

Higgs boson searches with the ATLAS detector in the channels $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ and $H \rightarrow b\bar{b}$

Jornadas do LIP 2012

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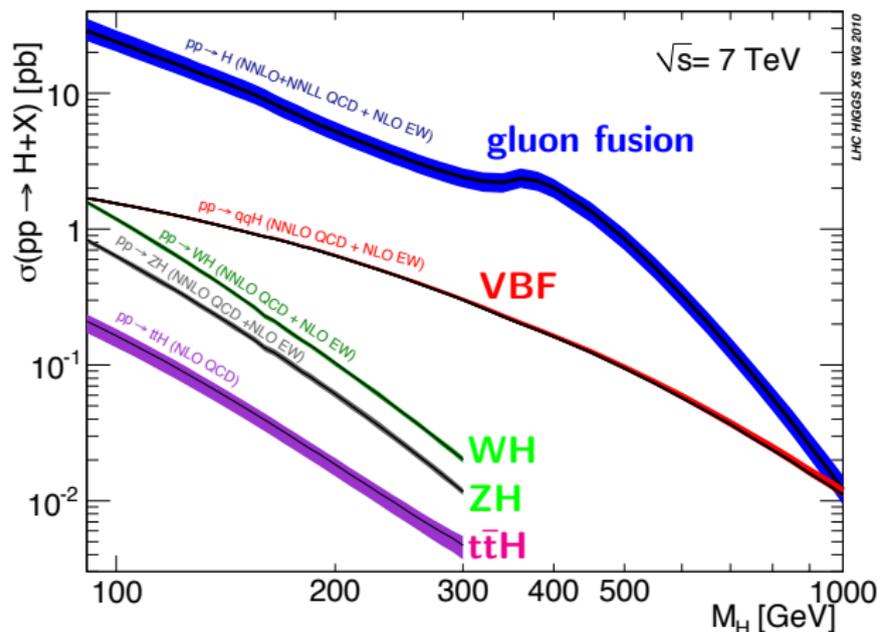
on behalf of the ATLAS - PT group

April 22nd 2012

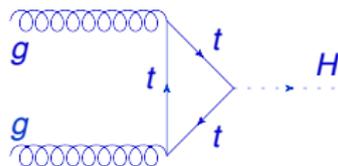


Higgs boson at the LHC

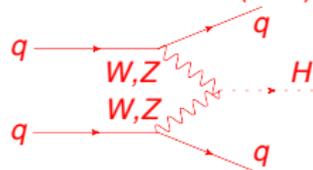
- Only Standard Model particle not yet observed.
- Centerpiece of the LHC physics program.
- Only unknown is its mass.



gluon fusion



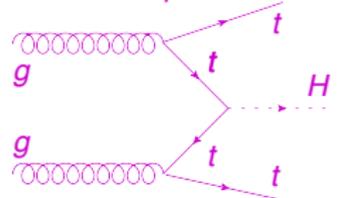
vector boson fusion (VBF)



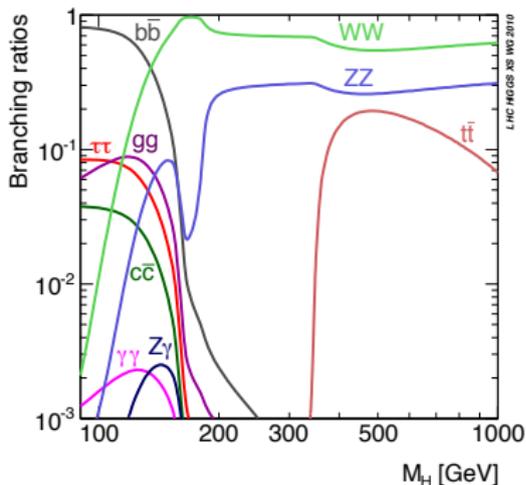
associated prod. with W/Z



associated prod. with $t\bar{t}$

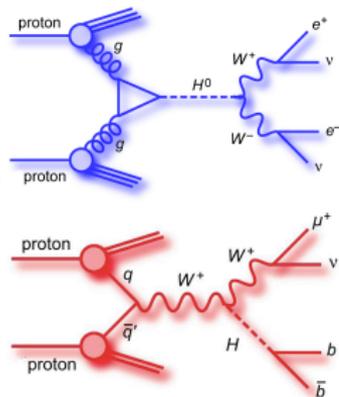


Motivation for $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ and $H \rightarrow b\bar{b}$



Why $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$?

- $H \rightarrow WW$ is largest BR for $m_H \gtrsim 135$ GeV.
- Sizable $W \rightarrow e\nu/\mu\nu$ decay rates.
- Clean lepton identification with ATLAS.
- Explores the two main Higgs production processes.
- Has greatest sensitivity for $120 < m_H < 200$ GeV.
- Has provided most of ATLAS exclusion power.



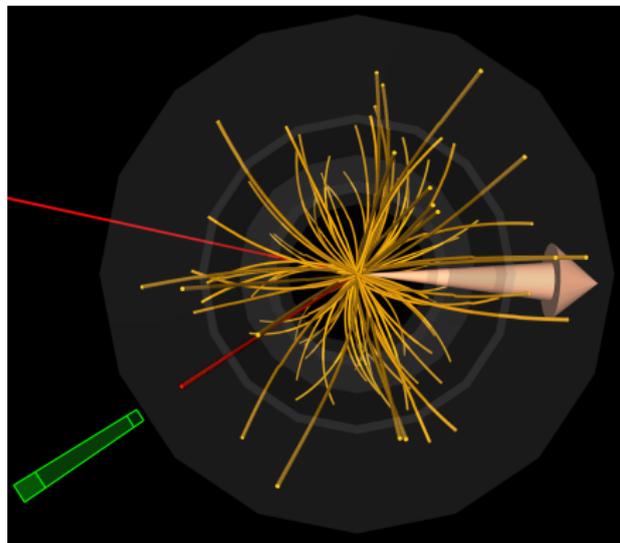
Why $H \rightarrow b\bar{b}$?

- $H \rightarrow b\bar{b}$ is largest BR for $m_H \lesssim 135$ GeV.
- Difficult due to overwhelming $b\bar{b}$ backgrounds.
- Can only be explored in associated production modes.
- Important to measure H coupling to b quarks.
- May be enhanced in SUSY scenarios.

Signal signature

- ▶ 2 isolated opposite-sign leptons (e or μ)
- ▶ Large missing transverse energy - E_T^{miss}
- ▶ No mass reconstruction possible due to ν
- ▶ Signal manifests as excess in:

$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{\text{miss}})^2 - |\vec{p}_T^{\ell\ell} + \vec{p}_T^{\text{miss}}|^2}$$



Selection criteria

Split according to jet multiplicity

- ▶ 0-jet dominated by WW and $Z/\gamma^* + \text{jets}$

Further rejection of $Z/\gamma^* + \text{jets}$

- ▶ $p_T^{\ell\ell} > 45(30)$ GeV for $ee/\mu\mu(e\mu)$

Separation from WW using Higgs spin

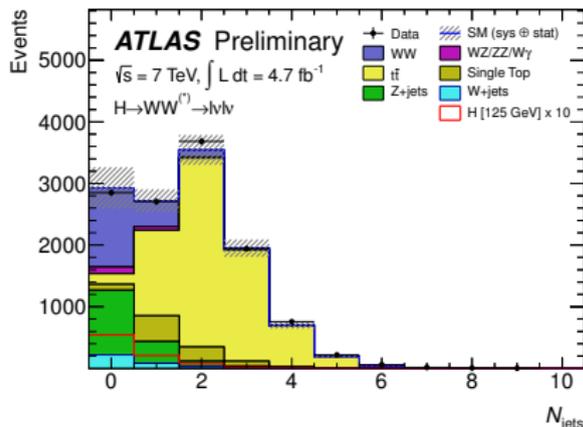
- ▶ $\Delta\phi(\ell, \ell) < 1.8$ rad

Low-mass Higgs (125 GeV reference)

- ▶ $m_{\ell\ell} < 50$ GeV

Other backgrounds

- ▶ $t\bar{t}$, single top, WZ , ZZ , $W\gamma^{(*)}$, $W+\text{jets}$



$Z/\gamma^* + \text{jets}$ background in $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ analysis

$Z/\gamma^* + \text{jets}$ background

All backgrounds, except non- WW diboson, partially or fully determined from data.

