PROCEEDINGS

International Europhysics Conference on HEP

ATLAS Liquid Argon Calorimetry : Test beam results for the Hadronic Endcap calorimeter and the Electomagnetic calorimeters.

Lionel Neukermans*, **on behalf of the ATLAS Liquid Argon calorimeters group**
LAPP: Chemin de Bellevue, BP110 74941 Annecy-le-Vieux CEDEX, France
E-mail: neukerma@lapp.in2p3.fr

Abstract: Prototypes modules of the ATLAS liquid argon electromagnetic calorimeter have been tested at CERN in 1999 and 2000. The preliminary performances of these barrel and endcap modules are presented. The uniformity of the energy response in a full η range is found to be 0.7% and the angular resolution better than 50mrad/$\sqrt{\mathrm{E}}$. Performances of the first six serie modules of the hadronic endcap calorimeter are also presented. The linearity of the response to electrons is observed to be within 1% and the energy resolutions for electrons and hadrons are found to be $21.4\%/\sqrt{E} \oplus 0.3\%$ and $70.5\%/\sqrt{E} \oplus 5.7\%$.

1. Introduction

The ATLAS collaboration has chosen liquid Argon sampling calorimeters, with lead as absorber and an accordion geometry for the electromagnetic part [1], and copper as absorber for the hadronic endcap calorimeter. Detailed descriptions of the complete ATLAS liquid Argon system, represented in Figure 1, can be found in reference [2]. Full size prototype modules for the electromagnetic part have been built and the construction of the first hadronic serie modules has started. This paper reports on the test beam results of these modules. It is organised as follows; in section 2, the geometry and the readout electronics of the detectors are summarised. The signal reconstruction is discussed in section 3. The test beam results are discussed in section 4 and 5 respectively followed by the conclusions.

2. Overview of the detectors

2.1 Electromagnetic calorimeters

The barrel (EMB) is made of two half-barrels covering a pseudo-rapidity range up to 1.475. Once assembled, there is no discontinuities in ϕ, but for ease of construction, a half barrel

*Speaker.

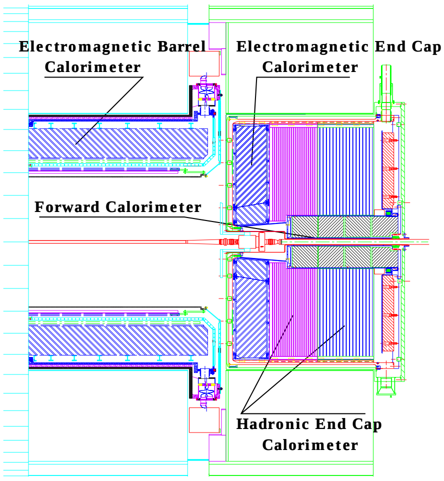

Figure 1: Overview of the ATLAS liquid Argon Calorimetry

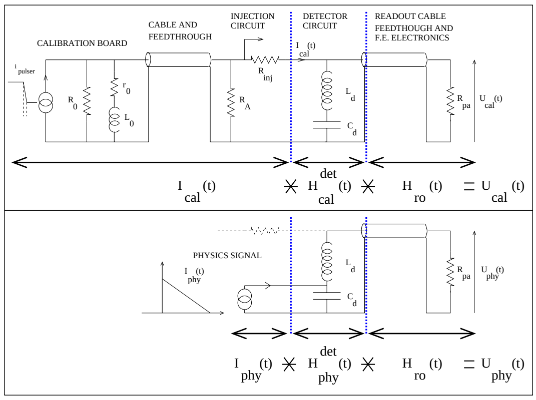

Figure 2: Electrical description of one channel. The top drawing shows the calibration system and how the calibration signal is injected into the calorimeter readout chain. The bottom drawing explains where the ionisation signal is injected.

is divided into 16 modules composed of 64 electrodes. A preshower detector is installed in front of the module. Each electromagnetic endcap calorimeter (EMEC) is divided into two coaxial wheels, covering respectively the regions $1.375 < |\eta| < 2.5$ and $2.5 < |\eta| < 3.2$. One EMEC wheel is mechanically divided into 8 modules in ϕ.

2.2 Hadronic endcap calorimeter (HEC)

The HEC covers the region $1.5 < |\eta| < 3.2$. It consists of two equal diameter independant wheels with different sampling fractions. One module represents 1/32 of the full azimuthal coverage.

2.3 Read out electronics

The electronic readout featured all the final requirements except for radiation hardness. The front-end electronics is housed in a crate attached to the cold-to-warm feedthrough. It consists of front-end boards (FEB) which preamplify, shape in a 3 gain system, sample at 40 MHz, store in analog memories and digitize the triggered signals [3]. Mostly for reliability reasons the preamplifiers are located on the FEB for the EM calorimeters whereas they are cold preamplifiers for the HEC for noise reasons.

