
CERN

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Ångström laboratory

SM18 CRYO UPGRADE

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on behalf of TE-CRG

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OUTLOOK

SM18 : CERN main facility for testing SC accelerator magnets and SC RF cavities

SM18 cryo infrastructure is being significantly upgraded (starting in 2019) to meet requirements for :

- **LHC High Luminosity project (HL LHC)**
- **R&D program for SC magnets**
- **RF equipment until 2023 and beyond**

RF cavities & Cryomodules

Horizontal test benches

SOME OF THE SYSTEMS CURRENTLY IN OPERATION IN SM18

- **5 vertical magnet cryostats :**
  HFM, CLUSTER D, SIEGTAL, LONG, DIODES (80K, 4.5 K, 1.9 K)
- **10 Horizontal test benches for magnets** (80K, 4.5 K, 1.9 K)
- **1 test bench for SC Link :**
  (30 - 4.5 K, 2 ~ 15g/s)
- **4 test benches for RF cavities : V3, V4, V5, V6**
  (4.5 K, 1.9 K)
- **2 test benches for Cryomodules : M7, M9**
  (80K, 4.5 K, 1.9 K)
- **1 independent test Bench :**
  Eu HIT GReC (10 - 4.5K)


Vertical magnet tests


Hor. Magn, feed box


Horizontal magnets test benches


SC links tests


RF cavities & CM tests


Vertical magnet tests

In Operation

SOME DEVICE OF THE CRYOGENIC INFRASTRUCTURE CURRENTLY IN OPERATION

6kW Linde Cold Box

27g/s (~700L/h) @4.5K

Purification units

3 x 130 Nm3/h Burckardt recovery compressors + 2 Purifiers 200 Nm^3/h at 180 bars

In Operation

Very Low Pressure compressors (WPU)

Values per WPU unit :
6 g/s @ 10 mbar
12 g/s @ 20 mbar
18 g/s @ 30 mbar (max)

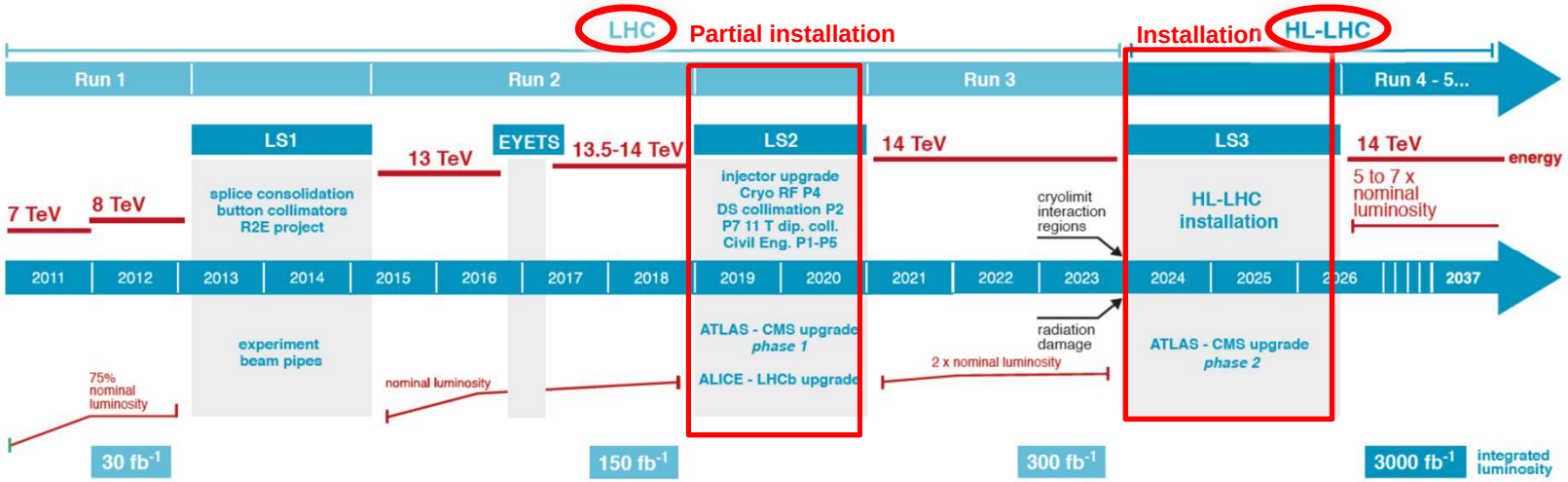
Cool down - warm up unit (CWU)

