Electromagnetic showers shapes and data-driven corrections

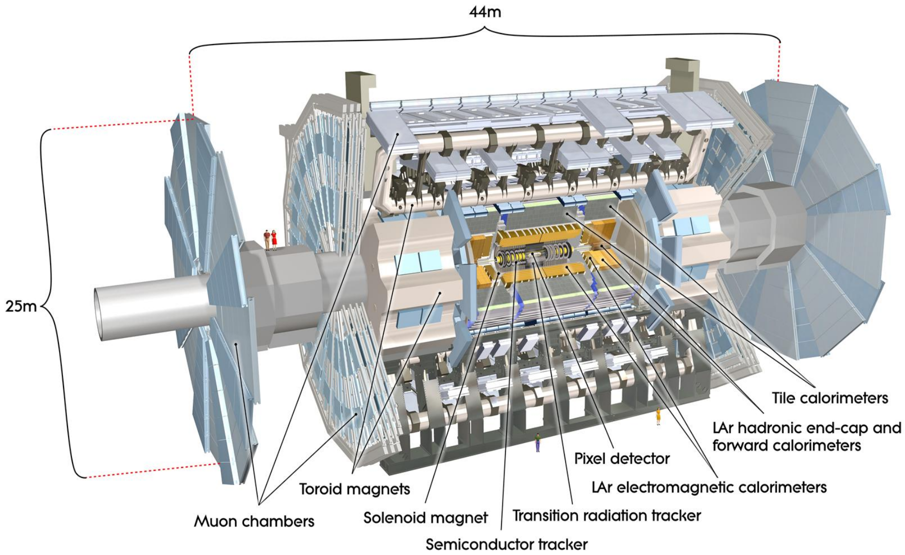
Mykola Khandoga

CEA Saclay

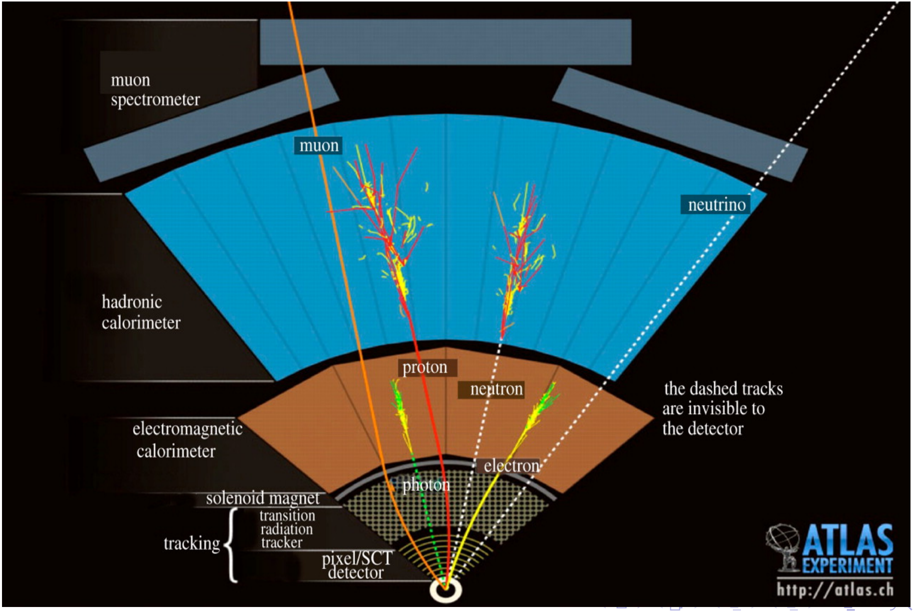
Journées de Rencontre des Jeunes Chercheurs 2018, Lège-Cap-Ferret

