# 1st Accelerators Technology Sector Workshop

## Engineering Design Tools and Processes
## Project Management Methodologies and Tools

Chair: Mike Lamont

Interconnecting knowledge, experience, methods, people & data to foster learning & collaboration

CERN

ATS
Accelerators and Technology Sector

# Coordinating High Luminosity LHC project

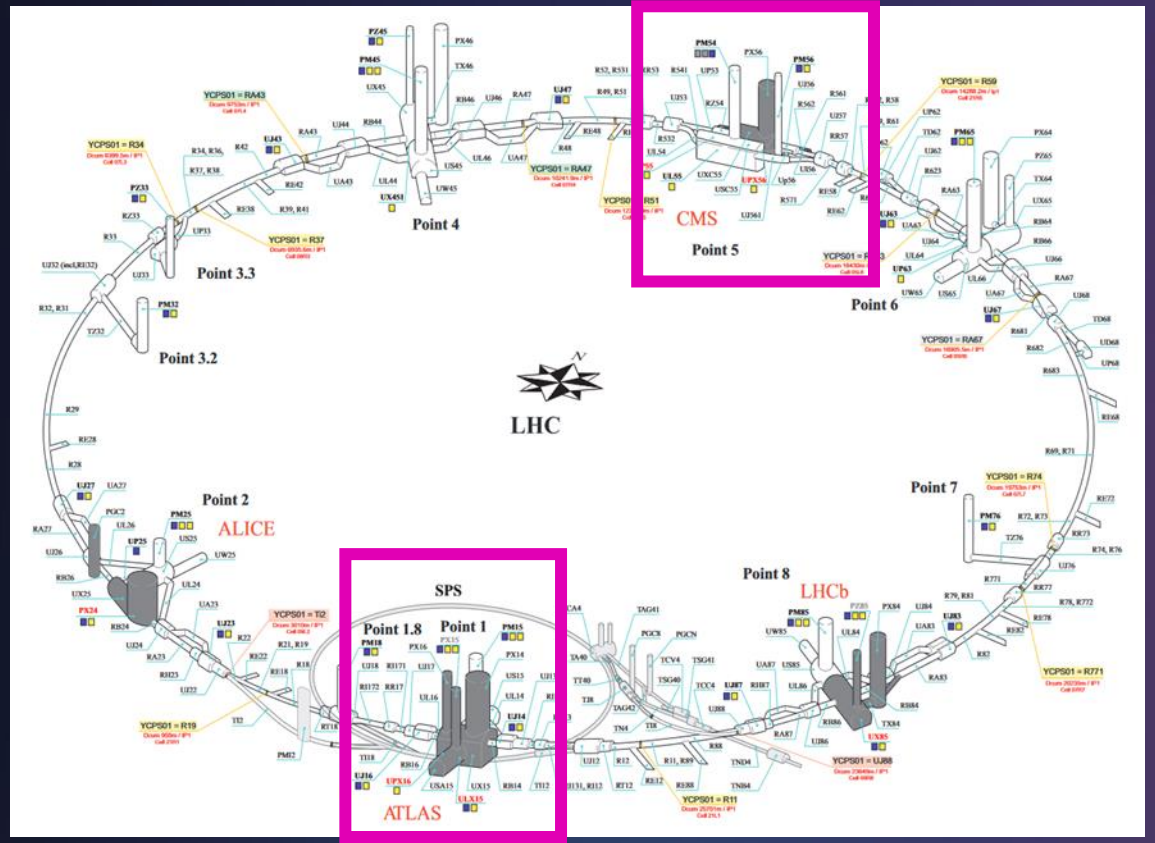
Estrella Vergara Fernandez

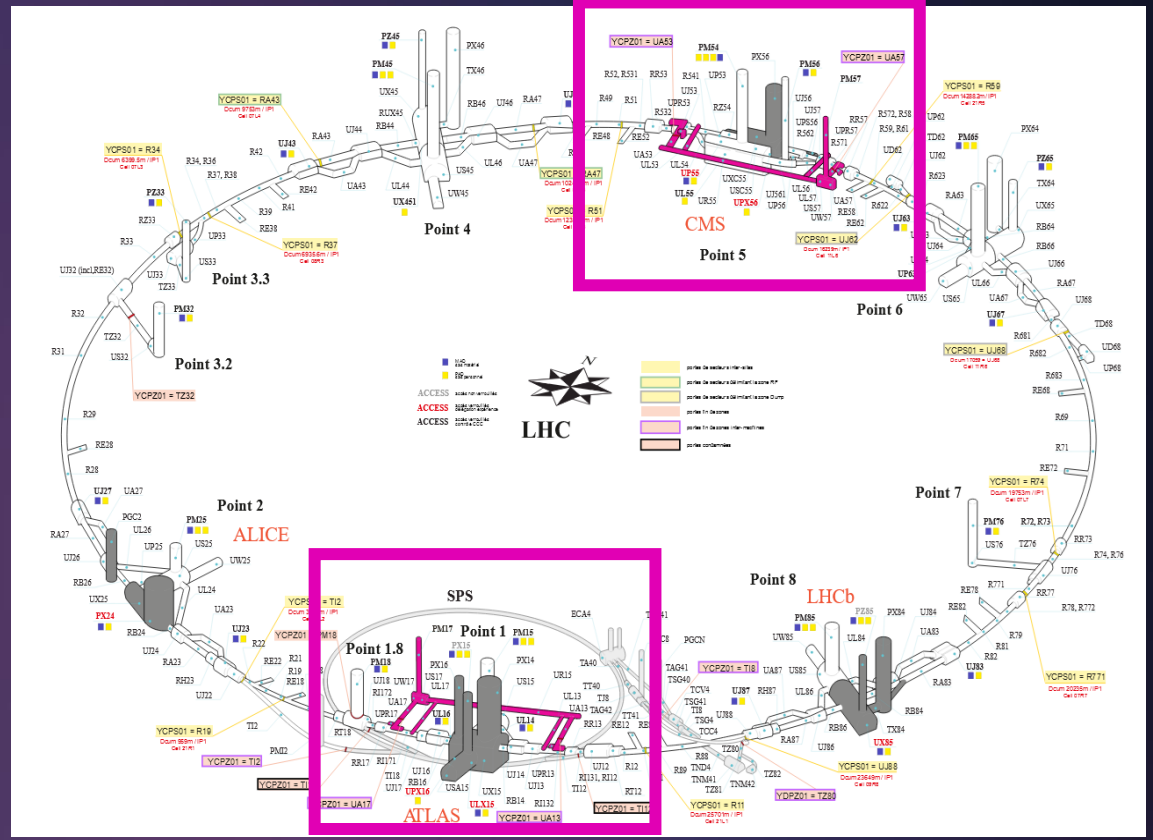
CERN

ATS
Accelerators and
Technology Sector

# Coordination management

## Why do we need it?



# Coordination management

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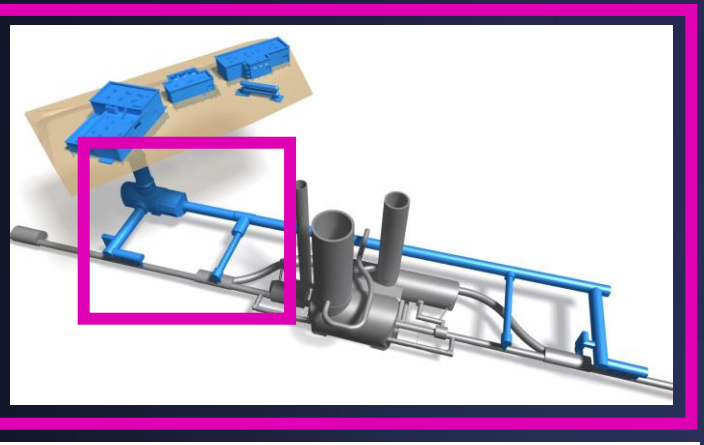
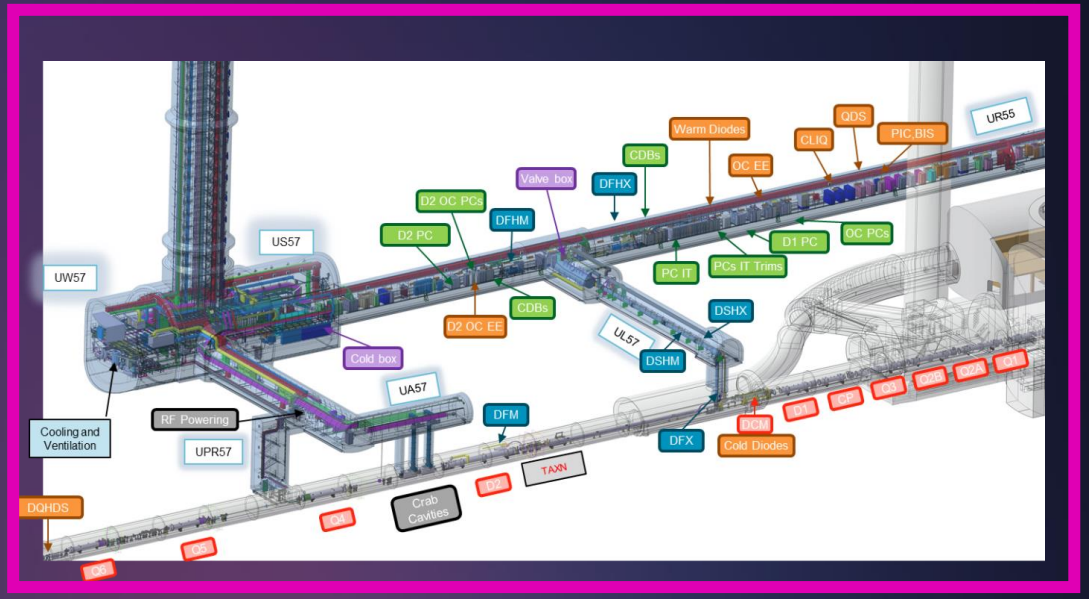
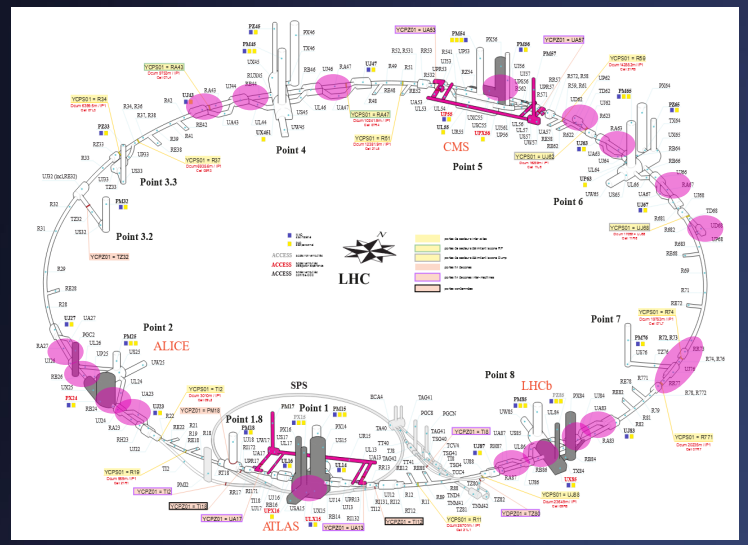


Surface buildings

Underground galleries




Equipment, systems and services installation and commissioning




HL-LHC impact on the LHC

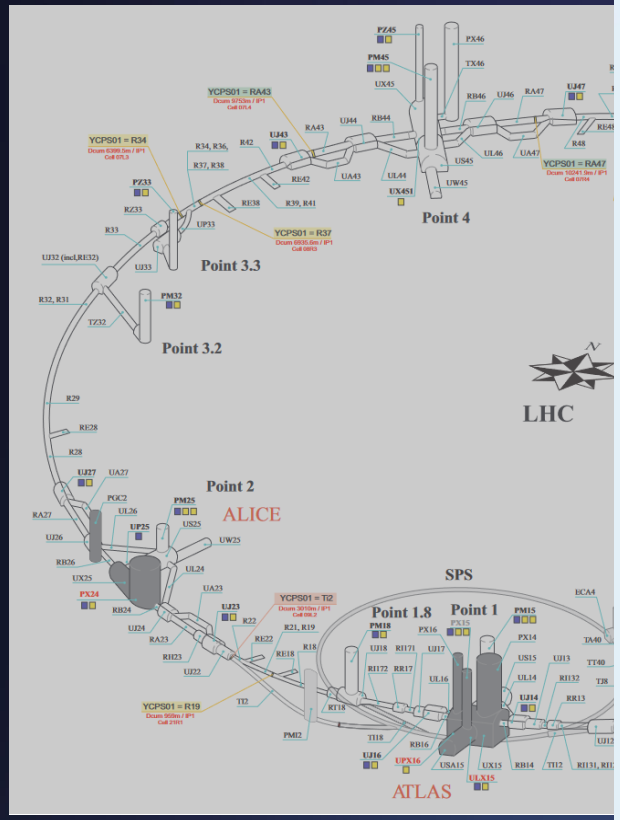
**Complex and interlinked large scale scientific project:**

**20 WPs, many CERN groups, systems, equipment, service involved**

# Coordination management

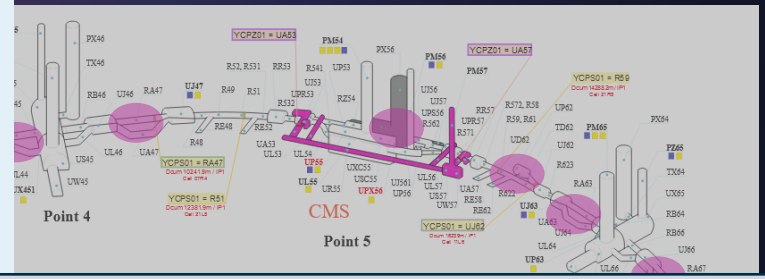
## Why do we need it?

