Cryogenics for Liquid Argon Calorimeters

Caroline Fabre

on behalf of the ATLAS Liquid Argon Cryogenics Collaboration

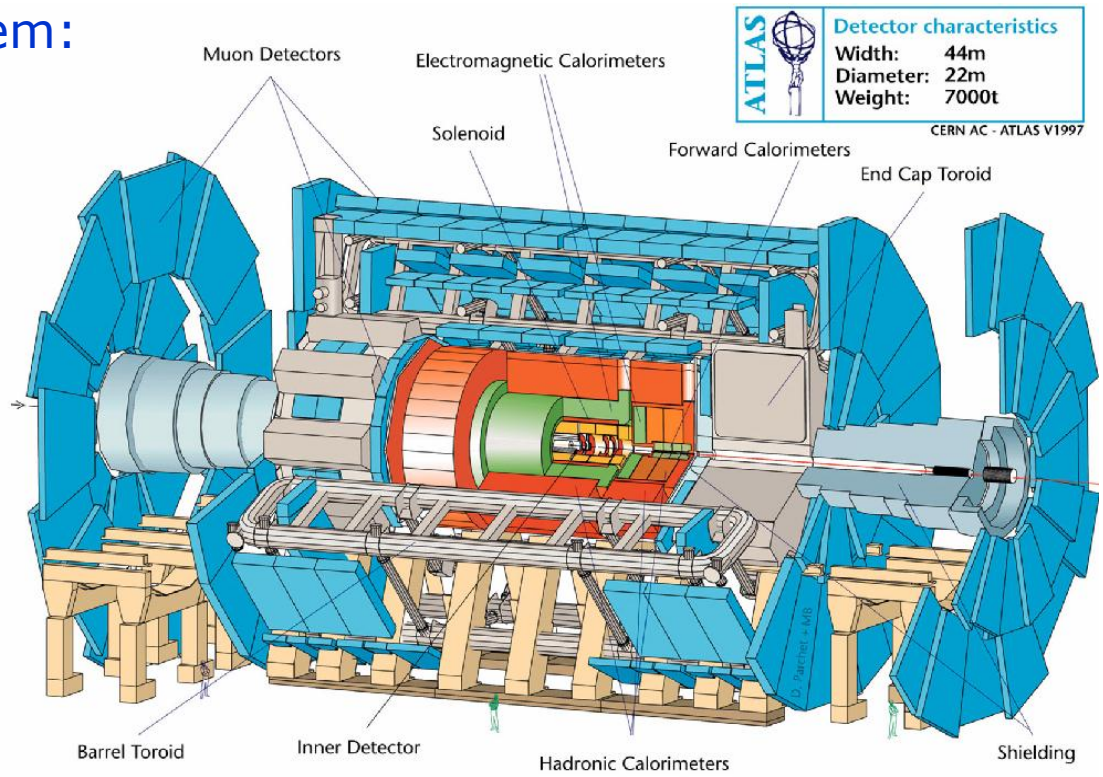
Cryogenics for Liquid Argon Calorimeters

CONTENTS:

1. The ATLAS liquid argon calorimeters
2. Main requirements for the associated cryogenic system
3. The LAr cryogenic system:

   adopted solutions

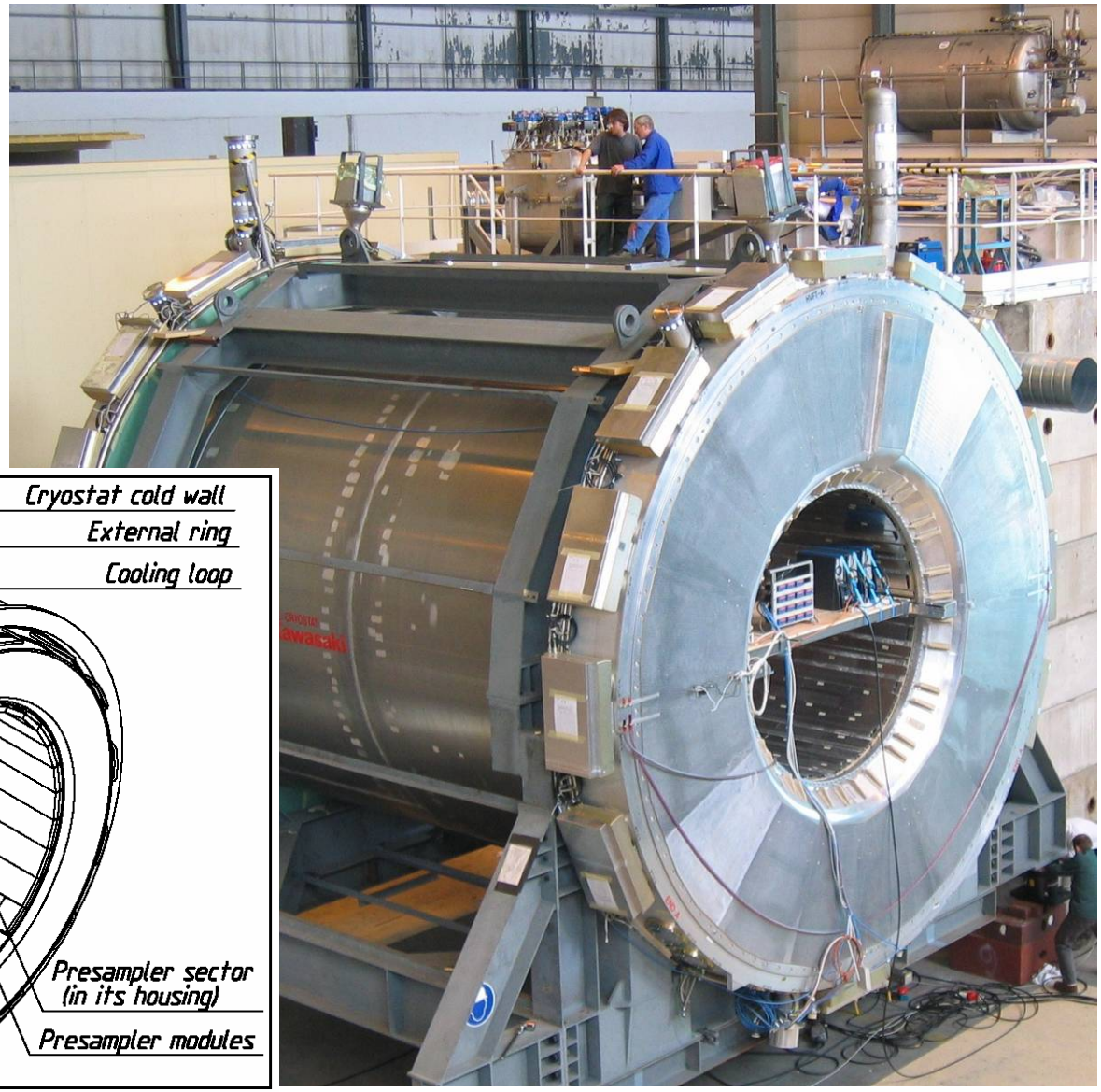
   and results
4. Special features
5. Conclusion



