Performance of the ATLAS Liquid Argon Hadronic Endcap Calorimeter

Modules Zero Testbeam Results from April and August 1998

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Abstract

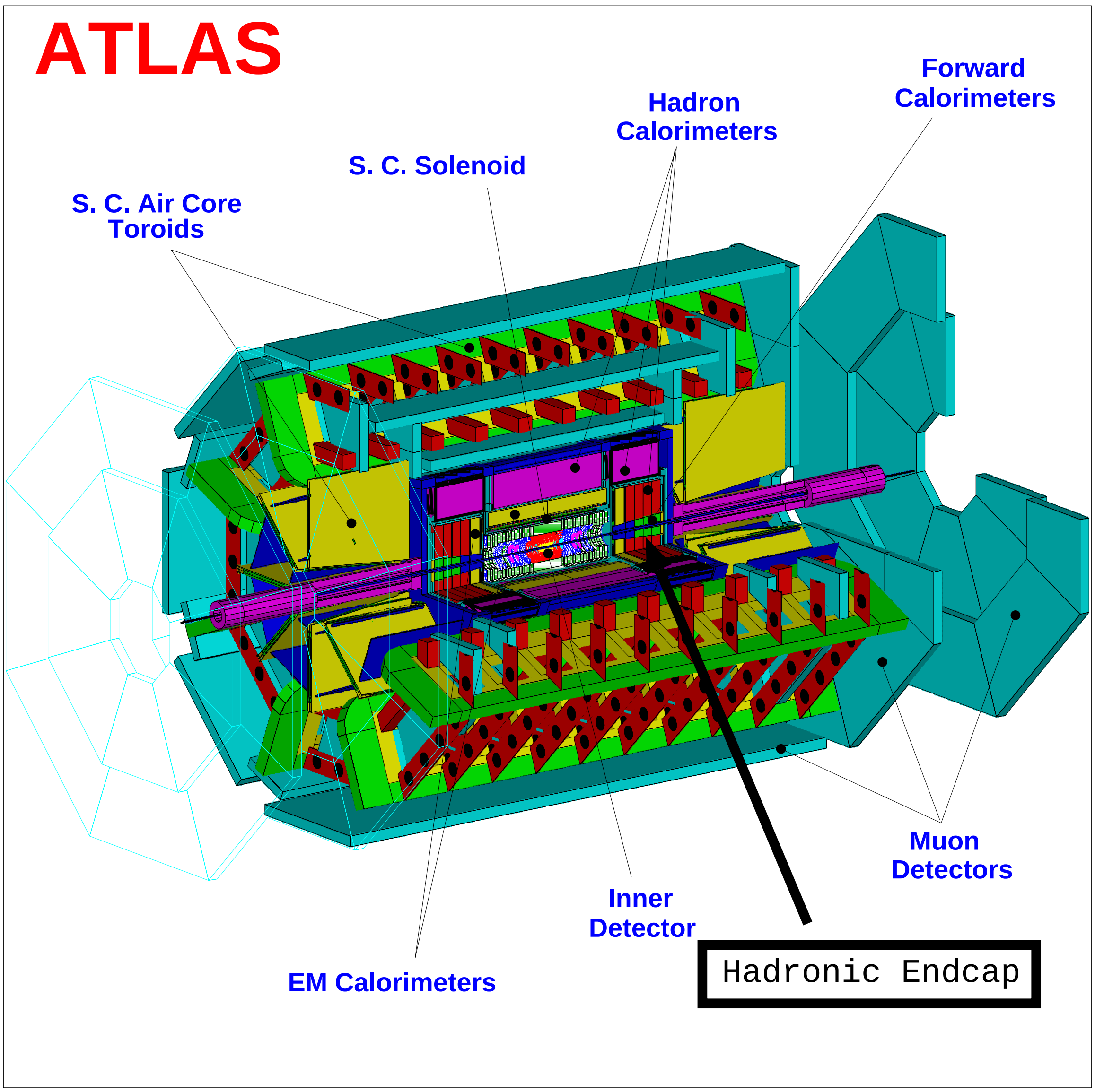
ATLAS is a general purpose detector designed to exploit the full physics potential of the Large Hadron Collider, currently under construction at CERN, near Geneva. Canada plays a major role in the construction, design, and testing of the Hadronic Endcap Calorimeter (HEC). The HEC is a liquid argon sampling calorimeter with copper absorbers. The first modules built to the final ATLAS specifications were tested in the H6 beamline at CERN in April 1998 with electron, pion, and muon beams over an energy range of 20 to 180 GeV. Unlike previous prototypes, these modules contain 10 interaction lengths providing near full containment of hadronic showers. The HEC will be described and test beam results from the University of Victoria analysis will be presented.

