



# Search for a heavy resonance decaying into a Z boson and a Higgs boson in final states with leptons and b-jets with the ATLAS detector

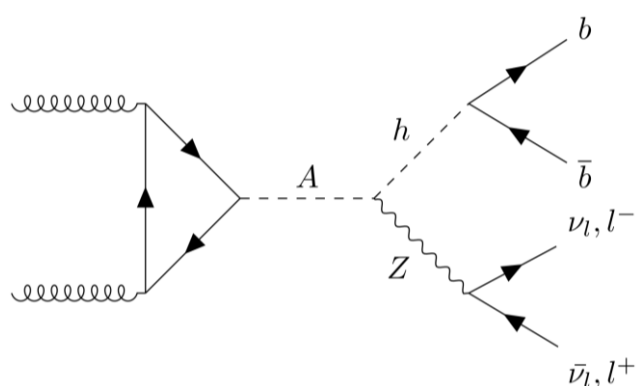
LHCC meeting poster session, CERN

18 November 2021

## Signals

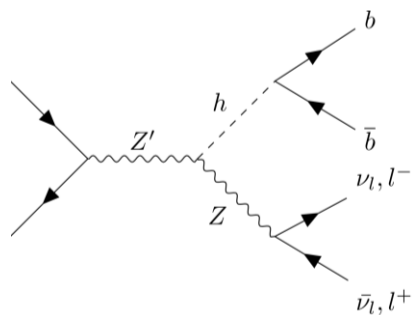
### 2HDM

- Two complex scalar Higgs doublets.
- Five Higgs bosons: two neutral CP-even bosons (h and H), two charged scalar bosons (H<sup>+</sup> and H<sup>-</sup>) and a neutral CP-odd boson (A)
- Models specified by the Yukawa couplings of the Higgs doublets: type I, type II, lepton-specific and flipped
- Search for gluon-fusion production of a CP-odd A



### HVT

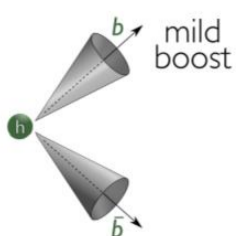
- Simplified model with an additional SU(2)<sub>L</sub> field
- Two new heavy vector bosons (W', Z') couple to SM particles
- Models specified by coupling strengths of the new field to SM fermions and gauge bosons: Type A and Type B
- Search for Drell-Yan production of Z'



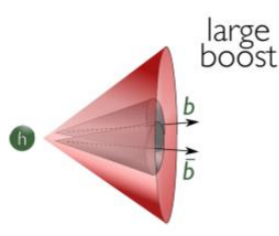
## Analysis Strategy

- Z boson candidates are reconstructed from two oppositely-charged electrons or muons in the 2-lepton channel, or indicated by the missing transverse momentum in the 0-lepton channel
- Higgs boson candidates are reconstructed from either two small-radius jets (anti-kT R=0.4) or one large-radius jet (anti-kT R=1.0)
- Requiring at least one b-tagged small-radius jet or track jet associated with the large-radius jet

