Mass measurement in H → γγ in ATLAS

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on behalf of the ATLAS Collaboration

Higgs Hunting 2013

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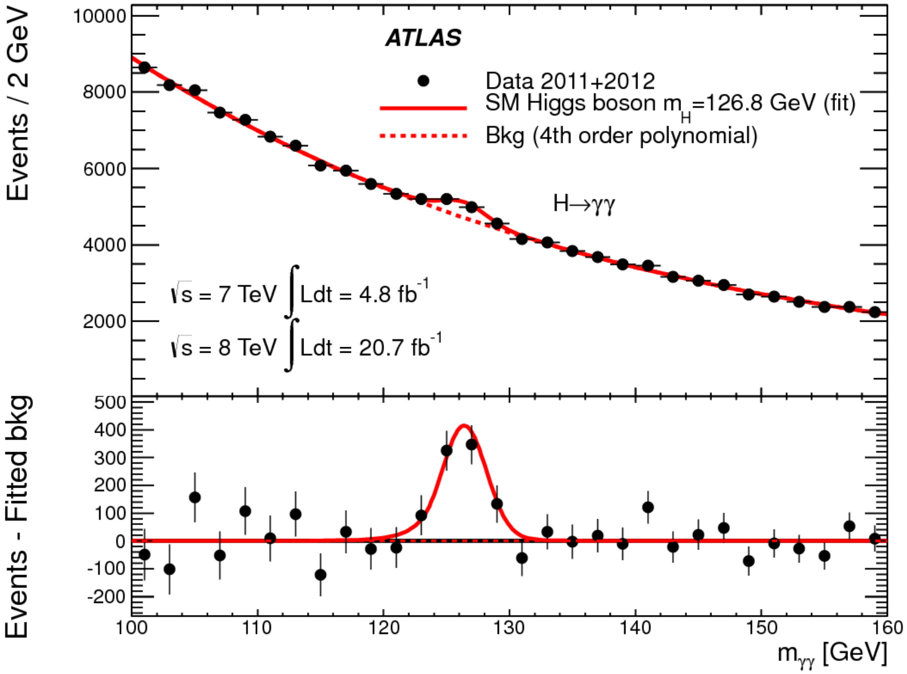
Higgs couplings paper: https://cds.cern.ch/record/1559924

Higgs to Diphoton conf. note: https://cds.cern.ch/record/1523698

Introduction

- Higgs discovery in July 2012 → ATLAS measures its properties
- m_H is measured in $H \rightarrow \gamma\gamma$ and $ZZ \rightarrow 4l$ channels
- $H \rightarrow \gamma\gamma$ channel has an excellent resolution on m_H
  - narrow mass peak
  - 80 (2011, 7TeV) + 395 (2012, 8TeV) expected signal events

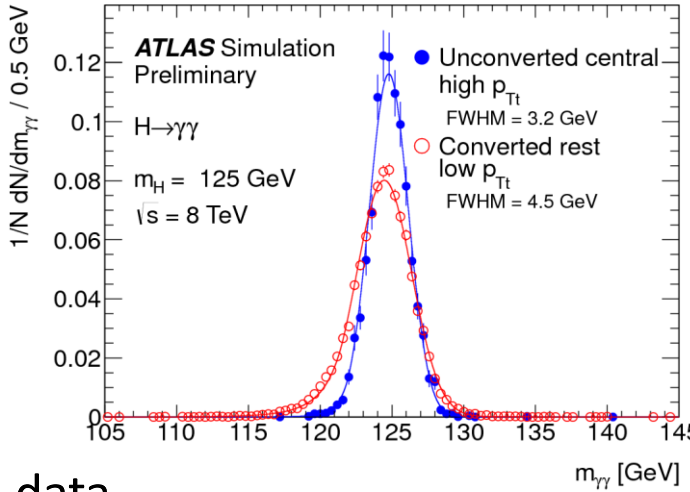
observed mass distribution



Higgs Mass Measurement

- Event selection and categorization
  - 2 tightly identified and isolated photons (E_T>40/30 GeV, $|\eta|$<2.37 w/o crack)
  - 10 (7TeV) and 14 (8TeV) categories: better mass determination ~ 10%

