ATLAS mono-phase cooling systems

Jan Godlewski,

The H.Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences

On behalf of all participants in ATLAS cooling projects with special emphasis on TS/CV/DS, ATLAS TC, ATLAS ID and all piping and cabling teams

Basic arrangements

ATLAS cooling systems were built on site in close collaboration with TS/CV/DC Detector Cooling Section. Overall agreement between ATLAS and TS/CV/DC concerning work package for each cooling system has being signed. For each system user requirements have being made. Cooling group prepared detailed design, material specification, schedule and cost prediction. Once agreed manufacturing, assembly, installation inside the cavern and commissioning were done by TS/CV cooling section together with ATLAS TC and or ATLAS ID team

Organization

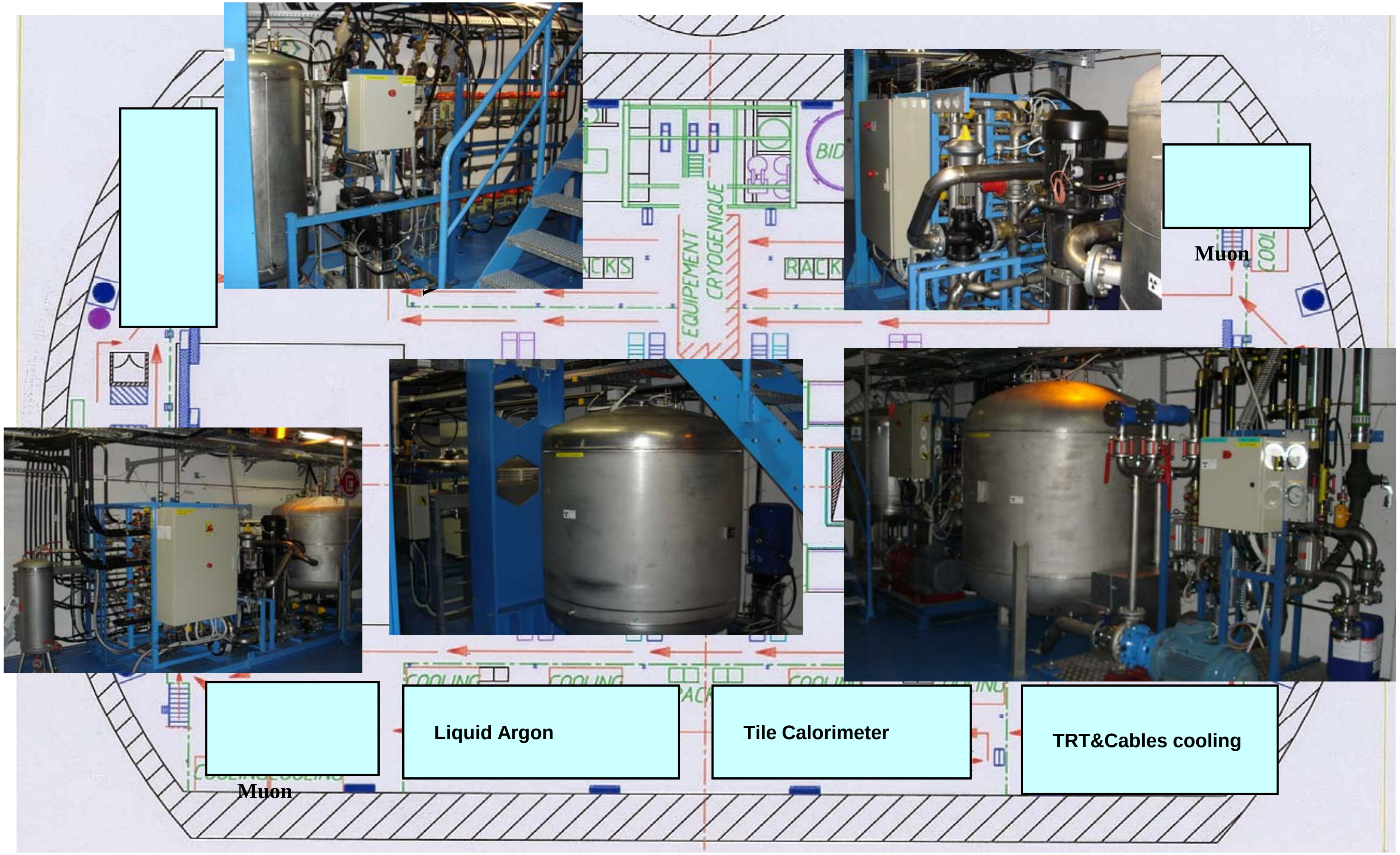
- **Workshop on site shared between ATLAS TC and TS/CV/DS**
  - **Machines**
  - **Storage and construction area**
  - **Crane**
- **Manpower**
  - **10 FTEs in form of Project Associates (PJAS) for TS/CV/DS**
  - **Piping teams for on detector pipes provided by ATLAS TC and ATLAS Inner Detector**
  - **Cabling team from ATLAS**
  - **Many designers preparing drawings for cooling units inside ATLAS and 3D routing for cooling pipes and cables**
  - **ATLAS fluids coordinator to coordinate all the efforts**

Mono-phase cooling systems

- **Water cooling systems**
  - **Liquid Argon**
    - *(water, “leakless”,255 kW@ 18 – 23 °C, 24 lines)*
  - **Tile calorimeter**
    - *(water, “leakless”, 55kW@18 – 23 °C, 24 lines)*
  - **Diffusion pumps**
    - *(water, “leakless”, 54kW@15 – 20 °C, 12 lines)*
  - **Muon and general purpose**
    - *(water, “leakless”, 2 x 55k W@18 – 23 °C 2 x 13 lines)*
  - **Rod racks cooling system**
    - *(water, “leakless”, 4kW@18 – 23 °C 7 lines)*

