Electron and photon energy measurement calibration with the ATLAS detector

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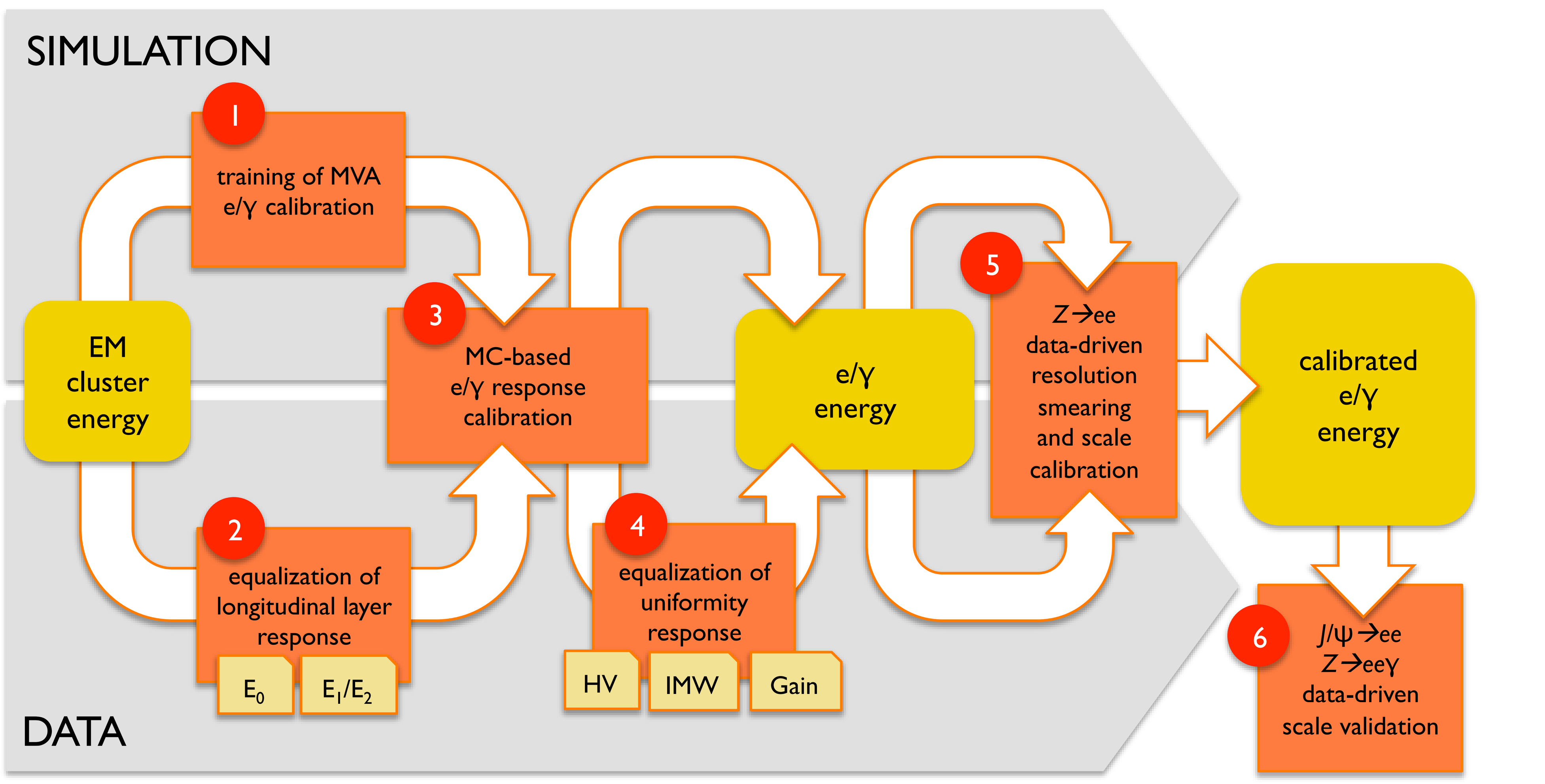
Calibration procedure

The energy of an electron or photon candidate is built from the energy of a cluster of cells in the electro-magnetic (EM) calorimeter. The energy calibration scheme can be summarized in three main steps:

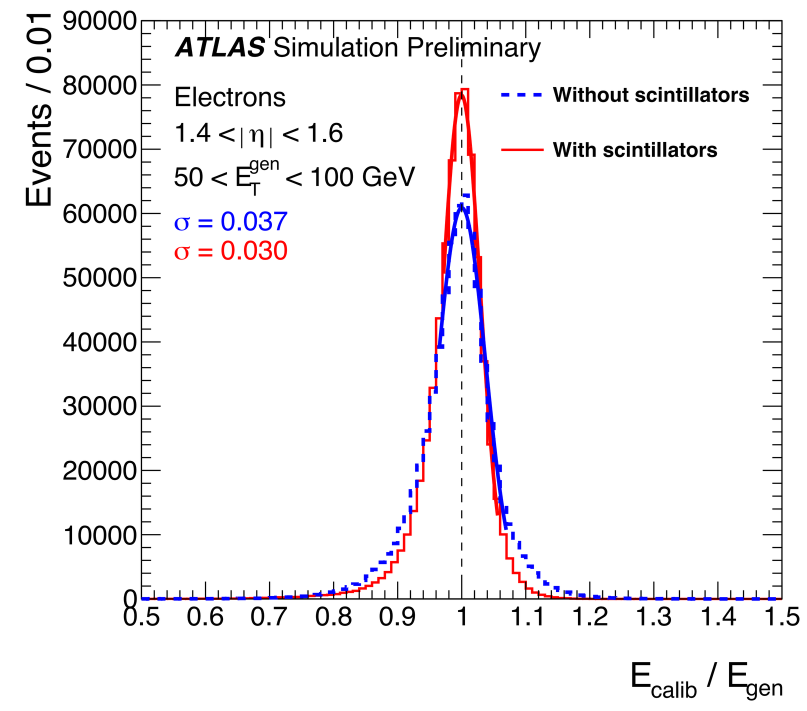
- simulation-based calibration (applied to data and simulation);
- data-driven corrections optimized to mitigate the non-uniformity in detector response (applied only to data);
- data-driven corrections with energy scale factors (applied on data) and correction of the resolution (applied on simulation).

