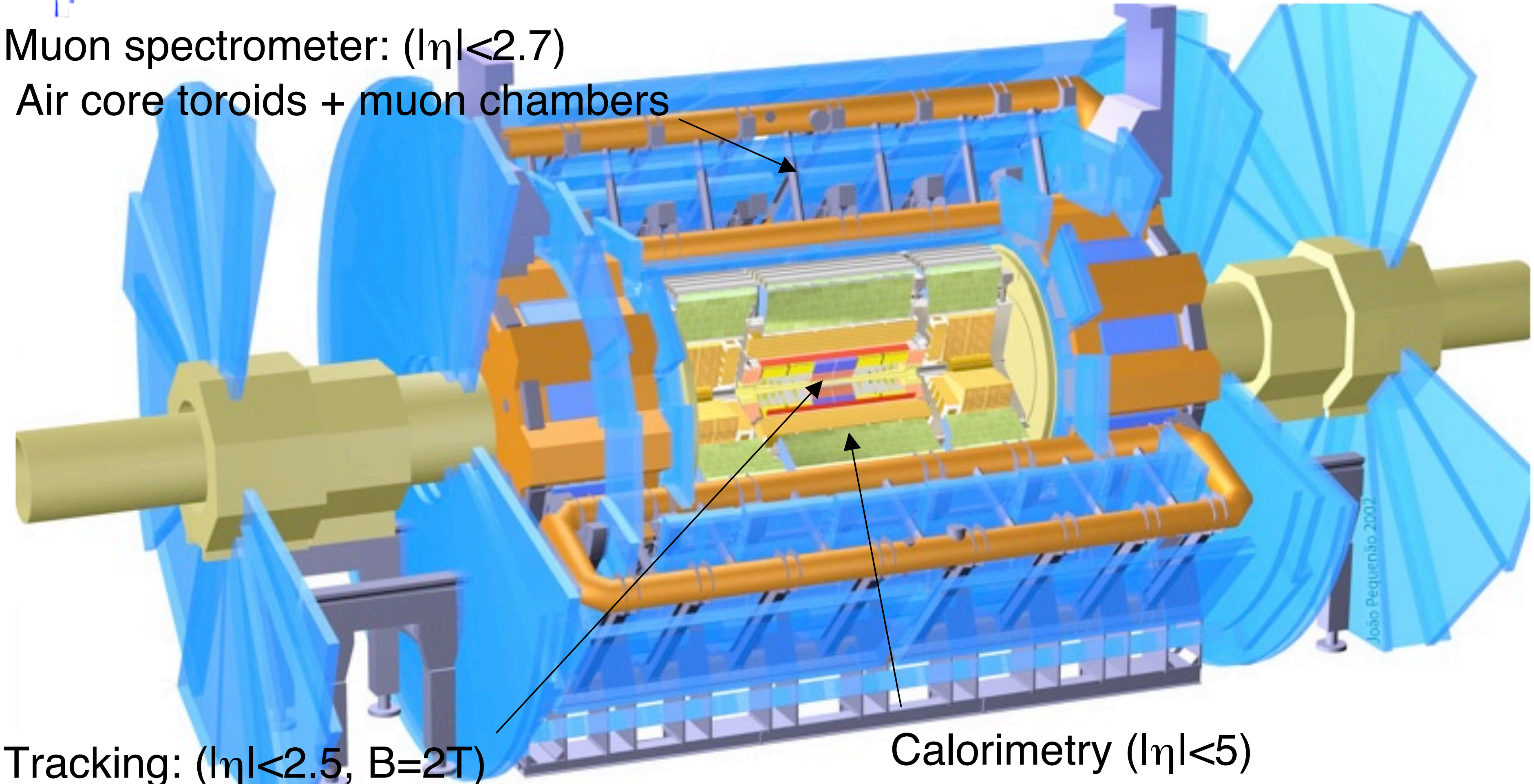
The Atlas LArg Calorimeters
Calor-08 Pavia

On behalf of the ATLAS LArg group

The Atlas Experiment

Muon spectrometer: (|η|<2.7)
Air core toroids + muon chambers



Tracking: (|η|<2.5, B=2T)
- Si pixels and strips
- Transition radiation detector (e/π)

Calorimetry (|η|<5)
-EM:Pb-Liquid Argon (LAr)
-HAD: Fe/scintillator, Cu/W-LAr

Physics requirements

The discovery potential at the LHC drives the performance requirements, especially H to $\gamma\gamma$ and H to 4e, for EM calorimetry, but also SUSY, and precision measurements for the overall calorimeter system:

-Large acceptance: full ϕ coverage, $|\eta| < 3.2$ (with high precision $|\eta| < 2.5$)
-Energy resolution: stochastic term <10%GeV$^{1/2}$, noise term < 300MeV, constant term <0.7% (precise mechanics and electronics calibration)
-Linearity for precision measurements (M_w): <0.1% (pre-sampler detector for dead material corrections)
-Particle identification:
- $e^{+,-}$/jets
- γ/π^0 (π^0 rejection better than 3 above P_T=50GeV/c)

-Angular resolution: <50 mrad/$E^{1/2}$ (very fine granularity in first sampling layer)
-Hadronic and missing E_T: acceptance up to $|\eta|<4.9$
- $|\eta|<3$ $\sigma_E/E \sim 50\%/E^{1/2} \oplus 3\%$
- $|h|>3$ $\sigma_E/E \sim 100\%/E^{1/2} \oplus 10\%$

