# Search for Scalar Leptoquark Pair Production Decaying into Top Quarks and Leptons at $\sqrt{s}$ = 13 TeV with the ATLAS detector

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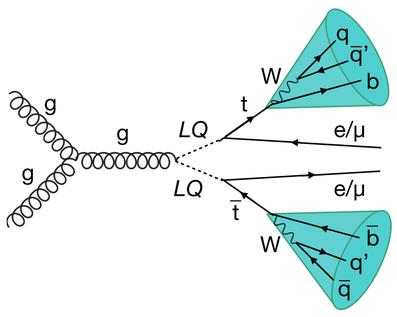
## 1 Motivation

- Leptoquarks (LQs) are predicted by several GUT model, e.g. SU(5) and Pati-Salam model
- LQ model are promising explanation to some measured deviations from the Standard Model:
  - Hints of lepton universality violation in flavour-changing neutral current B-meson decays
  - A long standing 3.3σ deviation of $(g-2)_\mu$ measurement by E821
- The first search for top-philic cross-generational LQs

## 2 Signal model

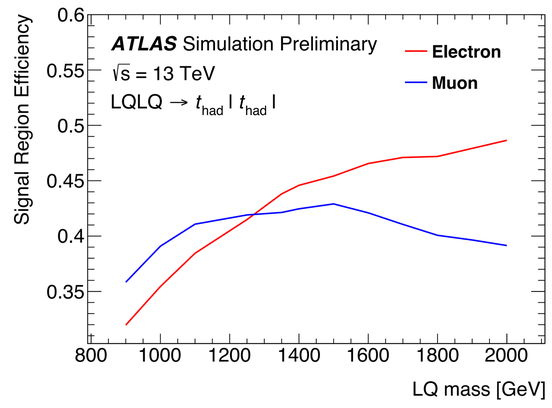
- Focusing on LQ pair production decaying to te te and tμ tμ final states
- Pair production cross-section is driven by QCD, and insensitive to the unknown Yukawa LQ-lepton-quark coupling constant λ
- The coupling constant λ was set to give a LQ width of about 0.2% of its mass




- Targetting the **hadronic** decay channel in the **boosted** regime

## 3 Event selections

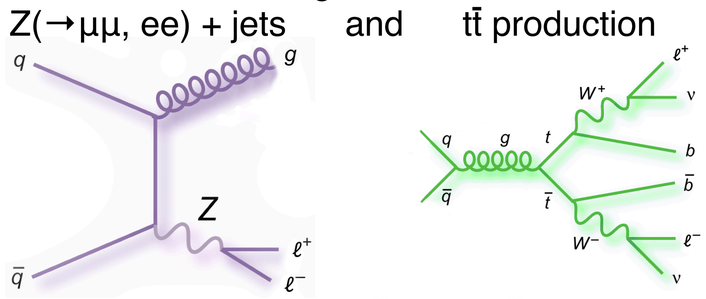
| | $t\bar{t}$ CR | SR | Z CR |
|---|---|---|---|
| Leptons | $p_T$ > 100 GeV, $\lvert\eta_{e(\mu)}\rvert$ < 2.47 (2.5) | | |
| | $N_\ell$ = 2 (opposite-sign) | | |
| Large-*R* jets | $p_T$ > 200 GeV, $\lvert\eta\rvert$ < 2.0, m > 50 GeV | | |
| | $N_{LRJ} \geq 2$ | | |
| Small-*R* jets | $p_T$ > 25 GeV, $\lvert\eta\rvert$ < 2.5 | | |
| | $N_{SRJ} \geq 2$ | | |
| Dilepton invariant mass $m_{\ell\ell}$ | > 120 GeV | | (70 – 110) GeV |
| Lepton flavour | *eμ* | *ee* or *μμ* | |




## 4 Event selections

Two dominant background sources:

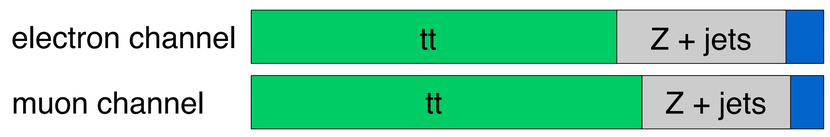
Z(→μμ, ee) + jets and tt̄ production



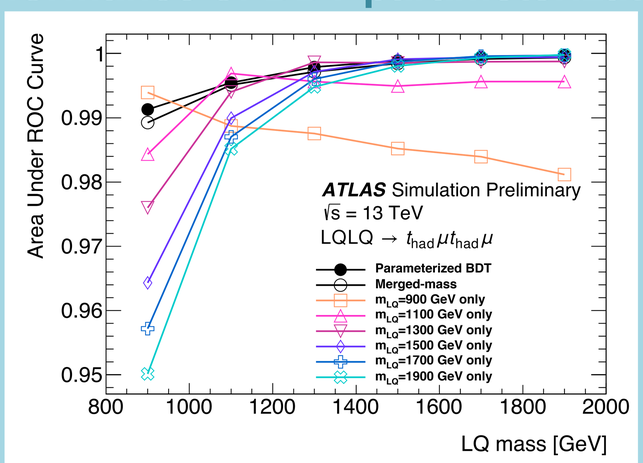

Estimated using Monte Carlo (MC) simulation, with normalization constrained by dedicated control regions.

