Revision of the LHC Helium WG
Introduction to HL Cryogenics

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pour le compte des équipes projets, et
en qualité de responsable de la partie cryogénie pour les derniers 10 ans

09-Jan-2025, Meeting#1

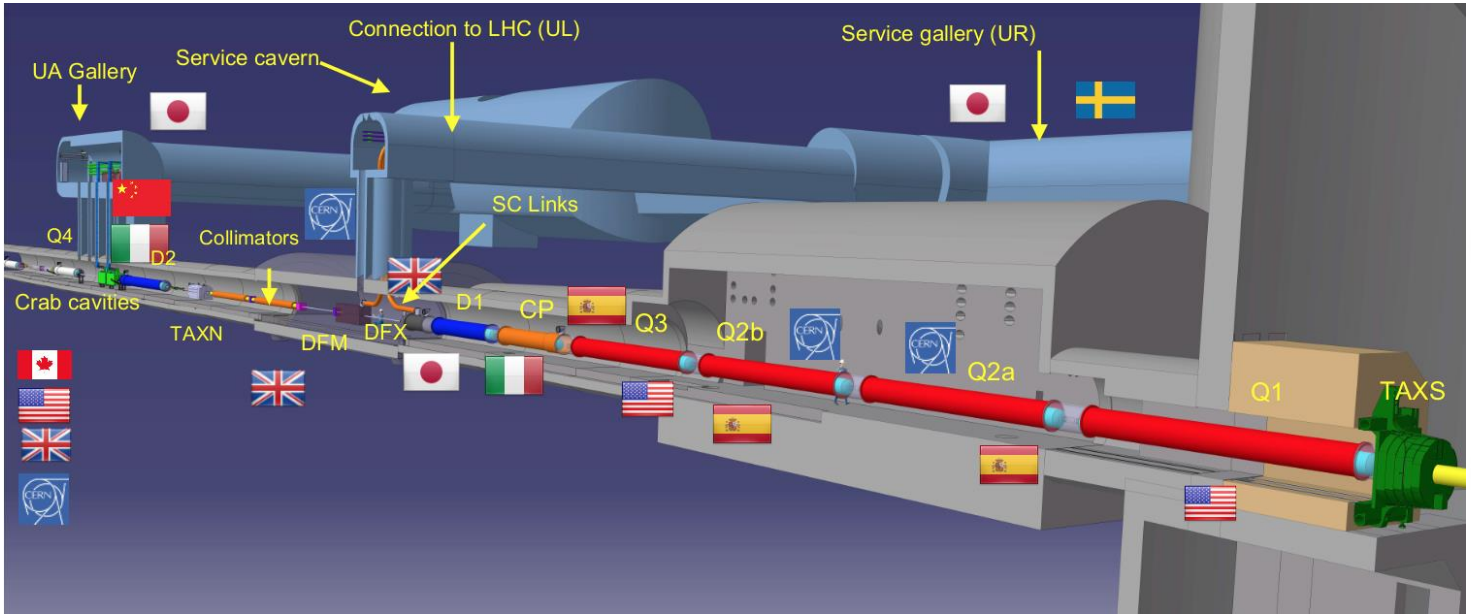
https://indico.cern.ch/event/1491143/

Content

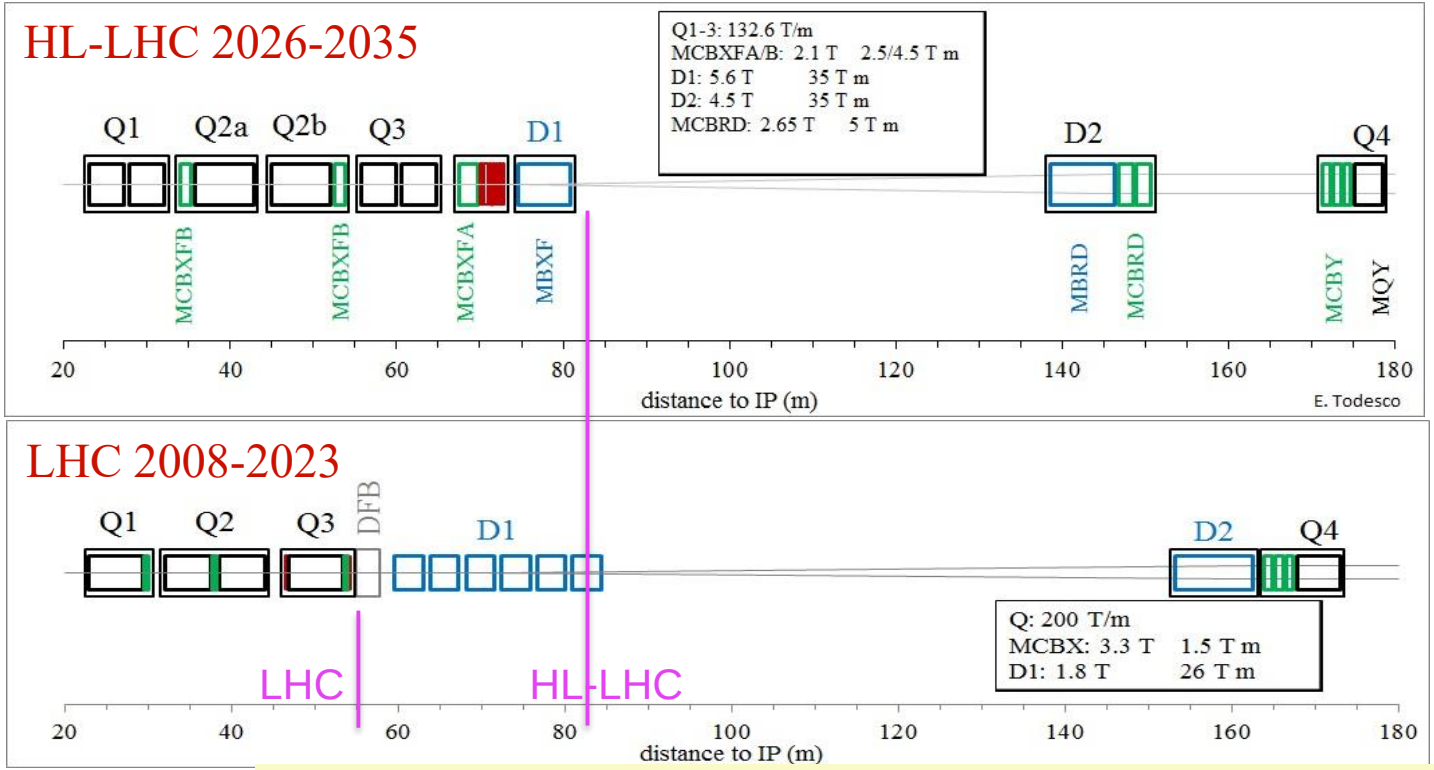
- Introduction: from HL magnets to P1/P5 cryolines
- Sectorisation (TCC#141, mid 2021)
- He release considerations so far (Aut'23)