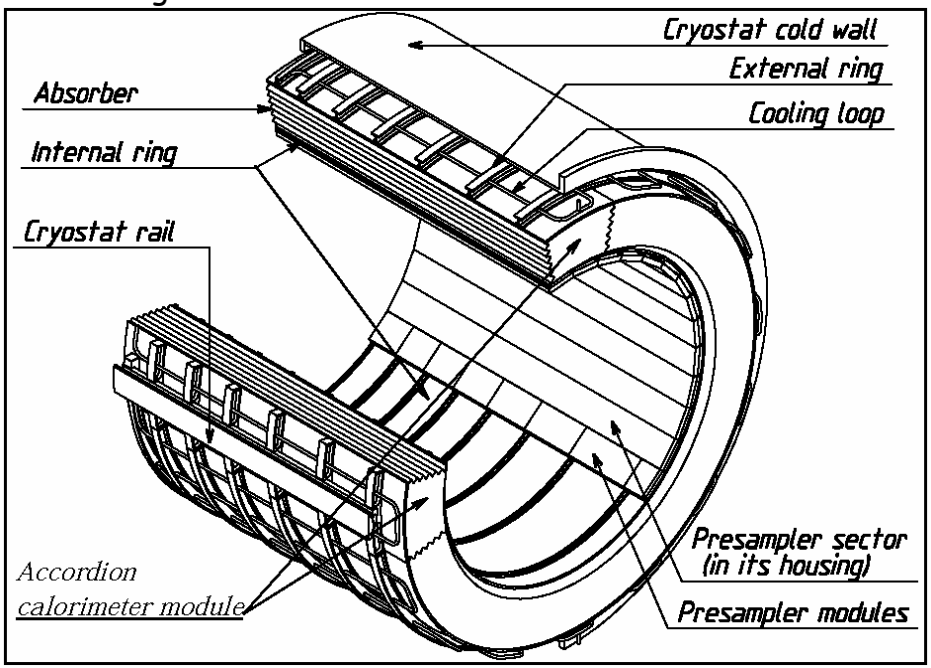
The ATLAS Liquid Argon Calorimeters (1)

✓ Barrel Calorimeter:

