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 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 GeV) [1].
At the LHC Leptoquarks would be produced in pairs via strong interactions (figure 1).

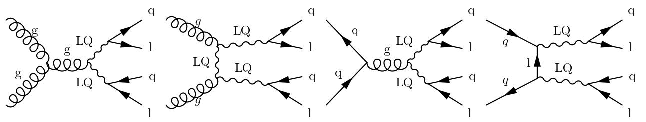

Fig. 1: Pair production of Leptoquarks

This article deals with scalar Second Generation Leptoquarks pairs decaying into μ + jet + μ + jet to be measured with the ATLAS detector at the LHC. We assume the branching fraction of Leptoquarks 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 fulfilling the isolation cut (energy deposited in the calorimeter in a cone of $\Delta R = 0.2$ / $E_T^{muon} \leq 0.3$) with opposite sign, with a transverse momentum of at least 60 GeV and with $|\eta| \leq 2.5$ and 2 jets with a transverse momentum of at least 25 GeV with $|\eta| \leq 4.5$. 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 main backgrounds are $t\bar{t}$ events decaying leptonically and Z/γ^* ($\rightarrow \mu\mu$). The following S_T, dimuon-mass and reconstructed-Leptoquark-mass-range cuts have been optimized for each Leptoquark mass to achieve a 5σ discovery at the lowest luminosity possible. The mass distribution of the reconstructed Leptoquarks for m_{LQ} = 400 GeV and the major backgrounds after the basic cuts (left) and after all other cuts (right) can be seen in figure 2.

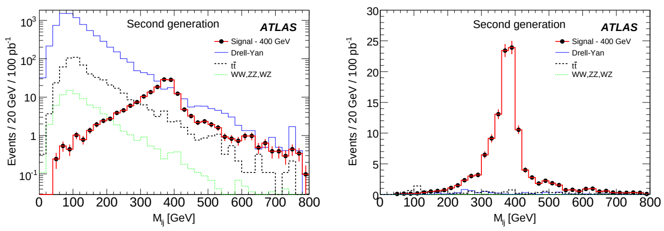

Fig. 2: reconstructed Leptoquark mass, after the preselection (left) and after all other cuts (right)

S_T has to be at least 600 GeV for m_{LQ} = 400 GeV. The dimuon-mass has to be at least 110 GeV for all Leptoquark masses. The integrated luminosities needed for a 5σ discovery for the different Leptoquark masses after all described cuts can be seen in table 1 [2,3]. The systematic uncertainties which add up to about 30% of the signal efficency and 50% of the background efficency have been included in this calculation; the main uncertainties are the errors on the integrated luminosity, cross-sections, jet energy scale and the statistical uncertainty of the Monte Carlo samples.

Tested Leptoquark mass	Expected luminosity needed for a 5σ discovery
300 GeV	1.6 pb^{-1}
400 GeV	7.7 pb^{-1}
600 GeV	103 pb^{-1}
800 GeV	663 pb^{-1}

Table 1: Integrated luminosities at $\sqrt{s}$=14 TeV needed for a 5σ discovery

A change in the center-of-mass energy from 14 TeV to 10 TeV will decrease the pair production cross section for a 400 GeV scalar Leptoquark by a factor of 3 while the background cross-sections are reduced by a factor of typically 2. The reduced cross-sections will change the expected lumisoty needed for a 5σ discovery to about 5 pb^{-1} for a 300 GeV scalar Leptoquark and to about 30 pb^{-1} for a 400 GeV scalar Leptoquark.

For the analysis of early data it is important to estimate the amount of background in the signal region from data in control regions. The top background can be estimated from events with one electron and one muon. The Z/Drell-Yan background can be estimated either from events with only one or zero jets or from events at the Z resonance with two jets. Using the first sample to estimate the number of events in the signal region one has to assume that the jet production is simulated correctly while for the second sample one has to assume that the shape of the Drell-Yan spectrum is simulated correctly. By reweighting Monte Carlo events it has been shown that the background estimate is stable at the 10% level against changes in the Drell-Yan spectrum, the jet rates and their momentum spectrum which would change the expected number of background events by a factor of two. For a center-of-mass energy of 10 TeV and a luminosity of 30 pb^{-1} the estimated statistical uncertainty of each of the background estimations is about 30%.

References

[1] M. Leurer, Phys.Rev. **D49** (1994) 333
[2] Expected Perfomance of the ATLAS Experiment - Detector, Trigger and Physics, arXiv:0901.0512 (2009)
[3] G. Krobath, Search for Second Generation Leptoquarks with ATLAS at the LHC, PhD thesis LMU München 2008