2 true leptons from $Z/\gamma^* + \text{jets}$ with fake E_T^{miss} will mimic our signal.

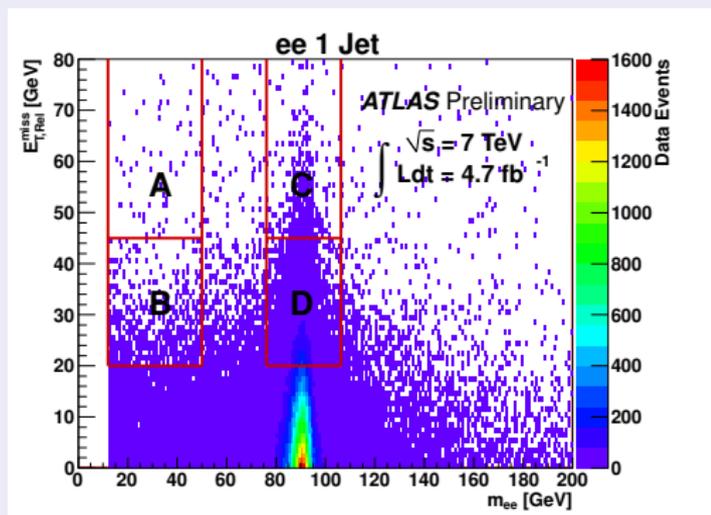
$Z/\gamma^* + \text{jets}$ background became more important with increasing pile-up.

ABCD method was chosen to estimate $Z/\gamma^* + \text{jets}$.

Important points on ABCD

- 1 Assumes $m_{\ell\ell}$ and $E_{T,\text{rel}}^{\text{miss}}$ are uncorrelated.
- 2 Expects small contributions from other backgrounds in each region, since they are subtracted from data for the calculation.
- 3 Does not account for possible mismodelling of the $m_{\ell\ell}$ lineshape.

The ABCD method



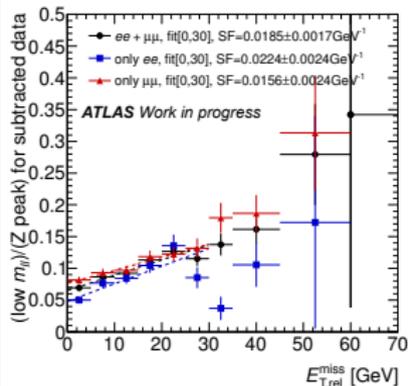
Assuming $A/B = C/D$, $Z/\gamma^* + \text{jets}$ contribution in signal region can be fully extracted from data:

$$A_{Z/\gamma^* + \text{jets}}^{\text{estimate}} = B^{\text{observed}} \times \frac{C^{\text{observed}}}{D^{\text{observed}}}$$

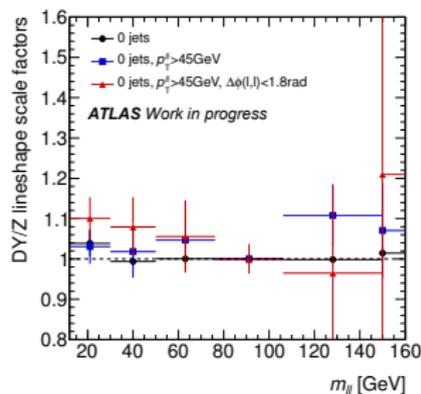
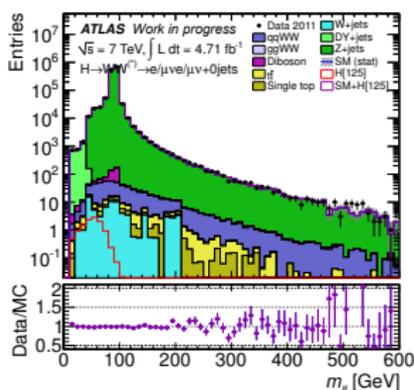
Systematic uncertainty on the estimate from verifying constant ratios assumption in MC.

Corrections on $Z/\gamma^* + \text{jets}$ estimate

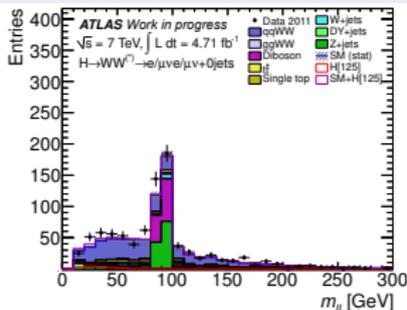
$m_{\ell\ell} - E_{T,rel}^{\text{miss}}$ correlation



$m_{\ell\ell}$ lineshape at low E_T^{miss}



Purified region C



summary of ABCD corrections

purified region C

$m_{\ell\ell} - E_{T,rel}^{\text{miss}}$ correlation

$m_{\ell\ell}$ lineshape

combined

ee

$\mu\mu$

0.76±0.11 0.85±0.04

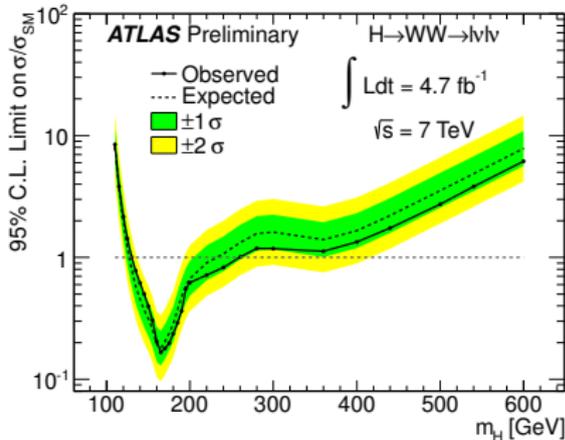
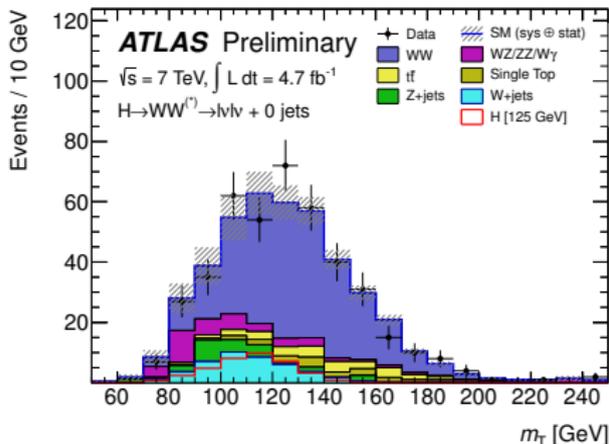
1.51±0.05 1.43±0.06

1.00±0.15 1.00±0.15

1.15±0.19 1.22±0.17

$H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ Results

$H + 0\text{-jet}$	Signal	WW	WZ/ZZ/W γ	$t\bar{t}$	$tW/tb/tqb$	Z/ γ^* + jets	W+ jets	Total Bkg.	Obs.
Jet Veto	54.5 ± 0.2	1285 ± 79	106 ± 6	175 ± 12	95 ± 7	1038 ± 28	217 ± 4	2916 ± 115	2851
$m_{\ell\ell} < 50$ GeV	53.8 ± 0.2	316 ± 20	48 ± 5	30 ± 2	19 ± 2	157 ± 13	69 ± 2	640 ± 34	644
$p_T^{\ell\ell}$ cut	38.8 ± 0.2	285 ± 18	41 ± 4	28 ± 2	18 ± 2	24 ± 7	49 ± 2	444 ± 27	441
$\Delta\phi(\ell, \ell) < 1.8$ rad	37.7 ± 0.2	279 ± 17	39 ± 4	27 ± 2	18 ± 2	23 ± 7	44 ± 1	429 ± 27	427



