Search for New Physics with Top quarks in ATLAS at 8 TeV ($t\bar{b}$, $t\bar{t}$, vector-like quarks)

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This contribution presents results from searches for new resonances (W', Z', g_{KK}), decaying to a top-antibottom pair or a top-antitop pair, including the use of boosted top quark reconstruction techniques. Results from the search for vector-like quarks (focusing on the decay channels $T \to Zt$ and $B \to Zb$) are also presented. These searches use the data sample recorded in 2012 at $\sqrt{s} = 8$ TeV centre-of-mass energy by the ATLAS experiment at the LHC. Data are in good agreement with the Standard Model predictions, therefore limits are derived on the production of these new processes.

1 Introduction

The Standard Model (SM) of particle physics is a tremendous success, in particular with the recent discovery at LHC of a new scalar boson that is compatible with the one predicted by the Brout-Englert-Higgs mechanism. However, several aspects indicate that the SM cannot be the ultimate theory and many extensions[1] have been proposed in the past. Most of them predict the existence of new heavy particles, usually coupled preferentially to the top quark due to its very high mass. Among these new particles, this contribution will focus on W' decaying to $t\bar{b}$, new $t\bar{t}$ resonances (Z' and g_{KK}) and vector-like quarks (VLQ), with the ATLAS [1] detector.

2 $W' \to t\bar{b}$

In the SM, the W boson couples only to left-handed fermions. It is therefore natural to search for a partner of the W that would couple to right-handed fermions, the W'_R. Moreover, some theories beyond the SM (BSM), including extra-dimensions or technicolor, predict the existence of a heavier partner of the standard W, still coupling to left-handed fermions, the W'_L. In this contribution, the W' is supposed to decay mainly to $t\bar{b}$ (or $\bar{t}b$), with an unknown coupling constant g', and the analysis presented here [2] is designed for the reconstruction of the hadronic decay of the top quark. The main target of this analysis is a very heavy W' (from 1.5 to 3 TeV), thus ensuring the decay products are highly boosted.

The selected events must have been triggered by the presence of at least 700 GeV of transverse energy in the calorimeters. Events are not accepted if a high quality electron or muon is present. Each event must contain exactly one b- and one top-quark candidate. The b-quark candidate is a small-R (R=0.4) b-tagged jet with $p_T > 350$ GeV. Being highly boosted, the

[1] In this contribution, only non-SUSY extensions of the SM are considered.

top-quark candidate must be reconstructed as a single large-R (R=1.0) jet with $p_T > 350$ GeV. Both jets must be well separated[2] ($\Delta R > 2.0$). The events are then splitted in two categories: the *one b-tag* category and the *two b-tag* category. In the latter one, a small-R b-tagged jet must be present inside the top-quark candidate.

The background is composed of 99% multijet events in the one b-tag category and of 88% multijet events and 11% $t\bar{t}$ events in the two b-tag category. The multijet background is estimated from data using control regions while the $t\bar{t}$ background is estimated from Monte Carlo (MC) simulation. Figure 1 shows the distributions of the mass of the two jets (m_{tb}) observed in the data for the two categories. The result of background-only fits to these spectra are also shown and exhibits no excess with respect to the SM production. Therefore, 95% confidence level (C.L.) upper limits on the production cross-sections times BR($W' \to t\bar{b}$) are derived as a function of the W' mass, and range from 0.16 pb to 0.33 pb for the W'_L, and from 0.10 pb to 0.21 pb for the W'_R. Assuming $g' = g_{\mathrm{SM}}$, these limits can be translated to a lower limit of 1.68 TeV (1.63 TeV expected) for the mass of the W'_L and 1.76 TeV (1.85 TeV expected) for the mass of the W'_R. Removing this assumption, limits can be set in the $(g' - m_{W'})$ plane as can be seen in Fig. 2.

