ATLAS Higgs Searches

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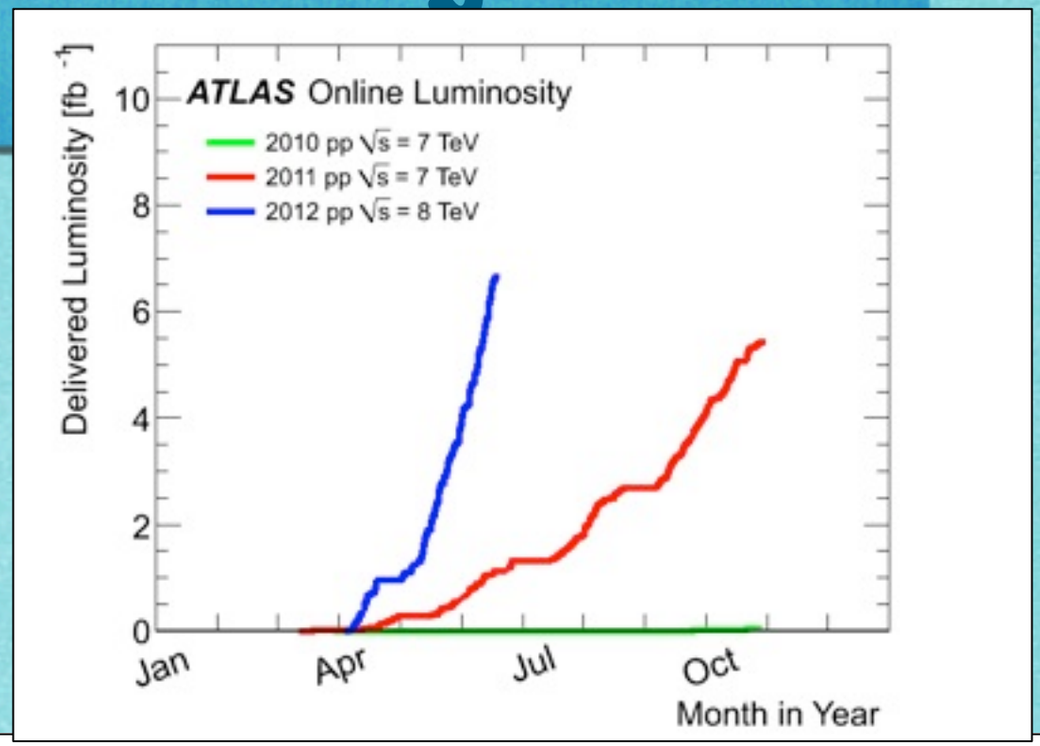
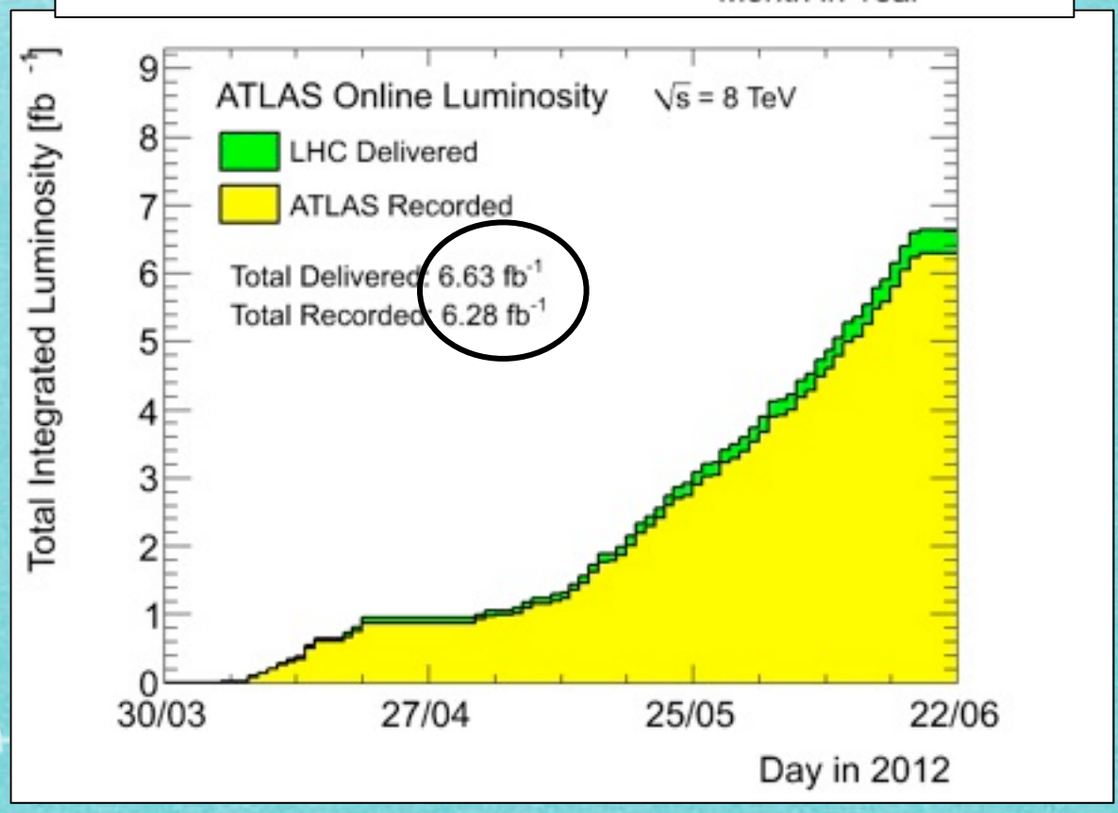
LHC Physics lecture, 12/07/2012

2012 Data Taking

- Increased √s to 8 TeV
- Inst. luminosity L ≃ 3-6 10^{33} $cm^{-2}s^{-1}$
- ≃ 6.3 fb^{-1} recorded (≃ 95% of delivered)
- ≃ 5.8 fb^{-1} with good detector performance (≃ 94% of efficiency)

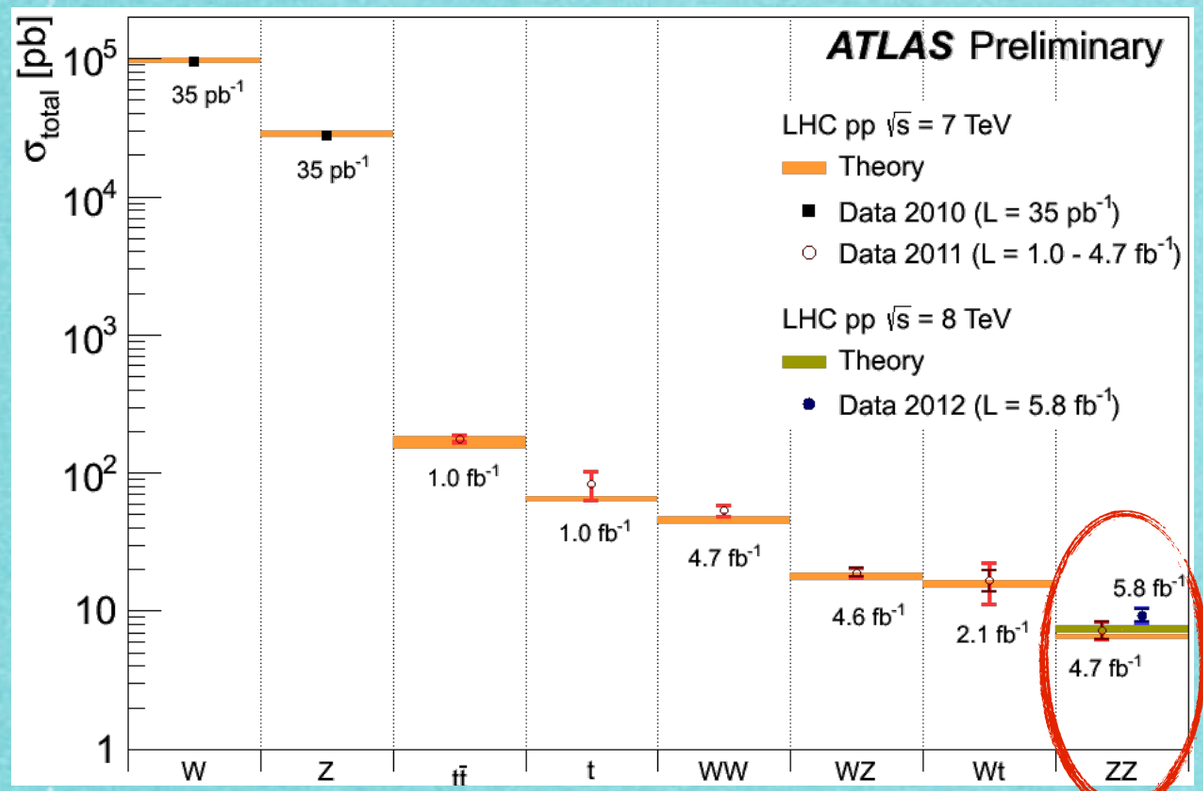




ATLAS p-p run: April-June 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.6	100	96.2	99.1	100	99.6	100	100	99.4	100
All good for physics: 93.6%										

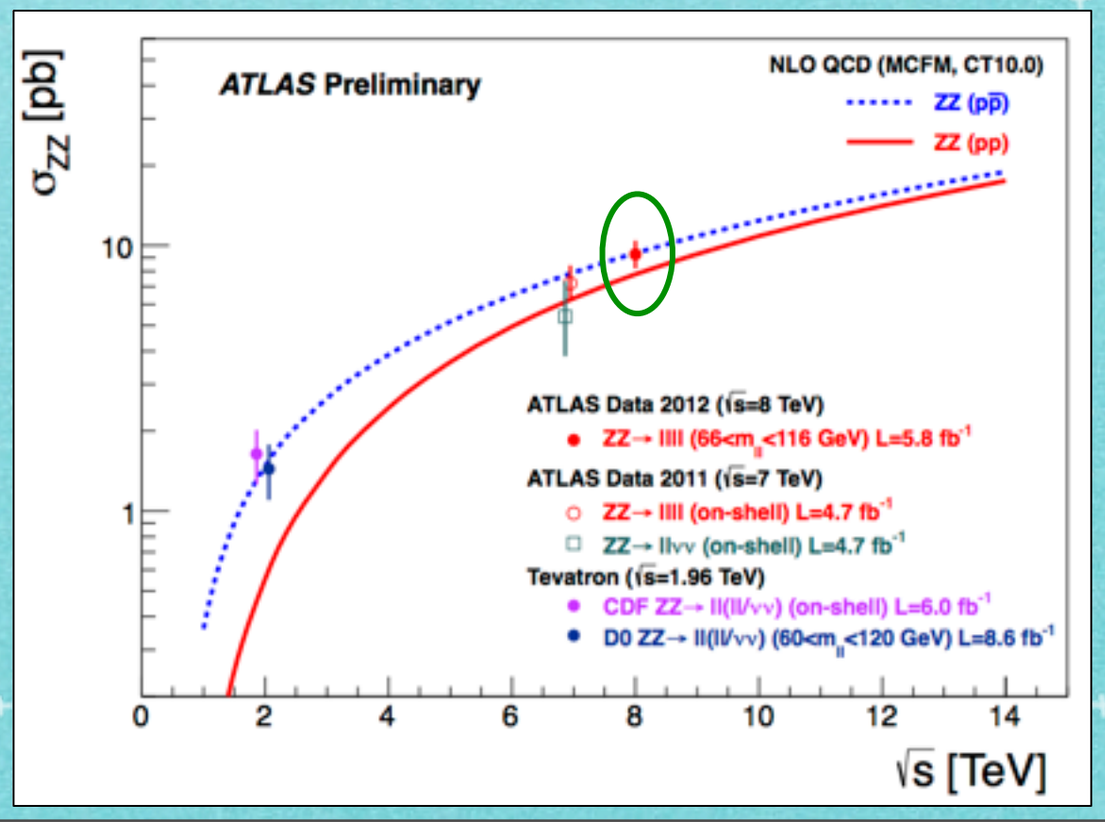
Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at √s=8 TeV between April 4th and June 18th (in %) – corresponding to 6.3 fb^{-1} of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

Standard Model Measurements



- SM measurements important for validation
- top and diboson processes studied and well measured
- experimental cross-section for many background processes (ZZ, ttbar) at 8 TeV

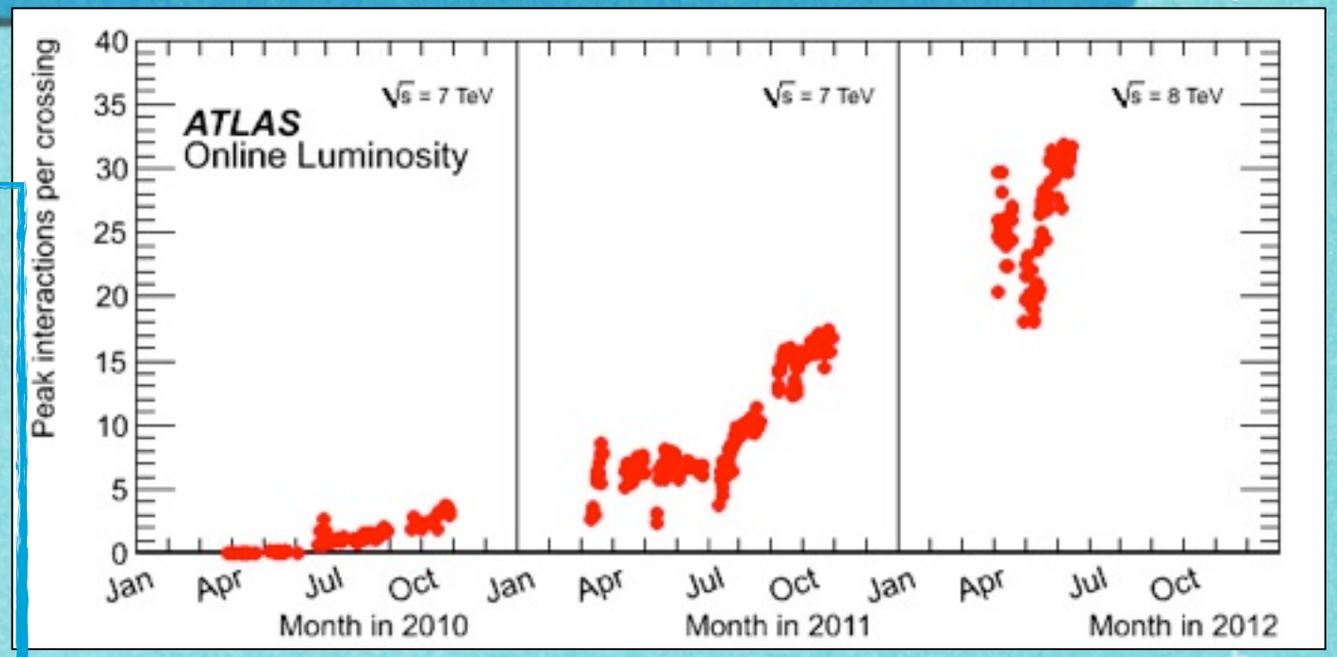
- Measured $\sigma(ZZ) = 9.3 \pm 1.2$ pb
- SM (NLO) $\sigma(ZZ) = 7.4 \pm 0.4$ pb

