Design Principles and Operational Results of the Cryogenic System for the ATLAS Liquid Argon Calorimeter

Caroline Fabre
CERN
Accelerator Technology Department
Cryogenics Group

on behalf of the ATLAS Liquid Argon Cryogenics Collaboration

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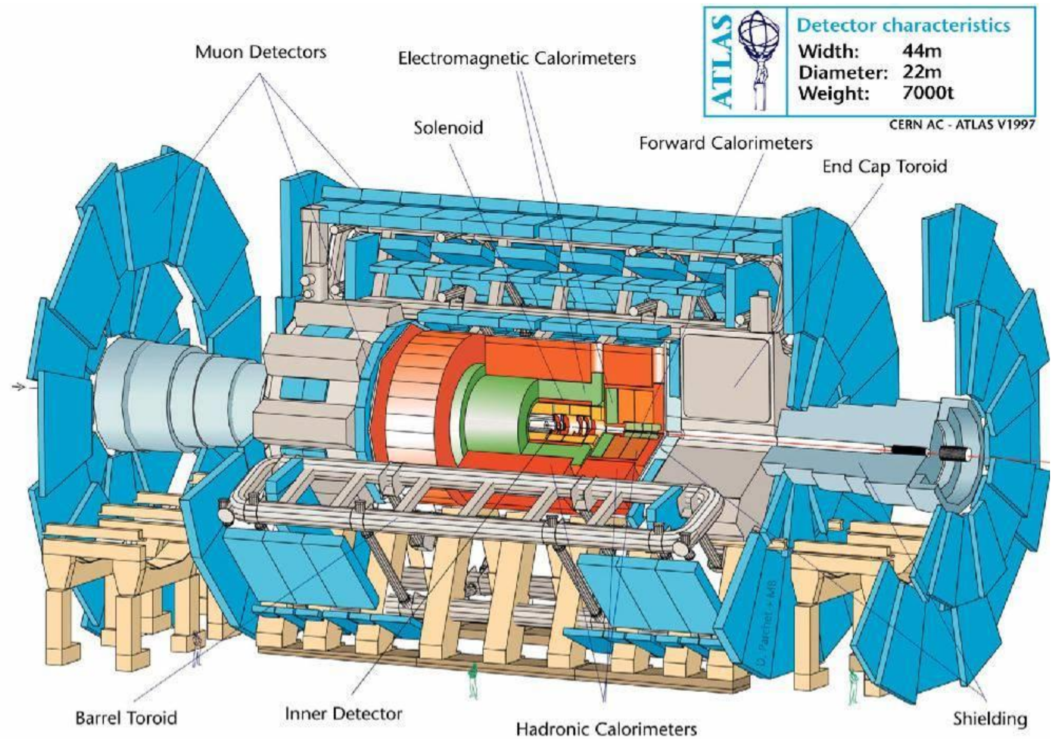
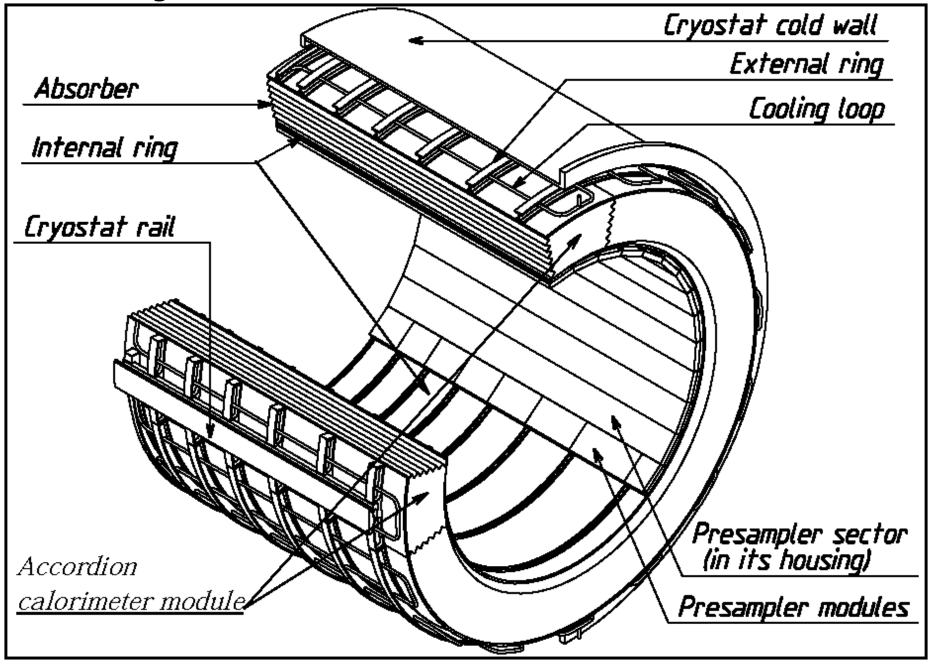


