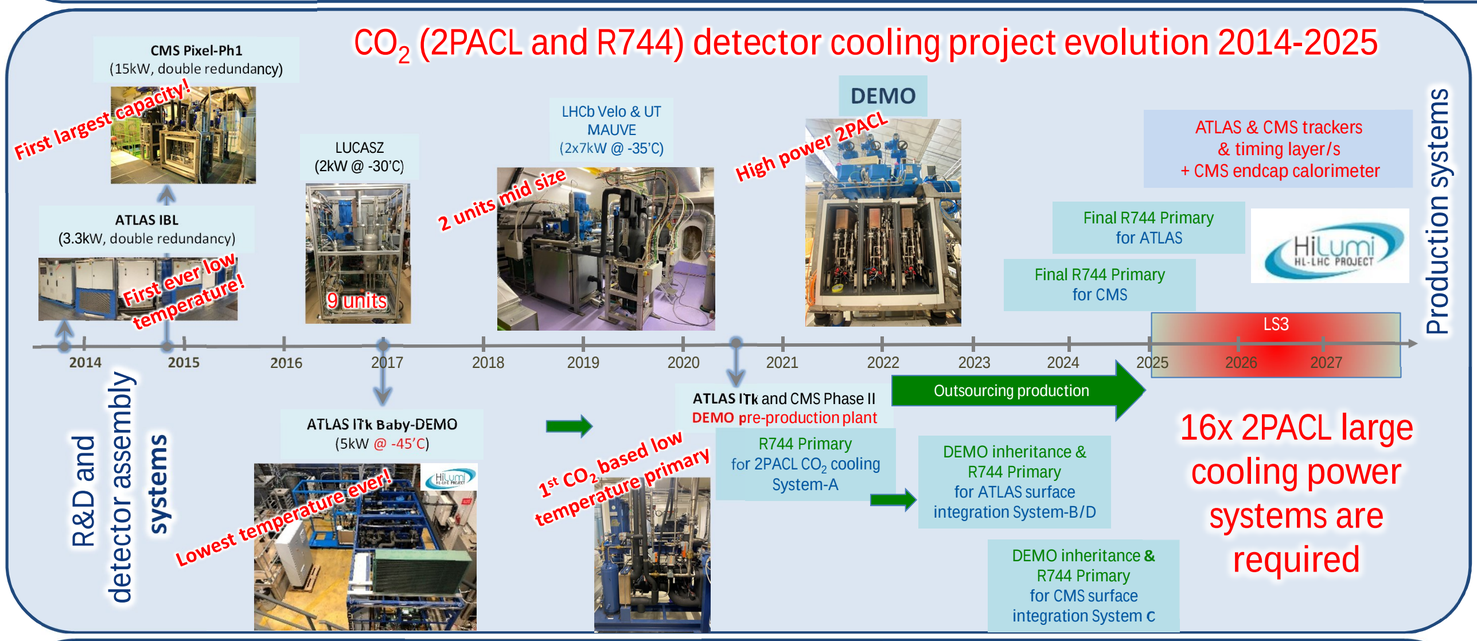
EP-DT Detector Technologies
EN NTNU

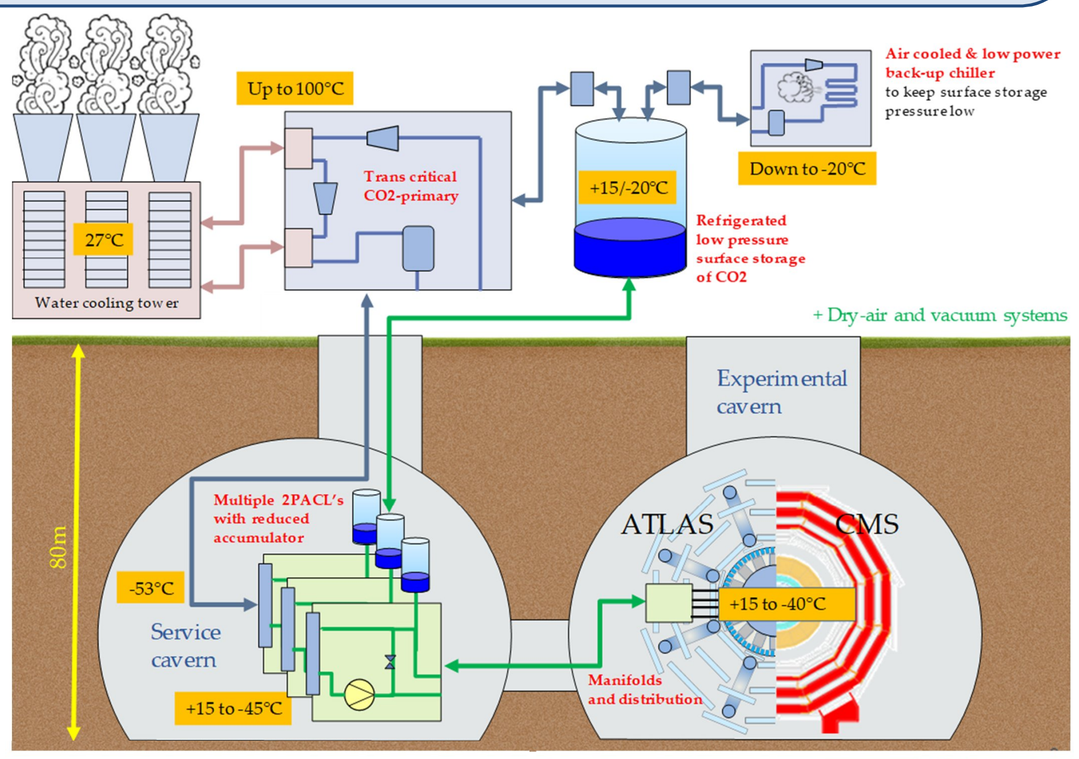
Progress in new environmental friendly low temperature detector cooling systems development for the ATLAS and CMS experiments.

ABSTRACT

In the frame of the progress towards the High Luminosity Program of the Large Hadron Collider at CERN, the ATLAS and CMS experiments are boosting the preparation of their new environmental friendly low temperature detector cooling systems. This paper will present a general overview of the progress in development and construction of the future CO_2 cooling systems for silicon detectors at ATLAS and CMS (trackers, calorimeters and timing layers), due for implementation during the 3rd Long Shut Down of LHC (LS3). We will describe the selected technology for the primary chillers, based on an innovative transcritical cycle of R744 (CO_2) as refrigerant, and the oil-free secondary "on detector" CO_2 