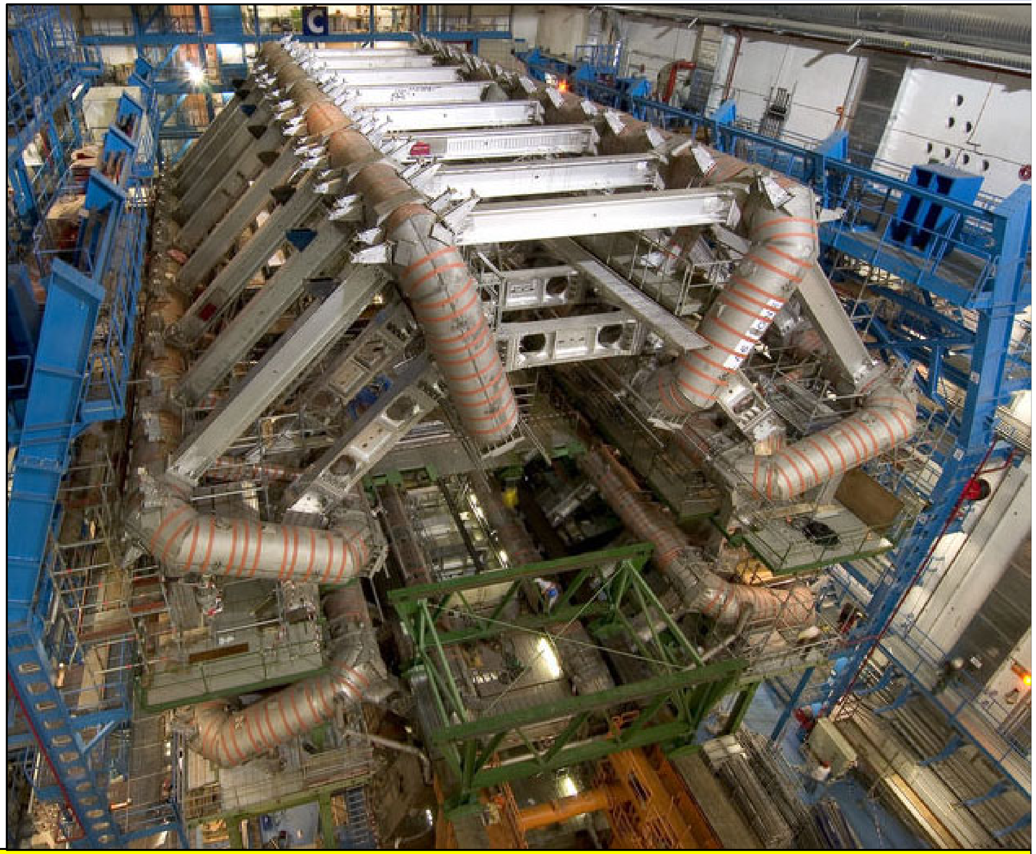
The ATLAS Liquid Argon Calorimeter: Construction, Integration, Commissioning

M. Aleksa on behalf of the ATLAS LAr Group

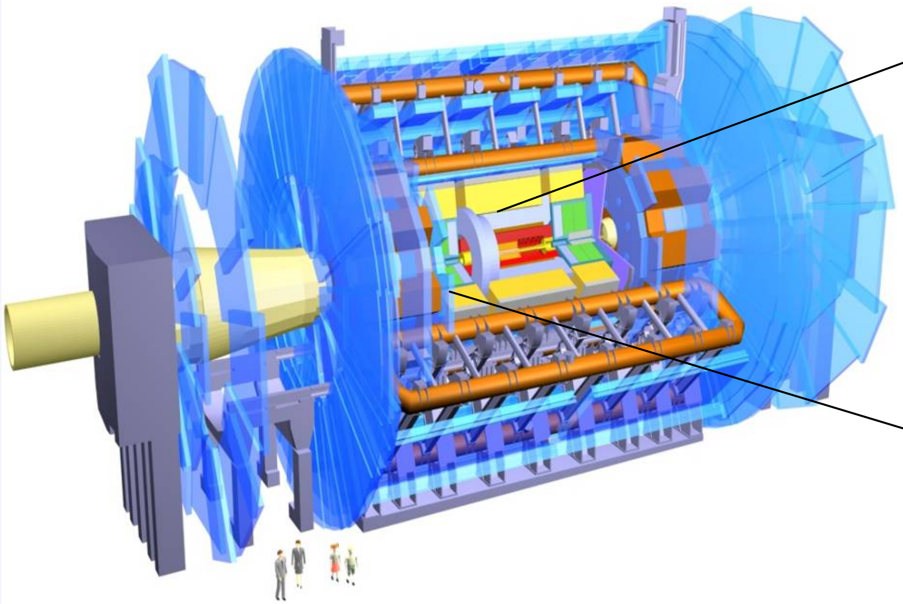
- Introduction
- Integration and Commissioning on the Surface
- Installation and Commissioning after Installation in the Cavern

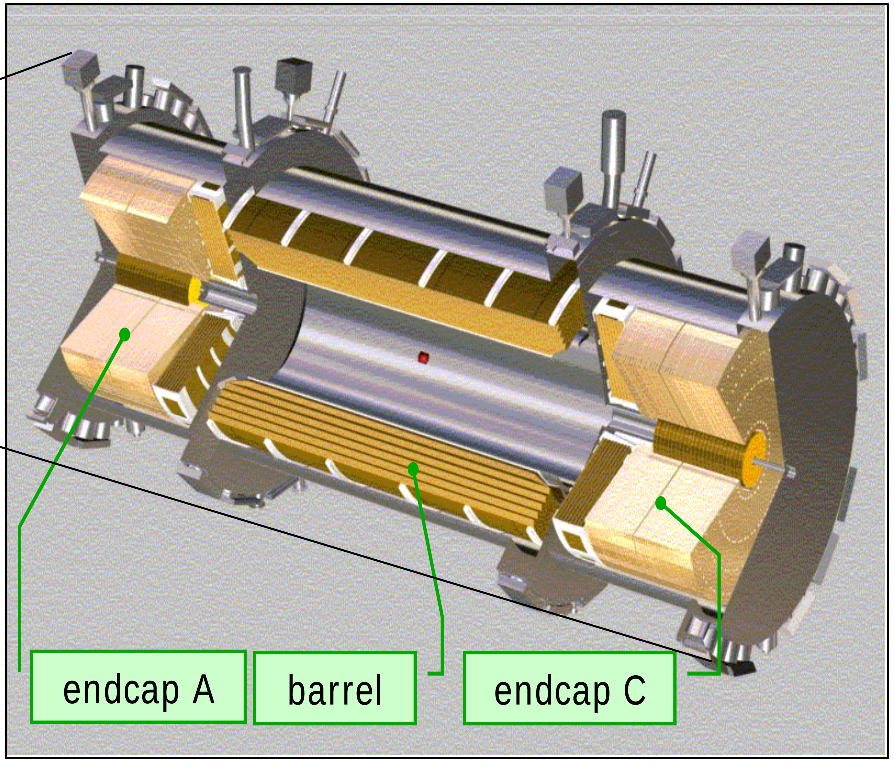


In this session there will follow other talks on the ATLAS LAr calorimeter that will complement this presentation

- Electronics commissioning
- Performance results obtained in standalone testbeams and the 2004 combined testbeam

Introduction – The ATLAS Liquid Argon Calorimeter



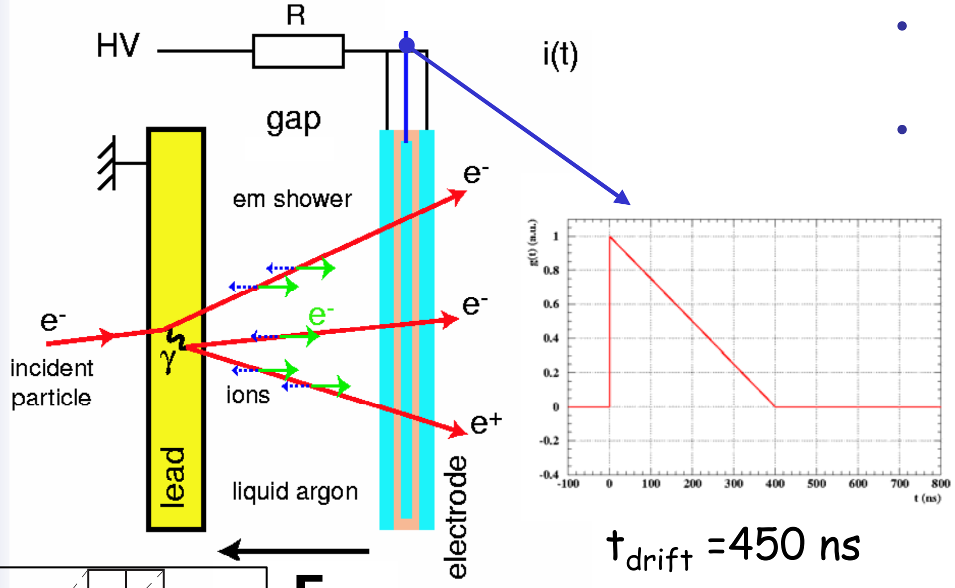


- LAr Calorimeters:
  - EM Barrel : ($|\eta|<1.475$) [Pb-LAr]
  - EM End-caps : $1.4<|\eta|<3.2$ [Pb-LAr]
  - Hadronic End-cap: $1.5<|\eta|<3.2$ [Cu-LAr]
  - Forward Calorimeter: $3.2<|\eta|<4.9$ [Cu,W-LAr]
- ~190K readout channels

