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Higgs searches at ATLAS

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on behalf of the
ATLAS Collaboration

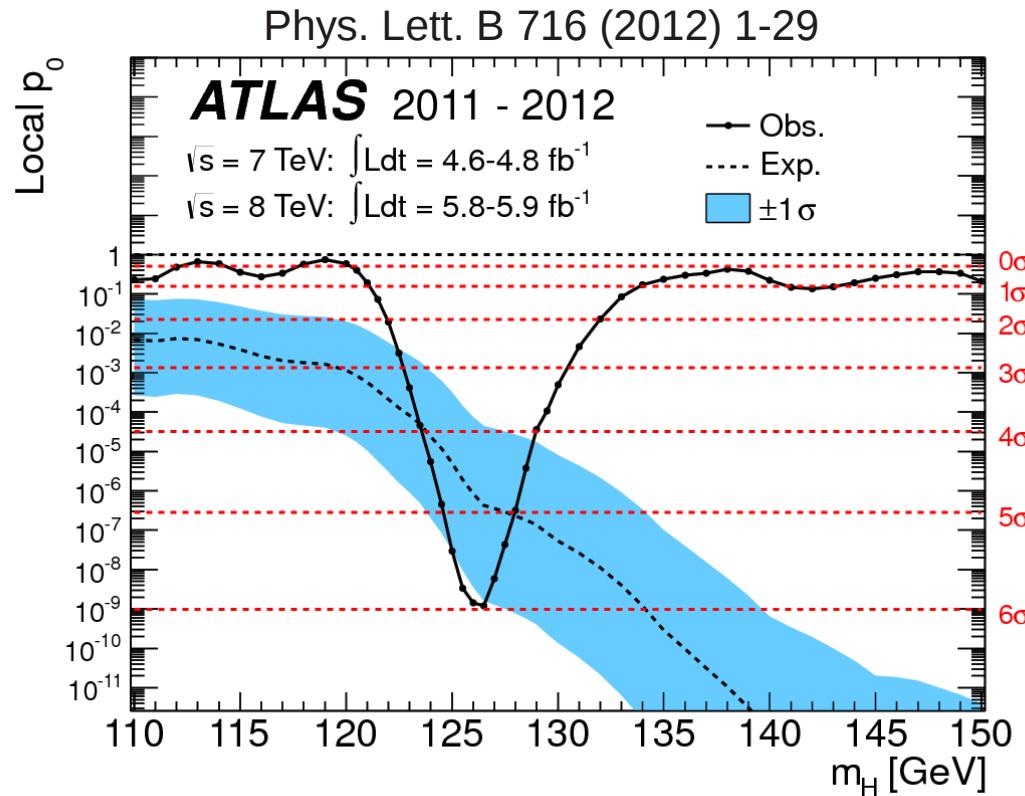
IHEP-LHC

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Introduction

On the 4th of July 2012, ATLAS and CMS announced the discovery of a new boson with a mass of ~ 126 GeV in the search for the Higgs

- Using $\sim 5+6 \text{ fb}^{-1}$ of 2011 (7 TeV) and 2012 (8 TeV) data
- Search sensitivity dominated by $\gamma\gamma$, $ZZ^{(*)}$, $WW^{(*)}$ decay channels
- Compatible with the expected Standard Model Higgs



Overview

The effort on the Higgs searches in the Collaboration has been focused on

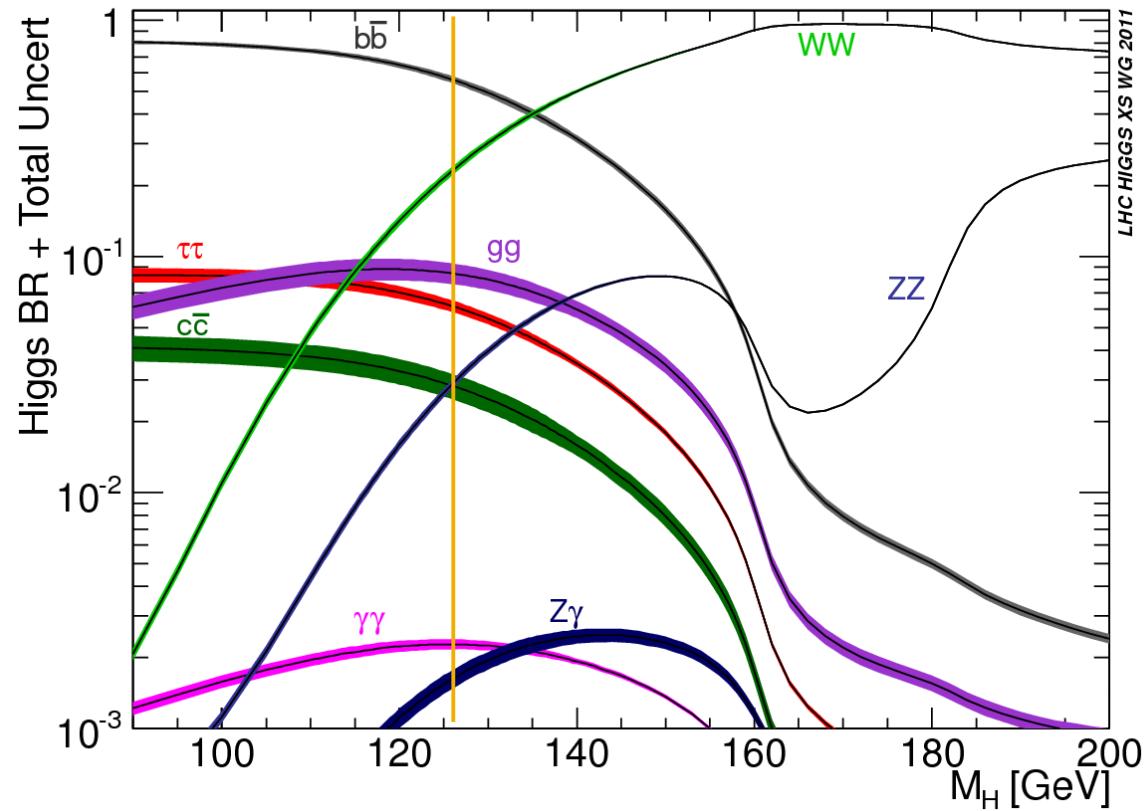
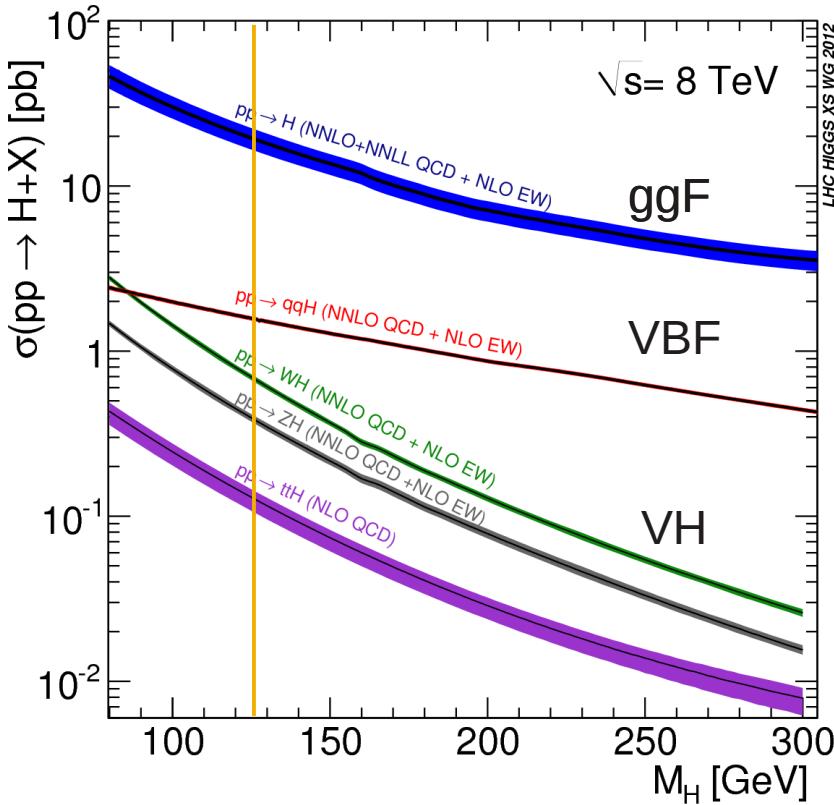
- Strengthen the evidence and measure the cross section of the new boson
- Include other refined and updated decay channels: $H \rightarrow b\bar{b}$, $H \rightarrow \tau\tau$
- Measurement of mass and other properties
- Keep looking for other possible signals of (beyond Standard-Model) Higgs

Overview

The effort on the Higgs searches in the Collaboration has been focused on

- (1) • Strengthen the evidence and measure the cross section of the new boson
- (2) • Include other refined and updated decay channels: $H \rightarrow b\bar{b}$, $H \rightarrow \tau\tau$
 - Measurement of mass and other properties → See C. Schmitt talk
- (3) • Keep looking for other possible signals of (beyond Standard-Model) Higgs

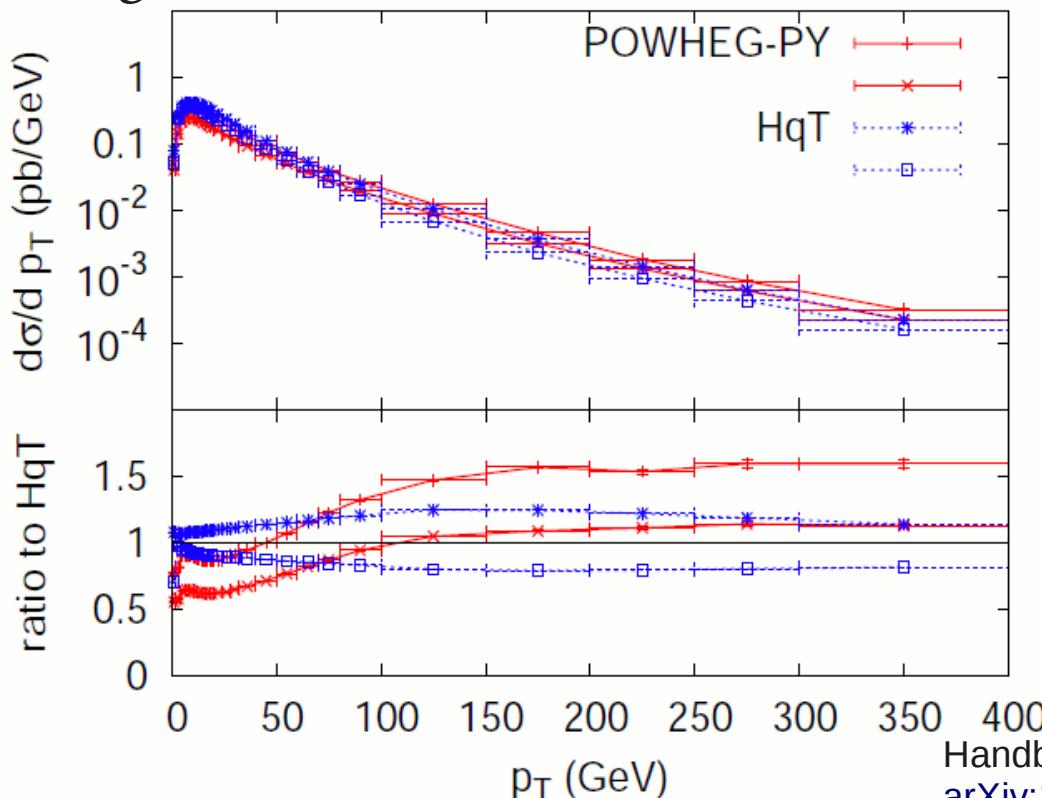
The Standard Model Higgs boson @ LHC



- Direct production by gluon fusion (ggF) is the dominant mechanism
 - Vector Boson Fusion (VBF) and W/ZH production play an important role
- Decays with sizable branching ratio to numerous final states
 - Can further constrain Higgs couplings, if observed

Theoretical modeling

- Accurate inclusive cross section calculations, typically NNLO QCD, NLO EWK
 - Not a dominant uncertainty for most Higgs analyses
- More recently focused on differential distributions
 - Important to assess “shape” uncertainties (e.g., $p_T(H)$, $m(jj)$ for VBF, ...)
- Using NLO event generators when available for both signal and backgrounds



Handbook of LHC Higgs cross sections:
arXiv:1101.0593 and arXiv:1201.3084

The ATLAS detector at the LHC

Muon system ($|\eta| < 2.7$)

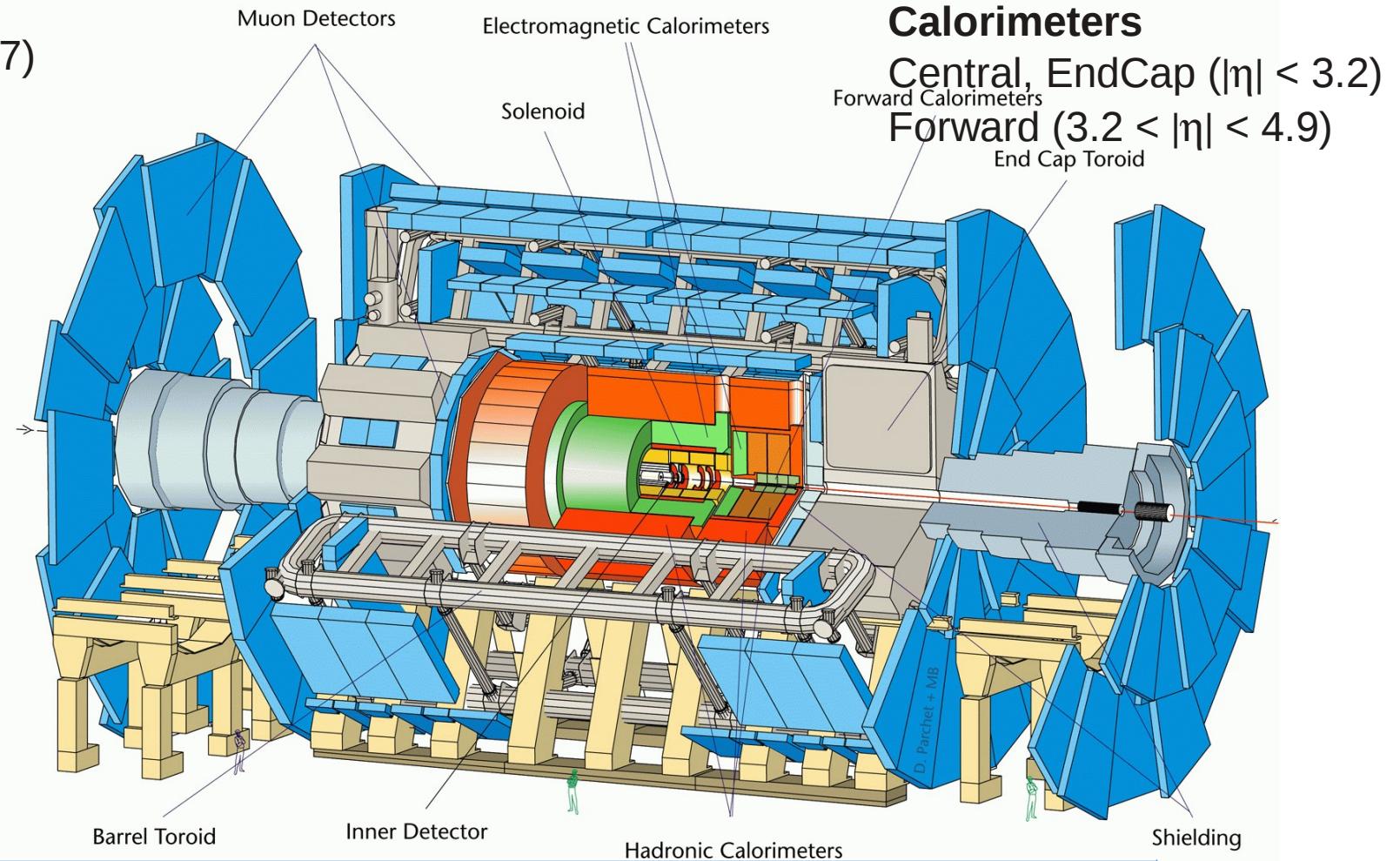
Strong bending power
(air-core toroid)
Trigger chambers

