

The Baby-DEMO small scale low temperature CO₂ cooling demonstrator for ATLAS ITk PIXEL at CERN

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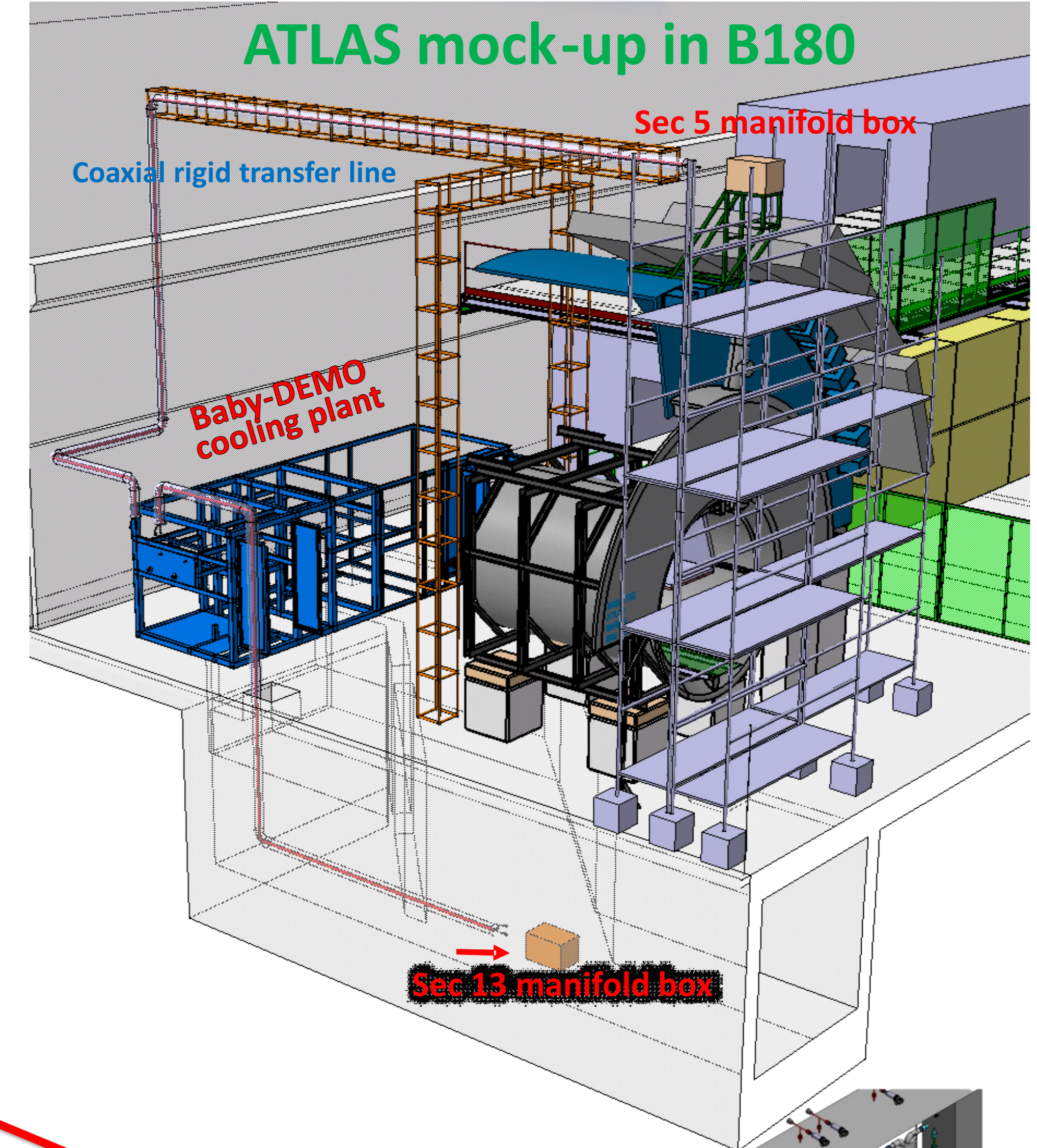
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ABSTRACT

The evaporative CO₂ has been selected as a detector cooling technology for Phase II upgrade of the silicon detectors at CERN. In order to provide input to the ATLAS Pixel TDR about minimum attainable cooling temperature by the end of 2017 as it will have an impact on technological choices for the new detector sensing elements. ATLAS together with contribution of CMS, has launched a dedicated detector cooling R&D study called Baby-DEMO.

