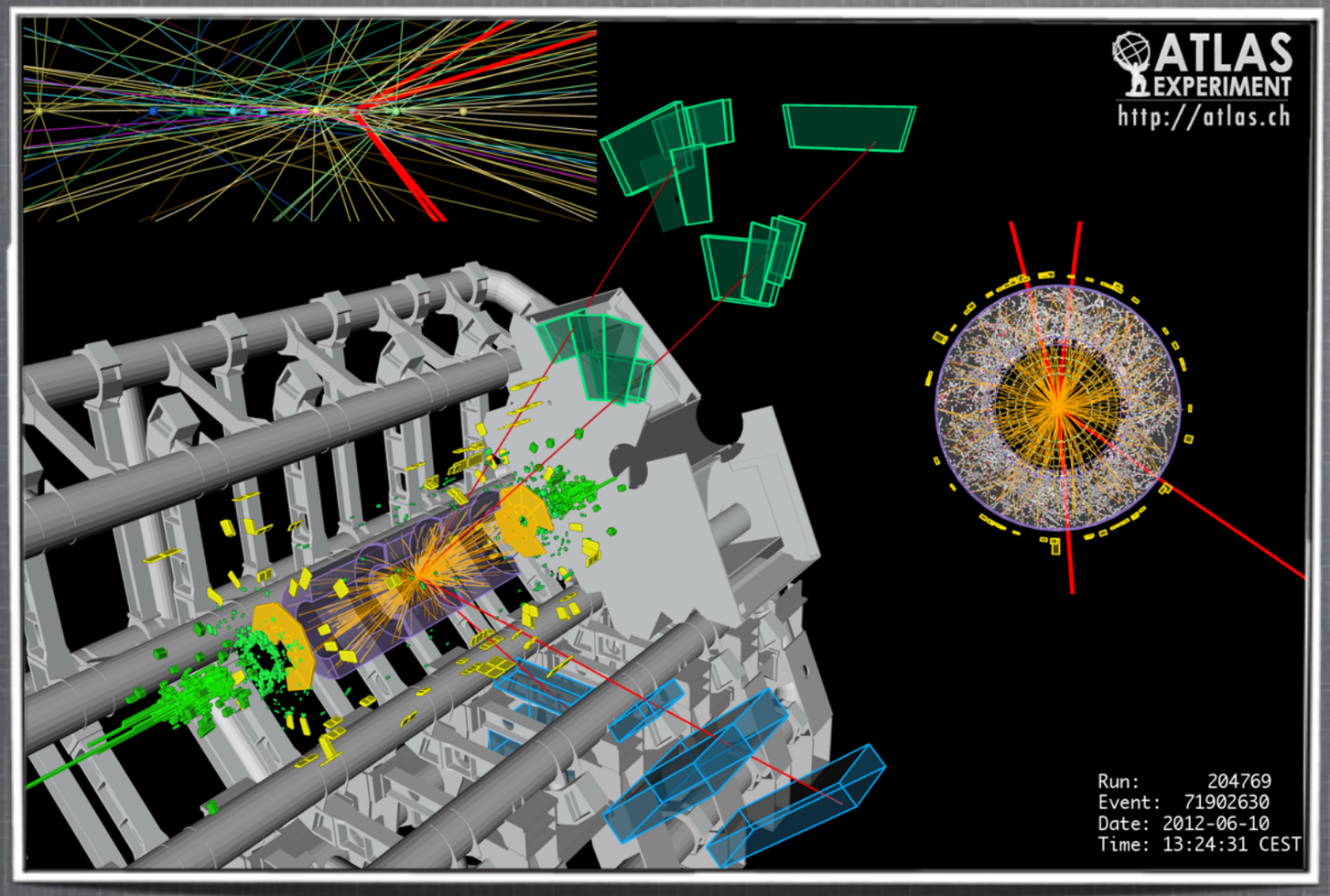

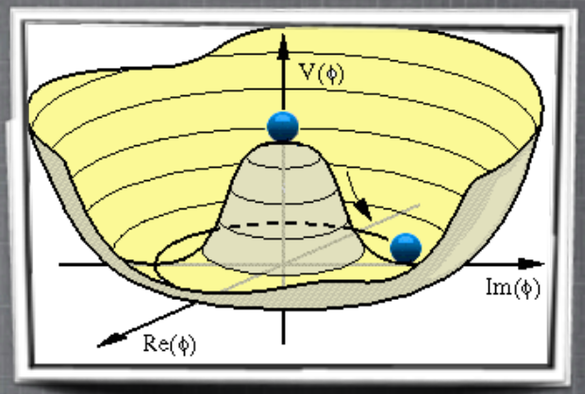

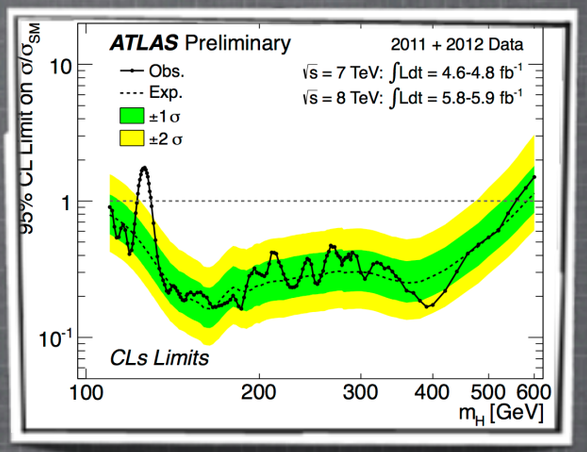

Standard Model Higgs Boson Searches at ATLAS

Jana Kraus
University of Bonn
On behalf of the ATLAS Collaboration

Beyond The Standard Model of Particle Physics, Quy Nhon, Vietnam, 15th - 21th July 2012

universitätbonn

News on
04/07/2012

la Repubblica.it

Cern, scoperta la "particella di Dio"

« PRECEDENTE Foto 1 di 19 SUCCESSIVO

Higgs boson-like particle discovery claimed at LHC

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Sân bóng của các hạt nhân

06/07/2012

Ngày 4.7 tại Geneva, Thụy Sĩ, Viện Nghiên cứu hạt nhân châu Âu (CERN) công bố đã phát hiện ra một loại hạt co
mới được cho là tương ứng với hạt Higgs - còn gọi là "hạt của Chúa" mà các nhà khoa học dày công tìm kiếm tr
5 thập niên qua. Nếu thông tin này hoàn toàn chính xác, khám phá trên sẽ có tầm ảnh hưởng
tương đương với việc Christophe Columbus tìm ra châu Mỹ.

ZEIT ONLINE | WISSEN

WISSENSCHAFT

Scoperto il Bosone di Higgs la particella di Dio esiste davvero

The New York Times

U.S. | N.Y. / REGION | BUSINESS | TE

Le boson de Higgs découvert avec 99,9999 % de certitude

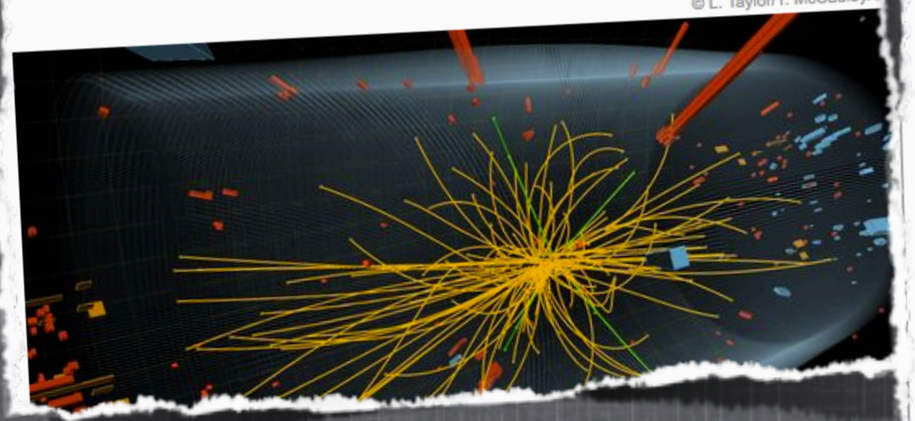
Le Monde.fr | 04.07.2012 à 13h39 • Mis à jour le 04.07.2012 à 13h39

PHYSIK

Haarscharf am gottverdammten Teilchen vorbei

Die Belege scheinen überwältigend: Forscher könnten ein neues Teilchen gefunden haben. Unklar ist, ob es das Higgs-Boson ist, der letzte Baustein im Weltbild der Physik.

© L. Taylor/T. McCauley/C



Physicists Find Elusive Particle Seen as Key to Universe

Scientists in Geneva on Wednesday applauded the discovery of a

theguardian

News | Sport | Comment | Culture | Business | Money | London 2

Comment is free

The Higgs boson discovery is another giant leap for humankind

The Cern discovery of the Higgs particle is up there with putting man on the moon – something all humanity can be proud of

Let's find out the story behind it all...

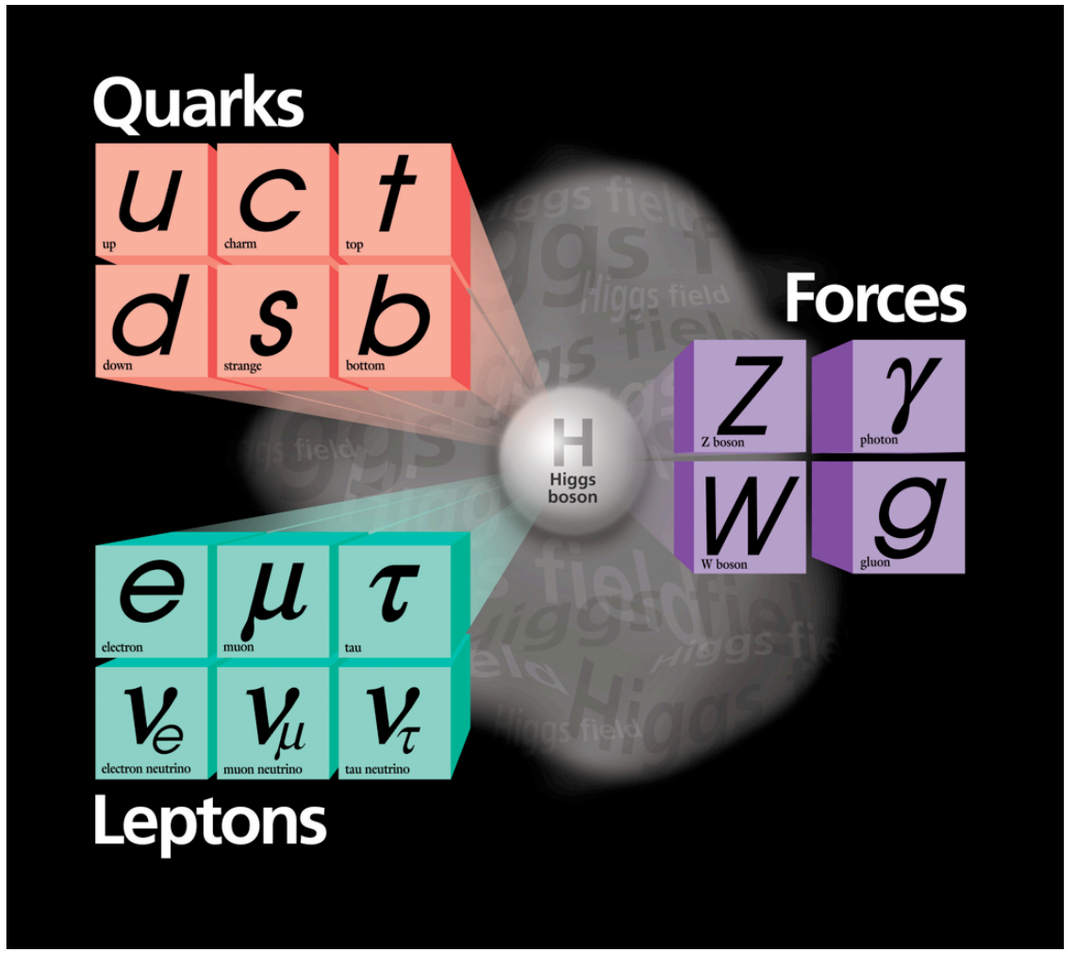
Higgs in the Standard Model

- Higgs mechanism explains **electroweak symmetry breaking** in the Standard Model

- Fermions and vector bosons acquire **masses** by coupling to the Higgs field

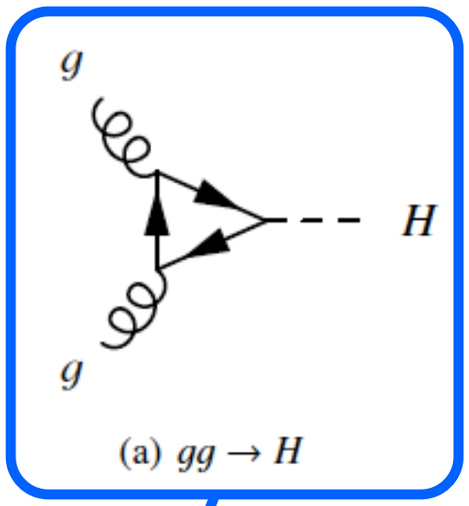
- Physical consequence: existence of a **scalar Higgs boson**

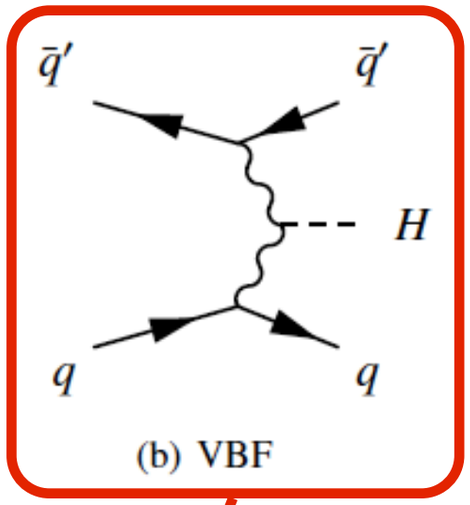
- All particles predicted by the Standard Model have been observed, except for the **Higgs boson**

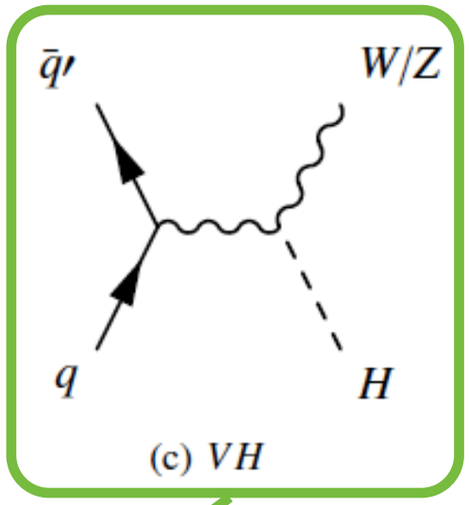


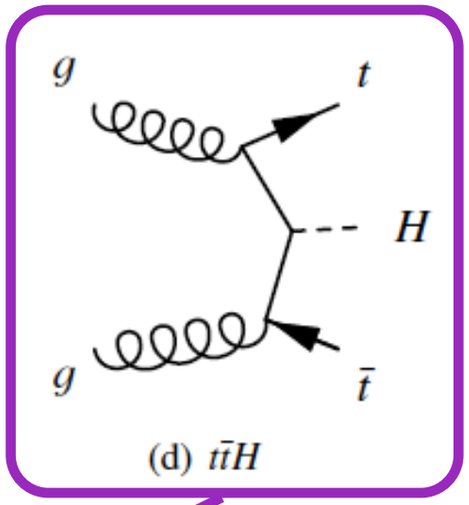
Constraints on Higgs mass: previous collider experiments (**LEP, Tevatron**), electroweak precision measurements (indirect), theory constraints

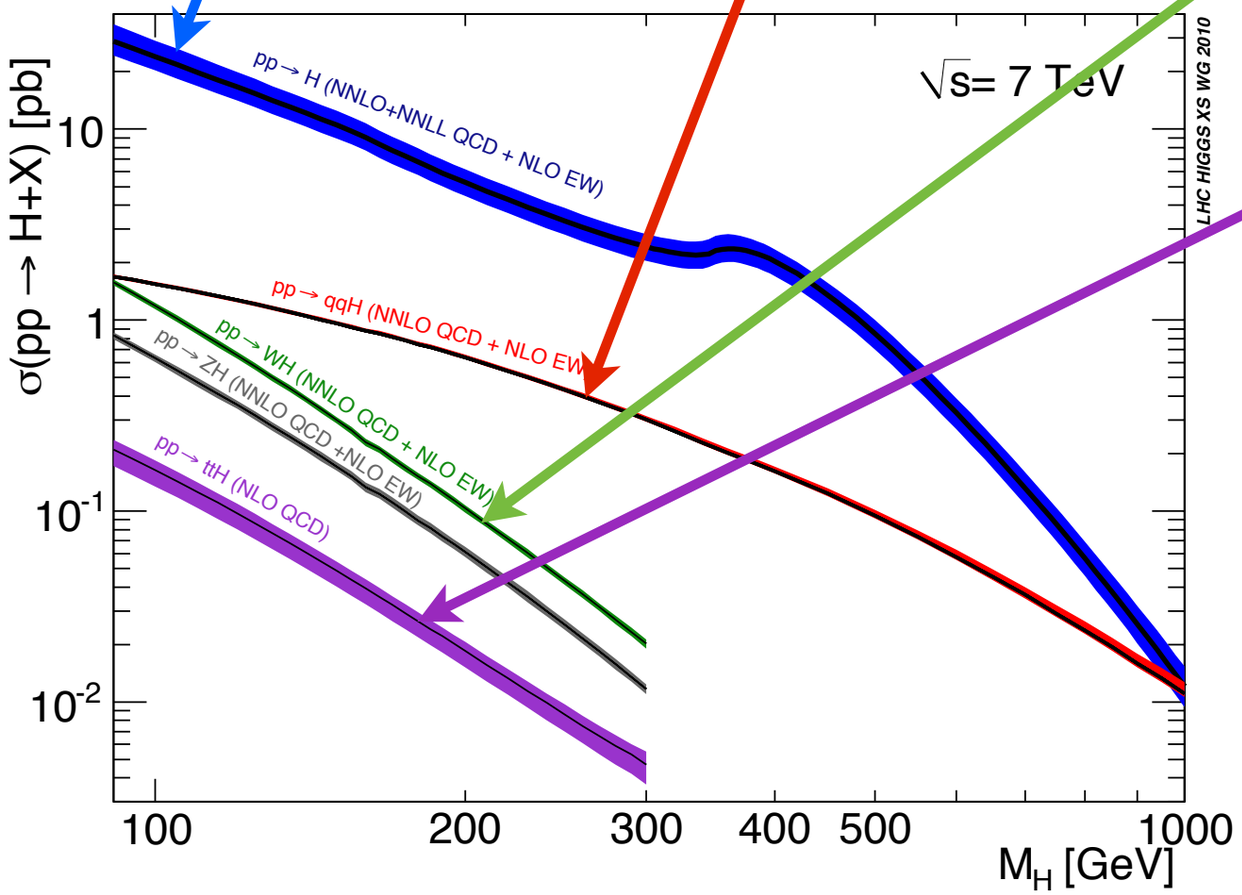
SM Higgs production at the LHC











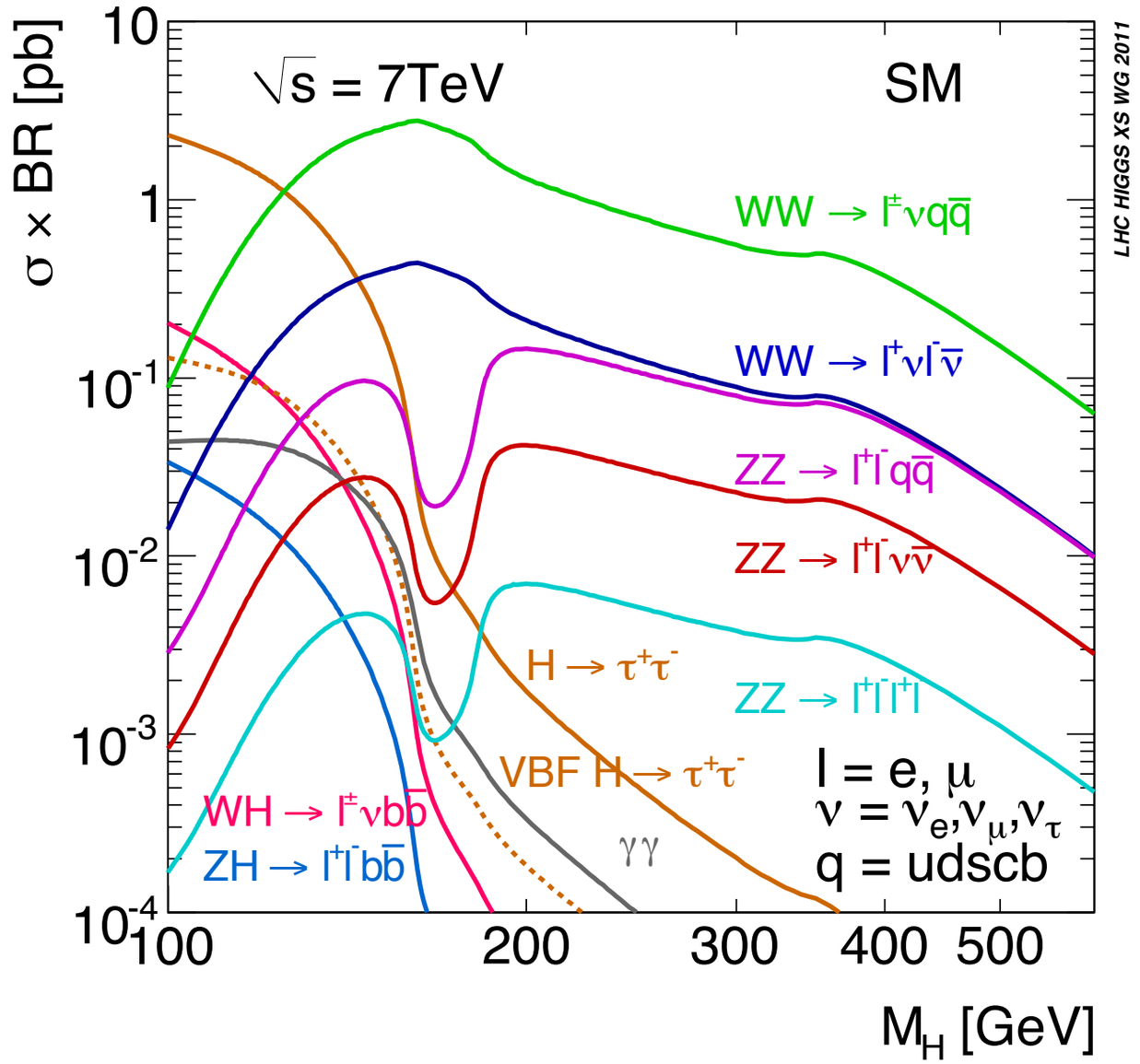
- At $\sqrt{s}$ = 8 TeV cross section 25-30% higher than at 7 TeV at low masses
- VBF, VH and ttH have smaller cross section but better S/B

Higgs decays

- 5 decay modes studied:
  - High masses: **ZZ, WW**
  - Low masses: **bb, ττ, γγ, WW, ZZ**

- low mass especially challenging due to huge backgrounds (esp. bb, ττ)

- best **mass resolution** (1-2%):
  - H→γγ, H→ZZ→llll



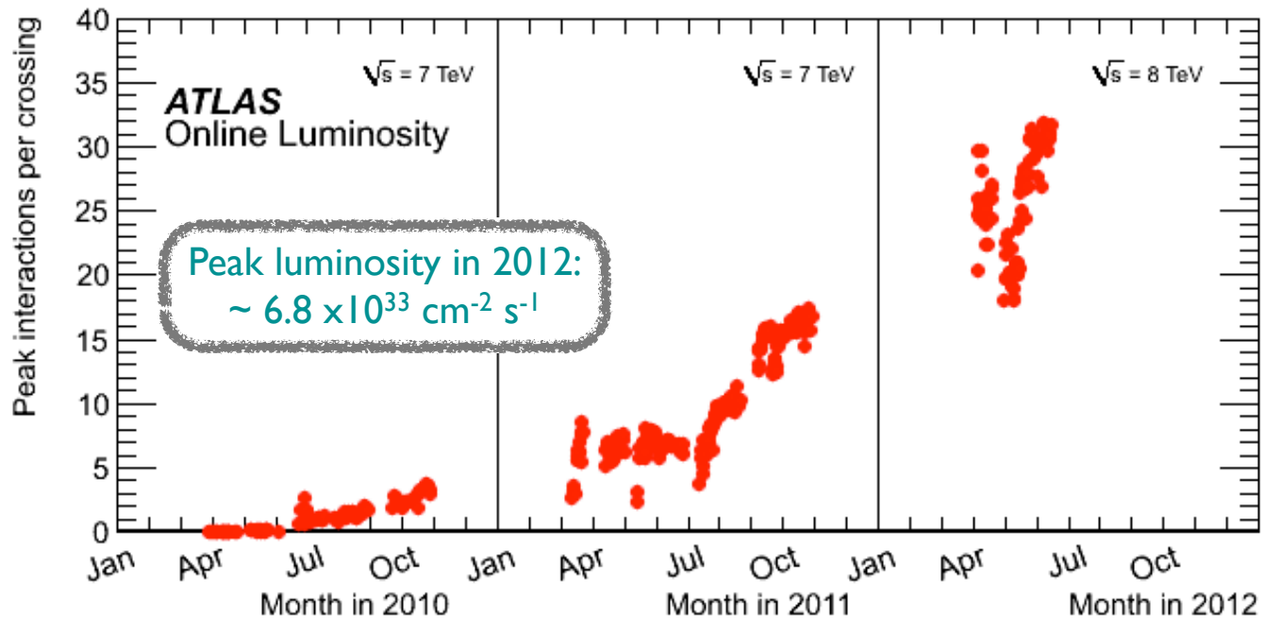
ATLAS data taking

Year	√s	Luminosity recorded
2010	7 TeV	45 pb^{-1}
2011	7 TeV	5.25 fb^{-1}
2012	8 TeV	6.6 fb^{-1}

Further data taking until March 2013 planned

2011 data results in all channels presented, **2012** updates in most sensitive channels, **~90-93%** of recorded data used (require good detector conditions)

- Increasing **pile up** with increasing luminosity extremely challenging for object reconstruction/identification esp. $\mathbf{E_T^{miss}}$



Current ATLAS results

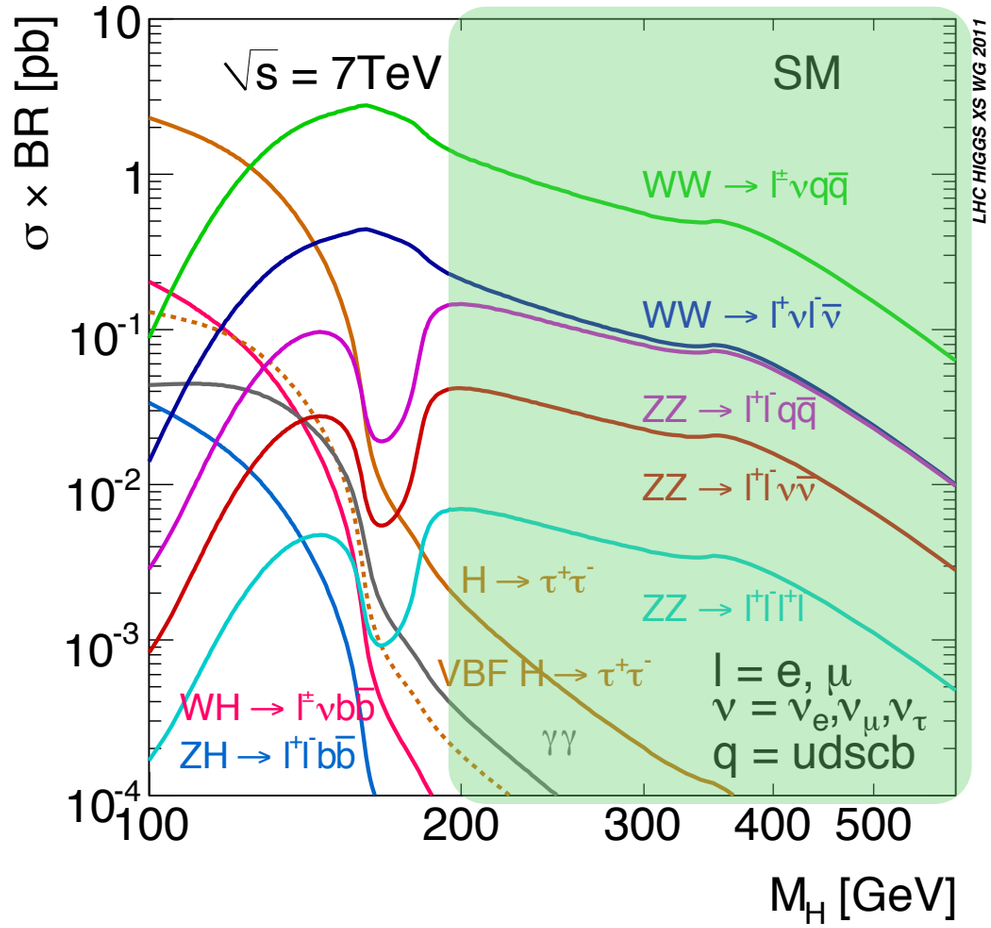
- Searches performed in 12 channels in the range 110 GeV < m_H < 600 GeV