Tracking system

$|\eta| < 2.5$
Si Pixels, Strips,
Transition-Radiation
Tracker
2T magnetic field

Three-level triggering system

Output rate ~ 400 Hz



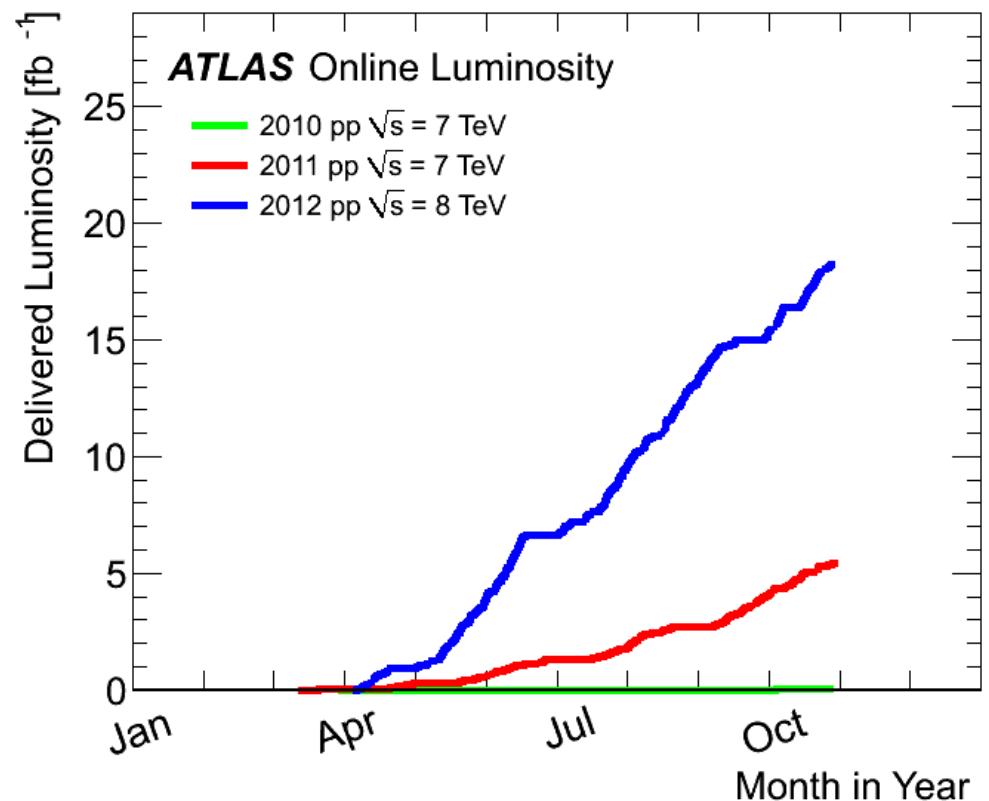
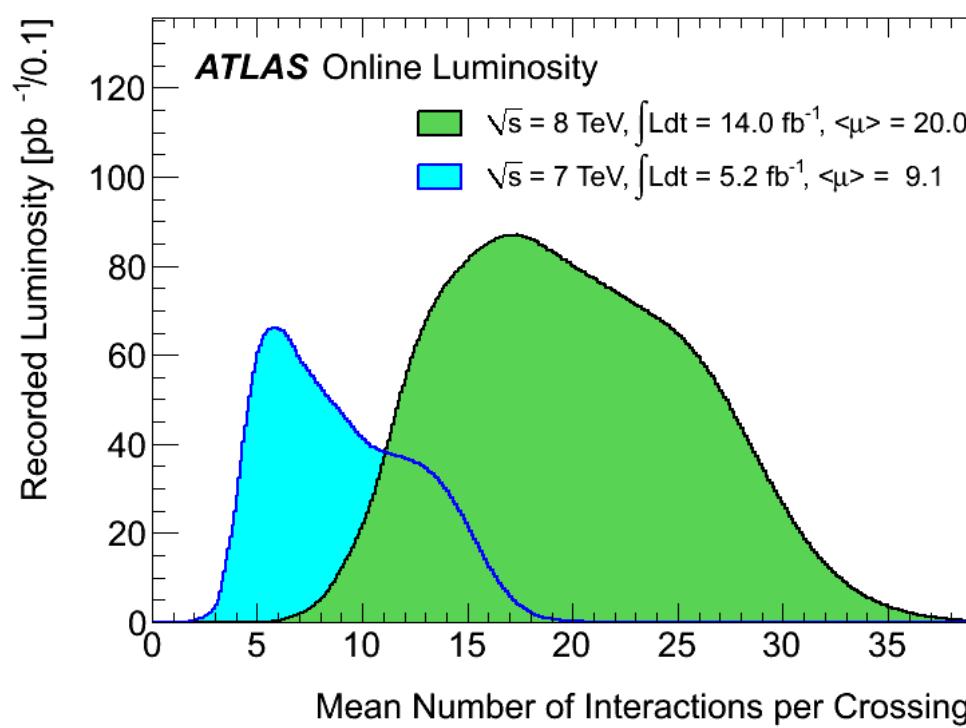
ATLAS p-p run: April-Sept. 2012

Inner Tracker			Calorimeters			Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid	
100	99.3	99.5	97.0	99.6	99.9	99.8	99.9	99.9	99.7	99.2	

All good for physics: 93.7%

Data taking conditions

- Impressive work by LHC colleagues to maximize integrated luminosity
 - Updated analyses use up to 13fb^{-1} of 8 TeV (2012) data
 - Instantaneous luminosity up to $L = 0.77 \cdot 10^{34} \text{cm}^{-2}\text{s}^{-1}$
- Pile-up conditions exceed design → big effort to keep the optimal performance in object reconstruction (e.g. jets, Σ_T , ...)



(1) Strengthen the evidence and measure the cross section of the new boson

- $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu, l=e,\mu$ **Updated**
- $H \rightarrow ZZ^{(*)} \rightarrow 4l, l=e,\mu$
- $H \rightarrow \gamma\gamma$

$$H \rightarrow WW^{(*)} \rightarrow e\nu_e \mu\nu_\mu$$

Total L = 13.0 fb⁻¹

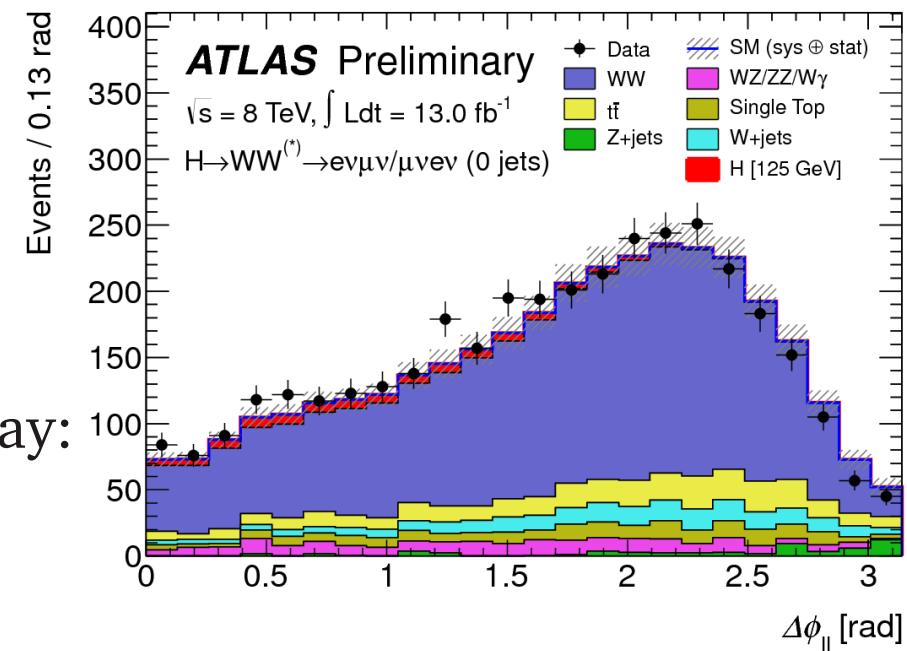
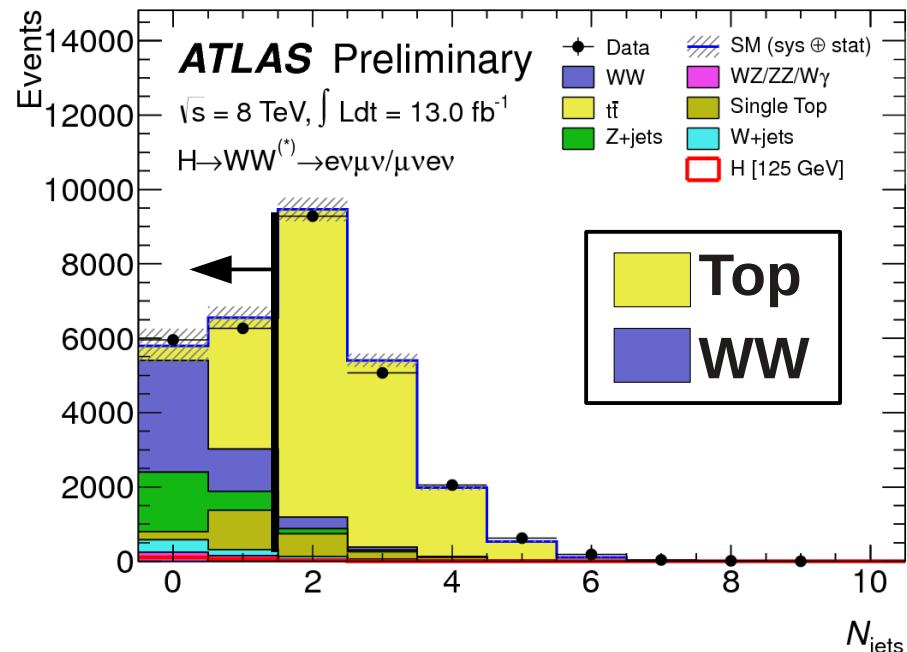


- Update analysis with focus on ggF production and low m_H
- Two isolated leptons (e, μ) with opposite charge and flavor ($p_T > 25, 15$ GeV)
- Reject Drell-Yan and multi-jet requiring significant Missing Energy
- Divide analysis in 0 and 1-jet events

- Very different background

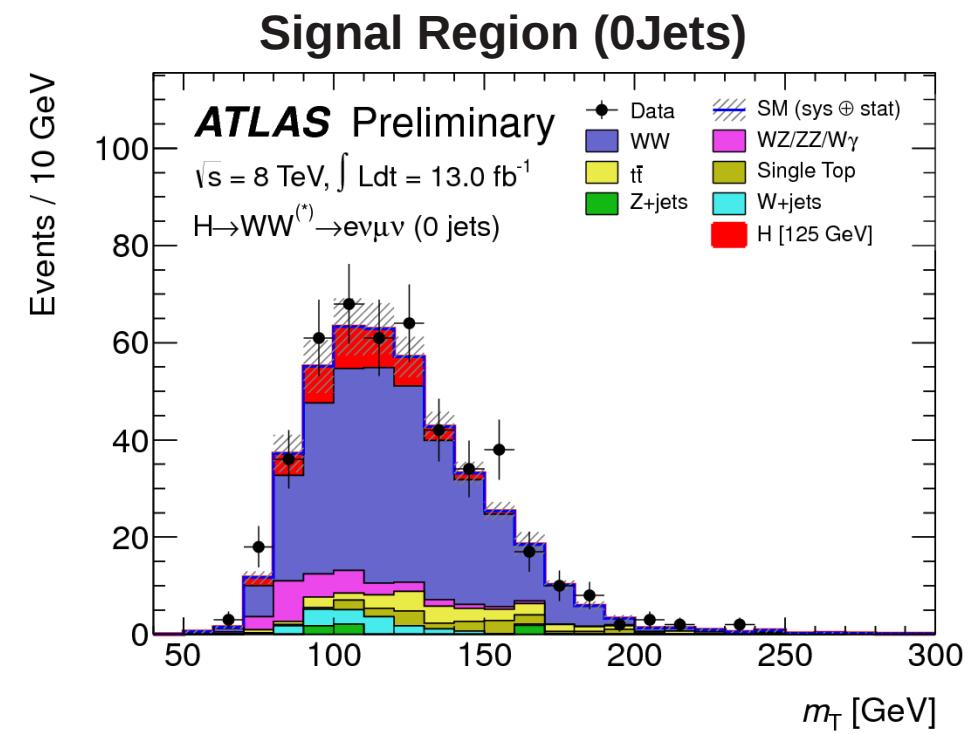
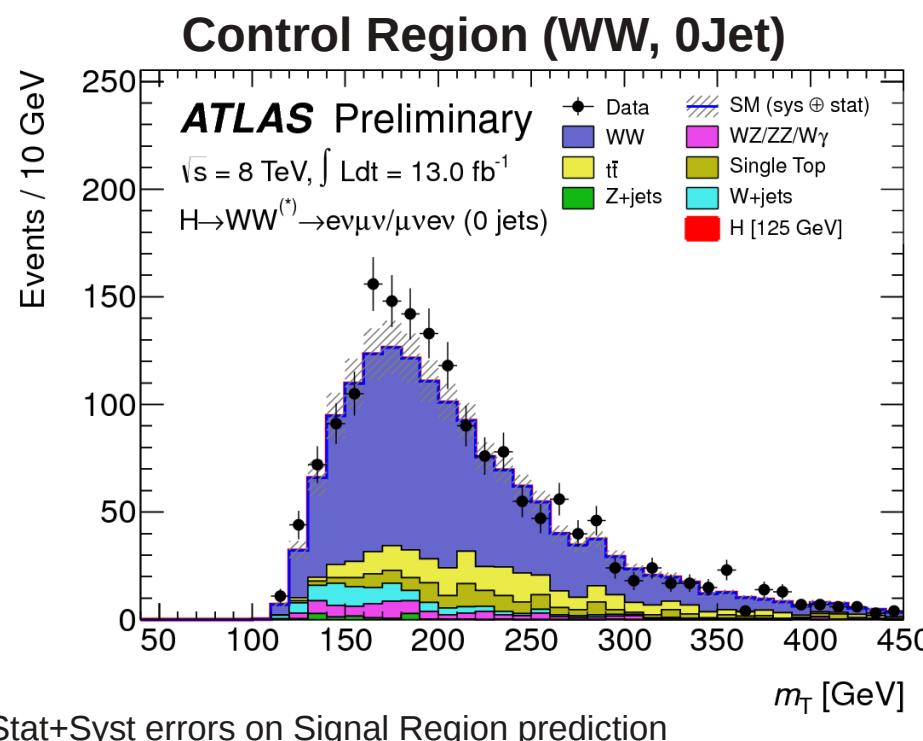
$e\mu + 0\text{Jet}$	$e\mu + 1\text{Jet}$
$p_T(l) > 30$ GeV	No b-jets ($\epsilon_b \sim 85\%$)
$\Delta\phi(l, E_T) > \pi/2$	$ m_{\tau\tau} - m_Z > 25$ GeV

- Exploit expected spin-0 Higgs, V-A W decay:
 $m(l) < 50$ GeV, $\Delta\phi(l) < 1.8$



Background estimation

- Data-driven estimation of fake-lepton background
- Normalize WW, Top and $Z \rightarrow \tau\tau$ using control region in each jet multiplicity
 - Correlations from control region composition fully taken into account



Stat+Syst errors on Signal Region prediction

Scale Factor	0-jet CR	1-jet CR
WW	1.13 ± 0.11	0.84 ± 0.42
Top	1.04 ± 0.15	1.03 ± 0.38
$Z \rightarrow \tau\tau$	0.87 ± 0.13	0.85 ± 0.15

- Final discriminant

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

$H \rightarrow WW^{(*)} \rightarrow e\nu_e \mu\nu_\mu$: Results

- Statistical analysis: binned likelihood fit on m_T
- Dominant source of uncertainty on signal strength: Statistics, theoretical uncertainty on WW normalization extrapolation (Control \rightarrow Signal region)
- Expected $p_0 = 0.03$ (1.9σ) @ $m_H = 125$ GeV
 - p_0 = probability that a background fluctuation is more signal-like than the observed data

2012-only results

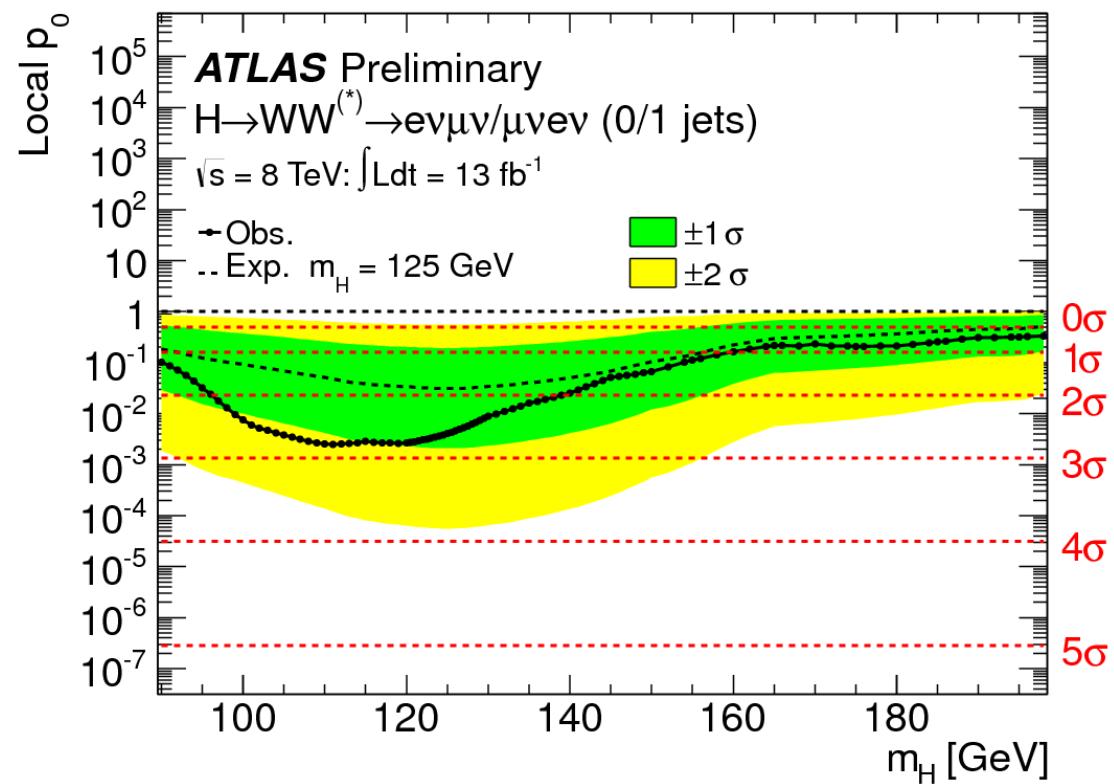
$p_0 = 0.003$ (2.8σ) @ $m_H = 125$ GeV

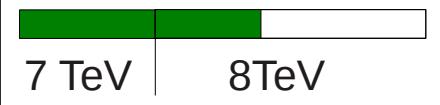
$\mu = \sigma/\sigma_{SM} = 1.5 \pm 0.6$

2011 (published) results

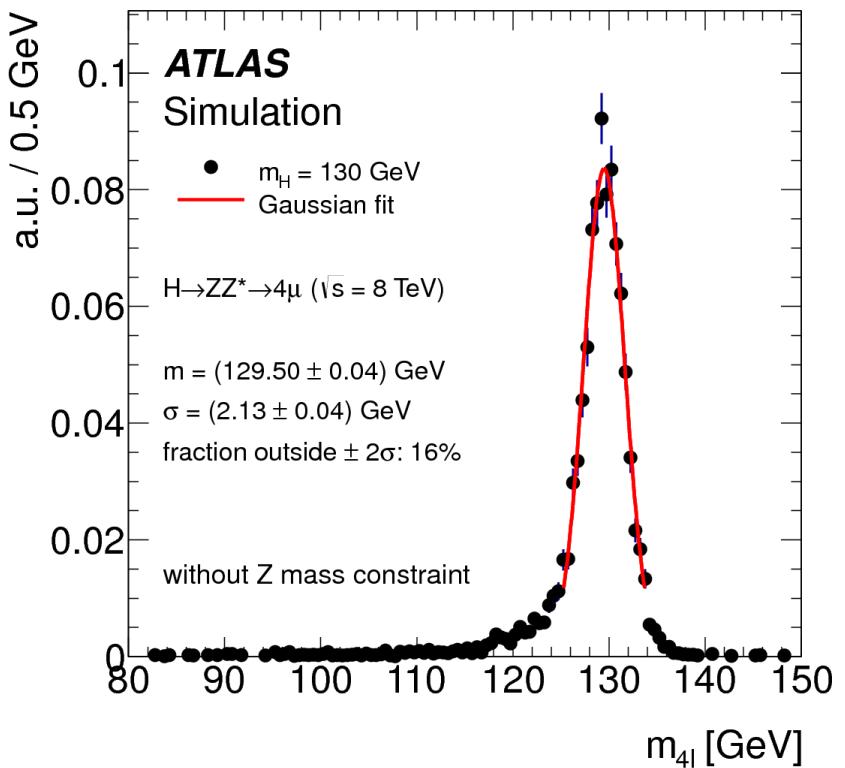
$p_0 = 1.1\sigma$ @ $m_H = 135$ GeV (min p_0)

