SECTOR TEST WITH BEAM IN 2006

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Abstract

An LHC sector test with beam was approved in 2003. The requisite machine configuration for this test is described, along with the requirements and planning for the associated hardware commissioning. The planned beam tests are detailed together with the associated implications for radiation and access. The potential impact on ongoing installation is reviewed. Finally an overview of planning for the test is presented.

INTRODUCTION

An LHC sector test with beam was approved in 2003. This test plans to inject beam down TI8, into the LHC at the injection point right of IP8, traverse IR8 and LHCb, through sector 8-7 to a temporary dump located near the position of Q6 right of point 7. The test will involve 3.3 km of the LHC including one experiment insertion and a full arc and as such it may be regarded as very representative of the challenge will be faced in commissioning the whole machine.

The motivations for performing this test have been well debated [1,2] and outlined in detail [3]. The consequences and the potential impact have also been studied. Such a test will allow one to:

1. Check that the ensemble of installed equipment works with beam, and that there are no problems with ongoing installation.
2. Pre-commission essential acquisition and correction procedures.
3. Verify the system wide integration necessary for beam, which goes beyond hardware commissioning.
4. Last, but not least, it will provide an extremely high profile milestone forcing the preparedness of all components.

Operationally the exercise would be extremely valuable and it is argued that the time and effort spent on the test will be more than compensated by a more efficient start-up of the completed machine. Discovering any problems during a sector test will give a year, at least, to resolve any problems, perform a critical analysis of the performance of the systems involved and implement improvements. A successful test would also validate the project to the wider world.

REQUIREMENTS

TI8

The transfer line TI8 needs to be fully commissioned. TI8 will be commissioned to the last TED before the LHC in 2004. The additional section between the TED and the LHC septa is relatively simple and will have to be commissioned with beam at the same time as the LHC sector test. The requirements for the transfer line commissioning are well described elsewhere [4].

The main requirements for the injection test are a stable, well corrected, well matched trajectory with the designated emittance. Orthogonal steering of injection point will be required. An operational interlock system will be required.

IR8 & Injection region

The beam enters the LHC at the septa right of IP8, in this region the requirements include:

- Septa installed & fully commissioned, along with the associated power converter, controls, and interlocks.
- Injection kickers installed, baked-out, and tested together with controls, timing, pre-pulses, and analogue acquisition.
- Q5, Q4, D2 right of IP8 cold and commissioned.
- TDI commissioned, with controls and appropriate radiation monitoring.
- TCDD installed.
- D1 and inner triplet left and right, cold and commissioned. Inner triplet higher multipole compensation not needed. All orbit correctors in this region commissioned.

LHCb

LHCb's planning takes test as scheduled into account. The final vacuum pipe will be in place, but not fully baked out (this shouldn't be a problem for single pass, low intensity beam). The vertex locator detector will not be in place for test. It will be installed after test and then fully commissioned by September 2006.

The experimental cavern at point 8 must receive only minimal irradiation. To ensure this, the foreseen RAMSES monitors will be in place along with additional PMI monitors. Additional Beam Loss Monitors will also be installed every 10 m [5].

The spectrometer magnet compensation elements should be de-commissioned and the spectrometer magnet shall be off.

Magnets/Circuits

Clearly only those circuits affecting beam 2 will be required. All orbit correctors should be available. Higher order correctors (> b_3) are not required. It is planned to cycle the magnets but taking them to the 7 TeV equivalent is not mandatory for the test. A full list of required circuits has been presented elsewhere [6].

Beam Instrumentation

The following beam instrumentation is required; details have been presented [6]:

- Beam Position Monitors, as planned for beam 2.

- Beam Loss Monitor, as planned, plus additional monitors in LHCb.
- Screens: before the septa (TI8), after the septa, before and after the kickers and the screen before the TDI. A temporary screen is required before the dump in IR7.
- Beam Current Transformer, as planned at the end of TI8 plus the temporary installation of spare fast BCT right of IP7 between Q6 and the dump.
- BST (TTC) will be needed.