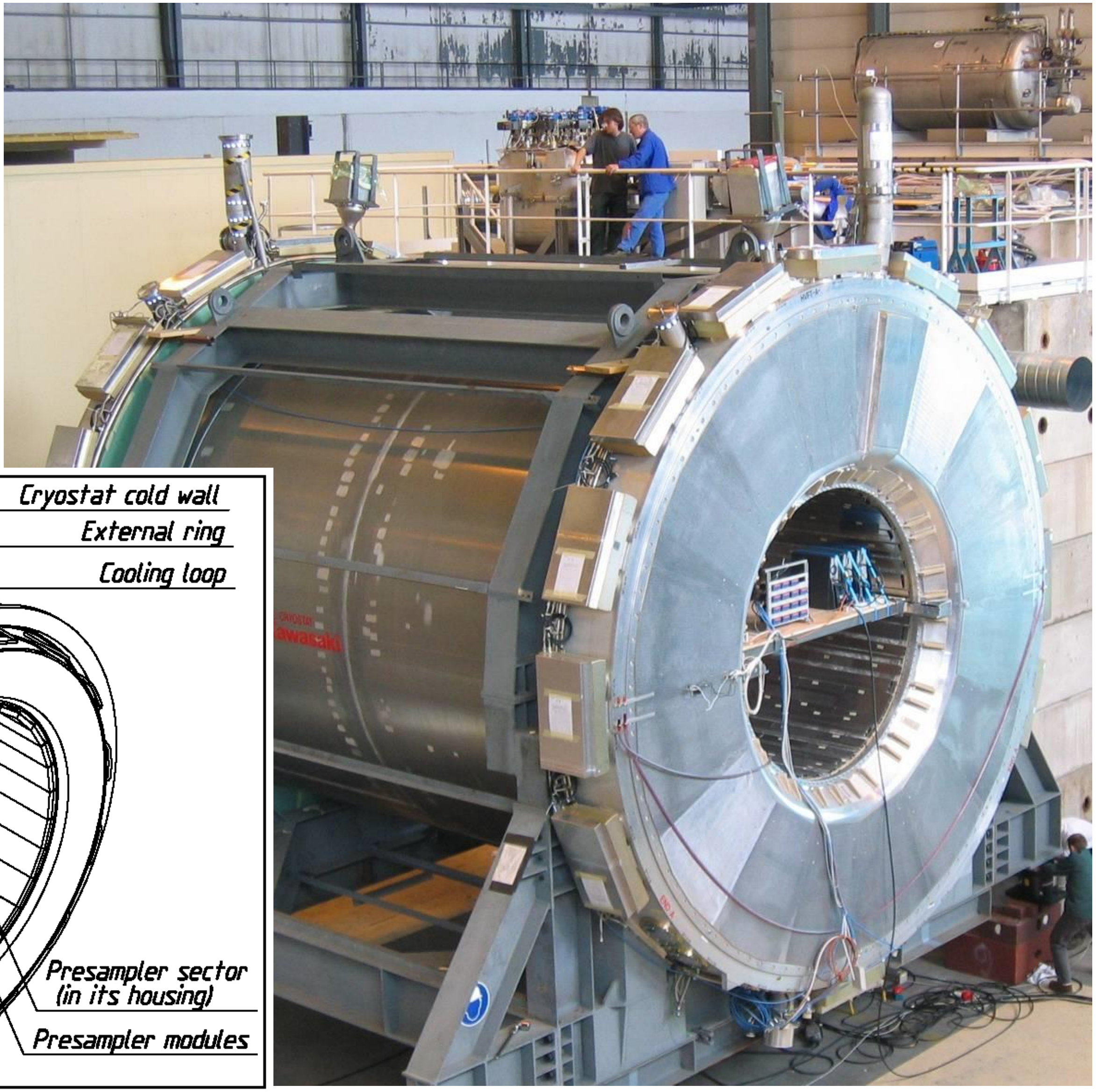
Muon Detectors
Electromagnetic Calorimeters
ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

✓ Barrel Calorimeter:

- D: 4.3 m; L:6.5 m
- Weight: 120 t
- Argon volume: 40 m^3

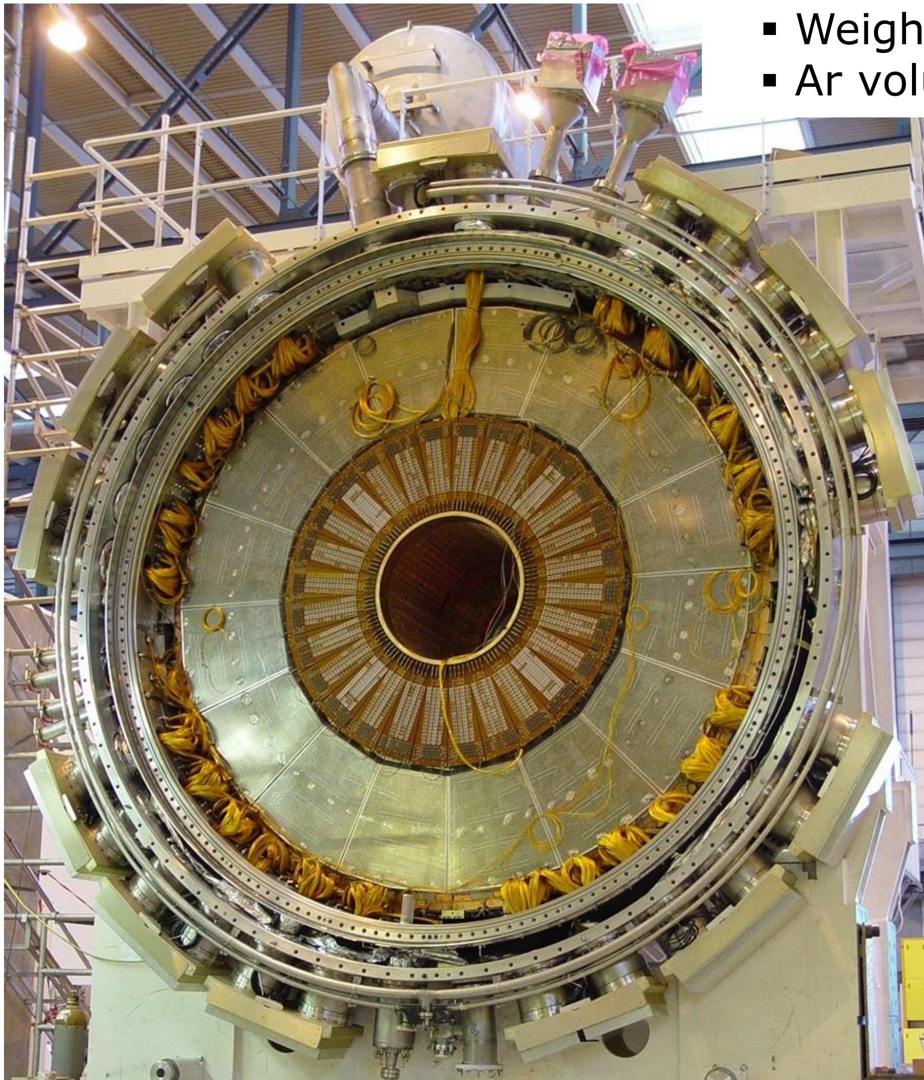
Electromagnetic barrel half-wheel

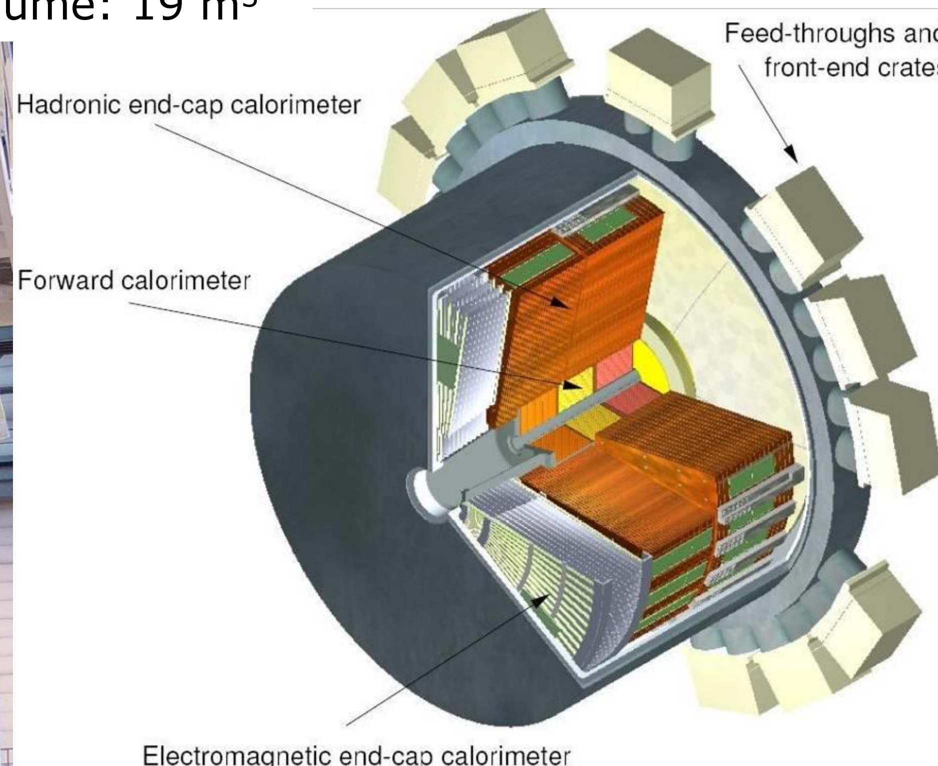




✓ End-cap Calorimeter:

- D: 4.3 m; L: 3 m
- Weight: 219 t
- Ar volume: 19 m^3





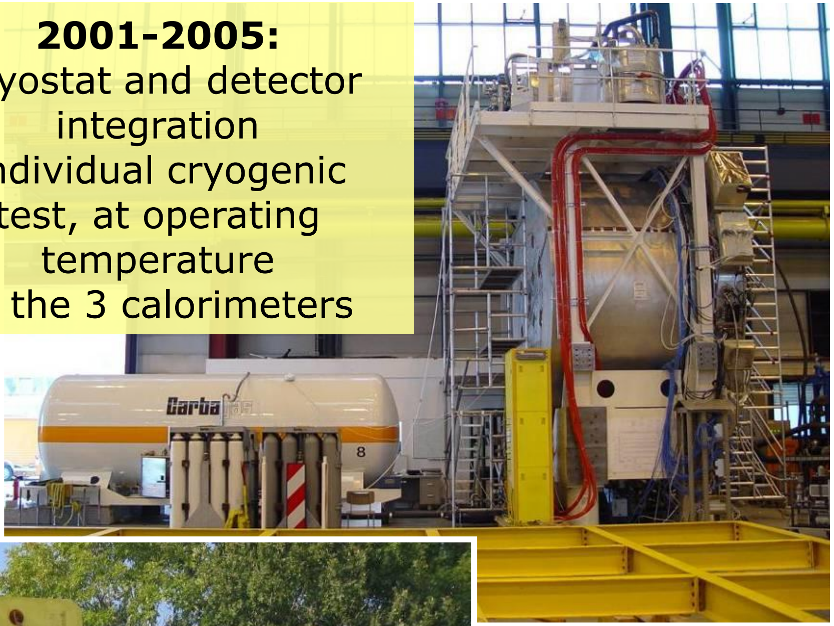
Calorimeters are highly complicated composite structures made of copper, lead, stainless-steel and glass-epoxy… placed in aluminium cryostats

The ATLAS liquid argon calorimeters (3)

✓ Project stages:

1997-2004:
Cold performance test
and calibration in particle beam
of the 128 individual detector modules

2001-2005:
Cryostat and detector
integration
Individual cryogenic
test, at operating
temperature
of the 3 calorimeters



