Maintenance et methodes pour les installations cryogeniques au CERN

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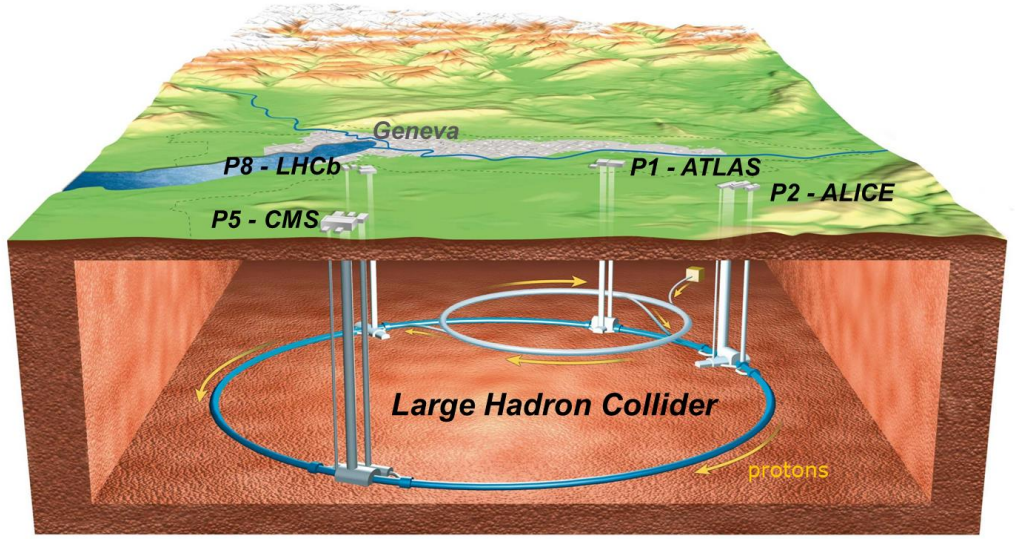
On behalf of CERN Cryogenics Group

