CONSOLIDATION day in view of HL-LHC

Cryogenic aspects

S. Claudet, TE-CRG

With valuable inputs from D. Delikaris away this day

26 Sept'17

Disclaimer

This exercise has been done in a short time, considering similar past events and conclusions, with the strict minimum iteration with the Group Leader and Section Leaders or colleagues.

We believe however that we have addressed the right issues, and we will develop further the evaluations (technical, cost) based on your feedback.

I personally apologise for not having followed the proposed template, and I am confident that you will anyway find what you are looking for

CONTENT

For LHC machine only, Cryogenics for detectors treated via experiments

- Approved CONSOLIDATIONS so far
- Possible Non-Conformities pushed to HiLumi era
- Concerns for HiLumi operation

  Capacity – Availability - Reliability
- Summary

OFFICIAL status of CONSOLIDATIONS for TE-CRG

Accelerator consolidation Arbitration September 2017 **TE-CRG**

A APT
B Snapshot B: Consolidation before Sept 2017 review

Active workunits

Group	Status	Project	BC	Workunit description		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
TE-CRG	**Active**	**ADCONS**	**22154**	**New AD cryo distribution**	**APT**		**550**	**250**								
TE-CRG	Draft 5	ADCONS	22154	New AD cryo distribution	Snapshot B											
TE-CRG	**Active**	**LHC-CONS**	**99572**	**migration to the UNICOS/PVSS controls system**	**APT**	**278**										
TE-CRG	Active	LHC-CONS	99572	migration to the UNICOS/PVSS controls system	Snapshot B	115										
TE-CRG	**Active**	**LHC-SPARES**	**22085**	**3.3 kV electrical motors consolidation**	**APT**		**250**	**120**	**110**	**120**	**150**	**150**	**100**			
TE-CRG	Draft 4	LHC-SPARES	22085	3.3 kV electrical motors consolidation	Snapshot B											
TE-CRG	**Active**	**LHC-SPARES**	**22085**	**Consolidations of the LHC ¿ex-LEP cryoplants electrical cabinet**	**APT**		**150**	**100**	**200**			**400**	**500**			
TE-CRG	Draft 4	LHC-SPARES	22085	Consolidations of the LHC ¿ex-LEP cryoplants electrical cabinet	Snapshot B											
TE-CRG	**Active**	**LHC-SPARES**	**99500**	**Continuation of the compressor station consolidation : cold spares**	**APT**	**416**										
TE-CRG	Active	LHC-SPARES	99500	Continuation of the compressor station consolidation : cold spares	Snapshot B	350										
TE-CRG	**Active**	**LHC-SPARES**	**99515**	**DFB spares**	**APT**	**250**	**250**									
TE-CRG	Active	LHC-SPARES	99515	DFB spares	Snapshot B	250	250									

Draft 5 - out of scope - no changes

TE-CRG	**Draft 5**	**LHC-CONS**	**22084**	**Continuation of the compressor station consolidation: hot spares**	**APT**			2,000	1,000							
TE-CRG	Draft 5	LHC-CONS	22084	Continuation of the compressor station consolidation: hot spares	Snapshot B			2,000	1,000							
TE-CRG	**Draft 5**	**LHC-SPARES**	**22085**	**LHC sectorisation upgrade**	**APT**			**971**								
TE-CRG	Draft 5	LHC-SPARES	22085	LHC sectorisation upgrade	Snapshot B			971								

OFFICIAL LHC_related CONSOLIDATIONS for TE-CRG

Active wo

All figures in kCHF

Project	Topic	2017	2018	LS2 2019	LS2 2020	2021	2022	2023	LS3 2024	LS3 2025	LS3 2026	LS3 2027	
LHC-CONS	**migration to the UNICOS/PVSS controls system**	**278**											
LHC-SPARES	**3.3 kV electrical motors consolidation**		**250**	**120**	**110**	**120**	**150**	**150**	**100**				Recent line, really justified ?
LHC-SPARES	**Consolidations of the LHC ex-LEP cryoplants electrical cabinet**		**150**	**100**	**200**			**400**	**500**				Recent line, see HL_Reliability
LHC-SPARES	**Continuation of the compressor station consolidation : cold spares**	**416**											
LHC-SPARES	**DFB spares**	**250**	**250**										

Draft 5 - out of scope - no changes

LHC-CONS	**Continuation of the compressor station consolidation: hot spares**			**2,000**	**1,000**								
LHC-SPARES	**LHC sectorisation upgrade**			**971**									

