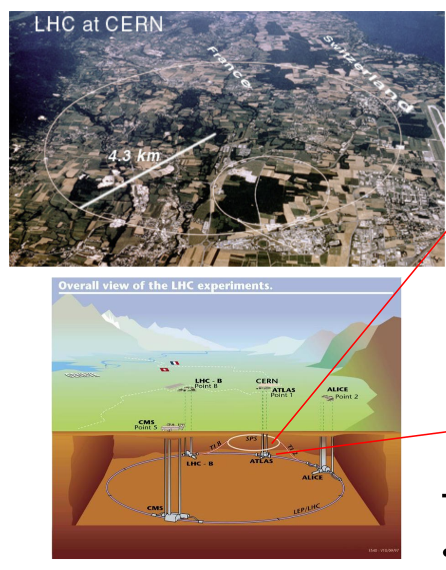
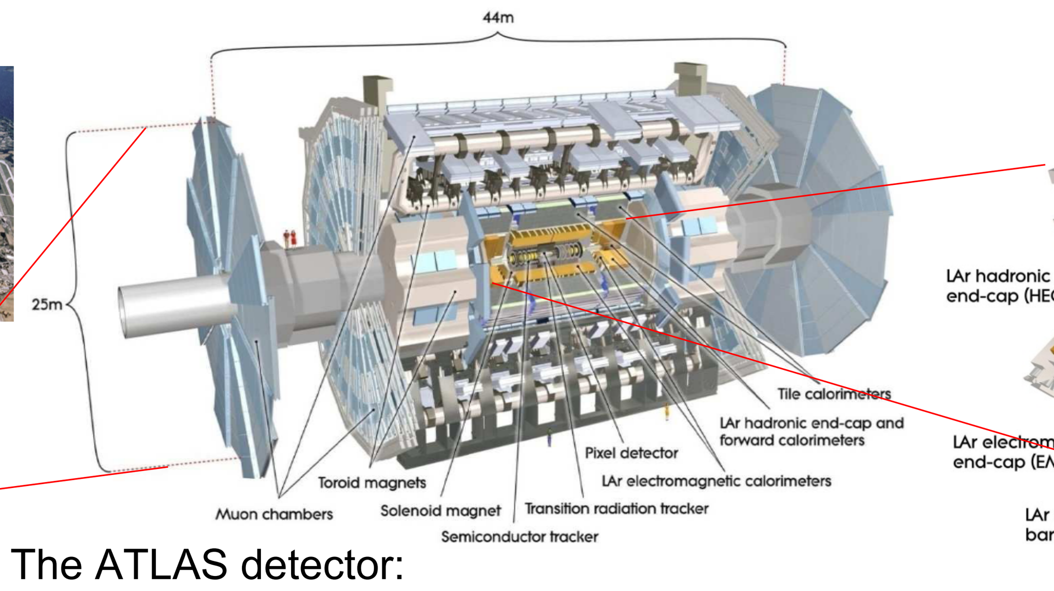
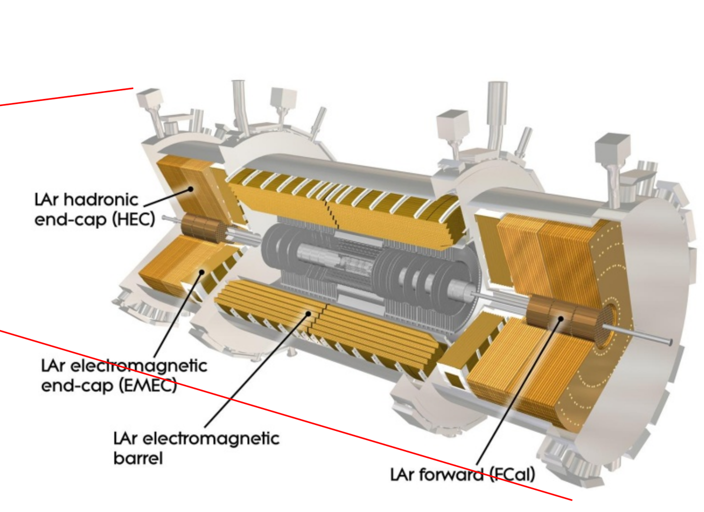
Electronics of the Atlas Liquid Argon Calorimeter and its Precision Calibration

The Large Hadron Collider (LHC) at CERN:

- Particle accelerator with world's highest design energy.
- Proton-proton collide at 14 TeV center of mass energy.
- Luminosity $L = 10^{34}$ cm^{-2}s^{-1}
- Situated in the former LEP tunnel, ~27 km long and 100 m underground.







