Searches for Leptoquark Production at DØ

Thomas Nunnemann

Ludwig-Maximilians-University, Munich
on behalf of the DØ collaboration

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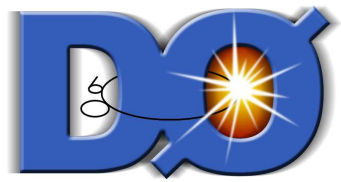
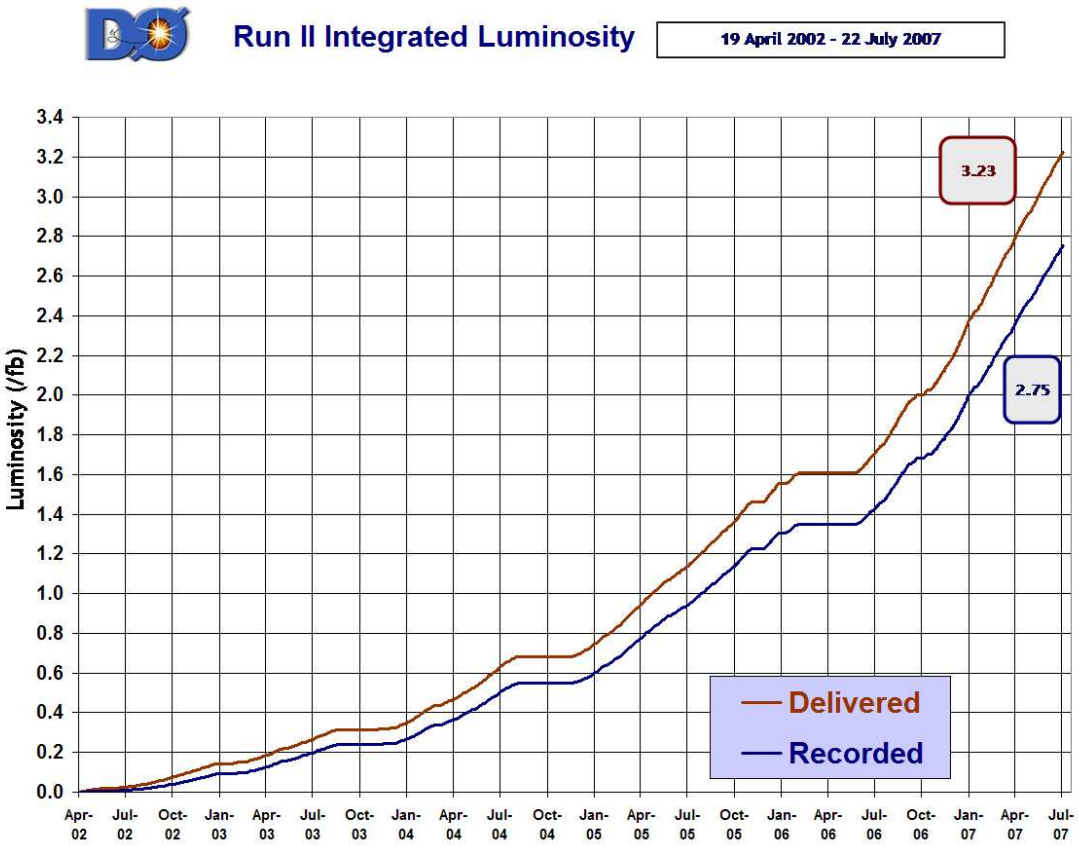


Outline

- Tevatron Run II luminosities
- Leptoquark production at hadron colliders
- Searches for Leptoquarks:
  - Pair production of 2^{nd} generation scalar leptoquarks in $\mu\nu jj$
  - Single production of scalar leptoquarks in $\mu\mu j$
  - Pair production of 3^{rd} generation scalar leptoquark in $\tau\tau bb$
  - Pair production of 3^{rd} generation scalar leptoquarks in $bb\not{E}_T$
- Note: all limits reported here are 95 % C.L.

