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Search for TeV scale diboson resonances

Nicolò Vladi Biesuz(1)(2)

(1) *University of Pisa - Pisa, Italy*
(2) *INFN, Sezione di Pisa - Pisa, Italy*

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Summary. — A wide range of theoretical Standard Model extensions gives rise to narrow resonances decaying to massive vector bosons. A TeV scale resonance gives a very prominent signature over an almost null background of the diboson mass spectrum. I will give a brief introduction to the theoretical models used as benchmarks for the diboson resonance searches, I will show the main experimental techniques and give a review of the past and current results. I will also describe the main areas of improvement that we expect for the next data-taking phase.

1. – Introduction

One of the goals of the ATLAS Collaboration is to find new hints of physics beyond the Standard Model. Weak diboson TeV scale narrow resonances are a promising detection channel for many models such as technicolor, extended gauge models, composite Higgs models and high mass gravitons. Given the wide variety of models extending the Standard Model, benchmarks models are kept general using predictions based on two versions of effective Lagrangian models: the Heavy Vector Triplet [1] model, that foresee the presence of three mass-degenerate spin-1 particles ($W'^{\pm}$, Z'), and bulk Randall-Sundrum model that foresees spin-2 gravitons (G*) [2, 3].

The search for massive dibosons carried out by the ATLAS Collaboration with a $20.3\,\mathrm{fb}^{-1}$ data-set collected at $\sqrt{s} = 8\,\mathrm{TeV}$ has excluded Extended Gauge Model W' with masses up to 1.81 TeV and bulk G* with masses up to 810 GeV [4]. Nevertheless an excess of events with respect to the predicted mass spectrum with local p-value of $\sim 2\sigma$ was observed in the region around 2 TeV. A similar situation was found by the CMS Collaboration that observed an excess of events of $\sim 1.8\sigma$ with respect to the background only hypothesis for the mass region around 1.8–2 TeV [5].

2. – Experimental techniques

TeV scale diboson resonances are searched selecting highly boosted bosons through their decay products. This is especially important for hadronic decays of vector bosons that are commonly used to exploit their high branching ratio. Indeed at high transverse momentum the two quarks will generate in the calorimeter two coalesced showers which are reconstructed using a single AntiKt jet with large distance parameter ($R \sim 1.0$). Bosons are then identified using new techniques, such as *grooming* [6] and *boson tagging* [7] of large R jets that had to be developed and calibrated up to TeV scale. Grooming techniques are used to reject pile-up contamination and isolate the hard scattered consituents of the jet. Boson tagging then uses these hard constituents to evaluate the jet mass and to select jets with a two-prong structure. On the other hand, leptonic decays of vector bosons are selected with standard identification methods. The lepton produced from the leptonic decays is also used as trigger signature. Therefore searches are performed both in fully hadronic and semi-leptonic final states.

The events containing two candidate bosons are then divided in different regions, namely signal and control regions. The Monte Carlo invariant mass distribution is fitted to the observed mass spectrum simultaneously in signal and control regions in order to constrain the systematic variations of the background and signal processes. Exclusion limits are set comparing the observed and expected diboson invariant mass spectrum in the signal region.

New results based on $\sqrt{s} = 13\,\text{TeV}$ data acquired during 2015 where obtained for different final states of the diboson system ($VV \rightarrow (\nu\nu qq, \ell\nu qq, \ell\ell qq, qqqq)$) [8-11]. Even if there is still no clear evidence of new physics, with the current integrated luminosity of $3.3\,\text{fb}^{-1}$ no diboson channel was able to exclude the 2 TeV region for all benchmark models. The limits set with this limited statistic are comparable to the ones reported for 8 TeV data.