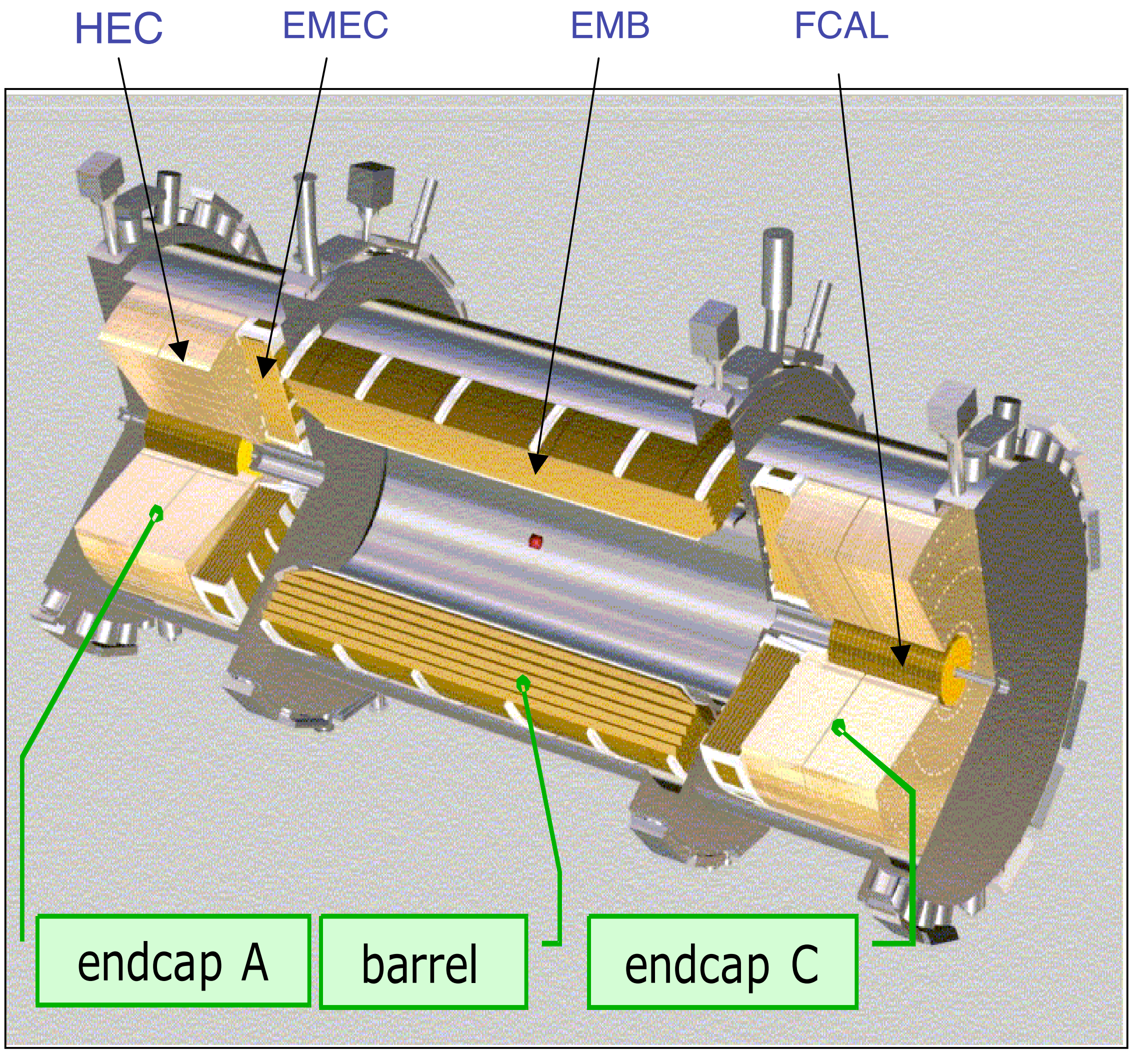
-Large dynamic range: 20MeV to 2TeV
-Fast response to minimize pile up.

The LArg Calorimeters

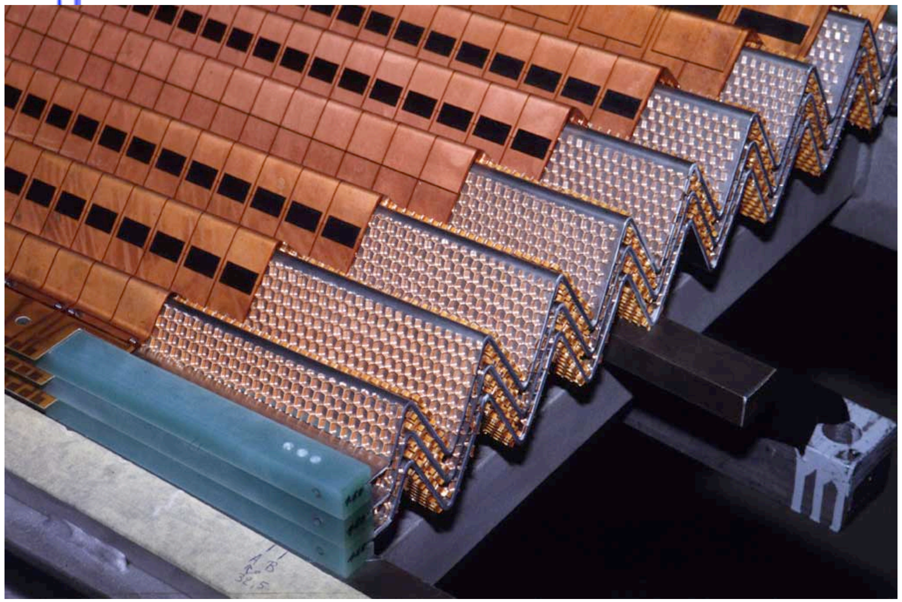
The LArg calorimeters are hosted in 3 large cryostats
The barrel cryostat contains the EMbarrel.
The endcap cryostats contains EM, Hadronic and forward detectors.

Parameters:

Cryostats	Barrel	EndCap
Volume (m^3)		
Cold vessel	**58**	**43**
Expansion vessel	**5**	**2**
Liquid argon	**45**	**19**
Insulating vacuum	**26**	**6**
Weight (t)		
Cold vessel	**12**	**14**
Detector	**110**	**219**
Vacuum vessel	**13**	**9.5**
Solenoid	**5.5**	
Full cryostat	**203**	**269**

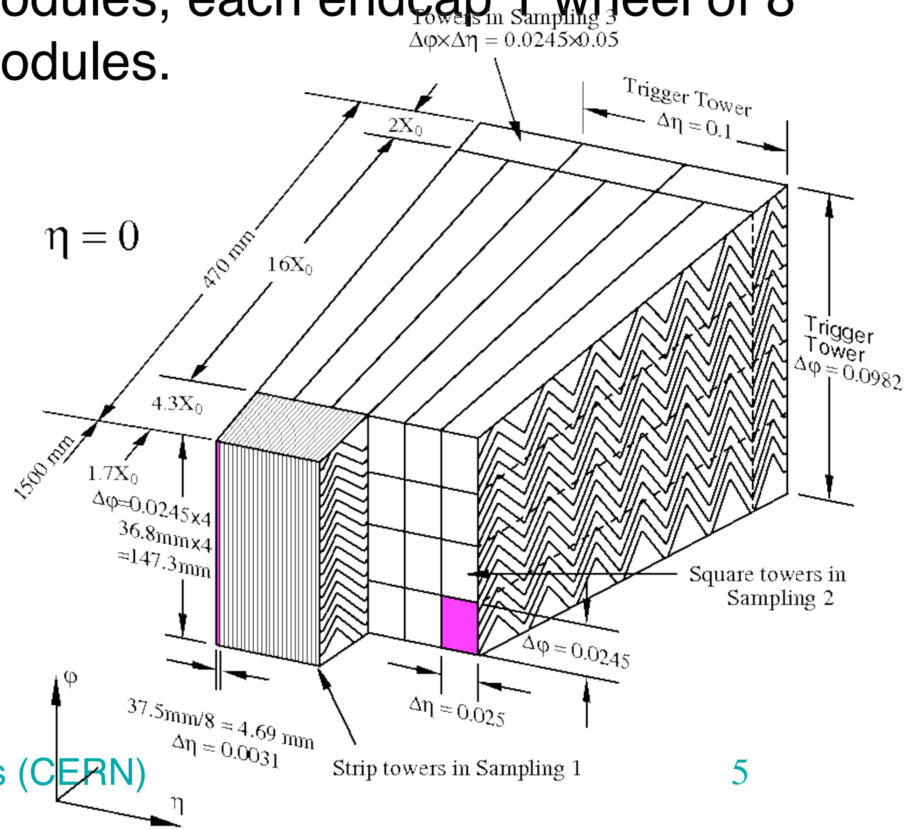


Electromagnetic calorimeters



Pb/Ar sampling calorimeter with accordion shape:

- Full Phi coverage, no cracks
- Rapidity (η) up to 3.2
- Inherently radiation hard.
- Barrel build out of 2 wheels of 32 modules, each endcap 1 wheel of 8 modules.