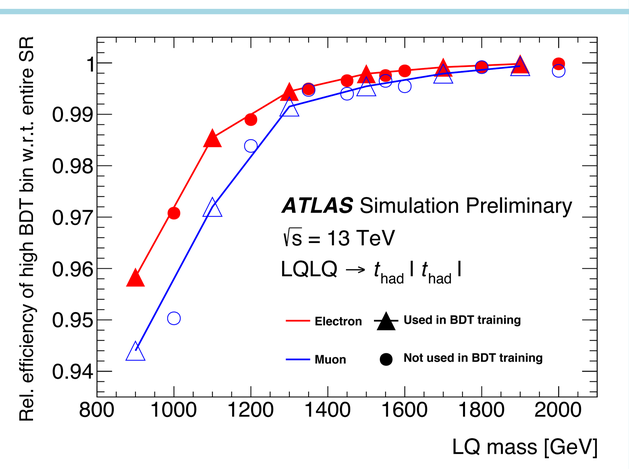
Other small contributions from single-top quark, dibson, ttV, and W + jets were also modelled by MC.

Signal region background composition:




## Performance of BDT parameterization



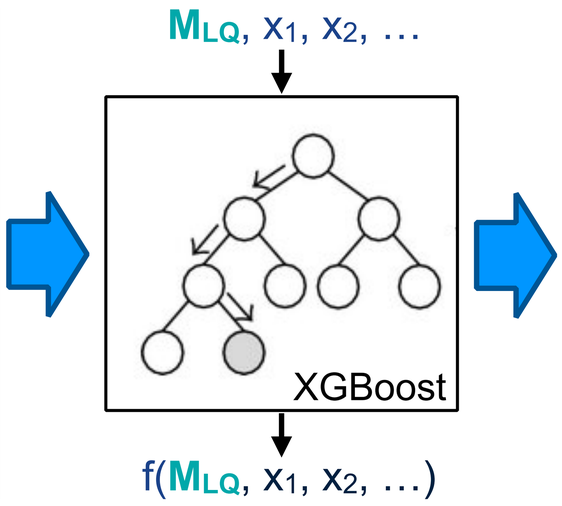

**The parameterized BDT:**

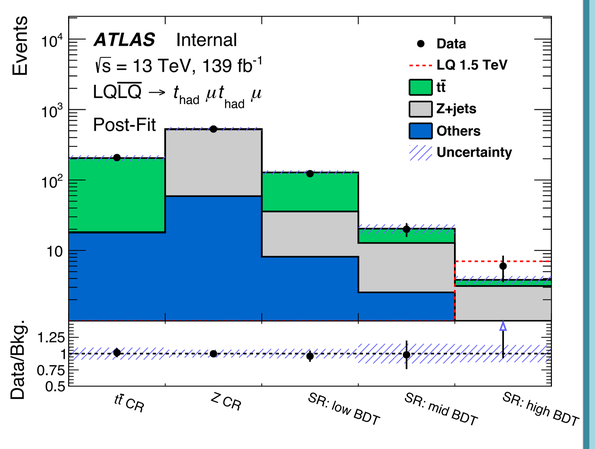
- provides similar performance as the dedicated BDTs for specific LQ mass, and
- interpolates well between mass points involved in training

## 5 Analysis strategy

A gradient boosting BDT approach was adopted to classify signal from backgrounds in the signal region.

| Input variable | |
|---|---|
| LQ hypo. | $m_{\ell1,J1}^{max}$, $m_{\ell2,J2}^{min}$, $m_{\ell1,J2}$, $m_{\ell2,J1}$, $E_{l1}^{LQ}$, $E_{l2}^{LQ}$… |
| dileptonic ttbar hypo. | $m_{top1}$, $m_{top2}$, $m_{W1}$, $m_{W2}$, $E_{l2}^{W2}E_{l1}^{W1}$… |
| Z→ℓℓ hypo. | $m_{\ell\ell}$, $pT_Z^{LAB}$ |
| LAB frame | $L_T$, $H_T$, $S_T$, $E_T^{miss}$, $E_T^{miss}$ sig. |
| substructure variables | $\sqrt{d_{23}}$, $\tau_{32}$, $Q_W$ |
| MVA parameterizatio | test mass point $m_{LQ,hypo}$ |




