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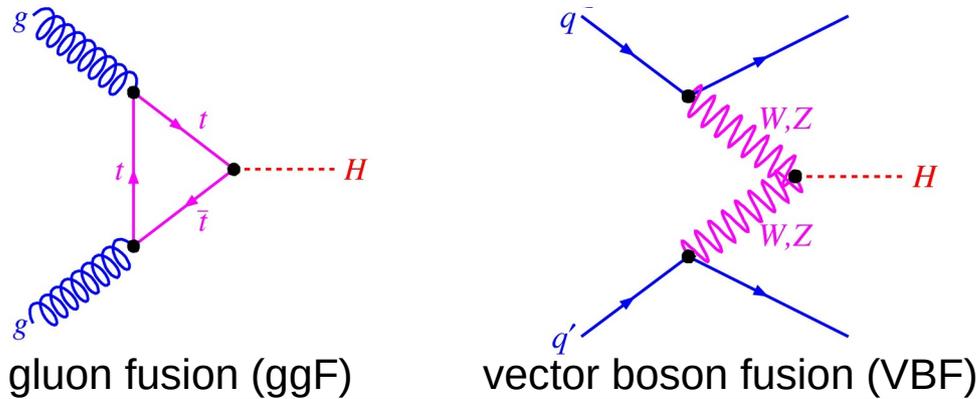
Observation of the VBF production in the $H \rightarrow WW^* \rightarrow e\nu\mu\nu$ decay channel with the ATLAS detector

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Standard Model (SM) Higgs Boson (H)

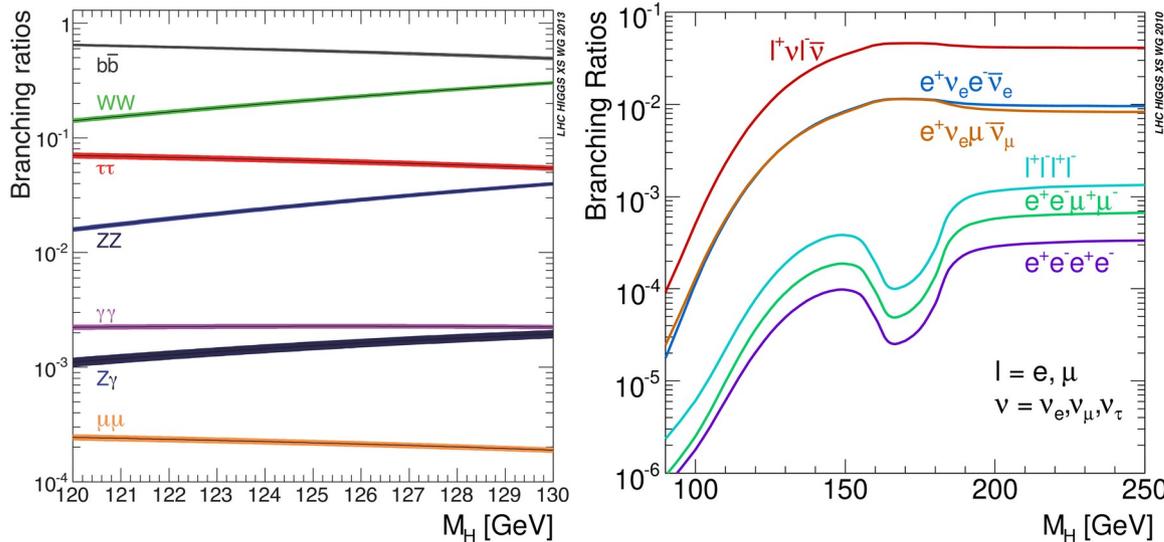
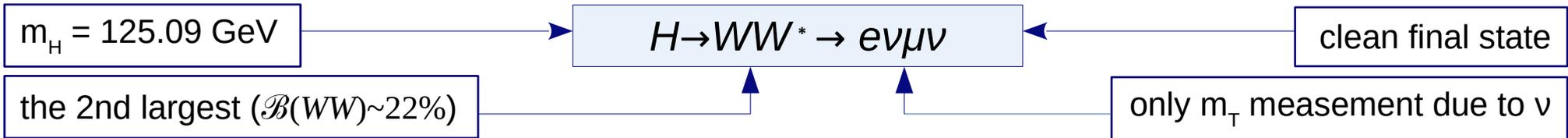
The main Higgs boson production modes ([link](#))