Updated with 2012 data

Higgs decay	Subsequent decay	Mass range [GeV]	L [fb^{-1}]	Publication (arXiv)
H→γγ		110-150	4.8 **+ 5.9**	1202.1414
H→ZZ	lll′l′	110-600	4.8 **+ 5.8**	1202.1415
	llνν	200-600	4.7	1205.6744
	llqq	200-600	4.7	1206.2443
H→WW	lνqq	300-600	4.7	1206.6074
	lνlν	110-600	4.7	1206.0756
H→ττ	ll4ν	110-150	4.7	1206.5971
	lτ_{had}3ν		4.7	
	$\tau_{had}\tau_{had}$2ν		4.7	
VH→bb	lνbb	110-130	4.7	1207.0210
	llbb		4.7	
	ννbb		4.6	

Outline

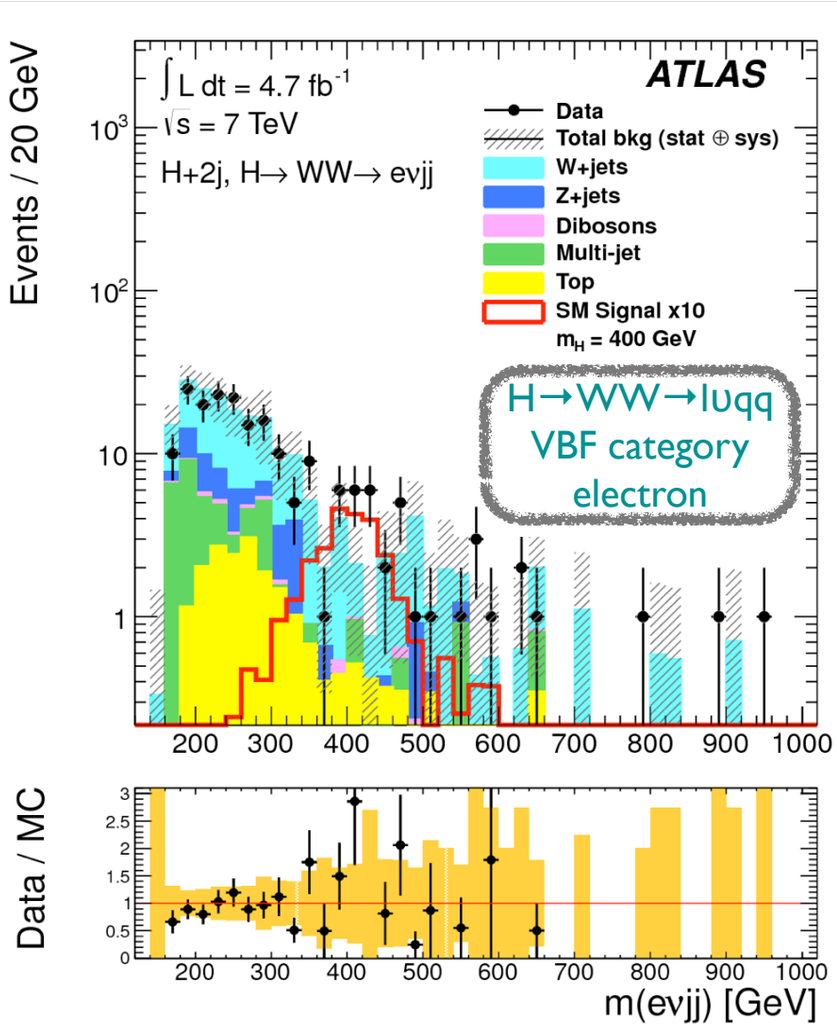
- **High Higgs mass**
  - H→WW→lνqq
  - H→ZZ→llqq
  - H→ZZ→llνν
- **Low Higgs mass, limited resolution**
  - H→WW→lνlν
  - VH→bb
  - H→ττ
- **Low Higgs mass, high resolution**
  - H→γγ
  - H→ZZ→llll
- **Combination**



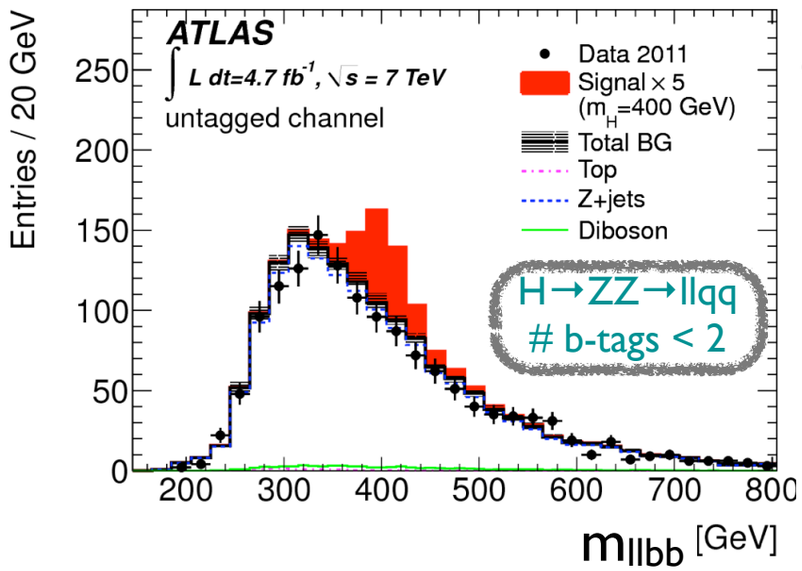
High mass searches

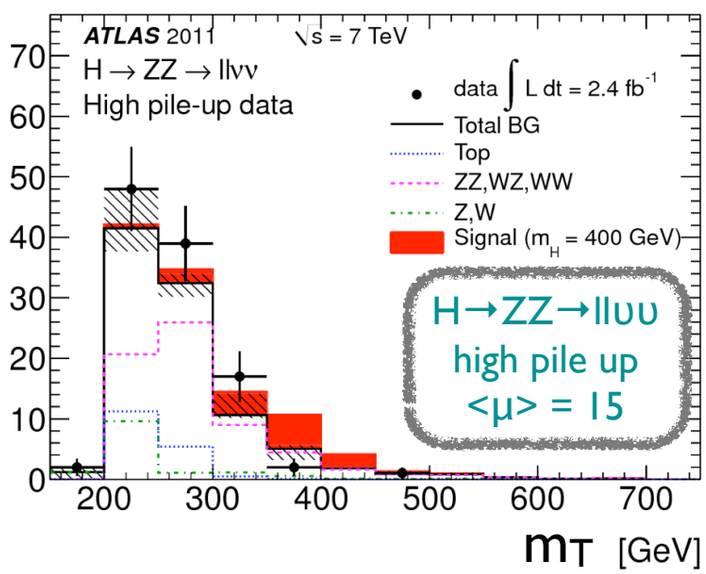
Channel	Analysis categories	Discriminative variable
H→WW→lνqq	**0, 1 jet** (gg) and **2 jets** (VBF)	inv. mass $\mathbf{m_{l\upsilon jj}}$ with $m_{l\upsilon}=m_W$
H→ZZ→llqq	**2 b-tagged jets** and **less than 2 b-tags**	inv. mass $\mathbf{m_{lljj}}$ with $m_{jj}=m_Z$
H→ZZ→llνν	**low** and **high pile up**	**transverse mass** (2 neutrinos)

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



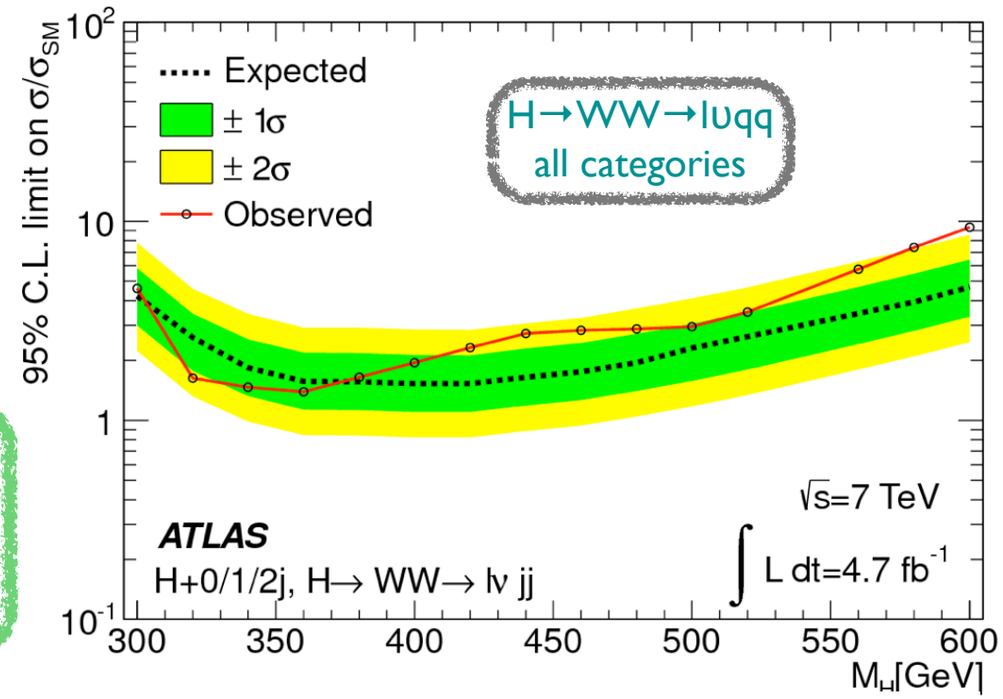
- Main backgrounds: W+jets, Z+jets, top, dibosons, multijets



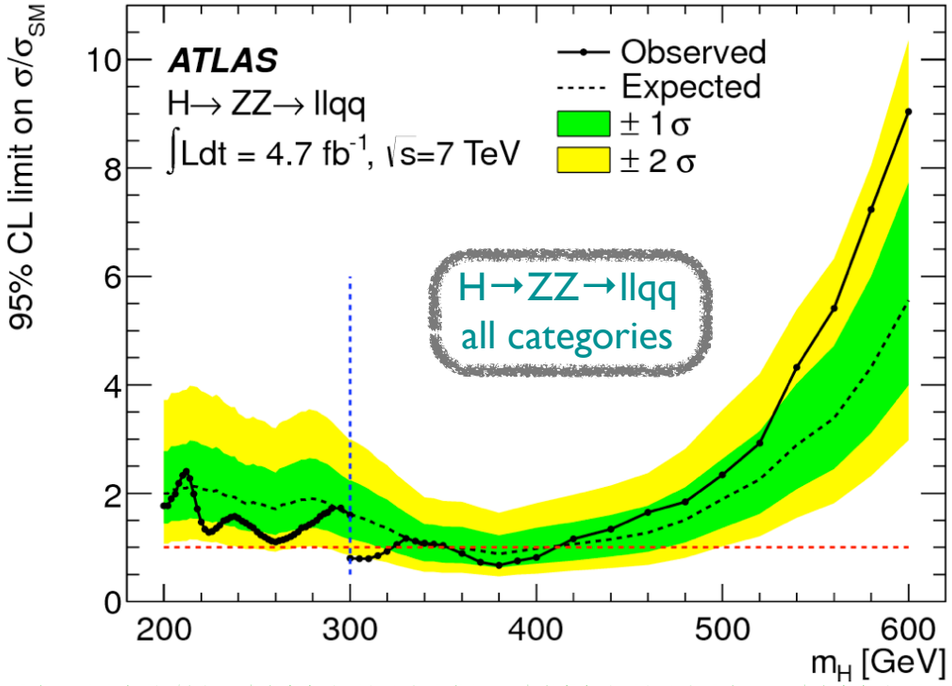


High mass searches: Results

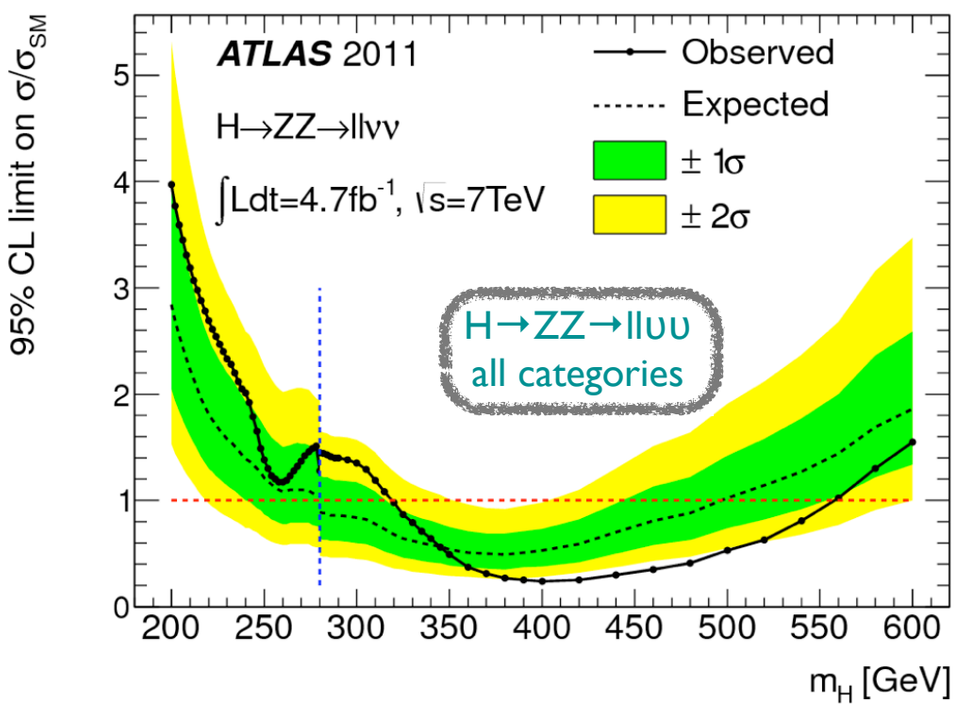
- No excess observed for m_H between 200-600 GeV



- Best **observed upper limit** on cross section: 1.9 x σ_{SM}
  expected limit: 1.6 x σ_{SM}



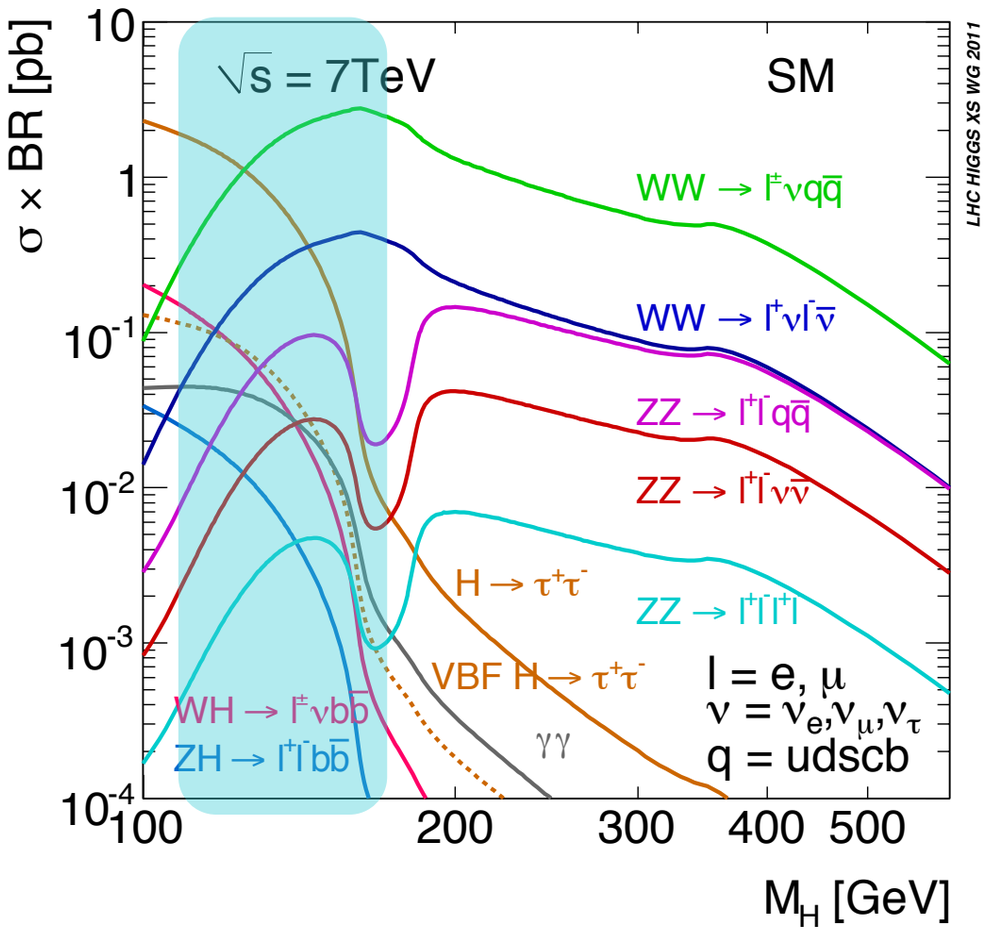
- **Observed exclusion:** 300-323 GeV, 353-410 GeV
  Expected exclusion: 351-404 GeV



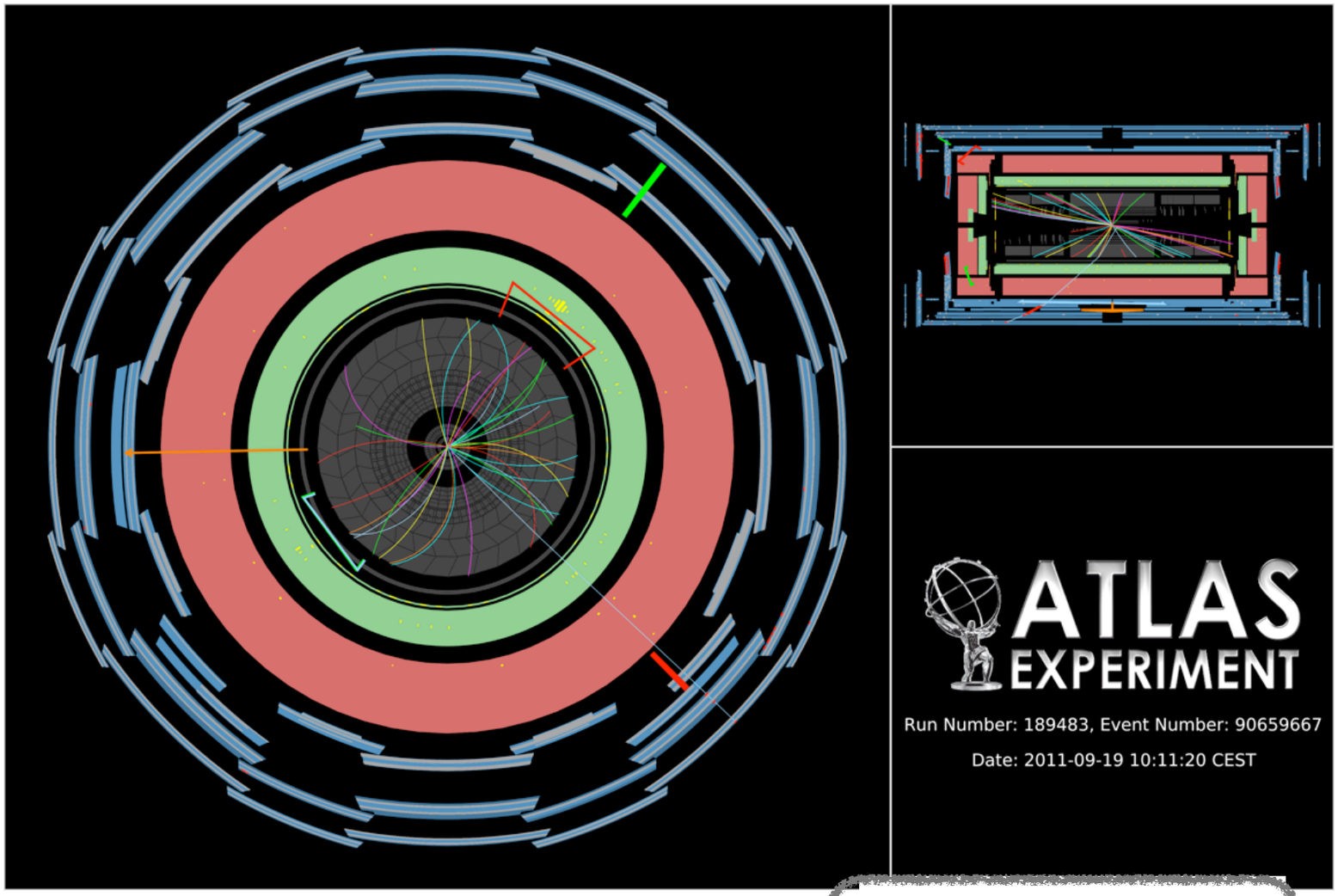
- **Observed exclusion:** 319-558 GeV
  Expected exclusion: 280-497 GeV

Outline

- High Higgs mass
  - H→WW→lνqq
  - H→ZZ→llqq
  - H→ZZ→llνν
- **Low Higgs mass, limited resolution**
  - H→WW→lνlν
  - VH→bb
  - H→ττ
- Low Higgs mass, high resolution
  - H→γγ
  - H→ZZ→llll
- Combination



H→WW→lνlν



H→WW→μνeν candidate

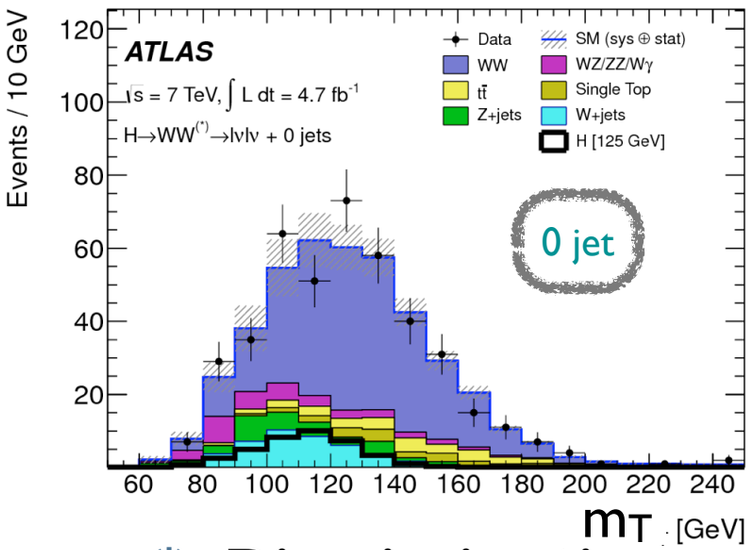
Characteristics

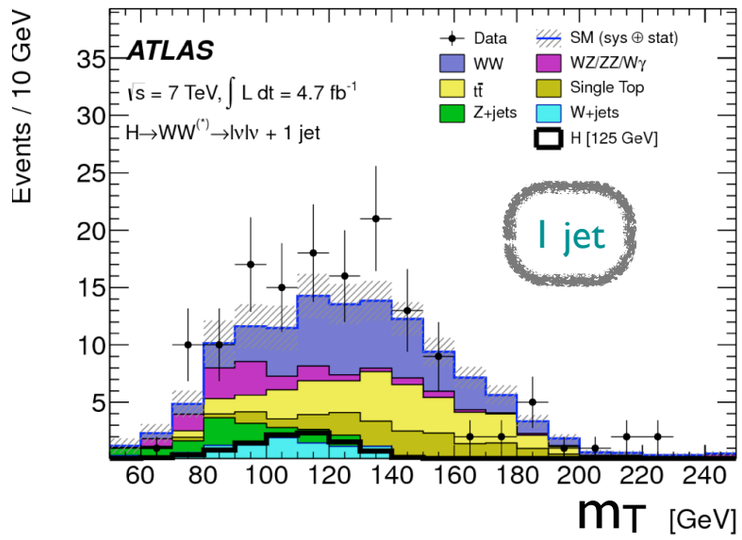
- High BR, but low mass resolution
- Two opposite sign electrons/muons & E_T^{miss}
- analysis categories: **0, 1 and 2 jets (VBF)**
- angular correlation leptons (small $\Delta\varphi_{ll}$ and m_{ll} if from spin-0 Higgs) used to discriminate against WW

Backgrounds

- mainly WW, ttbar, W+jets
- shape from simulation, normalized/validated in data control regions (e.g. inverted b-tag veto, high m_{ll} region)

H→WW→lνlν





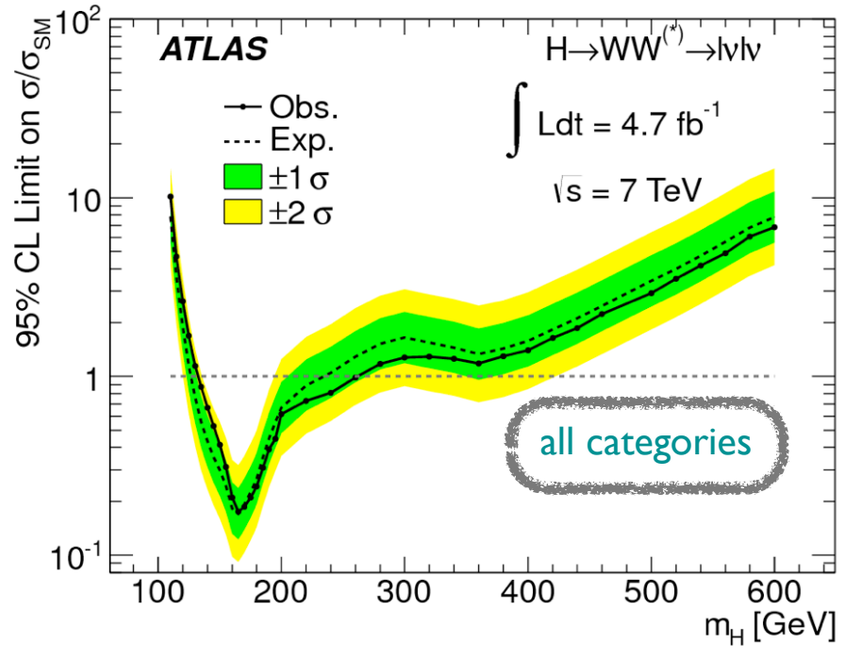
Discriminating variable

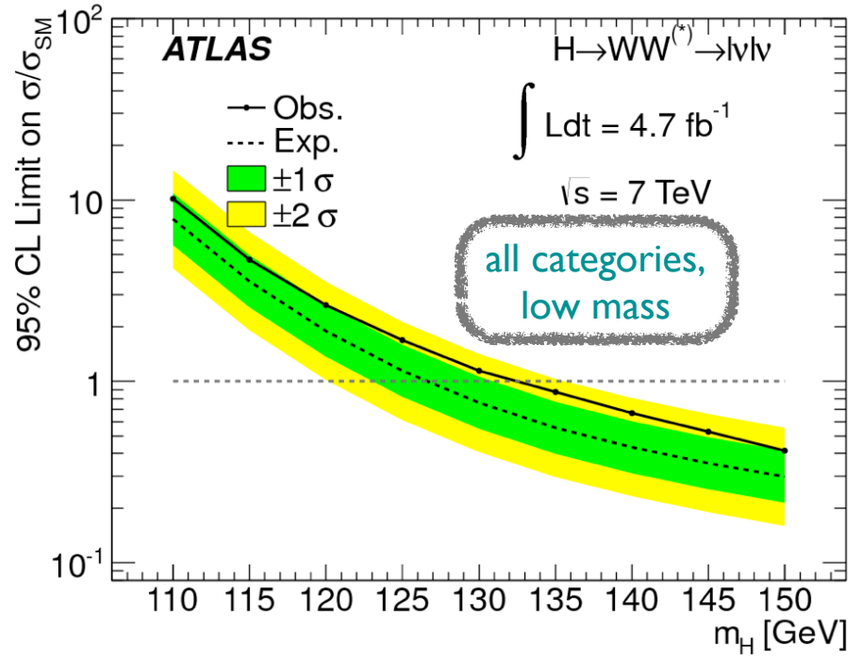
- **transverse mass m_T**

$$m_T^2 \equiv \sqrt{\left(E_T^{ll} + E_T^{miss}\right)^2 - \left|\vec{p}_T^{\,ll} + \vec{p}_T^{\,miss}\right|^2} \qquad E_T^{ll} \equiv \sqrt{\left|\vec{p}_T^{\,ll}\right|^2 + m_{ll}^2}$$