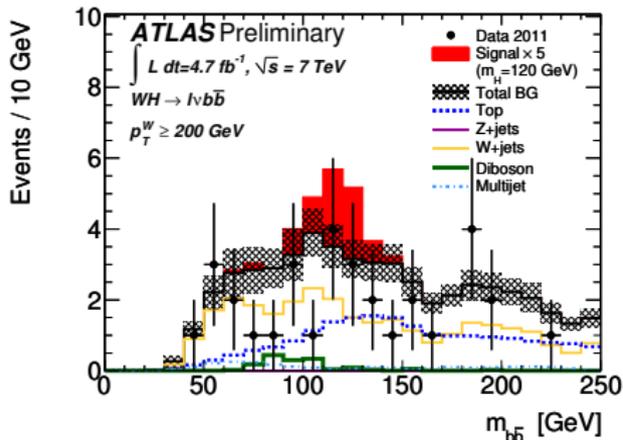
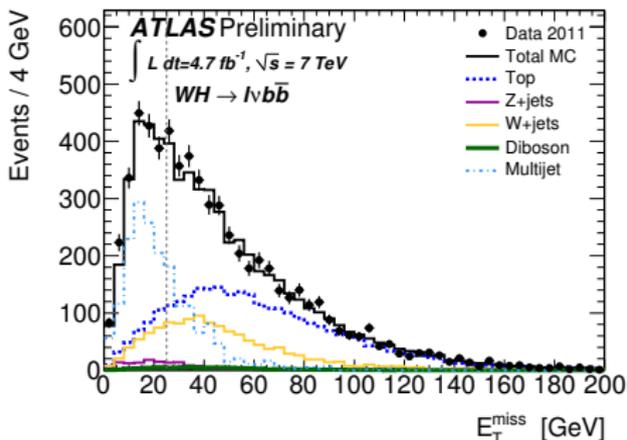
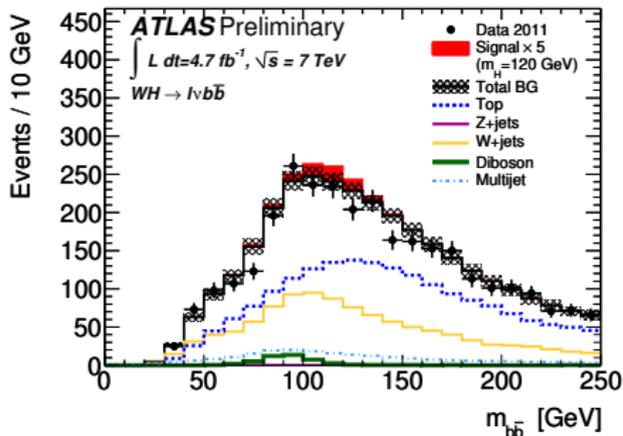
- m_T distribution fitted to test presence of signal.
- No significant excess of events over the expected background is observed.
- Expected exclusion at 95% CL: $127 < m_H < 234$ GeV
- Observed exclusion at 95% CL: $130 < m_H < 260$ GeV

Selection criteria for $WH \rightarrow \ell\nu b\bar{b}$

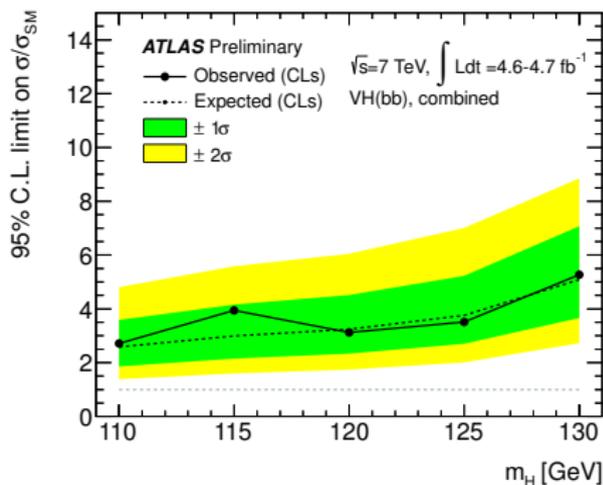
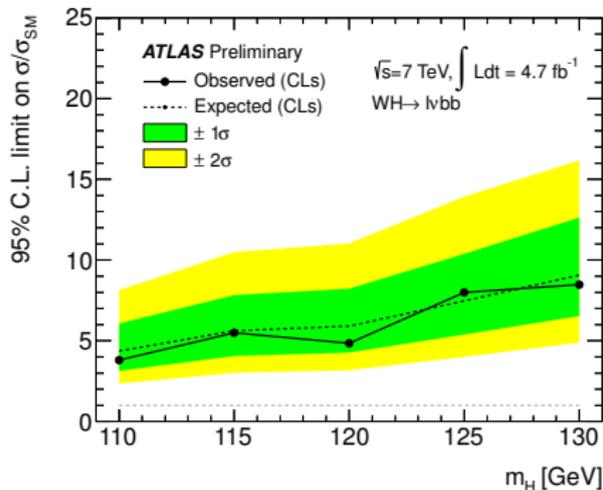
- ▶ **Trigger:** e ($p_T^e > 20$ GeV) or μ ($p_T^\mu > 18$ GeV)
- ▶ **Exactly 1 isolated lepton:** $p_T > 25$ GeV
- ▶ **Missing transverse energy:** $E_T^{\text{miss}} > 25$ GeV
- ▶ **Large transverse mass:**

$$m_T = \sqrt{2p_T^\ell p_T^\nu (1 - \cos\Delta\phi_{\ell\nu})} > 40 \text{ GeV}$$

- ▶ **Exactly 2 (b-tagged) jets:** $E_T > 25$ GeV
- ▶ **Split analysis in p_T^W bins:** increase sensitivity
- ▶ **Main backgrounds:** W/Z + jets, QCD multijet, top, diboson (WZ , WW , ZZ)



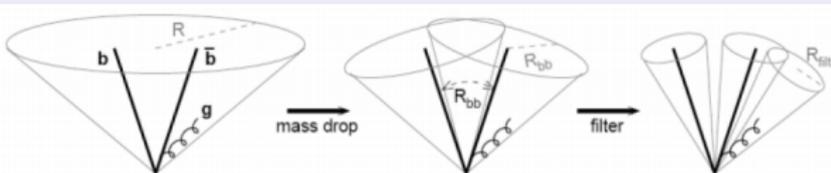
$H \rightarrow b\bar{b}$ results



- No significant excess of events observed over the expected background.
- Observed upper limits at 95% CL on Higgs with $110 < m_H < 130$ GeV CL: $2.7 - 5.3 \times \sigma_{SM}$

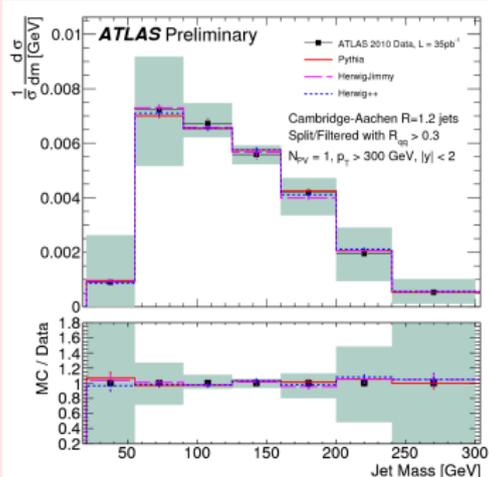
For the future: boosted $H \rightarrow b\bar{b}$

Alternative procedure



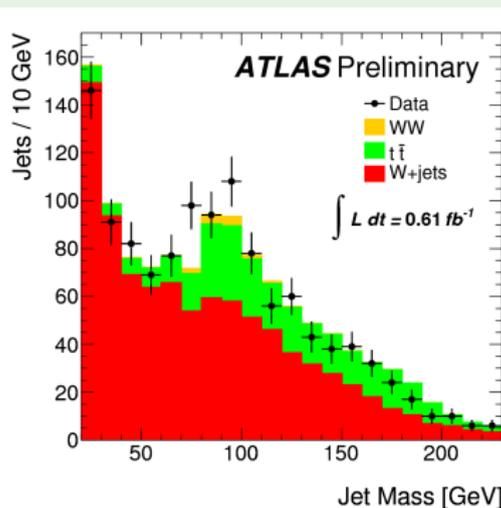
► In the $p_T^W > 200$ GeV bin, search for a single $b\bar{b}$ jet and reverse jet clustering until a mass drop is found, to find sub-jets.

Studies of QCD substructure



► After splitting/filtering, the jet mass is well modelled by the LO parton shower generators.

