Search for Second Generation Scalar Leptoquarks with the DØ Detector

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As predicted by numerous extensions of the standard model, leptoquarks are hypothetical bosons allowing lepton-quark transitions. In hadron collisions, the pair-production of scalar leptoquarks is a pure QCD process. Thus its cross section only depends on the leptoquark mass and not on the unknown coupling λ between the leptoquark and its associated lepton and quark. Single leptoquarks can be produced in quark-gluon scattering via t-channel leptoquark exchange, of which the cross-section is proportional to λ. Leptoquarks can decay either into a charged lepton and a quark or into a neutrino and a quark. We study second generation leptoquarks which couple to either muon or muon-neutrino and define β as the branching ratio for the decay of a leptoquark into a muon and a jet ($\beta = BR(LQ \to \mu q)$).

The search for second generation leptoquark pairs in the $\mu j \mu j$ channel [1] has been combined with a search for single leptoquarks production in association with a muon in the $\mu j \mu$ channel. Limits on the leptoquark mass were calculated as function of λ. For scalar leptoquarks with assumed couplings to an u quark and a muon with $\lambda = 1$ lower mass limits of $m_{LQ} > 274\,\mathrm{GeV}$ and $m_{LQ} > 226\,\mathrm{GeV}$ were derived for $\beta = 1$ and $\beta = 0.5$, respectively [2].

In the following we describe a new search for second generation scalar leptoquark pair-production in the channel $LQ\overline{LQ} \to \mu\nu q$, i.e. a final state consisting of one muon, one neutrino and two second generation quarks that then subsequently hadronise to jets. By assuming that the branching fraction for the decay of a leptoquark into a muon and a jet is $\beta = 0.5$, the branching ratio for this final state is maximised and equal to $BR(LQ\overline{LQ} \to \mu\nu qq) = 2\beta(1-\beta) = 0.5$.

The analysis is based on the data taken with the DØ detector at the Fermilab Tevatron collider ($\sqrt{s} = 1.96$ TeV) during Run IIa, which corresponds to the time period between August 2002 and February 2006. The data has been triggered with a collection of 33 single muon triggers and corresponds to a total integrated luminosity of 1.05 fb^{-1} Signal and background expectations (except QCD multijet production) have been simulated by Monte-Carlo event generators (Alpgen [3] and Pythia [4]). For the standard model background to the $\mu\nu jj$ final state, we consider Monte-Carlo samples for the decay of the W boson to a lepton, a neutrino, and associated jets; the decay of the Z boson to two muons; and the inclusive decay of pair-produced top quarks. The multijet contribution has been estimated from the data sample.

The leptoquark signals have been generated with a modified version of Pythia in order to allow the pair-produced leptoquarks to decay into two different final states (muon plus quark and neutrino plus quark).

The muons are reconstructed using hits in the three layers of the muon detector and in the central tracking system. To suppress background from QCD heavy flavour production, the muons are required to be isolated from other tracks, nearby energy deposition in the calorimeter, and reconstructed jets. Jets are reconstructed with an iterative cone algorithm with a cone radius $\Delta R = 0.5$.

Events are required to have exactly one muon found within a pseudo-rapidity range $|\eta| < 2$, with a transverse momentum exceeding 20 GeV, at least two jets in the region $|\eta| < 2.5$ with transverse energies greater than 25 GeV, and a missing transverse energy (due to the escaping neutrino) larger than 30 GeV. The signal is discriminated from most of the background by cutting on the energy sum of the decay products and topological variables reconstructed from the four-momenta or transverse momenta of the muon, neutrino, and the two jets, respectively. A 200 GeV leptoquark signal sample has been used to optimise the selection cuts.

After all cuts we find 6 candidate events with a predicted background of $6.4 \pm 0.7(\mathrm{stat.}) \pm 0.8(\mathrm{syst.})$ events, with main contributions from $W(+\mathrm{jets}) \to l\nu + \mathrm{jets}$ and $t\bar{t}$ production. Since no excess in data over predicted Standard model background has been observed, a 95% confidence level upper limit on the leptoquark pair-production cross section times branching ratio $\sigma_{\mathrm{limit}} \times BR$ as function of the assumed leptoquark mass has been set. All systematic uncertainties on the background estimate and the signal acceptance have been taken into account [5]. Fig. 1 shows the measured and expected $\sigma_{\mathrm{limit}} \times BR$ in comparison with the theoretical prediction on the cross section. From their intercepts we derive a lower observed and expected mass limit for second generation scalar leptoquarks of 214 GeV and 210 GeV, respectively, assuming $\beta = 0.5$.

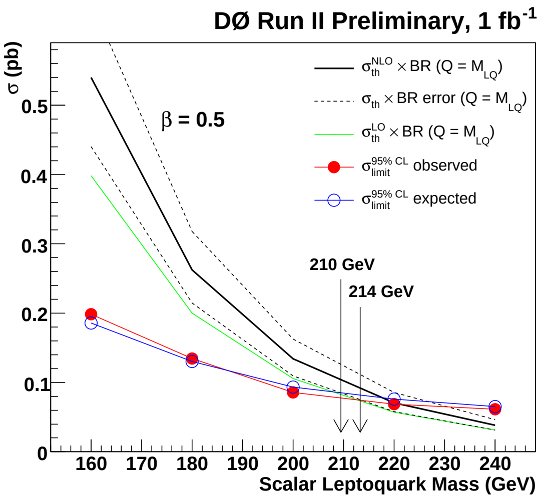

Fig. 1: The observed and expected limits on cross-section times branching ratio (95% C.L.) as function of the assumed leptoquark mass. The limit is compared to the theoretical prediction to derive a lower limit on the leptoquark mass.

References

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