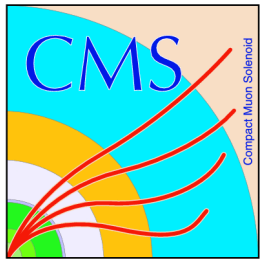


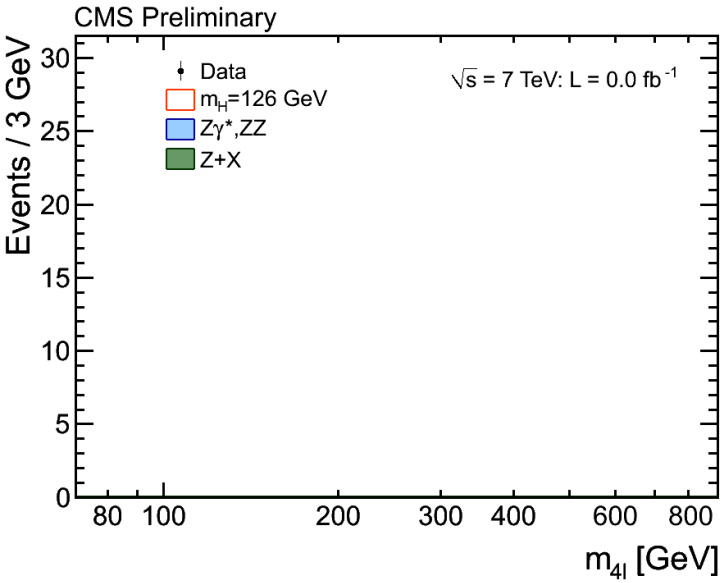
Mass measurement of the Higgs boson

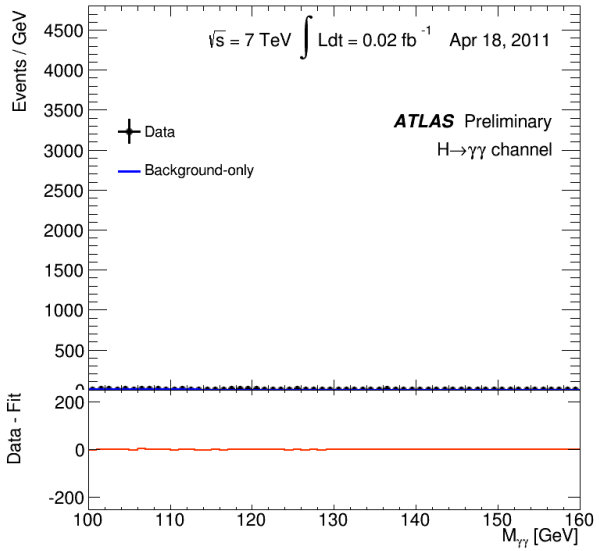
Mykhailo DALCHENKO

(on behalf of the ATLAS and CMS collaborations)

Discovery

Channel	Integrated luminosity (CMS)	Integrated luminosity (ATLAS)
H→γγ	5.1(2011)+19.6(2012)	4.6(2011)+20.7(2012)
H→ZZ*→4l	5.1(2011)+19.6(2012)	4.6(2011)+20.7(2012)
H→WW→lνlν	4.9(2011)+19.5(2012)	4.6(2011)+20.7(2012)
H→ττ	4.9(2011)+19.4(2012)	4.6(2011)+13(2012)
H→bb	5.0(2011)+12.1(2012)	4.6(2011)+13(2012)





Next questions

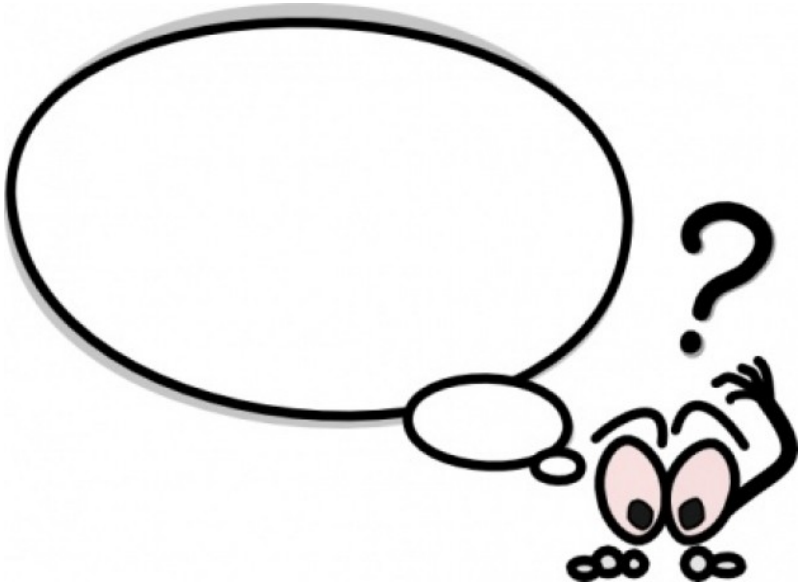
- Statistically significant?
- Yes
- Spin/parity?
- See talk by

