Higgs Searches at ATLAS

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On Behalf of the ATLAS Collaboration

SLAC Seminar

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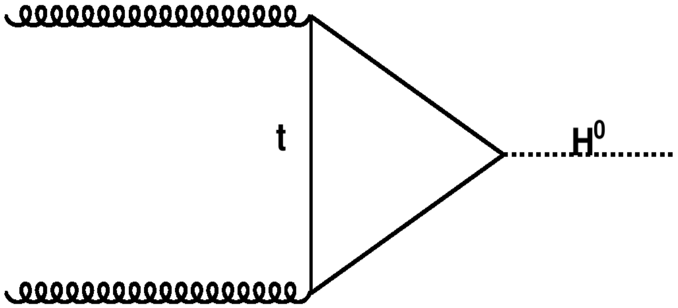
Higgs Production & Decays (1)

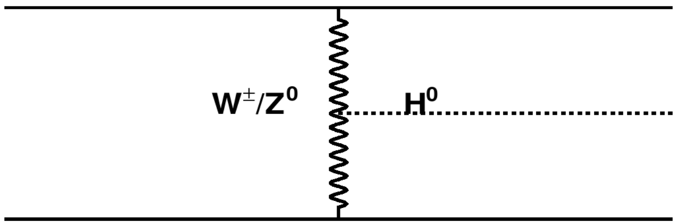
- In the Standard Model, Higgs boson production primarily through gluon fusion and Weak Boson Fusion (WBF)
  - In some searches (e.g. $H \rightarrow \gamma\gamma$, bb), WH/ZH/ttH are important too

- In MSSM/2HDM, $h^0/A^0/H^0$ is also produced in with two b quarks (if tan β is large). $H^\pm$ is produced in top decays if $M_{H+} < M_{top}$, or in association with top (gb fusion) if $M_{H+} > M_{top}$

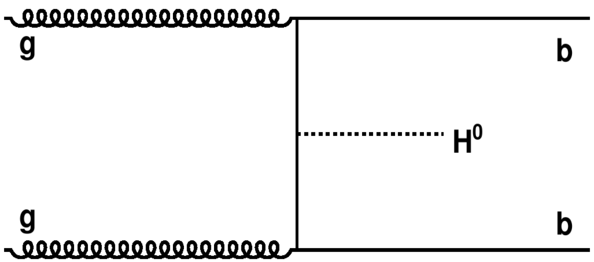
gluon Fusion



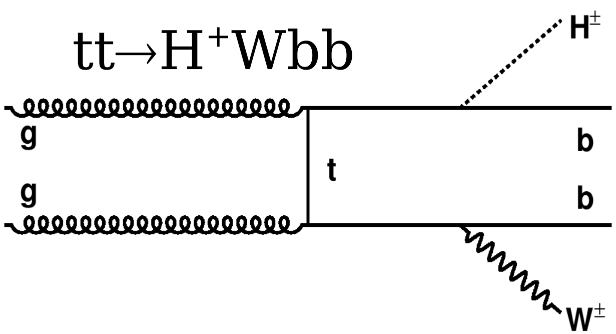
Weak Boson Fusion



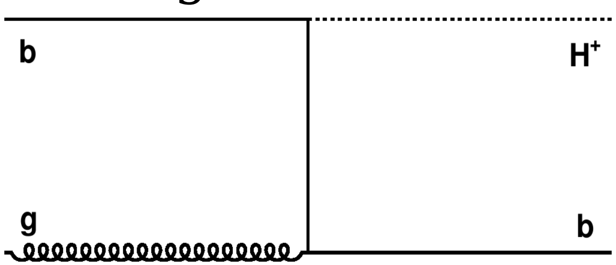
bbH^0



tt→H$^+$Wbb

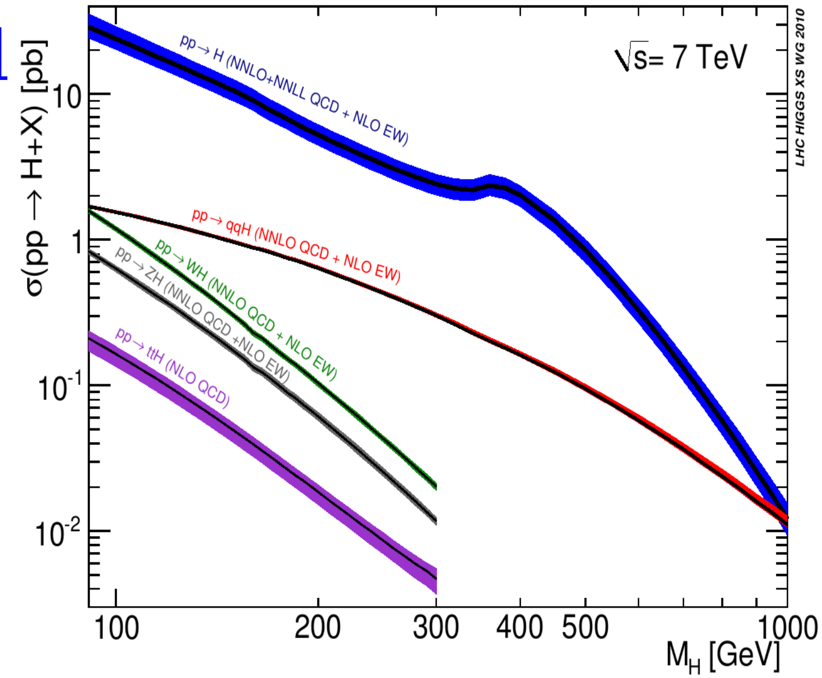


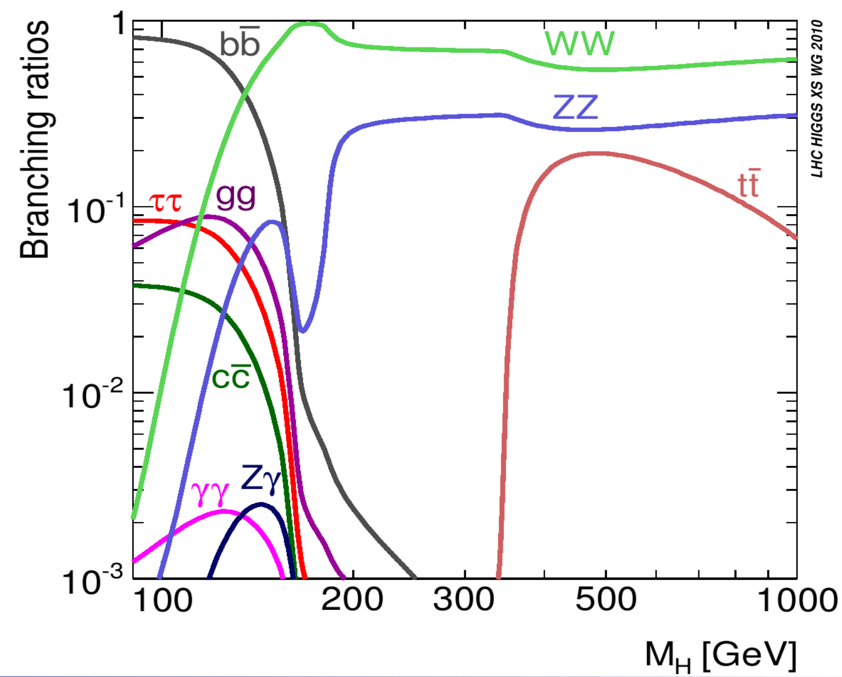
gb fusion



Higgs Production & Decays (2)

- Right: cross-sections (top) and branching ratios (bottom) in the Standard Model (SM)
- Standard Model decay modes which have been analyzed in data:
  - $H\rightarrow WW$, $H\rightarrow ZZ$ at high mass
  - $H\rightarrow bb$, $H\rightarrow\tau\tau$, and $H\rightarrow\gamma\gamma$ at low m_H
- Two MSSM decay modes have been analyzed in data so far:
  - $H^+\rightarrow\tau\nu$, $A/H^0\rightarrow\tau\tau$
- Recently updated:
  - $H\rightarrow ZZ\rightarrow 4l$ & $H\rightarrow\gamma\gamma$ to 4.8-4.9 fb^{-1}
  - $H\rightarrow WW\rightarrow l\nu l\nu$, $H\rightarrow ZZ\rightarrow llqq$, and $H\rightarrow ZZ\rightarrow ll\nu\nu$ now use 2.1 fb^{-1}

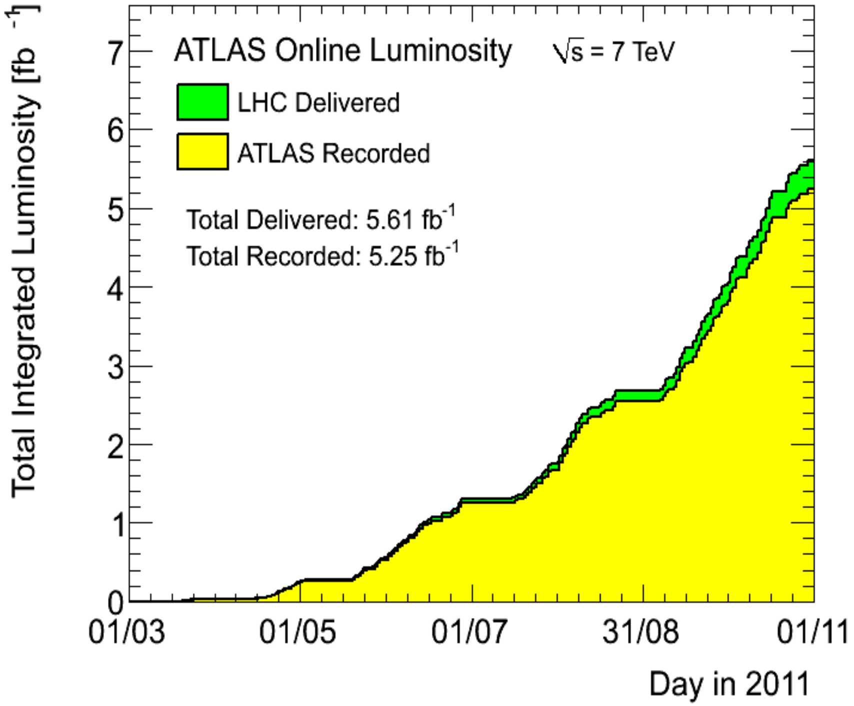


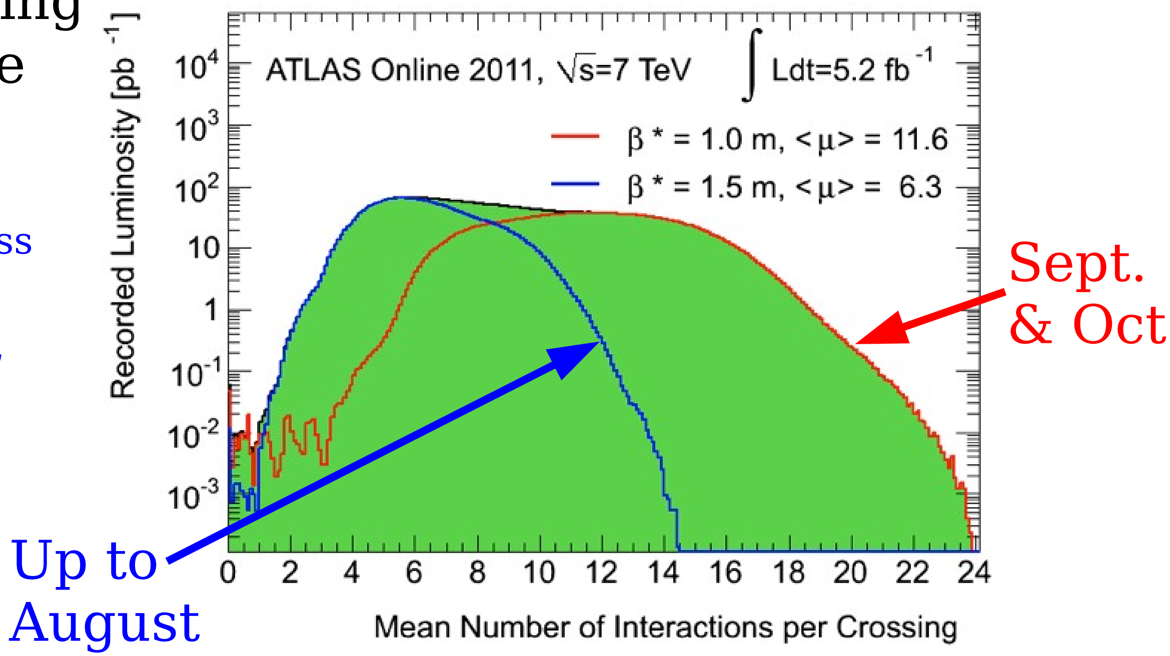


arXiv:1101.0593

LHC & Pileup

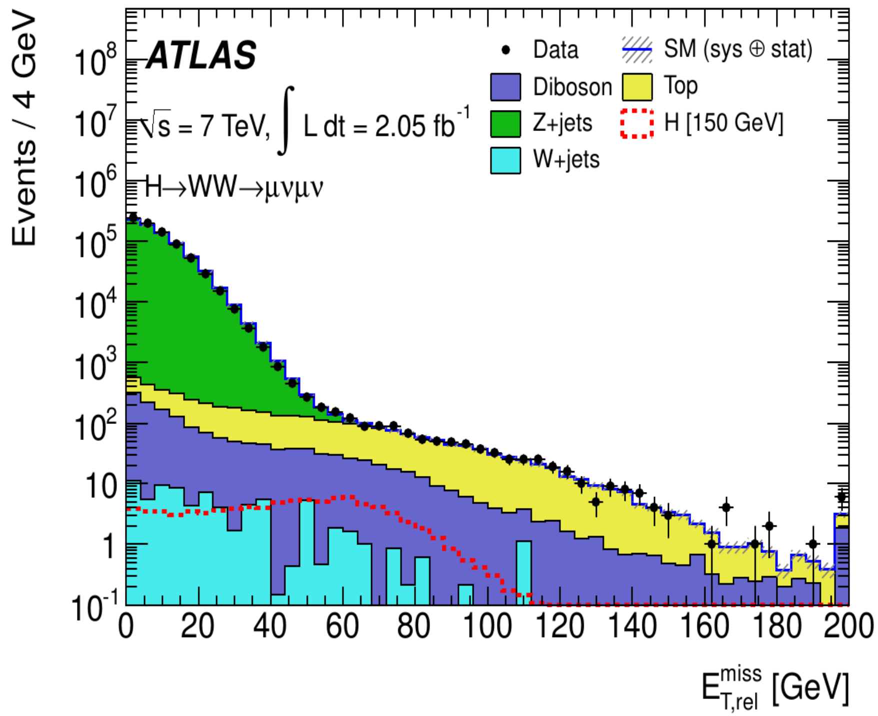
- Excellent LHC performance: 5.61 fb^{-1} delivered to ATLAS
  - Recorded by ATLAS with 93.5% effic.
  - Data quality selections cut another 4-10%, depending on the analysis
- High luminosity comes from improvements like narrower beams and 50 ns bunch spacing
  - Most feasibility studies over the last 20 years assumed ~2 interactions per bunch crossing during the 10^{33} phase, but we get some events with more than 20 now
- Important impact on E_T^{miss} reconstruction, simulation, trigger, etc.
  - precise modeling of both in-time and out-of-time pileup is crucial

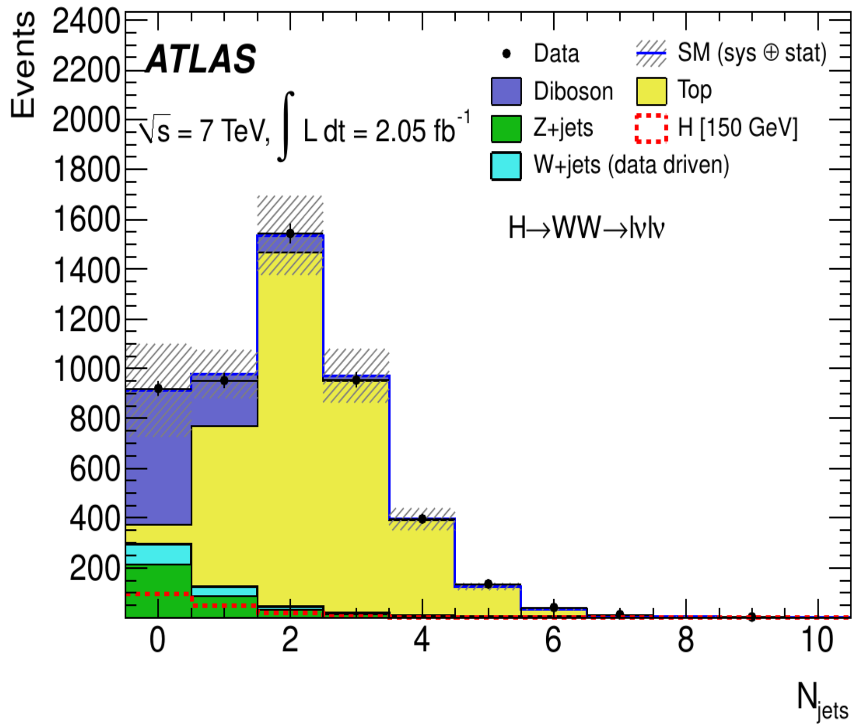




H→WW→lνlν (1)

arXiv:1112.2577

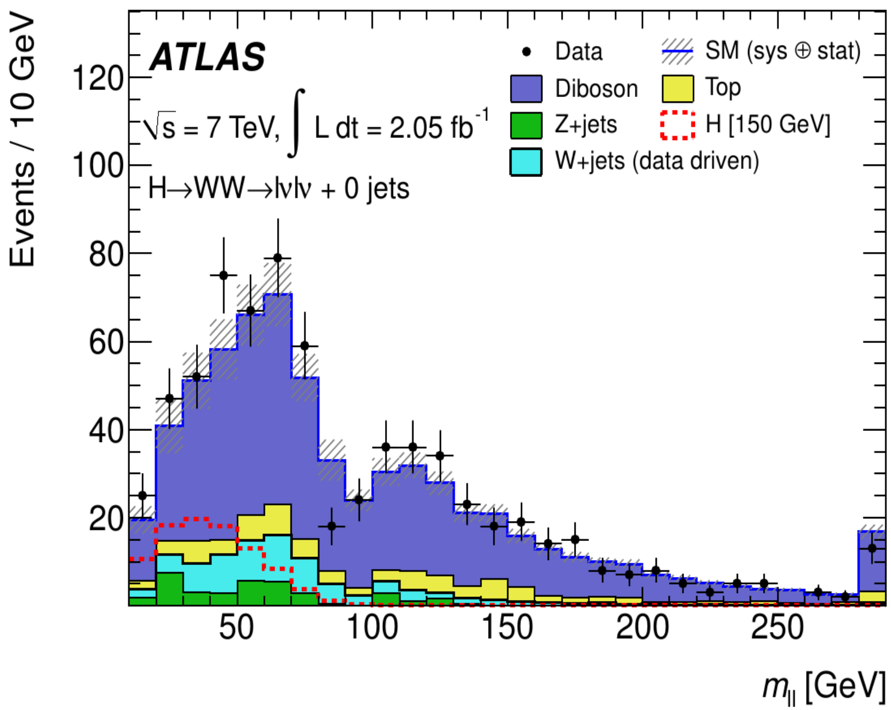


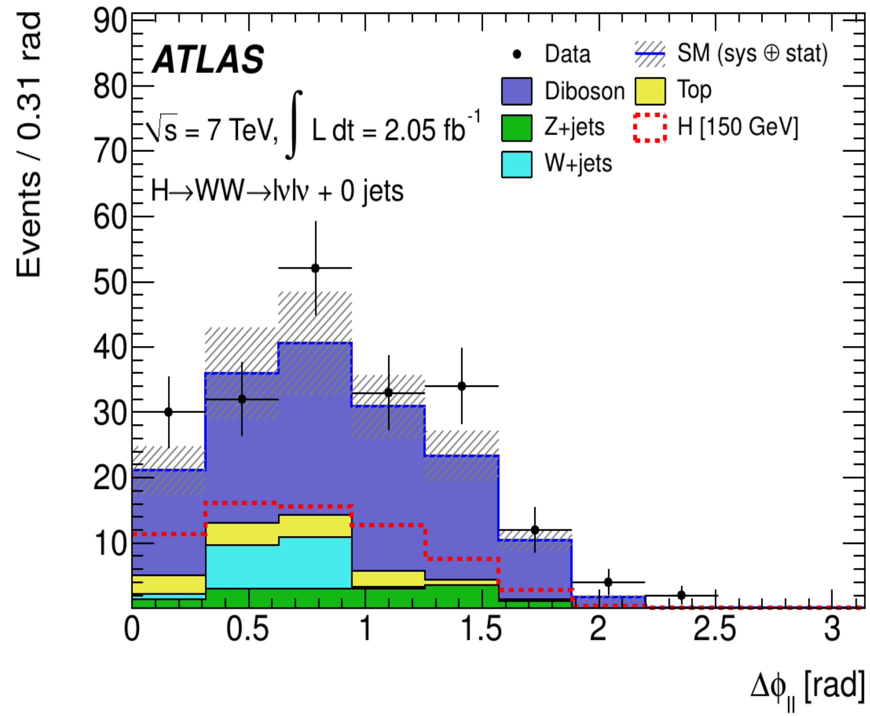


- Requiring two leptons suppresses QCD multijet background to negligible levels
- Large background from Z is suppressed by requiring large E_T^{miss} in same-flavor events (left)
- Top events are rejected by cut on jet multiplicity (right).
  - N_{jet}=0 and N_{jet}=1 considered in current analysis
  - N_{jet}=2 is hopefully coming sometime this winter

H→WW→lνlν (2)

arXiv:1112.2577





- Event selection exploits different angular distributions caused by kinematics and by spin correlations. Above: M_{ll} (left) and $\Delta\phi_{ll}$ (right) in events with no jets
- Backgrounds are estimated with control samples:
  - Diboson: count events in a region with altered M_{ll} and $\Delta\phi_{ll}$ cuts
  - Top (in H+1j): reverse b-veto and drop cuts on M_{ll}, M_T, and $\Delta\phi_{ll}$

Control Region	Expected BG	Observed
WW+0j	296±59	296
WW+1j	171±8	184
tt+1j	270±79	249

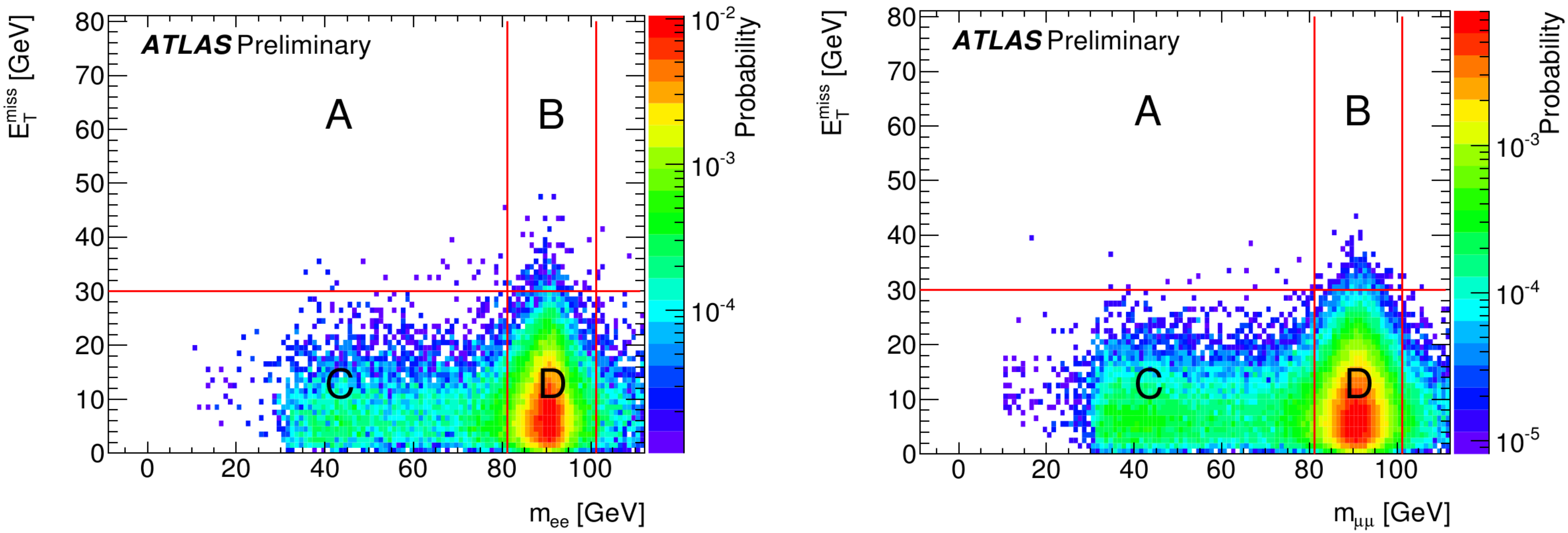
$H \rightarrow WW \rightarrow l\nu l\nu$ (3)

- For major BGs (WW+0/1j and tt+1j), control samples are modeled in fit using ratio of cross-sections in signal region over control region taken from MC
  - Uncertainties in table

Source	WW+0j	WW+1j	tt+1j (SR)	tt+1j (CR)
Q^2 scale	2.5%	4%	9%	-
MC Modeling	3.5%	3.5%	4%	-
PDF	3.8%	3.5%	3%	-
Jet E scale/res	+1.7/-0.6%	+1.9/-8%	+0.7/-17%	+3.6/-2.6%
MET uncert.	+1.7/-0.6%	+3.9/-13%	+6.9/-13%	+1.4/-5.5%
Lept. eff & res	+0.2/-0.1%	+1/-2.3%	+0.6/-1.4%	+0.7/-0.6%
b-tagging	-	-	+24/-29%	-23/+28%
MC stats	4.3%	12.9%	6%	-

- Control sample strategies for other (minor) backgrounds:
  - Top in H+0j uses two control samples:
    - Two leptons and E_T^{miss} w/non-top backgrounds removed using MC
    - Two leptons and E_T^{miss}, w/ ≥1 b-tagged jet; used to estimate an efficiency for the jet veto
    - Efficiency from second control sample and corrections from MC are applied to first control sample to estimate top in signal region
  - W+jets is estimated using a loosened lepton selection.
  - Z+jets is taken from MC, but with a scale factor derived from data in the Z peak