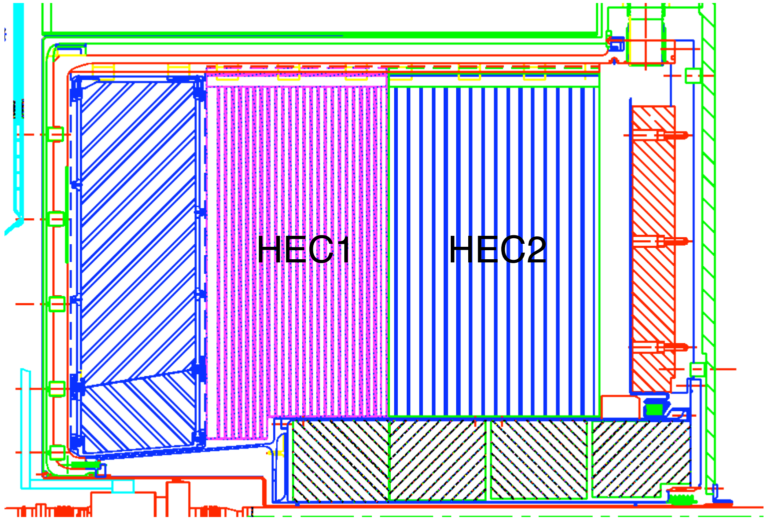
The Cu etched electrodes allow fine granularity and longitudinal segmentation: 3 layers + Presampler detector up to η=1.8

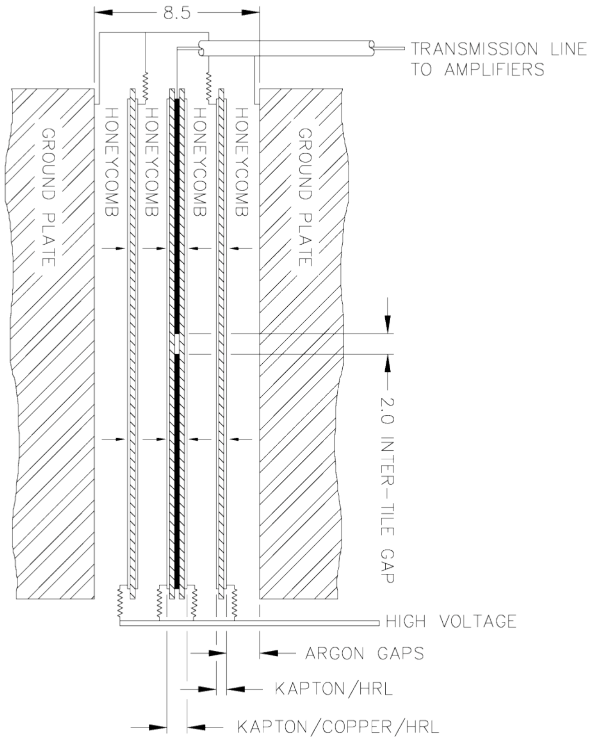
~ 170000 channels.

Fast signal: Tdrift~450ns, shower development follows signal propagation.

Hadronic Endcap Calorimeter

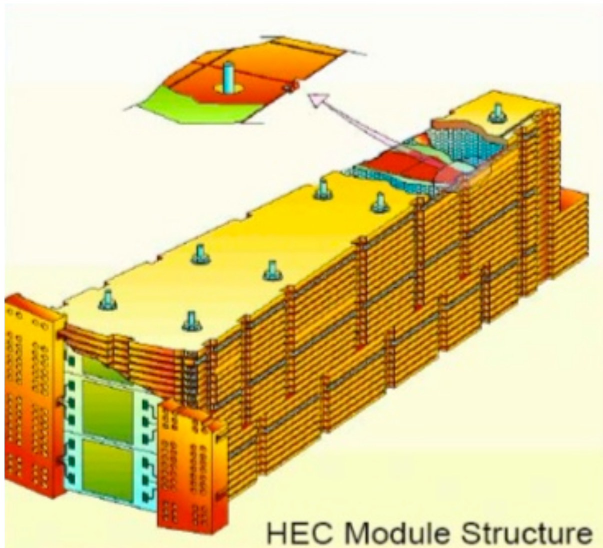
Cu-Ar sampling calorimeter:
Coverage: $1.5 < |\eta| < 3.2$
2 wheels of 32 modules.



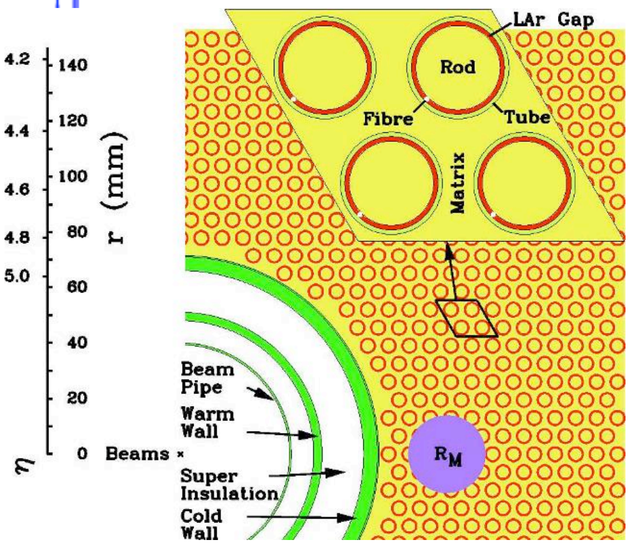


Cold GaAs preamps.
Double gaps on each sides of the electrode

Granularity: ($\Delta\eta$ x $\Delta\phi$)
$\eta<2.5$ 0.1 x $2\pi/64$
$\eta>2.5$ 0.1 x $2\pi/32$



