Canadian Association of Physicists - Congress

Quebec – June 2-5 2002

Overview of ATLAS Canada Calorimeter Projects

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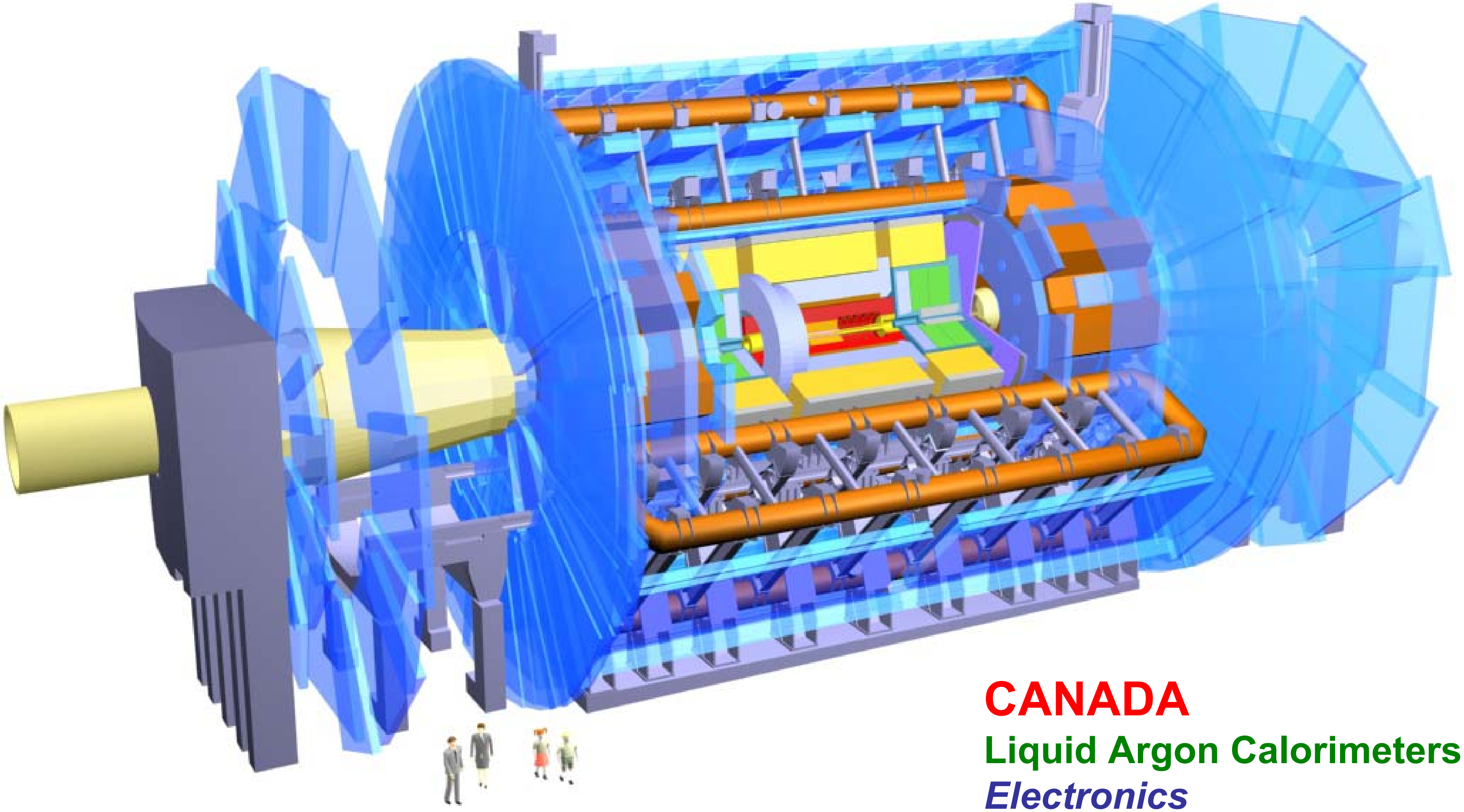
University of Toronto
on behalf of the
ATLAS Canada Group

Progress of the ATLAS Canada Detector Projects



CANADA

Liquid Argon Calorimeters

Electronics

Computing & Event Filters

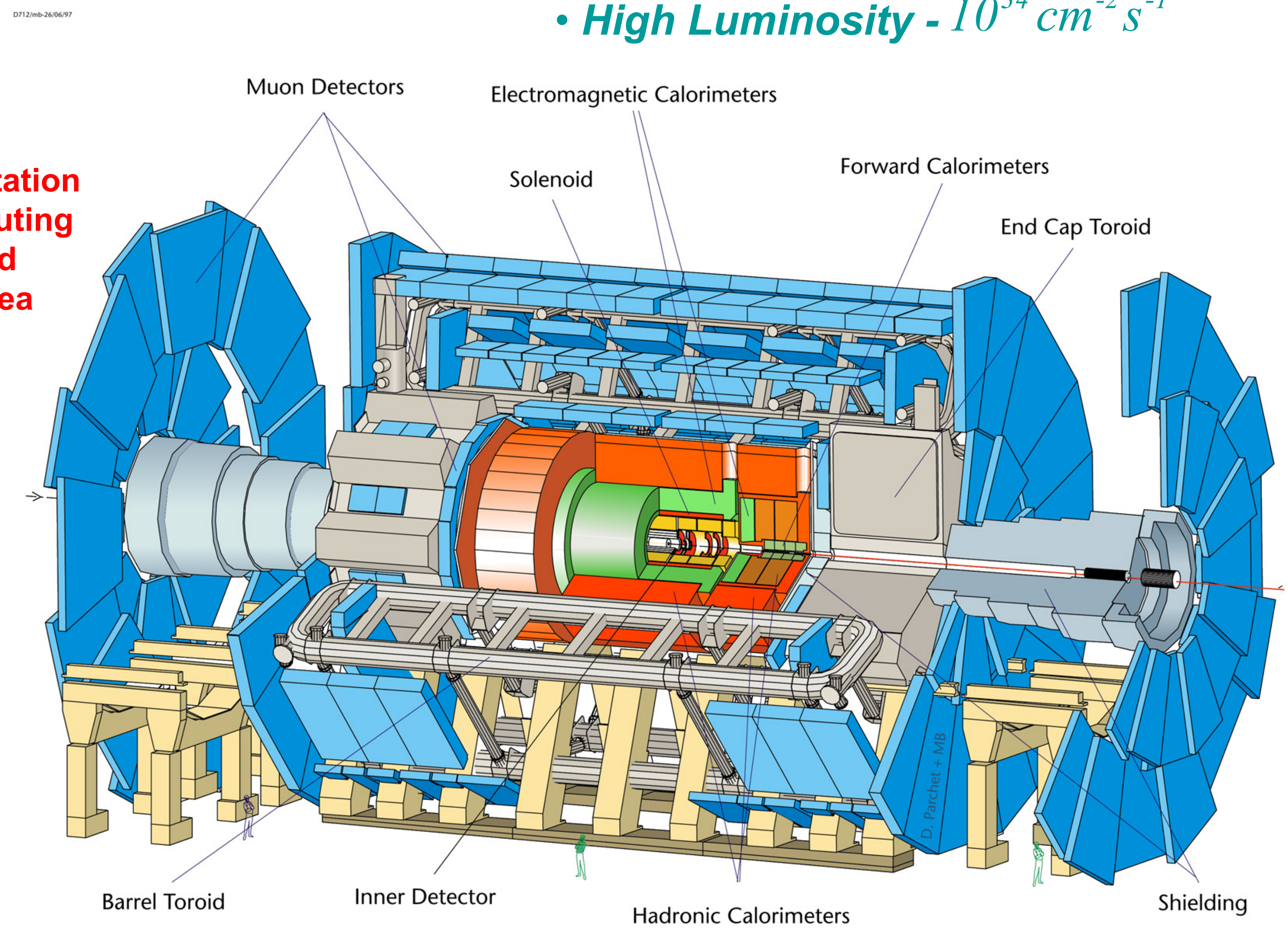
Physics Studies

Construction Status of the Detector Components

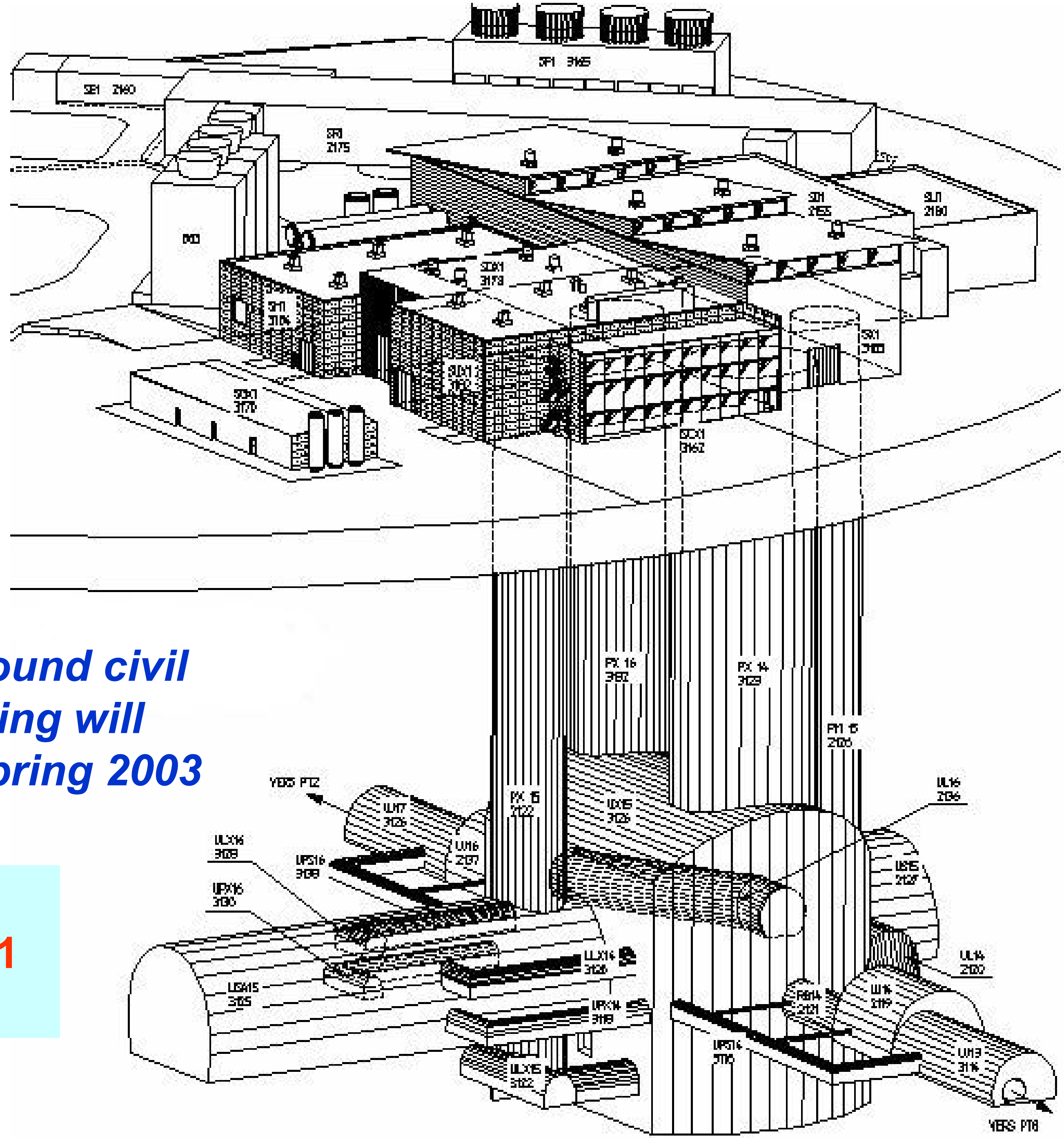
LHC

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

Magnet system
Inner detector
Calorimetry
Muon instrumentation
TDAQ and computing
Infrastructure and
experimental area



Experimental Area



Most of the surface building will be handed over to ATLAS this year (Oct-Nov 2002)

Underground civil engineering will end in Spring 2003

ATLAS will start installation at Point-1 in April 2003

Excavation will end in May 2002

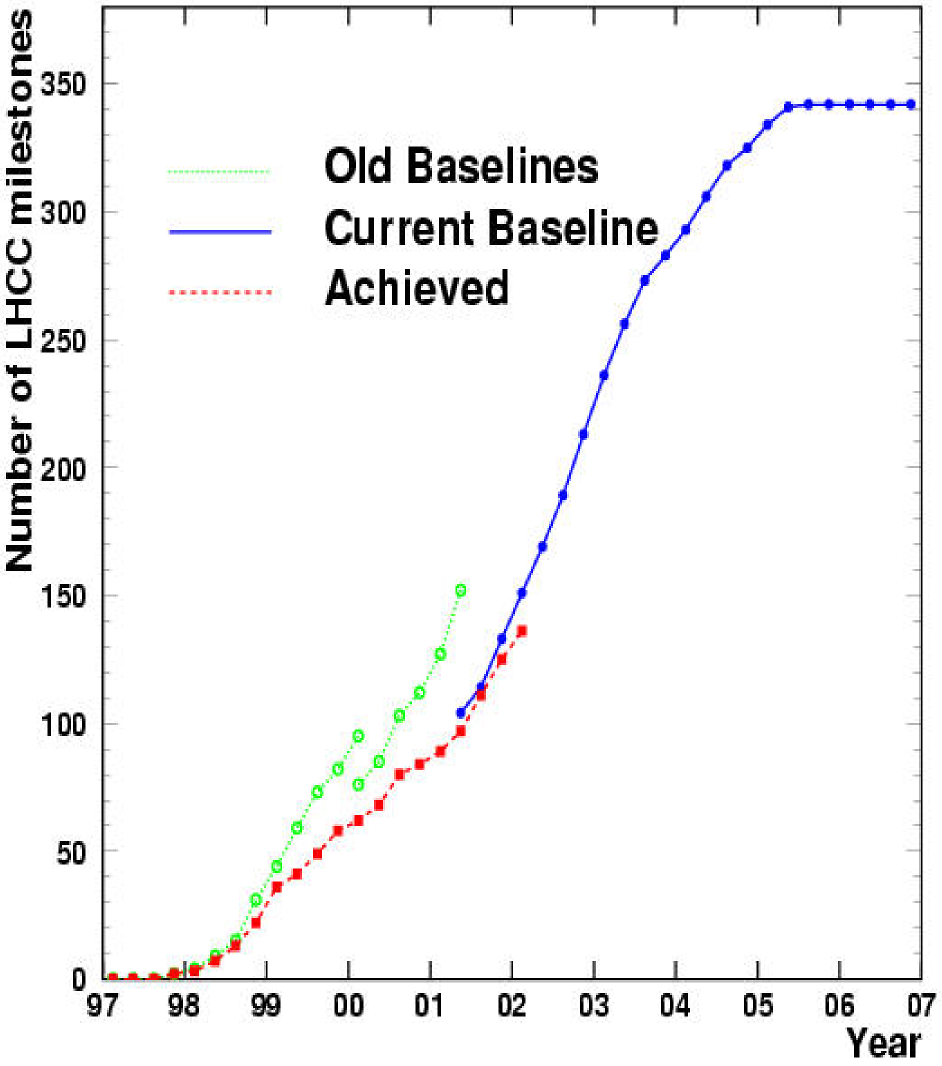
Status of ATLAS Overall

- LHCC Milestones = Progress Monitor.

- Passed milestones compared to the planning.

- Adjusted spring 2001, after the LHC project schedule change at that time.

