Search for scalar leptoquarks in the $b\tau\tau$ final state

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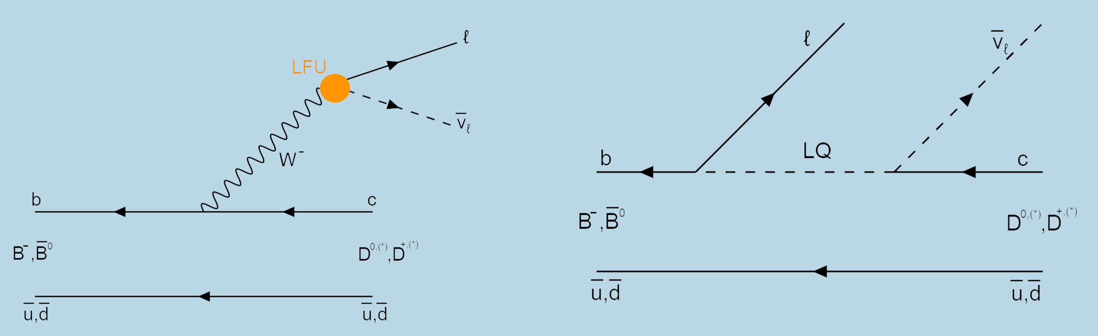
Introduction

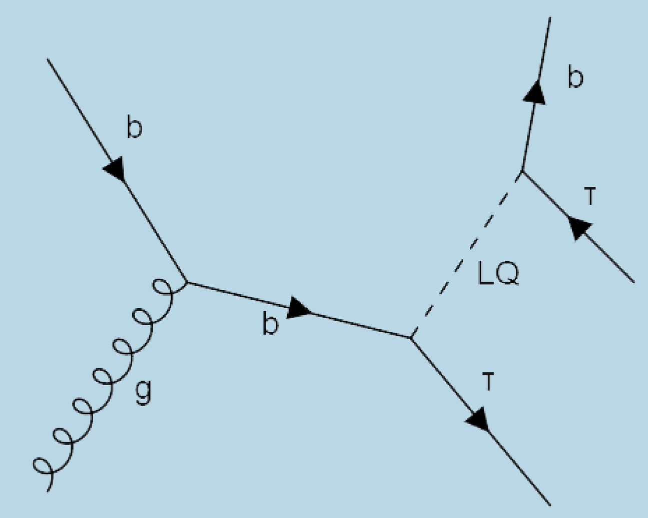
As there are existing similarities between the structure of the quark and lepton sectors in the Standard Model, it raises the possibility that there is an underlying symmetry between them. Therefore, many beyond the Standard Model theories that attempt to unify the forces predict Leptoquark (LQ) particles that couple to both quarks and leptons. Besides, Several recent results from Belle, Babar and LHC show hints of deviations from lepton-flavour universality, which could be caused by the existence of Leptoquarks. Some of the most compelling evidence comes from B-meson decays, which show non-unitary ratios of the decays $B \to D\tau\nu / B \to D\mu\nu$ [2]. This analysis performed a search for singly-produced scalar leptoquarks decaying to $b\tau\tau$ in proton-proton collisions.

LFV & Signal Model

Lepton-flavour universality violation (LFV) can be caused by Leptoquark, the Feynman diagrams below showed the hints that the existence of Leptoquark can explain the non-unitary ratios of the decays $B \to D\tau\nu / B \to D\mu\nu$.



The scalar Leptoquark model chosen is $\tilde{S}_1$, with fermion number $F = 3B + L = -2$ and electric charge of 4/3e.