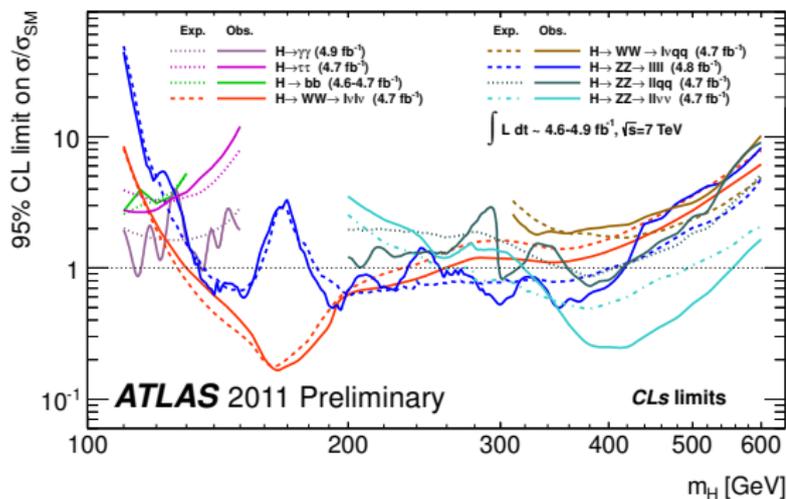
First boosted $H \rightarrow b\bar{b}$ studies



► Peak consistent with $W \rightarrow jj$ in $t\bar{t}$ events.

Summary, conclusions and outlook...

- Searches for $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ and $H \rightarrow b\bar{b}$ were performed in ATLAS with 4.7 fb^{-1} of LHC pp collisions.
- $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ is challenging channel:
 - ▶ Neutrinos in the final state.
 - ▶ Needs precise estimate of backgrounds and their uncertainties
 - ▶ Work by ATLAS-PT group on $Z/\gamma^* + \text{jets}$ background.

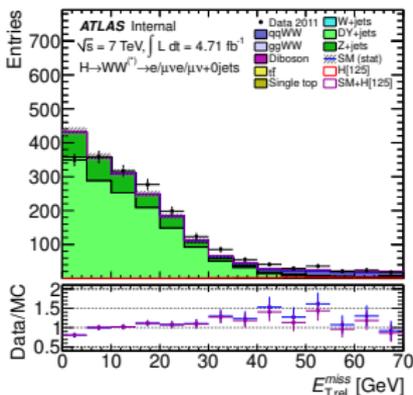


- $WH \rightarrow \ell\nu b\bar{b}$ is important channel:
 - ▶ Measure branching ratios and test nature of Higgs (if found).
 - ▶ ATLAS-PT analysis with 2 different strategies.
- The $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$ analysis has excluded a SM Higgs with $130 < m_H < 260 \text{ GeV}$.
- $H \rightarrow b\bar{b}$ is approaching SM sensitivity.
- The LHC will provide 15 fb^{-1} of $\sqrt{s} = 8 \text{ TeV}$ pp collisions during 2012:
 - ▶ Enough to find or exclude the Higgs in the full mass range!
 - ▶ Exciting year ahead!

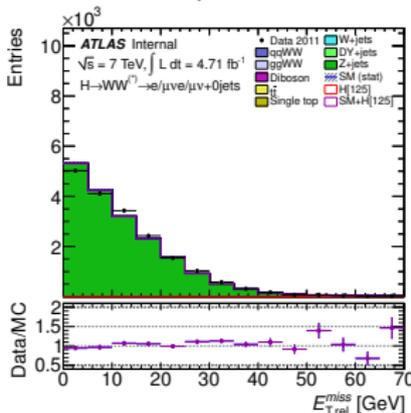
Back Up

$m_{\ell\ell} - E_{T,rel}^{miss}$ correlations

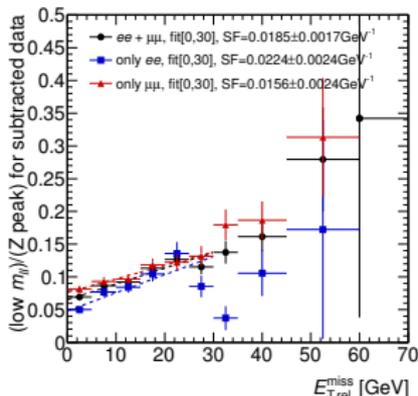
low- $m_{\ell\ell}$



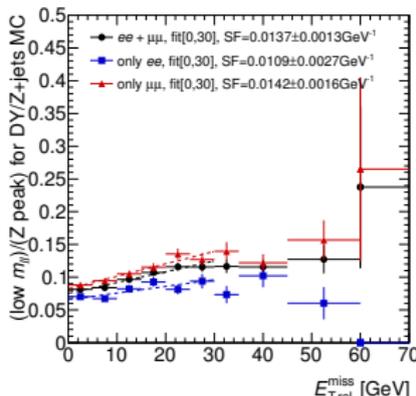
Z-peak



(low- $m_{\ell\ell}$)/(Z-peak) data



(low- $m_{\ell\ell}$)/(Z-peak) MC



- (low- $m_{\ell\ell}$)/(Z-peak) vs. $E_{T,rel}^{miss}$ shows a non-flat ratio:

- ▶ $m_{\ell\ell}$ and $E_{T,rel}^{miss}$ are correlated!
- ▶ Different correlations for ee and $\mu\mu$ and for data and MC.

- Assume the correlation is linear and fit the visible slope:

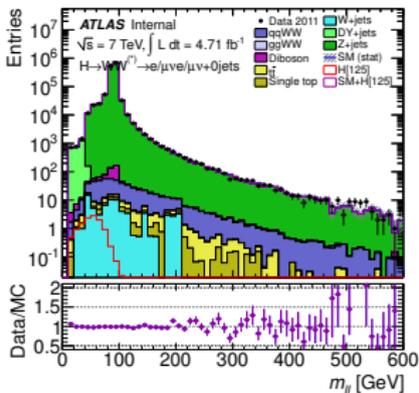
- ▶ correction factor per $E_{T,rel}^{miss}$ unit.

- Correction on ABCD of extrapolation from region B to region A:

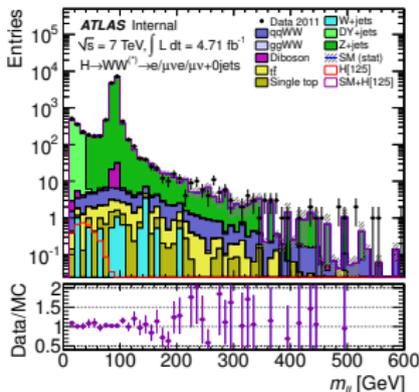
- ▶ ee : 1.51 ± 0.05
- ▶ $\mu\mu$: 1.43 ± 0.06

$m_{\ell\ell}$ lineshape at low $E_{T,rel}^{\text{miss}}$

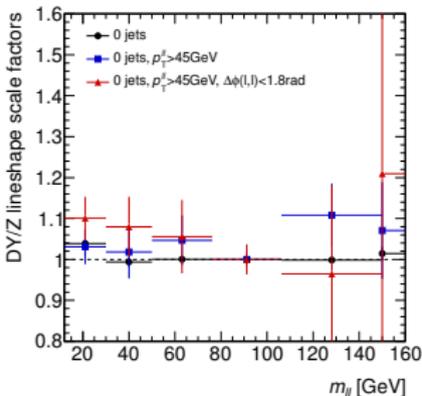
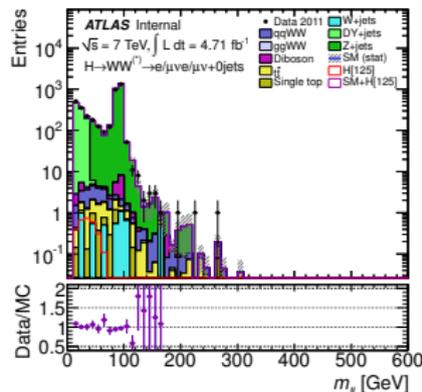
0 jets



0 jets, $p_T^{\ell\ell} > 45 \text{ GeV}$



0 jets, $p_T^{\ell\ell} > 45 \text{ GeV}$,
 $\Delta\phi(\ell, \ell) < 1.8 \text{ rad}$



- $m_{\ell\ell}$ lineshape evaluated at low $E_{T,rel}^{\text{miss}}$.