- BEAM IN SPRING 2007



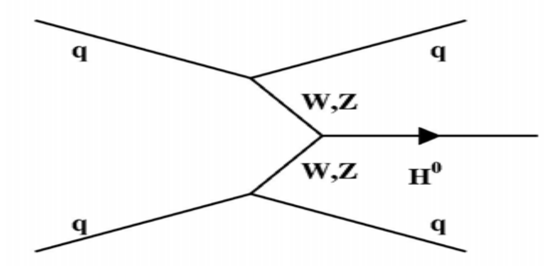
Status of ATLAS Overall

Financial Situation - Initial Staged Detector

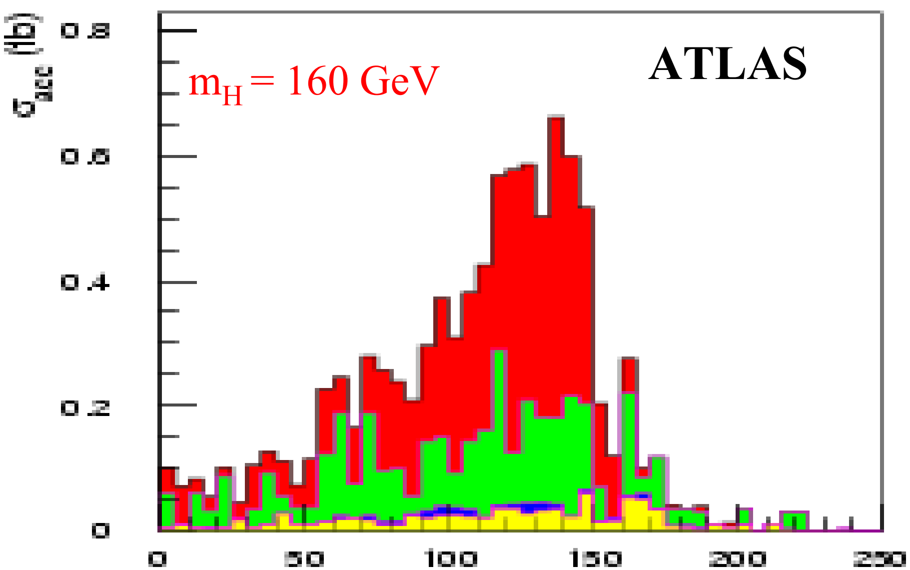
- **Discovery Potential for Higgs Degraded by 10%**
- **Need 20% more Lumi to Compenstate**

Staged items	Main impact expected on	Loss in significance
One pixel layer	$ttH \rightarrow ttbb$	~ 8%
Outermost TRT wheels + MDT	$H \rightarrow 4\mu$	~ 7%
Cryostat Gap scintillators	$H \rightarrow 4e$	~ 8%
MDT	$A/H \rightarrow 2\mu$	~ 10% for m ~ 300 GeV

Higgs production via Vector Boson Fusion



$\sigma \approx 4$ pb is ~20 % of the total Higgs cross-section for $m_H \sim 120$ GeV
However: distinctive signature of two very forward jets + little additional jet activity (tools against background)

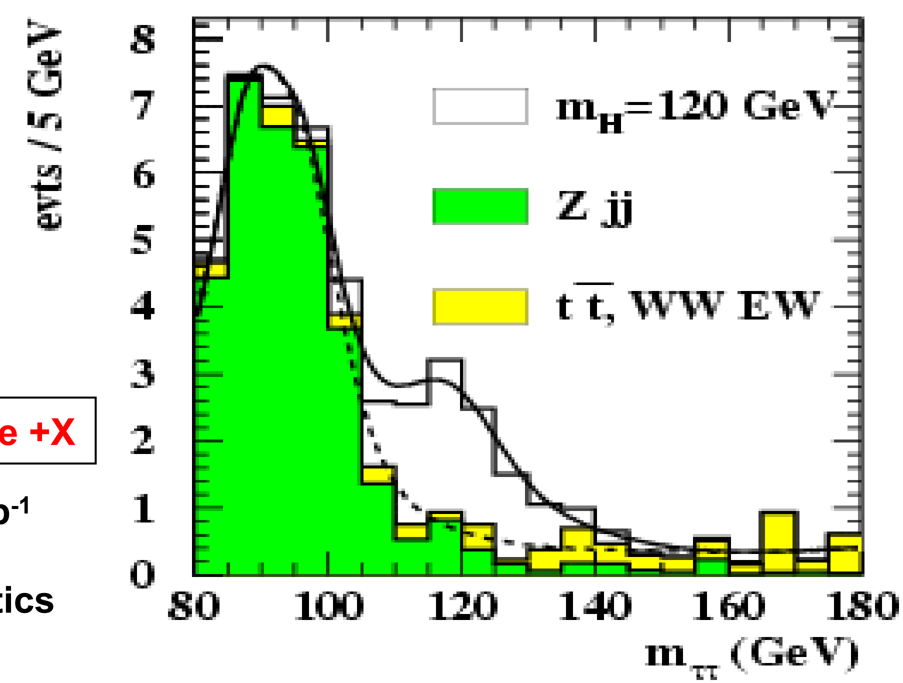


$$m_T = \sqrt{2\, p_T^{\ell\ell}\, E_T^{miss}\, (1 - \cos\Delta\varphi)}$$

qqH → qqWW → qq μνeν

$S/\sqrt{B} \sim 8$ for 10 fb^{-1}
$m_H = 160$ GeV

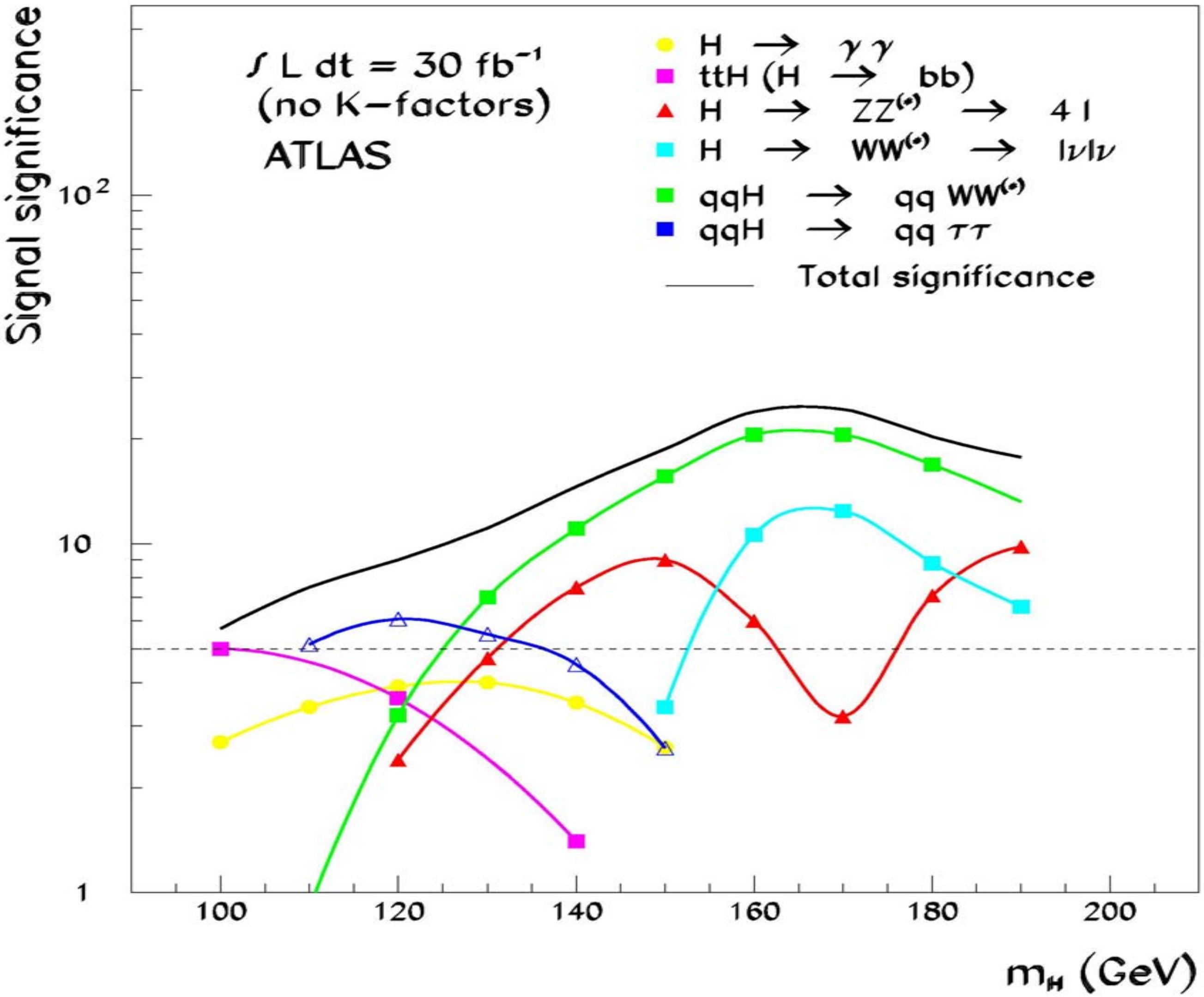
ATLAS, 30 fb^{-1}



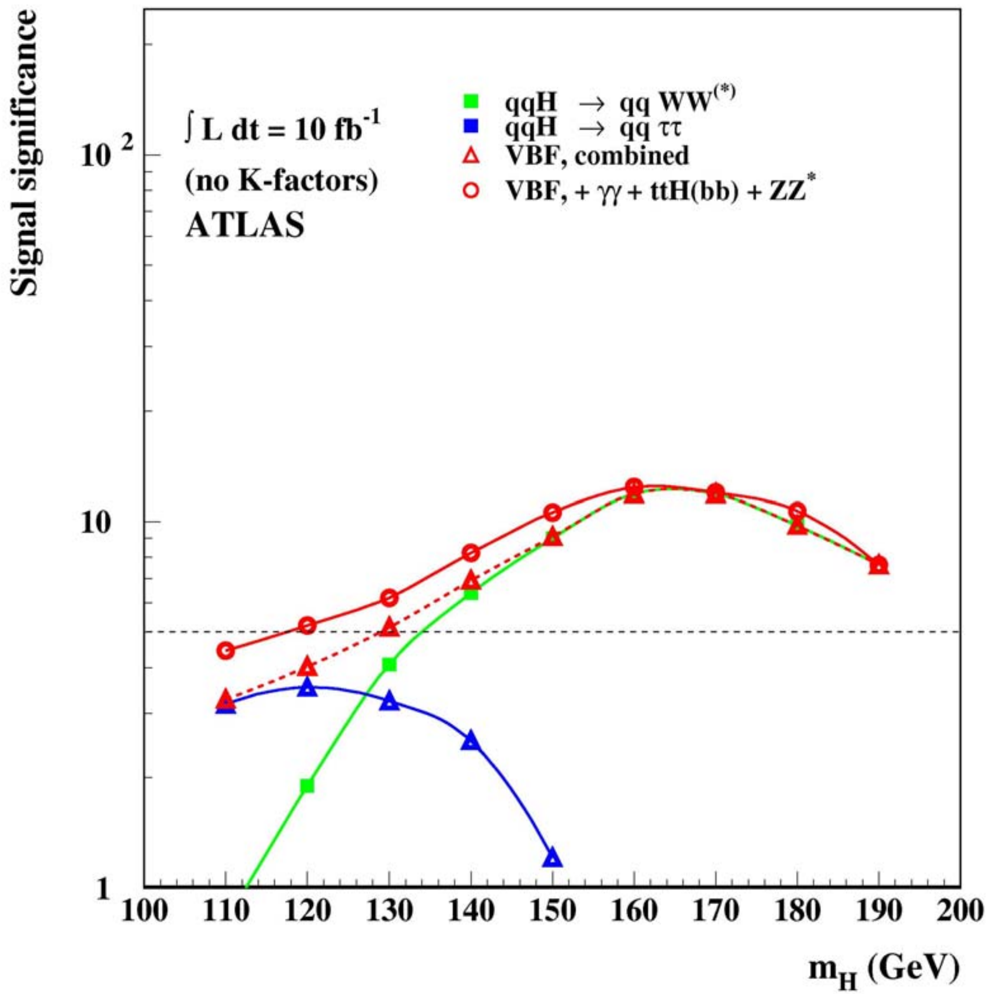
qqH → qq ττ → qqμe +X

$S/\sqrt{B} \sim 3$ for 30 fb^{-1}
$m_H = 120$ GeV
(10% B systematics included)

Higgs discovery potential for 30 fb^{-1} in the low-mass region



Higgs discovery potential for 10 fb^{-1} in the low-mass region



Vector boson fusion channels (in particular WW*) are discovery channels at low luminosity

For 10 fb^{-1} ATLAS alone:

≥ 5 s significance for $120 \leq m_H \leq 190$ GeV

by combining standard $H \to \gamma\gamma$ and $ttH \to ttbb$ channels with VBF channels

VBF channels improve the sensitivity significantly in the low mass region

Several channels available over the full mass range (important for Higgs parameter determination)

LAr Calorimetry

- 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

- Physics Requirements

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

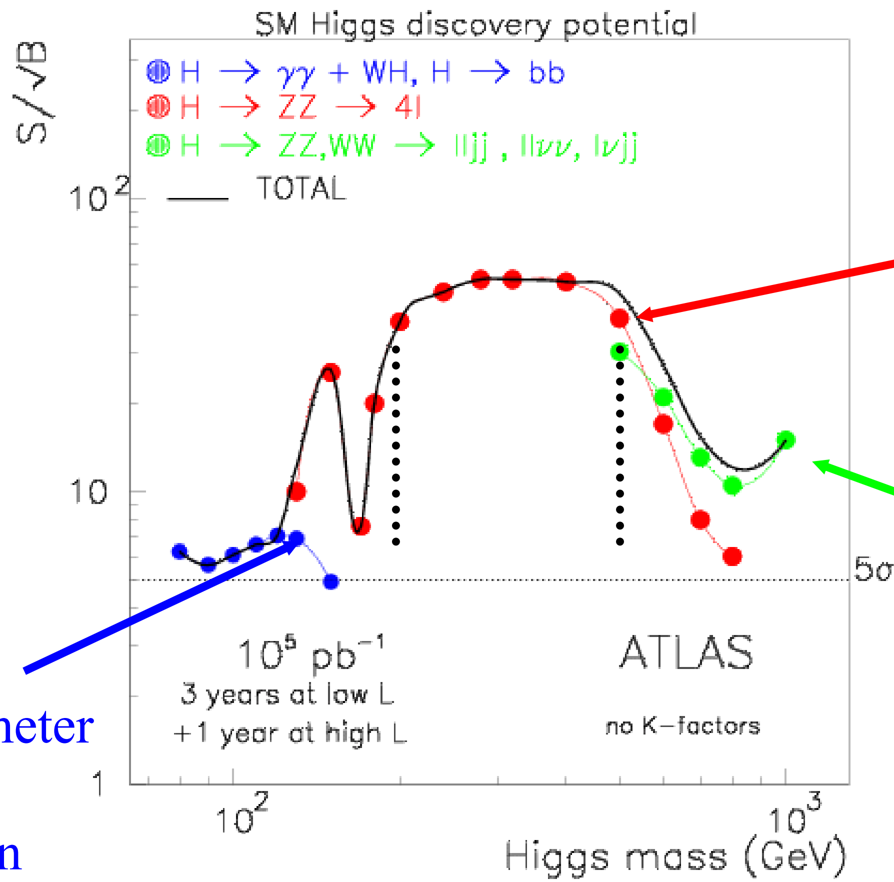
  Reconstruction $P_{\mathrm{e}}, P_{\gamma}, P_{\mathrm{jet}}, E_{\mathrm{T}}^{\mathrm{miss}}, (P_{\mu})$, bunch
  Separation γ / π^0, e/π

