ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPAF044

SCHEDULE EVOLUTION OF THE LINAC4 INSTALLATION DURING THE LIFETIME OF THE LINAC4 PROJECT AND CONNECTION FORECAST

J. Coupard, A. Berjillos, J-P. Corso, K. Foraz, B. Nicquevert, E. Paulat, M. Vretenar,
CERN, EN Department, 1211 Geneva 23, Switzerland

Abstract

The new CERN linear accelerator Linac4 started the installation phase in 2010 after the delivery of the new building and tunnel by the civil engineering and was inaugurated six years later. It will be connected to the CERN accelerators chain and replace the current proton linear accelerator, Linac2, during the second long shutdown (LS2) of the Large Hadron Collider (LHC) in 2019. This paper aims to summarize the schedule evolution through the different phases of installation, from general services to machine installation, highlight the key factors that contributed to drive the schedule (safety, logistics and integration) and describe the coordination study of the future connection (integration, schedule, logistics, constraints and priorities).

INTRODUCTION

Initially, in 2008 [1] [2], the schedule of the Linac4 installation, based on the civil engineering works, was planned from April 2008 to the end of 2012; starting with civil engineering works until end of 2010, and followed by the installation of infrastructure and then of the machine components until 2012. This very tight schedule estimated a commissioning and connection of the Linac4 during the first long shutdown (LS1) of the CERN accelerators complex in 2012/2013.

INSTALLATION PHASES

Based on the experience of the LHC installation [3], the Linac4 installation has been divided in four different phases:

- Civil engineering works
- Installation of the general services
- Installation of the machine elements
- Connection to CERN accelerator chain

The first phase of civil engineering was handled by the expert service of civil engineering construction while a dedicated team, in collaboration with all the services and equipment stakeholders, coordinated the three installation phases. The studies of the detailed plan and schedule started in 2008 and included several commissioning phases:

- Low energy section at 3MeV
- Medium energy section at 10 MeV
- Medium energy section at 50 MeV
- High energy section at 100 MeV
- High energy section at 160 MeV

The connection of the Linac4 was initially considered in the shadow of the PS Booster modifications, estimated at three months of works [2]. The schedule studies then considered four phases of connection:

- Partial dismantling of the Linac2 transfer line
- Completion of the Linac4 transfer line
- Connection of the Linac4 at the civil engineering interface between Linac2 and Linac4
- Reconfiguration of the beam emittance measurement line

SCHEDULING FACTORS

Several factors can have a direct impact on the schedule of installation and are closely analysed by dedicated teams [4]; the main ones are the 3D integration, the readiness of equipment and the worksite safety coordination.

3D Integration Studies

The 3D integration office was in charge of centralizing the 3D models provided by the different design, identifying the interferences, proposing solutions and reserving space for future installations (Fig. 1).

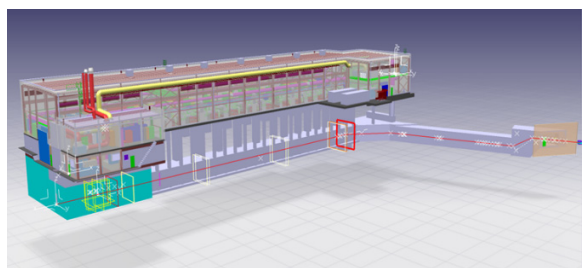

Figure 1: 3D view of the Linac4 building and underground.

The integration studies started at the early stage of the civil engineering design and defined the sequence of installation for the scheduling. The integration studies detailed the positioning of the infrastructure, volumes for the transport and handling, volumes for the alignment survey, general services and machine elements. Official drawings were edited as reference (Fig. 2) to all the design offices.

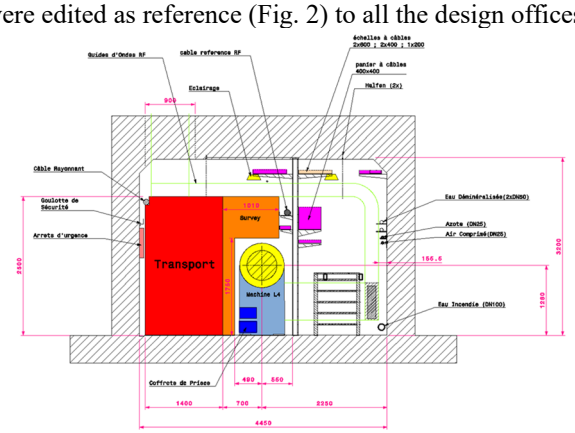

Figure 2: Typical cross-section of the Linac4 tunnel.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPAF044

Installation Readiness

The information on the readiness date for installation of the various equipment were included in the schedule of installation as milestones and allowed identifying any activities on the critical path of the project.