Forward CALorimeter



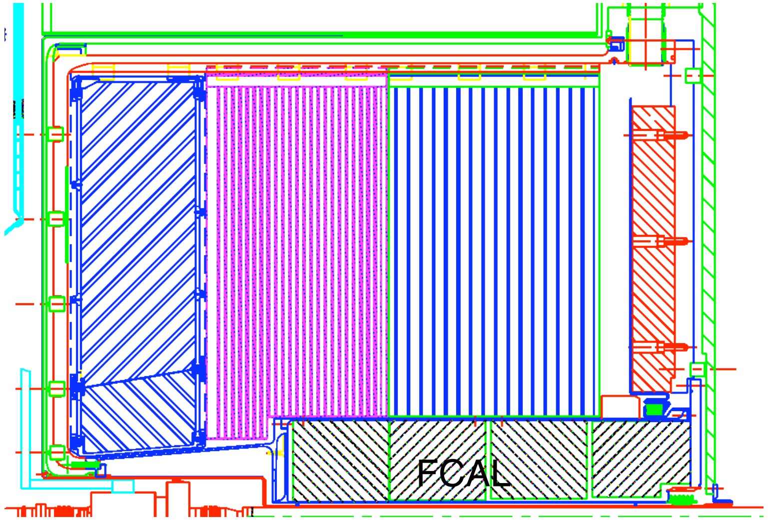
3 Compartments followed by an absorber:

1 EM module (Cu):

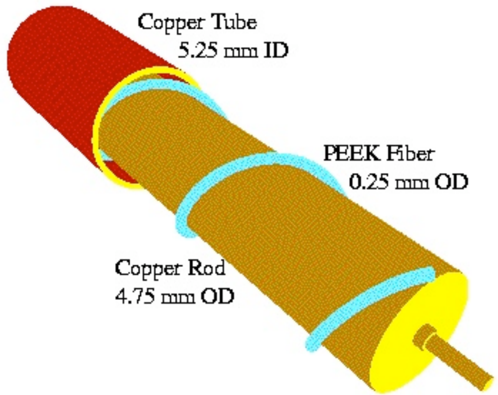
- 12004 gaps, 1008 channels

2 Hadronic (W):

- 10200 gaps , 500 channels
- 8224 gaps, 254 channels



2.66λ 3.76λ 3.6λ



Charges collected on thin tubes maintained between absorber matrix and rods.

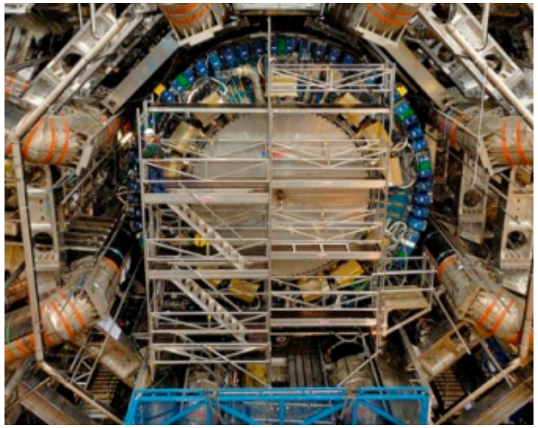
Coverage: $2\pi \times 3.2 < |\eta| < 4.7$

Installation in the Experiment Hall

Some Milestones:

April 2006: All cryostats in the Cavern.
Aug 2006: First cosmic signal recorded, together Tile calorimeter
May 2007: Back End electronics completed.
Summer 2007: Low voltage power supplies fully available.
Sept 2007: Endcap C electronics installation completed.
Dec 2007: Endcap A electronics installation completed.
April 2008: Barrel front end installation finished.
May 2008: Readout of the full calorimeter,
Closure of the apparatus.

A few numbers:
~180000 channels
over 1600 Front end boards
56 Front end crates
56 power supplies systems
16 rod crates
192 rod boards
115 High voltage modules
...

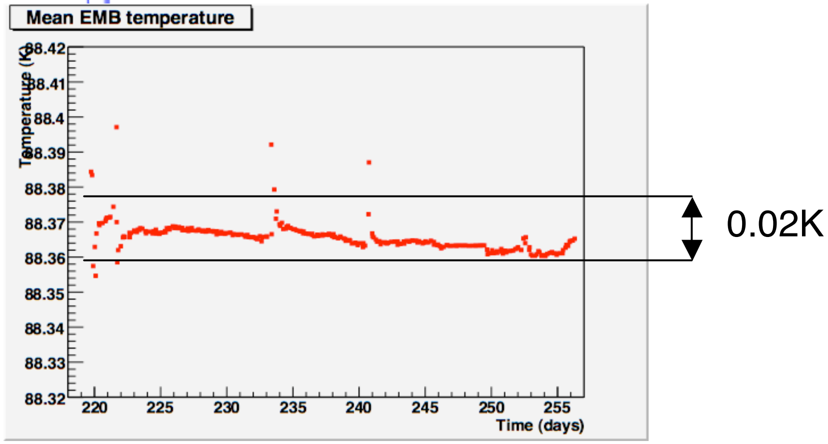

Calo. end cap during installation


Fiber cabling on the readout system


Cabling & Testing of trigger system


Installing and testing power supplies

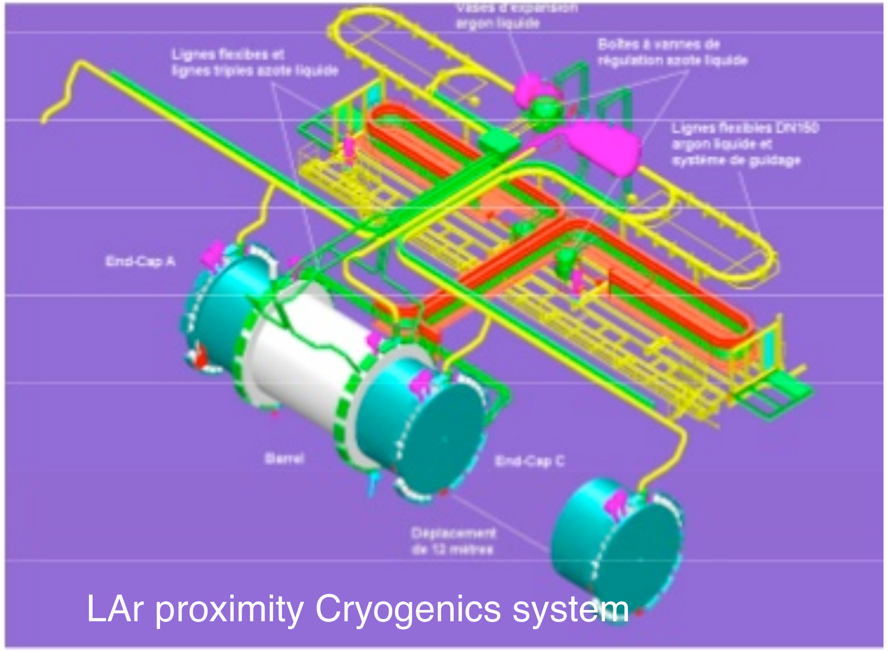
Cryogenics Monitoring



LAr temperature:
-Collected charge sensitivity 2%/K
-Barrel 192 sensors, (ΔT=10mK)
-Endcaps 255 sensors.

