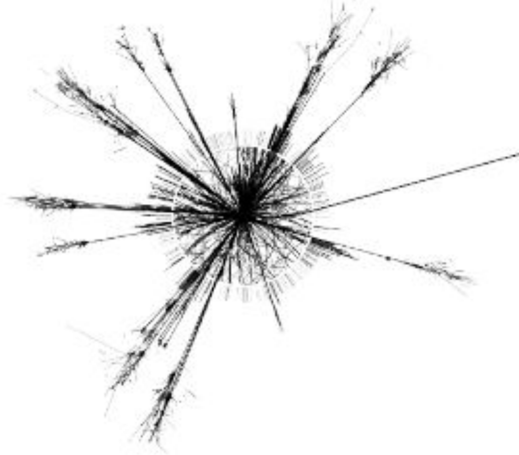
Workshop RENAFAE 2022



CALIBRAÇÃO DE ENERGIA NA ETAPA RÁPIDA DO *HIGH LEVEL TRIGGER* DE ELÉTRONS DO EXPERIMENTO ATLAS UTILIZANDO ANÉIS CONCÊNTRICOS E ESTRUTURAS ASSIMÉTRICAS

ATLAS EXPERIMENT

Micael V. de Araujo[1], Paulo C. M. A. Farias[2], Werner S. Freund[1], Bertrand Laforge[3], Juan L. Marin[2], João Victor da F. Pinto[1], José M. de Seixas[1], Eduardo F. Simas Filho[2], Edmar E. P. de Souza[2].

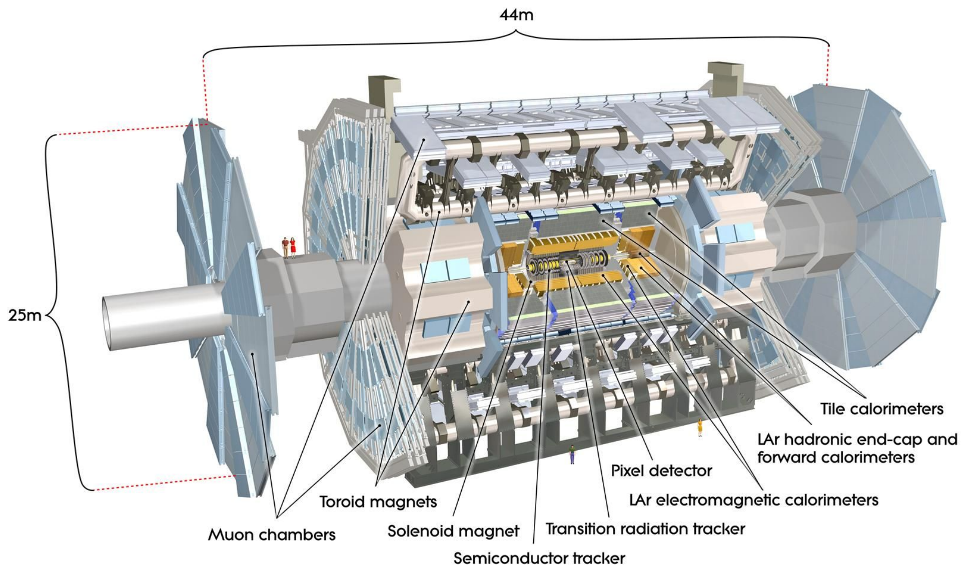
[1] Laboratório de Processamento de Sinais - COPPE-Poli, UFRJ
[2] Laboratório de Sistemas Digitais - PPGEE / UFBA
[3] LPNHE - Sorbonne Université

LSD Laboratório de Sistemas Digitais

VIRTUTE SPIRITUS 1808

Introduction

ATLAS Experiment



- Massive amount of information (LHC collisions every 25 ns + ~1,3 MB per event => ~52 TB/s).