**Input variables to BDT:**

- Natural basis of kinematics based on the hypothesis of signal and backgrounds
- Visible and invisible event-level activities
- Jet substructure variables

**Parameterization of BDT:**

- Expanding the inputs to include the **hypothetical LQ mass**
- One single classifier optimized for a range of mass

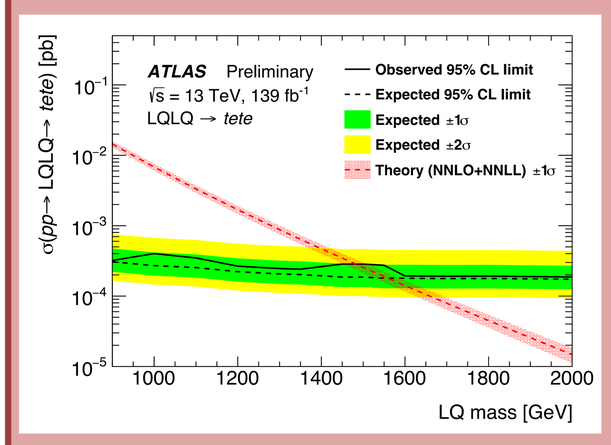
**BDT output score profile:**

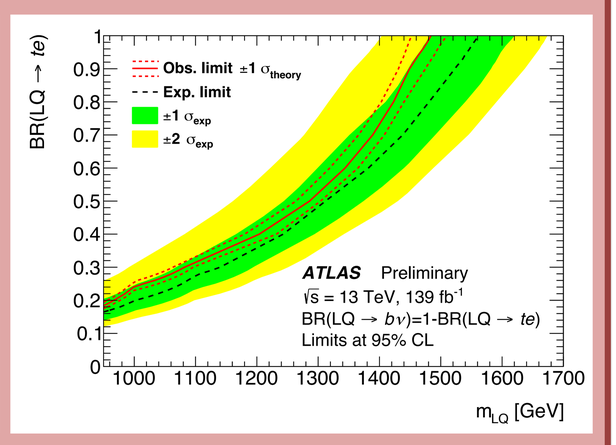
- used as final discriminant in profile-likelihood fit
- divided SR into three bins to maximize signal sensitivity

## 6 Results

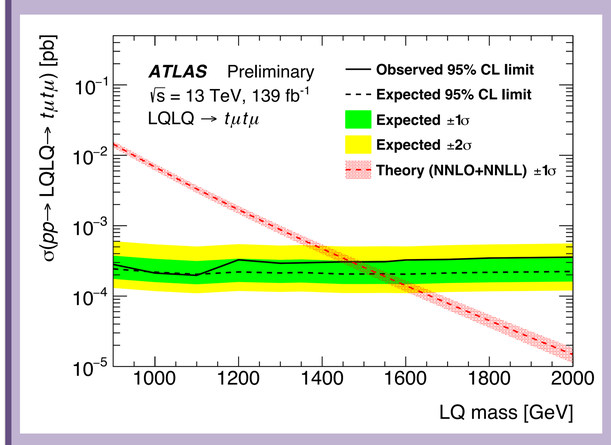
In the absence of any significant deviations from the SM prediction, the frequentist $CL_S$ approach was used to set 95% confidence intervals.

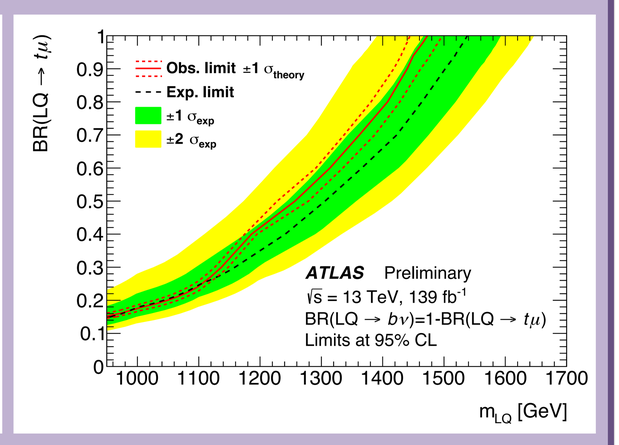
### Electron channel




### Muon channel




$m_{LQ}$ < **1480 GeV** and **1470 GeV** are excluded at BR(LQ→tℓ)=1 for **electron** and **muon** channel respectively.

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