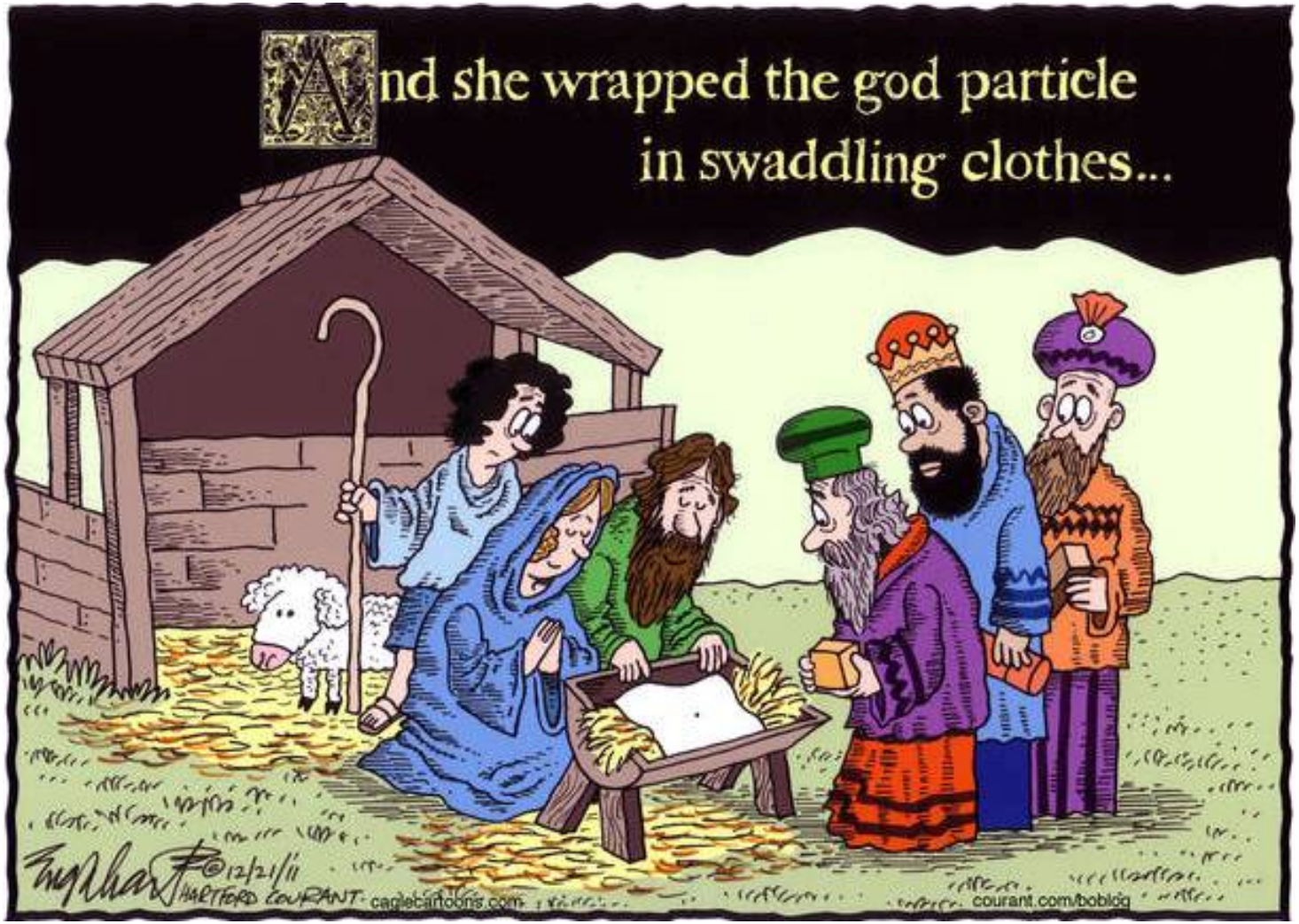
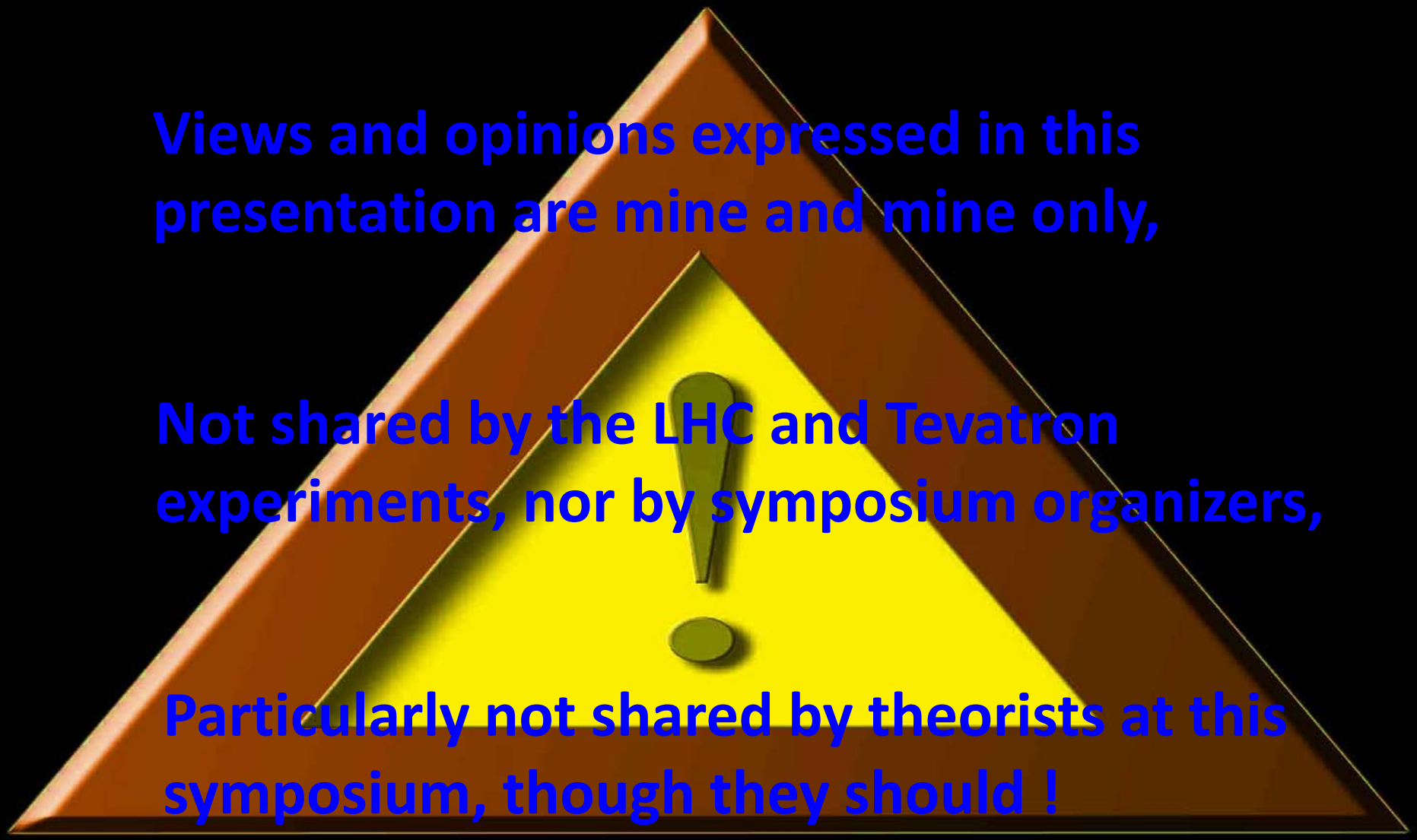
Have we seen a Higgs boson?





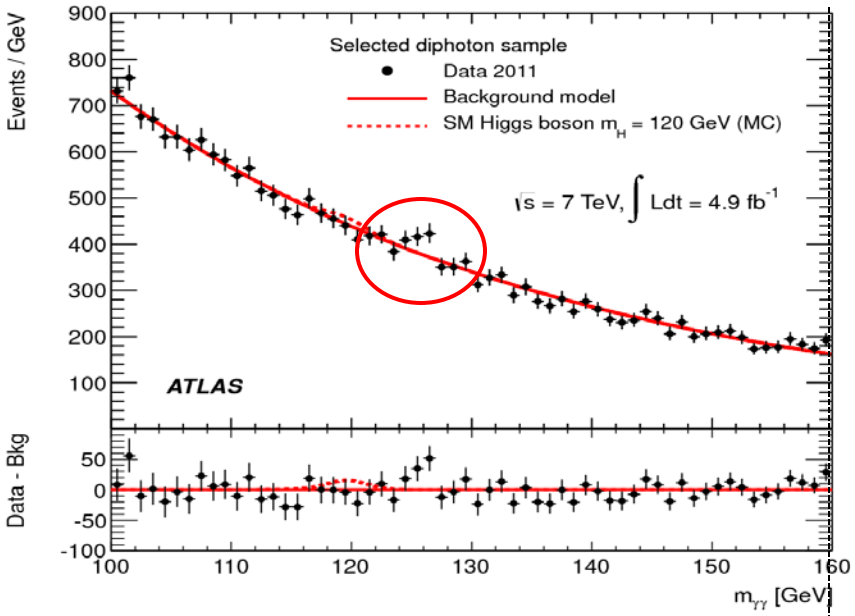
Views and opinions expressed in this presentation are mine and mine only,

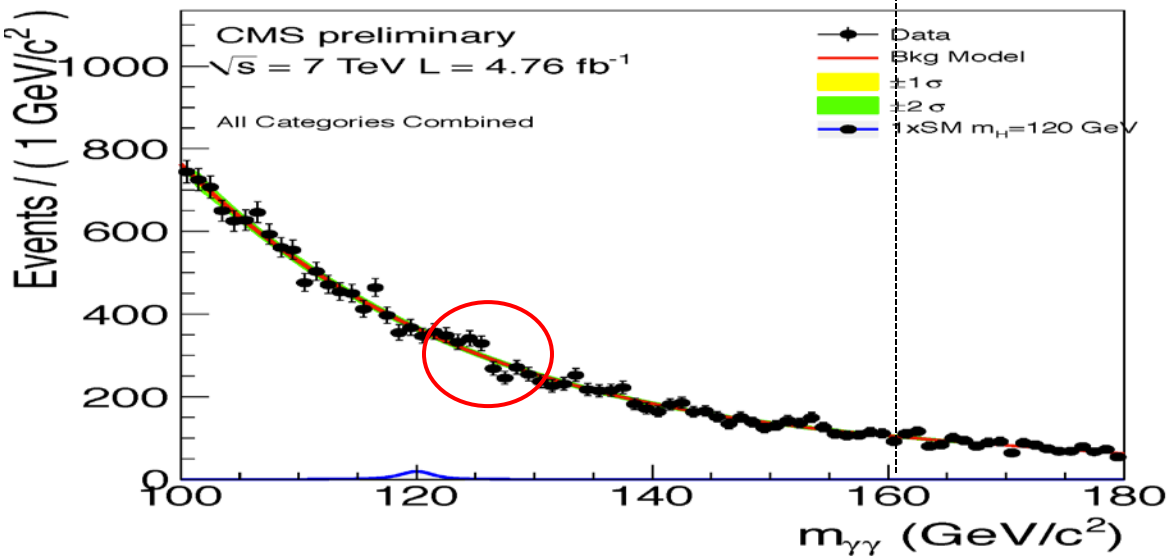
Not shared by the LHC and Tevatron experiments, nor by symposium organizers,

Particularly not shared by theorists at this symposium, though they should !

Disclaimer

H→γγ: Mass Spectrum





Not your grandpa's bump hunting, very complicated analyses…

S/B ~ 1/50

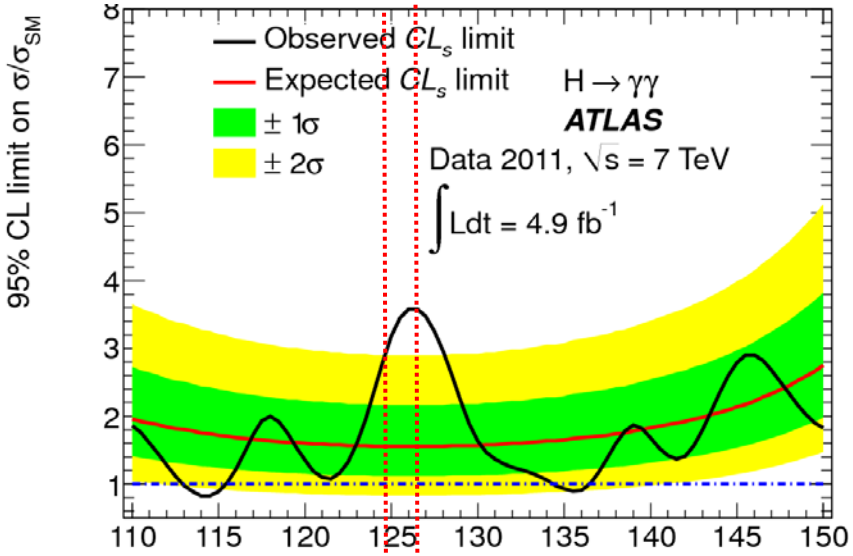
ATLAS: 9 categories

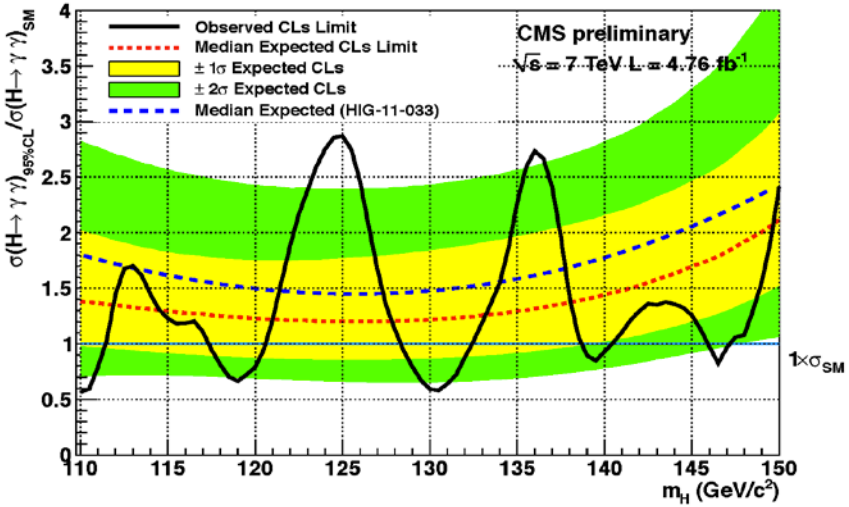
$$\eta_\gamma \otimes \text{conversion} \otimes p_T^{\gamma\gamma}$$

