LHC TRANSFER LINES AND SECTOR TESTS IN 2014

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Abstract

Sector tests in the past were undoubtedly invaluable and fully met 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.

Being sector tests an essential precursor and a high profile milestone in preparation for full beam commissioning, two sector tests are proposed for 2014. This paper summarizes the proposed dates, the pre-requisites, how to stop the beam with collimators, the proposal for beam measurements, and gives a first detailed plan of the tests as a base for discussion.

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. Some 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 always in preparation for final beam commissioning. 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.

In all occasions the tests were undoubtedly an essential precursor to the successful start of LHC Beam Commissioning.

STRATEGY

Three weekends have been proposed and approved at the LMC 176 to perform the transfer lines and sector tests in 2014:

- ST1: 1-2 Nov 2014 ➔ TI2 and TI8 transfer line tests and beam through sector 23.
- ST2: 22-23 Nov 2014 ➔ TI8 transfer line tests and beam through sectors 78 and 67 up to the beam 2 dump block.
- ST3: 13-14 Dec 2014 ➔ contingency

ST3 is a contingency date and it will only be used in case ST1 and/or ST2 fail.

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 TT60/TT40 extraction will be done before the sector test. The date is still to be defined.

During the first sector test, beam will be sent down TI2 and TI8 and time will be dedicated to commission both transfer lines. Then the beam will be sent to the TDI with the injection kickers (MKI) of beam 1 off. After the required setup time in this configuration, the same exercise will be done with the MKI 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 following sections.

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 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.

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:

- Place collimators with the minimum possible gap between jaws on anti-collision switches ➔ 0.5 mm gap.
- Move the collimator gap 5 mm aside from the reference orbit to assure the beam impacts on the jaw.
- If required, the collimator can be tilted in addition.

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 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.

ENERGY INFORMATION

The Beam Energy Tracking System (BETS) for 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 will not be available. Those sectors are 45, 56, 67 and 78.

EXPERIMENTS SHIELDING

During the sector tests the experiments involved in the tests, i.e. ALICE and LHCb, should have their full shielding in place. This will be the case for LHCb but not for ALICE. ALICE foresees to install the shielding at the end of December only. A scenario has, however, been worked out by the ALICE Technical Coordination office that would allow closing the shaft shielding without major impact on the ALICE schedule. The PX24 shielding plug is made of two distinct layers, the "beams" (2 m thick material) on the bottom, and the "blocks" (0.8 m thick) on the top. ALICE will install the beams the night between Thursday 30 and Friday 31, and they will be removed the night between Monday 3 and Tuesday 4.

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>
<tr><td>TCSG.5L3.B1</td><td>6520.9928</td><td>H</td><td>INTERMEDIATE</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>

Radiation protection made the corresponding dose calculations for this configuration. It has to be pointed out that during LS1 (including the sector test), the ALICE cavern and counting room (CR) are considered *Non Designated Areas* with a dose per hour limited to 2.5 μSv/h. During normal operation ALICE CR and cavern are classified as a *Supervised Radiation Areas* with a dose limited to 15 μSv/h.

The dose calculation concluded that with 2 m shielding in place at PX24, two to four shots (for 5.0×10^9 to 10.0×10^9 particles per bunch (max), respectively), would be enough to reach the dose limit per hour at the counting room if the beam is lost at the unshielded beam pipe region. Therefore, the requirement is to lock the access to the CR during the sector test.

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	

The situation at the "top of the pit" is more relaxed since up to twenty shots at the unshielded beam pipe would be needed to reach the dose limit. At 1 m distance from this position, 100 shots would be needed. The radiation monitors in those areas will all be operational. Injection will be stopped before the radiation limit is reached. More details on the dose calculation can be found in [5].

BEAM MEASUREMENTS

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

- Transfer line optics and aperture checks and matching between the transfer lines and LHC injection.
- Establish injection:
  - kicker synchronization
  - 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.

PRELIMINARY PLAN

Figure 1 and 2 show the preliminary measurement plan for the two proposed sector tests. They will account for 63 hours and 66 hours, respectively, corresponding to around 8 full shifts. The plan takes into account the request from the experiments, ALICE and LHCb, which would like to have shots on TED and TDI. Note that the final plan for the second sector test will depend on the outcome of the first one.

CONCLUSIONS

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

Two sector tests are proposed for 2014:

- ST1: 1-2 Nov 2014 ➔ TI2 and TI8 transfer line tests and beam through sector 23.
- ST2: 22-23 Nov 2014 ➔ TI8 transfer line tests and beam through sectors 78 and 67 up to the beam 2 dump block.
- ST3: 13-14 Dec 2014 ➔ contingency

A draft measurement plan is circulating for comments and optimization.