Introduction
Physics Requirements

- Discovery potential of Higgs (into $\gamma\gamma$ or $4e^{\pm}$ for what concerns the EM calorimetry) determines most of the performance requirements for the EM calorimetry
- Largest possible acceptance ($\rightarrow$ accordion)
- Large dynamic range : 20 MeV…2TeV ($\rightarrow$ 3 gains, 16bits)
- Energy resolution ($e^{\pm}\gamma$): $\sigma_E/E \sim 10\%/\sqrt{E} \oplus 0.7\%$
  - $\rightarrow$ precise mechanics & electronics calibration (<0.25%)…
- Linearity : 0.1 % (W-mass precision measurement)
  - $\rightarrow$ presampler (correct for dead material), layer weighting, electronics calibration
- Particle id: $e^{\pm}$-jets , γ/π_0 (>3 for 50 GeV p_t)
  - $\rightarrow$ fine granularity
- Position and angular measurements: 50 mrad/$\sqrt{E}$
  - $\rightarrow$ Fine strips, lateral/longitudinal segmentation
- Hadronic – E_t miss (for SUSY)
  - Almost full 4π acceptance (η<4.9)
- Jet resolution
  - $\sigma_E/E \sim 50\%/\sqrt{E} \oplus 3\%$ $\eta<3$,
  - $\sigma_E/E \sim 100\%/\sqrt{E} \oplus 10\%$ $3<\eta<5$
- Non-compensating calorimeter $\rightarrow$ granularity and longitudinal segmentation very important to apply software weighting techniques
- Speed of response (signal peaking time ~40ns) to suppress pile-up

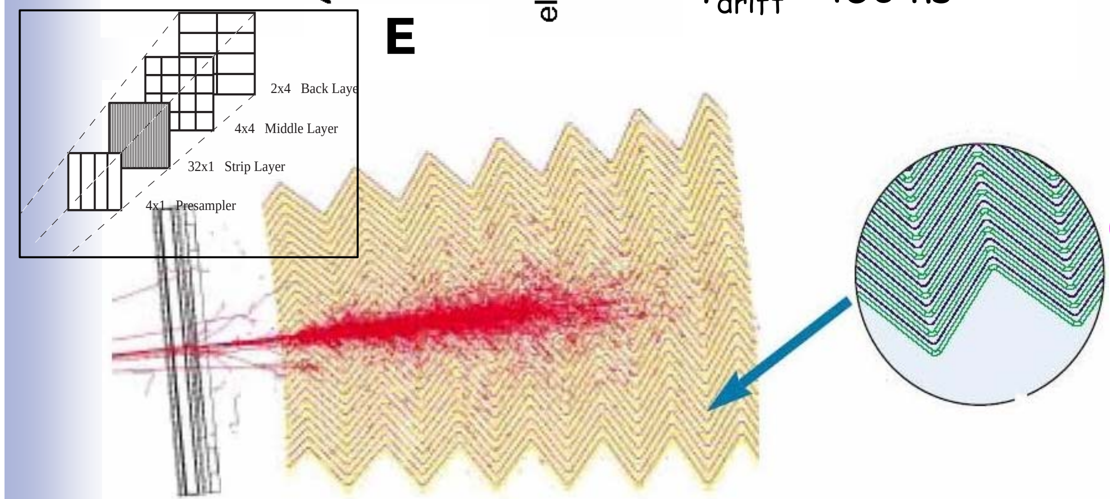
The ATLAS Electromagnetic (EM) Calorimeter

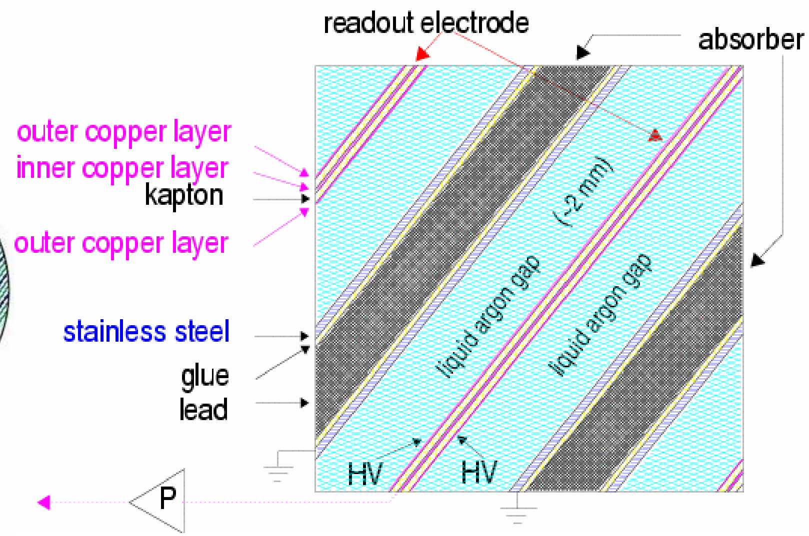


- Accordion shape in EM barrel and end cap calorimeters (>22X_0)
- 2 wheels (16 modules) in the barrel and 1 wheel (8 modules) per endcap

Main advantages

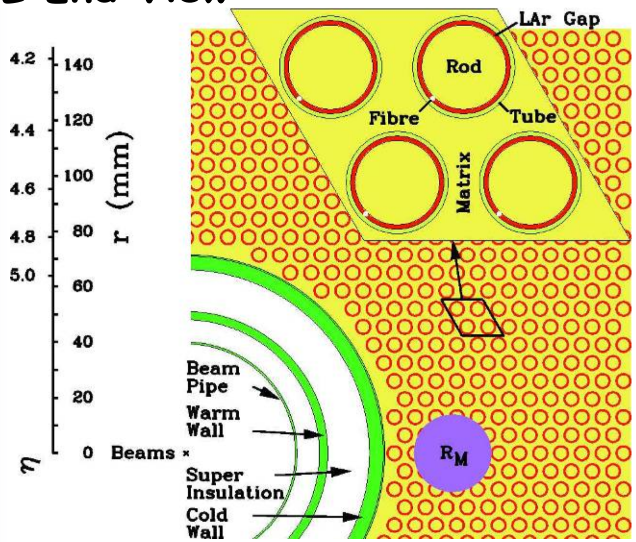
- LAr as act. material inherently linear
- Hermetic coverage (no cracks)
- Longitudinal segmentation
- High granularity (Cu etching)
- Inherently radiation hard
- Fast readout possible



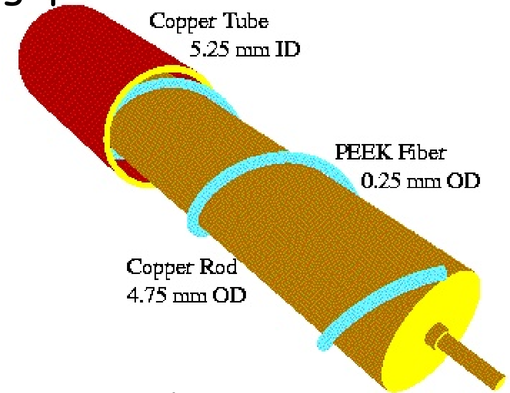


The ATLAS Forward and Hadronic Calorimeters

FCAL End View

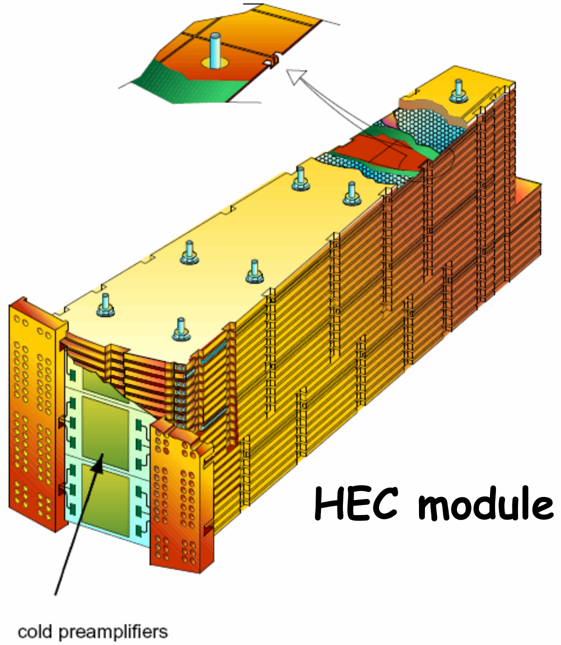


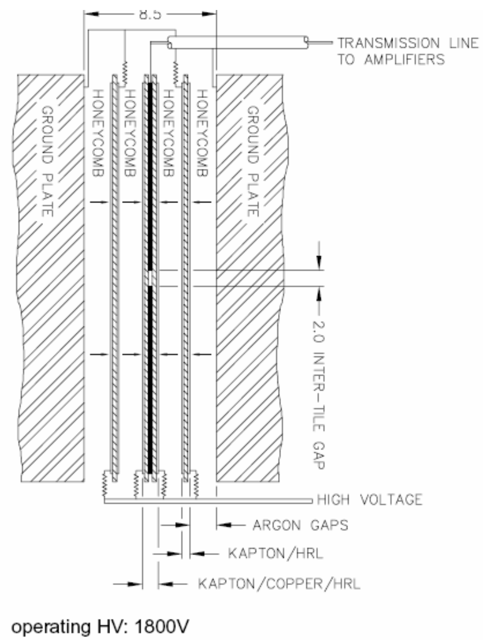
LAr gap FCAl 1/2/3: 250/375/500 μm



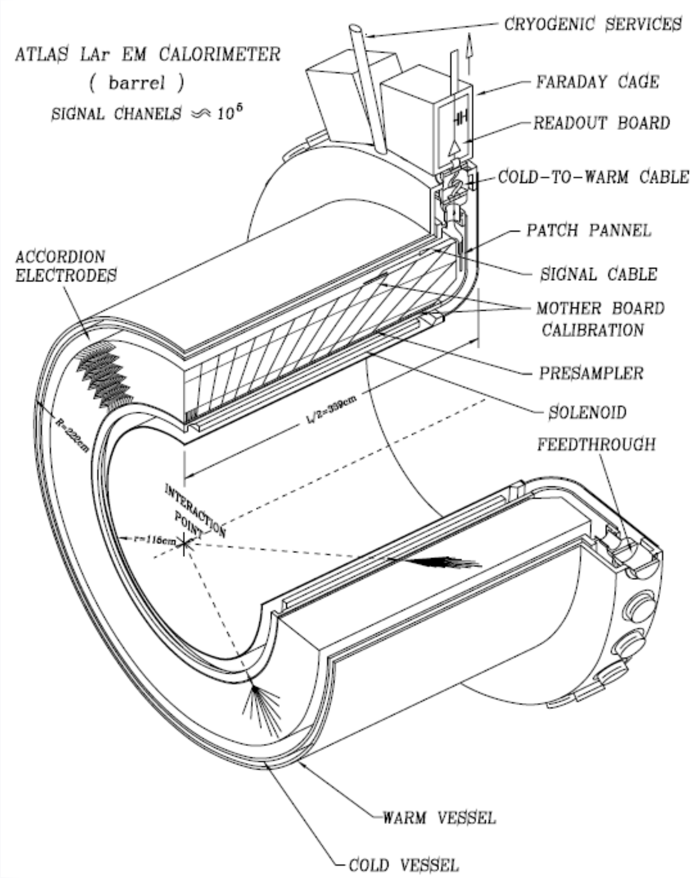
FCAL1 Anode Structure

- Forward Calorimeter (FCal)
  - 3 wheels per endcap (10λ)
    - Cu matrix for the first wheel (2.6λ, $28X_0$)
    - W matrix for the other two wheels (2x 3.7λ)
- Hadronic Endcap Calorimeter (HEC)
  - 2 wheels per endcap (10λ), 32 modules each
    - Cu absorbers (25mm/50mm thick)
    - Each gap consists of 4 sub gaps of 1.85mm



