HL-LHC
LS3: Installation Schedule and Project Readiness.

HL Installation Technical Coordination
HL-LHC WPLs and DWPLs
EN-ACE-OSS

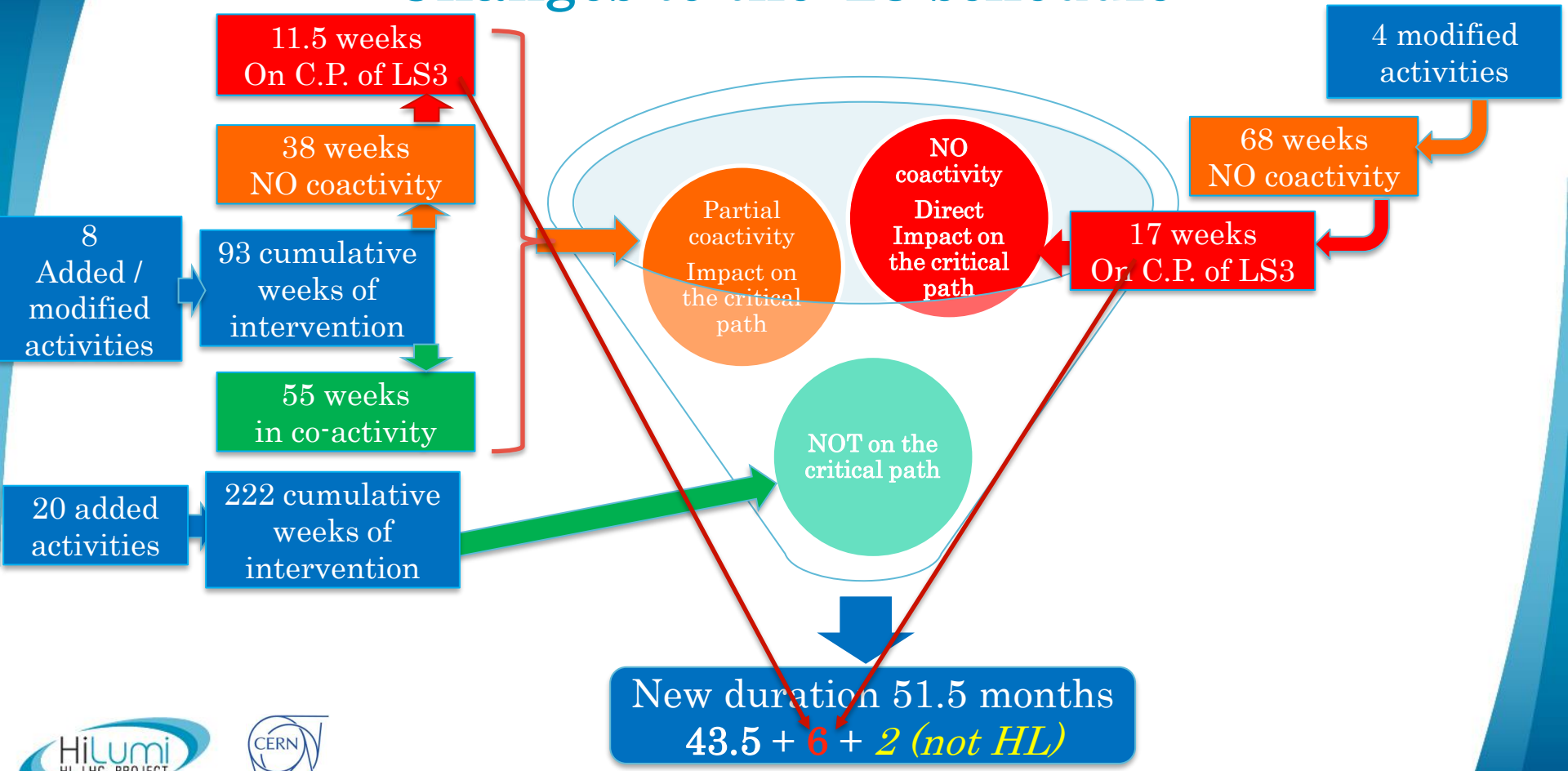
Presented by P. Fessia

14th HL-LHC Collaboration Meeting, Genoa 08/10/2024

Outline

- New inputs and schedule optimization since C&S ‘23 (November ‘23)
- Impact on the installation schedule and resulting working version to be optimized
- Recent LS3 schedule decisions and target to be achieved
- Brief description of the schedule and its main phases
- The HL-LHC Readiness for Installation and Installation Schedule Float taking into account the logistic challenge
- Conclusions

Changes to the ‘23 schedule



NOT on the critical path

Newly inserted activities with respect to HL-LHC EDMS 2400939 v.2.0 (C&S review '23, Chamonix '24)

with no impact on LS3 critical path

Activity	P1	P5	Other	Approx. cumulative working duration [weeks]
BGI,BSRT			P4	46
Installation 10 collimators			P7	16
MKIs Cool			P2/P8	12
IT beam screen treatment			P2/P8	64
60A Rad-tol PC installation	DS	DS	DS P2	18
120 A Rad-tol Power Converters	X	X	P7	12
Quench Heater Power Supplies	X	X		16
Energy Extraction 600 A	X	X		2
ElQA interface board for CP circuits	X	X		2
Dump exchange			P6	20
TCDS			P6	14

On the critical path partial coactivity

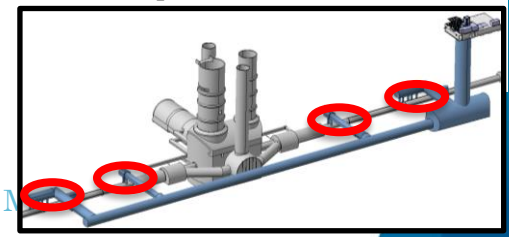
New or revised activities with respect to LS3 HL-LHC EDMS 2400939 v.2.0 (C&S review '23, Chamonix '24) with impact on the critical path

	P1	P5	Duration	Of which with impact on critical path
Water and compress air pipes overhaul IP to RR (Durations in double shift. If not X 1.7) [NEW]	X	X	Deinstallation 3 weeks per side Reinstallation 4.7 weeks per side	1 + 2 weeks *2+2.7 weeks in // with EN-EL, but geographically shifted*
Revision of HL Minor Civil Engineering works P1	X		5-7 weeks per IP side	2 weeks per IP side (1 for floor preparation 1 for the IT rails installation) *3-5 weeks in // with cores (6 months window)*
Revision of HL Minor Civil Engineering works P5		X	14-16 weeks per IP side	5 weeks per IP side (5R & 5L 2 grinding for QXL 5R & 5L 1 floor preparation 5L 2 cores/grinding for cables 5R 2 metallic structure UJ57) *9-11 weeks in // with cores (6 months window)*
Revision of QRL re-installation and DSL modification	X	X	Possibly 4 weeks extra work duration due to complexity of QRL/DSL parallel activities[1)]	2 weeks per IP side
P1 Minor Civil Engineering Works for ZDC P1 **(NEW NOT HL project)**	X		1 week	1 week
P5 Minor Civil Engineering Works for ZDC P5 and PPS2 **(NEW NOT HL project)**		X	2 weeks (1 on 5L)	1 week (0 5L)

Vertical Cores

ON the critical path NO coactivity

- The Invitation to Tender for the core excavation, issued in November 2023, did not allow to select a suitable contractor
  - Many bidders dropped out during the process
  - The remaining bidders did not demonstrate to have suitable technical solutions to carry out the work (exceeded allocate time and risky execution)
- The unsuccessful outcome of the tender was attributed, in addition to the inherent civil engineering complexities of the project, to the request to have only 2 months of excavation in the LHC tunnel. The proposed strategy was to have separate excavation phases between HL galleries and LHC tunnel: from HL in the EYETS and LHC in the LS3. The target was to minimize the LS3 duration. Unfortunately, this approach contributed to have potential bidders dropping out.
- For the upcoming tender it was decided to revert back to 2017 baseline planning **to allow 6 months for execution of vertical cores in the LHC tunnel (instead of 2 months→+4 months on the critical path).**
- A set of core test with new techniques will take place in the upcoming weeks at CERN
- As the execution of the vertical cores in the LHC tunnel is on the critical path of LS3, a contract will be developed to motivate bidders to **reduce** the proposed planning (e.g. financial incentives).

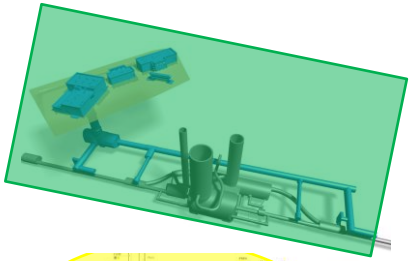


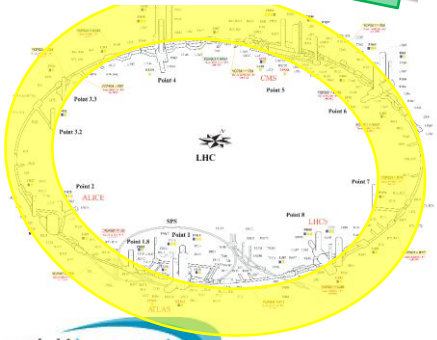
Presented Schedule and recent Schedule decisions

- The schedule version, used as reference in this presentation, features
  - 51.5 months duration
  - Start mid November 2025
- This schedule was the version presented by the HL-LHC project at the LS3 Readiness Review (LS3RR) of the 11-13 September
- This schedule will be the reference for the WPs presentations at the upcoming C&S review 2024
- After the LS3RR the Research Board endorsed a LS3 schedule with
  - 47 months duration
  - Start 1st July 2026
- It is therefore necessary to optimize the activities in order to gain **4.5 months to meet the allocated window** while start is delayed of 7.5 months

