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Scheduling the installation of the LHC injection lines

L. Lari, H. Gaillard, V. Mertens, *CERN, Geneva, Switzerland*

Abstract

The installation of the two Large Hadron Collider (LHC) injection lines has to fit within tight milestones of the LHC project and of CERN's accelerator activity in general. For instance, the transfer line from the Super Proton Synchrotron (SPS) to LHC point 8 (to fill the anti-clockwise LHC ring) should be tested with beam before the end of 2004 since the SPS will not run in 2005. It will first serve during the LHC sector test in 2006. Time constraints are also very strong on the installation of the transfer line from the SPS to LHC point 2 (for the clockwise LHC ring): its tunnel is the sole access for the LHC cryo-magnets and a large part of the beam line can only be installed once practically all LHC cryo-magnets are in place. Of course, the line must be operational when the LHC starts. This paper presents the various constraints and how they are taken into account for the logistics and installation planning of the LHC injection lines.

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The installation of the two Large Hadron Collider (LHC) injection lines has to fit within tight milestones of the LHC project and of CERN's accelerator activity in general. For instance, the transfer line from the Super Proton Synchrotron (SPS) to LHC point 8 (to fill the anti-clockwise LHC ring) should be tested with beam before the end of 2004 since the SPS will not run in 2005. It will first serve during the LHC sector test in 2006. Time constraints are also very strong on the installation of the transfer line from the SPS to LHC point 2 (for the clockwise LHC ring): its tunnel is the sole access for the LHC cryo-magnets and a large part of the beam line can only be installed once practically all LHC cryo-magnets are in place. Of course, the line must be operational when the LHC starts. This paper presents the various constraints and how they are taken into account for the logistics and installation planning of the LHC injection lines.

INTRODUCTION

Two Transfer Injection (TI) lines with a combined length of 5.6 km, TI2 and TI8, are presently built at CERN to transport 450 GeV proton beams from SPS to LHC. The very first part of TI8, called TT40, is also to be used to send beam to the future CERN Neutrinos to Gran Sasso (CNGS) facility [1]. The overall layout of the LHC transfer lines is given in Figure 1.

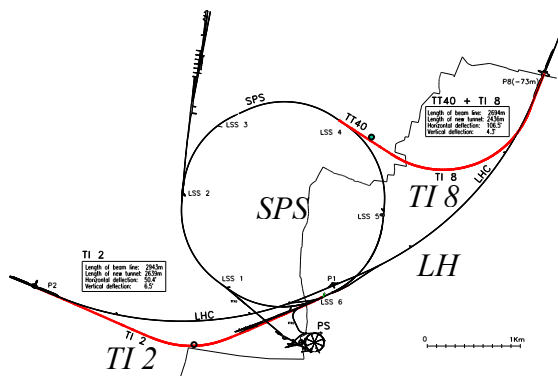


Figure 1: Overall layout of TI2 and TI8 [2]

The TI8 beam line installation will be finished by summer 2004 and the first beam tests are foreseen in October: it represents one of the first installation milestone of the LHC project. Conversely, the assembly of the downstream part of TI2 will be the last major piece of installation work of the LHC. Commissioning of TI2 needs to be finished in the first quarter of 2007.

Various constraints have to be taken into account during the construction of these transfer lines: size of the tunnels that often forbids co-activities; slope of the tunnels that require special transport and handling

equipment; proximity to the SPS where radiation levels interdict access to certain areas during machine operation. Moreover, the LHC cryomagnets will pass through the downstream part of TI2, which causes a strong interdependence between the LHC and the TI2 installations.

The following chapters describe the specificities of TI8 and TI2 that are relevant for the installation planning and the installation scenario that is common to both transfer line.

TRANSFER LINE TI8

Figure 2 shows the schematic longitudinal profile of the TI8 line and Table 1 summarises its main parameters to be accounted for the planning of the installation. More parameters and a description of the optics are given in Reference [4].

