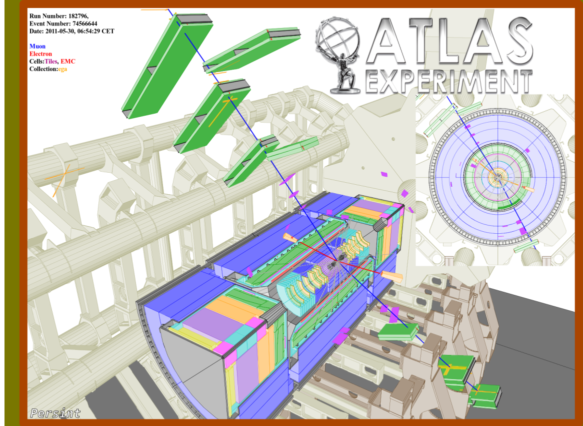
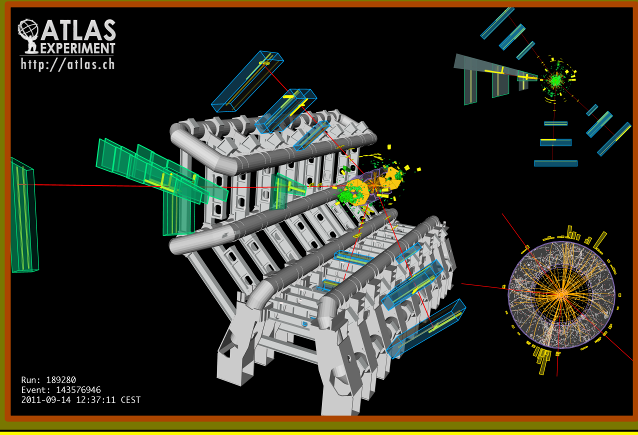
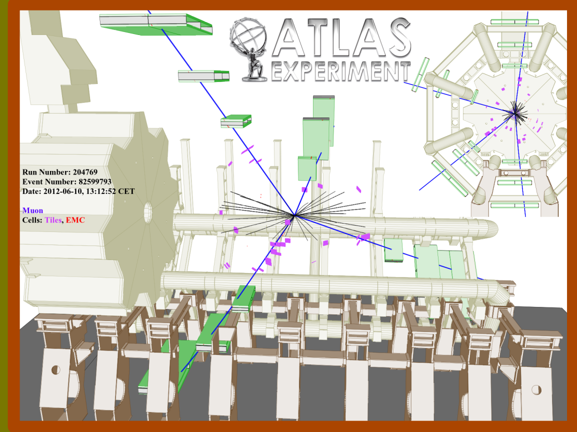
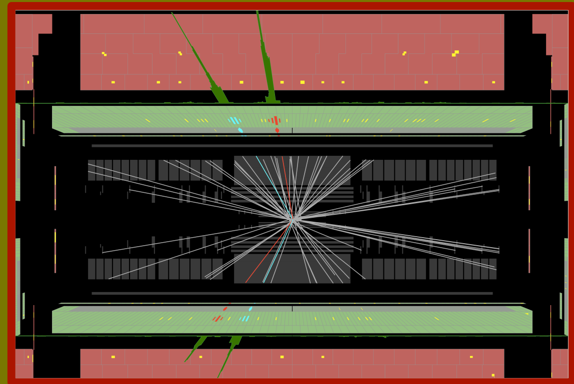




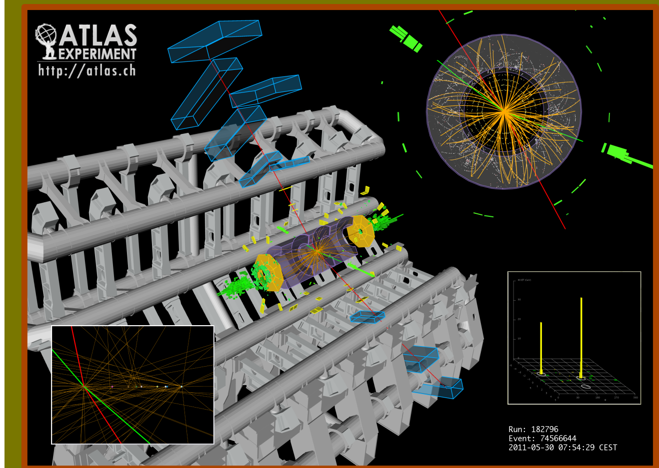


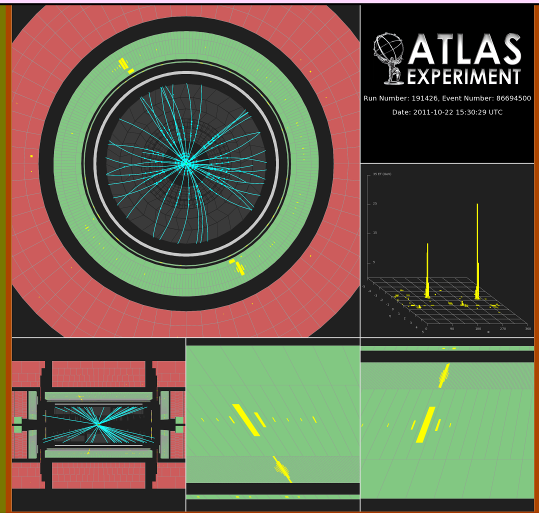
Status of Standard Model Higgs searches in ATLAS

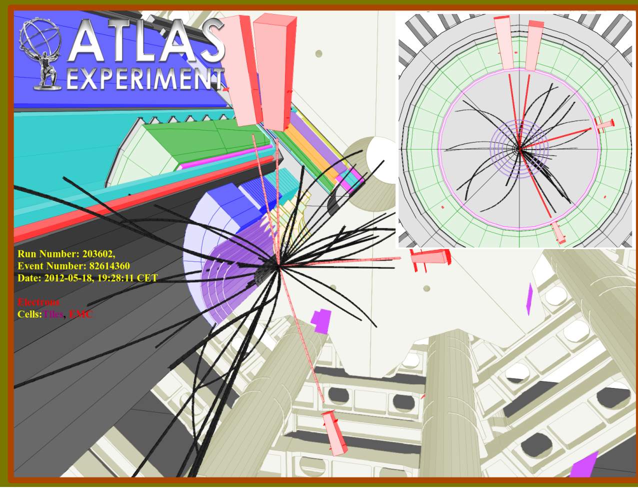


Using the full datasets recorded in 2011 at √s= 7 TeV and 2012 at √s=8 TeV: up to 10.7 fb^{-1}

Fabiola Gianotti (CERN), representing the ATLAS Collaboration







Blick am Abend
Tuesday, 19 June 2012

Gottesteilchen versetzt Physiker in Aufregung

GERÜCHTE → Vom Genfer Cern drangen Messdaten nach draussen, die auf die Existenz des «Higgs-Boson» deuten. Es wurde noch nie experimentell nachgewiesen. Dieses mysteriöse Teilchen ist enorm wichtig, es gilt indirekt als Beweis, dass Materie Masse erzeugt. Darum wird es auch Gottesteilchen genannt. Da die Messdaten erst in etwa drei Wochen seriös ausgewertet sein werden, haben die Forscher die Entdeckung noch nicht bestätigt. sci

Gottesteilchen
So könnte das Higgs-Boson aussehen.

...os: Ausriss ... Matin, Thomas Lüthi, Sven Thomann, Keystone, ZVG

"This is how the Higgs boson could look"

We present updated results on SM Higgs searches based on the data recorded in 2011 at $\sqrt{s}$=7 TeV (~4.9 fb^{-1}) and 2012 at $\sqrt{s}$=8 TeV (~5.9 fb^{-1})

Results are preliminary:
- 2012 data recorded until 2 weeks ago
- harsher conditions in 2012 due to ~ x2 larger event pile-up
- new, improved analyses deployed for the first time

H → γγ and H→ 4l: high-sensitivity at low-m_H; high mass-resolution; pile-up robust
- analyses improved to increase sensitivity → new results from 2011 data
- all the data recorded so far in 2012 have been analyzed

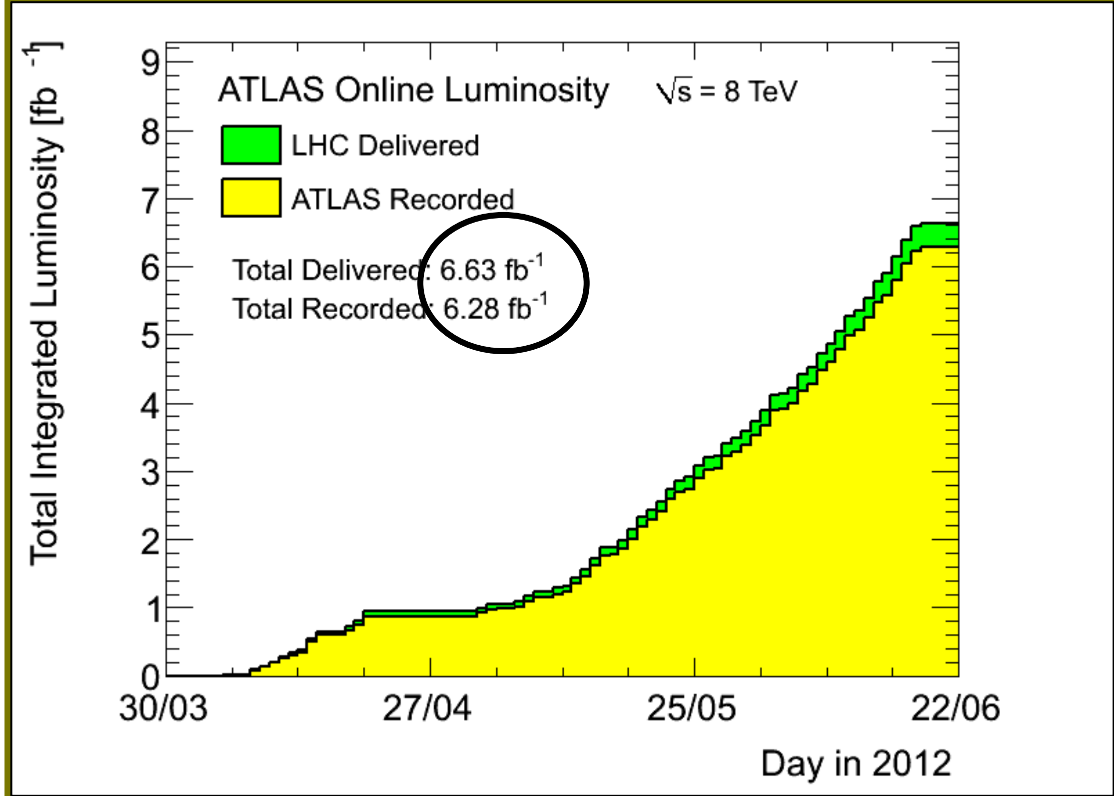
→ results are presented here for the first time

Other low-mass channels: H→ $WW^{(*)}$→ lνlν, H→ ττ, W/ZH→ W/Z bb:
- E_T^{miss} in final state → less robust to pile-up
- worse mass resolution, no signal "peak" in some cases
- complex mixture of backgrounds

→ understanding of the detector performance and backgrounds in 2012 well advanced, but results not yet mature enough to be presented today

→ 2011 results used here for these channels for the overall combination

2012 data-taking so far ...



Peak luminosity in 2012:
~ 6.8×10^{33} cm^{-2} s^{-1}

Fraction of non-operational detector channels:
(depends on the sub-detector)

few permil (most cases) to 4%

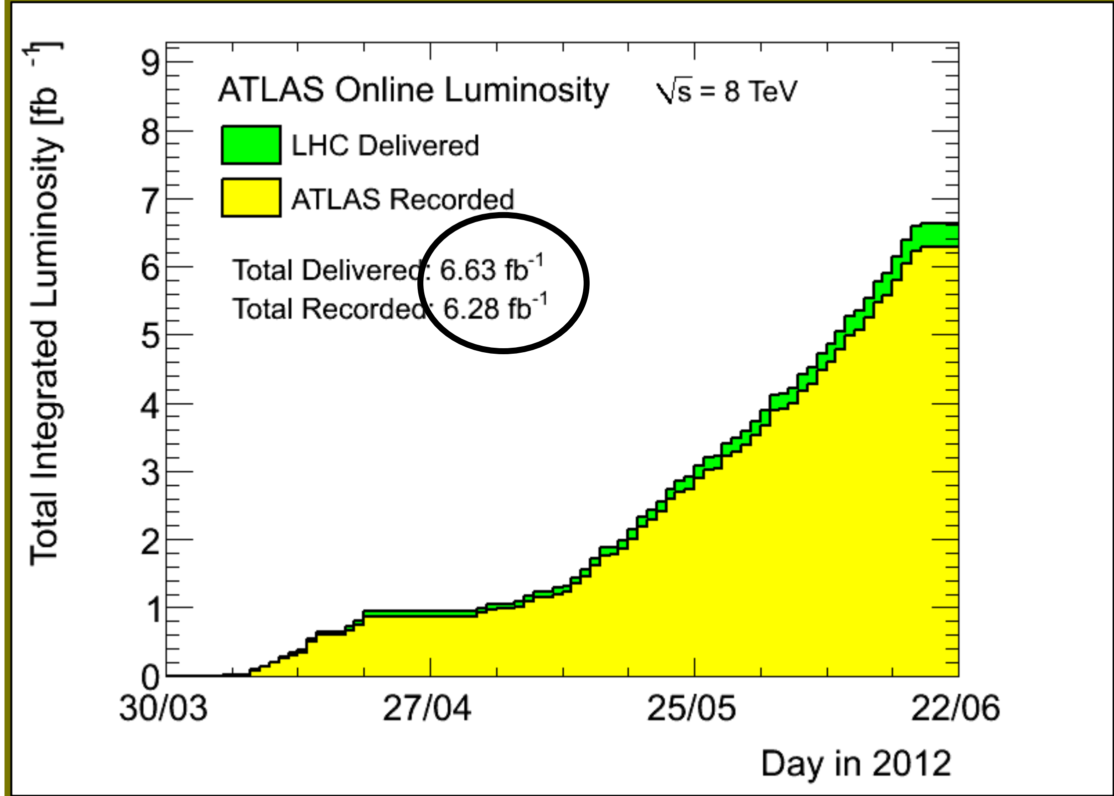
Data-taking efficiency = (recorded lumi)/(delivered lumi):

~ 94.6%

Good-quality data fraction, used for analysis :
(will increase further with data reprocessing)

~ 93.6%

2012 data-taking so far …



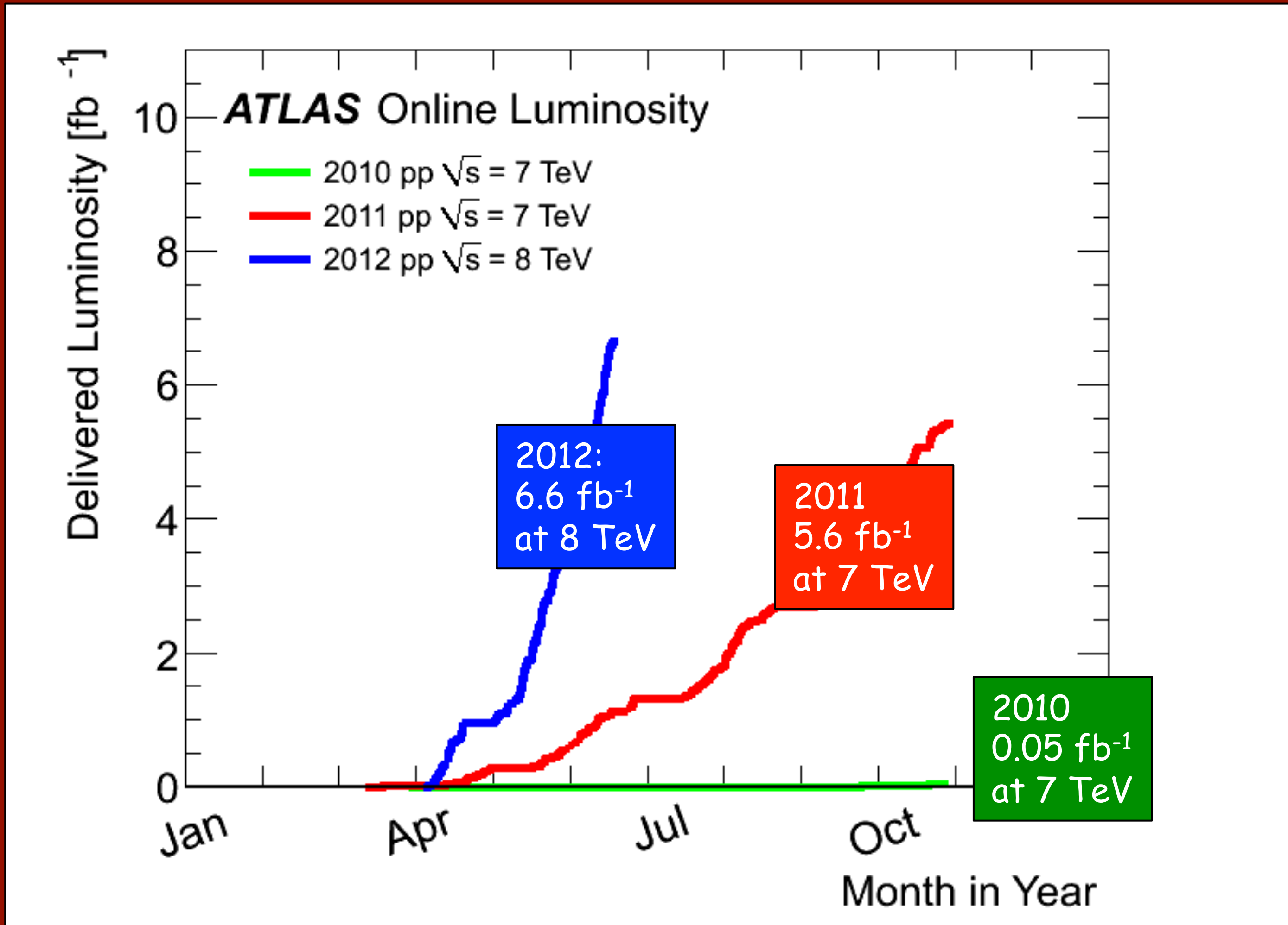
Peak luminosity in 2012:
~ 6.8 $\times 10^{33}$ cm^{-2} s^{-1}

~ 90%

<u>of the delivered luminosity used for these results</u>
(slightly larger fraction than in 2011):

- in spite of the very fresh data
- in spite of the harsher conditions

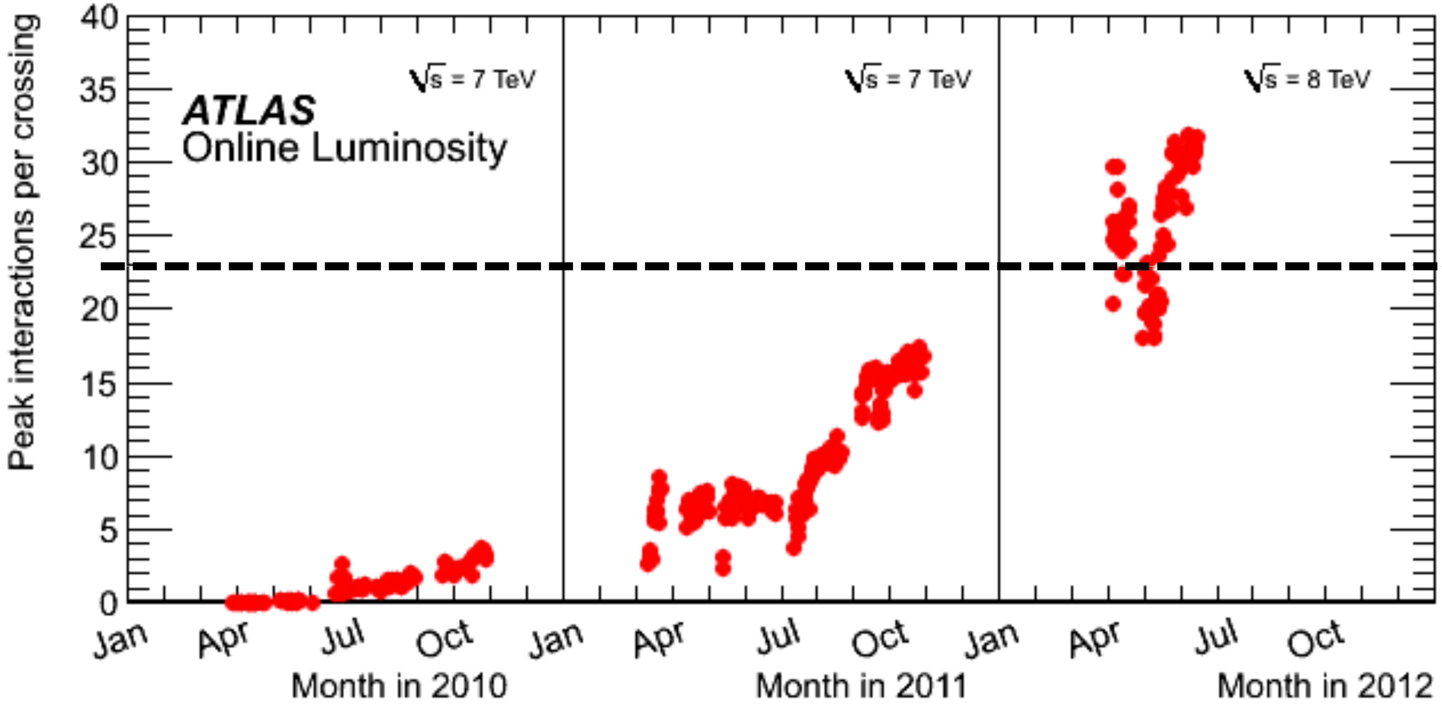
Luminosity delivered to ATLAS since the beginning



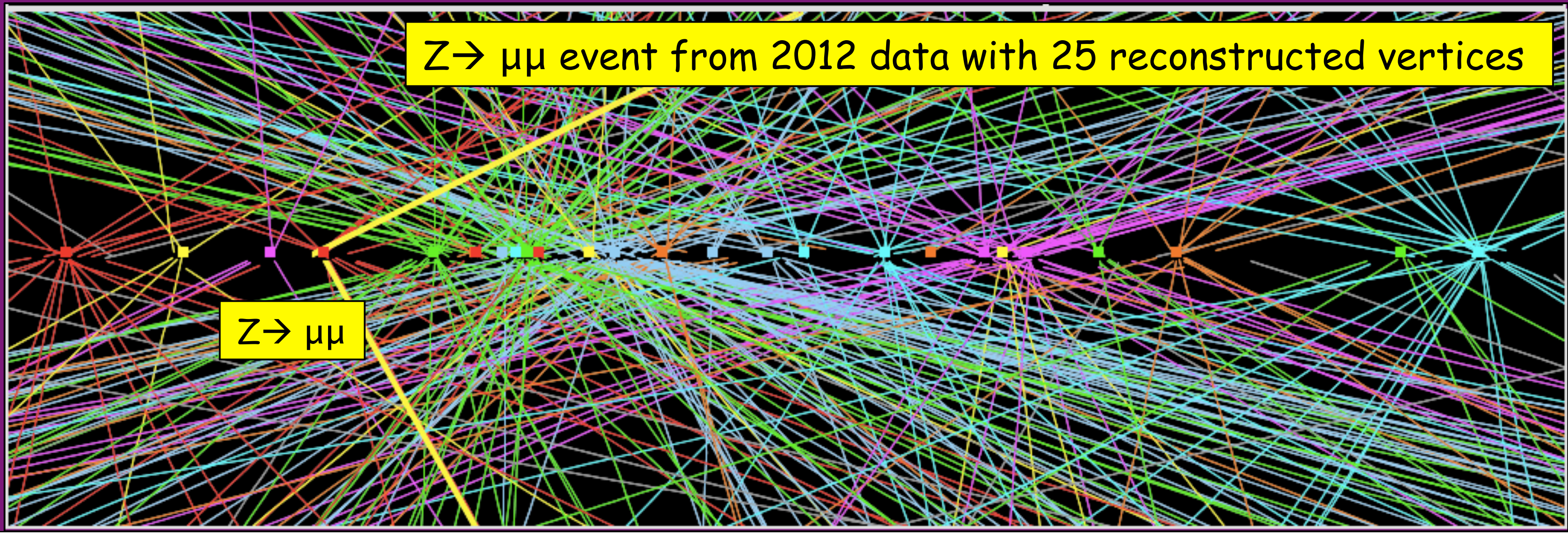
BIG THANKS

To the whole LHC exploitation team, including the operation, technical and infrastructure groups, for the OUTSTANDING performance of the machine, and to all the people who have contributed to the conception, design, construction and operation of this superb instrument

The BIG challenge in 2012: PILE-UP



Experiment's design value (expected to be reached at $L=10^{34}$!)



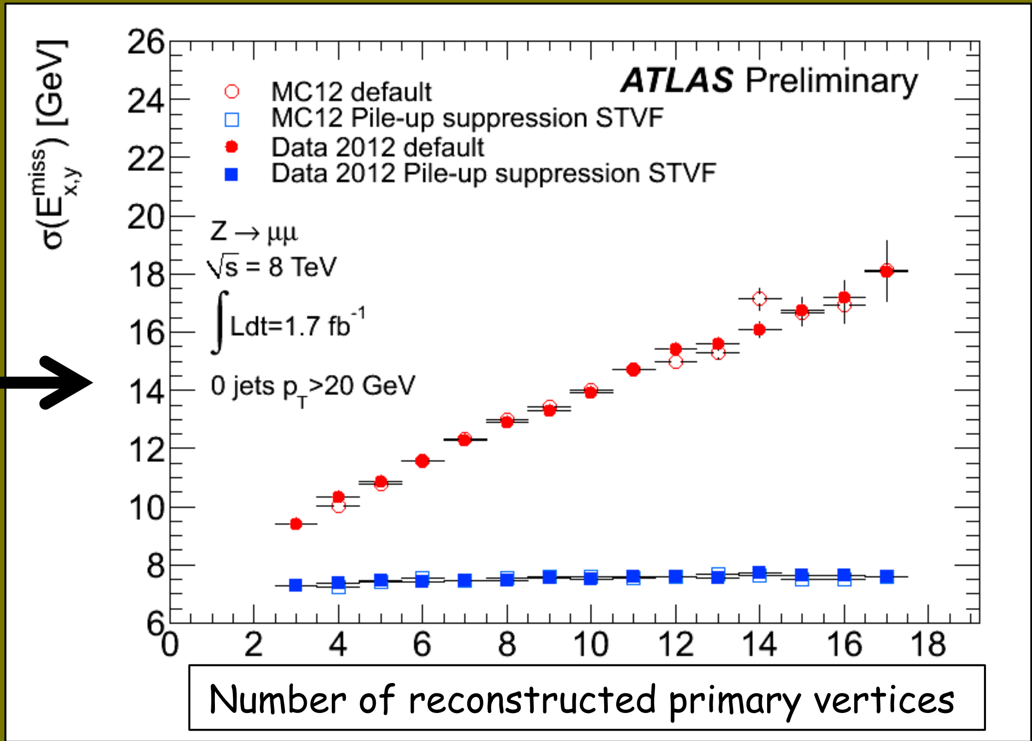
Huge efforts over last months to prepare for 2012 conditions and mitigate impact of pile-up on trigger, reconstruction of physics objects (in particular E_T^{miss}, soft jets, ..), computing resources (CPU, event size)

- Pile-up robust, fast trigger and offline algorithms developed
- Reconstruction and identification of physics objects (e, γ, μ, τ, jet, E_T^{miss}) optimised to be ~independent of pile-up → similar (better in some cases!) performance as with 2011 data
- Precise modeling of in-time and out-of-time pile-up in simulation
- Flexible computing model to accommodate x2 higher trigger rates and event size as well as physics and analysis demands

Understanding of E_T^{miss} (most sensitive to pile-up) is crucial for H→ WW(*) → lνlν , W/ZH→W/Zbb, H→ττ

E_T^{miss} resolution vs pile-up in Z→ μμ events **before** and **after** pile-up suppression using tracking information

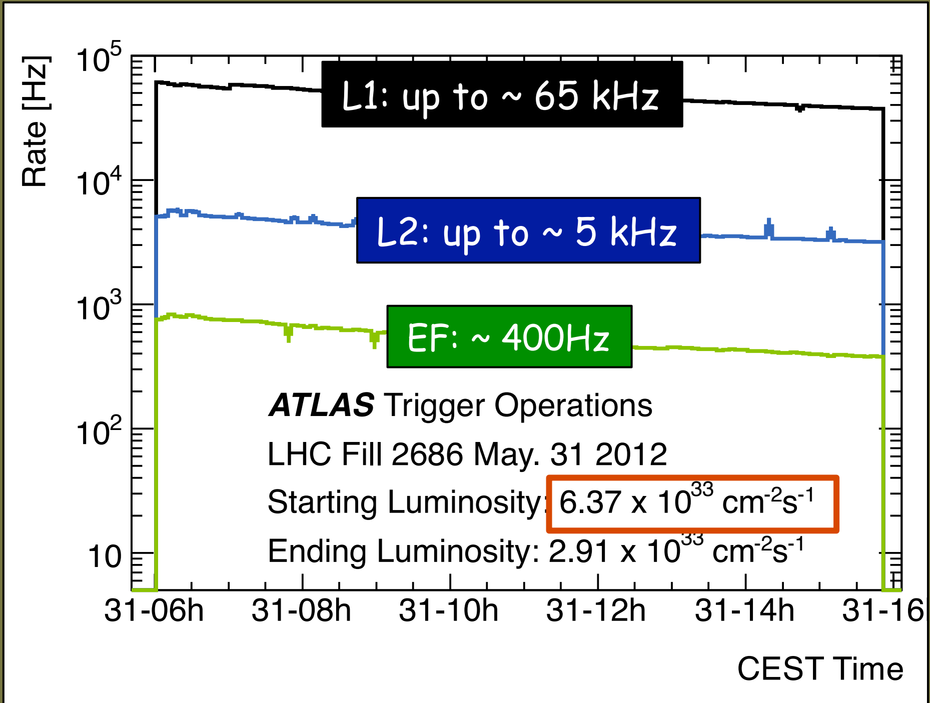
Note: number of reconstructed primary vertices is ~ 60% number of interactions per crossings



Trigger in 2012

- Optimization of selections (e.g. object isolation) to maintain low un-prescaled thresholds (e.g. for inclusive leptons) in spite of projected x2 higher L and pile-up than in 2011
- Pile-up robust algorithms developed (~flat performance vs pile-up, minimize CPU usage, ...)