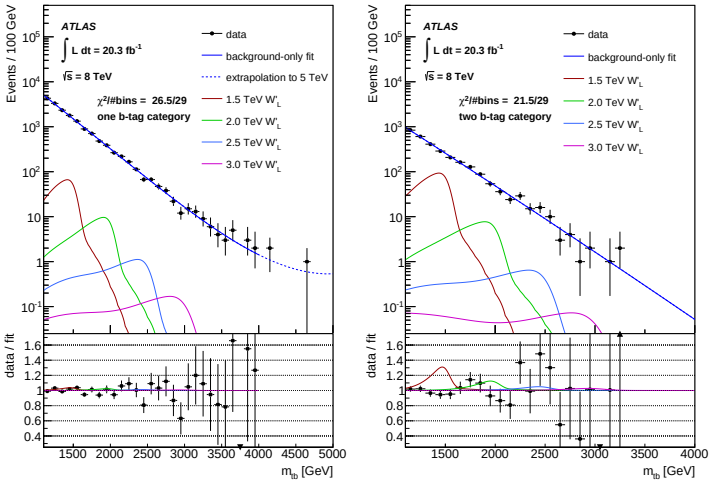

Figure 1: m_{tb} distributions in data in the one b-tag (left) and two b-tag (right) categories. Background-only fits are shown and the bottom plots show the ratio of the data and the fit. Potential W'_L signal shapes with $g'_L = g_{\mathrm{SM}}$ are also overlaid.

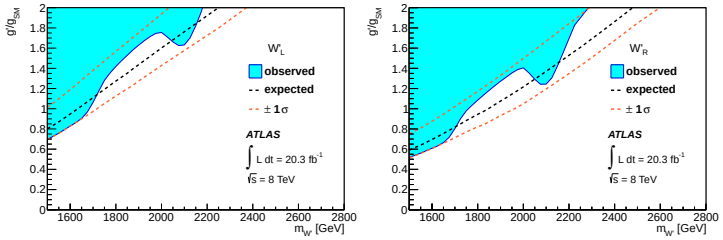

Figure 2: Observed and expected 95% C.L. limits on the ratio of coupling g'_L/g_{SM} (g'_R/g_{SM}) of the W'_L (W'_R) model as a function of the W' mass.

3 $g_{KK}/Z' \to t\bar{t}$

New bosons that could decay to $t\bar{t}$ are predicted by several BSM models. In the analysis [3] described in this contribution, two benchmark models are tested: a narrow leptophobic Z' and a Kaluza-Klein (KK) excitation of the gluon in the Randall-Sundrum model.

[2] $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$

The selected events must have been triggered by the presence of one electron or muon and each event must contain at least one b-tagged jet. The events are then splitted in two categories: the *resolved* and the *boosted* ones. In the resolved category, the $t\bar{t}$ system is reconstructed using the lepton, the missing transverse momentum and three or four small-R jets. In the boosted category, the top quark that decays leptonically is reconstructed using the lepton, the missing transverse momentum and one small-R jet, while the hadronically decaying top is reconstructed as one high-mass large-R jet.

Figure 3 shows the distribution of the mass of the reconstructed $t\bar{t}$ system observed in data, compared to the SM prediction. No significant excess is observed, therefore 95% C.L. upper limits on the production cross section of new bosons are set. For the Z', these limits can be translated to a lower limit on its mass of 1.8 TeV, while for the KK gluon, the limit on the mass is 2.0 TeV. These results have been obtained with 70% of the statistics available, a refined analysis on the full dataset is being performed.

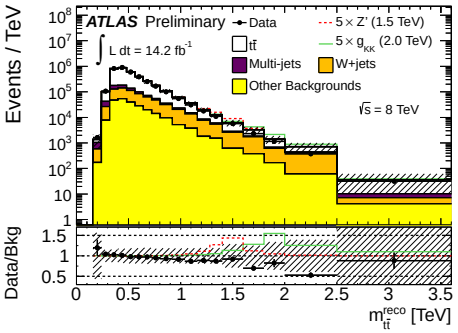

Figure 3: The $t\bar{t}$ invariant mass spectrum, summing the spectra from the resolved and boosted categories.

4 Vector-like quarks

The simple implementation of a fourth generation of quarks is now excluded by the LHC data. Vector-like quarks, predicted by various BSM models, including composite Higgs, are not ordinary quarks because their left- and right-handed components have the same weak isospin. Thanks to this property, such new quarks are still allowed by the current data. In the analysis [4] described in this contribution, the new T (with charge +2/3) and B quarks (with charge -1/3) are searched for, both in the pair and single production processes, concentrating on the $T \to Zt$ and $B \to Zb$ decays, but also including the decays $T \to Wb/Ht$ and $B \to Wt/Hb$.

