Performance studies for the new ATLAS LAr Level-1 trigger digitization system

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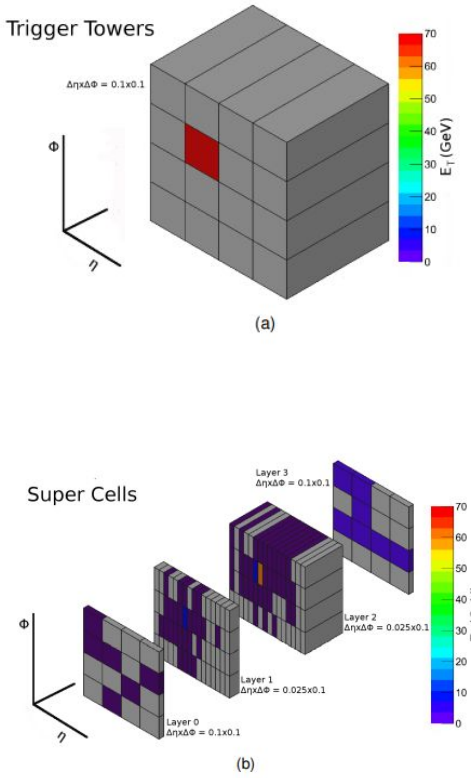
LAr Phase-I Upgrade

- Aims to prepare the ATLAS LAr Calorimeters to operate in higher luminosities expected on Run 2
- Increase trigger granularity to a factor of ten
- The information gain with the higher granularity allows for more efficient event selection yet on Level 1 Trigger (lowest level):
  - Electrons, photons, tau leptons
  - Etmiss
  - Better background rejection
- Introduces the concept of SuperCells
- As a design choice the legacy system will be kept operating in parallel to the new system



An electron as seen by the legacy trigger system (Trigger Towers) and by the new trigger (Super Cells)

Image Source: ATLAS Liquid Argon Calorimeter Phase-I Upgrade Technical Design Report,
tech. rep. CERN-LHCC-2013-017. ATLAS-TDR-022, CERN, 2013,
url: https://cds.cern.ch/record/1602230.

LAr Phase-I Upgrade

- **Main readout path (cells)**
  - FEBs (readout boards, controller boards, calibration boards), TTC system, RODs
- **Legacy trigger readout path (trigger towers)**
  - FEBs to TBBs to L1Calo receivers
- **New digital trigger readout path (super cells)**
  - FEBs to LTDB to back-end
  - Integration in ATLAS