pumped loop, based on the evolution of the successful 2PACL concept. Different detector layers will profit from an homogenized infrastructure and will share multi-level redundancy that we will describe in details. The technical progresses achieved by the EP-DT group at CERN over the last years will be discussed in view of the challenges and key solutions developed to cope with the unprecedented scale of the systems. We will finally present how mechanics- and controls-related problems have been addressed via a vigorous prototyping programme, aiming at cost- and resource-effective construction of the final systems, which is starting now.

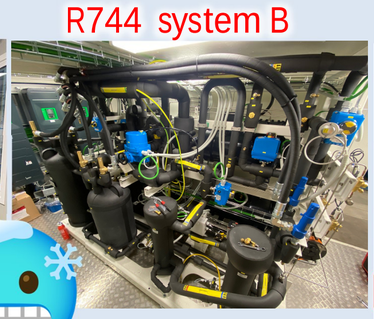
CO_2 (2PACL and R744) detector cooling project evolution 2014-2025



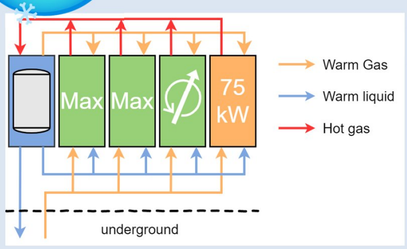


R744 system A

R744 system B



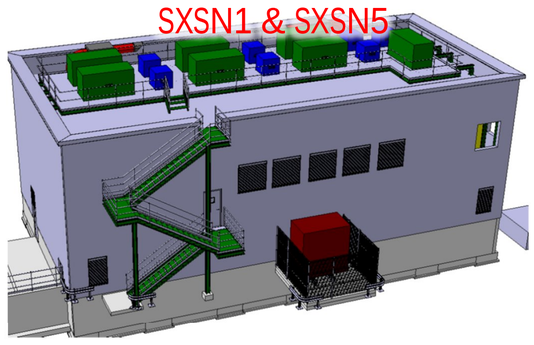
Final R744 primary systems are multi slice installations
ATLAS = 6+1
CMS = 12+1



