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The consolidation programs of the cryogenic systems of the ATLAS and CMS experiments

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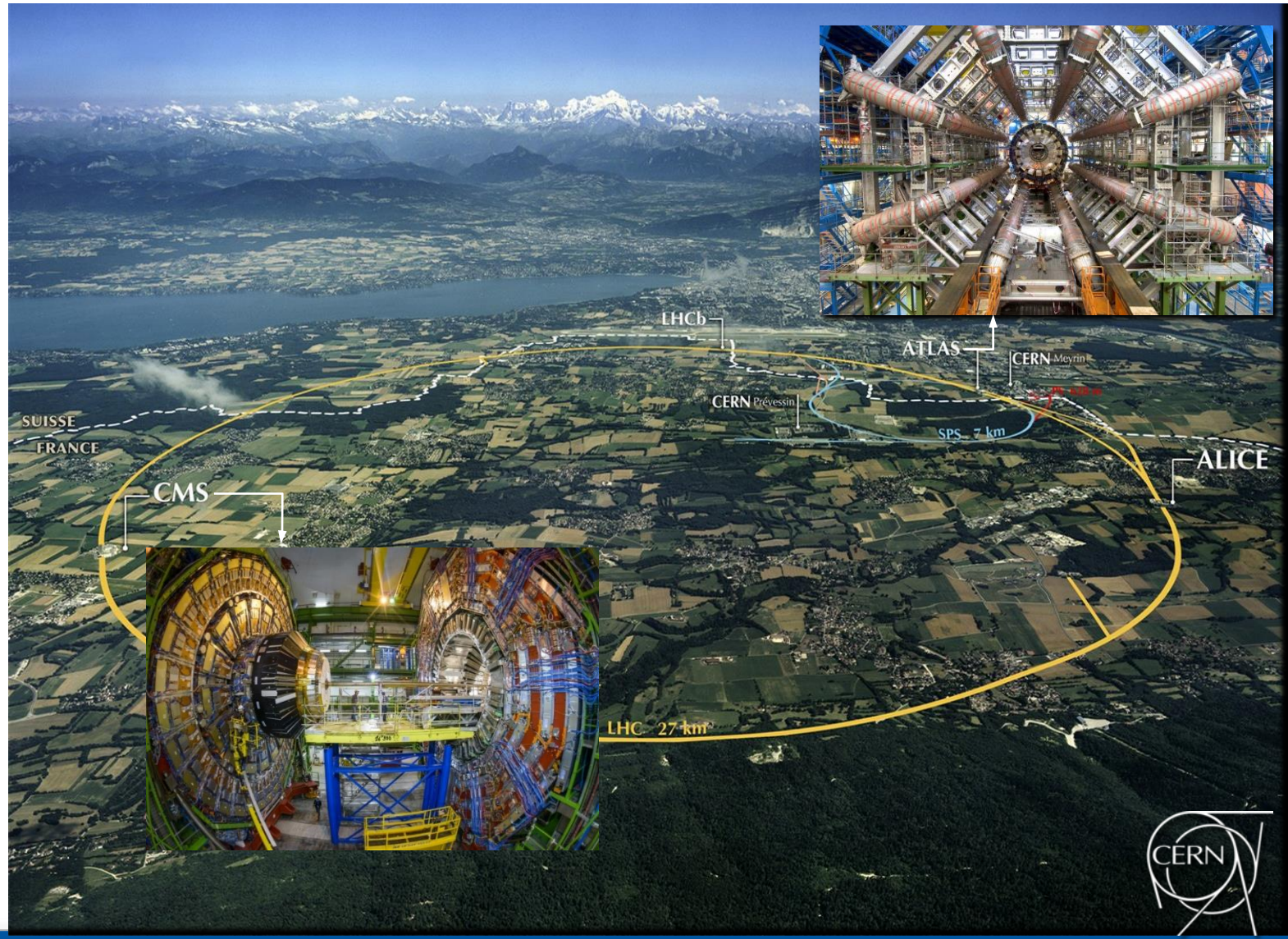
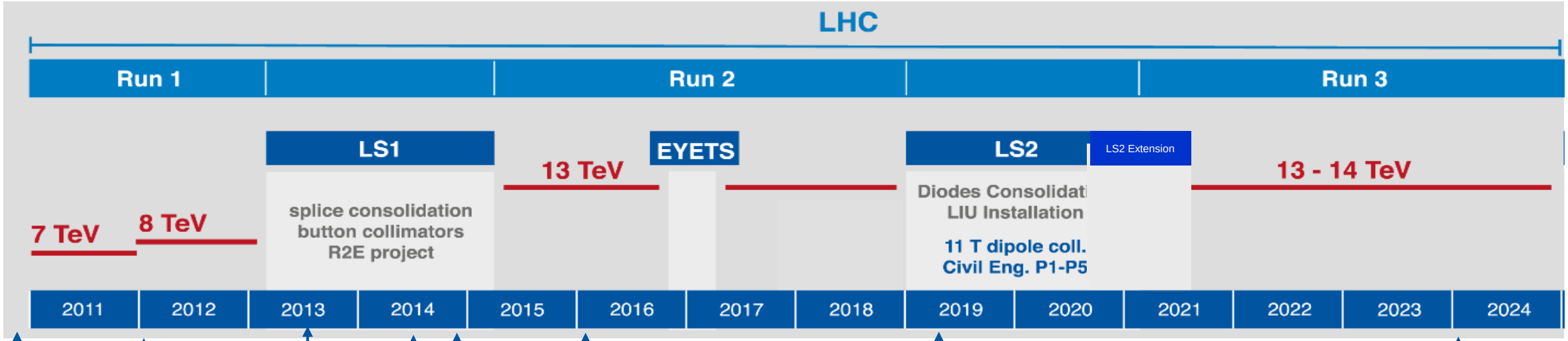
Introduction

