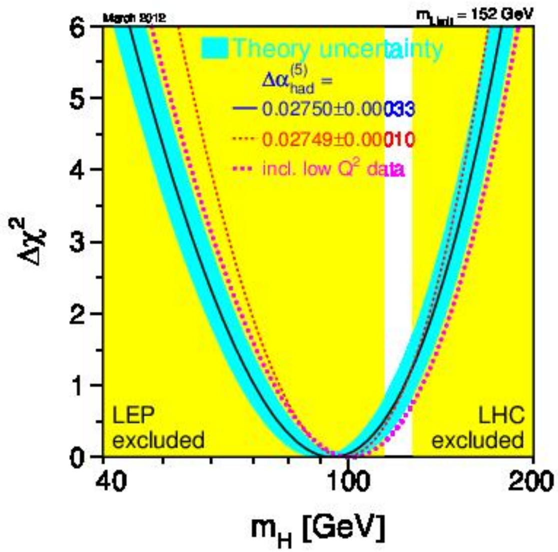
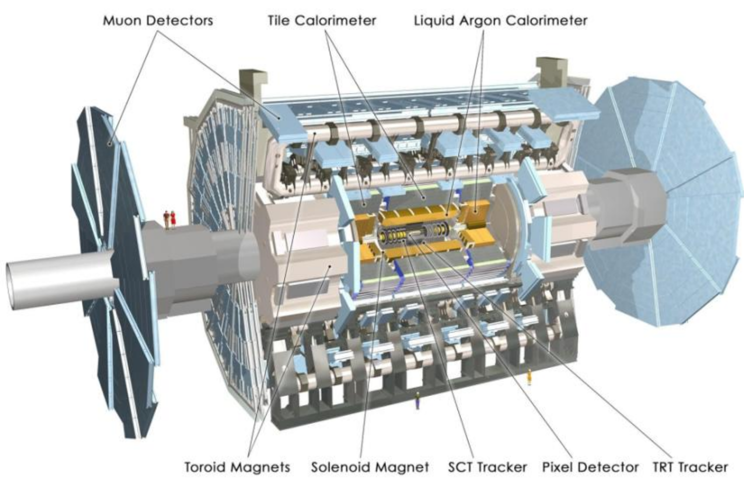
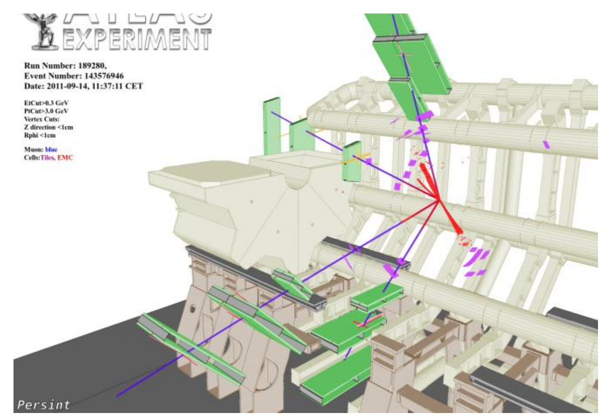
Current status of Standard Model Higgs boson searches from ATLAS

on behalf of the ATLAS collaboration





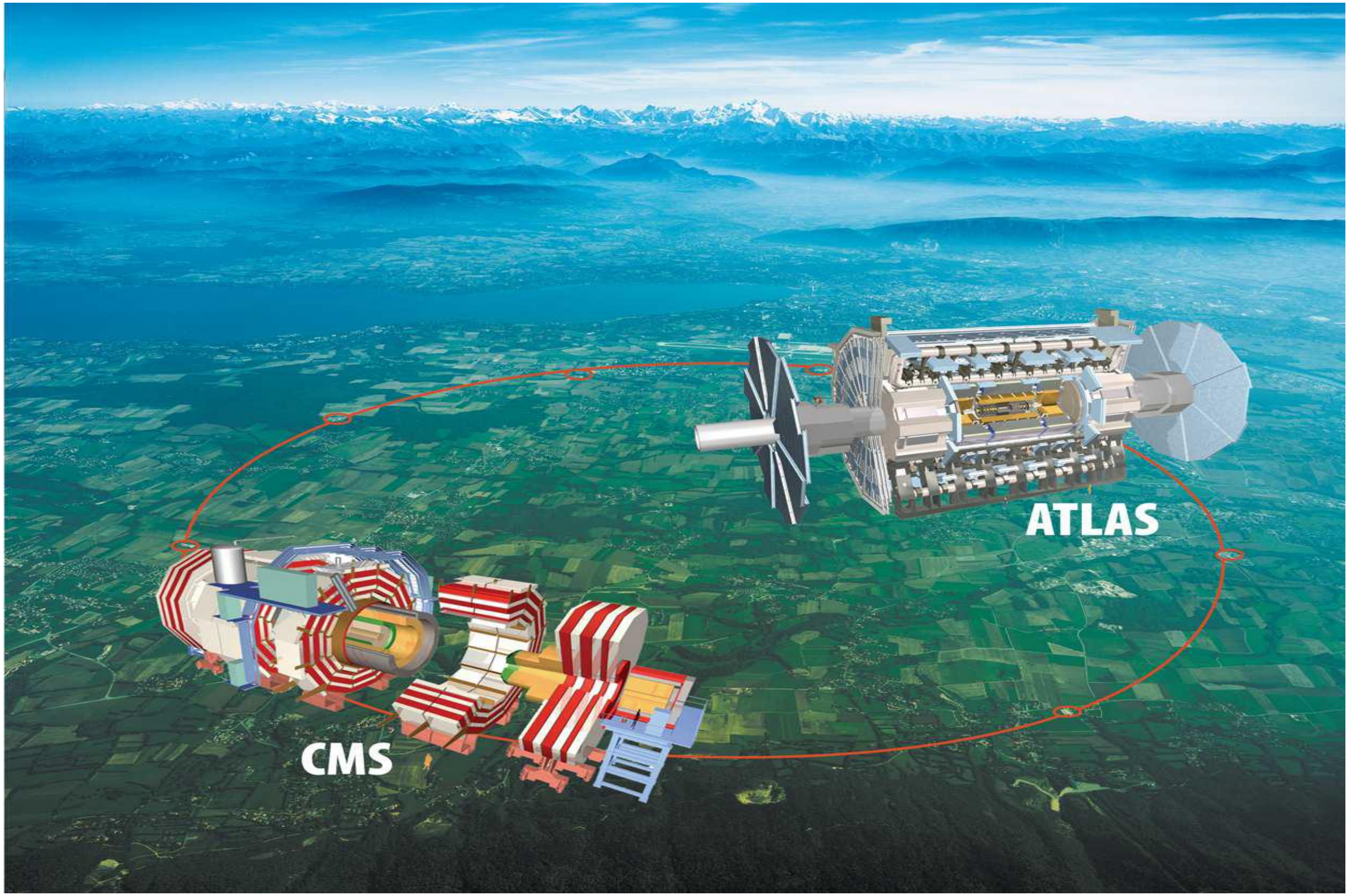


Jonas Strandberg **Origin of Mass, June 11, 2012**

Introduction

- For 50 years now, particle phycisists have been searching for a particle called the Higgs boson.
  - Postulated to exist in the 1960's to solve problems in the theory of elementary particles.
- This talk will review the latest public results for the Standard Model Higgs boson searches from ATLAS.
  - Non-SM Higgs searches from ATLAS are covered by Trevor on Thursday morning.
  - The results from CMS will be covered by Chiara (SM Higgs) tomorrow and by Mario (non-SM Higgs) on Wednesday.

The Large Hadron Collider



The LHC

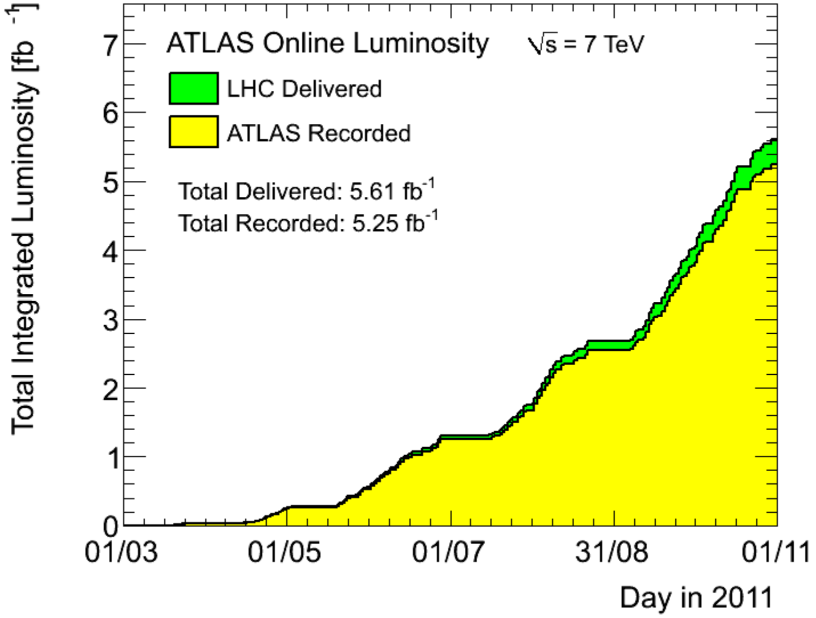
- The LHC is the latest in the series of energy frontier colliders, taking over from the Tevatron and LEP before it.
  - LHC collides two beams of protons at a center of mass energy of 7 TeV (in 2011) or 8 TeV (in 2012).
  - In comparison, the Tevatron was a $p\bar{p}$ collider at 2 TeV, and LEP an e^+e^- collider at around 200 GeV collision energy.
- The idea of the LHC is to explore the physics at the electro-weak scale and to search for any new physics beyond the SM.
  - To close the book on the question of the Higgs boson existance in the full mass range up to 1 TeV.
  - To investigate whether there are new particles from for example Supersymmetry, where the WIMP miracle favors a DM particle to have a mass of the order of 100 GeVs.

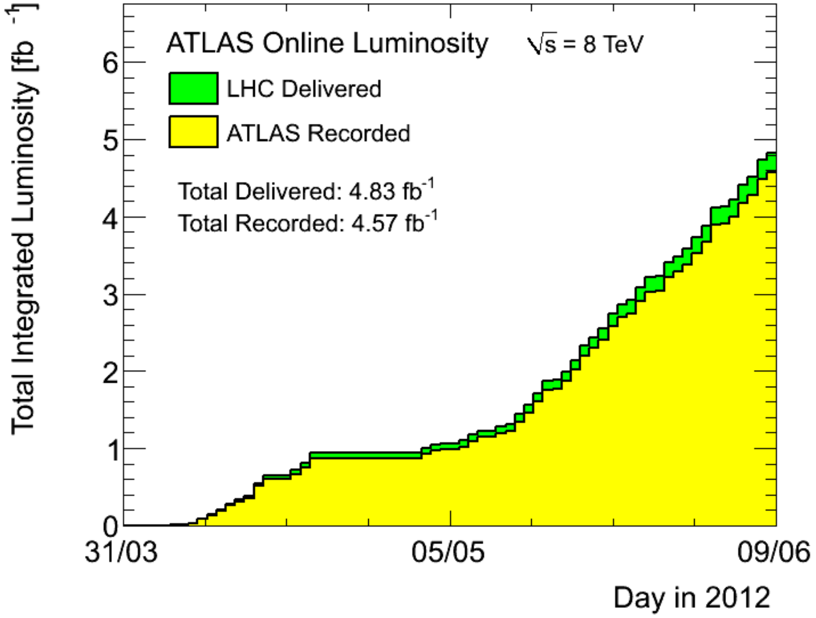
The Data Sample

- The ”amount” of collision data is measured in integrated luminosity. Dimensions of inverse cross section:

$$N = \sigma \cdot \int L\,dt$$

- Only the data from 2011 (7 TeV) has been analysed so far!

