# Final Performances for electron and photon calibration, reconstruction and identification with the ATLAS detector

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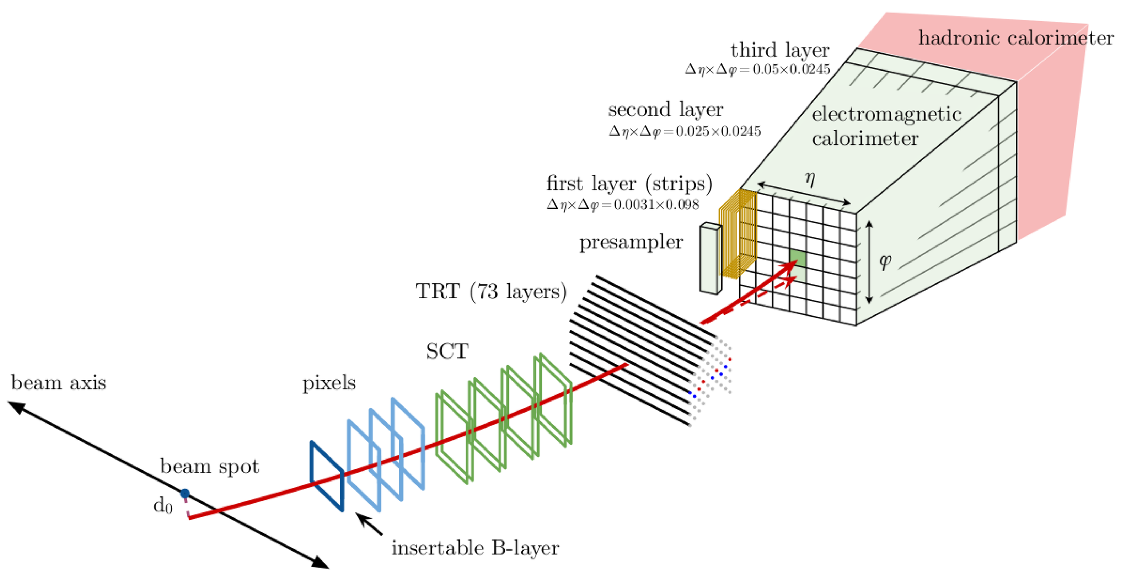
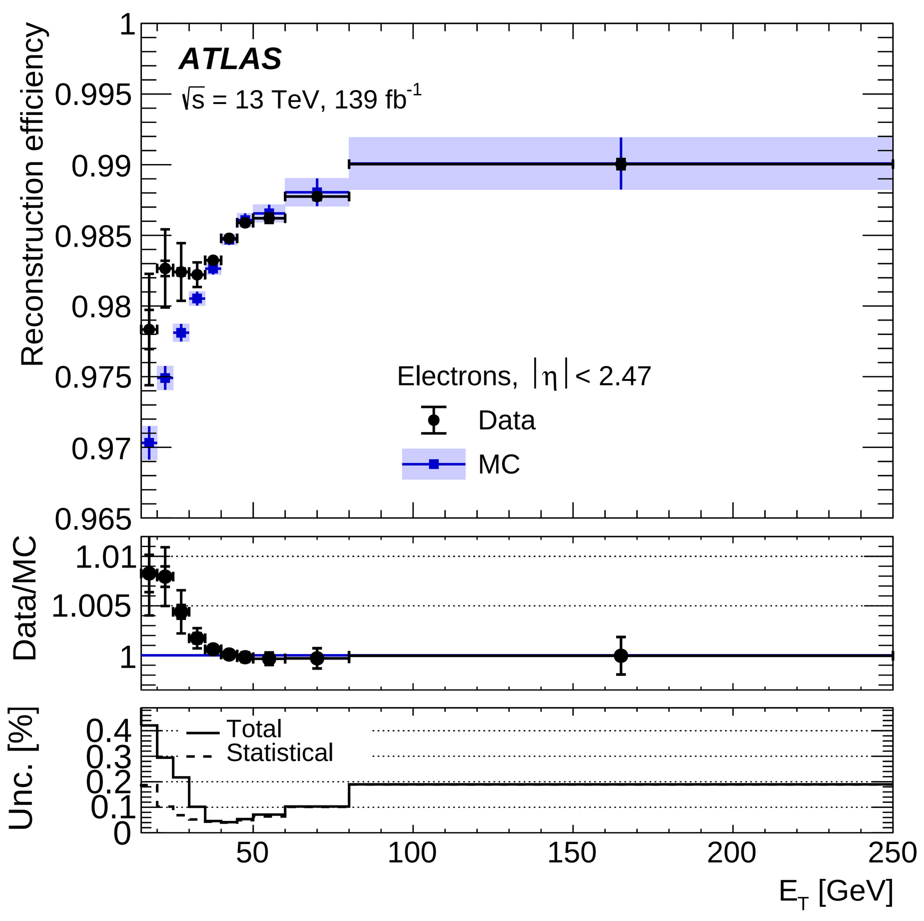
## Overview

