Study of the ATLAS Hadronic Endcap Calorimeter Performance

August 99 Beam Test Results

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Abstract

The ATLAS detector is one of two multipurpose detectors under construction for the Large Hadron Collider at CERN. The Hadronic Endcap Calorimeter (HEC) is a copper-liquid argon sampling calorimeter that covers most of the forward regions of the ATLAS calorimeter system. Each wheel is devided into 32 modules and up to one module out of eight will be tested in particle beams at CERN. The first set of "production" modules were tested in the H6 beamline at CERN during summer 1999. The modules performance is evaluated at four impact points for electron and pion beams of energy ranging from 10 to 200 GeV. Different methods for signal reconstruction are used. Preliminary results on electronic noise and performance, energy response, and energy resolution are presented.

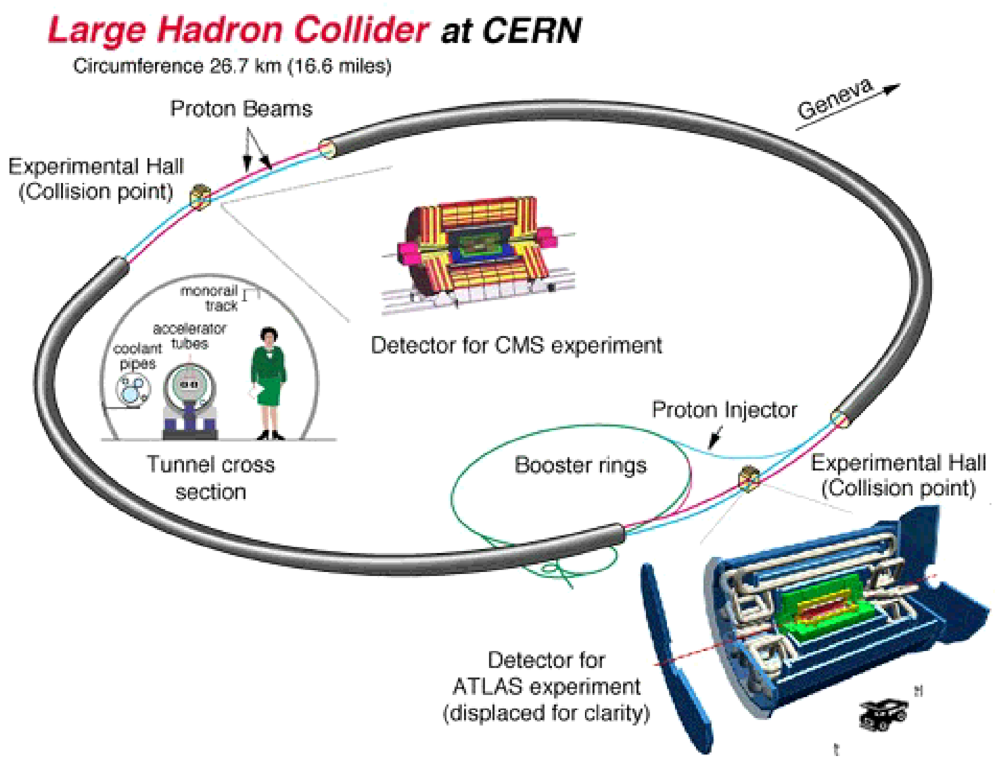
Outline

- The ATLAS experiment
  - Introduction to the LHC at CERN
  - The ATLAS collaboration
  - The ATLAS detector
- The Hadronic Endcap Calorimeter (HEC)
  - What is the HEC
  - Design and Goals of the HEC
- The HEC August 99 Beam Test
  - Electron Beams Results
  - Pion Beams Results
- Conclusions

LHC : Large Hadron Collider

- Under construction at CERN near Geneva, Switzerland
- Magnet system to be installed in the existing LEP tunnel
- 14 TeV Center-of-Mass proton-proton collisions
- Designed luminosity of $10^{34}\text{cm}^{-2}\text{s}^{-1}$
- To be operational in 2005
- Four experiments will make use of the LHC :

- ATLAS	- ALICE (heavy ions)
- CMS	- LHC-B (B physics)



ATLAS Collaboration

- >1700 physicists from 33 countries
- Canadian Collaboration consists of :

