FUTURE
CIRCULAR
COLLIDER

INSTALLATION SCHEDULE

S. Fleury | J.P Burnet | M. Bernardini

Together with valuable contributions of FCC teams

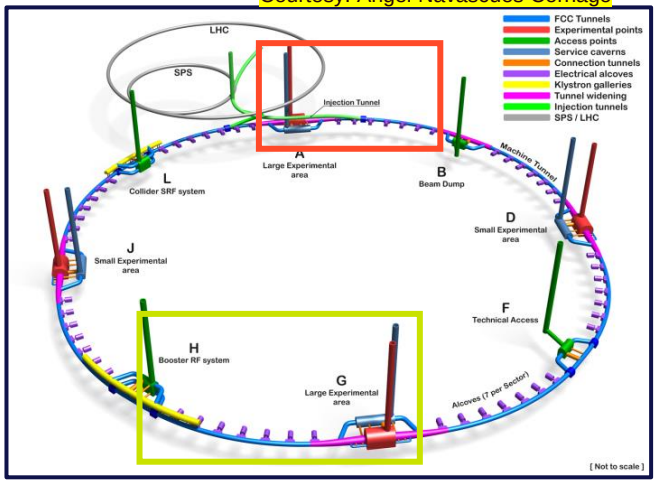
Outline

- Civil engineering and installation schedules optimisation
- Technical infrastructure sequence new inputs
- Installation sequence in shafts, arcs and radio frequency points
- Overall FCC-ee and FCC-hh installation schedule
- Next steps

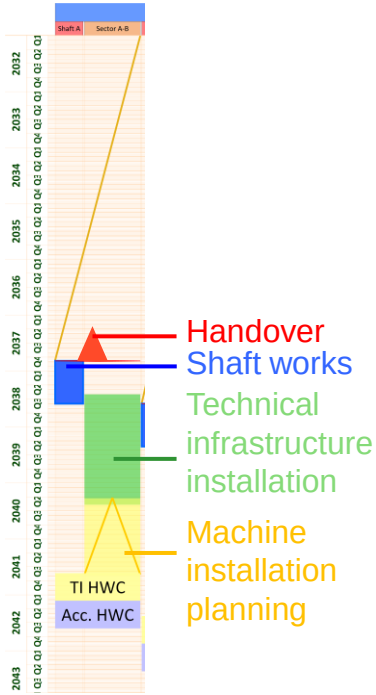
May 2024: Civil engineering strategy

- During the FCC week 2024, civil engineering schedule included a **single handover (shafts and one adjacent sector simultaneously)**.
- In total, **8 such handovers** are planned to initiate the installation sequence.

Courtesy: Angel Navascues Cornago



Civil engineering release strategy explained with overall machine layout

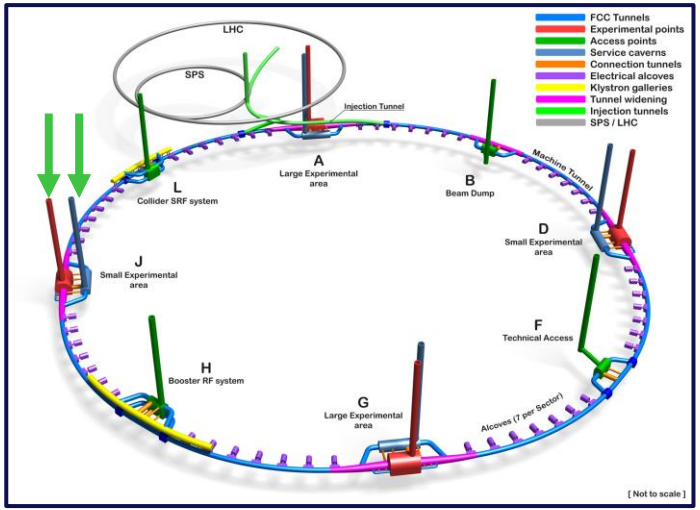


Example of installation schedule from point A to point B with the single handover strategy

May 2024: Two schedules to be aligned

The single handover would imply:

- Shafts (for experimental points - 2 shafts): no possibility to start the installation in one shaft while civil engineering is still ongoing in the other.



FCC Machine layout

May 2024: Two schedules to be aligned

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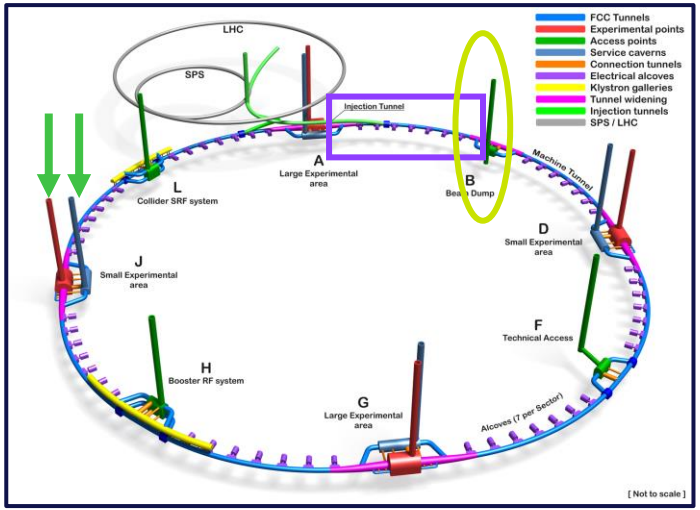

FCC Machine layout

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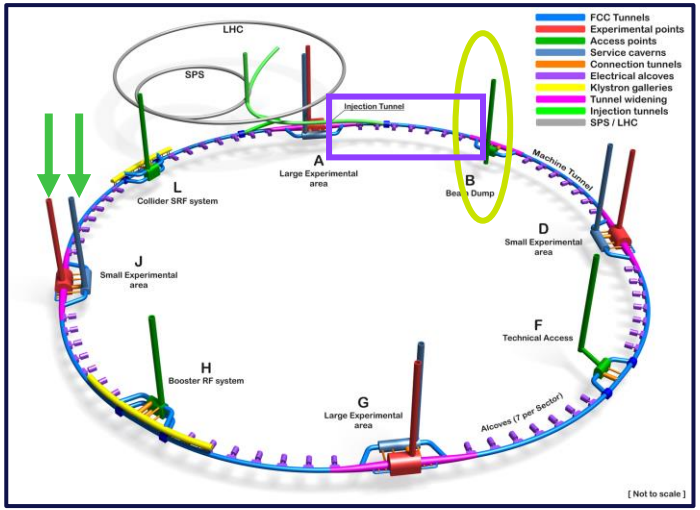
➢ Opportunity for schedule optimisation

