Search for 2$^{\rm nd}$-Generation Leptoquarks in $p\bar{p}$-Collisions at the TeVatron

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The existence of leptoquarks (LQ), colour-triplets of bosons with lepton and quark quantum numbers, is predicted by various theories beyond the Standard Model of Particle Physics. Limits on proton decays, on lepton flavour violation, and on flavour-changing neutral currents lead to the assumption of three different generations of leptoquarks, each one of them only interacting within one lepton and quark family. Figure 1 shows Feynman graphs of the dominant production processes in $p\bar{p}$ collisions.

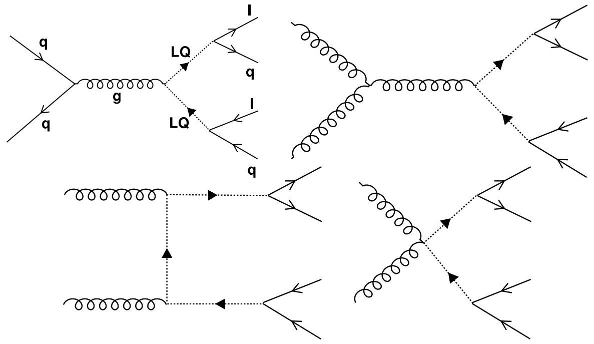

Fig. 1: Leading-order diagrams for leptoquark pair production.

If both leptoquarks decay into a muon and a quark, two muons and two jets can be reconstructed. This article presents the first results of a search for 2$^{\rm nd}$-generation leptoquarks (LQ_2) in the $\mu j \mu j$ channel with the DØ detector at a centre-of-mass energy of $\sqrt{s} = 1.96$ TeV.

Muons are identified with the DØ muon spectrometer [1] and are matched to tracks measured in the inner tracking detectors [2]. For a more detailed description of the muon reconstruction, the reader is referred to [3].

The left plot in figure 2 shows the invariant di-muon mass distribution for data taken between September 2002 and January 2003 as compared to Monte-Carlo simulations of the Drell-Yan Z/γ^* processes. ¿From a fit of the simulated events to the data in the Z^0 resonance, one can extract the efficiency-corrected integrated luminosity, using the measured cross section from Run I, scaled for the difference in centre-of-mass energy:

$$\frac{\varepsilon(\text{data})}{\varepsilon(\text{MC})} \cdot \int \mathcal{L} dt = (21 \pm 3)\,\text{pb}^{-1}.$$

Herein, $\varepsilon(\text{data})/\varepsilon(\text{MC})$ accounts for the difference of the di-muon reconstruction efficiency in data and Monte Carlo as well as the trigger efficiency.

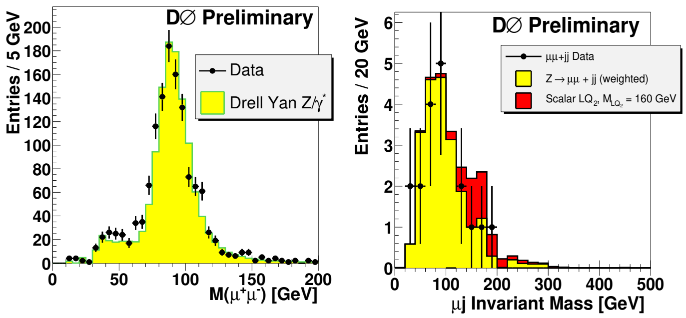

Fig. 2: *Left*: Invariant di-muon mass of all events with at least two isolated muon with opposite charge and $p_t^\mu > 15\,\text{GeV}$. *Right*: Best invariant μj-mass of each $\mu\mu + jj$ event with $M(\mu\mu) > 60\,\text{GeV}$.

When requiring, in addition to the two muons, two hadronic jets with $E_t > 20\,\text{GeV}$, reconstructed from energy depositions in the liquid-argon calorimeter, 18 events remain in the data sample, while 21.4 ± 3.5 are expected from Standard-Model background.

The right plot in figure 2 shows the invariant μj-mass distributions (i.e. the reconstructed LQ-mass) for the 18 $\mu j \mu j$ events as well as the Standard-Model background. The red histogram shows the expected contribution of scalar LQ_2 with a mass of $M(LQ_2) = 160\,\text{GeV}$. The mass is defined as the mean of the two μj-masses, taking the muon-jet combination which has the smaller difference between its two candidate masses.

Distributions like the invariant μj-mass will be used in the future to even better distinguish between signal and background. Due to the currently limited understanding of the jet quantities, the invariant μj-mass has not yet been used in this analysis. Instead, an additional cut on the di-muon mass, $M(\mu^+\mu^-) > 110\,\text{GeV}$, has been applied. No events remain in the data after this cut. Therefore, 95 % confidence level (C.L.) upper bounds of the cross sections for scalar 2$^{\rm nd}$-generation leptoquarks can be determined (see figure 3). Comparing these limits to theoretical calculations, the 95 % C.L. lower limit on the mass of 2$^{\rm nd}$-generation leptoquarks is 157 GeV for 100 % branching fraction into charged leptons ($\beta = 1$).

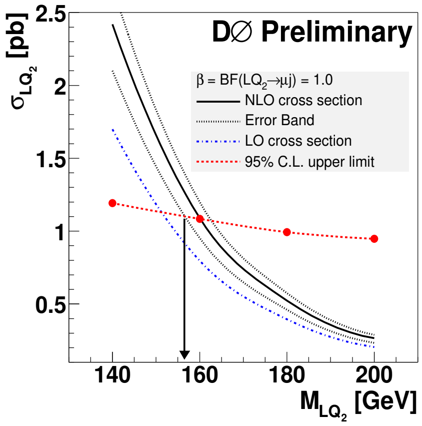

Fig. 3: Calculated cross sections for scalar 2$^{\rm nd}$-generation leptoquarks in leading and next-to-laeading order as compared to the 95 % C.L. upper limit on the cross section, assuming 100 % branching fraction to charged leptons, $\beta = BF(LQ_2 \to \mu j) = 1$.

Adding more integrated luminosity and taking advantage of the improved muon acceptance and muon-p_t resolution of the DØ-Run-II detector, the DØ collaboration will shortly be capable to extend its leptoquark searches to parameter regions far beyond those already excluded in Run I. [4]

References

[1] T. Christiansen, D. Schaile, R. Ströhmer, and T. Trefzger, Annual report 2001, p. 44.
[2] The DØ Collaboration, S. Abachi *et al.*, Fermilab Pub-96/357-E (1996).
[3] M. Binder, O. Biebel, T. Christiansen, J. Elmsheuser, F. Fiedler, T. Nunnemann, D. Schaile and R. Ströhmer, this report, p. 50
[4] The DØ Collaboration, B. Abbott *et al.*, Phys. Rev. Lett. **84** (2000) 2088