Event Filter Monitoring with the ATLAS Tile Calorimeter

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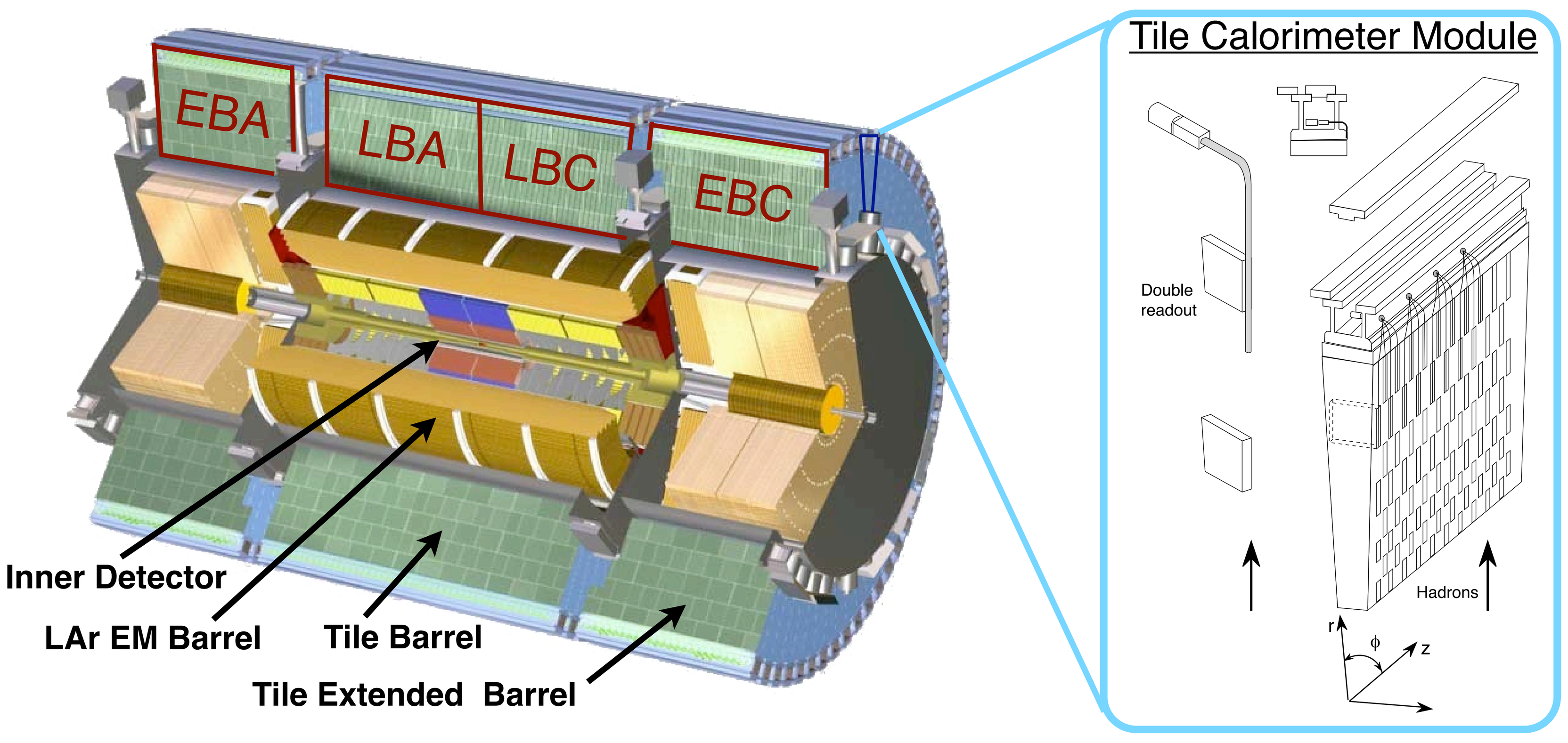
ATLAS is one of the four experiments currently being assembled at CERN's Large Hadron Collider (LHC) that will provide proton-proton collisions at an unprecedented center-of-mass energy of 14 TeV. The complete ATLAS detector comprises roughly 140 million electronics channels registering collisions at the LHC's bunch crossing frequency of 40 MHz. A three stage trigger system will reduce the number of processed events from 10^5 events/sec at the first level to 200 events/sec finally written to tape storage. In order to ensure that only good quality data is stored, various monitoring systems are deployed at different levels of the online data-flow in order to detect potential problems as soon as possible already at the trigger level.