PROPOSAL for LHC_related CONSOLIDATIONS for TE-CRG

Action 1: TERMINATE what is started today

Action 2: TERMINATE "cold" spares with split between Compressors & Motors

Active wo

All figures in kCHF

				LS2					LS3			
Project	Topic	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
LHC-CONS	migration to the UNICOS/PVSS controls system	278										
LHC-SPARES	3.3 kV electrical motors consolidation		250	200	110	120	150	150	100			
LHC-SPARES	Consolidations of the LHC ex-LEP cryoplants electrical cabinet		150	100	200			400	500			
LHC-SPARES	Continuation of the compressor station consolidation : cold spares	416										
LHC-SPARES	DFB spares	250	250									

1- Complete spares,
2- see HL_Reliability

Recent line,
see HL_Reliability

Draft 5 - out of scope - no changes

LHC-CONS	Continuation of the compressor station consolidation: hot spares			2,000	1,000							
LHC-SPARES	LHC sectorisation upgrade			971								

Action 3: COMPLETE studies for HL-era ageing issues

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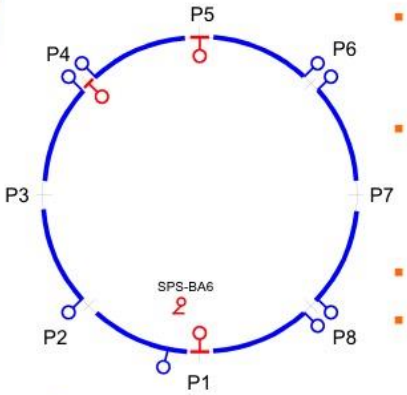
HiLumi-WP9 Baseline

HL-LHC cryogenics (upgrade)



- 2 new cryoplants (~18 kW @ 4.5 K incl. ~3 kW @ 1.8 K) at P1 and P5 for high-luminosity insertions
- 1 new cryoplant (~4 kW @ 4.5 K) at P4 for SRF cryomodules. (Alternative under study: upgrade of 1 existing LHC cryoplant and distribution)
- 11T + Q5@P6
- SRF test facility with beam at SPS-BA6 primarily for Crab-Cavities

SM18 related activities not reported here

Global evaluation of the 8 arcs now considered

16Nov'16 HiLumi Cryogenics Progress

However, these two points could have an impact on CONS_budget(s)

Baseline Oct' 16 - Major changes w.r.t 2015

(Set of project decisions including Cost-to Performance Jun'16)

- SPS-BA6 selected for sc RF test facility with beam
- Double decker lay-out for P1/P5
- LS2 shifted (6m) and extended (6m), LS3 shifted (1yr)
- No longer "Ultimate" mode as design criteria
- Cryodistribution scheme including a valve box
- Temperature: Beam screens SAM@4.5-20K, Q6@4.5K
- Q5-P6@1.9K for LS3
- P4-RF: Decision to change from dedicated refrigerator to upgraded cryoplant (and possibly cryo-distribution)

16Nov'16 HiLumi Cryogenics Progress 4

CONTENT

!!! SM18 !!! Potential additional spares to confirm expected test rate for HiLumi magnets (Motors, Pumping units, others)
CRG: Study/Proposal Aut'17 for decision by TE/HL management

- Possible Non-Conformities pushed to HiLumi era

None !!!

Thanks to the Cryogenic architecture, sound design and work done so far by the group combined with the (responsible-sustainable-rational) approach to evaluate each case,
Validated consolidations have been made (LHe storage tanks) or about to be terminated ("cold" spares for compressors & motors)

HiLumi related activities only concerns new scopes/features not part of the LHC baseline

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CAPACITY

- 18kW@4.5K Refrigerators:
  - Ex-LEP Li (34-67), ex-LEP AL (23-78), it could be possible to treat the weakest sectors and align them on the next required (and possible) level

  ⇒ Need to work and study what could be gained by doing what, 2-3 MCHF could help per Refrigerator, implementation most likely only possible during LS, decision 2-3 years before

- 1.8K Units (Cold Compressors):
  - Recent performance tests have demonstrated the impact of not using expansion turbines to re-cool the outlet to main 4.5K Refrigerators (for sake of availability while matching today's required capacity)

  ⇒ Need to work on process & HW to make use of existing rotating machinery, 0.5 to 1.0 MCHF for all (8) units, implementation most likely only possible during LS, decision 1-2 years before

- Cryogenic Distribution Line (QRL):
  - Recent performance tests combined with studies for HiLumi have demonstrated the difficulty to provide cold gas (20K) for the current leads at injection, with delicate settings of valves at the return modules (1 or 2 % of opening with 0.1% accuracy required) inducing significant losses