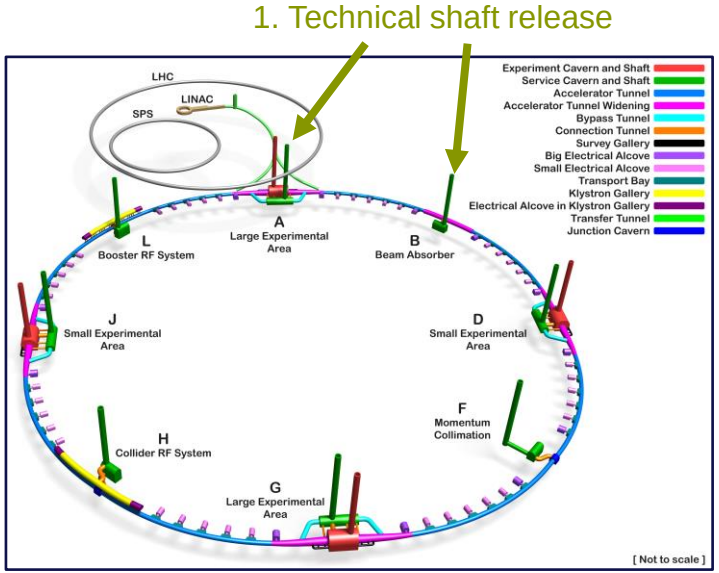


FCC Machine layout

Post FCC Week 2024: optimization

Until the end of the feasibility study, several iterations with civil engineering were conducted to define an **optimal** and **feasible** handover strategy:

- The Tunnel Boring Machines (TBM) will be extracted from the experimental points.
  - ➢ This enables for an **earlier release of technical shaft.**
  - ➢ The installation in the arc can start only after the TBM drive.



FCC Machine layout

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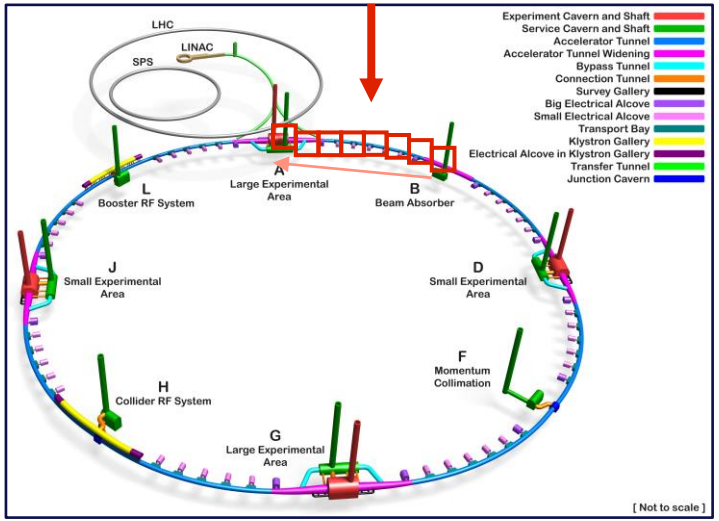
- Multiple arc releases phases are foreseen, each covering at least one alcove and ~1600 metres of tunnel.
  - ➢ This strategy implies two independent worksites along the arc: final civil engineering works and installation activities.
  - ➢ This allows an **anticipated start of installation across the arc**.

2. Arc gradual release corresponding distance between two alcoves



FCC Machine layout

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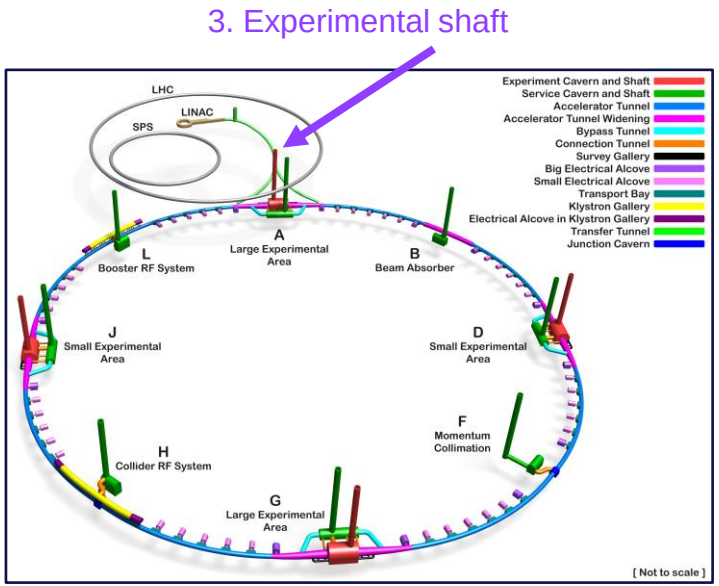
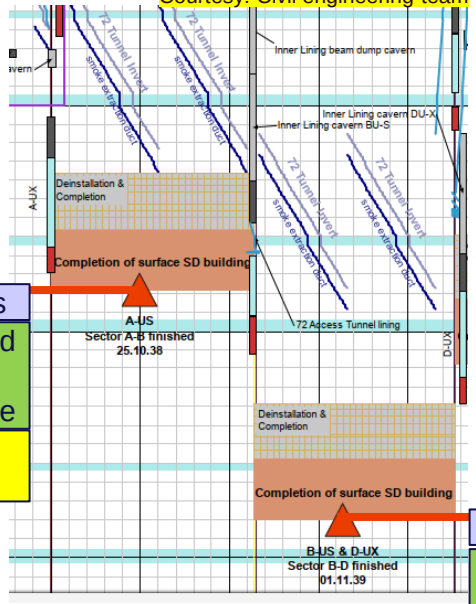