### BEFORE HL-LHC

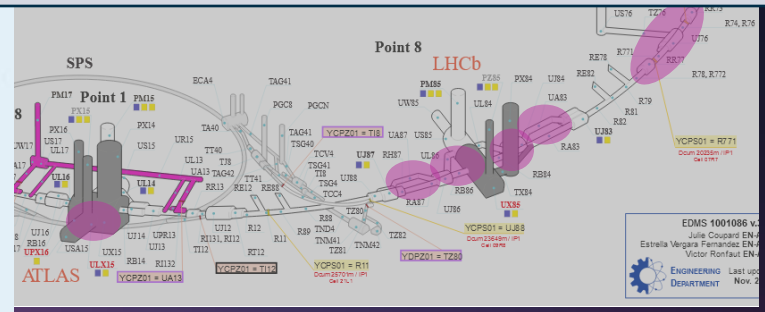



### Coordination team

### AFTER HL-LHC

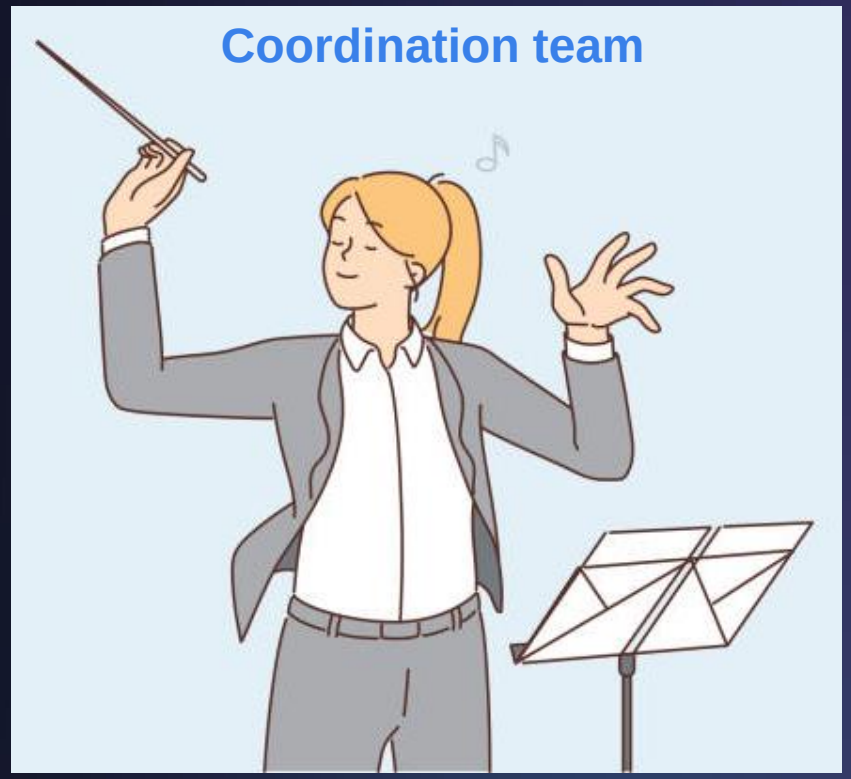



- **INSTALLATION and COMMISSIONING**
- **INTEGRATION in the LHC**



# Coordination management

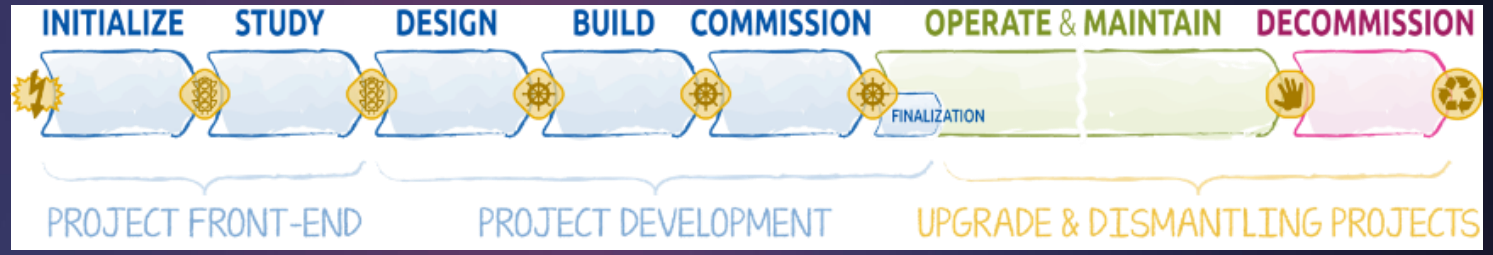
## Central coordination




Technical expertise

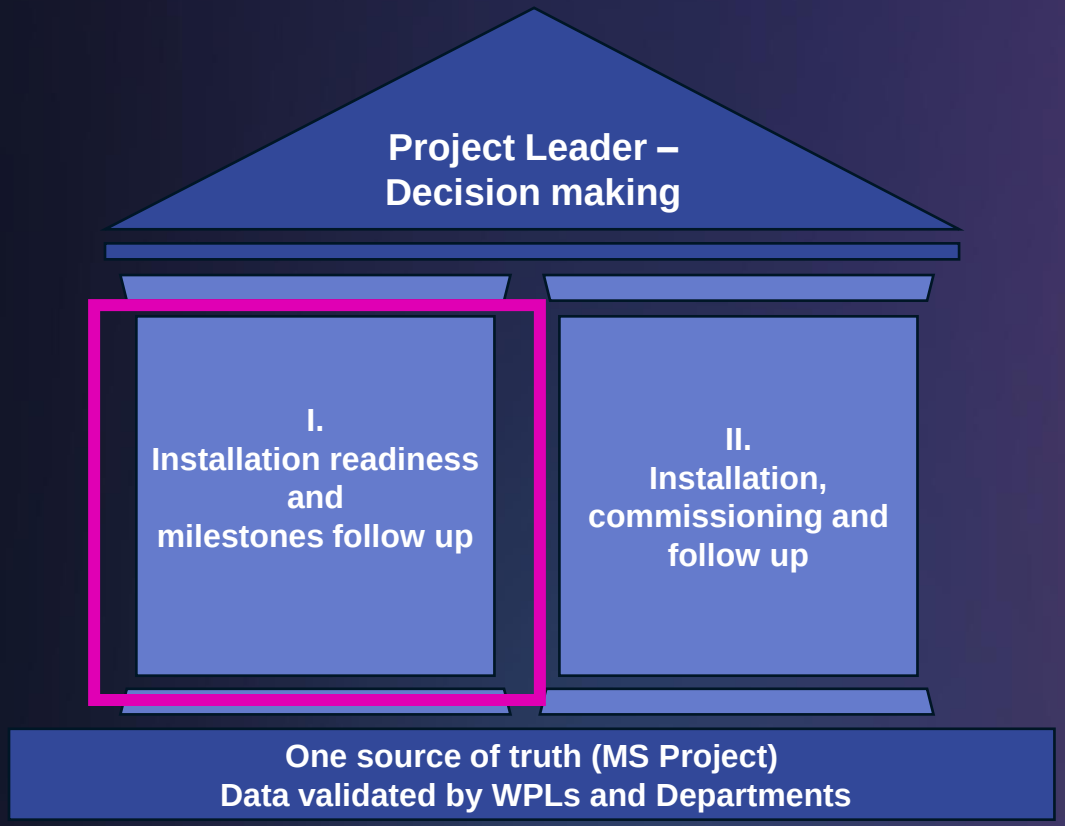
Project management standards

OpenSE framework




- A common understanding of a facility or system lifetime
- A common understanding of the expected results

# Coordination management

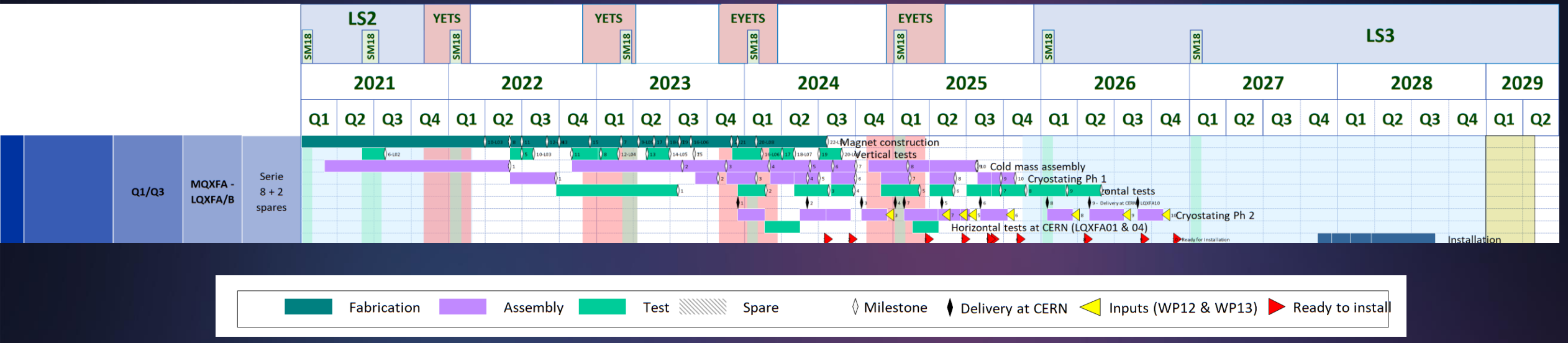



## One single source

- Consolidated methodology and coherent set of data
- One single source → tool for decision taking
- 2 pillars for coordination management
- Process for change management