$\mu = 0.5 \pm 0.6$



$H \rightarrow ZZ^{(*)} \rightarrow 4l (l=e,\mu)$


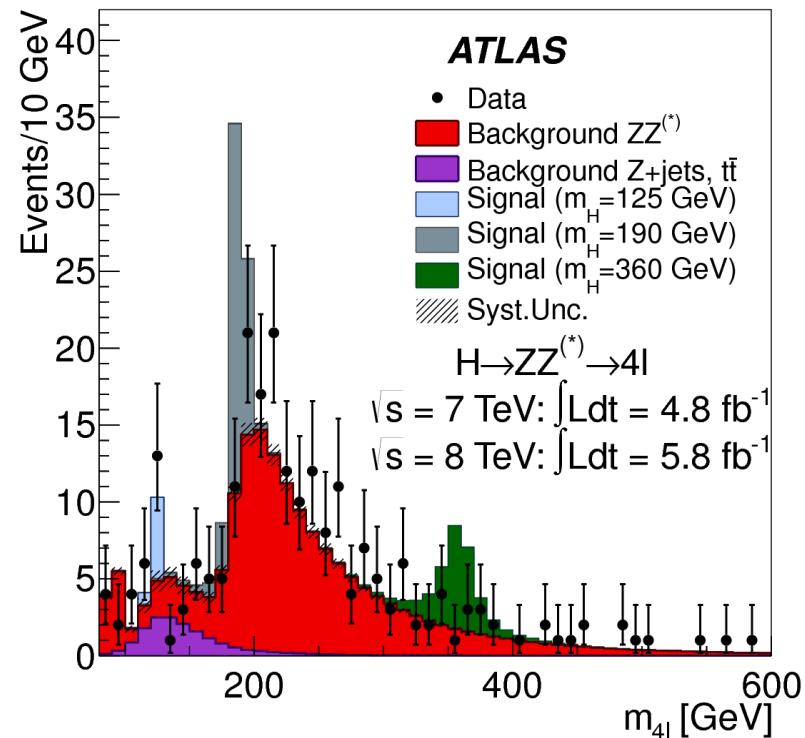
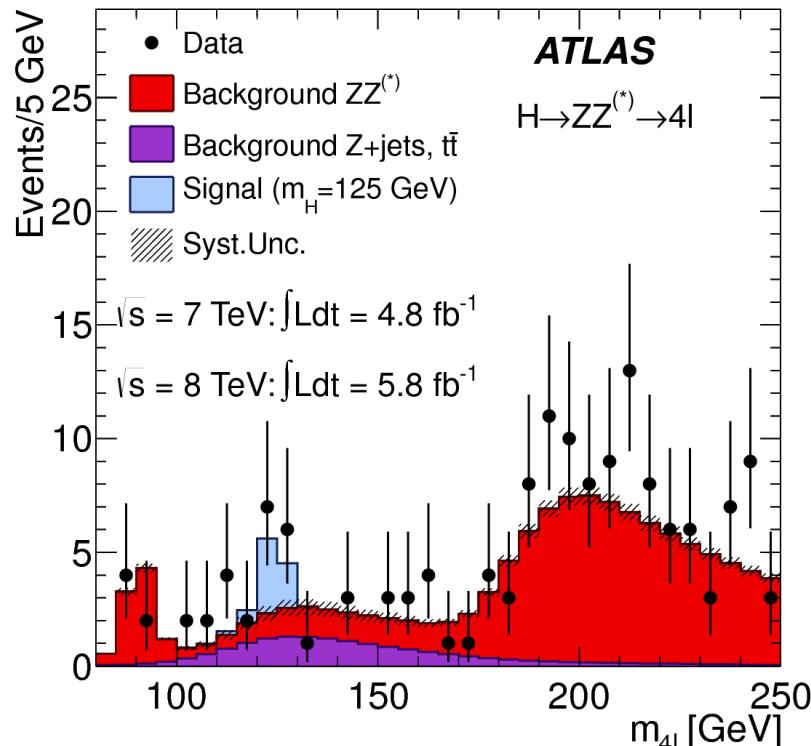
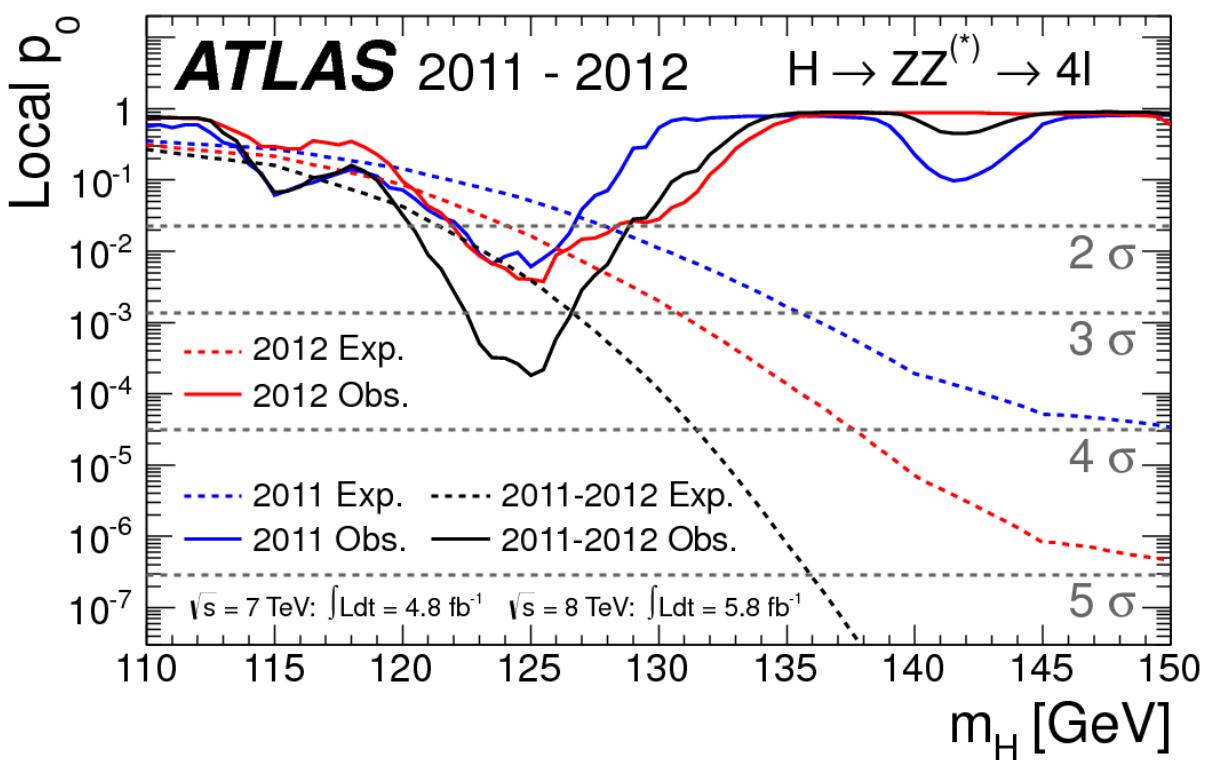
- Two pairs of opposite-sign, same-flavor isolated primary leptons (e, μ)
 - $p_T(l=e(\mu)) > 20, 15, 10, 7(6) \text{ GeV}$
- Loose mass cuts to select offshell $Z^{(*)}$ as well:
 - $50 \text{ GeV} < m_{12} < 106 \text{ GeV}$
 - $m_{34} < 115 \text{ GeV}, m_{34} > 17.5-50 \text{ GeV}$ (sliding with $m(4l)$)

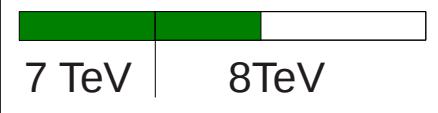


- Main backgrounds: non-resonant $ZZ^{(*)}/\gamma^*$, $t\bar{t} + \text{jets}$, $Z/\gamma^* + \text{jets}$ (mostly $Z + bb$)
- $m(4l)$ resolution: 2.1-2.8 GeV

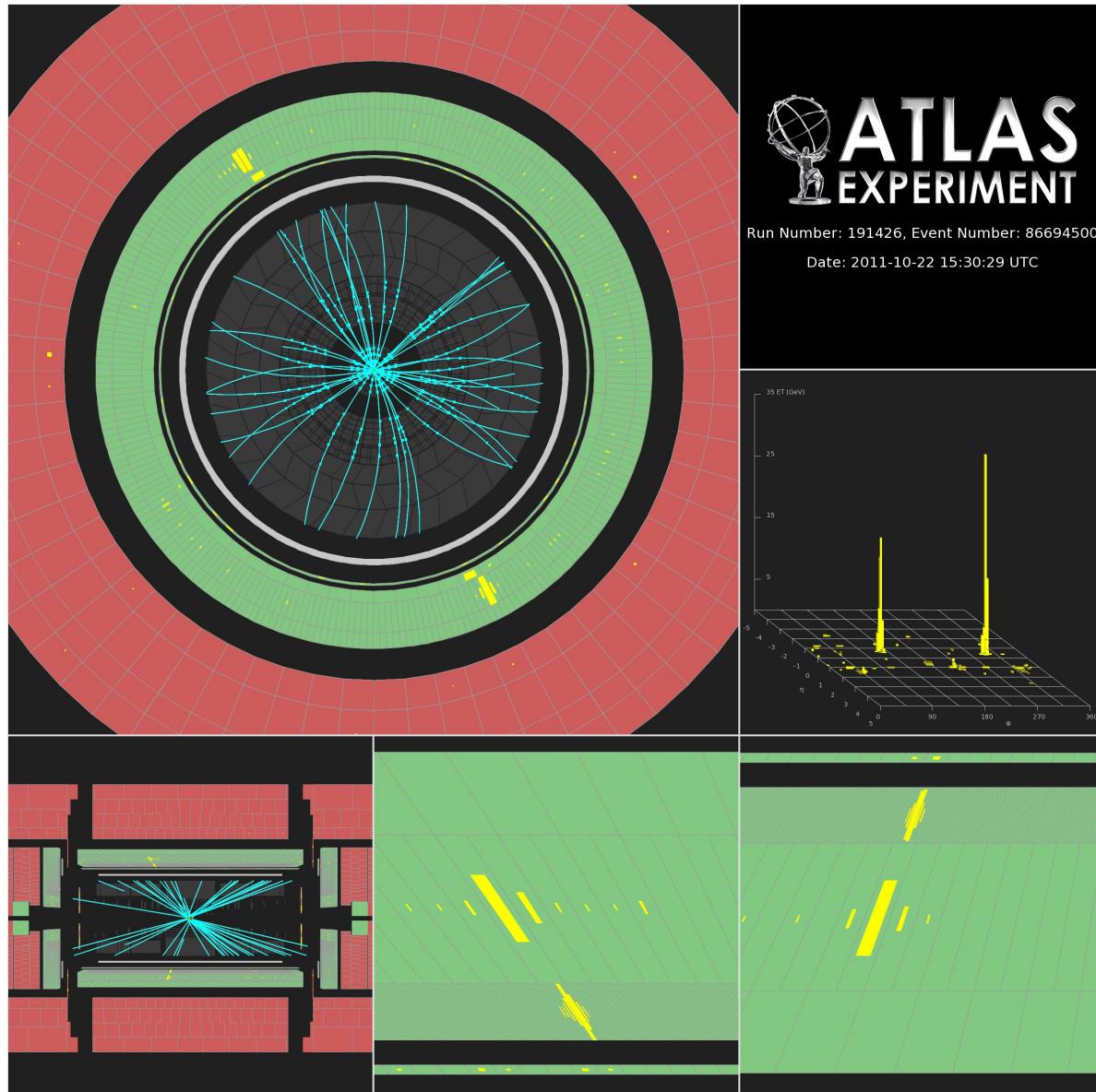
$H \rightarrow ZZ^{(*)} \rightarrow 4l$: Results

- Expected 95% C.L. exclusion of SM Higgs
 m_H 124-164 GeV, 176-500 GeV
- Observed exclusion: 131-162, 170-460 GeV
 - $p_0 \sim 3.6\sigma$ @ $m_H = 125$ GeV (2.7 σ expected)
 - $\mu = 1.2 \pm 0.6$



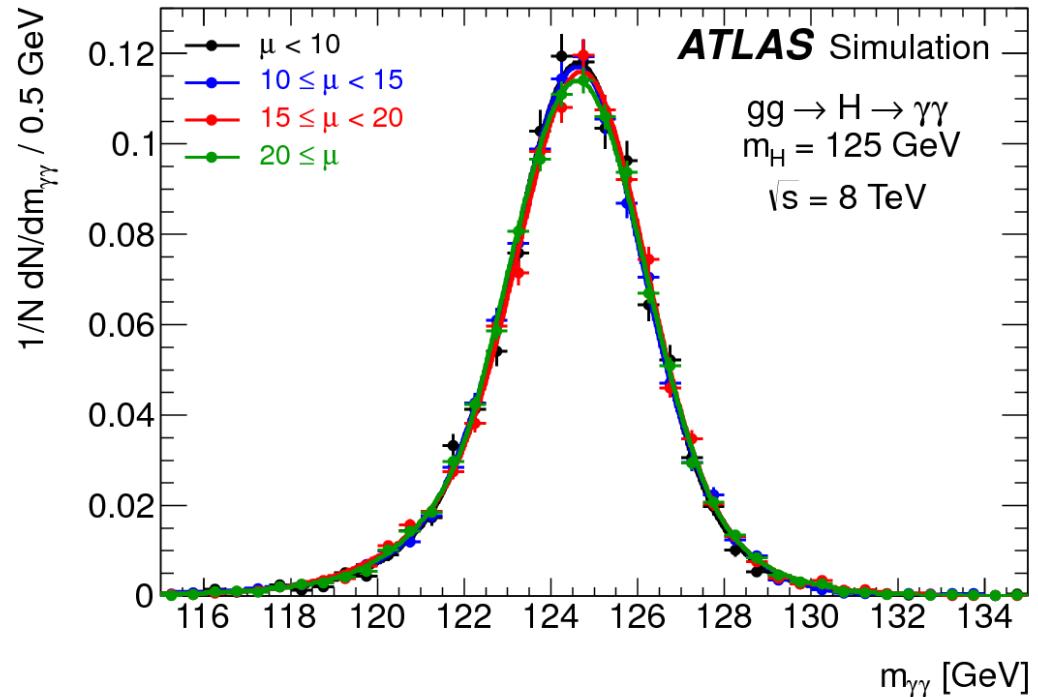
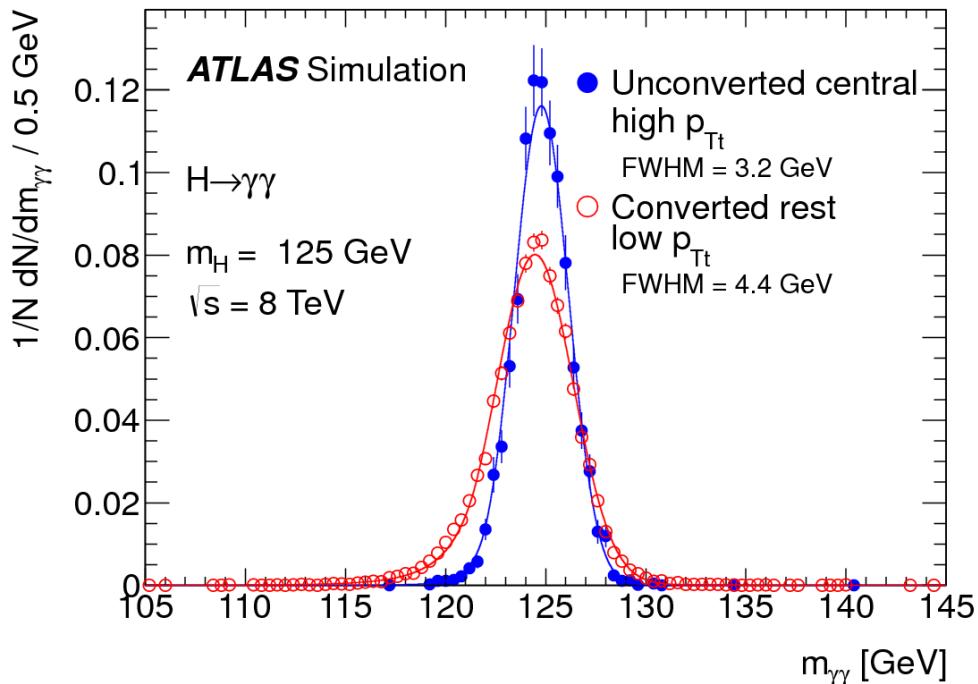
$H \rightarrow \gamma\gamma$ 

- Two isolated photons, $p_T(\gamma_1) > 40$ GeV, $p_T(\gamma_2) > 30$ GeV ($|\eta| < 2.37$)
 - di-photon trigger
- Split into categories to enhance sensitivity and favor different productions:
 - VBF: $>= 2$ jets
 $|\Delta\eta_{JJ}| > 2.8$, $m_{JJ} > 400$ GeV
 $\Delta\phi(\gamma\gamma, JJ) > 2.6$
 - 9 more categories based on conversion- p_T - η of di-photon candidates
- Main background from non-resonant $\gamma\gamma$ (75-80%), γ +jet, di-jets