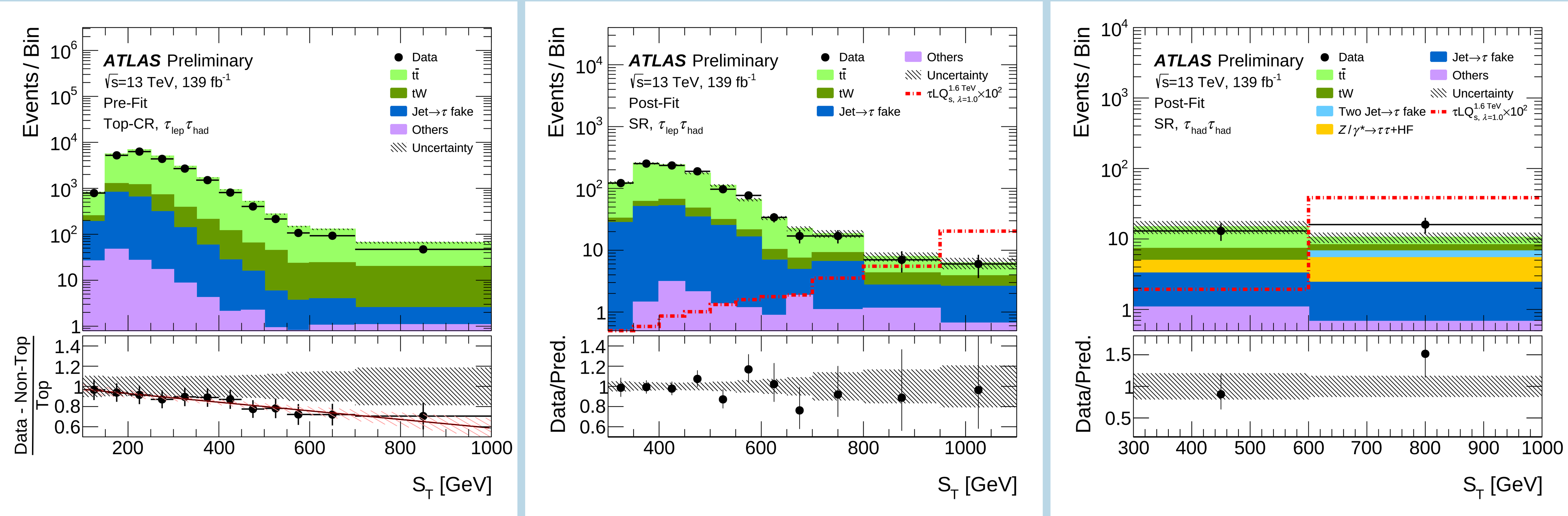


Event Selection

The event selection is split into two channels based on the decay modes of the final state τ -lepton—— $\tau_{lep}\tau_{had}$ and $\tau_{had}\tau_{had}$ channels. The two channels follow a similar event selection strategy. The visible mass of the two taus, $m_{\text{vis}}(\ell, \tau_{had})$ is required to be $>$ 100 GeV. An additional selection on the $\Delta\phi(\ell, E_T^{miss}) < 1.5$ is applied in the $\tau_{lep}\tau_{had}$ channel. Lastly, the p_T of leading p_T b-jet must be above 200 GeV. Finally, the discriminating variable is selected as the scalar p_T sum of the two τ and the leading-p_T b-jet, S_T, and a minimum cut on $S_T > 300$ GeV is applied.

Background Estimation

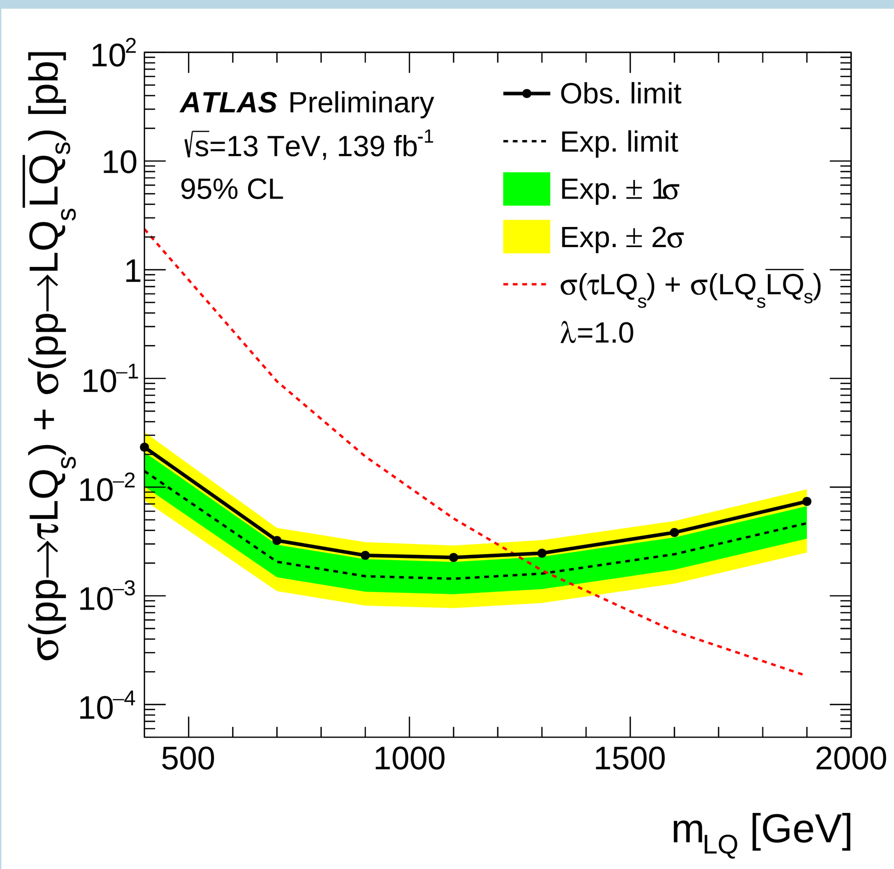
The dominant background contributions in this analysis are from $t\bar{t}$ and single top-quark events, a Top-CR is thus defined in the $\tau_{lep}\tau_{had}$ channel to ensure that this background is accurately modeled. A correction is derived from this region as a function of S_T.