→ Results from 2012 operation show trigger is coping very well (in terms of rates, efficiencies, robustness, ..) with harsh conditions while meeting physics requirements



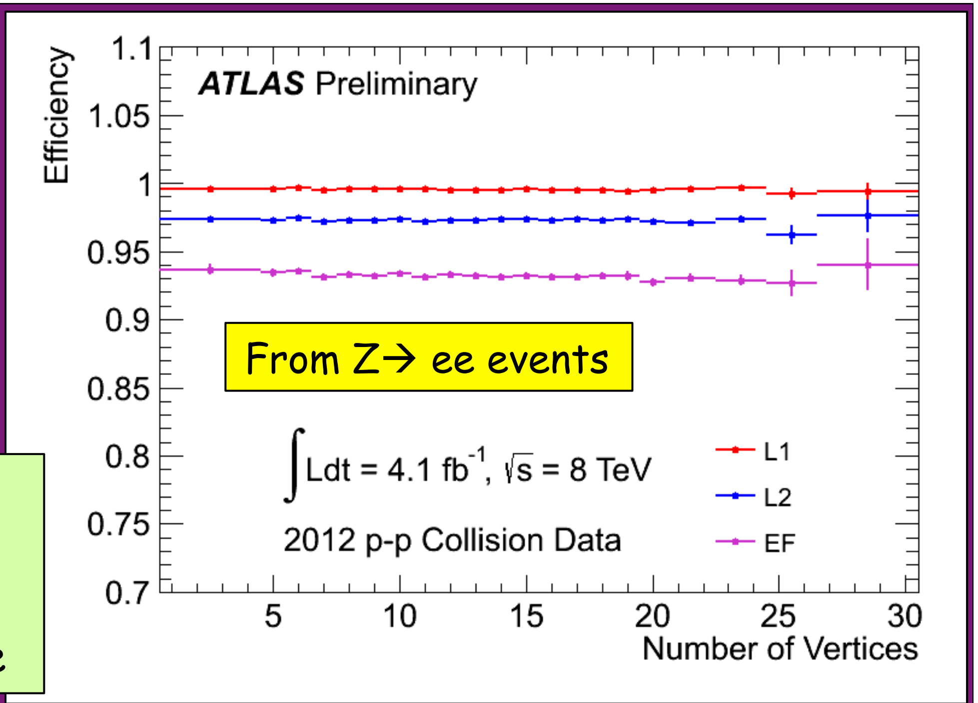
Lowest un-prescaled thresholds (examples)

Item	p_T threshold (GeV)	Rate (Hz) 5×10^{33}
Incl. e	24	70
Incl. μ	24	45
ee	12	8
μμ	13	5
ττ	29,20	12
γγ	35,25	10
E_T^{miss}	80	17
5j	55	8

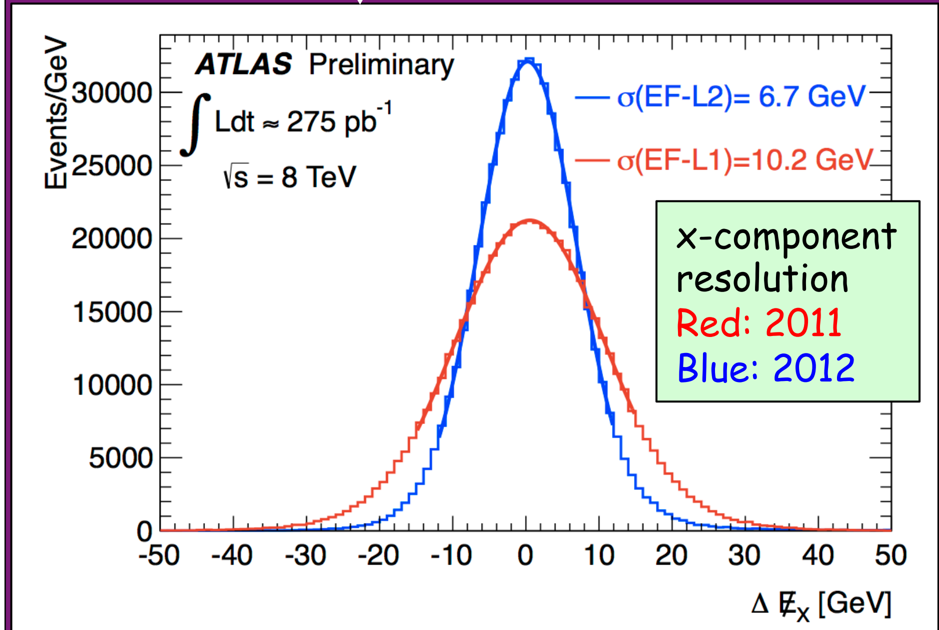
Note: ~ 500 items in trigger menu !

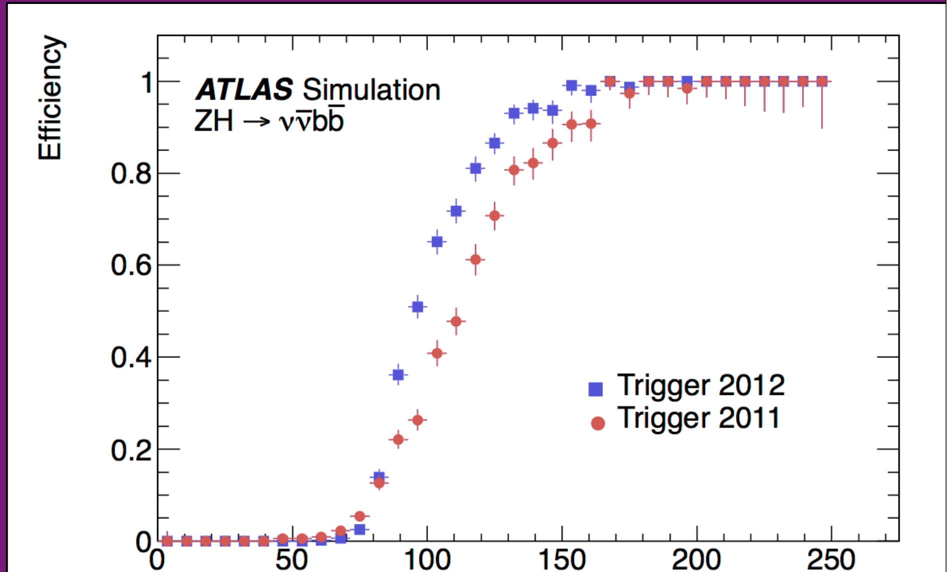
Managed to keep inclusive un-prescaled lepton thresholds within ~ 5 GeV over last two years in spite factor ~ 70 peak lumi increase

Efficiency of inclusive electron trigger (E_T thresholds as low as 24) as a function of "pile-up"



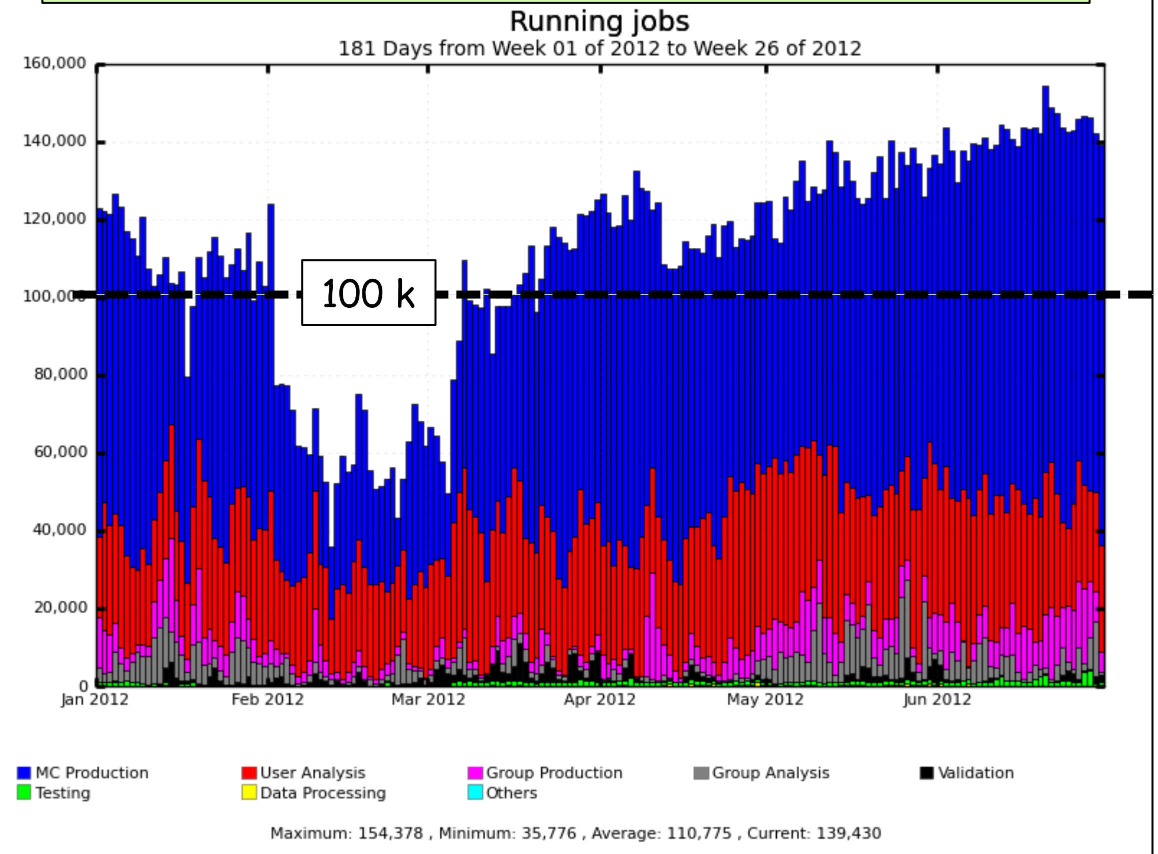
Many improvements in E_T^{miss} trigger: e.g. pile-up suppression, L2 fast front-end board sums instead of L1 only → same threshold as in 2011, sharper turn-on curve





It would have been impossible to release physics results so quickly without the outstanding performance of the Grid (including the CERN Tier-0)

Number of concurrent ATLAS jobs Jan-July 2012

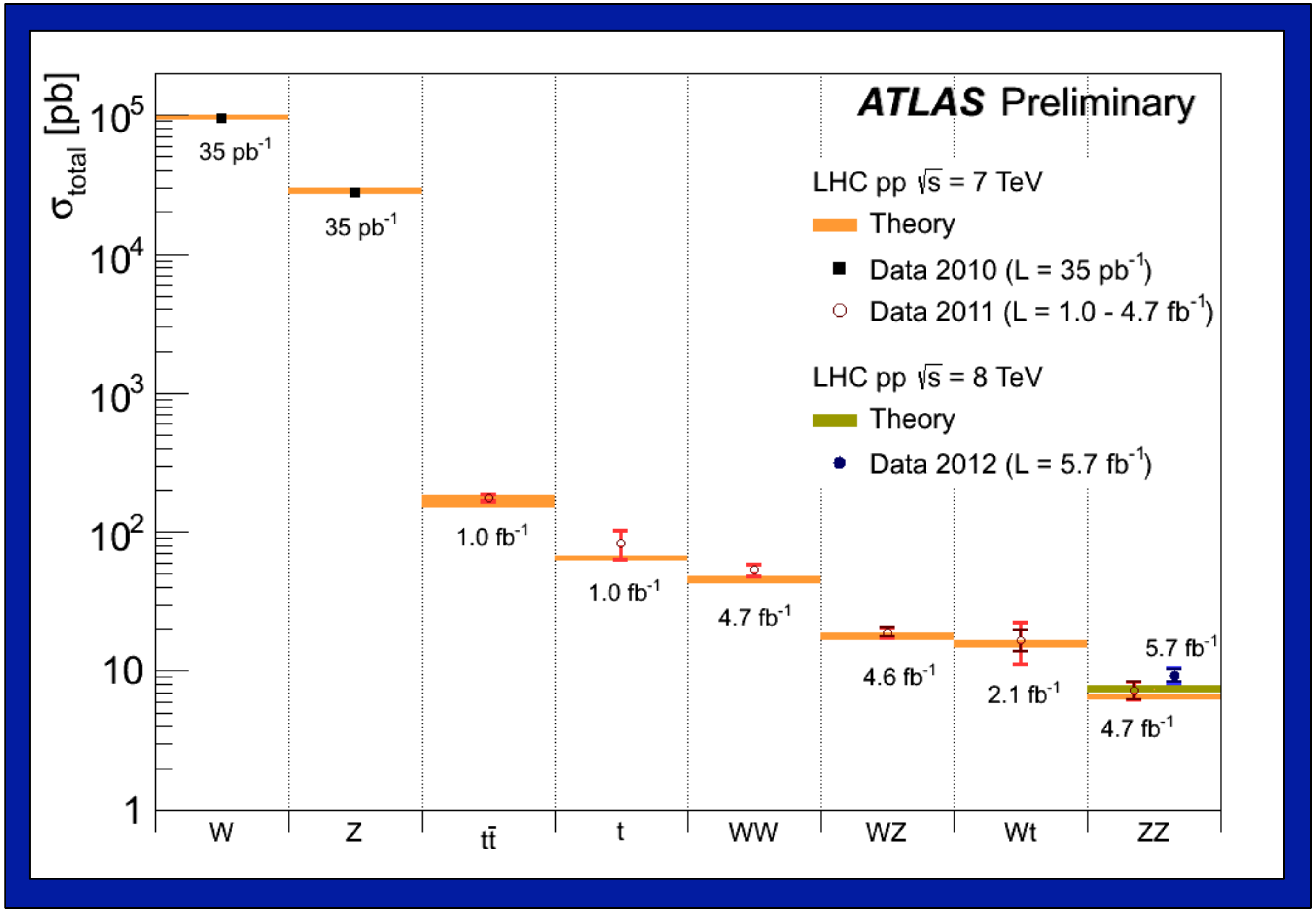


Includes MC production, user and group analysis at CERN, 10 Tier1-s, ~ 70 Tier-2 federations → > 80 sites

> 1500 distinct ATLAS users do analysis on the GRID

- Available resources fully used/stressed (beyond pledges in some cases)
- Massive production of 8 TeV Monte Carlo samples
- Very effective and flexible Computing Model and Operation team → accommodate high trigger rates and pile-up, intense MC simulation, analysis demands from worldwide users (through e.g. dynamic data placement)

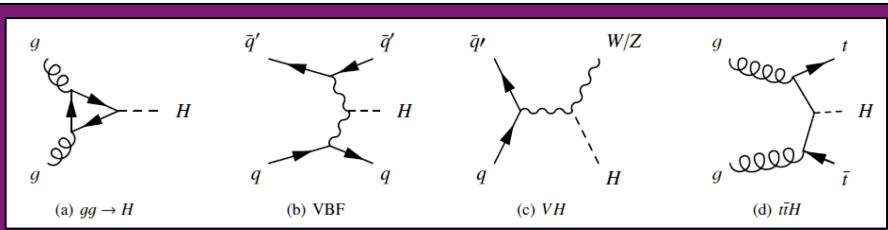
Most recent electroweak and top cross-section measurements

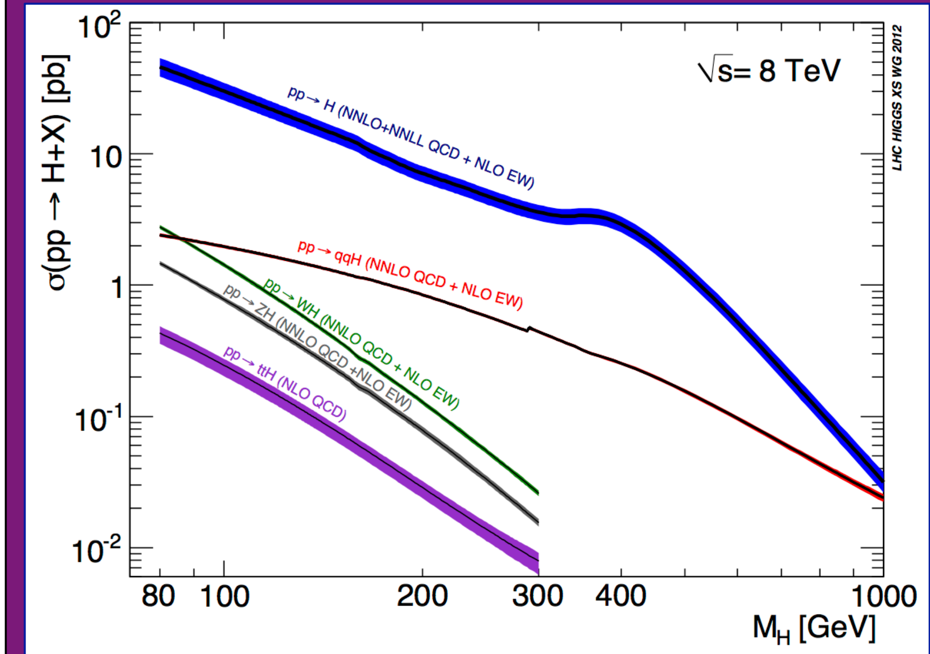


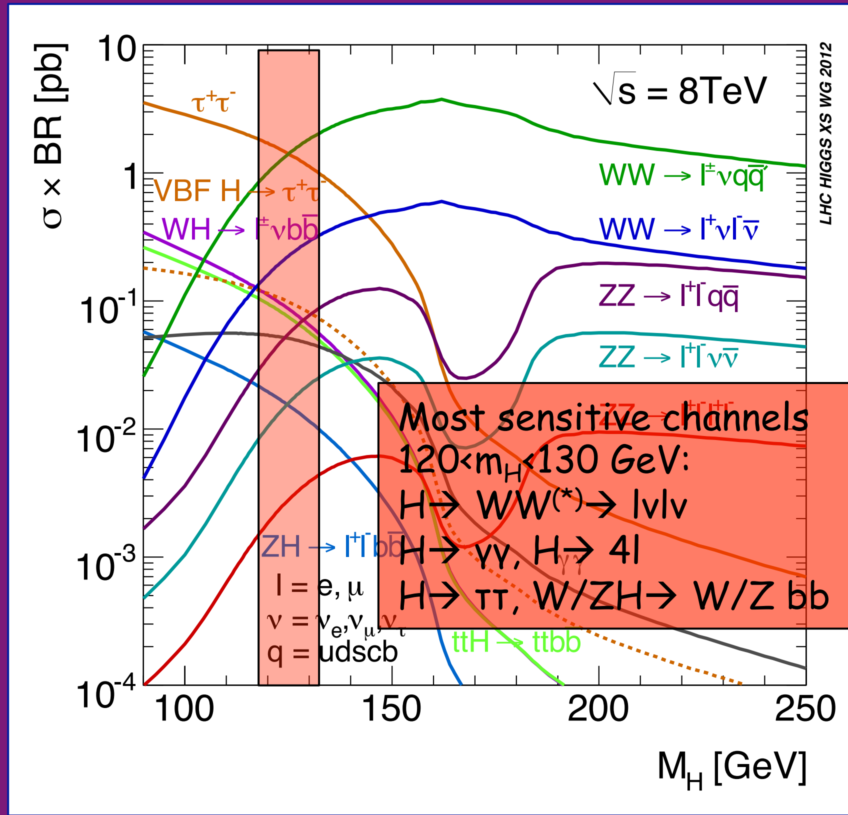
Inner error: statistical
Outer error: total

- Important on their own and as foundation for Higgs searches
- Most of these processes are reducible or irreducible backgrounds to Higgs
- Reconstruction and measurement of challenging processes (e.g. fully hadronic tt, single top, ..) are good training for some complex Higgs final states

SM Higgs production cross-section and decay modes







Most sensitive channels
$120<m_H<130$ GeV:
H→ WW$^{(*)}$→ lνlν
H→ γγ, H→ 4l
H→ ττ, W/ZH→ W/Z bb

$\sqrt{s}$=7 → 8 TeV:

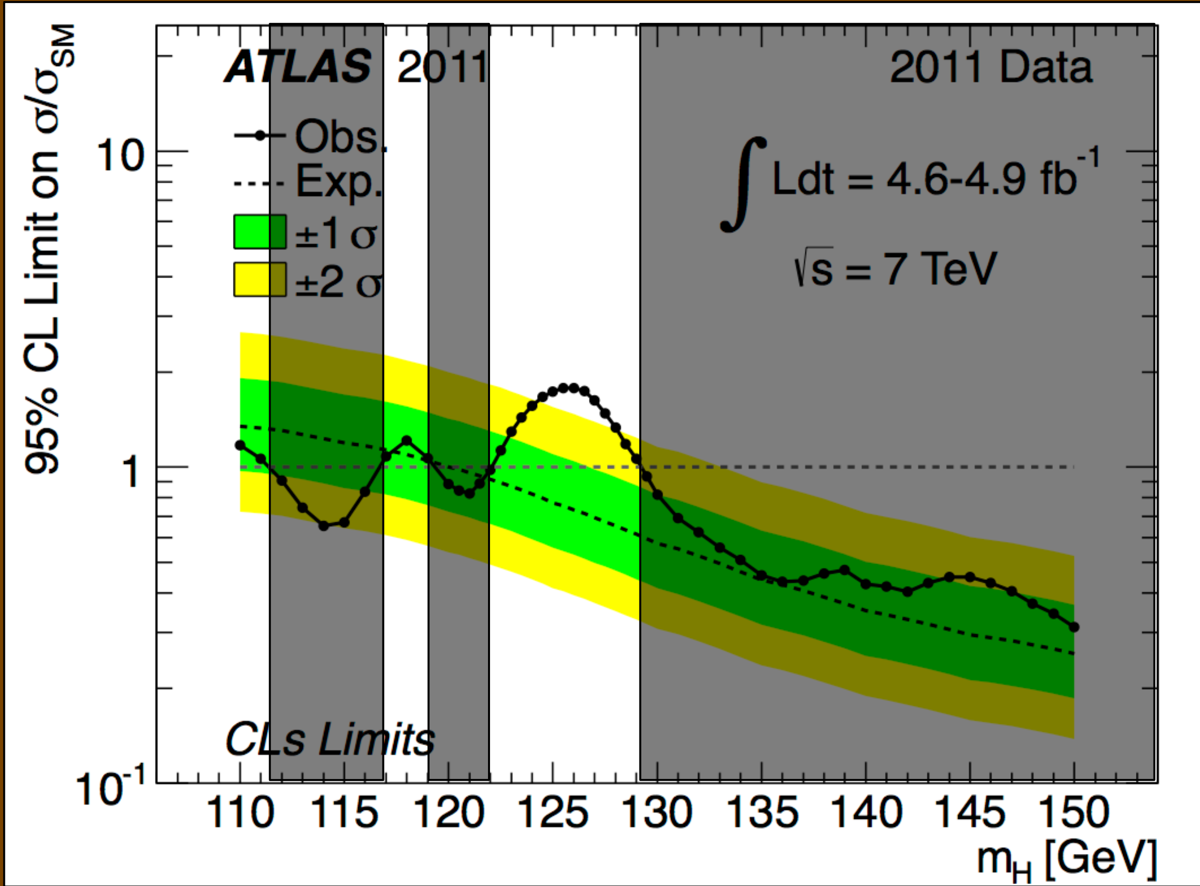
- ❑ Higgs cross-section increases by ~ 1.3 for m_H ~ 125 GeV
- ❑ Similar increase for several irreducible backgrounds: e.g. 1.2-1.25 for γγ, di-bosons
- ❑ Reducible backgrounds increase more: e.g. 1.3-1.4 for tt, Zbb

→ Expected increase in Higgs sensitivity: 10-15%

Note: huge efforts and progress from theory community to compute NLO/NNLO cross-sections for Higgs production and for (often complex !) backgrounds

Status of ATLAS searches … until this morning

Results on the full 7 TeV dataset submitted for publication



Combination of 12 channels:

- $H \rightarrow \gamma\gamma$
- $W/ZH \rightarrow W/Z\ bb$ (3 final states)
- $H \rightarrow \tau\tau$ (3 final states)
- $H \rightarrow ZZ^{(*)} \rightarrow 4l$
- $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$
- $H \rightarrow ZZ \rightarrow llqq$
- $H \rightarrow ZZ \rightarrow ll\nu\nu$
- $H \rightarrow WW \rightarrow l\nu qq$

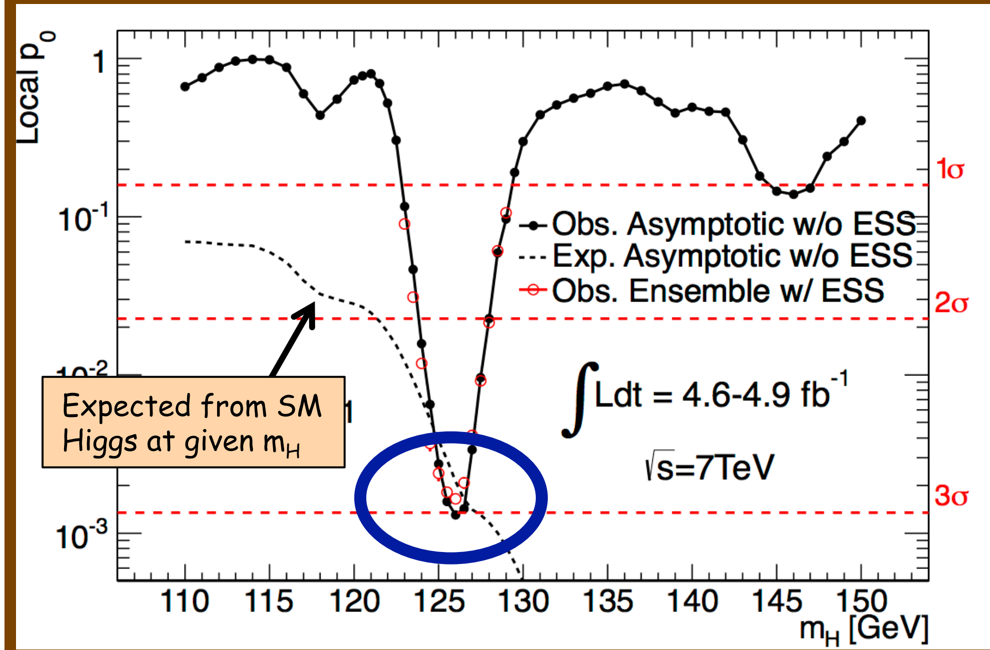
Excluded at 95% CL: $111.4 < m_H < 122.1$ GeV (except 116.6-119.4); $129.2 < m_H < 541$ GeV

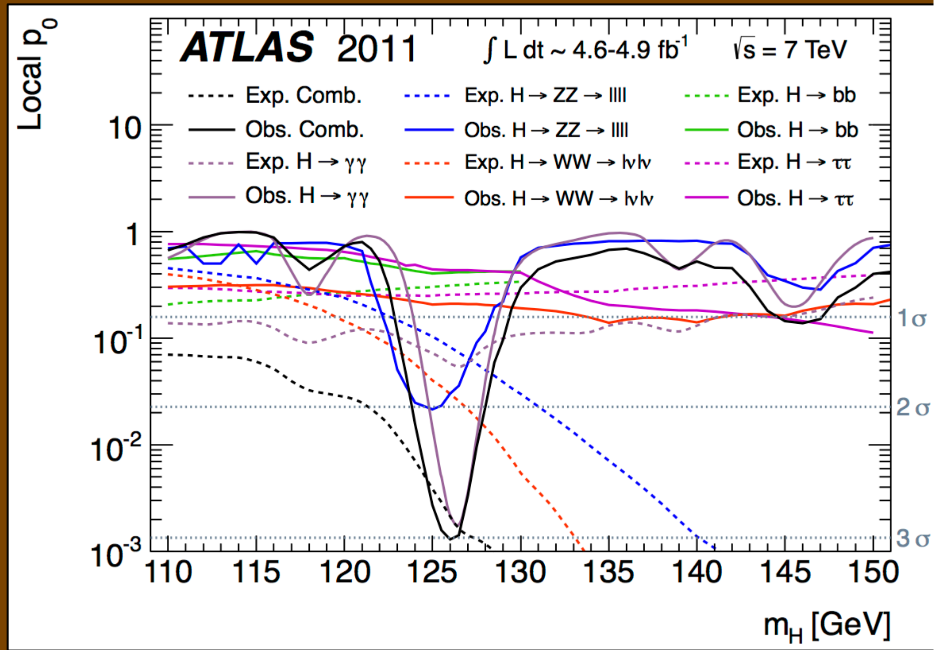
Expected if no signal: 120-560 GeV

Excluded at 99% CL: $130.7 < m_H < 506$ GeV

Status of ATLAS searches … until this morning

Consistency of the data with the background-only expectation (p-value)





2.9 σ excess observed for m_H ~ 126 GeV

Probability to occur anywhere over 110-600 (110-146 GeV): 15% (6%) (Look-Elsewhere Effect)

Local significance	Observed	Expected from SM Higgs
Total	2.9 σ	2.9 σ
$H \rightarrow \gamma\gamma$	2.8 σ	1.4 σ
$H \rightarrow 4l$	2.1 σ	1.4 σ
$H \rightarrow l\nu l\nu$	0.8 σ	1.6 σ

What's new in the results presented today ?

Experience gained with the 2011 data propagated to reconstruction and simulation (improved detector understanding, alignment and calibration, pile-up, …)

In particular: improved reconstruction and identification of physics objects → sizeable gain in efficiency for e/γ/μ, pile-up dependence minimized, smaller systematic uncertainties

→ Huge amount of painstaking foundation work !