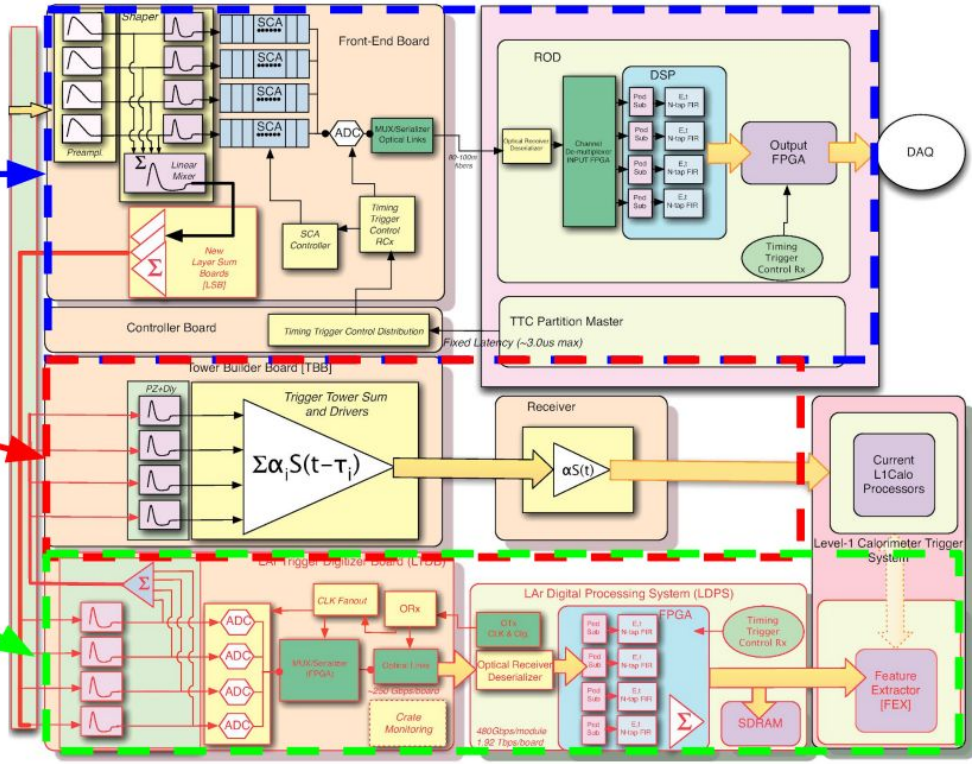
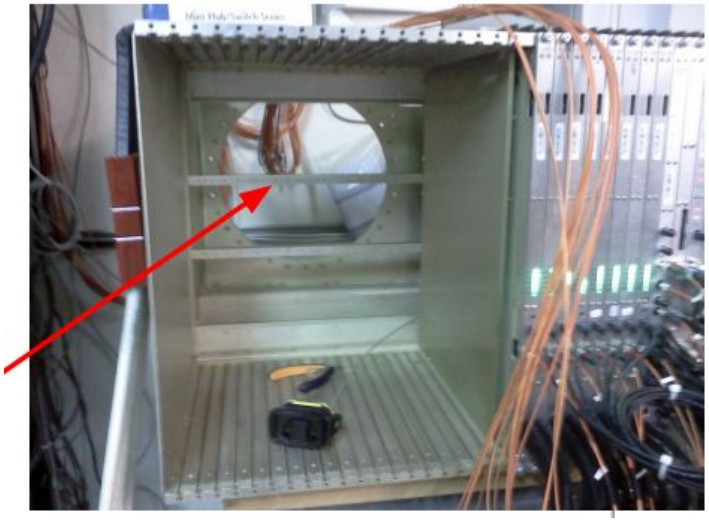
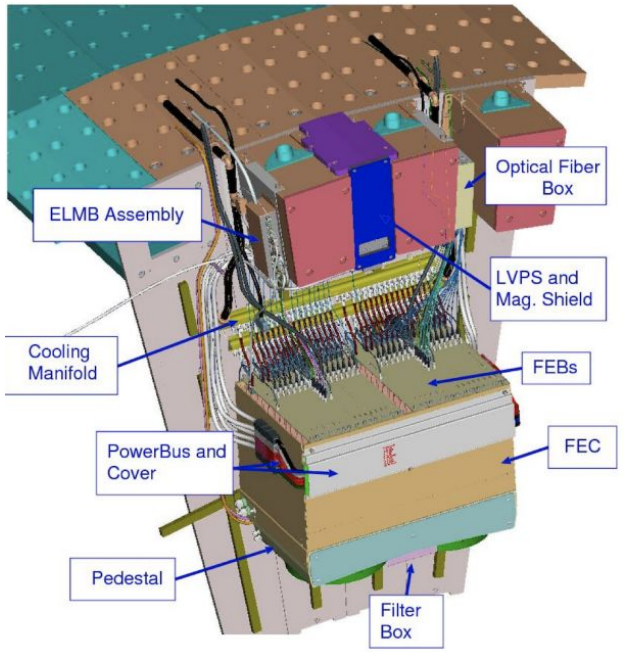


Image Source: Calibration data taking and available tools, Electronics calibration tutorial by Adriana Milic

Frontend Crates

- The crates are “attached” in the calorimeter
- Each FEB reads 128 cells of one dedicated layer
- We have 1524 FEBs in total





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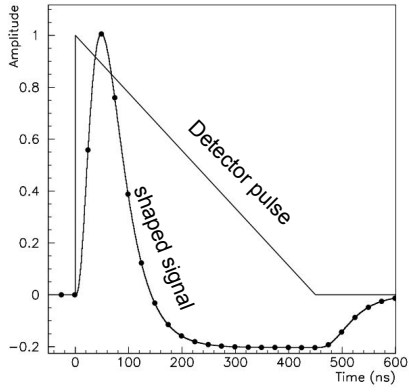
LTDB Prototype Signal reconstruction studies