LHC machine cryogenics

LHC cryogenics
8 x 18 kW @ 4.5 K
8 x 2.4 kW @ 1.8 K
helium inventory of 130 tons



LHC accelerator
circumference of ~ 27 km
constructed at ~100 m underground

SURFACE

Compressor Stations

4.5K Cold Boxes

Liquid & Gas storages

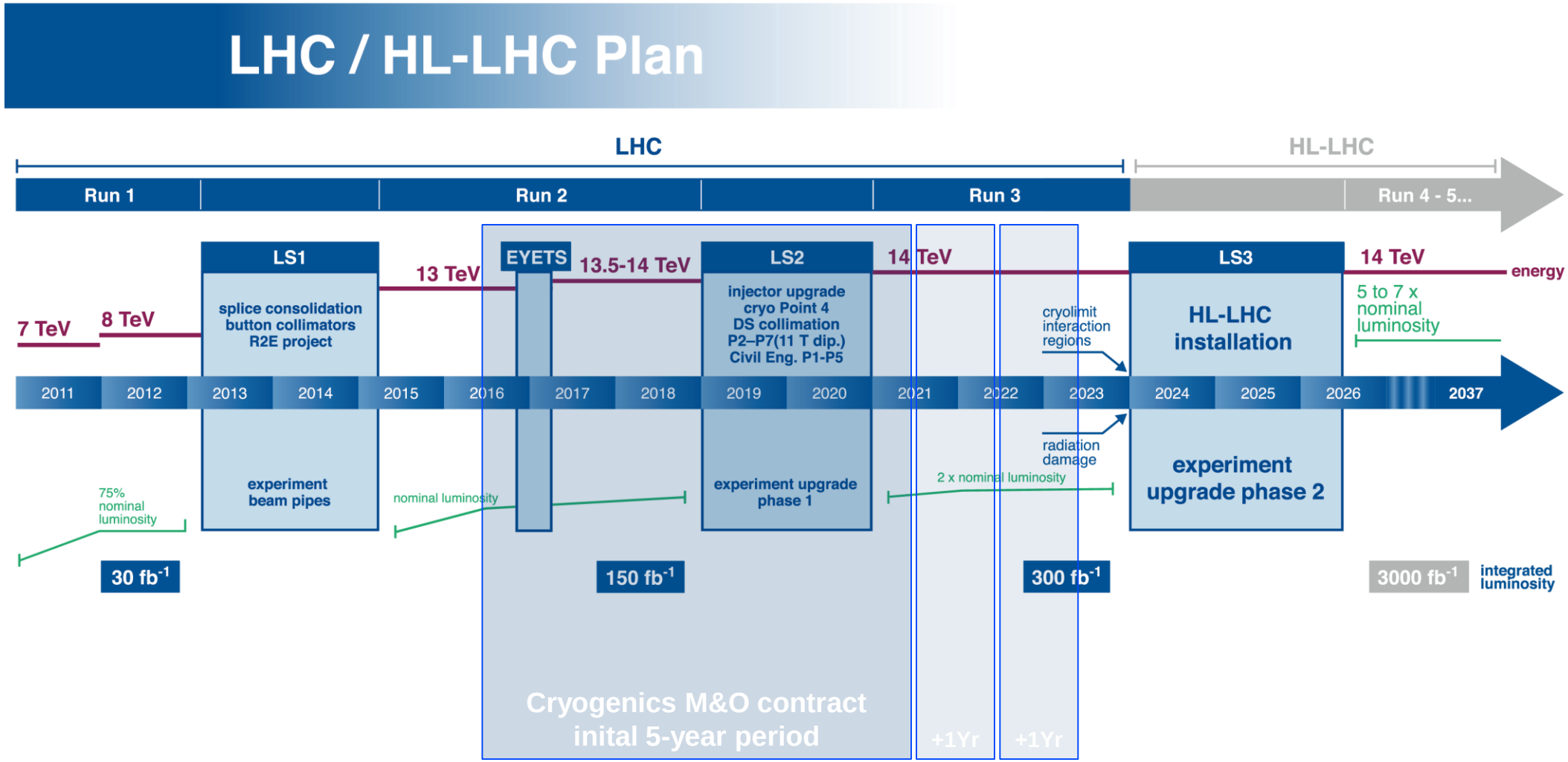
UNDERGOUND

4.5K & 1.8K Cold Boxes

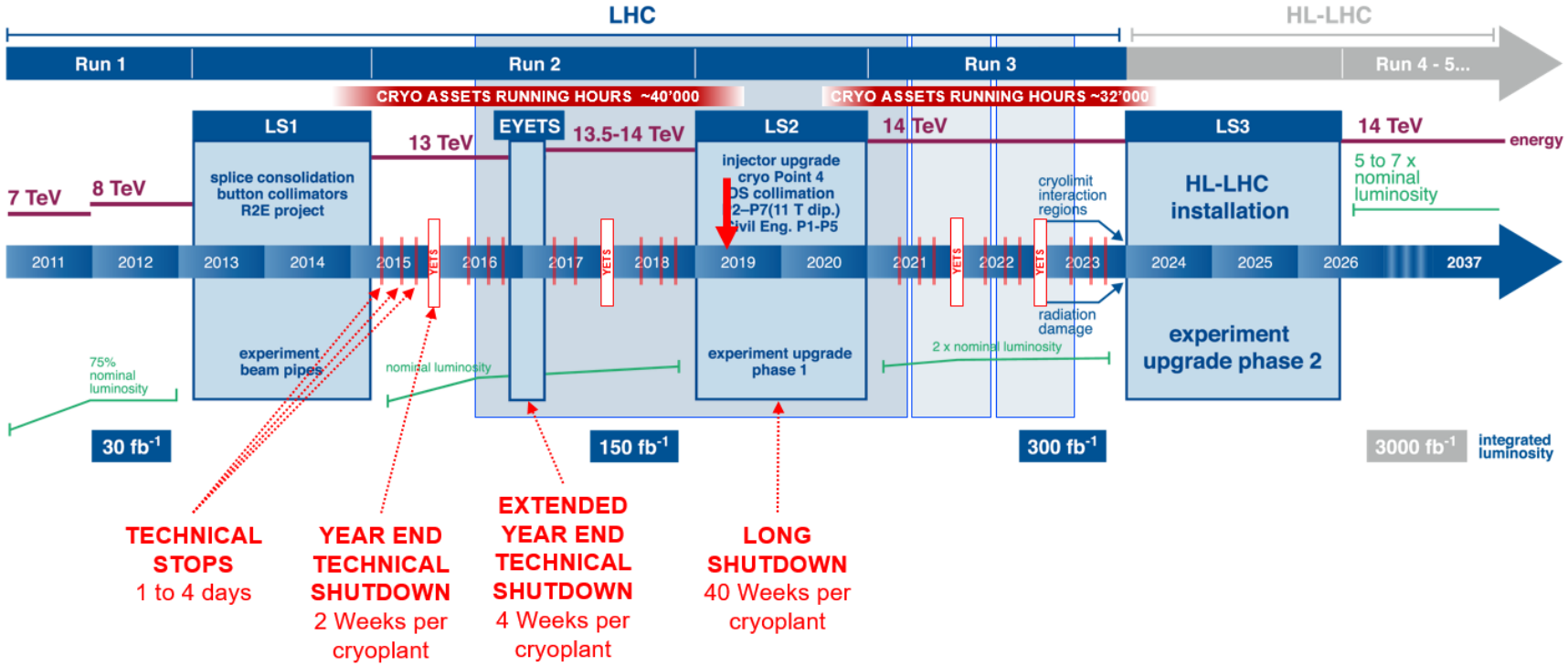
Distribution Valve Boxes

Distribution System

LHC Machine Cryogenics Maintenance Windows



Maintenance results



Maintenance shutdown management

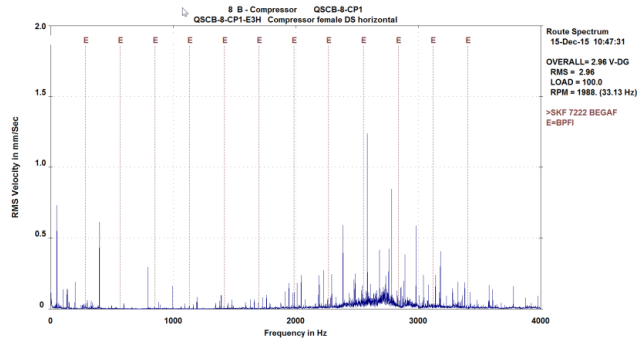
- Preparation and scheduling before intervention
- Cryoplant transfer from operation to maintenance with work authorization
- Local coordination of maintenance work to handle co-activities
- Cryoplant return from maintenance to operation team
- Reviewing and closing of work orders and reports

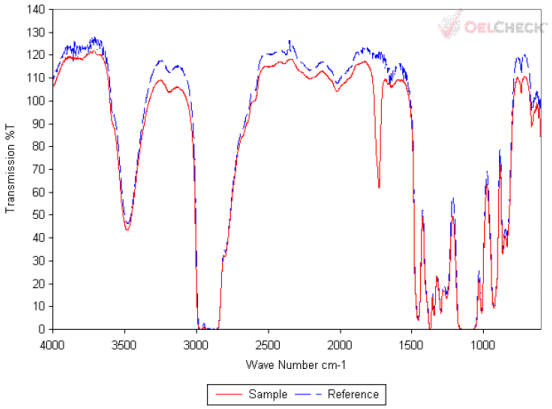
Maintenance results

Delegation of Condition Based Maintenance

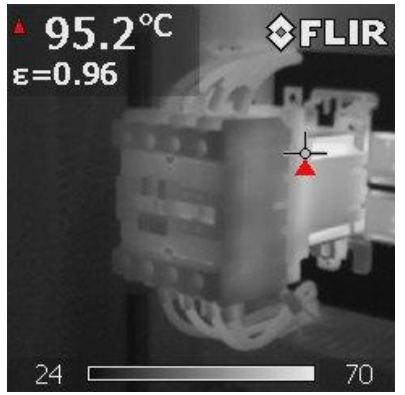
- Contractor is in charge of measurements or samples taking on the field, together with a first level of expertise for task oriented facilities
- Expertise remains within the cryogenics group for LHC and detectors
- For result oriented cryoplants contract the contractor shall apply the recommended CERN cryogenics maintenance policy and is liable to undertake necessary action to ensure availability of the cryoplant

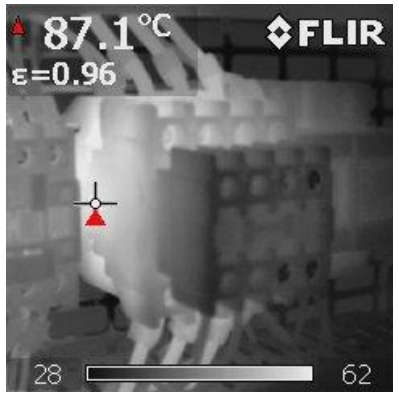
	July 2016 to June 2017	July 2017 to June 2018	July 2018 to June 2019	Unit
Vibration measurement	1215	1270	946	Measurement point x,y,z
Oil analysis	81	44	62	Samples
IR Thermography	85	96	94	Electrical cabinets



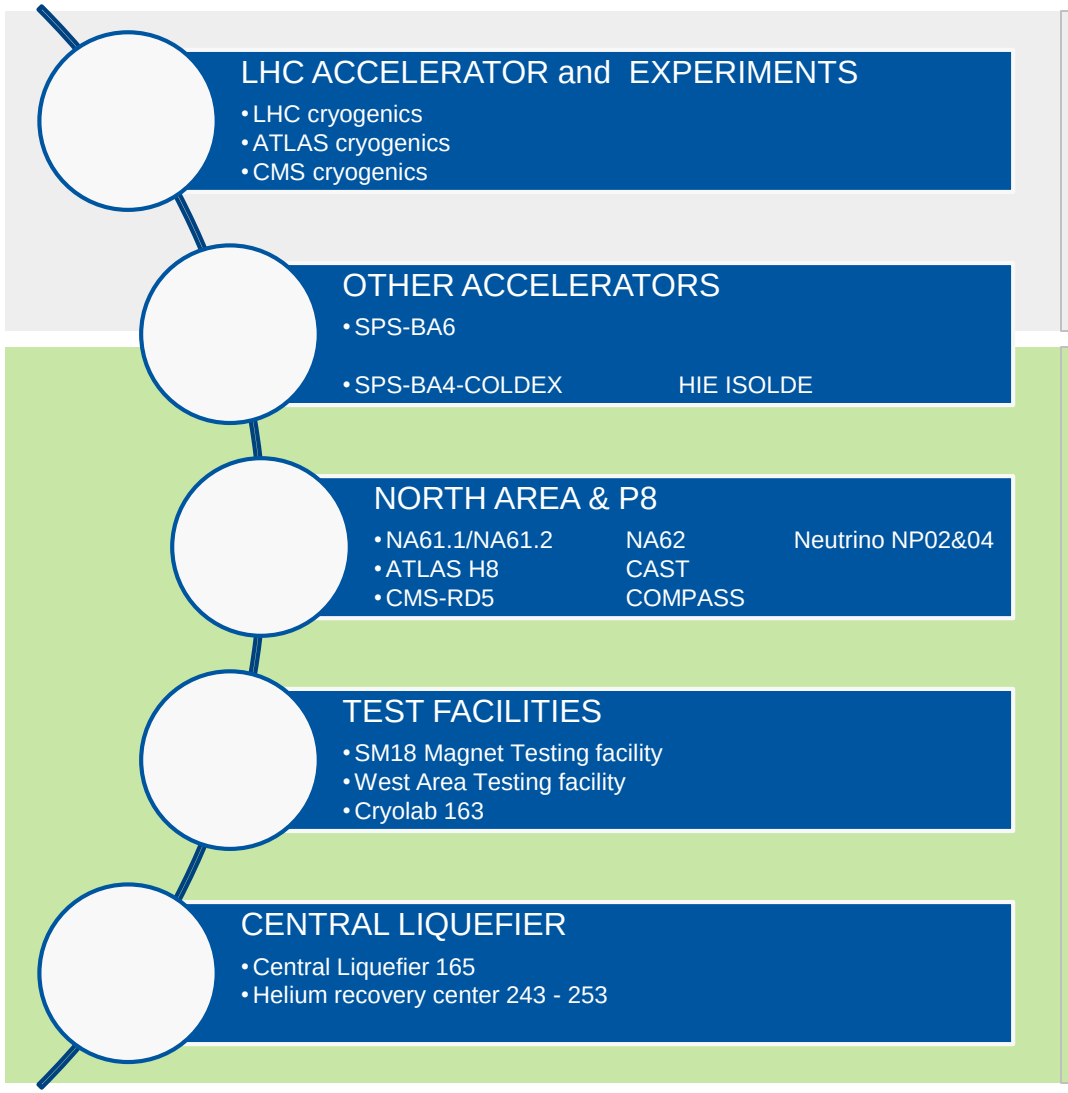


WEAR			
Iron	Fe	mg/kg	3
Chrome	Cr	mg/kg	0
Tin	Sn	mg/kg	4
Aluminum	Al	mg/kg	1
Nickel	Ni	mg/kg	0
Copper	Cu	mg/kg	1
Lead	Pb	mg/kg	2
Molybdenum	Mo	mg/kg	0
Manganese	Mn	mg/kg	0
PQ index	-		< 25
CONTAMINATION			
Silicon	Si	mg/kg	3
Potassium	K	mg/kg	0
Sodium	Na	mg/kg	12
Silver	Ag	mg/kg	1
Tungsten	W	mg/kg	2
Cadmium	Cd	mg/kg	1
Water K. F.	ppm		1040
OIL CONDITION			
Viscosity at 40°C	mm²/s		32.49
Viscosity at 100°C	mm²/s		6.75
Viscosity index	-		172
Oxidation	A/cm		-
IR index	-		99.82
Color	Color index		-
ADDITIVES			
Calcium	Ca	mg/kg	0
Magnesium	Mg	mg/kg	0
Boron	B	mg/kg	0
Zinc	Zn	mg/kg	0
Phosphorus	P	mg/kg	0
Barium	Ba	mg/kg	0
Sulphur	S	mg/kg	< 10





