Search for the SM Higgs Boson with ATLAS

Linear Collider Forum 2012

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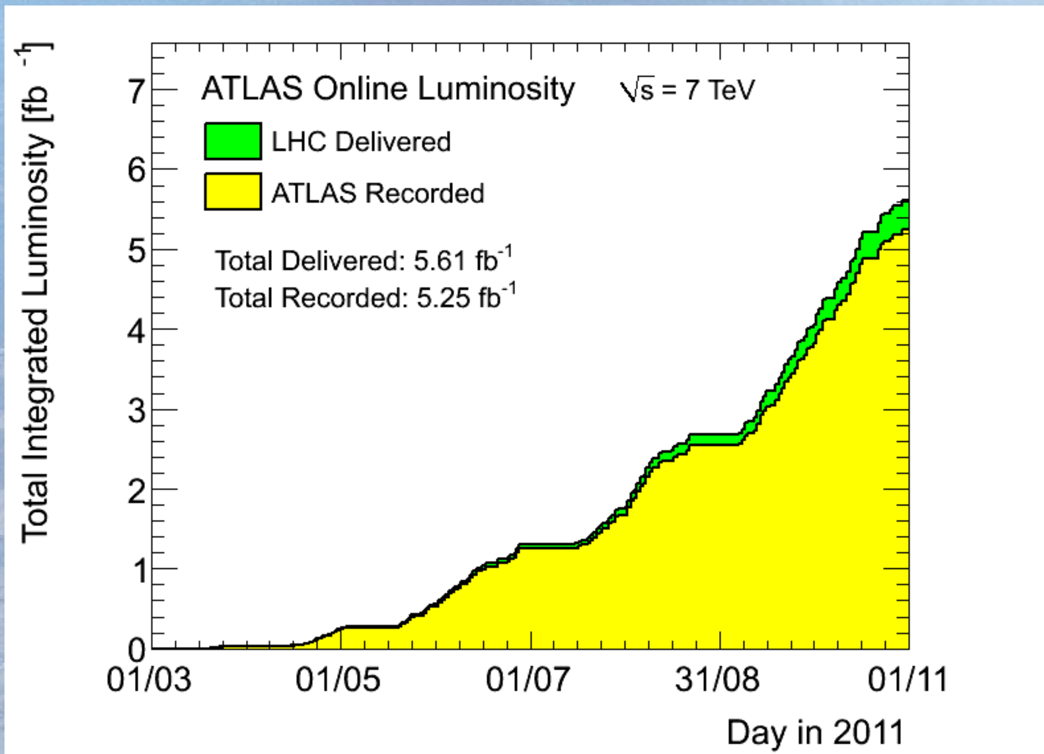
Data Taking in 2011

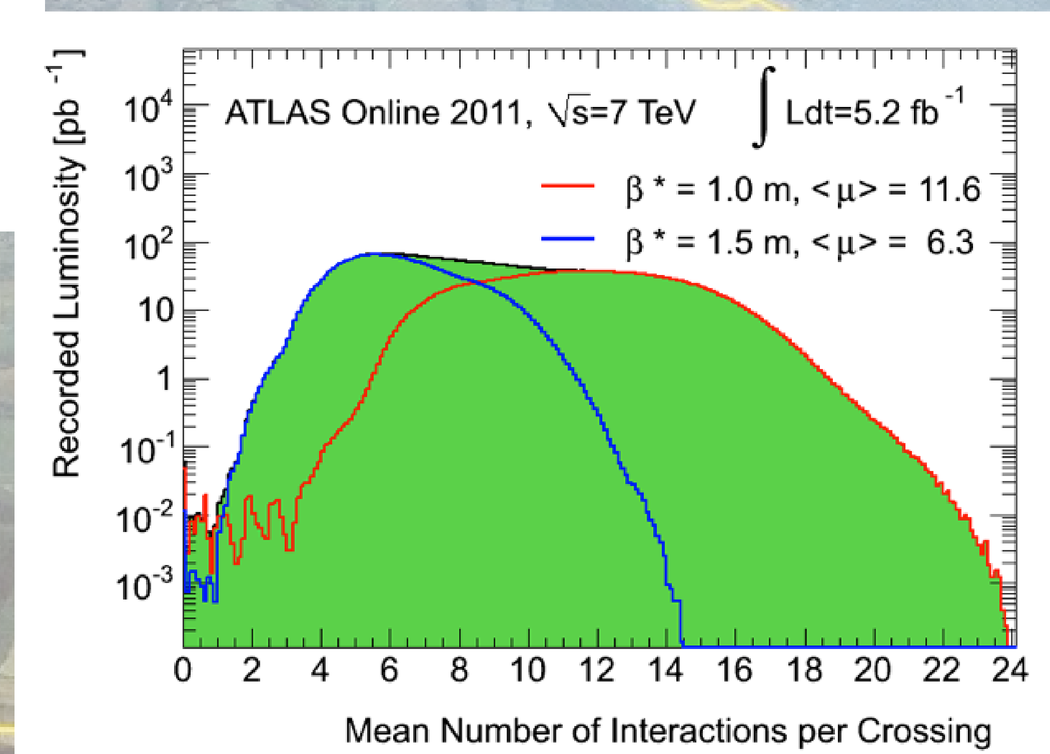
- Recorded **5.2 fb^{-1}** of data taken at $\sqrt{s}$=7 TeV and 50 ns bunch spacing in 2011
- Peak luminosity: $3.6 \cdot 10^{33}$ cm^{-2} s^{-1}
- Design parameters: 10^{34} cm^{-2} s^{-1}, $\sqrt{s}$=14 TeV, 25 ns bunch spacing
- Splendid ATLAS performance in 2011



- Pileup increased in second phase of 2011 data taking, change of β^*

  $\rightarrow$ Increase of average interactions per bunch crossing $\langle\mu\rangle$ from 6 to 12

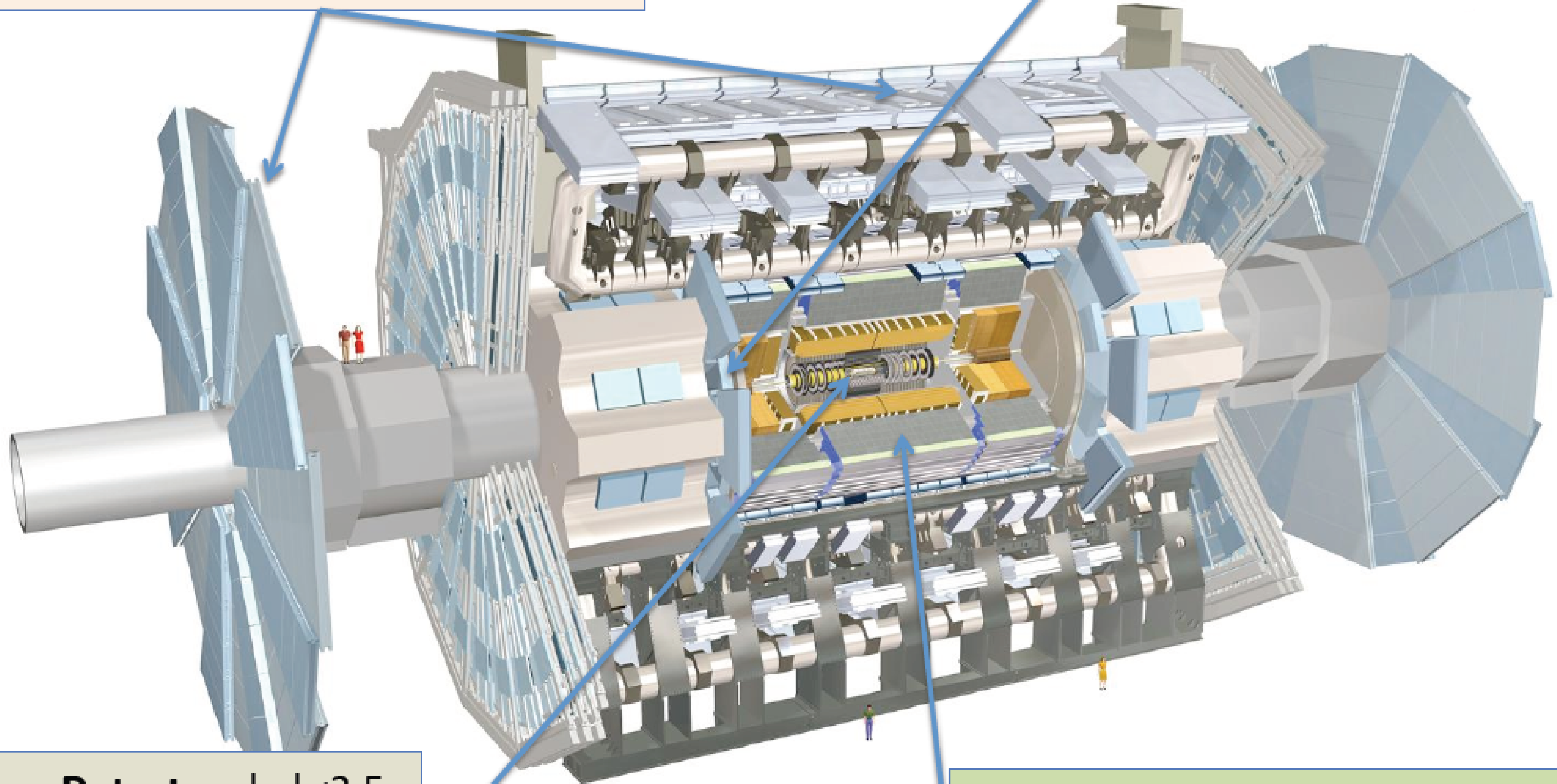
- Recorded events with more than 20 reconstructed vertices



The ATLAS Detector

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

EM Calorimeter: |η|<3.2
Pb-LAr Accordion σ/E=10% √E⊕0.7%

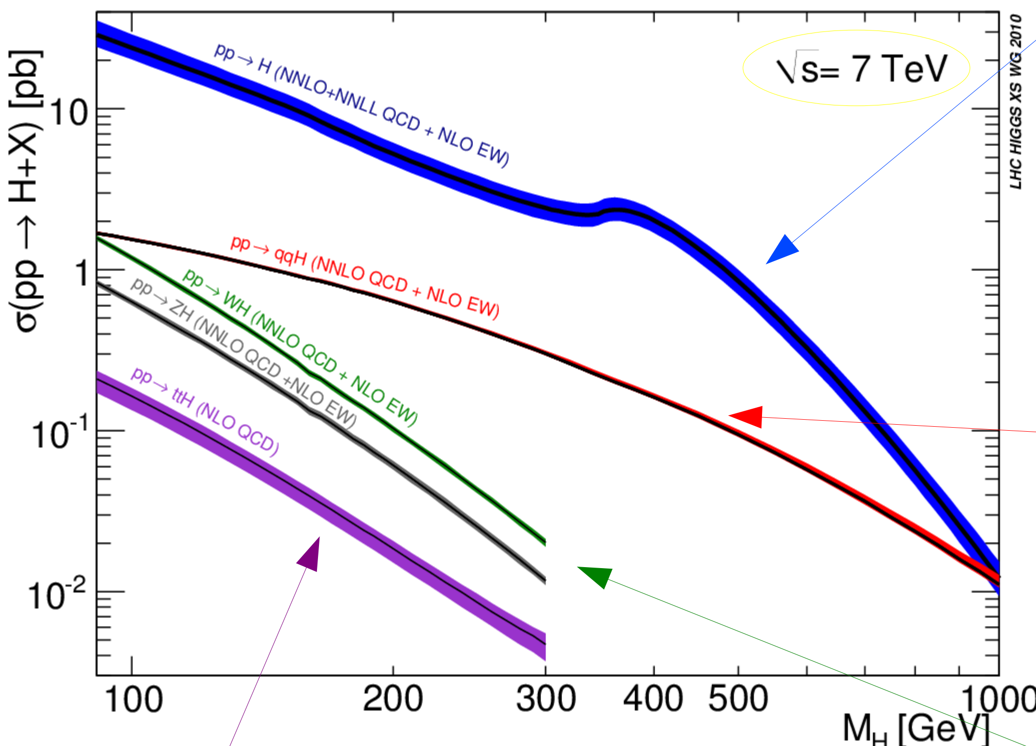


Inner Detector: |η|<2.5, B=2T, Si pixels/strips and Trans. Rad. Det.; σ/pT = 0.05% pT (GeV) ⊕ 1%

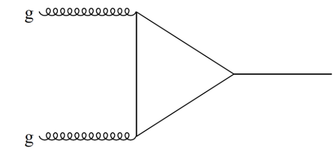
Hadronic calorimeter: |η|<1.7 Fe/scintillator 1.3<|η|<4.9 Cu/W-LAr; σ/Ejet= 50%/√E ⊕ 3%

Higgs Boson Production at the LHC

LHC cross-section working group arXiv:1101.0593v3

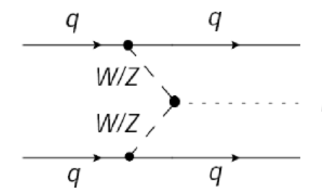


Gluon fusion (ggF)



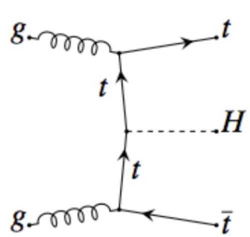
- dominant process at LHC
- 10x higher rate than at Tevatron
- known to NNLO + NNLL + NLO EW
- 15-20% theory uncertainty

Vector boson fusion (VBF)



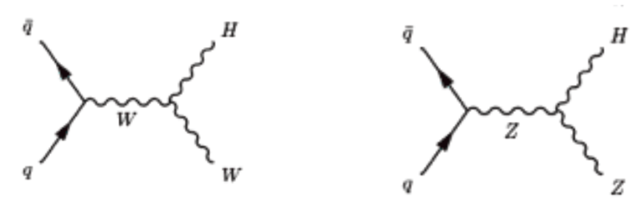
- known at NLO, ~5% theory uncertainty
- distinctive experimental signature
- becomes more important at high mass

Associated production with $t\bar{t}$



- known at NLO, ~15% theory uncertainty
- Provides little additional sensitivity

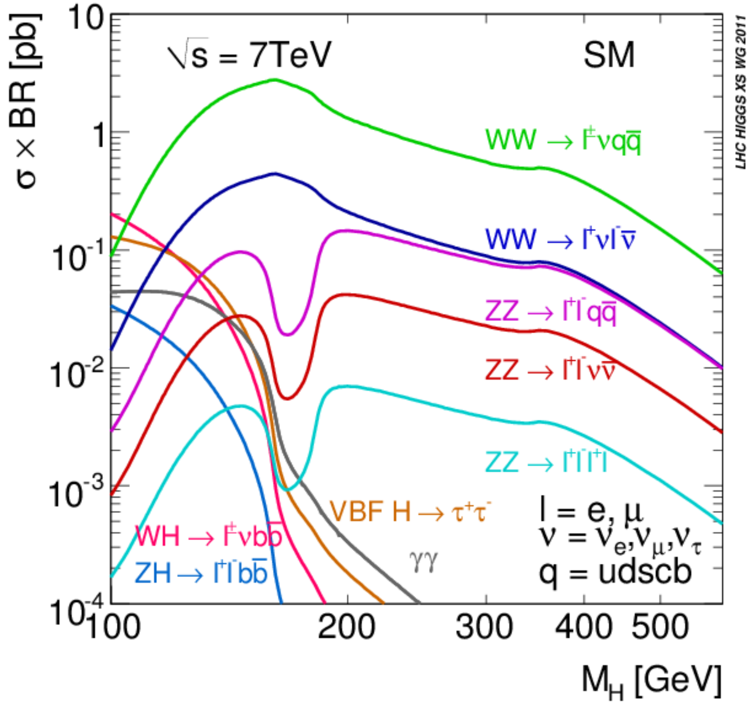
Associated production with W or Z

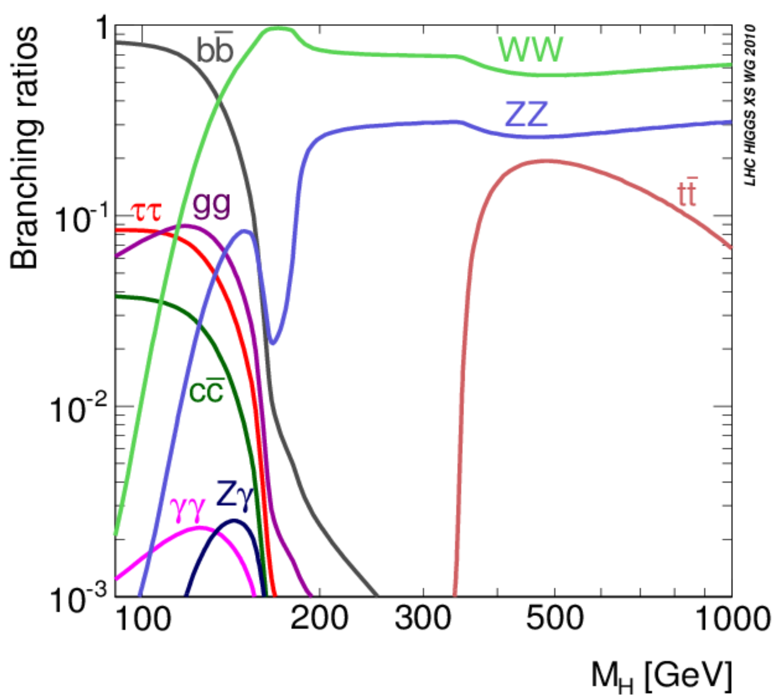


- known at NNLO, ~5% theory uncertainty
- Leptonic signature useful for study of $H \to b\bar{b}$

Theory uncertainty mostly from scale variations, PDFs and α_s

Higgs Boson Decay





High mass searches (200-600 GeV):

$H \rightarrow W\,W \rightarrow l\nu qq$

$H \rightarrow Z\,Z \rightarrow llqq$

$H \rightarrow Z\,Z \rightarrow ll\nu\nu$

Wide Range Searches (110-600 GeV):

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

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

Low Mass Search (110-150 GeV):

$H \rightarrow \gamma\gamma$

$H \rightarrow \tau\tau$

$H \rightarrow b\bar{b}$

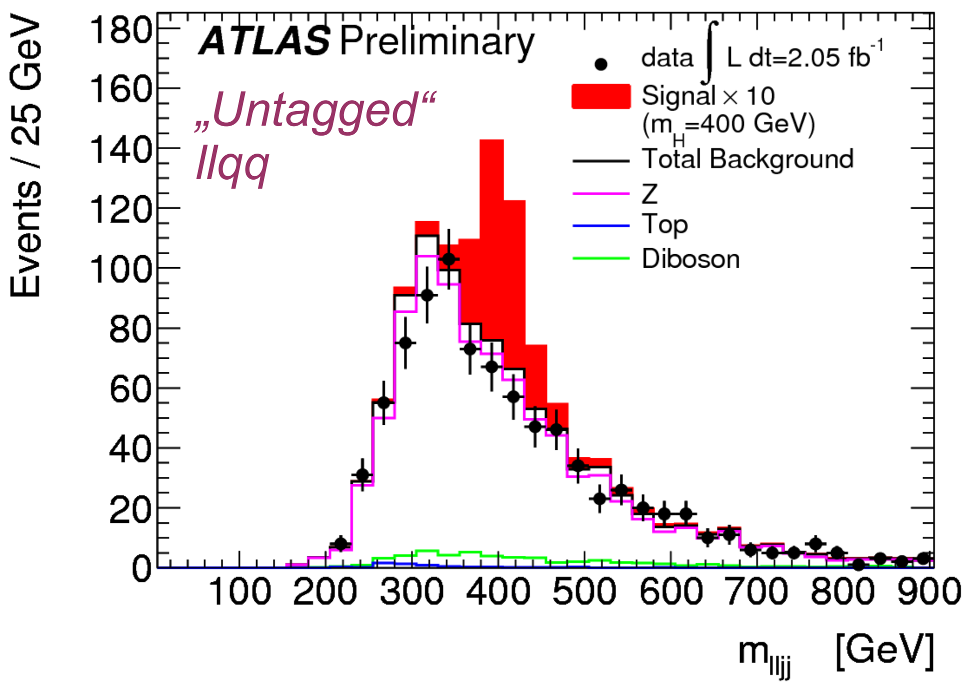
are presented here. More results in the backup.

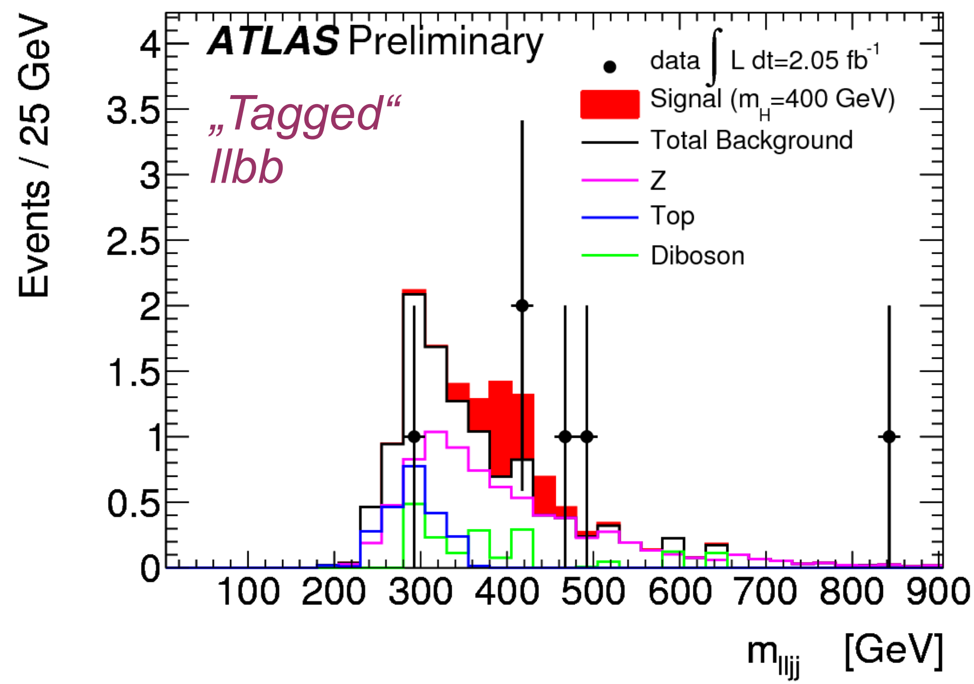
ATLAS-CONF-2011-150

Event selection:

- Two same flavor leptons (e/μ), two jets
- $|m_{ll}-m_Z| < 15$ GeV
- $E_T^{miss} < 50$ GeV
- $llb\bar{b}$ and llqq subsample (*tagged & untagged*)

- Special **high mass selection**:
  Jet pT > 45 GeV, $\Delta\Phi(l,l) < 1.6$, $\Delta\Phi(j,j) < 1.6$

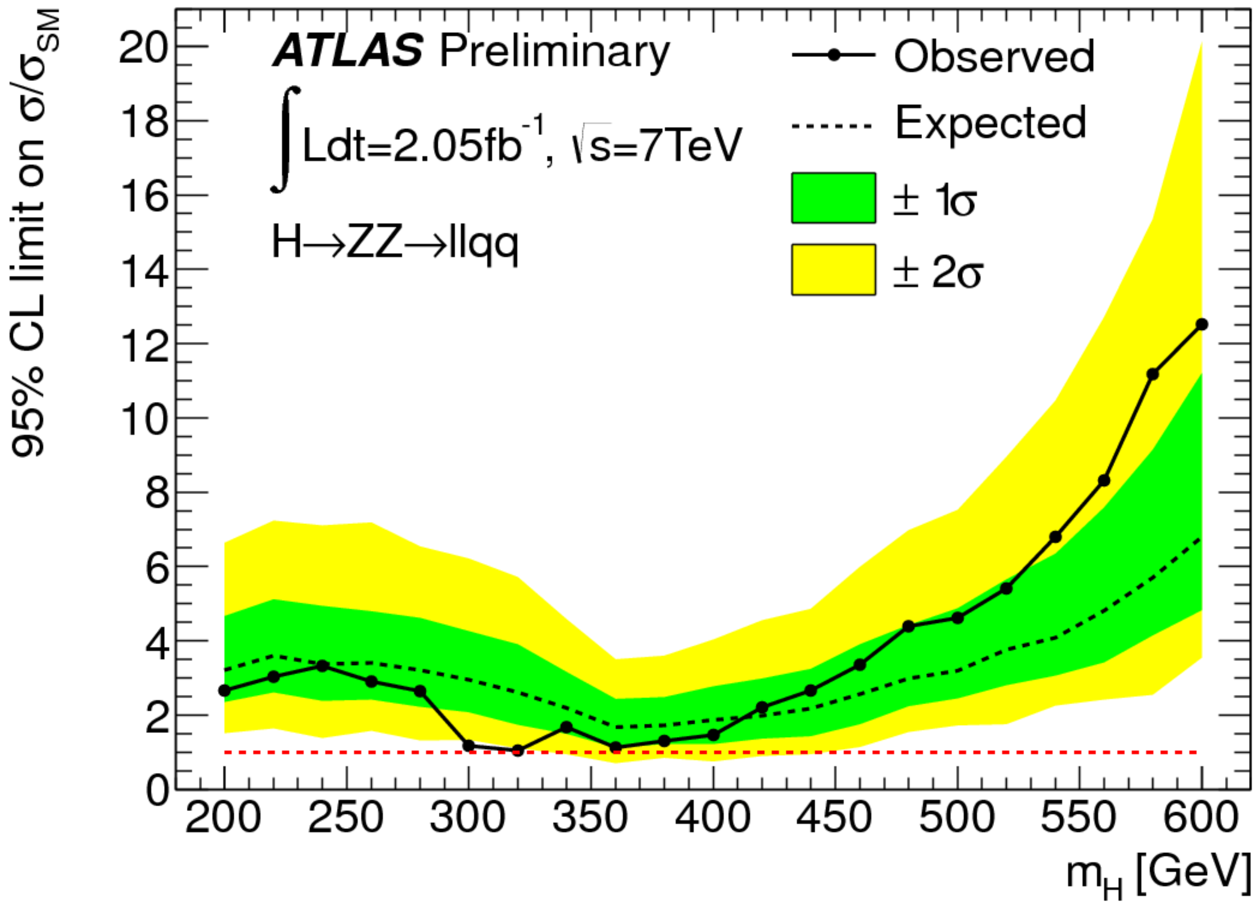




	Data	Total BG	m_H=400 GeV
untagged	851	$919 \pm 20 \pm 103$	$21.1 \pm 0.5 \pm 3.4$
tagged	6	$11.6 \pm 0.6 \pm 1.6$	$2.1 \pm 0.2 \pm 0.6$

ATLAS-CONF-2011-150

Combined limit of tagged and untagged analyses:



- Both categories contribute roughly equally
- Best sensitivty at 360 GeV: excl. 1.2 x SM cross section
- No significant excess, smallest p_0 13 %

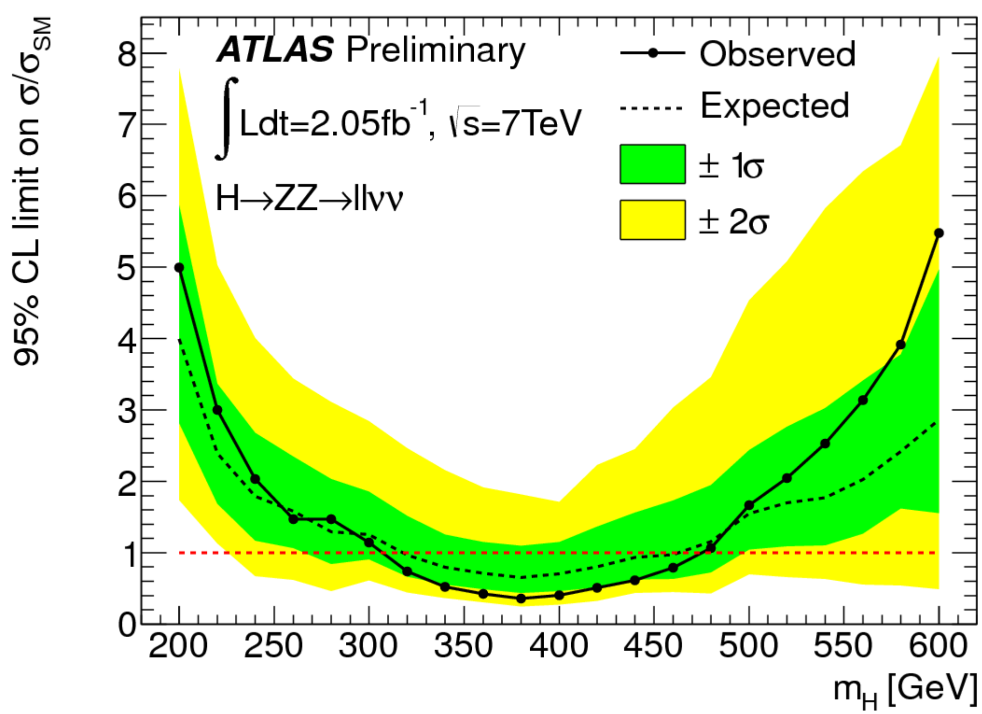
	Data	Total BG	m_H=400 GeV
untagged	851	$919 \pm 20 \pm 103$	$21.1 \pm 0.5 \pm 3.4$
tagged	6	$11.6 \pm 0.6 \pm 1.6$	$2.1 \pm 0.2 \pm 0.6$

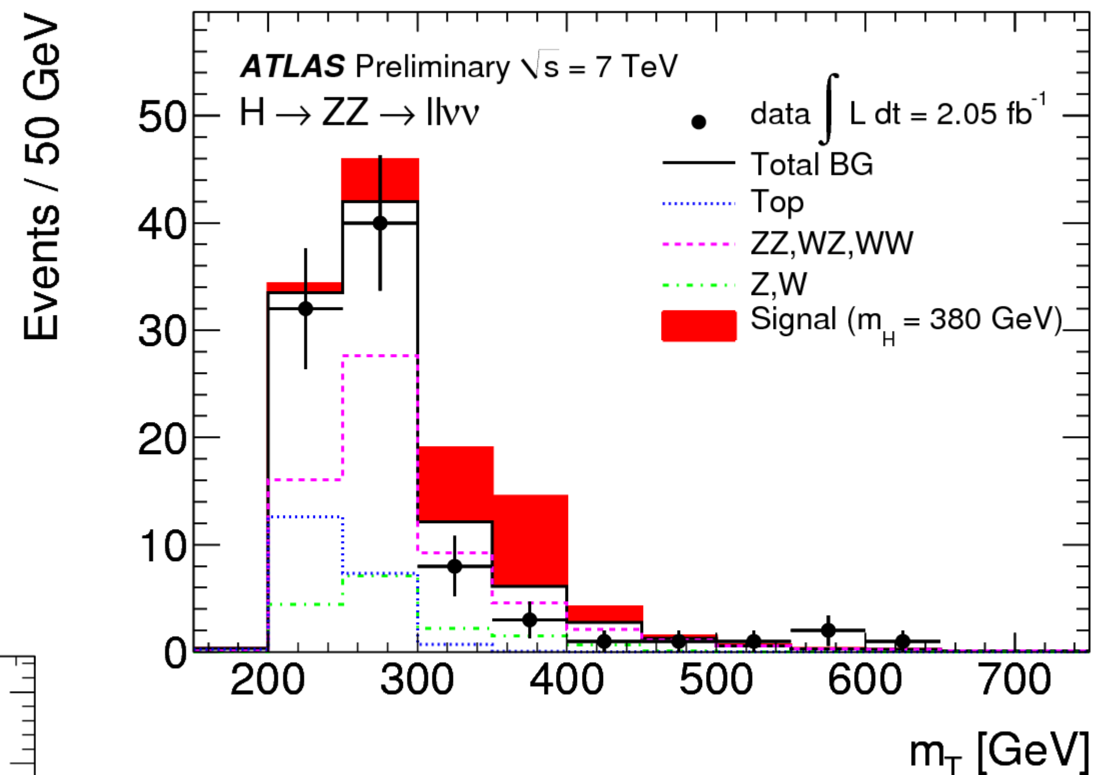
ATLAS-CONF-2011-148

Event selection:

- Pair of same flavor opposite sign leptons
- Veto events with b-tags
- $|m_Z - m_{ll}| < 15$ GeV
- $\Delta\Phi(E_T^{miss}, p_T \text{ leading jet}) > 0.3$
- Cuts on E_T^{miss}, $\Delta\Phi(l,l)$, $\Delta\Phi(E_T^{miss}, p_T^{ll})$

Special selections for low and high mass
(separated at m_H = 280 GeV)





$$m_T^2 \equiv \left[\sqrt{m_Z^2 + |\vec{p}_T^{\,\ell\ell}|^2} + \sqrt{m_Z^2 + |\vec{p}_T^{\,\rm miss}|^2}\right]^2 - \left[\vec{p}_T^{\,\ell\ell} + \vec{p}_T^{\,\rm miss}\right]^2$$

Data	Total BG	m_H=400 GeV
89	100 ± 3 ± 17	19.6 ± 0.2 ± 3.4

Observed exclusion: 310 GeV < m_H < 470 GeV

Expected exclusion: 320 GeV < m_H < 460 GeV arXiv:1112.2577

Most sensitive channel in intermediate mass range.

