7th International Conference
on
Advanced Technology & Particle Physics

Como 15-19 October 2001

Overview of ATLAS Liquid Argon Calorimetry

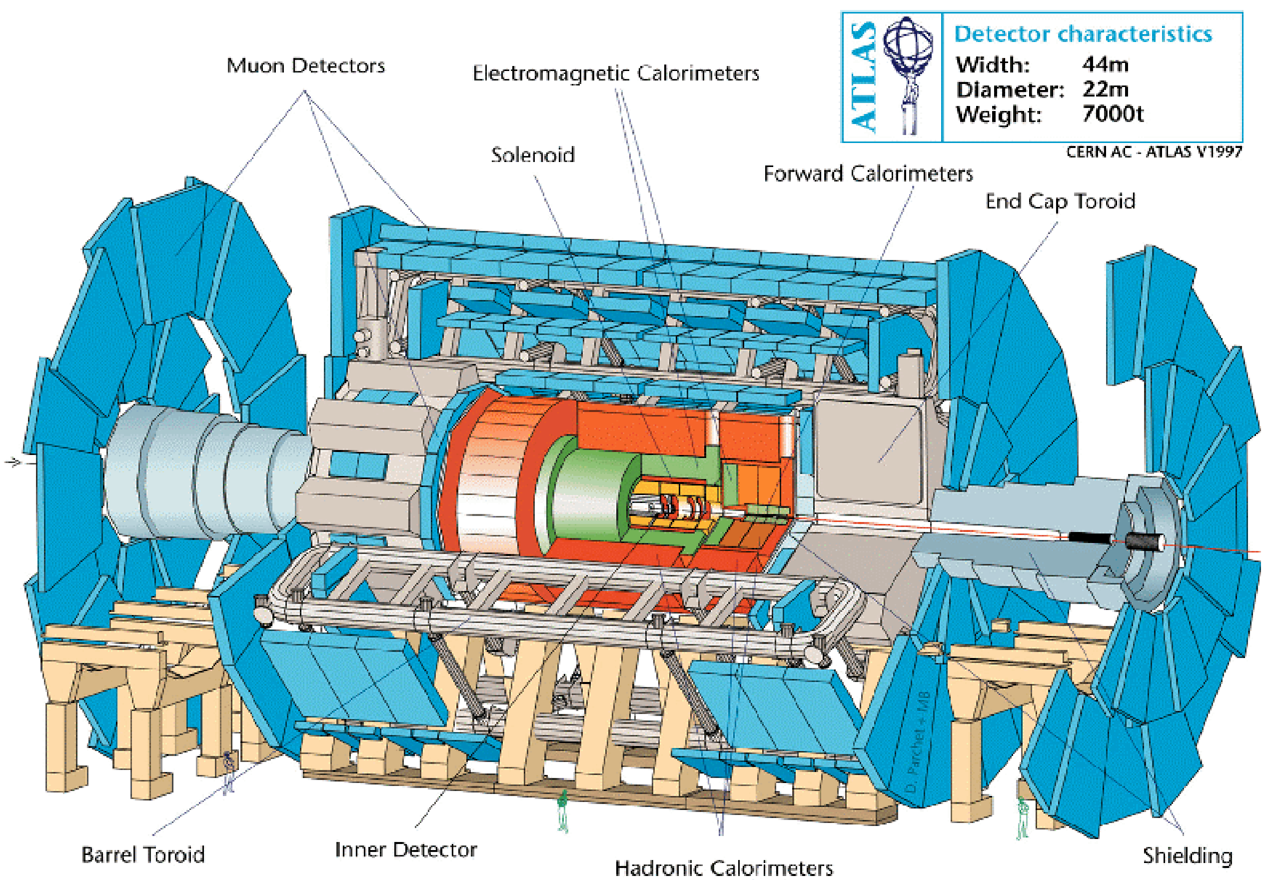
Robert S. Orr

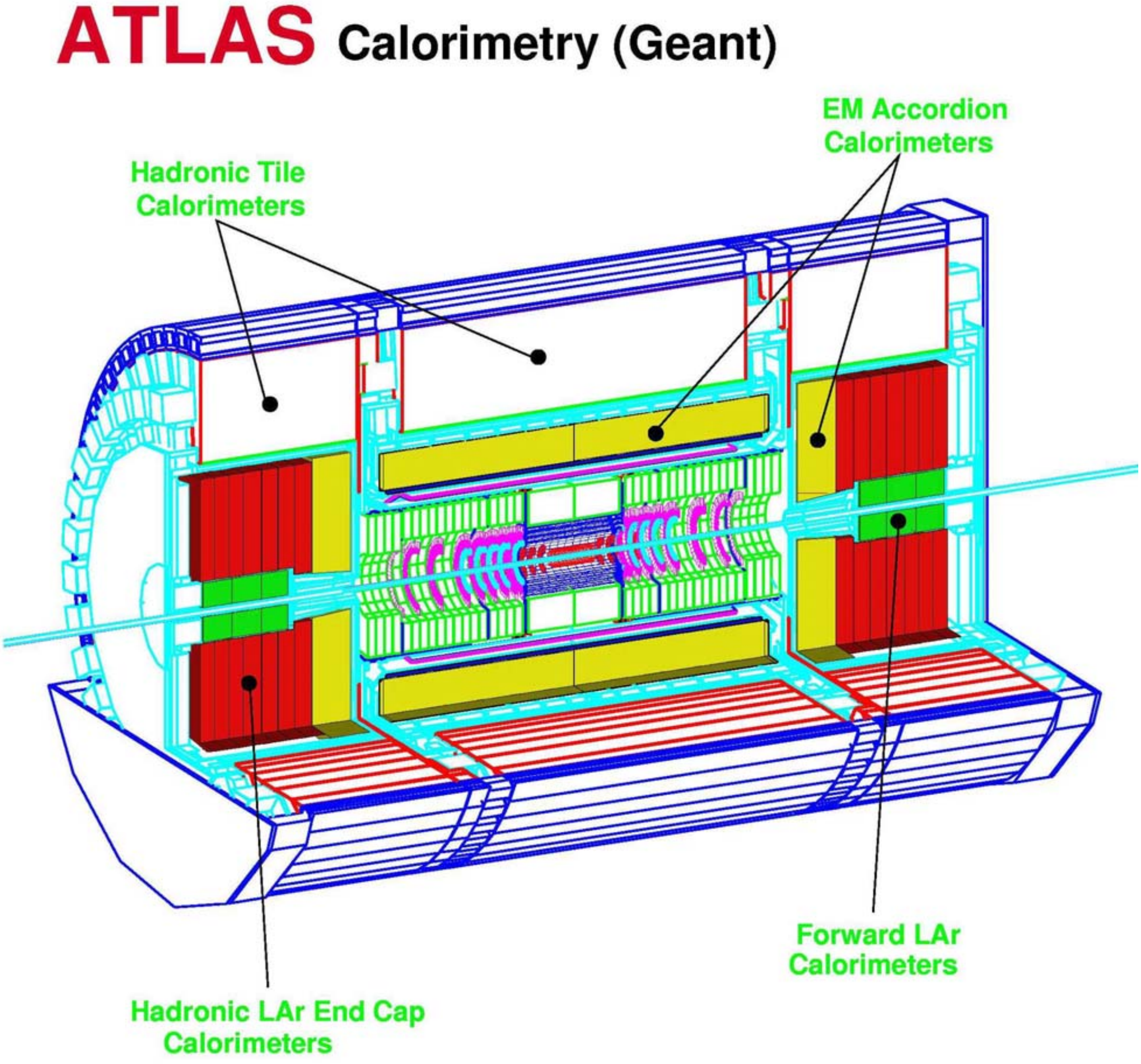
University of Toronto
on behalf of the
ATLAS Liquid Argon Calorimeter Group

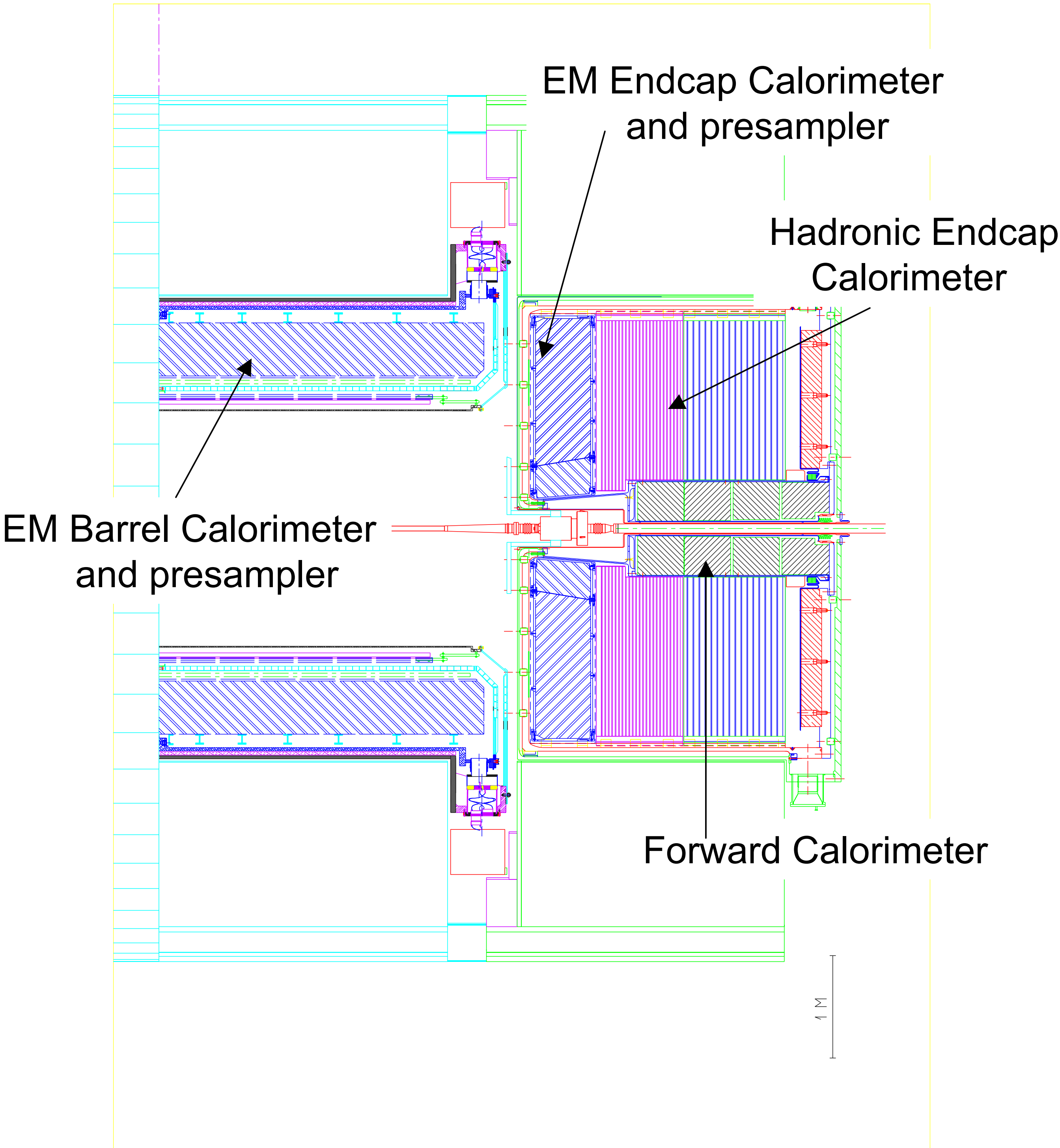
LHC

- High Centre of Mass Energy - 14 TeV
- High Luminosity - $10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

ATLAS




ATLAS Calorimetry (Geant)
EM Accordion Calorimeters
Hadronic Tile Calorimeters
Forward LAr Calorimeters
Hadronic LAr End Cap Calorimeters



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Liquid Argon Calorimetry
19 October 2001

LAr Calorimetry

Physics Requirements

Discovery Physics - Higgs, SUSY, …..
Precision Physics - t, b, ...

Reconstruction → $P_e \ , P_\gamma \ , P_{jet} \ , E_T^{miss} \ , (P_\mu),$ bunch
Separation → γ / π^0 , e/π

General Requirements

Fast readout scheme
Radiation hard
High segmentation
Uniformity of response
Dynamic range (from 1 mip to 5 TeV)
Hermiticity down to $|\eta| \approx 5$
Long term stability
"Ease" of calibration
Mechanical consideration: cost
modular construction
installation in ATLAS

LAr Calorimeter Technology Overview

Design Goals ➡ Technology

- EM Calorimeters ($0 \le |\eta| \le 3.2$) and Presampler ($0 \le |\eta| \le 1.8$)

$$\frac{\sigma}{E} \le \frac{10\%}{\sqrt{E(\mathrm{GeV})}} \oplus 0.7\% \oplus \frac{0.27}{E(\mathrm{GeV})} \qquad \sigma_\theta \le \frac{40\ \mathrm{mrad}}{\sqrt{E(\mathrm{GeV})}} \qquad \sigma_{\vec{r}} \le \frac{8\ \mathrm{mm}}{\sqrt{E(\mathrm{GeV})}}$$

Lead/Copper-Kapton/Liquid Argon *Accordion* Structure

- Hadronic Endcap ($1.5 \le |\eta| \le 3.2$)

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

Copper/Copper-Kapton/Liquid Argon *Plate* Structure

- Forward Calorimeter ($3 \le |\eta| \le 5$)

$$\frac{\sigma}{E}(\mathrm{jets}) \le \frac{100\%}{\sqrt{E(\mathrm{GeV})}} \oplus 10\%$$