Jean Baptiste de Vivie

- Couplings?
- See talk by

José Ocariz

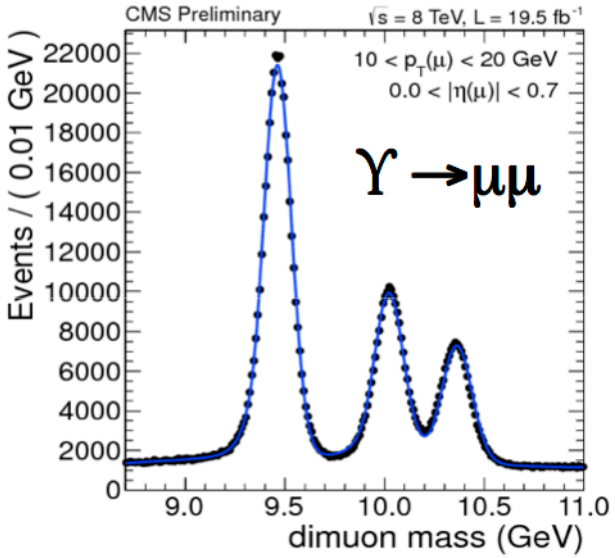
- Mass: <u>let's concentrate on this</u>



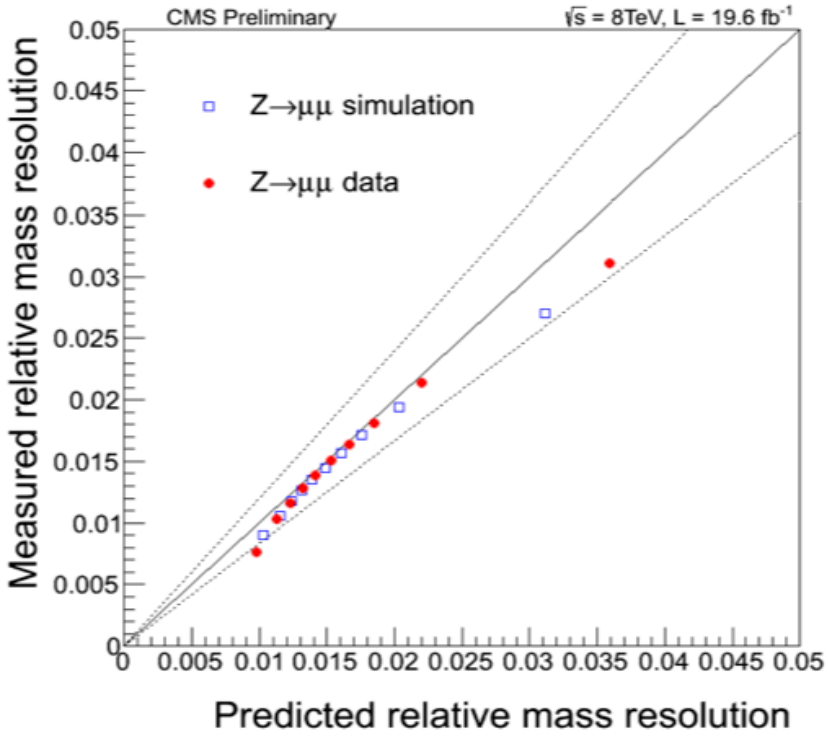
Mass measurement methods

- *the mass is obtained from a likelihood fit performed for test mass scanning the interesting mass range*
- *signal template taken from MC, systematics added on the peak position and on the peak width*
- *data corrected for scale using Z→ll*
- *MC corrected so to match resolution in data*
- *CMS is using mass uncertainties i.e. giving 3D mass measurement in H→ZZ→4l case*

Scale uncertainties: muons



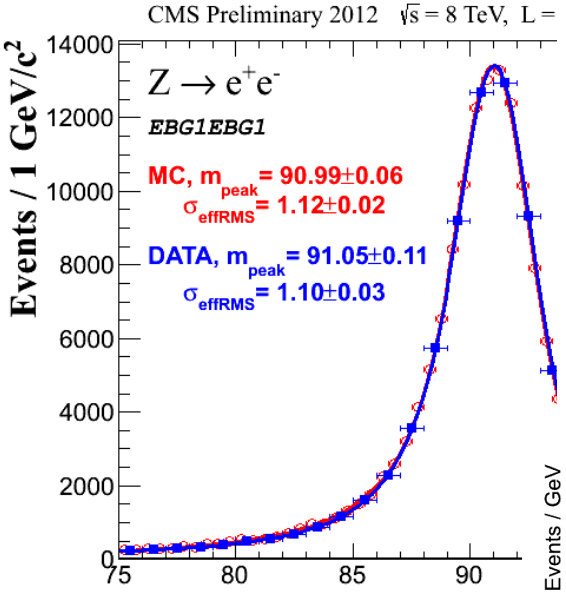
Muon scale and resolution is obtained and validated with Z, J/ψ and Υ

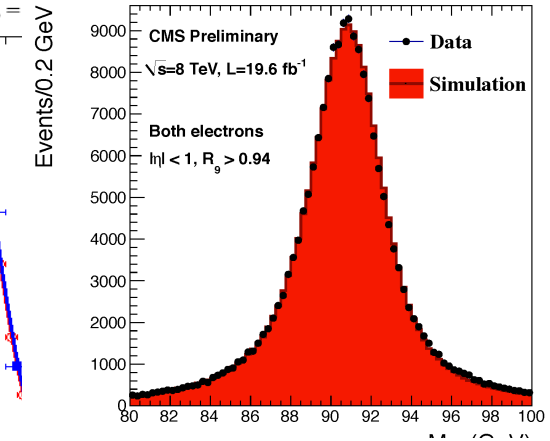


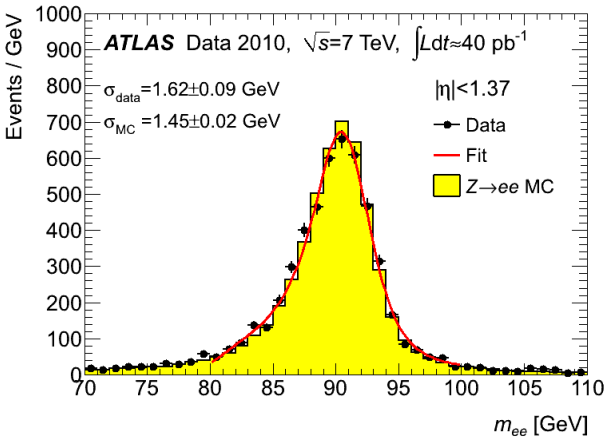
Data/MC agreement then is:

- *within 0.1% in energy scale*
- *agreement between predicted and measured higgs mass resolution is within 20%*

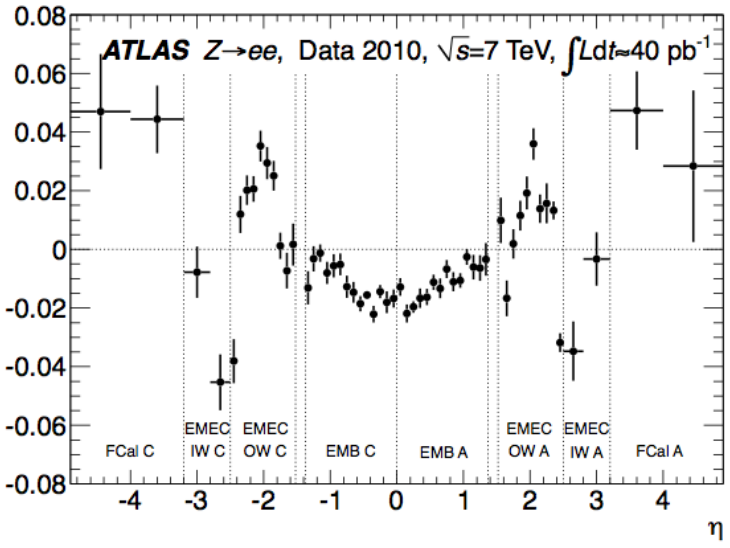
Scale uncertainties: e/γ







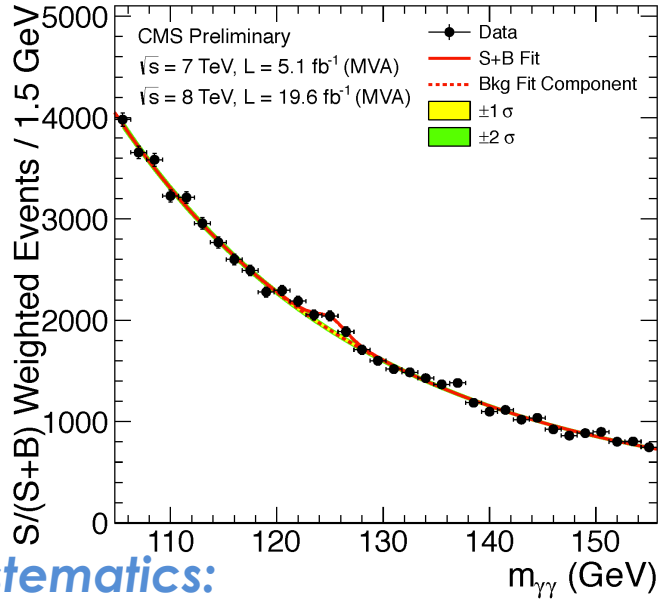
Energy scale for electrons and photons is very well controlled. Verification is done with Z (high-pT) and J/ψ (low-pT) for electrons. For the photons Zee mass spectrum with electrons reconstructed as photons is provided.



Data/MC agreement on energy scale is from 0.2% (high-pT, barrel) to 1.5% (low-pT, endcaps)

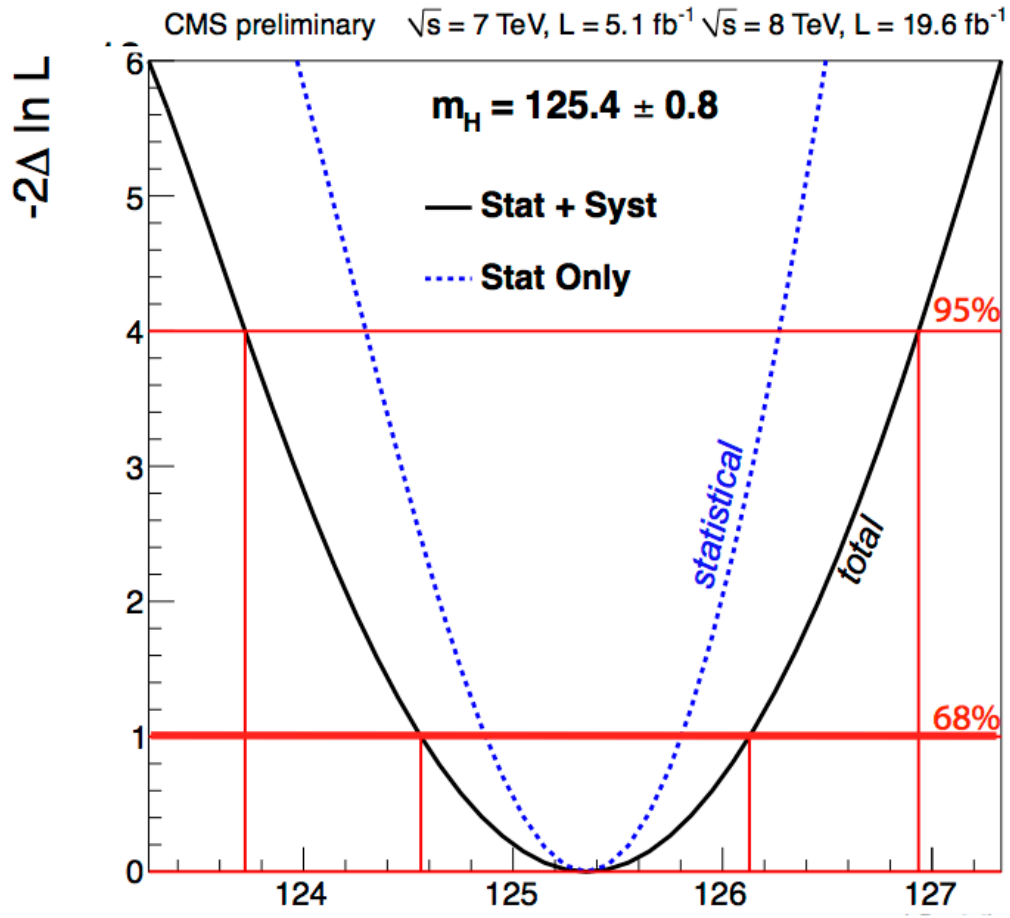
Results: H→γγ (CMS)