The Event Filter (EF) is the highest trigger level and has access to the complete event information and conditions databases. The EF Monitoring installed at this level is the only online monitoring system capable of performing detector and data quality control on complete and calibrated physics events. Both individual subdetector as well as global reconstruction quantities can be monitored, using the same code base as applied in the offline reconstruction. The EF Monitoring is successfully deployed during the Tile Calorimeter commissioning with cosmic rays and has been integrated with other subdetector systems.

ATLAS' Tile Calorimeter detector (TileCal) contributes about 10000 readout channels and is presently in an intense phase of commissioning with cosmic ray data. With its good signal over noise ratio and fast response time it plays a central role for detecting the passage of cosmic rays through the ATLAS detector in commissioning runs.

The ATLAS Tile Calorimeter



The ATLAS Tile Calorimeter is based on a sampling technique: Plastic scintillating plates (tiles) are embedded in iron absorber plates and read out by wavelength shifting fibers. Groups of tiles are bundled together into cells, each of which is read out by two photo-multiplier tubes (PMTs).

- **Dimensions:** Hollow cylinder with R_i=2.28m and R_o=4.23m. The length of the central Long Barrel (LB) is 5.64m, the length of the Extended Barrels (EB) is 2.91m each.
- **Partitions:** The Long Barrel is divided into two partitions, **LBA** & **LBC**. The two Extended Barrels are labeled as **EBA** and **EBC** respectively.
- **Modules:** Each partition is assembled out of 64 wedge-shaped modules, staggered in ϕ.
- **Granularity**: $\Delta\eta \times \Delta\phi$ cell segmentation of 0.1 × 0.1, three layers of cells in radial direction.
- **Readout Channels:** ≈10000
- **Weight:** 2300 tons