Other

Controls will include slow timing, fast timing, alarms, logging, post mortem, fixed display, equipment control, settings managements, measurements, trajectory acquisition and correction, ramping etc. [7]. The Beam Interlock system should be operational.

The RF system will provide pre-pulses via a skeleton installation at point 4.

HARDWARE COMMISSIONING

The required cryostats, DFBs and power interlock controllers and their associated powering subsectors have been detailed [8]. Clearly these systems have to be ready in time for a thorough cold checkout before beam. A tentative planning is presented below.

Sector 7-8

Hardware commissioning is foreseen for August 2005 to March 2005. This will be proceeded by individual system tests, namely: cryogenic production and distribution; power converter short circuit tests; evacuation; leak tests; closure of the interconnects; QPS checks, and alignment.

The hardware commissioning proper of continuous arc cryostat & LSS cryostats (Q6.R7, Q6, inner triplet, etc.) will then start. The key systems being: cryogenics, vacuum, QPS, PIC, and powering. The basic commissioning sequence is: cool-down; leak tests; electrical quality assurance; tests prior to powering; powering (QPS, PC, MPS) of all circuits one by one; powering of all the circuits of a sector in unison.

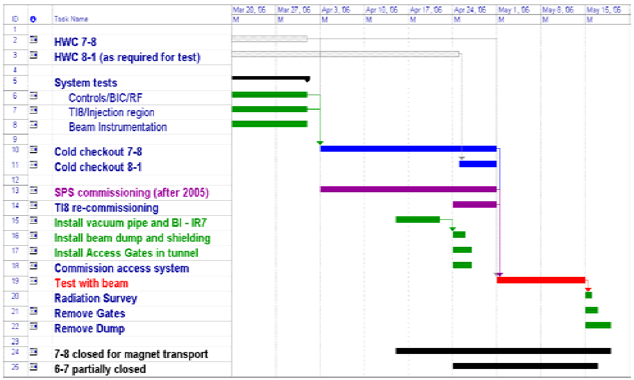
Detailed breakdown has been presented and documented in detail [9].

Sector 8-1

Commissioning is foreseen from October 2005 to June 2006. The baseline is to have whole sector cold for the sector test but back-up solutions exist if equipment is missing [10]. The priority is clearly to have the inner triplet, D1, D2, Q4, Q5 right of IP8 ready for the test.

Other systems must also be commissioned and these include the TCDD, TID, Kickers, Septa, Beam Instrumentation, RAMSES, TI8, IR 8 warm vacuum and controls. Planning for the installation and commissioning of these is ongoing.

An outline summary of the planning for 2006 is shown below:



TESTS WITH BEAM

The LHC pilot Beam will be used for the most part i.e. a single bunch with intensity of 5 to 10 x 10^9 protons. This is below the quench limit if losses are diluted over more than 5 m. and 2 orders of magnitude below damage threshold. Working initially with the so-called de-Gauss cycle, the proposed tests with beam include:

- Commission injection region with the TDI closed, including the end of TI8, the septa, kickers, timing, and synchronisation. Commission BLMs in the region, plus trajectory acquisition, screens, and BCT. Steer injection point. Beam onto TDI.
- TDI out. Commission trajectory acquisition and correction. Check all related beam instrumentation: BLMs, BPMs. First, provisional check of the aperture. Check energy matching. Thread beam to dump.
- Commission BLM system.
- Linear optics checks: check trajectory versus kick, phase advance, BPM and corrector polarity. Coupling. Matching between TI8 and sector. Determination of Twiss functions via kick/trajectory measurements.
- Mechanical aperture checks. Using bumps, check the aperture. Check the momentum aperture.
- Field quality checks. Check design fields, field harmonics, fields due to offsets between beam and magnet.
- Commission normal cycle or a variation, check reproducibility from cycle to cycle. Examine energy offset versus time on flat bottom. Study variation of field errors during decay.
- Determination of quench level by bumping beam into a chosen magnet and inducing localised loss. Spatial distribution of beam losses.