FCC Machine layout

Impact on installation schedule

Courtesy: Civil engineering team



Shaft works

Underground technical infrastructure

Machine installation

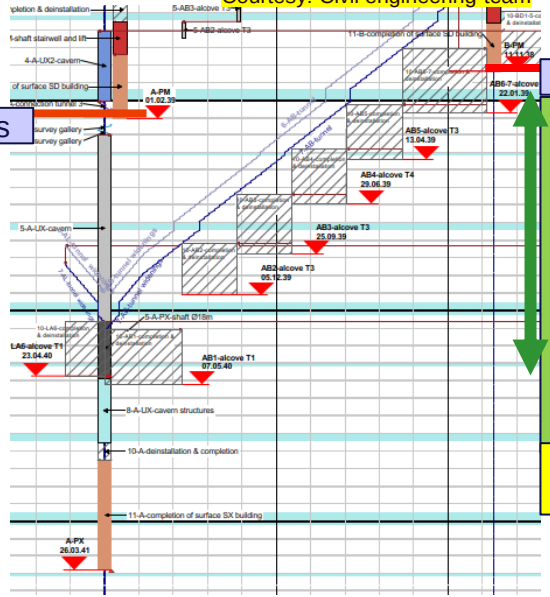
Shaft works

Underground technical infrastructure

Machine installation

May 2024 civil engineering schedule with main installation blocks

Courtesy: Civil engineering team



Shaft works

Shaft works

Underground technical infrastructure

Machine installation

May 2025 civil schedule with main installation blocks

A significant part of technical infrastructure work is in the shadow of civil engineering schedule

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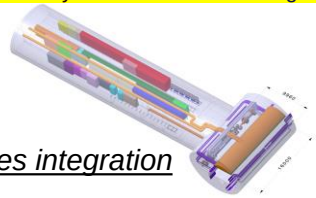
EN-EL technical infrastructure installation

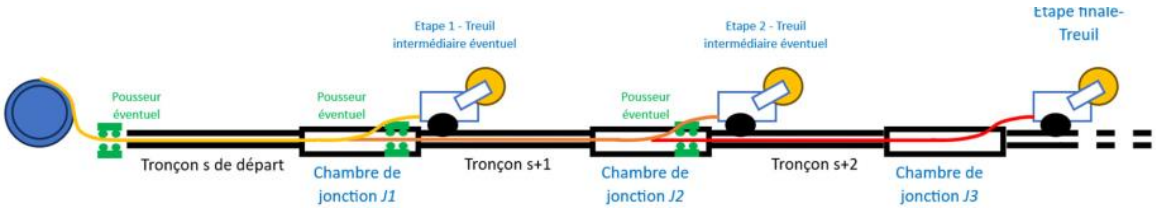
Courtesy: Fani Valchkova-Georgieva



Small alcoves integration

Alcove installation duration:
Installing a **small alcove**, including all required equipment up to commissioning, takes approximately **18 weeks (based on 1 team working in 1 shift).**

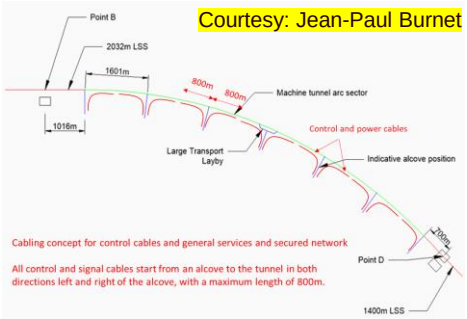
➢ This should be completed **prior to the start of high-voltage cabling activities**.



Courtesy: EN-EL team

Installation methodology of High Voltage cable needs

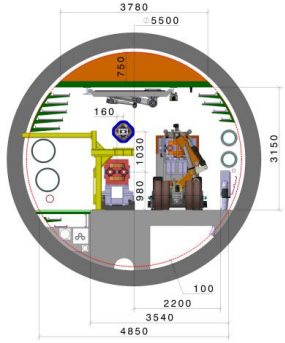
Courtesy: Jean-Paul Burnet



Alcoves layout along the arc

EN-EL input for technical infrastructure installation

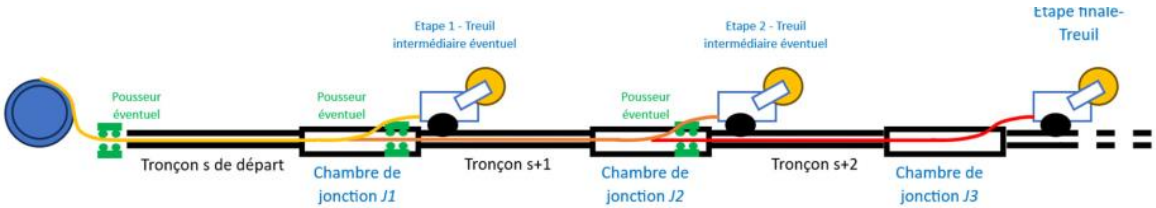
Courtesy: Fani Valchkova-Georgieva



FCC cross section in the arcs

High-voltage cable installation considerations:

- The currently planned cable drum (which covers **one alcove distance of cable**) is too **large to fit in the tunnel**.
- Only one cable tube is available to transport the cable along the arc.
  - ➢ The closest accessible cable tube must be used to install cables in the furthest sections. The installation **requires the overall arc released by civil engineering**.
- **Work** is carried out in front of the **alcoves**. Installation in the arc is possible only if the winch can be positioned within the transport corridor.



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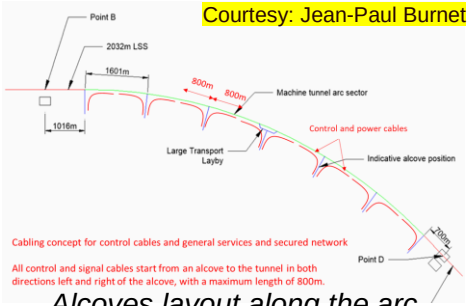
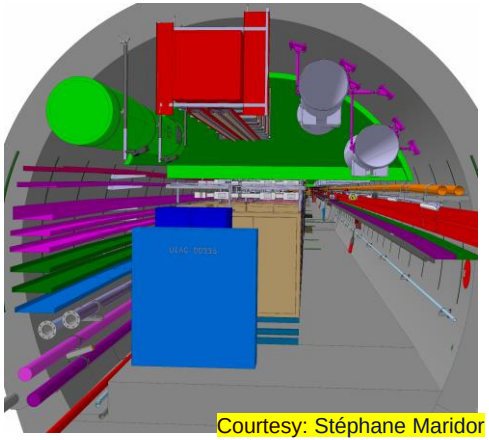