2 x CWU 80g/s – 2 x 120kW @80K

With 3 Kaesers compressors

New SC devices for the HL-LHC project require the SM18 cryostructure upgrade

- 11T dipoles
- Standalone magnets
- SC link
(Cables & current leads)
- Crab RF cavities
- Inner Triplet magnets



Project

Low-β magnets - Nb3Sn technology - peak field of 11.4 T
With : 2 outer quadrupoles, Q1 & Q3 +
a central one divided into 2 identical magnets, Q2a and Q2b

HL LHC String will be a new test stand to validate the collective behaviour of a structure including IT magnets

''HL-LHC IT STRING TEST'', M. Bajko,
LHC Performance Workshop 2018 Chamonix

Project

I INTRODUCTION & CONTEXT

II SM18 SIMPLIFIED CRYO DEVICES : BEFORE & AFTER UPGRADE

III KEY FIGURES

IV UPGRADE HANDOVER & RESTART PROTOCOL

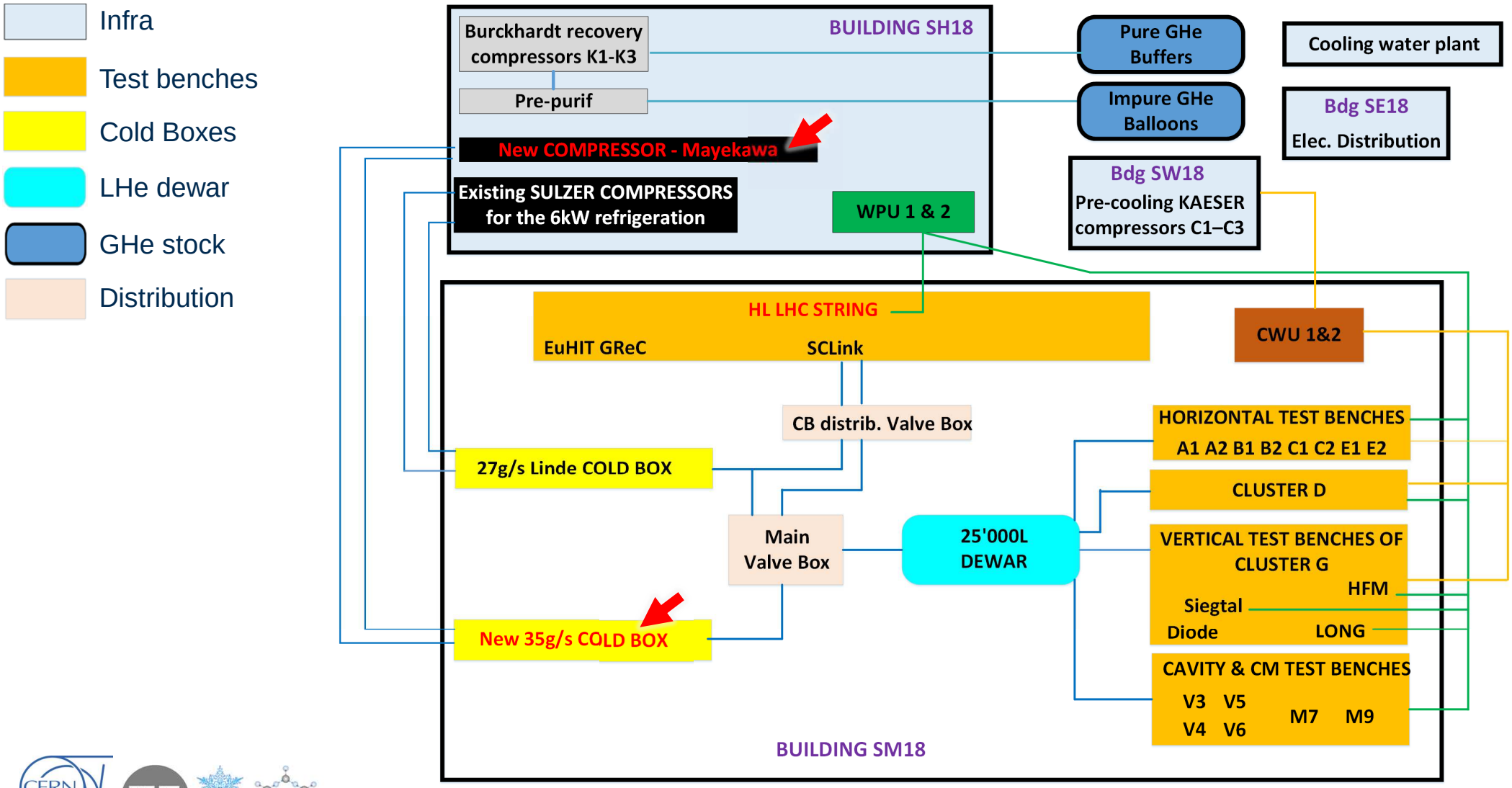
V OVERVIEW

REQUIREMENTS FOR THE UPGRADE OF THE CRYOGENICS INFRASTRUCTURE

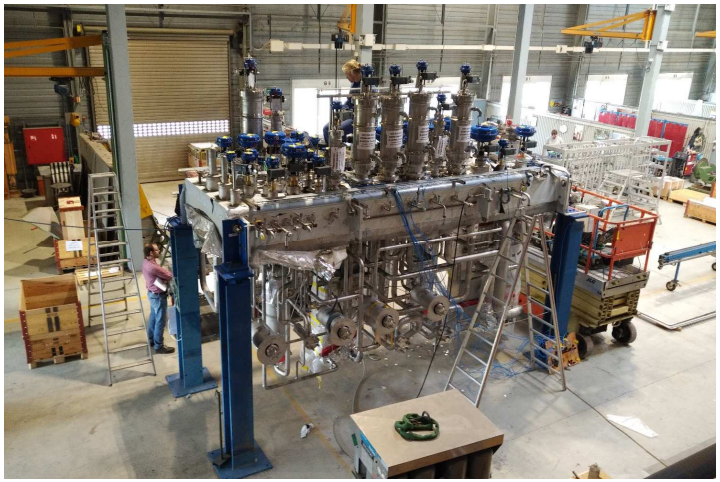
BASED ON TEST PROGRAM - ASSUMPTIONS FOR COVERING THE MAIN TEST BENCHES

- Magnet test benches: 2 vertical & 2 horiz. magnets at cold / month with 2 magnets powered simultaneously
- Superconducting cavities: 1 cavity /2 weeks & 1 cryomodule test every 6 months
- Parallel test of a superconducting link (SC Link) and/or the IT string (String)
- Possibility of additional individual systems tests on dedicated facilities

SCHEMATIC LAYOUT OF THE SM18 CRYO INFRASTRUCTURE AFTER UPGRADE



SM18 NEW COLD BOX



Mechanical Integration, Electrical and Control System review held at Linde Kryotechnik AG (LKT) in 2018 and beginning of 2019

Transport and arrival at the SM18
2019 MAY, 14

Cold Box installed in the SM18
2019 MAY, 15

SH18 NEW MAYEKAWA COMPRESSOR

PROCESS UPGRADE FOR Nb3Sn MAGNETS

Nb3Sn SC magnet tests at the SM18 need a control of the ΔT during cool down and warm up, in the 80 – 300K range