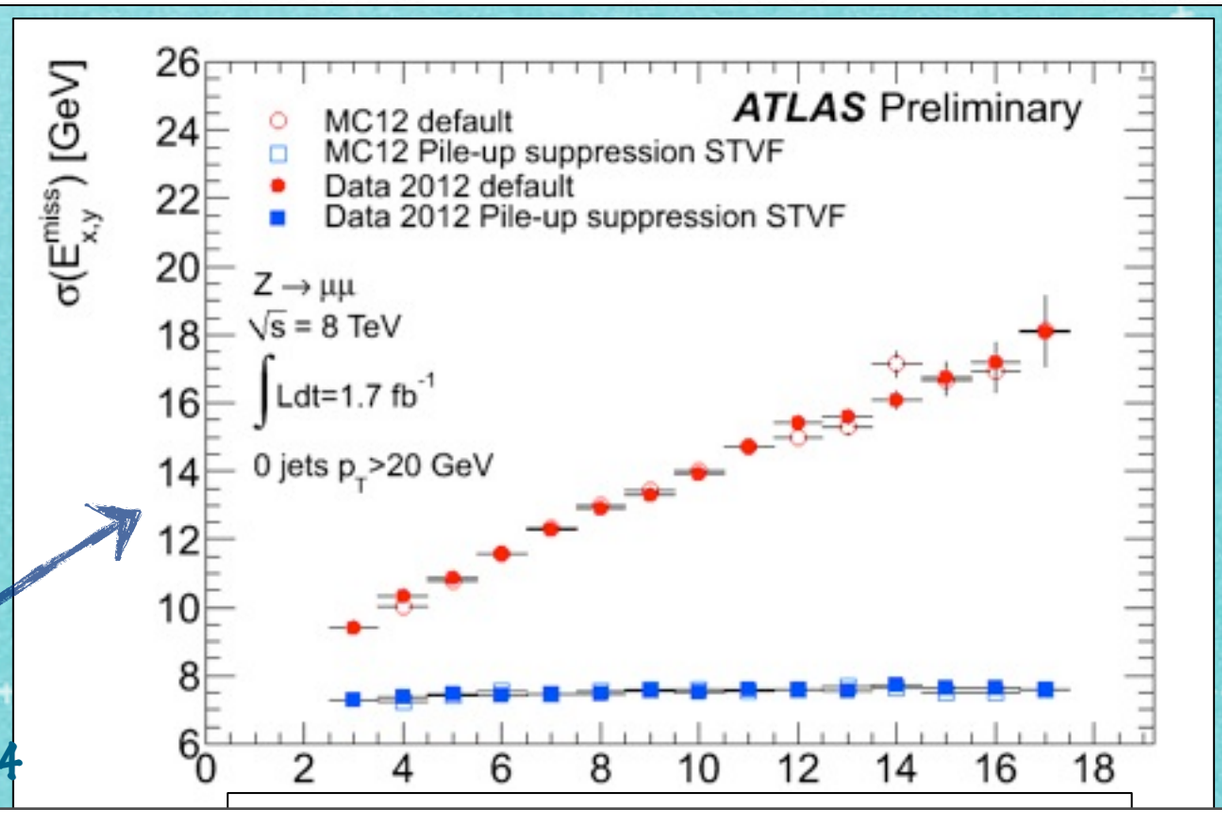


A difficult environment

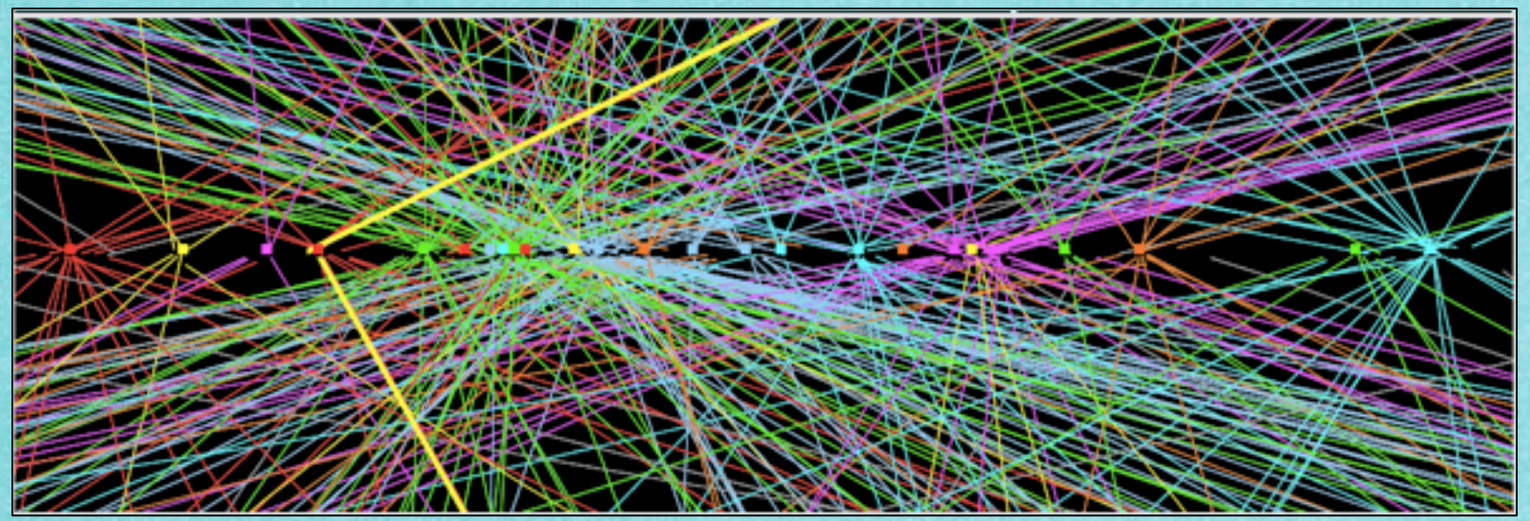
- Peak level of pile-up ~ 30 int/cross
- Trigger and reconstruction algorithms optimized (MET, soft jet, ecc.)
- Pile-up suppression using track informations
- Reconstruction and identification ~ indipendent from pile-up
- Primary vertices reconstructed ≃ 60% of int/cross
- Stable resolutions

missing E_T resolution

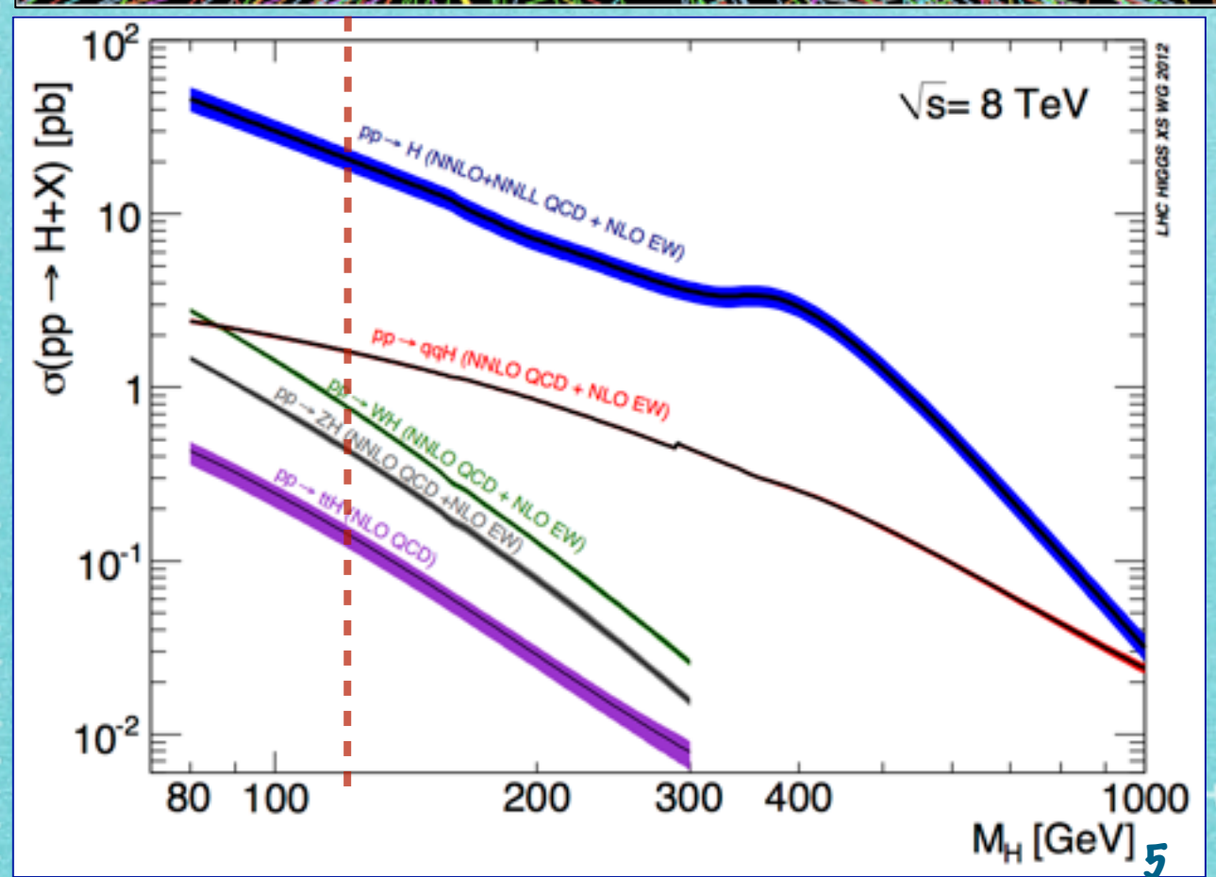




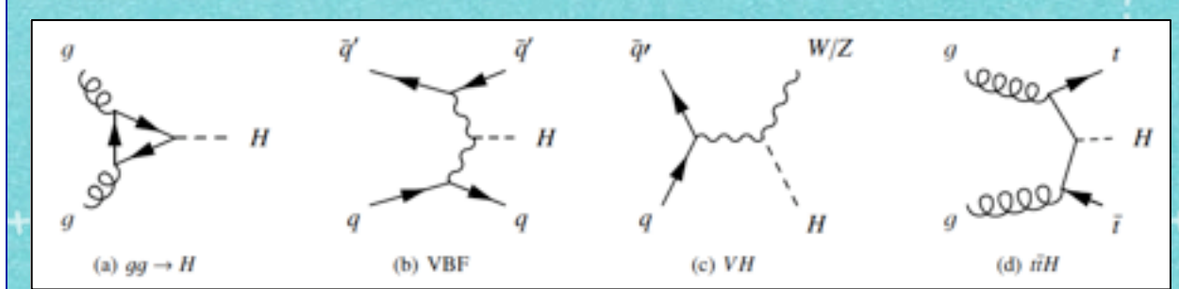
Higgs hunting



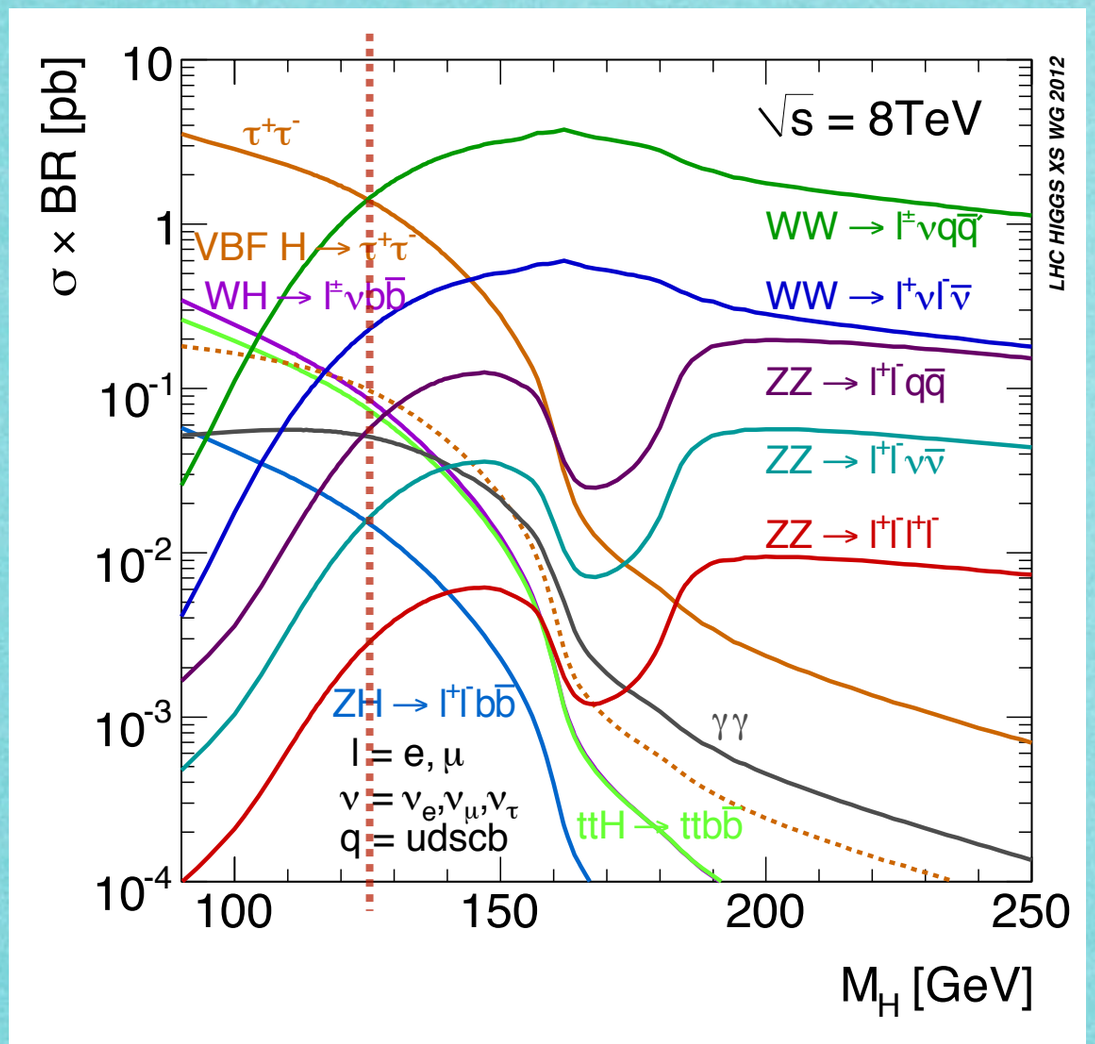
A $Z \rightarrow \mu\mu$ event with 25 reconstructed vertices