New insertion regions (Q1 to Q4)

Stronger focussing quadrupoles (Q1-Q2-Q3) with larger beam pipes

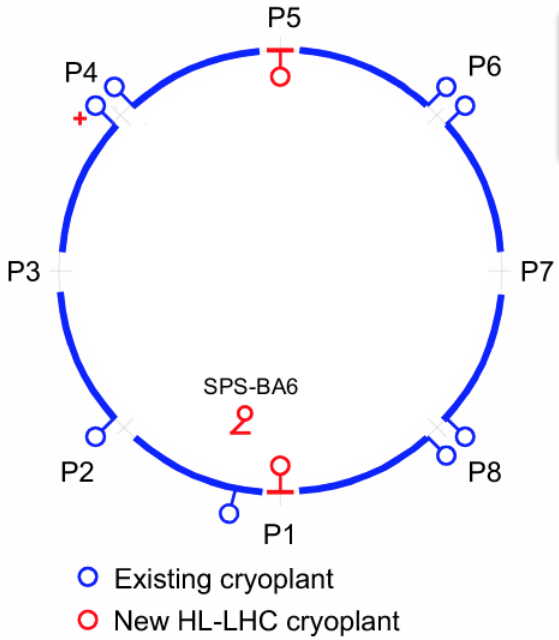


Final focussing area, superconducting magnets



Longer inner triplet continuous cryostat & multiple stand-alones

HiLumi-WP9-Cryogenics, Global scope overview



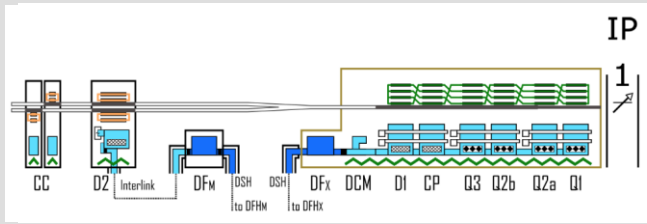
P1-P5: 2 new cryoplants (~14 kW @ 4.5 K incl. 3.25 kW @ 1.9 K) and 2 x 750m cryo-distribution for high-luminosity insertions

P4: upgrade (+2 kW @ 4.5 K) of an existing LHC 18 kW @ 4.5K cryoplant

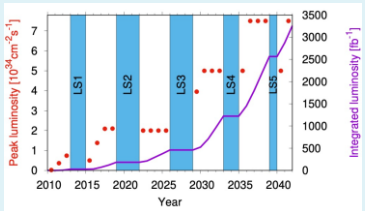
SPS-BA6: SRF test facility with beam primarily for Crab-Cavities

To provide adequate cooling for:

P1-P5 machine devices



HL-LHC performance



HL-LHC P1/P5 Cryogenic architecture

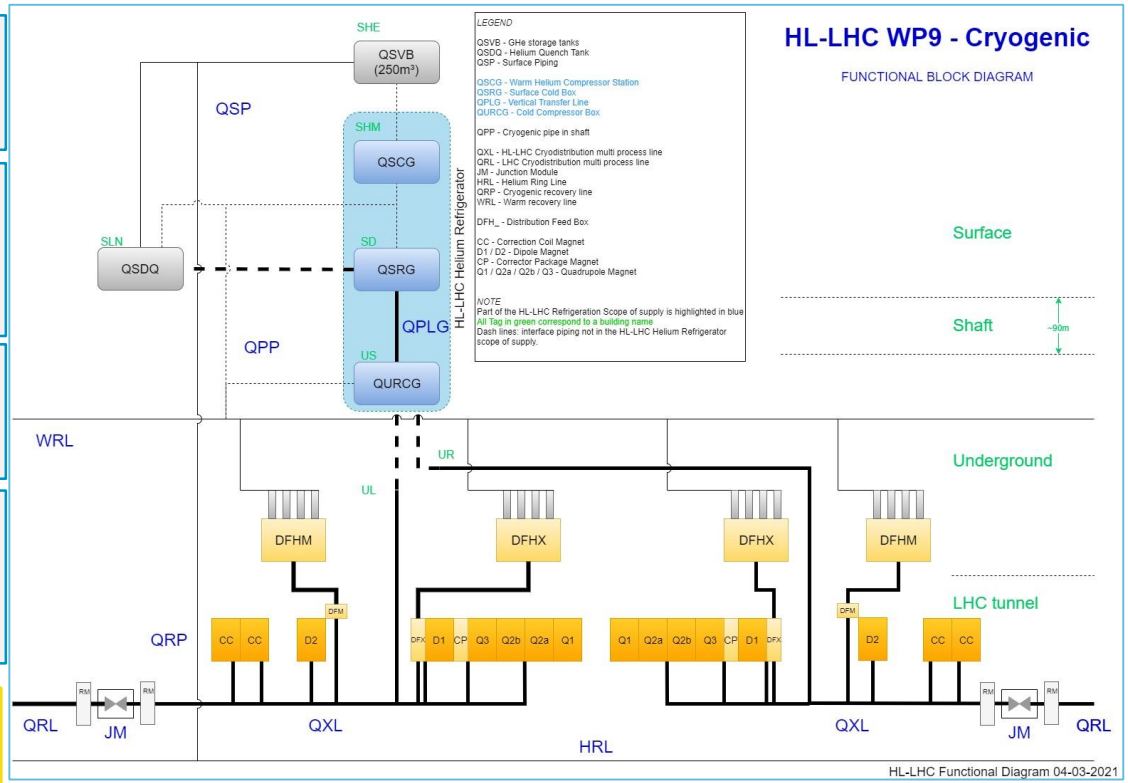
QSCG : Compressor station providing gaseous helium **20 B**

QSRG : 4.5K refrigerator providing supercritical helium at **3 bara and 4.6 K**

QPLG : Vertical transfer line (~100 m height)

QURCG : Cold compressor box providing cooling capacity at **1.8 K**

Users at tunnel level

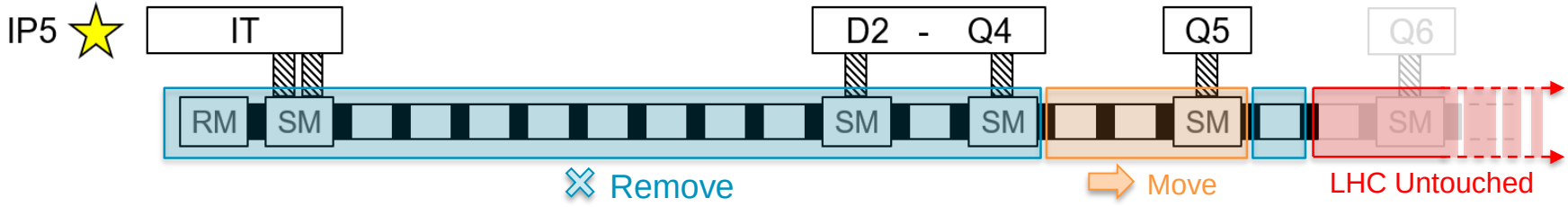


QXL : Distribution line distributing C,E and returning B,D,F

- 70 m for the common branch
- 270 m for the long branch
- 60 m for the short branch