Cryogenic test and experimental facilities



TASK

ORIENTED OPERATION

Operation support under CERN's supervision

RESULT

ORIENTED OPERATION

Full delegation of responsibility to the contractor

MAINTENANCE

METHODOLOGY

Operational achievements

Task Oriented Operation for LHC

- A third of LHC and detectors operation resources working daytime
- Two operation stand by duty services with 50 to 80 interventions per year
- Availability of the LHC cryogenics from April 2015 to December 2018 amount to 97.2% (excl. planned shutdowns)

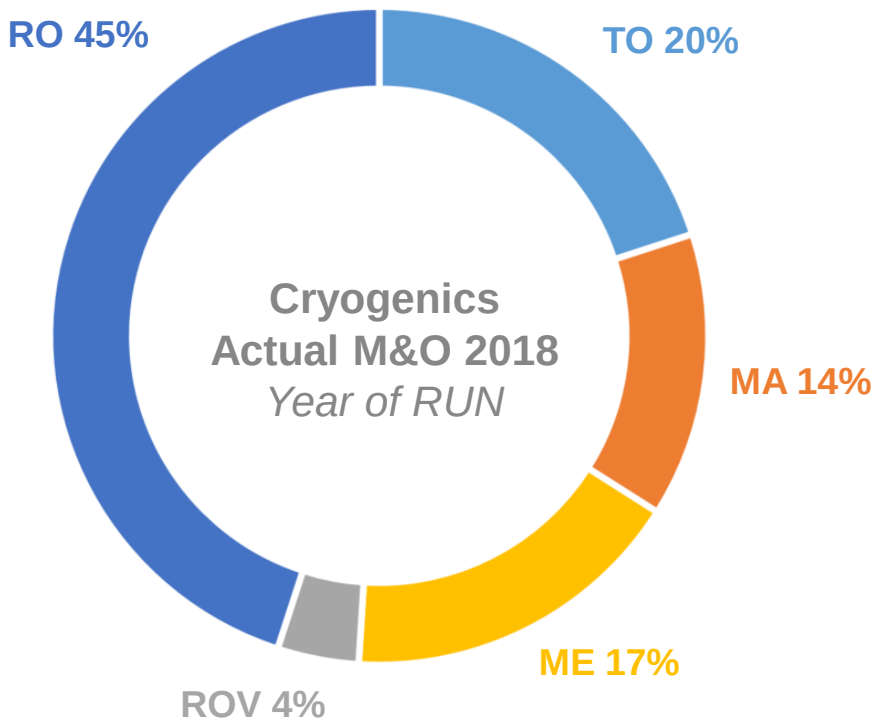
Result Oriented Operation for non-LHC

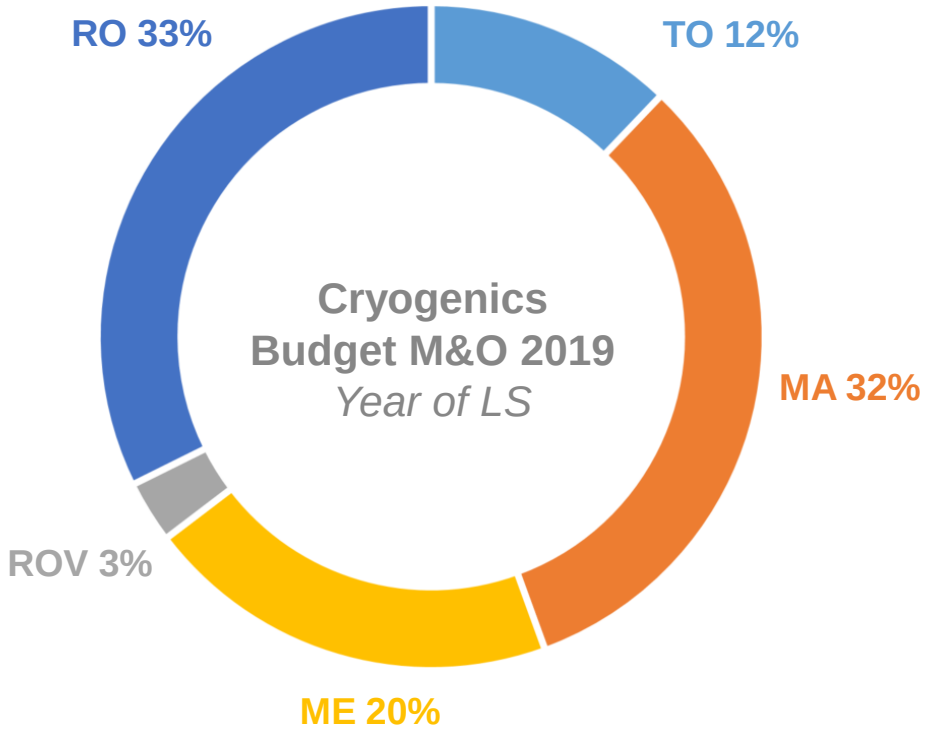
Distribution downtime responsibility over the last 3 years is shared between

- CERN with 62%
  - Utility fault
  - User events
  - Obsolescence
- Contractor with 38%
  - Compressor breakdown
  - Instrumentation issues
  - Turbine breakdowns
  - Clogging of water circuit or
  - Recovery time too long after user events

			July 2016 - June 2017		July 2017 - June 2018		July 2018 - June 2019	
			RUN	Availability	RUN	Availability	RUN	Availability
Meyrin	Central Liquefier 165	LHe Liquefier	7,715 h	99.5%	7,574 h	100.0%	6,023 h	98.8%
	Cryolab 163	LHe Liquefier	7,886 h	99.9%	7,308 h	96.2%	8,239 h	99.8%
SM18	Testing Facility	LHe Liquefier	7,630 h	99.4%	6,969 h	99.3%	5,793 h	99.6%
North Area	NA61.1	LHe Refrigerator	4,524 h	97.9%	4,115 h	99.5%	1,772 h	91.9%
	NA61.2	LHe Refrigerator	4,657 h	99.7%	4,166 h	99.6%	1,888 h	96.4%
	ATLAS H8	LHe Refrigerator			2,154 h	99.9%	1,716 h	93.8%
	COMPASS	LHe Refrigerator			2,652 h	100.0%	3,739 h	99.3%
	CMS RD5	LHe Refrigerator	4,559 h	98.8%	3,735 h	92.8%		
	NA62	LKr Calorimiter	8,760 h	99.9%	8,760 h	100.0%	8,760 h	100.0%
Isolde accelerator	HIE-Isolde	LHe Refrigerator			6,207 h	99.6%	3,825 h	97.9%
SPS accelerator	BA4 Coldex	LHe Refrigerator	1,680 h		4,488 h		3,720 h	
	BA6 RF Cavity test	LHe Refrigerator					2,952 h	
LHC Point 8	CAST	LHe Refrigerator			3,755 h	97.3%	2,275 h	95.1%
Neutrino	NP04	LAr Calorimiter					6,168 h	
	NP02	LAr Calorimiter						
Total cumulated running hours			47,411 h		61,883 h		56,870 h	

Cryogenics M&O contract framework



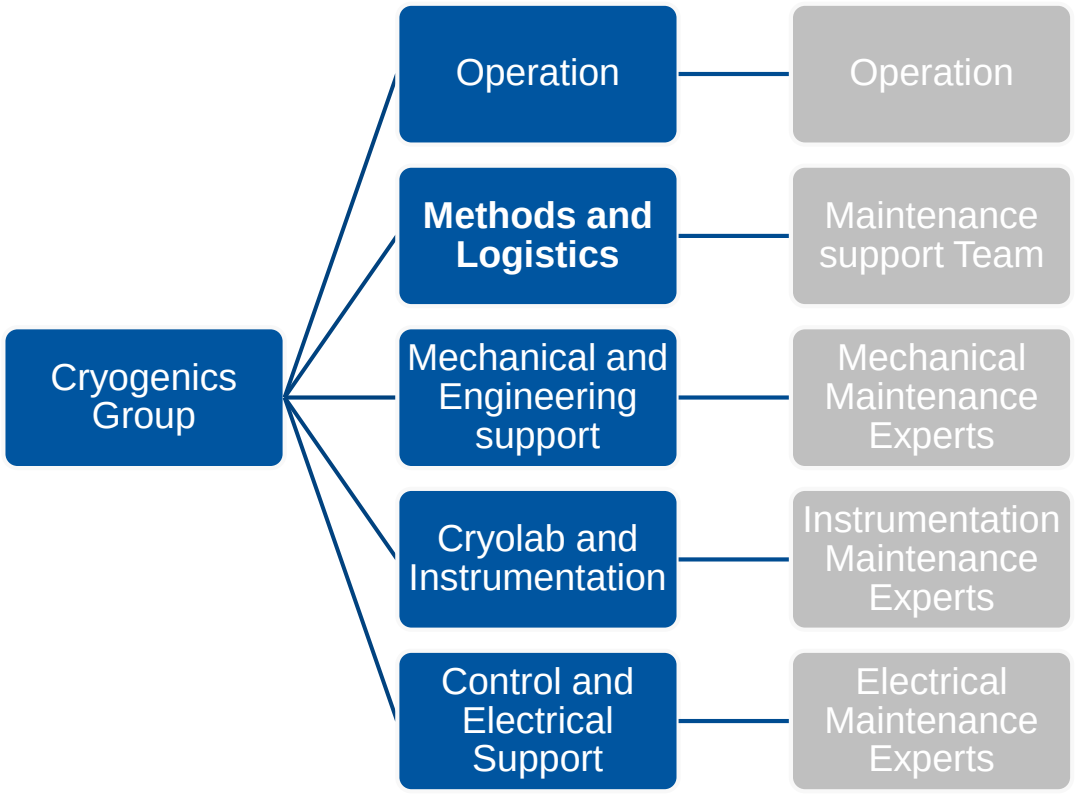


RO – Result Oriented operation
ROV – Result Oriented Variable
TO – Task Oriented operation