- ATLAS and CMS are the two largest detectors operated at the LHC accelerator. Both detectors hold superconducting magnets which are cooled and maintained in nominal operation at 4.5 K by helium cryogenic systems
- Continuous operation is required to exploit the LHC beams for the research in physics
- Reliability analyses and feedback from the run periods led to propose consolidations to cryogenic systems in order to improve their global reliability and availability.



Introduction

Timeline of LHC experiment consolidations



ATLAS SR Dryer1

ATLAS MR CP6

ATLAS MR CP2,
CMS CP1 & CP2

ATLAS CS Dewar

Dryers ATLAS MR & CMS

CMS ORS

ATLAS MR CP1, P2, P6

ATLAS SR Dryer2

Upgrade and installation works for the consolidations can only be performed during long technical shutdowns (LS) or year-end technical stops (YETS)

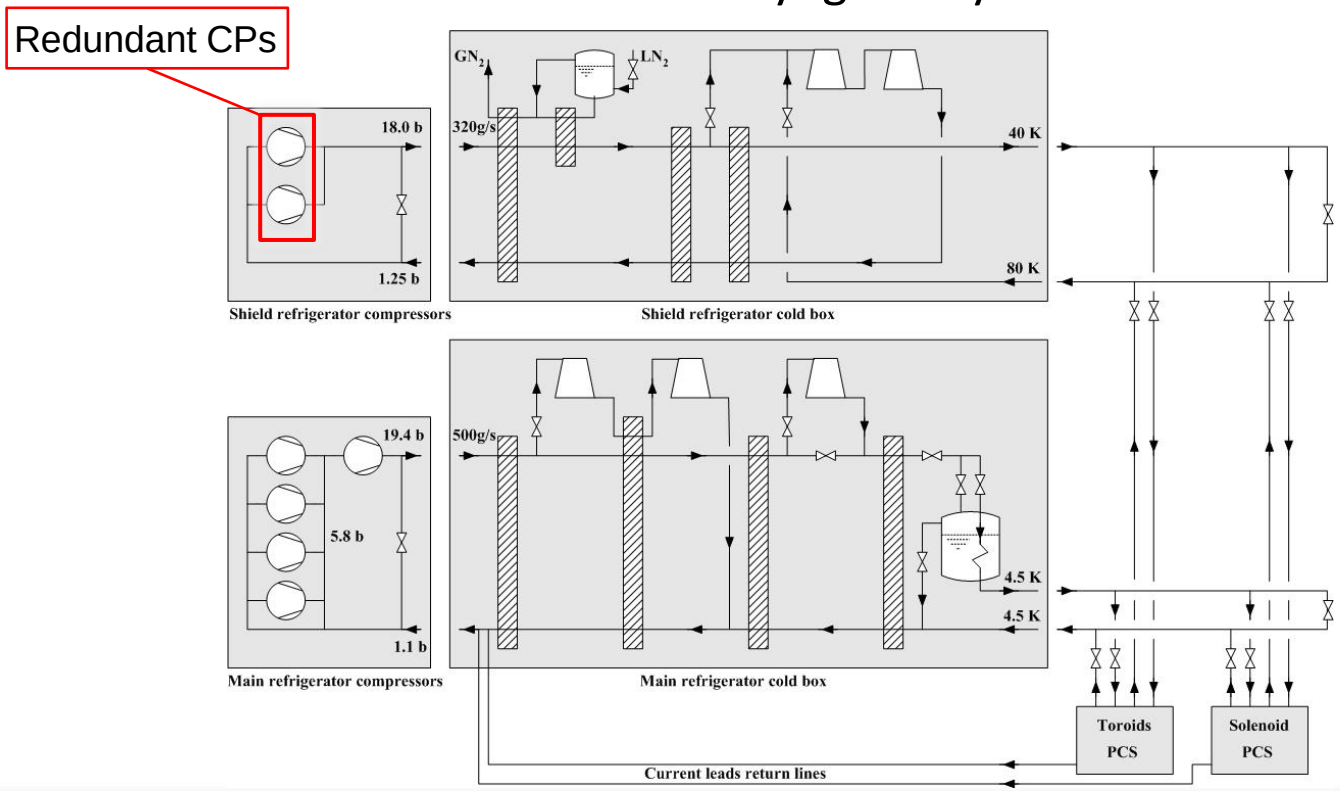
Hot Spare Compressors

Goal : avoid major downtime in case of a compressor failure

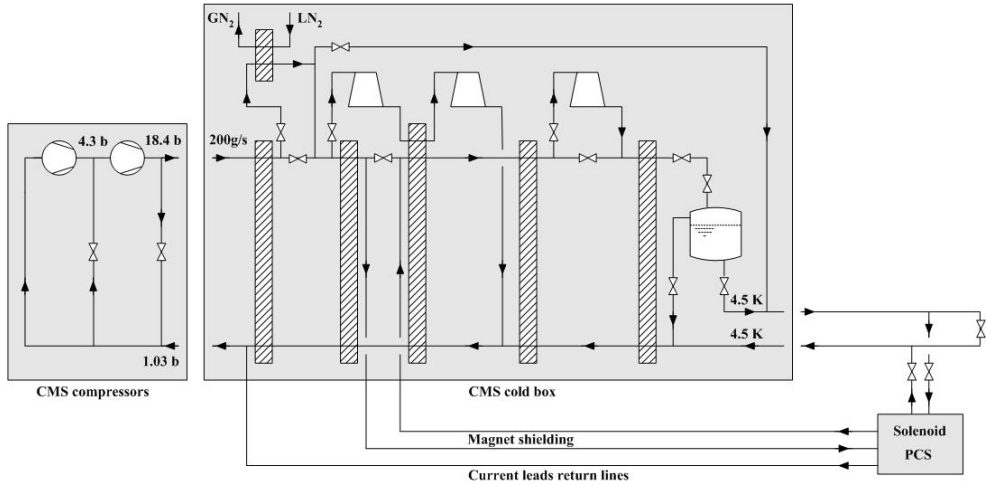
(No spare compressor available at the start of LHC)