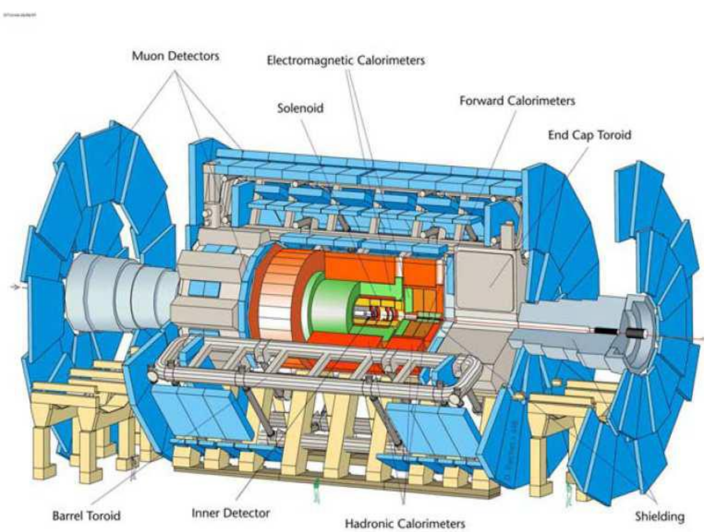




The ATLAS Detector

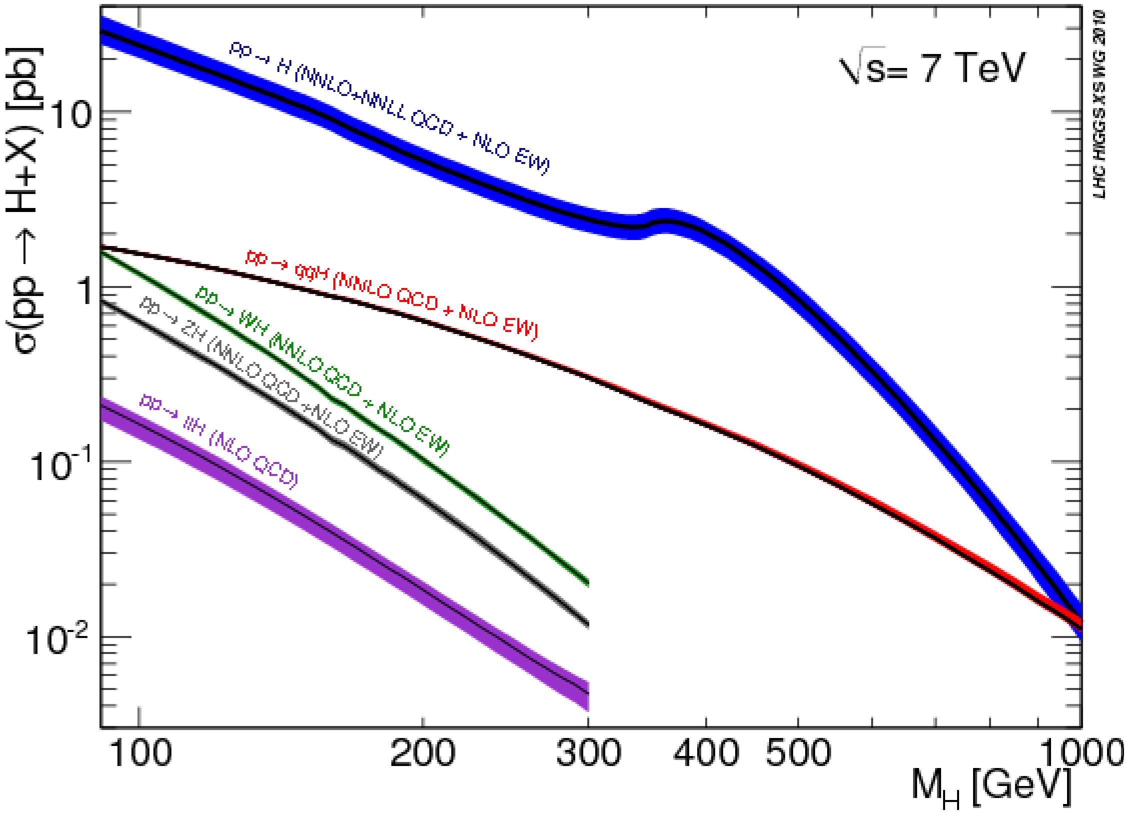
- ATLAS is, together with CMS, one of the general purpose detectors at the LHC. Designed to be able to do any kind of physics analysis to high precision.
  - The ATLAS collaboration consists of about 3,000 members from 174 universities in 38 countries.

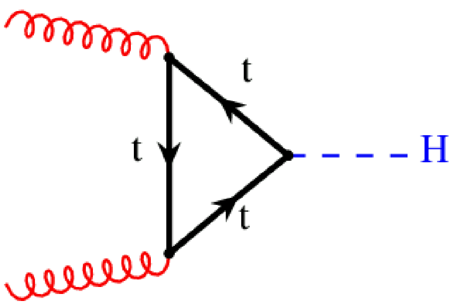
- To achieve the physics goals, ATLAS needs to be able to measure the decay products from the rapidly decaying new particles produced with high precision.

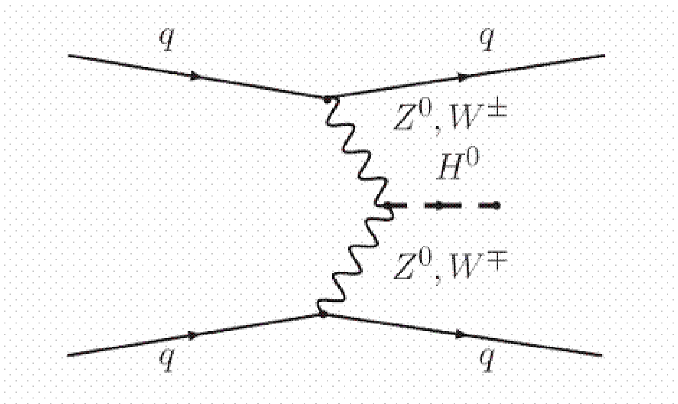


Higgs Production at the LHC

- Total cross section, σ, at the LHC is roughly 10^{11} pb.
  - A Higgs boson is produced in 1 out of 10^{10} collisions.

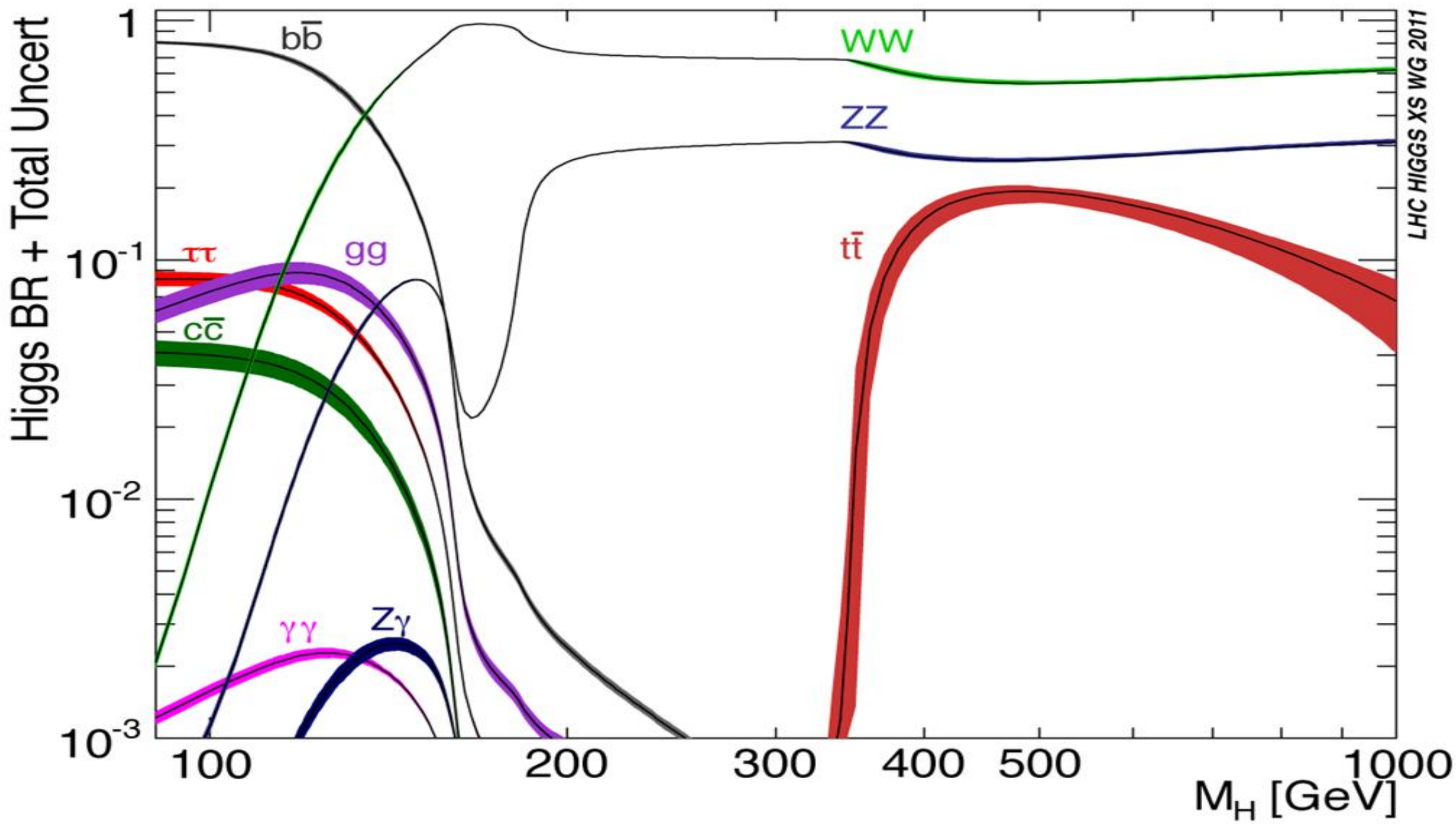






Higgs Boson Decays

- Depending on the mass of the Higgs boson, it tends to decay to the heaviest available pair of particles.



Search Channels

- H→γγ and H→ZZ→4l channels at low Higgs mass with great mass resolution.
- H→WW→lνlν, H→ττ (ll, lh, hh) and VH, H→bb channels at low mass with limited mass resolution.
- H→ZZ→llνν, H→ZZ→lljj and H→WW→lνjj for high masses.

Channel	m_H range (GeV)	Backgrounds	L (fb-1)	Reference
H→γγ	110-150	γγ, γj, jj	4.9	arXiv:1202.1414
H→ZZ→4l	110-600	ZZ, Z+jets, $t\bar{t}$	4.8	arXiv:1202.1415
H→WW→lνlν	110-600	WW, tt, W/Z+jets	4.7	arXiv:1206.0756
H→ττ (ll, lh, hh)	100-150	Z→ττ, $t\bar{t}$	4.7	CONF-2012-014
VH, H→bb	110-130	W/Z+jets, $t\bar{t}$	4.7	CONF-2012-015
H→ZZ→llνν	200-600	VV, $t\bar{t}$, Z+jets	4.7	arXiv:1205.6744
H→ZZ→lljj	200-600	Z+jets, $t\bar{t}$, VV	4.7	CONF-2012-017
H→WW→lνjj	300-600	W+jets, $t\bar{t}$, QCD	4.7	CONF-2012-018

Object Uncertainties

Physics Object	Source	Uncertainty on signal yield	Most affected search channels
Photons	Efficiency	11%	γγ
Electrons	Efficiency Energy Scale Energy Resolution	< 3% < 1% < 0.5%	4-lepton
Muons	Efficiency Momentum Res	< 1% < 1%	4-lepton
Jets	Energy Scale Energy Resolution	Up to 12% Up to 20%	ττ, bb, lljj, lvjj lvjj
b-tagging	Efficiency	Up to 15%	bb
τ-jet	Efficiency	Up to 8%	ττ
	Luminosity	3.9%	

High Higgs Boson Mass Searches

$H \rightarrow ZZ \rightarrow ll\nu\nu$

- 4 sub-channels: (ee, μμ) * (low-, high-pileup).
- $|m_Z - m_{ll}| < 15$ GeV.
- Different selections for $m_H < 280$ GeV & $m_H > 280$ GeV.
- Cuts on MET, opening angle between the leptons and opening angle between MET and other leptons and jets.
- Use m_T distribution for the limit setting.

$H \rightarrow ZZ \rightarrow lljj$

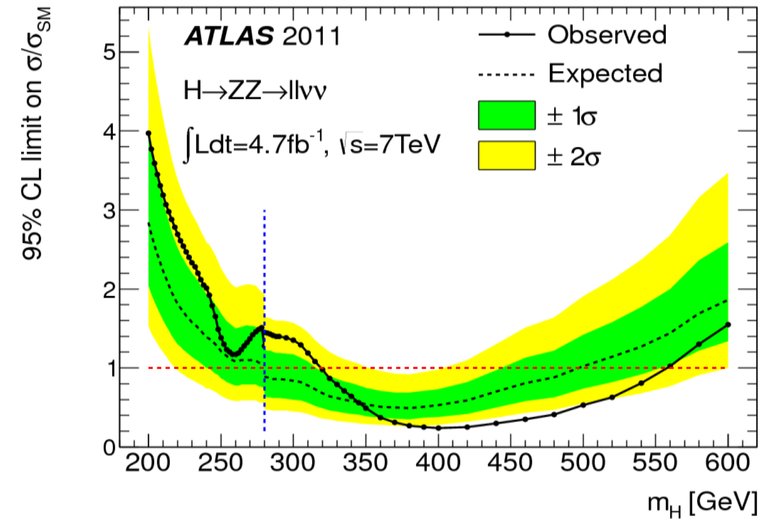
- 2 sub-channels: (btag, untag).
- $83 < m_{ll} < 99$ GeV, $70 < m_{jj} < 105$ GeV.
- Cuts on MET, opening angle between the jets.
- For $m_H > 300$ GeV, cut on opening lepton angle.
- Use m_{lljj} distribution for the limit setting.