$m_H = 125.4 \pm 0.5\,(\text{stat.}) \pm 0.6\,(\text{syst.})$ GeV



Systematics:

- *0.25% from the imperfect modelling by the MC of e/ γ differences*
- *0.4% from the possible non-linearity of the scale extrapolated from Z mass to 125 GeV*



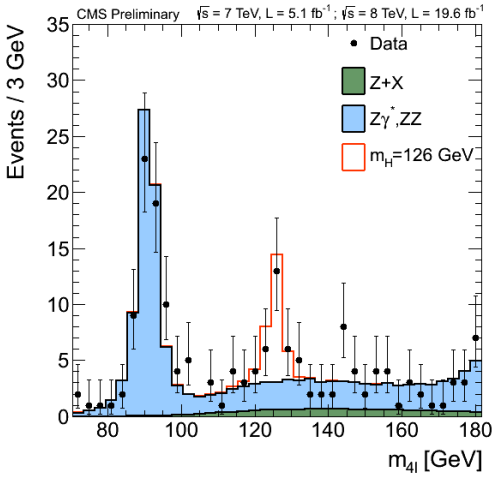
Statistical component obtained from a scan with the nuisance parameters fixed to their best-fit values

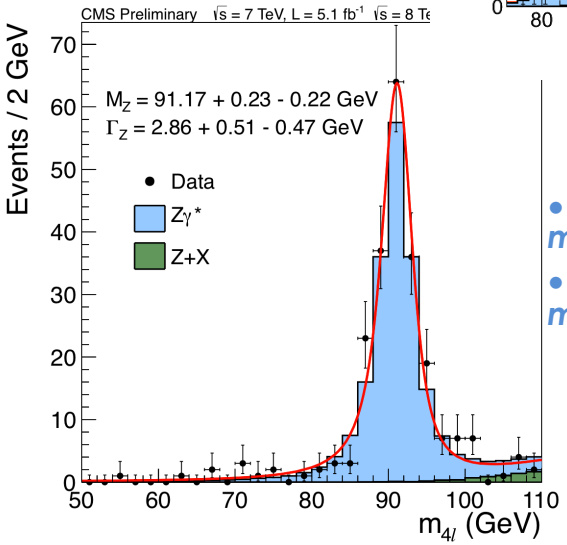
Results: H→ZZ→4l (CMS)

- 3D model (m4l, KD, per-event m4l uncertainty)

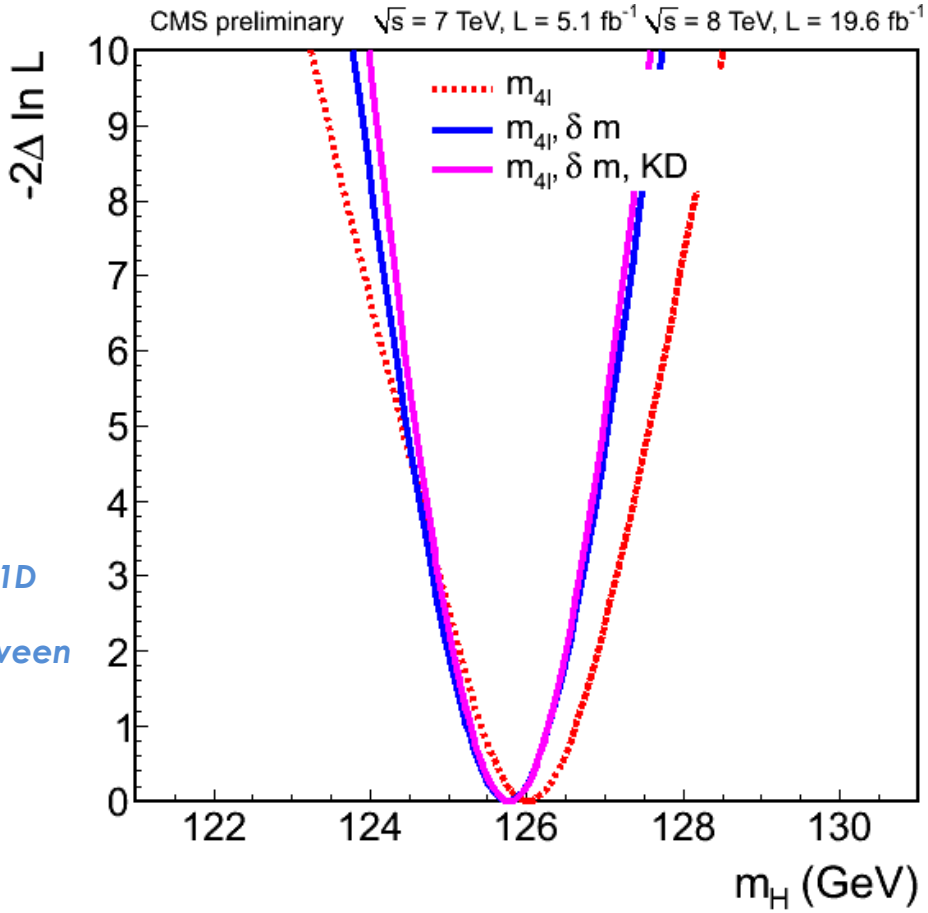
$$m_H = 125.8 \pm 0.5\ (\text{stat.}) \pm 0.2\ (\text{syst.})$$