# Pillar 1: Installation readiness and milestones follow-up

## Master Schedule: Phases and deliverables

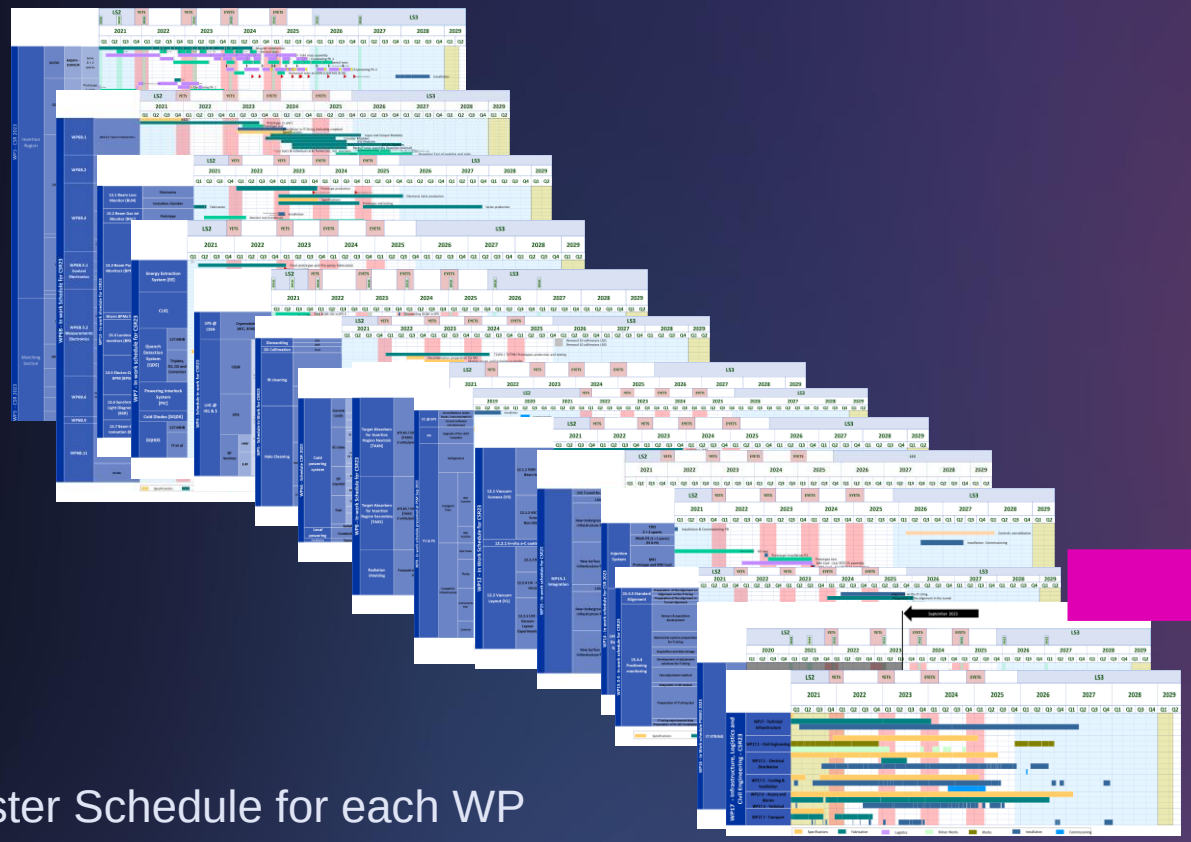


# Pillar 1: Installation readiness and milestones follow-up

## Master Schedule: One source

MS Project as single source of truth

| Task Name | Duration | Start | Finish |
|---|---|---|---|
| HL LHC | 3961 days? | 04/03/13 | 29/12/28 |
| WP1: Management | 2231 days | 02/11/15 | 29/11/24 |
| WP2: Accelerator Physics and performance | 2091 days | 04/06/15 | 06/12/23 |
| WP3: Magnets for insertion regions | 2985.1 days | 18/08/14 | 07/09/26 |
| WP4: Accelerating cavities and RF systems | 3119 days | 05/06/14 | 11/01/27 |
| WP5: Collimation | 3571 days | 04/03/13 | 02/07/27 |
| WP6A: Cold Powering | 2645 days | 18/08/14 | 02/05/25 |
| WP6B: Warm powering | 2801 days | 01/12/14 | 03/04/26 |
| WP7: Machine Protection | 3189 days? | 18/08/14 | 30/06/27 |
| WP8: Collider Experiment interface | 3182 days | 18/08/14 | 21/06/27 |
| WP9: Cryogenics | 2963 days | 29/06/15 | 29/06/27 |
| WP10: Energy Deposition& Absorber Coordination | 1920 days | 26/11/15 | 04/10/23 |
| WP11: 11T DS dipole | 2624 days | 30/01/15 | 16/09/25 |
| WP12: Beam Vacuum | 3614 days | 01/01/14 | 30/06/28 |
| WP13: Beam Diagnostics | 3412 days? | 01/01/14 | 22/09/27 |
| WP14: Beam Transfert&Kickers | 3331 days | 01/01/14 | 01/06/27 |
| WP15: Integration & Installation (24/06/2021) | 3133 days? | 07/08/14 | 02/04/27 |
| WP16: Hardware Commisioning | 1691 days? | 02/11/20 | 18/08/27 |
| WP17: Infrastructure, Logistics and Civil Engineering | 3106 days? | 18/08/14 | 05/03/27 |
| WP18: Controls Technologies | 2599 days | 05/01/17 | 30/06/27 |
| Test Facilities | 2807 days | 29/07/14 | 25/11/25 |
| Safety | 2700 days | 25/12/14 | 25/11/25 |
| External Events | 3588 days | 07/08/14 | 29/12/28 |

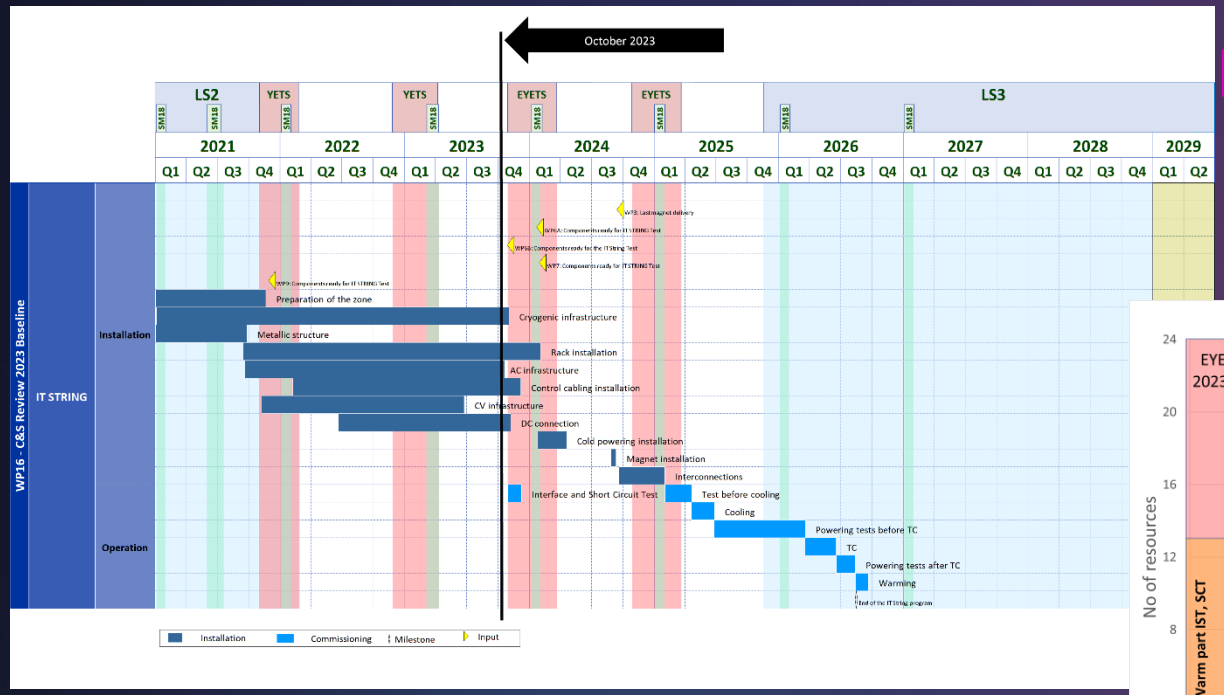


Master Schedule for each WP

HL-LHC Project Master Schedule

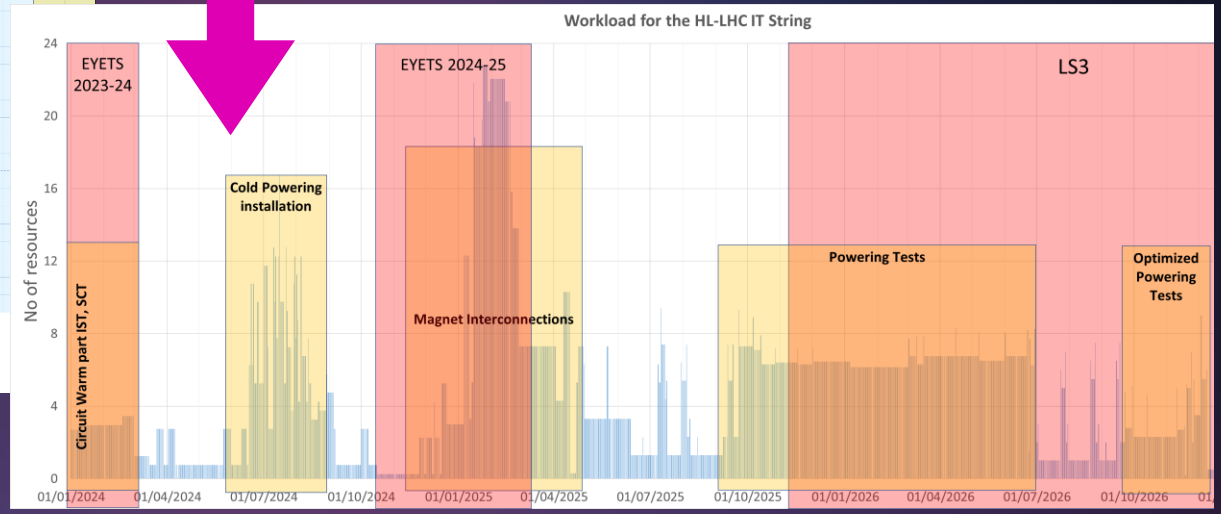
# Pillar 1: Installation readiness and milestones follow-up

## Master Schedule: Link to EVM - IT String case



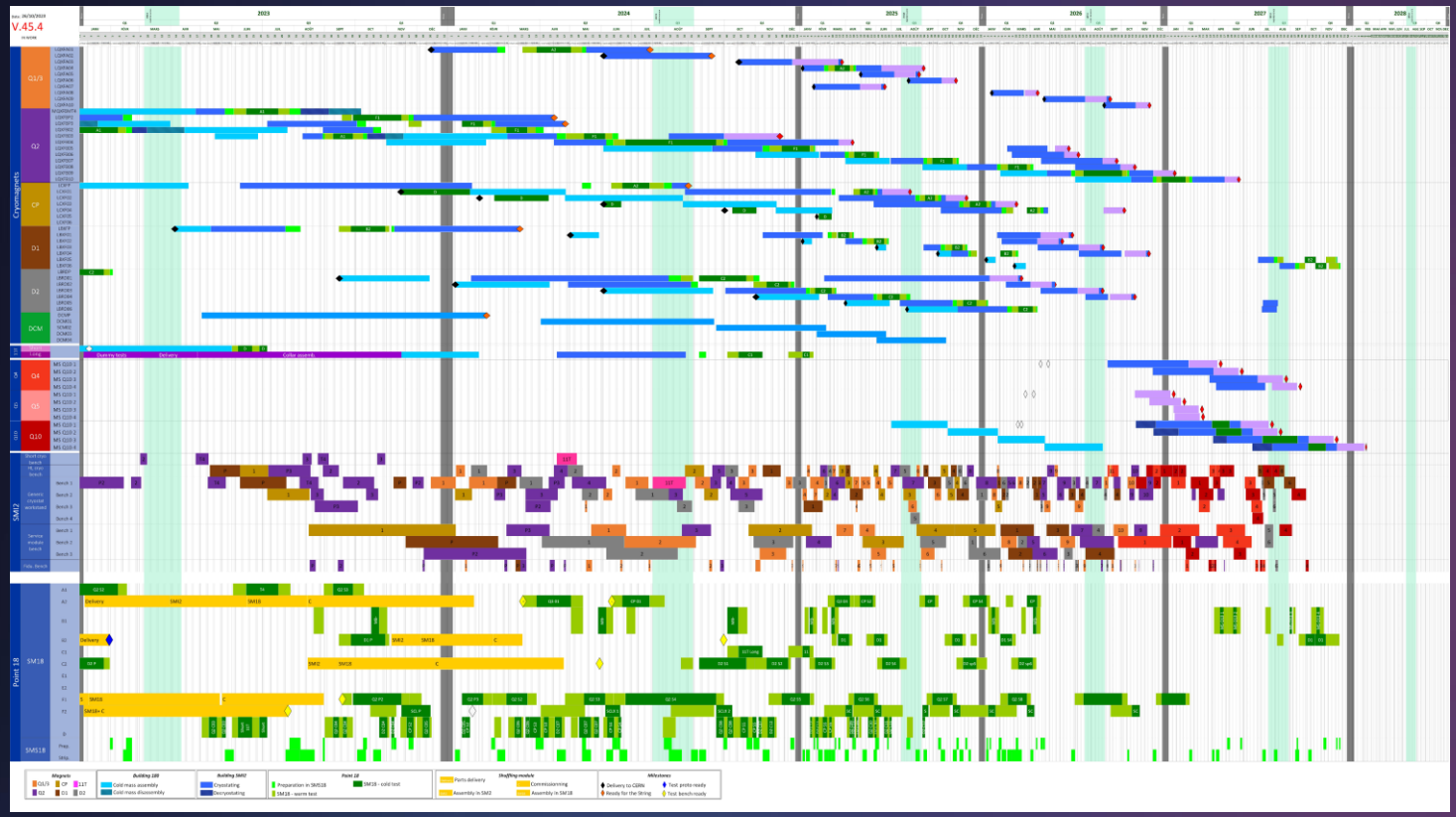

**Resource analysis: combination of resources (EVM) and detailed planning**

***Work done by EN-ACE and IT String team (WP16)***



# Pillar 1: Installation readiness and milestones follow-up

## Dedicated resource analysis: WP3 (IR Magnets) case



### Input: WP3 process

Interfaces: WP18, 15, 6A, 12, 13, 19

Resources:

- Building 180
- Facility SMI2
- SM18 & Point 18

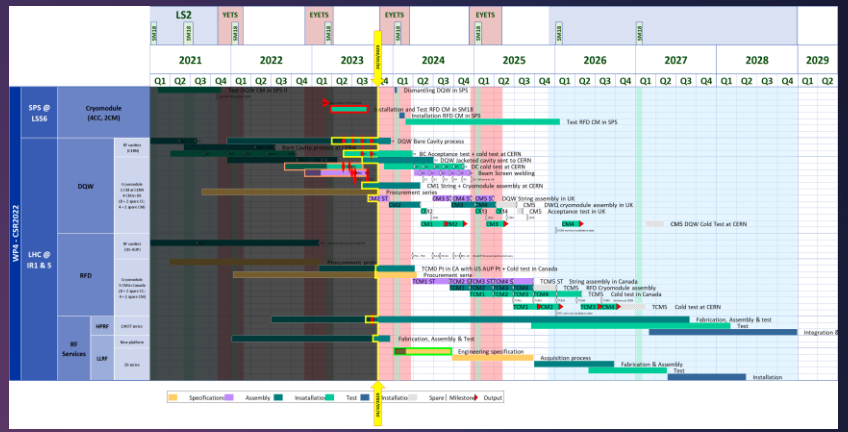
### Output: Resource loaded and levelled planning

# Pillar 1: Installation readiness and milestones follow-up

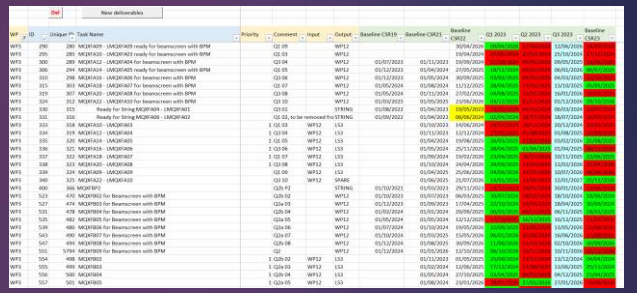
## Reporting tools

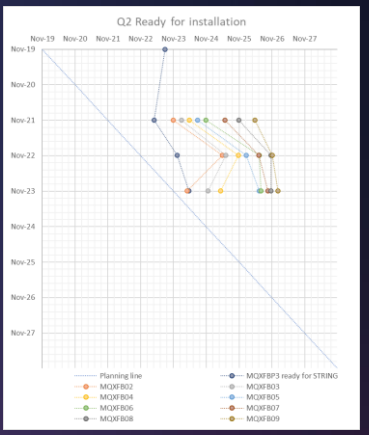
- **Project Steering Meetings (PSM): Assessment and decision on budget and schedule changes for each WP**
- **HL-LHC Cost & Schedule Review**

**Broken line**

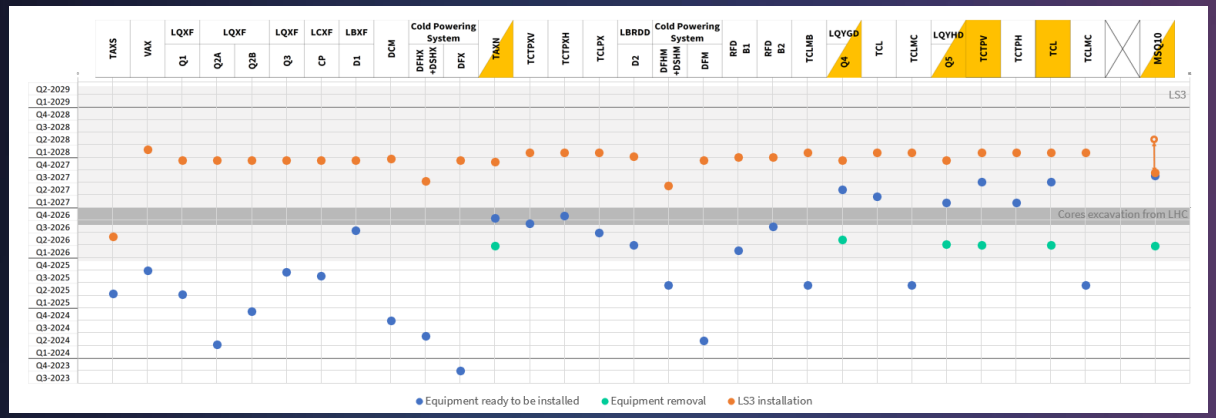



**Milestone tracking table**



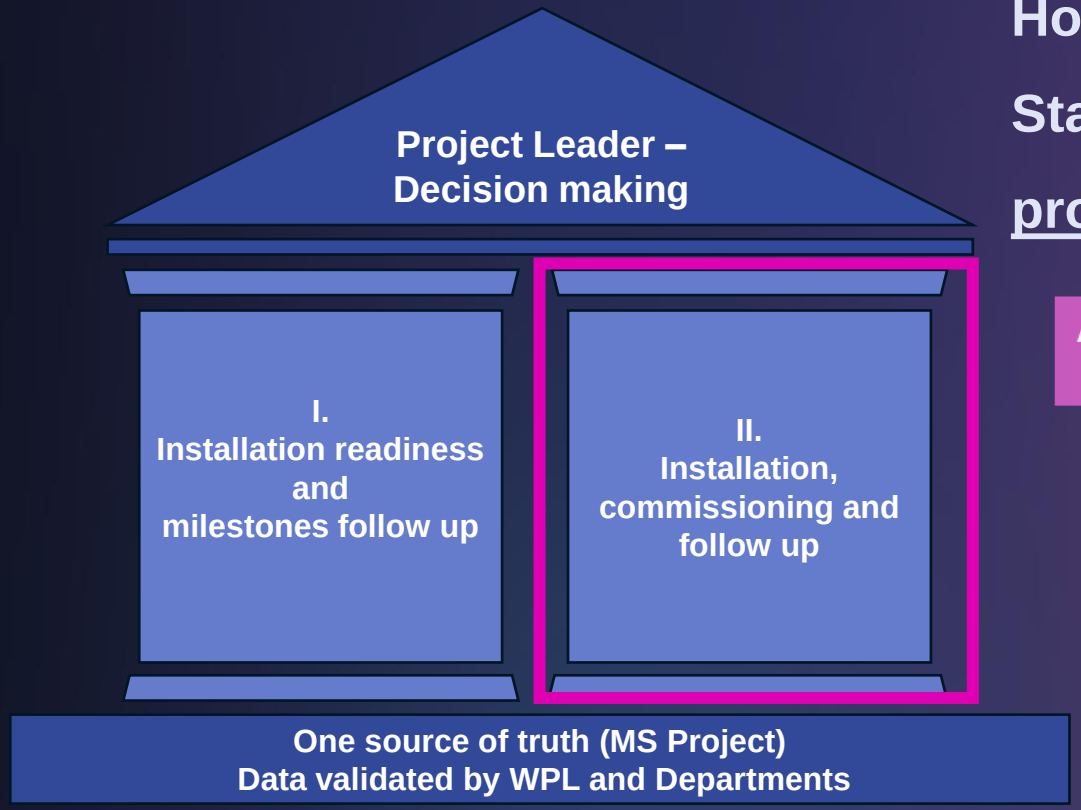



**TREND analysis follow-up**




**Float schedule: Equipment ready to install vs LS3 installation**

# Pillar 2: Installation, commissioning and follow-up




**How do we integrate HL-LHC inside the LHC?**

**Standard methodology used for the LHC and its injectors**

**programmed stops:**


Beam run

- Technical stops **(TS)**
- Year End Technical Stops **(YETS)**
- Extended Year End Technical Stops **(EYETS)**

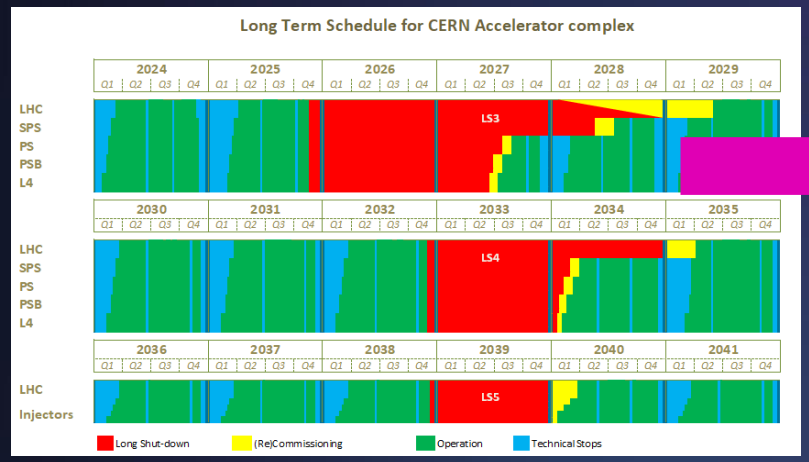
Long Shutdown **(LS)**

**HL-LHC installation mainly during the LS3**

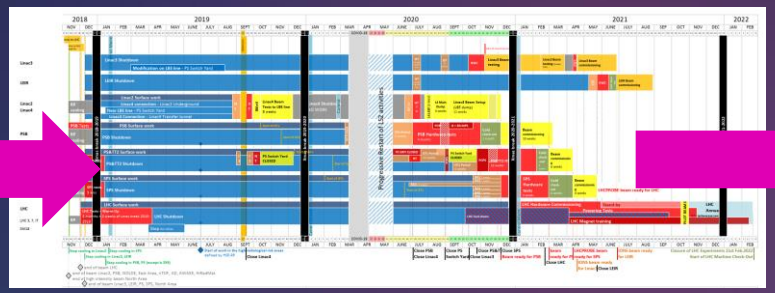
# Pillar 2: Installation, commissioning and follow-up

## Three levels of scheduling  Top-down approach


### Long Term Schedule - Strategic

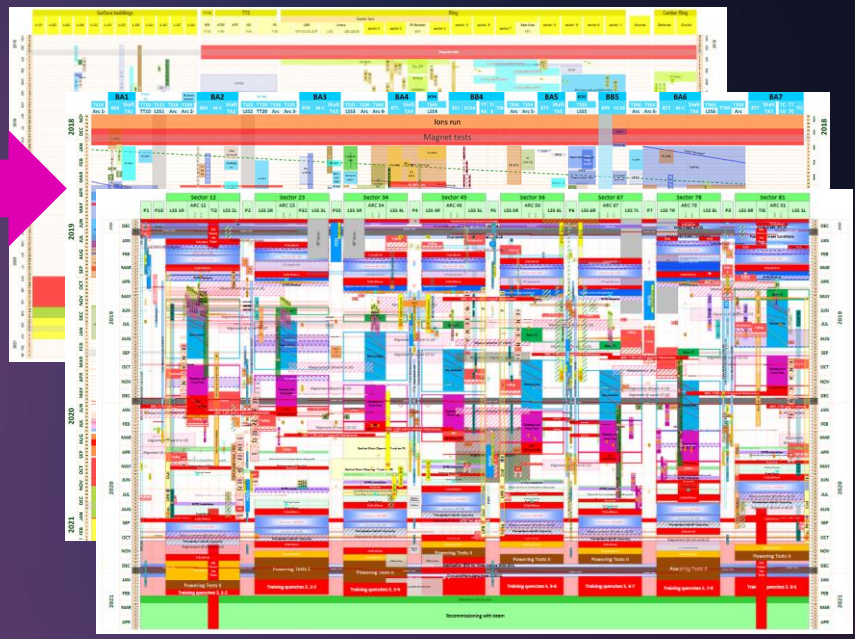



### Master Schedule - Operational



Example of the LS2 Master Schedule

### Detailed Linear Planning



Example of the LS2 Detailed Linear Planning


# Pillar 2: Installation, commissioning and follow-up

## How to build the LHC LS3 linear planning

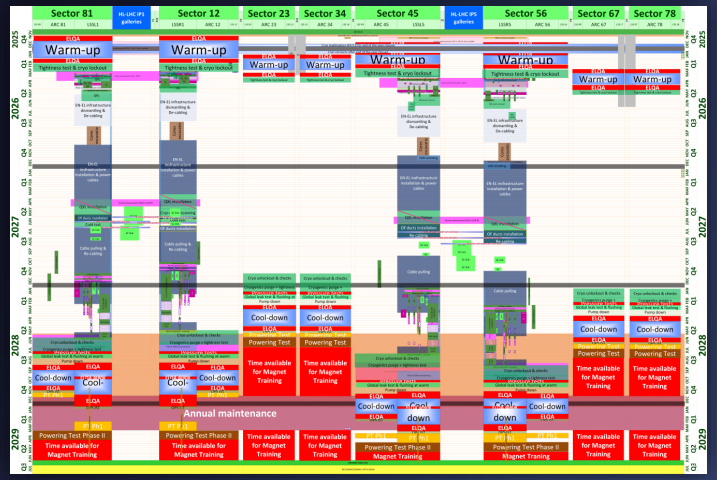
Follow-up

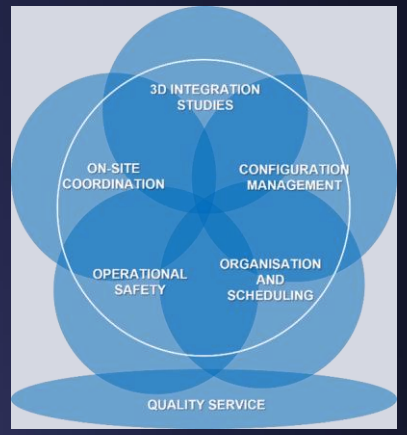
Gather the inputs form stakeholders and on-site visits

