CHAPTER 31

COMMISSIONING

31.1 INTRODUCTION

The installation of the TI 8 transfer line was finished at the end of July 2004. It was followed by a hardware commissioning period of 12 weeks and a cold checkout period of two weeks. The commissioning with beam took place during two 48-hour periods during two weekends at the end of October and the beginning of November 2004. The tests have taken place at the time of writing and the details and results of the different test periods together with their conclusions are described below.

The TI 8 commissioning followed the commissioning of the extraction in LSS4/TT40 in 2003. The early commissioning of TI 8 in 2004 has the advantage of disentangling issues related to injection (sector test planned for 2006) from those concerning TI 8. It also served as an important test-bed for beam instrumentation and the control system. All equipment to the downstream beam absorber (TED) was commissioned with beam. The remaining part of TI 8, downstream of the TED, will be commissioned together with the injection elements in LHC point 8 during the sector test. At this time the commissioning of the transfer line collimators will be done, since these were not installed at the time of the 2004 beam tests.

TI 2 can only be completely tested after the transport of LHC magnets through the lower part of the transfer line and installation of the lower part of the line has been completed. As a result, hardware commissioning of the complete line is currently planned for the beginning of 2007 and beam commissioning will take place just before the commissioning of the injection in LHC point 2. However, hardware commissioning of the upstream part of TI 2 in the middle of 2005 is possible.

31.2 HARDWARE COMMISSIONING OF TI 8

The aim of the hardware commissioning period was to check all equipment in the transfer line without beam. It took place between 26 July and 11 October 2004. The main tasks performed during this period were the following:

- The running of all power converters up to their maximum specified currents. If necessary, adjustments were made to stabilise their currents.
- Generation of conditions for air flow and other checks of the ventilation system.
- Verification of the magnet temperature interlock system.
- Verification of the magnet polarities – corrections were made where necessary.
- Vacuum tests: verification of remote information from the ion pumps, gauges; remote opening and closing of the valves (one magnet was replaced where the vacuum chamber had a leak).
- Calibration of the water cooling system of the magnets – adjustment of the valves controlling the water flow.
- Tests of the control system (on the SPS fixed target super cycle).
- Test of the Beam Interlock Controller.
- Test of the beam diagnostic devices (beam position monitors, beam loss monitors, screens and BCT).

In the same period, the alignment of the magnets was verified and some adjustments in the horizontal plane were made to a few magnets that were found to have significant alignment errors. Some of the water hoses for the magnets only became available for installation during the hardware commissioning period and had to be installed then. All tests were concluded with positive results in the time allocated.

31.3 COLD CHECKOUT OF TI 8

After the hardware commissioning period, two weeks were used for cold checkout (12 to 25 October 2004). During the cold checkout period the complete system was operated from the Prévessin Control Room (PCR) by the Operations Group together in collaboration with the people responsible for the beam commissioning. The following tests were performed:

- Cycling of all magnets together on the fixed target cycle. The corrector magnets were run at their maximum current without cycling. All control was made using the controls applications from the control room.
- Temperatures of the different types of magnets (coil and yoke) and tunnel air temperatures were monitored.
  - The tunnel air temperature interlock which inhibits extraction and then switches off the main power converters was set at 35°C. The interlock temperature was never reached. Fig. 31.1 shows the temperatures measured during the cold checkout period during operation with a 16.8 s cycle.
  - The coil temperature was measured on the main dipole MBI 81620. It indicates that when all TI 8 magnets were powered at their nominal currents, the air temperatures in the vicinity of that magnet reached an equilibrium temperature about 3°C higher than when the magnets were not powered.
  - The temperature measured in the concrete of the tunnel wall continued to rise very slowly by a small amount during the test period. From the measurements it can be concluded that it will be possible to run the LHC transfer lines continuously for many days before tunnel temperatures limit operation.
- Tests of the Beam Interlock Control system and its interface with the other operational systems.
- Tests of the access control system and their related safety elements (TED and TBSE) in collaboration with the Departmental Safety Officer.
- Checks of the correct functioning of and communication with all beam instrumentation.
- Checks of the logging and retrieval of all signals (magnet currents, beam diagnostics, temperatures).
- Checks of the 'remote oscilloscope system' (OASIS) used for diagnosis and setting up of the extraction kicker MKE.
- Checks of the correct function of all control applications software including the fixed displays.
- Checks of the radiation monitoring displays.
- Checks of the vacuum displays.

All tests during the cold checkout period were performed successfully.