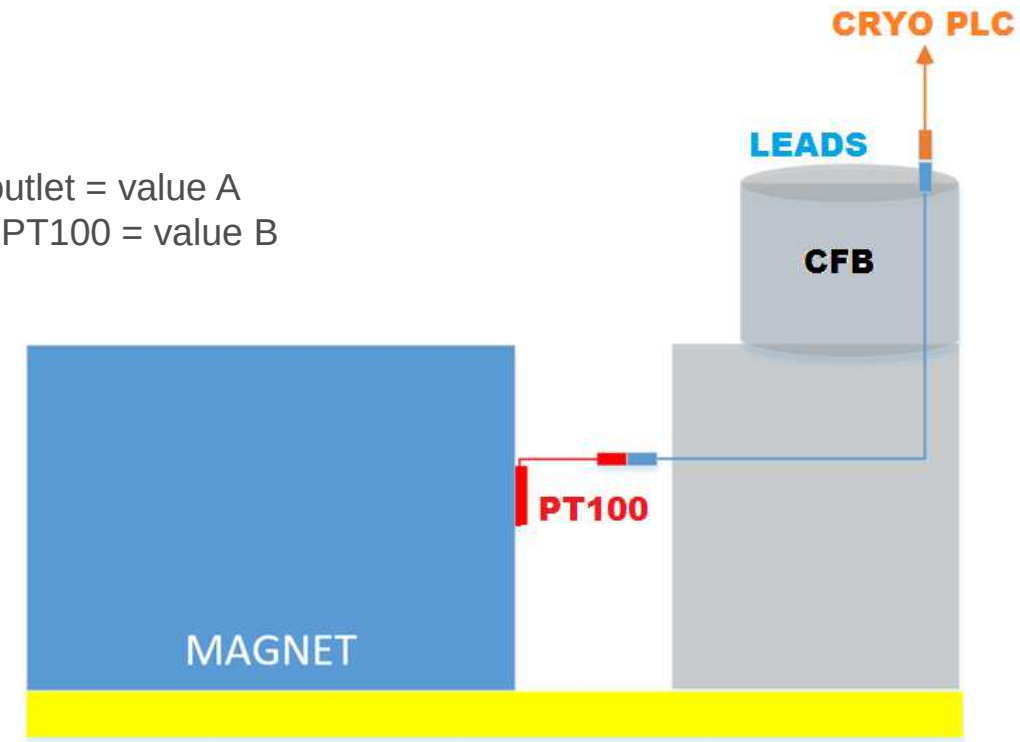
⇒ Automated ΔT control during cool down / warm up of Nb3Sn magnets has been implemented and need to be evaluated in real conditions

- Installation of a new PT100 close to the magnet cold mass

- Measurement of the ΔT between CFB Temp_inlet – CFB Temp_outlet = value A
- Measurement of the ΔT between CFB Temp_inlet – Magnet new PT100 = value B

- Continuous regulation of the ΔT based on the max value : A or B

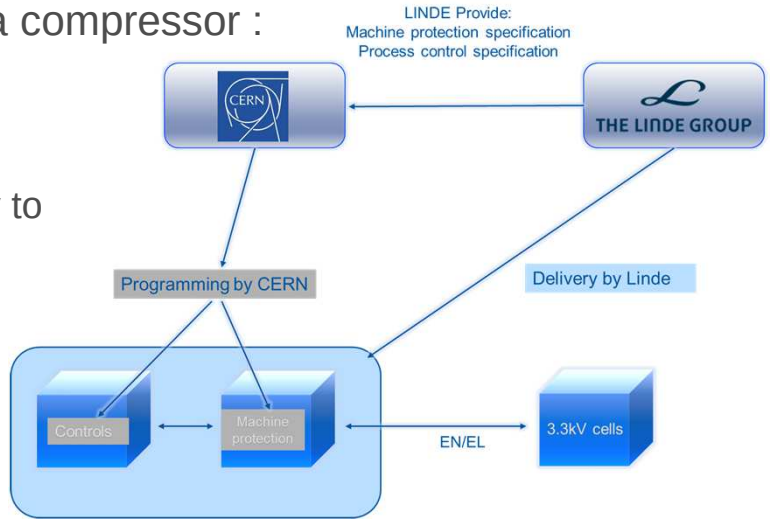
- Redundancy for the PT100 is necessary
- Particular case for the reconnexion after a trip