The ATLAS detector:

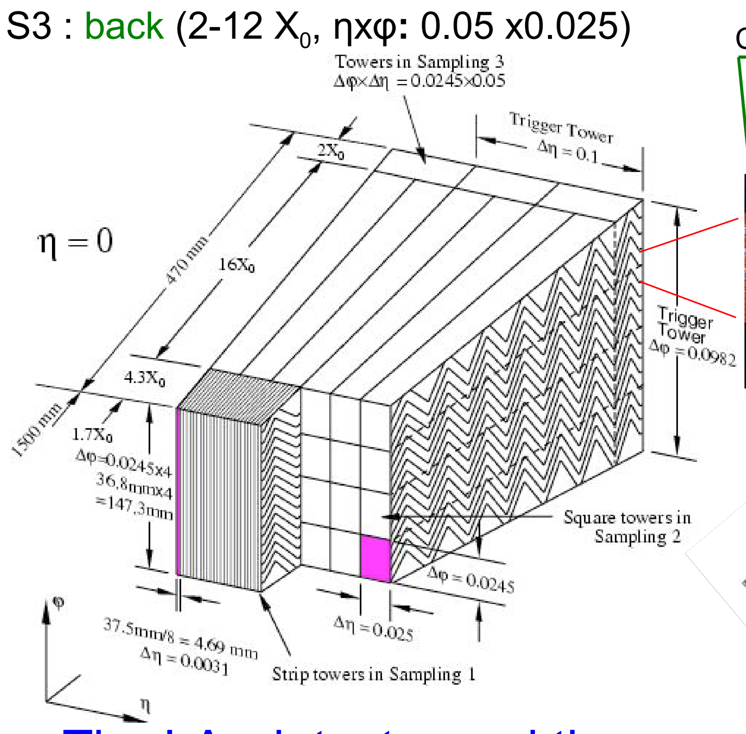
- General purpose detector in particle physics.
- Precisely measures photons, electrons, muons and hadrons.
- 44 m long, 25 m tall, 7000 tons. "Density" ~ 0.08 g/cm³

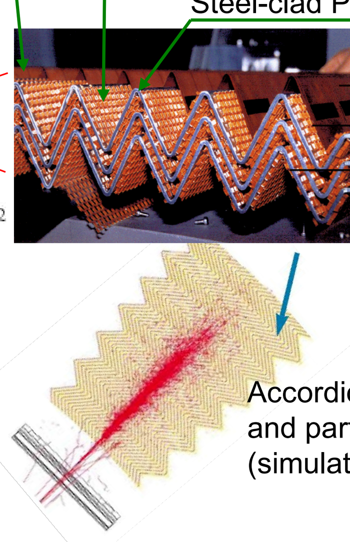
The LAr calorimeters:

- Measures electron and photon energies.
- Ionizing particles generate current signals between electrodes in LAr.
- The whole LAr detector has ~182,000 readout channels, read out by electronics on-the-detector (front-end) with a dynamic range from 30 MeV to 3 TeV.
- Data are transmitted to off-the-detector (back-end) electronics for processing via radiation tolerant gigabit optical links.

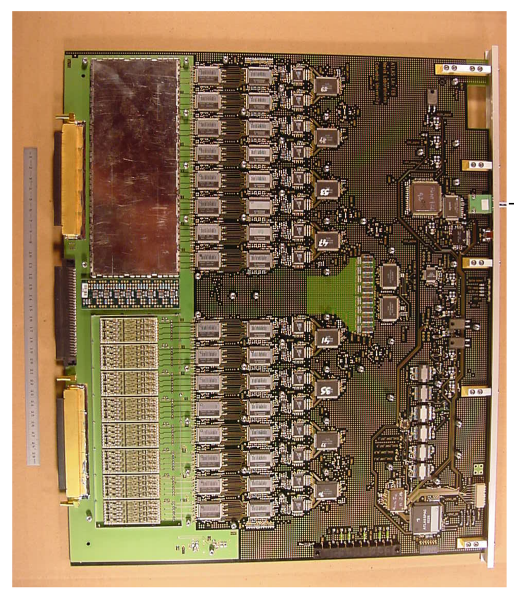
LAr detector Longitudinal segmentation & fine granularity:

S0 : presampler
S1 : front (~4 X_0, ηxφ: 0.025/8x0.1)
S2 : middle (~16 X_0, ηxφ: 0.025x0.025)
S3 : back (2-12 X_0, ηxφ: 0.05 x0.025)



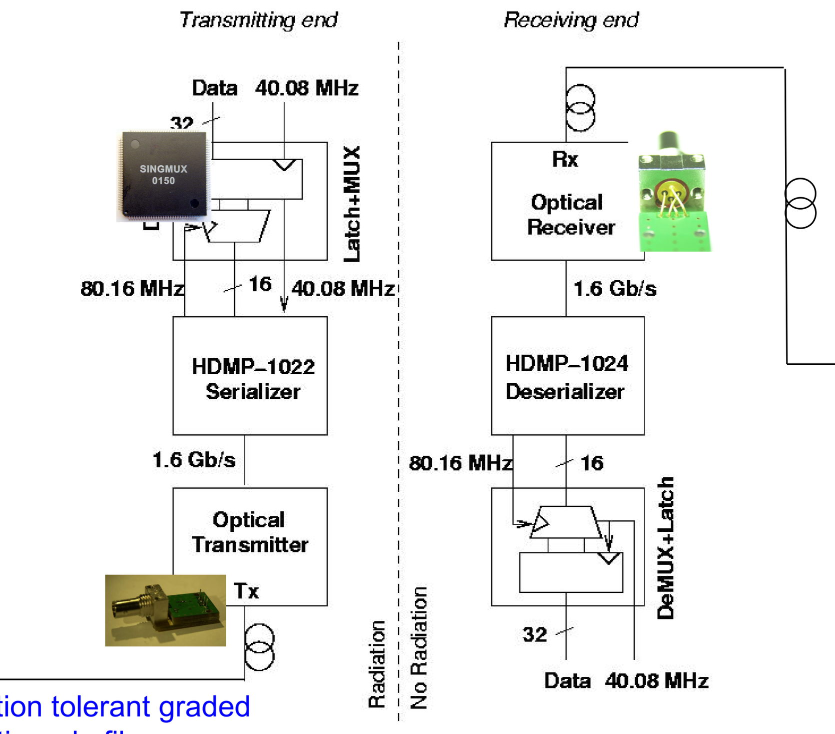


The LAr detector and the accordion geometry



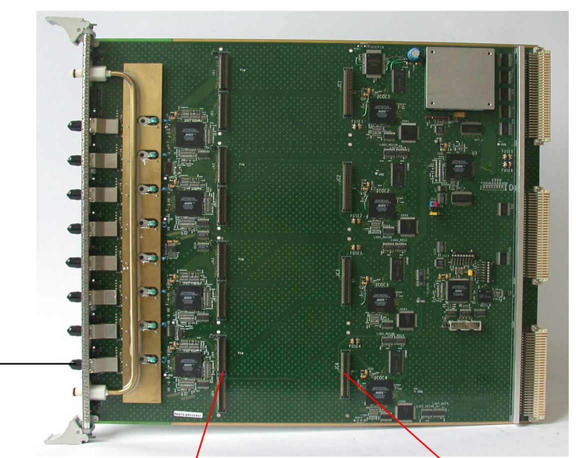
The front-end board or FEB

The optical link connecting the FEB to the ROD



The radiation tolerant graded index multi-mode fiber

The read-out-driver or ROD, reads 8 FEBs

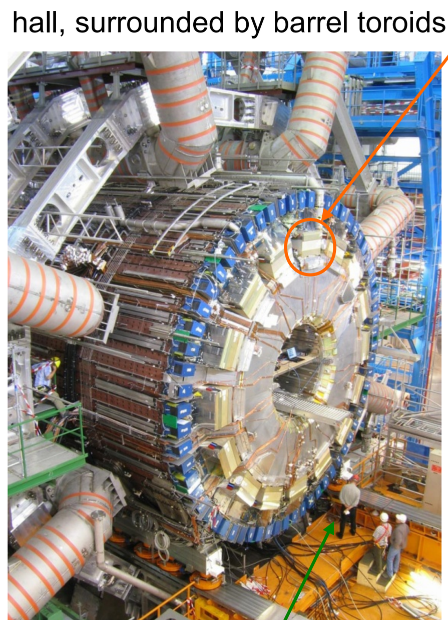


The DSP based processing unit calculates energy and timing information on-the-fly.

