ATLAS Liquid Argon Calorimeter: Construction, Installation, Commissioning and Combined Test Beam Results

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(On behalf of the ATLAS LAr group)
LAPP-Annecy

- Construction & Integration
- 2004 Combined test beam results
- Test at cold with liquid argon
- Commissioning in the pit
- Cosmic
ATLAS Liquid Argon Calorimeter

EM Barrel
\(|\eta| < 1.475\)
LAr-Pb

Hadronic end-cap
\(1.4 < |\eta| < 3.2\)
LAr-Pb

Forward Calorimeter
\(3.2 < |\eta| < 4.9\)
LAr-W/Cu

REQUIREMENTS

Driven by the Higgs (H\(\rightarrow\gamma\gamma\), H\(\rightarrow4e\))

and W', Z' searches

Electron/photon:
\(\sigma(E)/E = 10\%/\sqrt{E}\text{(GeV)} \oplus 0.7\%
linearity better than 0.5\%

Jets
\(\sigma(E)/E = 50\%/\sqrt{E} \oplus 3\%\) for \(|\eta| < 3\)
\(\sigma(E)/E = 100\%/\sqrt{E} \oplus 10\%\) for \(3 < |\eta| < 5\)
Electromagnetic Calorimeter

- LAr-Pb
- 2 wheels in the barrel (16 modules) and 1 wheel per end cap (8 modules)
- 25-33 $X_0$
- Accordion geometry
  - Full azimuthal coverage
  - Pseudo-rapidity coverage up to 3.2
  - High granularity (>200000 channels)
  - Longitudinal segmentation
- Presampler for $|\eta| < 1.8$
- Barrel: gap (2.1 mm)
- End cap: gap varies from 0.9 to 3.1 mm
7 modules of the EM end cap

EM end cap wheel integration
Hadronic End-Cap Calorimeter

- Cu-LAr
- 4 wheels (2 per endcap rear and front):
  - 4 x 32 modules
  - 10 λ
  - 24 (16) gaps/front (rear) wheel
  - 4 'subgaps' (1.85 mm) per gap
- Electrostatic Transformer (EST)
  - Reduces the high voltage requirement
  - Optimizes signal-to-noise ratio
- 4 longitudinal samplings
- $\Delta \eta \times \Delta \phi = 0.1 \times 0.1$ and $0.2 \times 0.2$ for $|\eta| > 2.5$
Twenty-five modules of HEC1 and HEC2 wheels inserted into cryostat.
Forward Calorimeter

- 3 modules in each end-cap:
  - FCal 1: electromagnetic, LAr-Cu, 28X0
  - FCal2/3: hadronic, LAr-W, 2x3.7λ
- $3.2 < |\eta| < 4.9$
- Resistant to high radiation
- Very narrow LAr gaps
  - 0.25, 0.375, 0.5 mm for FCal1, 2 & 3
- Total number of channels: 2822
Integration Summary

- Cryostats preparations
  - Feed throughs, warm cables installation at CERN 2002-2003
- Test under beams of multiple production modules
- Most recent: 2004 Combined run
- Wheel assembly in clean rooms from 2002 - 2004
- Electromagnetic barrel insertion: May 2003
- Electromagnetic EndCap insertion
  - EM wheel insertion in Aug. 2003 / July 2004
- Hadronic EndCap insertion
  - HEC1 insertion in Sept. 2003 / Aug. 2004
- Forward calorimeter insertion
- Final closing of the cryostat
  - Final closing and welding of cold vessel
  - Closing warm vessel in Oct. 2004 / April 2005
- Following steps:
  - Commissioning on the surface
  - Commissioning in the ATLAS Cavern
Configuration very close to ATLAS

Full central slice of ATLAS:
- MBPS magnet with horizontal field (1.4T)
- few pixel and SCT planes
- TRT
- LAr barrel module
- 3 TILE Calo. Modules
- Muon chambers
- Read-out/DAQ/software as in ATLAS
- Beams: e, γ, π, p, µ (from 1 to 350 GeV)
2004 Combined Test Beam Results-1

- **Energy resolution**
  - **Subtracted:**
    - Electronic noise
    - Beam spread
  - Local constant term = 0.43%
  - Sampling term = 10.6%