	Time	SECTOR TEST 1: TI8, TI2 & S23	Δt (h)
Friday	12	Patrol and closure of LHC and Experiments. Magnets pre-cycle. Last interlock checks/tests. TT40/TT60 extraction (TEDs in)	3
	15	Beam down to TI2 TED, establish rough trajectory. LHC mastership. MSI & MKI pulsing. First TL BI commissioning. Timing of beam and	4
	19	TI2 TED out, MKI off/on, beam to TDI. Thread last part of TI2 and MSI. Set TDI, TCLI	2
	21	TDI out, beam to IR3 right. First BI commissioning (BLM, BPM, BTV). Threading	3
Saturday	0	BPMs and orbit corrector polarity checks TI2 & Ring, Linear optics & dispersion TI2 & Ring	8
	8	Beam down to TI8 TED, establish rough trajectory. LHC mastership. MSI & MKI pulsing. First TL BI commissioning. Timing of beam and	4
	12	Screen matching TI2 + injection	2
	14	TDI in, physical aperture measurements in TI2 and the injection region. ALICE BCM+BLM calibration in parallel	8
	22	MKI2 waveform scan	2
Sunday	0	TL trajectory stability TI2 - beam on TED. More TL BI commissioning	3
	3	MKE waveform scan LLS4/LLS6	4
	7	BLM latency check	1
	8	BLM response (collimator splashes)	2
	10	Aperture IR2 and S23	8
	18	Magnet polarity (skew quads, sample of MQT, MQTL)	3
	21	BMPs and orbit corrector polarity checks TI8	2
	23	Set TCDI, automatic application TI2	3
Monday	2	Rough LSS4 extraction region aperture scan	1
	3	Pre-cycle - effects	3
	6	End of TI2/TI8/S23 test. RP survey	2

Figure 1: Sector test 1 schedule. The total test duration is 63 hours, which corresponds, to 8 full shifts.

	Time	SECTOR TEST 2: TI8, S78-S67, LBDS B2	Δt (h)
Friday	12	Patrol and closure of LHC and Experiments. Magnets pre-cycle. Last interlock checks/tests. TT60 extraction (TEDs in)	3
	15	Beam down to TI8 TED, establish trajectory. LHC mastership. MSI & MKI pulsing. LHCb TED shots in parallel.	2
	17	TI8 TED out, MKI off/on, beam to TDI. Thread last part of TI8 and MSI. Set TDI, TCLI. More TL BI commissioning	2
	19	TDI out, beam to IR7 right. First BI commissioning (BLM, BPM, BTV). Threading	3
	22	Beam to IR6 LBDS B2 with orbit correctors (TCDQ & TCSG in beam and interlocked). Steering. Beam dump line BI commissioning. Synchronization. Rough check of extraction channel aperture.	3
Saturday	1	Beam to IR6 LBDS B2 with "inject and dump" (TCDQ & TCSG in beam and interlocked). Steering. More check BI. Synchronization. Rough check of extraction channel. MKD knob test. MKB	6
	7	BPMs and orbit corrector polarity checks TI8 & S78-S67, Linear optics & dispersion TI8 & S78-S67	9
	16	Screen matching TI8 + injection	2
	18	TDI in, physical aperture measurements in TI8 and the injection region. LHCb BCM+BLM calibration in parallel	8
Sunday	2	MKI8 waveform scan	2
	4	TL trajectory stability TI8 - beam on TED. More TL BI commissioning. LHCb TED shots in parallel	3
	7	Rough LSS6 extraction region aperture scan. LHCb TED shots in parallel	1
	8	BLM latency check	1
	9	BLM response (collimator splashes)	2
	11	Aperture IR8 and S78S67	9
	20	Magnet polarity (RCO.A78B2, Q5L8, skew quads, sample of MQT, MQTL)	4
Monday	0	Set TCDI, automatic application TI8 (if not done in ST1)	3
	3	Pre-cycle - effects	3
	6	End of TI8/S78S67/LBDS B2 test. RP survey	2

Figure 2: Sector test 2 schedule. The total test duration is 66 hours, which corresponds, to about 8 full shifts.

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[4] M. Lamont et *al.*, "The LHC Injection Tests", LHC Performance Note 2008-10-21, PAC 2009 Conference Proceedings.

[5] https://indico.cern.ch/event/327035/