The Baby-DEMO will be the demonstration of a typical 2PACL CO₂ plant to operate at the lowest temperature ever achieved. It will investigate capability to reach an operational temperature down to -45°C taking into account that at -56°C CO₂ freezes and CO₂ pumps require to operate with safe sub cooling margin. The target is to bring the on evaporator temperature down to -40°C or lower. System composed of cooling plant, low temperature chiller and typical distribution beyond ATLAS PP2 will be constructed at CERN. The real size ATLAS mock-up will be used to hold realistic manifolding as it's critical path might have strong impact on cooling performance. Additionally the Baby-DEMO programme address study of the high power flexible vacuum insulated transfer lines and warm nose boiling enhancement as possible solutions for phase 2 upgrade.

This presentations will show the system design including CO₂ plant, primary chiller and typical distribution. We will describe challenges and solutions that we put in place to achieve lowest temperature operation. Results will become of a great value for Phase II upgrade cooling systems design for both for ATLAS and CMS.



R&D for ATLAS ITk low temperature CO₂

Program time span for the first results: Dec 2017

Plant & chiller design and construction: outsourced to CUT (PL)

Goals:

- Provide input to the Pixel TDR about **minimum attainable cooling temperature** by the end of 2017 as it will have an impact on technological choices for the detector sensing elements.

Challenges:

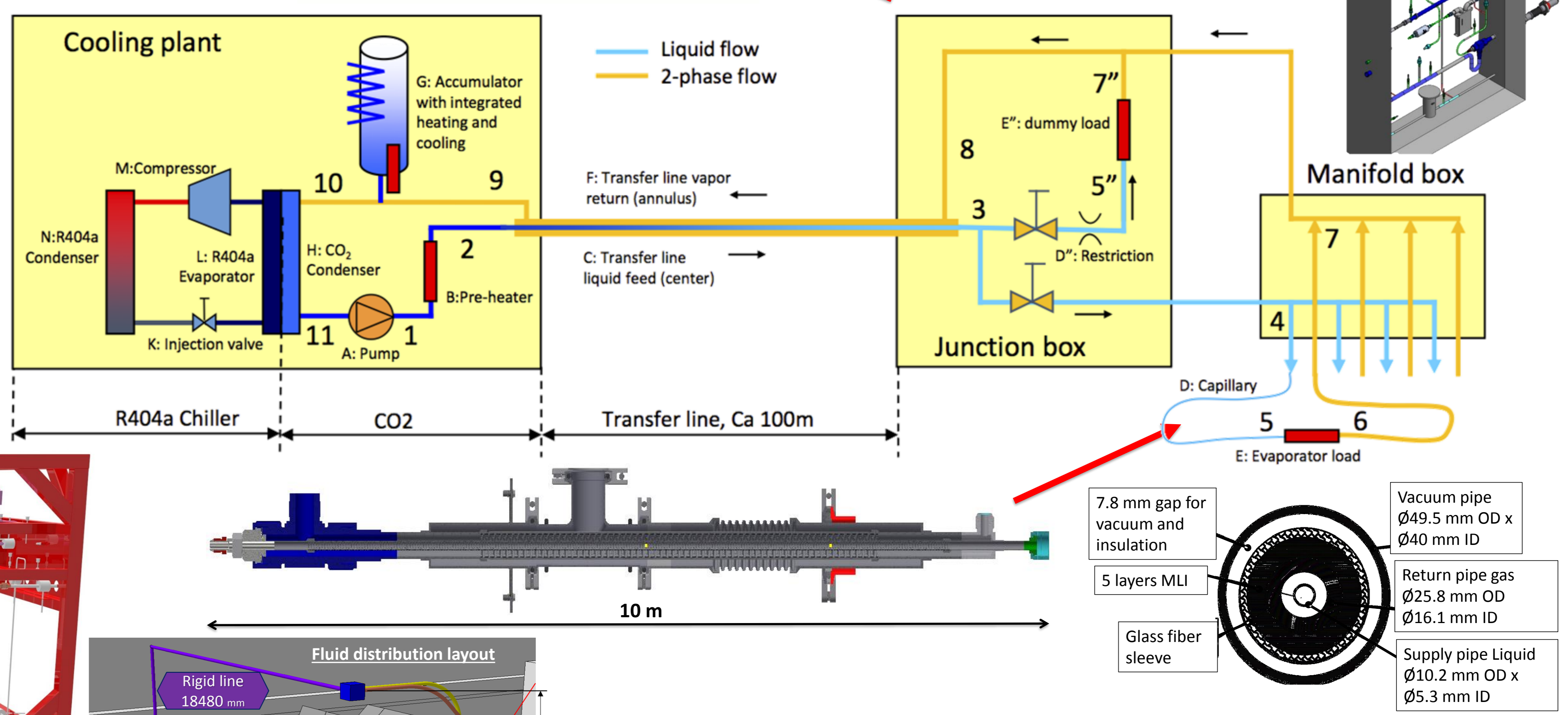
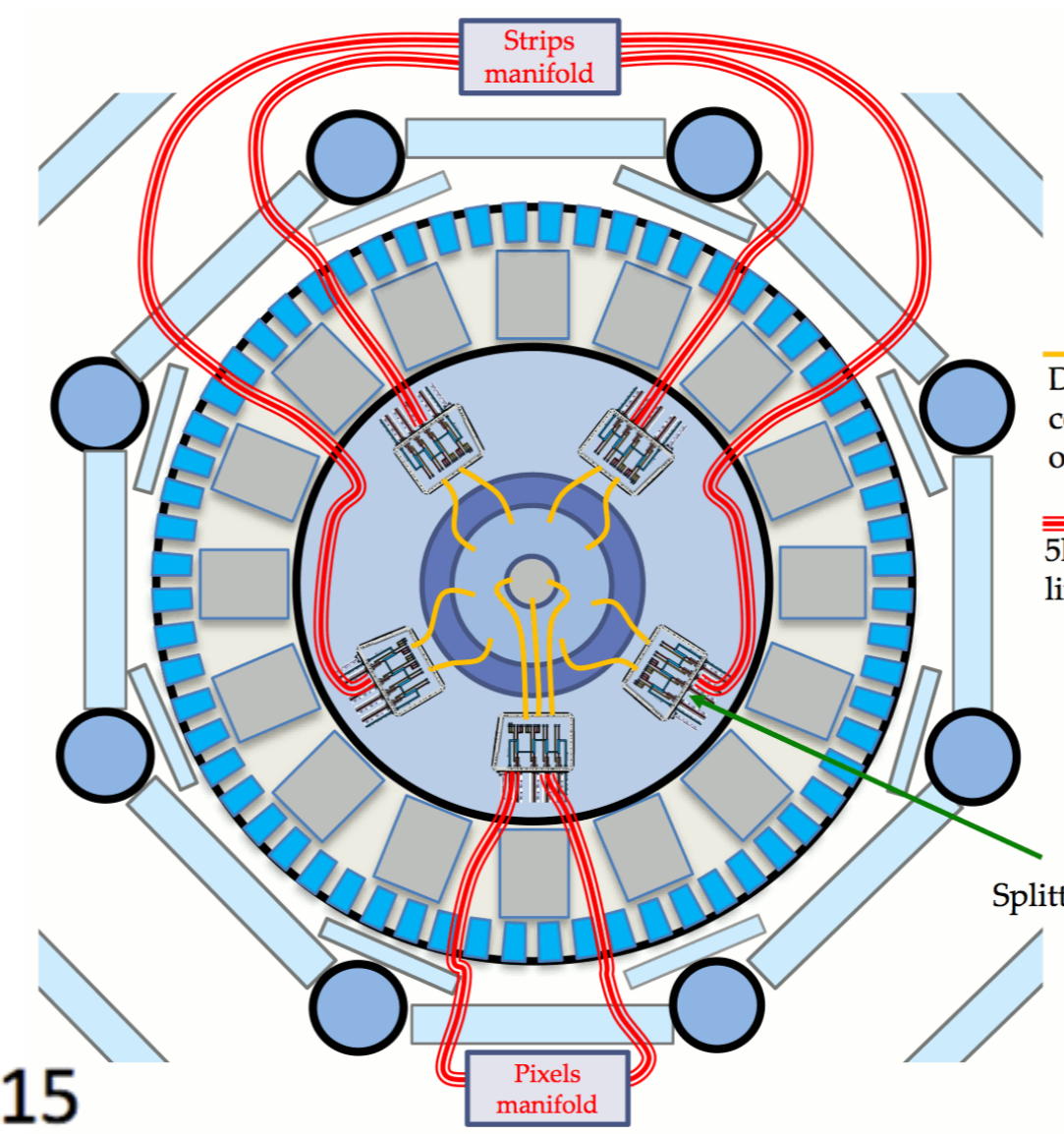
- Demonstration of a typical 2PACL CO₂ plant to operate at the lowest temperature ever achieved!
- Investigate capability to reach an operational temperature down to -45°C (at -56°C CO₂ freezes & CO₂ pumps require to operate safe sub cooling margin).
- The target is to bring on the evaporator temperature down to -40°C or lower, if possible!
- Typical distribution beyond PP2 manifold is required as it is the critical path due to pressure drop.