CMS: 5 categories

- **BDT output**
- **VBF**
- **Recently updated**

H→γγ: Limits





ATLAS at 126.5 GeV

- 2.8σ local
- 1.5σ global (110-150 GeV)

$$\sigma\left(m_{\gamma\gamma}\right) \sim 1.7 \text{ GeV}$$

CMS excess at 125 GeV

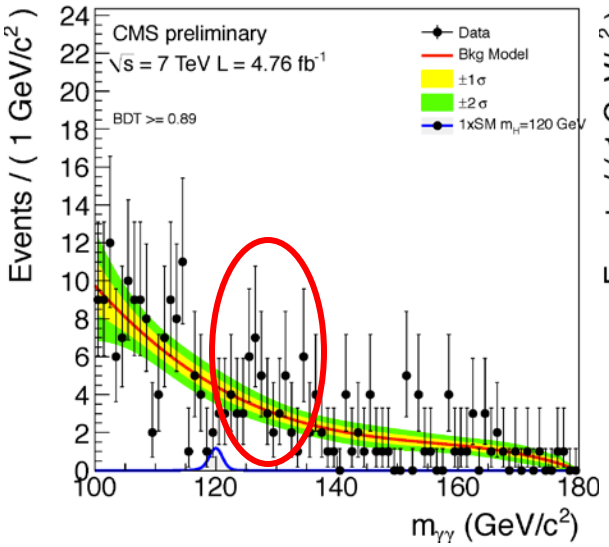
- 3.1σ local
- 1.8σ global (110-150 GeV)

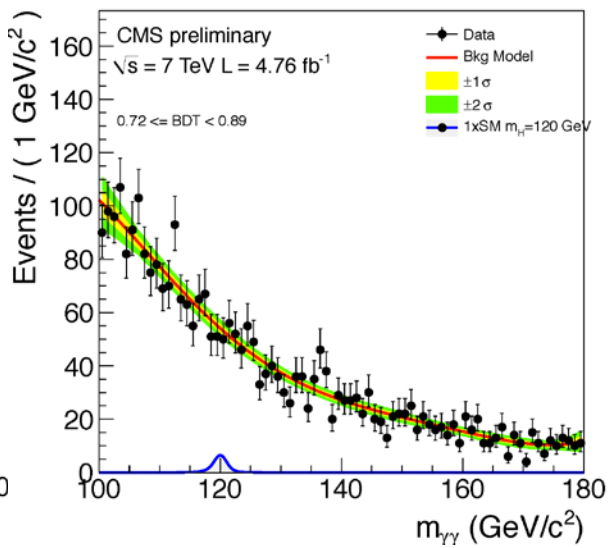
$$\sigma\left(m_{\gamma\gamma}\right) \sim 1.4 \text{ GeV}$$

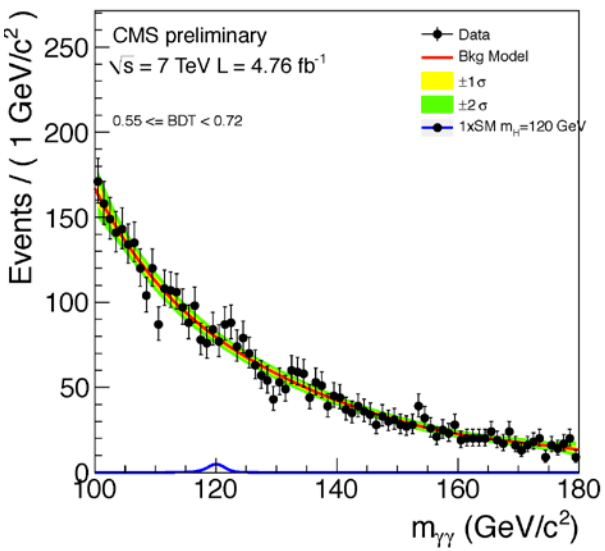
Note that $\sigma\left(\bar{m}_{\gamma\gamma}\right) = \dfrac{\sigma\left(m_{\gamma\gamma}\right)}{\sqrt{N_{\gamma\gamma}}}$

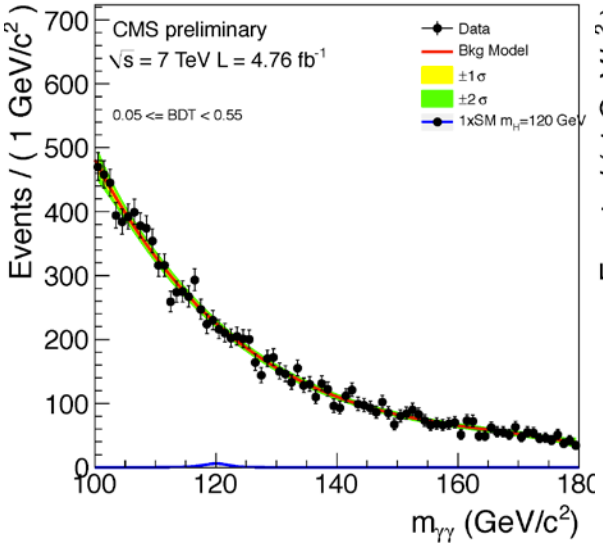
Are the two mass peaks compatible?

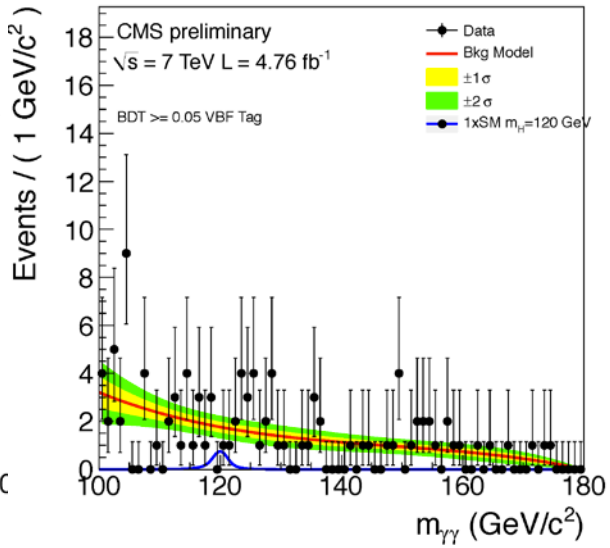
H→γγ Mass Spectrum







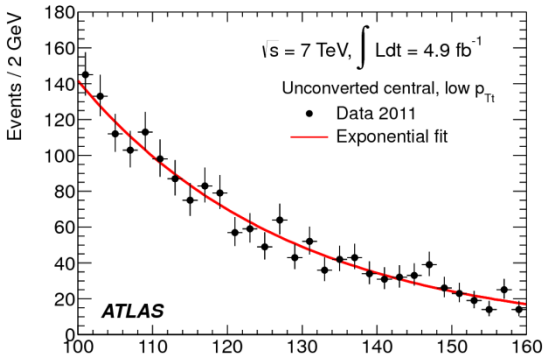


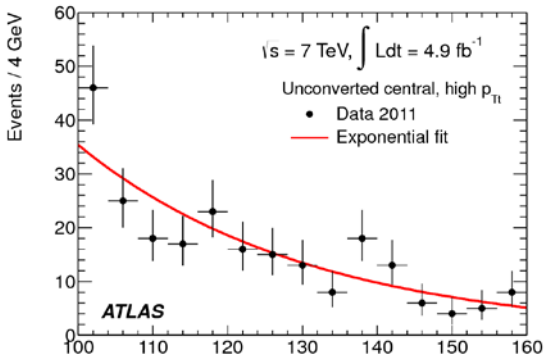


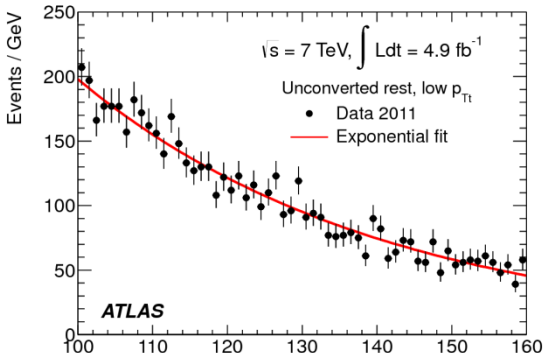
CMS

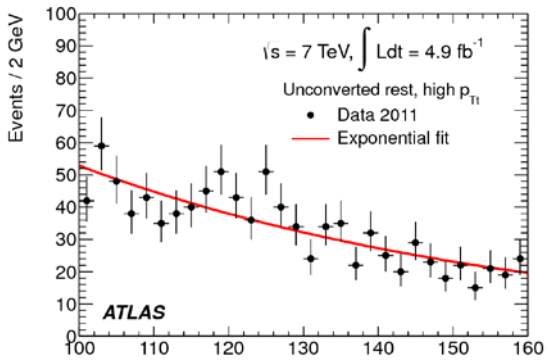
Excesses in multi-categories, but dominated by VBF-type analysis

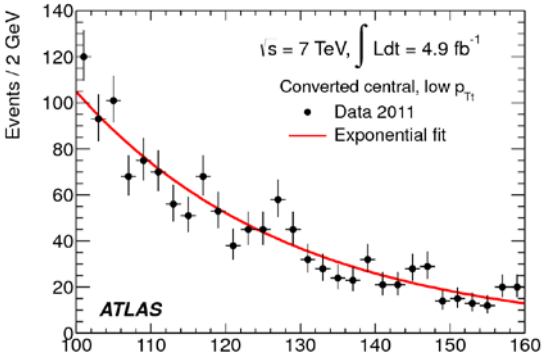
H→γγ Mass Spectrum

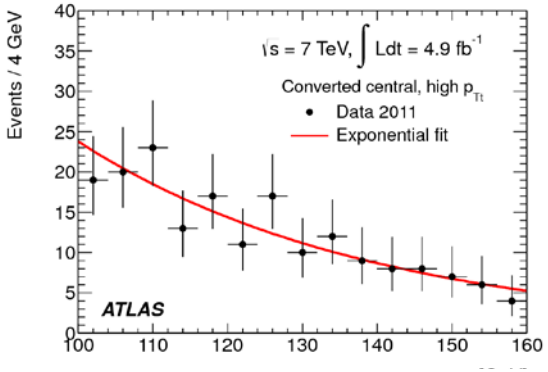


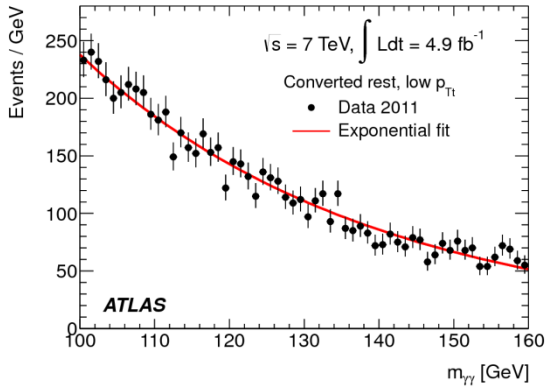


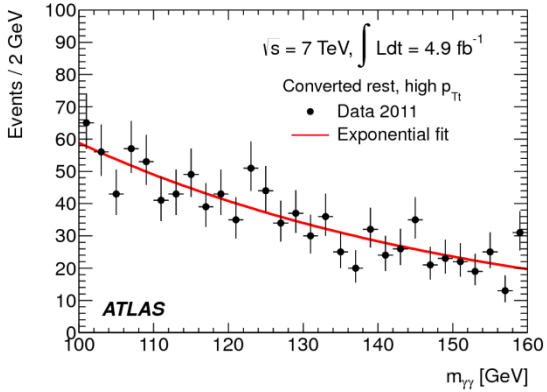


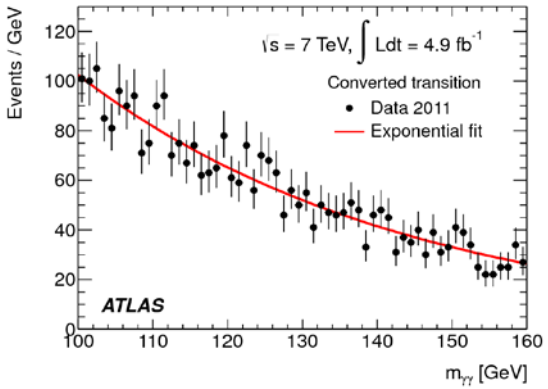






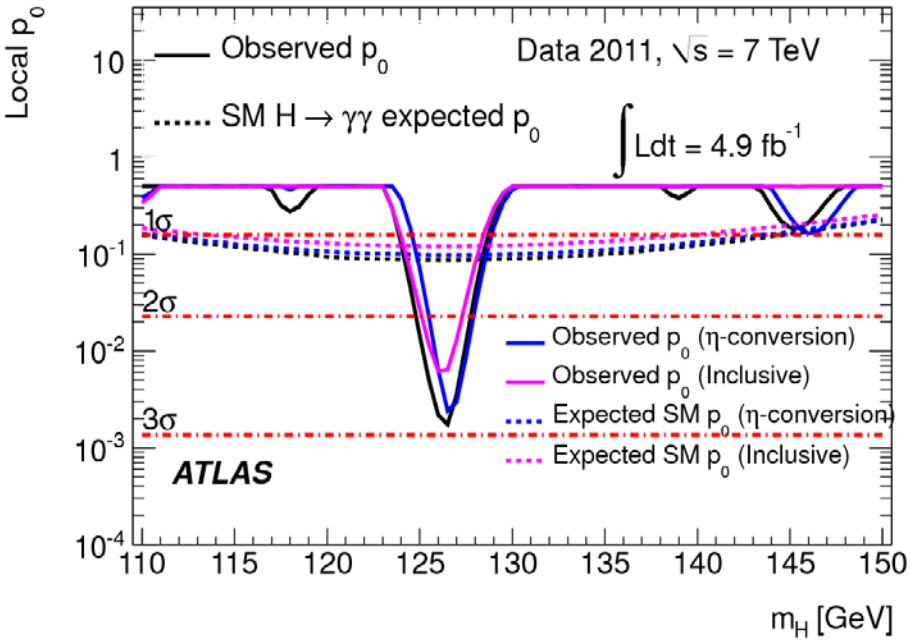


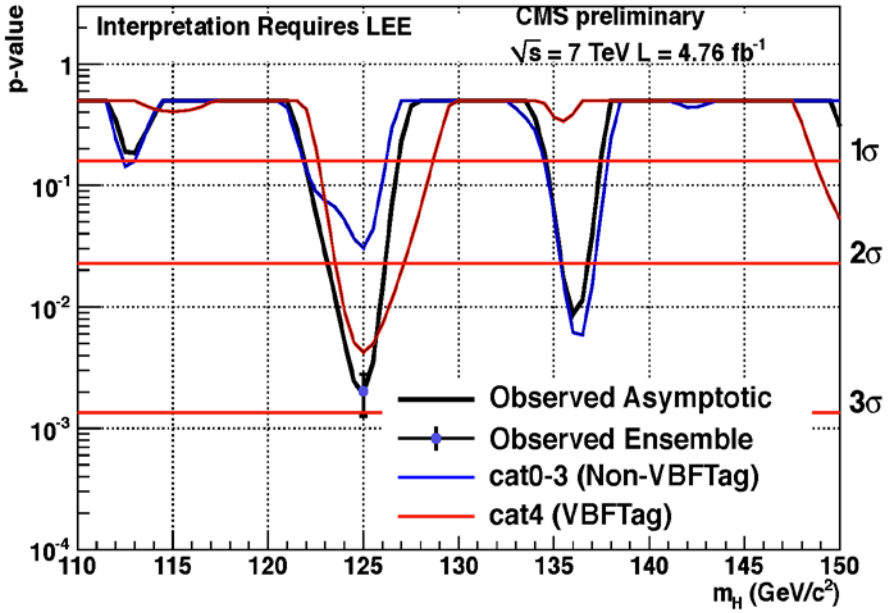




H→γγ: p-value

Small excesses in multi-categories add up. Expected p-value for a standard model Higgs signal at 125 GeV is about 10% while the observed p-value is about 0.1%.