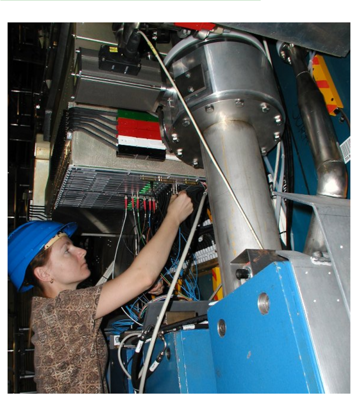
The LAr readout boards and the optical link

The barrel calorimeters in detector hall, surrounded by barrel toroids

The front-end crate located on the detector



Size of a person



SMU physicist is installing the optical link to the FEBs in the front-end crate

The "front-end"

The calibration board injects exponential current pulses of known amplitude on the detector cell, at the MB level, in order to probe the actual electronic response

The preamplifier amplifies (and integrates) the current signal

The SCA stores in analogue format the signal samples in 3 gains, waiting for the trigger

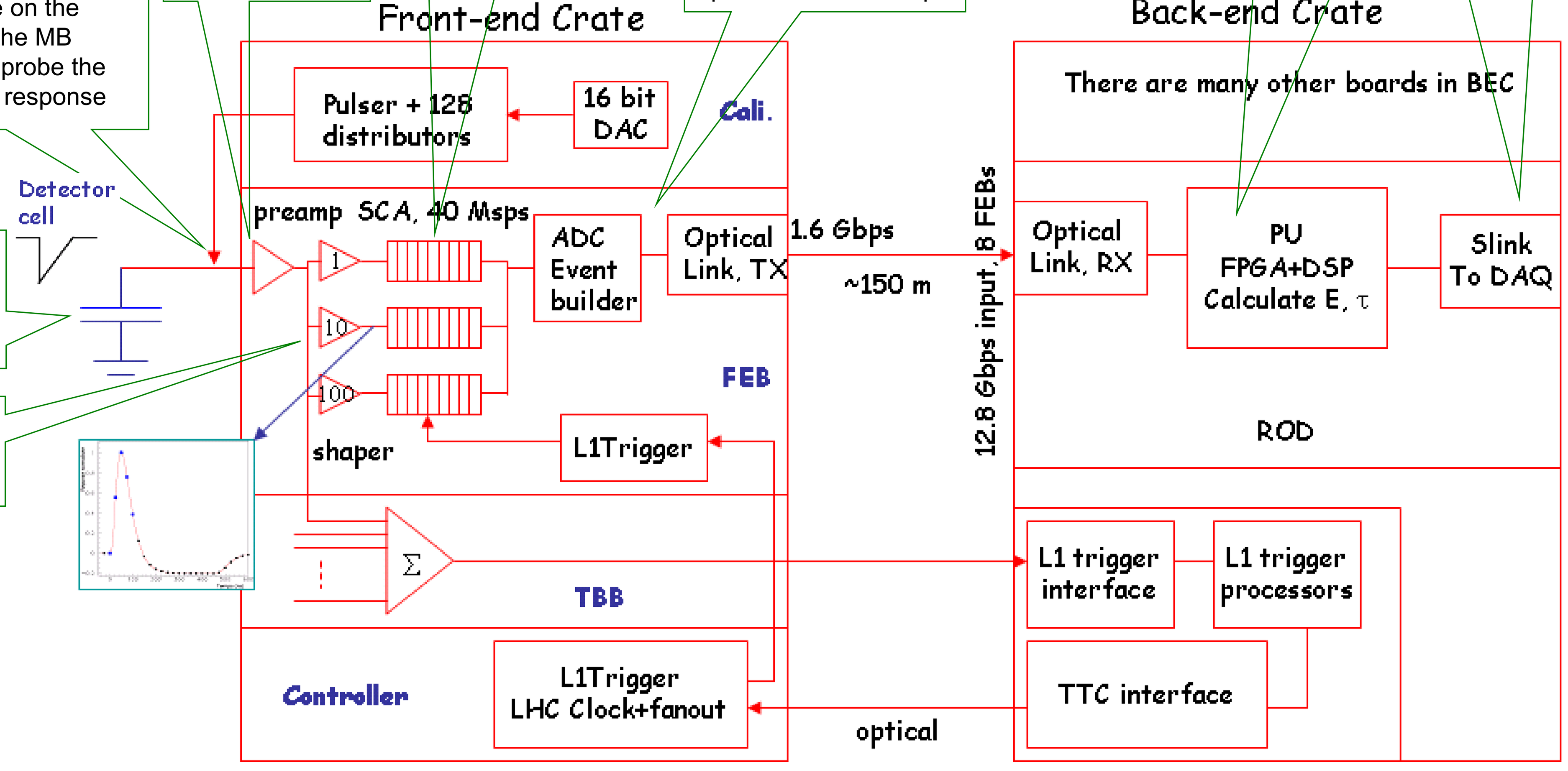
Once triggered, the selected samples are digitized by the 12 bit ADC, the transmitted to the back-end via optical link at 1.6 Gbps