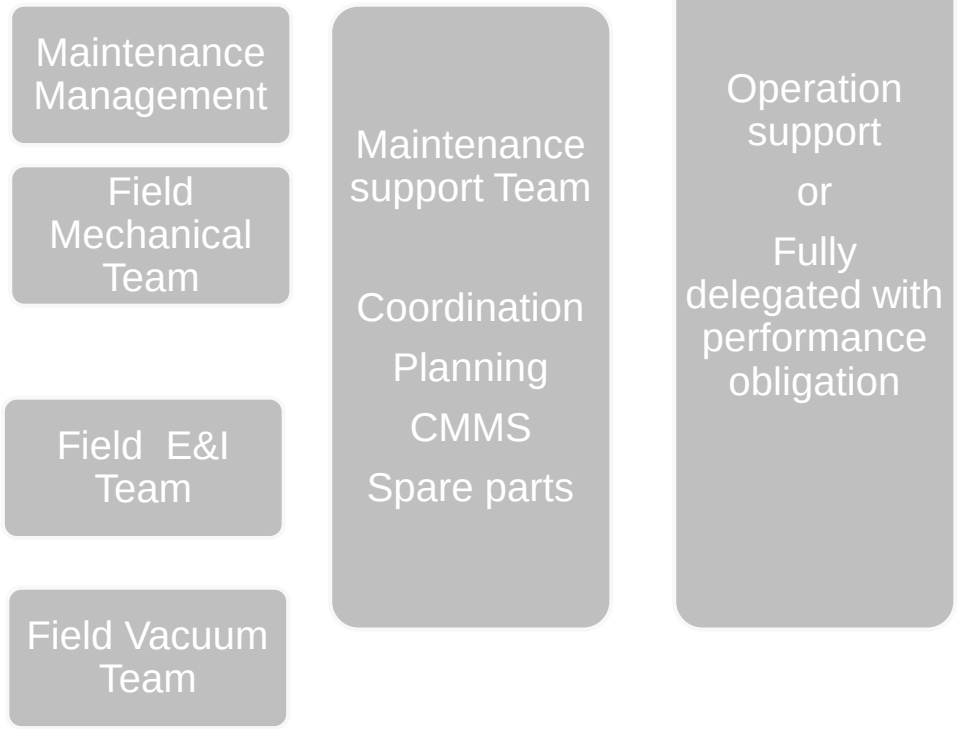
ME – Methodology
MA – Maintenance

Work Organization implementation

CERN Cryogenics group



Industrial Partnership

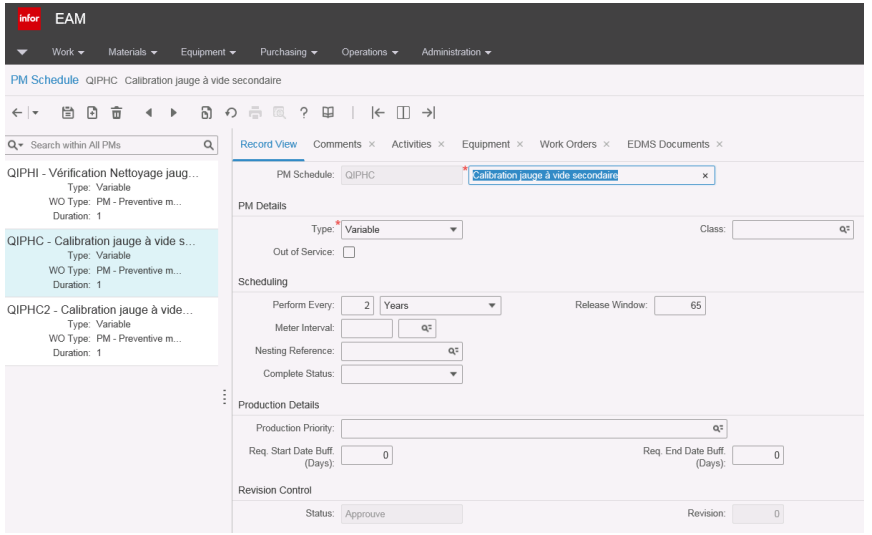


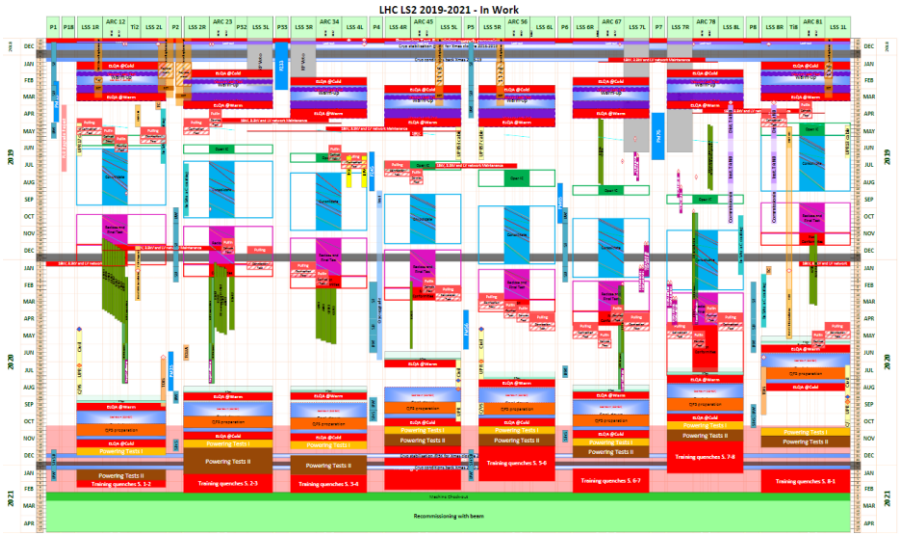
Work Organization implementation

infor EAM

Computerized Maintenance Management System

- All Maintenance Plans are review by:
  - Maintenance experts by field
  - Method & Logistic support section
  - Contractor Maintenance Support team
- Reference matrix is updated and shared with the team
- Update of the of the CMMS is done by the contractor



