Search for a Light Higgs Boson at ATLAS

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University of Tokyo (ICEPP)
on behalf of the ATLAS Collaboration

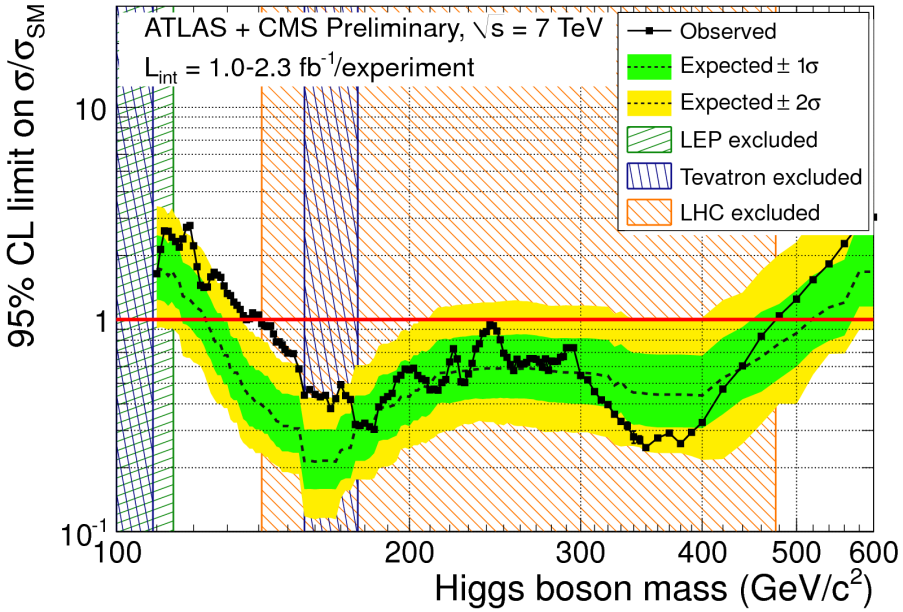
Outline

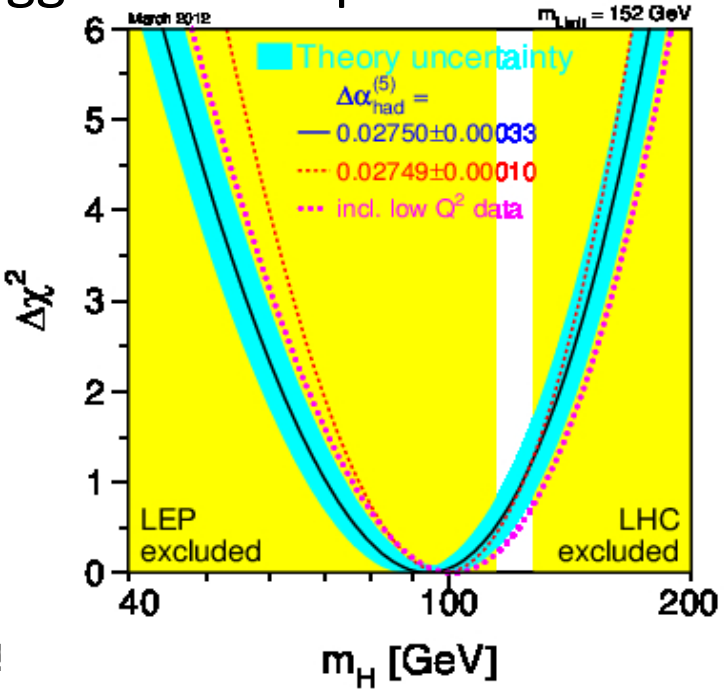
- Introduction
- Higgs Search Strategy at ATLAS
- Results of Each Channel
- Summary

Introduction and Motivation

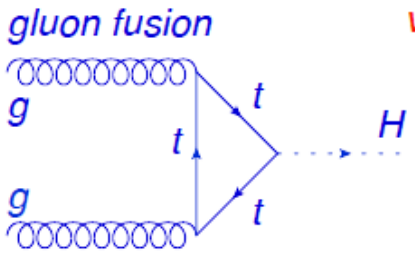
- Direct and indirect Higgs boson search
  - ATLAS+CMS excluded the range of $141 < m_H < 476$ GeV in 2011 summer ($1.0\text{-}2.3 fb^{-1}$)
  - LEP excluded up to 114.4 GeV
  - The preferred value is 94^{+29}_{-24}GeV, $m_H < 152$ GeV @ 95% CL from EW global fit

➔ If SM Higgs boson exists, light Higgs boson is preferred!!

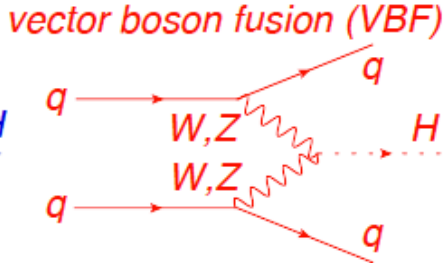




Higgs Production and Decay



NNLO+NNLL QCD
+NLO EW



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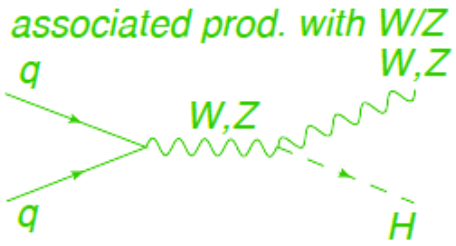

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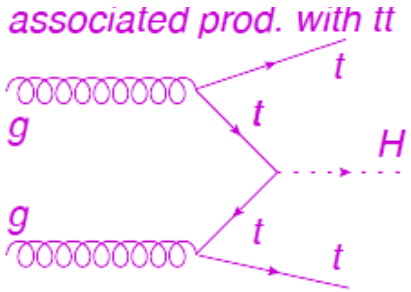
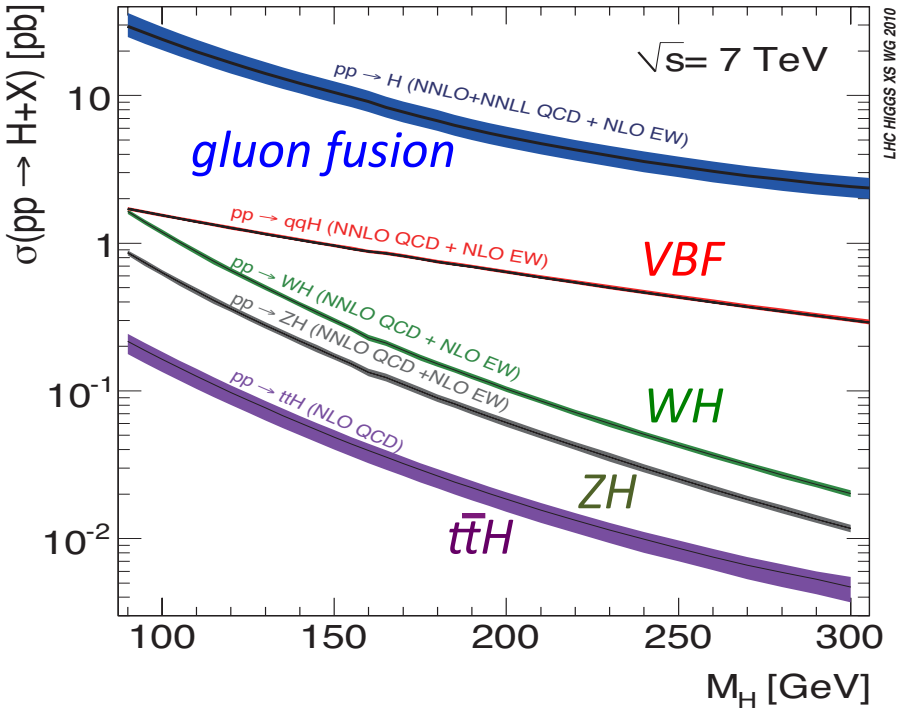
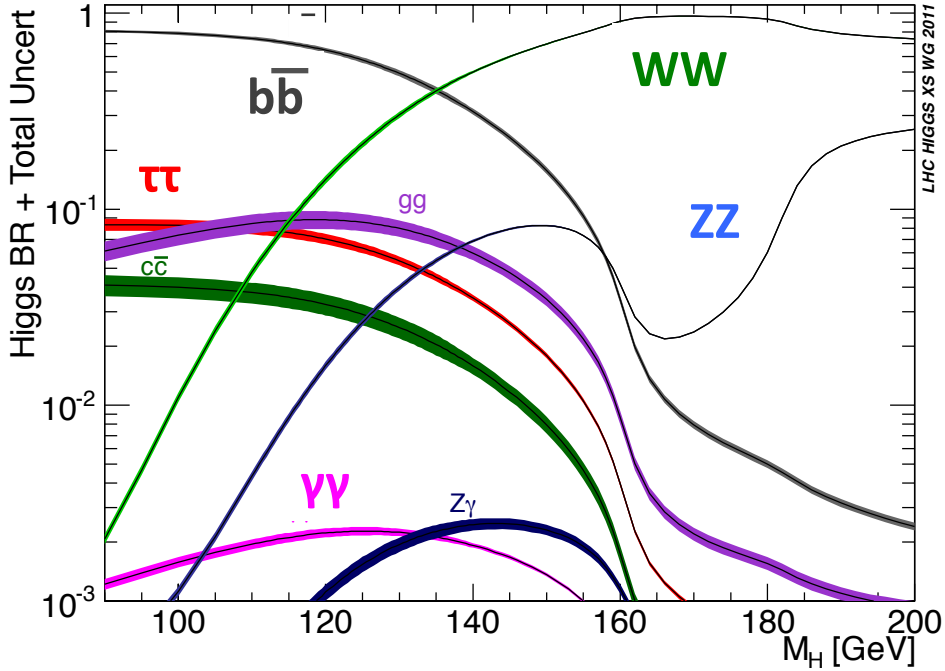


NLO QCD





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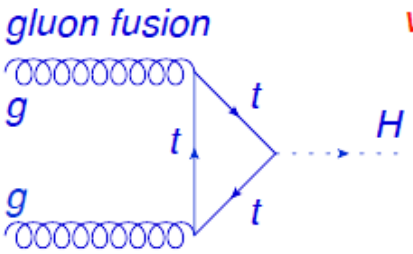

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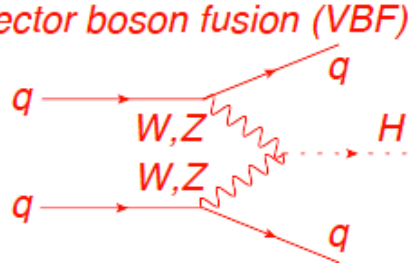

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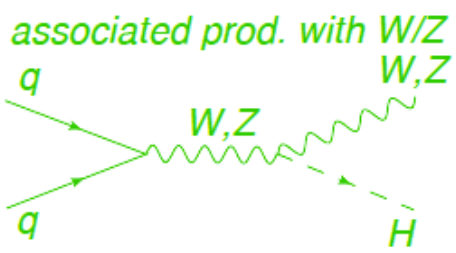

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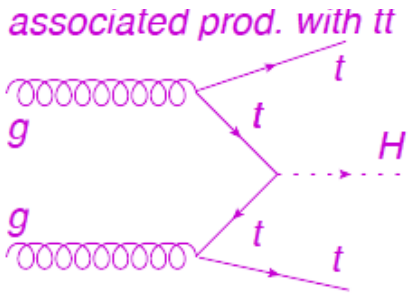

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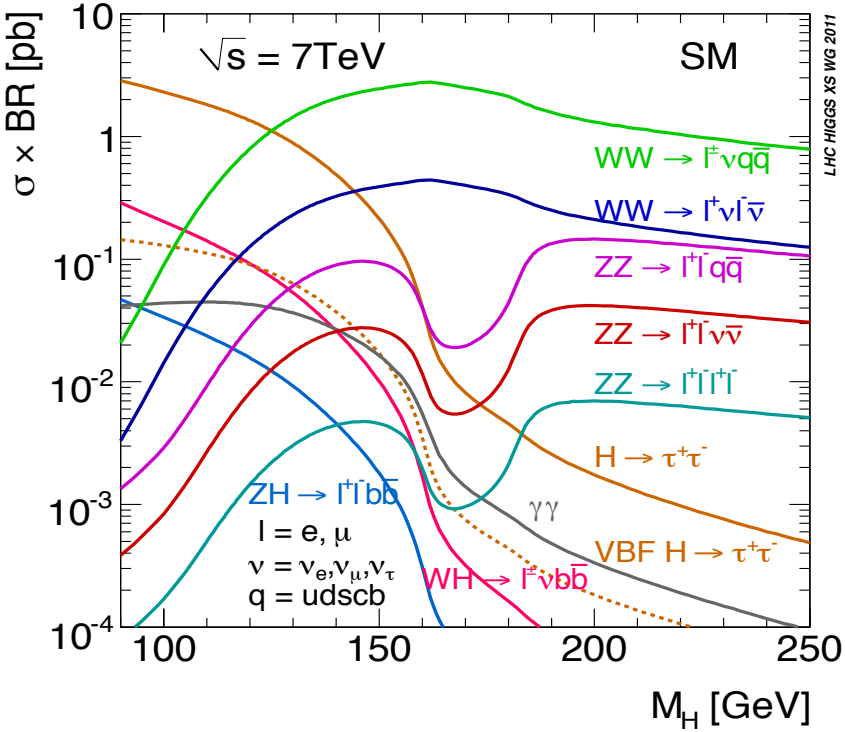