October 18^{th}, 2018

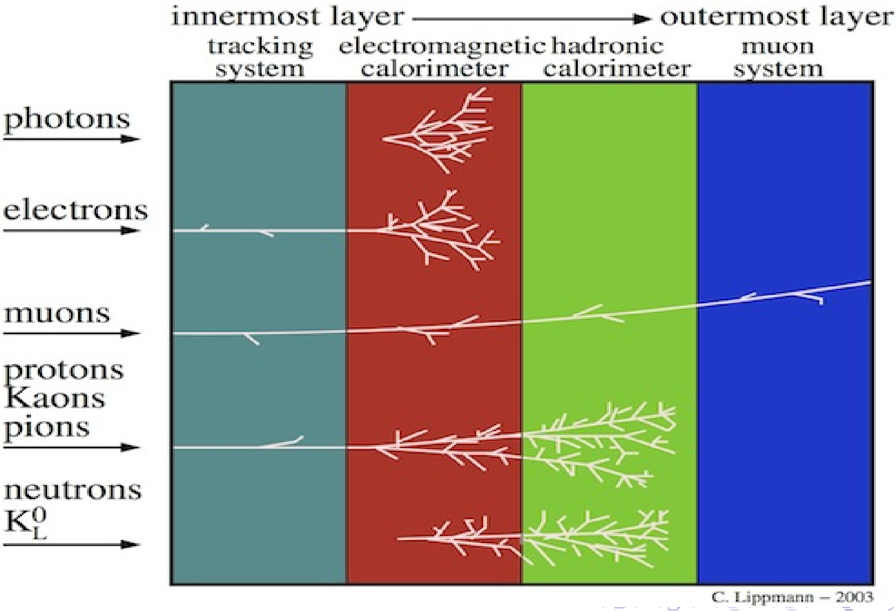
The ATLAS detector



ATLAS detector systems

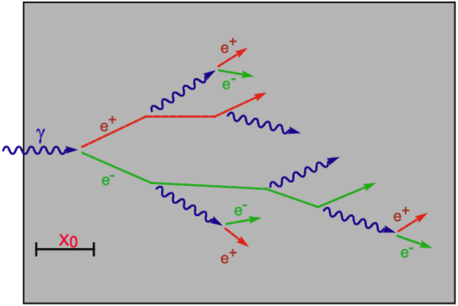


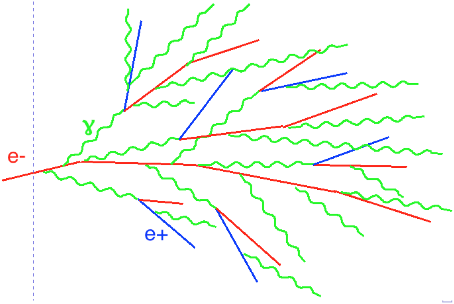
Particle ID



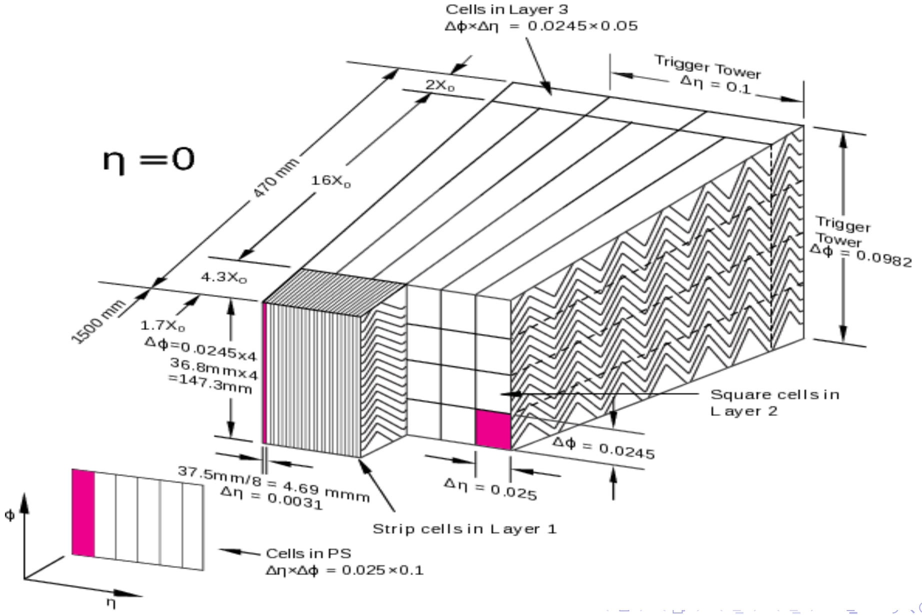
innermost layer
outermost layer
tracking system
electromagnetic calorimeter
hadronic calorimeter
muon system
photons
electrons
muons
protons
Kaons
pions
neutrons
K^0_L
C. Lippmann – 2003