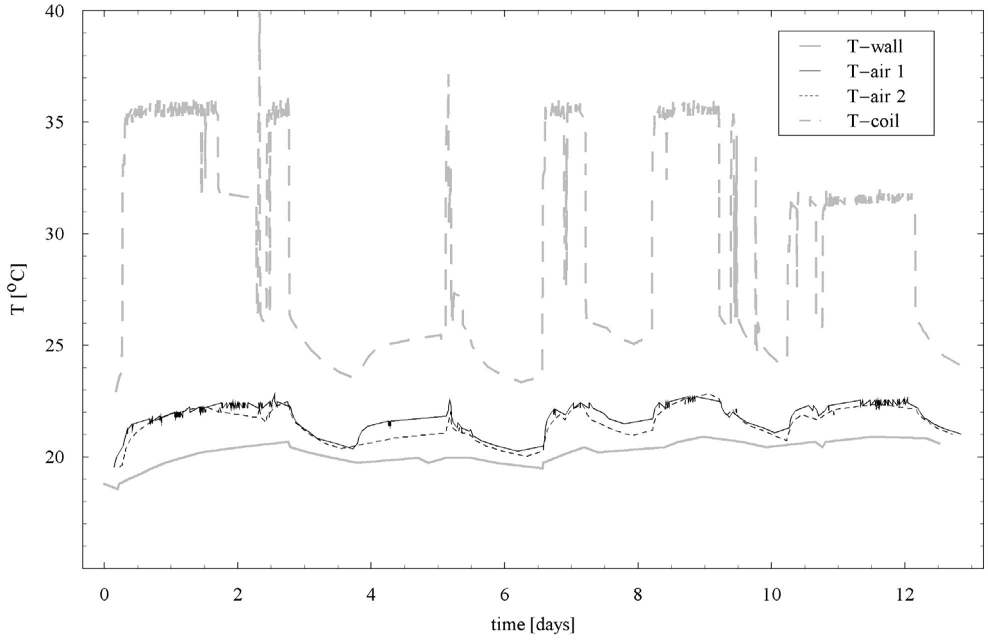
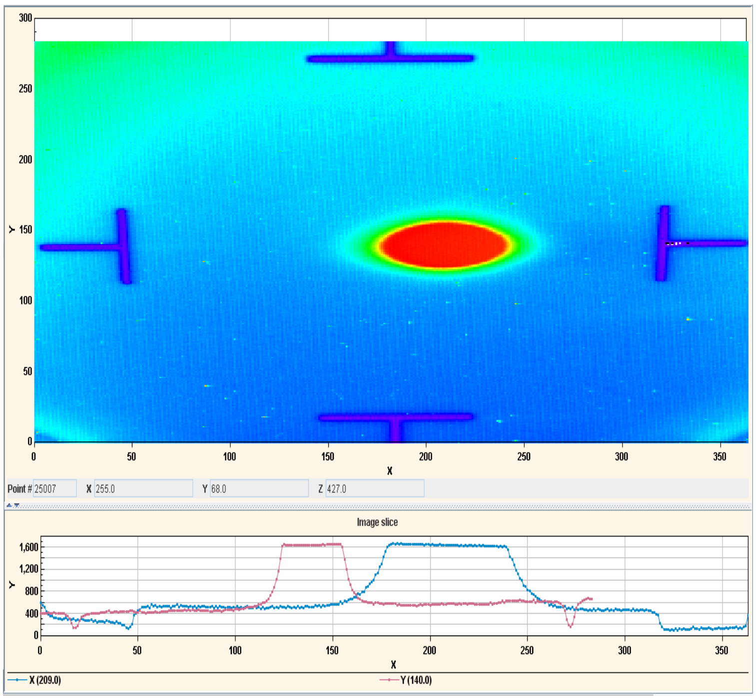


Figure 31.1: Temperatures measured in the TI 8 tunnel during the cold checkout period using a 16.8 s cycle.

31.4 BEAM COMMISSIONING OF TI 8

The commissioning with beam took place over two weekends, 23-25 October and 6-8 November 2004. The SPS extraction was set-up first, with beam being sent to the TT40 beam absorber (TED). The energy of TI 8 was set to 449.2 GeV/c following an energy calibration of the SPS [1,2]. After moving the TT40 TED and the TI 8 beam stopper (TBSE) out, the beam travelled the additional 2.5 km to the absorber block at the end of the TI 8 tunnel without any steering. The picture of the first beam arriving on the luminescent screen just in from of the TED at the end of TI 8 is shown in Fig. 31.2.