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



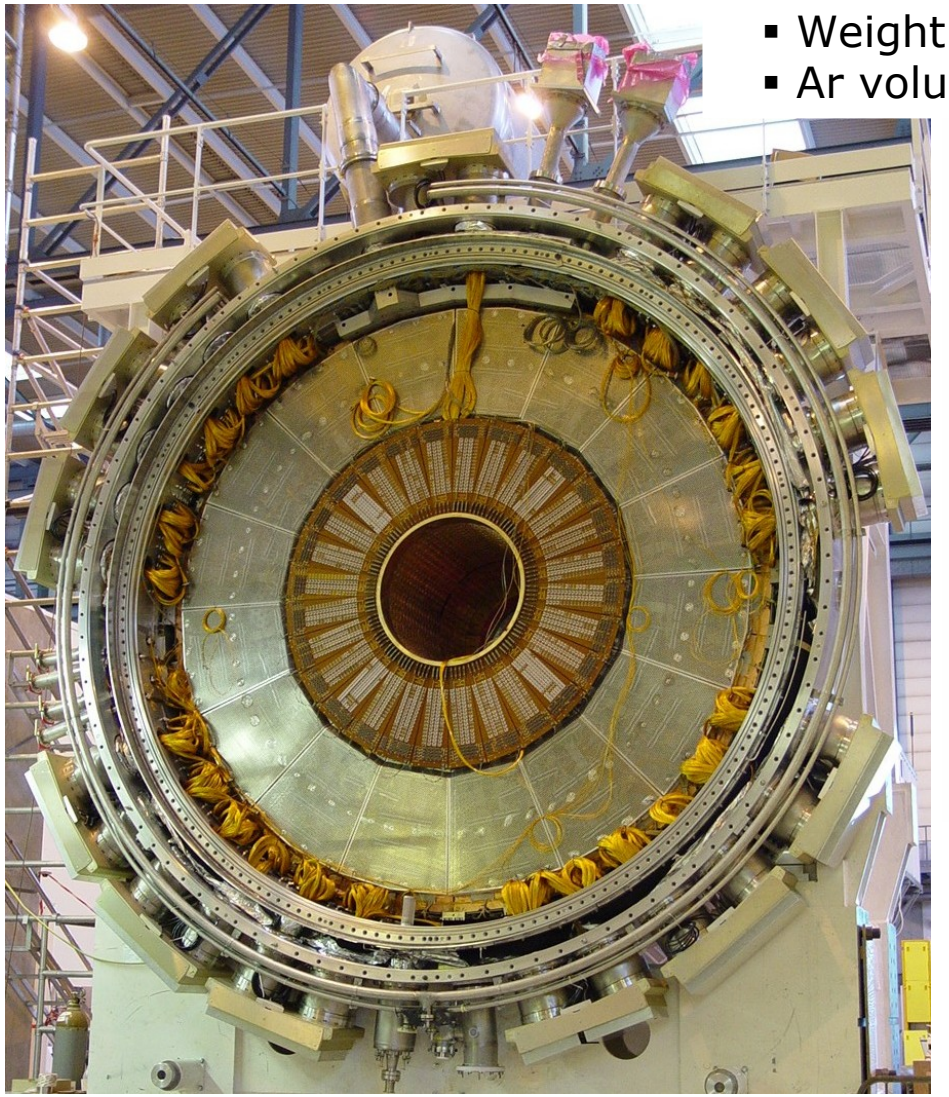
Electromagnetic barrel half-wheel

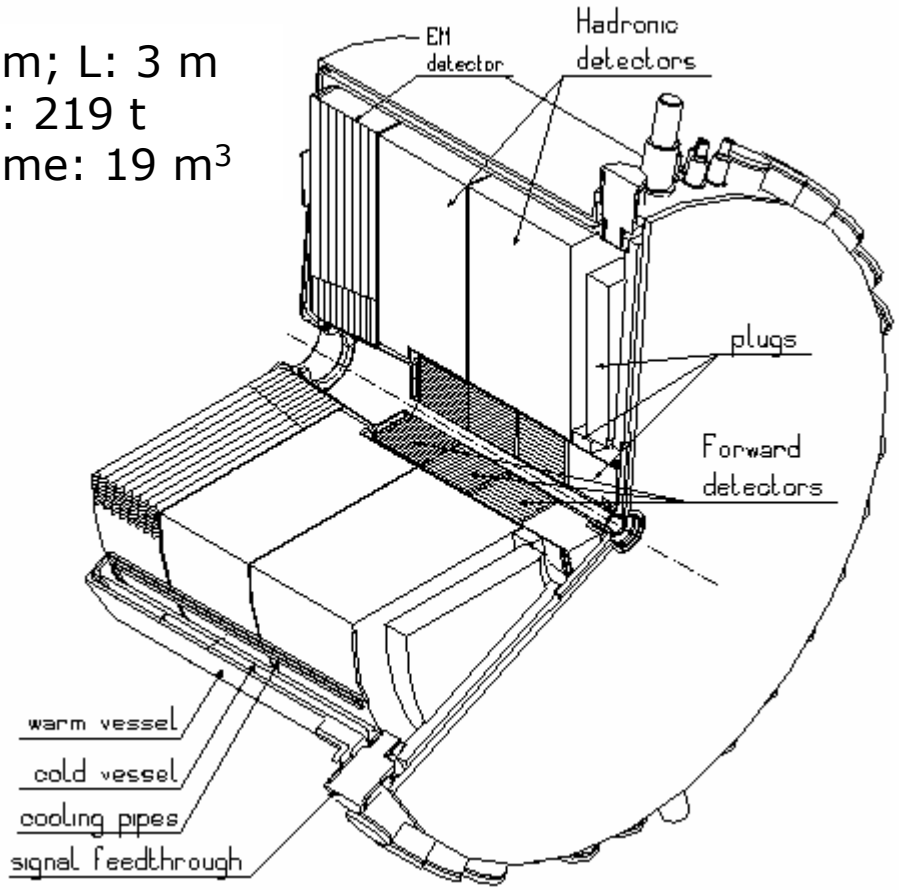


The ATLAS Liquid Argon Calorimeters (2)

✓ 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

Main Cooling Requirements

✓ Cool-down criteria:

ΔT must be kept within strict limits to avoid excessive stresses or displacements

In total: 7 criteria defined for the barrel

11 criteria defined for the end-cap (T dependence)

✓ Steady-state requirements:

- No gas bubble formation
- Liquid argon bath temperature constant at about 88.4 K
- Temperature gradient across bath < 0.7 K
- Argon purity < 2 ppmv of O2-equivalent

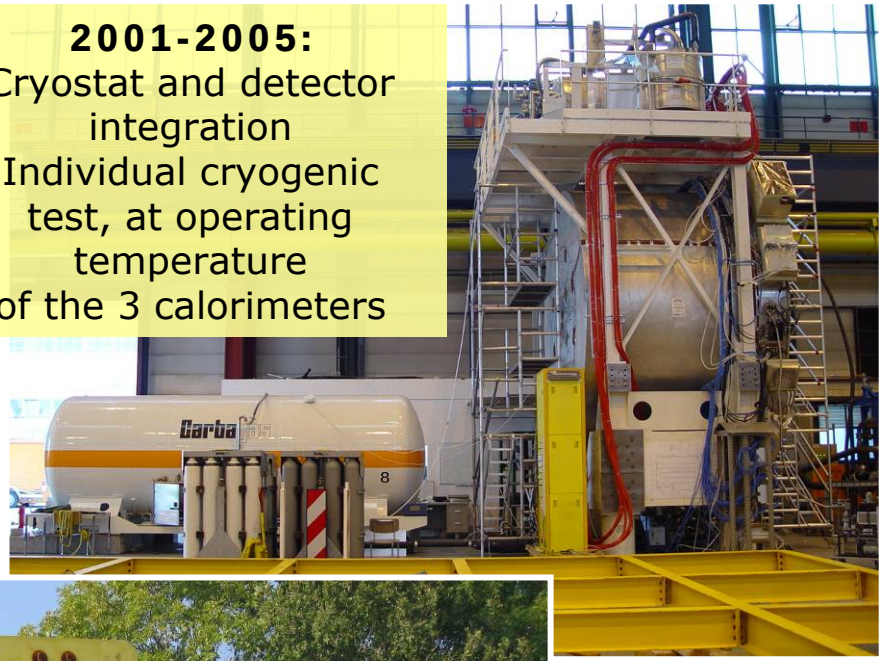
Energy measurement sensitivity: 2 % per K

The LAr Cryogenic System (1)

✓ 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

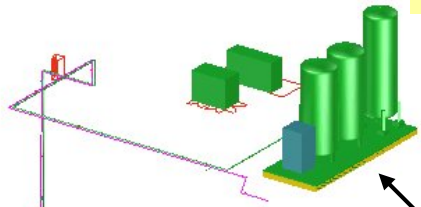
Sept. 2005:
Transport of an end-cap calorimeter towards Point 1

The LAr Cryogenic System (2)

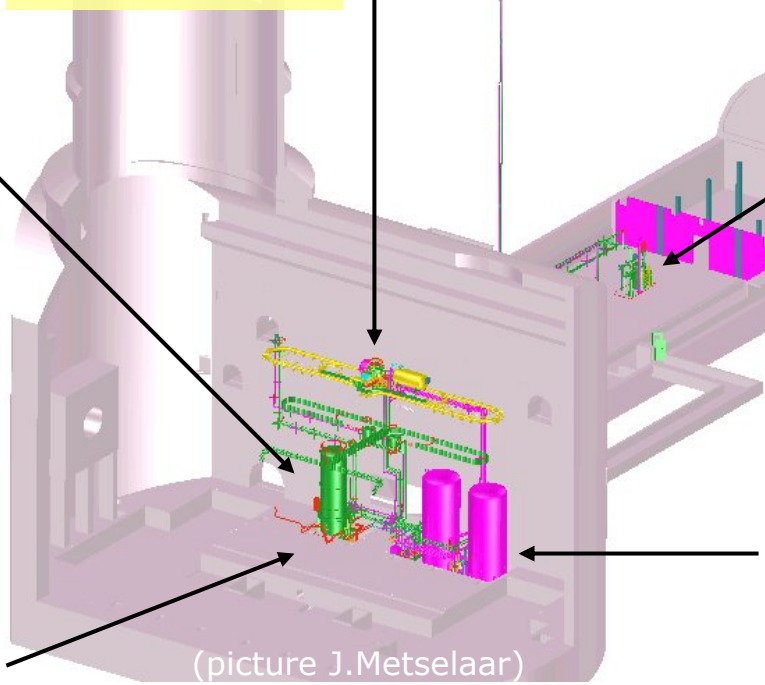
15m^3 N_2 Phase Separator Dewar

1.3 km interconnecting LAr & LN_2 transfer-lines

2x50m^3 LN_2 storage tanks
1x80m^3 GN_2 Buffer



20kW@84K N_2 refrigerator



(picture J.Metselaar)