- Mechanical consideration:

  cost
  modular construction
  installation in ATLAS

LAr Calorimetry

- Five different detectors, different technologies
- Needed for ATLAS calorimetry coverage to $|\eta| \cong 5$



H → llll
⇒ EM calorimeter

H → ZZ and H → WW
⇒ hadronic and forward calorimeters

H → γγ
⇒ EM calorimeter

WW Fusion
Tag jets in Forward Cal

LAr Calorimeter Technology Overview

Design Goals ➡ Technology

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

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

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

- **Hadronic Endcap** $(1.5 \leq |\eta| \leq 3.2)$

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

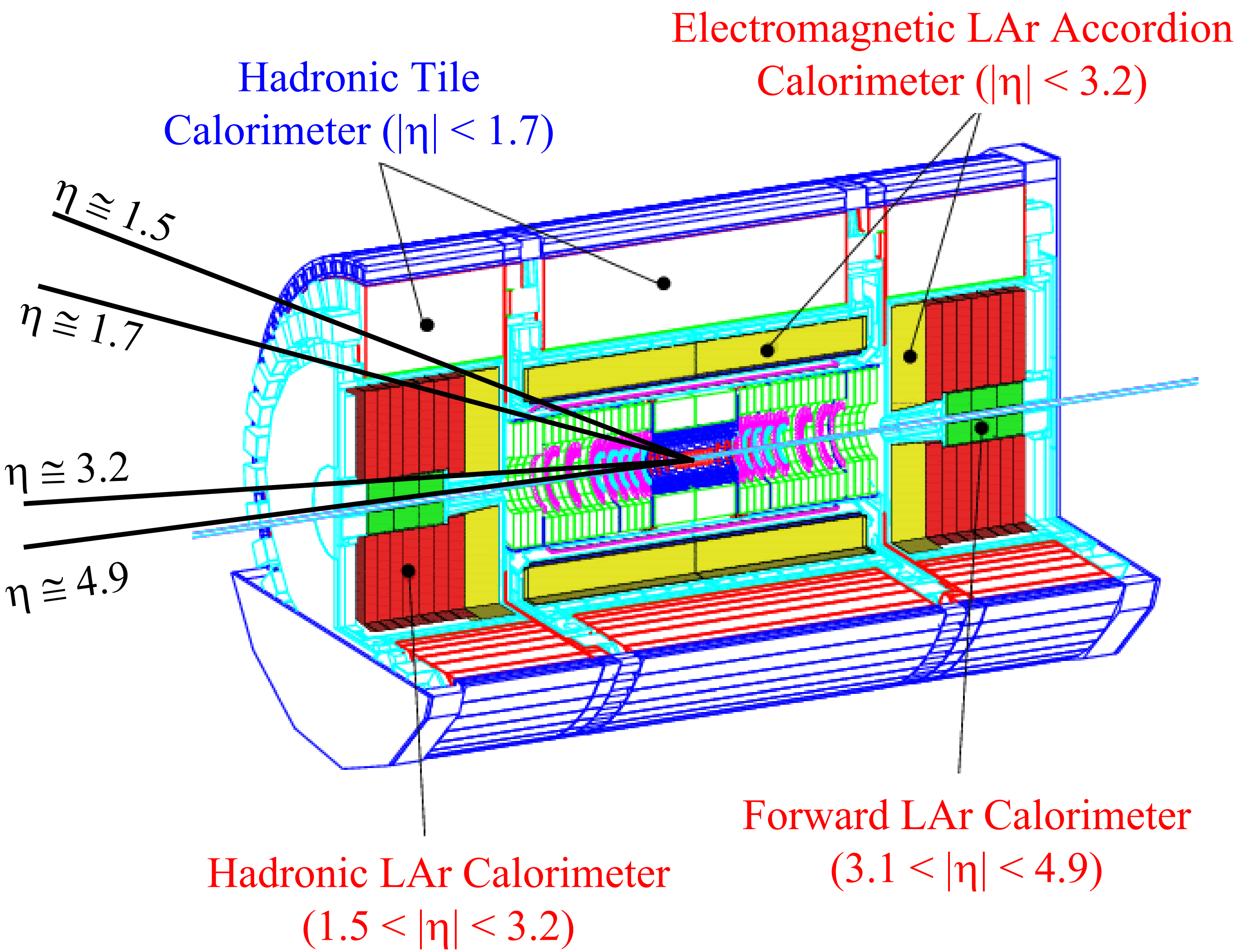
⇨ Copper/Copper-Kapton/Liquid Argon *Plate* Structure

- **Forward Calorimeter** $(3 \leq |\eta| \leq 5)$

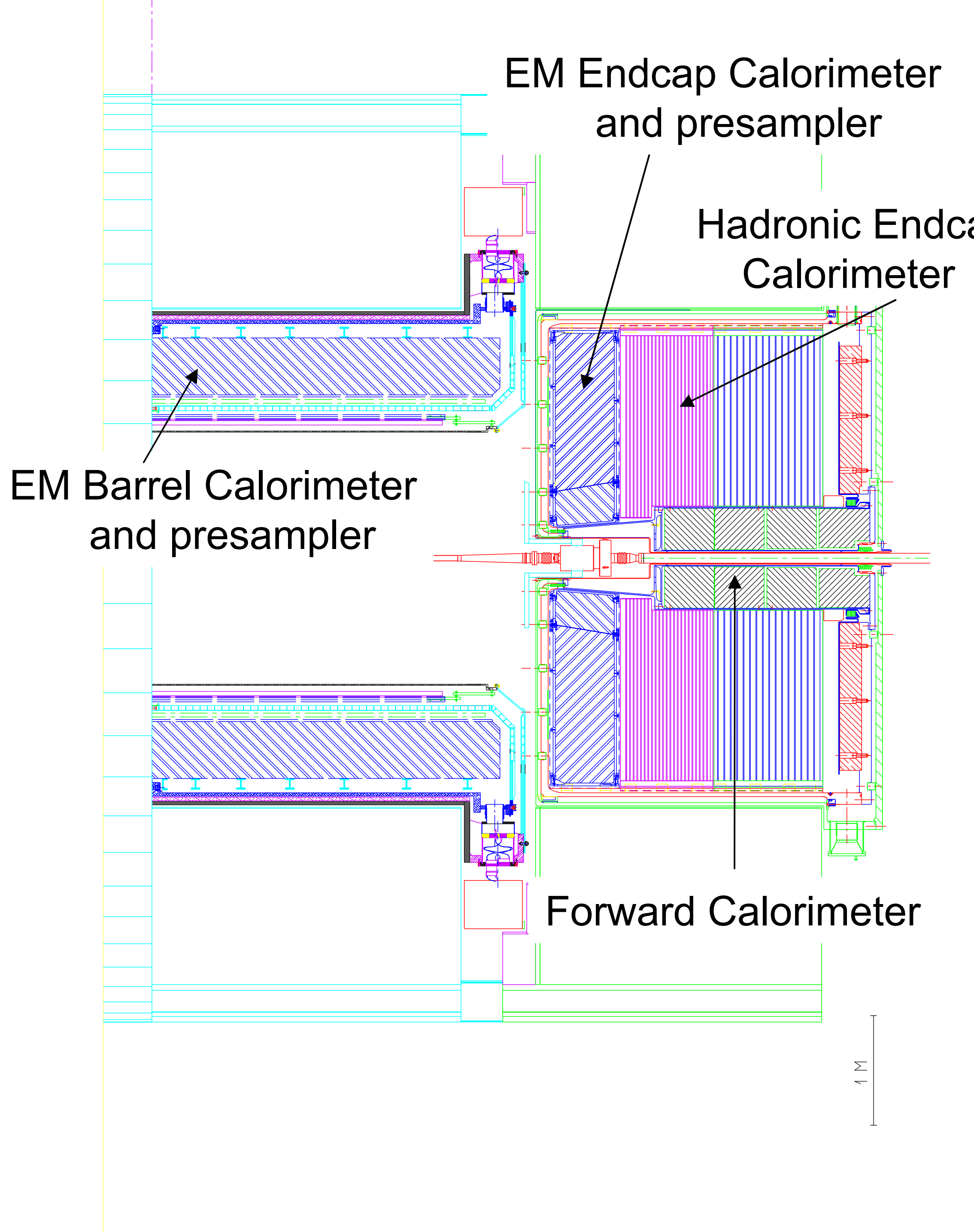
$$\frac{\sigma}{E}(\mathrm{jets}) \leq \frac{100\%}{\sqrt{E(\mathrm{GeV})}} \oplus 10\%$$

⇨ Tungsten/Copper/Liquid Argon *Paraxial Rod* Structure

ATLAS Calorimetry

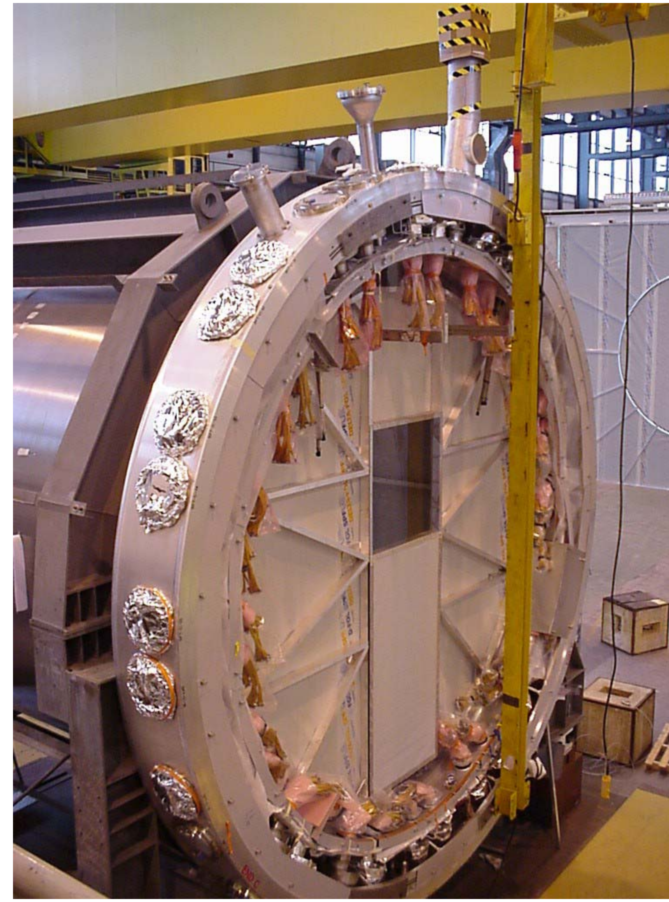


Total weight is about 4000 t



EM Endcap Calorimeter and presampler
Hadronic Endcap Calorimeter
EM Barrel Calorimeter and presampler
Forward Calorimeter
1 M