The "Baby-DEMO"

The "Baby-DEMO" R&D project can be split in 2 sub-projects:

BD1: the design, construction and operation of a small cooling plant – equipped with one typical distribution and evaporator line - to demonstrate the operation of the CO₂ plant with distribution at the lowest attainable temperature;

BD2: the design, construction and R&D on a full scale "PP2 distribution line", including manifolds and with realistic height variations, to be coupled to the produced BD1 cooling plant to demonstrate the full system loop performance in realistic conditions with realistic prototype detector structures.



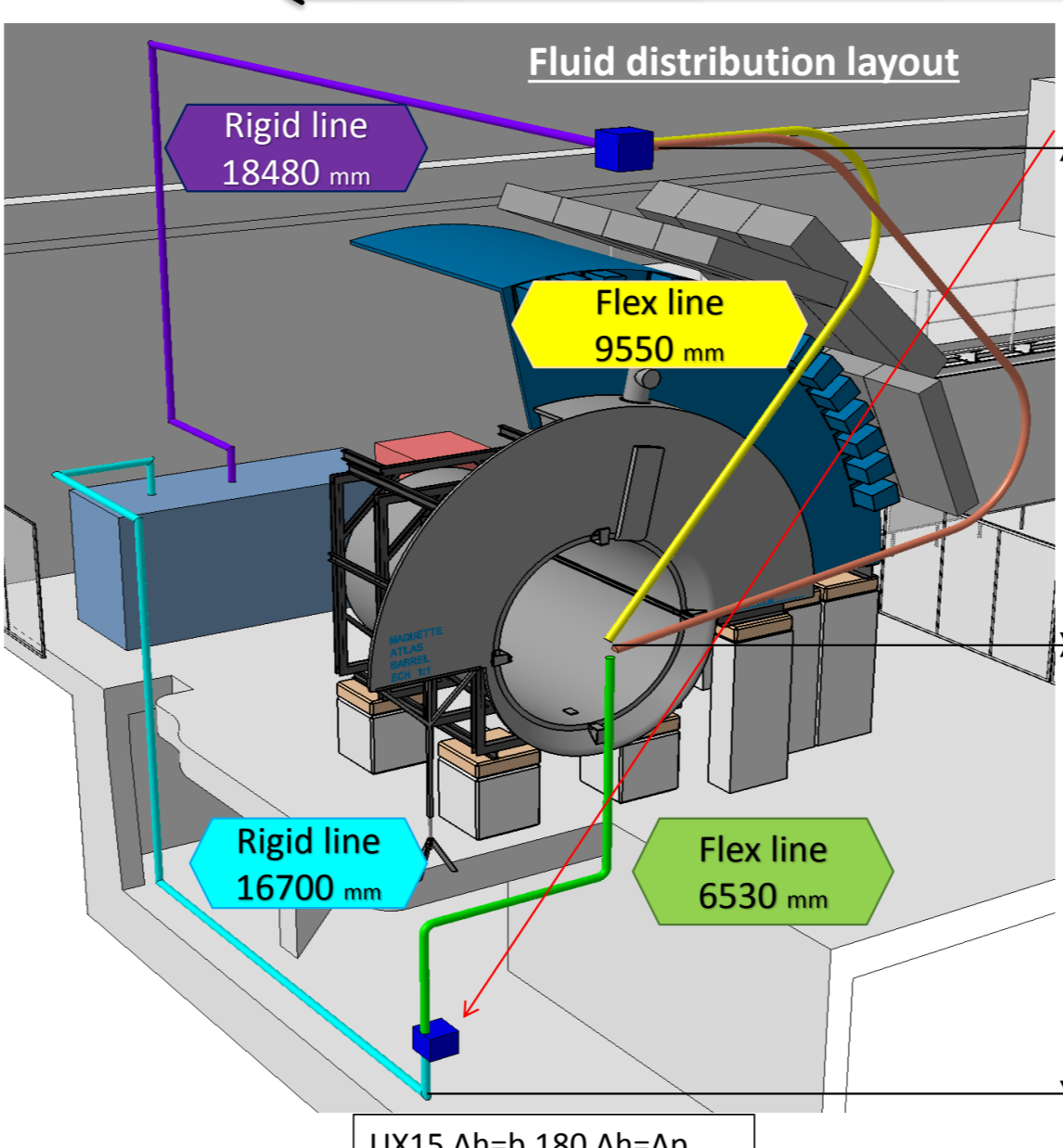
The Baby-DEMO cooling system



CO₂ cooling plant and chiller concept

The "Baby-Demo" will be the demonstration of a 2PACL & I2PACL CO₂ plant, based on latest experience gained in evaporative CO₂ cooling technology for HEP, equipped with low temperature chiller and remote head membrane pump capable to operate at the lowest temperature ever shown before. Operational temperature down to -45°C temperature target quickly come dangerously close to physical limits, as CO₂ freezes at -56°C and the pumps used for the 2PACL cycle require to operate with a safe sub cooling margin.

It is therefore proposed to use custom made low temperature chiller equipped with two stage compressor unit, hot gas by-pass and liquid injection to guaranty stable operation in all load conditions. Additionally it is supplied with several CO₂ condensers providing different work conditions. It is intendent to find best possible solution for stable CO₂ condensation close to -56°C limit via direct evaporation, brine system using NOVEC 649 or combination of both.