RM/JM : Return module and junction module at extremities for transient handling and back-up

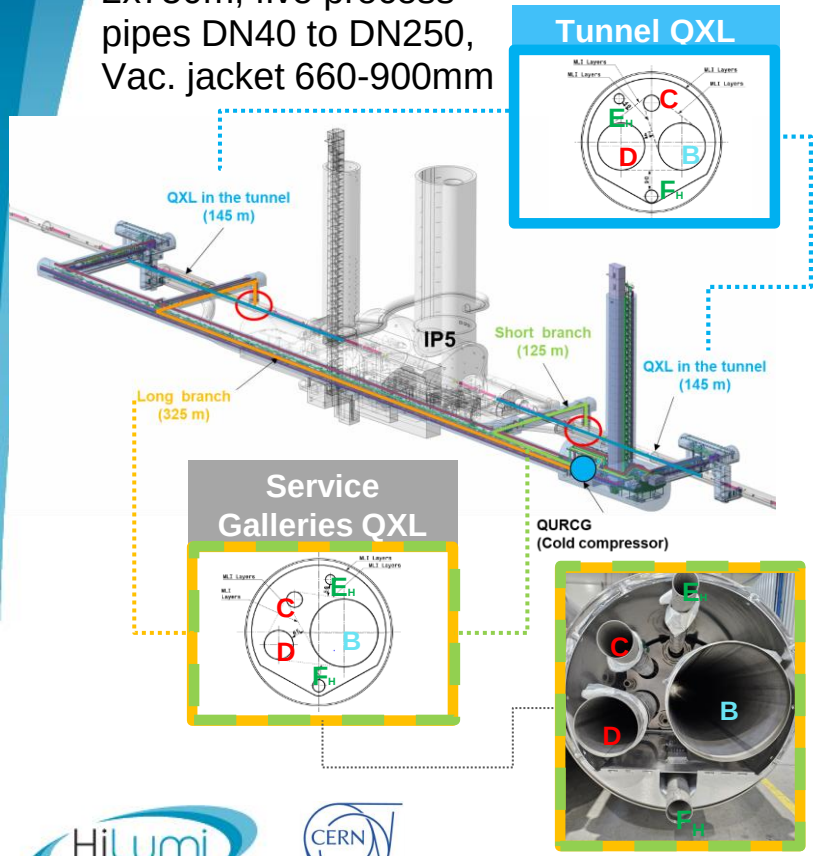
Radiation Safety: Waste Management

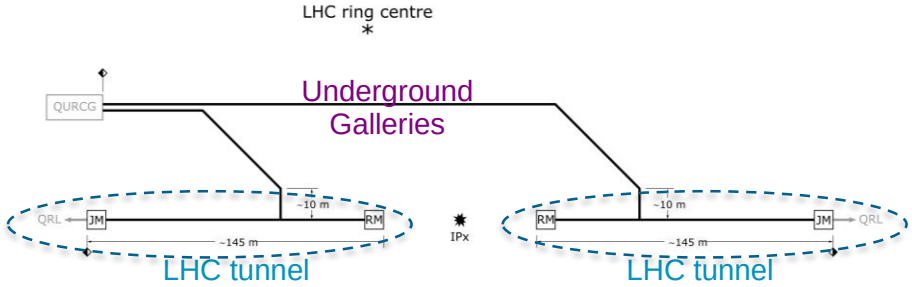


LS3 requirement	Estimated Mass	Sub-assemblies	RP Action	Storage Required
Move	~ 20 ton.	4 x SM 6 x PE	Temporary storage	Modification underground in **UX65** before reinstallation in tunnel
Spares	Up to ~ 10 ton.	2 x RM 2 x SM 1 x PE	Long term storage	**BUFFER ZONE** Classification of elements as LSA 1 or 2 → 100 m² long term spares storage – **Location TBC** → Short term ≈ 800 m² PE's disassembly and cutting **Location TBC** → Long term ≈ 100 m² SM's awaiting destruction with **HSE-RP-RWN**
Remove	Up to 110 ton.	2 x RM 10 x SM 43 x PE Warm pipes	Disposal	

HL-LHC Cryogenic distribution system (QXL)

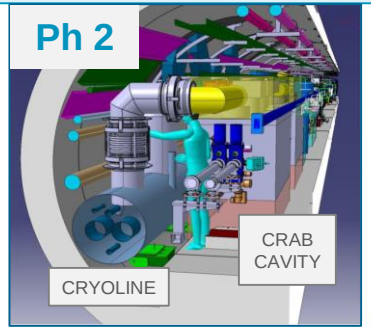
2x750m, five process pipes DN40 to DN250, Vac. jacket 660-900mm





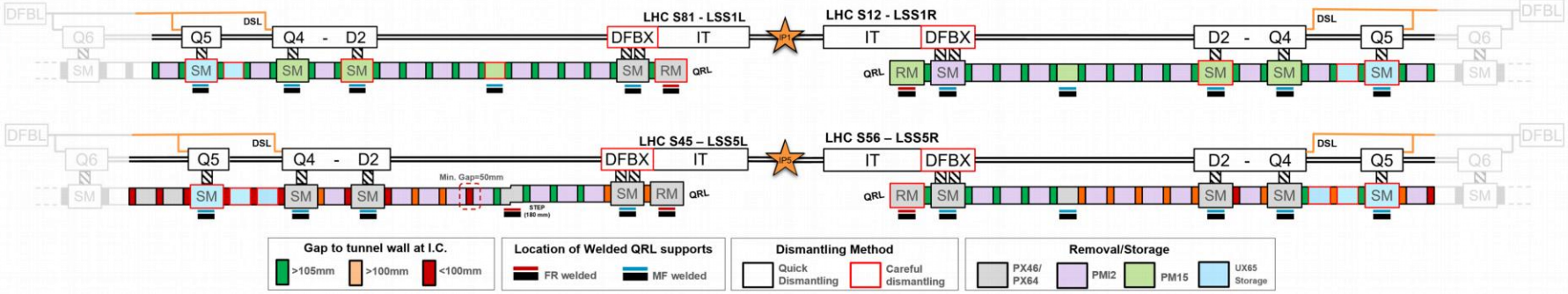
Installation strategy in two steps:

- Phase 1: in the underground galleries, independent from LHC machine operation
- Phase 2: in the LHC tunnel, after when the machine dismounting during Long Shutdown 3

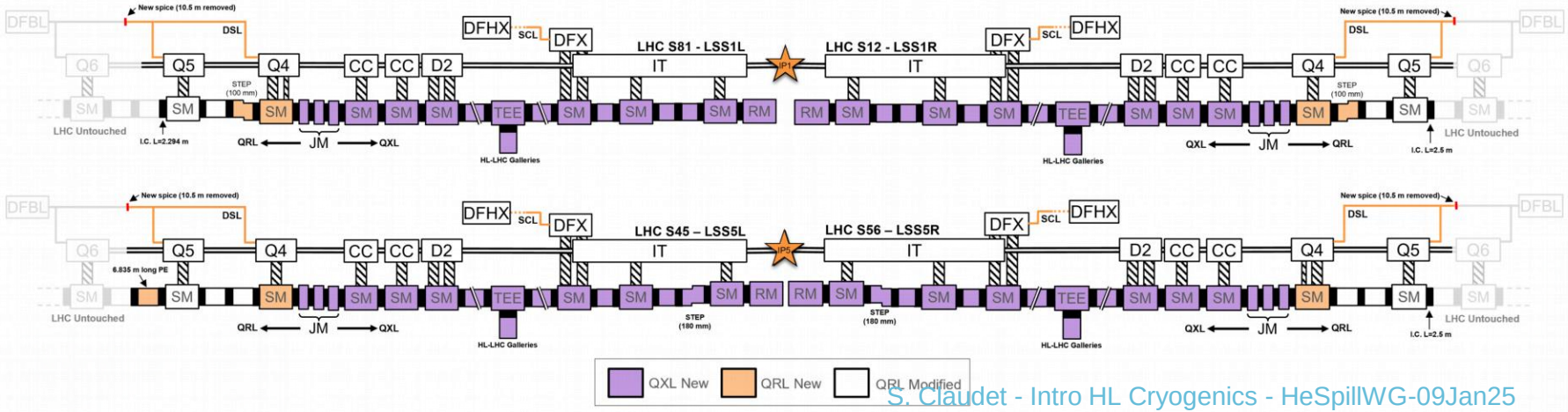


QRL Layout Overview

LHC Point 1 and 5 LSS – QRL Dismantling Constraints



HL-LHC Point 1 and 5 LSS – WP9 Reinstallation



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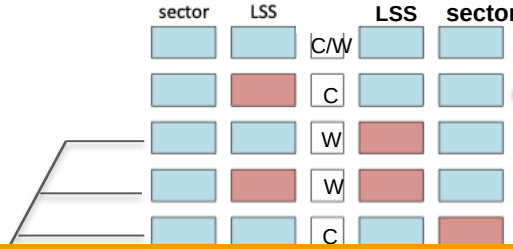
- Introduction: from HL magnets to P1/P5 cryolines
- Sectorisation (TCC#141, mid 2021)
- He release considerations so far (Aut'23)

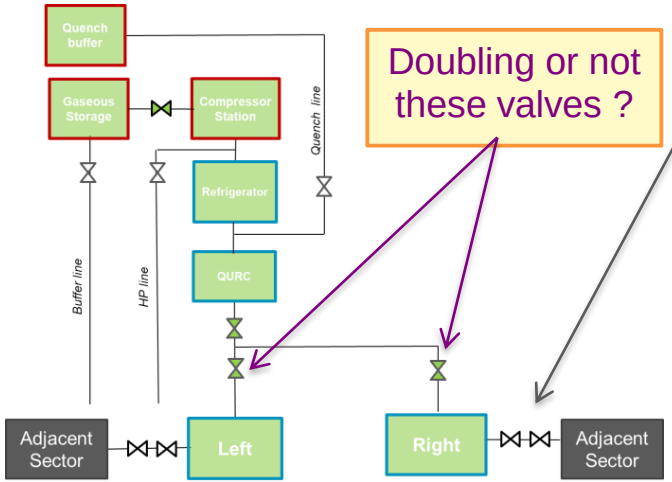
(HL-TCC#141) Sectorisation

- HiLumi magnets/users can be cooled by :
  - Adjacent sectors
  - New Refrigerators which will be installed
- Several considerations :
  - *HiLumi baseline is to cool-down both LSS at the same time*
  - *Due to access constraints during cooldown, **at this stage**, LSS/sector have to be in same state.*
  - *Periodic testing configuration shall be covered*



Normal operation

If Intervention needed on one LSS, need for double valve for left and right sides
(Not in HiLumi baseline)



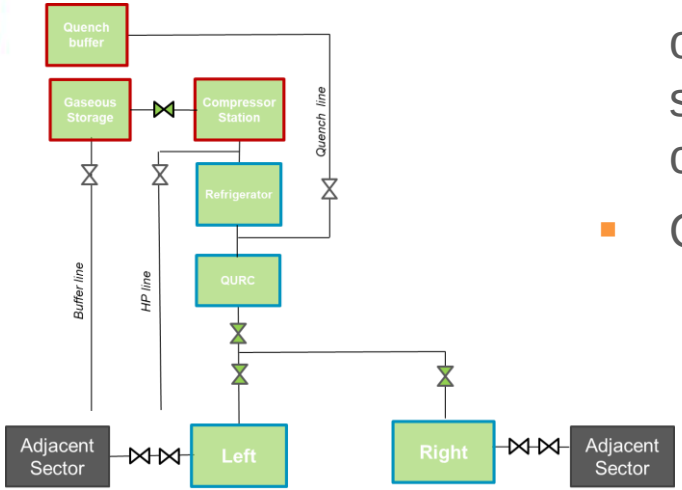
Doubling or not these valves ?