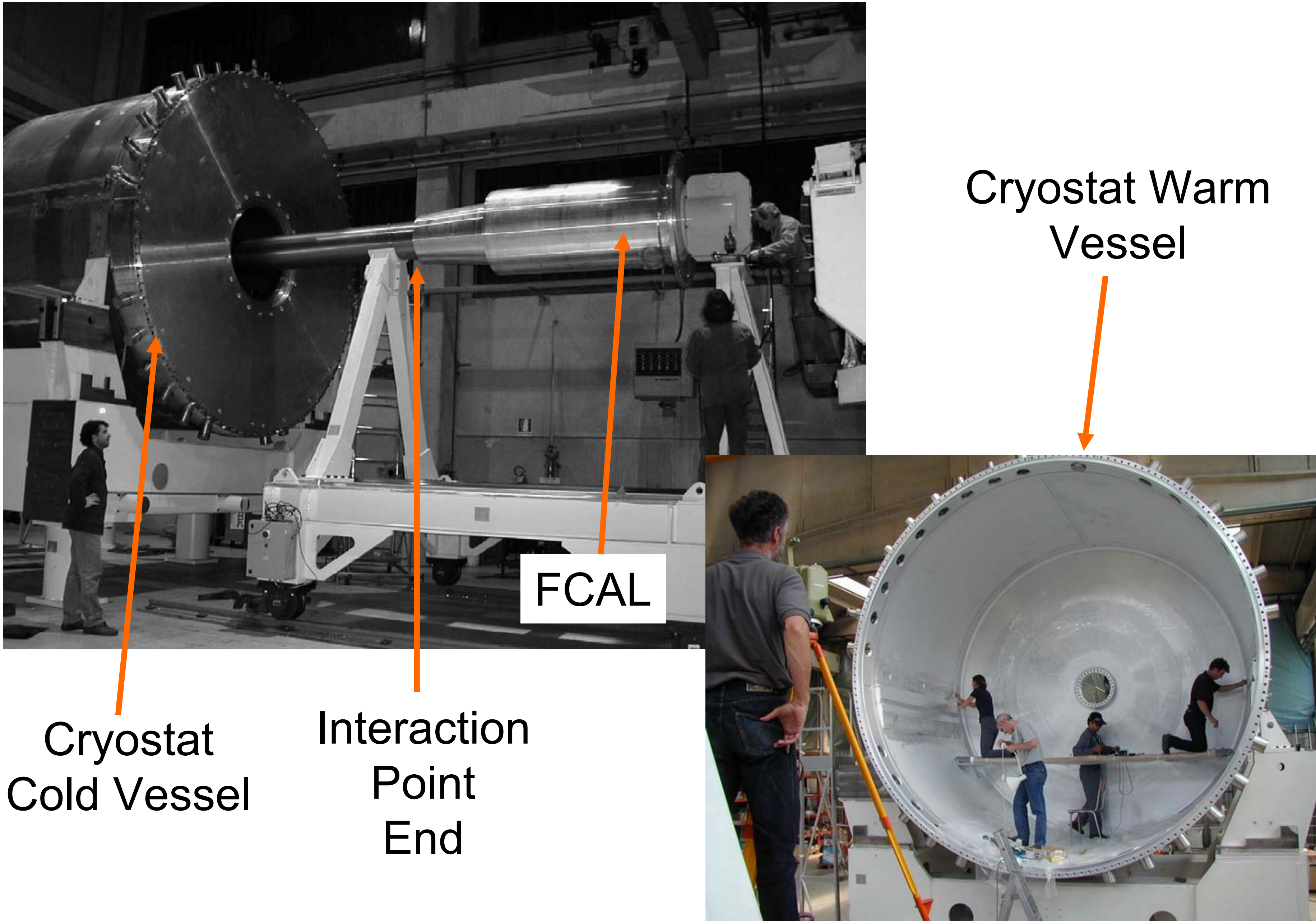
LAr Barrel Cryostat and Feedthroughs



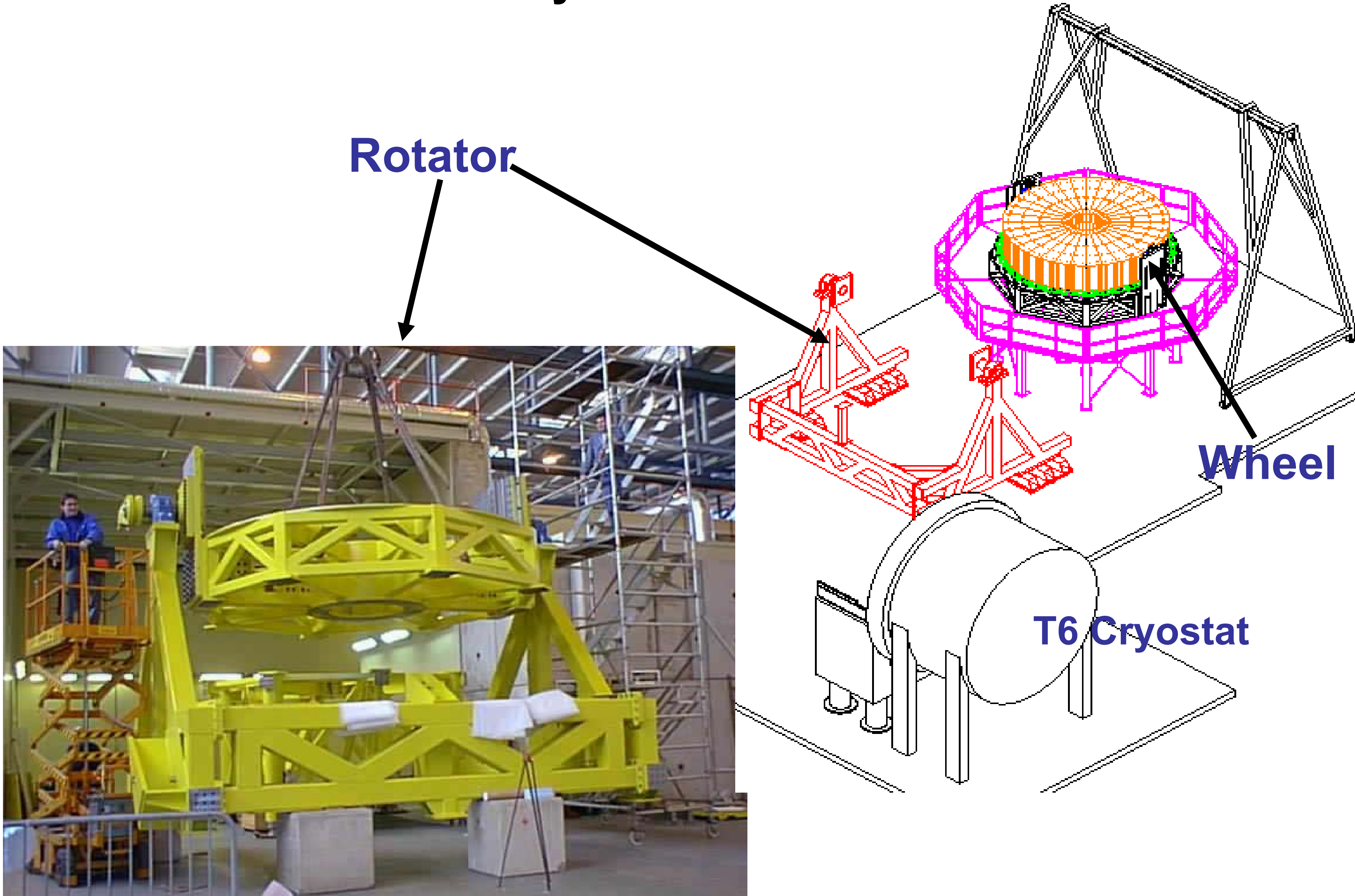
- **Barrel Cryostat is at CERN ready detector installation:**
  - **Integration work is now finished**
  - **All feedthroughs installed (signal and HV)**
  - **All cryolines installed**
  - **Leak tests successfully done**

- **Next steps:**
  - **EM calorimeter installation**
    - **→ Nov 2002 to June 2003**
  - **Install solenoid**
    - **→ July 2003**

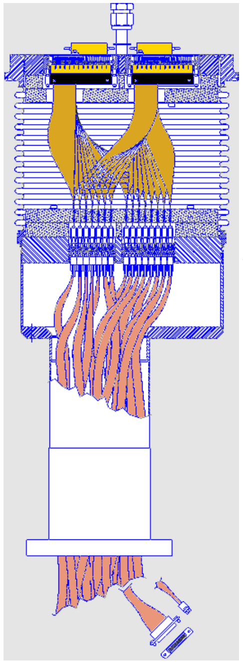
LAr End-Cap Cryostats and Feedthroughs

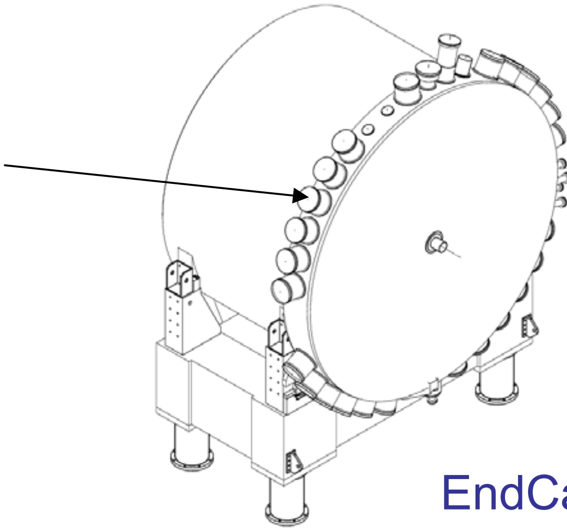


HEC Assembly

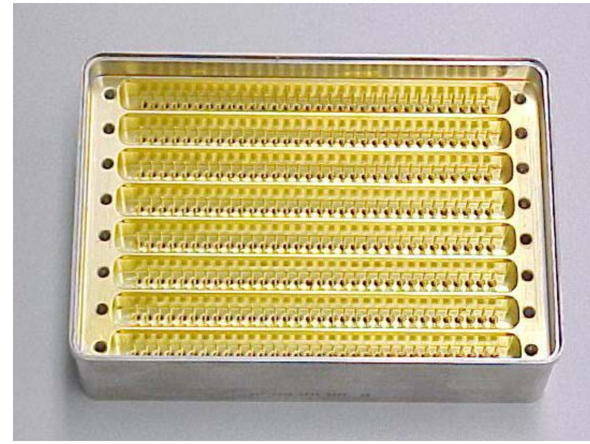


Liquid Argon Signal Feedthroughs





EndCap
Cryostat



8-row pin carrier

Warm/cold flange

Over 180k signal channels in the LAr calorimetry

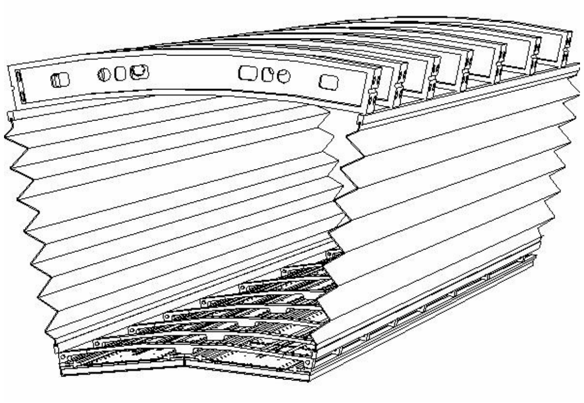
High density and reliability required:

1920 pins per feedthrough unit

- barrel: 64 units
- endcaps: 50 units total

Electromagnetic Barrel

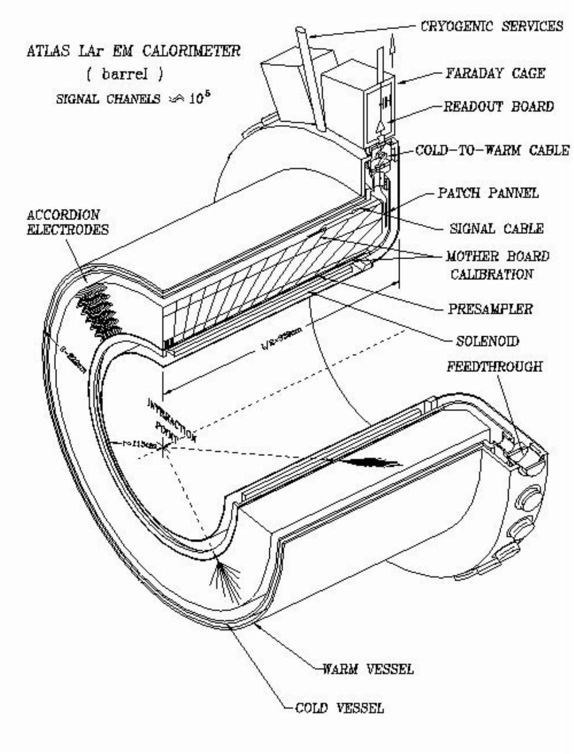
$0 < \eta < 1.4$



Barrel Module Schematic with presampler

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

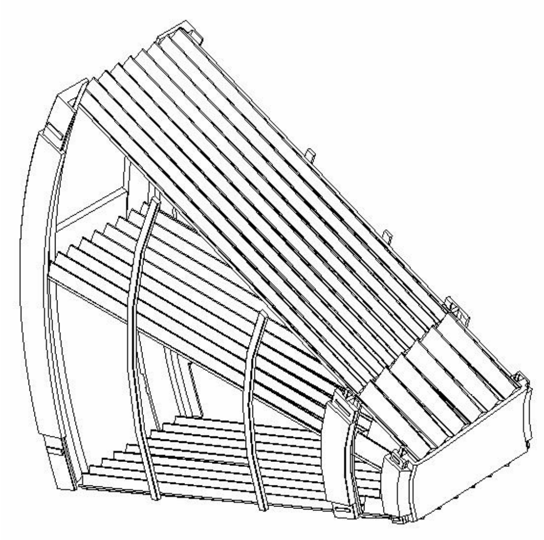
Half Barrel Assembly

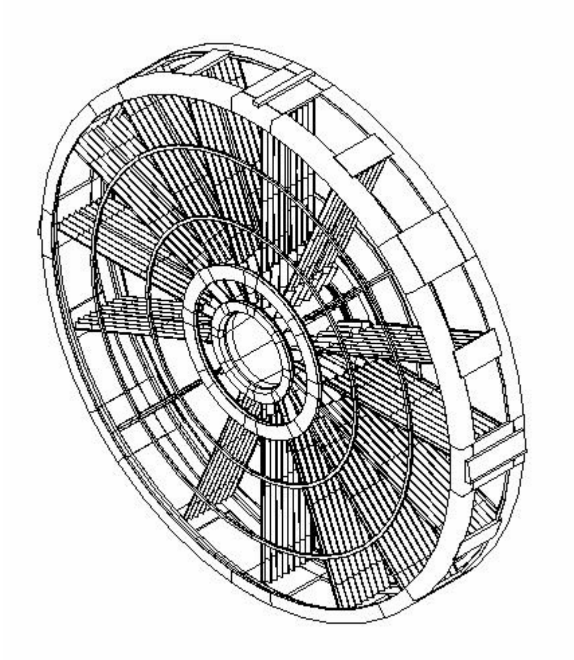


- 2x16 modules
- I.R/O.R 1470/2000 mm
- 22 - 33 X_0
- 3 longitudinal samples
- $\Delta\eta \times \Delta\varphi \quad 0.025 \times 0.025$
- presampler $|\eta| < 1.8$

Electromagnetic Endcap

$1.4 < \eta < 3.2$





- 96 gaps /module outer wheel
  32 gaps/module inner wheel

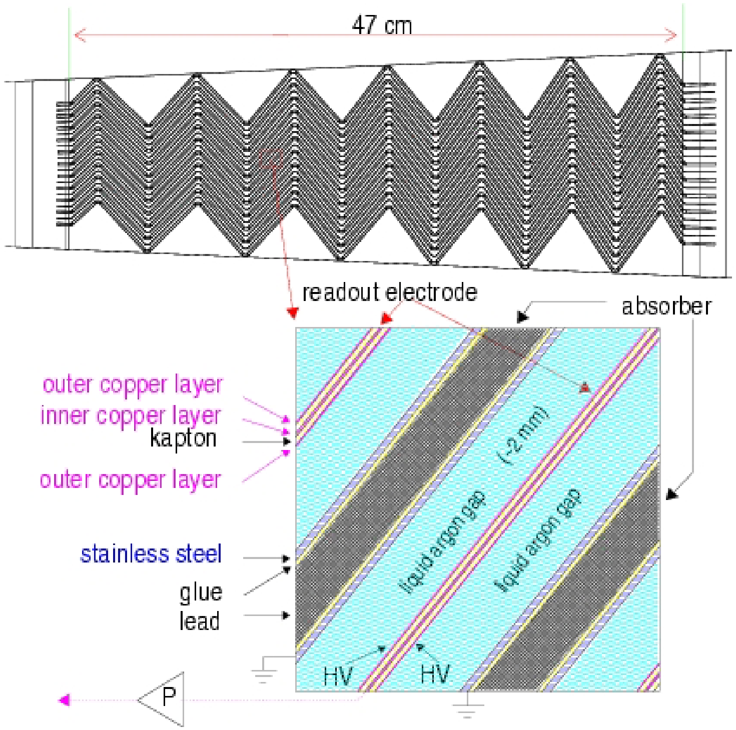
- 2.8 - 0.9 mm gap outer
  3.1-1.8 mm inner