signal model using signal MC



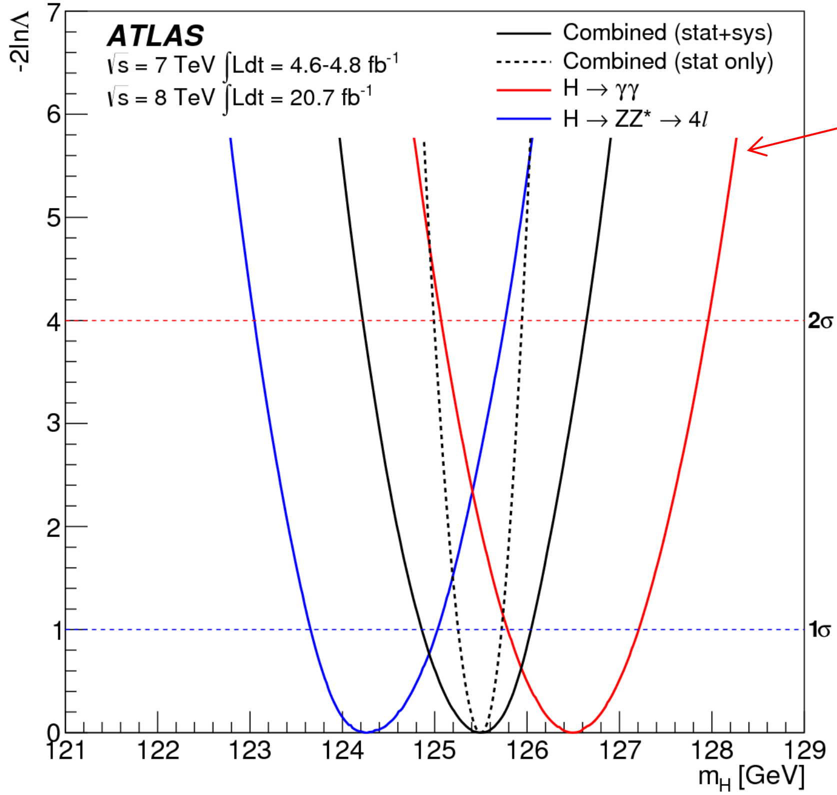
- Signal modeling
  - function = CrystalBall + Gaussian
  - mass resolution is 1.6 GeV on average and varies ~ 1 GeV according to photon conversion status and η region
- BG modeling
  - BG is obtained from fit to $m_{\gamma\gamma}$ distribution in data
  - function is different for each category (e.g. 4th order Bernstein polynomial for inclusive)
- Profile likelihood
  - likelihood is calculated from (S+B) fit to $m_{\gamma\gamma}$ distribution

$$-2\ln\lambda(m_H) = -2\ln\frac{L\left(m_H,\hat{\hat{\mu}},\hat{\hat{\theta}}\right)}{L\left(\hat{m}_H,\hat{\mu},\hat{\theta}\right)}$$

m_H: Higgs mass, μ: signal strength (free)

θ : Nuisance Parameters

Results



$$m_H = 126.8 \pm 0.2\,(\text{stat}) \pm 0.7\,(\text{syst})\ \text{GeV}$$

Red line shows H → γγ results

$$m_H = 126.8 \pm 0.2\,(\text{stat}) \pm 0.7\,(\text{syst})\ \text{GeV}$$

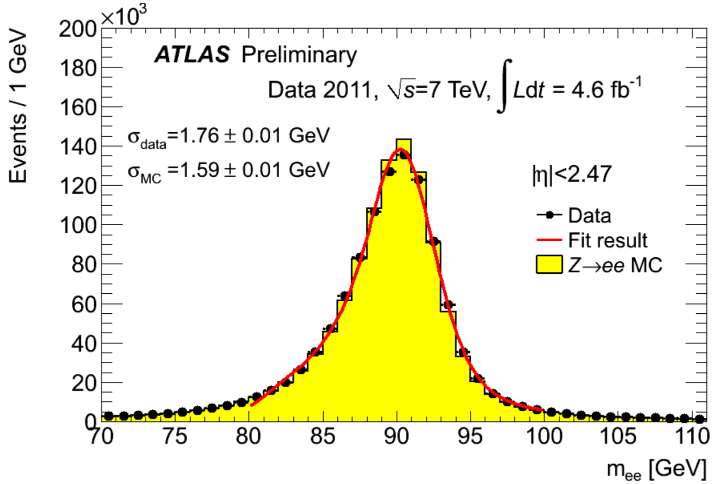
- Statistical uncertainty is smaller than systematic uncertainty
- Dominant systematics sources are photon energy scale uncertainties
- Systematics on the angle reconstruction is small
  - thanks to the MVA based vertex selection using "photon pointing" and tracks

"Method"	0.4 GeV	(next slide)
"Material"	0.4 GeV	(next-to-next slide)
PreSampler	0.1 GeV	Energy scale uncertainty of the presampler
Other	0.4 GeV	e.g. Difference of lateral leakage between electrons and photons, Uncertainty of direction of the photons

"Method" Systematics 0.4 GeV

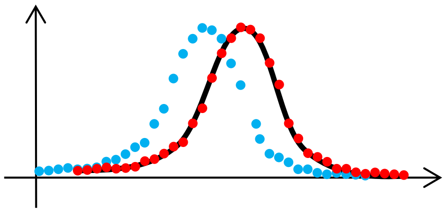
Final calorimeter energy scales are obtained from a comparison of Z → ee line-shape between data and MC

