Search for Second Generation Leptoquarks at the DØ Experiment

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Leptoquarks are hypothetical colored bosons allowing lepton-quark transitions and thus appearing naturally in numerous extensions of the standard model. At hadron colliders, leptoquarks are predominantly produced in pairs via pure QCD processes, which implies that their production cross-section does not depend on the unknown leptoquark-lepton-quark coupling. Leptoquarks could, in principle, decay into any combination of a quark and a lepton, but leptoquarks with masses as low as $\mathcal{O}(100\,\text{GeV})$ are only allowed to couple to one generation of quarks and leptons, since they otherwise would generate lepton number violation and sizable flavor-changing neutral currents. The branching fraction for the decay of a second generation leptoquark into a muon and a quark is defined as $\beta = Br(LQ \to \mu q)$.

A search for the pair-production of second generation leptoquarks both decaying into a muon and a quark, leading to final states consisting of two muons and two jets, is described here. The branching fraction for this final state is equal to $Br(LQ\overline{LQ} \to \mu\mu qq) = \beta^2$. The search for leptoquark pair-production in final states with a single muon, two jets and missing transverse energy was presented previously [1].

The analysis is based on data recorded with the DØ detector at the Fermilab Tevatron $p\bar{p}$-collider ($\sqrt{s}$ = 1.96 TeV) during Run IIa. A combination of eight single muon triggers was utilized to collect an integrated luminosity of $1\,\text{fb}^{-1}$. The leptoquark signal was simulated with the PYTHIA [3] event generator. The standard model background, which is dominated by Z/γ^* production with associated jets and top-pair production was determined using the ALPGEN [2] and PYTHIA generators.

Muons are reconstructed based on track segments in the muon detector which are required to be matched to tracks in the central tracking system in order to improve the transverse momentum resolution. The muons are required to be isolated from nearby tracks to suppress non-prompt muons. Jets are reconstructed by an iterative cone algorithm with cone radius $\Delta\mathcal{R} = 0.5$.

Events containing at least two muons, which are reconstructed within the pseudo-rapidity range $|\eta| < 2$ and with transverse momenta p_T exceeding 20 GeV, were selected. In addition, at least two jets with transverse energy $E_T >$ 25 GeV and $|\eta| < 2.5$ were required. In order to discriminate the signal from the background, cuts on the di-muon invariant mass $M_{\mu\mu}$ and on the scalar sum of the final state objects' transverse momenta $S_T = p_T^{\mu_1} + p_T^{\mu_2} + p_T^{jet_1} + p_T^{jet_2}$ were applied. The background from Z boson production containing muons with overestimated p_T was reduced by utilizing the transverse momentum balance in both signal and background events to recalculate the leading muon p_T and the di-muon invariant mass. The latter is shown in Fig. 1.

After the selection, which was optimized assuming a leptoquark mass of M_{LQ} = 280 GeV, $2.9 \pm 0.1\,(stat.) \pm 0.4\,(syst.)$ predicted background events were remaining. The main systematic uncertainties were found to originate from uncertainties in the muon reconstruction, the jet energy calibration and the modeling of the Z/γ^*+ jet background. An expected upper limit (95% C.L.) on the leptoquark pair-production cross-section times branching fraction, $\sigma_{ul} \times Br$, as function of M_{LQ} was calculated. Fig. 2 shows the expected $\sigma_{ul} \times Br$ in comparison with the theoretical predictions on the cross section calculated at next-to-leading QCD [4] assuming $\beta = 1$ or $\beta = 0.5$. Lower expected mass limits for scalar second generation leptoquarks of 280 GeV and 225 GeV, assuming $\beta = 1$ and $\beta = 0.5$, respectively, were derived.

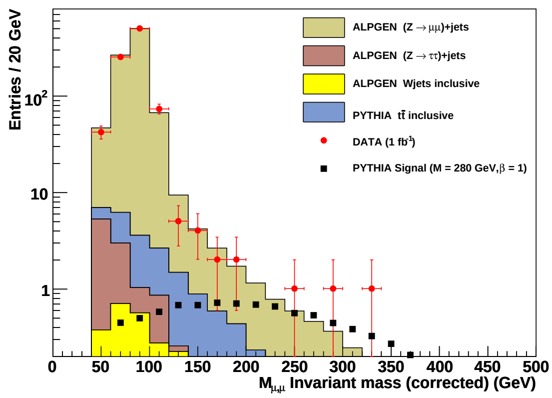

Fig. 1: Corrected di-muon invariant mass in comparison to the standard model background prediction and the expected leptoquark signal.

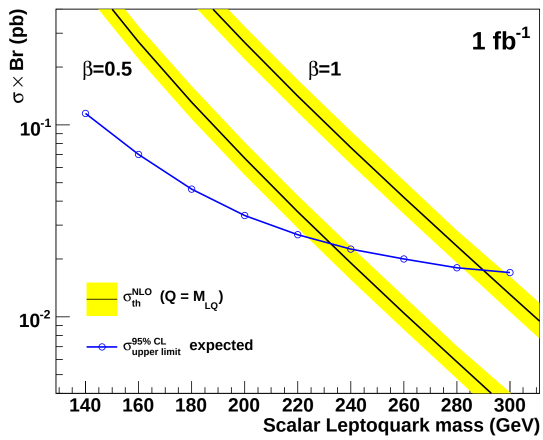

Fig. 2: The expected limit on cross-section times branching ratio (95% C.L.) as function of the assumed leptoquark mass. The limit is compared to the theoretical predictions for $\beta = 1$ and $\beta = 0.5$.

References

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