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

Accordion Structure

Pb Absorber

Barrel absorbers



• Honeycomb spacer

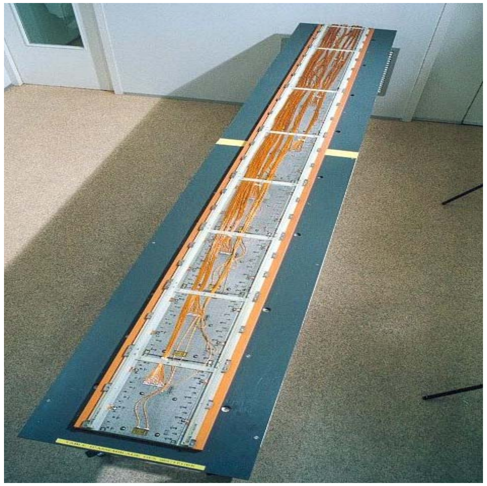
&

• Cu/Kapton electrode

EM Barrel Module

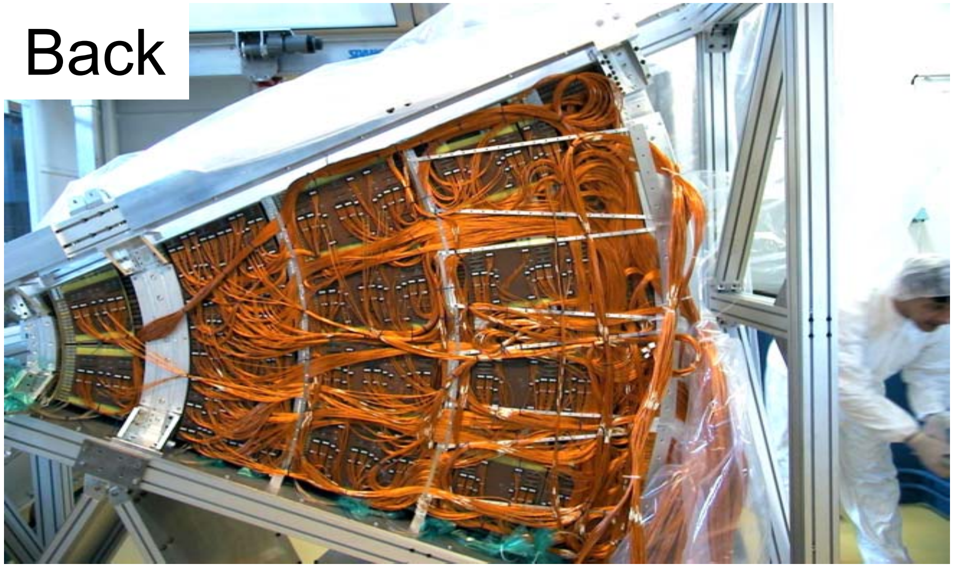
Trial assembly of two EM barrel modules

Presampler



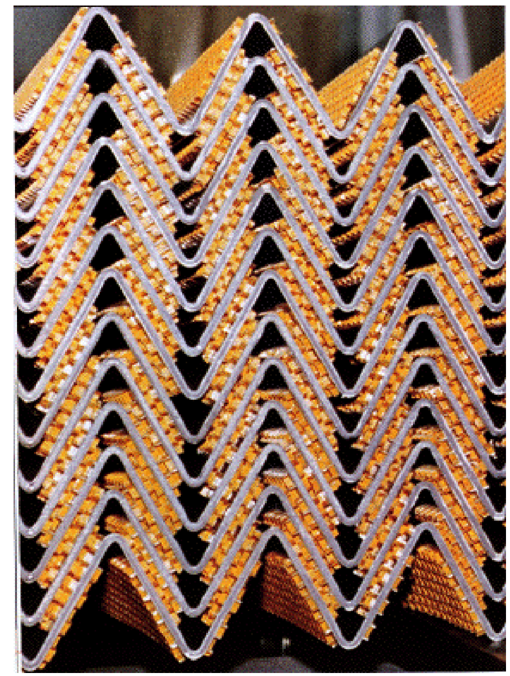
Electromagnetic Endcap

Back



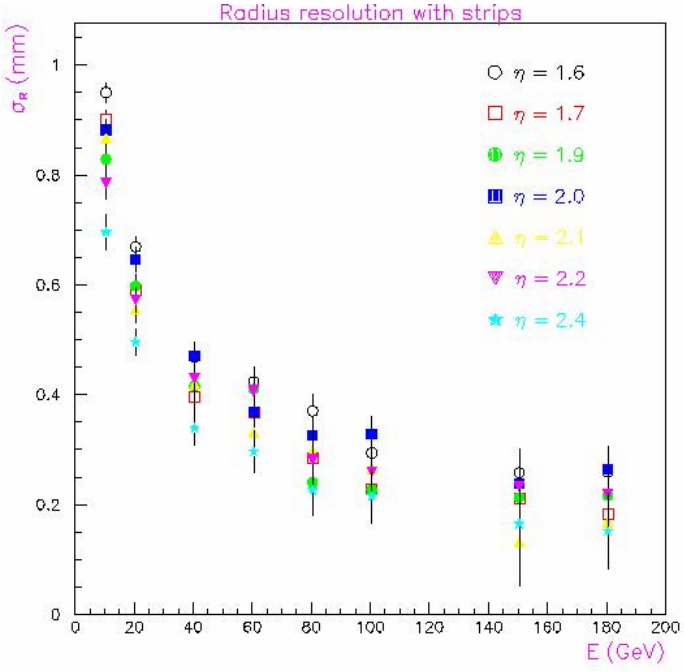
Front

Detail of Kaptons



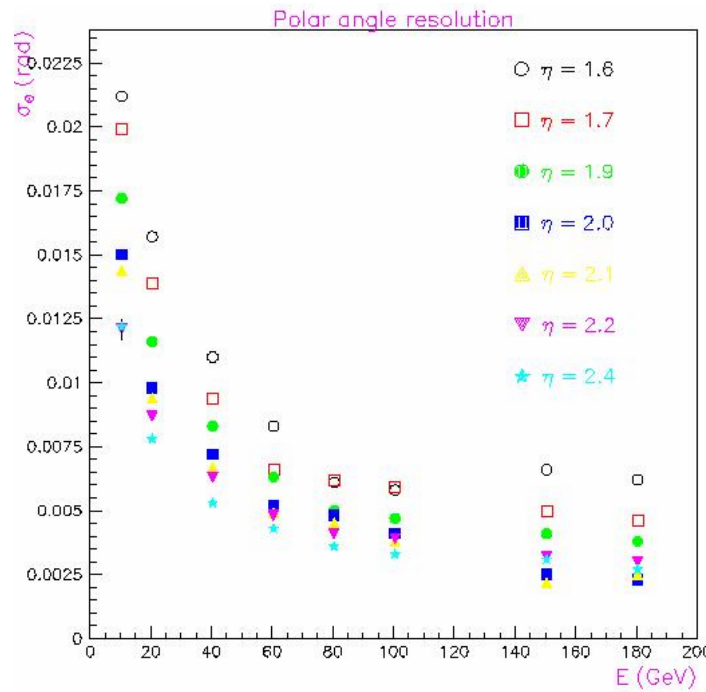
Electromagnetic Endcap

Test Beam Spatial Resolution



Resolution satisfactory
< 0.3 mm in strip section

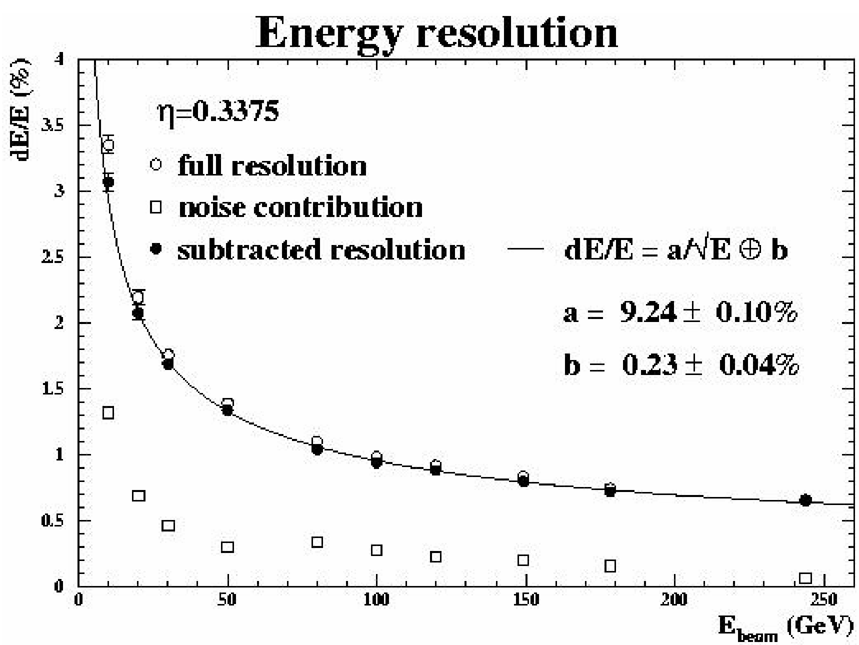
Test Beam Angular Resolution



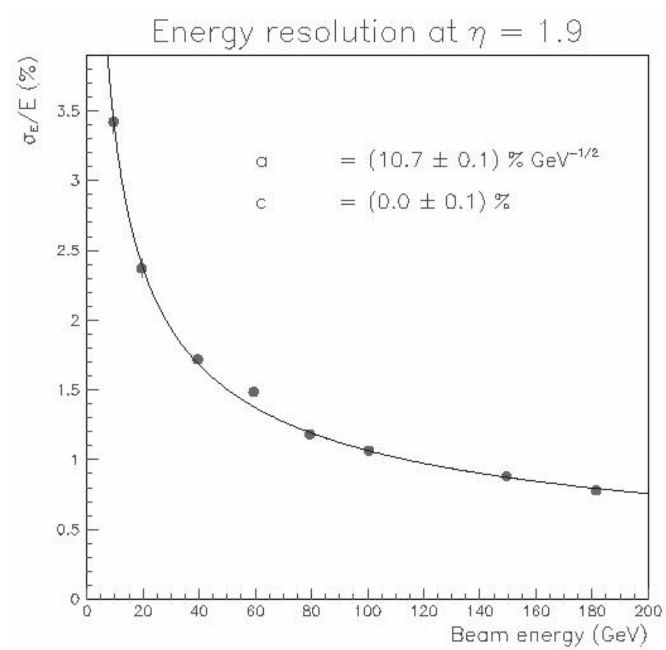
Resolution satisfactory
< 50 mrad/√E on angular measurements