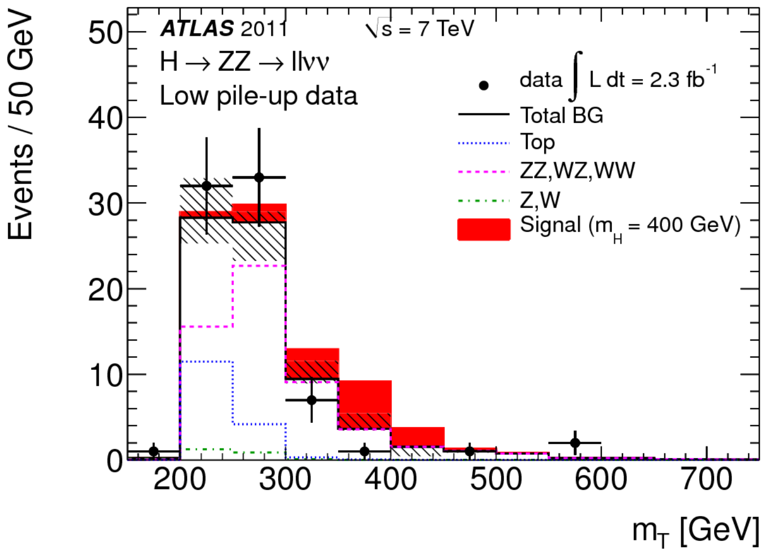
$H \rightarrow WW \rightarrow l\nu jj$

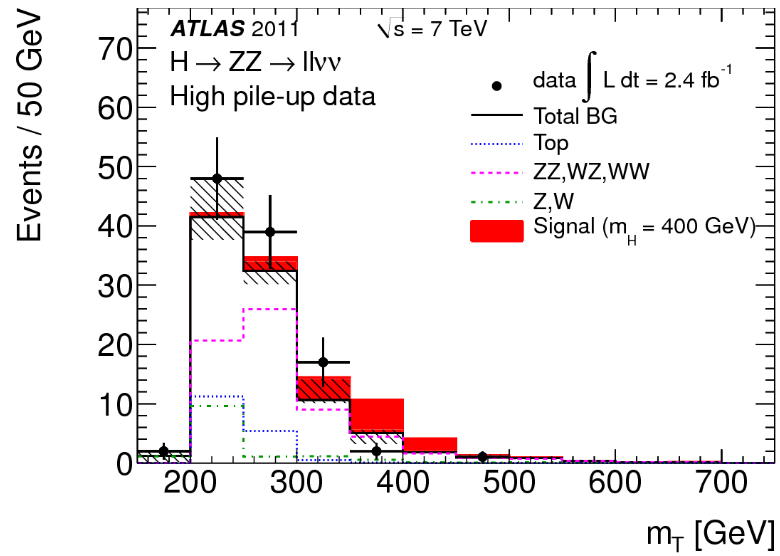
- 6 sub-channels: (e, μ) * (0, 1, 2 jets).
- $71 < m_{jj} < 91$ GeV.
- Cut on MET.
- Require $m_{l\nu} = m_W$.
- For 2-jet channel, require m_{jj} and jet opening angle cuts.
- Use $m_{l\nu jj}$ distribution for the limit setting.

The H→ZZ→llνν Channel

- Most sensitive channel in the high mass region.
  - Expected exclusion 280-497 GeV.
  - Observed exclusion 319-558 GeV.

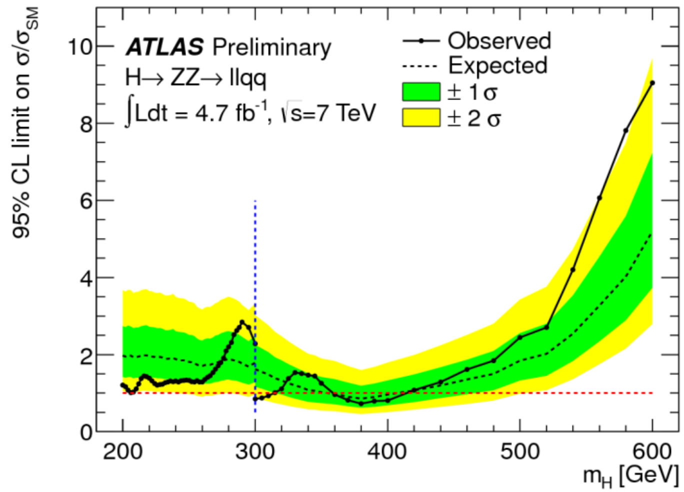


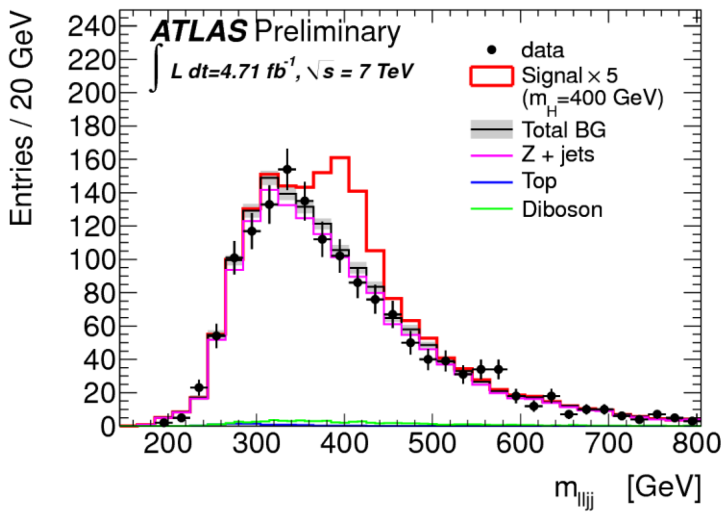


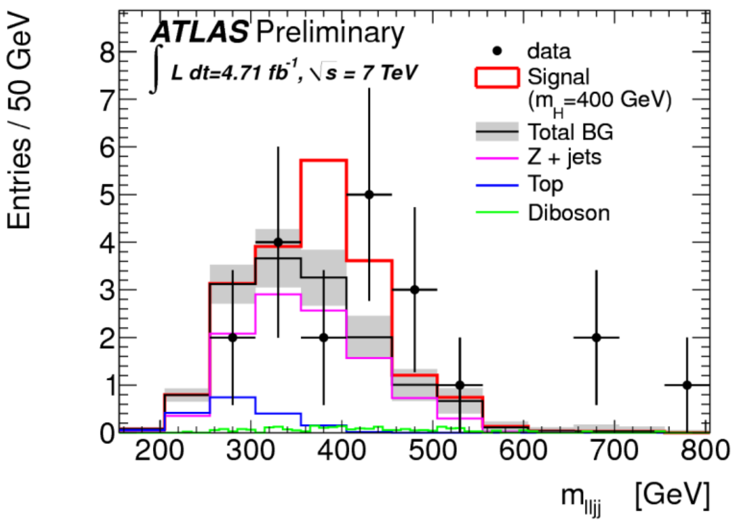


The H→ZZ→lljj Channel

- Background extraction of Z+jets from m_{jj} sidebands and the $t\bar{t}$ background from m_{ll} sidebands.
  - Expected exclusion: 360-400 GeV.
  - Observed exclusion: 300-310, 360-400GeV.

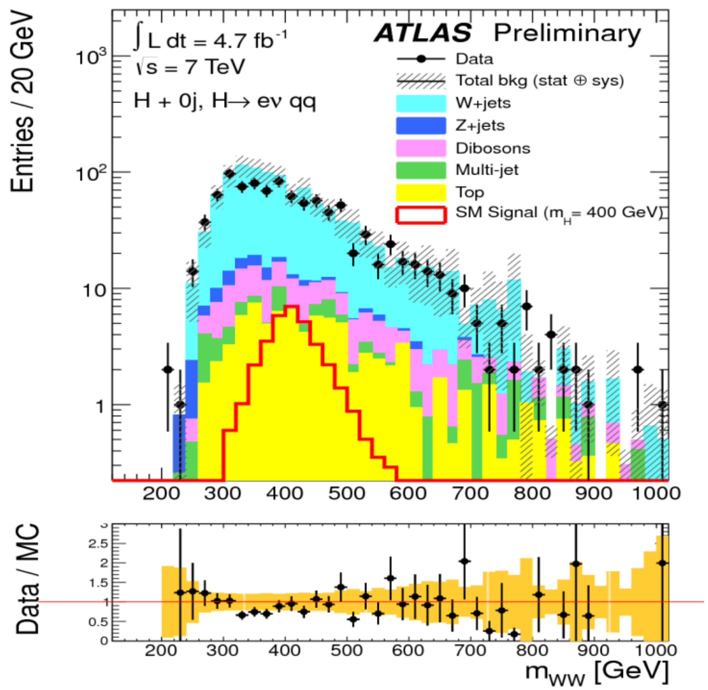


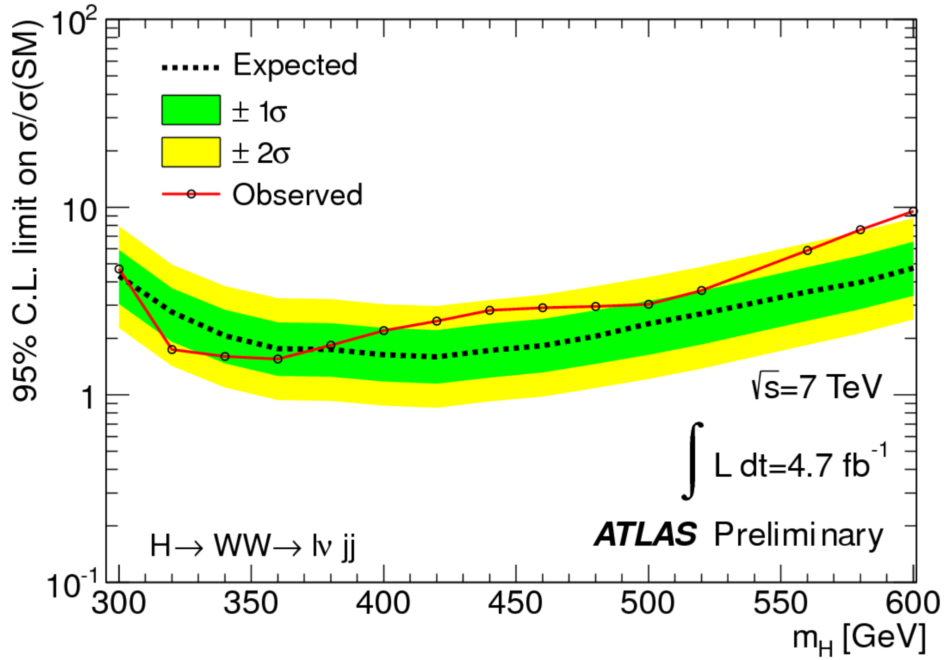




The H→WW→lνjj Channel

- Invariant mass of the Higgs boson candidate reconstruction by means of the m(lν) = m(W) mass constraint.
- Background modeled directly from the fit to the m_{jj} spectrum.





Searches in the Low Mass Region

$H \rightarrow ZZ \rightarrow 4l$

- 4 sub-channels: (4e, 4μ, 2e2μ, 2μ2e)
- Use 4l invariant mass spectra for the limit setting.

$H \rightarrow \gamma\gamma$

- 9 sub-categories: (p_T^{thrust}, η, conversion)
- Use the γγ invariant mass spectra for the limit setting.

$H \rightarrow WW \rightarrow l\nu l\nu$

- 9 sub-channels: (ee, eμ, μμ) * (0, 1, 2 jets reconstructed).
- Use m_T shape for the limit setting.

$H \rightarrow \tau\tau$ (ll, lh, hh)

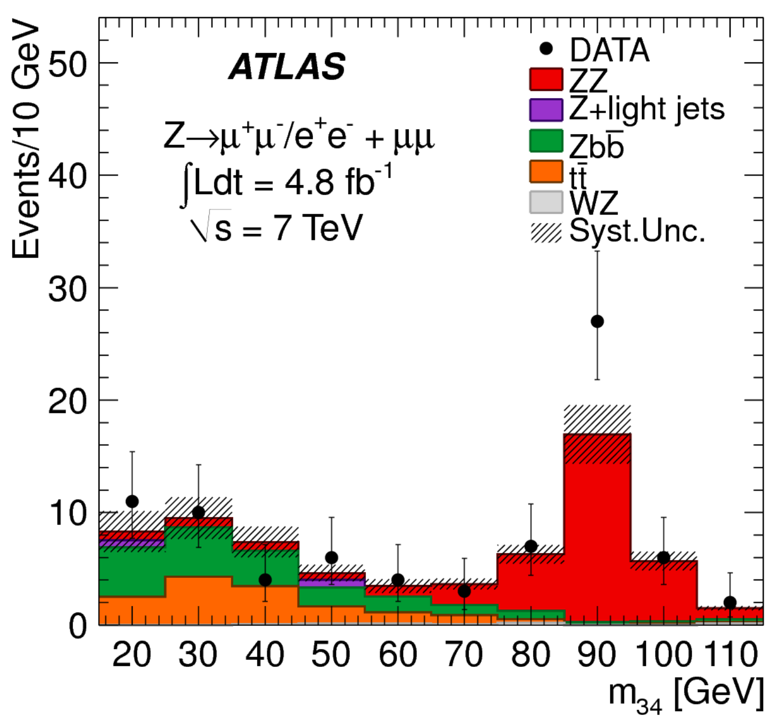
- 12 sub-channels (different jet bins considered).
- Use m_{eff} or $m_{\tau\tau}$ distributions for limit setting.