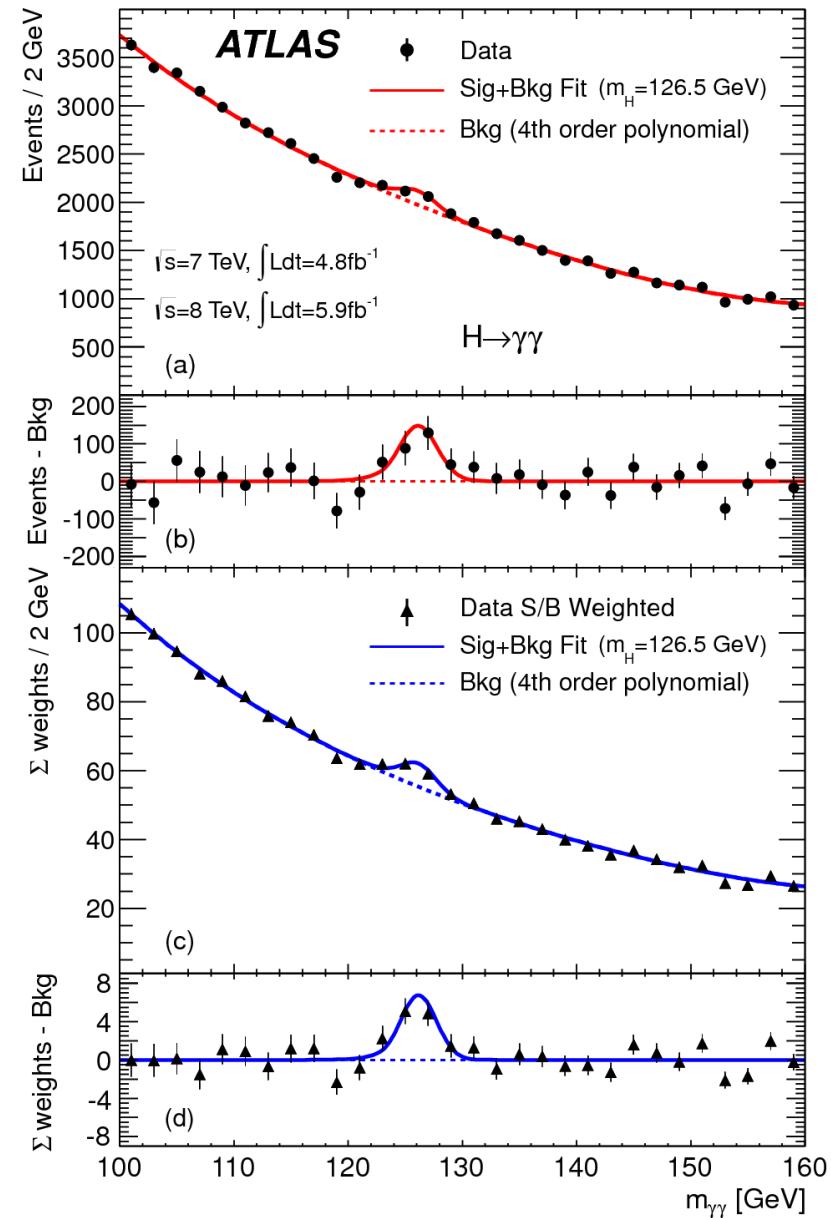
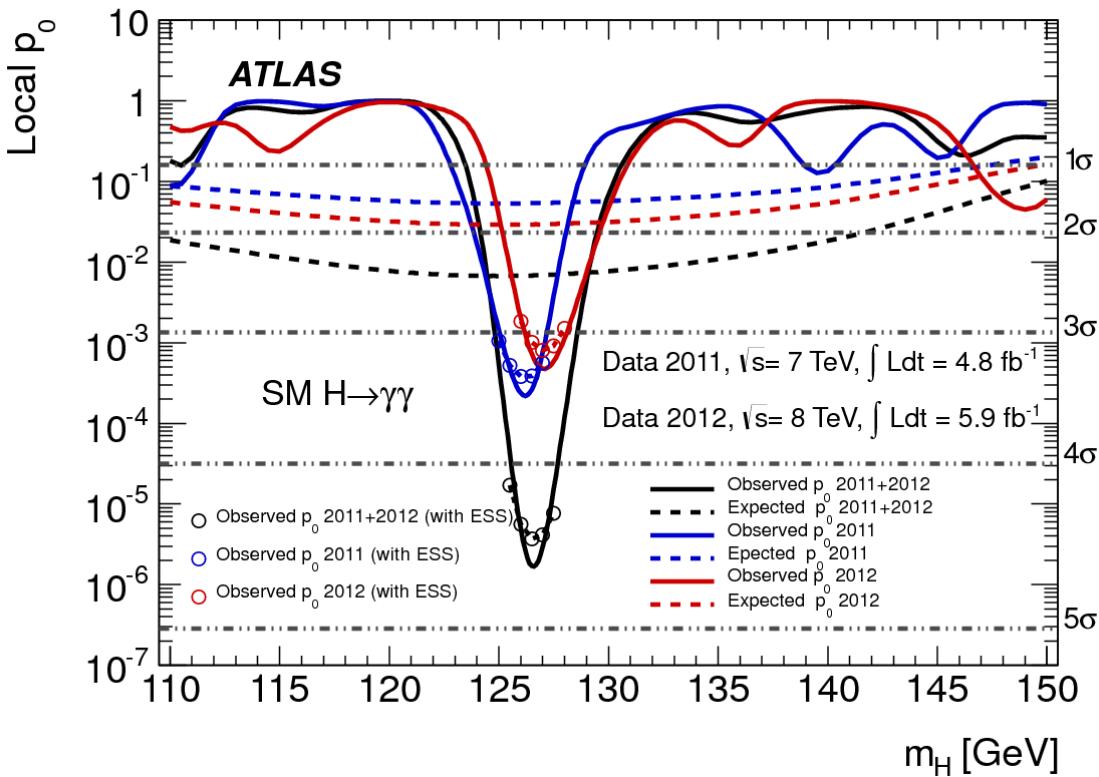
Photon ID and mass resolution

- Photon ID based on EM calorimeter shower shapes
 - Cut-based approach (2012) or combined with a Neural Network (2011)
 - Stable performance against fast raising pile-up
- Energy scale determined from $Z \rightarrow ee$ events and simulation, well controlled
- Mass resolution dominated by energy term $m = E_1 E_2 \cdot \sin(\Delta\theta)$
 - Expected resolution (FWHM) ranging 3.2-6.1 GeV (average: 3.9 GeV)



$H \rightarrow \gamma\gamma$: Results

- Fit $m(\gamma\gamma)$ with analytic models for signal and background
 - Shape validation on simulation
- Dominant uncertainties: energy resolution, background modeling,
- $p_0 \sim 4.5\sigma$, $m_H = 126.5 \text{ GeV}$, $\mu = 1.8 \pm 0.5$



(2) Include other refined and updated decay channels

- $H \rightarrow \tau\tau (\tau_l\tau_l \oplus \tau_l\tau_h \oplus \tau_h\tau_h)$ Updated
- $H \rightarrow b\bar{b}$
 - Associated production with W,Z Updated
 - $t\bar{t}H$ production NEW

$$H \rightarrow \tau\tau (\tau_\ell\tau_\ell, \tau_\ell\tau_h, \tau_h\tau_h)$$

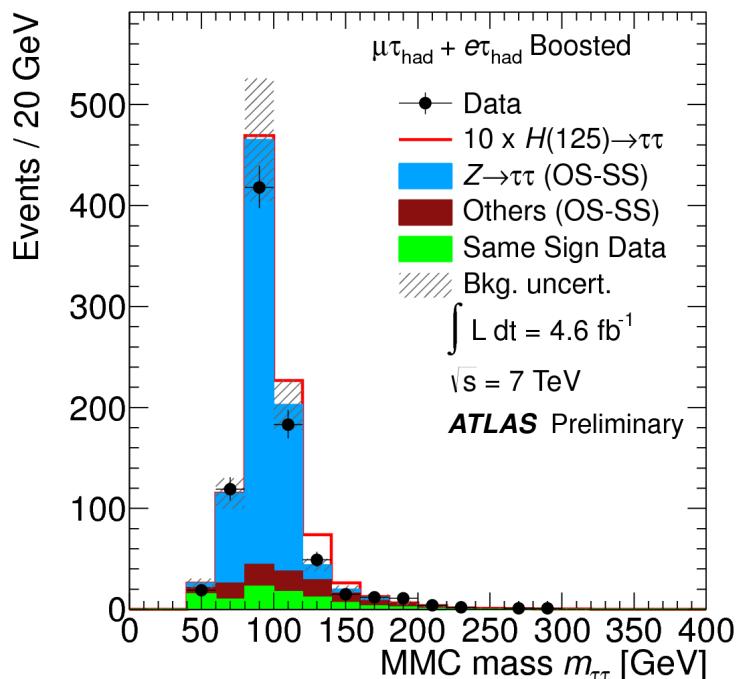
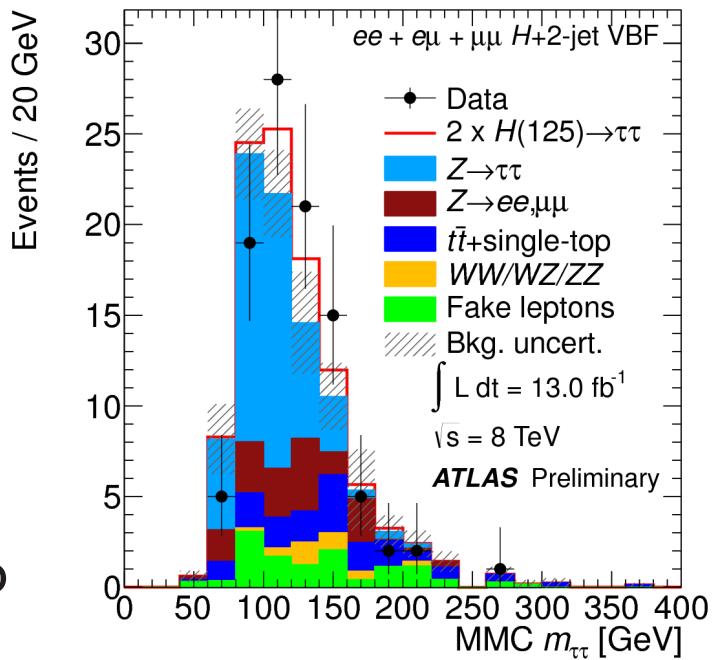
Total L = 17.6 fb⁻¹

7 TeV 8 TeV

- Trigger on single/di-lepton, lepton+ τ_h and di- τ_h
- Divide each search in different S/B categories
 - VBF \rightarrow 2-jet events with $\Delta\eta_{JJ}$, m_{JJ} requirements
 - Boosted \rightarrow select high $p_T(H)$ events (mainly ggF Higgs production)
 - Lower S/B^{1/2} categories to maximize acceptance
- Main background from $Z/\gamma^* \rightarrow ll$ (mostly $\tau\tau$), Fakes, Top
- Reconstruct $m(\tau\tau)$ exploiting kinematic correlation of E_T and visible decays products from τ
 - MMC method
 - 13-20% resolution

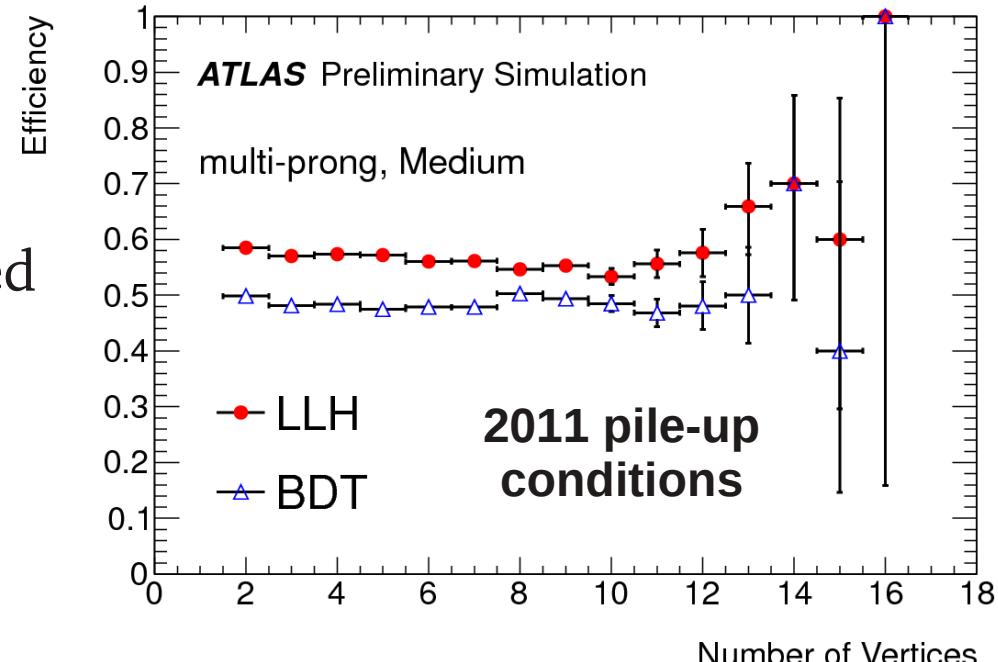
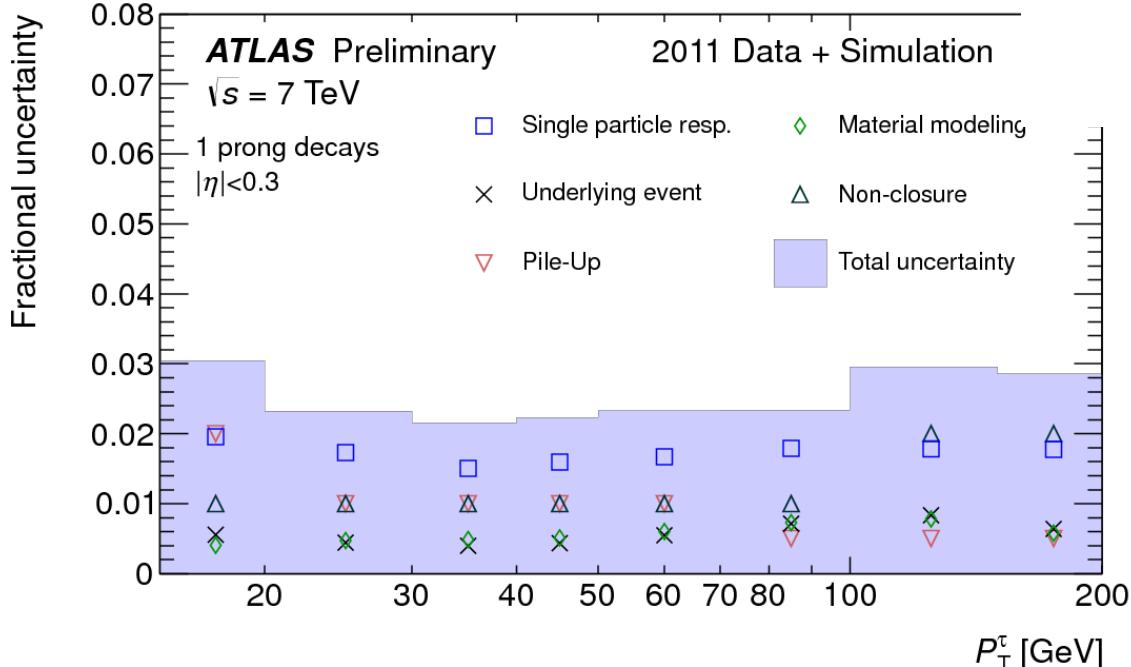
Fully re-optimized analysis

- Re-analysis of 2011 data
- Improved τ identification
- Re-optimize S/B categories



τ_h reconstruction and energy calibration

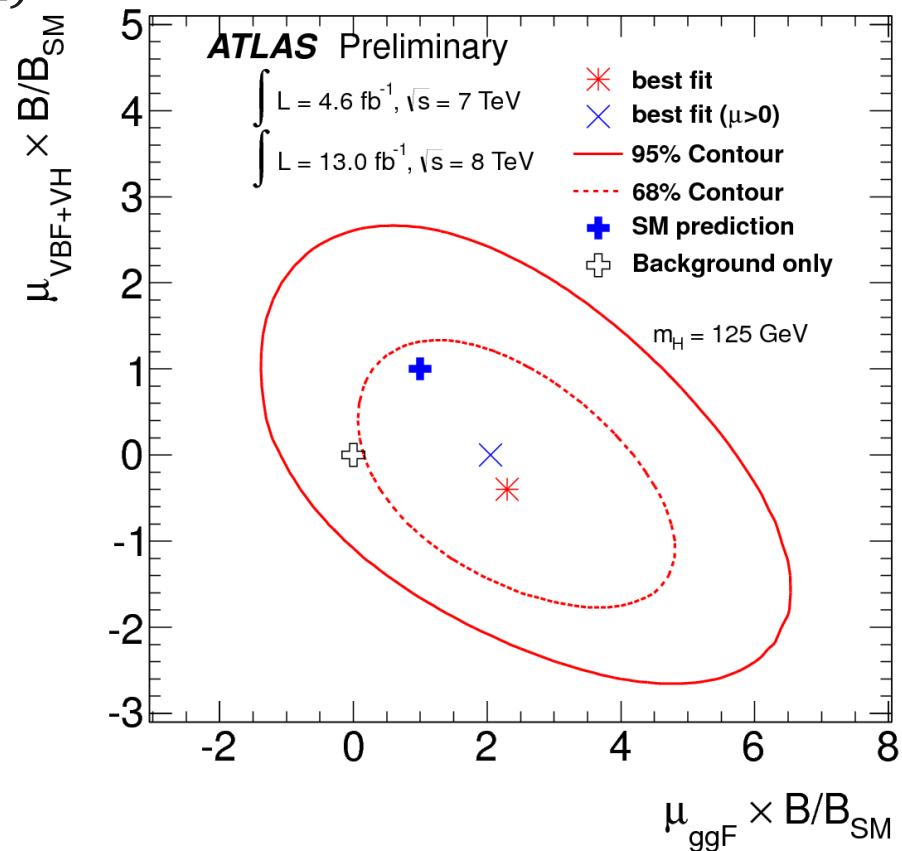
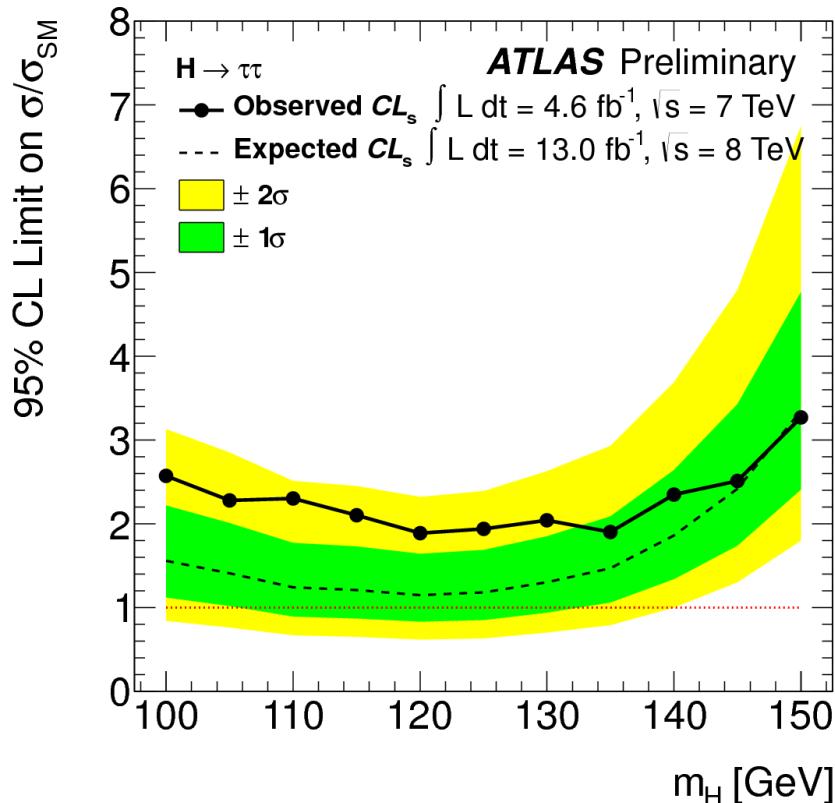
- Reconstruct 1/3-prong hadronic τ using tracking+calorimeter information
- Identify with Boosted Decision Tree
 - Enhanced pile-up robustness
 - Higher purity than likelihood-based
- Measure efficiency/ lepton fake rate using W and Z events.