At the LHC, electrons and photons play a crucial role for precision measurements of the Higgs Bosons properties as well as of Standard Model parameters such as the weak mixing angle or the W boson mass. In addition, they are crucial for searches such as Di-Higgs production or Beyond Standard Model processes with multi-lepton final states. These challenging measurements rely on a good understanding of the detector performance in order to keep under control the systematic uncertainties arising from electron and photon detection.
After triggering, prompt electron and photon detection goes through the steps: **reconstruction** $\longrightarrow$ **energy calibration** $\longrightarrow$ **identification**

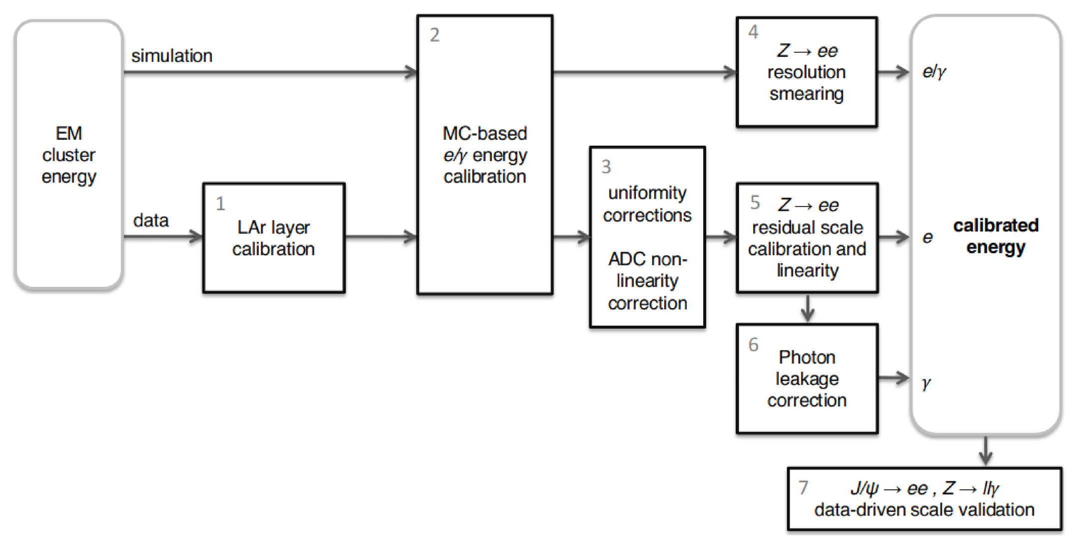
## Object reconstruction




Both electrons and photon deposit their energy in the electromagnetic calorimeter through electromagnetic showering, forming energy clusters. Charged particles leave in addition a visible trajectory inside the inner detector tracker. Clusters matched with a track give reconstructed electrons or converted photons (depending on the track), while those not matched are reconstructed as unconverted photon candidates.




