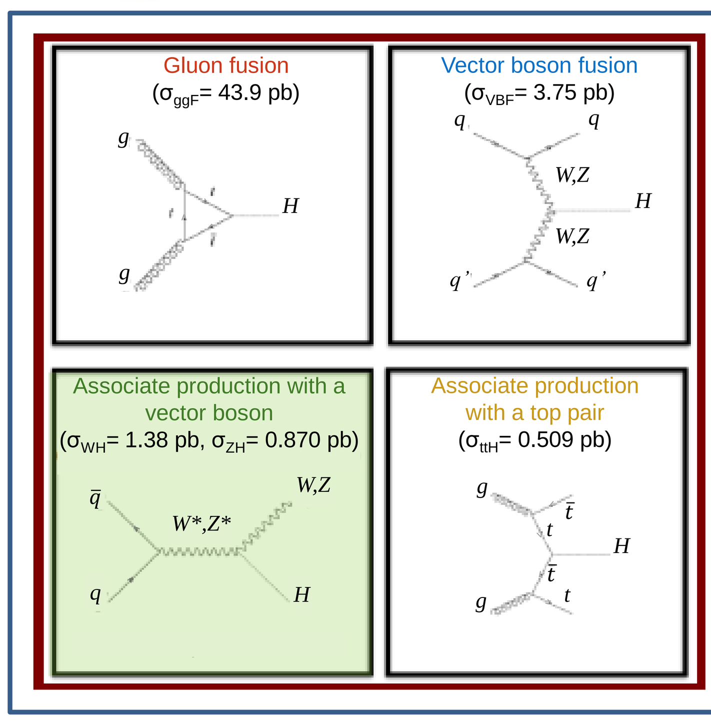
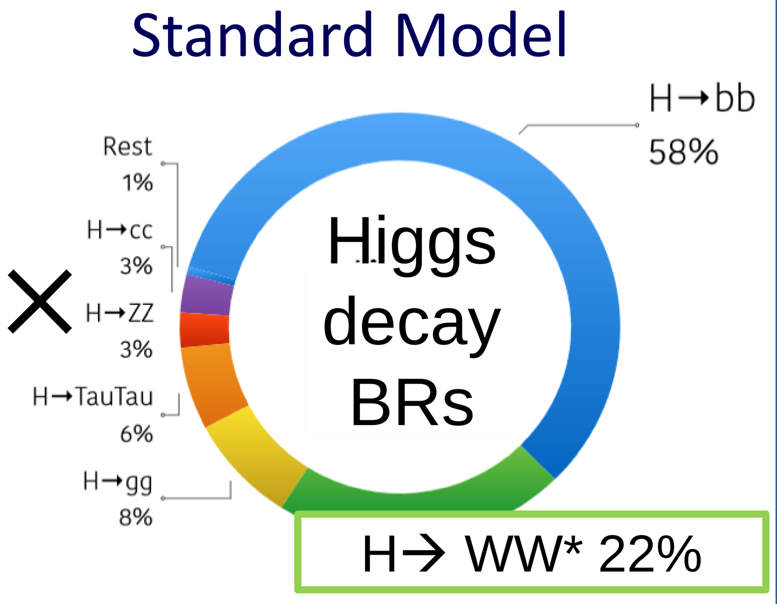
Measurement of the (W)H→ (W)WW* process in the 3 leptons (Z-dominated) sub-channel with ATLAS detector at √s =13 TeV