- **Inner Detector (C6F14)**
  - **TRT**
    - *(C6F14, overpressure, 60 kW@ 15 – 20 °C 4 distribution racks)*
  - **Cables**
    - *(C6F14, overpressure, 70 kW@ 15 – 20 °C 32 distribution manifolds)*
- **Small mobile units for VA beam-pipe and Lucid detector cooling during beam-pipe bake-out**

Cooling units in UX15



Water cooling systems 1

Water based cooling systems are built using LCS v.2 principle

The liquid is held in a storage tank (3) maintained below atmospheric pressure by a vacuum pump (2). A check valve (5) discharges any excess air in the event of drainage and prevents the pressure in the storage tank from rising above atmospheric pressure. The liquid is moved into the exchangers (1) incorporated through the electronic system by a circulator (4).
The pressure at the various points of the circuit depends on the head losses and hydrostatic pressures.
At start-up, if the pressure in the storage tank is not low enough the vacuum pump is activated. While the later is in operation, in the event of an air intake for instance, the circulator cannot run. The pressure throughout the circuit still equal to the pressure in the storage tank

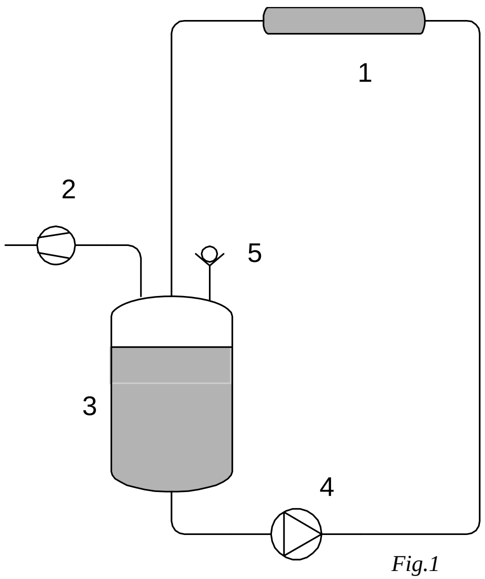
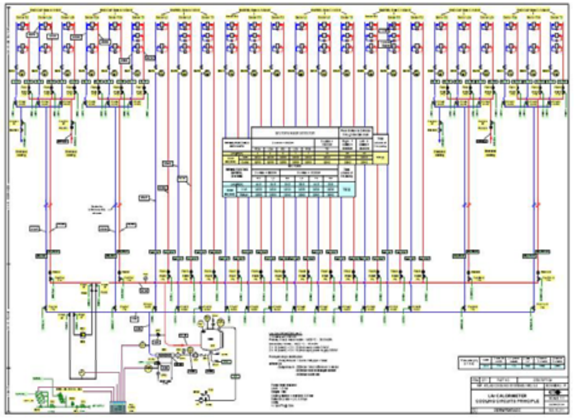
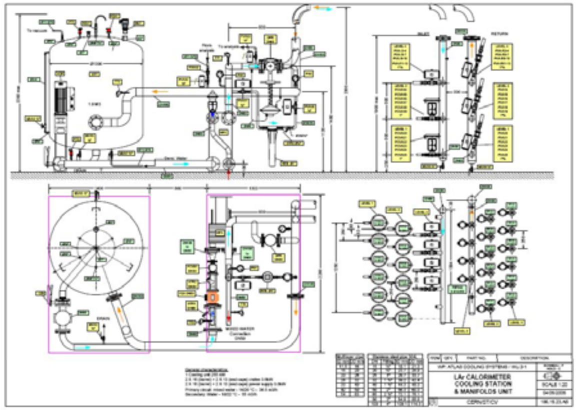


Fig.1

Full scale hydraulic tests in 185

Calorimeters – Liquid Argon and TileCal





Cooling unit assembled in the workshop using 1:1 footprint of assigned place in the cavern. All hydraulic connections were made and pressure tests performed. Next cooling unit has been disassembled and reconnected inside the cavern.

A lot of design effort to fit into dedicated space, several iterations have been made

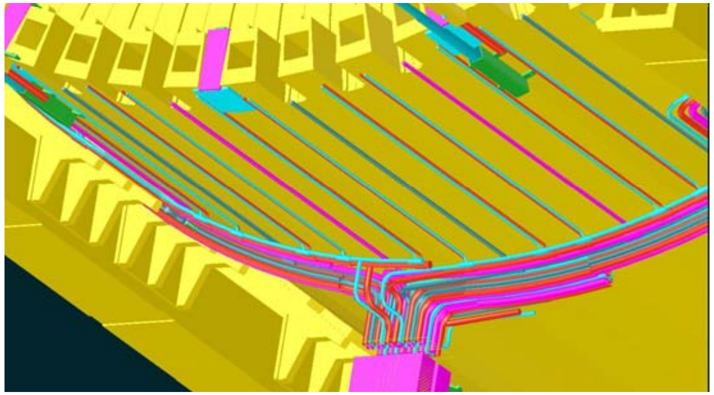
Piping around the barrel has been tested in bldg 190 were Tile Calorimeter was preassembled

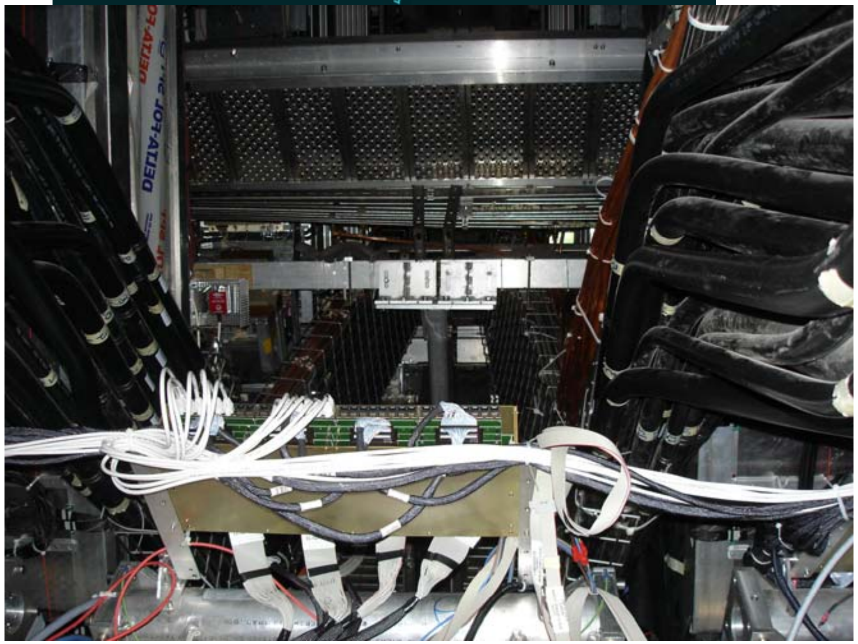
Final piping on the Barrel and End-caps have been done in the parking positions.