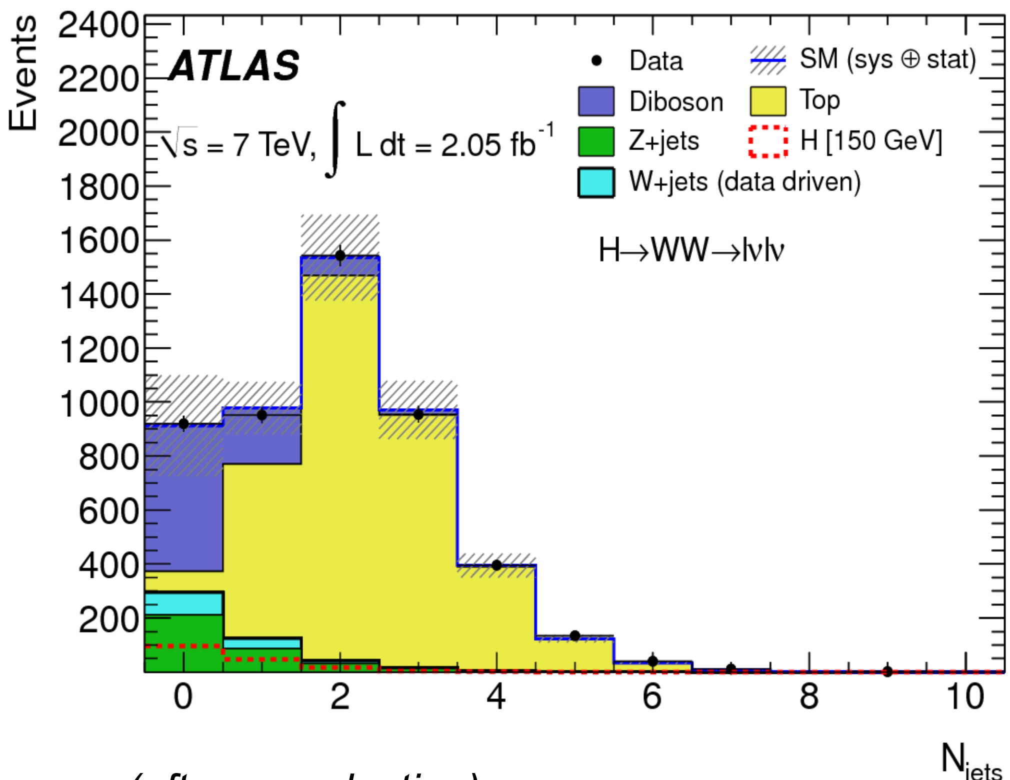
Event Selection:

- Two isolated leptons with pT > 15 (20) GeV for μ (e), leading lepton pT > 25 GeV
- ee/μμ: $|m_{ll}-m_Z|$ >15 GeV, m_{ll}> 15 GeV, $E_{T,rel}^{miss}$ > 40 GeV

  eμ: m_{ll}> 10 GeV, MET_{rel} > 25 GeV

$$E_{\mathrm{T,rel}}^{\mathrm{miss}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \cdot \sin\Delta\phi & \text{if } \Delta\phi < \pi/2 \end{cases}$$

$\Delta\Phi=\min(\Delta\Phi(E_T^{miss},\mathrm{lep}) , \Delta\Phi(E_T^{miss},\mathrm{jet}))$



(after preselection)

H+0jet selection:

→ WW background dominant

Cut p_T^{ll} > 30 GeV

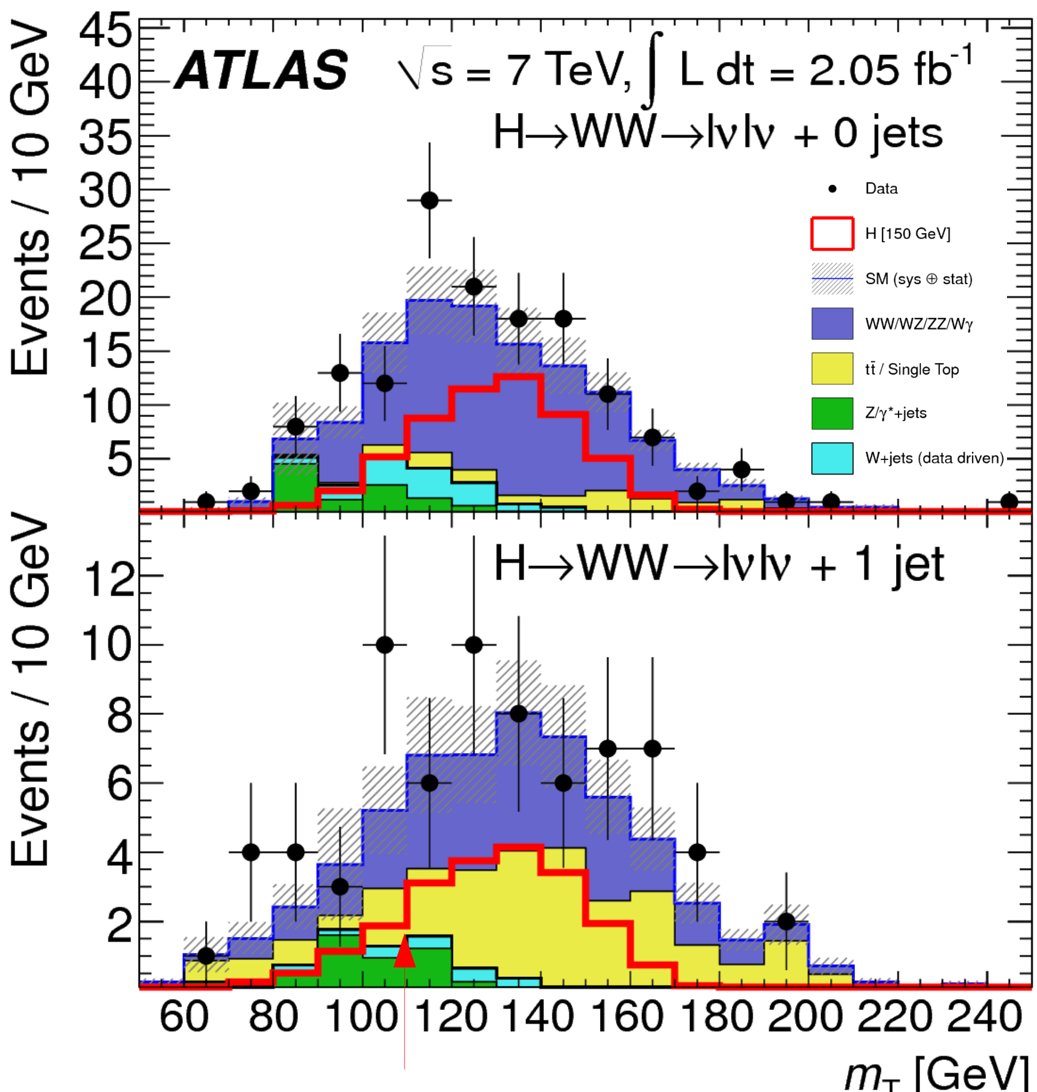
H+1jet selection:

→ Large $t\bar{t}$ background

- Veto on jets with a b-tag
- $Z\rightarrow\tau\tau$ veto by $|m_{\tau\tau}-m_Z|$ > 25 GeV
- Total pT < 30 GeV (E_T^{miss} + leptons +jet)
- Cuts on m_{ll}, $\Delta\phi_{ll}$

Cuts optimized for three different mass ranges.

Mass reconstruction not fully possible, instead m_T



m_H = 150 GeV

Final cut: m_T window dependent on m_H

Background control

W+jets
Estimated entirely from a control region

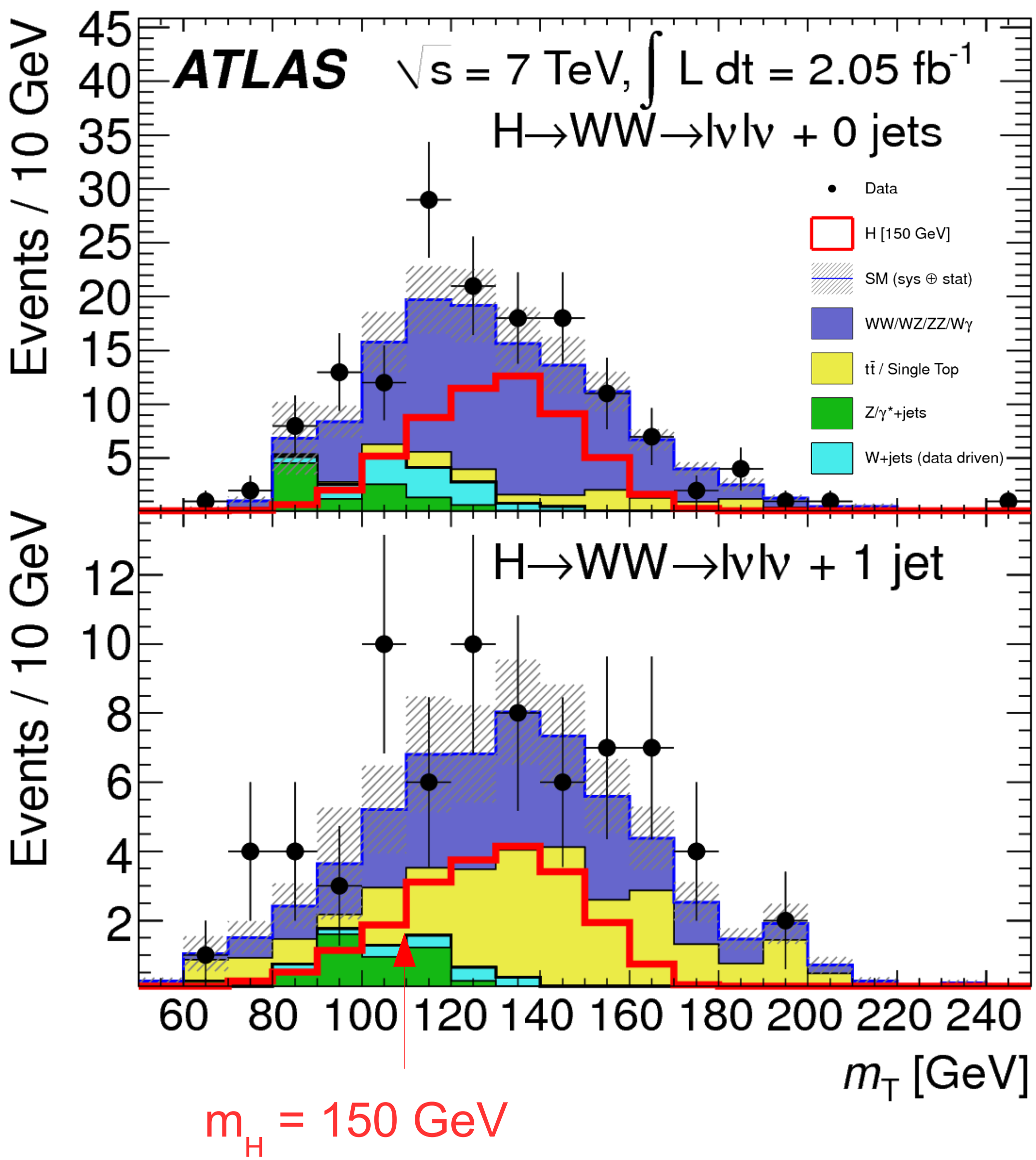
WW and top:
Shape from MC,
normalization from control region

Z+jets:
scaled by ~0.8-0.9 to account for $E_{T,rel}^{miss}$ mismodelling, shape from MC

Total uncertainties after selection:

	0-jet	1-jet
WW	13 %	21 %
top	26 %	64 %
W+jets	43 %	31 %
Z+jets	240 %	140 %
Signal	22 %	21 %

Mass reconstruction not fully possible, instead m_T

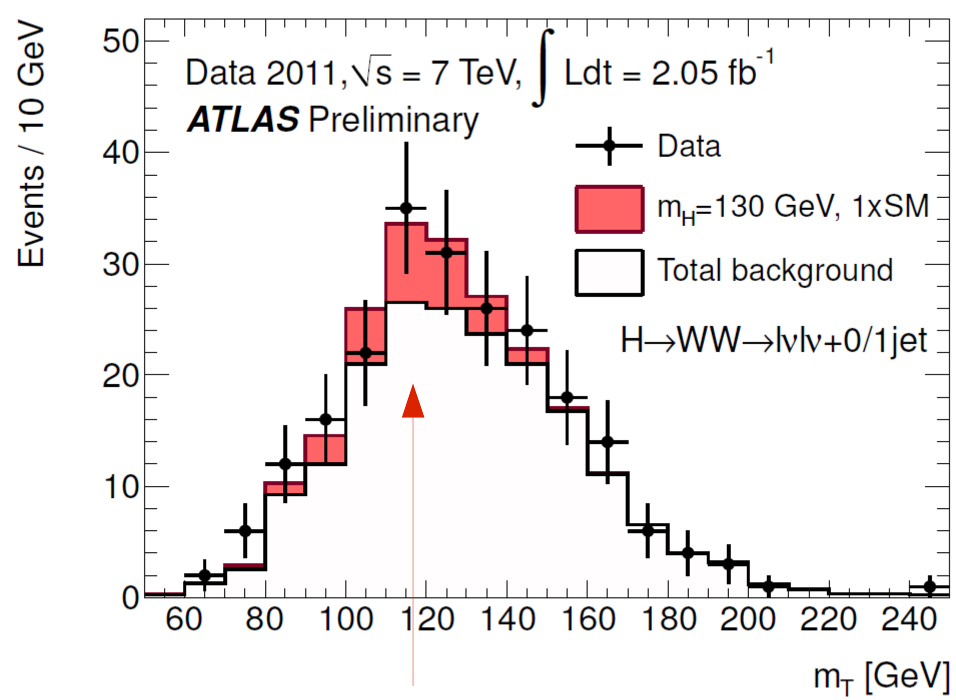


Final cut: mT window dependent on mH

Expected and observed events:

	0-jet	1-jet
Background	63 ± 9	28 ± 4
Data	81	29
mH=150 GeV	40 ± 9	14 ± 3

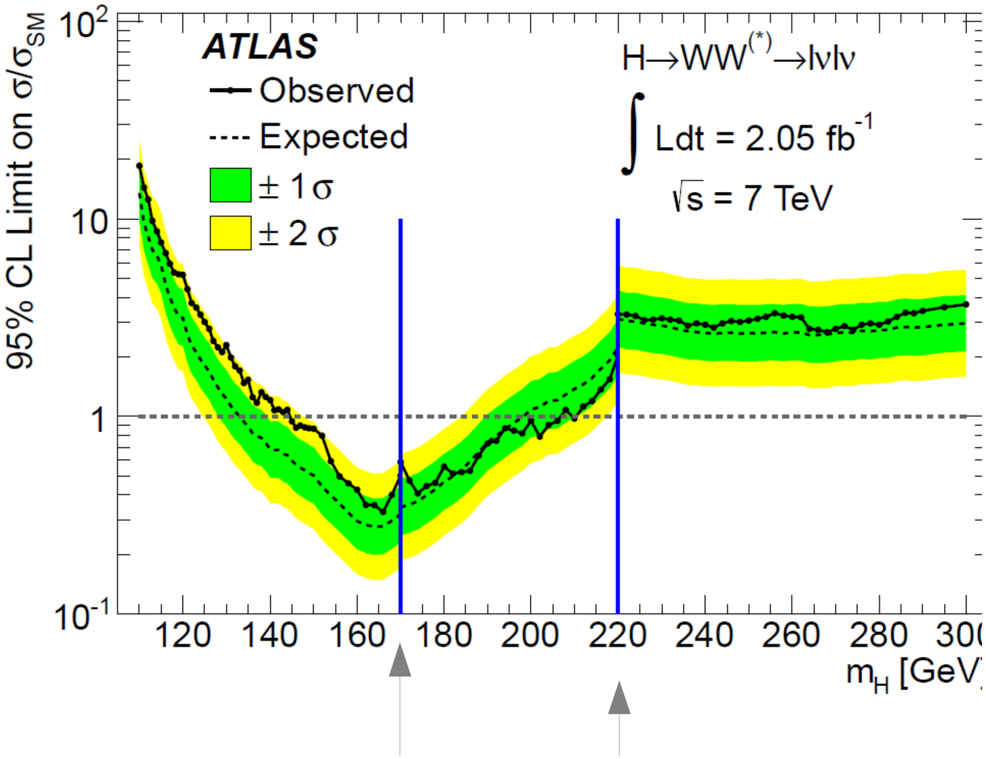
Sum of 0/1 jet channels:



Signal (stacked) mH=130 GeV

Results:

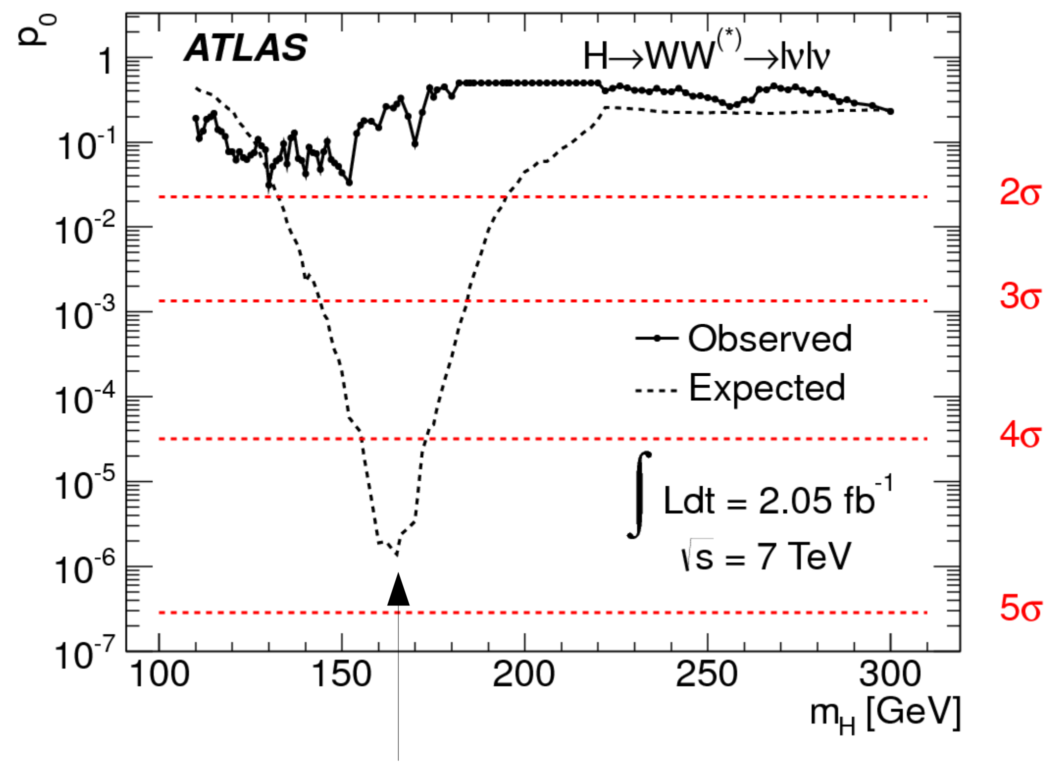
Upper limits on cross section



Selection changes

Local p_0 value

Probability that the background fluctuates to the data or higher



Expected p_0 would almost reach 5 sigma

Very strong exclusion in this region m_H ~160 GeV

- Broad excess in low mass region, corresponding to a significance of **1.9σ**
- Observed exclusion: 145 – 206 GeV
- Expected exclusion: 134 – 200 GeV

Clean but very rare channel. BR ($H \to 4l$) ~0.04% for 150 GeV

ATLAS-CONF-2011-162

Event selection

- Isolated e or μ, cut on impact parameter, two OS pairs: **ee ee, μμ μμ, ee μμ**
- Lepton p_T > 7 GeV, but at least two with p_T > 20 GeV
- $|m_{12} - m_Z| < 15$ GeV (one on-shell Z)
- Cut on mass of other pair, m_{34}, depending on m_{4l}

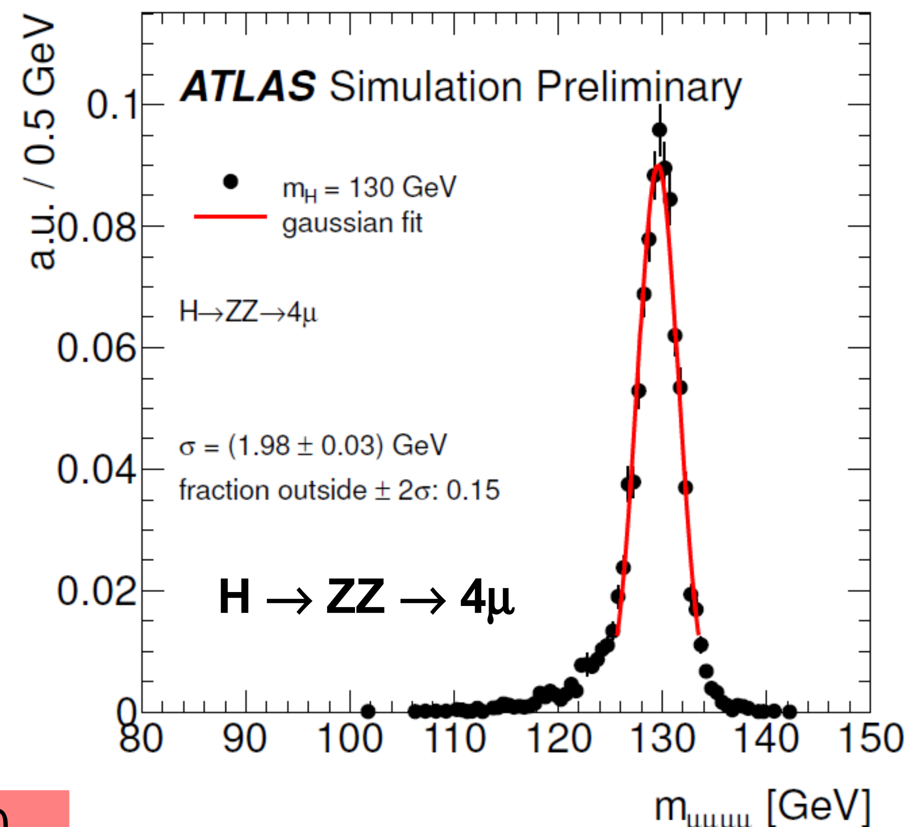
4l mass resolution

Gaussian σ: m_H=130 GeV 4μ: 1.98 GeV, 2e2μ: 2.18 GeV, 4e: 2.53 GeV

FWHM: m_H=130 GeV: 4.5 – 6.5 GeV

m_H=400 GeV: 35 GeV

At high mass natural width dominant.

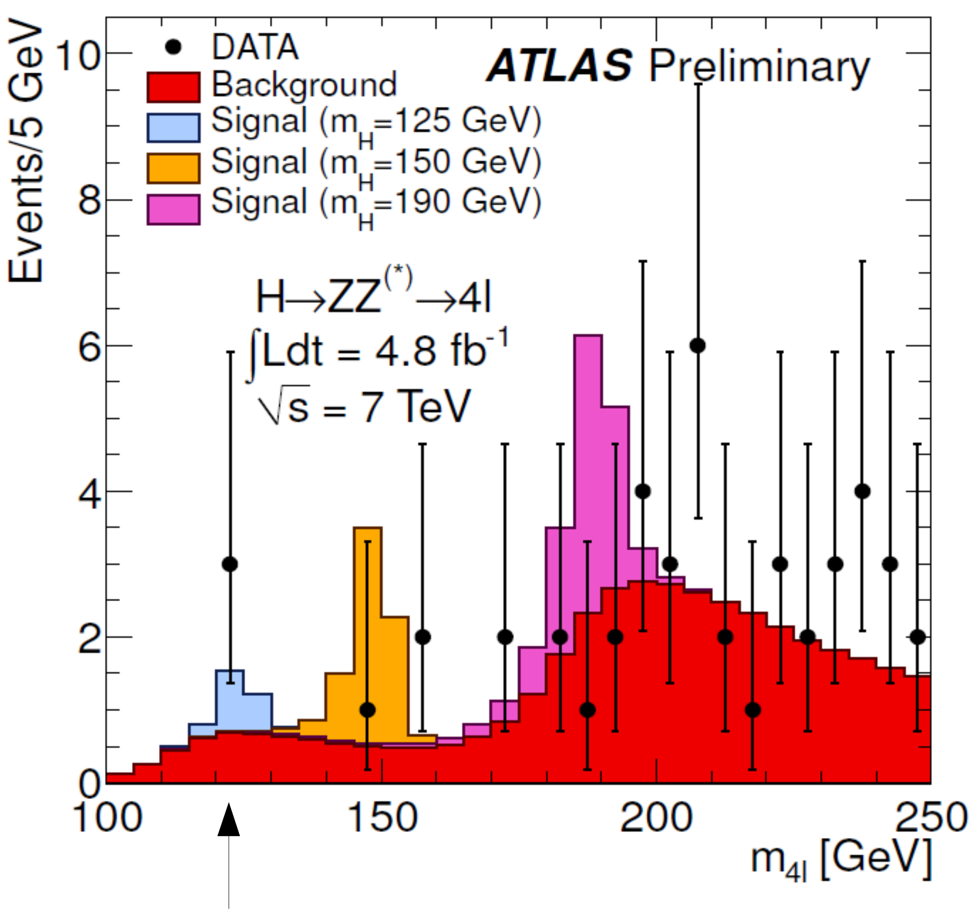


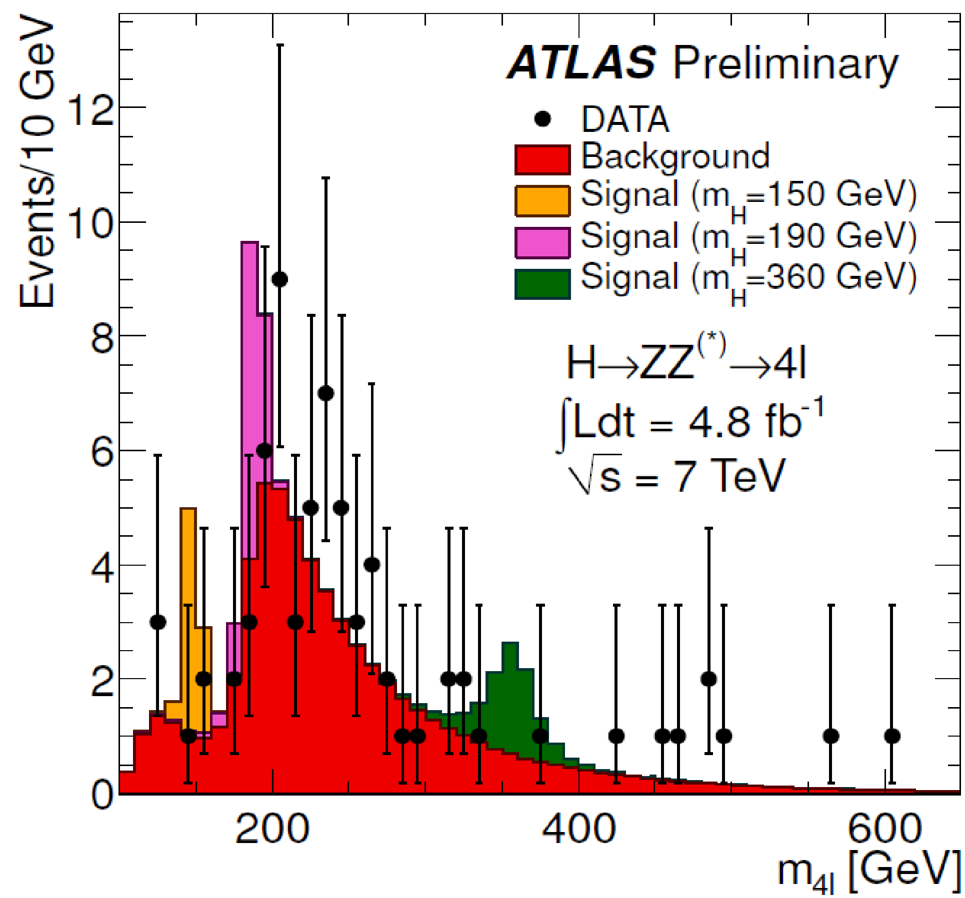
Signal predicition for 4.8 fb^{-1}:

m_H / GeV	130	150	200	400	600
S	2.7	6.1	15.7	6.8	1.3

	4μ	2e2μ	4e
Background, m_{4l} < 180 GeV	2.2 ± 0.3	4.2 ± 0.8	2.9 ± 0.8
Data, m_{4l} < 180 GeV	3	3	2

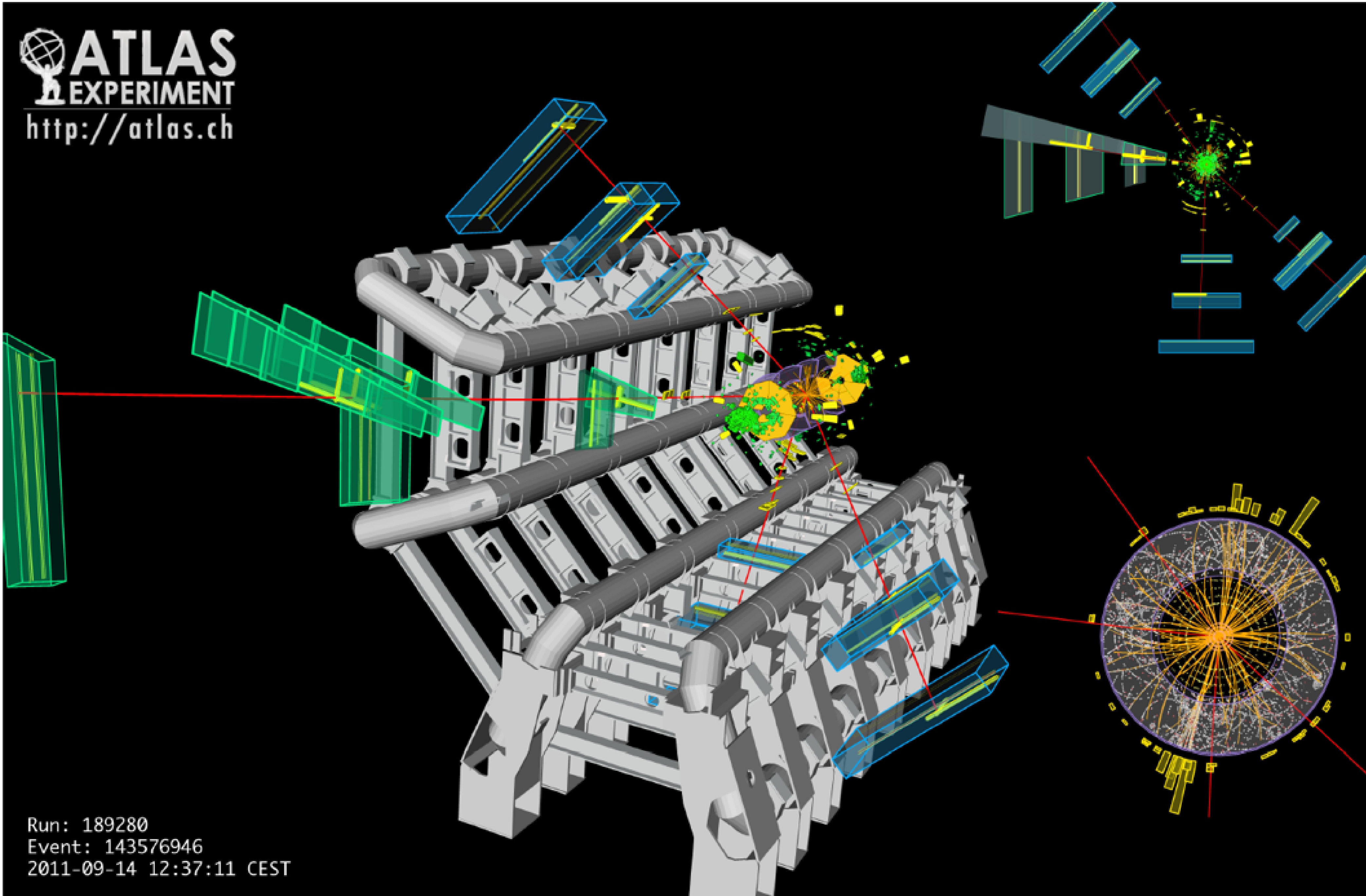
- $ZZ^{(*)}$ continuum estimated from MC, 15% uncertainty assigned
- Top-pairs and Z+jets normalizations from control regions: 10% error on $t\bar{t}$, ~40% on Z+jets



