PROCEEDINGS OF SCIENCE

Diboson resonance and vector-like quark searches at ATLAS and CMS

Miaoran Lu[a,*]

[a] *University of Science and Technology of China,*
No.96, JinZhai Road Baohe District,Hefei,Anhui, 230026,P.R.China

E-mail: miaoran.lu@cern.ch

This letter reports some latest results of Diboson resonance and vector-like quark searches at ATLAS and CMS. The diboson searches includes hunting for VV, VH, and HH resonances in fully hadronic or semi-leptonic final states. A novel model-independent dijet resonance search with weak supervision is also introduced. The vector-like quark section includes searches for single VLQ production that has been carried out recently.

The Eighth Annual Conference on Large Hadron Collider Physics-LHCP2020
25-30 May, 2020
online

*Speaker

PoS(LHCP2020)016

1. Introduction

Many beyond standard model theories has been proposed predicting new heavy bosons like the spin-0 radion in Randall–Sundrum (RS) framework [1, 2], the spin-1 W' and Z' in HVT model [3], and the spin 2 Kaluza-Klein graviton (G_{KK}) in the bulk RS model [4–6]. These heavy bosons could decay into a pair of standard model bosons like W, Z, H, or γ. Thus a search for the diboson resonance is a good probe of beyond standard model physics.

The vector like quarks (VLQ) are heavy non-chiral quarks with symmetric left and right handed couplings to standard model particles. VLQs are predicted in many BSM theories and could help to stabilize the higgs mass and offer a potential solution to the hierarchy problem. The decay of the VLQs provides a rich set of possible signatures.

2. Diboson resonance and vector-like quark searches

A search for heavy resonances decaying into a W or Z boson and a Higgs boson [7] was carried out based on the sample collected by the ATLAS detector, corresponding to 139 fb^{-1} of integrated luminosity. The search exploits jet substructure techniques to study the fully-hadronic $qqbb$ final state which results from the dominant decay modes of the W/Z and Higgs bosons. No significant excess of events is observed over the expected background and upper limits on the cross section for $pp \to W' \to WH$ and $pp \to Z' \to ZH$ are set at 95% CL as shown in Figure 1. These results translate into lower-mass limits on $W'(Z')$ bosons of 2.90 TeV (2.20 TeV) in the context of the weakly coupled HVT model A and of 3.20 TeV (2.65 TeV) in the context of the strongly coupled HVT model B, at 95% CL.

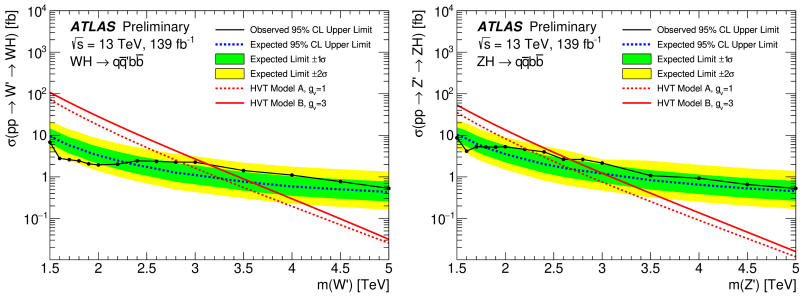

Figure 1: Observed and expected 95% CL upper limits on the cross section for $pp \to V' \to VH$ in the WH (left) and ZH (right) channels.

Searches for the production of heavy diboson resonances in the 0-lepton, 1-lepton and 2-lepton final states [8] are performed using data with an integrated luminosity of 139 fb^{-1} collected by the ATLAS detector. The data are found to be in good agreement with background expectations. Upper limits on the production of heavy resonances in the mass range 300-5000 GeV through gluon–gluon fusion, Drell–Yan or vector-boson fusion processes are derived for Standard Model extensions with an additional neutral scalar, a heavy vector triplet, or warped extra dimensions. Combining the WW and ZZ decay modes, the observed 95% confidence-level upper limit on $pp \to X \to VV$ for the ggF (VBF) process ranges from 1.8 (0.60) pb at 300 GeV to 0.38 (0.23) fb at 5 TeV for an RS radion

and from 1.4 (0.40) pb at 300 GeV to 0.26 (0.30) fb at 5 TeV for an RS graviton. These observed limits set lower mass limits of 3.2 TeV for the ggF production of an RS radion, and 2.0 (0.76) TeV for the ggF (VBF) production of an RS graviton. For the production of W' and Z' bosons in the HVT framework, the observed upper limit on the cross section $pp \to W' \to WZ$ varies from 1.9 pb at 300 GeV to 0.16 fb at 5 TeV for DY production and from 1.3 pb at 300 GeV to 0.35 fb at 4 TeV for VBF production. Similarly, the limits on the cross section $pp \to Z' \to WW$ are observed to vary from 0.9 pb at 300 GeV to 0.18 fb at 5 TeV for DY production and from 1.36 pb at 300 GeV to 0.25 fb at 4 TeV for VBF production. In the benchmark Model A (Model B), these cross-section upper limits exclude the ggF production of a W' boson with $m(W') < 3.9(4.3)$ TeV and a Z' boson with $m(Z') < 3.5(3.9)$ TeV.