RADIATION

With an assumed operational efficiency 50% the proposed tests will deliver ~3000 shots and a total intensity of around 2 x 10^{13} protons. Scaling the simulations performed by RP group [11] based on a total of 1.3 x 10^{15} protons in 24 hours we would expect typical dose rates, if the above total of 2 x 10^{13} were delivered in 1 day, after 1 day cooling, of:

- along side the TED: ≈40 µSv/h
- on the downstream face of TED: ≈500 µSv/h.

There will be an extra beam stop after the TED, as for TI8, and some short-lived irradiation of concrete walls around the TED. If the beam is lost uniformly along the sector between point 8 and point 7 there will be negligible activation and even if beam is lost in one dipole repeatedly the level will be only 4 - 10 µSv/h.

The above figures have been confirmed by measurements performed after the TT40 extraction tests where comparable intensities were delivered.

In conclusion, a low level of activation is foreseen. The dump will be removed after a cool-down period and all areas will be surveyed after the test, and perhaps during the test, to ensure that activation remains low. Restrictions will be declared as appropriate: either "Surveyed" (< 0.5 µSv/h) or "Simple Controlled Areas". Personal dosimeters will be required for the latter. There could be potential fencing off of elements to minimise exposure.

As regards monitoring, RAMSES has the injection test as a milestone. For LHCb some 4 to 5 monitors are planned, however, extra monitors are required to ensure the requisite limit of 0.5 µSv/h is respected. The ventilation system and access gates will be monitored. BLMs, which are sensitive to losses at 1% level with pilot bunch intensity, will be also be used. The extracted, injected, and to dump, beam intensities will be logged.

ACCESS

Clearly there will be no access to the zones that see beam or the radiation from the beam during the test. This implies interlocked gates in tunnel sectors 6-7 and 8-1, along with interlocked access restrictions at PM76, PM85 and PZ85. Much of this infrastructure will be necessary in the final LHC configuration and can be made available for the test without too much extra cost [12].

For sector 6-7, a gate must be installed and interlocked at least 800 m from IP7. A simple interlocked gate is required. The gate will have to be removed after the test. This distance has been determined following simulations of the downstream radiation from the dump [13]. The infrastructure would be temporary and would need to be replaced after the test.

The machine access point at Point 7 (PM76) should be operational. The situation there is fairly simple and if the final configuration of the access system were not to be ready it should be possible to have a blocking gate, necessarily interlocked.

The machine access point at Point 8 (PM85) will be operational. An interlocked gate must be placed at the top of PZ85 or in the LHCb shielding wall. The gate in sector 1-8 (also required for the TI8 tests) must be operational & interlocked. The gate will have to be removed after the test.

CONCLUSIONS

The LHC injection test plans to take low intensity beam though the injection region right of IP8, through sector 7-8 to a dump right of IP7. The test will last 2 weeks and, at present, is planned to take place in May 2006.

The requirements for the test have been detailed and have been incorporated into the associated hardware commissioning planning.

The planned tests with been have been outlined. The low intensities involved imply a low level of activation but comprehensive simulations and measurements have been performed and the necessary precautions are foreseen. Simple Controlled areas in after the test in some zones have to be anticipated. Access and monitoring requirements have been defined.

Follow-up on a number of issues arising from the above is planned for 2004.

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REFERENCES

1. F. Rodriguez-Mateos, Proc. XIIth Chamonix LHC workshop on LHC performance, 2003.
2. R. Assmann, Proc. XIIth Chamonix LHC workshop on LHC performance, 2003.
3. M. Lamont, TCC minutes 2003-07
4. See, for example, http://proj-lti.web.cern.ch/proj-lti/
5. B. Denhing, private communication.
6. M. Lamont, TCC minutes 2003-11
7. M. Lamont, http://cern.ch/lhc-injection-test/
8. R. Saban, TCC minutes 2003-11
9. See http://cern.ch/LHC-HCWG/
10. L. Tavian, TCC minutes 2003-11
11. D. Forkel-Wirth, S. Roesler, G.R. Stevenson, H. Vincke, "Radiation Issues Associated with the LHC Machine Sector Tests, Radiation Safety Officers Committee", May 2003.
12. P. Ninin, private communication.
13. G. Stevenson, private communication.