ALLEGRO HCAL update

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FCC Full Sim Working Meeting
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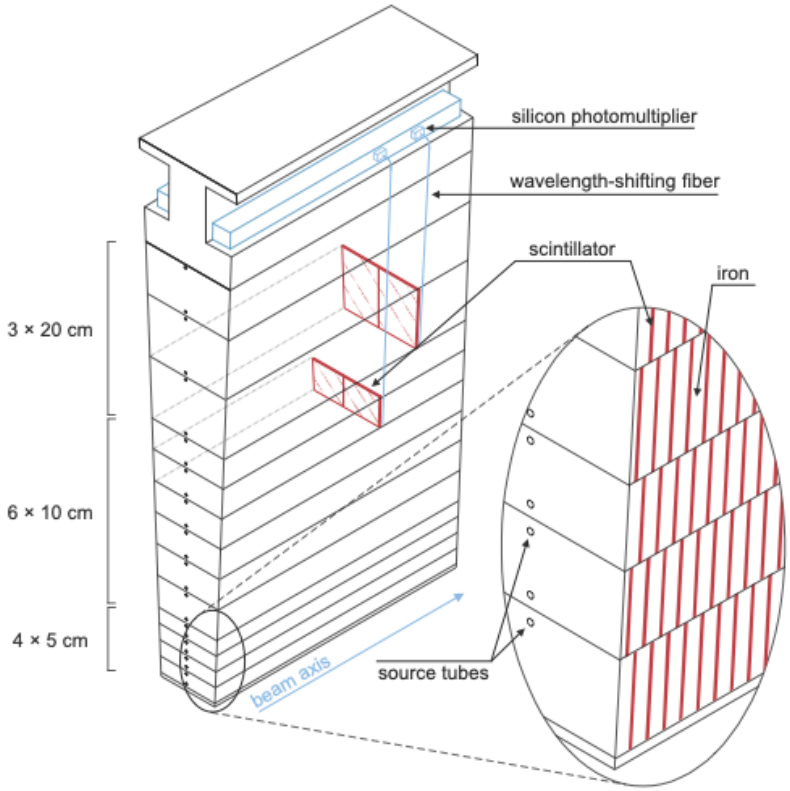
ALLEGRO Hadronic Calorimeter

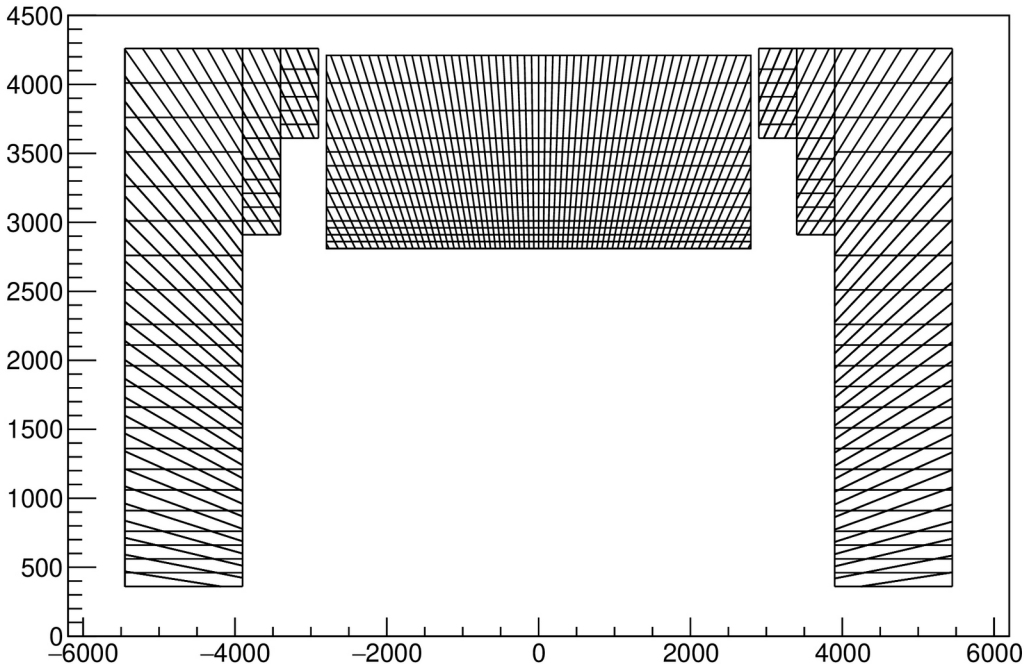
- Design based on alternating steel and scintillator layers
  - Well studied and tested design
  - 5 mm absorbers, 3 mm scintillators
- **Barrel**: 13 radial layers
- **Endcap**: 6 / 9 / 22 radial layers
- 128 modules in ϕ, 2 tiles per module $\rightarrow \Delta\phi$ ~ 0.025rad
- Proposed implementation of θ-segmentation in the simulation is presented today
- Submitted pull requests:
  - k4geo: #409
  - k4RecCalorimeter: #128