The selected events must have been triggered by the presence of one electron or muon. Each event must contain at least two central jets ($|\eta| < 2.5$) and an opposite-sign same-flavour pair of electrons or muons that is compatible with the mass of the Z boson and with a p_T above 150 GeV. The events are then splitted in two categories: the *dilepton* category when no additional lepton (e or μ) is present, and the *trilepton* category when at least a third lepton is present. The number of b-tagged jets must be at least one in the trilepton category and at least two in the dilepton category. For the selection of the pair production signal, the scalar sum of the p_T of the jets must also be at least 600 GeV in the dilepton category. For the single production, the presence of at least one forward jet ($2.5 < |\eta| < 4.5$) is required in both categories. Background processes are dominated by Z+jets, WZ and $t\bar{t} + Z$ and are estimated from simulated samples. For the Z+jets samples, a reweighting is applied, determined from a fit of the Z p_T spectrum observed in data in the zero b-tag control region. After selection of the dilepton events, the spectra of the mass of the $Z - b$ system (m_{Zb}) observed in data are compared to the expected ones, both for the pair production selection and for the single production. Similarly, for the trilepton events, the spectra of the scalar sum of the p_T of the jets and the leptons (H_T) are examined. All observed spectra are compatible with the expectations, thus 95% C.L. upper limits on the T and B production cross sections are set.

For the pair production, these limits can be translated to lower limits on the mass of the

new quarks assuming some specific values of the decay branching ratios. In the case of $SU(2)$ singlets, these limits are 685 GeV for the B and 655 GeV for the T. If the new quarks are members of $SU(2)$ doublets, the limits are 755 GeV for the B and 735 GeV for the T. Without any assumption on the branching ratios, lower limits on the masses can be set for any configuration, as shown in Figure 4: the best sensitivity is achieved in the lower-left corner, where the branching ratio to Zb/t is 1.

For the single production, the upper limits on the production cross sections are shown in Figure 5 as a function of the new quark mass. As for the pair production, the limits on the T single production are obtained combining the dilepton and trilepton categories, while the limits on the B single production are obtained only with the dilepton events, the trilepton ones being insensitive to this signal.

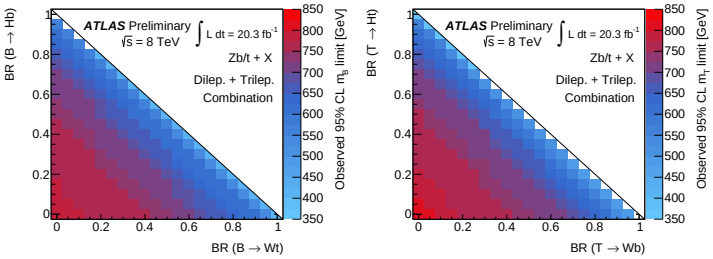

Figure 4: Observed 95% C.L. lower limits on the mass of the B (left) and the T (right) quark as a function of the branching ratios, assuming the pair production hypothesis.

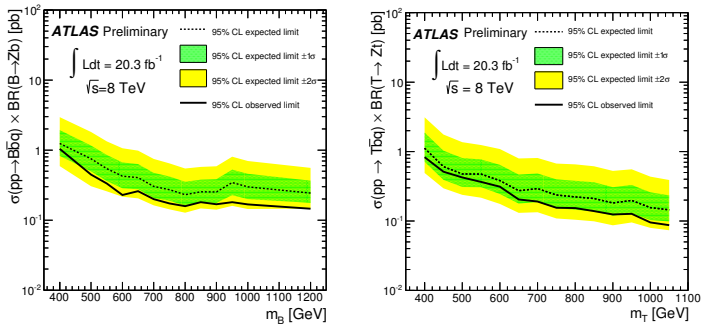

Figure 5: Expected and observed 95% C.L. upper limits on the single production cross section times the branching ratio as a function of the B (left) and the T (right) quark mass.

5 Conclusion

Many analyses are performed by the ATLAS Collaboration searching for non-SUSY new bosons or new fermions with top quarks. In this contribution, only the most recent results have been presented for the W' decaying to $t\bar{b}$, new $t\bar{t}$ resonances and vector-like quarks. The W' search presented here is focusing on high mass W' (above 1.5 TeV), leading to highly boosted top quarks, and the candidates are reconstructed in a fully hadronic mode. The $t\bar{t}$ resonances search combines the resolved and boosted topologies and constrains the Z' and g_{KK} productions. The VLQ search that was presented is designed for the decays $T \to Zt$ and $B \to Zb$ with the Z boson decaying to electrons or muons. None of these analyses exhibit any deviation from the SM prediction, therefore various limits have been derived.

References

[1] ATLAS Collab., JINST 3 S08003 (2008), doi:10.1088/1748-0221/3/08/S08003.

[2] ATLAS Collab., arXiv:1408.0886 [hep-ex].

[3] ATLAS Collab., ATLAS-CONF-2013-052, `https://cds.cern.ch/record/1547568`.

[4] ATLAS Collab., ATLAS-CONF-2014-036, `https://cds.cern.ch/record/1735195`.