

THE WAY TO THE LHC

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Abstract

The new fast extraction channel in SPS LSS4 and the first 100m of TT40 will be commissioned in 2003. This will allow beam to be extracted from the SPS machine and transported onto TED400354. The present status of the extraction and transfer line equipment will be given, including the planning for the remaining work and for the extraction tests proper. The test objectives, for both equipment and beam aspects, will be discussed. The proposed measurements are presented, in the context of the limitations to the beam parameters (intensity, time structure and emittance) which arise through hardware limits and radioprotection concerns, and attention will be paid to the still outstanding requirements. The present schedules for the installation and commissioning of the remainder of TI8 and TI2, will be briefly reviewed. Finally, the question of beam quality checks before extraction in the SPS will once again be mentioned.

INTRODUCTION

Two new transfer lines TI 2 and TI 8 [1], figure 1, with a combined length of 5.6 km, are being built to transport 450 GeV/c protons from the SPS to the LHC collider. Fast extraction will be used for both lines [2]. The first part of TI 8, called TT40, is in common with the future neutrino production line for the CNGS project. The TI 2 and TI 8 lines will use in total over 700 room temperature magnets, of which some 74 are recuperated from other installations. The 348 main dipoles (MBI, gap height 25 mm) and 178 main quadrupoles (MQI, inscribed diameter 32 mm) have been built by the Budker Institute for Nuclear Physics at Novosibirsk. Detailed information on the magnet system can be found in [3]. Both lines use a FODO structure with a half cell length of 30.3 m and 4 dipoles per half cell, resembling the SPS. Civil engineering for TI 2 and TI 8 started in 1998, and is now nearly completed. The first use of the complete lines with beam is foreseen for autumn 2004 (TI 8) and spring 2007 (TI 2) respectively.