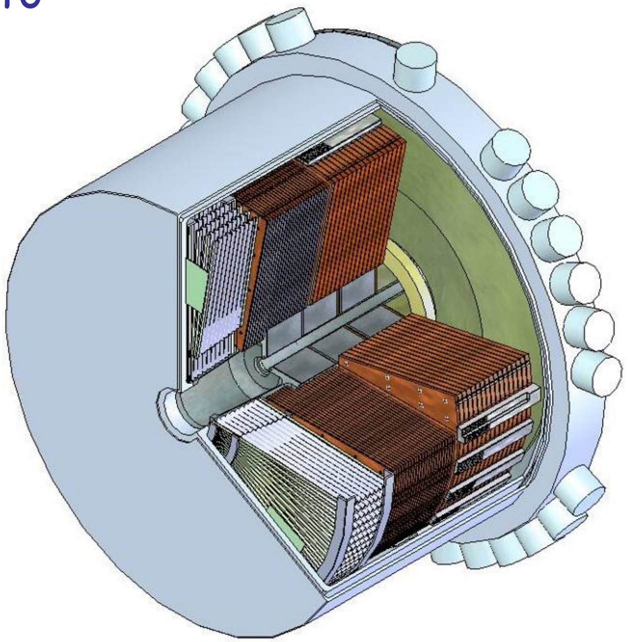


Integration Summary



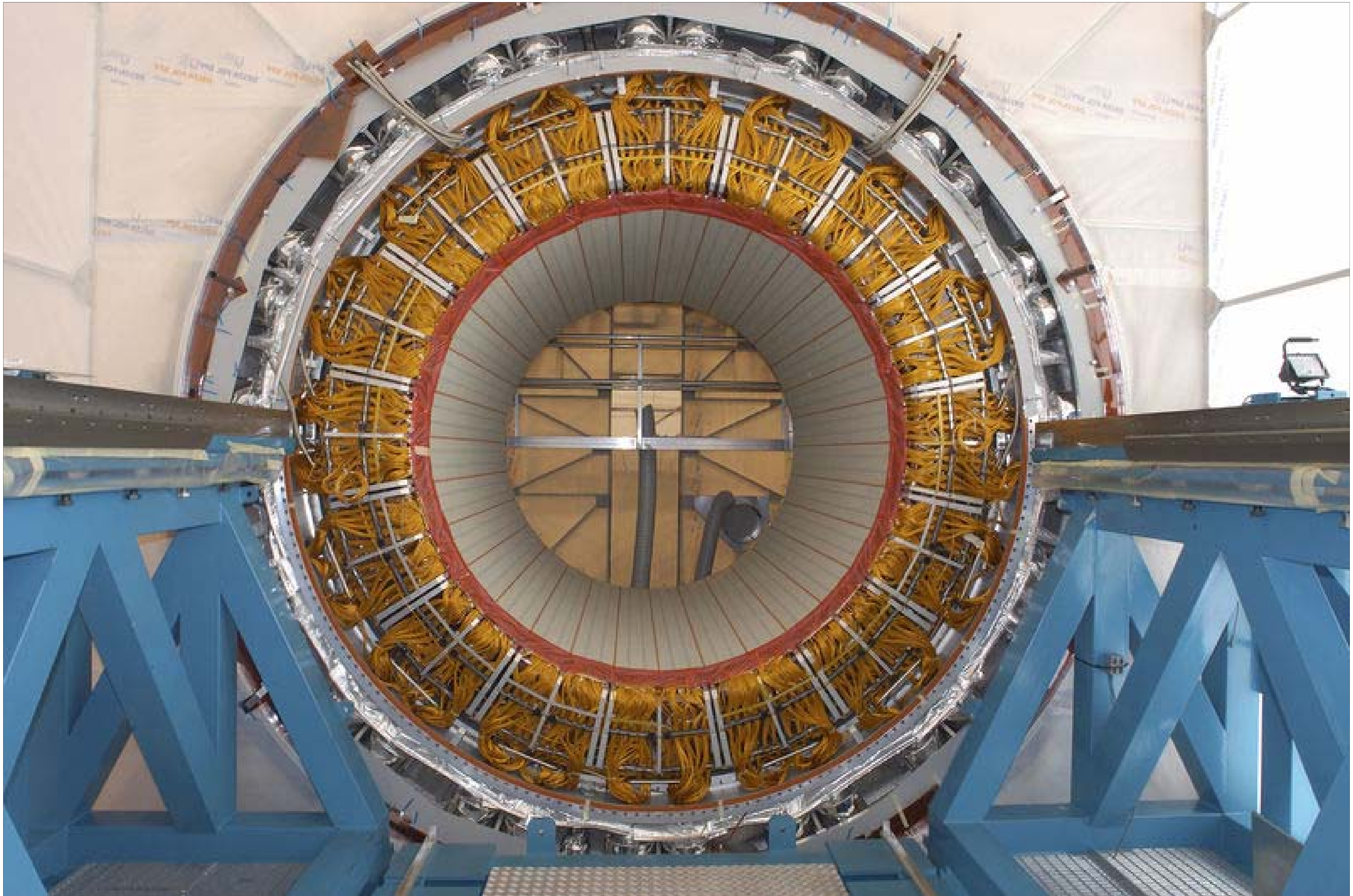
Half barrel cryostat

- Delivery of 3 cryostats and preparations of cryostats at CERN starts in 2002
- Module production in institutes and delivery to CERN from 2001 – 2004
- Wheel assembly in clean rooms from 2002 – 2004
- Wheel insertion into cryostats from 2003 – 2004
- Cold tests on the surface 2004 – 2005