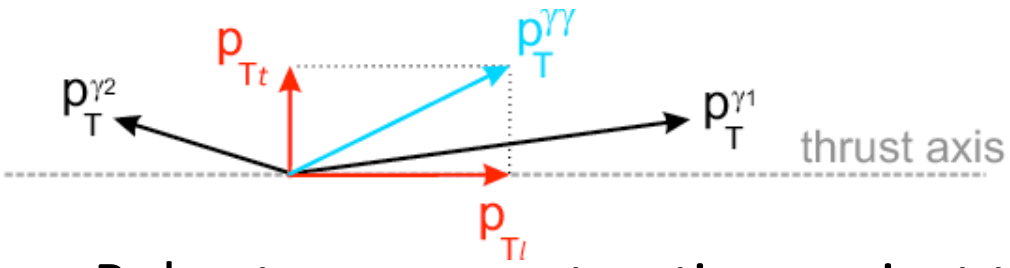
Analysis Status	
H→γγ	4.9fb^{-1}(110 < m_H < 150 GeV)
H→WW→lνlν	4.7fb^{-1}(110 < m_H < 600 GeV)
H→ZZ→4l	4.8fb^{-1}(110 < m_H < 600 GeV)
H→ττ	4.7fb^{-1}(100 < m_H < 150 GeV)
W/Z+H→bb	4.6-4.7fb^{-1}(110 < m_H< 130 GeV)

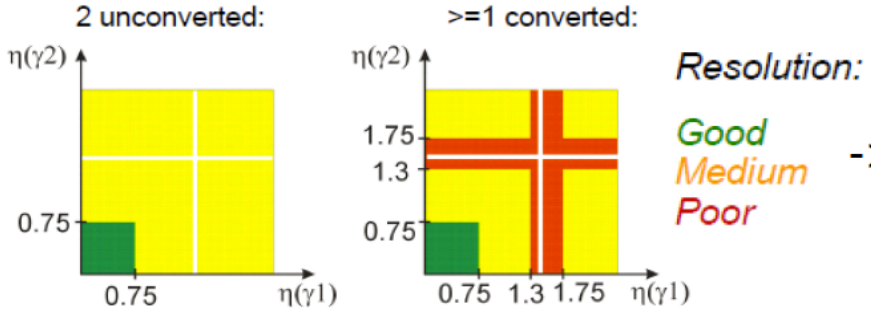
*** High mass region of WW and ZZ is covered by Alex's talk**

H→γγ

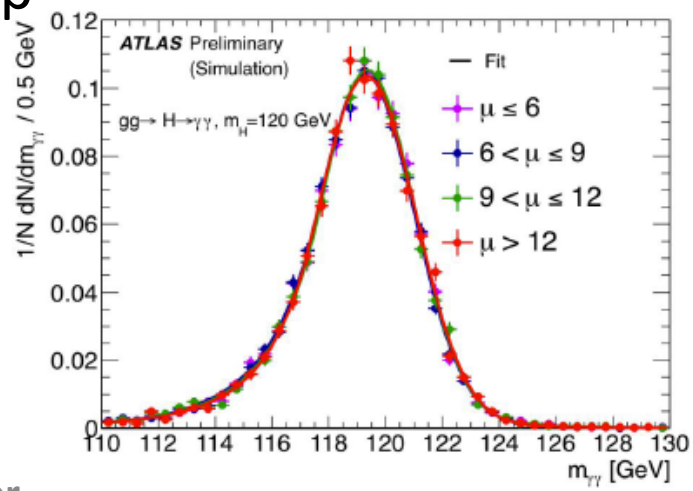
ATLAS-CONF-2011-161

- Di-photon trigger (trigger efficiency is 99% w.r.t. offline selection)
- Two isolated photons with $E_T(\gamma 1) > 40$ GeV, $E_T(\gamma 2) > 25$ GeV
- Candidate diphoton events are subdivided into 9 orthogonal categories (converted/unconverted, η range, p_{Tt})
  ➔ Extract better $m_{\gamma\gamma}$ resolution and S/B region





- Robust $m_{\gamma\gamma}$ reconstruction against the pileup
  ➔ important to measure photon direction
  - Use conversion vertex and calorimetric information for converted photons
  - Use longitudinal information of EM calorimeter for unconverted photons
- Uncertainty on $m_{\gamma\gamma}$ mass peak (±0.7 GeV)



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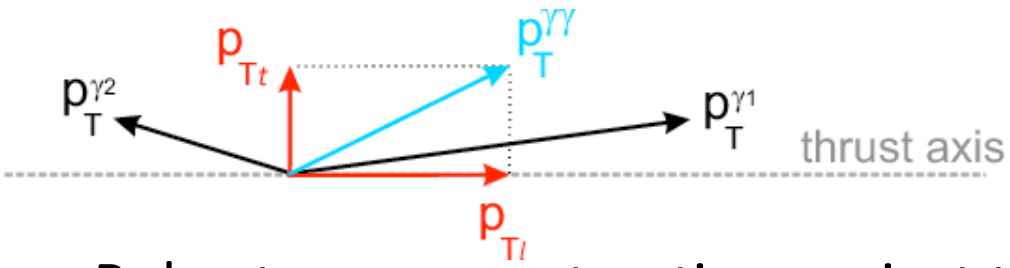

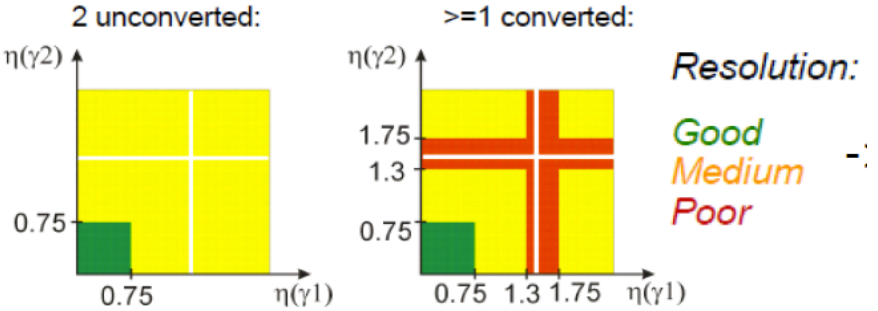

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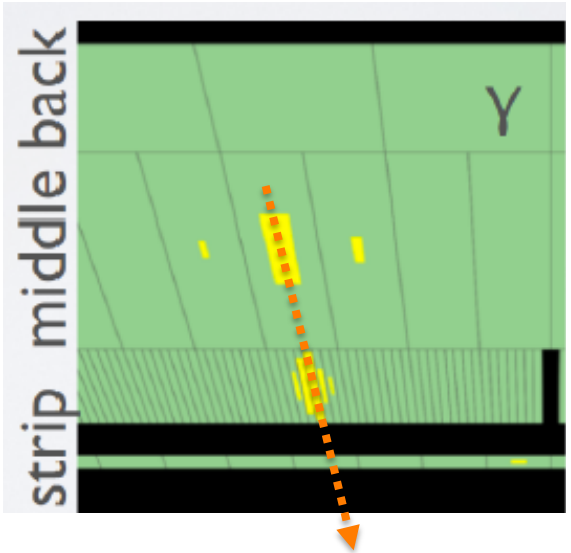
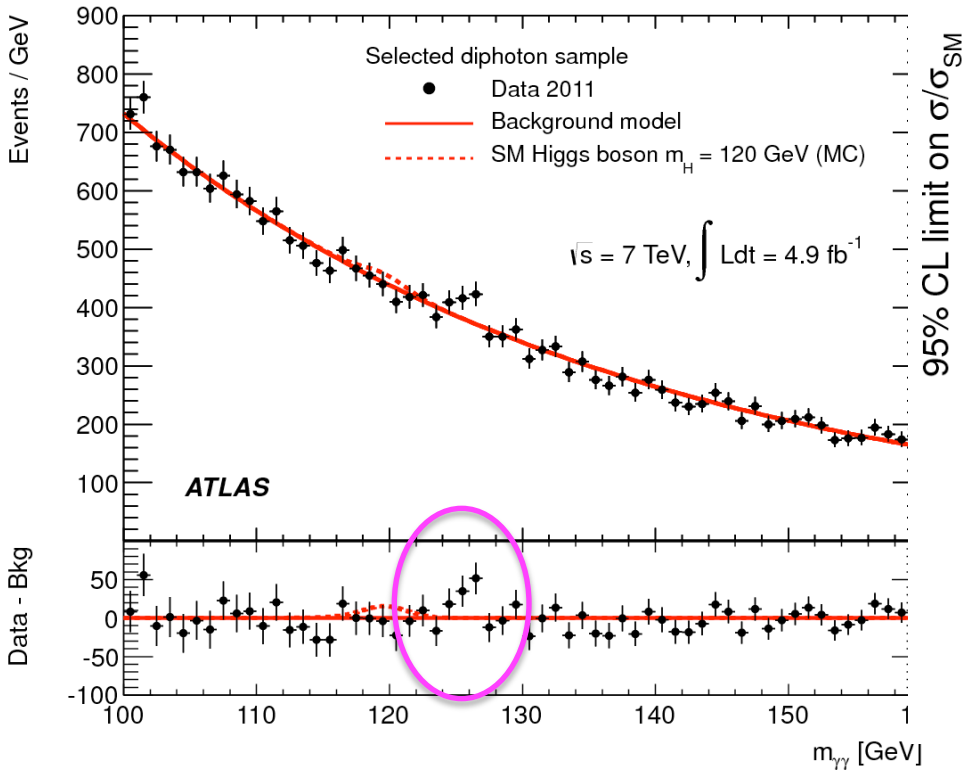


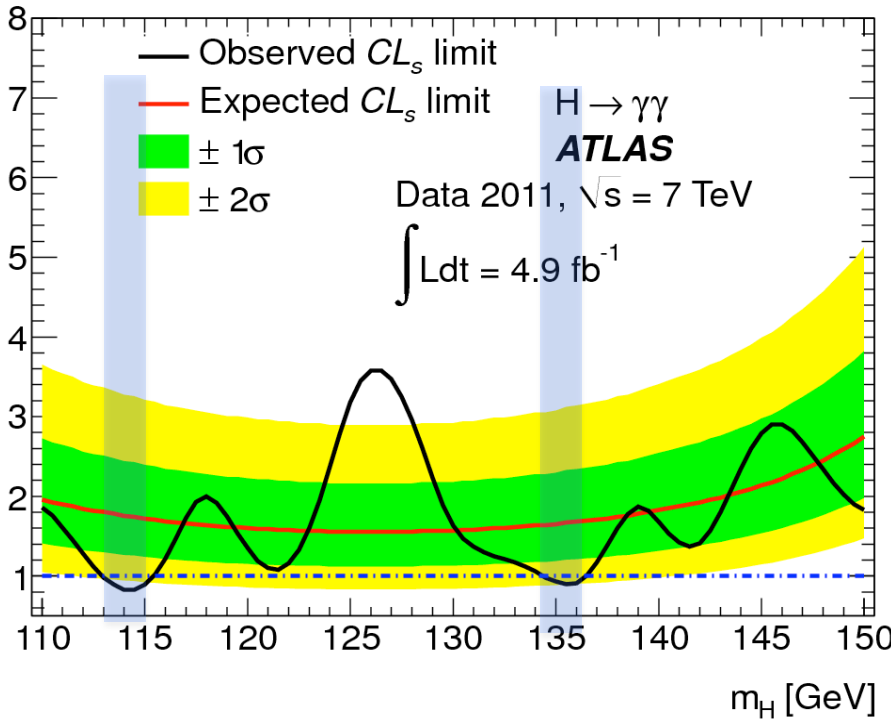
H→γγ

Phys. Rev. Lett. 108 (2012)