- Aimed to apply OFC calculation on SuperCells information
- Optimal Filter Calculation (OFC) is a method used to calculate the amplitude and timing of a signal from liquid ionization calorimeters in a high luminosity environment
  - Account for thermal noise and “pileup” noise
- Evaluation and refinement of the OFC calculation:
  - The calibration and ionization (detection) signal have different phases. As OFCs are calculated using calibration signals, a timing offset have to be introduced
  - Evaluation of different OFC configurations



Energy from OF (optimal filter)

$$E(t) = \sum_{i=t}^{t+n} a_i \cdot s_i$$

filter coefficients

pulse samples

Composite of all 30 Presampler Waveforms

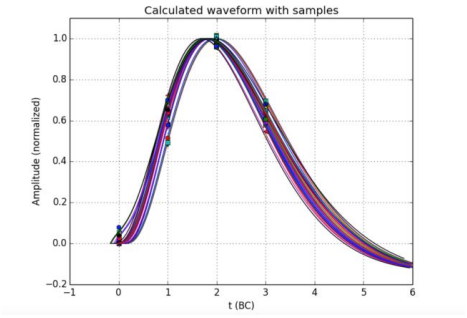
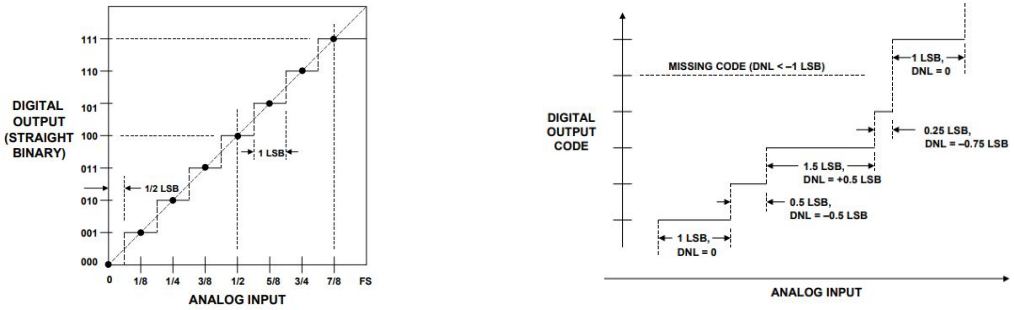


Image Source: The ATLAS Collaboration et al 2008 JINST 3 S08003

In-situ LTDB ADCs linearity studies

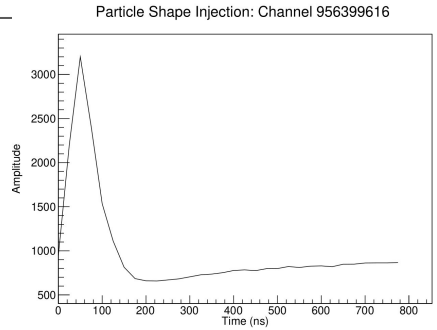
- LTDBs are the first component of the new trigger system. They are responsible to digitize the signals from the Super Cells.
  - Approximately 34400 Super Cells
- The ADCs are custom designed, and needs to be loaded with calibrations constants for correct operation
- This can be done during beam downtime
- It is impossible to get rid of non-linearity errors completely. The focus here is to keep them at an acceptable level.

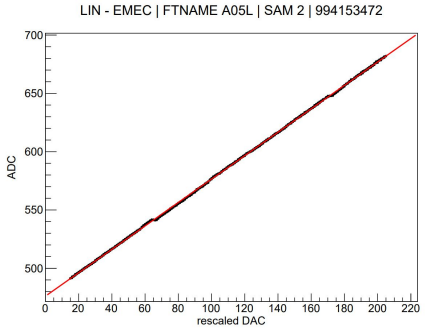


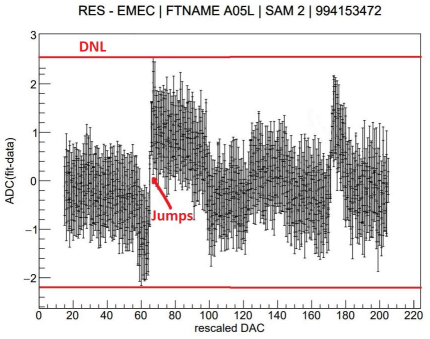
Typical ADC transfer function and details of ADC Differential Nonlinearity (DNL)