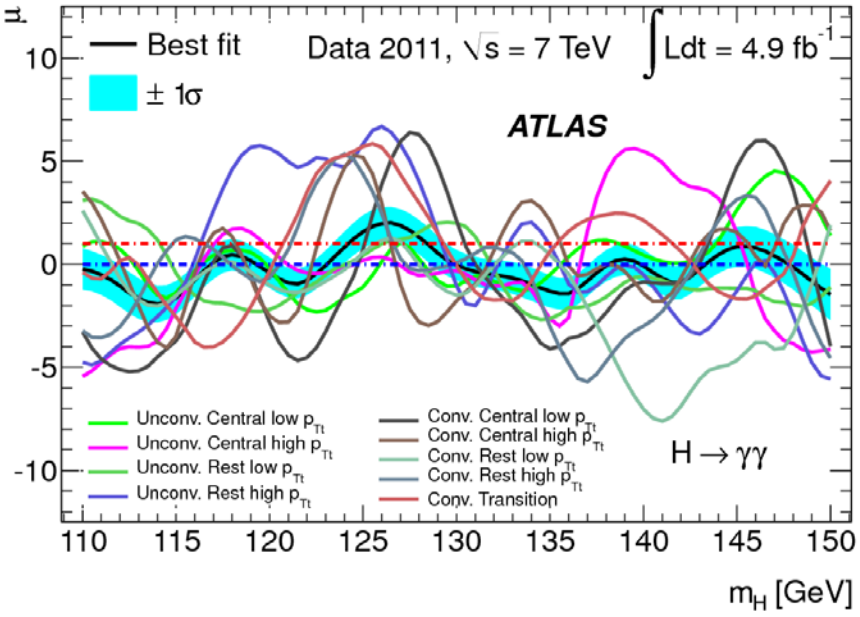


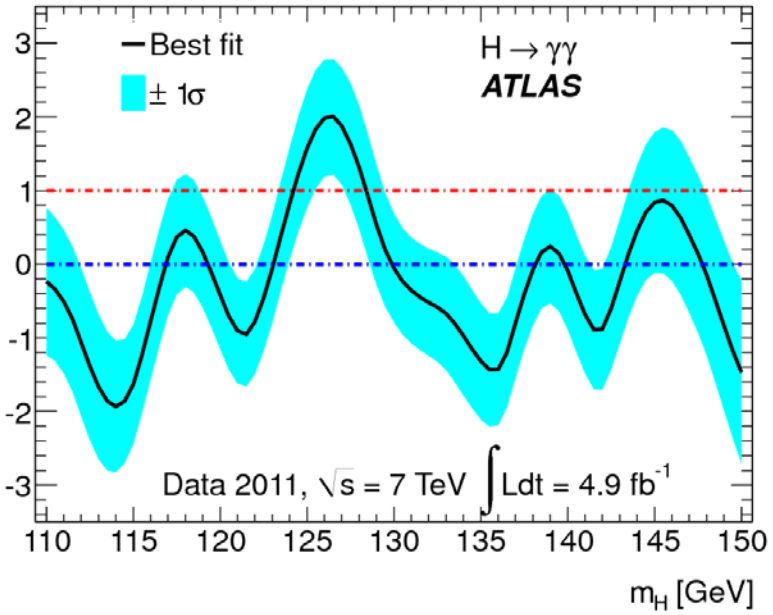
H→γγ: Signal Strength

The rate seen by ATLAS is about twice of that expected from the standard model, similar for CMS. But the uncertainties are large.

Upward fluctuation if it is indeed a standard model signal

"typical" for the first observation





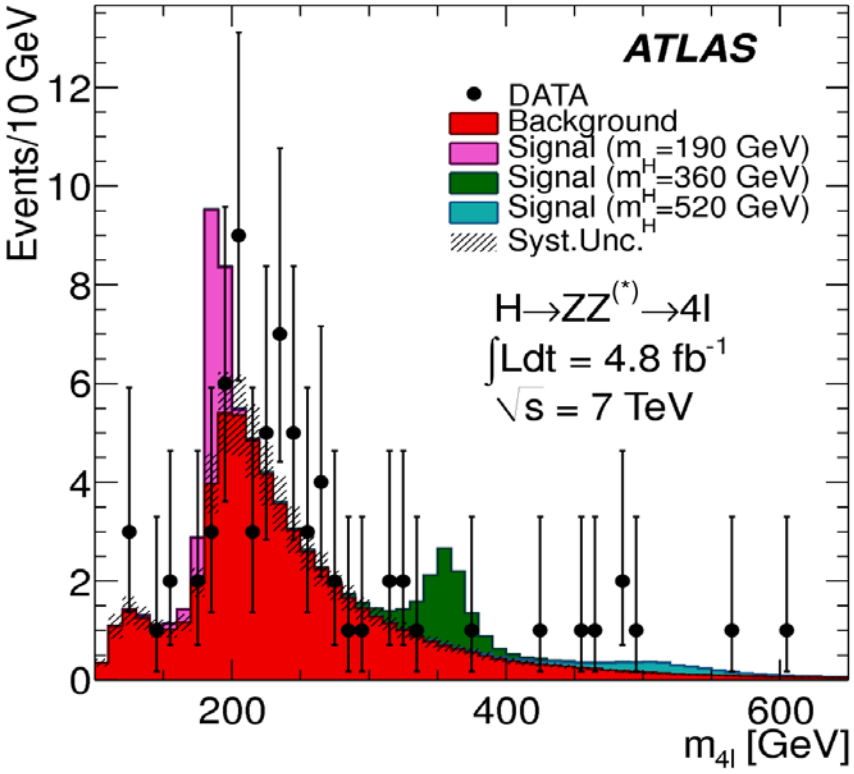
H→ZZ→4l: Mass Distribution

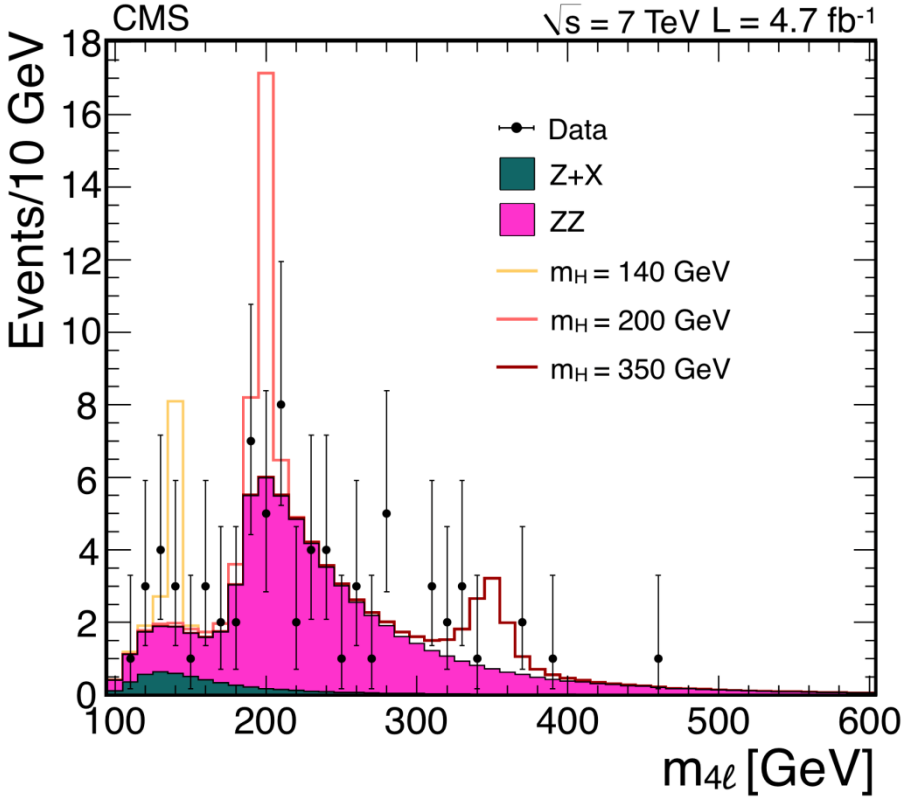
Overall, the sensitivities between ATLAS and CMS are similar.

Number of observed events with m_{4l} > 100 GeV:

71 events in ATLAS compared with 72 in CMS

and the expected distributions are very similar as well.





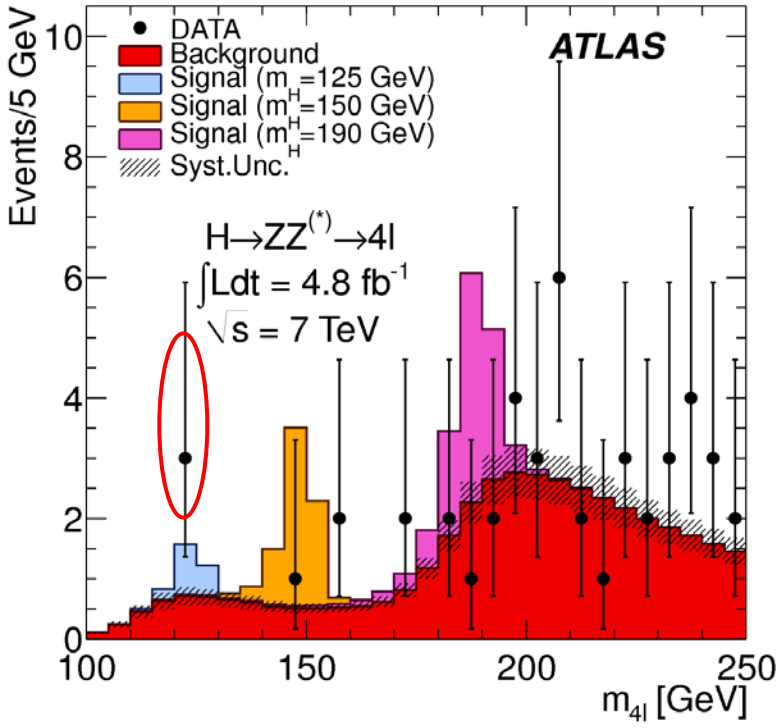
H→ZZ→4l: Low Mass

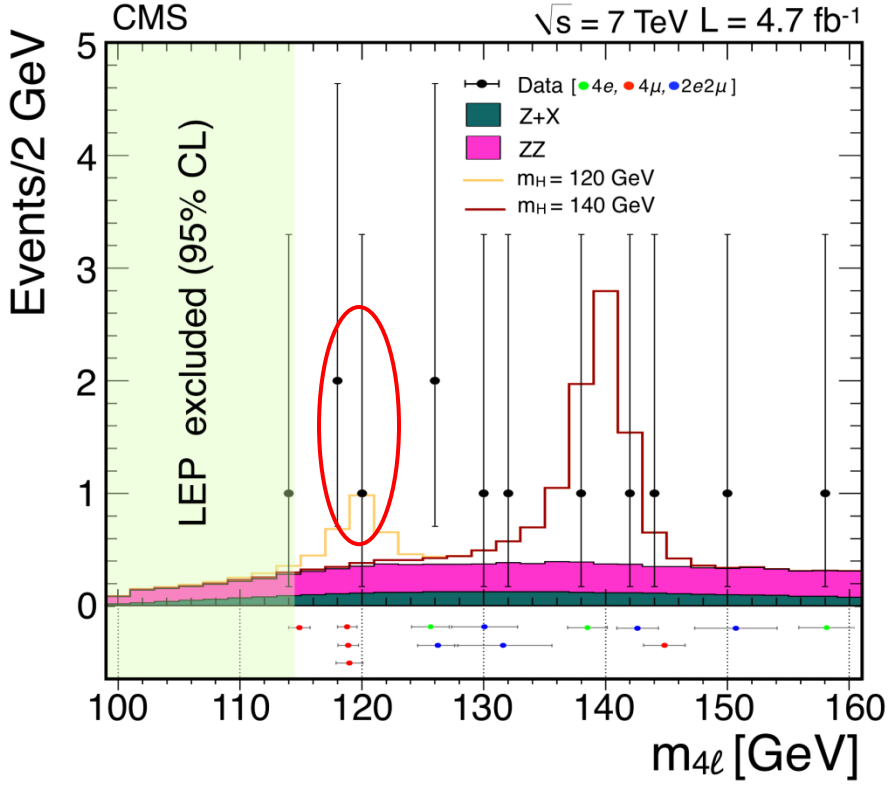
But there is an important difference in the low mass region.

Number of events with $m_{4l} < 150$ GeV:

4 events in ATLAS compared with 12 events in CMS

Why? Is the difference due to cuts? Statistics?