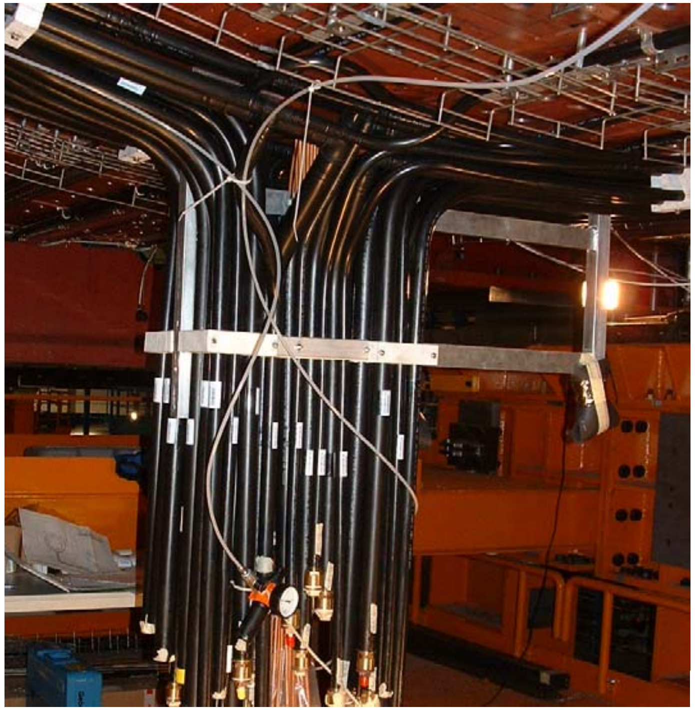
Multilayer pipes are used between cooling stations and detectors.