Tungsten/Copper/Liquid Argon *Paraxial Rod* Structure

Barrel Cryostat

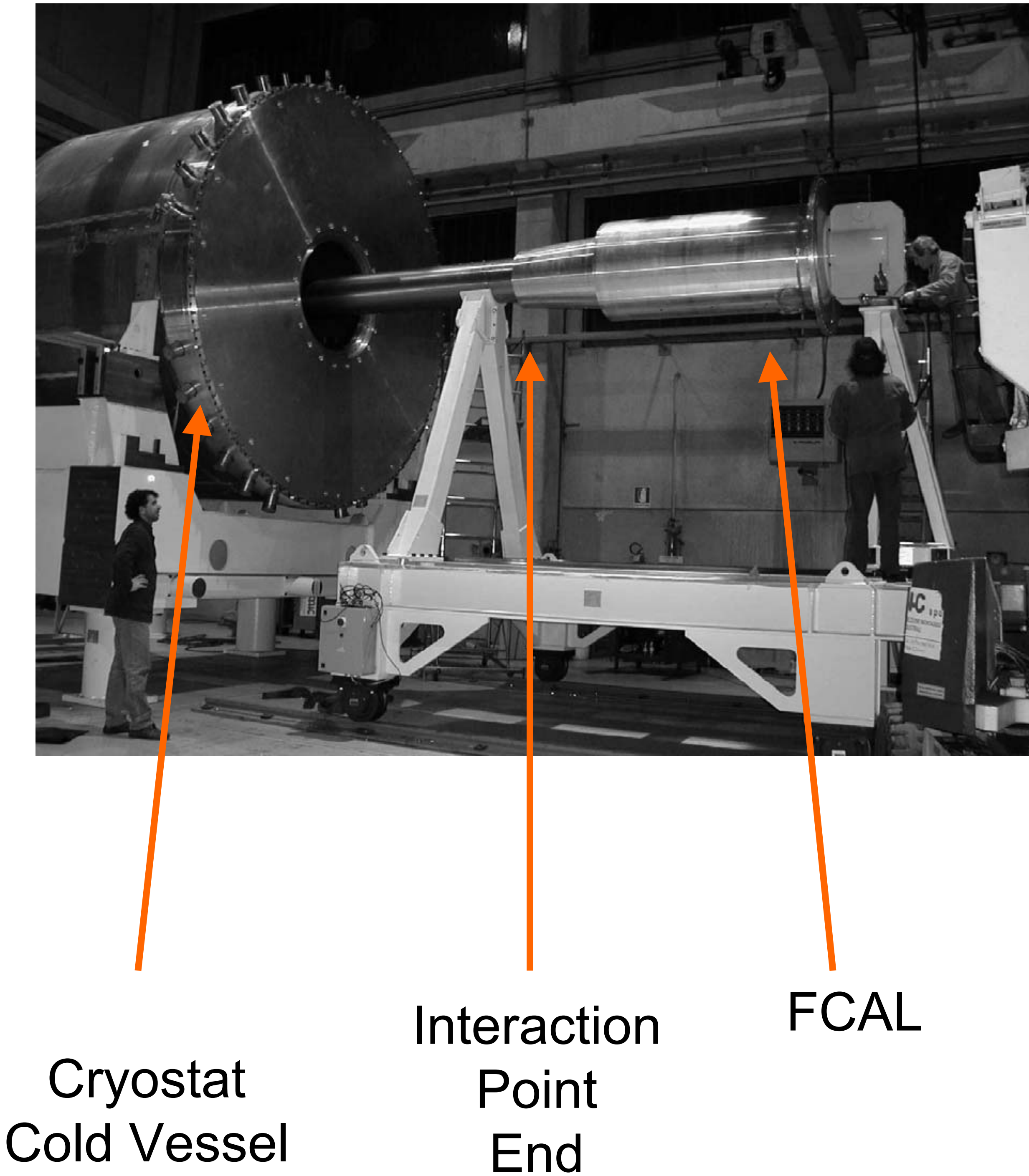
Leak Test at KHI - June 2000

CERN September 2000

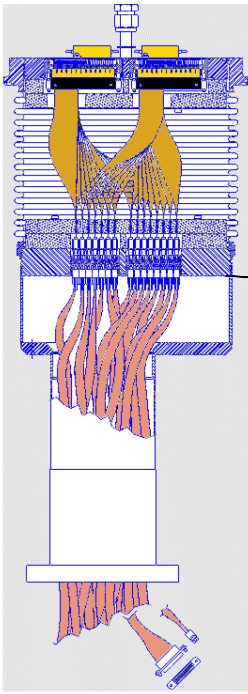
Endcap Cryostat Cold Vessel

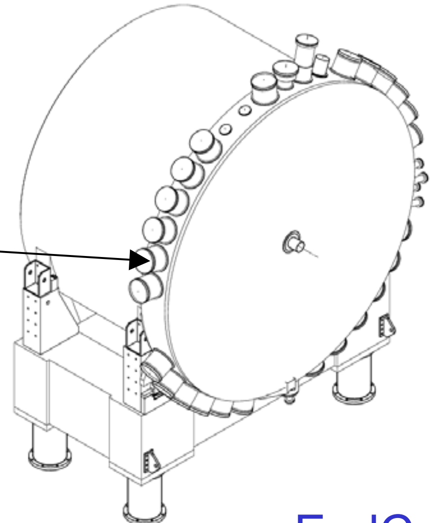
Feedthrough Ports

Insertion of FCAL in Endcap Cryostat



Liquid Argon Signal Feedthroughs





EndCap
Cryostat

Over 180k signal channels in the LAr calorimetry

High density and reliability required:
1920 pins per feedthrough unit
barrel: 64 units
endcaps: 50 units total

8-row pin carrier

Warm/cold flange

Signal Feedthroughs

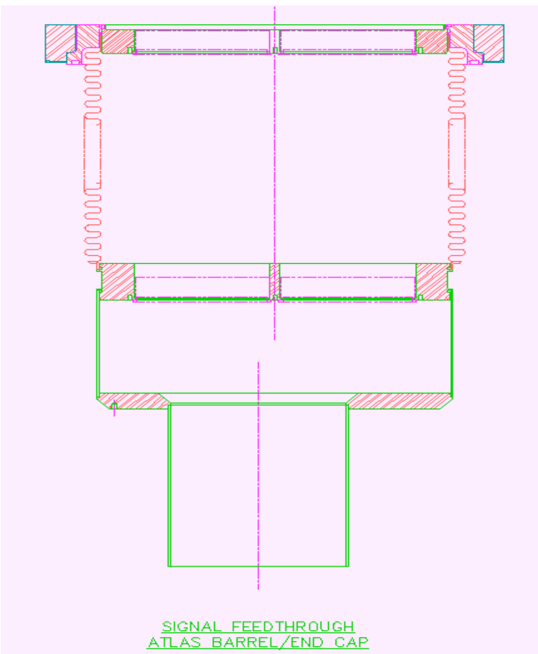
Over 180k signal channels in the LAr calorimetry

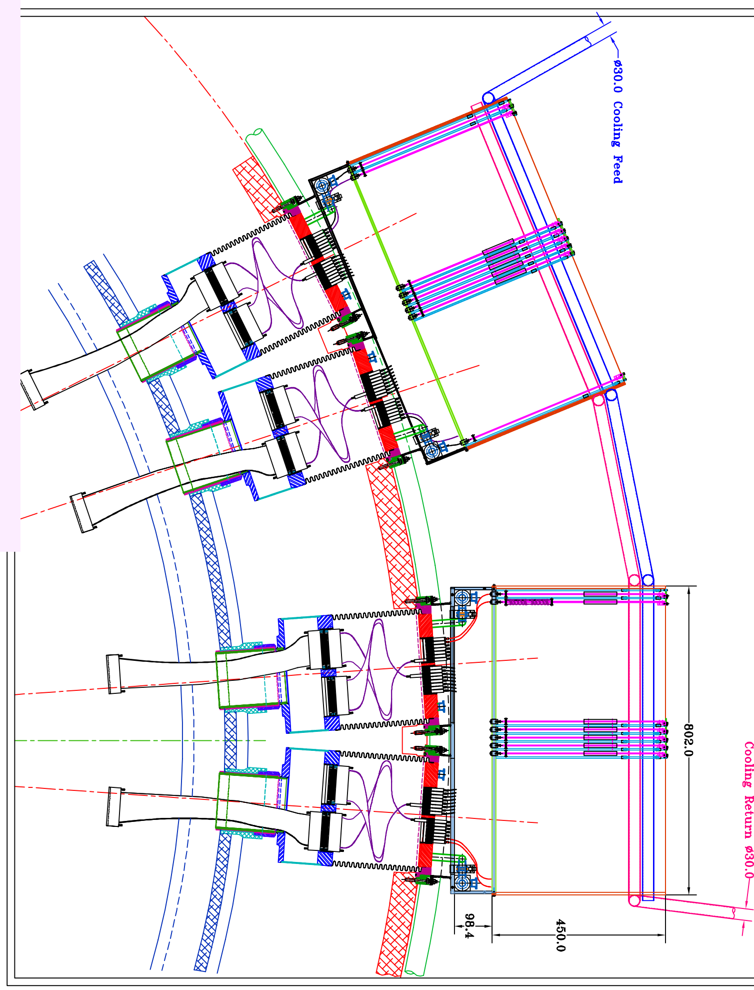
High density and reliability required:

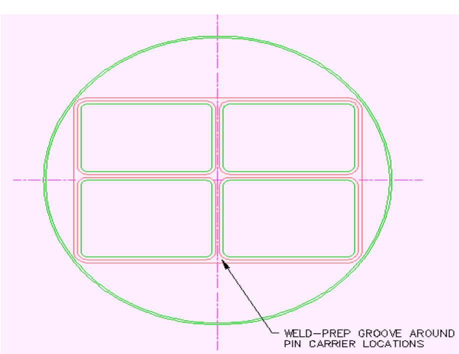
1920 pins per feedthrough unit

barrel: 64 units

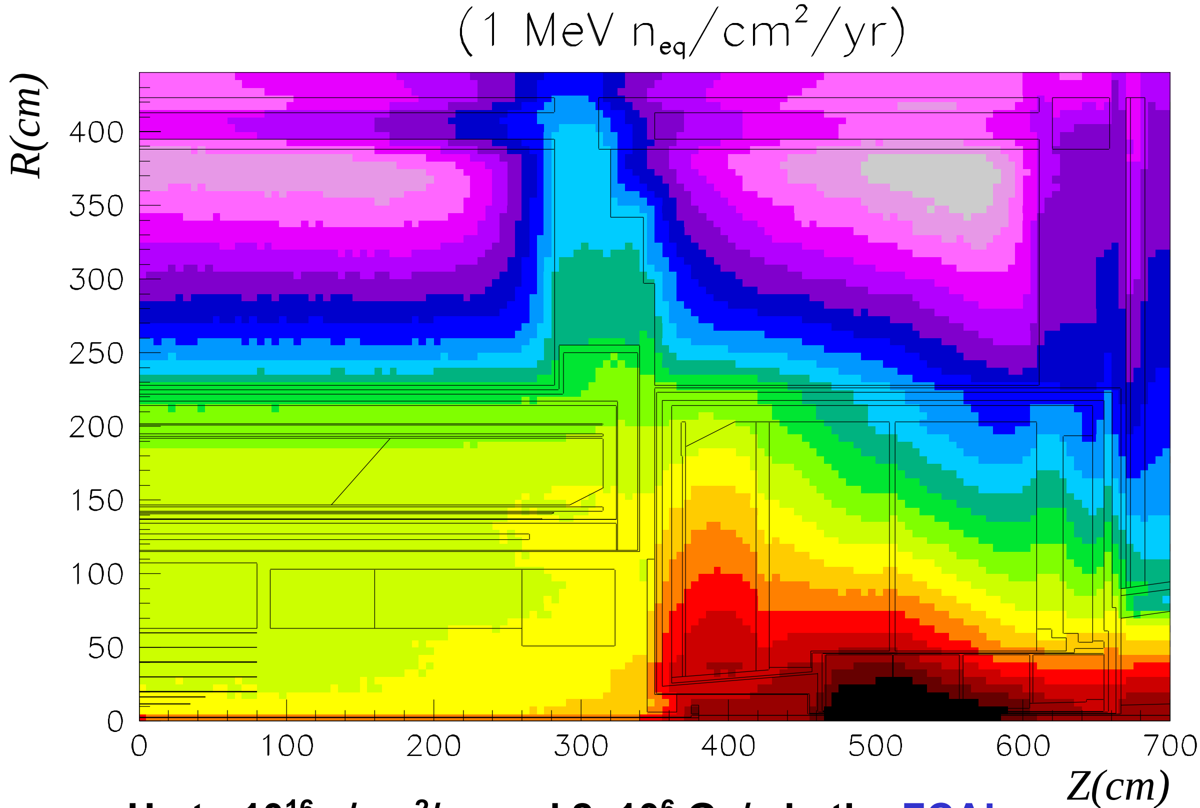
endcaps: 50 units total



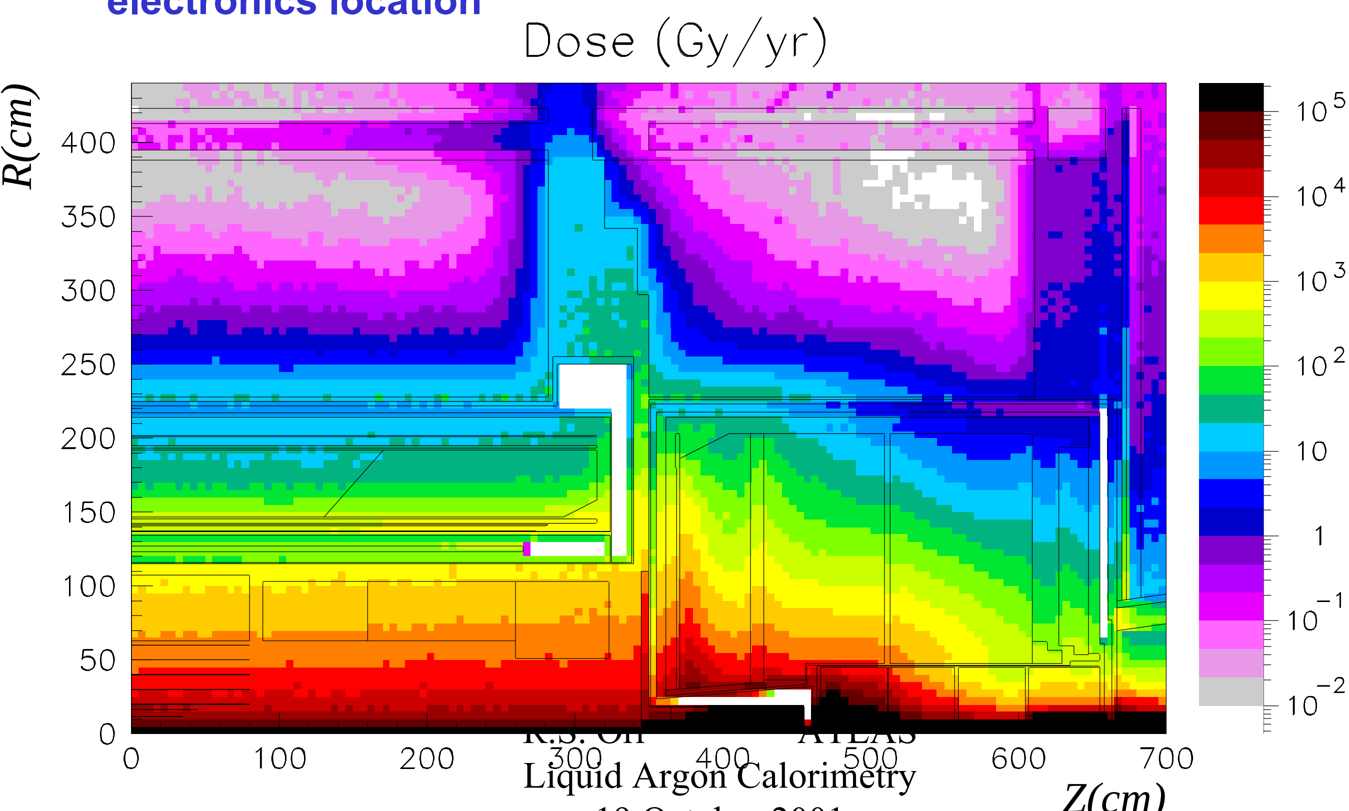




Radiation Environment



- Up to 10^{16} n/cm²/yr and 2×10^{6} Gy/y in the **FCAL**
- Less than 10^{12} n/cm²/yr and 20 Gy/y at the **EM electronics location**
- Less than 5×10^{12} n/cm²/yr and 50 Gy/y at the **Hadronic Endcap electronics location**