Infrastructure

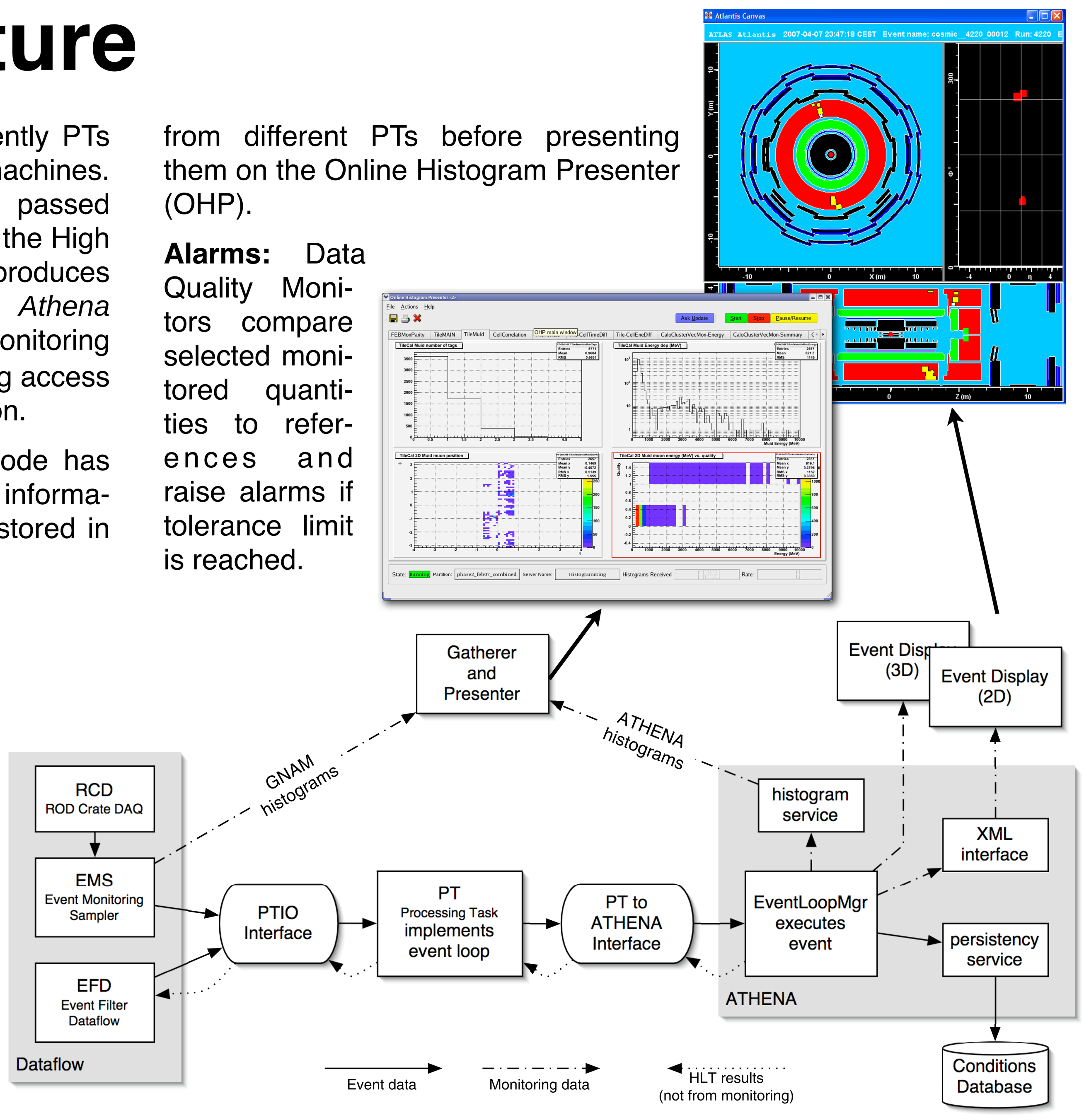
Processing Tasks (PT): Currently PTs run on dedicated monitoring machines. Each PT spies on the data passed through a specific input node to the High Level Trigger (HLT) farm and produces monitoring histograms using *Athena* (offline framework) code. ➔ Monitoring of events before EF level, having access to the complete event information.

Global view: Only EF level code has access to the complete event information, including calibration data stored in the conditions database:
* Monitoring of combined and calibrated calorimeter quantities (like clusters) possible.
* Monitoring of PMT and electronics , consistency check of Digital Signal Processor reconstruction performance.

Event Display: Events reconstructed by a PT are exported using an XML protocol and picked up by event display clients.

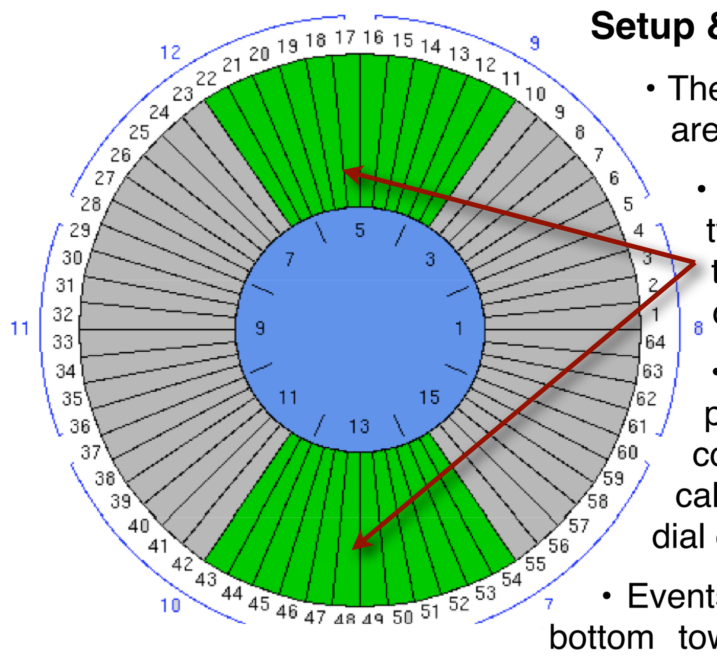
Gatherer & Presenter: A gatherer combines histograms from different PTs before presenting them on the Online Histogram Presenter (OHP).