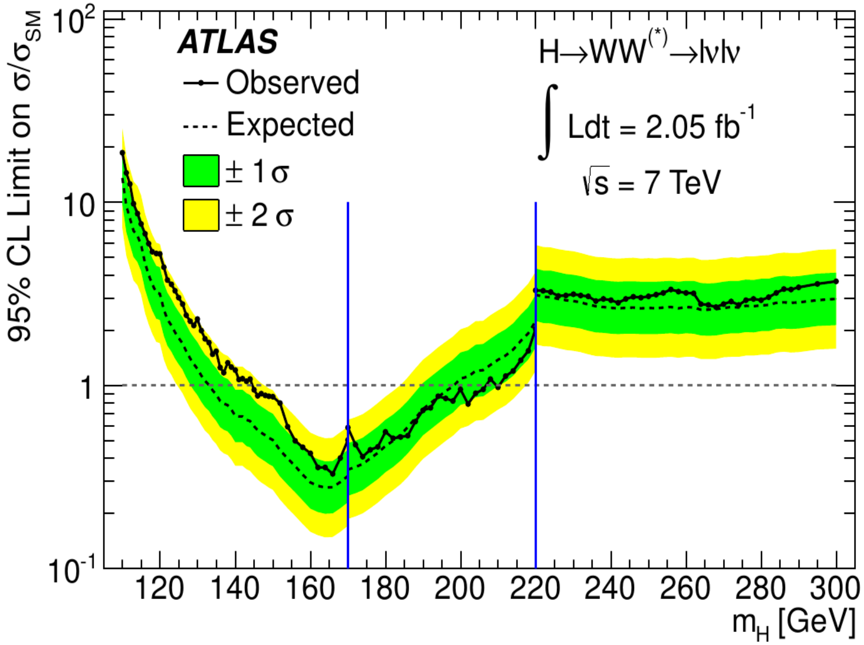
H→WW→lνlν (4)

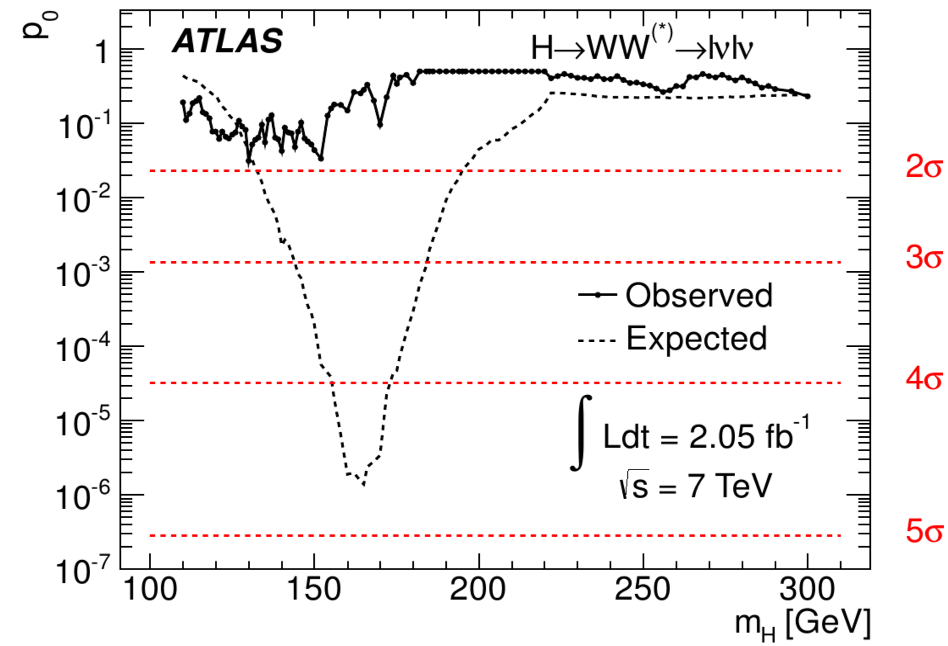


- Z+jets is taken from MC, but with a scale factor derived from an "ABCD" method:
  - Take (N in reg. B)/(N in reg. D) from data in the Z peak and multiply by (N in reg. D)/(N in reg. B) from MC to get a scale factor to apply to the MC estimate of N in reg. A
  - Scale factors this way are ~0.8-0.9, indicating that MC slightly overestimates the high-MET tail

H→WW→lνlν (5)

arXiv:1112.2577

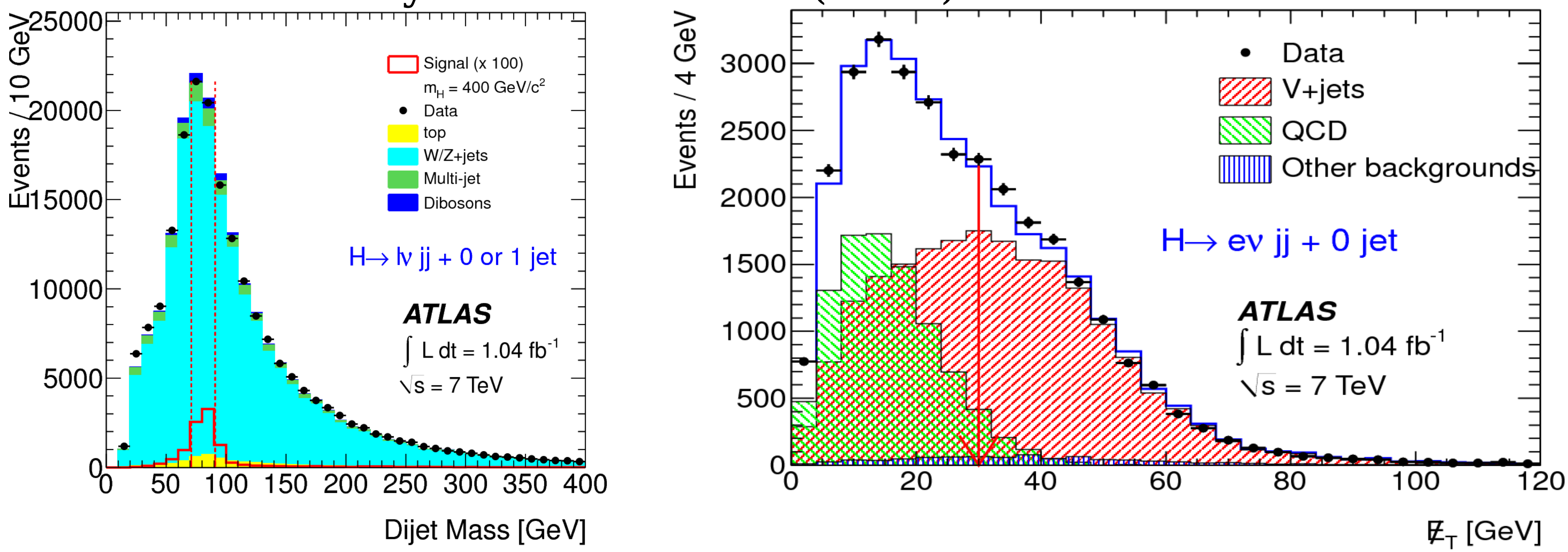




- Upper bounds on production cross-section (left) and probability to find a similar or larger excess if there is only background (right).
  - No significant excess, always less than 2σ
  - Excess is driven by a fluctuation in the μμ channel
  - Upper limit is set as a function of m_H, in units of the Standard Model prediction. ATLAS excludes $145<m_H<206$ GeV ($134<m_H<200$ GeV expected)

H→WW→lνqq (1)

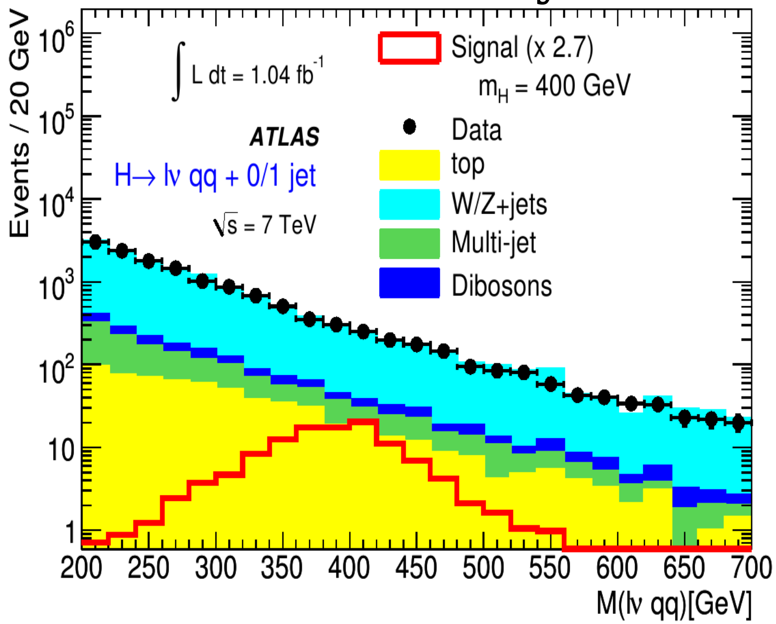
Phys. Rev. Lett. 107 (2011) 231801

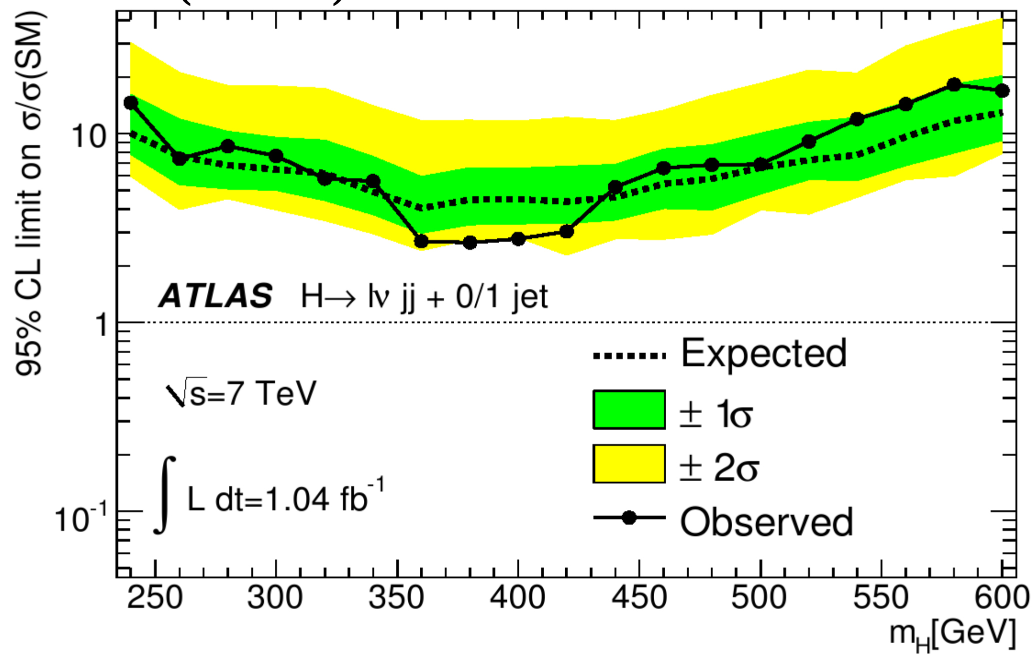


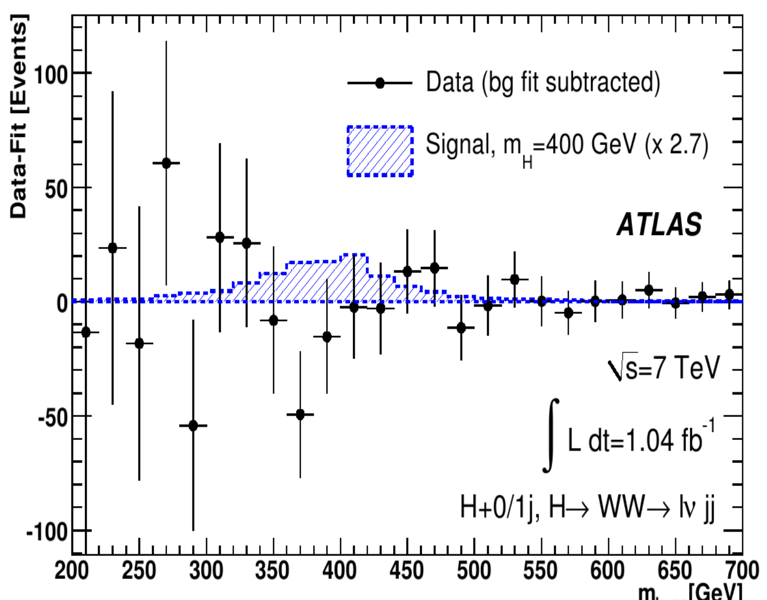
- Select events with one lepton, two or three jets, and E_T^{miss}.
- Two jets must have m_{jj} close to m_W (left)
  - Contributes to large systematic from the jet E scale uncertainty
- Estimate background from jets misidentified as leptons using a sample of events in data with lepton isolation cut reversed.
  - Can estimate the shapes of most kinematic variables by just plotting. See, for example, green region in upper right plot
  - A normalization factor is estimated with a template fit to the E_T^{miss} distribution (right). Shape of V+jets taken from MC, but it floats in the fit too and both contributions are rescaled for the final plots.

H→WW→lνqq (2)

Phys. Rev. Lett. 107 (2011) 231801



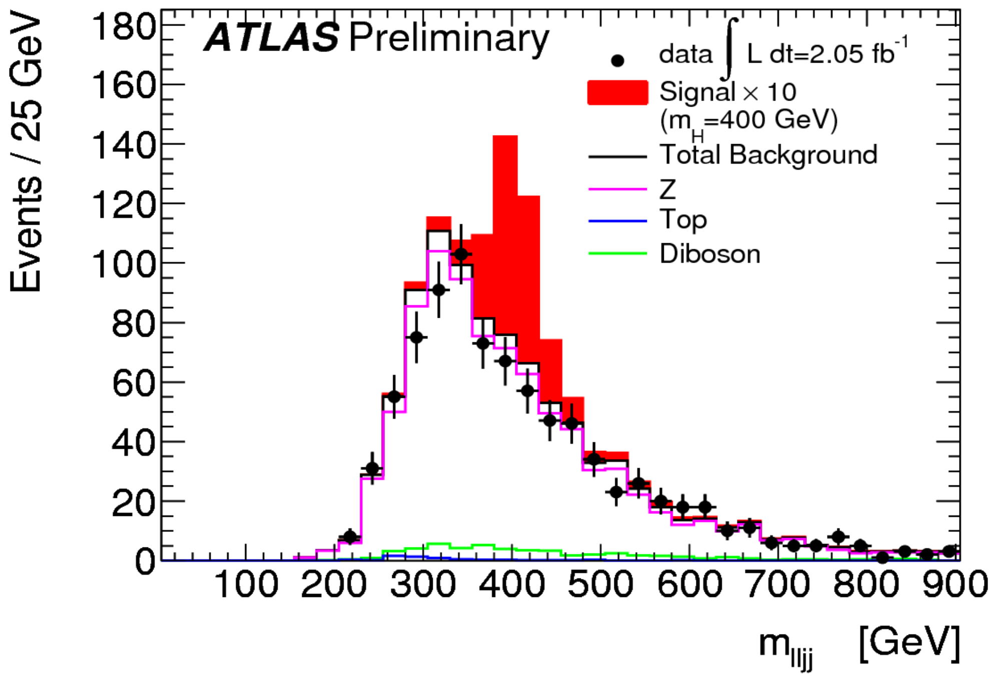


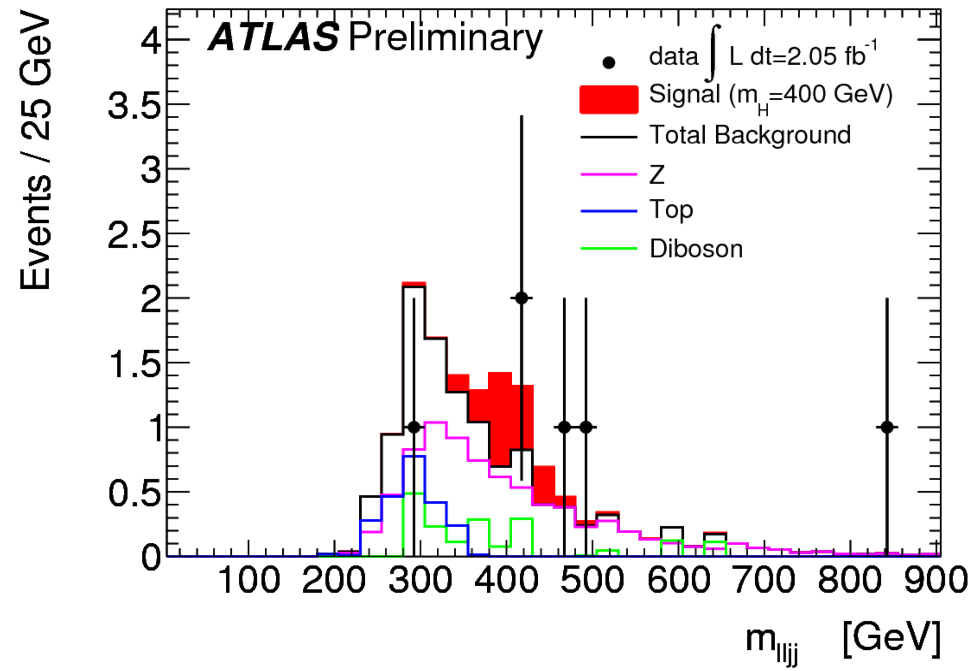


- Estimate P_Z^{ν} and M_{WW} by solving $M_W = M_{l\nu}$. Require two real solutions; take one with smaller $|P_Z^{\nu}|$
- Fit $M_{l\nu qq}$ distribution with a double exponential for background, hist PDF for signal)
- Exclude 2.7xSM for m_H=400 GeV

H→ZZ→llqq (1)

ATLAS-CONF-2011-150

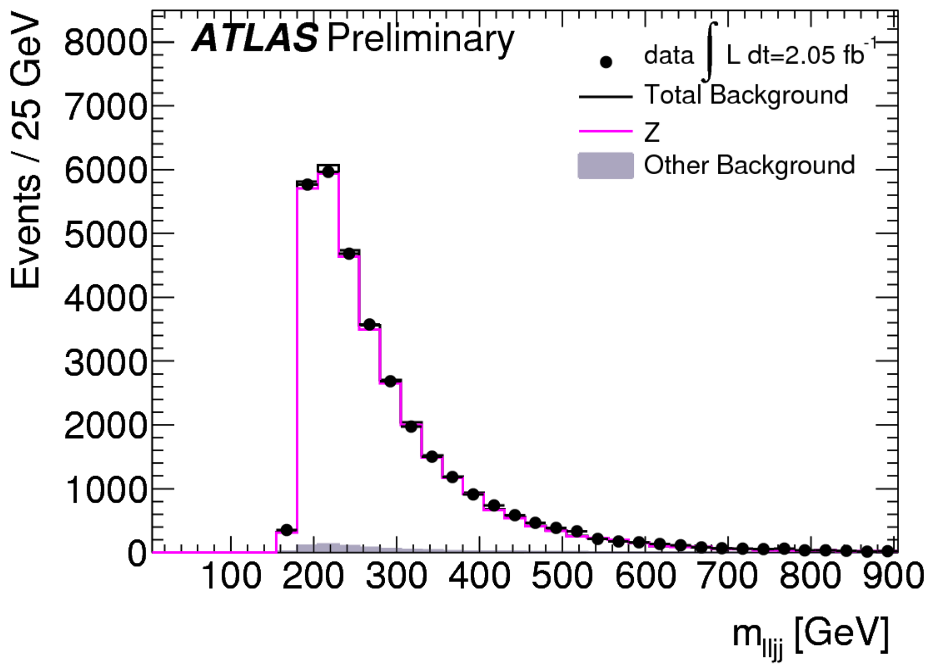


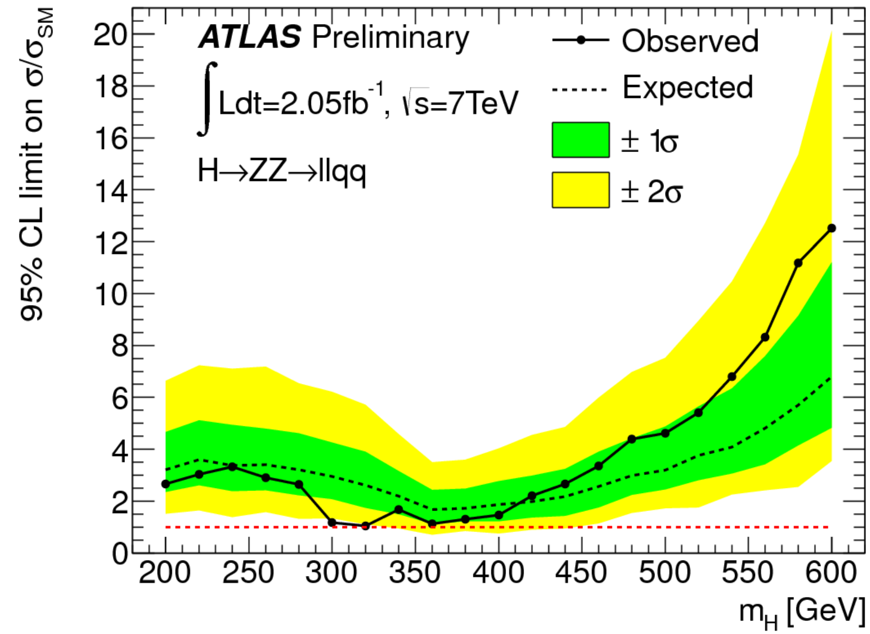


- Signature is two leptons and two jets, with small MET, and with M_{ll} and M_{qq} near M_Z.
- Divide the signal into events with fewer than two b-tagged jets (left) and events with two (right)
- For $m_H \geq 300$ GeV, also use angular information about the jets and leptons to suppress background.
  - Require $\Delta\phi_{ll} > \pi/2$, $\Delta\phi_{jj} > \pi/2$, and $p_T^{j1,j2} > 45$ GeV

H→ZZ→llqq (2)

ATLAS-CONF-2011-150

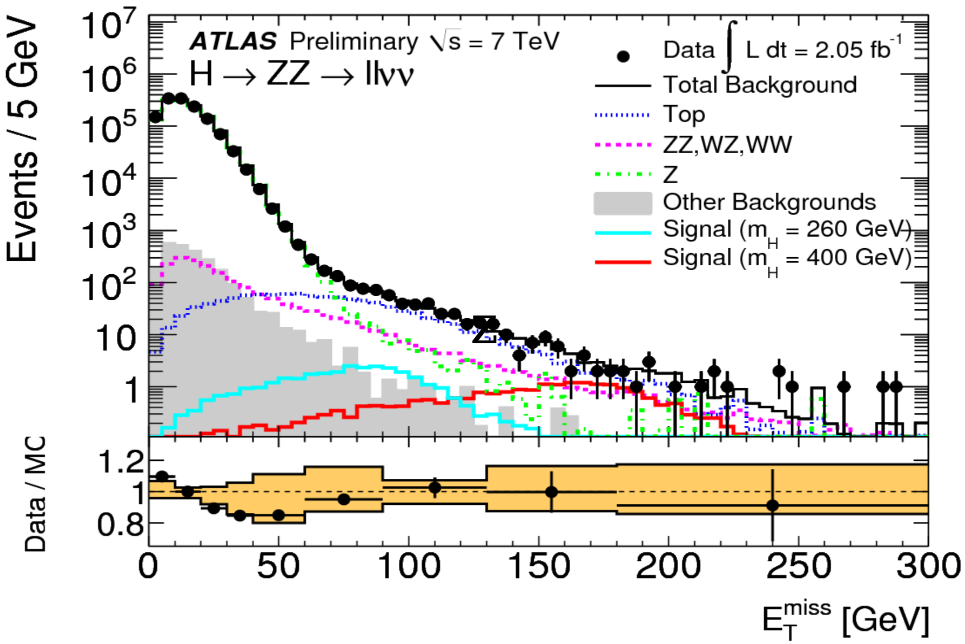


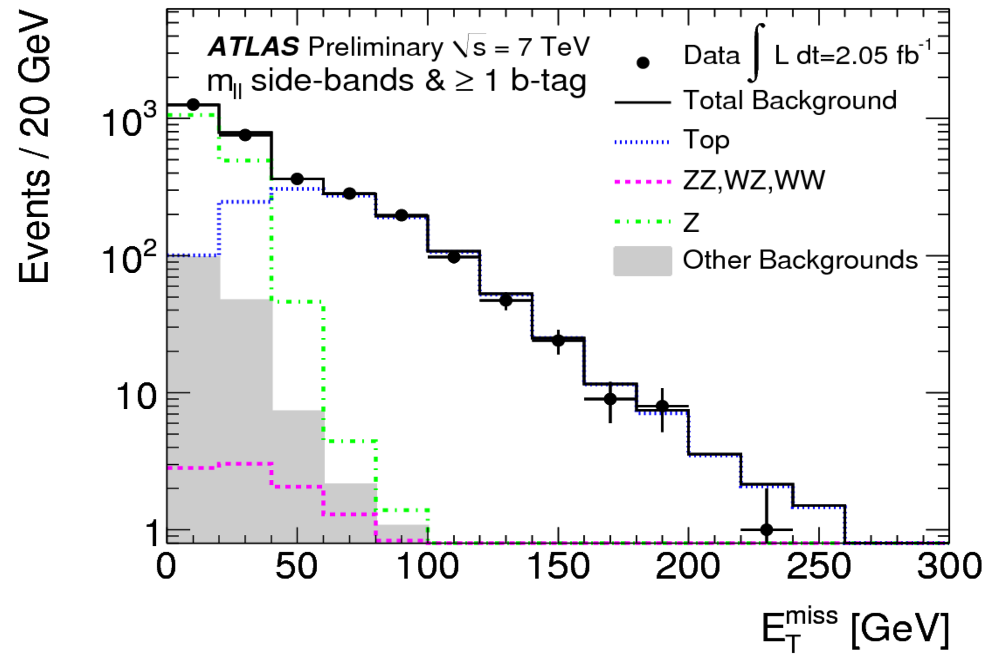


- Background shape and normalization in MC is validated by data/MC comparisons in m_{jj} sidebands (left) and m_{ll} sidebands (not shown)
  - Systematic error on the Z+jets normalization comes from comparisons of these sidebands, and ranges from 1.4% for low-m_H untagged selection to 18% for high-m_H b-tagged selection. Shape uncertainty comes from comparisons between Pythia and Alpgen
- Observed limits are approaching the Standard Model prediction for m_H near ~300-400 GeV