Current implementation of HCal segmentation

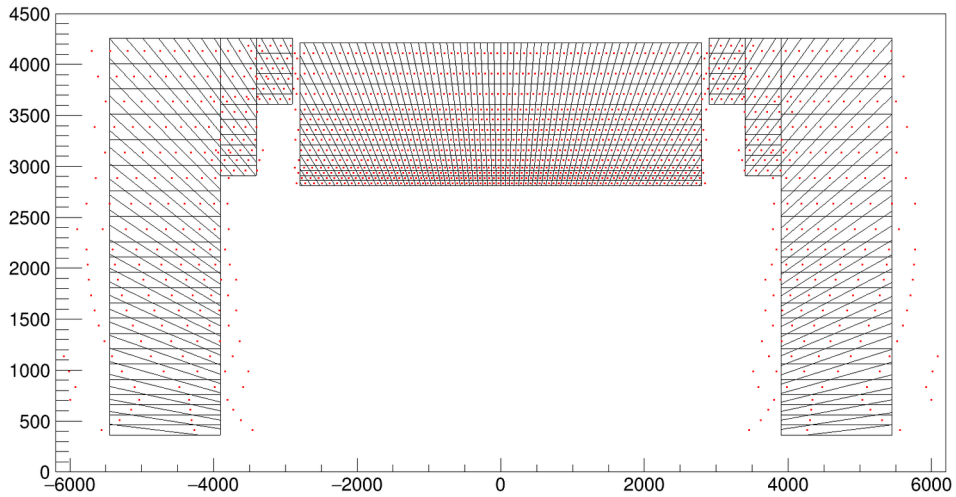
- Current segmentation class for HCal:
  - *FCCSWGridPhiTheta_k4geo*
  - with grid_size_theta="0.022180"
- Each G4 hit is assigned a *cellID* formed based on the hit position in the theta grid: *FCCSWGridPhiTheta_k4geo::cellID()*
- *CellID* encodes the theta bin number in the grid
- A cell energy is calculated by collecting the hits with the same *cellID* hence with the same theta bin number:

  CreatePositionedCaloCells
  → effectively this means the inclined cell geometry → this is unphysical for Tile Calorimeter (with vertically oriented tiles)



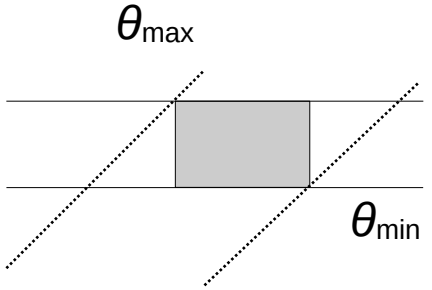
Assigned cell positions

- Cell positions are assigned using the *CellPositionsHCalPhiThetaSegTool*
- This tool use the *position()* function of the segmentation class which determines the theta and phi bin center values based on theta and phi bin numbers encoded in the *cellID*
- Cell position z-coordinate is calculated at the cell center radius using the theta value corresponding to the theta bin center → for some cells it results in a position outside the HCal range