Z → ee line-shape in 2011 data (E_T > 25 GeV, |η| < 2.47)



- Template Method
  - Correction factors (α) are applied to data
  - α is determined such that m_{ee} shapes in data agree with the MC histograms

$$E_{Data} \rightarrow E'_{Data} = \frac{E_{Data}}{1+\alpha}$$



m_{ee}

m_{ee} in data before correction

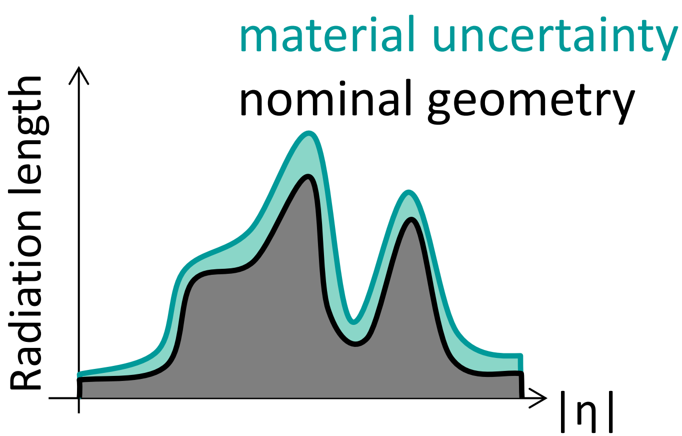
after correction

Reference histogram

  - Uncertainty Sources
    - QCD di-jet contamination
    - Closure test

“Material” Systematics 0.4 GeV

- Energy scales of photons use extrapolation electron → photon
- If Geant4 material mapping is different from actual geometry, there is a mis-calibration for photons
  - shower development of photons is different from electrons



- Studies for material estimation
  - Hadron interaction
  - Calorimeter shower shape
  - …

create

Nominal geometry

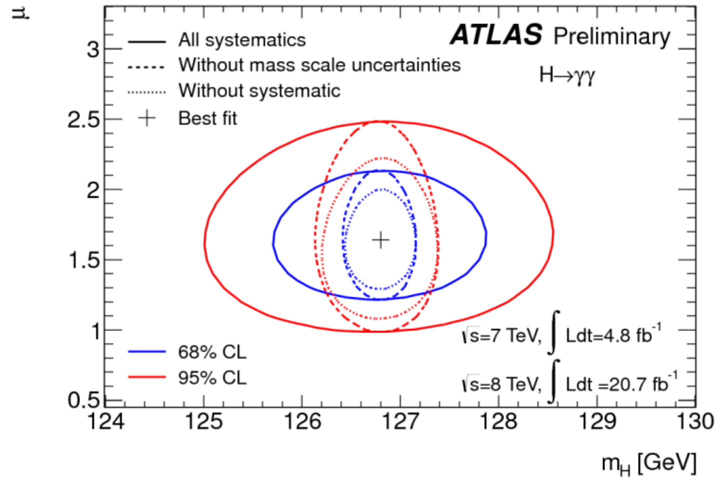
Geometry with different material budget

Energy scale comparison

↓

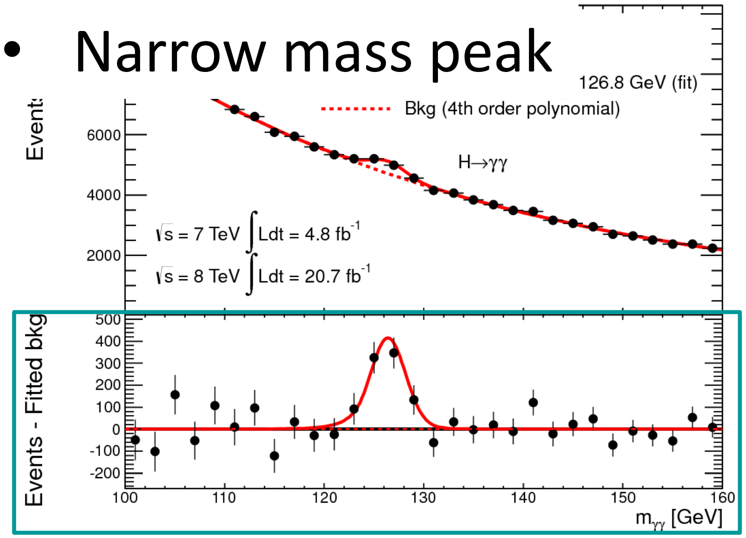
Mass systematics due to material uncertainties 0.4 GeV