Energy and timing information is computed by a DSP and FPGA based processing unit. Raw data are not stored.

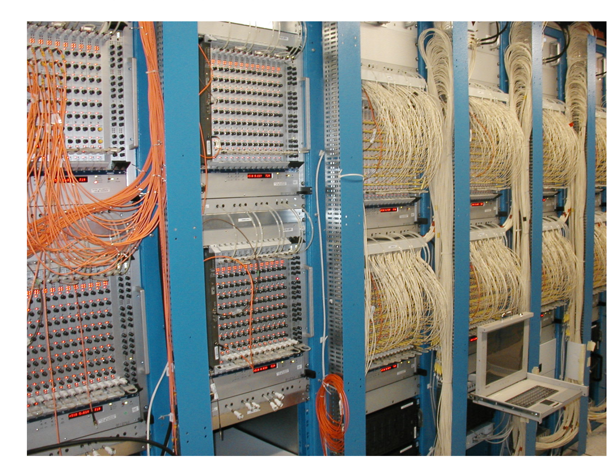
Processed data are transmitted to the Data Acquisition (DAQ) system for further processing.

The cell electrode in LAr collects ionization charges that drift in the electrical field generated by the HV

The CR-RC² filter shapes the amplified signal in 3 gains



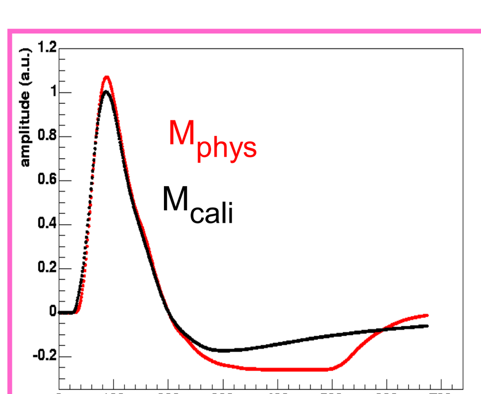
The back-end racks with optical fibers connected to the RODs



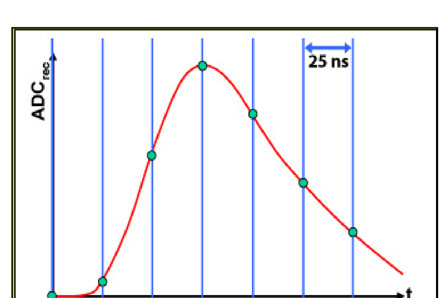
The "back-end"

The LAr readout electronics system

From ADC counts to energy and the calibration



The physics signal and calibration signal are different even with the same injected charge. A correction is needed



