Measurement of the Higgs boson properties in $WW^{(*)}$ di-lepton decay mode at ATLAS

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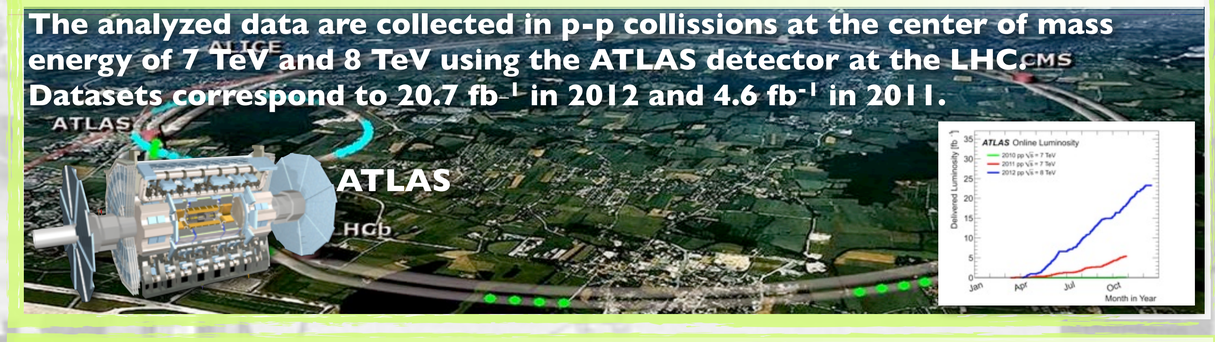
Introduction

- The evidence of a Higgs boson production in the $H \to WW^{(*)} \to \ell\nu\ell\nu,\ (\ell = e, \mu)$ decay mode is presented. Analysis is focused on the Standard Model Higgs boson with the mass of 125 GeV produced through the gluon-gluon (ggF) and vector-boson (VBF) fusion.
- Combined result with $H \to WW^{(*)} \to \ell\nu\ell\nu$, where Higgs boson is produced in association with a W or Z boson (where W and Z decay leptonically), is shown.
- The exclusion limits are set on the presence of a high-mass Higgs boson with the Standard Model production cross-section and couplings.

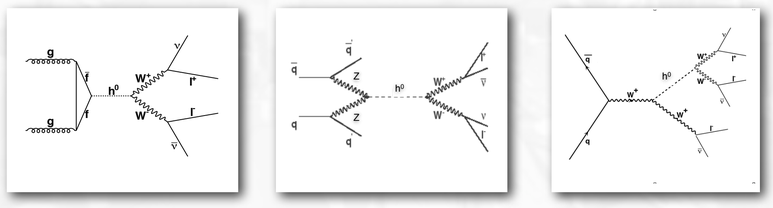
Experiment

The analyzed data are collected in p-p collissions at the center of mass energy of 7 TeV and 8 TeV using the ATLAS detector at the LHC. Datasets correspond to 20.7 fb^{-1} in 2012 and 4.6 fb^{-1} in 2011.



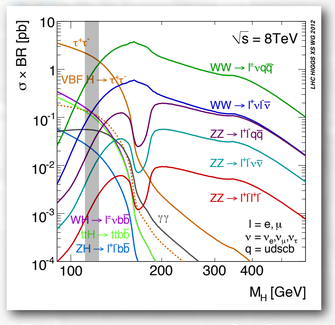
Signatures and expected rates

gluon-gluon fusion **ggF** | vector-boson fusion **VBF** | associated production **VH**



2 oppositely charged high-p_T leptons (e,μ) and large $E_T^{miss.}$
+
2 well separated jets

WH - 3 leptons
ZH - 4 leptons
and large $E_T^{miss.}$



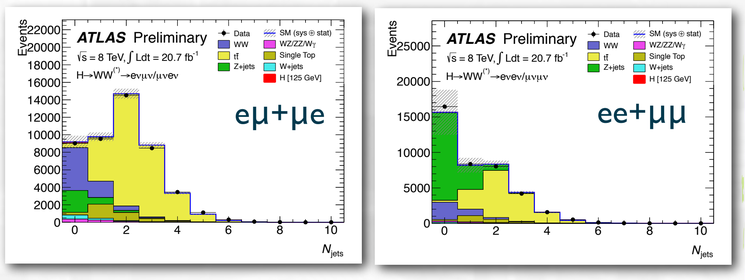
Poor mass resolution, but high rate!