Outline

- Overview of the ATLAS Hadronic Endcap Calorimeter
  - physical construction
  - design considerations/goals
- Testbeam Results
  - electron beams
  - muon beams
  - pion beams
- Conclusions

Overview: Hadronic Endcap Calorimeter

Construction and design: Canada is primarily involved with calorimetry in the Endcap region of ATLAS



Overview: Hadronic Endcap Calorimeter

The ATLAS HEC

- Design is Canadian responsibility (TRIUMF)
- Liquid Argon sampling calorimeter
- Copper plate absorbers
- $1.5 \leq |\eta| \leq 3.2 \qquad \eta = -\ln\tan\frac{\theta}{2} \qquad (25.2^o \rightarrow 4.7^o)$
- Shares 43m^3 cryostat w/ EMEC, FCAL
  - 19m^3 bath of liquid Argon at 92.5 K & 1.7 bars

Design Goals/Requirements

- Fast Readout (short integration time)
- Ease of Calibration
- Radiation Hard, Long Term Stability
- Dynamic Range mip $\rightarrow$ 5 TeV
- Modular construction, installation in ATLAS
- Cost
- Performance Goal:

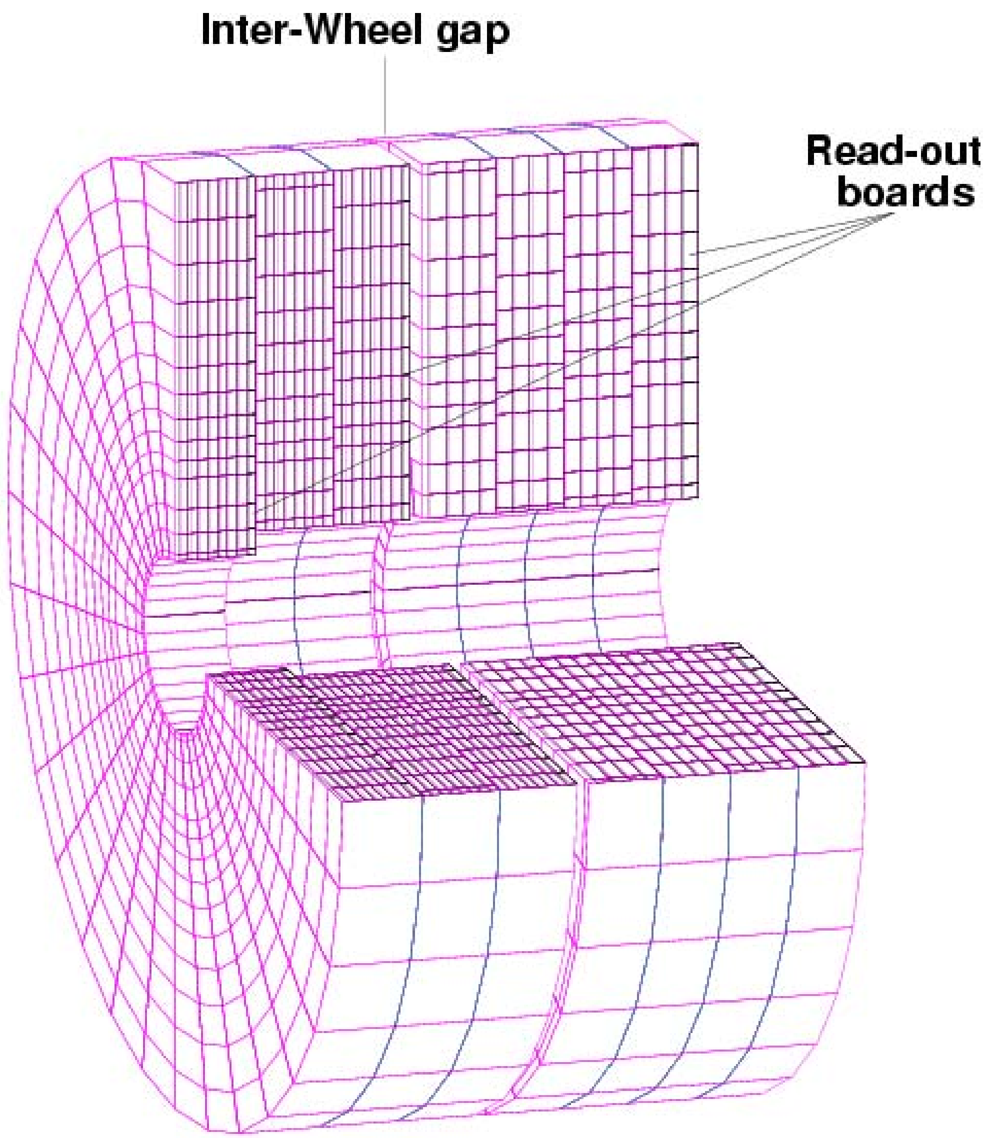
$$\frac{50\%}{\sqrt{E_o(GeV)}} \oplus 3\% \leq \frac{\sigma}{E}(jets) \leq \frac{100\%}{\sqrt{E_o(GeV)}} \oplus 10\%$$