Result

- No observable excess for m_H between 110-600 GeV
- **Observed exclusion:** 130-261 GeV, **expected exclusion:** 127-233 GeV
- Similar result from analysis using MVA method



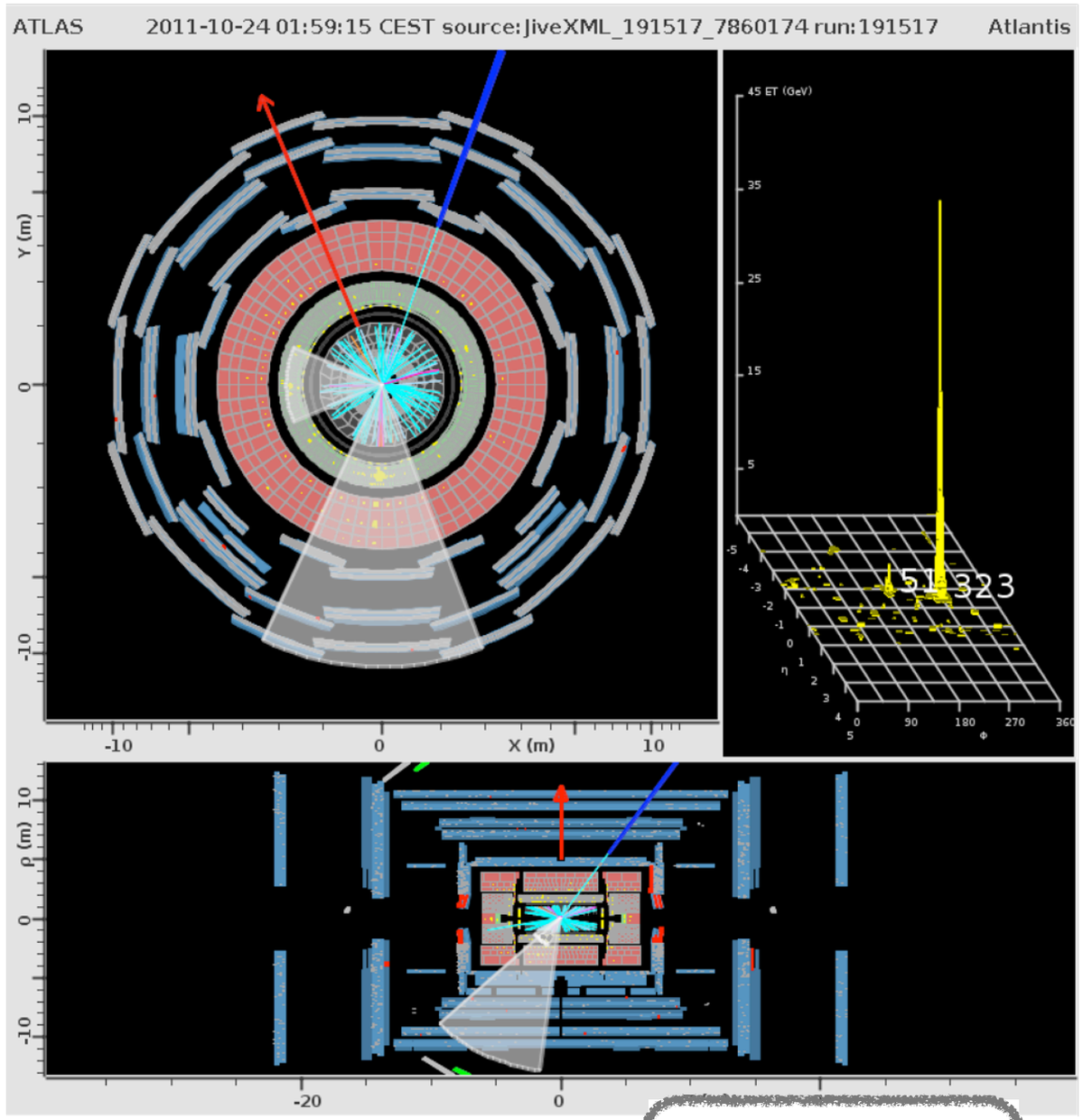


VH→bb

- **Characteristics**
  - Three decay channels studied:

    ZH→llbb
    ZH→υυbb
    WH→lυbb

  - exactly **2 b-tagged jets**
  - analysis categories: **different $P_T^{W/Z}$, E_T^{miss}** bins

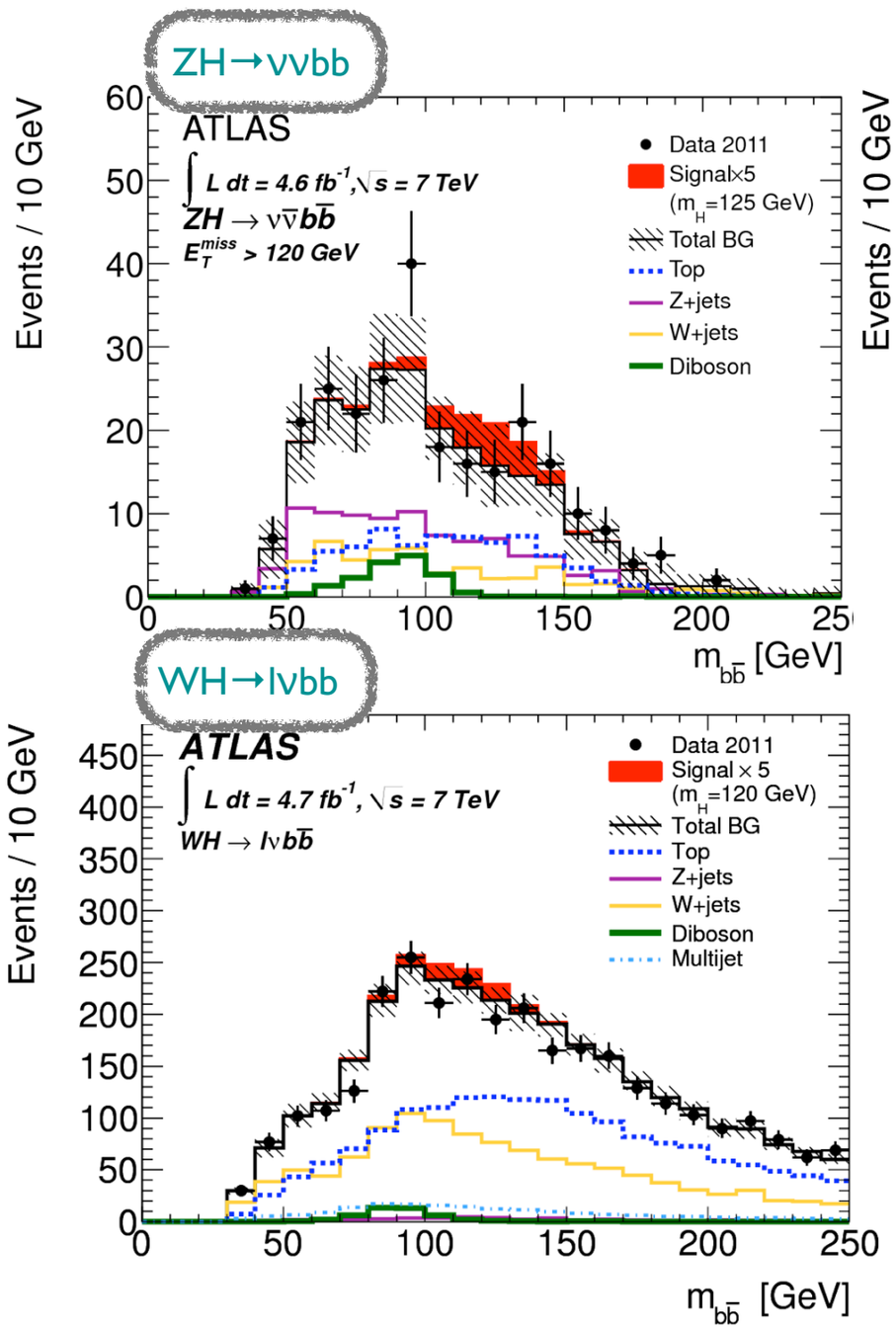


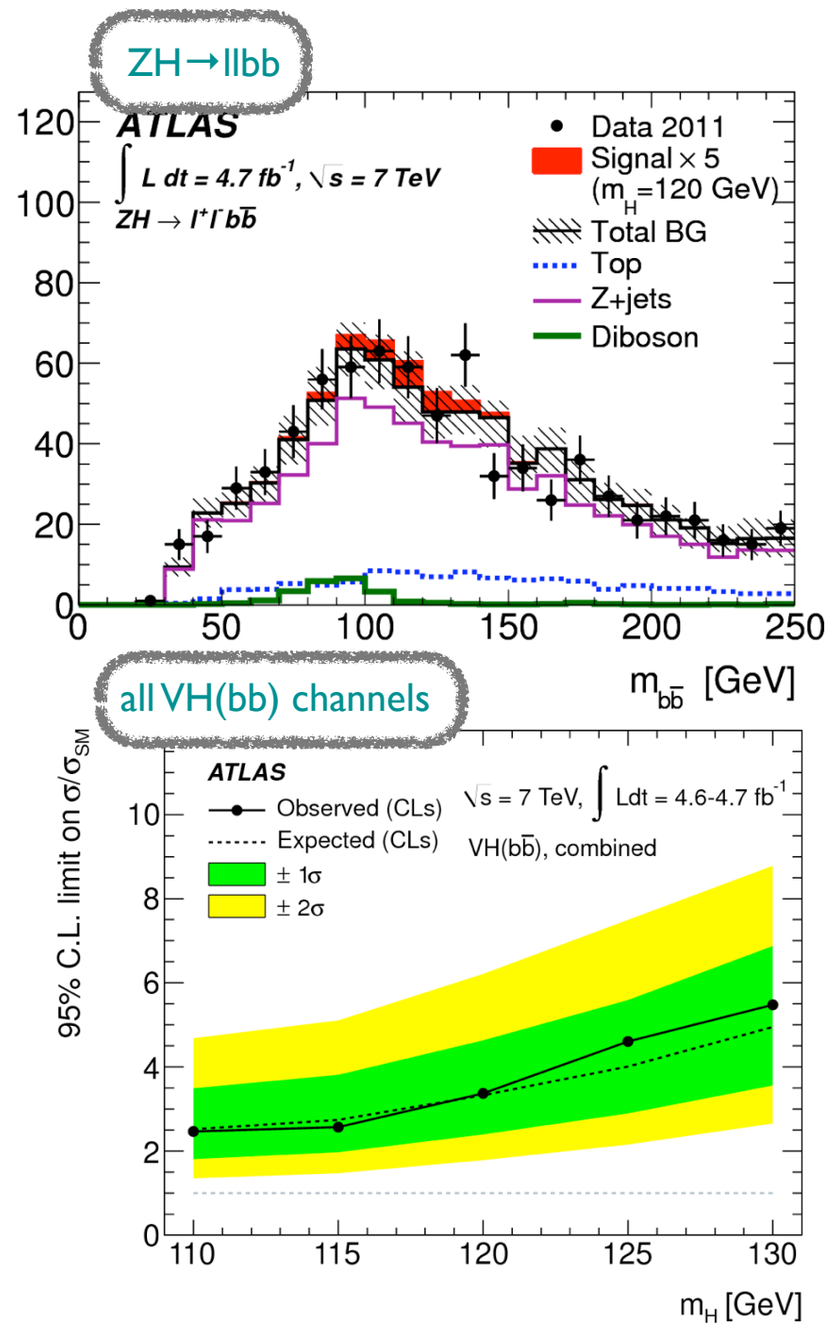
WH→μυbb candidate

- **Backgrounds**
  - W+jet, Z+jets, top, dibosons, multijets derived from data control regions

VH→bb

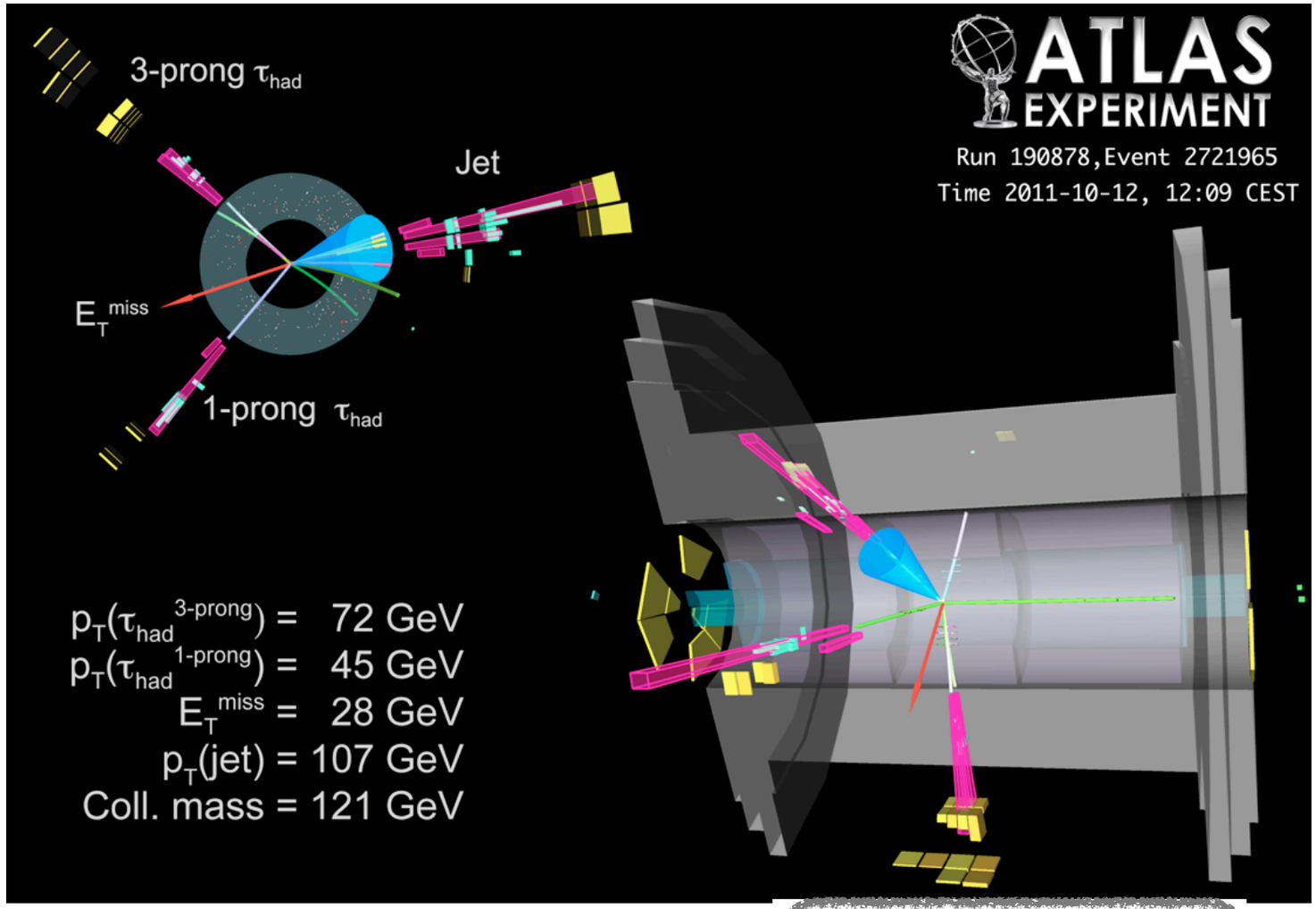
- **Discriminating variable**
  - **invariant mass m_{bb}**





- **Result**
  - No observable excess for m_H between 110-130 GeV
  - **Observed limit:** 2.7 - 5.3 x σ_{SM}, **expected limit:** 2.6 - 5.1 x σ_{SM}

H→ττ



$H\to\tau\tau\to\tau_{had}\tau_{had}UU$ candidate

Characteristics

- Three decay channels studied:

  $H\to\tau\tau\to llUUUU$
  $H\to\tau\tau\to l\tau_{had}UUU$
  $H\to\tau\tau\to\tau_{had}\tau_{had}UU$

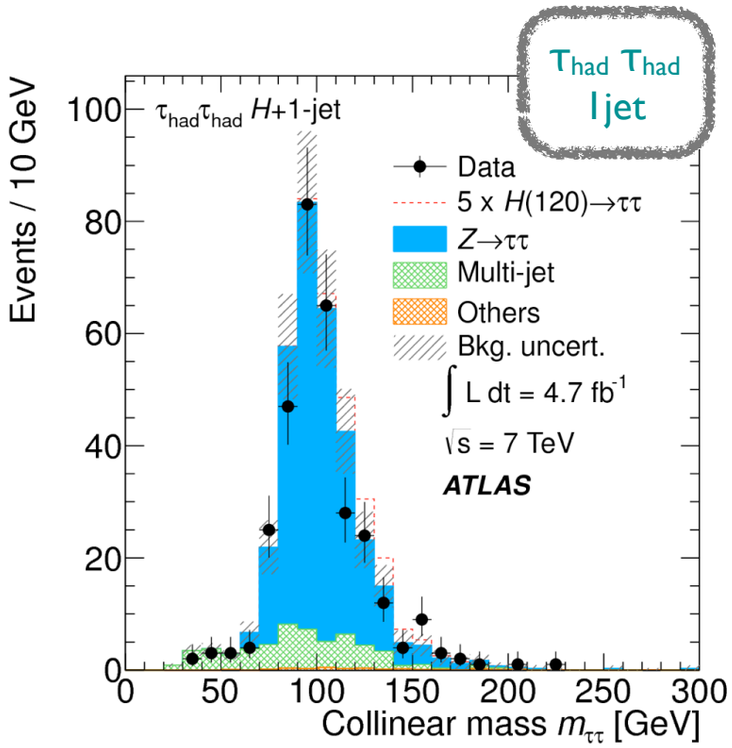
- analysis categories: **0,1 jet (gg), 2 jet VH and VBF**

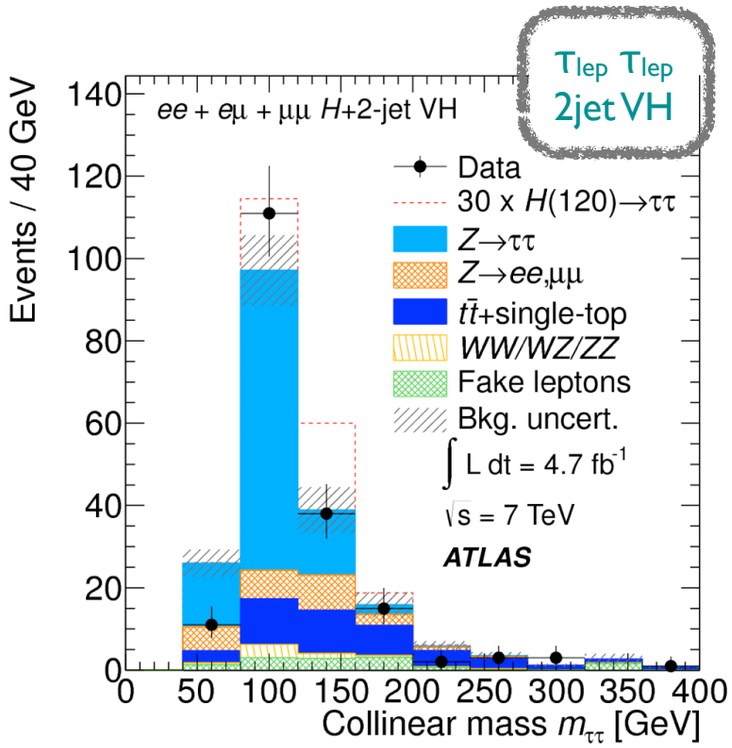
Backgrounds

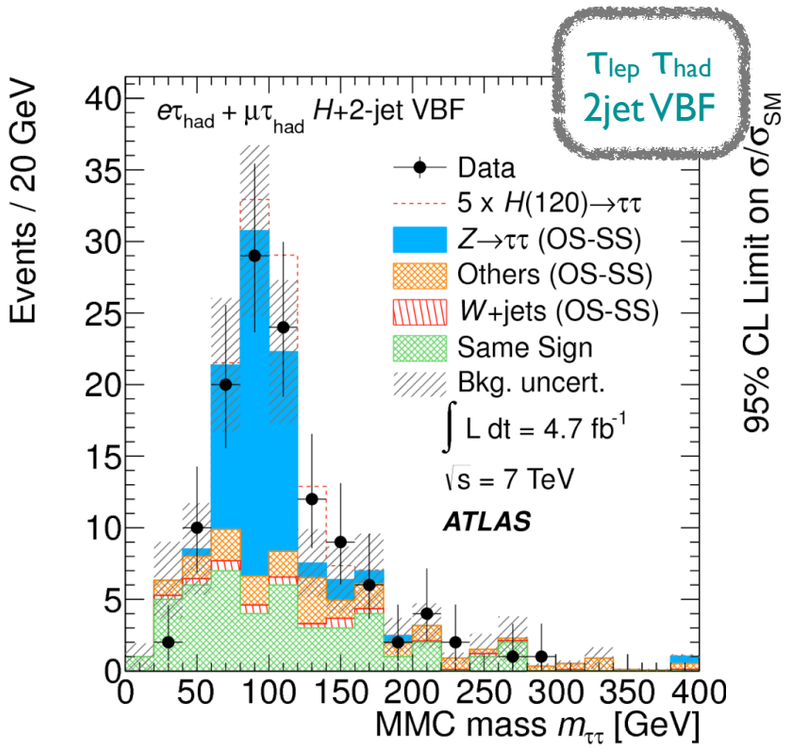
- $Z\to\tau\tau$ (irreducible), estimated from $Z\to\mu\mu$ data, where μs are replaced by simulated τs and their decay products

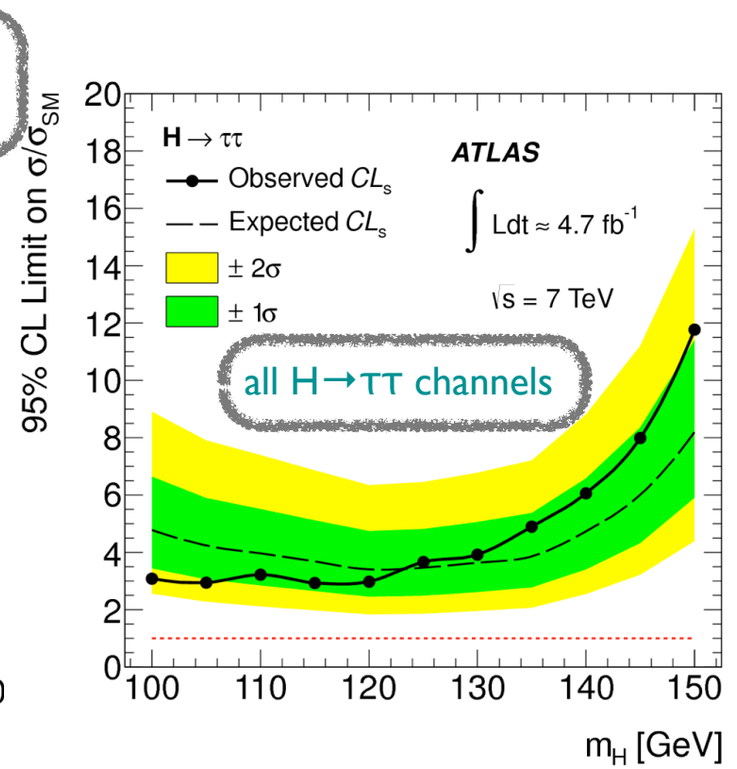
- τ/lepton fakes, data control regions

H→ττ







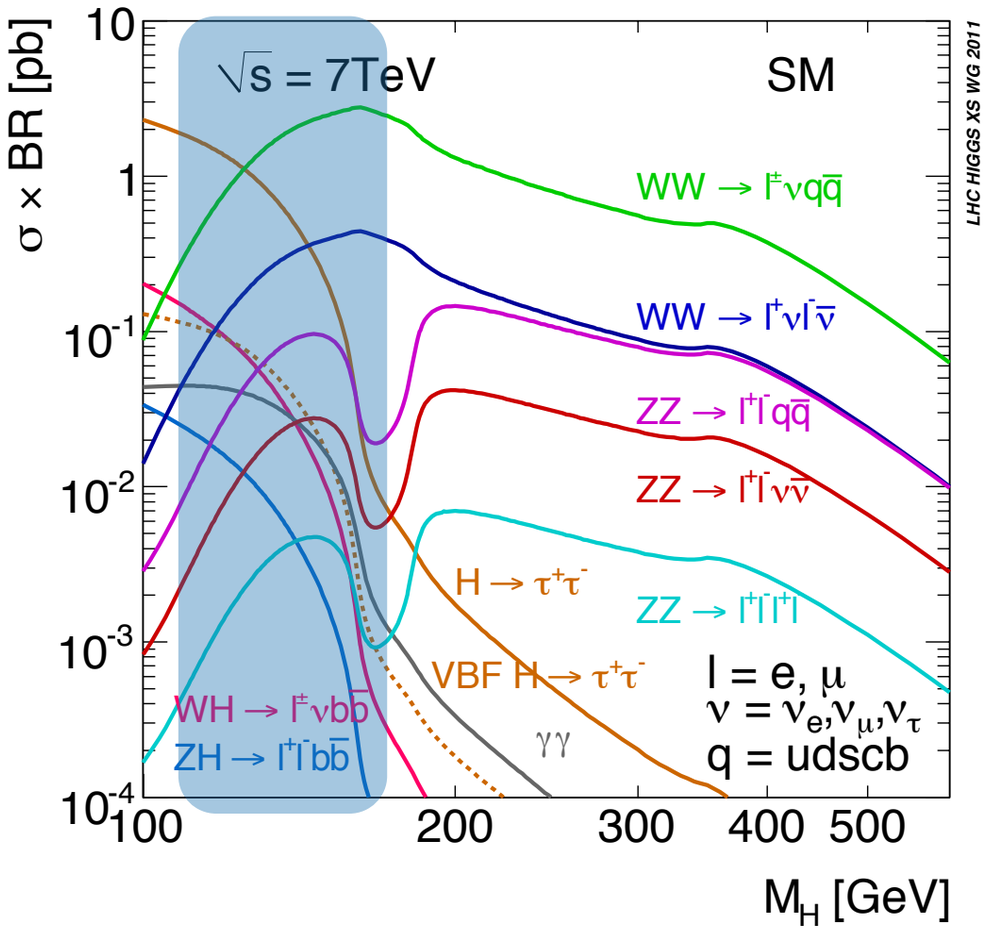


- **Discriminating variable**
  - invariant mass $m_{\tau\tau}$ from τ decay products and E_T^{miss} **(collinear approximation/ Missing mass Calculator)**

- **Result**
  - No observable excess for m_H between 110-150 GeV
  - **Observed limit:** 2.9-11.7xσ_{SM}
    Expected limit: 3.4-8.2xσ_{SM}

Outline

- **High Higgs mass**
  - H→WW→lνqq
  - H→ZZ→llqq
  - H→ZZ→llνν
- **Low Higgs mass, limited resolution**
  - H→WW→lνlν
  - VH→bb
  - H→ττ
- **Low Higgs mass, high resolution**
  - H→γγ
  - H→ZZ→llll
- **Combination**