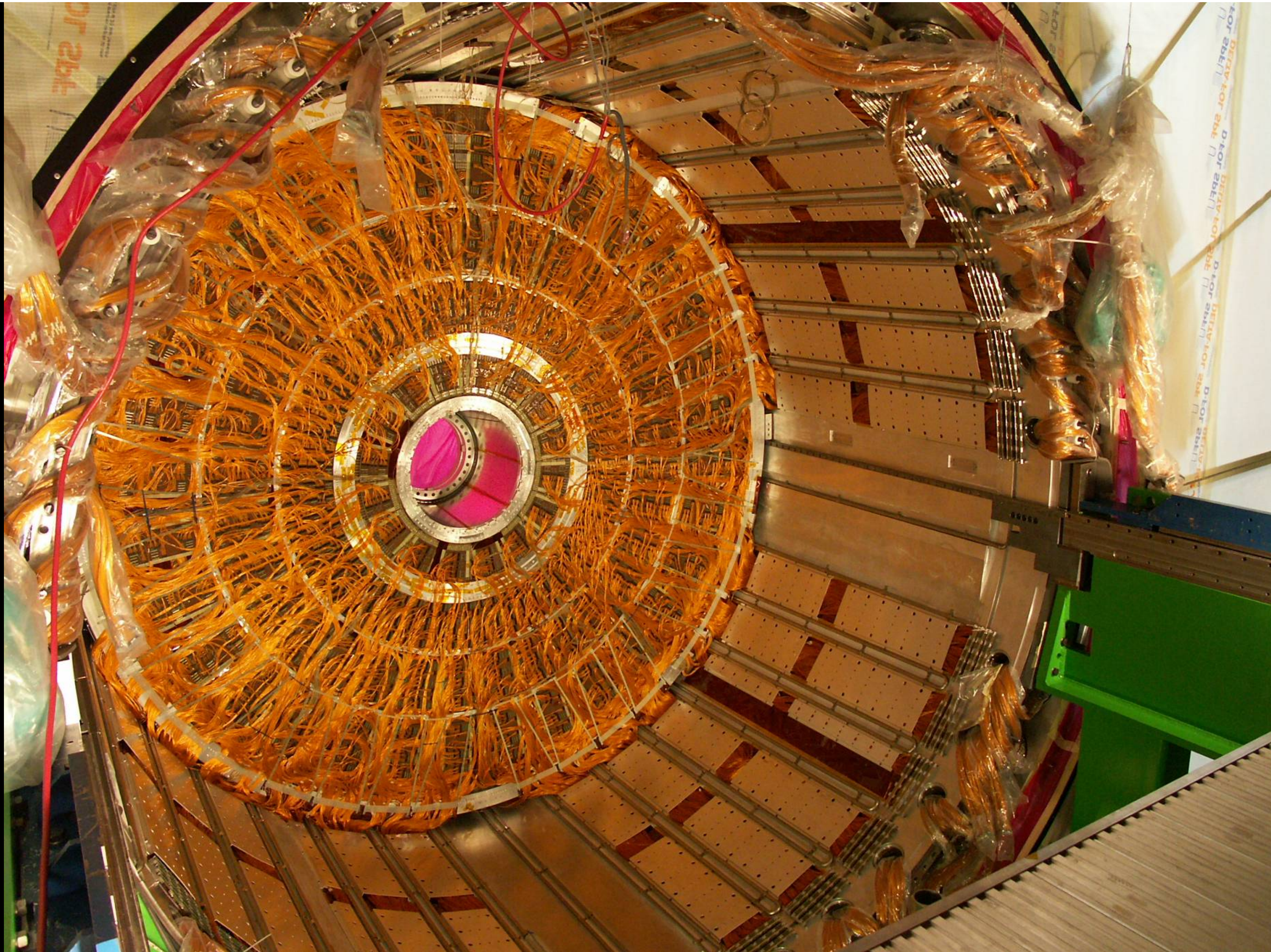


Endcap cryostat

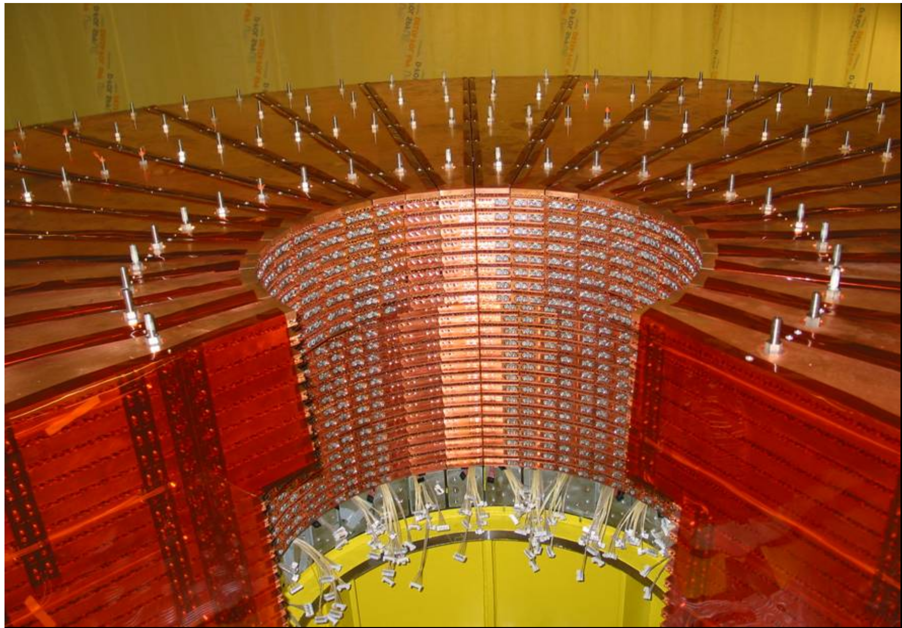
Closing the P-wheel, May 2003

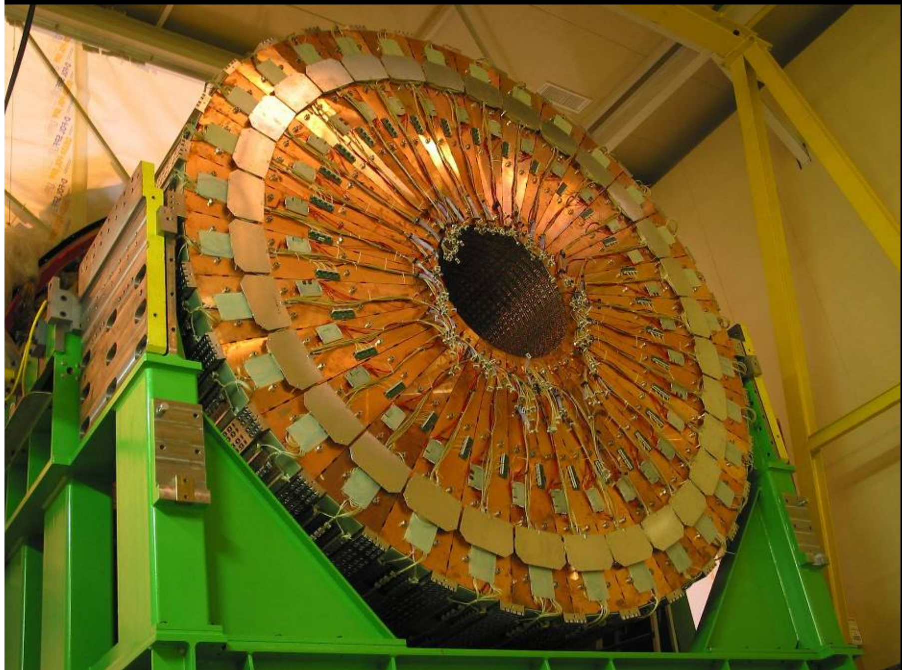


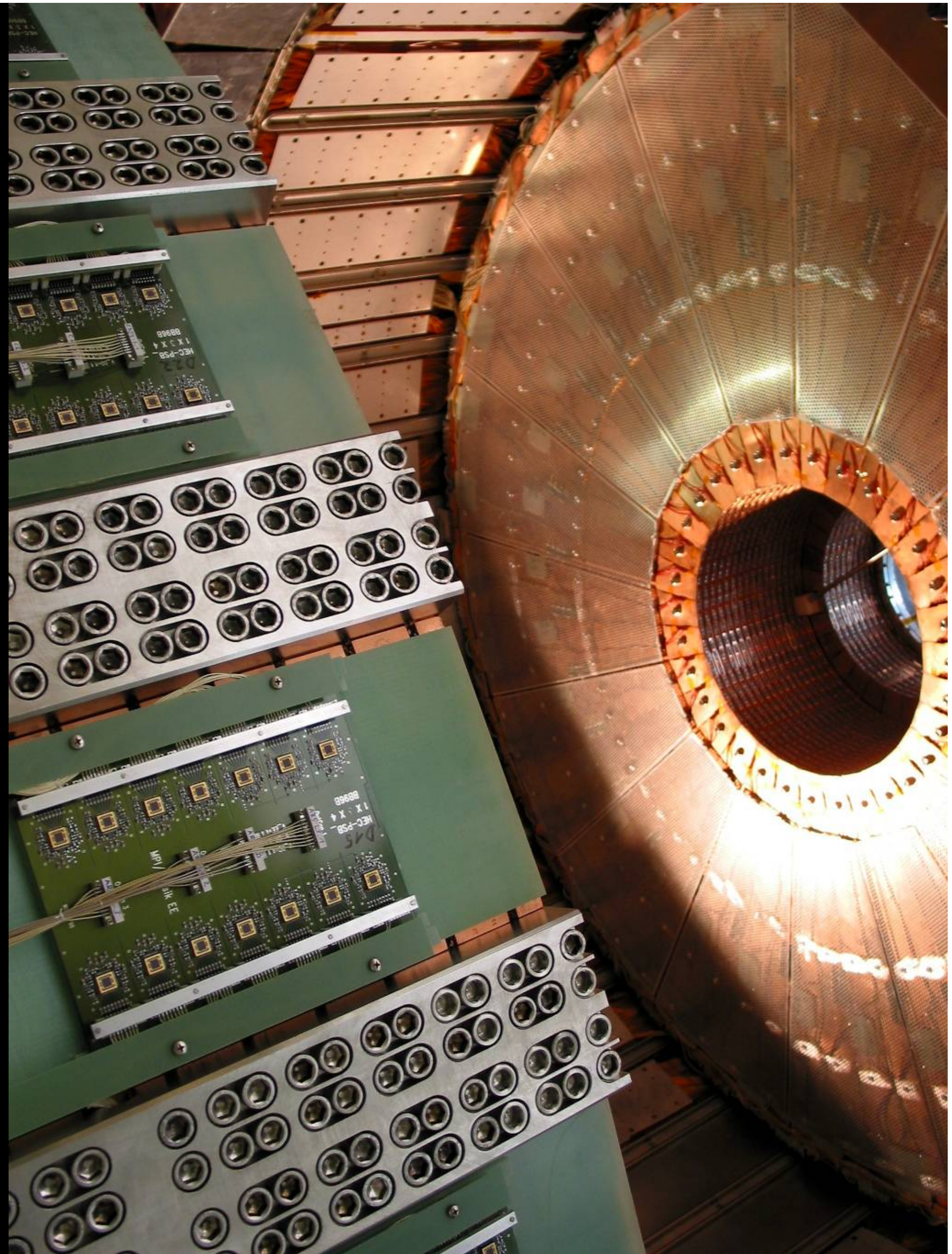
M-wheel inside the cryostat, March 2003



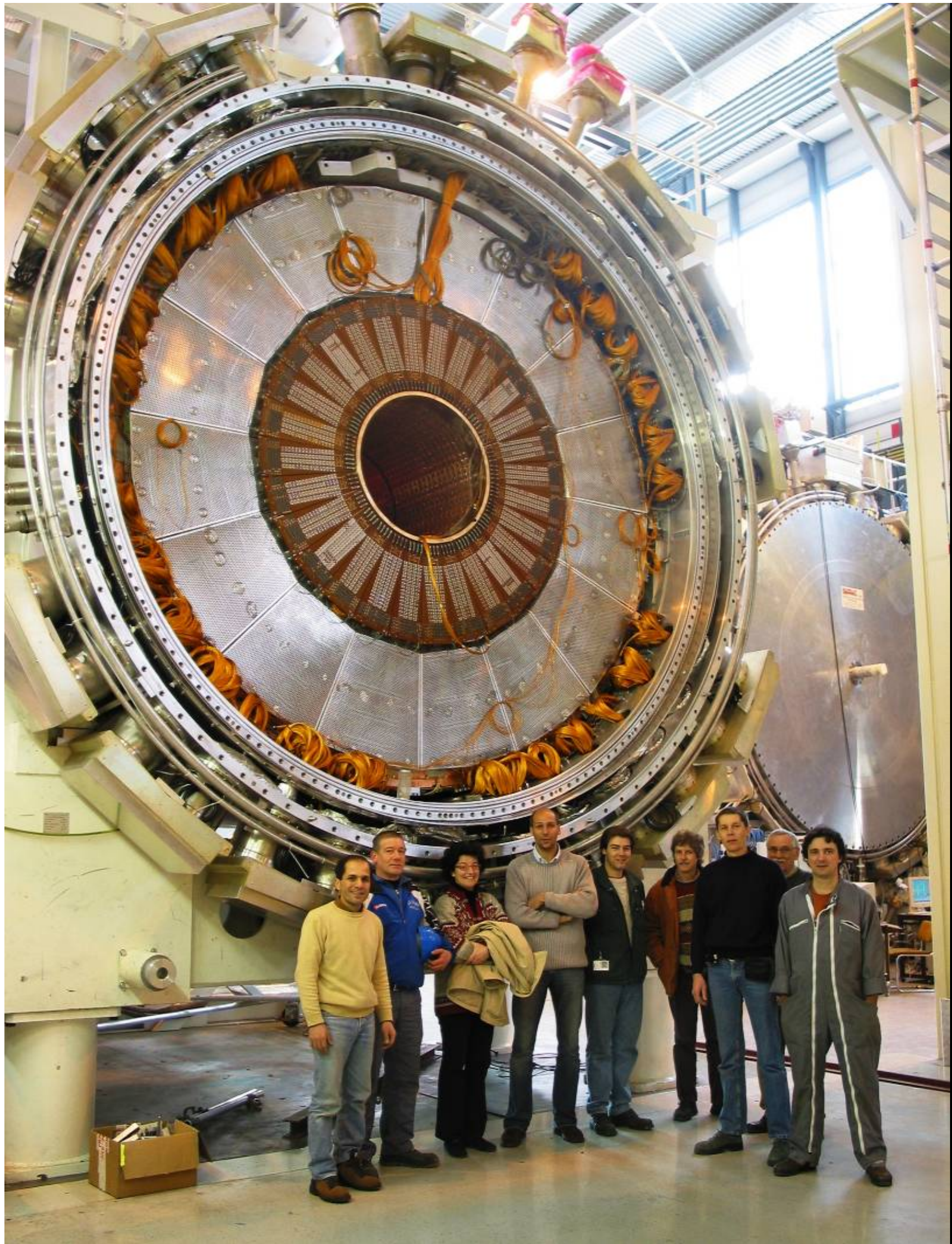
EM EndCap A wheel after its insertion, cabling finished, July 2004







HEC wheel assembly and insertion into the cryostat



ECA cryostat before closing

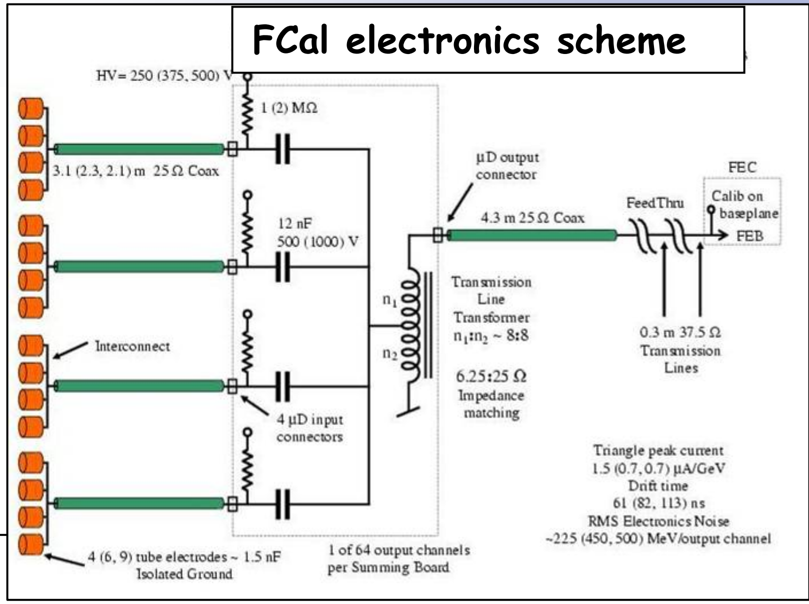
FCal C insertion, August 2004

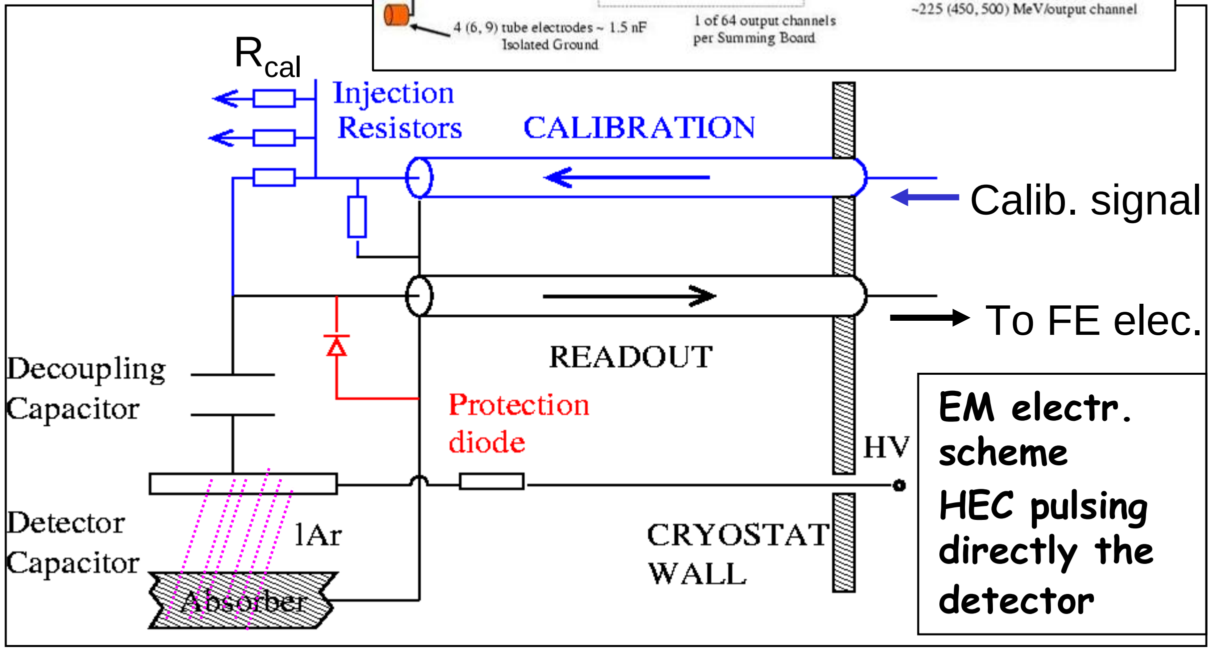
Cold Commissioning On the Surface

- All three cryostats were commissioned at LAr temperatures (87K) filled with LAr on the surface (cold commissioning)
- The goal of the cold commissioning was to
  - Check the connectivity and integrity of the connections and all the detector channels and calibration lines at LAr temperatures
  - Test the integrity of all HV channels at nominal voltage at LAr temperatures
  - Measure calibration resistors and cell capacitances at LAr temperatures