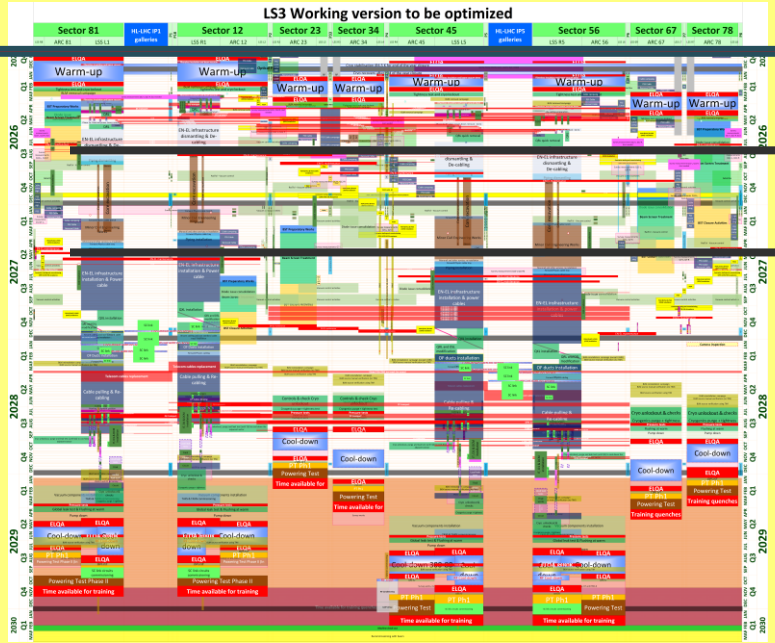
HL installations during Run3 and LS3

LS3 starts 17th November 2025



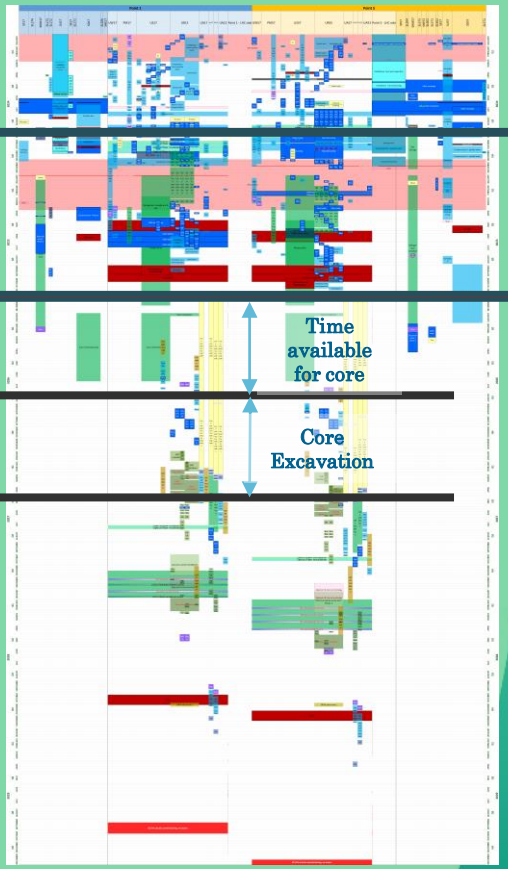


LHC LS3 schedule



HL-LHC new installations

LS3RR



Courtesy M. Barberan

HiLumi HL-LHC PROJECT

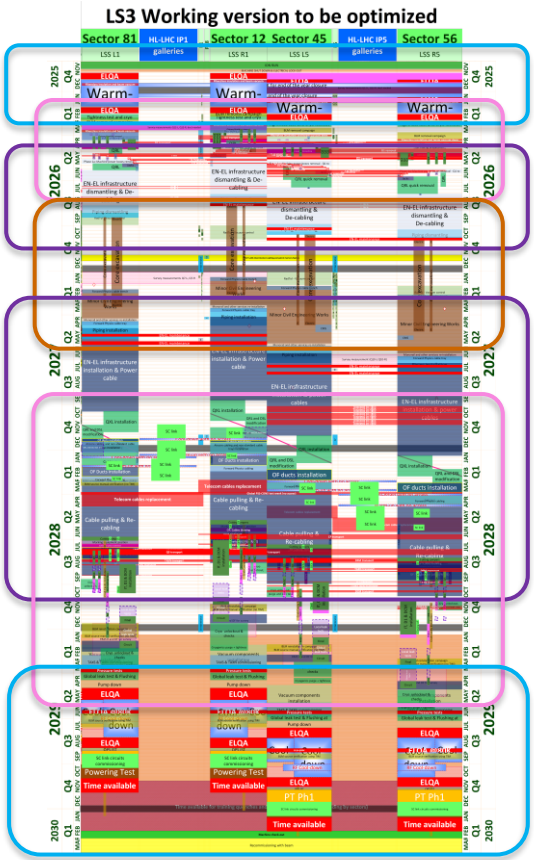
HL-LHC project LSS1 and LSS5

Warm-up and related tests

Cabling and CV dismantling

Cabling and CV installation

Cool-down, related test & HWC



LSS dismantling after cryo lockout

Core excavation and MCEW

LSS installation

LSS dismantling after cryo lockout

- Beam vacuum, magnets, collimators, QRL dismantling

Cabling and CV dismantling

- Optical fibre duct cut and displaced, de-cabling and EN-EL infrastructure dismantling
- Piping dismantling

Core excavation

- Core excavation and Minor Civil Engineering work

Cabling and CV installation

- Power cable infrastructure installation (from core excavation to QXL installation)
- Piping installation

LSS installation

- QXL installation + Cold test
- SC link(DSHX/M) unspooling (after first QXL installation)

Cabling installation

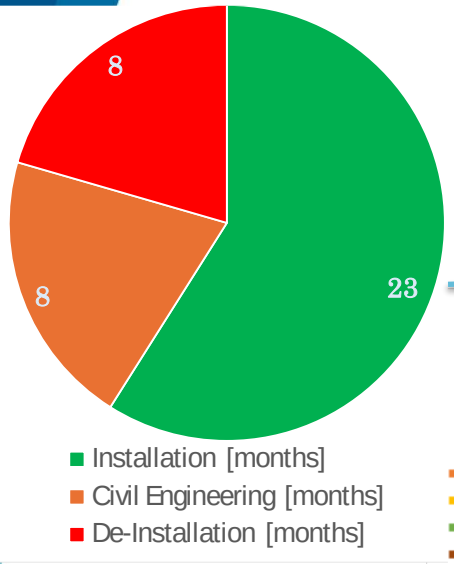
- Optical fibre installation, re-cabling, pulling/blowing cables and test

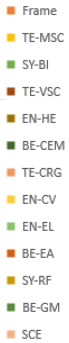
LSS installation

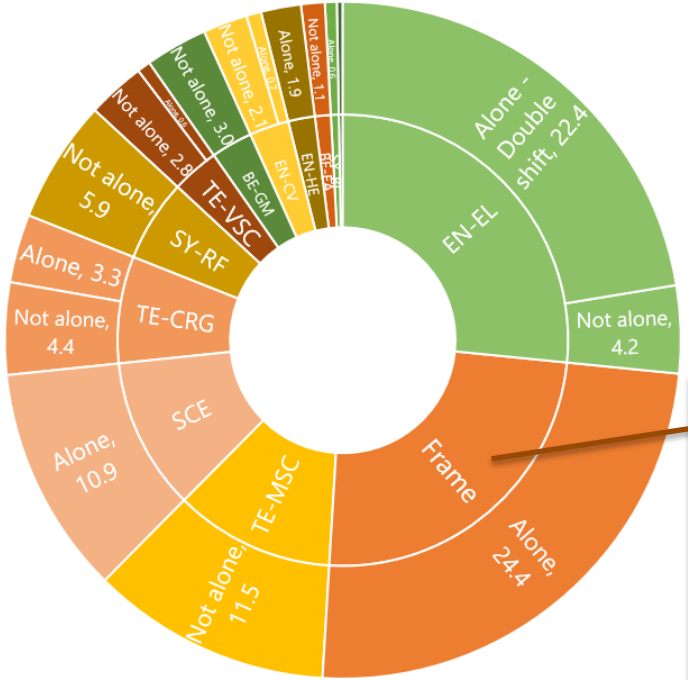
- Beam vacuum, magnet, Crab cavities, collimators, TAXN, DFX/M, …

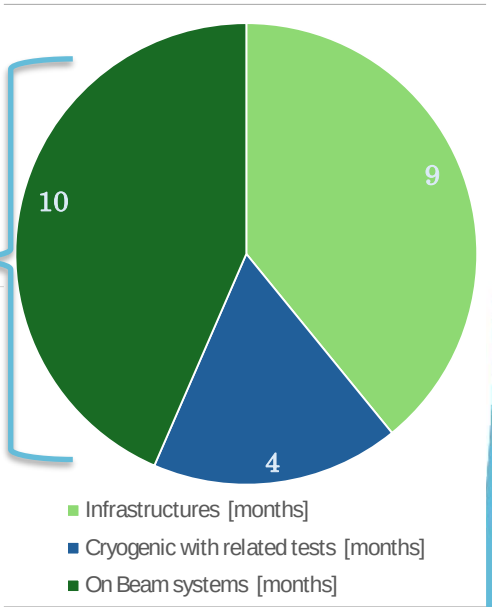
Courtesy M. Barberan

The phases of HL-LHC intervention and critical path





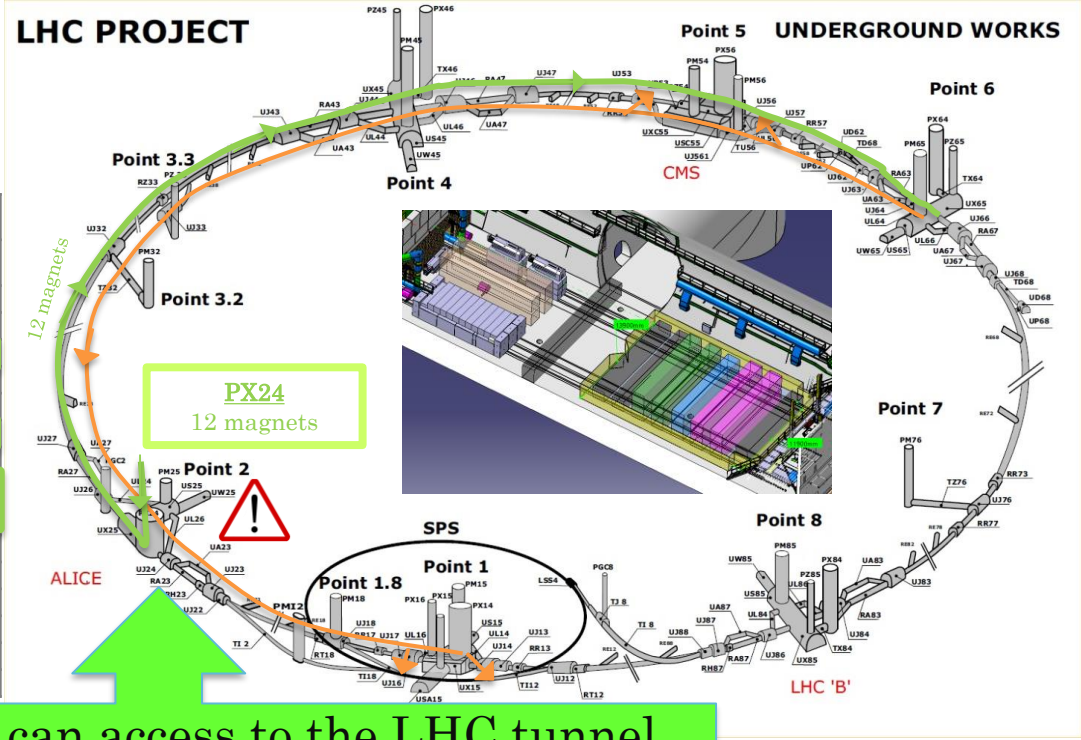




Frame:
The set of operations that needs to be carried out independently of the activities to be executed during an LS and needed to make the machine available for intervention and to bring it back in operation