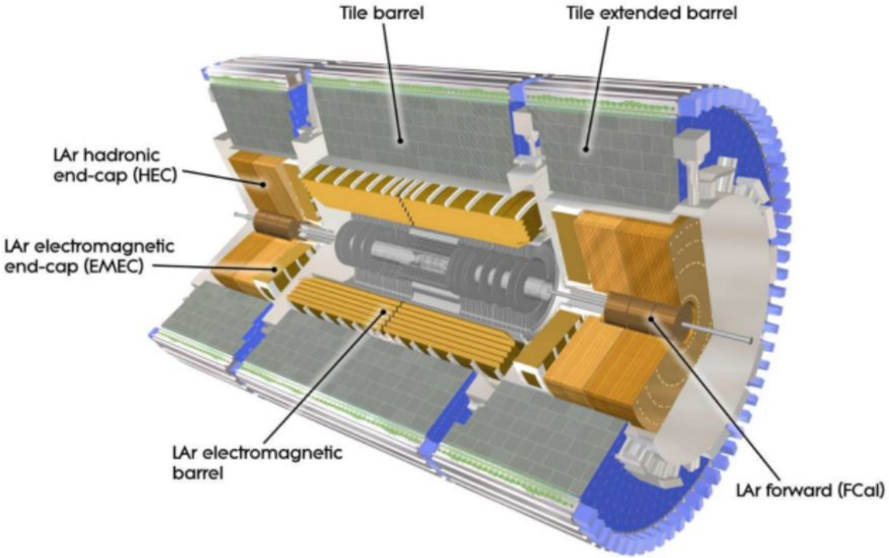
- Event selection => two-level online trigger system:
  - L1 (*Level one*) -> FPGA;
  - HLT (*High Level Trigger*) -> parallel-processed software:
    - **Fast step**
    - Precision step

- **Calorimeters**: energy estimation + particle characterization:
  - 4 electromagnetic layers
  - 3 hadronic layers

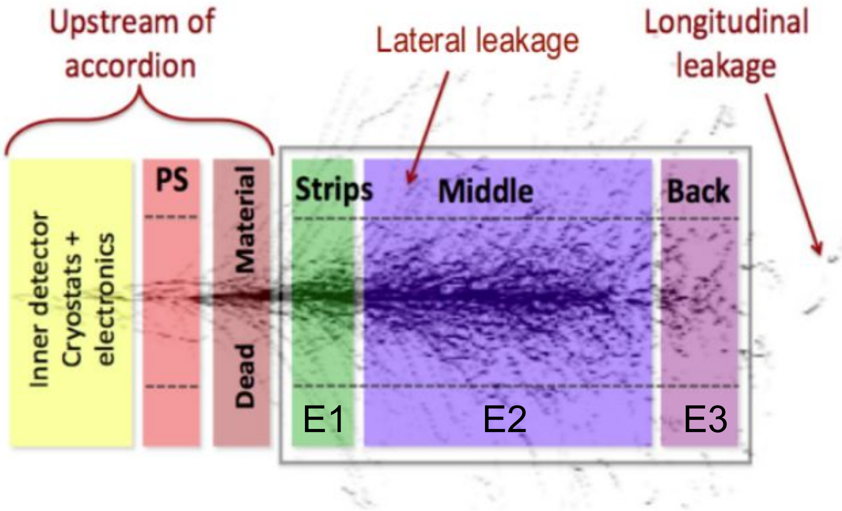
- Instrument limitations can produce errors in the energy estimation.

ATLAS Experiment calorimeters

Segmentation in layers and modules:

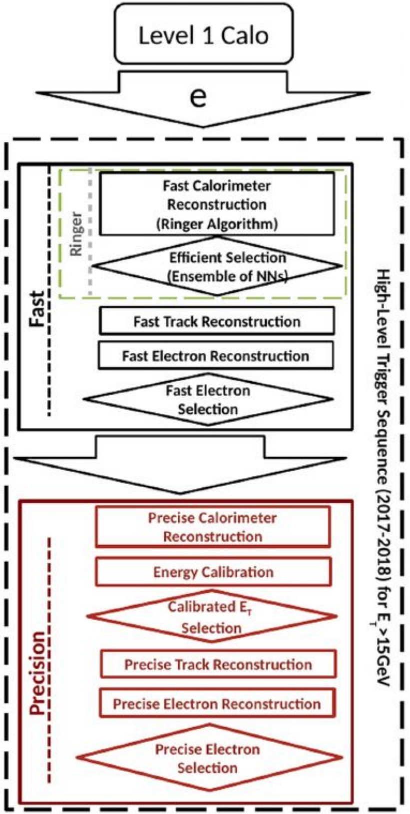


Possible error sources in energy estimation:

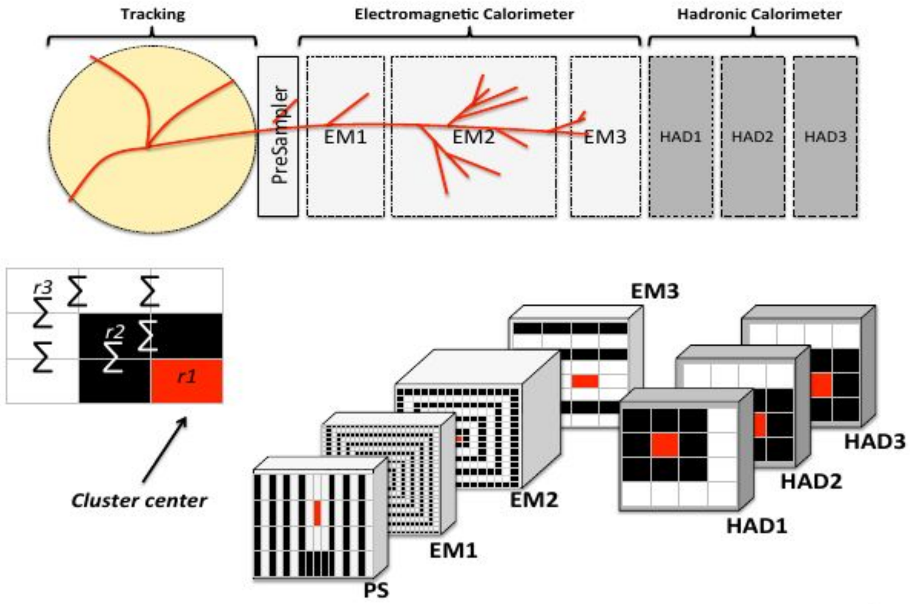


High Level Trigger - Calorimetry

- HLT is implemented on a distributed computing system.
- The selection of electromagnetic particles in the trigger depends on the response of the calorimeter.
- HLT Fast Calo Step:
  - Cells in each layer of the calorimeter formatted into concentric rings;
  - An ensemble of Artificial Neural Networks makes the acceptance or rejection decision.
- **Energy calibration**: available only in the Precision Step and in the offline analysis.



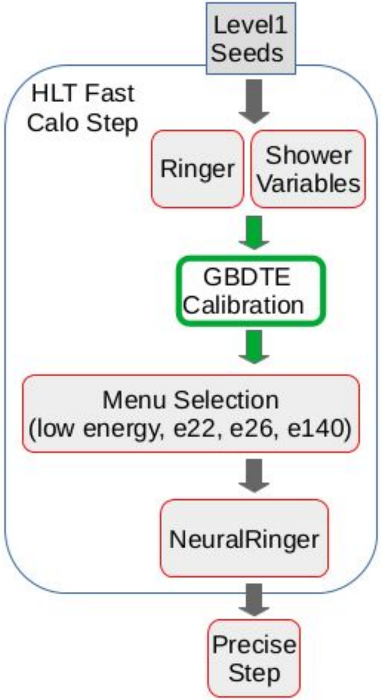
Concentric energy rings



- Compacting the shower information using concentric energy rings.
- Rings are built in each layer, centered around the most energetic cell.
- The value of the ring is the sum of the energy of its cells.
- Produce discriminating information for the characterization of the particles.
- Because they are circular around the hottest cell, they do not describe asymmetries present in the energy deposition shower.
- Information from the asymmetries can be important for calibration.

Proposed method

FastCalo Step calibration proposal



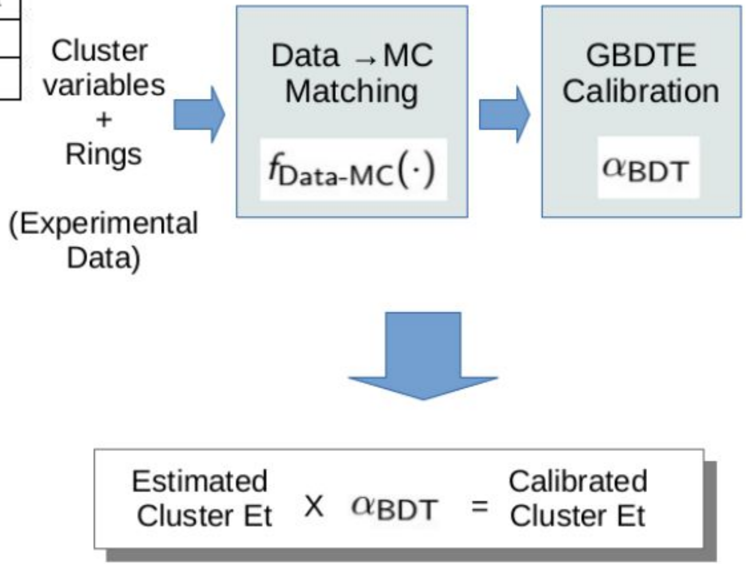
- Design for the FastCalo trigger an energy calibration strategy similar to the ones available in the PrecisionCalo trigger step and in offline analysis.
- Inputs: Shower variables and Rings.
- Energy regression using a Gradient Boosted Decision Trees Ensemble (GBDTE) trained with simulated data.
- Energy correction is meant to operate before the FastCalo step, allowing an optimized trigger menu selection.

