LHC TRANSFER LINES AND SECTOR TESTS IN LHC

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Abstract

Transfer Line and Sector tests were conducted in the past and proved to be invaluable, fully meting their goals. They resolved a long list of problems, debugged and tested the control system, the beam instrumentation, timing and synchronization, software, etc. Measurements with beam allowed detailed optics and apertures checks to be performed, discovering aperture bottlenecks and polarity issues that could be solved before beam commissioning.

Being those tests an essential precursor and a high profile milestone in preparation for full beam commissioning, transfer line and sector tests are again proposed before beam commissioning starts in 2015. This paper summarizes the proposed dates, the pre-requisites, how to stop the beam with collimators and the goals in what accelerator equipment commissioning and beam measurements are concerned.

MOTIVATION

During LS1 most of the accelerator subsystems and the control system underwent important changes in view of improving availability and reliability. Most of the magnet interconnections have been opened and the machine has been exposed to air. Fifteen main dipole magnets and other equipment have even been changed. The accelerator control system was upgraded with effects on most of the accelerator equipment. A complete summary of all the interventions made in all the accelerator subsystems can be found in these proceedings.

The proposed transfer line and sector tests will provide the unique opportunity to debug and test the accelerator subsystems involved, resolve possible problems at an early phase, carry out the first commissioning of the most critical systems, injection and dump, and perform the first measurements with beam, assessing the performance of the beam instrumentation and, in general, of the accelerator subsystems after the Long Shutdown One (LS1).

Several sector tests have been performed in the past in preparation for final beam commissioning. The TI8 transfer line was commissioned for the first time with beam in 2004 [1, 2]. In 2005 the TI8 test was repeated with high intensity beams. TI2 saw beam for the first time in 2007 [3]. In preparation for first circulating beam in 2008, five sector tests were performed [4]. Finally, after the 2009 shutdown, following the sector 34 incident, two injection tests were accomplished, together with the first ion injection in the LHC. On all occasions the tests were undoubtedly an essential precursor to the successful start of LHC Beam Commissioning.

STRATEGY

Three weekends are proposed to carry out the transfer line and sector tests in LHC. The dates are different from the ones presented in [5] since the overall LHC schedule has changed and new dates had to be found to make those tests compatible with the new plan:

- Transfer Line TI2 and TI8: 22-23 Nov 2014 - beams dumped in the movable beam dump block (TED) down stream the lines.
- Sector Test 1: 7-8 Feb 2015 - beam 1 through sector 23 and dumped in the IR3 collimators.
- Sector Test 2: 21-22 Feb 2015 - beam 2 through sectors 78 and 67 up to the beam 2 dump block in point 6.

The tests are scheduled weekends to minimize the impact on the experiments and hardware commissioning.

Single pilot bunches of 2-5×10^9 protons will be used for the test in order to reduce the ambient radiation and therefore have less or no impact on post-test tunnel activities.

The setting up of SPS TT60/TT40 extraction region will be done before the transfer lines and sector tests.

Goals of the Transfer Lines Test

During the transfer lines test the beams will be sent to the down stream TED. The goals of these tests are listed below:

1. With SPS as mastership of the injection request:
   a. threading and steering of the lines;
   b. commissioning with beam of the beam instrumentation: Beam Position Monitors (BPM), Beam Loss Monitors (BLM), beam screens (BTV), Beam Current Transformer (BCT), etc;
   c. commissioning of the beam interlock system of the SPS extraction and LHC injection;
   d. SPS-Transfer Line energy matching and energy acceptance.
2. Commissioning of the LHC mastership injection request.
3. LHC injection septa (MSI) and injection kickers (MKI) synchronization.
4. Beam measurements:
   a. BPM and orbit corrector polarity and gain checks.
   b. Rough linear optics and dispersion checks.
   c. Trajectory stability
5. SPS Extraction Kicker (MKE) waveform scans (LSS4/LSS6).
6. Extraction region aperture scans.

7. Initial commissioning of transfer line collimators (TCDI) and set up with automatic application.
8. LHC Beam Dump System-MKI synchronization (without beam).
9. Inject and dump commissioning (without beam).

The transfer line tests require closing the following areas:

- Transfer Line TI2: TI2, PM25, PM32, UJ23, UJ27, UP2 and PX24 (ALICE).
- Transfer Line TI8: TI8, PM85, UJ83, UJ87 and UX85 (LHCb).

CMS and ATLAS are not concerned, however, the other sectors might be closed because of powering test activities that can be performed in parallel to the transfer line tests.

A preliminary plan for the different commissioning steps to be performed during the transfer line tests is under preparation and it will be circulated soon for comments in order to elaborate the final version by middle of October 2014.

