Evaporative CO₂ 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 OMS, has launched a dedicated detector cooling R&D study nick-named Baby-DEMO. The Baby-DEMO is the demonstration of a typical 2PACI CO₂ 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 coastal transfer lines and warm nose boiling enhancement as possible solutions for Phase II upgrade. This presentation will discuss the system design including CO₂ 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.

**ABSTRACT**

**R&D for ATLAS ITK low temperature CO₂**

Program time span for the first results: Dec 2017
Plant & chiller design and construction: outsourced to consortium CUT1: Phonon, CEBBA (PL)

- Provide input to the Pixel TDR about minimum attainable cooling temperature by the end of 2017 so it will have an impact on technological choices for the detector sensing elements.
- Demonstration of a typical 2PACI CO₂ plant to operate at the lowest temperature ever achieved!
- Investigate capability to reach a operational temperature down to -45°C (at -50°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" R&D project can be split in 2 sub-projects:

**BD1: design, construction and operation of a medium size cooling plant**
- equipped with a typical distribution and evaporator line - to demonstrate the operation of the CO₂ plant with distribution at the lowest attainable temperature.

**BD2: 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.

**CO₂ cooling plant and chiller concept**

The "Baby-DEMO" is the demonstration of a 2PACI & 1 PANGI CO₂ plant, based on latest experience gained in evaporative CO₂ cooling technology for HEP equipped with low temperature chiller and remote head membrane pumps 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 guarantee stable operation in all load conditions. Additionally it is supplied with several CO₂ condensers providing different working 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 (ST4880) from -47°C to 0°C were made with different heat loads from 1 to 5 kW. The cycle speed for the measurement was as low as 6°C/ch so that the results can be treated as being steady state values. After the first cycle with 1 and 5 kW a cold record attempt was performed manually by the expert.

**Controls**

The “Baby-DEMO” control system for both CO₂ plant and primary chiller is based on Siemens S7 317 PLC equipped with ET200 distributed IOs communicating via PROFINET, PC/PC and SCADA software conforms to CERN UNICOS framework standard. The SCADA layer uses Siemens WinCC OA 15.1.

**Conclusion**

Target achieved at 1°C cool down (S8W @ -40°C at dummy load)
Larger than expected temperature gradients observed in flex lines -6°C at 40°C (1.4°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...)

**Vacuum insulated flexible transfer lines**

The 10mm 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 the Moon 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 insualted with 5 layers of Multi Layer Insulation (MLI) embedded in a glass cloth.