ADC Calibration Run

- To test the ADCs linearity we need to plot its transfer function
- We pulse the detector with pulse shapes with different amplitudes to get a range of an ADC channel
  - trigger 100 pulses with the same amplitude
  - pulse 1000 different amplitudes*
- From the transfer function (DAC vs ADC) we define a residual curve
  - difference between conversion result and linear fit
- Metrics
  - Maximum residual error (DNL)
  - Jump Amplitude
- Evaluate Performance Improvement after ADC Constants recalibration

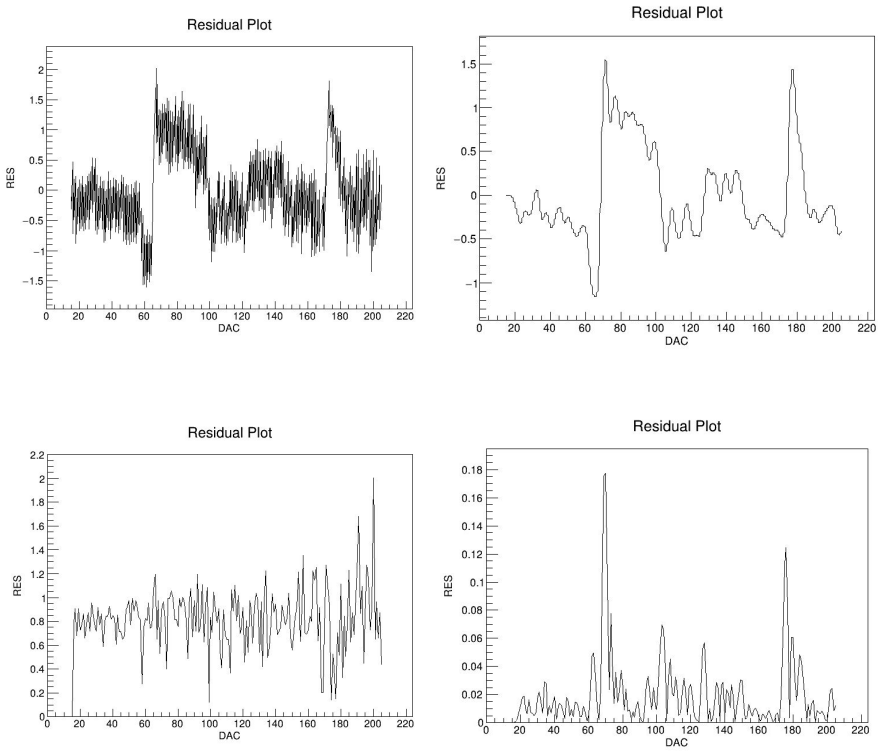






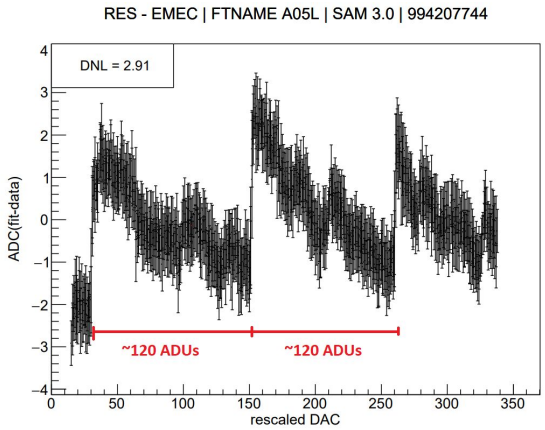
Automatic Detection of discontinuities

- High-frequency changes impact the derivative more than the gradual but bigger jumps
- We implemented a low-pass filter to eliminate ‘high frequency’ changes
- After applying this filter, the derivative is easier to analyse and give us the information on where the “big jumps” are.
- We take the absolute value of the derivative, as we want to analyse “jumps” in both directions.