- Need ad-hoc energy calibration to account for specific mixture of charged and neutral pions
 - 3-5% total uncertainty
 - Very important systematic for $H \rightarrow \tau\tau$ searches

$H \rightarrow \tau\tau$ results

- Use binned likelihood fit to reconstructed $\tau\tau$ mass
- Sensitivity approaching Standard Model
 - Expected limit $\sim 1.2 \sigma^{\text{SM}}$ @ $m_H = 125$ GeV, Observed $1.9 \sigma^{\text{SM}}$
 - Local significance $p_0 = 1.1\sigma$ (1.7σ expected), $\mu = \sigma/\sigma_{\text{SM}} = 0.7 \pm 0.7$
- Also fit separately $\mu(\text{ggF})$ vs $\mu(\text{VBF+VH})$



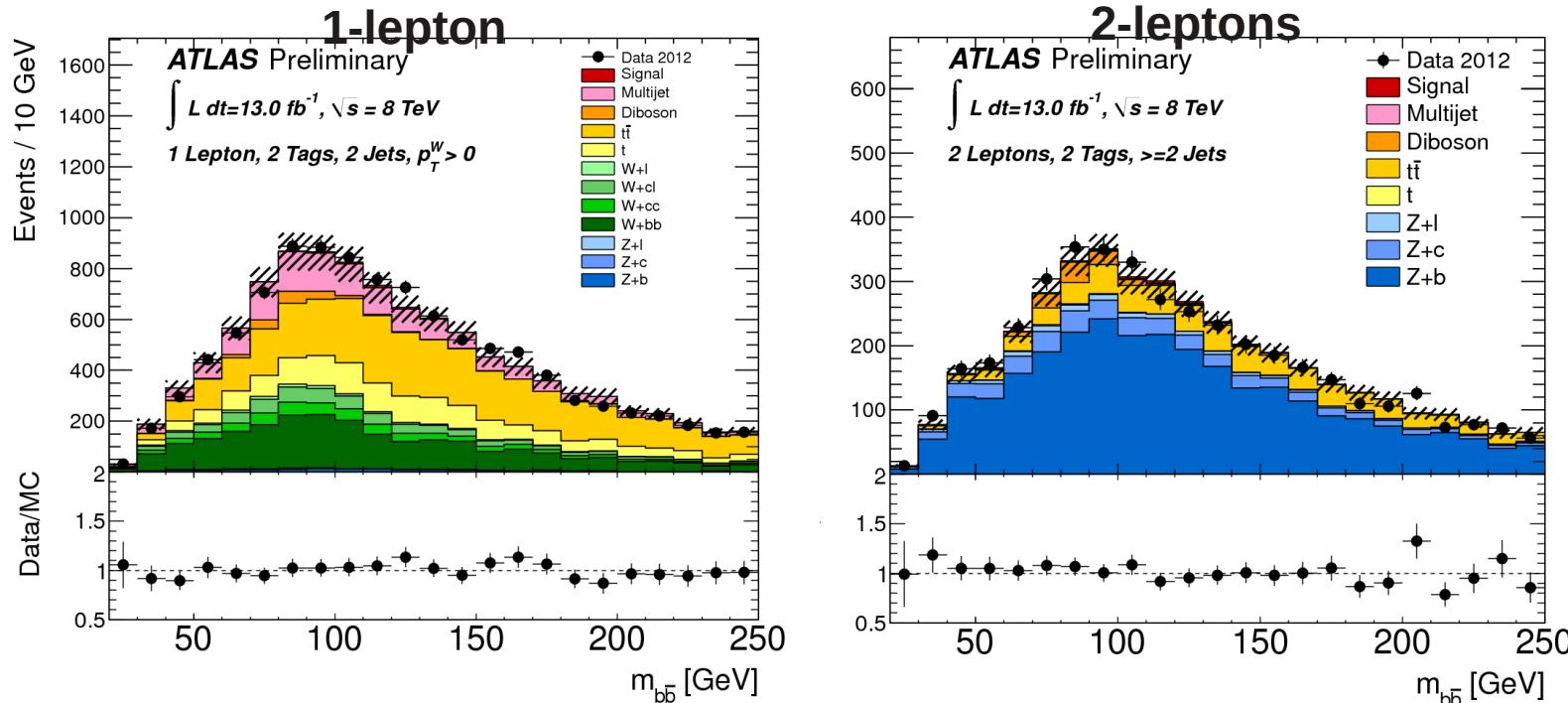
VH $\rightarrow b\bar{b}+X$ search (V=W,Z)

- Three searches: $b\bar{b} + (0, 1, 2)$ leptons (e, μ) in bins of $p_T(V)$
 - Re-analysis of 2011 dataset as well, re-optimized selections
 - E_T trigger for 0-lepton, single/di-lepton triggered 1,2-leptons samples
 - Exactly 2 jets ($p_T > 45,20$ GeV) b-tagged @ 70% efficiency
- Main backgrounds: W/Z+jets, Top(, Multi-jet) \rightarrow mostly b,c-hadrons
- Use sidebands of $m(b\bar{b})$ and control regions to normalize W/Z+jets and Top

Z+b,c,light

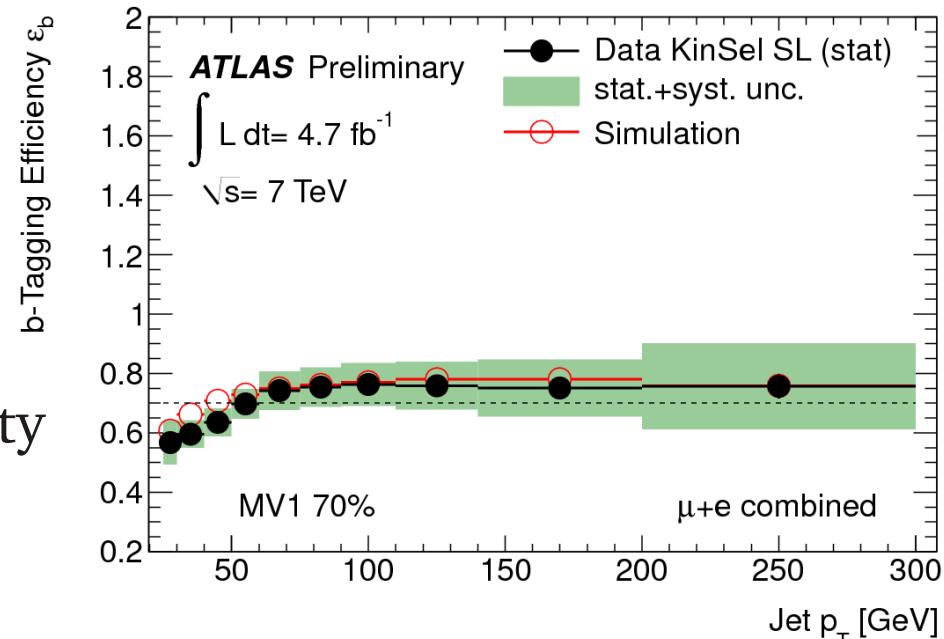
W+b,c,light

t \bar{t} , single top



Heavy-flavor jets

- Jets with heavy flavor (b,c) hadrons tagged using multivariate technique
 - Exploit secondary vertices, high transverse impact parameter tracks
 - Greatly reduced efficiency uncertainty thanks to calibration in $t\bar{t}$ events
- Fit control regions with 0,1,2 b-jets to extract W/Z+jets flavor composition
 - The fit is performed simultaneously in all channels

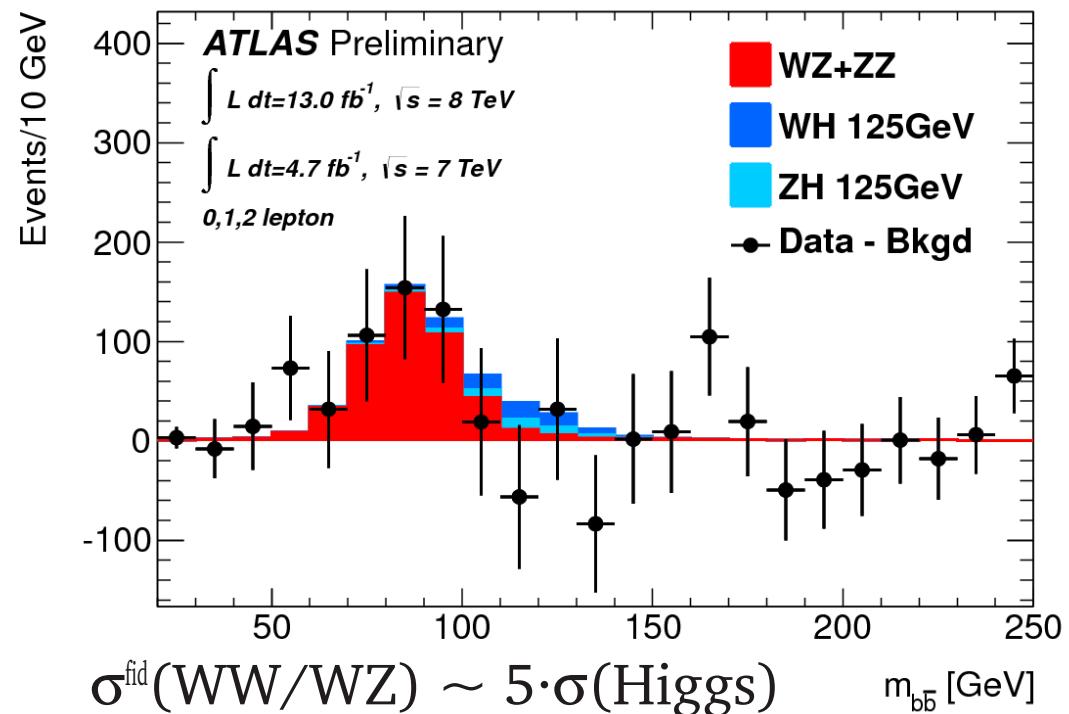
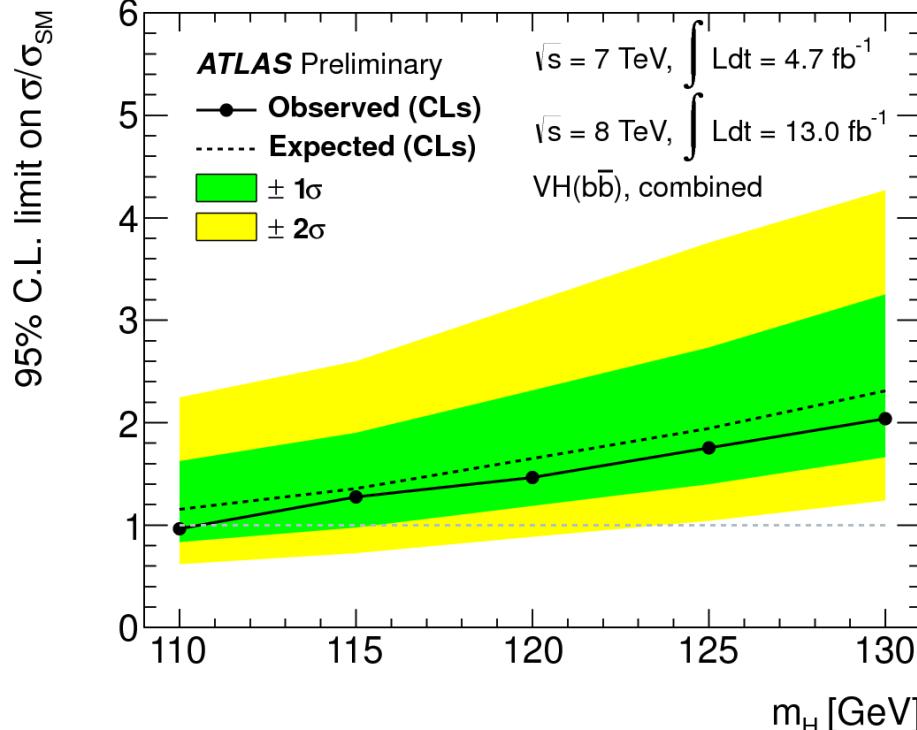


Data/MC	$\sqrt{s} = 7 \text{ TeV}$	$\sqrt{s} = 8 \text{ TeV}$
$Z + c$	1.99 ± 0.51	0.71 ± 0.23
$Z + \text{light}$	0.91 ± 0.12	0.98 ± 0.11
$W + c$	1.04 ± 0.23	1.04 ± 0.24
$W + \text{light}$	1.03 ± 0.08	1.01 ± 0.14

W/Z+b and Top from final fit		
Data/MC	$\sqrt{s} = 7 \text{ TeV}$	$\sqrt{s} = 8 \text{ TeV}$
Top	1.10 ± 0.14	1.29 ± 0.16
$Z + b$	1.22 ± 0.20	1.11 ± 0.15
$W + b$	1.19 ± 0.23	0.79 ± 0.20

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

- Fit $m(b\bar{b})$ distribution
- Main systematic uncertainties:
b-jet efficiency, jet energy scale
- Measure $WZ/ZZ \rightarrow b\bar{b} + X$ as validation of analysis techniques
 - $\mu^{WW/WZ} = 1.09 \pm 0.30$ (4.0σ)

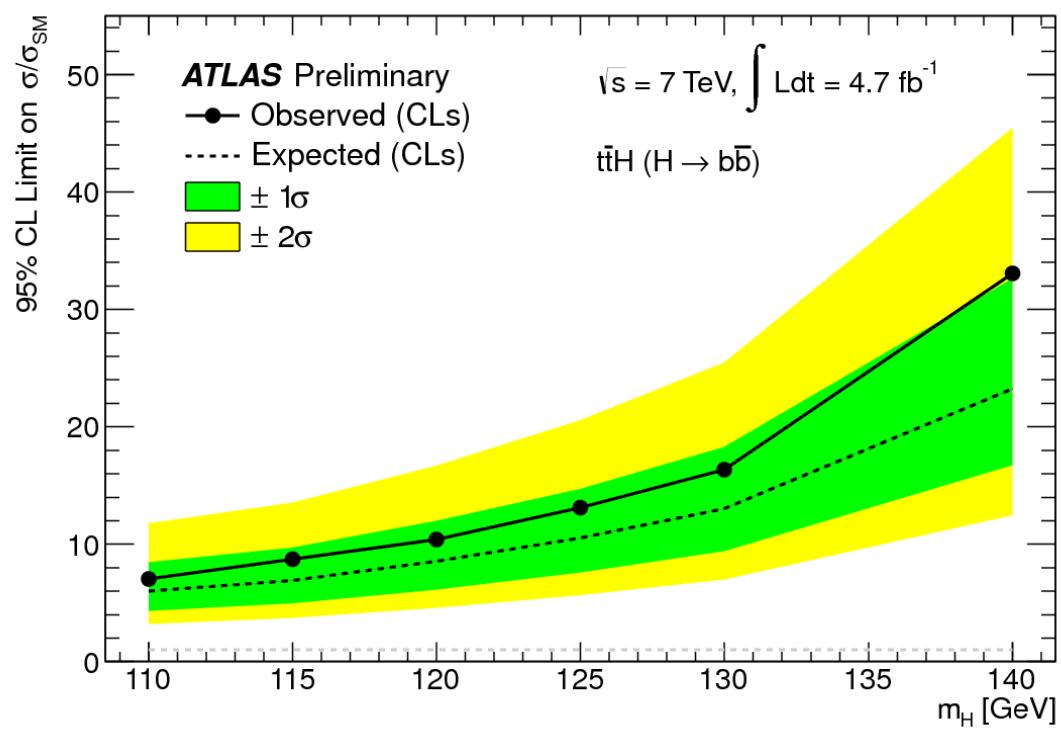
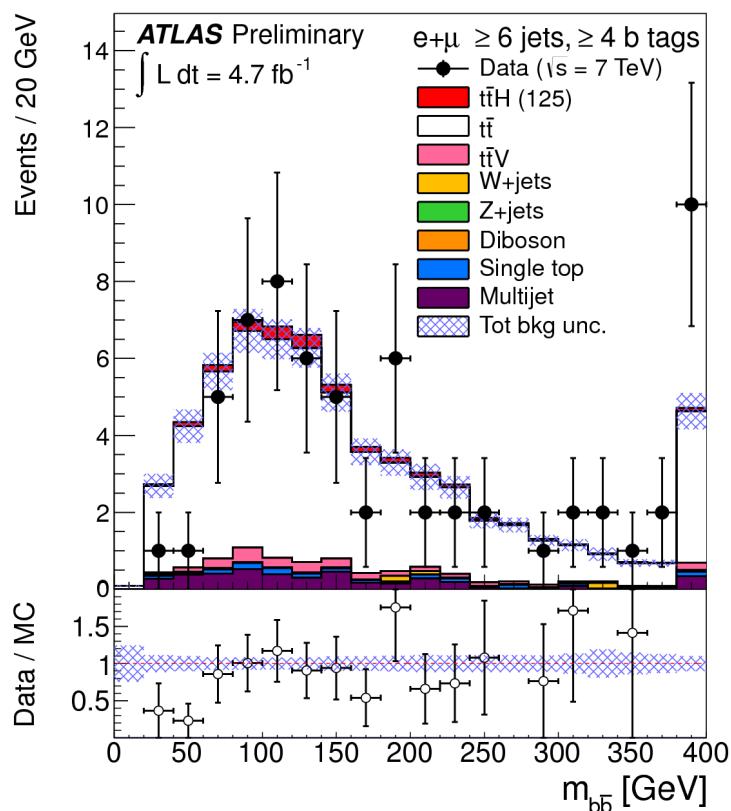