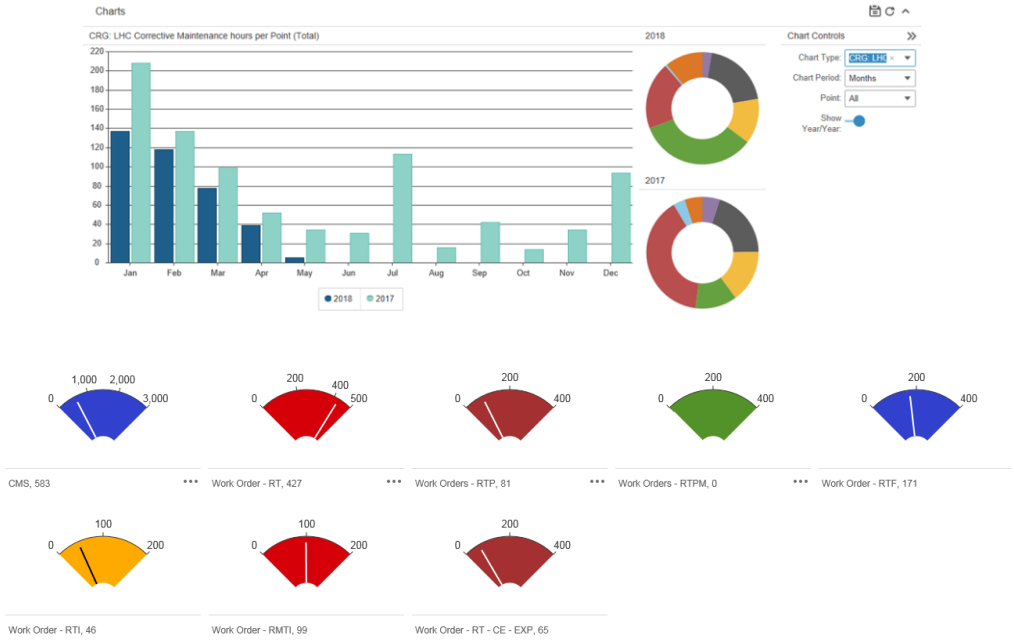


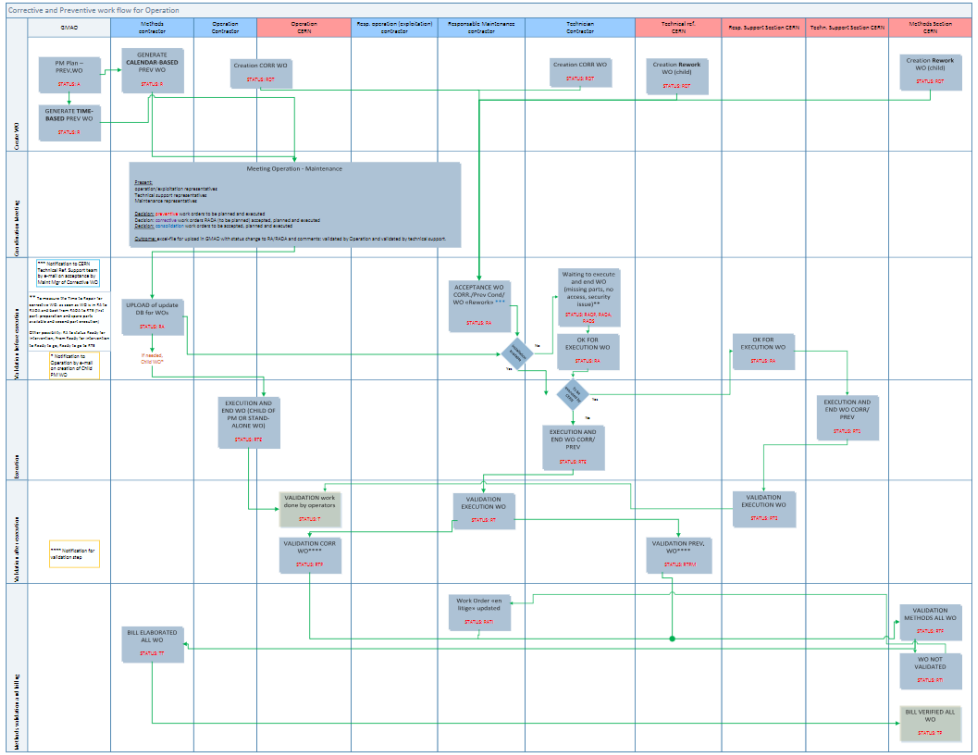
Work Organization implementation

infor EAM

Computerized Maintenance Management System

- Technical Stop 3-4d **30-80wo**
- YETS 2-3wk **1’000-1’200wo**
- Long Shutdown 1yr **3’000-4’000wo**





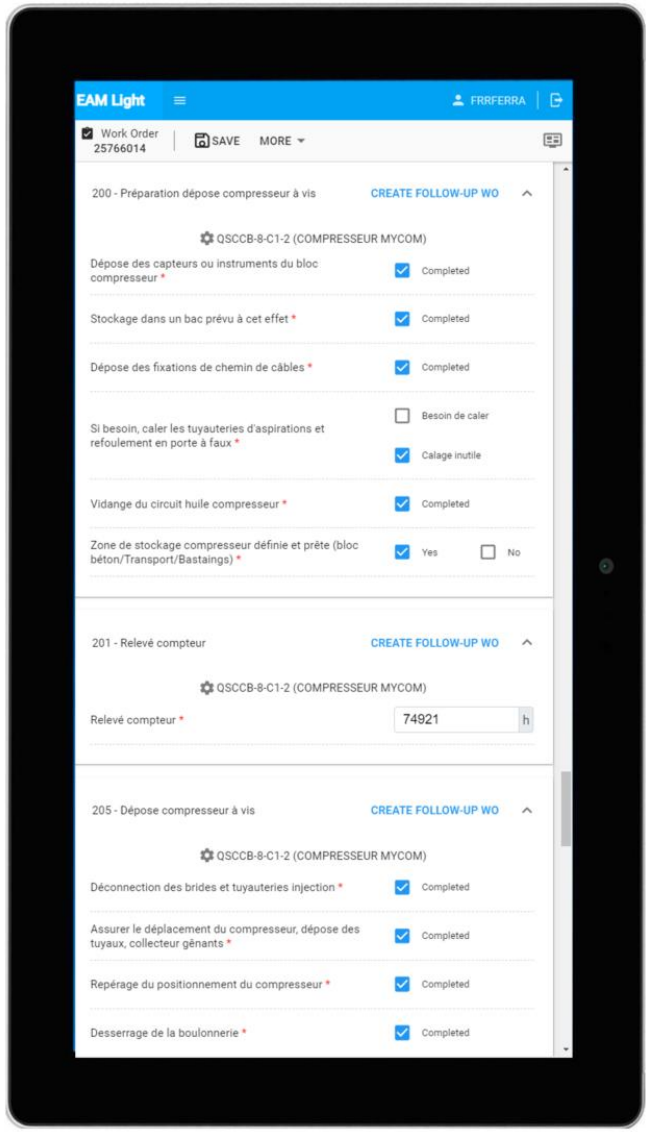
Workflow is in place and each WO is check and validated by CERN technical expert in the field and quality controller

Development of methodologies

Maintenance Procedures

- Technical content of all work instructions for mechanical and vacuum tasks have been reviewed and updated before Long Shutdown 2
- Technicians can now fill checklists directly on digital tablets
- Implementation of industrial instrumentation calibrators and database

	Tasks	Reviewed Work Instruction	Reviewed Forms	Comment
Mechanical & Vacuum	71	71	174	Checklists
Electrical & Instrumentation	45	32	14	Checklists
			8	Automated reports using calibration device

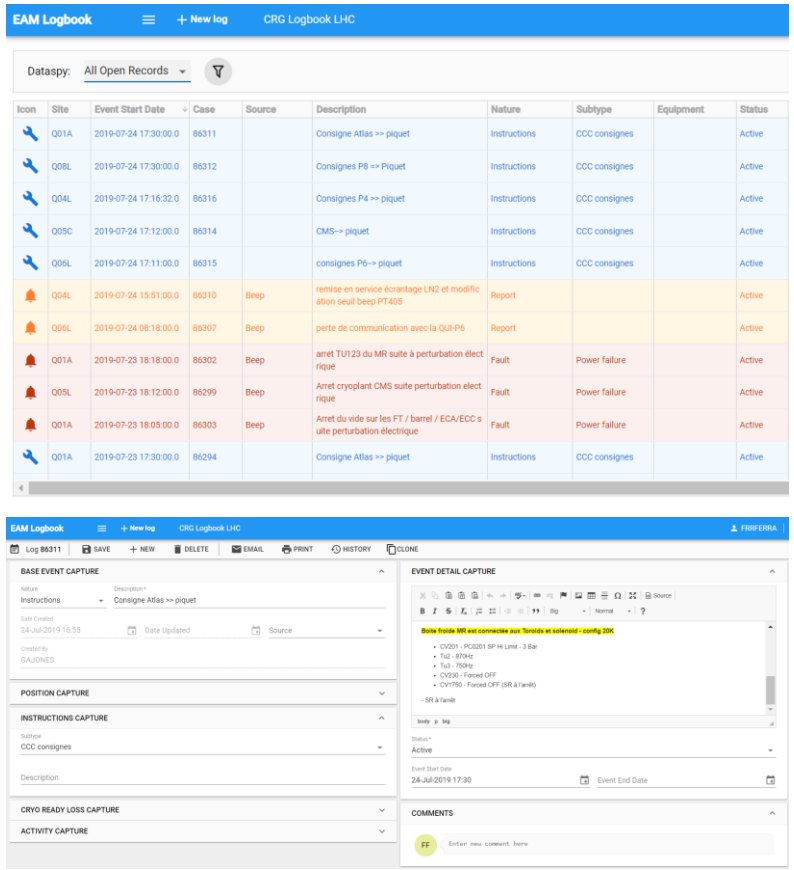


Development of methodologies

Operation electronic Logbook

- Captures and tracks all activities occurring on cryoplants
- Migrated to the same database as the CMMS in March 2018
- Different use between LHC and other cryoplants

	Events	Events subcategories		Generated Work Orders
LHC and Detectors cryogenics	6026	Report	13%	45
		Ongoing operation	0%	
		Fault	4%	
		Information	30%	
		Instructions	51%	
		Others	1%	
Non-LHC cryogenics	1381	Report	39%	84
		Ongoing operation	20%	
		Fault	19%	
		Information	17%	
		Instructions	3%	
		Others	1%	