Event selection

Analysis categories:

- 4 lepton flavour combinations: **ee, μμ, eμ, μe**
- 3 jet multiplicities:
  0 jet, 1 jet - ggF
  ≥ 2 jetss - VBF

Background composition depends on the lepton flavour final state and number of jets



After preselections, dominant backgrounds in the eμ and μe channels come from top quark and WW, while in the ee and μμ come from Drell-Yan (in 0/1 jet cat.) and top (in 2 jet cat.)

Preselections

- Exactly 2 oppositely charged, well isolated leptons with p_T > 25,15 GeV (W+jets,) $W\gamma$
- High relative E_T^{miss} and lower bound on m_{ll} to reduce Drell-Yan and QCD background
- Veto events with the m_{ll} corresponding to the Z mass.

H + 0 jet:

- High p_T^{ll} to reduce Drell-Yan

H + 1 jet:

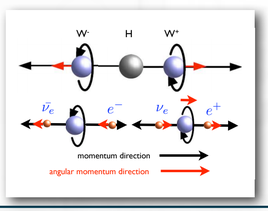
- Veto b-jets reduce 75% of top
- Veto $Z \to \tau\tau$ decays using a collinear approximation for m_{TT}

H + 2 jets:

- H+1jet selections + selections on M_{jj}, ΔY_{jj}, central jet veto are applied to enhance the VBF topology.

Topological selection:

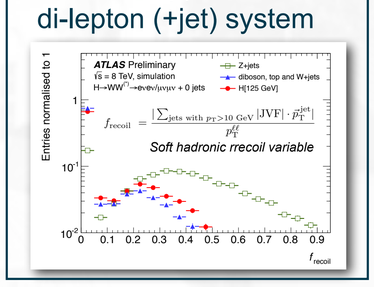
Exploit the angular correlations of the WW system to discriminate between pp→H→WW and other pp→WW production



Drell-Yan suppression:

Apply cuts on:

- Rel. track-based $E_T^{miss.}$
- Soft hadronic recoil radiation opposite to the di-lepton (+jet) system



High mass search: Requires selection of higher p_T leptons. Higgs with m_H = 125 GeV is considered as background for this search and suppressed by m_{ll} > 50 GeV selection.

- The m_T spectra of events satisfying all selections are fit using the binned likelihood.
- Systematics parametrised by nuisance parameters.

Results for 7/8 TeV for m_H = 115 - 200 GeV

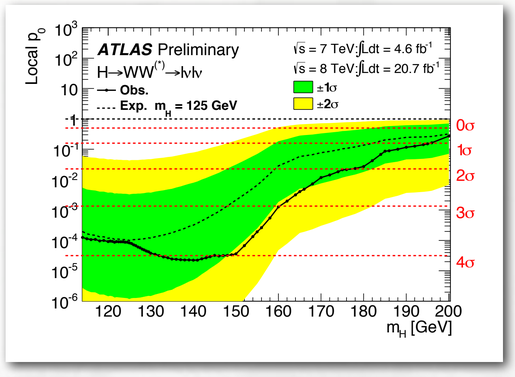
- The Higgs boson with the SM cross-section is excluded with 95% C.L. for m_H > 133 GeV (exclusion expected for m_H > 119 GeV)
- Excess is observed for a wide m_H range, with local p_0 minimum at m_H = 140 GeV corresponding to 4.1σ significance.
- The observed signal significance at m_H = 125 GeV is **3.8σ** (expected 3.7σ).
- The best fit signal strength at m_H = 125 GeV