- @125 GeV gg fusion dominates O(10 pb)
- important contribution O(pb) also from others production channel (VBF, VH)
- Higgs production cross section increases ~ 1.3 w.r.t. $\sqrt{s}$ = 7 TeV (similar for backgrounds)
- Expected increase in signal sensitivity → 10-15%

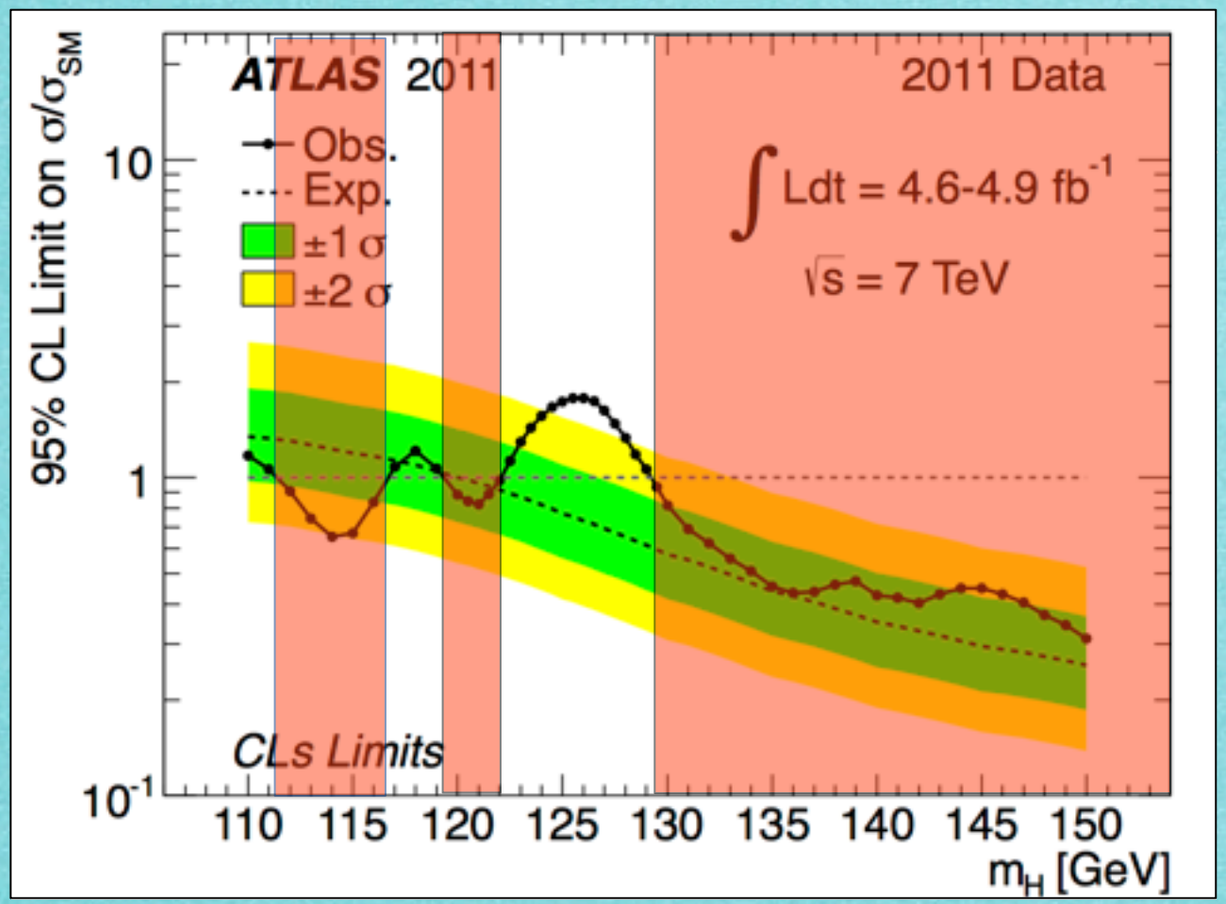


Higgs searches



- Higgs searches @125 GeV achievable in different channels
- H ➔ WW, **ττ** are dominant but difficult (jets, missing E_T signatures)
- Significant contributes from H ➔ ZZ, **γγ** decay channels

2011 Exclusion limits



Combination of several channels:

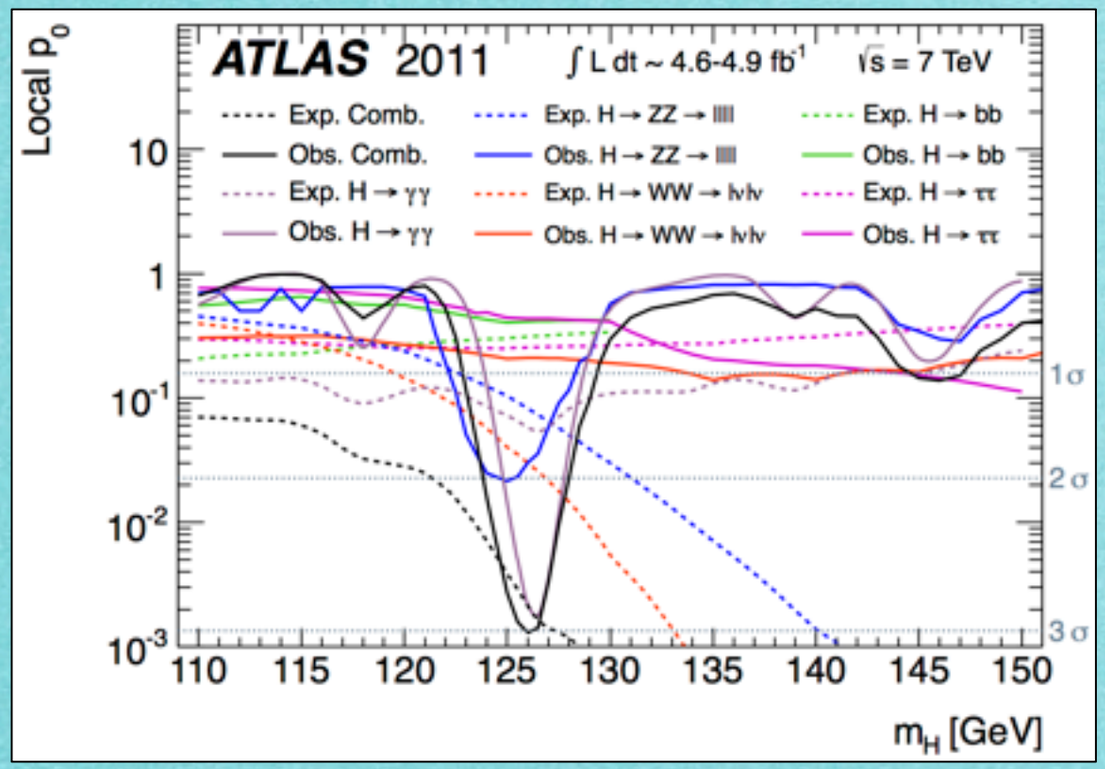
- $H \rightarrow \gamma\gamma$
- $H \rightarrow \tau\tau$ (3 final states)
- $H \rightarrow ZZ(*) \rightarrow 4l$, llqq, llvv
- $H \rightarrow WW(*) \rightarrow lvlv$, lvqq
- $VH \rightarrow Vbb$ (3 final states)

Excluded at 95% CL 3 regions →

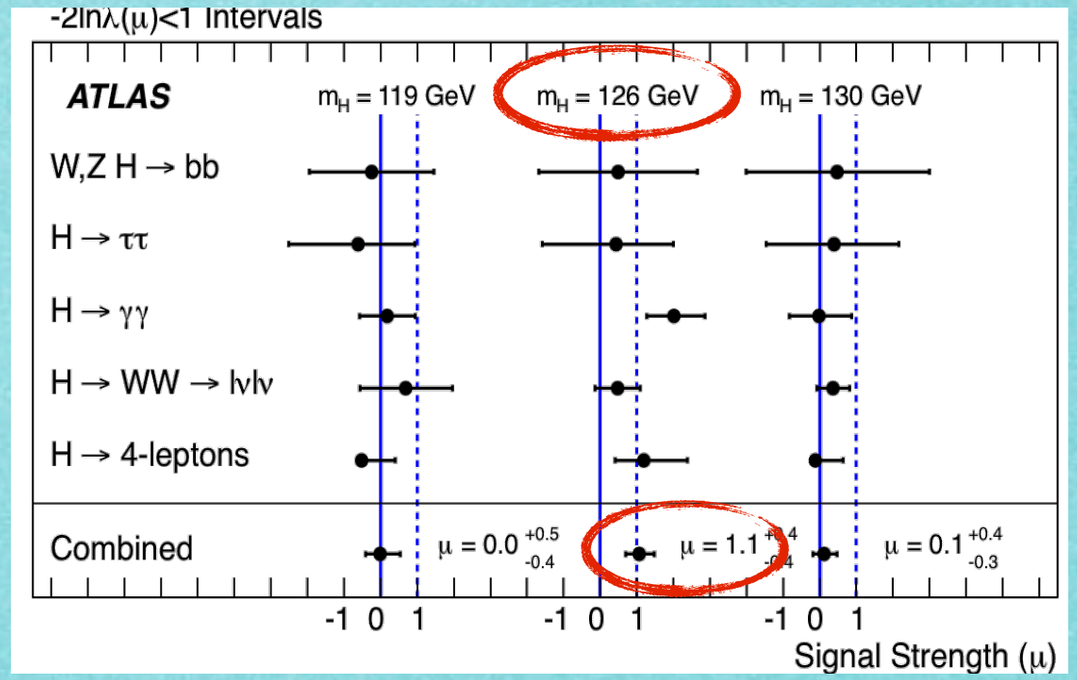
111.4 < mH < 116.6 GeV
119.4 < mH < 122.1 GeV
129.2 < mH < 541 GeV

Status before 4th July

Local p_0 → consistency with background-only hypothesis



For SM Higgs boson signal → **signal strength μ = 1**



Channel	Obs	Exp
γγ	2.8	1.4
ZZ* → 4l	2.1	1.4
WW* → lνlν	0.8	1.6
Comb	2.9	2.9

- minimum p_0 observed @126 GeV
- small differences b/w observed and expected values in the single channels but
- combination compatible with SM expection ($\mu = 1.1 \pm 0.4$ for $m_H = 126$ GeV)

2012 Analysis update

Improvements

- improved reconstruction and identification of physics objects
- gain in e/γ/μ efficiencies
- pile-up dependences minimized
- smaller systematic uncertainties
- well studied detector performances

Analysis strategy

MC based optimization

↓

data check in signal sidebands and background control regions

↓ if all is undertood

signal region data inspection

H → γγ channel

- $\sigma \simeq 50$ fb @126 GeV
- simple signature → 2 high-p_T photons ($E_T > 40, 30$ GeV)
- Main background → $\gamma\gamma$ continuum
- 10 different categories based on γ rapidity, converted/unconverted γ, p_{Tt} variable, 2jets bin
- VBF channel introduced (+3% in sensitivity)
- optimized γ identification and isolation (+15% in sensitivity)

Category	σ_{CB} [GeV]	FWHM [GeV]	Observed [N_{evt}]	S [N_{evt}]	B [N_{evt}]
Inclusive	1.63	3.87	3693	100.4	3635
Unconverted central, low p_{Tt}	1.45	3.42	235	13.0	215
Unconverted central, high p_{Tt}	1.37	3.23	15	2.3	14
Unconverted rest, low p_{Tt}	1.57	3.72	1131	28.3	1133
Unconverted rest, high p_{Tt}	1.51	3.55	75	4.8	68
Converted central, low p_{Tt}	1.67	3.94	208	8.2	193
Converted central, high p_{Tt}	1.50	3.54	13	1.5	10
Converted rest, low p_{Tt}	1.93	4.54	1350	24.6	1346
Converted rest, high p_{Tt}	1.68	3.96	69	4.1	72
Converted transition	2.65	6.24	880	11.7	845
2-jets	1.57	3.70	18	2.6	12

After all selections:

B = 3635 exp.