Tevatron Run II Luminosities



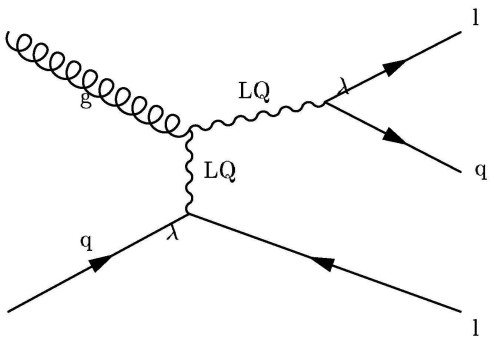
- large increase in instantaneous luminosities
- nearly $3\,\text{fb}^{-1}$ recorded both by CDF and DØ
  - presented here: results based on 0.3 to $1\,\text{fb}^{-1}$
- Run IIb since 06/2006: upgraded DØ detector
  - additional innermost silicon layer, improved L1 calo and track triggers

Leptoquark Production and Decay

- Leptoquarks (LQ): hypothetical scalar or vector bosons with both baryon and lepton number
  - in many extensions of SM: GUT, extended gauge models, compositness etc.
- *Minimal Buchmüller-Rückl-Wyler model*: general effective Lagrangian, but:
  - no intra-generational couplings ($\leftarrow$ FCNC)
  - pure chiral couplings to SM fermions ($\leftarrow$ chirally supressed decays)

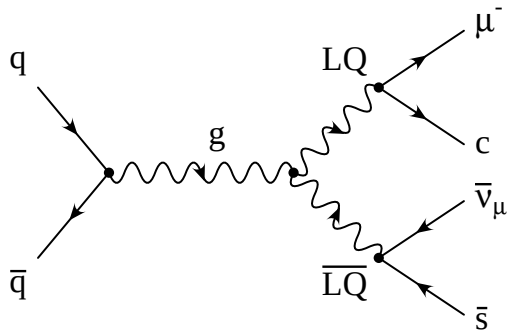
$\Rightarrow$allows small LQ masses in reach of Tevatron

Single LQ production:



depends on unknown $LQ - l - q$ coupling λ

LQ pair-production:

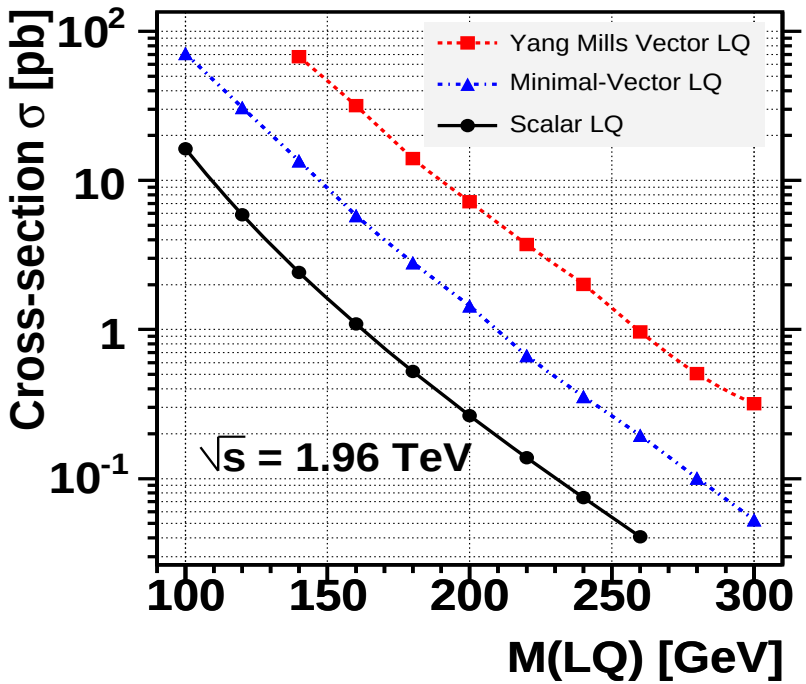


independent of λ, for scalar LQ cross section depends only on $M(LQ)$

Final state depends on $Br(LQ \to \ell^{\pm} q)$, $Br(LQ \to \nu q)$

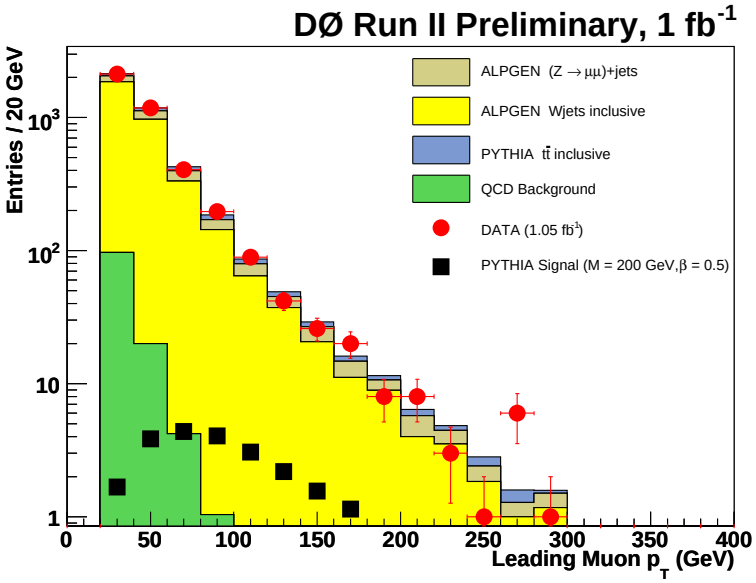
Leptoquarks Production and Decay

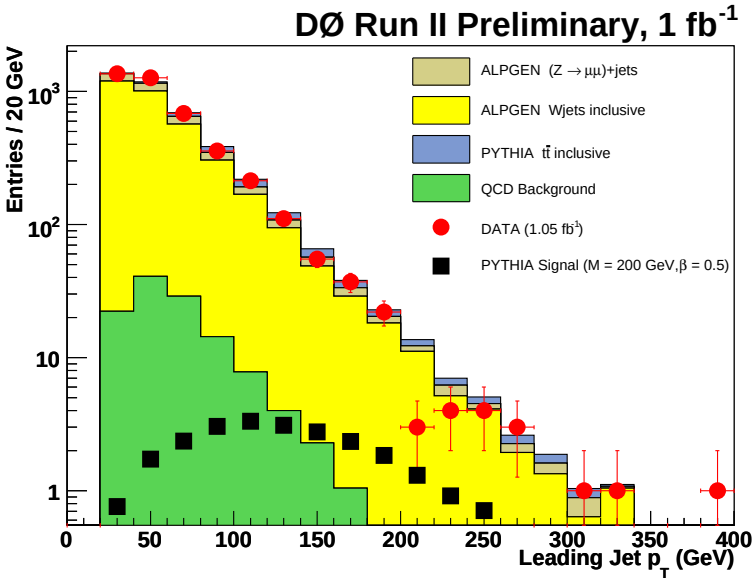
- **Scalar LQ** pair production: pure QCD process, calculated up to NLO
- **Vector LQ** pair production cross section much higher, only calculated up to LO
  - Yang-Mills model: no anomalous couplings
  - Minimal Vector model: anomalous couplings chosen to approximately minimize the cross section



Only searches for scalar LQ covered here. Be cautious when comparing to mass limits for vector LQ!

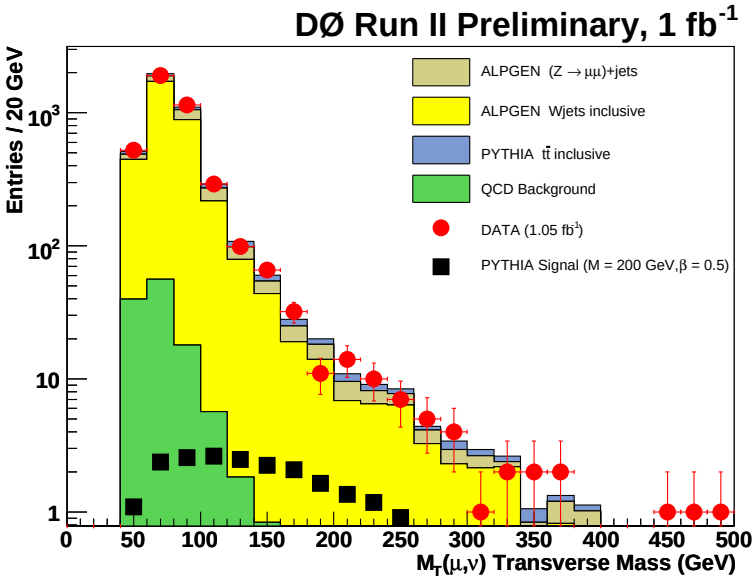
Search for Pair Production of 2nd Generation Scalar LQ in $\mu\nu jj$

