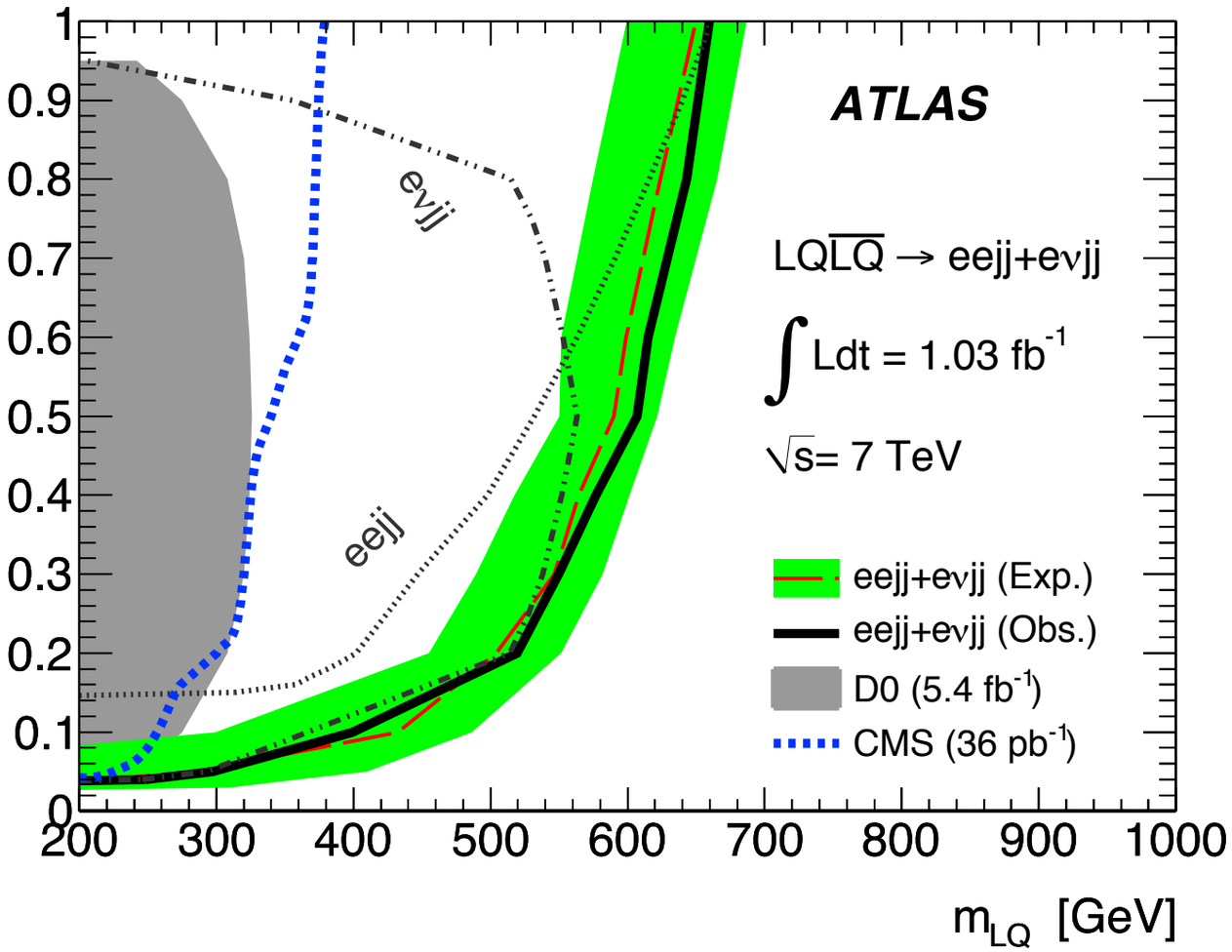
Summary

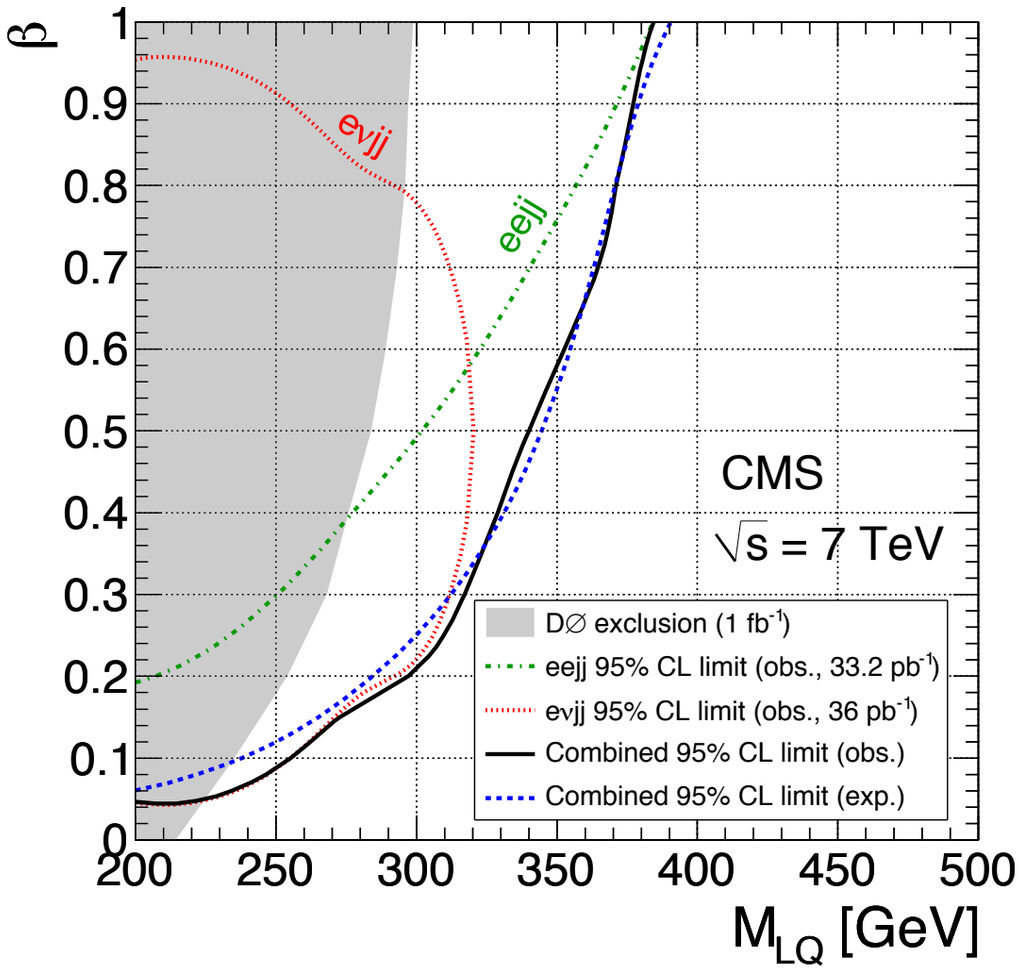
- Tevatron delivered 12fb^{-1} of data
- Results on the search for first generation scalar LQ pair production in evjj final state
- Scalar LQ with mass below 326 GeV for β=0.5 excluded
- DØ/Tevatron had rich program searching for New Physics
- Strong limits set, no discovery
- Torch of NP (Exotics, Susy) has been handed over to the LHC, hope for exciting news soon

Backup

Existing Searches

- **Previous published DØ result puts lower limit on a scalar LQ mass at 264 GeV in ejvj channel, and 284 GeV when combined with ejej and νjνj (β = 0.5)**





- **Recent ATLAS and CMS dominating all searches**