Nice peak in the ZZ→4l invariant mass spectrum



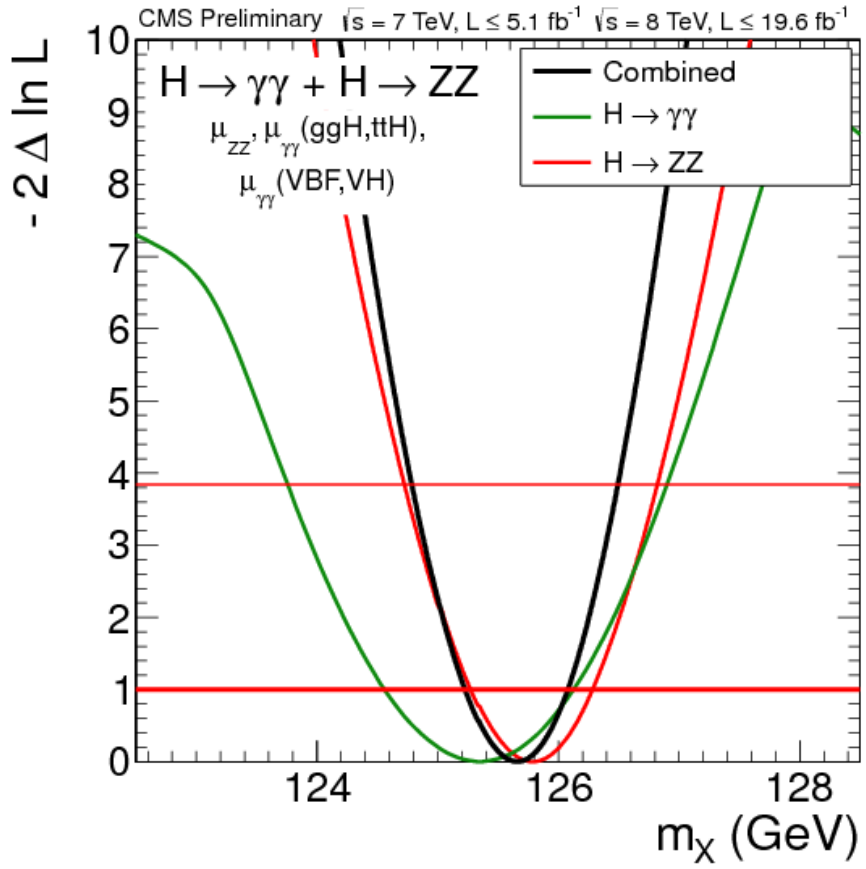


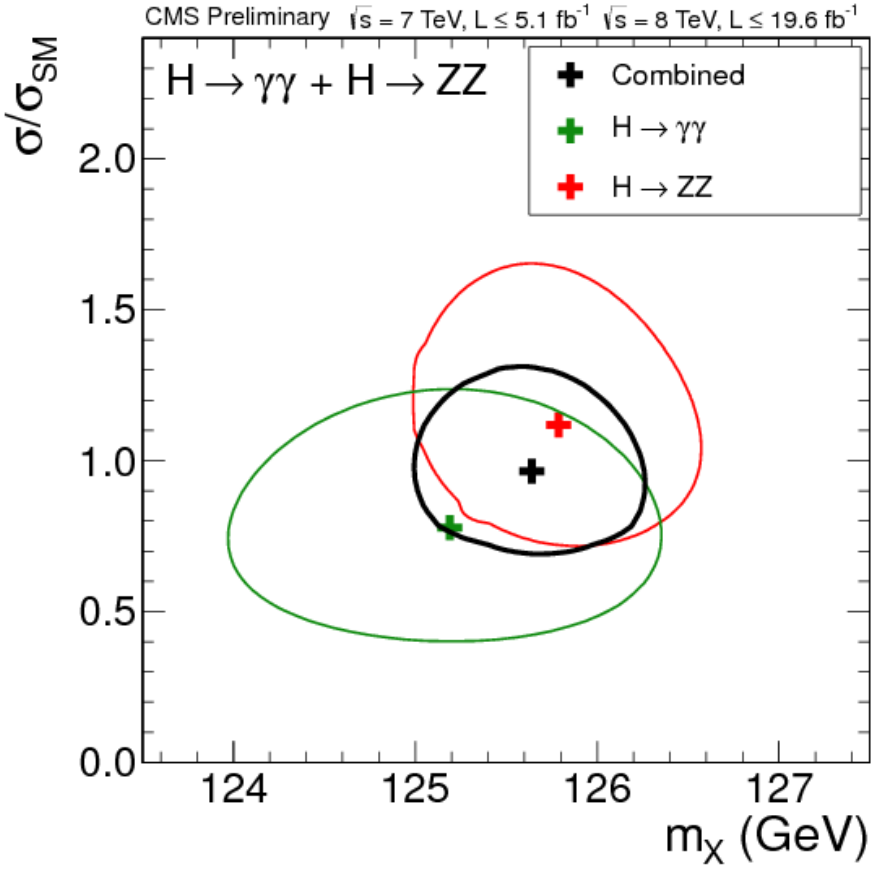
- *Z→4l used to validate 1D mass measurement*
- *Good agreement between measured & PDG values*