EM Showers





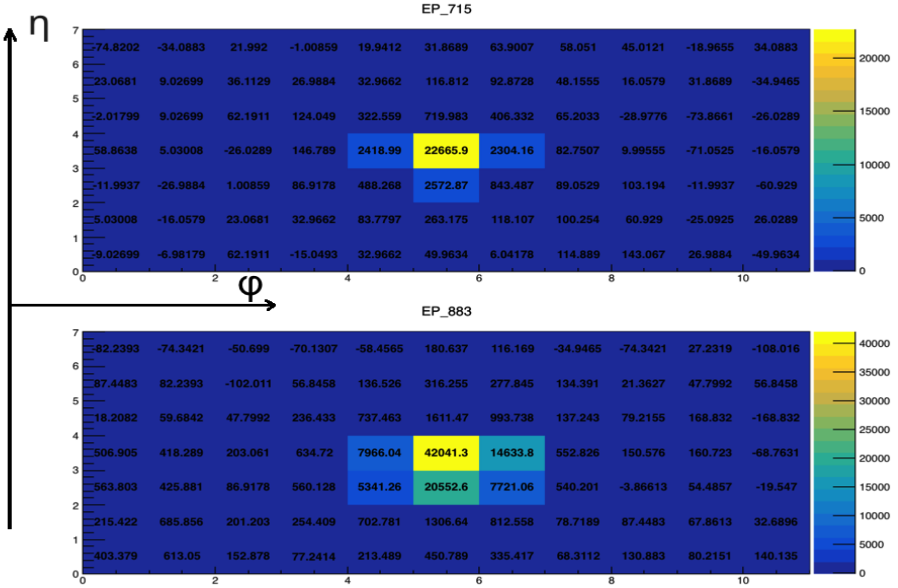
EM Calorimeter structure



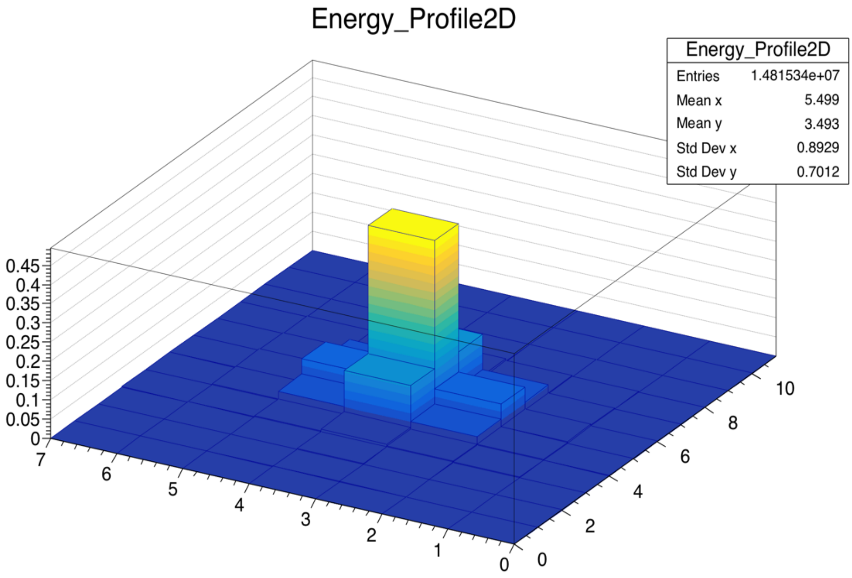
Electron reconstruction challenges

- It is possible that the reconstructed electrons are not signal electrons, but come from hadronic jets, converted photons, heavy flavour decays etc.
- Discriminating signal electrons is crucial for analysis.
- For electron ID the MVA analysis is applied with $>$20 variables using information from the inner detector, EM calorimeter and hadronic calorimeter.
- Electron ID algorithm is very sensitive to information about shower shapes from the 2nd layer of EM calorimeter.
- We would like ID efficiency for Data and MC to be as close as possible (scale factors close to 1).