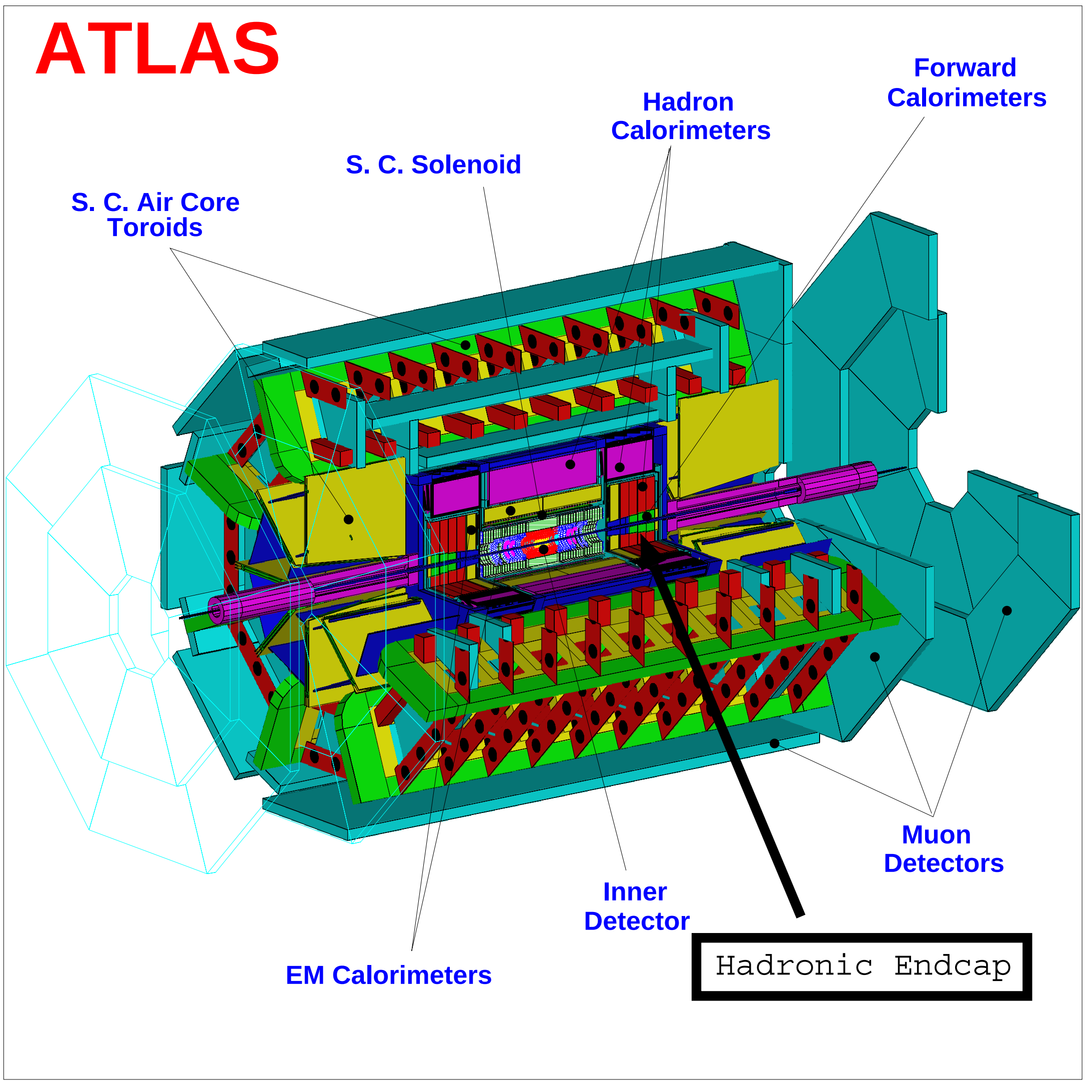
  - TRIUMF
  - Université de Montréal
  - University of Alberta
  - University of British Columbia
  - University of Carleton / C.R.P.P.
  - University of Toronto
  - University of Victoria
  - York University

- Canadian Activities are mainly focussed on calorimetry
  - Hadronic Endcap Calorimeter
  - Forward Calorimeter
  - Readout Electronics
  - Cryogenic Feedthroughs
  - Studies on Radiation Hardness
  - Physics Simulations

ATLAS : A Torodial LHC ApparatuS

The ATLAS dectector is made up of several subdetectors :

- Inner tracker : measures path and $\vec{p}$ of charged particles
- Calorimeter : measures energy of particles
- Muon spectrometer : identifies and measures $\vec{p}$ of muons



The Hadronic Endcap Calorimeter (HEC)

The ATLAS HEC :

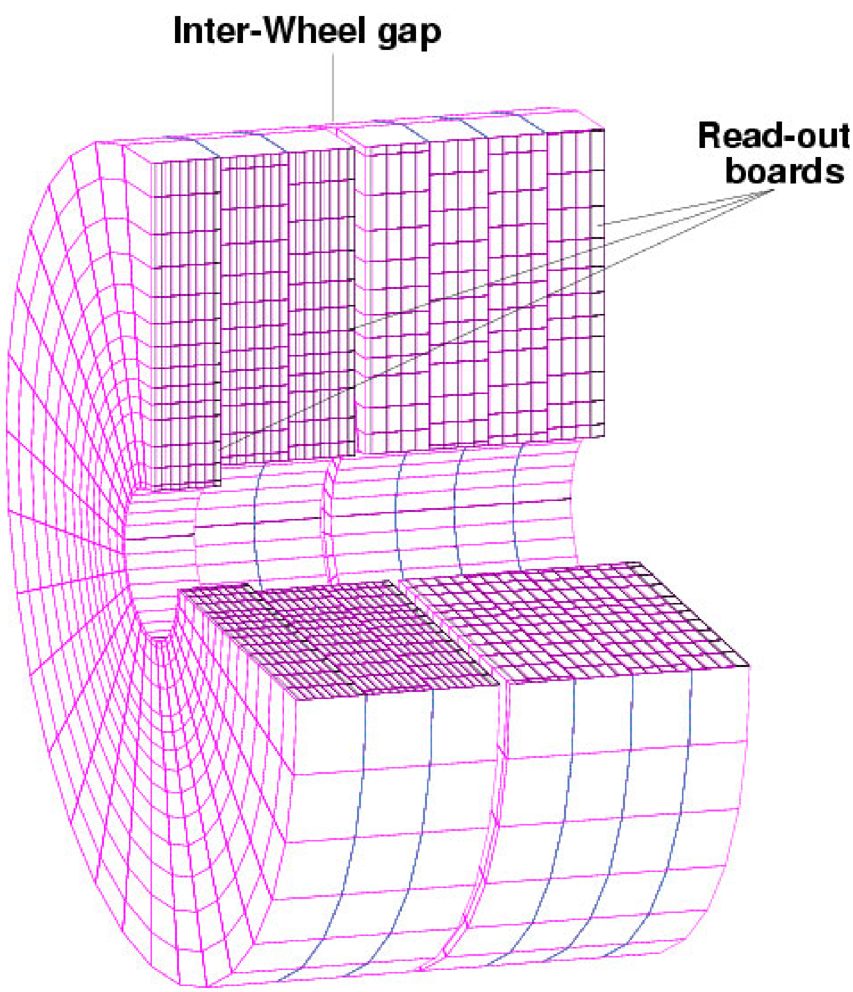
- Its Mechanical design is the responsibility of TRIUMF
- It is a Sampling Liquid Argon Calorimeter
- It uses copper plates as absorber
- It Covers $1.5 \leq |\eta| \leq 3.2$ i.e. $25.2^o \rightarrow 4.7^o$ $(\eta = -\ln\tan\frac{\theta}{2})$
- Shares 43 m^3 cryostat with EMEC and FCAL
- Liquid argon maintained at 92.5 K and 1.7 bars
- Modular production in Europe and Canada
- Production over by 2002
- Performance Goal:

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

The Hadronic Endcap Calorimeter (HEC)

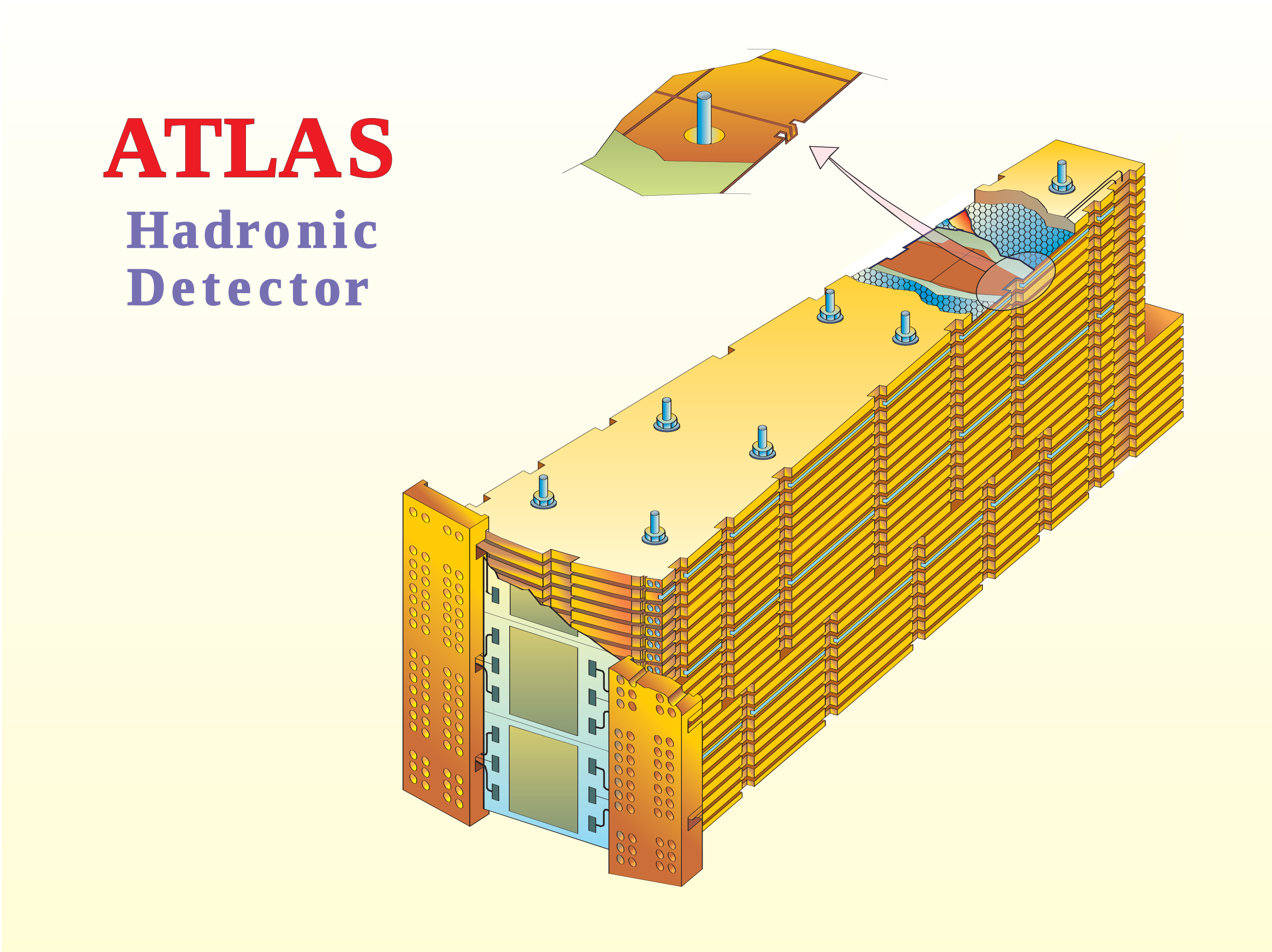
Two endcaps each made up of a front and a rear wheel

- Front wheel : 2 readout segments, 25 mm thick Cu plates, 24×8.5 mm gaps of argon
- Rear wheel : 2 readout segments, 50 mm thick Cu plates, 16×8.5 mm gaps of argon



The Hadronic Endcap Calorimeter (HEC)