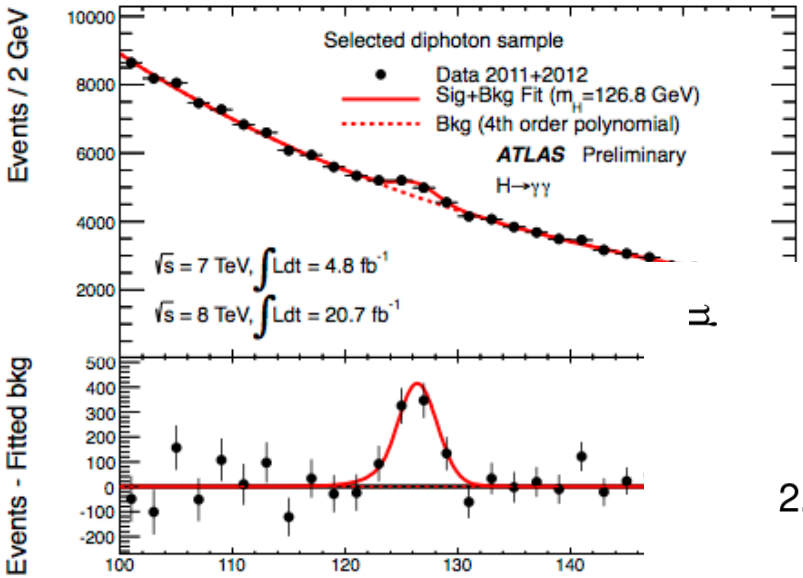
Results:
High-resolution channels combined (CMS)

$$m_H = 125.7 \pm 0.3(stat) \pm 0.3(syst)\ GeV$$

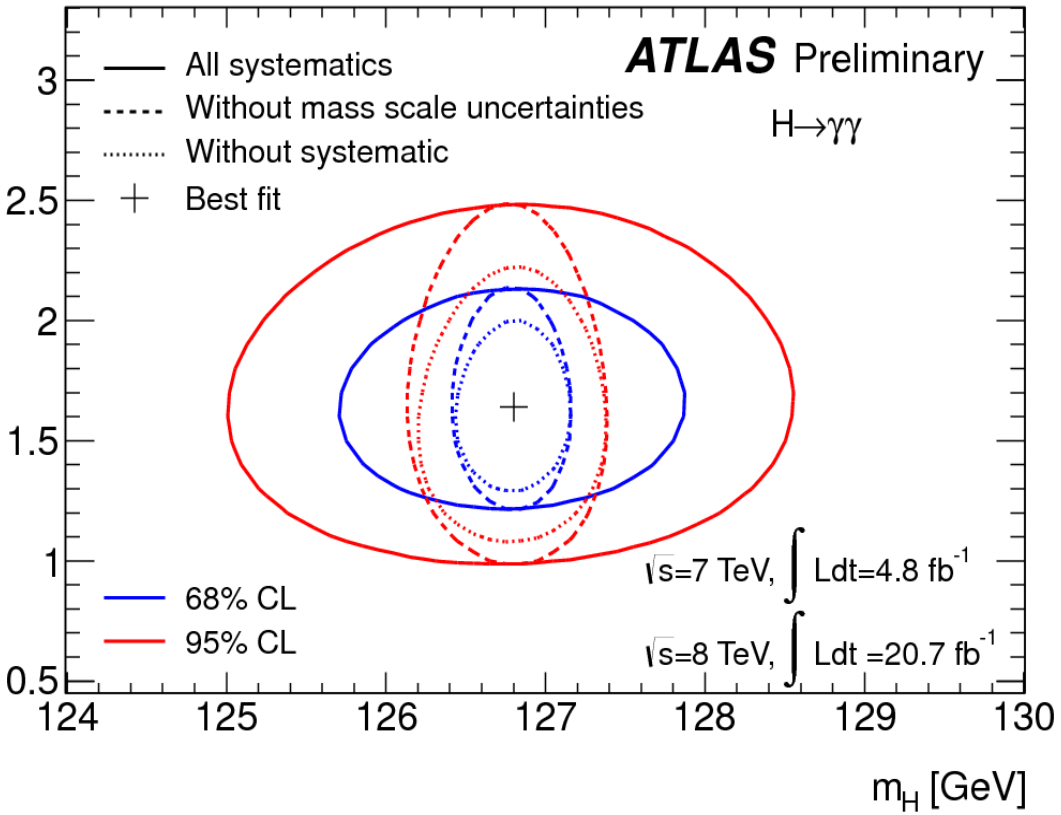




Results: H→γγ (ATLAS)



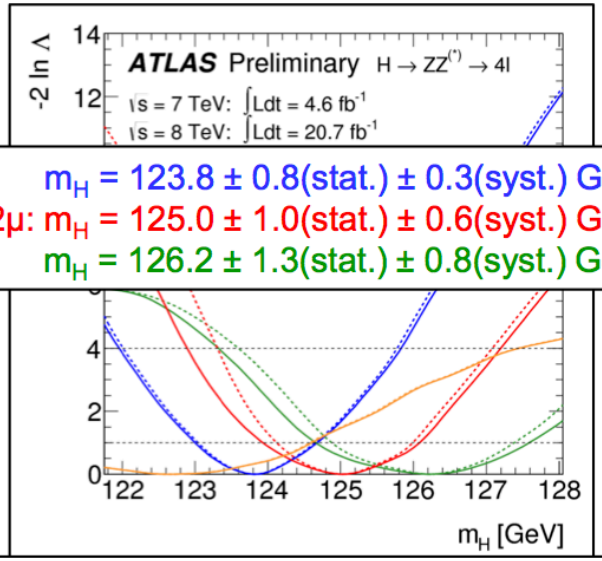
$M_{\gamma\gamma}$ = **126.8 ± 0.2 (stat.) ± 0.7 (syst.) GeV**