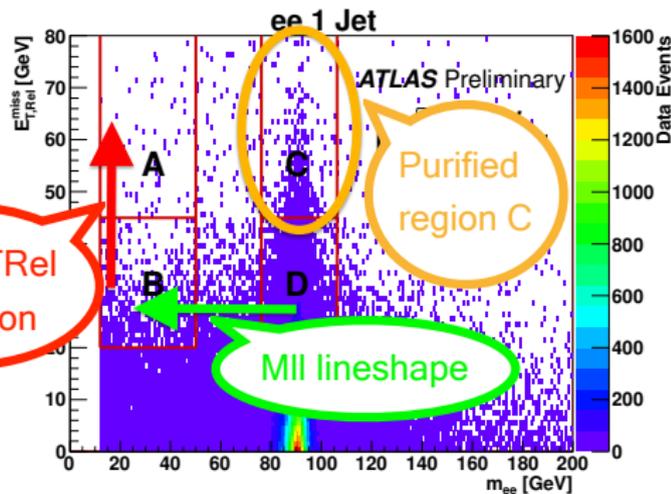
- $S/B \sim 100$ of $Z/\gamma^* + \text{jets}$ events w.r.t. other processes.

- Good modelling after jet veto and topological selections on $p_T^{\ell\ell}$ and $\Delta\phi(\ell, \ell)$.

- Scale factors calculated in bins of $m_{\ell\ell}$ w.r.t. the Z peak:

- $m_{\ell\ell}$ lineshape correctly described within 15% uncertainty.

Results on $Z/\gamma^* + \text{jets}$ background

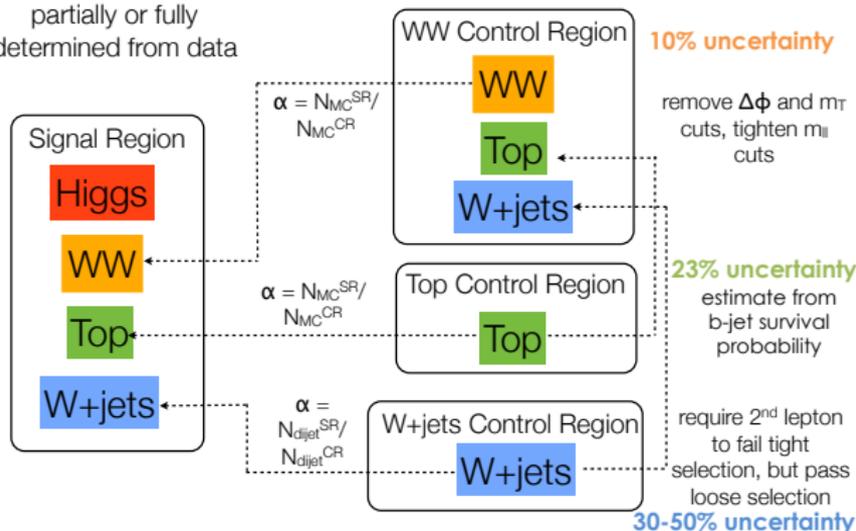


- Individual corrections show large discrepancies.
- Combination compatible with 1 within uncertainties.
- Current uncertainty from MC closure test: 56%.
- No further systematic was added.
- Large uncertainties reduce sensitivity:
 - ▶ Need to revisit $Z/\gamma^* + \text{jets}$ estimate for this year.

	ee	$\mu\mu$
purified region C	0.76 ± 0.11	0.85 ± 0.04
$m_{\ell\ell} - E_{T,\text{rel}}^{\text{miss}}$ correlation	1.51 ± 0.05	1.43 ± 0.06
$m_{\ell\ell}$ lineshape	1.00 ± 0.15	1.00 ± 0.15
combined	1.15 ± 0.19	1.22 ± 0.17

Other backgrounds and systematic uncertainties

Backgrounds either partially or fully determined from data



experimental systematic uncertainties

WW	8%
W + jets	40%
Z/ γ^* + jets	20%
$t\bar{t}$	26%
single top	19%
diboson	23%

- Mainly coming from jet energy scale, jet energy resolution and E_T^{miss} uncertainties.

Typical size of uncertainties (exact values depend on M_H):

	ggF	VBF	WH/ZH	$t\bar{t}H$
QCD scale:	+12% -8%	$\pm 1\%$	$\pm 1\%$	+3% -9%
PDF + α_s :	$\pm 8\%$	$\pm 4\%$	$\pm 4\%$	$\pm 8\%$
Mass line shape:	$(150\%) \times \left(\frac{M_H}{TeV}\right)^3$			

POWHEG+PYTHIA

for ggF^(*) & VBF;

(*) Scalar boson p_T reweighted to HqT (v2.0) predictions.

PYTHIA for WH/ZH & $t\bar{t}H$.

Backgrounds simulation I

- ALPGEN is used to model the production of single gauge bosons decaying to electrons or muons in association with jets. In these samples hadronisation is handled with HERWIG and the MLM matching scheme is used to combine samples with different final-state parton multiplicities: up to 5 for $W/Z + \text{jets}$ and up to 3 for $Wb\bar{b}$.
- MC@NLO is used to model $t\bar{t}$ and continuum diboson production (using HERWIG for the parton hadronisation).
- An additional contribution to the continuum WW background from gluon-initiated diagrams is modelled using gg2WW interfaced with HERWIGs hadronisation routines.
- $W\gamma$ is modelled with MADGRAPH.
- AcerMC is used to model s-channel, t-channel and Wt single top production.
- PYTHIA is used to model the multijet QCD backgrounds including dijets and bb .
- CTEQ6.6 was used for the MC@NLO samples, CTEQ6L1 for the ALPGEN samples, and MRST2007 for the PYTHIA and HERWIG samples.

Backgrounds simulation II

Table 1: Cross-sections at the centre-of-mass energy of $\sqrt{s} = 7$ TeV for background processes. The branching fractions are included with the cross-sections for processes that specify a decay mode. Processes that do not specify a decay mode are inclusive. The $W \rightarrow \ell\nu$ and the $Z/\gamma^* \rightarrow \ell\ell$ cross-sections include the branching ratio to a single lepton flavour, while the γW and two WW process include all three lepton flavors. The generators used for the simulation of the various processes are also indicated.

Process	Generator	cross-section σ (pb) (\times BR)
Inclusive $W \rightarrow \ell\nu$	ALPGEN	10.5×10^3 [36, 37]
Inclusive $Z/\gamma^* \rightarrow \ell\ell$ ($M_{\ell\ell} > 40$ GeV)	ALPGEN	10.7×10^2 [37, 38]
Inclusive $Z/\gamma^* \rightarrow \ell\ell$ ($10 < M_{\ell\ell} < 40$ GeV)	ALPGEN	3.9×10^3 [38]
$t\bar{t}$	MC@NLO	164.6
Single top t-channel	AcerMC	64.2 [39, 40]
Single top Wt	AcerMC	15.6 [39, 40]
Single top s-channel	AcerMC	4.6 [39, 40]
WZ	MC@NLO	18.0
ZZ	MC@NLO	5.6
$qq qg \rightarrow WW \rightarrow \ell\nu\ell\nu$ ($\ell = e, \mu, \tau$)	MC@NLO	4.7
$gg \rightarrow WW \rightarrow \ell\nu\ell\nu$ ($\ell = e, \mu, \tau$)	gg2WW	0.14
$\gamma W \rightarrow \ell\nu$ ($\ell = e, \mu, \tau$)	MADGRAPH	135.4
$b\bar{b}$ (2- ℓ filter, $p_T > 10$ GeV)	PYTHIA	4270

Object selection

Muons:

- STACO combined with $p_T > 15$ GeV
- MCP ID requirements recommendation
- $|z_0| < 1$ mm and $\sigma(d_0) < 3$
- $\text{etconeCorr30}/p_T < 0.14$ and $\text{ptcone30}/p_T < 0.15$

Electrons:

- tight++ with $p_T > 15$ GeV
- $|z_0| < 1$ mm and $\sigma(d_0) < 10$
- $\text{etconeCorr30}/p_T < 0.14$ and $\text{ptcone30}/p_T < 0.13$

Jets:

- AntiKt4TopoEM jets $p_T > 25$ GeV (increased to 30 GeV in the region $2.75 < |\eta| < 3.25$)
- $|\eta| < 4.5$
- $|j_{vf}| > 0.75$

MET:

- METRefFinal out-of-the-box

e-mu, e-e, e-jet overlap removal



Triggers for $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$

Table 2: Period dependent trigger setup used in the analysis.