The estimates of the energy E and the arrival time Δt for each cell are built from the samples S_i through a linear combination:

$$E = \sum_{i=1}^{(5)} a_i S_i \quad \textit{and} \quad E\Delta t = \sum_{i=1}^{(5)} b_i S_i$$

where the optimal filtering coefficients a_i and b_i are related to the noise autocorrelation matrix and the signal shapes as explained in [5].

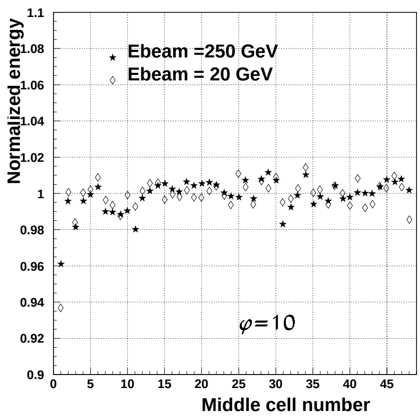

Figure 3: EMB Energy response normalized to 1 as a function of η for 250 GeV (stars) and 20 GeV (circles) e^- beam. Each point corresponds to a cell of size $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$.

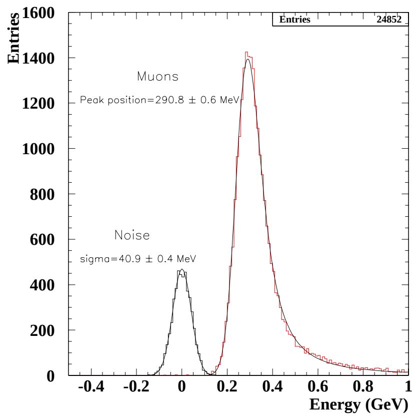

Figure 4: Response to muons signal in the middle sampling compared to the noise (estimated by random events)

3. Signal reconstruction

The precision in physics aimed at ATLAS requires a small constant term (better than 0.7% in the EM) in the energy resolution. The signal reconstruction consists in predicting the electronic response (in ADC counts) caused by a known ionisation current in the cell. As shown in Figure 2, the response to calibration signal U_{cal} and the response to ionisation signal U_{phy} can be expressed as a function of the different part of the system (calibration circuit and its transfert line, the detector and the readout transfert line). The calibration and ionisation signals share the same readout line. The response to ionisation U_{phy} can therefore be expressed as the convolution of the calibration signal U_{cal} obtained during the calibration procedure by a transfer function H: $\mathcal{L}[U_{phy}](s) = H(s)\ \mathcal{L}[U_{cal}](s)$ in the frequency domain. $H(s)$ takes into account the different injection point separated by L_d (Figure 2) and also the difference between the triangular shaped physics current I_{phy} and the exponential shaped calibration current I_{cal}. The inductance L_d is mainly due to the readout strips on the electrodes and the transfer lines on the cold electronics boards.

This signal reconstruction method (a similar approach has been used in the HEC) has been applied on the EMB data (see Figure 3). The dispersion of the energy response over the full EMB η range is found to be at the level of 0.7%. This study has shown unexpected variations of L_d as a function of η and has lead to modifications for the serie modules in order to reach the expected energy response uniformity.

4. Electromagnetic calorimeters performances

In 1999 and 2000, prototype modules of the EM calorimeters have been tested at CERN [4].

Muons in the high energy electrons beam have been used to test the response to minimum ionising particles (see Figure 4). The signal to noise ratio is found to be 7.1 $\pm$ 0.1

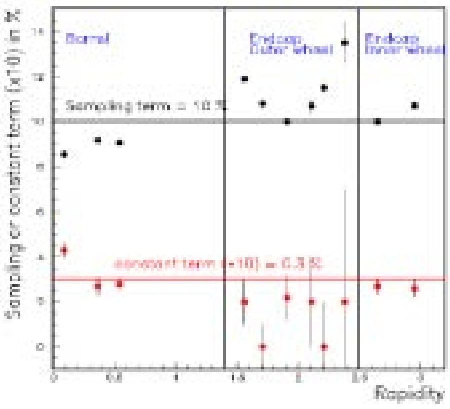

Figure 5: Sampling term and local constant term as a function of η position. The noise contribution has been substracted.

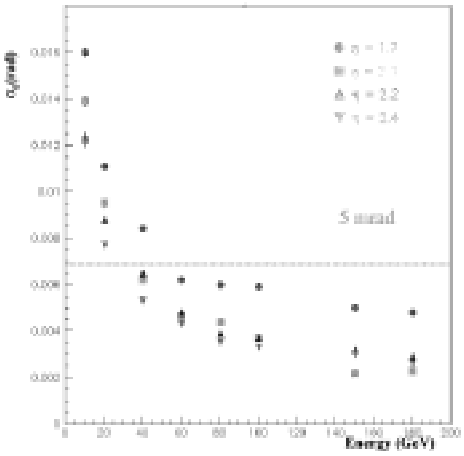

Figure 6: Position resolution vs beam energy in the EMEC.

leading to a e/μ ratio of 0.75 $\pm$ 0.03. Several η, ϕ points of the calorimeter have been hit with different electrons beam energies. The Figure 5 shows the obtained energy resolution parameters. The sampling term is at the level of 10% for a local constant term below 0.3%. The fine granularity in η in the first sampling allows to reconstruct precisely the impact point. The Figure 6 shows the results on the pointing resolution in the EMEC for various positions in η. The resolution on the impact position in the first sampling is found to be $< 300\mu m$ leading to an angular resolution compatible with the ATLAS requirement of 50 $mrad/\sqrt{E}$.