Design Considerations

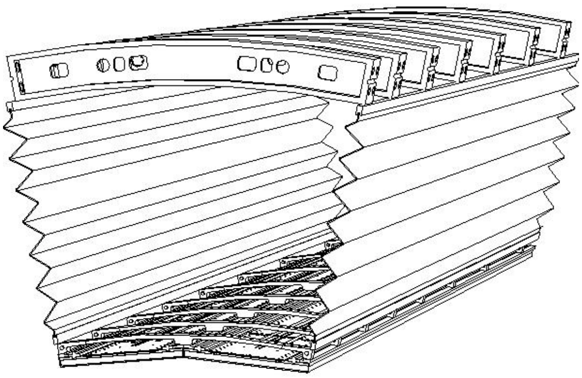
- Electromagnetic
  - Precise energy & angle resolution
  - fine granularity - mechanics & cabling
  - fast - low pileup
  - hermetic (no cracks)
  - radiation tolerant
  - Accordion Pb/Liquid Argon

- Hadronic Endcap
  - Energy resolution matched to physics
  - compact
  - rendundant H.V.
  - cost
  - radiation tolerant
  - Copper Plate/Liquid Argon

- Forward
  - Very radiation hard
  - high reliability
  - immune to space charge
  - cost
  - Paraxial tubes/Cu/W/Liquid Argon

Electromagnetic Barrel

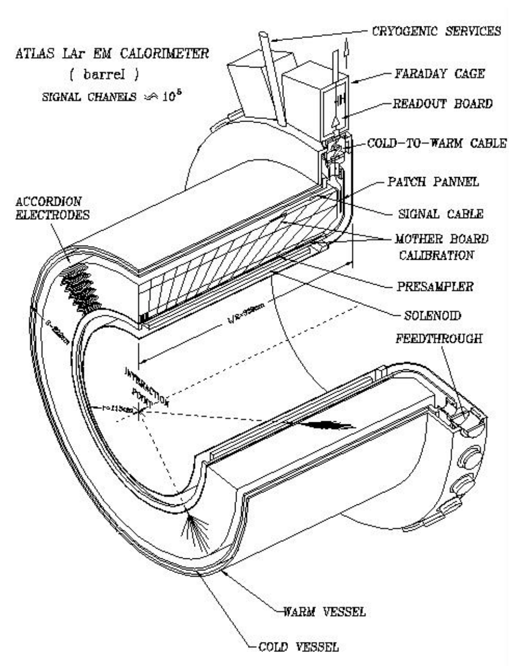
$0 < \eta < 1.4$



Barrel Module Schematic
with presampler

- 64 gaps /module
- 2.1 mm gap
- 2x3100 mm long

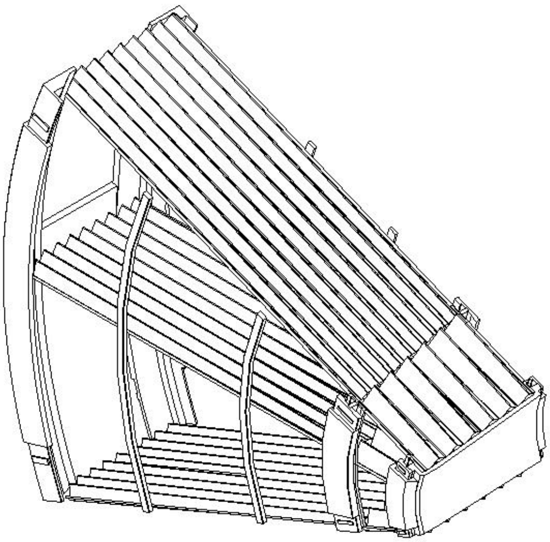
- 2x16 modules
- I.R/O.R 1470/2000 mm
- 22 - 33 X_0
- 3 longitudinal samples
- $\Delta\eta\times\Delta\varphi \quad 0.025\times0.025$
- presampler $|\eta| < 1.8$



Half Barrel Assembly

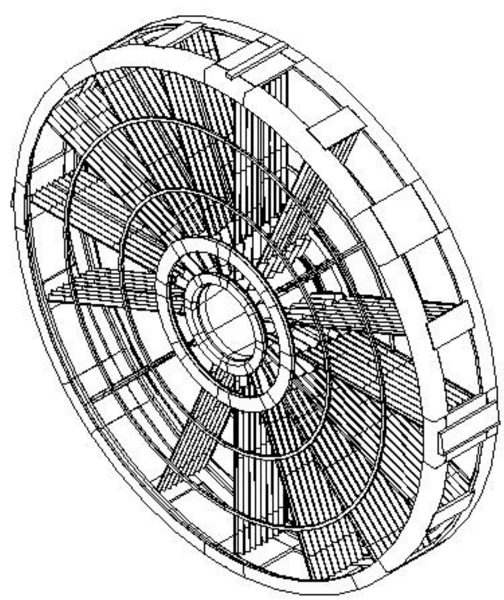
Electromagnetic Endcap

$1.4 < \eta < 3.2$



- 96 gaps /module outer wheel
  32 gaps/module inner wheel
- 2.8 - 0.9 mm gap outer
  3.1-1.8 mm inner

- 2x8 modules
- Diam. 4000 mm
- 22 - 37 X_0
- 3 longitudinal samples
- $\Delta\eta \times \Delta\varphi \quad 0.025 \times 0.025$
  $|\eta| > 2.5 \rightarrow 0.1 \times 0.1$
- Front sampling of 6 X_0
  for $|\eta| < 2.5$, ♒ - strips.



Accordion Structure

Pb Absorber

• Honeycomb spacer

&

• Cu/Kapton electrode

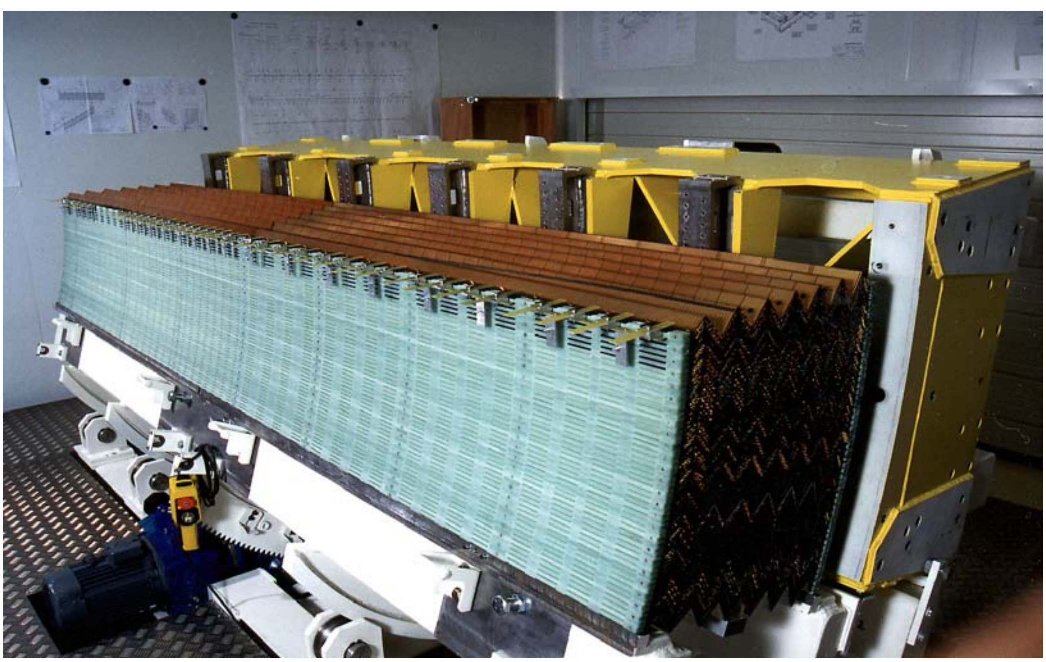
Barrel Module 0

Module 0

Beam Tested @CERN in 1999/2000.

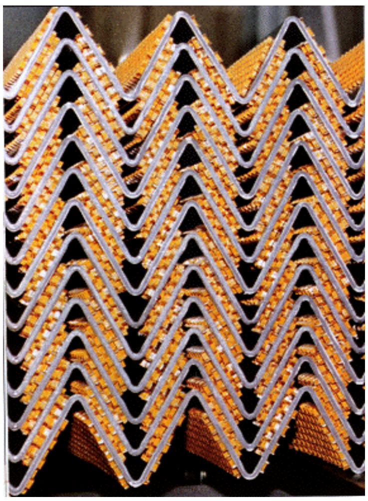
Production

- mechanically satisfactory.
- electrical studies underway on 1st four modules, warm and cold.
- 6/32 complete.

