The ATLAS Liquid Argon Calorimeter: Construction, Integration, Commissioning
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- Introduction
- Construction, Integration and Commissioning on the Surface
- Installation and Commissioning after Installation in the Cavern
- First cosmics data

In this session there are two other talks on the ATLAS calorimeter system that will complement this presentation
- Calorimeter performance obtained in testbeam
- Electron/photon reconstruction performance of ATLAS
Introduction – The ATLAS Liquid Argon Calorimeter

- **LAr Calorimeters:**
  - EM Barrel: $|\eta|<1.475$ [Pb-LAr]
  - EM End-caps: $1.4<|\eta|<3.2$ [Pb-LAr]
  - Hadronic End-cap: $1.5<|\eta|<3.2$ [Cu-LAr]
  - Forward Calorimeter: $3.2<|\eta|<4.9$ [Cu,W-LAr]

- ~190K readout channels
Introduction

Physics Requirements

- Discovery potential of Higgs determines most of the performance requirements for the EM calorimetry
- Largest possible acceptance
- Large dynamic range: 20 MeV...2 TeV (→ 3 gains, 12 bits)
- Energy resolution ($e^\pm /\gamma$): $\sigma_E/E \sim 10\%/\sqrt{E} \oplus 0.7\%$
  - → precise mechanics & electronics calibration (<0.25%)...
- Linearity: 0.1 % (W-mass precision measurement)
  - → presampler (correct for dead material), layer weighting, electronics calibration
- Particle id: $e^\pm$-jets, $\gamma/\pi_0$ (>3 for 50 GeV $p_t$)
  - → fine granularity
- Position and angular measurements: 50 mrad/$\sqrt{E}$
  - → Fine strips, lateral/longitudinal segmentation
- Hadronic - $E_\perp$ miss (for SUSY)
  - Almost full 4\pi acceptance ($\eta$<4.9)
- Jet resolution
  - $\sigma_E/E \sim 50\%/\sqrt{E} \oplus 3\% \eta<3$,
  - $\sigma_E/E \sim 100\%/\sqrt{E} \oplus 10\% 3<\eta<5$
- Speed of response (signal peaking time ~40 ns) to suppress pile-up
- Non-compensating calorimeter → granularity and longitudinal segmentation very important to apply software weighting techniques

Jets, Missing $E_\perp$

Jets, Photons

Electrons
The ATLAS Electromagnetic (EM) Calorimeter

- 2 wheels (16 modules) in the barrel and 1 wheel (8 modules) per endcap
- Accordion shape in EM barrel and end cap calorimeters (>22X₀)
- Main advantages:
  - LAr as act. material inherently linear
  - Inherently radiation hard
  - Hermetic coverage (no cracks)
  - Longitudinal segmentation
  - High granularity (Cu etching)
  - Fast readout possible

Diagram showing the structure and components of the calorimeter, including layers and drift time (450 ns).
The ATLAS Forward and Hadronic Calorimeters

- **Forward Calorimeter (FCal)**
  - 3 wheels per endcap ($10\lambda$)
    - Cu matrix for the first wheel ($2.6\lambda$, $28X_0$)
    - W matrix for the other two wheels ($2 \times 3.7\lambda$)
- **Hadronic Endcap Calorimeter (HEC)**
  - 2 wheels per endcap ($10\lambda$), 32 modules each
    - Cu absorbers (25mm/50mm thick)
    - Each gap consists of 4 sub gaps of 1.85mm
Construction

HV and electrical tests after module assembly

Repair of abnormal channels

Mechanical measurements during production/assembly:
- Stability at 1% level
- Resulting constant term ≤0.5%
Integration

• Delivery of 3 cryostats and preparations of cryostats at CERN starts in 2002
• Module production in institutes and delivery to CERN from 2001 – 2004
• Wheel assembly in clean rooms from 2002 – 2004
• Wheel insertion into cryostats from 2003 – 2004
• Cold tests on the surface in 2004 – 2005

Module construction in the labs
Barrel wheel inside cryostat
EM EndCap A wheel after its insertion, cabling finished, July 2004
HEC wheel assembly and insertion into the cryostat
Cold Commissioning on the Surface

- All three cryostats were commissioned at LAr temperatures (88K) filled with LAr on the surface (cold commissioning)
- The goal of the cold commissioning was to:
  - Check the connectivity and integrity of the connections and all the detector channels and calibration lines at LAr temperatures
  - Test the integrity of all HV channels at nominal voltage at LAr temperatures
  - Measure electronics parameters needed for signal reconstruction
  - Measure the noise and coherent noise (with ATLAS electronics boards)
- The barrel commissioning lasted 10 weeks in summer 2004
- The end cap C commissioning lasted 8 weeks in winter 2005
- The end cap A commissioning lasted 6 weeks in summer 2005
- Number of channels to be tested on all three subdetectors:
  - 190304 read out channels
  - 14592 calibration lines
  - 4248 HV channels
Cold Commissioning - Tests