A follow-up of presentation done at TCC#138_08July'21

Specific meetings held during the summer with project-safety and cryo operation

Expressed need to develop usual cases (nominal, respective CD, repairs)

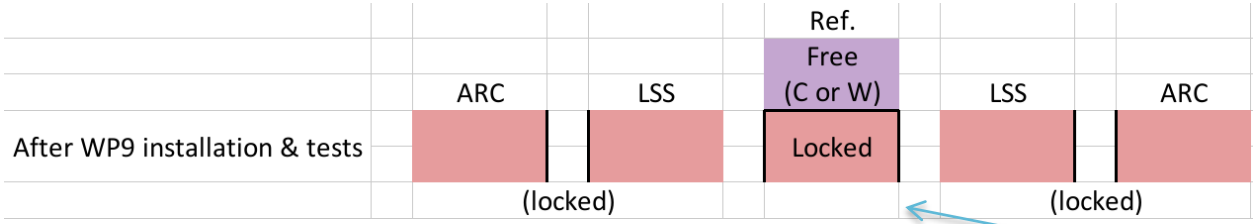
Considerations independant from decision



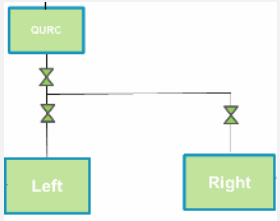
- All modes known today with LHC will be possible *(Pressure tests, lock-out, cool-down or warm-up, stable operation at 80K, 20K, 4.5K, 3K, 1.9K, IT@20K-LSS/ARC@nominal)*
- "only" one refrigerator at P1/P5 does not allow to operate the 2 LSS in a different mode. A different status of LSS can only be considered with at least one connection to an adjacent arc
- OdH and ventilation (dedicated wg to confirm):
  - Early cooling (or powering) of adjacent arc would prevent access/work in LSS
  - Early cooling of LSS could be envisaged while working in adjacent arc(s)

Some typical cases illustrated (1/4)

After HL-WP9-Cryo Installation work (LS3):

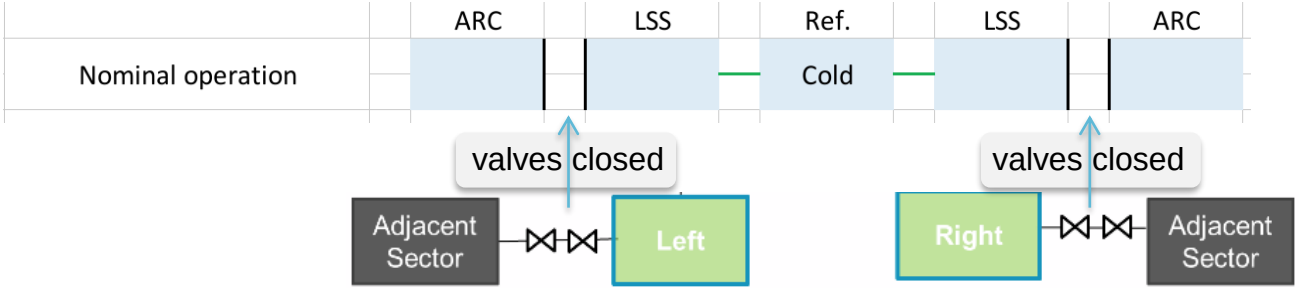


3 valves closed with pressure control and bleed in between



3 valves open

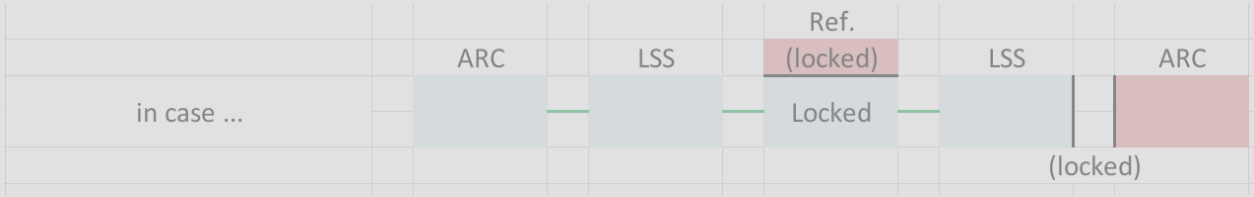
Nominal situation during Run:



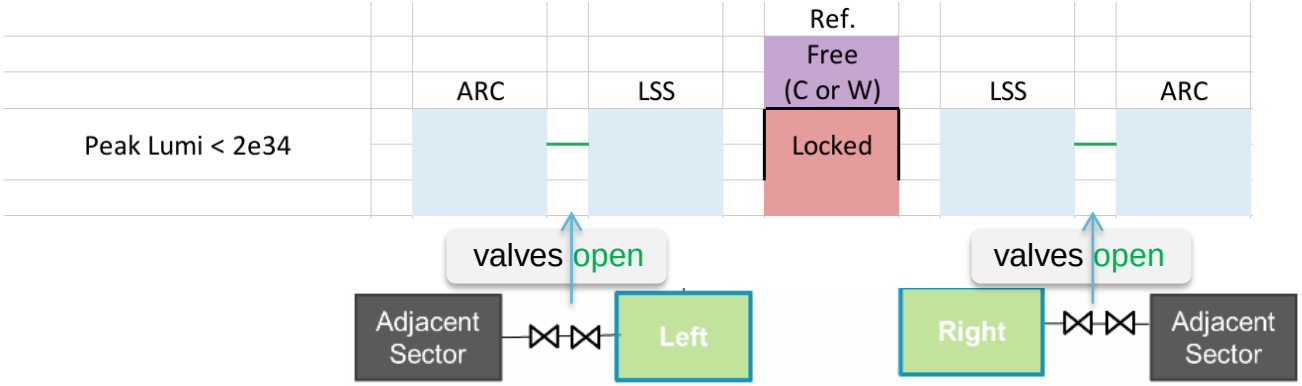
Some typical cases illustrated (2/4)

in case ...

For any reason, ... :

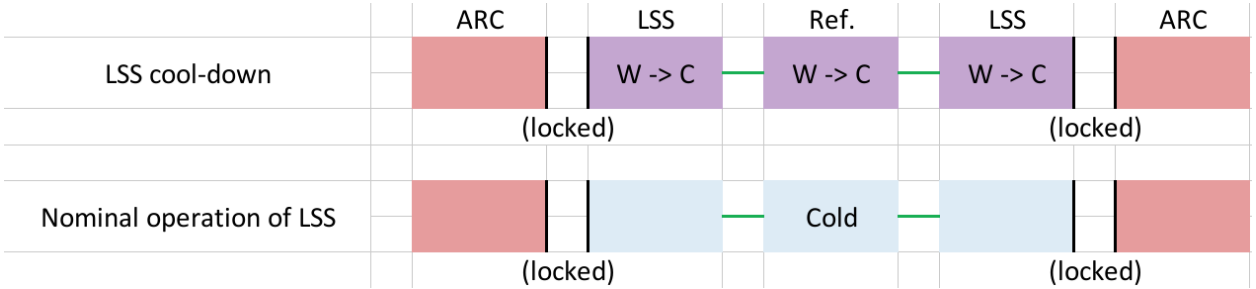


For any reason, compatible for peak luminosity below 2e34:

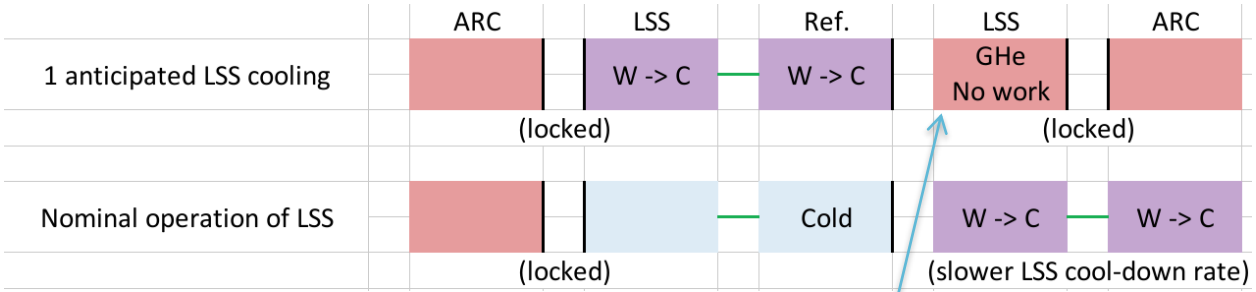


Some typical cases illustrated (3/4)

Early cool-down of 2 HL-LSS:



Early cool-down of 1 HL-LSS:



(sectorisation in QUIG would have allowed to keep working in warm LSS)

Some typical cases illustrated (4/4)

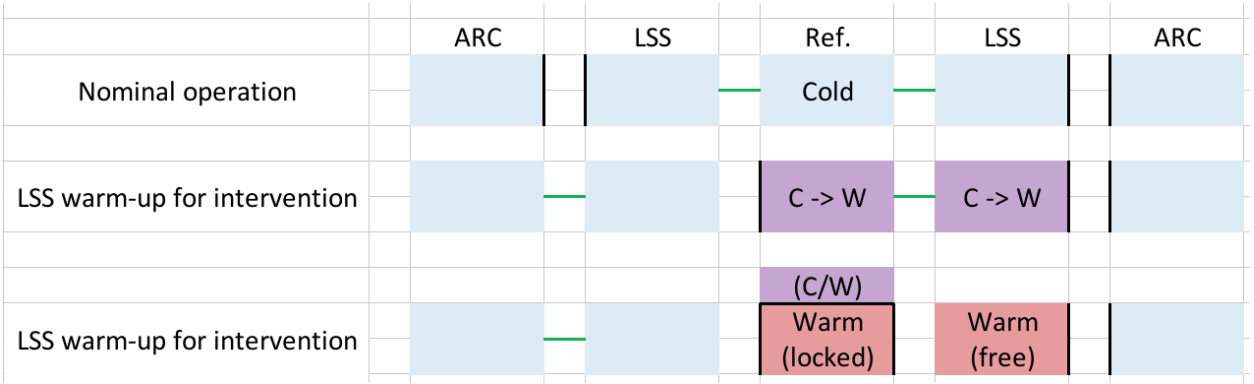
Possible

HL-LSS cold stand-by, arcs warm (LS?):

(and if later 1 LSS has to be warmed-up, 2nd will follow as 1 Ref. = 1 mode)

To be kept in mind: HL refrigerator will need 2-3 months maintenance as well (independant from the proposed simplification)

Intervention on 1 HL-LSS:



(No need for QUIG for that, the 1+2 valves in QURCG could do the job)

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HL-WP9-Cryo He release studies, Aut'23

Typical cases considered:

- A. Helium circuits

(protection against over-pressure)

- B. Helium pipe breach

(into insulation vacuum)

- C. MCI or any case

(due to powering energy)

=> Sizing of safety devices

=> Propose access conditions

CASE A - helium circuit overpressure – Preliminary flow and inventory

	Liquid inventory [kg]	SV design case	SV SP [barg]	SV flow [g/s]	BD design case	BD SP [barg]	BD flow [g/s]	Reference
DFX	~60	2x Static load	1.8	10 g/s	LIV	2.2	550 g/s	EDMS 2365987
DFM	~50	2x Static load	1.8	10 g/s	LIV	2.2	500 g/s	Private communication
CC	~20	2.5 x Static load	0.75	5 g/s	Beam vacuum loss	1.1	3510 g/s	EDMS 1900654
JM line C QXL	<0.05	LIV	20	<10 g/s	NA	NA	NA	TBA
RM QXL	*~15 (TBC)*	LIV	4	270 g/s *(TBC)*	NA	NA	NA	TBA

(limited inventory, failure open outlet process valve)

It is understood that below 1 kg/s, the release in the tunnel does not lead to a helium jam (refer to Note 2010-057)

HL-WP9-Cryo He release studies, Aut'23

(approach proposed to HL-PSO, well aligned with LHC current practice)

Different accesses cases with potential helium release to tunnel environment

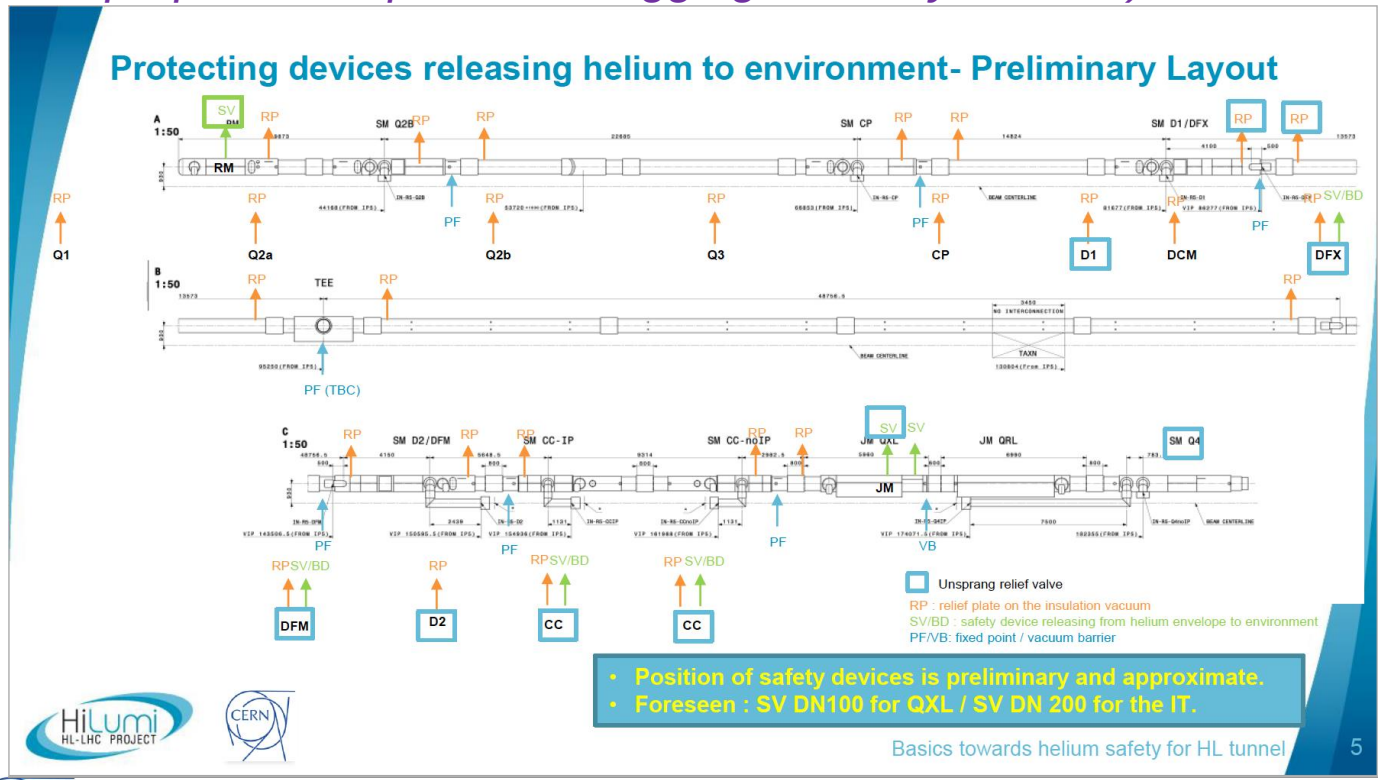
Case	A	B		C	
Volume to be protected	Helium	Insulation vacuum	Insulation vacuum	Insulation vacuum	Insulation vacuum
Operating cases	Nominal conditions	First Cooldown	Other Cooldown / *Nominal conditions*	Powering > 1.1 kA *(powering level TBC)*	Powering < 1.1 kA *(powering level TBC)*
Access	Access	NO ACCESS	Access	NO ACCESS	Access
Failure modes	LIV 2 x Static HL	Any line full rupture	Line partial rupture	Electrical arc leading to line full rupture + Quench	Limited electrical arc (partial rupture)
System	DFX DFM CCs RM QXL JM QXL	QXL line C IT CM interco *D2* *CC* *DFM* *DFX*	All	IT line M or N D2 DFX DFM *CC?*	IT D2 DFX DFM *CC?*
Goal	*Sizing of the protecting device*	*Sizing of the protecting device*	Define the release location and staggering	*Sizing of the protecting device*	Define the release location and staggering