On the Higgs search, data shows no excess on top of expected backgrounds

- Expected limit $1.9 \sigma/\sigma_{\text{SM}}$ @ $m_H = 125 \text{ GeV}$
 - Observed limit $1.8 \sigma/\sigma_{\text{SM}}$
- $p_0 = 0.64$ (0.15 expected), $\mu = -0.4 \pm 1.1$

$t\bar{t}H \rightarrow b\bar{b} + X$ search

- Exploit production mechanism to reduce backgrounds
- High- p_T isolated $e/\mu + E_T + 4\text{-}6$ jets (0-4 b-tagged), $S/B^{1/2}$ up to 0.25
 - Use kinematic fit to assign jets and $m(b\bar{b})$ (most sensitive categories) or use $\Sigma p_T(\text{jets})$ as discriminating variable
- Main backgrounds: $t\bar{t} + \text{jets}$ (simulation), Multi-jet (data-driven)



(3) Keep looking for other possible signals of (beyond Standard-Model) Higgs

- High-mass Higgs searches
- MSSM Higgs
- Fermiophobic Higgs
- NMSSM searches (photons, muons)

High-mass Higgs searches

- Presented searches look for Higgs-like bosons with m_H as high as 600 GeV
- Some final state are particularly sensitive to the region $m_H > 200$ GeV

$H \rightarrow ZZ \rightarrow ll + E_T$ ($l=e,\mu$)

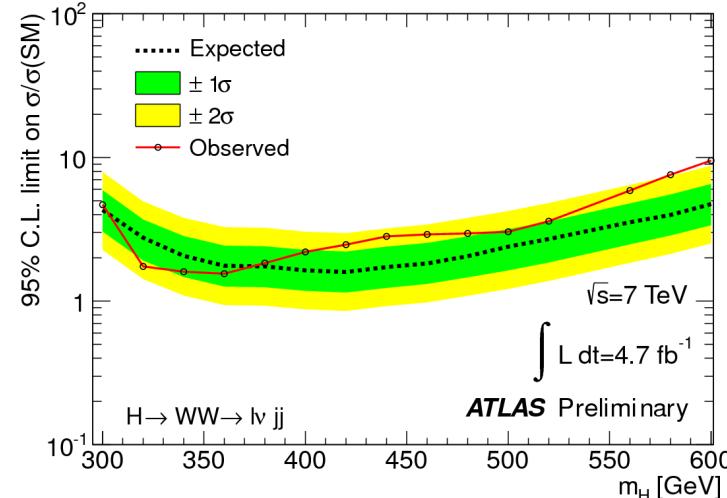
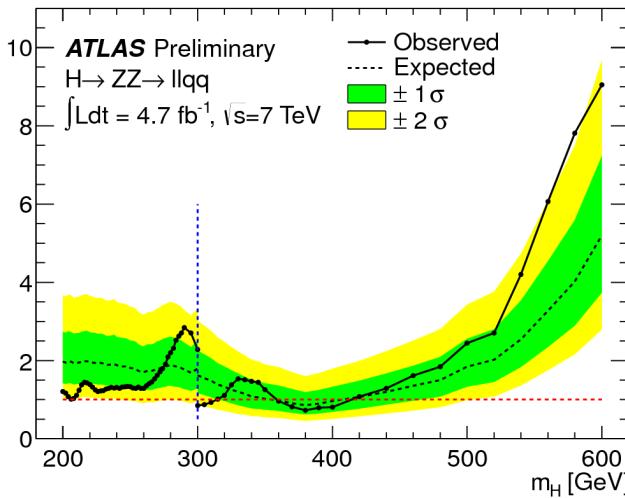
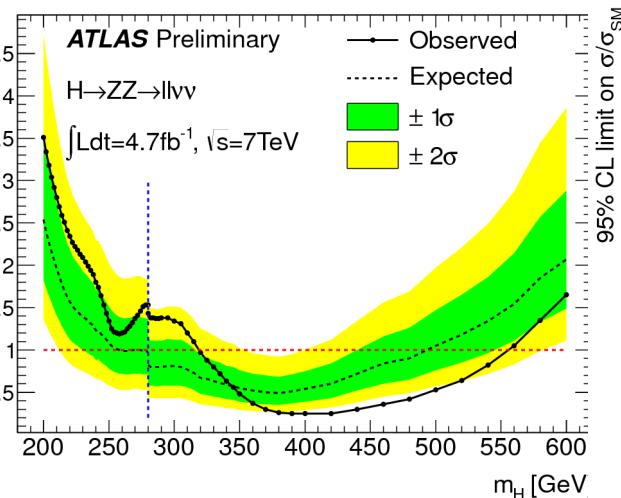
- high E_T , veto b-jets
- $\Delta\phi(l)$ based on expected Z boost
- Main background: ZZ/WW/WZ, Top
- Look at $m_T(ll, E_T | ZZ)$

$H \rightarrow ZZ \rightarrow lljj$ ($l=e,\mu$)

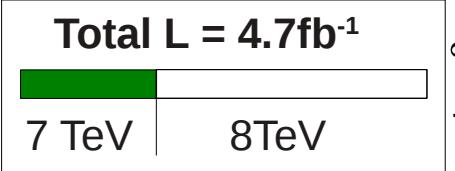
- Split in <2 , $=2$ b-tags
- Z window in $m(ll)$, low E_T
- Main backgrounds: Drell-Yan, Top
- Fully reconstructed $m(lljj)$

$H \rightarrow WW \rightarrow l+E_T + jj$ ($l=e,\mu$)

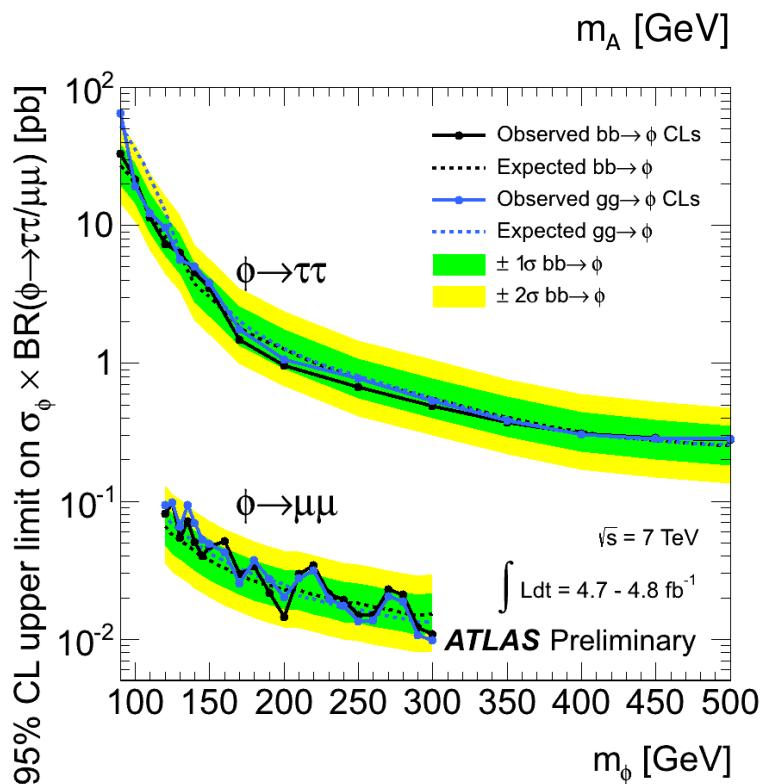
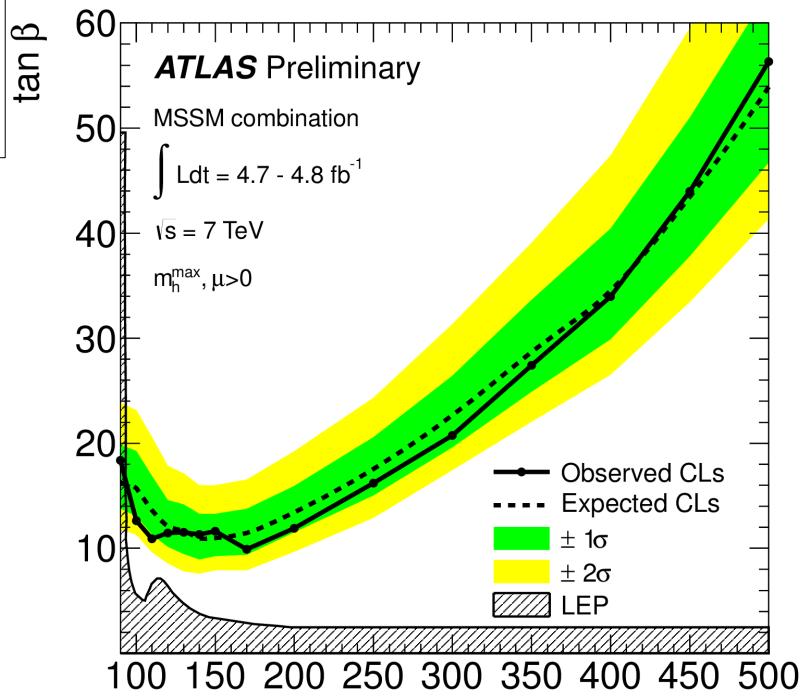
- $\Delta R(jj)$ to mitigate W+jets
- Restrict $\eta(j)$ to reduce Jet Energy scale syst.
- Main Background: W+jets
 - Data-driven+MC, fit E_T
- Fit to $m(lvjj)$



MSSM Neutral Higgs

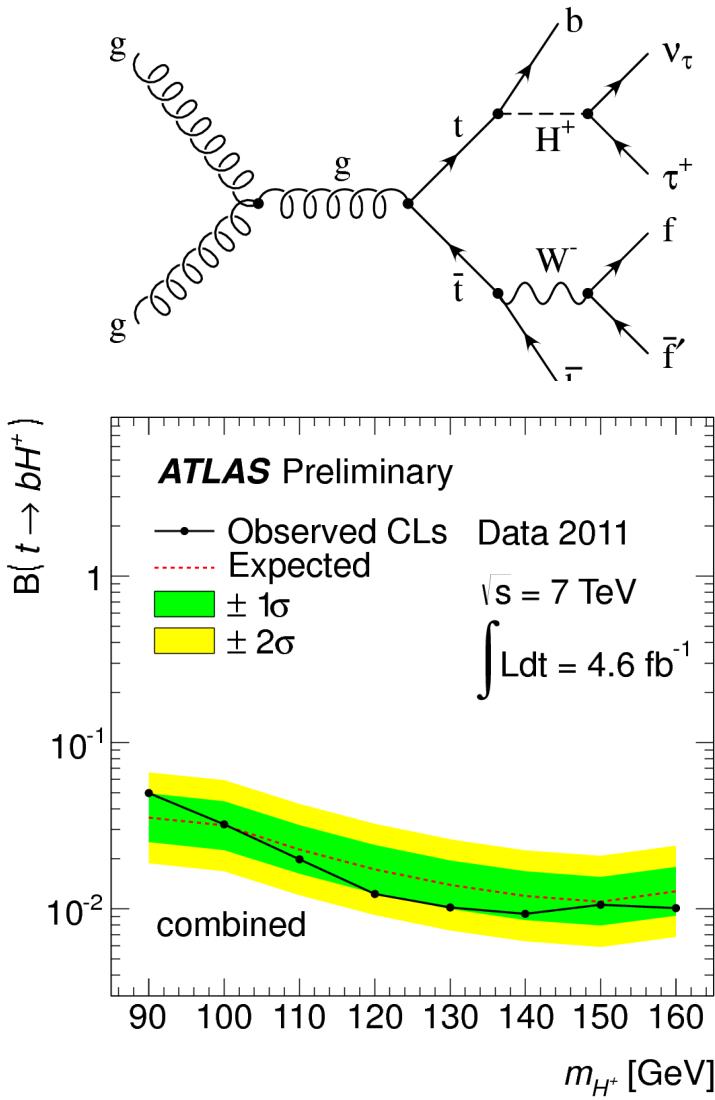
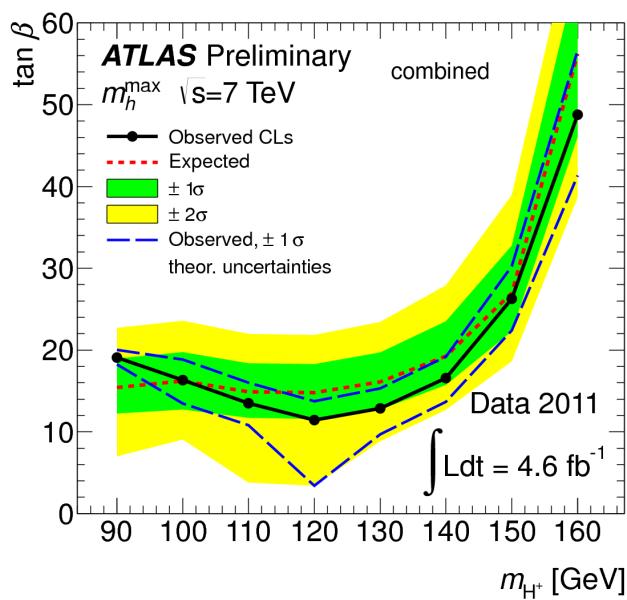


- Probe Higgs coupling to leptons:
 $\phi \rightarrow \tau^+ \tau^-$, $\phi \rightarrow \mu^+ \mu^-$
- ϕ produced by gluon fusion or in association to b-quarks
 - Split searches in events with at least one jet b-tagged or not
- $H \rightarrow \mu\mu$: use local sideband fit in $m(\mu\mu)$ to estimate background (mostly $Z/\gamma^* \rightarrow \mu\mu$)
- $H \rightarrow \tau\tau$: use both leptonic and hadronic: $\tau_1 \tau_1$, $\tau_1 \tau_h$, $\tau_h \tau_h$
 - Analysis technique similar to SM search
- Interpret results as generic scalar resonance decay and in MSSM model (m_h^{\max} scenario)



Charged Higgs searches

- MSSM Charged Higgs mainly decays to $\bar{c}s$ ($\tan\beta < 1$), $\tau\nu$ ($\tan\beta > 3$), $W\bar{b}b$
- Search for $m(H^\pm) < m(\text{top})$ focus on top decay to charged Higgs
- $H^\pm \rightarrow cs$: reconstruct top kinematic, use di-jet mass as discriminating variable
- $H^\pm \rightarrow \tau\nu$: divide analysis in three channels
 - $t\bar{t} \rightarrow b\bar{b} jj (e/\mu) E_T$
 - $t\bar{t} \rightarrow b\bar{b} jj \tau_{\text{had}} E_T$
 - $t\bar{t} \rightarrow b\bar{b} (e/\mu) \tau_{\text{had}} E_T$



Conclusions

- More information available on the newly discovered boson
 - $H \rightarrow ZZ^*$, $\gamma\gamma$ and WW^* entering the era of precision measurements
- Presented the first results on 2012 dataset of searches for $H \rightarrow b\bar{b}$ and $H \rightarrow \tau\tau$
 - Sensitivity close to SM expectation, no excess yet \rightarrow need full 2012 data!
- Keep looking for beyond-SM Higgs (particularly SUSY extensions)
 - Make limits easy to be interpreted in other models as well
- Exciting times of measurements (and new discoveries?) are ahead,
 - LHC will deliver $> 20\text{fb}^{-1}$ in 2012
 \rightarrow significantly increasing the available dataset
 - Those data will certainly tell us more about the nature of the newly discovered boson!