Proposed calibration system

Precision step GBDTE calibration:

Inputs
$\eta_{cluster}$: cluster center position
$E1_{raw}/E2_{raw}$: EM1 to EM2 energy ratio
$E_{raw} = E1_{raw} + E2_{raw} + E3_{raw}$: energy sum
$E0_{raw}/E1_{raw}$: PS to EM1 energy ratio
E_{Tile1}/E_{raw}: HAD1 to EM energy ratio
$\Delta\eta$ and $\Delta\phi$: asymmetry with respect to the most energetic cell
Output target
$\alpha_{BDT} = \frac{E_{true}}{E_{raw}}$: correction factor

This work proposes to replicate the calibration in the Fast step including Rings and Asymmetric Structures:



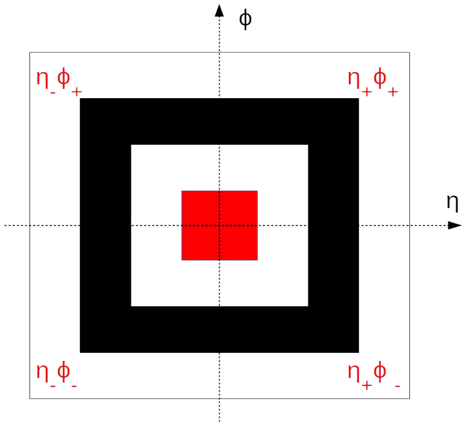
Linear Matching: Data -> MC

$$\hat{R}_{\text{MC}} = aR_{\text{MC}} + b$$

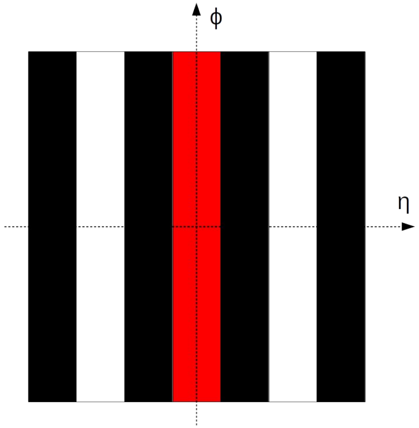
$$a = \sqrt{\frac{\sigma^2_{\text{Data}}}{\sigma^2_{\text{MC}}}}$$

$$b = E\{R_{\text{Data}}\} - aE\{R_{\text{MC}}\}$$

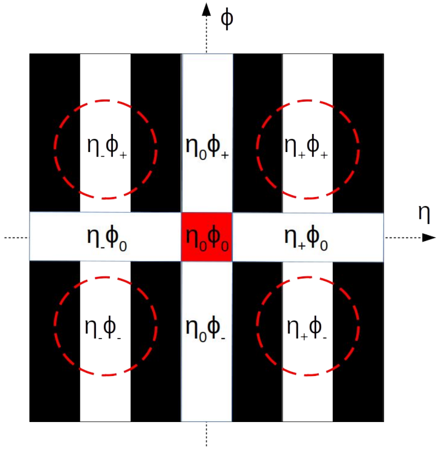
Quarter Rings, Super Strips and Quarter Strips



Quarter Rings (QR)