Period	ee channel	$\mu\mu$ channel	$e\mu$ channel
B - I	EF_e20_medium	EF_mu18_MG	EF_e20_medium EF_mu18_MG
J	EF_e20_medium	EF_mu18_MG_medium	EF_e20_medium EF_mu18_MG_medium
K	EF_e22_medium	EF_mu18_MG_medium	EF_e22_medium EF_mu18_MG_medium
L - M	EF_e22vh_medium1	EF_mu18_MG_medium	EF_e22vh_medium1 EF_mu18_MG_medium

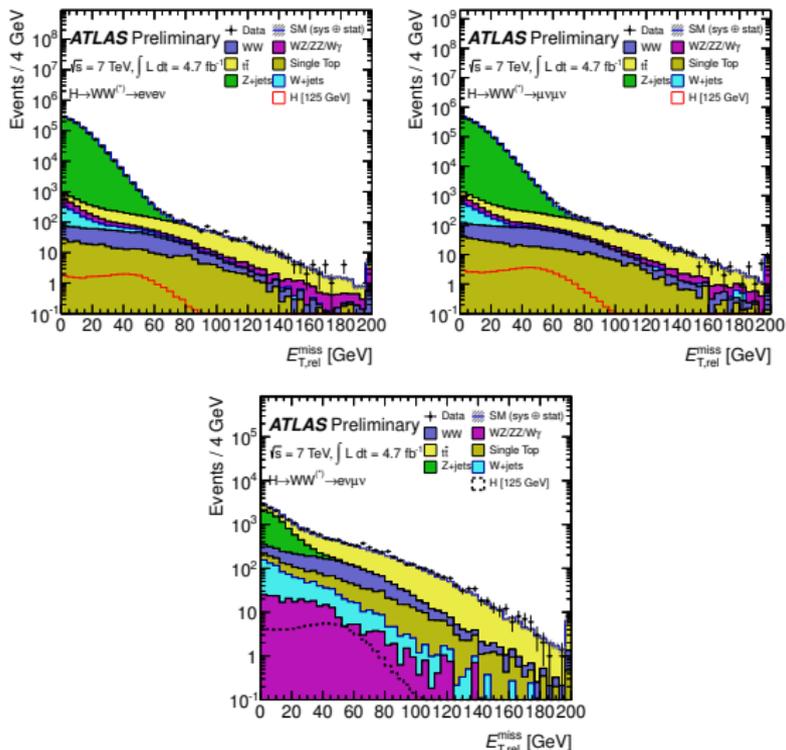


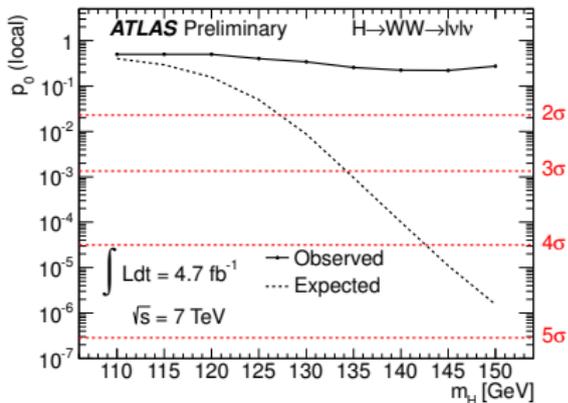
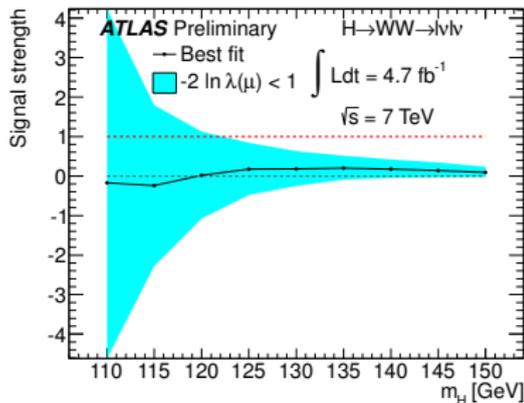
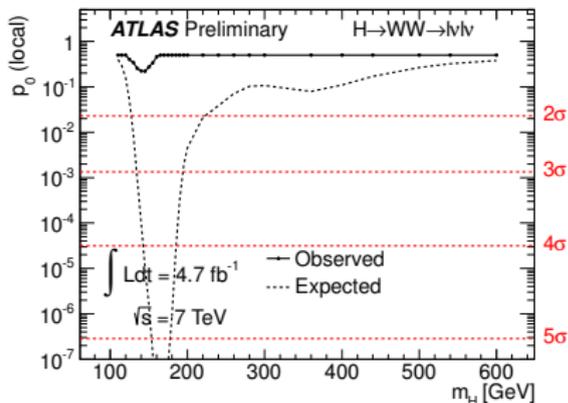
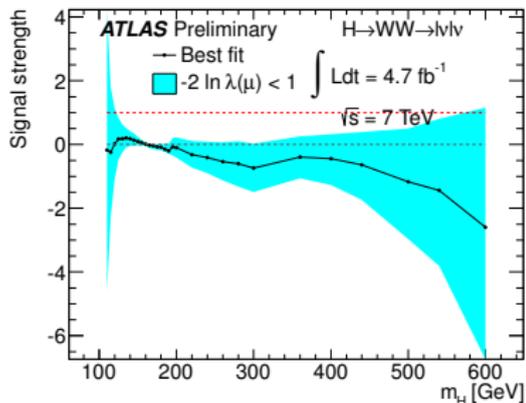
Figure 1: The $E_{T,rel}^{miss}$ distributions for the ee (top left), $\mu\mu$ (top right), and $e\mu$ (bottom) channels with the minimum lepton p_T and $m_{\ell\ell}$ requirements applied. The expected signal for a SM Higgs boson is shown for $m_H = 125$ GeV. The final bin includes the overflow.

Experimental systematic uncertainties

Table 7: Experimental sources of systematic uncertainty per object or event.

Source of Uncertainty	Treatment in the analysis
Jet Energy Resolution (JER)	MC jet resolution smeared using jet p_T , η -dependent parametrization
Jet Energy Scale (JES)	global JES: $< 14\%$ for jet $p_T > 25$ GeV and $ \eta < 4.5$ pileup: $< 5\%$ for jet $p_T > 20$ GeV
Electron Selection Efficiency	Separate systematics for electron identification, reconstruction and isolation, added in quadrature Identification: 8% for $p_T < 15$ GeV, decreasing to 1% for $p_T > 30$ GeV in the central region Reconstruction: $0.6 - 1.2\%$ for $p_T > 15$ GeV trigger: 1% uncertainty Total uncertainty of $2-5\%$ depending on η and E_T
Electron Energy Scale	Uncertainty smaller than 1% , depending on η and E_T
Electron Energy Resolution	Energy varied within its uncertainty, 0.6% of the energy at most
Muon Selection Efficiency	$0.3-1\%$ as a function of η and p_T reconstruction smaller than 1%
Muon Momentum Scale and Resolution	Uncertainty smaller than 1%
b-tagging Efficiency	p_T dependent scale factor uncertainties, $4.8 - 13.7\%$
Missing Transverse Energy	Using METUtility package
Missing Transverse Energy PileUP	10% from JetTauEtMiss 2010 recommendations
Luminosity	3.9% [50]

Signal strenght and p_0



ATLAS - a multi-purpose detector for the LHC

Magnet system:

$B=2\text{T}$ in ID from solenoid
 $B=0.5\text{-}1\text{T}$ from toroid

Inner Detector: $|\eta| < 2.5$

Si pixels/strips
 Trans. Rad. Det.
 $\sigma/p_T = 0.05\% p_T (\text{GeV})^{\oplus} 1\%$