Overview: Hadronic Endcap Calorimeter

Each Endcap is constructed of two wheels

Front Wheel: 2 readout segments, 24 $\times$ 8mm LAr gaps, 25mm Cu plates

Back Wheel: 1 readout segment, 16 $\times$ 8mm LAr gaps, 50mm Cu plates



Overview: Hadronic Endcap Calorimeter

Modules Zero:

- first HEC modules built to the final ATLAS design specifications
- contain 10 interaction lengths effecting near full longitudinal containment of hadronic showers
- Tested in the H6 beamline at CERN in April & August 1998
- 10 $\rightarrow$ 180 GeV $e,\ \pi,\ \mu$ beams

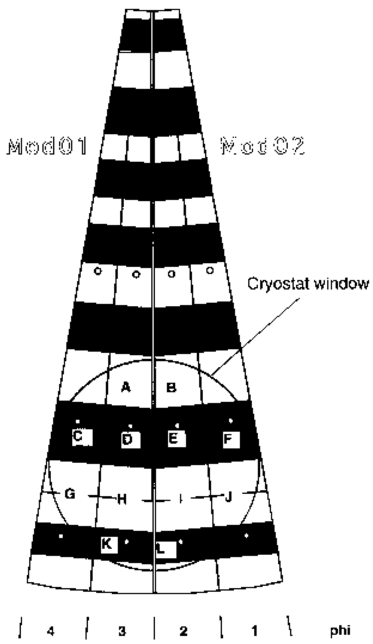
Overview: Hadronic Endcap Calorimeter

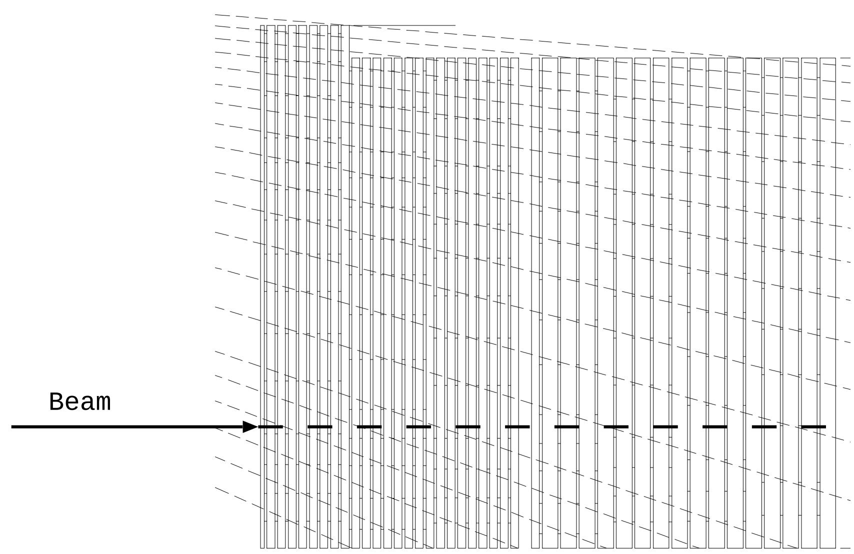
- One endcap: Constructed in Russia, Assembled in Germany
- One endcap: Constructed & Assembled in Canada (UofA, TRIUMF)