5. Hadronic endcap calorimeter performances

In 1999 six final modules of the HEC were tested at CERN [6]. The conversion factor I_p, defined as the ratio of the ionisation current collected to the energy deposited in the argon has been measured to be 7.143$\pm$ 0.060 nA/MeV in good agreement with expected value I_p^{theo} = 7.135 nA/MeV. The Figure 7 shows, for one channel, the residue to a linear fit of the conversion factor as a function of the energy. The linearity is found to be better than 1% within the requirements for the ATLAS detector. The Figure 8 gives the resolution to electrons at 3 impact positions. After noise substraction it leads to a sampling term of 21.4 $\pm$ 0.2% and a local constant term of 0.3 $\pm$ 0.2% which has to be compared to the expected resolution $\sigma(E)/E = (20.7 \pm 0.4)\%/\sqrt{E} \oplus (0.7 \pm 0.1)\%$. The response to muons have been also studied and the measured ratio $e/\mu = 0.93 \pm 0.04$ is well described by the Monte Carlo. The performance of the calorimeter is also assessed in terms of the energy resolution for pions (Figure 9). The overall combined average parametrization of the resolution is measured to be $\sigma(E)/E =$

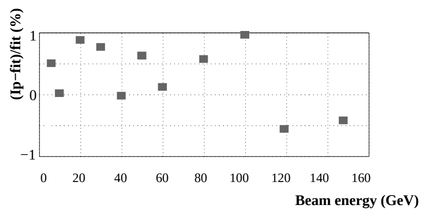

Figure 7: Residue of the fitted conversion current

$(70.5\pm1.5)\%/\sqrt{E}\oplus(5.7\pm0.2)\%$. Finally the ratio of electromagnetic to hadronic response is found to be $e/h = 1.51 \pm 0.02$.

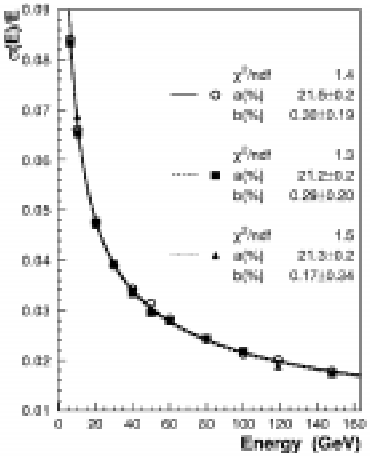

Figure 8: Energy resolution for electrons for 3 impact positions.

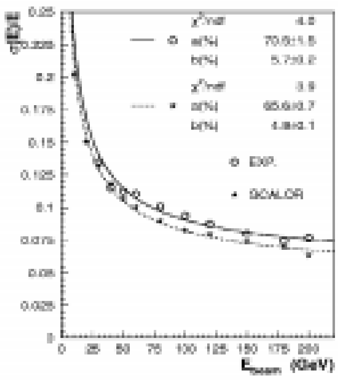

Figure 9: Energy resolution for pions for data (circles) and Monte-Carlo (triangles).

6. Conclusions

In 1999 and 2000 prototype and serie modules of the ATLAS liquid argon calorimeters have been extensively tested at CERN to demonstrate the performance of these detectors, in particular the energy response uniformity for the electromagnetic part and the energy resolution for the hadronic one. The production of the serie modules is currently on the way.

References

[1] RD3 Collaboration, *Nucl. Instrum. Meth.* **A** (389) 398.

[2] ATLAS Coll., *Liquid Argon Calorimeter Technival Design Report*, CERN/LHCC/96-41.

[3] J. Colas, *Overview of the ATLAS LArg Electronics*, CERN/LHCC/99-33 p217.

[4] ATLAS accordion collaboration,*Performance of the Barrel Module 0 of the ATLAS Electromagnetic Calorimeter*, to be submitted to *Nucl. Instrum. Meth.*
ATLAS accordion collaboration,*Performance of the Endcap Module 0 of the ATLAS Electromagnetic Calorimeter*, to be submitted to *Nucl. Instrum. Meth.*

[5] W.E. Cleland, E.G. Stern, *Signal processing for liquid argon calorimeters in a high rate environment*, *Nucl. Instrum. Meth.* **A** (338) 467-497.

[6] ATLAS Liquid Argon HEC collaboration, *The ATLAS Hadronic End-Cap Calorimeter:Beam Calibration*, accepted by *Nucl. Instrum. Meth.*

Acknowledgments

The author would like to thank L. Kurchaninov, L. Serin and P. Perrodo for their help in preparing the talk.