- $m_{\gamma\gamma}$ distribution summed over all categories

95% CL limit on SM Higgs cross section divided by SM expectation





95% CL excluded region : 113-115,134.5-136 GeV

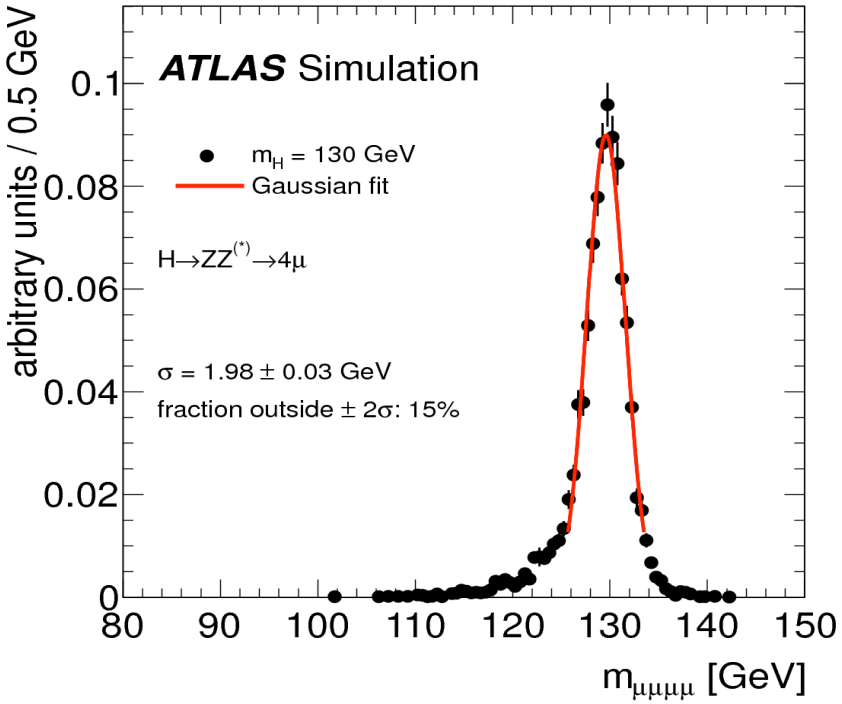
Largest significance 2.8σ is observed at 126.5 GeV :

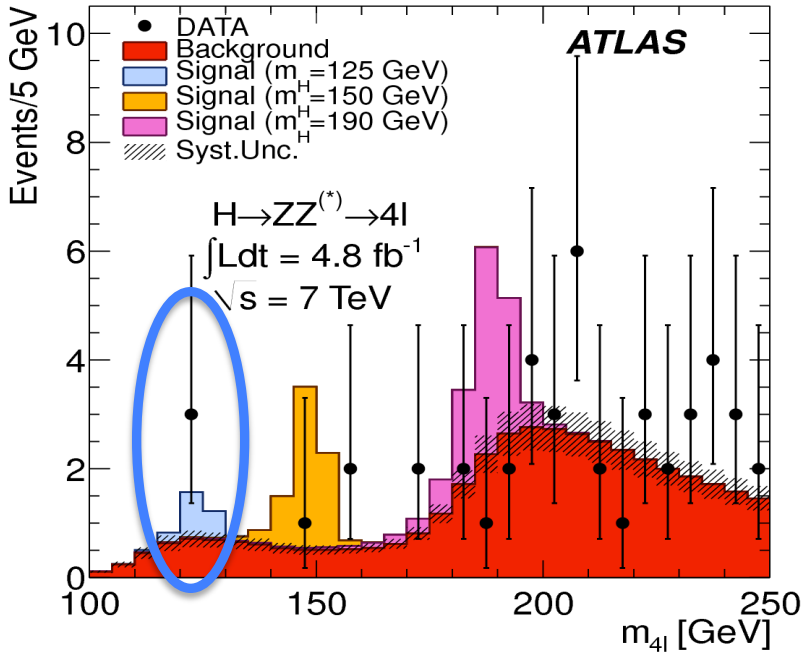
(1.5σ with Look-elsewhere-effect for 110-150 GeV)

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

Phys.Lett. B710 (2012) 383-402

- Clean signature : Require 4 isolated leptons (4e,4μ,2e2μ)
  - low background level : SM ZZ, Z+jets, ttbar
  - Mass resolution : ~1-2% level (low mass region)
  - Event Selection : $|m_Z - m_{12}| < 15$ GeV, m_{34} selection is optimized depending on m_{4l} to improve signal-to-background ratio ($20 < m_{34} < 115$ GeV for m_{4l}=130 GeV)





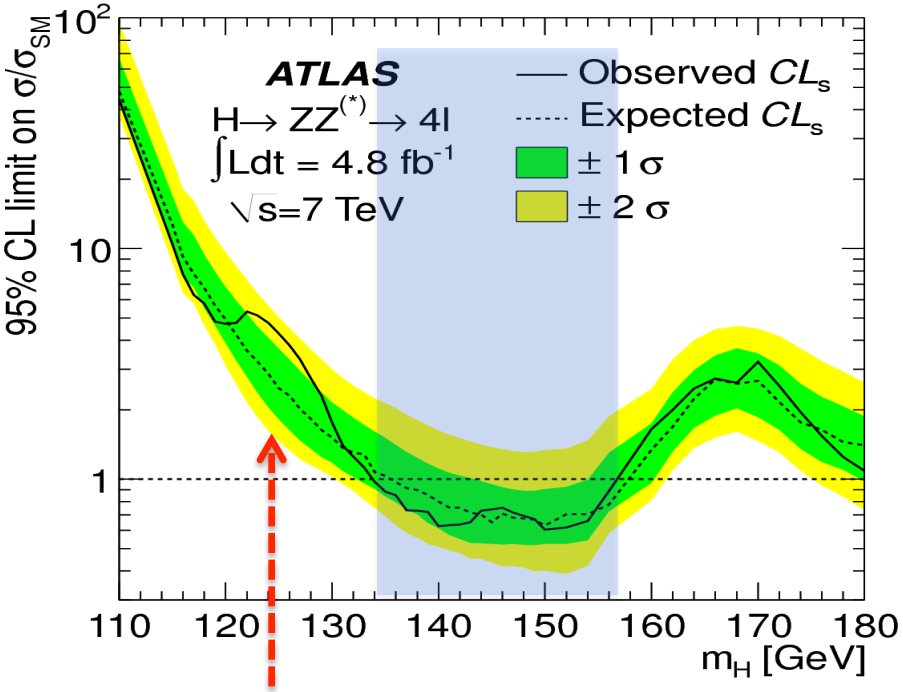
$H \rightarrow ZZ^{(*)} \rightarrow 4l$

Phys.Lett. B710 (2012) 383-402

95% CL excluded region

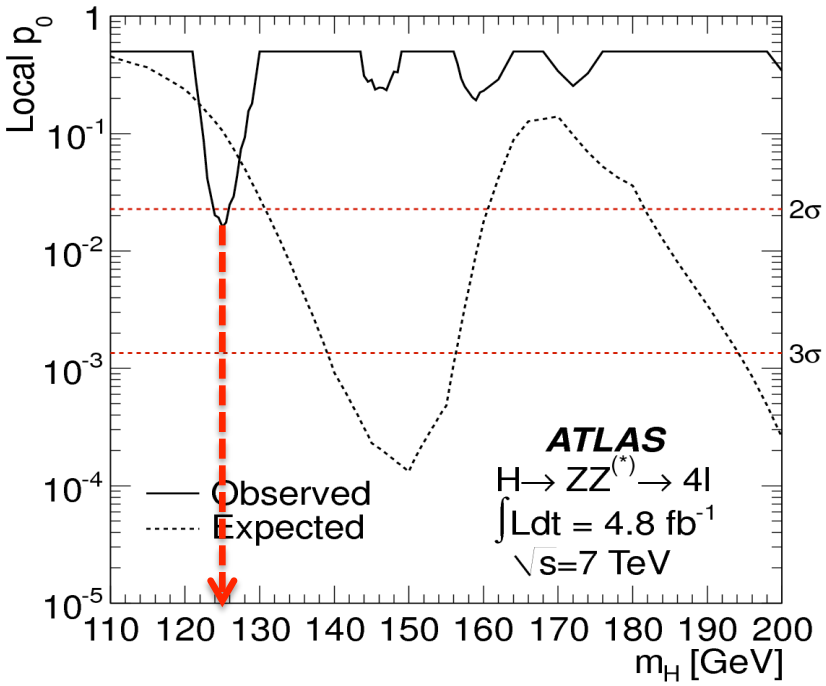
Observed : 134-156 GeV

Expected : 136-157 GeV



Excess around 125 GeV due to 3 observed events

Probability that a background-only experiment is more signal-like than that observed



Lowest local p_0

1.6% (obs:2.1σ,exp:1.3σ) at 125 GeV

➔ With look-elsewhere-effect, this excess is not significant (~50%)

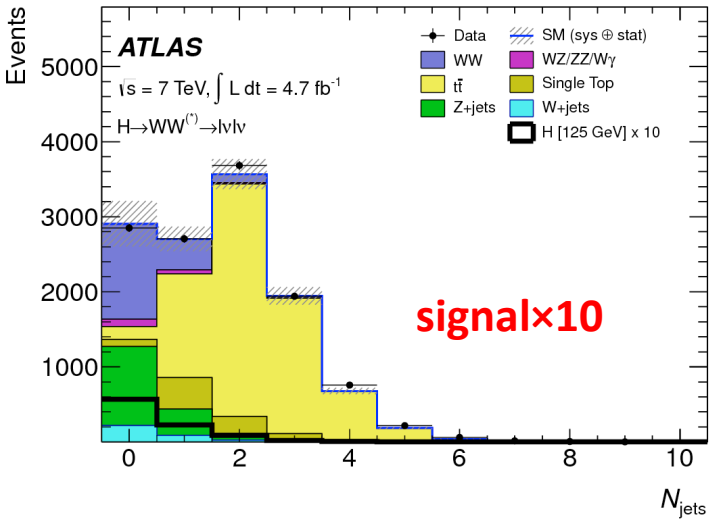
$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$

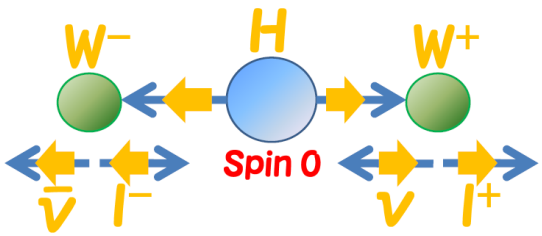
arXiv:1206.0756
CERN-PH-EP-2012-126

- Most sensitive channel in $120 < m_H < 200$ GeV
  - High signal yield but no full mass reconstruction possible due to 2ν
- Signature : dilepton+E_T^{miss} rel +(0,1,2) jets
  - Event selection is optimized for each jet bin to maximize sensitivity (different background composition)
- Background suppression

Selection	Suppression
Two high-p_T isolated lepton	W+jets, QCD
Large missing transverse energy	Z+jets, QCD
jet-bin specific : high p_{ll} for 0jet b-jet veto for 1/2 jet, VBF cut for 2jet	Z+jets ttbar, single top
Topological selection (low $\Delta\phi_{ll}$, m_{ll})	SM WW

Background normalization is estimated in each control region (e.g. high m_{ll} for WW control region)

