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Search for scalar leptoquarks at $\sqrt{s} = 13$ TeV with ATLAS

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Pair-produced scalar leptoquarks were sought in proton-proton collisions at a center-of-mass energy of 13 TeV by the ATLAS experiment. A dataset corresponding to an integrated luminosity of 3.2 fb^{-1}delivered by the LHC was used. First and second generation scalar leptoquarks were searched for in events with at least two jets and two electrons or muons, respectively. No excess over the Standard Model prediction was observed. Limits of 1100 GeV (1050 GeV) were set at 95% CL on the first (second) generation leptoquark mass, given $\beta = 1$.

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1. Introduction

This article summarizes a search for first and second generation scalar leptoquarks (LQs) with ATLAS in proton-proton (pp) collisions at a center-of-mass energy of 13 TeV using 3.2 fb^{-1}of data delivered by the LHC [1].

LQs are predicted by many theories beyond the Standard Model (SM). Recently, they were suggested as an explanation of the observed excesses in flavour physics [2]. LQs carry both baryon and lepton numbers and they couple to a lepton and a quark simultaneously. They are color triplets and carry fractional electric charge. They can be either scalar or vector bosons. Scalar LQs couple to the SM fermions via a Yukawa coupling with a coupling constant λ_l. The minimal Buchmüller–Rückl–Wyler model (mBRW) [3] assumes that there are three generations of LQs and each LQ only couples to fermions of the same generation. Such a LQ can only couple (and therefore decay) to a charged lepton and a quark or a neutrino and a quark. The branching fraction of a decay involving a charged lepton is denoted as β.

In proton-proton (pp) collisions, LQs can be produced in pairs. This production proceeds via the strong interaction and it is independent of λ_l. In this case, the only free parameters (to a good approximation) are the LQ mass and β. Both LQs in the pair belong to the same generation. If they both decay to a charged lepton then there are two same flavour opposite sign leptons in the final state together with two high energetic quarks that give rise to two jets.

2. ATLAS detector

The ATLAS detector [4] is a multipurpose device built to precisely measure properties of electrons, muons, jets, tauons and photons. The presented analysis mainly profits from the Inner Detector with a coverage of $|\eta| < 2.5$, the Electromagnetic (EM) calorimeter ($|\eta| < 3.2$) and the Muon Spectrometer (MS) covering the region $|\eta| < 2.7$.

ATLAS has a trigger system with two levels. The first level is hardware-based whereas the second is based on software algorithms that are similar to those used in offline reconstruction.

3. Signal and background processes

The main background consists of Drell–Yan (DY) production with associated jets and $t\bar{t}$ production with both W bosons decaying leptonicaly. DY+jets production is simulated with the Sherpa 2.1.1 [5] generator whereas $t\bar{t}$ production is simulated with the POWHEG-BOX v2 generator [6, 7, 8, 9] interfaced to PYTHIA 6.428 [10]. A somewhat smaller background process is diboson production (simulated with Sherpa 2.1.1), where one boson decays to two quarks and the other one is a Z, decaying to a pair of charged leptons. A fourth source of background is single top production, simulated with Powheg+PYTHIA 6. Small but non-negligible background is due to objects (e.g. jets) misidentified as electrons. This background is estimated with a data-driven method, the so-called Matrix Method. For the signal generation, PYTHIA 8.160 [11] is used.

4. Event and object selection

The dataset used corresponds to an integrated luminosity of 3.2 fb^{-1} of high-quality data recorded by the ATLAS detector in 2015. For the dielectron event selection, a two-electron trigger with a transverse energy threshold of 17 GeV is used. The dimuon events are selected with a combination of two single muon triggers, with 26 GeV and 50 GeV p_{T} thresholds, respectively. Events with at least one primary vertex reconstructed by the Inner Detector are used.