11 distribution valve boxes

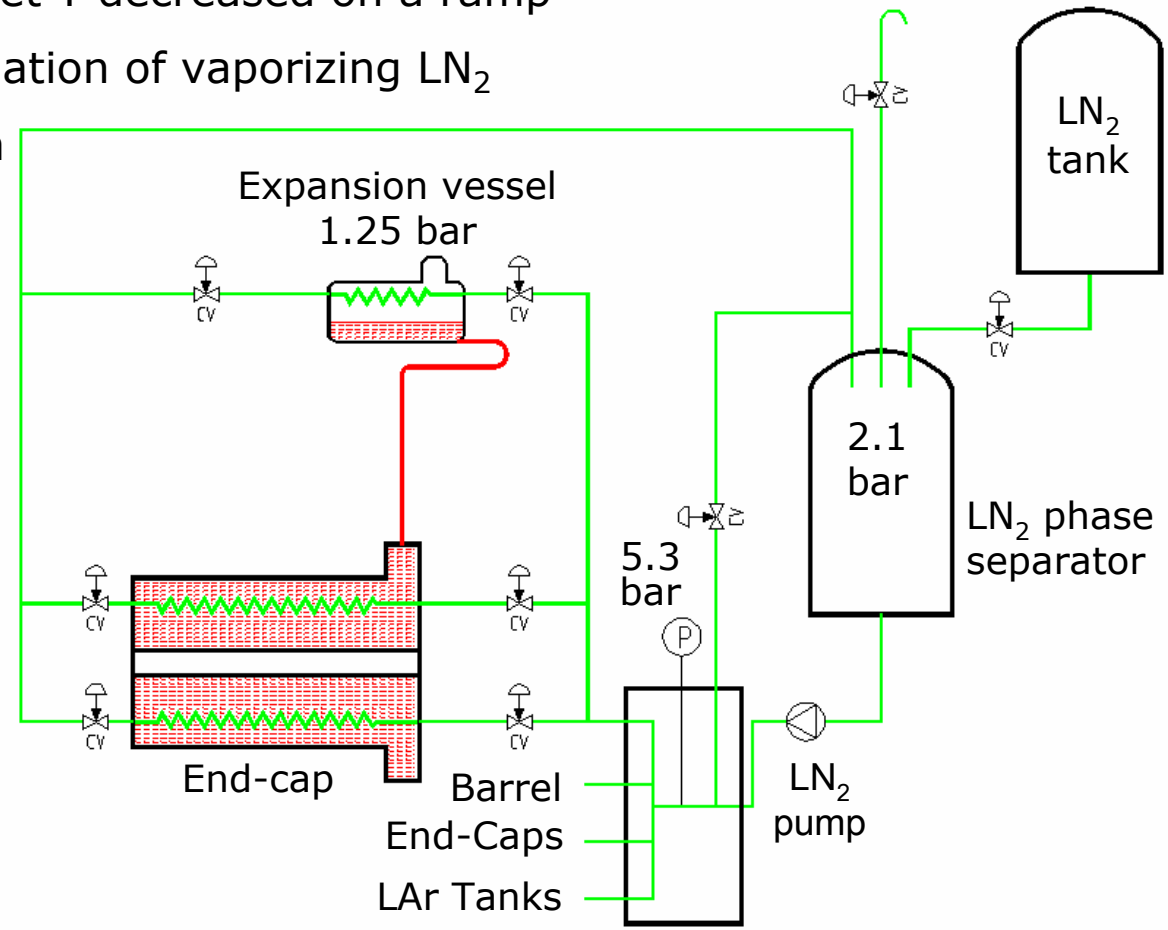
2x50m^3 LAr storage tanks

The LAr Cryogenic System / Solutions (3)

✓ Procedures during cool-down:

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. Condensing of argon

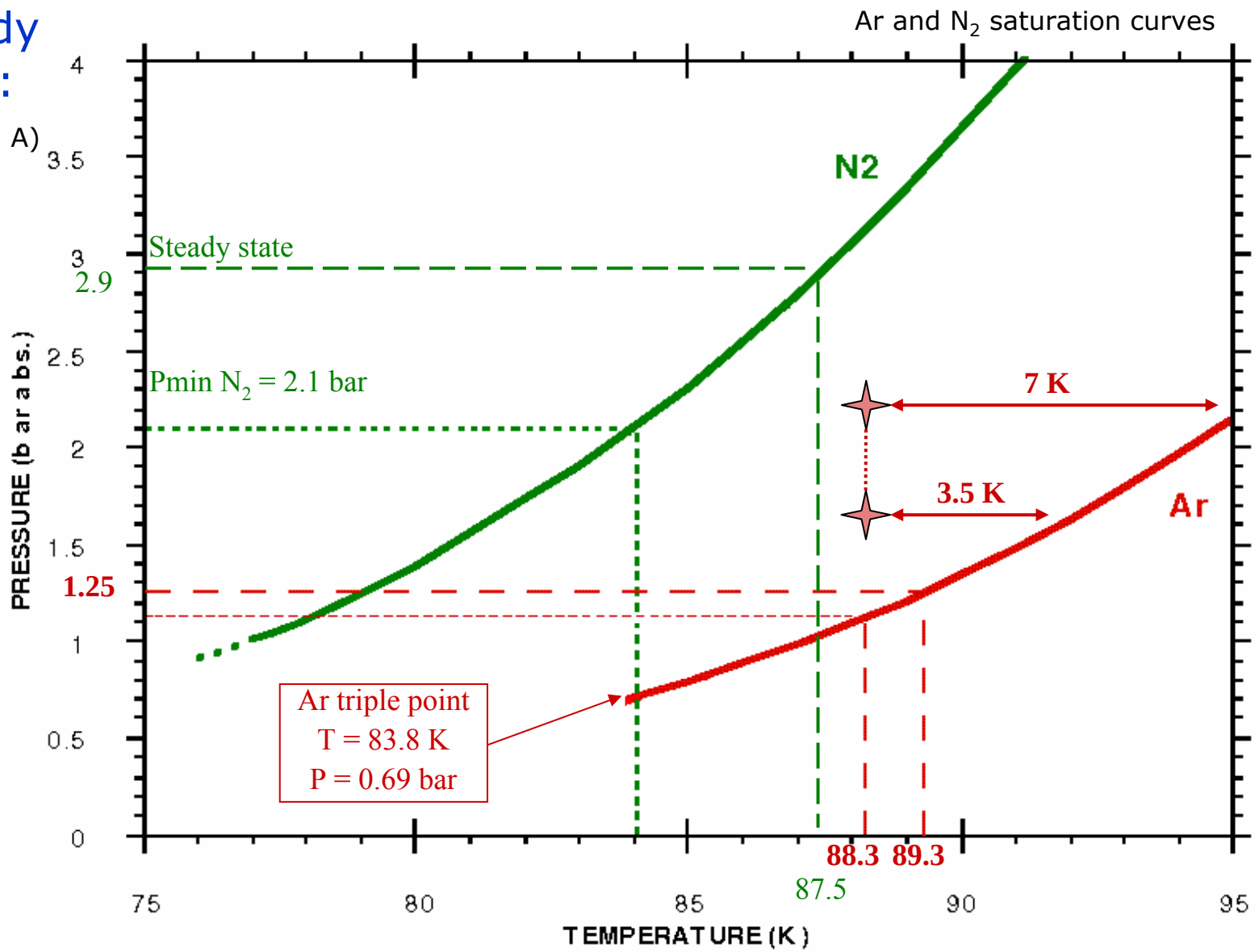
Cool-down rate limited by an interlock triggered by the cooling criteria