New segmentation classes

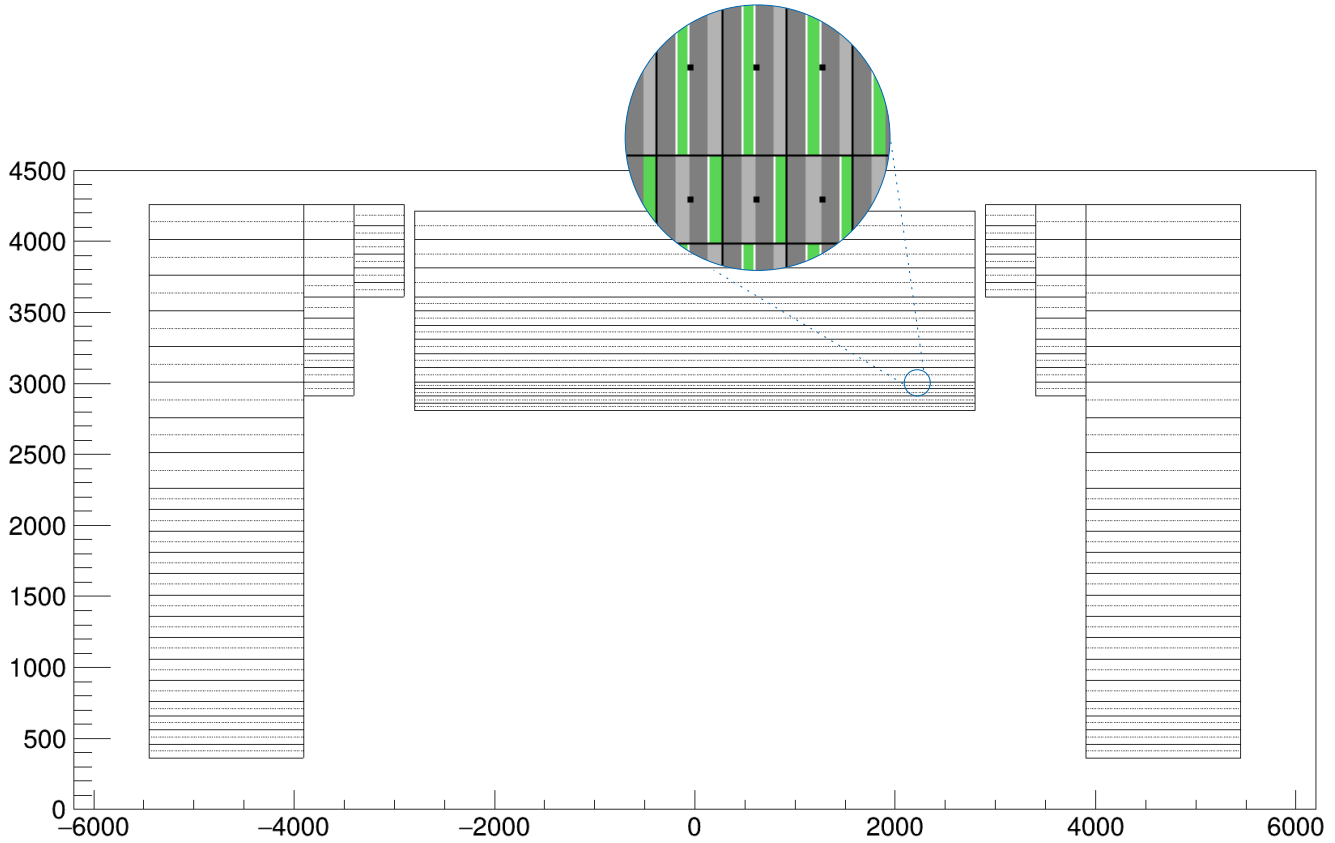
- Two new segmentation classes are created in the *k4geo* package:
  - *FCCSWHCalPhiRow_k4geo* (not used by default)
    - Assigns the *cellID* to the G4 hits based on the "row" id of the volume
    - The "row" id is the number of row in a layer
    - Row: 2×Master plate + 1×Spacer plate + 1×Scintillator
  - *FCCSWHCalPhiTheta_k4geo* (used by default)
    - Defines a cell borders in z-axis and assigns the same *cellID* to the G4 hits which are inside a given cell borders



- Both classes have the *position()* function that returns the global position of a cell
  - This function is now used by *CellPositionsHCalPhiThetaSegTool* to assign the cell position
- Both classes have the *cellTheta()* function that returns a two element array of the cell *thetaMin* and *thetaMax*
  - This can be used to find neighbour cells between HCal Barrel and HCal Endcap, also between HCal and ECal
- Both classes have the *neighbours()* function that returns a vector of neighbours *cellIDs* within the same system (Barrel or Endcap)

FCCSWHCalPhiRow_k4geo segmentation

- Each row in a layer is considered as a cell
  - Width of the row: 18mm
  - Can group several rows in a single cell by changing the *grid_size_row* parameter in the xml file
  - Value can be different for different layers
- 310 cells per layer in the Barrel
- 27 / 27 / 85 cells per layer in the Endcap in one side
- Center of the row is considered as a cell position