Alcoves layout along the arc

HL-LHC feedback & sequence



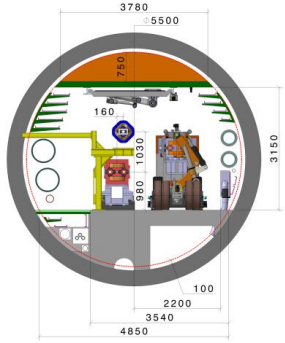
Courtesy: Stéphane Maridor

HL-LHC cross-section of underground galleries in point 1 and point 5 extracted from 3D reference ST1120748_01 12/05/2025

Courtesy: Henry de Maynard

Picture of Point 5 underground gallery

Courtesy: Fani Valchkova-Georgieva



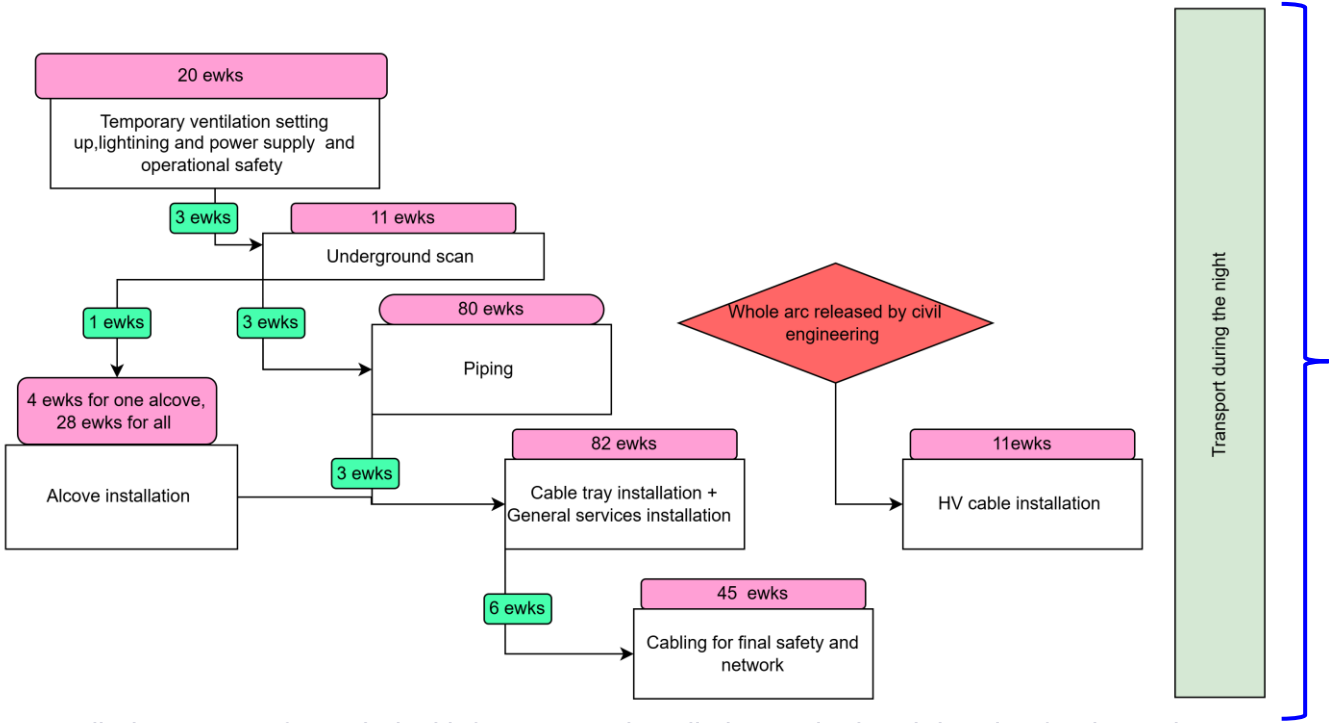
FCC cross section in the arcs

Many thanks to Henry de Maynard and Thomas Bauler managing installation of HL-LHC galleries for their valuable input !

The most recent tunnel construction and underground installation of service galleries (80 m deep and 300 m long) was carried out at Points 1 and 5 of the LHC.

The FCC technical infrastructure design draws on the experience gained from the HL-LHC project.

Technical infrastructure sequence in arcs



Detailed sequence for technical infrastructure installation and related duration for the entire arc

Hypothesis and parameters for technical infrastructure installation

Technical infrastructure installation in the arc is foreseen as follows:

- The durations are expressed in calendar days.
- Installation activities are planned in two shifts dedicated to installation and one shift for transport.
- Disclaimer: For reference, this corresponds to a pace approximately four times faster than HL-LHC installation rates. However, due to the larger scale of the FCC project and the associated need for automation, the effort required for technical infrastructure installation differs significantly from that of HL-LHC.

Outline

- Civil engineering and installation schedules optimisation
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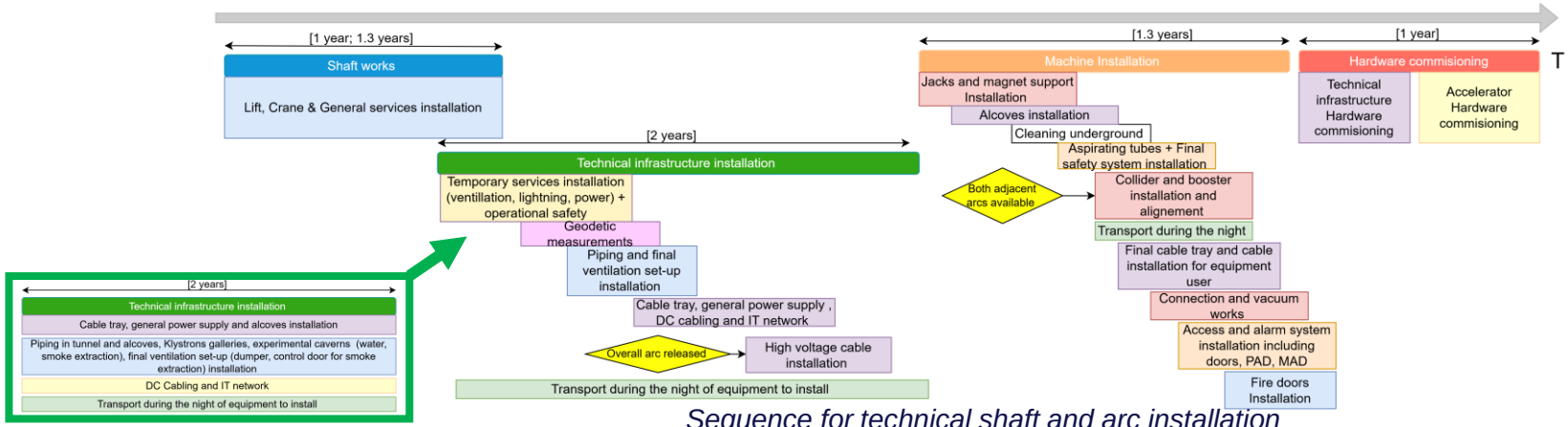
General arc sequence