Elements to be installed in LHC tunnel

Point 1		
Magnets/ Element	Qty	Shafts
Q1	2	PMI2
Q2A	2	PMI2
Q2B	2	PX24
Q3	2	PMI2
CP	2	PX46/PX64
D1	2	PX24
D2	2	PMI2
Q4	4	PX24
Q5	2	PX24
Q10	2	PMI2
TAXN	2	tbd
DFM	2	PM15
DCM	2	PM15
CC type A	2	PM15
CC type B	2	PM15



Storage UX 65
4x 2Q2B
4x D1
2x Q4 (4)
2x Q5

Point 5		
Magnets/ Element	Qty	Shafts
Q1	2	PMI2
Q2A	2	PMI2
Q2B	2	PX24
Q3	2	PMI2
CP	2	PX46/PX64
D1	2	PX24
D2	2	PMI2
Q5	2	PMI2
Q10	2	PMI2
TAXN	2	PX46/PX64
DFM	2	PX46/PX64
DCM	2	PX46/PX64
CC type A	2	PX46/PX64
CC type B	2	PX46/PX64

These magnets can access to the LHC tunnel only through the experimental cavern of ALICE. The transport blocks ALICE activity hence limited window is available

Courtesy M. Perez Ornedo

Installation Schedule Float along each main installation front

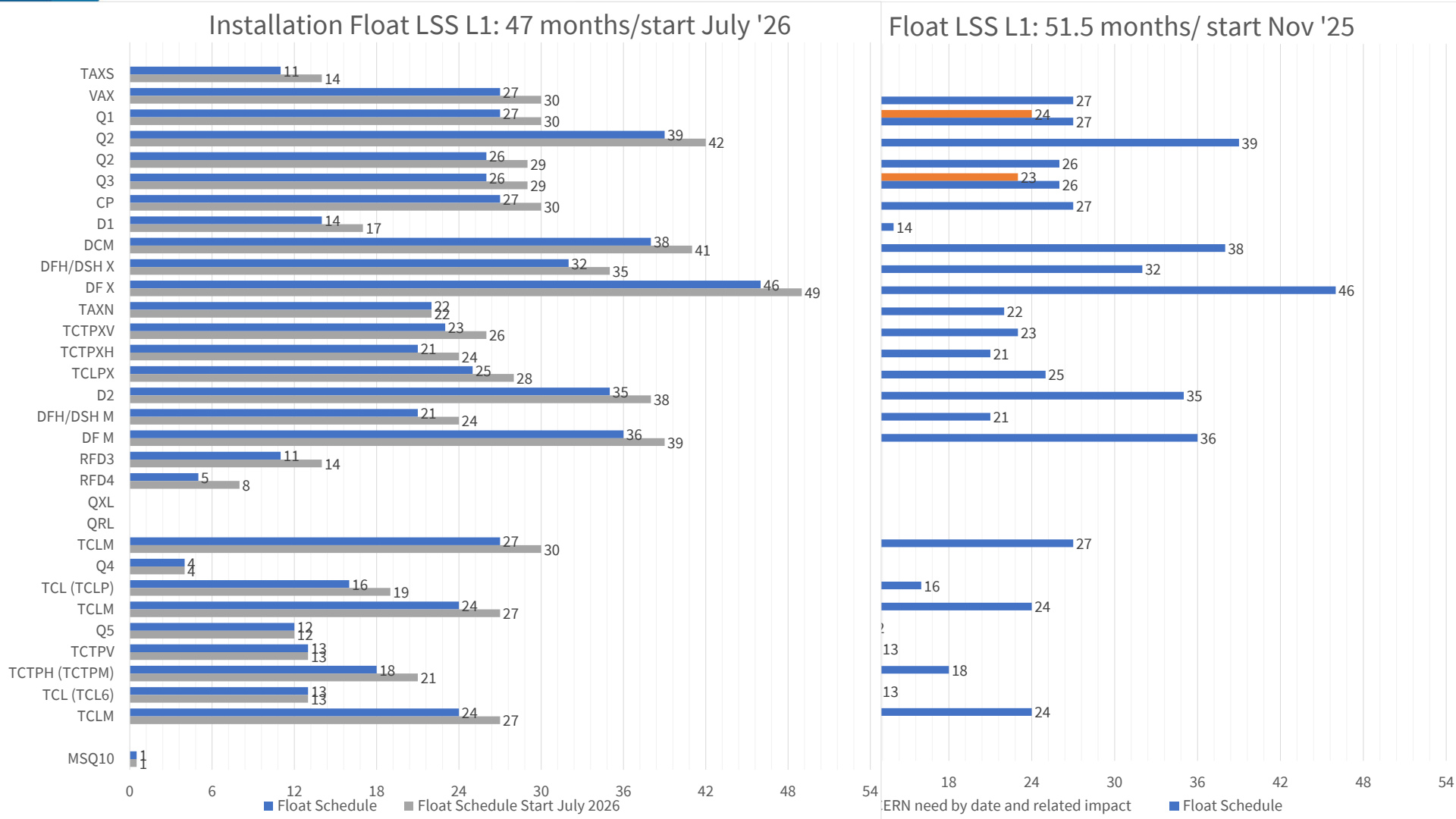
Installation Schedule Float =
Equipment Transport date – Equipment Readiness date

Reference data used for the float evaluation

- From WPs:
  - Ready for installation dates. The ready for installation is the date when the equipment is ready to be transported from storage on CERN site to its installation position (or to the intermediate tunnel storage). It accounts for all the required preparatory phases and final tests. Provided by the WPs. It accounts for any intervention (contribution) required by the various groups (i.e. final vacuum tests)
  - These dates are reported in the Master Schedule of each WPs. Modification in excess of 2 months are circulated at full project level via Schedule Change Request (SCR). These documents are presented to the HL Project Steering Meeting (PSM) and to the HL-TCC (selected ones). The dates are discussed (at least) in the WP PSM (between 2 and 4 times per year). The WP Master Schedules are included in the WP reports.
  - This early October '24 data updates are taken from the latest PSM/SCR or topical schedule discussions. Dates and data are validated previously by WPLs. As consequence this presentation does not account for any schedule change communicated during this Meeting.
- From the HL Installation Technical Coordination and EN-ACE-OSS
  - The installation dates
    - The working version of the schedule to be optimized presented at the LS3 Readiness Review 12/09/2024 by EN-ACE OSS that integrates the 6 months (4+2) duration increase requested by HL (see previous slides) plus other changes not HL related
    - For reference previous approved baseline schedule *Schedule for New Underground galleries installation and LS3 HL-LHC activities EDMS 2400939 v.2.0 LHC-_-MS-0003 v.2.0*
  - The transport dates, these are moment when the equipment has to be removed from its storage to be transported to the tunnel and arrive to its installation location. Therefore, it accounts also possible stops in intermediary storage areas as UX65 and sector transport restrictions.

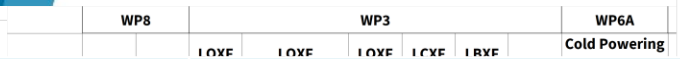
Remarks on data used for AUP deliverables

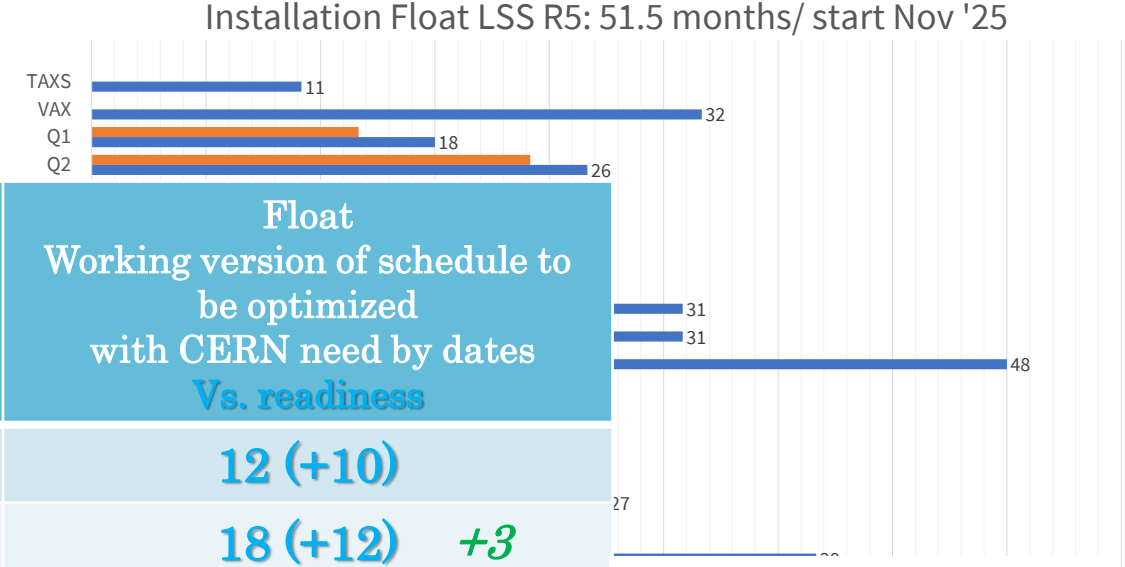
- For magnets two sets of data are shown
  - AUP optimistic delivery dates
  - AUP CERN Need By Date (previously referred as Contractual Dates) and their impact on non-AUP delivered units
- For RFD Crab Cavities
  - Only AUP CERN Need By Date (previously referred as Contractual Dates) in all analysis


Installation Float LSS L1: 47 months/start July '26
TAXS 11 14
VAX 27 30
Q1 27 30
Q2 39 42
Q2 26 29
Q3 26 29
CP 27 30
D1 14 17
DCM 38 41
DFH/DSH X 32 35
DF X 46 49
TAXN 22 22
TCTPXV 23 26
TCTPXH 21 24
TCLPX 25 28
D2 35 38
DFH/DSH M 21 24
DF M 36 39
RFD3 11 14
RFD4 5 8
QXL
QRL
TCLM 27 30
Q4 4 4
TCL (TCLP) 16 19
TCLM 24 27
Q5 12 12
TCTPV 13 13
TCTPH (TCTPM) 18 21
TCL (TCL6) 13 13
TCLM 24 27
MSQ10 1 1
0 6 12 18 24 30 36 42 48 54
Float Schedule
Float Schedule Start July 2026
Float LSS L1: 51.5 months/ start Nov '25
27
24
27
39
26
23
26
27
14
38
32
46
22
23
21
25
35
21
36
27
16
24
13
18
13
24
18 24 30 36 42 48 54
ERN need by date and related impact
Float Schedule

Installation Flo

IP side





Magnets Assembly	Float Working version of schedule to be optimized with CERN need by dates Vs. transport		Float Working version of schedule to be optimized with CERN need by dates Vs. readiness	
Q4	2		12 (+10)	
D1	6	+3	18 (+12)	+3
Q2b	8	+3	20 (+12)	+3
Q3	10	+3	12 (+2)	+3
Q1	14	+3	16 (+2)	+3
Q5	18		18 (0)	
CP	18	+3	20 (+2)	+3
Q2a	23	+3	25 (+2)	+3

Potential effect of the LS3
shift of start to July '26 and 47 months duration
vs.
start Nov. '25 and 51.5 months duration

Conclusions I

- The presented HL-LHC working version of the schedule to be optimized requires 6 months more for its implementation with respect to the baseline presented in C&S '23 and Chamonix '24.
  - The extra time is required by a series of installation activities (+2 months) and to provide a window of 6 months (+4) in the LHC tunnel, compatible with the 2nd IT (under preparation) for the execution of the cores.
  - The results of the IT (end Q1 2025) will allow to fix the core execution schedule in that window

- A shifted start to July '26 is not "a ready to grab" opportunity to advance HL activities before LS3.