R744 primary cooling system needs

	Prototype phase		Detector assembly phase		Detector operation	
	System-A (reference)	System-B	System-C	System-D	Final system CMS	Final system ATLAS
2PACL cooling capacity in normal operation [kW]	80-100 Incl. 2PACL control	0 (there is no 2PACL)	45	45	610	310
2PACL functional load [kW]		0	5	5	130	60
Surface Storage keep cool load [kW]		0	0	0	10	10
R744 cooling capacity requirement [kW]	∑	50 (By dummyload)	50	50	750kW	380kW
2PACL functional load peak [kW]		0	7	7	260	140
Surface Storage load peak [kW]		0			50	50
R744 cooling capacity requirement peak [kW]	∑	60 (By dummyload)	52	52	920	500
Peak load factor wrt nominal		120%	104%	104%	123%	132%
R744 evaporation T requirement [° C] (at underground evaporator)	-53	-53	-53	-53	-53	-53
R744 cooling capacity requirement in case of detector off [kW]					60	50

New multi service buildings SXSN1 & SXSN5

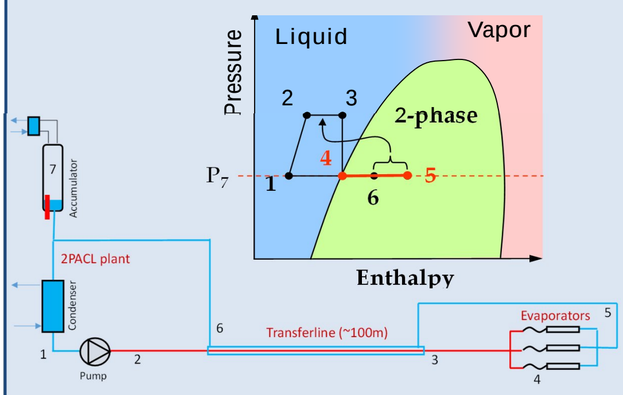


New SXSN1 construction status

2PACL 3 head cooling plant with nominal cooling power of 103kW

Final 2PACL cooling plants

ATLAS = 6 + 1 spare
CMS = 8 + 1 spare



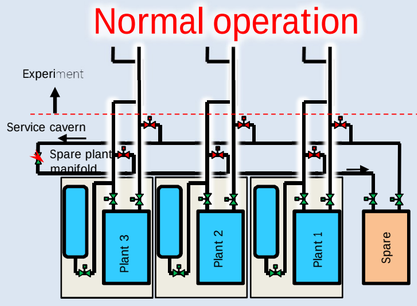
2PACL cooling and the detector needs

ATLAS	Temp. at detector exit	Heat per cooling unit	Cooling units	Plant type (Pump heads)	Max power/unit	Detector distribution lines
	°C	kW	#	#	kW	#
Pixel End Cap (PEC)	-40	57	2	2	69	6
Pixel Barrel (POB)	-40					16
Pixel inner system (PXI)	-40	29	1	1	34	6
Strip End Cap (SEC)	-38	55	2	2	69	8
Strip barrel (SBR)	-38					16
HGTD	-40	54	1	2	69	8
Spare plant			1	3		
Total cooling power requested				kW	309	