ATLAS SR cryo-plant equipped with two redundant compressors

ATLAS external cryogenic system



CMS external cryogenic system

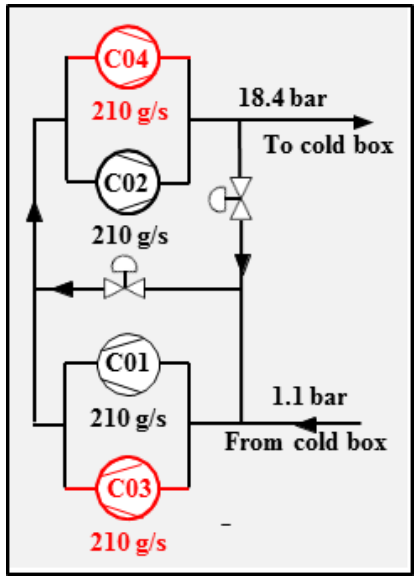


Hot Spare Compressors

➔ **Consolidation strategy : ensure a redundant compressor for each stage**

CMS

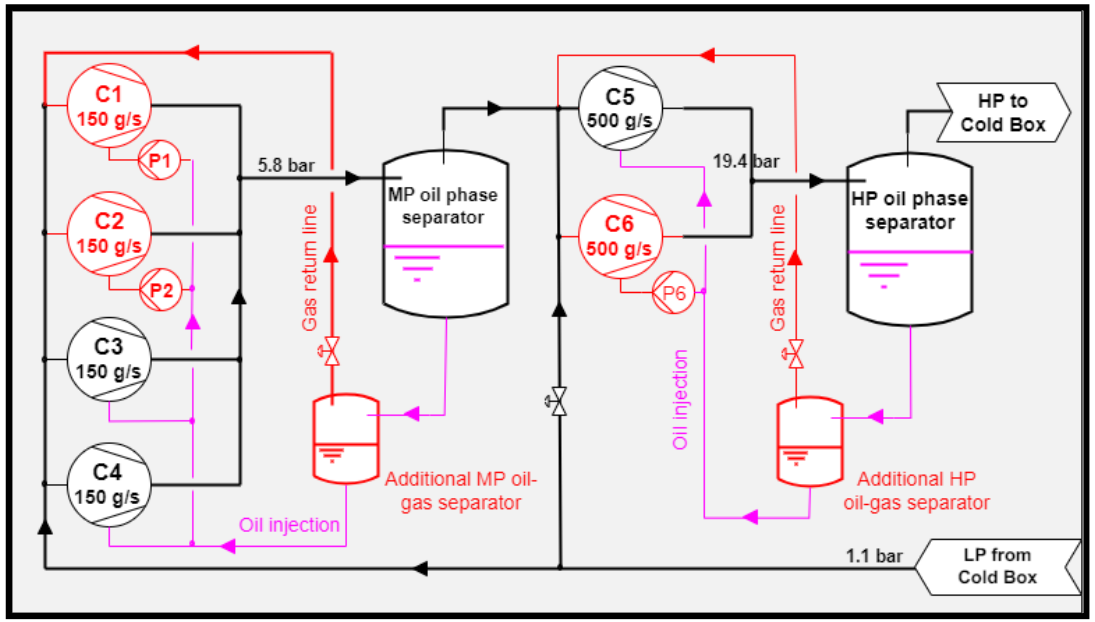
Hot spare compressors installed for each stage during LS1



Hot Spare Compressors

ATLAS MR

- Installation of C6 (hot spare) during YETS 2011-2012
- At LS1 (2013), replacement of C2 (initially 100 g/s) with new C2 (150 g/s) to ensure minimum required process flow (390 g/s) for ATLAS
- C6 and C2 commissioning : major pressure instabilities of the oil injection → installation of additional oil gas separators
- At LS2 (2019) :
  - Exchange of centrifugal pumps P2 and P6 by volumetric pumps to ensure a stable and controlled injection flow and pressure
  - Replacement of C1 (100 g/s) with new C1 identical to new C2 (150 g/s)