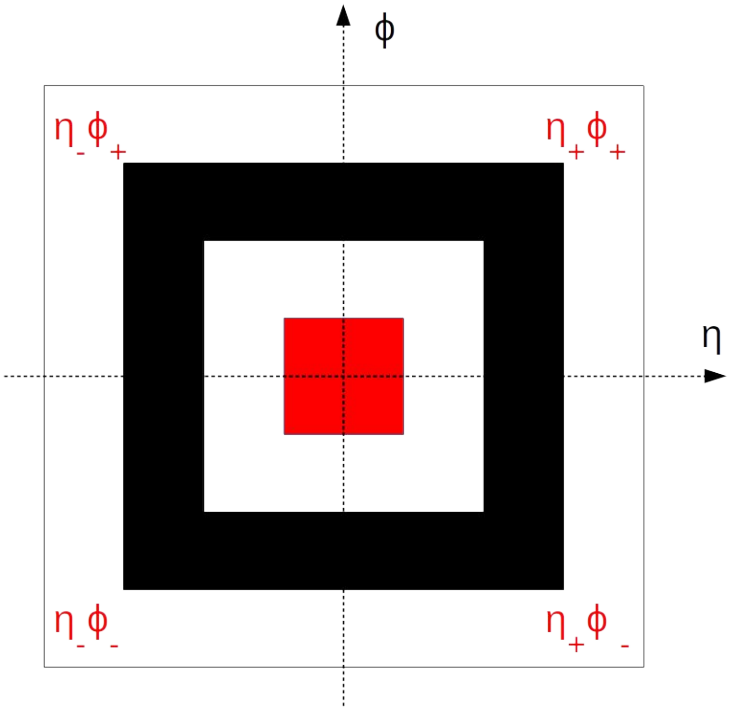
Super Strips (SS)



Quarter Strips (QS)

Quarter Rings (QR)

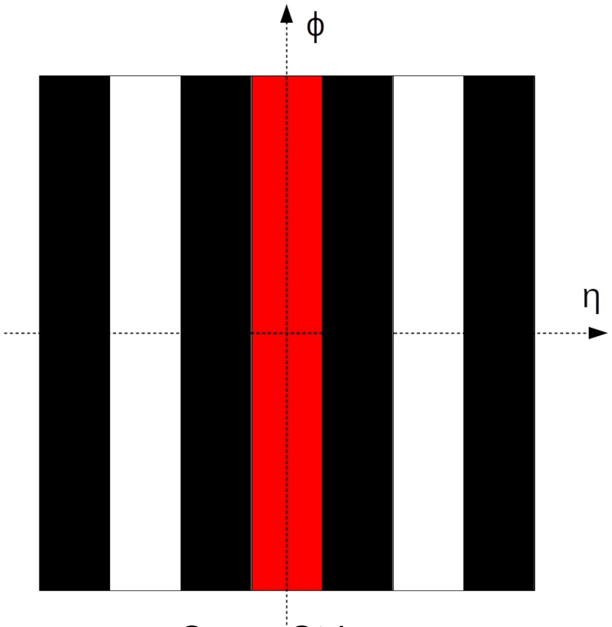
- Axial oriented ring division.
- Each ring (except the first one) is divided by 4.
- This topology increase the mapping granularity to capture asymmetric information from showers.
- Four quadrants arbitrarily named **η+ϕ+**, **η+ϕ-**, **η-ϕ-** and **η-ϕ+**



Super Strips (SS)

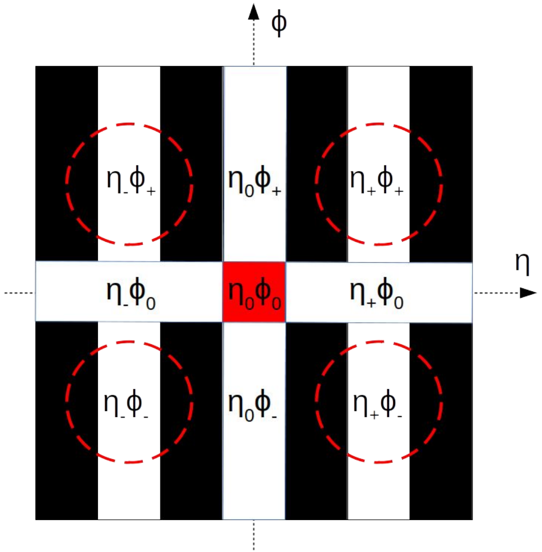
- Strips equidistant to the hotcell η coordinate

- Each layer has 2*N-1 strips, where N is the number of correspondent Standard Rings



Super Strips

Quarter Strips (QS)