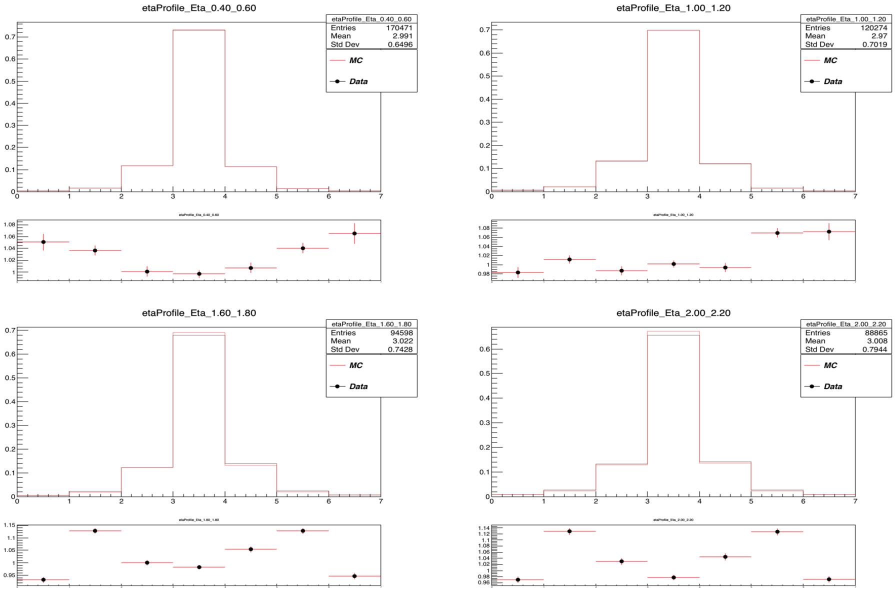
Second layer energy profile



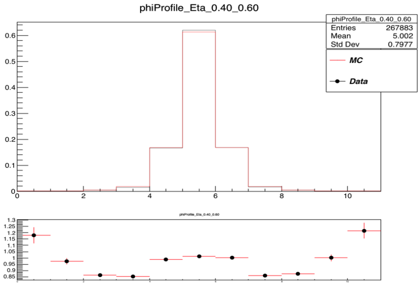
Second layer energy profile

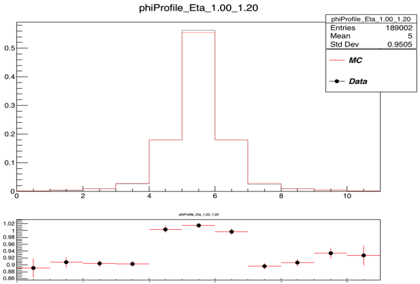


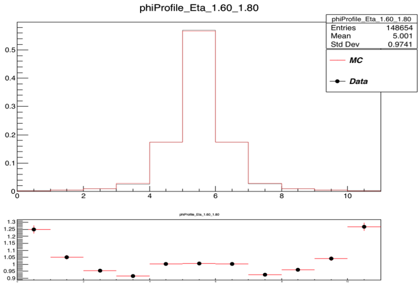
Eta energy profile - 7 cells

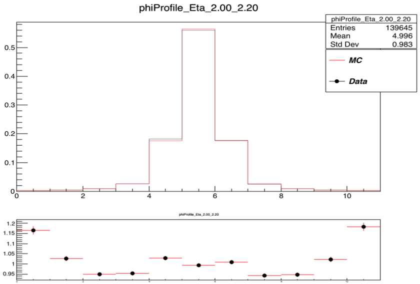


Phi energy profile - 11 cells







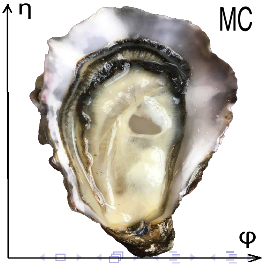


Energy profiling conclusions

- The shower shapes are η-dependent, so 14 slices in η were considered in the range of $|\eta| = 0 - 2.4$
- The barrel $|\eta| = 0 - 1.37$ and the endcap $|\eta| = 1.52 - 2.4$ regions demonstrate different behavior.
- MC-modelled shower is wider than the data in ϕ and narrower in η.
- The discrepancy is higher in the barrel for ϕ profile and in the endcap for η.

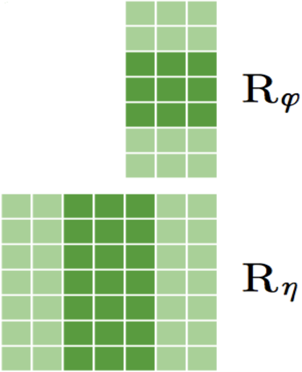
Energy profiling conclusions

- The shower shapes are η-dependent, so 14 slices in η were considered in the range of $|\eta| = 0 - 2.4$
- The barrel $|\eta| = 0 - 1.37$ and the endcap $|\eta| = 1.52 - 2.4$ regions demonstrate different behavior.
- MC-modelled shower is wider than the data in ϕ and narrower in η.
- The discrepancy is higher in the barrel for ϕ profile and in the endcap for "η.

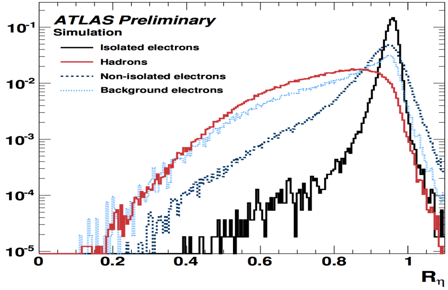


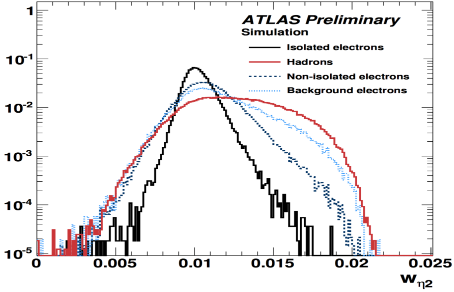
Quantifying shower shapes: 2nd layer variables

- Lateral shower width $W_{\eta^2} = \sqrt{\sum(E_i\eta_i^2) - (\sum(E_i\eta_i)/\sum(E_i))^2}$ calculated within a window of 3x5 cells
- R_ϕ - ratio of the energy in 3x3 cells over the energy in 3x7 cells centered at the electron cluster position.
- R_η - ratio of the energy in 3x7 cells over the energy in 7x7 cells centered at the electron cluster position.