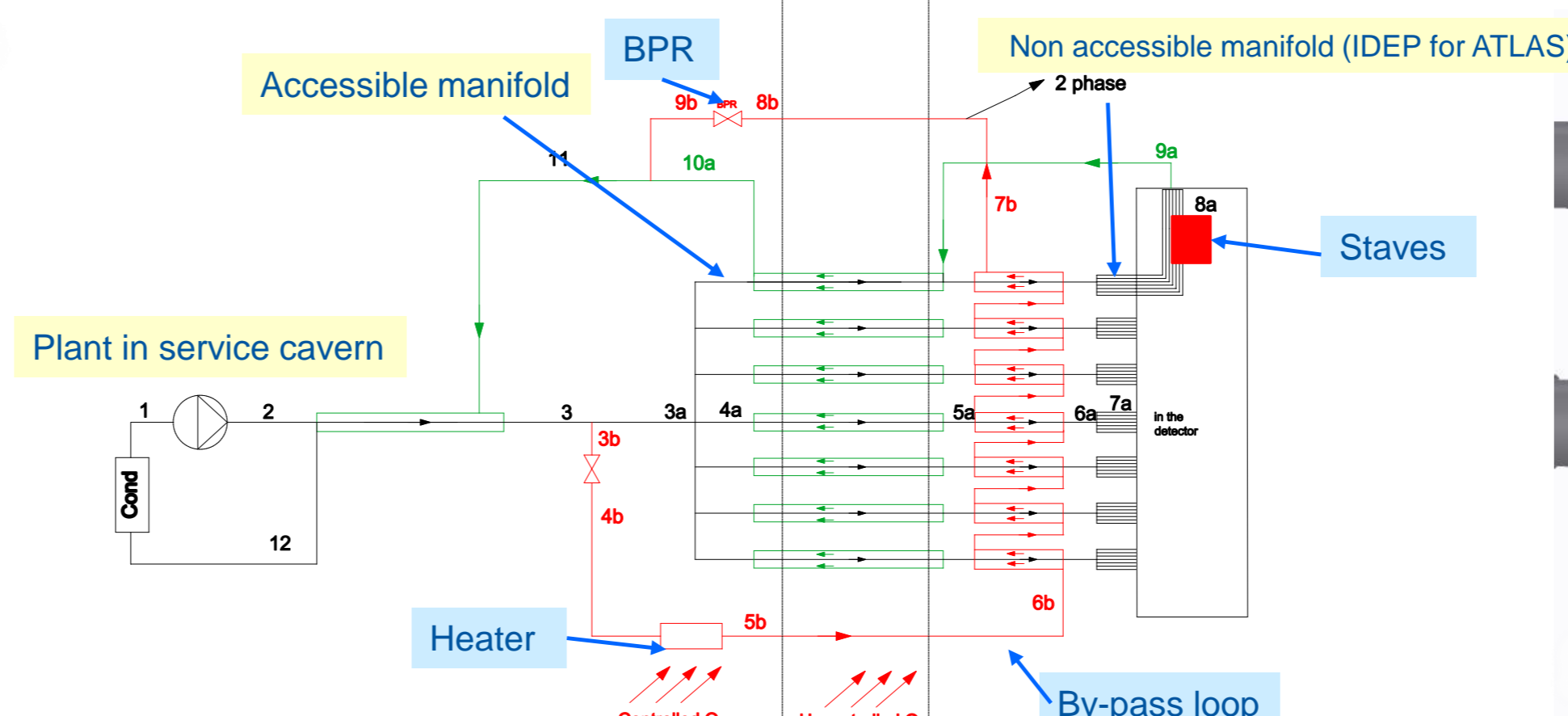
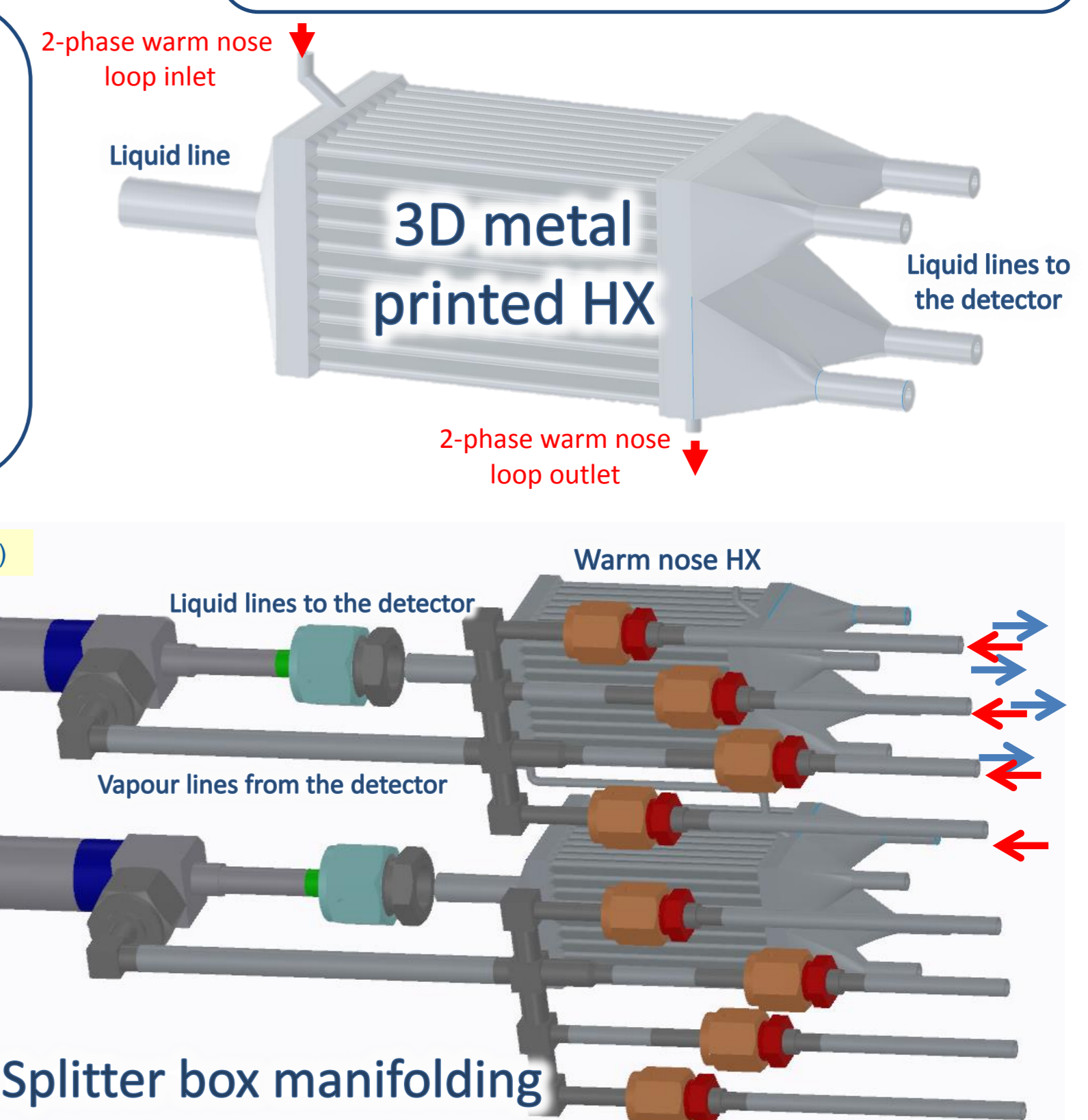
Vacuum insulated flexible transfer lines