Refer to talk of S.Claudet during last meeting for cases A, B, C definition

HL tunnel 8

HL-WP9-Cryo He release studies, Aut'23

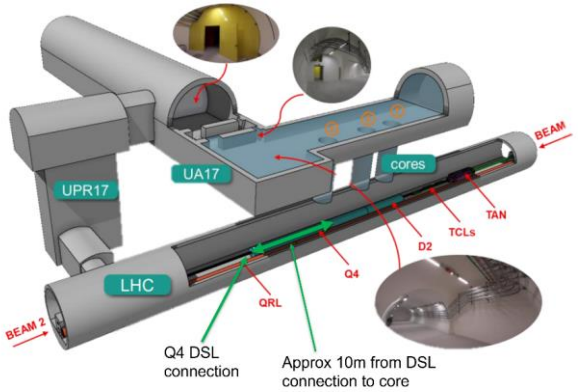
(approach proposed for possible stagging of safety devices)

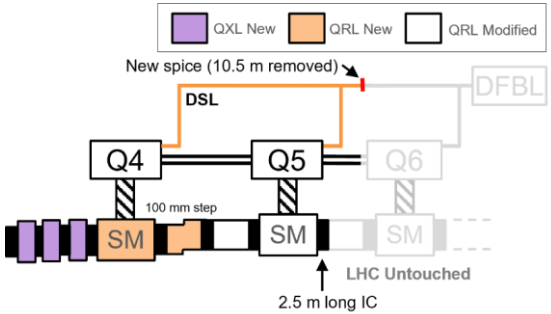


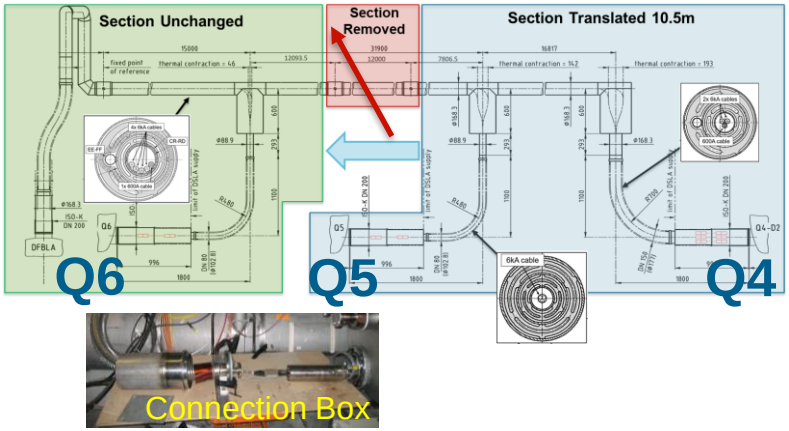
Complements

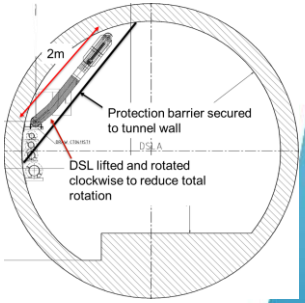
DSL dismantling / re-installation

- **One new splice box** required : Mechanical design of splice box in collaboration with TE-MSC-LMF.
- **Store** the superconducting link in the tunnel during LS3 : require a DSL protection and tooling to rotate the DSL.
- **Translate DSL** to final location and **reconnection**.

