ICTP Poster Session - May 29th 2019

Search for heavy ZZ resonances in the $l^+l^-l^+l^-$ and $l^+l^-\nu\bar{\nu}$ final states using proton-proton collisions at $\sqrt{s}$ = 13TeV with the ATLAS detector

A search for heavy resonances decaying into a pair of Z bosons leading to $l^+l^-l^+l^-$ and $l^+l^-\nu\bar{\nu}$ final states, where ℓ stands for either an electron or a muon, is presented. This search looks for an excess in distributions of the $4l$ invariant mass (m_{4l}) for the $4l$ final state and the transverse invariant mass (m_T) for the $2l2\nu$ final state. Proton–proton collision data was used at a centre-of-mass energy of 13 TeV corresponding to an integrated luminosity of 36.1 fb^{-1} collected with the ATLAS detector during 2015 and 2016 at the Large Hadron Collider. Different mass ranges for the hypothetical resonances are considered, depending on the final state and model. The $4l$ channel is well suited for a search for a narrow resonance with mass $200 < m_H < 1200$ GeV because it has a very good mass resolution. The $2l2\nu$ search dominates at high masses due to its larger branching ratio and covers the $300 < m_H < 1400$ GeV range.

1. Analysis Overview

The signal modes considered:

- *Production mode:* ggF and VBF.
- *Spin*: spin-0 or spin-2 resonance; The upper limits for the spin-0 resonance are translated to exclusion contours in the context of Type-I and Type-II two-Higgs-doublet models (2HDM) while those for the spin-2 resonance are used to constrain the Randall–Sundrum model.

Width assumption: Narrow-Width approximation (NWA) and Large-Width assumption (LWA). For NWA, limits on the production rate of a heavy scalar decaying into ZZ bosons are set separately for ggF and VBF production modes

Background estimations:

$H \rightarrow 4l$: 97% of the background is from the ZZ production. Additional backgrounds comes from the Z + jets and $t\bar{t}$ processes.

- $H \rightarrow 2l2\nu$: 60% from ZZ production, WZ production (~30%) & Z + jets(~6%).

2. Event Selection

$H \rightarrow 4l$	
Lepton quadruplets (2 same-flavor opposite-sign (SFOS) lepton pairs(e,μ))	e,μ: P_T ≥7(5) GeV and $\eta \leq 2.47(2.7)$ $P_T \geq 20, 15, 10$ GeV; for 3 leading leptons 50 GeV $< m_{12} <$ 106 GeV 12 GeV $< m_{34} <$ 115 GeV
VBF category requires 2 leading jets $P_T > 30$ GeV; $\lvert\eta_{jj}\rvert > 3.3$ & $m_{jj} > 400$ GeV	
$H \rightarrow 2l2\nu$	
2 Leptons (SFOS e,μ) consistent with the Z_0 mass	$P_T > 30$ GeV and $P_T > 20$ GeV
Reject additional lepton	$P_T > 7$ GeV and "loose" identification
Neutrino requires $E_T^{miss} > 120$ GeV and $\Delta\phi(ll, \vec{E}_T^{miss}) > 2.7$ & fractional P_T difference < 20%, defined as: $\lvert p_T^{miss,jet} - p_T^{ll}\rvert / p_T^{ll}$	
VBF category requires 2 leading jets with $P_T > 30$ GeV, $\Delta\eta_{jj} > 4.4$ & $m_{jj} > 550$ GeV.	