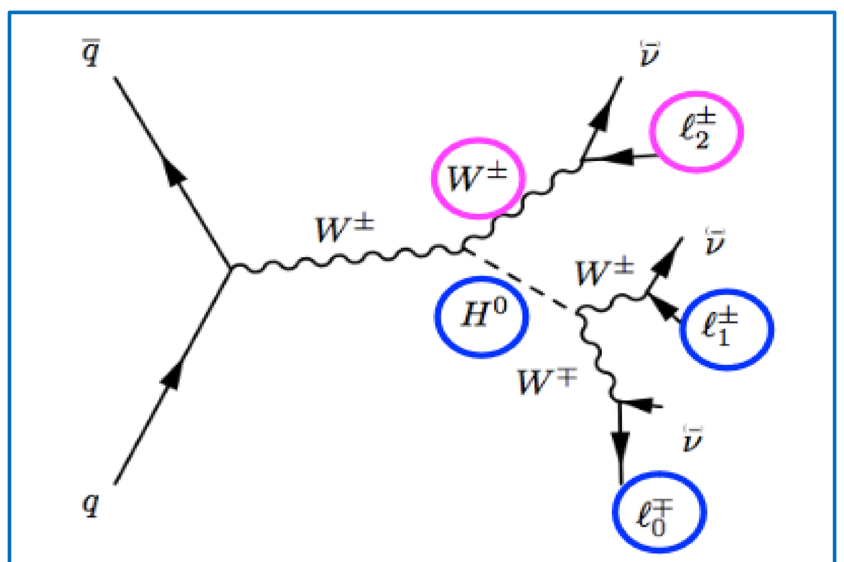
Great interest is addressed to the (W)H → (W)WW* process which allows studying the properties of the Higgs boson when it is only coupled with the W boson. Independent analyses of the 139 fb^{-1} of ATLAS data have been carried out, according to the number of charged leptons in the final state.





With 3 charged leptons (3ℓ) in final state, two independent signal regions (**Z-dom** and **Z-dep** SR) were studied. They have different sensitivity w.r.t. the background processes that include Z bosons.

1. Pre-selection of final state objects in common to different SR
2. SR definition optimisation + **MVA to separate signal and backgrounds for each sub-channel**
3. **Study of data / MC modeling**
4. Uncertainties estimation
5. Likelihood fit on MVA discriminators to evaluate μ



l_0: lepton with diff. charge (H decay)
l_1: closest to l_0 (from H decay)
l_2: from the associated W decay

MVA details

Quantities	Cuts and vetos	Actions of Cuts and vetos
Preselection	3 isolated leptons (> 15 GeV) total lepton charge ±1	SR definition **Z-dom**
Number of SFOS	2 or 1	
E_T^{miss} [GeV]	> 30	Suppression of Z+jets and ZZ* processes
Number of b-jets	0	Suppression of processes including top quark
$\lvert m_{\ell\ell}^{SFOS} - m_Z\rvert$ [GeV]	> 25 (SFOS)	Suppression of WZ/Wγ, ZZ* , Z+jets and Zγ* processes
$m_{\ell\ell}$ [GeV]	> 12 (min. SFOS)	Low mass resonance events from heavy-flavour quarkonia

An Artificial Neural Network (ANN$_{Zdom}$) classifier was implemented to improve the signal sensitivity in **Z-dom** SR w.r.t the above background processes, more suppressed by the **Z-dep** definition (i.e. **without** Same-Flavour-Opposite-Sign leptons). ANN$_{Zdom}$ has 15 input variables (from grid search optimisation):

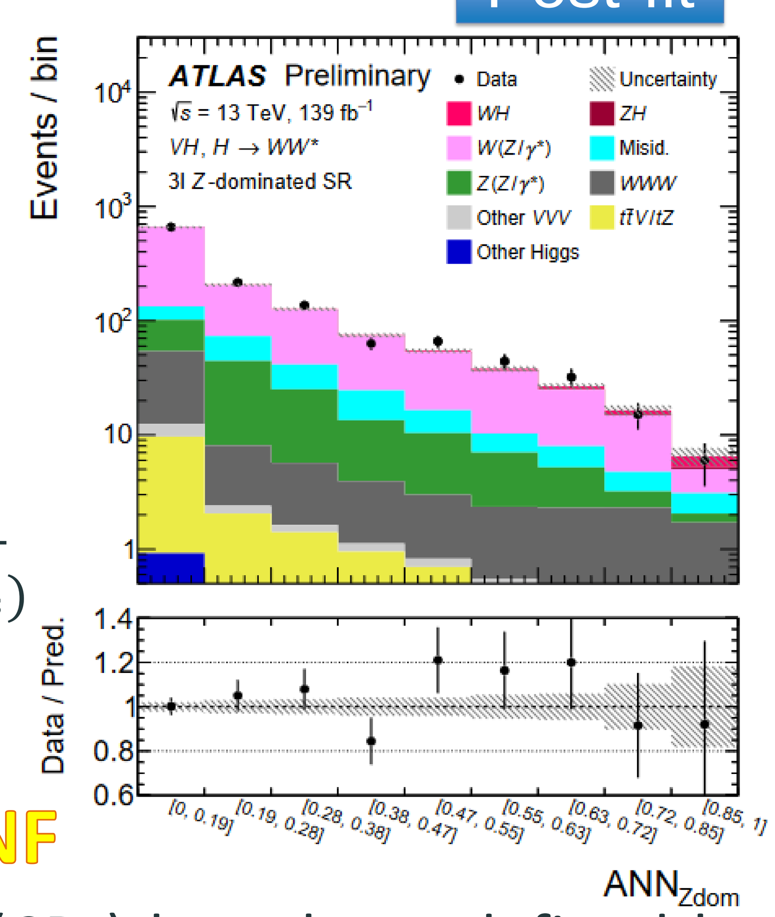
$$p_T^{l0}, \left|\sum_i \boldsymbol{p}_T^{li}\right|, \Delta\eta_{l0l1}, \Delta\eta_{l1l2}, \Delta\phi_{l0l2},$$