A model-independent dijet resonance search with weak supervision from ATLAS is also carried out recently [9]. This analysis uses a machine learning anomaly detection procedure that does not rely on any signal model and search for new particles in final state jets and dijet resonances at the same time. The core of this analysis is a technique called classification without labels (CWola) that uses a network trained to distinguish the difference of M_{jj} shape between a given signal region and the two neighboring side-band regions. For jets produced from Lorentz-boosted heavy-particle decays, this search is more sensitive than the inclusive dijet search and extends the coverage of the all-hadronic diboson search to regions away from the SM boson masses.

A search is presented for resonances with masses above 1.2 TeV that decay to WW, ZZ, or WZ boson pairs from CMS collaboration [10]. Each of the two bosons decays into one large-radius jet, yielding dijet final states. No evidence is found for a signal, and upper limits on the resonance production cross section are set as shown in Figure 2.

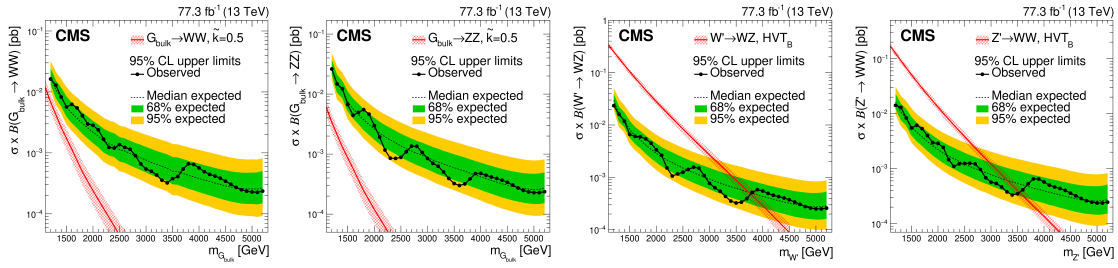

Figure 2: Observed and expected 95% CL upper limits on the product of the production cross section and the branching fraction, obtained after combining categories of all purities with 77.3 fb^{-1} of 13 TeV data, for $G_{\text{bulk}} \to WW$, $G_{\text{bulk}} \to ZZ$, $W' \to WZ$, and $Z' \to WW$ signals.

A search for new particles decaying to a pair of Higgs bosons where one decays to a bottom quark pair and the other into two W bosons that subsequently decay into a lepton, a neutrino, and a quark pair [11] has been carried out using a sample collected by the CMS detector, corresponding to an integrated luminosity of 35.9 fb^{-1}. The data are consistent with expected standard model background. The results are upper limits on the product of cross section and branching fraction for new bosons decaying to HH. The observed limit at 95% confidence level for a spin-0 resonance ranges from 123 fb at 0.8 TeV to 8.3 fb at 3.5 TeV, while the limit for a spin-2 resonance is 103 fb at 0.8 TeV and 7.8 fb at 3.5 TeV.

A search for the production of a single vector-like quark Q, where Q can be either a T or Y quark, with the subsequent decay into Wb [12] has been carried out with the ATLAS experiment corresponding to an integrated luminosity of 36.1fb^{-1}. The observed data distributions are compatible with the expected Standard Model background and no significant excess is observed. Limits at 95% CL are set on the coupling parameters and cross-section times branching ratio as shown in Figure 3.

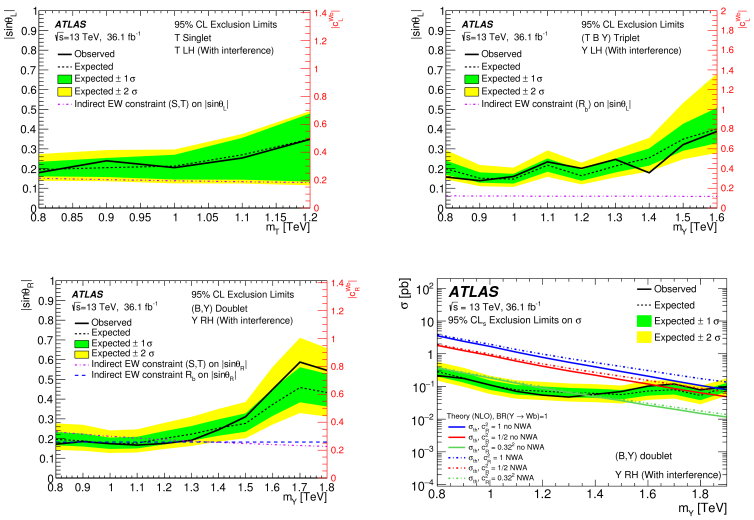

Figure 3: Observed (solid line) and expected (short-dashed line) 95% CL limits on the mixing angle $|sin\theta_{\mathrm{L}}|$ and the coupling value c_{L}^{Wb} for a singlet T-quark model assuming Br$(T \to Wb) \approx 0.5$, $|sin\theta_{\mathrm{L}}|$ and c_{L}^{Wb} for a (T, B, Y) triplet model, $|sin\theta_{\mathrm{R}}|$ and c_{R}^{Wb} for a (B, Y) doublet model assuming a branching ratio Br$(Y \to Wb)$ = 1, and cross-section times branching ratio for the case of the right-handed Y quark for a (B, Y) doublet model, as a function of the VLQ mass.