S = 100.4 exp. @126 GeV

S/B inclusive ≃ 3%

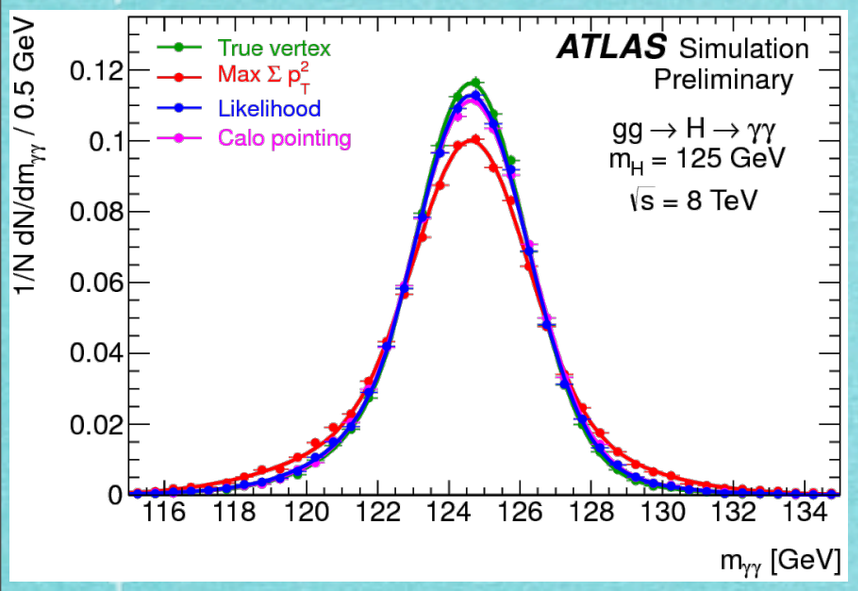
Mass resolution

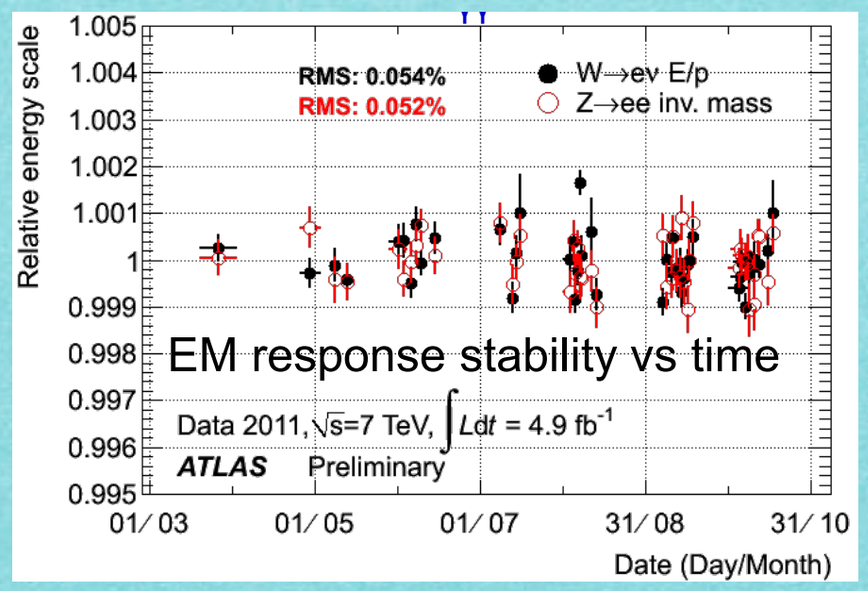
$$m^2_{\gamma\gamma} = E_1 E_2 (1 - \cos\alpha)$$

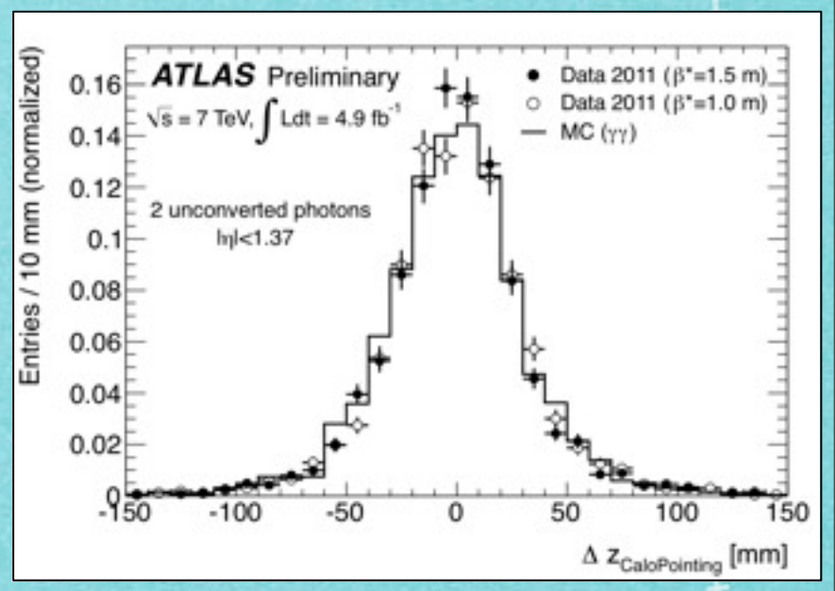
Gaussian+Crystal Ball model

depends on calorimeter response

depends on z_0 reconstruction





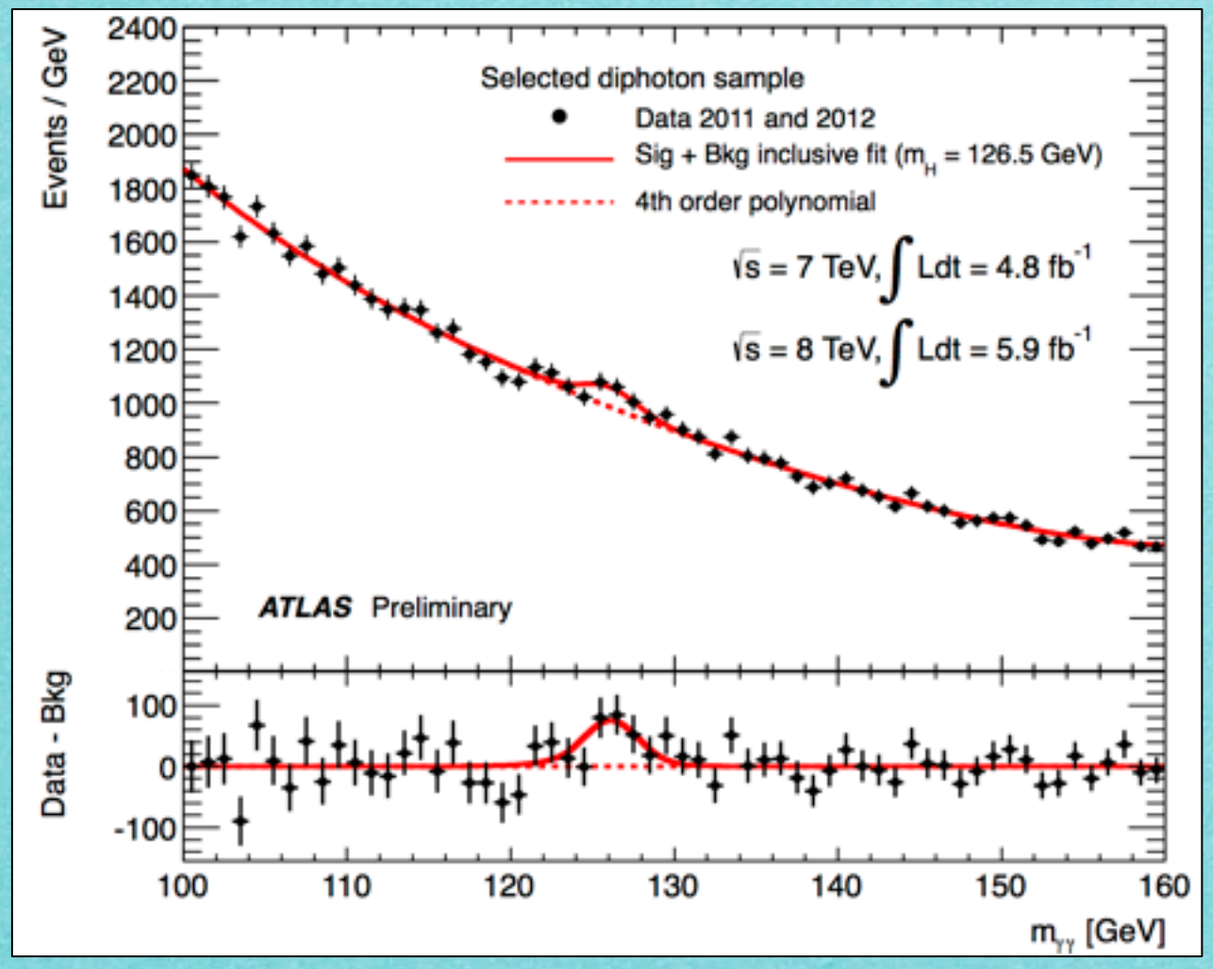


- good mass resolution
- inclusive mass resolution ➙ 1.6 GeV

- MC and data performances studies
- linearity better than 1%
- uniformity ~ 1%

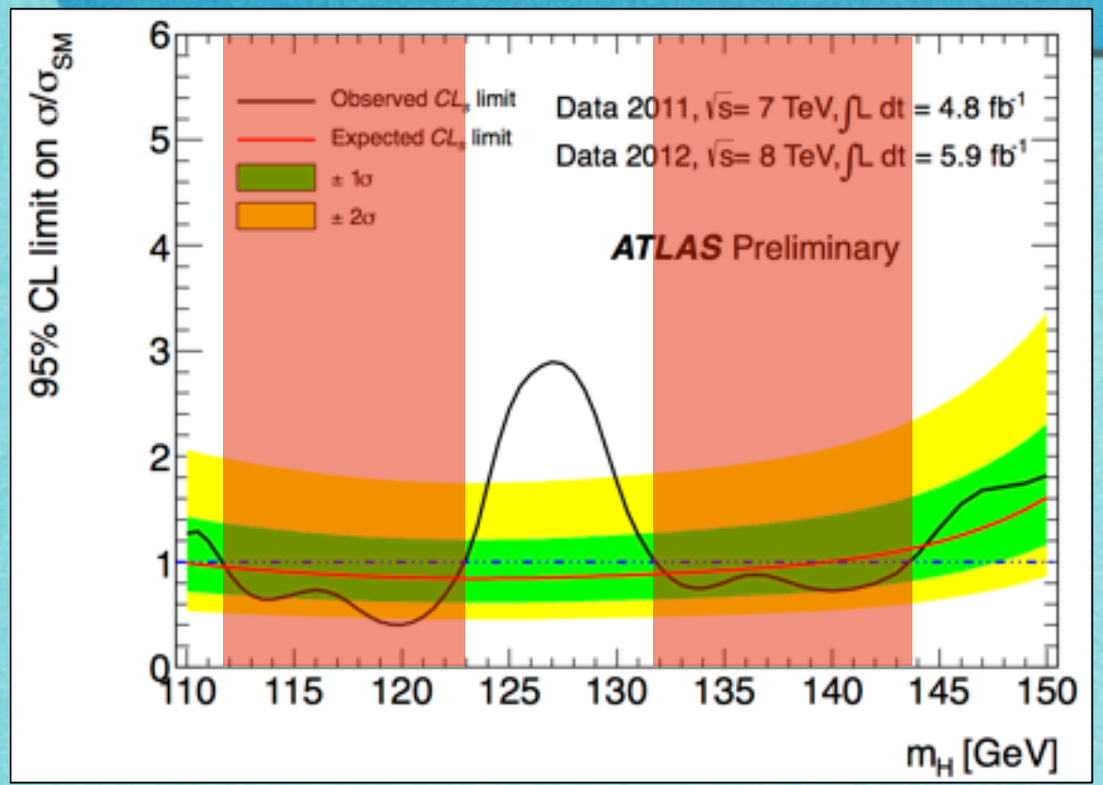
- calorimeter segmentation (longitudinal and lateral)
- tracks from converted γ
- $\sigma_Z \simeq 1.5$ cm

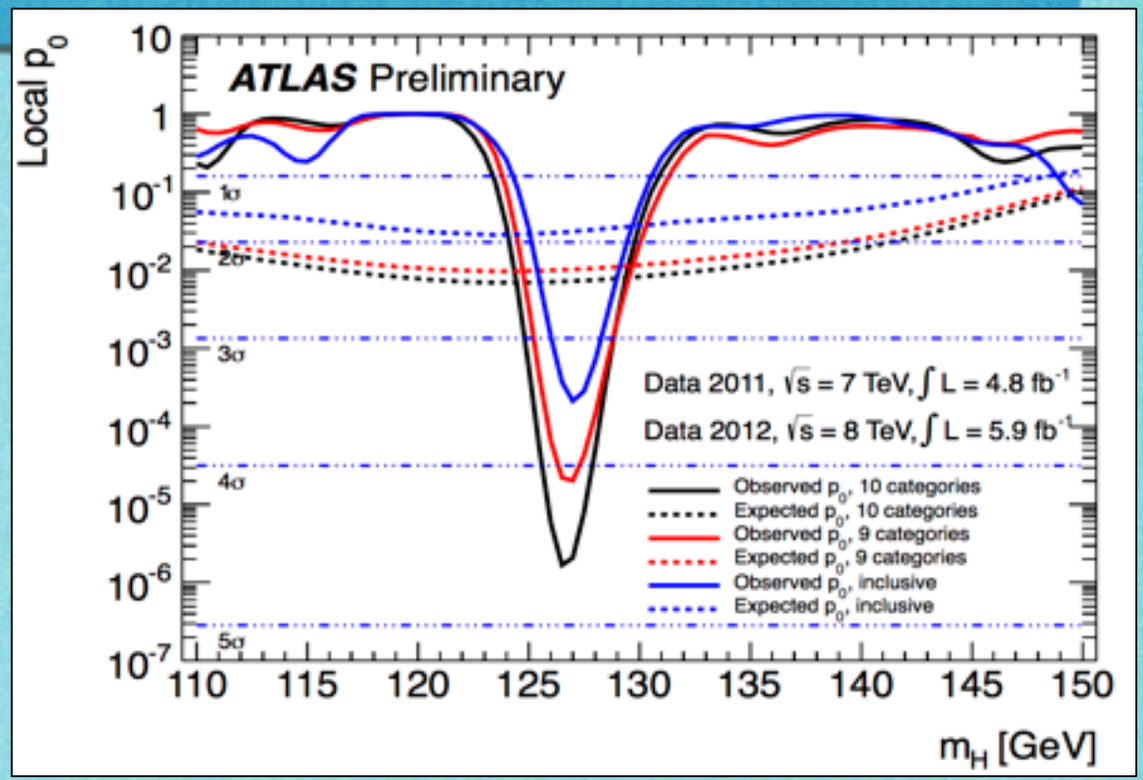
$M_{\gamma\gamma}$ spectrum fit



- $\gamma\gamma$, γj, jj background model
- invariant mass spectrum fit in each categories
- signal plus background (4th Bernstein pol.) fit model
- model with small potential bias @125 GeV
- unweighted sum of events passing kinematic selections