- The new endorsed LS3 schedule (start July '26 and 47 months duration) requires aggressive actions in order to gain the 4.5 months necessary to fit in the provided window

Conclusions II

- Taking into account the time to be gained, the shift of LS3 start date from mid-November'25 to 1st July '26 could provide perhaps 3 months of extra float at this stage of the schedule optimisation [to be updated once the exact duration of the core drilling becomes available after the contract signature].

- These 3 months SHALL NOT BE USED to postpone the presently set delivering dates. It is paramount to reach those targets in order not to endanger the smooth flow of LS3 taking into account also the logistic challenges.

- The on-time readiness of the equipment is a key asset in order to deploy aggressive policies allowing to reach the target duration of 47 months.

- **Possible implications on the installation scope and schedule, of delivery date updates not yet evaluated/approved by the WPLs, were not part of this presentation**

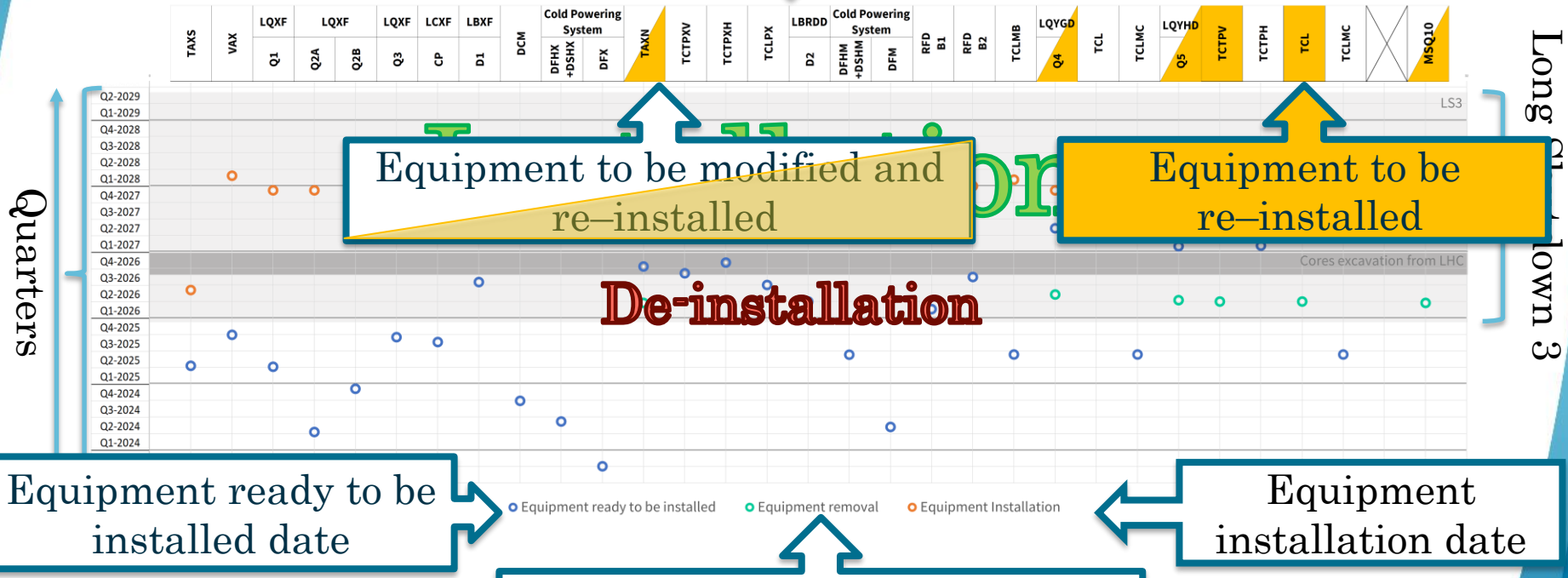
Annexes

Quick explanation of graphs

Interaction Point

Equipment, geographically ordered

Arc



Quarters

Long Shutdown 3

Equipment to be modified and re–installed

Equipment to be re–installed

Equipment ready to be installed date

Equipment installation date

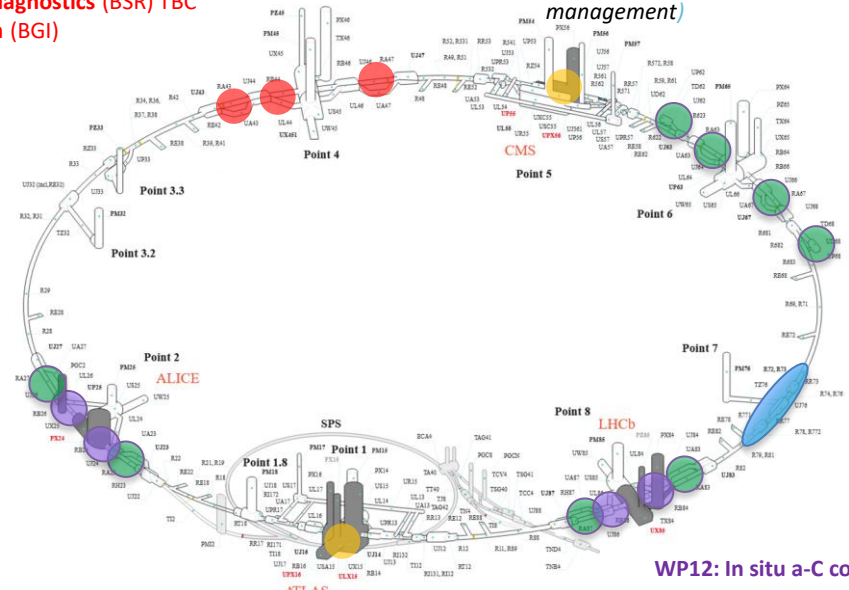
Removal date for equipment to be modified and re–installed

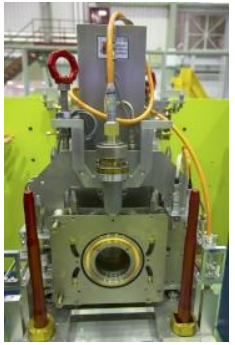
HL-LHC during LS3:
Experiments and other activities than P1 & P5 *DRAFT*

WP5
WP8
WP12
WP13
WP14

WP13: Beam Gas Curtain
WP13: Synchrotron Light Diagnostics (BSR) TBC
WP13: Beam Gas Ionisation (BGI)

WP8: VAX installation at CMS
(VAX/TAXS installation: boundary conditions due also by CMS Schedule; under discussion with CMS management)

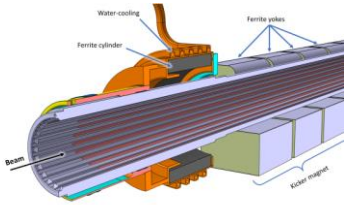




VAX mock-up

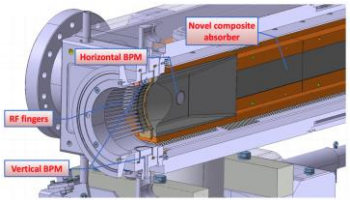
WP14: TDE Dump at TD62 and TD68
WP14: TCDS absorbers

WP12: In situ a-C coating on IT
WP14: 4 MKI cool at P2/P8
WP14: Mask D1 at P2 and P8



MKI cool

WP5: 10 TCSPM secondary collimator



TCSPM 3D jaw layout

WP12: In situ a-C coating on IT

WP14: 4 MKI cool at P2/P8
WP14: Mask D1 at P2 and P8

WP8: VAX installation at ATLAS
(VAX/TAXS installation: boundary conditions due also by ATLAS Schedule; under discussion with ATLAS management)

HiLumi HL-LHC PROJECT

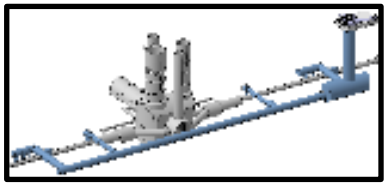
Courtesy E. Vergara

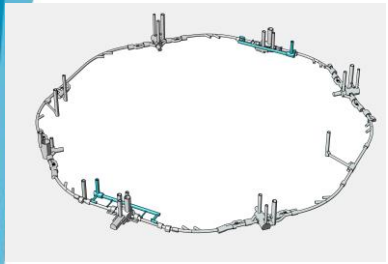
Optimization approach

- Scrutinize critical path activities (procedures, duration, resources, …) with the involvement of departments management
- Enhance co-activity and parallelism
- Expand the use of staggered work where beneficial
- Identify activities where exceptional measures (Punctual injection of extra resources, work outside of normal working days) could significantly shorten the critical path
- Reexamine pragmatically the access and safety constraints
- Review the deployment of resources during dismounting period
- Explore cost-effective options to improve logistics
- Use the YETS 2025-26 in case of LS3 shift
- Seek possibilities of deferred installations