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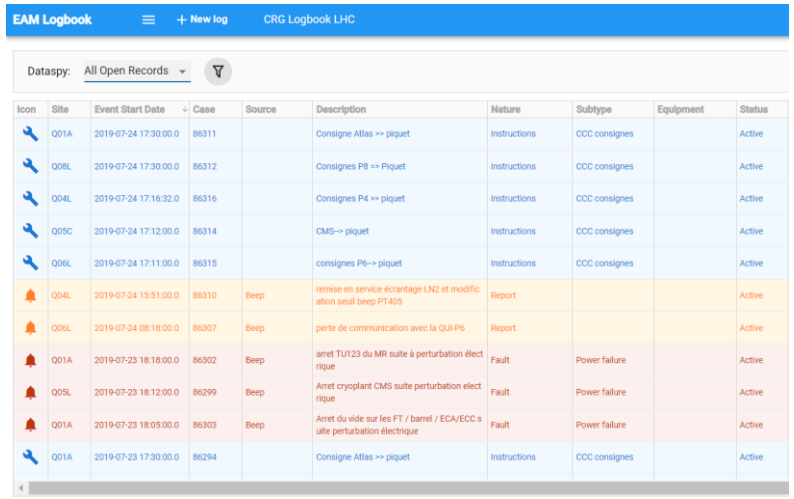
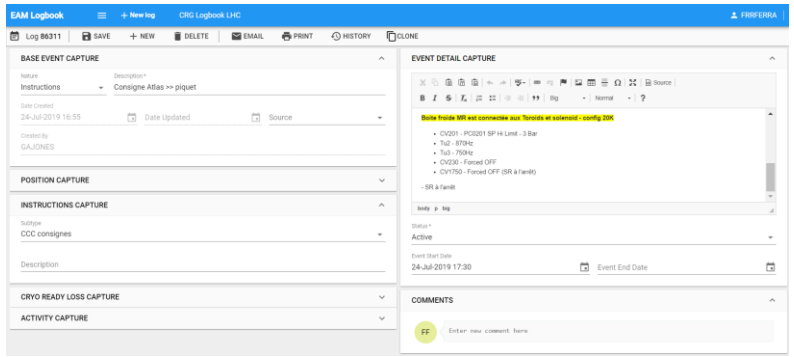
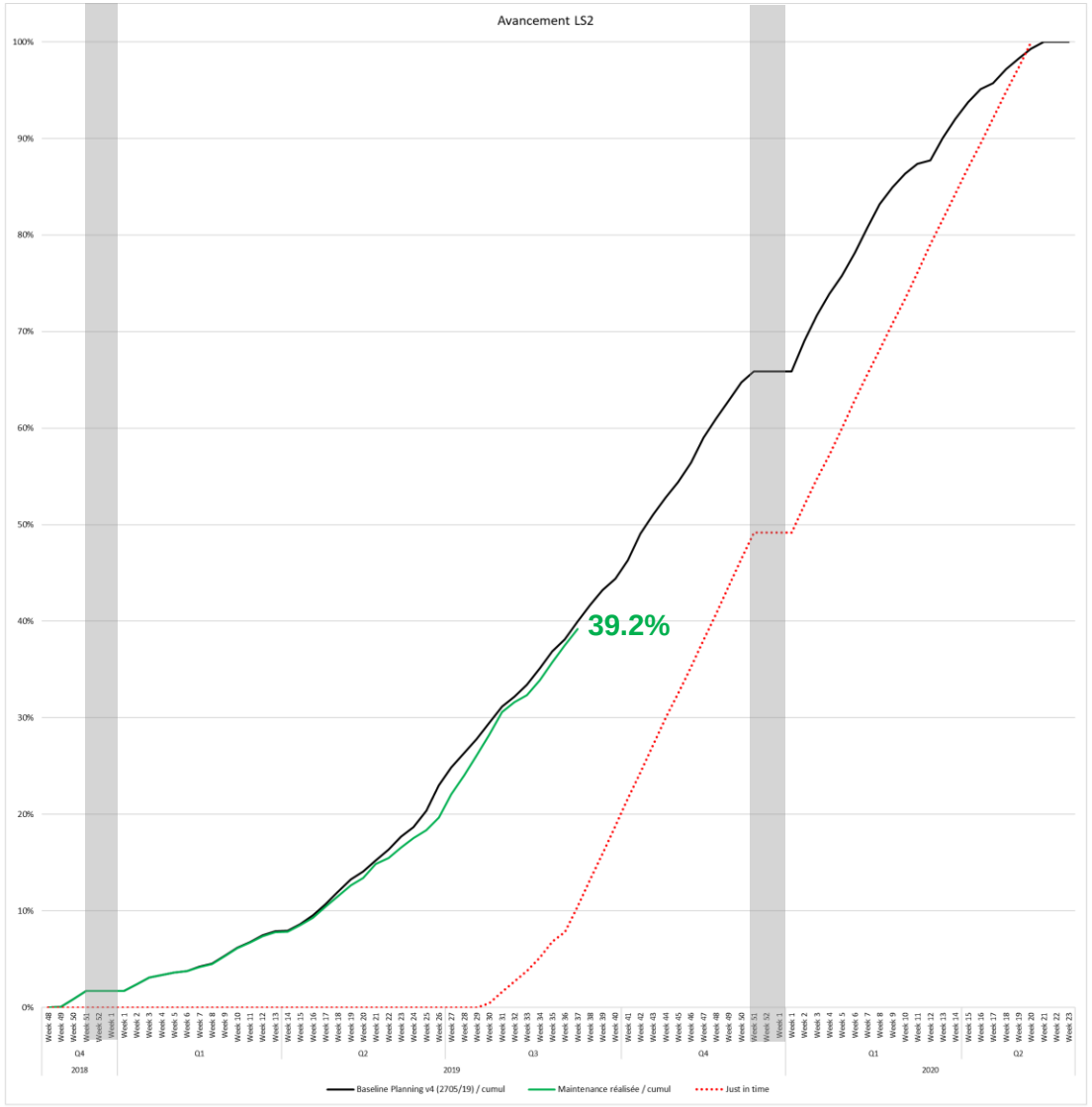
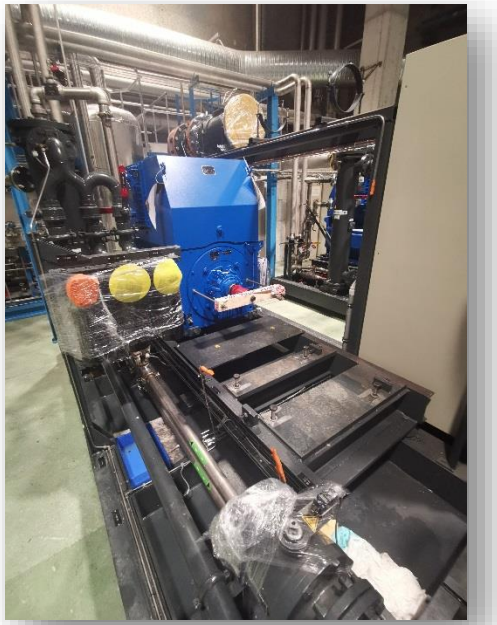




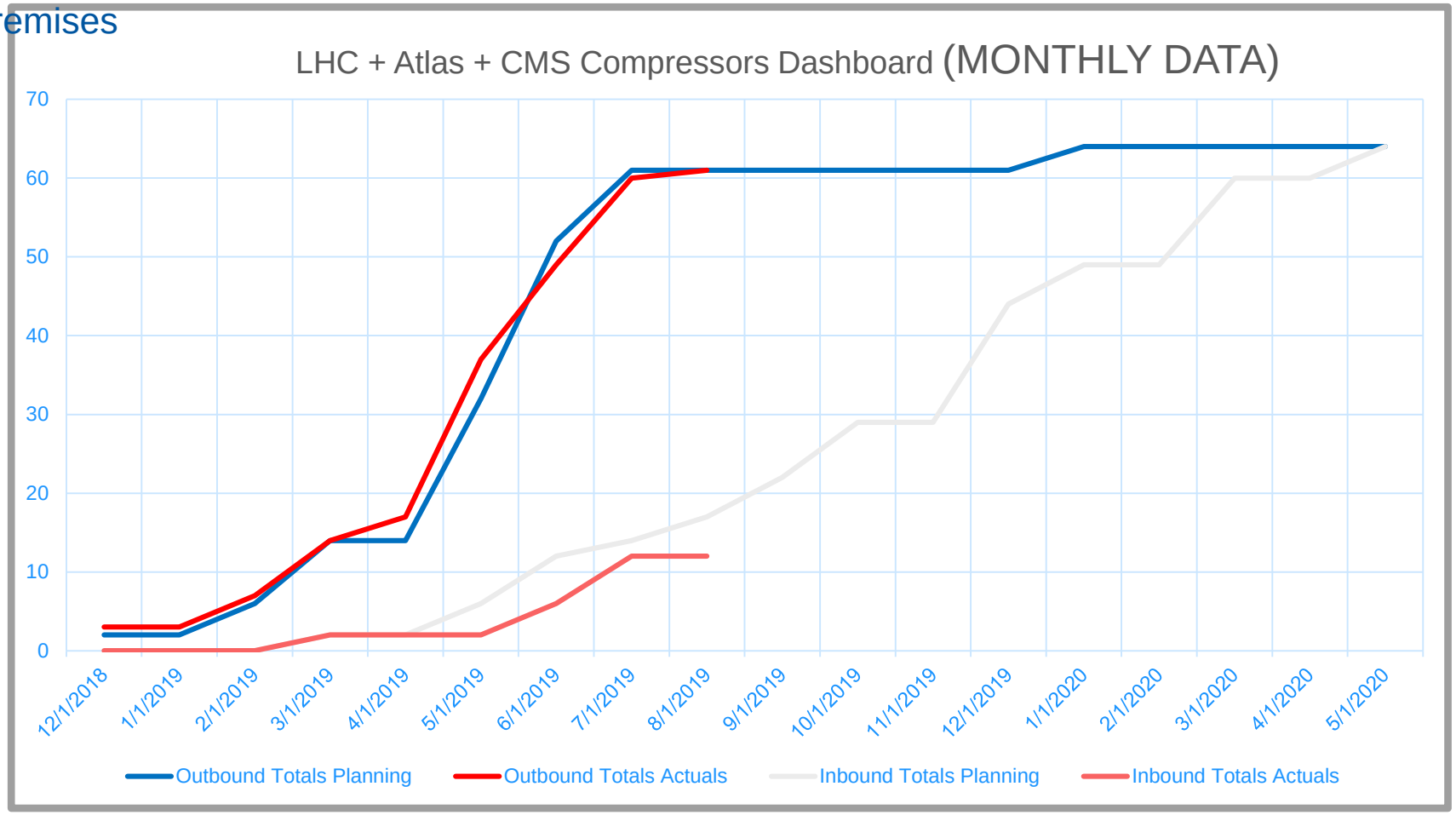
LS2 Maintenance activities - Week 37-2019