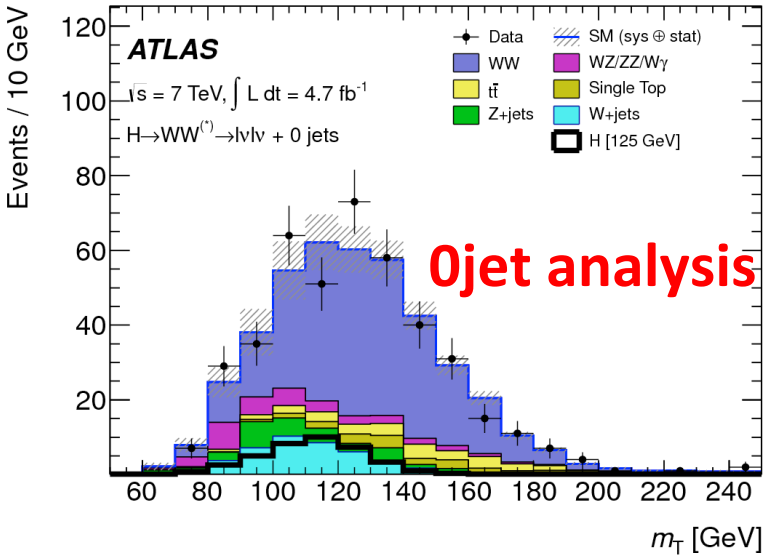


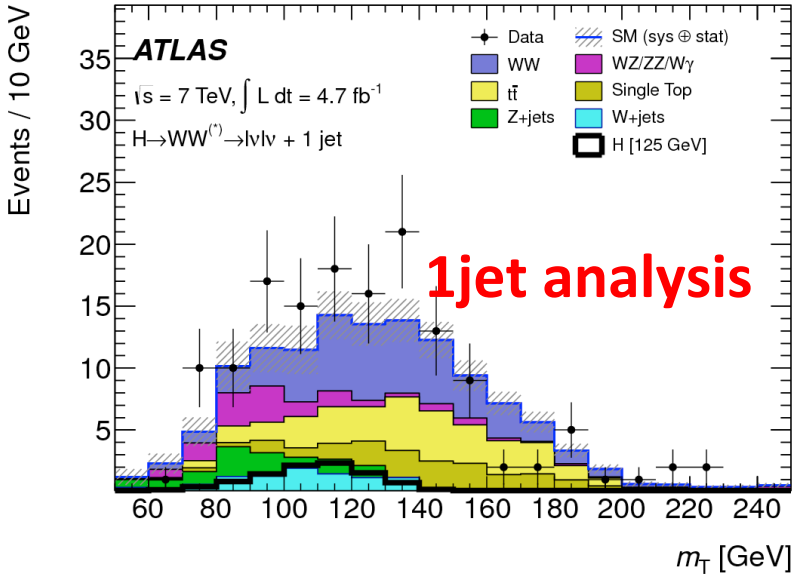


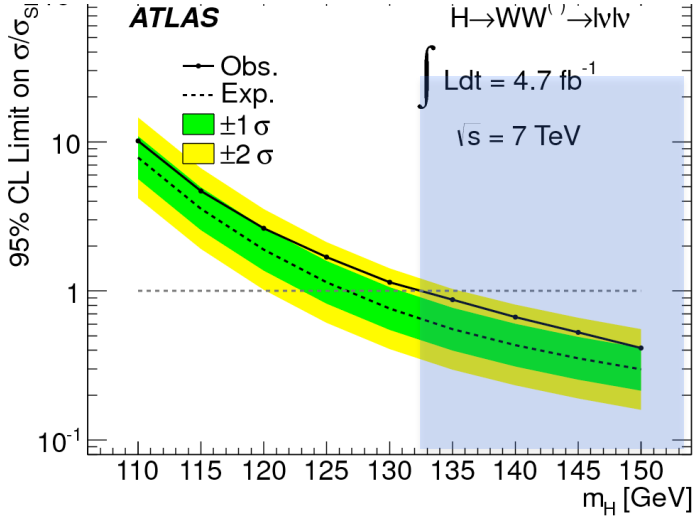
H→WW(*)→lνlν

arXiv:1206.0756
CERN-PH-EP-2012-126

$$m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - (\mathbf{P_T^{ll}} + \mathbf{E_T^{miss}})^2} \qquad E_T^{ll} = \sqrt{(P_T^{ll})^2 + m_{ll}^2}$$







No significant excess in all jet bins

95% CL excluded region

Observed : 133-261 GeV

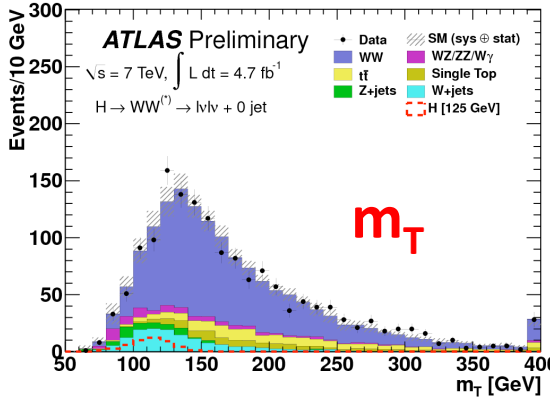
Expected : 127-233 GeV

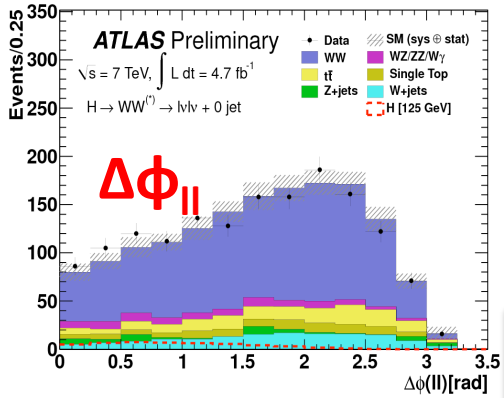
NEW

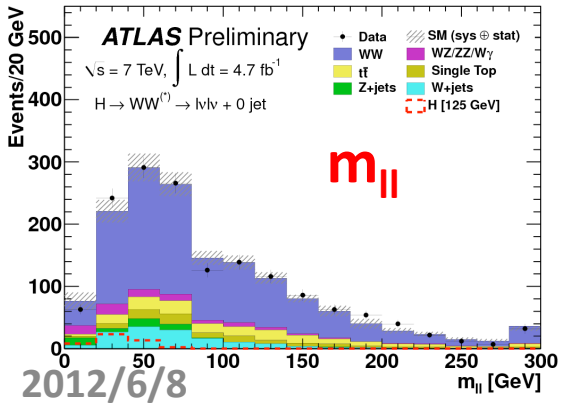
MVA in H→WW→lvlv

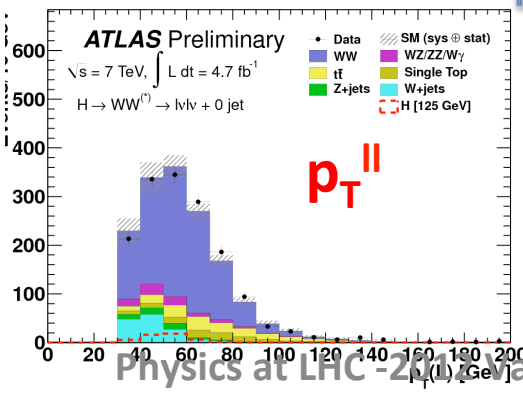
ATLAS-CONF-2012-060

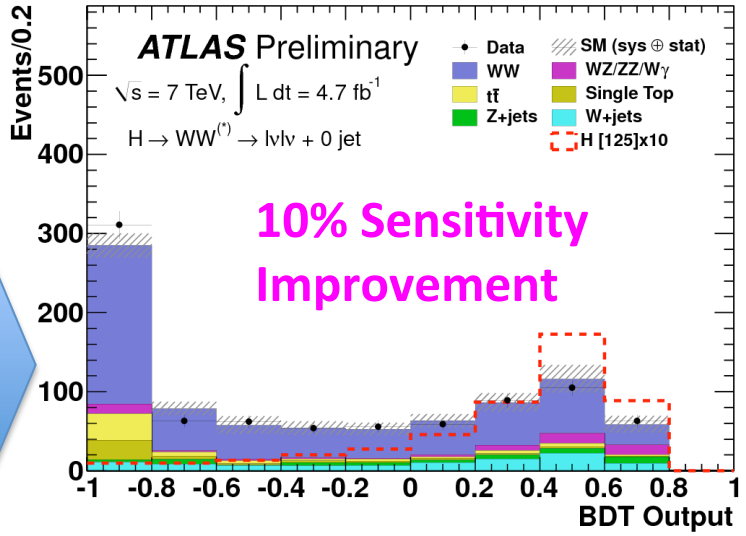
- First result using MVA (BDT) in ATLAS Higgs search
  - Preselection : Same object selection, E_T^{miss}, p_T^{ll} cut as m_T fit analysis
  - Train signal vs. combined background (WW,WZ,ZZ, ttbar, single top and Z+jets) for 0,1jet separately in each mass point
  - 4 topological variables (m_T, $\Delta\phi_{ll}$, m_{ll}, p_T^{ll}) are used











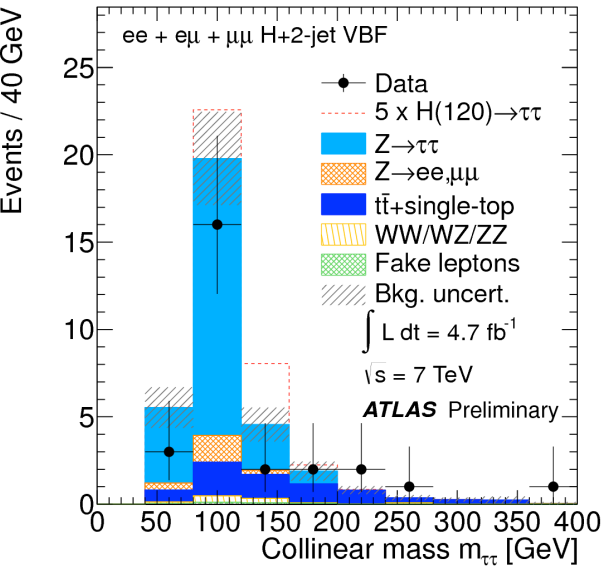
95% CL excluded region

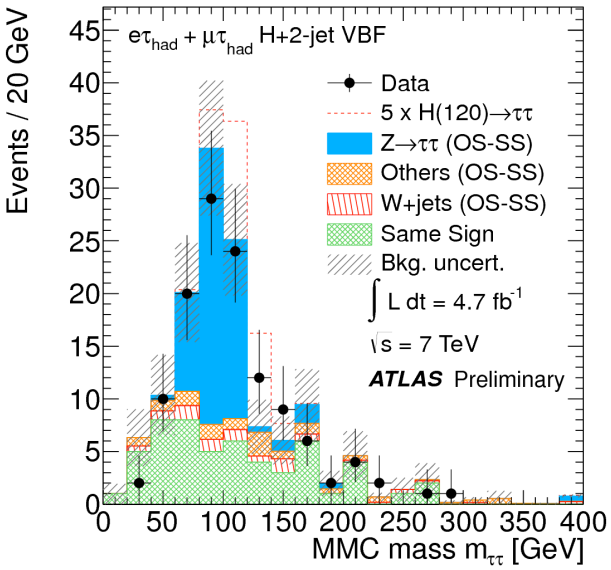
Observed : 130-281 GeV

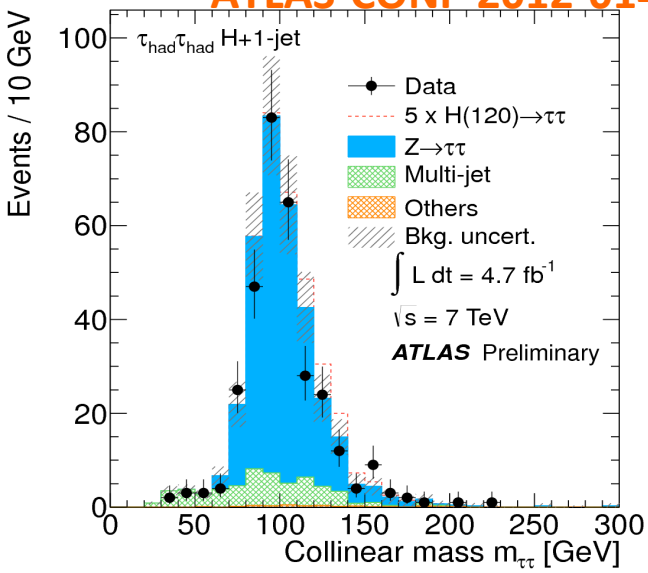
Expected : 127-255 GeV

$H \rightarrow \tau\tau$ ($\tau_{lep}\tau_{lep}$, $\tau_{lep}\tau_{had}$, $\tau_{had}\tau_{had}$)

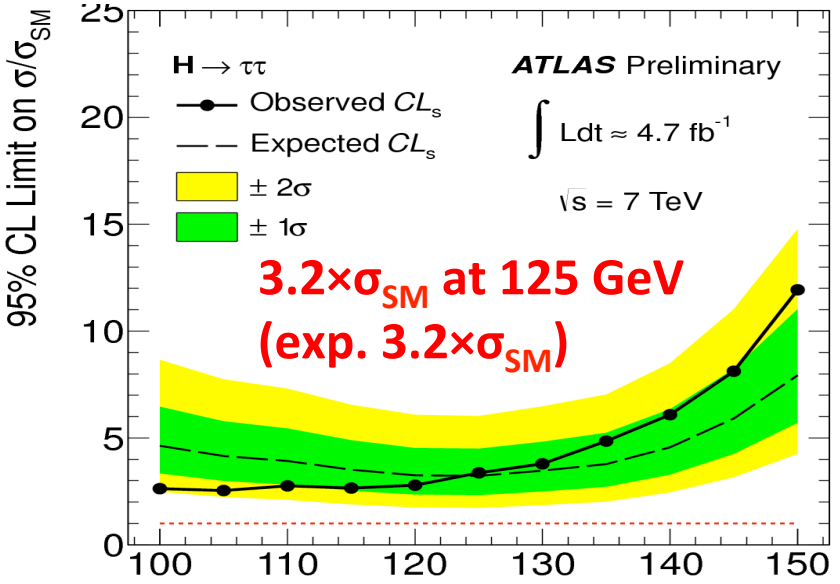
ATLAS-CONF-2012-014







- Each sub-channel separated into different jet categories
  - $\tau_{lep}\tau_{lep}$: H+2jets (VBF), H+2jets(VH), H+1jet, H+0jet (only eμ-ch)
  - $\tau_{lep}\tau_{had}$: H+2jets (VBF), H+1jet, H+0jets with low/high MET
  - $\tau_{had}\tau_{had}$: H+1jet