The VBF process:

- ✓ two highly energetic forward jets
- ✓ pure electroweak
- ✓ no color flow between colliding protons within hard interaction

The Higgs boson decay channel ([link](#))



SM Higgs boson decay branching ratios \mathcal{B}

VBF is the only process considered as signal in the analysis.

Background processes:

- ggF and VH
- top quark production (tW and $t\bar{t}$)
- dibosons (non-resonant WW)
- other VV ($WZ, ZZ, W\gamma, W\gamma^*$)
- Drell-Yan ($Z+jets$ or $Z/\gamma^* \rightarrow \tau\tau$)
- Mis-Id ($W+jets$) and multi-jets (QCD)

Analysis

New: ATL-CONF-2020-045 Old: PL B789 (2019) 508

What's new?

- full run 2 dataset: $36 \text{ fb}^{-1} \rightarrow 139 \text{ fb}^{-1}$ at 13 TeV
- enhanced signal tagging via Deep Neural Network (DNN), previously Boosted Decision Trees (BDT)

discriminant variables (used in DNN only)

$\Delta\phi_{\ell\ell}, m_{\ell\ell}, m_T, \Delta y_{jj}, m_{jj}, p_T^{\text{tot}}, \sum_{\ell} C_{\ell}$
 $m_{\ell 1j1}, m_{\ell 1j2}, m_{\ell 2j1}, m_{\ell 2j2}, p_T^{\text{jet1}}, p_T^{\text{jet2}},$
 p_T^{jet3} and E_T^{miss} significance

- improved object reconstruction (leptons, jets, E_T^{miss})

What are the results?

The observed (expected) signal significance:

$$\mathcal{Z}^{\text{old}} = 1.9 (2.7)\sigma \quad \mathcal{Z}^{\text{new}} = 7.0 (6.2)\sigma$$

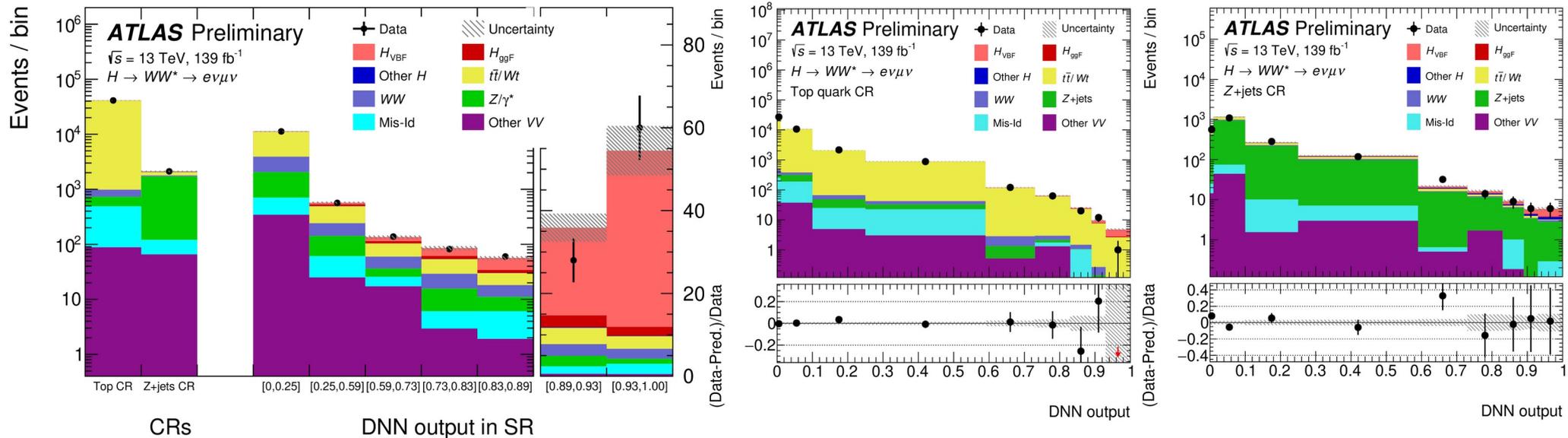
The cross-sections times branching fractions:

$$\sigma_{VBF} \cdot \mathcal{B}_{H \rightarrow WW^*}^{\text{observed}} = 0.85_{-0.17}^{+0.20} \text{ pb}$$

in agreement with SM predicted value:

$$\sigma_{VBF} \cdot \mathcal{B}_{H \rightarrow WW^*}^{\text{predicted}} = 0.81_{-0.02}^{+0.02} \text{ pb}$$

Post-fit distributions of DNN output in SR and CRs



CRs included as single bins in the fit.

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Introduction

Observed vector-boson-fusion (VBF) Higgs production in the $H \rightarrow WW^* \rightarrow e\nu\mu\nu$ channel at ATLAS.

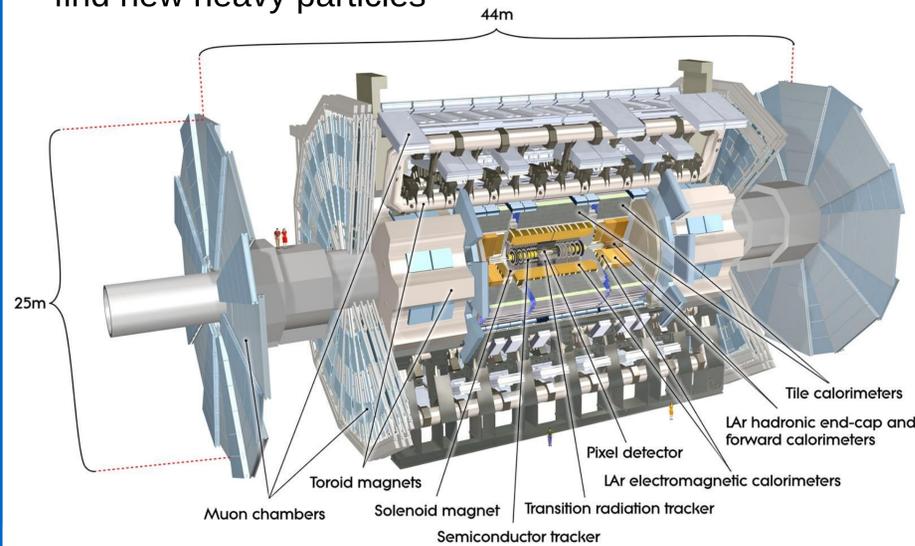
Several improvements (w.r.t. [1]):

- full run 2 dataset: 139 fb^{-1} at 13 TeV
- enhanced signal tagging via Deep Neural Network (DNN), previously BDT
- improved object reconstruction (leptons, jets, E_T^{miss})

ATLAS detector

ATLAS is a multipurpose detector:

- test Standard Model (SM) in the new energy range
- study SM Higgs boson properties
- find new heavy particles



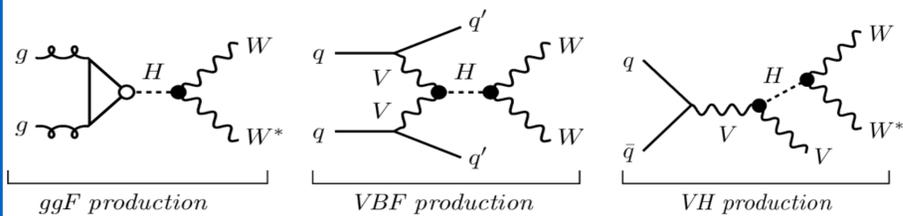
Signal and background processes

The Higgs boson production modes:

- gluon fusion (ggF)
- VBF (signal)
- associated WH/ZH (VH)

Other background processes:

- top quark production
- dibosons (WW)
- other VV
- Drell-Yan ($Z/\gamma^* \rightarrow \tau\tau$)
- Mis-Id and multi-jets



Event selection and multivariate analysis

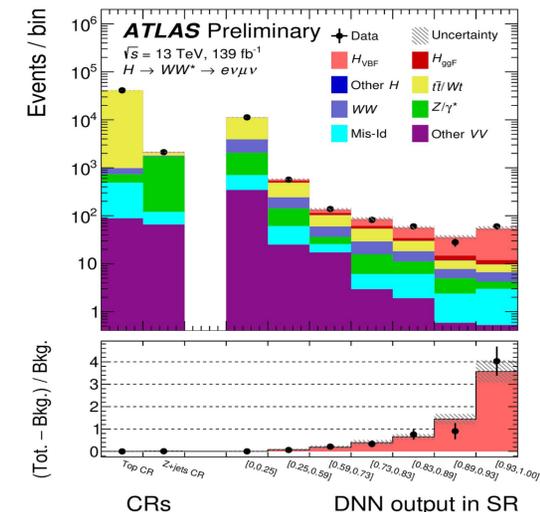
	SR	Z+jets CR	Top quark CR
Pre-selection	Two isolated, different-flavour leptons ($\ell=e,\mu$) with opposite charge $p_{T}^{\text{lead}} > 22 \text{ GeV}$, $p_{T}^{\text{sublead}} > 15 \text{ GeV}$ $M_{\ell\ell} > 10 \text{ GeV}$, $N_{\text{jet}(p_{T>30 \text{ GeV}}; \eta <4.5)} \geq 2$		
	$N_{b\text{-jet}(p_{T>20 \text{ GeV}})} = 0$	$N_{b\text{-jet}(p_{T>20 \text{ GeV}})} = 0$	$N_{b\text{-jet}(p_{T>20 \text{ GeV}})} = 1$
Selection	$m_{\tau\tau} < m_{Z-} - 25 \text{ GeV}$ $m_{jj} > 120 \text{ GeV}$	$ m_{\tau\tau} - m_{Z-} < 25 \text{ GeV}$ - $m_{\ell\ell} > 70 \text{ GeV}$	$m_{\tau\tau} < m_{Z-} - 25 \text{ GeV}$ - -
	lepton outside && additional jet with $p_{T>30 \text{ GeV}}$ in veto		the interval between the two tagging jets in η
DNN is applied in the SR that uses 15 discriminant variables: $\Delta\phi_{\ell\ell}$, $m_{\ell\ell}$, $m_{\tau\tau}$, Δy_{jj} , m_{jj} , p_{T}^{tot} , $\sum C_{\ell}$, $m_{\ell 1j1}$, $m_{\ell 1j2}$, $m_{\ell 2j1}$, $m_{\ell 2j2}$, $p_{T}^{\text{jet}1}$, $p_{T}^{\text{jet}2}$, $p_{T}^{\text{jet}3}$ and E_T^{miss} significance			

The VBF process:

- two highly energetic forward jets
- pure electroweak
- no color flow between colliding protons within hard interaction