LS2 activities

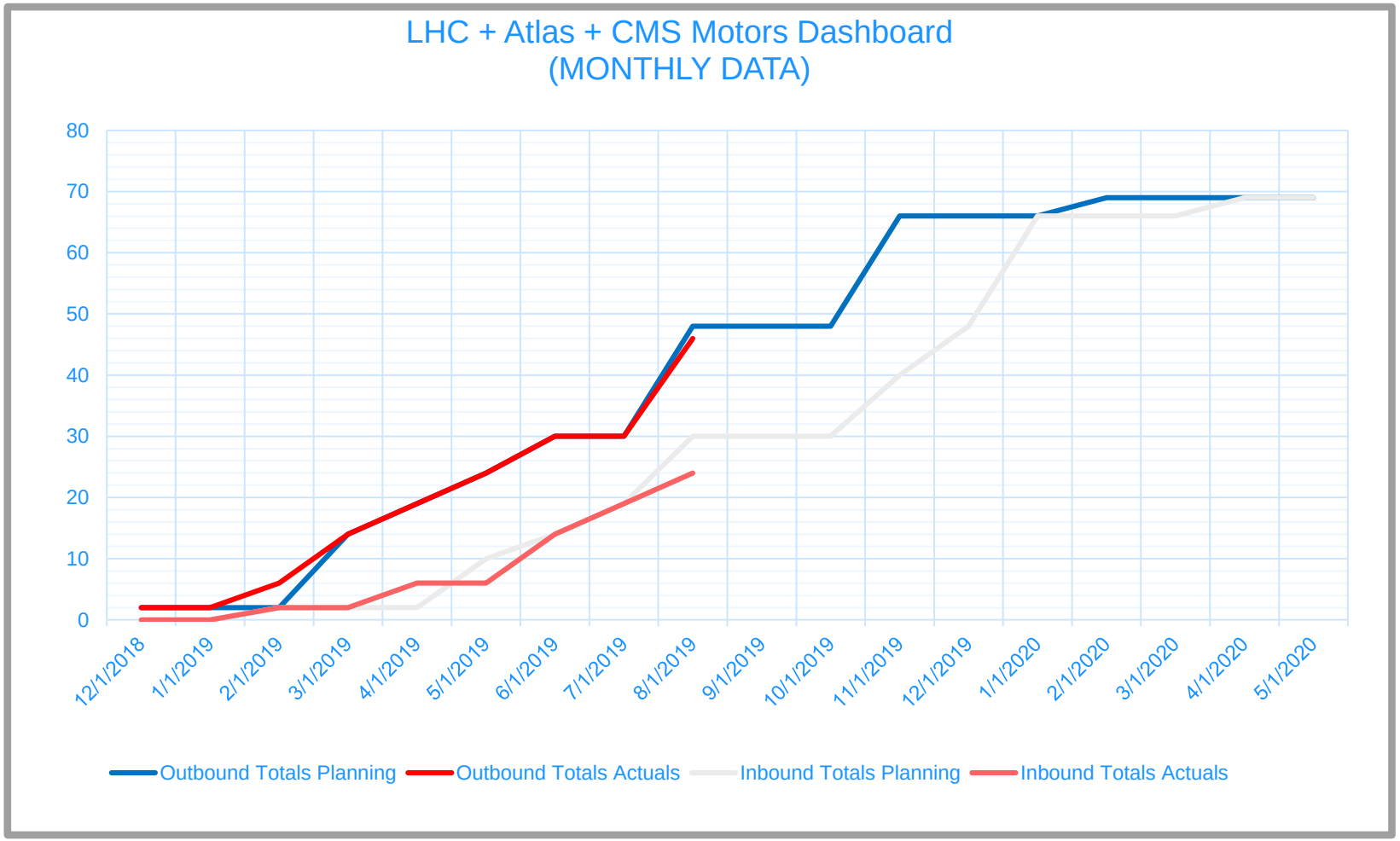


Maintenance - Major overhauling Compressors logistics at contractor premises



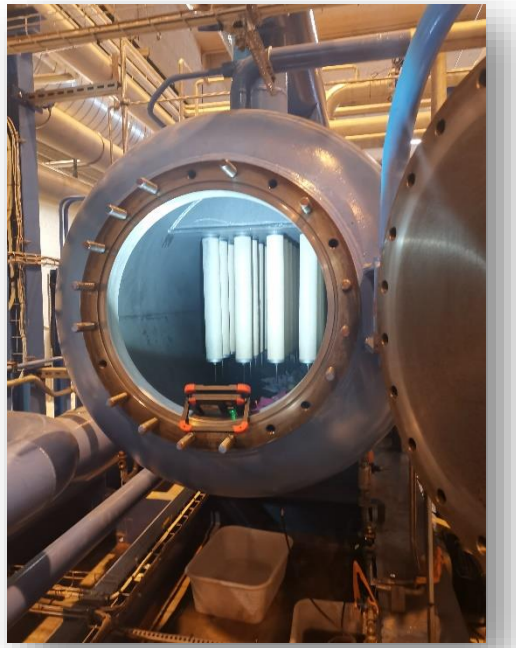
Maintenance - Major overhauling HV motors logistics

