Search for heavy resonances in the llqq final state in pp collisions at $\sqrt{s} = 13$ TeV with ATLAS

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Introduction

A search for heavy resonances decaying to a pair of Z bosons is performed using proton-proton collision data produced at $\sqrt{s} = 13$ TeV and recorded by the ATLAS detector at the LHC [1]. The data correspond to an integrated luminosity of 3.2 fb^{-1}. Diboson resonant production is expected in several Standard Model (SM) extension scenarios. The ZZ decay mode considered corresponds to one Z boson decaying to a pair of charged leptons and the other decaying to a pair of quarks. Heavy resonances are modeled using a neutral CP-even spin-0 Higgs boson H with SM-like couplings, as well as a spin-2 graviton G*. The gluon-gluon fusion (ggF) process, gg→H or G*, is used to model the production of both ZZ resonances.

Event Classification

Two complementary approaches utilized for the reconstruction of the Z→qq decay:

- **Resolved channel**: Two separate jets (jj) are reconstructed. Candidate events are further categorized based on the number of b-tagged jets Events with two b-tagged jets (tagged category) and events with fewer than two b-tagged jets (untagged category).
- **Merged channel**: Heavy resonances decay to Z-bosons producing a highly boosted system in which the two fermions are emitted within a small opening angle in the laboratory frame. The hadronization of the quarks coming from the Z boson in this case produces two partially overlapping jets reconstructed as a single jet.

The Merged channel has priority over the Resolved channel in the event selection flow

Resolved Selection Highlights

- At least 2 central jets
- Leading jet $p_T \geq 60$ GeV
- Subleading jet $p_T \geq 25$ GeV
- $70 \leq M_{jj} \leq 105$ GeV
- p_T-balance: $\sqrt{p_T^2(\ell\ell) + p_T^2(jj)}/m_{\ell\ell jj} > 0.5$ (applied only to the untagged category)

Process	Merged analysis	Resolved analysis	
		untagged category	tagged category
Z+jets	185 ± 9	4130 ± 50	204 ± 16
Diboson	17.3 ± 3.5	143 ± 14	23.2 ± 3.3
Top quark	1.5 ± 0.6	113 ± 10	151 ± 6
Total background	203 ± 11	4380 ± 50	378 ± 15
Data	201	4484	373
H (750 GeV)	12.9 ± 3.2	7.3 ± 2.1	2.03 ± 0.33
G^* (750 GeV)	15 ± 4	7.9 ± 2.3	2.0 ± 0.4

Figure 1: Data and MC yields after full selection

Large-R jets and substructure

In the merged channel, jet-substructure techniques are used to identify the qq pair, reconstructed as a single large-radius jet.

Grooming: Reduces the effect of pileup and other noisy sources on the resolution with ***trimming*** algorithm

- Begin from an anti-kT jet with radius parameter R=1.0
- Subjets are constructed with the kT algorithm with $R_{subjet} = 0.2$
- Subjets with $p_T < 5\%$ of the large-R jet, are removed

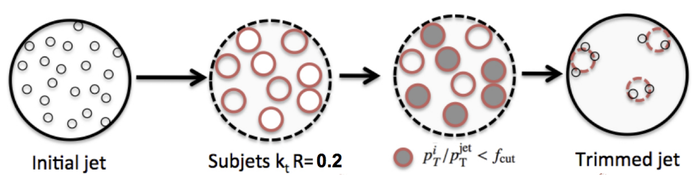


Figure 2: Schematic view of jet grooming technique using the trimming algorithm

Merged Selection Highlights

- Z boson tagging in 2-step process:
  1. A p_T-dependent requirement on the jet substructure variable $D_2^{(\beta=1)}$ (ratio of energy correlation functions of subjets) [2]
  2. Large-R jet mass m_J in a window of 93.4 ± 15 GeV (central value based on MC simulations, $\approx 68\%$ efficient for the signals studied)
- Leading jet $p_T \geq 200$ GeV
- p_T-balance: $p_T(\ell\ell)/m_{\ell\ell J} > 0.3$

Background estimation

Background from Z+jets, diboson and top events are estimated by a simultaneous maximum likelihood fit to $m_{\ell\ell J}$ or $m_{\ell\ell jj}$, in signal (SR) and control regions (CR) enriched in the main backgrounds Z+jets, Z+bb and top