Each wheel made up of 32 modules

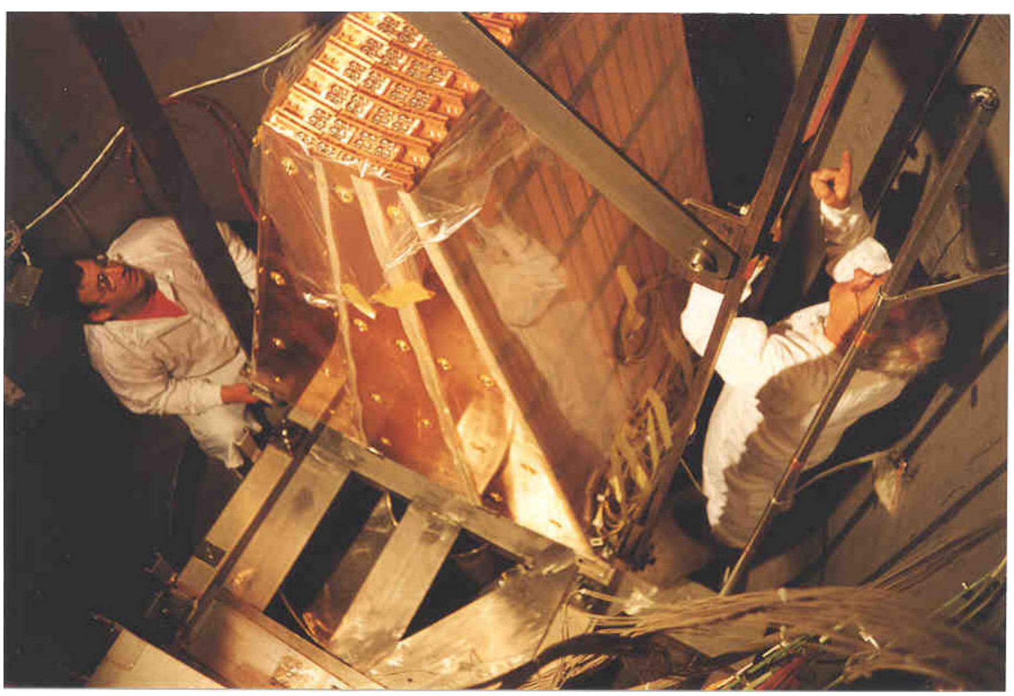


- One front wheel (32 modules) assembled at TRIUMF
- One module out of 8 tested in liquid argon at CERN