EM calorimeter: $|\eta| < 3.2$

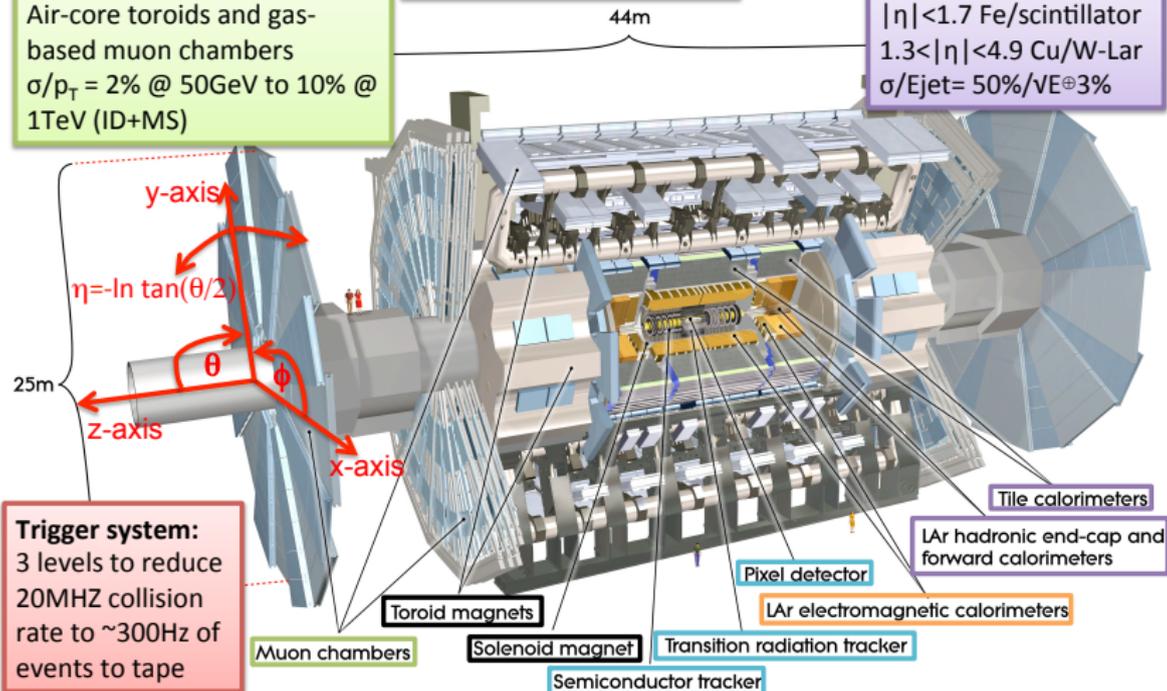
Pb-LAr Accordion
 $\sigma/E = 10\%/VE^{\oplus} 0.7\%$

Muon Spectrometer: $|\eta| < 2.7$

Air-core toroids and gas-based muon chambers
 $\sigma/p_T = 2\% @ 50\text{GeV}$ to $10\% @ 1\text{TeV}$ (ID+MS)

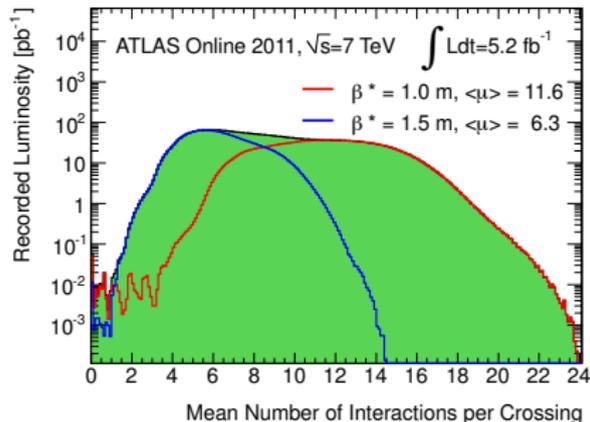
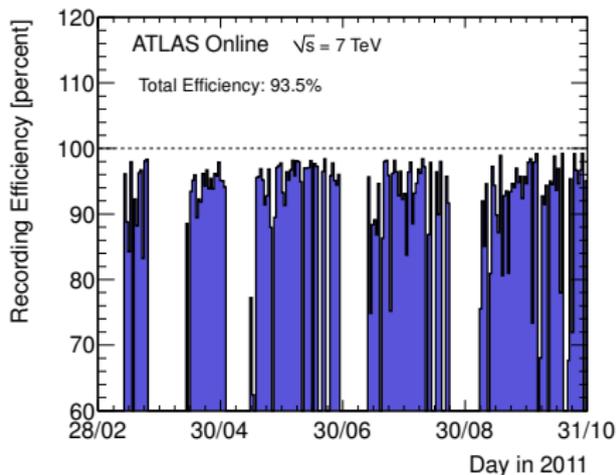
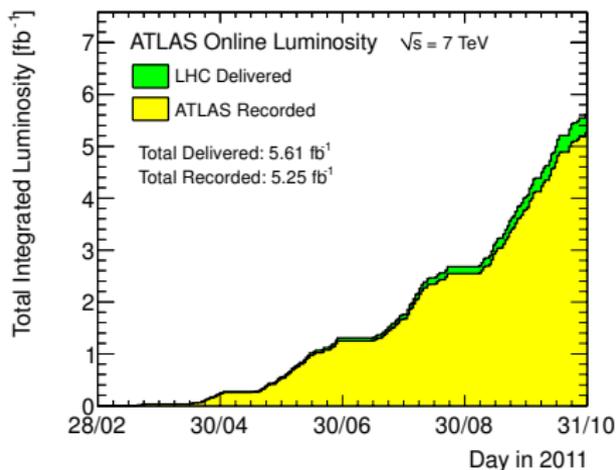
Hadronic calorimeter: $|\eta| < 1.7$

$1.3 < |\eta| < 4.9$ Cu/W-Lar
 $\sigma/E_{jet} = 50\%/VE^{\oplus} 3\%$



$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ search relies on information from all sub-detectors!

The year 2011



Summary of 2011 pp collision data taking:

Center-of-mass energy $\sqrt{s} = 7$ TeV

Peak luminosity $3.65 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

Integrated luminosity 5.25 fb^{-1}

Bunch crossing rate 20 MHz

Peak interaction rate 24/bunch crossing

Data taking efficiency 93.5%

Pre-selection of events

- **Event quality:**

- ▶ Nominal detector operating conditions
- ▶ Good quality primary vertex
- ▶ Suppression of non-collision backgrounds

- **Trigger:** inclusive single-muon/electron

- **Exactly two isolated opposite-charge leptons:**

- ▶ $p_T^{\text{lead}} > 25 \text{ GeV}$, $p_T^{\text{sub}} > 15 \text{ GeV}$
- ▶ Separate analysis in ee , $\mu\mu$ and $e\mu$

- **Suppress $Z/\gamma^* + \text{jets}$:**

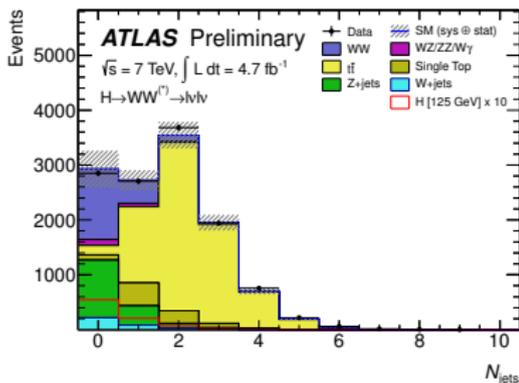
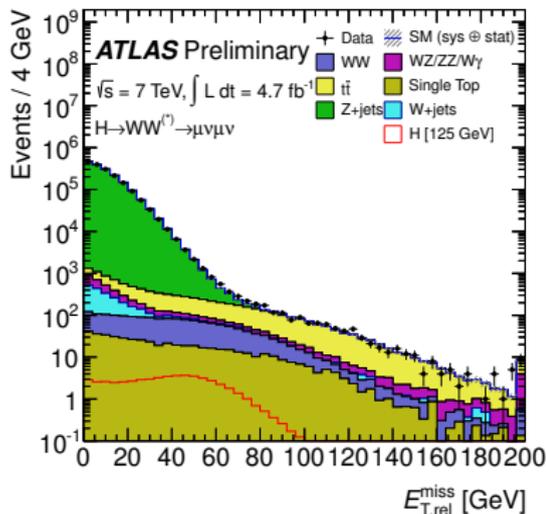
- ▶ $m_{\ell\ell} > 12(10) \text{ GeV}$ for $ee/\mu\mu(e\mu)$
- ▶ $|m_{\ell\ell} - m_Z| > 15 \text{ GeV}$ for $ee/\mu\mu$ only