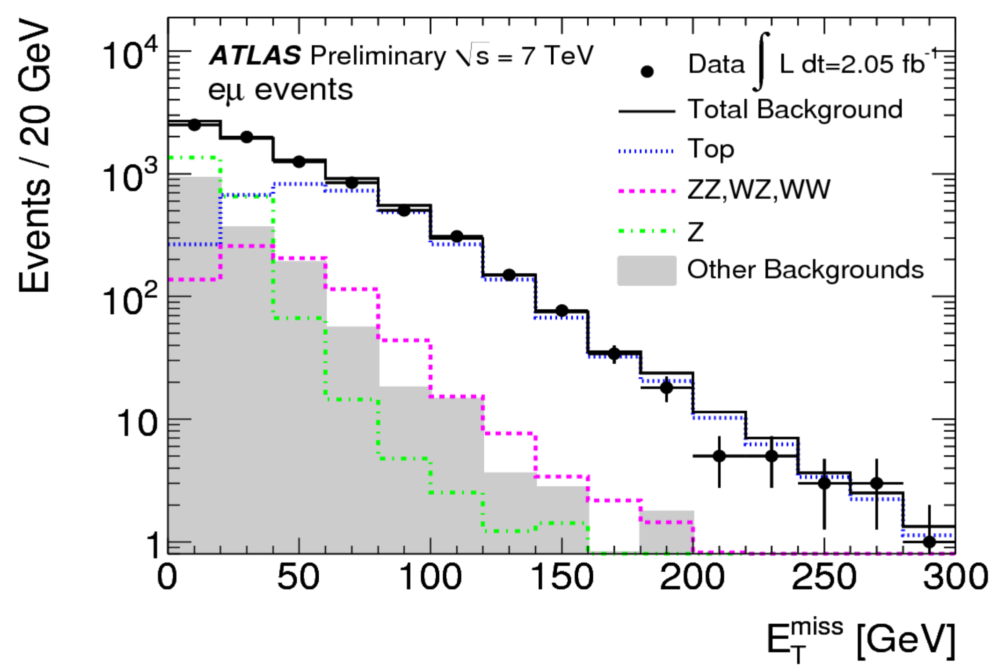
H→ZZ→llνν (1)

ATLAS-CONF-2011-148





- Two leptons with $m_{ll}=m_Z$ and very large MET (left)
- Diboson BG is from MC
- E_T^{miss} performance in top BG checked using events with m_{ll} outside Z peak (top right) and eμ events (bottom right)
- Z and W+jets evaluated from MC with data/MC comparisons



H→ZZ→llνν (2)

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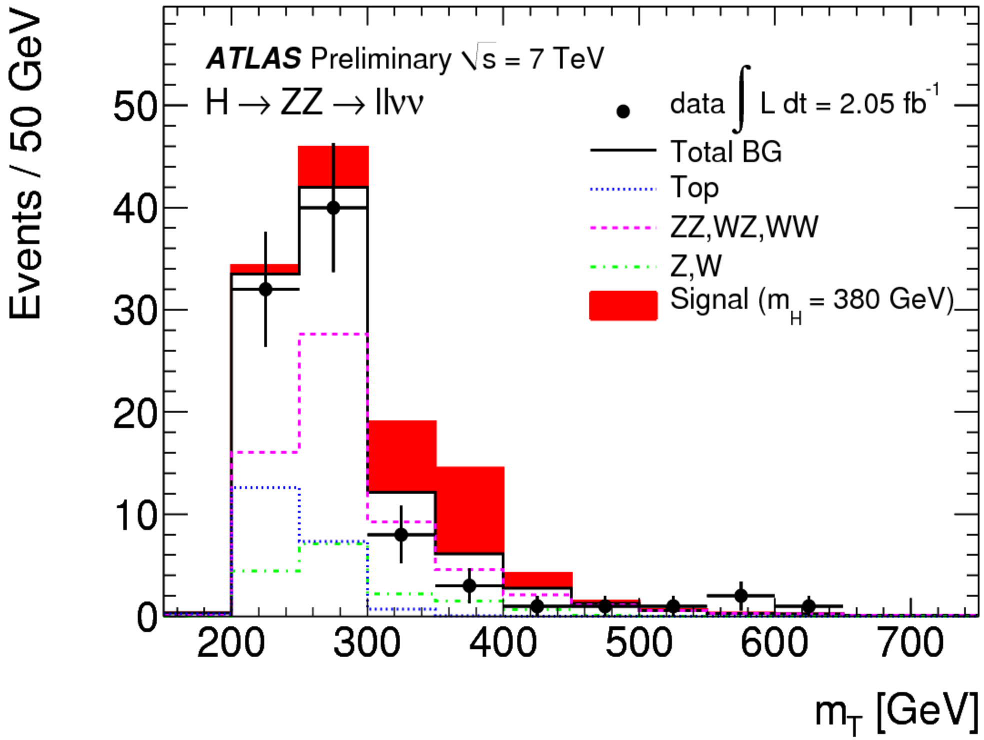
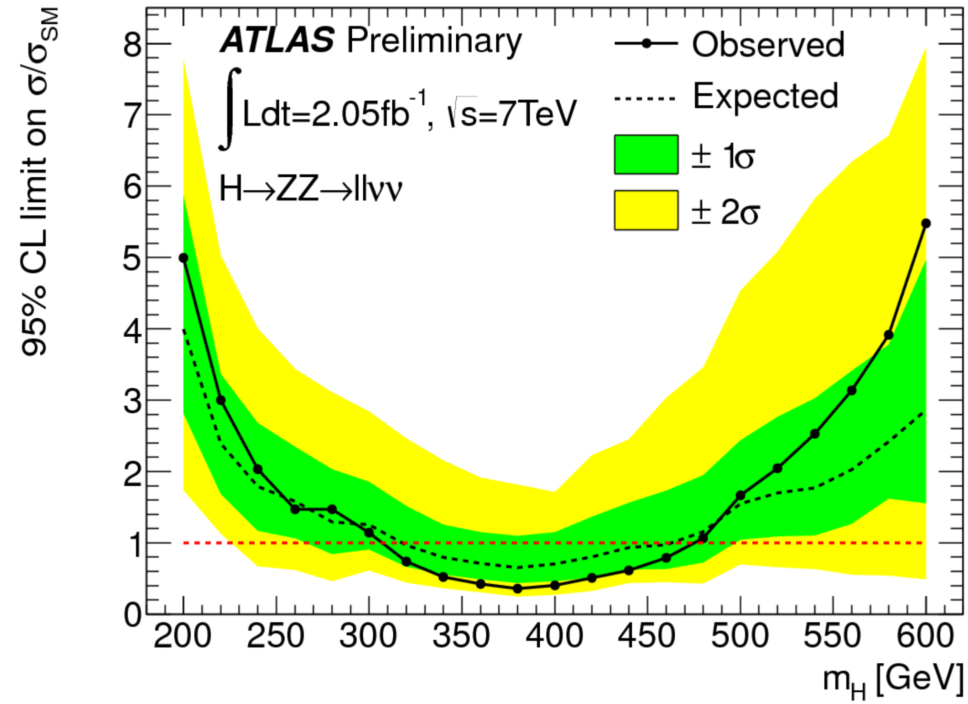
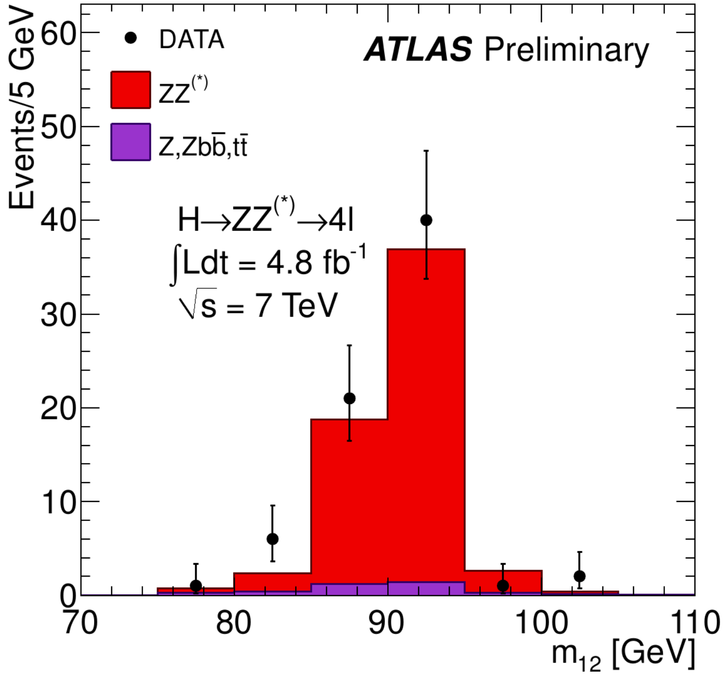


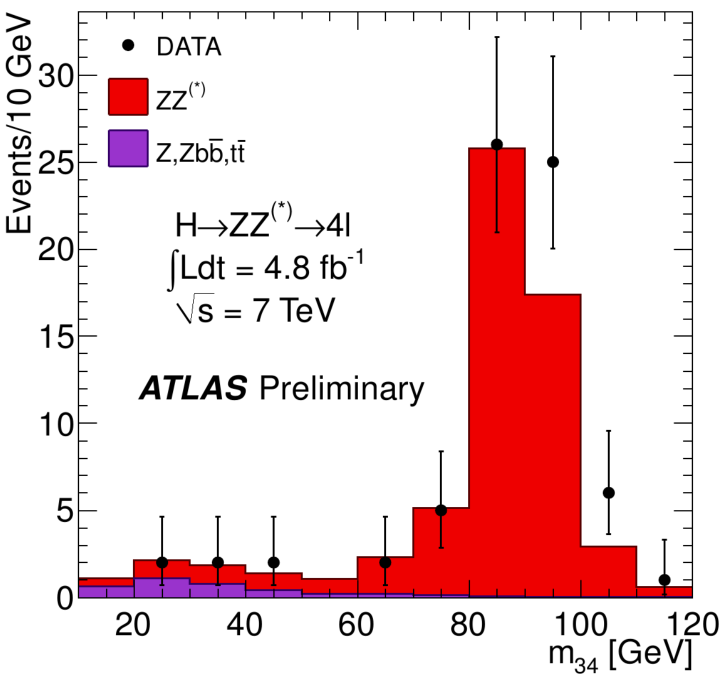


- Left: set limits based on the transverse mass distribution
  - Systematic errors based on theory: gluon fusion signal (+12/-7%), VBF signal (1%) and diboson background (10%)
  - Systematic errors based on comparisons to data: Z boson production (2.5%), top quark production (9%), W+jets (100%), and QCD multijet (50%)
- Right: current measurement excludes a Standard Model Higgs boson in the range $310<m_H<470$ GeV

H→ZZ→4l (1)

- Very clean: four leptons (e or μ)
- Dilepton mass, lepton isolation, and impact parameter cuts suppress top and Z+jets
- Recent updates:
  - Luminosity increased to 4.8 fb^{-1}
  - Alignment between inner detector and muon spectrometer has been improved
  - Bremsstrahlung refitting for electrons to improve performance at low p_T





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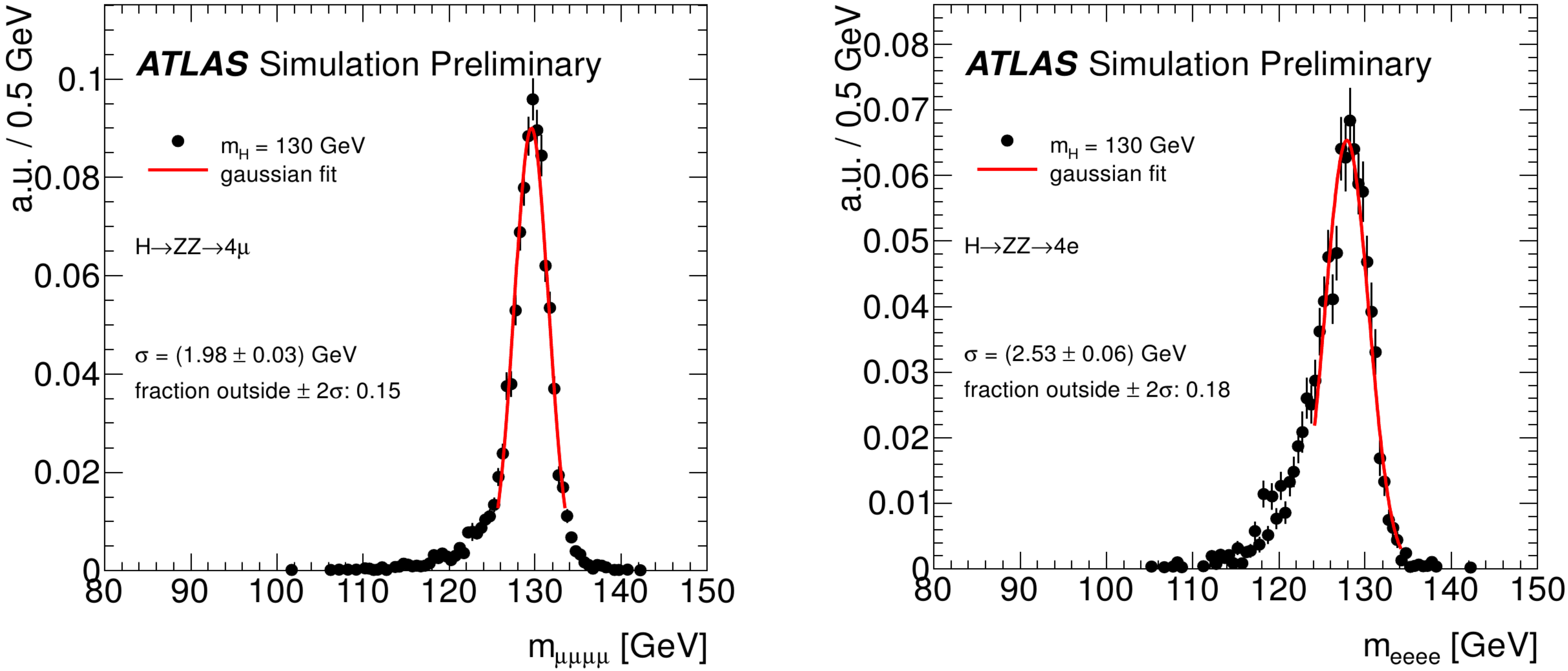
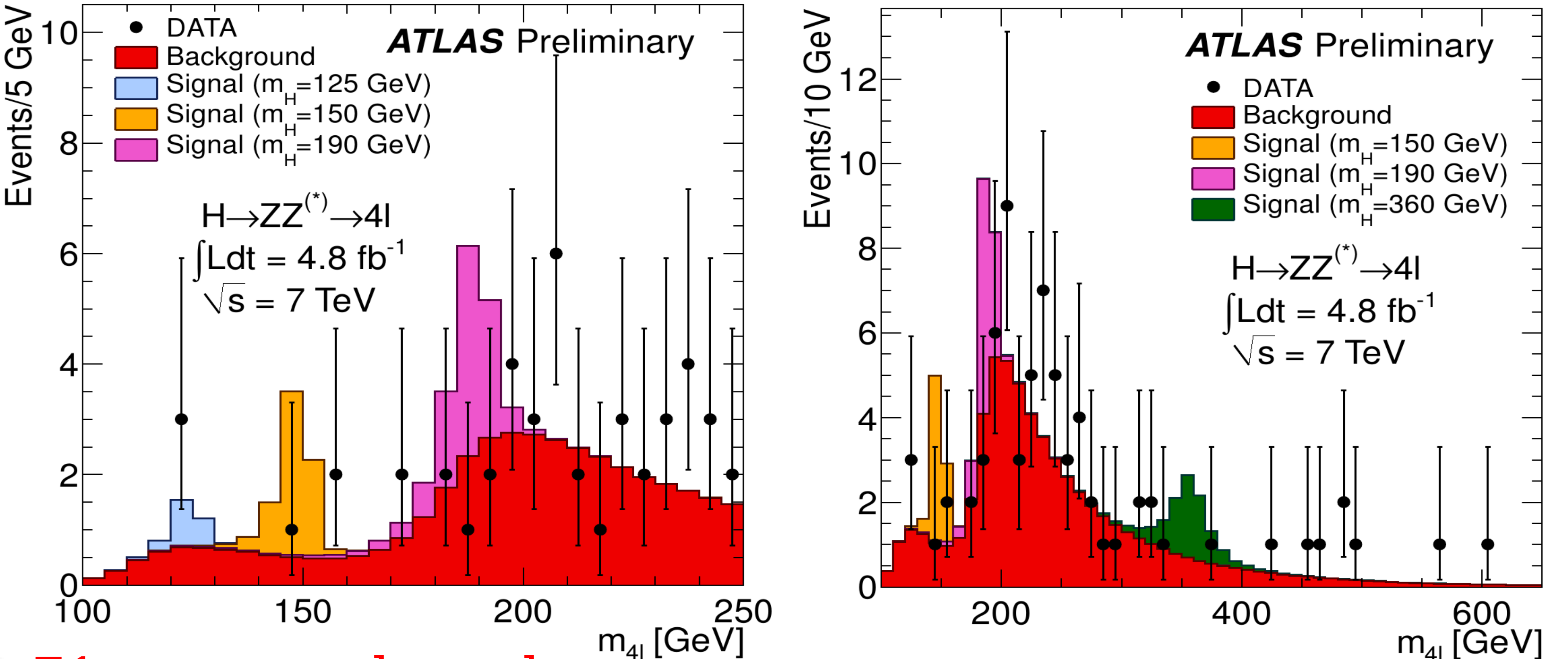
H→ZZ→4l (2)



ATLAS-CONF-2011-162

- Very good mass resolution helps to discriminate signal from otherwise irreducible continuum ZZ background
  - Above: resolution for m_H=130 GeV is 1.98 GeV for 4μ channel (left) and 2.53 GeV for 4e channel (right) based on signal MC
  - 15% of events outside of ±2σ region for 4μ channel, 18% for 4e

H→ZZ→4l (3)

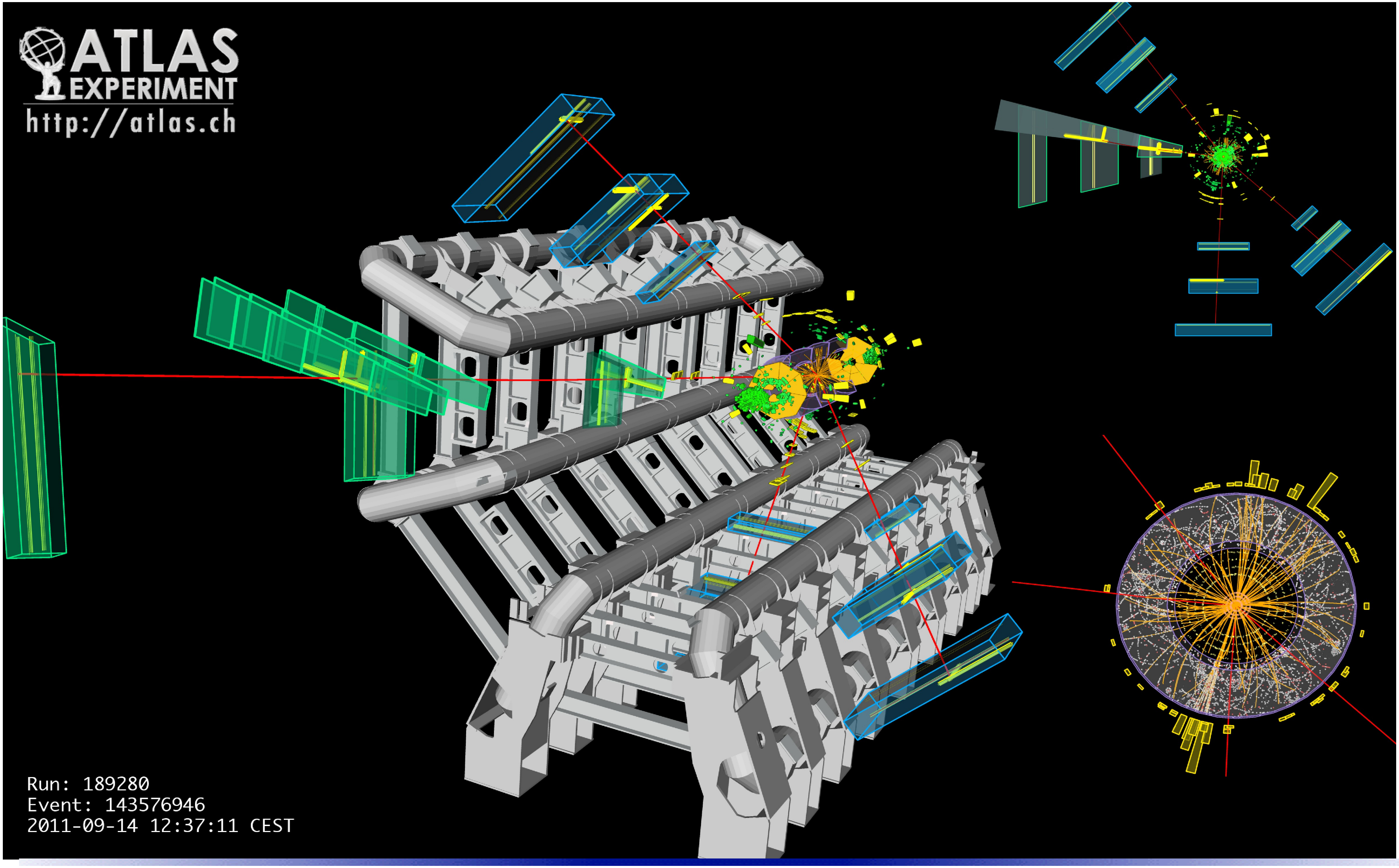


ATLAS-CONF-2011-162

- 71 events selected:
  - With m_{4l}>180 GeV: 15 ee, 27 eμ, and 21 μμ, with 10.5±1.4, 25.4±3.5, and 16.3±2.3 expected, respectively.
  - For m_{4l}<180 GeV: 2 ee, 3 eμ, and 3 μμ observed, with 2.9±0.7, 4.2±0.8, and 2.2±0.3 expected, respectively.
  - Above: m_{4l} dist. below 250 GeV (left) and for all masses (right)
- There are three interesting events at around 125 GeV.
  - Probability to see as significant an excess anywhere is >50%, so these events are not a real excess on their own

H→ZZ→4l (4)

4-muon event. Lepton pair masses: 89.7 GeV and 24.6 GeV. m_{4l}=124.6 GeV



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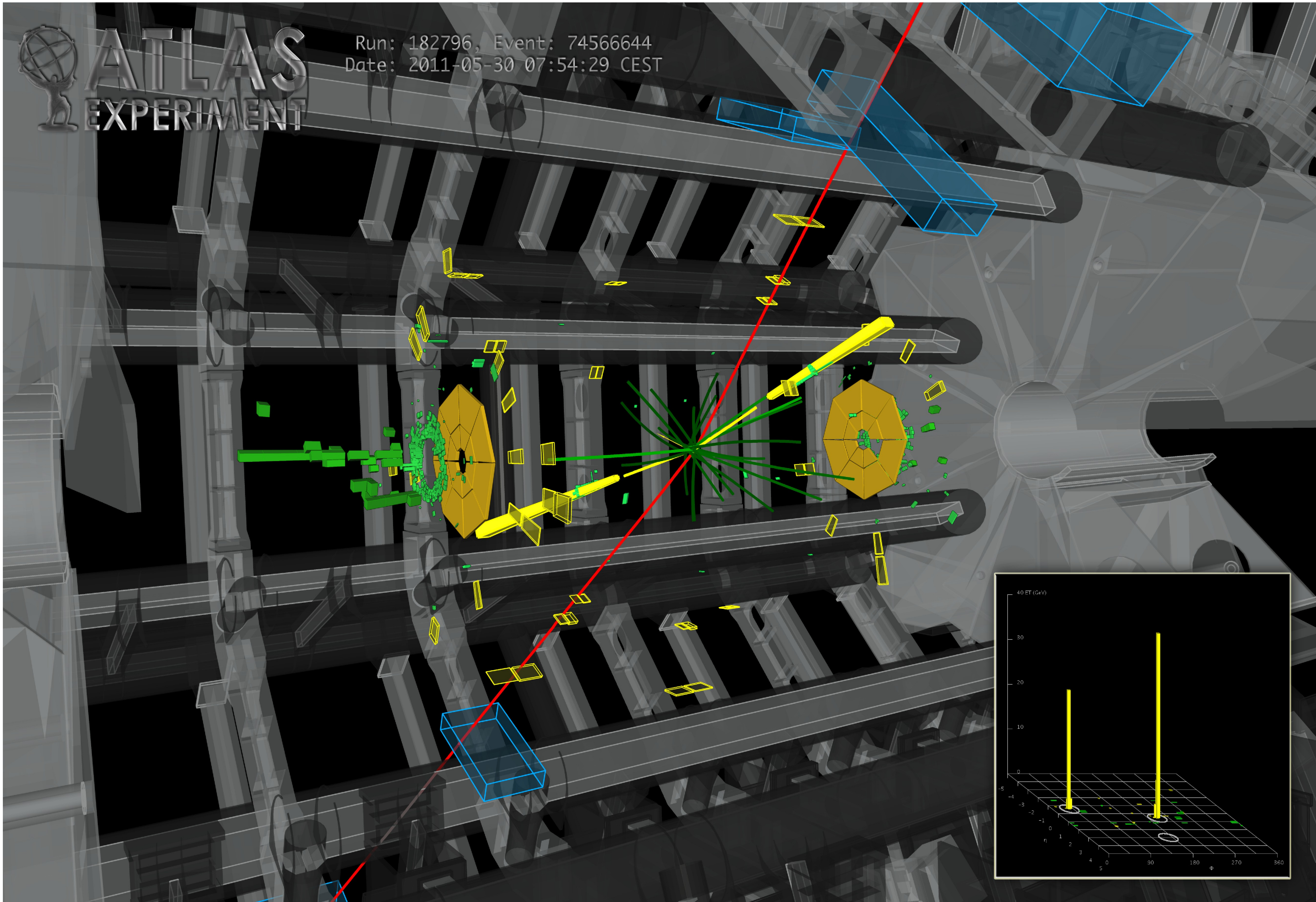
H→ZZ→4l (5)