H→ZZ→4l: p-value

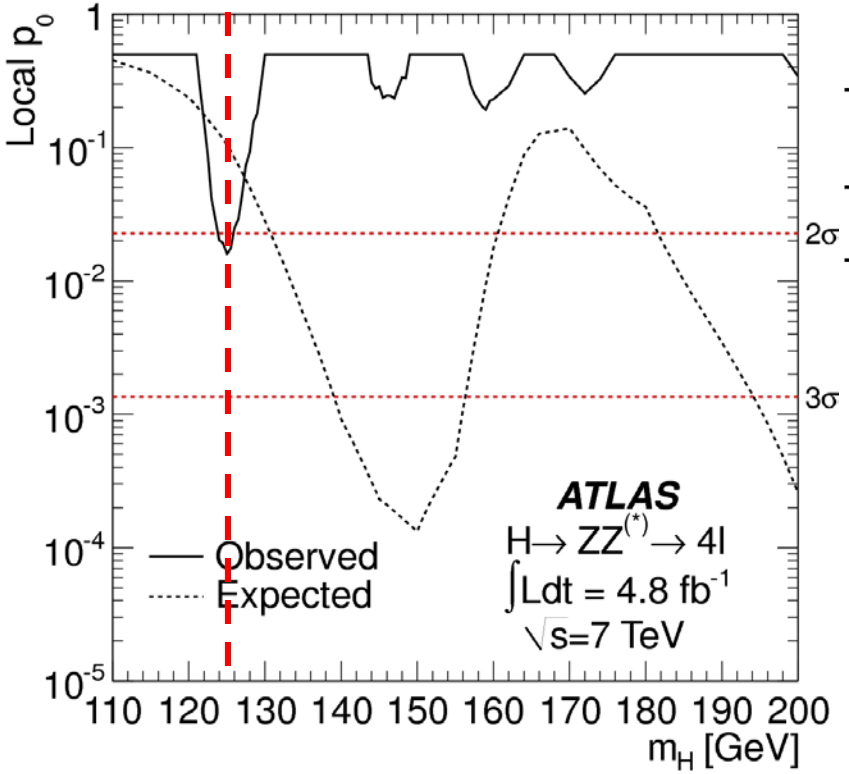
Several small excesses in both experiments

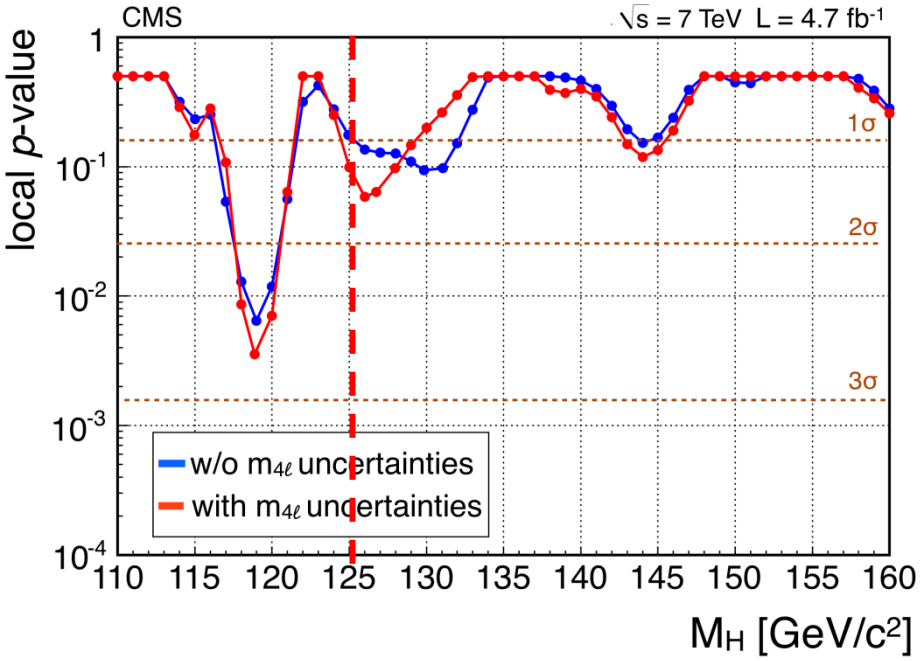
ATLAS: 125, 244 and 500 GeV (2.1σ, 2.2σ, 2.1σ)

CMS: 119, 126 and 320 GeV (2.5σ, 1.5σ, 2σ)

At low mass, the common denominator is 125-126 GeV.

The expected significance at 125 GeV is 1.4σ (ATLAS).





CMS: most significant excess at 119 GeV

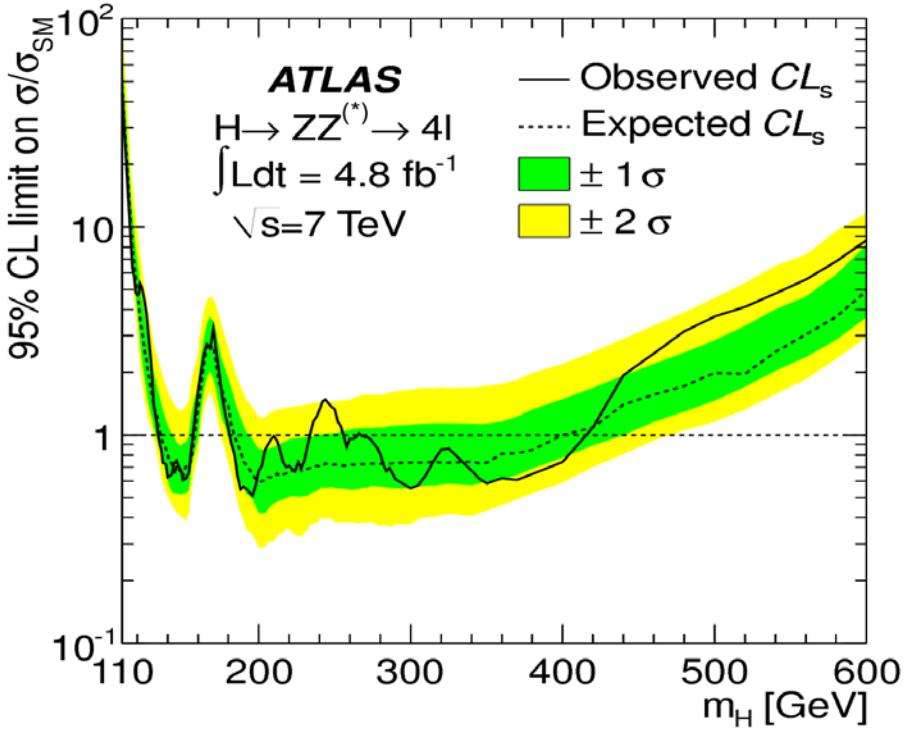
H→ZZ→4l: Exclusions

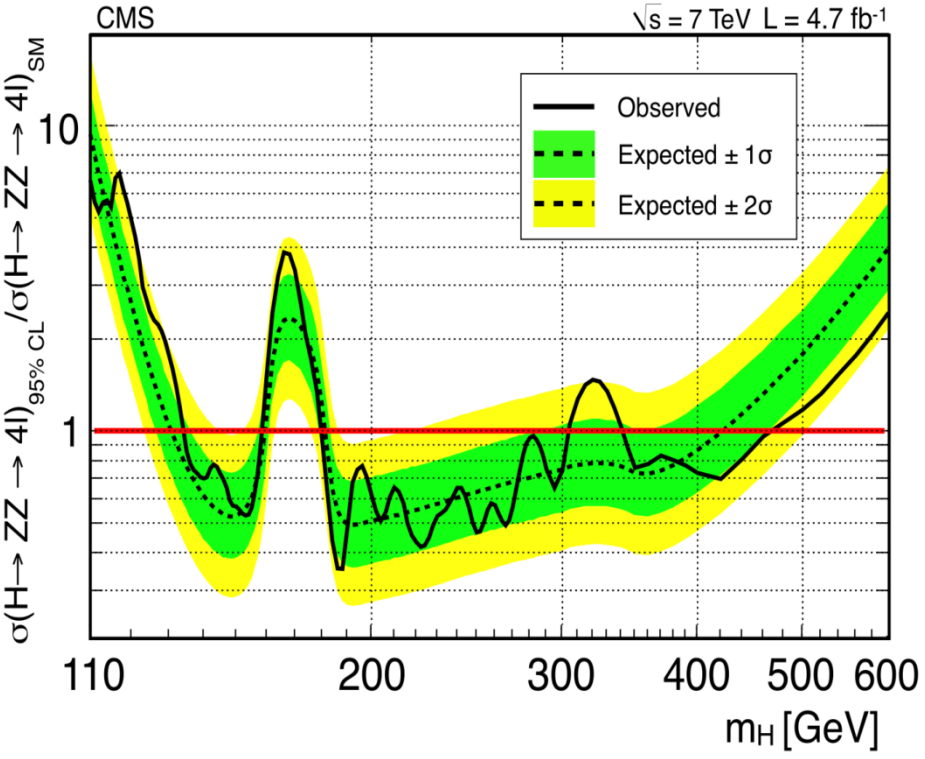
Observed exclusions at 95% CL:

ATLAS: 134-156, 182-233, 256-265 and 268-415 GeV

CMS: 134-158, 180-305 and 340-465 GeV

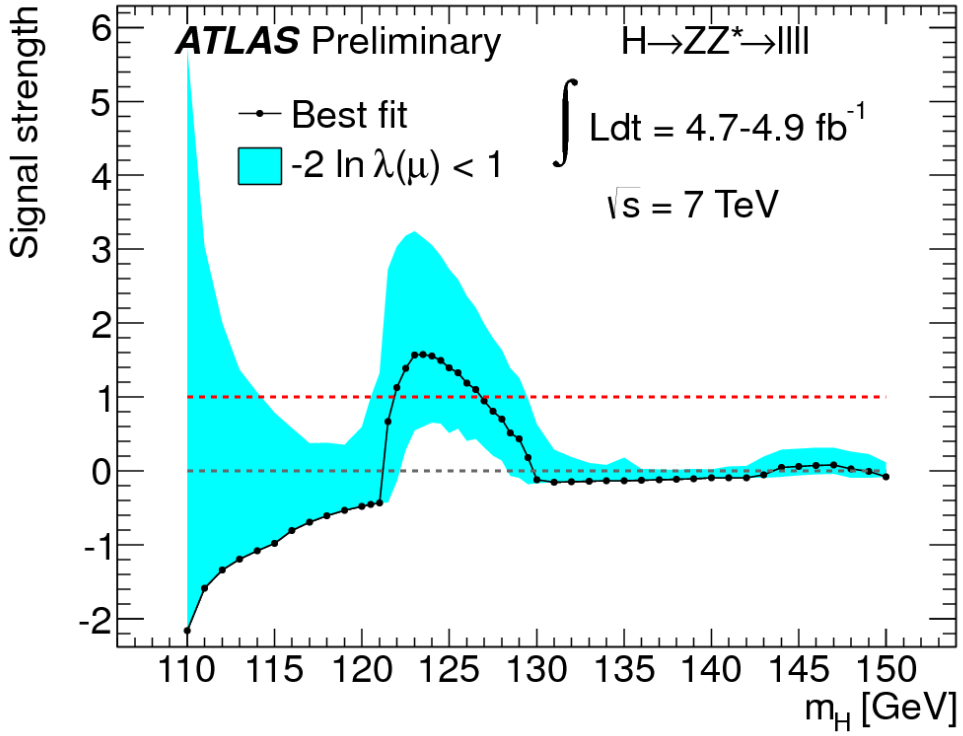
Similar expected exclusions

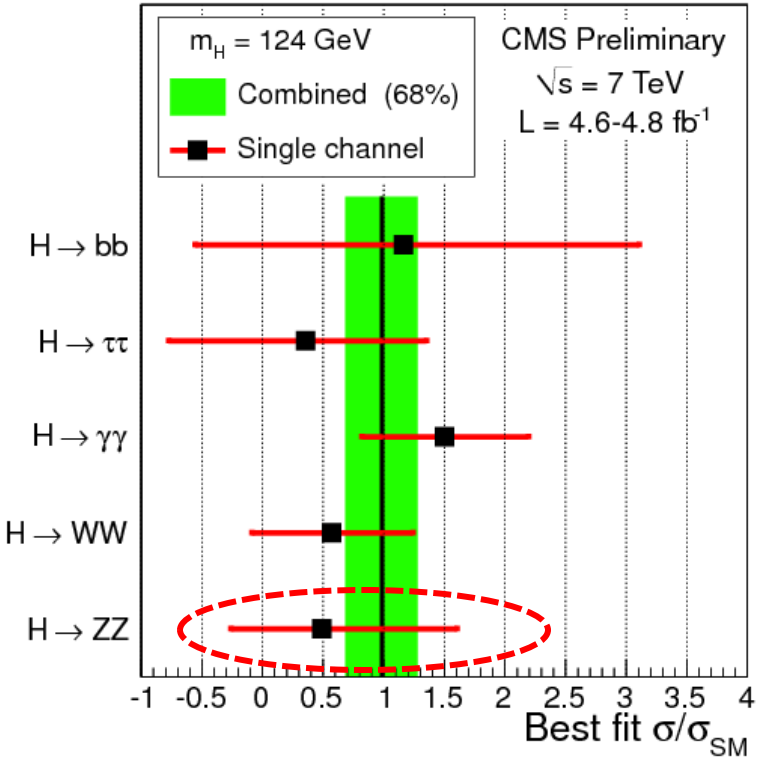




H→ZZ→4l: Signal Strength

Consistent with a standard model Higgs boson
… and *not inconsistent* with no Higgs boson either





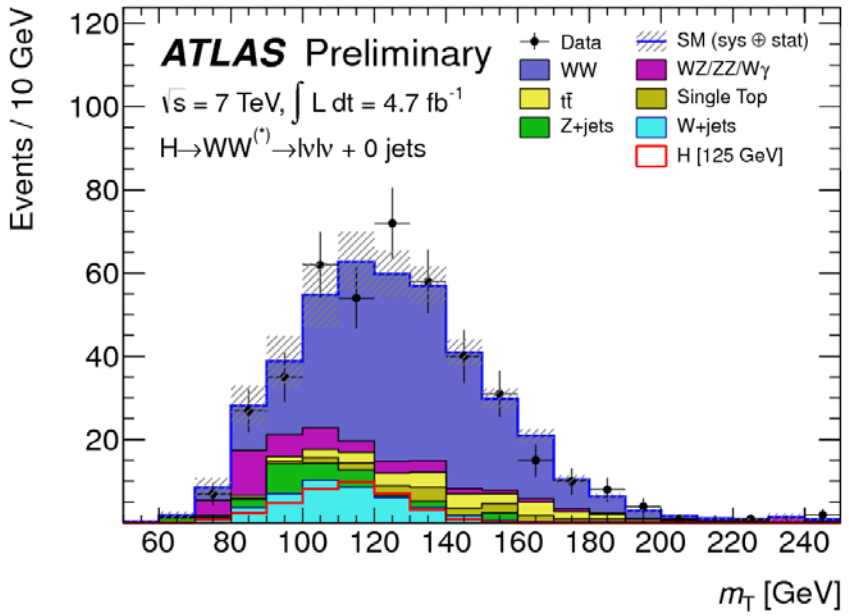
H→WW→lvlv

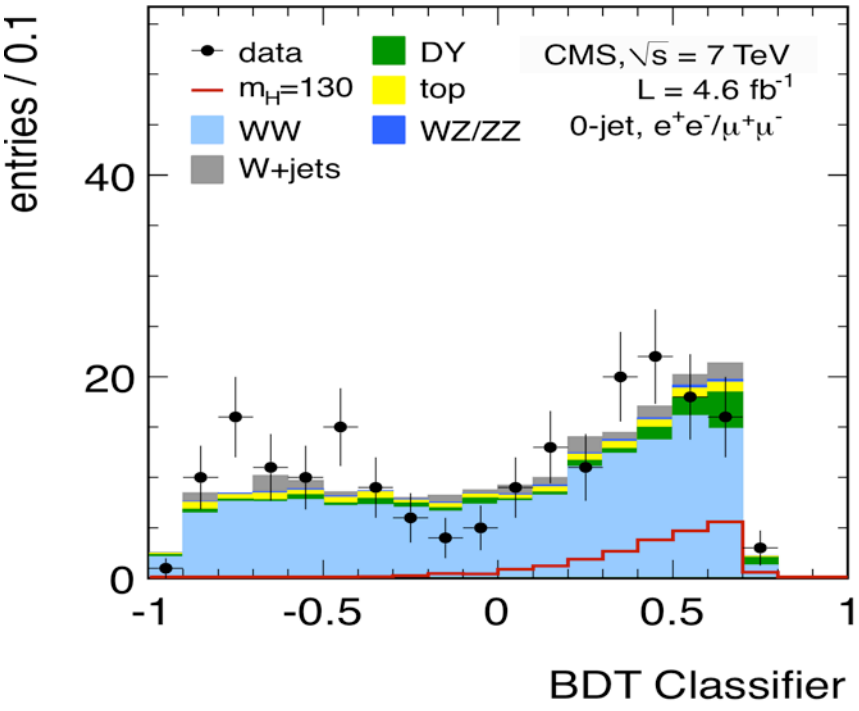
No mass reconstruction, but still the most sensitive final states over a wide Higgs mass range