Worksite Safety Coordination

During the installation phase, the activities could generate hazards, constraints or required storage and logistics space. To mitigate the risk of accident, the safety coordination aspects were evaluated from the integration studies to the implementation.

The schedule was organized per area to avoid any co-activities. The installation procedures were taken into account to manage the space on the worksite (Fig. 3), evaluate any infrastructure constraints (i.e. installation of scaffolding) and confirm the transport and handling of the equipment.

Figure 3: Linac4 hall during the general services installation.

SCHEDULE EVOLUTION

Civil Engineering

During the civil engineering construction, the master schedule of the Linac4 project was extended by two years to compensate for a slower start due to the larger than foreseen amount of resources required at CERN in 2008/2009 for the repairs following the LHC incident of 2008. It was, then decided to delay the connection to the end of 2013 [5] and then to the end of 2014 [6].

General Services

After the delivery of the building in October 2010, the installation of the general services, foreseen to be completed in April 2012, was finally completed in October 2012, a date that was still compatible with the new master schedule for the project.

Electrical System

The installation of the overall electrical powering network and infrastructure (cable trays, racks) was completed in 16 months, four months more than initially foreseen because of minor delays due to redesign of some cable trays, conflicts between supporting structures of cable trays and some demineralized water pipes not included in the integration studies, and late delivery of some electrical switchboards.

Cooling and Ventilation Systems

The cooling and ventilation systems were split in work packages corresponding to technical rooms, surface hall or underground areas.

Eight months were initially estimated to install the cooling and ventilation systems in surface and underground areas of the Linac4, starting from January 2011. The actual installation time was longer because of late validation of some designs and delayed delivery of equipment. In addition, the schedule had to be levelled with respect to resources availability and co-activities. The installation finally started in March 2011 and commissioning of systems was performed between March and July 2012.

Cabling Campaigns

The initial estimates for the cabling works was of nine months, but this activity eventually required four additional months. Additional cables required for temporary measurement equipment in the transfer line were housed in two spare waveguide shafts connecting the klystron hall with the tunnel, indicated in Fig. 4, which were foreseen for future energy upgrades of the accelerator.

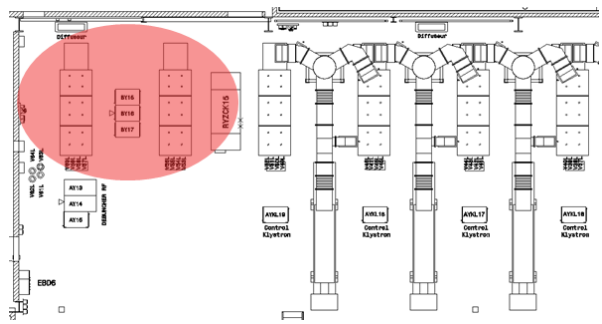

Figure 4: Linac4 hall with less klystrons.

MACHINE INSTALLATION

In 2010, a detailed analysis of the activities required in the PS Booster for rebuilding the injection sector to house the new equipment required for Linac4 connection indicated that the required time of seven months was too long to do the connection during a normal year-end LHC shutdown. The consequence was that the master schedule of Linac4 was once again increased by one year to match the LHC long-shutdown schedule, with a connection foreseen by end of 2015 [7][8].

The installation of the machine equipment located on surface started end of 2012, in parallel with the remaining general services, according to integration and worksite safety coordination.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPAF044

Figure 5: Linac4 layout.

The installation of the beam line was planned in the order of the machine elements on the beam, from the Source, the RFQ, the Chopper, DTL, CCDTL and PIMS cavities, with the goal of interlacing installation with progressive commissioning periods. In 2012, due to delay of the LS2 at CERN, a new baseline was defined, sequencing the installation and the commissioning (Fig. 5) from 2012 to end of 2015, followed by one year of "reliability run" in 2016. At that time, the LS2, therefore the connection of the Linac4, was brought to 2017/2018. The reliability run was intended to address and solve potential reliability problems of Linac4 that could affect the overall availability of the LHC.