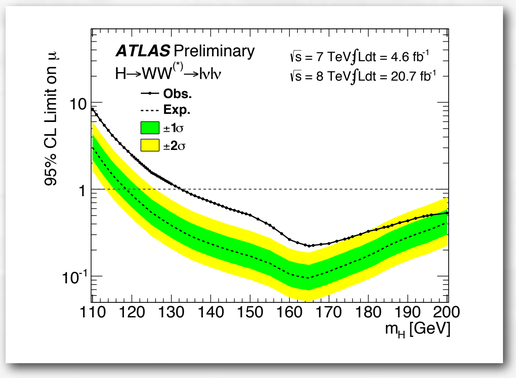
  $\mu = 1.01 \pm 0.21_{stat} \pm 0.19_{theo} \pm 0.12_{exp} \pm 0.04_{lumi}$
- Measured cross section for 8 TeV and m_H = 125 GeV:

  $\sigma \times BR\ (WW^{(*)}) = 6.0 \pm 1.6$ pb

  SM prediction: 4.8 ± 0.7 pb.

Results consistent with the Standard Model!





Final estimates and systematics

Event yields at 8 TeV for the signal of m_H = 125 GeV

Background estimation:

1. W + jets, same-flavour Drell-Yan - from data,
2. WW, top ($t\bar{t}$+single t), $Z \to \tau\tau$ - normalized to the data in control regions,
3. $W\gamma, W\gamma^*, WZ$ - from simulation and validated in data,
4. VBF di-boson and WW - from simulation (difficult to construct pure CR)

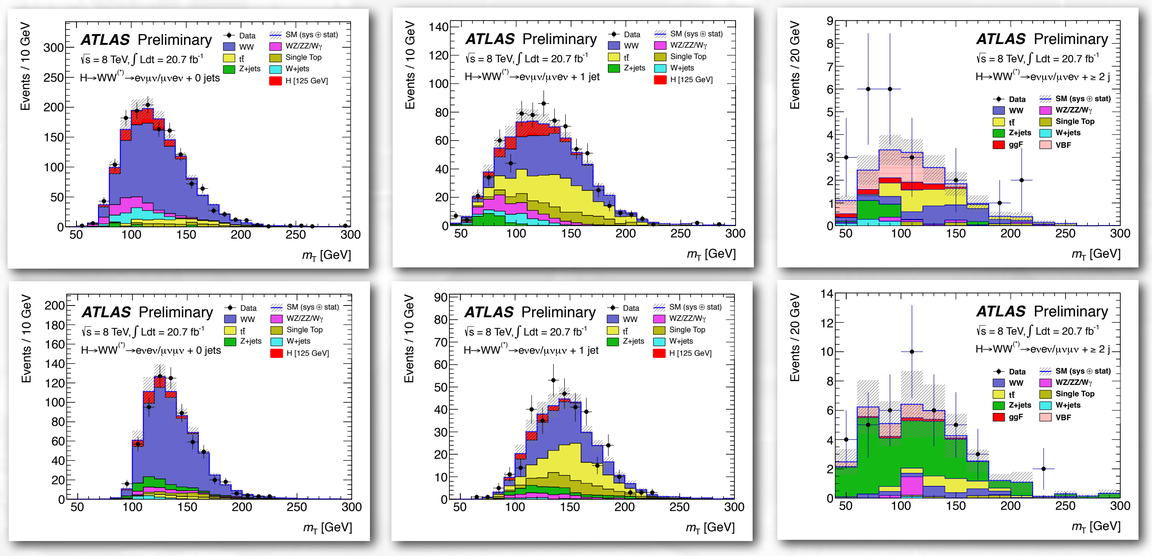
N_{jet}	N_{obs}	N_{bkg}	N_{sig}
= 0	831	739 ± 39	97 ± 20
= 1	309	261 ± 28	40 ± 13
≥ 2	55	36 ± 4	10.6 ± 1.4

