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Search for heavy mass diboson resonances in the ATLAS experiment

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Summary. — Searches for high mass resonances decaying in a couple of vectorial bosons (Z or W) are presented. The results refer to an integrated luminosity of 36.1 fb^{-1} recorded with the ATLAS detector in 2015–2016 at $\sqrt{s} = 13$ TeV at the Large Hadron Collider. Final states in which one boson decays in leptons and the other one decays in hadrons are considered. Also fully hadronic final states are considered. These results are interpreted within the context of Standard Model extensions with additional Higgs bosons, a heavy vector triplet or warped extra dimensions.

1. – Introduction

A major goal of the physics programme at the Large Hadron Collider (LHC) is the search for new phenomena that may become visible in high-energy proton-proton (pp) collisions. One possible signature for new physics is the production of a heavy resonance with the subsequent decay into a final state consisting of a pair of vector bosons (WW, WZ, ZZ). Many models of physics beyond the Standard Model (SM) predict such a signature. These include extensions to the SM scalar sector as in the two-Higgs-doublet model (2HDM) [1] that predict new spin-0 resonances. In the heavy vector triplet (HVT) [2] phenomenological Lagrangian model, a new heavy vector triplet (W', Z') is introduced with the new gauge bosons degenerate in mass. Warped extra dimensions Randall-Sundrum (RS) [3] models predict spin-2 Kaluza-Klein (KK) excitations of the graviton, G_{KK}. Searches in final states in which one boson decays in leptons and the other one decays in hadrons, or in which both bosons decay in hadrons have been reported. The results refer to an integrated luminosity of 36.1 fb^{-1} recorded with the ATLAS detector [4] in 2015 and 2016 at $\sqrt{s} = 13$ TeV. These searches lead to different research

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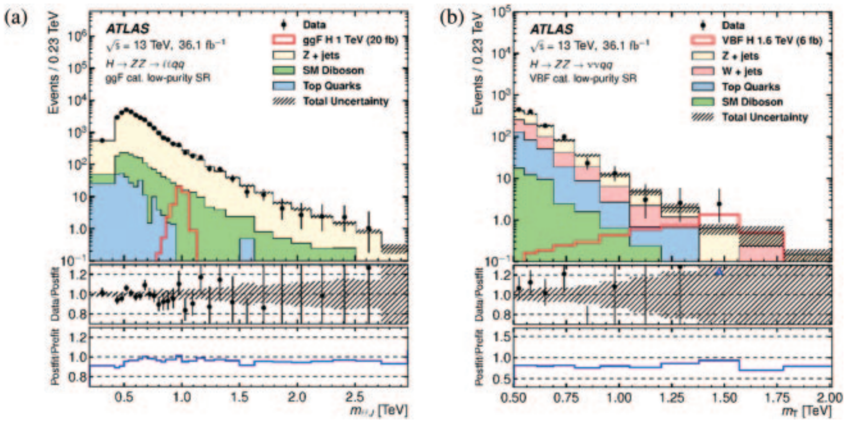

Fig. 1. – Comparisons of the observed data and expected background distributions of the final discriminants: (a) m_{llJ} discriminant for the ggF category for the $H \to ZZ \to llqq$ searches; (b) m_T discriminant for the VBF category for the $H \to ZZ \to \nu\nu qq$ search. The expected distribution from the ggF (VBF) production of a 1 TeV (1.6 TeV) Higgs boson in panel (a) (b) is also shown [5].

analyses: $X \to ZV \to llqq$ [5], $X \to ZV \to \nu\nu qq$ [5], $X \to WV \to l\nu qq$ [6], $X \to VV \to qqqq$ [7]. Production through gluon-gluon fusion (ggF), Drell-Yan (DY) and vector-boson fusion (VBF) processes is considered, depending on the assumed model. Heavy resonances would manifest themselves as resonant structures above the SM background in the invariant-mass distributions of the final state and in the $X \to ZV \to \nu\nu qq$ channel as broad enhancements in the transverse-mass distributions of the $\nu\nu qq$ final state. As an example, see fig. 1 in which the final discriminant variables for $H \to ZZ \to llqq/\nu\nu qq$ are shown.