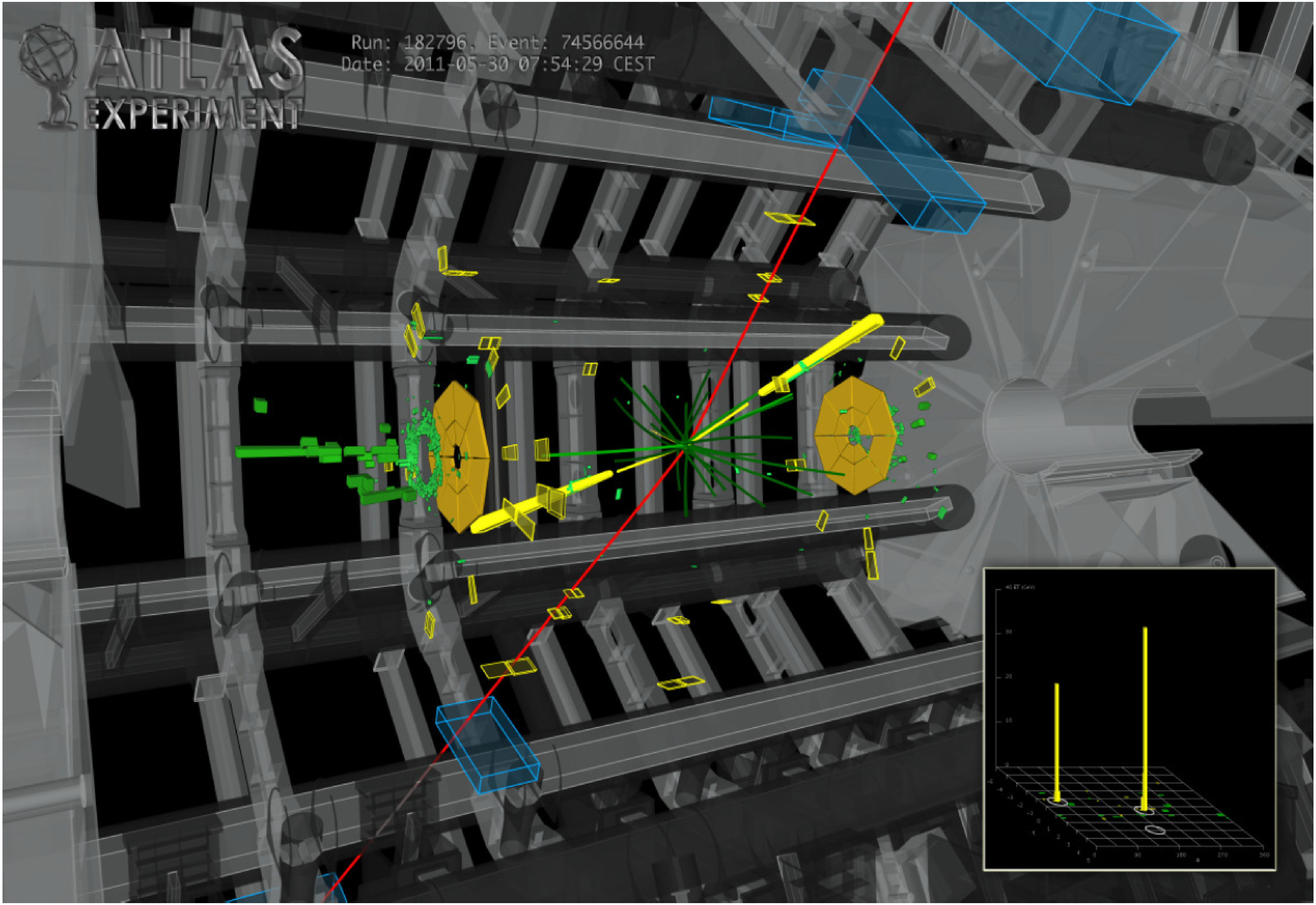


Three events: $m_{4\mu}$ = 124.6 GeV, $m_{2e2\mu}$=124.3 GeV, $m_{2\mu 2e}$=123.6 GeV

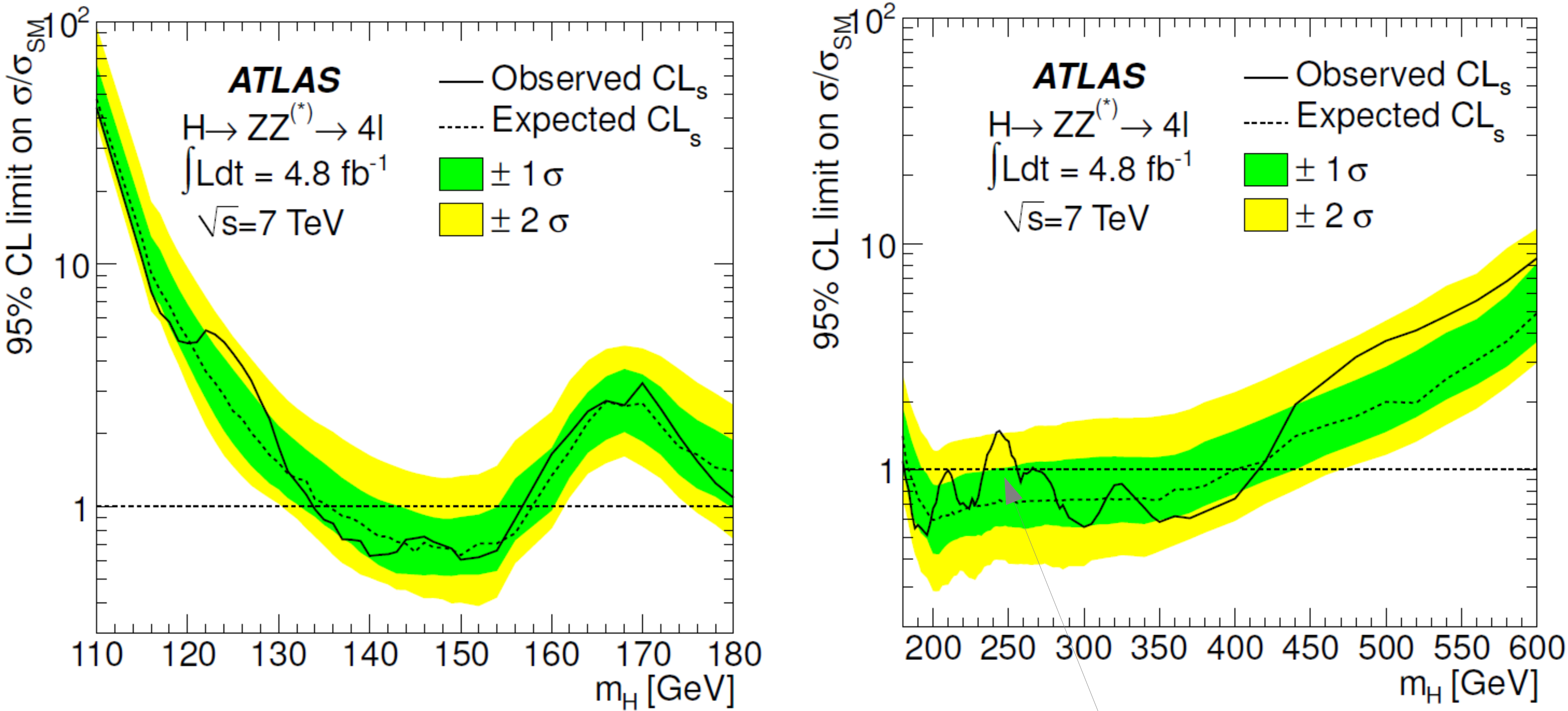
H $\to$ 4 μ candidate, m = 124.6 GeV



$H \to 2e\ 2\mu$ candidate, m = 124.3 GeV



Limits on the production cross section in units of SM Higgs cross section:



Observed exclusion ranges:

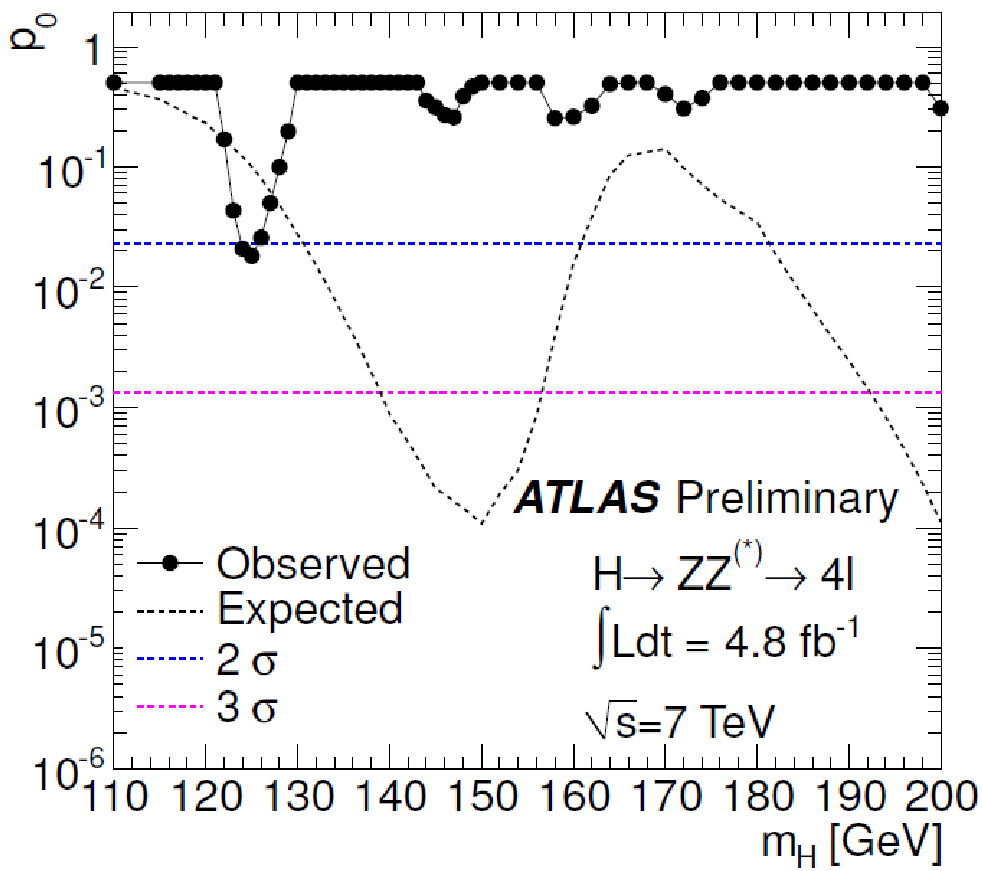
135 – 156 GeV
181 – 234 GeV
255 – 415 GeV

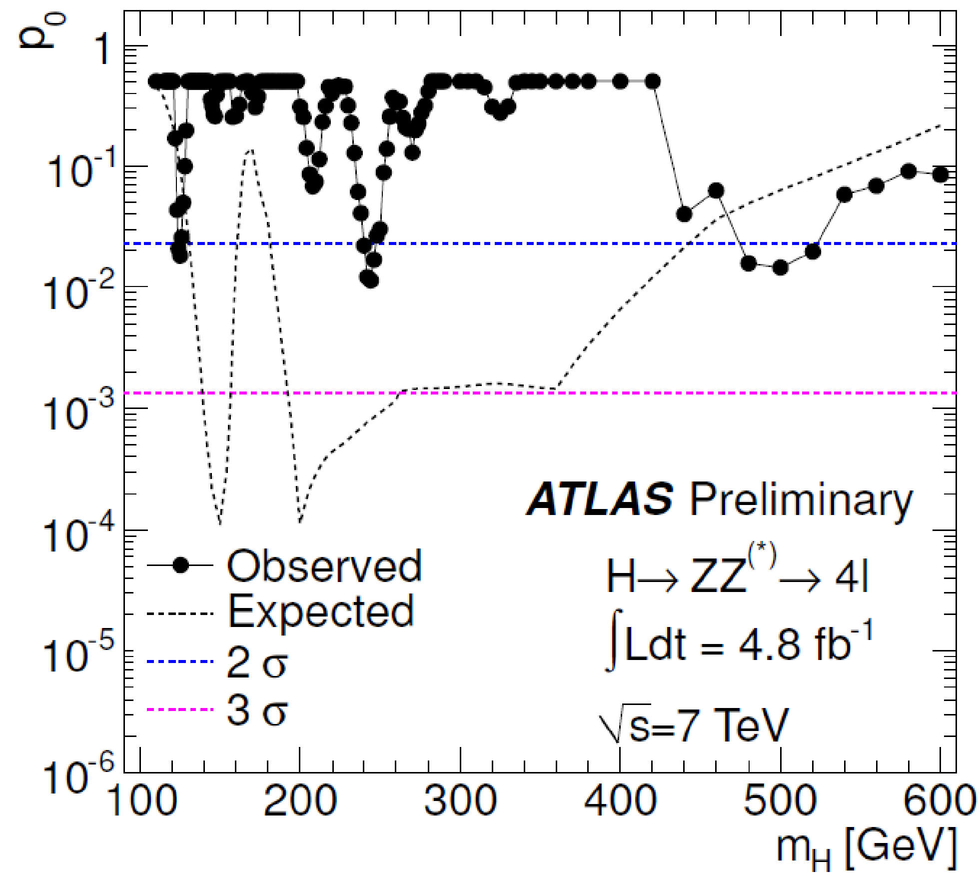
Expected exclusions:

137 – 158 GeV
185 – 400 GeV

Excluded by CMS (preliminary)

p_0: Probability that background fluctuates to the observed number of events





Local p_0-values:

m_H = 125 GeV 1.8% (2.1σ)
m_H = 244 GeV 1.1% (2.3σ)
m_H = 500 GeV 1.4% (2.2σ)

After **look-elsewhere correction**:
Excesses no longer significant.

Full mass range: p_0 ~50%

Only allowed mass region (m_H<146 GeV): p_0 ~30%

ATLAS-CONF-2011-161

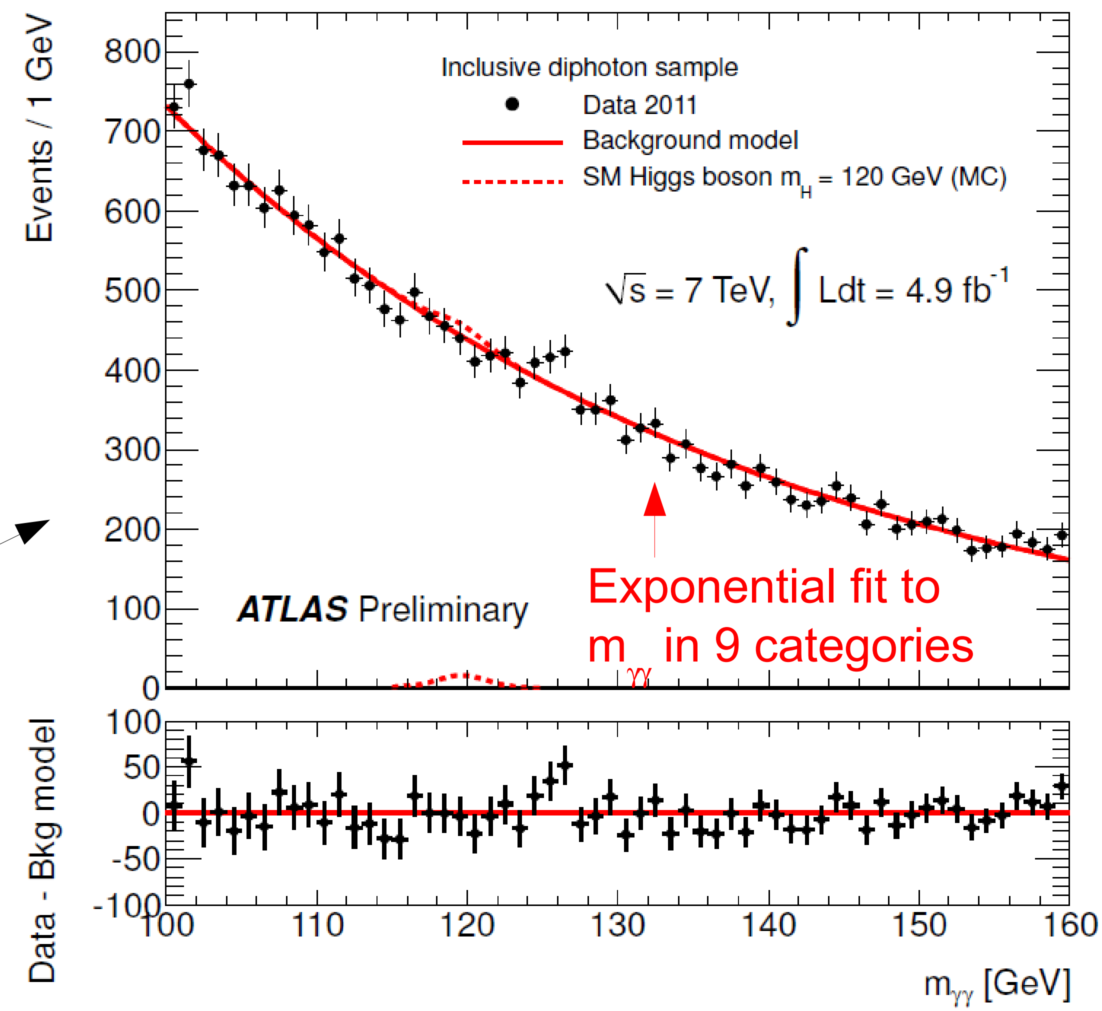
Event selection

- Trigger on two γ with $E_T > 20$ GeV
- Converted and unconverted photons $|\eta|<2.37$, excluding $1.37<|\eta|<1.52$
- Isolation: $E_{T,corrected} < 5$ GeV
- Shower shape based γ identification
- p_T cuts: 40 GeV (leading photon), 25 GeV (subleading photon)
- Diphoton mass: 100-160 GeV

22 489 events

71% of them true diphoton events

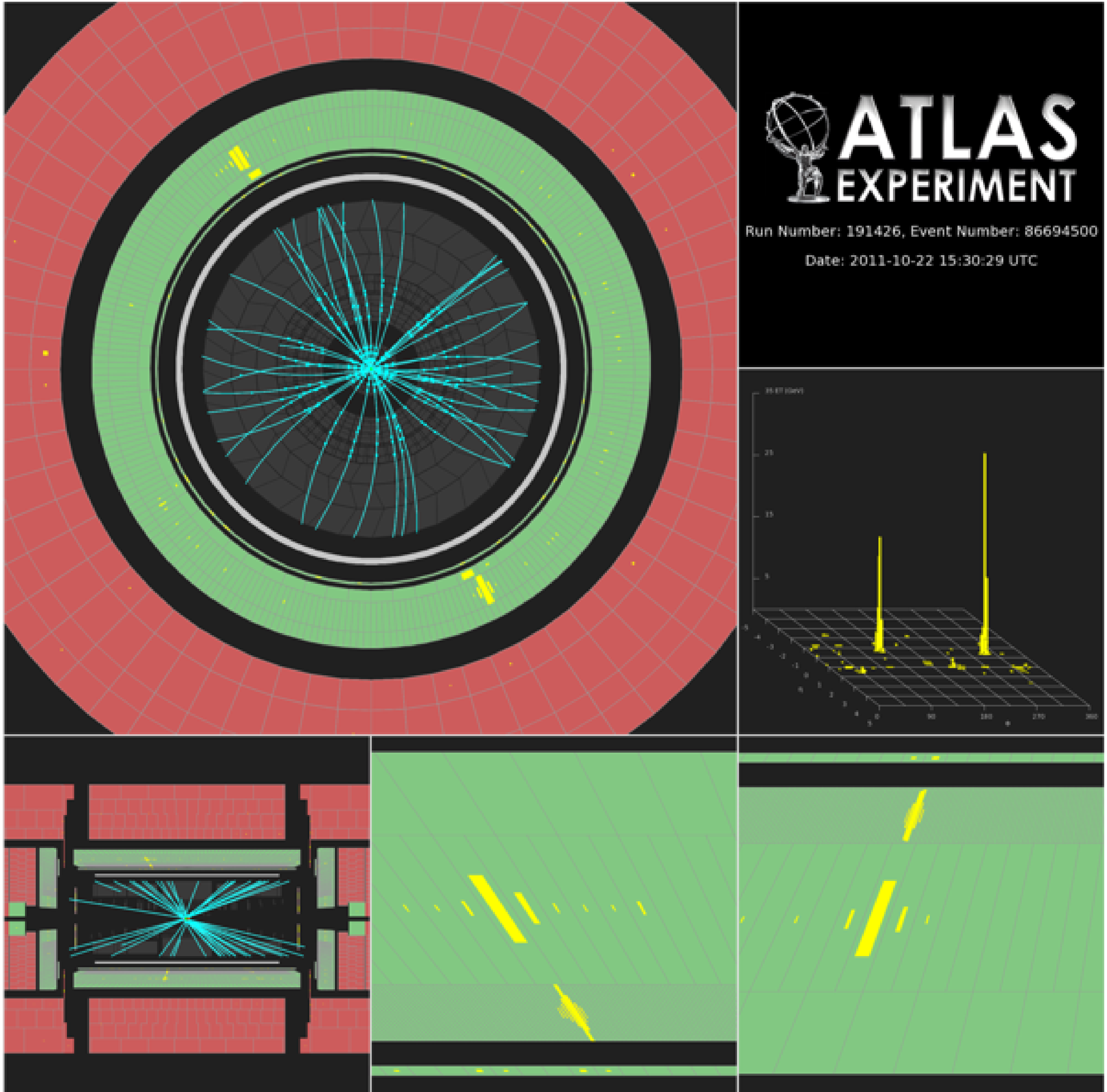
Diphoton mass after event selection



Expected signal yield BR(H → γγ): ~0.2 %

m_H [GeV]	110	120	125	130	140	150
S	70	71	68	64	50	31

Signal selection efficiency: ~35%



Both photons unconverted, in central region.

$m_{\gamma\gamma}$=126.6 GeV

$p_T^{\gamma\gamma}$ = 6.1 GeV

pTt = 5.4 GeV

E_{T1} = 64.2 GeV

E_{T2} = 61.4 GeV

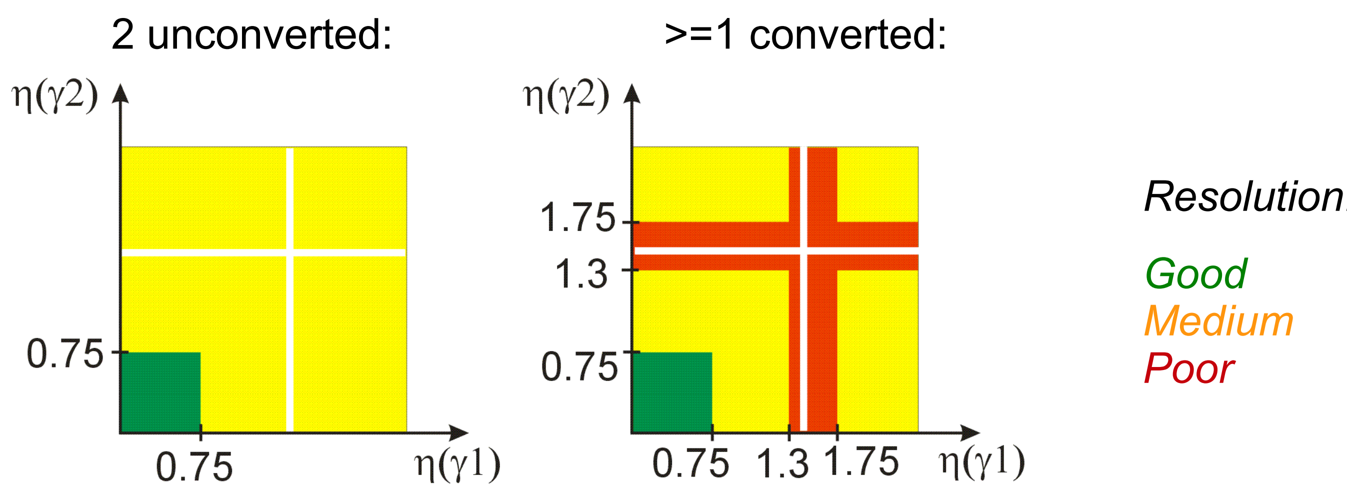
9 categories based on conversion status, position in the calorimeter, pTt

Both unconverted:

- Central
- Rest

At least one converted:

- Central
- Transition
- Rest

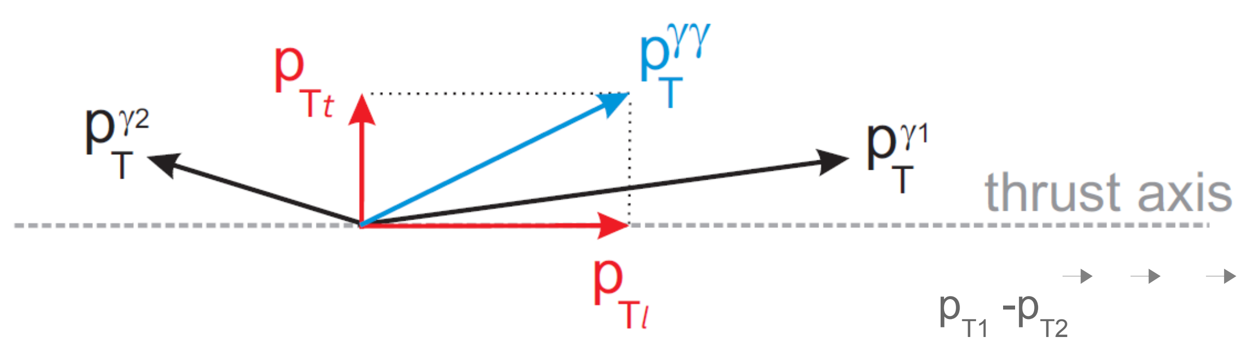


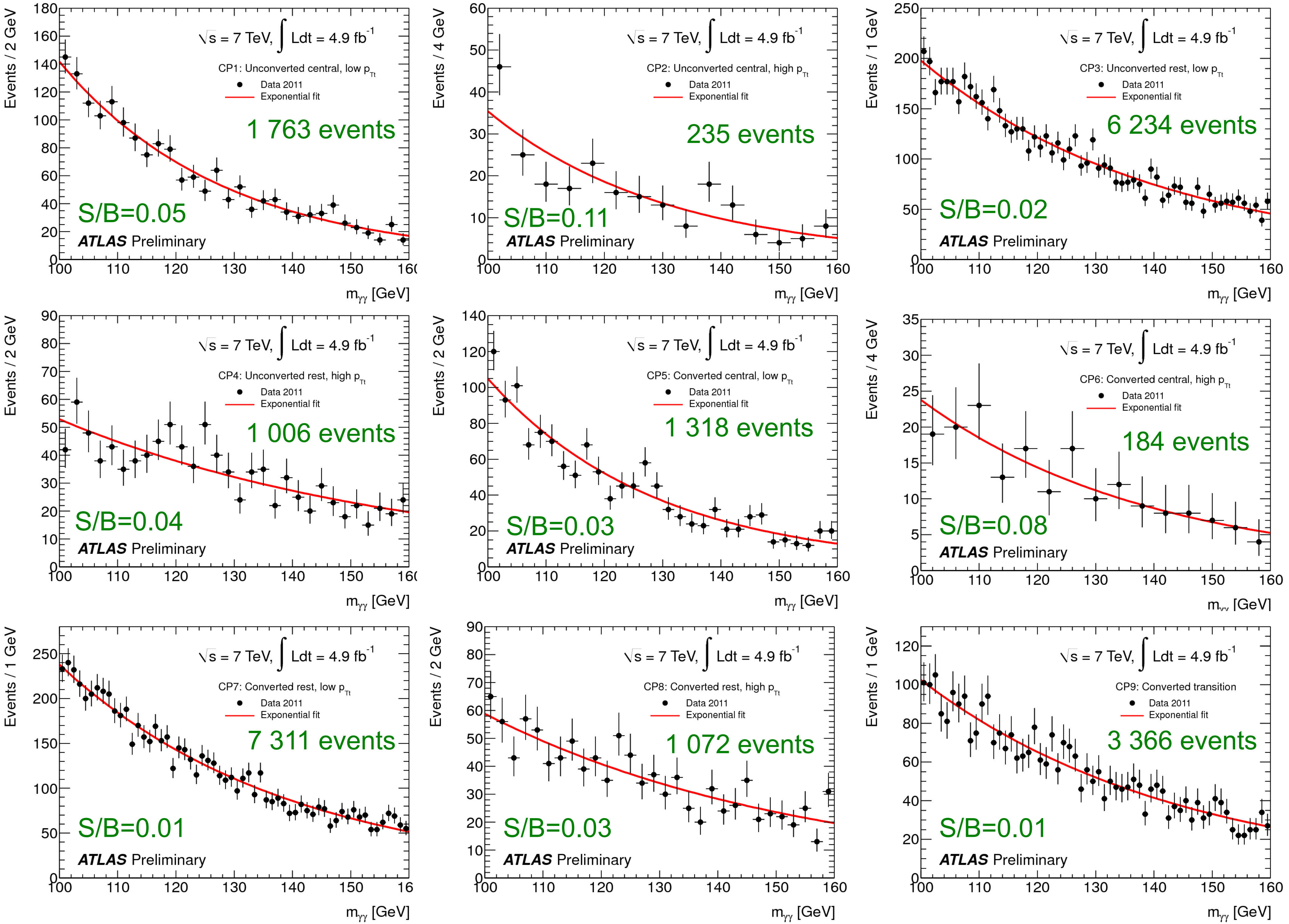
„Central“ and „Rest“ categories further divided: „Low pTt“: pTt < 40 GeV

„High pTt“: pTt > 40 GeV

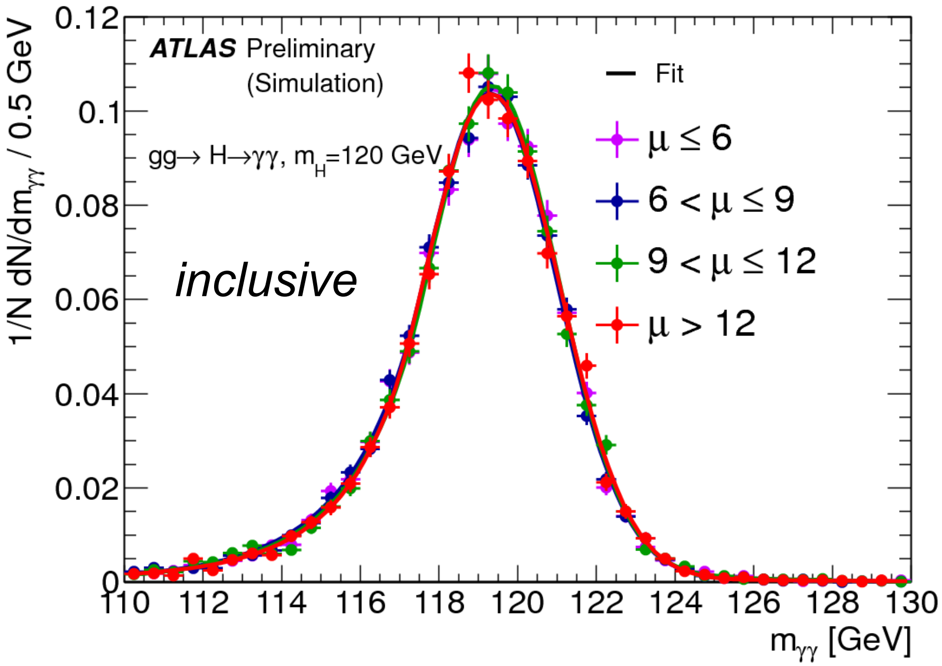
- Signal events have larger pTt than the backgrounds, in particular the VBF and associated production modes
- **Expect 5-10 % gain in sensitivity with usage of pTt categories**