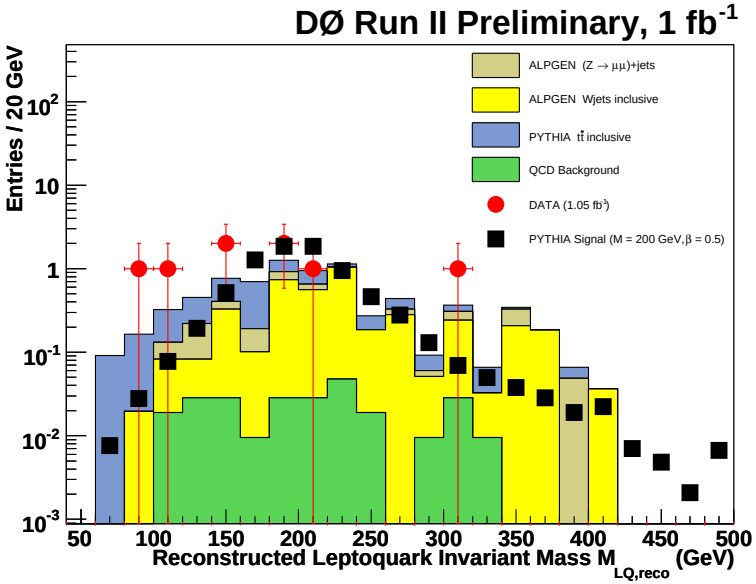




- Preliminary March 2007
- $\mathcal{L} = 1$ fb^{-1}, collected using combination of 33 single-μ triggers
- Main backgrounds: W+jets, $t\bar{t}$
- W+jets: ALPGEN (v2 incl. MLM matching) normalized to data within $50\,\mathrm{GeV} < M_T(\mu, \nu) < 110\,\mathrm{GeV}$
- QCD:
  - shape from QCD enriched data sample (muon anti-isolation)
  - normalization to preselected data in QCD-dominant region ($\not{E}_T < 10$ GeV)

Search for Pair Production of 2nd Generation Scalar LQ in $\mu\nu jj$



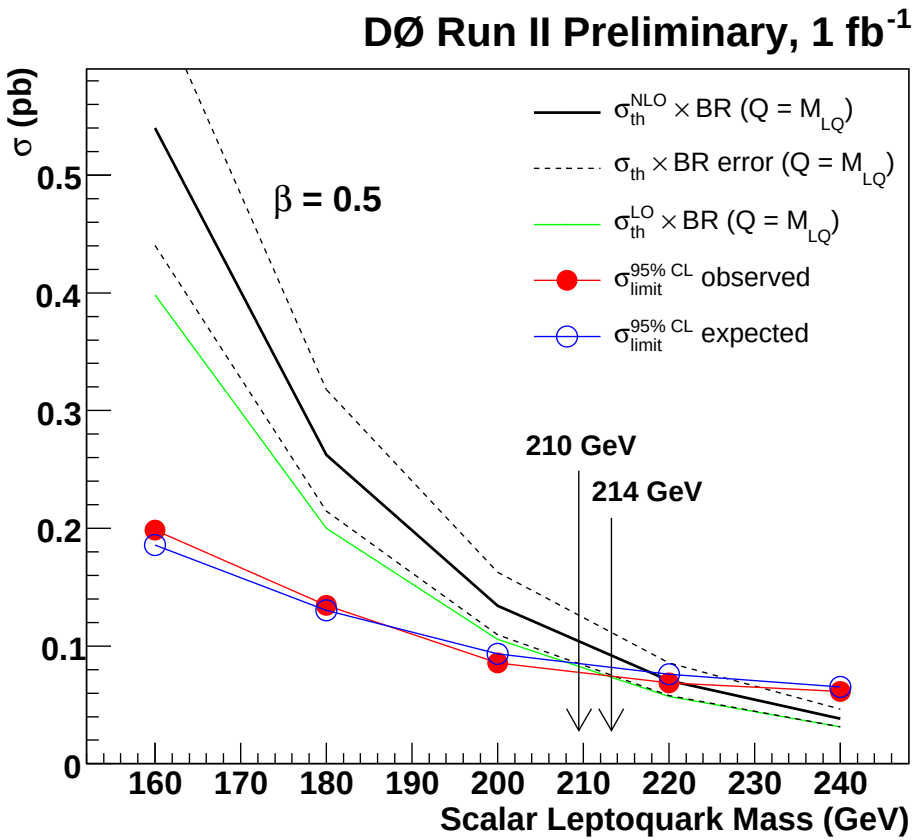


- Selection variables:
  - $M_T(\mu,\nu) \leftarrow W$ veto
  - $M_T(jet_1,\nu) \leftarrow M_{LQ}$
  - $S_T = p_T^{\mu} + \not{E}_T + p_T^{jet_1} + p_T^{jet_2}$
  - $M_{LQ,reco}$: $M(\mu, jet_i)$ closest to $M_{LQ,gen}$
    $|M_{LQ,reco} - M_{LQ,gen}| < 100$ GeV

  $\Rightarrow$ for $M_{LQ,gen} = 200$ GeV
  6 data events observed with
  $6.4 \pm 0.7 \pm 0.8$ expected

- Main systematics:
  - Jet energy scale (background): 9-11%
  - W+jet: $p_T(\text{jet})$ modeling: 17%
  - $t\bar{t}$ production cross section: 18%

Search for Pair Production of 2nd Generation Scalar LQ in $\mu\nu jj$



- Mass limit:

  $Br(LQ \to \mu q) =: \beta \to$
  $Br(LQ\overline{LQ} \to \mu\nu qq)$
  $= 2\beta(1-\beta)$

  Assumption:
  $\beta = 0.5$ (best sensitivity)

  w.r.t. lower theory prediction

$\Rightarrow$ $M_{LQ} > 214$ GeV

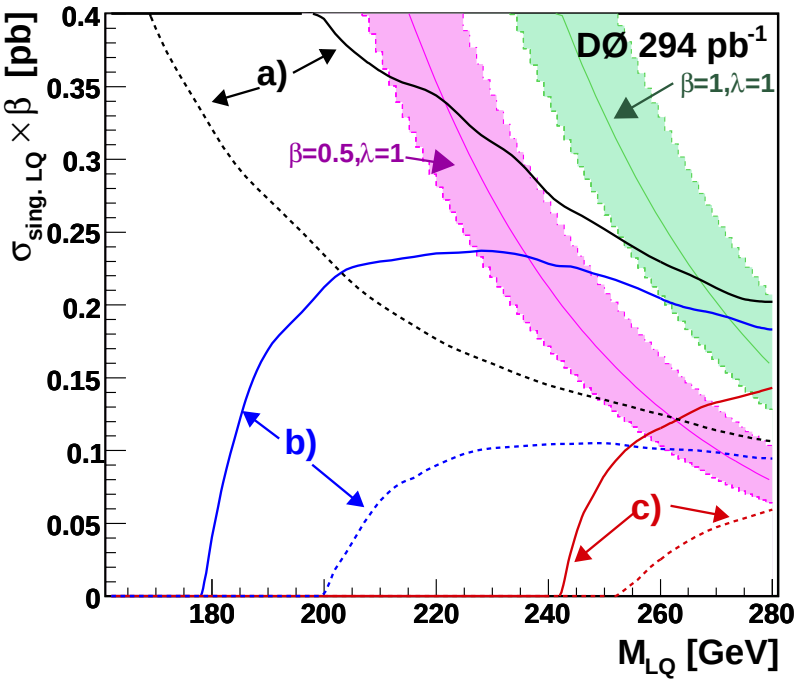
- Previous best limits:

  $\mu\nu jj$, CDF Run II, 200 pb^{-1}:
  $M_{LQ} > 170$ GeV

  combination, CDF, 200 pb^{-1}:
  $M_{LQ} > 208$ GeV

Search for Single Production of Scalar LQ in $\mu\mu j$

- *Phys.Lett.B647:74-81,2007*, first search for single LQ production at hadron colliders
- $\mathcal{L} = 294\ \text{pb}^{-1}$
- Assumption: LQ couples to 1^{st} generation quarks and 2^{nd} generation leptons
  $\Rightarrow$ no suppression due to PDF in IS



- Main background: Z+*jets*
- Selection: 2D cut in ($M_{\mu\mu}$, $E^{jet}_{T,max}$) plane $\rightarrow$ 4 signal bins
- Combination with 3 signal bins of $\mu\mu jj$ analysis (*Phys.Lett.B636:183-190,2006*)

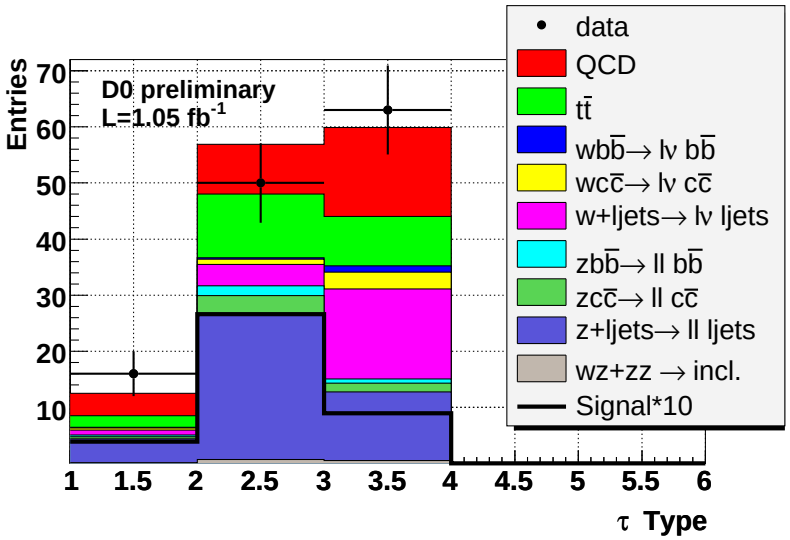
- 3 scenarios are considered:
  - (a): no contribution from $LQ\overline{LQ} \to \mu\mu jj$
  - (b): pairs contributes with $\beta = \frac{1}{2}$
  - (c): pairs contributes with $\beta = 1$