Updated Limit Results

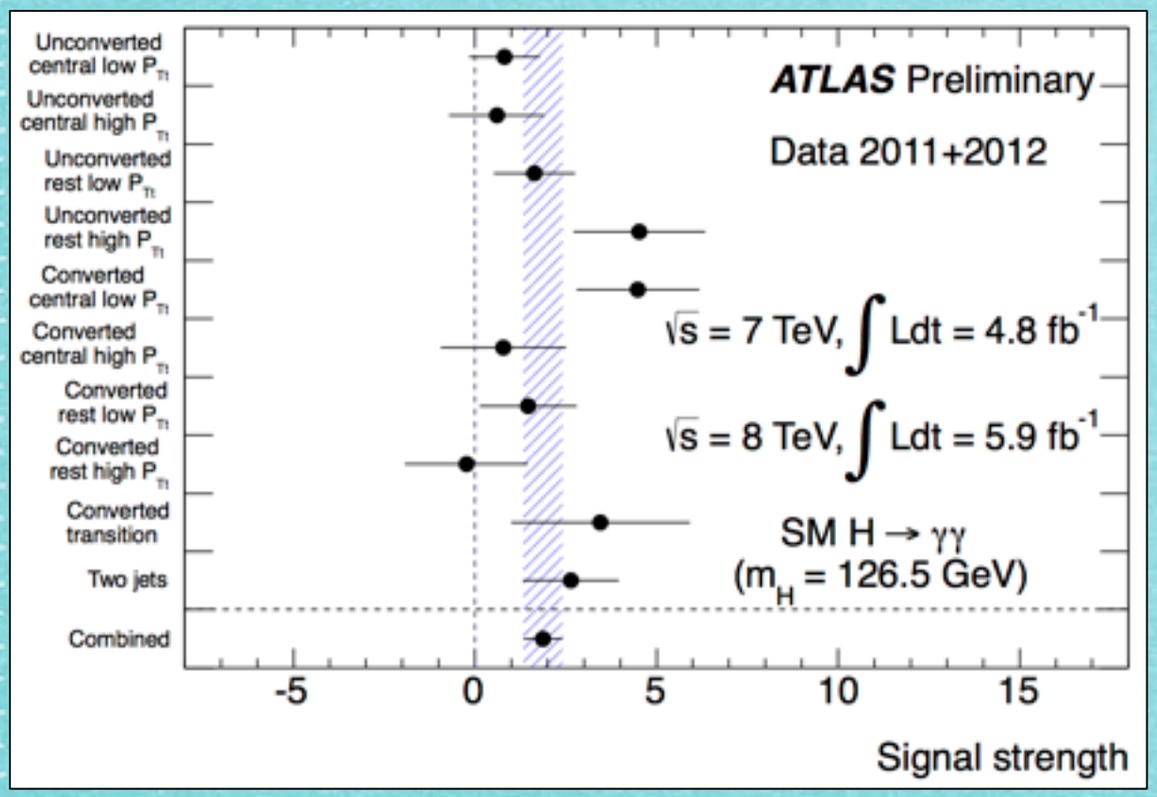


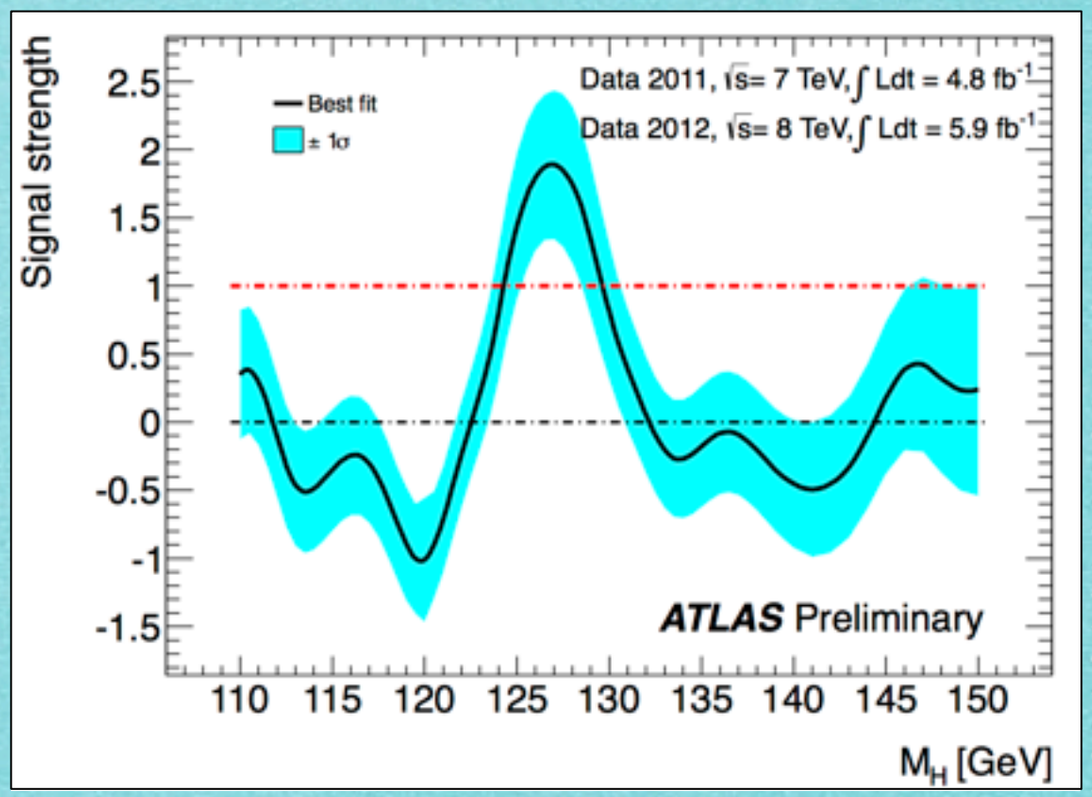


- Expected exclusion (95% CL): 110-139.5 GeV
- Observed exclusion (95% CL): 112-122.5 GeV and 132-143 GeV

Data	p_0 min @	Obs	Exp
2011	126 GeV	3.5	1.6
2012	127 GeV	3.4	1.9
2011+2012	126.5 GeV	4.5	2.4

Signal strength μ





- almost all the categories analized are consistent with the SM but
- there are some small deviations

- Best fit value for m_H = 126.5
  → $\mu = 1.9 \pm 0.5$

H → ZZ* → 4l channel

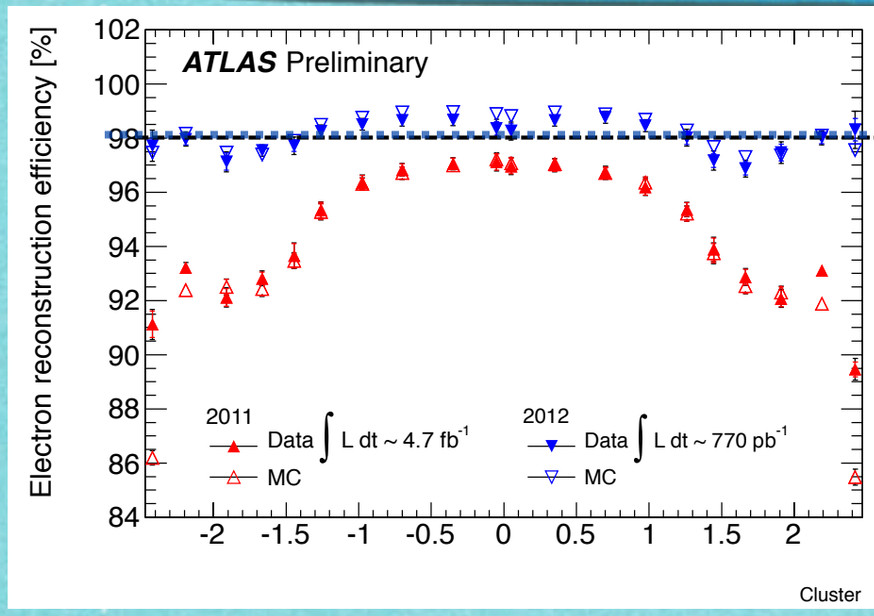
- σ x BR ≃ 2.5 fb (@126 GeV)
- clear leptonic signature
- good signal to background ratio S/B ≃ 1
- Main background: irreducible ZZ* and Zbb, Z+jets and tt (at low mass region)
- High acceptance and good leptons reconstruction and identification for low-p_T
- Good E_T/p_T lepton resolutions

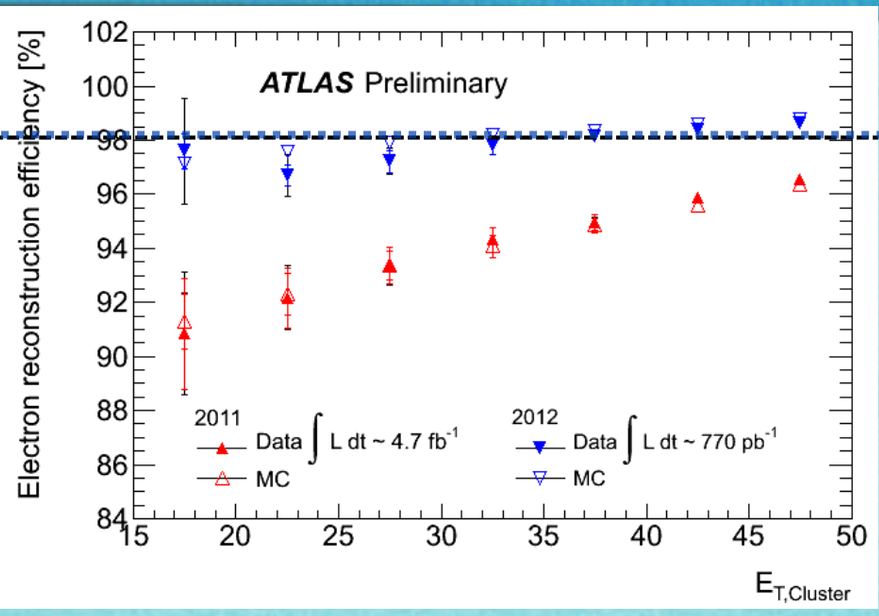
Improvements

- kinematic cuts optimized
- increased electron-ID efficiency (brem.,ecc.)
- standalone and calo-tagged muons added
- gain of 20% (μ) and 30% (e) in signal significance

Selection	Original	Optimized
Lepton p_T (e/μ)	20,20,7,7	20,15,10,7/6
m_{12} cut	$\lvert m_{12} - m_Z \rvert < 15$ GeV	$50 < m_{12} < 106$ GeV
m_{34} cut	$m_{th} < m_{12} < 115$ GeV	$m_{th} < m_{12} < 115$ GeV

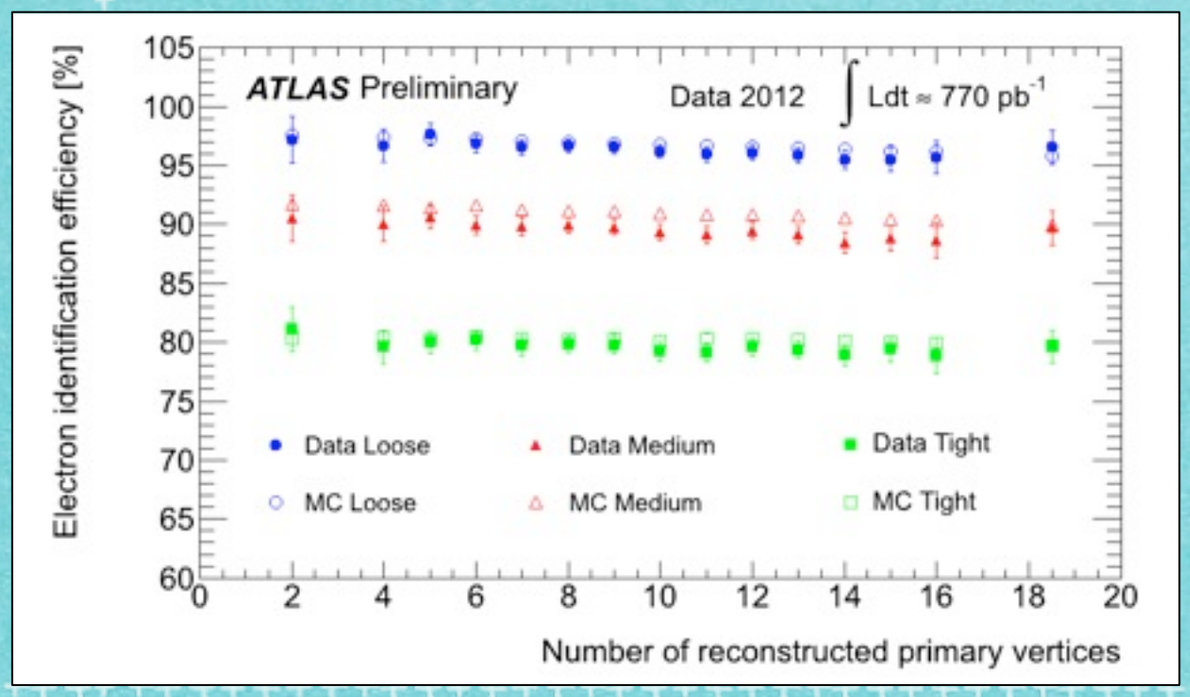
Electron Reconstruction and Identification