3. Results

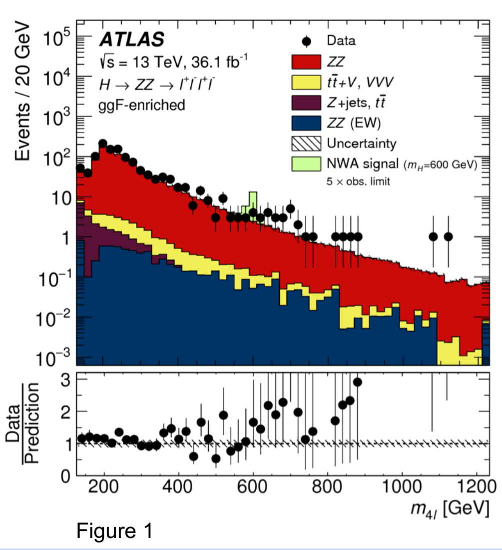

Figure 1

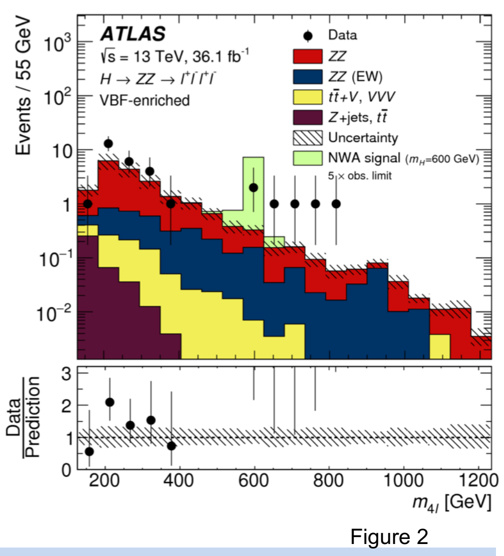

Figure 2

Fig 1 & 2: Distribution on the $4l$ invariant mass in the $4l$ search for the ggF- enriched category and the VBF category.

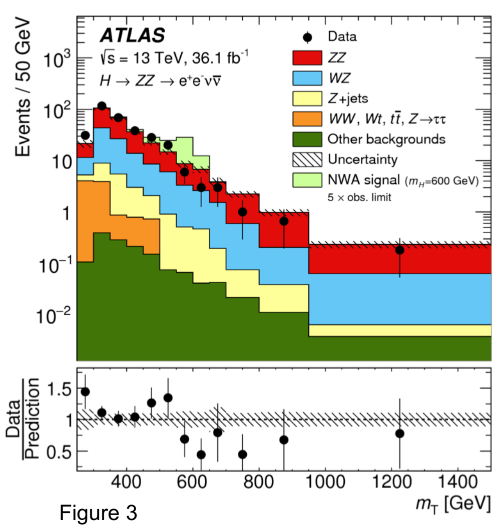

Figure 3

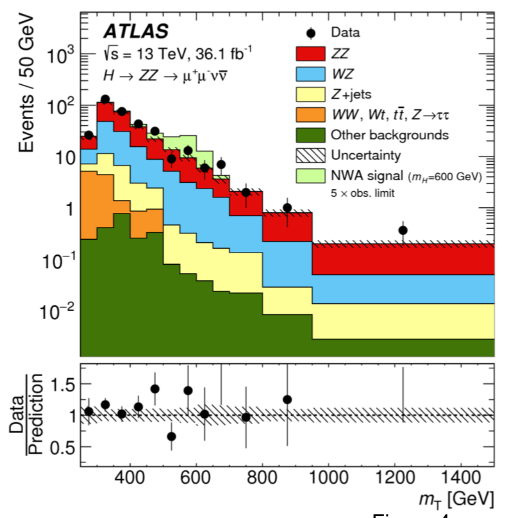

Figure 4

Fig 3 & 4: Transverse mass m_T distribution in the $l^+l^-\nu\,\nu$ search for the electron and muon channel, including the ggF-enriched and the VBF-enriched categories.