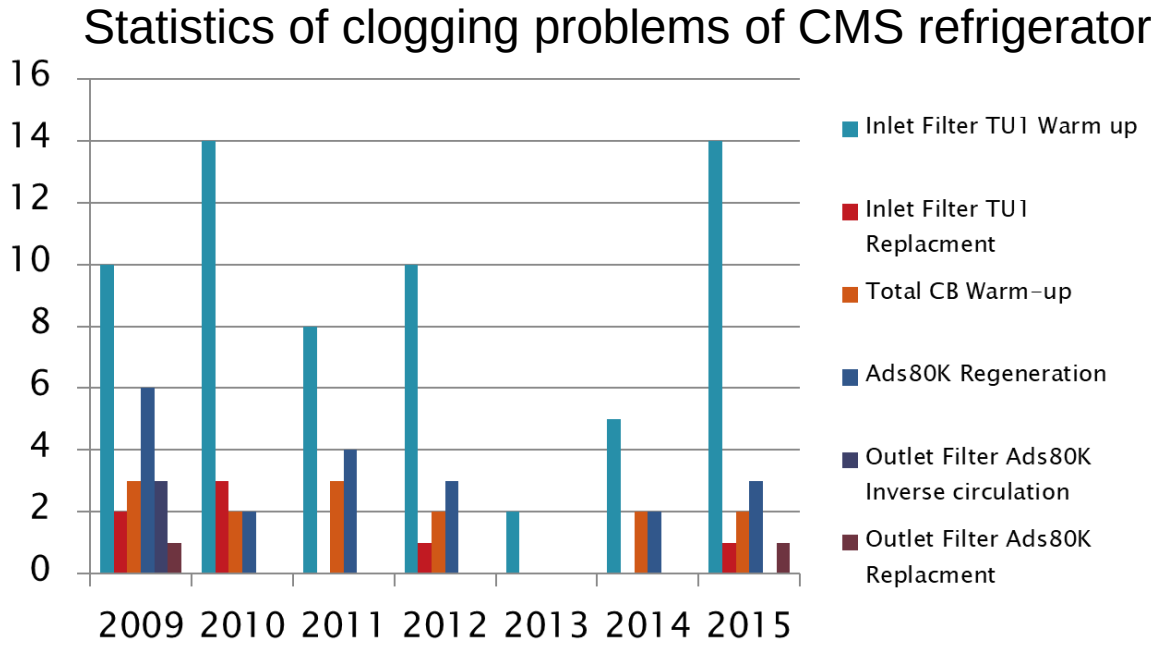


Dryers and Oil Removal System

Goal : avoid clogging of helium refrigerator

Long history of clogging for ATLAS and CMS refrigerators due to water, air or oil pollutions

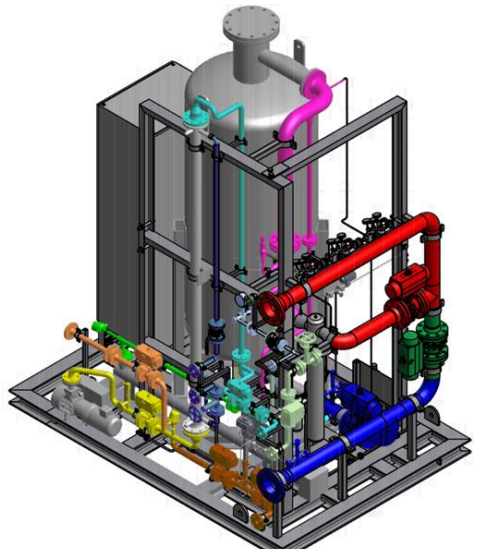
1. At start of LHC (2009) : repetitive clogging of ATLAS SR
   ➔ 2010, installation of a refurbished dryer from a previous installation
2. During run 1 : repetitive clogging of ATLAS MR and CMS refrigerators
   ➔ LS1, installation of single bed dryers (ReiCat™) for CMS and ATLAS MR
3. At start of run 2 : repetitive clogging of the CMS refrigerator due to oil pollution
   ➔ YETS 2015-2016 : upgrade of CMS ORS
4. At start of run 3 : increase in clogging rate of ATLAS SR (water accumulated in CB 1st HX)
   ➔ YETS 2023-2024 : installation of second and bigger dryer



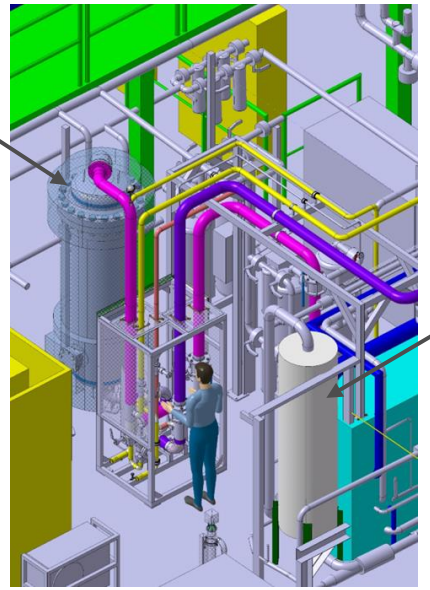
Dryers and Oil Removal System

CMS AND ATLAS dryer characteristics

	CMS	ATLAS - MR	ATLAS - SR (1)	ATLAS - SR (2)
Helium mass flow [g/s]	100-200	200 - 500	160 - 320	160 – 320
Operating pressure [bar]	11 - 19	11 - 19	14 – 16	14 – 19
Bed diameter [m]	0.9	1.2	0.457	0.6
Bed height [m]	1.45	1.847	1.864	1.925
Process flow direction	bottom to top	bottom to top	top to bottom	bottom to top