HEC Beam Test

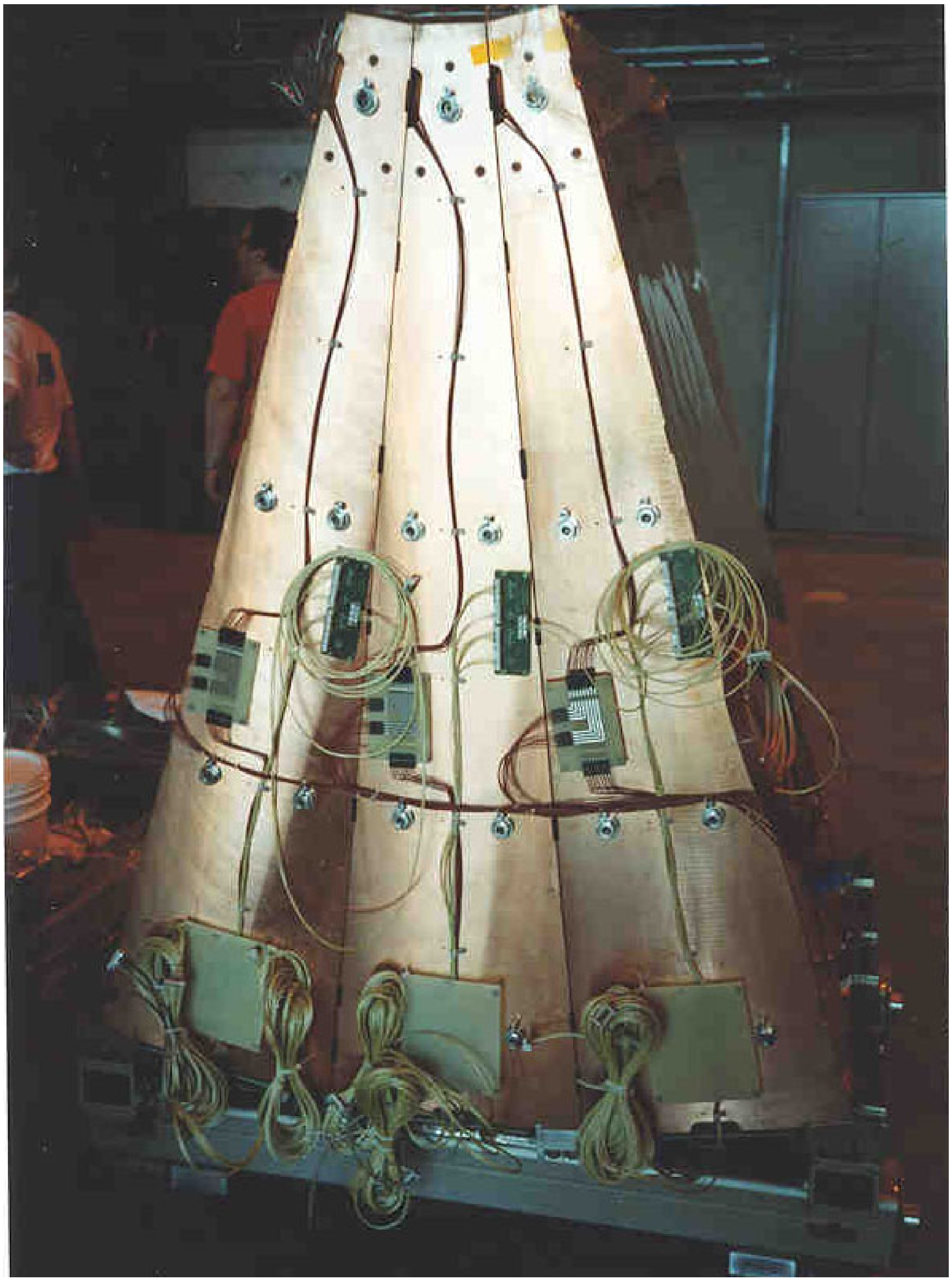
Summer 1999 Beam Test

- Quality Control and Design's Specifications Crosscheck
- First testing of production modules
- Conducted at CERN on the H6 beamline of the SPS
- 3 full modules (Front and Rear) were installed in cryostat
- e^+, π^+ and μ^+ beams between 10 - 200 GeV were used
- Experiment repeated at different impact points by :
  - Moving cryostat (changing x of impact)
  - Using bending magnet (changing y of impact)



HEC Beam Test

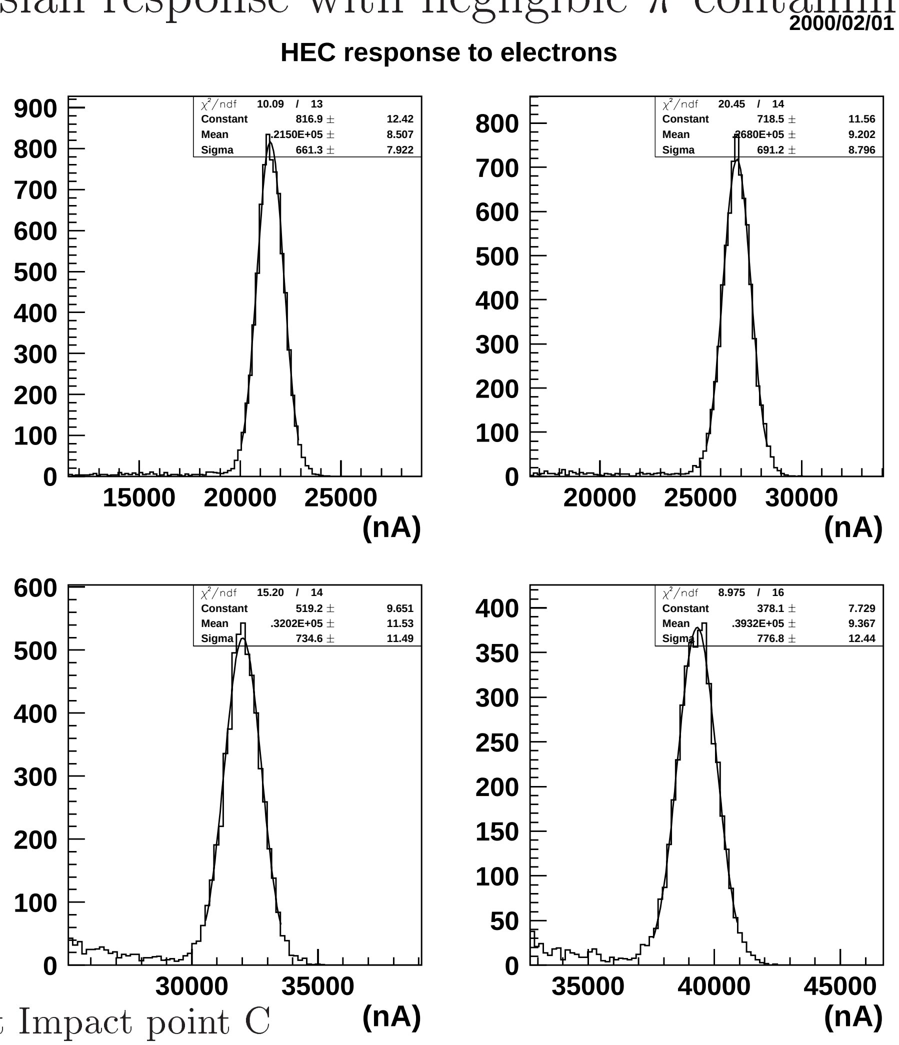
View of 3 HEC modules assembled



August 1999 Beam Test Results

HEC Response to $e^{\pm}$

- 9 cells clusters chosen such that full containment of shower is achieved to obtain a non-biased EM scale
- Gaussian response with negligible π contamination