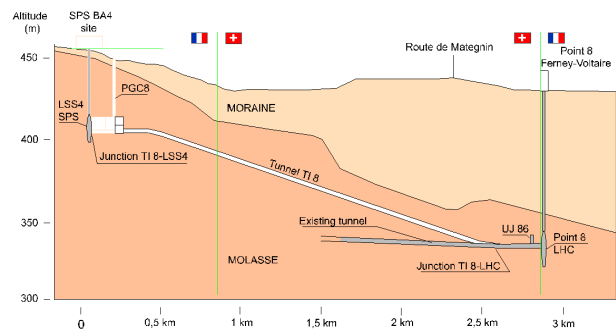


Figure 2: Transfer line layout TI8 [4]

A long SPS shutdown is scheduled from the end of 2004 until 2006 and the TI8 line should be tested with beam before of that period. Beam time is allocated for October and November 2004: clearly, by that time, all equipment must be installed with powering and control fully functional.

Table 1: Main parameters for TI8

Beam line length	~ 2700 m
Depth difference (SPS-LHC)	~ 70 m
Maximum slope	3.8 %
Tunnel diameter	3.0 m
No. Main Dipoles MBI	236
No. Main Quadrupoles MQI	83
No. total Magnets	401
Magnet range	0.3-13 tons
No. total Power Converter	28

TRANSFER LINE TI2

A schematic longitudinal profile of the transfer tunnel TI2 is given in Figure 3, showing:

- The separation in Downstream and Upstream parts;
- The shaft PMI2 to lower the LHC cryomagnets;
- The vehicle storage area at the bottom of PMI2;
- The radiation limit area (the first 300 m close to SPS).

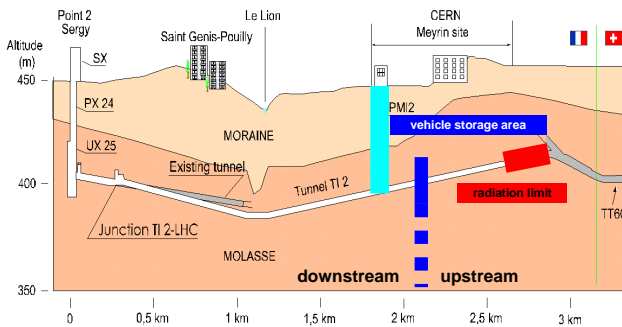


Figure 3: Transfer line layout TI2 [2]

The main parameters are summarised in Table 2 and more information, together with a description of the optics, is also available in Reference [3].

Table 2: Main parameters for TI2

Beam line length	~ 2950 m
Maximum Depth difference (S)	~ 30 m
Maximum slope	4.2 %
Tunnel diameter	3.0 m
No. Main Dipoles MBI	112
No. Main Quadrupoles MQI	95
No. total Magnets	308
Magnet range	0.3-13 tons
No. total Power Converter	26

The installation of the TI2 line is on the critical path of the LHC project: the downstream part of the tunnel (~2km) must be left free for the transport of the LHC cryomagnets and the installation of the injection line in this area would have to wait until all these cryomagnets are in place in the main tunnel, which is expected by October 2006; however, the TI2 line must be fully installed and commissioned by April 2007 according to the general coordination schedule [5]. This downstream part of the injection line requires the installation of 165 main magnets (MBI and MQI) and represents about 70 % of the elements in the TI2 tunnel.

The installation in the upstream part has different time constraints: the radiation level in the upper part prevents the access when the SPS is running, and the SPS shutdown starts end of 2004 as already mentioned; the

transport vehicles that have been designed to handle the main TI magnets (MBI and MQI) in a narrow tunnel with a steep slope will also be used for the installation of the CNGS beam line that is scheduled to start in July 2005 [2]. The upstream part of TI2 houses 70 main magnets, 27 of them within the SPS radiation limit.

INSTALLATION SEQUENCE

Figure 4 represents a typical cross section of the TI tunnel showing as a stripped area the space left for access and transport once the main magnets (here a MBI dipole) are in place.