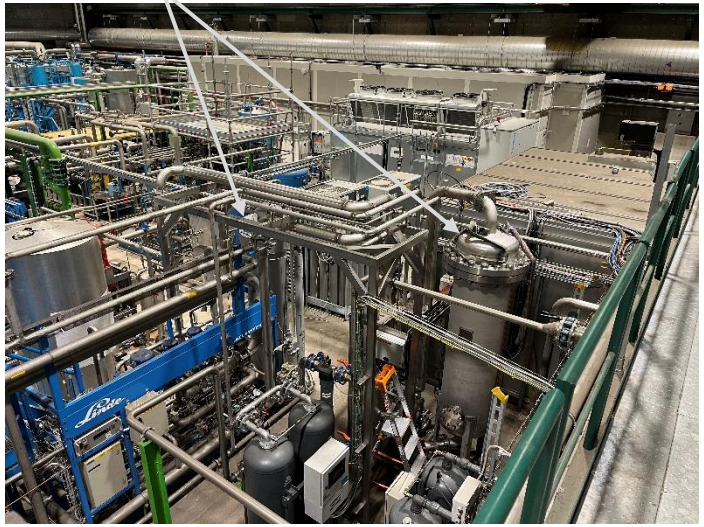


ReiCat™ dryer (CMS & ATLAS-MR)



