Data-based calibration of the electro-magnetic calorimeter at the LHC-ATLAS experiment

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- Data-based calibration on the EM-Calo
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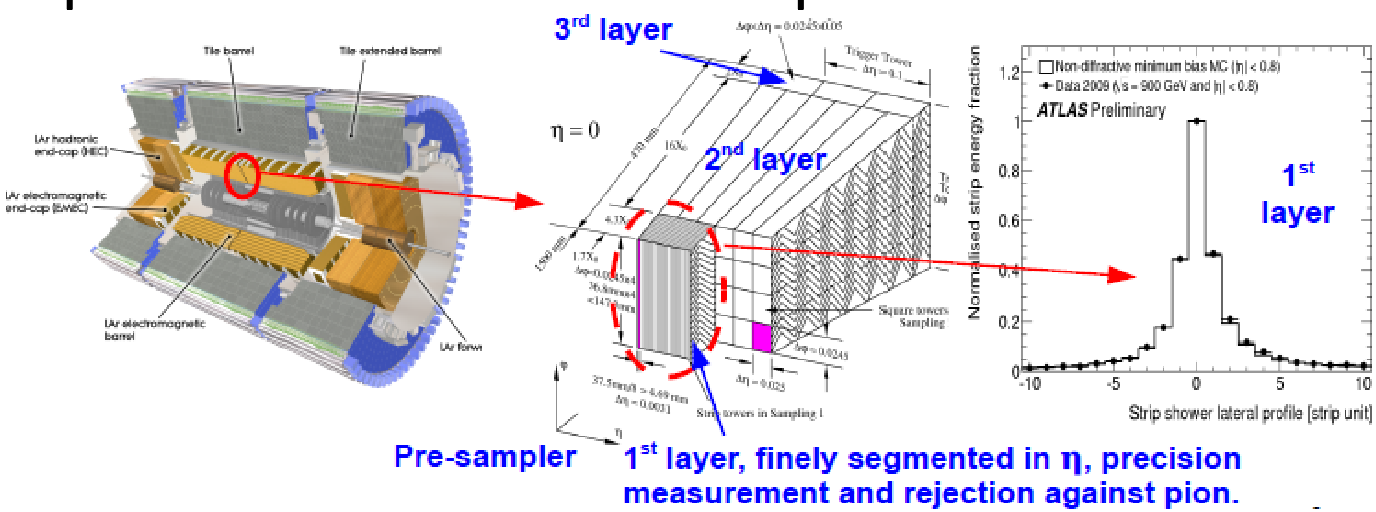
- Summary

