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EP-DT Detector Technologies

ATLAS Baby-DEMO

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ABSTRACT

Evaporative CO_2 has been selected as the main detector cooling technology for Phase II upgrade of the LHC silicon detectors at CERN. In order to provide input to the ATLAS Pixel TDR about the minimum attainable cooling temperature by the end of 2017, ATLAS, with a contribution of CMS, has launched a dedicated detector cooling R&D study nick-named Baby-DEMO. The Baby-DEMO is the demonstration of a typical 2PACL CO_2 cooling plant operating at the lowest temperature ever achieved. A real size ATLAS mock-up is used to hold realistic manifolding as its critical path might have strong impact on the cooling performance. Additionally, the "Baby-DEMO" program addresses the study of high power flexible vacuum insulated coaxial transfer lines and warm nose boiling enhancement as possible solutions for Phase II upgrade. This presentations will discuss the system design including CO_2 plant, primary chiller and typical distribution. We will describe the challenges and the solutions that we put in place to achieve the lowest evaporation temperature in operation. Preliminary results are of a great value for the Phase II upgrade cooling systems design for both ATLAS and CMS.

R&D for ATLAS ITk low temperature CO_2

Program time span for the first results: Dec 2017

Plant & chiller design and construction: outsourced to consortium CUT, PONAR, CEBEA (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 CO_2 plant to operate at the lowest temperature ever achieved!
- Investigate capability to reach an operational temperature down to -45'C (at -56'C CO_2 freezes & CO_2 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:

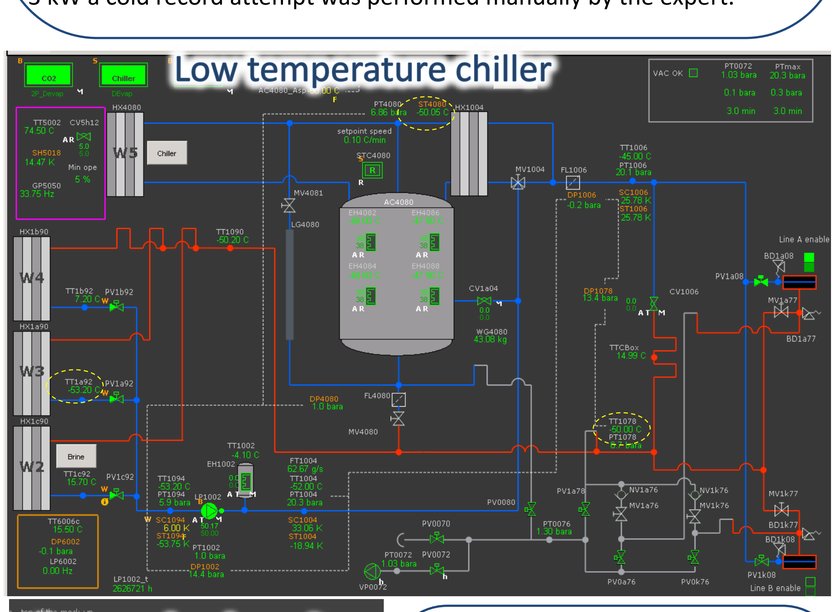
BD1: the design, construction and operation of a medium size cooling plant – equipped with one typical distribution and evaporator line - to demonstrate the operation of the CO_2 plant with distribution at the lowest attainable temperature;

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.

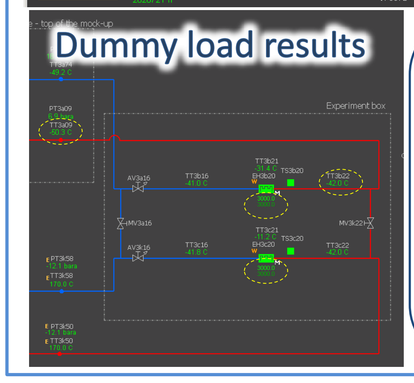
CO_2 cooling plant and chiller concept

The "Baby-Demo" is the demonstration of a 2PACL & I-2PACL CO_2 plant, based on latest experience gained in evaporative CO_2 cooling technology for HEP, equipped with low temperature chiller and remote head membrane pump capable to operate at the lowest temperature ever shown before. It was 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 CO_2 condensers providing different work conditions.

In December 2017 the Baby-DEMO plant was run successfully for the first time and evaporative cooling temperatures of -47°C were achieved at the plant level. Accumulator saturation temperature set-point cycles (ST4080) from -47°C to 10°C were made with different heat loads from 1 to 6kW. The cycle speed for the measurement was as low as 6°C/h so that the results can be treated as being steady state values. After the first cycle with 5 and 3 kW a cold record attempt was performed manually by the expert.