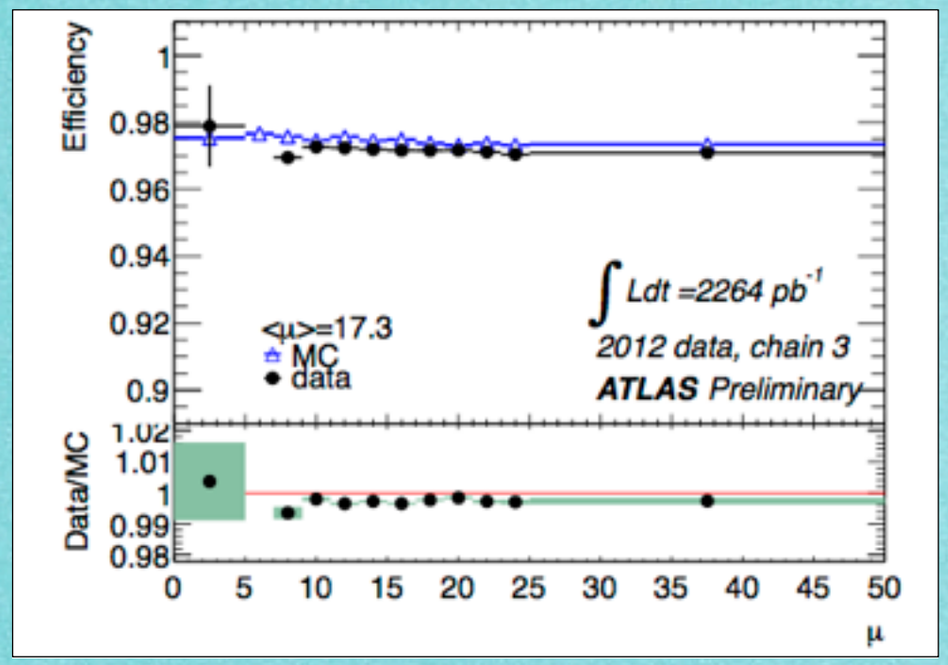
98%

electron reconstruction efficiency ~ stable vs η and E_T

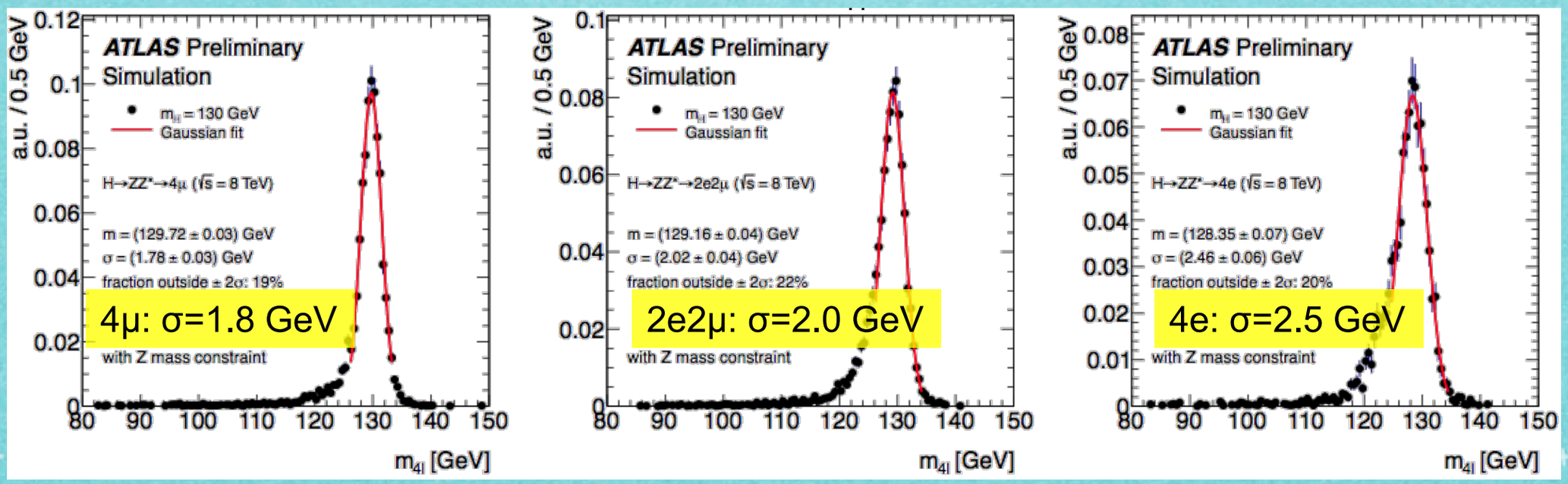


- Re-optimized e-ID using pile-up robust variables (TRT, calo-strip, ecc.)
- Identification efficiency ~ indipendent from pile-up
- Efficiency 95(80)% for loose(tight) identifications quality

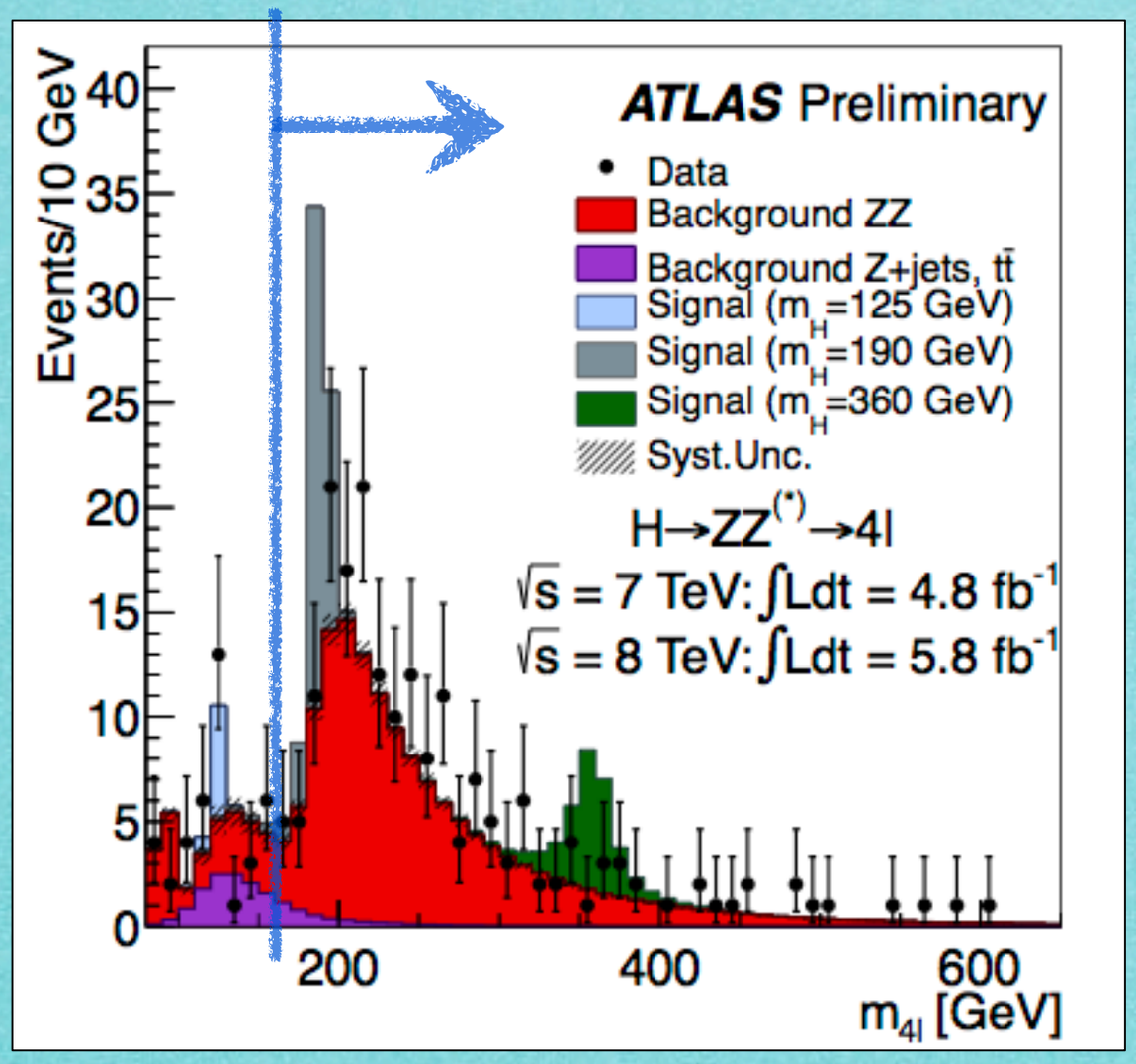
Muon Reconstruction and Mass Resolutions



- Muon reconstruction efficiency stable (~ 97%) vs E_T up to 6 GeV
- Mass resolutions measured in 3 different channels (1.8-2.5 GeV)

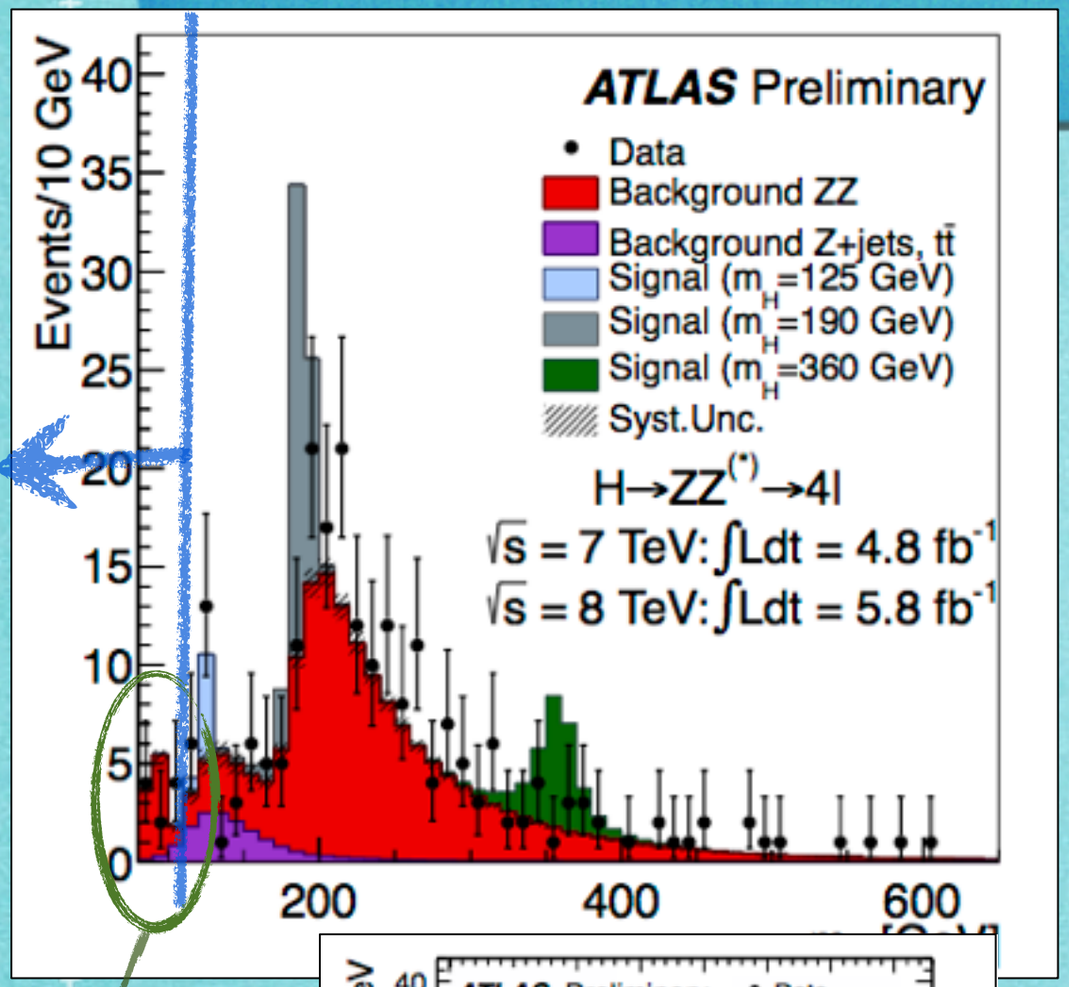


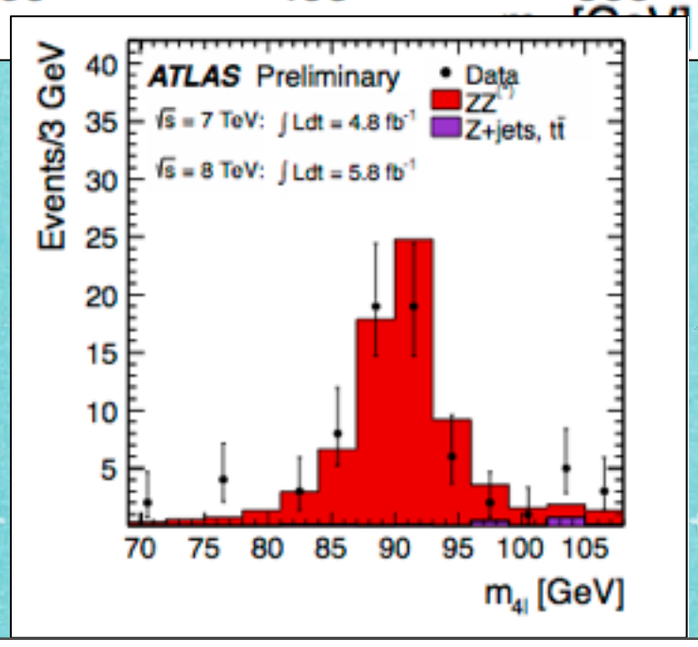
High Mass control region



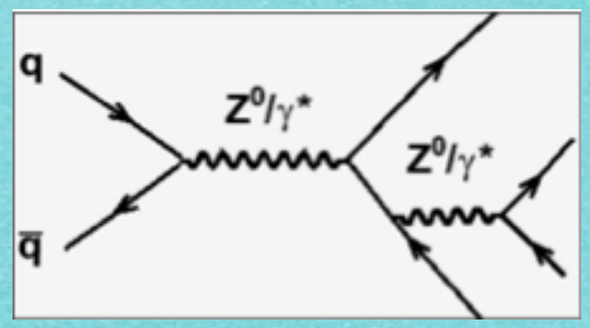
- m_{4l} > 160 GeV control region → dominated by ZZ* background
- Events expected = 147 ± 11
- Events observed = 191
- ≈ 1.3 times ZZ* SM prediction
- deviation consistent with experimental ZZ* cross section value
- local p0 values unchanged leaving ZZ* normalization free to float