Testbeam Results

Energy Reconstruction

- trigger & signal shape cuts
- digital filtering signal shape reconstruction
- cluster size optimized
  - pions 19 - 40 cells
  - electrons 3 cells
- depth weights for constant sampling fraction





HEC Segmentation

$\simeq$ 2200 channels /endcap

$\frac{2\pi}{64}$ in ϕ, 0.1 in η

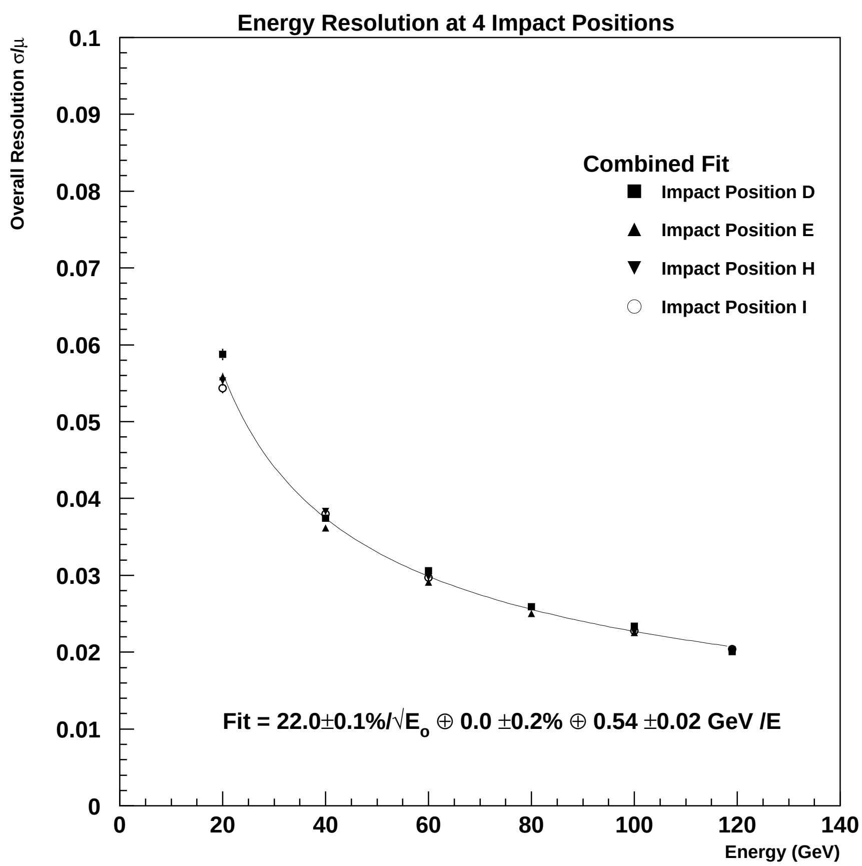
Testbeam Results: Electrons

Energy Resolution

Parameterization: $\frac{\sigma}{E} = \frac{\text{sampling}}{\sqrt{E_0}} \oplus \text{constant} \oplus \frac{\text{noise}}{E}$