Sensitivity of H → γγ and H → 4l analyses improved using the following procedure:

- optimization only done on MC simulation
- then looked at 2012 data in signal sidebands and background control regions (note: large and sometimes not well-known backgrounds estimated mostly with data-driven techniques using background-enriched-signal-depleted control regions) → validate MC simulation
- signal region inspected only after above steps satisfactory

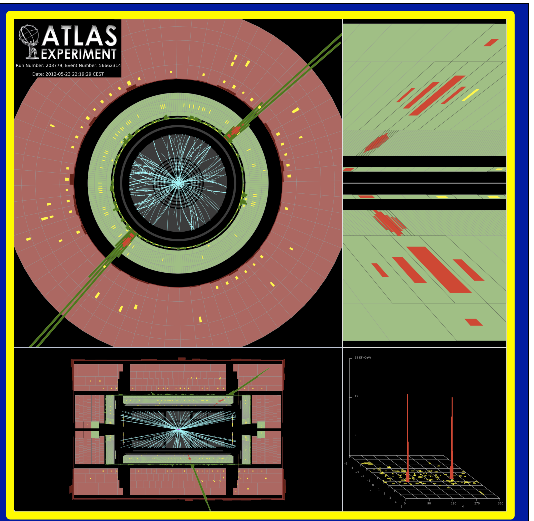
Improved analyses applied also to 2011 data → updated H→ γγ, 4l results at 7 TeV

Presented here:

- H→ γγ, 4l results with full $\sqrt{s}$=7 TeV and $\sqrt{s}$=8 TeV datasets (~10.7 fb^{-1}) and improved analyses
- new overall combination (all channels other than H→ γγ, 4l based on 7 TeV data)

$H \rightarrow \gamma\gamma$

$110 \leq m_H \leq 150$ GeV



$\sigma \times$ BR ~ 50 fb m_H ~ 126 GeV

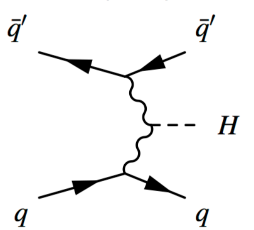
- ❑ Simple topology: two high-p_T isolated photons
  E_T (γ_1, γ_2) > 40, 30 GeV
- ❑ Main background: $\gamma\gamma$ continuum (irreducible, smooth, ..)

To increase sensitivity, events divided in 10 categories based on γ rapidity, converted/unconverted γ; p_{Tt} ($p_T^{\gamma\gamma}$ perpendicular to $\gamma\gamma$ thrust axis); 2jets

Main improvements in new analysis:
- ❑ 2jet category introduced → targeting VBF process
- ❑ γ identification (NN used for 2011 data) and isolation

→ Expected gain in sensitivity: + 15%
Background fit procedure also improved

σ_{SM} (VBF) ~7%



2 jets with
p_T > 25-30 GeV
$|\eta|$<4.5
$|\Delta\eta|_{jj}$ > 2.8
M_{jj} > 400 GeV
$|\Delta\varphi|$ ($\gamma\gamma$-jj) > 2.6

Expected gain in sensitivity: 3%

After all selections, expect (10.7 fb^{-1}, m_H~ 126 GeV)
~ 170 signal events (total signal efficiency ~ 40%)
~ 6340 background events in mass window
→ S/B ~ 3% inclusive (~ 20% 2jet category)

Crucial experimental aspects:
- ❑ excellent $\gamma\gamma$ mass resolution to observe narrow signal peak above irreducible background
- ❑ powerful γ identification to suppress γj and jj background with jet → π^0 → fake γ
  (cross sections are 10^4-10^7 larger than $\gamma\gamma$ background)

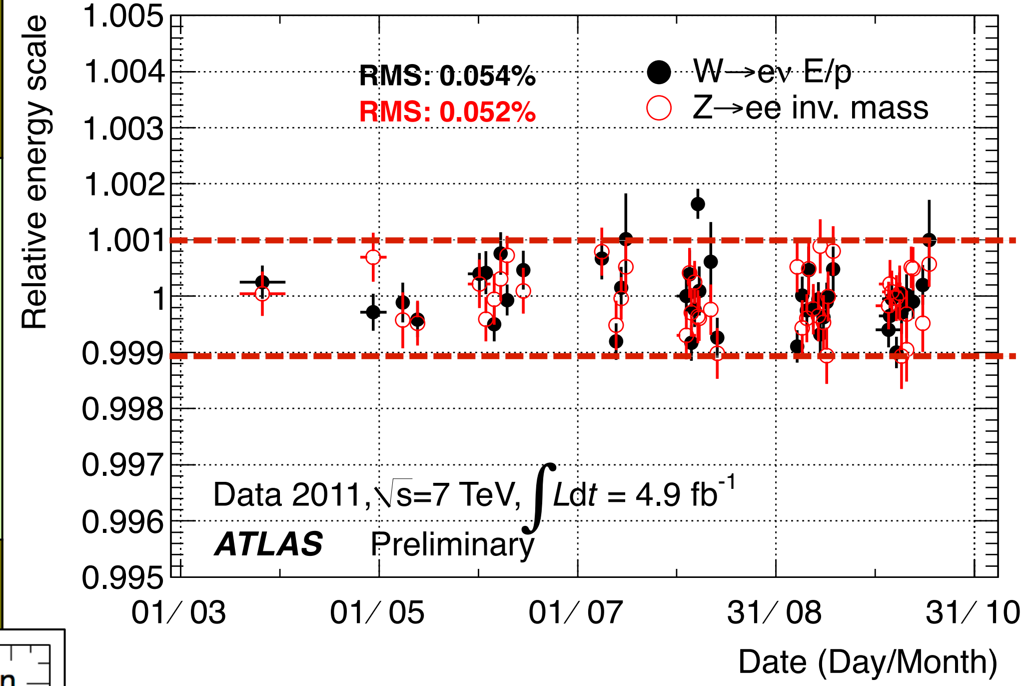
Mass resolution

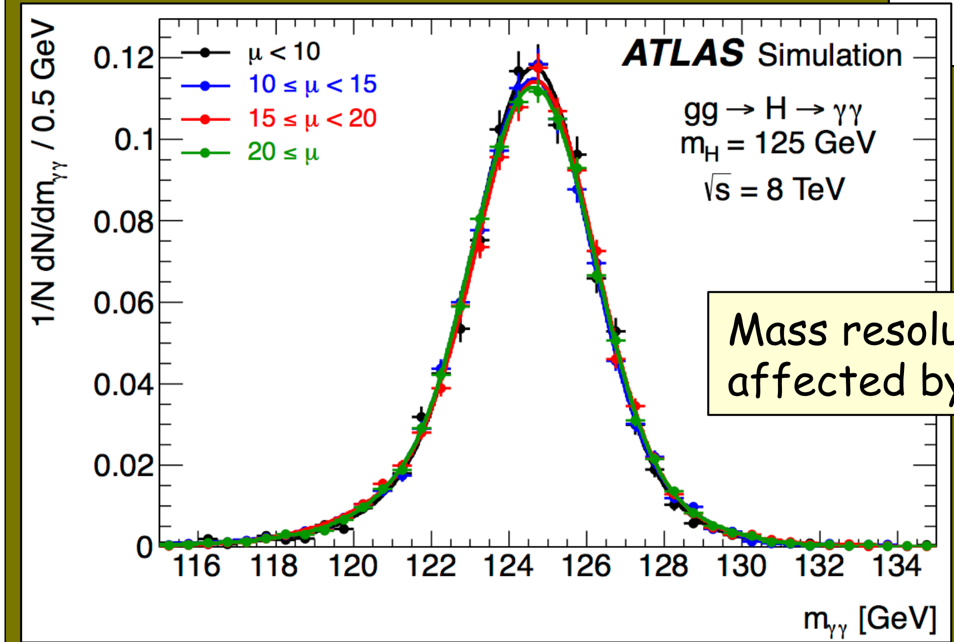
$m^2_{\gamma\gamma} = 2 E_1 E_2 (1-\cos\alpha)$

Present understanding of calorimeter E response (from Z, $J/\psi \rightarrow ee$, $W \rightarrow e\nu$ data and MC):

- E-scale at m_Z known to ~ 0.3%
- Linearity better than 1% (few-100 GeV)
- "Uniformity" (constant term of resolution): ~ 1% (2.5% for $1.37<|\eta|<1.8$)

Stability of EM calorimeter response vs time (and pile-up) during full 2011 run better than 0.1%





Mass resolution not affected by pile-up

Electron scale transported to photons using MC (small systematics from material effects)

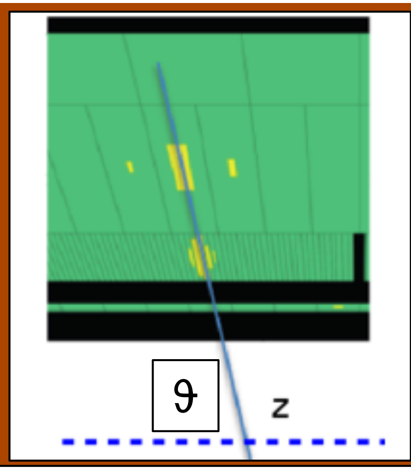
Mass resolution of inclusive sample: 1.6 GeV
Fraction of events in $\pm 2\sigma$: ~90%

$m^2_{\gamma\gamma} = 2\,E_1\,E_2\,(1-\cos\alpha)$

α=opening angle of the two photons

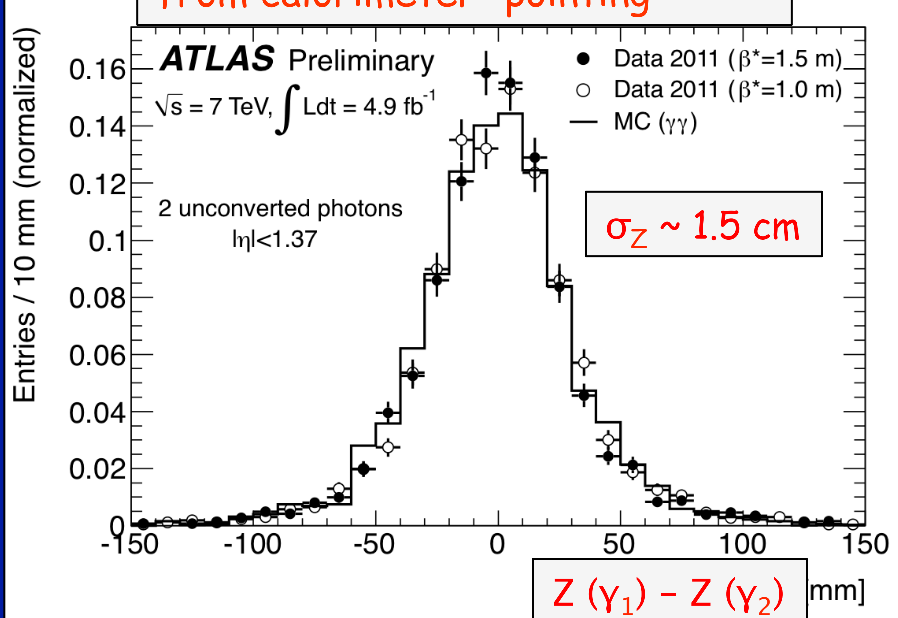
High pile-up: many vertices distributed over σ_Z (LHC beam spot) ~ 5-6 cm
→ difficult to know which one has produced the γγ pair

Primary vertex from:
- ❑ EM calorimeter longitudinal (and lateral) segmentation
- ❑ tracks from converted photons



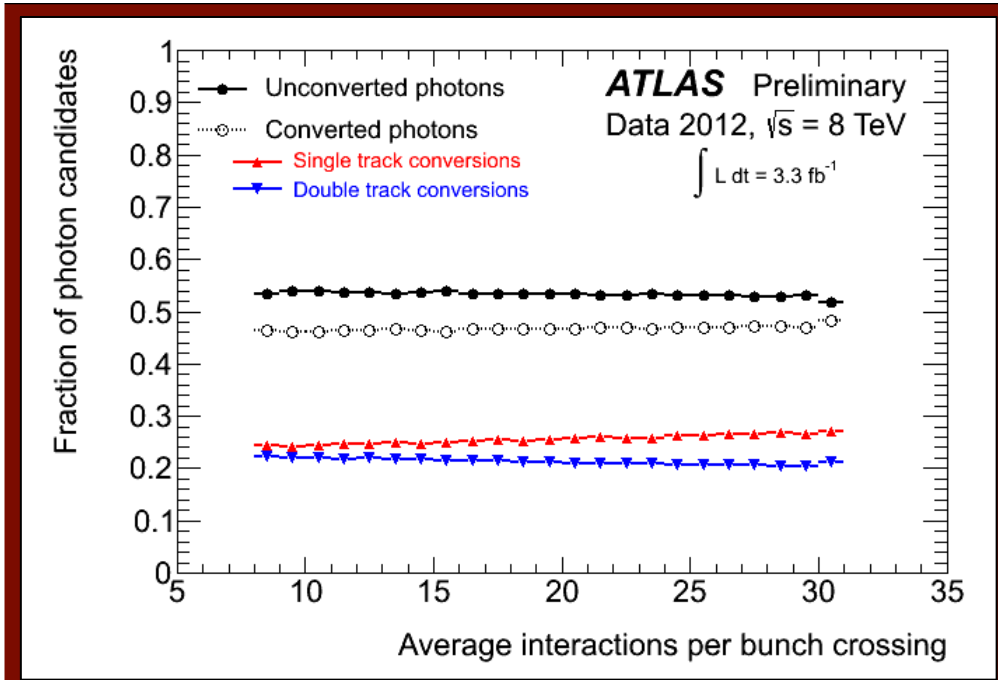
Measure γ direction with calo
→ get Z of primary vertex

Z-vertex measured in γγ events from calorimeter "pointing"



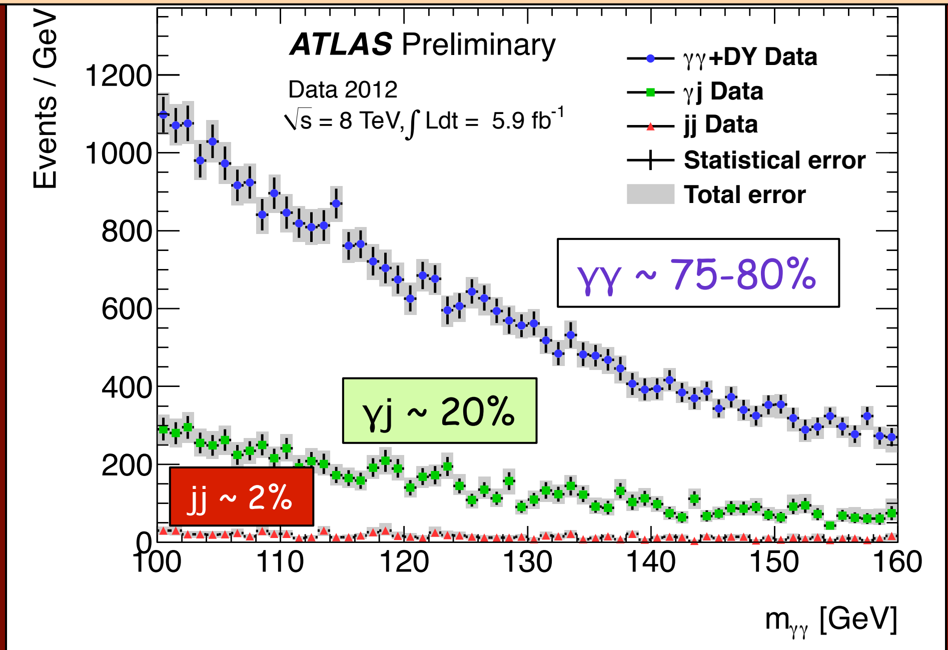
Note:
- ❑ Calorimeter pointing alone reduces vertex uncertainty from beam spot spread of ~ 5-6 cm to ~ 1.5 cm and is robust against pile-up
- → good enough to make contribution to mass resolution from angular term negligible
- ❑ Addition of track information (less pile-up robust) needed to reject fake jets from pile-up in 2j/VBF category

γ reconstruction, γ/jet separation



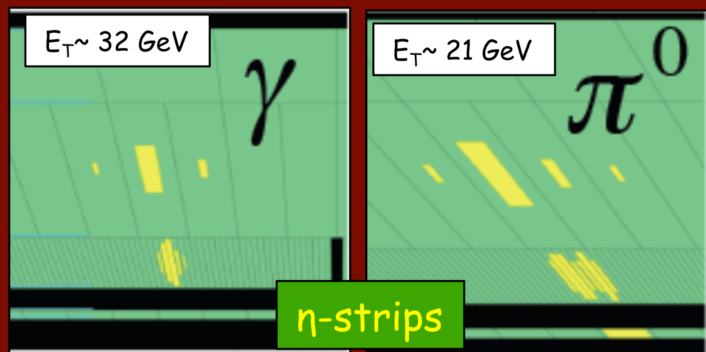
Fraction of converted and unconverted γ vs pile-up is now stable (within 1%)
→ small migration between categories, accurate specific calibration

Data-driven decomposition of selected γγ sample



High γγ purity thanks to:

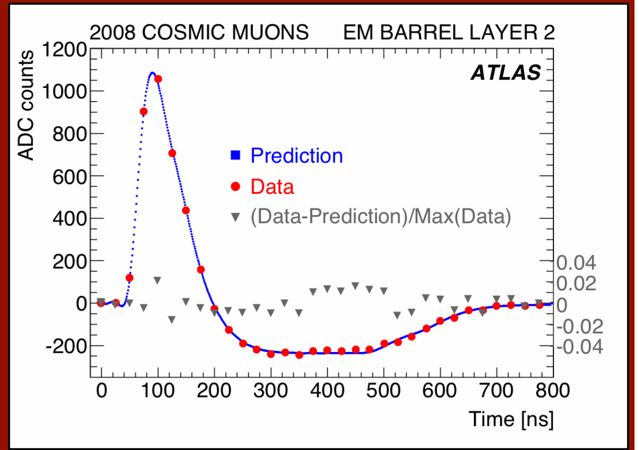
R_j ~10^4
ε (γ) ~ 90%



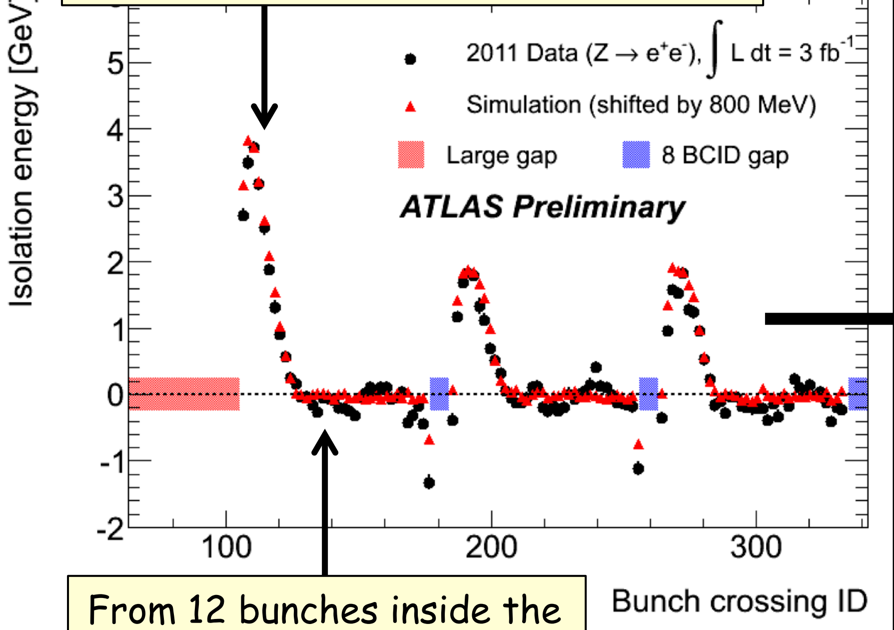
Photon isolation requirement: $E_T < 4$ GeV inside cone $\Delta R < 0.4$ around γ direction.
Pile-up contribution subtracted using an "ambient energy density" event-by-event

If subtraction is not perfect, residual dependence of the isolation energy on the bunch position in the train observed, due to impact of out-of-time pile-up from neighbouring bunches convolved with EM calorimeter pulse shape.

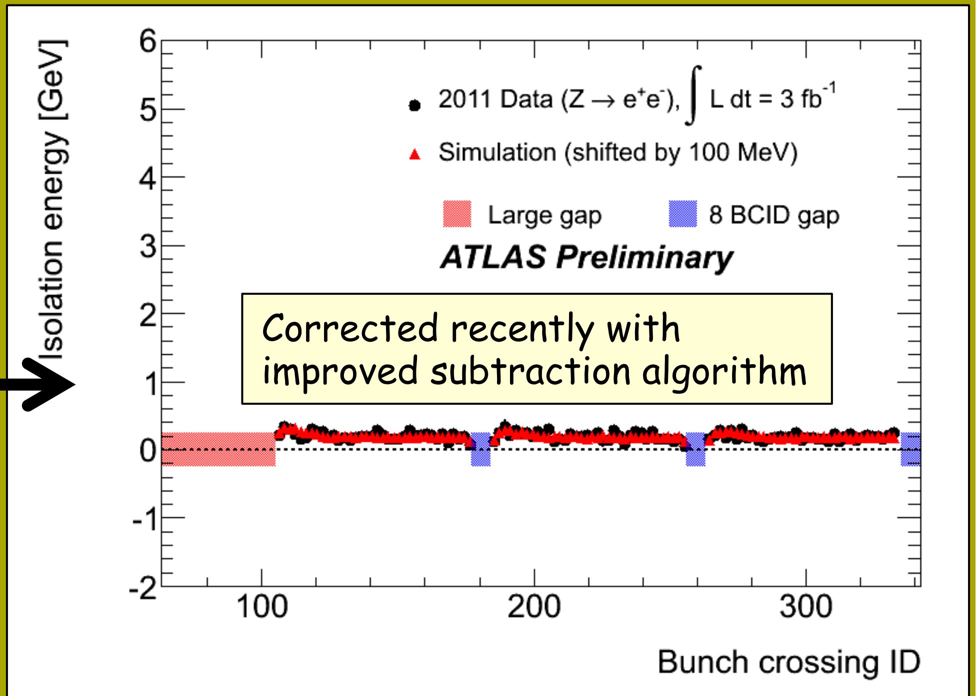
Calorimeter bipolar pulse shape: average pile-up is zero over ~ 600 ns (~12 bunches)



Beginning of the train: no cancellation from previous bunches

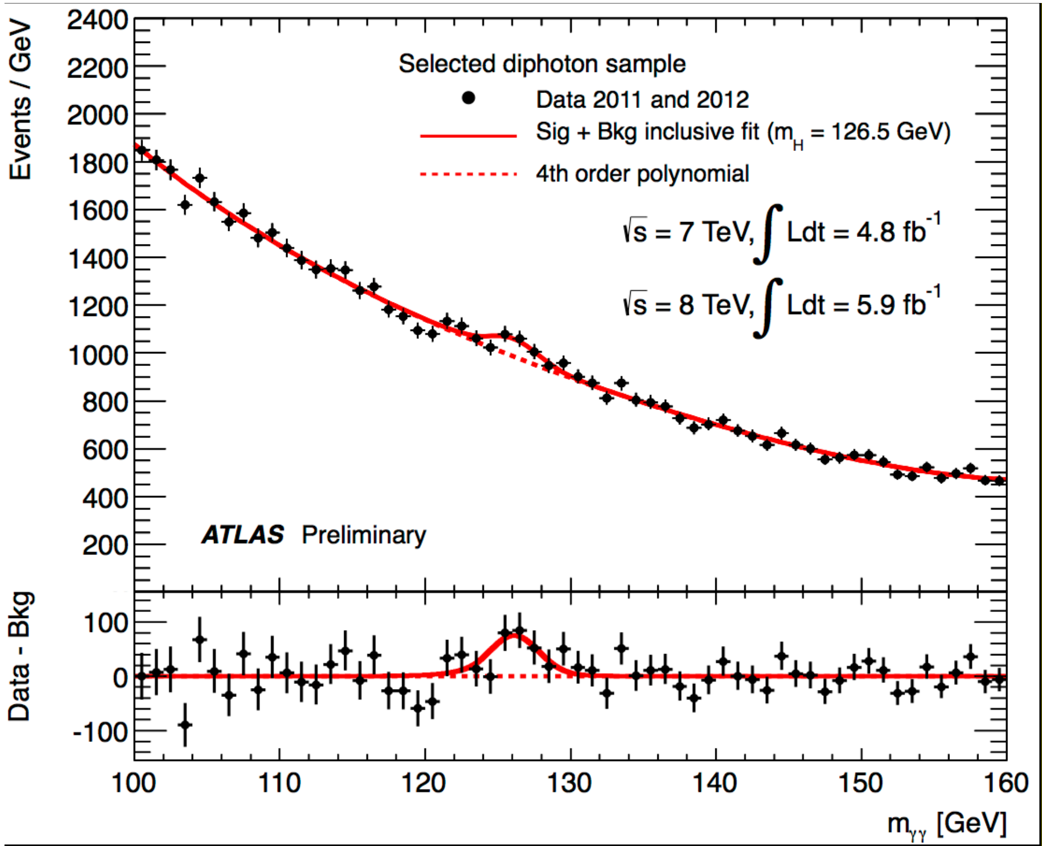


From 12 bunches inside the train: full cancellation



Corrected recently with improved subtraction algorithm

Effect well described by (detailed !) ATLAS simulation



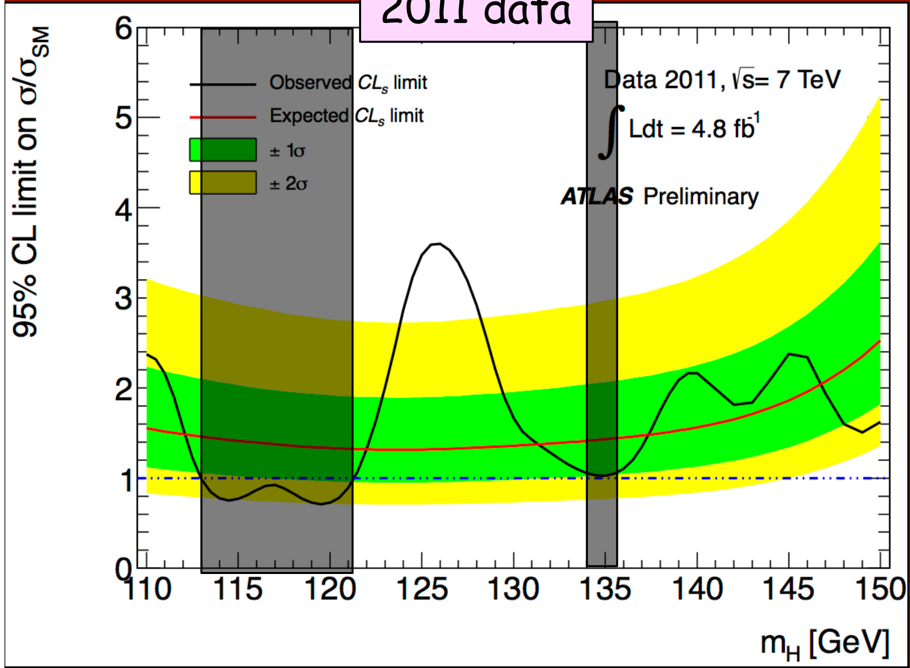
Total after selections: 59059 events

$m_{\gamma\gamma}$ spectrum fit, <u>for each category</u>, with Crystal Ball + Gaussian for signal plus background model optimised (with MC) to minimize biases
Max deviation of background model from expected background distribution taken as systematic uncertainty

Main systematic uncertainties

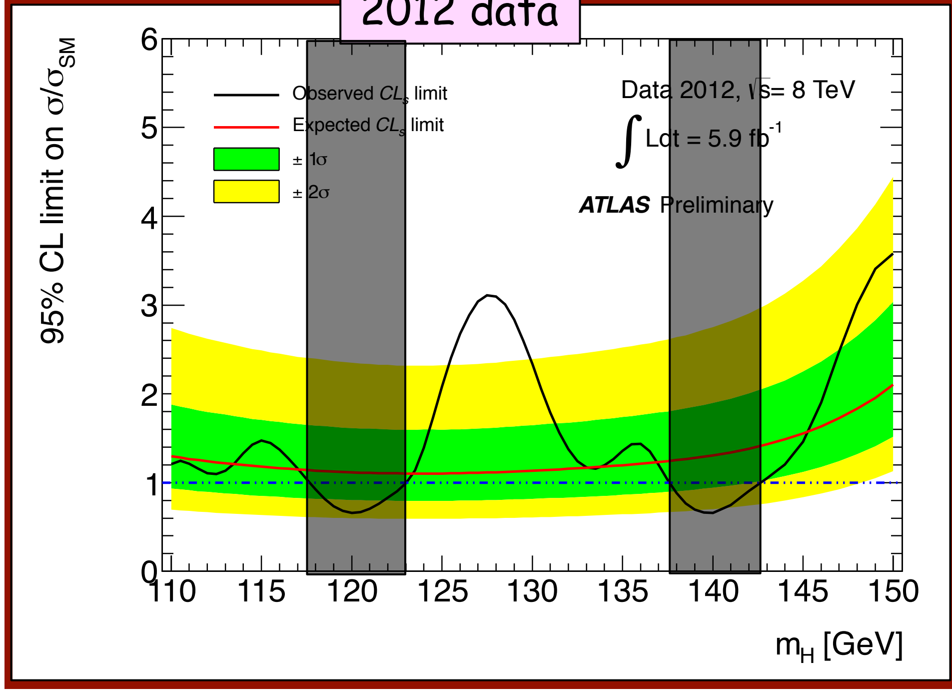
Signal yield	
Theory	~ 20%
Photon efficiency	~ 10%
Background model	~ 10%
Categories migration	
Higgs p_T modeling	up to ~ 10%
Conv/unconv γ	up to ~ 6%
Jet E-scale	up to 20% (2j/VBF)
Underlying event	up to 30% (2j/VBF)
H→ γγ mass resolution	~ 14%
Photon E-scale	~ 0.6%