  ⇒ Need to work and study what could be gained by doing what, 0.5 to 1.0 MCHF for all (4-4) units, implementation most likely only possible during LS, decision 1-2 years before

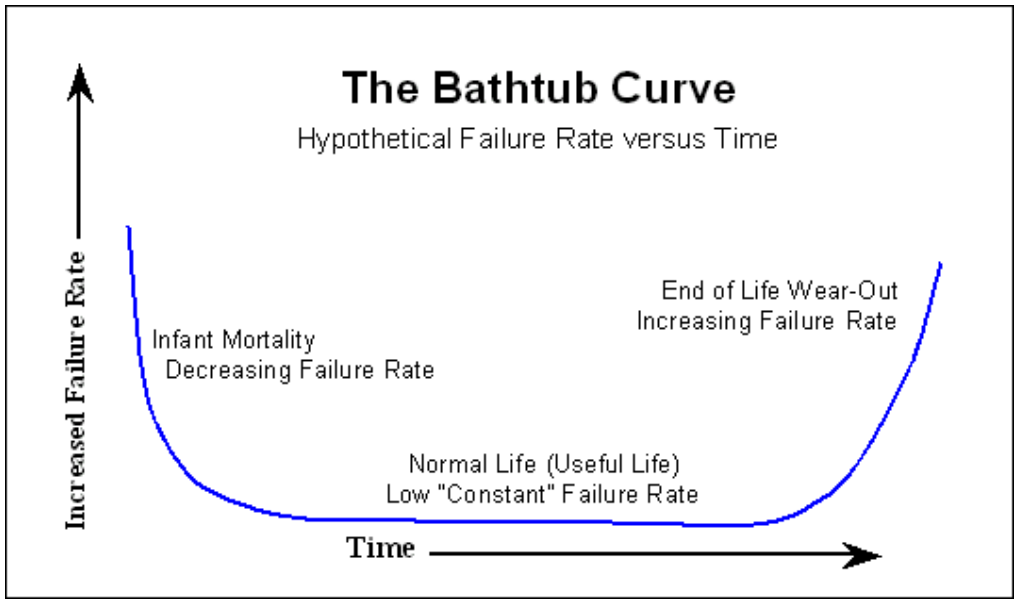
AVAILABILITY

- A decision has been made to cover major spares with “cold” spares requiring 1 week of Cryo downtime for exchange and to reject possible “hot” spares allowing to reduce cryo downtime to 1 day

- A request to change the HiLumi baseline for P4-RF is being prepared to minimise the number of cryoplants to be operated for HiLumi, aiming at not reducing further the present availability

- Sectorisation valves & temperature mixing chambers in interconnecting Boxes (QUI): New approach
  - A study could be made to confirm the expected potential gain of 1-2 hrs at each Refrigerator or 1.8K Unit stop (5 to 10 per year), and to define more precisely what could be gained by doing what, 1.0-1.5 MCHF, at best prototype for LS2, most likely series for LS3

RELIABILITY



Failure Rate

Which scenario for which type of component ?!?

Done

Spares

More Spares

Replacement

Time

RELIABILITY

- Teething problems treated and spares for routine M&O about to be completed.
- Proposed moderate increase of spare level to address the start of increased failures to allow preparing projects for replacement, combined with systematic evaluation of lifetime expectancy at each LS to define replacement/new spares to be used (at least for compressors, motors, …)

- Electrical cabinets (ex-LEP):
  - Already 1+ MCHF quoted in existing CONSO tables

- Electrical 3.3kV Motors:
  - Estimated to 1 MCHF at LS3, to be revised for LS4 and after

Evolution of present "on-the-fly" approach

New approach

- HP compressors at P2 and P8 (2x2):
  - Already visible signs of aging (vibrations, record WO for checks & maintenance)
  - Proposal to replace the 2 large existing compressors by 3 medium compressors, combined with re-arrangement of the compressor station lay-out (piping, cabling)
  - ⇒ Need to work and study what could be gained by doing what, 4 MCHF for all (P2-P8), implementation only possible during LS, decision 2-3 years before. Still possible for LS2? 2 sites at LS3 ?