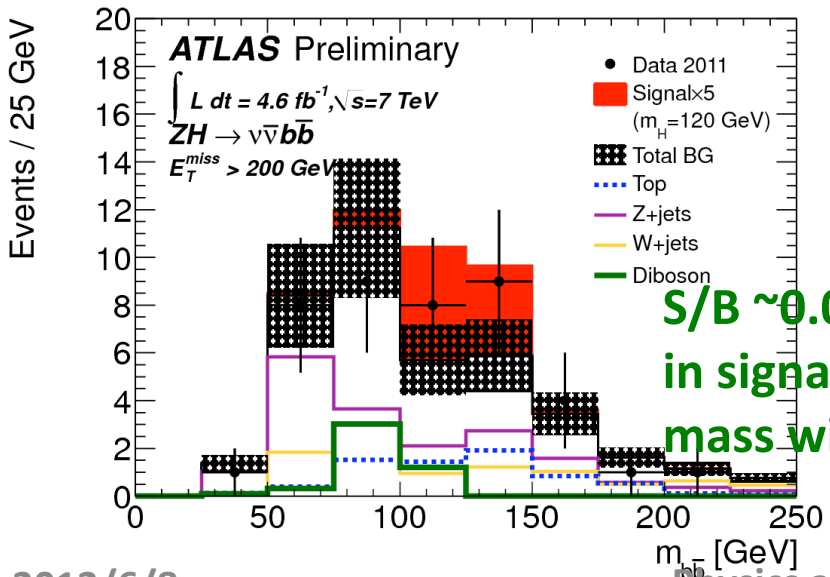


W/ZH(→bbar)

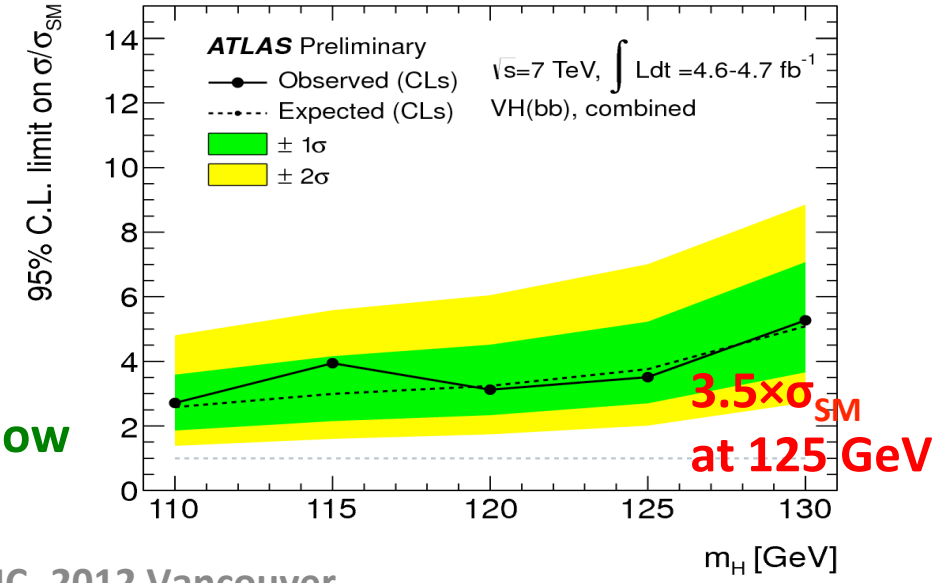
ATLAS-CONF-2012-015

WH→lνbb	ZH→llbb	ZH→νν̄bb
one lepton (e,μ)	two leptons (ee, μμ)	E_T^{miss} > 120 GeV
E_T^{miss} > 25, GeV, m_T > 40 GeV	84 GeV < m_{ll} < 99 GeV, E_T^{miss} < 50 GeV	p_T^{miss} > 30 GeV, $\|\Delta\phi(E_T^{miss}, p_T^{miss})\| < \pi/2$, $\|\Delta\phi(E_t^{miss}, jet)\|>1.8$
Two b-jets (45,25 GeV)		
Categorize events depending on vector boson p_T (p_{TV}) or MET (Boost VH Events)		
p_{TV}<50,50<p_{TV}<100,100<p_{TV}<200, p_{TV}>200 GeV		120<E_T^{miss}<160,160<E_T^{miss}<200, E_T^{miss}>200 GeV

m_{bb} distribution in ZH→νν̄bb

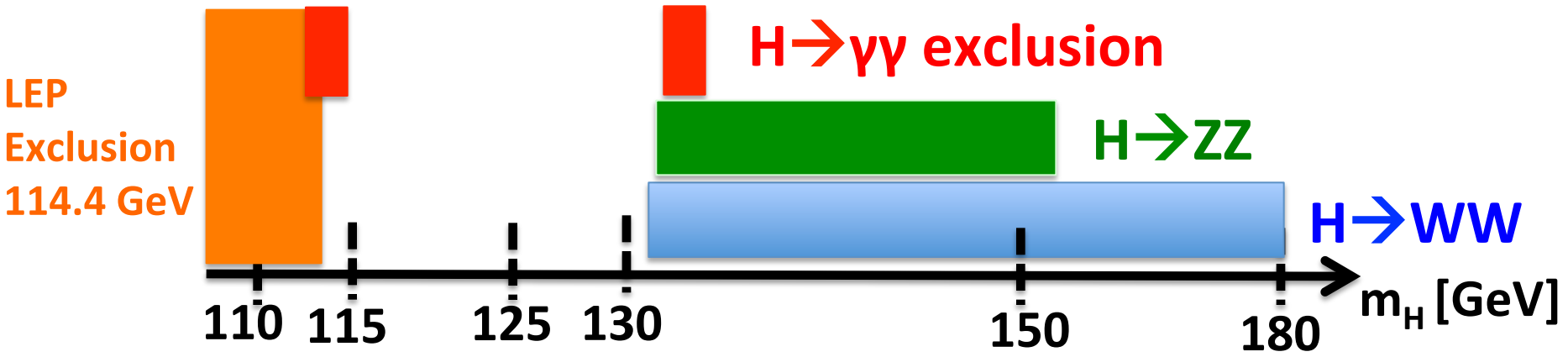


95% CL Limit combined all channels



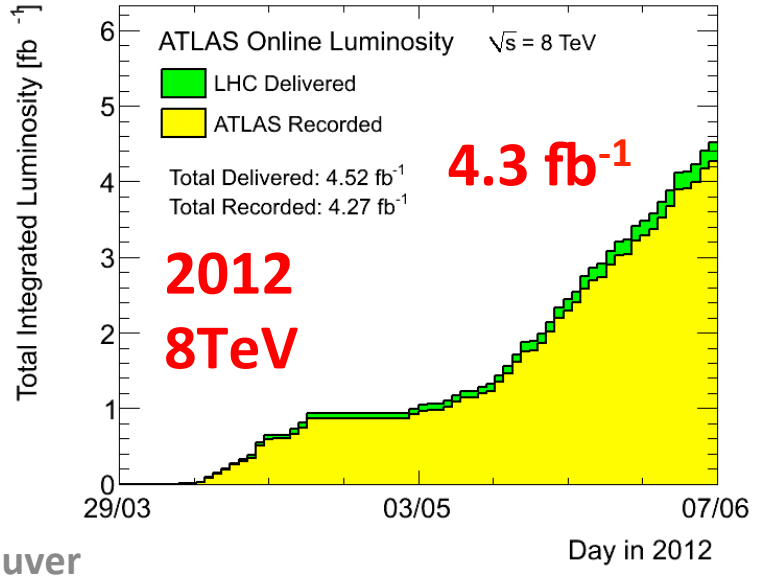
Summary

- Large low mass region is excluded in 2011 analysis



  - ~2σ level excess in local p_0 is observed around 125 GeV in H→γγ and H→ZZ→4l

- 8TeV run is going smoothly
  - More statistics (15-20 fb^{-1}) in 2012
  - ggF x-sec increase by 27% at 125 GeV
  - We have an answer, either discovery or exclusion, in the remaining low mass region this year



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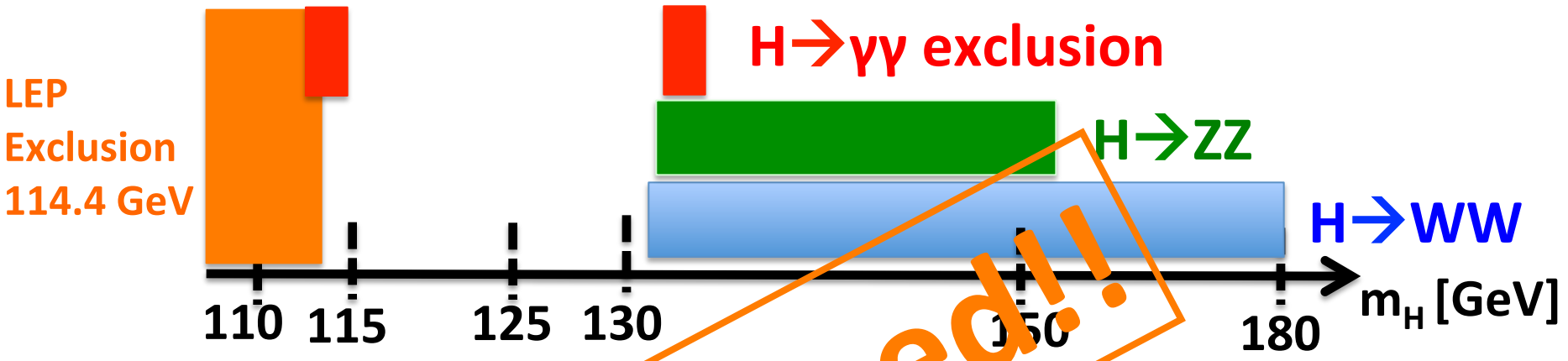

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Stay Tuned!!