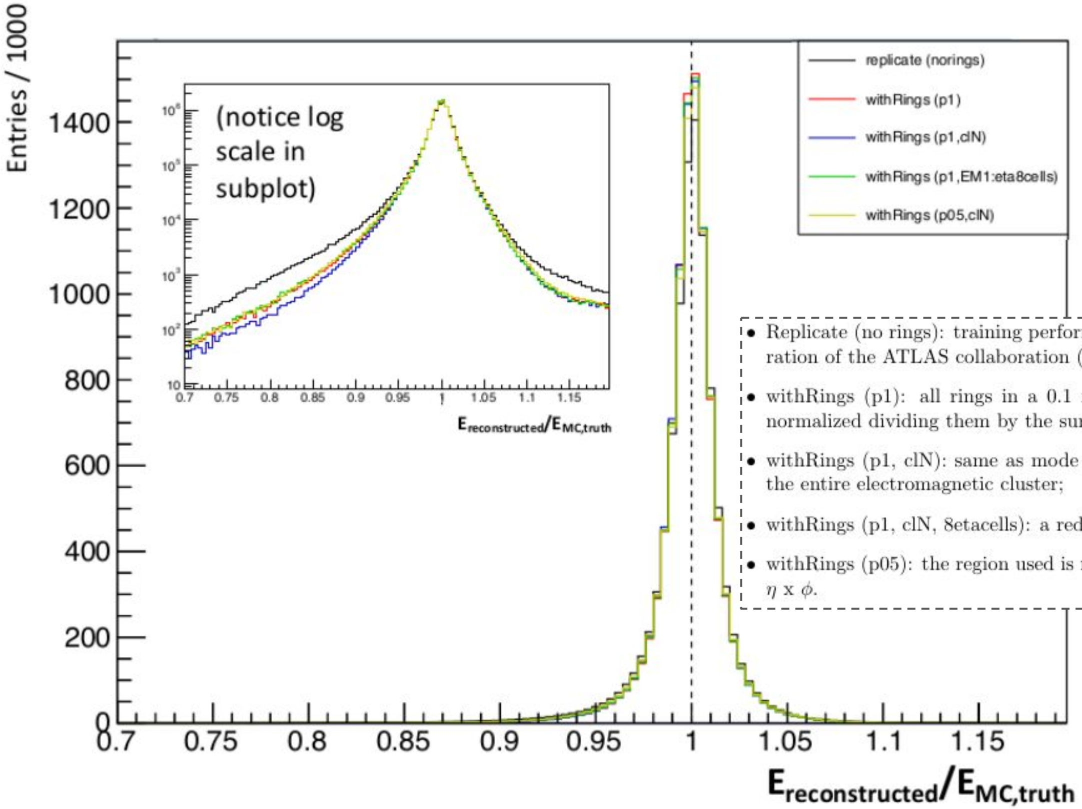
Quarter Strips (QS)

- $\eta_0\phi_0$ represents the hottest cell.
- $\eta_0\phi_+$, $\eta_0\phi_-$, $\eta_+\phi_0$, $\eta_-\phi_0$: coordinate axis η and ϕ.
- $\eta_+\phi_+$, $\eta_+\phi_-$, $\eta_-\phi_+$, $\eta_-\phi_-$: the 4 quadrants. The strips in these quadrants can considered individually or summed altogether.
- The η and ϕ indexes are considered in relation to hotcell.
- The QS cover the same amount of energy cells as the Standard Rings.

Results

Results:

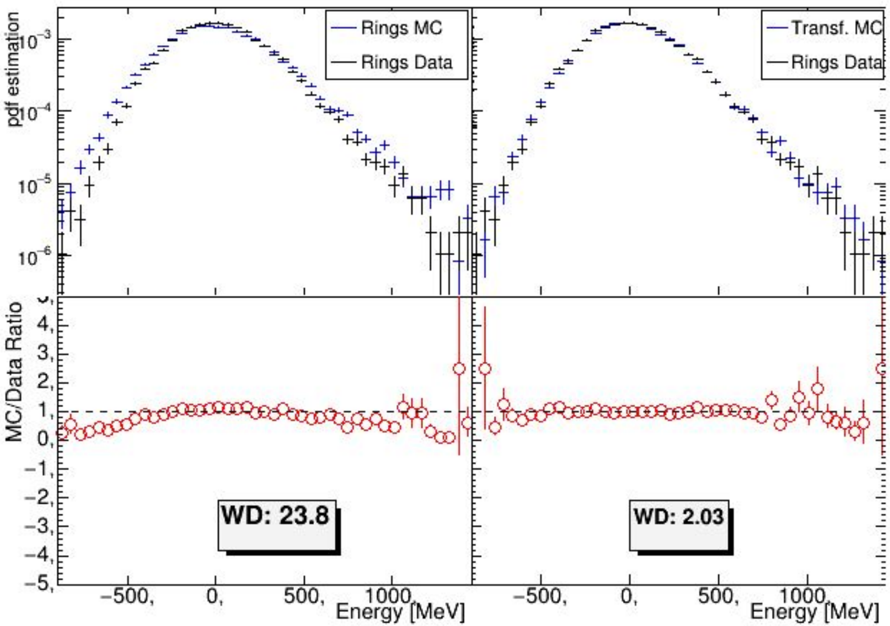
- With the addition of the ring information the calibration with GBDTE reduced the error between the true and reconstructed energy.
- For some regions of phase space the reduction in the Inter Quartile Dist. is more than 30%.