- ATLAS analysis is based on the fit of the mT distribution
- CMS performed both cut-and-count and BDT analyses

Background understanding is more critical

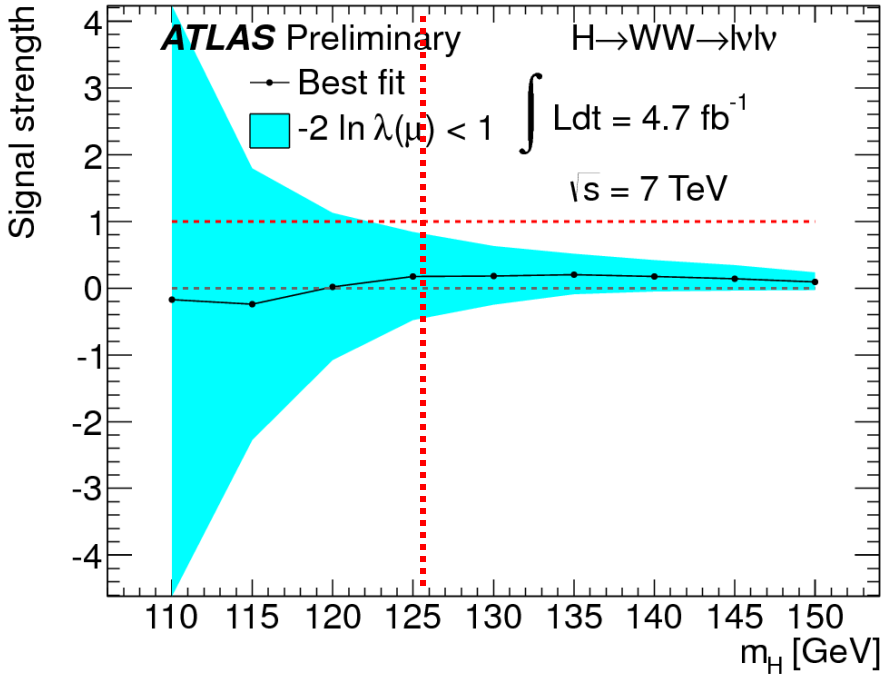
- Small backgrounds (Z/γ*+jets, W+jets, Wγ(*), …) become important at low mass

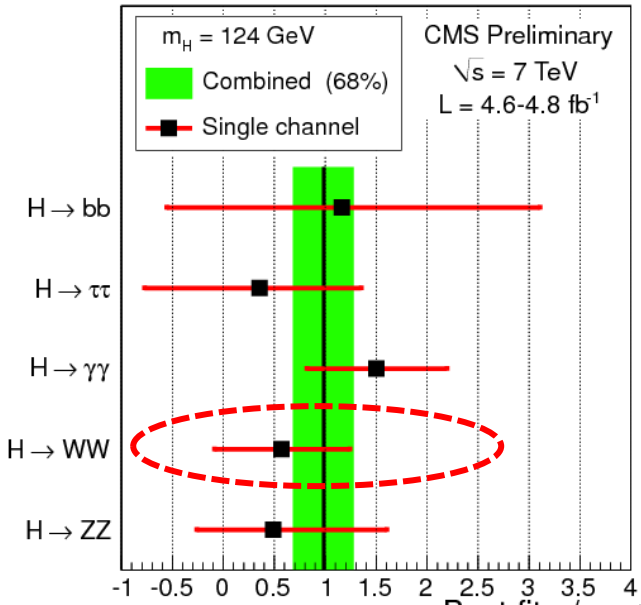


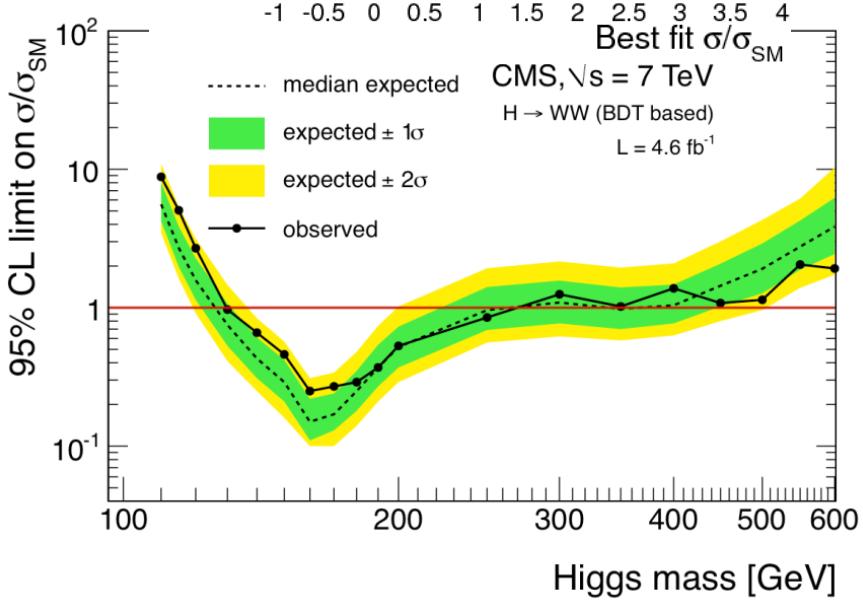


H→WW→lνlν

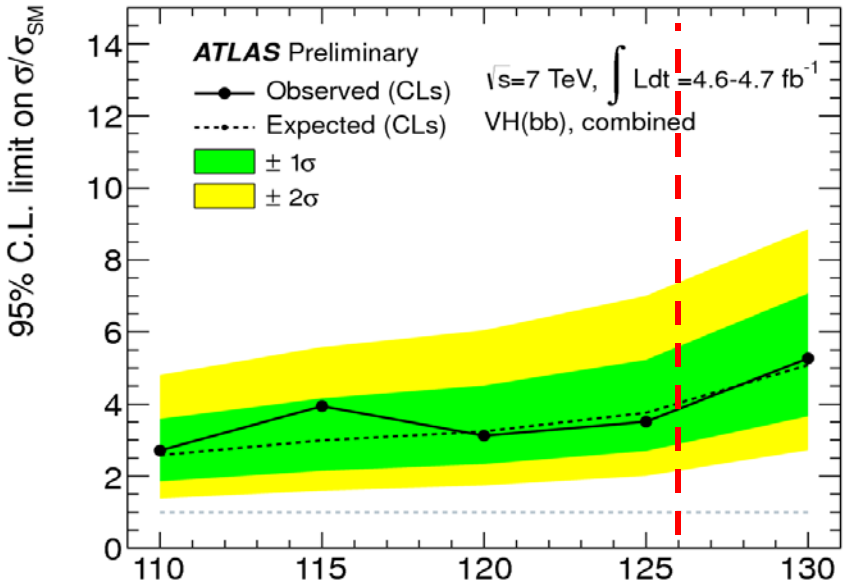
No significant excess over the entire mass range, but not sensitive enough to exclude a 125-126 GeV Higgs boson.

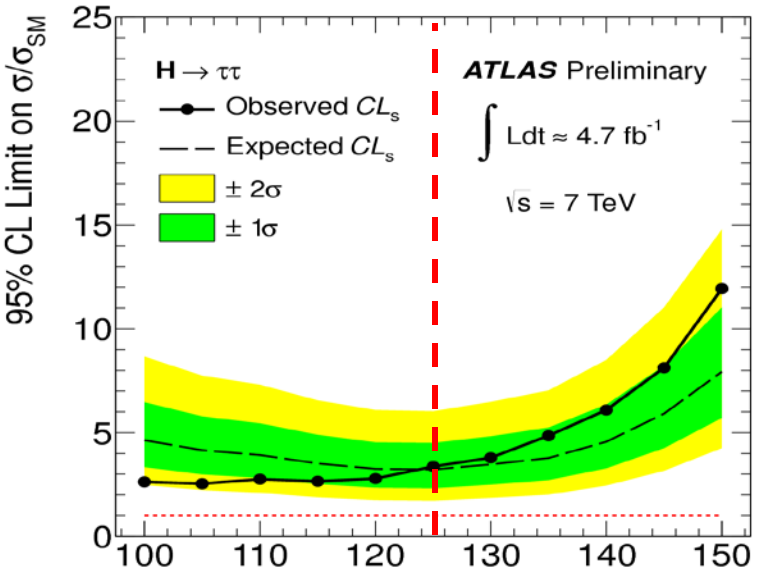


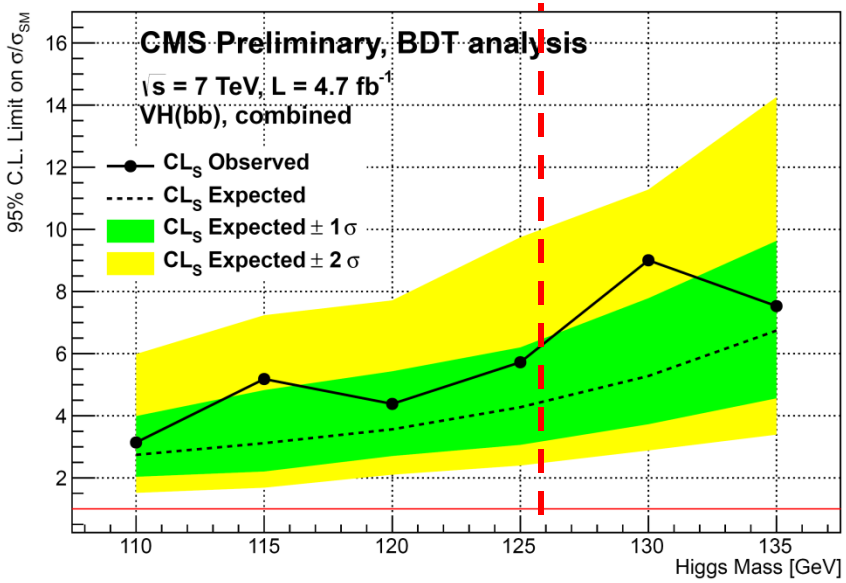


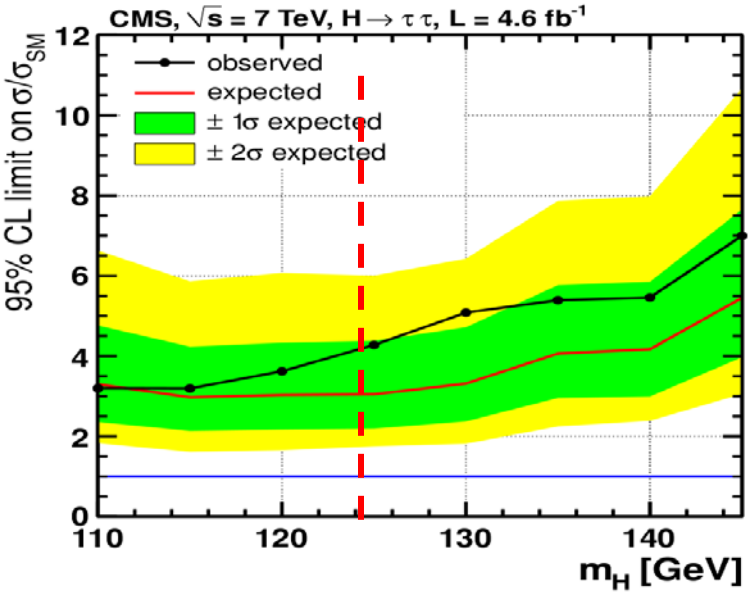


bb and ττ

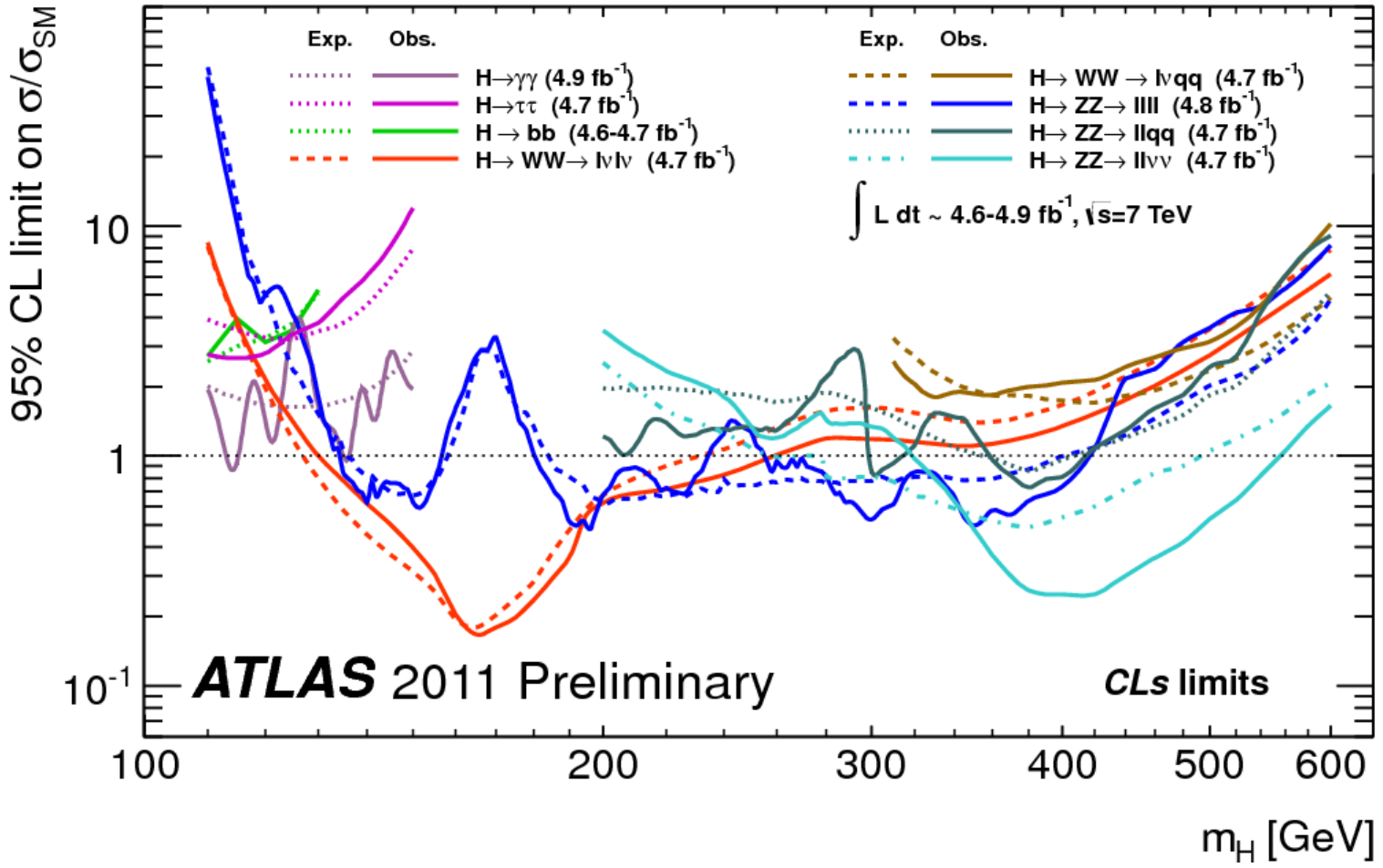

ATLAS Preliminary
√s=7 TeV, ∫ Ldt =4.6-4.7 fb-1
Observed (CLs)
Expected (CLs)
± 1σ
± 2σ
VH(bb), combined
95% C.L. limit on σ/σSM


H → ττ
ATLAS Preliminary
Observed CLs
Expected CLs
± 2σ
± 1σ
∫ Ldt ≈ 4.7 fb-1
√s = 7 TeV
95% CL Limit on σ/σSM


CMS Preliminary, BDT analysis
√s = 7 TeV, L = 4.7 fb-1
VH(bb), combined
CLs Observed
CLs Expected
CLs Expected ± 1σ
CLs Expected ± 2σ
95% C.L. Limit on σ/σSM
Higgs Mass [GeV]


CMS, √s = 7 TeV, H → ττ, L = 4.6 fb-1
observed
expected
± 1σ expected
± 2σ expected
95% CL limit on σ/σSM
mH [GeV]

Combination: Individual Channels



Every channel contributes, H→WW and H→ZZ provide most of the exclusion power. The H→WW→lvlv channel has the best sensitivity down to 120 GeV (ATLAS), 125 GeV (CMS)!