2011 data

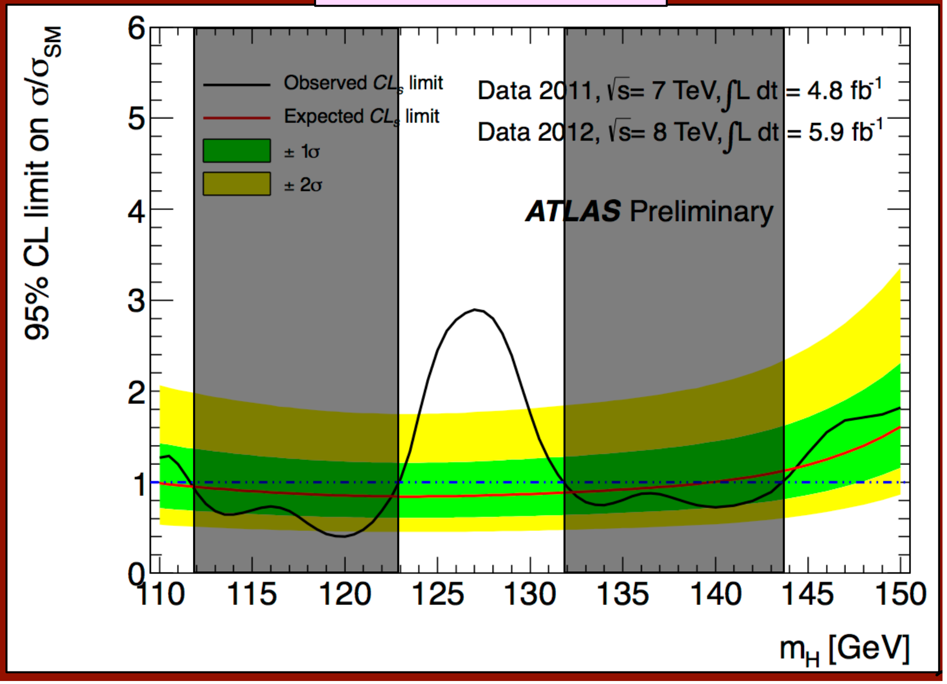


Excluded (95% CL):
112-122.5 GeV, 132-143 GeV
Expected: 110-139.5 GeV

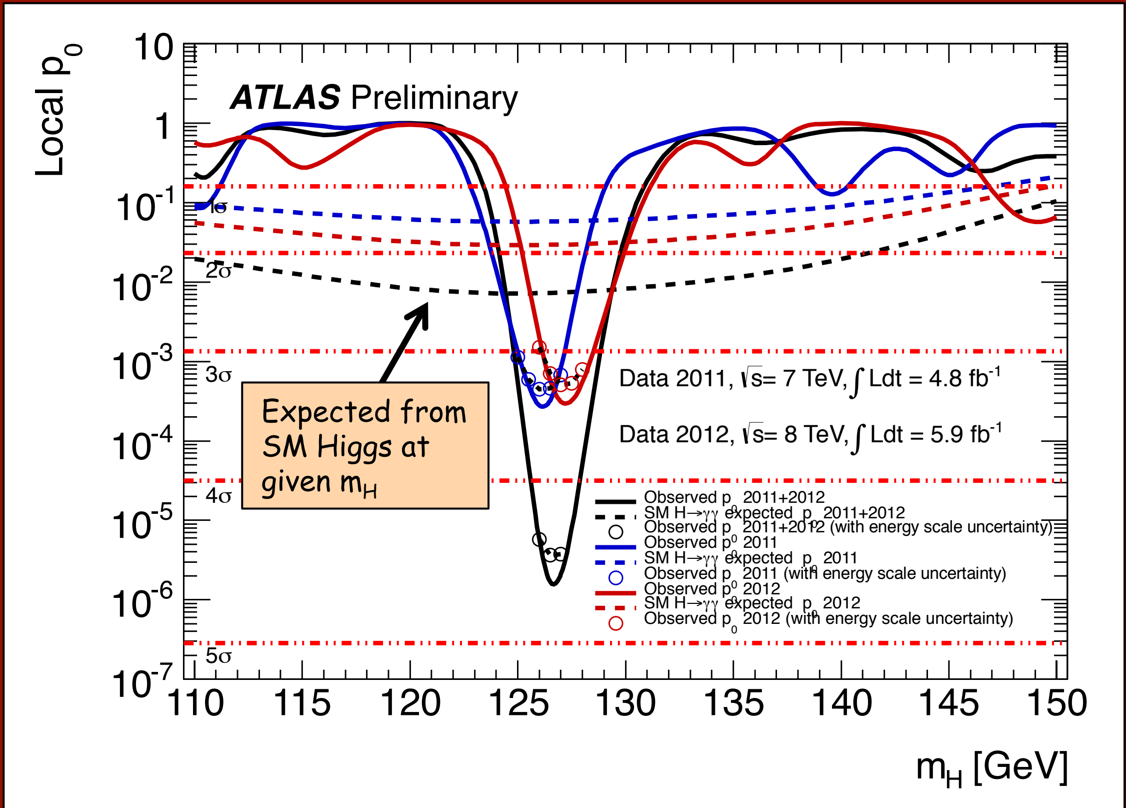
2012 data



2011+2012 data



Consistency of data with background-only expectation



Points indicate impact of 0.6% uncertainty on photon energy scale: ~ 0.1 sigma

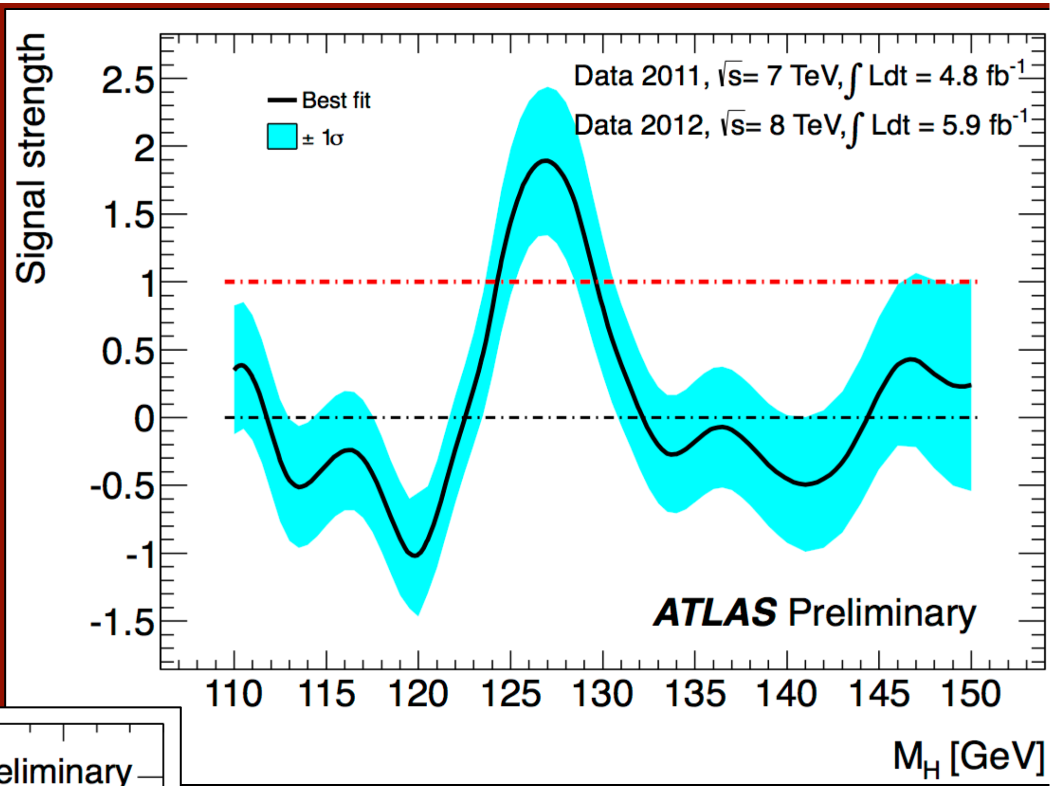
Data sample	m_H of max deviation	local p-value	local significance	expected from SM Higgs
2011	126 GeV	3×10^{-4}	3.5 σ	1.6 σ
2012	127 GeV	3×10^{-4}	3.4 σ	1.9 σ
2011+2012	126.5 GeV	2×10^{-6}	4.5 σ	2.4 σ

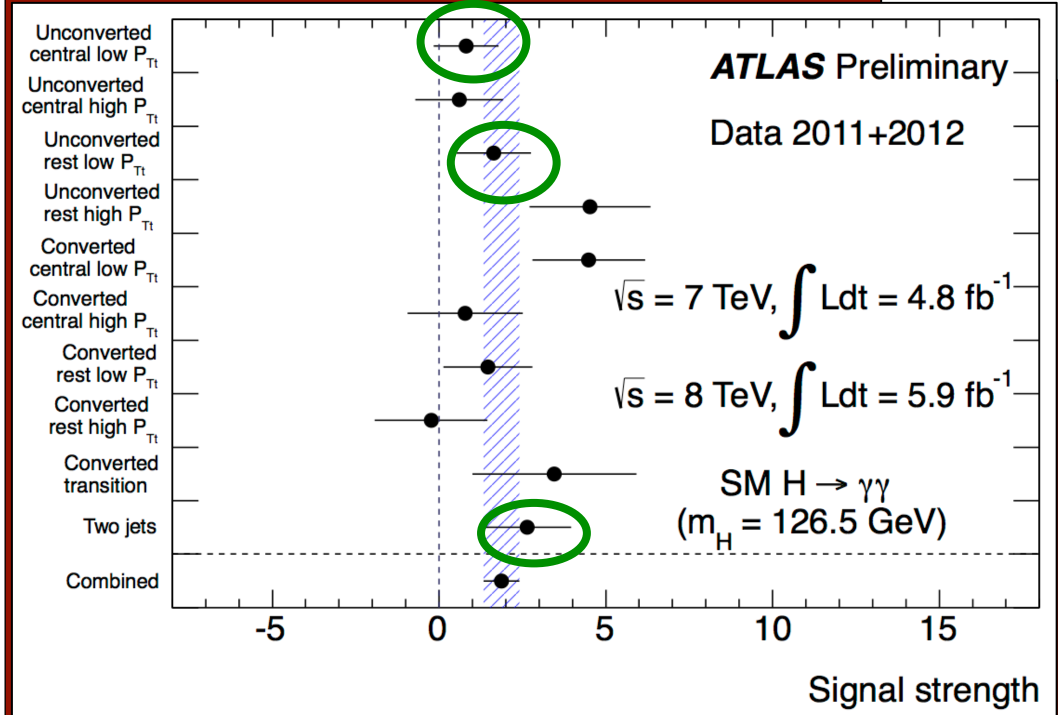
Global 2011+2012 (including LEE over 110-150 GeV range): 3.6 σ

Fitted signal strength

Normalized to SM Higgs expectation at given m_H (μ)

Best-fit value at 126.5 GeV: μ=1.9 ± 0.5





Consistent results from various categories within uncertainties (most sensitive ones indicated)

$H \to ZZ^{(*)} \to 4l$ (4e, 4μ, 2e2μ)

$110 < m_H < 600$ GeV

$\sigma \times BR \sim 2.5$ fb $m_H \sim 126$ GeV

- ❑ Tiny rate, BUT:
  -- mass can be fully reconstructed → events should cluster in a (narrow) peak
  -- pure: S/B ~ 1
- ❑ 4 leptons: $p_T^{1,2,3,4} > 20,15,10,7\text{-}6$ (e-μ) GeV; $50 < m_{12} < 106$ GeV; $m_{34} > 17.5\text{-}50$ GeV (vs m_H)
- ❑ Main backgrounds:
  -- $ZZ^{(*)}$: irreducible
  -- low-mass region $m_H < 2m_Z$: Zbb, Z+jets, tt with two leptons from b-jets or q-jets → l

→ Suppressed with isolation and impact parameter cuts on two softest leptons

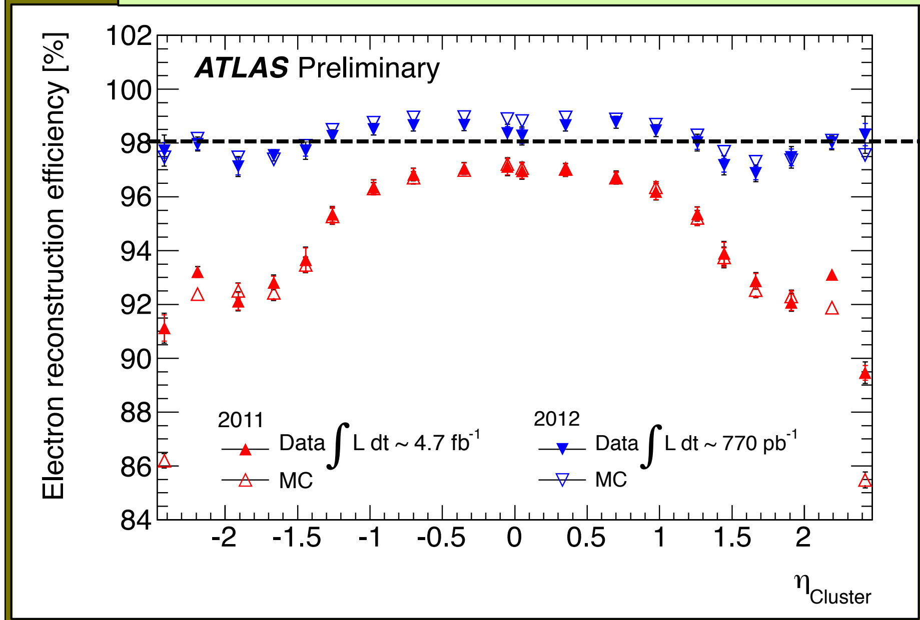
Crucial experimental aspects:
- ❑ High lepton acceptance, reconstruction & identification efficiency down to lowest p_T
- ❑ Good lepton energy/momentum resolution
- ❑ Good control of reducible backgrounds (Zbb, Z+jets, tt) in low-mass region:
  → cannot rely on MC alone (theoretical uncertainties, b/q-jet → l modeling, ..)
  → need to validate MC with data in background-enriched control regions

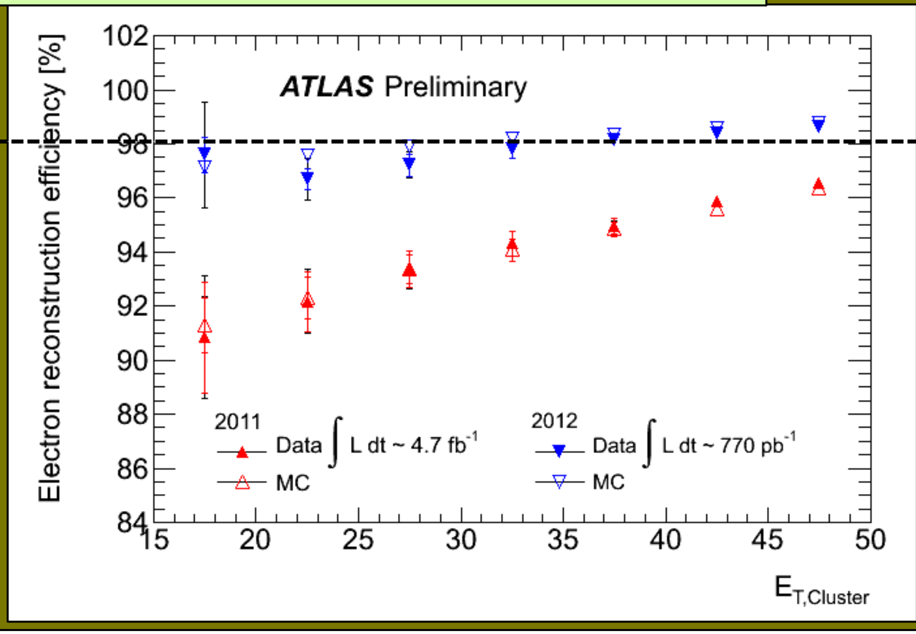
Main improvements in new analysis:
- ❑ kinematic cuts (e.g. on m_{12}) optimized/relaxed to increase signal sensitivity at low mass
- ❑ increased $e^{\pm}$ reconstruction and identification efficiency at low p_T , increased pile-up robustness, with negligible increase in the reducible backgrounds

→ Gain 20% (4μ) to 30% (4e) in sensitivity compared to previous analysis

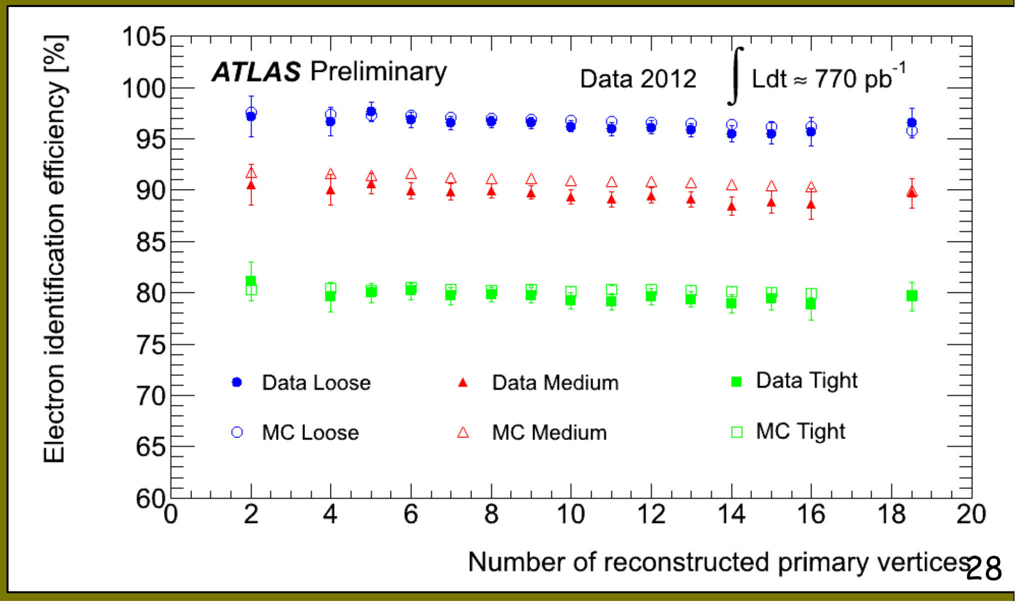
High efficiency for low-p_T electrons (affected by material) crucial for H→ 4e, 2μ2e

Improved track reconstruction and fitting to recover e± undergoing hard Brem
→ achieved ~ 98% reconstruction efficiency, flatter vs η and E_T





Re-optimized e± identification using pile-up robust variables (e.g. Transition Radiation, calorimeter strips) → achieved ~ 95% identification efficiency, ~ flat vs pile-up; higher rejections of fakes



Results are from Z→ ee data and MC tag-and-probe

High efficiency for low-p_T electrons (affected by material) crucial for H→ 4e, 2μ2e

Improved track reconstruction and fitting to recover $e^{\pm}$ undergoing hard Brem
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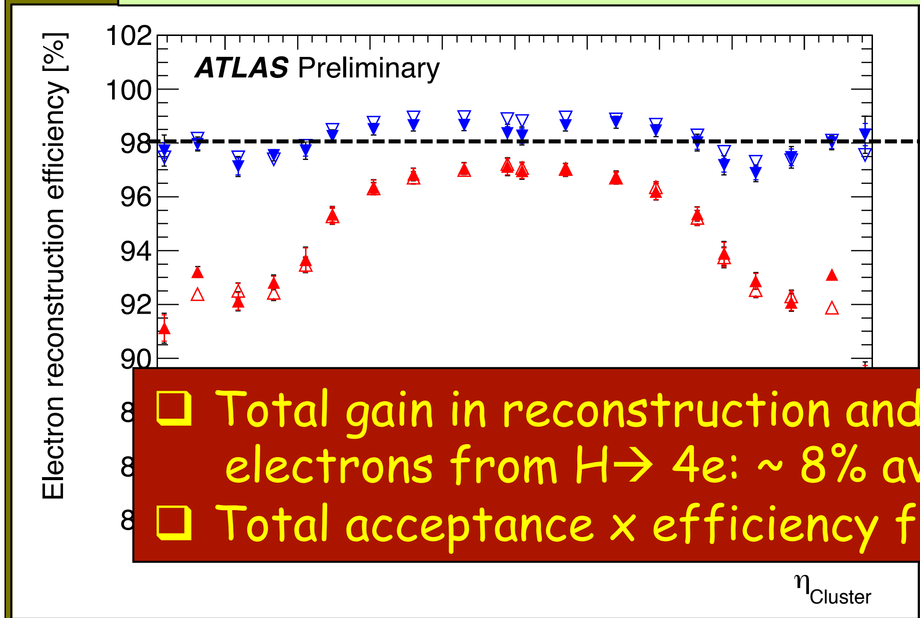
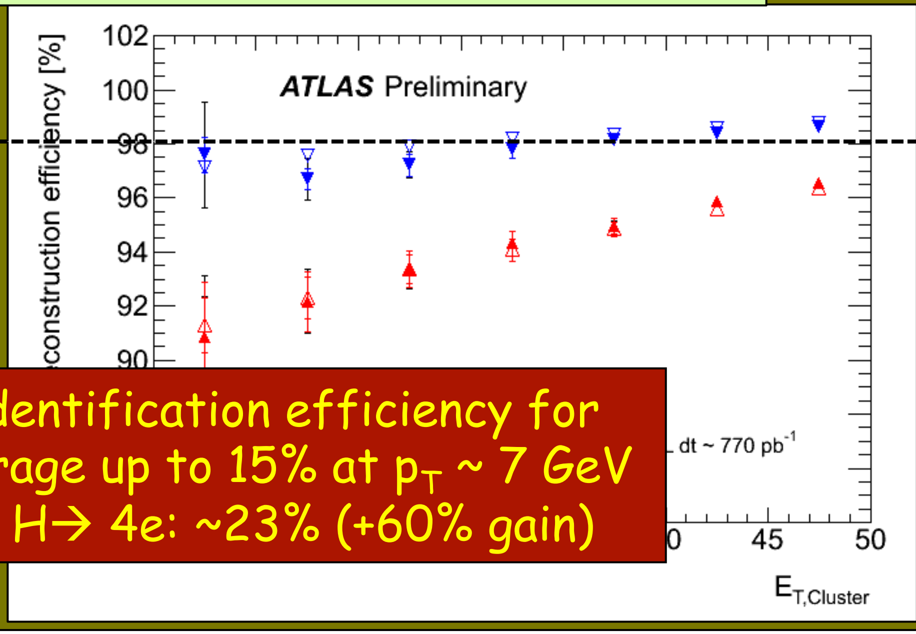
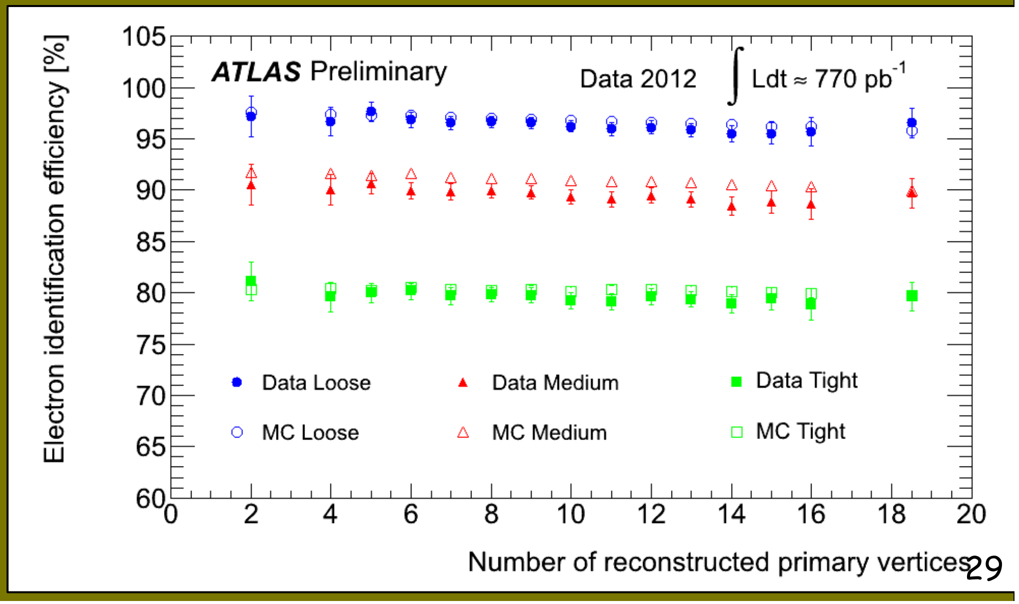




- ❑ Total gain in reconstruction and identification efficiency for electrons from H→ 4e: ~ 8% average up to 15% at p_T ~ 7 GeV
- ❑ Total acceptance x efficiency for H→ 4e: ~23% (+60% gain)

Re-optimized $e^{\pm}$ identification using pile-up robust variables (e.g. Transition Radiation, calorimeter strips) → achieved ~ 95% identification efficiency, ~ flat vs pile-up; higher rejections of fakes



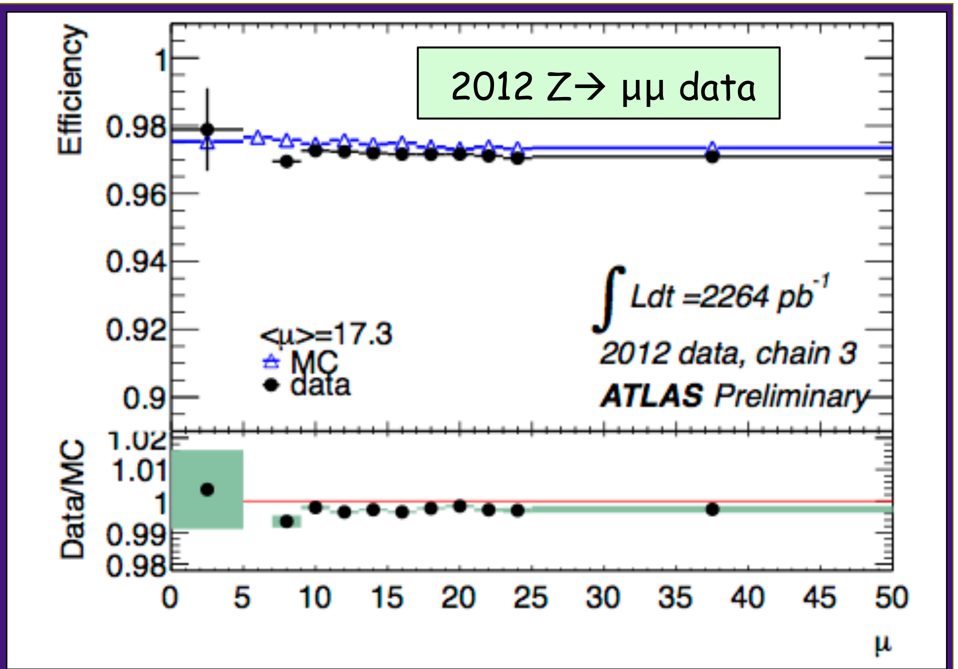
Results are from Z→ ee data and MC tag-and-probe

Muons reconstructed down to p_T = 6 GeV over |η|<2.7

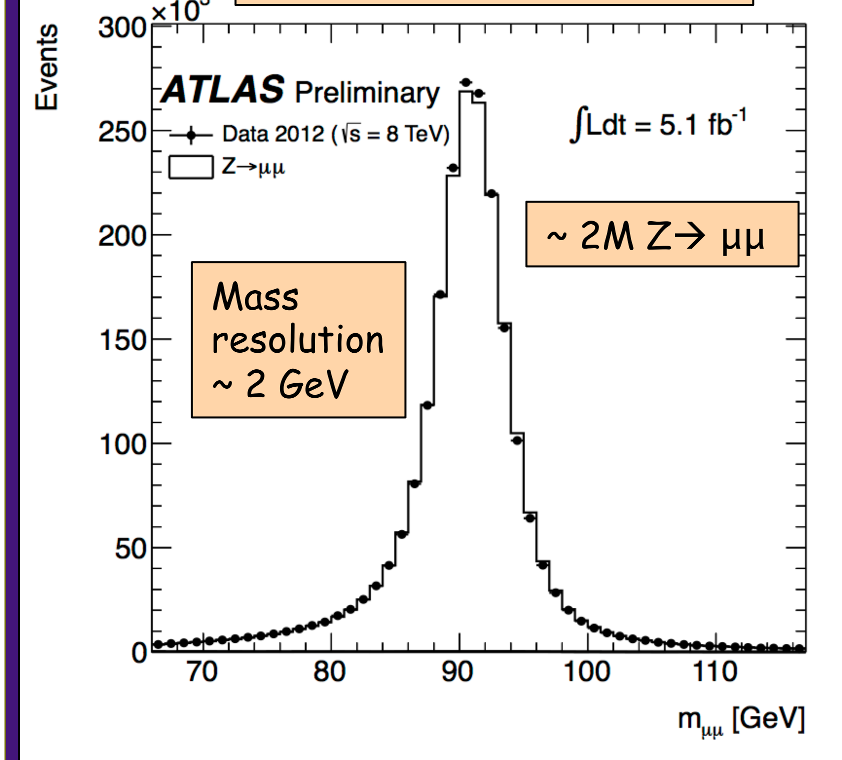
Reconstruction efficiency ~ 97%,
~ flat down to p_T ~ 6 GeV and over |η|~2.7

Total acceptance x efficiency for H→ 4μ: ~ 40% (+45% gain)