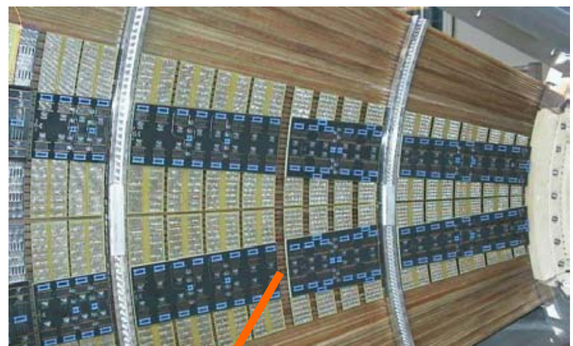


Endcap Module 0

Detail of Kaptons

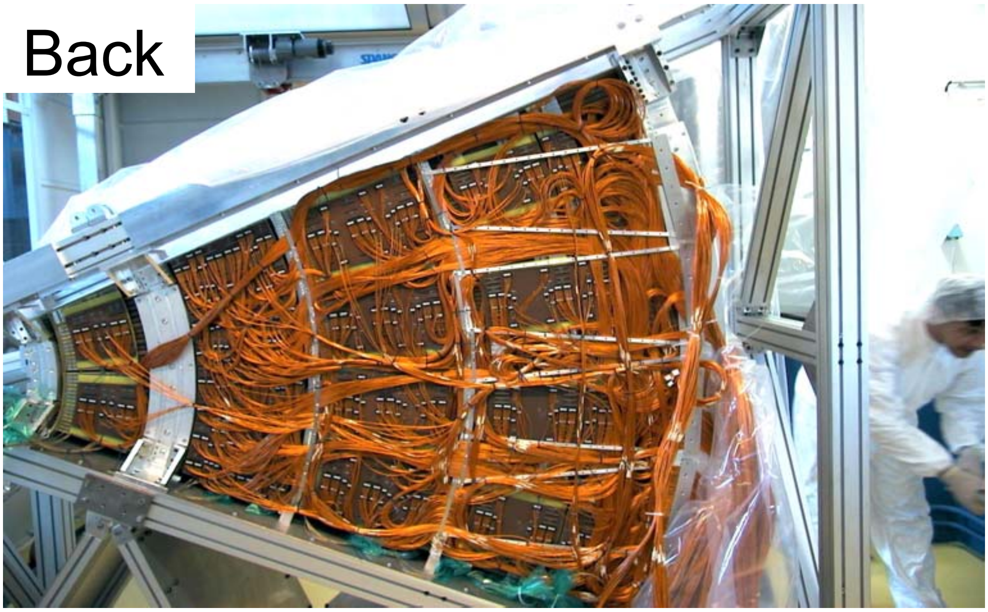


Summing Mother Boards



Endcap Production Module

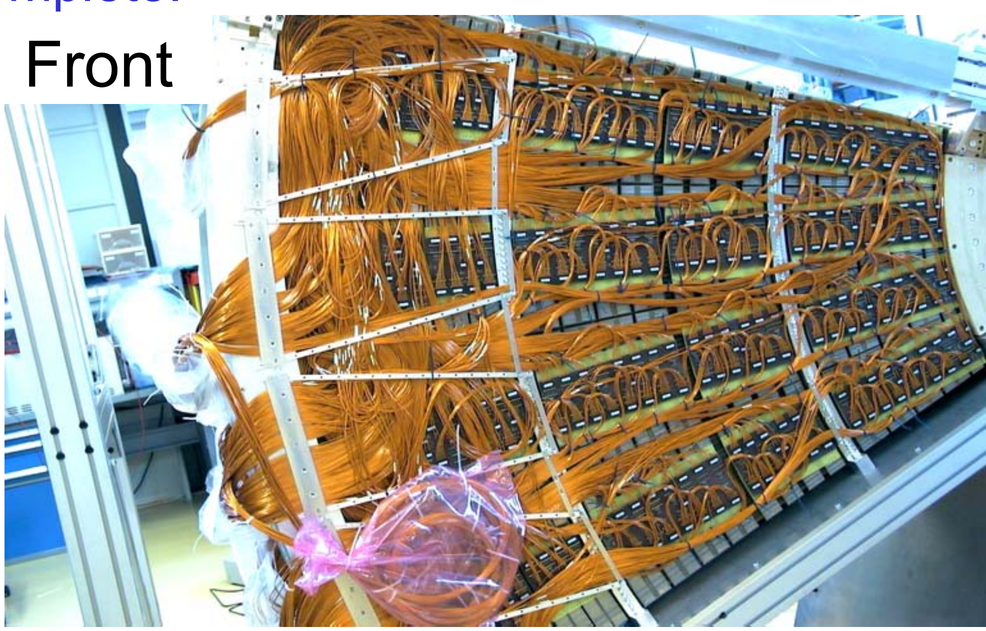
Back



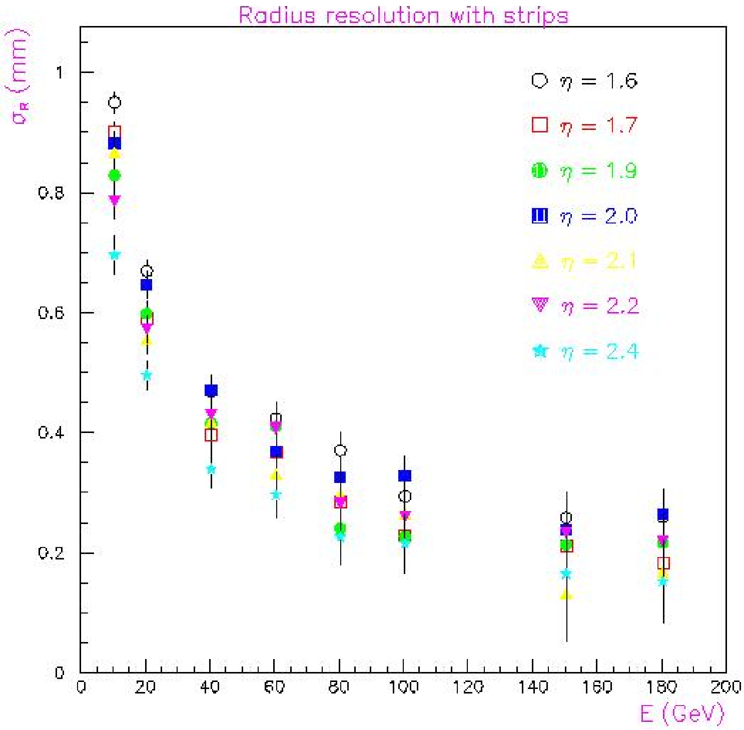
Production

- modifications from beam test (mother boards, grounding, mechanics).
- 3/16 complete.