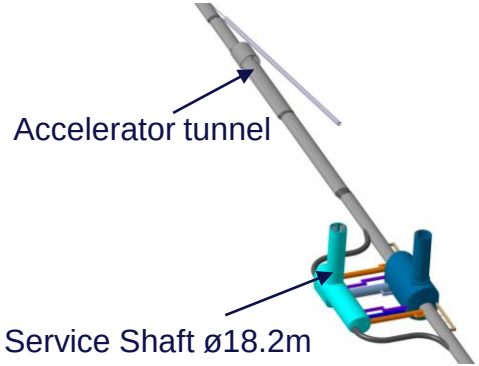


May 2024 sequence of technical infrastructure installation

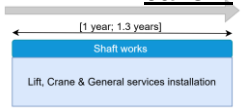
Sequence for technical shaft and arc installation

- The installation sequence follows the same block structure as presented last year. The sequence for the technical infrastructure has since been refined into a train-like progression.
- According to the resource-loaded schedule, a maximum of four arcs can be in the same installation phase simultaneously (i.e., within the same main block).

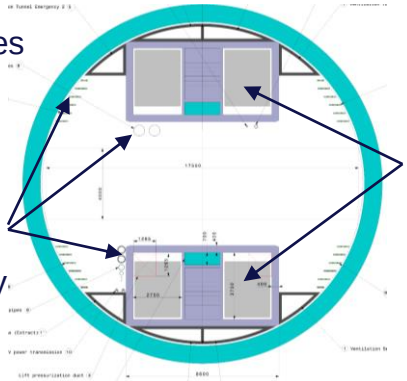
Technical shaft installation



Service shaft at Point A with respect to the tunnel and the experiment cavern



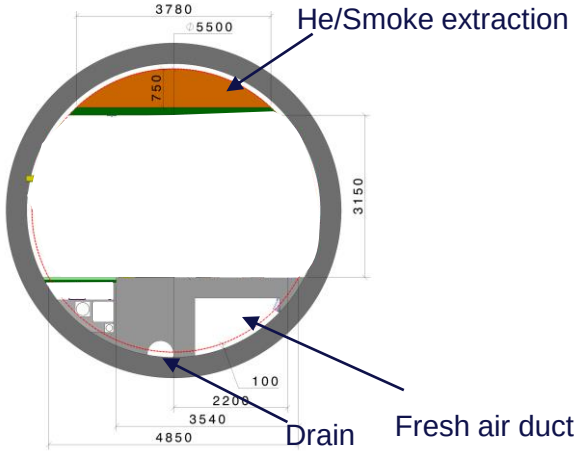
1.Crane
2.Temporary services



Courtesy: Fani Valchkova-Georgieva

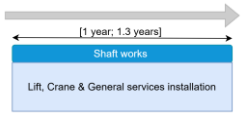