$$\Delta R_{l0l1}, \Delta R_{l0l2}, m_{l0l1}, m_{l0l2}, m_{l1l2},$$

$$E_T^{miss}, \Delta\phi_{li\,E_T^{miss}}\ (i = 1,2,3),$$

$$m_T^W = \sqrt{2p_T^{lW} \cdot E_T^{miss}\left(1 - cos\Delta\phi_{lW\,E_T^{miss}}\right)}$$

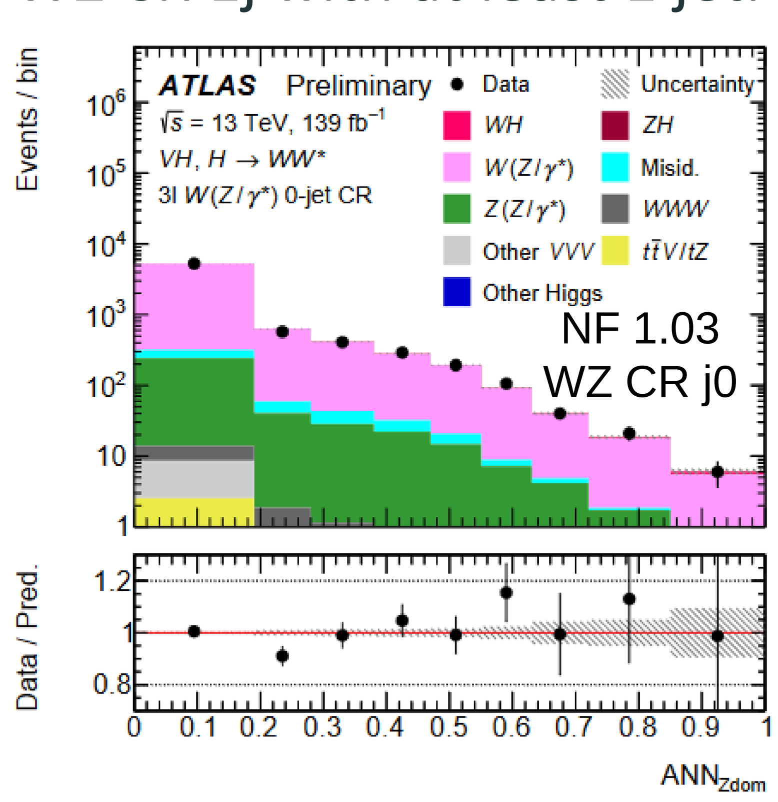
Post-fit

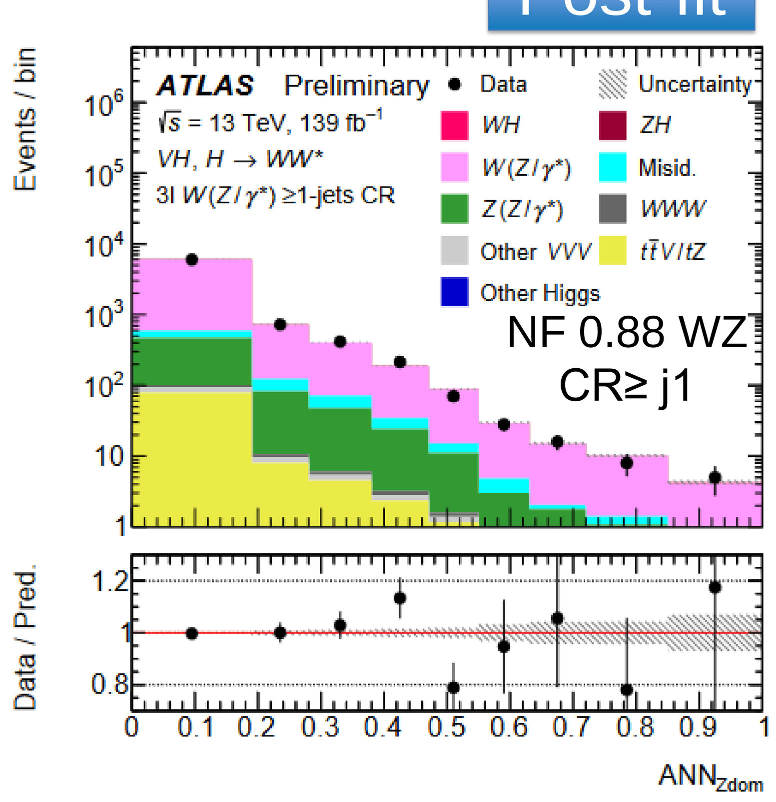


Data / MC modeling and NF

Two different Control Regions (CRs) have been defined by inverting the ($|m^{SFOS}_{\ell\ell} - m_Z| > 