3.1 Spin-0 resonance interpretation

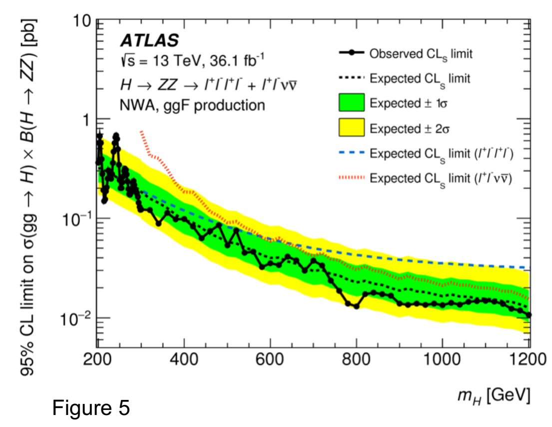

Figure 5

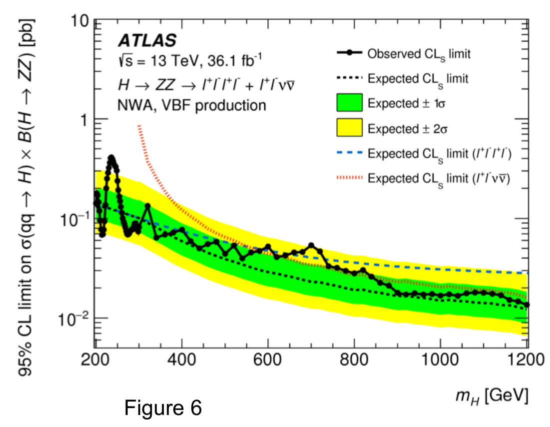

Figure 6

The upper limits at 95% CL on the cross section times branching ratio as a function of the heavy resonance mass; Fig 5 for the ggF production mode and Fig 6 for the VBF production in the case of the NWA.

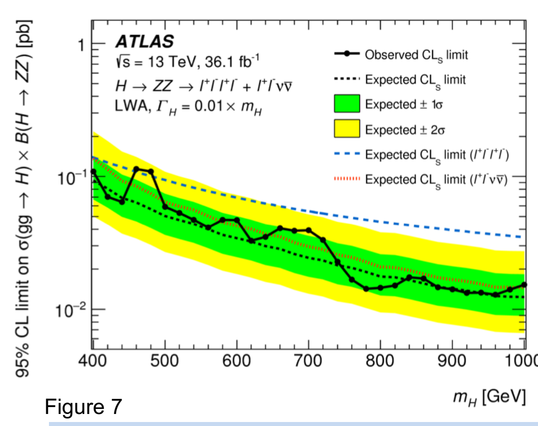

Figure 7

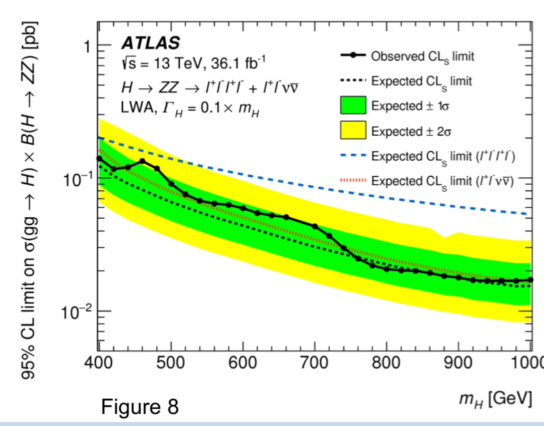

Figure 8

For the LWA, limits are set for different widths of the heavy scalar. The upper limits at 95% CL on the cross section for the ggF production mode times branching ratio as function of m_H for an additional heavy scalar assuming a width of (Fig 7) 1% and (Figure 8 10% of m_H.