- Replicate (no rings): training performed according to the default configuration of the ATLAS collaboration (without rings);
- withRings (p1): all rings in a 0.1 x 0.1 η x ϕ window. The rings are normalized dividing them by the sum of all 100 rings;
- withRings (p1, clN): same as mode p1, but normalized by the energy of the entire electromagnetic cluster;
- withRings (p1, clN, 8etacells): a reduced window of 0.05 in η is used.
- withRings (p05): the region used is reduced to a window of 0.05 x 0.05 in η x ϕ.

ATLAS EXPERIMENT

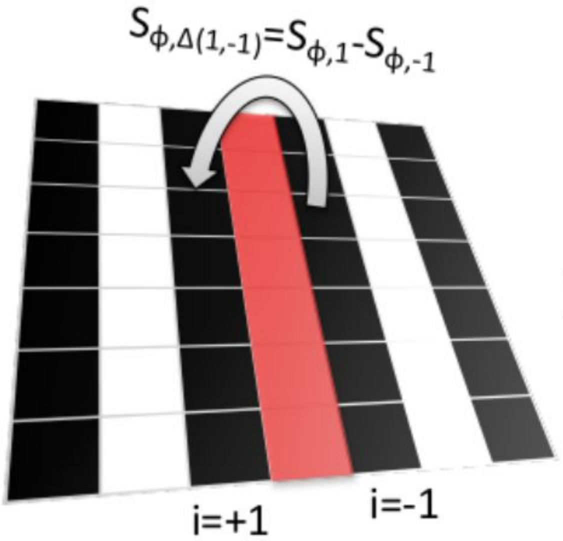
Matching between simulated and experimental data

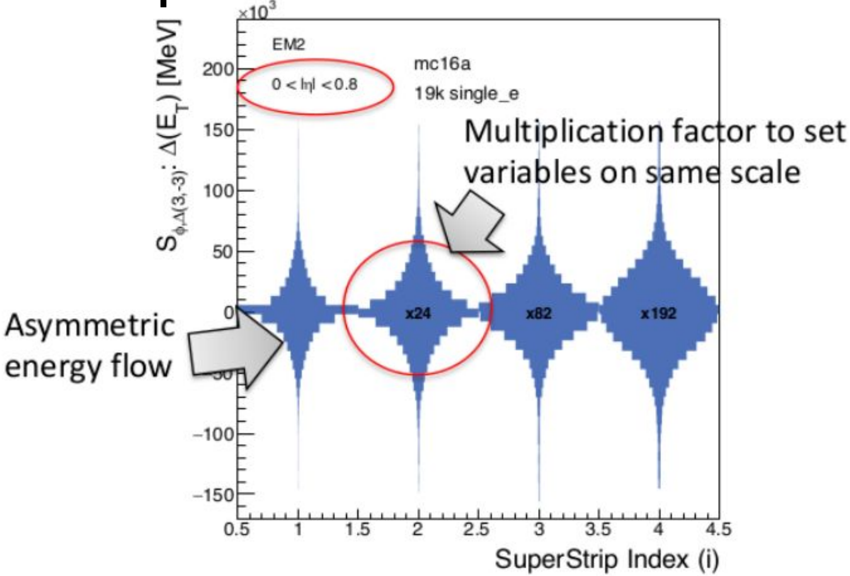


- The linear transformation works well for matching only when distributions are approximately symmetric.

- In cases of variables with asymmetric pdfs (with long tails) the linear transformation is not able to reduce the distance between Data and Simulation.
- Non-linear transformations may improve the result (future work).