optimization and co-activity management

Process the information, including resource analysis

Transforming information into data: Linear Planning

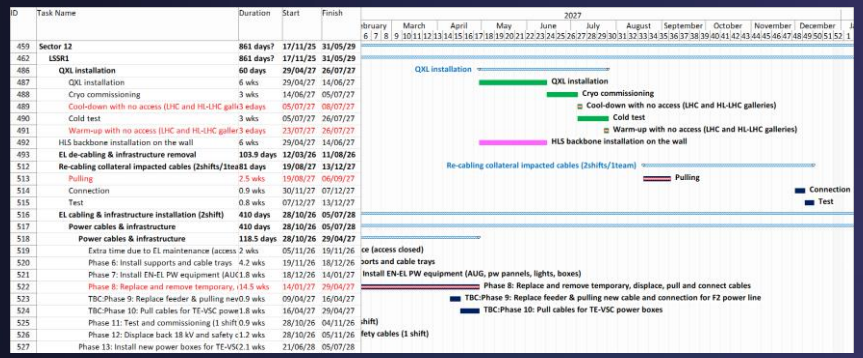



EN-ACE Group areas of expertise

# Pillar 2: Installation, commissioning and follow-up

## How to build the LHC LS3 linear planning



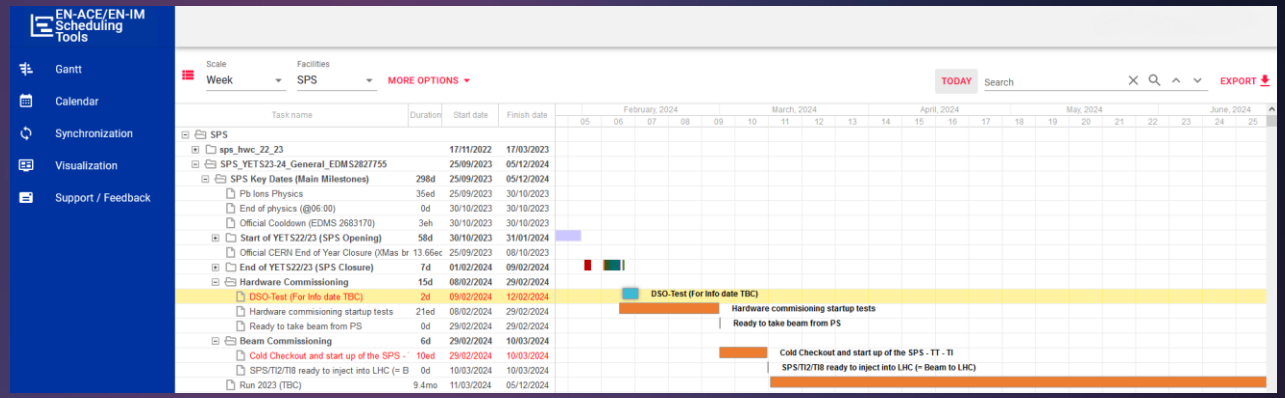
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 459 | **Sector 12** | **861 days?** | **17/11/25** | **31/05/29** |
| 462 | **LSSR1** | **861 days?** | **17/11/25** | **31/05/29** |
| 486 | **QXL installation** | **60 days** | **29/04/27** | **26/07/27** |
| 487 | QXL installation | 6 wks | 29/04/27 | 14/06/27 |
| 488 | Cryo commissioning | 3 wks | 14/06/27 | 05/07/27 |
| 489 | Cool-down with no access (LHC and HL-LHC galle | 3 edays | 05/07/27 | 08/07/27 |
| 490 | Cold test | 3 wks | 05/07/27 | 26/07/27 |
| 491 | Warm-up with no access (LHC and HL-LHC galle | 3 edays | 23/07/27 | 26/07/27 |
| 492 | HLS backbone installation on the wall | 6 wks | 29/04/27 | 14/06/27 |
| 493 | **EL de-cabling & infrastructure removal** | **103.9 days** | **12/03/26** | **11/08/26** |
| 512 | **Re-cabling collateral impacted cables (2shifts/1tea** | **81 days** | **19/08/27** | **13/12/27** |
| 513 | Pulling | 2.5 wks | 19/08/27 | 06/09/27 |
| 514 | Connection | 0.9 wks | 30/11/27 | 07/12/27 |
| 515 | Test | 0.8 wks | 07/12/27 | 13/12/27 |
| 516 | **EL cabling & infrastructure installation (2shift)** | **410 days** | **28/10/26** | **05/07/28** |
| 517 | **Power cables & infrastructure** | **410 days** | **28/10/26** | **05/07/28** |
| 518 | **Power cables & infrastructure** | **118.5 days** | **28/10/26** | **29/04/27** |
| 519 | Extra time due to EL maintenance (access | 2 wks | 05/11/26 | 19/11/26 |
| 520 | Phase 6: Install supports and cable trays | 4.2 wks | 19/11/26 | 18/12/26 |
| 521 | Phase 7: Install EN-EL PW equipment (AUG | 1.8 wks | 18/12/26 | 14/01/27 |
| 522 | Phase 8: Replace and remove temporary, c | 14.5 wks | 14/01/27 | 29/04/27 |
| 523 | TBC:Phase 9: Replace feeder & pulling nev | 0.9 wks | 09/04/27 | 16/04/27 |
| 524 | TBC:Phase 10: Pull cables for TE-VSC powe | 1.8 wks | 16/04/27 | 29/04/27 |
| 525 | Phase 11: Test and commissioning (1 shift | 0.9 wks | 28/10/26 | 04/11/26 |
| 526 | Phase 12: Displace back 18 kV and safety c | 1.2 wks | 28/10/26 | 05/11/26 |
| 527 | Phase 13: Install new power boxes for TE-VS | 2.1 wks | 21/06/28 | 05/07/28 |




**CERN Database**

**Project Online**

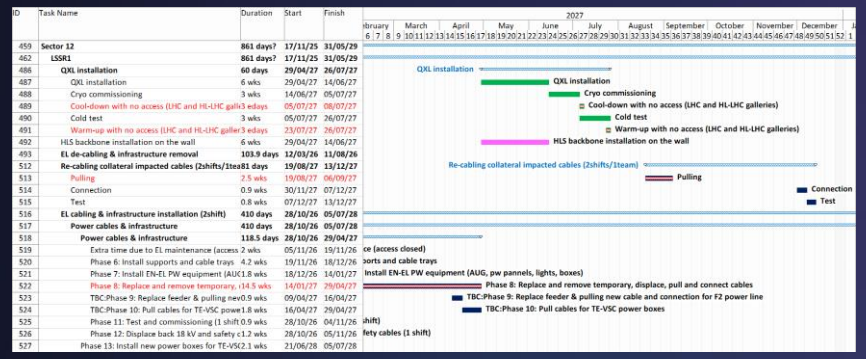
### Gantt Viewer




https://oss-coordination.web.cern.ch/gantt/latest

# Pillar 2: Installation, commissioning and follow-up

## How to build the LHC LS3 linear planning



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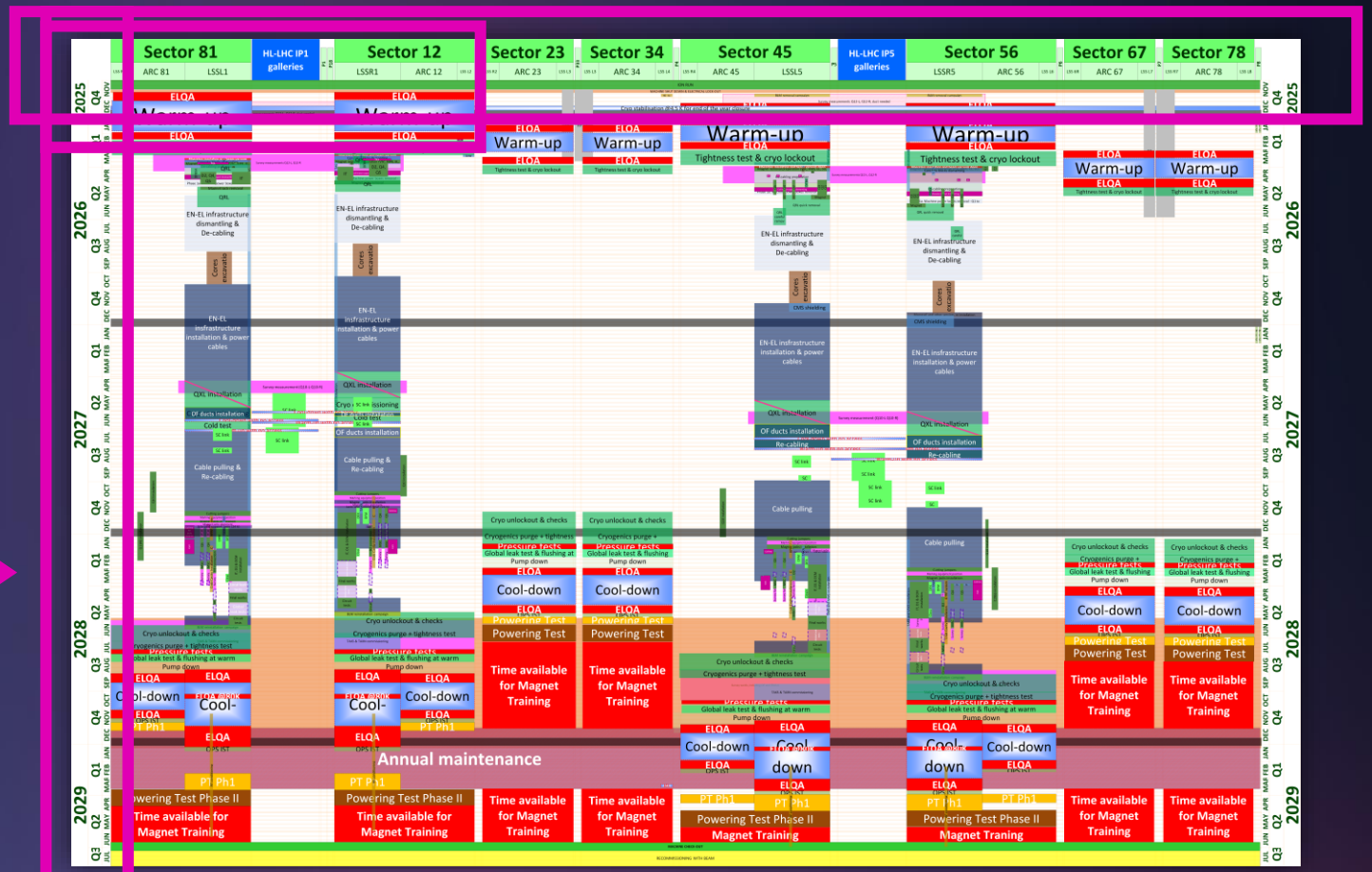
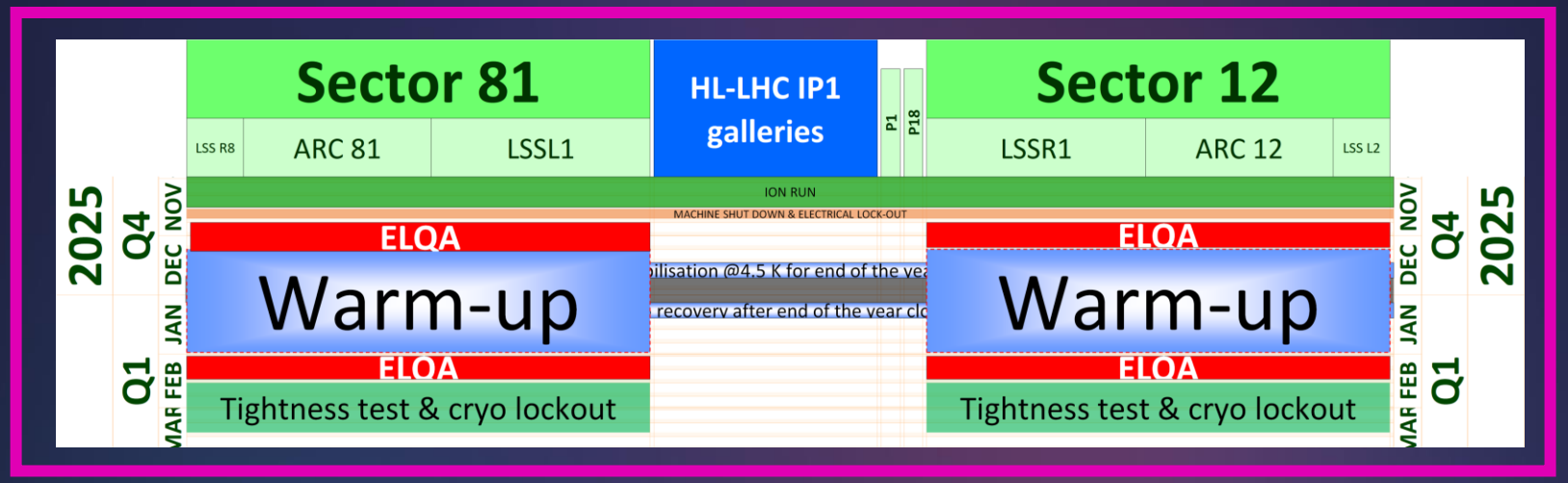


