ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-WECD1

FCC-EE LARGE-SCALE PROJECT INSTALLATION PLANNING: CHALLENGES & PROPOSALS

S. Fleury*, J.-P. Burnet, M. Bernardini, M. Benedikt, CERN, Geneva, Switzerland
F. Valchkova-Georgieva, CEGELEC SA, Carouge, Switzerland

Abstract

CERN is contemplating further advancements in the energy frontier through the Future Circular Collider (FCC) study, envisioning a 90.7 km underground accelerator with multiple energy stages over time. Following the European Strategy for Particle Physics recommendation in 2020, CERN initiated a feasibility study to scrutinize all aspects of the FCC project.

A crucial component of this study involves developing a timeline from project approval to the beam operation of FCC-ee, the first collider with electron and positron. Since the last planning iteration in 2018, modifications in the machine layout and shaft configuration necessitated a re-evaluation of the planning.

This paper focuses on the updated planning for FCC-ee, spanning from civil engineering completion to beam operation. It compiles pertinent elements, including the civil engineering release date, layout data, and human resources regulations and limitations. These elements were analyzed systematically to derive a sector sequence. Employing a bottom-up approach in conjunction with resource constraints, an overarching plan for the FCC-ee machine until the start of operations was formulated.

INTRODUCTION

The exploration of new physics shall have a bright future at CERN with the Future Circular Collider (FCC). Situated in the Geneva area, the project entails a 90.7 km underground accelerator, spanning from the FCC-ee, 90-350 GeV (e+e-) machine, to FCC-hh, 100 TeV (pp) machine [1]. The FCC holds the promise of a diverse program, enabling physicists to push the frontier of the unknown. As part of the feasibility study, the installation planning aims to evaluate the timeline from the completion of civil engineering to the operation of the machine. For the first collider, the electrons and positrons [1] are accelerated through a booster and collider ring located in the same tunnel and principally composed of resistive magnets. This paper outlines the current installation planning for the FCC-ee machine considering the elements presented at the mid-term review in November 2023.

REASONS FOR UPDATE

During the first phase of the study in 2018, the installation planning for FCC-ee was drafted with the baseline presented in the Conceptual Design Report [2]. The initial layout of the machine was designed with 12 shafts distributed along the 97.75 km circumference underground tunnel machine. Shafts were separated by different lengths of arcs. The booster and the collider rings were positioned next to each other as shown on Fig. 1. During the feasibility study started in 2021, a new machine layout was studied with 8 sectors of the same length of 11 km and thus 8 access shafts. This evolution has impacted the schedule of civil engineering, which in turn influences the starting date of technical infrastructure and machine equipment installation. Figure 1 exhibits also the new version released in the mid-term report in 2023: the collider now sits below the booster to optimize the space occupation in the tunnel [3]. The new cross section leads to changes in the installation sequence and the associated duration. The FCC installation schedule was then updated based on the experiences gathered through projects such as the installation of the LHC Machine, LINAC4 and HL-LHC.

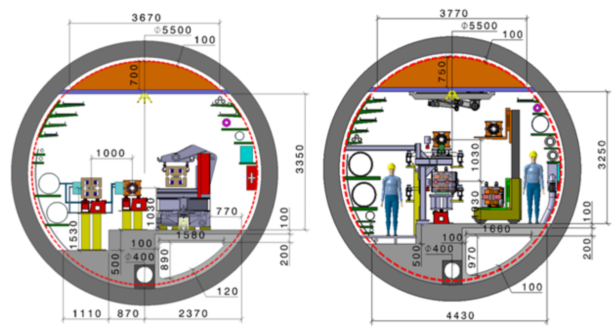

Figure 1: Cross section of FCC-ee machine: 2018 version (left); current version after updates (right).

WORKING BASELINE

To perform the update, key parameters are collected and defined as inputs in the planning analysis. Civil engineering planning is the first important element to consider as a basis, which starts in 2033. It is structured so that the 8 sectors and shafts are being built in parallel by 8 different Tunnel Boring Machines (TBM). The order of release depends on the shaft depth or the type of ground to be excavated as seen in Fig. 2. The civil engineering planning presented at the Mid-term review [4] presents a release order that is therefore not linear and once one sector is released, the adjacent shaft might still be under work and therefore not accessible for other installations. The first sector (A-B) is released 6.5 years after the start, whereas the last one after 8.5 years (F-G).

The planning update is performed with the help of the equipment owners and support groups, to define the installa-

* sarah.agathe.fleury@cern.ch

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-WECD1

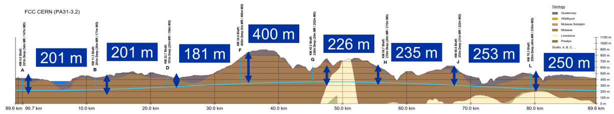

Figure 2: Shaft layout and depth with respect to surroundings.

tion methodology, the sequence, the constraints generated, as well as the different stages and the associated duration.

Given the diverse release dates provided by civil engineering, considering the unique characteristics of each pit and sector, it becomes imperative to update the planning through a bottom-up approach. This entails analyzing each equipment and system individually and constructing the comprehensive sequence for one sector. Subsequently, integration of the eight sectors follows.