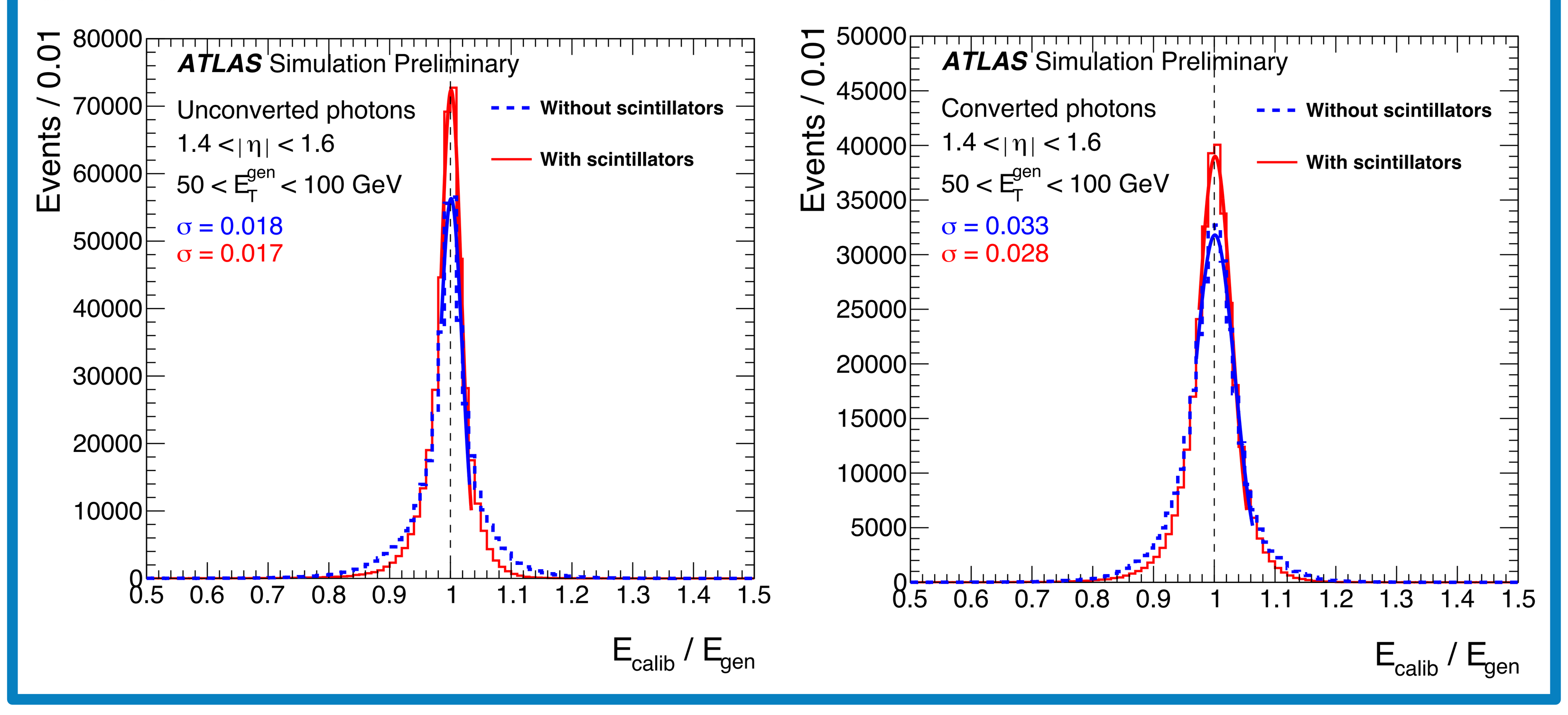


MC based calibration

The EM clusters are calibrated to the original electron and photon energy in simulated MC samples. The calibration correction is evaluated using a boosted decision tree with gradient boosting trained separately for electrons, converted and unconverted photons. With respect to the Run-1[1]:

- cover the whole region |η| in [0, 2.5];
- in the transition region, 1.4<|η|<1.6, scintillators have been introduced as an additional variable to the training of the calibration.