CMS new ORS

ATLAS-SR dryers

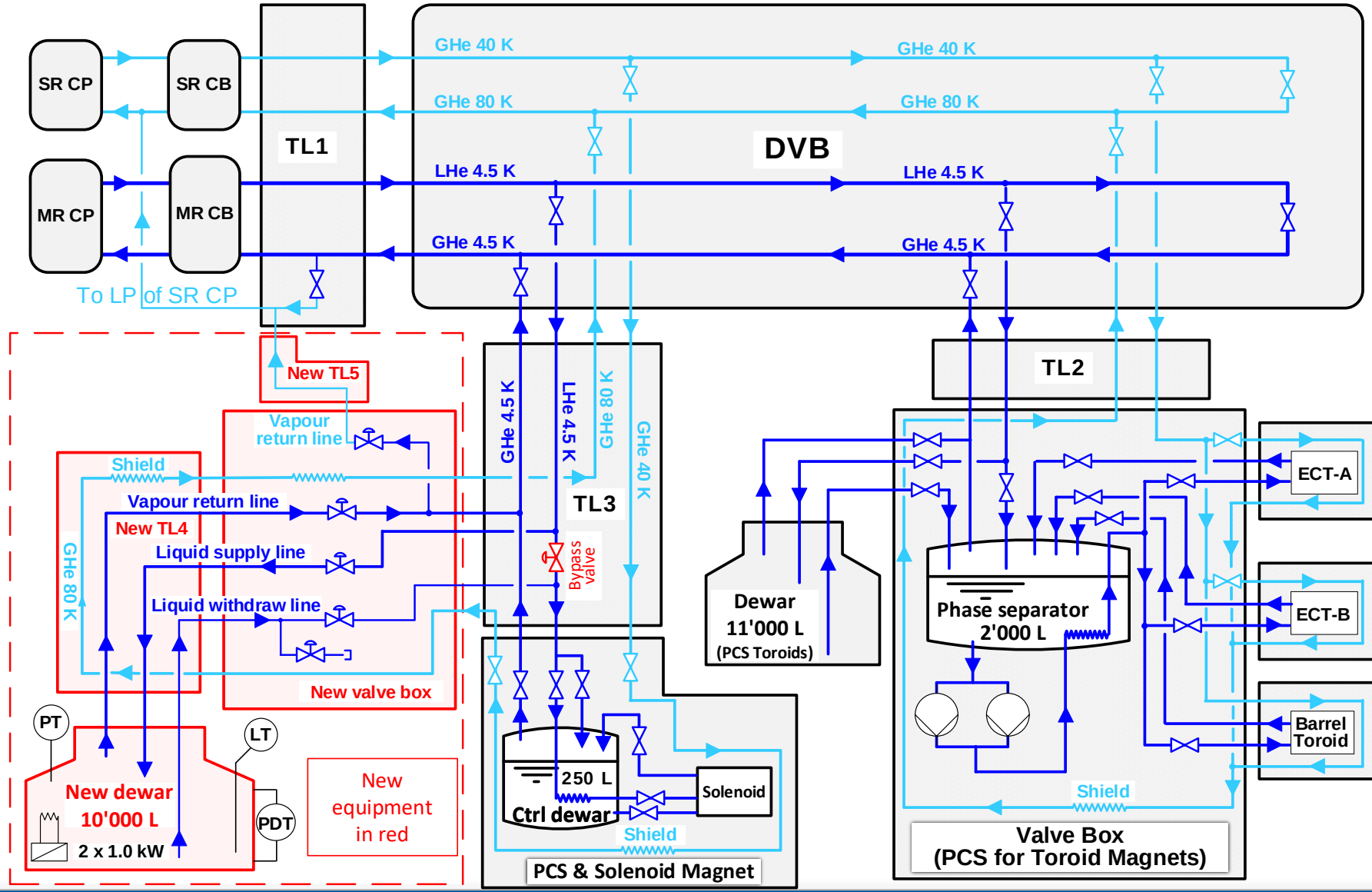


ATLAS - Additional 10'000 liter buffer Dewar

Goal : keep ATLAS solenoid magnet operational and avoid interruption of physics after a fast dump of a toroid magnet

- During run 1, several fast dumps of toroid magnet triggered by MSS
- Original design could not cope with a re-cool down of a toroid magnet -> loss of physics for ATLAS inner detector (solenoid magnet)

