Prospects for early discoveries at the LHC with dileptons, jets and no missing energy with the ATLAS detector

Raimund Ströhmer for the ATLAS Collaboration

LMU München, Am Coulombwall 1, 85748 Garching, Germany

Abstract. This article describes a search for leptoquark pair production and a right-handed W in the cascade decay $W_R \rightarrow lN_l \rightarrow lqlq$ in final states containing two leptons, additional jets and no missing transverse energy. Both final states with two electrons and two muons are studied. With a center of mass energy of $\sqrt{s} = 14$ TeV leptoquarks with masses up to 500-600 GeV and the studied scenarios of left-right symmetric models (LRSM) with W_R masses up to 1800 GeV can be discovered with about 100pb^{-1} [1]

Keywords: SUSY, Leptoquark, LRSM, ATLAS, LHC
PACS: 12.60.-i; 14.80.-j

ATL-PHYS-PROC-2009-084
01 September 2009

INTRODUCTION

Final states containing two leptons, additional jets and no missing transverse energy offer a great potential for early discoveries at the LHC. They can be produced by the decay of leptoquark pairs or the cascade of a right-handed W in left-right symmetric models.

Leptoquarks

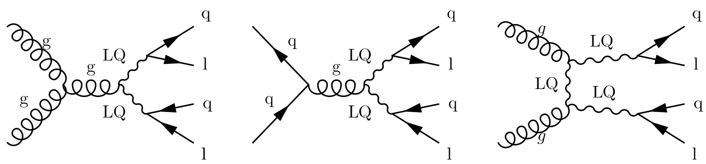

FIGURE 1. Leptoquark pair production via the strong interaction

Leptoquarks are particles with both lepton and quark quantum numbers. They appear naturally in GUT's. Leptoquark pairs could be produced at the LHC via the strong interaction (see Fig. 1) resulting in large production cross sections (e.g. $\sigma = 2.24$pb for a 400 GeV scalar leptoquark [2]). Limits on lepton flavor conservation and FCNC require that a leptoquark which would be observable at the TeV scale only couples to one quark and one lepton generation. Leptoquarks will decay into a lepton and a quark. The lepton can either be charged or a neutrino. The branching ratio into charged leptons is commonly denoted as $\beta = Br(LQ \rightarrow ql^{\pm})$. The number of events in the final state with two charged leptons is therefore reduced by β^2 from the total number of produced leptoquark pairs.

Left-right symmetric models

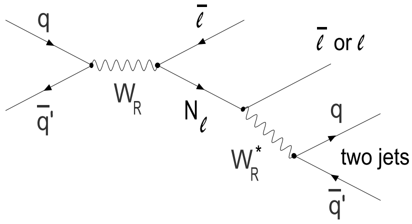

FIGURE 2. W_R decay

In left-right symmetric models (LRSM) a right-handed W (W_R) can be produced via a Drell-Yan process similar to a Standard Model W. It can decay into a charged lepton and a Majorana neutrino (N_l) which in turn will decay into a charged lepton and two jets (see Fig. 2). The kinematic properties of the leptons and jets will depend on the masses of W_R and N_l. For strongly boosted N_l its decay products will be close together making the electron jet separation especially challenging. Two example mass points have been studied: $LRSM\_18\_3$ with $m(W_R) = 1800$ GeV and $m(N_l) = 300$ GeV ($\sigma = 24.8$pb) and $LRSM\_15\_5$ with $m(W_R) = 1500$ GeV and $m(N_l) = 500$ GeV ($\sigma = 47.0$pb).

EVENT SELECTION

The following basic selections were applied: two isolated electrons or two isolated muons with $p_T > 20$ GeV and $|\eta| < 2.5$; an invariant lepton pair mass above 70 GeV; and two jets with $p_T > 20$ GeV and $|\eta| < 4.5$. Individual cuts where then applied for the different analyses in order to optimize the 5 sigma discovery potential of the analysis. The major backgrounds are due to leptonic $t\bar{t}$ decays and Drell-Yan events with two or more jets. Additional background sources are vector boson pair production and multijet events with fake leptons.

Leptoquarks

In order to separate signal from background, cuts on the sum of the jet and lepton transverse momenta $S_T = p_T^{j1} + p_T^{j2} + p_T^{l1} + p_T^{l2}$, the invariant lepton pair mass and the invariant lepton-jet mass were applied. There are two possibilities to combine two leptons and two jets into two lepton-jet pairs. The combination for which the difference between the invariant masses of the two lepton-jet pairs is smallest was selected. A sliding mass window on the lepton-jet mass was applied as a function of the tested leptoquark mass. For 400 GeV, the optimal cuts for the dielectron analysis were $S_T >$ 490 GeV, $M_{ee} > 120$ GeV and 320 GeV $< M_{12}^{ej} <$ 480 GeV. For the the dimuon analysis, cuts of $p_T(\mu) > 60$ GeV and $p_T(\text{jet}) > 25$ GeV were applied in addition to the cuts $S_T > 600$ GeV and 300 GeV $< M_{avr}^{\mu j} < 500$ GeV. Figure 3 shows the invariant lepton-jet mass after cuts on S_T and M_{ll} for the dielectron and dimuon channel.