- Electron reconstruction

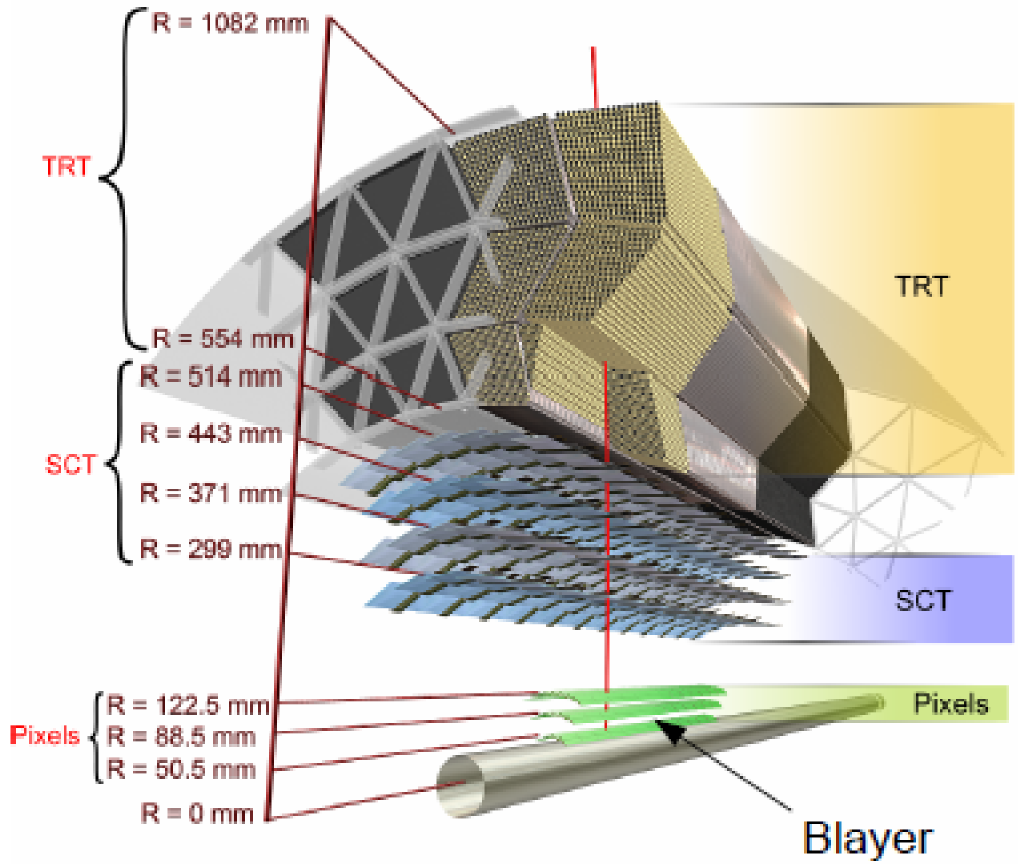
ATLAS Electro-Magnetic Calorimeter

- Liquid Argon EM Calorimeter with accordion geometry covers $|\eta|<3.2$.
  - The fine granularity for $|\eta|<2.5$ allows precision measurements of electrons and photons.
  - The EM-Calo is separated into four volumes: two half-barrels and two endcaps.
- Four layers perform energy/position measurements and provide information for particle identification.

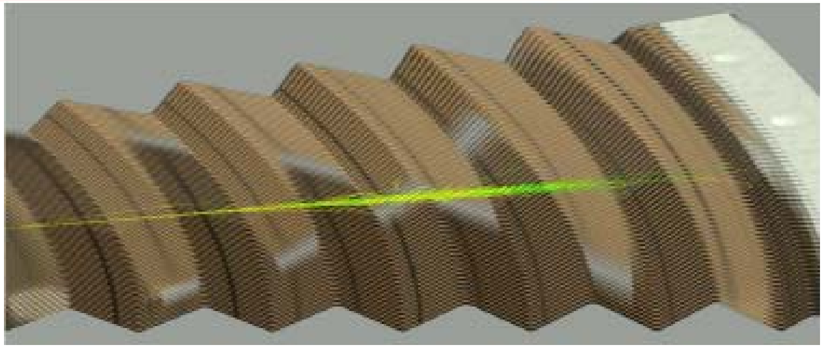


ATLAS Inner Detector Tracking System

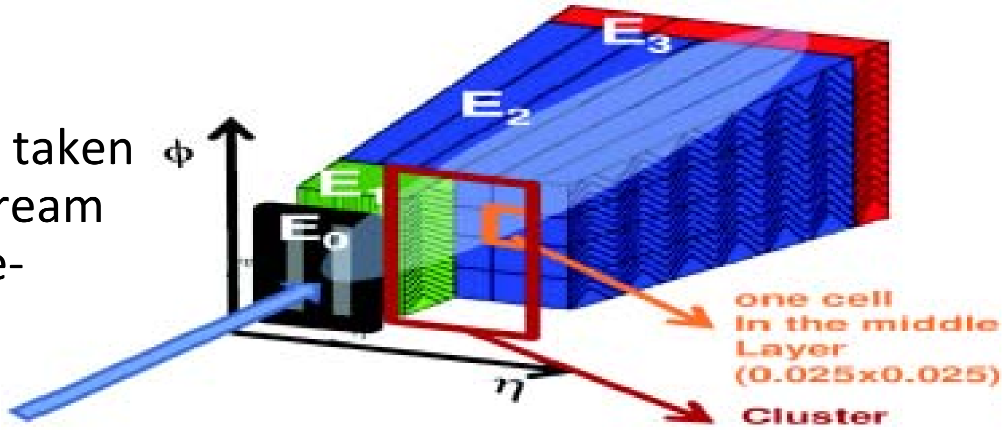
- The ID, consisting of PIXEL, SCT and TRT trackers, provides precision measurements of momentum and direction of tracks with $|\eta|<2.5$, and identification information.