  - Measure the noise and coherent noise (with ATLAS electronics boards)
- The barrel commissioning lasted 10 weeks in summer 2004
- The end cap C commissioning lasted 8 weeks in winter 2005
- The end cap A commissioning lasted 6 weeks in summer 2005
- Number of channels to be tested on all three subdetectors:
  - 190304 read out channels
  - 14592 calibration lines
  - 4248 HV channels

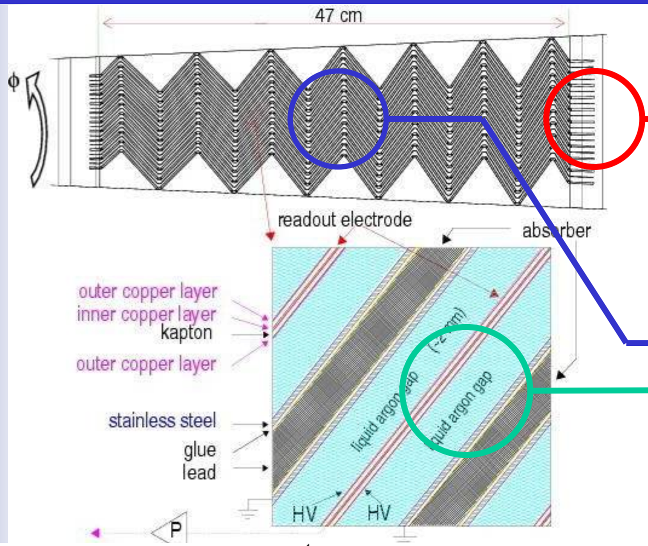
Cold Commissioning – Tests

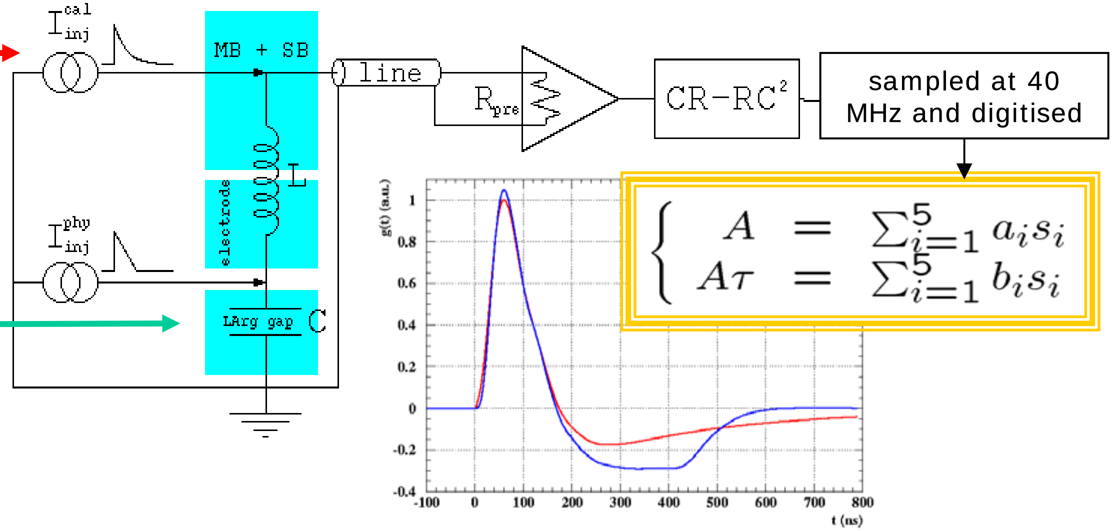
- Applying High Voltage
  - Slow ramp up (measure current draw)
  - Stability test during several weeks
- HV continuity tests (EM and FCal only):
  - AC signal applied on the HV line
  - Via the detector capacity a signal is induced on the signal cables
  - Checks connectivity of the HV and signal lines
- Pulsing all lines with the calibration board, and reading pulses back with the front end boards
- Reflectometry measurements
- LC, R_{cal} measurements (EM)
  - Measure these parameters at cold
  - Used in the calibration run analysis
- Tests of the final Front-End-Crate electronics
  - Noise measurements