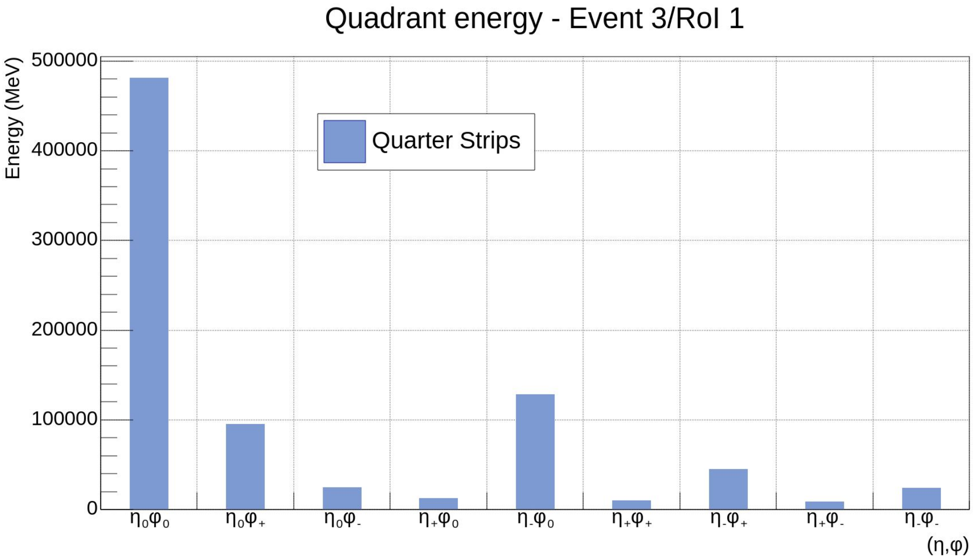
Asymmetry in Energy Flow - Super Strips



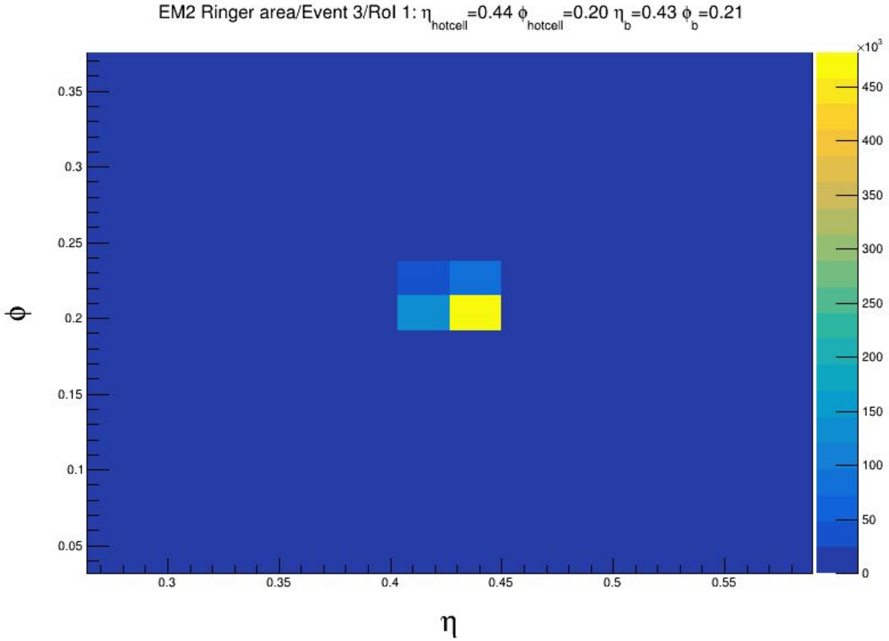


- Extensions of the difference distributions between opposing strips indicates the existence of asymmetries.
- This information can be useful for calibration.

Asymmetry in Energy Flow - Quarter Strips



QS energy distribution



Energy cell map

Conclusions and Perspectives

Conclusions

- The observed results indicate that the proposed calibration method is able to reduce the energy estimation error in the fast step.
- The proposed system can contribute to optimize online event selection.
- The new proposed structures are able to capture asymmetries in the energy deposition profile of particles.

Future work:

- Testing new forms of mapping Experimental Data x Simulation (Smirnov Transform, Optimal Transport)
- Using data from Run 3, it will be evaluated whether asymmetry information can contribute to improving the energy calibration process in the HLT fast step.

Thank you !

email: paulo.farias@ufba.br