# *Higgs Mass matters*

Florian Bernlochner, University of Bonn, Germany

ATLAS
EXPERIMENT

# Overview of this talk

- **4 Measurements** out from both experiments (great!)
    - **3 fix** the Higgs mass, **1 floats** the Higgs mass
- What are the stated reasons for fixing or floating?

*CMS 4lep*

and are unfolded to the particle level. Due to the strong dependence of the $\sigma \times$ BR on the true Higgs boson mass $m_{\mathrm{H}}$ in the region around 125 GeV, and in order to facilitate easier comparison of the measurement results with the theory predictions, the measurements are performed assuming the Higgs boson mass of $m_{\mathrm{H}} = 125.0$ GeV, as measured by the CMS experiment using the decay channels H $\rightarrow 4\ell$ and H$\rightarrow 2\gamma$ [10].

*CMS yy*

For a given observable, the fit is performed simultaneously over all the bins, and the nuisance parameters are profiled in the fit. The signal mass is also considered a nuisance parameter and profiled for each observable. This choice is made to avoid using the same data twice, first to measure the signal mass, then to measure the kinematic distribution at this mass. As a consequence the differential cross section for each observable is evaluated at slightly different best fit values of the signal mass (see appendix A). As an example, Fig. 3 shows the sum of the

*ATLAS yy*

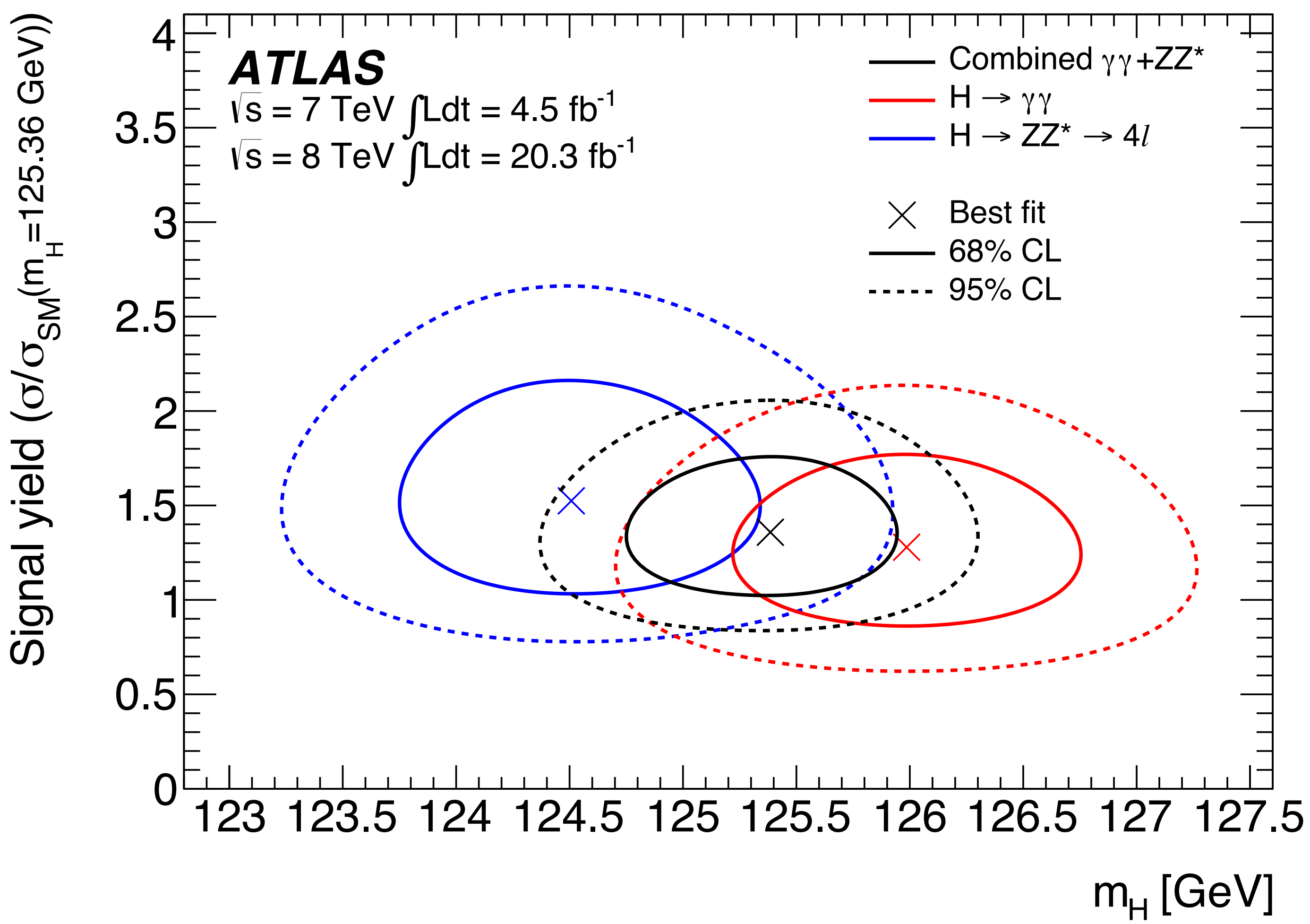
Figure 1 shows the result of the signal-plus-background fit to the diphoton invariant mass reconstructed in different jet multiplicity bins. The difference in the extracted signal yield between fixing the Higgs boson mass and allowing it to float in the fit is 3.2% in the baseline fiducial region, with the largest effect being 16% for $N_{\mathrm{jets}} = 1$. These differences are smaller than statistical uncertainties in the fit itself for all the results presented in this