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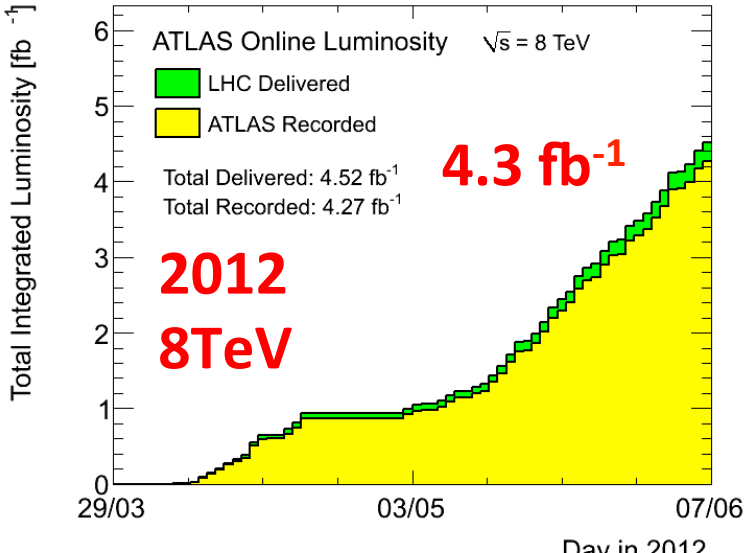
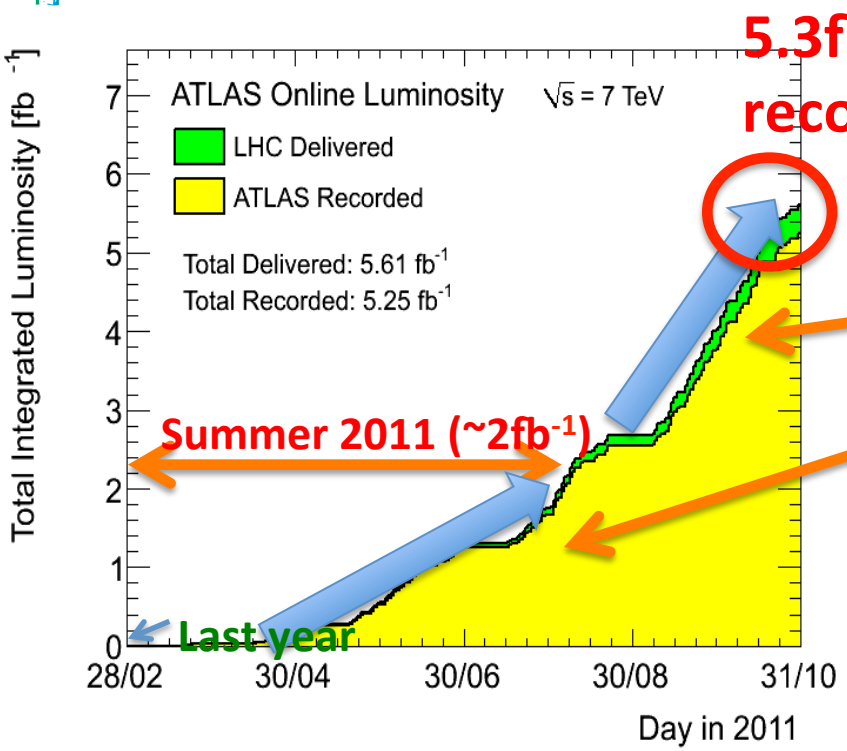
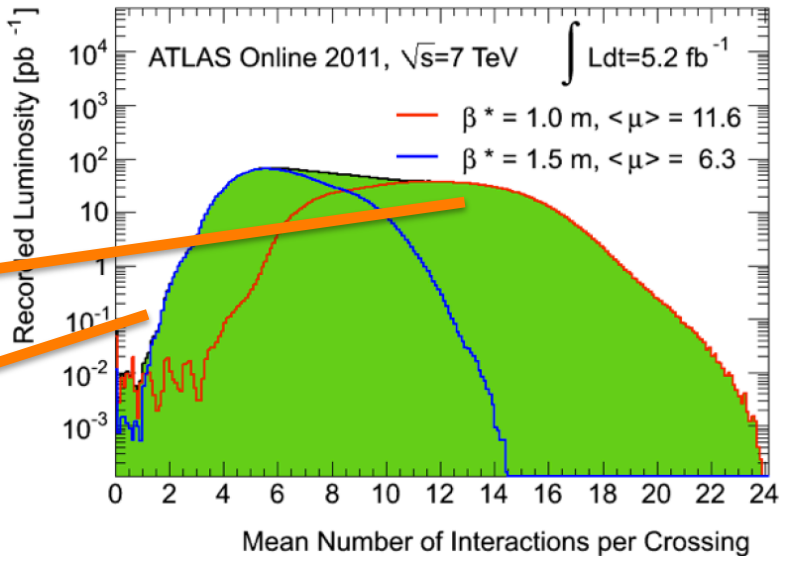
  - ggF x-sec increase by 27% at 125 GeV
  - We have an answer, either discovery or exclusion, in the remaining low mass region this year

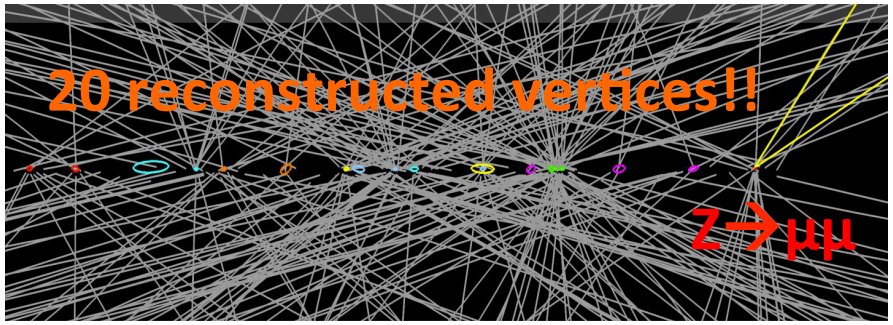


Back up

ATLAS Data Taking in 2011







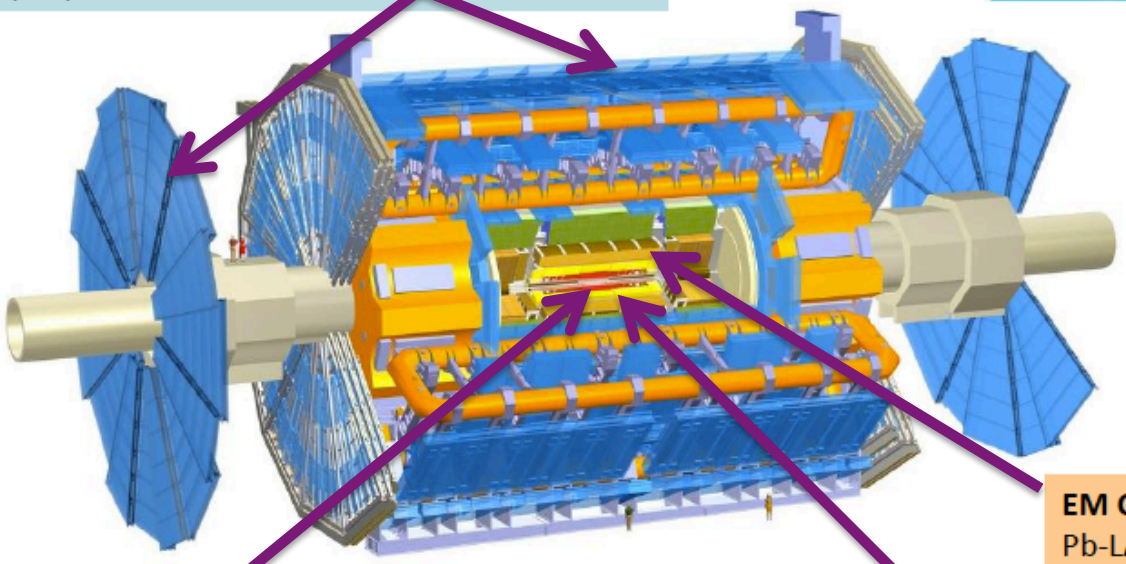
- Excellent LHC performance in 2011 (far beyond expectation)
- Peak luminosity : 3.7×10^{33} $cm^{-2}s^{-1}$
- High luminosity ➔ high pile-up

- Very challenging for trigger, reconstruction of physics object, analysis strategies

ATLAS Detector

Muon Spectrometer: |η|<2.7
Air-core toroids with gas based muon chambers
$\sigma(p_T)/p_T$ = 2% @ 50GeV to 10% @ 1TeV (ID+MS)

ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997



EM Calorimeter: |η|<3.2
Pb-LAr Accordion
$\sigma(E)/E = 10\% \sqrt{E} \oplus 0.7\%$

Inner Detector: |η|<2.5, B=2T
Si pixels/strips and Trans. Rad. Det.
$\sigma(p_T)/p_T = 0.05\% \, p_T \oplus 1\%$

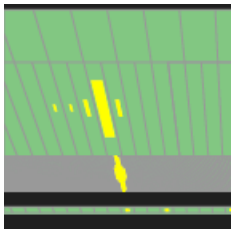
Hadronic Calorimeter: |η|<4.9
Fe/scintillating Tiles (central), Cu/W LAr (fwd)
$\sigma(E_{jet})/E_{jet} = 50\% \sqrt{E} \oplus 3\%$

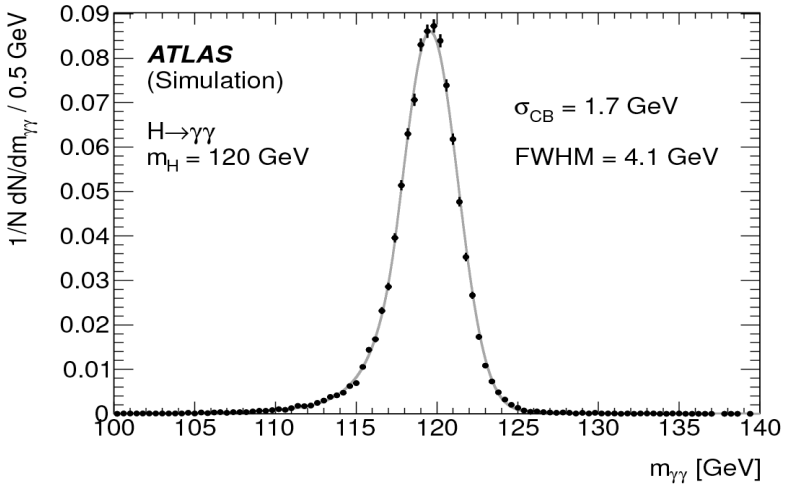
Excellent performance of ATLAS

- Data-taking efficiency : 93.5%
- High operational fraction of all sub-detectors : >95%

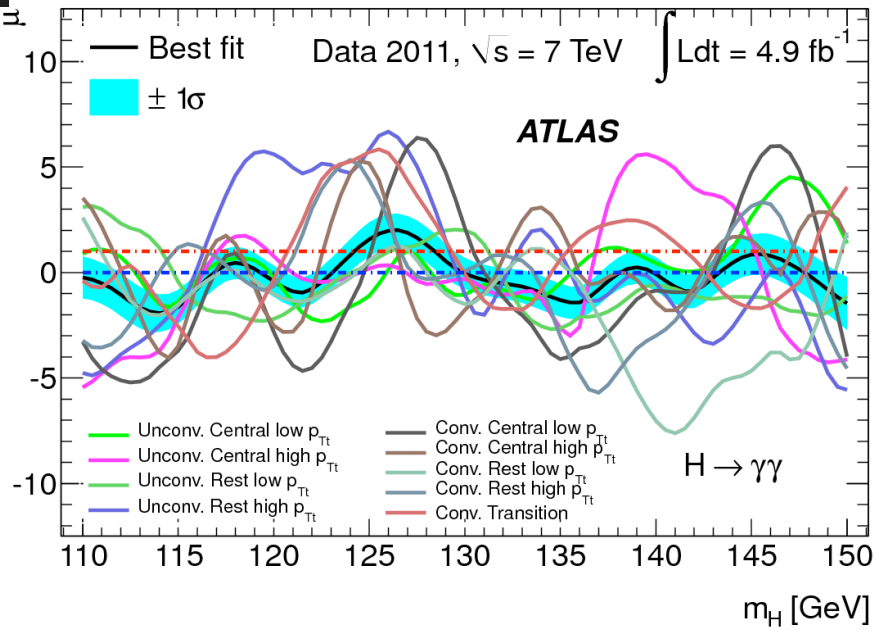
H→γγ

- mass resolution for each category
- observed μ for each category
- z position resolution is ~6mm for converted photon, ~15mm for unconverted photon



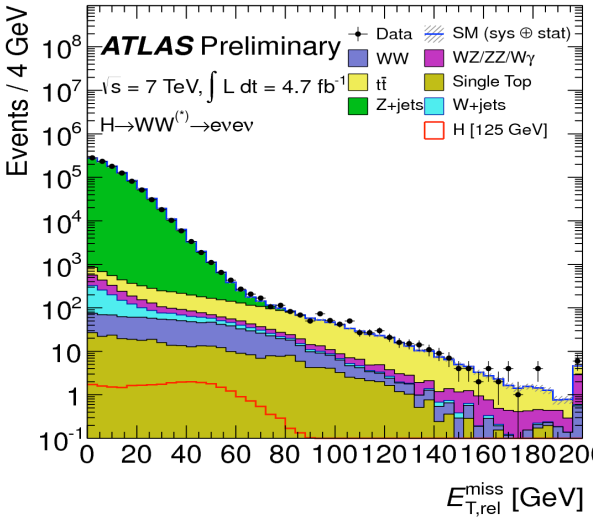


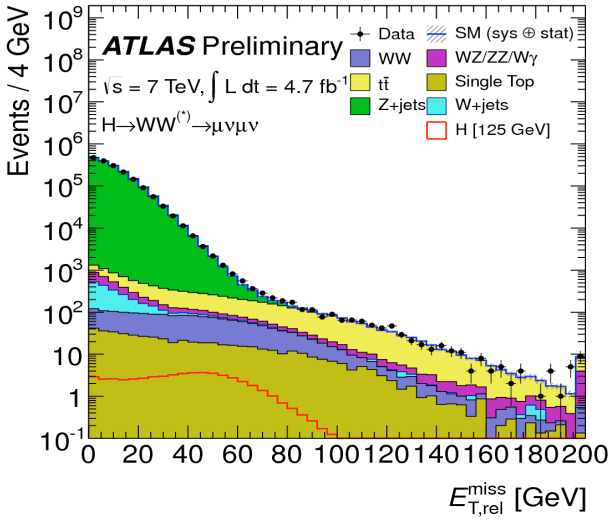
Category	σ_{CB}	FWHM	N_S	N_D	S/B
Unconverted central, low p_{Tt}	1.4	3.4	9.1	1763	0.05
Unconverted central, high p_{Tt}	1.4	3.3	2.6	235	0.11
Unconverted rest, low p_{Tt}	1.7	4.0	17.7	6234	0.02
Unconverted rest, high p_{Tt}	1.6	3.9	4.7	1006	0.04
Converted central, low p_{Tt}	1.6	3.9	6.0	1318	0.03
Converted central, high p_{Tt}	1.5	3.6	1.7	184	0.08
Converted rest, low p_{Tt}	2.0	4.7	17.0	7311	0.01
Converted rest, high p_{Tt}	1.9	4.5	4.8	1072	0.03
Converted transition	2.3	5.9	8.5	3366	0.01
All categories	1.7	4.1	72.1	22489	0.02