Algorithm of the electron reconstruction



- Clusterization:
  - scan over η-ϕ plane and find the maximum of the local energy deposit.
- Track-cluster matching:
  - decide whether the cluster is classified as an electron or photon candidate.
- Energy measurement:
  - combine energy of each layer taken into account energy lost upstream and laterally measured by pre-sampler $|\eta|<1.8$.
- Position measurement:
  - cluster positions in the EM-Calo
    - η from the 1st layer
    - ϕ from the 2nd layer



The calibration of the EM energy scale

- 1: The LAr calorimeter calibration
  - Convert the raw signal extracted from each cell in ADC counts into an energy deposit
- 2: Monte-Carlo based calibration
  - Apply the correction at the cluster level for energy loss such as dead-material and leakage and for energy modulation in η and ϕ .
  - Not yet perfect
    - Due to the imperfect knowledge of the temperature of the LAr, there is 3% uncertainty.
    - The response should be locally uniform within 0.5% over the regions of the typical size $\Delta\eta \times \Delta\phi = 0.2 \times 0.4$ in order to achieve the global constant term of <0.7%.
- 3: Data-based calibration
  - Determine the absolute energy scale and inter-calibrate the different regions of the EM-Calo using Z->ee events.

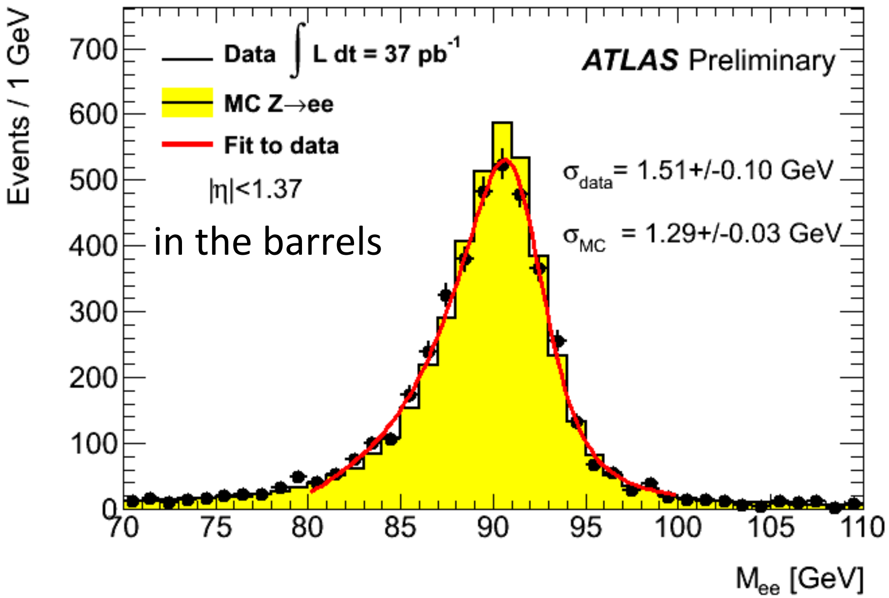
- Data-based calibration on the EM-Calo

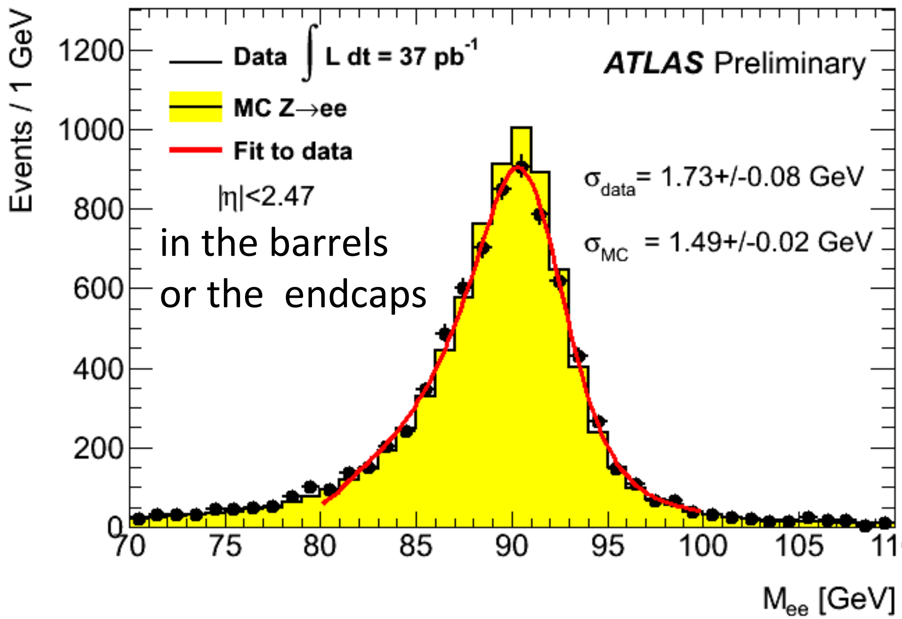
The calibration of the EM energy scale with Z->ee