Since the new delayed schedule for Linac4 connection raised concerns for the risk of failure of the old Linac2 due to its deteriorating vacuum conditions, at the end of 2012 it was decided to maintain the schedule for installation and commissioning of Linac4 and to allow for a longer reliability run period after the end of beam commissioning. In this way, the new linac could be a back-up for Linac2 in the period of run between the two long shutdowns [9][10].

The teams made huge efforts to respect the deadline and get the Linac4 ready end of 2016.

The Linac4 was completed end of 2016 and the new accelerator was inaugurated on 9th May 2017. Since summer 2017, the new linac entered in its operational phase, sending beam round-the-clock to the beam dump placed at the end of the linac for the needs of the reliability run.

CONNECTION OF THE LINAC4

Because of the extensive works required in the PS Booster for the installation of the H- injection equipment, the connection of the Linac4 can only be performed during a long shutdown of the CERN accelerators chain. Since 2010, the connection of the Linac4 is scheduled during the LS2. During the past five years, the priorities coming from the experimental programme have induced the CERN management to progressively delay the start of the LS2, and thus the connection of the Linac4, up to the final date of 2019.

The schedule of the connection has been studied into the detail of the activities with respect to the schedule factors. The summary schedule was presented at the Linac4-PSB 160 MeV connection readiness review in 2016 [11].

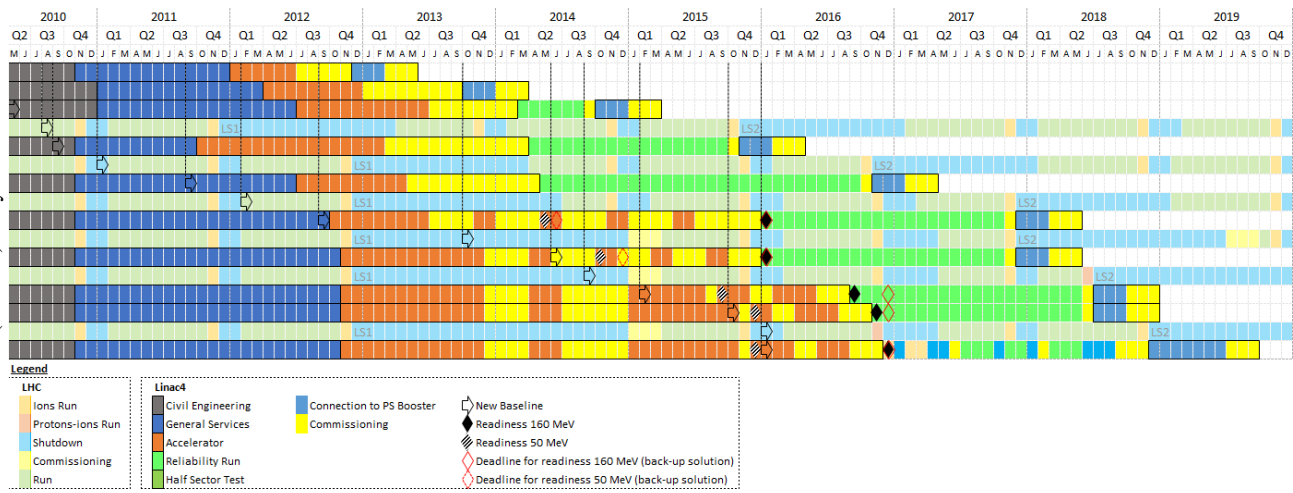

Figure 6: CERN accelerators chain and Linac4 schedules evolution.

A total of six months is required before starting the hardware tests of the Linac4 transfer line and new emittance measurement line:

- Two months to complete the Linac4 transfer line installation (removal of the temporary dump put in place for the debuncher beam commissioning)
- Six weeks of radiation protection cool-down
- Two months for the partial dismantling of the Linac2 transfer line
- Three months for the connection (including mandatory civil engineering works with respect to safety; emergency exit, radiation protection)
- Three and a half months for the reconfiguration of the emittance measurement line

The last phase of connection of the Linac4 is now fully integrated in the LHC Injectors Upgrade (LIU) Project [12] and part of the LS2 master schedule [13].

CONCLUSION

The Linac4 master schedule has been reviewed several times in the lifetime of the project to match the overall CERN schedule and availability of resources. Management strategies successfully re-baselined the project with strong deadlines, such as the readiness for connection end 2016, to avoid slippage until the LS2. Depending on the CERN accelerators program evolution, the connection of the Linac4 has been delayed several times, from a first estimate connection in 2012/2013 during the LS1 to a final connection planned in 2019 during the LS2 (Fig. 6).

