

Search for Second Generation Leptoquarks with ATLAS at the LHC

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The astonishing similarities between the leptonic and the quark sector of the standard model lead to the assumption that there could be particles which connect these two so far unconnected sectors. Leptoquarks, color triplets with fractional charge, carrying both lepton and quark quantum numbers, would be perfect candidates for such particles and are predicted by many extensions of the standard model, i.e. superstring-inspired E_6 models, Grand-Unifying-Theories etc. Limits coming from experiments on the proton decay, lepton flavor violating decays and on flavor changing neutral currents lead to the assumption that there must be three different generations of Leptoquarks, each coupling to just one generation of quarks and one generation of leptons. With this assumption Leptoquarks could be as light as $O(200 \text{ GeV})$ [1].

At the LHC Leptoquarks would be produced in pairs via strong interactions (figure 1). Studying this has also the advantage that pair production, in contrast to single production, does not depend on the unknown Yukawa coupling constant (i.e. the coupling between the quark, lepton and the Leptoquark), but only on the Leptoquark mass and QCD.

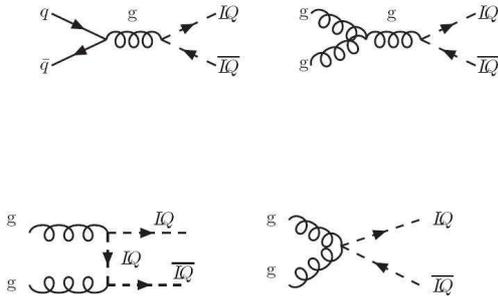


Fig. 1: pair production of leptoquarks

This article deals with scalar Second Generation Leptoquarks pairs decaying into $\mu + \mu + \text{jet} + \text{jet}$ to be measured with the ATLAS detector at the LHC. We assume the branching fraction of leptoquark decaying into a muon and a jet to be 1. The Monte Carlo data for this study has been created with a full simulation of the ATLAS detector. All events are required to have 2 reconstructed muons, with $\Delta R = 0.2$ between them, with opposite sign, with a transverse momentum exceeding 60 GeV (125 GeV for $m_{LQ} = 800 \text{ GeV}$) and with $|\eta| < 2.4$ and 2 jets with a transverse momentum exceeding 25 GeV (100 GeV for $m_{LQ} = 800 \text{ GeV}$) with $|\eta| < 4.5$. In a cone of $\Delta R = 0.4$ around the muon may not be more than 60 GeV of transverse energy deposited in the calorimeter. S_T is the scalar sum of the transverse energies of the 2 muons and 2 jets. $M(\mu\mu)$ is the invariant mass of the dimuon system. The 2-dimensional event distribution can be seen in figure 2 for $m_{LQ} = 400 \text{ GeV}$ (left) and for $t\bar{t}$ (right).

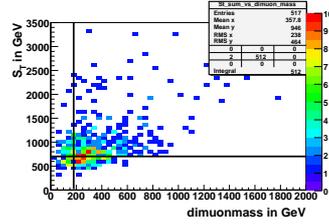


Fig. 2: $m_{LQ} = 400 \text{ GeV}$

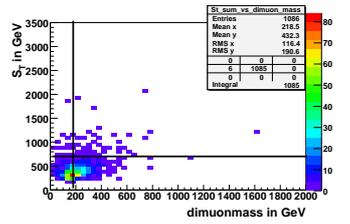


Fig. 2: $t\bar{t}$

The main backgrounds are $t\bar{t}$ events decaying leptonically and $Z/\gamma^* (\rightarrow \mu\mu) + \text{jets}$. To cut away the Z boson resonance a cut on the dimuon mass has been made; it has to exceed 180 GeV. The cut on S_T has been optimized for S/\sqrt{B} and is at 700 GeV for $m_{LQ} = 400 \text{ GeV}$. For $m_{LQ} = 800 \text{ GeV}$ the S/\sqrt{B} optimized S_T cut is at 1100 GeV. The mass distribution of the reconstructed Leptoquarks for $m_{LQ} = 400 \text{ GeV}$ (left) and $m_{LQ} = 800 \text{ GeV}$ (right) after all previous cuts can be seen in figure 3. In each event 2 Leptoquarks are reconstructed, so there are 2 possibilities to combine one muon with a jet. The combination which minimizes the difference $\Delta M = |M(\mu_1 j_{1'}) - M(\mu_2 j_{2'})|$ is used and the mean of the two reconstructed Leptoquark masses is taken. The reconstructed Leptoquark mass for signal events depends on the real Leptoquark mass, therefore a scan of Leptoquark masses is performed with the requirement that the reconstructed Leptoquark mass is in a range around the true Leptoquark mass. The range increases with increasing true Leptoquark masses from 200 GeV at $m_{LQ} = 400 \text{ GeV}$ to 300 GeV at $m_{LQ} = 800 \text{ GeV}$.

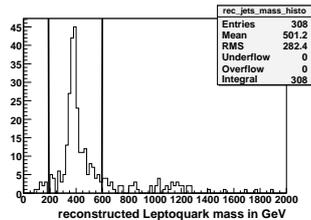


Fig. 3: $m_{LQ} = 400 \text{ GeV}$

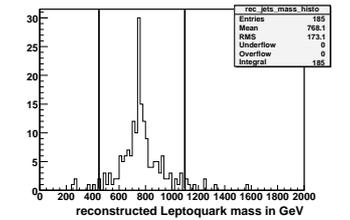


Fig. 3: $m_{LQ} = 800 \text{ GeV}$

The surviving cross-sections of Leptoquarks with $m_{LQ} = 400 \text{ GeV}$ is 0.535 pb and of Leptoquarks with $m_{LQ} = 800 \text{ GeV}$ it is 0.013 pb. The surviving cross-sections for the backgrounds after applying the cuts for $m_{LQ} = 400 \text{ GeV}$ are: 0.046 pb for $t\bar{t}$, 0.044 pb for $Z/\gamma^* (\rightarrow \mu\mu) + \text{jets}$ and 0.0002 pb for the backgrounds WW and ZZ together. With an integrated luminosity of 10 pb^{-1} one expects for $m_{LQ} = 400 \text{ GeV}$ and the corresponding cuts 5.3 Leptoquark events but only 0.5 Standard model background events. For $m_{LQ} = 800 \text{ GeV}$ the integrated luminosity required for a discovery is around 500 pb^{-1} .

References

[1] M. Leurer, Phys.Rev. D49(1994) 333