Low Mass control region



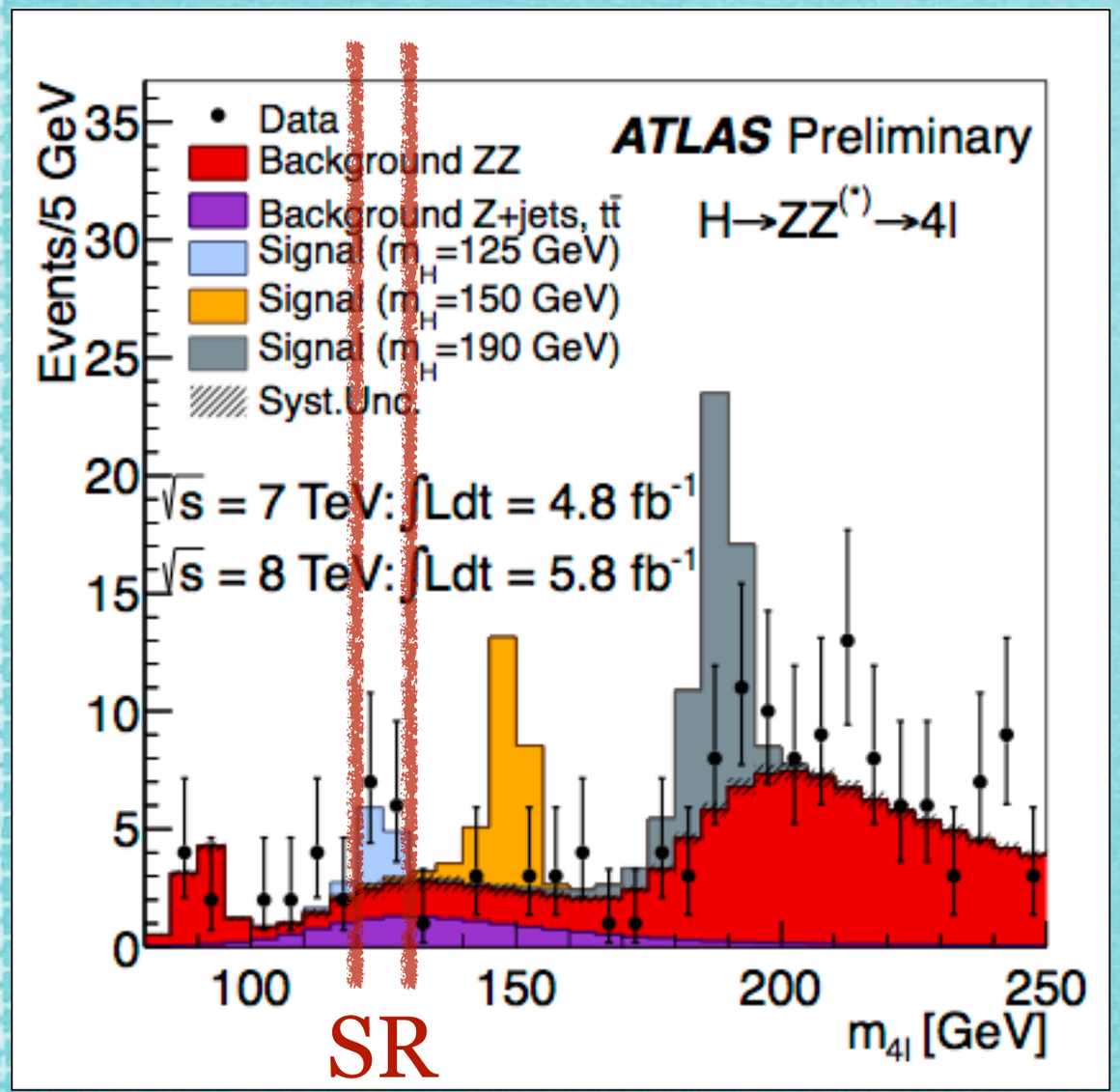


- $m_{4l} < 105$ GeV control region ➙ peak at m_Z for single-resonant 4l production
- Events expected = 65 ± 5
- Events observed = 57
- Consistency b/w data and SM prediction within uncertainties
- Data-driven methods for background estimation



Enhanced relaxing cuts on $m_{12(34)}$ and $p_{T,4}$

4l Signal Region



In the mass range 120-130 GeV (SR)

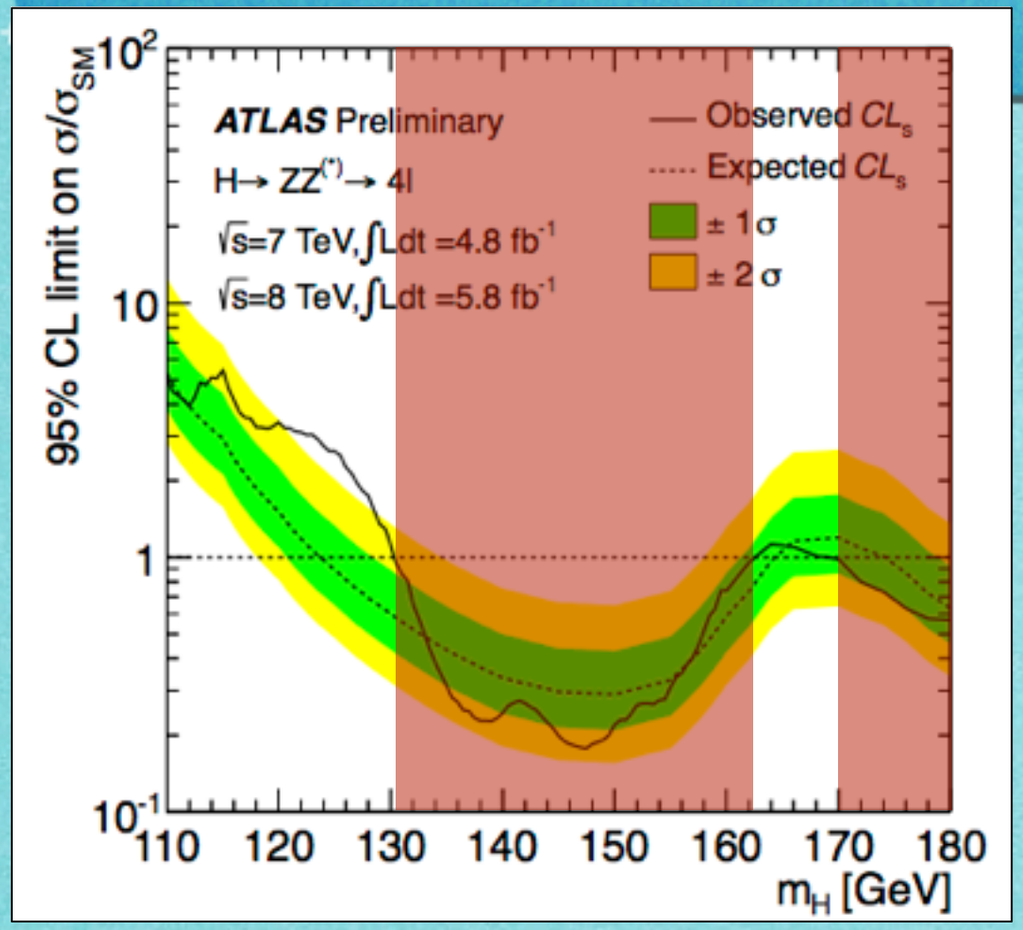
Data Sample	Exp. B	Exp. H(125)	Obs
2011	2 ± 0.3	2 ± 0.3	4
2012	3 ± 0.4	3 ± 0.5	9
2011+2012	5.1 ± 0.8	5.3 ± 0.8	13

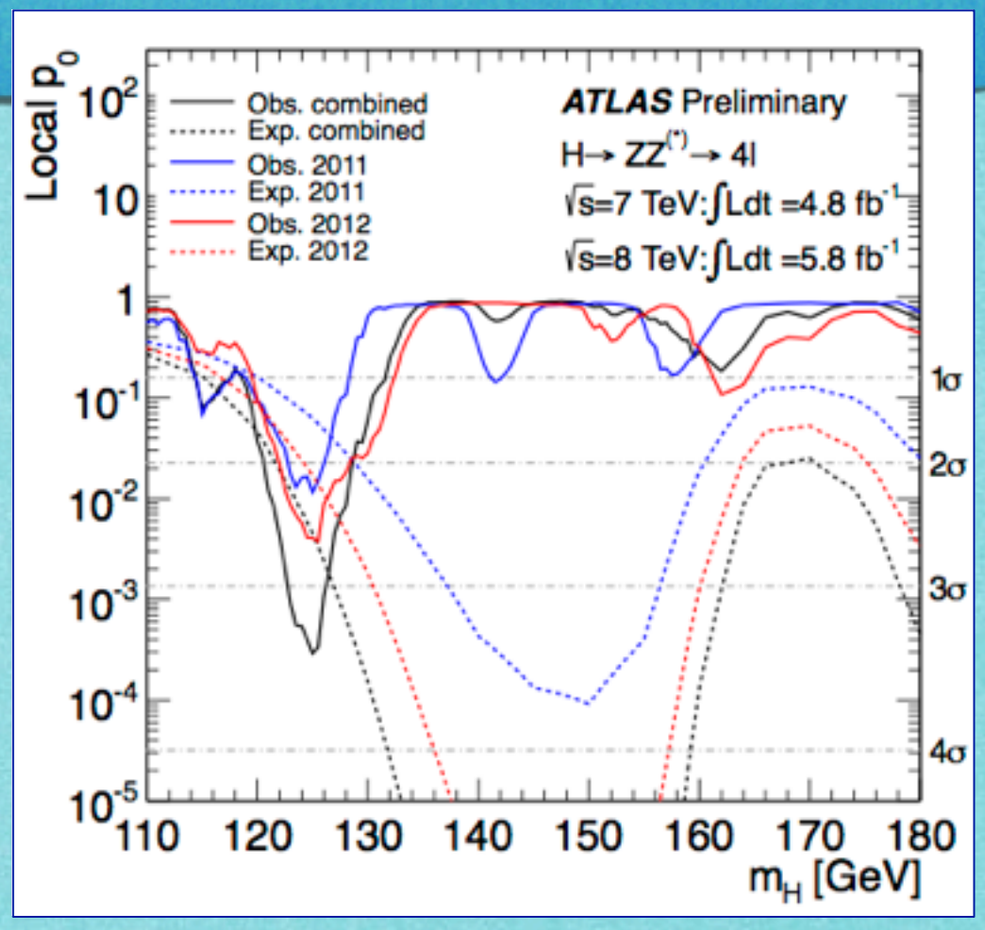
3 leptonic sub-channels

2011+2012	4μ	2e2μ	2e
Data Obs	6	5	2
Exp. S/B	1.6	1	0.5

Data observation consistent with signal plus background SM prediction

Updated Limit Results

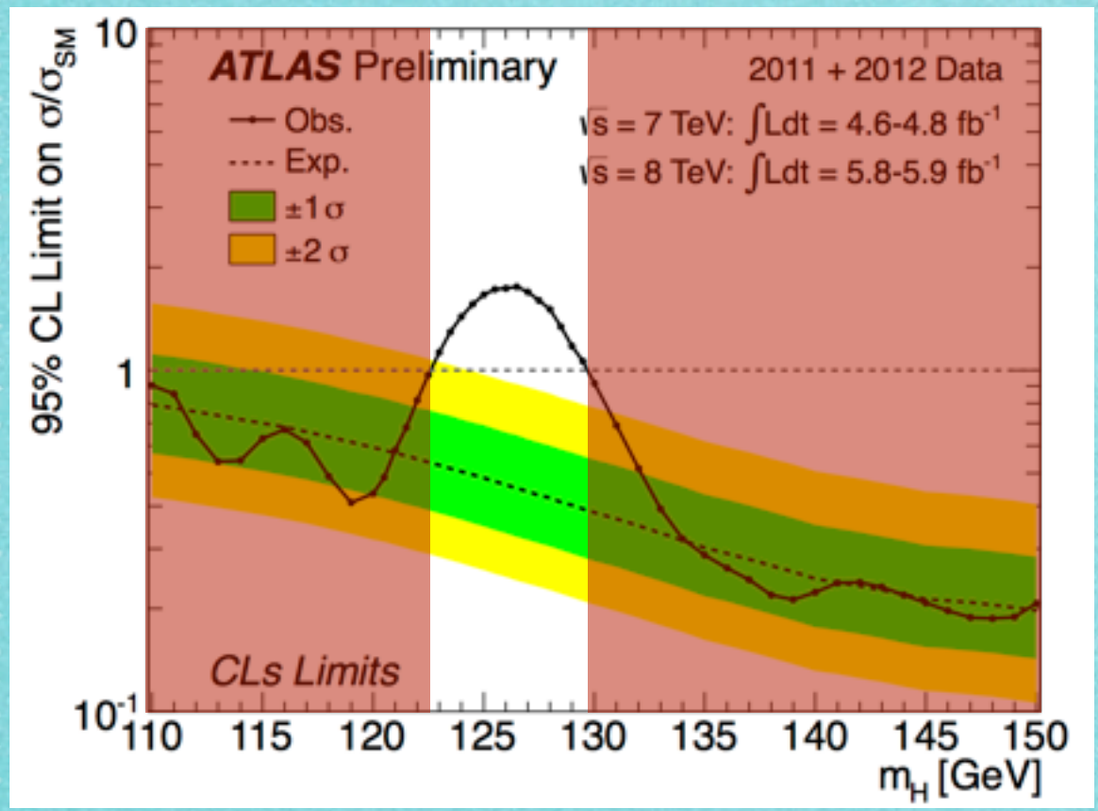


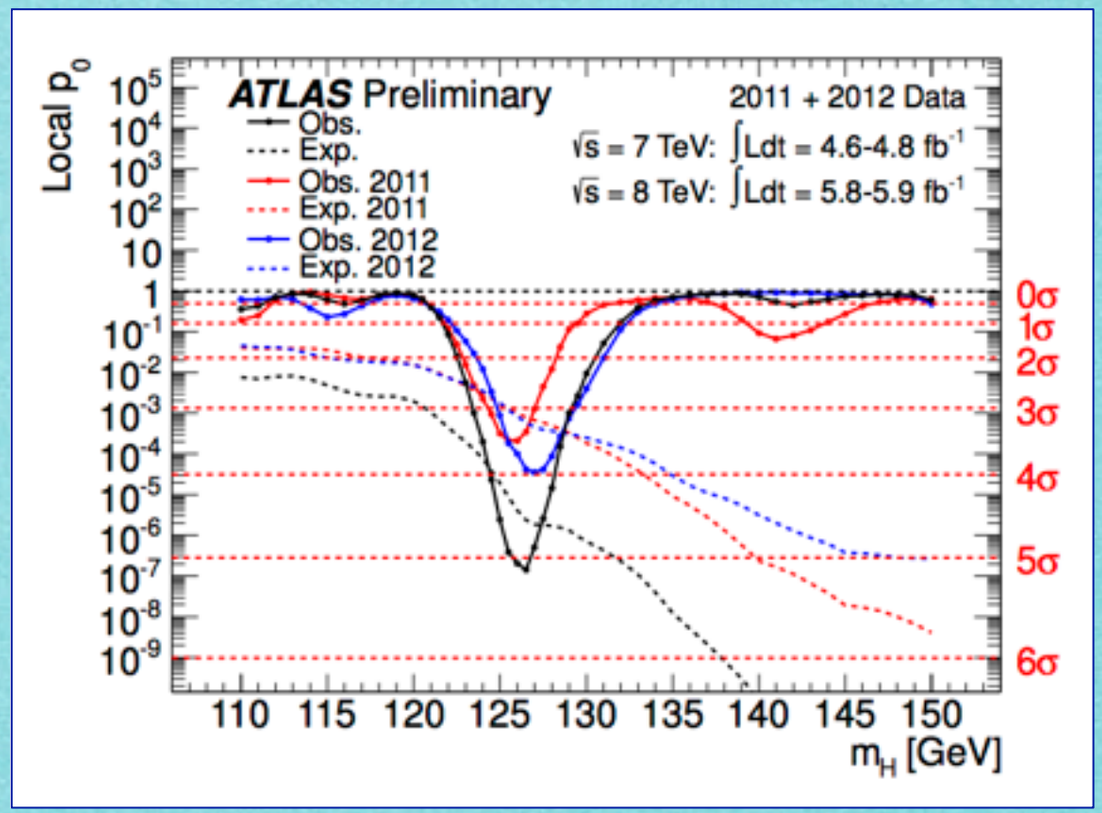


- Expected exclusion (95% CL): 124-164 GeV and 176-500 GeV
- Observed exclusion (95% CL): 131-162 GeV and 170-460 GeV