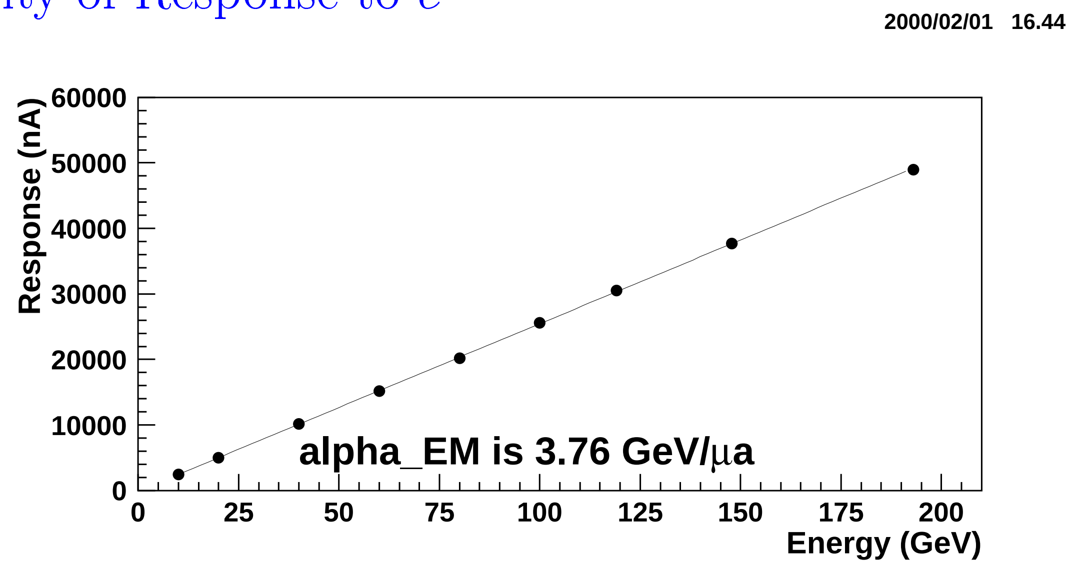
Response at Impact point C

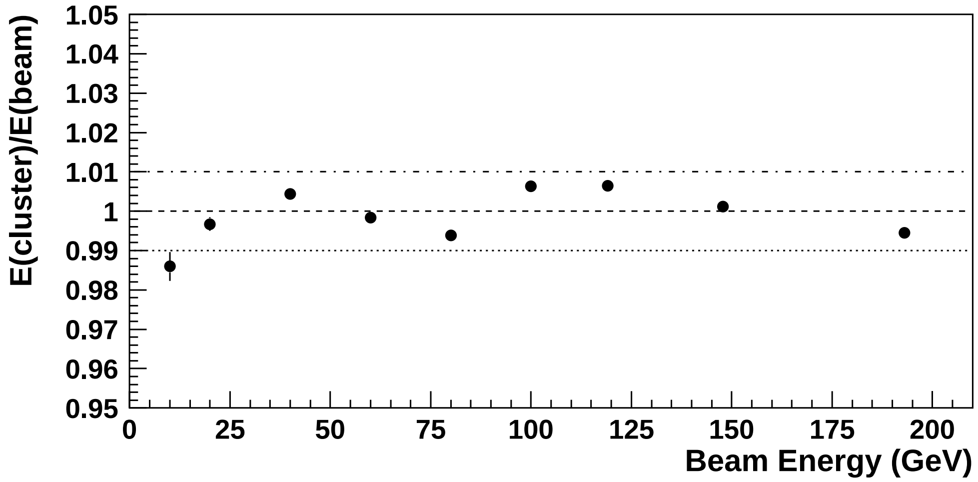
Fits were done on interval $\pm 2\sigma$

Digital filtering and 12/10/99 calibration files used

August 1999 Beam Test Results

Linearity of Response to e^+





Note that only statistical errors are included

Most of reconstructed energy lies within 1% of beam energy

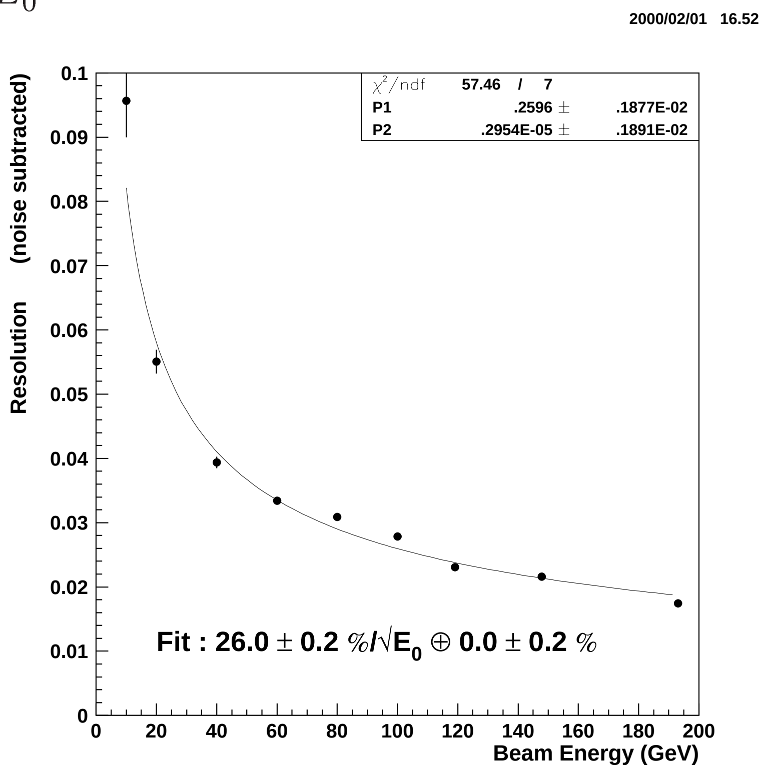
Average α_{EM} over 4 impact points :

$$\overline{\alpha_{EM}} = (3.90 \pm 0.04)\mathrm{GeV}/\mu\mathrm{A}$$

August 1999 Beam Test Results

HEC Resolution to e^+

- Resolution of Calorimeter Parameterized as :
$$\frac{\sigma}{E} = \frac{\text{sampling}}{\sqrt{E_0}} \oplus \text{constant} \oplus \frac{\text{noise}}{E}$$
- Noise can be measured independently such that :
$$\frac{\sigma'}{E'} = \frac{\text{sampling}}{\sqrt{E_0}} \oplus \text{constant}$$