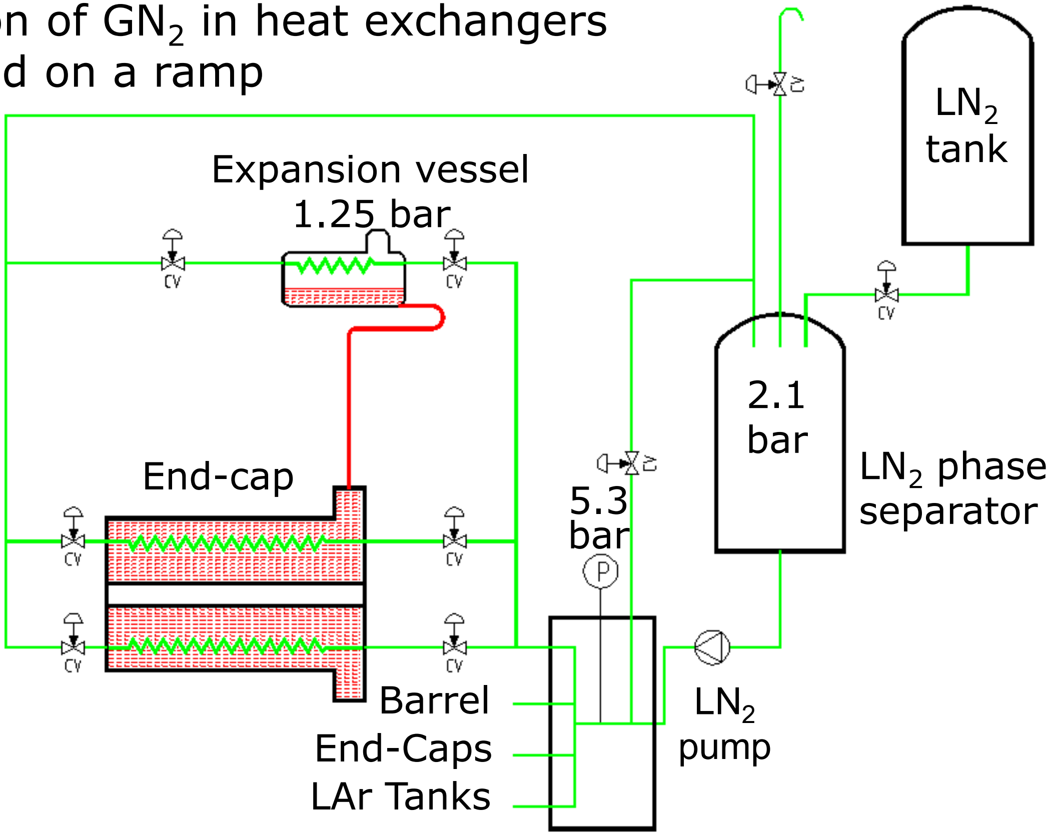
Nov. 2004:
Barrel lowering in ATLAS pit

Sept. 2005:
Transport of
an end-cap
calorimeter
towards Point 1

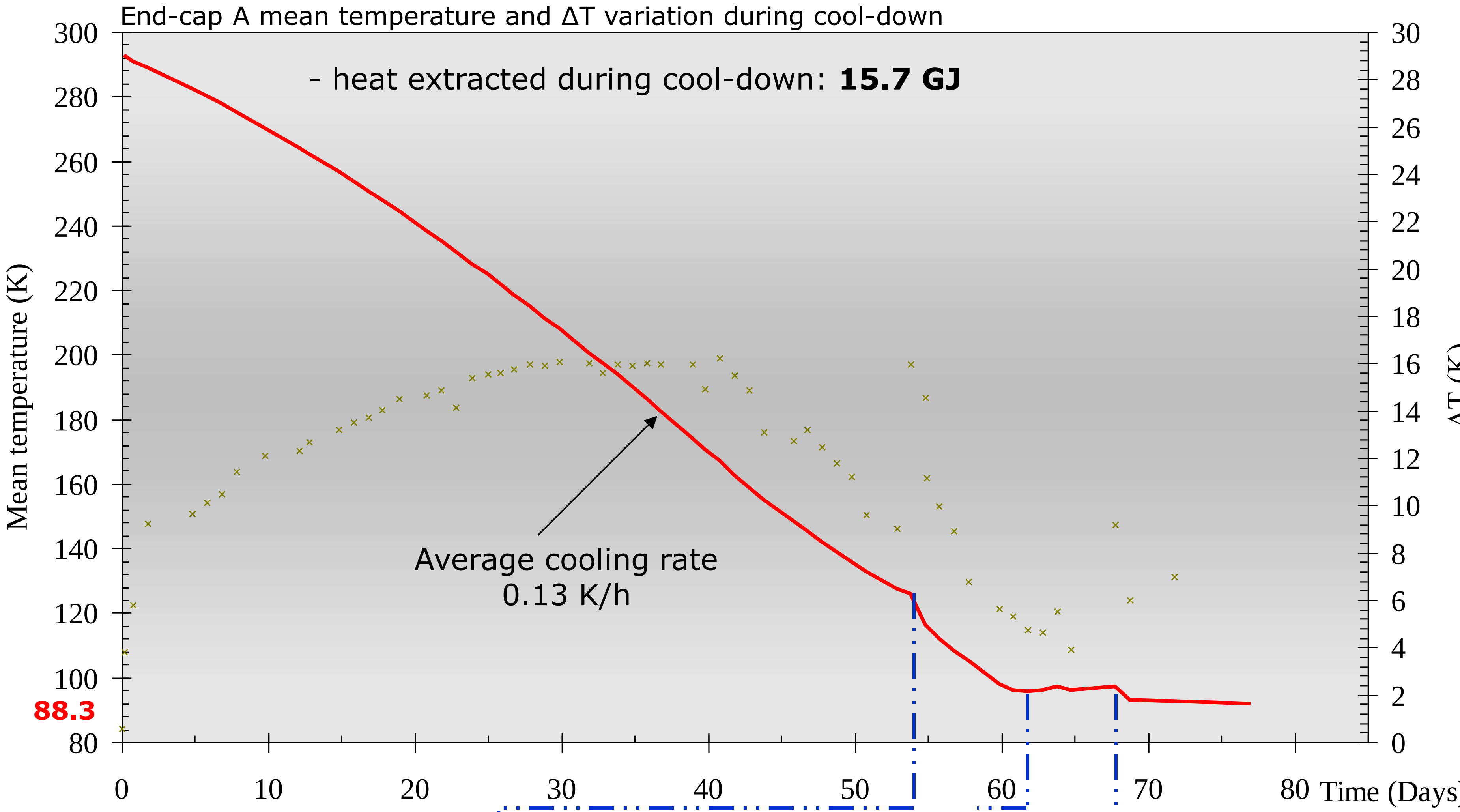
The procedures during cool-down (1)

- ✓ **Cooling criteria:** ΔT must be kept within strict limits to avoid excessive stresses or displacements (< 6…45 K)
- ✓ **Procedures :**
  1. Rinsing cycles
  2. Gas cooling: forced convection of GN_2 in heat exchangers
     inlet T decreased on a ramp
  3. Liquid cooling:
     circulation of vaporizing LN_2
  4. Filling:
     Condensing of argon

Cool-down rate limited by an interlock triggered by the cooling criteria



The procedures during cool-down (2)