## Energy calibration




To calibrate the energy response of electrons and photons, the successive steps are:
- estimation of the energy from the energy deposits in the calorimeter using a simulation-based BDT regression algorithm
- adjustment of the relative energy scale for each calorimeter layer
- correction for residual non uniformities in the calorimeter response (e.g. high voltage settings)
- adjustment of the overall energy scales ($\alpha$) and resolutions ($c$) in data using $Z \to ee$ samples

$$E_{data} = E_{MC}(1 + \alpha(\eta))$$

$$(\frac{\sigma_E}{E})_{data} = (\frac{\sigma_E}{E})_{MC} \bigoplus c(\eta)$$

Ultimately, the calibrated energy measurements achieved an average precision of [1]:

- 0.4% (resp. 0.3%) for electrons $p_T$=10 GeV (resp. 1 TeV)
- 0.2% for photons of $E_T$=60 GeV

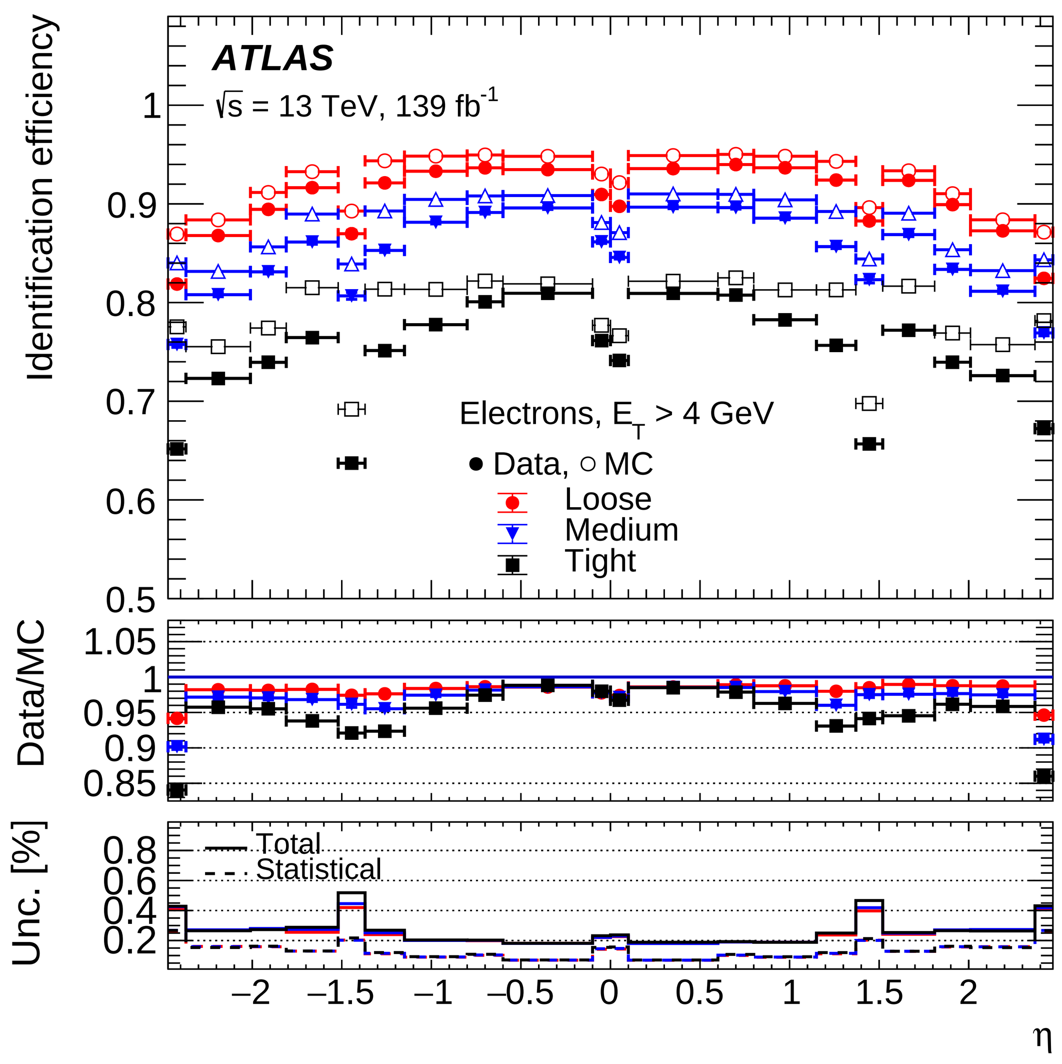
These improvements are validated using independent event samples.