2012 Z→ μμ data



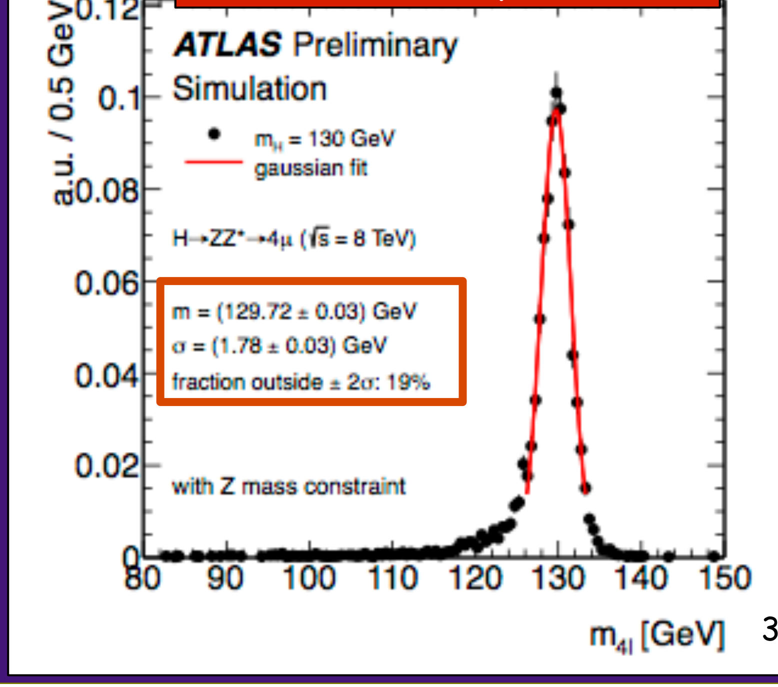
2012 Z→ μμ mass peak



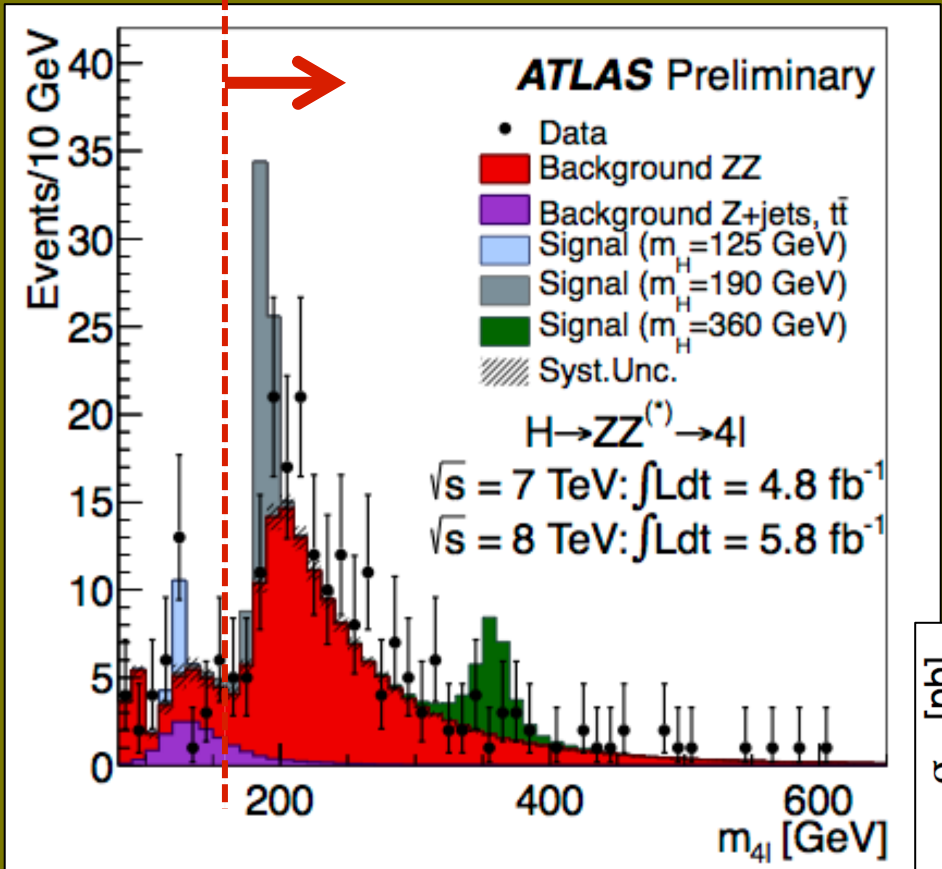
Mass resolution ~ 2 GeV

~ 2M Z→ μμ

H→ 4μ mass spectrum



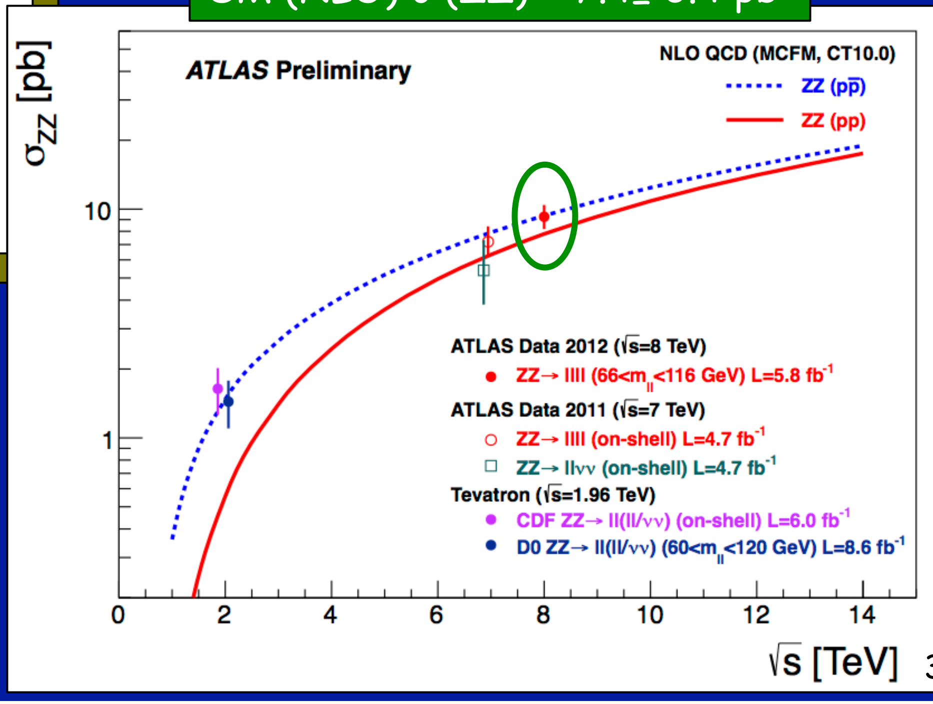
H→ 4l mass spectrum after all selections: 2011+2012 data



m(4l) > 160 GeV
(dominated by ZZ background):
147 ± 11 events expected
191 observed

~ 1.3 times more ZZ events in data than SM prediction →in agreement with measured ZZ cross-section in 4l final states at $\sqrt{s}$ = 8 TeV

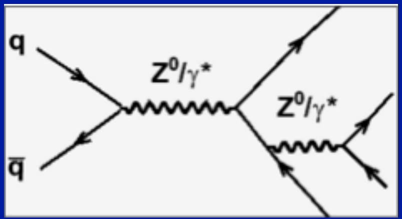
Measured σ (ZZ) = 9.3 ± 1.2 pb
SM (NLO) σ (ZZ) = 7.4± 0.4 pb



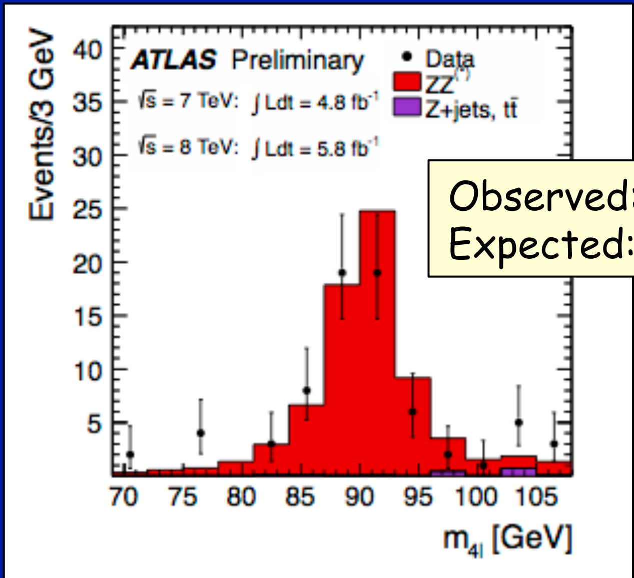
Discrepancy has negligible impact on the low-mass region < 160 GeV
(no change in results if in the fit ZZ is constrained to its uncertainty or left free)

H→ 4l mass spectrum after all selections: 2011+2012 data

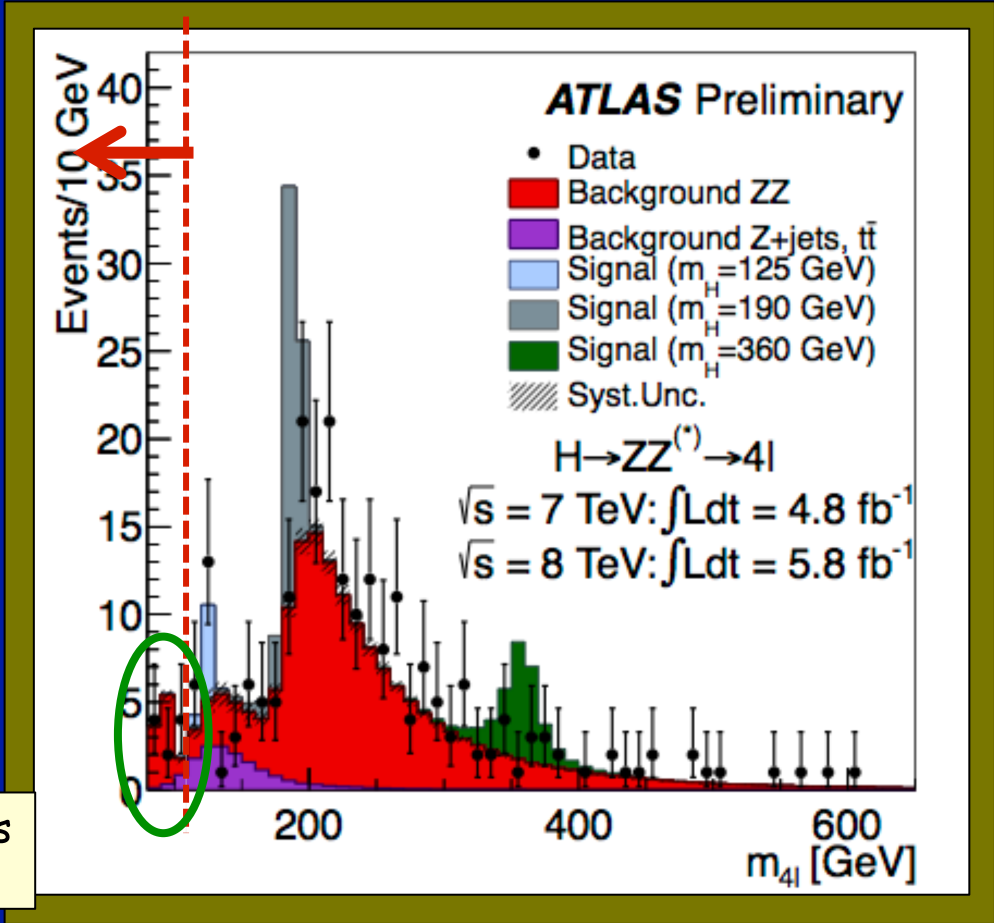
Peak at m(4l) ~ 90 GeV from single-resonant Z→ 4l production



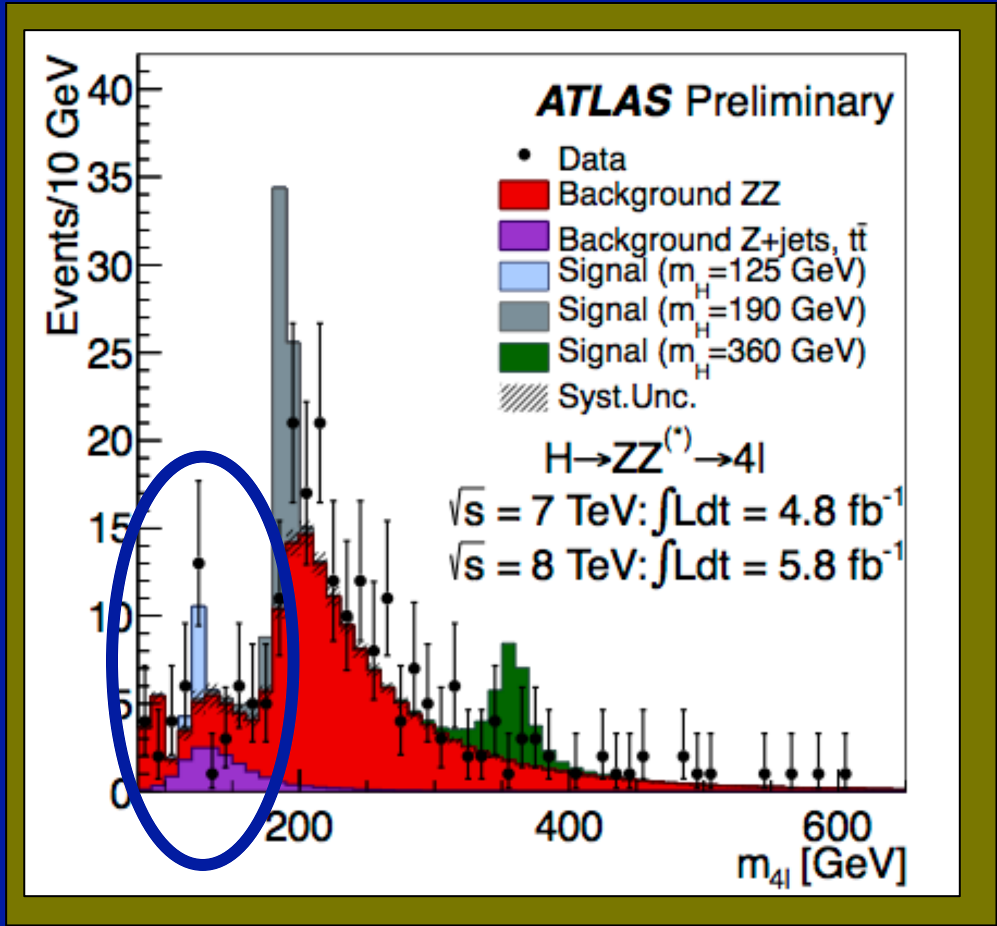
Enhanced by relaxing cuts on m_{12}, m_{34} and $p_T(\mu_4)$

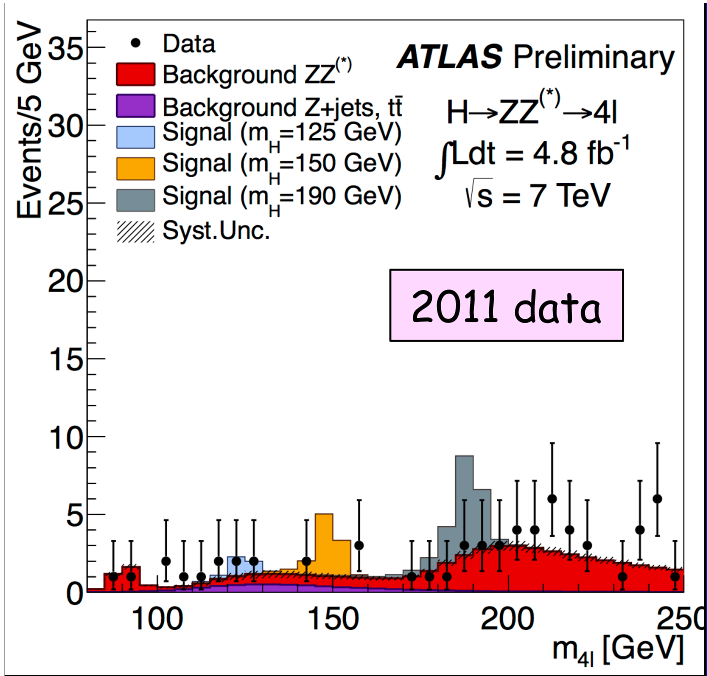


Observed: 57 events
Expected: 65 ± 5



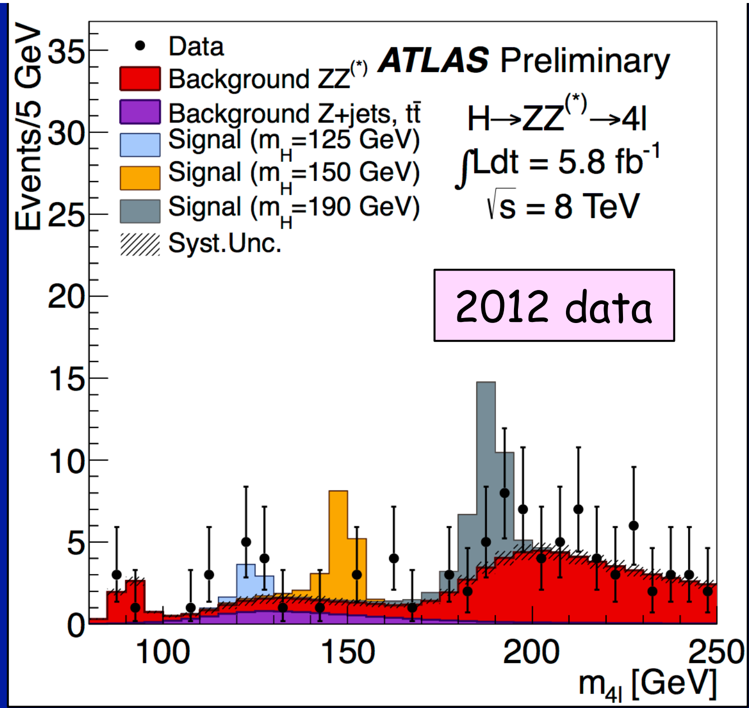
H→ 4l mass spectrum after all selections: 2011+2012 data



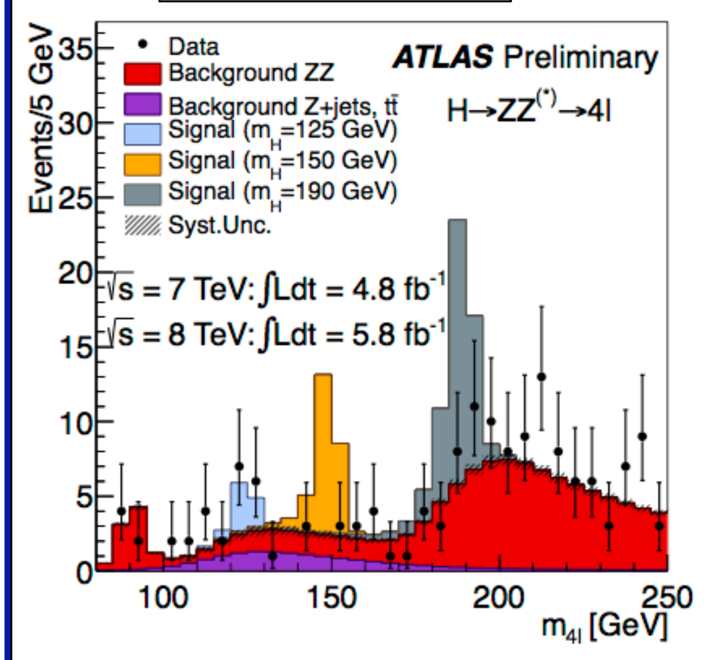


The low-mass region

m4l <160 GeV:
Observed: 39
Expected: 34± 3



2011+2012 data



In the region 125 ± 5 GeV

Dataset	2011	2012	2011+2012
Expected B only	2±0.3	3±0.4	5.1±0.8
Expected S m_H=125 GeV	2±0.3	3±0.5	5.3±0.8
Observed in the data	4	9	13

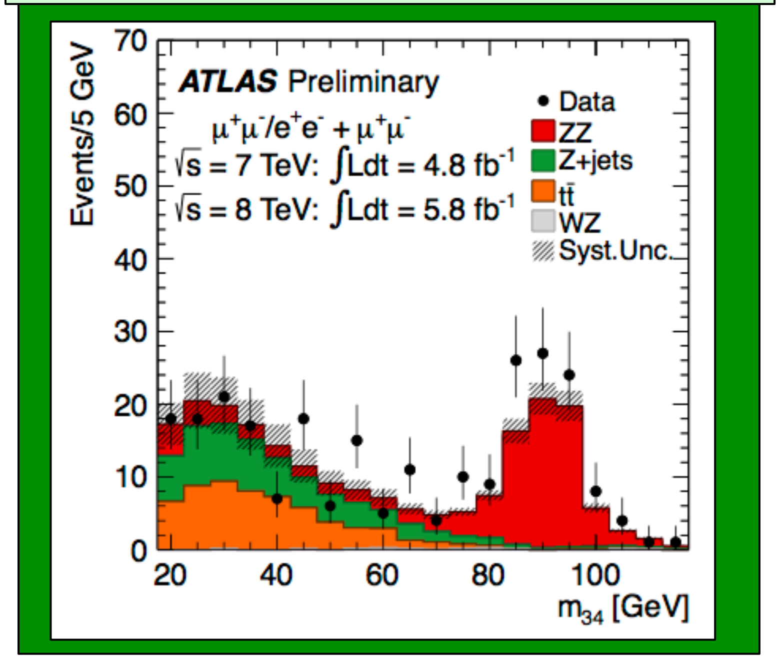
2011+ 2012	4μ	2e2μ	4e
Data	6	5	2
Expected S/B	1.6	1	0.5
Reducible/total background	5%	45%	55%

Reducible backgrounds from Z+jets, Zbb, tt giving 2 genuine + 2 fake leptons measured using background-enriched, signal-depleted control regions in data

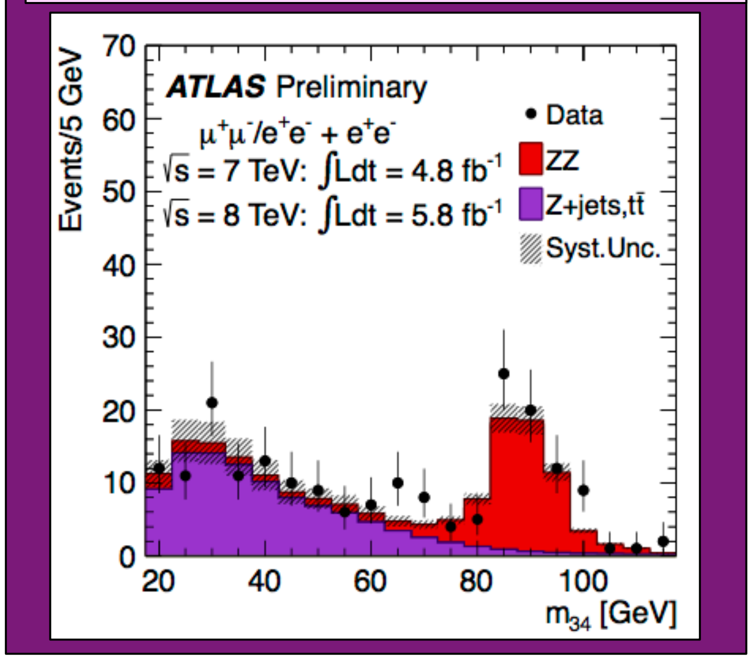
Typical control regions:

- ❑ leading lepton pair ($l_1 l_2$) satisfies all selections
- ❑ sub-leading pair ($l_3 l_4$): no isolation nor impact parameter requirements applied

$l_3 l_4 = \mu\mu$ → background dominated by tt and Zbb in low mass region



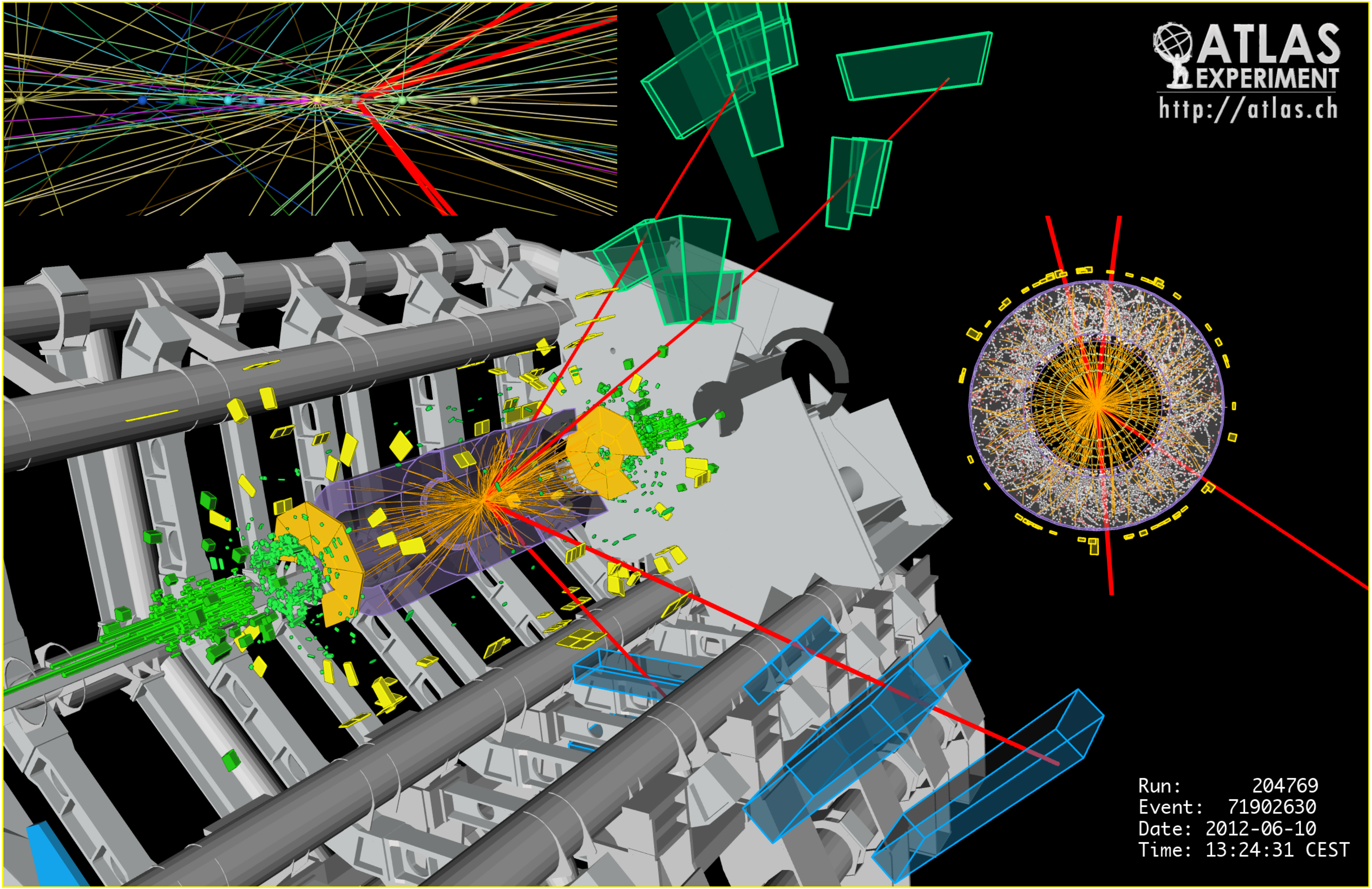
$l_3 l_4 = ee$ → background dominated by Z+jets in low mass region



- ❑ Data well described by MC within uncertainties (ZZ excess at high mass …)
- ❑ Samples of Z+"μ" and Z+"e" used to compare efficiencies of isolation and impact parameter cuts between data and MC → good agreement → MC used to estimate background contamination in signal region
- ❑ Several cross-checks made with different control regions → consistent results

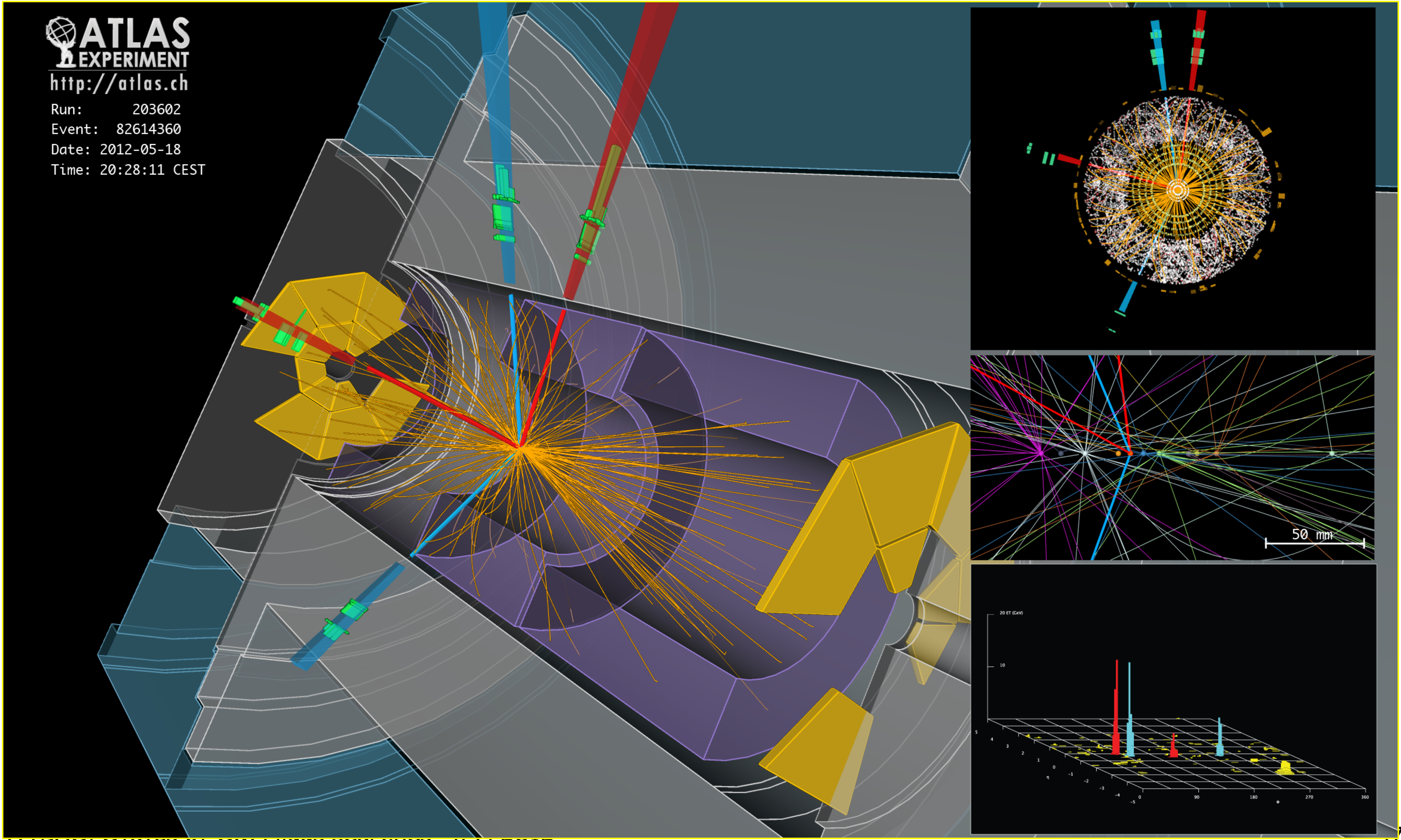
4μ candidate with $m_{4\mu}$= 125.1 GeV

p_T (muons)= 36.1, 47.5, 26.4, 71 .7GeV m_{12}= 86.3 GeV, m_{34}= 31.6 GeV
15 reconstructed vertices