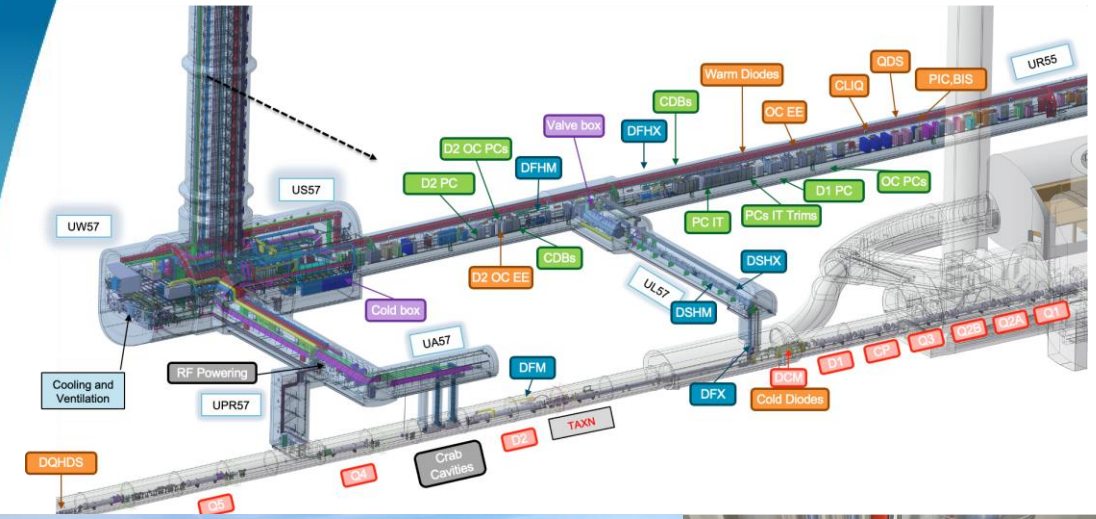


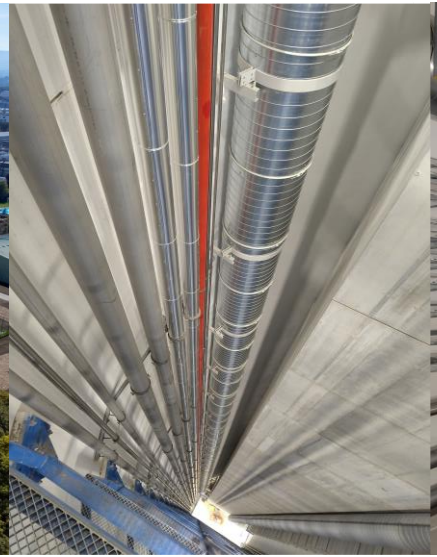






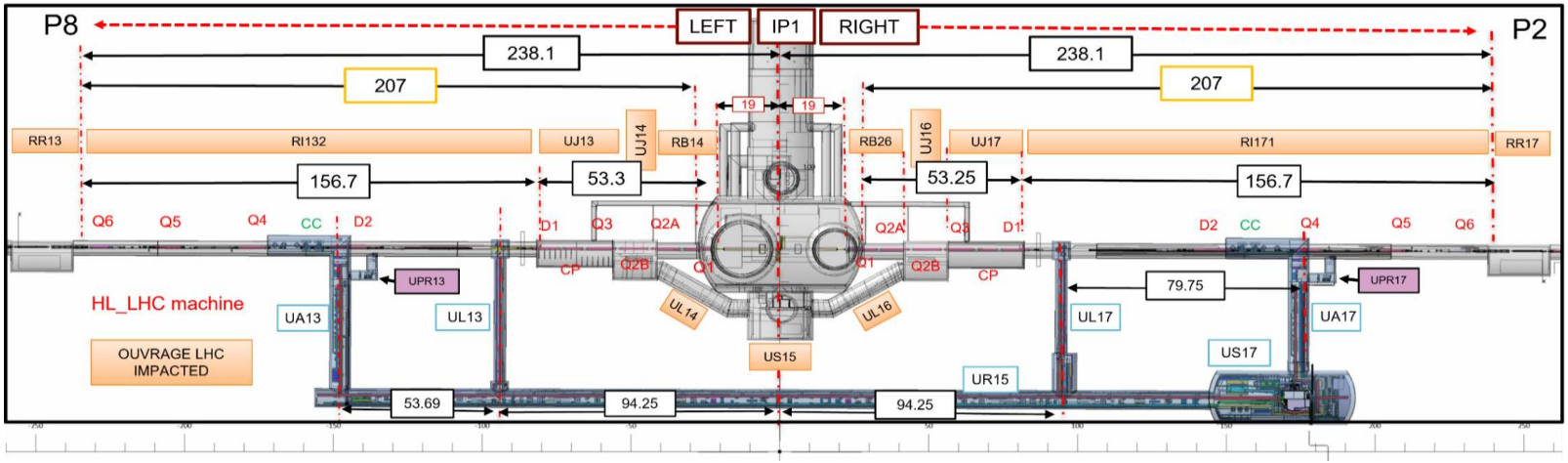
New infrastructure required and built *(surface-shaft cavern-galleries)*





Configuration in case of access

IP1 ZONE



Many relief plates to be expected:

- Q1 to DFX and QXL "T" below ULx3-x7 cores
- D2/DFM to Q4

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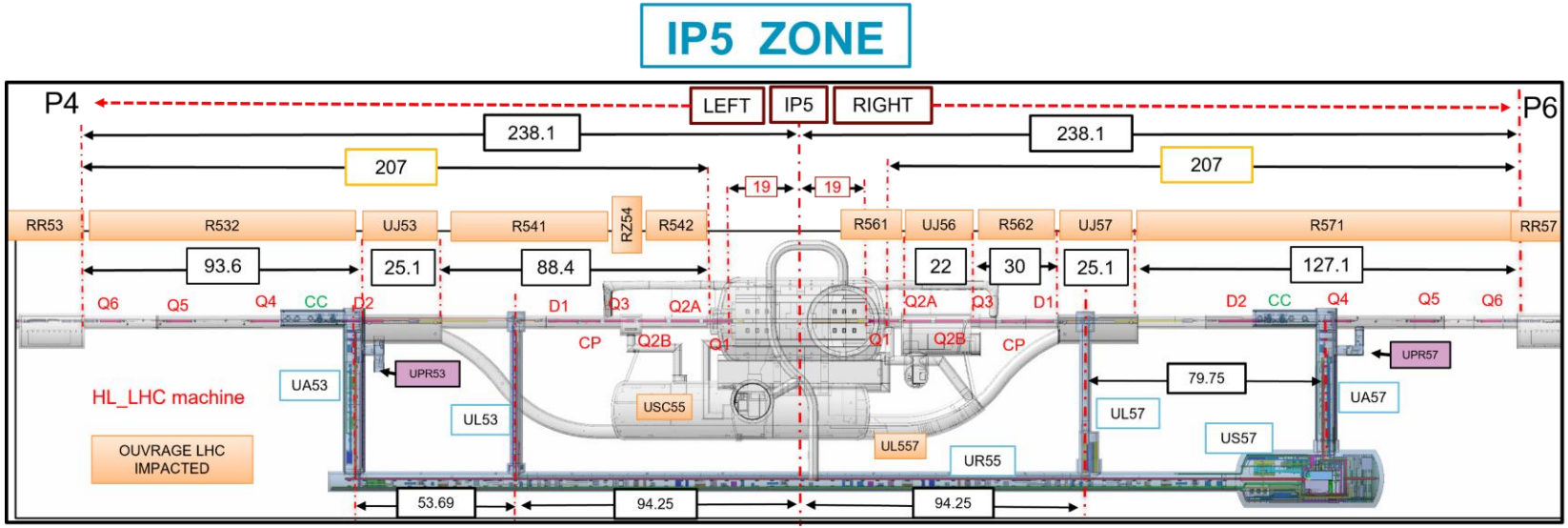

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