RMS of temperature for Barrel ~ 67mK

LAr purity:
- 10 monitors per cryostat.
- $Q_{Bi(1MeV\ e)}/Q_{Am(\alpha\ 5.5MeV)}$ gives O_2 content



LAr proximity Cryogenics system

cryostat	O_2 (in ppb)
Endcap A	~170
Barrel	~240
Endcap C	~120

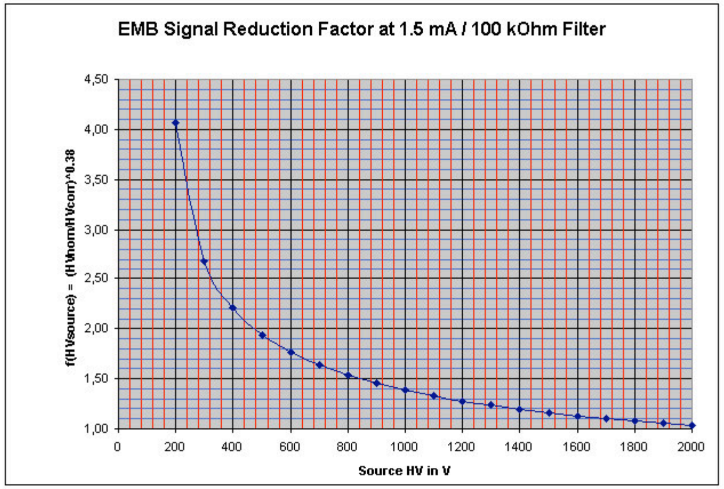
Calorimeter High Voltage

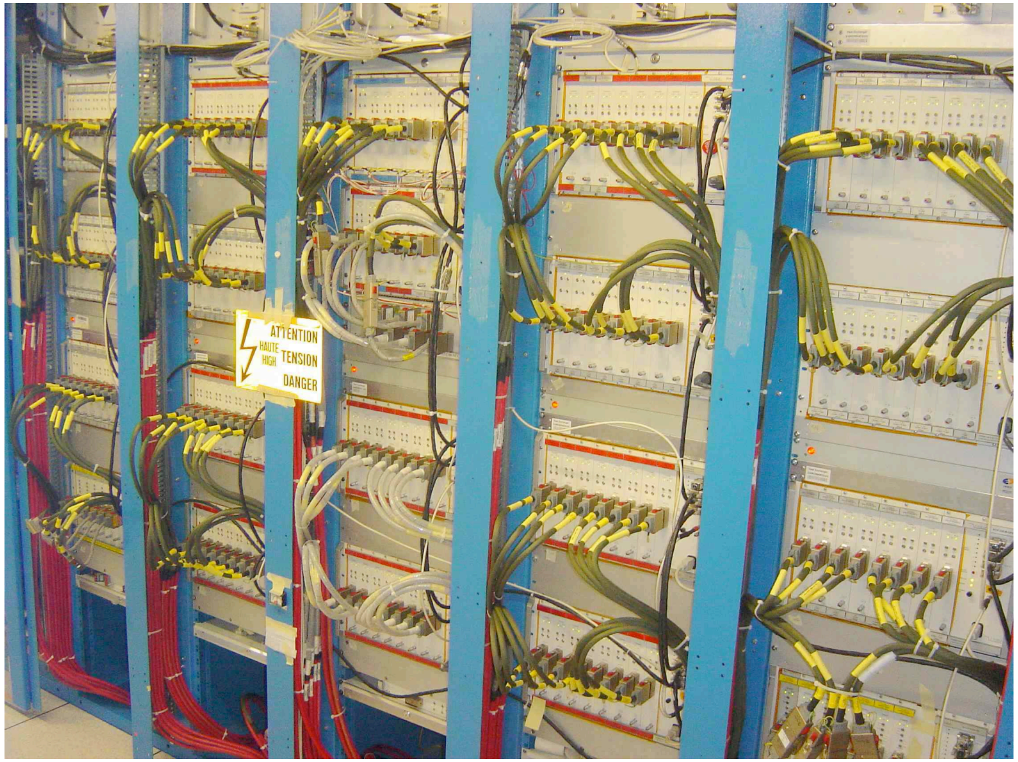
System fully installed and operational.

Short circuits in barrel pre-sampler and Emec detectors were cured with current discharged into the calorimeter.

Less than 1% of channels at reduced voltage.

All electrodes have sufficient voltage to provide usable signals:





High voltage backend

$Q \sim V^{0.37}$, ie weak dependence on the high voltage setting. Cost is slightly increased noise.