### Resolved



### Merged



## Introduction

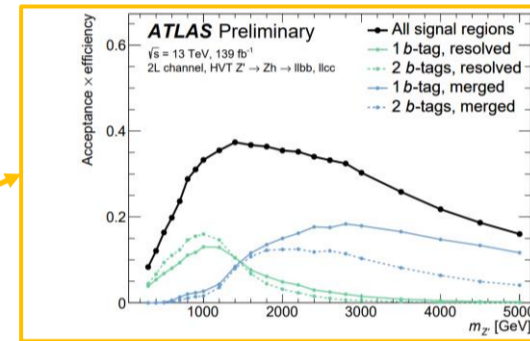
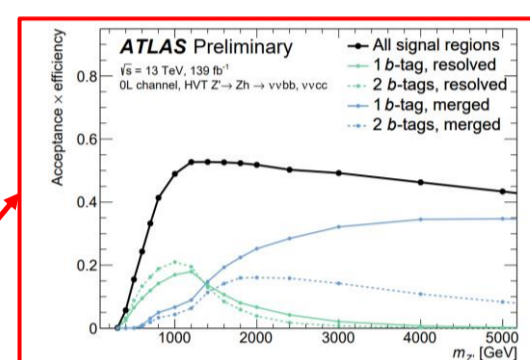
- Search for a heavy resonance decaying into a Z boson and a SM Higgs boson in the  $\ell^+\ell^-b\bar{b}$  or  $\nu\bar{\nu}b\bar{b}$  final state
- Use full Run 2 ATLAS data corresponding to an integrated luminosity of  $139 \text{ fb}^{-1}$
- Examine reconstructed invariant mass or transverse mass distributions of the Zh system
- Set 95% confidence level (CL) upper limits on the signal production cross section for the mass range 300-5000 GeV
- Result interpreted in the two Higgs doublet models (2HDM) or Heavy Vector Triplet models (HVT)

## Event Selections

- Use the same cut-based event selections for both signal models
- Multijet background is found to be negligible after the event selection

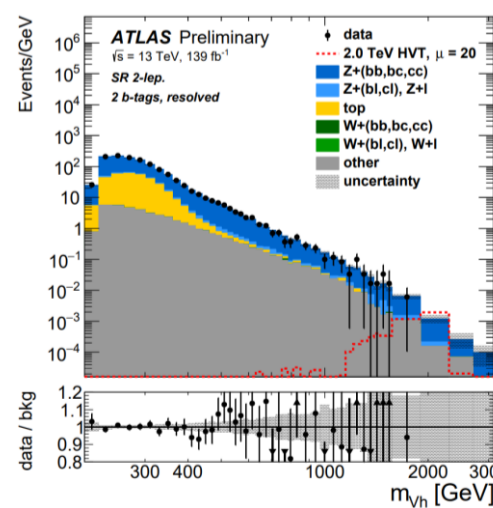
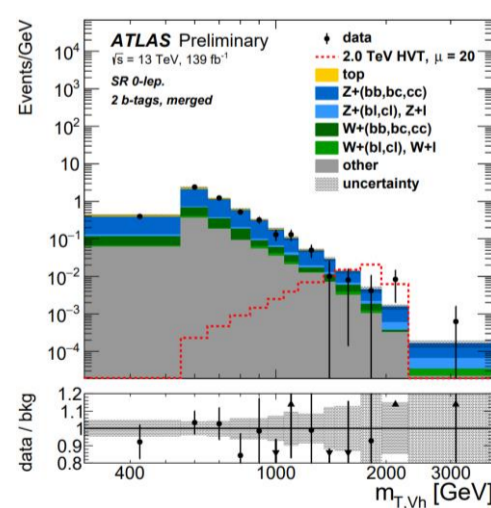
Variable	Resolved	Merged
Common selection		
Number of jets	$\geq 2$ central Small-R jets (0, 2-lep.)	$\geq 1$ large-R jet
Leading jet $p_T$ [GeV]	$> 45$	$> 250$
$m_{jj}$ [GeV]	110–140 (0-lep.), 100–145 (2-lep.)	75–145
0-lepton selection		
$E_T^{\text{miss}}$ [GeV]	$> 150$	$> 200$
$H_T$ [GeV]	$> 150$ ( $120^\circ$ )	–
$\Delta\phi_{bb}$	$< 7\pi/9$	–
$p_T^{\text{miss}}$ [GeV]	–	$> 60$
$\Delta\phi(\vec{E}_T^{\text{miss}}, p_T^{\text{miss}})$	–	$< \pi/2$
$\Delta\phi(\vec{E}_T^{\text{miss}}, h)$	–	$> 2\pi/3$
$\min[\Delta\phi(\vec{E}_T^{\text{miss}}, \text{Small-R jet})]$	–	$> \pi/9$ (2 or 3 jets), $> \pi/6$ ( $\geq 4$ jets)
$N_{\text{rad}}$	–	0
$E_T^{\text{miss}}$ significance	$> 9$	if $m_{Vh} < 400 \text{ GeV}$ , $> 6.6 + 0.01 \cdot m_{Vh}/(1 \text{ GeV})$ if $400 \text{ GeV} < m_{Vh} < 700 \text{ GeV}$ , $> 13.6$ if $m_{Vh} > 700 \text{ GeV}$ .
2-lepton selection		
Leading lepton $p_T$ [GeV]	$> 27$	$> 27$
Sub-leading lepton $p_T$ [GeV]	$> 20$	$> 25$
$E_T^{\text{miss}}/\sqrt{H_T}$ [ $\sqrt{\text{GeV}}$ ]	–	$< 1.15 + 8 \times 10^{-3} \cdot m_{Vh}/(1 \text{ GeV})$
$p_{T,\ell\ell}$ [GeV]	–	$> 20 + 9 \cdot \sqrt{m_{Vh}}/(1 \text{ GeV}) - 320$ for $m_{Vh} > 320 \text{ GeV}$
$m_{\ell\ell}$ [GeV]	–	$[\max[40, 87 - 0.030 \cdot m_{Vh}/(1 \text{ GeV}), 97 + 0.013 \cdot m_{Vh}/(1 \text{ GeV})]$