Electrons and muons are required to be isolated, to originate from the hardest primary vertex in an event, to pass certain identification criteria and to be within the region $|\eta| < 2.47$ and $|\eta| < 2.5$, respectively. Electrons falling in the region $1.37 < |\eta| < 1.52$ are rejected. Electron and muon p_{T} cuts are 30 GeV and 40 GeV respectively. Jets are required to be within the region of $|\eta| < 2.8$, to have p_{T} above 50 GeV and to pass certain loose identification criteria (jet cleaning). For a 1 TeV LQ signal, the acceptance times efficiency is 70% (43%) for dielectron (dimuon) events.

5. Search strategy

Given the above object definitions, events with exactly two leptons and at least two jets are preselected. The next step is the definition of a region of phase space where the signal is expected to appear. This signal region (SR) is delimited by cuts on the dilepton invariant mass m_{ll} and on S_{T}, defined as the scalar sum of transverse momenta of the two leptons and the two leading jets. The cuts are: $m_{ll} > 130$ GeV and $S_{\text{T}} > 600$ GeV. The SR definition is the same for both considered channels. The lepton–jet pairing algorithm requires the lowest possible difference between the masses of the two pairs. The SR is further split in seven bins according to the minimal mass of a lepton–jet pair in the event, $m_{\text{LQ}}^{\text{min}}$.

In addition to the SR, two control regions (CRs) are defined to constrain the normalization of the two main background processes and the systematic uncertainties of the corresponding event yields. Given the event preselection described above, the Z CR is defined as a window around the Z peak, namely $70 \text{ GeV} < m_{ll} < 110 \text{ GeV}$. The $t\bar{t}$ CR consists of events with exactly one electron, one muon and at least two jets.

The statistical interpretation of the results uses a profile-likelihood fit of signal plus background templates to the data. The fit is performed simultaneously in the two CRs and the seven bins of the SR. All systematic uncertainties are incorporated into the likelihood function as constrained nuisance parameters.

6. Systematic uncertainties

The largest systematic uncertainties come from modelling of the two main background processes, DY+jets and $t\bar{t}$. In the SR, the uncertainty on the DY+jets ($t\bar{t}$) event yields is 20% (30%). Also, the uncertainty in the signal production cross-section due to higher order effects and due to uncertainties in the parton distribution functions (PDFs) can reach up to 30%. Other sources of systematic uncertainty are: determination of the jet and electron energy scale and resolution as well as of the muon momentum scale and resolution, uncertainties on MC efficiency scale factors (due to the various object selection cuts) and the trigger requirements, PDF uncertainties in the background predictions, and the luminosity uncertainty.

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7. Results

Fig. 1 shows the observed and predicted event yields in the SR as a function of $m_{\mathrm{LQ}}^{\mathrm{min}}$. No excess over the SM prediction is observed and thus, limits are set on the cross-section times branching ratio at 95% CL in both first and second generation LQ searches. Consequently, the observed limit on the first (second) generation LQ mass is 1100 GeV (1050 GeV), given $\beta = 1$. Finally, limits on β as a function of the LQ mass are set, see Fig. 2.