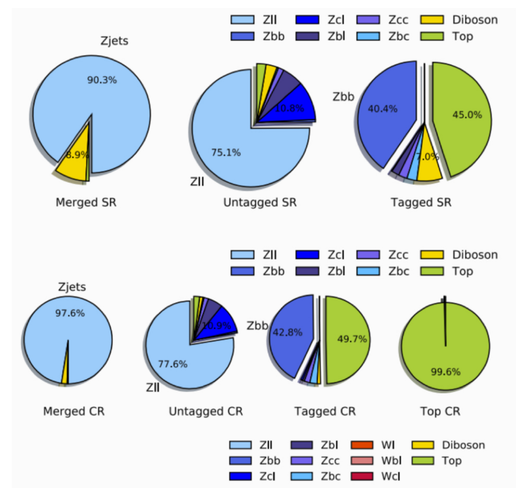


Figure 3: Breakdown of background sources contributions to SR and CR

Z+jets and top events normalization constrained from data CR (side-bands of the dijet mass and $e\mu$ respectively). Diboson normalization obtained from MC.

Systematic uncertainties and their correlations added as nuisance parameters.

Shapes for all sources are MC driven.

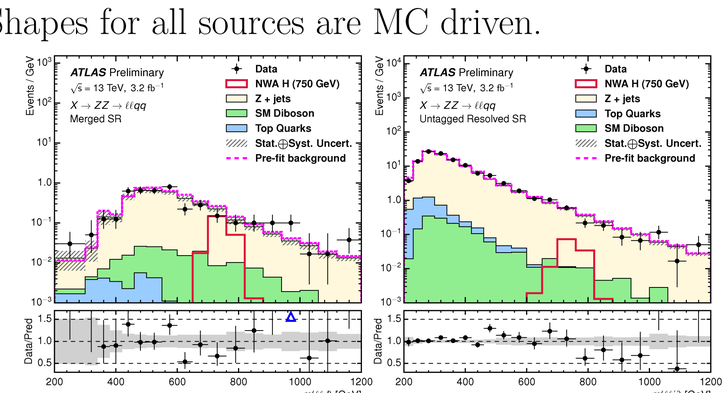
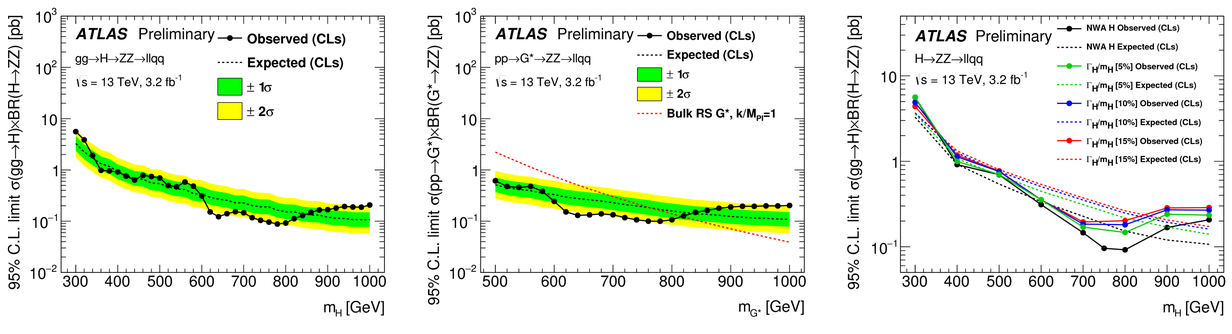


Figure 4: Post-fit $m_{\ell\ell J}$ and $m_{\ell\ell jj}$ distributions

Results

The data are found to be consistent with the background expectations and no evidence for heavy resonance production is observed. Upper limits at 95% CL on the production cross section of the heavy resonance times its branching ratio to ZZ are derived for H→ZZ (left) and G* → ZZ (middle) as functions of the resonance mass. The observed (expected) limits range from 5.6 (3.3) pb at 300 GeV to 0.21 (0.11) pb at 1000 GeV for the heavy Higgs boson and from 0.62 (0.52) pb at 500 GeV to 0.20 (0.11) pb at 1000 GeV for the graviton. Limits are derived also for gg→H→ZZ production of Higgs bosons (right) with a narrow width (black) and three different values of the width: 5% (green), 10% (blue), and 15% (red) of the Higgs boson mass.



References

[1] ATLAS Colaboration.
Search for zz resonances in the $\ell\ell$qq final state in pp collisions at $\sqrt{s} = 13$ tev with the atlas detector.
ATLAS-CONF-2016-016.

[2] I. Moult A. J. Larkoski and D. Neill.
Power counting to better jet observables.
JHEP, 12(009), 2014.

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