CMS	Temp. at detector exit	Heat per cooling unit	Cooling units	Plant type (Pump heads)	Max power/unit	Detector distribution
	°C	kW	#	#	kW	#
Outer Tracker (OT)	-35	86	2	3	103	46
Inner Tracker (IT)	-35					24
Barrel Timing Layer (BTL)	-35	46	1	2	69	12
Calorimeter Endcap (CE) +z NEAR	-35	62	1	2	87	12
Calorimeter Endcap (CE) +z FAR	-35	62	1	2	87	12
Calorimeter Endcap (CE) -z NEAR	-35	62	1	2	87	24
Calorimeter Endcap (CE) +z FAR	-35	62	1	2	87	24
Endcap Timing Layer (ETL) +/-z	-35	85	1	3	103	4
Spare plant			1	3		
Total cooling power available (30% VQ)				kW	552	

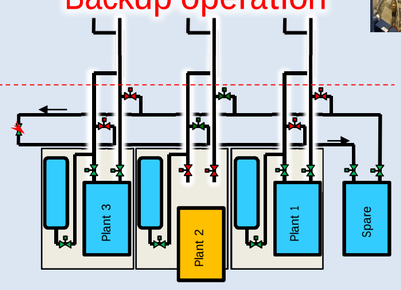
- No interruption of CO_2 flow to detector acceptable in case of power cut.
- CO_2 systems are designed as N+1 redundant, supplied via UPS backed-up by diesel, both for 2PACL and part of R744 to allow for continuous running and ambient heat pickup removal even when detector power is off.
- Fully CERN UNIOCS based control system with redundant PLCs architecture using distributed I/Os spread over long distance between surface and underground.
- Very advanced detailed integration studies both in ATLAS and CMS.
- Further optimization and redesign study for 2PACL plant and accumulators are ongoing.
- Multiple complex procurement process are starting this days to fulfill challenging schedule of CMS and ATLAS.
- On going DEMO commissioning.
  (R744 sys. A & 2PACL: 3H plant + 1H plant + accumulator + 2s 50kW dummy loads)

Normal operation

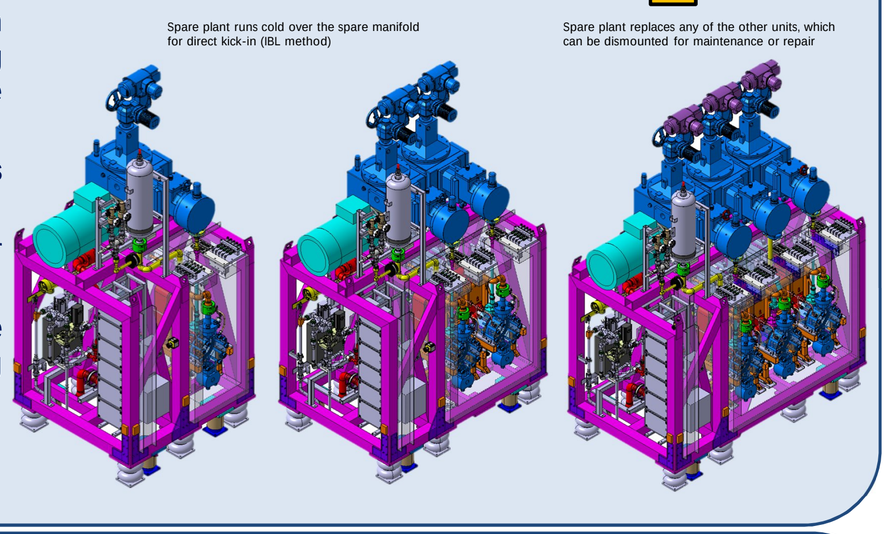


Spare plant runs cold over the spare manifold for direct kick-in (IBL method)

