Search for Pair Production of Second Generation Scalar Leptoquarks

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Leptoquarks (LQ) are hypothetical bosons allowing transitions between leptons and quarks. At the Fermilab Tevatron $p\bar{p}$ Collider, such particles would predominantly be produced in pairs via $q\bar{q}$ annihilation into a gluon in the s-channel, independently of the unknown coupling λ between the leptoquark and its associated lepton and quark.

The search for the pair production of second generation scalar leptoquarks is carried out in the decay modes $LQ\overline{LQ} \rightarrow \mu q \nu q$ and $LQ\overline{LQ} \rightarrow \mu q \mu q$, using $p\bar{p}$ collisions at the center of mass energy $\sqrt{s} = 1.96$ TeV recorded with the D0 detector. These channels lead to topologies with one muon, missing transverse energy (from which the transverse momentum of the neutrino is inferred), and two jets ($\mu \not\!\!E_T jj$ signature), or with two muons and two jets ($\mu\mu jj$ signature), respectively. Since one of the muons of the $LQ\overline{LQ} \rightarrow \mu q \mu q$ decay mode might not be reconstructed, this signal contributes to the single muon signature as well, which is taken into account in our analysis. The contribution of $LQ\overline{LQ} \rightarrow \mu q \nu q$ in the dimuon selection can be neglected due to the small probability for a jet to mimic an isolated muon.

The signal sensitivity for both signatures depends on the branching fraction $\beta = \mathrm{BR}(LQ \rightarrow \mu q)$ for the decay of a leptoquark to a muon and a quark. Preliminary Searches for leptoquark pair production with single muon [1] and dimuon [2] signatures were presented previously, assuming $\beta = 0.5$ and $\beta = 1$ or 0.5, respectively. These analyses, based on an integrated luminosity of $1.0\,\mathrm{fb}^{-1}$, have been updated and combined. Results are derived for $\beta \geq 0.1$ and for assumed leptoquark masses from 140 to 320 GeV [3].

The main background from the Standard Model for the $\mu \not\!\!E_T jj$ and $\mu\mu jj$ channels are $W+$ jets and $t\bar{t}$ production, and Z/γ^*+ jets and $t\bar{t}$ production, respectively. The discrimination of lepptoquark signal against background is significantly improved in both channels by a multivariate technique based on the k-Nearest-Neighbor (kNN) algorithm [4]. The distribution of the kNN discriminant is divided into bins of variable size which decreases with increasing signal efficiency in order to optimize the sensitivity due to the difference in its shape for signal and background.

The dominant systematic uncertainties on the background prediction include uncertainties on the $t\bar{t}$ cross section, the modeling of jet radiation in $W/Z+$ jets events, the resolution of the muon transverse momentum, and the jet energy scale. The latter two also contribute to the uncertainty on the signal efficiency and acceptance, besides uncertainties on the the modeling of parton distribution functions and of initial and final state radiation. In addition, the uncertainty on the integrated luminosity is taken into account.

For both selections no excess of data over the predicted background is observed. Expected and observed upper limits at the 95% C.L. on the leptoquark production cross section σ are calculated for both selections separately, and for their combination, as illustrated in Fig. 1 (left plot) together with the theoretical prediction for σ calculated at next-to-leading order QCD. The bins in the kNN discriminant are treated as individual channels and their likelihoods are combined with correlations of systematic uncertainties taken into account.

Limits on the leptoquark mass are extracted from the intersection of the observed upper bound on the cross section with the NLO prediction and also the lower edge of its uncertainty band. Combining the $\mu \not\!\!E_T jj$ and $\mu\mu jj$ selections and using the central theoretical prediction, lower bounds on the mass of second generation leptoquarks are determined at the 95% C.L. to be $M_{LQ} > 316$ GeV, $M_{LQ} > 270$ GeV, and $M_{LQ} > 185$ GeV for $\beta = 1$, $\beta = 0.5$, and $\beta = 0.1$, respectively. Fig. 1 (right plot) shows the excluded region in the β versus M_{LQ} parameter space together with the exclusion limits obtained for the $\mu \not\!\!E_T jj$ and $\mu\mu jj$ selections separately. The bound at $\beta = 0$, where this analysis has no sensitivity, is given by the D0 search in the acoplanar jet topology [5].

These results improve on previous leptoquark searches at the Tevatron by exceeding the corresponding previous bounds by 55 GeV at both $\beta = 1$ and $\beta = 0.5$, which constitutes the most constraining direct limits on second generation leptoquarks to date.

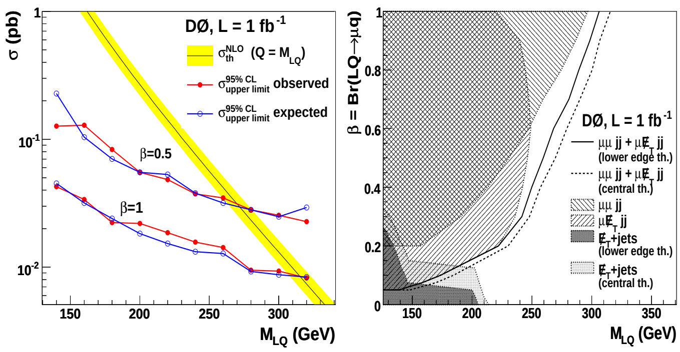

Fig. 1: *Left: Expected and observed limit on the leptoquark pair production cross section, together with the theoretical prediction, as function of the assumed leptoquark mass. Right: Lower limits on the leptoquark mass as function of β, in the case of the single and dimuon selections and their combination. The limits obtained by the search in the acoplanar jet topology are also provided.*

References

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