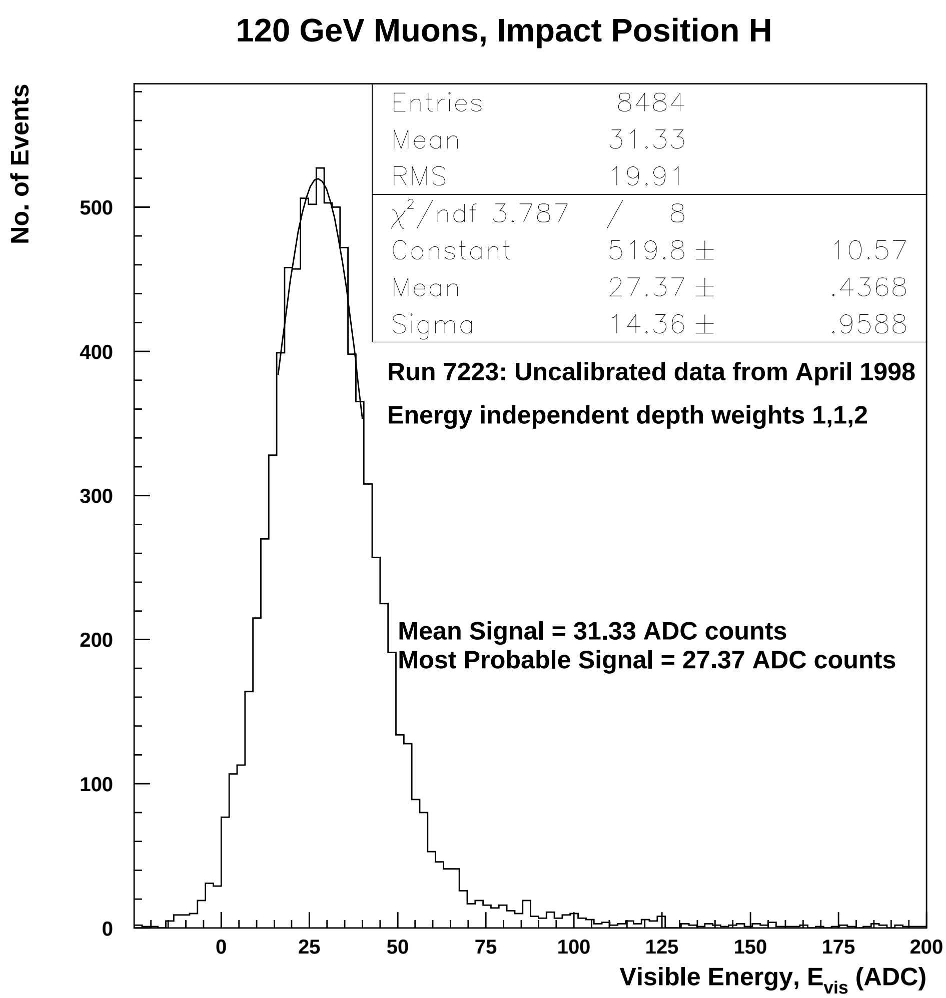
$$\frac{\sigma}{E} = \frac{22.0 \pm 0.01\%}{\sqrt{E_0}} \oplus 0.0 \pm 0.2\% \oplus \frac{0.54 \pm 0.02}{E}$$

Response is linear within 1%.



Testbeam Results: Muons

Muon (MIP) signals are visible with the H.E.C.!