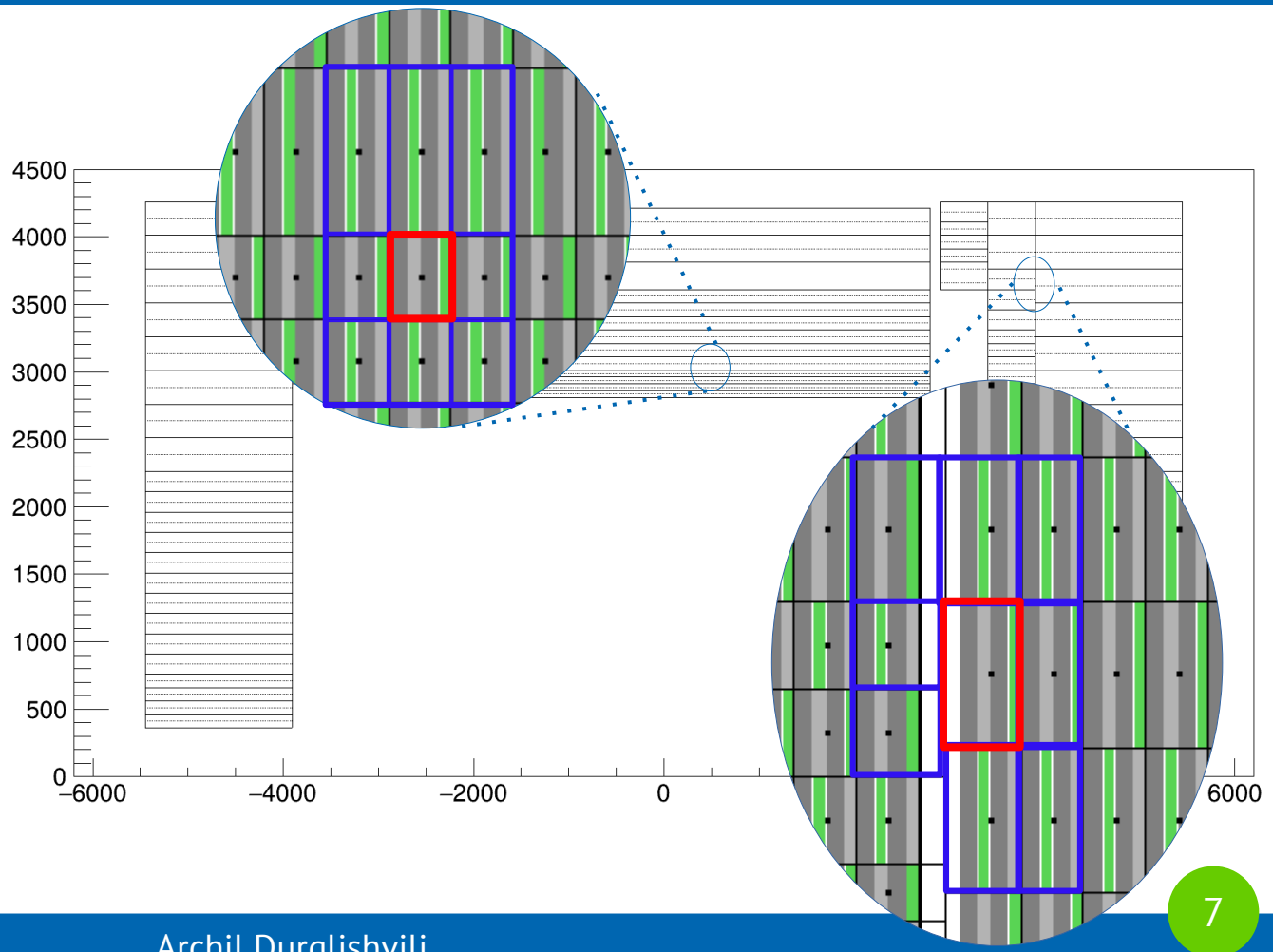


FCCSWHCalPhiRow_k4geo: cell neighbours

- In each part of the HCal, a cell neighbours are defined as all surrounding cells of a given cell in the same phi bin
- Linking three parts of the Endcap:
  - All surrounding cells in the same partition
  - The cells from the adjacent partition with:

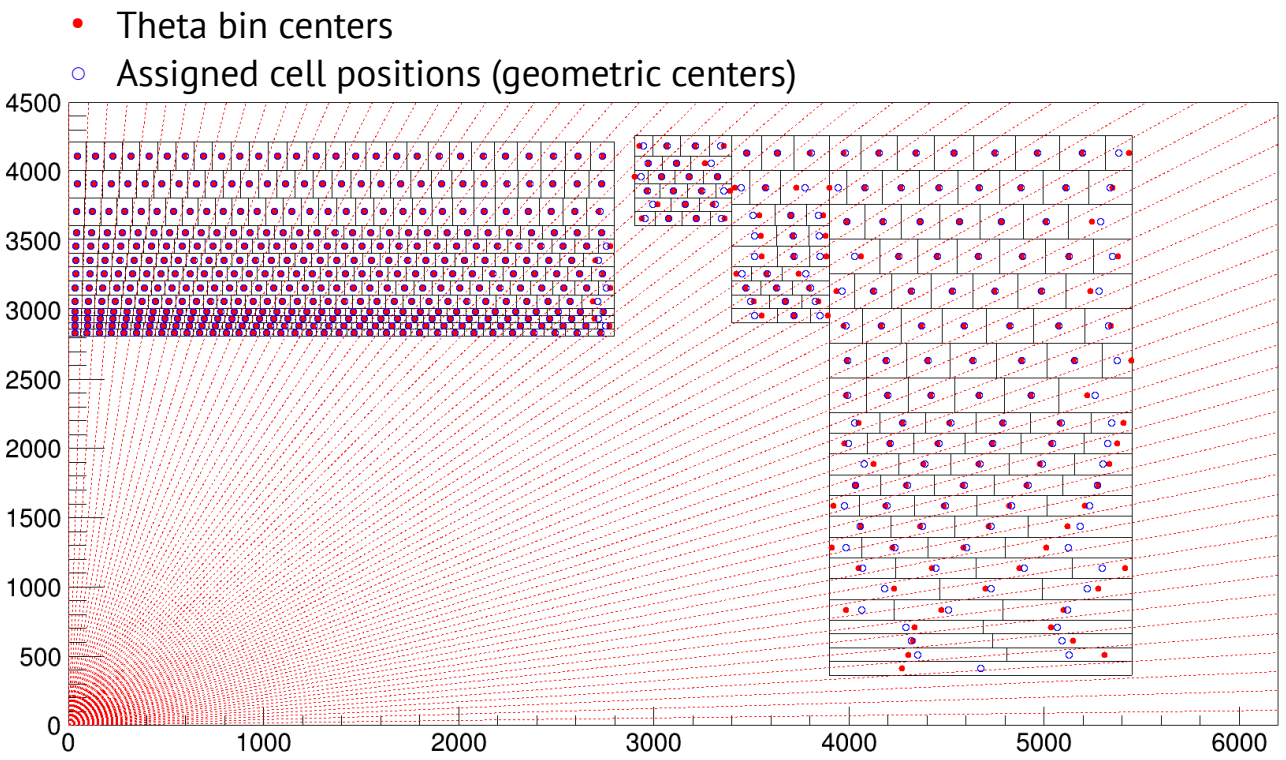
$$R_{inner} \leq R^{nei.}_{inner} \leq R_{outter}$$
$$\text{or } R_{inner} \leq R^{nei.}_{outter} \leq R_{outter}$$
$$\text{or } R^{nei.}_{inner} \leq R_{inner} \leq R^{nei.}_{outter}$$
$$\text{or } R^{nei.}_{inner} \leq R_{outter} \leq R^{nei.}_{outter}$$

- Linking Barrel and Endcap: first cells from the different partition overlapping in the theta range of the given cell
- Adding neighbours from the adjacent phi bins leads to a very off reconstructed polar angle from the truth angle, using TopoClusters of single charged pions
  - This is under under investigation…



FCCSWHCalPhiTheta_k4geo segmentation

- Cell borders are defined such that closely follow the theta projective towers with the size of $\Delta\theta = 0.02218$ rad
- No hard-coded numbers for grouping of the cells
- The algorithm finds the theta bin centers within the z-range of each layer and takes the middle point between each pair of theta bin centers as a cell border
- All the hits with the z-coordinate within the given cell borders are assigned the same *cellID*



FCCSWHCalPhiTheta_k4geo: cell neighbours

- Barrel:
  - Previous and next adjacent cells in the same layer
  - From the previous layer: the cell with the same theta bin number + the cell with the previous (next) theta bin number if $\theta < \pi/2$ ($\theta > \pi/2$)
  - From the next layer: the cell with the same theta bin number + the cell with the next (previous) theta bin number if $\theta < \pi/2$ ($\theta > \pi/2$) + the cell with the next-to-next theta bin number if it overlaps with the given cell in z-coordinate
- Endcap: all surrounding cells that share at least part of a border with the given cell
- Linking three parts of the Endcap:
  - All surrounding cells in the same partition
  - The cells from the adjacent partition with:

$$R_{inner} \leq R^{nei.}_{inner} \leq R_{outter}$$
or $$R_{inner} \leq R^{nei.}_{outter} \leq R_{outter}$$
or $$R^{nei.}_{inner} \leq R_{inner} \leq R^{nei.}_{outter}$$
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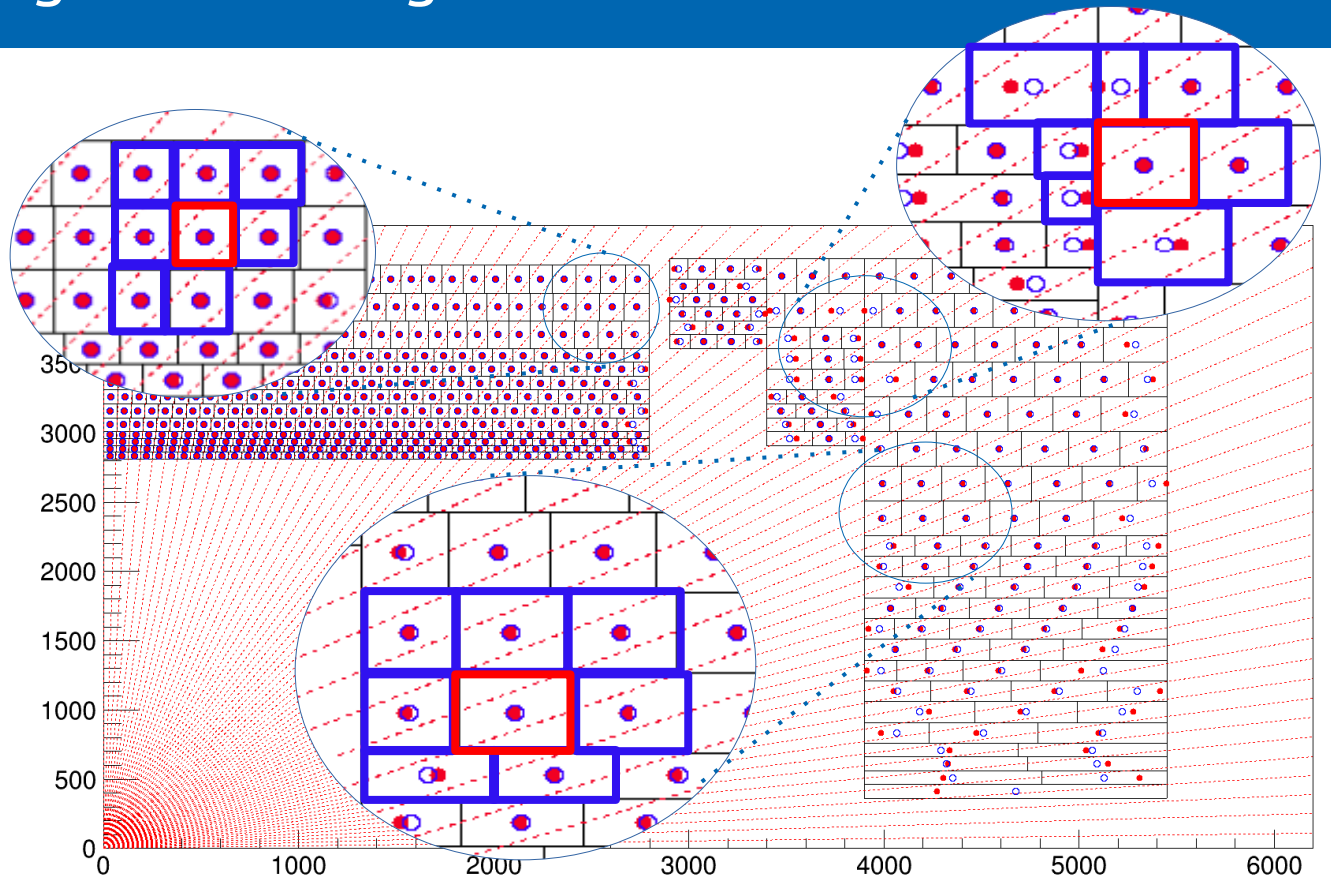
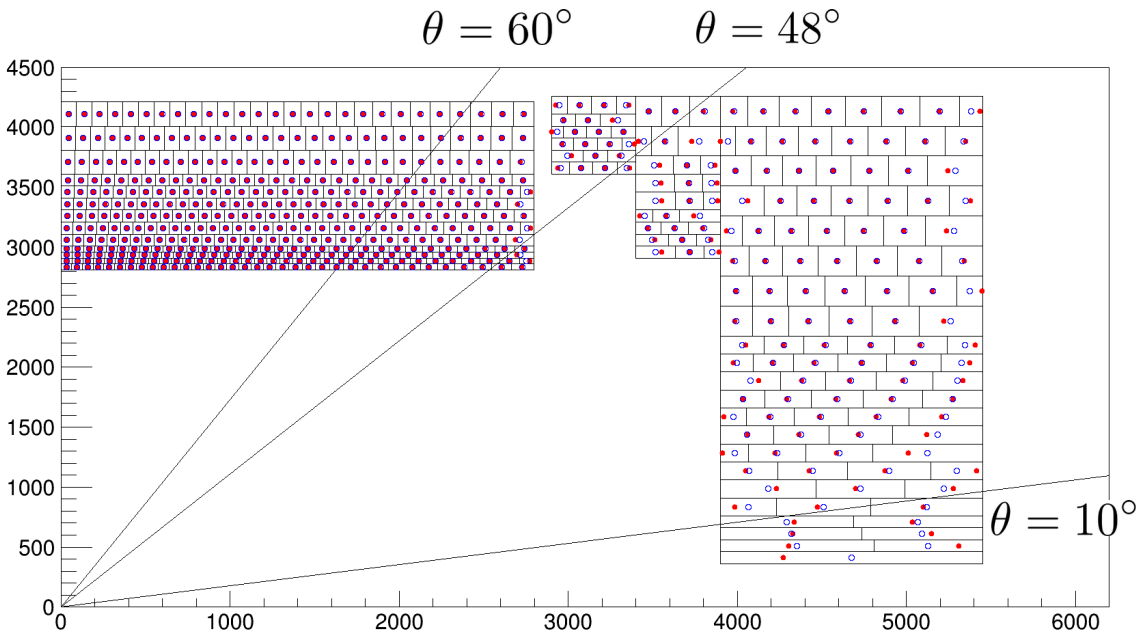
- Linking Barrel and Endcap: first cells from the different partition overlapping in the theta range of the given cell