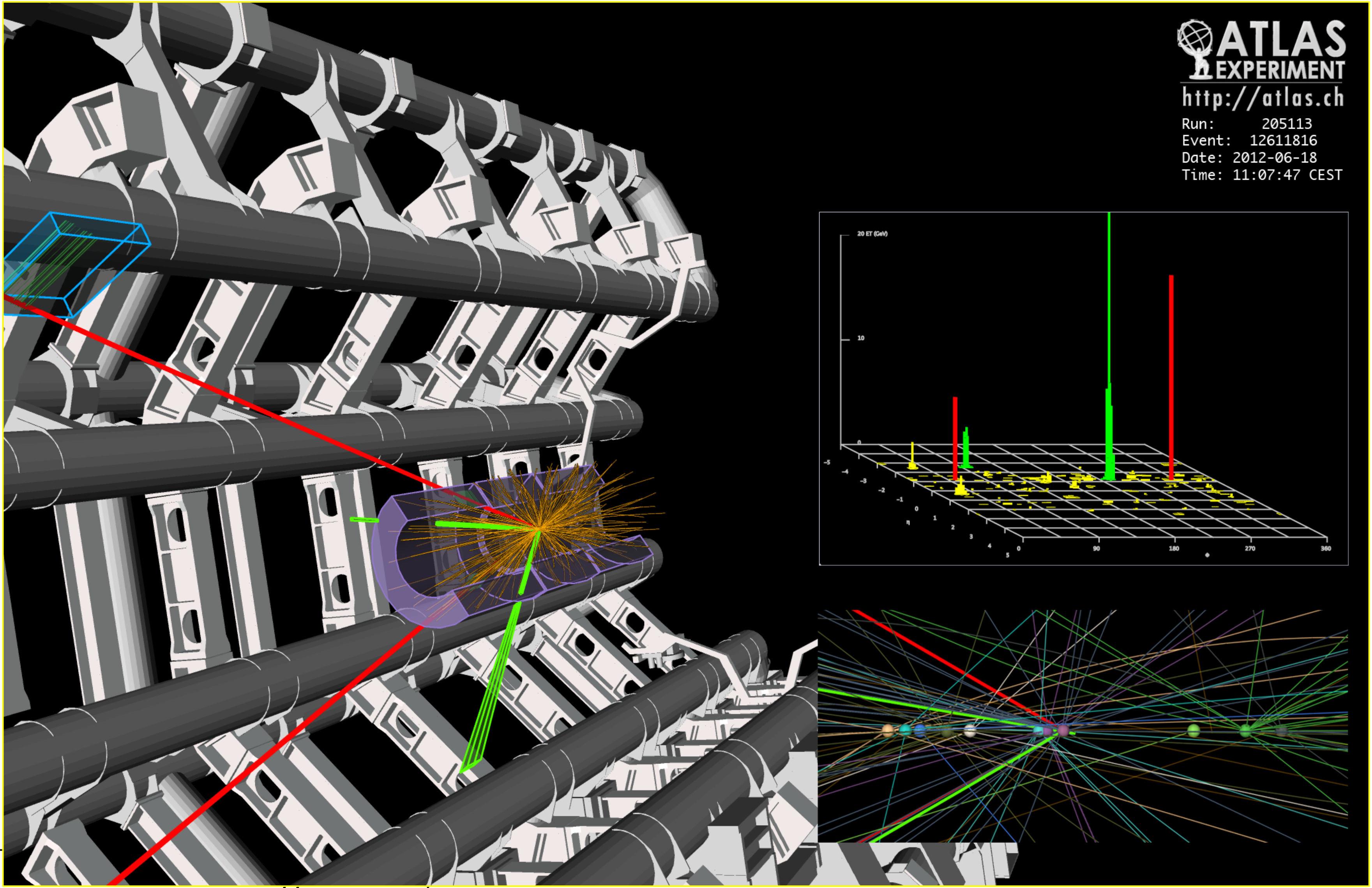
4e candidate with m_{4e}= 124.6 GeV

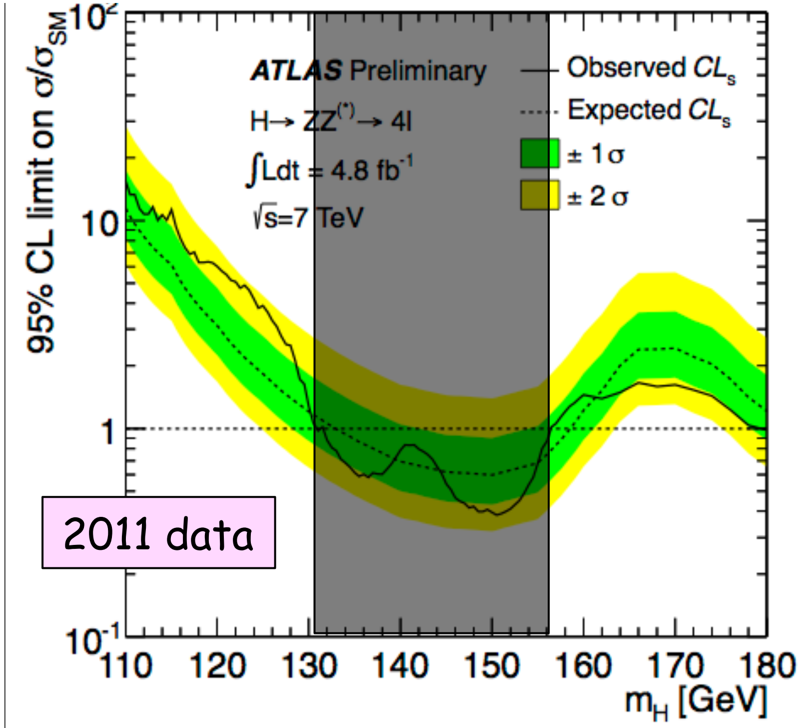
p_T (electrons)= 24.9, 53.9, 61.9, 17.8 GeV m_{12}= 70.6 GeV, m_{34}= 44.7 GeV
12 reconstructed vertices



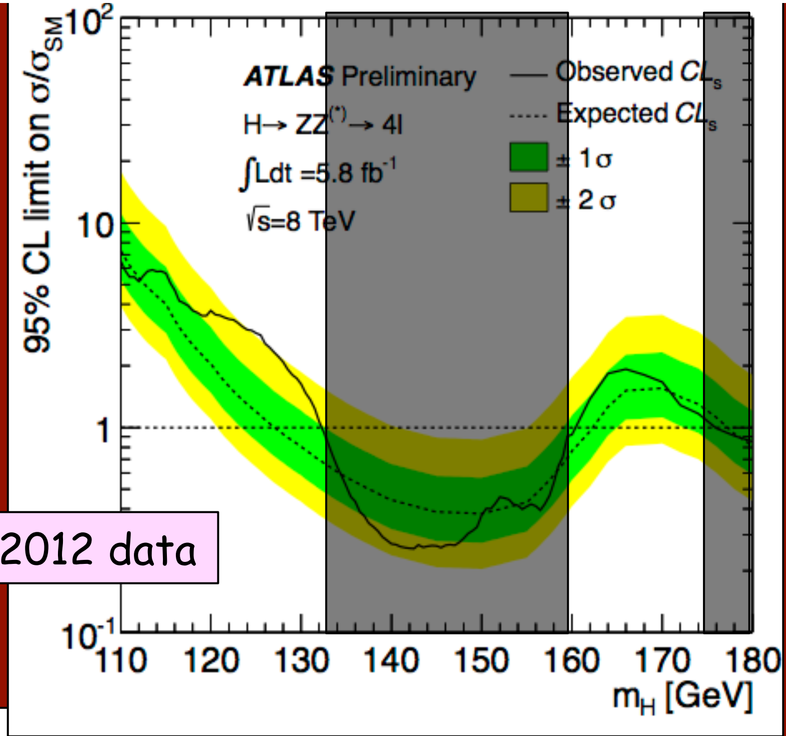
2e2μ candidate with $m_{2e2\mu}$= 123.9 GeV

p_T (e,e,μ,μ)= 18.7, 76, 19.6, 7.9 GeV, m (e^+e^-)= 87.9 GeV, m($\mu^+\mu^-$) =19.6 GeV
12 reconstructed vertices



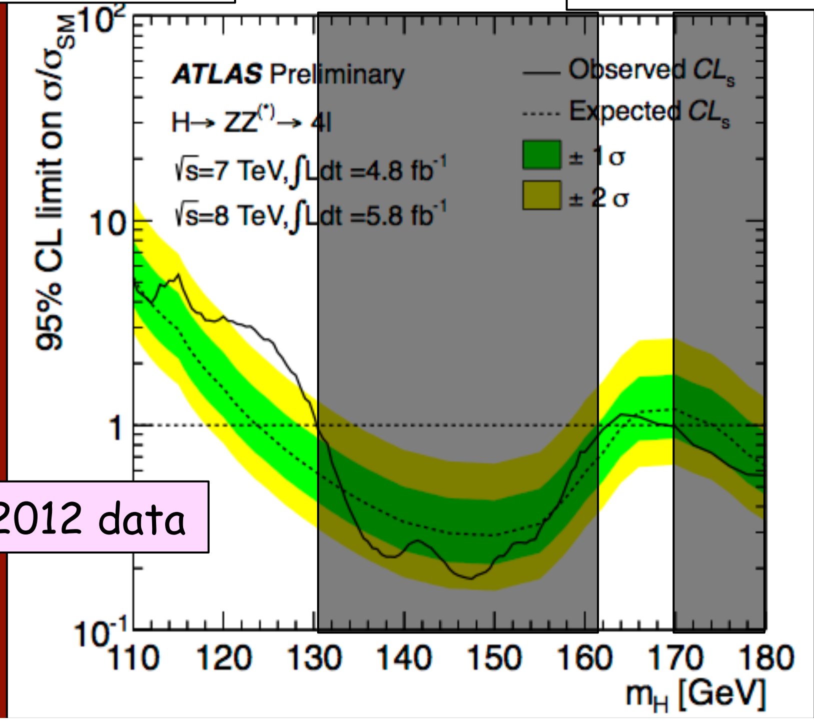


2011 data



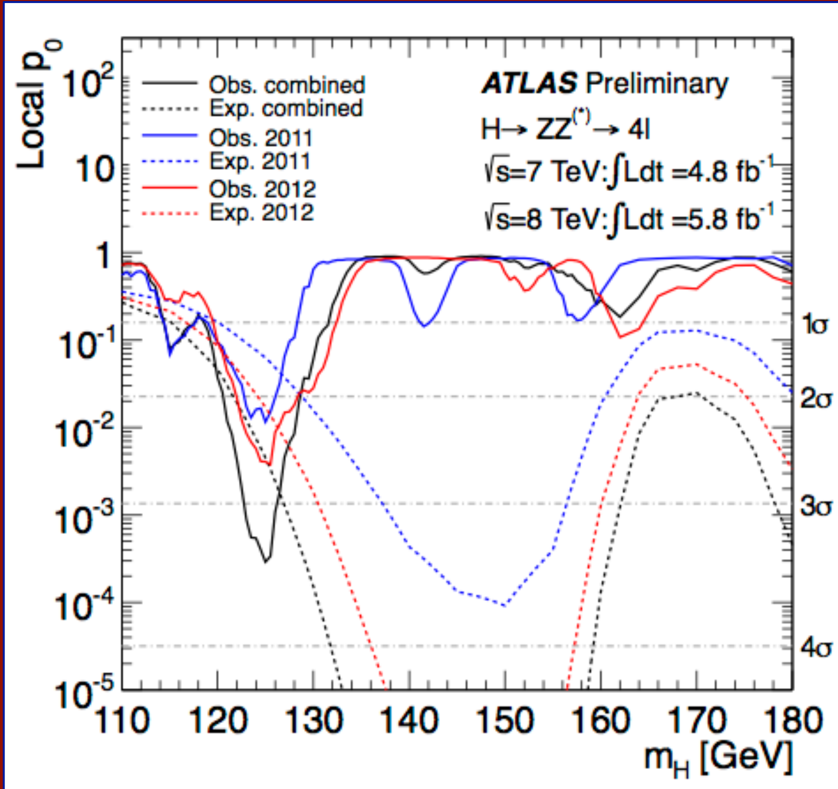
2012 data

Excluded (95% CL):
131-162, 170-460 GeV
Expected:
124-164, 176-500 GeV



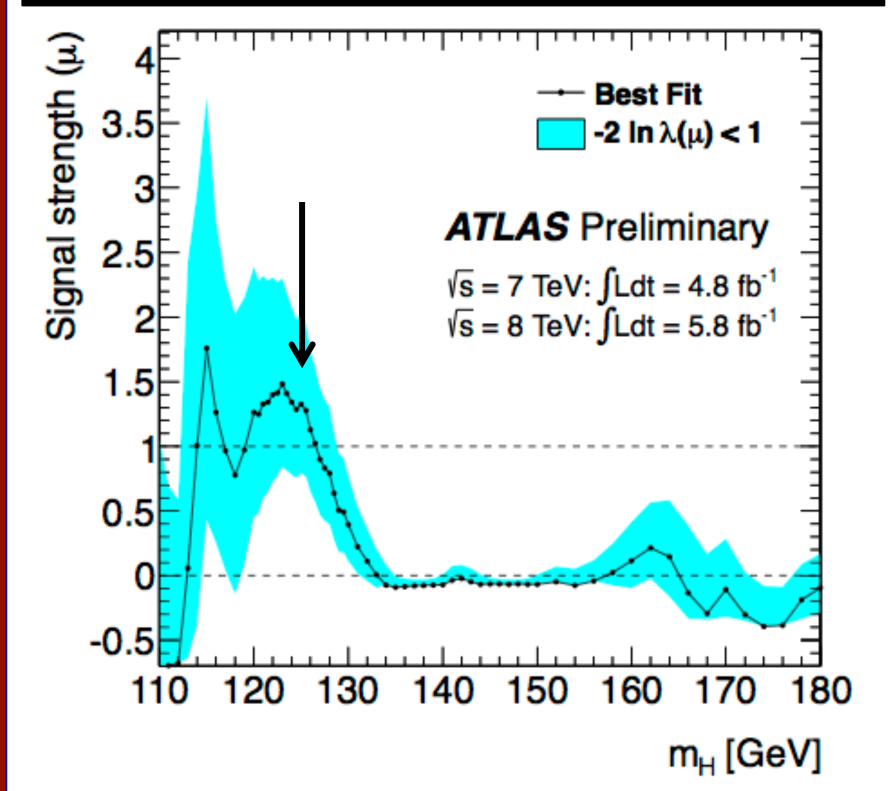
2011+2012 data

Consistency of the data with the background-only expectation



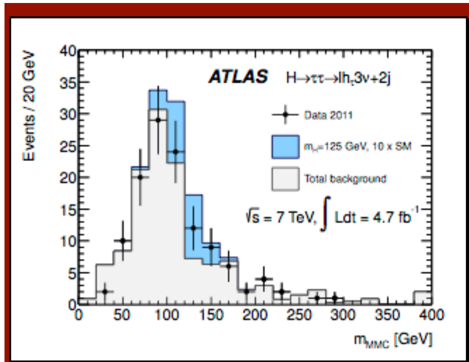
Fitted signal strength

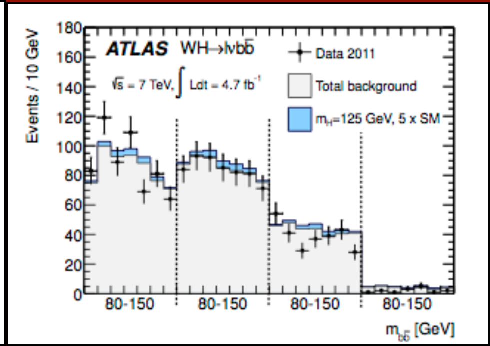
Best-fit value at 125 GeV: μ=1.3 ± 0.6

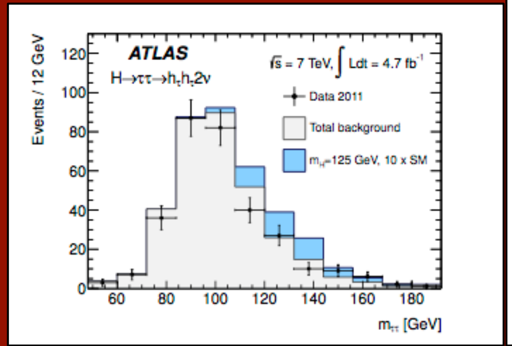


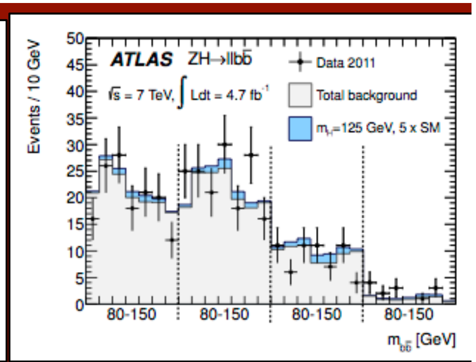
Data sample	m_H of max deviation	local p-value	local significance	expected from SM Higgs
2011	125 GeV	1.1%	2.3 σ	1.5 σ
2012	125.5 GeV	0.4%	2.7 σ	2.1 σ
2011+2012	125 GeV	0.03%	3.4 σ	2.6 σ

Global 2011+2012 (including LEE over full 110-141 GeV range): 2.5σ



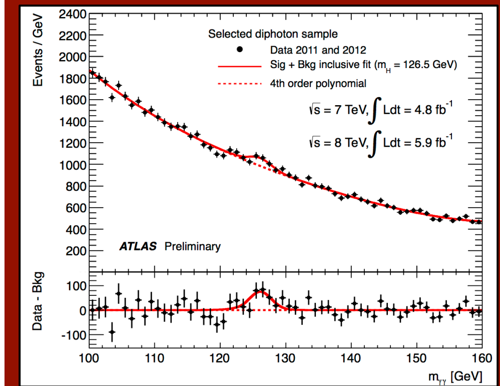


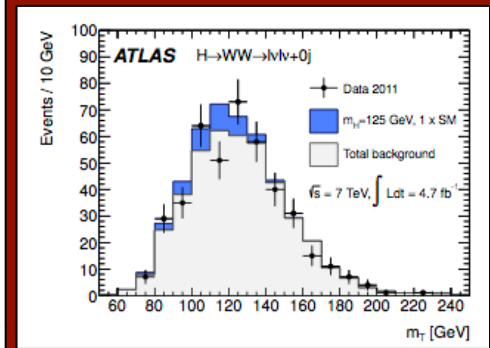


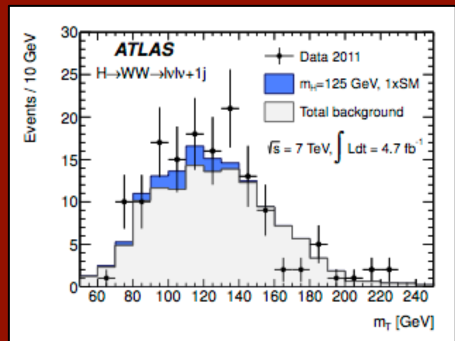


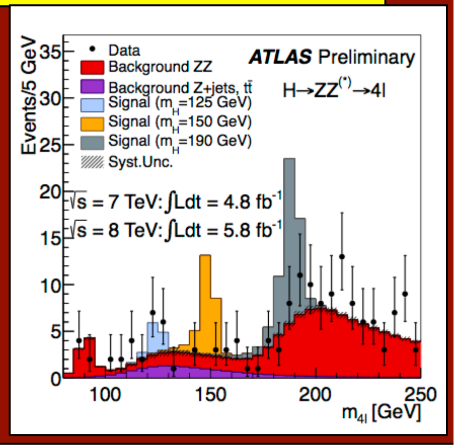
Combining all channels together:

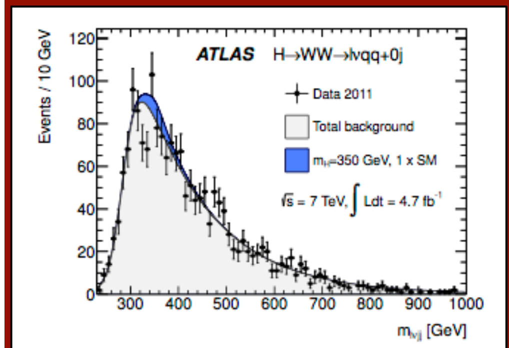
- H→ γγ, 4l: full 2011 and 2012 datasets (~ 10.7 fb^{-1}) and improved analyses
- all other channels (H→ $WW^{(*)}$→ lνlν, H→ ττ, WH→ lνbb, ZH→ llbb, ZH→ ννbb, ZZ → llνν, H→ ZZ → llqq; H→ WW→lνqq): full 2011 dataset (up to 4.9 fb^{-1})

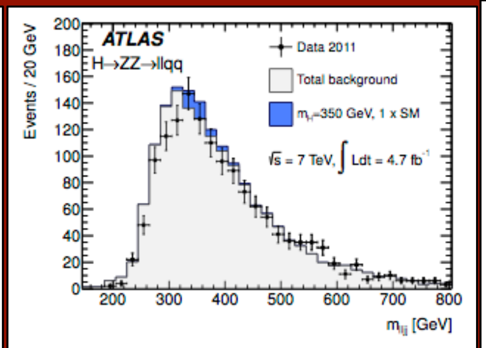


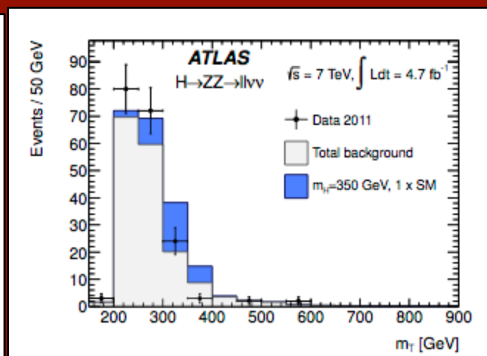


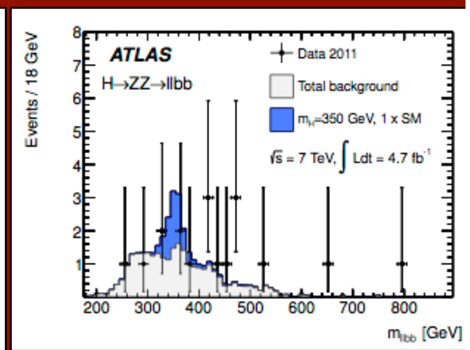








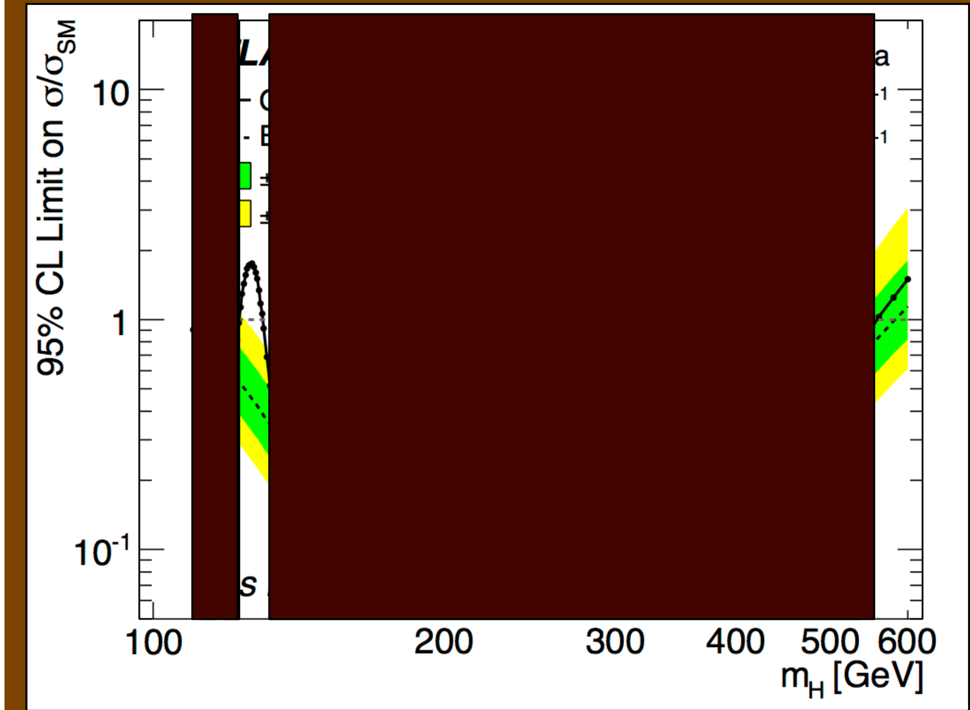


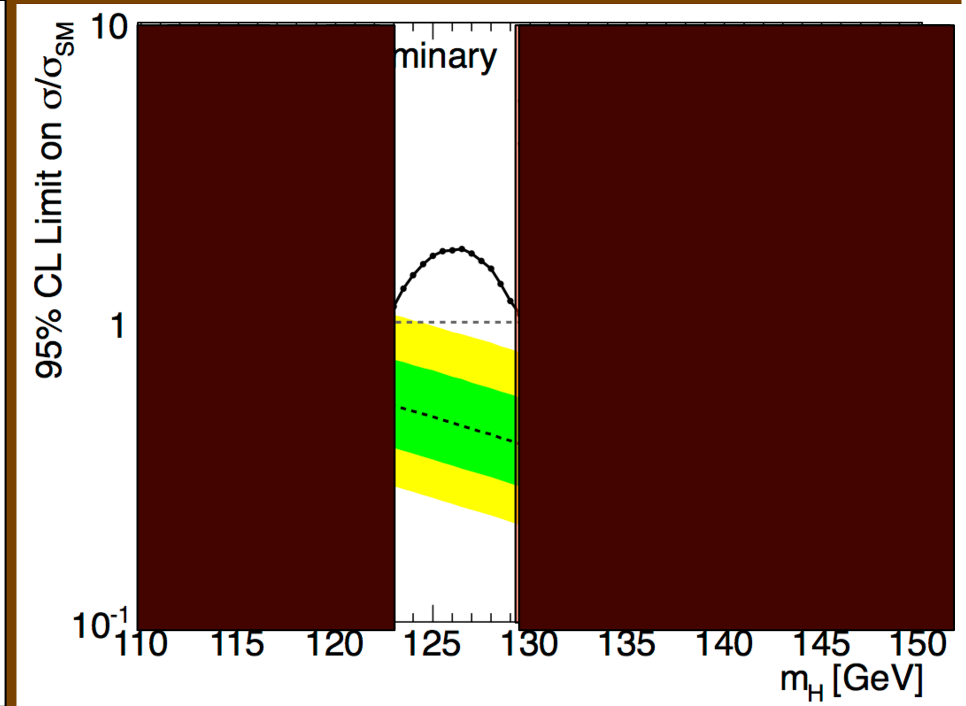


Combined results : exclusion limits

ATLAS today

Previous ATLAS results



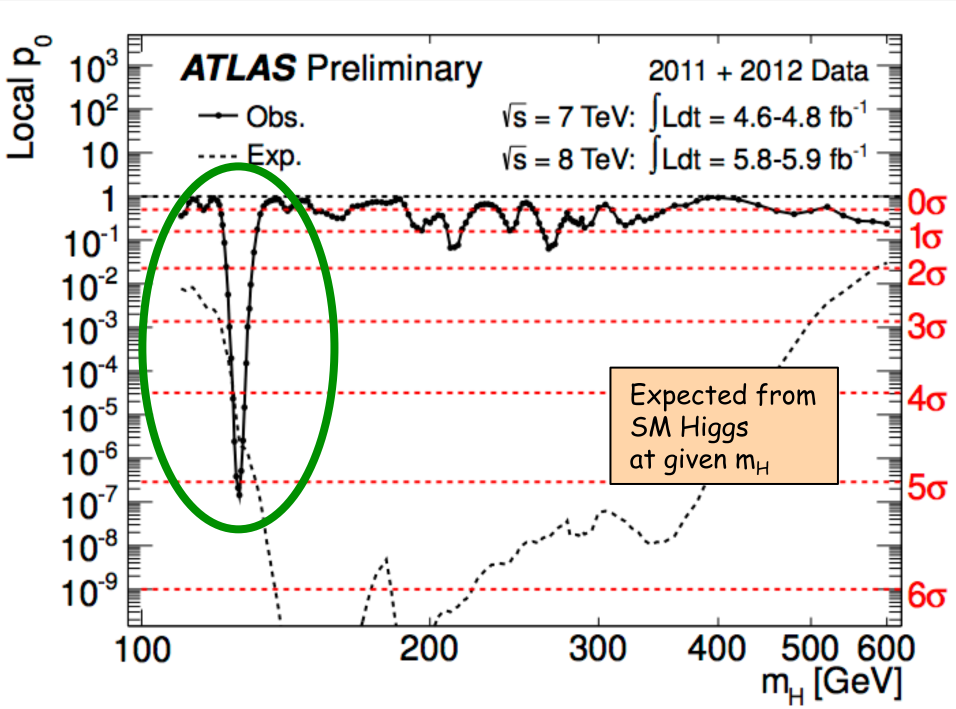


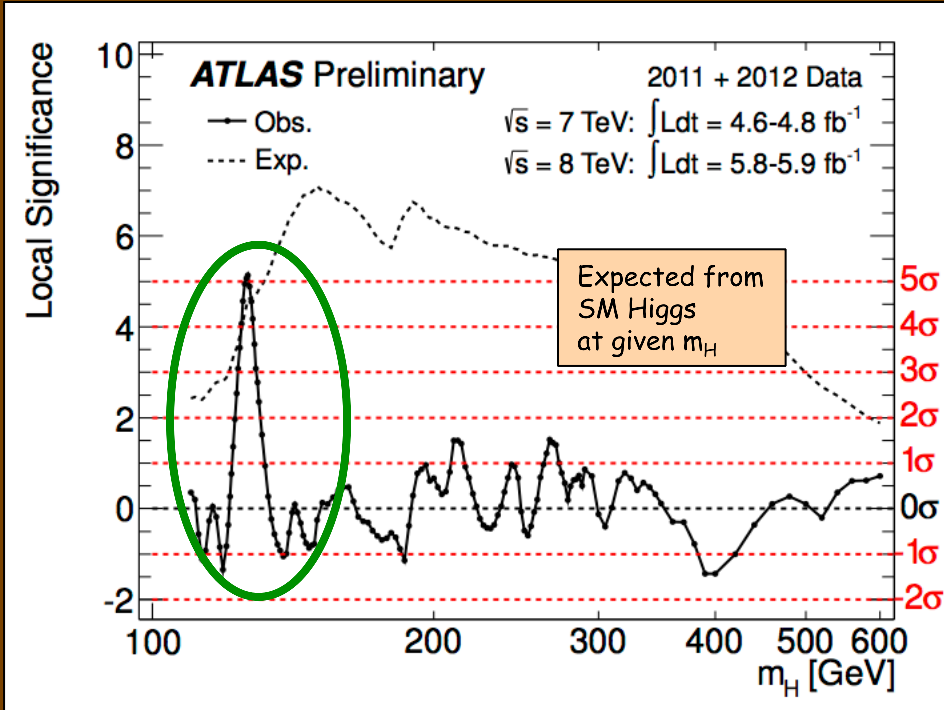
Excluded at 95% CL	110-122.6 129.7-558 GeV
Excluded at 99% CL	111.7-121.8 GeV 130.7-523 GeV

