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Measurement of the Higgs boson mass from the $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4\ell$ channels with the ATLAS detector at the LHC

This poster presents an updated measurement of the Higgs boson mass with the combined fit of two decay channels $H \rightarrow ZZ^* \rightarrow 4\ell$ and $H \rightarrow \gamma\gamma$. The analyses are based on 4.5 fb^{-1} and 20.3 fb^{-1} of proton-proton collisions at $\sqrt{s} = 7 \text{ TeV}$ and $\sqrt{s} = 8 \text{ TeV}$ respectively, recorded with the ATLAS detector at the LHC. This result includes improved energy-scale calibrations for photons, electrons, and muons, as well as other analysis improvements.

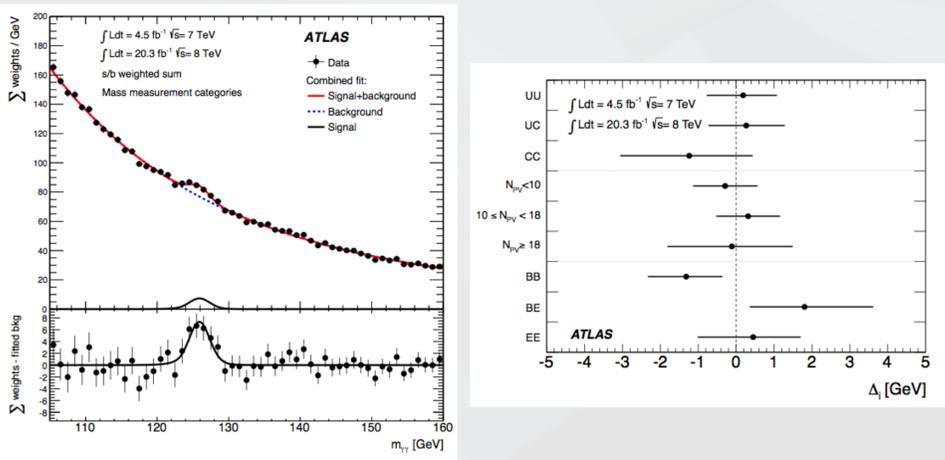
$H \rightarrow \gamma\gamma$ (exp. mass resolution: $\sigma \sim 1.2\text{-}2.4 \text{ GeV}$)

Selection cuts: as Moriond 2013

Improvements:

- $E_T > 0.35$ (0.25) $\times m_{\gamma\gamma}$ for γ_1 (γ_2), track and calo iso for 2011
- new e/γ calibrations (expected shift $-0.45 \pm 0.35 \text{ GeV}$)
- dedicated analysis with categories based on conversions, η and $p_{T\ell}$, to minimize expected $\sigma(m_H)$
- HRes 2 p_T reweighting for ggF process

Invariant mass distribution in the $H \rightarrow \gamma\gamma$ analysis for 7 and 8 TeV data (left), difference Δ between the mass measured in a given $\gamma\gamma$ alternative sub-sample and the combined $\gamma\gamma$ mass (right)



$$m_H = 125.98 \pm 0.42 \text{ (stat)} \pm 0.28 \text{ (sys)} \text{ GeV}, \mu = 1.29 \pm 0.30$$

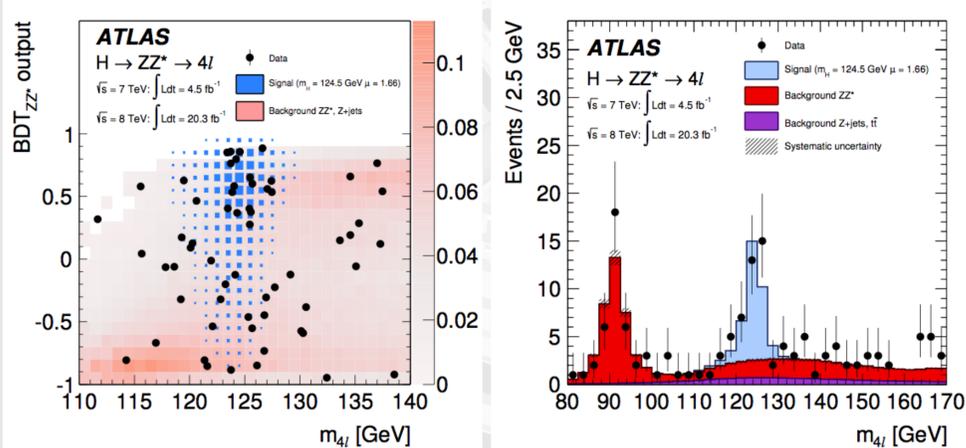
$H \rightarrow ZZ^* \rightarrow 4\ell$ (exp. mass resolution: $\sigma \sim 1.6\text{-}2.2 \text{ GeV}$)