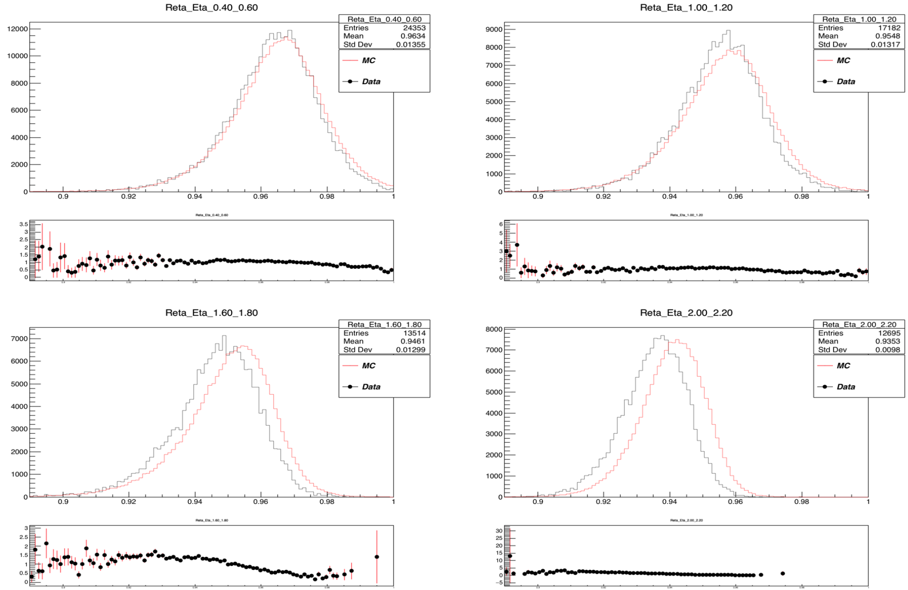


Simulation plots

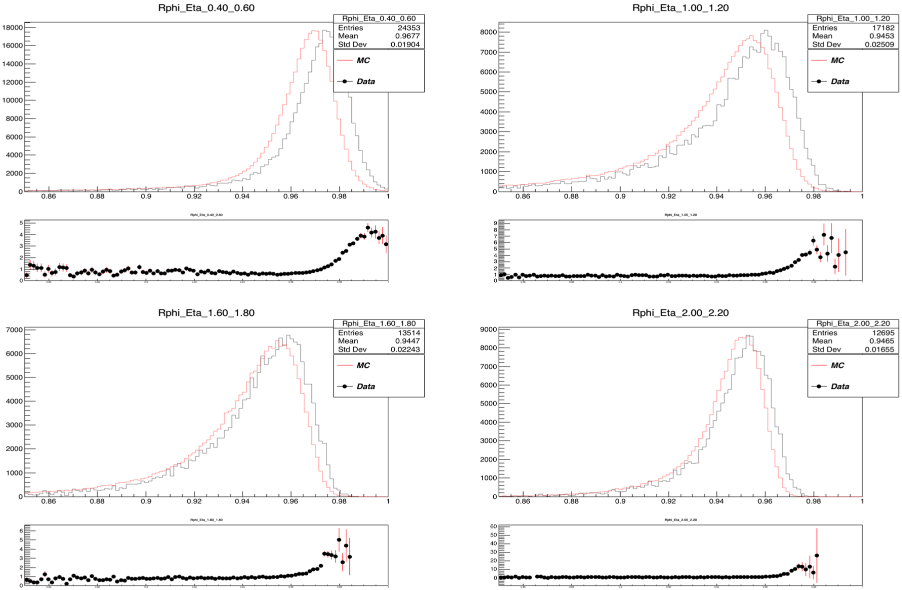




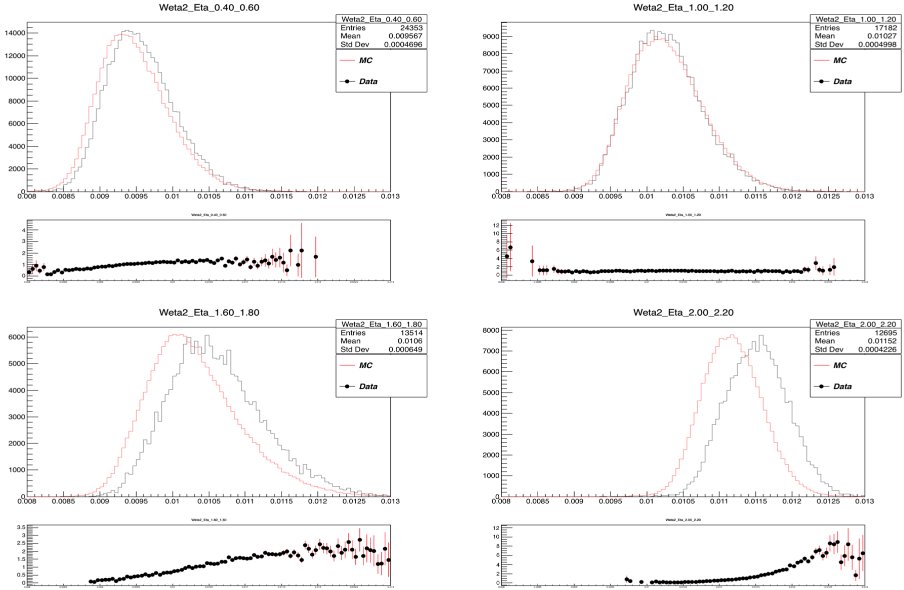
R_η in 4 different eta bins - Data vs MC



R_ϕ in 4 different eta bins - Data vs MC



W_{η^2} in 4 different eta bins - Data vs MC



Reweighting procedure

Reweighting is performed in two steps:

- Calculation of the 2D correction matrix containing cluster cell corrections for each η slice

$$E_i^{Correction} = \frac{E_i^{Data}}{\sum E^{Data}} - \frac{E_i^{MC}}{\sum E^{MC}}$$