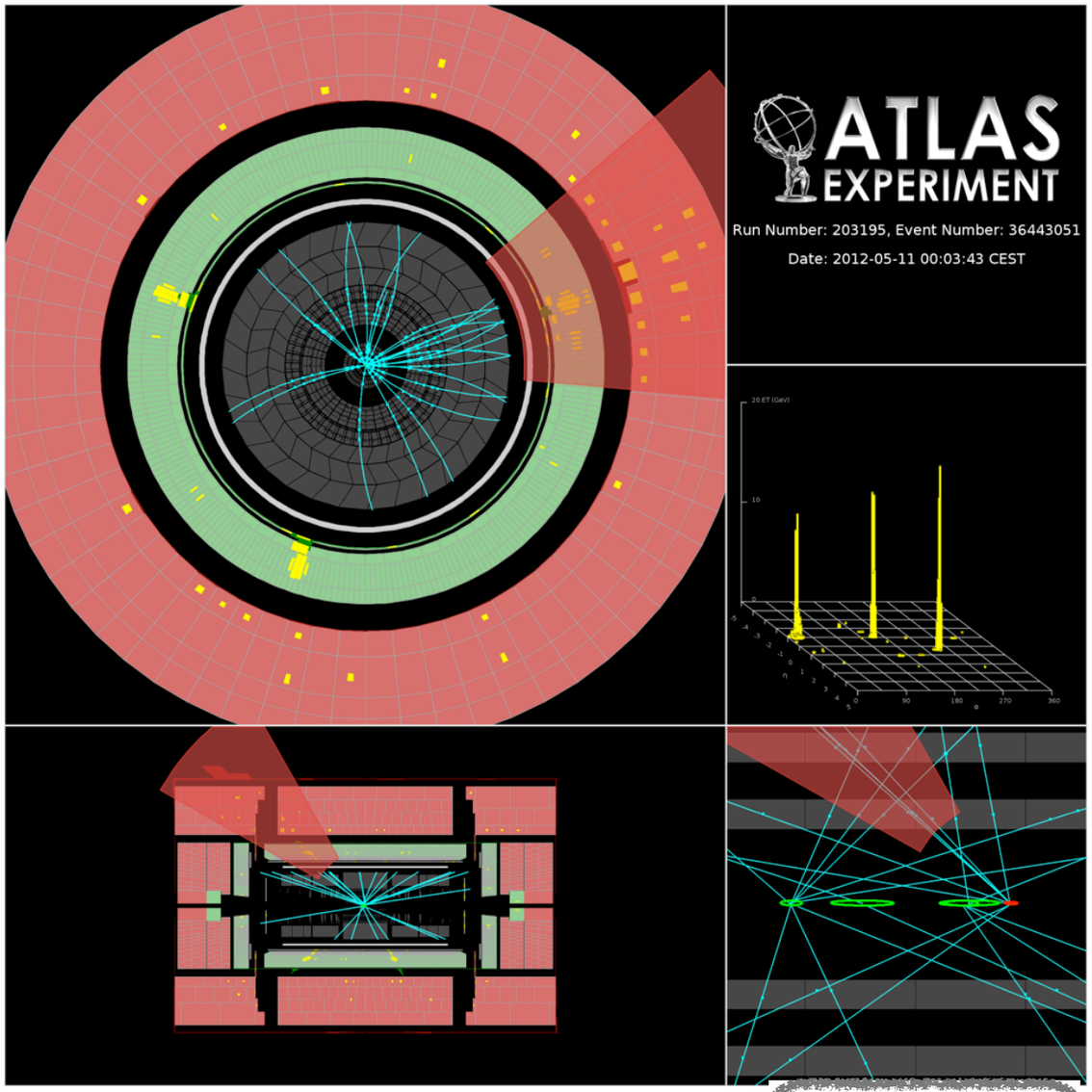


$H \rightarrow \gamma\gamma$

further details in talk of *Ruggero Turra*

Characteristics

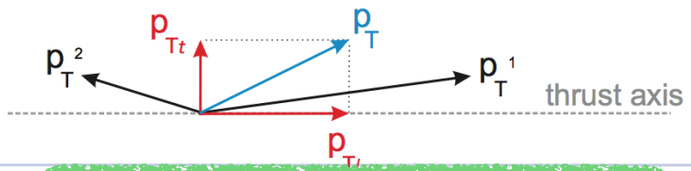
- Two isolated photons, E_{T1} >40 GeV, E_{T2} > 30 GeV
- 10 analysis categories: **converted/ unconverted**, detector **region**, **p_T thrust**, **2 jets** (VBF)
- crucial aspects: good mass resolution, good jet rejection



H→γγ candidate

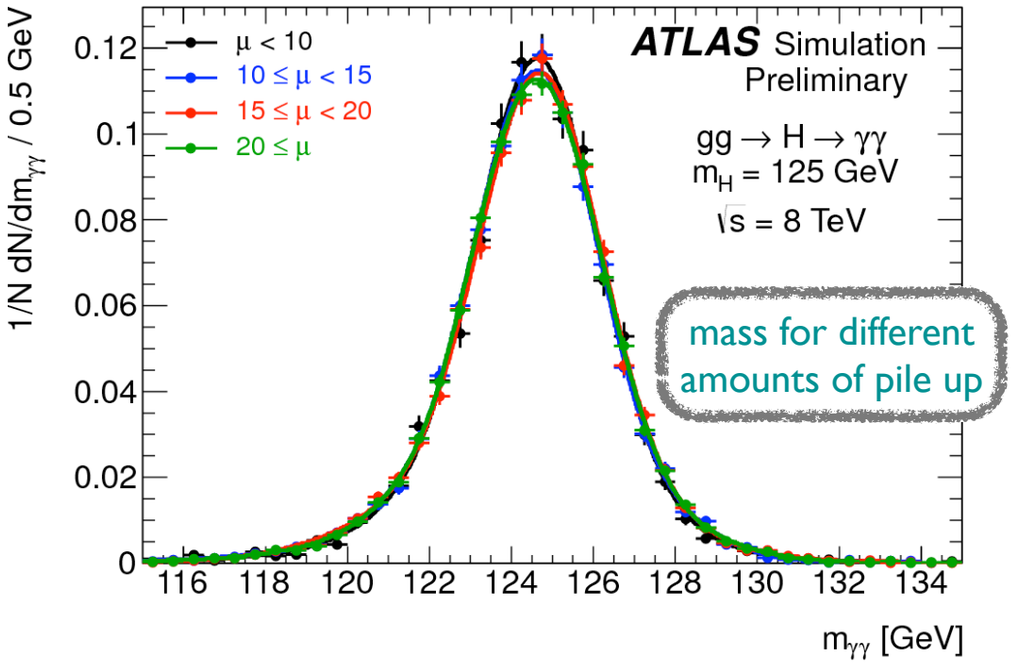
Backgrounds

- γγ (irreducible, 3 orders of magnitude higher), jγ, jj
- validate composition in data control regions (inverted photon ID and isolation), true γγ ~75-80%



pT thrust: orthogonal component of total pT of the system with respect to thrust axis

H→γγ



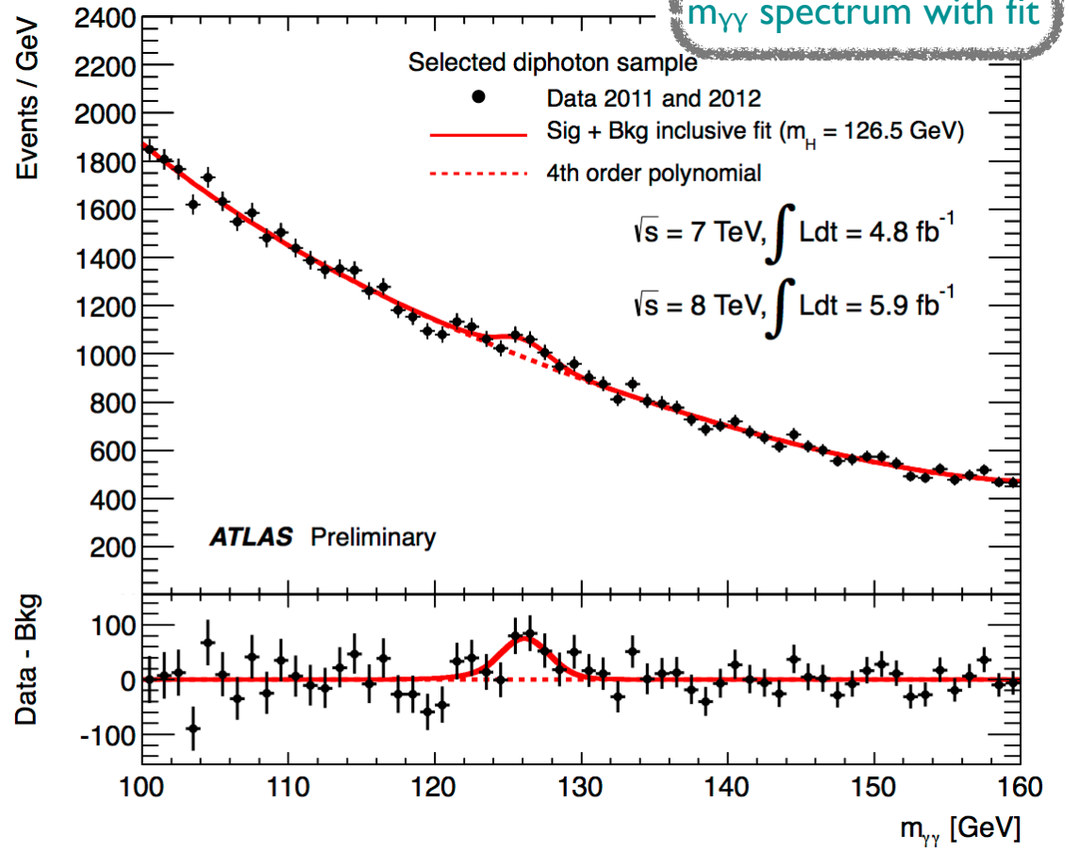
mass for different amounts of pile up

Combined 2011+2012 dataset used (4.8+5.9 fb^{-1})

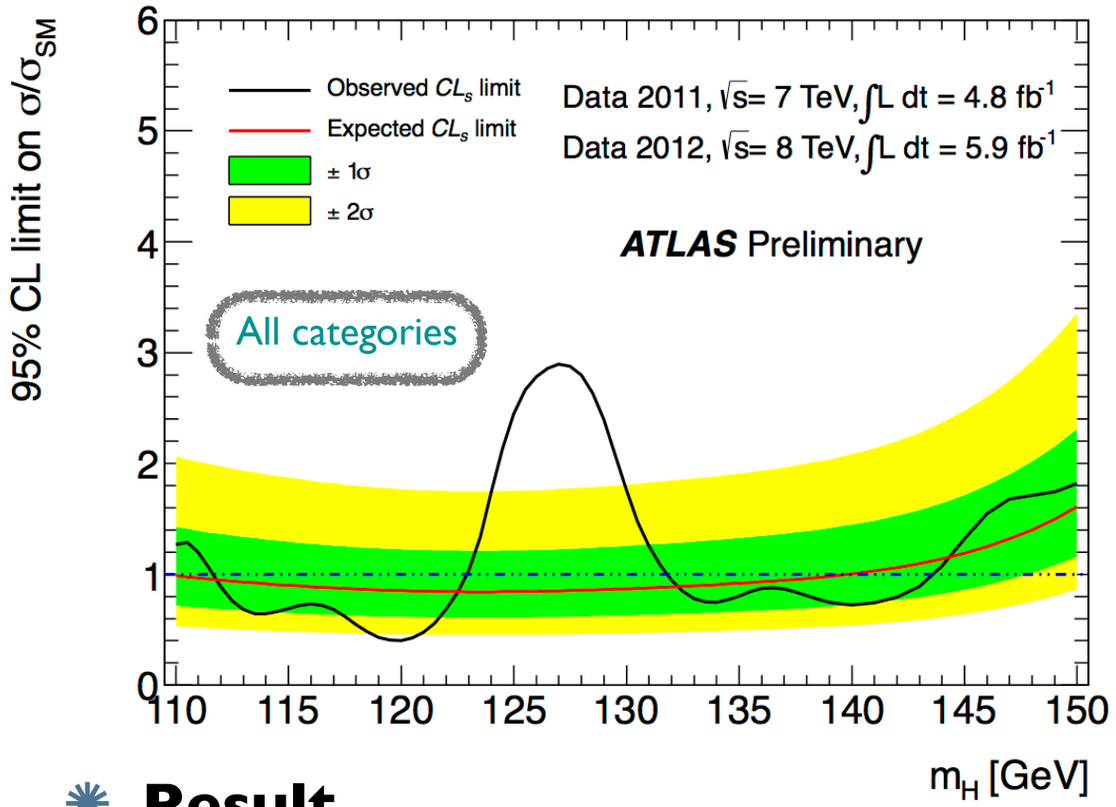
- **Fit of $m_{\gamma\gamma}$ spectrum** in each category, combined signal (Crystal Ball plus wide Gaussian) and background (various analytic functions)

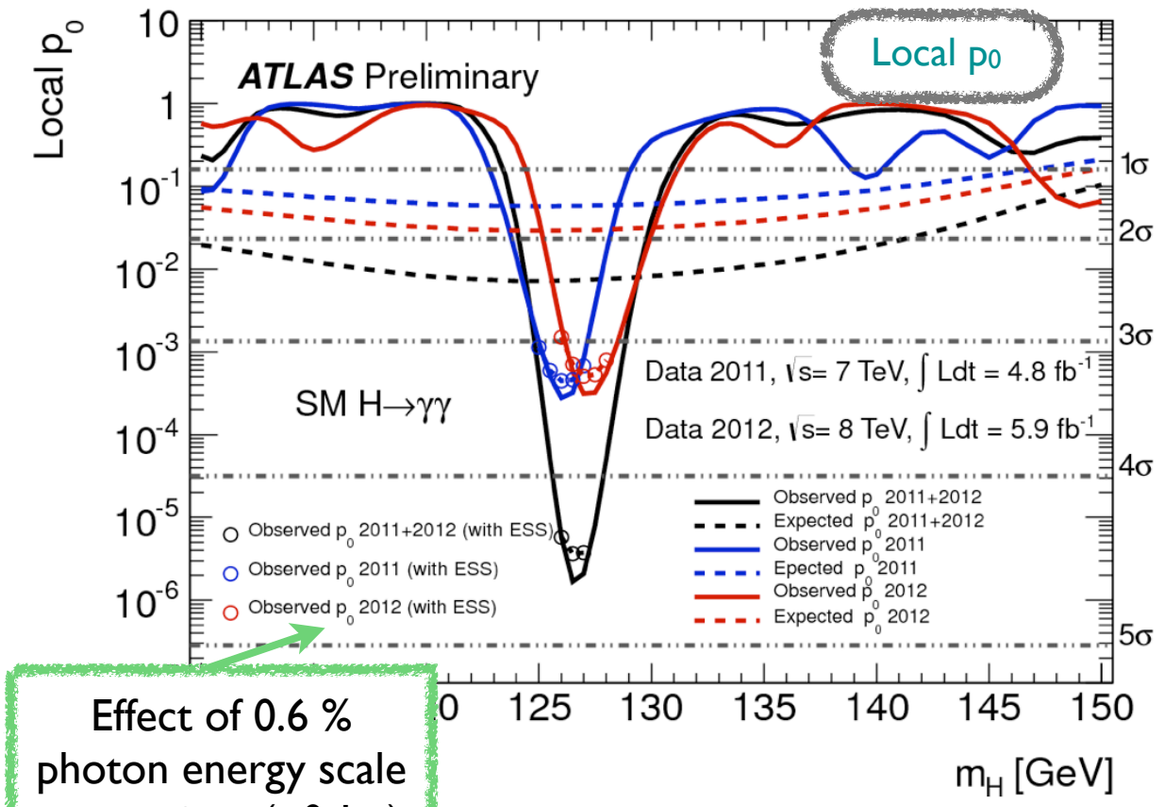
- **Discriminating variable**
  - **invariant mass $m_{\gamma\gamma}$,** $m_{\gamma\gamma}^2 = 2\, E_1 * E_2 * (1-\cos\alpha)$
  - excellent mass resolution σ = **1.6-3.1 GeV,**
    - good calorimeter energy measurement (scale uncertainty on signal yield ~0.3%)
    - identifying primary vertex via photon pointing (σ_z ~ 1.5 cm), stable against pile up

combined categories $m_{\gamma\gamma}$ spectrum with fit



H→γγ





Effect of 0.6 % photon energy scale uncertainty (~0.1σ)

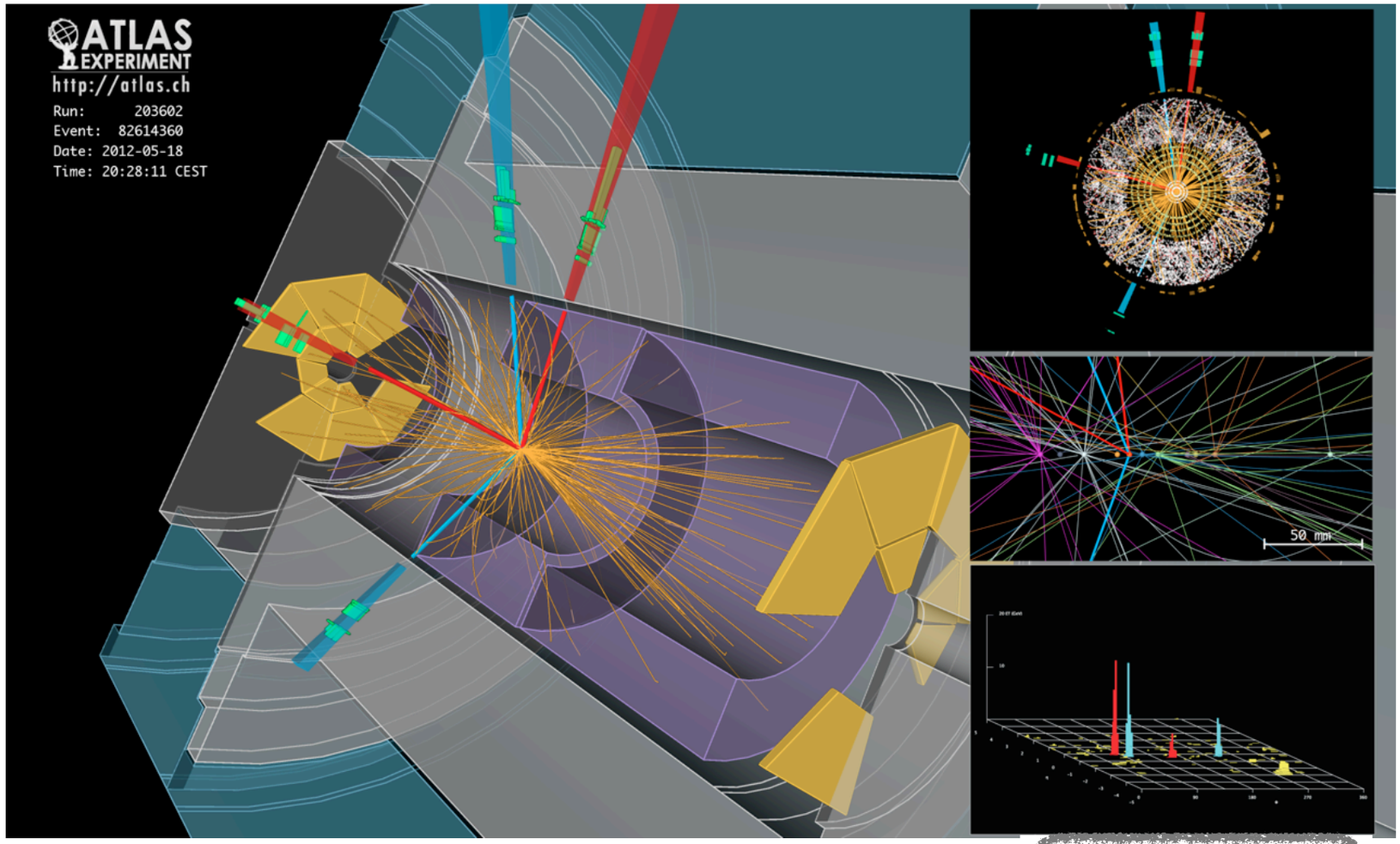
- **Result**
  - **Observed exclusion:** 112 -122.5 GeV, 132 -141 GeV, expected: 110 - 139.5 GeV
  - **Excess** observed consistently in 2011/2012 data

Maximum excess observed at:	**m_H = 126.5 GeV**
Local significance (with ESS):	**4.5σ**
Probability of background up fluctuation:	**2 x 10^{-6}**
Expected significance from SM Higgs at m_H = 126.5 GeV:	**2.4σ**

Global significance including Look Elsewhere effect (LEE), probalility to observe excess anywhere in mass range 110-150 GeV: 3.6σ

H→ZZ→llll

further details in talk of *Giacomo Artoni*



H→ZZ→4e candidate

Characteristics

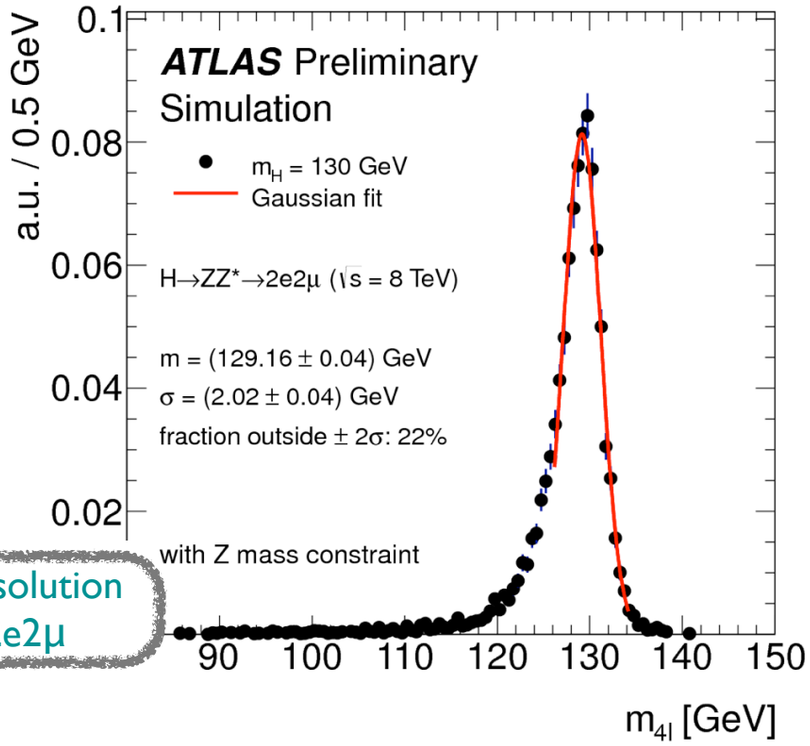
- Small rate, but pure (S/B~1)
- Four isolated leptons, p_T^{1234} >20,15,10,7/6 GeV for e/μ
- analysis categories: **lepton flavours**
- crucial aspects: good mass resolution, reconstruction/ identification efficiency of leptons

Backgrounds

- ZZ (irreducible) from Monte Carlo simulation
- Z+jets, ttbar, measured and fitted in data control regions (inverted ID/isolation and impact parameter requirements for softest leptons)

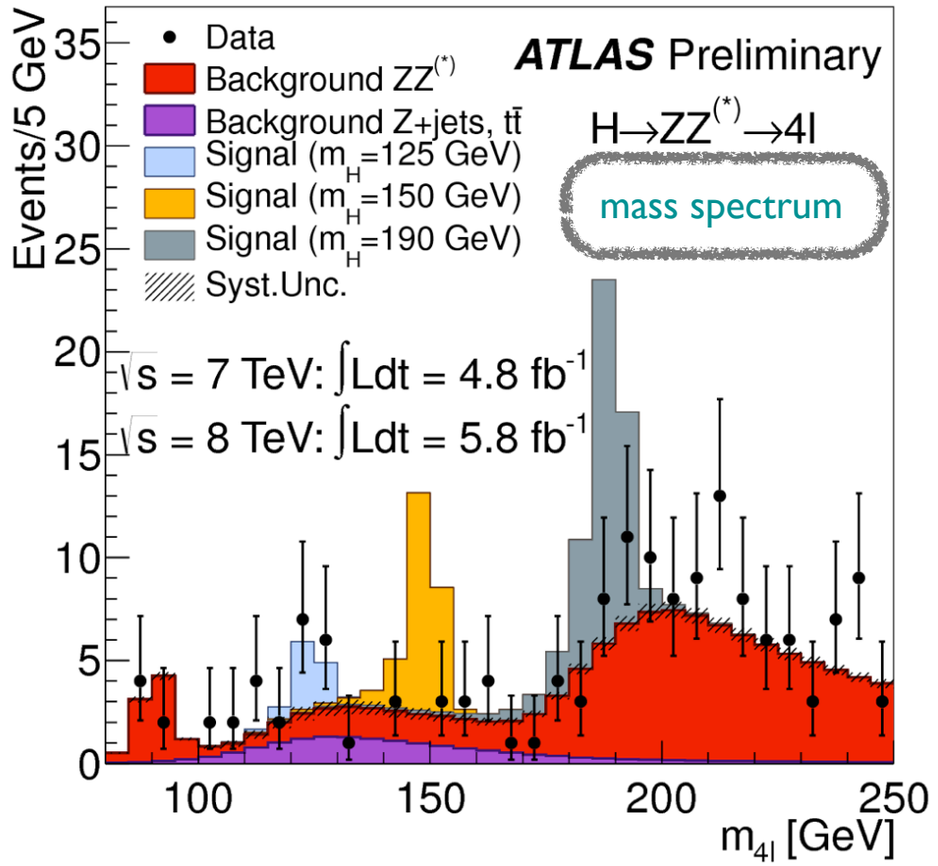
H→ZZ→llll

- **Discriminating variable**
  - **invariant mass m_{lll}**
  - excellent mass resolution σ = **1.8-2.5 GeV** (4μμ/4ee),
  - very good e/μ reconstruction efficiency esp. in low pT region (μ reco ~97% for p_T>6 GeV, e reco ~98%, e ID ~95%), robust against pile-up



mass resolution for 2e2μ

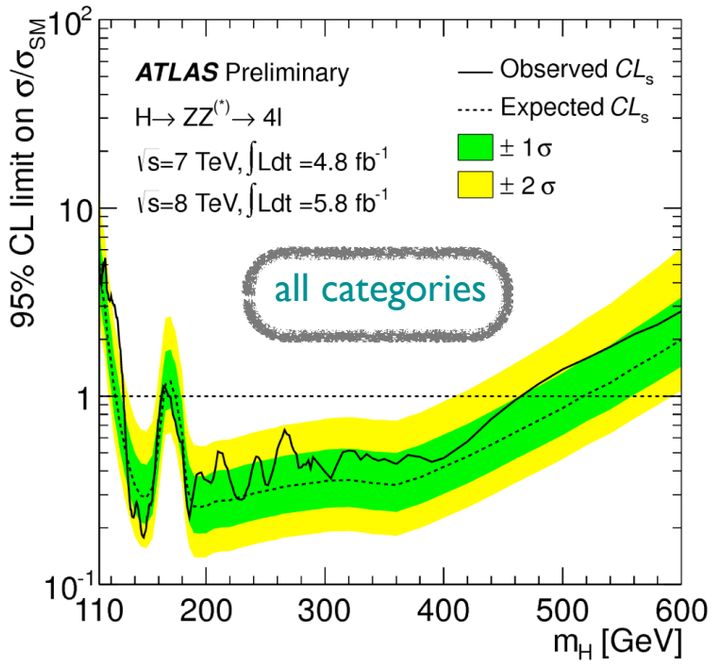
Combined 2011+2012 dataset used (4.8+5.8 fb^{-1})

