ATLAS PUB Note
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Summary Plots from ATLAS Searches for Pair-Produced Leptoquarks

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This note collects four summary plots with exclusion contours derived for different pair-production scenarios of scalar leptoquarks. In all four scenarios, the decay products of the leptoquarks include only quarks from the third generation, whereas depending on the scenario they can either include third-generation leptons (neutral or charged) or first-/second-generation leptons. Several dedicated searches and two reinterpretations of searches for supersymmetric particles target these signal models. The full Run-2 dataset recorded with the ATLAS detector in proton–proton collisions at $\sqrt{s} = 13$ TeV is used, corresponding to an integrated luminosity of 139 fb^{-1}. The contours indicate the observed and expected exclusion limits as a function of the leptoquark mass and the branching ratio of the leptoquarks into a quark and a charged lepton.

1 Overview of LQ Models

In total, four different models with pair production of scalar leptoquarks are employed in the four summary plots in this note. The plots overlay contours obtained from different dedicated searches for leptoquarks and reinterpretations of two searches for supersymmetric particles, all of which are based on the full Run-2 dataset of 139 fb^{-1}. No statistical combination of the different analyses is done.

Third-Generation Model: Figures 1 and 2 present limits on the pair production of scalar leptoquarks, where all possible decays of the leptoquark into a quark of the third generation (t, b) and a lepton of the third generation (τ, ν) are considered. The limits are presented as a function of the leptoquark mass and the branching ratio into a charged lepton and a quark for up-type ($\text{LQ}_3^{\text{u}} \to t\nu/b\tau$) and down-type ($\text{LQ}_3^{\text{d}} \to b\nu/t\tau$) leptoquarks. The previous versions of these figures based on 36.1 fb^{-1} of data taken in 2015 and 2016 can be found in Ref. [1]. The contours from this earlier paper are shown in the new summary plots as grey contours.

Mixed-Generation Model: Figures 3 and 4 present limits on the pair production of scalar leptoquarks, where all possible decays of the leptoquark into a quark of the third generation (t, b) and a lepton of the first or second generation (ℓ, ν, with $\ell = e, \mu$) are considered. The limits are presented as a function of the leptoquark mass and the branching ratio into a charged lepton and a quark for up-type ($\text{LQ}_{\text{mix}}^{\text{u}} \to t\nu/b\ell$) and down-type ($\text{LQ}_{\text{mix}}^{\text{d}} \to b\nu/t\ell$) leptoquarks. These two models are new and thus no previous results based on a partial Run-2 dataset are available.

Signal sample generation: Signal samples for the third-generation model were generated at next-to-leading order (NLO) in QCD with MadGraph5_aMC@NLO 2.6.0 [2], using the LQ model of Ref. [3] that adds parton showers to previous fixed-order NLO QCD calculations [4, 5], and the NNPDF 3.0 NLO [6] parton distribution functions, interfaced with Pythia 8.230 [7] using the A14 set of tuned parameters [8] for the parton shower and hadronization. The mixed-generation model was produced in the same way but using an extended version of the LQ model of Ref. [3] that adds the possibility of decays to different generations. The LQ pair-production cross sections were obtained from the calculation of direct top-squark pair production, as this process has the same production modes, computed at approximate next-to-next-to-leading order (NNLO) in QCD with resummation of next-to-next-to-leading logarithmic (NNLL) soft gluon terms [9–12]. The cross sections do not include lepton t-channel contributions, which are neglected in Ref. [3] and may lead to corrections at the percent level [13]. Madspin [14] was used for the decay of the LQ, where the couplings of the leptoquark to the quark–lepton pair are determined by two parameters: a model parameter β and the coupling parameter λ. The coupling to a charged lepton and a quark is given by $\sqrt{\beta}\lambda$, and the coupling to a neutrino and a quark by $\sqrt{1-\beta}\lambda$. Note that for equal couplings, i. e. $\beta = 0.5$, the branching ratio will not be 50 % due to the sizeable top-quark mass. The samples were produced for a model parameter of $\beta = 0.5$ or $\beta = 1$, and target branching ratios were obtained by reweighting the samples based on generator-level information. The parameter λ was set to 0.3, resulting in a LQ width of about 0.2 % of its mass [15, 16].