- The Z->ee candidates among 37 pb^{-1} collision data
  - By combining two opposite sign reconstructed electrons with E_T>20GeV, $|\eta|$<2.47, passing through the medium electron selection, 7241 Z candidates are found within the mass window [80,100] GeV/c^2.

- Determination of the correction factors
  - The e^+e^- invariant mass distribution is fitted with the well known Z line-shapes <<A Breit-Wigner convoluted with a Crystal ball function>>, considering the correction to the electron energy as $E_{corrected}=E_{measured}/(1+a)$.
  - The corrections depend on the 28 regions in the EM-Calo.

The calibrated Z->ee invariant mass





MC distribution is normalized to the number of entries in data within the fit range of [80-100] GeV/c^2.

The obtained corrections in average are -0.98+/-0.05% for the barrel, 2.29+/-0.17% (1.61+/- 0.16%) for the endcaps in $\eta < 0$ ($\eta > 0$), which are compatible with the expectation (+/-3%) from the uncertainty in the LAr temperature.

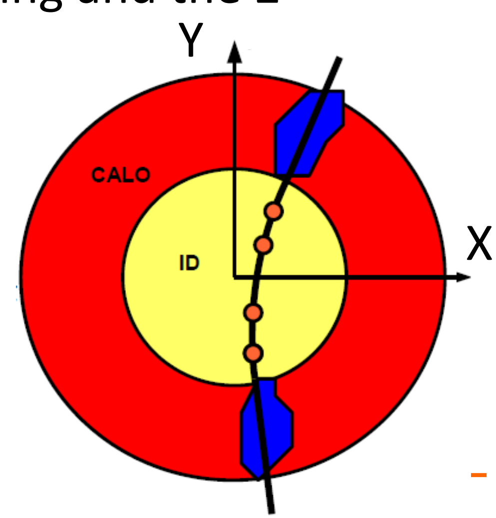
Definitions of the positions in the EM-Calo

- For the inter-alignment b/w the EM-Calo and the ID, we compare the two positions in the EM-Calo
  - ID track impact position (η_{track} ϕ_{track})
  - Electron cluster position ($\eta_{cluster}$ $\phi_{cluster}$)

    $\Delta\sinh\eta = \sinh\eta_{cluster} - \sinh\eta_{track}$, $\Delta\phi = \phi_{cluster} - \phi_{track}$
  - The ID is assumed to be perfectly aligned.