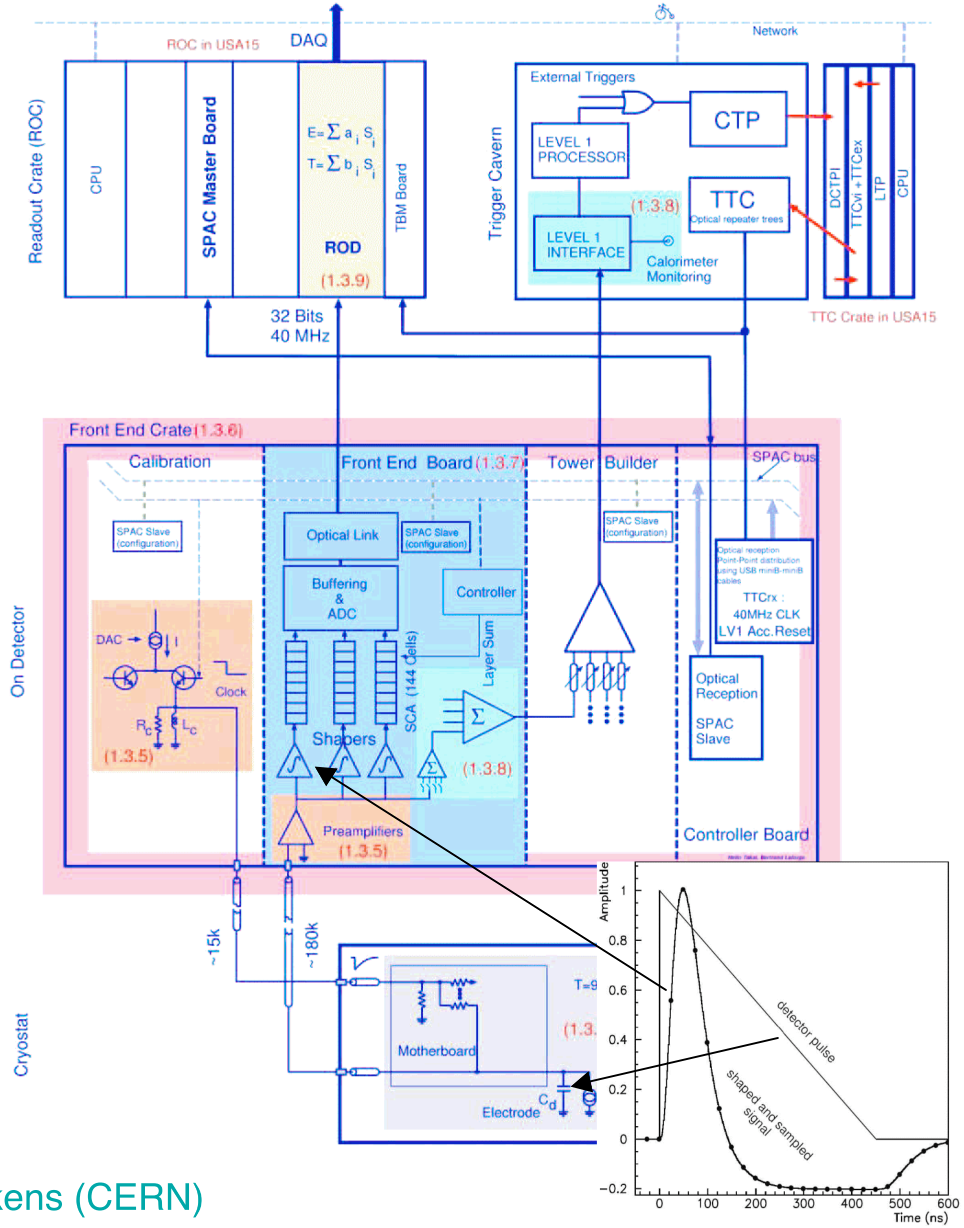
Readout Chain

All the readout electronics installed and used daily for commissioning.

Large dynamic range (20MeV to 2TeV): 3 gains per channel, 12bit ADC, digitization at 40 MHz.

Energy (Time and Quality) calculated in readout drivers.
Also provides energy weight position moments for higher level trigger (for missing E_T calculations), and monitoring histograms.

From 3 to 32 samples readout. 5 for Atlas Physics running. 32 used for many commissioning studies.



Level 1 trigger inputs

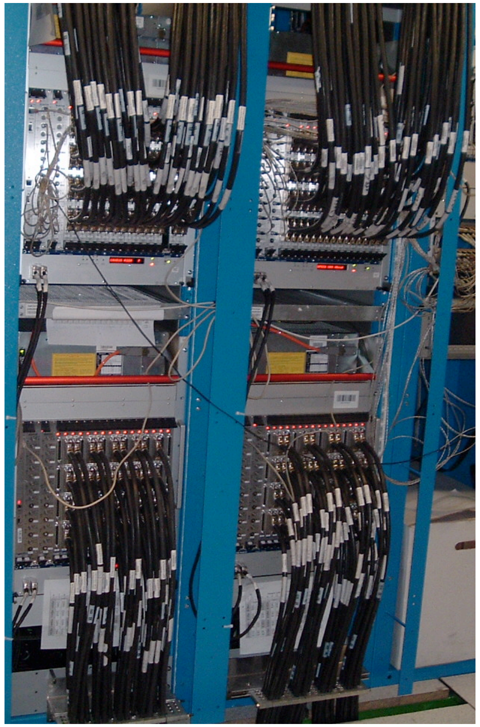
Analogue signals from the calorimeter are shaped summed and time aligned in the Front End electronics, building η=0.1x ϕ=01 trigger towers, combining the different sampling layers

At the receiver end, adjustable gains are applied and further transmitted to the Atlas Level 1 trigger system.
Also signals can be routed to monitoring system composed of ADCs & oscilloscopes.

Intense testing using calibration pulse allowed:
- identify/fix all cabling problems.
- determine timing offsets at ns level.
- determine gains comparing with E reconstructed from main readout.
- understand & fix coherent noise issues.