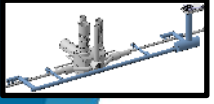
For the next slides

- Installation activities in the new underground





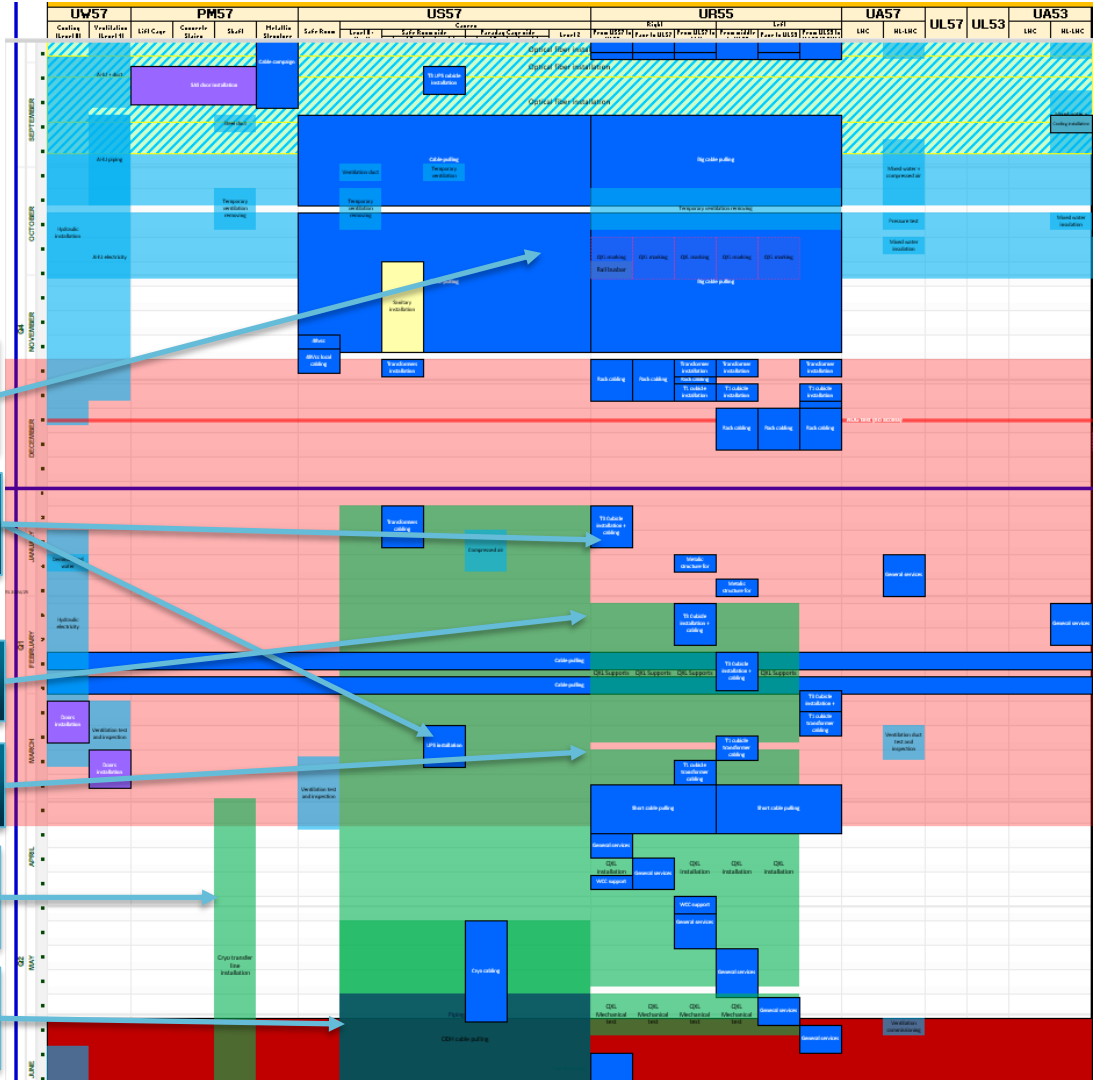
- Installation activities in the LHC tunnel

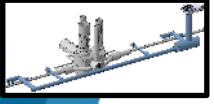


September 2024 – June 2025

From cabling campaign to cryogenic refrigeration system installation

- Cabling campaign
- Electrical infrastructures
- QXL supports
- QXL installation
- Cryogenic transfer line
- Cryogenic refrigeration system





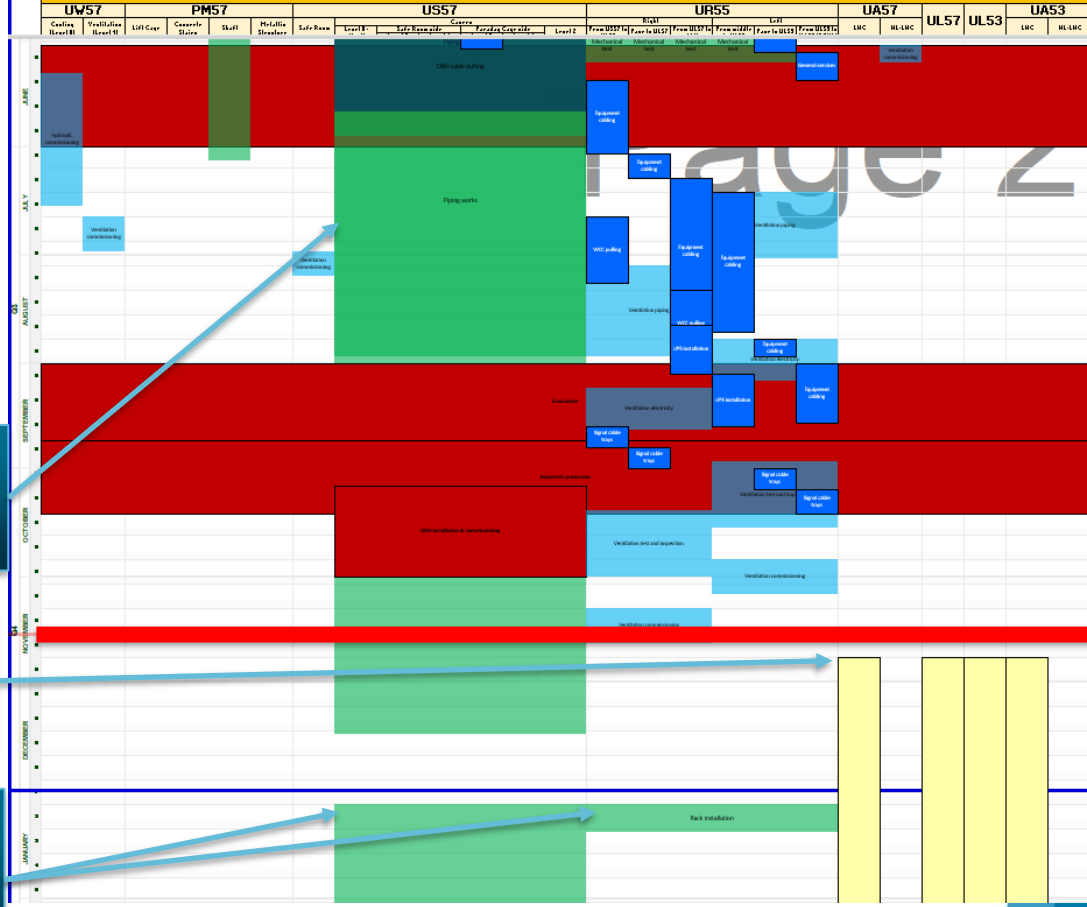
June 2025 – January 2026

From cryogenic refrigeration system to start of the possible slot for core drilling from HL side

Cryogenic refrigeration system Installation and test

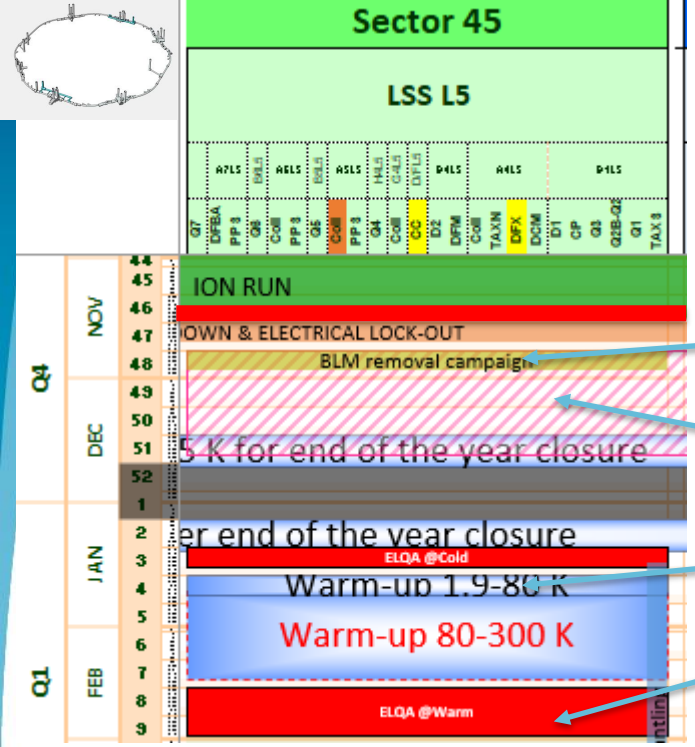
Start of possible slot for core activities HL side only

Racks installation and cryo commissioning new refrigeration system



November 2026- February 2026

From BLM removal to ElQA at warm



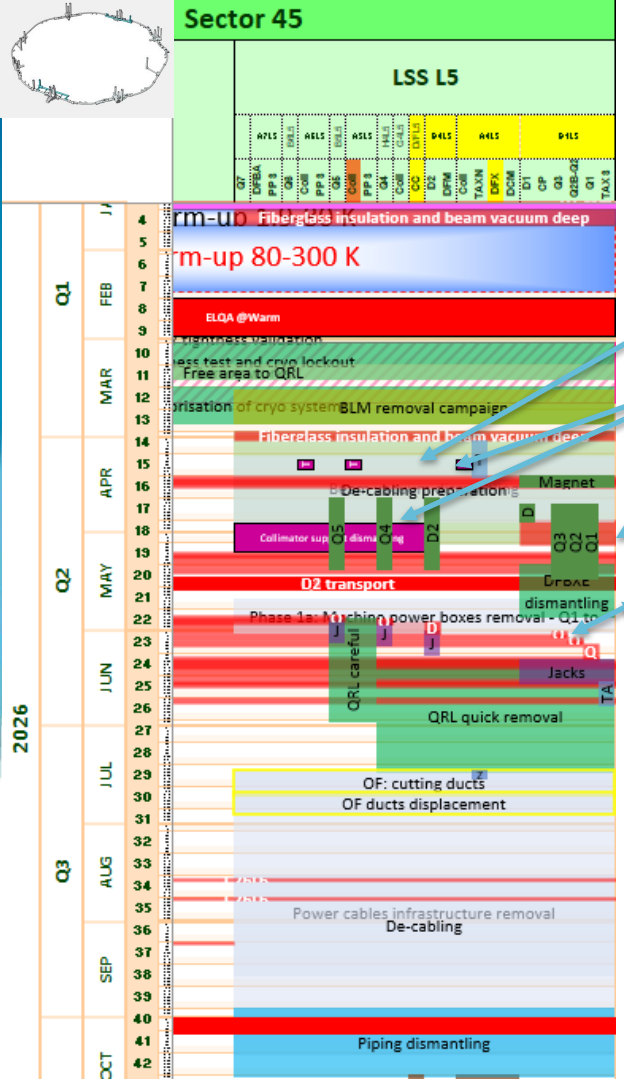
BLM removal

Full survey measurements

Warm up

ElQA at warm

January 2026 - October 2026
From warm up to pipe dismantling



De-cabling preparation. Vacuum system dismantling

Collimator and supports for collimator removal

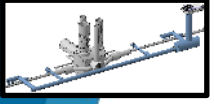
TE-MSC magnet de-interconnection

Magnet transport

TE-CRG removal activities
DFBX/QRL for recovery/DSL/and QRL destructive dismantling in // with jacks dismantling

Optical fiber de-installation in // with cable removal

Water and compress air dismantling in // with cable removal, except 1 week to create enough geographic separation. EN-CV activities in double shift