at contractor premises



LS2 activities

Nettoyage chimique et mécanique de la station QSCA du point 2



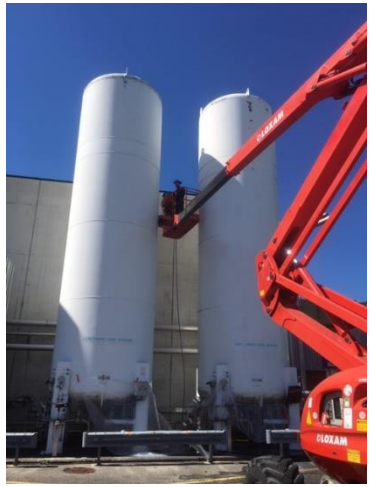
Remplacements coalesceurs

Charbons stations QSCA/B-2/8

Réaménagement atelier vide P2

Calibrations avec outil Beamex

LS2 activities



QSV

QSDN

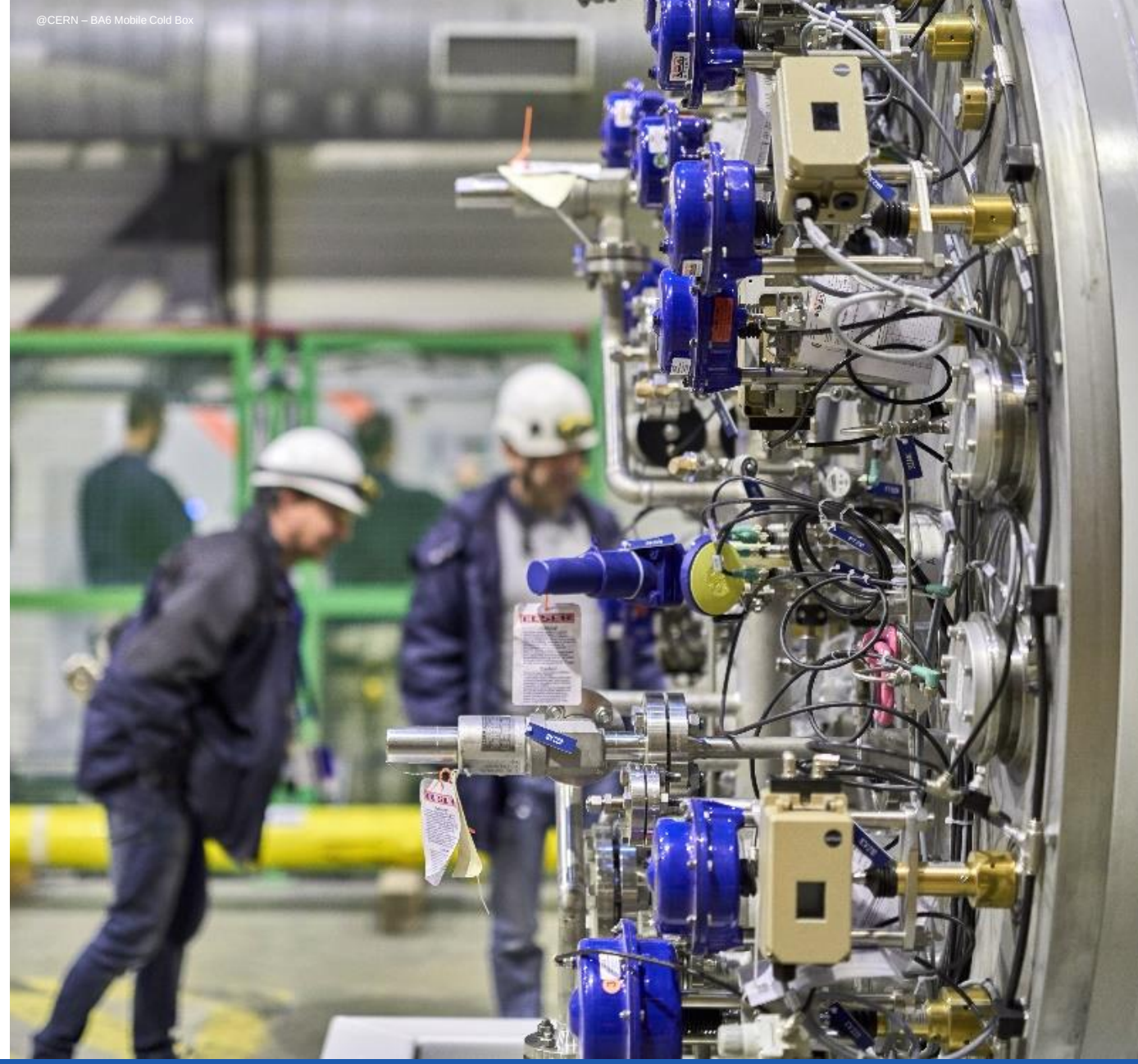
QSDH

Conclusions and perspectives

- Over the last three years the M&O contract has:
  - Provided support to sustain continuous improvement of LHC availability,
  - Maintained a good level of availability for a significant number of cryoplants
  - Adapted to the requirements between run and shutdown periods
  - Developed M&O methodologies together with CERN team

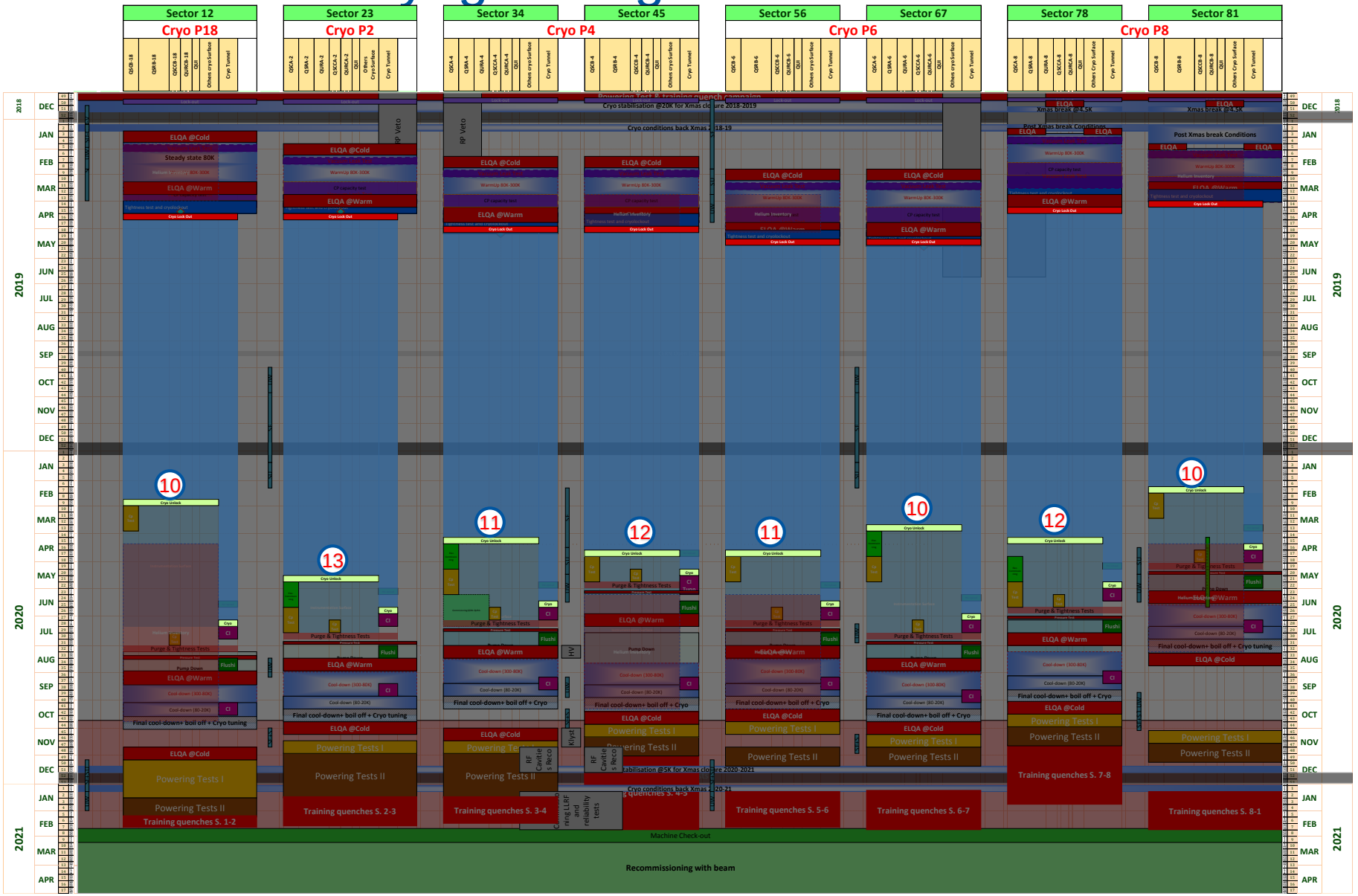
- In the next two years the contract shall:
  - Deliver the maintenance scope of work for Long Shutdown 2
  - Resume LHC operation at nominal capacity for the third run

Questions ?



Back-up slides

LS2 cryogenics general frame



Compressor station & Oil Removal System

PREDICTIVE Maintenance program – Condition Based Monitoring

	Checked	Criteria
• Vibration analysis	Monthly	Multiple : spectrum analysis, RMS
• Oil analysis program	Yearly	Multiple : oxidation, particles
• Electrical cabinets thermography	Yearly	Over heating temperature
• Critical instrumentation checks	4-Yr	Deviating value

PREVENTIVE Maintenance program

• Oil pumps Revision	8’000(minor) & 24’000(major) running hours
• Activated charcoal load replacement	24’000 running hours
• Coalescing filters replacement	None or 24’000 running hours
• Screw compressor Major Overhauling	40’000 running hours
• High Voltage Motors	30’000(bearings) & 40’000(sleeve bearings) running hours
• Vacuum pumps revisions	8’000 to 40’000 running hours
• Safety chain check	Yearly
• Safety valves test bench test	2-Yr, 4Yr, 5-Yr
• Water Heat Exchangers chemical cleaning	4-Yr
• Critical instrumentation & valves check	4-Yr

Cold Boxes

PREDICTIVE Maintenance program – Condition Based Monitoring

	Checked	Criteria
Electrical cabinets thermography	Yearly	Over heating temperature
Critical instrumentation checks	4-Yr	Deviating value
Cold Compressors	4-Yr	Mechanical clearance
Heat exchangers	4-Yr	Tightness test
Turbine filters	Yearly	Delta P

PREVENTIVE Maintenance program

Safety valves test bench or local test	2-Yr, 4Yr, 5-Yr
Safety chain check	Yearly
Water Heat Exchangers chemical cleaning	4-Yr
Vacuum pumps revisions	8’000 to 24’000 running hours
Critical valves & instrumentation check	4-Yr
Turbine filters	4-Yr (when vacuum break required)

RUN to FAIL

- Turbines

Storage, Distribution & Cryostat


@CERN – LHC Nitrogen tank during LHC pre cooling


@CERN – LHC Point 2 Distribution Valve Box

PREDICTIVE Maintenance program – Condition Based Monitoring

	Checked	Criteria
• Line integrity test during warm-up	4-Yr	Pressure and vacuum tests
• Critical instrumentation checks	4-Yr	Deviating value
• Critical valves check	4-Yr	Leak tightness
• Capacity legal pressure check	10-Yr	Pressure test according to EU

PREVENTIVE Maintenance program

• Safety valves	2-Yr, 4Yr, 5-Yr
• Safety chain check	Yearly
• Vacuum pumps revisions	8’000 to 24’000 running hours
• Critical valves check	4-Yr
• Critical instrumentation check	1 to 4-Yr

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