Pulse Samples

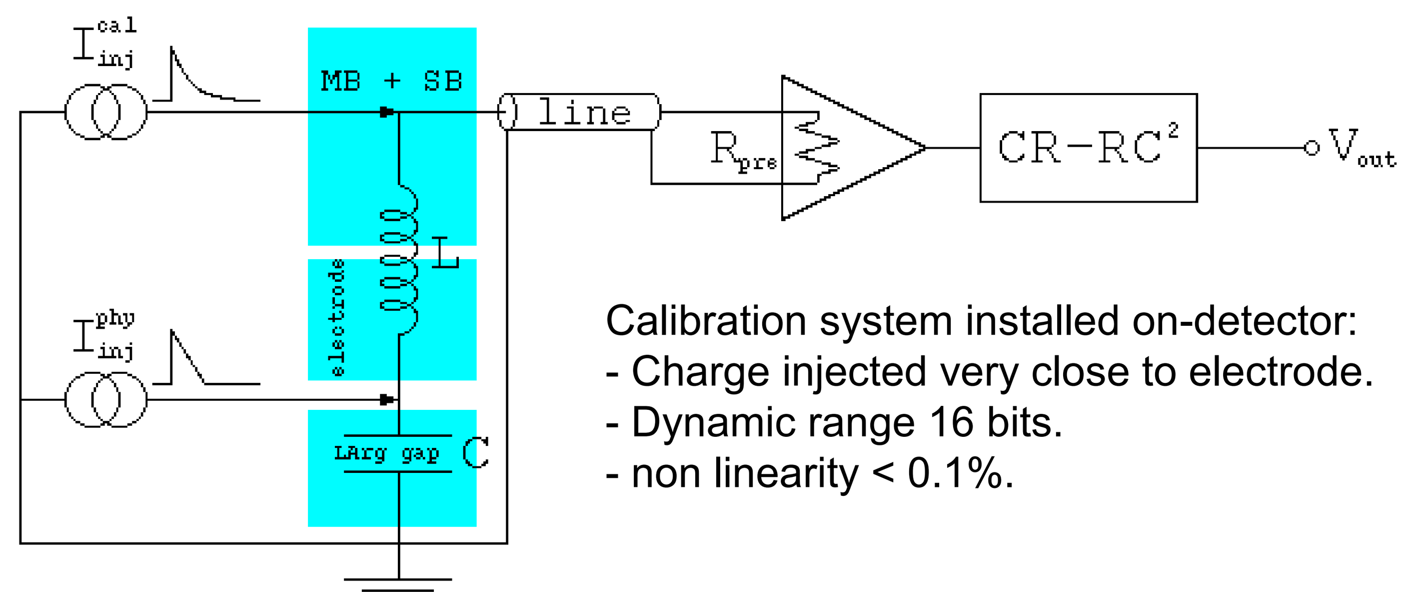
ADC to DAC (Ramps)

$$E_{\text{cell}} = F_{\mu A \to MeV} \cdot F_{DAC \to \mu A} \cdot \frac{1}{\frac{M_{phys}}{M_{cali}}} \cdot R \left[\sum_{j=1}^{N_{\text{samples}}} a_j \left(s_j - p \right) \right]$$

Cell energy | Charge to E conversion | Calibration board | Optimal Filtering Coefficients | Pedestals

Calibration of the electronic response, $F_{DAC \to \mu A}$

A known exponential current pulse is injected at the MB level and reconstructed through the full readout chain. The actual gain of each readout channel is computed.

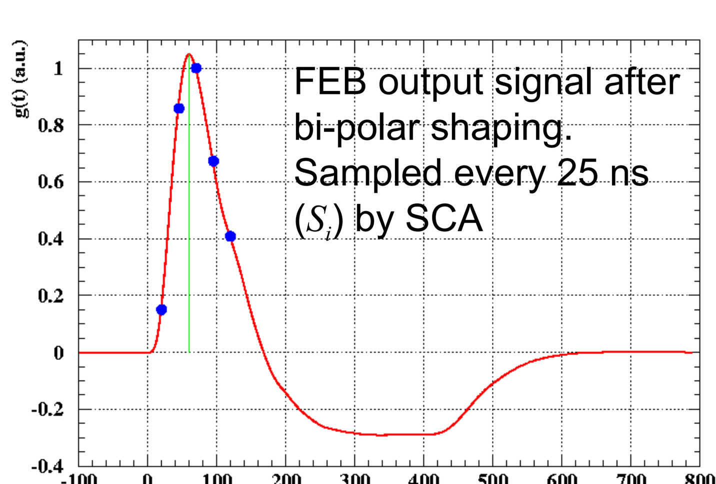


Calibration system installed on-detector:
- Charge injected very close to electrode.
- Dynamic range 16 bits.
- non linearity < 0.1%.