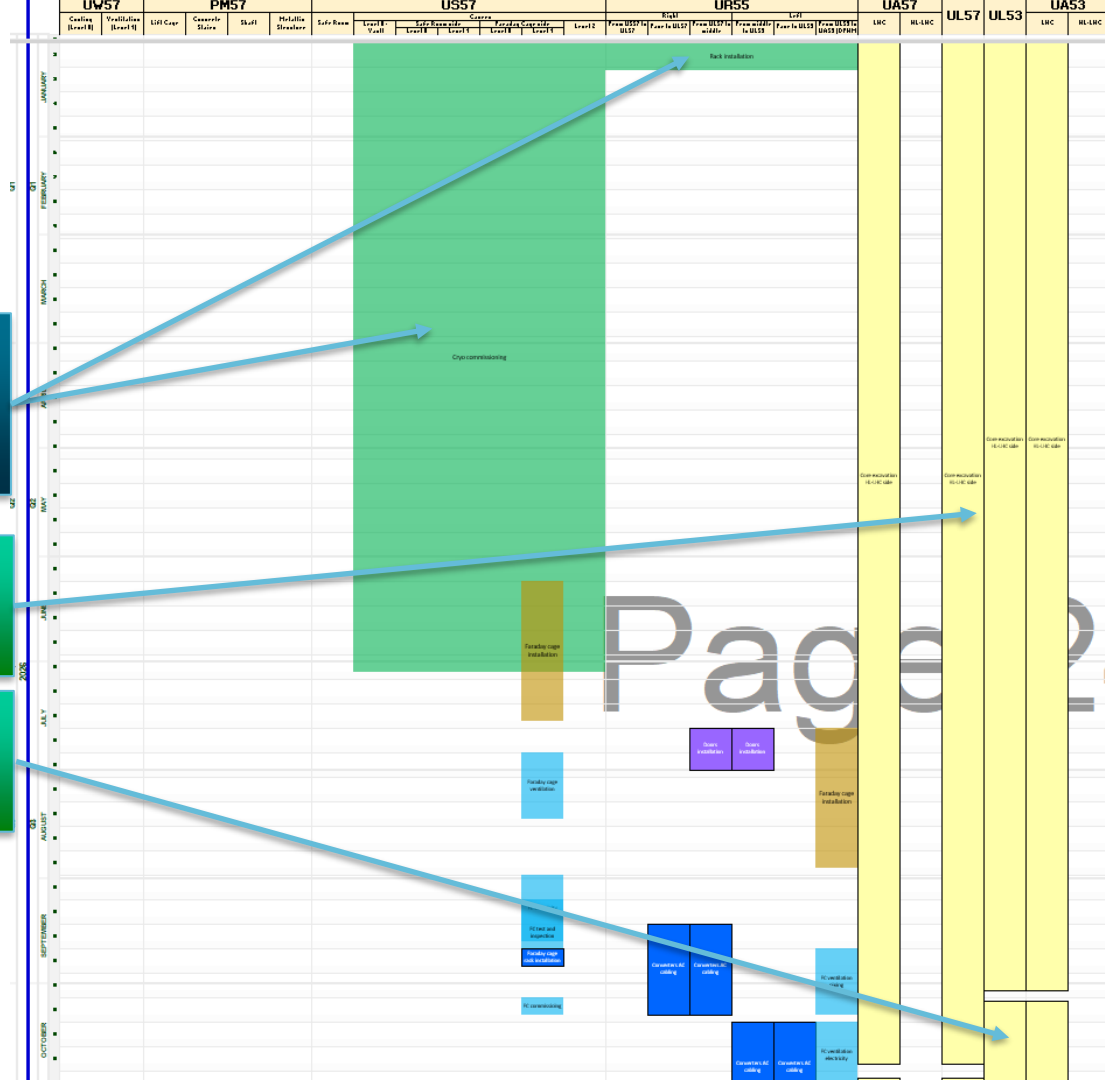
January 2026 – October 2026

From cryogenic racks installation to core phase I completion

Racks installation and cryo commissioning new refrigeration system

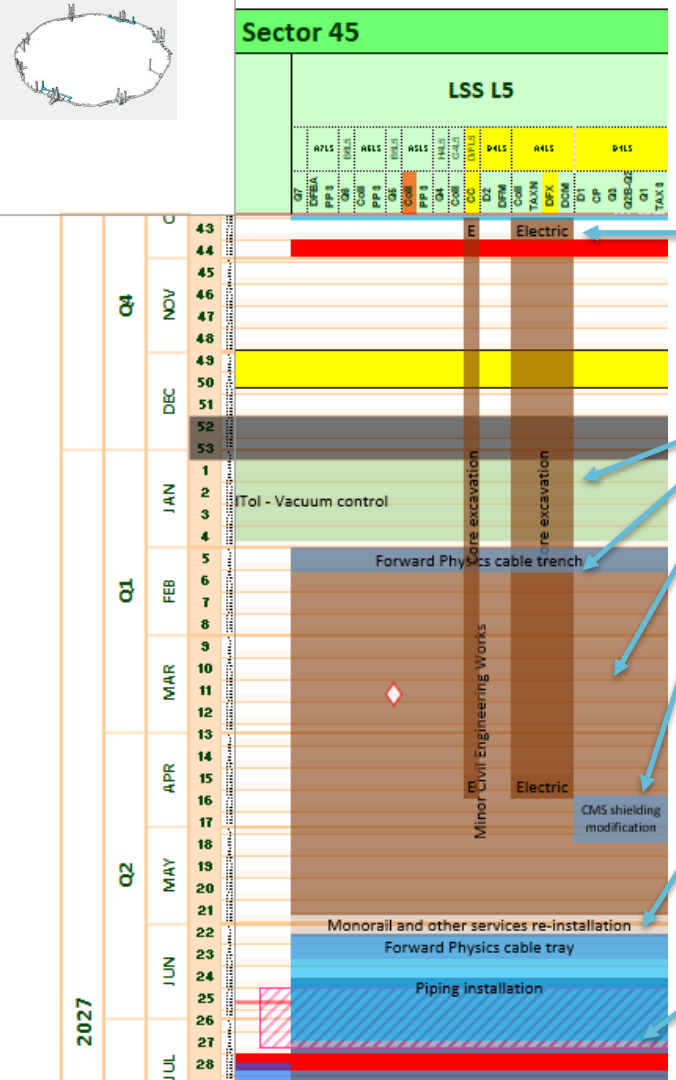
Possible slot for core activities HL side only

Start of core excavation LHC and HL side



October 2026 - July 2027

From core to pipe installation

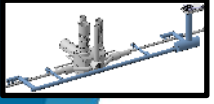


Installation protection for electrical and signal services to be maintained during core drilling

Core excavation partially in // with other Minor Civil Engineering Works and other modifications
(FIN for new VAX services)

Re- installation of transport monorails

Water pipes and compress air installation
Activities in double shifts
In // with EN-EL installation, but two weeks offset to create geographical separation