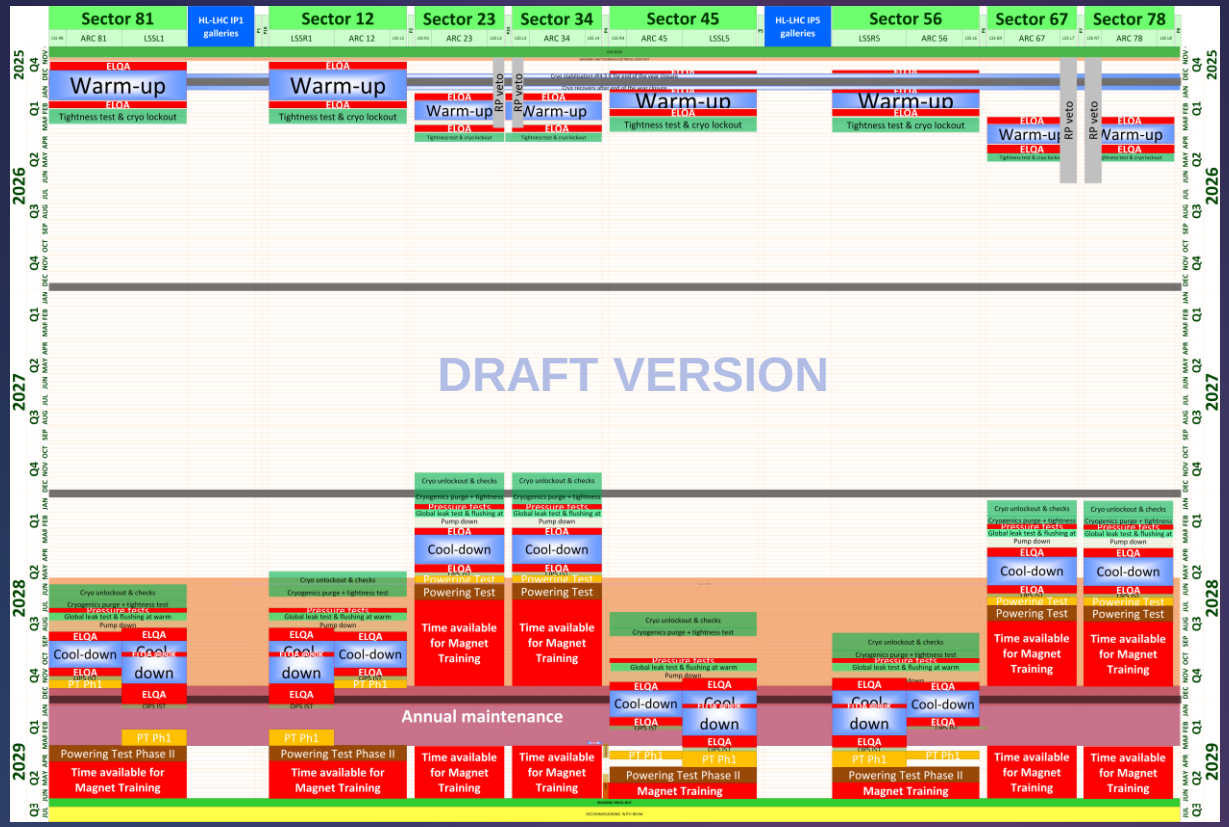
# Pillar 2: Installation, commissioning and follow-up

## How to build the LHC LS3 linear planning



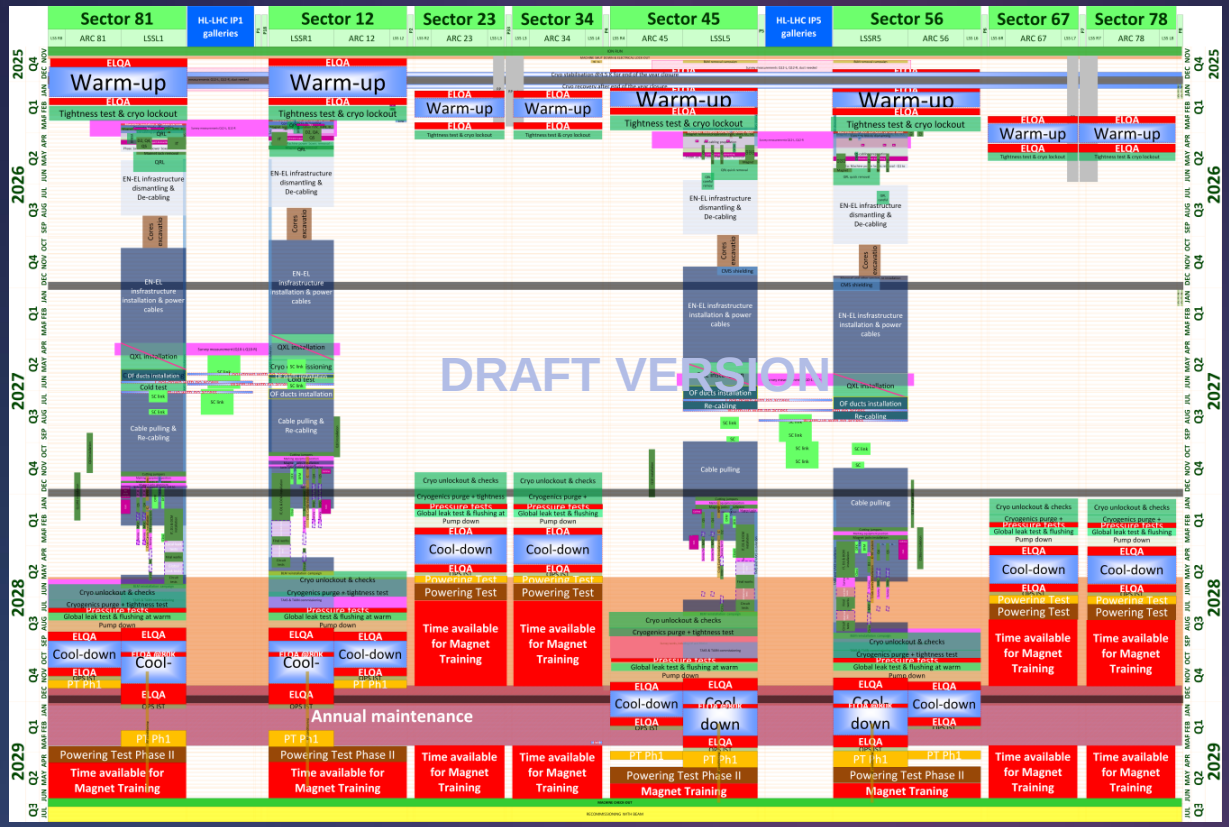
# Pillar 2: Installation, commissioning and follow-up

## How to build the LHC LS3 linear planning LS3 frame



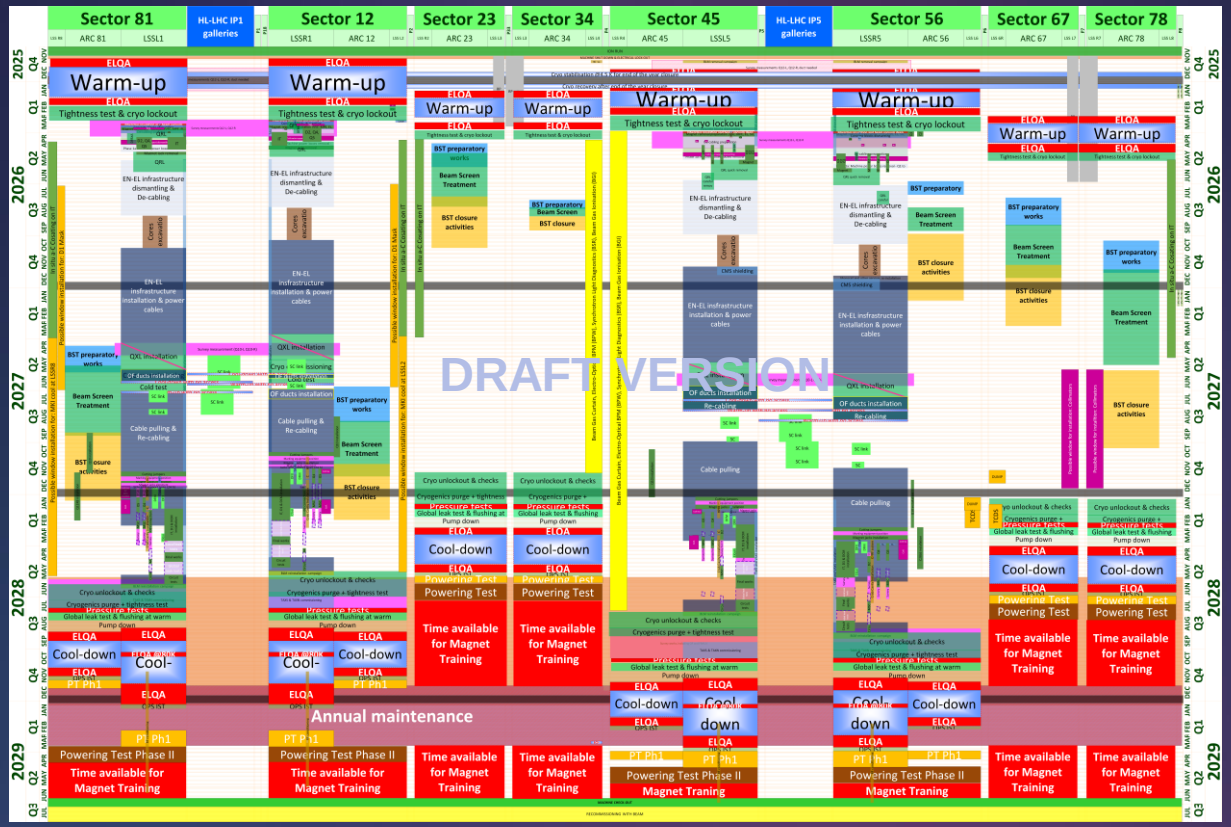
# Pillar 2: Installation, commissioning and follow-up