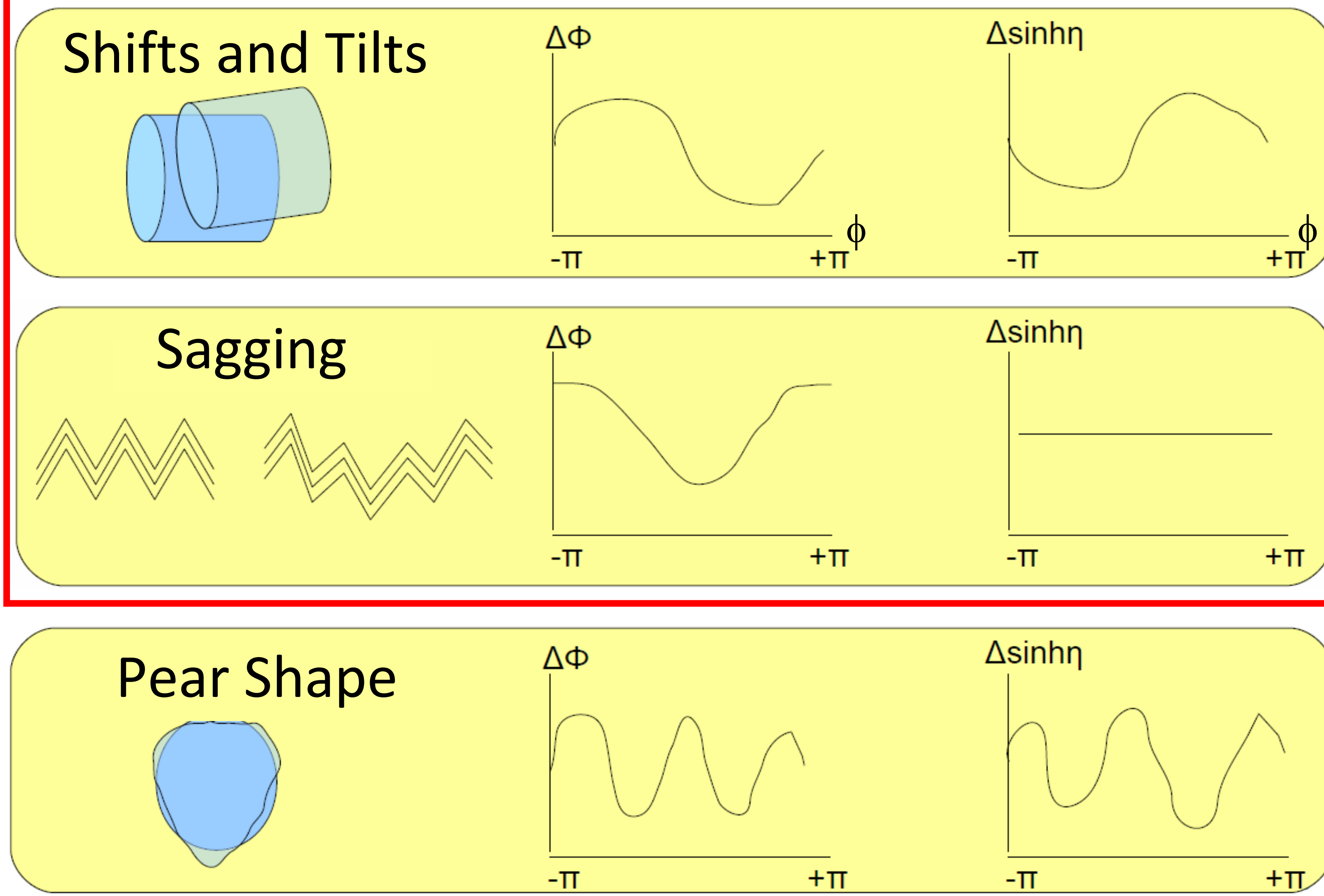
- The track extrapolation: (η_{track}, ϕ_{track})
  - We start from perigee after rescaling of the momentum to the calorimeter energy considering the brems effects.
  - We extrapolate to the shower depth in the 1st sampling and the 2nd sampling for (η_{track}, ϕ_{track}), respectively.

- The electron cluster position: ($\eta_{cluster}$, $\phi_{cluster}$)
  - $\eta_{cluster}$ is obtained from the 1st sampling: $\eta_{cluster} = \eta_1$
  - $\phi_{cluster}$ is from the 2nd sampling: $\phi_{cluster} = \phi_2$