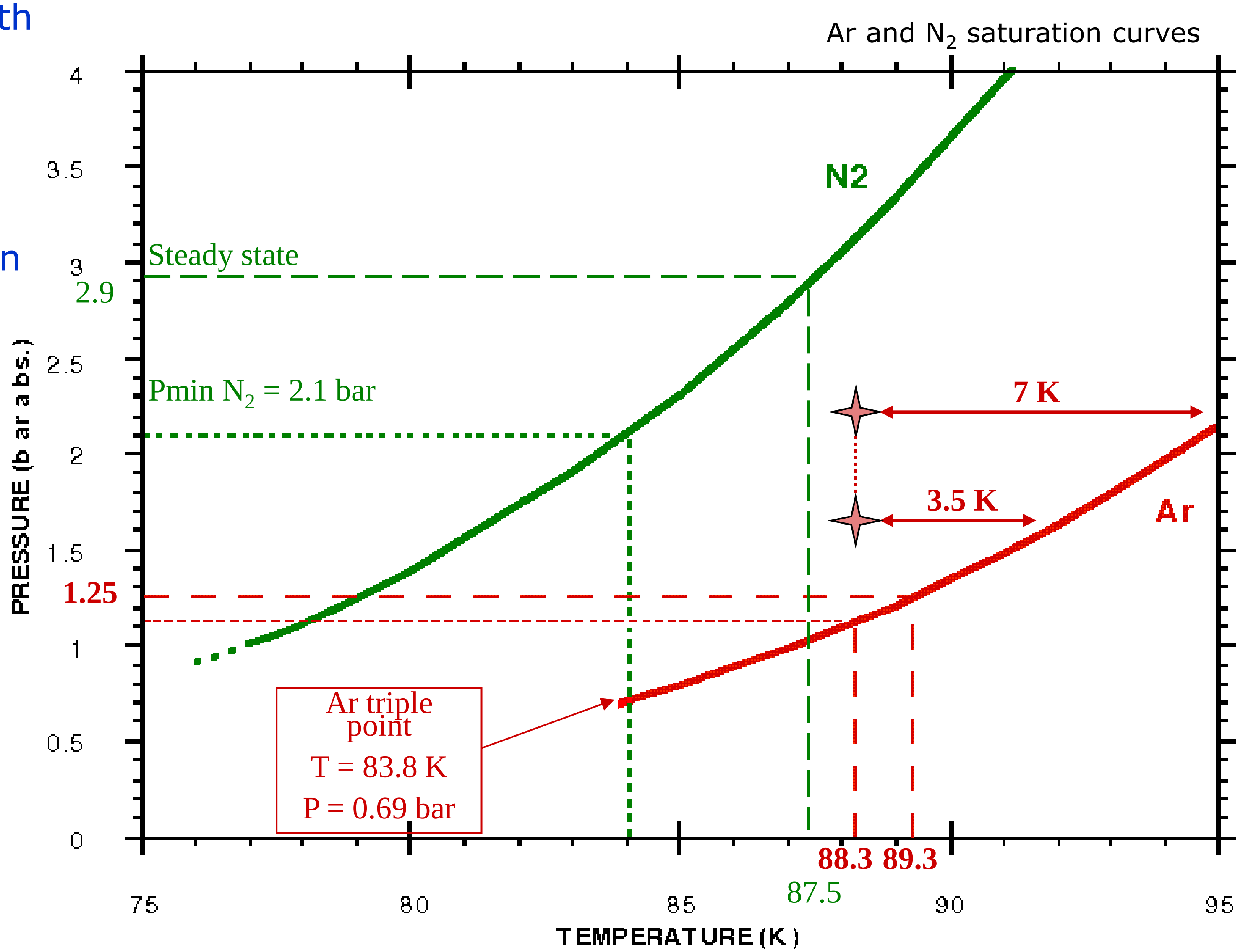
From 295K to 120K : GN_2 cooling

Between 120K and 90K: LN_2 cooling

Purges

Cryostat filling
Argon condensing

✓ The argon bath is sub-cooled to about 88.3 K to prevent gas bubble formation



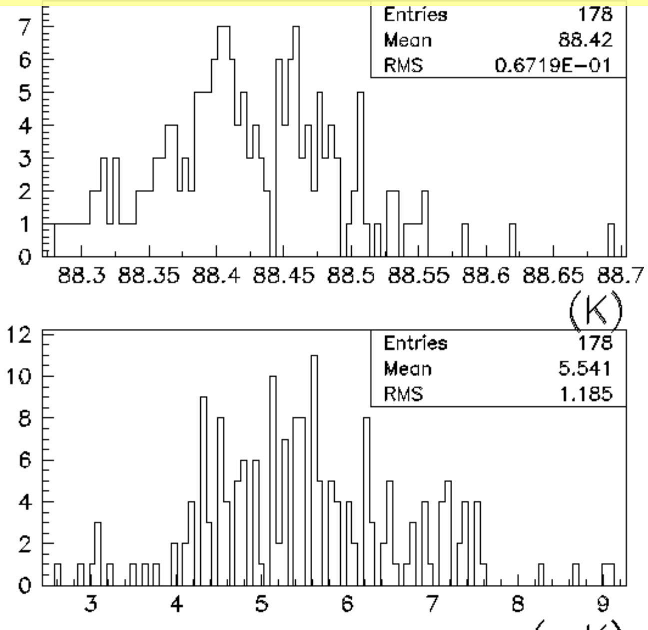
(End-cap A)

✓ Barrel steady-state performance:

- Temperature uniformity over detector volume: < 70 mK rms
- Temperature stability: < 5 mK rms
- LAr bath sub-cooled with 4.2 K to 7.7 K
- Argon purity: between 0.1 and 0.3 ppm of O2-equivalent

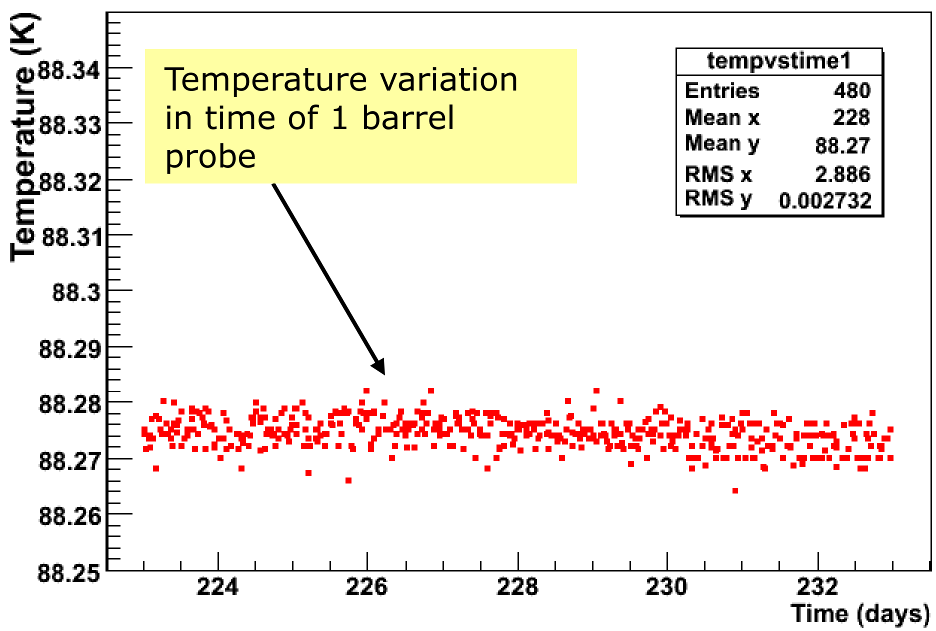
Energy measurement sensitivity: 2 % per K