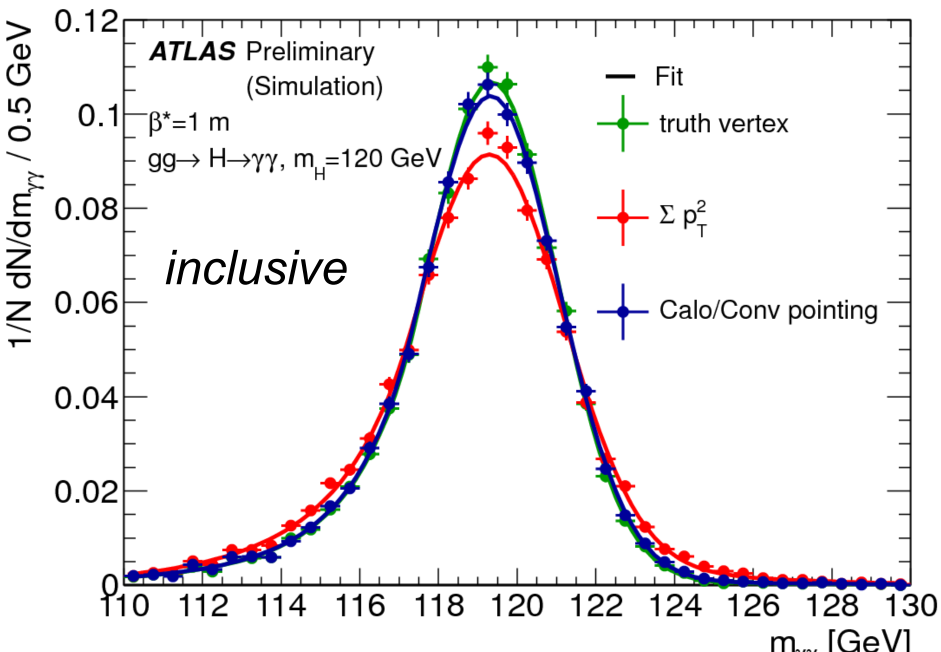
Illustration of the pTt definition:

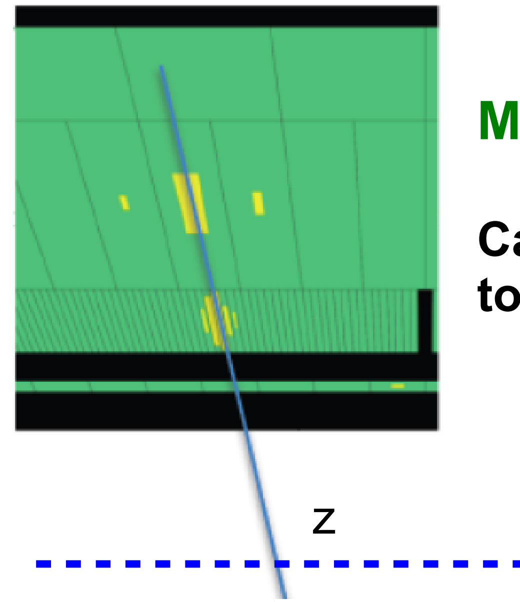




√s = 7 TeV, ∫ Ldt = 4.9 fb-1
CP1: Unconverted central, low pTt
Data 2011
Exponential fit
1 763 events
S/B=0.05
ATLAS Preliminary
Events / 2 GeV
mγγ [GeV]
CP2: Unconverted central, high pTt
235 events
S/B=0.11
Events / 4 GeV
CP3: Unconverted rest, low pTt
6 234 events
S/B=0.02
Events / 1 GeV
CP4: Unconverted rest, high pTt
1 006 events
S/B=0.04
CP5: Converted central, low pTt
1 318 events
S/B=0.03
CP6: Converted central, high pTt
184 events
S/B=0.08
CP7: Converted rest, low pTt
7 311 events
S/B=0.01
CP8: Converted rest, high pTt
1 072 events
S/B=0.03
CP9: Converted transition
3 366 events
S/B=0.01







Mass reconstruction

Calorimeter pointing to deduce PV

Determine photon direction from 1st and 2nd calorimeter layer. Combine 1st layer with inner detector information if photon is converted.

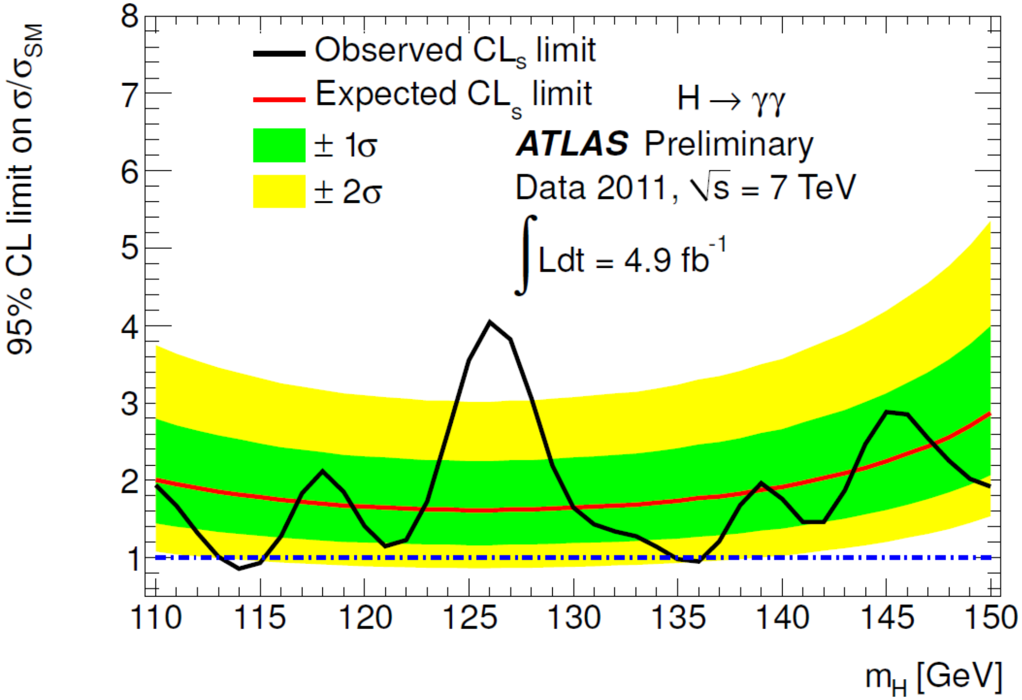
→ σ(z) = 1.5 cm (unconverted, Barrel)

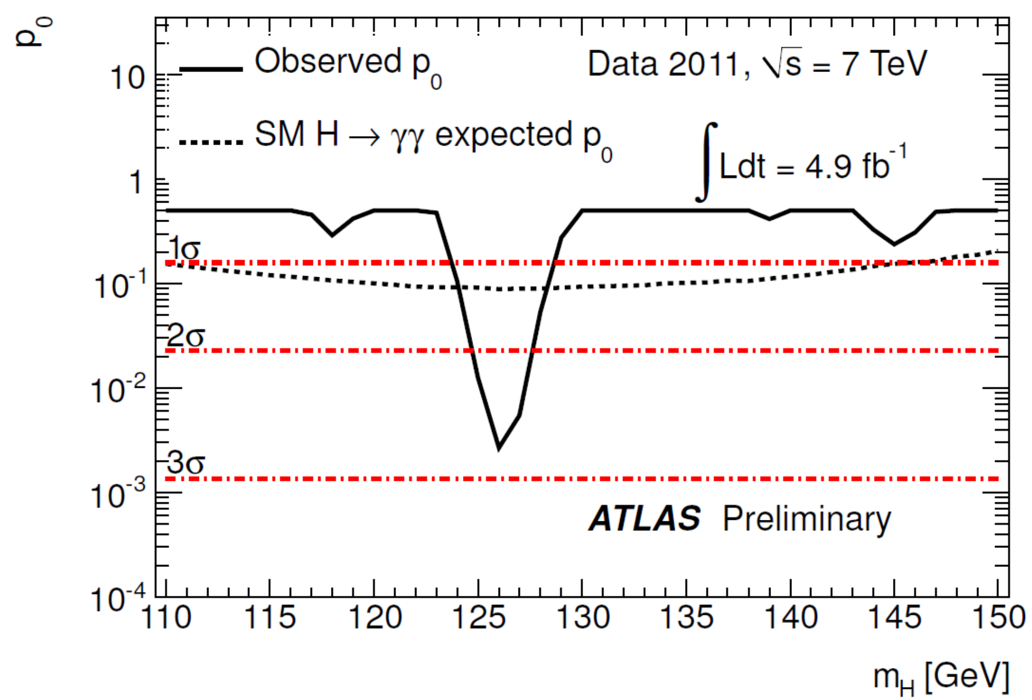
Expected mass resolution (m_H=120 GeV):

[GeV]	FWHM	σ_{Core}
Best category	3.3	1.4
Worst category	5.8	2.3
Inclusive	4.0	1.7

5-20% improvement of resolution with pointing

Results





Simultanious fit of all nine categories
with a correlated signal strength.

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Expected 95% CL limits on σ/σ_{SM}:

1.6-2.9, in 115-130 GeV: 1.6-1.8

Observed exclusions:

m_H=114-115 GeV, m_H=135-136 GeV

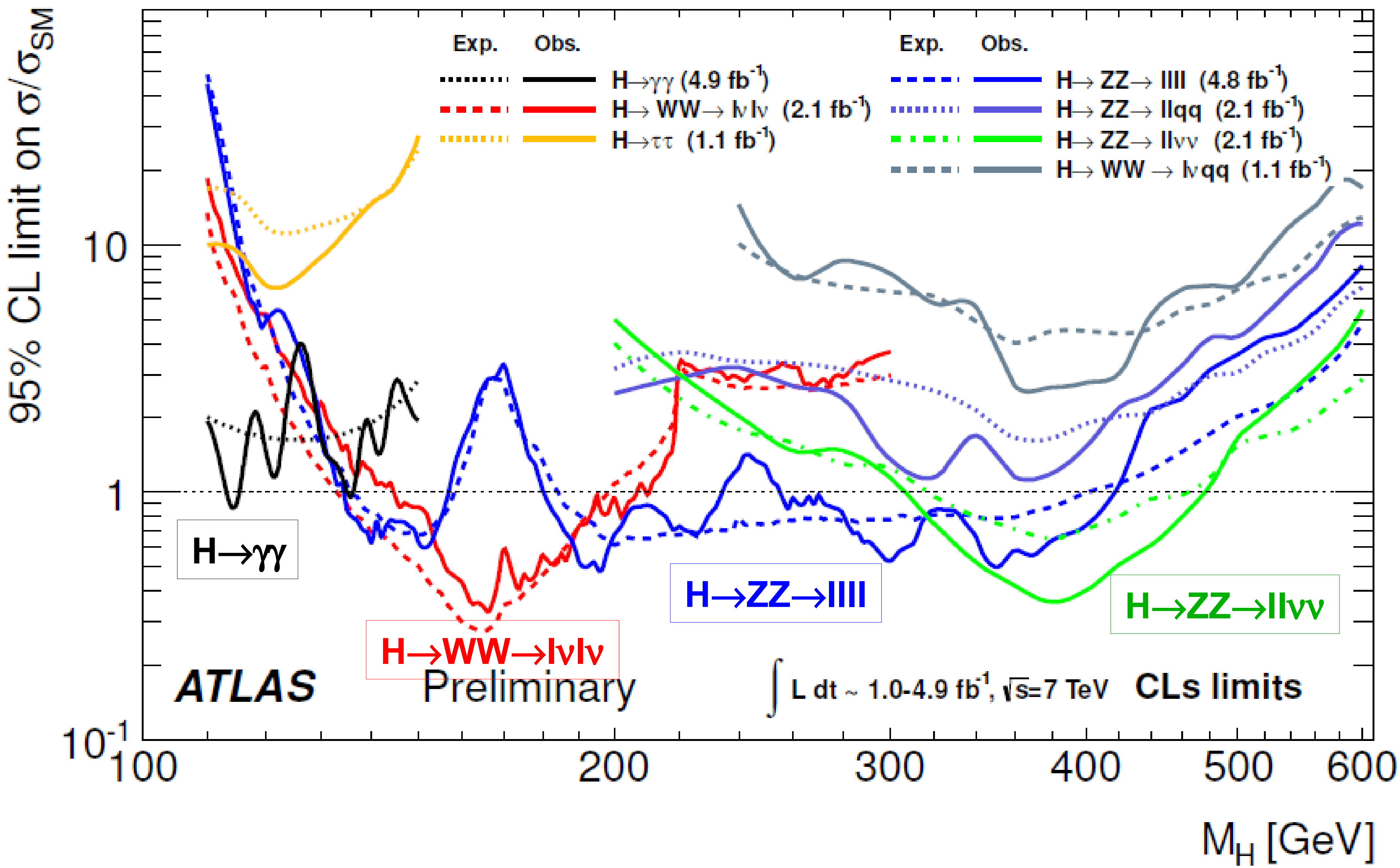
The smallest **local p0**:

0.24% (**2.8 σ**) at m_H=126 GeV

The **global significance**
(with look-elsewhere-correction) is **1.5 σ.**

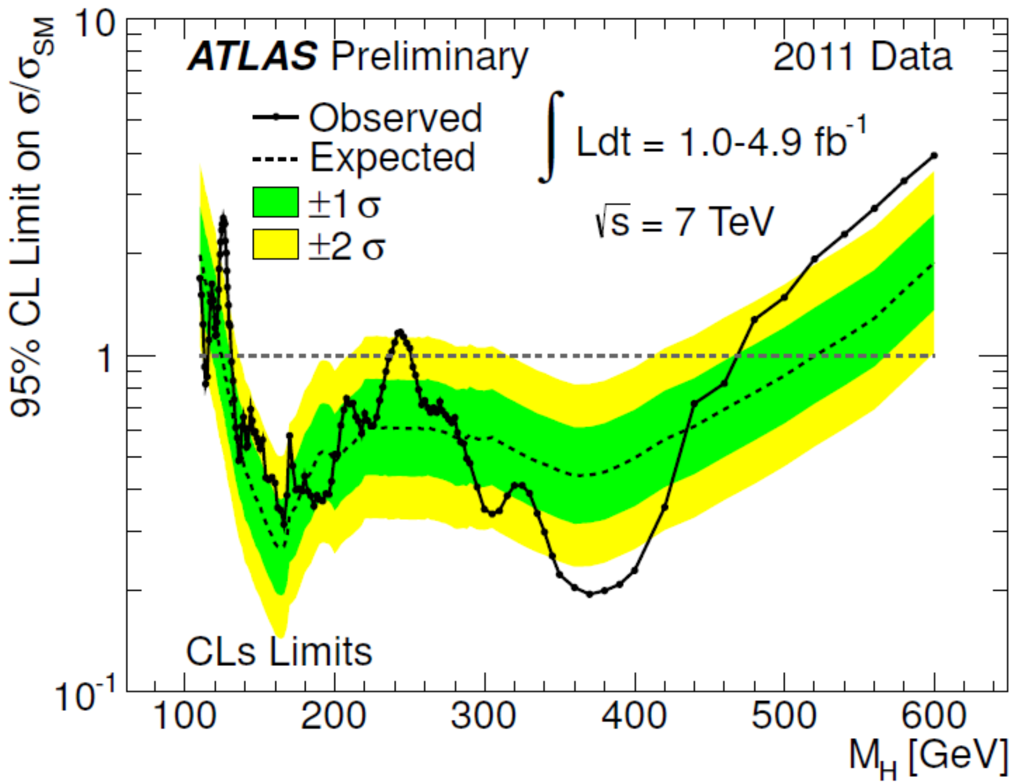
ATLAS-CONF-2011-163

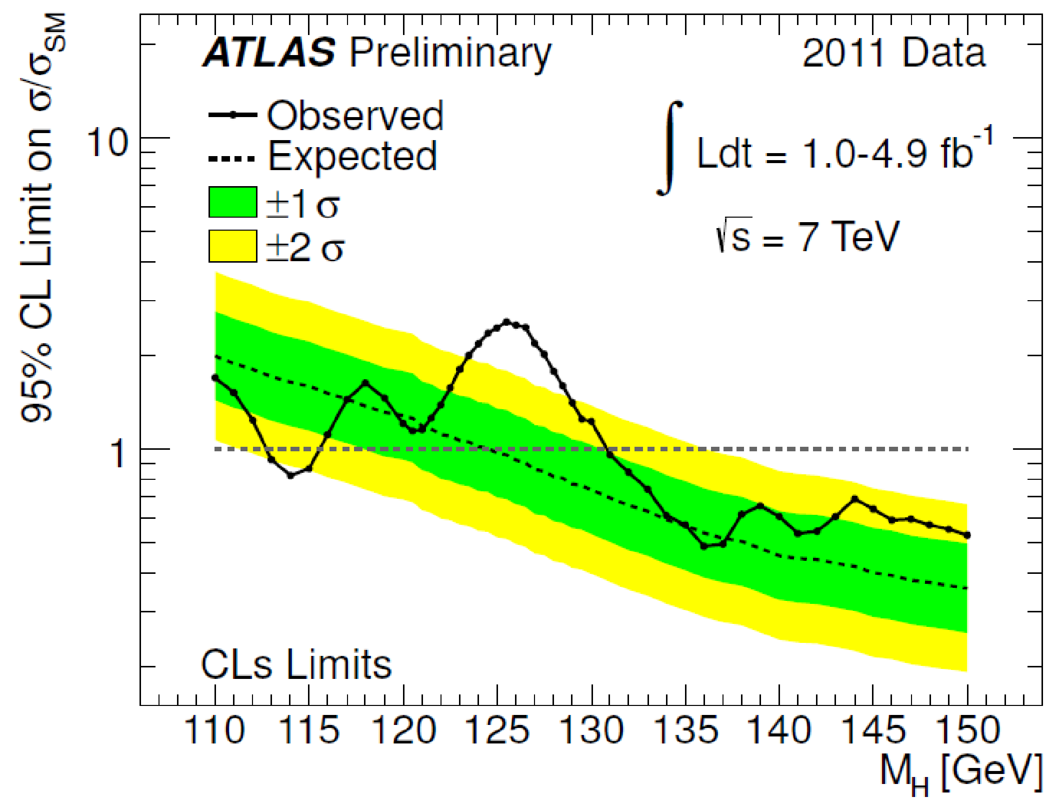
Expected (dashed lines) and observed (solid lines) exclusion limits per channel



W/Z $H \to b\bar{b}$ with 1fb^{-1} not included here due to little sensitivity.

Combined upper limits on Higgs cross section:



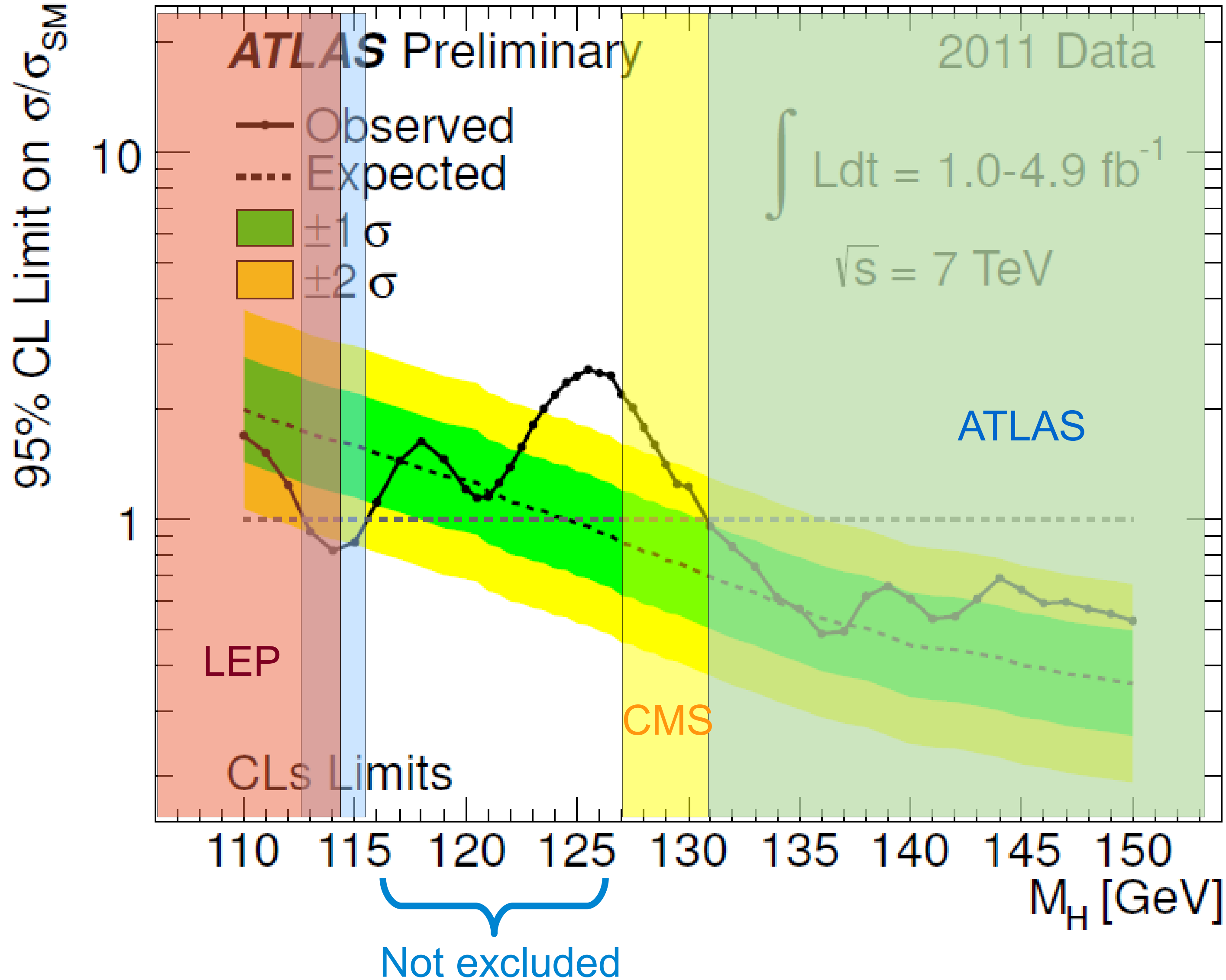


Expected 95% CL. exclusions: 124.6 – 520 GeV.

Observed 95% CL exclusions: 112.7 – 115.5 GeV, 131 – 237 GeV, 251-468 GeV

Non excluded range around 245 GeV due to 4l excess already excluded by LHC combination.

Observed 99% CL. Exclusions: 133-230 GeV, 260-437 GeV.



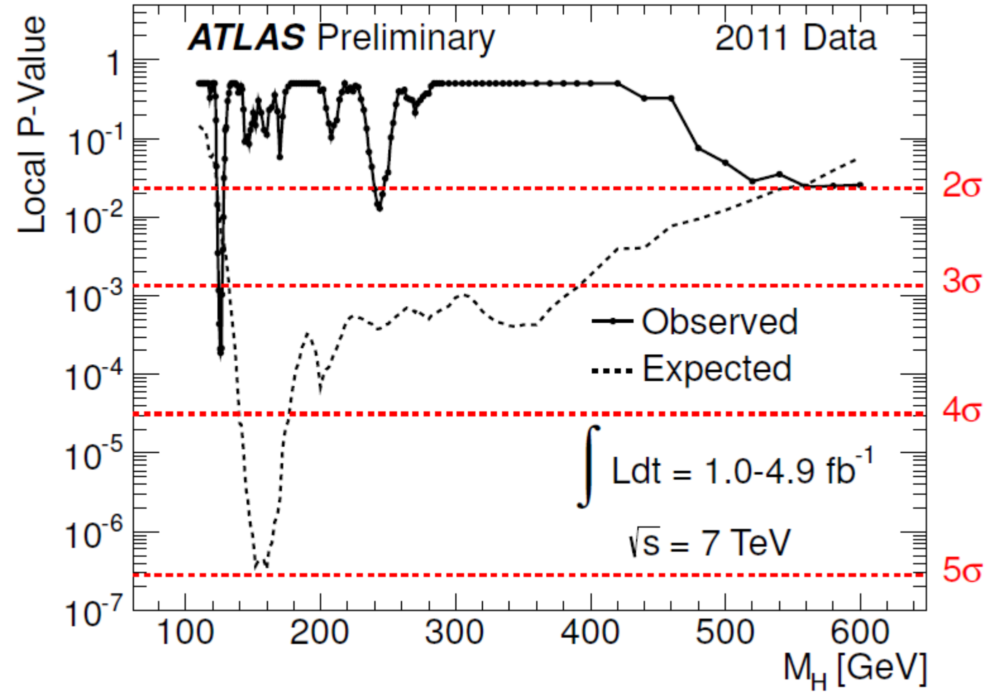
Observed exclusions:

LEP: < 114.4 GeV

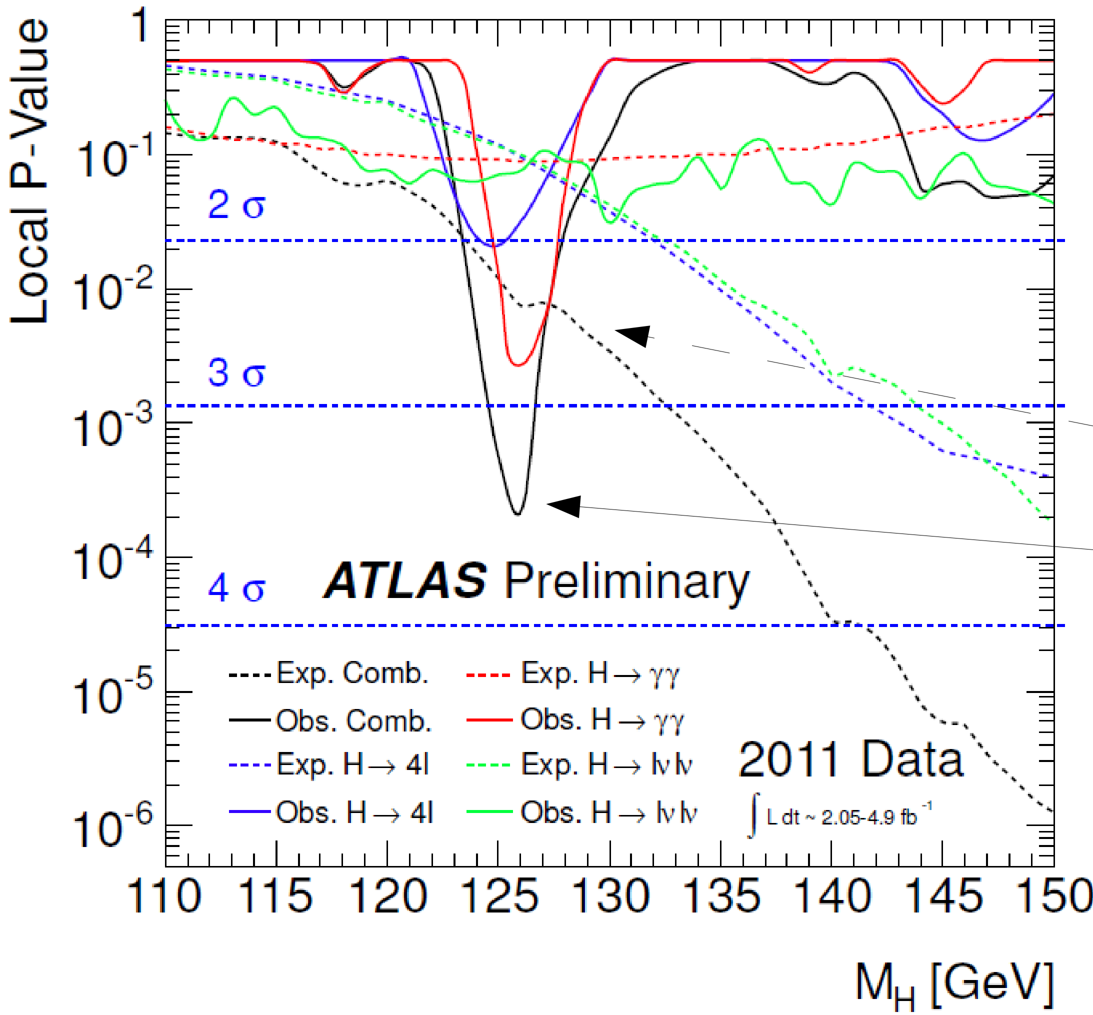
ATLAS: 112.7 -115.5 GeV, 131 – 237 GeV, 251-468 GeV

CMS: 127 – 600 GeV

Combined p0 in full mass range



p0 in low mass region



Expected significance: 2.4σ

Combined local p_0 at 126 GeV:

0.02% (3.8σ)

Combining only γγ and 4l: 3.6σ

Combined global p_0 at 126 GeV:

0.6% (2.5σ) for allowed mass region

1.4% (2.2σ) for full mass region

Outlook

Higgs Searches Updates

- Many channels soon updated with full 2011 statistics:

  $H \to WW \to l\nu l\nu/lnqq$, $H \to \tau\tau$, $H \to b\bar{b}$, $H \to ZZ \to llqq$, $H \to ZZ \to ll\nu\nu$, ...

- Updated ATLAS combination for Moriond 2012
- After Moriond: Probably ATLAS + CMS combination

Prospects for 2012+

- Beam energy increase: $\sqrt{s}$ = 8 TeV
- Expect to collect 15 fb^{-1} in 2012
- More pile-up: up to 27 interactions per crossing
- 2013-2014: Long shutdown

Possible: 5σ discovery by ATLAS alone at 125 GeV.

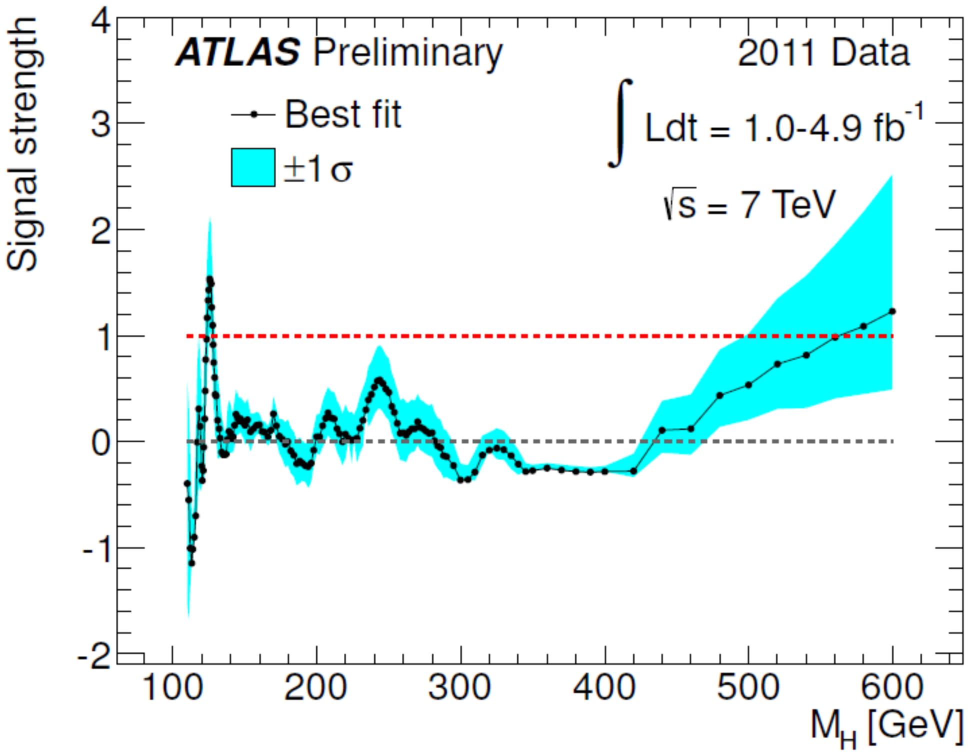
CMS+ATLAS together can achieve 5σ at 115 GeV.