2 Input Analyses

All contours shown in the summary plots have previously been published in the conference notes or papers cited below unless otherwise stated.

Contours from the following four dedicated analyses are included in the plots:

- $b\tau b\nu$: "Search for new phenomena in pp collisions in final states with tau leptons, b-jets, and missing transverse momentum with the ATLAS detector" [17].
- $t\tau t\tau$: "Search for pair production of third-generation scalar leptoquarks decaying into a top quark and a τ-lepton in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector" [18].
- $b\ell b\ell$: "Search for pairs of scalar leptoquarks decaying into quarks and electrons or muons in $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector" [19].
- $t\ell t\ell$: "Search for pair production of scalar leptoquarks decaying into first- or second-generation leptons and top quarks in proton-proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector" [20].

Contours from the following reinterpretations of searches for pair production of supersymmetric particles are included in the plots:

- stop-0ℓ: "Search for a scalar partner of the top quark in the all-hadronic $t\bar{t}$ plus missing transverse momentum final state at $\sqrt{s}$ = 13 TeV with the ATLAS detector" [21].
- sbottom-0ℓ: "Search for new phenomena in final states with b-jets and missing transverse momentum in $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector" [22].

3 Up-type Third-Generation Model (LQ_3^u)

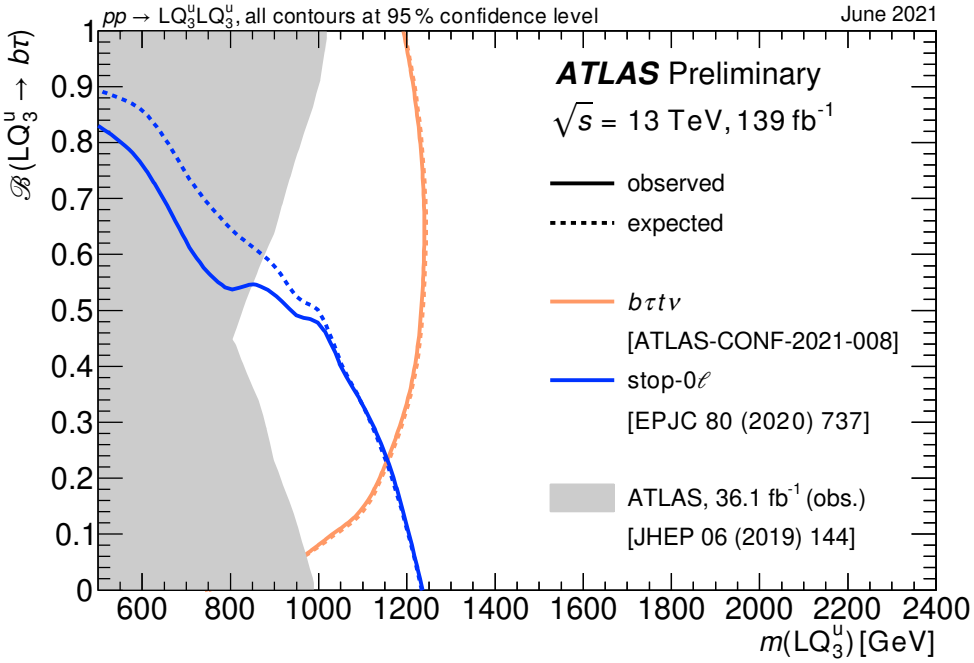

Figure 1: Expected and observed exclusion contours at the 95 % confidence level for pair-produced scalar third-generation up-type leptoquarks with decays $LQ_3^u \to t\nu/b\tau$, as a function of the leptoquark mass and the branching fraction $\mathcal{B}(LQ_3^u \to b\tau)$ into a charged lepton and a quark. The area shaded in gray corresponds to the observed exclusion contours from the previous ATLAS publication [1] based on 36.1 fb^{-1} of data taken in 2015 and 2016. In addition to the dedicated search for leptoquarks, the plot includes a reinterpretation of the search for pair production of supersymmetric top squarks with no leptons (stop-0ℓ) in the final state.