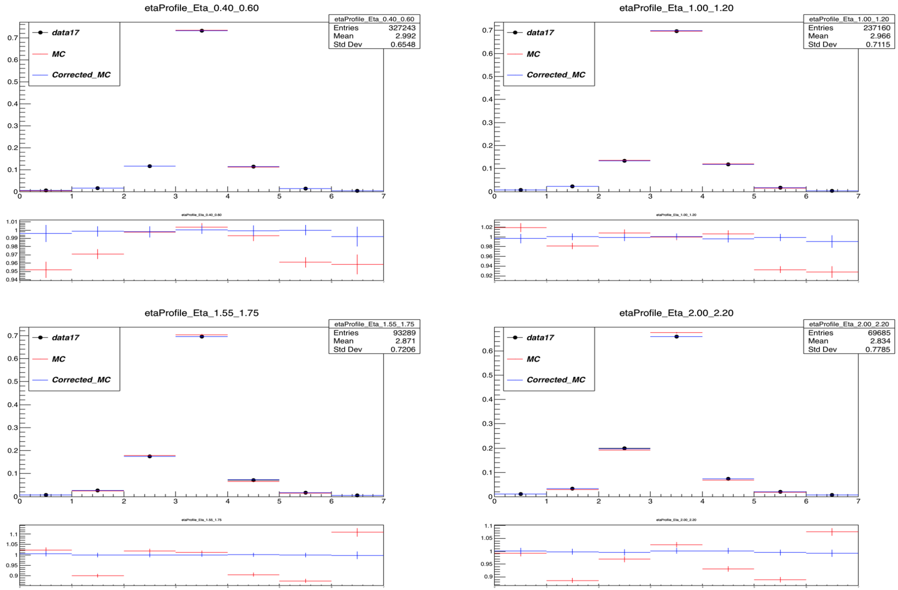
  where i is the number of the cell.The integral of the correction matrix is the re-scaled to 1.

- Calculation of the reweighted energy for electron cluster cells in every MC event

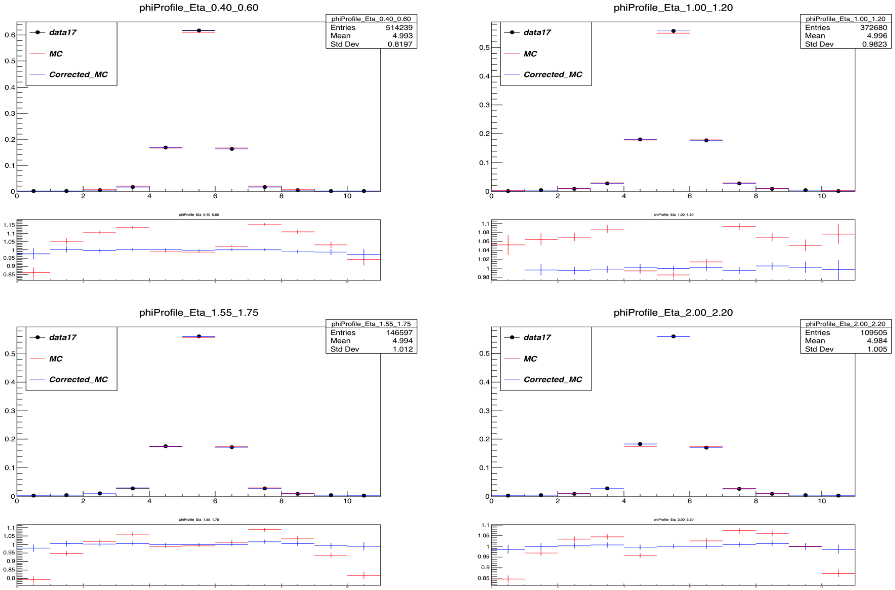
$$E_i^{Reweighted} = E_i^{Non-reweighted}(1 + E_i^{Correction})$$

The total energy is then rescaled to ensure that it remains the same after reweighting.

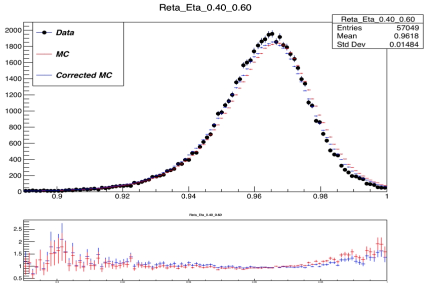
Reweighted Eta profile in 4 eta bins - Data vs MC

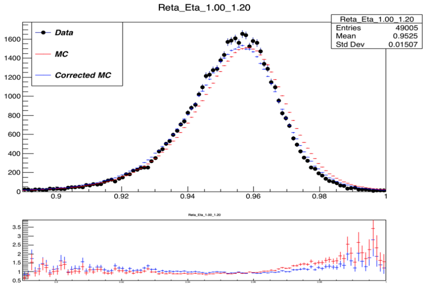


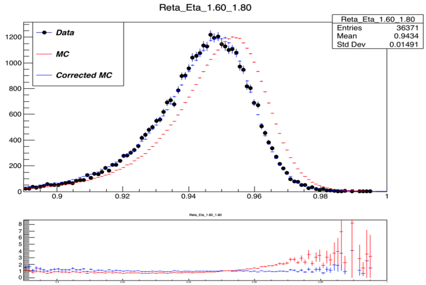
Reweighted Phi profile in 4 eta bins - Data vs MC