*ATLAS 4lep*

The difference between the number of signal events extracted with the two methods is mainly due to fixing the Higgs boson mass to 125.4 GeV in the fit method. As reported in Ref. [10], the best fit mass in the $H \rightarrow ZZ^* \rightarrow 4\ell$ channel alone is 124.5 GeV, causing smaller weights for some events in the fit.

# Arguments for fixing the mass:

- Parameter of interest (Yield) versus Higgs mass
  - Plot from ATLAS Higgs mass combination:

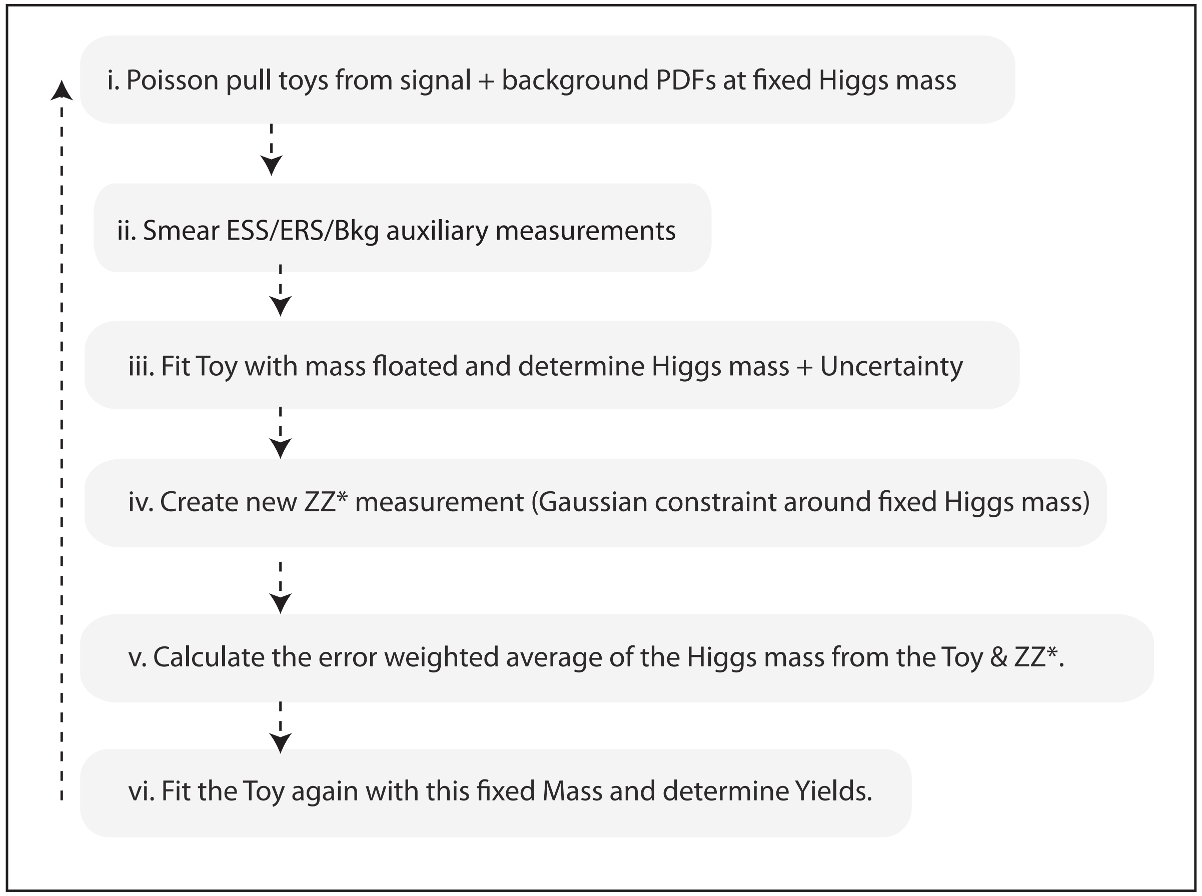



In order to check that the fitted signal yield is not significantly correlated with the measured mass, the profile likelihood ratio as a function of both $m_H$ and the normalized signal yield $S$, $\Lambda(S, m_H)$ is used. The normalized signal yield is defined as $S = \sigma/\sigma_{SM}(m_H{=}125.36\ \text{GeV})$. It is similar to the signal strength $\mu = \sigma/\sigma_{SM}(m_H)$, except the $m_H$-dependence of the expected SM cross-sections and branching ratios that enter into the denominator, principally for the $H \to ZZ^* \to 4\ell$ channel, is removed by fixing $m_H$ to the combined best-fit mass. Asymptotically, the test statistic $-2 \ln \Lambda(S, m_H)$ is distributed as a $\chi^2$ distribution with two degrees of freedom. The resulting 68% and 95% CL contours are shown in Fig. 9. No significant correlation between the two fitted variables is observed, confirming the model-independence of the mass measurement described in this paper.

- Mass and Yield fairly uncorrelated.
  - If uncorrelated both parameters can be extracted independently.
  - i.e. change in yield only marginally changes mass.
- Main reason why ATLAS coupling strength measurements did fix the mass at combination values.