Selection cuts: as Moriond 2013

Improvements:

- new $e/\gamma/\mu$ calibrations and momentum scale sys
- new electron identification $E-p$ combination for the electrons
- sys uncertainties reduced by factor ~ 8
- far FSR recovery for electrons and muons
- 2D fit: $m_{4\ell}$ vs $BDT_{ZZ^*}(\eta, p_{T\ell}, D_{ZZ^*})$, BDT_{ZZ^*} gives expected improvement of 10% for statistical error

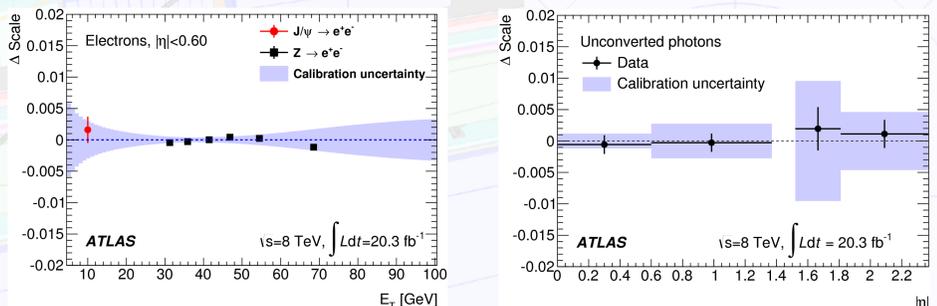
Distributions of $m_{4\ell}$ (left) and $m_{4\ell}$ vs BDT_{ZZ^*} (right) for the selected candidates in the mass range: $110 < m_{4\ell} < 140 \text{ GeV}$



$$m_H = 124.51 \pm 0.52 \text{ (stat)} \pm 0.06 \text{ (sys)} \text{ GeV}, \mu = 1.66 +0.45/-0.38$$

Photon and electron reconstruction, energy scale calibration and systematic uncertainties:

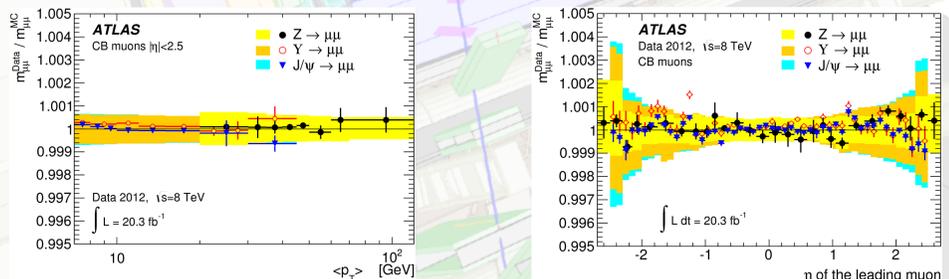
- $Z \rightarrow ee$ is used at end for the overall scale, verification is done with $J/\psi \rightarrow ee$, $Z \rightarrow ee\gamma$
- $e-\gamma$ calibration: multivariate regression (improvement of 10% on $m_{\gamma\gamma}$ resolution)
- cell energy calibration and stability
- data driven layer inter-calibration and upstream material determination
- correction of know effects and non-uniformities



Comparison of the measured electron/ γ energy scale as a function of E_T , with the nominal energy scale