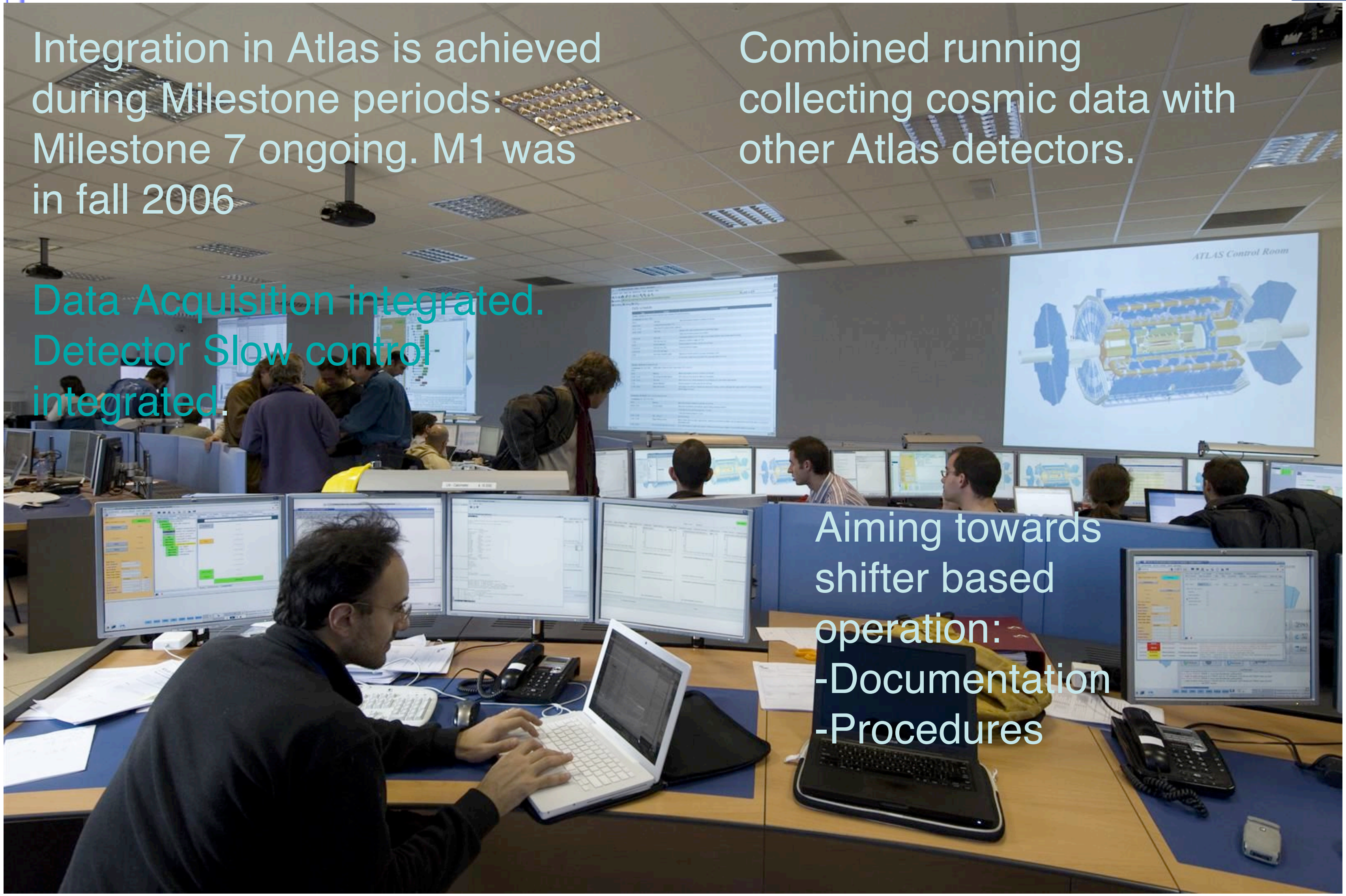
Calo signals arrive in the back

Signals to LVL1 trigger system



Level 1 receiver system in Atlas counting room

Integration in Atlas



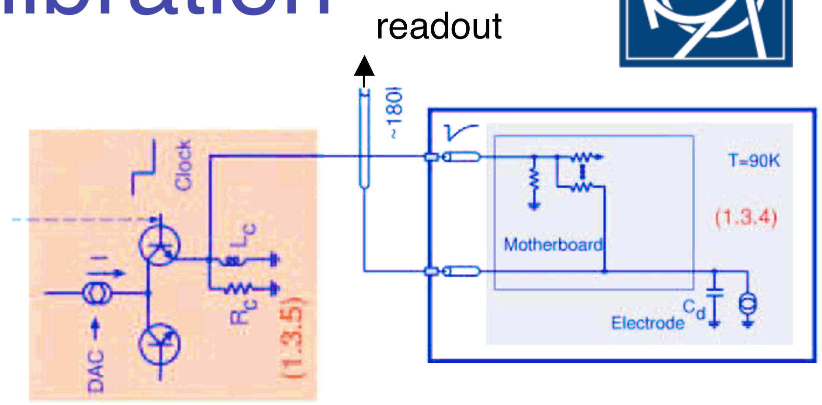
Integration in Atlas is achieved during Milestone periods: Milestone 7 ongoing. M1 was in fall 2006

Combined running collecting cosmic data with other Atlas detectors.

Data Acquisition integrated. Detector Slow control integrated.

Aiming towards shifter based operation:
- Documentation
- Procedures

Electronics calibration



Calibration pulsing system:
- Charge injected very close to electrode.
- Dynamic range 16 bits.
- non linearity < 0.1%.
- signal shape close to ionization signal.
- characteristics of each signal line carefully measured.

Has been extensively used to qualify each step calorimeter installation

Typical Calibration data set:

- Pedestal (random triggers)
- Ramp (16 diff. amplitudes)
- Delay (24 diff. phases)

x 3 gains.

Data volume ~120Gb

Runs will be taken in between each LHC fill.

Provides:

Baseline, noise, auto-correlation.
Electronics gain.
Pulse shape -> physics pulse prediction, Cross-talk corrections.
Optimal filtering coefficients.

~ 1Gb of constants written to database

Used to calculate Energy online in the readout driver.

Big effort ongoing to provide fast update & insure thorough quality checks.

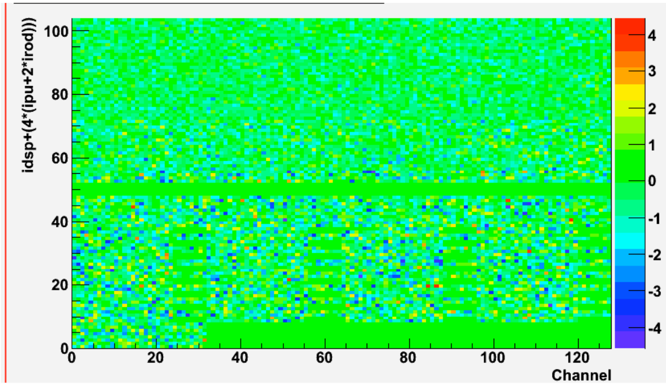
Monitoring of LAr Data

Data is monitored at many stages:
At ROD level:
- signal base line.
- data integrity.

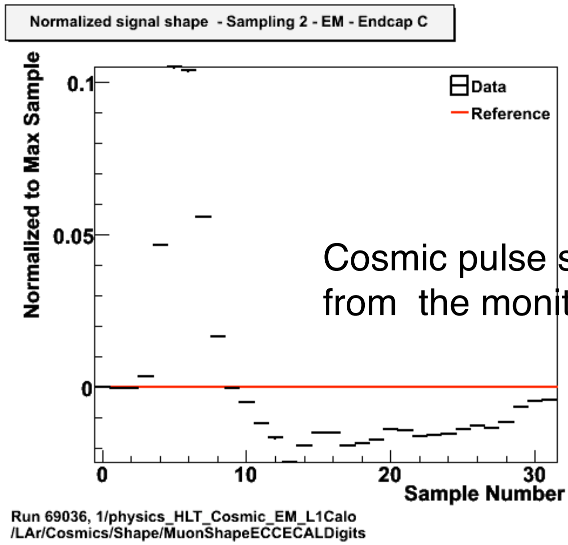
At Event Building: (full events)
- raw readings or computed energies.
- data integrity
- signal base line, noise, pulse shapes, timing
- energy density distributions.
- clusters, correlations with other detectors (eg Tile Cal)

At Offline processing:
 same as above.
+ calibration signals monitoring.