## Electron identification

Identification (ID) aims to discriminate electrons originating from the hard scatter from background electrons (e.g. secondary decays, jets). Depending on the $p_T$, several methods are used to measure ID efficiency [2]:

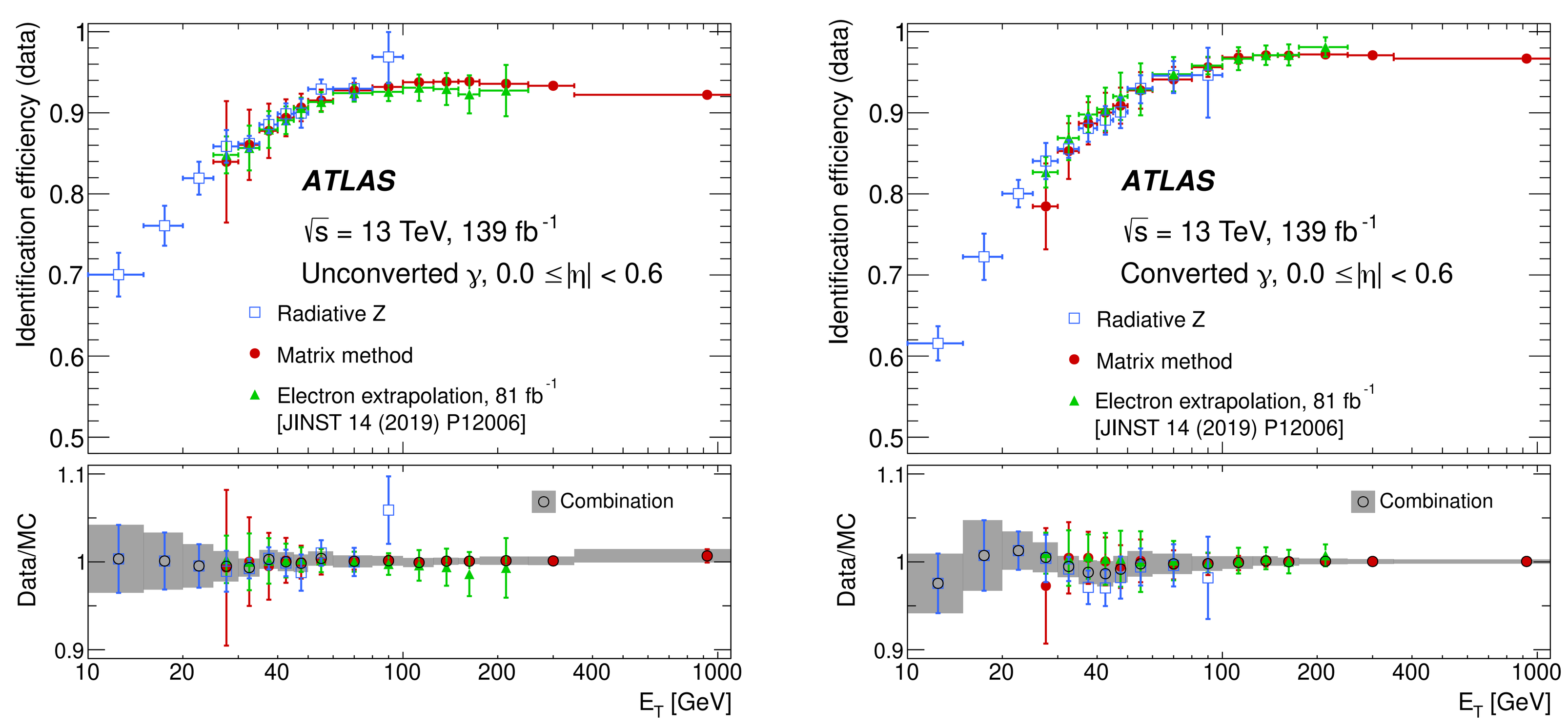
- from $J/\psi \to ee$ invariant mass resonance for $p_T$ down to 4.5 GeV and up to 20 GeV
- from $Z \to ee$ invariant mass resonance for $p_T$ from 15 to 250 GeV
- from $Z$ decay electrons isolation distribution for $p_T$ from 15 to 250 GeV