Scale factors from Z ⟶ ee

The overall electron response in data is calibrated so that it agrees with the expectation from simulation. The residual mismatch is corrected by an in-situ procedure developed in Run-1[1] using the Z ⟶ ee events selected in the 2015 data sample. The energy mis-calibration is defined as the difference in response between data and simulation, and is parametrized as:

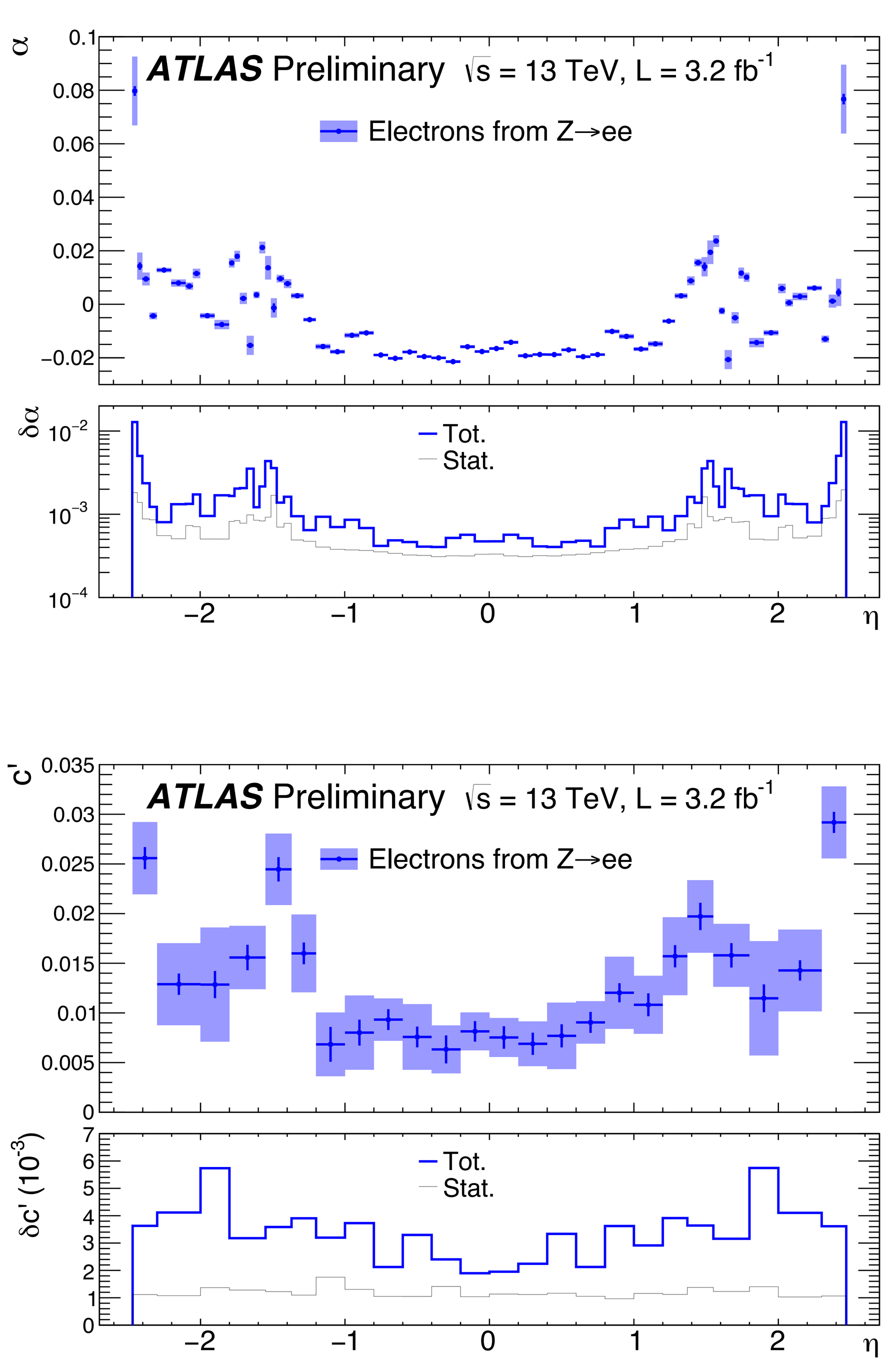
$$E^{\text{data}} = E^{\text{MC}}(1+\alpha)$$