CONTROL & ELECTRIC UPGRADE

For the 35g/s Cold Box & Mayekawa compressor :

- Electrical cabinet installation for the 35g/s CB & Mayekawa CP
- CP logic document sent to LKT, ready to be commissioned
- CB logic sent to LKT



Control & Elec upgrade for the SH18 :

Buffers and Burkhardt controlled by an independent system to allow independent maintenance and debugging

Done

2019 : New rack with independent M580 PLC + RIO (Remote I/O)

Done

2020 : M580 PLC moved to Infra Cabinet and RIO linked with fiber optic

2020

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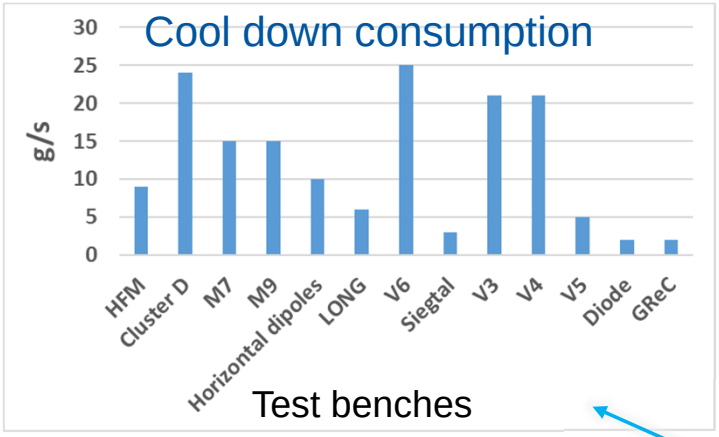
SM18 CRYOPLANT GENERAL KEY FIGURES : AFTER UPGRADE

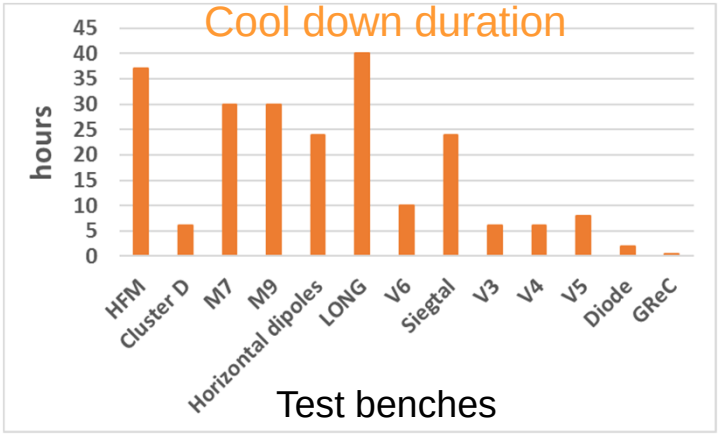
Sytem	Characteristics
EXISTING 6kW CB – ''LINDE A''	27g/s *(~700L/h) @4.5K*
NEW Linde CB – ''LINDE B''	**35g/s *(~1000L/h)* @4.5K**
Process compression station	3 Stal He compressors (350 g/s @19 bar), 1.6 MW elec. power + ORS **+ new MAYEKAWA compressor (main drive motor of 1.4 MW)**
Very Low Pressure Pumping (WPU)	2 warm pumping units, each one : 6 g/s @ 10 mbar 12 g/s @ 20 mbar 18 g/s @ 30 mbar (max) To each WPU is dedicated a very low pressure heater of 32 kW (20g/s)
Pre-cooling to 80K	2 x CWU (80g/s - 2 x 120kW @80K) - With 3 Kaesers compressors
GHe Purification	5 x 80 m^3 Balloons at 1 bar (3 Burckardt recovery compressors + 2 Purifiers 200 Nm^3/h at 180 bars)
Pure GHe storage	8 x 75m3 @18 bars
LHe storage	1 x 25 m^3 LHe storage at 1.6 bar (+ 1x 10 m^3 mobile)
LN2 storage	50'000L Dewar