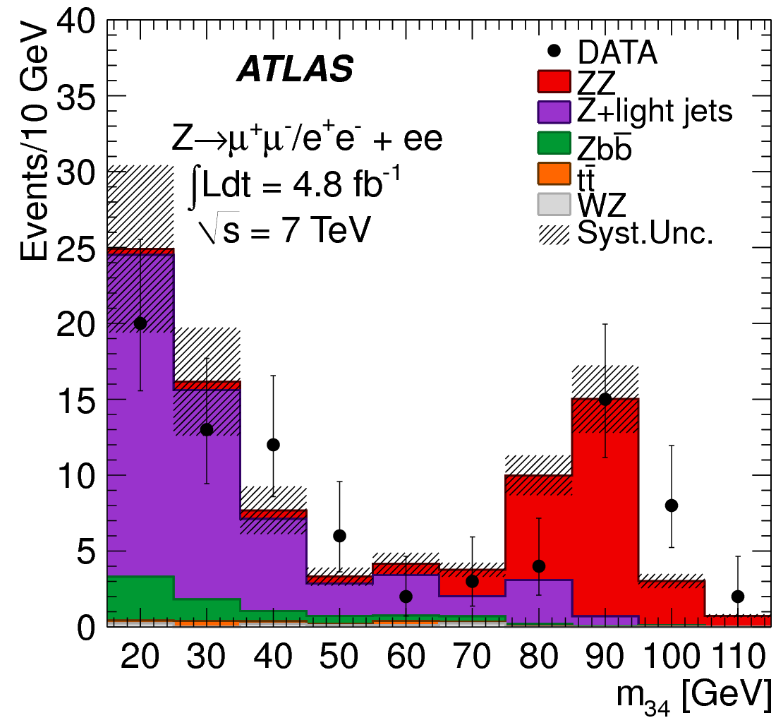
VH, $H \rightarrow bb$

- 11 sub-channels, depending on p_T of the W/Z boson and MET.
- Use m_{bb} distribution for the limit setting.

The H→ZZ→4l Channel

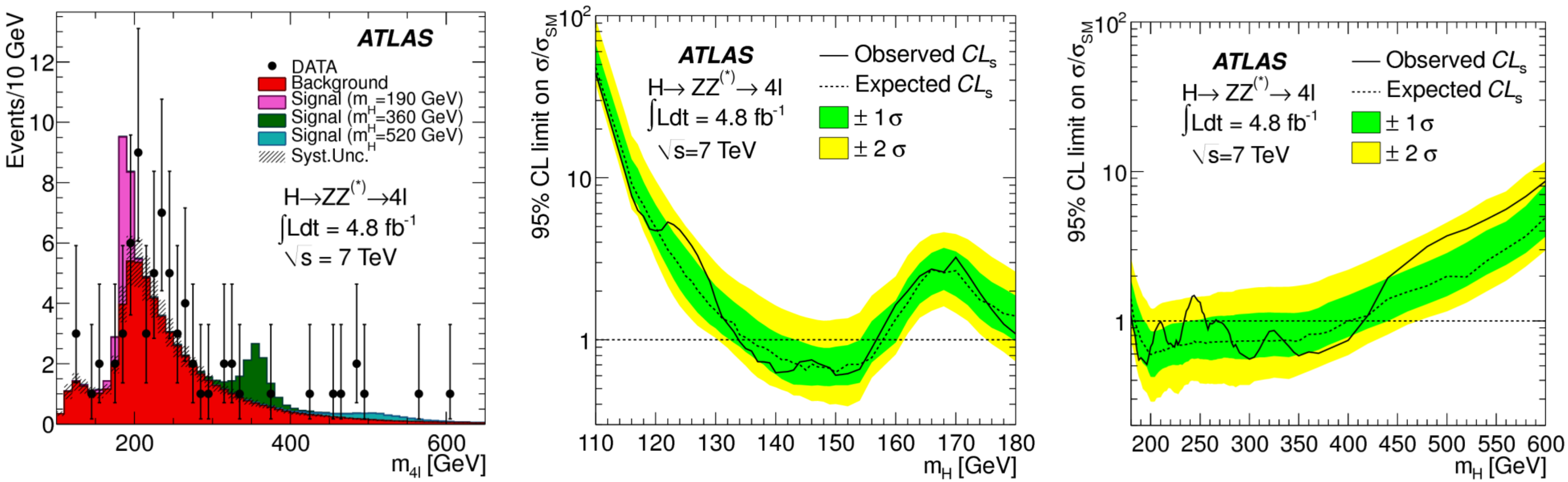
- High mass resolution (at 130 GeV: around 1.5-2%). Above Higgs boson masses of 350 GeV the natural width dominates.
- Reducible background estimation largely done from the data:





H→ZZ→4l Results

- The invariant mass distribution shows excesses at three different masses.
  - Expected limit: 137-157, 184-400 GeV.
  - Observed limit: 134-156, 182-233, 256-265, 268-415 GeV.



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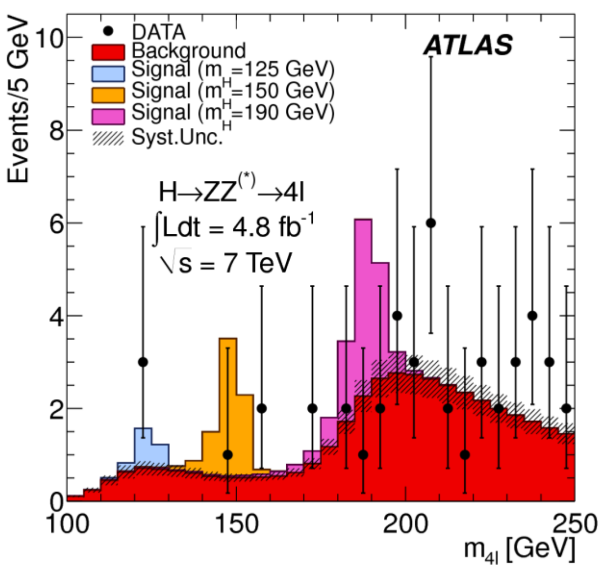
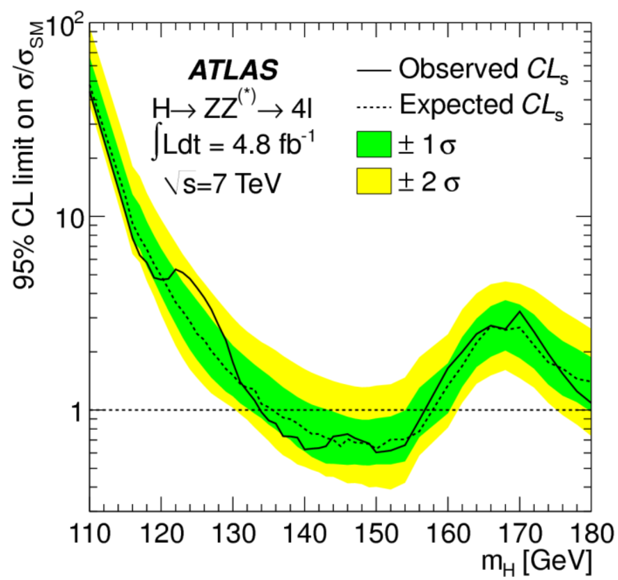
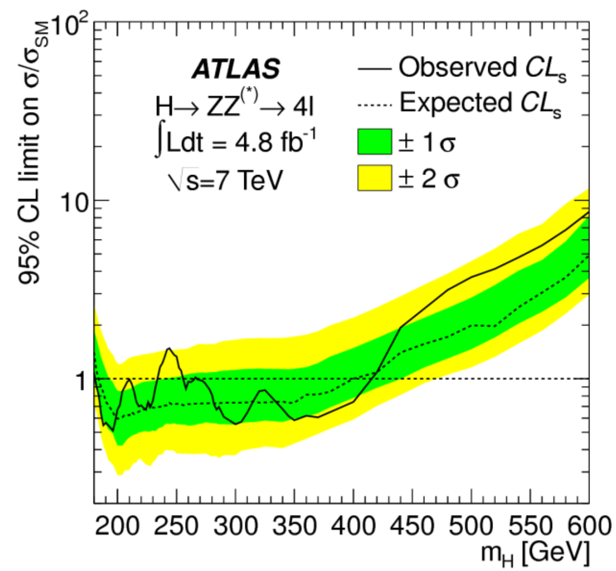
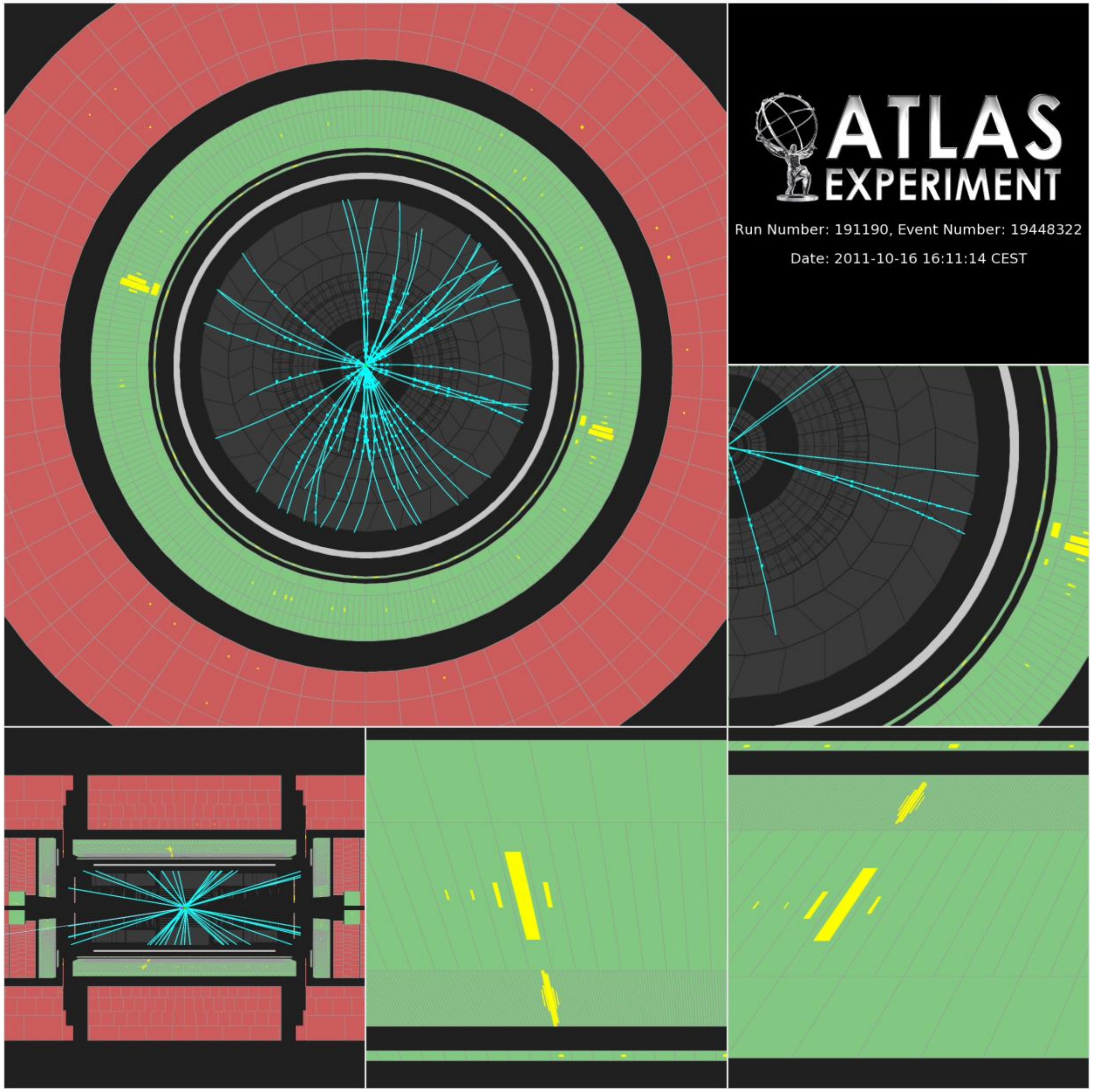