Point # 25007 X 255.0 Y 68.0 Z 427.0

Figure 31.2: Image of the first beam on the downstream TI 8 beam absorber.

Subsequently the beam diagnostics were tested and calibrated with beam. The response of each beam position pick-up was measured by individually powering orbit correctors in both planes. This measurement, together with a detailed measurement of the dispersion, showed a small difference in the optics with respect to the design values. This was later traced to two quadrupoles at the beginning of the transfer line, QTRF4002 and QTLF4004, which had an incorrect maximum current setting in the database and this resulted in a 20% error in their current setting. This was corrected for the subsequent weekend of beam tests. During this second weekend many of the beam tests were repeated with the corrected optics. The overall programme included:

- Optics measurements using different corrector settings and measuring the trajectory response.
- Measurement of the dispersion functions in the transfer line by changing the beam energy of the SPS with the RF frequency.
- Measurement of the energy acceptance of the line. This was also performed by changing the RF frequency in the SPS. The results are shown in Fig. 31.3.
- Measurement of the physical aperture of the line by making trajectory oscillations with different phases and measuring the transmission.
- The Twiss parameters were measured by combining the OTR screen data.
- Parasitic beam stability measurements throughout the beam tests.
    - The average value of the beam stability for the different beam position monitors was found to be around 100 µm RMS [4]. This corresponds to about 1/8 of the 1 σ nominal beam size.
- Parasitic beam coupling measurement throughout the beam tests. The coupling between the two planes was found to be around 2 % [4].
- No significant effect of the magnet’s temperature on the trajectory was measured
- Multi-bunch commissioning of the beam instrumentation.

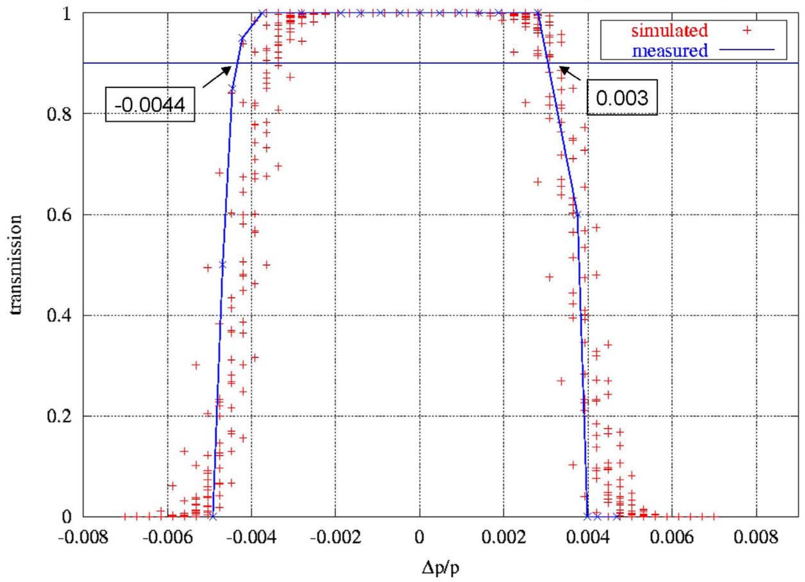


Figure 31.3: Measured TI 8 energy acceptance compared with tracking results for which realistic operational conditions were considered [3].

The beam period in the second weekend was also used to test the transfer line collimator alignment procedure with beam. The jaws of the collimator installed just in front of the TT40 TED were moved and the effect on the beam transmission was measured by the beam current transformer (BCT) installed in the lower part of the transfer line.