A search for anomalous production of events with large E_{T}^{miss} and a single top-quark [13] was also carried out using data collected by the ATLAS detector in 2015 and 2016. Single production of VLQ was used as one of its signal model. No deviations with respect to SM predictions are observed and 95% CL upper limits on the production cross-section of the single production of vector-like T quarks decaying into $tZ(\to \nu\bar{\nu})$ is obtained. The limits are also interpreted in terms of the excluded regions in the parameter space. Couplings of the T singlets to top-quarks and W bosons, c_W, above 0.7 are excluded for m_T = 1.4 TeV and below.

A search for a vector-like top quark partner T in the electroweak single production mode with fully hadronic final states [14] has been performed using data collected by the CMS experiment in 2016 corresponding to an integrated luminosity of 35.9fb^{-1}. No significant excess of data above the standard model background is observed and upper limits at 95% confidence level are set on $\sigma \times Br(T \to tH)$ and $\sigma \times Br(T \to tZ)$, which vary between 2 pb and 20 fb for T masses ranging from 0.6 to 2.6 TeV in the Tbq and Ttq production channels. The combined $T \to tH$ and $T \to tZ$ results for associated production with a bottom quark lead to constraints on T quarks in the T singlet model for masses below 1.00 TeV. The expected sensitivity for this model extends to 1.28 TeV (for 30% fractional width).

References

[1] W. D. Goldberger and M. B. Wise, *Modulus Stabilization with Bulk Fields*, *Phys. Rev. Lett.* **83** (1999) 4922, arXiv: hep-ph/9907447 [hep-ph].

[2] W. D. Goldberger and M. B. Wise, *Phenomenology of a stabilized modulus*, *Phys. Lett. B* **475** (2000) 275, arXiv: hep-ph/9911457 [hep-ph].

[3] D. Pappadopulo, A. Thamm, R. Torre and A. Wulzer, *Heavy vector triplets: bridging theory and data*, *JHEP* **09** (2014) 060, arXiv: 1402.4431 [hep-ph].

[4] L. Randall and R. Sundrum, *A Large Mass Hierarchy from a Small Extra Dimension*, *Phys. Rev. Lett.* **83** (1999) 3370, arXiv: hep-ph/9905221 [hep-ph].

[5] T. Han, J. D. Lykken and R.-J. Zhang, *On Kaluza-Klein states from large extra dimensions*, *Phys. Rev. D* **59** (1999) 105006, arXiv: hep-ph/9811350 [hep-ph].

[6] K. Agashe, H. Davoudiasl, G. Perez and A. Soni, *Warped gravitons at the LHC and beyond*, *Phys. Rev. D* **76** (2007) 036006, arXiv: hep-ph/0701186 [hep-ph].

[7] ATLAS Collaboration, *Search for resonances decaying into a weak vector boson and a Higgs boson in the fully hadronic final state produced in proton−proton collisions at* $\sqrt{s} = 13$ *TeV with the ATLAS detector*, arXiv:2007.05293 [hep-ex].

[8] ATLAS Collaboration, *Search for heavy diboson resonances in semileptonic final states in* pp *collisions at* $\sqrt{s} = 13$ *TeV with the ATLAS detector*, arXiv:2004.14636 [hep-ex].

[9] ATLAS Collaboration, *Dijet resonance search with weak supervision using* $\sqrt{s} = 13$ *TeV* pp *collisions in the ATLAS detector*, arXiv:2005.02983 [hep-ex].

[10] CMS Collaboration, *A multi-dimensional search for new heavy resonances decaying to boosted* WW, WZ, *or* ZZ *boson pairs in the dijet final state at* $\sqrt{s} = 13$ *TeV*, *Eur. Phys. J. C* **80** (2020) 237, arXiv:1906.05977 [hep-ex].

[11] CMS Collaboration, *Search for resonances decaying to a pair of Higgs bosons in the* HH *in* $b\bar{b}q\bar{q}'\ell\nu$ *final states at* $\sqrt{s} = 13$ *TeV*, *JHEP* **10** (2019) 125.

[12] ATLAS Collaboration, *Search for single production of vector-like quarks decaying into* Wb *in* pp *collisions at* $\sqrt{s} = 13$ *TeV with the ATLAS detector*, *JHEP* **05** (2019) 164, arXiv:1812.07343 [hep-ex].

[13] ATLAS Collaboration, *Search for large missing transverse momentum in association with one top-quark in* pp *collisions at* $\sqrt{s} = 13$ *TeV with the ATLAS detector*, *JHEP* **05** (2019) 041, arXiv:1812.09743 [hep-ex].

[14] CMS Collaboration, *Search for electroweak production of a vector-like* T *quark using fully hadronic final states*, *JHEP* **01** (2020) 036, arXiv:1909.04721 [hep-ex].