Alarms: Data Quality Monitors compare selected monitored quantities to references and raise alarms if tolerance limit is reached.

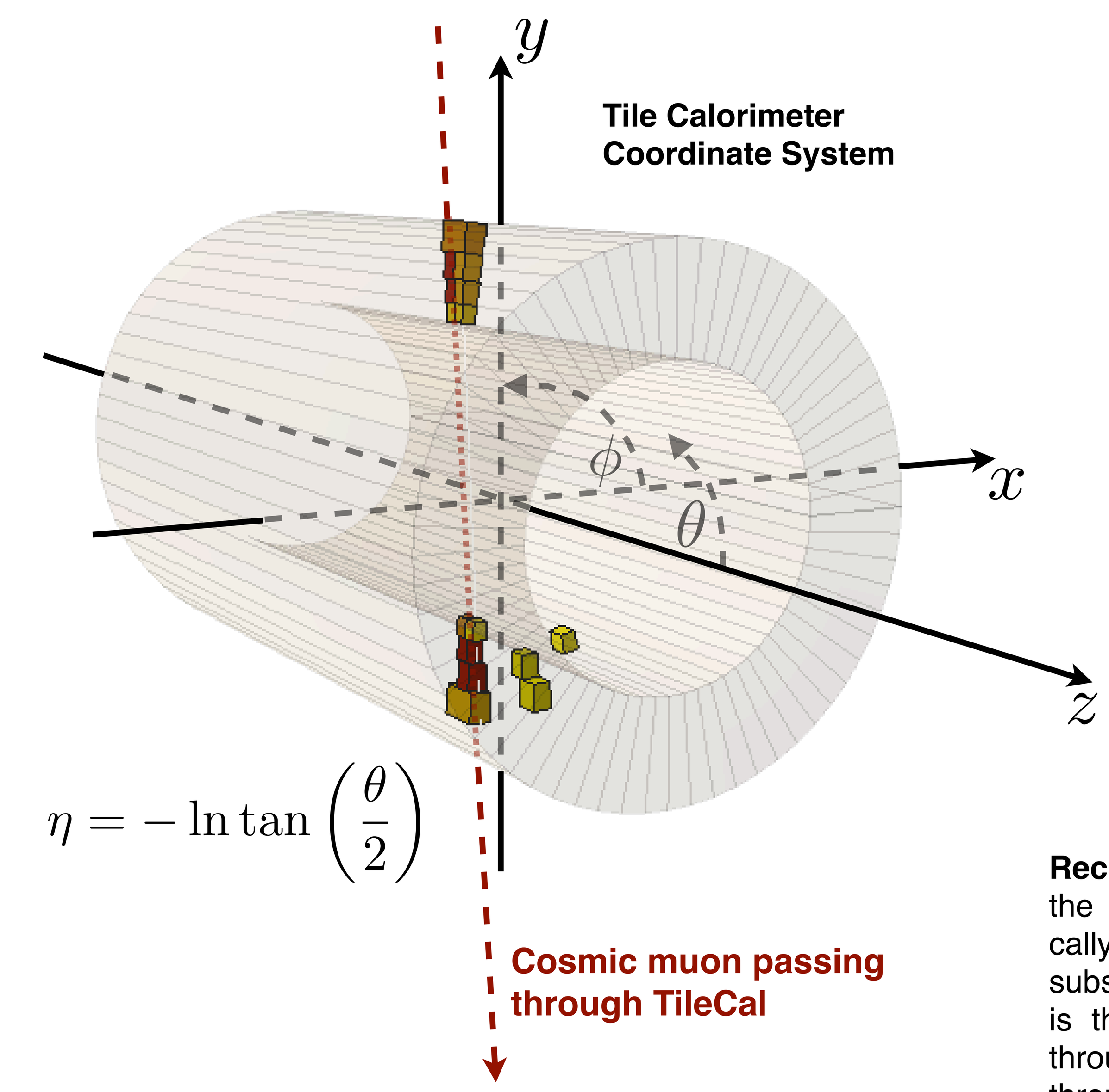


Monitoring Cosmic Muons with TileCal

Setup & Trigger

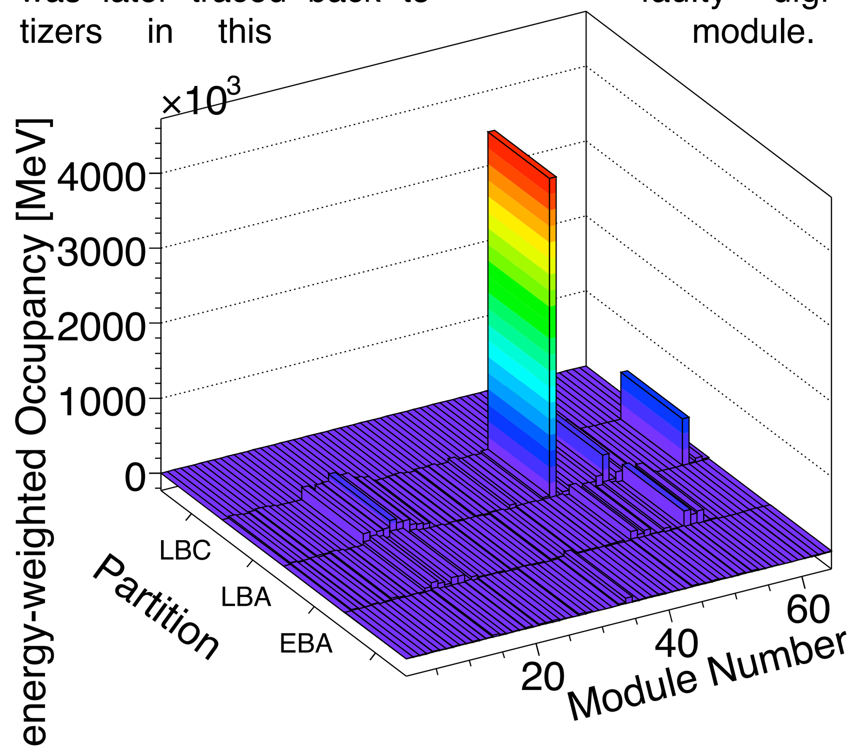


- The three partitions EBA, LBA and LBC are read out.
- Twelve modules at the top and twelve at the bottom of each of the three partitions are used to trigger on cosmic muons.
- Each long (extended) barrel module provides eight (five) trigger towers, constructed out of three consecutive calorimeter readout cells along the radial direction.
- Events are accepted if both a top and a bottom tower show a significant signal over noise in coincidence, signaling the passage of a cosmic muon through the detector.