3. – Future improvements

In order to improve the analysis sensitivity various improvements are under study. One of the possible improvements is the use of the finer spatial resolution of tracks to gather information on the line of flight of the decay products of the boson while the calorimetric information is used to measure the neutral component of the decay. An example of the application of this technique is the "track-assisted" jet mass that will be used to better select large-R jets with a mass compatible with that one of vector bosons. Further improvements can be achieved by the introduction of new event categories useful to explore different resonance production methods, to enhance the sensitivity in the low-mass region or to recover the efficiency of boson tagging techniques. For instance categories specifically tuned to select the Vector Boson Fusion production could be used. Furthermore, since the standard boson tagging efficiency is $\sim 50\%$ a $WZ/ZZ \rightarrow Xb\bar{b}$ category could be introduced to retrieve events failing the boson tagging. A strong effort is also going towards the optimization of the analysis in the lower mass spectrum that regained importance after the results on the exotic di-photons resonance searches at $\sqrt{s} = 13\,\text{TeV}$ where a mild excess was found at $\gamma\gamma$ invariant mass of roughly 750 GeV [12].

4. – Conclusion

A brief review of benchmark models that predict the presence of new particles decaying in two massive vector boson was given. The most recent results and exclusion limits were reported. The experimental techniques used to select the signal were described. As reported no significant deviation from the background only hypothesis were observed but a huge effort is going towards the implementation of the described analysis improvements.

REFERENCES

[1] Pappadopulo D., Thamm A., Torre R. and Wulzer A., *JHEP*, **09** (2014) 060, DOI: 10.1007/JHEP09(2014)060, 1402.4431.
[2] Randall L. and Sundrum Raman, *Phys. Rev. Lett.*, **83** (1999) 3370, DOI: 10.1103/PhysRevLett.83.3370, arXiv:hep-ph/9905221.
[3] Davoudiasl H., Hewett J. L. and Rizzo T. G., *Phys. Rev. D*, **63** (2001) 075004, DOI: 10.1103/PhysRevD.63.075004.
[4] ATLAS Collaboration (Aad G. *et al.*), *Phys. Lett. B*, **755** (2016) 285, DOI: 10.1016/j.physletb.2016.02.015, arXiv:1512.05099 [hep-ex], CERN-PH-EP-2015-269.
[5] CMS Collaboration (Khachatryan V. *et al.*), *JHEP*, **08** (2014) 173, DOI: 10.1007/JHEP08(2014)173.
[6] ATLAS Collaboration (Aad G. *et al.*), *JHEP*, **09** (2013) 076, DOI: 10.1007/JHEP09(2013)076, arXiv:1306.4945, CERN-PH-EP-2013-069.
[7] ATLAS Collaboration (Aad G. *et al.*), *Eur. Phys. J. C*, **76** (2016) 154, DOI: 10.1140/epjc/s10052-016-3978-z, arXiv:1510.05821 [hep-ex], CERN-PH-EP-2015-204.
[8] ATLAS Collaboration, *Search for diboson resonances in the $\nu\nu qq$ final state in pp collisions at $\sqrt{s} = 13\,TeV$ with the ATLAS detector*, CERN, Geneva, ATLAS-CONF-2015-068, Dec. 2015, ATLAS-CONF-2015-068, http://cds.cern.ch/record/2114840.
[9] ATLAS Collaboration, *Search for WW/WZ resonance production in the $\ell\nu qq$ final state at $\sqrt{s} = 13$ TeV with the ATLAS detector at the LHC*, CERN, Geneva, ATLAS-CONF-2015-075, Dec. 2015, ATLAS-CONF-2015-075, http://cds.cern.ch/record/2114847.
[10] ATLAS Collaboration, *Search for diboson resonances in the llqq final state in pp collisions at $\sqrt{s} = 13\,TeV$ with the ATLAS detector*, CERN, Geneva, ATLAS-CONF-2015-071, Dec. 2015, ATLAS-CONF-2015-071, http://cds.cern.ch/record/2114843.
[11] ATLAS Collaboration, *Search for resonances with boson-tagged jets in 3.2 fb^{-1} of pp collisions at $\sqrt{s} = 13\,TeV$ collected with the ATLAS detector*, CERN, Geneva, ATLAS-CONF-2015-073, Dec. 2015, ATLAS-CONF-2015-073, http://cds.cern.ch/record/2114845.
[12] ATLAS Collaboration, *Search for resonances in diphoton events with the ATLAS detector at $\sqrt{s} = 13\,TeV$*, CERN, Geneva, ATLAS-CONF-2016-018, Mar 2016, ATLAS-CONF-2016-018, http://cds.cern.ch/record/2141568.