Summary

- We have to terminate what was identified and funded, mostly to provide spares for routine M&O
- Most likely, no work foreseen for HiLumi-Cryo to be considered as “LHC consolidation postponed to HL-LHC”
- Series of proposal to maintain performance and availability for HiLumi to be discussed, studied, prioritised, decided/postponed/rejected, with so far from 1 to 10+ MCHF of possible cases for Cryogenics

BACK-UP Slides

Presented by D. Delikaris October 2015

AD Cryogenic Distribution Line

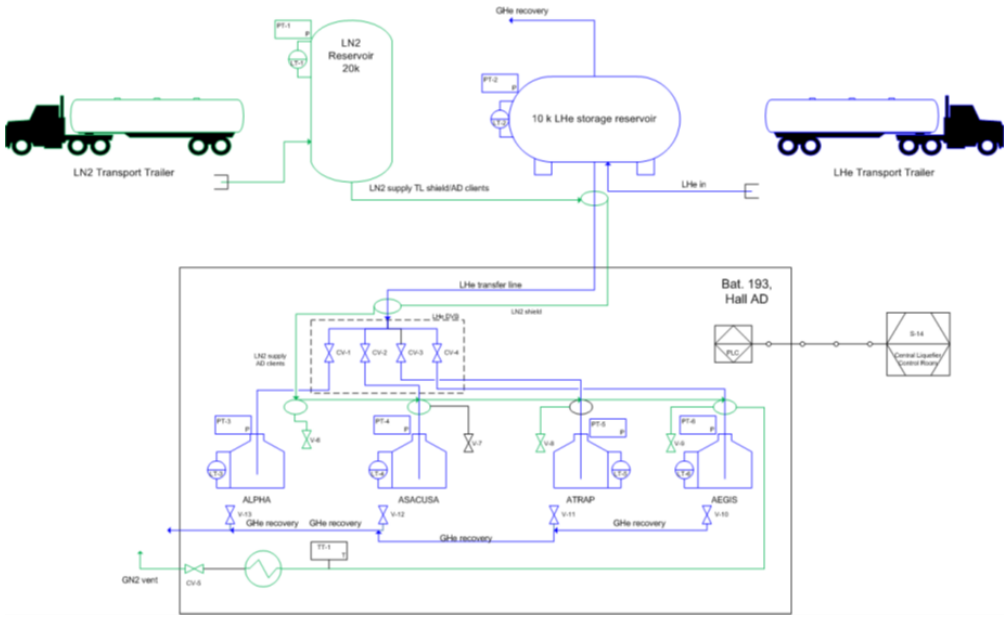
INDEX	MACHINE	CATEGORY		
1	AD	2	DESCRIPTION	Implementation of a multiple cryogenic distribution line to AD experiments
			BENEFIT (if done) CONSEQUENCES (if not done)	Distribution of cryogen (helium and nitrogen) to AD experiments by means of a dedicated cryogenic line (reduction of heavy logistics)

	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
RESOURCES	M (kCHF)		550	250				800		
	P (cat II, p-y)		0,1	0,1				0,2	0,2	
	P (cat III, p-y)		0,3	1,0				1,3	1,3	
	SUM P (p-y)		0,4	1,1				1,5	1,5	

Distribution of cryogen (helium and nitrogen) to AD experiments by means of a dedicated cryogenic line (thus reducing heavy delivery logistics from the central helium liquefier infrastructure);
The consolidation includes the installation of 10'000 litres liquid helium container outside AD premises (re-filled on weekly basis) connected to the cryogenic distribution line;

Conflict with ELENA installation; proposal to postpone the consolidation for 2021-2022

Presented to IEFC



HIE Isolde Helium Compressors Station

INDEX	MACHINE	CATEGORY		
2	HIE Isolde	1	DESCRIPTION	Procurement of two spare helium compressors
			BENEFIT (if done)	Procurement of two "cold" spare helium compressors for the HIE-Isolde cryogenic installation in order to reduce the MTTR to one week (instead of 3 or 9 months for repair or delivery of new unit respectively)
			CONSEQUENCES (if not done)	

RESOURCES	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
	M (kCHF)	400						400		
	P (cat II, p-y)	0,1						0,1	0,1	
	P (cat III, p-y)									
	SUM P (p-y)	0,1						0,1	0,1	

HIE-Isolde is making use of the former LEP-ALEPH cryogenic installation; The helium compressor station consists in two AERZEN screw units (VMY236 & VMY436) with no spare available
(CAST is using two identical units)

In case of failure, 3 to 9 months of downtime in case of major failure (repair or new unit to be delivered respectively)
Proposal: define operational priority (use CAST compressors) or launch the procurement of two spare units (available for both HIE-Isolde and CAST) with a mean time to restore of 1 week

To be taken in charge by the project?
Presented to IEFC

LHC 24 V Distribution

INDEX	MACHINE	CATEGORY		
3	LHC	1	DESCRIPTION	LHC 24 V surface redundancy
			BENEFIT (if done) CONSEQUENCES (if not done)	The LHC 24 V distribution is redundant for all underground cryogenic equipment. This consolidation will extend and complete the redundancy to all surface 24 V distribution

	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
RESOURCES	M (kCHF)	100	100					200		
	P (cat II, p-y)									
	P (cat III, p-y)	0,1	0,1					0,2	0,2	
	SUM P (p-y)	0,1	0,1					0,2	0,2	

The LHC 24 V distribution is redundant for all underground cryogenic equipment.