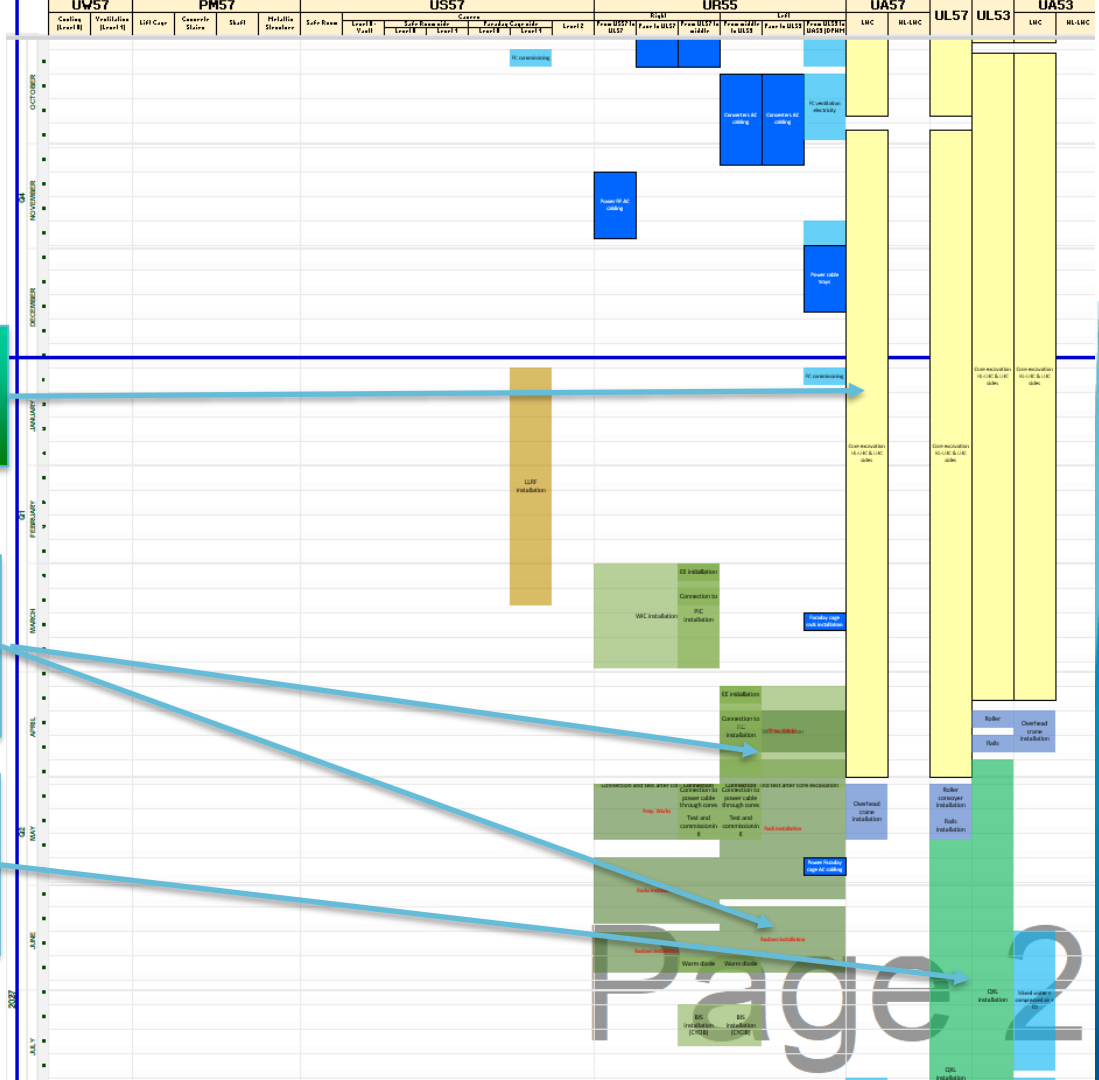
October 2026 – July 2027

From core phase II and start QXL installation in the UL

Core excavation
LHC AND HL side

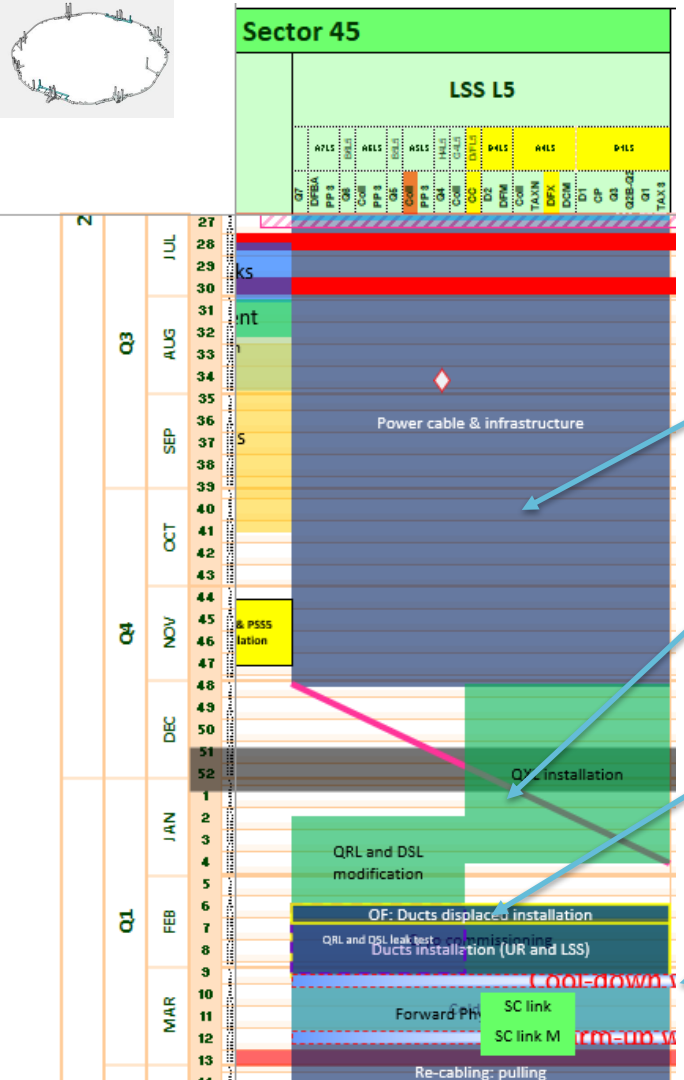
Power converters and machine protection installation

QXL installation in the ULs



July 2027 - March 2028

From electrical infrastructures to signal re-cabling

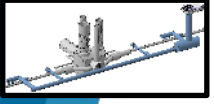


Re-installation of all electrical infrastructures, 1st signal cable campaign

Installation of new QXL, modified QRL, modification of the warm piping, DSL medication

Optical fiber installation in // with
QRL and DSL leak tests in // with
Cryo commissioning in preparation to cold test

QXL Cold test
section below 80 K in // with
SC link installation in // with
Forward physics cabling in two shifts



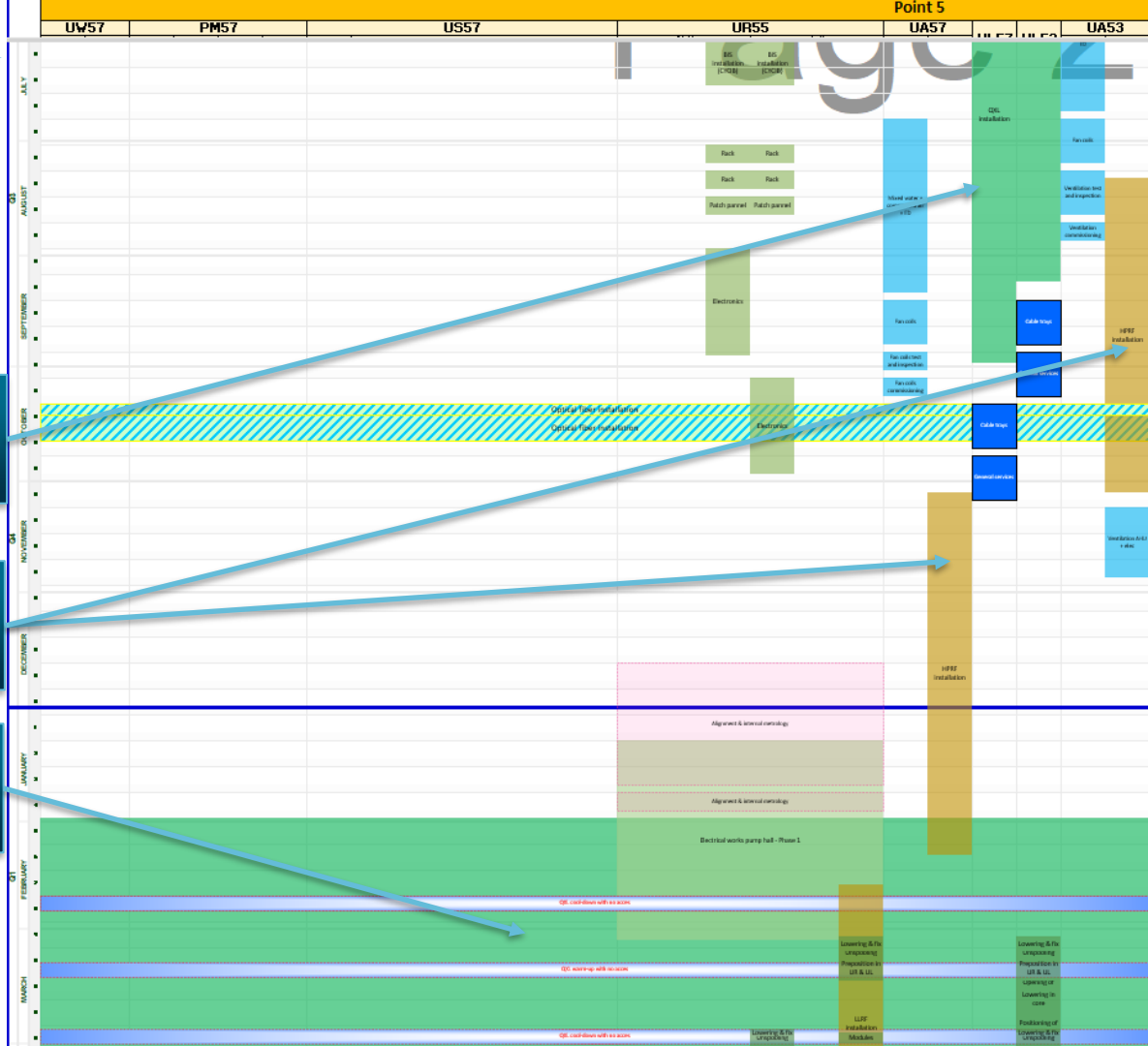
July 2027 – March 2028

From Completion QXL to full QXL cold test commissioning

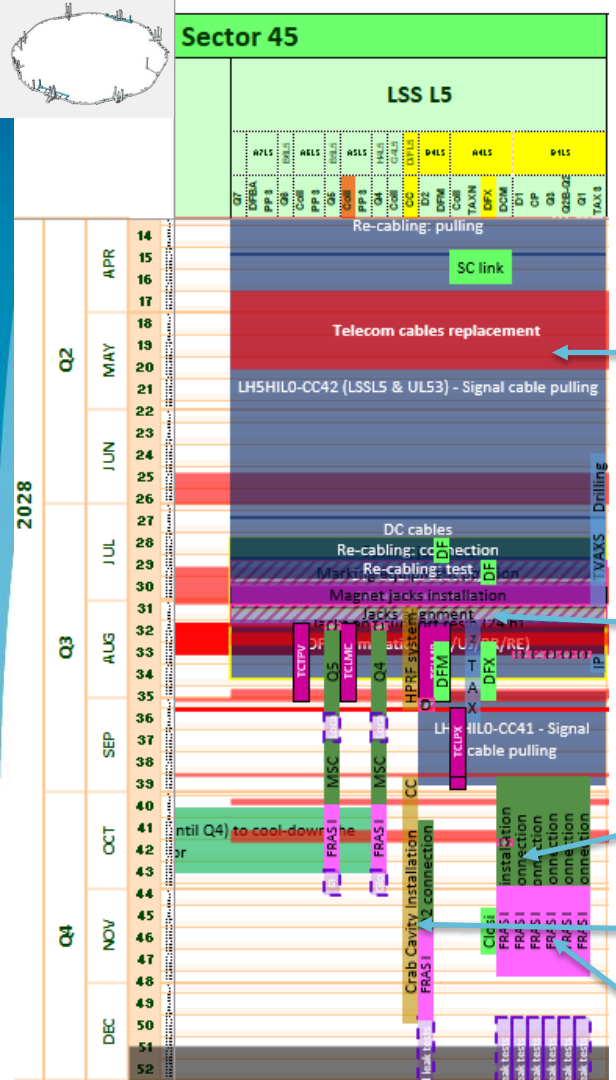
QXL completion

High Power RF Installation

QXL full commissioning and cold test



March 2028-December 2028
From signal re-cabling to global leak tests



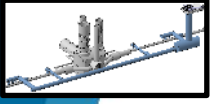
Re-cabling in // with
SC link in // with
GSM installation

Final phases cabling in // with
Cutting the QXL/QRL jumpers open
Jacks marking
Installation of jacks