Online & Offline there are automated check of the quality of the data to guide the operator to the interesting histograms

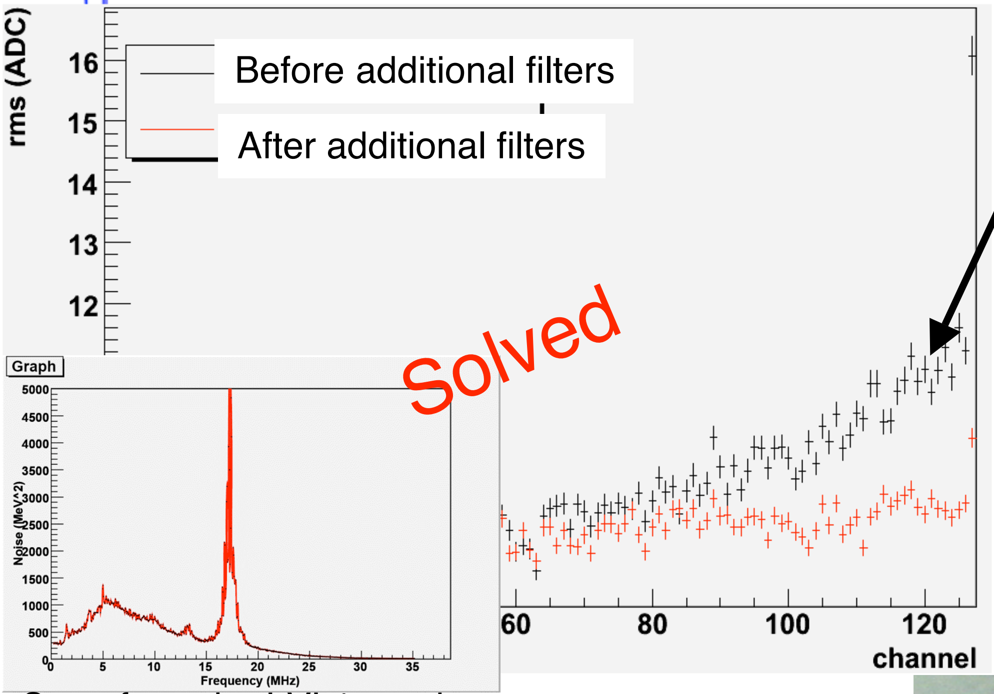


Avg. deviations from base line for a region of the EMC detector obtained at ROD level (ADC units)



Cosmic pulse shape from the monitoring

Commissioning studies: a few cases



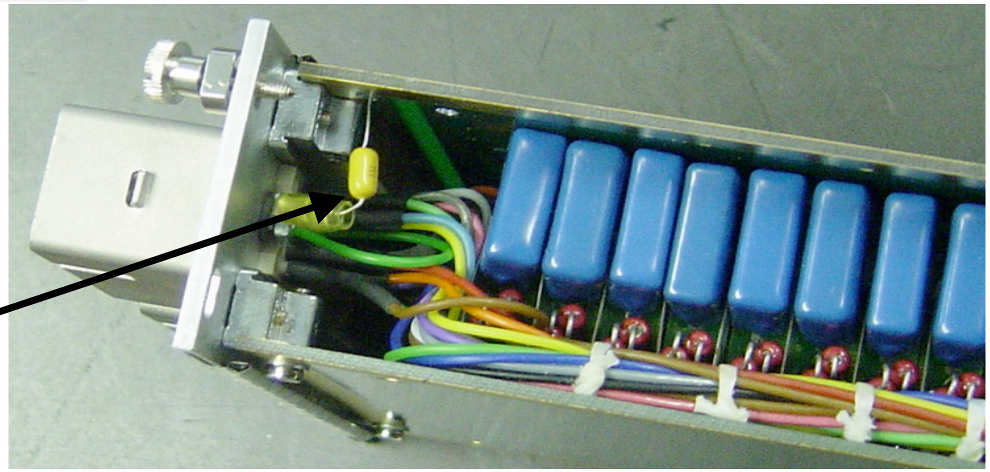
Seen from the LVL1 receiver

Increased Noise: studies with spectrum analyzer showed strong 17MHz component.

Additional filtering installed for service cables at the entrance of the Faraday cage solved this noise.

Increase noise observed in the Presampler detector:

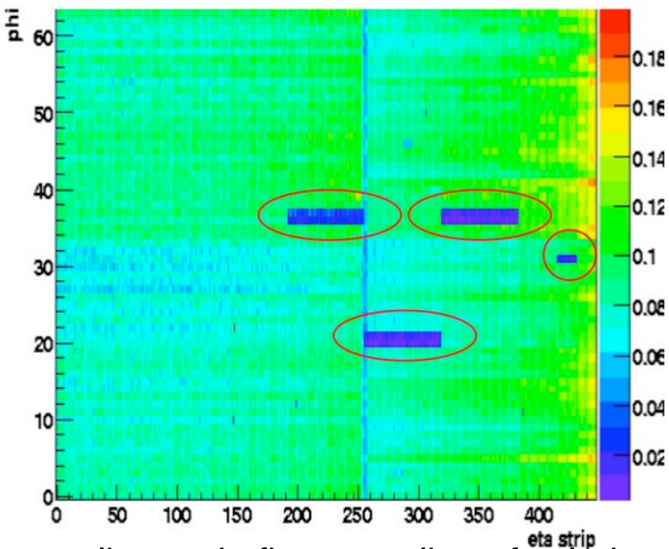
Solved by adding 1μF capacitor between high voltage ground and Cryostat ground.



Commissioning studies: a few cases

All along the installation process the electrical isolation of the cryostats w.r.t. other Atlas component was closely monitored. Prompt investigation of any problem was essential (lost screw, metal chips...).

Maintain electrical isolation in this environment is a challenge



Cross talk map in first sampling of calorimeter (%)

The study of cross talk reveals miscablings at different levels:
- some could be easily fixed.
- others required special patch cards.
- remaining addressed in the software. (not affecting analogue trigger path)

Calorimeter performances

Detailed presentation involving the ATLAS LAr Calorimeters performances will be given throughout the following presentations:

Today:

Performance of the ATLAS LAr barrel calorimeter in the 2004 combined test beam, Nicolas Kerschen.

Calibration of the ATLAS LAr Calorimeter and Commissioning with Cosmic Muon Signals, Carolina Gabaldon Ruiz.

Thursday:

Performance of the ATLAS Forward Calorimeter, Louise Heelan.

Test of the ATLAS Pion Calibration Scheme in the ATLAS Combined Test-Beam, Francesco Spano.

GEANT4 Physics Evaluation with Testbeam Data of the ATLAS Hadronic End-Cap Calorimeter, Andrey Kiryunin.

Performance of the ATLAS Liquid Argon Endcap Calorimeter in Beam Tests, Pavol Strizenec.

Overview of the ATLAS local hadron calibration, Gennady Pospelov.

Validation of the ATLAS hadronic calibration in beam tests, Teresa Barrillari.

Conclusions

- The apparatus is now closed, full installation has been completed.
- Preliminary studies show an extremely satisfactory situation, no dead regions:
  - Problematic high voltage channels < 1% of all high voltage channels.
  - Isolate dead readout channels ~0.013%.
  - Calibration channels without signal ~0.05%, require refined calibration strategy.
- Careful testing, using all available tools, at each step of the installation process was key to this achievement.
- Only possible thanks to the dedication, motivation, and hard work of large team.
- Now the LArg community is moving toward routine operation of the calorimeter, with proper shift & expert procedures. Continuous operation of the Atlas detector scheduled for July.
- Eagerly awaiting first particles from collisions, and the exiting physics to follow.