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

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LAPP-Annecy

- ❖ Construction & Integration
- ❖ 2004 Combined test beam results
- ❖ Test at cold with liquid argon
- ❖ Commissioning in the pit
- ❖ Cosmics

ATLAS Liquid Argon Calorimeter

①
EM Barrel
 $|\eta| < 1.475$
LAr-Pb

②
EM end-cap
 $1.4 < |\eta| < 3.2$
LAr-Pb

③
Hadronic end-cap
 $1.5 < |\eta| < 3.2$
LAr-Cu

④
Forward Calorimeter
 $3.2 < |\eta| < 4.9$
LAr-W/Cu

REQUIREMENTS

Driven by the Higgs ($H \rightarrow \gamma\gamma$, $H \rightarrow 4e$)
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)
- ❖ $25\text{--}33 X_0$
- ❖ 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
- ❖ 10λ
- ❖ 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
- ❖ $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$ and 0.2×0.2 for $|\eta| > 2.5$

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 insertio: May 2003
- ❖ Electromagnetic EndCap insertion
 - ◆ EM wheel insertion in Aug. 2003 / July 2004
- ❖ Hadronic EndCap insertion
 - ◆ HEC1 insertion in Sept. 2003 / Aug. 2004
 - ◆ HEC2 insertion in Oct. 2003 / Sept. 2004
- ❖ Forward calorimeter insertion
 - ◆ FCal insertion in Aug. 2004 / Jan. 2005
- ❖ 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%

electrons data

❖ 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

	Bad channels number (%)	Bad calib. number (acceptance %)	Dead signal ch. number (%)	HV corr. number (acceptance %)	Dead HV sect. number (acceptance %)
EMEC C	40 (0.13)	1 (0.04)	6 (0.02)	25 (5.00)	0 (0.00)
HEC C	3 (0.11)	3 (0.37)	3 (0.11)	12 (7.50)	0 (0.00)
FCal C	10 (0.70)	0 (0.00)	0 (0.00)	8 (1.80)	0 (0.00)
EMEC A	20 (0.06)	4 (0.16)	8 (0.03)	35 (8.75)	1*(0.25)
HEC A	0 (0.00)	1/3 (0.8)	3 (0.11)	13 (8.10)	0 (0.00)
FCal A	9 (0.63)	0 (0.00)	0 (0.00)	11†(4.19)	0 (0.00)
EM Barrel	49 (0.04)	1 (0.01)	31 (0.03)	8.5 (1.90)	0 (0.00)

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

LAr barrel descending to the ATLAS pit

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

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 %

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)