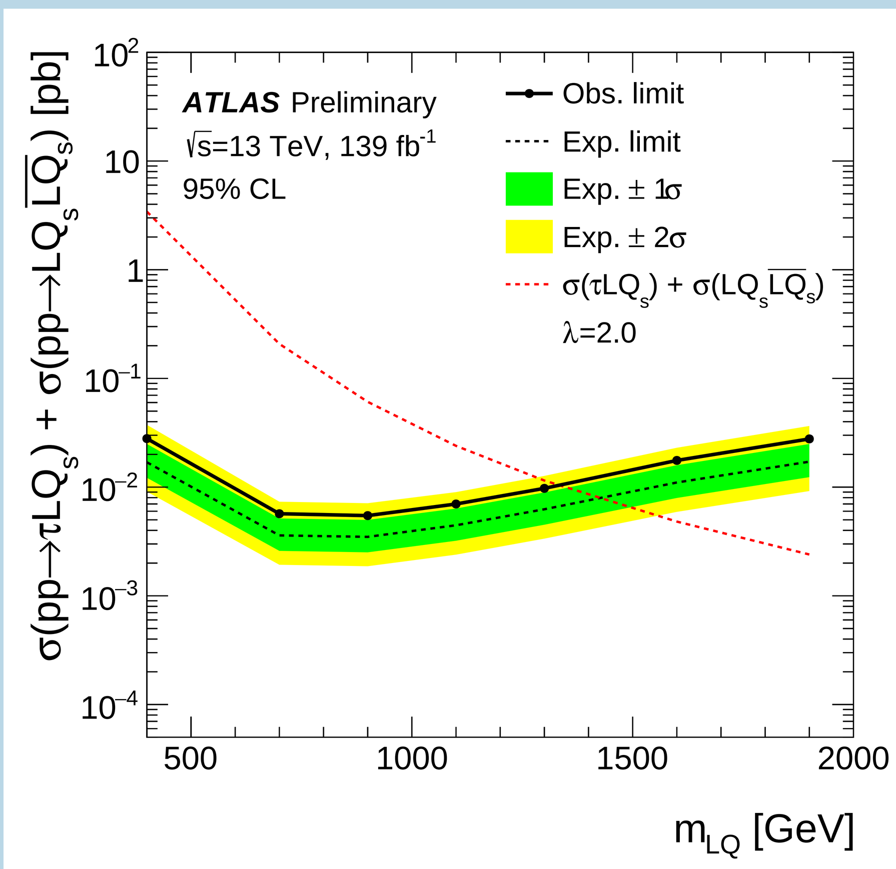


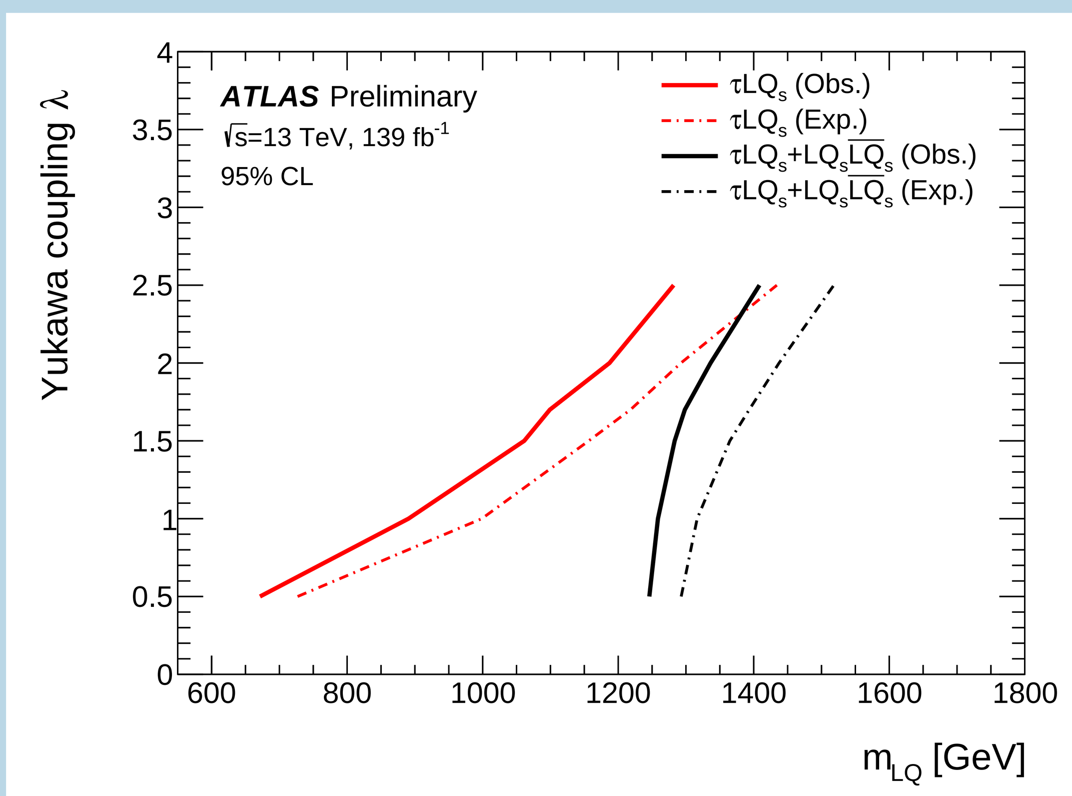
Systematic Uncertainty & Results

Systematic Uncertainties can be assigned to three main groups: the experimental uncertainties, the modelling uncertainties for the backgrounds and the modelling uncertainties for the signal. They are in the range between 11% to 22% totally.

As good agreement is found with the background expectation, upper limits are set on the cross-section times branching fraction. This is done with the frequentist CL_s method. A production cross-section for a given signal scenario is excluded at the 95% confidence level (CL) when $\text{CL}_\text{s} < 0.05$. The single Leptoquark production and the combined single plus pair Leptoquark production (LQ+LQLQ) are considered in the result. The upper limit with $\lambda = 1.0$ and the exclusion limits in the $\lambda - m_{\text{LQ}}$ plane are shown below.







Conclusion

A search for scalar Leptoquarks in $b\tau\tau$ final states is performed. Final states with semi-leptonic and fully hadronic decays of two τ-leptons are considered. The benchmark model is $\widetilde{S}_1$, for a