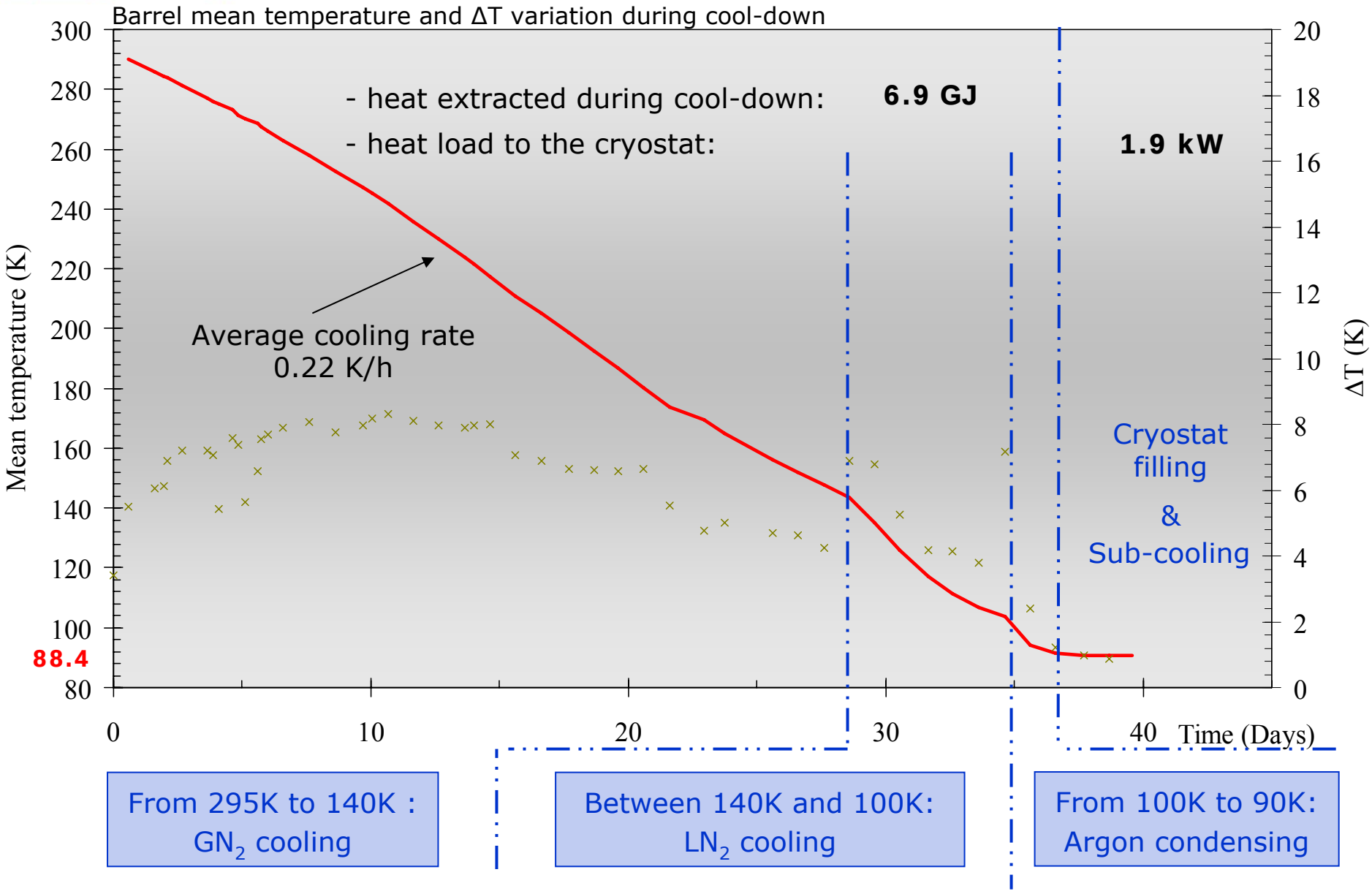
The LAr Cryogenic System / Solutions (4)

✓ Steady state:

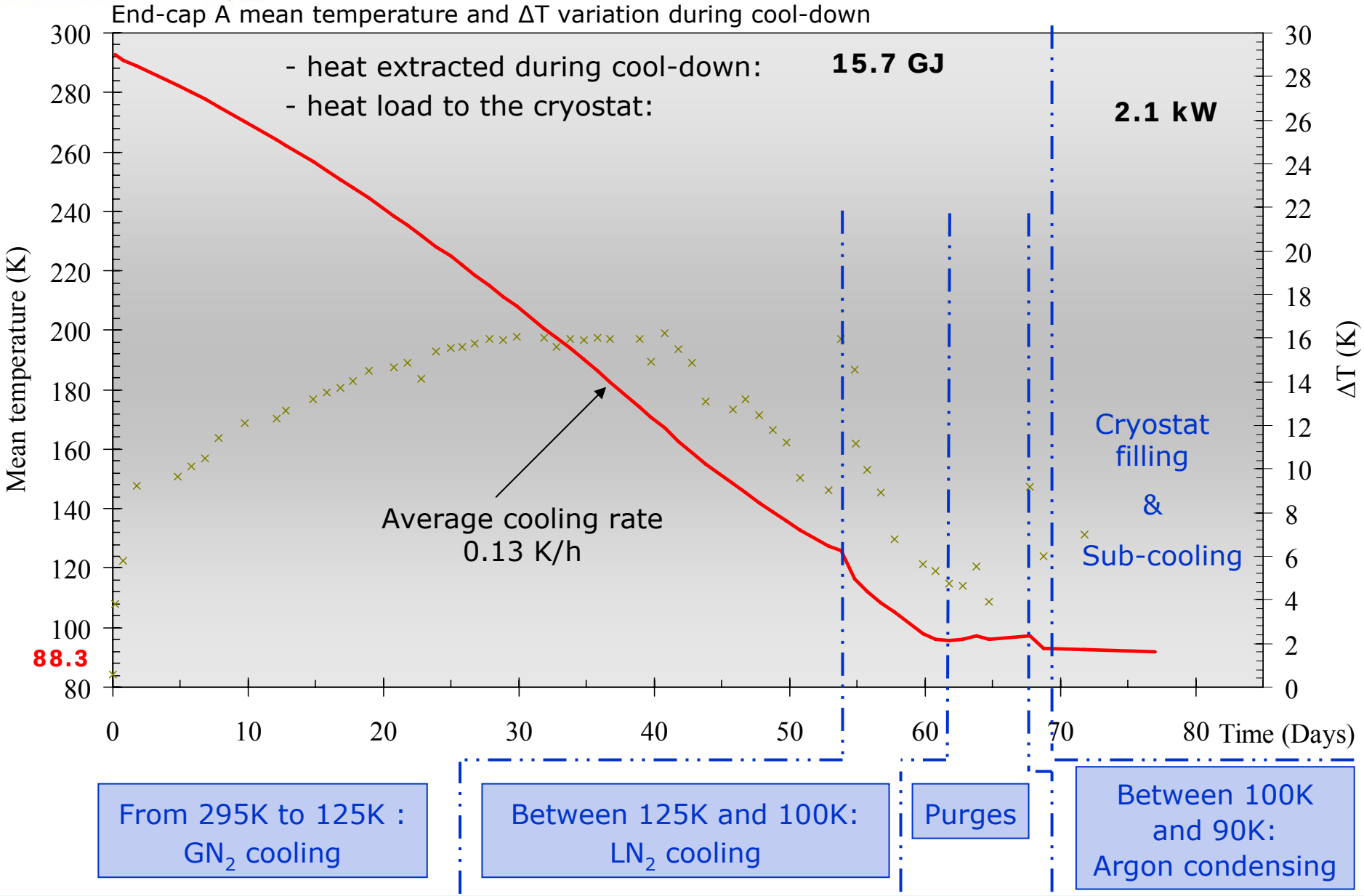
(End-Cap A)