Neighbour from the adjacent phi bins of all selected cells are added in the list of neighbours.

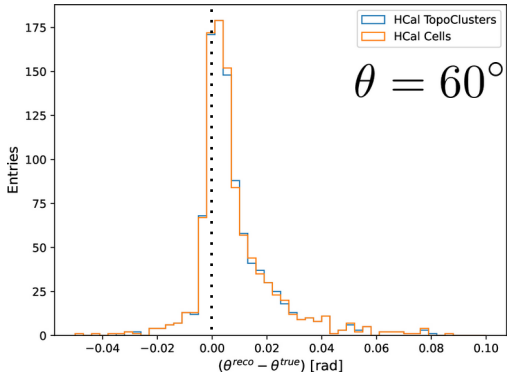
Polar angle reconstruction performance check

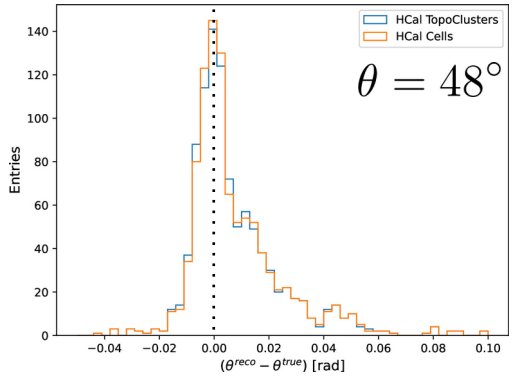
- Single charged pions are simulated at three different polar angles
- Both ECal and HCal are included in the simulation
- Topo-Clusters are built using only HCal cells without electronic noise map
- The theta angle is reconstructed as the energy weighted sum of:
  - a) all HCal cells theta positions
  - b) all topo-clusters theta positions