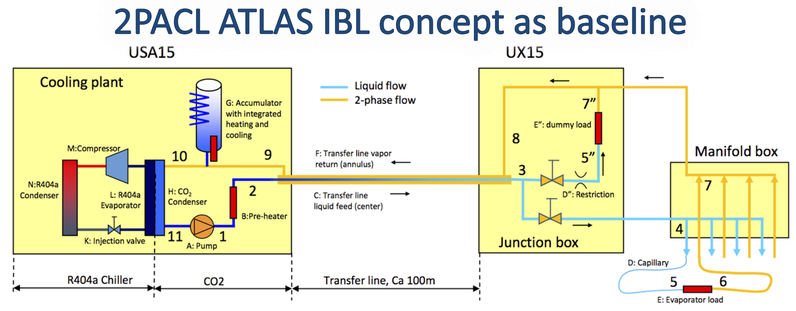
Dummy load results

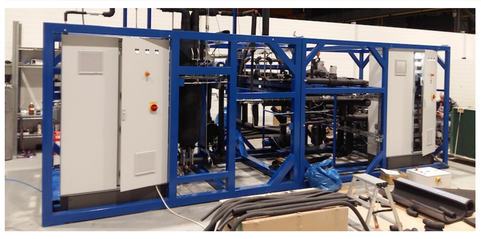


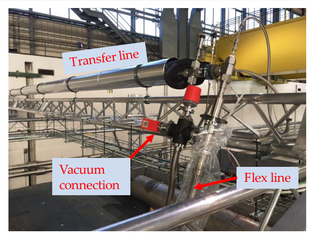
Controls

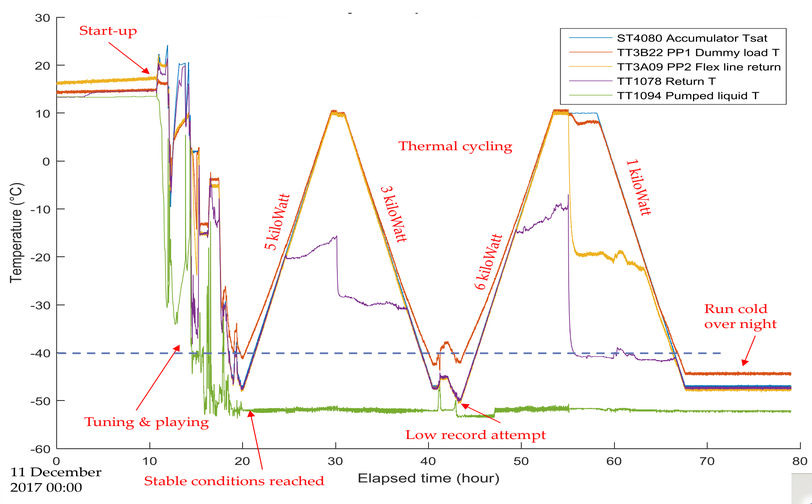
The "Baby-Demo" control system for both CO_2 plant and primary chiller is based on Siemens S7 317 PLC equipped with ET200 distributed I/Os communicating via PROFINET. PLC and SCADA software conforms to CERN UNICOS framework standard. The SCADA layer uses Siemens WinCC OA 3.15.