Front



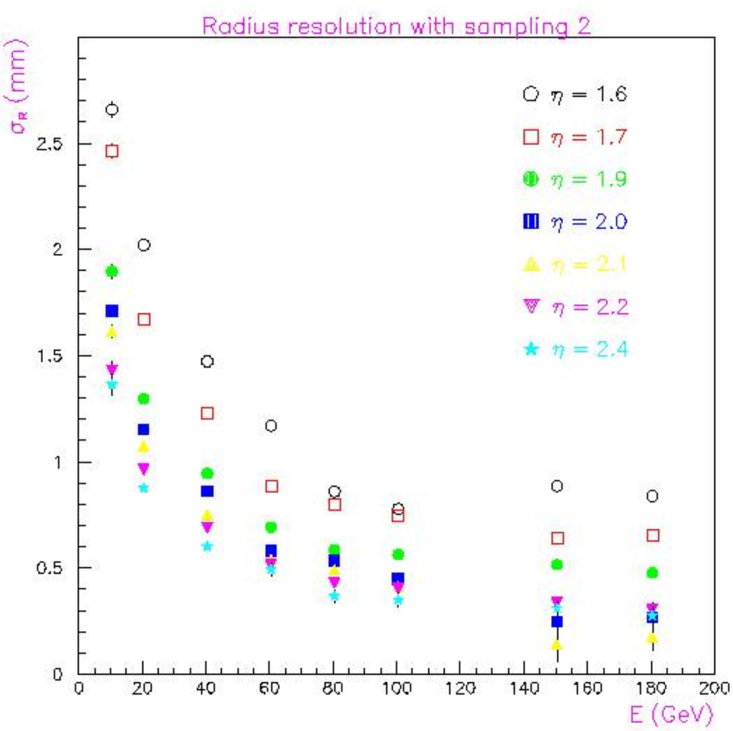
Test Beam Spatial Resolution



Strips

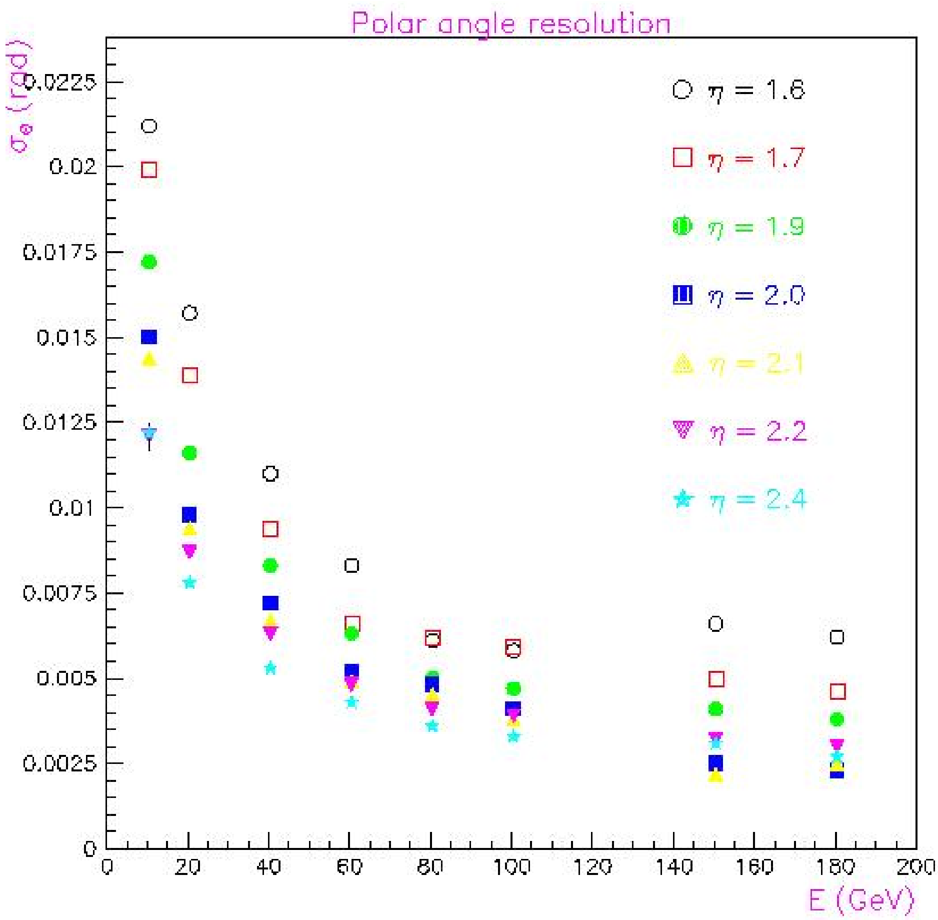
Resolution satisfactory

0.3 mm in strip section



2nd Sampling

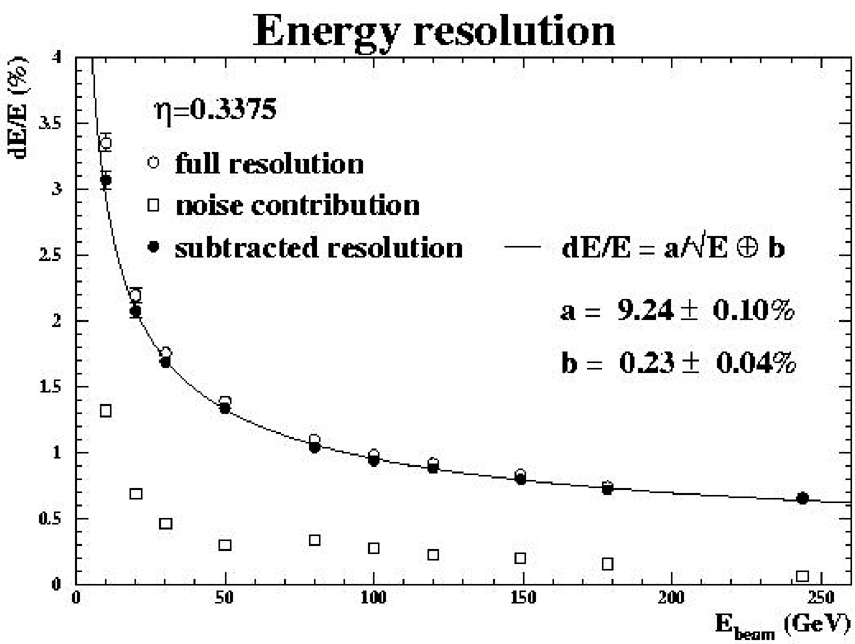
Test Beam Angular Resolution



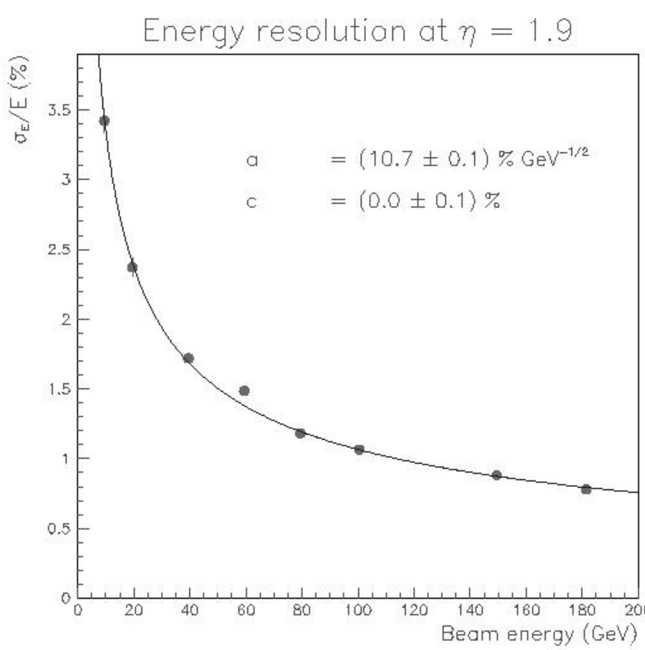
Resolution satisfactory

< 50 mrad/√E on angular measurements

Test Beam Energy Resolution



Barrel

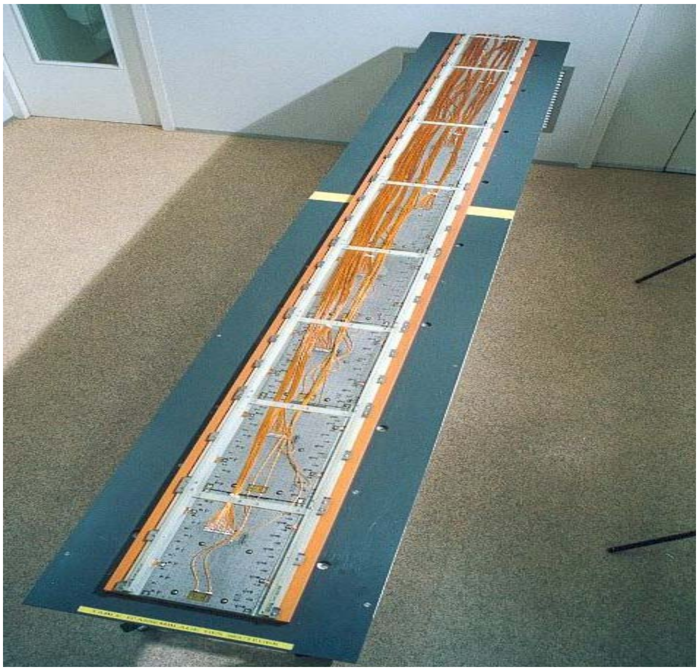


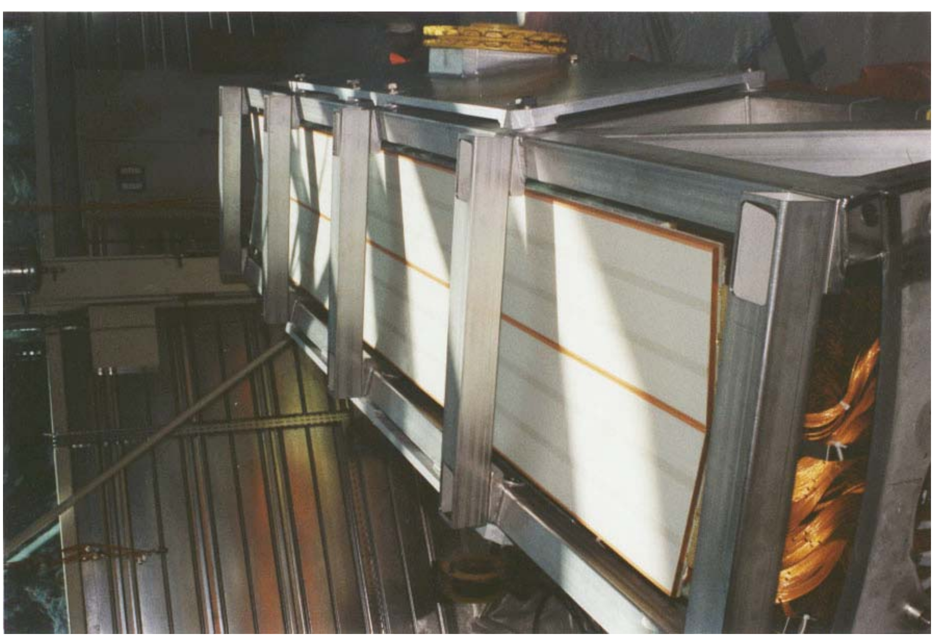
Endcap

Local constant and sampling term in the expected range

Pre Sampler

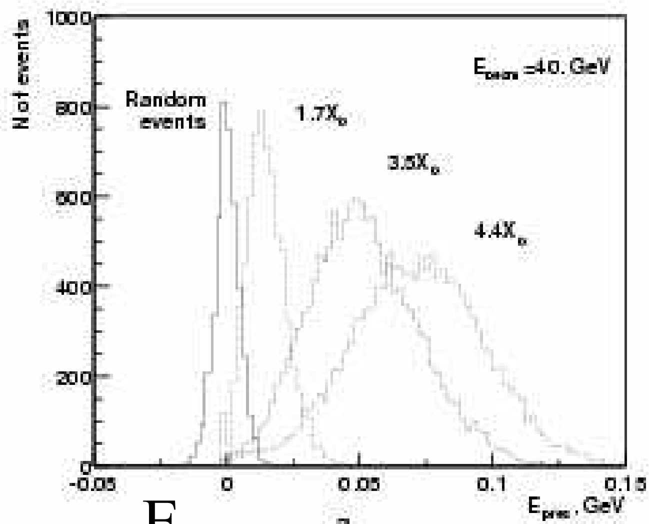
Cabled Pre Sampler sector



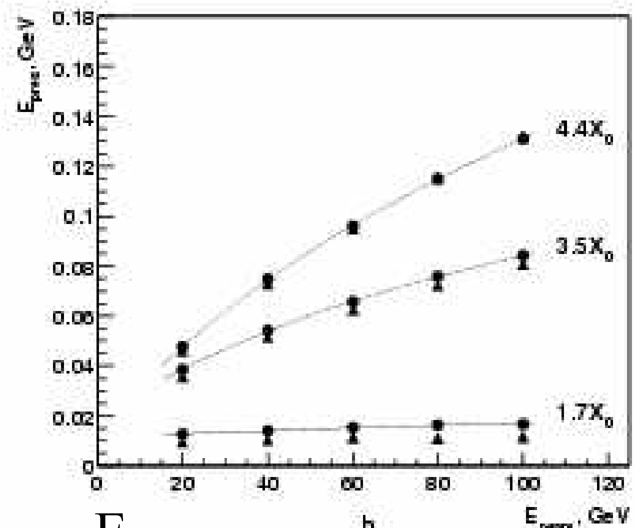


Test Beam Presampler

$E_{Presampler}$

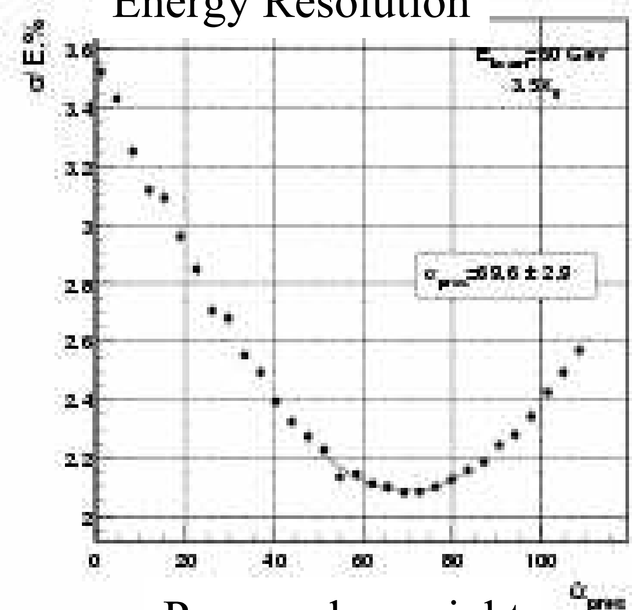


$E_{Presampler}$



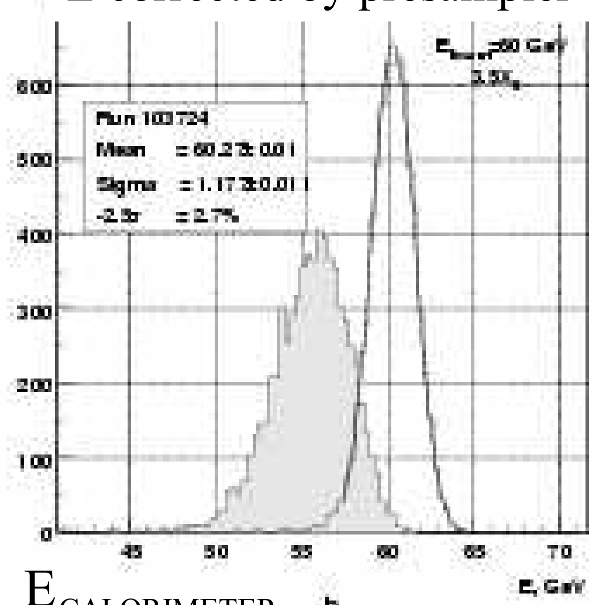
E_{BEAM}

Energy Resolution



Presampler weight

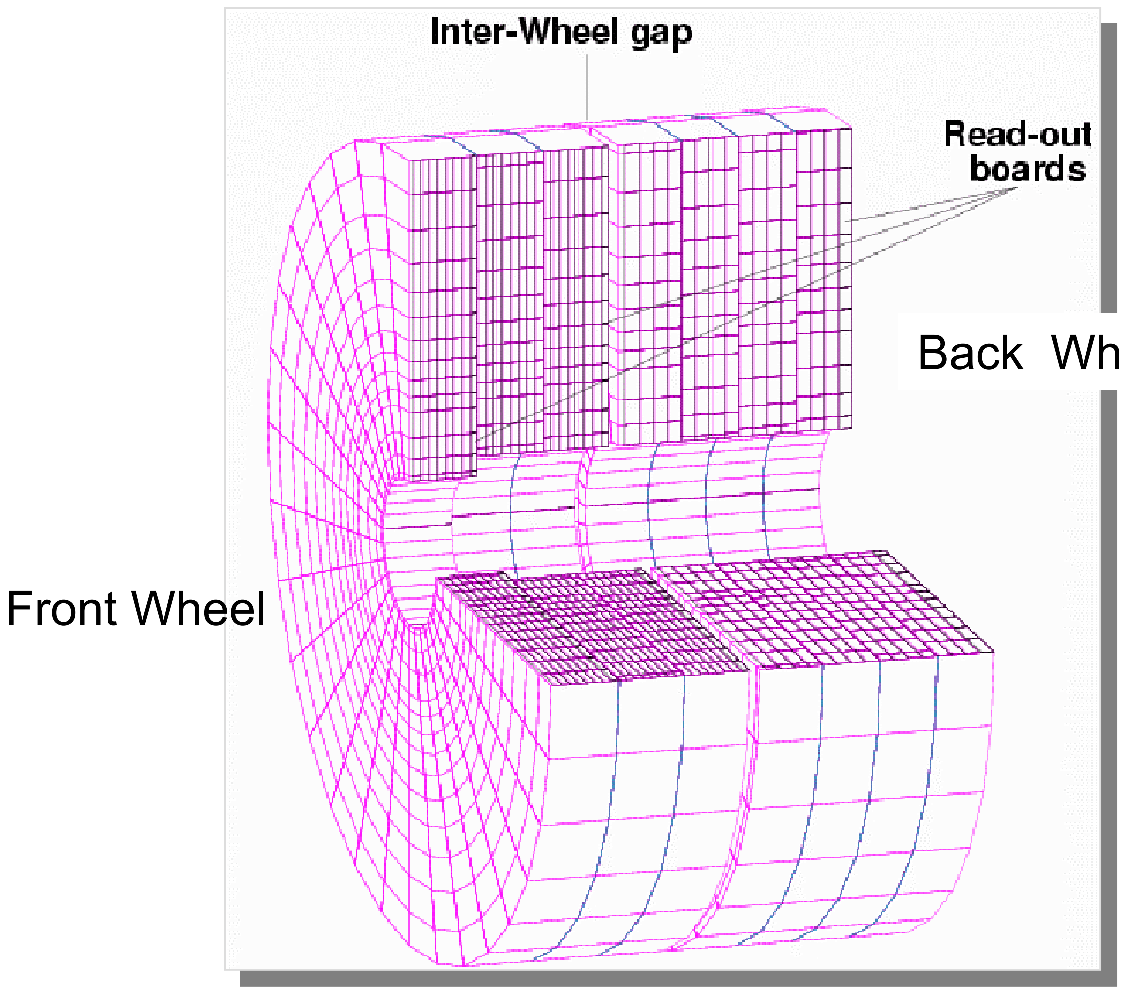
E corrected by presampler



$E_{CALORIMETER}$

Hadronic Endcap Calorimeter

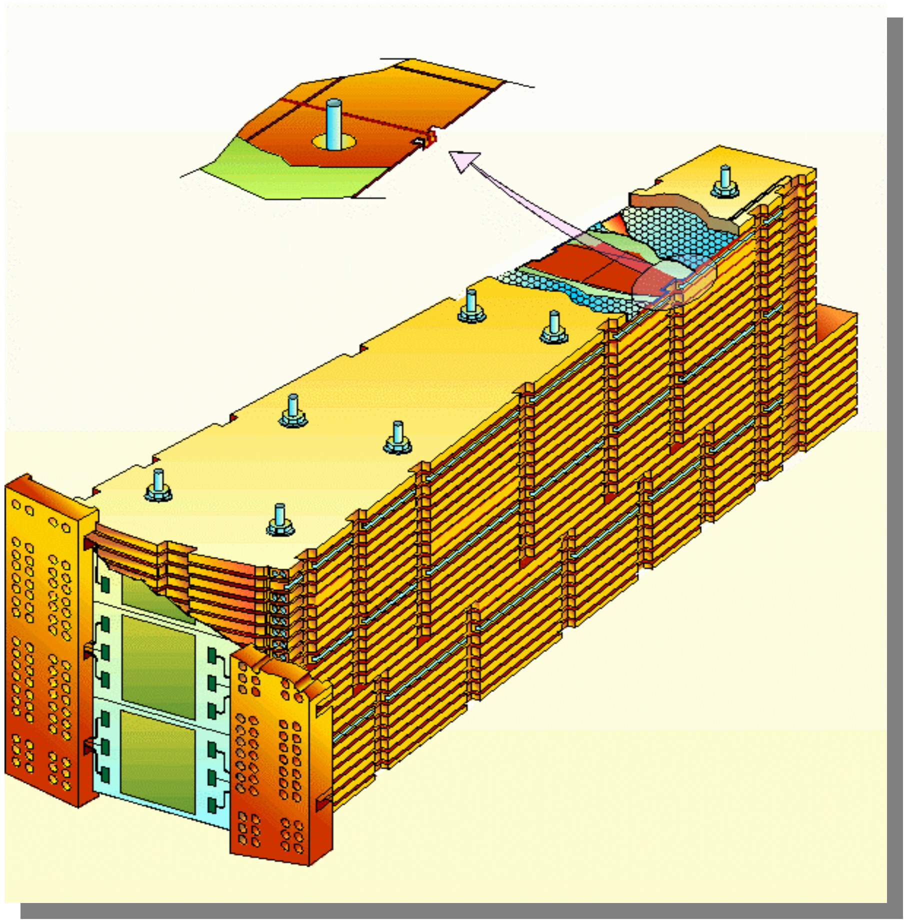
LAr-Cu sampling calorimeter covering 1.5 < γ < 3.2

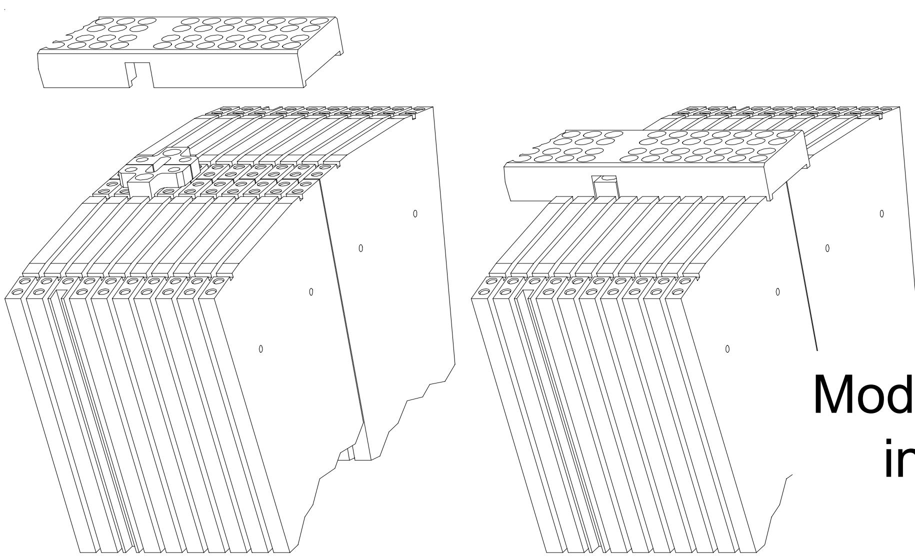


Composed of 2 wheels per end, 32 modules per wheel
Front wheel:67 t25 mm Cu plates
Back wheel:90 t50 mm Cu plates

