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.

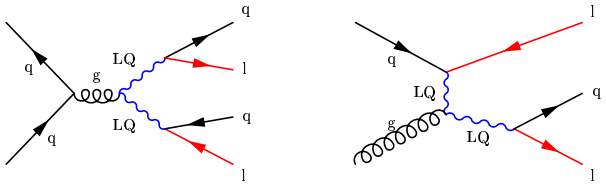

Fig. 1: Production of leptoquark pairs and of single leptoquarks in association with a lepton in $p\bar{p}$ collisions

This article describes the search for second-generation leptoquarks (LQ_2) in the $\mu j\mu j$ and the $\mu j\nu j$ channels (leptoquark pairs) as well as in 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.

The results in the $\mu j\mu j$ channel based on an integrated luminosity of $300\,\mathrm{pb}^{-1}$ have been recently published [3]. 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 [2] for details of the event reconstruction). The two-dimensional event distribution in the S_T-$M(\mu\mu)$ plane is used to select events with similar signal to background ratio (see figure 2). $S_T = \sum E_T$ is the scalar sum of transverse energies of the $\mu j\mu j$ system and $M(\mu\mu)$ the invariant mass of the two muons. The number of observed and expected events in these bins are used to calculate limits on the production cross section as function of the leptoquark mass (see figure 3). By comparing the cross section limits with the expected cross section scalar leptoquarks with $m_{LQ} < 247$ GeV have been excluded for a branching ratio $Br(LQ \to \mu j) \equiv \beta = 1$.

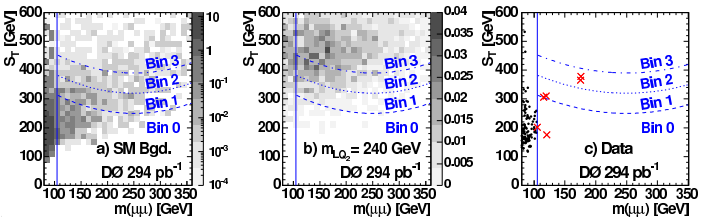

Fig. 2: S_T vs. $M(\mu\mu)$ distribution for the expected background and signal and observed in data

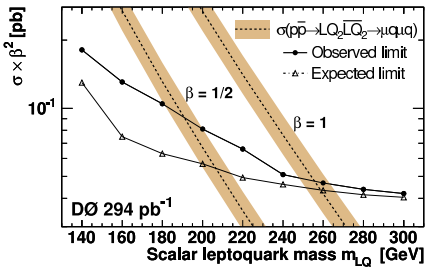

Fig. 3: Limit for the production of second generation scalar leptoquarks in the channel $\mu j\mu j$ and the expected cross section.

The search for single leptoquarks uses the same preselection as the analysis described above except that the requirement for two jets is replaced by requiring only one jet. Events with similar signal to background ratio are selected based on $M(\mu\mu)$ and the transverse energy (E_T) of the highest E_T jet. Events selected by the pair analysis are vetoed in order to have statistically independent samples which are combined in the final limit calculation taking into account the contributions of leptoquark pair events and single leptoquark events to both selections.

The search for pairs of second generation leptoquarks in the channel $\mu j\nu j$ requires different preselection cuts. The events selected must have at least one reconstructed isolated muon with a transverse momentum greater than 15 GeV and two reconstructed hadronic jets with a transverse energy exceeding 25 GeV. The missing transverse energy in the calorimeter, which in the signal is caused by the neutrino, must be greater than 30 GeV. The selection cuts are designed to remove the main background coming from Standard Model processes, namely the decay of the W boson into a muon and a neutrino. We reject events for which the transverse mass of the muon and the neutrino is lower than 140 GeV, and the scalar sum of all transverse energies lower than 410 GeV. Applied in a Monte Carlo study, these cuts yields a signal efficiency of about 20%.

References

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M. Leurer, Phys.Rev. **D49** (1994) 333
[2] T. Christiansen, Ph.D. thesis, LMU München, 2003.
[3] The DØ Collaboration,V.M. Abazov *et al.*, Submitted to Phys. Lett. B, hep-ex/0601047.