2PACL ATLAS IBL concept as baseline





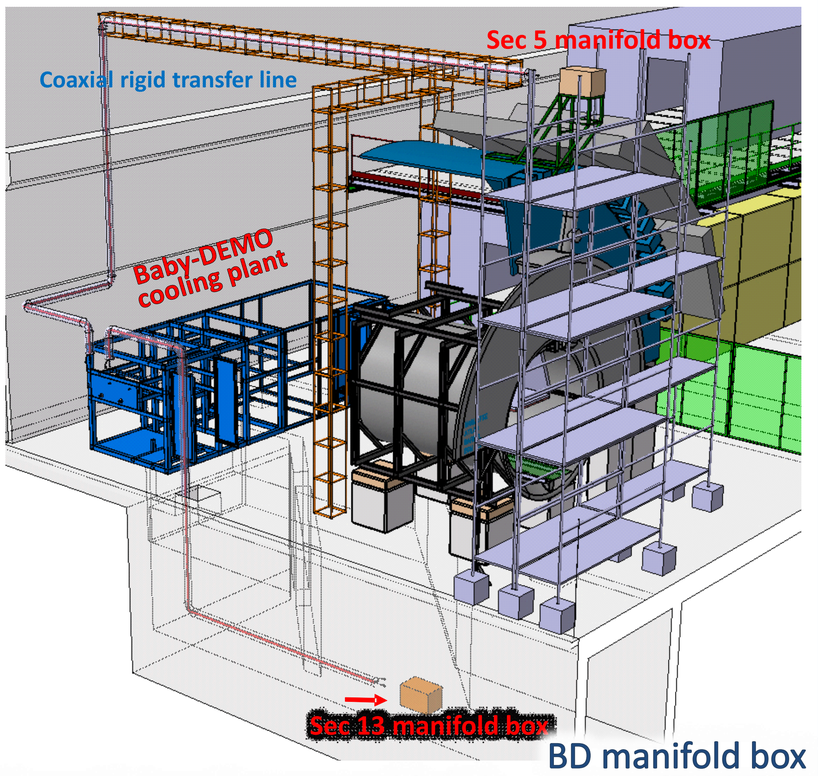




Conclusions

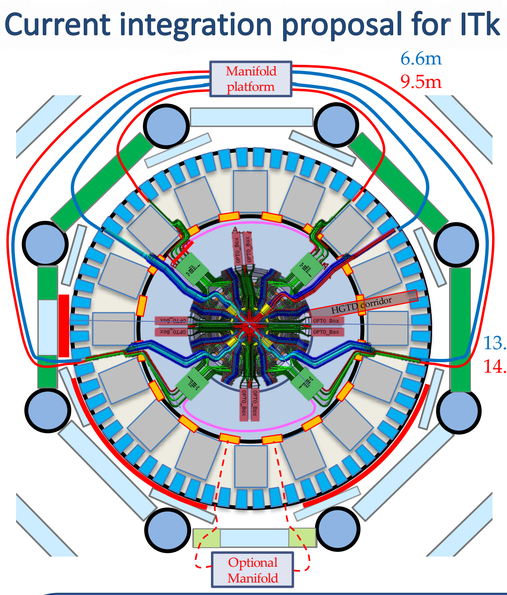
Target achieved at 1st cool down (5kW @ <-40°C at dummy load). Larger than expected temperature gradients observed in flex lines 6°C gradient at -40°C dummy load (-46°C accumulator).

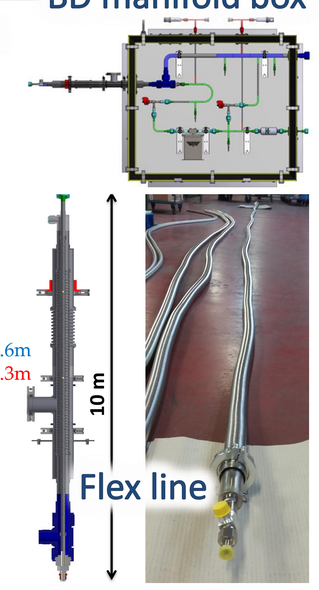
Stable long term operation at -47°C accumulator cooling. Pump looks not sensitive to low sub cooling failure. Record low temperature of **-50°C** achieved with manual tricks. (not operational target!!!)



BD manifold box

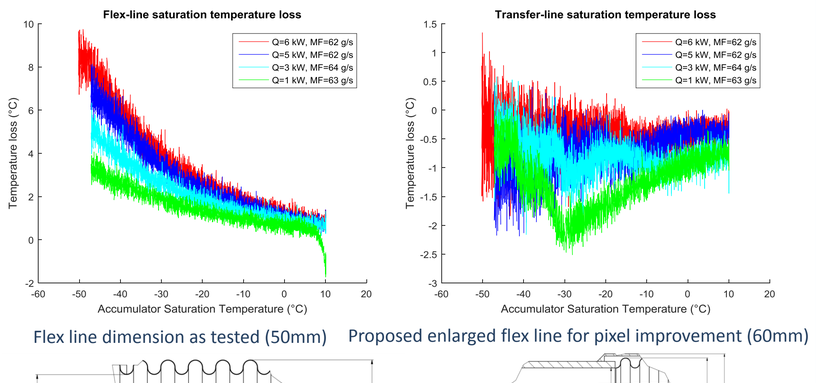
Current integration proposal for ITk



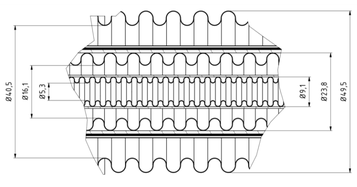


Vacuum insulated flexible transfer lines

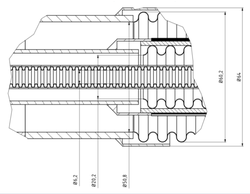
The 10m flex line is design to connect the manifold boxes to the splitter boxes. The concept was successfully developed for the IBL, to facilitate the routing from Muon sector 5 to the ID endplate preventing problems of humidity on the external pipe surface. The new 5 kW flex lines are bigger in diameters and flex corrugated hoses for both inlet and return CO_2 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.



Flex line dimension as tested (50mm)



Proposed enlarged flex line for pixel improvement (60mm)



Warm nose concept

The warm nose circuit contain back pressure regulator HX and a heater to control the temperature of the CO_2 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 constrains, the dimensions are very small and therefore it will be printed in 3D (stainless steel).

3D metal printed HX

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

Splitter box