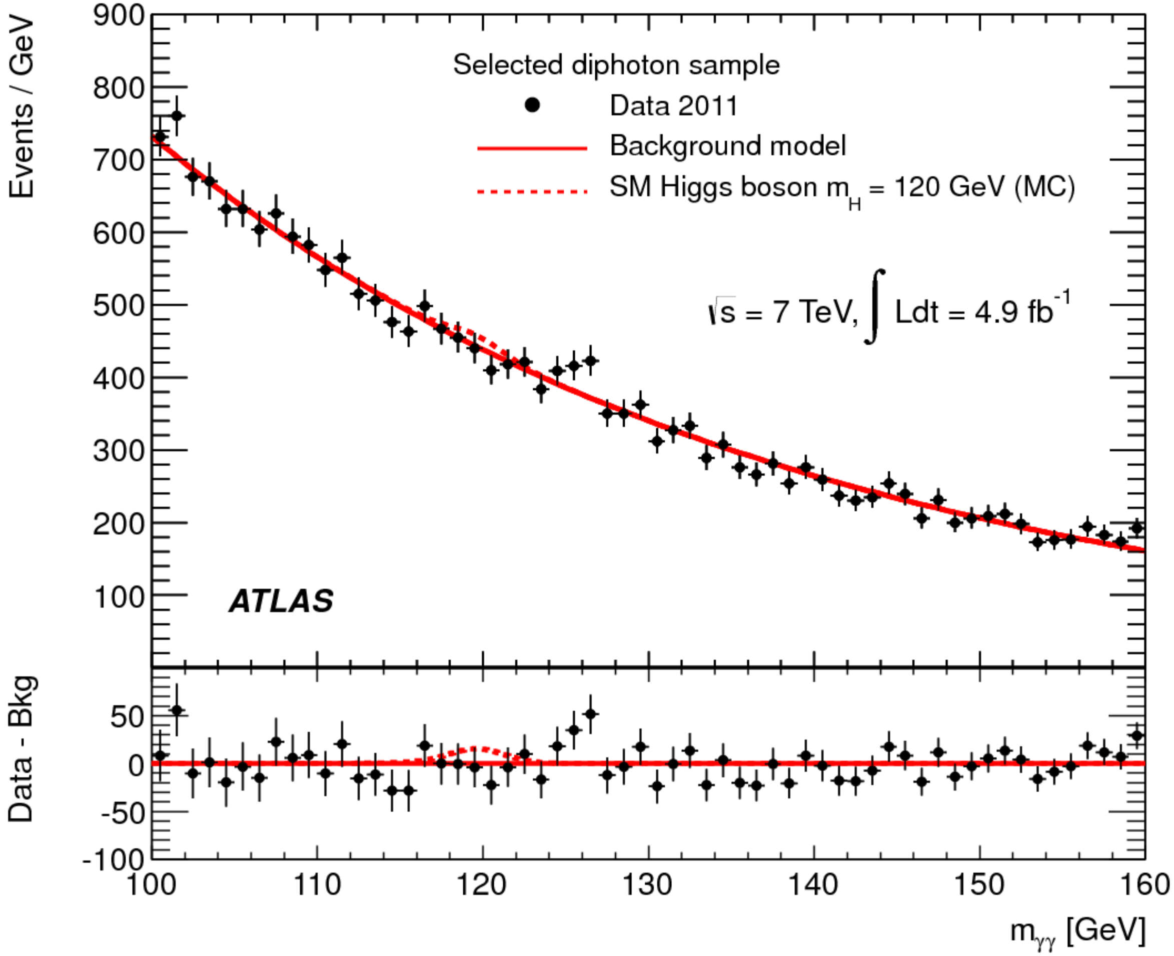


The H→γγ Channel

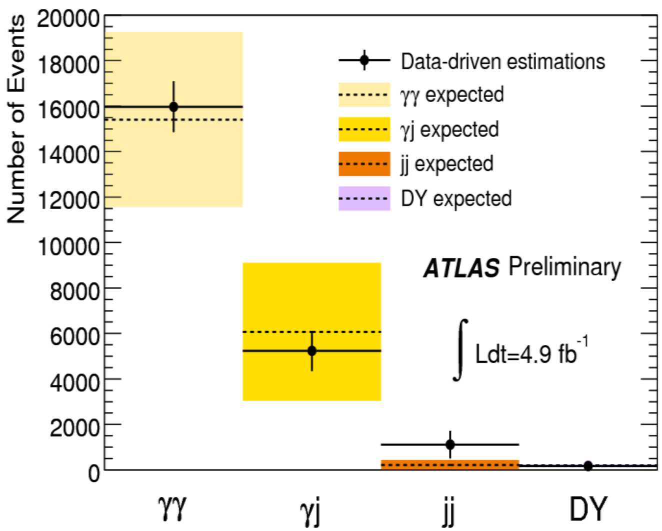
- Require two isolated photons above 40 and 25 GeV.
- Powerful γ/jet separation necessary.
- Relies on being able to see the signal due to the excellent γγ resolution.



H→γγ Results

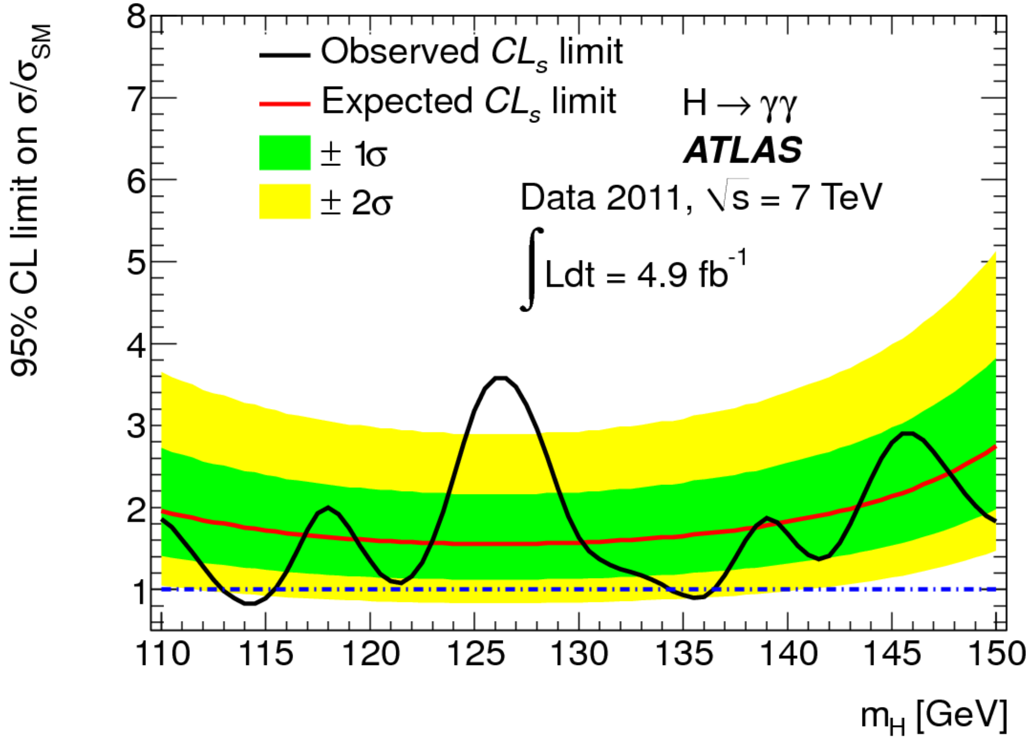


- Background fitted with exponential.
  - Largest excess at a mass of 126 GeV.



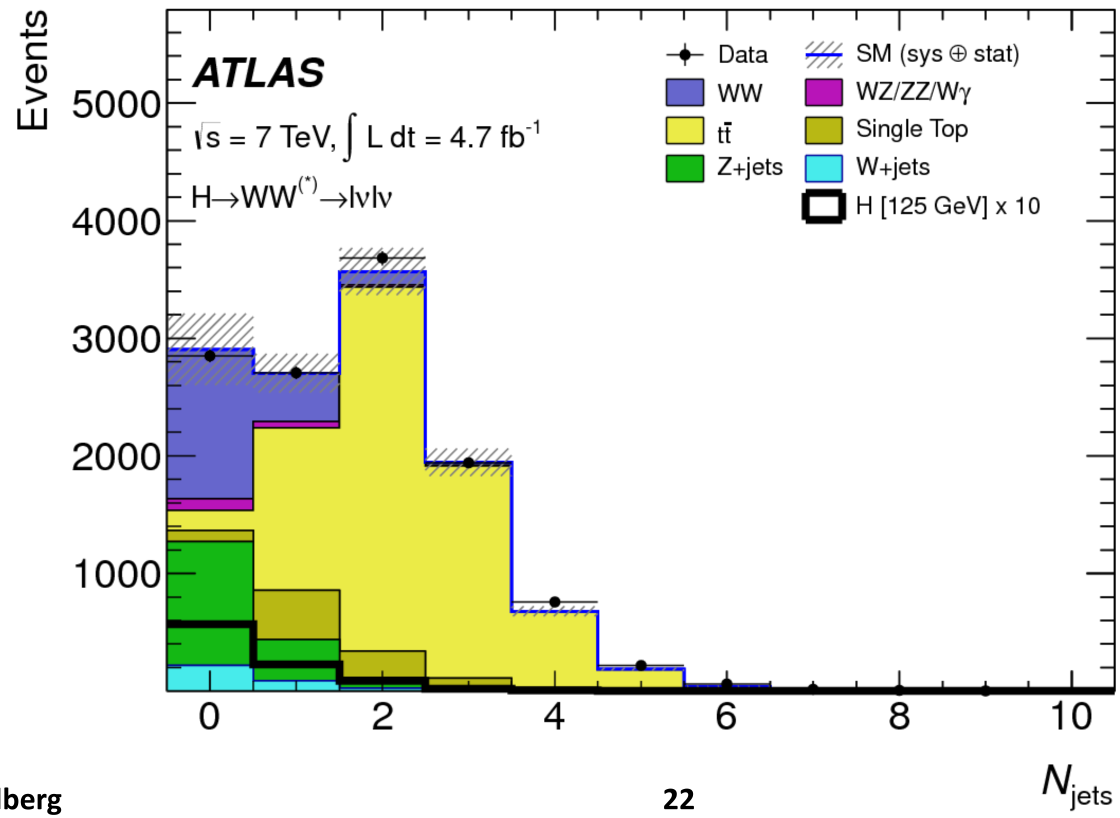
H→γγ Results

- Observed exclusion: 113-115 GeV, 134.5-136 GeV.
- Significance: 2.8σ local, 1.5σ global (entire range)



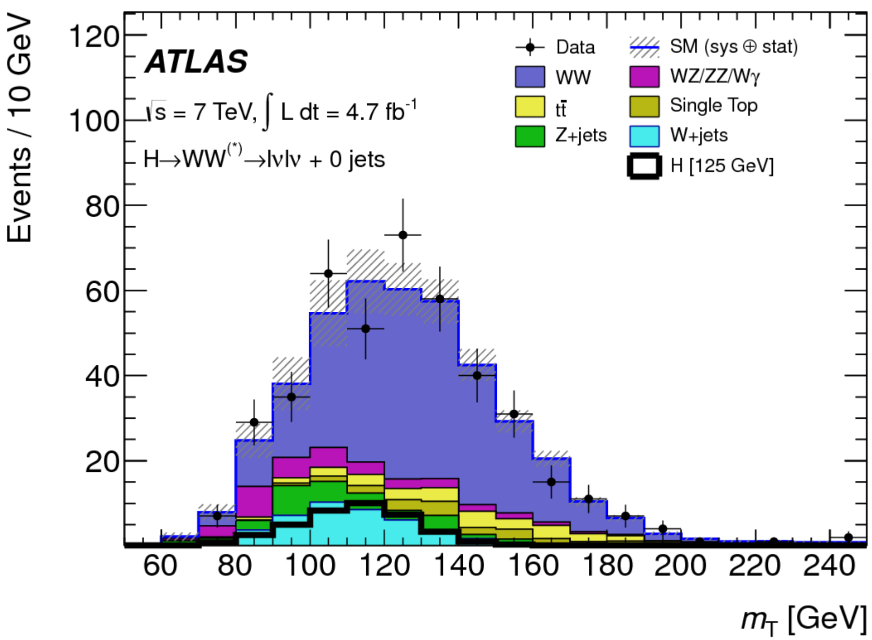
The H→WW→lνlν Channel

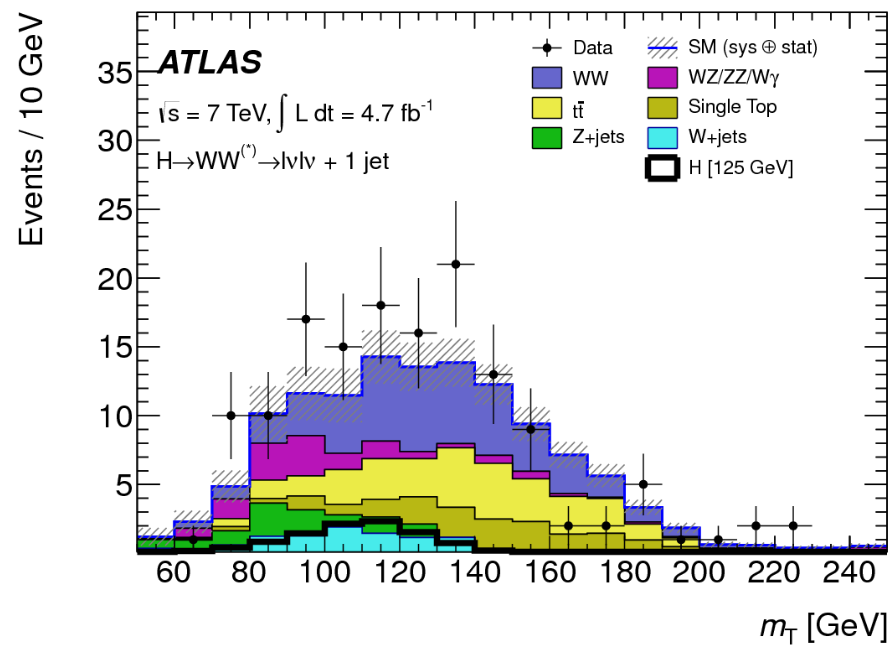
- Most sensitive channel in a broad mass range 120-180 GeV.
- Select two leptons and large MET, then look in the 0-, 1- and 2-jet multiplicity bins separately.