As in CMS the main source of systematic uncertainty is the photon energy scale

Results: H→ZZ→4l (ATLAS)

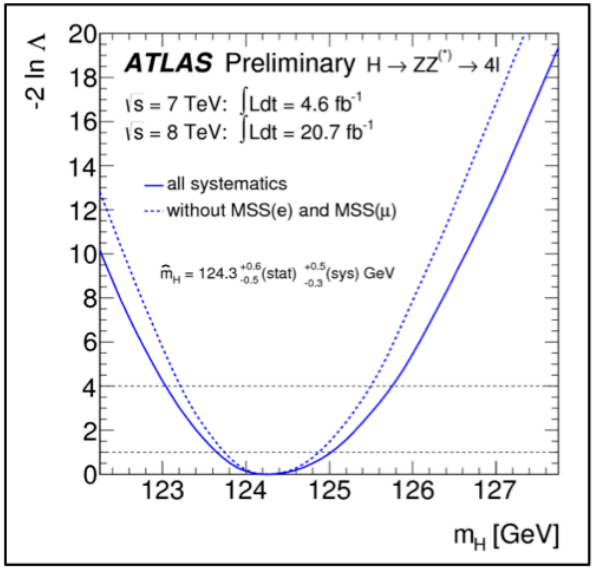
Mass fit per subchannel



4μ: m_H = 123.8 ± 0.8(stat.) ± 0.3(syst.) GeV
2e2μ: m_H = 125.0 ± 1.0(stat.) ± 0.6(syst.) GeV
4e: m_H = 126.2 ± 1.3(stat.) ± 0.8(syst.) GeV

The main systematics comes from the momentum/energy scale uncertainty: 0.3 GeV for 4μ and 0.8 GeV for 4e.

Combined mass fit



m_H = 124.3 ± 0.6(stat.) ± 0.5(syst.) GeV

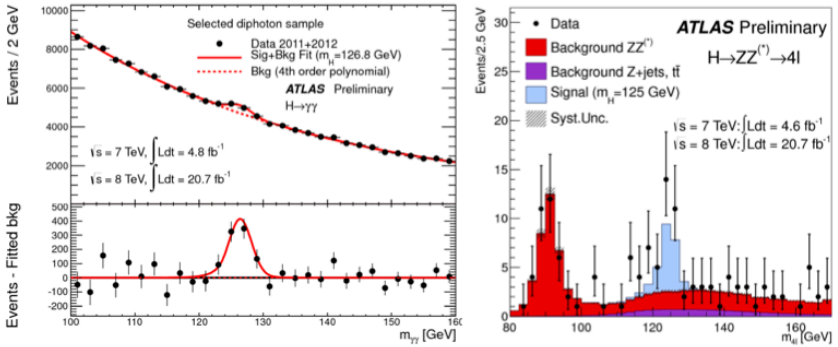
Previous result (18 fb^{-1} versus 25 fb^{-1}): **m_H = 123.5 ± 0.9(stat.) ± 0.3(syst.) GeV**

Two distinct effects are produced by the new candidates:

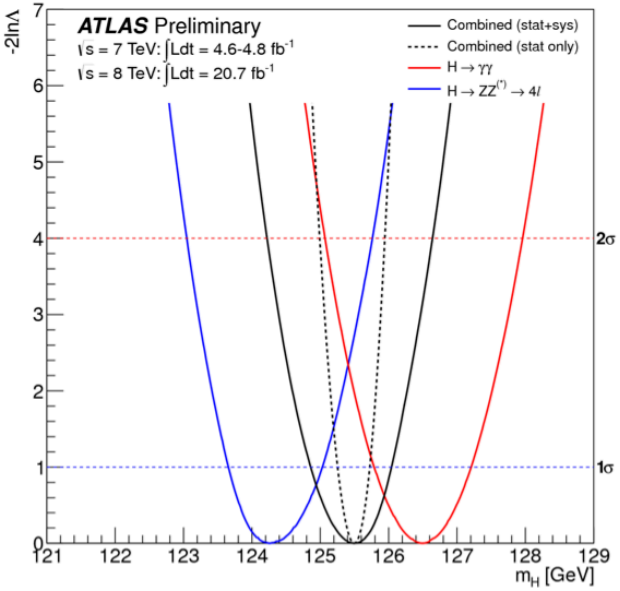
- The central value in the 4μ subchannel has changed from 123.2 to 123.8 GeV.
- The relative weight of the 4μ subchannel has decreased.