Combination: Exclusions

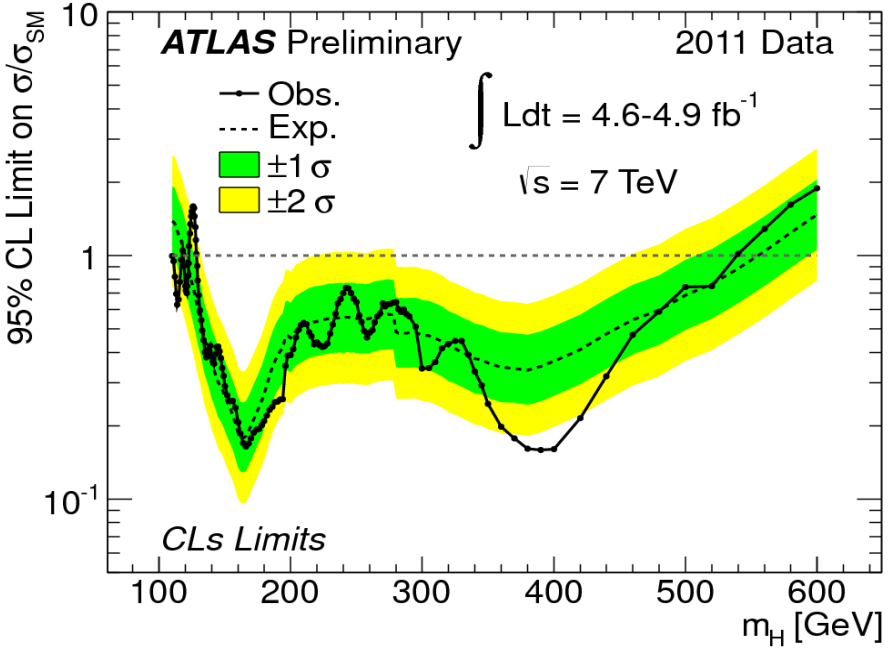
Combined exclusion ranges:

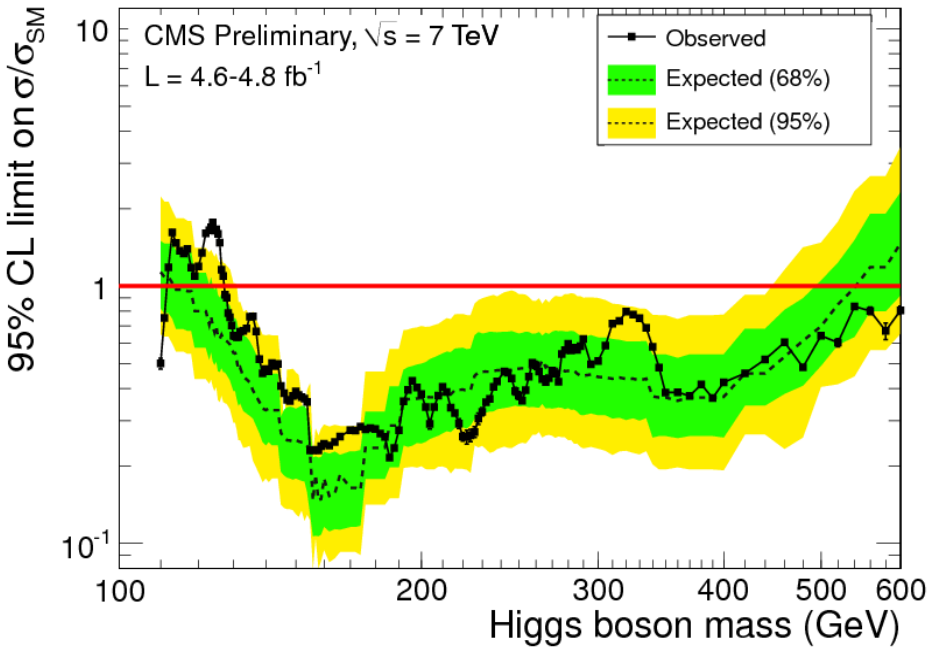
ATLAS: 110-117.5, 118.5-122.5 and 129-539 GeV

CMS: 127-600 GeV

Unexcluded low mass ranges by any experiment:

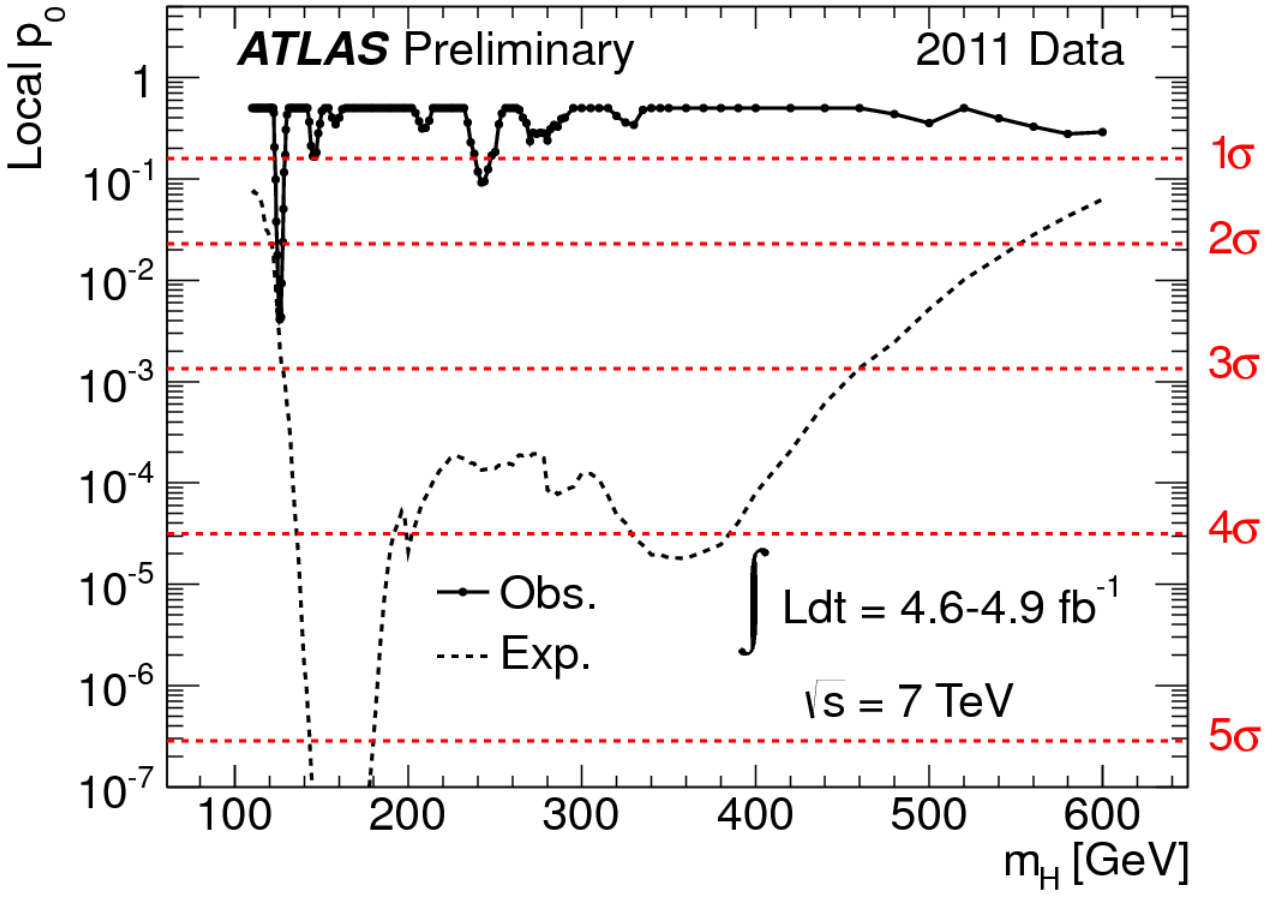
117.5-118.5 and 122.5-127 GeV ⇒ 5 GeV windows



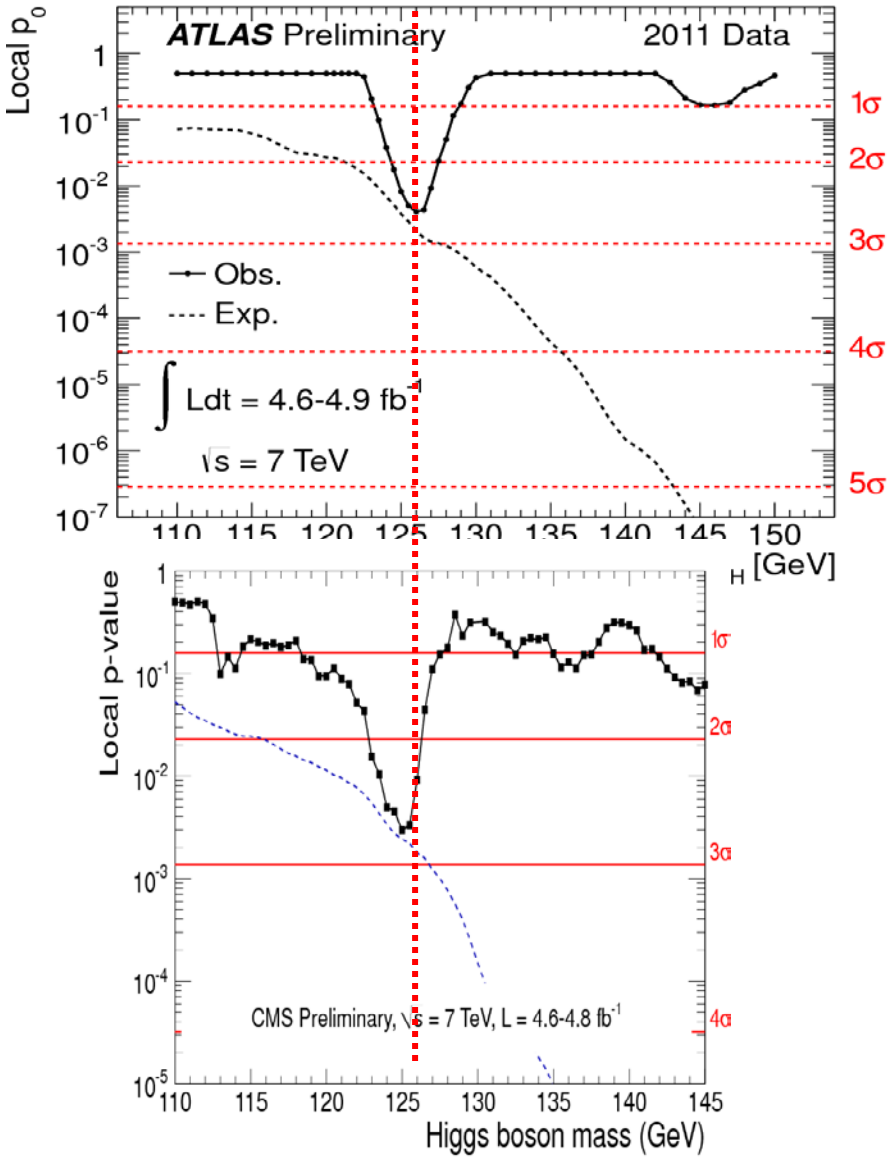


Combination: p-value

Only one excess with more than 2σ local significance over the entire mass search range



Combination: Excess



Excess from combination with a local significance

- **ATLAS: 2.5σ at 126 GeV**
- **CMS: 3.1σ at 125 GeV**

The corresponding global significances:

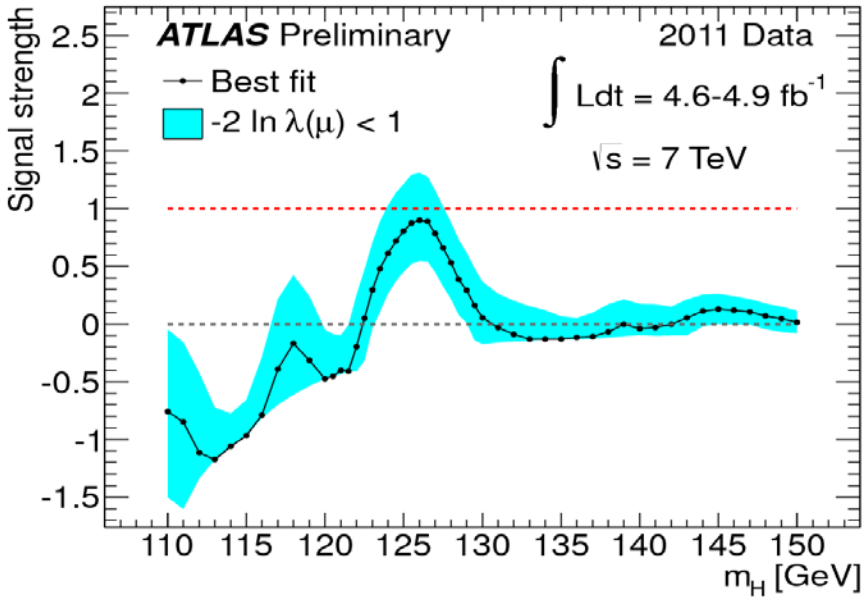
- **ATLAS: 30% for 110-600 GeV, 10% 110-146 GeV**
- **CMS: 1.5σ for 110-600 GeV, 2.1σ for 110-145 GeV**

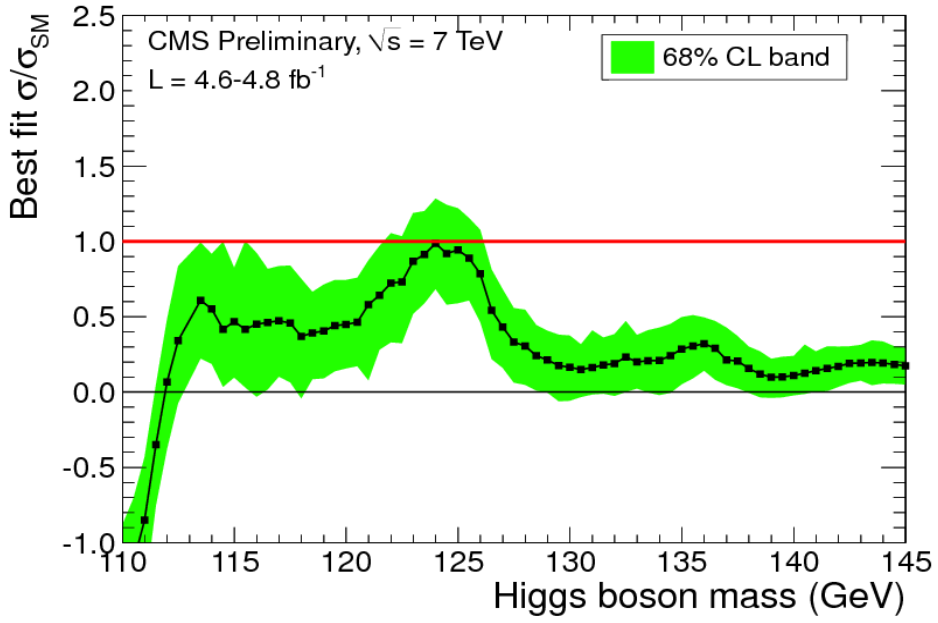
Not small probabilities for potential background fluctuations.