N_{WW}	N_{VV}	$N_{t\bar{t}}$	N_t	N_{Z/γ^*}	N_{W+jets}
551 ± 41	58 ± 8	23 ± 3	16 ± 2	30 ± 10	61 ± 21
108 ± 40	27 ± 6	68 ± 18	27 ± 10	12 ± 6	20 ± 5
4.1 ± 1.5	1.9 ± 0.4	4.6 ± 1.7	0.8 ± 0.4	22 ± 3	0.7 ± 0.2

Observed events and expected yields after all selections in region $0.75\ m_H < m_T < m_H$

Final discriminant - transverse mass

$$m_T^2 = \left(\sqrt{m_{\ell\ell}^2 + \vec{p}_{T\ell\ell}^{\,2}} + E_T^{miss}\right)^2 - \left(\vec{p}_{T\ell\ell} + \vec{E}_T^{miss}\right)^2$$



An excess of events over the expected background has been observed in data for a broad m_T range in all final states

Leading uncertainties on the signal strength

The breakdown of uncertainties on the signal strength:

- statistical: **21%**
- theoretical syst.: **19%**
- experimental syst.: **12%**
- luminosity uncert.: **4%**

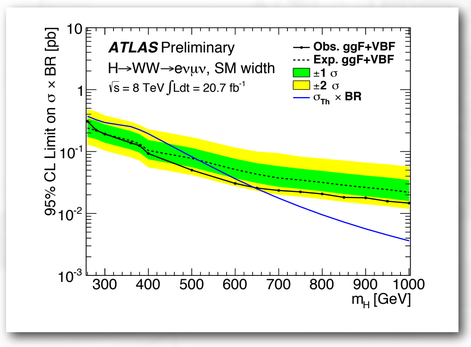
Category	Source	Uncertainty, up (%)	Uncertainty, down (%)
Statistical	Observed data	+21	−21
Theoretical	Signal yield ($\sigma \cdot \mathcal{B}$)	+12	−9
Theoretical	WW normalisation	+12	−12
Experimental	Objects and DY estimation	+9	−8
Theoretical	Signal acceptance	+9	−7
Experimental	MC statistics	+7	−7
Experimental	W+ jets fake factor	+5	−5
Theoretical	Backgrounds, excluding WW	+5	−4
Luminosity	Integrated luminosity	+4	−4
Total		+32	−29

Results

High-mass Higgs search (8TeV)

- 95% CL exclusion limit on SM-like signal lineshape and couplings (ggF + VBF):

260 GeV < m_H < 642 GeV



- Exclusion limits on the $\sigma_{ggF} \times BR\ (WW^{(*)})$

$W \to \ell\nu,\ \ell = e, \mu, \tau$

m_H	300 GeV	600 GeV	1 TeV
SM like [fb]	250	34	19
N.W.A.[1] [fb]	230	32	29
SM prediction (fb)	263	31	2

[1] N.W.A. - Narrow Width Approximation

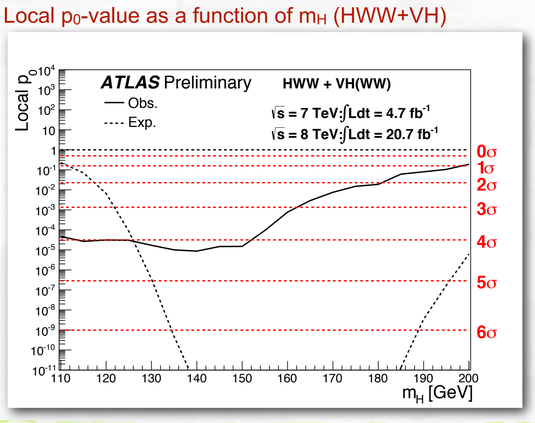
Combination with VH (7+8 TeV)

$H \to WW^{(*)} \to \ell\nu\ell\nu$
$WH \to WWW^{(*)} \to \ell\nu\ell\nu\ell\nu$
$ZH \to ZWW^{(*)} \to \ell\ell\ell\nu\ell\nu$

Expected and observed significance for m_H=125 GeV

significance	HWW	VH	HWW+VH
expected	3.7	0.7	3.8
observed	3.8	2.0	4.0

Local p_0-value as a function of m_H (HWW+VH)



References:
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