4 Down-type Third-Generation Model (LQ_3^d)

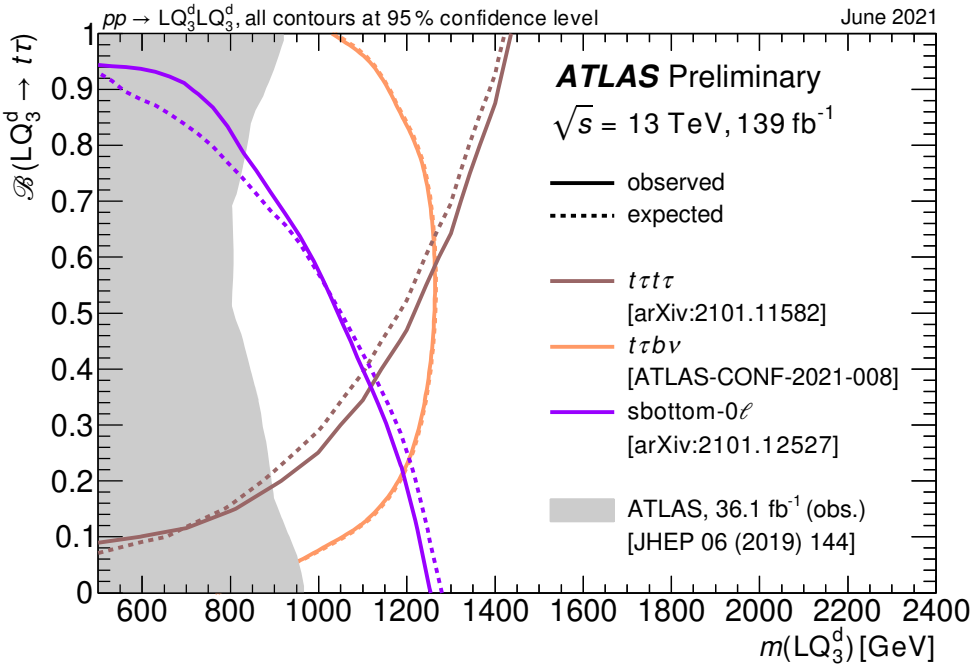

Figure 2: Expected and observed exclusion contours at the 95 % confidence level for pair-produced scalar third-generation down-type leptoquarks with decays $LQ_3^d \to b\nu/t\tau$, as a function of the leptoquark mass and the branching fraction $\mathcal{B}(LQ_3^d \to t\tau)$ into a charged lepton and a quark. The area shaded in gray corresponds to the observed exclusion contours from the previous ATLAS publication [1] based on 36.1 fb^{-1} of data taken in 2015 and 2016. In addition to the dedicated searches for leptoquarks, the plot includes a reinterpretation of the search for pair production of supersymmetric bottom squarks with no leptons (sbottom-0ℓ) in the final state.