The LAr Cryogenic System / Results (5)



The LAr Cryogenic System / Results (6)

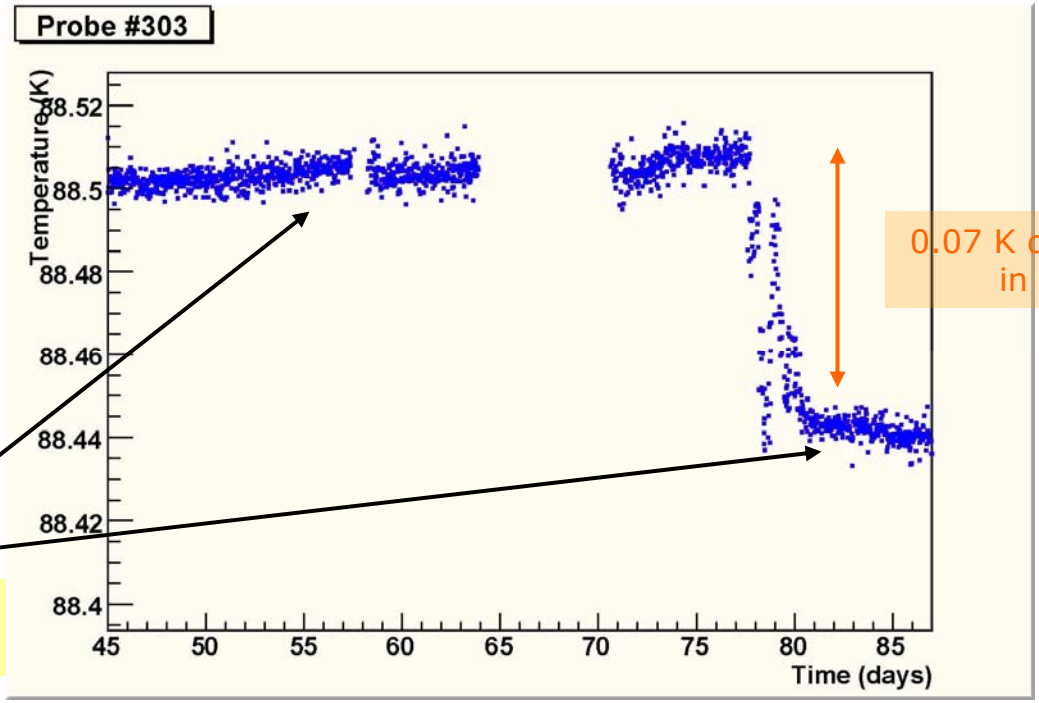


The LAr Cryogenic System / Results (7)

✓ Steady state:

- Temperature uniformity: < 0.3 K
- Temperature stability: < 0.02 K
- LAr bath sub-cooled with 4.2 K to 7.7 K
- Argon purity: between 0.1 and 0.3 ppm of O2-equivalent

(Barrel)



0.07 K drop due to change in LN2 pressure

Detector temperature stability: < 0.02 K

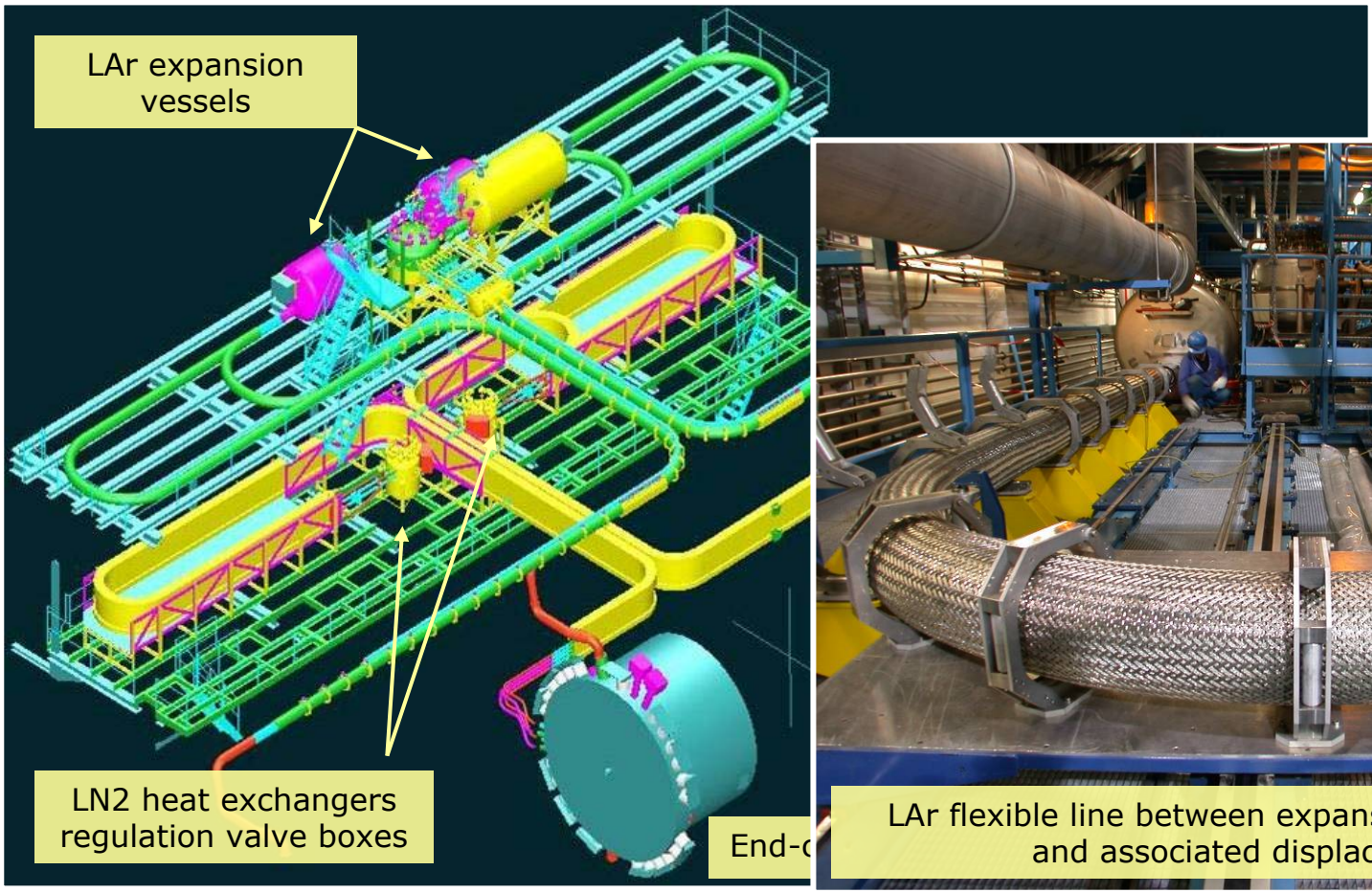
(plot P.Puzo)