Inter-alignment b/w the EM-Calo and the ID

Sources The mis-alignment measurements

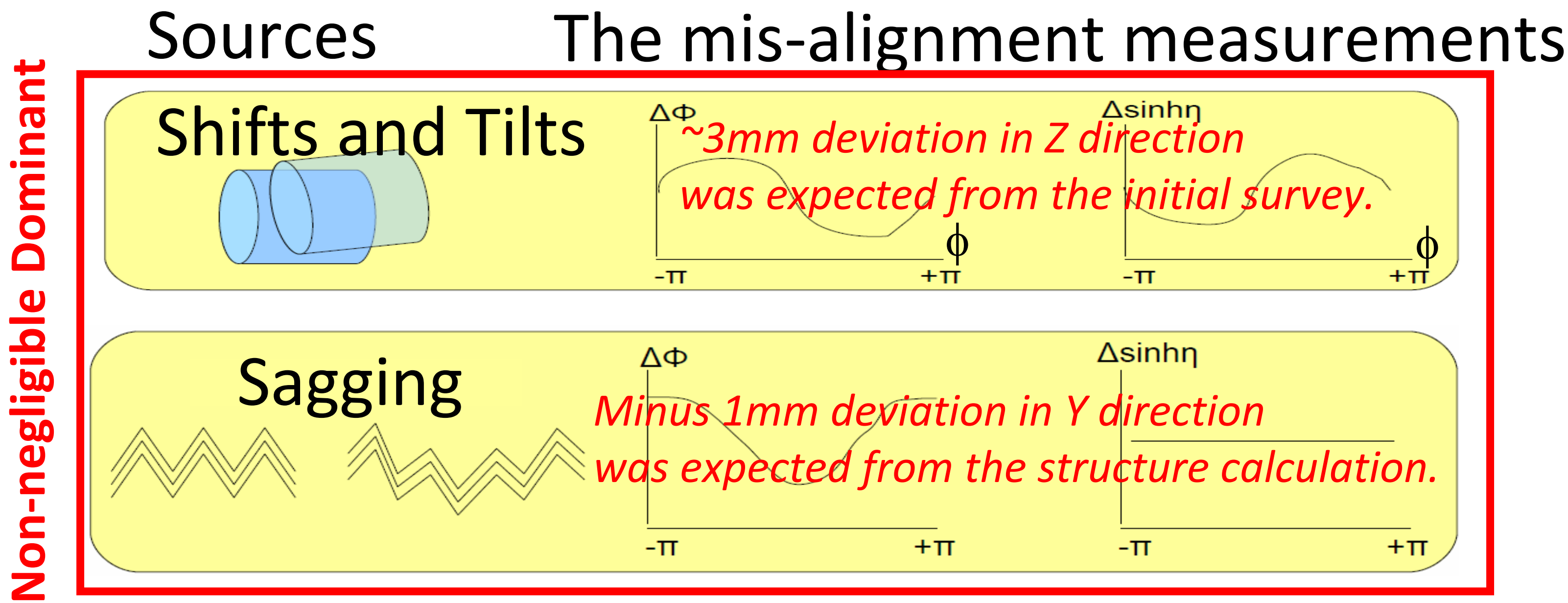


Dominant

Non-negligible

Negligible in the 1st order

Determination of the mis-alignment values



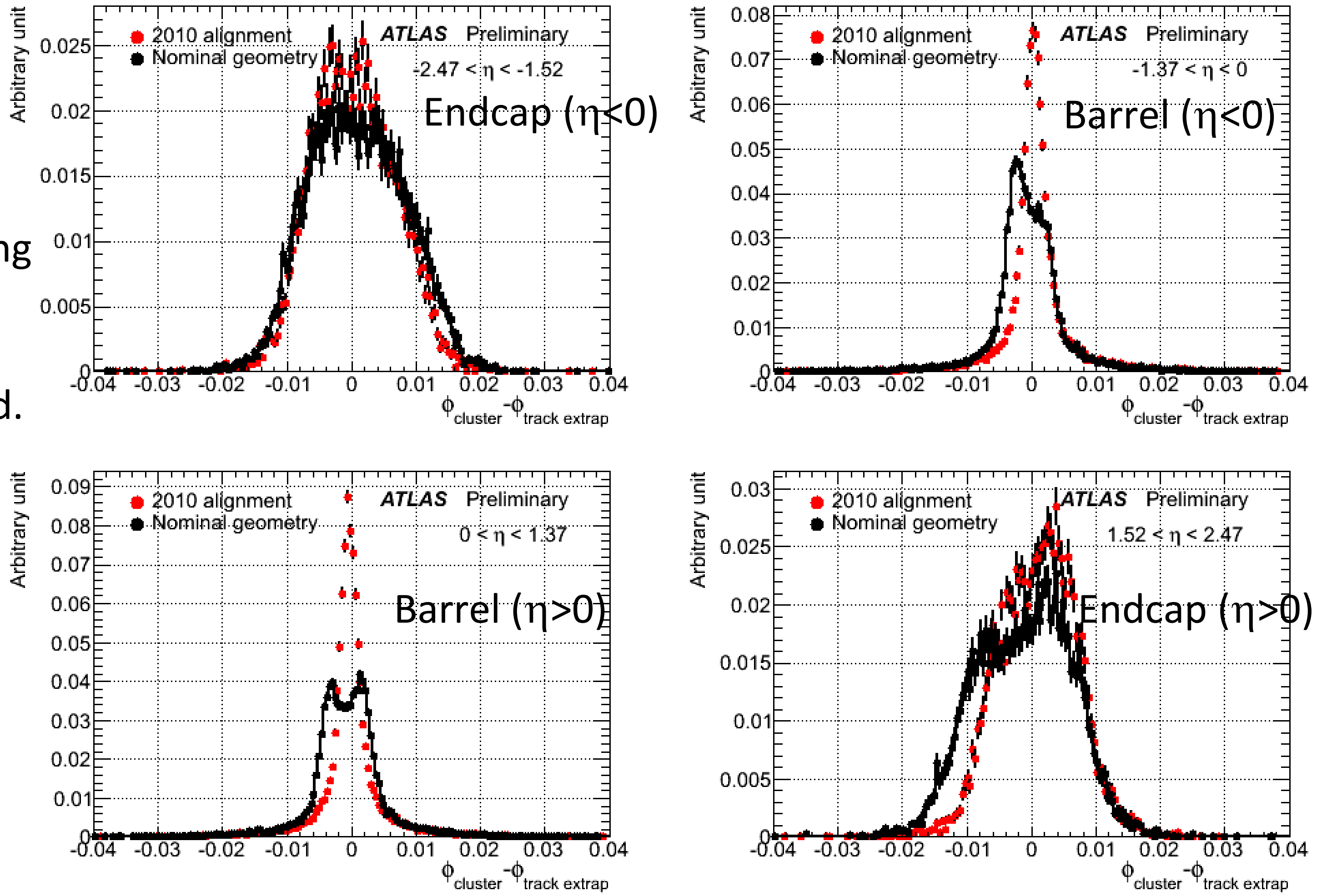
•The position precision of O(1mm) is required for most of the electron performances such as track-cluster matching and photon-pointing.

•With ~300k inclusive electron candidates ($P_T \geqq 20GeV/c$), the shifts and tilts for two half-barrels and two endcaps were determined from the ($\Delta\phi$ vs ϕ_{track}) and ($\Delta\sinh\eta$ vs ϕ_{track}) distributions depending on η.

=> Finally, we put the cell-by-cell position corrections "calculated from the mis-alignment values and simulated for the sagging effect by -1mm in the Y direction of the barrels" into the ATLAS database for the electron reconstruction.