References

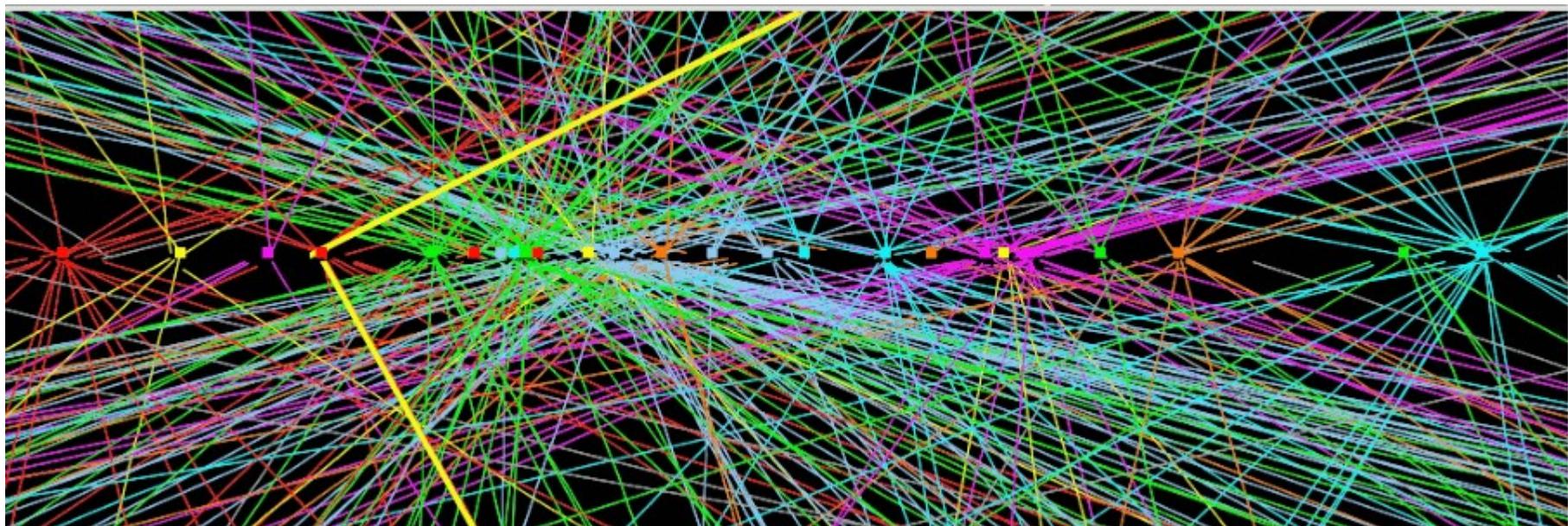
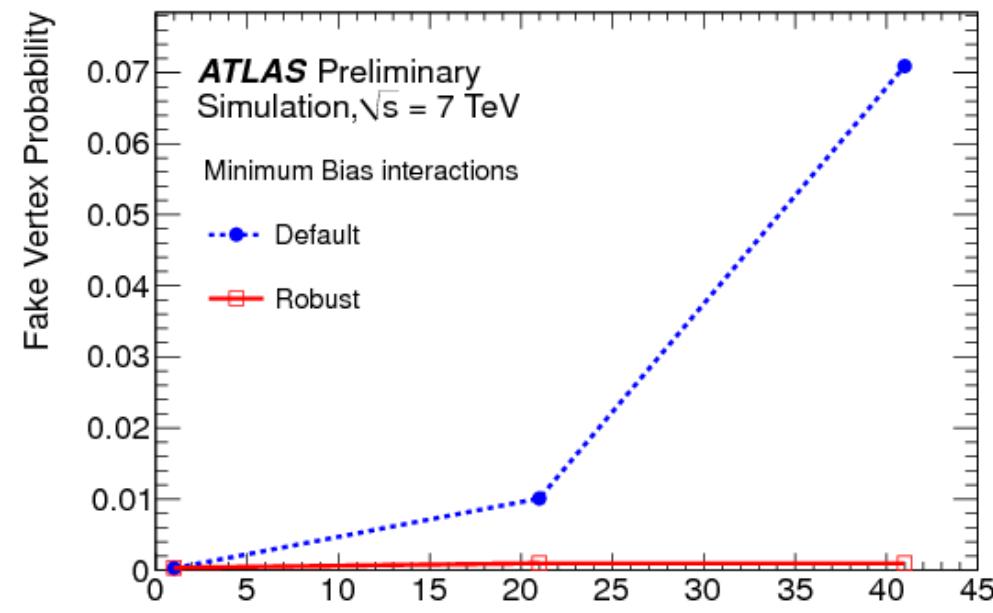
- $H \rightarrow WW \rightarrow e\mu\nu\nu$ ATLAS-CONF-2012-158
- $H \rightarrow ZZ \rightarrow 4l$, $H \rightarrow \gamma\gamma$, 2011 $H \rightarrow WW$ Phys. Lett. B 716 (2012) 1-29
- $H \rightarrow \tau\tau$ ATLAS-CONF-2012-160
- $VH \rightarrow bb + X$ ATLAS-CONF-2012-161
- $ttH \rightarrow bb + X$ ATLAS-CONF-2012-135
- $H \rightarrow ZZ \rightarrow ll\nu\nu$ ATLAS-CONF-2012-016
- $H \rightarrow ZZ \rightarrow lljj$ ATLAS-CONF-2012-017
- $H \rightarrow WW \rightarrow lljj$ ATLAS-CONF-2012-018
- MSSM Neutral Higgs ATLAS-CONF-2012-024
- Charged Higgs ATLAS-CONF-2012-011
ATLAS-CONF-2011-094

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic>

BACKUP

Data taking conditions

- Impressive work by LHC colleagues to maximize integrated luminosity
 - Last updated analyses use up to 13fb^{-1} of 8 TeV (2012) data
- Pile-up conditions exceed design → big effort to keep the optimal performance in object reconstruction (e.g. jets, E_T , ...)

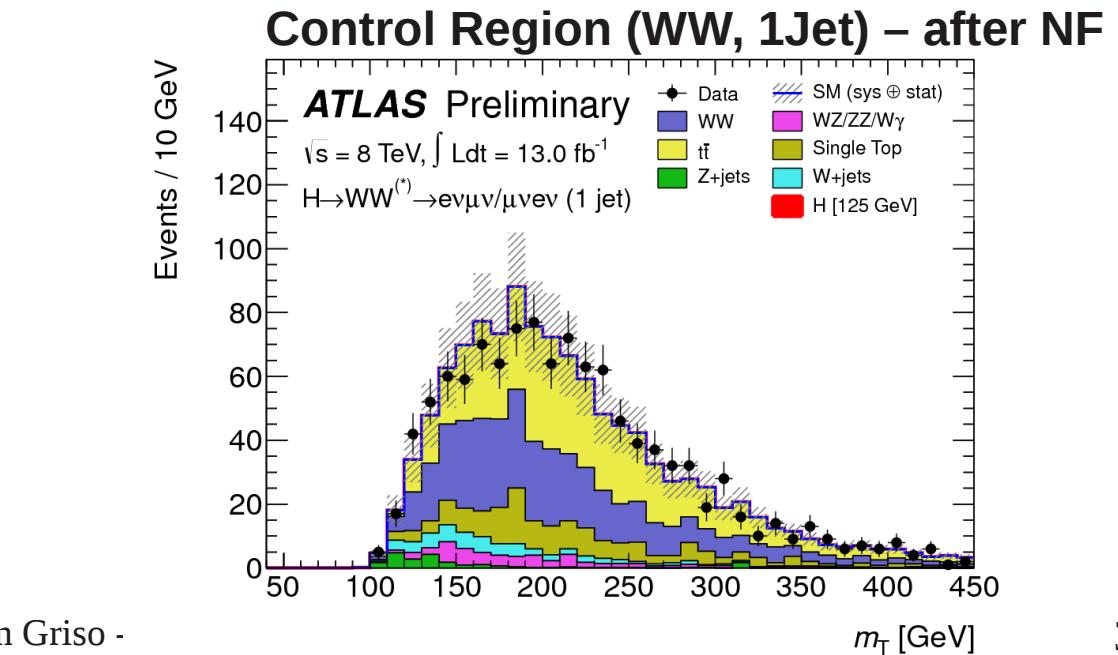
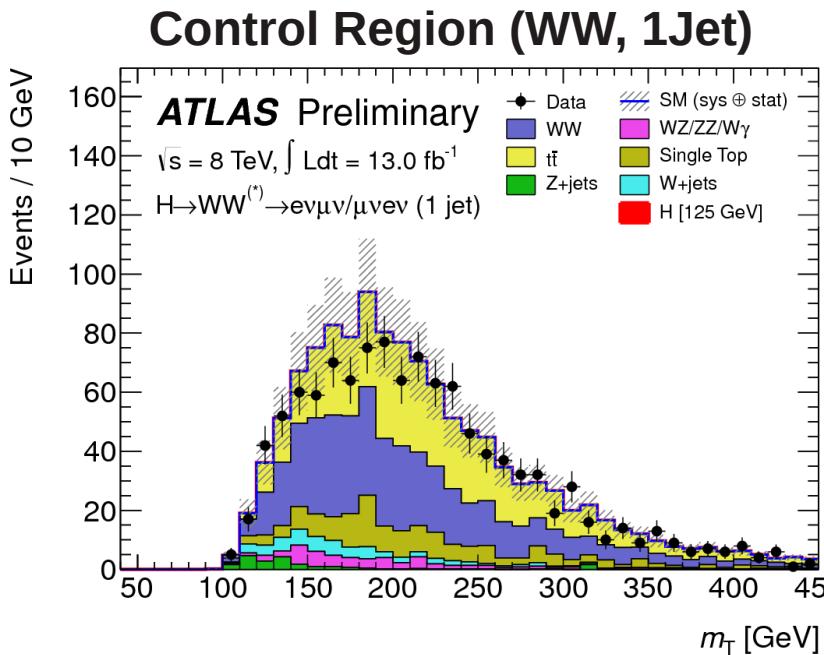
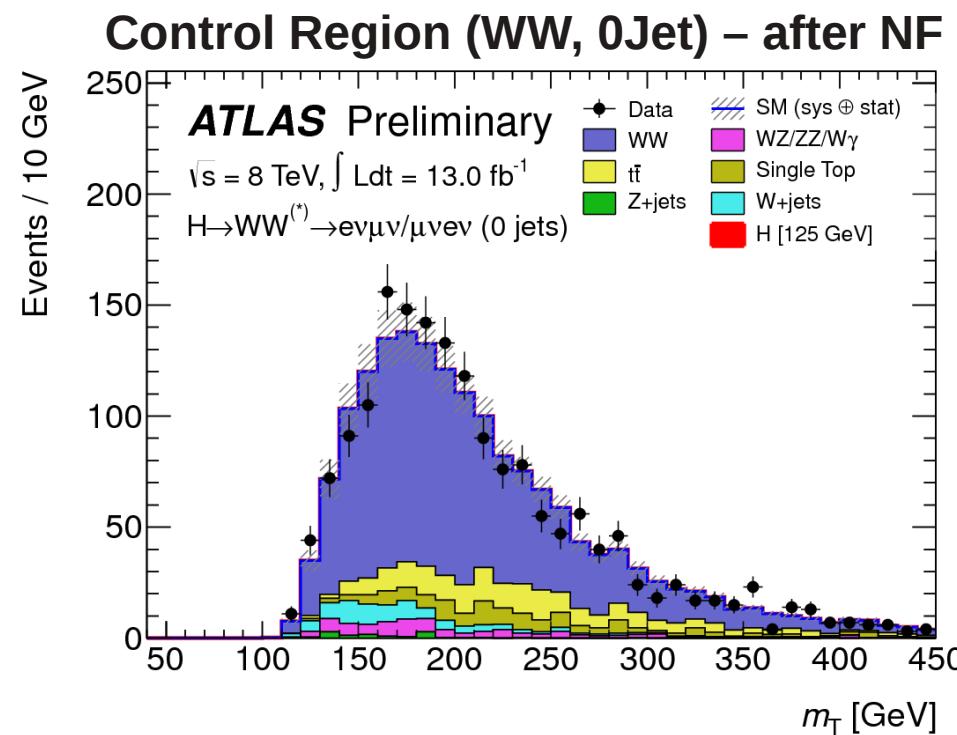
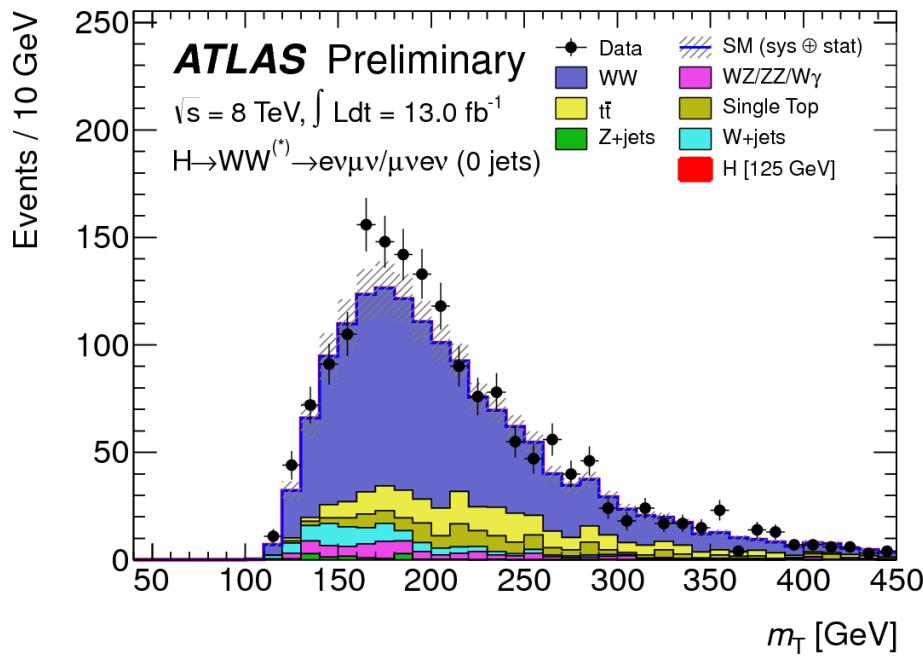


$$\mathcal{L}(\mu, \theta) \sim \prod P(\text{Obs}|\text{Exp}(\mu, \theta)) \cdot \prod_i N(\theta_i)$$

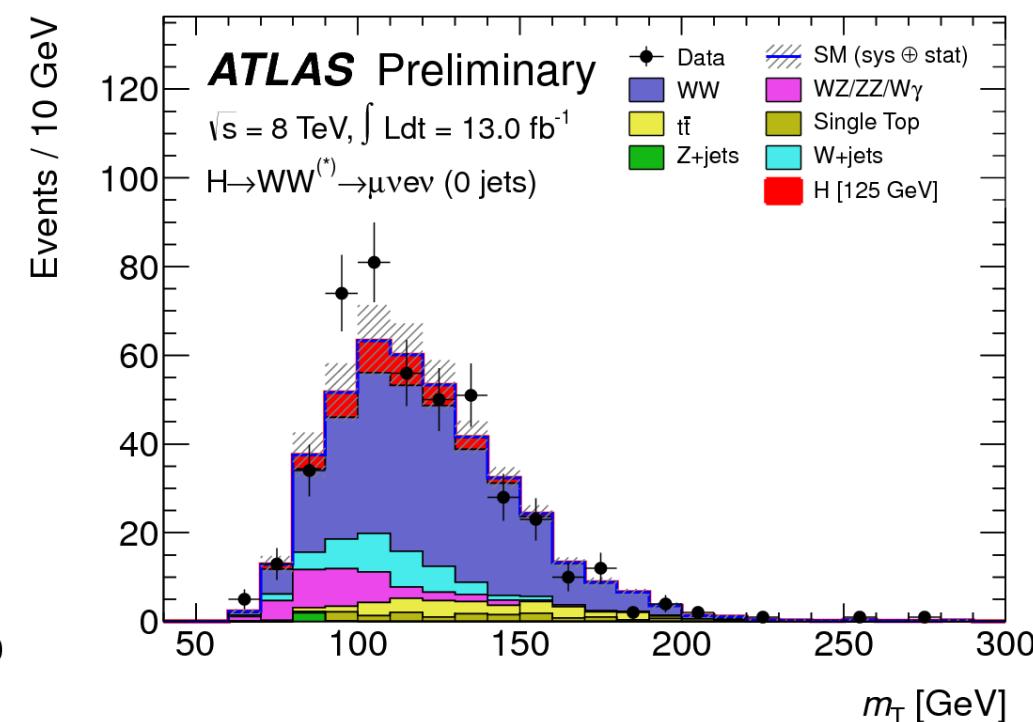
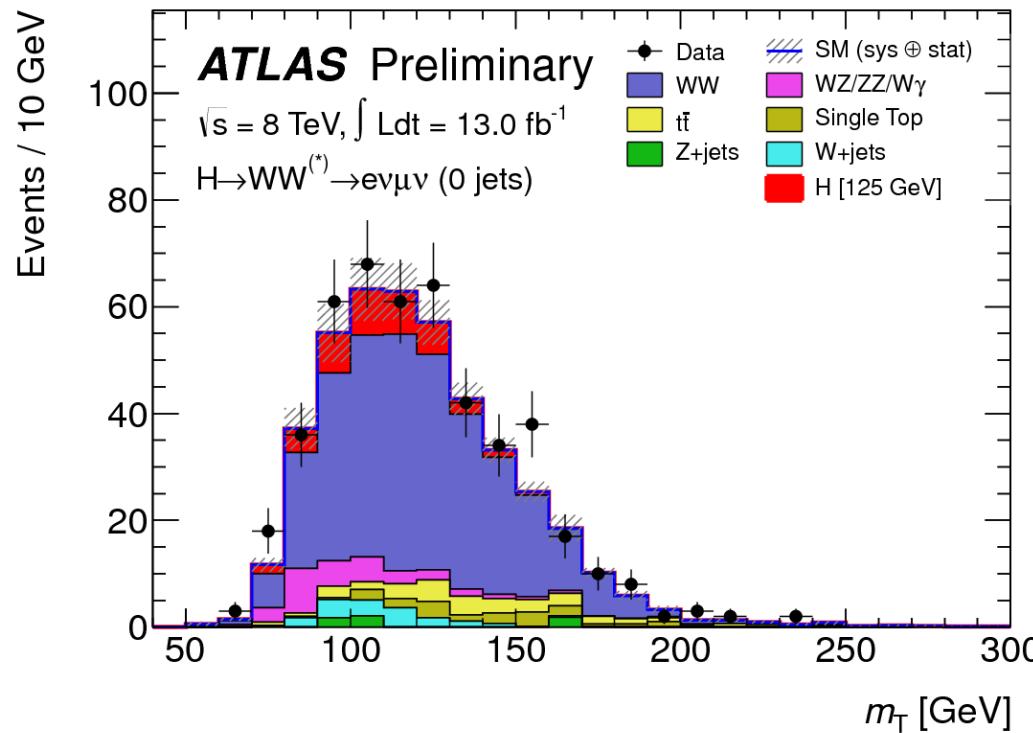
$\mu = \sigma^H / \sigma_{\text{SM}}^H$, θ_i = nuisance parameters (log-normal)
Auxiliary measurement in control regions: WW, Top

$$q_\mu = -2 \ln \frac{\mathcal{L}(\mu, \hat{\theta}_\mu)}{\mathcal{L}(\hat{\mu}, \hat{\theta})}, \text{ use } \text{CL}_s \text{ method with } q_\mu$$