Channel count for both endcaps
Front1536
Middle1472
Back1408
Total4416

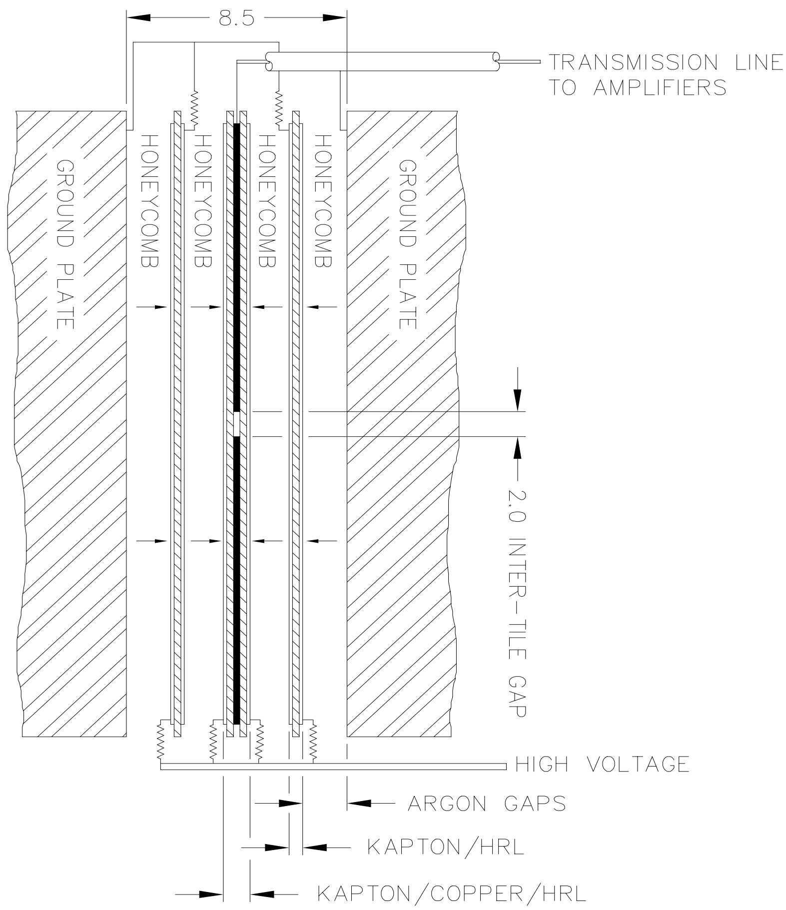
HEC Module Structure





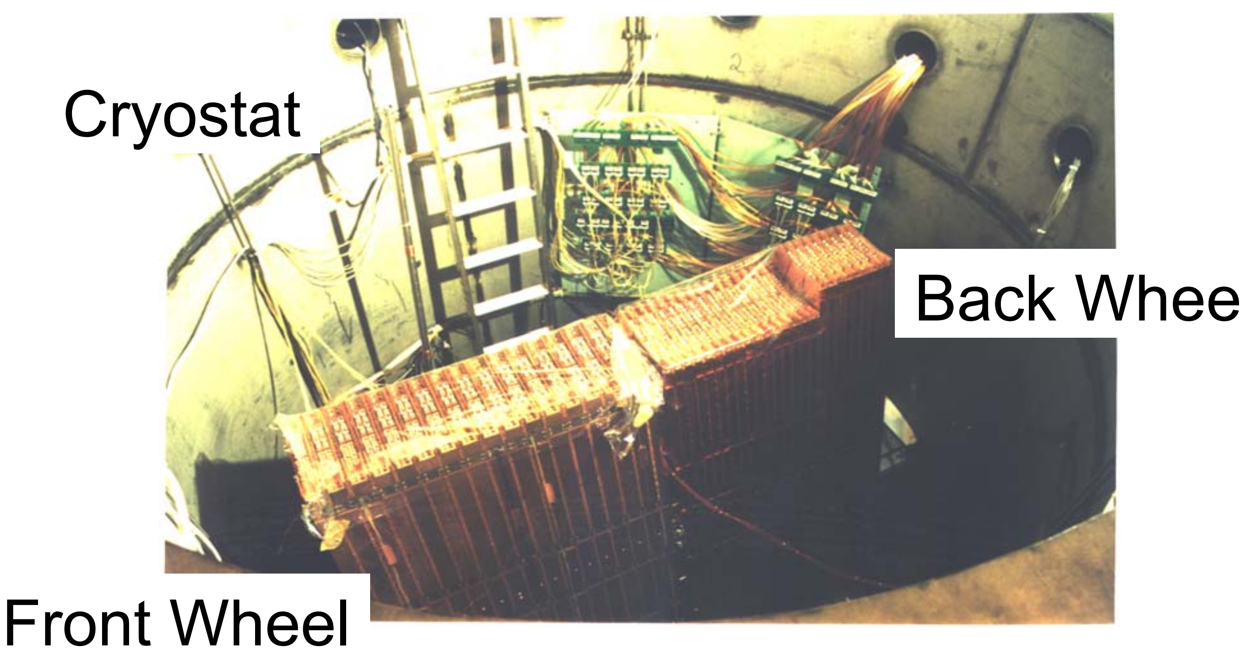
Module Assembly
into Wheels

HEC Electrode Structure

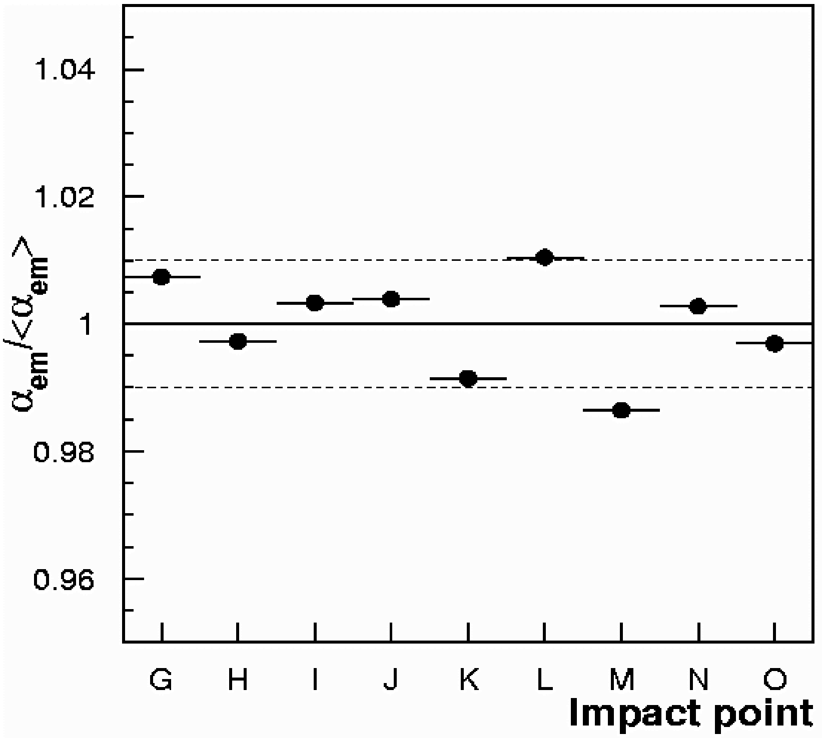


Distance between Cu plates	8.5 mm
Liquid argon gaps	1.954 mm
Honeycomb thickness	1.774 mm
Pad and EST board thickness	0.685 mm

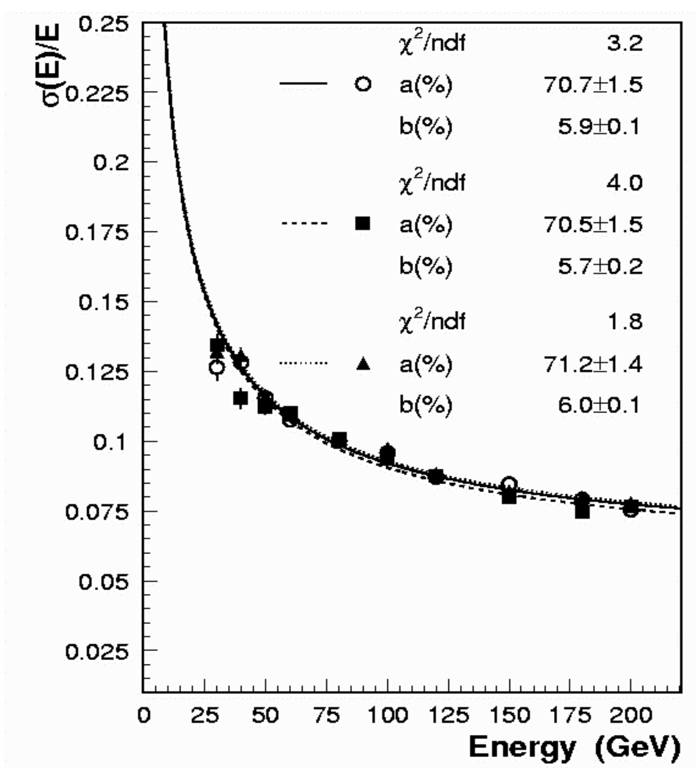
HEC Module Assembly for Testbeam



Summary of HEC Testbeam Results

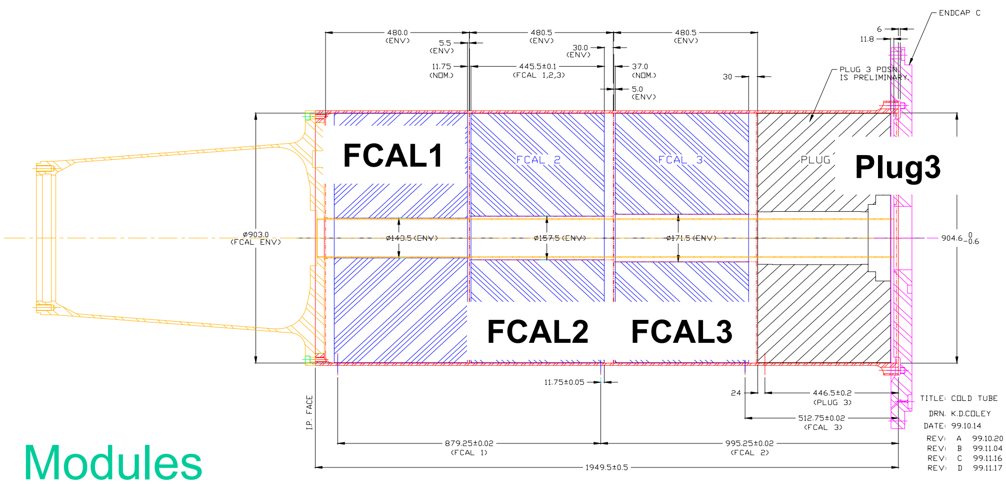


Module Uniform ~ 1%



Energy Resolution

Forward Calorimeter



Modules

0.9 m Diameter

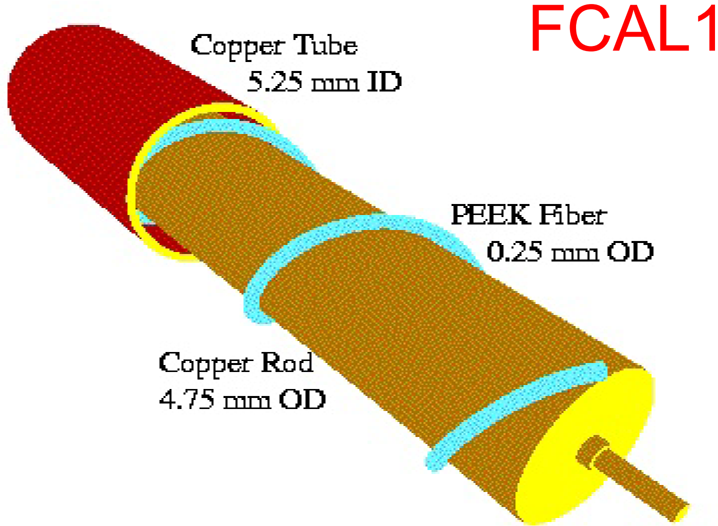
.45 m long

	FCAL1	FCAL2	FCAL3
η_{min}	3.0	3.1	3.2
η_{max}	4.9	4.9	4.9
Absorber material	Cu	W	W
Mass (t)	2.3	4.1	4.0
dE/dx sampling %	1.49	1.36	1.68
Depth (λ)	2.6	3.5	3.4
Gap width (mm)	0.25	0.375	0.50
Drift time (ns)	50	75	100