This consolidation will extend and complete the redundancy to all surface 24 V distribution.

To be taken in charge by Operation budget?

DFBA

INDEX	MACHINE	CATEGORY		
4	LHC	1	DESCRIPTION	LHC DFBA spare components .
			BENEFIT (if done) CONSEQUENCES (if not done)	Procurement of all necessary DFB spare components allowing the prompt assembly of a DFBA type equipment thus allowing to reduce downtime by 6 months (on-going, to be competed by 2016).

	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
RESOURCES	M (kCHF)	500						500		
	P (cat II, p-y)	0,1						0,1	0,1	
	P (cat III, p-y)									
	SUM P (p-y)	0,1						0,1	0,1	

Procurement of all necessary DFB spare components allowing the prompt assembly of a DFBA type equipment thus allowing to reduce downtime by 6 months

Already approved, on-going, components for 200 kCHF have been procured, to be completed by 2016

Bus-bar procurement by MSC (300 kCHF)

DFBX spares are not included in the present procurement

Presented to LMC

LHC Helium Compressors Stations (1/2)

INDEX	MACHINE	CATEGORY		
5	LHC	1	DESCRIPTION	LHC helium motor-compressors "cold spares" procurement
			BENEFIT (if done) CONSEQUENCES (if not done)	Completing the procurement of the LHC helium motor-compressors "cold spares" (present MTTR 1 week); already approved, on-going

	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
RESOURCES	M (kCHF)	1000						1000		
	P (cat II, p-y)									
	P (cat III, p-y)									
	SUM P (p-y)									

Completing the approved procurement of the LHC helium motor-compressors "cold spares" (present MTTR 1 week);

Consolidation already approved, on-going, orders in preparation

Presented to LMC

LHC Helium Compressors Stations (2/2)

INDEX	MACHINE	CATEGORY		
6	LHC	2	DESCRIPTION	LHC helium motor-compressors “hot spares” procurement
			BENEFIT (if done) CONSEQUENCES (if not done)	Completing the procurement of the LHC helium motor-compressors by implementing "hot spares" thus allowing to reduce the MTTR from 1 week to 1 day

	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
RESOURCES	M (kCHF)			2000	1000			3000		
	P (cat II, p-y)			0,1	0,1			0,2	0,2	
	P (cat III, p-y)			0,5	0,5			1,0	1,0	
	SUM P (p-y)			0,6	0,6			1,2	1,2	

Completing the procurement of the LHC helium compressors by implementing "hot spares" thus allowing to reduce the MTTR from 1 week to 1 day

Classified Consolidation or Upgrade?

Presented to LMC

LHC Quench Line

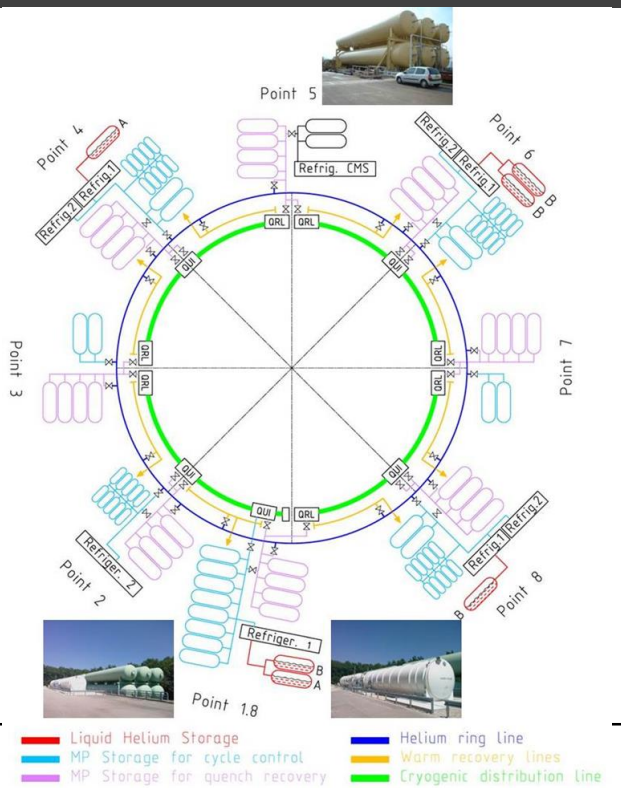
INDEX	MACHINE	CATEGORY		
7	LHC	2	DESCRIPTION	LHC Quench Line
			BENEFIT (if done)	Restore the functionality of the LHC quench line allowing the helium recovery to the dedicated gaseous surface storage after a full sector quench (rare); the non functionality of the quench line may lead to the loss of one sector helium inventory (750 kCHF)
			CONSEQUENCES (if not done)	