Results:
High-resolution channels combined (ATLAS)

- High resolution mass measurements from $H\to\gamma\gamma$ and $H\to ZZ^{(*)}\to 4l$ spectra



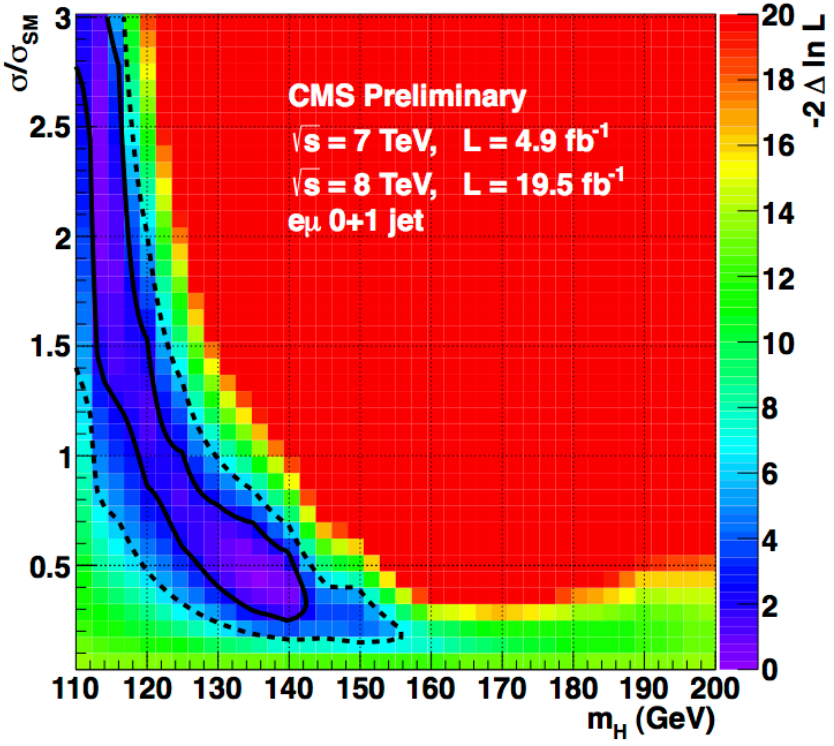
- Combine $\gamma\gamma$ and $4l$ mass measurements
  - Signal strengths, $\mu_{\gamma\gamma}$ and μ_{4l}, allowed to vary independently
    - → Don't assume SM couplings
- $m_H = 125.5 \pm 0.2\ (\text{stat})\ ^{+0.5}_{-0.6}\ (\text{sys})$ GeV
  (4.8 fb^{-1} + 20.7 fb^{-1})
- Previous measurement, Dec 2012:
  - $m_H = 125.2 \pm 0.3\ (\text{stat}) \pm 0.6\ (\text{sys})$ GeV
    (4.8 fb^{-1} + 13 fb^{-1})



- Use profile likelihood ratio
  $\Lambda(m_H) = \frac{L(m_H, \hat{\hat{\theta}}(m_H))}{L(\hat{m}_H, \hat{\theta})}$ to quantify m_H confidence intervals with nuisance parameters, θ ($\mu_{\gamma\gamma}$, μ_{4l}, theory, experimental systematics)
- Asymptotically, $-2\ln\Lambda$ distributed as a χ^2

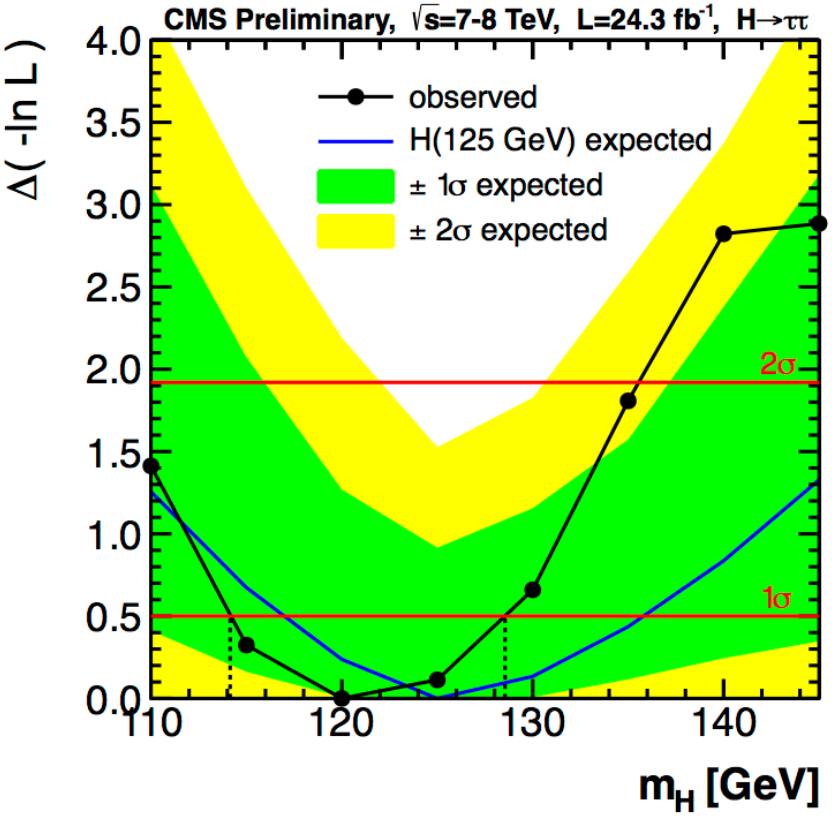
Results: low-resolution channel (CMS only)

Likelihood scan for mass and signal strength modifier



Wide spread of flat minimum compatible with the low resolution of the channel

Fit of the mass with freely floating signal strength modifier



$m_H = 120\ ^{+9}_{-7}$ (stat.+syst.) GeV

Summary

- All the data recorded in 2011 and 2012 was analyzed in two high-resolution channels (*H*→ZZ→4l and *H*→γγ) by both experiments
- The results are:

$$m_H = 125.5 \pm 0.2(stat)^{+0.5}_{-0.6}(syst)$$ ATLAS

$$m_H = 125.7 \pm 0.3(stat) \pm 0.3(syst)$$ CMS

- CMS reported first results from the low-resolution channels
- More data will lead to increased precision
- The work to reduce systematic uncertainties is ongoing
- Measurement of the width/check for the double resonance is coming