Each line can be individually remotely regulated

Calorimeters piping



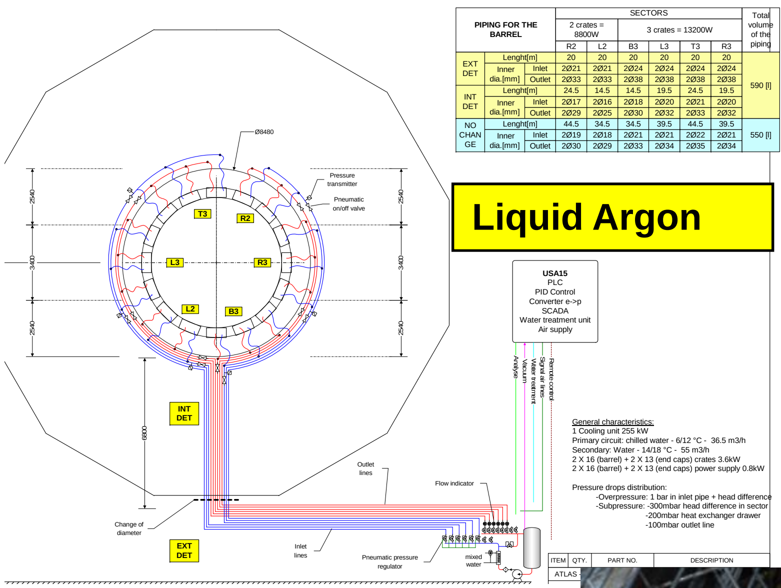




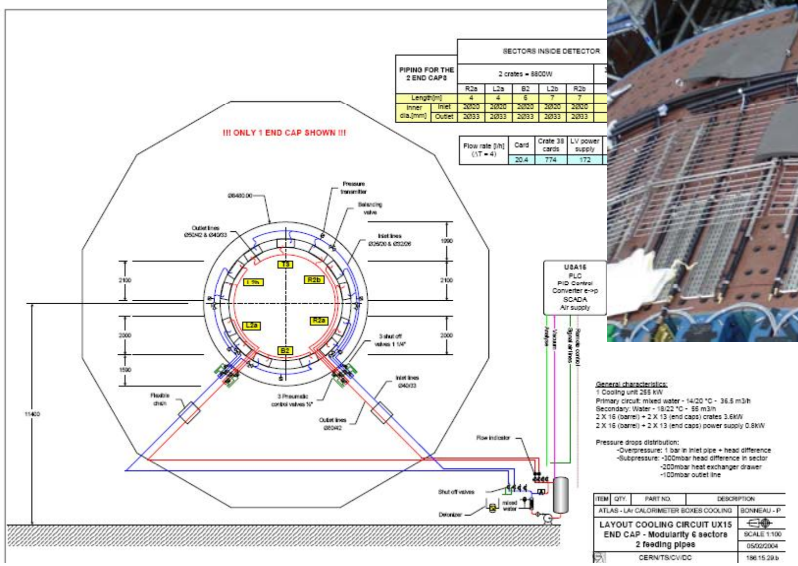
Calorimeters cooling units and piping

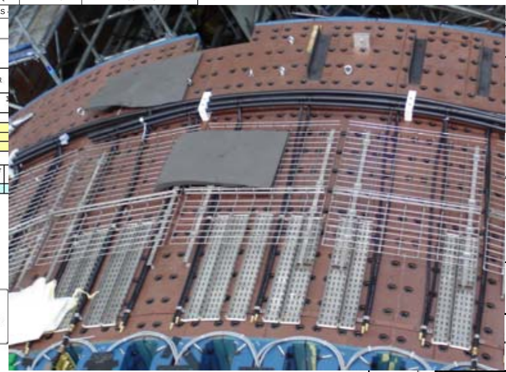


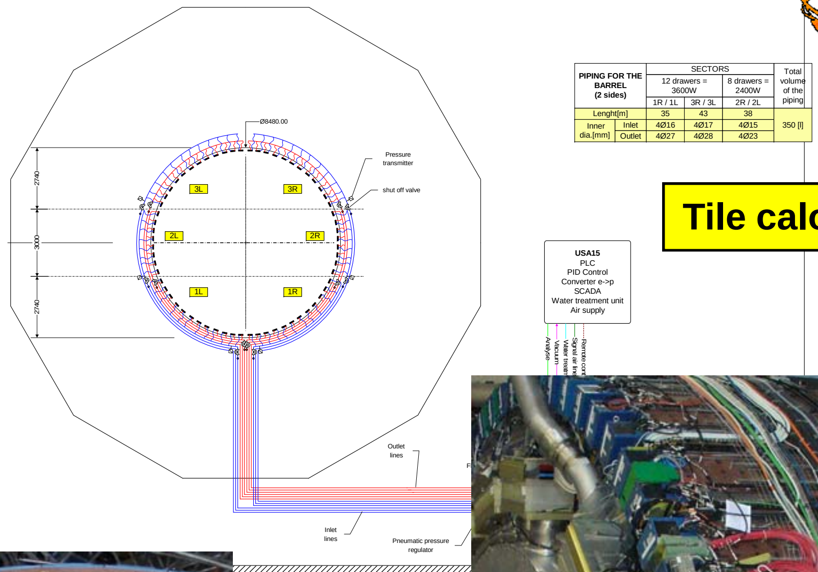




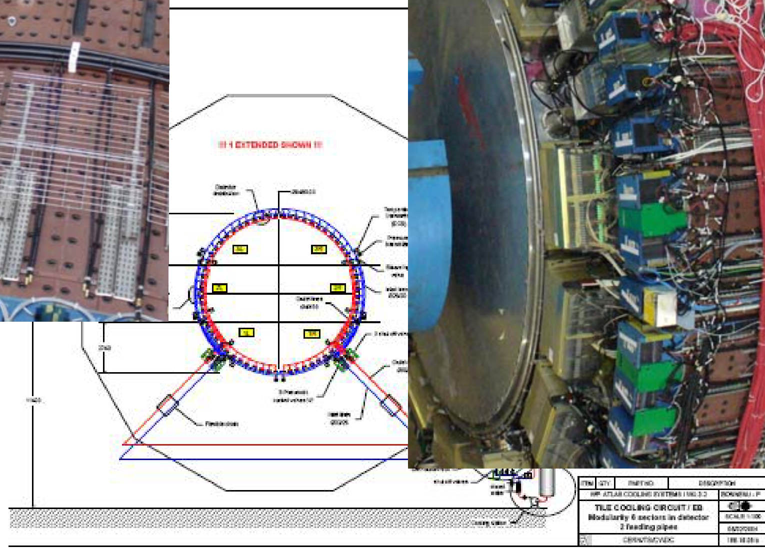
Liquid Argon

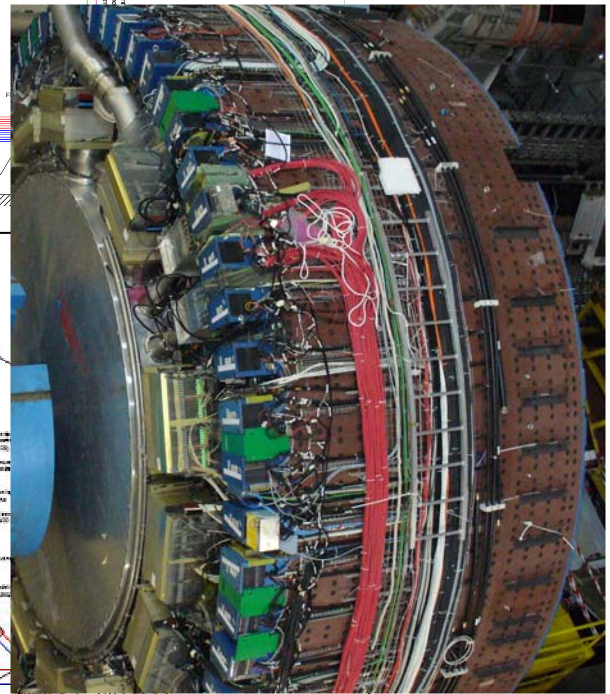






Tile calorimeter





64 crates, power supplies connected in parallel,

256 fingers to cool, power supplies inside the drawer, barrel return lines thermally connected to Tile Calorimeter

Diffusion pumps

System has to be very reliable and has to work all the year without break.

For the period of ATLAS cooling towers maintenance back-up connection is available

