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. 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 of them only interacting within one lepton and quark family. Demanding these additional constraints, leptoquarks could be as light as $\mathcal{O}$ (100 GeV) [1].

In hadron collisions, leptoquarks would be produced in pairs by the strong interaction (Figure 1a). Furthermore, single leptoquarks could be produced in association with an additional lepton (Figure 1b). The second production process contains a Yukawa like coupling of the leptoquark to a quark and a lepton and thus, the production cross-section is proportional to the square of the unknown coupling constant λ. The relevant Feynman diagrams for both processes are shown in Figure 1.

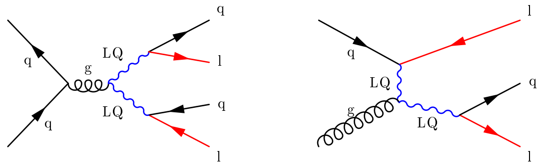

Fig. 1: Production of leptoquark pairs and of single leptoquarks in association with a lepton in $p\bar{p}$ collisions

This article describes the search for second-generation leptoquarks (LQ_2) in the $\mu j \mu j$ channel (leptoquark pairs) and the $\mu j \mu$ channel (single leptoquarks) with the Run-II DØ detector at a centre-of-mass energy of $\sqrt{s} = 1.96$ TeV.

All events must have at least two reconstructed isolated muons with a transverse momentum exceeding 15 GeV and at least two (one for the single leptoquark search) hadronic jets with transverse energy larger than 25 GeV (see [2] for details of the event reconstruction).

Last year we reported on an analysis based on an integrated luminosity of 114 pb^{-1} [3]. In a cut-based analysis of the $\mu j \mu j$ channel, a two-dimensional cut in the S_T-$M(\mu\mu)$ plane is applied, 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. The resulting limits on the leptoquark mass are shown in Figure 2.

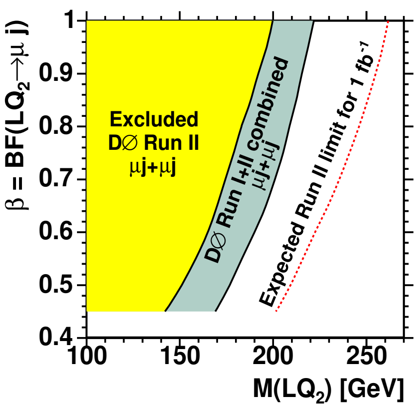

Fig. 2: 95 % C.L. exclusion of scalar second-generation leptoquarks from the Run II analysis based on an integrated luminosity of 114 pb^{-1} (yellow area) and from the combined Run I+II analyses (grey area). The dashed red line shows the projection of the Run II analysis for an integrated luminosity of 1 fb^{-1}.

We have updated this analysis to an integrated luminosity of 300 pb^{-1}. This has increased the expected mass limit on scalar second-generation leptoquark to 240 GeV. This limit will be further improved by replacing the limit calculation based on a single cut with a limit calculation which compares the data and the expected signal in different bins of signal to background ratio and which therefore makes better use of the available information.

The search for single-leptoquarks is based on exactly the same preselection cuts as the leptoquark-pair analysis except the requirement of a second jet. This approach simplifies the combination of the two analyses for the calculation of combined limits. For single-leptoquarks a two-dimensional cut in the di-muon mass and the transverse energy of the jet is applied(see Figure 3). Since only one jet is required this cut has to be significantly harder in order to have sufficient background rejection. The shape of the indicated cut has been determined with the help of an artificial neural network. With the indicated cut the overall efficiency for a 240 GeV single leptoquark would be around 9% with an expected background of 5 events for an integrated luminosity of 300 pb^{-1}.

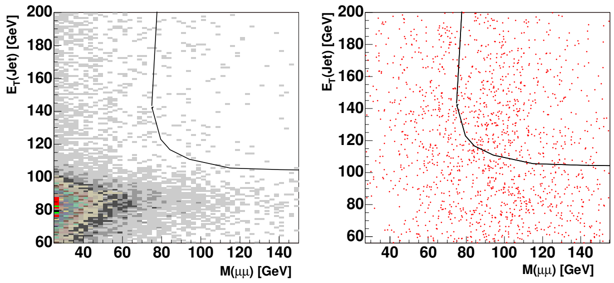

Fig. 3: Transverse energy of the jet versus di-muon mass: The left diagram shows the Standard-Model background. The right diagram shows the simulation of $LQ_2\mu \to \mu j + \mu$ events for a leptoquark mass of 240 GeV. The black lines illustrate the last cut determined by an artificial neural network: Events to the upper right of the line are considered signal.

The single-leptoquark and the leptoquark-pair analysis will be combined and in the absence of a signal, 2 dimensional exclusion regions as function of the leptoquark mass and the strength of the coupling constant λ of a leptoquark to a lepton and a quark will be calculated.

References

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