Expected at 95% CL if no signal

110-582 GeV

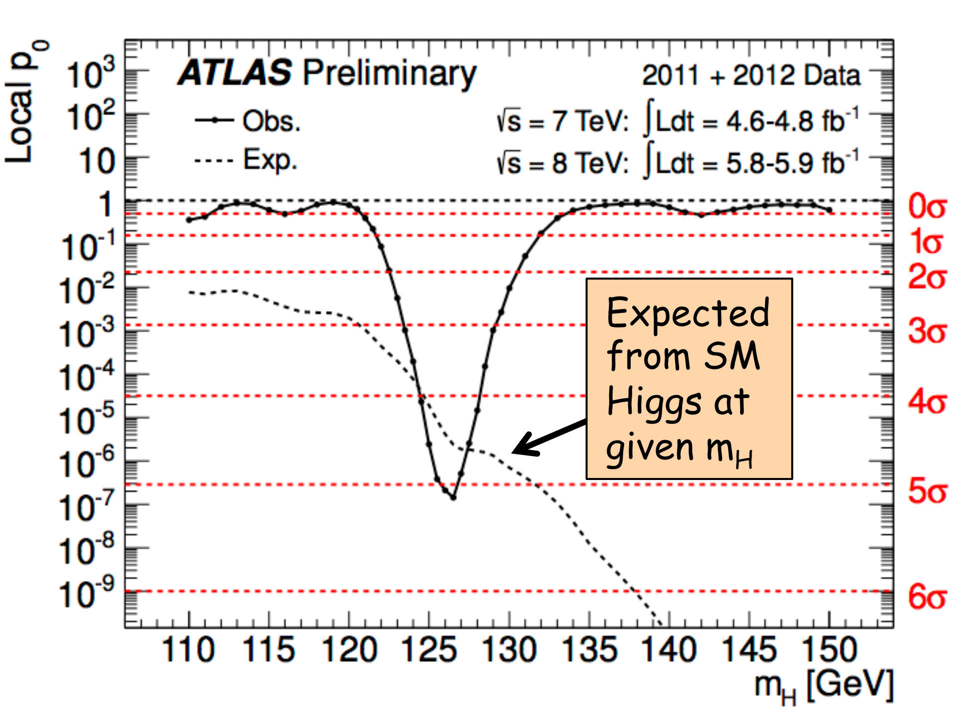
Combined results: consistency of the data with the background-only expectation and significance of the excess

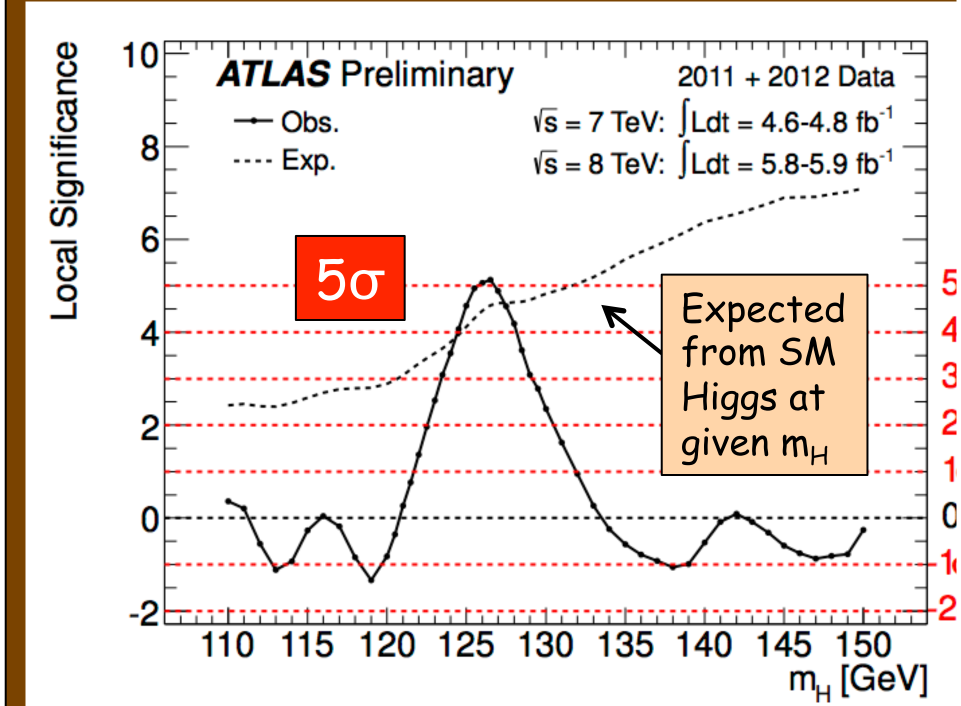




Excellent consistency (better than 2σ !) of the data with the background-only hypothesis over full mass spectrum except in one region

Combined results: the excess

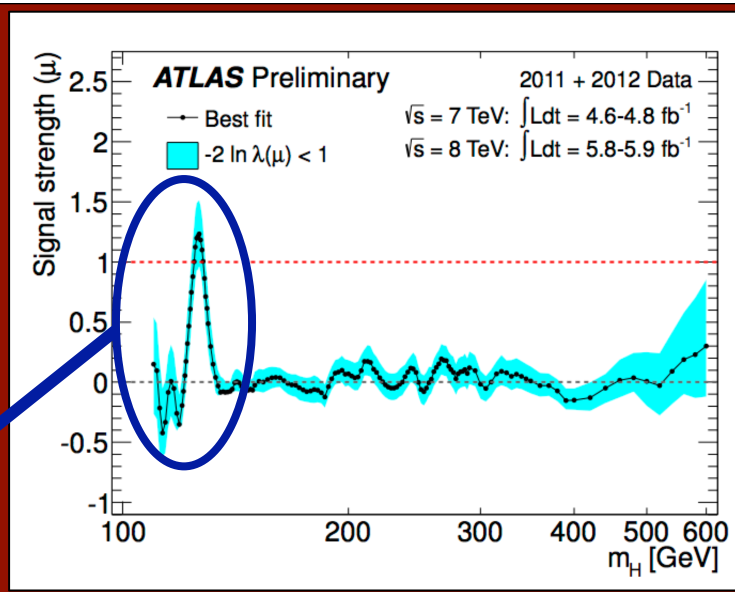




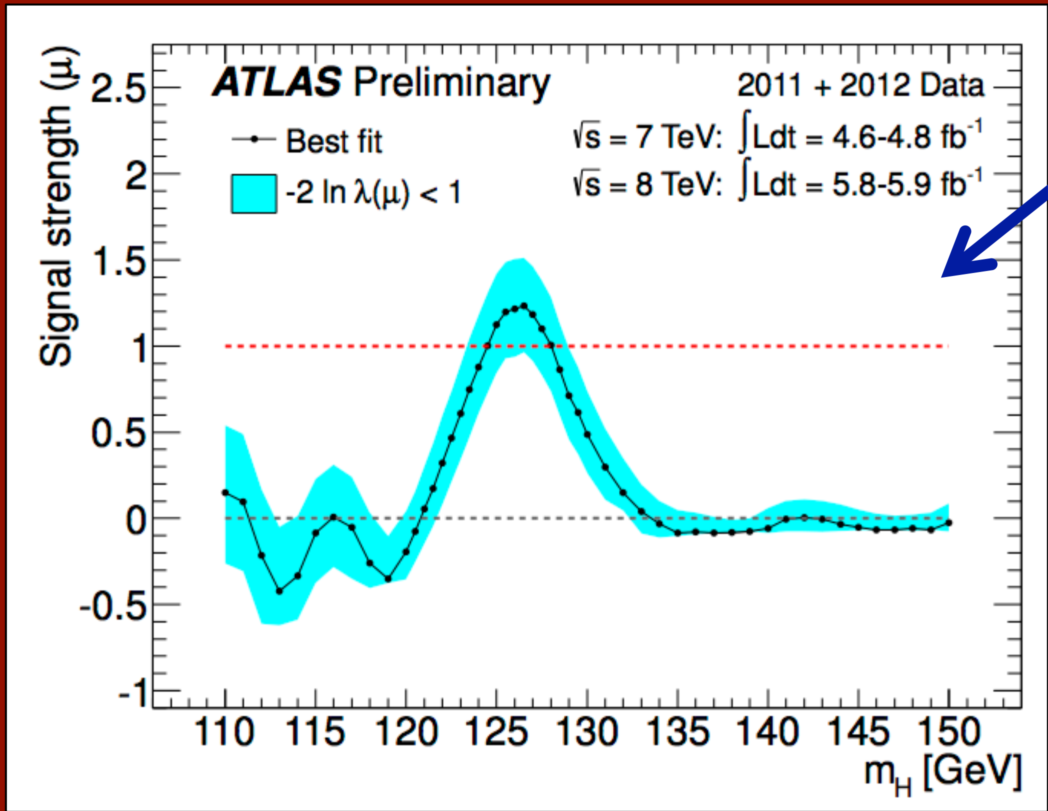
Maximum excess observed at	m_H = 126.5 GeV
Local significance (including energy-scale systematics)	5.0 σ
Probability of background up-fluctuation	3 x 10^{-7}
Expected from SM Higgs m_H=126.5	4.6 σ

Global significance: 4.1-4.3 σ (for LEE over 110-600 or 110-150 GeV)

Combined results: fitted signal strength



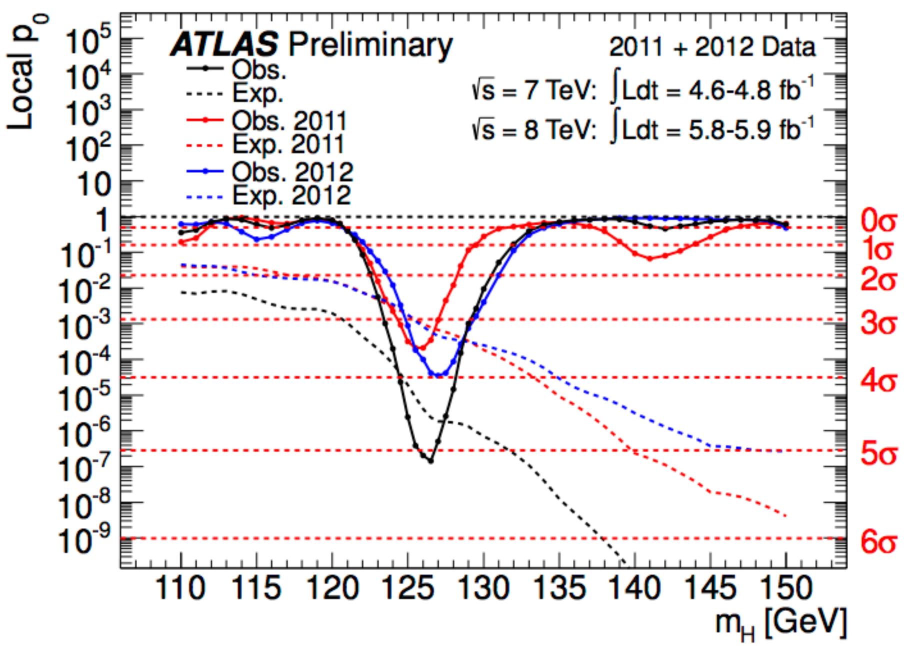
Normalized to SM Higgs expectation at given m_H (μ)



Best-fit value at 126.5 GeV:
$\mu = 1.2 \pm 0.3$

Good agreement with the expectation for a SM Higgs within the present statistical uncertainty

Combined results: sharing of the excess between years …

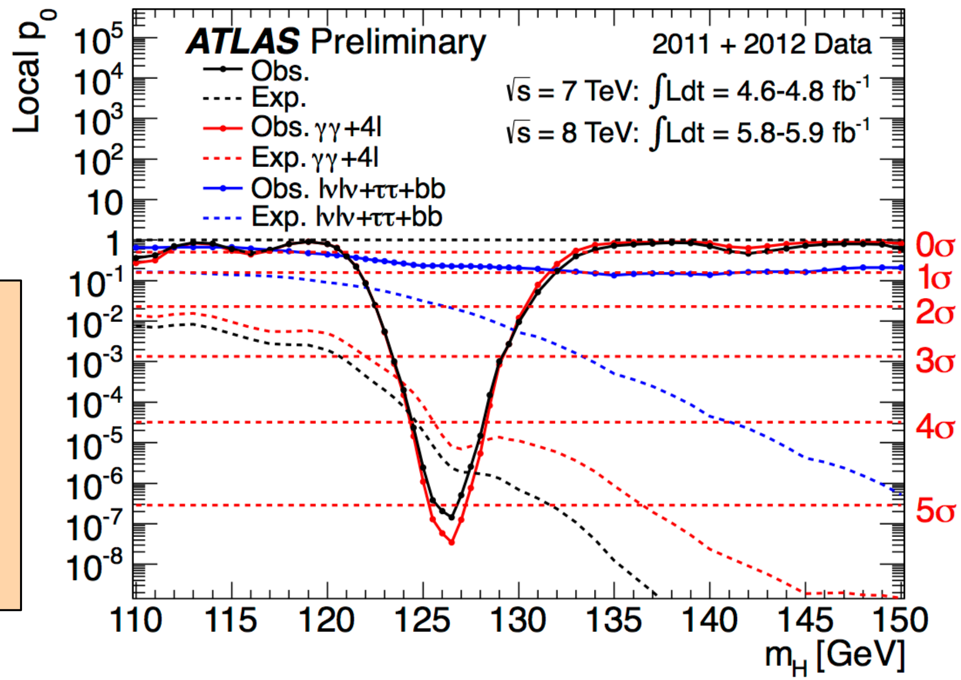


Similar expected significances in both years (more luminosity and larger cross-section in 2012, but only two channels included)

	Max deviation at m_H	Observed (exp.) significance
2011 data	126 GeV	3.5 (3.1) σ
2012 data	127 GeV	4.0 (3.3) σ

… and over channels

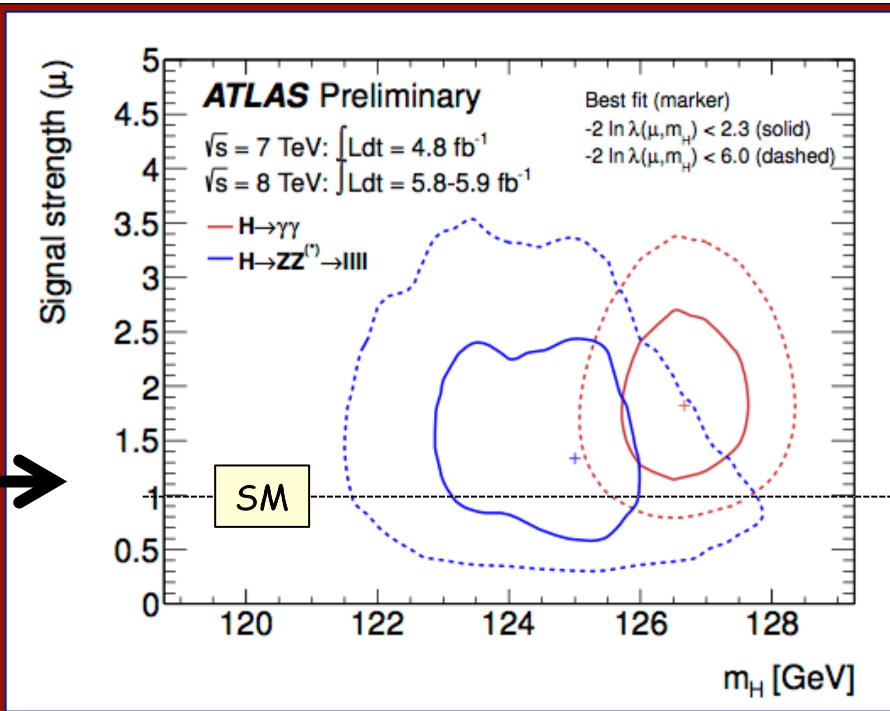
- Sensitivity (expected and observed) driven by "high-resolution" channels (γγ, 4l).
- "Low-resolution" channels (lνlν, bb, ττ) crucial to understand the nature of the "signal", measure its properties, and assess consistency of the overall picture

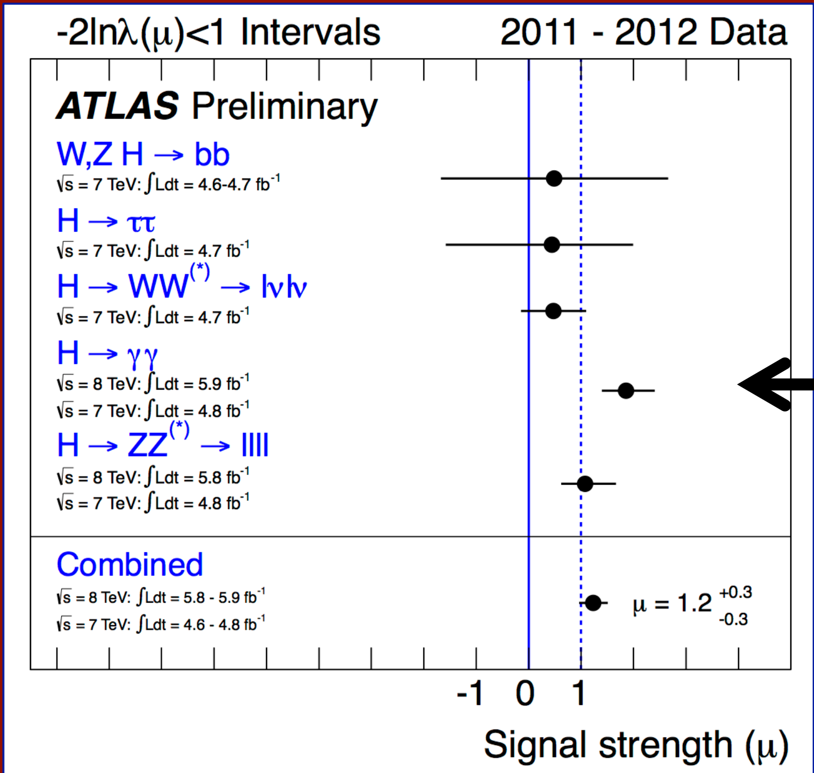


Combined results: consistency of the global picture

Are the 4l and γγ observations consistent ?

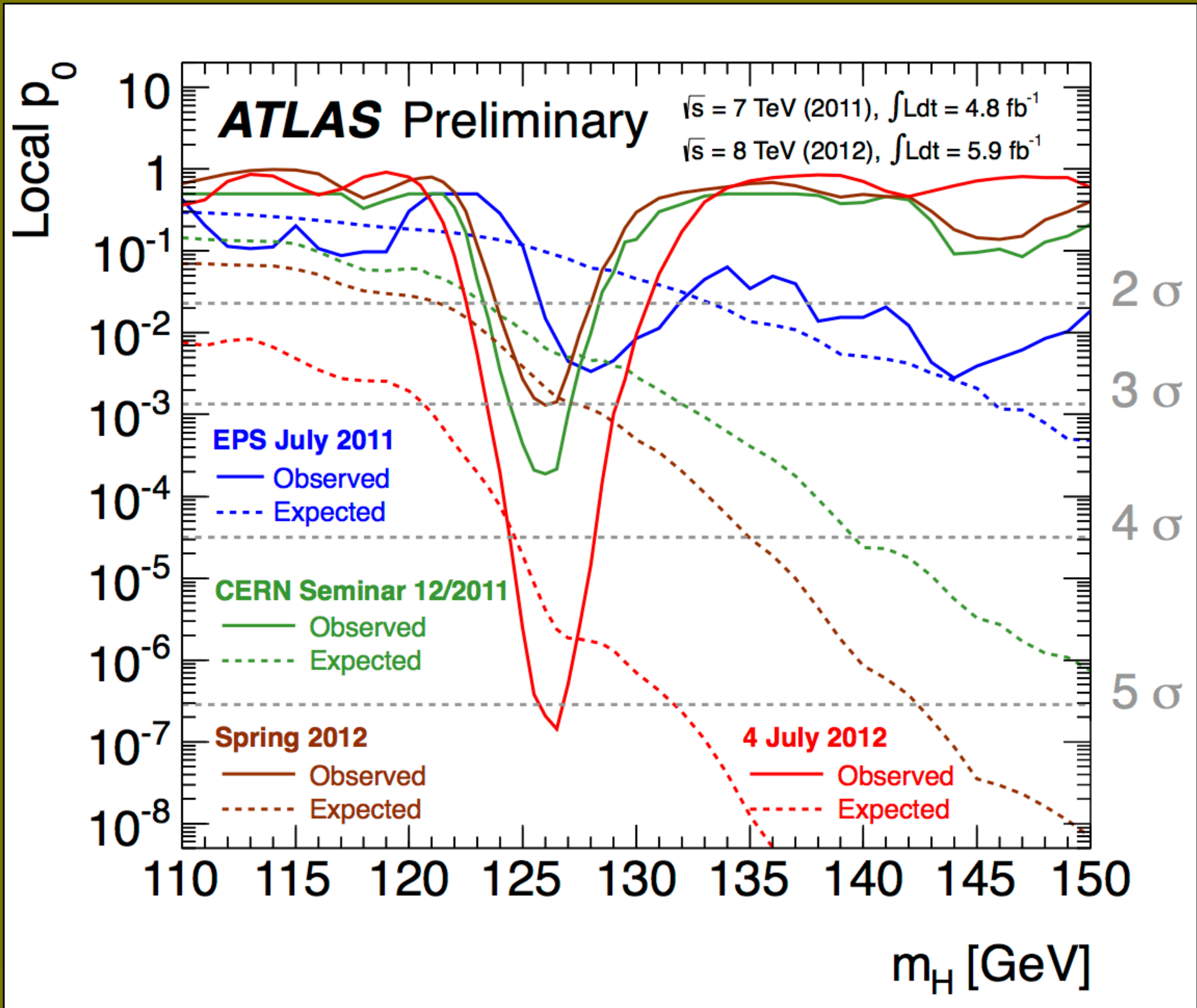
From 2-dim likelihood fit to signal mass and strength →curves show approximate 68% (full) and 95% (dashed) CL contours





Best-fit signal strengths, normalized to the SM expectations, for all studied channels, at m_H = 126.5 GeV,

Evolution of the excess with time



Energy-scale systematics not included

The next steps …

ATLAS plans to submit a paper based on the data presented today at the end of July, at the same time as CMS and to the same journal

$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ channel: plan is to include results in the July paper
$H \rightarrow \tau\tau$, $W/ZH \rightarrow W/Z\ bb$: first results with 2012 data expected later in the Summer

MORE DATA will be essential to:
- ❑ Establish the observation in more channels, look at more exclusive topologies
- ❑ start to understand the nature and properties of the new particle

This is just the BEGINNING !

We are entering the era of "Higgs" measurements
First question: is the observed excess due to the production of a SM Higgs boson ?

Note:
- ❑ we have only recorded ~ 1/3 of the data expected in 2012
- ❑ the LHC and experiments have already accomplished a lot and much faster than expected

Conclusions

We have presented preliminary results on searches for a SM Higgs boson using the full data sample recorded so far for H→ γγ and H→ 4l (√s=7, 8 TeV, ~10.7 fb^{-1}) and the 2011 data (√s=7 TeV, ~ 4.9 fb^{-1}) for the other channels

Impressive accomplishment of the experiment in all its components: first results with full 2012 dataset were available less than one week from "end of data-taking", with a fraction of good-quality data used for physics of ~ 90% of the delivered luminosity

We have looked for a SM Higgs over the mass region 110-600 GeV in 12 channels

We have excluded at 99% CL the full region up to 523 GeV except 121.8< m_H<130.7 GeV

We observe an excess of events at m_H ~ 126.5 GeV with local significance **5.0 σ**

- The excess is driven by the two high mass resolution channels: H→ γγ (4.5 σ) and H→ ZZ* → 4l (3.4 σ)
- Expected significance from a SM Higgs: 4.6 σ
- Fitted signal strength: 1.2 ± 0.3 of the SM expectation

If it is the SM Higgs, it's very kind of it to be at that mass → accessible at LHC in γγ, ZZ*→ 4l, WW*→ lνlν, bb, ττ

ATLAS today's main result (preliminary):

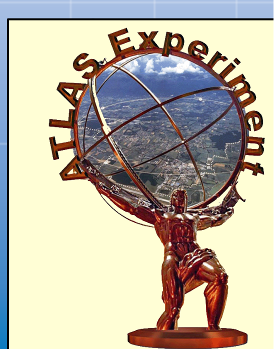
5.0 σ excess at m_H~126.5

These accomplishments are the results of more than 20 years of talented work and extreme dedication by the ATLAS Collaboration, with the continuous support of the Funding Agencies

More in general, they are the results of the ingenuity, vision and painstaking work of our community (accelerator, instrumentation, computing, physics)

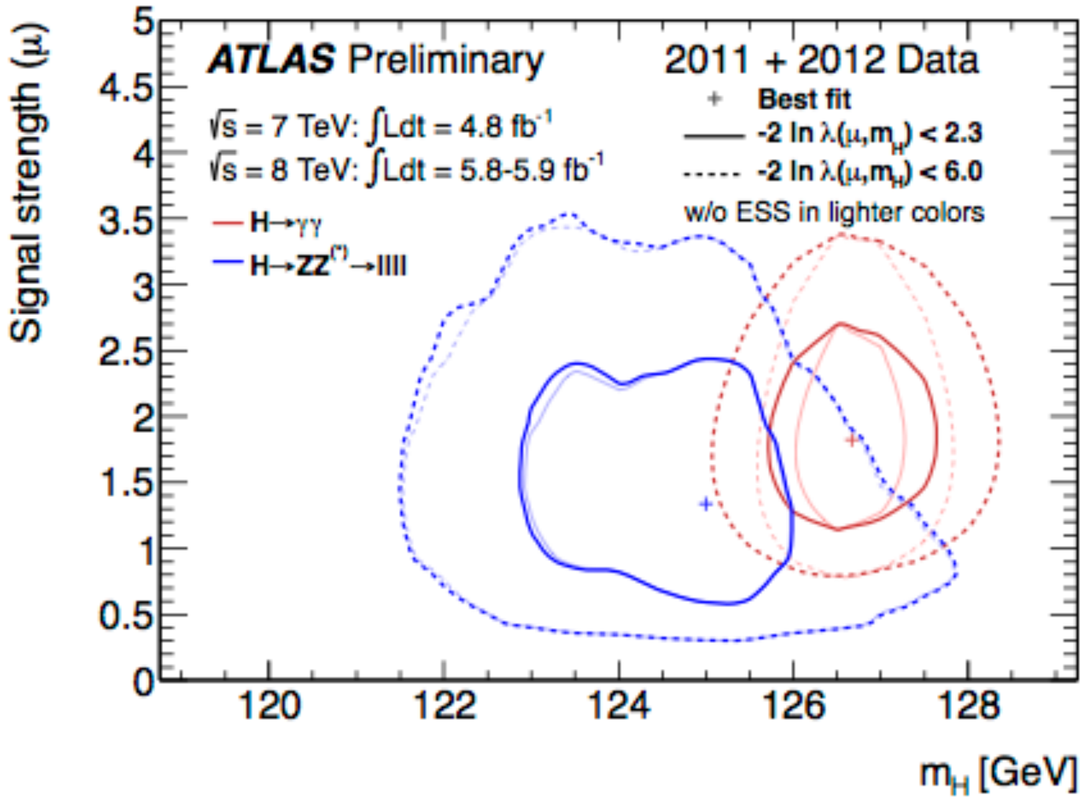
Argentina
Armenia
Australia
Austria
Azerbaijan
Belarus
Brazil
Canada
Chile
China
Colombia
Czech Republic
Denmark
France
Georgia
Germany
Greece
Israel
Italy
Japan
Morocco
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
South Africa
Spain
Sweden
Switzerland
Taiwan
Turkey
UK
USA
CERN
JINR