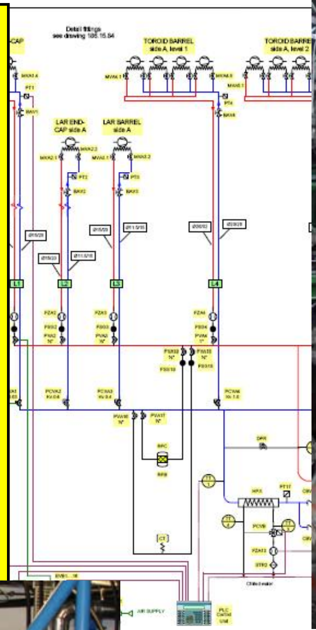
Whole system is on UPS

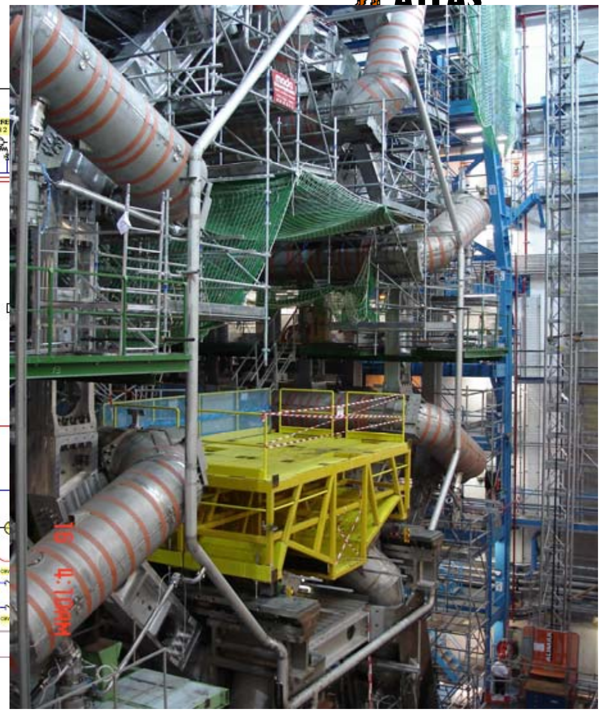
Primary circuit – chilled water

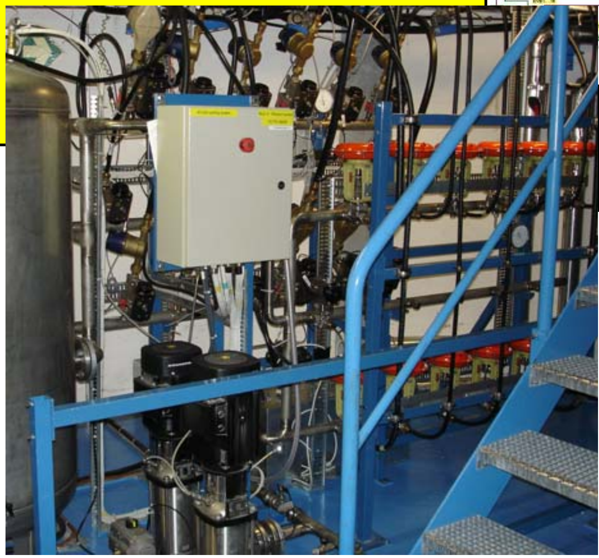
Treated water as a cooling liquid

Two circulating pumps in the station

Piping – multilayer pipes







Each circuit is cooling from 1 up to 4 diffusion pumps

Muon and General Purpose Cooling Units

Two identical cooling stations situated on both sides of ATLAS cavern to cool:

•MDT and TGC racks on Big Wheels

•CSC electronics on Small Wheels

•Thermal screens inside Muon Barrel

•Electronics racks inside ATLAS cavern UX15

As a primary circuit mixed water is used

As a cooling liquid – dematerialized water

Between cooling station and diffusion pumps multilayer pipes are used

Manual pressure regulation on each line.

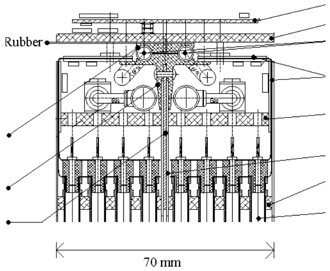
Additional pressure sensors on lines going to Big and Small Wheels

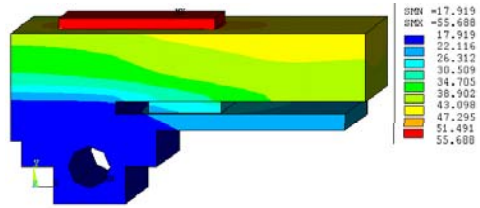
Inner Detector mono-phase cooling systems

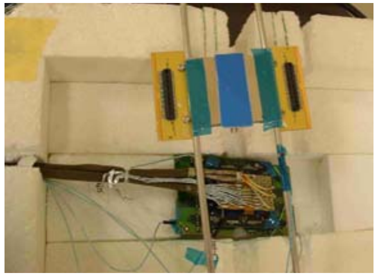
- **Distribution manifolds moved from cooling stations to HS structures around the detector**
  - **TRT – distribution racks**
  - **Cables cooling – manifolds**
- **Piping**
  - **Extremely difficult layout and very limited space**
  - **Responsibility**
    - **Up to Barrel calorimeter flange – ID**
    - **Over the Calorimeter Barrel through z=0 to distribution racks/manifolds TC&ID**
  - **Design – many designers involved both in ID and TC**
  - **Verification – ATLAS model in building 175; 1:1 scale**
    - **Piping over Calorimeter flange between LAr boxes and TileCal fingers up to PP2**
    - **Full scale tests for evaporative system**
  - **Preparation – Cable trays and brackets assembly inside LAr cryostat**
  - **Piping on the detector**
    - **Copper pipes and lockring fittings (tightness)**
    - **Many parallel teams**
    - **Some part given to the outside companies**
    - **Leak tightness**
    - **Labeling**
  - **C6F14 with multilayer pipes and metal fittings - electrostatics**

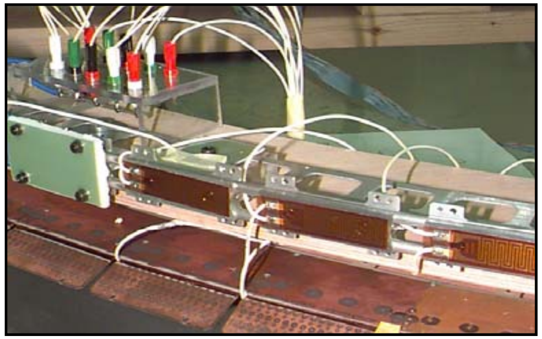
TRT C6F14 overpressure inside the detector