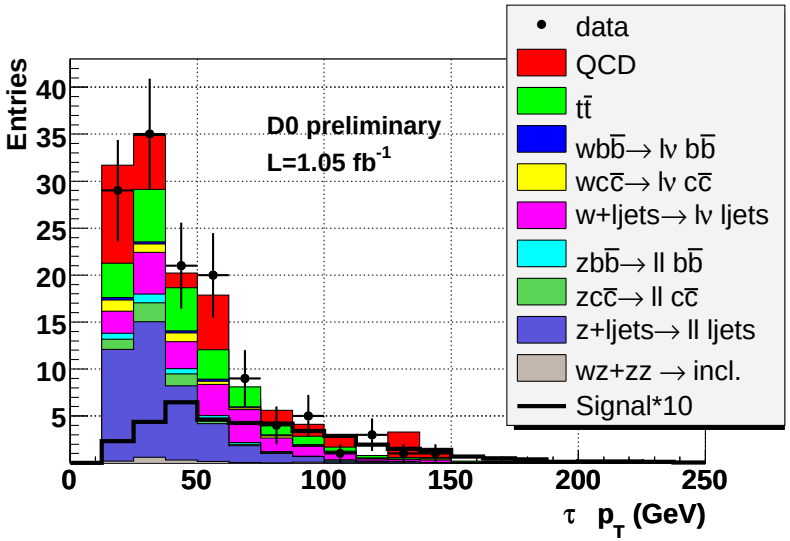
  $(\beta = Br(LQ \to \mu q))$
- Limits on M_{LQ}:

  $\Rightarrow$ $\beta = 1,\ \lambda^2 \ll 1$: $M_{LQ} > 247$ GeV

  $\Rightarrow$ $\beta = 1,\ \lambda^2 = 1$: $M_{LQ} > 274$ GeV

Search for Pair Production of 3rd Generation Scalar LQ in $\tau\tau bb$

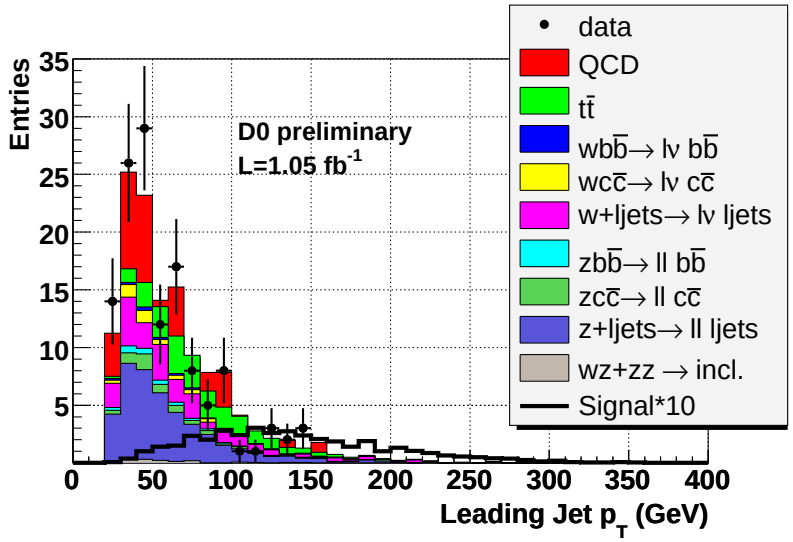


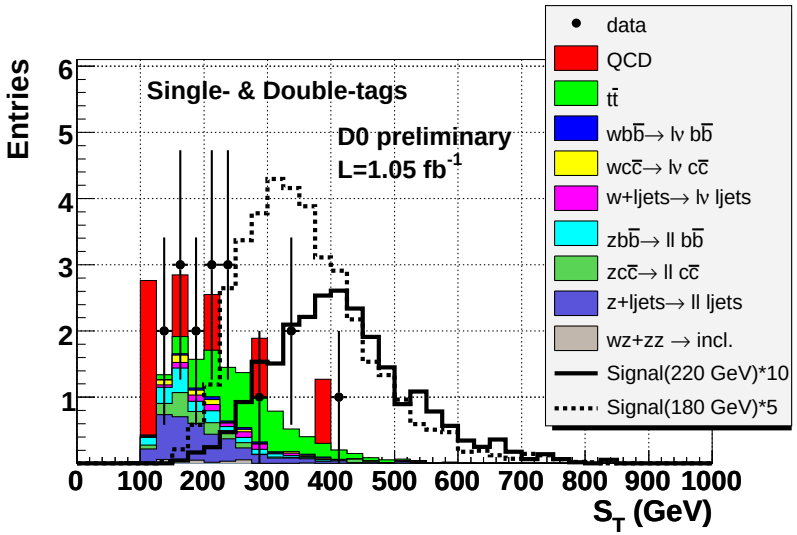


- New: July 2007,
  first DØ measurement in $\tau\tau bb$
- $\mathcal{L} = 1\ \text{fb}^{-1}$
- τ decays:
  - $\tau_1 \to \mu\nu_\mu\nu_\tau$, muonic decay ($\tau_\mu$)
  - τ_2 decays hadronically (τ_h)
- Identification of τ_h:
  - Type 1: $\tau_h^\pm \to \pi^\pm\nu_\tau$
  - Type 2: $\tau_h^\pm \to \pi^\pm\pi^0\nu_\tau$
  - Type 3: $\tau_h^\pm \to \pi^\pm\pi^\pm\pi^\mp\pi^0\nu_\tau$

$\to$ Neural networks to distinguish each τ_h type from background

Search for Pair Production of 3rd Generation Scalar LQ in $\tau\tau bb$





- *b*-tagging: neural network method

  very loose tagger: $\begin{cases} \mathcal{E}_b = 72.2\% \\ \mathcal{E}_{fake} = 5.9\% \end{cases}$

- Main backgrounds:
  - $t\bar{t}$
  - QCD estimated from like-sign $\tau_\mu - \tau_h$ candidates
  - $Z(W)$+jets (both heavy and light flavours)

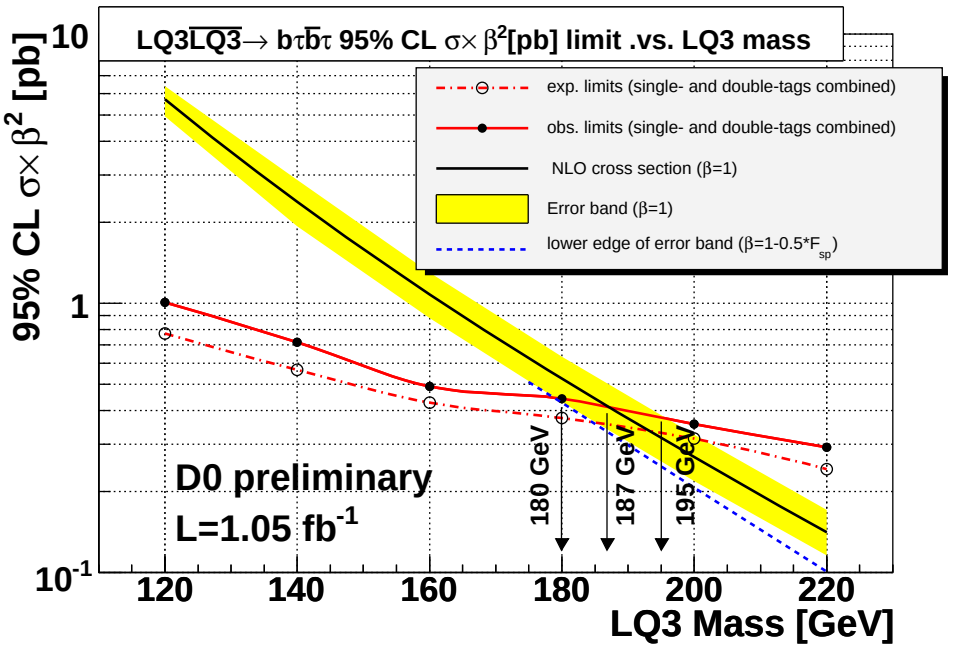
- Final discriminant for limit calculation:

  $S_T = p_T^\mu + p_T^{\tau_h} + p_T^{jet_1} + p_T^{jet_2} + \not{E}_T$

- Main systematics:
  - QCD: 12%
  - $\sigma(Z/W + j)$: 22%, $\sigma(t\bar{t})$: 18%
  - *b*-tagging: 7.5-15.2% (bgd+signal)

Search for Pair Production of 3rd Generation Scalar LQ in $\tau\tau bb$

- Mass limits:
  from combination of single-tag and double-tag subsamples
  - charge-4/3 LQ:
    $\Rightarrow$ $Br(LQ \to \tau b) = 1$
    $\Rightarrow$ $M_{LQ} > 180$ GeV
    ($\widehat{=}\ \sigma_{95\%CL} \times Br^2 = 0.42$ pb)