2e2μ event. Lepton pair masses: 76.8 GeV and 45.7 GeV. m_{4l}=124.3 GeV



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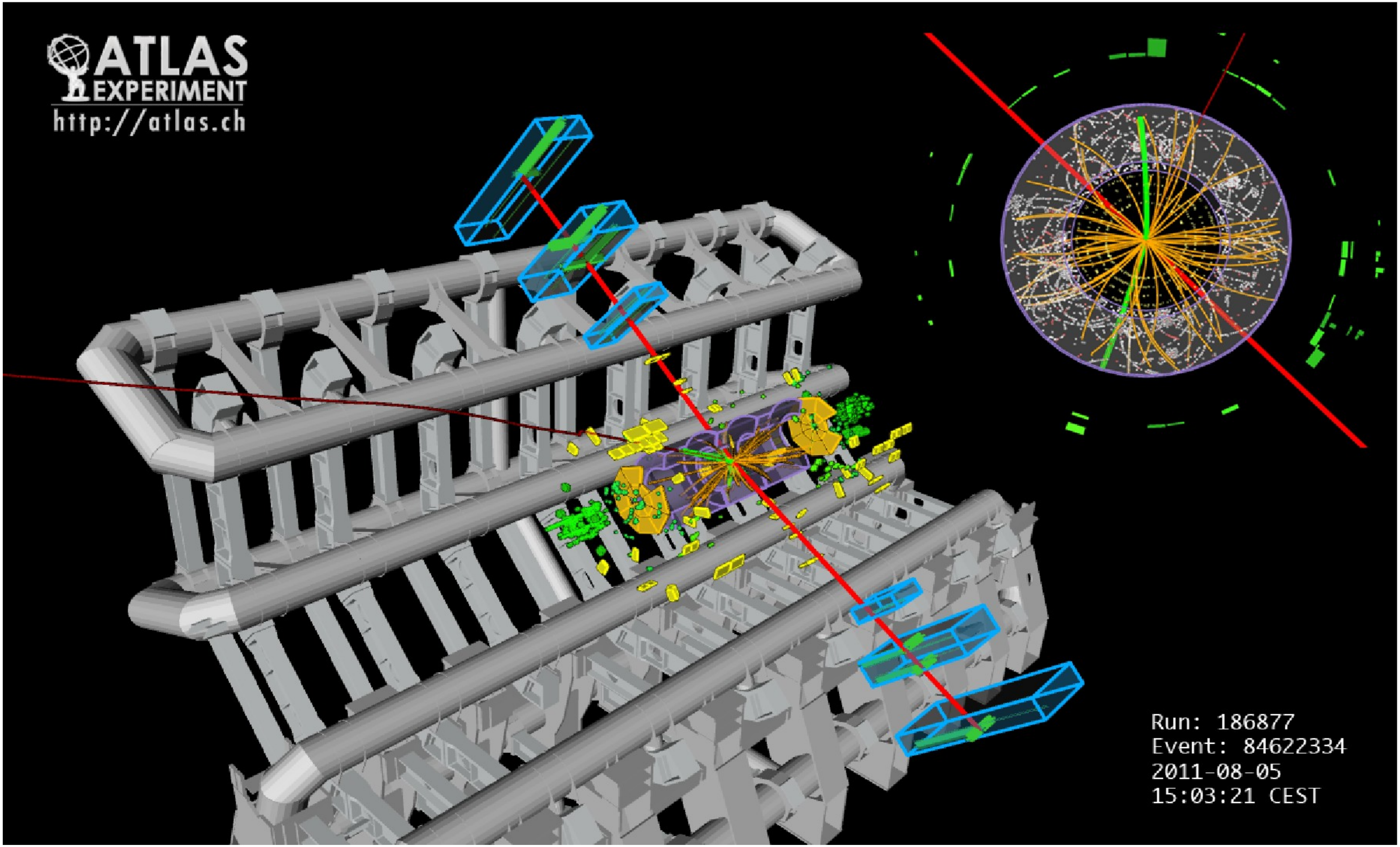
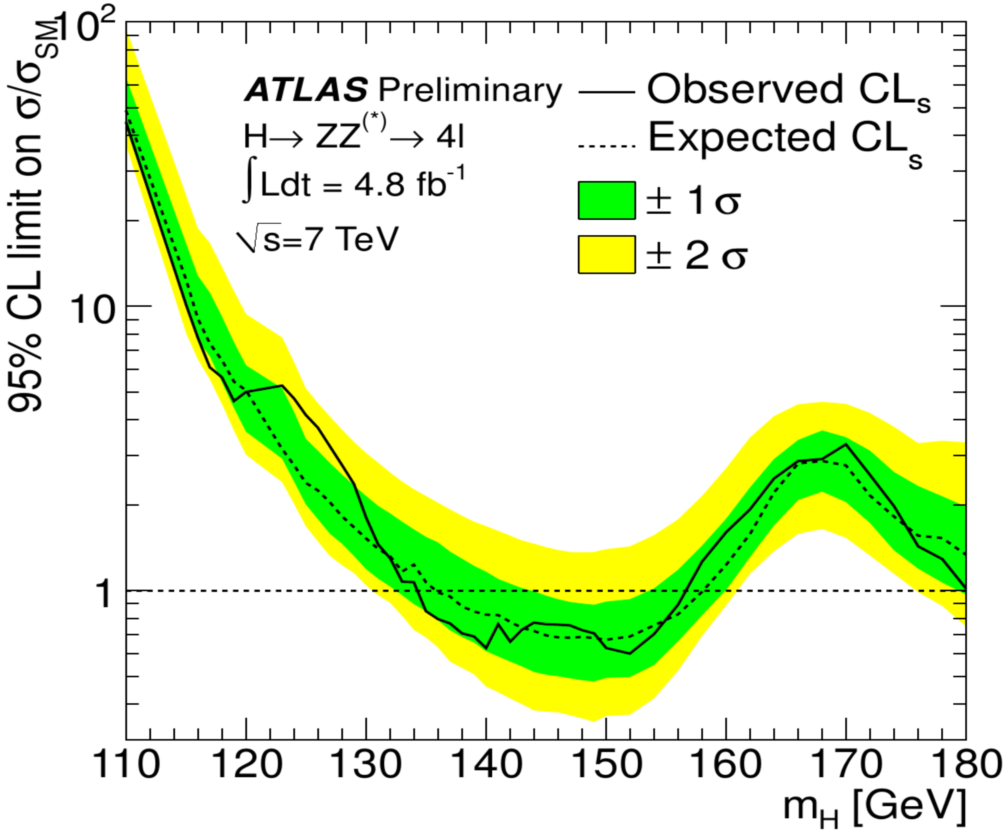
H→ZZ→4l (6)

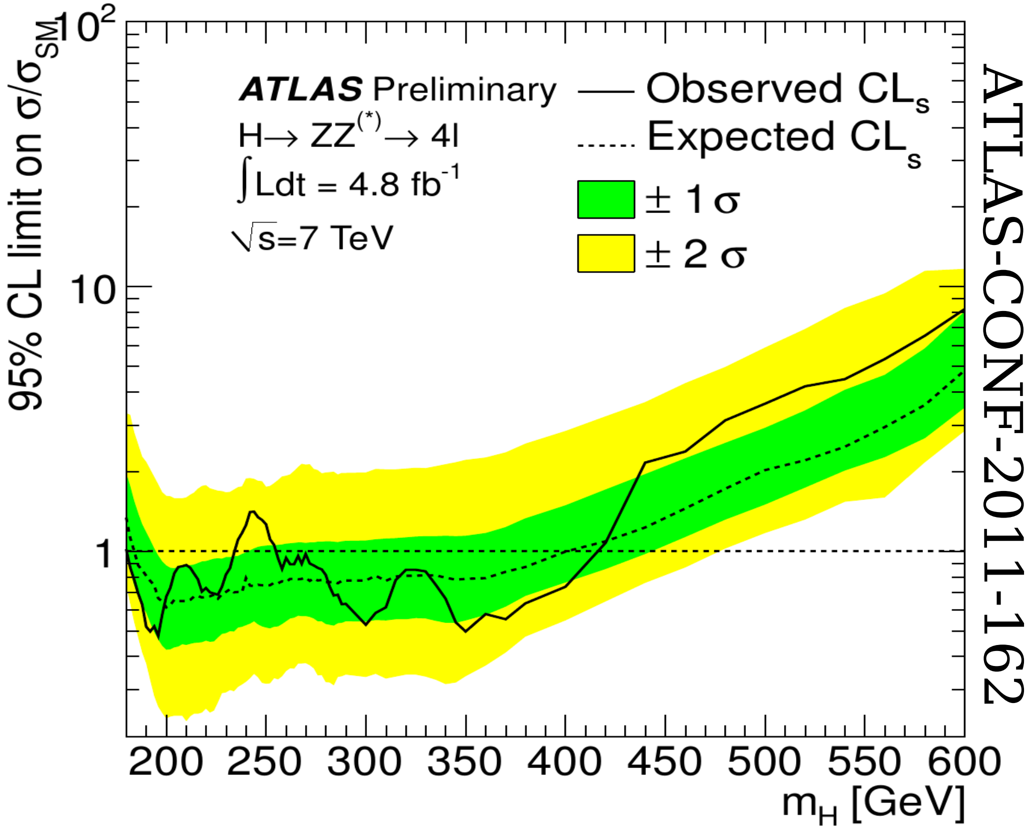
ATLAS-CONF-2011-162

2e2μ event. Lepton pair masses: 89.3 GeV and 30.0 GeV. m_{4l}=123.6 GeV



H→ZZ→4l (7)



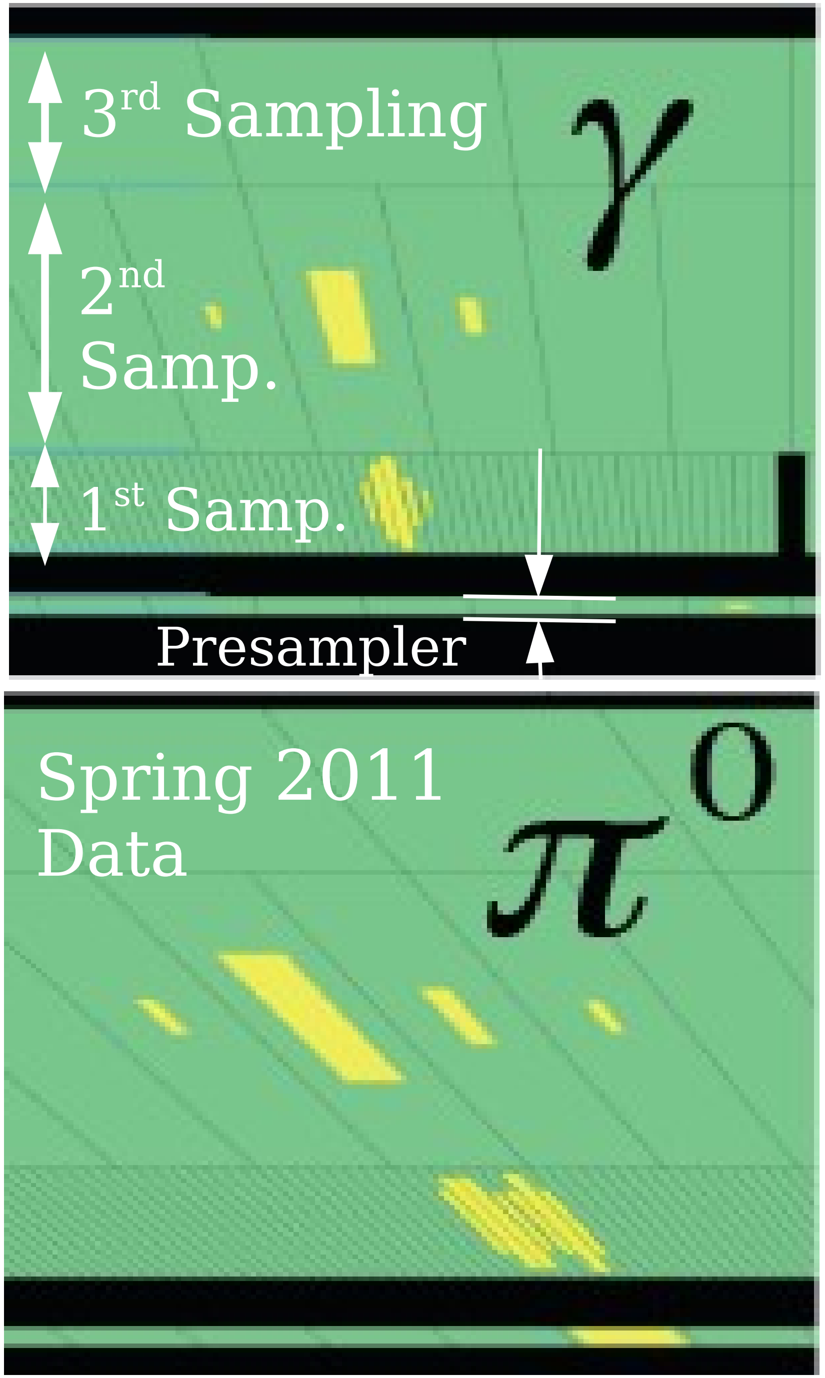


ATLAS-CONF-2011-162

- Background estimates:
  - ZZ and top from MC prediction, but top is validated in control region
  - Z+jets normalized to data using control region based on loosened isolation cuts for second lepton pair
- Exclude m_H: 135-156 GeV, 181-234 GeV, and 255-415 GeV.
- Most significant excesses are at m_H=125 GeV, 244 GeV, 500 GeV
  - Probability to see such bumps anywhere: >50% for all three cases

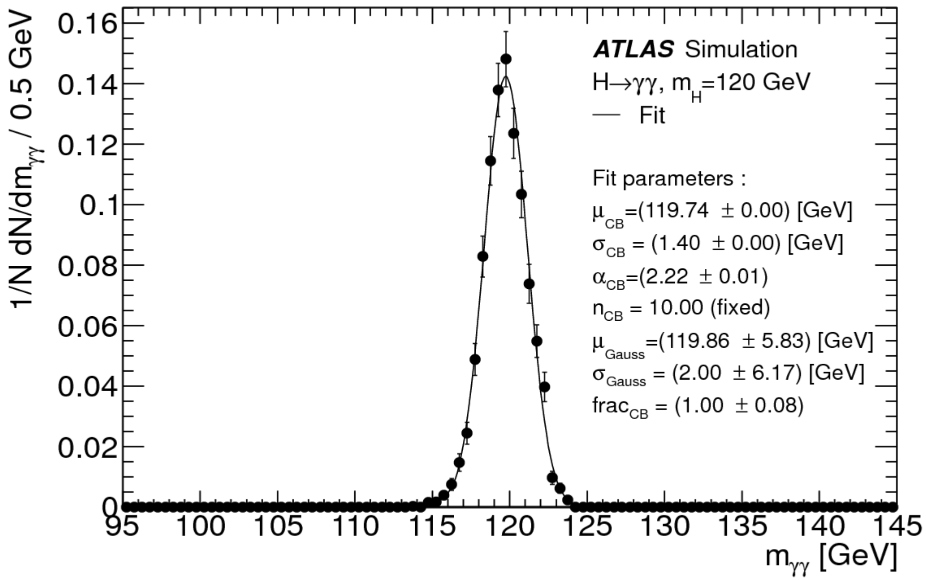
H→γγ (1)

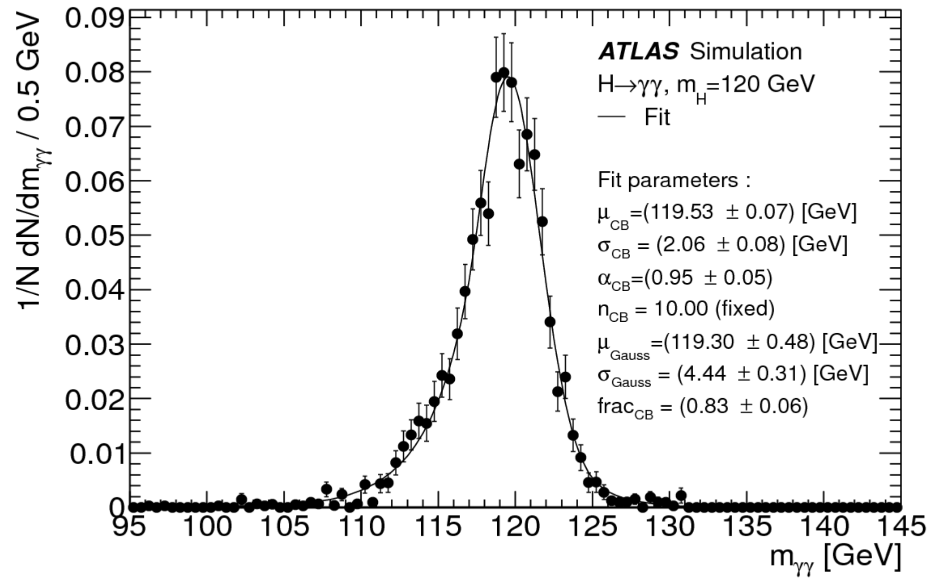
- H→γγ decay proceeds only via top and W loops, so BR(H→γγ) is small (~0.002). However, no subsequent decay as in the case of H→ZZ→4l.
- H→γγ signal is 0.04 pb, but background from continuum γγ is very large
  - Cross-section for qq→γγ is ~21 pb; for qg→γγ it's about 8 pb.
  - Background from γ+jet (before photon ID cuts) is ~1.8x10^5 pb
  - Background from dijets is ~5x10^8 pb.
  - Need large rejection, esp. against π^0 decays.
- Photon ID is based on lateral and longitudinal segmentation of the electromagnetic calorimeter.



H→γγ (2)

Phys. Lett. B 705 (2011) 452-470

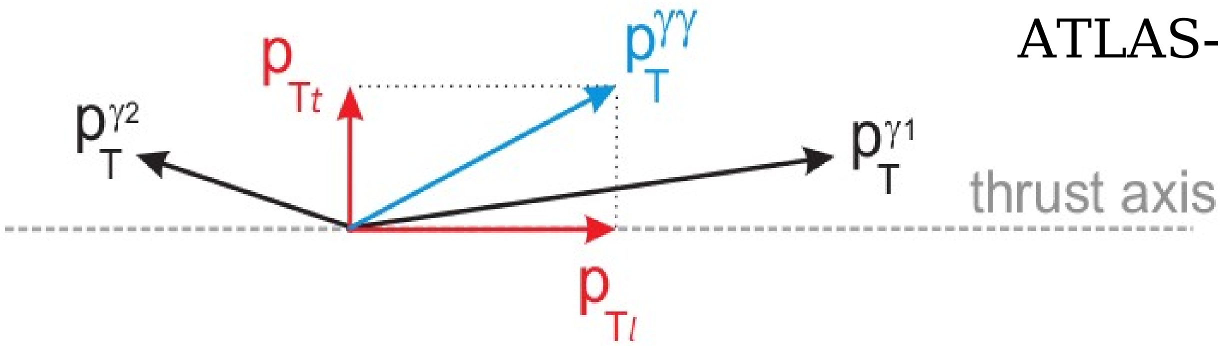




- Very good mass resolution of ~1.7 GeV helps distinguish between Higgs signal and continuum background
- Events are separated into categories based on the quality of photon reconstruction and location of photon candidates.
- Resolution ranges from ~1.4 GeV for unconverted photons in the central region of the detector (left) to ~2 GeV with asymmetric tails for photons which land in the region between the barrel and endcap and also show signs of having converted to an e^+e^- pair before reaching the calorimeter (right)

H→γγ (3)

ATLAS-CONF-2011-161



$$\hat{t} = \frac{\vec{p}_T^{\gamma_1} - \vec{p}_T^{\gamma_2}}{|\vec{p}_T^{\gamma_1} - \vec{p}_T^{\gamma_2}|}$$

Category	Conversion and η	p_{Tt} cut	Number of data events
CP1	Unconverted Central	$p_{Tt} \leq 40$ GeV	1763
CP2	Unconverted Central	$p_{Tt} > 40$ GeV	235
CP3	Unconverted Rest	$p_{Tt} \leq 40$ GeV	6234
CP4	Unconverted Rest	$p_{Tt} > 40$ GeV	1006
CP5	Converted Central	$p_{Tt} \leq 40$ GeV	1318
CP6	Converted Central	$p_{Tt} > 40$ GeV	184
CP7	Converted Rest	$p_{Tt} \leq 40$ GeV	7311
CP8	Converted Rest	$p_{Tt} > 40$ GeV	1072
CP9	Converted Transition	No cut	3366
Total			22489

- New in this update: split categories into high and low p_{Tt} (p_T relative to diphoton thrust axis)
  - Preserves exponential shape for background
  - Left: with 4.9 fb^{-1}, there are enough events to do this
- Definition of p_{Tt}:

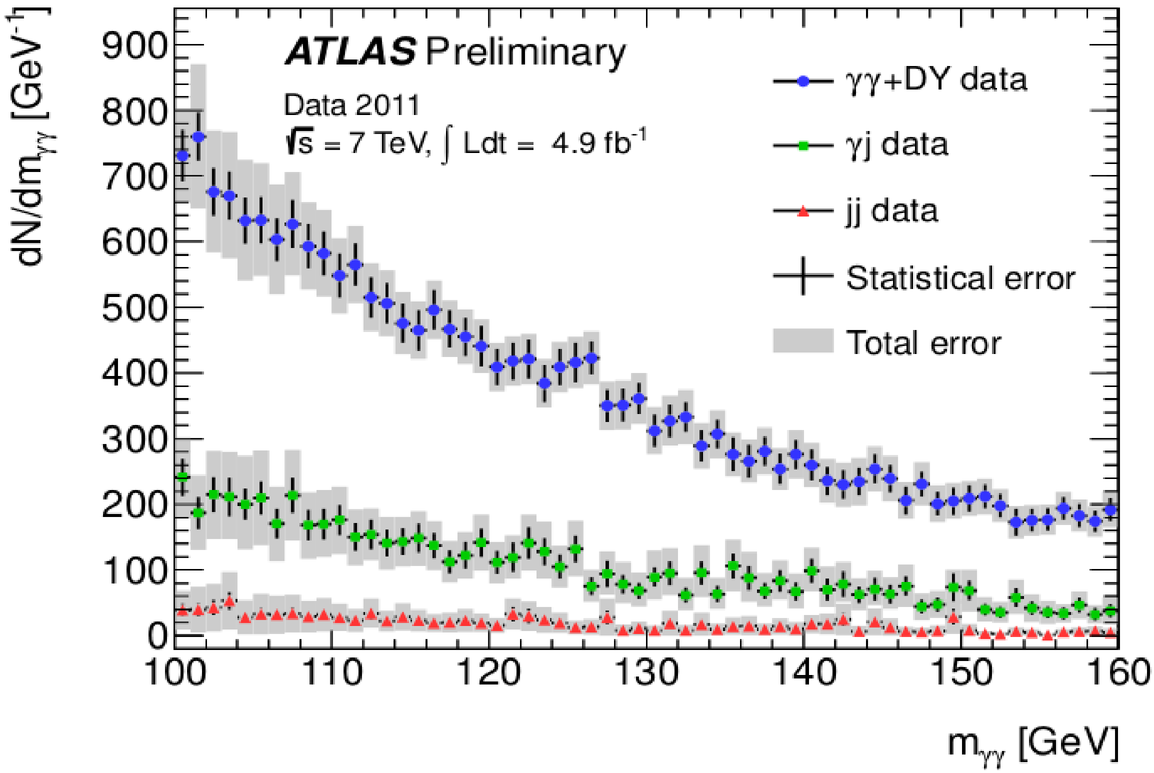
$$\vec{p}_T^{\gamma\gamma} = \vec{p}_T^{\gamma_1} + \vec{p}_T^{\gamma_2}$$

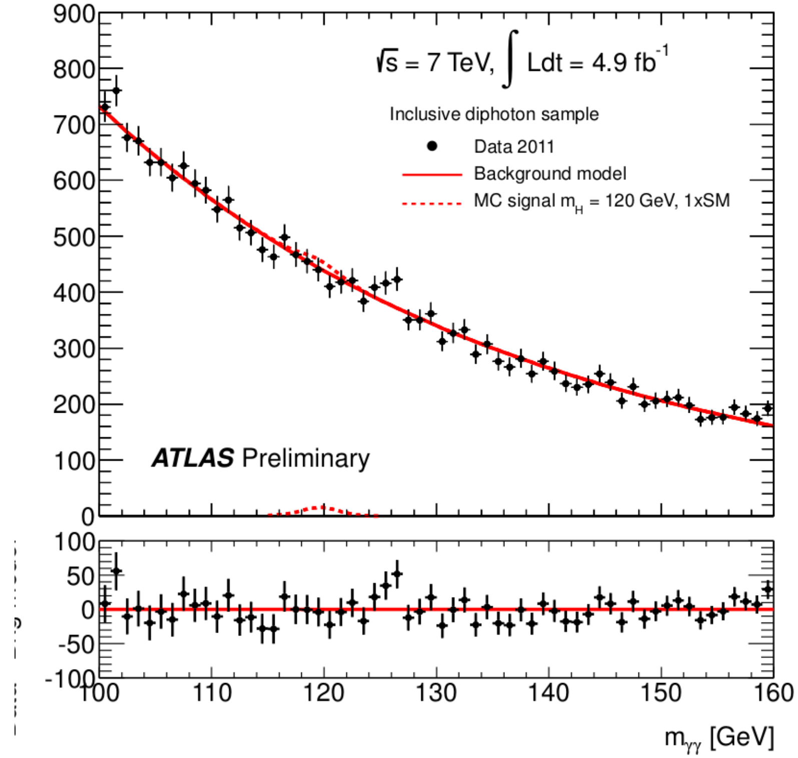
$$\vec{p}_{Tt} = \vec{p}_T^{\gamma\gamma} - (\vec{p}_T^{\gamma\gamma} \cdot \hat{t}) \cdot \hat{t}$$

$$p_{Tt} = |\vec{p}_T^{\gamma\gamma} \times \hat{t}|$$

H→γγ (4)

ATLAS-CONF-2011-161





- Composition of background (i.e. relative contribution from γγ, γ-jet, jet-jet) is checked using loosened photon ID & isolation cuts (left). Selected events are dominantly diphoton events.
- Signal is extracted using a fit to $M_{\gamma\gamma}$ (right). Plot shown above is inclusive, but fit treats pseudorapidity/conversion/p_{Tt} categories separately

H→γγ (5)

- Right: summary of systematic uncertainties on signal.
  - Uncertainties on yield and resolution are fully correlated among the different categories
  - Event migration uncertainties are anti-correlated between low/high-p_{Tt} categories and converted/unconverted categories
- Below: uncertainty on BG model is estimated based on fits to RESBOS/DIPHOX MC distributions.