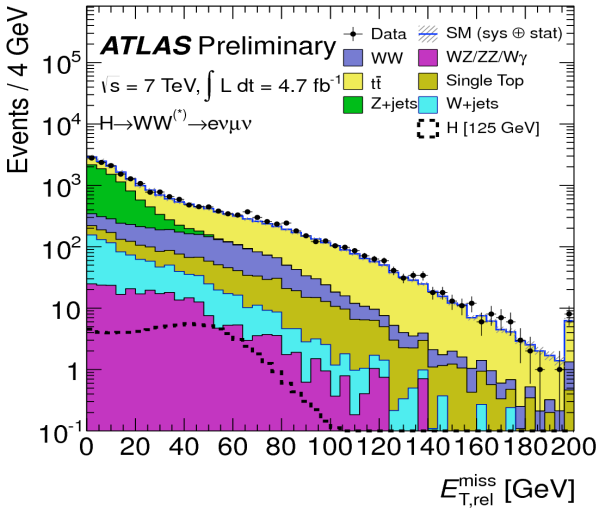


H→WW→lvlv

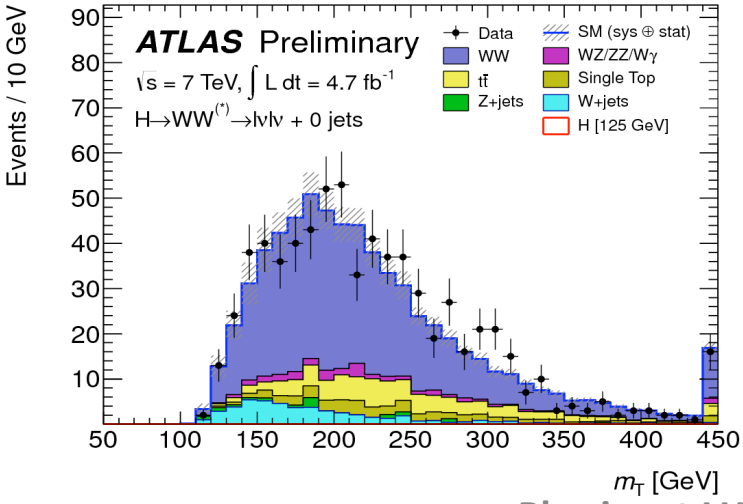
- **MET modeling in high pile up condition**

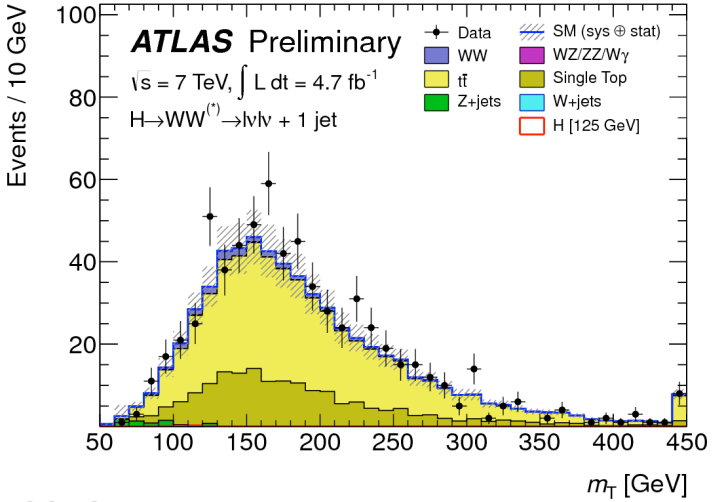






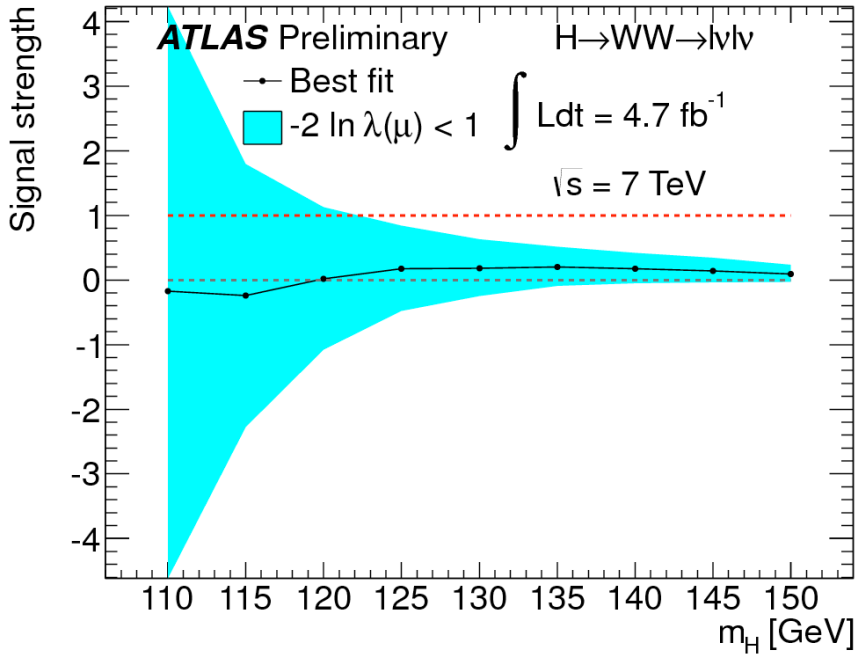
- **WW control region, top control region**

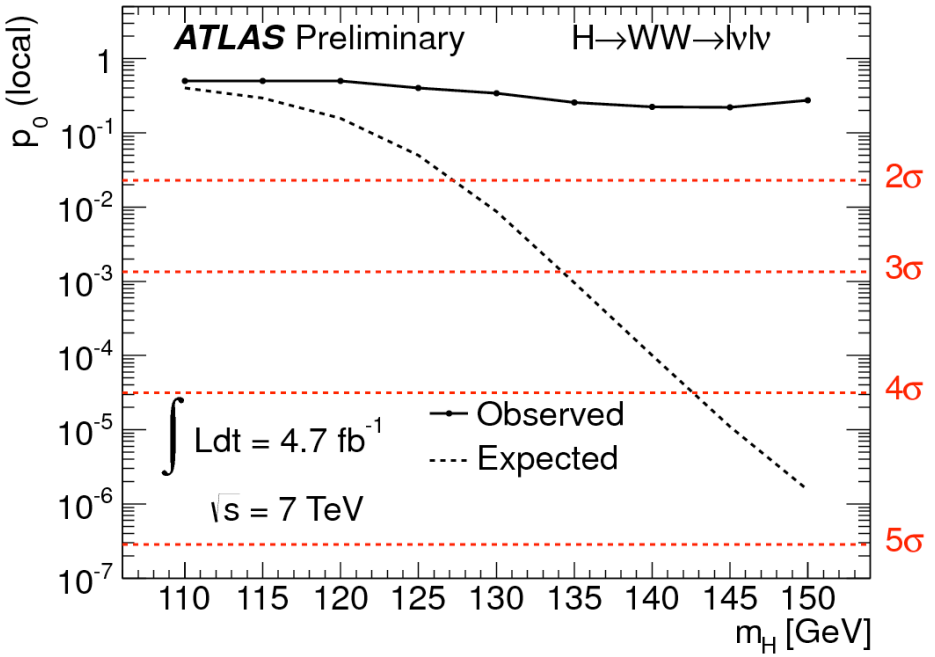




H→WW→lvlv

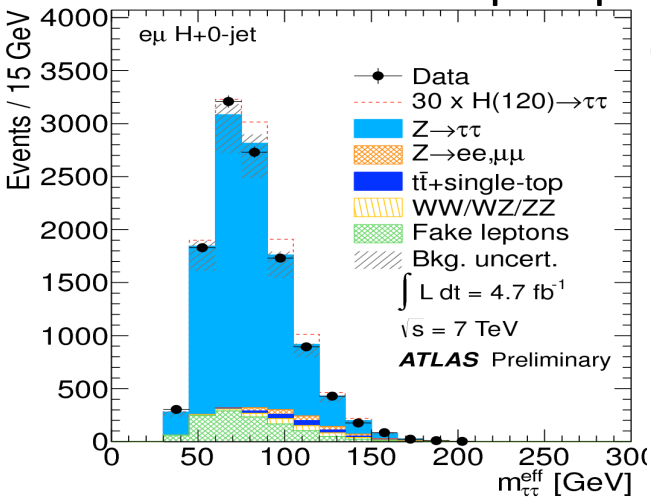
- H→WW p_0

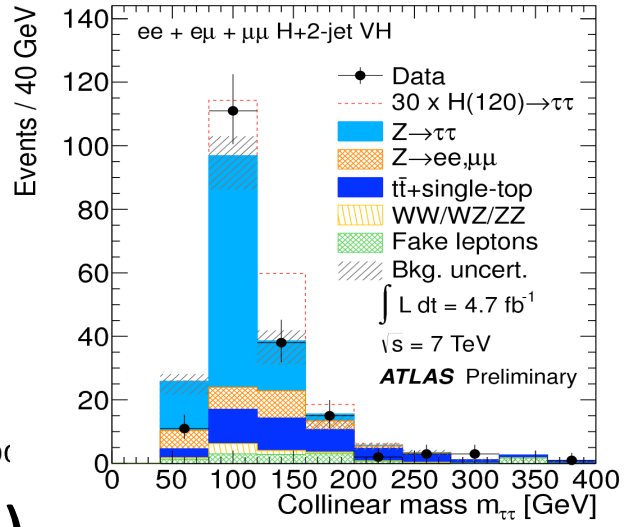


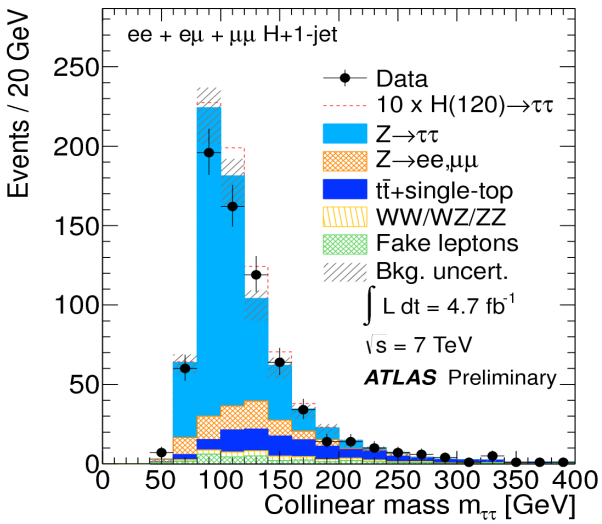


Other Categories in H→ττ

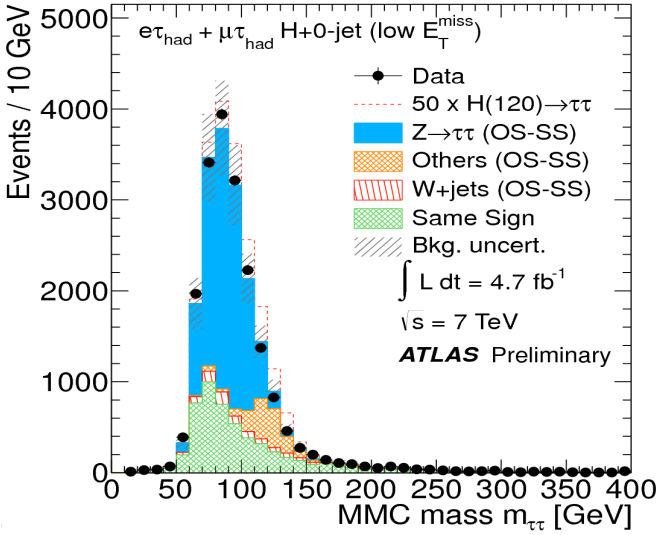
- H→ττ ($\tau_{lep}\tau_{lep}$)