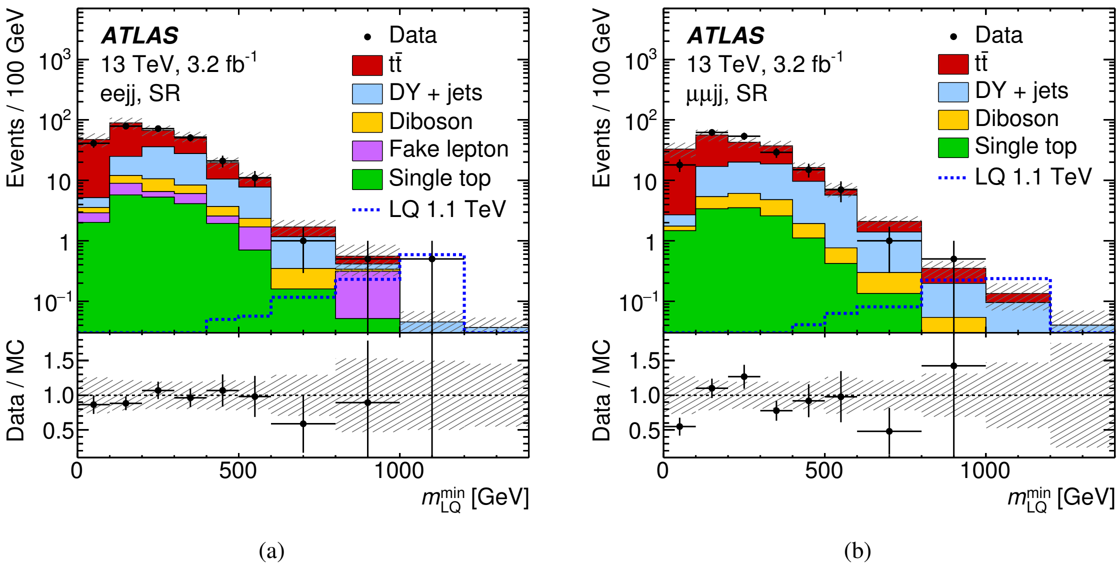

Figure 1: Distribution of $m_{\mathrm{LQ}}^{\mathrm{min}}$ in the SR of (a) the first and (b) the second generation LQ search [1]. Data is displayed in black, the background prediction is the colored area and a 1.1 TeV LQ signal prediction is shown by the dashed blue line. The hatched bands display the total systematic uncertainty on the background prediction.

8. Conclusion

A search for first and second generation scalar LQs based on 3.2 fb^{-1}of *pp* data collected by the ATLAS experiment at the LHC was presented. No excess over the SM prediction was observed and limits were set on β as a function of the LQ mass. For $\beta = 1$, first (second) generation LQ masses are excluded up to 1100 GeV (1050 GeV) at 95% CL.

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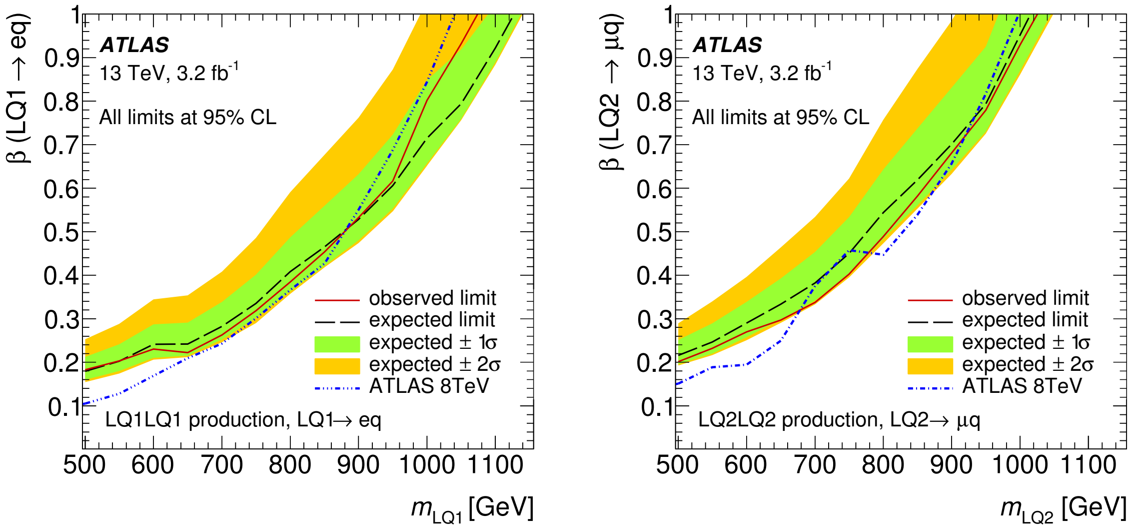

(a) (b)

Figure 2: Limits on β as a function of the LQ mass for (a) first and (b) second generation LQs [1]. Expected limits (black dashed line) are shown together with their uncertainty bands. The red lines display the observed limits. For comparison, the observed limits from the 8 TeV analysis [12] are shown (blue lines).

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