EP-DT
Detector Technologies

# Advancements and plans for LHC upgrade detector thermal management with $CO_2$ evaporative cooling

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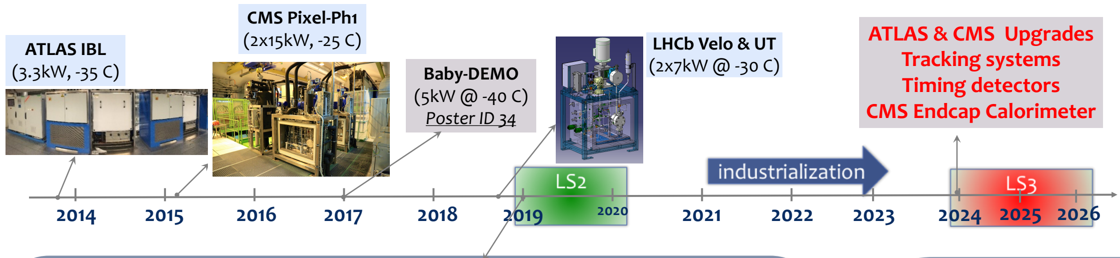
## $CO_2$ cooling @ LHC: a successful history & a long term perspective

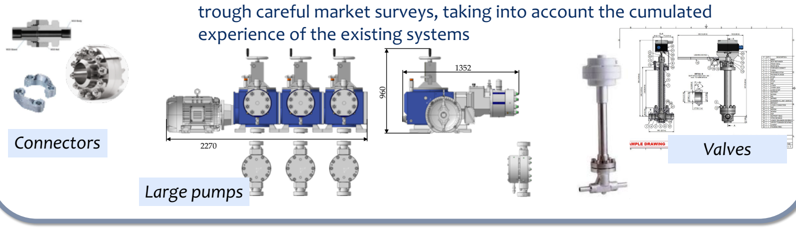



## The new challenges

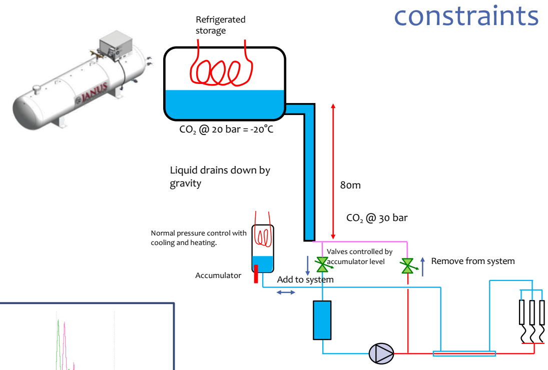
- Total power per experiment up to 500 kW
- Low (down to -45 C?) evaporation temperature
- Enhanced availability (to maintain silicon cold when irradiated)
- Integration severe constraints

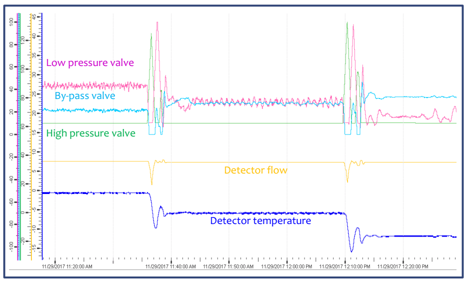
## The "Demo"

The first high cooling power (ranges 50-70 kW) low temperature CO2 cooling system is now in design phase: components are being selected trough careful market surveys, taking into account the cumulated experience of the existing systems