	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
RESOURCES	M (kCHF)				575			575		
	P (cat II, p-y)				0,1			0,1	0,1	
	P (cat III, p-y)				0,7			0,7	0,7	
	SUM P (p-y)				0,8			0,8	0,8	

Restore the functionality of the LHC quench line, actually partially non-operational due to a non-adapted mechanical design (risk to fail during the recovery of cold helium)

The LHC quench line allows the helium recovery to the dedicated 250 Nm^3, 2.1 MPa, gas tanks storage located at surface after a full sector quench (rare);

The non functionality of the quench line may lead to the loss of up to one sector helium inventory (equivalent to 750 kCHF)



LHC Cryogenics

INDEX	MACHINE	CATEGORY		
8	LHC	3	DESCRIPTION	LHC cryogenic sectorization
			BENEFIT (if done)	The proposed consolidation will allow to perform work on one dedicated LHC sector (room temperature) and keeping cold at operational temperature all other sectors (exception for S12)
			CONSEQUENCES (if not done)	

	YEAR	2016	2017	2018	2019	2020	> 2020	SUM	P available	P missing
RESOURCES	M (kCHF)				970			970		
	P (cat II, p-y)				0,1			0,1	0,1	
	P (cat III, p-y)				0,3			0,3	0,3	
	SUM P (p-y)				0,4			0,4	0,4	

Allow work to be performed on one dedicated LHC sector (room temperature) by keeping cold at operational temperature the all other sectors (7 sectors, except S12 due to the P2 configuration with the QRL return module integrated in the interconnection box)

Improvement of sectorization in-between sectors:

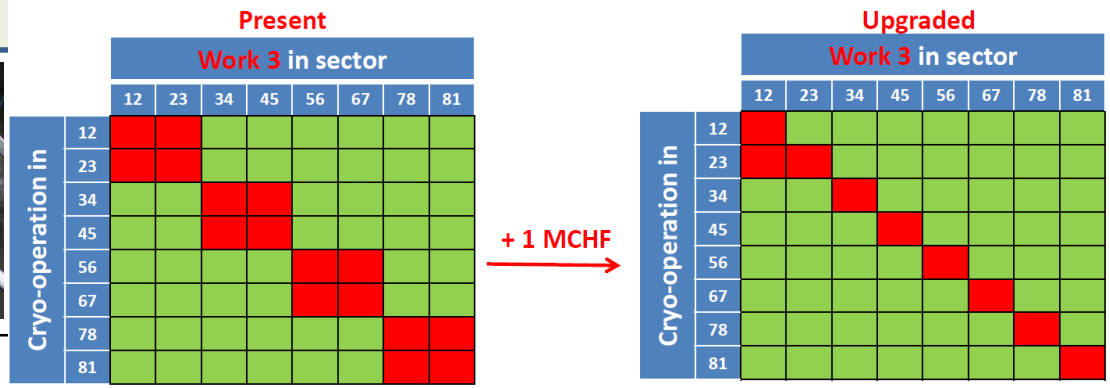
– Already optimized for Work 1 type (e.g. splice/diode repair)

– Optimized on 7 sectors for Work 2 type (e.g. intervention on SAM CM, on BS)

– Could be improved on 7 sectors for Work 3 type (e.g. Magnet removal)

970 kCHF for interconnection boxes upgrade (add cryogenic valves)