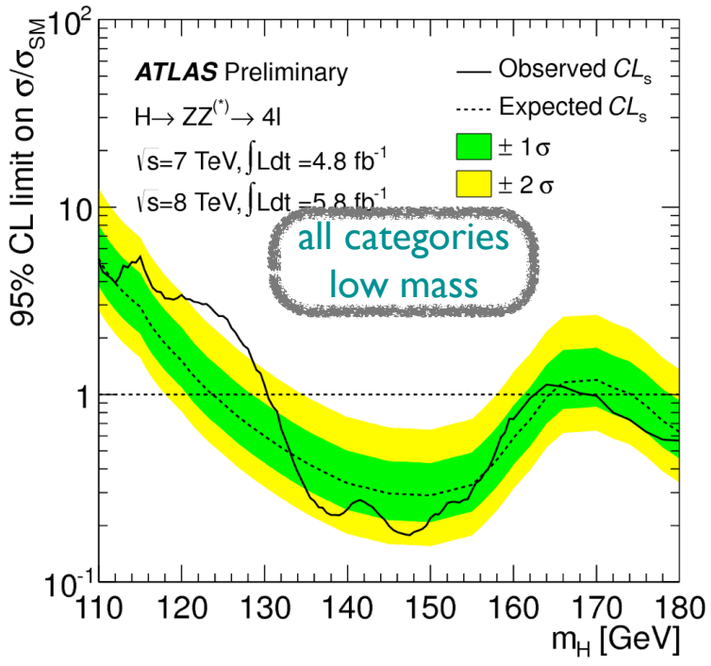


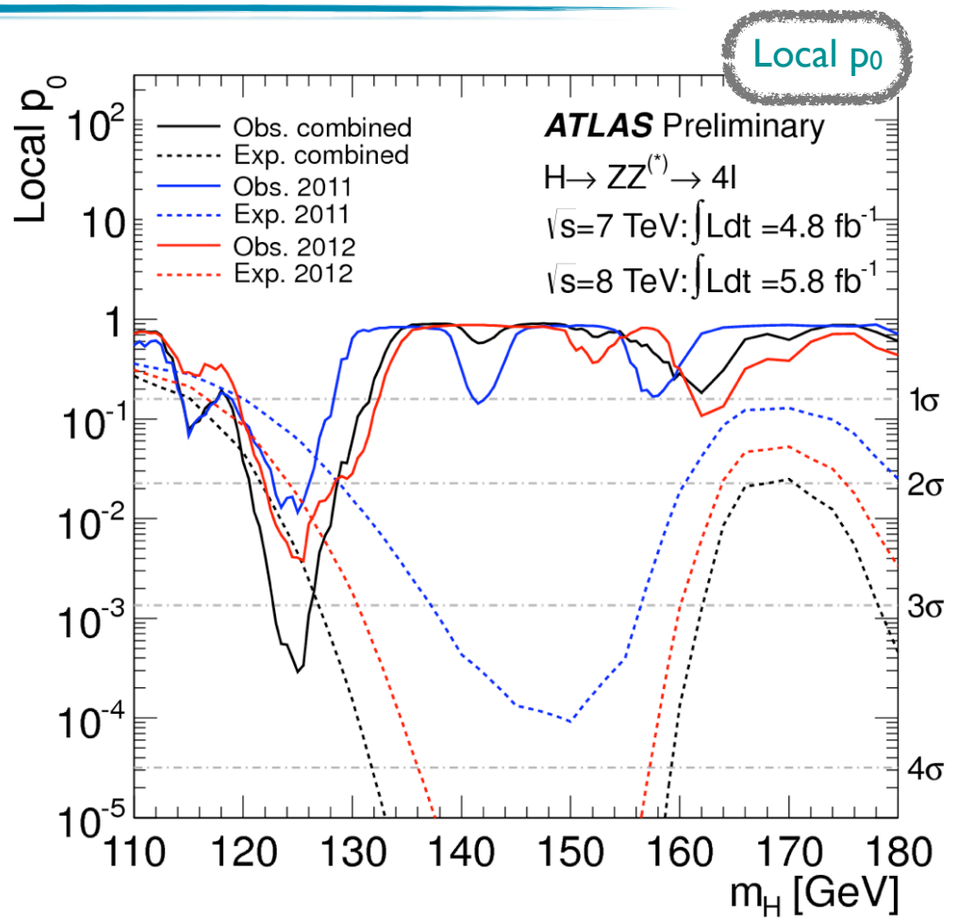
- Events in region 125±5 GeV

Dataset	Events
Expected background	5.1 ± 0.8
Expected signal m_H = 125 GeV	5.3 ± 0.8
Observed in data	**13**

H→ZZ→llll







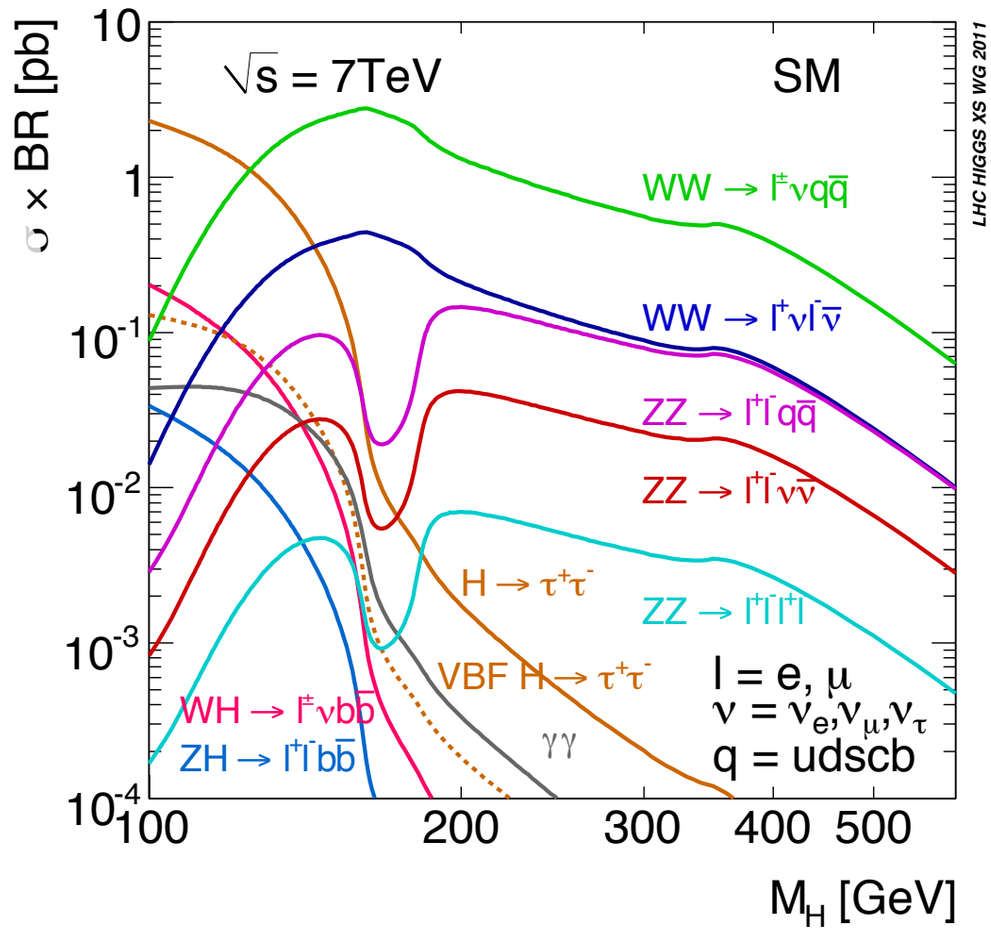
- **Result**
  - **Observed exclusion:** 131-162 GeV, 170-460 GeV, expected: 124-164 GeV, 176-500 GeV
  - **Excess** observed consistently in 2011/2012 data

Maximum excess observed at:	**m_H = 125 GeV**
Local significance:	**3.4σ**
Probability of background up fluctuation:	**3 x 10^{-4}**
Expected significance from SM Higgs at m_H = 125 GeV:	**2.6σ**

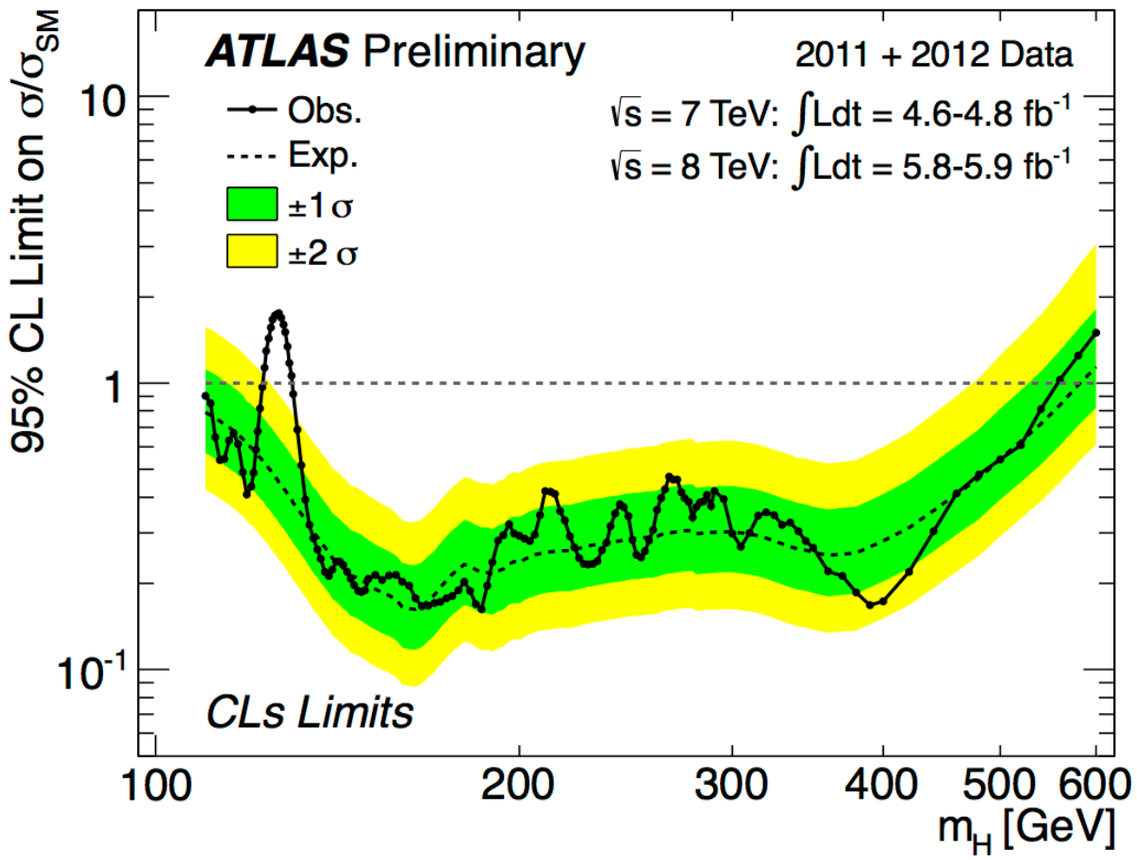
Global significance (including LEE): 2.5σ (in 110-141 GeV)

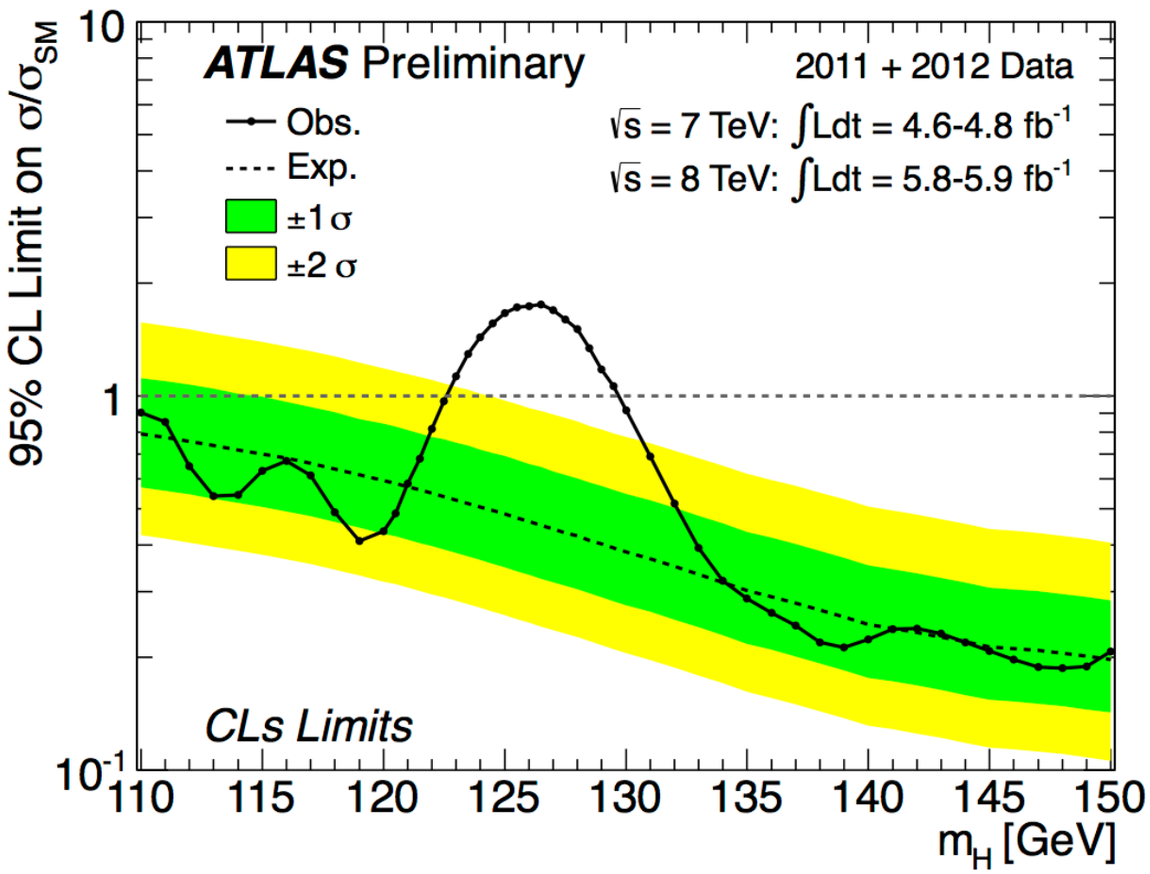
Outline

- High Higgs mass
  - H→WW→lνqq
  - H→ZZ→llqq
  - H→ZZ→llνν
- Low Higgs mass, limited resolution
  - H→WW→lνlν
  - VH→bb
  - H→ττ
- Low Higgs mass, high resolution
  - H→γγ
  - H→ZZ→llll
- **Combination**



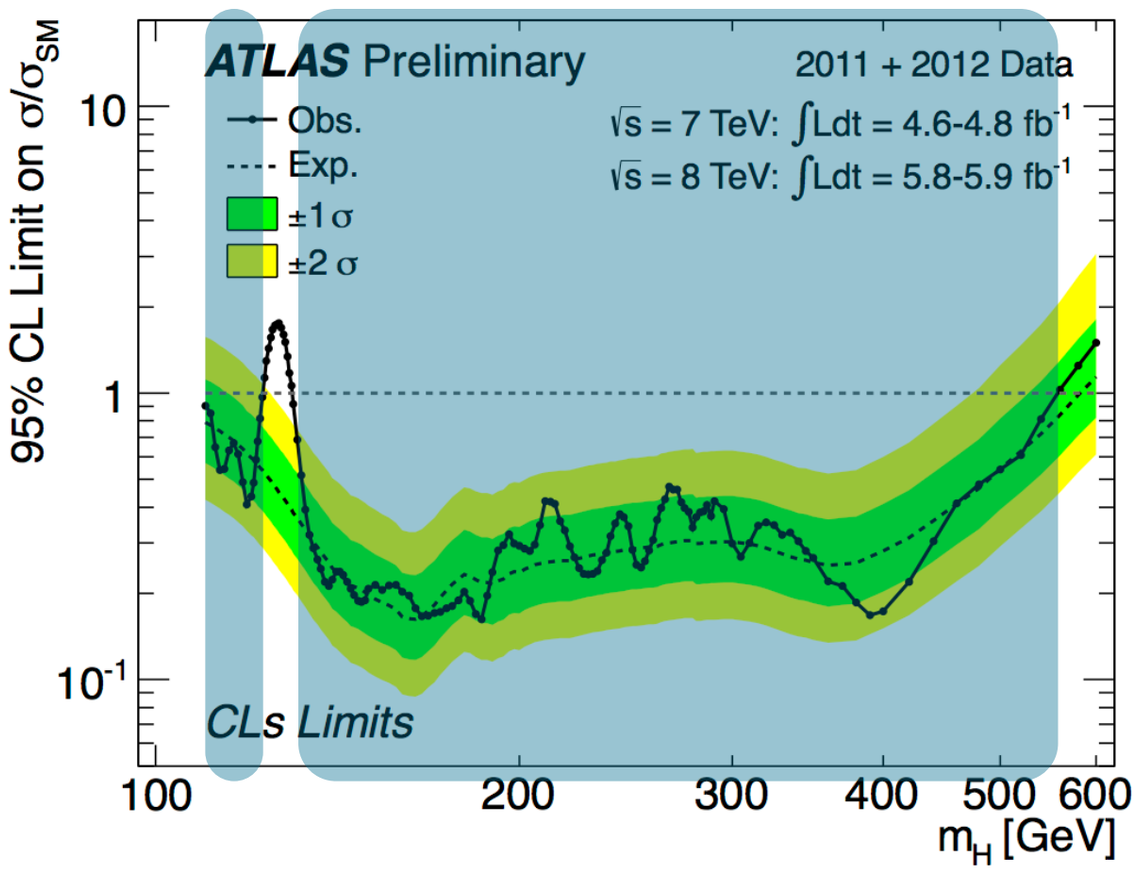
Combined results: Exclusion limits

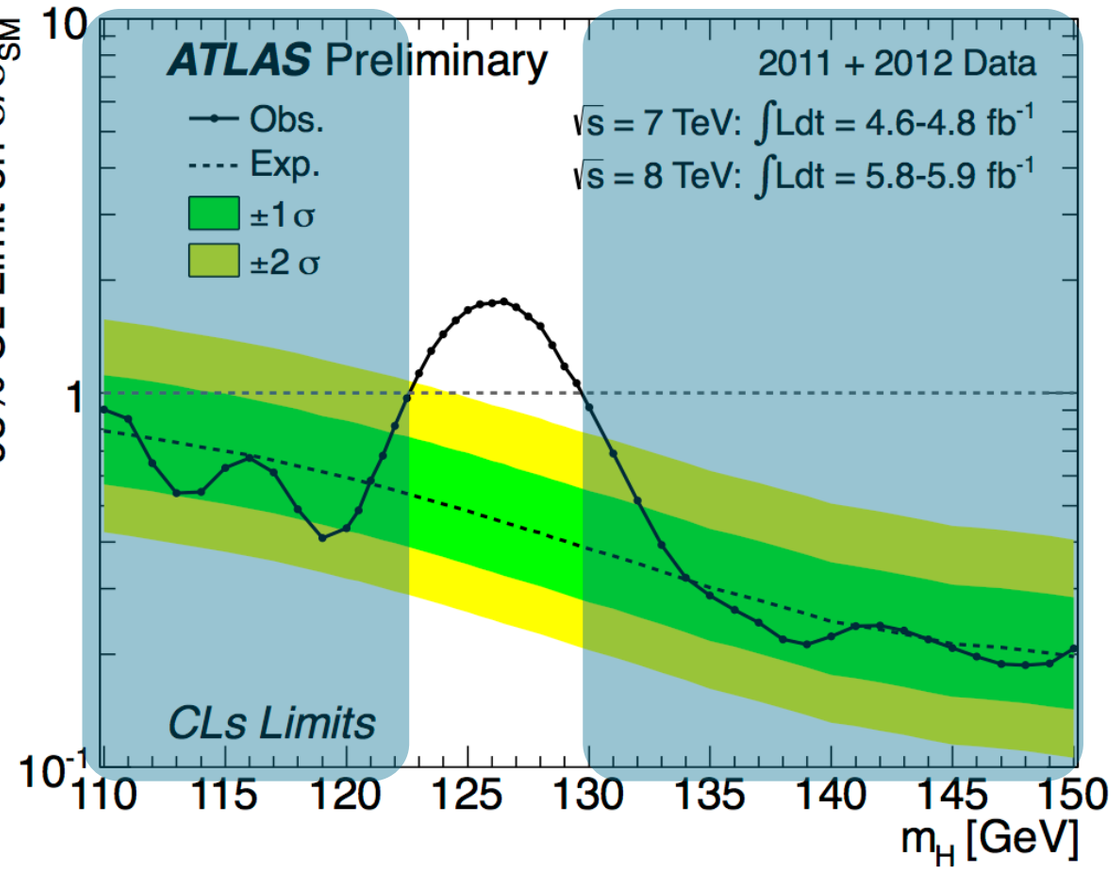




- **Excluded at 95% CL:** 110-122.6 GeV, 129.7-558 GeV
- **Excluded at 99% CL:** 111.7-121.7 GeV, 130.7-523 GeV
- **Expected exclusion at 95% CL (no signal):** 110-582 GeV

Combined results: Exclusion limits





- **Excluded at 95% CL:** 110-122.6 GeV, 129.7-558 GeV
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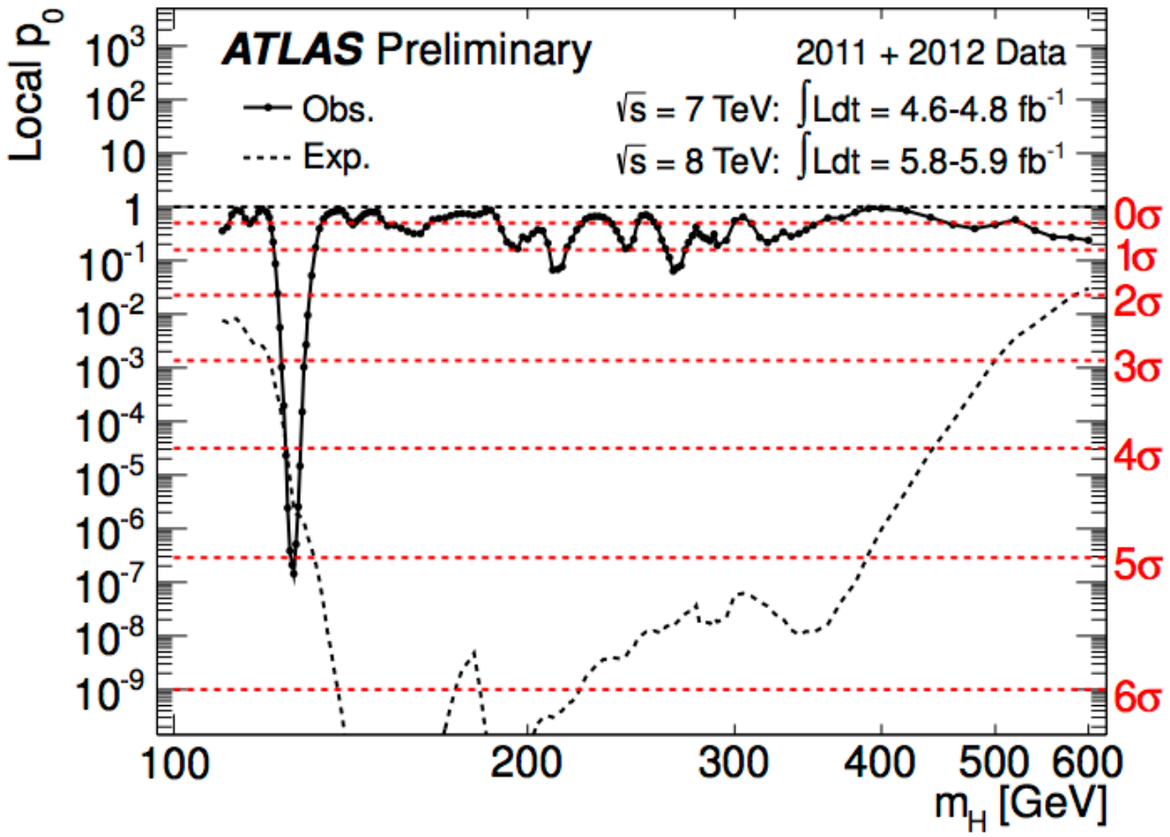
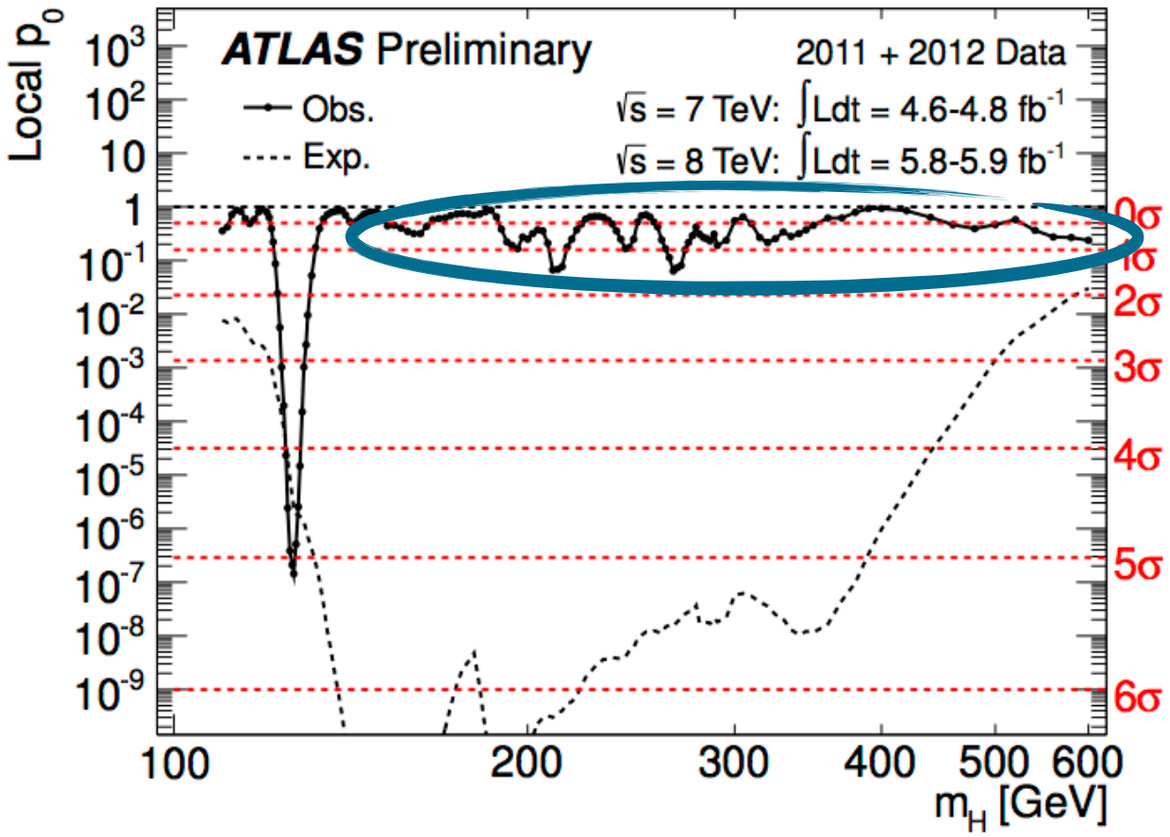
Background only expectation and significance