Combination: Signal Strength

The signal strengths from the combinations are consistent with the standard model expectation.

Best fit value from ATLAS: $\hat{\mu} = \frac{\sigma}{\sigma_{SM}} = 0.9^{+0.4}_{-0.3}$





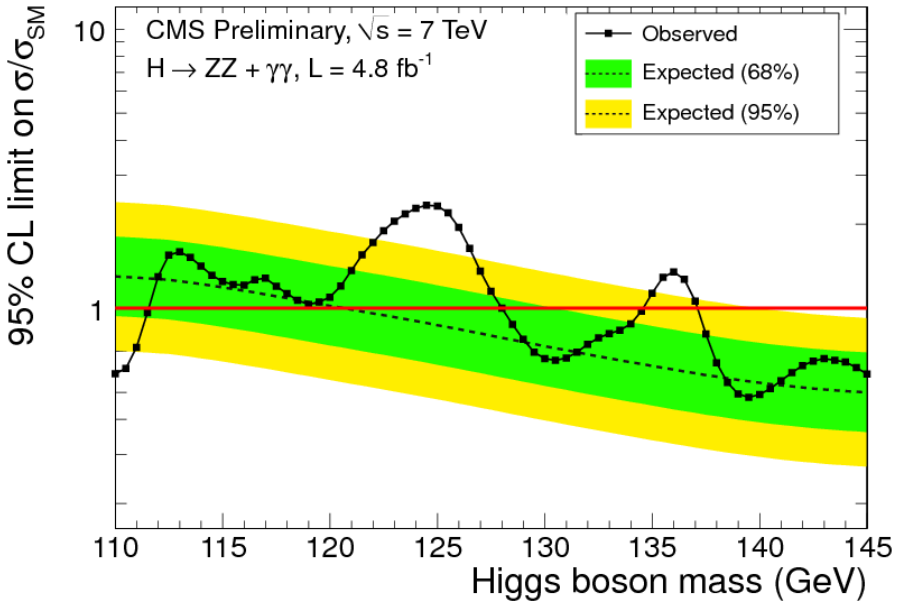
Combination: Breakdowns

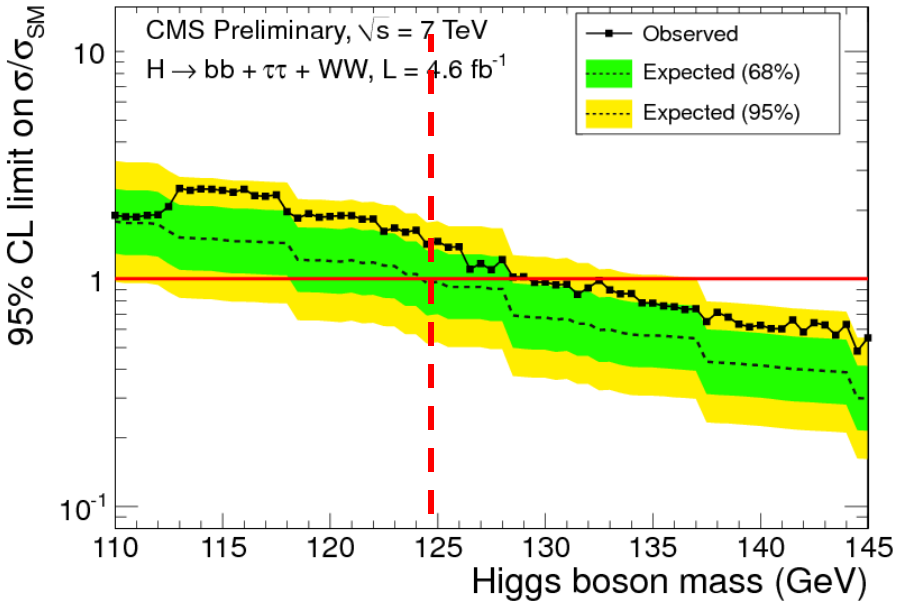
Breakdowns according to mass resolution:

High: $H \to \gamma\gamma,\ H \to ZZ^{(*)} \to 4\ell$ (leptons and photons)

Low: $H \to b\bar{b},\ H \to \tau\tau,\ H \to WW$ (leptons, jets and $\not{E}_T$)

Large excesses in high resolution channels, *at best* marginal corroborative results from low resolution channels.

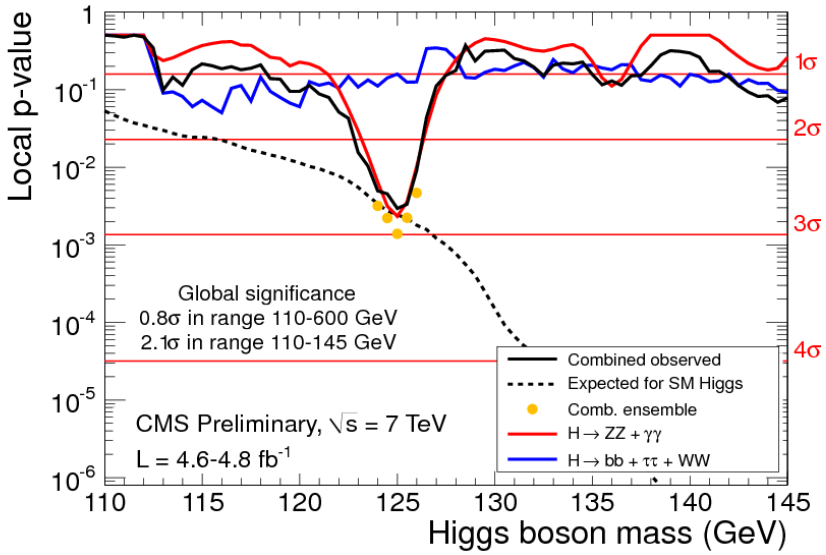


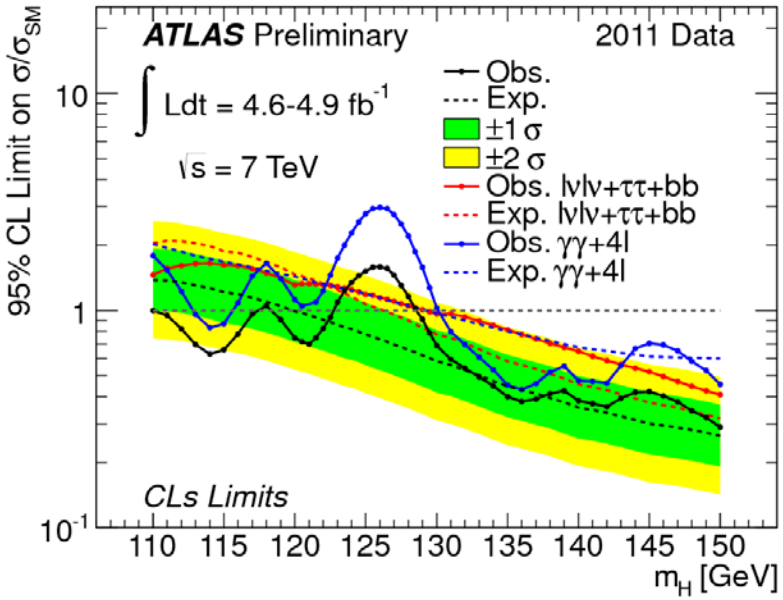


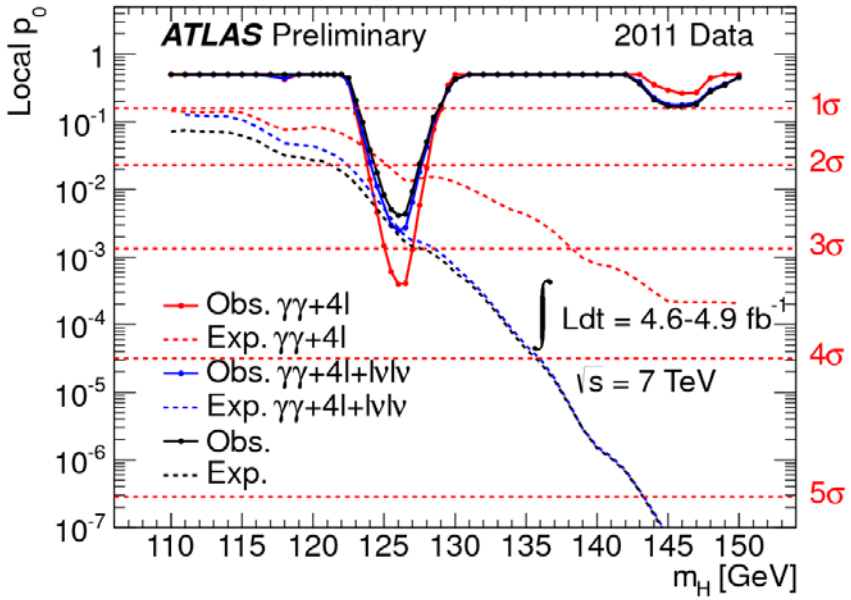
Combination: Breakdowns

ATLAS sees a similar pattern:

H→γγ and H→ZZ→4l have the largest excesses. The low resolution channels do not contribute much, in fact they reduce the significance.