- **Large missing transverse energy - $E_{T,\text{rel}}^{\text{miss}}$:**

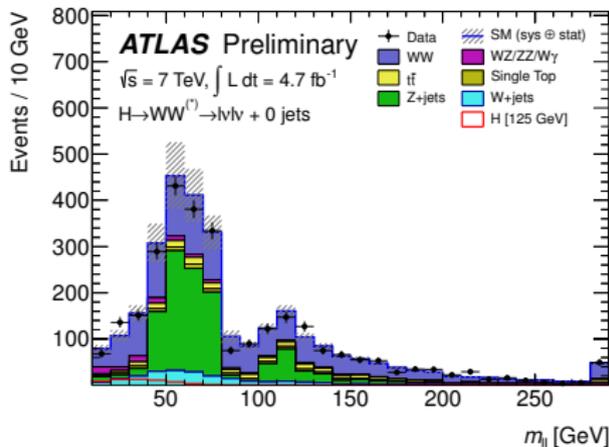
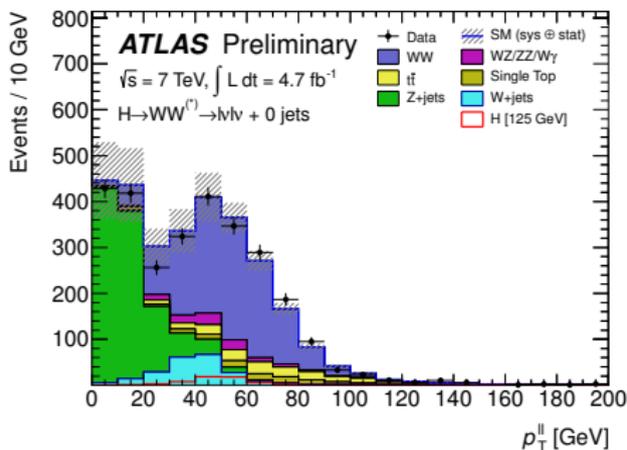
- ▶
$$E_{T,\text{rel}}^{\text{miss}} = \begin{cases} E_T^{\text{miss}} & \text{if } \Delta\phi \geq \pi/2 \\ E_T^{\text{miss}} \cdot \sin \Delta\phi & \text{if } \Delta\phi < \pi/2 \\ \Delta\phi = \min(\Delta\phi(E_T^{\text{miss}}, \ell), \Delta\phi(E_T^{\text{miss}}, \text{jet})) \end{cases}$$
- ▶ $E_{T,\text{rel}}^{\text{miss}} > 45(25) \text{ GeV}$ for $ee/\mu\mu(e\mu)$

- **Separate analysis in jet bins - $p_T^{\text{jet}} > 25 \text{ GeV}$:**

- ▶ 0-jet - gluon fusion, dominated by WW
- ▶ 1-jet - gluon fusion, dominated by WW and top
- ▶ > 2 -jet - VBF, dominated by top



Selection of events in the $H + 0\text{-jet}$ bin



Further rejection of $Z/\gamma^* + \text{jets}$:

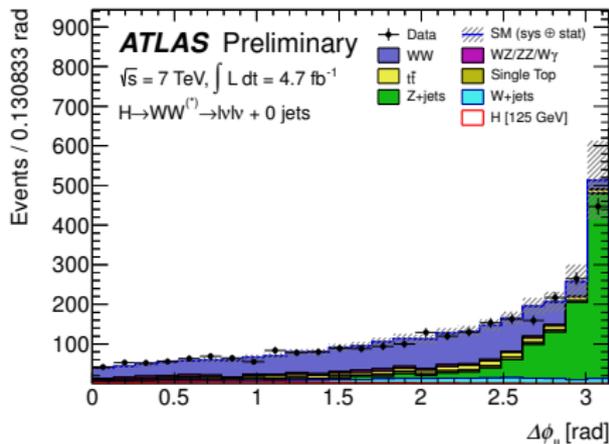
- $p_T^{\ell\ell} > 45(30) \text{ GeV}$ for $ee/\mu\mu(e\mu)$

Separation from WW by exploring Higgs spin:

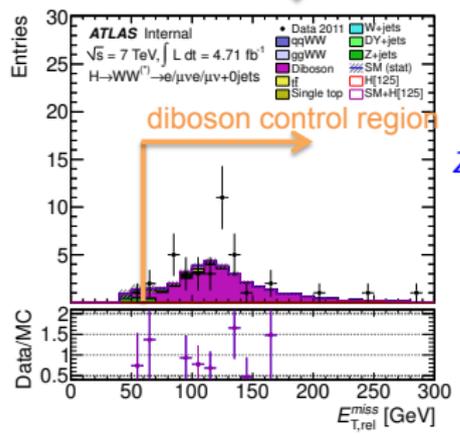
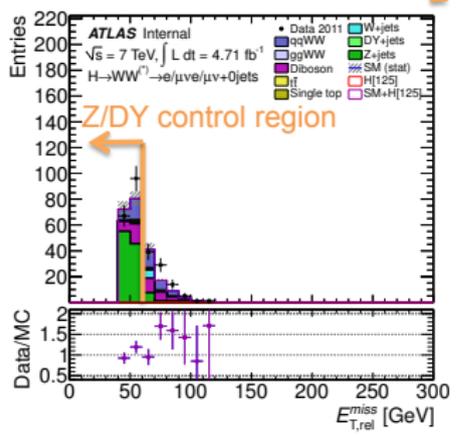
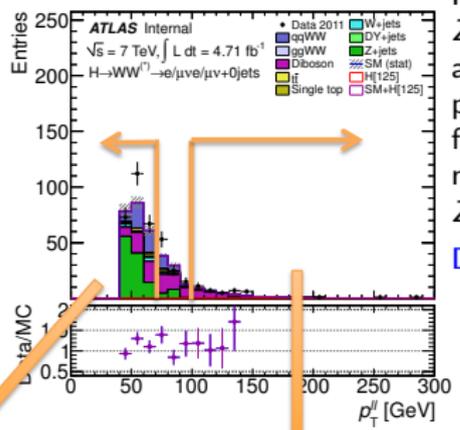
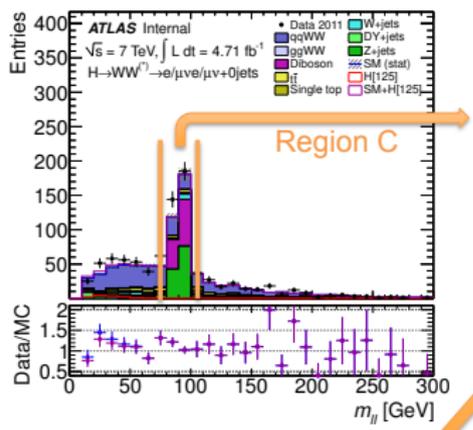
- $\Delta\phi(\ell, \ell) < 1.8 \text{ rad}$

Low-mass Higgs (125 GeV reference):

- $m_{\ell\ell} < 50 \text{ GeV}$



Non-WW diboson contributions in region C



Region C has only 37% of $Z/\gamma^* + \text{jets}$ events but additional selection cuts provide purer control samples for region C, both for non-WW diboson and $Z/\gamma^* + \text{jets}$.

Diboson control region

- $p_T^{\ell\ell} > 100 \text{ GeV}$
 $E_{T,rel}^{\text{miss}} > 60 \text{ GeV}$
- 88% purity
- $\sim 1/3 WZ, \sim 2/3 ZZ$
- Scale factor:
 - ▶ $ee: 1.26 \pm 0.34$
 - ▶ $\mu\mu: 1.09 \pm 0.27$

$Z/\gamma^* + \text{jets}$ control region

- $p_T^{\ell\ell} < 70 \text{ GeV}$
 $E_{T,rel}^{\text{miss}} < 60 \text{ GeV}$
- 66% purity
- Correction factor w.r.t. region C:
 - ▶ $ee: 0.76 \pm 0.11$
 - ▶ $\mu\mu: 0.85 \pm 0.04$