Electromagnetic Cal. Test Beam Energy Resolution

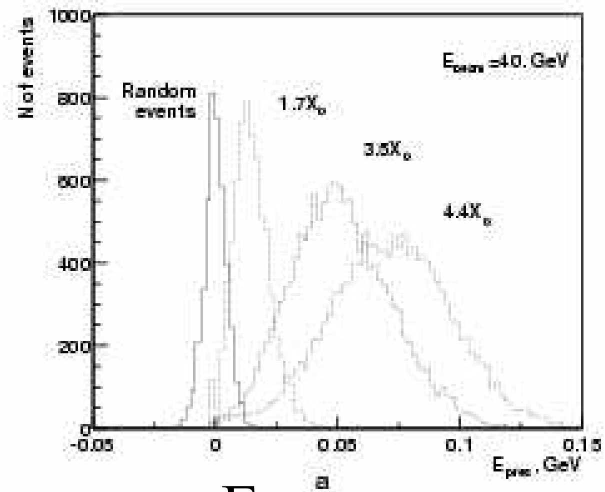
Barrel

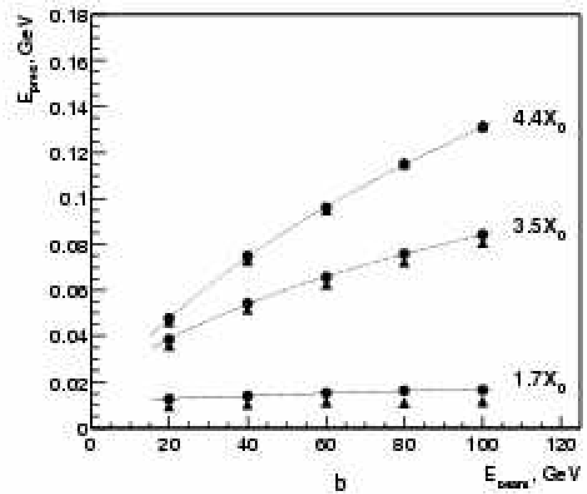


Endcap



Test Beam Presampler



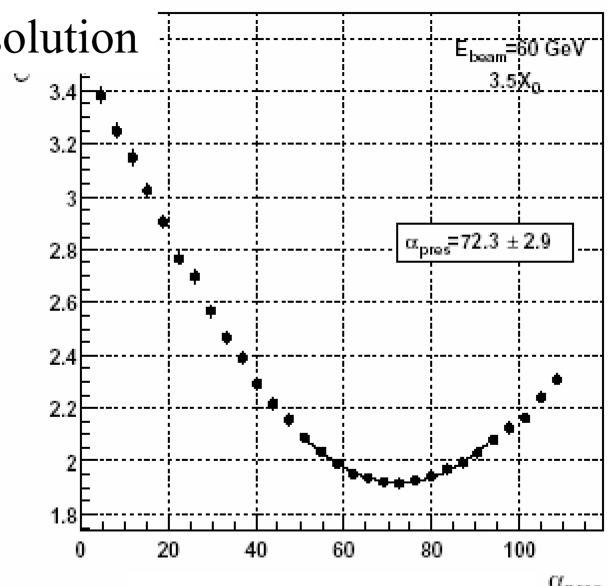


$E_{\text{Presampler}}$

E_{BEAM}

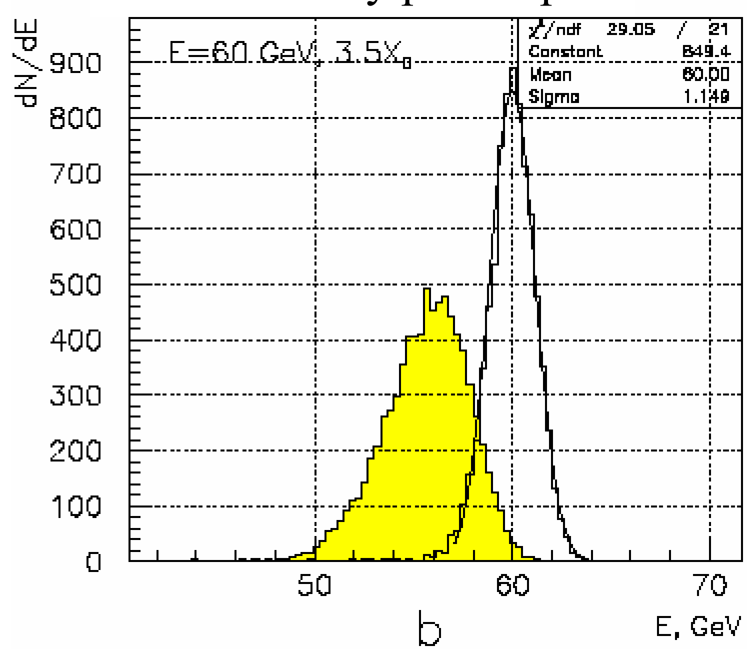
$E_{\text{Presampler}}$

Energy Resolution



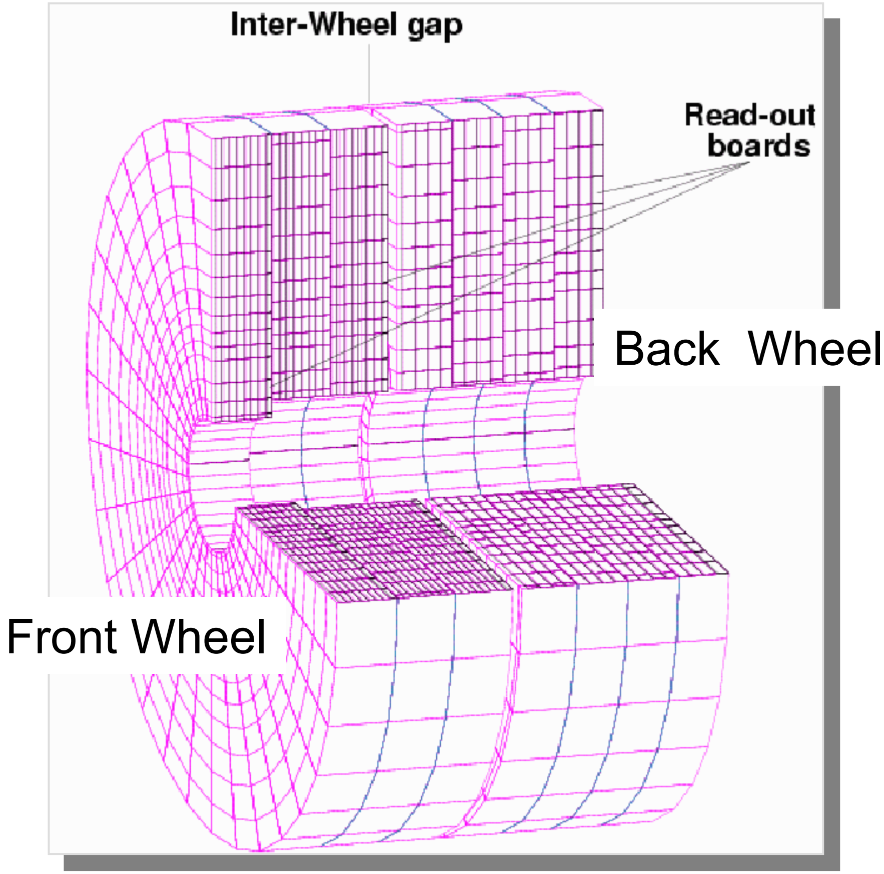
Presampler Weight

E corrected by presampler

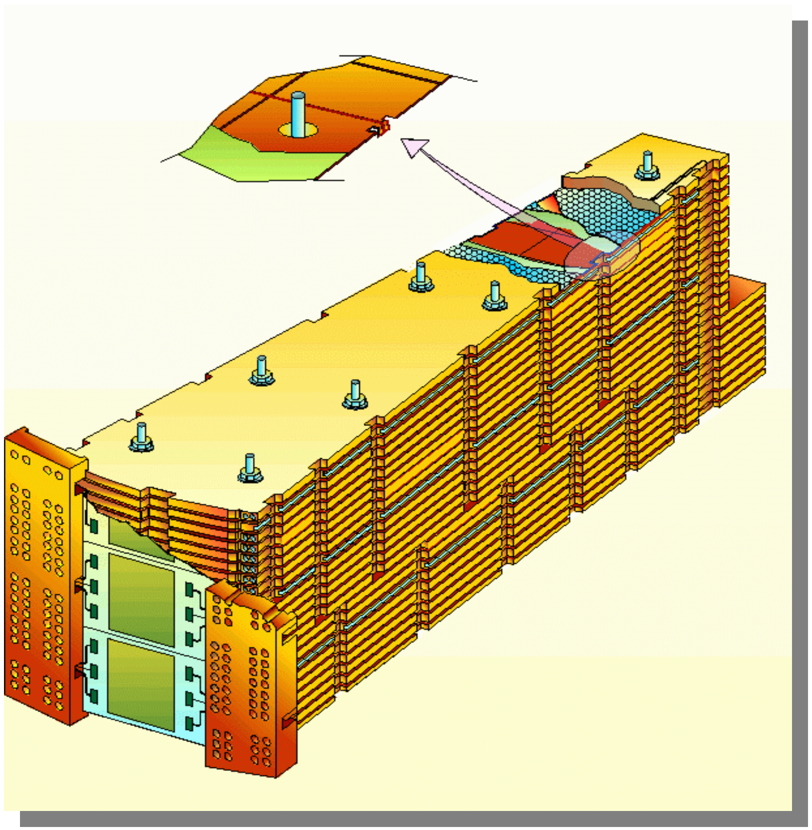


Hadronic Endcap Calorimeter

LAr-Cu sampling calorimeter covering 1.5 < η < 3.2



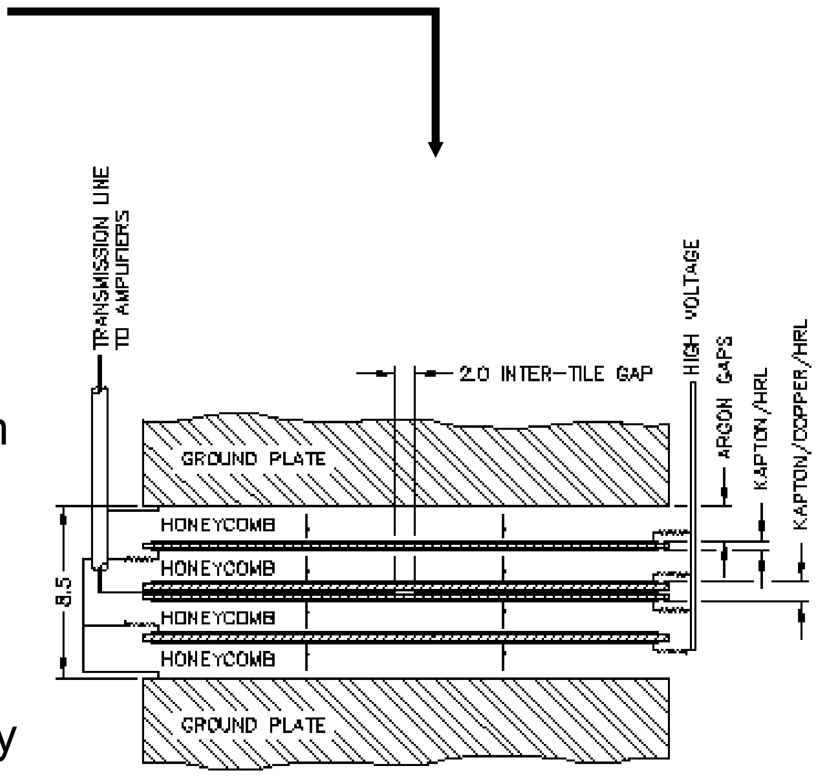
Composed of 2 wheels per end, 32 modules per wheel
Front wheel:67 t25 mm Cu plates
Back wheel:90 t50 mm Cu plates



HEC Module Structure

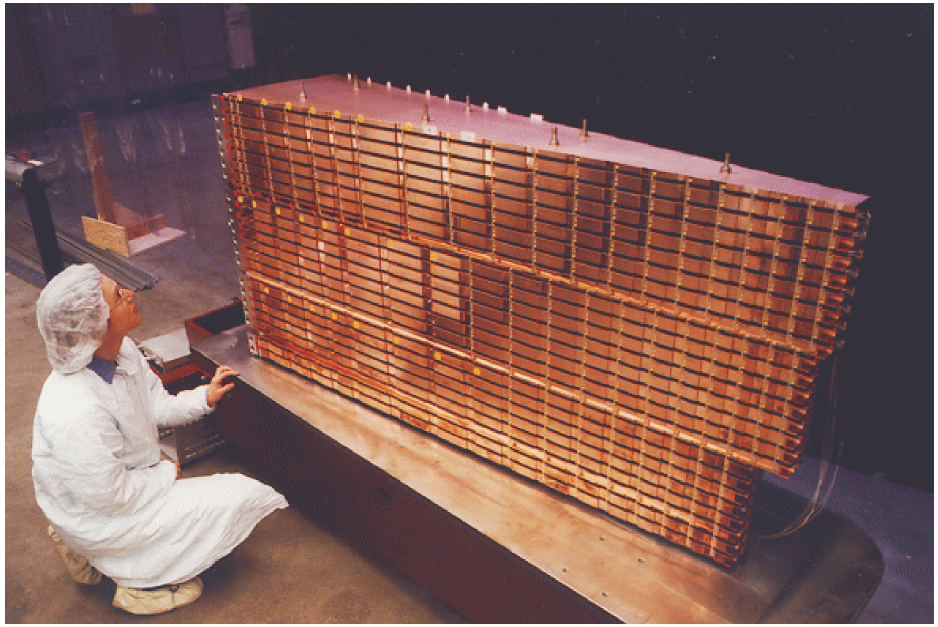
HEC Read-out Scheme

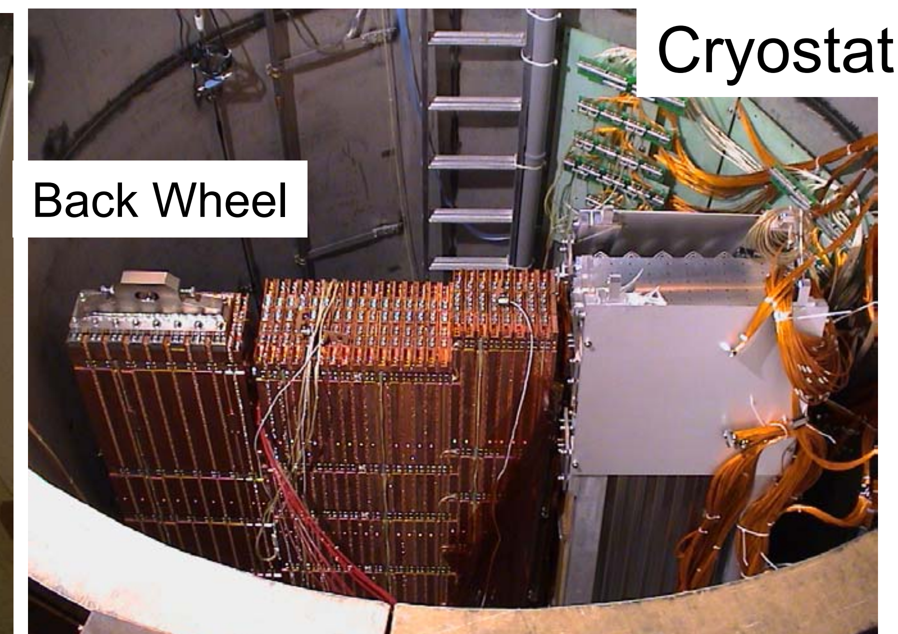
- The read-out structure is electrostatic transformer:
  - Small gap avoids ion build-up
  - Same behaviour as a 4 mm gap with lower HV (2 kV instead of 4 kV)



- Reduce capacitance seen by the preamplifiers, only 2 gaps are read (4 mm out of 8 mm of LAr)
- The GaAs preamplifiers in LAr.
- Cells are fully pointing in azimuth, but only « pseudo-pointing » in η
- Robust against H.V. shorts

HEC Module Assembly for Testbeam

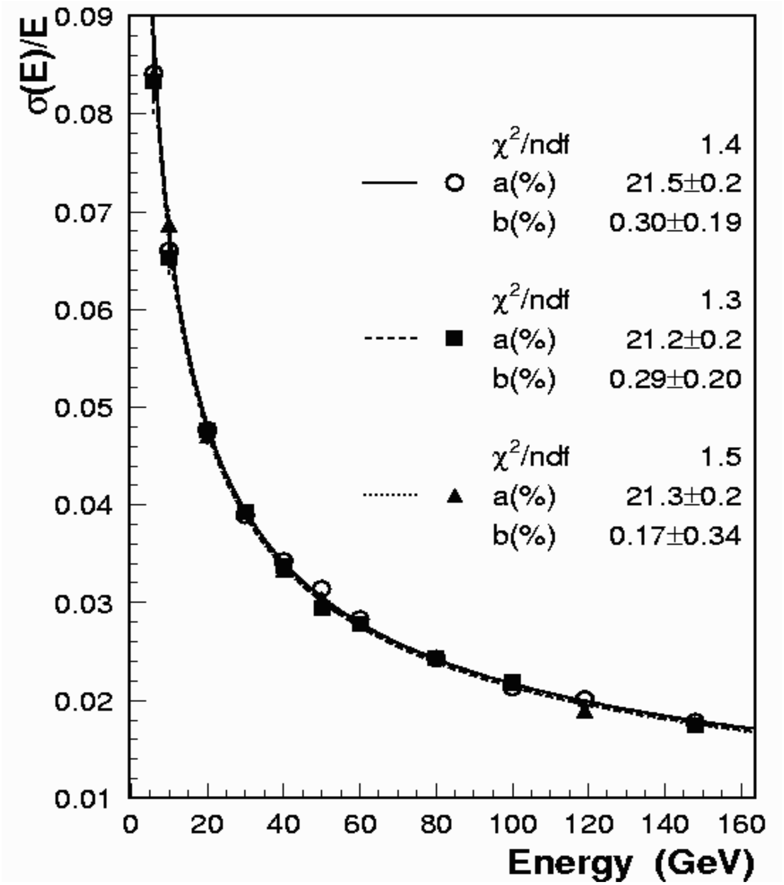




HEC Test Beam

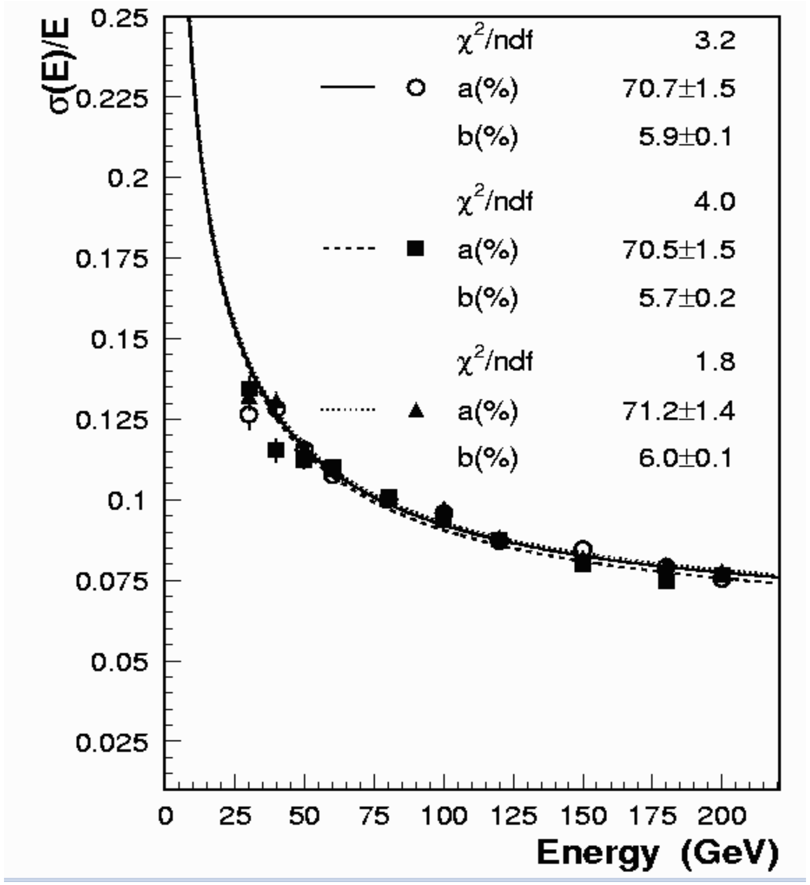
Electron Energy Resolution

$$\frac{\sigma(E)}{E} = \frac{21.4 \pm 0.2\%}{\sqrt{E_0(\mathrm{GeV})}} \oplus 0.3 \pm 0.2\,\%$$



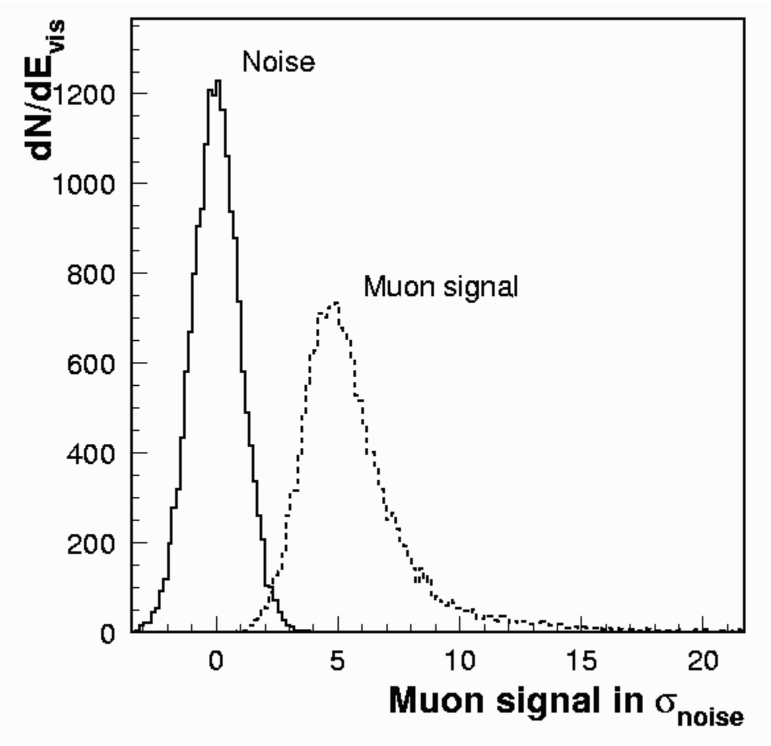
Pion Energy Resolution

$$\frac{\sigma(E)}{E} = \frac{(70.6 \pm 1.5)\%}{\sqrt{E_0(\mathrm{GeV})}} \oplus (5.8 \pm 0.2)\%$$