Magnet interconnection

Crab cavity installation

FRAS completion



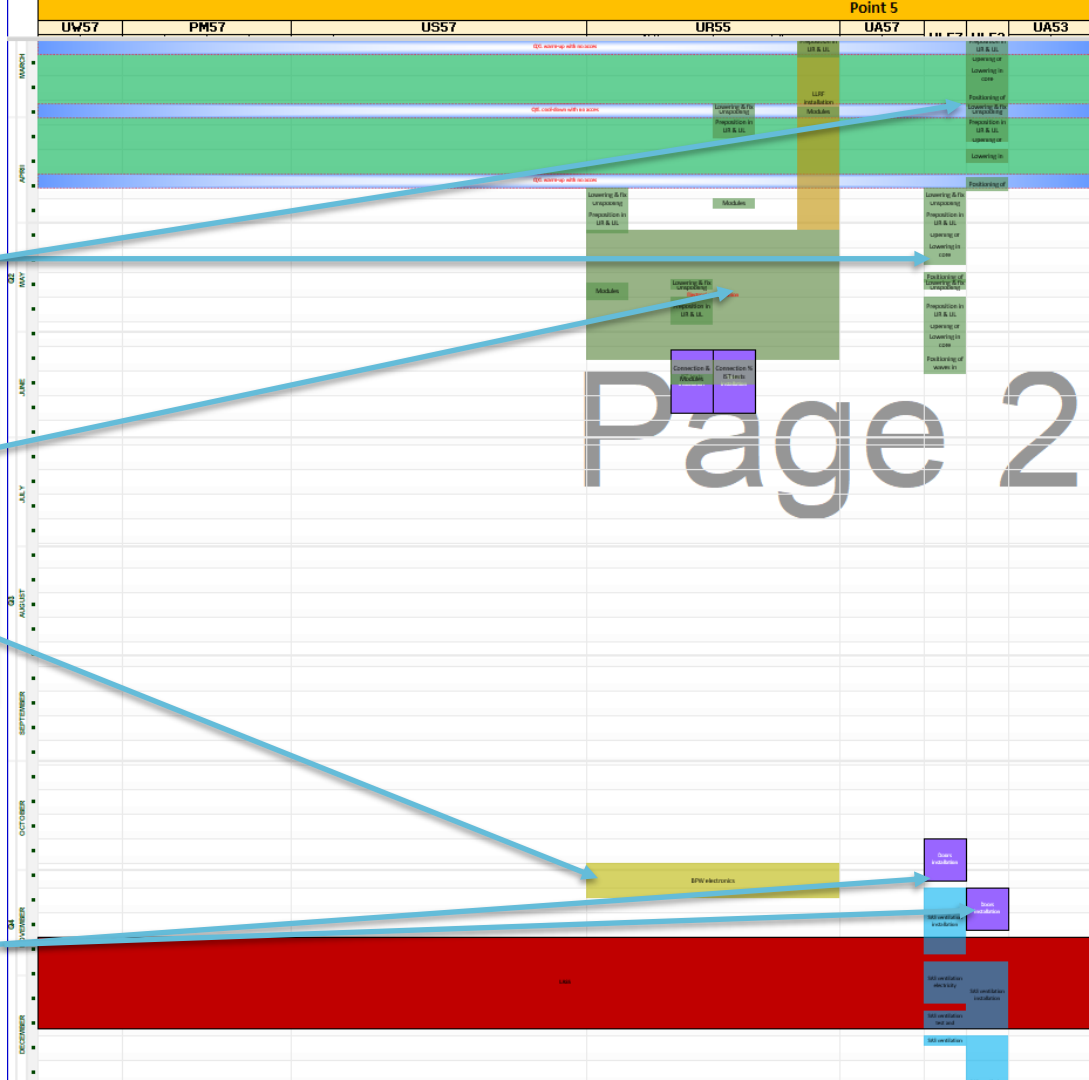
March 2028 – December 2028

SC links installation

Power converter installation phase II electronics

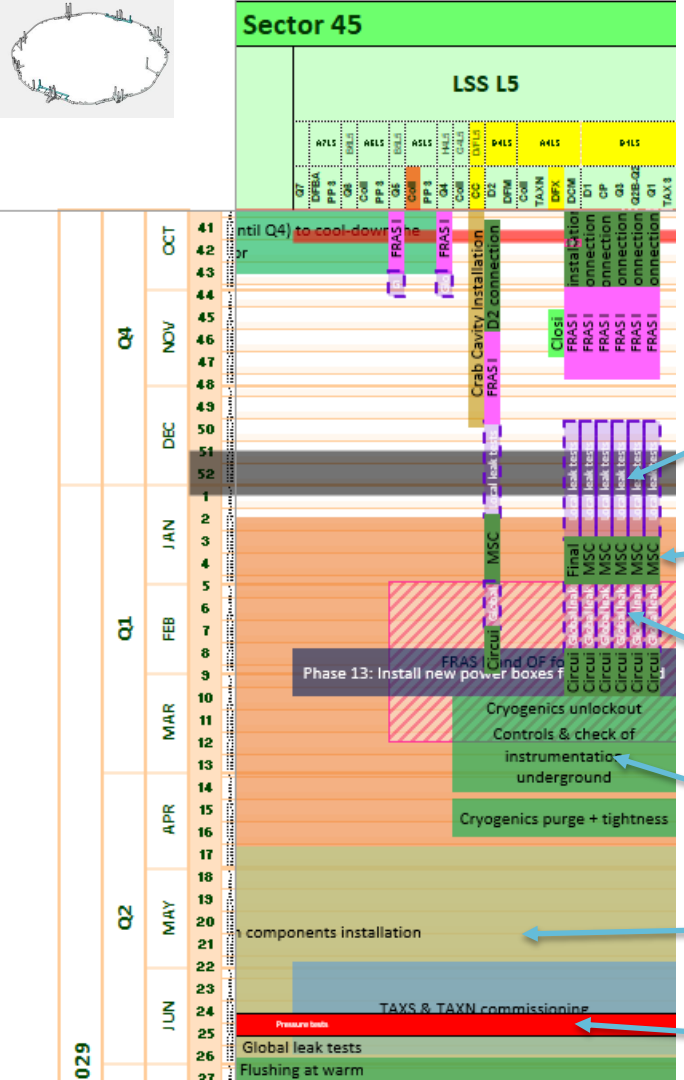
BPM electronics installation

Installation doors in the UL

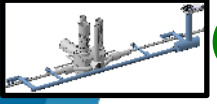


October 2028-June 2029

From magnet interconnection to flushing of cryogenic system at warm



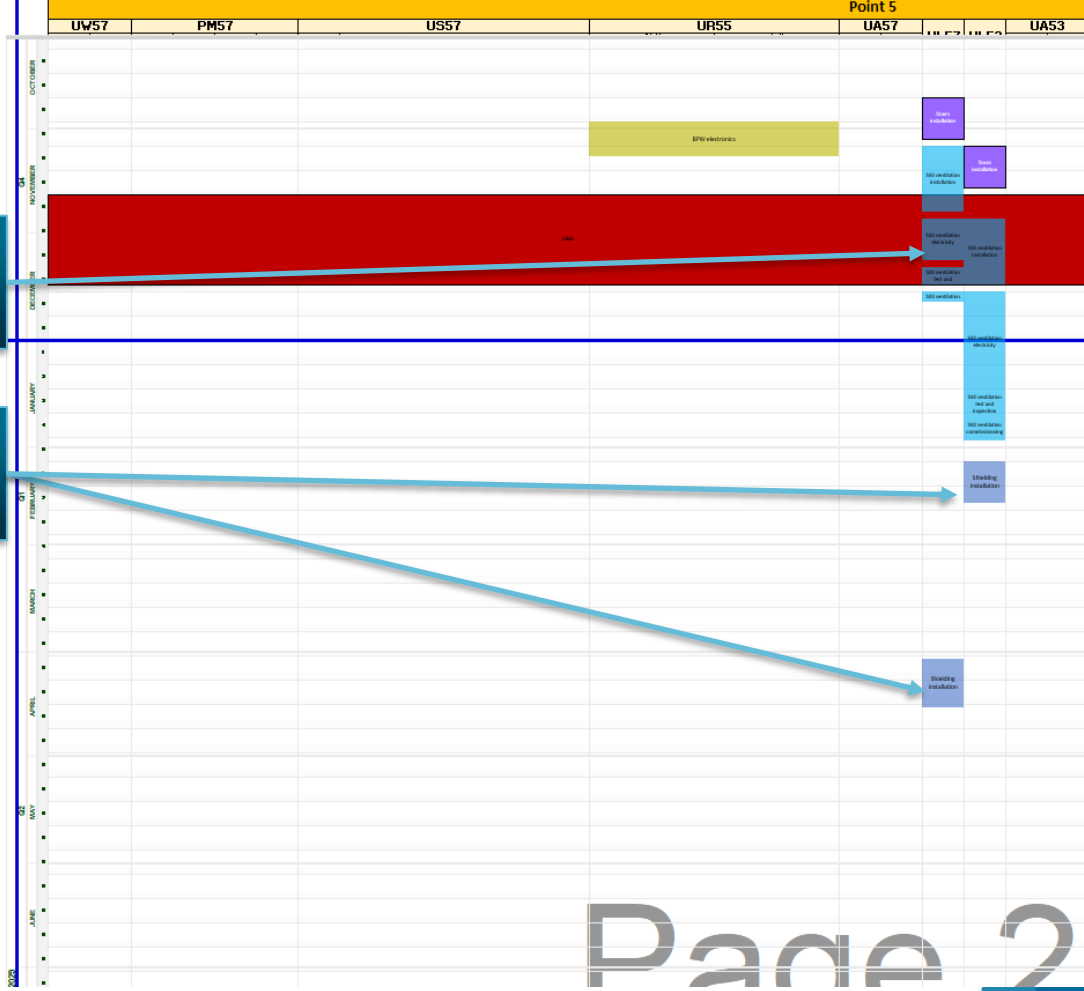
- Local leak tests
- Completion of magnet interconnection activities
- Global leak tests
- Circuit tests
- Completion of vacuum installation
- Pressure & leak tests



October 2028 – June 2029

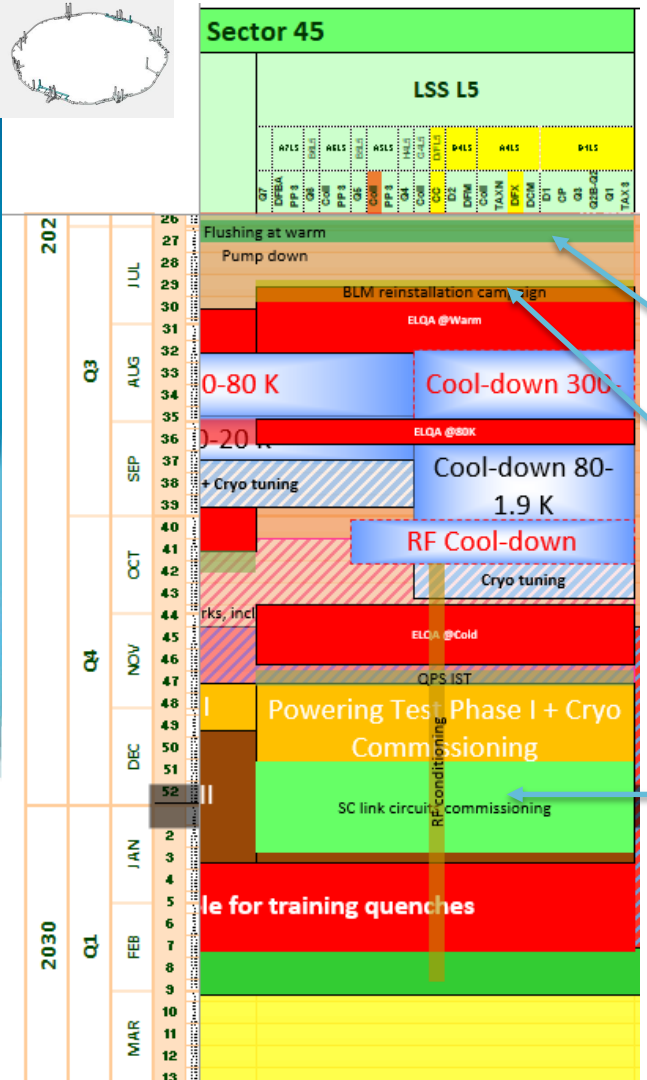
Ventilation UL completion with SAS

Radiation shielding installation



June 2029-March 2030

From flushing cryogenic system at warm to beam on



Flushing at warm

BLM

Commissioning of the new circuits running through the new SC links

Beam in