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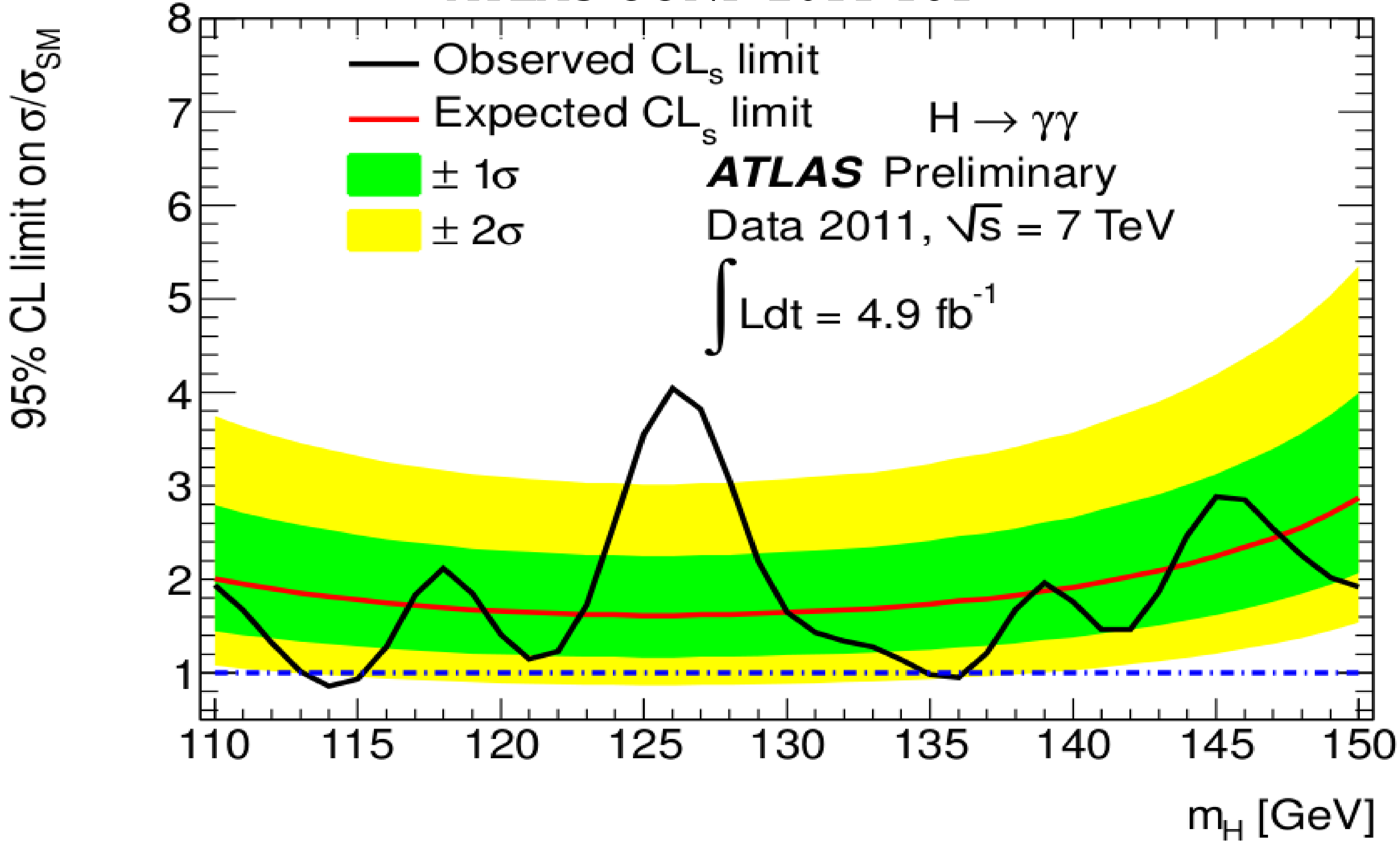
Type and source	Uncertainty
Event yield	
Photon reconstruction and identification	±11%
Pileup effect on photon identification	±4%
Isolation	±5%
Trigger	±1%
Higgs boson cross section	+15%/ − 11%
Higgs boson p_T modeling	±1%
Luminosity	±3.9%
Mass resolution	
Calorimeter energy resolution	±12%
Photon energy calibration	±6%
Pileup effect on energy resolution	±3%
Photon angle resolution	±1%
Migration	
Higgs boson p_T modeling	±8%
Conversion reconstruction	±4.5%

Category	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9
Events	±4.3	±0.2	±3.7	±0.5	±3.2	±0.1	±5.6	±0.6	±2.3

H→γγ (6)

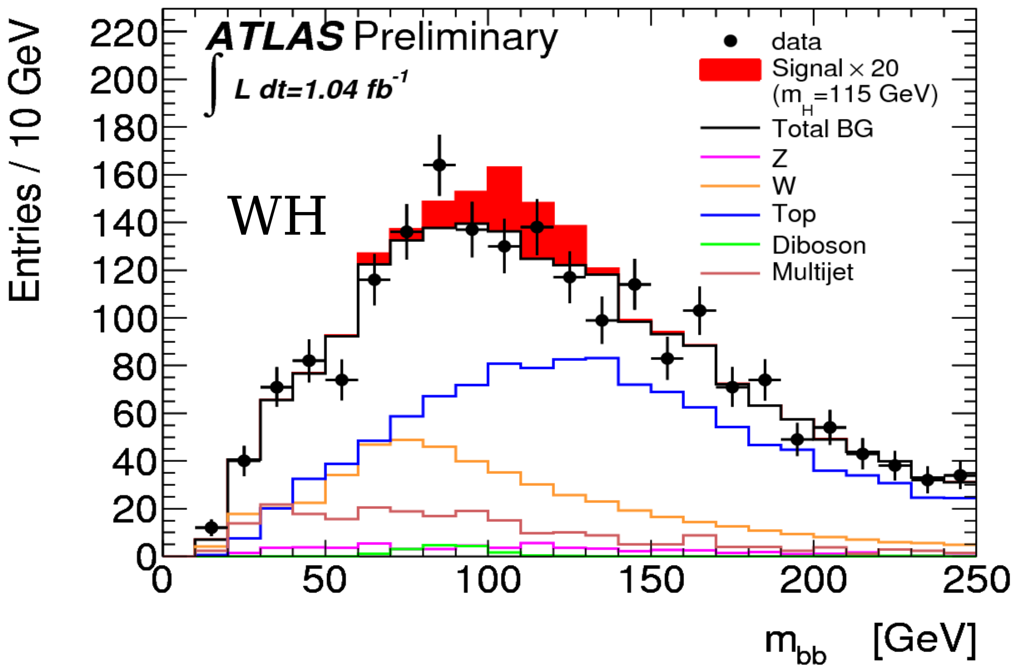
ATLAS-CONF-2011-161

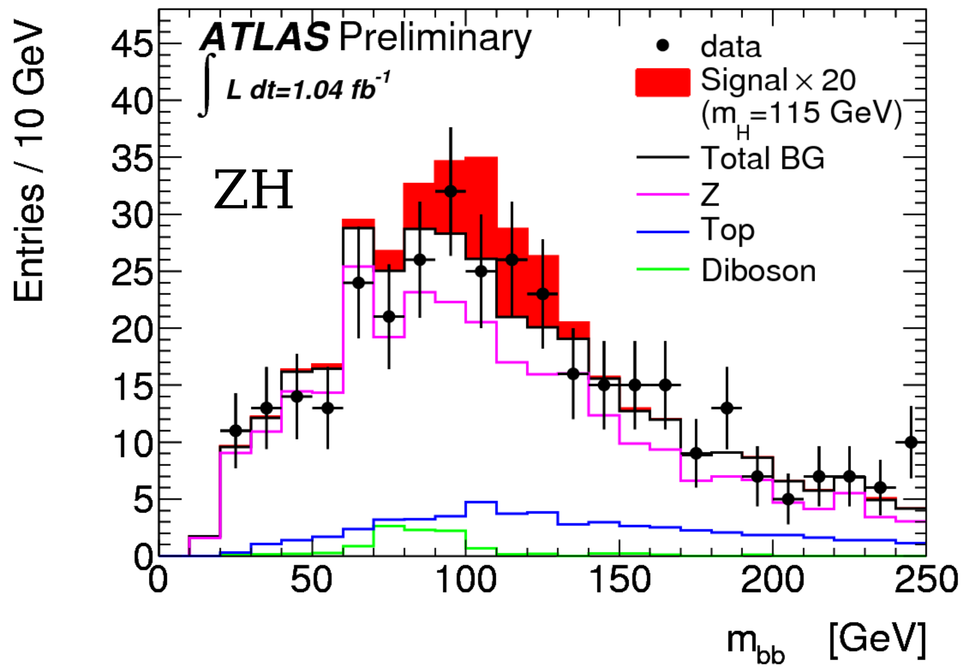


- Exclude m_H ranges: 114-115 GeV, 135-136 GeV
- Significance of largest excess (m_H=126 GeV) is 1.5σ after accounting for the look-elsewhere effect
  - Would be 2.8σ if we had been looking only at this mass

WH/ZH, H→bb (1)

ATLAS-CONF-2011-103

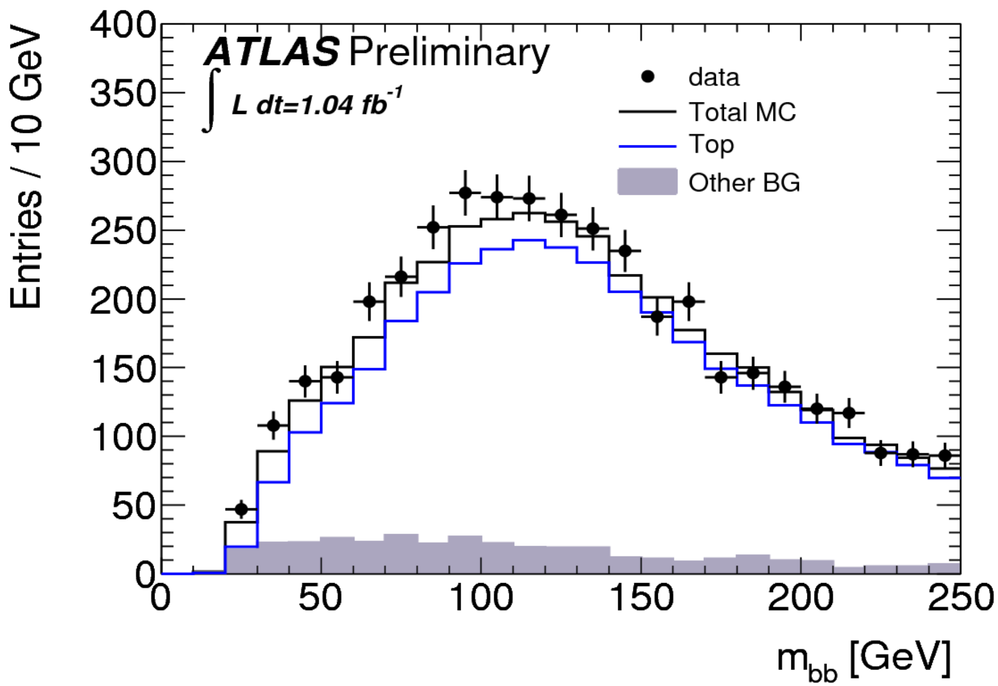


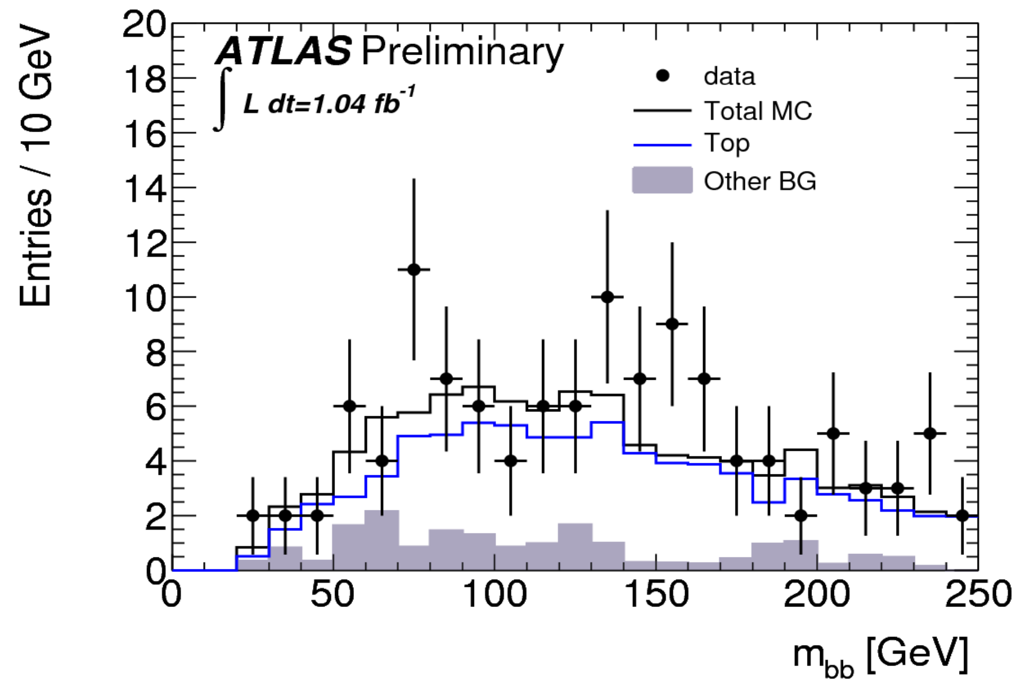


- ggH and WBF are dominant Higgs production mechanisms, but for H→bb these modes are overwhelmed by background. WH/ZH (H→bb) is best for this decay mode
- Select W→lν and Z→ll decays by requiring two leptons or one lepton and E_T^{miss}.
- Select two b-tagged jets with p_T>25 GeV
- Dominant backgrounds for both are W+jets, Z+jets, top

WH/ZH, H→bb (2)

ATLAS-CONF-2011-103





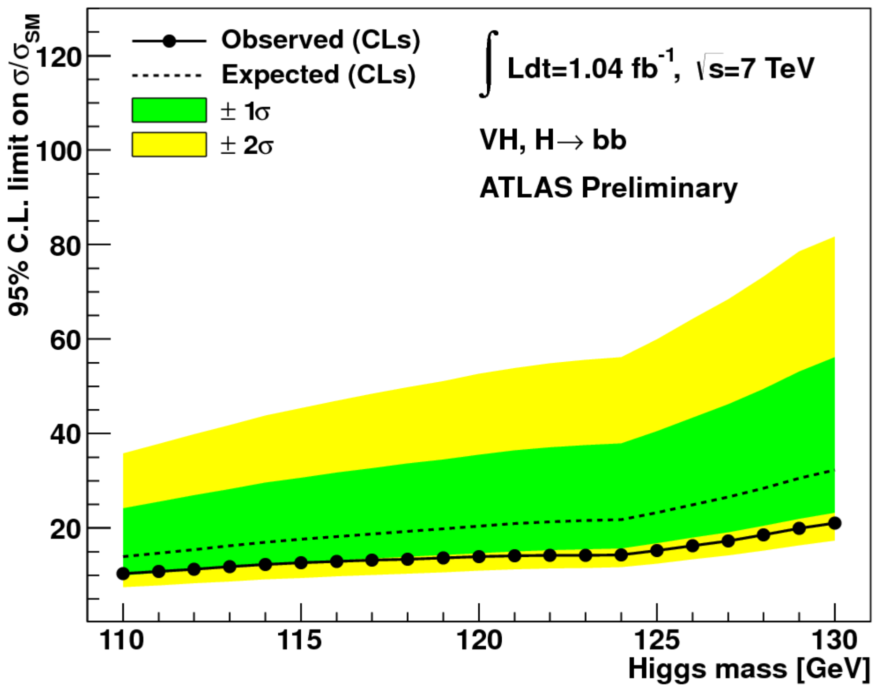
- Top quark backgrounds are checked with control samples.
- Left: control sample for WH consists of events with three jets (in the signal region only two are allowed)
  - Top normalization in signal region comes from fit to sidebands in m_{bb}
- Right: control sample for ZH consists of events with m_{ll} outside the Z peak
- Assign 9% uncertainty to top in ZH based on this comparison; 6% for top in WH based on the fit to m_{bb}

WH/ZH, H→bb (3)

ATLAS-CONF-2011-103

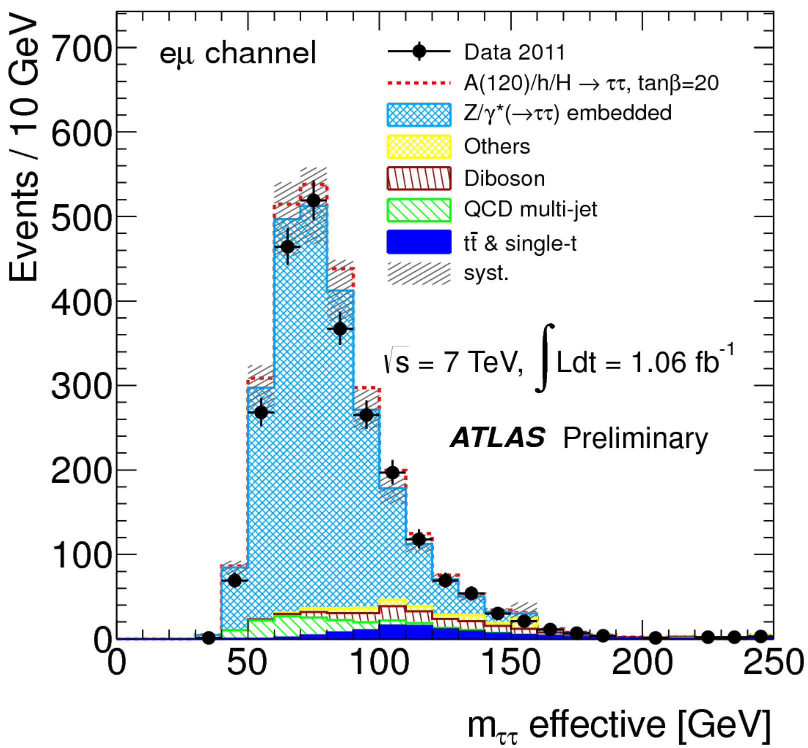
Uncertainty	ZH, 115 GeV	ZH, 130 GeV	WH, 115 GeV	WH, 130 GeV
Muon Res.	1%	4%	3%	1%
Jet E scale	9%	7%	1%	3%
E_T^{miss} Res.	2%	2%	2%	3%
b-tagging eff.	16%	17%	16%	17%
b-tag mistag	<1%	<1%	3%	3%
Luminosity	4%	4%	4%	4%
Higgs x-sec	5%	5%	5%	5%

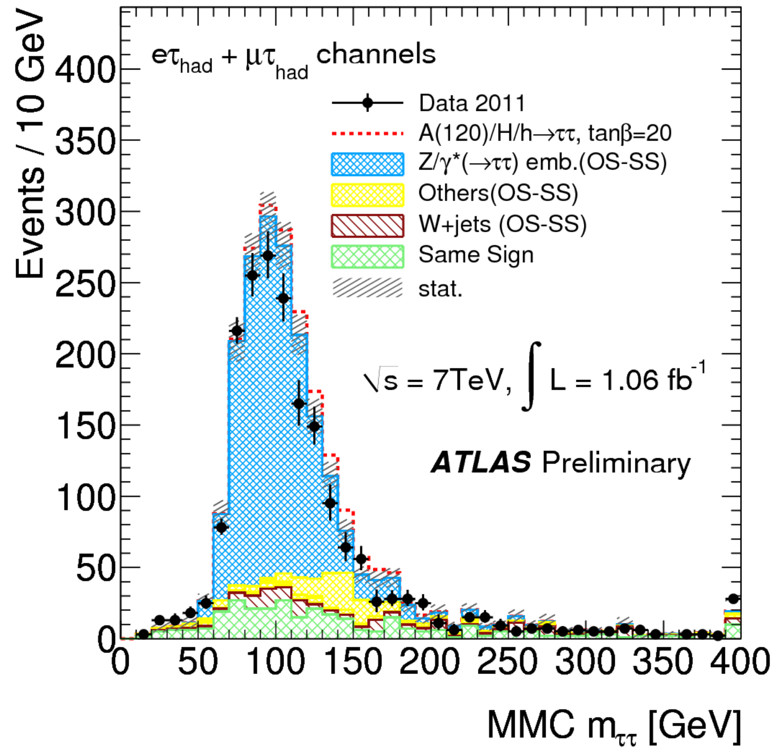
- Above: major sources of background uncertainty. Several other sources contribute at the level of 1% or less
  - Electron E scale & resolution, Jet E res., electron and muon efficiency
- Exclude Higgs production with cross-section ~10-20 times the Standard Model prediction



MSSM H/A→ττ (1)

ATLAS-CONF-2011-132

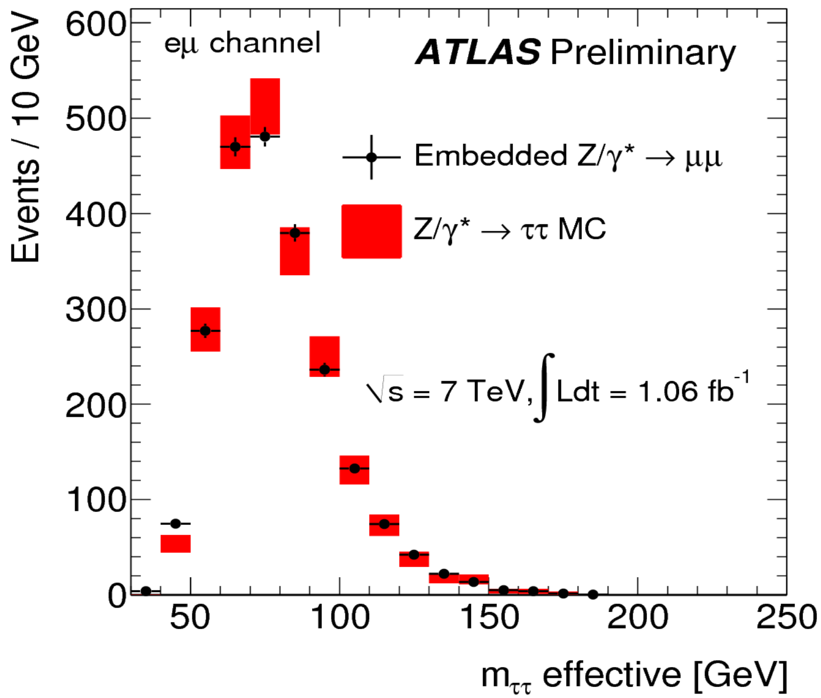


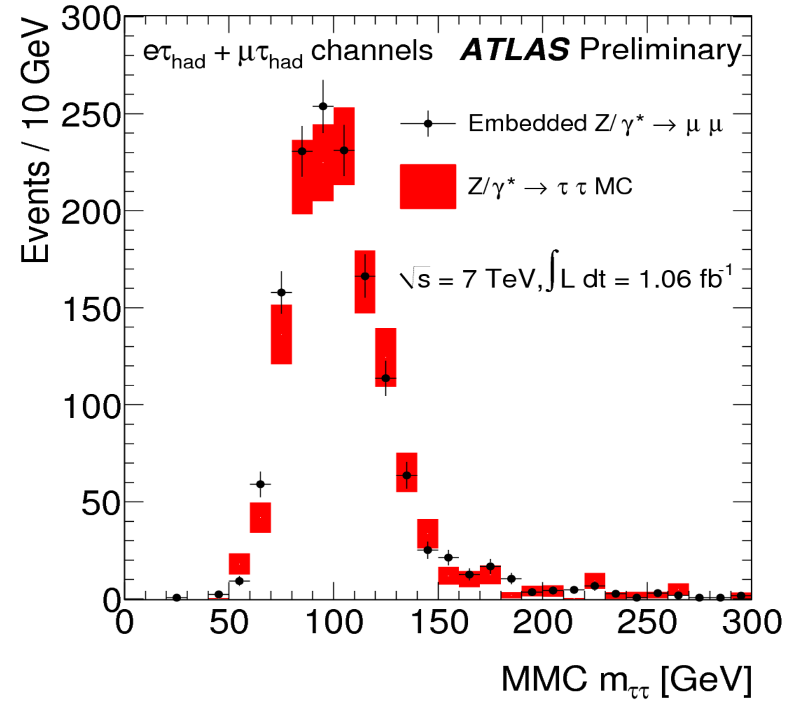


- Three channels considered:
  - eμ channel: require lepton p_T cuts, scalar sum of p_T^e, p_T^μ, and E_T^{miss} less than 120 GeV, and $\Delta\phi_{ll}>2$ radians. Analysis is based on $m_{\tau\tau}^{eff}=\sqrt{(p_e+p_\mu+E_T^{miss})}$, shown in the left plot
  - lh channel: require lepton& jet p_T cuts, $E_t^{miss}>20$ GeV, and $m_T(l,E_T^{miss})<30$ GeV. Analysis is based on the MMC mass, similar to collinear approximation but more sophisticated. (Right plot)
  - hh channel: hard τ-jet p_T cuts, $E_T^{miss}>25$ GeV (not shown)

MSSM H/A→ττ (2)

ATLAS-CONF-2011-132

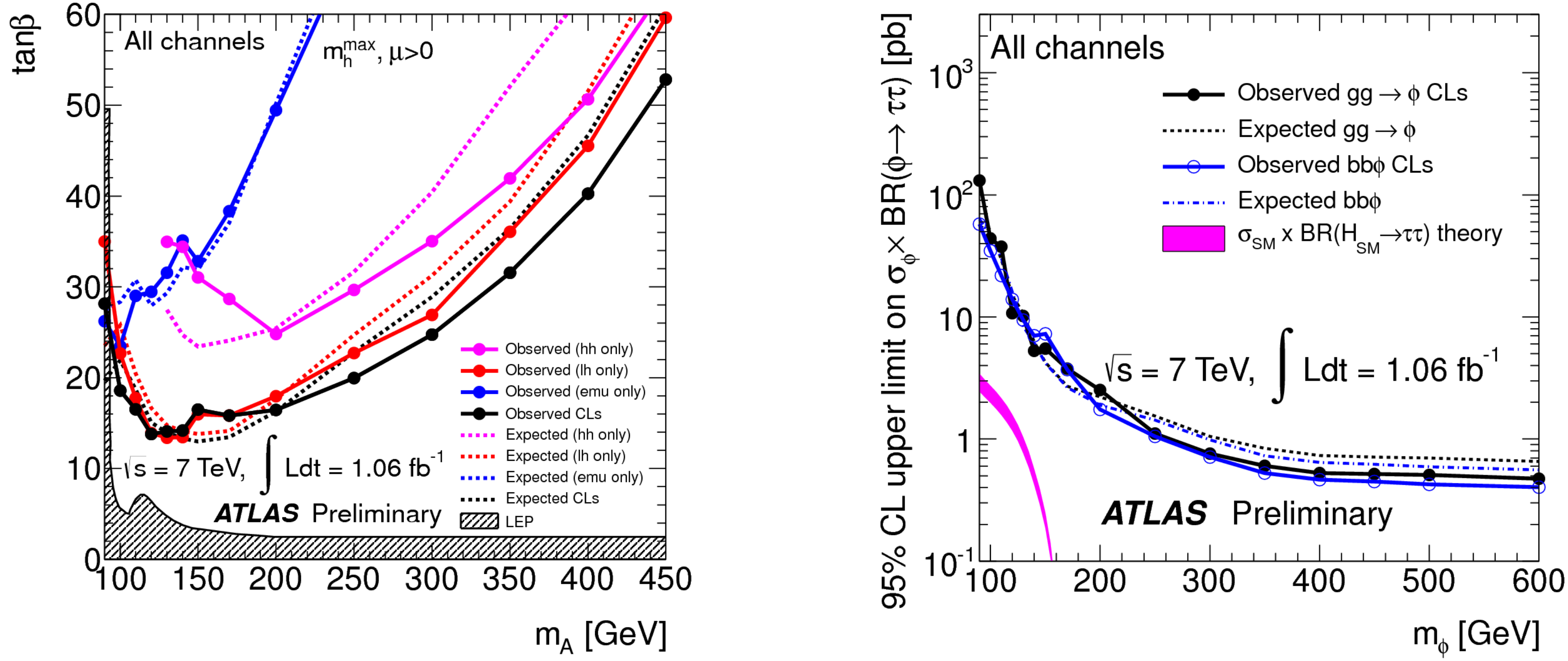




- QCD/W+jets backgrounds come from data:
  - eμ channel: shape is taken from a sample of anti-isolated leptons; normalization from a similar comparison for same-sign events.
  - lh channel: W+jets background is estimated from same-sign events times a factor from MC.
  - hh channel: shape from loose tau ID, norm. from same-sign samples
- Z+jets modeled using MC, validated with the τ embedding method used in the Standard Model search (above)
- Other backgrounds are modeled using MC