Methods are later combined for several ID likelihood based working points. [2]




## Photon identification

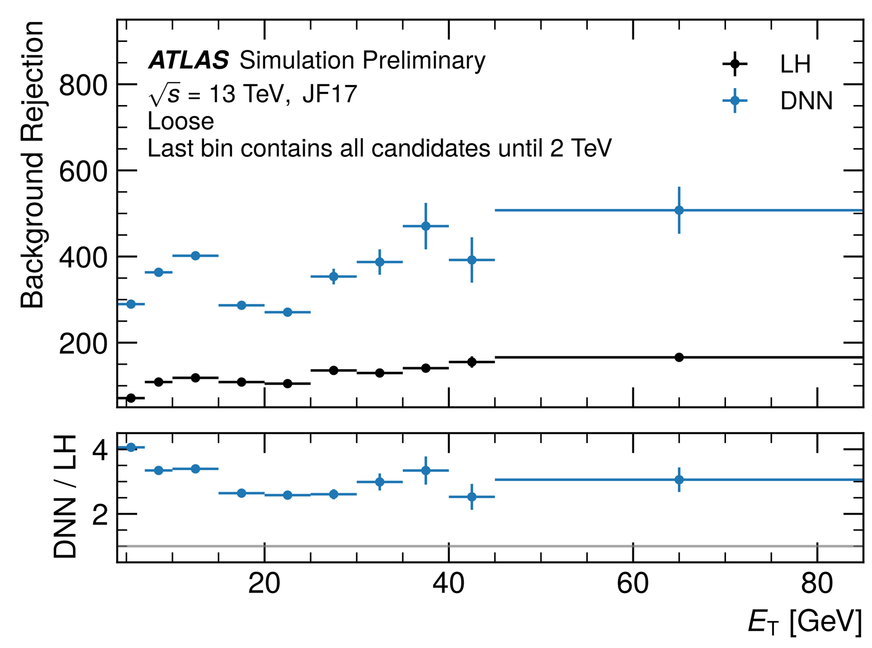
Two main types of photons are to be distinguished for identification purposes: unconverted and converted that are slightly less well described in simulation.




Three methods are used and combined: (1) radiative Z ($\to ll\gamma$) down to $E_T$ = 10 GeV, (2) extrapolation from electron ID measurement ($Z \to ee$) for same $E_T$ range by transforming shower shape variables and (3) matrix method based on ID cuts and isolation differences between prompt and background photons [2].

## Run 2 conclusion & early Run 3

Both $e$ and $\gamma$ ID efficiencies had a remarkable reduction in uncertainties from 30% to 50% compared to the previous Run 2 results. For Run 3, new techniques are used, such as moving from likelihood ID algorithm to deep neural networks [3].




## References

[1] ATLAS Collaboration. Electron and photon energy calibration with the ATLAS detector using LHC Run 2 data. *J. Inst.*, 19(02):P02009, February 2024. arXiv:2309.05471 [hep-ex].

[2] ATLAS Collaboration. Electron and photon efficiencies in LHC Run 2 with the ATLAS experiment. *J. High Energ. Phys.*, 2024(5):162, May 2024. arXiv:2308.13362 [hep-ex].

[3] ATLAS Collaboration. Identification of electrons using a deep neural network in the ATLAS experiment. http://cds.cern.ch/record/2809283/files/ATL-PHYS-PUB-2022-022.pdf, 2022.

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