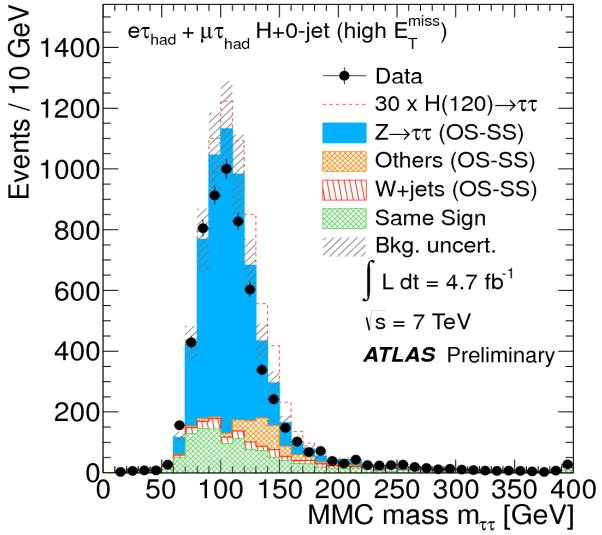


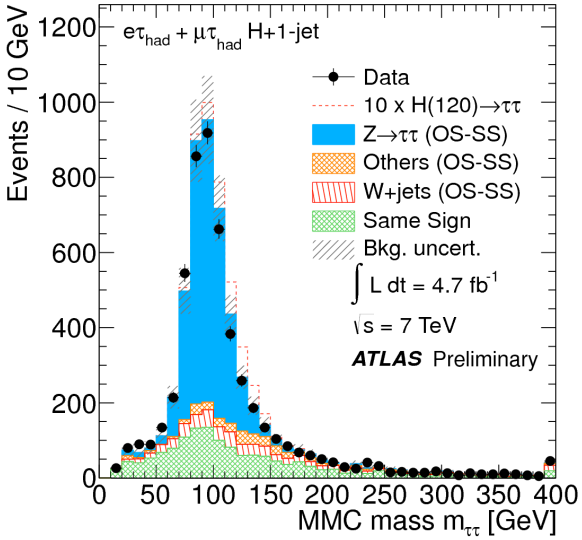




- H→ττ ($\tau_{lep}\tau_{had}$)

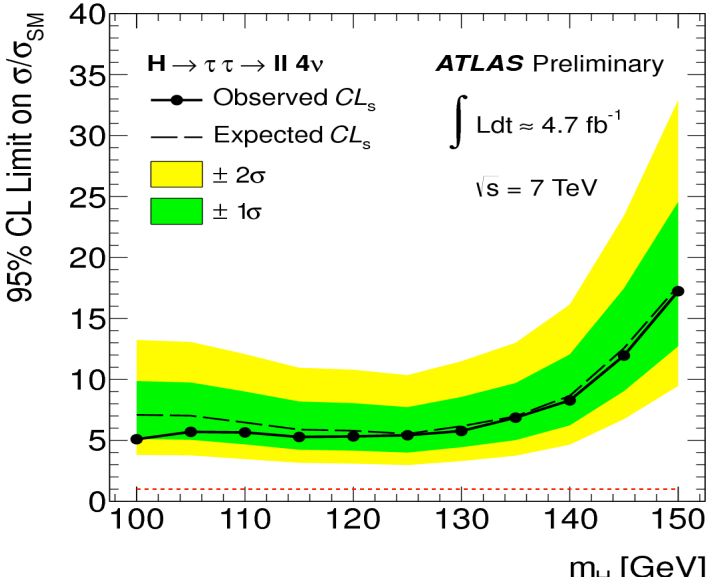


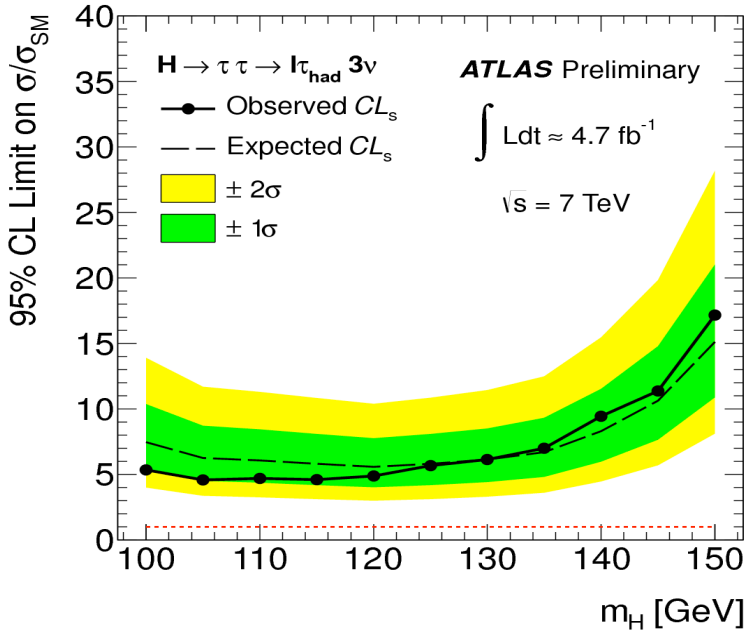


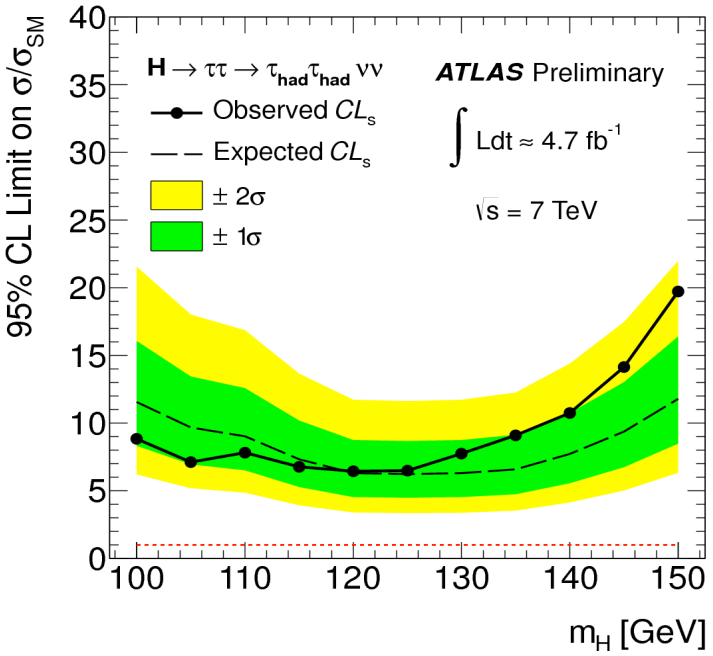


$H \rightarrow \tau\tau$ ($\tau_{lep}\tau_{lep}$, $\tau_{lep}\tau_{had}$, $\tau_{had}\tau_{had}$)

- 95% CL upper limit for each channel

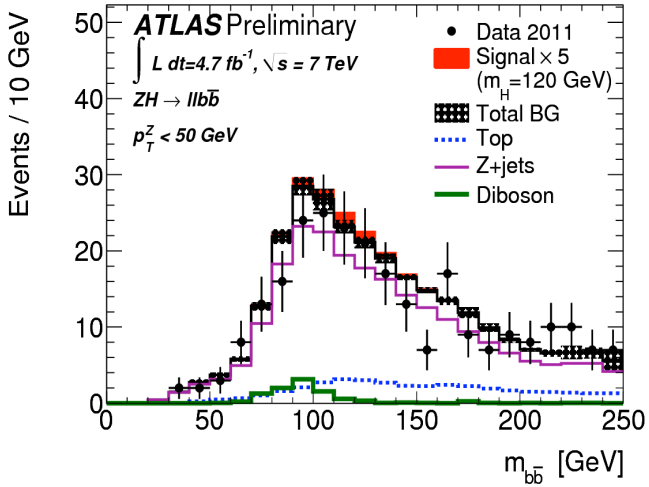


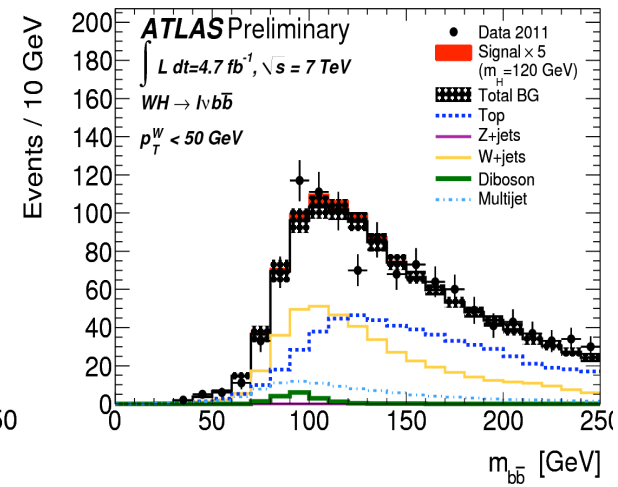


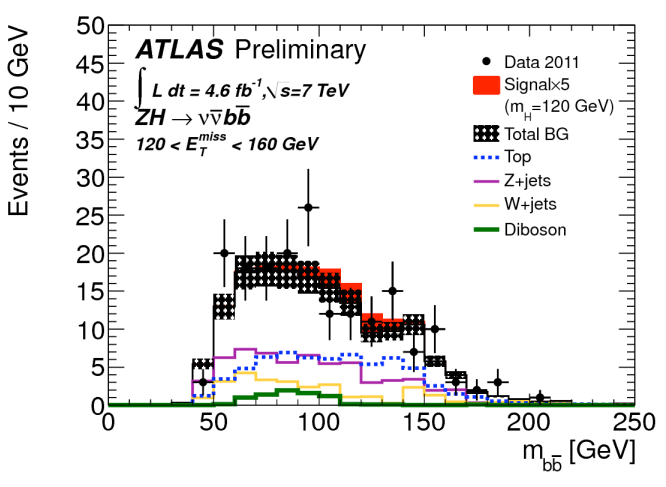


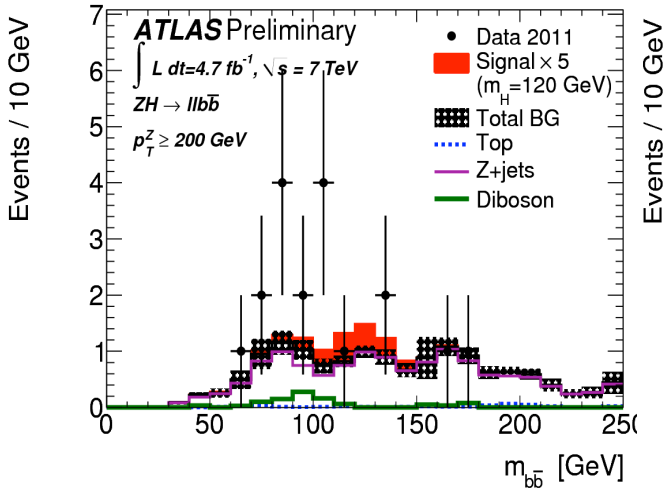
W/ZH(→bb)

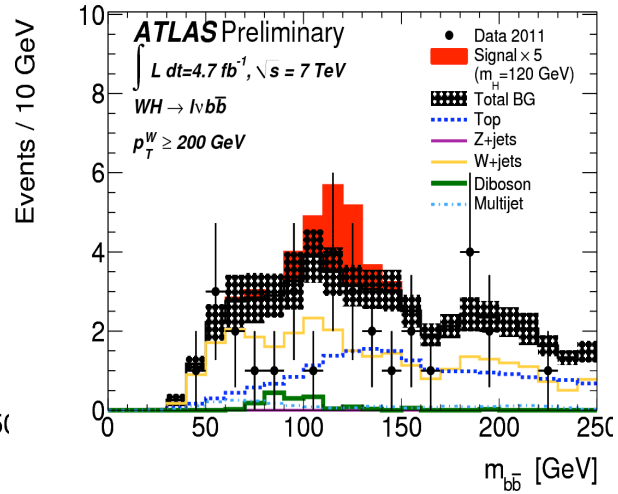
- Top (low pt category), bottom (high pt category)

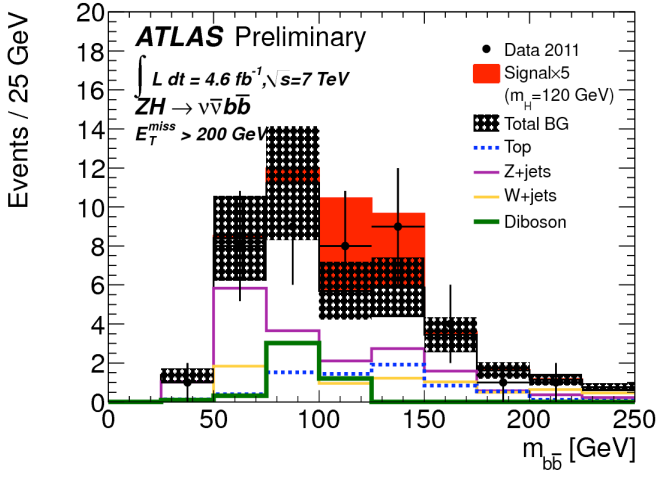












W/ZH(→bb)

- 95% CL upper limit for each channel