Statistical occurrence of barrel mean T



Stability measurements in barrel over 24 h

Probe #85 (Barrel)



✓ Heat load balance:

- Heat load to the cryostats measured at the test facility:

barrel	end-cap	
1.8 kW	2 x 2.1 kW	estimated (TDR 1996)
1.9 kW	2 x 2.5 kW	
~ 50 % feedthroughs	~ 25 % cold electronics	

- Heat load to the complete cryogenic system measured at the final installation:

  11.2 kW estimated (TDR 1996)

  9.2 kW

  (8 kW [EC cold electronics off] + 2 x 0.6 kW EC cold electronics)

- 2.3 kW resulting heat load to :

  2 argon tanks, PSD,

  5 valve boxes, LN2 circulator,

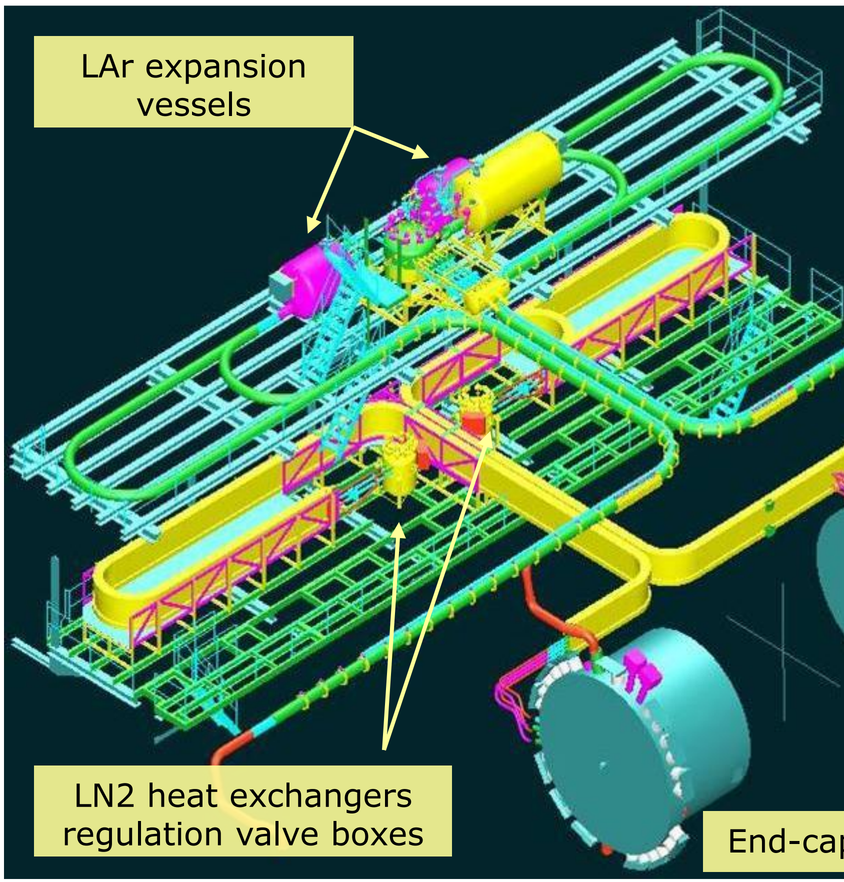
  ~ 700 m transfer-lines

Uninterrupted functioning over 15 years (1)

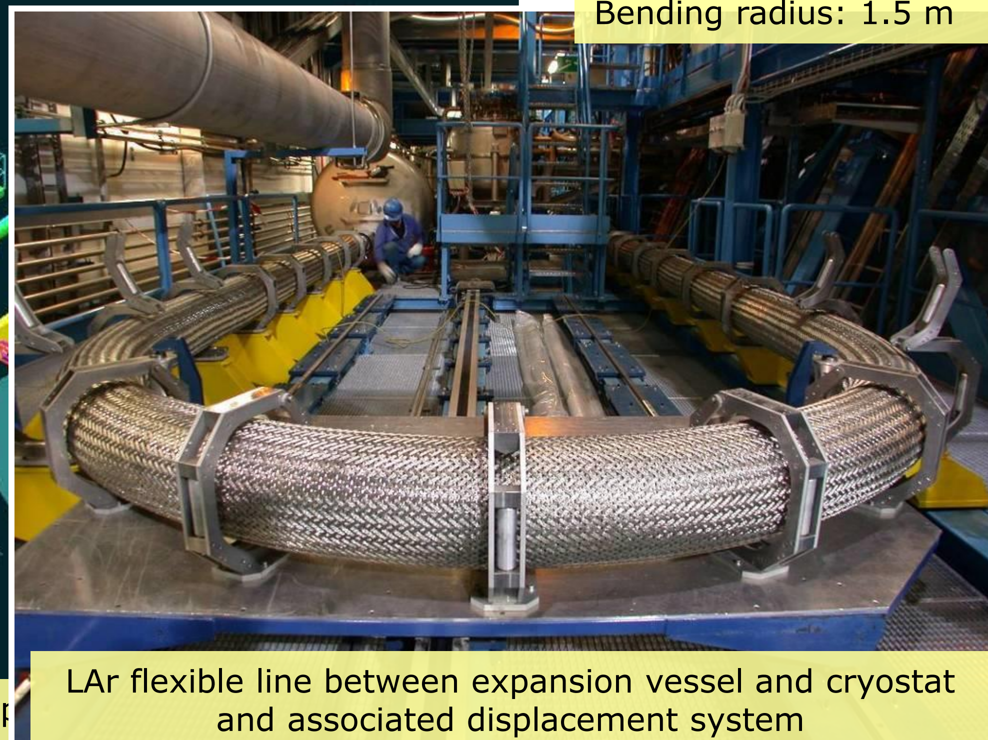
✓ 12 meter translation of the end-cap cryostats :

- Cryogenic lines between expansion vessel and cryostat
- Transfer-line supplying LN_2 to the heat exchangers
- Signal cables and compressed air pipes