$H \rightarrow WW$ control regions



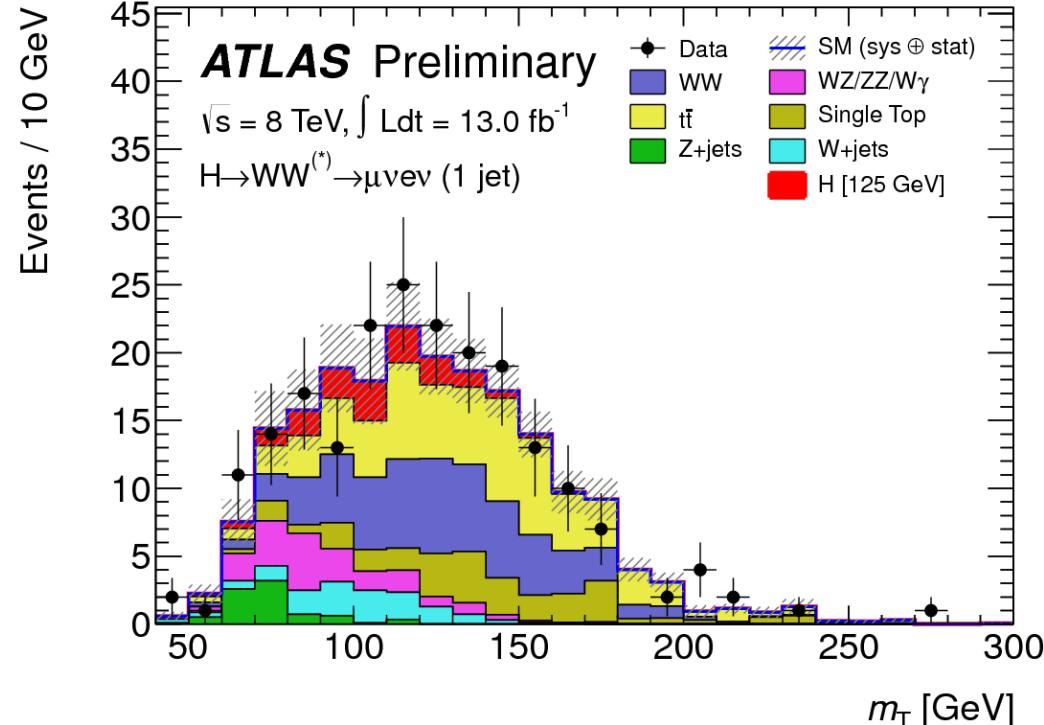
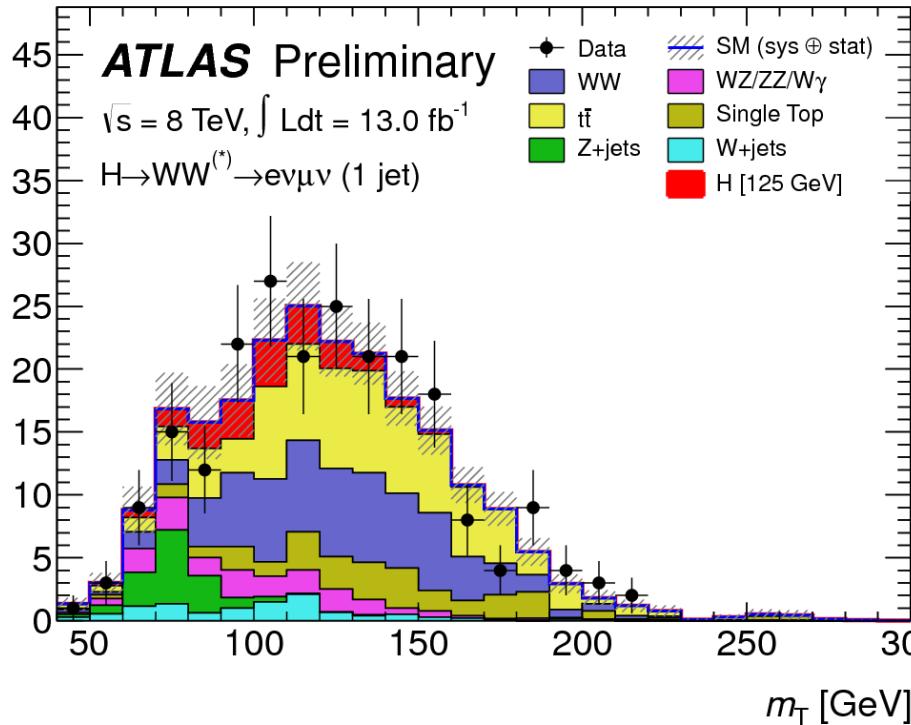
$H \rightarrow WW$ signal regions and uncertainties on μ



Source	Upward uncertainty (%)	Downward uncertainty (%)	Signal region yield for $e\bar{v}$ and $\mu\bar{v}$ channels separately			
Statistical uncertainty	+23	-22				
Signal yield ($\sigma \cdot \mathcal{B}$)	+14	-9				
Signal acceptance	+9	-6	0-jet $e\bar{v}$	0-jet $\mu\bar{v}$	1-jet $e\bar{v}$	1-jet $\mu\bar{v}$
WW normalisation, theory	+20	-20	Total bkg.	392 ± 7	382 ± 6	202 ± 6
Other backgrounds, theory	+9	-9	Signal	41.8 ± 0.6	33.8 ± 0.5	18.9 ± 0.4
W+jets fake rate	+11	-12	Observed	469	448	226
Experimental + bkg subtraction	+14	-11				207
MC statistics	+8	-8				
Total uncertainty	+41	-38				

$H \rightarrow WW$ signal regions and uncertainties on μ

Events / 10 GeV

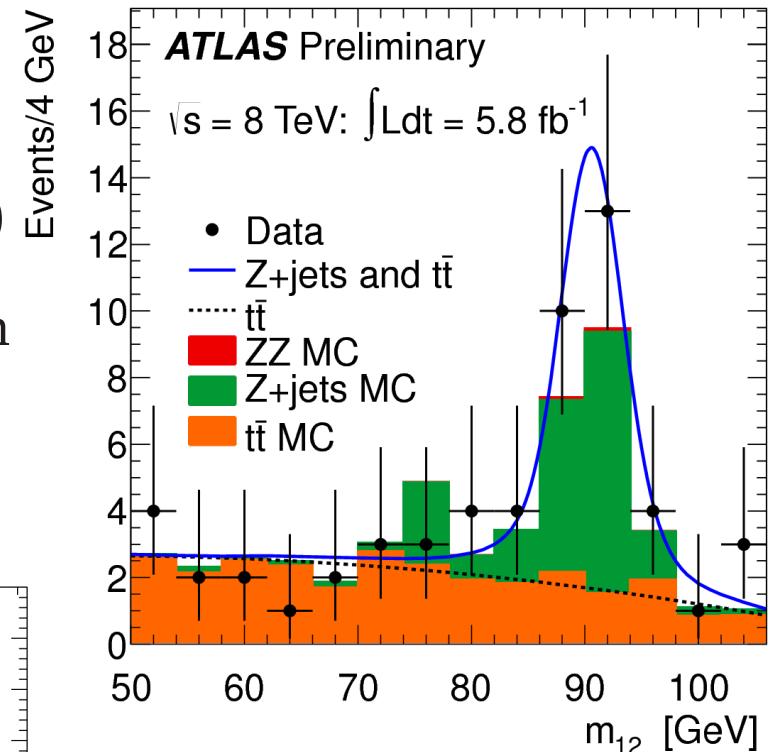
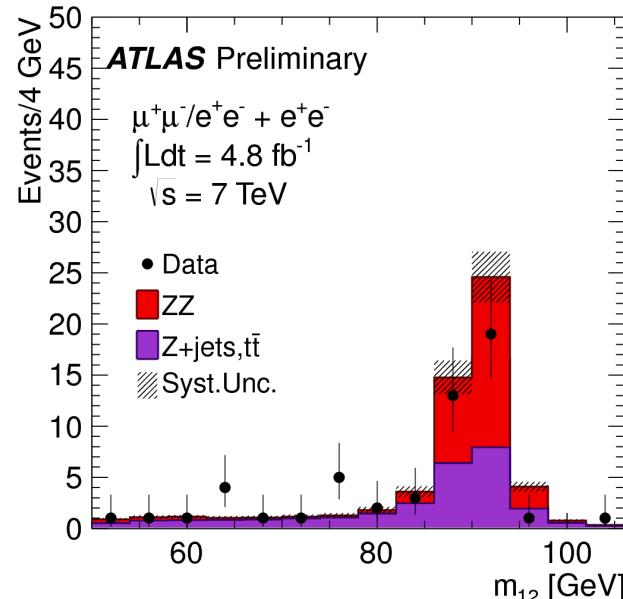
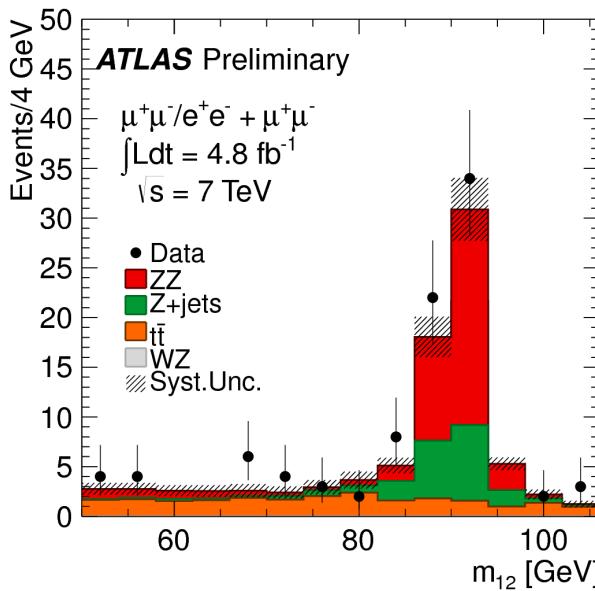


Source	Upward uncertainty (%)	Downward uncertainty (%)
Statistical uncertainty		+23
Signal yield ($\sigma \cdot \mathcal{B}$)		+14
Signal acceptance		+9
WW normalisation, theory		+20
Other backgrounds, theory		+9
W+jets fake rate		+11
Experimental + bkg subtraction		+14
MC statistics		+8
Total uncertainty	+41	-38

Signal region yield for $e\mu$ and μe channels separately				
	0-jet $e\mu$	0-jet μe	1-jet $e\mu$	1-jet μe
Total bkg.	392 ± 7	382 ± 6	202 ± 6	184 ± 5
Signal	41.8 ± 0.6	33.8 ± 0.5	18.9 ± 0.4	16.0 ± 0.4
Observed	469	448	226	207

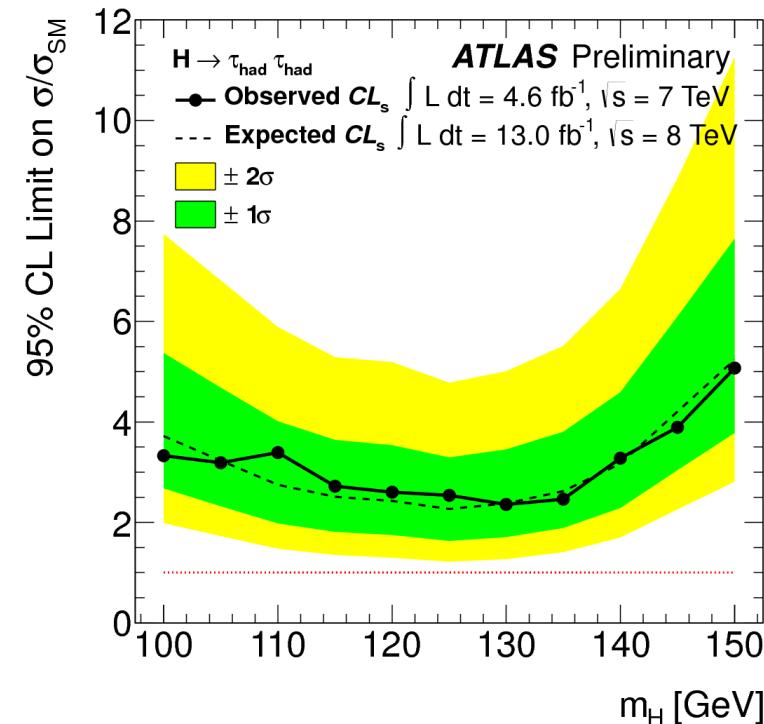
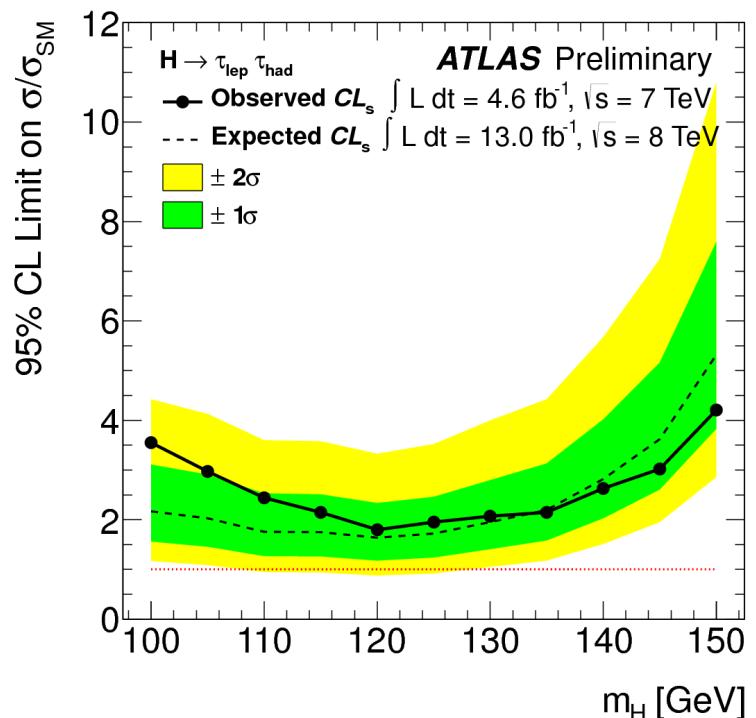
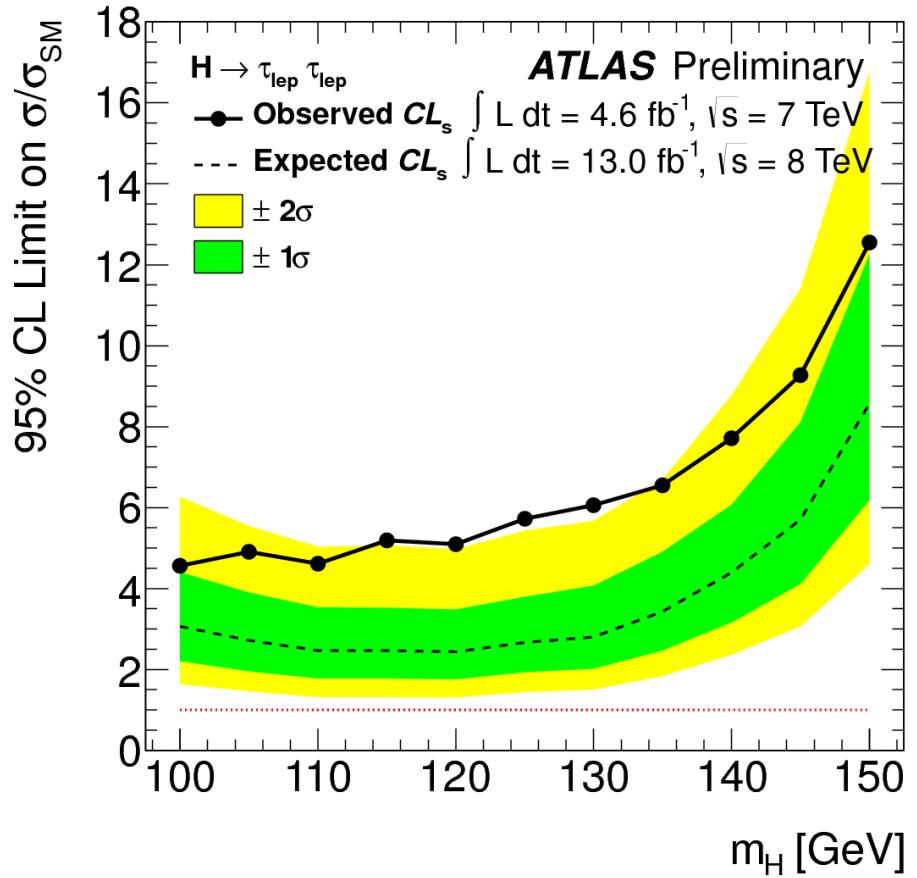
HZZ: Background estimation and control

- Main backgrounds: non-resonant $ZZ^{(*)}/\gamma^*$, $t\bar{t}+jets$, Z/γ^*+jets (mostly $Z+b\bar{b}$)
- Data-driven $ll+jets$ and $t\bar{t}+jets$ estimation
 - e.g. fit $m_{12}(\mu\mu)$ with relaxed μ selections
(and inverted $d_0/\sigma(d_0)$ cut for one lepton)
 - Estimate $t\bar{t}+jets$ and $Z+jets$ normalization
- Check modeling in various Control Regions
 - Relaxing/inverting isolation/ $d_0/\sigma(d_0)$, ...



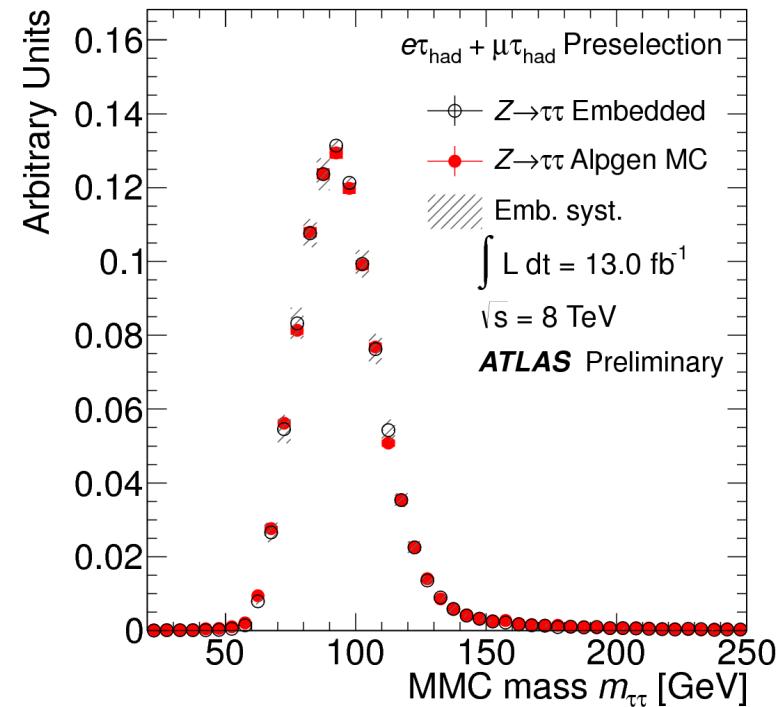
- data/MC comparison in m_{12} after selections

$H \rightarrow \tau\tau$



$Z \rightarrow \tau\tau$ background

- Use mix of simulation and data-driven background estimations
- Most important background from $Z \rightarrow \tau\tau$,
use **embedding technique**
 - Representative data sample of $Z \rightarrow \mu\mu$
 - Substitute muon with simulated τ
 - Accounts for pile-up effects,
underlying event, ...
 - Extensive validation in data and simulation
- Critical a **good resolution on $\tau\tau$ invariant mass**
 - Exploit kinematic correlation of missing
energy and visible decays product
expected from τ decays
 - Accounts for Missing Energy resolution
 - >99% efficiency, 13-20% resolution on $m(\tau\tau)$



$H \rightarrow b\bar{b}$