As the access for workers and equipment in the tunnel is made through the shafts, the lifts and cranes are first installed. Similarly, to bring technical infrastructure underground (e.g., ventilation, cooling, electrical power), the installation is performed in the shaft at the beginning of the sequence. In Figure 2, the shaft depth spans from 181 m to 400 m with an average of around 200 m. A proportional factor is therefore considered for the work duration in each shaft. Once the tunnel becomes accessible, the installation of technical infrastructure begins. This infrastructure primarily comprises electrical components, cooling systems, ventilation mechanisms, and network infrastructure, all of which are affixed to the walls. The installation process necessitates adequate space to maneuver the ducts and racks effectively. Furthermore, a parameter to consider is the considerable generation of dust during the installation process, especially the tunnel drilling.

Once the general services are available along the arc, the machine installation is organized similarly to a train. Each activity starts in sequential order with 1.5 month shift with respect to the previous one to globally optimize the amount of work to be done over a long distance. It is key to avoid to installing sensitive equipment, before the tunnel is cleaned by any dusts, this includes the magnets, vacuum pipes and the associated powering systems. The installation sequence finishes with the access and definitive safety system setting up, including the fire doors.

The coordination and safety teams defined a maximum number of 200 workers underground in one sector, at the same time. The activities to be performed are thus computed under this condition. This number is fixed considering the specification and design of the evacuation infrastructures and the associated paths. Ventilation plays a critical role in the installation process, serving as an essential prerequisite before undertaking any major activities underground within the tunnel. It is imperative to ensure a continuous flow of air throughout the tunnel environment. Currently, the ventilation strategy employs a half-sector airflow approach, with air inserted through ducts located at the bottom right of the cross-section (referenced as Fig. 1) and extracted through the tunnel. However, implementing and operating such a system necessitates the prior installation of fire doors and final ventilation equipment, typically done during the technical infrastructure phase or at the end of machine installation. Intermediate ventilation systems must be installed until these critical installations become operational (Fig. 3). The order in which shafts are released significantly impacts the type of temporary ventilation. Coordination between the release order of the civil engineering infrastructure and the ventilation group delineates the stages of ventilation deployment. Given that shaft release does not align sequentially with the machine layout, certain shafts and sectors will transition directly to the final stage of ventilation when adjacent shafts become operational. To uphold safety standards, a similar approach is adopted, necessitating the installation of temporary ventilation systems until the final equipment can be installed at the end of the sequence.

The final step before starting machine operation is the hardware commissioning. It is divided into technical infrastructure hardware commissioning and accelerator hardware commissioning, each phase has a duration of six months.

ENTIRE MACHINE PLANNING

Carrying on with the bottom approach, the entire machine underground planning is built to analyse the parallelization and the potential optimisation of the installation time.

To optimize the sector sequence outlined earlier for each shaft and sector, significant assumptions were integrated to manage parallelization effectively. Merely incorporating all sector sequences resulted in numerous simultaneous occurrences of similar installation activities. In any large-scale project, the allocation of resources dictates the installation duration and should be considered from the project's outset.

Consequently, it was determined that four teams could concurrently work for each primary block of activities as presented above. This decision aims to streamline the workflow and enhance efficiency by distributing tasks across multiple teams, thereby maximizing resource utilization while minimizing project duration.

The comprehensive overview of the project's planning can be observed in Figure 4. This visual encapsulates all significant civil engineering activities alongside the directional trajectory of the Tunnel Boring Machine (TBM) within a given sector, each associated with their respective duration on the top of the planning. The civil engineering activities lead to different release dates which give the starting point for installation activities in the shaft and sectors. Within each sector, the duration for each primary block of activities is delineated, providing a clear understanding of the project timeline. Additionally, upon completion of the installation in each sector, the planning includes technical infrastructure and machine accelerator hardware commissioning details specific to that sector, culminating in an overall machine commissioning phase. This holistic representation serves as a roadmap, guiding the progression of the project and ensuring the systematic execution of tasks.

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-WECD1

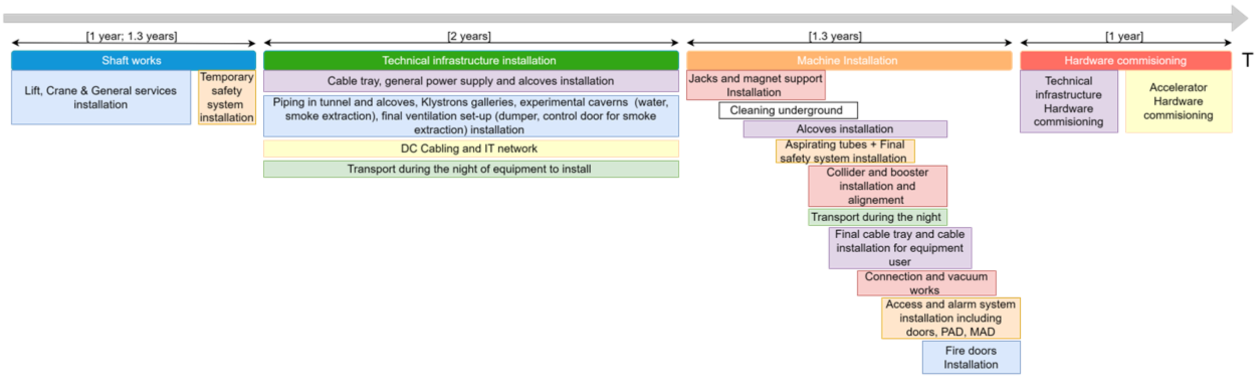

Figure 3: Sequence of activities in the critical path for one sector.