} designed to follow this displacement

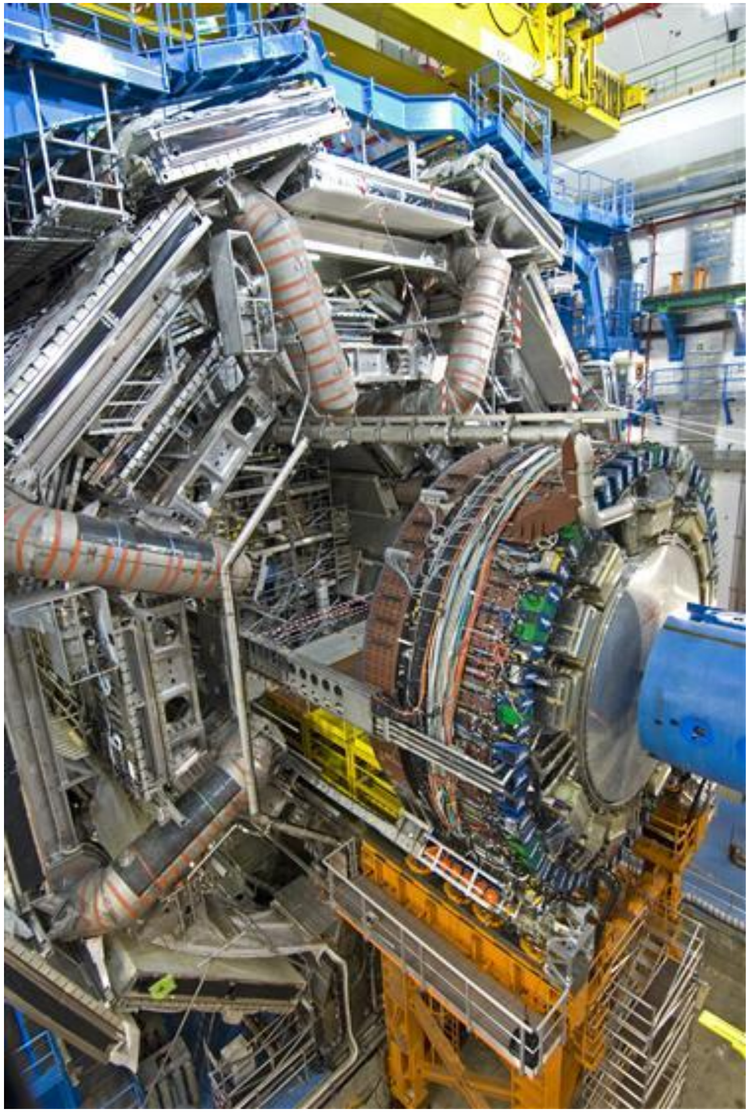


Inner diameter: DN150
Outer diameter: DN300
Length: 35 m
Bending radius: 1.5 m

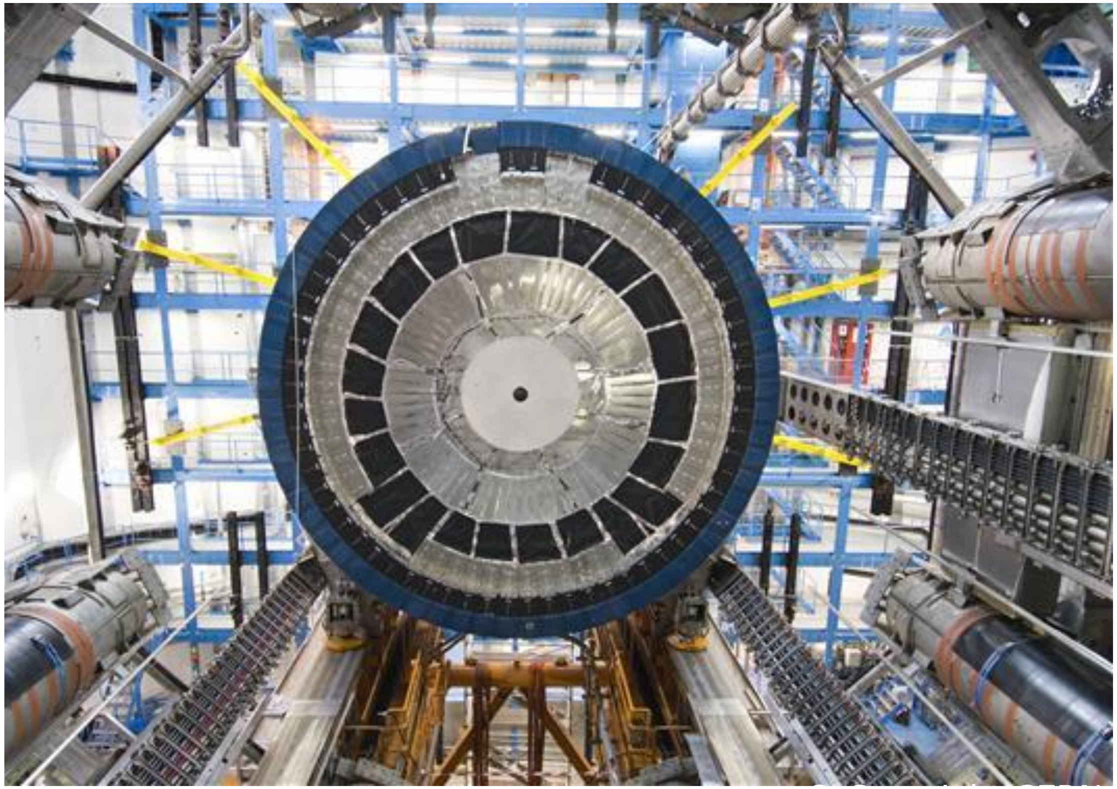


LAr flexible line between expansion vessel and cryostat and associated displacement system

Uninterrupted functioning over 15 years (2)