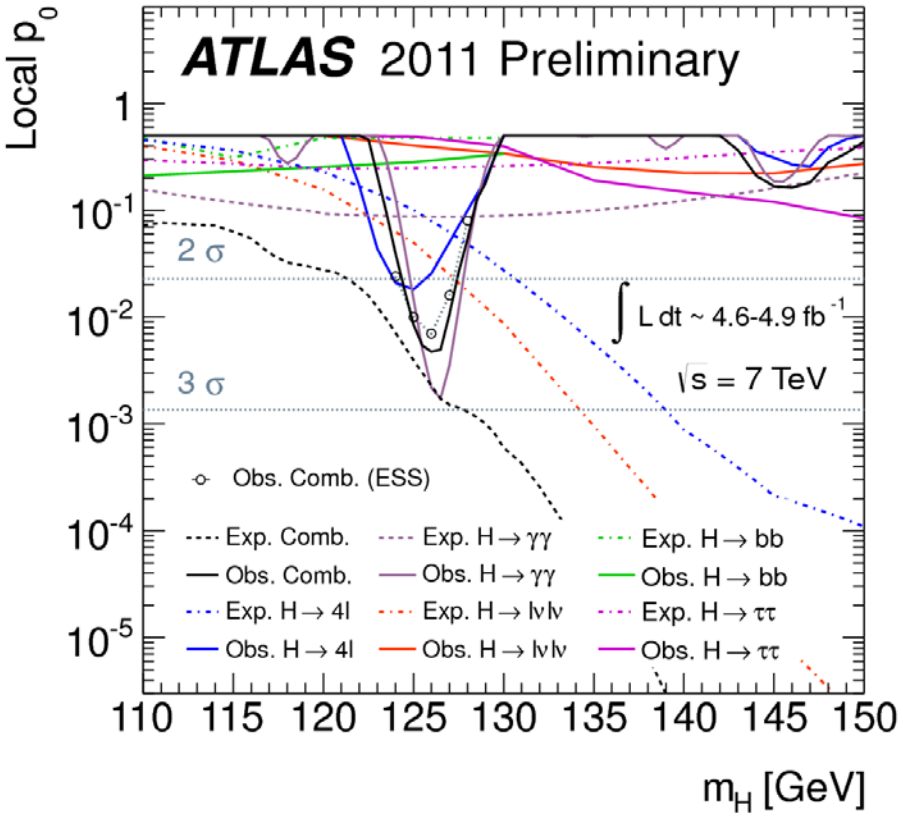


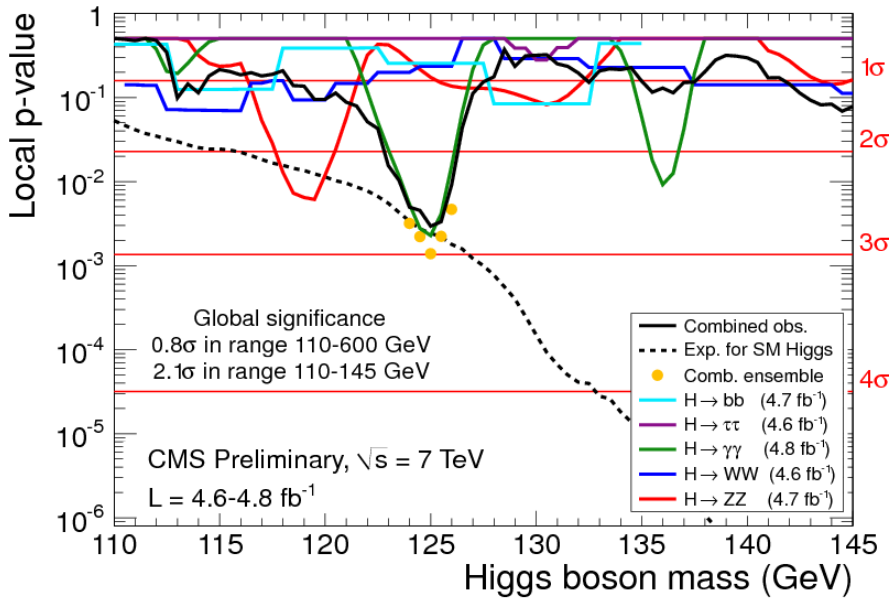




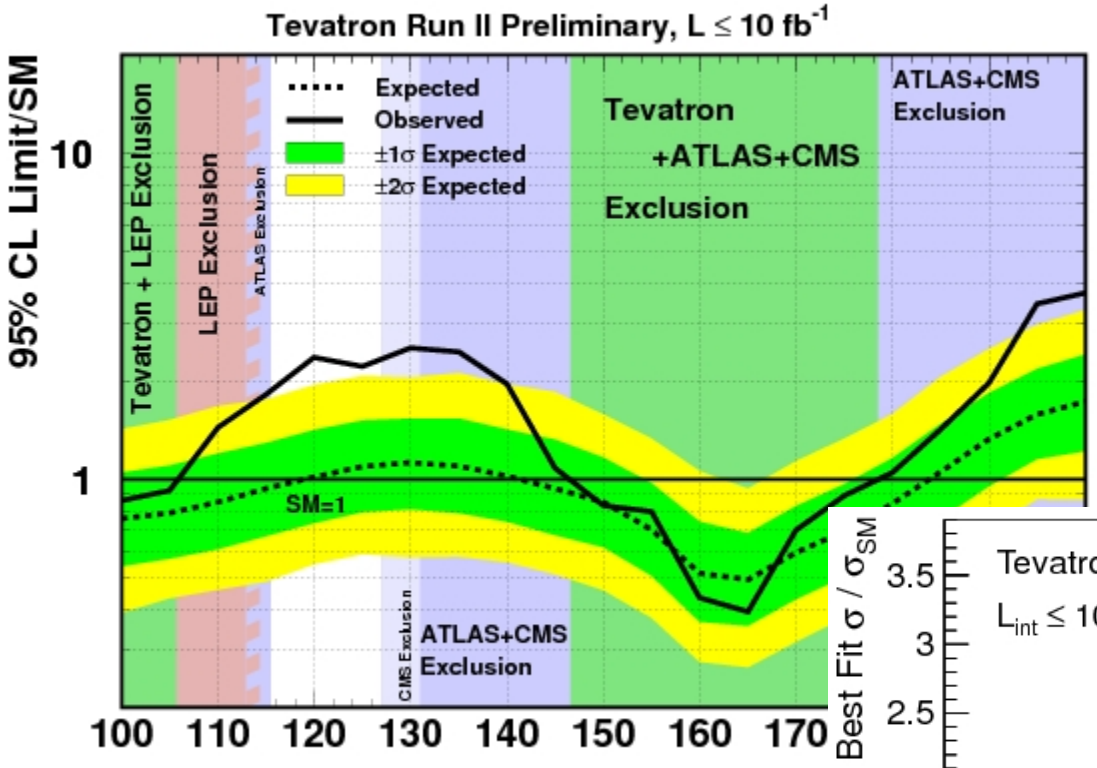
Combinations: Breakdowns

ATALS: both H→γγ and H→ZZ→4l contribute at 126 GeV
CMS: completely dominated by H→γγ at 125 GeV

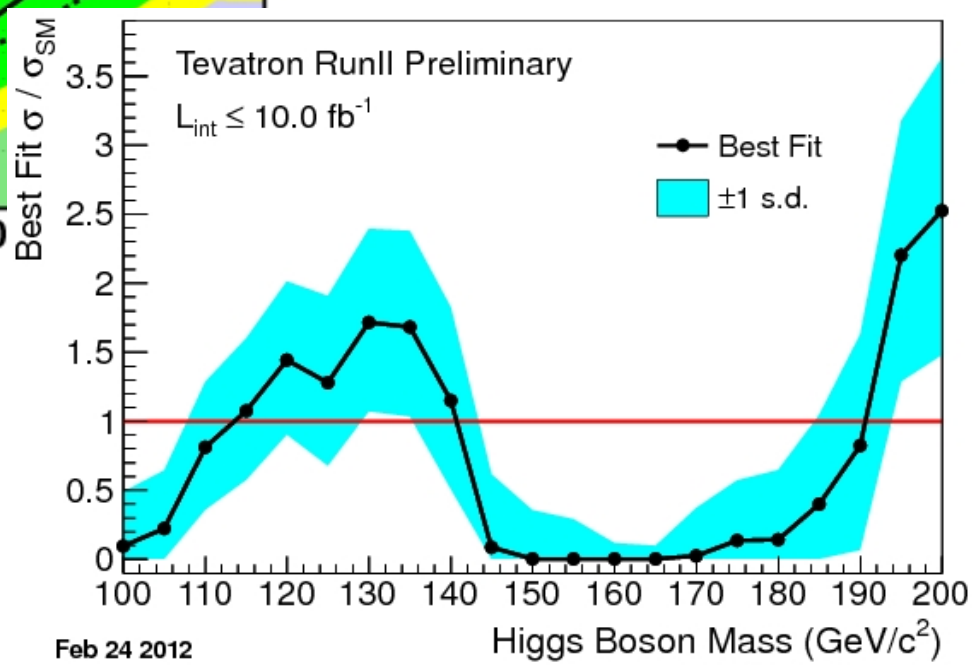




Tevatron

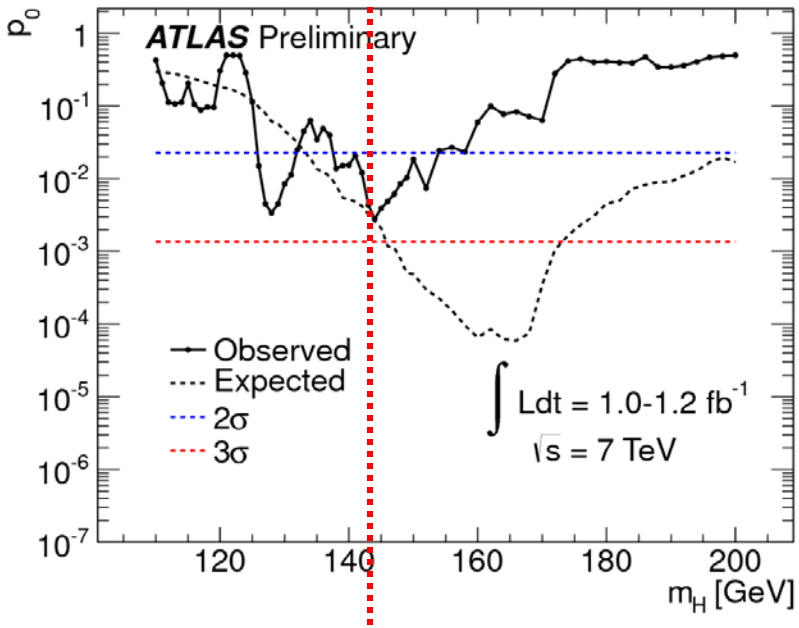


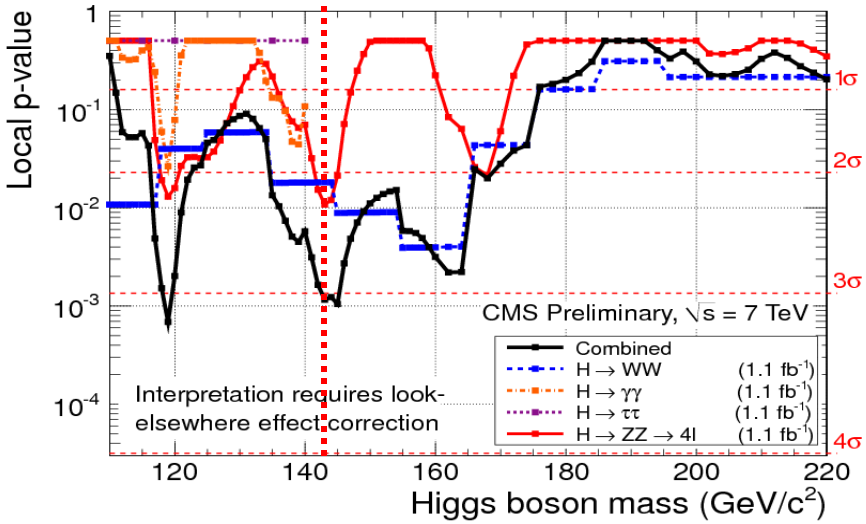
A broad excess around 120 GeV corresponding to a local significance of 2.7σ



The excess is mostly from H→bb and the overall rate is consistent with the SM expectation.

Once upon a time…





Both experiments had close to 3σ excess at 145 GeV from both low and high resolution channels

Higgs cornered in Grenoble

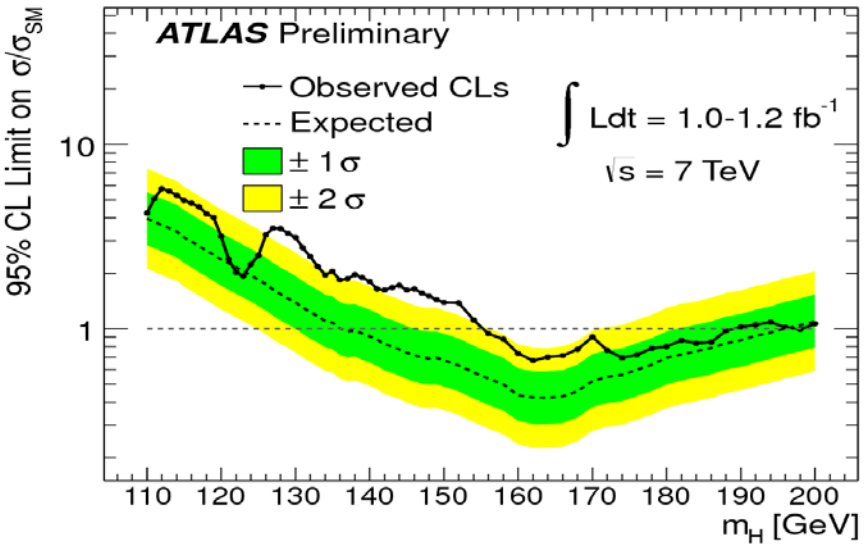
Jul 22, 2011 27 comments

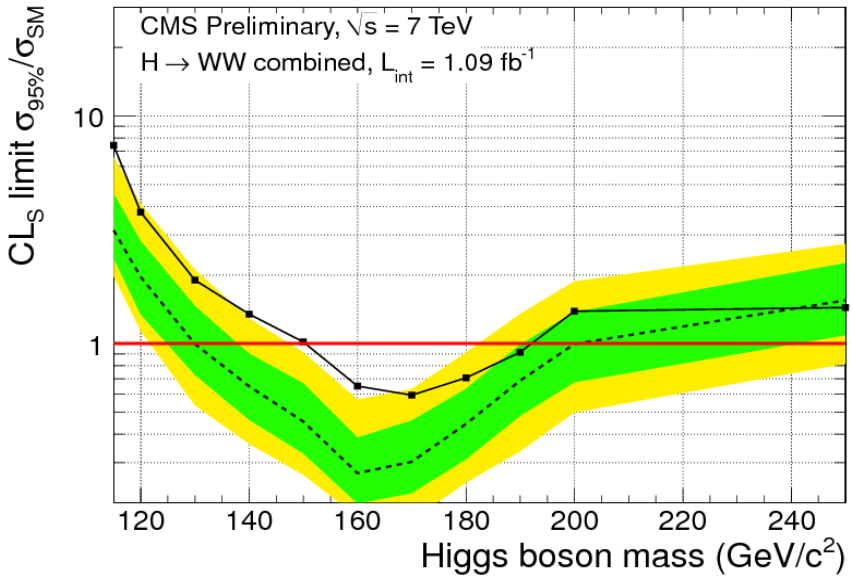
All eyes on Grenoble for the latest on the Higgs

The latest data from experiments at the Large Hadron Collider (LHC) leave significantly less room for the Higgs boson to hide – that is the take-home message from the Europhysics Conference of High-Energy Physics in Grenoble, France.

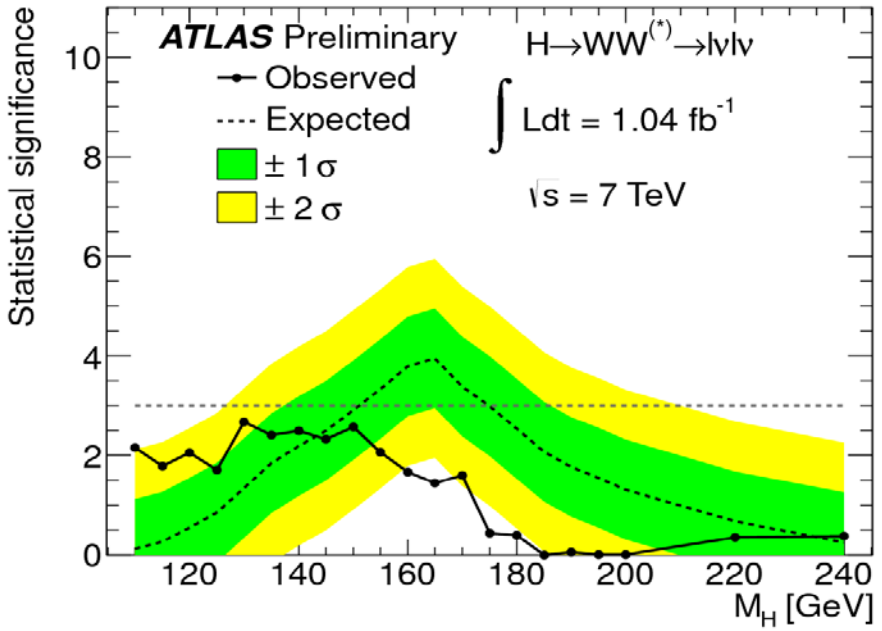
"It's getting real!" remarked one particle physicist excitedly as delegates emerged from Friday afternoon's session of the conference, which runs until 27 July. In the space of a few presentations, the possible hiding places for the Higgs boson have been shrunk dramatically thanks to data collected this year at the LHC at CERN.

What was shown…





Broad excess around 145 GeV in H→WW→lvlv observed in both experiments. The rates were consistent with expectation from the standard model expectation.



Final Comments

Both ATLAS and CMS have observed excesses of 2.5σ or more around 125-126 GeV. The excesses are dominated by the high mass-resolution $H\rightarrow\gamma\gamma$ and $H\rightarrow ZZ\rightarrow 4l$ channels.

The low mass-resolution $H\rightarrow WW$, $H\rightarrow bb$ and $H\rightarrow\tau\tau$ channels do not show significant excesses. However, they combined do not exclude the mass region 125-126 GeV either.

Don't discount look-elsewhere-effect beyond statistics: *look across ring (LHC), look across pond (Tevatron)*, …

Close but no cigar! Can only be resolved with more data, ICHEP this year will be exciting…