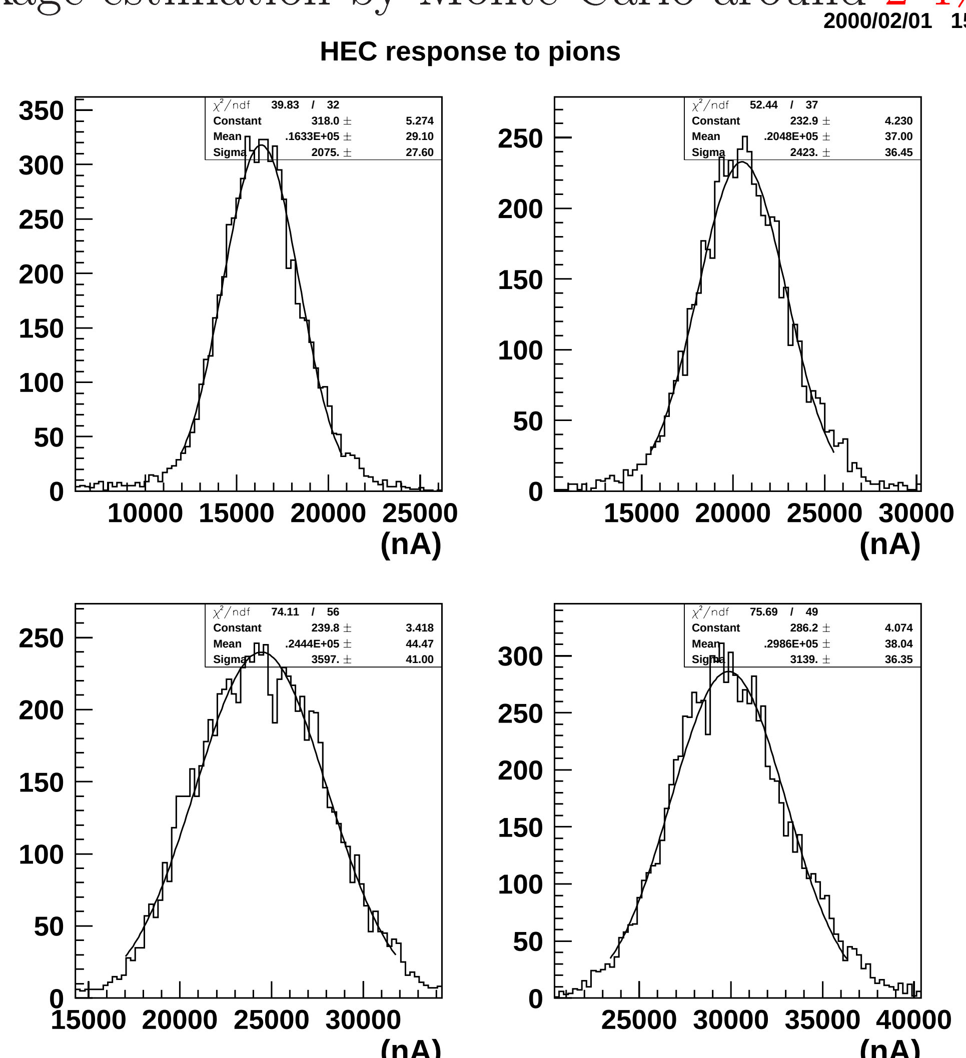
Average over 4 impact points :

$$\frac{\sigma'}{E'} = \frac{(24 \pm 1)\%}{\sqrt{E_0(\text{GeV})}} \oplus (0.26 \pm 0.13)\%$$

August 1999 Beam Test Results

HEC Response to $\pi^{\pm}$

- 53-54 cells clusters chosen such that full containment of shower is achieved
- Leakage estimation by Monte Carlo around 2-4% (1998)