Uninterrupted Functioning over 15 Years (1)

✓ 12 meter longitudinal movement 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

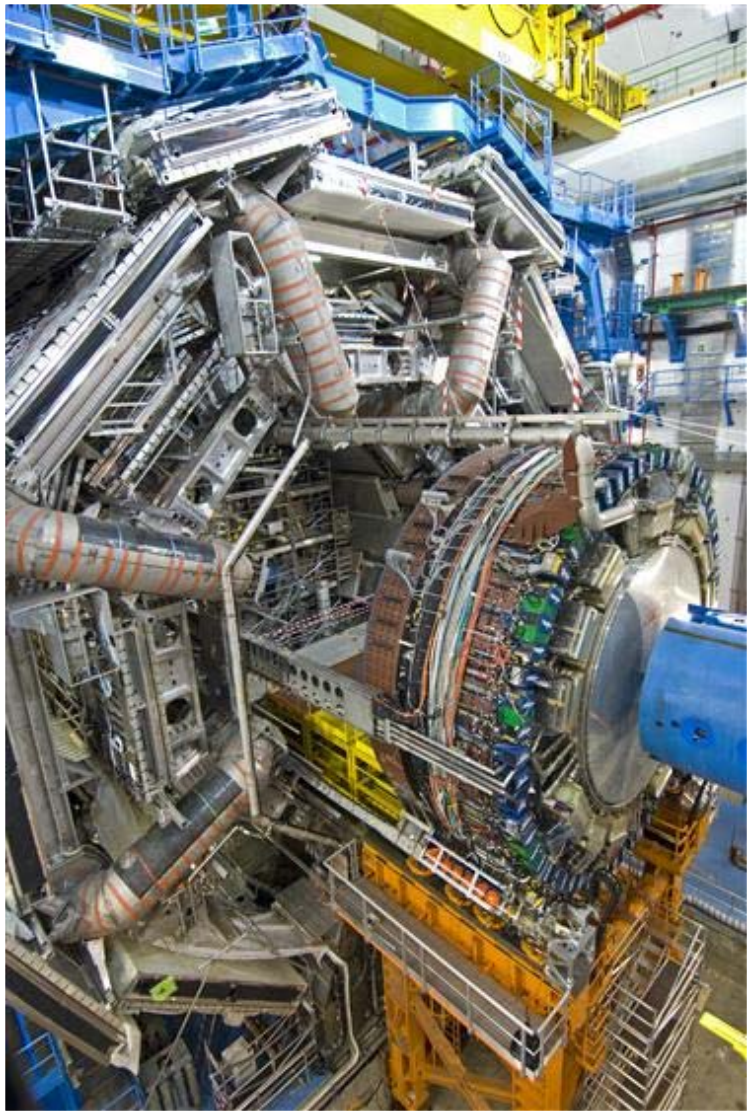
} designed to follow this movement



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

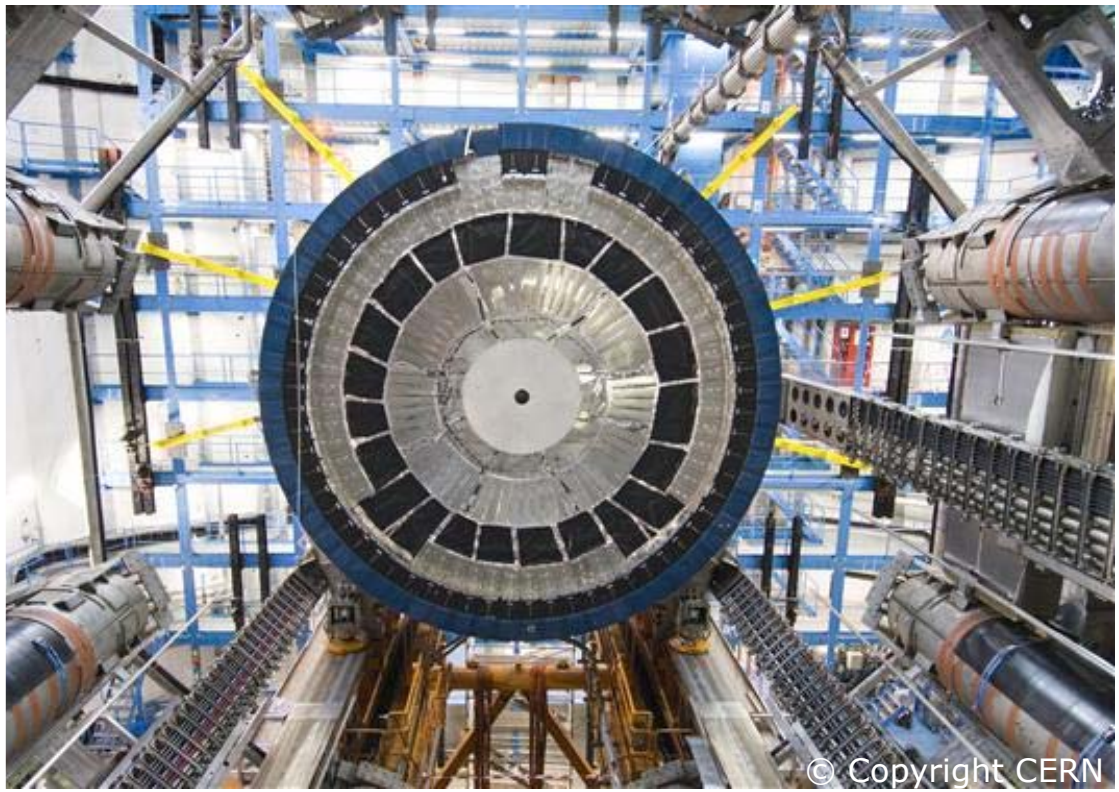
LAr flexible line between expansion vessel and cryostat and associated displacement system