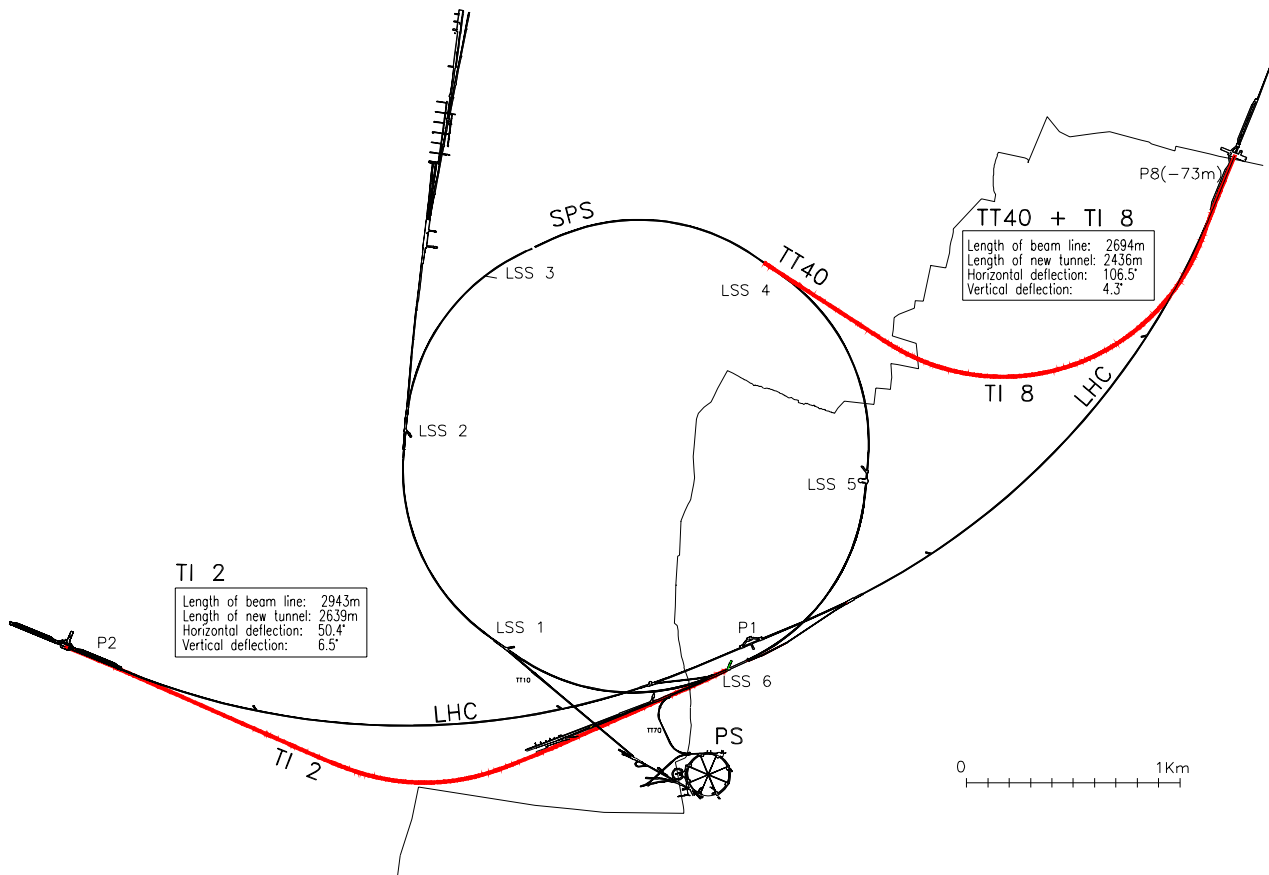


Figure 1. TI 2 and TI 8 lines for the transfer of 450 GeV/c protons from SPS to LHC.

PRESENT STATUS OF SPS LSS4 EXTRACTION AND TT40 LINE

The fast extraction in SPS LSS4 [4] is due to be commissioned with beam in 2003. The first ~100 m of TT40 will also be commissioned up to the TED beam stopper, and the installation of the various elements of the line is now well under way. The status of the required services and systems is now briefly reviewed:

Cabling

The cable trays are installed and the cabling for the TT40 elements proper is already complete. The power and controls cables for TI 8 are now being pulled through TT 40. The cooled cables for the MSE extraction septa are still being installed.

Services

The ventilation work has started and will be finished in the 2003/04 shutdown. All cooling pipes are in place and the power rail for the installation vehicle has been installed. The cooling station for the MSE septum is still being installed.

Magnets

Four horizontal and four vertical bumper magnets were installed in the SPS during the 2001/02 shutdown, and the horizontal units have already been tested with beam during an MD in 2002. The required TT 40 magnets have been installed and are awaiting vacuum, hydraulic and electrical connection.

MKE Extraction Kickers

A new kicker system is being built and installed, comprising five magnets and Pulse Forming Networks (PFNs), together with the associated switches and fast and slow controls. The water-cooled magnets and controls are being installed at the end of the 2002/03 shutdown, and the PFNs & switches are in preparation, and will be installed in ECA4 by end of June.

TPSG Diluter

The TPSG diluter has been built and installed, and will be baked and tested under vacuum at the end of the 2002/03 shutdown.

MSE Extraction Septa

The MSE extraction septa have been installed on the mobile support girder, together with the pumping modules (MP). All the water cooling, powering busbars and accessories are in place, as are the final control elements. Hydraulic and power testing remains to be carried out.

Beam Instrumentation

The three large aperture couplers (BPCEs) to measure beam position were installed one year ago and successfully tested in 2002. The other instruments, including the Optical Transition Radiation (OTR) screens,

Beam Current Transformers (BFCTs) and the various Beam Loss Monitors (BLMs), will be installed shortly ready for testing. The instruments and low-level servers will be ready for the 2003 startup.

TED beam dump

The TED beam dump has been installed and is awaiting vacuum, hydraulic and control connection. The TED cooling will be accomplished in 2003 and 2004 by direct connection to the main SPS demineralised water loop, pending an analysis by TIS of the general requirements for closed-loop cooling in the SPS.

2003 EXTRACTION TESTS

The commissioning of the LSS4 extraction and the TT 40 line will take place in autumn 2003. A large amount of work remains to be done before this commissioning can take place; the main items are the remaining installation and testing of the MKE system.

Test objectives

The objectives of the extraction tests have been defined and are given below in decreasing order of priority:

- Verify correct functioning of all equipment, to be done already during tests before extraction wherever possible (bumpers, MKE, MSE, BI, magnets, TED, access, interlocks, ...);
- Verify trajectory (including bumped beam), optics and settings;
- Measure acceptance of extraction channel;
- Performance tests on OTR screens (measure resolution);
- Test extraction interlock system;
- Measure reproducibility of trajectory;
- Test double batch extraction with 50 ms interval;
- Measure effect of MKE kicker ripple.

Outstanding issues

Several issues are outstanding and remain to be defined before the extraction tests take place. These include:

- Formalise TIS/RP safety procedures for access to the transfer lines and CNGS for installation work and to allow extraction tests to take place;
- Integration of the various elements (including instrumentation) into SPS control system;
- Load data tables with equip. names, settings etc.;
- Equipment protection interlock system.

Limitations

There are limitations on the intensity and bunch structure which can be used in the tests. Concerning the intensity, in order to avoid damaging the equipment, the total intensity per extraction will remain at or below 2.5×10^{11} ppp (at this intensity at 450 GeV/c, full impact of a beam of $\epsilon_{x,y}$ of 3.5 mm produces an instantaneous temperature rise of about 100°C in Cu). Low intensity will also minimise the irradiation of the TED in TT40 (with an

assumed ~50% efficiency, the total number of protons on the TED for 2 x 24 hours test is 1.08×10^{15} . Finally, the TED is on the normal cooling loop, with no heat exchanger, and so the irradiation of the cooling water must be minimised. For the bunch structure, the BPMs presently installed are only equipped with the LHC part of the double readout system, and can only readout bunches spaced at multiples of 25ns, so no test with CNGS type beam will be possible.