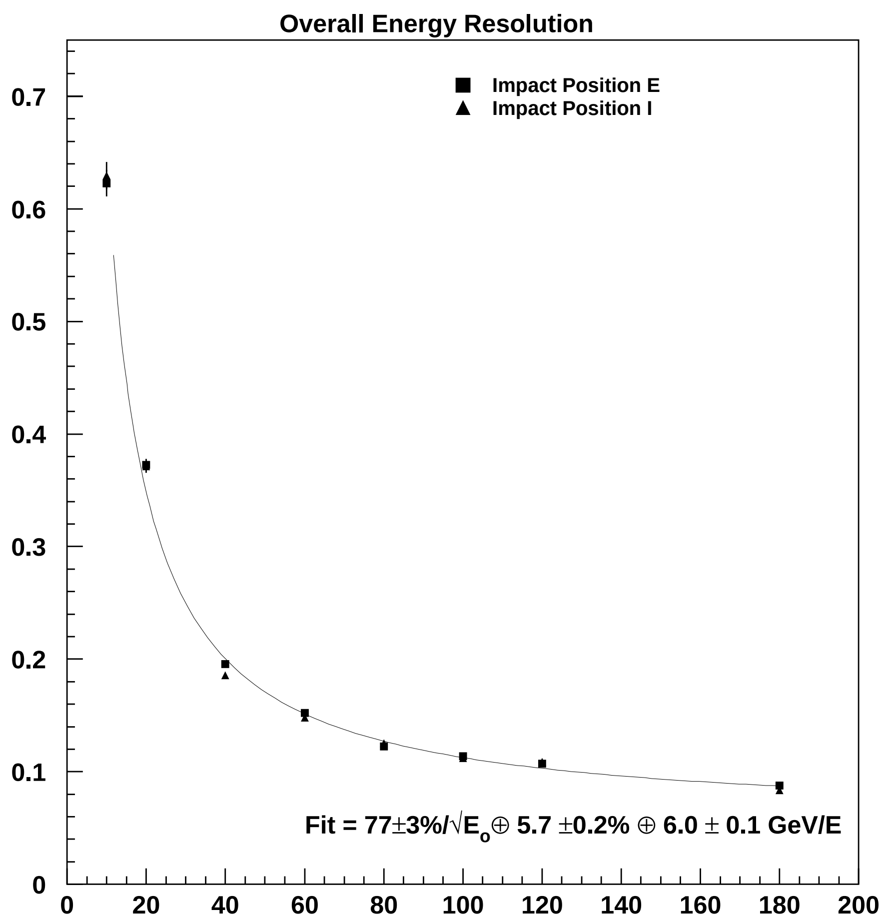


Testbeam Results: Muons

Energy Resolution (August)

Parameterization: $\frac{\sigma}{E} = \frac{\text{sampling}}{\sqrt{E_0}} \oplus \text{constant} \oplus \frac{\text{noise}}{E}$

$$\frac{\sigma}{E} = \frac{77 \pm 3\%}{\sqrt{E_0}} \oplus 5.7 \pm 0.2\% \oplus \frac{6.0 \pm 0.1}{E}$$

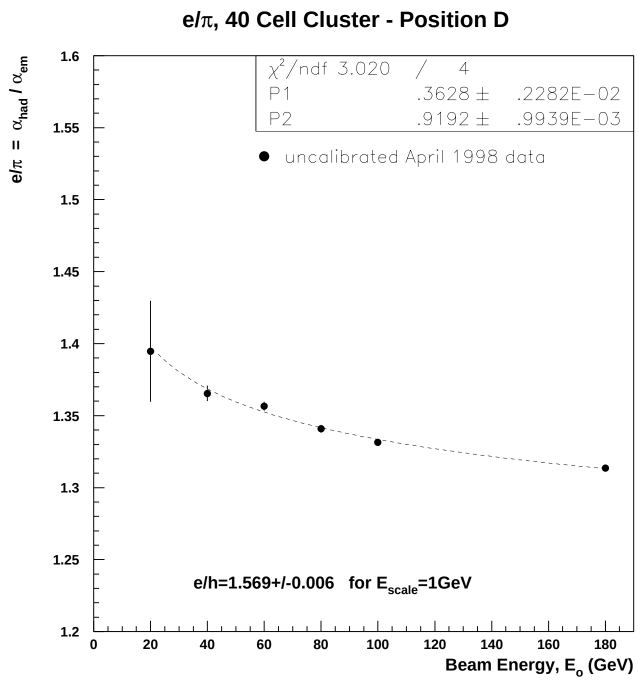


Testbeam Results: Intrinsic e/h, e/μ

$\frac{e}{\pi} = \frac{\alpha_{had}}{\alpha_{em}}$ has form [1]

$$e/\pi = \frac{1}{1 - aE_o^{m-1}} \quad \text{where } a = \frac{1-\frac{h}{e}}{E_{scale}^{m-1}} \Rightarrow \frac{e}{h} = \frac{1}{1 - aE_{scale}^{m-1}}$$