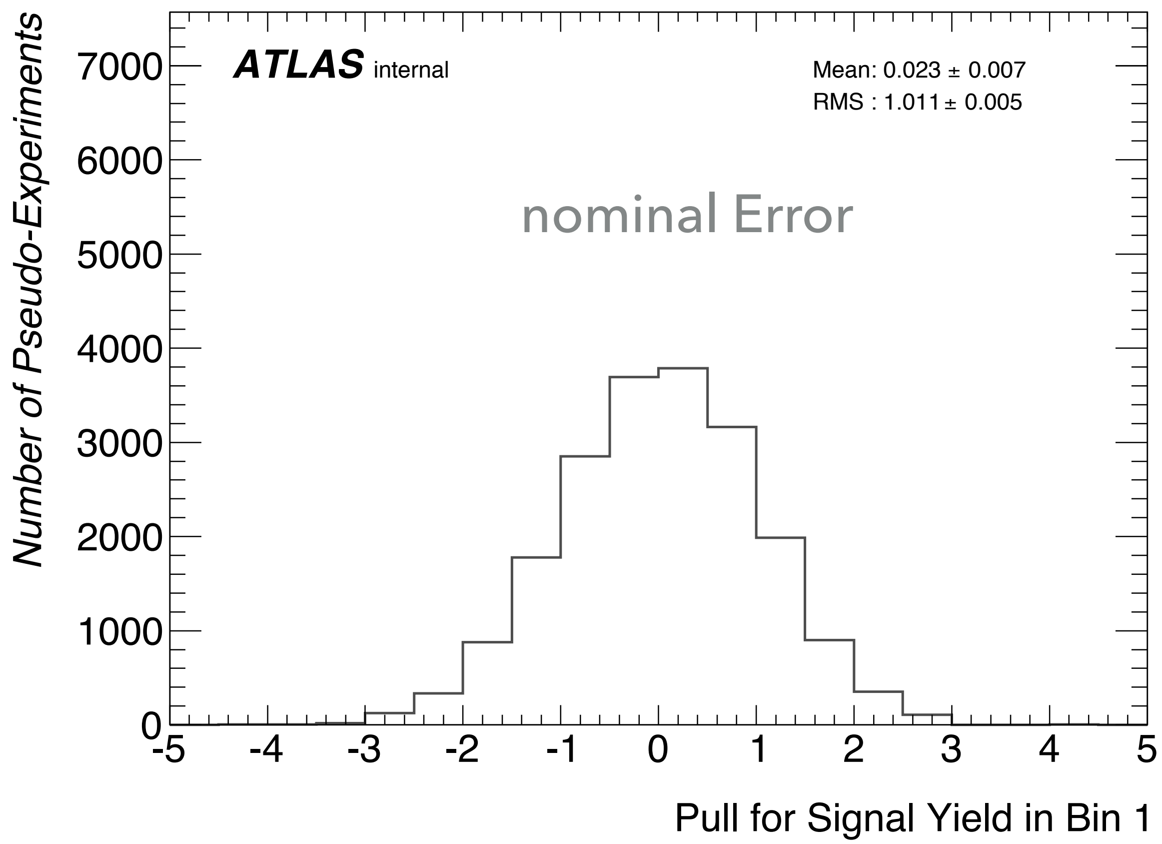
# Toy Study

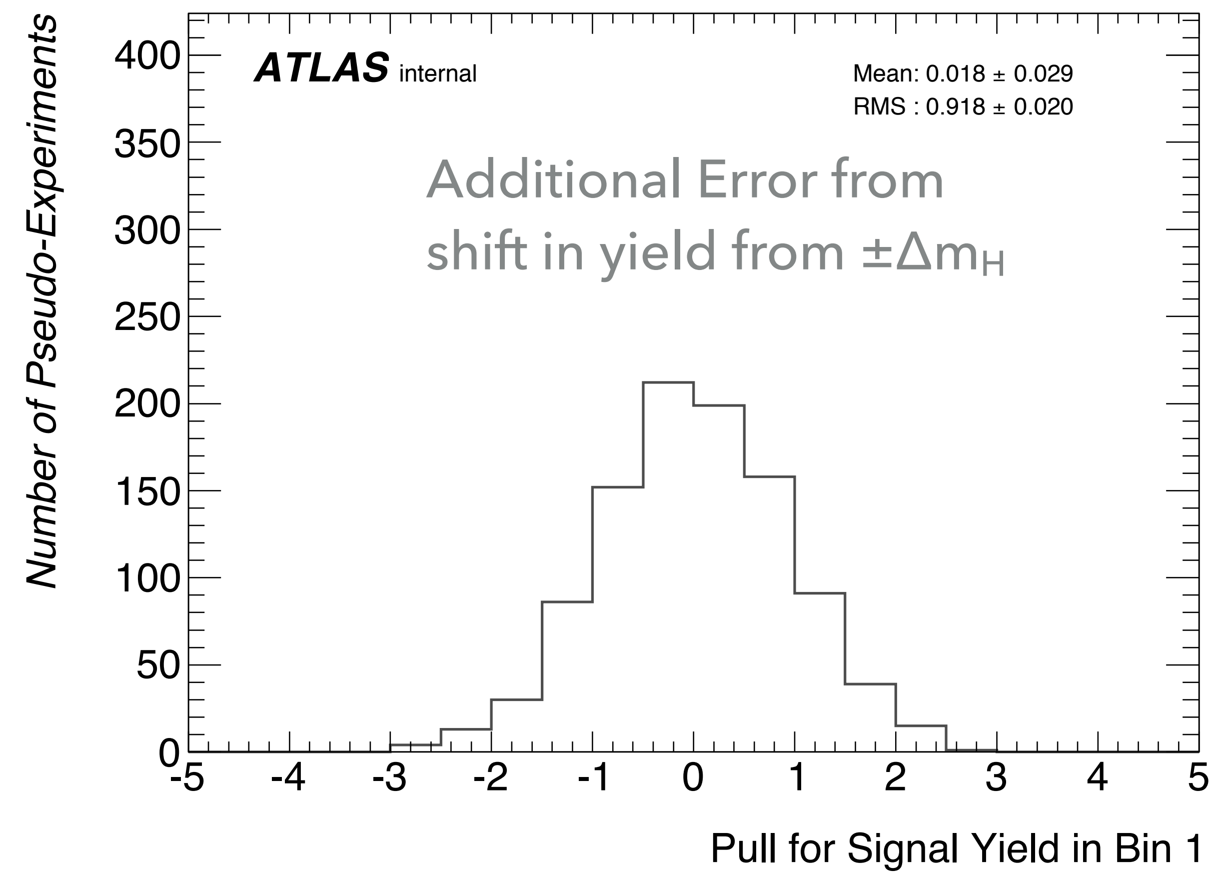
- When the idea of fixing the mass came up, we did cary out a small toy study to see if the coverage of the yield uncertainties indeed is compromises.
  - Toy Design: Average of sample Higgs mass with external measurement
    - (assuming that both measure the same fundamental parameter and no bias between channels exist)



# Toy Study

- Testes pulls from nominal fit error and pulls that adds an additional uncertainty on the yield using the difference in yield for $\pm\Delta m_H$




- No sign of under-coverage; adding an additional uncertainty (i.e. treating the mass as an external parameter) leads to an over-coverage of the error.
- Fit correlation between inclusive yield and Higgs mass in diphoton channel is of the order 0.3%

# Arguments for floating the mass:

- Don’t use the same data twice
  - should not really be a problem if yield and mass are uncorrelated
- More model independent:
  - Cross section does not rely on energy scale, i.e. one measures a narrow resonance in a window.
  - No potential bias from ill understood systematics from other channels.
- But also: every variable can have a slightly different mass value, nightmare for theorist to produce predictions
  - There assumptions of having a given mass enter again.

# Updating the Mass in measurements

- What do we do if the knowledge of the Higgs mass evolves over time?
  - Keep updating our results? (very painful)
  - Ignore the impact?
  - Provide the impact of $\pm\Delta m_H$ on they yield
    - This would allow to easily update new / existing measurements.
    - Similar post-measurement updates are being done by for instance HFAG (Heavy Flavour Averaging Group), that update branching fractions or other external constraints to keep measurements up-to-date.