## How to build the LHC LS3 linear planning LS3 frame + HL-LHC



# Pillar 2: Installation, commissioning and follow-up

## How to build the LHC LS3 linear planning Global LS3 planning

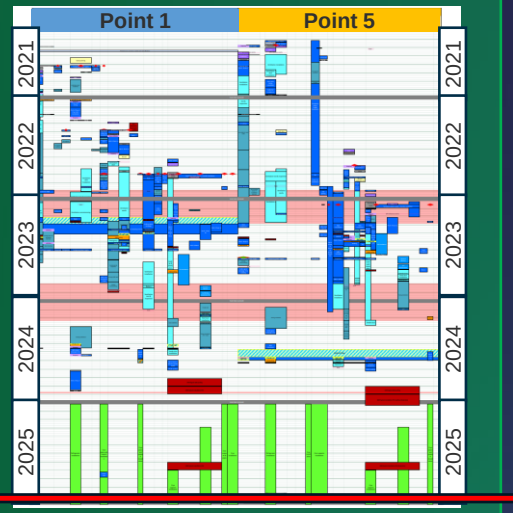


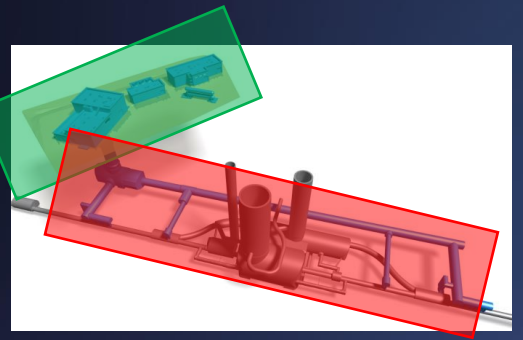
# Pillar 2: Installation, commissioning and follow-up

## HL-LHC linear plannings

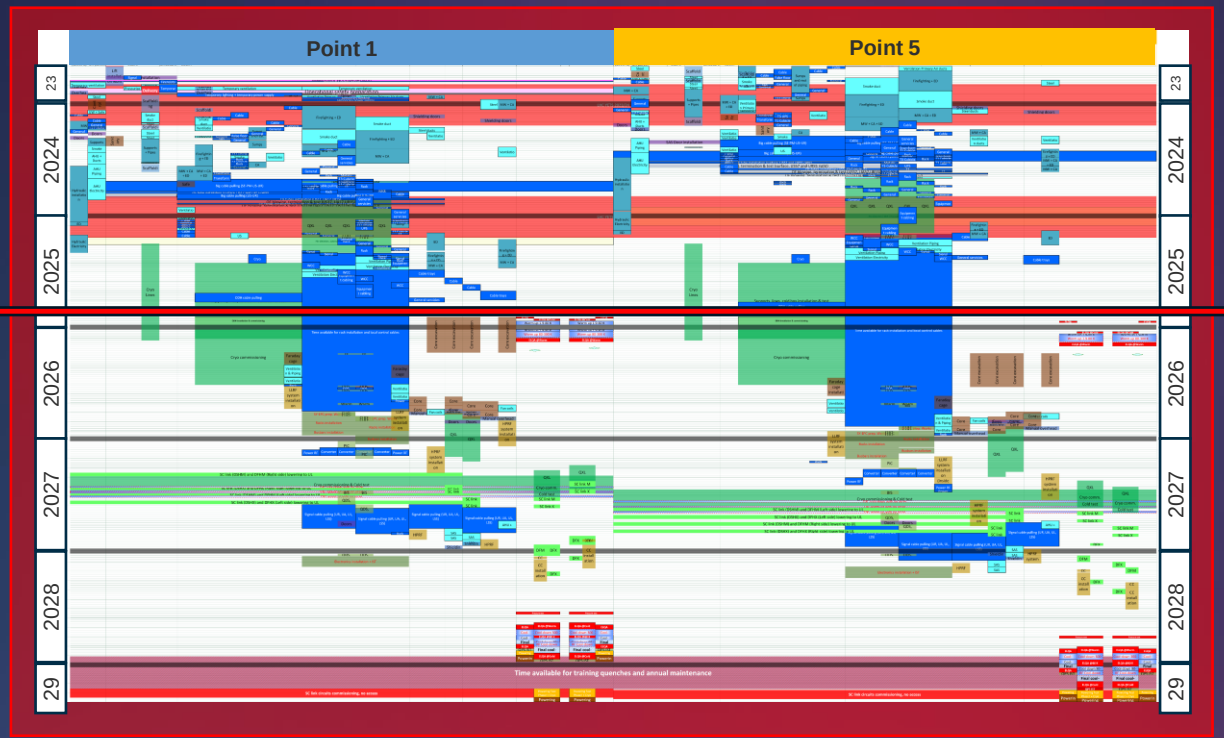
## Surface buildings, underground new galleries and LHC tunnel

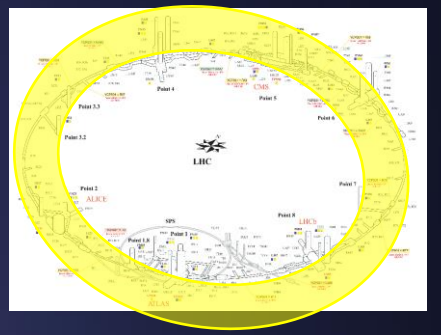
HL-LHC surface facilities



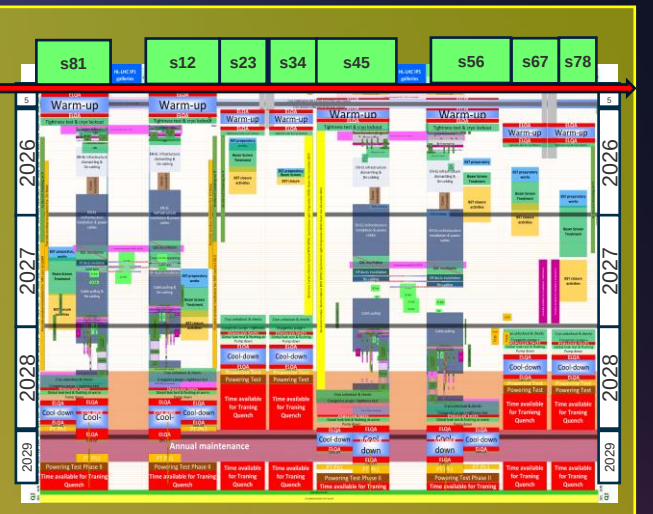



HL-LHC underground galleries



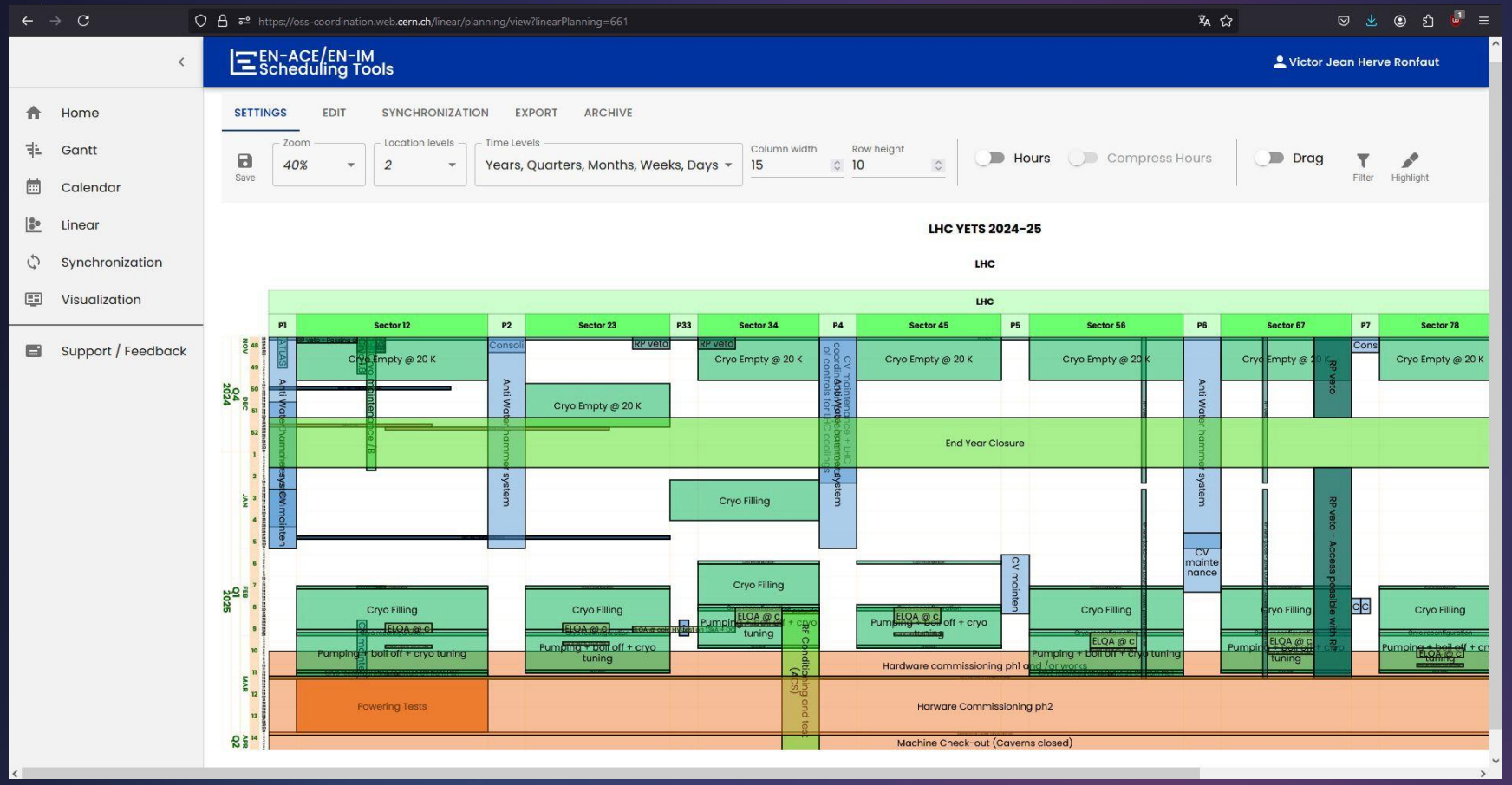



LHC LS3 schedule

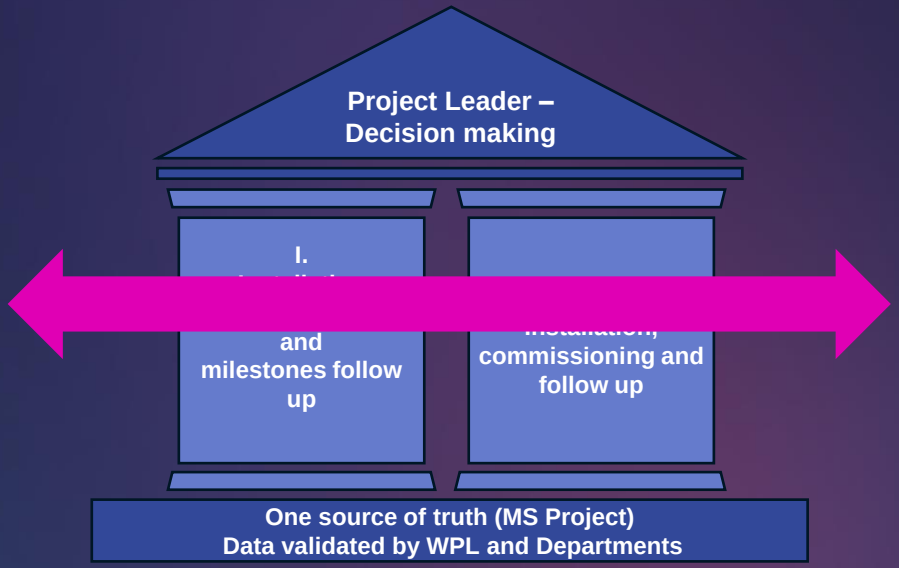


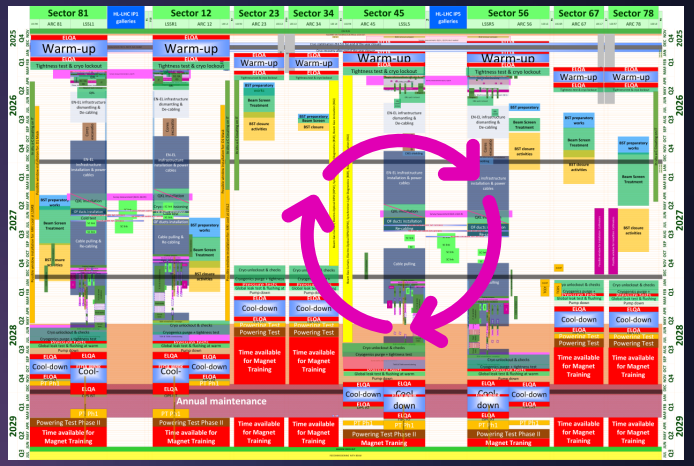
# Pillar 2: Installation, commissioning and follow-up