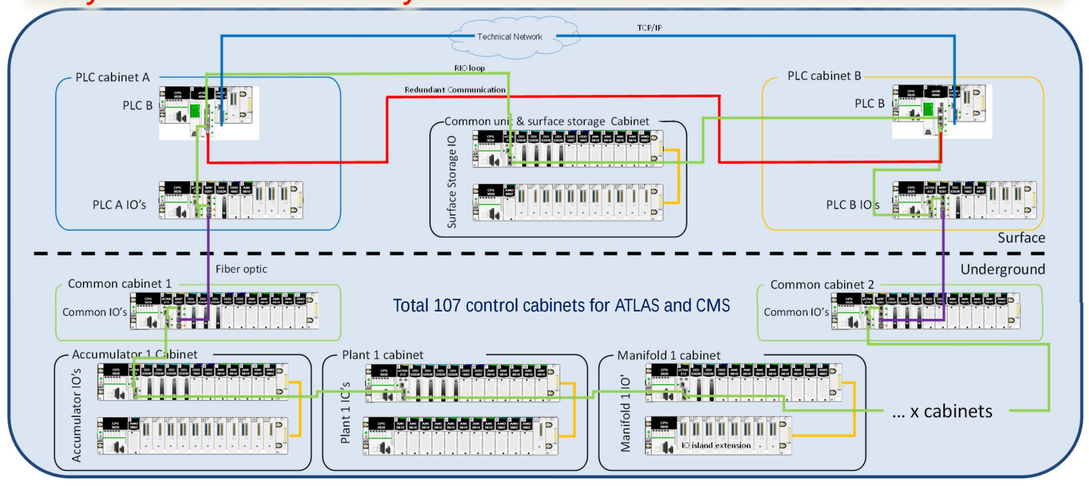
Backup operation

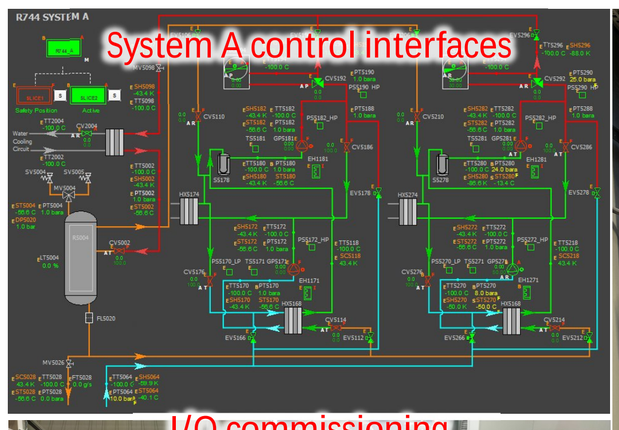


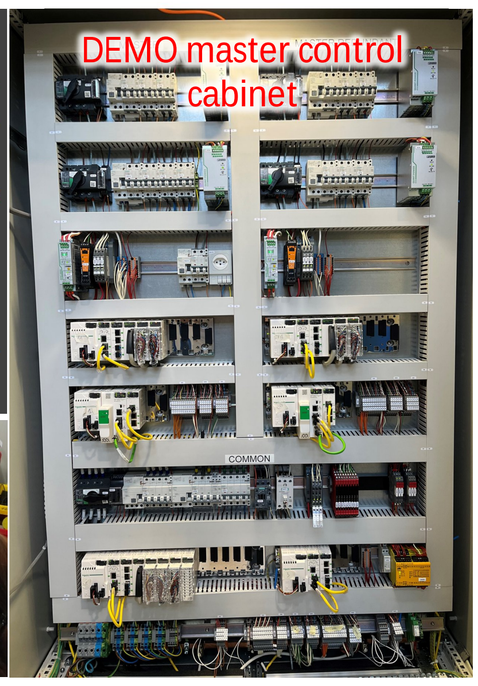
Spare plant replaces any of the other units, which can be dismounted for maintenance or repair



Fully redundant control system architecture for both R744 and 2PACL







CONCLUSIONS

Last years for CO_2 project, both the R744 primary and the 2PACL, have been used to move from initial design stage to prototyping and preparatory for serial production. Major step has been achieved resulting in startup of DEMO system commissioning which brings important feedback form a scale of the 2PACL cooling system that has never ever been build before. Results are immediately being translated to hardware and software solutions to be applied in final installation dedicated to new generation of HiLumi LHC detectors.
The commissioning of R744 System A at DEMO has been well completed and validated the principle of operation. Collected feedback was used during the design of larger System B, being pre-production slice of final large scale modular installation for ATLAS and CMS experiments. Today system B is undergoing extensive commissioning in ATLAS shaft. With dummy load installed ~80m in underground, the oil carry-over and maximum capacity is being determined.