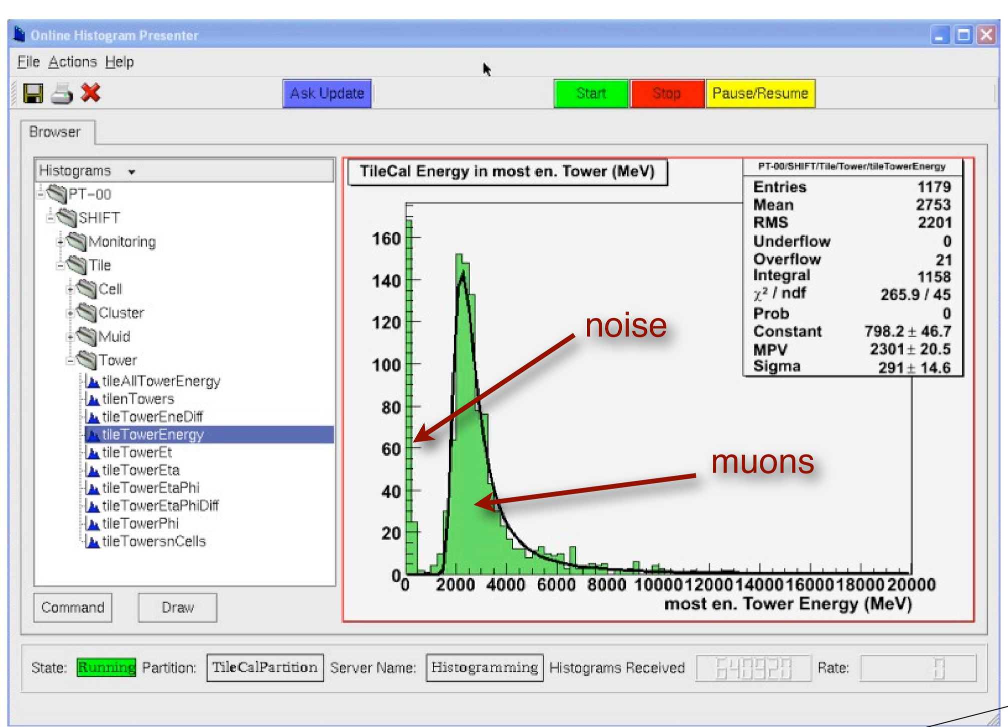


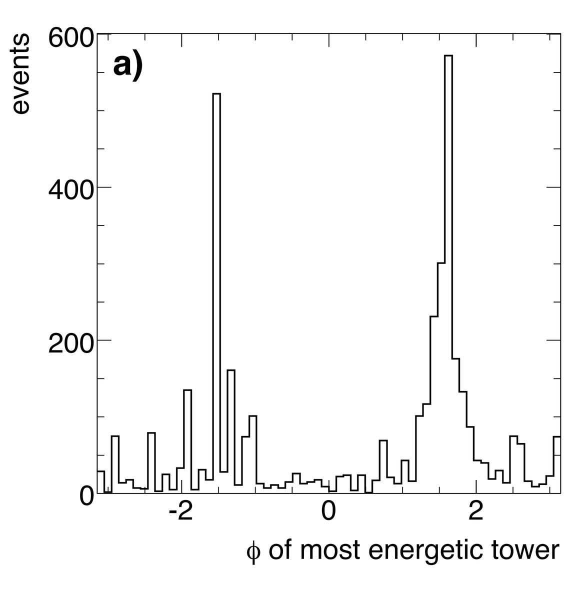
$$\eta = -\ln\tan\left(\frac{\theta}{2}\right)$$

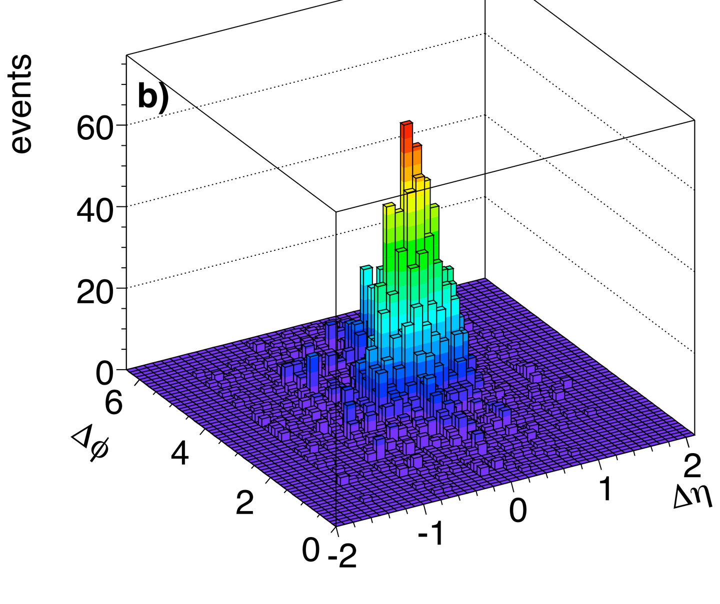
Noise Detection: Monitoring the TileCal occupancy allows for the fast detection of noisy channels, towers or modules which could then be masked during data taking. The plot below shows a significantly higher energy-weighted occupancy in module LBC41, which was later traced back to faulty digitizers in this module.