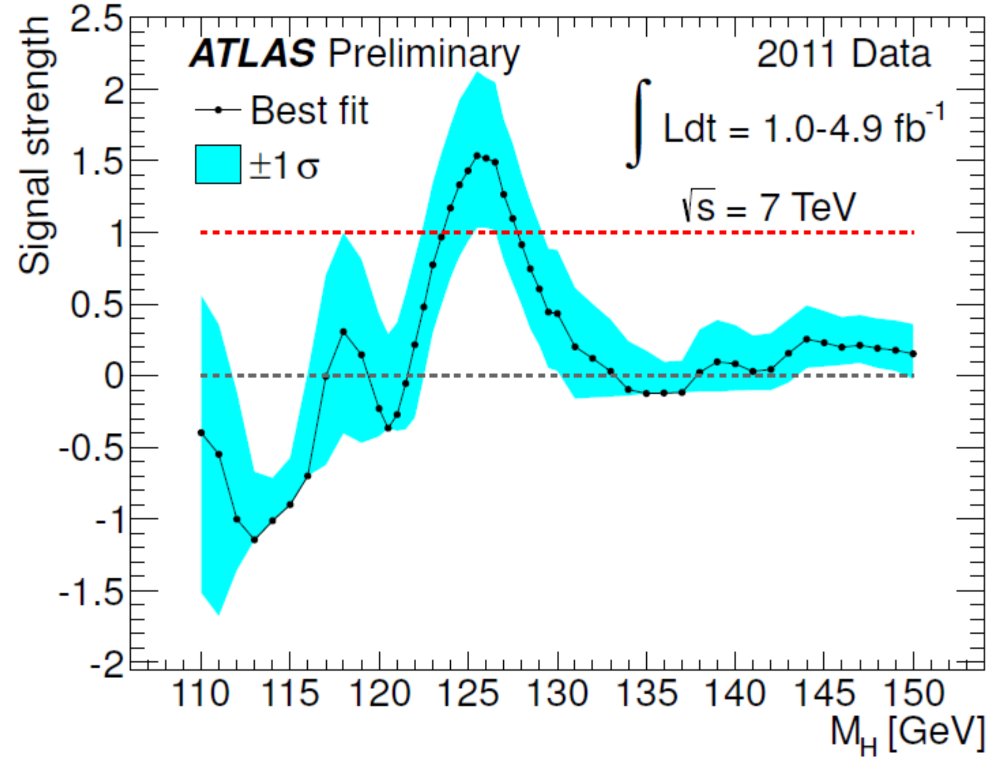
2012 should answer the question whether the SM Higgs exists or not!

Backup Slides

Combination

Fitted signal strength





Signal strength $\mu = \sigma / \sigma_{SM}$.

It indicates by what factor the SM Higgs boson cross section would need to be scaled to best fit the observed data.

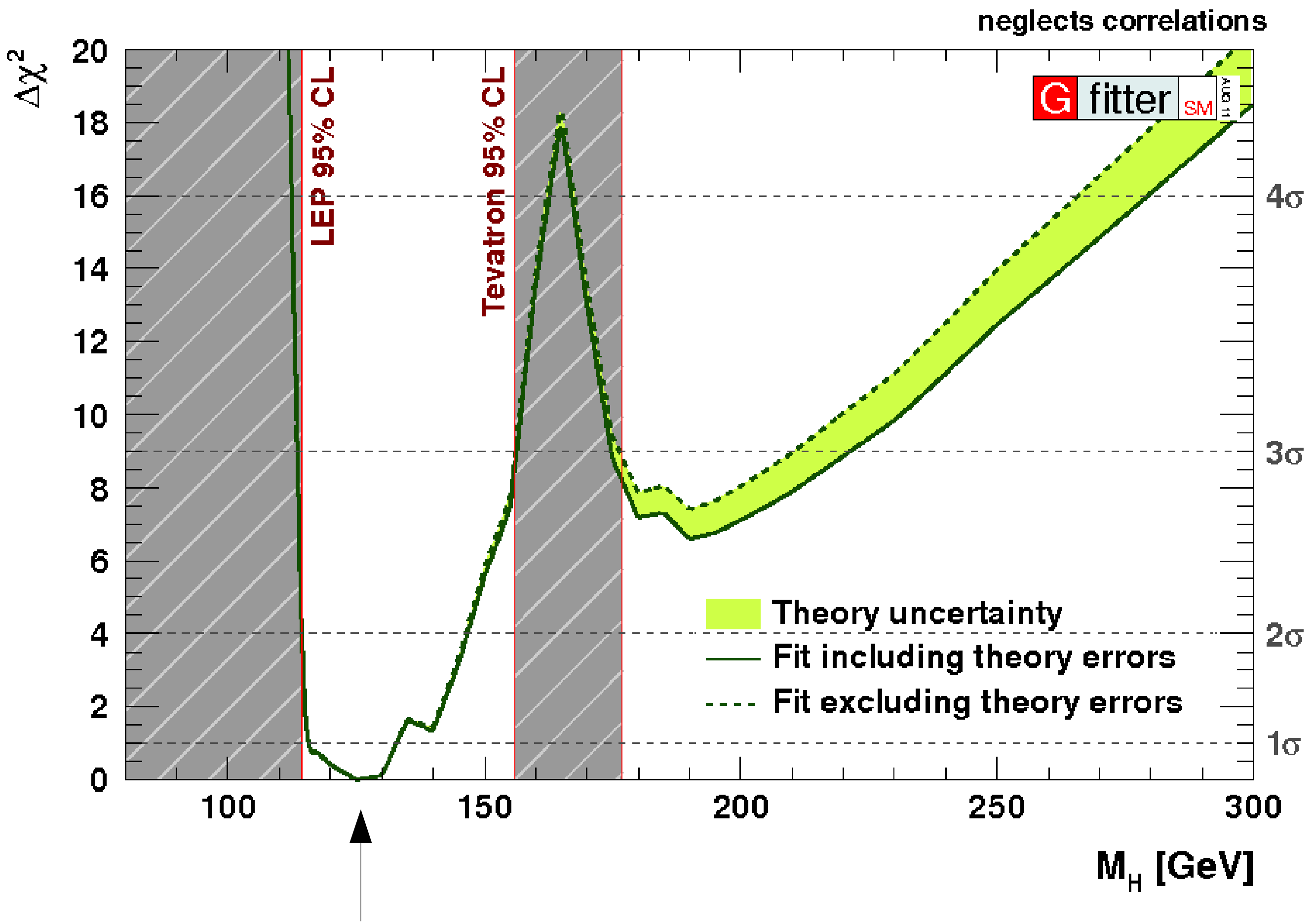
At 126 GeV: μ = 1.5 (due to $\gamma\gamma$ excess), consistent with 1 within $\pm1\sigma$ band.

Summer Results of EW Precision Data Fits

Latest update by the Gfitter group (http://gfitter.desy.de/Standard_Model/)

Includes LHC results presented at EPS 2011

(ATLAS: arXiv:1106.2748, CMS: arXiv:1102.5429) and Tevatron (arXiv:1107.5518)

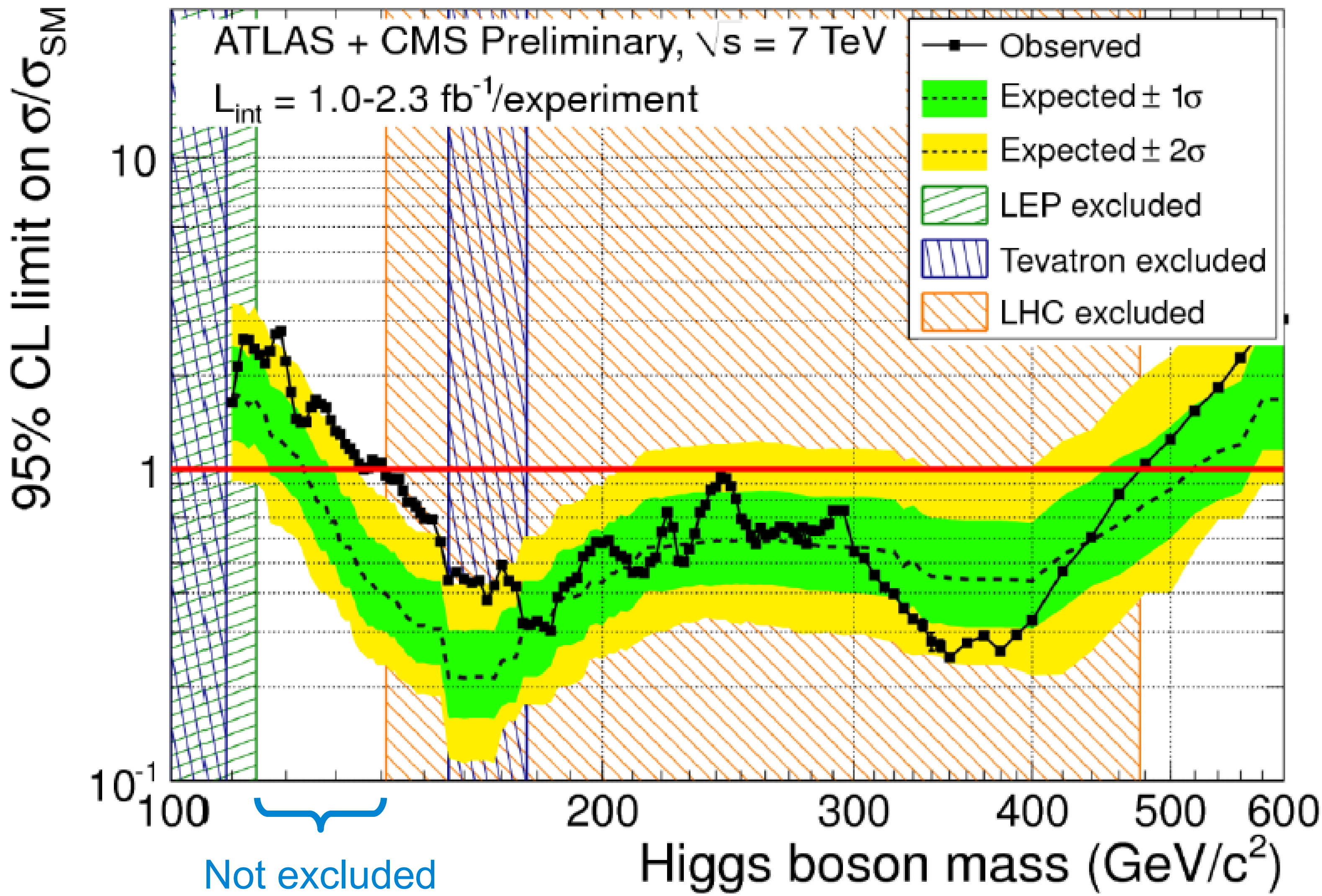


Most likely value of mH at ~125 $^{+8}_{-10}$ GeV

Status of Higgs Boson Searches Summer 2011

ATLAS-CONF-2011-157

ATLAS+CMS combination after Lepton-Photon conference



SM Higgs boson excluded for m_H >141 GeV and m_H < 476 GeV

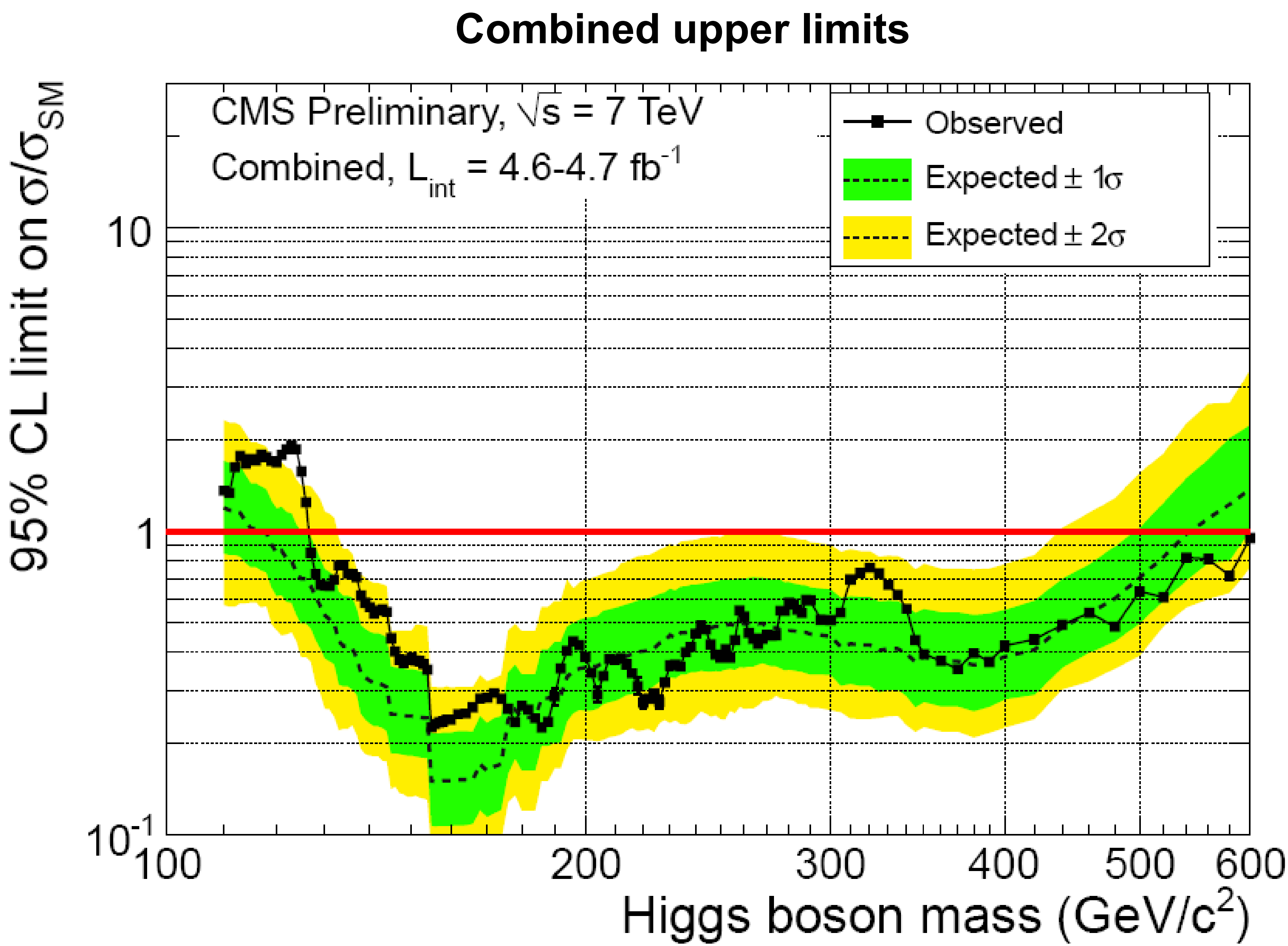
Constrain from below: LEP limit (114.4 GeV)

Comparison to CMS

Channels entering into the combinations

Channel	Lumi [fb^{-1}] ATLAS	Lumi [fb^{-1}] CMS	Mass range ATLAS [GeV]	Mass range CMS [GeV]	Remark
$H \rightarrow \gamma\gamma$	4.9	4.7	110-150	110-150	Categories: ATLAS: 9 CMS: 4
$H \rightarrow bb$	-	4.7	-	110-135	CMS: MVA
$H \rightarrow \tau\tau$	1.1	4.6	100-150	110-145	
$H \rightarrow WW \rightarrow l\nu l\nu$	2.1	4.6	110-300	110-600	ATLAS: 0/1 j CMS: 0/1/2 j
$H \rightarrow WW \rightarrow l\nu qq$	1.1	-	240-600	-	
$H \rightarrow ZZ \rightarrow 4l$	4.8	4.7	110-600	110-600	CMS: Looser cuts
$H \rightarrow ZZ \rightarrow llqq$	2.1	4.6	200-600	130-164 200-600	
$H \rightarrow ZZ \rightarrow ll\tau\tau$	-	4.7	-	190-600	
$H \rightarrow ZZ \rightarrow ll\nu\nu$	2.1	4.6	200-600	250-600	

Comparison to CMS



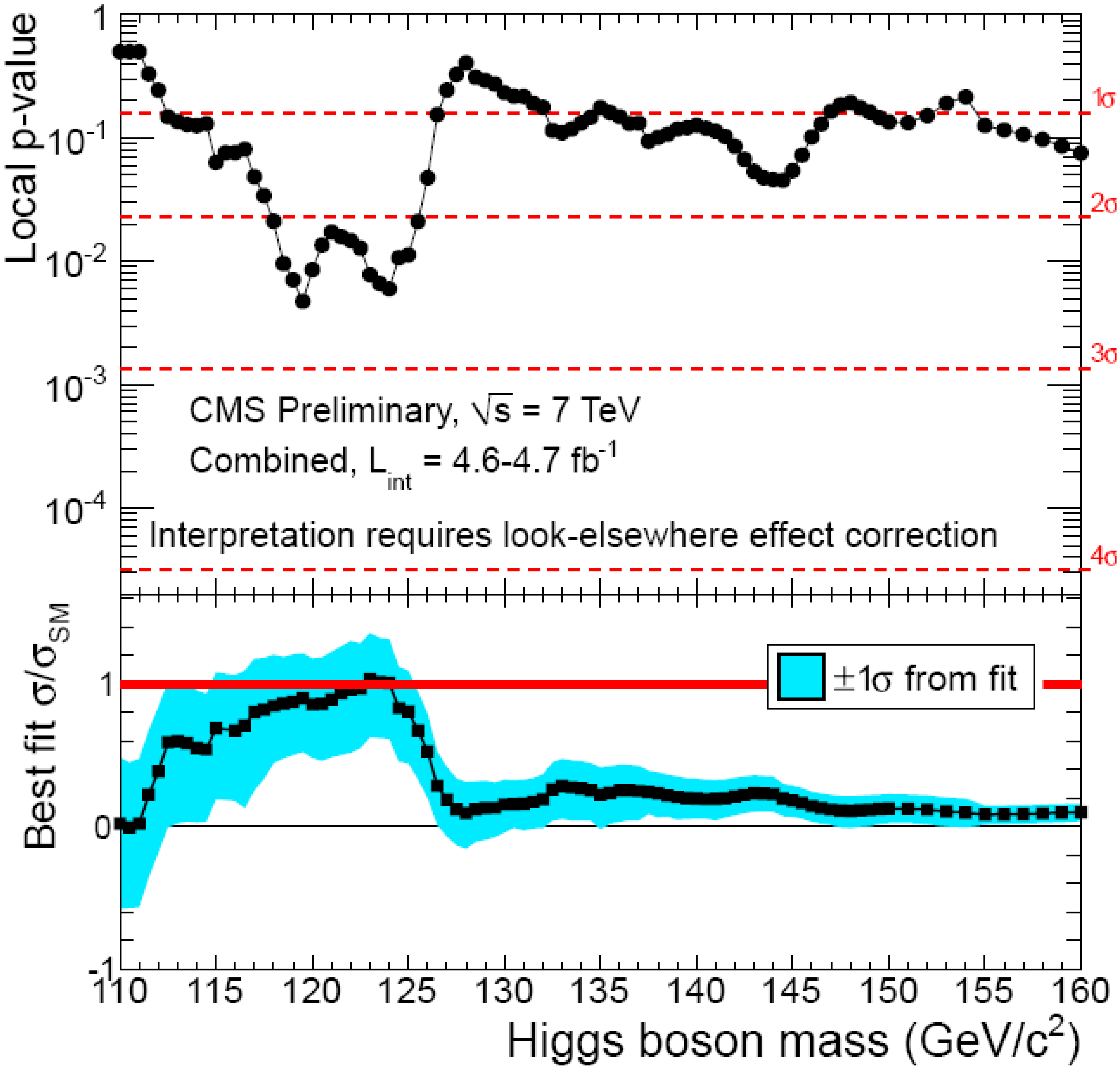
Observed 95% CL. exclusion: 127 – 600 GeV

Expected 95% CL. Exclusion: 117 – 543 GeV

Observed 99% CL. exclusion: 128 – 525 GeV

Comparison to CMS

Local p_0 and signal strength



Broad excess in non-excluded mass range.

Two narrow excesses seen:

119 GeV (4l), 124 GeV (γγ)

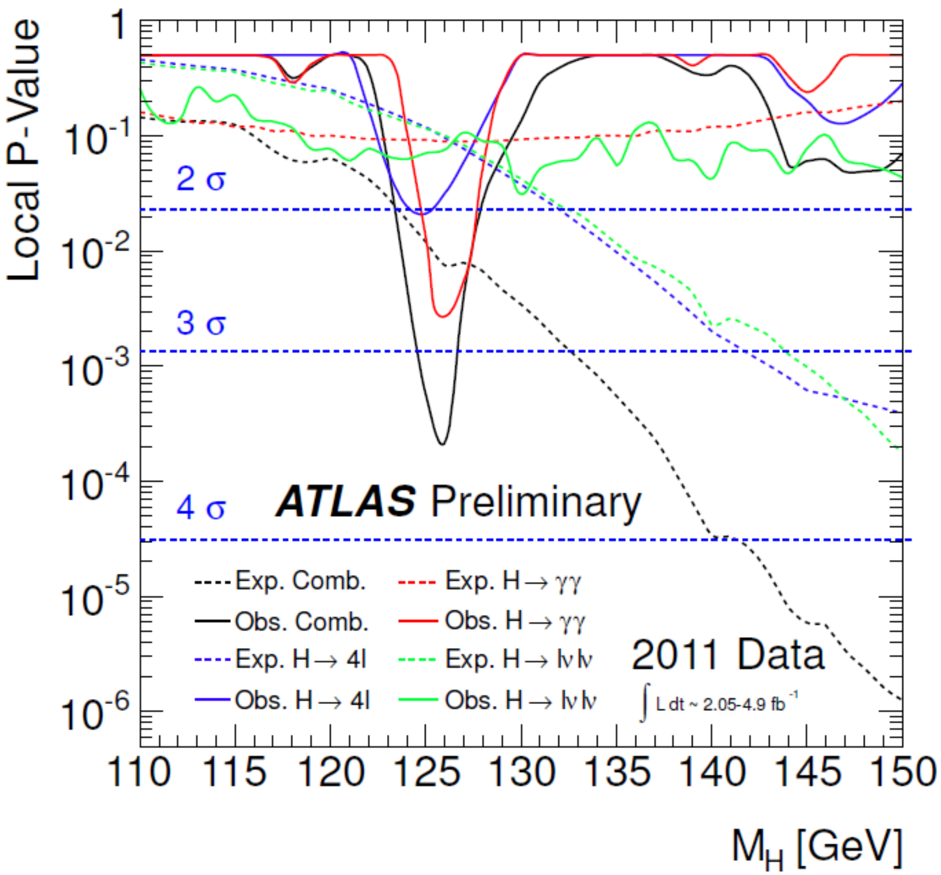
Minimal p_0: 0.5% (2.6σ)

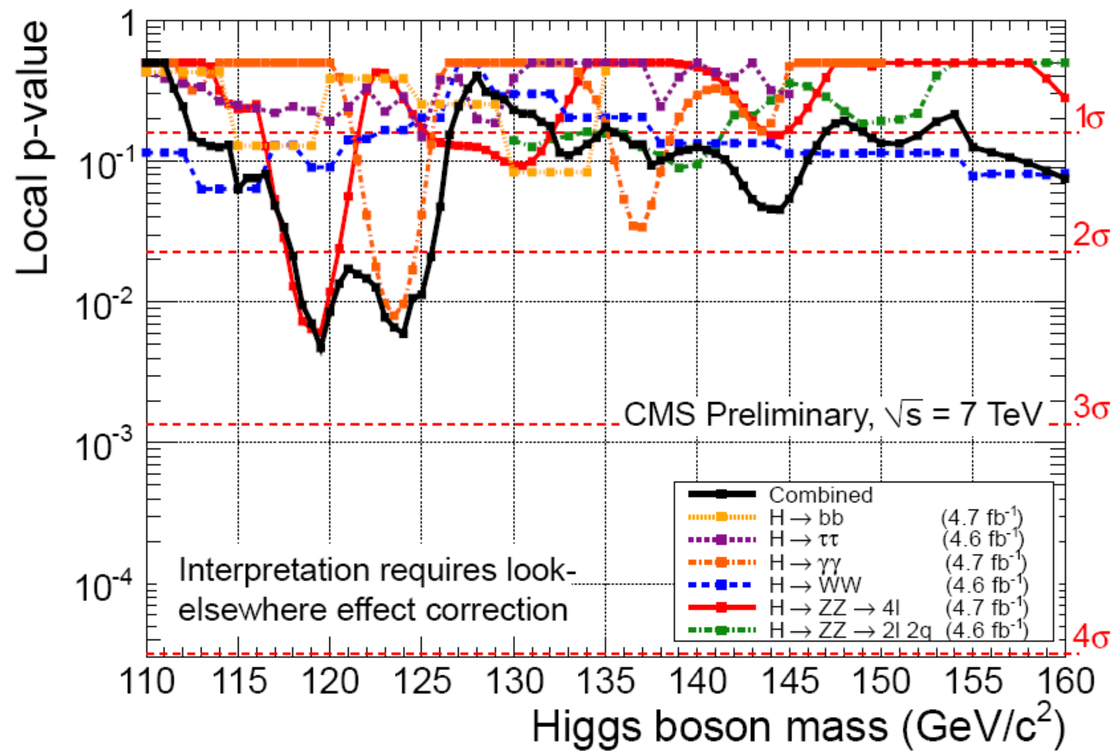
Global p_0 = 0.6σ (110-600 GeV)
or 1.9σ (110-145 GeV)

Fitted signal strength is consistent with 1 within ±1σ in low mass region.

Comparison to CMS

Low mass p_0

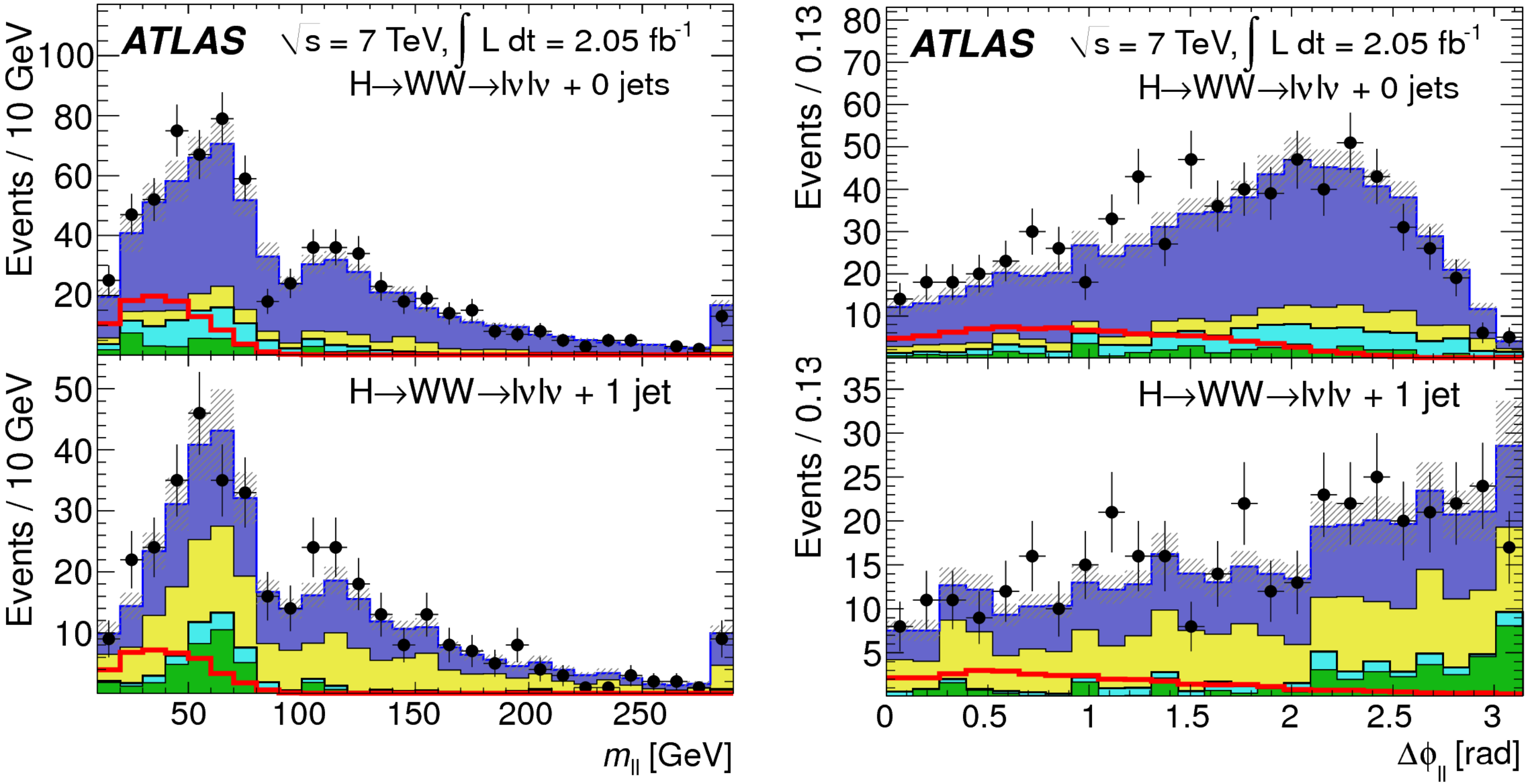




- Both experiments „not inconsistent with SM Higgs boson hypothesis“ each
- **How compatible are the two experiments with each other? 2012 data will tell!**

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

Kinematic distributions



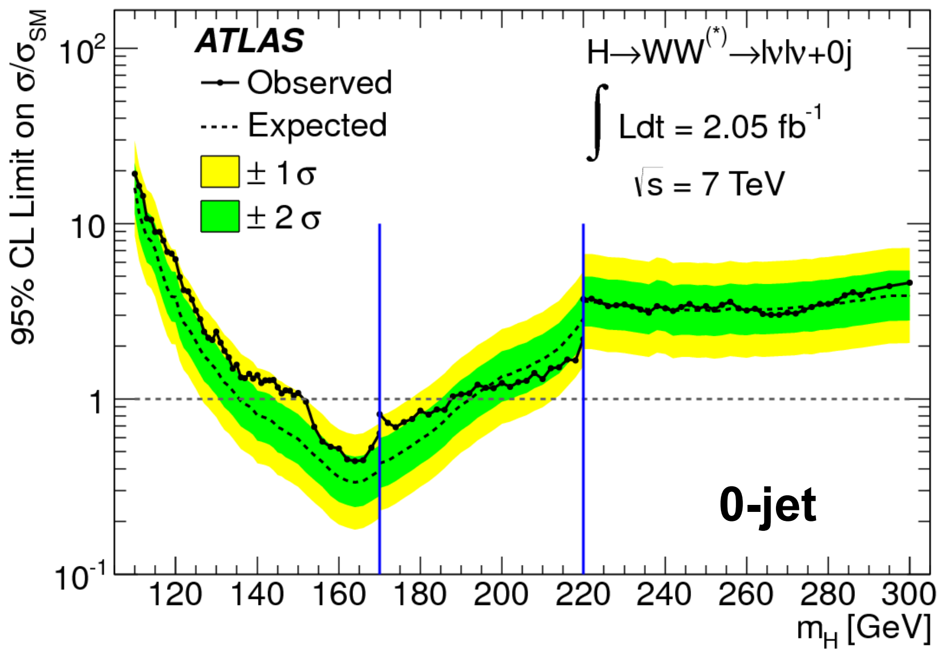
After cut on dilepton pT (total pT) in 0 (1) jet bin