- **Front-end electronics**
  - **Different solutions in Barrel and End-caps**
- **Straws**
  - **Heat-exchangers between the wheels for End-cap**
  - **Module shell cooling for Barrel**
- **Calculations, prototyping, tests**
  - **Heat transfer from source to the cooling liquid**
  - **Hydraulic, pressure drop**
  - **Check for subassemblies**
- **1:1 scale tests in SR1**

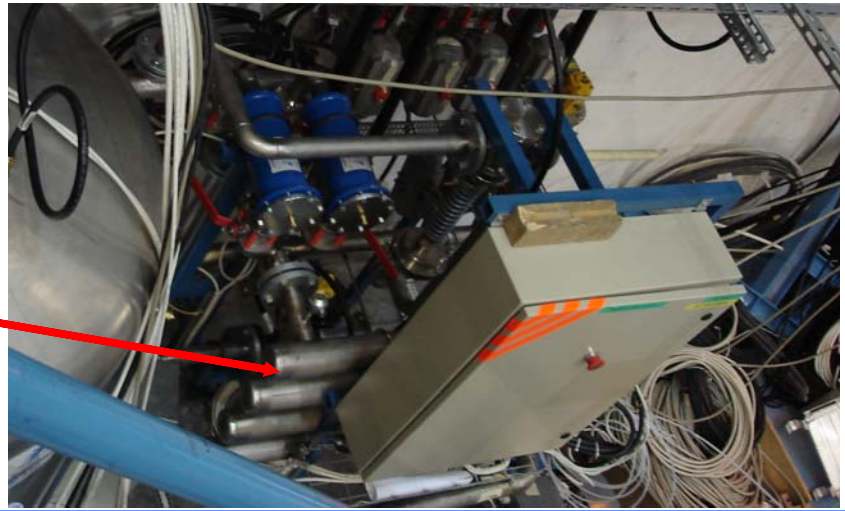








TRT cooling station is equipped in 45 kW heater to protect Inner Detector in the case of Liquid Argon cryostat failure



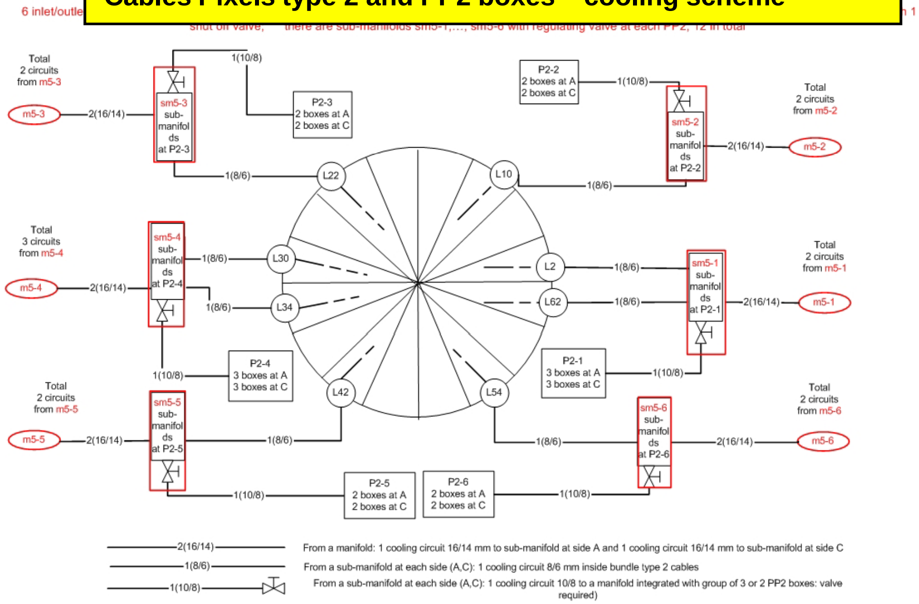
Cables cooling

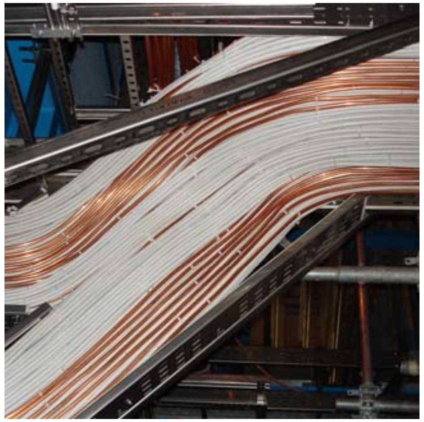
◆ **Power cables for inner detector**
  - SCT cables type 3 and 2
  - TRT cables type 3
  - TRT type 2 cables and PP2 boxes
  - Pixel cables type 3
  - Pixel type 2 cables and PP2 boxes
  - ID heater cables type 3
  - ID evaporative inlets type 3 and 2