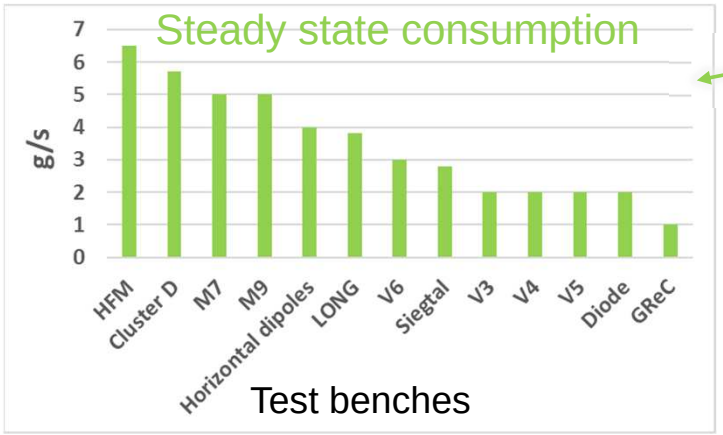
LHe CONSUMPTION FOR COOL DOWN TO 4.2K - COOL DOWN DURATION – STEADY STATE



- The 27g/s cold box will be dedicated to the **HL LHC String** and could complement the Dewar for the other test benches

- The new 35g/s cold box will directly and significantly increase the LHe capacity for :