STATUS OF TI 2 AND TI 8

The civil engineering works for the two lines is basically finished, with only minor works remaining in TJ8 (PGC8 and the junction with the CNGS line TT41). The installation of the services for the two lines has started and will continue into 2004 (this work started later and will take significantly longer than initially foreseen, which has a direct effect on the overall planning). The main dipole and quadrupole magnets for the lines are ready for installation – outstanding are the bulk of the orbit correctors which will be delivered in 2003. The fitting of the magnets with vacuum chambers, BPMs and other accessories is ongoing. The proposed collimation system (TCDI) is still in the conceptual phase – for more details on this subject see [5] from this workshop. Concerning the optics, the lines have been rematched to the LHC version 6.4, and a new vertical correction scheme has been implemented. The schedules for the installation and commissioning works in the two lines are shown in figures 2 and 3. Up to date status and schedule information can be found under [6].

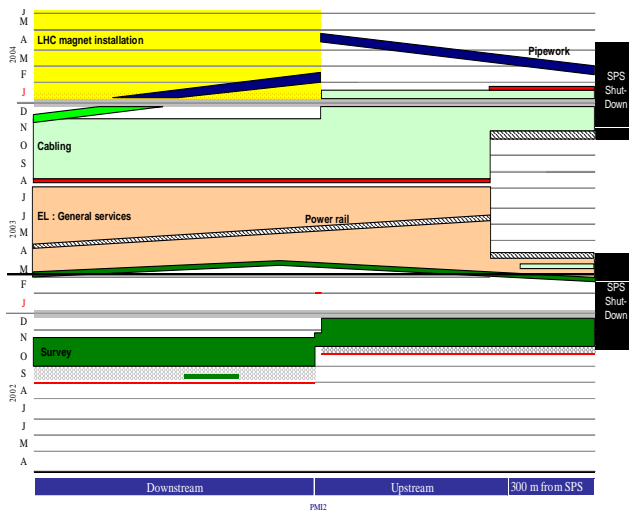


Figure 2. Schedule for TI 2 installation (beam line installation to start around May 2004).

BEAM QUALITY CHECKS IN THE SPS

The beam to be extracted to the LHC must satisfy certain requirements on the quality, as regards emittance, bunch intensity, ghost bunches, orbit and extraction trajectory etc. In addition, the beam characteristics as required by

the LHC (number of bunches, number of batches, bunch spacing, LHC ring) must also be communicated to, and verified by, the SPS in order to make sure that machine protection requirements are met. The different checks to be made, together with the tolerances required, the instruments foreseen, together with the controls framework within which this quality control will be managed, all remain to be defined. For more details on this subject, see [7] from this workshop.

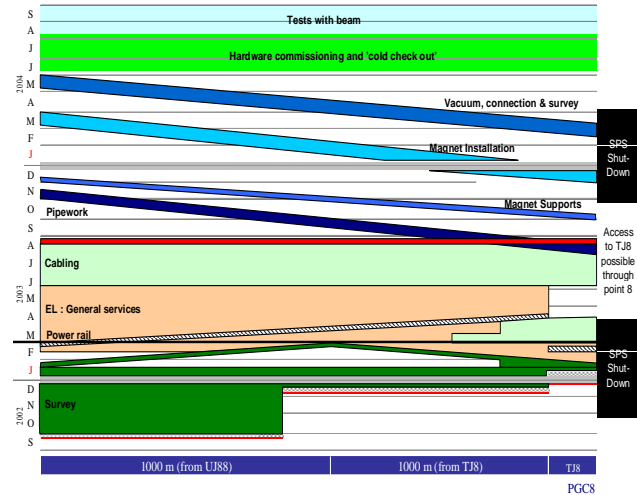


Figure 3. Schedule for TI 8 installation.

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REFERENCES

- [1] A. Hilaire *et al.*, "Beam Transfer to and Injection into LHC", proc. EPAC'98, Stockholm, June 1998, and LHC Project Report 208, 1998.
- [2] B. Goddard, "Fast Extraction", proc. Chamonix IX.
- [3] V. Mertens *et al.*, "Magnets for the LHC injection transfer lines", LHC Project Note 128, 2000.
- [4] B. Goddard, "Fast Extraction in SPS LSS4", SL Note
- [5] H.Burkhardt, "Do we need collimation in the transfer lines," proc. Chamonix XII.
- [6] <http://proj-lti.web.cern.ch/proj-lti/>
- [7] J.P.Delahaye, "Summary of Session 1: LHC proton injector chain" proc. Chamonix XII.