Presented to Chamonix session



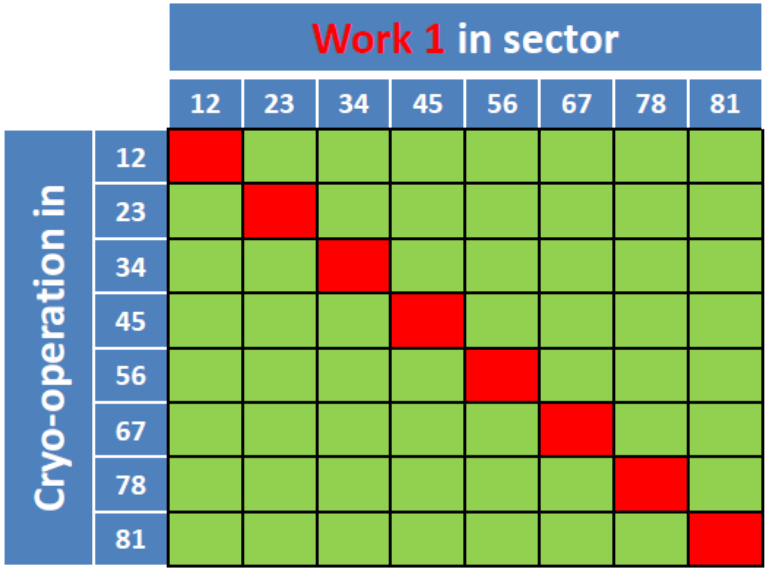
Backup slides

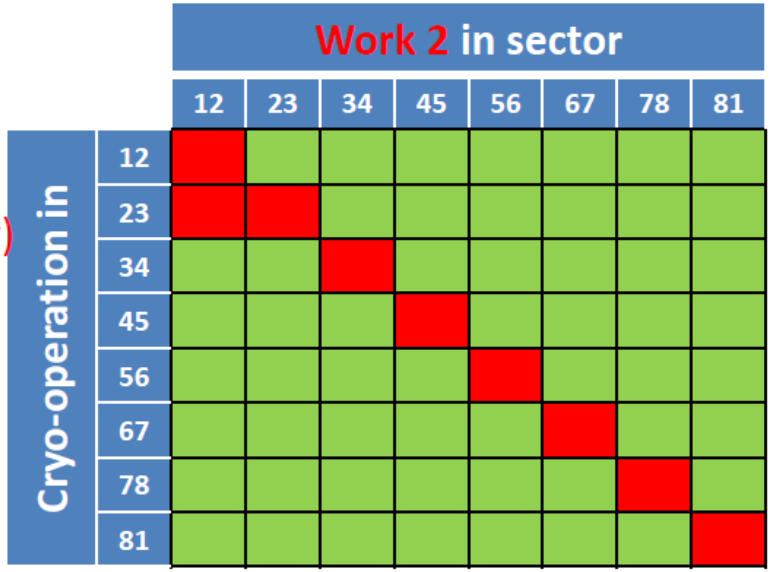
LHC sectorization, optional consolidation

Sectorization in between sectors: Present situation

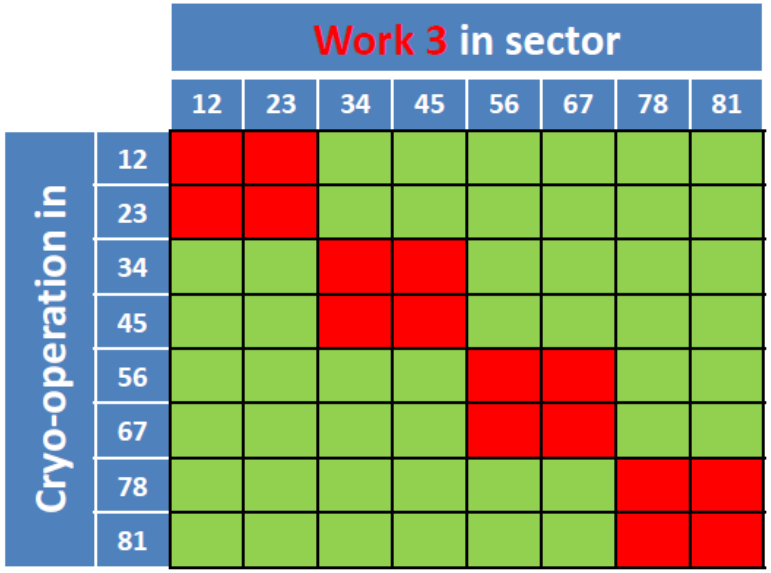
Work 1 : Opening of
- M lines, CC CM
- RF cavity CM
-V, W line
(e.g. Splice/diode repair)

Work 2 : Opening of
- E, F lines
- C, C', BS lines
- D line, SAM CM
(e.g. Q6 level capillary)