25$ GeV) cut and split according to the number of jets: WZ CR 0j without jets and WZ CR 1j with at least 1 jet.

Post-fit





The normalisation of the dominant WZ background is constrained by the data of these control regions.

Likelihood fit on MVA discriminator

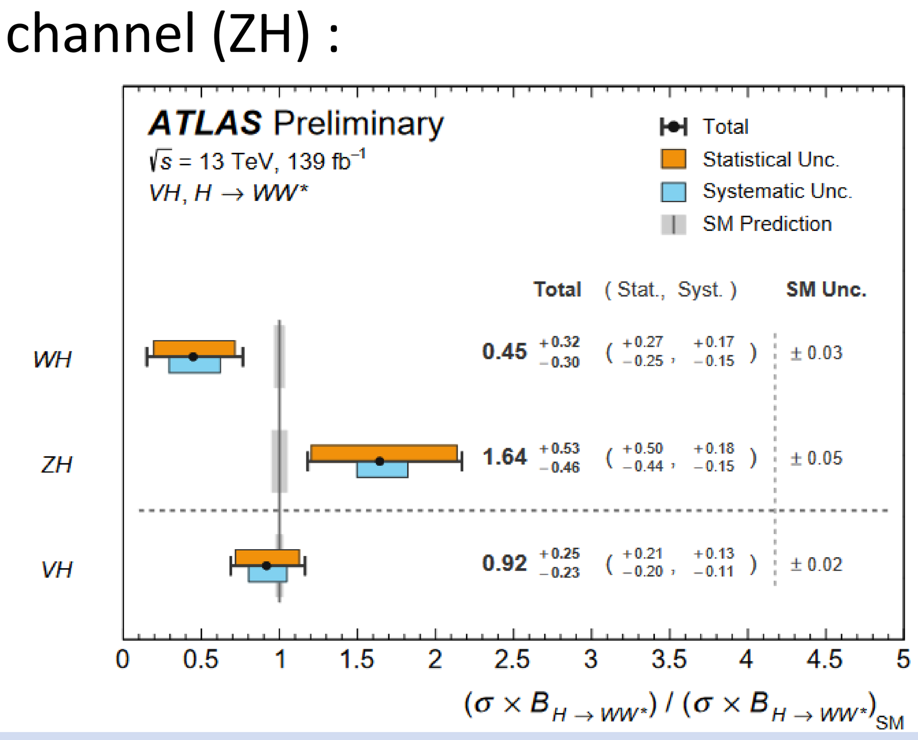
The ANN output was finally used to measure the signal strength parameter μ and the production cross section times the decay branching ratio.