Point A service shaft integration

Arc layout after the handover from civil engineering

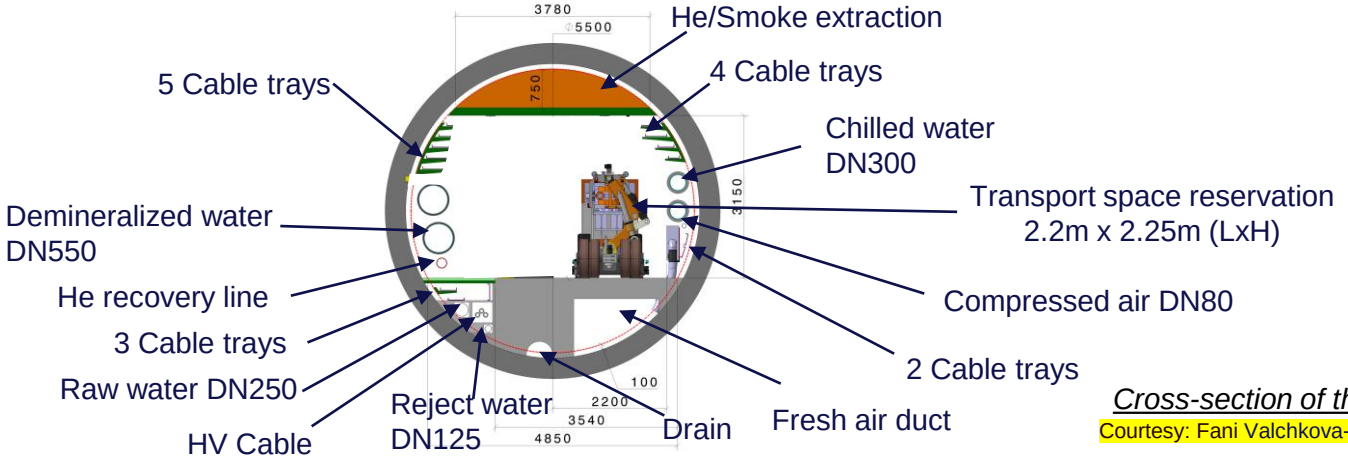


Cross-section of the arcs

Courtesy: Fani Valchkova-Georgieva



Technical infrastructure installation in arcs



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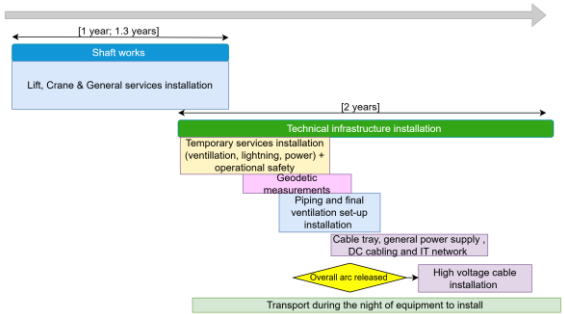
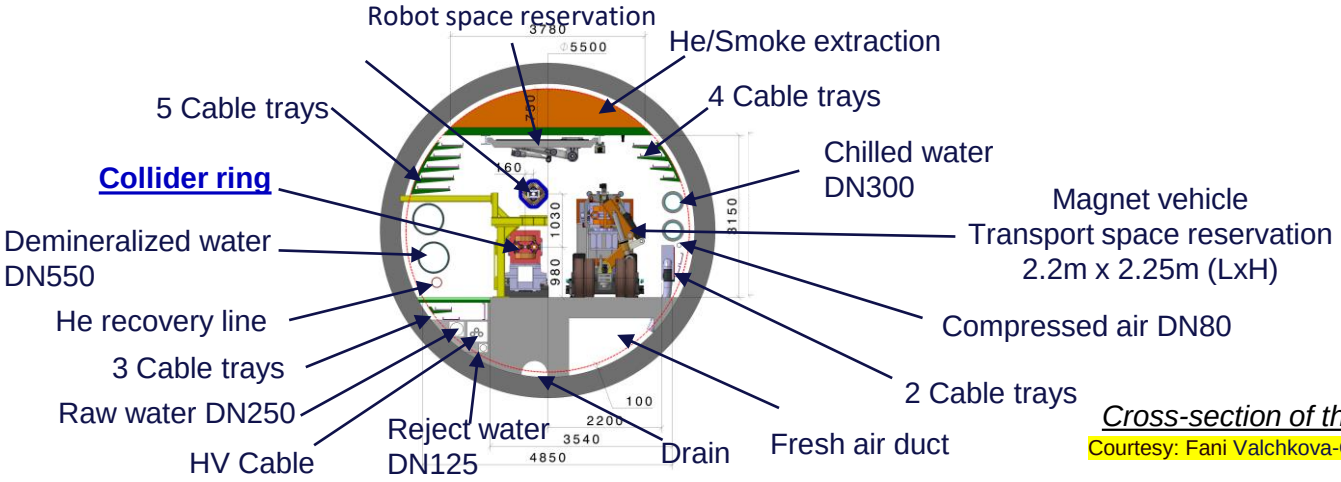


Machine installation in arcs



Cross-section of the arcs

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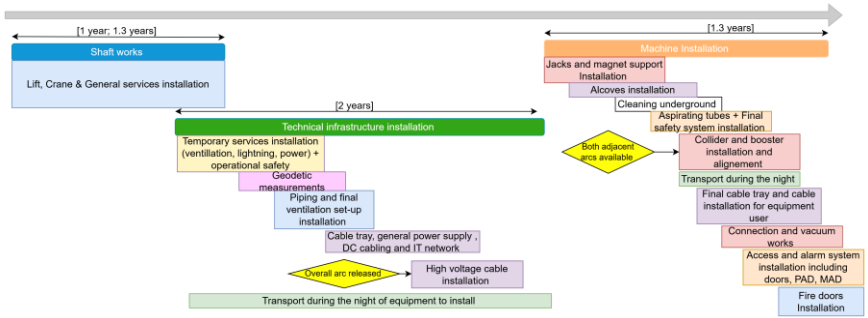
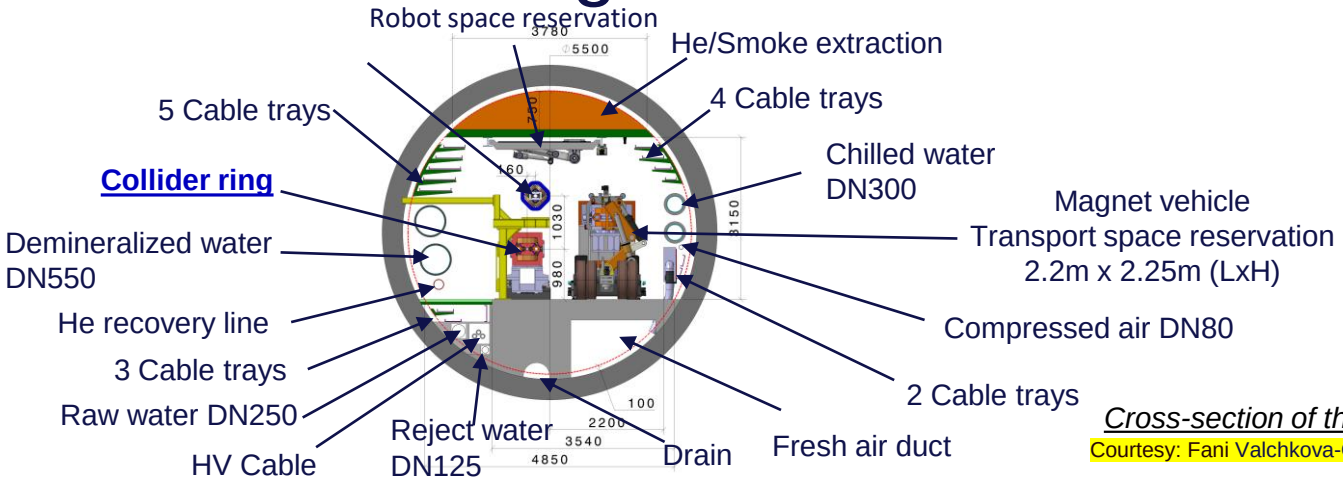


Hardware commissioning



Cross-section of the arcs

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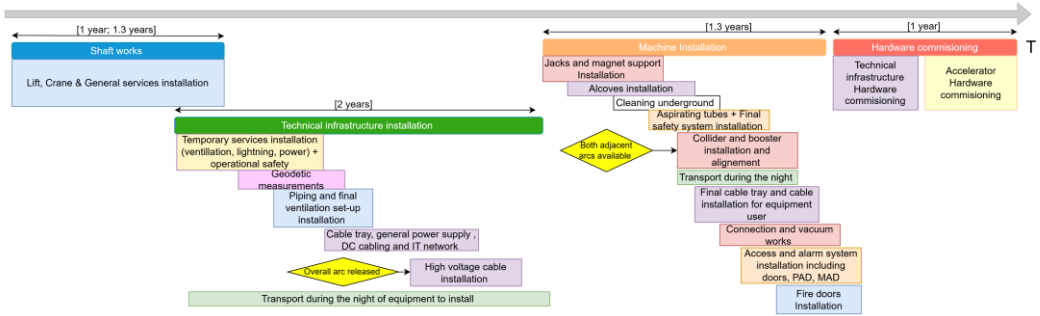
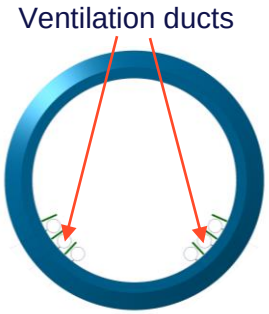
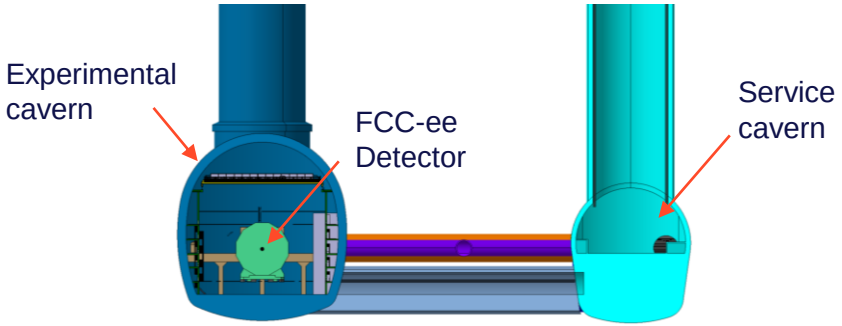