Data	p_0 min @	local p_0	Obs	Exp
2011	125 GeV	1.1%	2.3	1.5
2012	125.5 GeV	0.4%	2.7	2.1
2011+2012	125 GeV	0.03%	3.4	2.6

Updated Combination

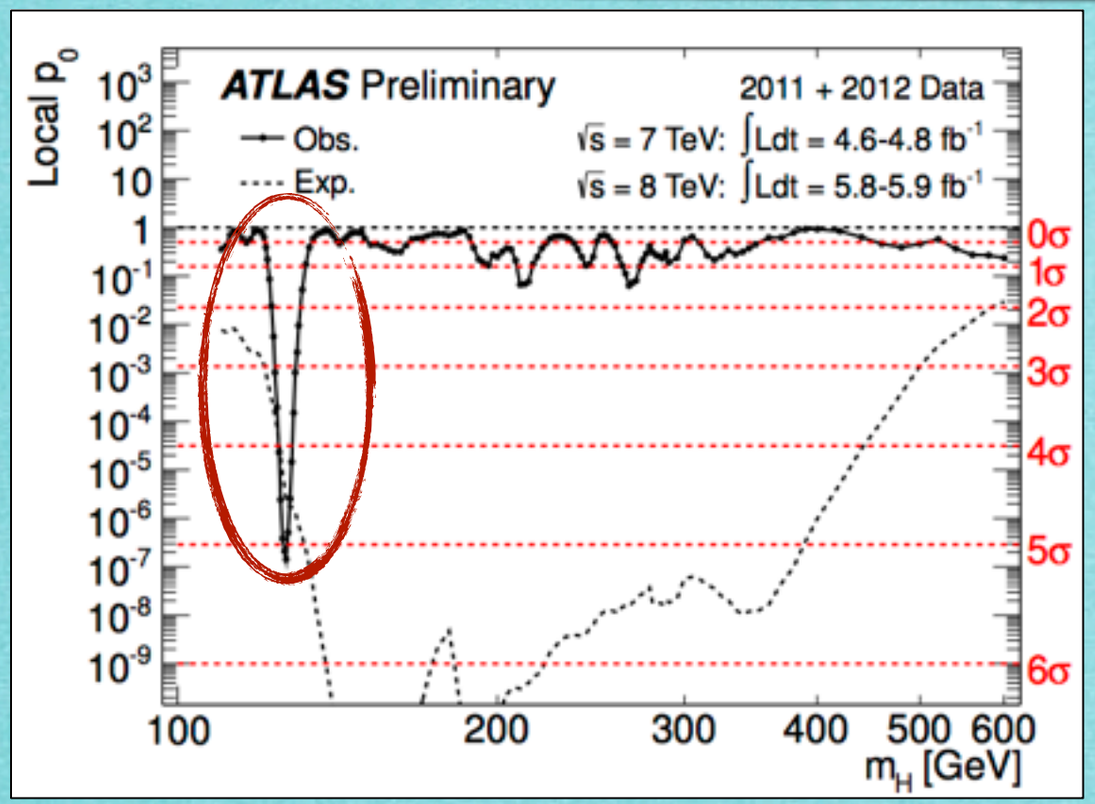


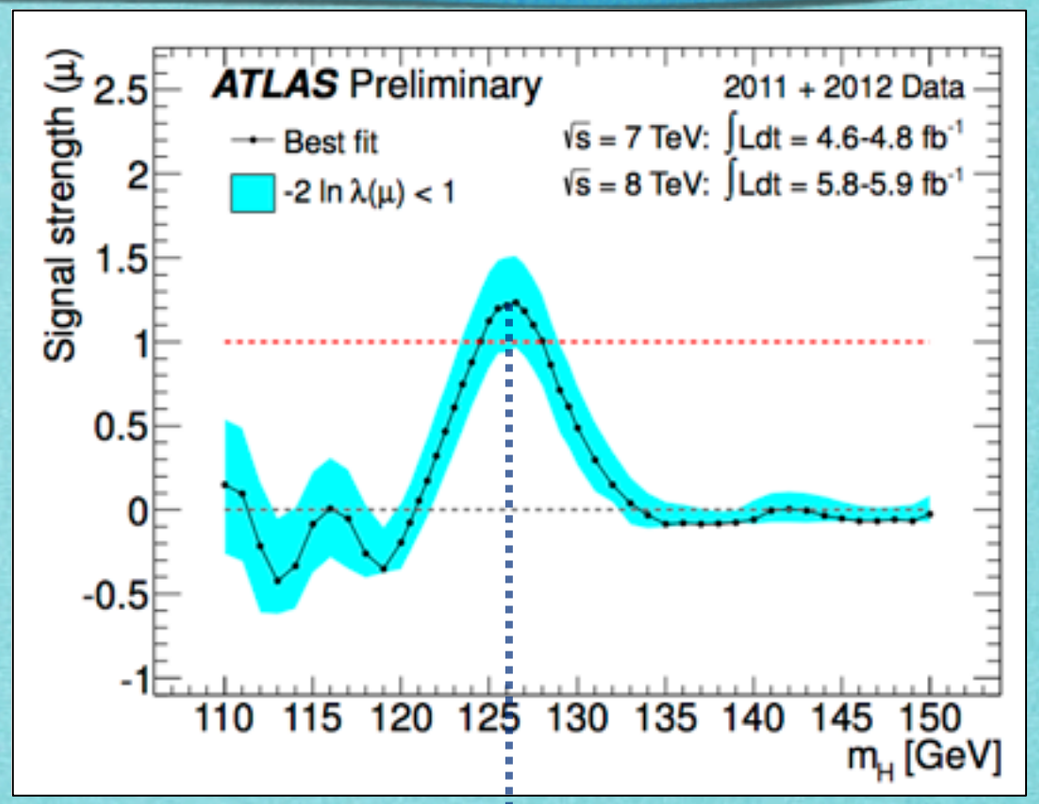


- Expected exclusion (95% CL): 110-582 GeV
- Observed exclusion (95% CL): 110-122.6 GeV and 129.7-523 GeV

Data	p_0 min @	local p_0	Obs	Exp
2011	126 GeV	< 1 ‰	3.5	3.1
2012	127 GeV	< 1 ‰	4.0	3.3
2011+2012	126.5 GeV	3×10^{-7}	5.0	4.6

Signal Strength





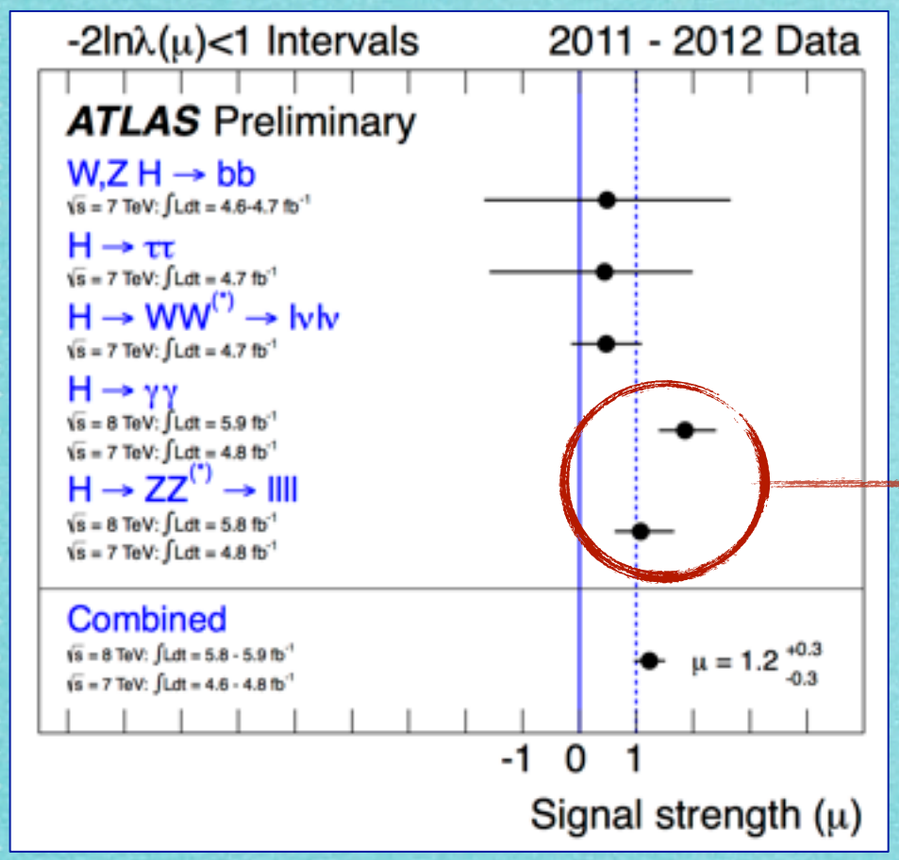
Good consistency with background-only hypothesis ($<2\sigma$) **except** in one region around 126 GeV

Best fit signal strength @126.5 GeV

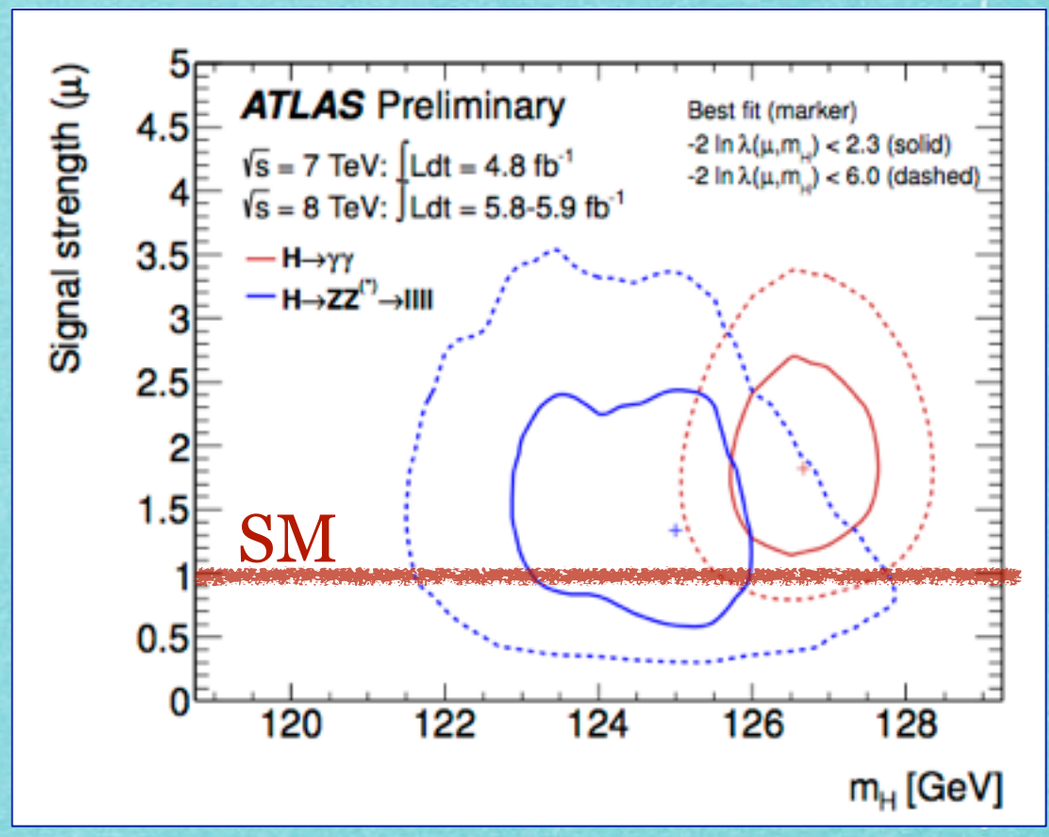
$\mu = 1.2 \pm 0.3$

(compatible with SM prediction)

Excess Inspection



γγ and 4l channels comparison



2-dim likelihood fit to signal mass (m_H) and strength (μ)

m_H and μ compatible within 95% CL contours

Conclusions

- Updated analysis based on 2011+2012 data in different channel
  - $H \to \gamma\gamma$ / $H \to ZZ^* \to 4l$, $llv\nu$ / $H \to WW^* \to l\nu l\nu$ / $H \to \tau\tau$ / $VH \to Vbb$
- Observation of significant excess in the search for SM Higgs boson
  - excess around $m_H = 126.5$ GeV with local significances of 4.5σ ($\gamma\gamma$) and 3.4σ (4l)
  - combined result gives a local significance of **5.0σ** at **$m_H = 126.5$ GeV**
- Evidences for a **new narrow resonance** (boson) with a mass ≃ 126 GeV