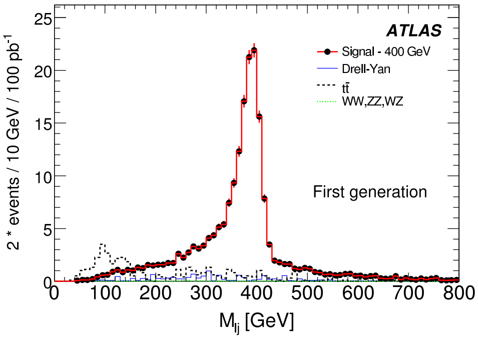

FIGURE 3. Invariant lepton-jet mass after cuts on S_T and M_{ll}

Left-right symmetric models

In the search for the decay of W_R, much harder cuts of $S_T > 700$ GeV and $M_{ll} >$ 300 GeV were applied. In addition, a cut on the invariant mass of the two jets and two leptons of $M_{lljj} > 1000$ GeV was applied. Figure 4 shows the M_{lljj} after the cuts on S_T and M_{ll}.

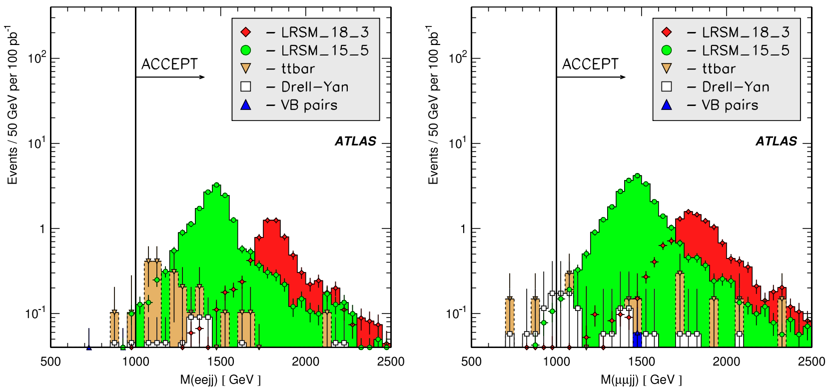

FIGURE 4. Invariant $lljj$ mass after cuts on S_T and M_{ll}

RESULTS

In order to calculate the expected discovery significance, systematic uncertainties on the expected number of signal and background events have to be taken into account. The sources of systematic uncertainties considered were the integrated luminosity, lepton trigger and selection efficiencies, jet energy scale and resolution, lepton energy scale and resolution, background and signal cross section, the production of additional jets in Drell-Yan events (by comparing predictions from ALPGEN based on Matrix-Element to

PYTHIA based on parton shower), PDF uncertainties and finally the uncertainty due to limited Monte Carlo statistics. This results in uncertainties of 30-50% on the number of expected events. Figure 5 shows the 5 σ discovery potential for the leptoquark searches. The left plot shows the minimal β^2 for a 40 GeV leptoquark as a function of the integrated luminosity and the right plot shows the minimal β^2 for an integrated luminosity of 100pb^{-1} as a function of the leptoquark mass. Figure 6 shows the minimal W_R production cross section needed for a 5 σ discovery as a function of the integrated luminosity. The two curves correspond to the two sets of W_R and N_l masses which were considered. Also shown are the corresponding predicted cross sections.

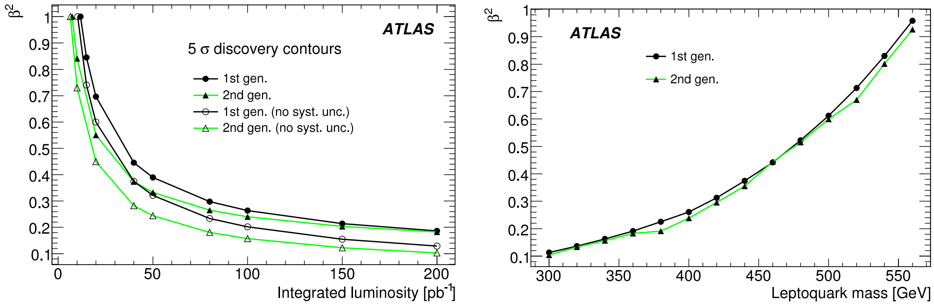

FIGURE 5. Integrated luminosity needed for a 5σ discovery of a 400 GeV leptoquark (left) and 5σ discovery reach for 100 pb^{-1} right

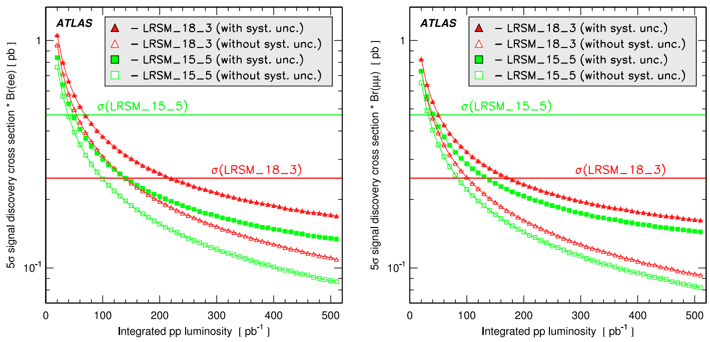

FIGURE 6. Integrated luminosity needed for a 5σ discovery.

CONCLUSION

Final states with two high pt leptons and two highly energetic jets look very promising for early data searches. Both leptoquarks with masses up to 500-600 GeV and LRSM with $W_R \rightarrow lN_l \rightarrow lqlq$ could be discovered with about 100pb^{-1} of integrated luminosity. For 10 TeV signal and background cross sections are a factor 2-3 smaller.

REFERENCES

1. CERN-OPEN-2008-020; ISBN978-92-9083-321-5; arXiv:0901.0512v1
2. M. Kramer, T. Plehn, M. Spira, and P. M. Zerwas, Phys. Rev. D71 (2005) 057503, arXiv:hep-ph/0411038.