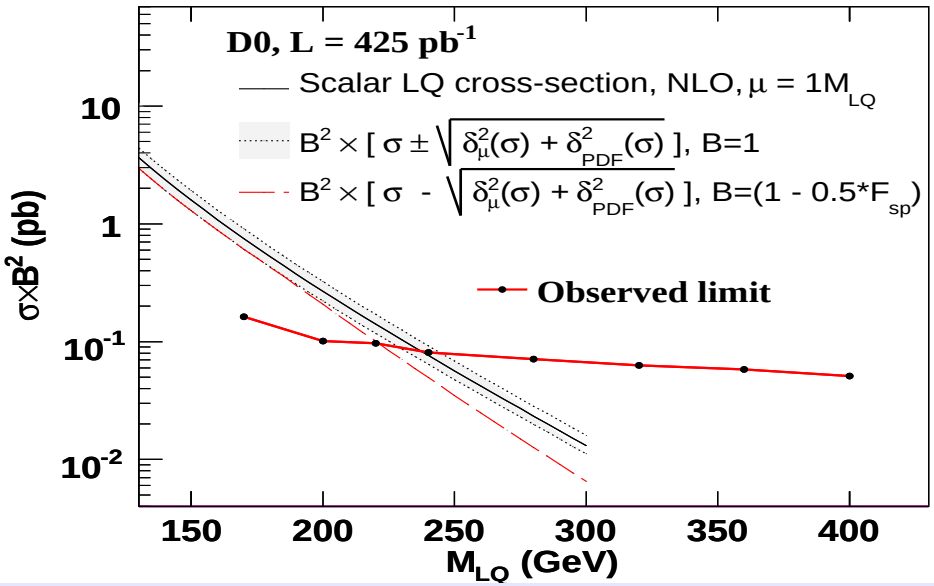
  - charge-2/3 LQ:
    $\Rightarrow$ $LQ \to t\nu_\tau$ allowed (kinematically suppressed by F_{sp})
    - assume equal couplings ($\beta = 0.5$) $\Rightarrow$ $Br(LQ \to \tau b) = 1 - \beta \times F_{sp}$

    $\Rightarrow$ no change in mass limit

- Comparison to CDF's 3rd gene. vector LQ search:
  - $\mathcal{L} = 322$ pb^{-1}, $\tau_e\tau_h$ and $\tau_\mu\tau_h$ channels
  - no theory uncertainty included!
  - minimal couplings: $M_{LQ} > 251$ GeV, Yang-Mills C.: $M_{LQ} > 317$ GeV
  - $\widehat{=}\ \sigma_{95\%CL} = \sim 1.0\,\mathrm{pb}\,(M_{LQ} = 180\,\mathrm{GeV}, MC) - 0.34\,\mathrm{pb}\,(320\,\mathrm{GeV}, YM)$

Search for Pair Production of 3rd Generation Scalar LQ in $bb\not{E}_T$

- Accepted by PRL (*hep-ex/0705.0812*)
- $\mathcal{L} = 425\ \text{pb}^{-1}$
- Combination of single μ- and $\not{E}_T$-triggers
- require 2 tagged b-jets:
  - $\geq$1 tag with significant impact parameter ($\mathcal{E}_b = 45\%$)
  - for μ-selection: 1 soft μ tag ($\mathcal{E}_b = 11\%$)



- Main backgrounds:
  - $t\bar{t}$
  - W/Z + heavy flavour quarks
- To suppress $t\bar{t}$ contribution:
  $\frac{p_T^{tag1} + p_T^{tag2}}{\sum_{jets} p_T} > 0.8$
- Selection cuts on $\not{E}_T$ and $H_T = \sum_{jets} |\overrightarrow{p_T}|$

- Mass limits (charge-$\frac{1}{3}$ LQ):
  - $Br(LQ \to b\nu_\tau) = 1 \Rightarrow$
    $M_{LQ} > 229$ GeV
  - with $LQ \to \tau t$ assume $\beta = 0.5$
    $\Rightarrow Br(LQ \to b\nu_\tau) = 1 - \beta \times F_{sp} \Rightarrow$
    $M_{LQ} > 221$ GeV

Conclusion

- No evidence for LQ, but significant improvement of limits
- BSM signal with characteristic topologies involving *leptons*, *jets*, and $\not\!\!E_T$
- Results shown based on 0.3 to 1 fb^{-1}

$\Rightarrow$ Prospects for luminosity: up to 8 fb^{-1} by 2009

- For further details, see:
  http://www-d0.fnal.gov/Run2Physics/WWW/results.htm