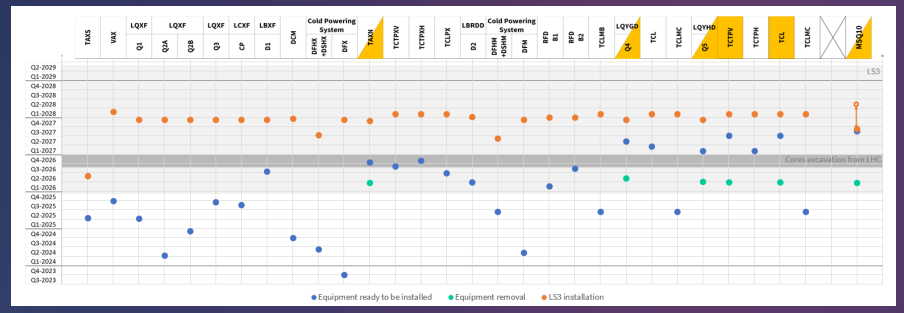
## Scheduling Tools Project Linear Planning Web Interface




# Schedule change management

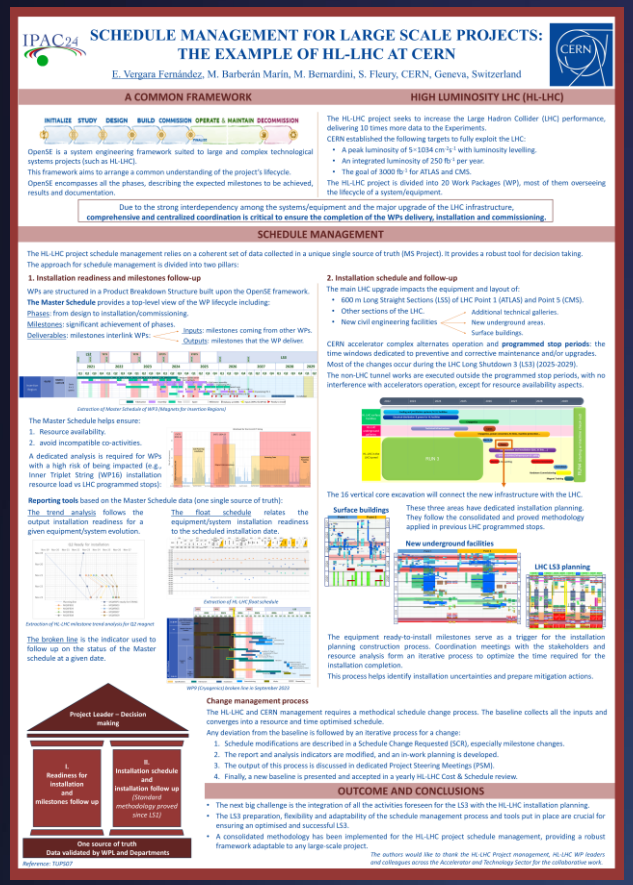



Float schedule: Equipment ready to install vs LS3 installation

# Conclusions



IPAC24

SCHEDULE MANAGEMENT FOR LARGE SCALE PROJECTS: THE EXAMPLE OF HL-LHC AT CERN

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A COMMON FRAMEWORK

HIGH LUMINOSITY LHC (HL-LHC)

INITIALIZE STUDY DESIGN BUILD COMMISSION OPERATE & MAINTAIN DECOMMISSION

OpenSE is a system engineering framework suited to large and complex technological systems projects (such as HL-LHC).
This framework aims to arrange a common understanding of the project's lifecycle.
OpenSE encompasses all the phases, describing the expected milestones to be achieved, results and documentation.

The HL-LHC project seeks to increase the Large Hadron Collider (LHC) performance, delivering 10 times more data to the Experiments.
CERN established the following targets to fully exploit the LHC:
- A peak luminosity of 5×10³⁴ cm⁻²s⁻¹ with luminosity levelling.
- An integrated luminosity of 250 fb⁻¹ per year.
- The goal of 3000 fb⁻¹ for ATLAS and CMS.

The HL-LHC project is divided into 20 Work Packages (WP), most of them overseeing the lifecycle of a system/equipment.

Due to the strong interdependency among the systems/equipment and the major upgrade of the LHC infrastructure, **comprehensive and centralized coordination is critical to ensure the completion of the WPs delivery, installation and commissioning.**

SCHEDULE MANAGEMENT

The HL-LHC project schedule management relies on a coherent set of data collected in a unique single source of truth (MS Project). It provides a robust tool for decision taking.
The approach for schedule management is divided into two pillars:

**1. Installation readiness and milestones follow-up**

WPs are structured in a Product Breakdown Structure built upon the OpenSE framework.
**The Master Schedule** provides a top-level view of the WP lifecycle including:
Phases: from design to installation/commissioning.
Milestones: significant achievement of phases.
Deliverables: milestones interlink WPs: Inputs: milestones coming from other WPs. Outputs: milestones that the WP deliver.

Extraction of Master Schedule of WP2 (Magnets for insertion Regions)

The Master Schedule helps ensure:
1. Resource availability.
2. avoid incompatible co-activities.

A dedicated analysis is required for WPs with a high risk of being impacted (e.g., Inner Triplet String (WP16) installation resource load vs LHC programmed stops):

**Reporting tools** based on the Master Schedule data (one single source of truth):

The trend analysis follows the output installation readiness for a given equipment/system evolution.

The float schedule relates the equipment/system installation readiness to the scheduled installation date.

Extraction of HL-LHC milestone trend analysis for Q2 magnet

Extraction of HL-LHC float schedule

The broken line is the indicator used to follow up on the status of the Master schedule at a given date.

WP9 (Cryogenics) broken line in September 2023

**2. Installation schedule and follow-up**

The main LHC upgrade impacts the equipment and layout of:
- 600 m Long Straight Sections (LSS) of LHC Point 1 (ATLAS) and Point 5 (CMS).
- Other sections of the LHC.
- New civil engineering facilities: Additional technical galleries. New underground areas. Surface buildings.

CERN accelerator complex alternates operation and **programmed stop periods**: the time windows dedicated to preventive and corrective maintenance and/or upgrades.
Most of the changes occur during the LHC Long Shutdown 3 (LS3) (2025-2029).
The non-LHC tunnel works are executed outside the programmed stop periods, with no interference with accelerators operation, except for resource availability aspects.

The 16 vertical core excavation will connect the new infrastructure with the LHC.

Surface buildings

These three areas have dedicated installation planning. They follow the consolidated and proved methodology applied in previous LHC programmed stops.

New underground facilities

LHC LS3 planning

The equipment ready-to-install milestones serve as a trigger for the installation planning construction process. Coordination meetings with the stakeholders and resource analysis form an iterative process to optimize the time required for the installation completion.
This process helps identify installation uncertainties and prepare mitigation actions.

Project Leader – Decision making

I. Readiness for installation and milestones follow up

II. Installation schedule and installation follow up (Standard methodology proved since LS1)

One source of truth
Data validated by WPL and Departments

**Change management process**

The HL-LHC and CERN management requires a methodical schedule change process. The baseline collects all the inputs and converges into a resource and time optimised schedule.
Any deviation from the baseline is followed by an iterative process for a change:
1. Schedule modifications are described in a Schedule Change Requested (SCR), especially milestone changes.
2. The report and analysis indicators are modified, and an in-work planning is developed.
3. The output of this process is discussed in dedicated Project Steering Meetings (PSM).
4. Finally, a new baseline is presented and accepted in a yearly HL-LHC Cost & Schedule review.

OUTCOME AND CONCLUSIONS

- The next big challenge is the integration of all the activities foreseen for the LS3 with the HL-LHC installation planning.
- The LS3 preparation, flexibility and adaptability of the schedule management process and tools put in place are crucial for ensuring an optimised and successful LS3.
- A consolidated methodology has been implemented for the HL-LHC project schedule management, providing a robust framework adaptable to any large-scale project.

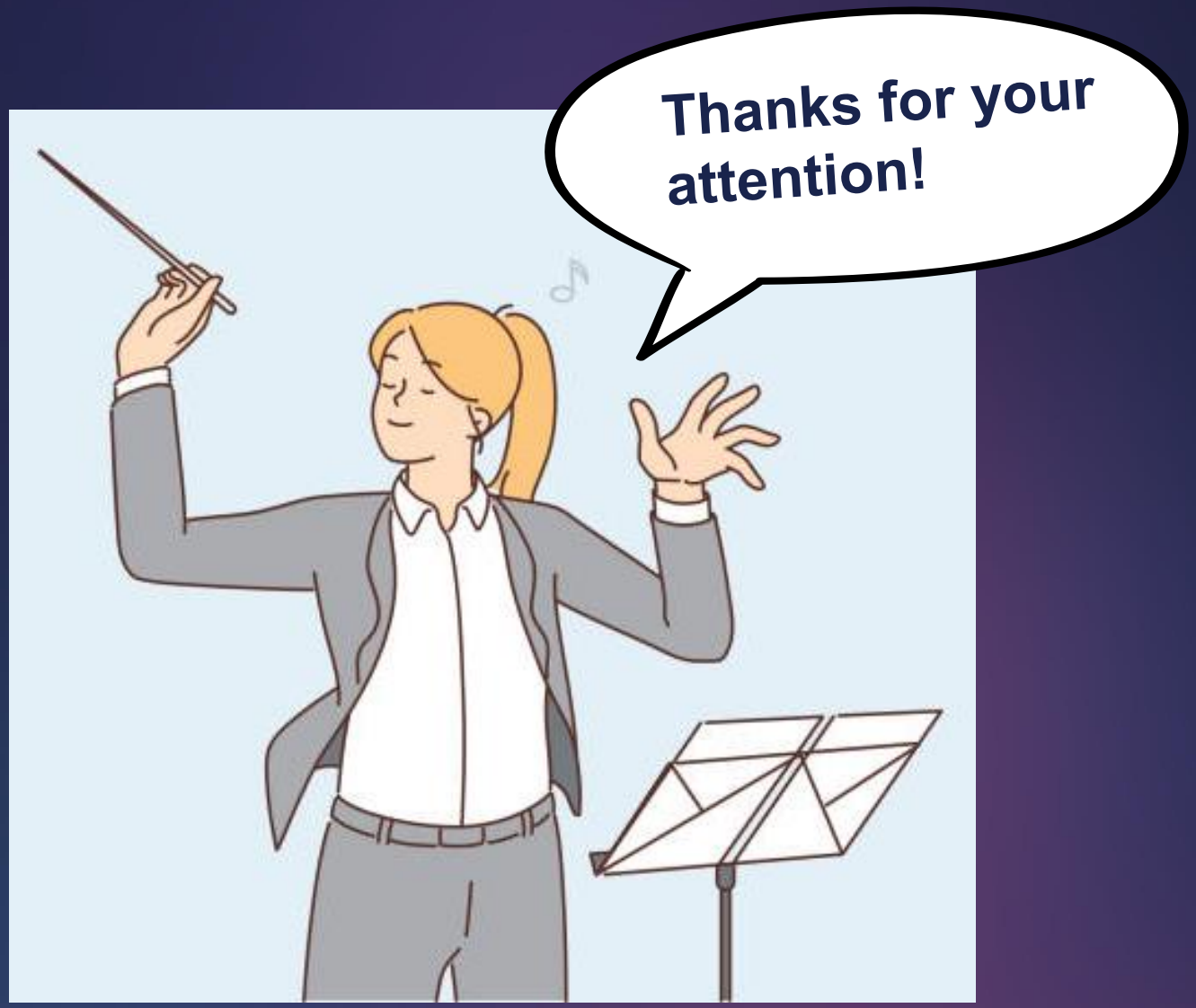
*The authors would like to thank the HL-LHC Project management, HL-LHC WP leaders and colleagues across the Accelerator and Technology Sector for the collaborative work.*

Reference: TUPS07

- The HL-LHC project represents a sophisticated integration of systems, equipment, and services within the LHC.
- The establishment of global HL-LHC coordination management has been a significant step forward for the LHC coordination.
- Our reliable methodology and specialized tools for large-scale scientific projects establish a good basis for CERN projects.
- Lessons learnt from previous LS: expertise, flexibility, accountability and communication are key success factors!

**Together is better.**

https://www.jacow.org/ipac2024/pdf/TUPS07.pdf


Thanks for your attention!