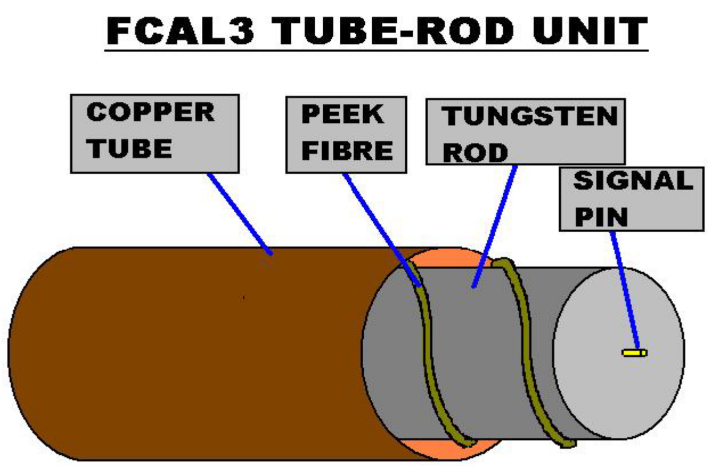
Channel count for both ends: 2822

FCAL Electrode Structure

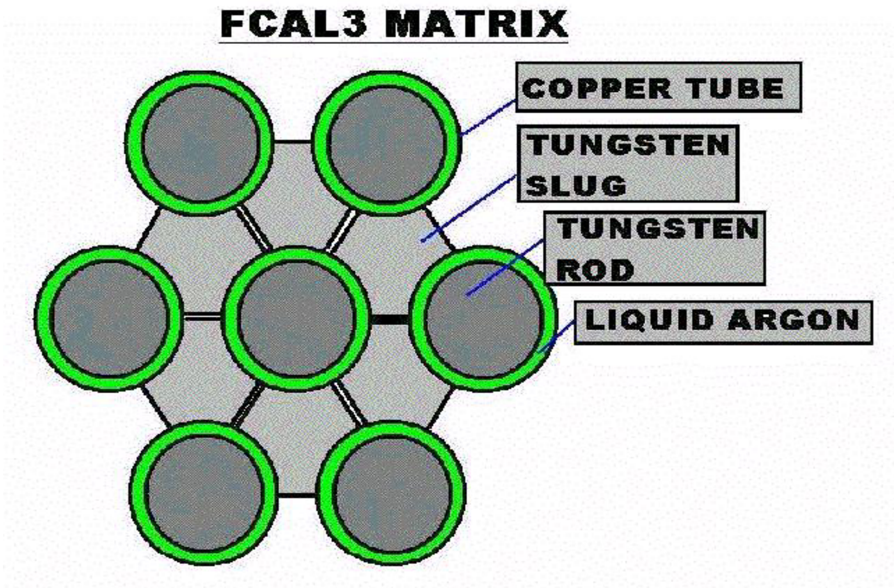
FCAL1



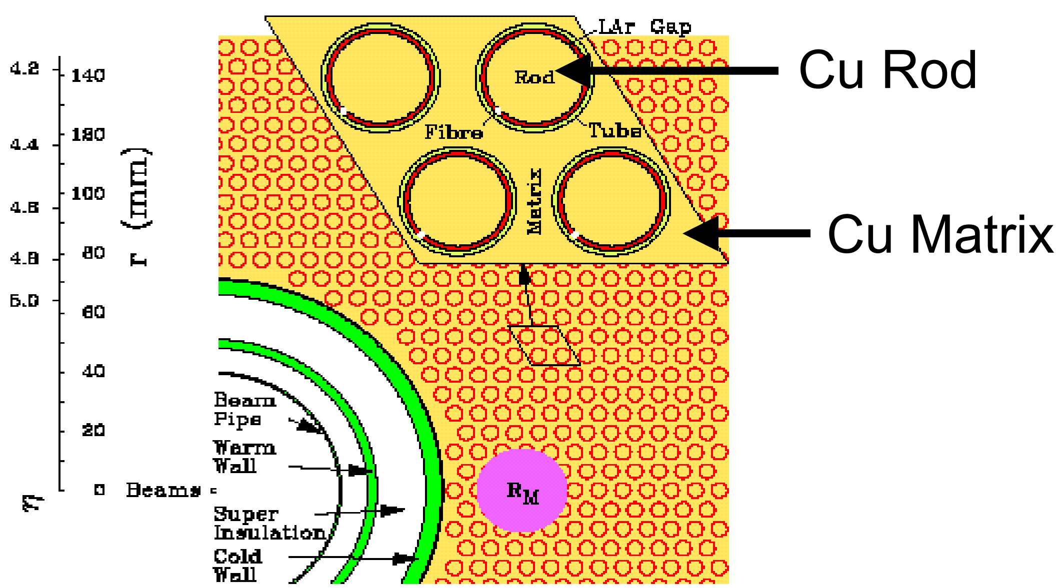
FCAL2/3



Tungsten Module Concept

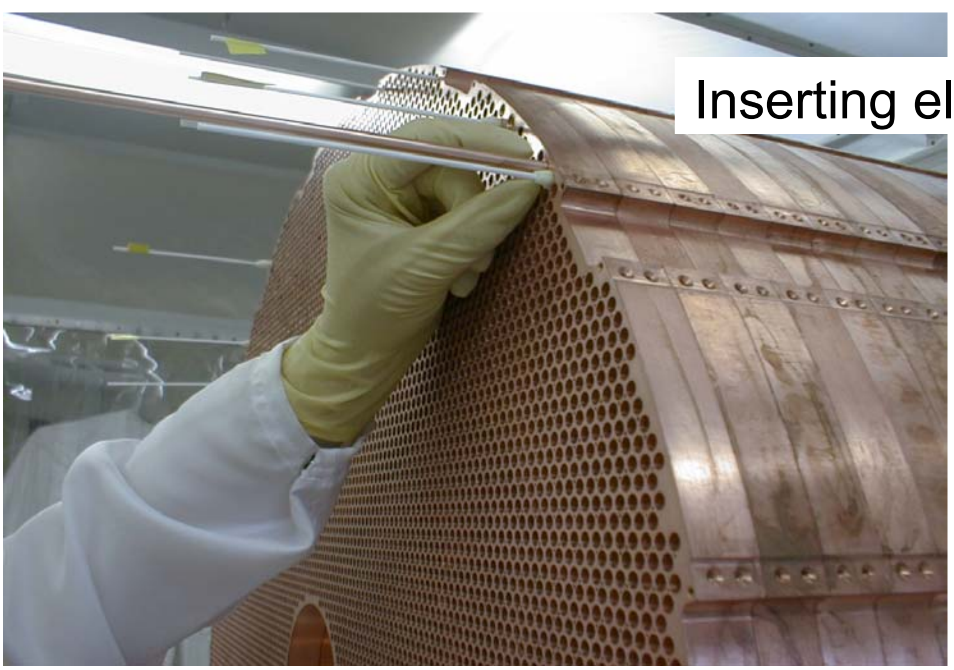


Copper Module Concept



FCAL1 Module

Stack of Cu Plates



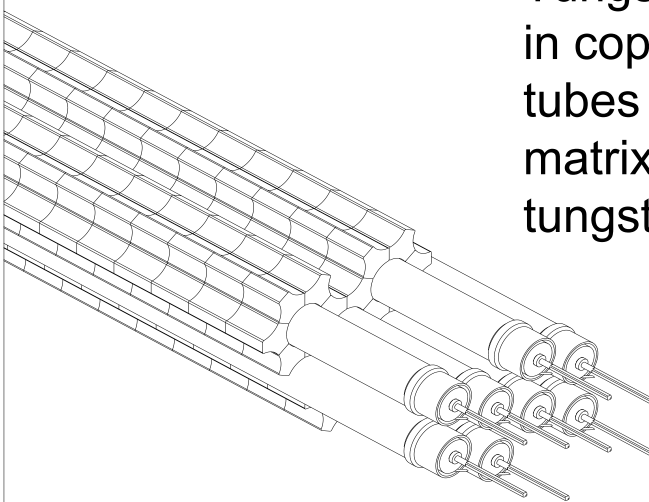
Inserting electrode tube

FCAL2 Assembly

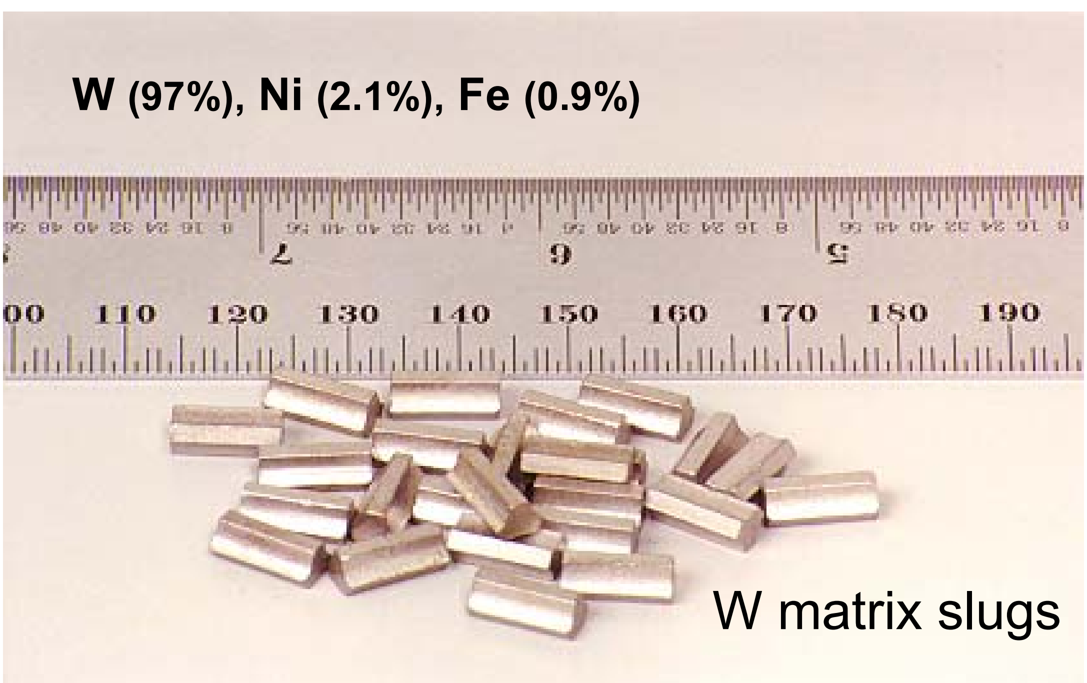
March 2001

September 2001

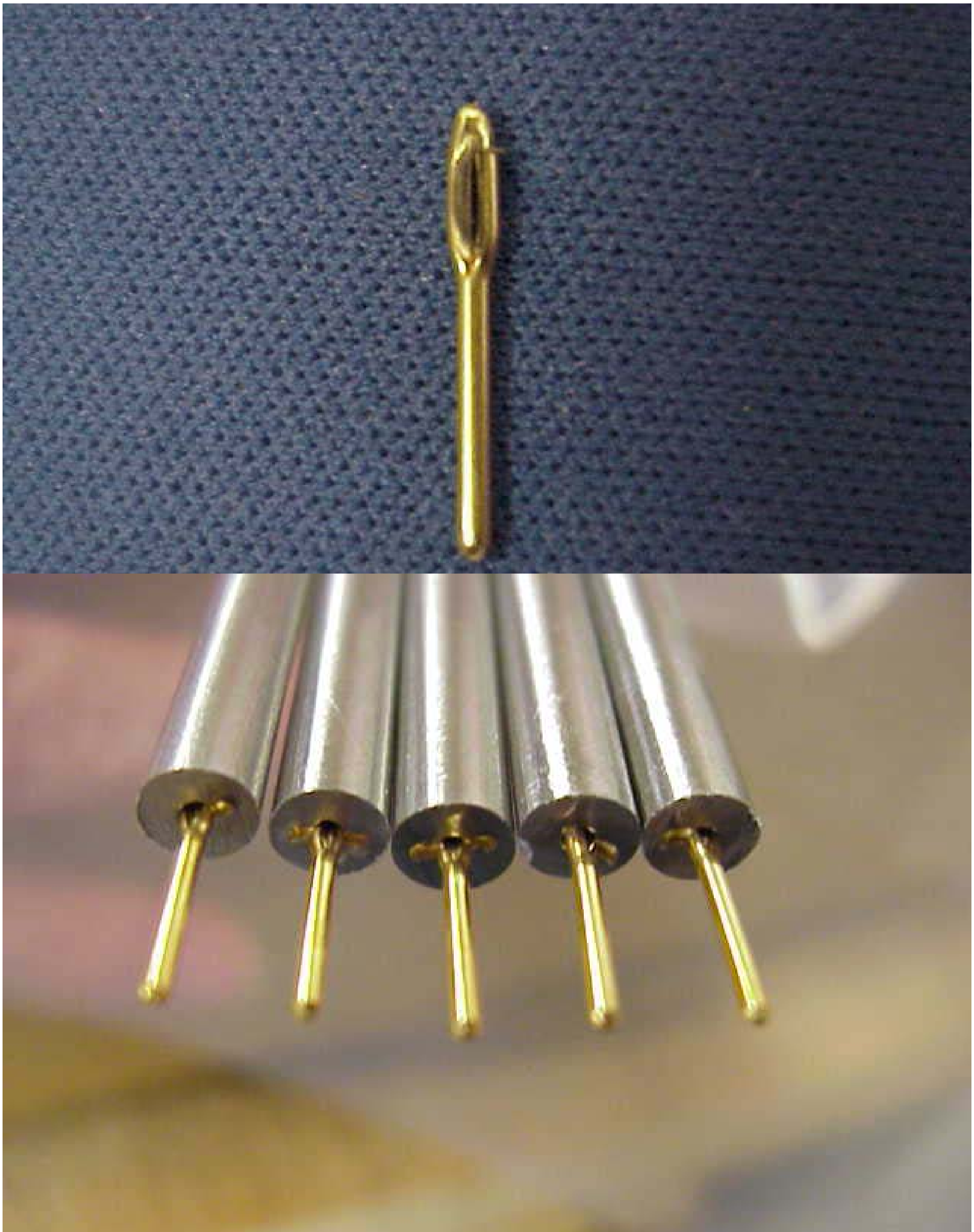
Forward Calorimeter Principle



Tungsten rods in copper tubes in a matrix built of tungsten slugs

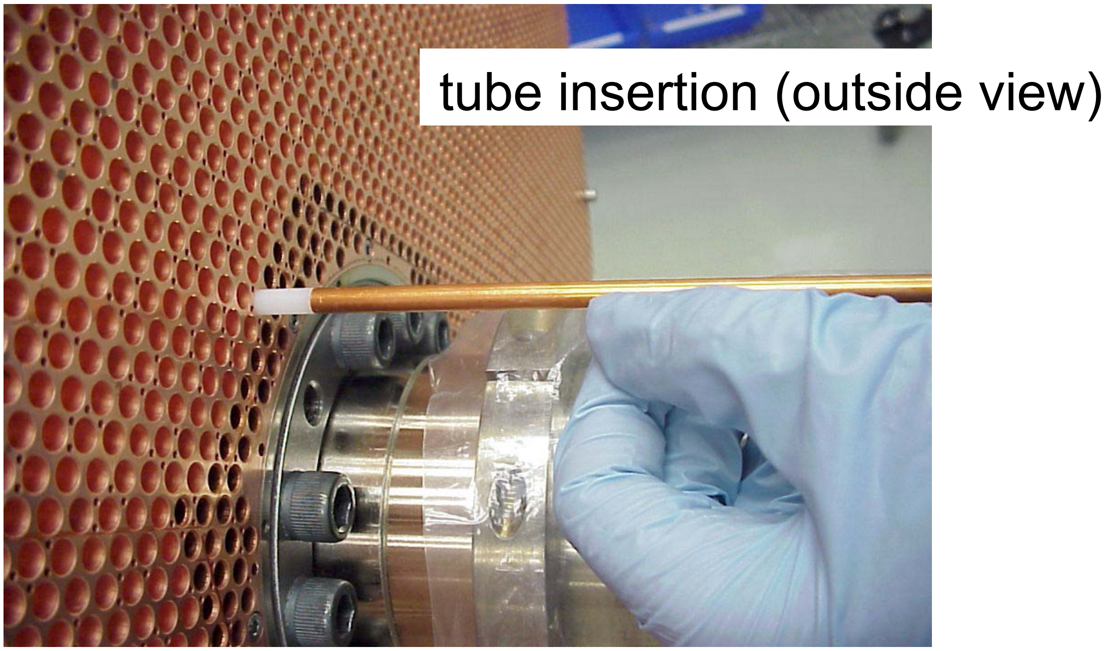


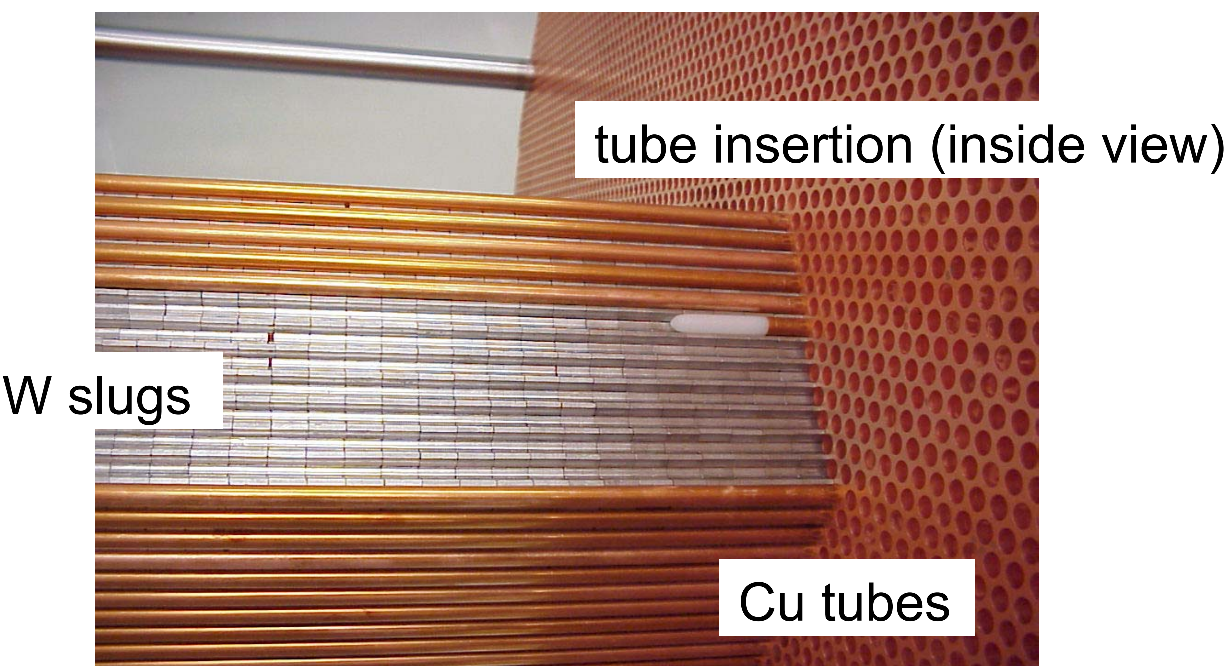
FCAL2 W Anode Rods and Signal Pins



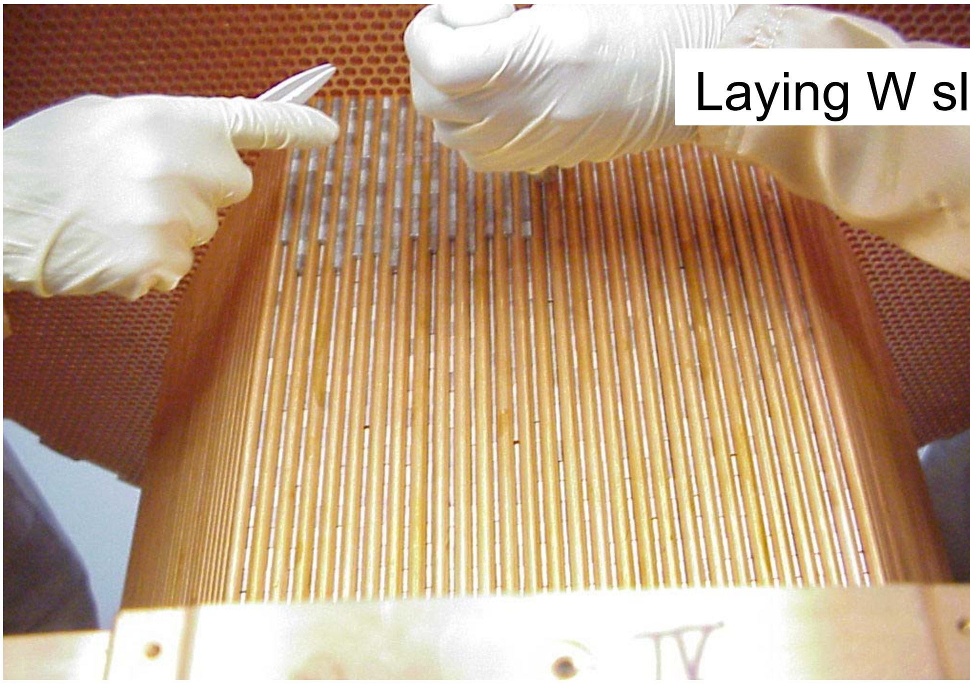
R.S. Orr ATLAS
Liquid Argon Calorimetry
19 October 2001

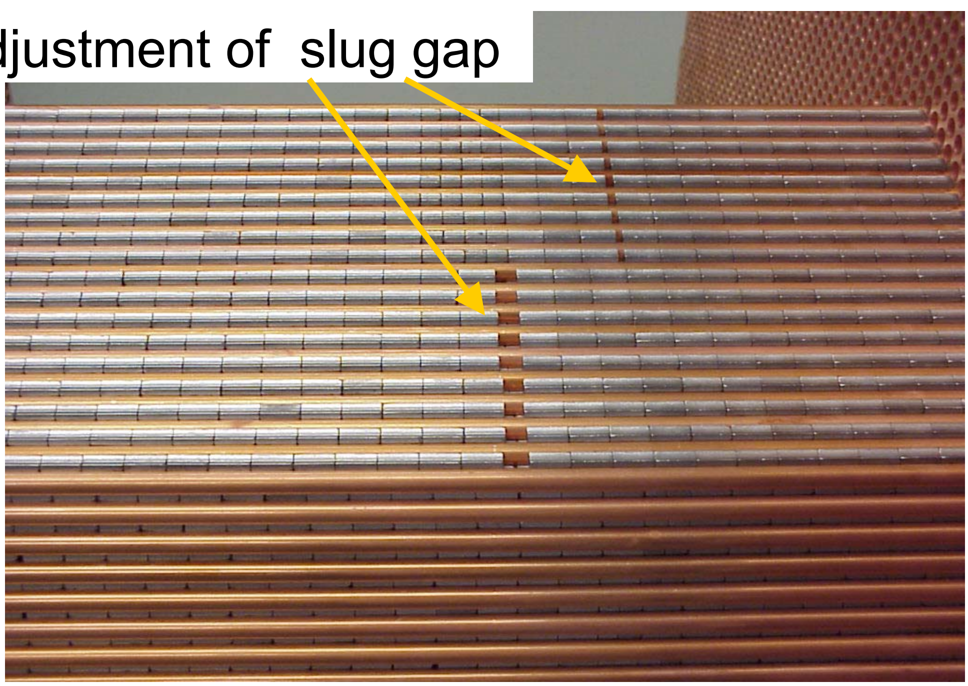
Tungsten Module Assembly





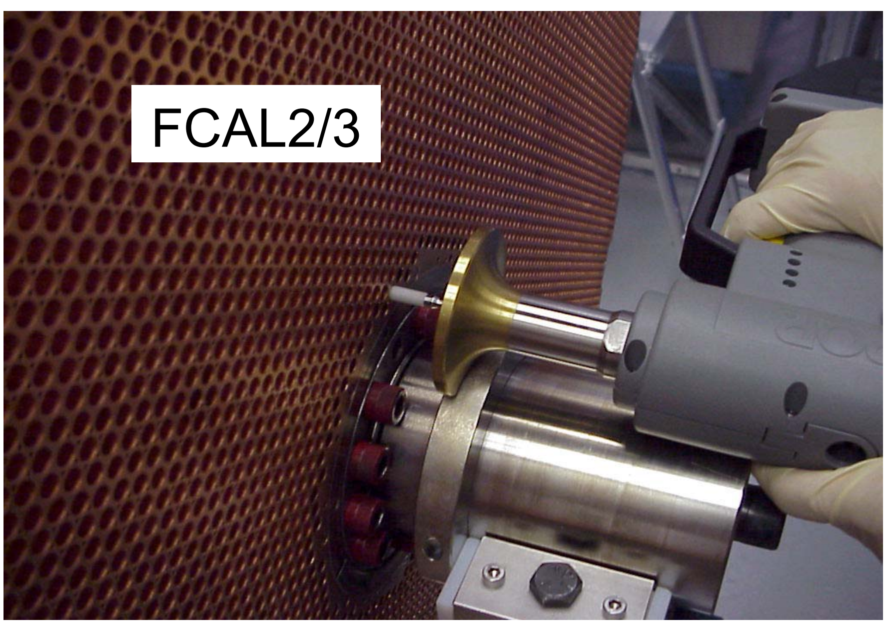