MSSM H/A→ττ (3)

ATLAS-CONF-2011-132



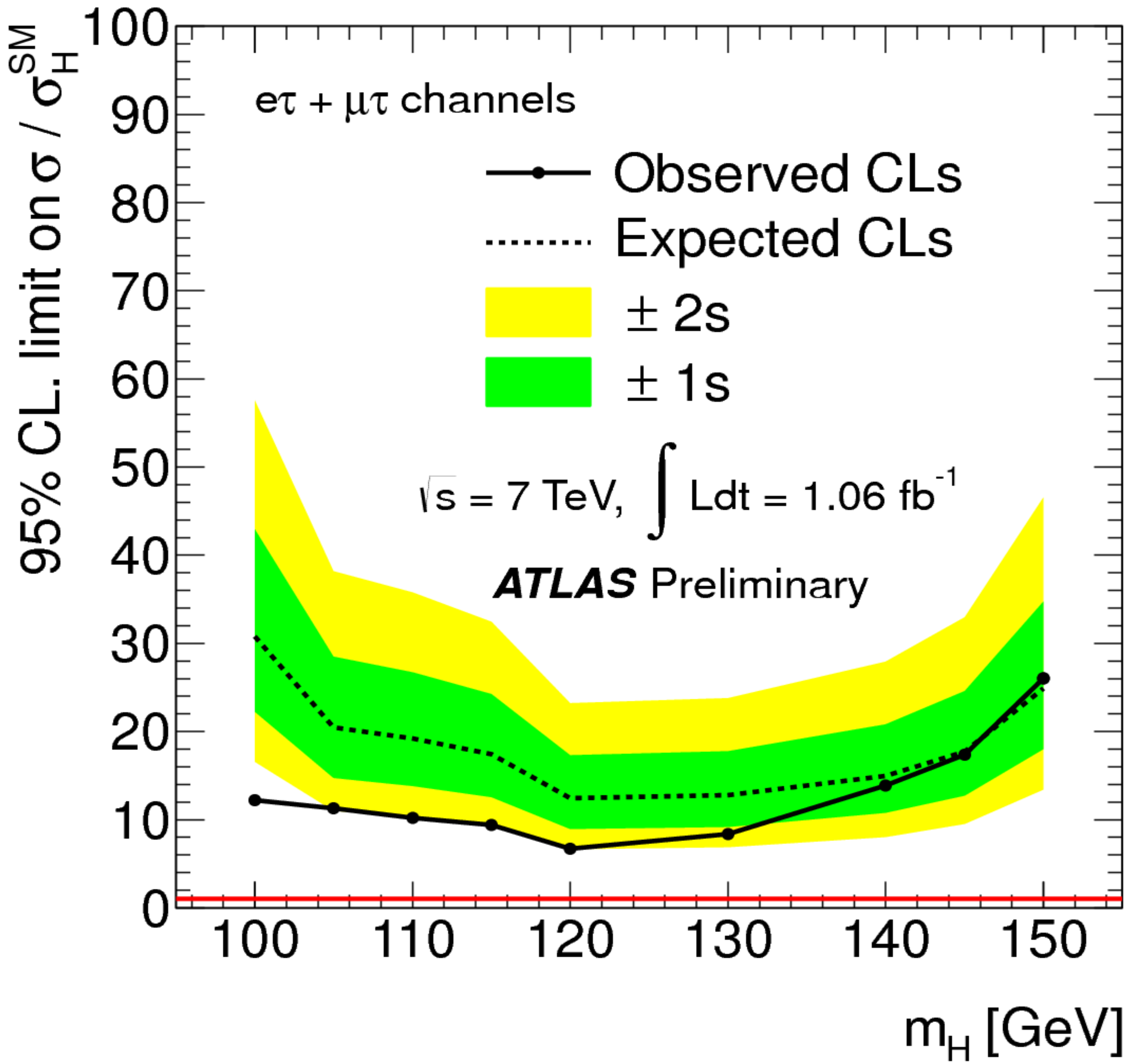
- For Z+jets (the dominant background in eμ and lh), the largest uncertainty is from theory error on the acceptance, amounting to 5% for eμ and 14% for lh channels.
- For the hh channel, the main uncertainty on QCD multijets (i.e. the largest BG) is the statistical error on the number of same sign events (used in the data-driven normalization)
- A large region of the m_A/tan(β) plane is excluded (left), and an upper bound on the cross-section vs m_A is set (right)

Standard Model H→ττ

ATLAS-CONF-2011-132

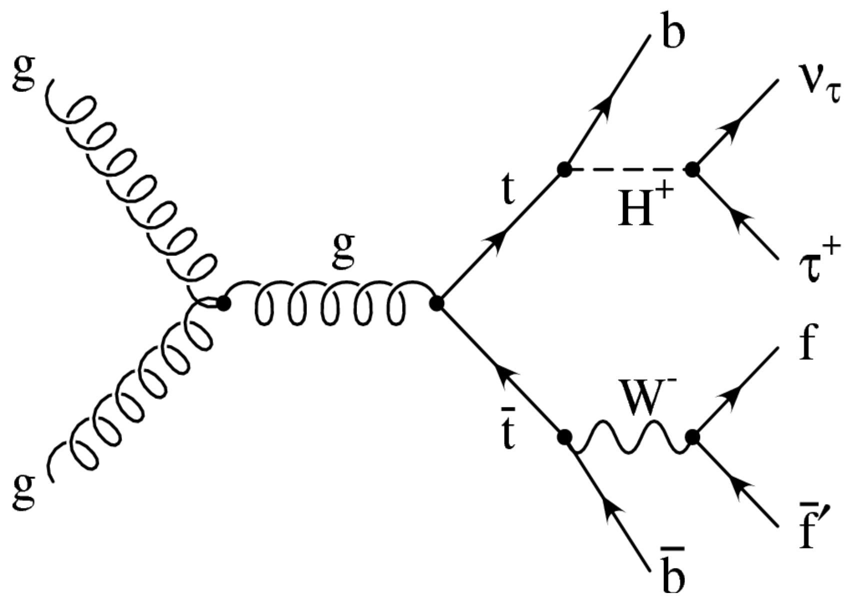
- The results for this channel have also been interpreted in terms of the Standard Model.

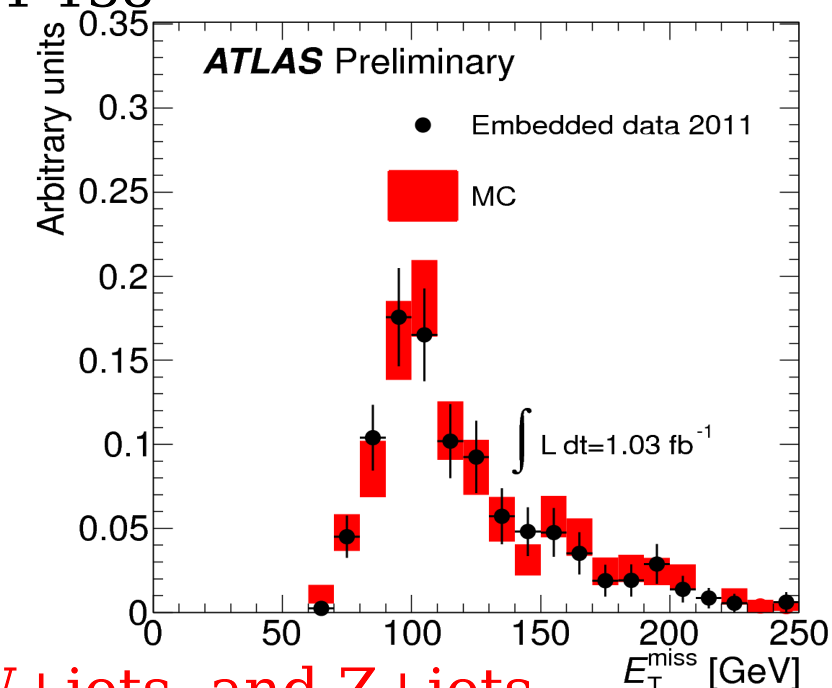
- The limits are at the level of about 10x the Standard Model cross-section



Charged Higgs (1)

ATLAS-CONF-2011-138

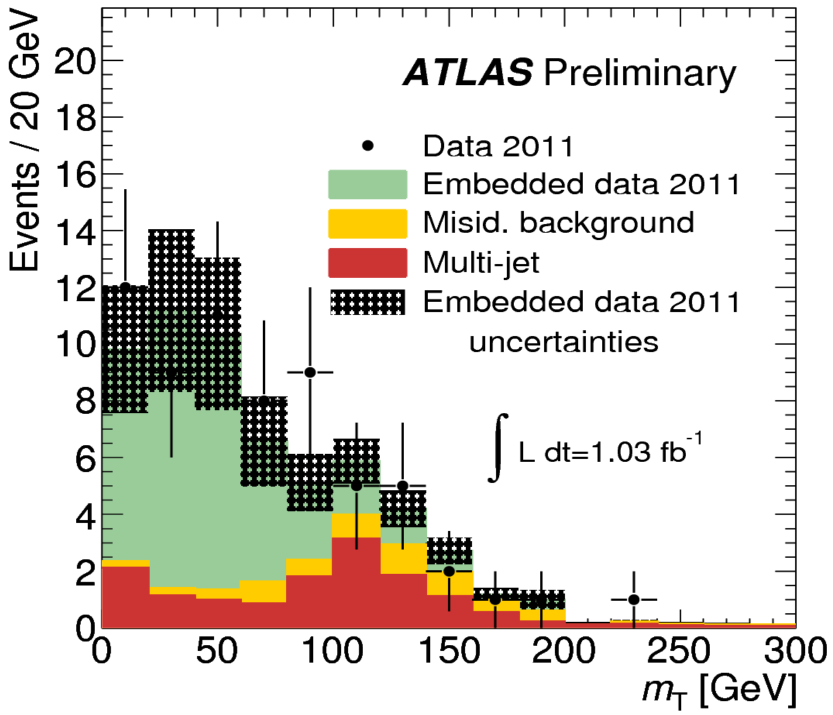


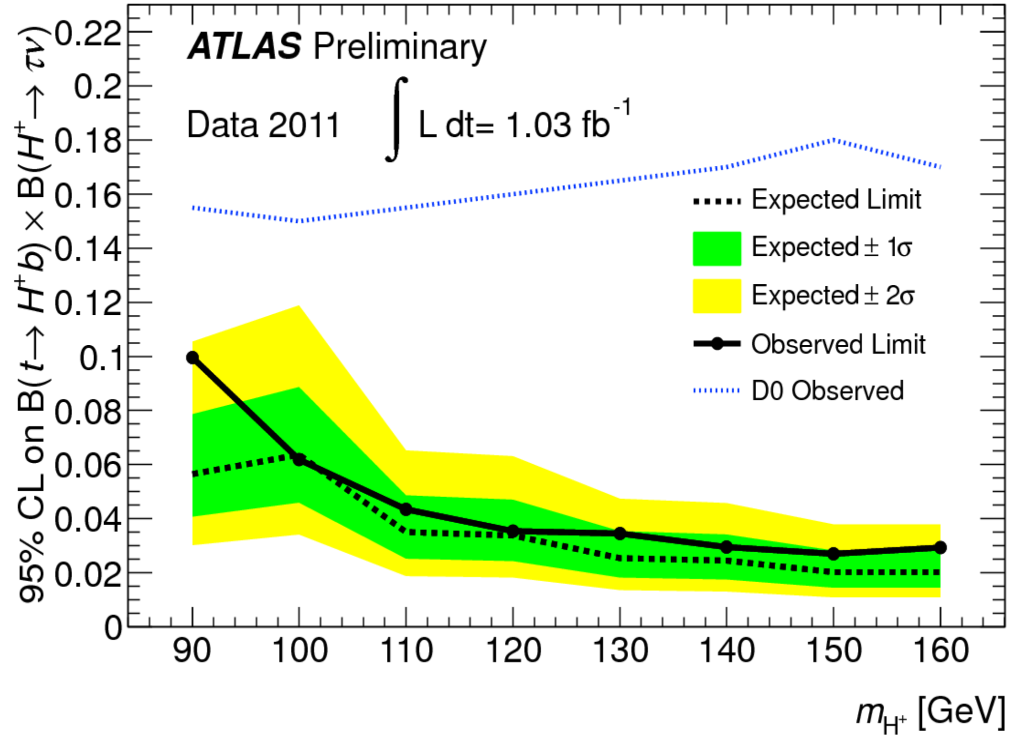


- Backgrounds are ttbar, single top, W+jets, and Z+jets
- Events with real MET from a W decay can include electrons/jets misidentified as taus and correctly identified tau jets
  - Electron fake rate is checked using tag & probe on the Z peak
  - Jet fake rate is checked using γ+jets events
  - True tau contribution is studied using embedding technique: select single-muon ttbar events, remove reconstructed muon, and replace with simulated τ
- Events with no intrinsic MET (multi-jet events) are controlled by a template fit to the MET distribution
  - Fake MET background is modeled by a control sample defined by reversed b-tagging and τ ID cuts; real MET background (W+jets, ttbar) modeled by MC

Charged Higgs (2)

ATLAS-CONF-2011-138





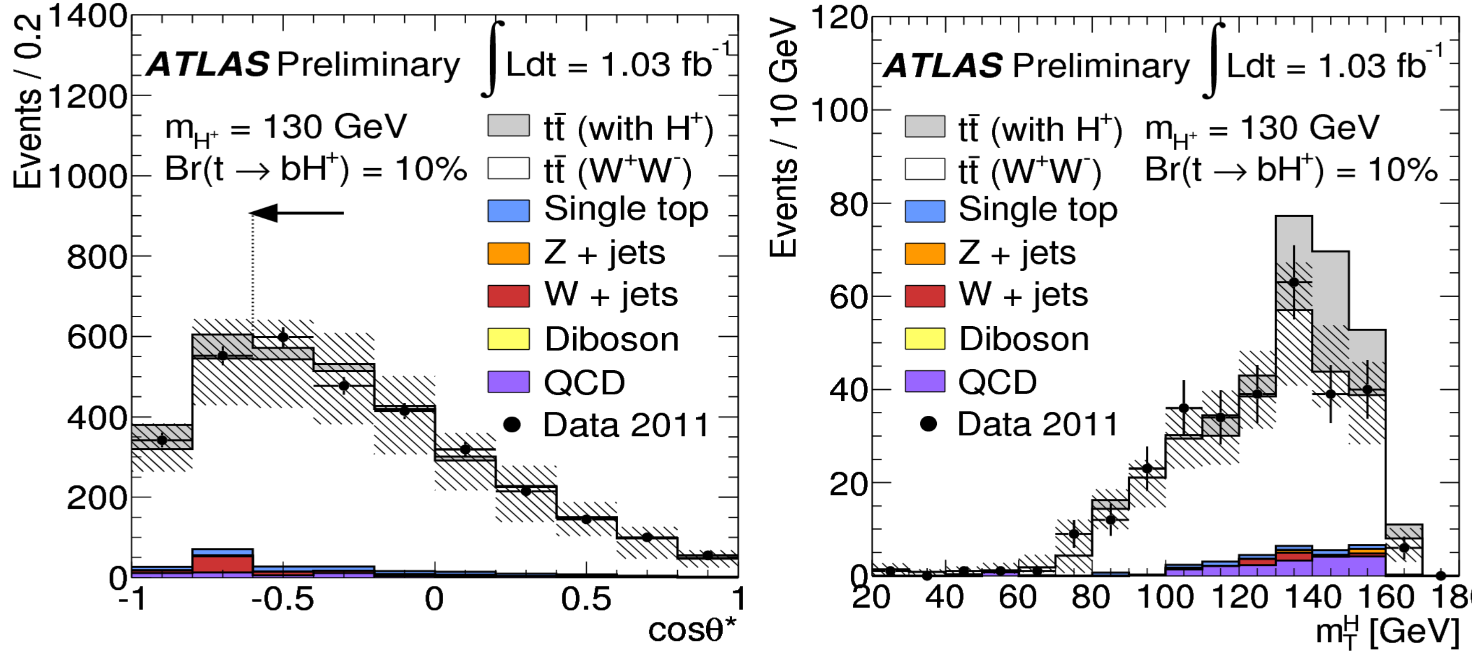
- The data-driven methods used for the various backgrounds describe the data in the signal region well.
  - Left: the transverse mass distribution in the signal region

- The current limit on the branching ratio for $t \rightarrow bH^+ \rightarrow b\tau\nu$ ranges from 3-10%, depending on mass

Charged Higgs (3)

- Can also use events with leptons. To match leptons to b-jets from the same top decay:
  - In one-lepton channel, pick the best $t \rightarrow jjb$ cand. and match lepton to the other b

ATLAS-CONF-2011-151



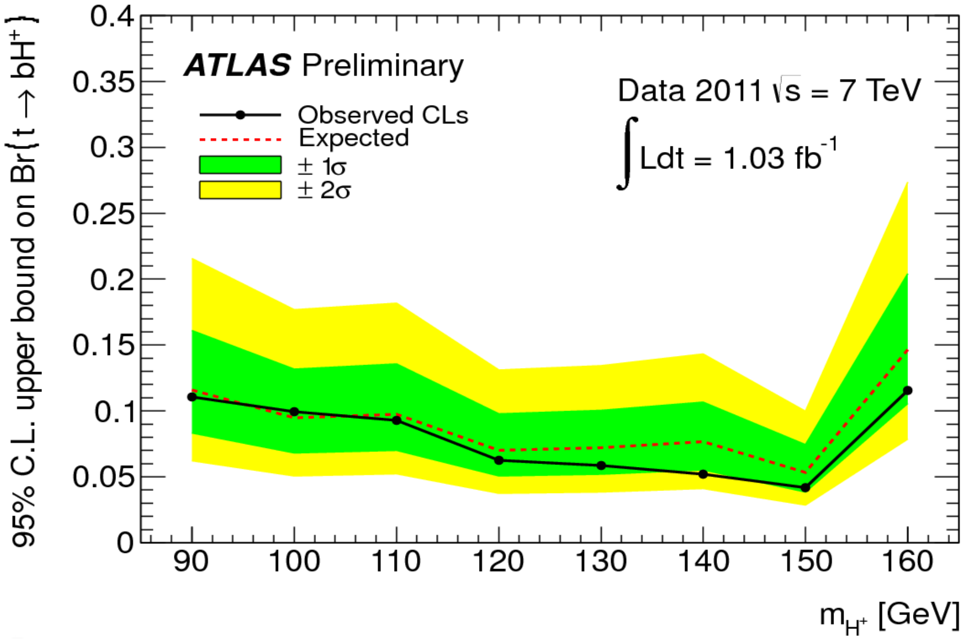
  - In two-lepton channel, reject pairings with $\cos(\theta^*)>1$, then choose the pairing that minimizes sum of ΔR separations for the two l-b pairs
- Use $\cos(\theta^*)=2m_{lb}^2/(m_{top}^2-m_W^2)-1$ to define a control sample.
  - Signal region is $\cos(\theta^*)<-0.6$, while control region is $\cos(\theta^*)>-0.2$ for single-lepton and $\cos(\theta^*)>-0.4$ for double-lepton analysis
- Final discriminating variable is m_T^H:

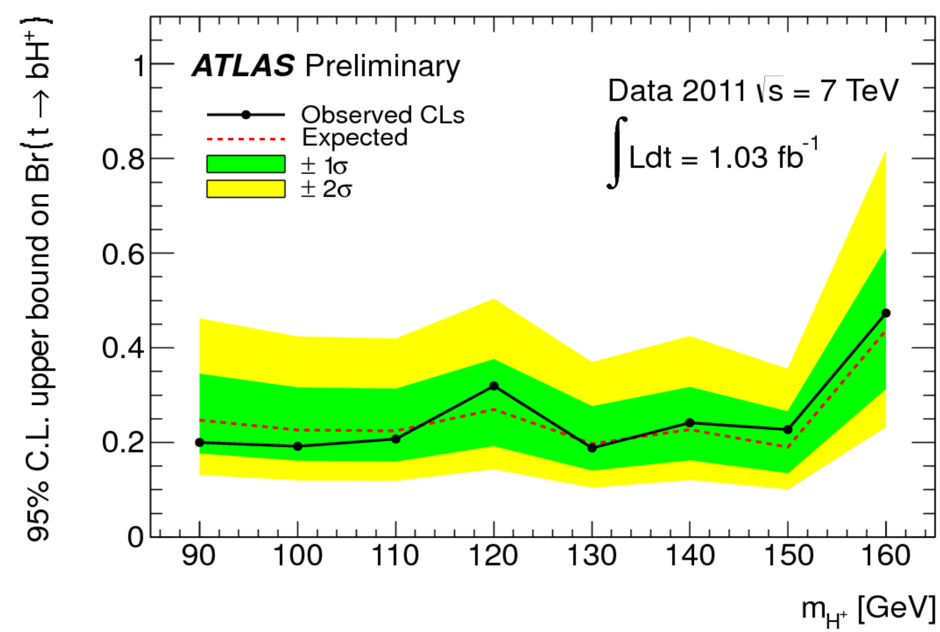
$$(m_T^H)^2 = \left(\sqrt{m_{top}^2 + (\vec{p_T}^{\,l} + \vec{p_T}^{\,b} + \vec{p_T}^{\,miss})^2} - p_T^b\right)^2 - \left(\vec{p_T}^{\,l} + \vec{p_T}^{\,miss}\right)^2$$

- For dilepton channel, maximize m_T^H over p_{H+} and p_ν subject to constraints from top masses and p_T^{miss}

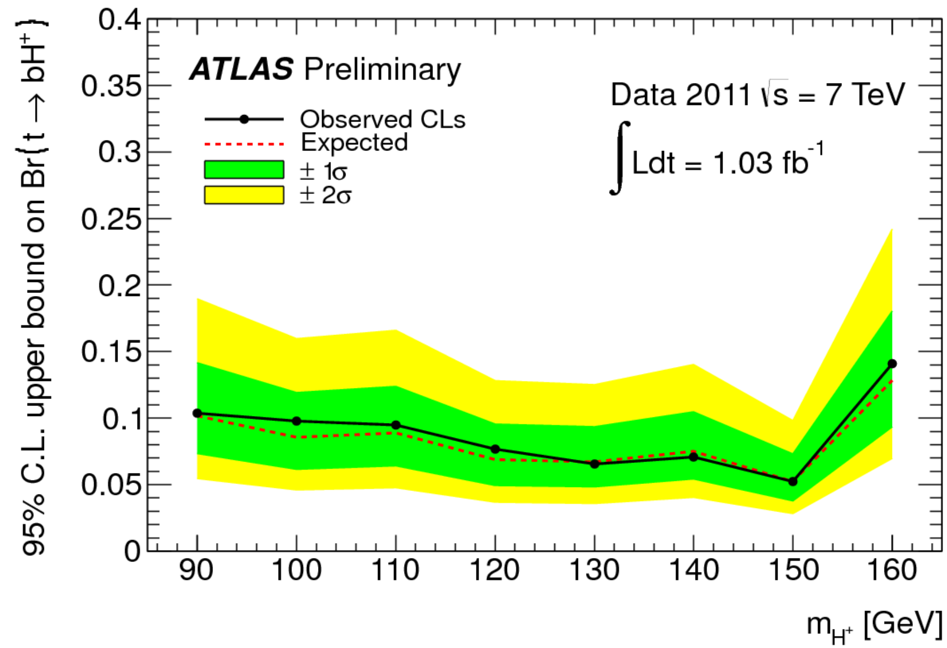
Charged Higgs (4)

ATLAS-CONF-2011-151



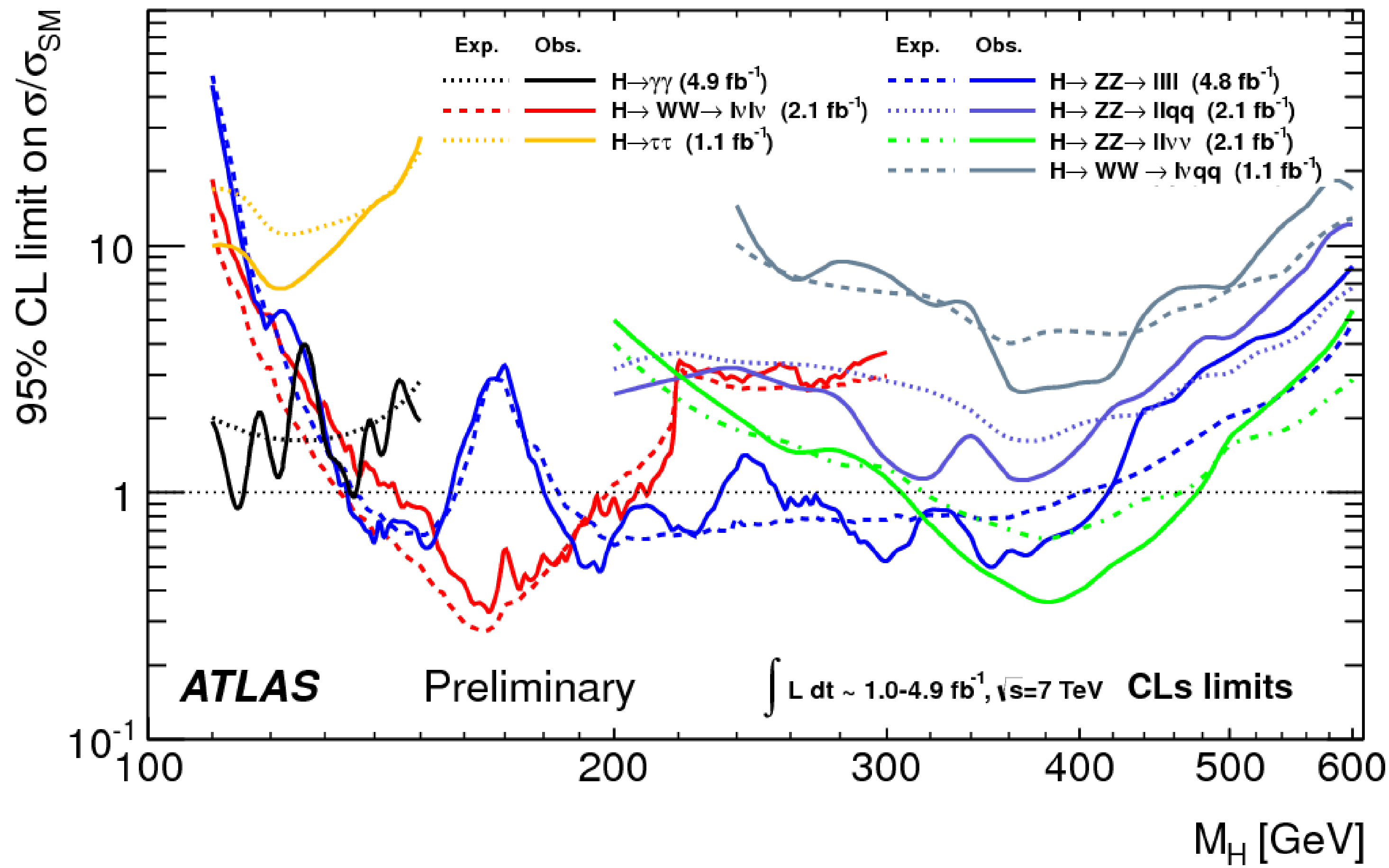


- Backgrounds with jets misidentified as leptons are measured using a control sample with loosened isolation cuts
- Above: the limits on BR($t \rightarrow bH^+$) from the single- (left) and double-lepton channel (right)
- Right: the limit obtained combining the 1-lepton and 2-lepton channels