H→WW→lνlν Results

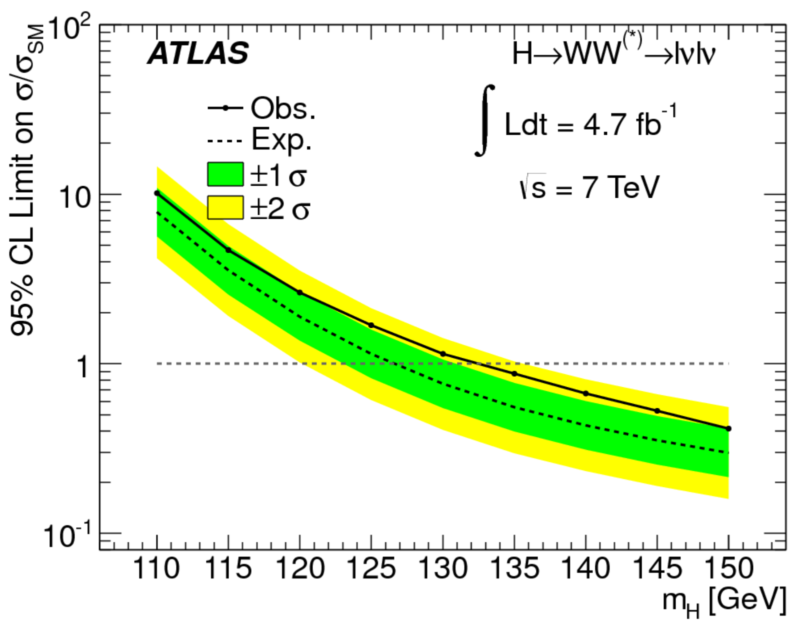
- Apply further selections that exploit the spin-0 nature of the Higgs boson, correlations in the lepton opening angles.
- Two neutrinos in the final state, no invariant mass peak. Use the transverse mass distribution to determine the limit.

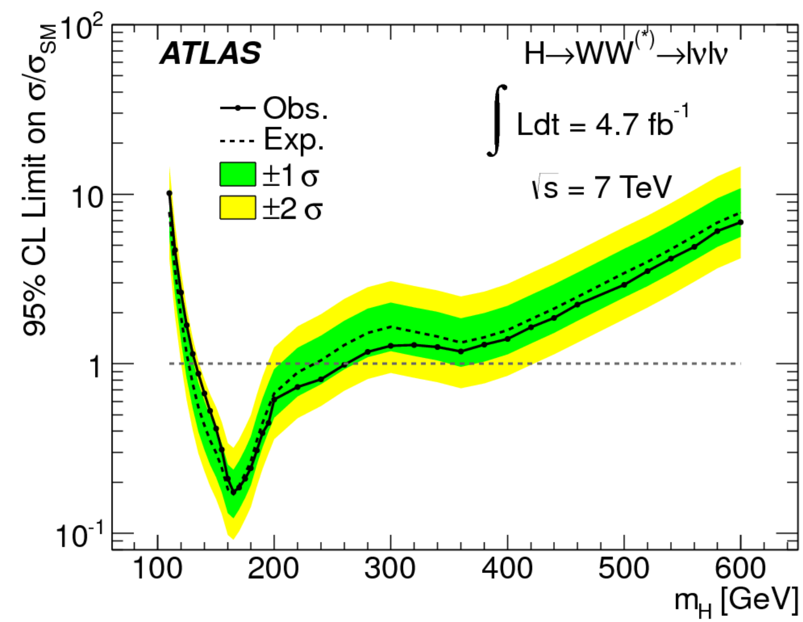




H→WW→lνlν Results

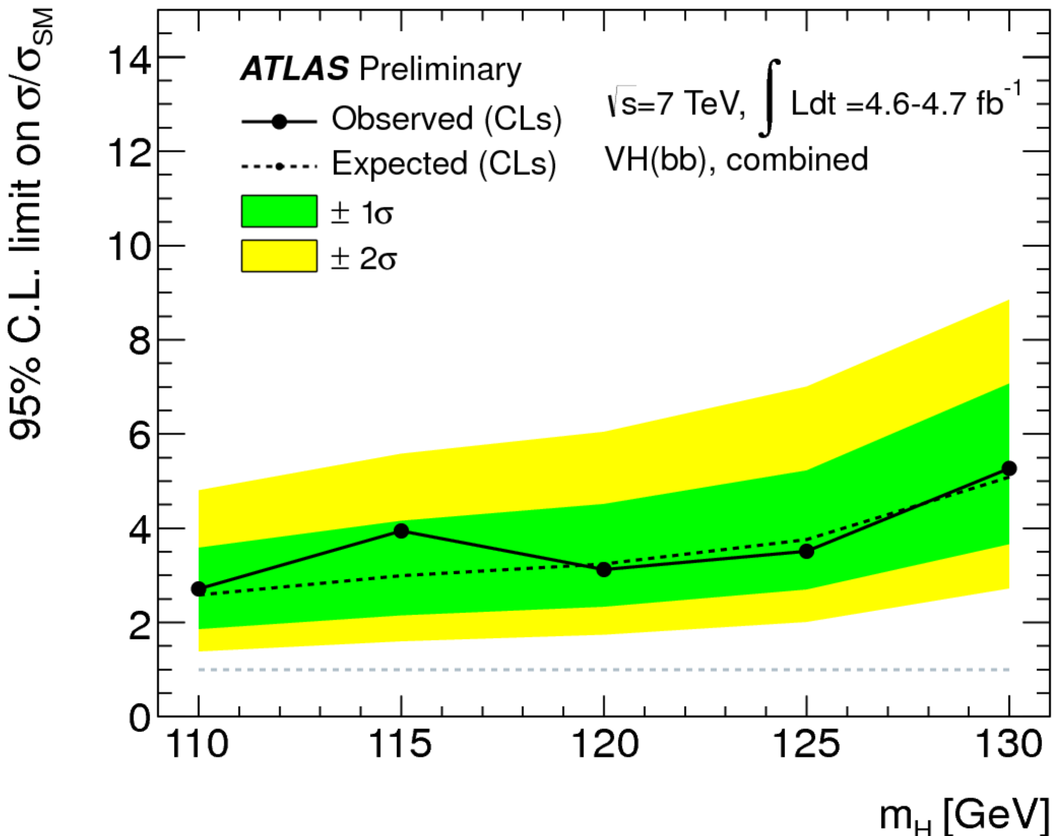
- The limit is derived from a fit to the transverse mass spectra:
  - Expected exclusion: 127-233 GeV.
  - Observed exclusion: 133-261 GeV.





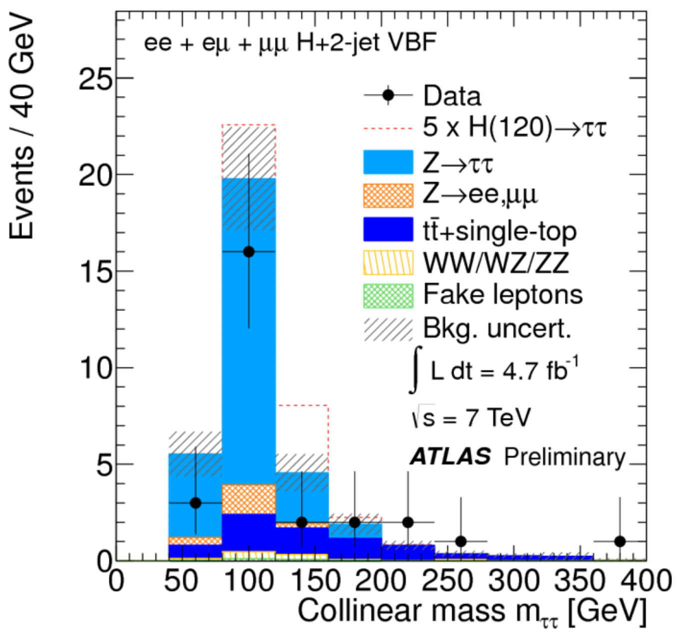
The (W/Z)H, H→bb Channels

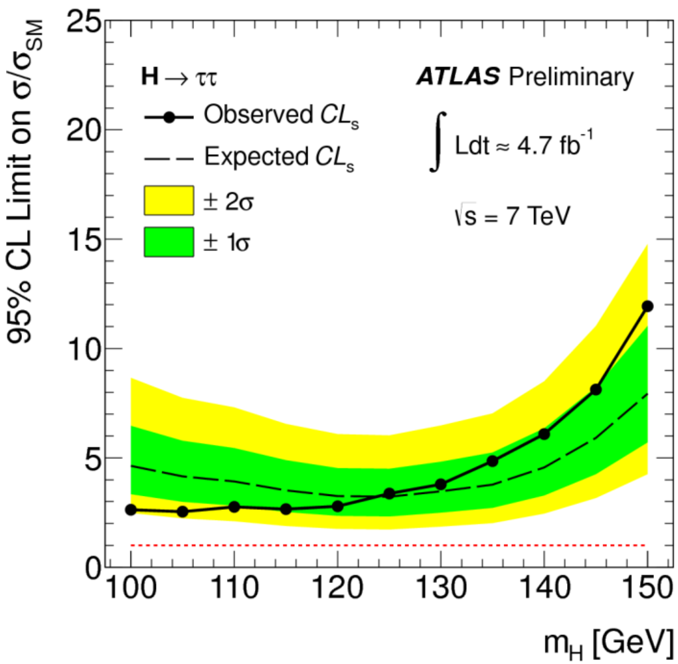
- Selection requires exactly two b-tagged jets, and identifies the leptonic decay products from the W or Z boson.