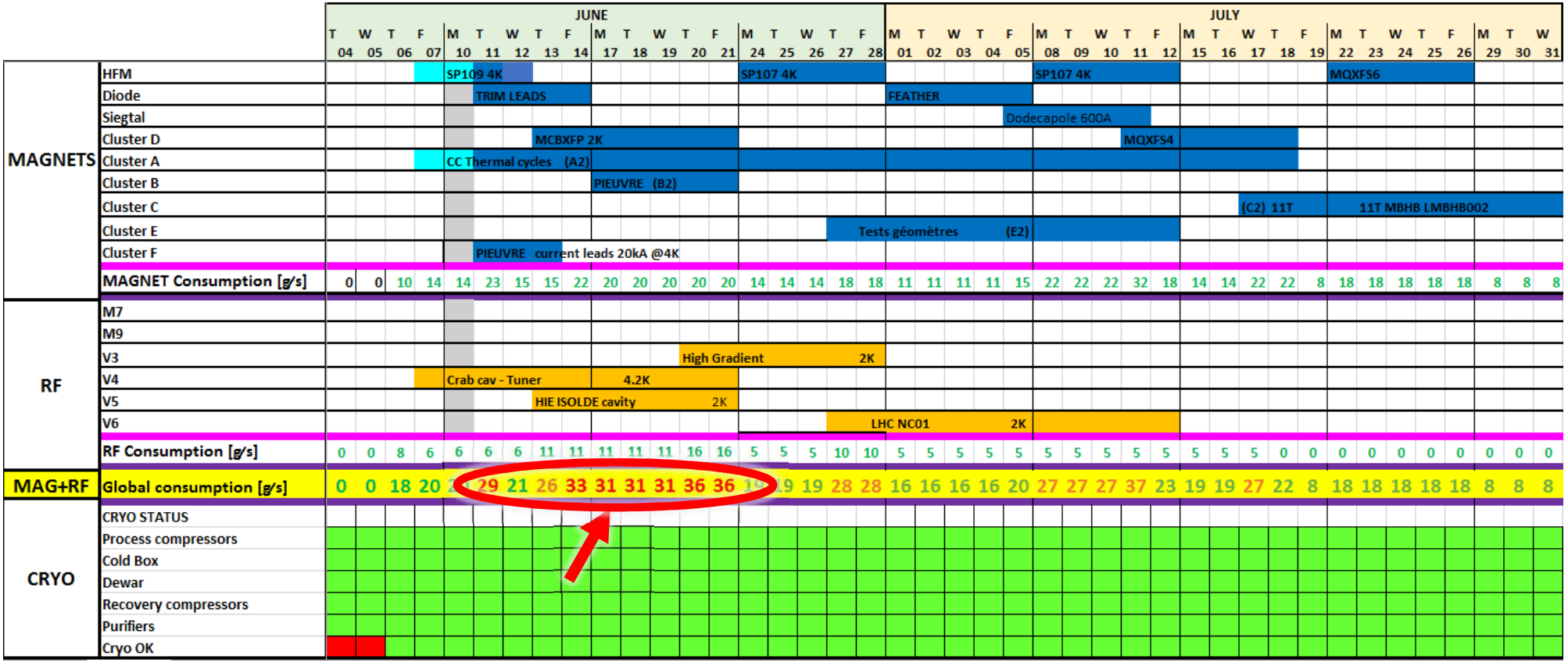




- The cool down
- The steady state
- The Quench recovery

EQUIPMENT	LHe FLOW FOR QUENCH RECOVERY [g/s]	QUENCH RECOVERY TIME [h]
HFM	12	4
Cluster D	12	4
Horizontal dipoles	14	2.25
LONG	6.8	2

SM18 TYPICAL CURRENT PLANNING : LHe DISTRIBUTION FOR THE TESTS



- A priority management is currently essential for the cool down organisation (capacity limited to 27 g/s)
- **The 35g/s cold box will be mandatory to operate HL LHC String in parallel of the current tests and reduce Quench recovery time**

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RESTART PROTOCOL : CHECKLISTS

CHECKLIST N°1 : COOLING, WARMING UP, POWERING CHECKLIST -TO BE COMPLETED BEFORE LAUNCHING THE OPERATING PHASE-			
EQUIPMENT NAME (of the Magnet, Cavity, Module)			
TEST BENCH NAME			
DESCRIPTION	Type of Magnet / Cavity : Main dimensions (m): Weight (kg) : Filling pieces -if applicable- (Y/N) : Estimated volume of LHe needed during nominal Operation (m3) :		Inductance -if magnet- : Number of current Leads -if applicable-: Position of the heaters -if applicable-:

TOPIC	SUB-TOPIC	WHO	YES	NO	VALUES	Date	Remarks	Names
SAFETY ASPECTS	Nominal pressures clearly defined (Pnom)	USERS						
	Maximal pressures clearly defined (Pmax)	USERS						
	Standard insert -if applicable-	USERS						
	Safety valves & rupture disks validated	USERS & CRG-ME & CONTRACTOR						
	Risk assessment performed	USERS & CRG-ME & CONTRACTOR						
EQUIPMENT PROTECTION	Interlock chain verified : Interlocks and alarms defined and implemented (cryo OK operational)	USERS & CRG						
	Delta_T instruction for cool down/warm up clearly defined -if applicable-	USERS						
	Max/min Helium flow instruction for cool down/warm up clearly defined -if applicable-	USERS						
	Requested flow for temperatures for the current leads -if applicable-	USERS						
FILLING PIECES	Filling pieces available and installed to reduce LHe consumption	USERS						
EQUIPMENT HARDWARE	Hardware ready for Cryo Operation : mechanical & instrumentation	USERS & CRG						
PROCESS & PROCEDURES & ASSOCIATED DOCUMENTS	Automated process needed and operationnal to operate without a permanent control of Cryo Operators	USERS & CRG						
	Operation procedure for cool down, warm up etc	USERS & CRG						
	P&ID of the Cryo Equipment	USERS & CRG						
	Electrical schemes for cryogenics USERS & CRG	USERS & CRG						
	Existing prior Cryo report	CRG						
	Existing prior USERS report	USERS						
ORGANISATIONNAL ASPECTS	Contacts clearly defined for the CRYO follow up	CRG						
	Contacts clearly defined for follow up by the USERS	USERS						
	Test sequence : Target of the tests - including evaluation of tests duration	USERS						
	Need to work outside standard operating hours *(notice period to be defined with the Contractor)*	USERS & CRG						
OK FOR A REQUEST FROM USERS TO CRYO								