Experimental shaft and cavern installation



Experimental shaft ø18m at Point A



Cavern layout in point A

Courtesy: Fani Valchkova-Georgieva

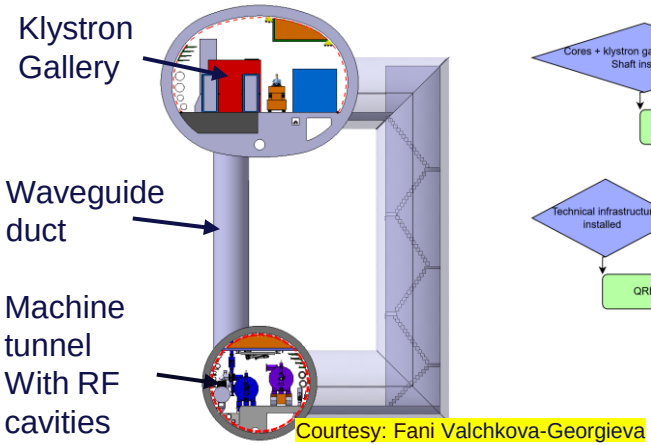
Sequence for experiment shaft and cavern

The shaft works on the experimental shaft are expected to take approximately 6 months to complete.

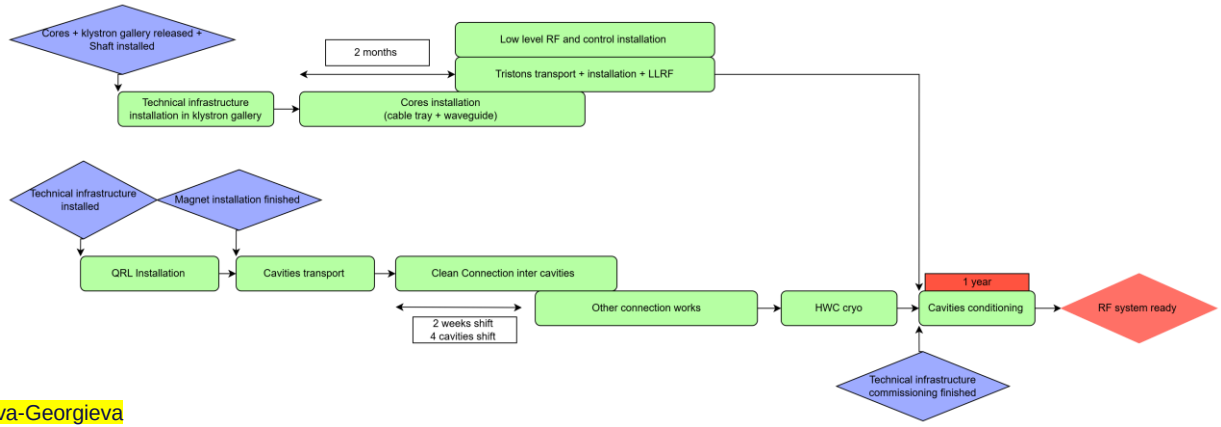
For each of the four experimental points, the installation of the experiment in the cavern is planned to last 2 years, followed by 6 months of synchronized hardware commissioning in coordination with the machine.

Radio Frequency systems installation

- Radiofrequency systems will be installed in Point H and Point L Long Straight Section and klystron galleries. The installation of the QRL was also studied and placed in the sequence.
- Two stages of installation are foreseen for cryomodules and RF power stations to first operate for Z, W, ZH FCC-ee modes and then tt-bar.