Tungsten Module Assembly





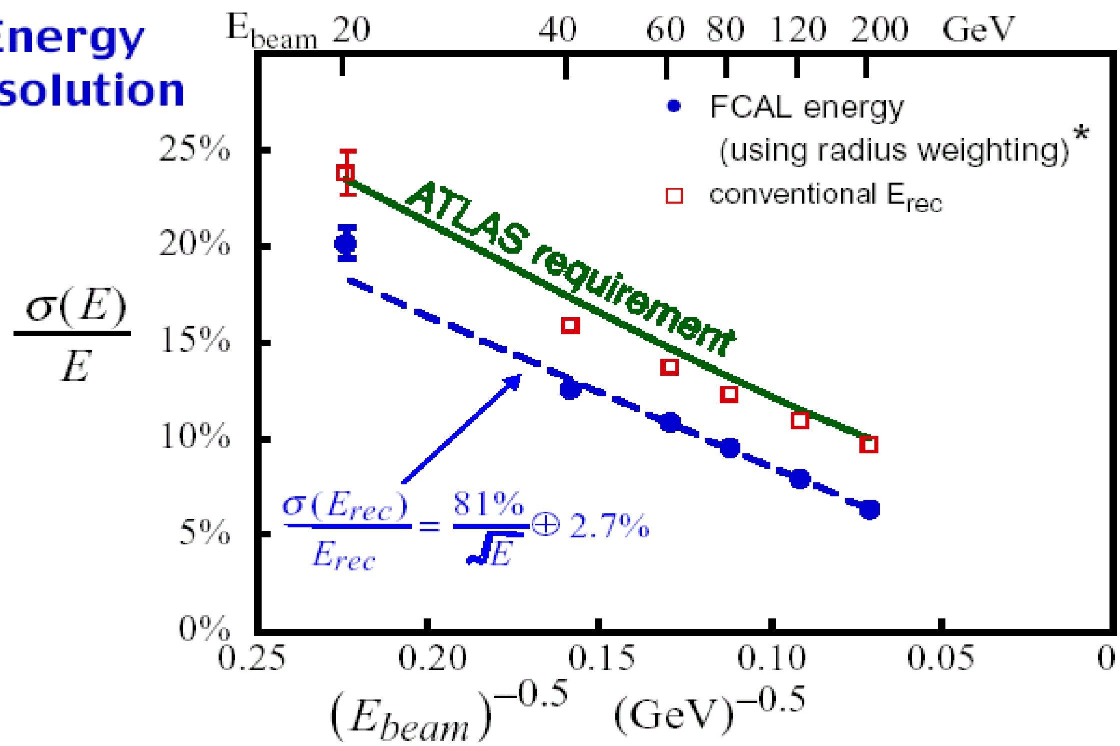
Tube Swaging

Swaging ensures good electrical and thermal connection between tubes and endplates. Also provide mechanical strength at inner and outer regions.

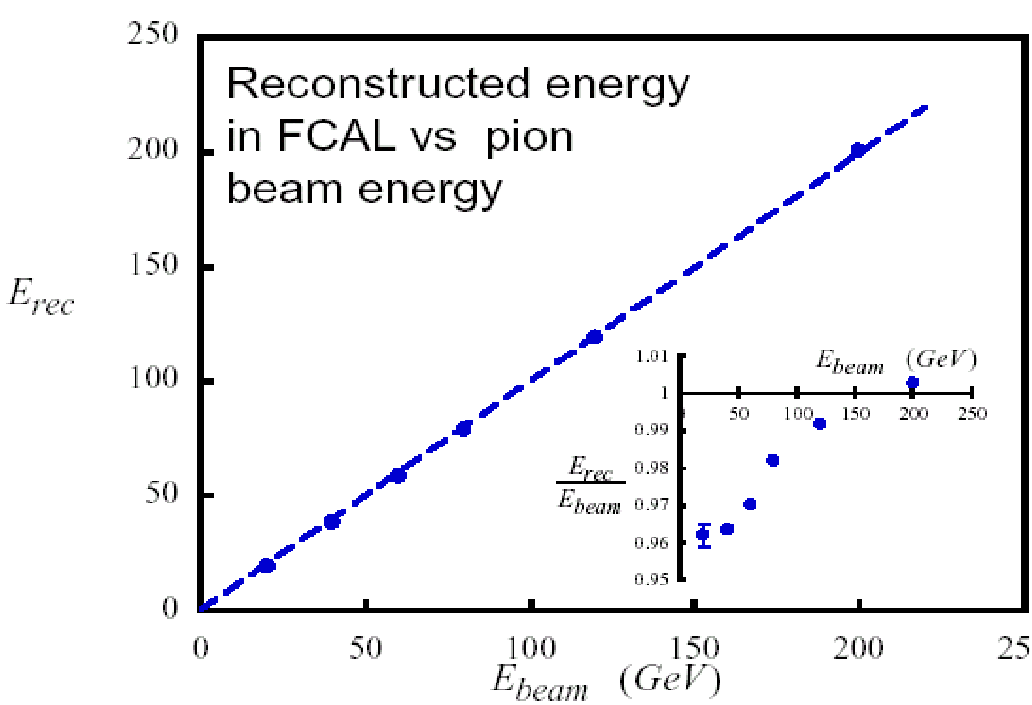


1998 Test Beam

Energy Resolution



FCAL Hadronic Linearity



Summary

- All ATLAS Liquid Argon are in production after lessons learned in test beam (which continues).

- Current Schedule:

    - Endcap C Assembly/Integration

• EMEC-C	March 2002 - Sept 2002
• HEC-C	March 2002 - Feb 2003
• FCAL-C	March 2003
• Cold Test	March 2003 - Sept 2003
• In Pit	Nov 2003

    - Endcap A Assembly/Integration

• EMEC-A	Feb 2003 - Oct 2003
• HEC-A	Oct 2002 - Dec 2003
• FCAL-A	Jan 2004
• Cold Test	Feb 2004 - Aug 2004
• In Pit	Oct 2004

    - Barrel Assembly/Integration

• Installation	July 2002 - March 2003
• Cold Test	July 2003 - June 2004
• In Pit	Jan 2004