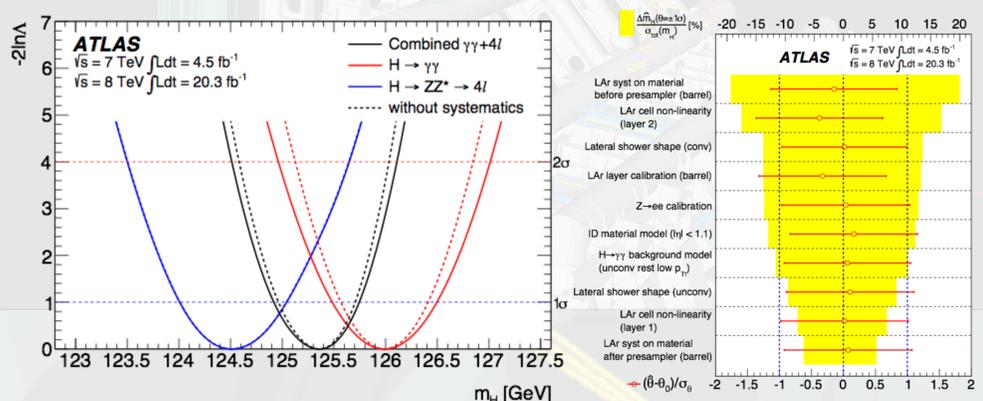
Muons reconstruction momentum scale and resolution systematic uncertainties:

- muon momentum scale $Z \rightarrow \mu\mu$, and $J/\psi \rightarrow \mu\mu$ used in the fit to get low p_T scale right
- add energy loss term for muon spectrometer p_T scale correction
- used $Y \rightarrow \mu\mu$ independent cross check



Ratio of the reconstructed dilepton invariant mass for the data to the corrected MC mass as a function of η of leading μ and p_T of the two μ s

Value of $-2 \ln \Lambda$ as a function of m_H for the individual channels and their combination, where the signal strengths $\mu_{\gamma\gamma}$ and $\mu_{4\ell}$ are allowed to vary independently (left). Pulls and impact on m_H for the principal constrained nuisance parameters (right).



Channel	Mass measurement [GeV]
$H \rightarrow \gamma\gamma$	$125.98 \pm 0.42 \text{ (stat)} \pm 0.28 \text{ (syst)} = 125.98 \pm 0.50$
$H \rightarrow ZZ^* \rightarrow 4\ell$	$124.51 \pm 0.52 \text{ (stat)} \pm 0.06 \text{ (syst)} = 124.51 \pm 0.52$
Combined	$125.36 \pm 0.37 \text{ (stat)} \pm 0.18 \text{ (syst)} = 125.36 \pm 0.41$

- final RUN 1 mass measurement produced
- $125.36 \pm 0.37 \text{ (stat)} \pm 0.18 \text{ (sys)} \text{ GeV} \rightarrow 3$ per mille accuracy!!
- thanks to better calibrations of $e/\gamma/\mu$ systematic uncertainties reduced by factor 3
- agreement between the two channels: $2.5 \sigma \rightarrow 1.98 \sigma$

ATLAS Collaboration: "Measurements of the Higgs boson mass from $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4\ell$ channels with the ATLAS detector using 25 fb^{-1} of proton-proton collision data", to be submitted to Phys. Rev. D 2014, arXiv:1406.3827v1 [hep-ex]
 ATLAS Collaboration: "Electron reconstruction and identification efficiency measurements with the ATLAS detector using the 2011 LHC proton-proton collision data", to be submitted to Eur. Phys. J. C 2014
 ATLAS Collaboration: "Muon reconstruction performance of the ATLAS detector during Run 1", to be submitted to Eur. Phys. J. C 2014
 ATLAS Collaboration: "Measurements of the Higgs boson production and couplings in the four lepton decay channel with the ATLAS detector using 25 fb^{-1} of proton-proton collision data", to be submitted to Phys. Rev. D 2014
 ATLAS Collaboration: "Measurements of the Higgs boson production in the diphoton decay channel with the ATLAS detector using 25 fb^{-1} of proton-proton collision data", to be submitted to Phys. Rev. D 2014