2. – Analyses strategies and results

Two different reconstruction techniques for the $V \to qq$ decay are considered: resolved and merged. When the resonance mass is significantly higher than the V boson mass, the qq pair from the V boson decay can be collimated. In this case, the merged regime, hadrons from the two quarks overlap in the detector and are more efficiently reconstructed as a single large-R jet. The resolved reconstruction instead attempts to identify two separate small-radius jets of hadrons from the V decay. The semileptonic analysis uses both resolved and merged reconstruction techniques, while the fully hadronic analysis only the merged one. Jets must be consistent with the originating from hadronic decays of W or Z bosons. In the merged regime, discrimination against background jets inside a mass window including the W/Z mass is based on the variable D_2, which is defined as a ratio of two-point to three-point energy correlation functions that are based on the energies and pairwise angular distances between the jet's constituents [8]. Signal regions dedicated for each analysis have been defined to improve the sensitivity. The main background processes for the $llqq$ analysis are the Z+jets, top quark and diboson productions mainly from the SM ZZ and ZW. For the $\nu\nu qq$ analysis the main backgrounds arise from Z+jets, W+jets and $t\bar{t}$ productions. W+jets and $t\bar{t}$ productions are also the main backgrounds for the $l\nu qq$ analysis while for the fully hadronic analysis the

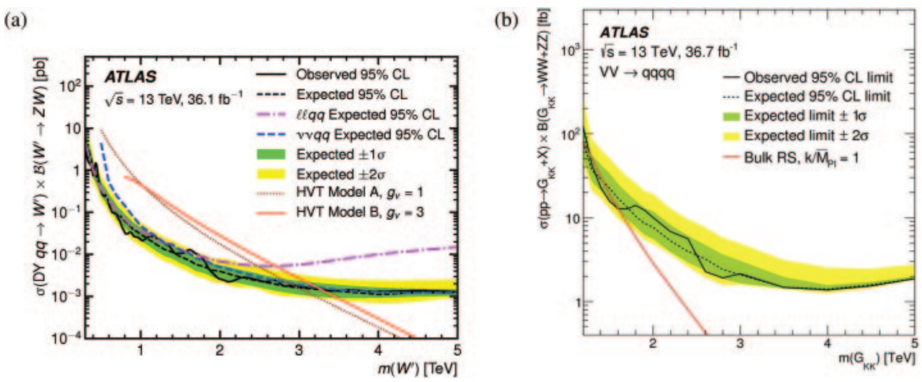

Fig. 2. – Observed (black solid curve) and expected (black dashed curve) 95% CL upper limits on: (a) $\sigma \times B(W' \to ZW)$ for the DY production of a W' boson in the HVT model as a function of its mass, combining $llqq$ and $\nu\nu qq$ searches. Theoretical predictions are overlaid in for the HVT Model A and Model B. (b) $\sigma \times B(G_{KK} \to WW + ZZ)$ for the DY production of a bulk RS graviton G_{KK} as a function of its mass, in the $qqqq$ search. Theoretical predictions are overlaid in for the bulk RS model with $k/\overline{M}_{Pl} = 1$. The green (inner) and yellow (outer) bands represent the $\pm 1\sigma$ and $\pm 2\sigma$ uncertainty in the expected limits. [5, 7].

background mostly consists of SM multijet events. Dedicated control regions have been defined to estimate the different background components. For each channel upper limits on the production cross-section of new resonances times their decay branching ratio to the diboson system as a function of the resonance mass are derived at 95% CL. As an example, see fig. 2 in which are shown the upper limits on $\sigma \times B(W' \to ZW)$ for the DY production of a W' boson in the HVT model, combining $llqq$ and $\nu\nu qq$ searches, and the upper limits on $\sigma \times B(G_{KK} \to WW + ZZ)$ for the DY production of a bulk RS graviton, in the $qqqq$ search. The observed limits are compared with theoretical predictions of HVT models and RS graviton models leading to exclusion limits on the mass for the various signal hypotheses. In $llqq$ and $\nu\nu qq$ searches, for the HVT Model A (Model B) with coupling constant $g_V = 1$ ($g_V = 3$), a spin-1 vector triplet produced via the DY process is excluded for $m(W') < 2.9$ (3.2) TeV. In the fully hadronic search, for the bulk RS model with $k/\overline{M}_{Pl} = 1$, a spin-2 Kaluza-Klein graviton is excluded in the range between 1.3 and 1.6 TeV. A detailed description of the analyses can be found in [5-7].

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