- Large μ and narrow mass peak are measured in observed data set
- Affect on mass measurement?
  - μ = 1.6 +- 0.3



- m_H and μ are not correlated in H → γγ channel

  - Narrow mass peak



- The best fit value of mass resolution in observed H → γγ resonance is narrower than expected by 1.8σ
  - σ: uncertainty of mass resolution
- Toy MC study shows mass resolution doesn't have influence on m_H measurement

Summary and Future Plan

- Summary
  - H → γγ channel shows m_H:

$$m_H = 126.8 \pm 0.2\,(\mathrm{stat}) \pm 0.7\,(\mathrm{syst})\ \mathrm{GeV}$$

  - Dominated by systematic uncertainties
  - Dominant systematics come from photon energy scale

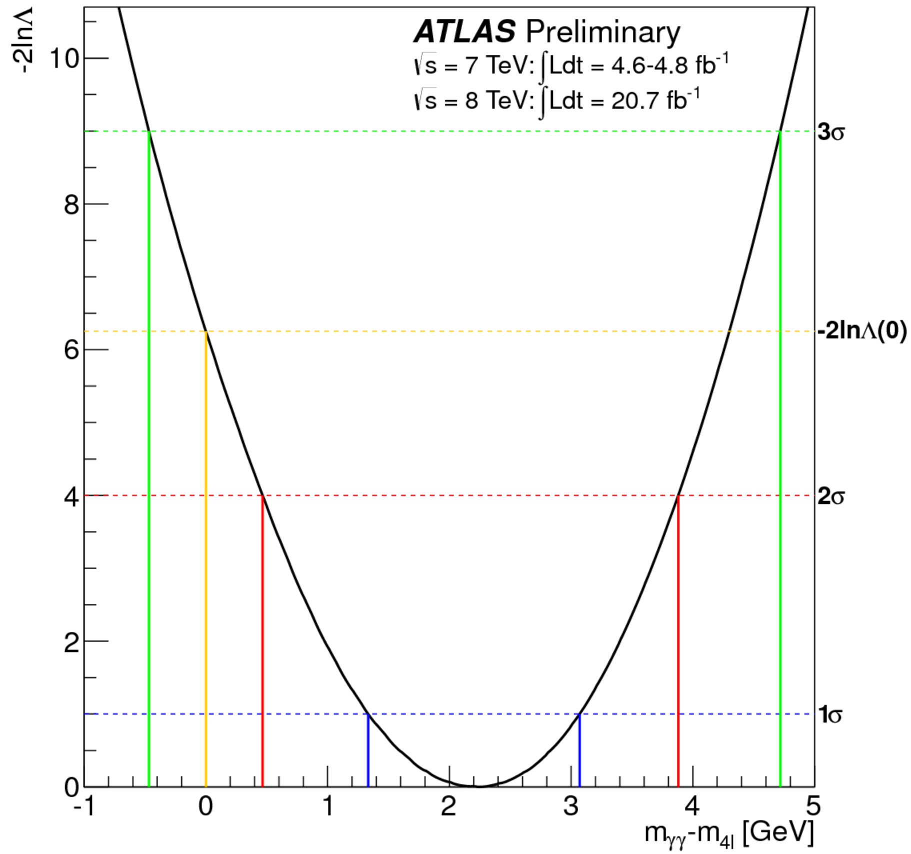
- Future plan
  - New detector geometry
    - Updated by studies of material estimation
    - Improve the description of the Z → ee line-shape
  - Improvement on intercalibration of each calorimeter layer
    - Reduce systematics on the presampler energy scale

BG modeling

Category	Function
Inclusive	4th order Bernstein polynomial
Unconverted central, low p_{Tt}	exponential of 2nd order polynomial
Unconverted central, high p_{Tt}	single exponential
Unconverted rest, low p_{Tt}	4th order Bernstein polynomial
Unconverted rest, high p_{Tt}	single exponential
Converted central, low p_{Tt}	exponential of 2nd order polynomial
Converted central, high p_{Tt}	single exponential
Converted rest, low p_{Tt}	4th order Bernstein polynomial
Converted rest, high p_{Tt}	single exponential
Converted transition	exponential of 2nd order polynomial
Loose high-mass two-jet	single exponential
Tight high-mass two-jet	single exponential
Low-mass two-jet	single exponential
E_T^{miss} significance	single exponential
One-lepton	single exponential

Comparison with H -> ZZ -> 4l

- Likelihood as a function of the mass difference, $\Delta m_H = m_H^{\gamma\gamma} - m_H^{4l}$
- the common mass m_H is profiled over
- the signal strength parameters $\mu_{\gamma\gamma}$ and μ_{4l} can be changed independently



$\Delta m_H = 0$ hypothesis by more than observed in the data is found to be at the level of 1.5% (2.4σ)