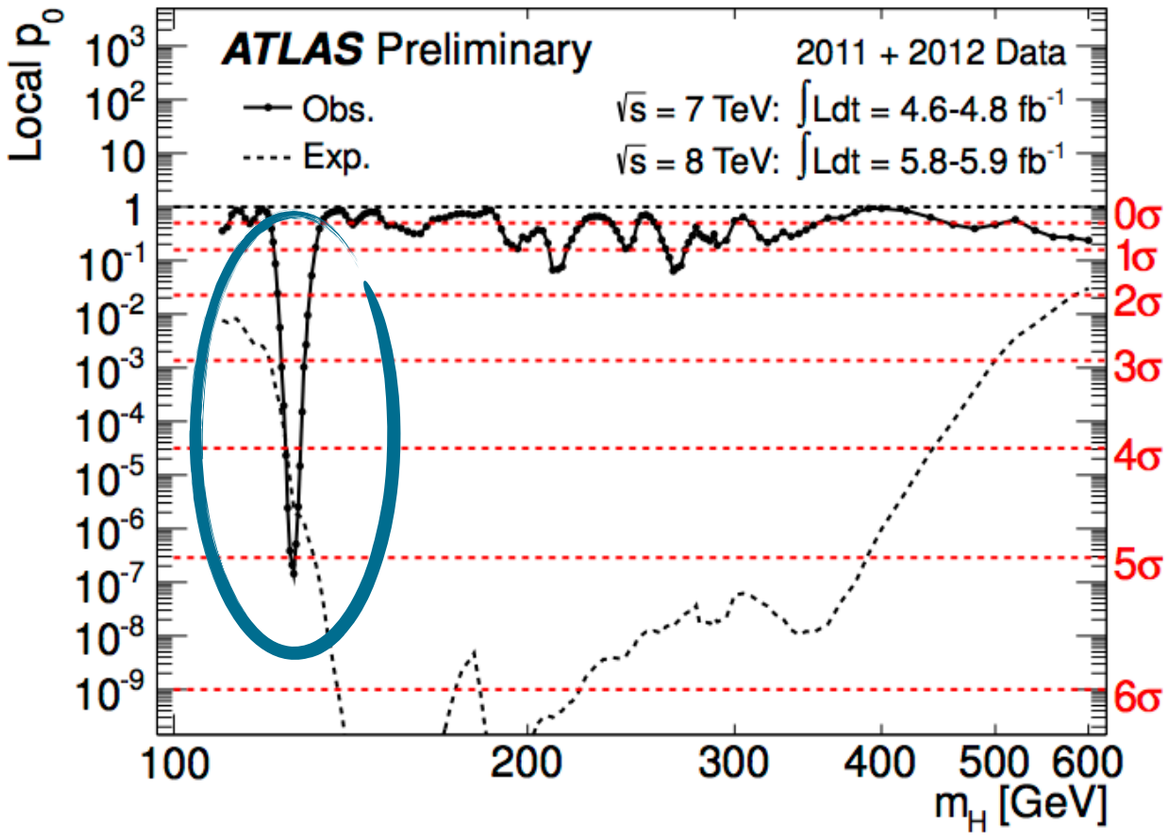


Background only expectation and significance



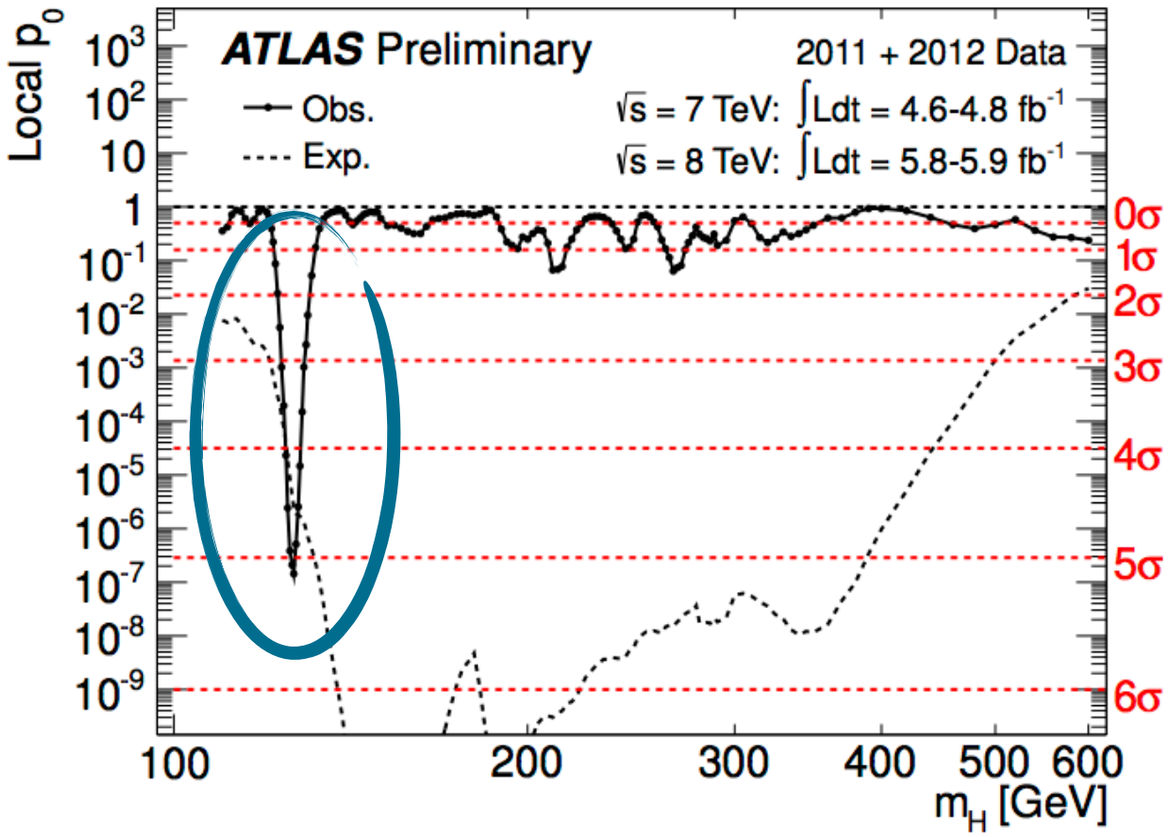
- Excellent **consistency** of data **with background only hypothesis** (less than 2σ) over full mass spectrum

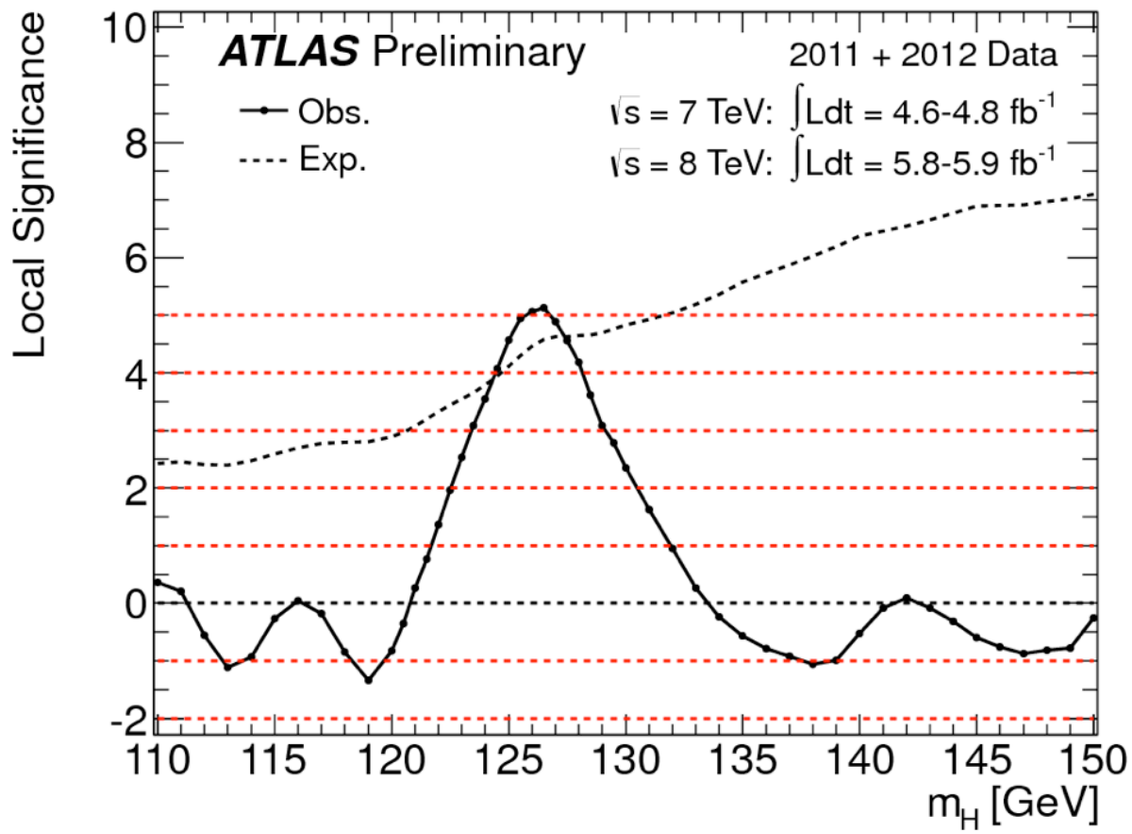
Background only expectation and significance



- Excellent **consistency** of data **with background only hypothesis** (less than 2σ) over full mass spectrum
- **excess in one region**

Background only expectation and significance





- Excellent **consistency** of data **with background only hypothesis** (less than 2σ) over full mass spectrum
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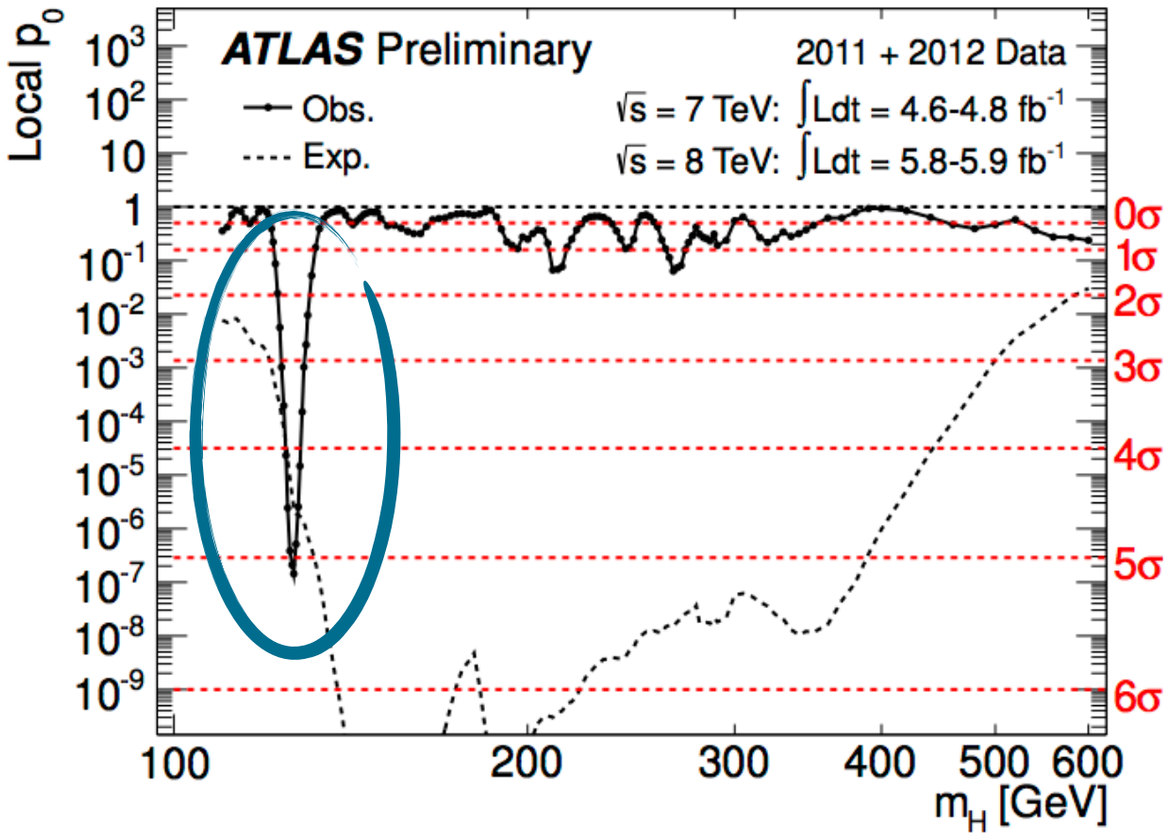
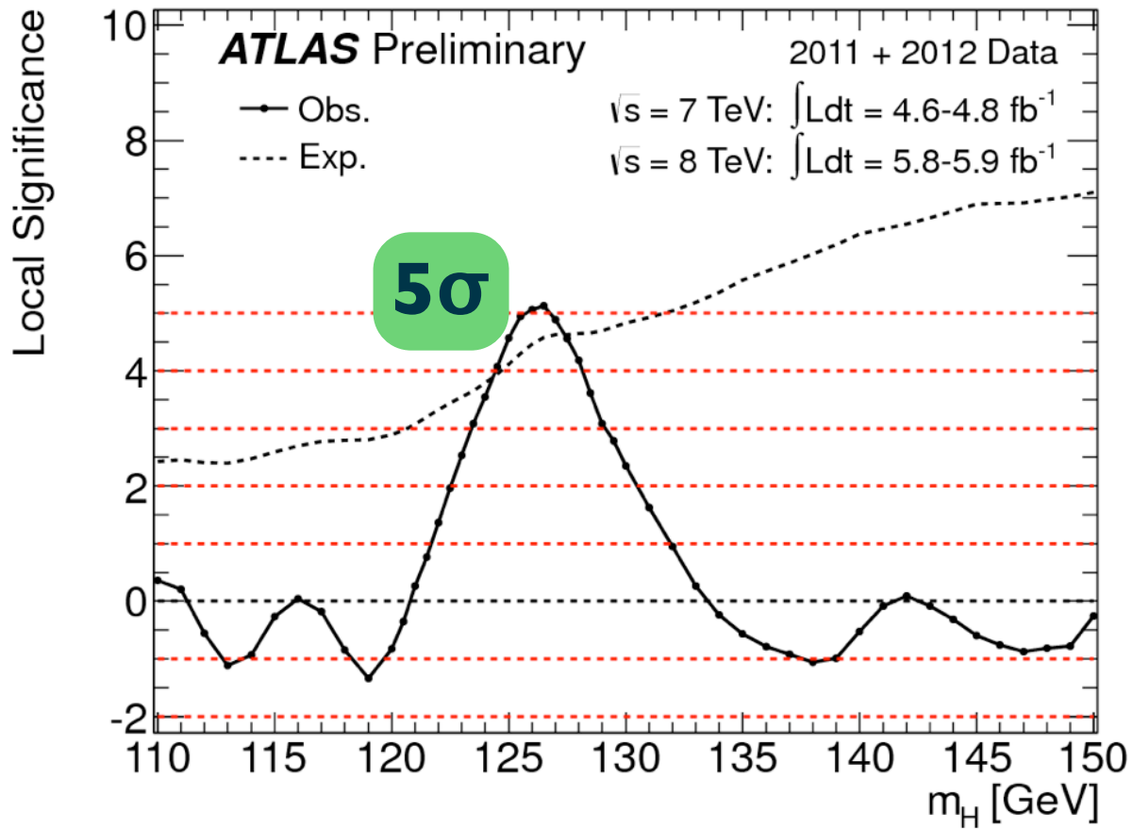
Background only expectation and significance





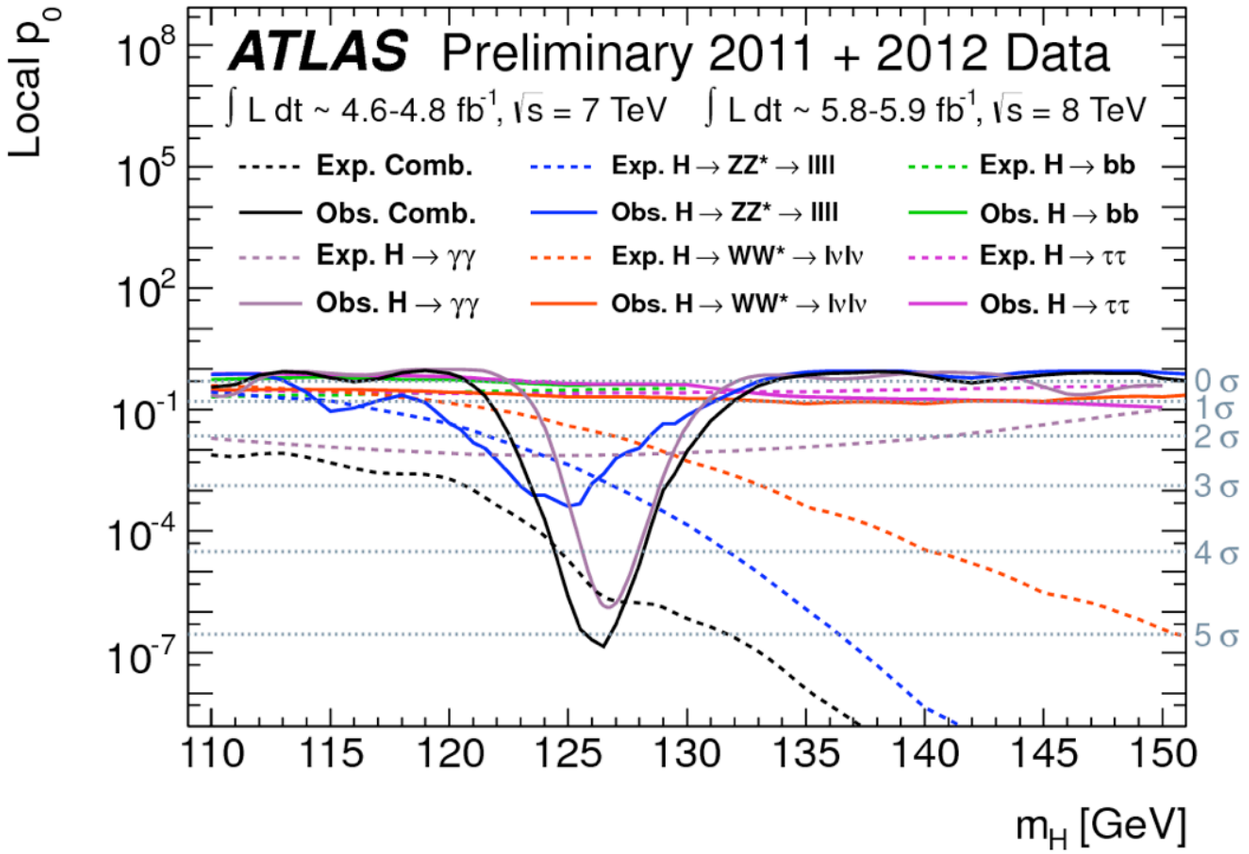
- Excellent **consistency** of data **with background only hypothesis** (less than 2σ) over full mass spectrum
- **excess in one region**

Maximum excess observed at:	**m_H = 126.5 GeV**
Local significance:	**5σ**
Probability of background up fluctuation:	**3 x 10^{-7}**
Expected significance from SM Higgs at m_H = 126.5 GeV:	**4.6σ**
Signal strength μ at m_H = 126.5 GeV:	**1.2 ± 0.3**

Global significance (including LEE): 4.1σ in 110-600 GeV or 4.3σ in 110-150 GeV

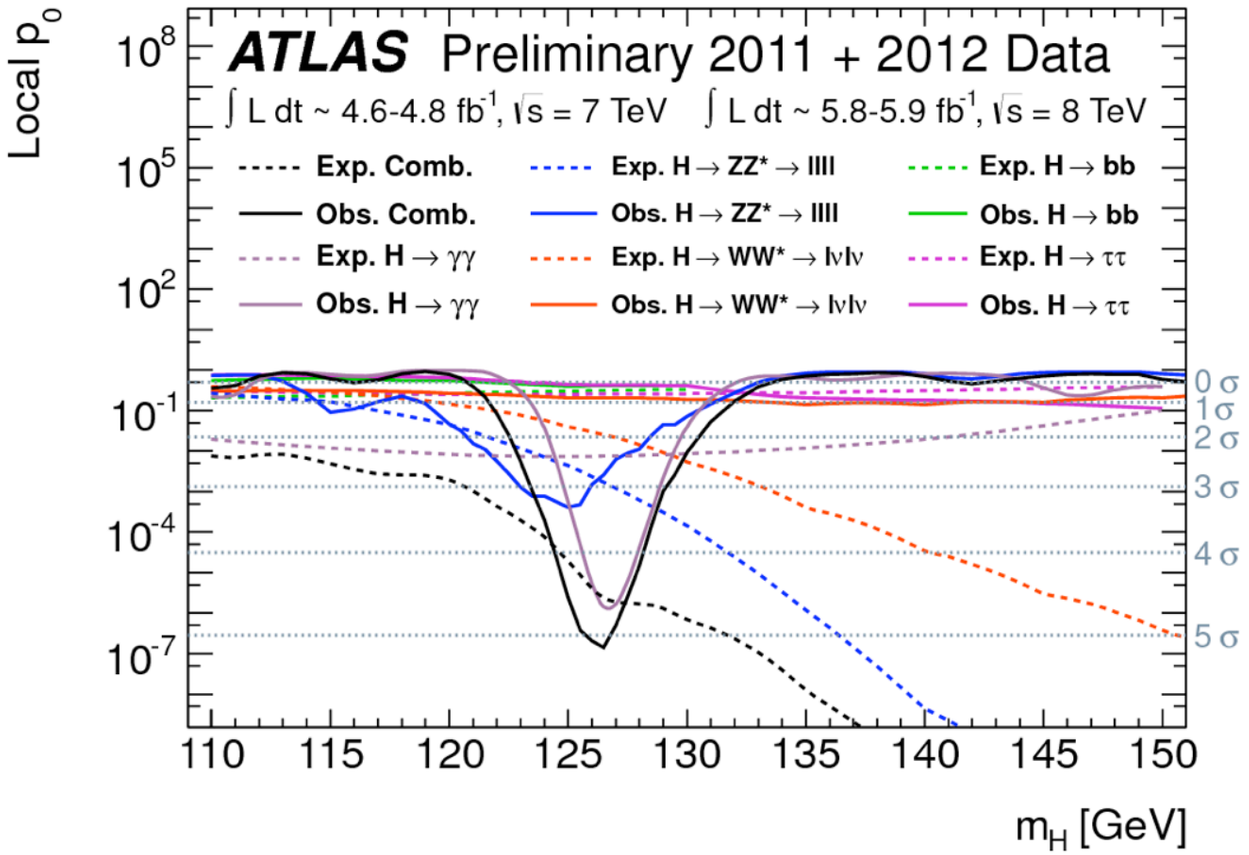
Excess in different channels and over time

Excess in different channels and over time

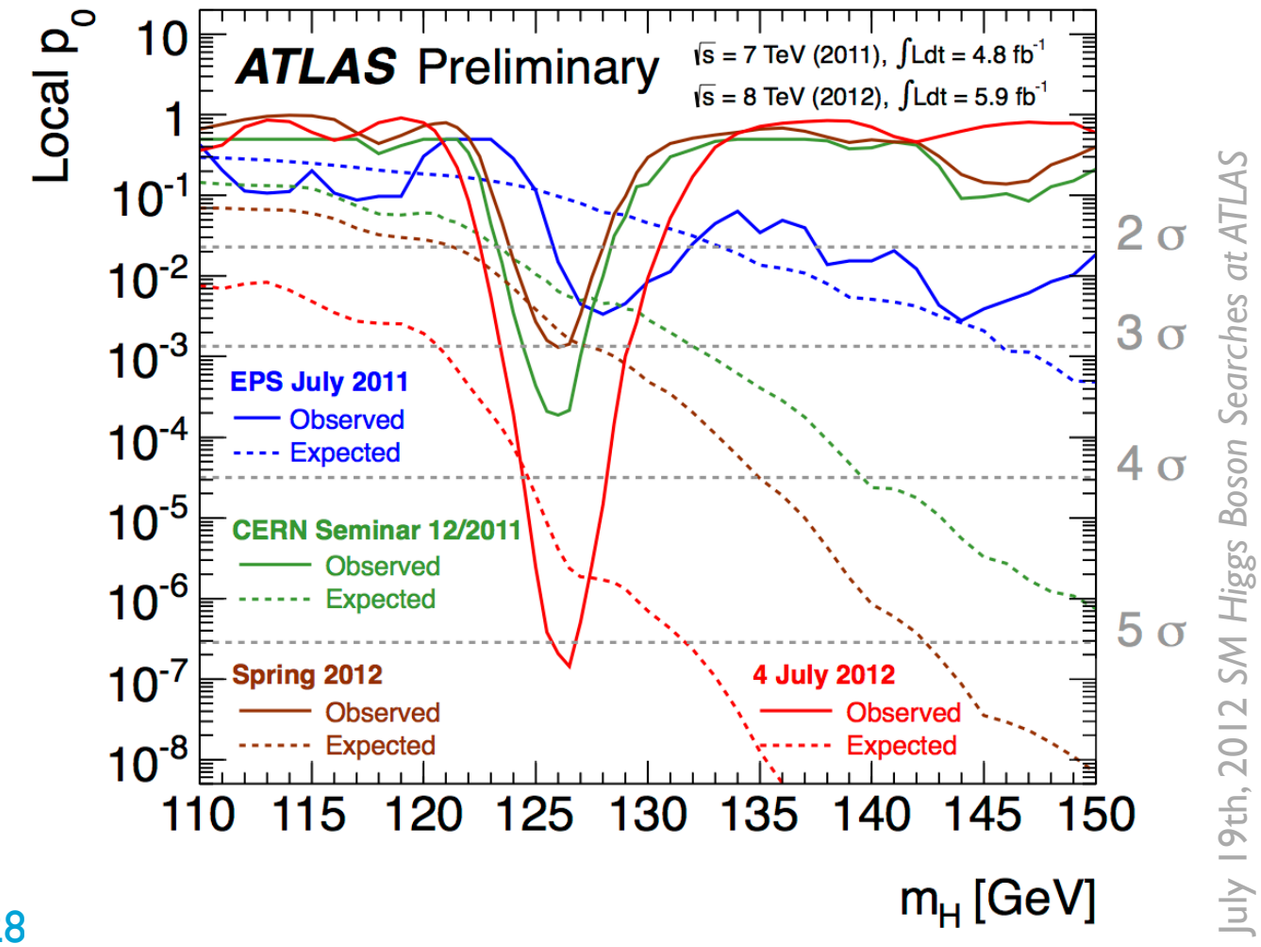


- **Excess consistent** in **γγ** and **llll decay**
- Low resolution channels (**lνlν, ττ, bb**) not yet as sensitive but will be important for measurement of **properties of signal**

Excess in different channels and over time



- **Steady** increase in excess over time



- **Excess consistent** in **γγ** and **llll decay**
- Low resolution channels (**lνlν, ττ, bb**) not yet as sensitive but will be important for measurement of **properties of signal**

Conclusion

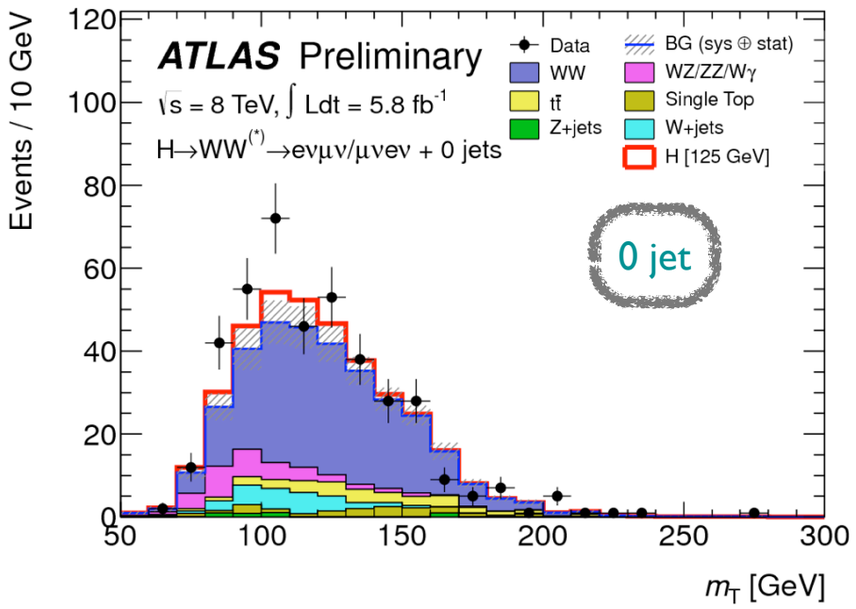
- **Search for the SM Higgs Boson** in $110 < m_H < 600$ GeV in 12 decay channels
  - Full results obtained from 2011 data ($\sqrt{s}$ = 7 TeV, ~4.7 fb^{-1})
  - Updated results added from 2012 data ($\sqrt{s}$ = 8 TeV, ~5.9 fb^{-1}) for $H \to \gamma\gamma$ and $H \to ZZ \to llll$

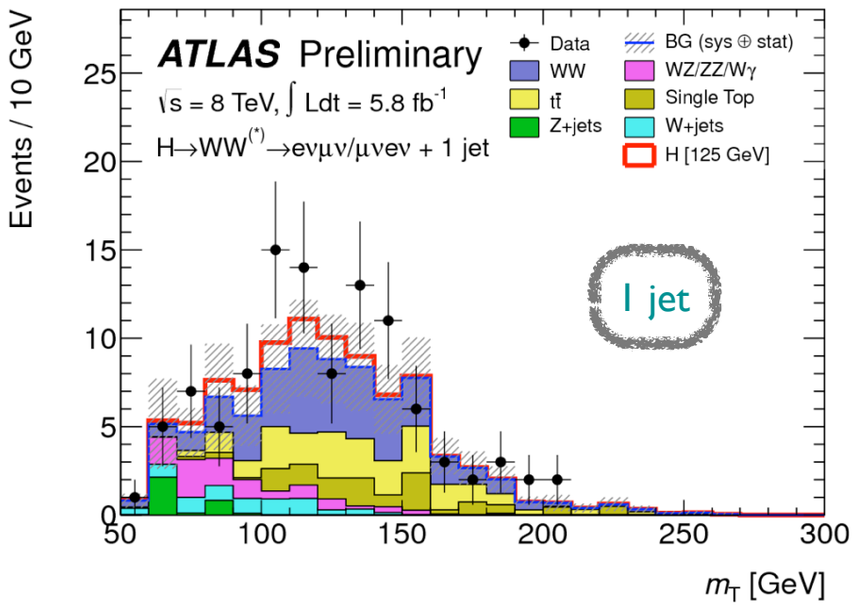
- **At 95% CL** mass ranges 110-122.6 GeV and 129.7-558 GeV have been **excluded**

- Excess observed in data at **m_H = 126.5 GeV with local significance 5σ** consistent with SM Higgs boson (expected significance 4.6σ)
  - Consistently seen in combination and individual **γγ (4.5σ)** and **4l (3.4σ)**

- Exciting times lie ahead:
  - Update all low mass channels to check compatibilty and add new data to **learn more** about this excess