5 Up-type Mixed-Generation Model (LQ^{u}_{mix})

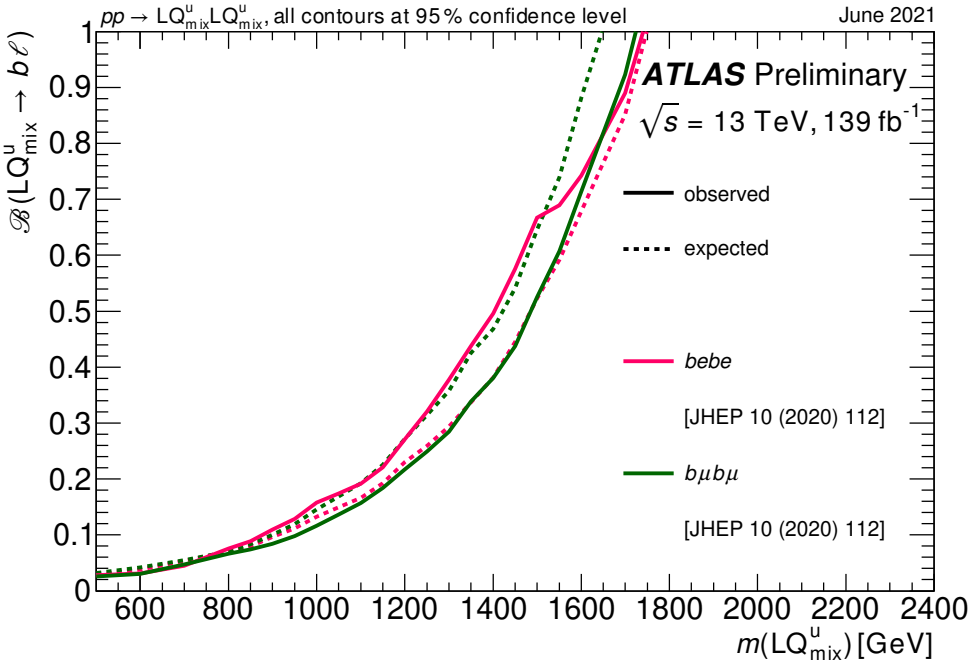

Figure 3: Expected and observed exclusion contours at the 95 % confidence level for pair-produced scalar up-type leptoquarks with mixed decays to third-generation quarks and leptons from the first or second generation $LQ^{u}_{mix} \to t\nu/b\ell$, as a function of the leptoquark mass and the branching fraction $\mathcal{B}(LQ^{u}_{mix} \to b\ell)$ into a charged lepton and a quark.

6 Down-type Mixed-Generation Model (LQ^{d}_{mix})

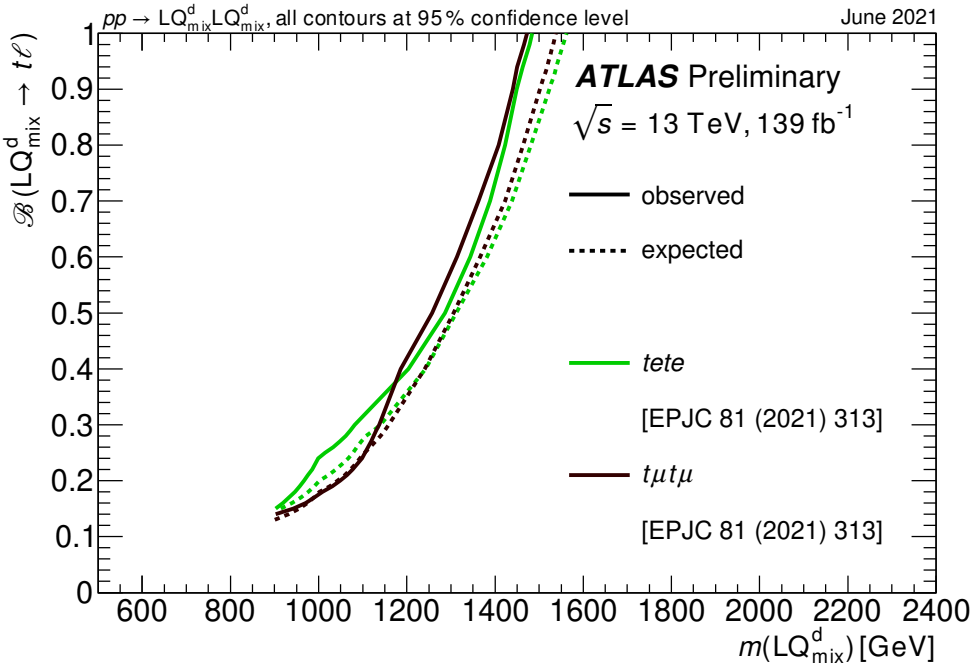

Figure 4: Expected and observed exclusion contours at the 95 % confidence level for pair-produced scalar down-type leptoquarks with mixed decays to third-generation quarks and leptons from the first or second generation $LQ^{d}_{mix} \to b\nu/t\ell$, as a function of the leptoquark mass and the branching fraction $\mathcal{B}(LQ^{d}_{mix} \to t\ell)$ into a charged lepton and a quark. The search shown here selects final states with boosted hadronically decaying top quarks and thus probes high leptoquark masses above 900 GeV.

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