range of λ between 0.5 and 2.5. The predictions from the Standard Model are in good agreement with the data. Upper limits on cross sections times branching ratios of singly-produced Leptoquarks decaying to $b\tau$ are set at 95% CL. For scalar Leptoquark exclusion limits are also provided in the plane of the Leptoquark mass and the LQ-ℓ-q Yukawa coupling at 95% CL. The observed (expected) lower limit on the singly-produced scalar Leptoquark mass is 0.89 TeV (1.0 TeV) for $\lambda = 1.0$, 1.01 TeV (1.22 TeV) for $\lambda = 1.7$ and 1.28 TeV (1.43 TeV) for $\lambda = 2.5$. After considering the combined single and pair production of scalar Leptoquark the observed (expected) lower limit becomes 1.26 TeV (1.32 TeV) for $\lambda = 1.0$, 1.30 TeV (1.40 TeV) for $\lambda = 1.7$ and 1.41 TeV (1.52 TeV) for $\lambda = 2.5$.

References

[1] ATLAS Collaboration, Search for scalar leptoquarks in the $b\tau\tau$ final state in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, ATLAS-CONF-2022-037, 2022, URL: http://cds.cern.ch/record/2815283

[2] S. Klaver, Lepton flavour universality in charged-current B decays, (2019), arXiv: 1907.01500