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPAF044

REFERENCES

[1] M. Vretenar, C. Carli, R. Garoby, F. Gerigk, K. Hanke, A. M. Lombardi, S. Maury, C. Rossi, "Status of the Linac4 Project at CERN", in *Proc. LINAC'08*, Victoria, British Colombia, Canada, 29 September – 3 October 2008, paper MOP007, pp. 64-66.

[2] M. Vretenar, C. Carli, R. Garoby, F. Gerigk, K. Hanke, A. M. Lombardi, S. Maury, C. Rossi, "The Linac4 Project: Overview and Status", Final CARE-HHH Workshop on Scenarios for the LHC Upgrade and FAIR, Chavannes-de-Bogis, Switzerland, 24 – 25 November 2008.

[3] K. Foraz, E. Barbero-Soto, H. Gaillard, C. Hauviller, S. Weisz, "Schedule evolution during the life-time of the LHC project", CERN-TS-2007-001, in *Proc. PAC'07*, Albuquerque, NM, USA, 25 - 29 June 2007, paper TUPAN092, pp. 1592-1594.

[4] M. Barberan Marin, S. Bartolome-Jimenez, M. Bernardini, T. Birtwistle, S. Chemli, J-P. Corso, J. Coupard, K. Foraz, S. Grillot, Y. Muttoni, A.-L. Perrot, "Integration, Configuration and Coordination: From Project to Reality at CERN", CERN-ACC-2016-267, in *Proc. 7th International Particle Accelerator Conference (IPAC'16),* Busan, Korea, 8 – 13 May 2016, paper TUPMW003, pp. 1407-1409, DOI:10.18429/JACoW-IPAC2016-TUPMW003

[5] C. Carli, R. Garoby, F. Gerigk, K. Hanke, A. M. Lombardi, R. Maccaferri, S. Maury, S. Ramberger, C. Rossi, M. Vretenar, "Construction status of Linac4", CERN-sLHC-PROJECT-Report-0027, in *Proc. PAC'09*, Vancouver, Canada, 04 - 08 May 2009, paper FR5REP052, pp. 4884-4886.

[6] C. Carli, R. Garoby, F. Gerigk, K. Hanke, A. M. Lombardi, S. Maury, C. Rossi, M. Vretenar, "Status of the Linac4 project at CERN", CERN-ATS-2010-183, in *Proc. 1st International Particle Accelerator Conference (IPAC'10)*, Kyoto, Japan, 23 - 28 May 2010, paper MOPD015, pp. 702-704.

[7] K. Foraz, S. Myers, "LHC and injectors schedule for the next decade", CERN-ATS-2010-075, August 2010.

[8] M. Vretenar *et al*., "The Linac4 Project at CERN", CERN-ATS-2011-041, in *Proc. 2nd International Particle Accelerator Conference (IPAC'11)*, San Sebastian, Spain, 4 - 9 Sep. 2011, paper TUOAA03, pp. 900-902.

[9] M. Vretenar *et al*., "Progress in the Construction of Linac4 at CERN", in *Proc. 26th Linear Accelerator Conference (LINAC'12)*, Tel Aviv, Israel, 9 - 14 Sep 2012, paper THPB010, pp. 864-866.

[10] S. Baird, K. Foraz, "What are the required maintenance and consolidation activities to run at design performance levels (injectors and LHC) until 2035?", RLIUP: Review of LHC and Injector Upgrade Plans, Centre de Convention, Archamps, France, 29 - 31 Oct 2013.

[11] A. Berjillos, J. Coupard, "Detailed timeline for dismantling, complete installation, including survey", Linac4-PSB 160 MeV connection review, CERN, 30 Aug 2017.

[12] J. Coupard, H. Damerau, A. Funken, R. Garoby, S. Gilardoni, B. Goddard, K. Hanke, A. Lombardi, D. Manglunki, M. Meddahi, B. Mikulec, G. Rumolo, E. Shaposhnikova, M. Vretenar, "LHC Injectors Upgrade, Technical Design Report, Vol. I: Protons", CERN-ACC-2014-0337, 2014.

[13] M. Barberan, A. Berjillos, M. Bernardini, Q. Bouirek, J. Coupard, D. Hay, S. Mataguez, D. Mcfarlane, E. Vergara, "Master Schedule of the Long Shutdown 2 (2019/2020)", ACC-PM-MS-0002 v.1.0, 13 Sep 2016.