The relative energy resolution is parametrized as:

$$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

Where a is the sampling term, b the electronic noise term and c is the constant term. The difference in energy resolution between data and simulation can be modeled by an additional constant term c':

$$\left(\frac{\sigma(E)}{E}\right)^{\text{data}} = \left(\frac{\sigma(E)}{E}\right)^{\text{MC}} \oplus c'$$

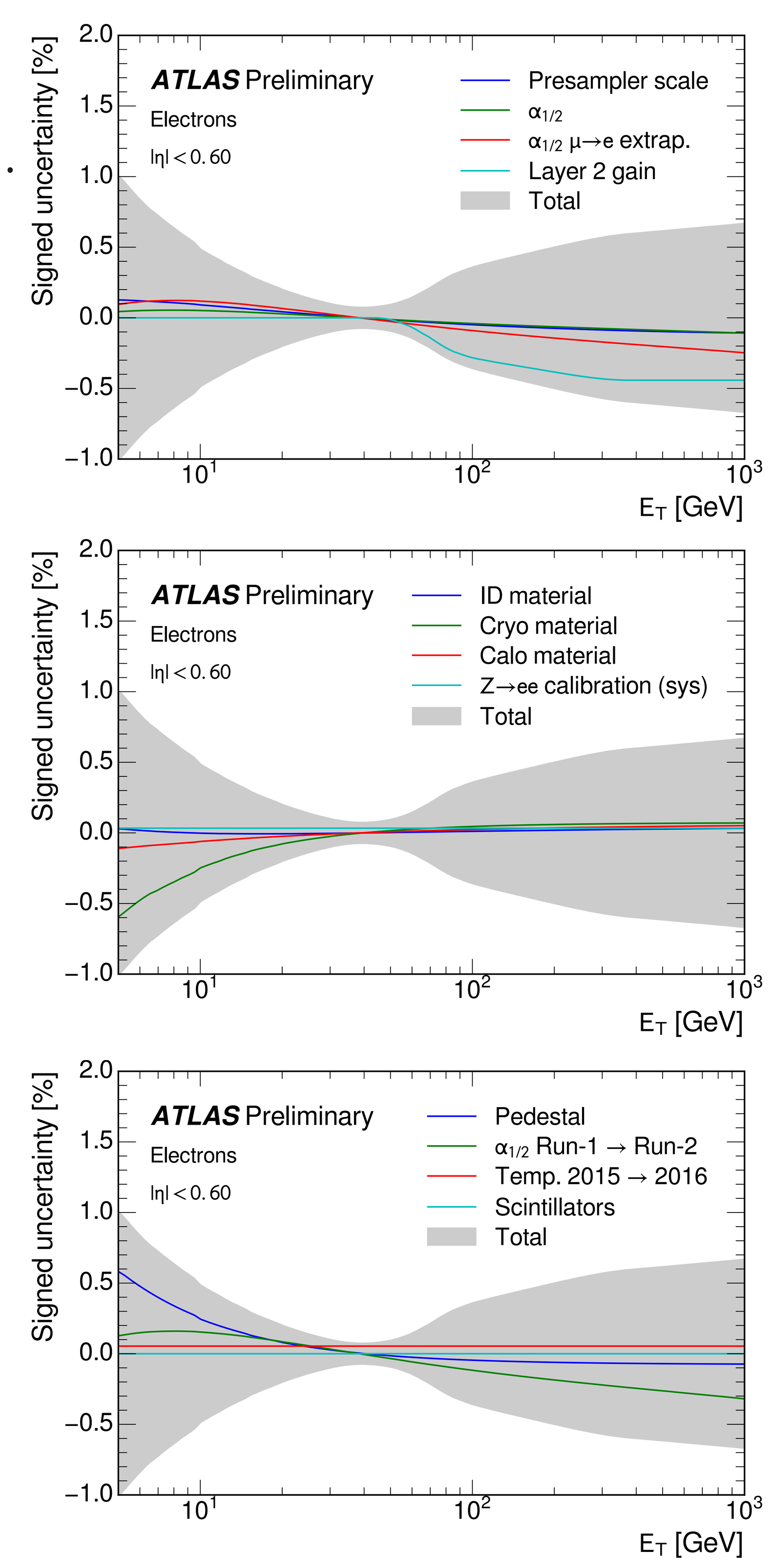


These corrections are computed as function of η. The systematic uncertainties for this procedure are due to: event selection, calibration procedure and mis-modeling of the material.

Uncertainties on energy scale and resolution

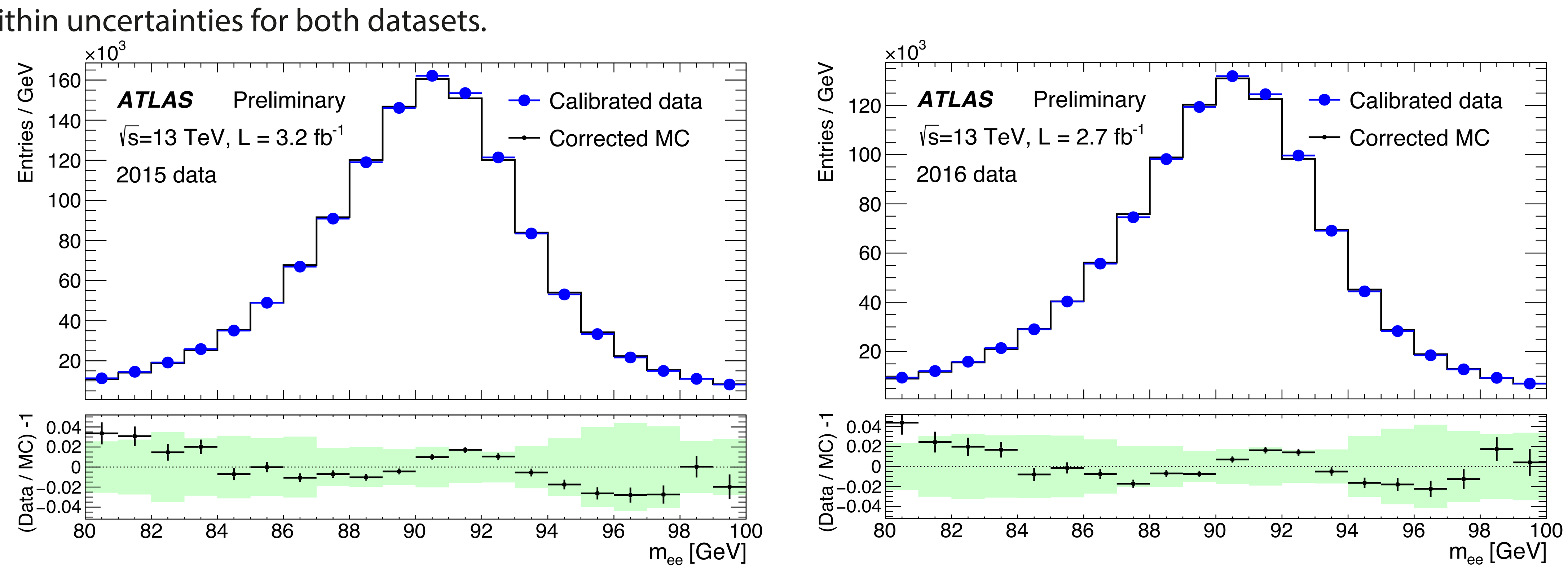
The main sources of uncertainty on the energy scale are:

- Presampler: the uncertainty on the calibration of the thin presampler layer is not expectected to be change in Run-2 respect to Run-1.
- Layer intercalibration: the scale factors used to intercalibrate the first two layers of the LAr calorimeter as a function of η have been found to be in good agreement between 2015 and the 2012 data. An additional systematic uncertainty equal to the maximum observed discrepancy (1.5%) has been included.
- Layer 2 gain: the values of the uncertainties relative to the energy response from the gain used in the readout chain has been retained as in Run-1.
- Material: the values of the uncertainties relative to the description of the material before the calorimeter for |η|<2.5.
- In-situ calibration (Z ⟶ ee).
- Pedestal: in 2012 data residual small baseline shifts ±10 MeV were observed in data and an effect coming from the pedestal determination in electronics calibration. In Run-2 this systematic uncertainty has been estimated to be ±20 MeV due to high pile-up condition.
- Temperature and pileup: in order to account for differences between 2015 and 2016 datasets in pileup conditions and in liquid argon temperature conditions, an uncertainty respectively of 0.02% and 0.05% has been included.
- Scintillators uncertainties: data-simulation difference (1% and 4.3%, depending on η); uncertainty on the Tile Calorimeter electromagnetic scale calibration factor (2.4%); initial intercalibration (1%); uncertainty of the calibration using laser (4%).

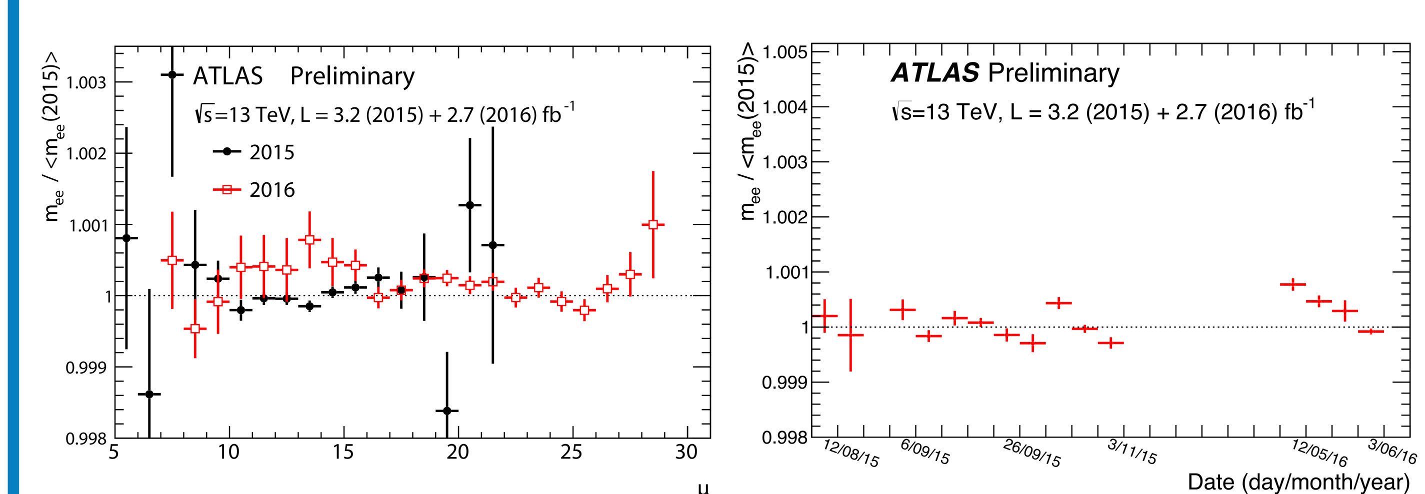


Calibration checks: Z invariant mass distribution

The accuracy of the whole calibration procedure has been checked with Z ⟶ ee mass distribution separately for the 2015 dataset (3.2 fb⁻¹ of integrated luminosity) and for the first part of the 2016 dataset (2.7 fb-1 of integrated luminosity). These comparisons are performed without applying any mass-dependent background subtraction to the data which would reduce the trend in the data to MC ratios observed in both datasets for masses below 84 GeV. Data and simulation agree within uncertainties for both datasets.



Calibration checks: pile-up and time stability



References

[1] ATLAS Collaboration, *Electron and photon energy calibration with the ATLAS detector using LHC Run 1 data*, Eur. Phys. J. C 74 (2014) 3071

[2] ATLAS Collaboration, *Electron and photon energy calibration with the ATLAS detector using data collected in 2015 at √s=13 TeV*, ATL-PHYS-PUB-2016-015

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