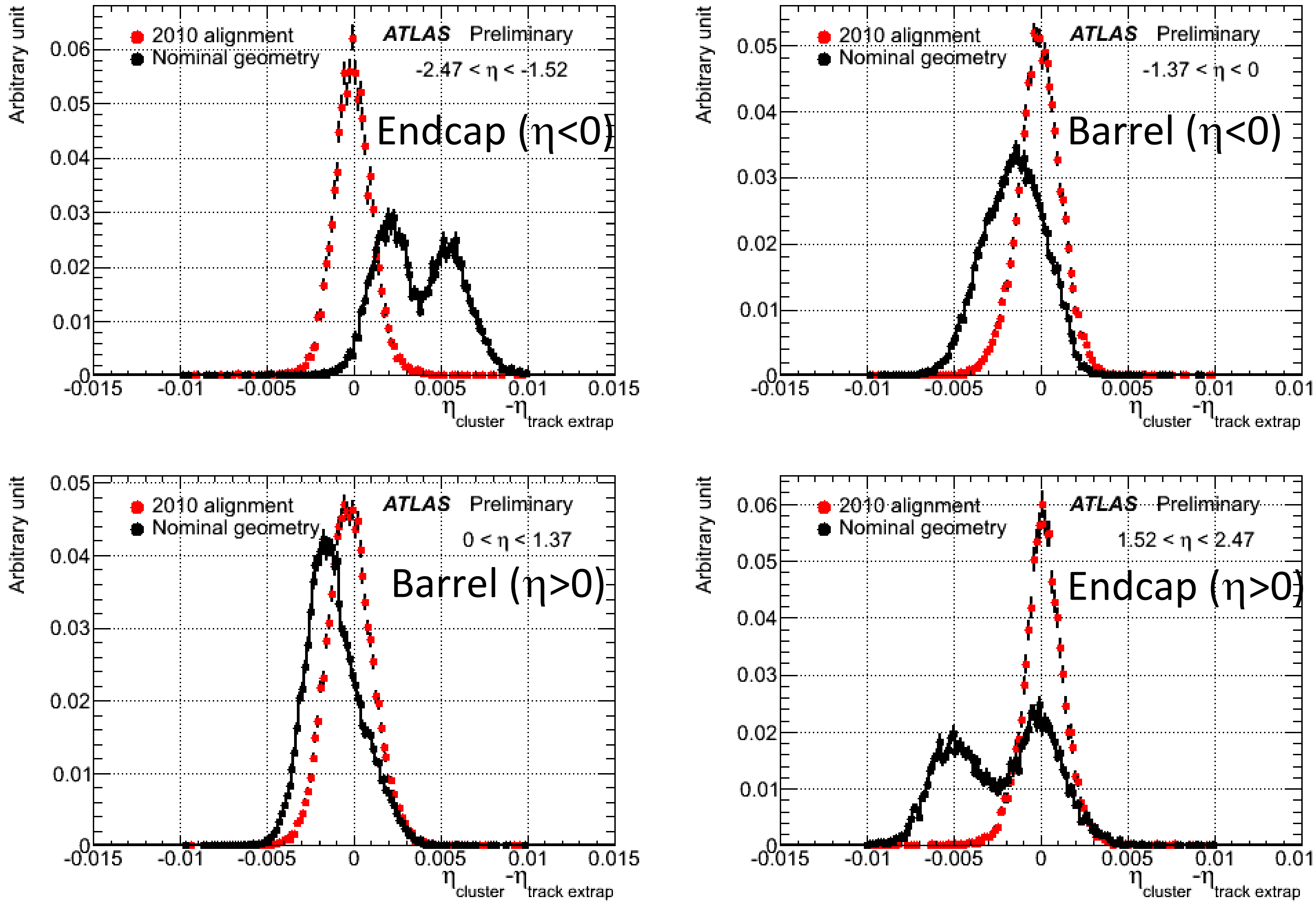
Improvements on the track-cluster matching variable $\Delta\phi$

The events compatible with the production of a W or Z boson including one or two high PT ($\geqq$20GeV/c) electron candidates are selected.



The $\Delta\phi$ distributions after the alignment corrections have been applied are much better centered on zero with narrower width, but can be more improved by the better description on the sagging effect.

Improvements on the track-cluster matching variable $\Delta\eta$



The two peak structure visible in the endcaps is gone by the alignment procedure for the transverse displacements of the order of 5mm.

=> After the alignment, $\Delta\phi$ and $\Delta\eta$ can be utilized for the electron identification.

Summary

- The precise determination of the energy scale and position of the LAr EM-Calorimeter is important for many physics analyses using electrons and photons.

- Data-based calibration of the LAr EM-Calo at the ATLAS was achieved.
  - The energy scale of the EM-Calo using the Z->ee events
    - for 28 regions in the EM-Calo in order to keep the response locally uniform.
    - It varies from ~1% in the barrel to ~2% in the endcaps.
  - The position: Inter-alignment b/w the EM-Calo and the ID using the inclusive electrons
    - After the correction for the shifts, tilts and the sagging effect, the distributions of the track-cluster matching variables, $\Delta\eta$ and $\Delta\phi$, are much better centered on zero with narrower width.
    - $\Delta\eta$ and $\Delta\phi$ have been used for the electron/photon identification.