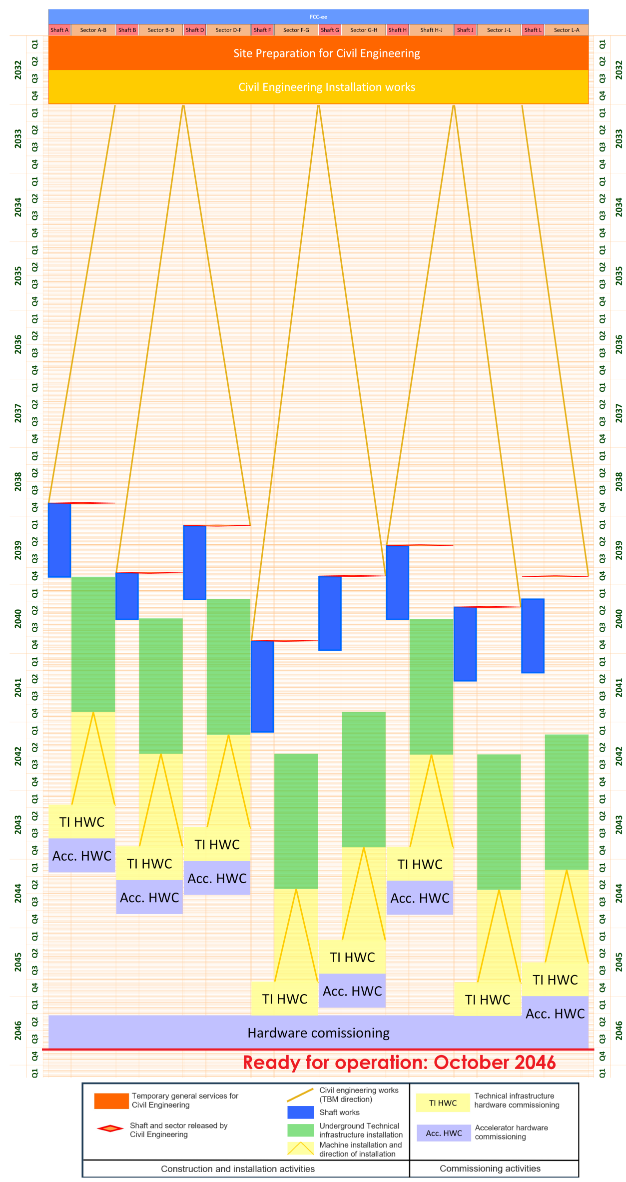

Figure 4: Overall planning for FCC-ee machine from civil engineering to operation.

The periods of idle time between the main blocks of activities stem from resource constraints within these blocks. This idle duration specifically applies to four sectors within the project. Notably, in sector J-L, the maximum idle time spans almost one year, primarily between the completion of shaft works and the commencement of tunnel technical infrastructure installation. This idle time is due to resource limitation and who are already committed in other sectors of the tunnel. These idle periods underscore the importance of resource management and strategic allocation to minimize downtime and optimize project efficiency. The ventilation stages do not directly impact the overall duration of the installation; however, they hold significant importance from a safety perspective. These stages must be considered to ensure a safe working environment throughout the project. The last shaft critical to the operation and lying on the critical path is Shaft F / Sector F-G, which also happens to be the deepest shaft of the machine.

CONCLUSION

In terms of results, the shortest estimated duration for the installation of one sector stands at 5.5 years, while the longest duration reaches 6.25 years. Therefore, the installation timeline from the initial release of the first shaft and sector, to the completion of the hardware commissioning extends to 8 years, with the project completed by October 2046. Based on the current information provided by the groups involved, achieving the target dates set by management is feasible, with the FCC-ee machine starting beam operation between 2045 and 2048.

REFERENCES

[1] CERN Courier `https://cerncourier.com/a/fcc-the-physics-case/`.

[2] M. Benedikt *et al.*, "FCC-ee: The Lepton Collider: Future Circular Collider Conceptual Design Report Volume 2", *Eur. Phys. J. Spec. Top.*, vol. 228, pp. 261–623, 2019. `doi:10.1140/epjst/e2019-900045-4`

[3] F. Valchkova-Georgieva, J.-P. Corso, and K. Hanke, "Challenges and solutions in the integration studies of the future circular collider", in *Proc. IPAC'23*, Venice, Italy, May 2023, pp. 3851–3854. `doi:10.18429/JACoW-IPAC2023-WEPM123`

[4] FCC Study Mid-term review, CERN, `https://cds.cern.ch/record/2888567`