Monitoring Towers: The distribution of the most energetic tower in each triggered event, displayed in the OHP below, shows a clear muon signal over the noise. Monitoring this distribution during data taking allows for a rough estimation of the efficiency for recording cosmic muons and ensures the quality of the data written to storage tape. The other plots show: **a)** The ϕ distribution of the most energetic tower, showing a clear preference for the upward direction ϕ=π/2. **b)** The correlation in the position, measured in the η-ϕ space, of the most energetic tower and the most energetic tower of the opposite hemisphere.



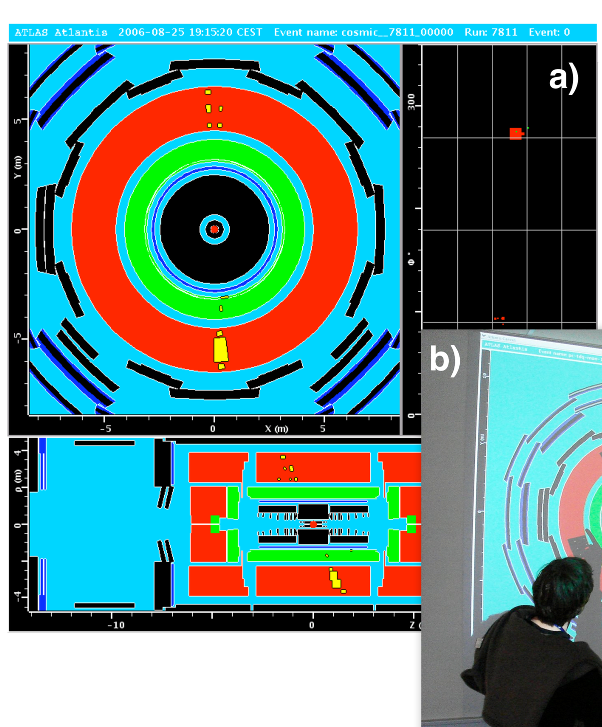




Event display: During commissioning runs with cosmic muons, the event display is an important instrument to both confirm the quality of triggered events and to quickly spot major detector malfunctions. Event data from all sub-detectors taking part in the data taking is reconstructed by a dedicated processing task and combined in the display.

a) The passage of a cosmic muon through the combined LAr and Tile Calorimeter is clearly visible. The size of the yellow boxes, representing hit cells, is proportional to the deposited energy.

b) Projection of an event display in the ATLAS control room during a recent data taking period.



Reconstructed Muon Tracks: The Event Filter Monitoring has the capability of monitoring reconstructed physics objects, typically constructed by applying pattern recognition algorithms to a subset of readout channels. A Tile Calorimeter specific application is the reconstruction of the tracks of cosmic muons passing through the detector. For each event, a straight line is fitted through the highest energy cells, minimizing the energy density weighted squared distance between each calorimeter cell and the track. Cell timing information determines the particle's direction along its track.

Attributes of the reconstructed muon tracks are monitored in order to confirm the expected muon passage through TileCal:

a) The intersection point of the muon with the x-z-plane at y=0,

b) the angle Θ of the track with respect to the z-axis, and

c) the angle β with respect to the vertical y-axis.

The plots show a preferred vertical direction of the reconstructed tracks passing centrally through the detector as expected.