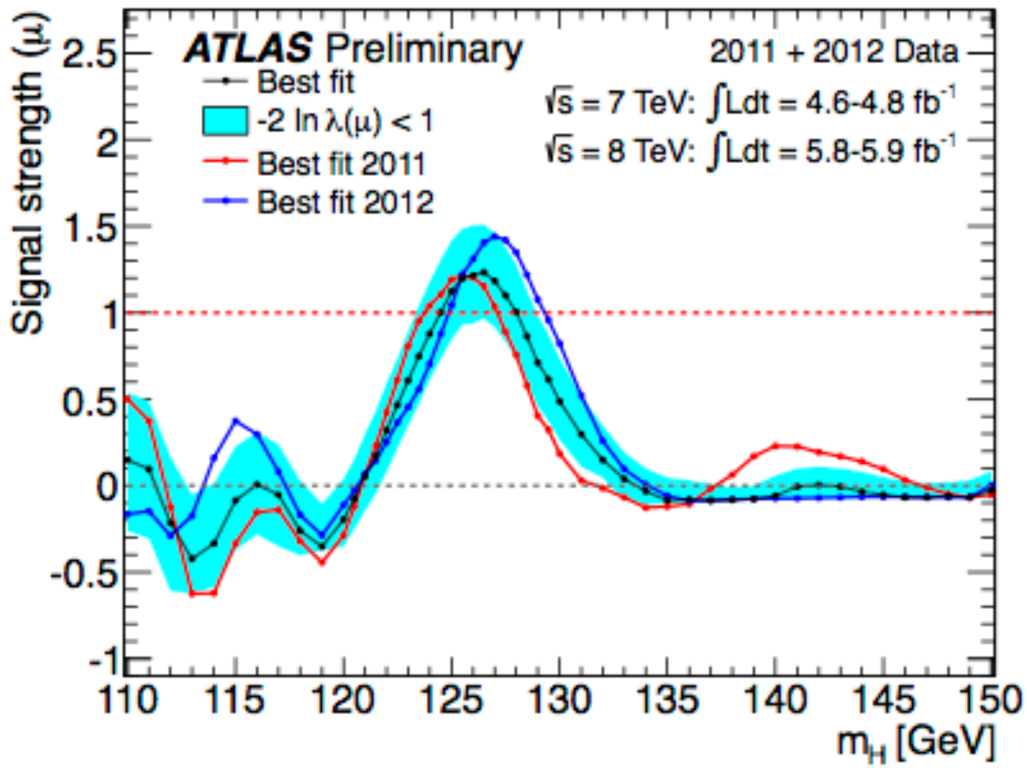
ATLAS Collaboration

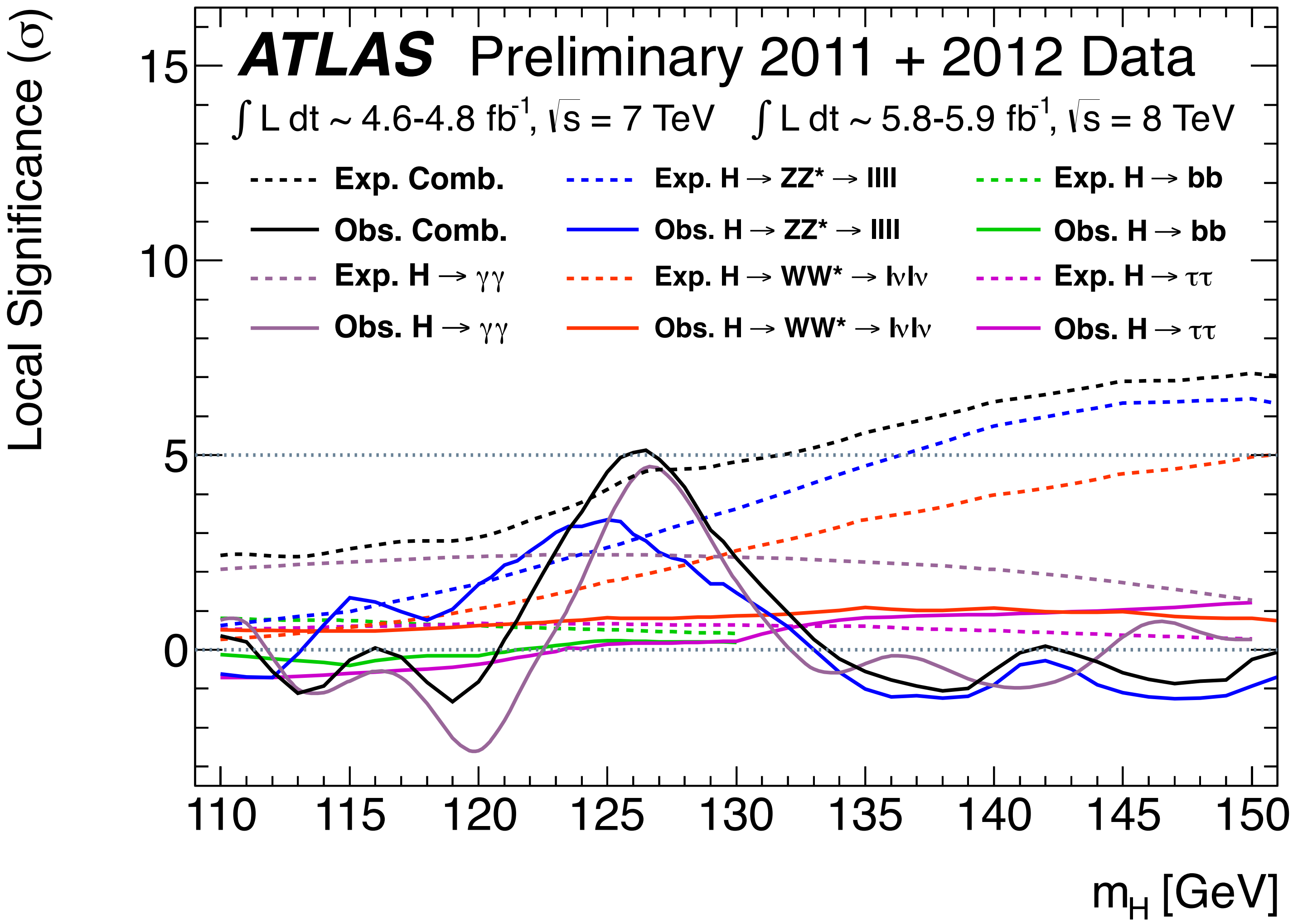


July 2010

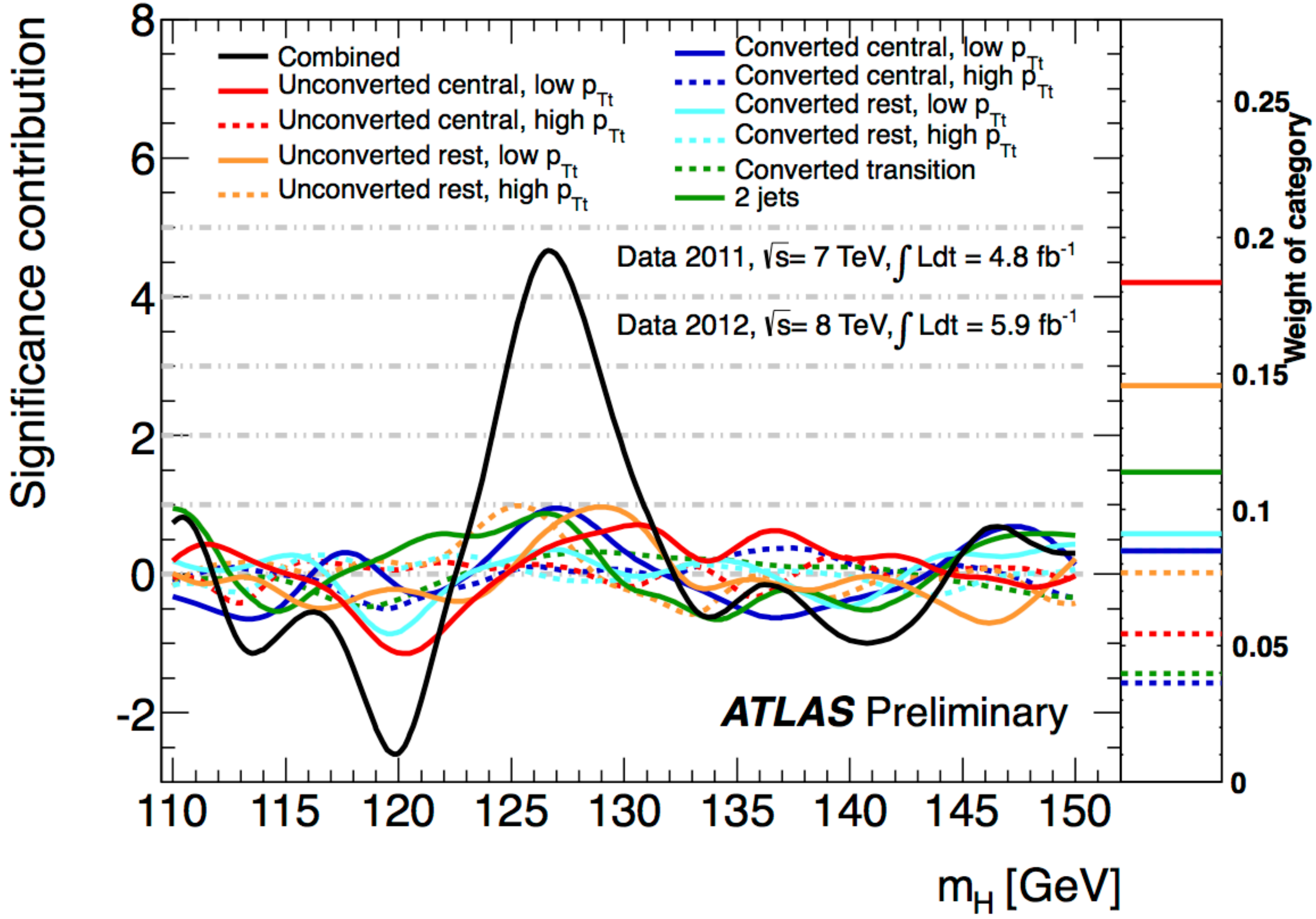
SPARES


ATLAS Preliminary
2011 + 2012 Data
√s = 7 TeV: ∫Ldt = 4.8 fb-1
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb-1
Best fit
-2 ln λ(μ,mH) < 2.3
-2 ln λ(μ,mH) < 6.0
w/o ESS in lighter colors
H→γγ
H→ZZ(*)→llll
Signal strength (μ)
mH [GeV]


ATLAS Preliminary
2011 + 2012 Data
Best fit
-2 ln λ(μ) < 1
Best fit 2011
Best fit 2012
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb⁻¹
Signal strength (μ)
m_H [GeV]



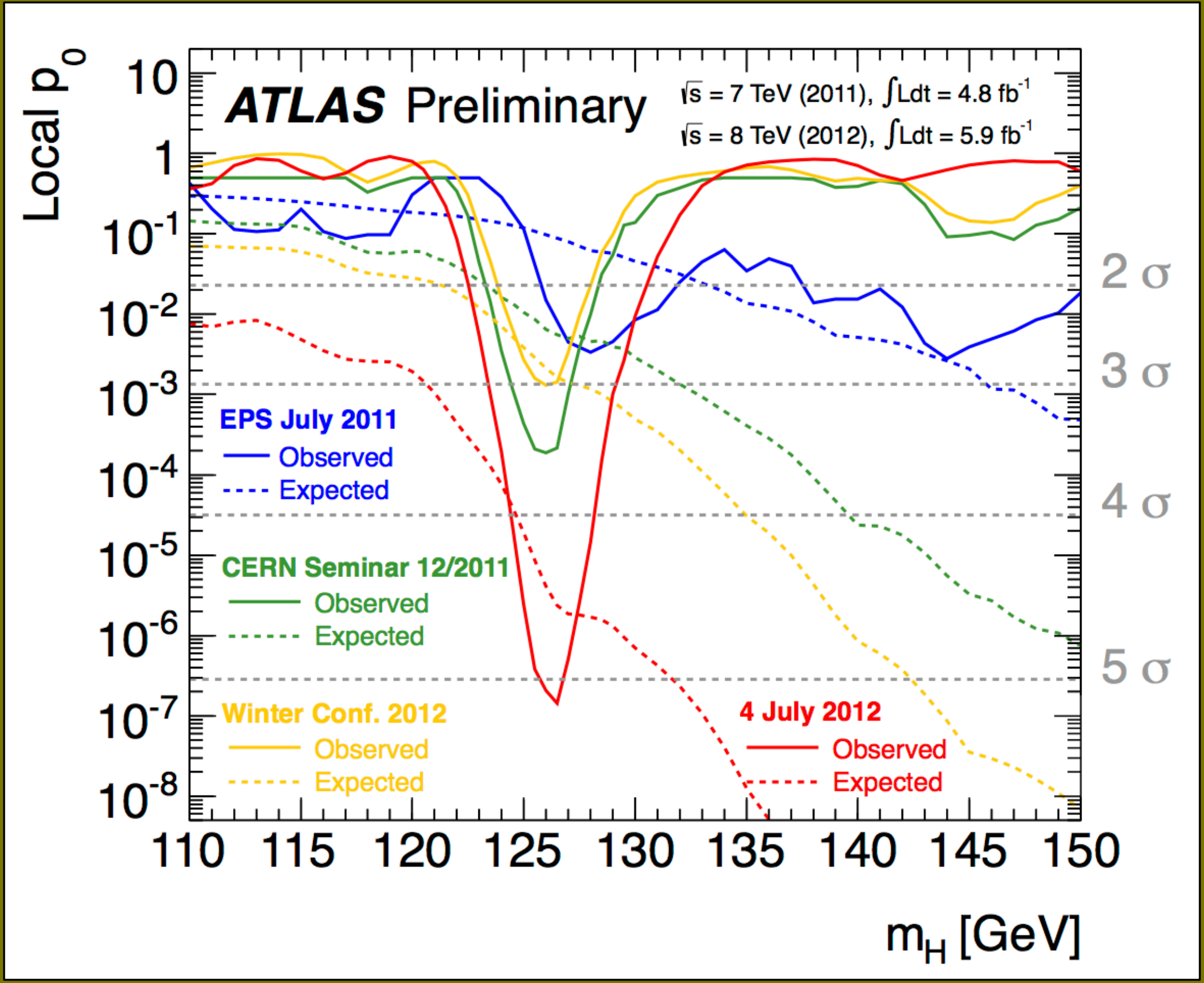
ATLAS Preliminary 2011 + 2012 Data
∫L dt ~ 4.6-4.8 fb^{-1}, √s = 7 TeV ∫L dt ~ 5.8-5.9 fb^{-1}, √s = 8 TeV
Exp. Comb.
Obs. Comb.
Exp. H → γγ
Obs. H → γγ
Exp. H → ZZ* → llll
Obs. H → ZZ* → llll
Exp. H → WW* → lνlν
Obs. H → WW* → lνlν
Exp. H → bb
Obs. H → bb
Exp. H → ττ
Obs. H → ττ
Local Significance (σ)
m_H [GeV]
15
10
5
0
110
115
120
125
130
135
140
145
150

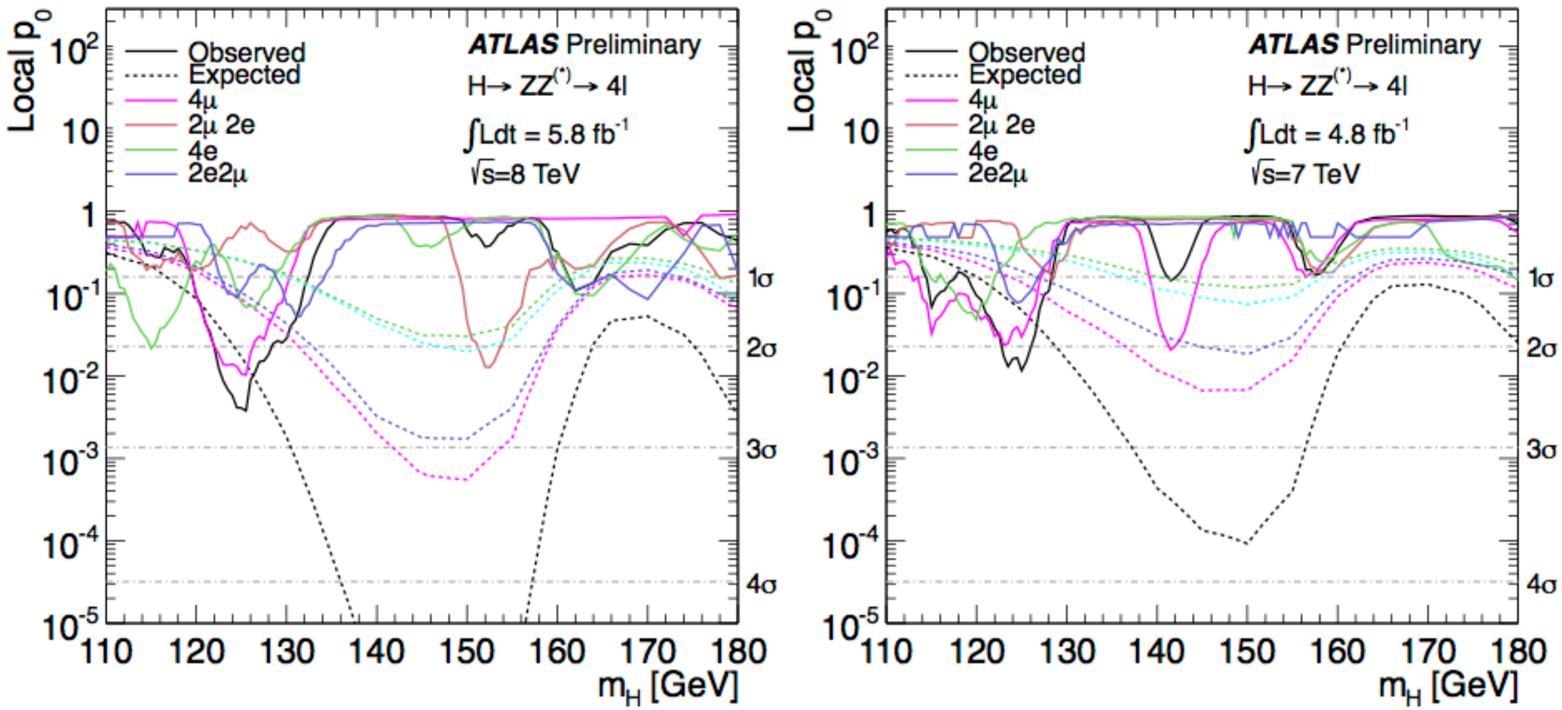


-2.5 σ downward fluctuation at $m_{\gamma\gamma}$~ 119 GeV

- probability 15% (~1 σ)
- does not affect significance of fitted signal
- unlike "signal" excess does not appear in most significant categories

Evolution of the excess with time





Local p0
Observed
Expected
4μ
2μ 2e
4e
2e2μ
ATLAS Preliminary
H→ ZZ(*)→ 4l
∫Ldt = 5.8 fb-1
√s=8 TeV
1σ
2σ
3σ
4σ
mH [GeV]
Local p0
Observed
Expected
4μ
2μ 2e
4e
2e2μ
ATLAS Preliminary
H→ ZZ(*)→ 4l
∫Ldt = 4.8 fb-1
√s=7 TeV
1σ
2σ
3σ
4σ
mH [GeV]

Table 8: The expected signal and background events together with the number of observed events, in a window of ±5 GeV around the hypothesized Higgs boson mass for the 5.8 fb^{-1}at $\sqrt{s}$ = 8 TeV and the 4.8 fb^{-1}at $\sqrt{s}$ = 7 TeV datasets as well as for their combination.

	$\sqrt{s}$ = 8 TeV			$\sqrt{s}$ = 7 TeV			$\sqrt{s}$ = 8 TeV and $\sqrt{s}$ = 7 TeV		
				4μ					
m_H	exp. signal	exp. bkg	obs	exp. signal	exp. bkg	obs	exp. signal	exp. bkg	obs
120	0.68±0.09	0.61± 0.04	2	0.48±0.06	0.46± 0.03	2	1.16± 0.15	1.07± 0.07	4
125	1.25±0.17	0.74± 0.05	4	0.84±0.11	0.56± 0.03	2	2.09± 0.28	1.30± 0.08	6
130	1.88±0.25	0.81± 0.05	2	1.38±0.18	0.63± 0.03	1	3.26± 0.43	1.44± 0.08	3
				$2e2\mu$ and $2\mu2e$					
m_H	exp. signal	exp. bkg	obs	exp. signal	exp. bkg	obs	exp. signal	exp. bkg	obs
120	0.81±0.12	1.15± 0.17	2	0.48±0.07	0.78± 0.10	1	1.29± 0.19	1.93± 0.18	3
125	1.45±0.20	1.30± 0.19	3	0.83±0.11	0.89± 0.11	2	2.28± 0.31	2.19± 0.21	5
130	2.24±0.32	1.34± 0.20	2	1.27±0.17	0.94± 0.11	1	3.51± 0.49	2.28± 0.21	3
				$4e$					
m_H	exp. signal	exp. bkg	obs	exp. signal	exp. bkg	obs	exp. signal	exp. bkg	obs
120	0.35±0.05	0.79±0.15	1	0.15±0.02	0.60±0.12	1	0.50±0.07	1.39±0.19	2
125	0.61±0.09	0.90±0.17	2	0.28±0.04	0.69±0.13	0	0.89±0.13	1.59±0.22	2
130	0.91±0.15	0.96±0.17	1	0.42±0.06	0.74±0.14	0	1.33±0.21	1.70±0.22	1

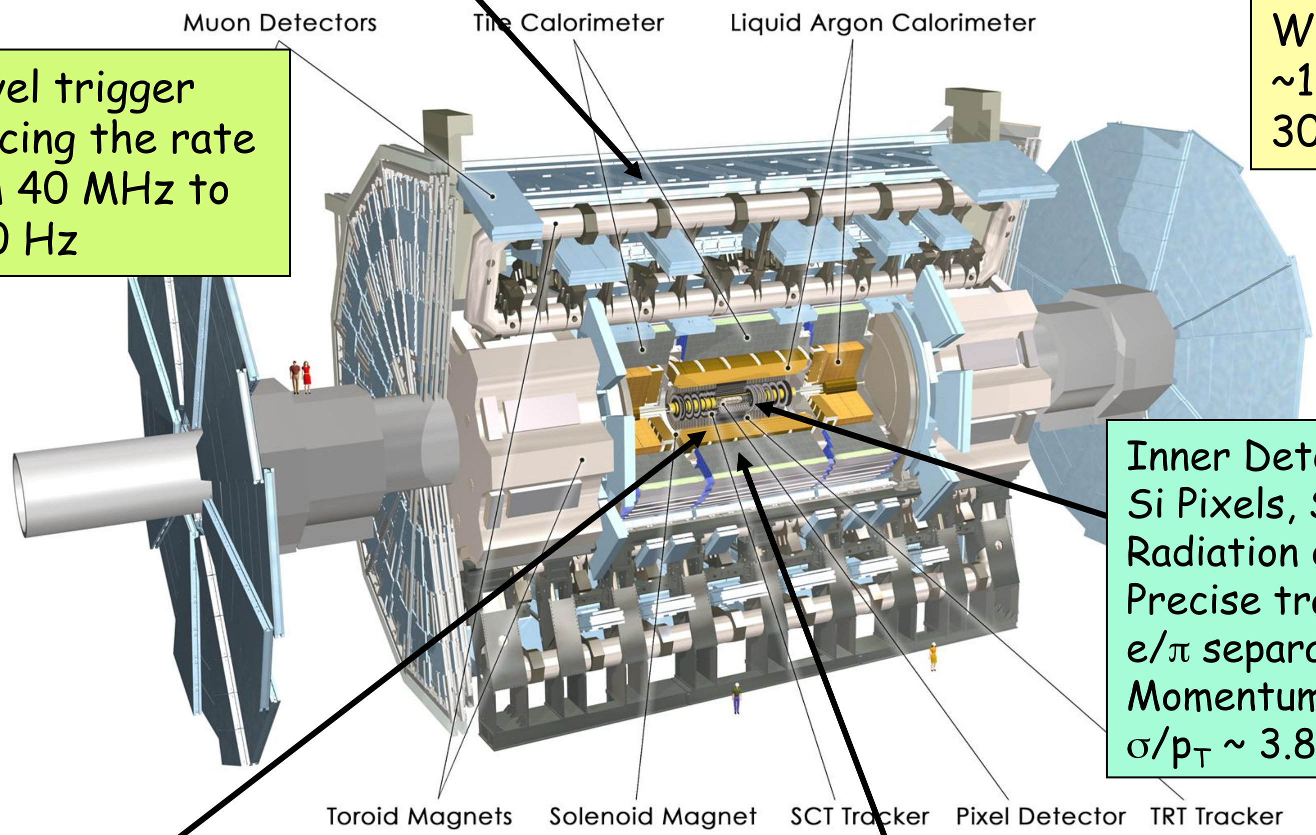
Main systematic uncertainties

Higgs cross-section : ~ 20%
Electron efficiency : ~8% (4e)
ZZ* background : ~ 15%
Reducible backgrounds : ~ 40%

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with momentum resolution < 10% up to E_μ ~ 1 TeV

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
3000 km of cables

3-level trigger reducing the rate from 40 MHz to ~200 Hz



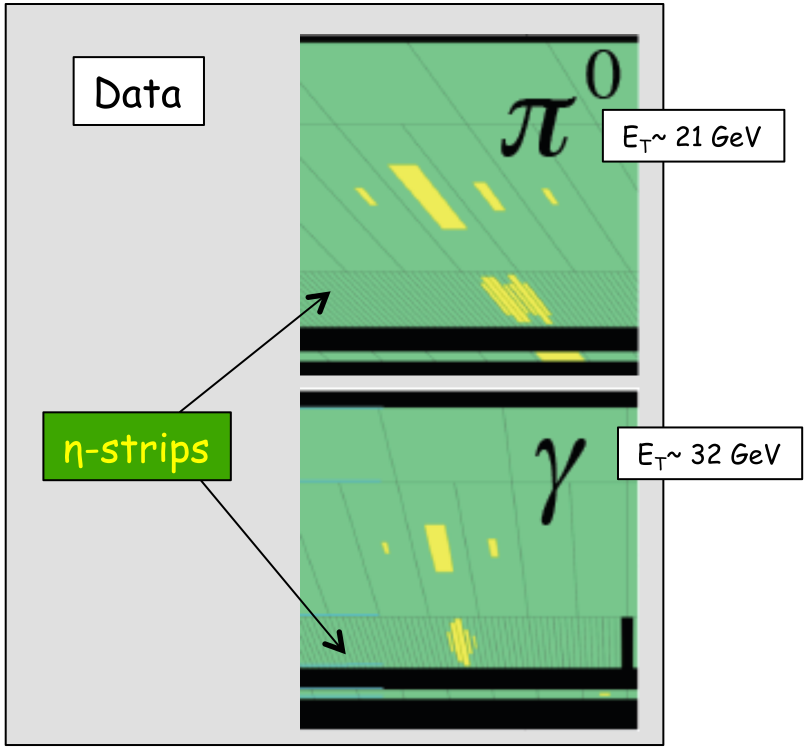
Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips, Transition Radiation detector (straws)
Precise tracking and vertexing, e/π separation
Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T(\mathrm{GeV}) \oplus 0.015$

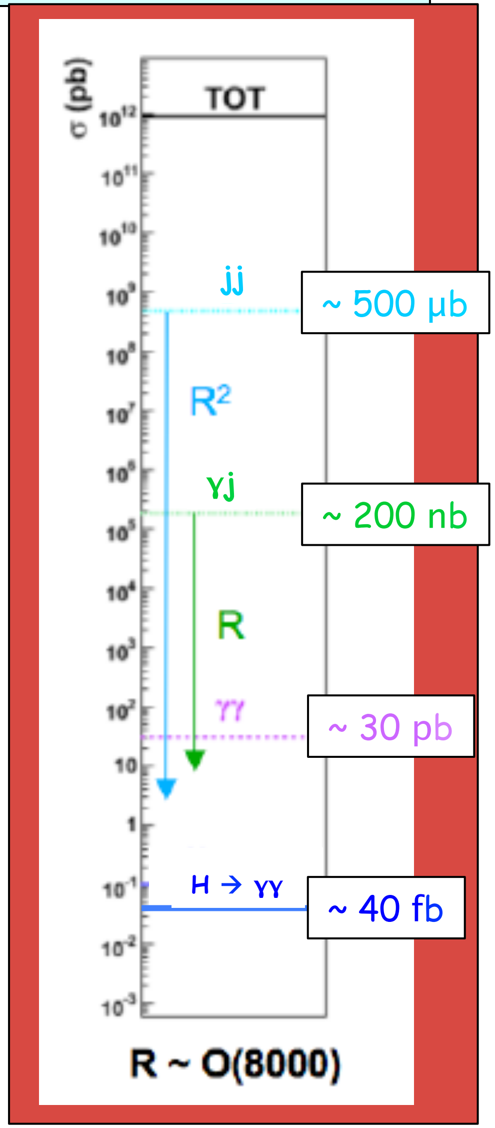
EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

HAD calorimetry ($|\eta|<5$): segmentation, hermeticity
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

Potentially huge background from γj and jj production with jets fragmenting into a single hard π^0 and the π^0 faking single photon

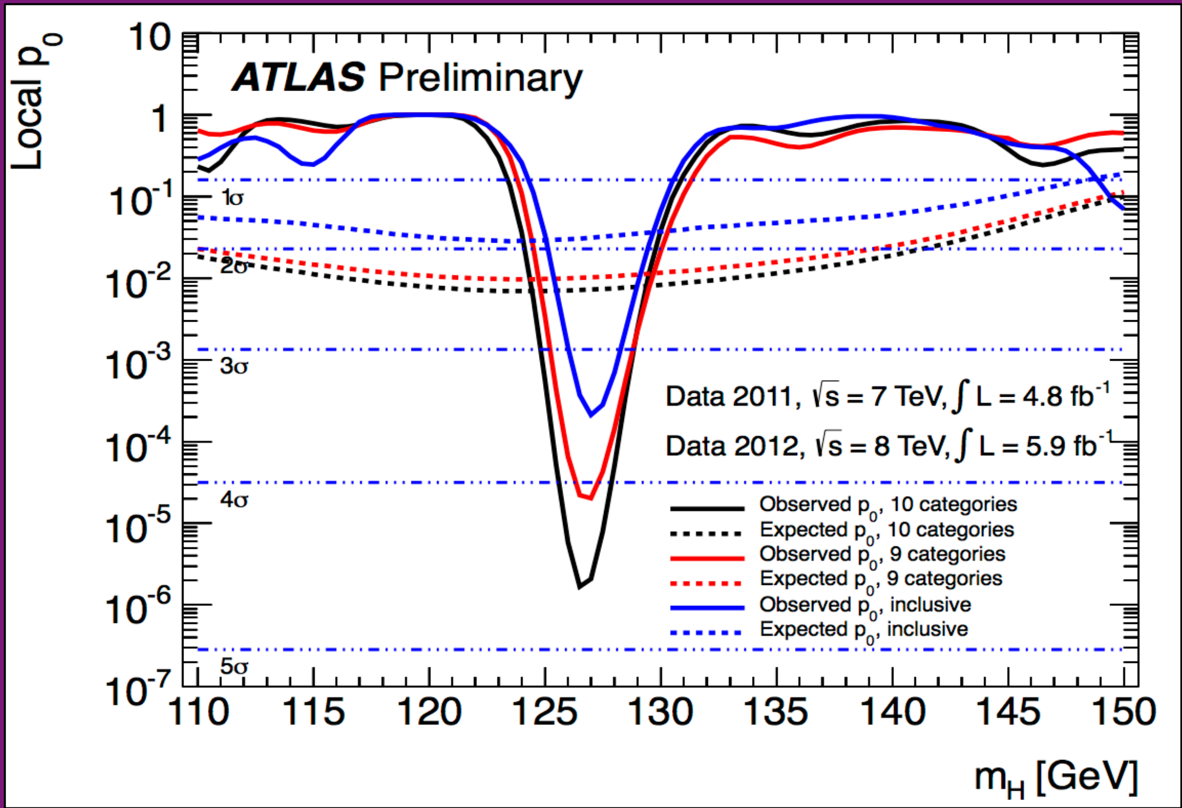
Determined choice of fine lateral segmentation (4mm η-strips) of the first compartment of ATLAS EM calorimeter





However: huge uncertainties on σ (γj, jj) !! → not obvious γj, jj could be suppressed well below irreducible γγ until we measured with data

Impact of categories on excess



Categories provide ~ 30% gain in sensitivity compared to inclusive analysis.
However, excess remains also with simpler inclusive analysis: ~ 3.5 σ

2jet/VBF category brings ~ 3% gain in expected sensitivity; observed gains in data are 10-15% (both years)
Caveat: 2jet category affected by largest systematics (~ 20% on signal yield)