Channels Periodic Discontinuities

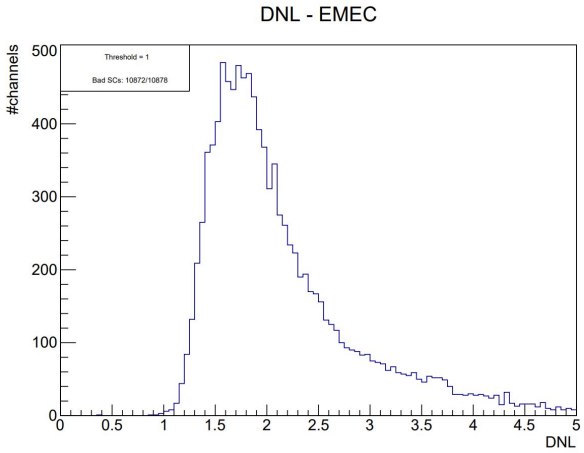
- Channels with periodic discontinuities were encountered in lab tests outside the detector.
- We detected the same feature on the boards installed on the detector
- Eventual goal: See if the jumps disappear with new (better?) ADC calibration constants.



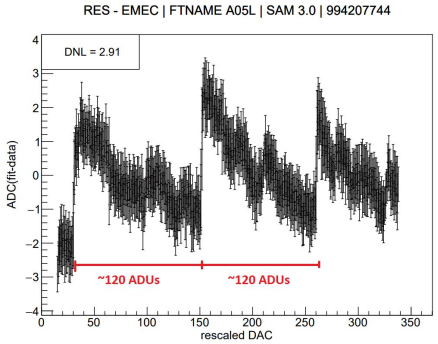
Example of channel with periodic discontinuities

Validation of new ADC Constants

- Complementary studies are responsible to recalculate new ADC Constants
- In this project we evaluate the performance of calibration constants
- Comparison of the DNL and jump values in each detector region
- Comparison of the number of channels with periodic discontinuities
  - This was a feature encountered in lab tests outside the detector. So, we know that this originates from the ADC calibration and not from other system from the detector



Summary histogram for DNL in the Electromagnetic EndCap (EMEC) region of the calorimeter

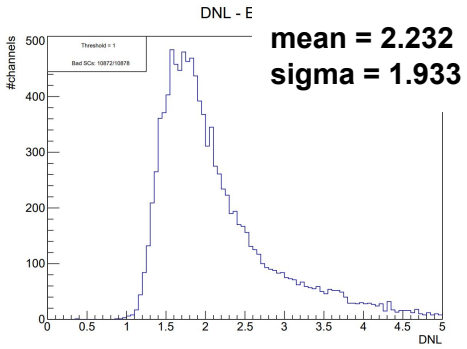


Example of channel with periodic discontinuities

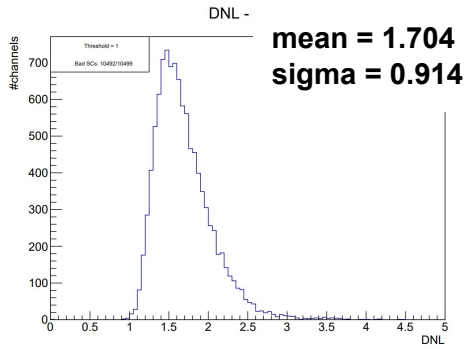
ADC Constants comparison

- We loaded new constants on validation process for one run and compared the performance with the constants *in-situ*
- Significant reduction of the mean DNL in every region
  - Reduction mean 18% - 34%
  - Reduction sigma 24% - 53%
- General reduction of channels with periodic discontinuities (3.63% to 1.30%)

Old ADC constants (407280)



New ADC constants (417413)



	Old	New
EMB	327 (1.76 %)	216 (1.16 %)
EMEC	744 (6.83 %)	174 (1.66 %)
HEC	49 (3.62 %)	3 (0.25 %)
Total	1120 (3.63 %)	393 (1.30 %)

Number of periodic channels per detector region

LTDB ADCs studies: Conclusions and Next Steps

Conclusions

- This project can effectively detect incorrectly calibrated ADC channels in the detector
- Developed a framework for comparing different ADC calibration constants

Next Steps

- Take runs with extended DAC range
- Extend to other calorimeter regions (FCAL)
- Integrate the workflow in the data quality framework

Thank you for your attention!

Questions?