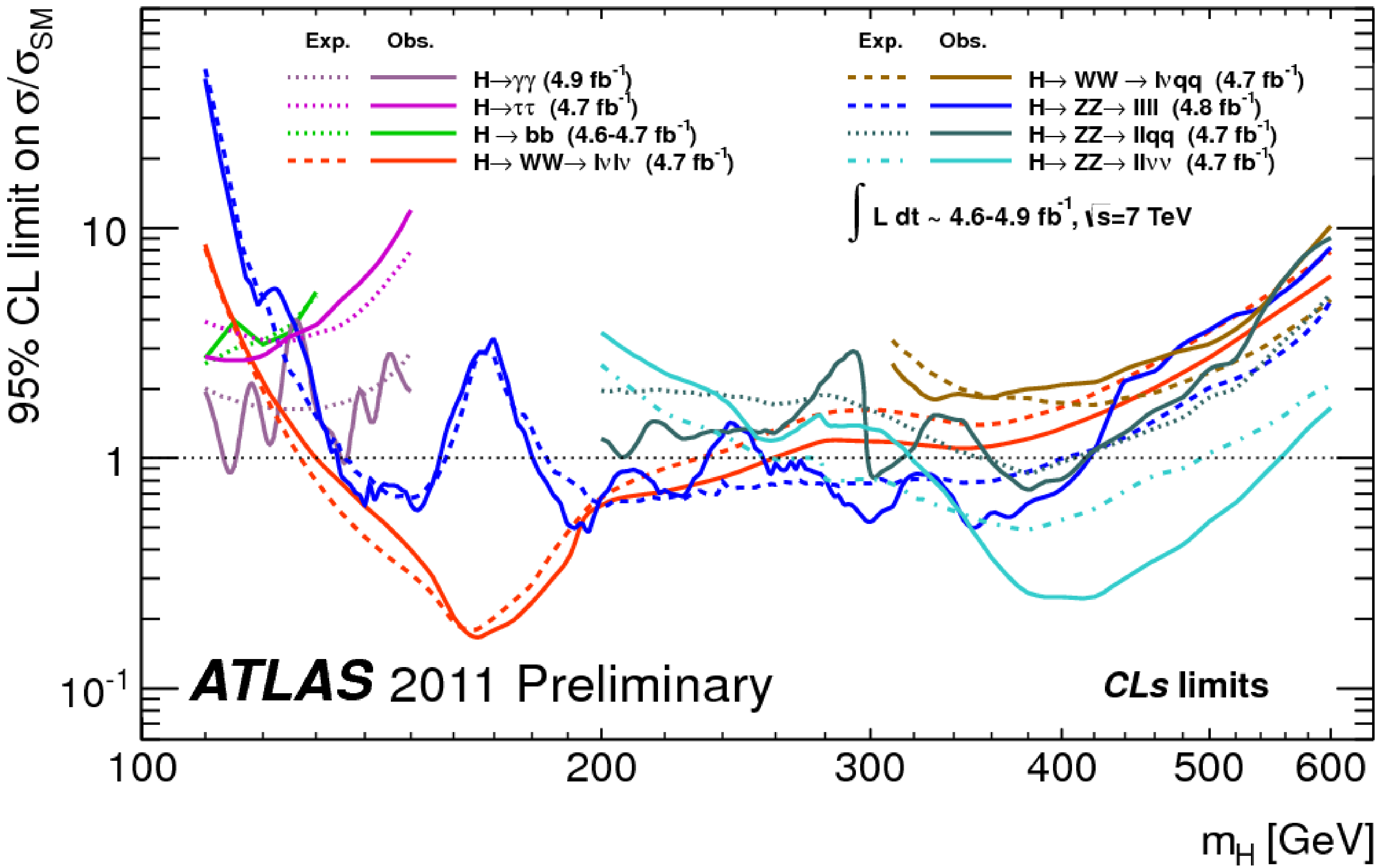
The H→ττ (ll, lh, hh) Channels

- Mass reconstruction possible due to assuming collinearity of the decay products from the tau leptons.
- Sub-channels separated into different jet categories (0-, 1-jet, 2-jet VH, 2-jet VBF).

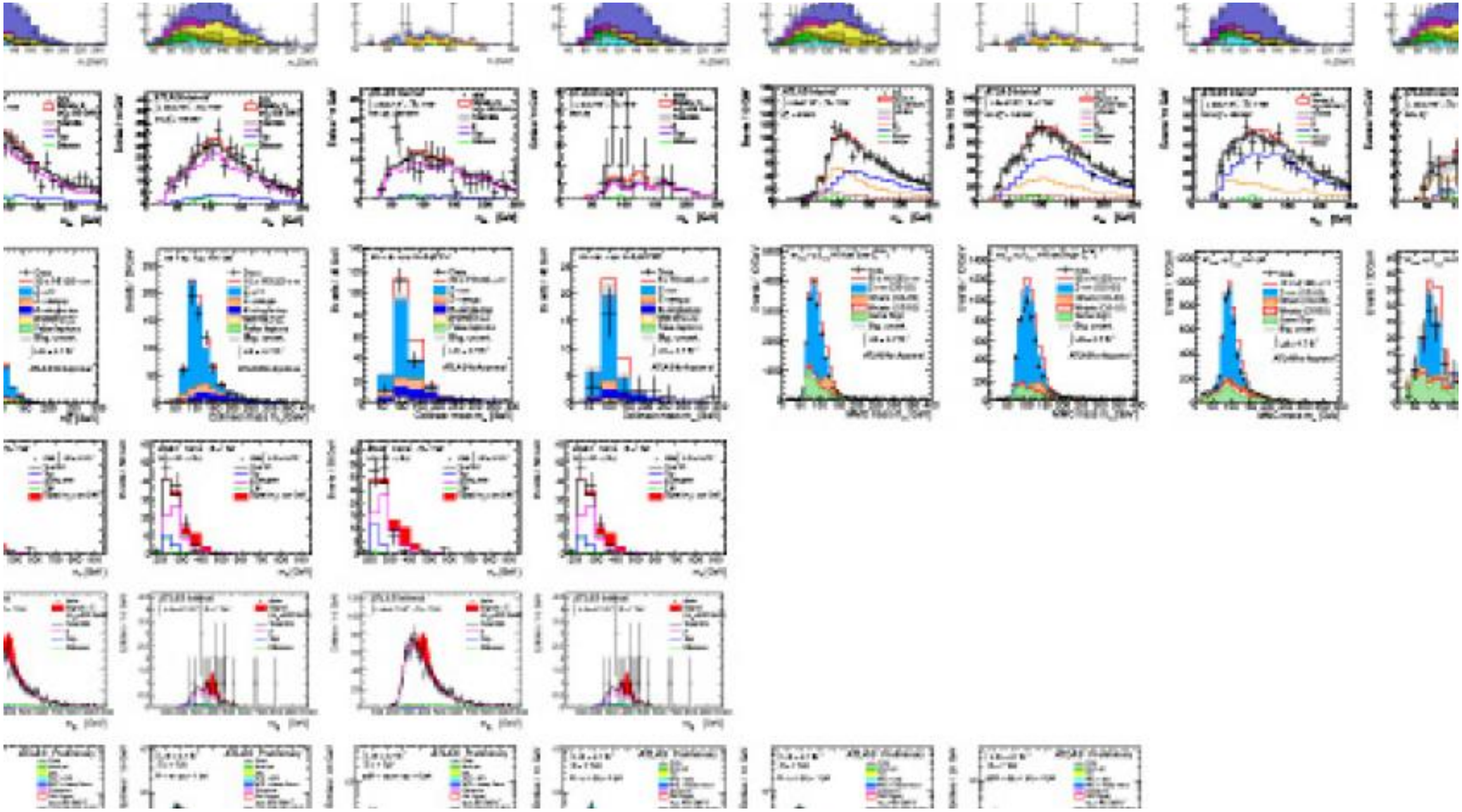




Results from All Channels

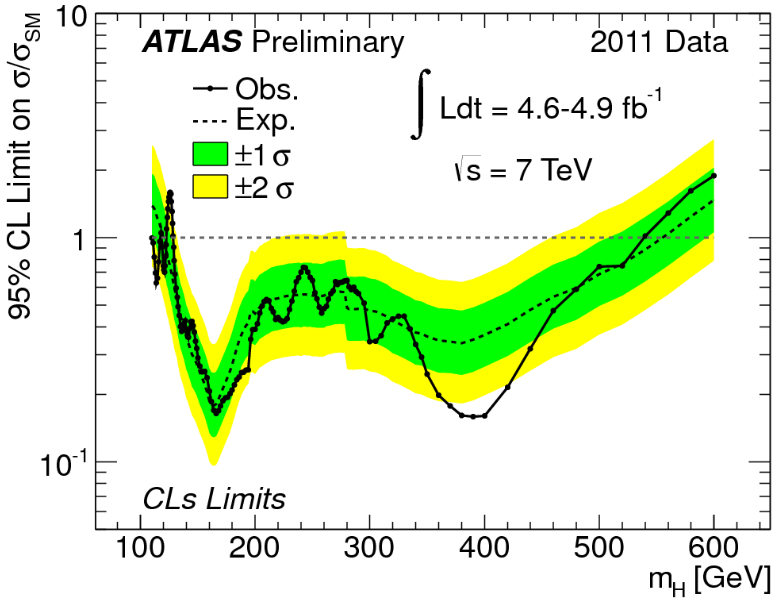


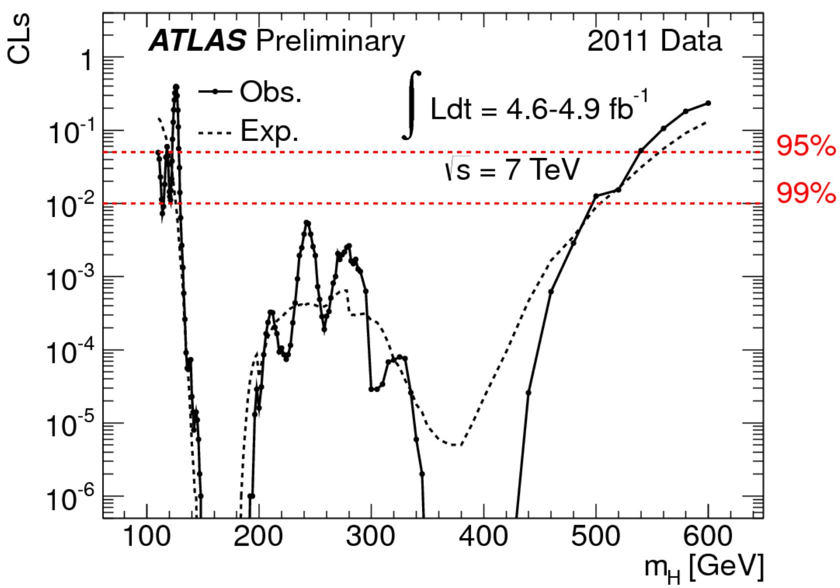
Combination



Combined Exclusion Limit

- Expected exclusion at 95% CL: 120-555 GeV.
  - Observed exclusion at 95% CL: 110-117.5, 118.5-122.5 and 129-539 GeV. Observed exclusion at 99% CL: 130-486 GeV.