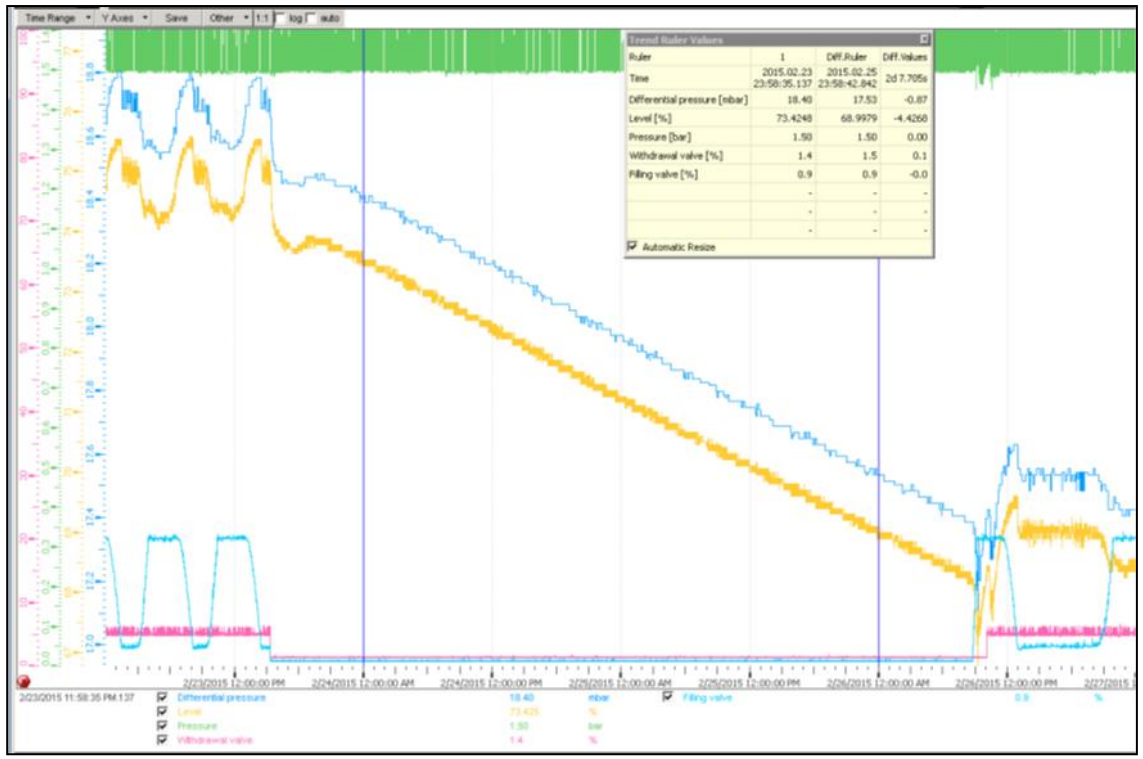
  ➔ add a buffer dewar during LS1



ATLAS - Additional 10’000 liter buffer Dewar

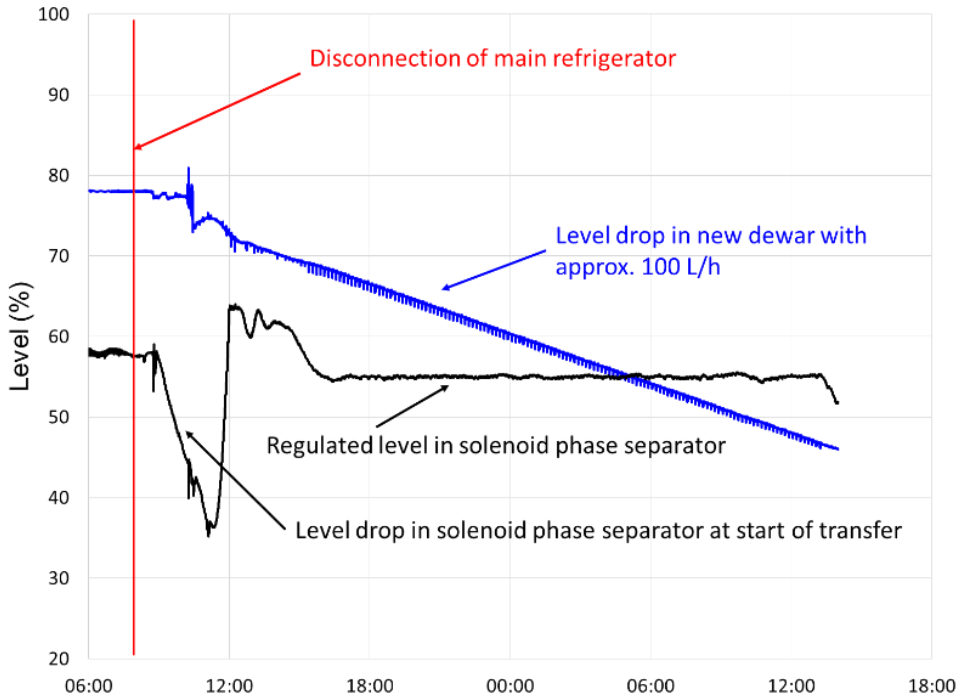
Dewar commissioning

- Measured static evaporation rate : 223 L / day (2.5 % of capacity)
- Can be reduced when putting the foreseen neck cooling in service



Transfer test

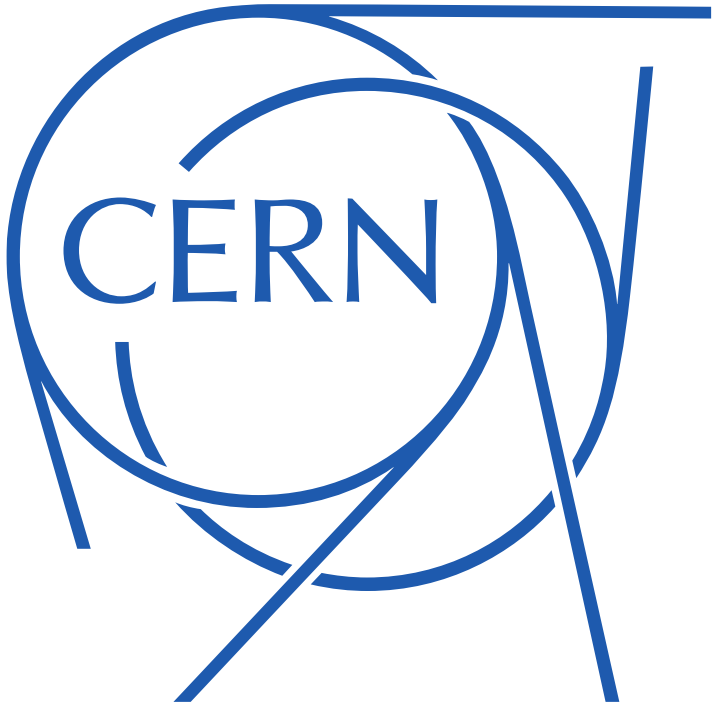
- Solenoid without current, total flow in current leads: 0.4 g/s -> level drop ~100 l /h
- Present autonomy with nominal flow in CLs (1 g/s) is ~80 hours



CONCLUSION

- The installation of hot spare compressors and dryers, as well as the upgrade of CMS ORS have reduced the risk of major downtime for the cryogenic installations cooling the superconducting magnets of the LHC experiments
- In addition the ATLAS detector operation has been maximized in case of problems with the ATLAS toroid system : the decoupling of the central solenoid operation from the toroid magnet system ensures a reliable and continuous operation of the ATLAS inner detector and the physics, even in case of short interruptions of the cryogenic plants.

Thank you for your attention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