Goals of the Sector Tests

During the first sector test, beam will be sent to the TED down stream TI2 and some time will be dedicated to re-setup the line, assuming the full commissioning was performed during the transfer line test in November 2014. Then the beam will be sent to the LHC injection beam stopper (TDI) with the injection kickers of beam 1 off. After the required setup time in this configuration, the same exercise will be done with the injection kickers on. Once the injection region is properly set up, the TDI will be retracted and the beam will be sent to the insertion region 3 where the momentum collimators are located. From then onwards, a series of measurements will be performed as detailed in the BEAM MEASUREMENTS section.

The same steps will be carried out during the second sector test, except that the TI8 transfer line will have been commissioned before. In addition, beam 2 dump line and the associated systems will be commissioned this time.

PREREQUISITIES

The success of the transfer lines and sector tests relies heavily on the success of the preparation activities carried out during the year like: hardware commissioning, individual system tests, powering tests, dry runs, access system commissioning, Departmental Safety Officer (DSO) acceptance test and machine checkout. A detail review of those activities can be found in these proceedings.

Those activities will exercise all the required systems and debug their integration, which is crucial to narrow down the problems or solve them before the beam comes.

The LHC access system commissioning with beam conditions i.e. machine closed and patrolled including the experiments, is scheduled November 8 and 9 2014. The DSO test will take place at the following weekend, November 15 and 16 2014, and again the LHC will be closed and patrol including the experiments.

During the sector tests the experiments involved in the tests, i.e. ALICE and LHCb must have their full shielding in place.

Table 1: Summary of collimators used for the different injection tests in 2008 with the corresponding type of settings. The arrows indicate the direction of the beam.

<table>
<tr><td>Beam 1 stopped at LEFT of IR3</td><td>
<table>
<tr><th>Collimator Name</th><th>s pos [m]</th><th>angle</th><th>settings</th></tr>
<tr><td>TCP.6L3.B1</td><td>6487.6713</td><td>H</td><td>OPEN</td></tr>
<tr><td>TCSG.5L3.B1</td><td>6520.9928</td><td>H</td><td>OVERSHOOT</td></tr>
<tr><td>TCSG.4R3.B1</td><td>6707.5758</td><td>H</td><td>OVERSHOOT</td></tr>
<tr><td>TCSG.A5R3.B1</td><td>6718.9208</td><td>S</td><td>OVERSHOOT</td></tr>
<tr><td>TCSG.B5R3.B1</td><td>6724.7408</td><td>S</td><td>INTERMEDIATE</td></tr>
<tr><td>TCLA.A5R3.B1</td><td>6755.2208</td><td>V</td><td>OVERSHOOT</td></tr>
<tr><td>TCLA.B5R3.B1</td><td>6757.2208</td><td>H</td><td>OVERSHOOT</td></tr>
<tr><td>TCLA.6R3.B1</td><td>6843.7703</td><td>H</td><td>OVERSHOOT</td></tr>
<tr><td>TCLA.7R3.B1</td><td>6915.1758</td><td>H</td><td>OVERSHOOT</td></tr>
</table>
Beam 1
</td></tr>
<tr><td>Beam 1 stopped at RIGHT of IR3</td><td>
<table>
<tr><th>Collimator Name</th><th>s pos [m]</th><th>angle</th><th>settings</th></tr>
<tr><td>TCP.6L3.B1</td><td>6487.6713</td><td>H</td><td>OPEN</td></tr>
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<tr><td>TCLA.7R3.B1</td><td>6915.1758</td><td>H</td><td>OVERSHOOT</td></tr>
</table>
Beam 1
</td></tr>
<tr><td>Beam 2 stopped at RIGHT of IR7</td><td>All IR7 collimators closed with overshoot technique</td></tr>
<tr><td>Beam 2 stopped at LEFT of IR7</td><td>TCLA.A6L7 (W collimator) overshoot</td></tr>
<tr><td>Beam 2 dumped in IR6</td><td>
<table>
<tr><th>Collimator Name</th><th>s pos [m]</th><th>angle</th><th>settings</th></tr>
<tr><td>TCSP.4L6.B2</td><td>16507.62818</td><td>H</td><td>OVERSHOOT</td></tr>
<tr><td>TCDQA.B4L6.B2</td><td>16511.53818</td><td>H</td><td>CLOSE</td></tr>
</table>
Beam 2
</td></tr>
</table>

HOW TO STOP THE BEAM

The same strategy as used in 2008 and 2009 for stopping the beams safely and reliably with collimators will be used. The technique is called overshoot and it is described in the following. The collimators will be set up with the minimum possible gap between jaws on anti-collision switches; which corresponds to 0.5 mm gap. Then the collimator gap will be moved 5 mm aside from the reference orbit to assure the beam impacts on the jaw. If required, the collimator can in addition be tilted.