Assumptions: fine sampling, uniform calorimeter, full containment



$$\left\langle \frac{e}{h} \right\rangle^{\text{eff}} = 1.592 \begin{array}{l} \pm 0.004 \ stat. \\ \pm 0.03 \ syst. \end{array}$$

Monte Carlo Prediction [2] $\frac{e}{h}\Big|_{\text{mc}} = 1.58$ (GEANT 3.21 GCALOR)

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[1] Groom, Don, "What really goes on in a hadron calorimeter?", presented at *VII International Conference on Calorimetry in High Energy Physics* at the University of Arizona, Tucson, Arizona, November 9-14, 1997. Refer to `http://pdg.lbl.gov/~deg/calor97.html`.

[2] Grauges, Eugeni, ATL-TILECAL-98-158, May 1997, p.143.

Testbeam Results: Intrinsic e/h, e/μ

Evaluation of e/μ yields

$$\frac{e}{\mu_{\mathrm{120GeV}}} = \frac{1}{\alpha_{em}} \times \frac{E_{MC,dep}^{\mu,120GeV}}{E_{vis}^{\mu,120GeV}} = 0.96$$

$$\frac{e}{mip} = \frac{1}{\alpha_{em}} \times \frac{E_{Th,dep}^{mip}}{E_{vis}^{\mu,120GeV} \times \frac{E_{Th,vis}^{mip}}{E_{MC,vis}^{\mu,120GeV}}} = 0.83$$

Agrees with Monte Carlo to within a few percent.

U. Victoria Group Testbeam Analysis Paper

ATL-LARG-99-001 N.I.M paper forthcoming

ATLAS Internal Note
ATL-COM-LARG-98-009
HEC-Note-59

Hadronic Endcap Modules Zero
Pion and Electron Energy Scan Analysis
from April 1998 Testbeam Data

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Abstract

The Hadronic Endcap modules Zero were tested in the H6 beamline at CERN in April 1998. The response and resolution are evaluated at four impact points for electrons and pions over an energy range of 20 to 180 GeV. The response varies within 1% for electrons. The electron energy resolution is parameterized as $\frac{\sigma}{E} = \frac{22.0\pm\ 0.01\%}{\sqrt{E_0}} \oplus 0.0 \pm\ 0.2\% \oplus \frac{0.54\pm\ 0.02}{E}$ where E_0 is expressed in GeV. The pion energy resolution (with pre-subtracted noise) is parameterized as $\frac{\sigma}{E} = \frac{78\pm\ 2\%}{\sqrt{E_0}} \oplus 5.0 \pm\ 0.3\%$.

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Conclusions

- Electron Energy Resolution

  Parametrization: $\frac{\sigma}{E} = \frac{\text{sampling}}{\sqrt{E_0}} \oplus \text{constant} \oplus \frac{\text{noise}}{E}$

  $$\frac{\sigma}{E} = \frac{22.0 \pm 0.01\%}{\sqrt{E_0}} \oplus 0.0 \pm 0.2\% \oplus \frac{0.54 \pm 0.02}{E}$$

- Muon (MIP) signals are visible

- Pion Energy Resolution

  $$\frac{\sigma}{E} = \frac{78 \pm 2\%}{\sqrt{E_0}} \oplus 5.0 \pm 0.3\%$$

- $\langle \frac{e}{h} \rangle^{\text{eff}} = 1.592 \begin{array}{l} \pm 0.004 \; stat. \\ \pm 0.03 \; syst. \end{array}$

- $\frac{e}{\mu_{120\text{GeV}}} = 0.96 \qquad \frac{e}{mip} = 0.83$

Performance goal for jets will be easily attainable:

$$\frac{50\%}{\sqrt{E_o(GeV)}} \oplus 3\% \leq \frac{\sigma}{E}(jets) \leq \frac{100\%}{\sqrt{E_o(GeV)}} \oplus 10\%$$

ATLAS HEC satisfies design requirements!

More information (and these transparencies) available from:

http://wwwhep.phys.uvic.ca/~uvatlas/testbeam/