◆ **PP2 boxes TRT and Pixel**

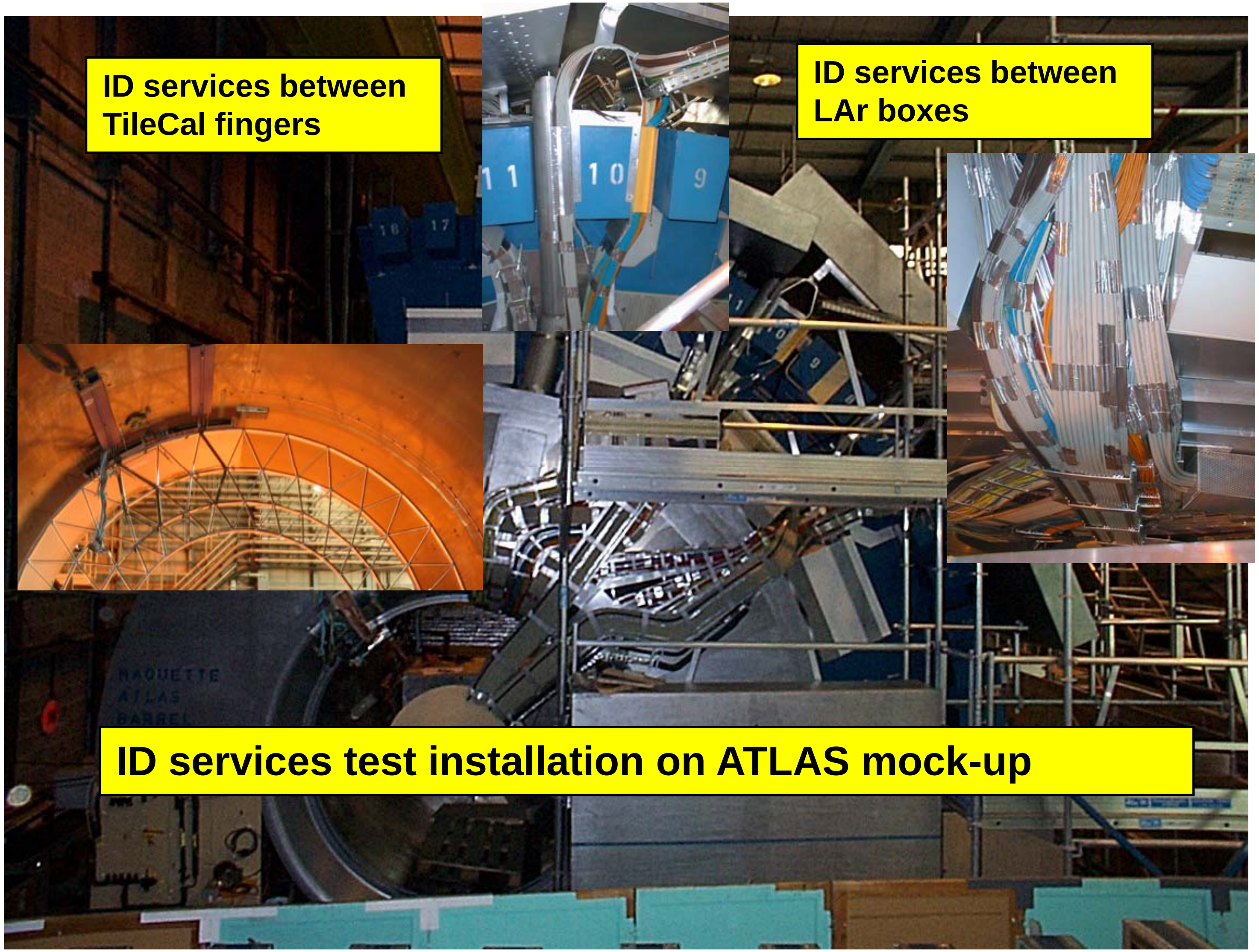
◆ **Calculations, tests, prototyping construction**
  - Both cable cooling and PP2 boxes were simulated, prototyped and tested before starting manufacturing or piping