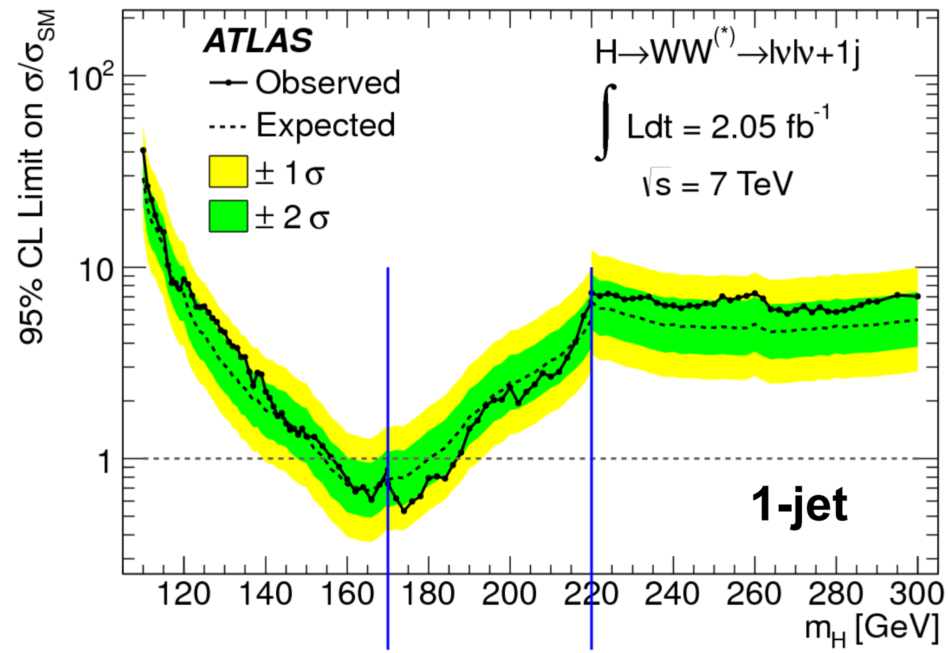
Systematic uncertainties

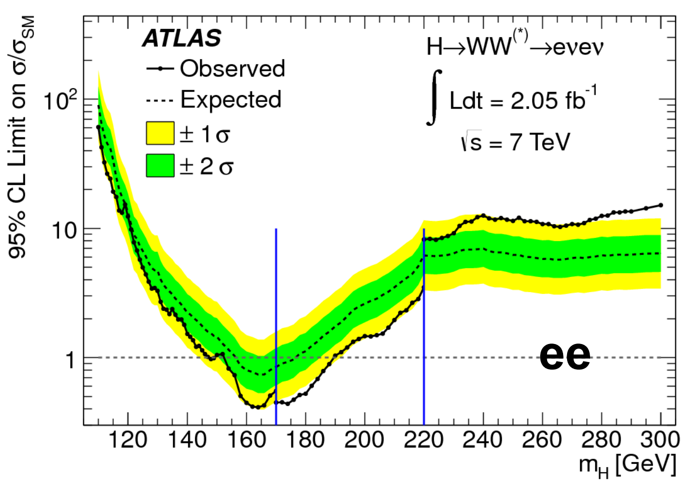
- Luminosity: $\pm$ 3.7%
- Cross sections (15-20%, 3-9% VBF, 3-4% W/ZH)
- Extra uncertainty assigned for exclusive jet bins (10% in 0-jet bin, 20% in 1-jet bin)
- Jet energy scale: 10% $\oplus$ 7% due to pile-up
- Lepton efficiency uncertainties: 2-5% (e) or 0.3-1% (μ)
- B-tagging efficiency: 6-15%, mistagging rate: 21 %
- 13% uncertainty on Etmiss measurement
- WW background normalization: 7.6% (21%) in 0-jet (1-jet) bin
- Top background normalization: ~38%

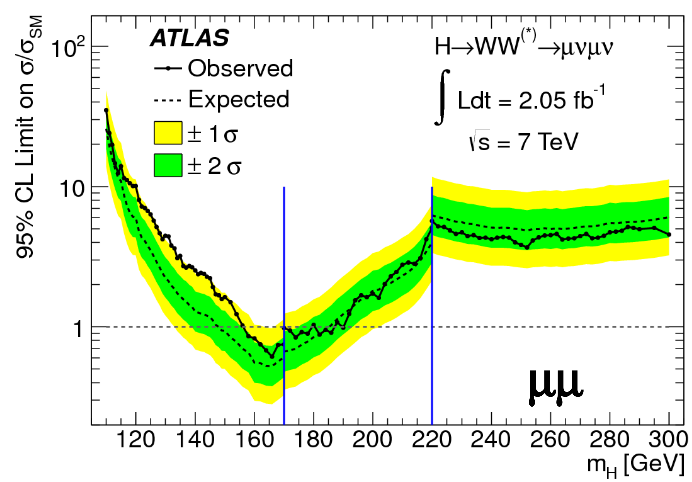
$H \to W W^{(*)} \to l\nu l\nu$

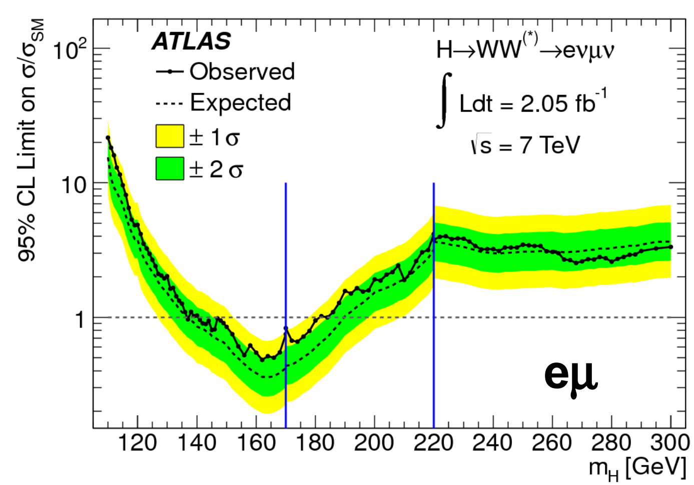
Results for all subchannels









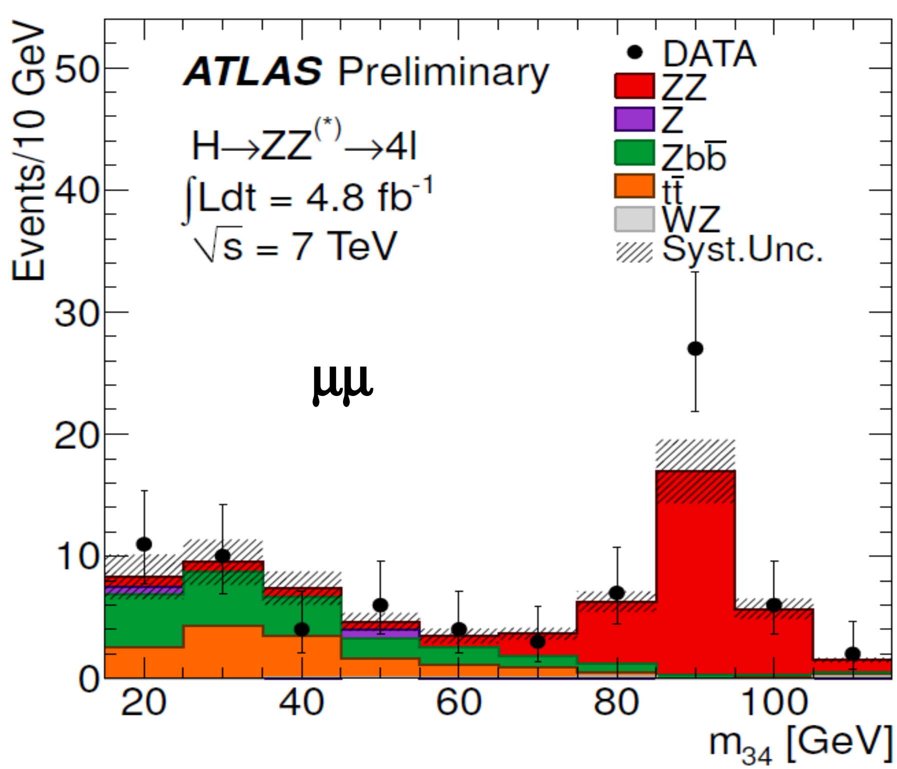


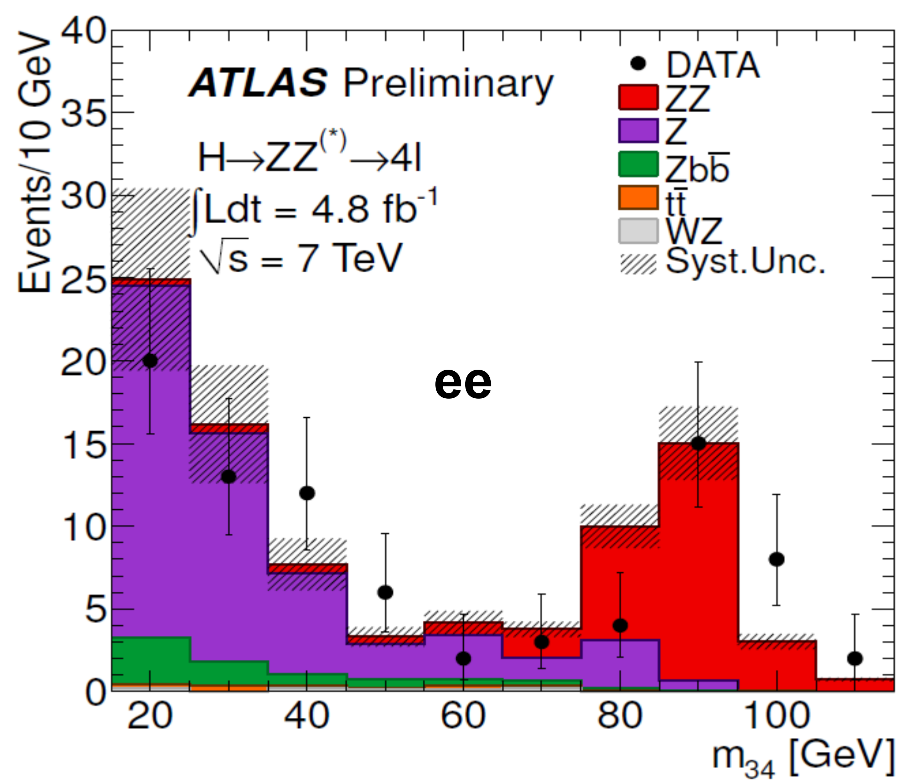
Background control and systematic uncertainties

- Dominant background: $ZZ^{(*)}$ continuum
  Shape and normalization estimated from MC, 15% uncertainty assigned
- Top-pairs checked on control region, 10% uncertainty on $t\bar{t}$ cross section
- Z+jets normalization from control region
  45% uncertainty on Z+light jets and 40% uncertainty on $Zb\bar{b}$ normalization

Background composition checked in a control region:

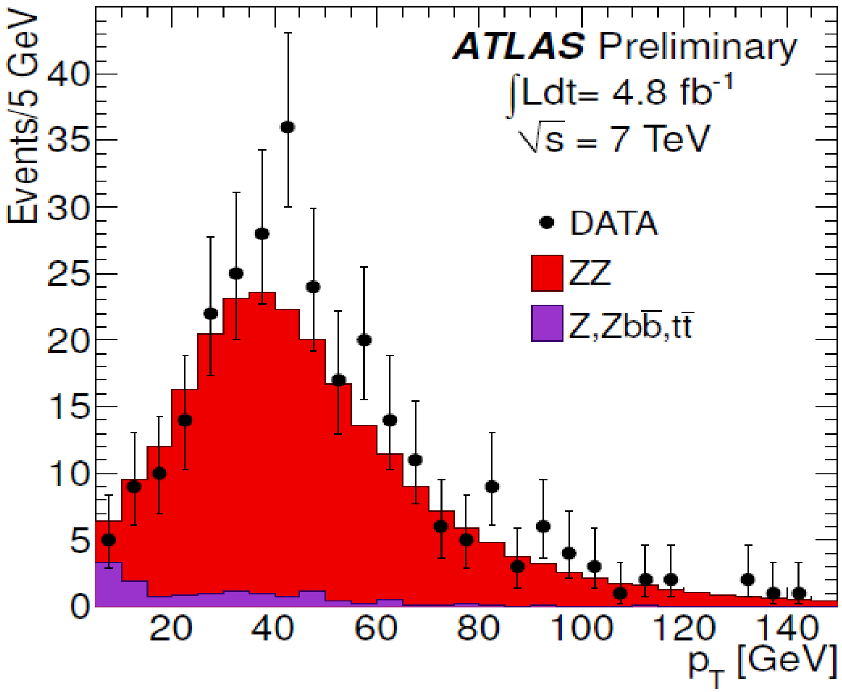
No charge, isolation and impact parameter requirements on second lepton pair

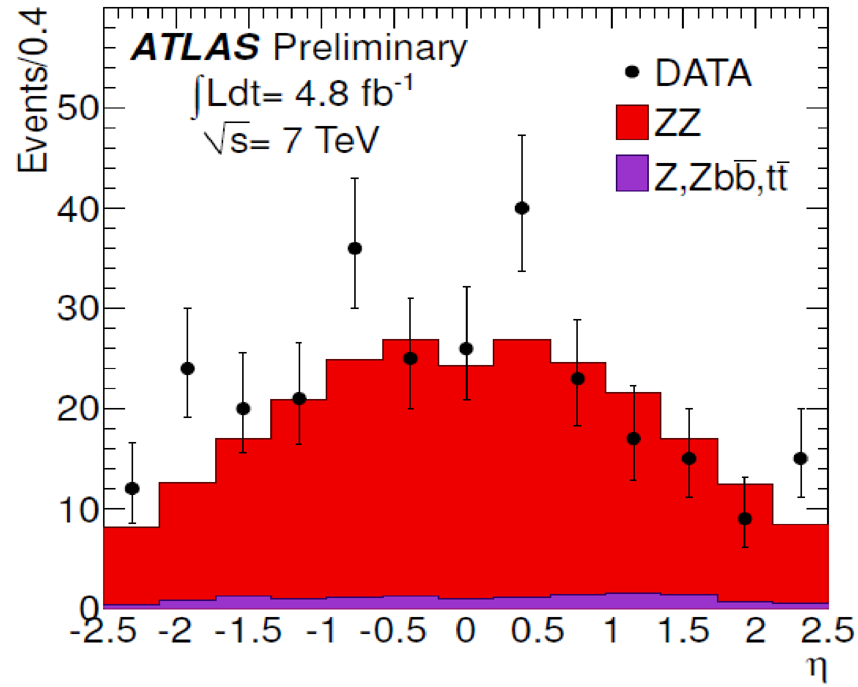




$H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ 4.8 fb^{-1}

pT and η of leptons of the selected events:





Uncertainties on lepton reconstruction and identification

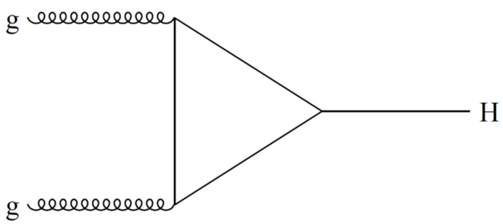
- Estimated from data with W, Z and J/Ψ events
- Signal and background accpetance uncertainties coming from μ uncertainties: 0.22% (4μ) and 0.16% (2e2μ) over full mass range
- Acceptance uncertainties coming from e uncertainties: Between 2.3% (4e) and 1.6% (2e2μ) at high mass, up to 8.0% and 4.1% at low mass

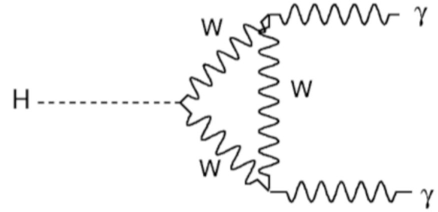
Further signal systematics:

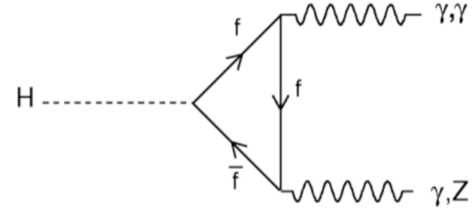
- Cross sections 15-20%, 3-9% VBF, 3-4% W/ZH
- 2% on signal acceptance by kinematic selection
- Luminosity uncertainty: ±3.9%

$H \to \gamma\gamma$ $4.9\ fb^{-1}$

Signal processes:





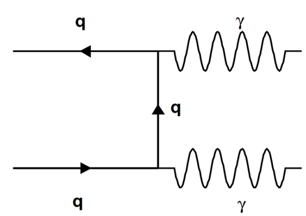


Dominantly by gluon fusion

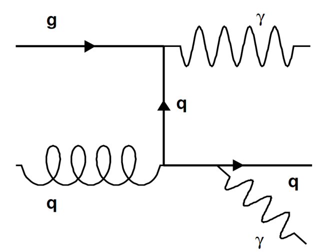
Vector-boson-fusion (VBF) and associated production (WH, ZH, $t\bar{t}H$) also considered

Background processes:

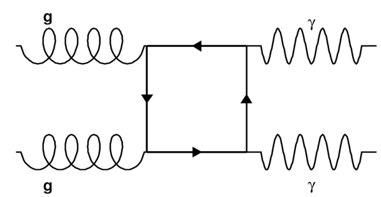
Irreducible $\gamma\gamma$ background



„Born“

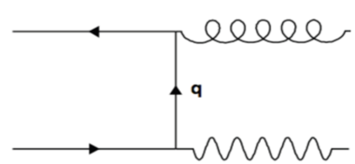


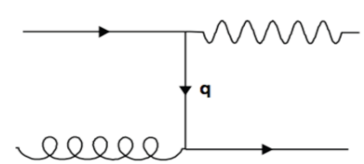
„Brem“



„Box“

Reducible QCD background





γ-Jet + Jet-Jet

Drell Yan (DY): $Z \to ee$ (both electrons mis-identified as γ)

Interference between $gg \to H \to \gamma\gamma$ and $gg \to \gamma\gamma$ accounted for (2-5% reduction of signal rate)

$H \rightarrow \gamma\gamma$ 4.9 fb^{-1}

Inclusive data sample composition

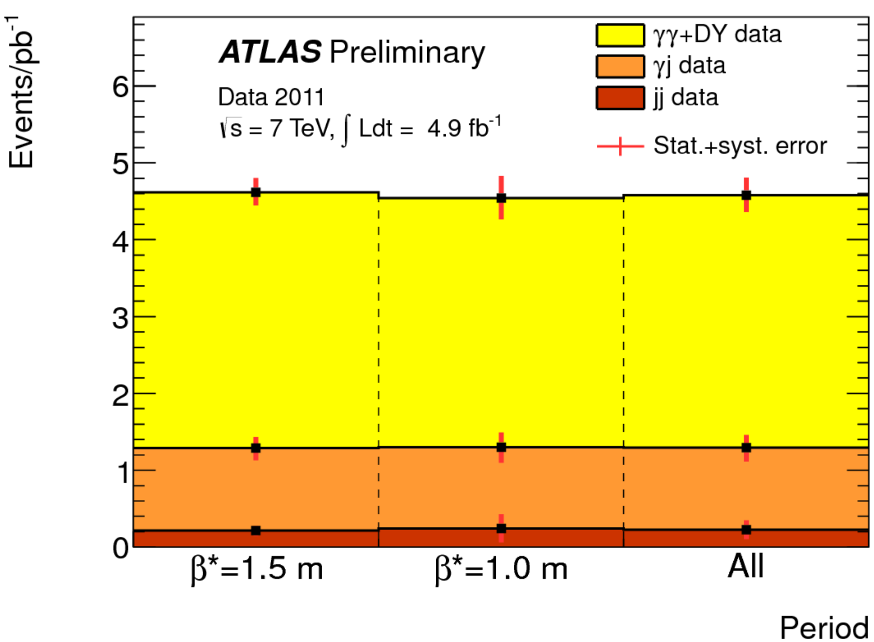
Evaluated with „double ABCD“ method

1st error: statistical, 2nd error: systematic uncertainty

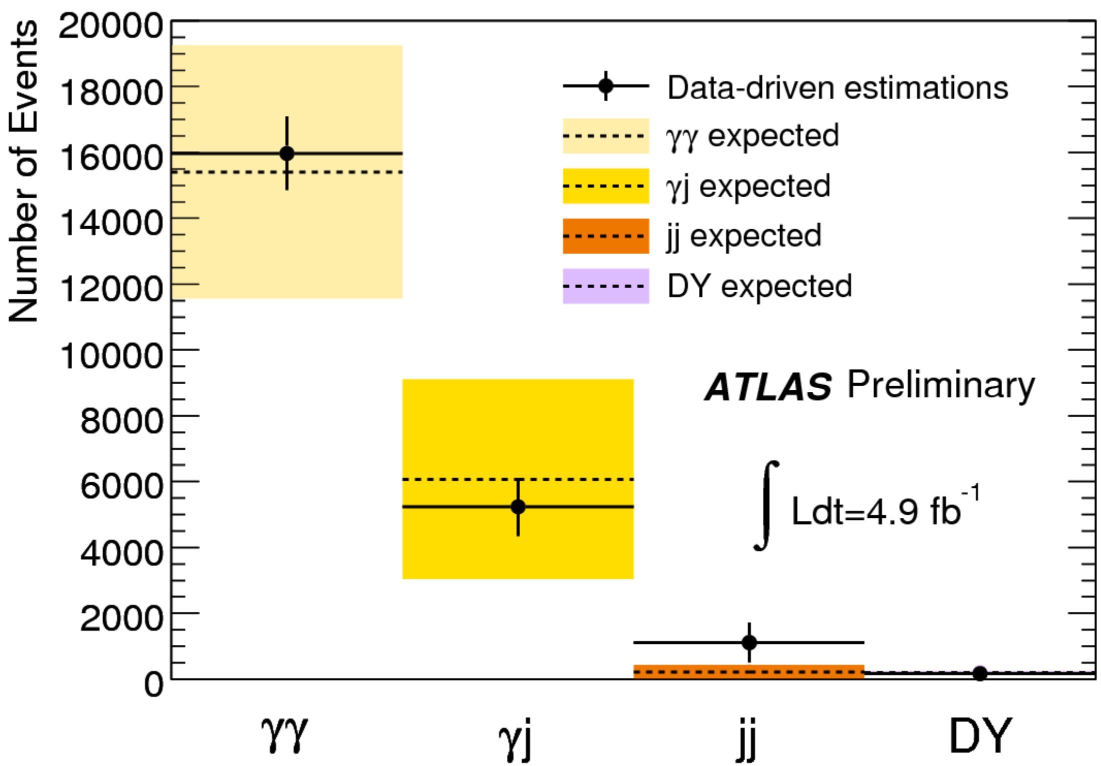
Composition	$\gamma\gamma$	γj	jj	DY
Events	$16\,000 \pm 200 \pm 1\,100$	$5\,230 \pm 130 \pm 880$	$1\,130 \pm 50 \pm 600$	$165 \pm 2 \pm 8$
Relative Fraction	71%	23%	5%	1%

$\gamma\gamma$ dominant

Excellent stability of the composition over large data taking period of 2011:



Comparison to MC predictions



Systematic uncertainties

Signal

Signal yield: ~20%
Dominated by uncertainties on cross sections and photon ID efficiencies.

Signal resolution: 14%
Dominated by calorimeter energy resolution

Signal migration among categories: 4.5%, 8%

Not included in nominal result:
Photon energy scale uncertainties → Uncertainty on the mass position of ~0.7 GeV

Background

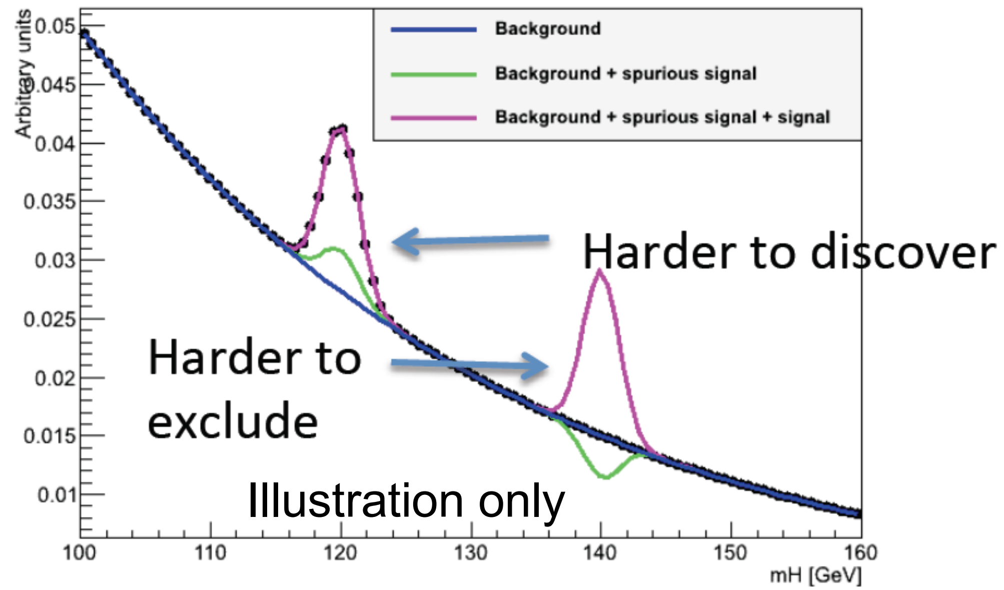
Uncertainty due to imperfect modelling of the true background shape: ±(0.1-5.6) events

Background Uncertainties

Uncertainty due to imperfect modelling of the true background shape: ±(0.1-5.6) events

Evaluated residual of true shape and the model with large quantities of RESBOS diphoton events

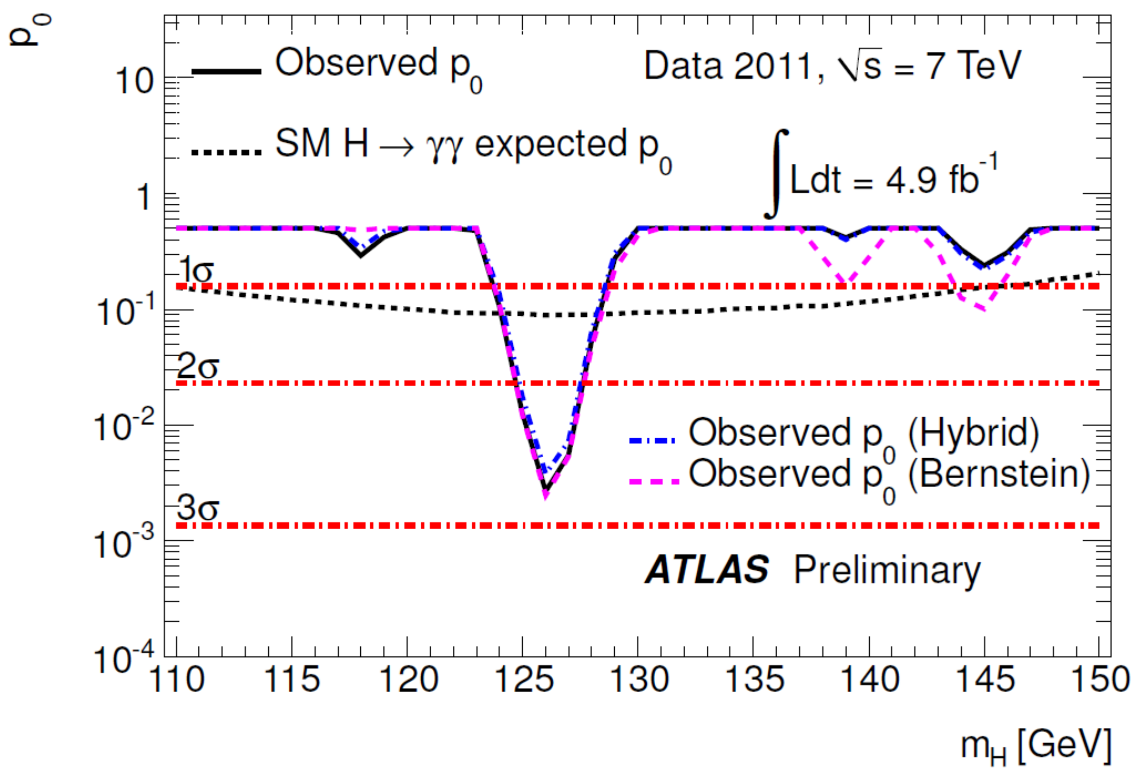
Attributed this uncertainty to an extra term with signal shape (worst case)



Uncertainty in number of events per category:

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

Alternative background models:



„Hybrid“: High pTt categories fit with Bernstein

„Bernstein“: All categories fit with Bernsetin

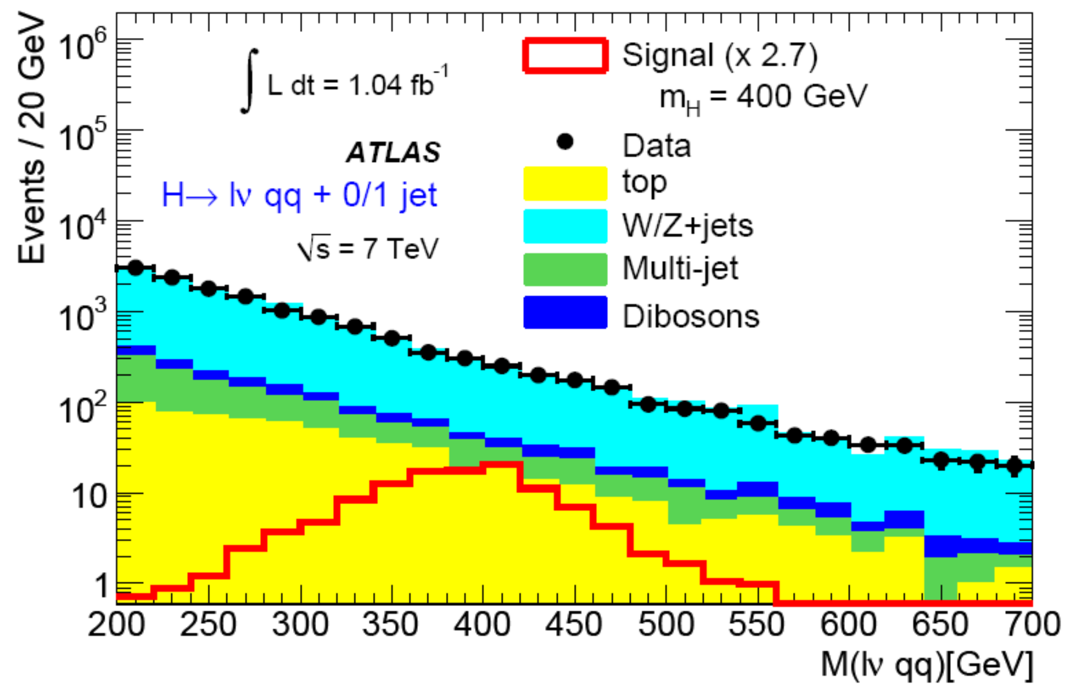
(Default: Fit with signle exponential)

$H \to WW \to l\nu qq$ 1.04 fb^{-1}

arXiv:1109.3615

Event selection:

- Isolated e or μ with $p_T > 30$ GeV
- $E_T^{miss} > 30$ GeV
- $|m_{qq} - m_W| < 10$ GeV
- Reject events with b-jets
- Split into 0 and 1 extra jet analyses