Standard Model Combination

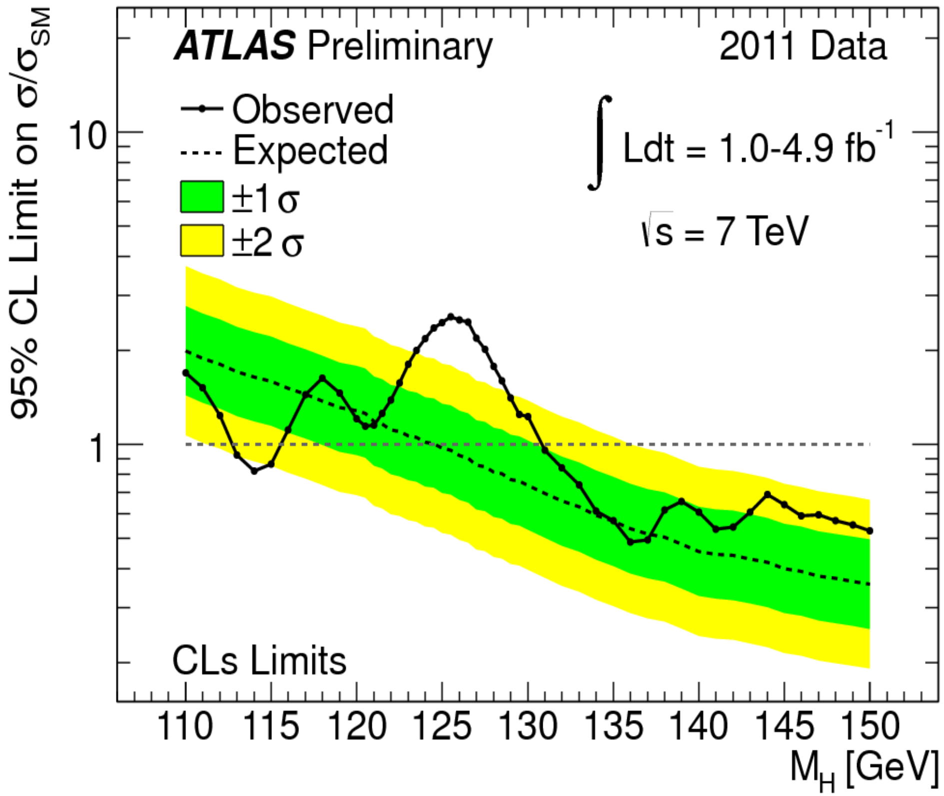
ATLAS-CONF-2011-163

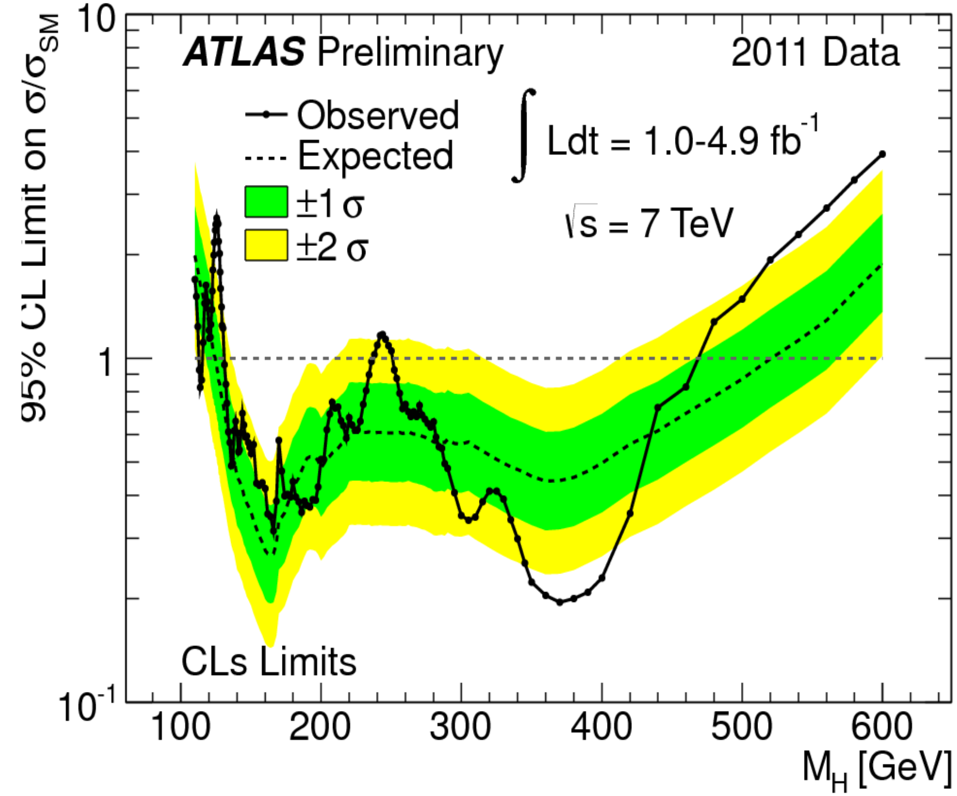


- Above: overview of channels included in the combination
- Main updates since previous combination:
  - Lumi used for H→ZZ→4l and H→γγ increased to 4.8 fb^{-1} and 4.9 fb^{-1}
  - H→WW→lνlν, H→ZZ→llνν, and H→ZZ→llqq updated to 2.1 fb^{-1}
  - Addition of H→WW→lνqq

Standard Model Combination

ATLAS-CONF-2011-163



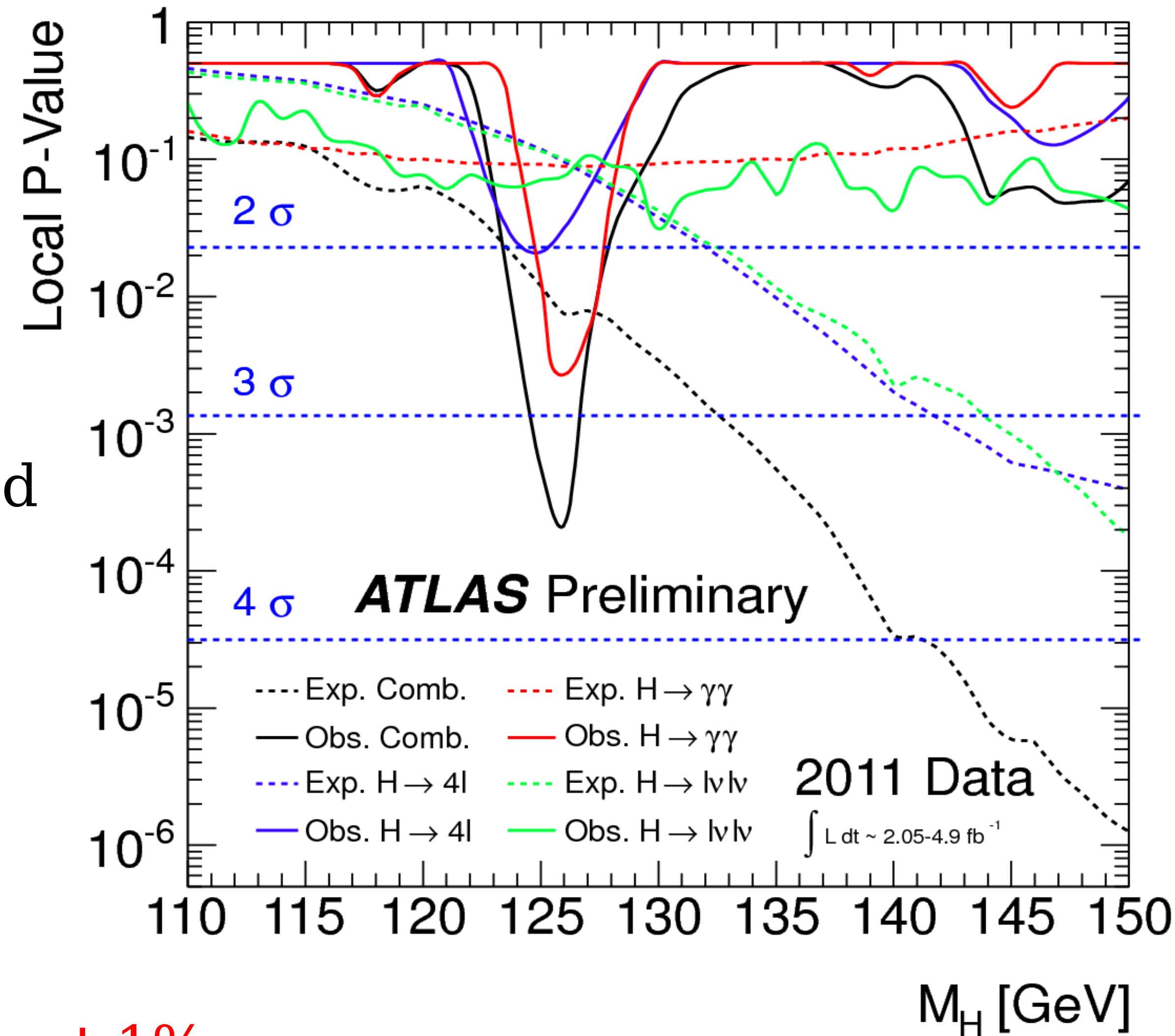


- Exclude Standard Model Higgs boson at 95% CL for m_H in ranges 112.7-115.5 GeV, 131-237 GeV, or 251-453 GeV.
  - Interesting feature at around 125 GeV

Standard Model Combination

ATLAS-CONF-2011-163

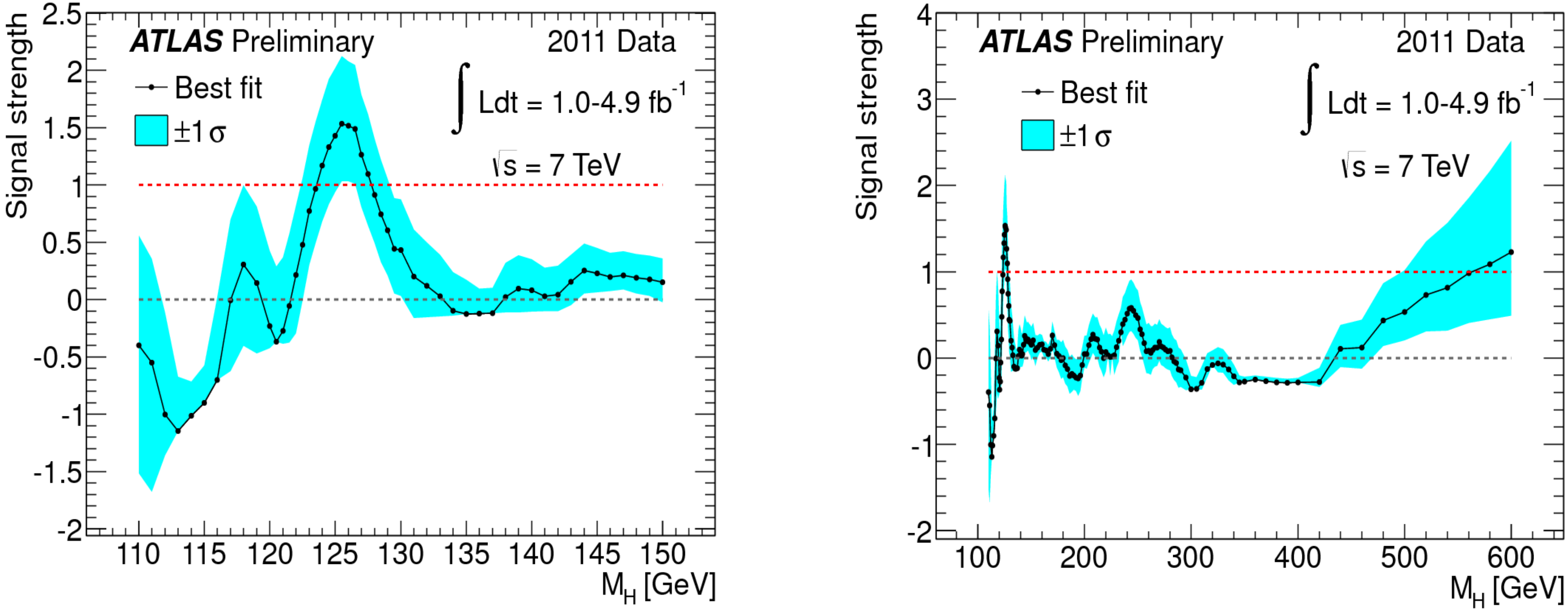
- Right: the "local" probability to see an excess as significant if there is only background, as a function of m_H
  - "Local" means that the calculation was performed for each m_H assuming that m_H was known a priori to be the true m_H
  - "Look-elsewhere" effect reduces the significance compared to the plot. Probability to see such an excess anywhere is about 1%



- The excess is driven by the features in H→γγ and H→ZZ→4l shown earlier, with a small contribution from H→WW→lνlν

Standard Model Combination

ATLAS-CONF-2011-163



- Above: the preferred value of the signal strength from the combined fit, as a function of m_H
  - Left and right plots are identical except for the range of the x-axis
  - Preferred signal strength near 125 GeV is compatible with Standard Model expectation, but it is an upward fluctuation

Summary

- LHC has had an amazingly successful run this year, and we have greatly extended the reach of our Higgs searches over the last few months
  - Range of most likely masses for Standard Model Higgs is now 115.5-131 GeV
- No convincing sign of a Higgs yet, but there is an interesting feature at about 125 GeV.
  - Present in both $H\to\gamma\gamma$ and $H\to ZZ\to 4l$
  - ~1% probability to see a fluctuation like this anywhere if there is only background
  - Too early to draw a conclusion about this excess
  - ~20 fb-1 next year would allow us to make firm conclusions (discovery or exclusion) over the full mass range
- The next year should be very interesting for the Higgs search

Backup

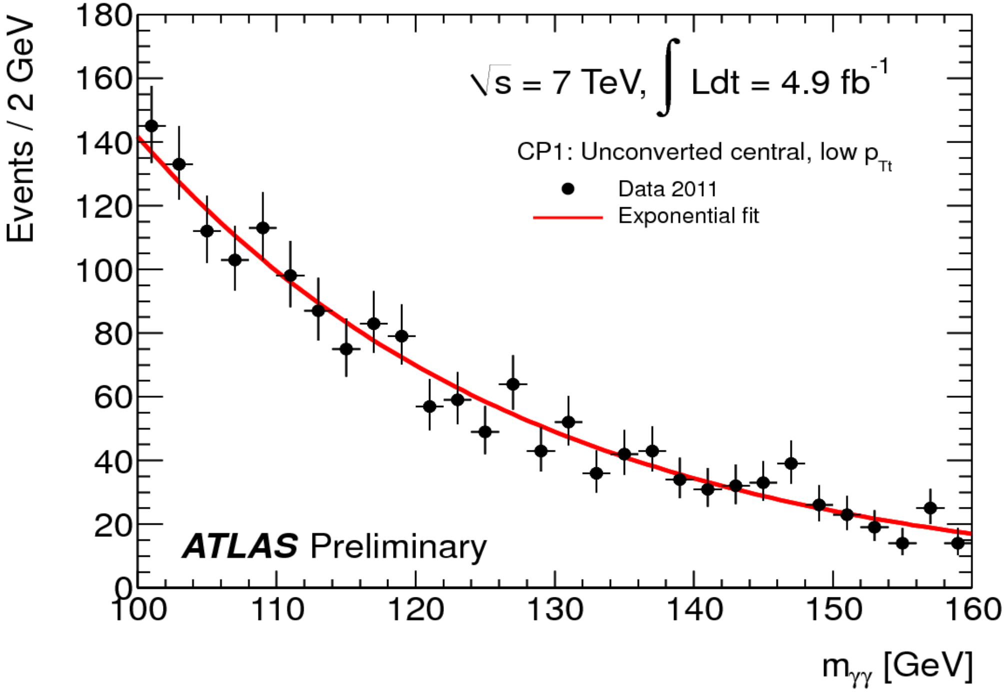
H→WW→lνlν

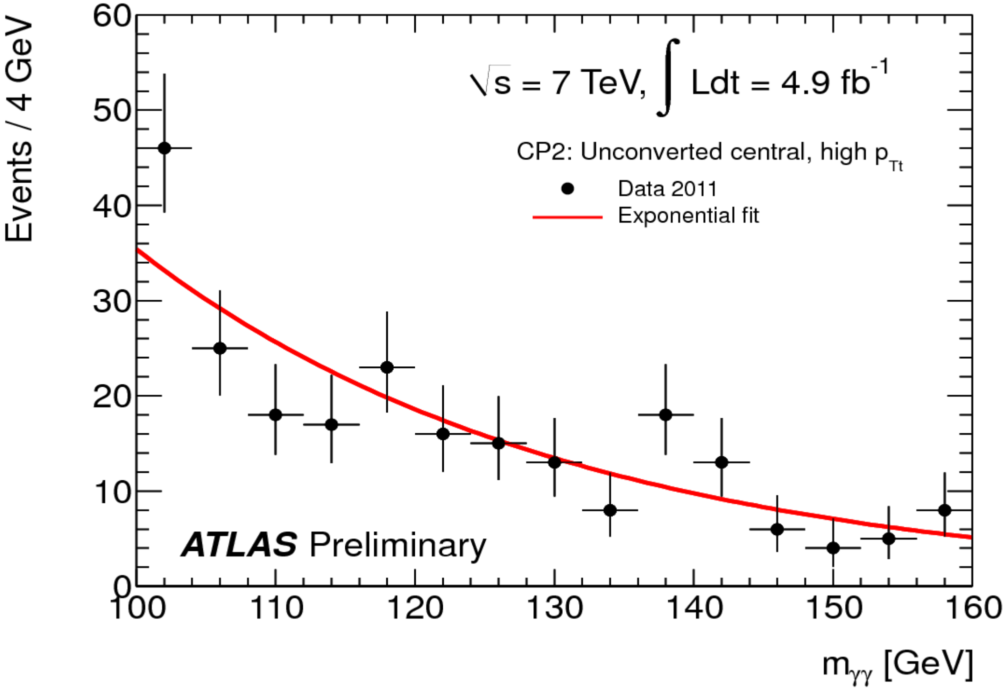
	Signal	WW	$W+$jets	Z/γ^*+jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
Jet Veto	36 ± 8	524 ± 52	84 ± 41	174 ± 169	42 ± 14	32 ± 8	15 ± 4	872 ± 168	920
$\lvert \mathbf{P}_T^{\ell\ell} \rvert > 30$ GeV	34 ± 7	467 ± 45	69 ± 34	30 ± 12	39 ± 14	29 ± 8	13 ± 4	648 ± 96	700
$m_{\ell\ell} < 50$ GeV	26 ± 6	118 ± 15	21 ± 8	13 ± 8	7 ± 4	5.8 ± 1.8	1.9 ± 0.6	166 ± 23	199
$\Delta\phi_{\ell\ell} < 1.3$	20 ± 4	91 ± 12	12 ± 5	9 ± 6	6 ± 3	5.8 ± 1.8	1.7 ± 0.6	125 ± 19	149
$0.75\, m_H < m_T < m_H$	14 ± 3	40 ± 5	8 ± 3	4 ± 9	1.8 ± 1.2	2.0 ± 1.2	0.9 ± 0.4	56 ± 10	67
ee	1.8 ± 0.4	4.9 ± 0.8	1.5 ± 0.7	2 ± 3	0.2 ± 0.3	0 ± 0	0.04 ± 0.03	8.2 ± 0.9	7
$e\mu$	7.4 ± 1.6	21 ± 3	4.5 ± 1.8	0 ± 0	1.1 ± 0.5	1.4 ± 0.9	0.6 ± 0.4	28 ± 7	29
$\mu\mu$	5.2 ± 1.1	13.8 ± 1.9	1.9 ± 1.1	2 ± 9	0.5 ± 0.8	0.6 ± 0.6	0.32 ± 0.10	19 ± 2	31

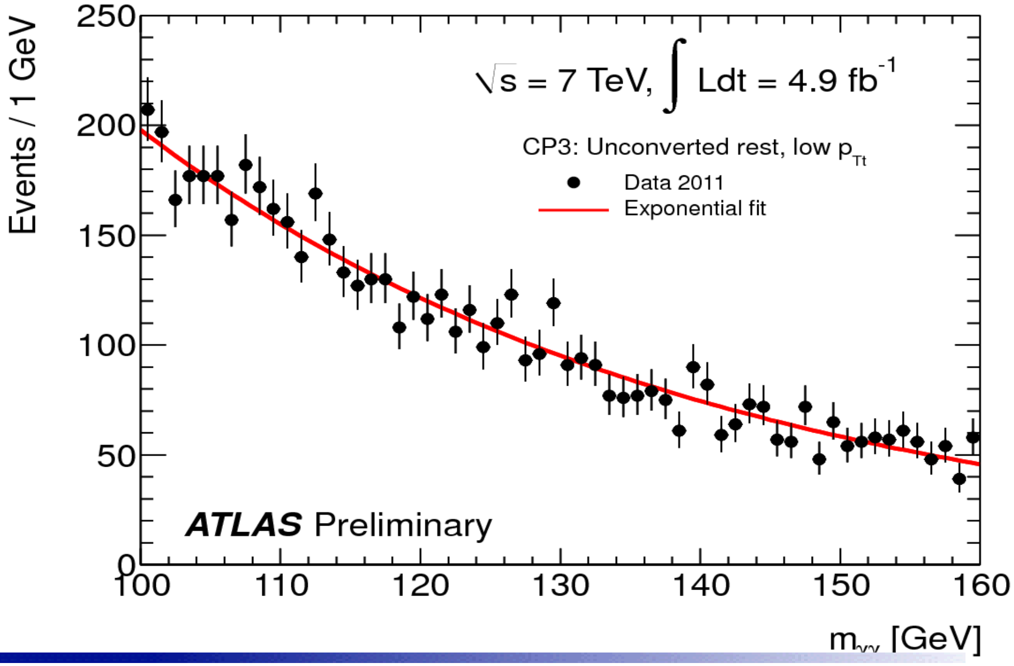
- The excess in H→WW→lνlν is driven by the μμ channel. There is good agreement between the observation and the expected background for ee and eμ.
  - Above: expected and observed yields in H+0j for m_H=130 GeV.
  - Below: the same for H+1j.