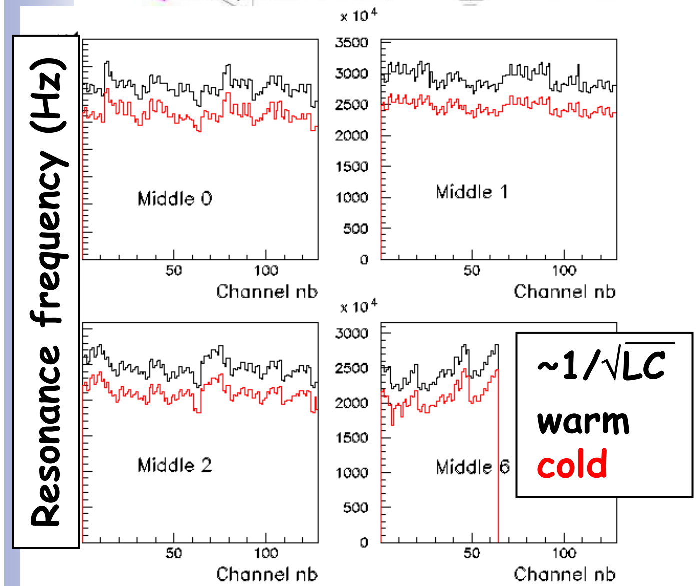


Cold Commissioning – R_{cal} and LC Measurements





$$\begin{cases} A = \sum_{i=1}^{5} a_i s_i \\ A\tau = \sum_{i=1}^{5} b_i s_i \end{cases}$$



- For optimal energy reconstruction (optimal filtering to minimize the noise) physics pulse shape and amplitude needs to be known with high accuracy
  - R_{cal} (0.1% accuracy, but sensitive to HV sparks) defines the amplitude of the calibration signal
  - LC of electrodes and LAr gap to be able to calculate the physics pulse shapes from calibration pulse shapes (=correction for the different points of injection)
- R_{cal} and LC have been measured during the cold commissioning

Cold Commissioning Test Summary

» 99.9% of detector channels work!

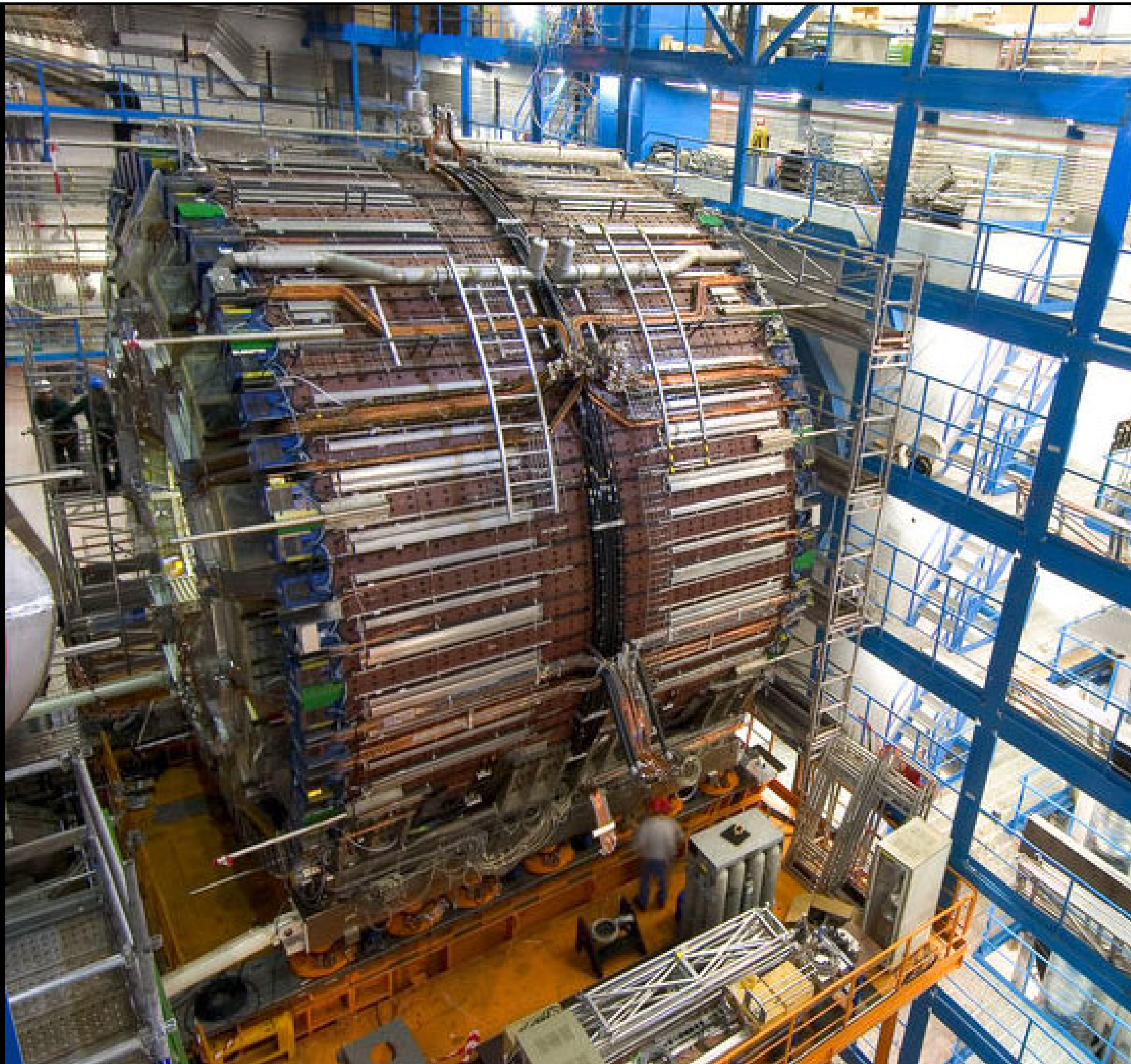
Signal & Calibration	Bad channels (#|%)	Bad calibration lines (#|acc.%)	Dead channels (#|%)
EMEC C	40 | 0.13	1 | 0.04	6 | 0.02
HEC C	3 | 0.11	3 | 0.37	3 | 0.11
FCal C	10 | 0.70	0 | 0.00	0 | 0.00
EMEC A	20 | 0.06	4 | 0.16	8 | 0.03
HEC A	0 | 0.00	1/3 | 0.8	3 | 0.11
FCal A	9 | 0.63	0 | 0.00	0 | 0.00
EM Barrel	49 | 0.04	1 | 0.01	31 | 0.03

HV	Correction needed (HV#|acceptance%)	Dead (HV#|acceptance%)
EMEC C	25 | 5.00	0 | 0.00
HEC C	12 | 7.50	0 | 0.00
FCal C	8 | 1.80	0 | 0.00
EMEC A	35 | 8.75	1* | 0.25
HEC A	13 | 8.10	0 | 0.00
FCal A	11* | 4.19	0 | 0.00
EM Barrel	8.5 | 1.90	0 | 0.00

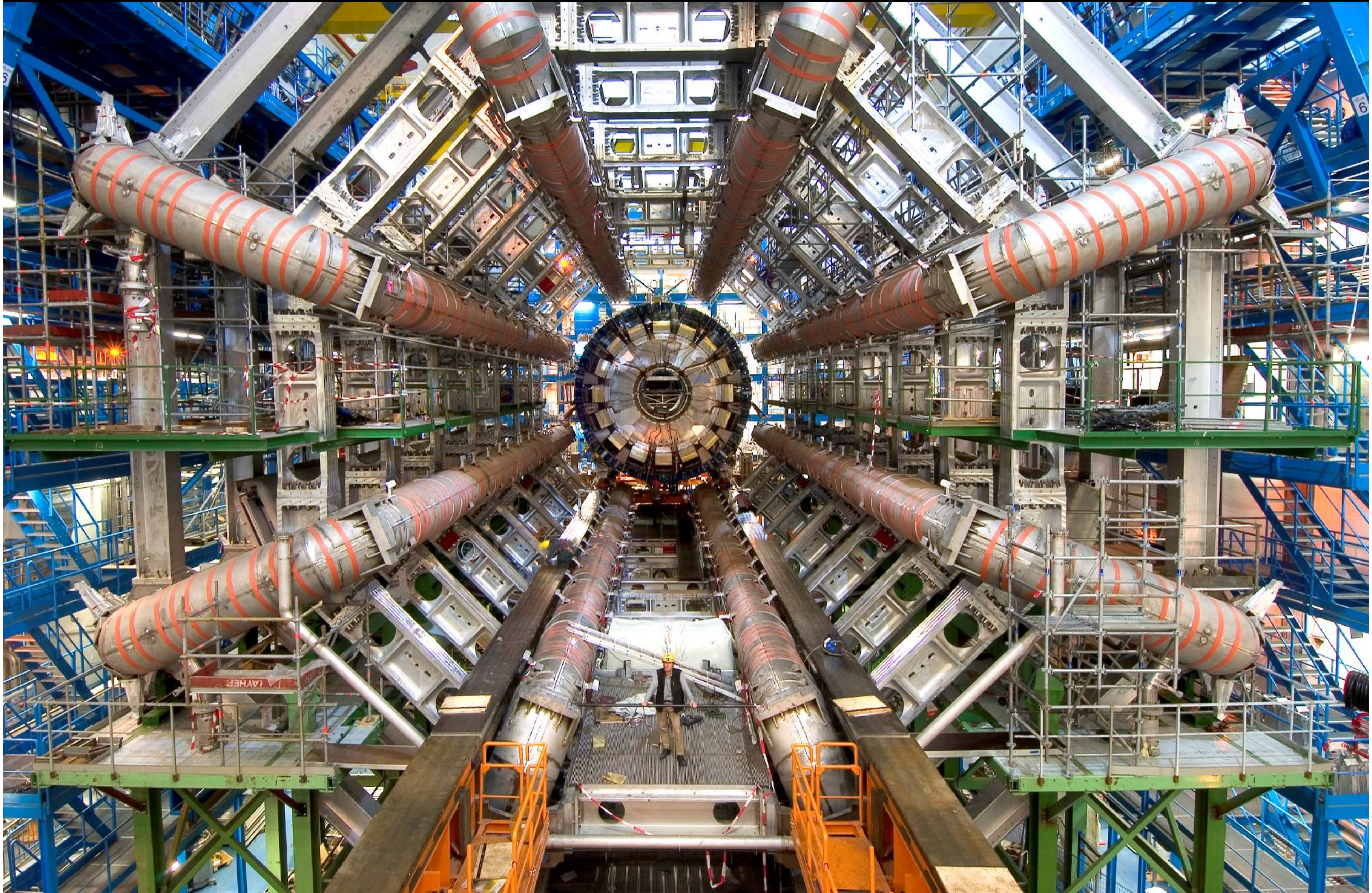
Tests on how to repair those HV channels marked with * are underway