- **Linearity between 20 & 250 GeV better than 0.2%**
2004 Combined Test Beam Results-2

- Uniformity response:
  - electrons at 180 GeV: \( \eta \) scan from 0.03 to 0.6
  - Non-uniformity: 0.44%

- Global constant term:
  - 0.62%
  - cross check: \([\text{non-uniformity} \oplus \text{local constant term}]^{1/2}\) \(\sim 0.62\%\)
Cold Tests Before Installation

- Pulsing all lines with the calibration board, and reading pulses back with the front end boards
- Tests of the final Front-End-Crate electronics
  - Noise measurements
- Applying High Voltage
  - Slow ramp up
  - Stability test during several weeks
- The barrel commissioning: 10 weeks in summer 2004
- The end cap C commissioning: 8 weeks in winter 2005
- The end cap A commissioning: 6 weeks in summer 2005
- Number of channels tested on all three subdetectors:
  - 190304 read out channels
  - 14592 calibration lines
  - 4248 HV channels

<table>
<thead>
<tr>
<th></th>
<th>Bad channels number (%)</th>
<th>Bad calib. number (acceptance %)</th>
<th>Dead signal ch. number (%)</th>
<th>HV corr. number (acceptance %)</th>
<th>Dead HV sect. number (acceptance %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMEC C</td>
<td>40 (0.13)</td>
<td>1 (0.04)</td>
<td>6 (0.02)</td>
<td>25 (5.00)</td>
<td>0 (0.00)</td>
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<tr>
<td>HEC C</td>
<td>3 (0.11)</td>
<td>3 (0.37)</td>
<td>3 (0.11)</td>
<td>12 (7.50)</td>
<td>0 (0.00)</td>
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<tr>
<td>FCal C</td>
<td>10 (0.70)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>8 (1.80)</td>
<td>0 (0.00)</td>
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<tr>
<td>EMEC A</td>
<td>20 (0.06)</td>
<td>4 (0.16)</td>
<td>8 (0.03)</td>
<td>35 (8.75)</td>
<td>1 (0.25)</td>
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<tr>
<td>HEC A</td>
<td>0 (0.00)</td>
<td>1/3 (0.8)</td>
<td>3 (0.11)</td>
<td>13 (8.10)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td>FCal A</td>
<td>9 (0.63)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>1/4 (4.19)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td>EM Barrel</td>
<td>49 (0.04)</td>
<td>1 (0.01)</td>
<td>31 (0.03)</td>
<td>8.5 (1.90)</td>
<td>0 (0.00)</td>
</tr>
</tbody>
</table>

No more than 0.1% of non-working channels!!
Installation

- **Detectors:**
  - All LAr Calorimeters are in their final position

- **Electronics:**
  - Front-end boards connected and tested for the barrel and the 2 end caps.
  - Back-end
    - Barrel: fully cabled and available
    - End cap: almost finished (not fully cabled)

- **HV system operational**
Commissioning in the Cavern

- Injection of a calibration pulse on the detector module inside the cryostat, and reading it back with the whole read-out chain

Ramps stability over two months better than 0.05%

Noise

Pedestal stability

E(MeV)
Commissioning with Cosmics

- Two run periods in August and October 2006
- About 80h of cosmics data taken giving ~80 kevents
  - Tile Muon identification top/bot: 49%
  - Projective muon ~15%

October: 231 ± 2 MeV
August: 232 ± 2 MeV
Conclusions

- ATLAS LAr Calorimeter is the fruit of the initial precious work of the RD3 collaboration
- Modules were produced in home institutes and delivered to CERN from 2001 – 2004
- Several tests under beam achieved and the expected requirements reached: the recent one is the combined run of an ATLAS central slice in 2004
- LAr Calorimeters integrated into their cryostat and tested at the LAr temperature (87K); less than 0.1% of the channels don’t work!
- Installation of the LAr cryostats in the ATLAS pit successfully achieved
- Commissioning with cosmics is ongoing; the barrel has already taken data with the Tile calorimeter
- ATLAS will be closed in August 2007

...Looking towards LHC startup (November 2007)