	Signal	WW	$W+$jets	Z/γ^*+jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
1 jet	16 ± 3	193 ± 20	38 ± 21	74 ± 65	473 ± 124	174 ± 26	14 ± 2	967 ± 144	952
b-jet veto	16 ± 3	188 ± 19	35 ± 19	73 ± 61	174 ± 49	66 ± 11	14.0 ± 2.0	549 ± 82	564
$P_T^{tot} < 30$ GeV	13 ± 2	154 ± 16	18 ± 9	38 ± 32	106 ± 30	50 ± 9	9.7 ± 1.5	376 ± 58	405
$Z \to \tau\tau$ veto	13 ± 2	150 ± 17	18 ± 8	34 ± 23	102 ± 23	48 ± 8	9 ± 2	361 ± 31	388
$m_{\ell\ell} < 50$ GeV	10 ± 2	33 ± 5	3.3 ± 1.4	8 ± 7	20 ± 7	11 ± 3	1.8 ± 0.5	77 ± 11	90
$\Delta\phi_{\ell\ell} < 1.3$	7.6 ± 1.7	25 ± 4	2.1 ± 1.0	4 ± 6	17 ± 6	9 ± 3	1.5 ± 0.4	60 ± 10	72
$0.75 m_H < m_T < m_H$	4.9 ± 1.1	8.9 ± 1.9	1.1 ± 0.5	2 ± 3	4.7 ± 1.3	1.8 ± 0.9	0.6 ± 0.3	19 ± 3	27
ee	0.46 ± 0.11	1.0 ± 0.3	0.20 ± 0.09	0.1 ± 0.2	0.6 ± 0.3	0 ± 0	0.07 ± 0.06	2.0 ± 0.7	3
$e\mu$	2.9 ± 0.7	5.1 ± 1.2	0.7 ± 0.3	0.6 ± 1.1	2.7 ± 1.0	0.8 ± 0.5	0.39 ± 0.20	10 ± 2	13
$\mu\mu$	1.6 ± 0.4	2.8 ± 0.6	0.3 ± 0.3	1.7 ± 0.8	1.4 ± 0.9	1.1 ± 0.9	0.09 ± 0.07	7 ± 2	11

$H\rightarrow\gamma\gamma$

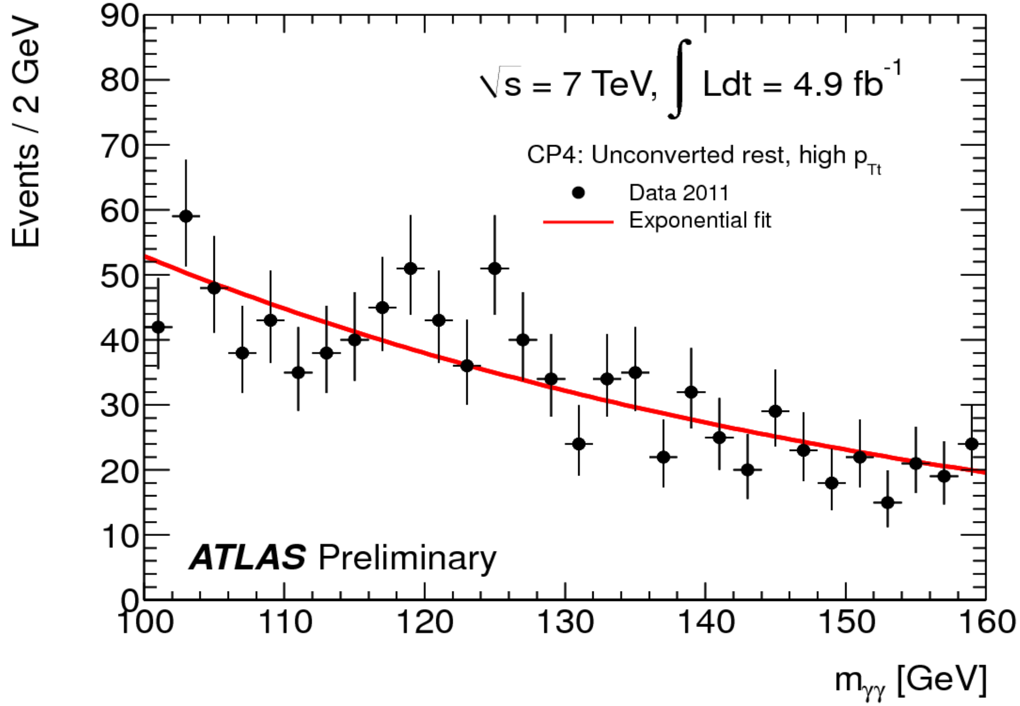


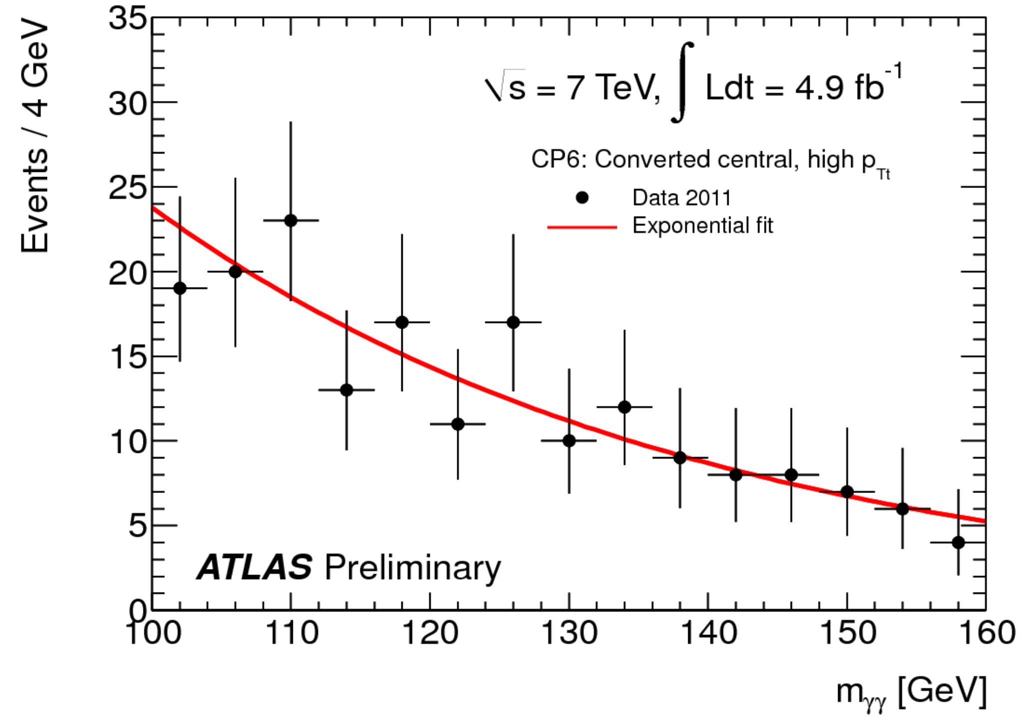




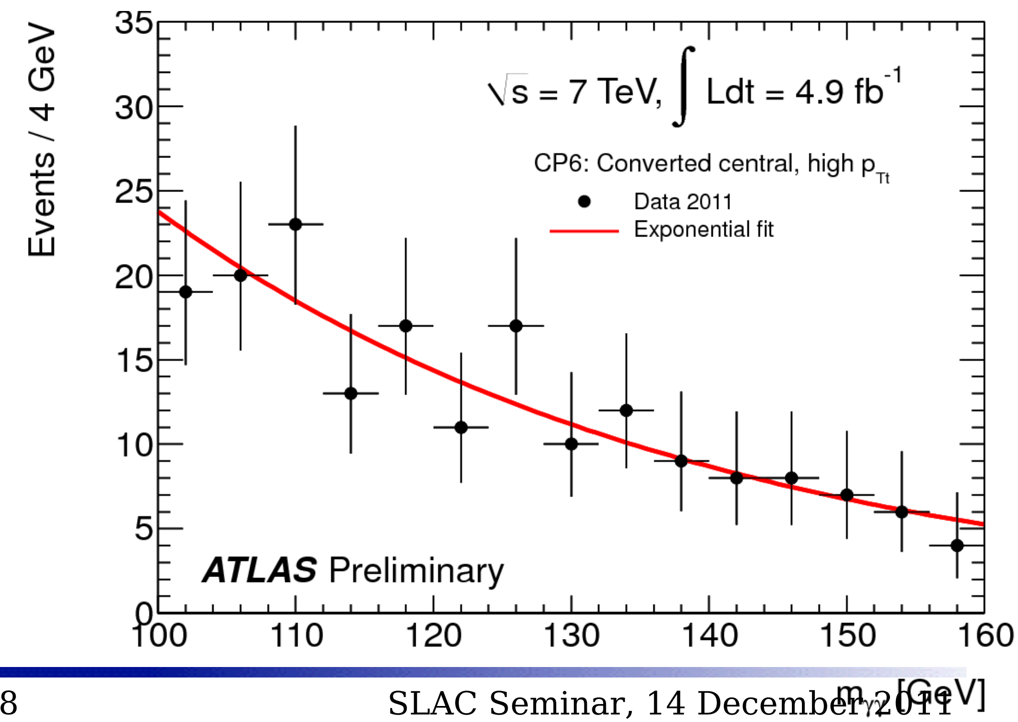
- $M_{\gamma\gamma}$ curves in each of the 9 categories. This page: CP1-C3

H→γγ

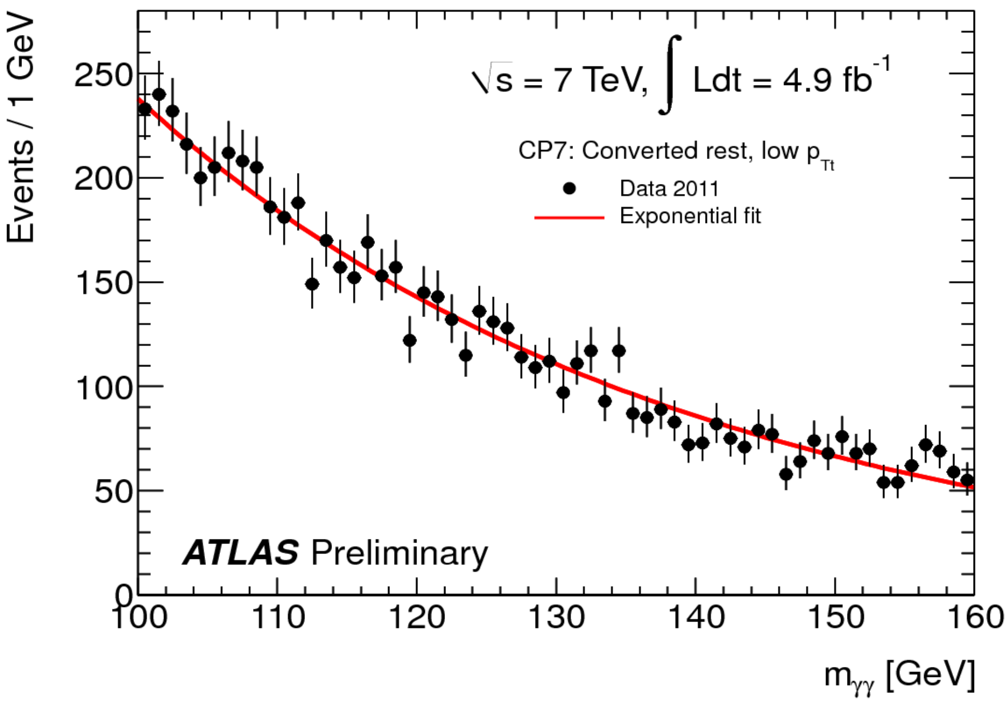


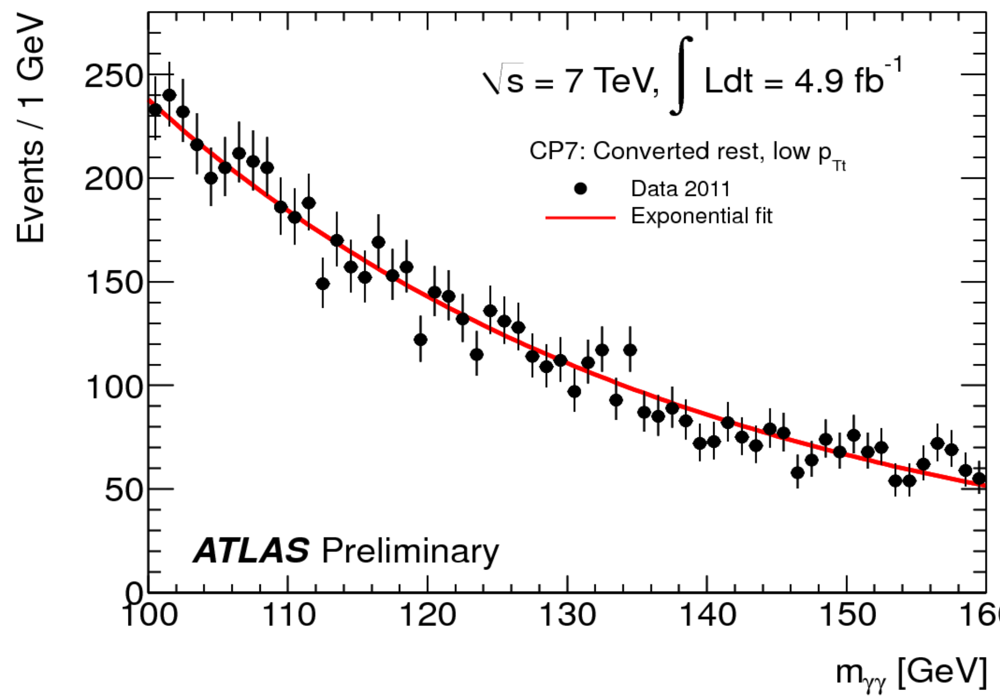


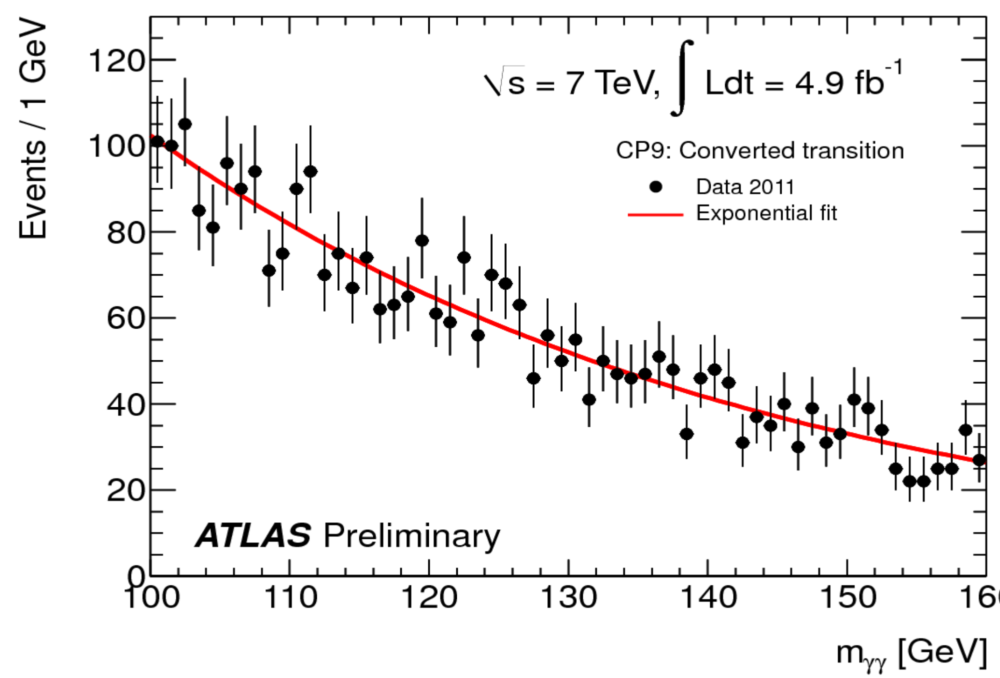
- $M_{\gamma\gamma}$ curves in each of the 9 categories. This page: CP4-C6



$H \rightarrow \gamma\gamma$

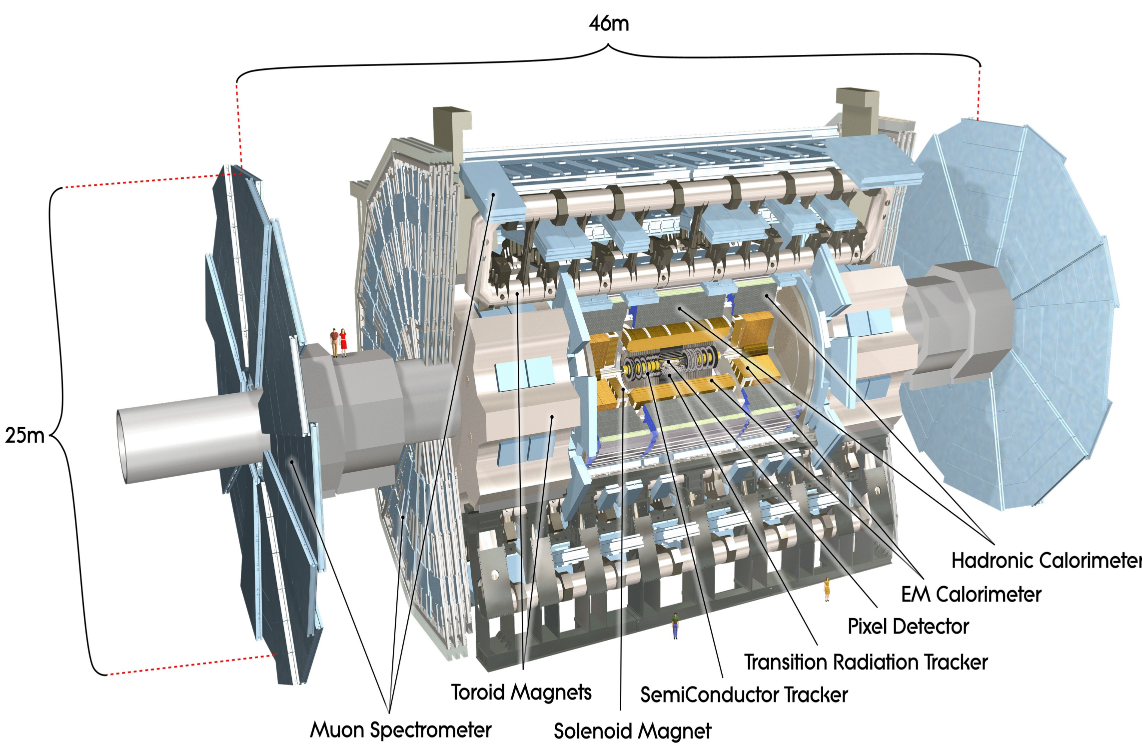






- $M_{\gamma\gamma}$ curves in each of the 9 categories. This page: CP7-C9

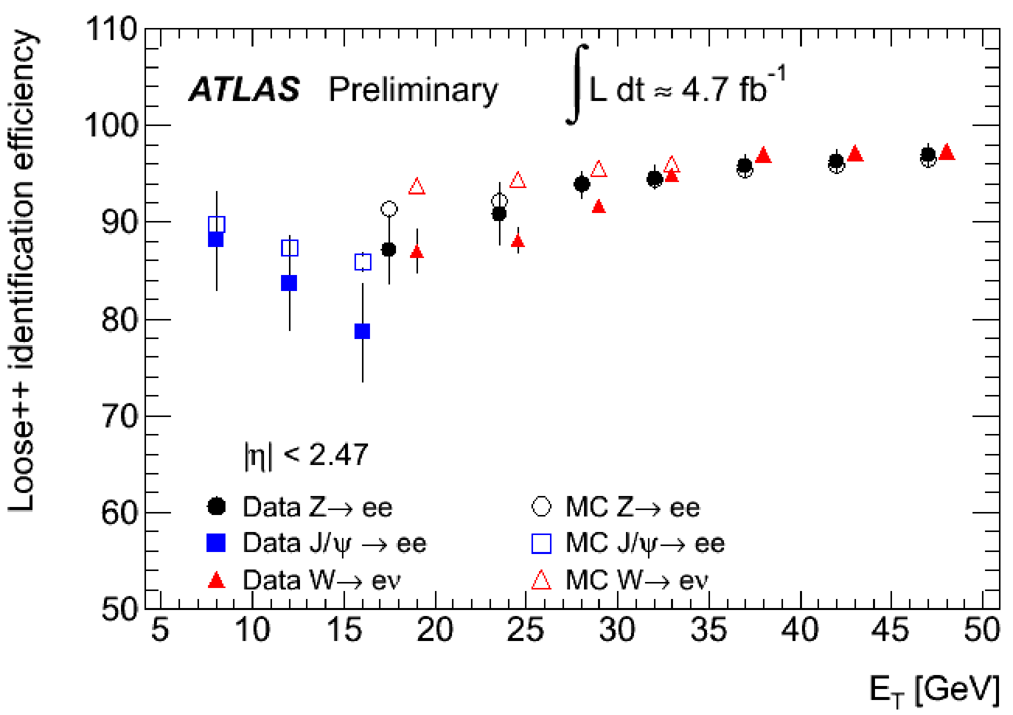
LHC & ATLAS

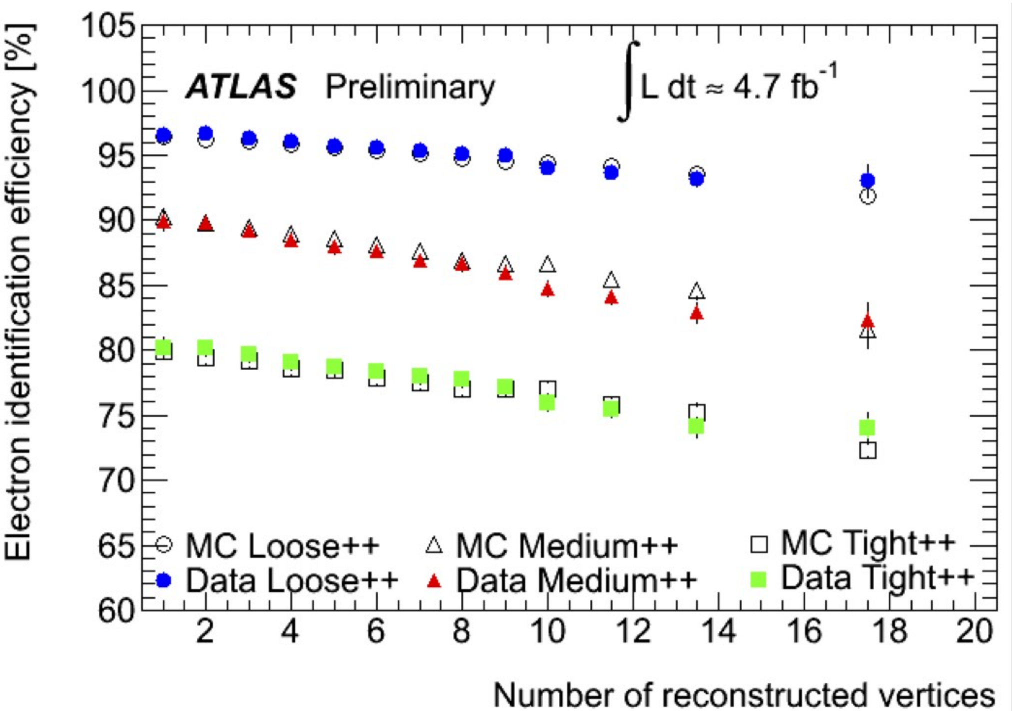


- LHC: 14 TeV pp collider (only 7 TeV for now)
- ATLAS: general-purpose detector with precision tracking in $|\eta|<2.5$, calorimeters in $|\eta|<4.9$, and muon spectrometer coverage in $|\eta|<2.7$

- Inner Tracker: B=2T, Si. Pixels/strips & Transition Radiation Tracker, $\sigma/p_T=0.05\%\ p_T(\mathrm{GeV})\oplus 1\%$
- EM Calo: Pb-LAr accordion, $\sigma/E=10\%/\sqrt{E}\oplus 0.7\%$
- Hadronic Calo: $|\eta|<1.7$ Fe/Scintillator; $1.3<|\eta|<4.9$ Cu/W/LAr; $\sigma/E_{jet}=50\%/\sqrt{E}\oplus 3\%$
- Muon spectrometer: Air-core toroids and gas-based muon chambers. $\sigma/p_T=2\%$ at 50 GeV to 10% at 1 TeV

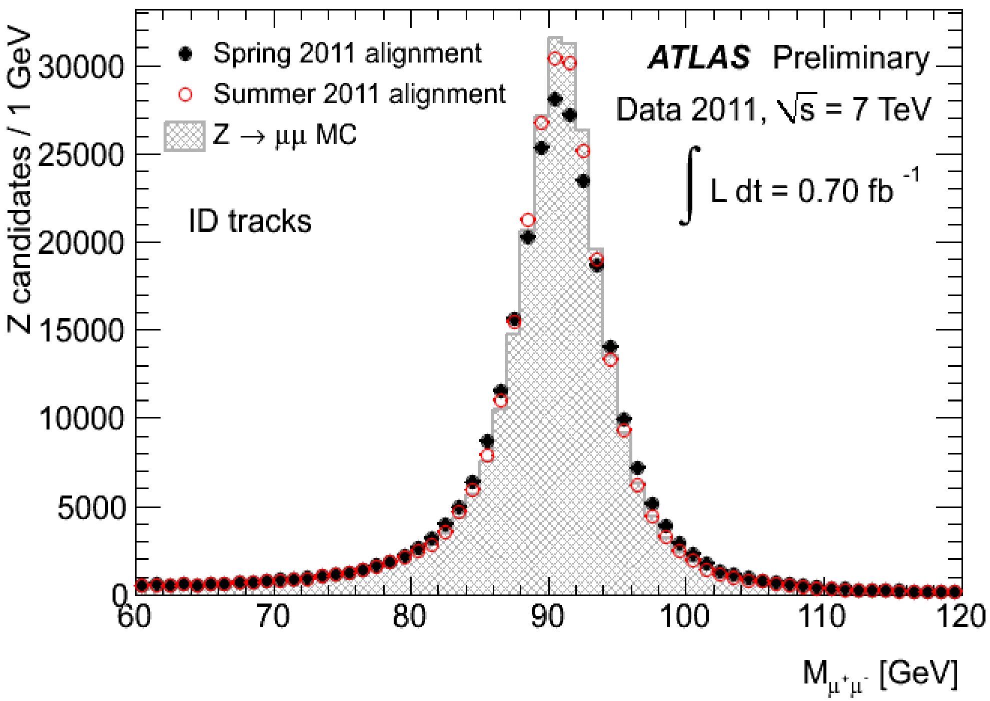
Electron ID Efficiency

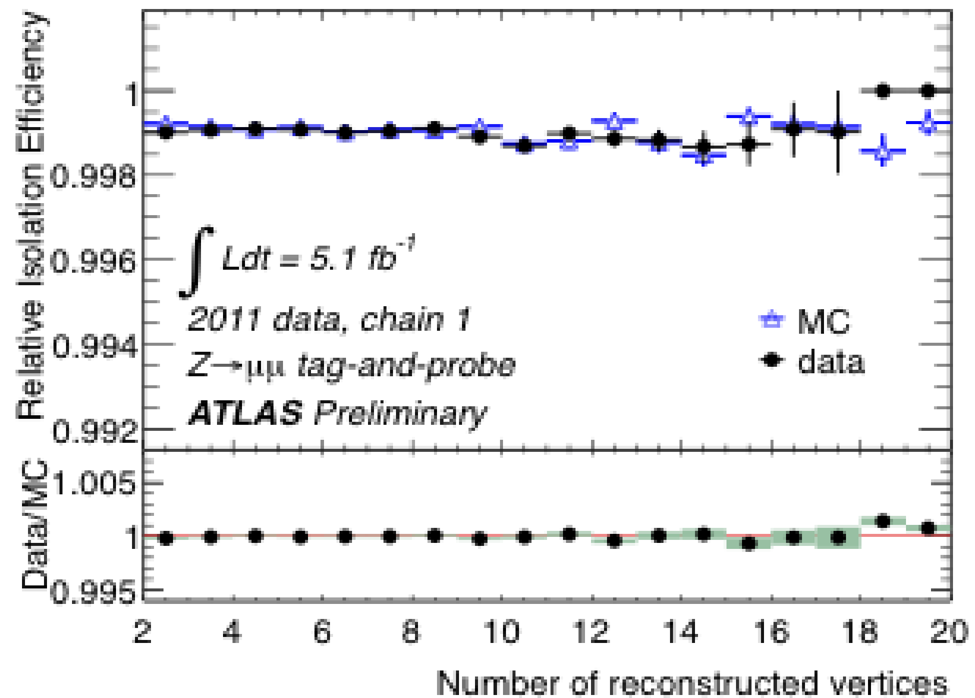




- Electron ID efficiency is checked using Z→ee, J/ψ→ee, and W→eν samples (left)
  - Typical uncertainty: 6% for p_T~7 GeV, <2% for p_T~50 GeV
- Variation of efficiency with pileup is well-modeled by MC
  - The cuts themselves have not yet been re-optimized for high pileup

Muon ID Efficiency





- Improved alignment decreases mass resolution of Z→μμ from 2.89±0.1 GeV during spring 2011 to 2.45±0.1 GeV during summer 2011 (left)
  - MC (perfect): 2.31±0.1 GeV
- Reconstruction efficiency is >95% over 4<p<100 GeV
  - Very stable against pileup (right)