- Applying High Voltage
  - Slow ramp up (measure current draw)
  - Stability test during several weeks
- HV continuity tests (EM and FCal only):
  - AC signal applied on the HV line
  - Via the detector capacity a signal is induced on the signal cables
  - Checks connectivity of the HV and signal lines
- Pulsing all lines with the calibration board, and reading pulses back with the front end boards
- Reflectometry measurements
- LC, $R_{cal}$ measurements (EM)
  - Measure these parameters at cold
  - Used in the calibration run analysis
- Tests of the final Front-End-Crate electronics
  - Noise measurements

0.1-0.2 % amplitude stability over one month

Few (<1‰) abnormal channels

Calib. signal
To FE elec.
### Cold Commissioning

#### Test Summary

| Signal & Calibration | Bad channels (#|%) | Bad calibration lines (#|acc.%) | Dead channels (#|%) | Correction needed (HV#|acceptance%) | Dead (HV#|acceptance%) |
|----------------------|------------------|-------------------------------|-------------------|-----------------------------------|-------------------|
| EMEC C               | 40 | 0.13 | 1 | 0.04 | 6 | 0.02 | EMEC C | 25 | 5.00 | 0 | 0.00 |
| HEC C                | 3 | 0.11 | 3 | 0.37 | 3 | 0.11 | HEC C | 12 | 7.50 | 0 | 0.00 |
| FCal C               | 10 | 0.70 | 0 | 0.00 | 0 | 0.00 | FCal C | 8 | 1.80 | 0 | 0.00 |
| EMEC A               | 20 | 0.06 | 4 | 0.16 | 8 | 0.03 | EMEC A | 35 | 8.75 | 1 | 0.25 |
| HEC A                | 0 | 0.00 | 1/3 | 0.8 | 3 | 0.11 | HEC A | 13 | 8.10 | 0 | 0.00 |
| FCal A               | 9 | 0.63 | 0 | 0.00 | 0 | 0.00 | FCal A | 11 | 4.19 | 0 | 0.00 |
| EM Barrel            | 49 | 0.04 | 1 | 0.01 | 31 | 0.03 | EM Barrel | 8.5 | 1.90 | 0 | 0.00 |

### Situation in April 2006

» 99.9% of detector channels work!
Installation in the ATLAS Cavern

- All three cryostats have been installed in the ATLAS cavern
  - Barrel cryostat: October 2004
  - Endcap C: December 2005
  - Endcap A: April 2006
- The Tile Calorimeter (ATLAS barrel hadronic calorimeter) has been built around the three cryostats
  - Barrel EM calorimeter alignment with respect to barrel Tile Calorimeter and the IP done with a precision better than 1 mm
ATLAS barrel calorimeter after barrel Tile completion, Oct. 2005
ATLAS barrel calorimeter being moved to the IP, Nov. 2005
ATLAS endcap calorimeters installation, winter-spring 2006
Commissioning After Installation

As soon as the front end boards are installed in the cavern and connected to the ATLAS read out system, regular calibration runs are recorded:

- Injection of a calibration pulse (via $R_{\text{cal}}$) on the detector module inside the cryostat, and reading it back with the whole read-out chain.
- Allows to check the integrity of all connections, the status of the detector cells and the functioning of the read out chain and the calibration system.

Ramp run pulsing 3 barrel modules

Calibration pulse shapes for ½ a barrel module (one plot per front end board)
Cosmics commissioning goals

- Exercise Front-End electronics and readout chain
- Look for dead/bad cells
- Check/adjust detector timing at ns level
- Check cell response uniformity at 1% level (with 370 000 projective muons, i.e. 3 months data-taking)
Commissioning with cosmics

13k events over one week
2% events projective
S/B about 10 in middle sampling

Individual cell signal
Projective muons energy deposit
(middle sampling)
Conclusions

All LAr calorimeters have been successfully integrated into their cryostats.
Cold tests on the surface and in the pit show the excellent condition of the calorimeter (more than 99.9% of channels work)
All three cryostats have been installed in the ATLAS cavern.
The electronics installation is finished for the barrel calorimeter and in full swing for the endcaps.
Cosmic muons have been recorded together with the hadronic Tile calorimeter. The muon system and the ID will join towards the end of the year.