Search for Second-Generation Leptoquarks in $p\bar{p}$ Collisions

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The existence of leptoquarks, colour-triplets of bosons with lepton and quark quantum numbers, is predicted by various theories beyond the Standard Model of Particle Physics [1]. 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. Demanding these additional constraints, leptoquarks could be as light as $\mathcal{O}(100\text{ GeV})$ [2].

In hadron collisions, leptoquarks would mainly be produced in pairs. If both leptoquarks decay into a muon and a quark, two muons (μ) and two jets (j) can be reconstructed. This article presents the latest results of a search for second-generation leptoquarks (LQ_2) in the $\mu j \mu j$ channel with the Run-II DØ detector at a centre-of-mass energy of $\sqrt{s} = 1.96$ TeV. The analysis is based on approximately 114 pb^{-1} of $p\bar{p}$ collisions recorded between August 2002 and June 2003.

All events must have at least two reconstructed isolated muons with a transverse momentum exceeding 15 GeV and at least two hadronic jets with transverse energy larger than 25 GeV (see [3] for details of the event reconstruction).

Two independent approaches were followed for a final cut to distinguish the leptoquark signal from Standard-Model background: In a purely cut-based analysis, a two-dimensional cut in the S_T-$M(\mu\mu)$ plane is applied (see Figure 1), leaving 0.37 ± 0.11 expected background events. $S_T = \sum E_T$ is the scalar sum of transverse energies of the $\mu j \mu j$ system.

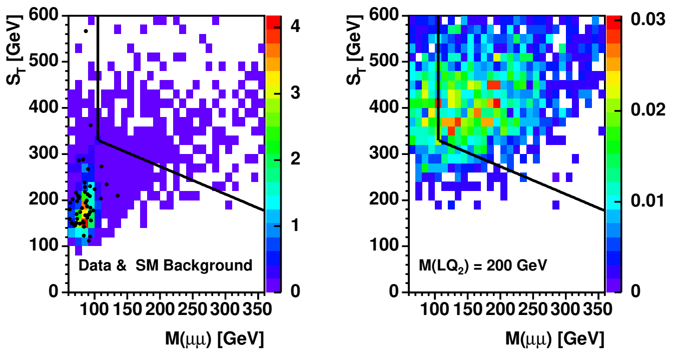

Fig. 1: Scalar sum of the transverse energies of the $\mu j \mu j$ system versus di-muon mass: The left diagram shows the data (black points) on top of the Standard-Model background (coloured). The right diagram shows the simulation of $LQ_2 LQ_2 \to \mu j + \mu j$ events for a leptoquark mass of 200 GeV. The black lines illustrate the last cut of the purely cut-based analysis: Events to the upper right of this line are considered signal-like.

The second approach takes advantage of a neural network, which is trained with Monte-Carlo simulated signal and background events. In addition to S_T and $M(\mu\mu)$, this network takes the total event mass, $M(\mu j \mu j)$, and the relative smallest difference of the two $\mu + j$ masses, $\Delta M(\mu j)/\langle M(\mu j)\rangle$, as inputs. The left distribution of Figure 2 shows the neural-network output for data, Standard-Model background and for leptoquark signal. Optimised for a simulated mass of 200 GeV, a cut on the neural-network output variable, NN > 0.2, leaves 0.35 ± 0.09 expected Standard-Model events. The signal efficiency for $LQ_2 LQ_2 \to \mu j + \mu j$ events is similar for both, the purely cut-based and the neural-network approaches, and ranges between 9 and 14 % for leptoquark masses between 160 and 260 GeV, respectively.

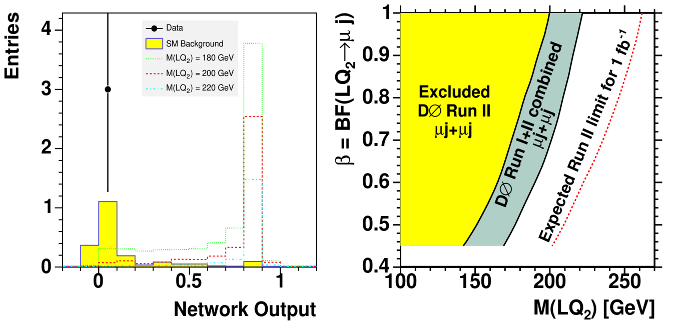

Fig. 2: *Left*: Neural-network output variable for data, Standard-Model background and leptoquark signal (assuming $\beta = BF(LQ_2 \to \mu j) = 1$). *Right*: 95 % C.L. exclusion of scalar second-generation leptoquarks from the Run II analysis presented in this article (yellow area) and from the combined Run I+II analyses (grey area). The dashed red line shows the projection of the Run II analysis for an integrated luminosity of 1 fb^{-1}.

Since no deviation of the data from the Standard-Model background is observed, 95 % confidence level (C.L.) upper limits on the cross-section of scalar second-generation leptoquarks are calculated and translated into lower limits on the leptoquark mass $M(LQ_2)$. Since this analysis is only sensitive to events where both leptoquarks decay into a charged lepton, these limits depend on the branching fraction $\beta = BF(LQ_2 \to \mu + j)$ into a muon and a jet. These exclusion limits are shown in the right plot of Figure 2. Furthermore, these limits are combined with earlier results from DØ Run I [4], thus yielding the best limits for $\beta \approx 1$ from a single experiment to date. A detailed description of this analysis and the combination of the Run I+II results can be found in [5].

Adding more integrated luminosity and taking advantage of additional analyses in the channels $\mu j + \nu j$, $\nu j + \nu j$, and $\mu j + \mu$ (single-LQ_2 production, cf. [6]), the DØ collaboration will soon be able to extend its sensitivity to leptoquarks of the second generation far into regions of the parameter space which has not been excluded yet.

References

[1] J. C Pati and A. Salam, Phys. Rev. **D10** (1974) 275 E. Eichten et al., Phys. Rev. **D34** (1986) 1547 W. Buchmüller and D. Wyler, Phys. Lett. **B177** (1986) 377 E. Eichten et al., Phys.Rev.Lett. **50** (1983) 811 H. Georgi and S. Glashow, Phys.Rev.Lett. **32** (1974) 438

[2] M. Leurer, Phys. Rev. Lett. **71** (1993) 1324 M. Leurer, Phys. Rev. **D49** (1994) 333

[3] T. Christiansen et al.,Annual report 2002, p. 51.

[4] The DØ Collaboration, B. Abbott et al.,Phys. Rev. Lett. **84** (2000) 2088.

[5] T. Christiansen, Ph.D. thesis, LMU München, 2003.

[6] R. Ströhmer et al., this annual report, p. 42.