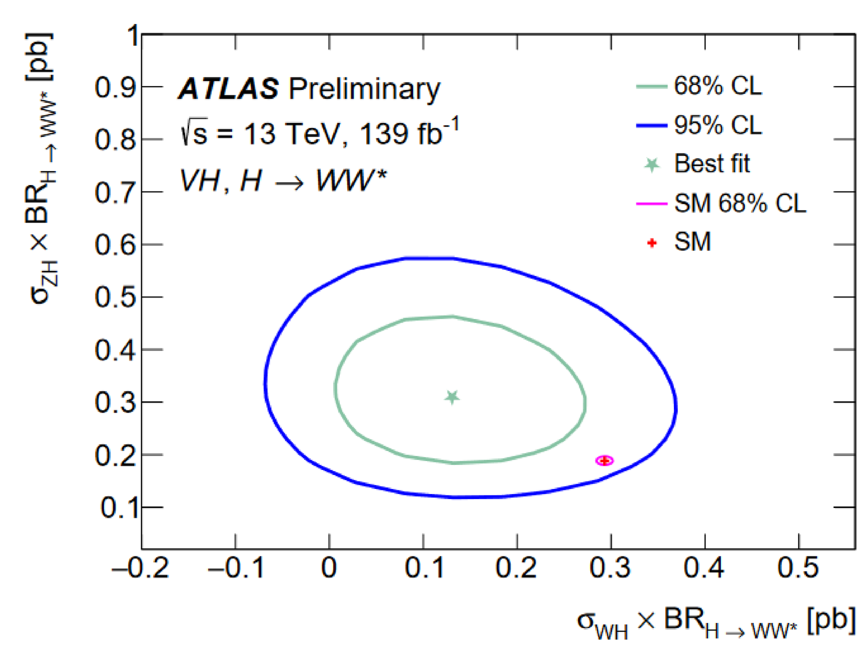
$$\mu = \frac{Measured\ signal\ yields}{SM\ signal\ yields} \Rightarrow \sigma_{VH} \times BR_{H\to WW^*}[pb]$$

Channel	POI / Z_0	Expected	Observed
3ℓ	μ_{WH}	$1.00^{+0.44}_{-0.40}$	$0.64^{+0.42}_{-0.37}$
	Z_0	2.8	1.8

For the single 3ℓ Z-dom signal region, exp significance Z_0 is 1.4 (obs is 1.7).

Combined results of 3ℓ channel (WH), 2ℓ channel (WH and ZH) and 4ℓ channel (ZH) :





The measurements are compatible with the SM expectations.

Average contributions to the total uncertainties on the combined 1-POI ($\sigma_{VH} \times BR_{H\to WW^*}$) and 2-POI($\sigma_{WH} \times BR_{H\to WW^*}$ and $\sigma_{ZH} \times BR_{H\to WW^*}$) fits.

Source	$\frac{\Delta(\sigma_{VH}\times\mathcal{B}_{H\to WW^*})}{\sigma_{VH}\times\mathcal{B}_{H\to WW^*}}$ [%]	$\frac{\Delta(\sigma_{WH}\times\mathcal{B}_{H\to WW^*})}{\sigma_{WH}\times\mathcal{B}_{H\to WW^*}}$ [%]	$\frac{\Delta(\sigma_{ZH}\times\mathcal{B}_{H\to WW^*})}{\sigma_{ZH}\times\mathcal{B}_{H\to WW^*}}$ [%]
Statistical uncertainties in data	22.3	57.9	28.4
Systematic uncertainties	13.3	36.6	9.9
Statistical uncertainties in simulation	6.4	14.4	5.9
Experimental systematic uncertainties	5.2	9.8	6.0
Theoretical uncertainties	6.0	18.6	4.7
RNN shape uncertainty for $W(Z/\gamma^*)$	8.8	27.3	0.3
Floating normalisations	0.1	0.2	0.1
Total	26.0	71.0	30.1

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https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-067

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