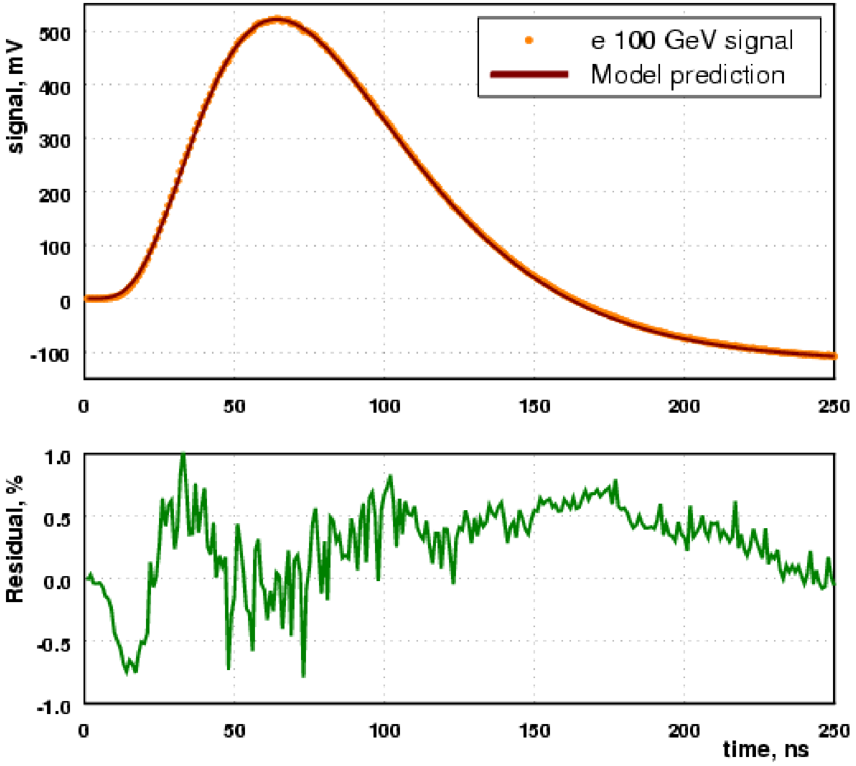
HEC Testbeam

Muon Detection



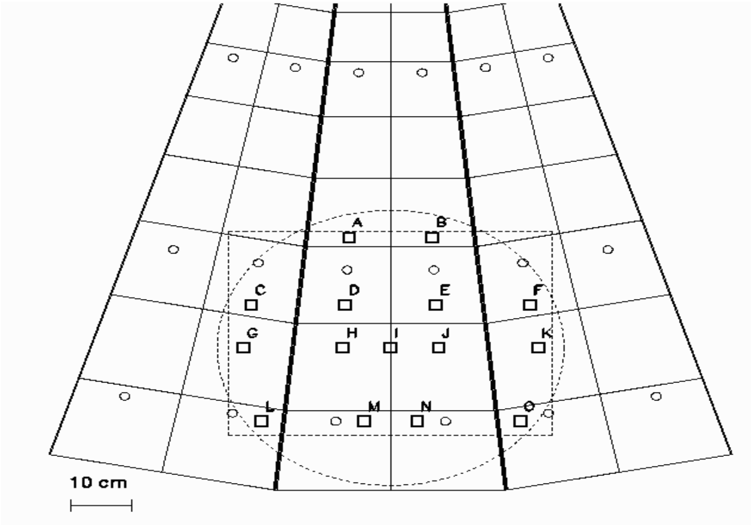
150 GeV muons

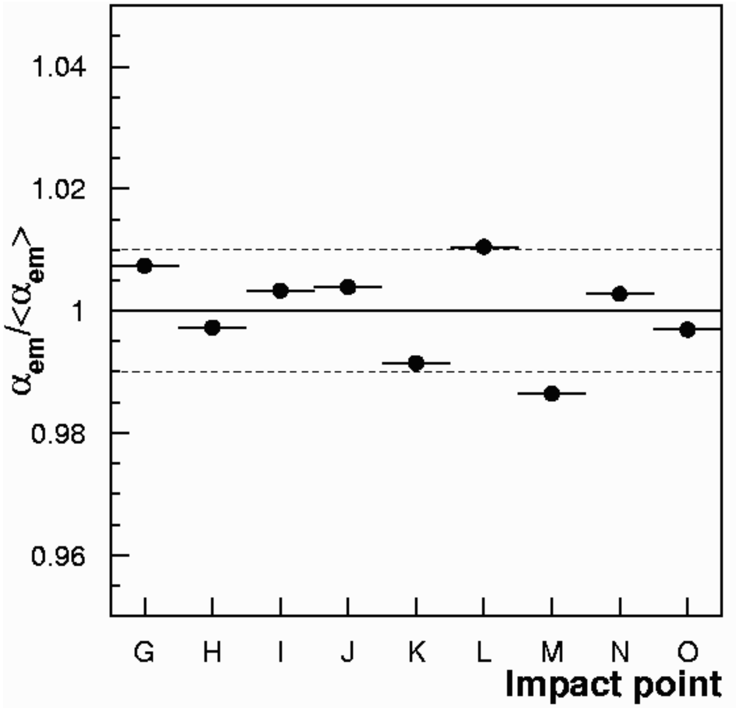
Signal Model



HEC Test Beam

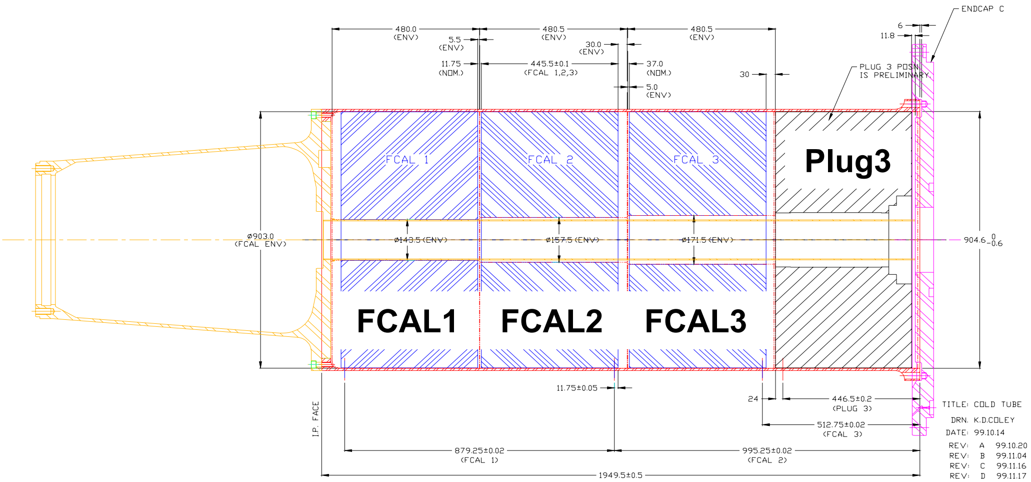
Spatial uniformity of response to electrons as a variation of EM calib. Const. variation