Klystron gallery and machine tunnel (LSS) at point H



Sequence of installation for Radiofrequency systems at point H and point L

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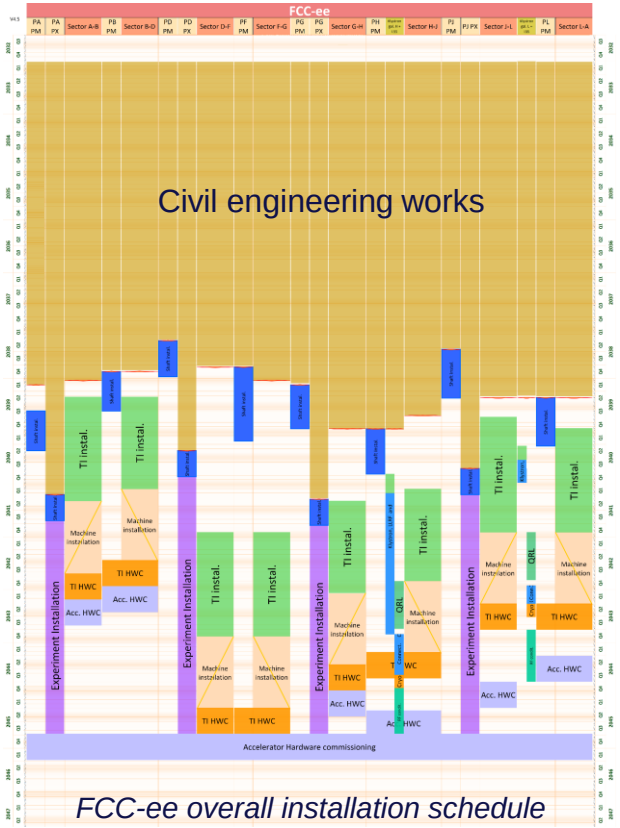
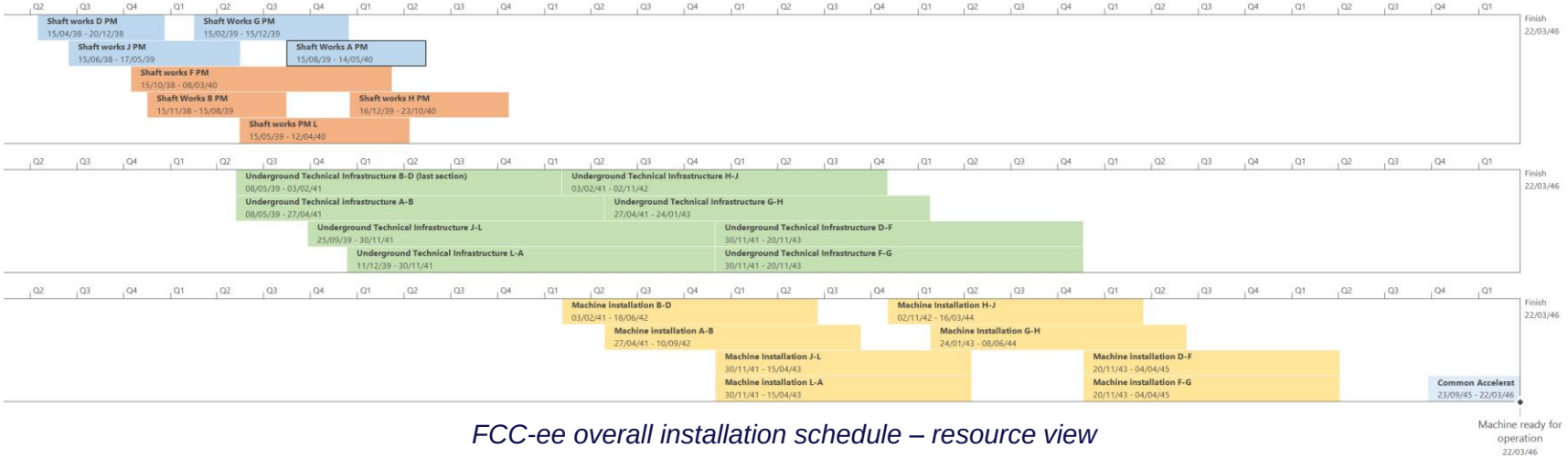
Overall installation schedule FCC-ee



FCC-ee overall installation schedule

- Civil engineering excavation is scheduled to begin in January 2033. The first technical shaft will be released in 2038, with the last area expected in 2041.
- These initial technical shaft releases will be the starting point for technical infrastructure installation.
- The installation of radio frequency systems at Point H and Point L is not on the project's critical path and will therefore not impact the overall schedule.
- Total duration for installation including hardware commissioning: **2038-2046**, **8 years.**
- Readiness for operation in **April 2046.**

Resource installation schedule FCC-ee



FCC-ee overall installation schedule – resource view

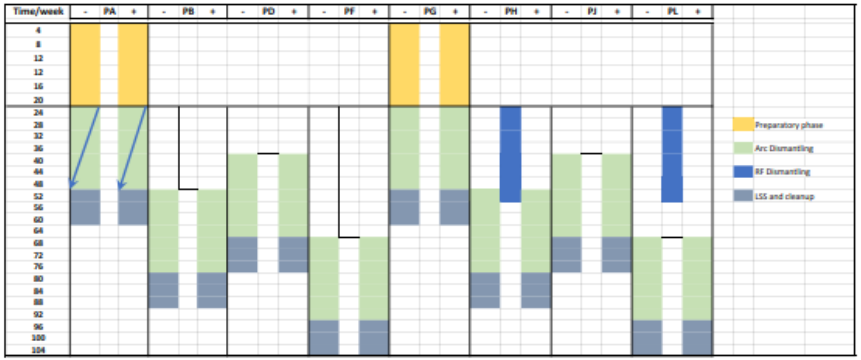
The resource limitation introduced to **balance the workload** indicates that a **maximum of four arcs can be engaged simultaneously in the same type of installation activities** *(technical shaft installation, technical infrastructure installation, or machine component installation)*.
The resource view enables verification that this constraint is respected.

FCC-hh installation schedule

After 15 years of operation, FCC-ee is planned to stop at the **end of 2061** (December 2061), with **dismantling activities** scheduled to begin by the **end of 2062**, i.e. 12 months after shutdown.
The target timeline for the transition to FCC-hh includes a total of 10 years:

- 2 years for dismantling,
- 8 years for installation activities.

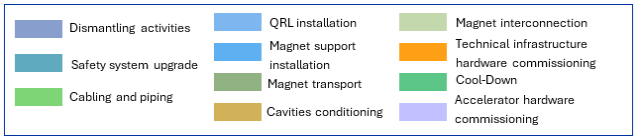
The dismantling strategy has been analysed and documented in a dedicated report by M. Benedikt, P. Collier, and J. Poole.



Courtesy: M.Benedikt, P. Collier, J. Poole

FCC-hh installation schedule

- 4 arcs maximum for one type of activities
- Dismantling + machine installation + HWC: **9.5 years**
- Machine ready for beam on **04/2072**



Summary

- The FCC-ee installation schedule has been **refined in coordination with the civil engineering timeline, to optimise the handover strategy** and **allow installation work to begin** while civil works are still ongoing in the arc.

- Drawing on experience from the HL-LHC underground gallery installations, a **refined sequence for technical infrastructure installation** was developed, including the integration of high-voltage cable installation.

- The **radiofrequency equipment installation sequence** has been incorporated into the overall schedule and does not impact the critical installation path.

- The transition from FCC-ee to FCC-hh is designed to **fit within a 10-year window**, including 2 years of dismantling and 8 years of FCC-hh infrastructure and machine installation.

Next steps

- Define the ventilation strategy during installation, in collaboration with EN-CV.
- Discuss the installation of safety systems and the management of degraded operational modes during installation, together with the Safety Team.
- Integrate the cryogenic systems into the installation sequence within the shaft and caverns, in coordination with the Cryogenics Team.
- Plan the installation of all remaining tunnels and underground caverns, in collaboration with the relevant groups.
- Continue to closely monitor the civil engineering schedule.

Thank you
for your attention.