Table 1 lists the collimators used during the injection tests in 2008. Open settings means the collimator is fully

retracted to let the beam go through. Intermediate settings correspond to gaps of the order of +/-10 mm and +/-12 mm depending on the collimator.

BEAM INTERLOCK CONFIGURATION

Two configurations have been prepared, one for the beam 1 sector test and the other for the beam 2 sector test. The configurations are summarized in Table 2 and 3.Only the inputs relevant for the sector tests will be enabled. To avoid modifying the hard-wired Power Interlock Controller (PIC) arrangement, the interlocking of the magnet circuits will be done with the Software Interlock System (SIS). The PIC input to the Beam Interlock System (BIS) will be disabled.

Table 2: User permits needed for the first sector test.

INJ1	CIB.SR2.INJ1.1	CIB.SR2.INJ1.2
	LHC Beam 1 Permit	Nothing needed
	Operator switch	
	MKI2 status	
	Vacuum	
	MKI2 erratic	
IR2 (B1)	CIB.UA27.R2.B1	L2.B1
	MKI	BLM
	Vacuum	Vacuum
	ALICE detector	
IR3 (B1)	CIB.UJ33.U3.B1	CIB.SR3.S3.B1
	ACCESS_SB	BLM
	WIC	

Table 3: User permits needed for the second sector test.

INJ2	CIB.SR8.INJ2.1	CIB.SR8.INJ2.2
	LHC Beam 2 Permit	LBDS.B2
	Operator switch	
	MKI8 status	
	Vacuum	
	MKI8 erratic	
IR6 (B2)	CIB.UA67.R6.B2	CIB.UA63.L6.B2
	Vacuum	Vacuum
	LBDS (TSU)	WIC (septa)
	LBDS (PLC)	BLM
	CIBDS B2	
IR7 (B2)	CIB.SR7.S7.B2	CIB.TZ76.U7.B2
	BLM	Vacuum
		WIC
IR8 (B2)	CIB.UA87.R8.B2	L8.B2
	Vacuum	Vacuum
	MKI	BLM
	LHCb detector	
	LHCb movable	

ENERGY INFORMATION

The Beam Energy Tracking System (BETS) of the Beam Dump System will get the energy from the BETS simulator. The main dipoles of the four sectors that provide the energy measurement under normal circumstances might not be available at that time. Those sectors are 45, 56, 67 and 78.

BEAM MEASUREMENTS

The beam measurements to be done during the sector tests are the following:

- Transfer line optics and aperture checks (if not done during the transfer line test) and matching between the transfer lines and LHC injection region.
- Establish injection:
  - kicker synchronization
  - kicker wave form study
  - kicker control
  - SPS-LHC RF synchronization
  - pre-pulse transmission
  - timing system functionality
  - injection sequencer commissioning
  - aperture checks
- Beam Position Monitor system commissioning:
  - response
  - acquisition
  - concentrator
- Threading:
  - establish first trajectory and first orbit correction
  - application software commissioning
- Kick response:
  - check BPM and orbit corrector polarities
  - linear optics checks
  - other circuits polarity checks
- Aperture measurement
- Beam Loss Monitors commissioning
- Collimators:
  - BLM response
  - Control system commissioning
  - BPM collimators first commissioning

Reference [4] compiles all the details of the tests performed in 2008 together with the beam measurements.

The preliminary measurement plans for the two sector tests have been presented in [5]. Those plans will have to be updated according to the results of the transfer line test in November 2014, and in particular the final plan for the second sector test will depend on the outcome of the first one.

CONCLUSIONS

Transfer lines and sector tests are essential precursor and a high profile milestone in preparation for full beam commissioning.

The TI2 and TI8 transfer line tests are scheduled in November 2014 and two sector tests are proposed for 2015:

- Transfer Line TI2 and TI8: 22-23 Nov 2014 - beams dumped in the TED down stream the lines.

- Sector Test 1: 7-8 Feb 2015 - beam 1 through sector 23 and dumped in the IR3 collimators.
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A draft measurement plan for the transfer line tests is under preparation and it will be circulated for comments and optimization. The plan for the sector tests have been already presented in [5] but an update will be needed that takes into account the results of the transfer line test.

REFERENCES

[1] B. Goddard, V. Mertens, T. Risselada, "Status and Plans for the SPS to LHC Beam Transfer Lines TI2 and TI8", LHC Project Report 751, EPAC 2004 Conference Proceedings.

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[3] J. Uythoven et *al.*, "Beam Commissioning of the SPS-TO-LHC Transfer Line TI2", EPAC 2008 Conference Proceedings.

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[5] V. Kain, R. Alemany, "LHC Transfer Lines and Sector Tests in 2014", EVIAN 2014 Workshop Proceedings