Teaser: H→WW→lνlν update



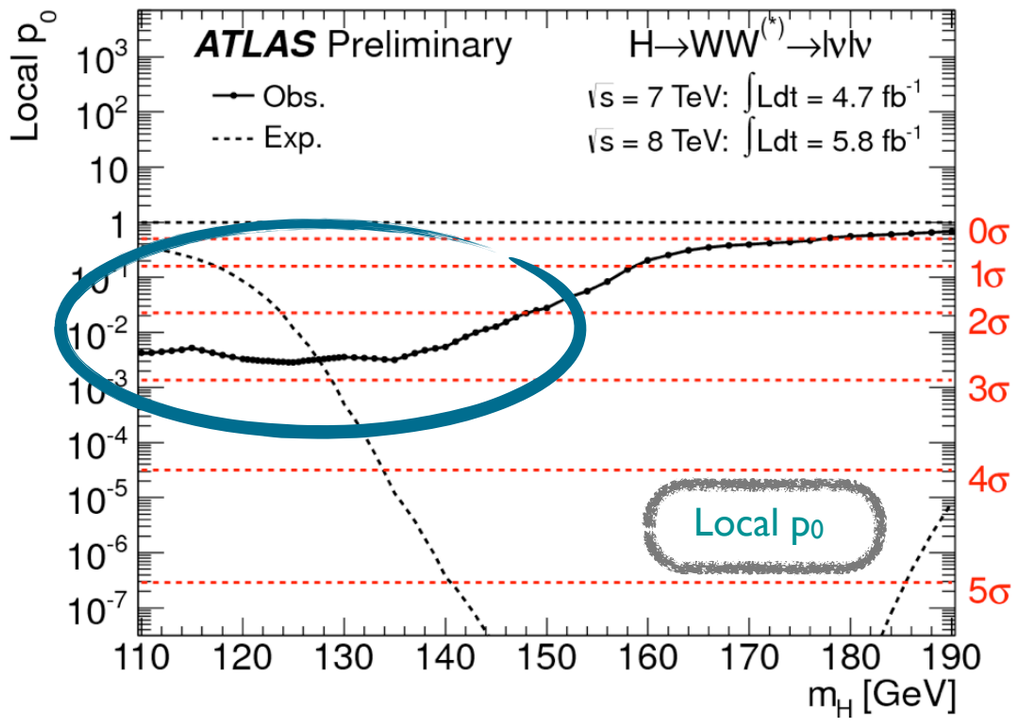


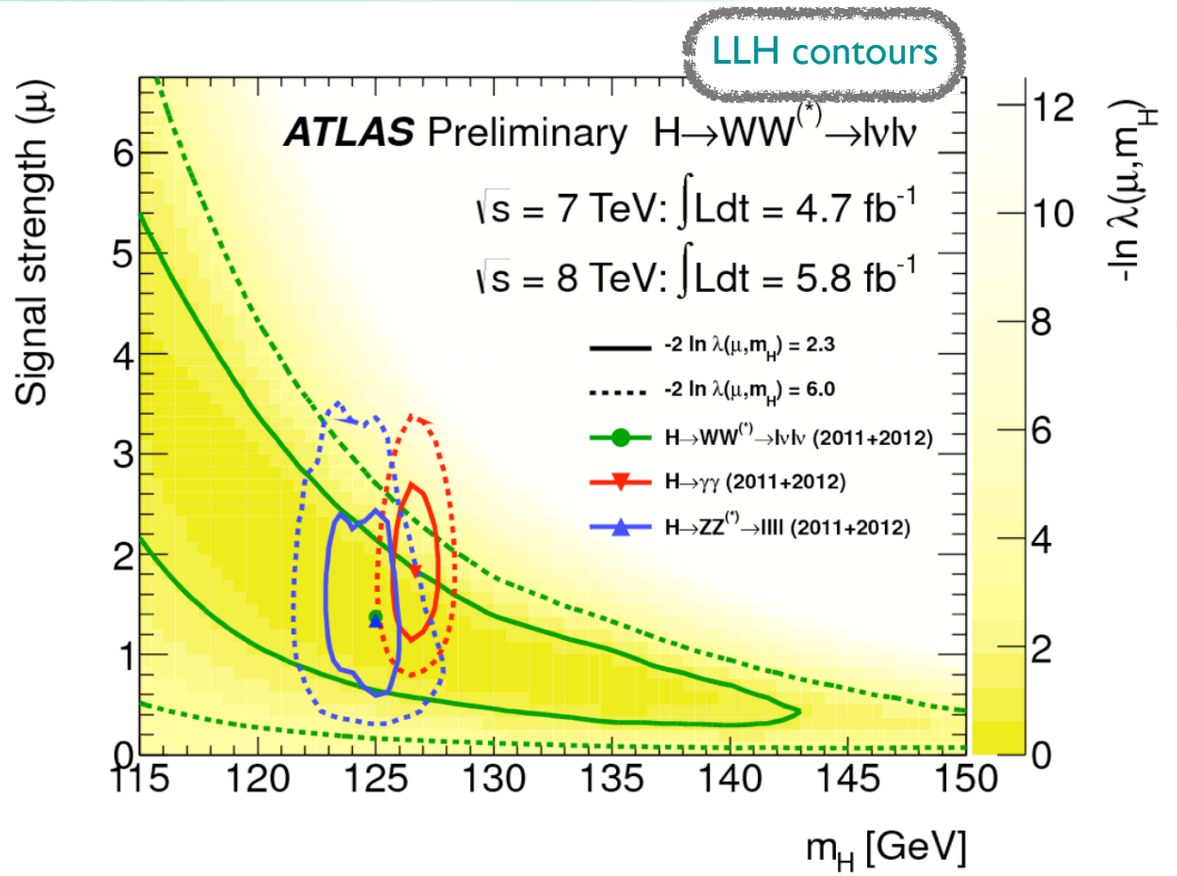
Update with combined 2011+2012 dataset used (4.7+5.8 fb^{-1}), *published this week!*

- Basically same analysis as in 2011, slight **changes in event selection** for higher pile up stability
- reduction to **e+μ** channel

Dataset	0 jet	1 jet
Expected background	339 ± 6	84 ± 4
Expected signal m_H = 125 GeV	33.6 ± 0.4	8.6 ± 0.2
Observed in data	**407**	**106**

Teaser: H→WW→lνlν update





J. Kraus, BSM Quy Nhon

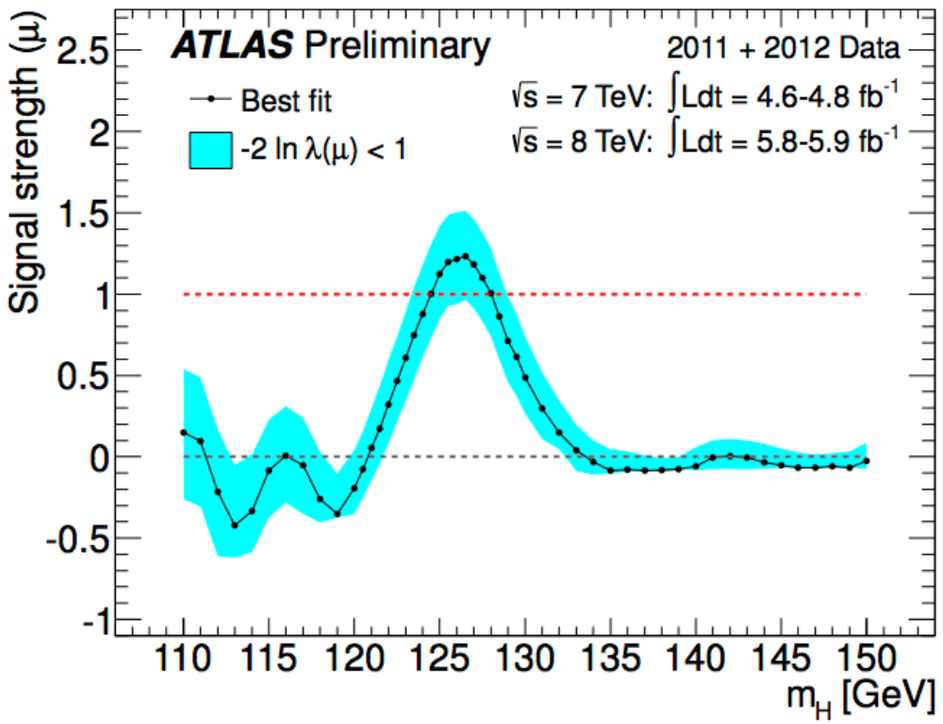
- **Broad excess** not consistent with background hypothesis observed

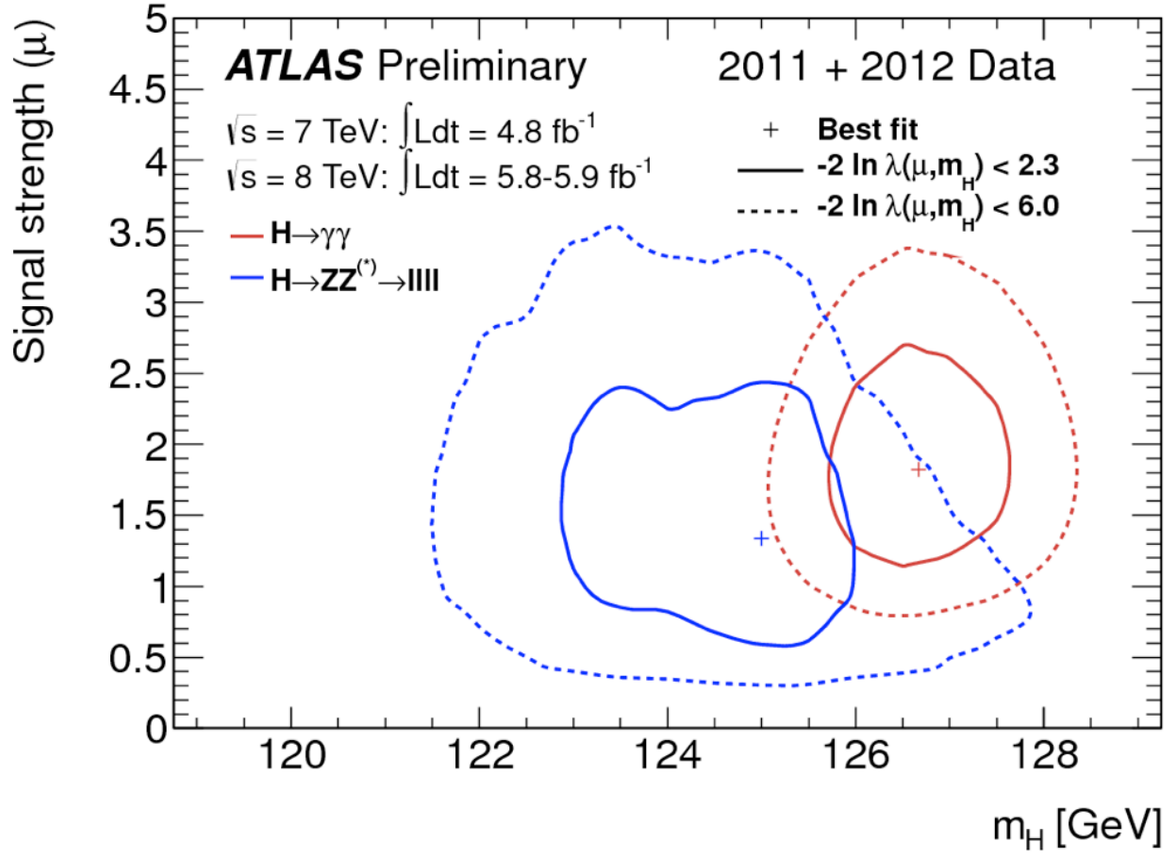
Maximum excess observed at:	**m_H = 125 GeV**
Local significance:	**2.8σ**
Probability of background up fluctuation:	**3 x 10^{-3}**
Expected significance from SM Higgs at m_H = 125 GeV:	**2.3σ**
Signal strength at m_H = 125 GeV:	**1.4 ± 0.5**

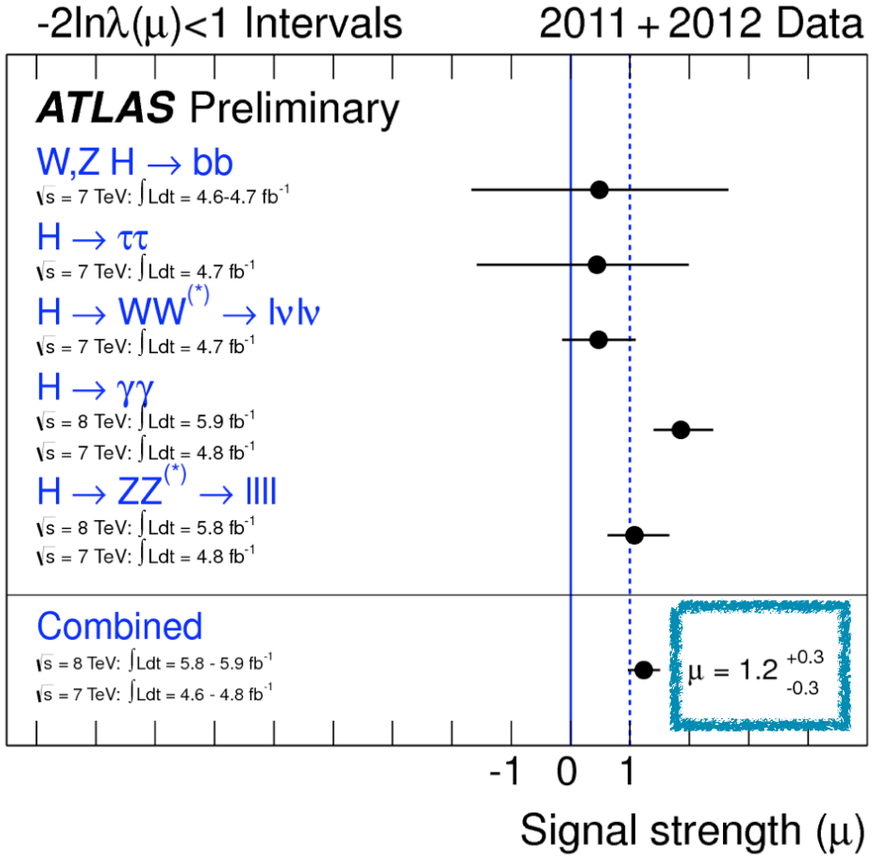
- **Result consistent with H→γγ and H→ZZ→llll**

Back Up

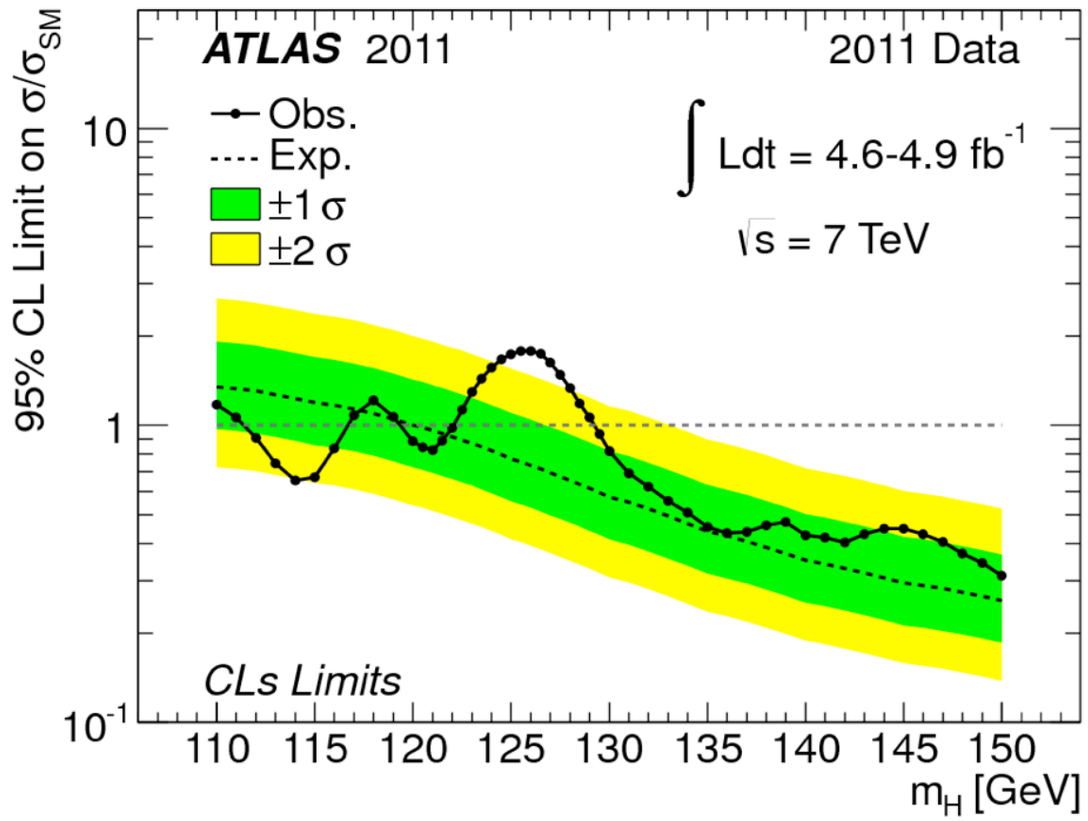
Combined results: Fitted signal strenght

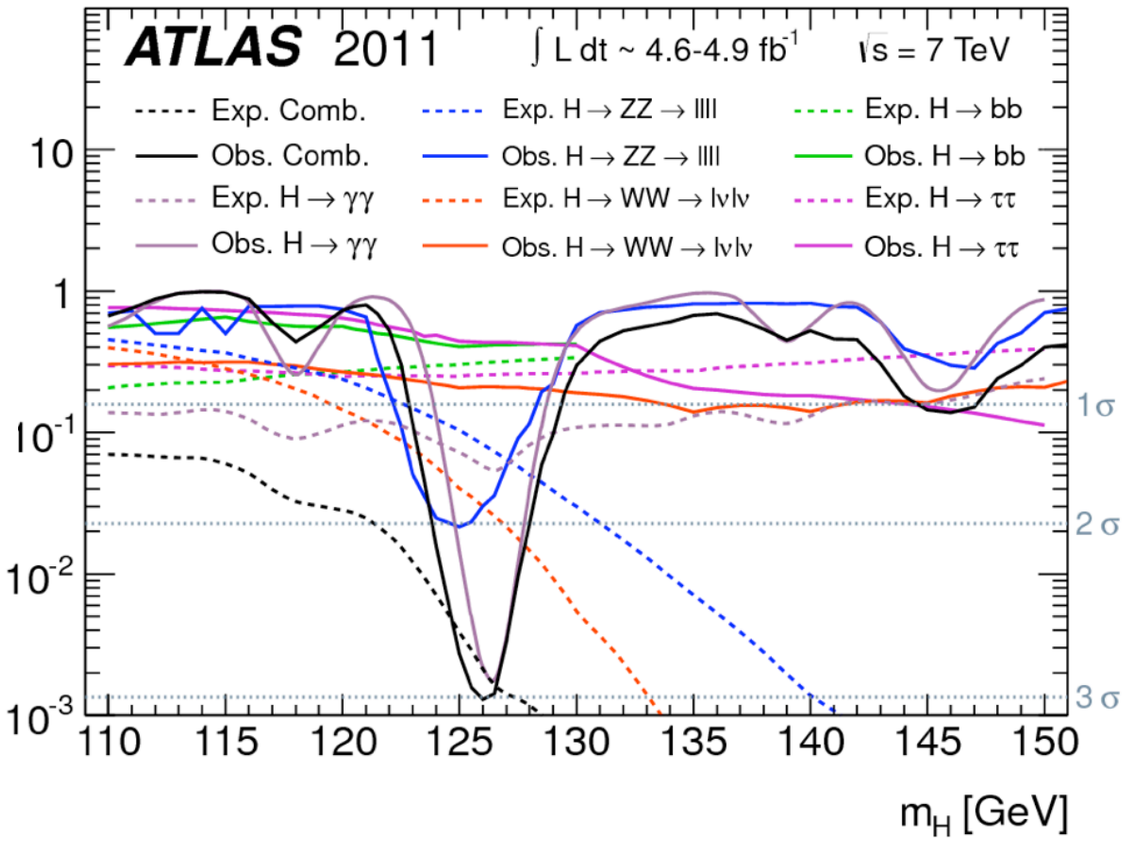




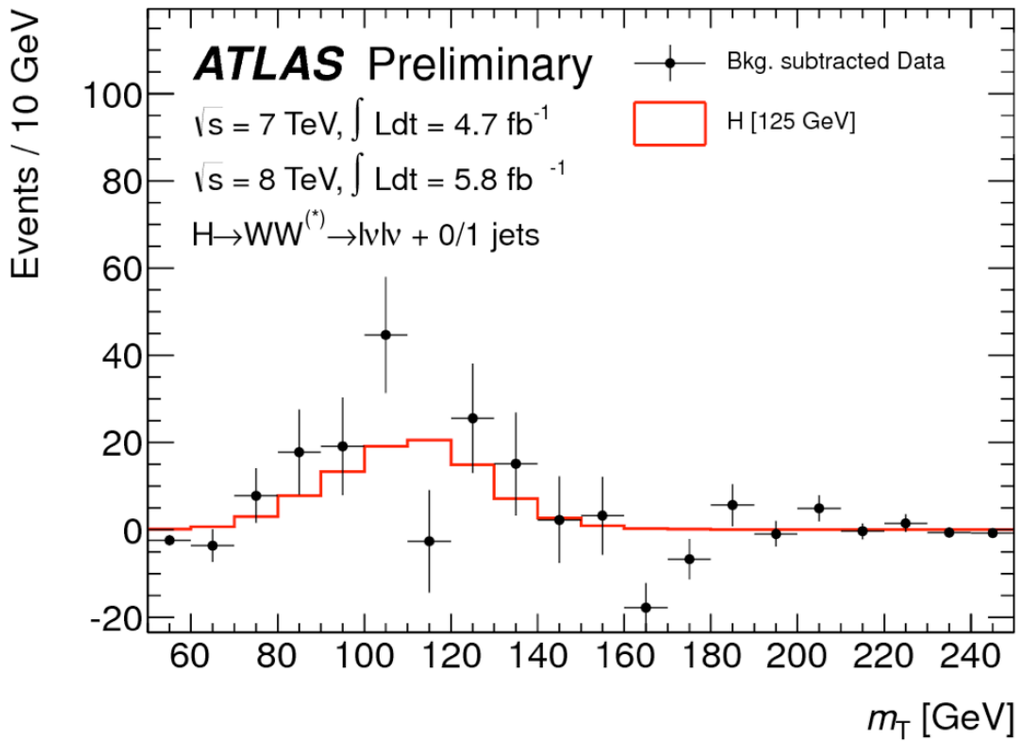


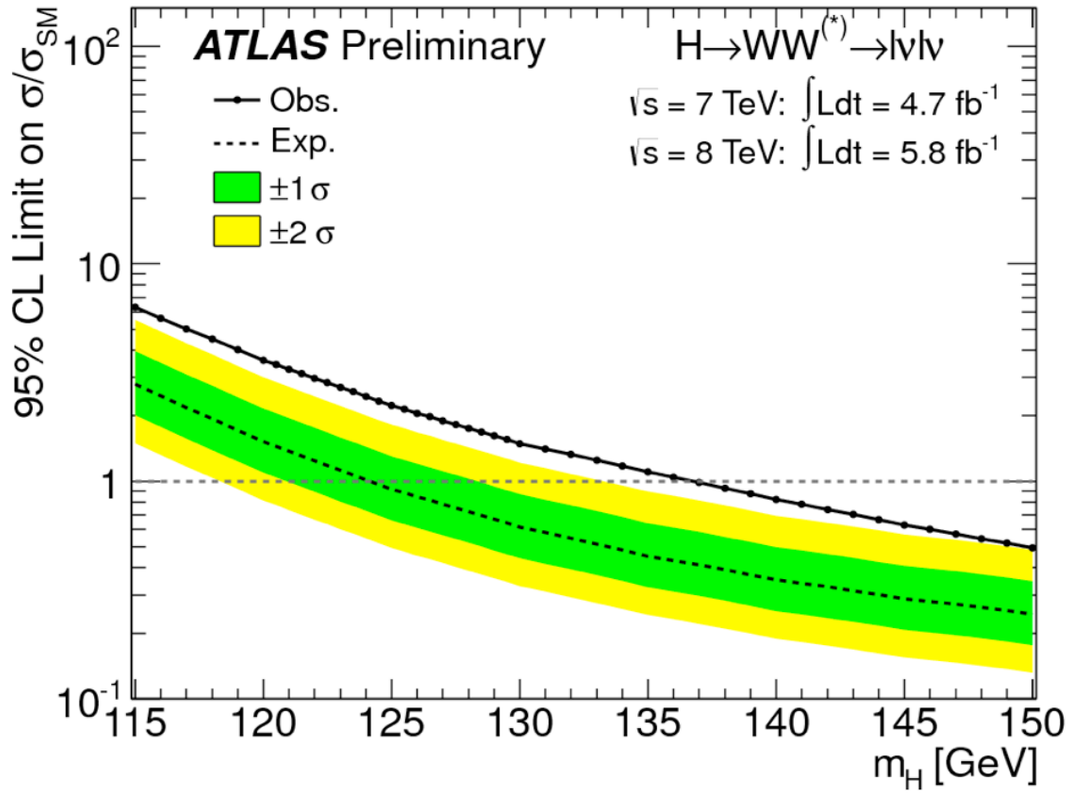
Excess in 2011 data





H→WW→lνlν update





Systematics

H→γγ

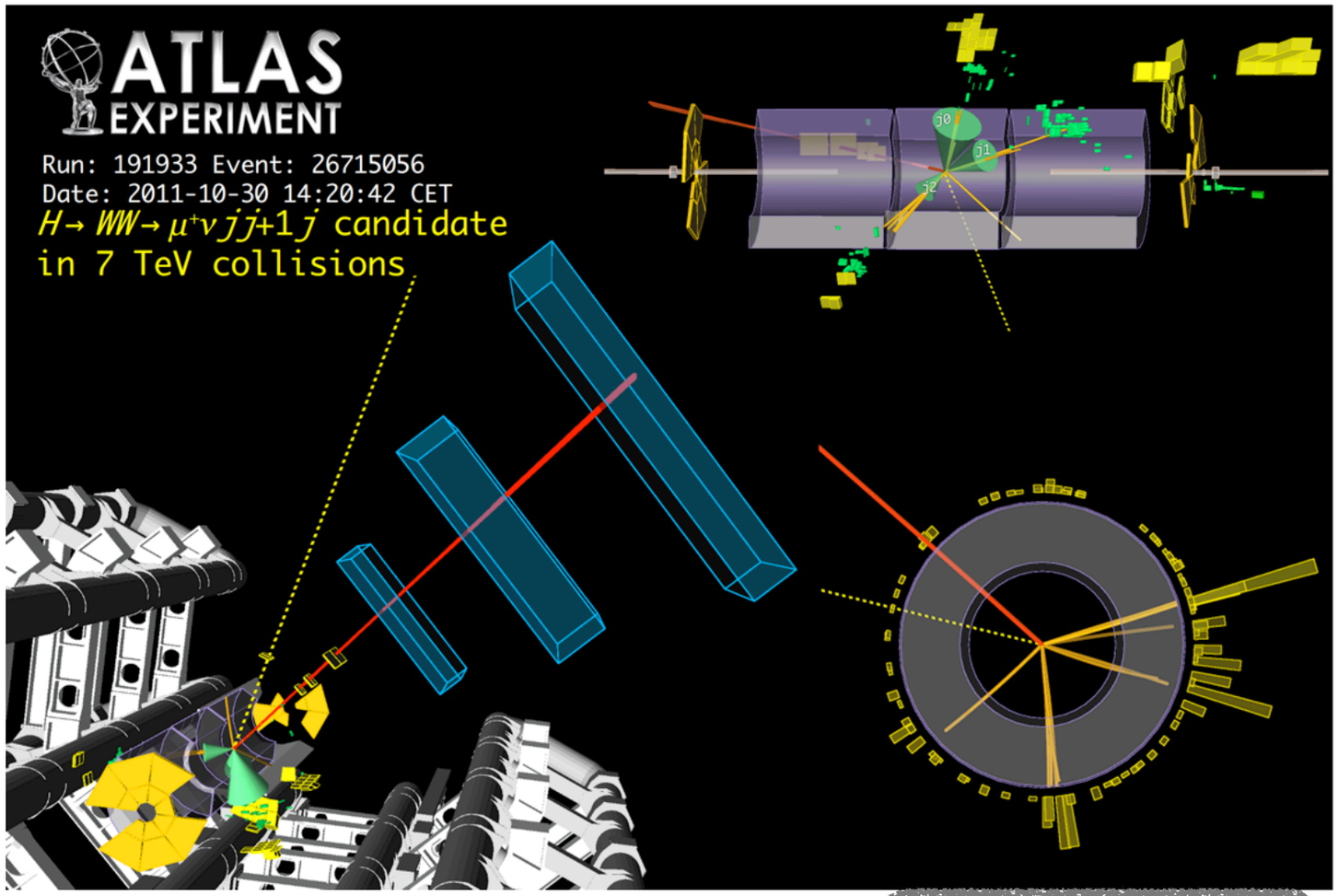
Systematic uncertainties	$\sqrt{s}$ = 7 TeV [%]	$\sqrt{s}$ = 8 TeV [%]
Signal event yield		
Photon identification	±8.4	±10.8
Effect of pileup on photon rec/ID	±4	
Photon energy scale	±0.3	
Photon Isolation	±0.4	±0.5
Trigger	±1	
Higgs boson cross section (perturbative)	$gg \to H$: $^{+12}_{-8}$, VBF: ±0.3, WH: $^{+0.2}_{-0.8}$, ZH: $^{+1.4}_{-1.6}$, ttH: $^{+3}_{-9}$	$gg \to H$: $^{+7}_{-8}$, VBF: ±0.2, WH: $^{+0.2}_{-0.6}$, ZH: $^{+1.6}_{-1.5}$, ttH: $^{+4}_{-9}$
	$gg \to H + 2$ jets: ±25	
Higgs boson cross section (PDF+α_S)	$gg \to H$: $^{+8}_{-7}$, VBF: $^{+2.5}_{-2.1}$, VH: ±3.5, ttH: ±9	$gg \to H$: $^{+8}_{-7}$, VBF: $^{+2.6}_{-2.8}$, VH: ±3.5, ttH: ±8
Higgs boson branching ratio	±5	
Higgs boson p_T modeling	low p_{Tt}: ±1.1, high p_{Tt}: ∓12.5, 2-jets: ∓9	
Underlying Event (2-jets)	VBF: ±6, Others: ±30	
Luminosity	±1.8	±3.6
Signal category migration		
Material	Unconv: ±4, Conv: ∓3.5	
Effect of pileup on photon rec/ID	Unconv: ±3, Conv: ∓2, 2-jets: ±2	Unconv: ±2, Conv: ∓2, 2-jets: ±12
Jet energy scale	low p_{Tt}	
	$gg \to H$: ±0.1, VBF: ±2.6, Others: ±0.1	$gg \to H$: ±0.1, VBF: ±2.3, Others: ±0.1
	high p_{Tt}	
	$gg \to H$: ±0.1, VBF: ±4, Others: ±0.1	$gg \to H$: ±0.1, VBF: ±4, Others: ±0.1
	2-jets	
	$gg \to H$: ∓19, VBF: ∓8, Others: ∓15	$gg \to H$: ∓18, VBF: ∓9, Others: ∓13
Jet-vertex-fraction		2-jets: ±13, Others: ∓0.3
Primary vertex selection	negligible	
Signal mass resolution		
Calorimeter energy resolution	±12	
Electron to photon extrapolation	±6	
Effect of pileup on energy resolution	±4	
Primary vertex selection	negligible	
Signal mass position		
Photon energy scale	±0.6	
Background modeling	see Table 3	