The Low Mass Exclusion

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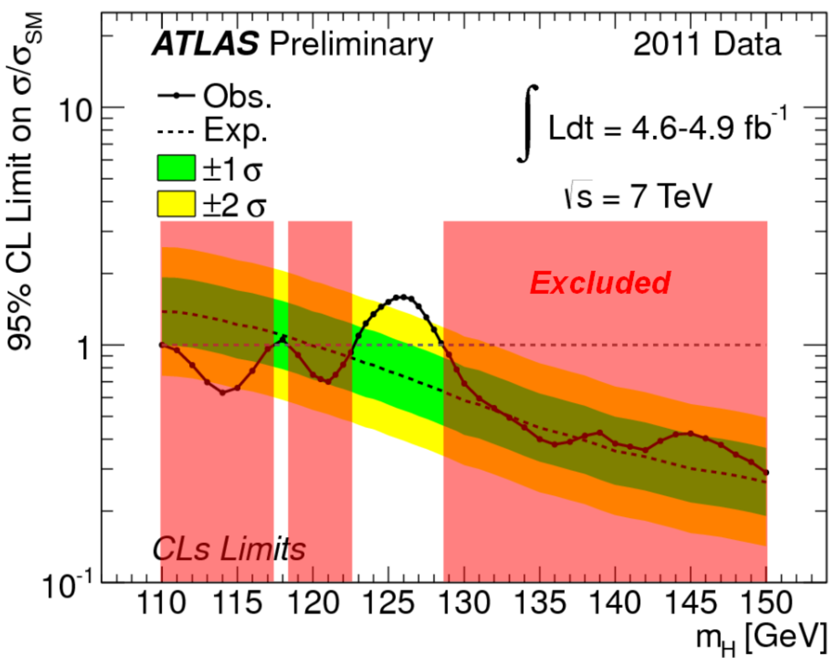
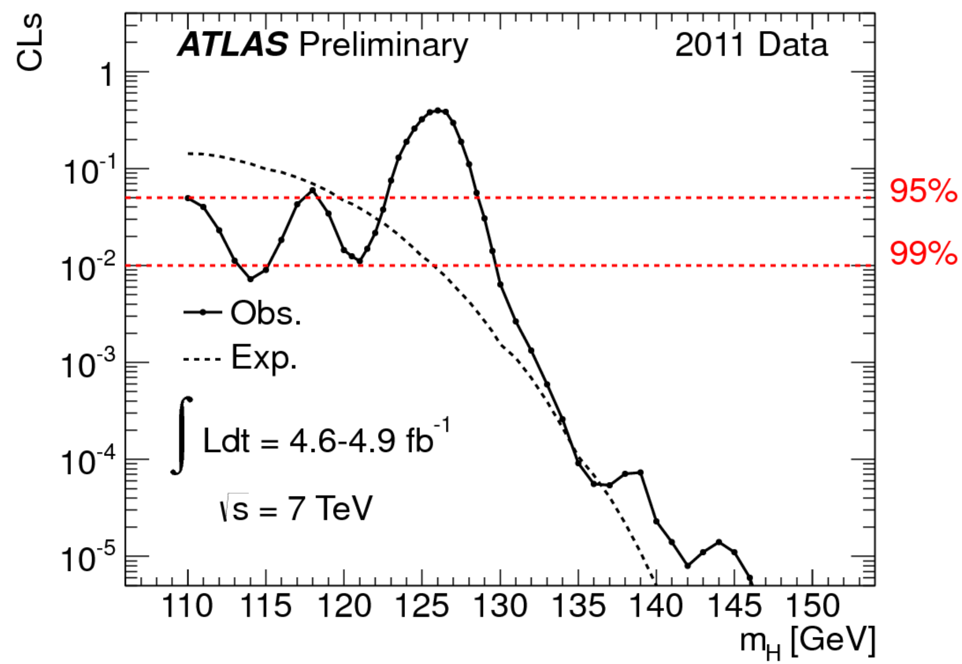
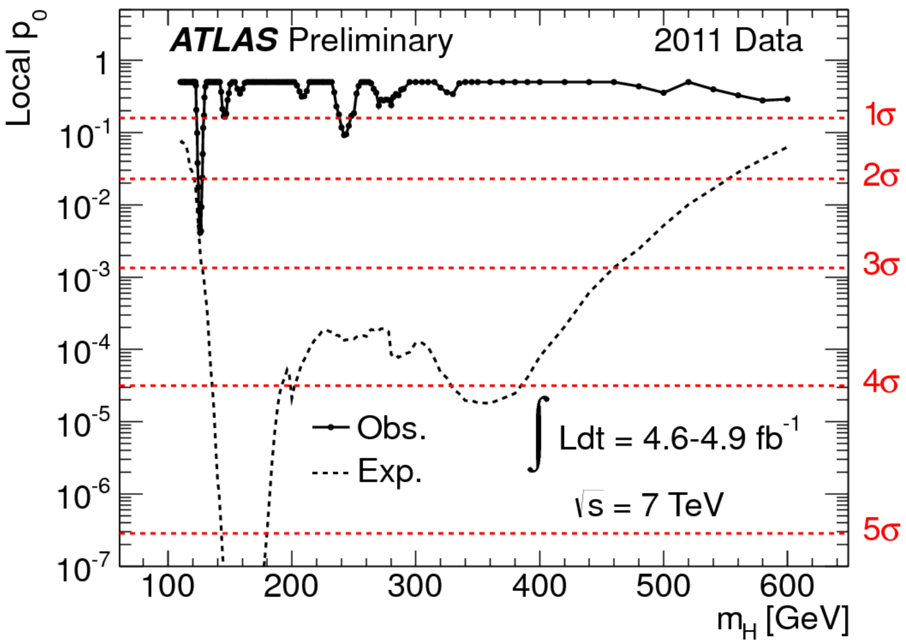
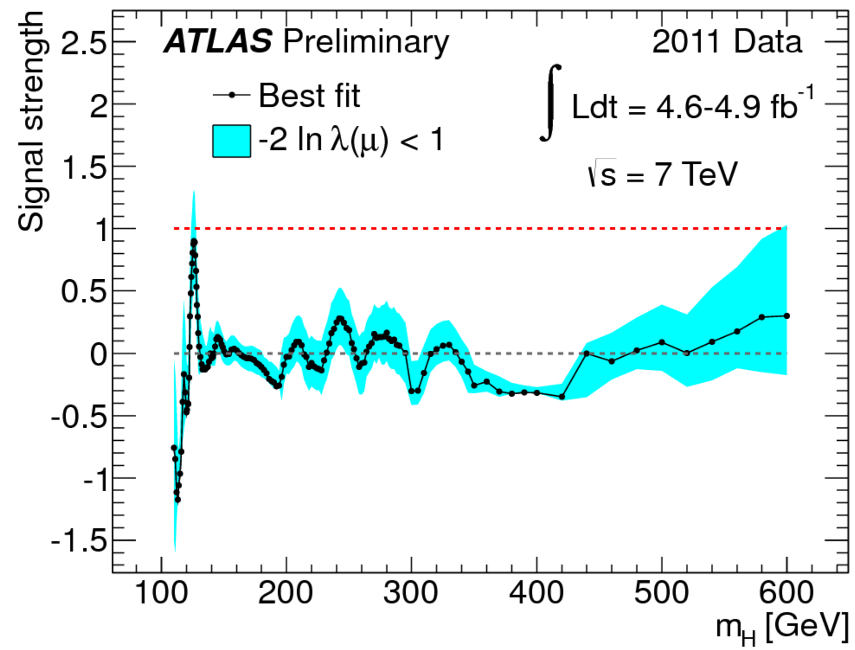


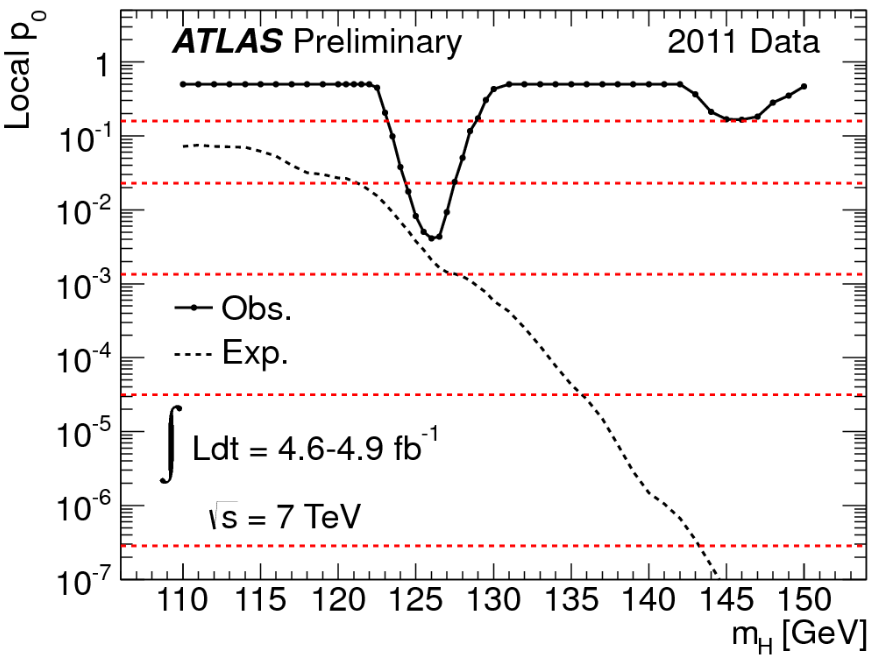


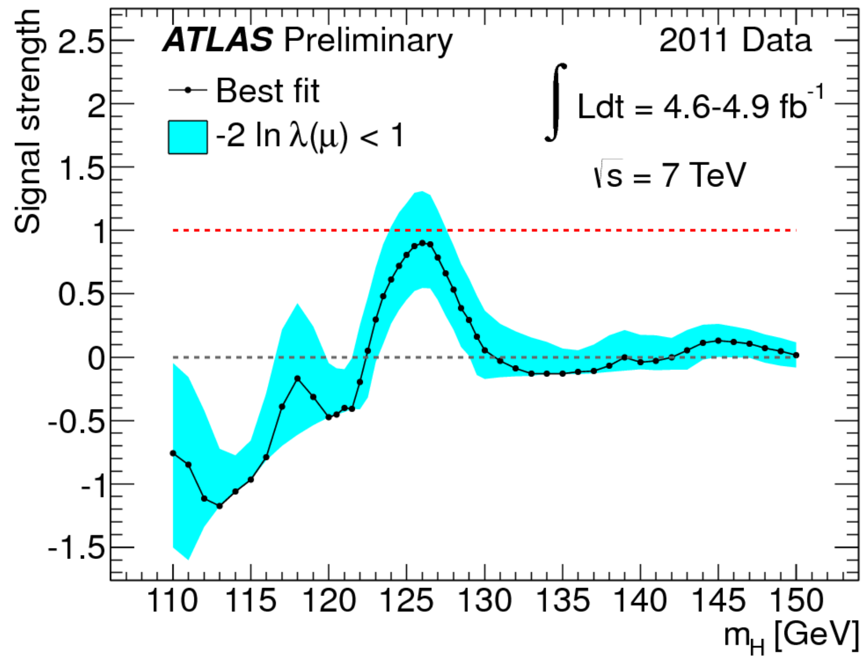
Looking at the Excess





The Excess at Low Mass

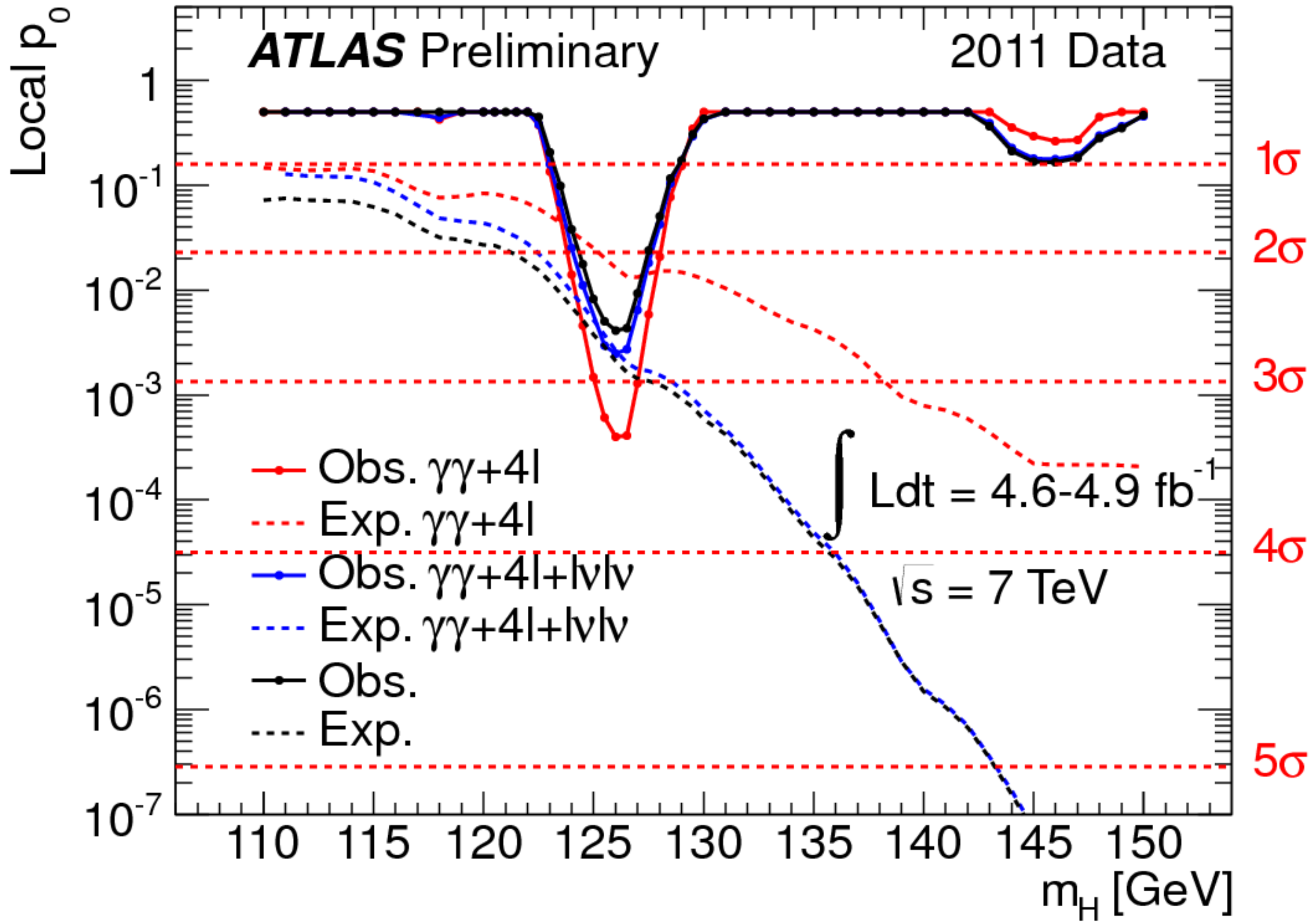




- Observed local significance 2.5σ (expected 2.9σ).
- Best-fit signal strength at 126 GeV = $0.9^{+0.4}_{-0.3}$.

The Excess by Channel

- Excess is mainly observed in two high-resolution channels.



Conclusions

- 2011 was a fantastic year in terms of LHC data taking.
  - Excellent ATLAS performance, from detector to physics (116 papers submitted or published).
- Allowed SM Higgs boson mass has been squeezed into a tiny region: 117.5-118.5 GeV or 122.5-129 GeV.
- In the low-mass region no exclusion was possible due to an excess of observed events compared to the expectation.
- The excess is compatible with the Standard Model Higgs boson hypothesis with m_H around 126 GeV. Statistical significance not large enough to draw definite conclusions.

Stay tuned for the analysis of the data from this year!