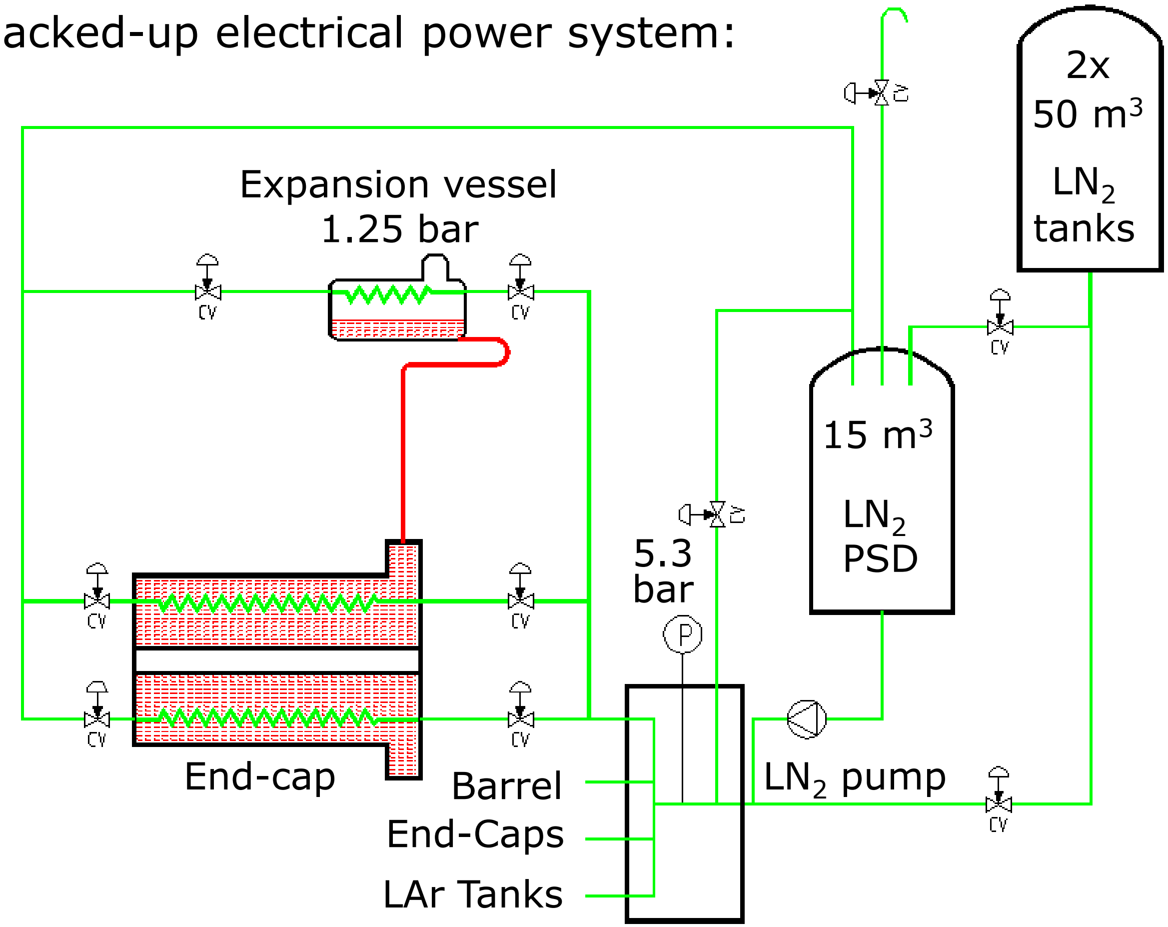


The 1000 t End-cap A calorimeter displaced to its extreme opening position with all services connected



✓ Redundancies :

- LN_2 pumps (x3)
- LN_2 supply services (x3)
- all essential devices on backed-up electrical power system:
  - EDF/EOS network
  - diesel generators
  - UPS
- compressed air and cooling water backed up



✓ Special features related to safe handling of large volume of cryogenic liquids in underground area

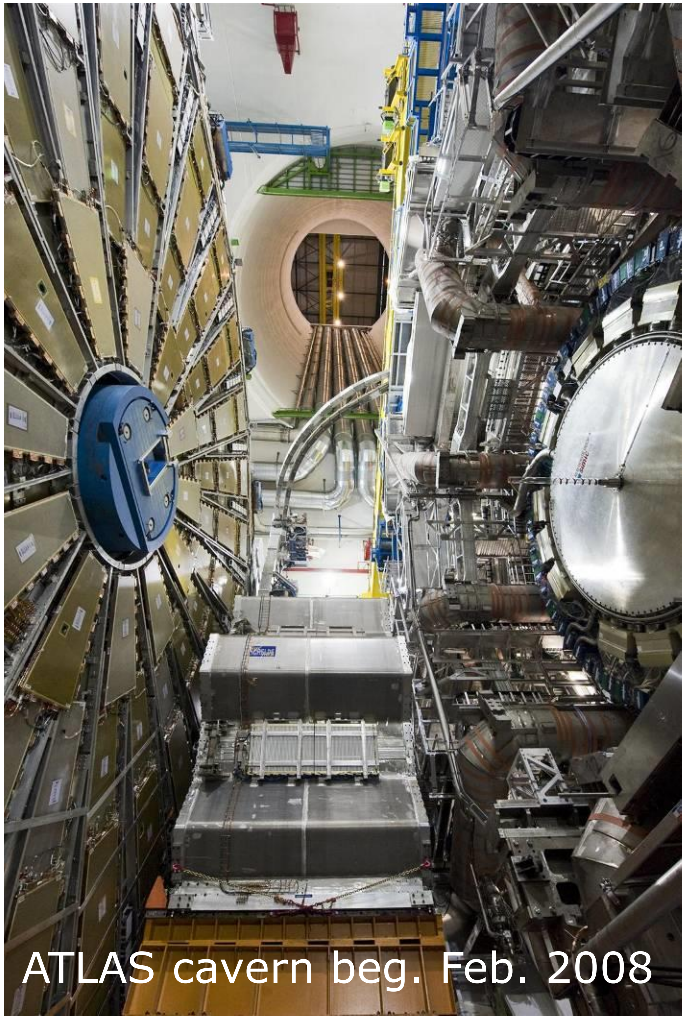
- Argon volume of the three cryostats can be emptied into 2 x 50 m^3 argon storage tanks by:
  - gravity
  - cryogenic pump
- Argon tanks are:
  - equipped with LN_2 condenser and kept cold
- Items containing large volumes are:
  - equipped with safety valves collected to a dedicated DN 500 pipe going to surface
  - placed above retention pits
- Gas constantly renewed from the retention pits by surface extraction system
- Insulation vacuum levels are monitored
- Oxygen detectors

✓ 3 cryostats successfully installed, cooled-down and filled with argon in the underground area

✓ Argon bath regulated to about 88.3 K with argon bath purity, temperature homogeneity and stability fully satisfactory for detector physics operation

✓ Continuous functioning for up to 8 year periods

⇨ demonstrates reliability of cryogenic system



ATLAS cavern beg. Feb. 2008

This achievement is the result of collaboration between:

BNL, CEA, CERN, LAL, LPSC and NTNU