## 2PACL evolution: dealing with integration constraints



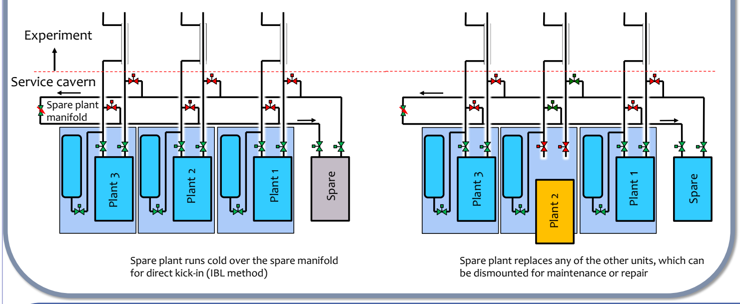




Storage of full $CO_2$ volume is done on surface and control of temperature is achieved with a small "accumulator" vessel close to the pump module. Alternative, further simplified model without local accumulator has been tested, using regulation valves to tune the evaporating temperature and achieving promising performances so far

## The numbers: ATLAS & CMS phase II

| Basis for estimate | Evaporation T at the detector exit | Heat load of detector | Ambient pick up | Heat per unit | Cooling units |
|---|---|---|---|---|---|
| | ºC | kW | kW | kW | # |
| **CMS** | | | | | |
| OT | -35 | 100 | 10 | 55 | 2 |
| IT | -35 | 45 | 4.5 | 73 | 1 |
| BTL | -35 | 21 | 2.1 | | |
| CE +z | -35 | 150 | 15 | 89 | 2 |
| ETL +z | -35 | 11 | 1.1 | | |
| CE -z | -35 | 150 | 15 | 89 | 2 |
| ETL -z | -35 | 11 | 1.1 | | |
| | | ***488*** | ***48.8*** | | ***7*** |
| | | | | | |
| **ATLAS** | | | | | |
| Pixel EC (Ring2,3,4) | -45 | 28.8 | 2.9 | 44.4 | 2 |
| Pixel Barrel (L2+L3+L4) | -45 | 51.9 | 5.2 | | |
| Pixel insertable (L0+L1+Rings 0-1) | -45 | 20.6 | 2.1 | 22.7 | 1 |
| Strip EC | -40 | 45.3 | 4.5 | 64.1 | 2 |
| Strip Barrell | -40 | 71.2 | 7.1 | | |
| HGTD | -40 | 25 | 2.5 | 27.5 | 1 |
| | | ***242.8*** | ***24.28*** | | ***6*** |

## 2PACL evolution: servicing multiple parallel users in the most flexible way!



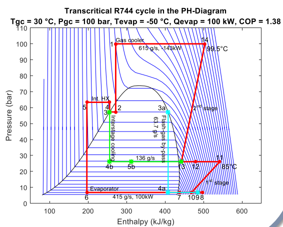

Spare plant runs cold over the spare manifold for direct kick-in (IBL method)

Spare plant replaces any of the other units, which can be dismounted for maintenance or repair

## Enhanced availability and green approach

Decoupling of low T cooling systems from traditional water cooling is a must in order to reduce downtime due to maintenance and other system malfunctioning to the minimum. R744 (CO2) industrial refrigeration solutions exists today on the market for operation ranges similar to the one needed and use ambient temperature water as primary source. Water is then rejected at high temperature and can be re-used.

A collaboration with the Norwegian University of Science and Technology (NTNU) and CERN Engineering Department is established to adapt such industrial solutions to the LHC experiment needs (stability of evaporating temperature, limited space availability in underground).




## Conclusions

- ATLAS and CMS detectors heavily rely on CO2 cooling for phase II upgrades, with power dissipations reaching unprecedent values for similar systems
- Existing CO2 cooling system is being upscaled and technical solutions to cope with new requirements are being validated trough independent tests & the "Demo" prototype unit
- R&D activities continues to understand the limits of the industrial systems for primary cooling and the benefits to the experiment long-perspective operation

## References

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2) Tropea, P. et al. 2014, *Design, construction and commissioning of a 15 kW $CO_2$ evaporative cooling system for particle physics detectors*, 3rd Conference on Technology and Instrumentation in Particle Physics, PoS(TIPP 2014)223
3) Daguin, J. et al, *$CO_2$ cooling for particle detectors: experiences from the CMS and ATLAS detector systems at the LHC and prospects for future upgrades, Proceedings of the 24th IIR International Congress of Refrigeration - Yokohama, Japan, 2015*

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