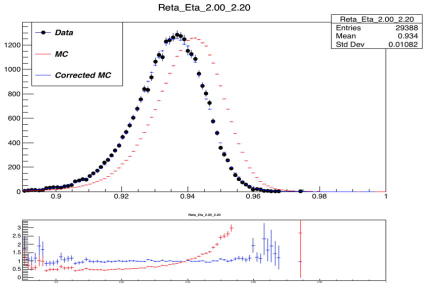


Reweighted Reta

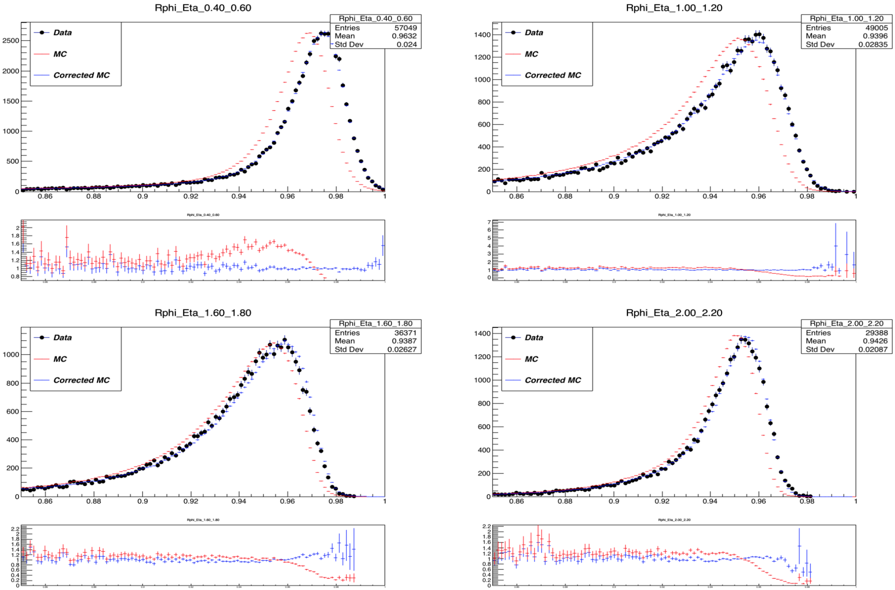




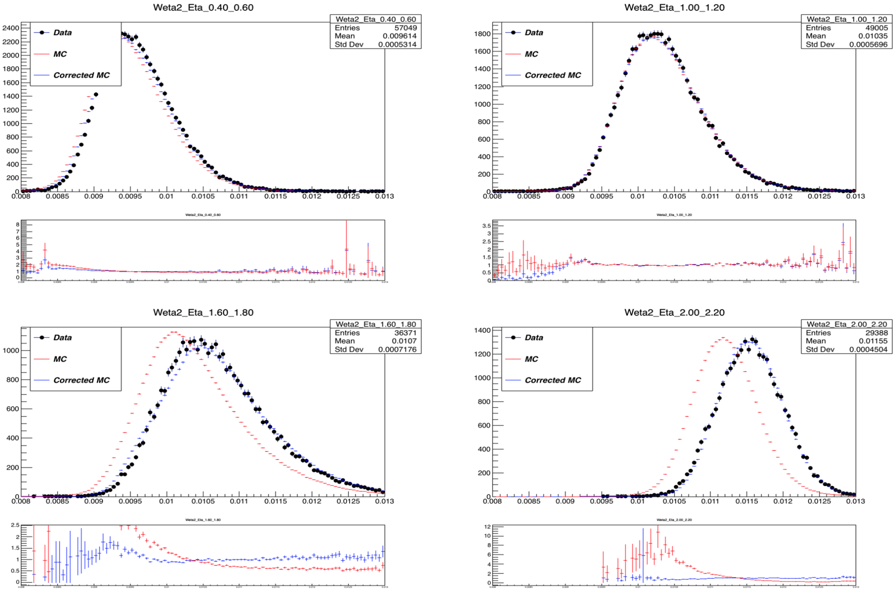




Reweighted Rphi



Reweighted Weta2



Conclusions

- The developed method is aimed to make the ID efficiency in MC as close as possible to the data.
- This would allow to decrease the systematic uncertainty, imposed by using the highly pT-dependent scale factors.
- The method was successfully tested in Athena release 21 framework.
- To be presented for approval as a part of an official Athena release.