Cables Pixels type 2 and PP2 boxes – cooling scheme

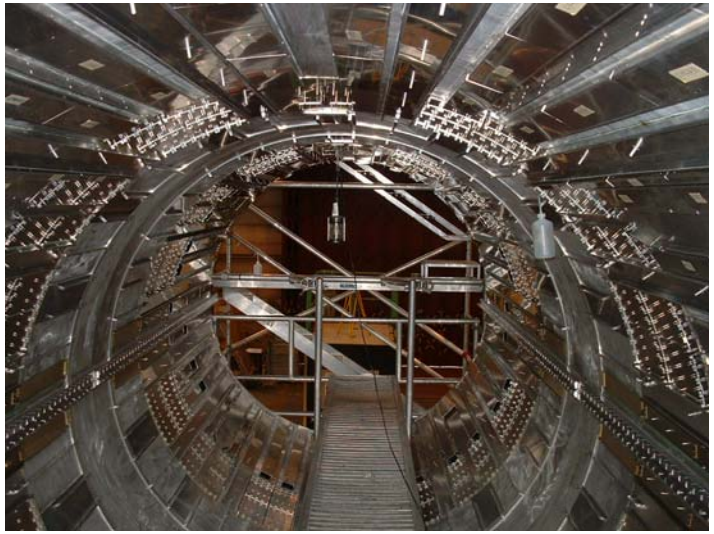




ATLAS mock-up in bldg 175

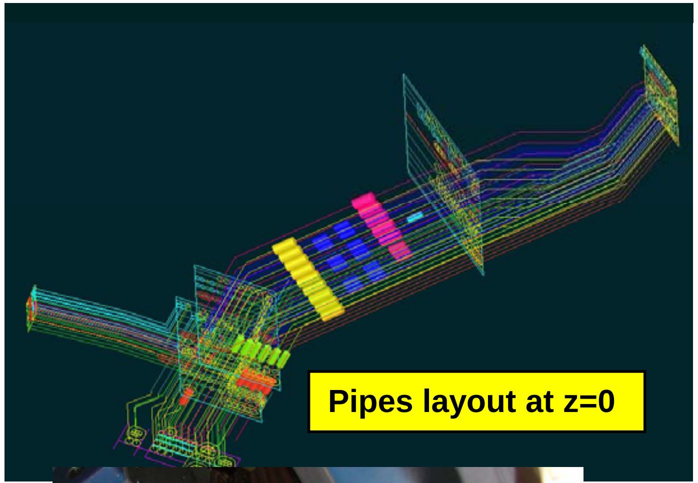


Inner Detector cable trays installation – bldg. 180



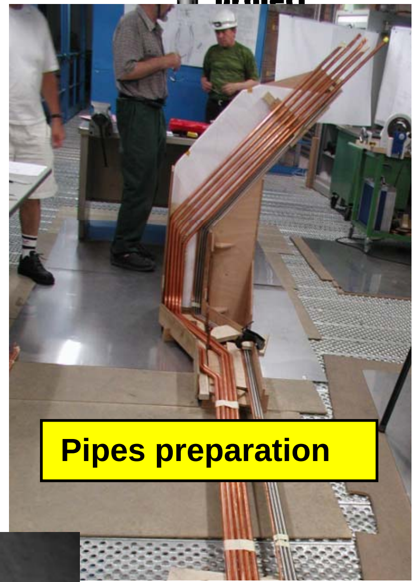
Inner Detector services

From 3-D model to reality

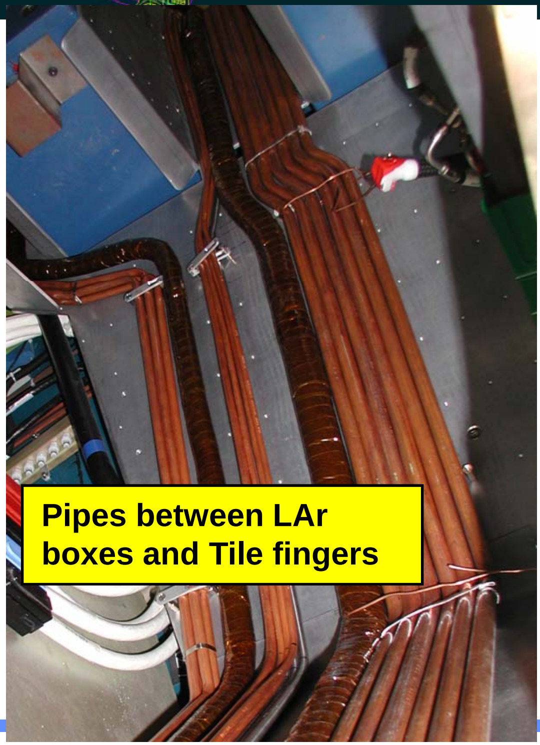


Pipes layout at z=0

Breaking area for pipes at z=0



Pipes preparation

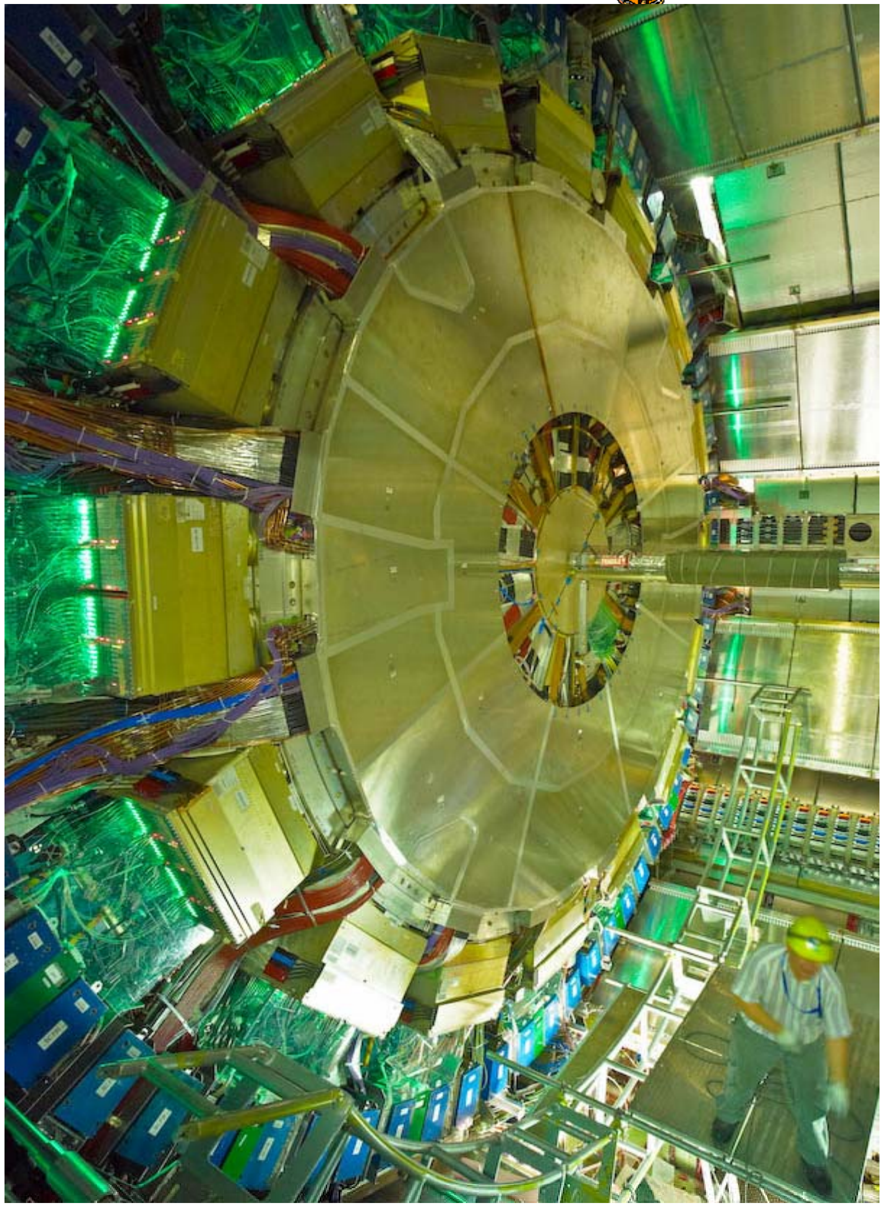


Pipes between LAr boxes and Tile fingers

Pipes at z=0

ID services


FRAGIL



Main problems during construction

- **User requirements**
  - Often not detailed and changing during construction
- **Partner in dedicated system**
  - Difficult to get one competent and dedicate partner during all the period of design, construction and commissioning.
  - Many partners - difficult to find common specification (materials compatibility)
- **Cost versus quality**
  - CERN procedures and available recourses are pushing against cheap solution resulting in multiply defects
- **Pipes routing**
  - Designers availability
  - Access problems – many interruptions, lost time etc
  - Schedule
- **Commissioning**
  - Partial commissioning
  - Conflicts during connection of the new lines while running already commissioned parts of he system
- **Store**
  - Missing materials, long delays