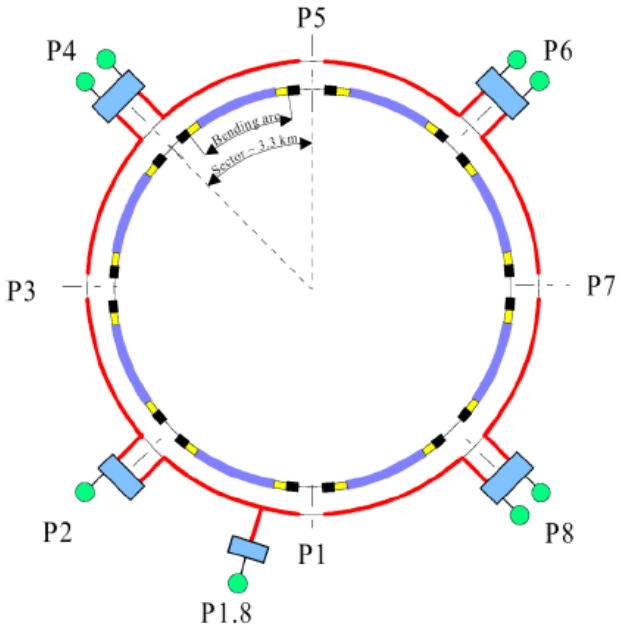




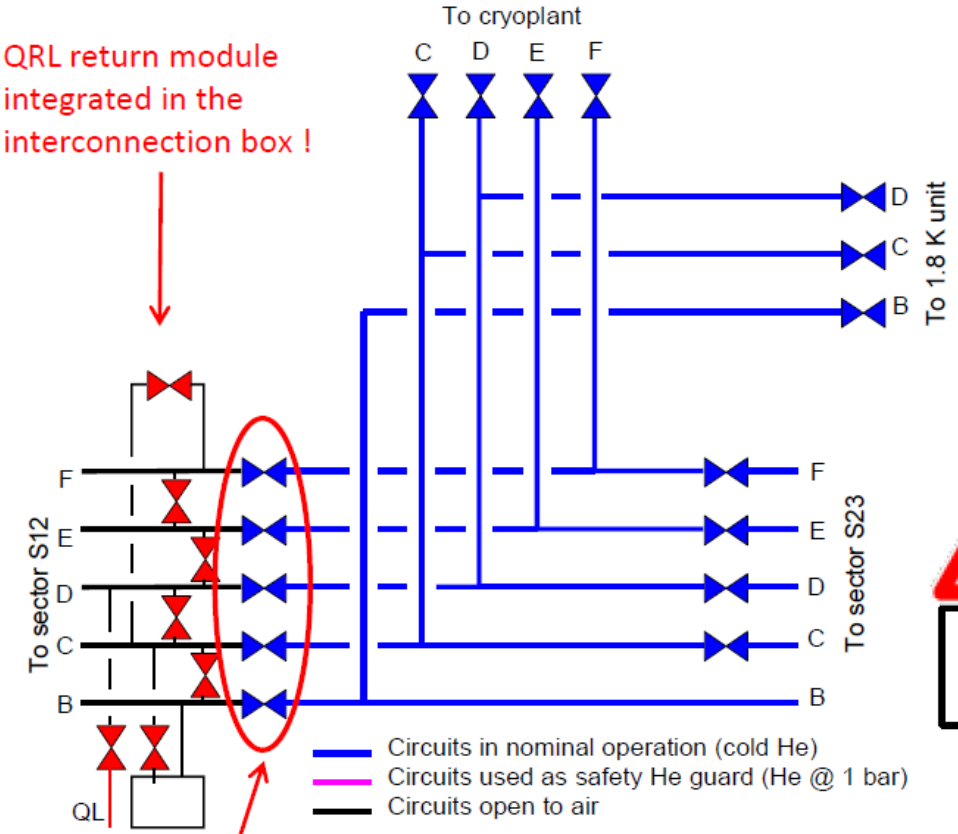
Work 3 : Opening of
- B, X, Y lines
(e.g line Y repair or magnet removal)



Sectorization: P2 configuration



QRL return module integrated in the interconnection box !



Today, no solution for work 2 and Work 3 in S12 in parallel with cryo operation in S23 !

Sectorization in between sectors: Summary

Work 1 : Opening of - M lines, CC CM - RF cavity CM -V, W lines	**Work 2** : Opening of - E, F lines - C, C', BS lines - D line, SAM CM	**Work 3 :** Opening of - B, X, Y lines

Work 1 → Ultimate sectorization already existing

Work 2 → Present sectorization does not allow Work 2 in S12 in parallel with cryo-operation in S23. Today no straight forward improvement envisaged.

Work 3 → the sectorization could be improved at the same level than Work 2 by upgrading the interconnection boxes → budget: ~ 1 MCHF