Non-uniformity < 1%

Forward Calorimeter



Modules

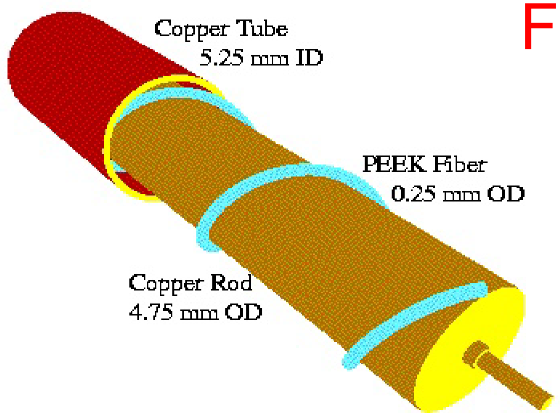
0.9 m Diameter

.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

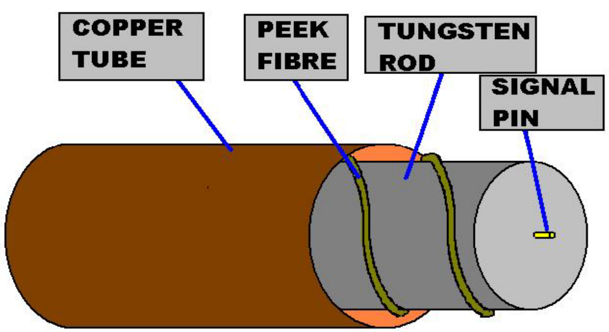
FCAL Electrode Structure

FCAL1

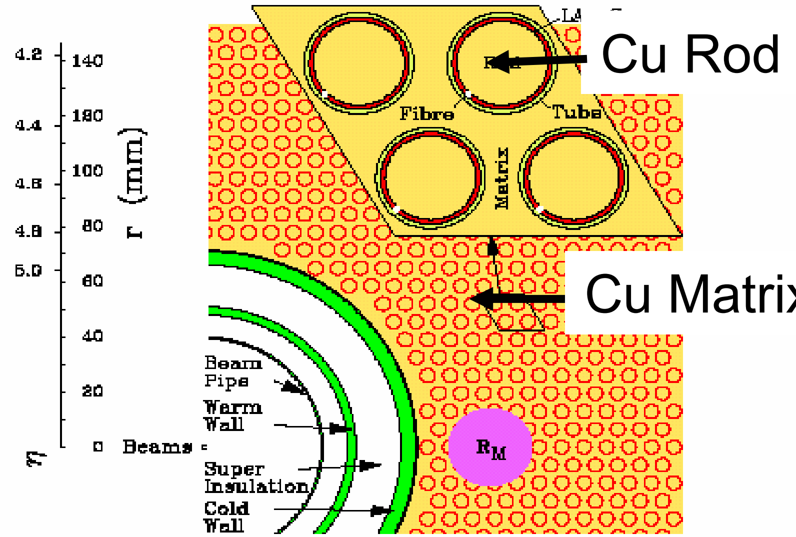


FCAL2/3

FCAL3 TUBE-ROD UNIT

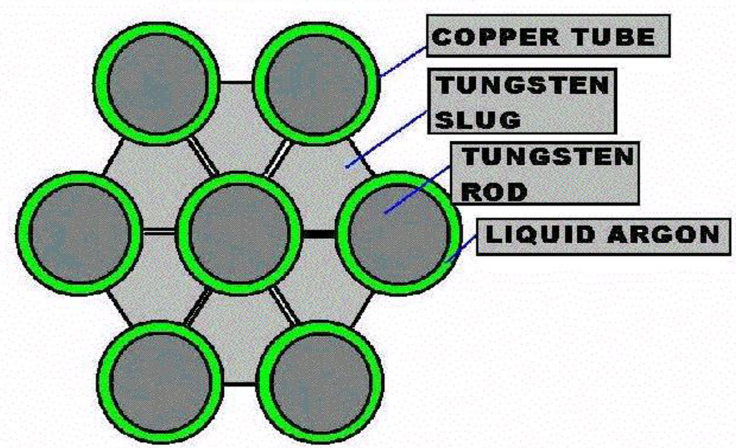


Copper Module Concept

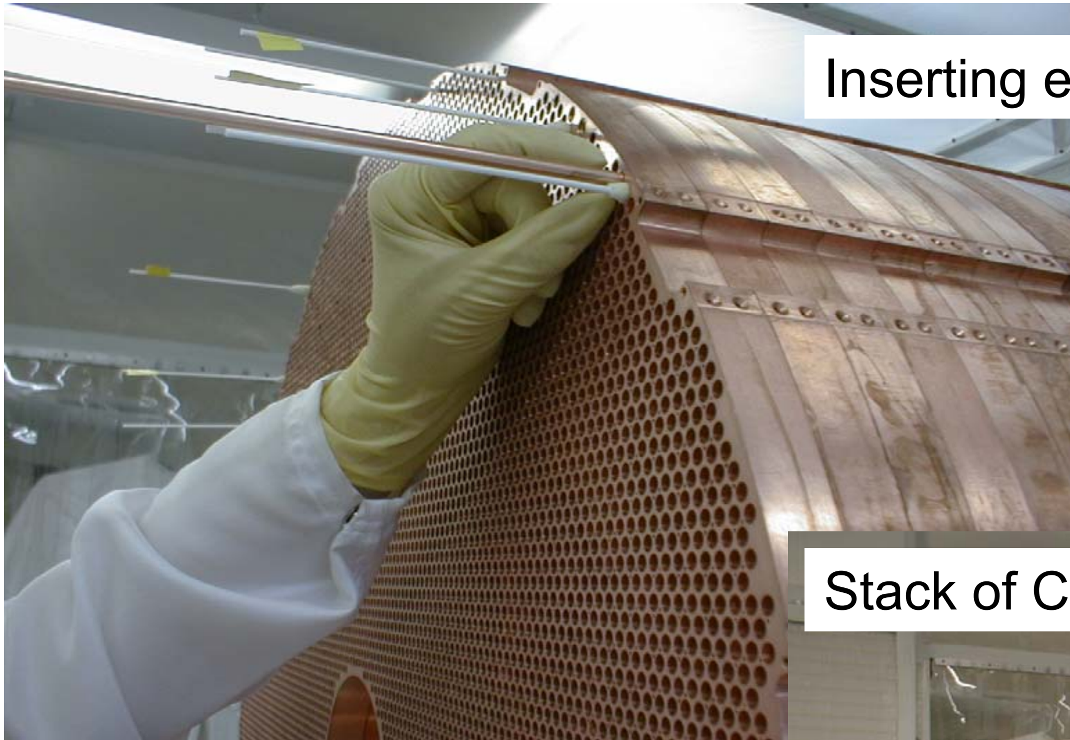


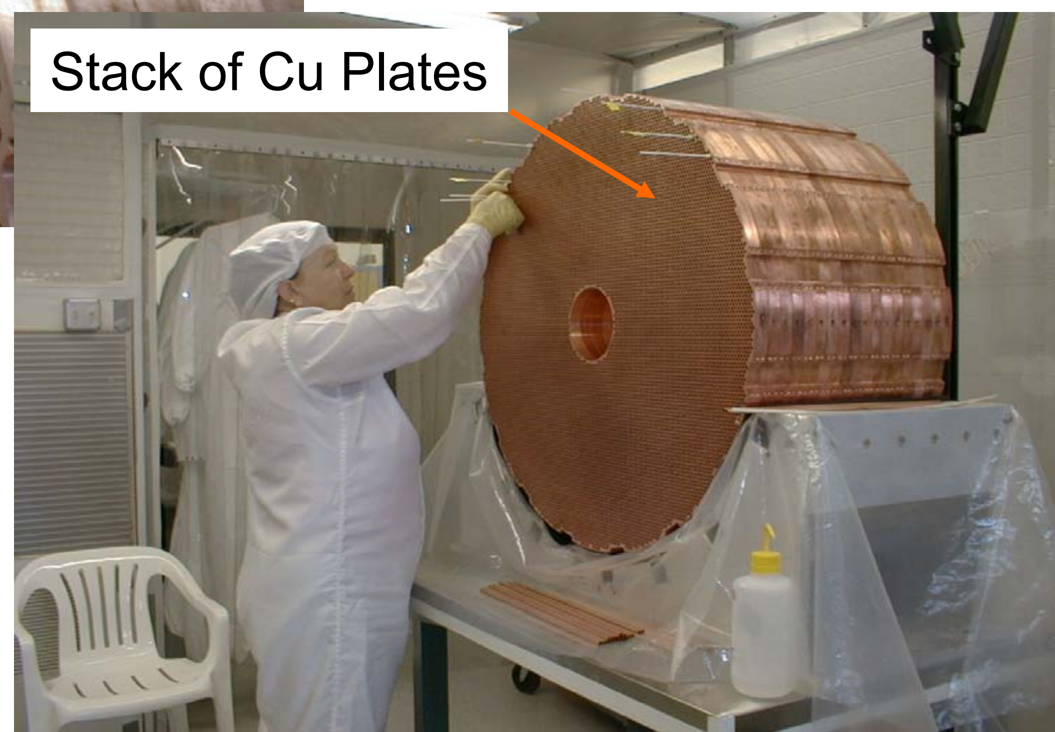
Tungsten Module Concept

FCAL3 MATRIX



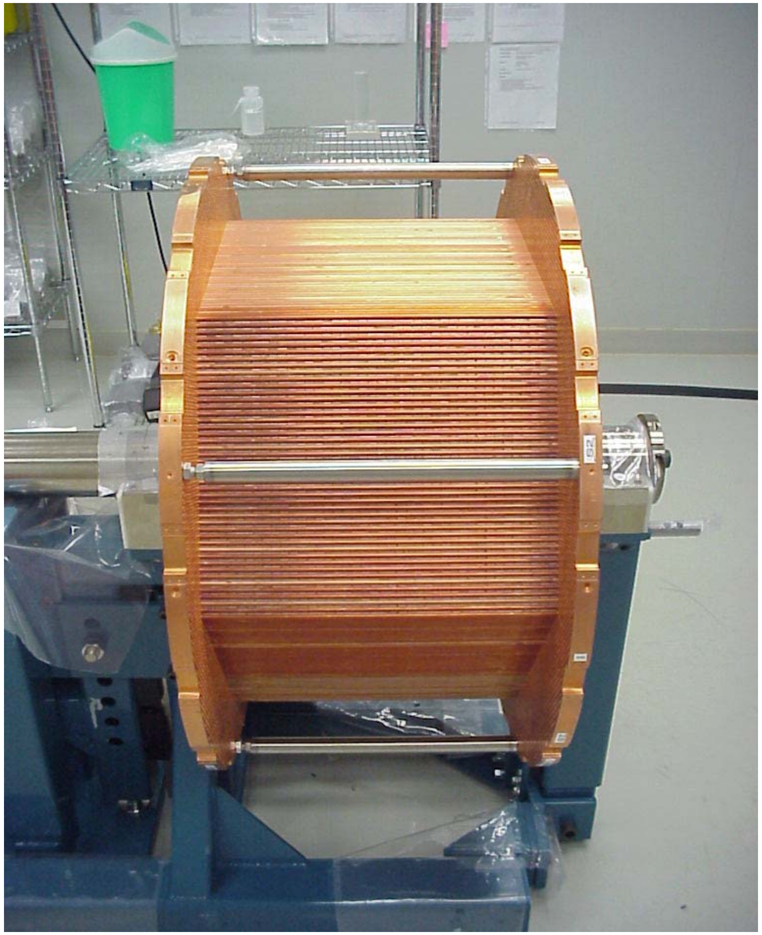
FCAL1 Module





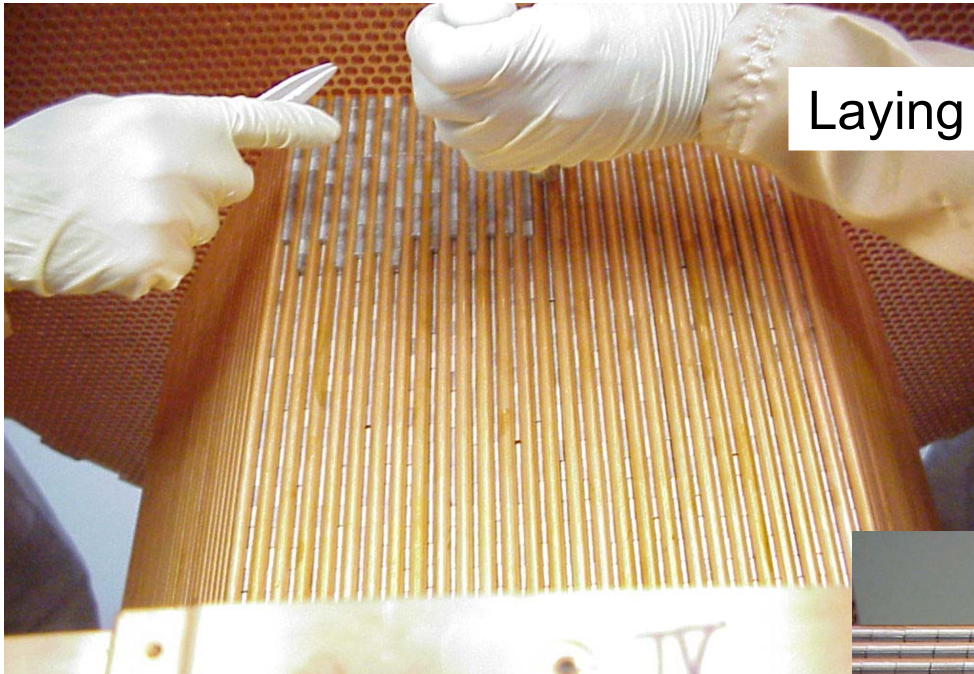
FCAL2/3 Assembly

March 2001

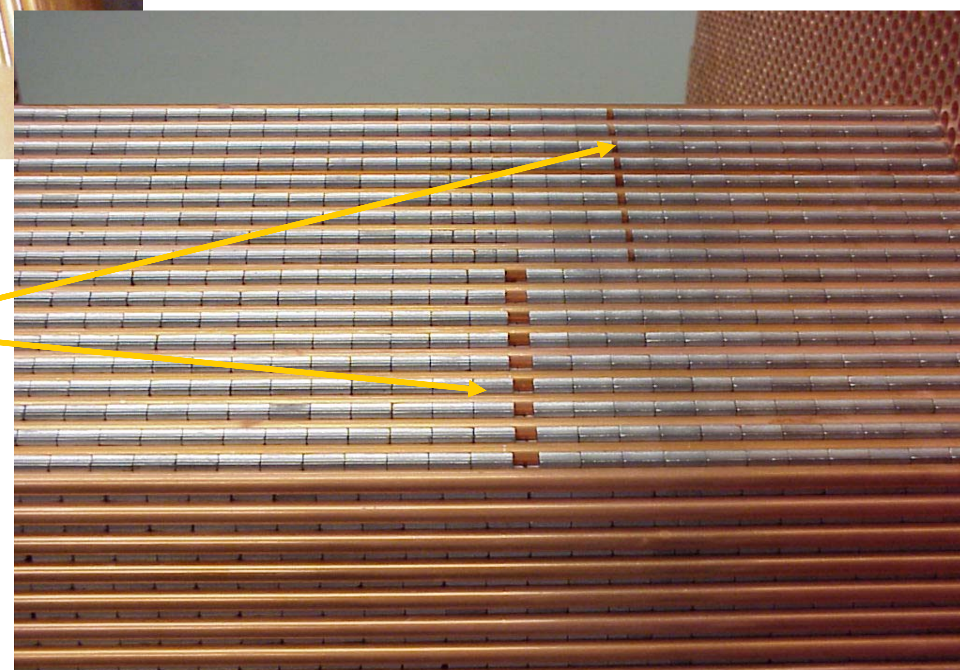


September 2001

Tungsten Module Assembly



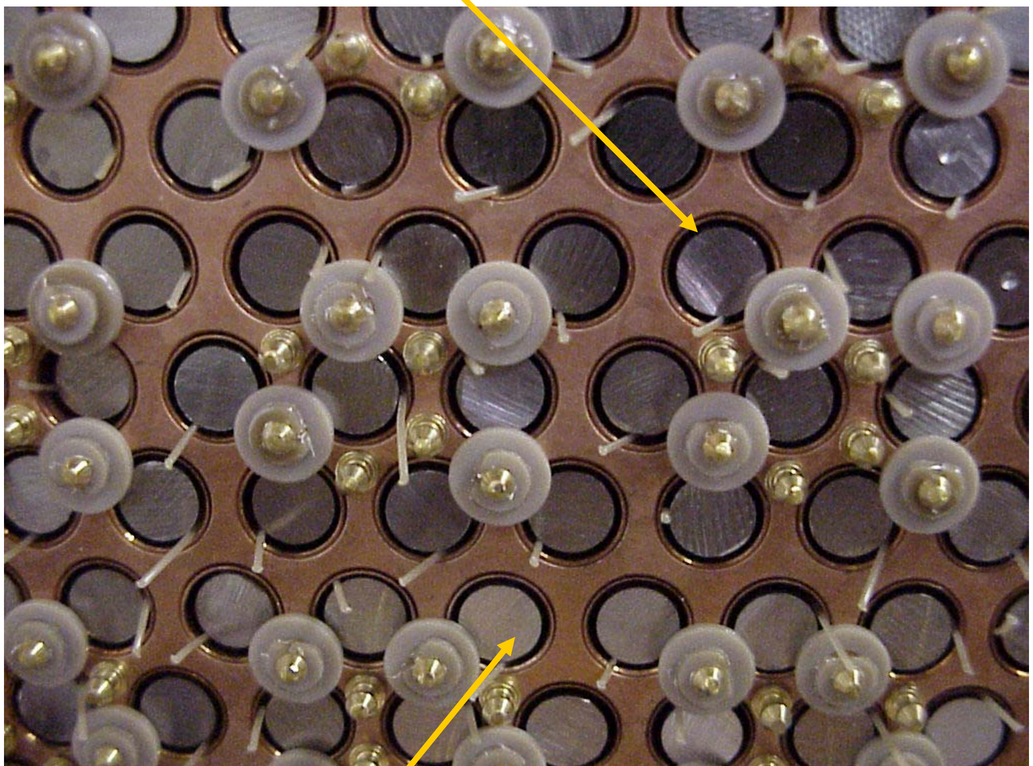
Laying W slugs



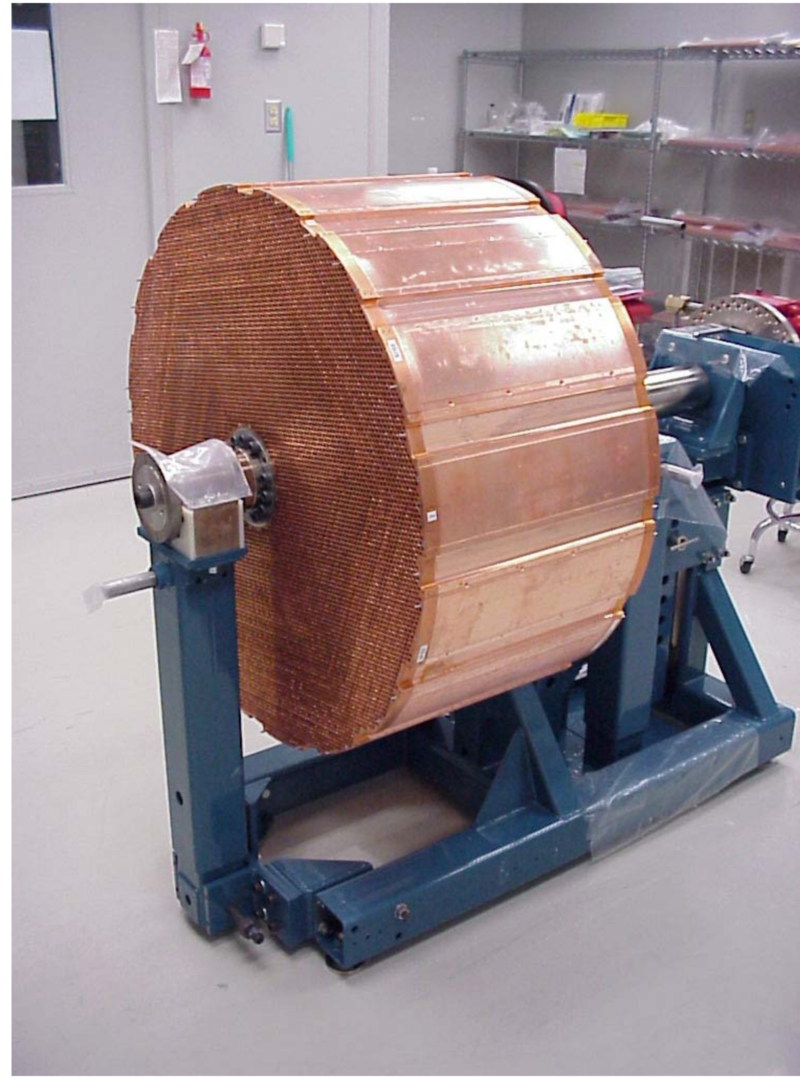
Adjustment of slug gap

FCAL2/3 Assembly

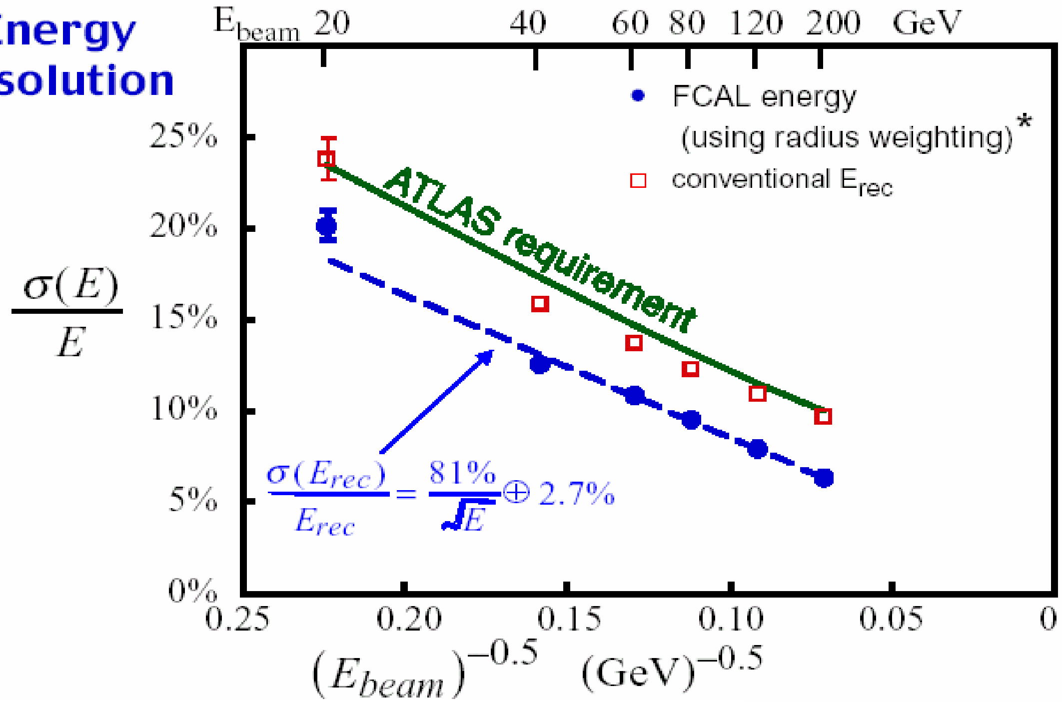
Liquid Argon Gap



Tungsten Rod



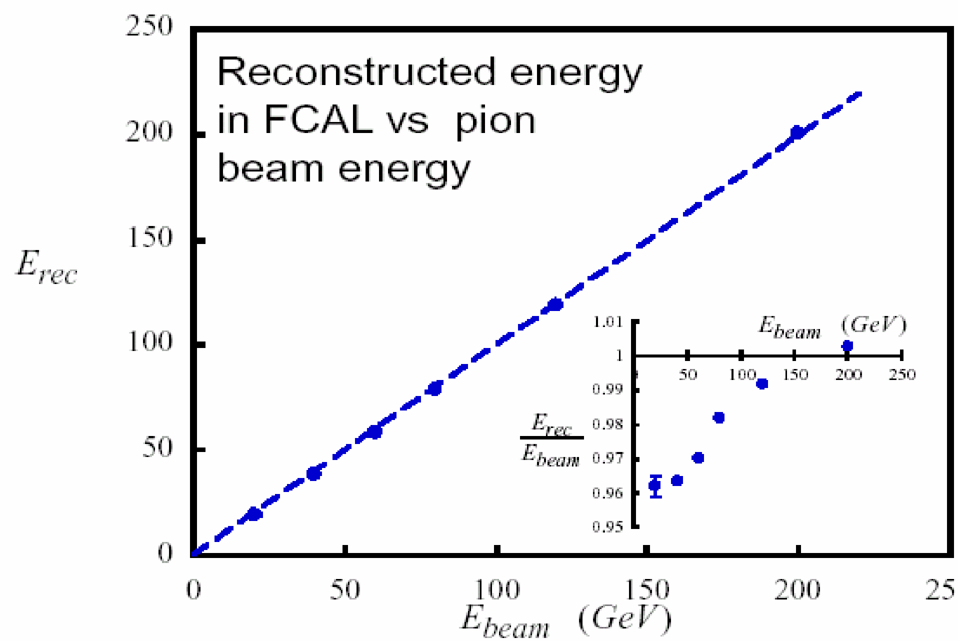
Energy Resolution



1998 Test Beam

FCAL Hadronic Linearity

¼(FCAL1+FCAL2)



Conclusion

- ATLAS on Track for Data in 2007
- Canadian Construction Projects Well Advanced
- Just have to wait for Eagerly Anticipated Physics