BACKUP

- BACKUP SLIDES

Samples used

- a slightly modified EGAM1 derivation was used in order to extract the calorimeter cell data usable within the AnalysisBase framework
- data17_13TeV.00337176.physics_Main.merge.AOD.r10258_p3399
  10258 means "Reprocessing tag with for after first event and no HLT monitoring"
- mc16_13TeV.361106.PowhegPythia8EvtGen_AZNLOCTEQ6L1
  _Zee.merge.AOD.e3601_s3126_r9781_r9778

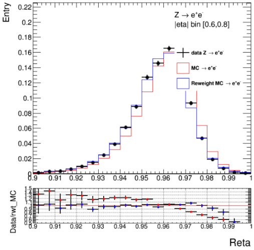
Event selection

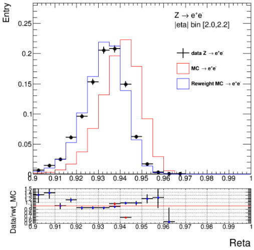
- Z->ee process considered
- event was required to have two electrons one of which has $p_T > 25 GeV$
- gradient isolation
- Tag and probe, no ID
- Z invariant mass window 80 - 120 GeV
- electron triggers: HLT_e26_lhtight_nod0_ivarloose, HLT_e60_lhmedium_nod0, HLT_e140_lhloose_nod0,HLT_e300_etcut
- no pile-up reweighting

Excerpt from the previous study - R_η and W_{η^2}

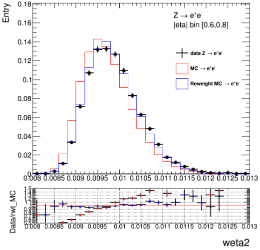
- Layer2 η related variables comparison bf/af reweighting in barrel and end-cap.

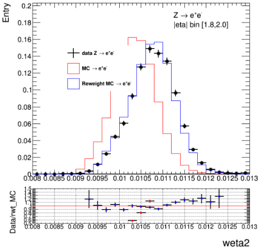
Reta



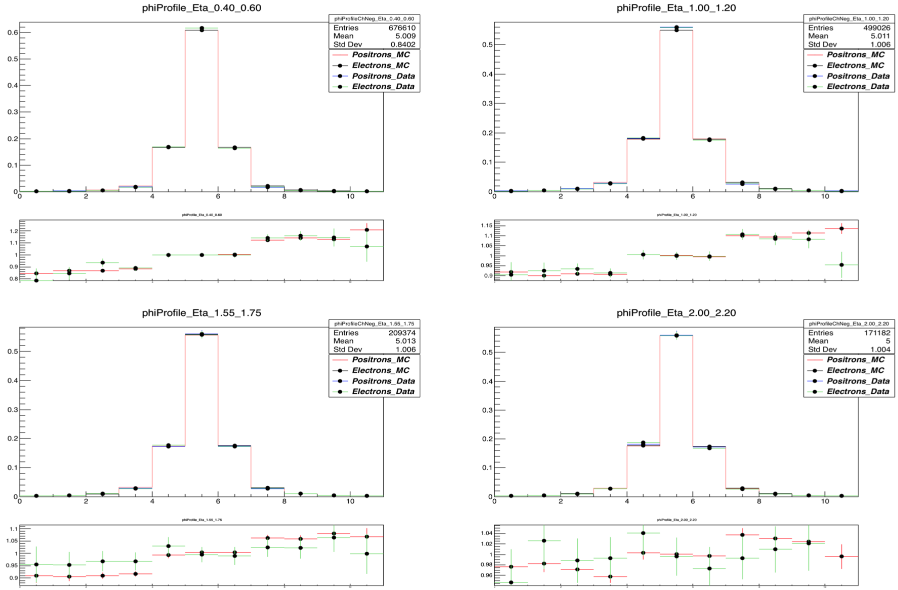


weta2

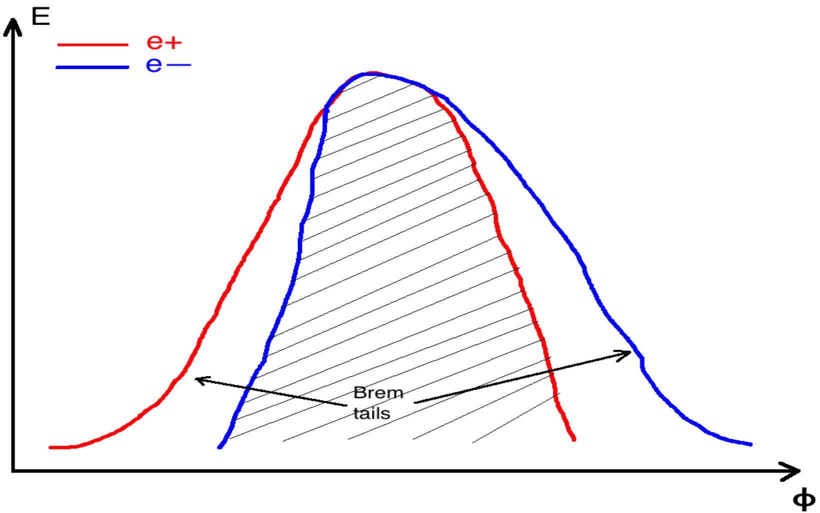




Phi profile - charge asymmetry, Data



Schematic energy profile



The hatched region is taken in order to obtain a brem-free profile hence same reweighting function for e+ and e-.