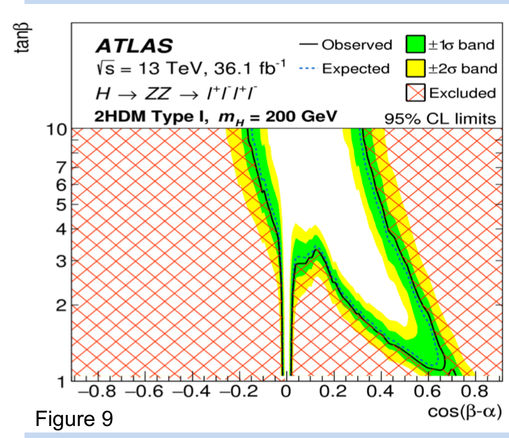

Figure 9

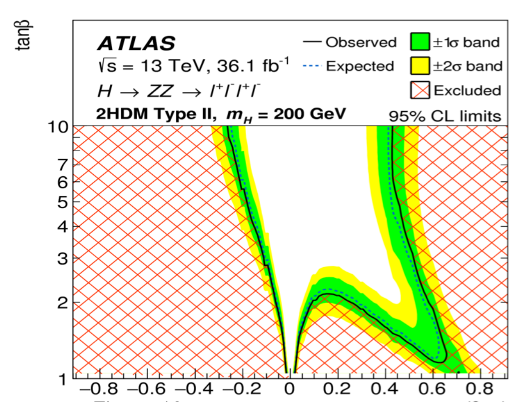

Figure 10

The exclusion contour in2HDM. Fig 7 Type-I and Fig 8 Type-II models for m_H = 200 GeV shown as a function of the parameters $\cos(\beta-\alpha)$and $\tan\beta$ the. At this low mass, only $4l$ final state contributes to this result. The green and yellow bands represent the $\pm 1\sigma$ and $\pm 2\sigma$ uncertainties in the expected limits. The hatched area shows the observed exclusion.

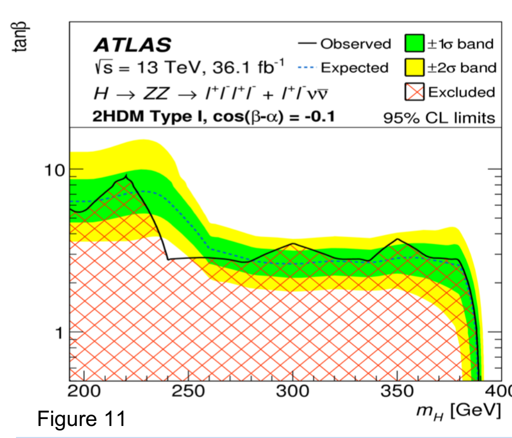

Figure 11

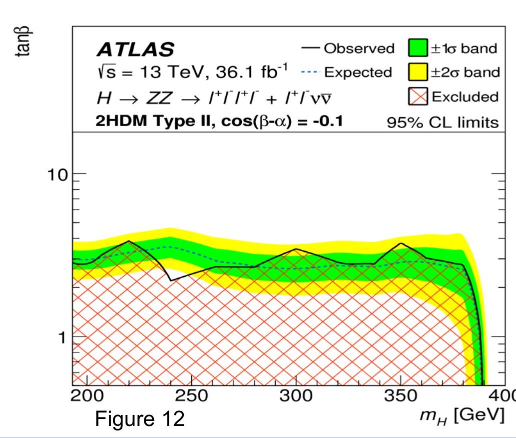

Figure 12

The exclusion contour in the 2HDM Fig 10 Type-I and fig 12, Type-II models for $\cos(\beta-\alpha)$ = -0.1, shown as a function of the heavy scalar mass m_H and the parameter $\tan\beta$.

3.2 Spin-2 resonance interpretation

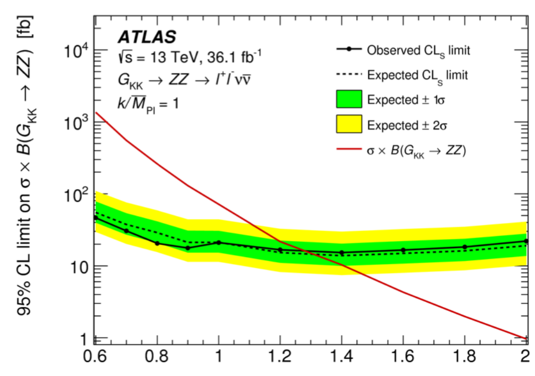

Figure 13

Fig 13 shows the upper limits at 95% CL on cross section times branching ratio for a KK graviton produced. The predicted production cross section times branching ratio as a function of the G_{KK} mass; m(G_{KK}) is shown by the red solid line.

Summary

- The limits on the production rate of a large-width scalar are obtained for widths of 1% and 10% of the mass of the resonance, with the interference between the heavy scalar and the SM Higgs boson as well as the heavy scalar and the $gg \rightarrow ZZ$ continuum taken into account.
- Combining the two final states, 95% CL upper limits range from 0.68 pb at m_H= 242 GeV to 11 fb at m_H= 1200 GeV for the gluon–gluon fusion production mode and from 0.41 pb at m_H = 236 GeV to 13 fb at m_H = 1200 GeV for the vector-boson fusion production mode.

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ATLAS EXPERIMENT

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