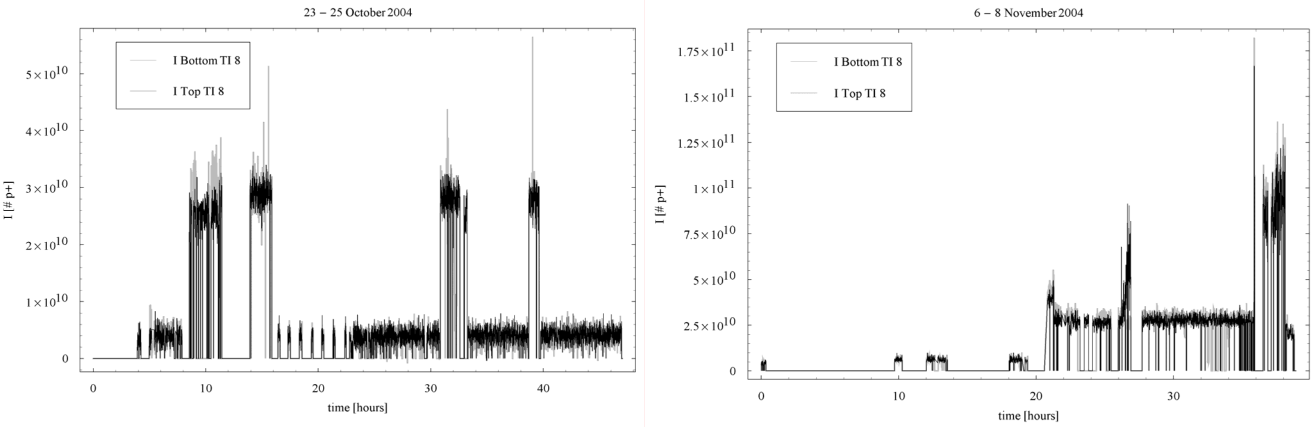


Figure 31.4: Beam intensities measured in the upper part and the lower part of TI 8 during the two test periods.

For most of the first test period single pilot bunches with an intensity around 5×10^{9} protons were used. To improve the resolution of the beam position monitors and the screens, higher single bunch intensities of around 3×10^{10} protons were used for some periods. During a limited period towards the end of the second test, the beam position monitor behaviour was tested with multiple bunches. The beam intensities over the two test periods are plotted in Fig. 31.4.

During the first test period the total beam intensity dumped on the beam absorber at the end of the line was around 3.5×10^{13} protons. During the second test period this was around 5.1×10^{13} protons. The predicted intensity was in the range of $5\text{-}15\times10^{13}$ protons for both periods. During the tests the experimental pit at LHC Point 8 (including several 100's of metres to either side) was closed for all access. Additional shielding was installed just downstream of the TED at the end of TI 8 and outside of the TI 8 tunnel (see Fig. 31.5). The radiation levels in the LHC tunnel were measured two hours after the beam was stopped. The levels were found to be highest at the wall in R88, immediately adjacent to the beam absorber block (see Fig. 31.5).

After the first test the measured value at this position was 1.5 µSv/h; after the second test this was higher, 7 µSv/h and local shielding was put up for several days in order to allow general access in this area. This higher measured dose was caused by the higher intensity multi-bunch operation towards the end of the test period and was in good agreement with calculations. General access, without the need to carry a film badge or personal dosimeter, was given for the LHC pit and the LHC tunnel only a few hours after both beam tests finished.

It was found very useful to have two periods for beam tests, separated by at least two weeks. This gave sufficient time to analyse the data of the first beam tests and to perform repairs for minor faults found during the first test period.

The general performance of the transfer line was according to the design criteria, with high beam stability and optics parameters very close to the design values. The beam diagnostics were tested and proved to be sufficiently performant to identify small errors in the settings.

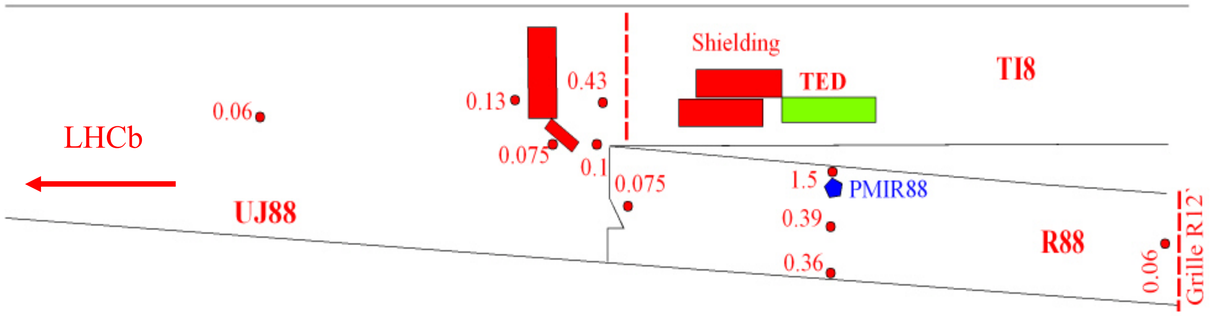


Figure 31.5: Measured activity at the end of the TI 8 transfer line, two hours after the beams were stopped [5]. Values are given in µSv/h.

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