H→WW→lνlν

Source (0-jet)	Signal (%)	Bkg. (%)
Inclusive ggF signal ren./fact. scale	13	-
1-jet incl. ggF signal ren./fact. scale	10	-
Parton distribution functions	8	2
Jet energy scale	7	4
WW modelling and shape	-	5
QCD scale acceptance	4	2
WW normalisation	-	4
W+jets fake factor	-	4
Lepton isolation	3	3
Source (1-jet)	**Signal (%)**	**Bkg. (%)**
1-jet incl. ggF signal ren./fact. scale	28	-
2-jet incl. ggF signal ren./fact. scale	16	-
WW normalisation	0	14
b-tagging efficiency	-	8
Top normalisation	-	6
Pile-up	5	5

H→WW→lνqq

- **Characteristics**
  - Isolated electron/muon & E_T^{miss} & 2 non b-jets
  - analysis categories: **0**, **1** jet (gg) and **2** jets (VBF)

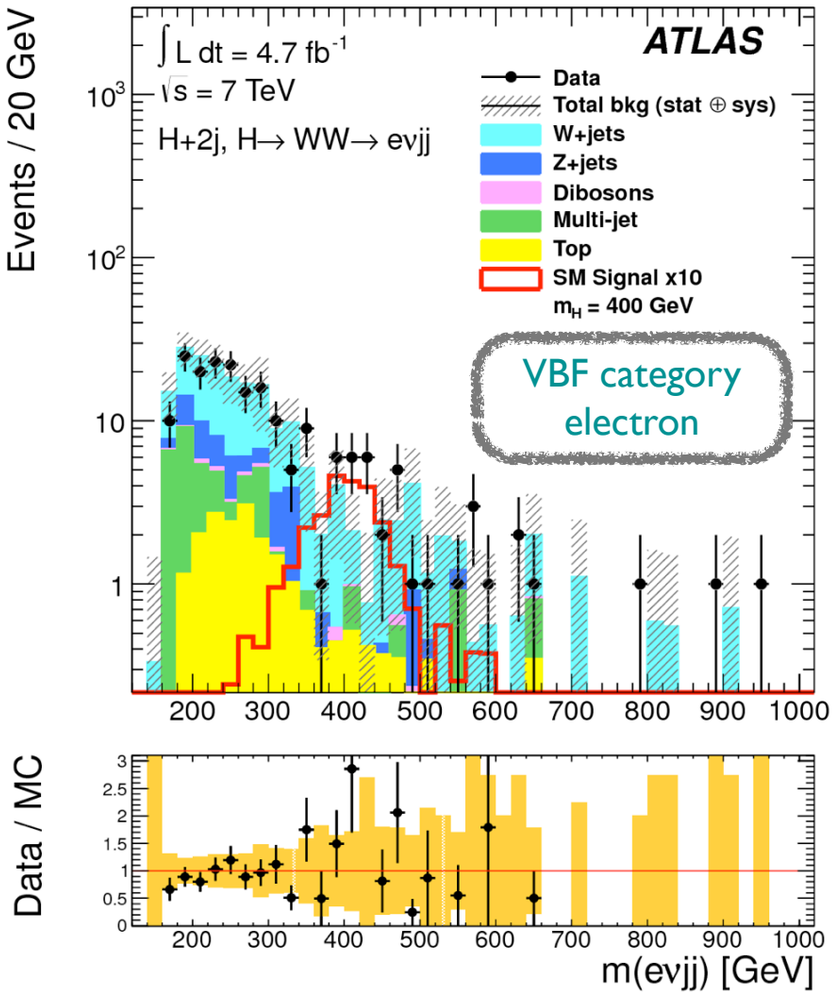


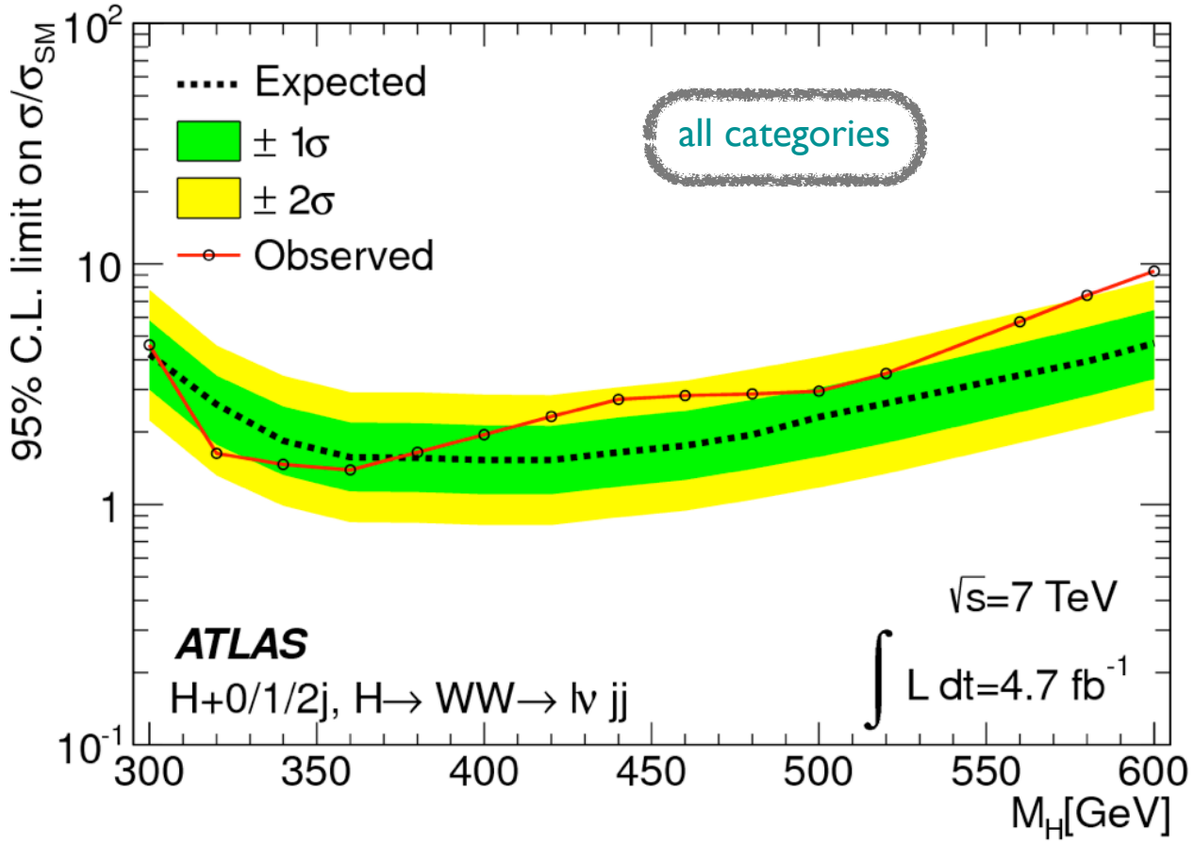
H→WW→μνjj candidate

- **Backgrounds**
  - W+jets, Z+jets, top, dibosons
  - estimated from **fit to mass spectrum** (composition estimated by MC/data driven methods)

H→WW→lνqq

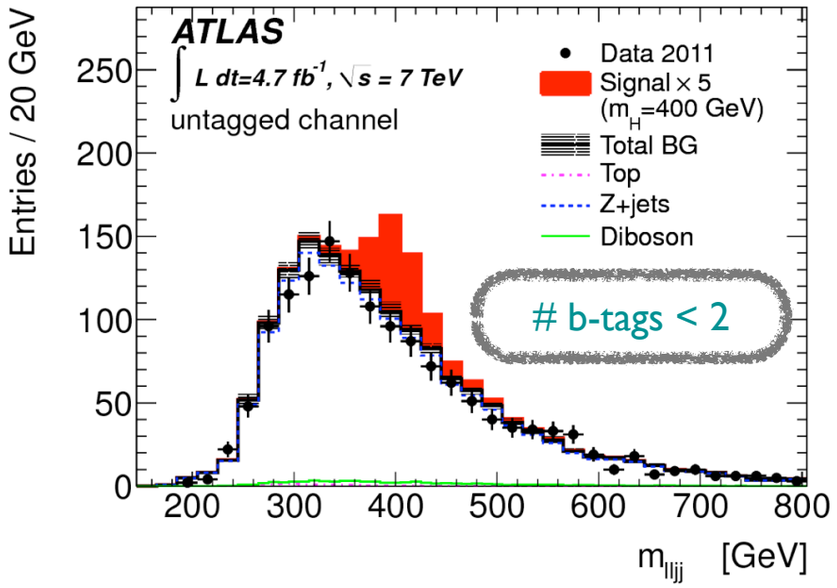
- **Discriminating variable**
  - **mass $m_{l\upsilon jj}$**
  - constraint: $m_{l\upsilon} = m_W$

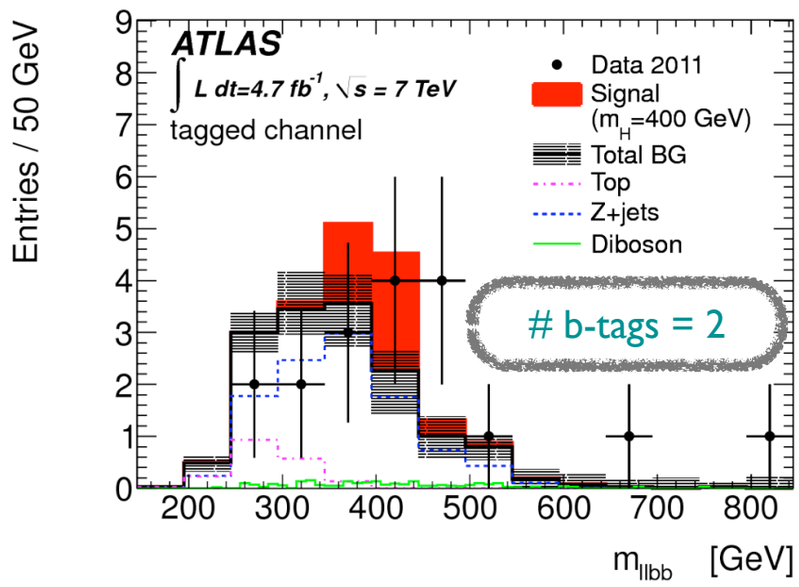




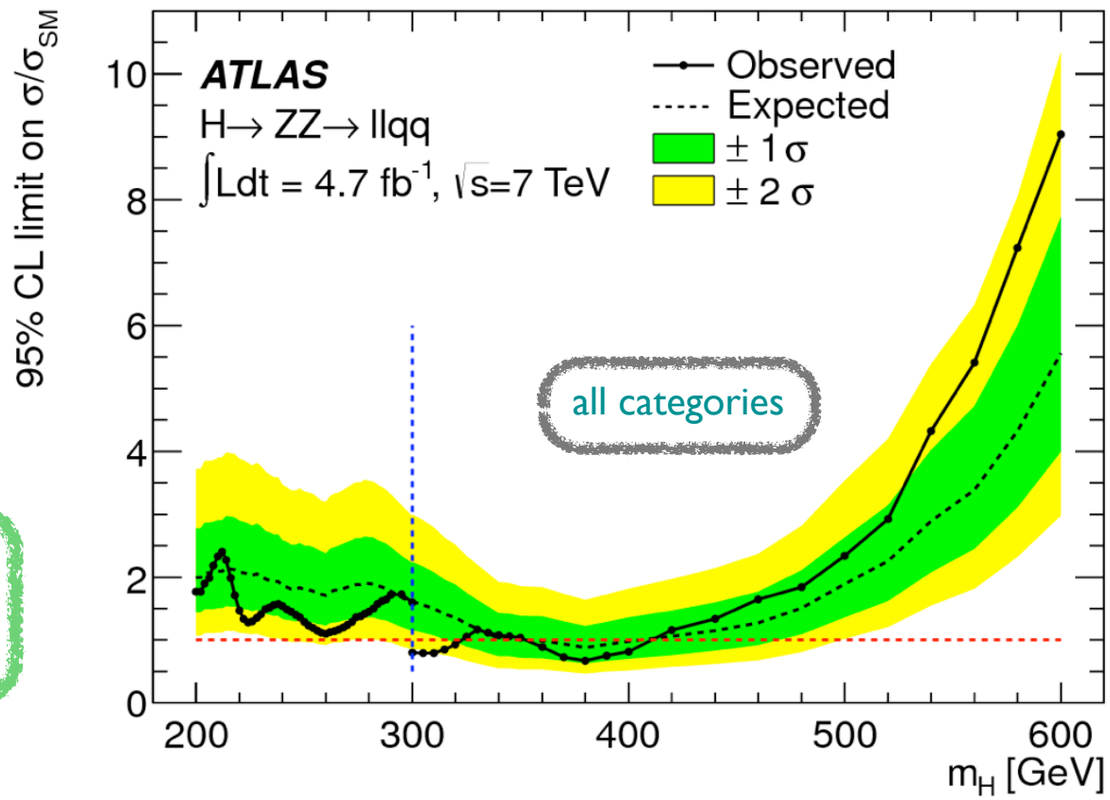
- **Result**
  - No excess observed for m_H between 300-600 GeV
  - Upper limit on cross section is **2.6 pb (2.2 x σ_{SM})**, expected 2.2 pb (1.7 x σ_{SM})

H→ZZ→llqq





- **Discriminating variable**
  - **mass m_{lljj}**
  - constraint: $m_{jj} = m_Z$
- **Result**
  - No excess observed for m_H between 200-600 GeV
  - **Observed exclusion:** 300-323 GeV, 353-410 GeV, expected: 351-404 GeV



- **Characteristics**
  - Two isolated electrons/ muons & 2 jets
  - analysis categories: **exactly 2 b-tagged jets** and **less than 2 b-tagged jets**

H→ZZ→llνν

Characteristics

- Two opposite sign electrons/muons & E_T^{miss}
- analysis categories: **low and high pile-up** (dependence due to E_T^{miss})

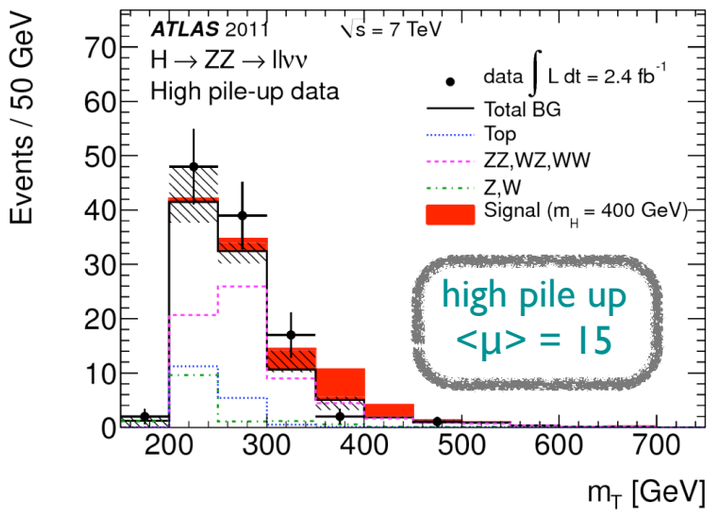
Result

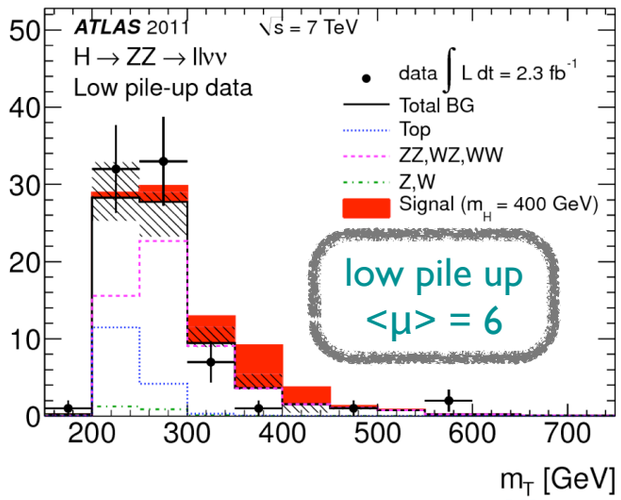
- No excess observed for m_H between 200-600 GeV
- **Observed exclusion:** 319-558 GeV
  Expected exclusion: 280-497 GeV

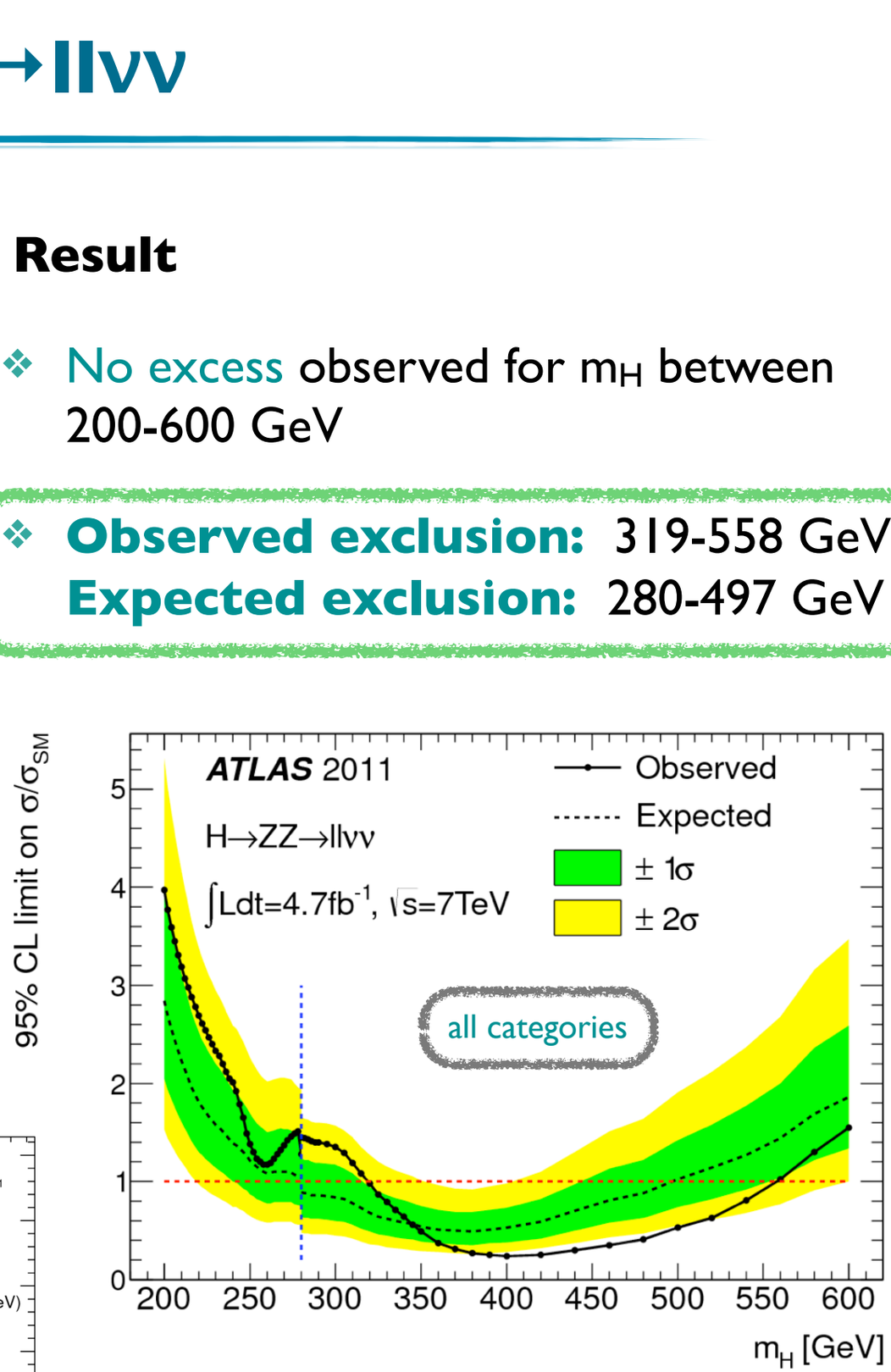
Discriminating variable

- **transverse mass m_T** (2 neutrinos)

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







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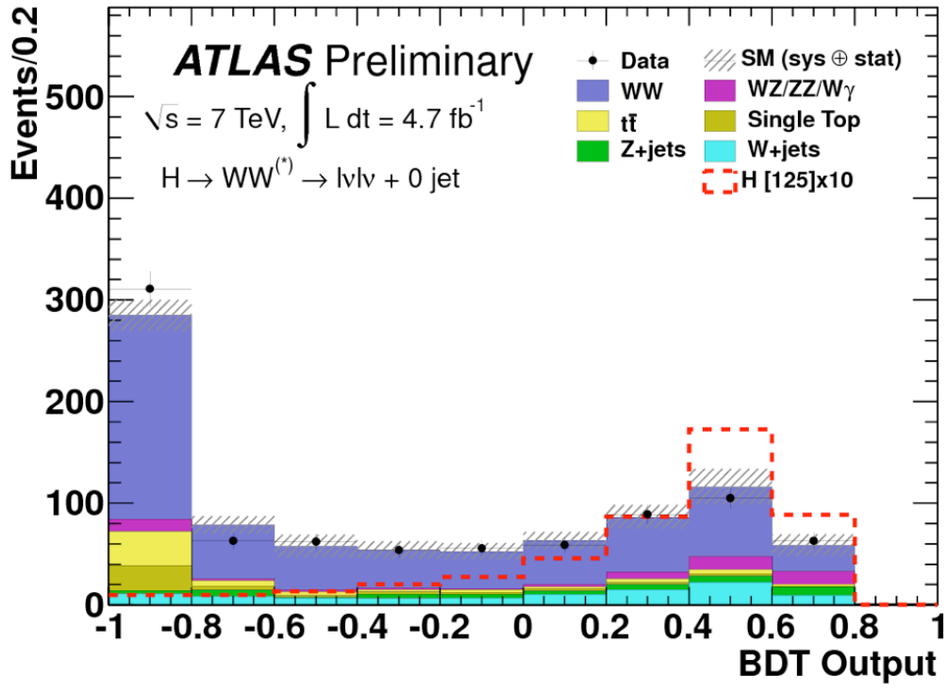
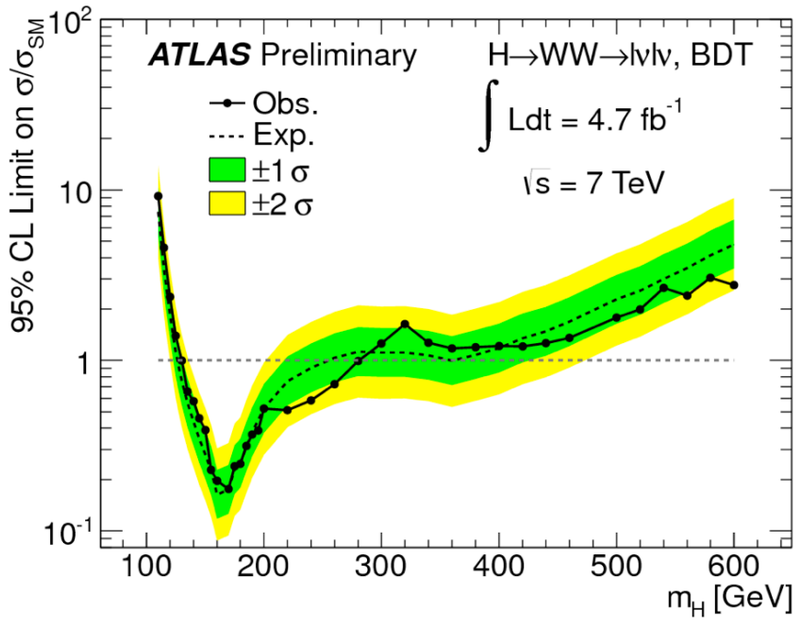
H→WW→lνlν MVA

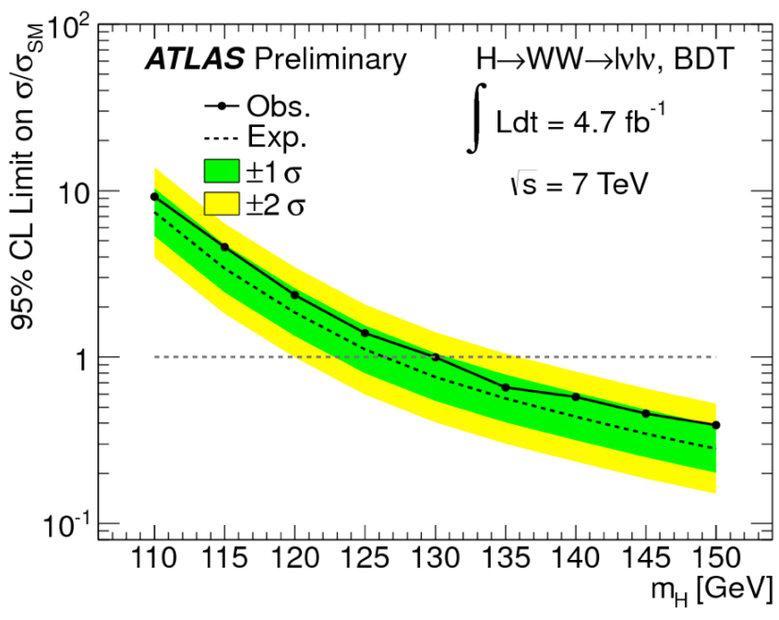
- **BDT method** used for signal selection (better use of correlations)
- **0,1 and 2 jet** categories



- **Result**
  - No observable excess for m_H between 110-600 GeV
  - Performance better than cut-based analysis at high masses

Observed exclusion: 130-281 GeV
Expected exclusion: 127-255 GeV





ATLAS Detector