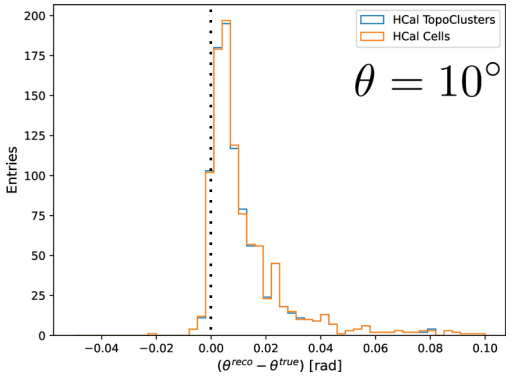


Polar angle reconstruction: cluster-based vs cell-based

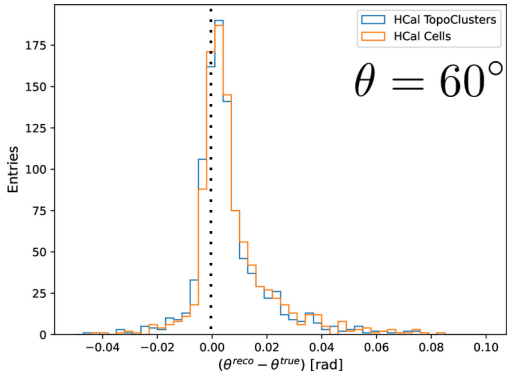
Phi-Row segmentation

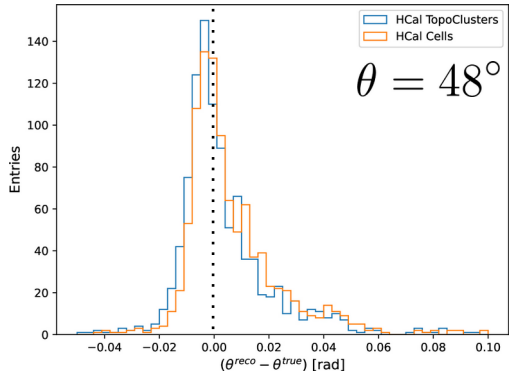


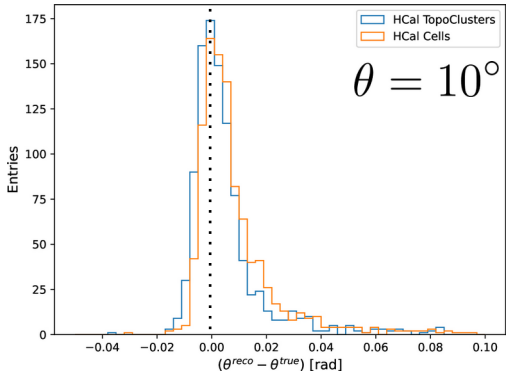




Phi-Theta segmentation

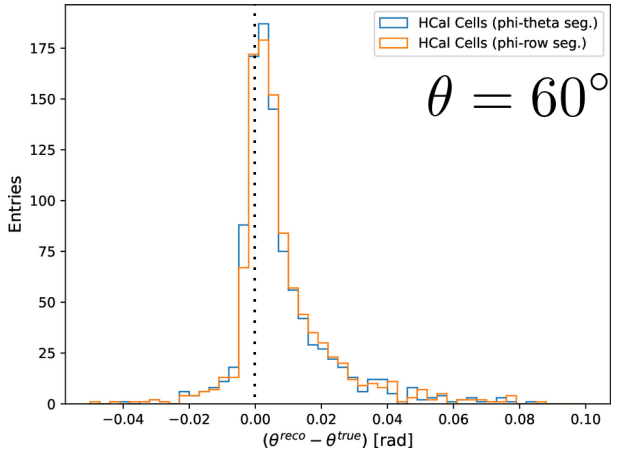


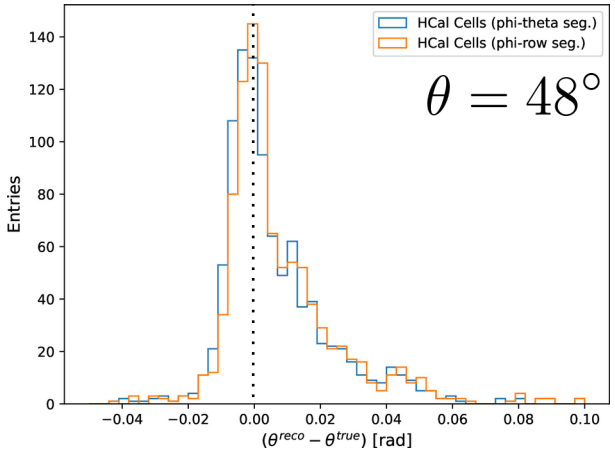


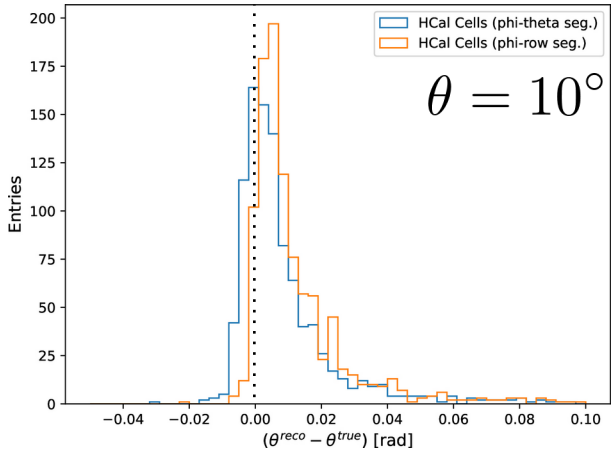


Polar angle reconstruction: cluster-based vs cell-based

Cell-based polar angle reconstruction







With a first look, phi-row and phi-theta segmentations seems to have a similar performance at large angles while phi-row is better at small angles

More detailed performance evaluation is needed

Summary

Two new HCal segmentation readout implementations are presented

- Phi-row
  - Single tile/row as a cell
  - Highest possible granularity
- Phi-theta
  - Groups several tiles into a cell such that closely follow the theta projective towers with the size of $\Delta\theta \sim 0.022$ rad
  - This is set as the default readout segmentation
- Pull Request of the changes are submitted:
  - k4geo: #409
  - k4RecCalorimeter: #128
- Calo Neighbours code is also updated for the new readouts, however, this is not included in the PR

Preliminary results of polar angle reconstruction performance are presented

- With a first look, phi-row and phi-theta segmentations seems to have a similar performance at large angles while phi-row is better at small angles
- More detailed performance evaluation is needed

Thank you for your attention

Backup