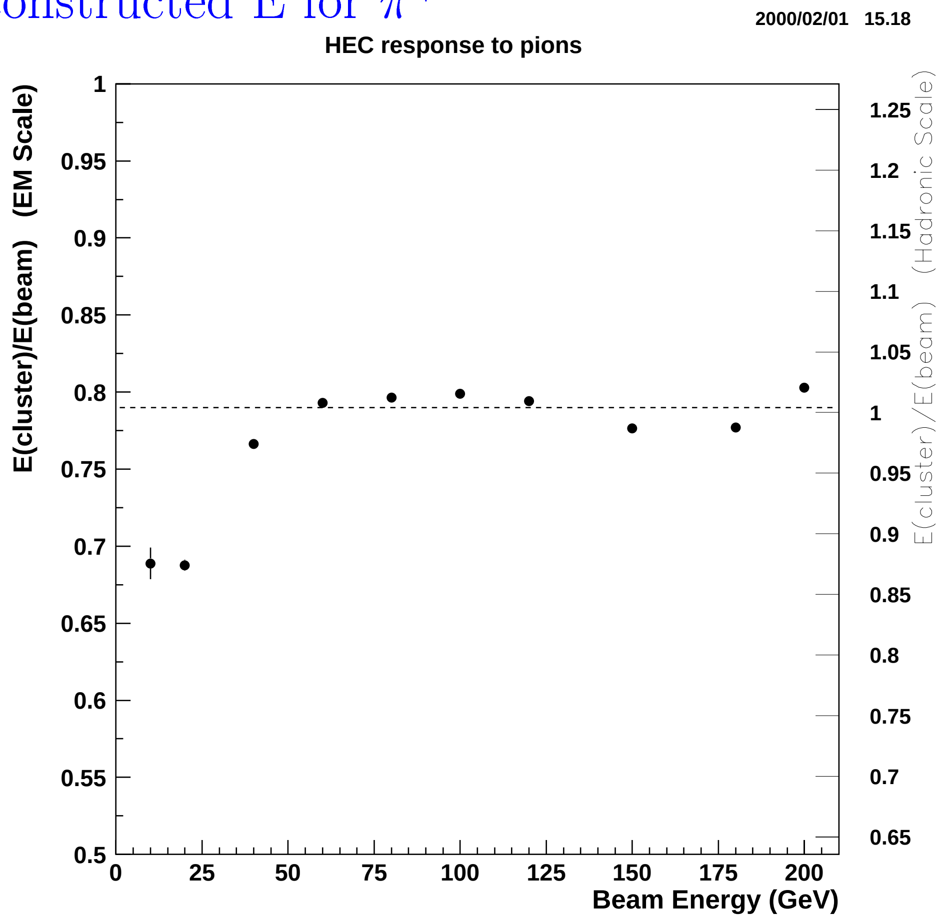
Impact point C chosen

Fits were done on interval $\pm 2\sigma$

Digital filtering and 12/10/99 calibration files used

August 1999 Beam Test Results

HEC Reconstructed E for π^+

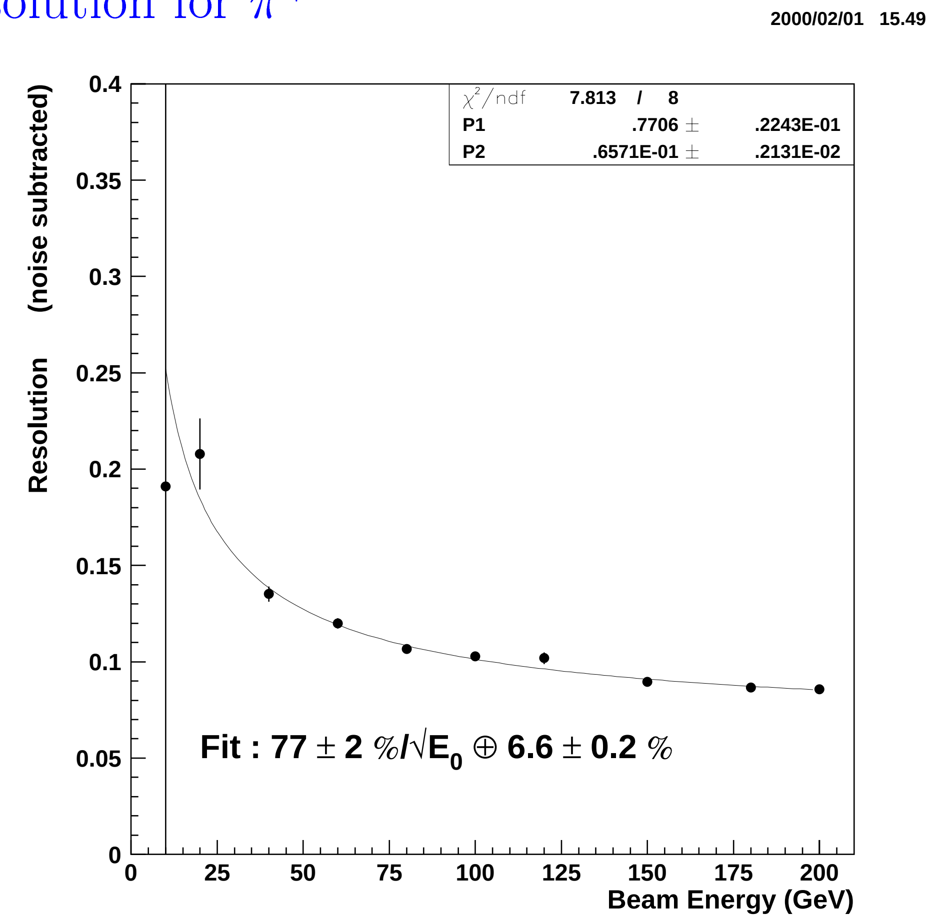


- Response using the EM scale is roughly 21 % less of response using Hadronic scale at $E > 40$ GeV
- Non-linearity of response vs E due to non-compensation : $F_{\pi^0} \cong k \ln E(\mathrm{GeV}) \qquad k \approx 0.1$ (for a few to a few 100's GeV's)

Note that only statistical errors are shown

August 1999 Beam Test Results

HEC Resolution for π^+



Note that only statistical errors are shown

Average Resolution over 4 impact points :

$$\frac{\sigma'}{E'} = \frac{(82.0 \pm 0.9)\%}{\sqrt{E_0(\mathrm{GeV})}} \oplus (6.05 \pm 0.13)\%$$

August 1999 Beam Test Results

Next Analysis Steps :

- Further studies of electronic noise
- Estimation of systematics
- Repeat analysis on more impact points
- X and Y scans for uniformity studies
- Measurement of e/h using e/π

Conclusions

- Electromagnetic constant :

$$\overline{\alpha_{EM}} = (3.90 \pm 0.04)\mathrm{GeV}/\mu\mathrm{A}$$

- Electron Energy Resolution

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

  Measured :

$$\frac{\sigma'}{E'} = \frac{(24 \pm 1)\%}{\sqrt{E_0(\mathrm{GeV})}} \oplus (0.26 \pm 0.13)\%$$

- Pion Energy Resolution Measured :

$$\frac{\sigma'}{E'} = \frac{(82.0 \pm 0.9)\%}{\sqrt{E_0(\mathrm{GeV})}} \oplus (6.05 \pm 0.13)\%$$

- Performance goal for jets will be easily attainable:

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

Contamination of beams

π^+ Contamination in e^+ beam