- Selected 0-lepton events are mostly sensitive to high mass signals while 2-lepton events are sensitive to low mass signals



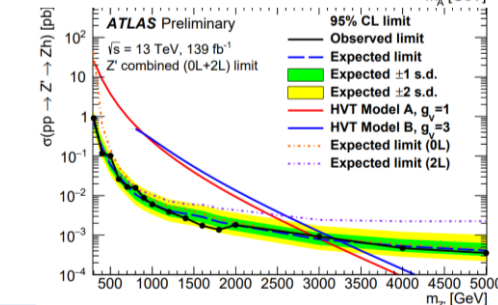
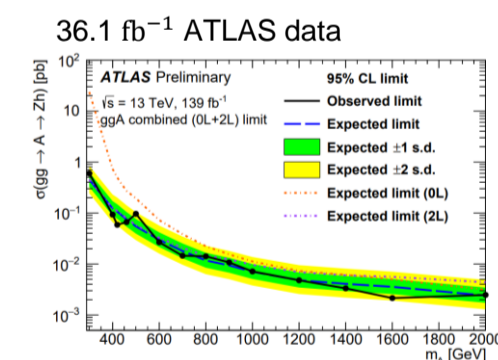
## Background Modelling

- Shapes of all backgrounds estimated by simulation, normalisations of main backgrounds (top, Z+jets) determined from data
  - A control region (containing an  $e\mu$  pair) enriched in top backgrounds to determine their normalisation
  - Data-driven corrections to the Z+jets background are derived using events found in the  $m_{bb}$  regions on either side of the Higgs boson candidate peak
- Experimental and theory uncertainties are nuisance parameters in the fit



## Results

- No significant excess is observed
- 95% CL cross-section upper limits between 1 pb and 0.4 fb for Z' -> Zh or A -> Zh production
- Significant improvement compared with the previous analysis using  $36.1 \text{ fb}^{-1}$  ATLAS data



## Summary

- Search for a heavy resonance performed using ATLAS full Run 2 data corresponding to an integrated luminosity of  $139 \text{ fb}^{-1}$ .
- No significant excess observed and 95% confidence level (CL) upper limits set between 1 pb and 0.4 fb for the mass range 300-5000 GeV
- Complementary search of a heavy resonance decaying into a W boson and a Higgs boson also published

[ATLAS-CONF-2021-026](https://arxiv.org/abs/ATLAS-CONF-2021-026)