Installation in the ATLAS Cavern

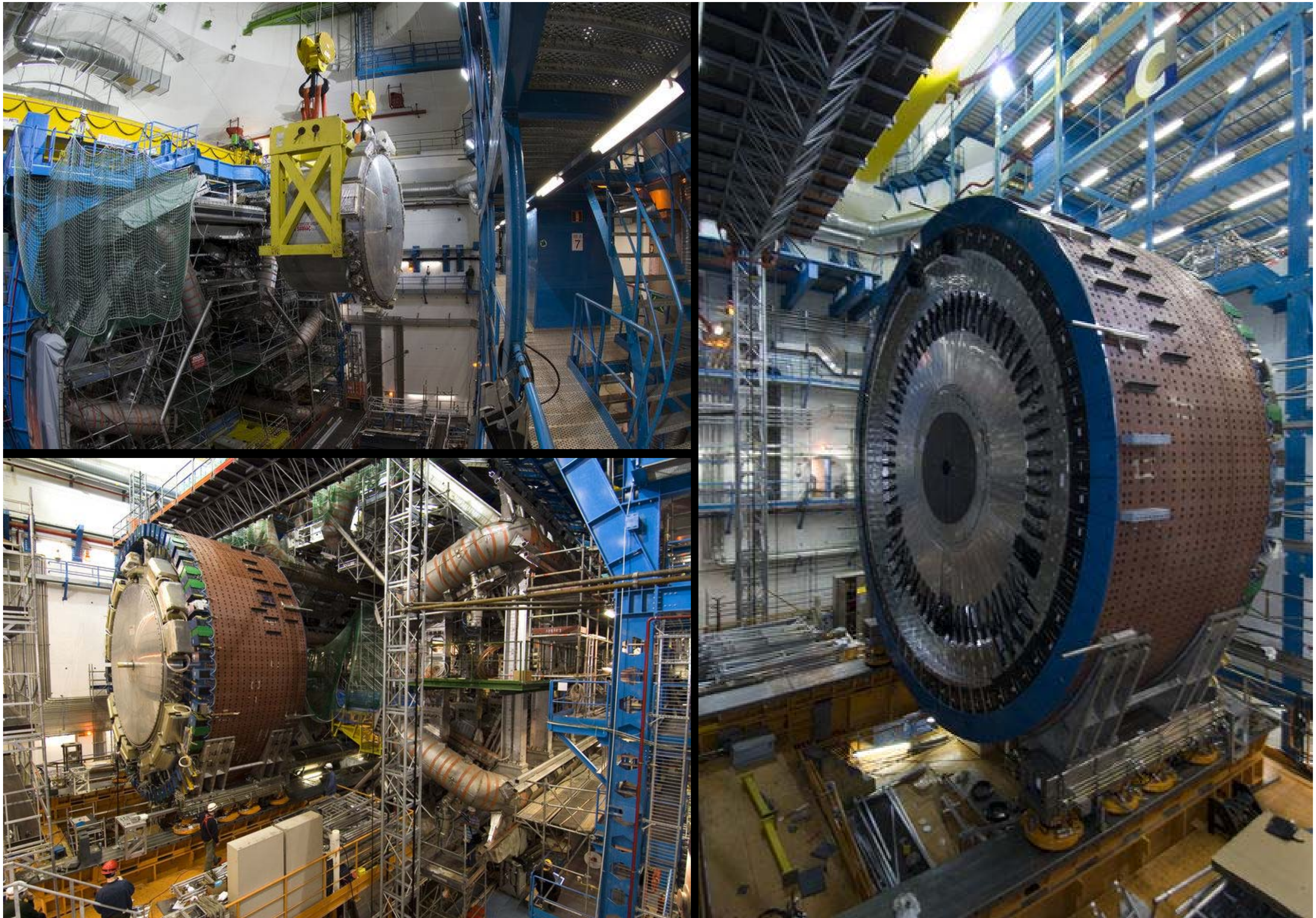
- All three cryostats have been installed in the ATLAS cavern
  - Barrel cryostat: October 2004
  - Endcap C: December 2005
  - Endcap A: April 2006
- The Tile Calorimeter (ATLAS barrel hadronic calorimeter) has been built around the three cryostats
- Barrel cryostat was already moved to its final position around the interaction point (Nov. 2005)
  - Alignment with respect to barrel Tile Calorimeter and the IP with a precision better than 1mm



ATLAS barrel calorimeter after barrel Tile completion, Oct. 2005



ATLAS barrel calorimeter being moved to the IP, Nov. 2005

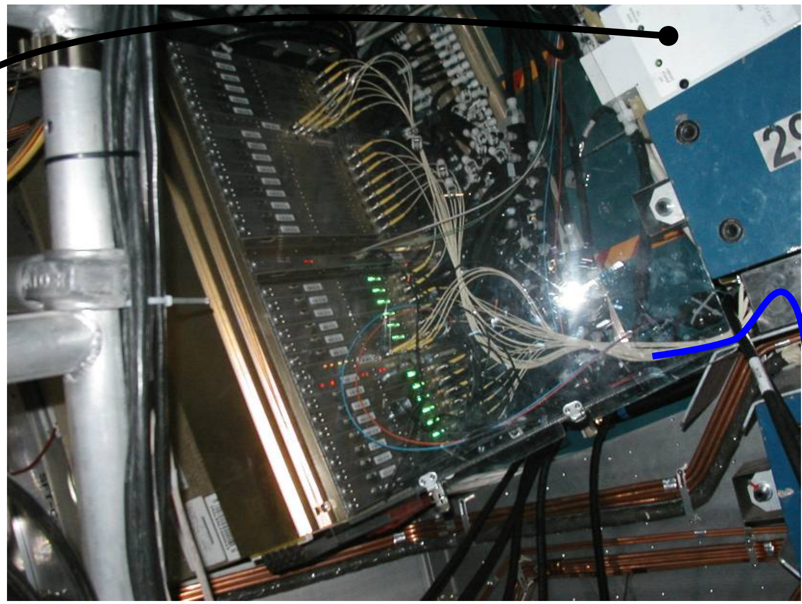


ATLAS endcap calorimeters installation, winter-spring 2006

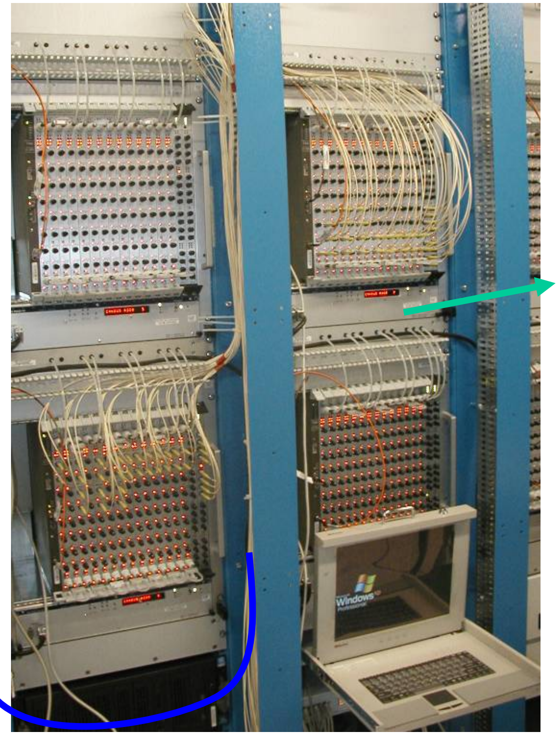
Underground Installation

- Installation and connection of front end boards on the barrel cryostat finished, on the endcaps started (still some problems with LVPS).
- Backend read out electronics installed in the underground service area
- HV system for the barrel operational (still some modifications for HVPS foreseen)
- Since several weeks regular calibration runs on readily commissioned front end crates
  - 3 crates read out for the moment on the barrel calorimeter ~10% of the barrel
  - 1 crate read out on the endcap C