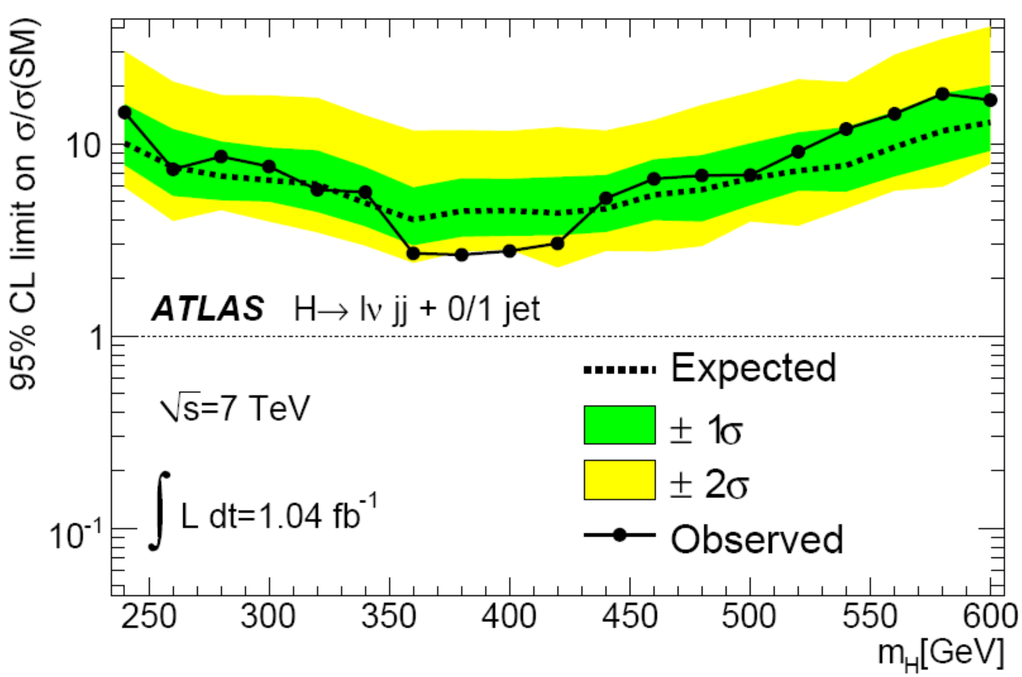


Mass reconstruction:

Constraint: $m(l\nu) = m(W)$

Rejects 45% of BG and 36% of signal

Mass resolution : 7.5% (for m_H=400 GeV)



Sample composition studied with MC and data (Multijet and W/Z data-driven)

Limits from **double exponential fit** to the mass

Dominant uncertainties:
Jet energy scale and jet resolution

Data	Total BG	m_H=400 GeV
41 687	42 600 ± 1 200	58 ± 15

$H \to WW \to l\nu qq$ 1.04 fb^{-1}

Event selection:

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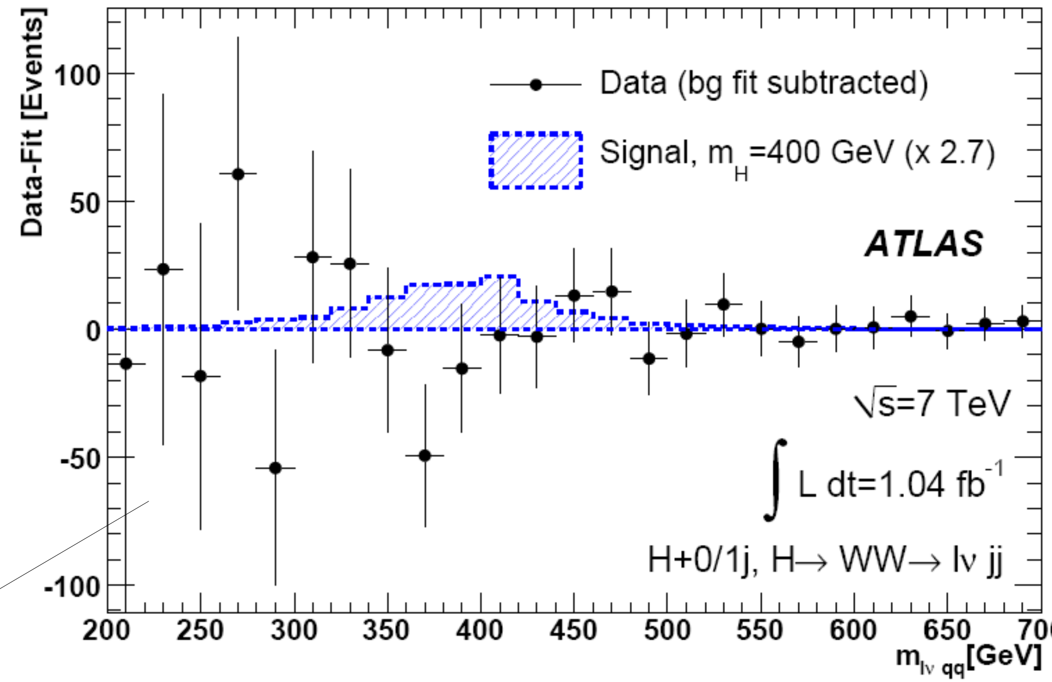
arXiv:1109.3615



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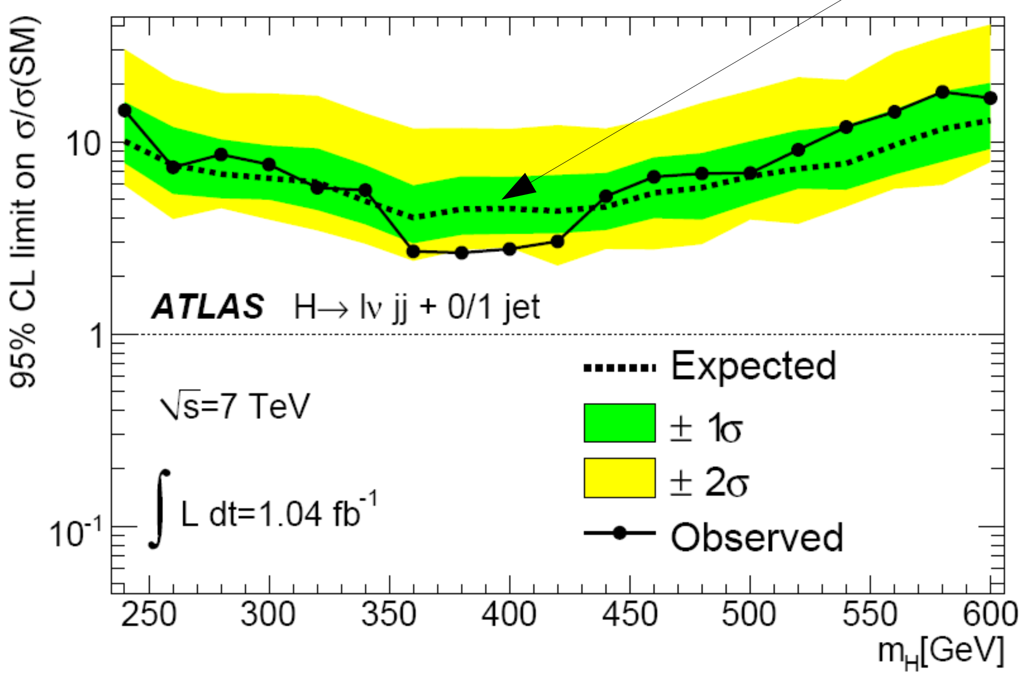


Sample composition studied with MC and data (Multijet and W/Z data-driven)

Limits from **double exponential fit** to the mass

Dominant uncertainties:
Jet energy scale and jet resolution

Data	Total BG	m_H=400 GeV
41 687	42 600 ± 1 200	58 ± 15

$H \rightarrow \tau\tau \rightarrow \tau_{lep}\tau_{lep}$ / $\tau_{lep}\tau_{had}$ 100 GeV < m_H < 150 GeV 1.06 /fb

ATL-CONF-2011-132,133,135

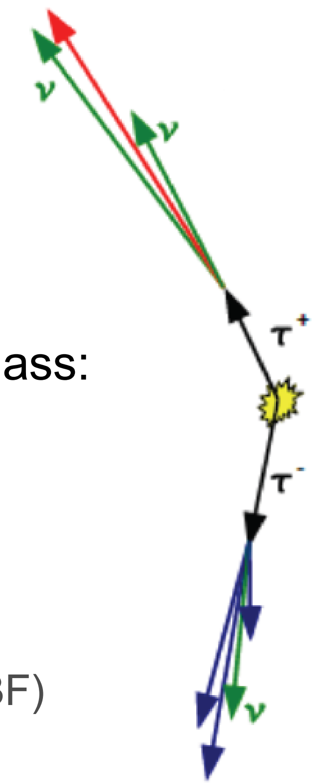
$\tau\tau \rightarrow ll + 4\nu$

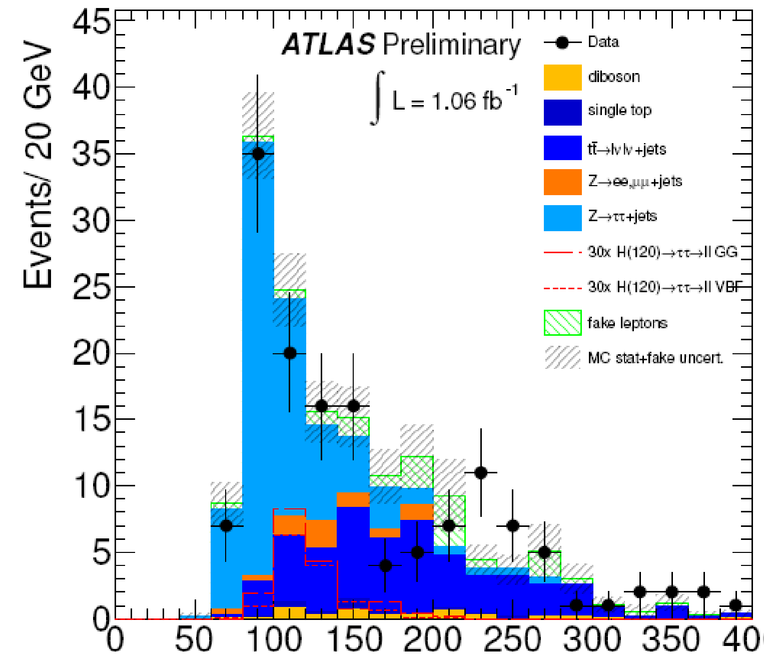
- Two isolated OS leptons
- Require a high p_T jet to boost the system
- Cuts on $\Delta\Phi(ll)$, $m_{\tau\tau j}$, m_{ll}
- Collinear approximation to reconstruct $\tau\tau$ mass:

$$m_{\tau\tau} = \frac{m_{vis}}{\sqrt{x_1 x_2}}$$

x is momentum fraction of visible decay products

- Mass resolution m_H=120 GeV ~ 24 GeV (bit less for VBF)

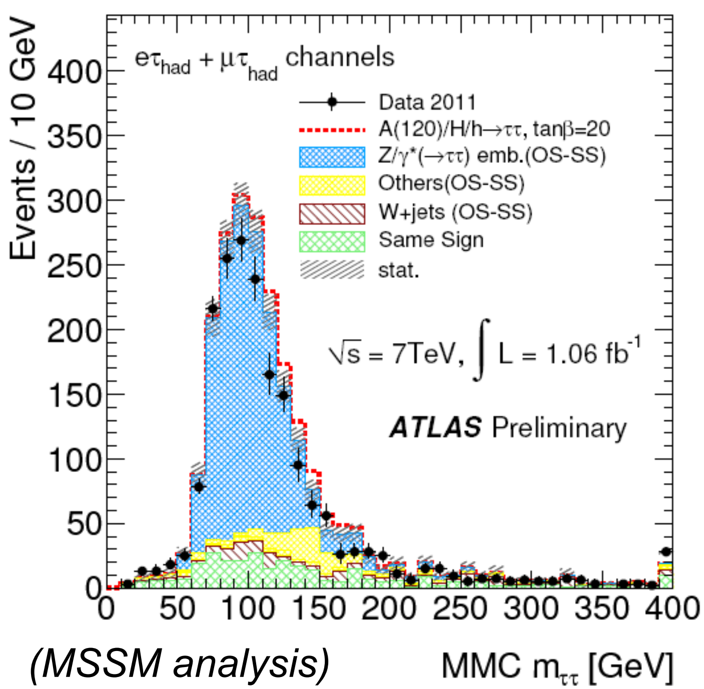




(dileptons)

$\tau\tau \rightarrow l\tau_{had} + 3\nu$

- More background (from fake τ): W, QCD
- τ pT: 20 GeV, neural net based τ ID
- MET > 20 GeV, m_T < 30 GeV
- Stronger at higher masses



(MSSM analysis)

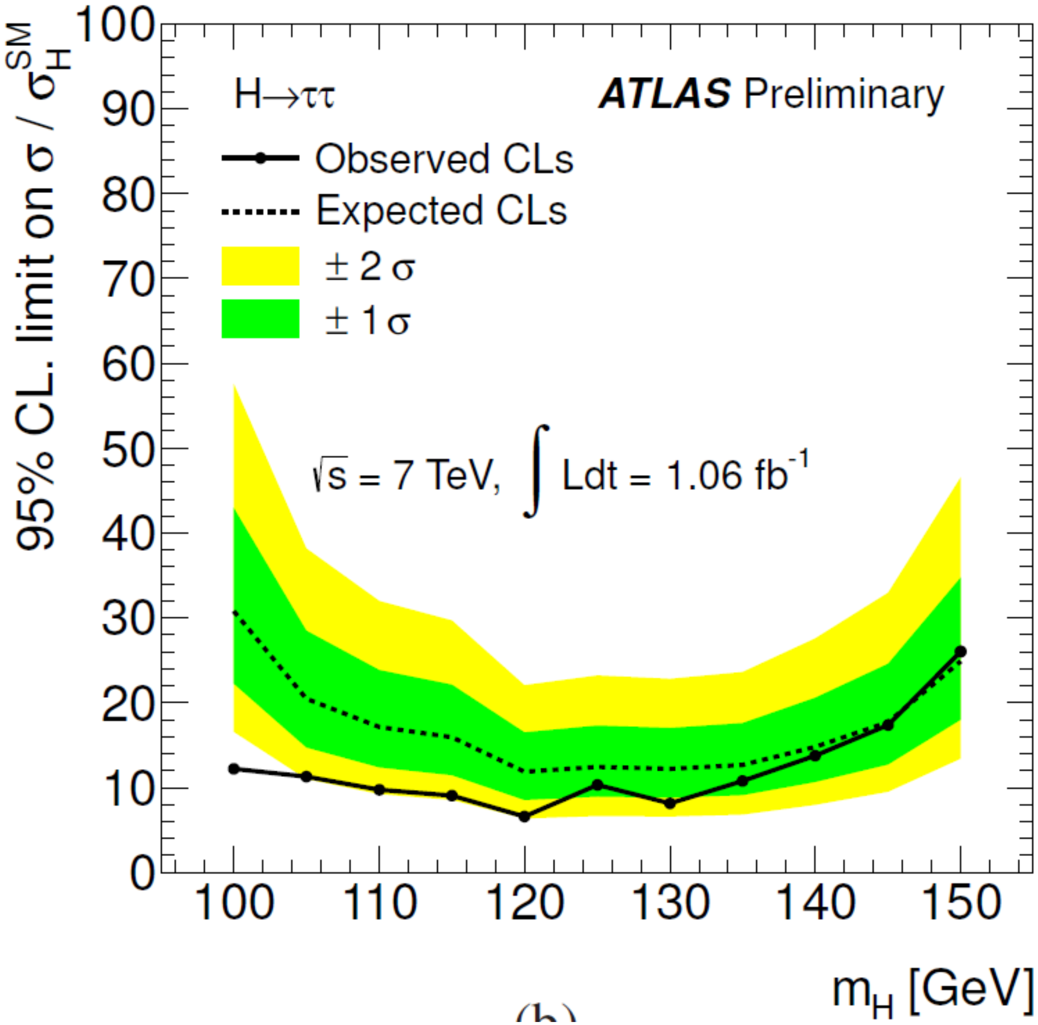
Missing Mass Calculator arXiv: 0901.0512

Background control:

- Irreducible $Z \to \tau\tau$ shape from τ embedding into $Z \to \mu\mu$ data events arXiv: 1107.5003v1
- Fake lepton backgrounds from control sample

Results:

leplep+lephad



Dilepton channel:

Data	Total BG	m_H=120 GeV
46	47.4±4.9	0.8

(ggF and VBF)

Dominant systematic uncertainties:

Jet and τ energy scale, τ ID and MET

Results of MSSM h/A/H $\to \tau\tau$ in backup slides.

Future: Dedicated VBF analysis.

ATL-CONF-2011-103

W/Z associated. Largest branching fraction at low mass, but huge backgrounds.

Event Selection:

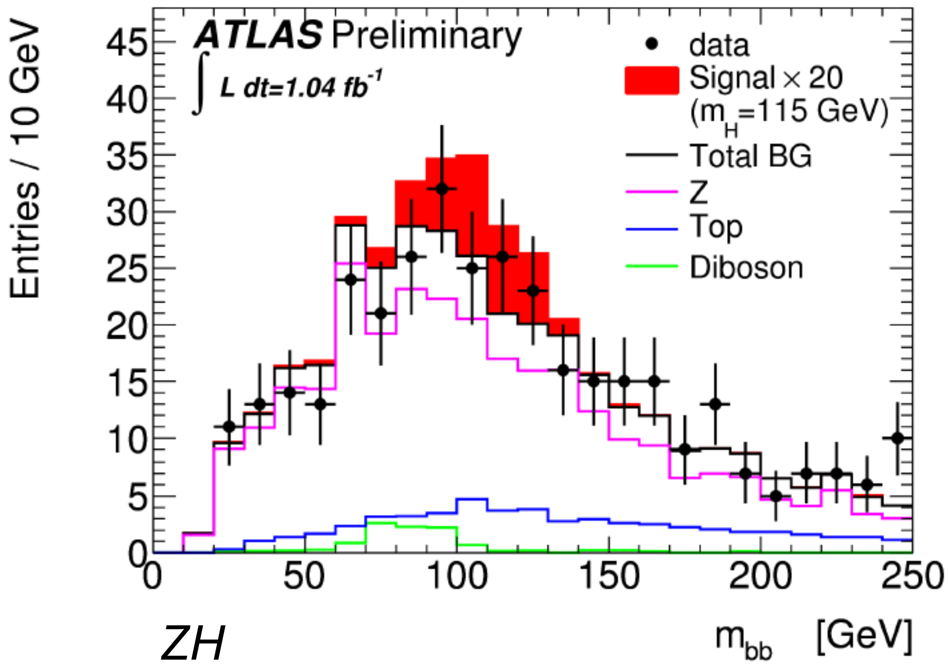
- Single lepton triggers: μ18, e20
- At least two jets with p_T > 25 GeV within $|\eta|$<2.5, two highes p_T jets b-tagged

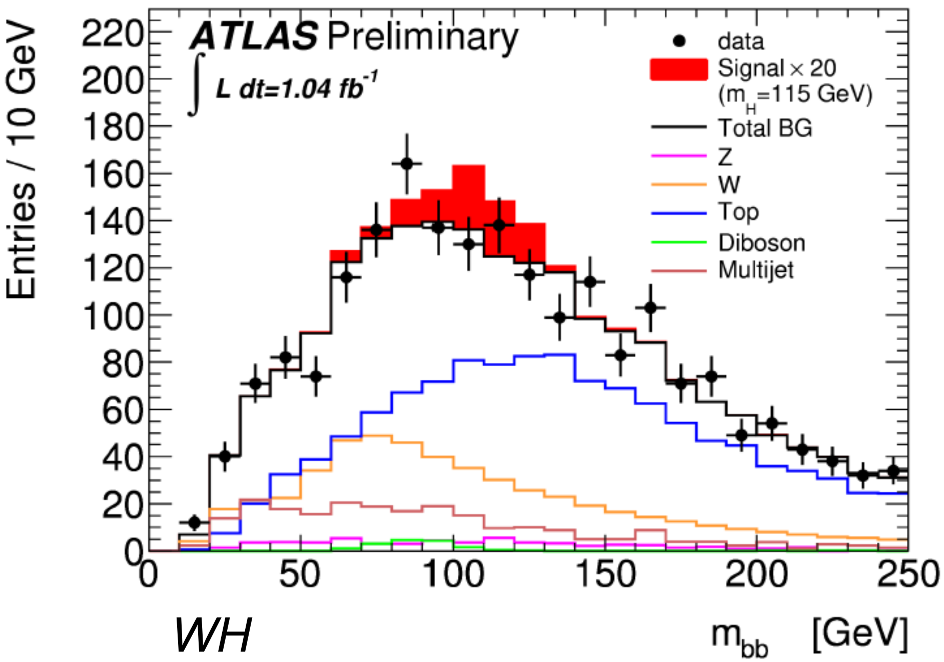
ZH $\to$ llbb

- Two isolated leptons (e/μ), p_T>20 GeV
- MET < 50 GeV (rejects top)
- $|m_{ll}-m_z|$ < 15 GeV

WH $\to$ lνbb

- One isolated lepton (e/μ) p_T > 25 GeV
- MET > 25 GeV
- m_T > 40 GeV $m_T = \sqrt{2p_T^\ell p_T^\nu(1 - cos(\phi^\ell - \phi^\nu))}$





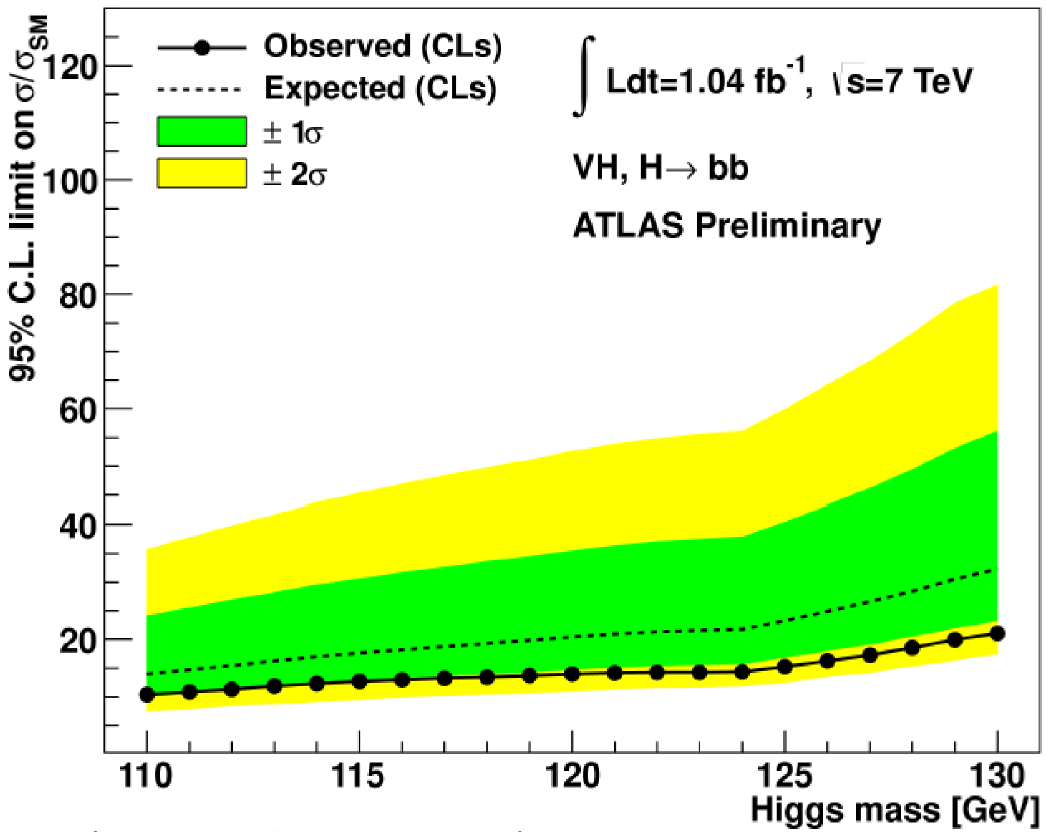
$H \rightarrow b\bar{b}$ 110 GeV < m_H < 130 GeV 1.04 /fb

Background Control:

All background checked on data using control samples.

Typically: Shape from MC, normalization from a sideband. $W_{b\bar{b}}$ and QCD shape from data.

Results:



(WH and ZH combined)

	Data	Total BG	m_H=120 GeV
ZH	329	325±8±28	1.6
WH	1 888	1 877±14±147	4.5

Dominant systematic uncertainties:

Jet energy scale: 2-7 %
Jet energy resolution: 5-12 %
B-tagging efficiency: 5-14 %
Mistagging rate: 8-12 %

Future: Boosted Higgs at high p_T, use jet substructure

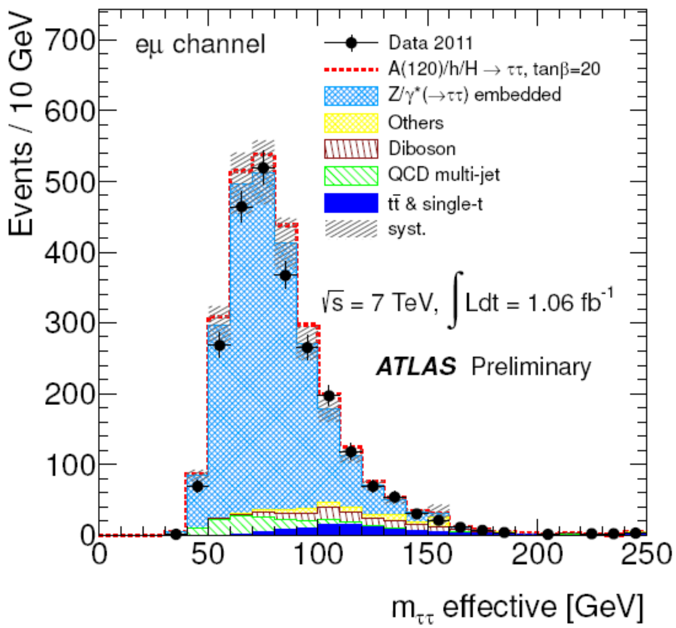
MSSM h/A/H → ττ 100 GeV < mA < 600 GeV 1.06 /fb

ATL-CONF-2011-132

In SUSY coupling to vector bosons supressed/absent.
Enhanced coupling to down-type fermions, ~tanβ

Considered final states: eμ, $e\tau_h$, $\mu\tau_h$, $\tau_h\tau_h$

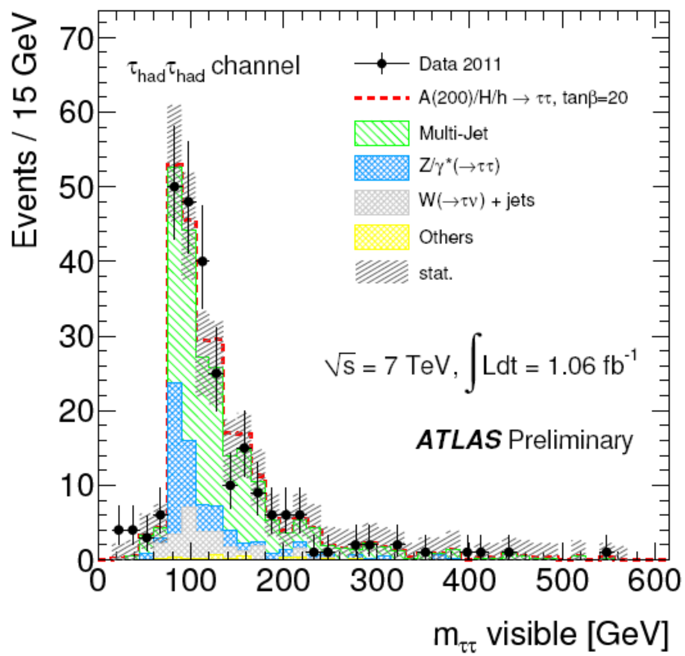
Leplep channel:



$$m_{\tau\tau}^{\text{effective}} = \sqrt{(p_{\tau^+} + p_{\tau^-} + p_{\text{miss}})^2}$$

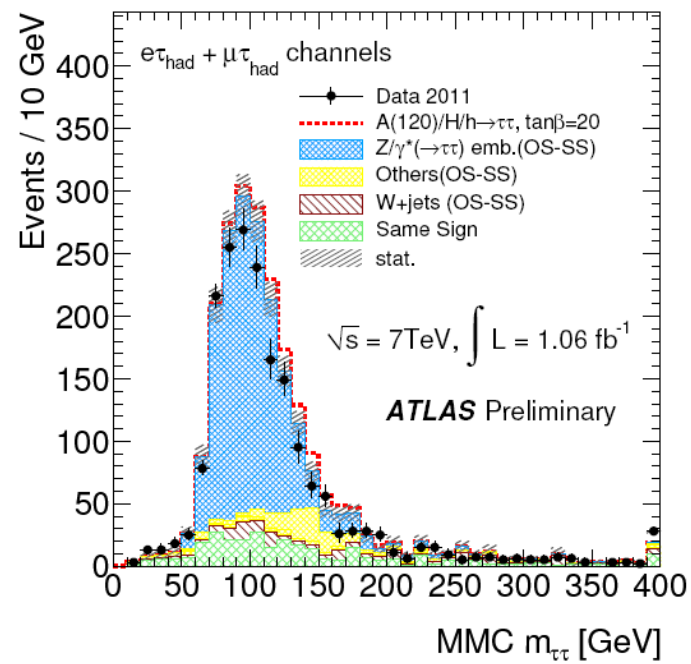
- Lepton pT cut trigger dependent: e (μ): 22 (10) GeV or 15 (20) GeV
- Sum lepton pT + MET < 120 GeV
- ΔΦ(eμ) > 2.0

Fully hadronic channel:



- Two-τ trigger
- Cut based τ ID
  τ pT > 45 (30) GeV
- MET > 25 GeV
- Veto events with high-pT leptons

Lephad channel



- Lepton pT: e (μ) 25 (20) GeV when more leptons in the event: e (μ) 15 (10) GeV
- τ pT: 20 GeV, τ ID BDT based
- MET > 20 GeV, mT < 30 GeV

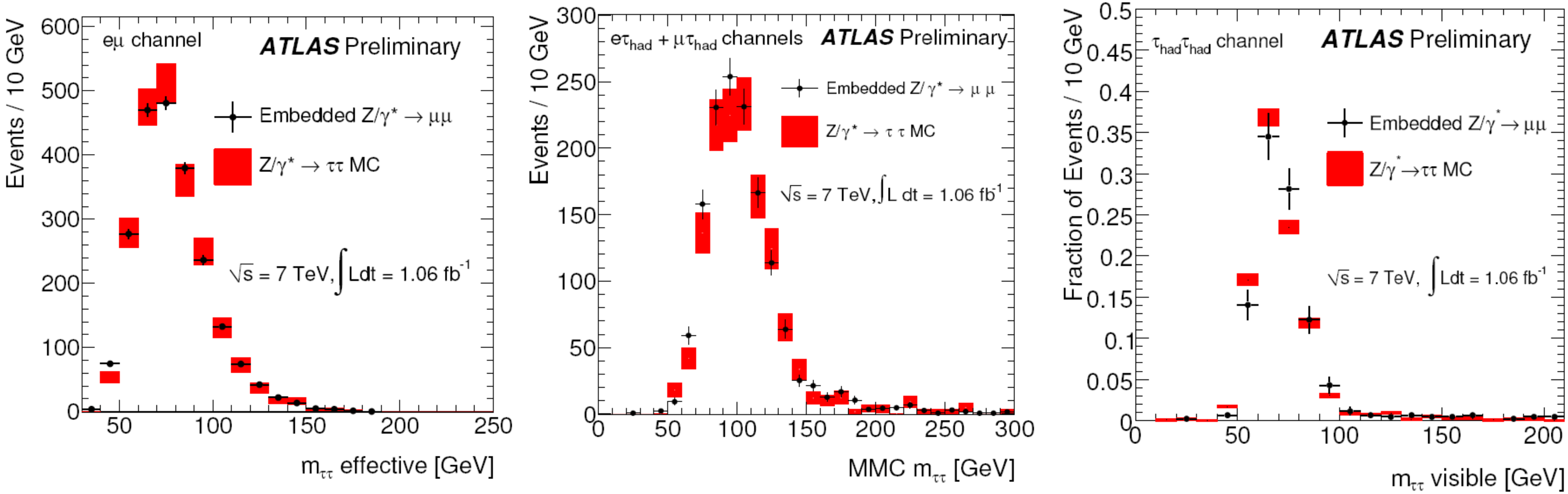
Missing Mass Calculator
arXiv: 0901.0512

MSSM h/A/H → ττ 100 GeV < mA < 600 GeV 1.06 /fb

Background control:

- **Z→ ττ from τ embedding into Z→ μμ data events**
- W+jets and QCD from SS mass shape in lephad channel
- QCD in fully hadronic channel from ABCD method (τ ID vs. charge product)

Leplep channel: Fully hadronic channel: Lephad channel



Systematic uncertainties:

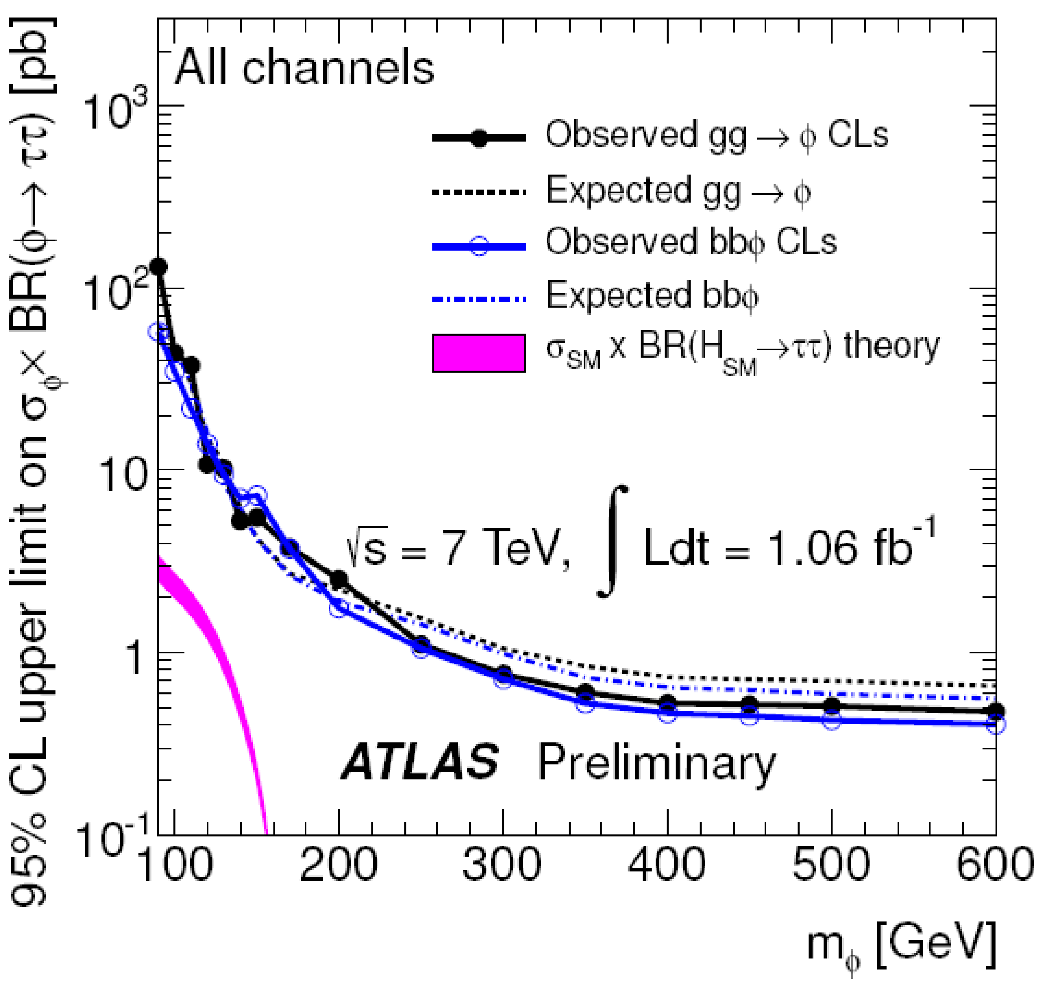
- Dominant τ_h ID efficiency & fake rate uncertainty: 10 %
- Also important: τ and jet energy scales and resolutions

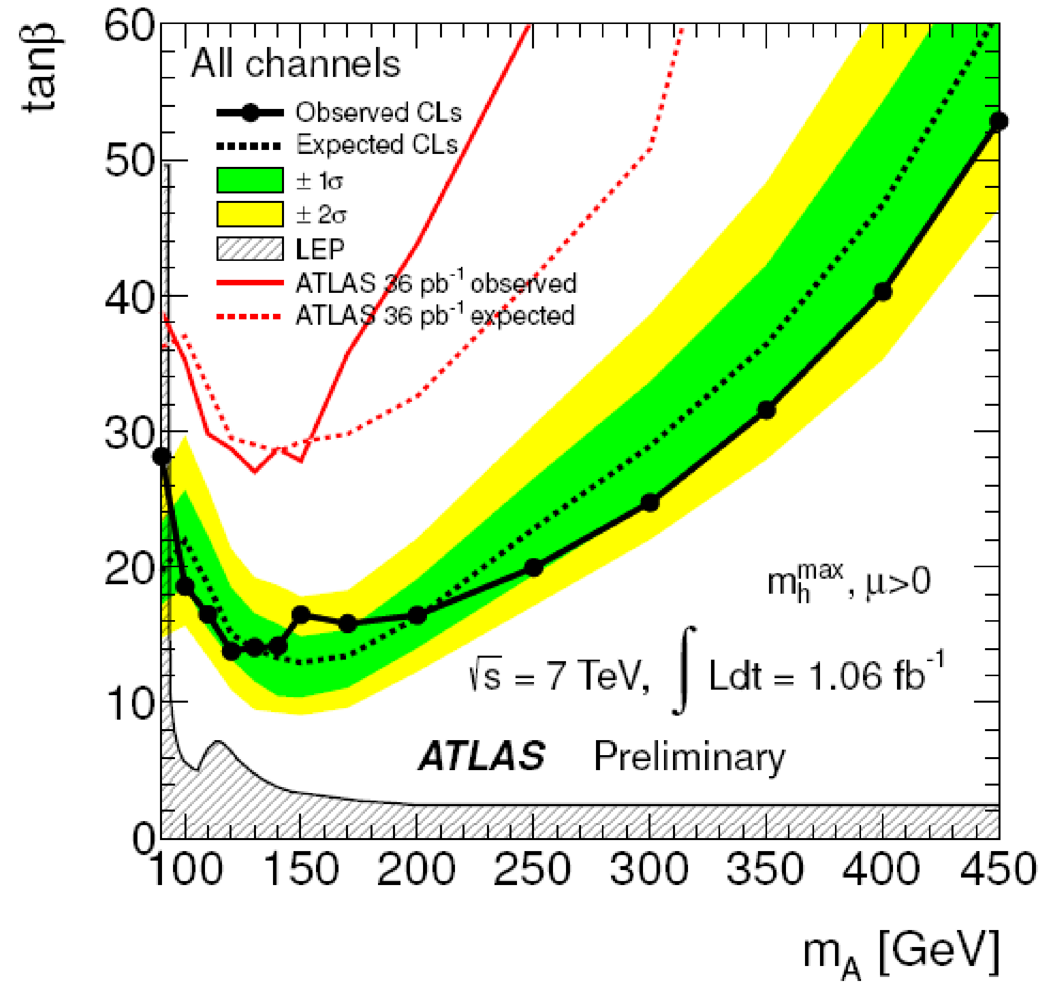
MSSM h/A/H → ττ   100 GeV < mA < 600 GeV   1.06 /fb

Results:

**ggF and b-associated production*

	Data	Total BG	Signal* tanβ=20
leplep	2 472	2 600 ± 200	mH=120 GeV:155±6
lephad	1 913	2 100 ± 400	mH=120 GeV:116±9
hadhad	245	233 +44 -28	mH=200 GeV:19±1





MSSM $H^+ \to \tau\nu$ 90 GeV < m_{H^+} < 160 GeV 1.03 /fb

ATLAS-CONF-2011-138

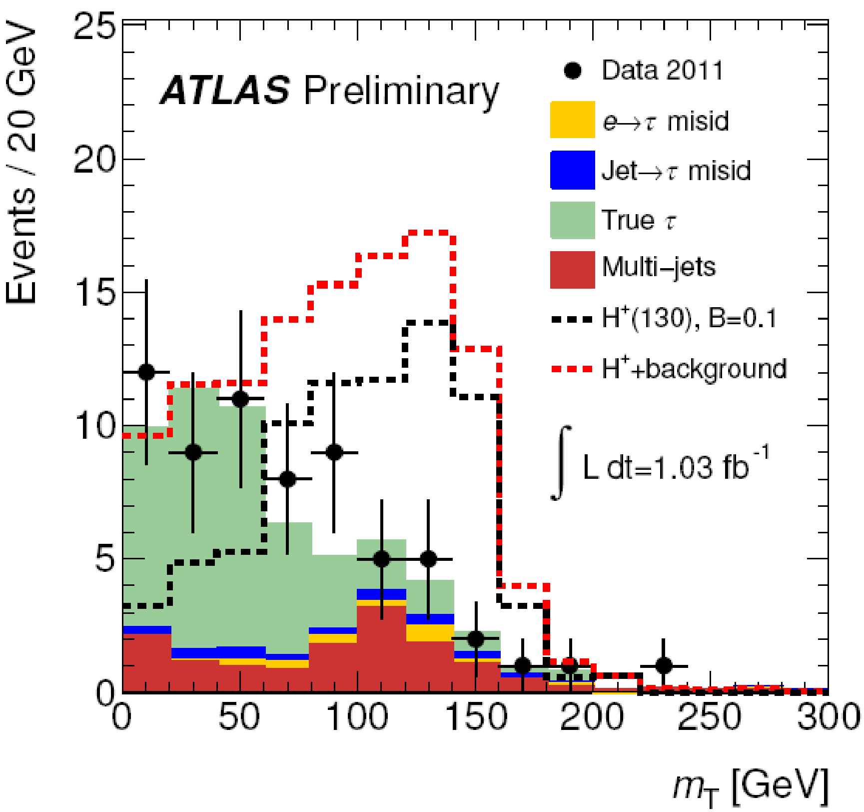
Search channel: $t\bar{t} \to H^+b + W^-b \to \tau\nu b + qq'\,b$

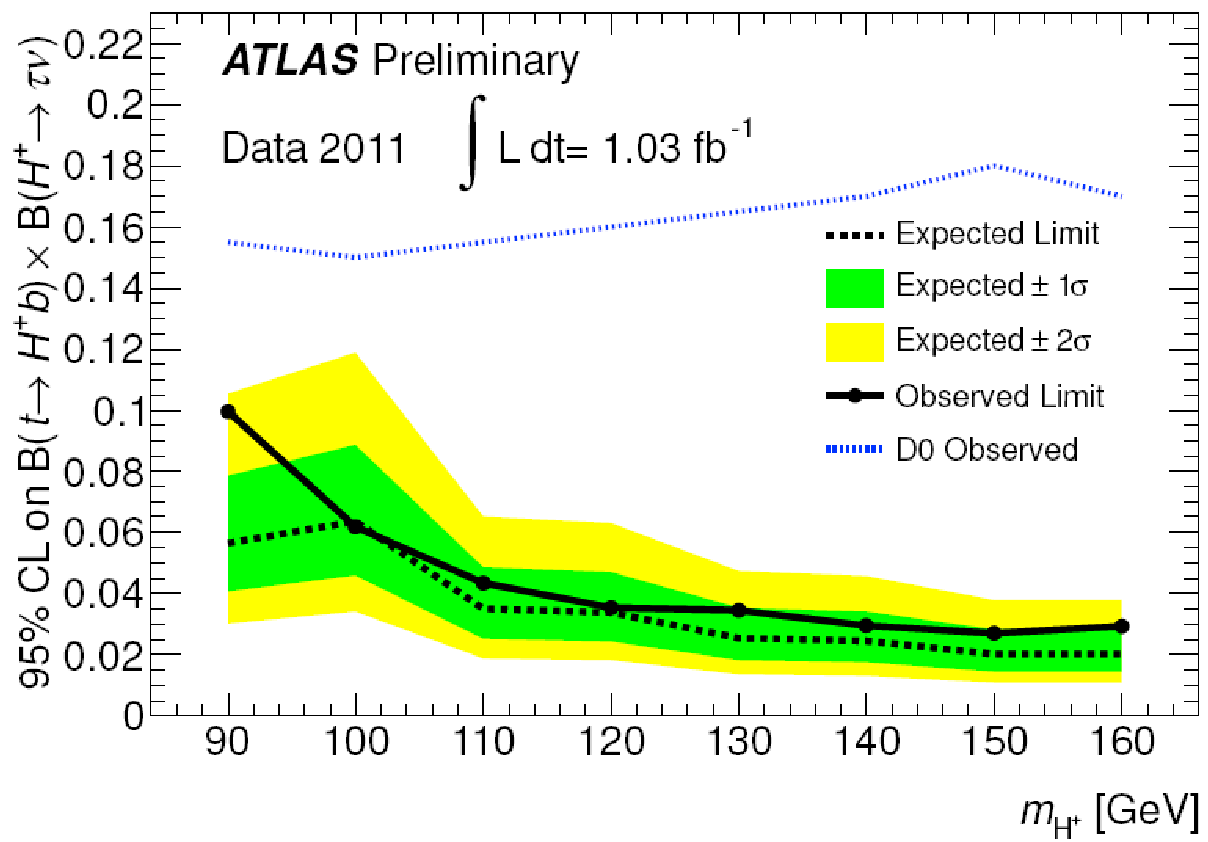
Event selection:

- MET + τ trigger
- MET > 50 GeV
- Hadronic t with pT > 35 GeV
- At least one b-tagged jet
- Two additional jets + b-jet
- Final discriminant: mT

Data	Total BG	m_{H^+}=130 GeV, BR ($t \to bH^+$)=0.1
43	37±7	70

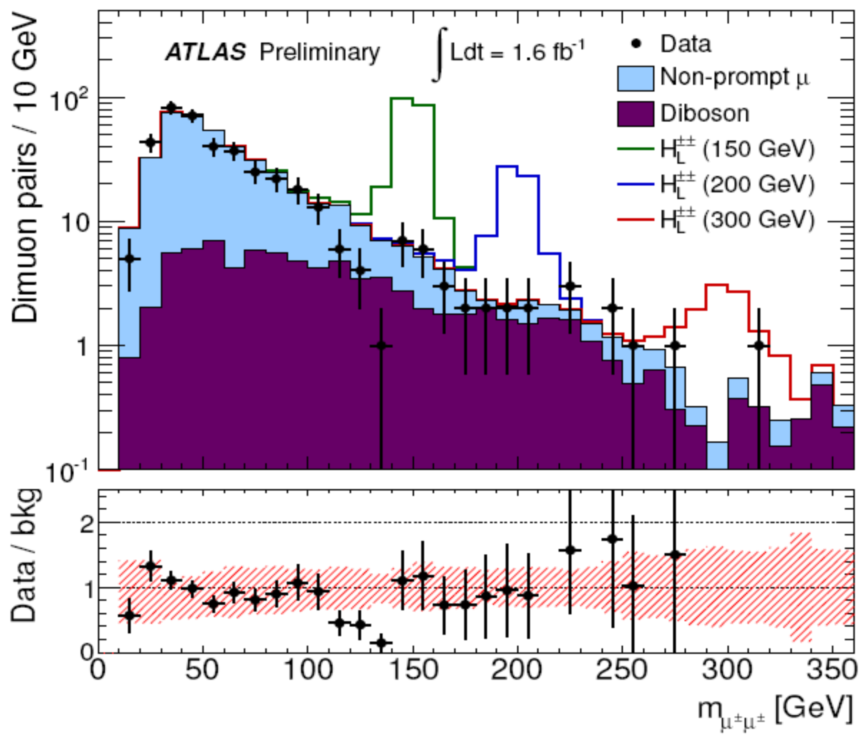
- Jet and τ related systematics dominant
- True τ background via τ embedding into μ+jets data sample





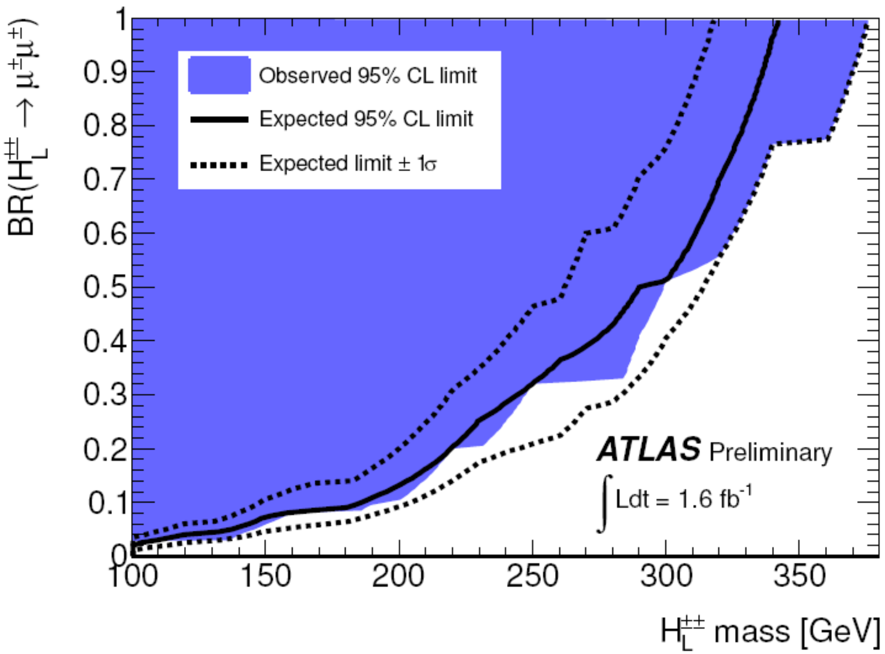
$H^{\pm\pm} \rightarrow \mu\mu$ 100 GeV < $m_{H^{\pm\pm}}$ < 400 GeV 1.6 /fb

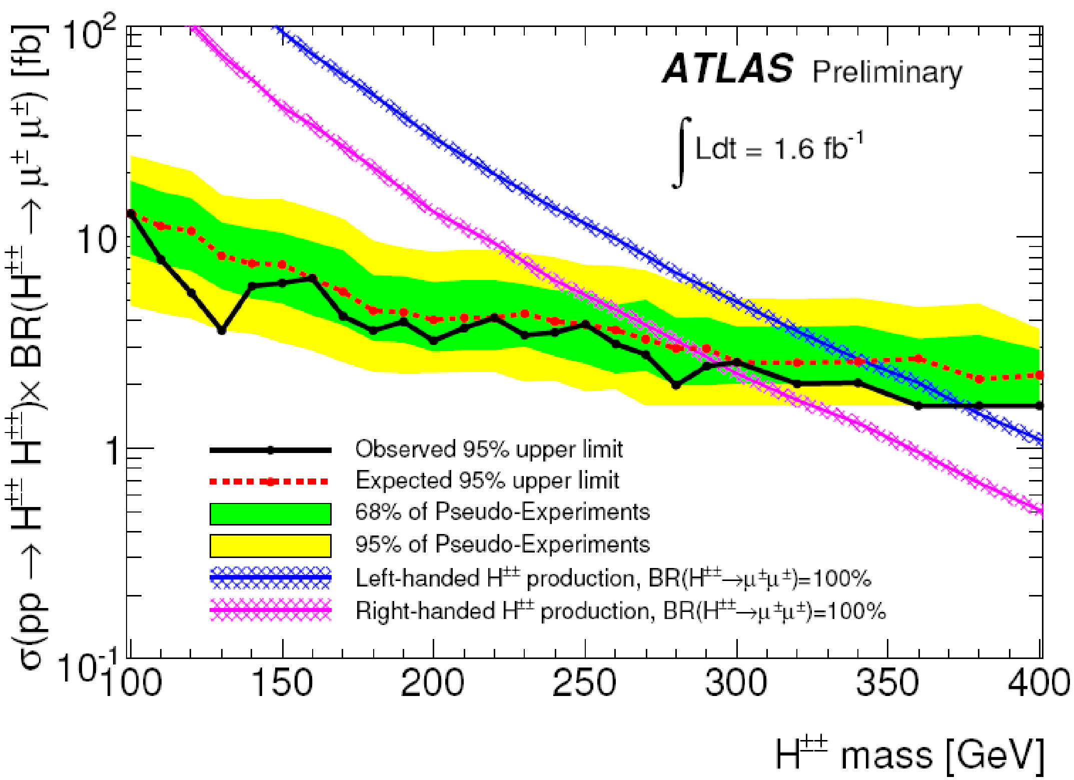
ATL-CONF-2011-127



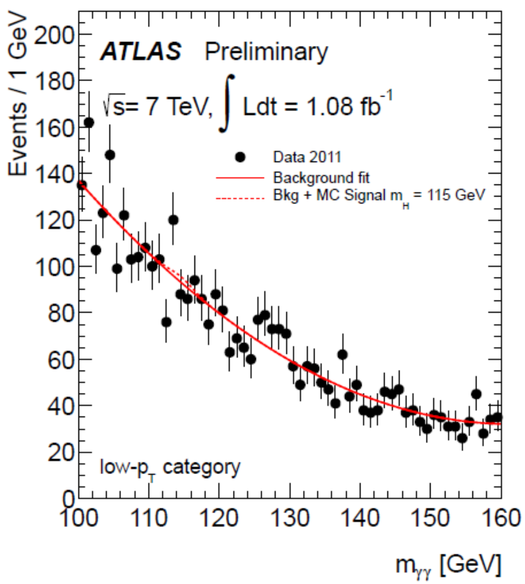
- Relevant models eg. Little Higgs, Higgs triplets
- Select events with 2 high pT same sign muons
- Production in DY process $q\bar{q} \rightarrow Z/\gamma^* \rightarrow H^{++}H^{--}$
- If BR=1, left-handed $H^{\pm\pm}$ excluded for m_H < 375 GeV, right-handed $H^{\pm\pm}$ excluded for m_H < 295 GeV

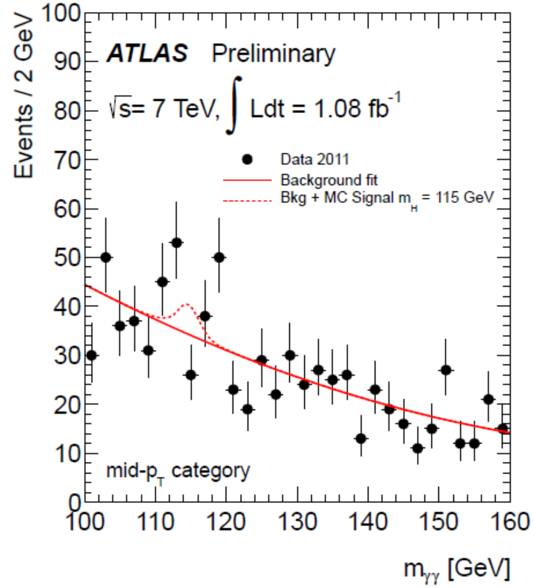
Data	Total BG
401	437 +96 -186

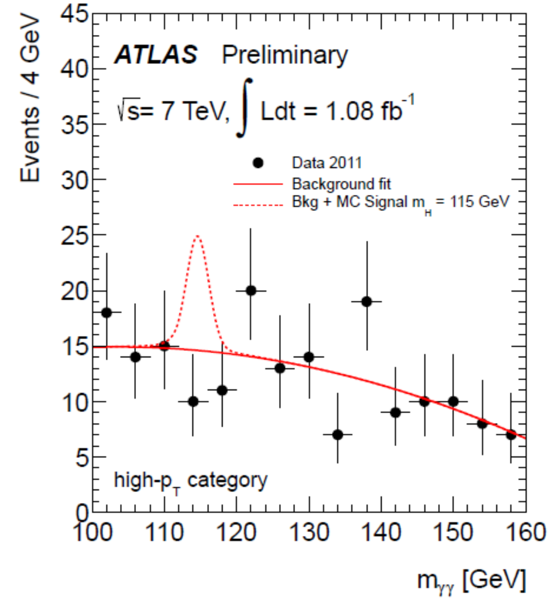




$H \to \gamma\gamma$ Fermiophobic Scenario (1.08 fb^{-1})



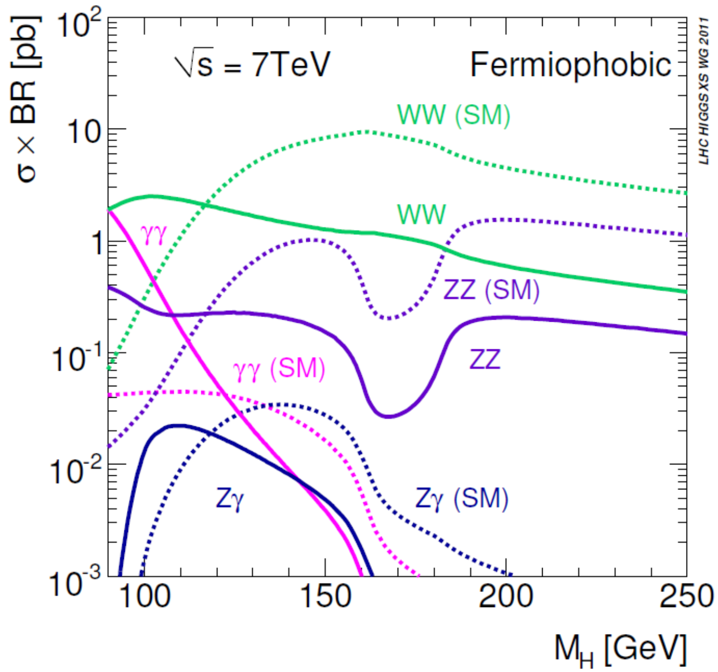


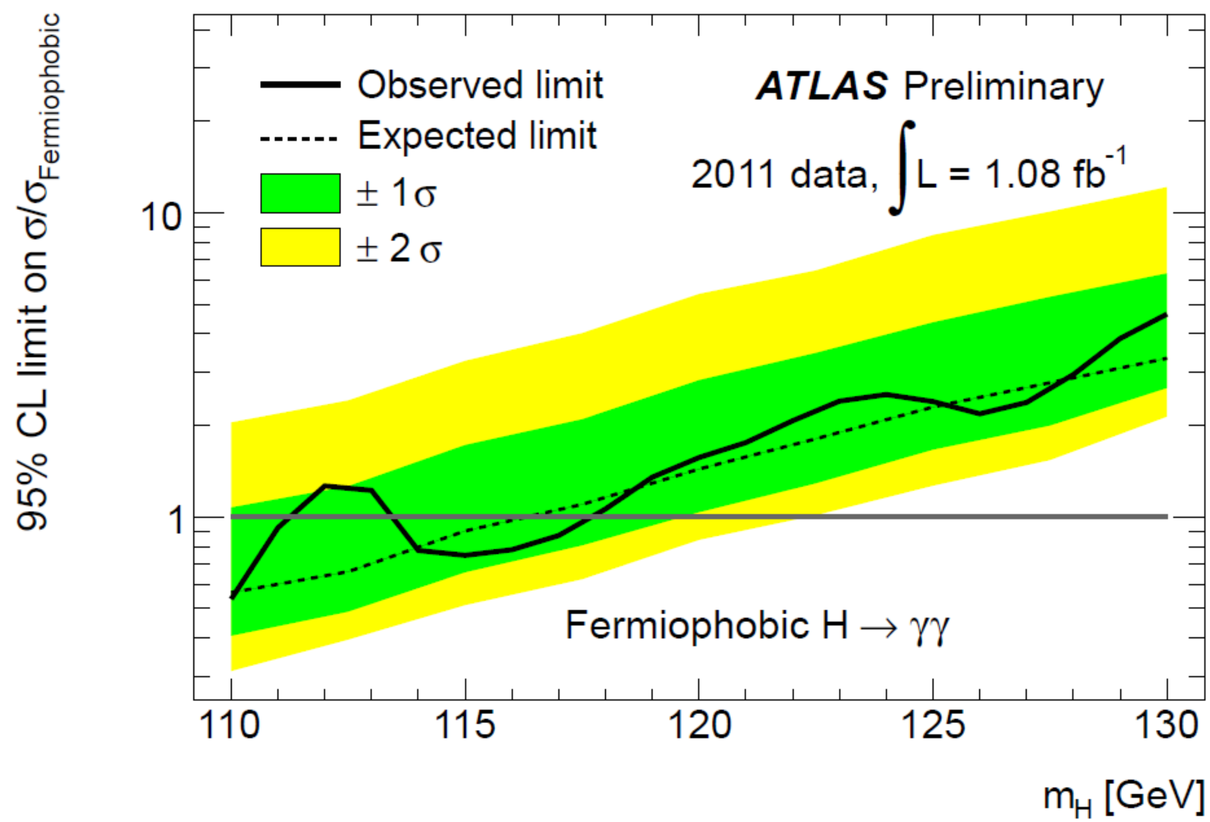


ATLAS-CONF-2011-149

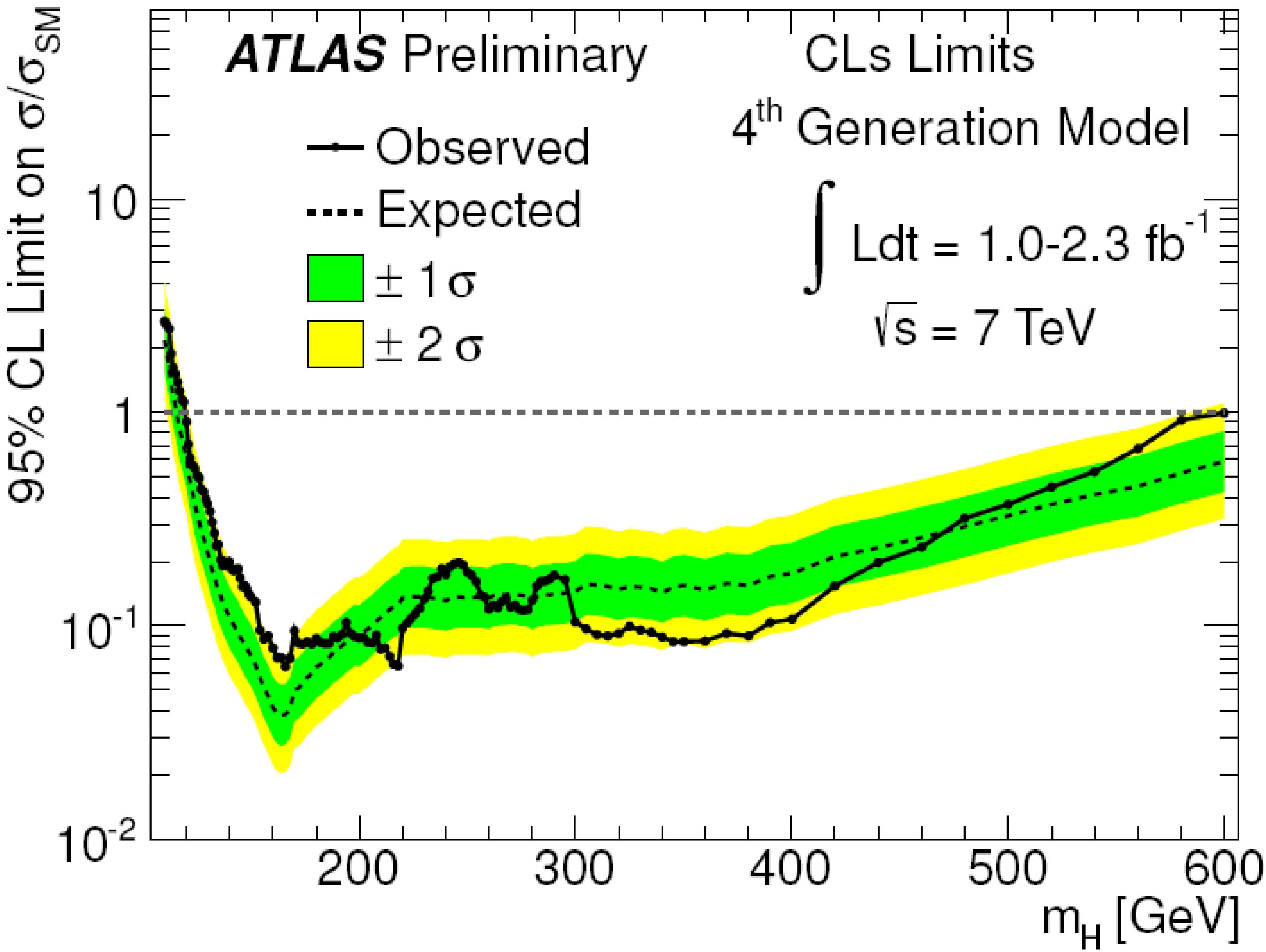
Three categories separated in $p_T^{\gamma\gamma}$

Updated results with 4.9 fb^{-1} in preparation





4^{th} Generation



- Heavy 4^{th} generation: m = 600 GeV
- Exclusion: 120 GeV – 600 GeV