Uninterrupted Functioning over 15 Years (2)



First displacements of end-cap A to its extreme opening position with all services connected:

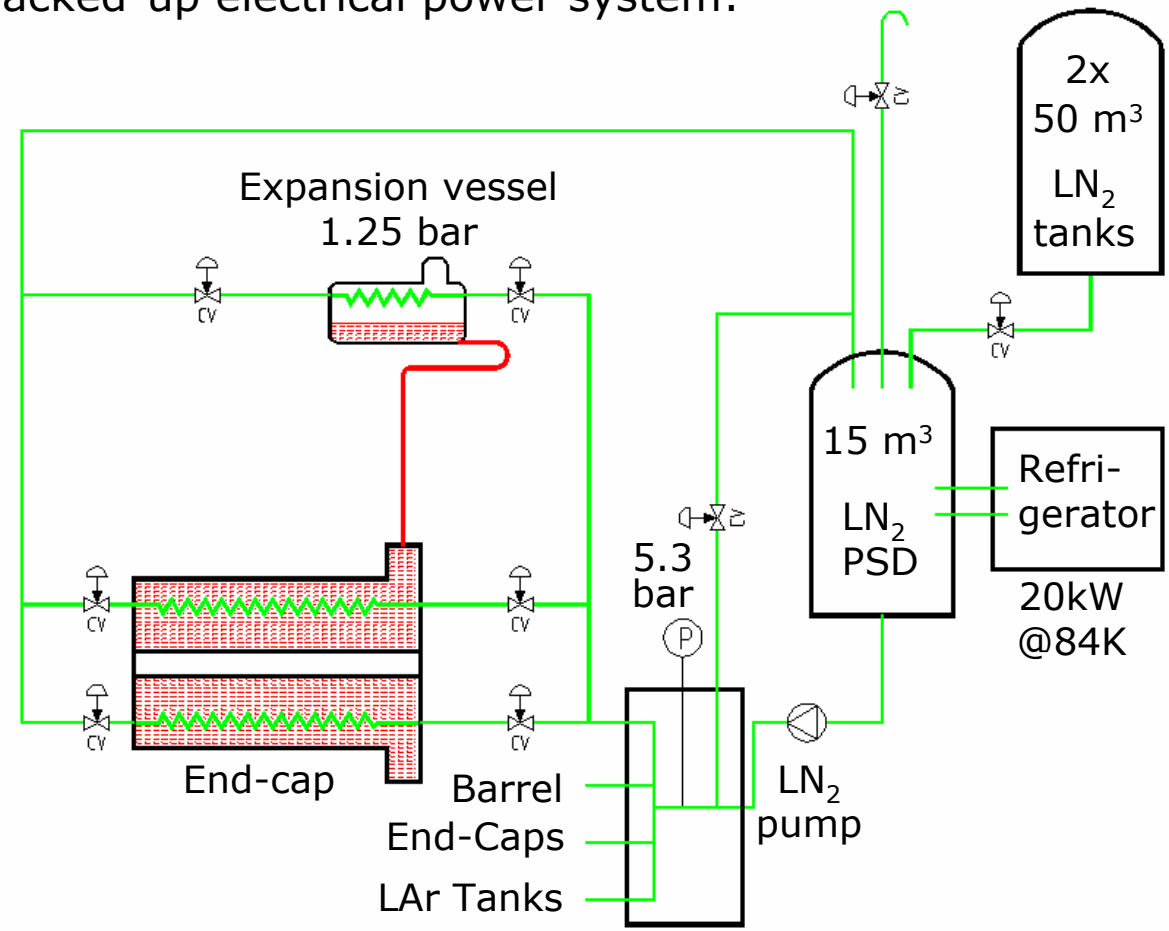
- ✓ cold & empty on 17-02-2007
- ✓ filled with LAr on 21-05-2007



Uninterrupted Functioning over 15 Years (3)

✓ 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



Safety Aspects

✓ 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
  - entirely made of stainless steel
- 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

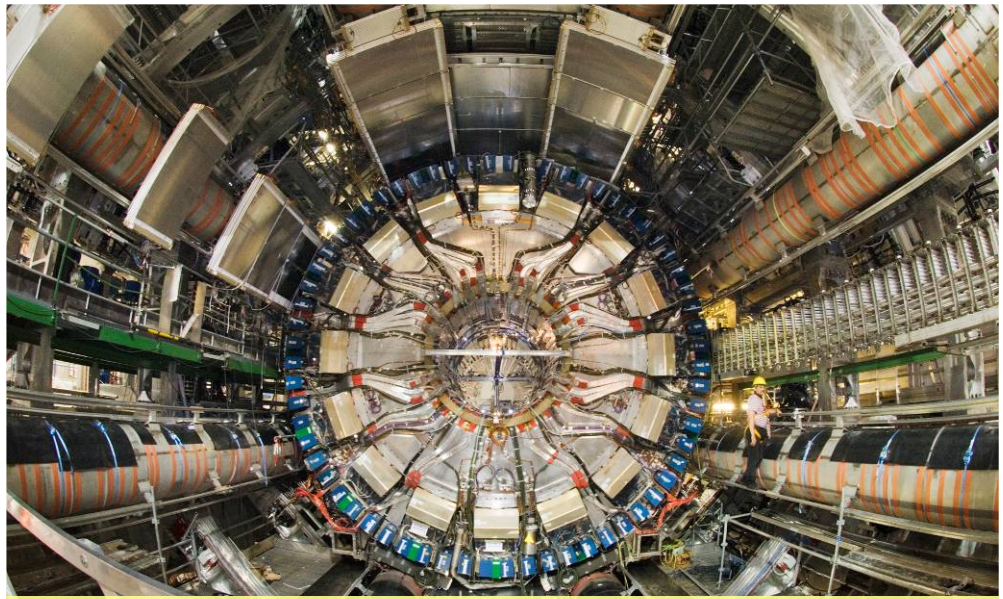
Conclusion

✓ Barrel and End-Cap A successfully cooled-down in 2006 and in stable situation for respectively 10 and 3 months:

- Argon bath purity, temperature homogeneity and stability fully satisfactory for detector operation purposes

✓ End-Cap C cold, to be filled mid-June:

- All three calorimeters fully operational from July onwards



Barrel Calorimeter in operation in its final position encircled by BT Magnets, Tile Calorimeter and Muon Chambers

This achievement is the result of collaboration between:

BNL, CEA, CERN, LAL, LPSC and NTNU