SAFETY

ORGANIZATION

OPIMIZATION & TOOLS

COMMUNICATION

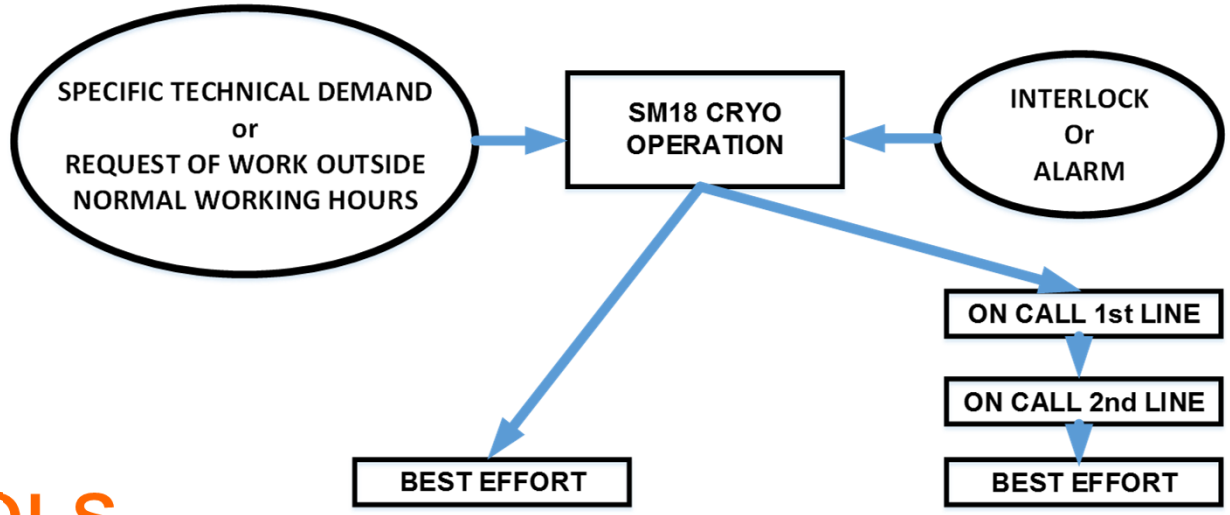
Could be implemented with CARPENTER SM18 Carpenter

OPERATIONAL PROTOCOLS

SAFETY

- Human safety ⇒ respect of rules and best practices for Operation
- Equipment safety ⇒ preventive maintenance, follow up with INFOR

ORGANIZATION



OPIMIZATION & TOOLS

- Excel forecast tool to anticipate and simulate LHe consumptions

COMMUNICATION

- ‘’Weekly’’ general Coordination meetings for the tests (priority definitions)
- Weekly Technical meetings
- Reports on activities

SUMMARY

The upgrade of the cryogenic system at the SM18 gives the possibility to :

- Increase the global LHe capacity for the Magnets and RF cavity tests
- Ease Quenches recovery for Magnet tests
- Allow the operation of the SM18 test benches while also running the test program of the HL-LHC String
- Allow one CB/Compressor system to be under maintenance while the LHe supply to dewar can continue

⇒ Operation flexibility & Redudancy in case of major issue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