The 10m flex line is design to connect the manifold boxes to the splitter boxes. The concept was successfully developed for the IBL, to facilitate the routing from Muon sector 5 to the ID endplate preventing problems of humidity on the external pipe surface. The new 5 kW flex lines are bigger in diameters and flex corrugated hoses for both inlet and return CO₂ pipes were used. In order to avoid any thermal bridge the cold return flex hose is insulated with 5 layers of Multi Layer Insulation (MLI) embedded in a glass cloth.

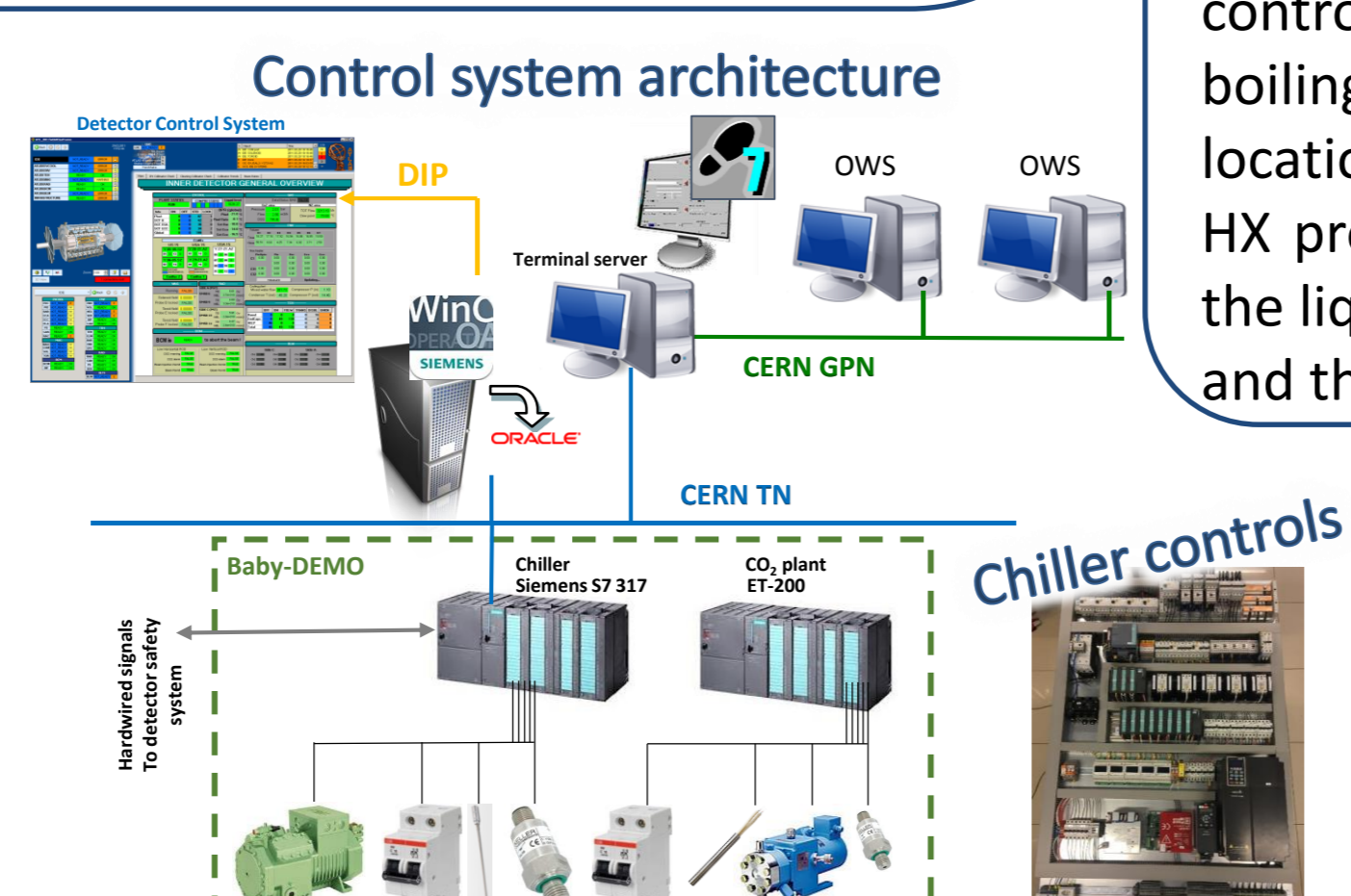
Counter flow HX, 3D printed stainless steel
Number of pipes = 100
Length of pipes = 75 mm
Overall dimensions = 50 x 50 x 178.5 mm

Warm nose concept

The warm nose circuit contain back pressure regulator HX and a heater to control the temperature of the CO₂ entering to the detector and hence the boiling conditions. All controlled hardware is placed in accessible manifold location. Multiple loops can be controlled with 1 by-pass loop. The warm nose HX provides two functionalities: counterflow heat exchanger and a splitter for the liquid lines. Due to the geometrical constraints, the dimensions are very small and therefore it will be printed in 3D (stainless steel).



Low temperature chiller



Controls

The "Baby-Demo" control system for both CO₂ plant and primary chiller is based on Siemens S7 317 PLC equipped with ET200 distributed I/Os. PLC and SCADA software conforms to CERN UNICOS framework standard. The SCADA layer uses Siemens WinCC OA 3.15.