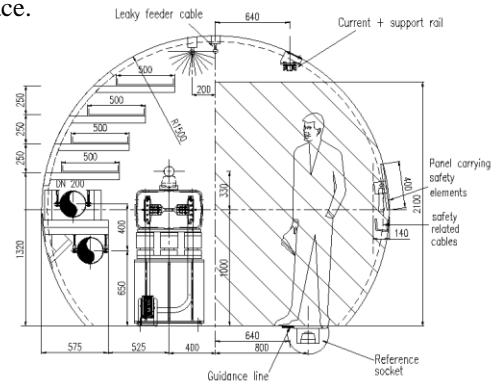


Figure 4: Typical TI cross section

This tunnel cross section and the longitudinal profiles of Figure 2 and 3 illustrate the major space constraints of the installation of the injection lines:

- The size and slope of the tunnels require special transport equipment. Its availability conditions the planning of installation as already mentioned for the upstream part of TI2.
- There are few access shafts which are shared by many users and this affects the procurement logistics of the underground works. As an example, all TI8 magnets were lowered on the SPS side since the access on the LHC side was heavily used by LHCb and by the teams working in sector 7-8.
- The length of the lines together with the reduced speed of the magnet transport vehicles limits the average installation rate to 4 dipoles and one quadrupole per day.
- Linear installation involves different teams working in parallel. Safety considerations become major constraints when defining modes of operation or managing co-activities.

The overall installation sequence is very similar for TI8 and TI2. It is divided into three phases: the General Services phase, the Machine phase and the Hardware Commissioning phase [6], [7].

General Services phase

The General Service phase includes the installation of safety equipments (red phones, evacuation alarms, GSM, emergency light, etc), cooling & ventilation line (pipes, ducts, etc), cable trays, cable (220V, 380V, 18kV,

magnet power, control, fibre optics), access utilities (doors, interlocks, cables), transport utilities (vehicle power & guide-line) and radiation utilities (monitors, cables). The General Service work also includes the survey of reference points and the positioning of the machine elements to be installed during the next phase [8].

Machine phase

The machine phase includes the following steps:

- Installation of magnets supports;
- Installation of the main Quadrupoles MQI;
- Alignment of the MQI;
- Installation of the main Dipoles MBI;
- Installation of specific supports;
- Installation of the vacuum pipe elements;
- Installation of beam instruments;
- Alignment of the MBI;
- Vacuum connections;
- Power and control cables connections;
- Installation of the access and security equipment;

The installation of the magnet supports starts while the last step of the General Service phase is still ongoing, thus insuring a linear progression of the different works to allow optimizing the resources available. The quadrupoles are the beam aperture limitation and this is why all MQIs are installed and aligned first. The 4 dipoles of each half-cell are placed at a later stage: as the MBIs installation progresses, vacuum pipes and beam instrumentations are fitted along the line. The connection of the vacuum equipment, of the cooling pipes and finally of the power and control cables follows a second survey operation. The installation of the machine elements is completed once the access and security systems are in place, leaving the field for the Hardware Commissioning of the transfer line [8].

Hardware Commissioning phase

The check-up of the beam elements is achieved during this Hardware Commissioning phase with a view to validate the line before injecting beam. The equipment groups take the responsibility of running pieces or group of their equipment. To be as efficient as possible, the validity of pre-commissioning partial system is being investigated, together with the possibility to test several systems in parallel [1], [8], [9].

When writing these lines, the general services infrastructure and the installation of the TI8 machine elements are almost completed and are on schedule for the tests with beam. For what concerns TI2, the installation of the general services is completed and the upstream part of the tunnel is ready for the installation of the machine elements when the SPS stops. The downstream part of the tunnel is used for the tests of the LHC cryomagnet transport vehicles.

CONCLUSION

Many time and space constraints drive the installation planning of the LHC injection line. The test with beam of the TI8 line, expected in fall 2004, is an important early milestone of the LHC. Conversely, the downstream installation and the commissioning of the TI2 line are delayed to the end of the project in order to allow lowering the LHC cryomagnets in PMI2 and their transport to the main ring.

The size and slope of the injection tunnels required the development of special transport and handling devices. The optimisation of the resources available calls for a linear installation that involves many teams working in parallel. Safety considerations then become major constraints when defining modes of operation or managing co-activities.

A well-thought planning is a necessity for the installation coordination in such an environment and the project is, at present, on schedule. The experience gained with the TI8 installation line will be an asset to optimise the installation of TI2: we expect an accelerating factor as well as a gain on organisational flexibility, both being most valuable when rushing for the termination of the LHC project.

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