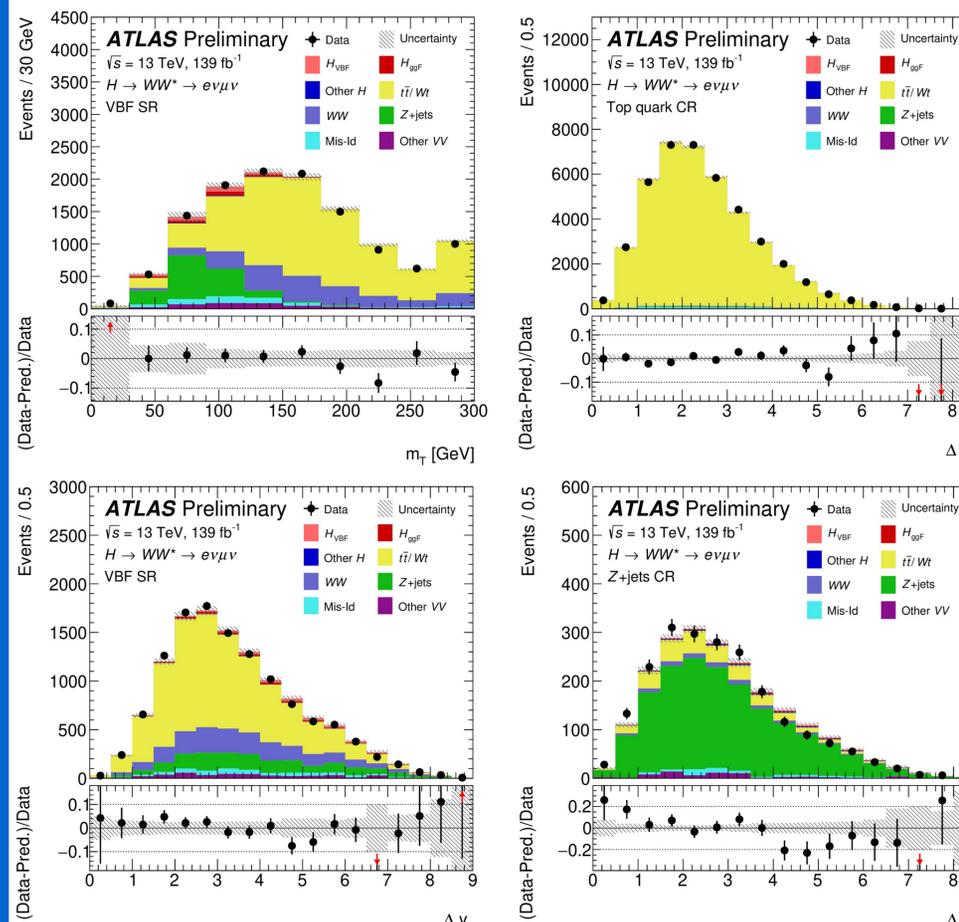
Control Regions (CRs):

- normalise the corresponding backgrounds in the Signal Region (SR)



DNN output in VBF SR and CRs.

Pos-fit distributions in SR and CRs



m_T (top) and Δy_{jj} (bottom) in the VBF SR.

Δy_{jj} in the top quark (top) and Z+jets (bottom) CRs.

Results

Process	Total	Highest DNN bin
H_{VBF}	209±37	42.5±6.5
H_{ggF}	169±62	2.2±1.5
Other Higgs	28±2	0.1±0.3
$t\bar{t}/Wt$	7520±830	3.0±1.7
Z/γ^*	1460±370	1.2±1.1
WW	2000±350	2.4±1.6
Mis-Id	416±58	2.5±1.6
Other VV	392±64	0.5±0.7
Total	12200±120	54.5±6.0
Observed	12189	60

MC and data yields in the VBF SR and the highest DNN output bin.

The **signal strength parameter** [2]:

$$\mu_{VBF} = 1.04^{+0.24}_{-0.20}$$

$$\mu_{VBF} = 1.04^{+0.13}_{-0.12}(\text{stat})^{+0.09}_{-0.08}(\text{exp.syst})^{+0.17}_{-0.12}(\text{sig.theo})^{+0.08}_{-0.07}(\text{bkg.theo})$$

The observed (expected) **significance** of 7.0 (6.2) σ .

Breakdown of impacts on the signal strength μ_{VBF} .

Source	$\Delta\mu/\mu$ [%]
Total systematics	17.8
Data Statistics	12.5
Experimental	8.8
Missing ET	4.7
MC statistics	3.1
Jet energy scale	2.2
...	...
Signal theory	14.4
Bkg. theory	7.7
ggF	5.2
Top-quark	3.3
WW	2.5
Z+jets	1.9
TOTAL	22

References

[1] PL B789 (2019) 508

[2] ATL-CONF-2020-045