The Optimal Filtering (OF):

a) signal maximum amplitude
b) temporal position

$$A_{max} = \sum_{i=1}^{n} a_i (S_i - p) \quad \Delta t = \frac{\sum_{i=1}^{n} b_i (S_i - p)}{A_{max}}$$



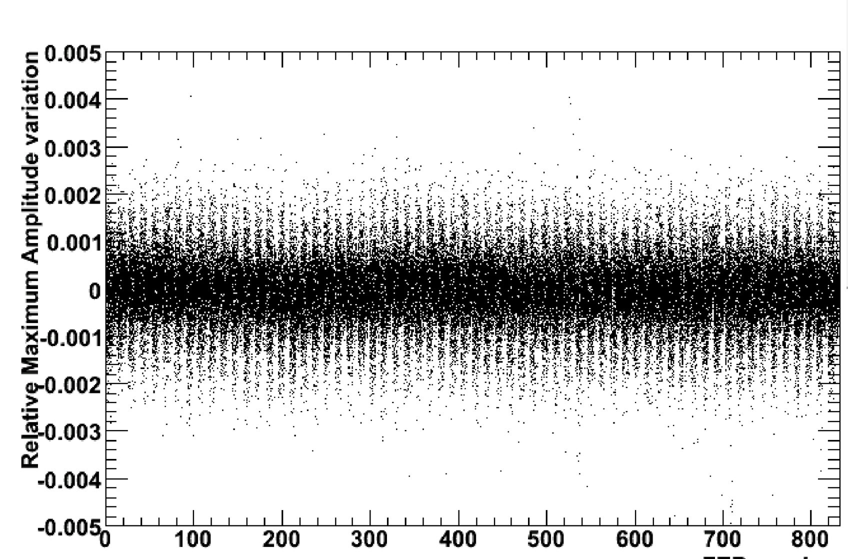
FEB output signal after bi-polar shaping. Sampled every 25 ns (S_i) by SCA

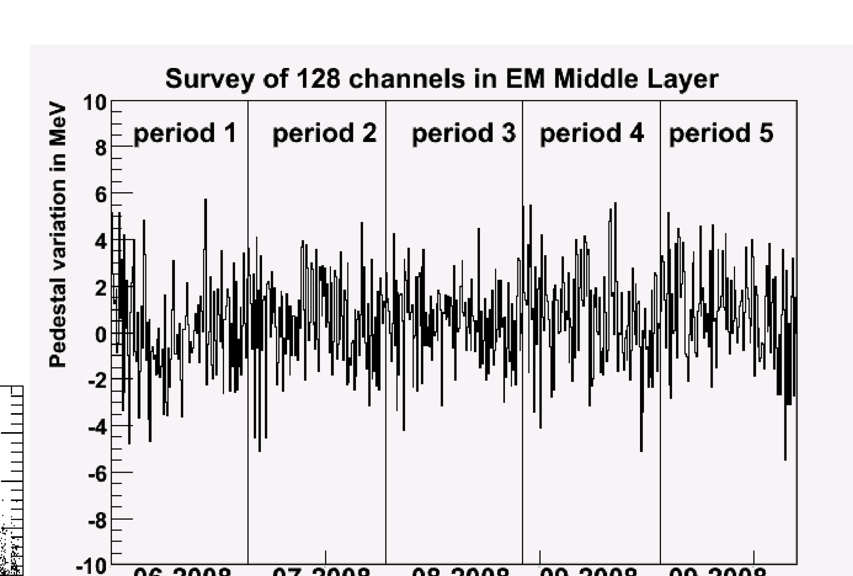
The OFC, a_i and b_i are evaluated while minimizing the dispersion in A_{max} and Δt arising from electronics and pile-up noise.

Optimal Filtering Coefficients
- OF is faster than a fit → important for online computation
- OF takes into account the time autocorrelation of noise
- Using 5 samples, the electronic noise is reduced by a factor ~1.7 with respect to a readout with only 1 sample

Constant stability

Pedestal data over 4 months show high stability. This automated process monitors the readout channels, and updates the constants database.





In smooth running conditions:
Pedestal variation < 1 MeV
Pulse amplitude variation < 0.1%

Jingbo Ye, Department of Physics, SMU, On behalf of the ATLAS Liquid Argon Calorimeter Group

RT2009, Beijing, May 10 – 15, 2009