280V bulk supply in USA15



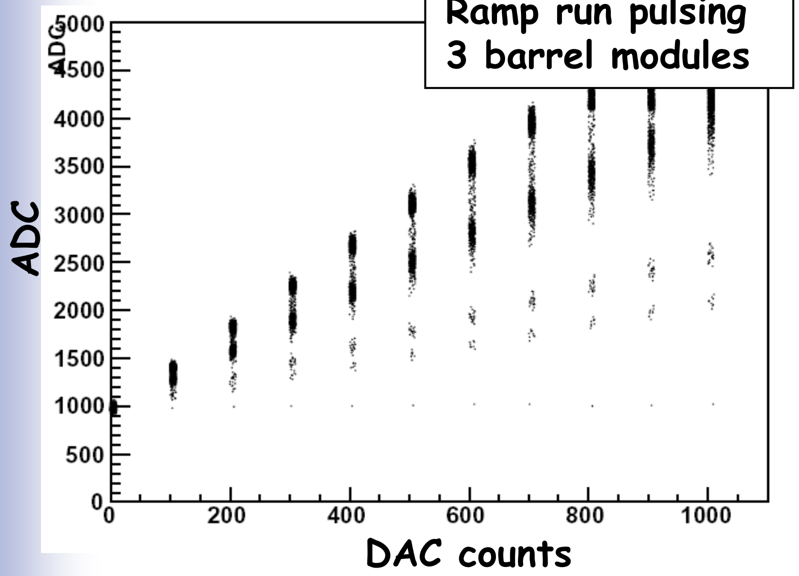
Front end crate H08

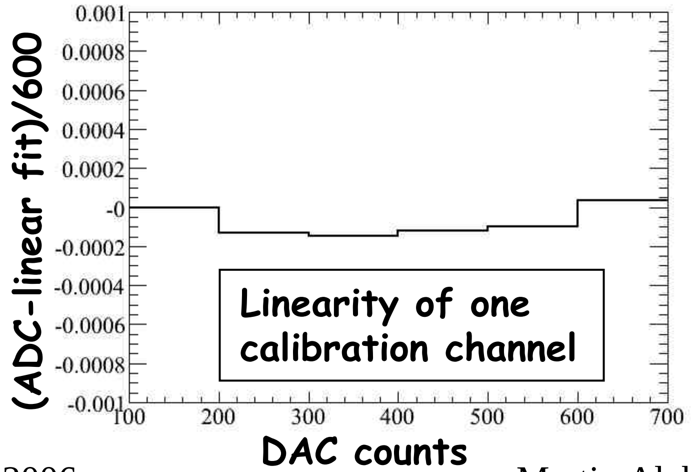


To ROSs and disks

Read out drivers

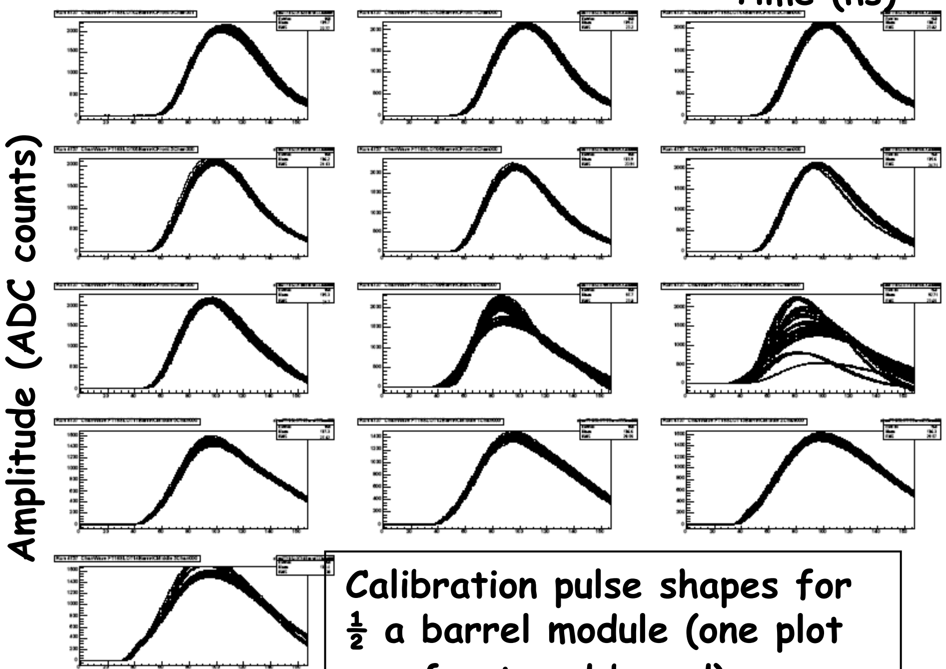
Commissioning After Installation





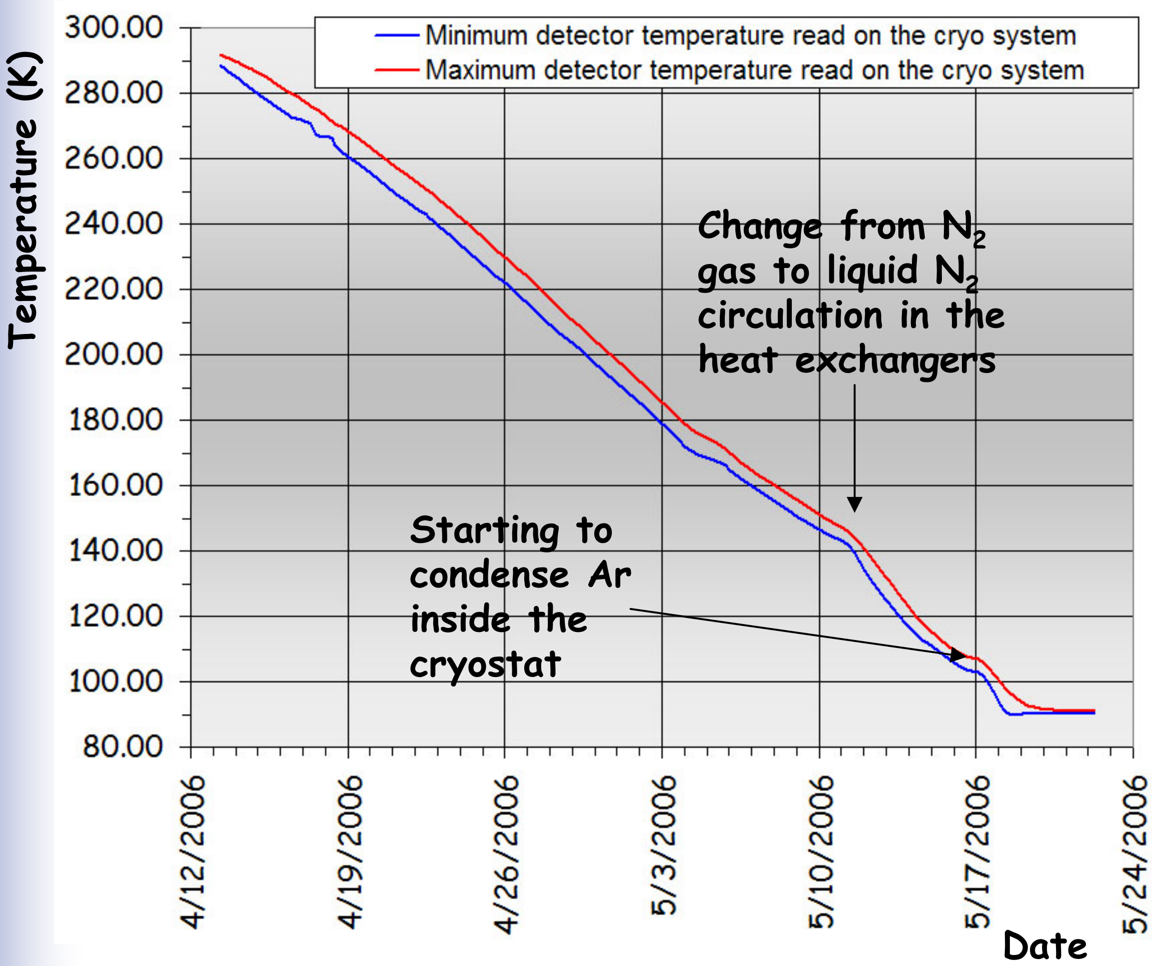
As soon as the front end boards are installed in the cavern and connected to the ATLAS read out system regular calibration runs are recorded

- Injection of a calibration pulse (via the R_{cal}) on the detector module inside the cryostat, and reading it back with the whole read-out chain
- Allows to check the integrity of all connections, the status of the detector cells and the functioning of the read out chain and the calibration system



Calibration pulse shapes for ½ a barrel module (one plot per front end board)

Barrel Cryostat Cool Down



- Cool down started mid April
- Filling with LAr since May 17 (condensing Ar gas) for 2 weeks
- Now cryostat filled to large extent with LAr (>90%)
- HV situation checked regularly
- During the coming weeks ramping up the HV
- After that the barrel detector is operational
- Continue connecting front end electronics
- Ready to take cosmic muon data in summer 2006

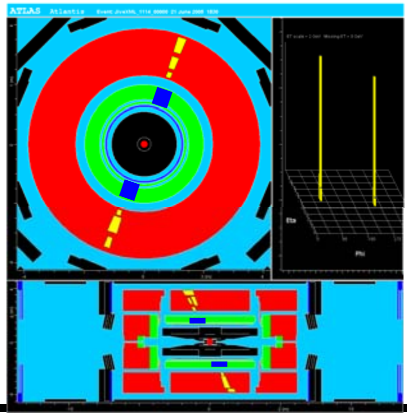
Conclusions

- All LAr calorimeters have been successfully integrated into their cryostats
- Cold tests on the surface show the excellent condition of the calorimeter (more than 99.9% of channels work)
- All three cryostats have been installed in the ATLAS cavern
- The electronics installation is finished for the barrel calorimeter and in full swing for the endcaps
- Starting in summer 2006 cosmic muons will be recorded together with the hadronic Tile calorimeter. The muon system and the ID will join towards the end of the year.

Commissioning – The Road to Physics

1: Testbeams

2: Subdetector Installation,
Cosmic Ray Commissioning



2.5: Spring ’07: Global cosmic run

3: Single beam

4: First LHC collisions

5: First Physics

2005 2006 2007 2008