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The LHC injection test

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Summary

The proposal to inject beam into a sector of the partially completed LHC in 2006 is presented. The motivation for the test is discussed, along with the proposed beam tests, the radiation protection issues, the requirements of LHCb, and requirements for the access system.

1. Introduction

An LHC injection test has recently been approved by the CERN management [1]. This test plans to inject beam from the SPS, down the transfer line TI8, into the LHC at the injection point right of IP8. The beam will then traverse IR8 and LHCb, pass through sector 7-8 to a temporary dump located near the position of Q6 right of point 7. The beam used will be single, low intensity bunches of 5 to 10 x 10^9 protons per bunch at 450 GeV.

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 representative of the challenges we will face in commissioning the whole machine.

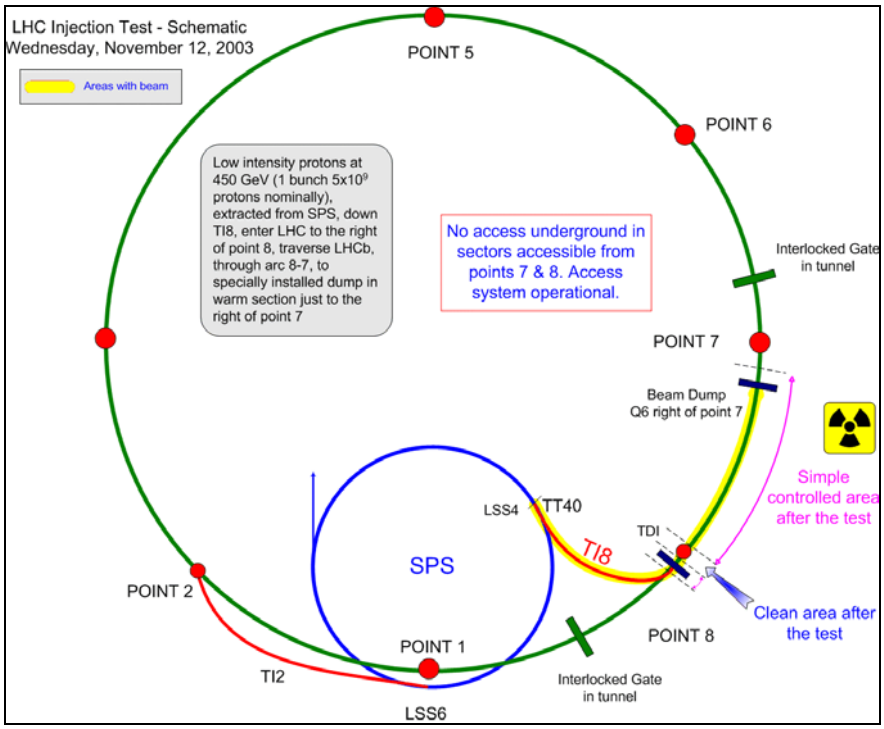

Figure 1: Overview of proposed injection test

2. Motivation

1. Ultimate tests of the equipment are only possible with beam: it will provide the means, for example, to check the mechanical aperture and field quality of the magnets in situ.
2. Commission essential acquisition and correction equipment and procedures. Verify the functionality of the control system.
3. Fully validate the system wide integration and highlight oversights. In case of possible problems with the ongoing installation, there might be still a chance to address any issues arising before the whole ring is finally installed.
4. Provide an extremely high profile milestone forcing the preparedness of all components.

Operationally the exercise would be extremely valuable and it can be 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. A successful test would also validate the project to the wider world.

3. Tests with beam

The duration of the test is planned to be two weeks. The LHC pilot Beam will be used for the most part i.e. a single bunch with an intensity of 5 to 10 x 10^9 protons per bunch. This is below the quench limit of the superconducting magnets at injection energy if losses are diluted over a distance greater than 5 m. To avoid unnecessary activation the clear aim will be to minimise losses and use beam sparingly throughout the test. One injection of one pilot bunch from the SPS is possible at a rate of about once per 20 seconds.

A preliminary list of possible tests with beam has been established [1]. The total intensity is predicted to be around 2 x 10^{13} protons if all these tests are performed. The total time allowed for the complete injection test is two weeks with an operational efficiency of around 50% anticipated if the tests are to be performed in their entirety. The operational efficiency is very likely to be less than this, implying that the figure for the total intensity injected represents an upper limit.

4. Radiation Protection Issues

As noted above it is planned to use LHC pilot intensities (5 x 10^9). A maximum of around 3000 shots is foreseen corresponding to a total intensity of 2 x 10^{13} proton over the two-week period. Simulations by the RPG [2] show that activation will be low. If the above total were to be delivered in one day, typical dose rates after one day's cooling would be of the order:

- 6 μSv/h along side the dump
- 140 μSv/h on the downstream face of the dump
- There would be negligible activation if the beam is lost uniformly along the sector between point 8 and point 7
- 4 to 10 μSv/h if the beam is lost repeatedly in one dipole (an unlikely scenario)

Some irradiation of the concrete walls along side the dump can be expected. There would be an extra beam stop after the dump to ameliorate its effect. These figures can be confirmed unequivocally by the careful measurements performed by the RPG following the injection tests in TT40 in 2003.

For prudence we anticipate that the zone that sees beam will be declared a "Simple Controlled Area"[1] with potential warm spots near the injection dump (TDI) and around the position of the beam dump. The beam dump itself will be removed after the test. The dose of the persons that have to enter these controlled areas will be individually monitored. The RPG will perform radiation survey measurements after the event to check levels of activation. If they find negligible activation – e.g. after some days of cooling - the simple controlled areas may be re-classified as "Supervised areas"[1] .

Radiation monitoring will be required during the test with the radiation monitors provided by TIS. The dedicated LHC monitoring system RAMSES has planned to use the injection test as a milestone. In addition to the 4-5 RAMSES monitors that are already foreseen to be installed in the LHCb area to measure ambient dose rates due to induced activity, 2 -3 monitors more will be installed to enable a decent radiation control of the whole area during beam operation. The LHC beam loss monitors will be in place and should be sensitive to losses at the 1% level with the pilot bunch intensity. The extracted, injected and to dump beam intensities will be logged.

The INB will need to be informed and estimated beam intensities, estimates for dose rates due to induced activity and estimates of personnel doses provided. Appropriate restrictions could then be discussed. A report needs to be provided to them in 2004.

5. 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 (see figure 2).

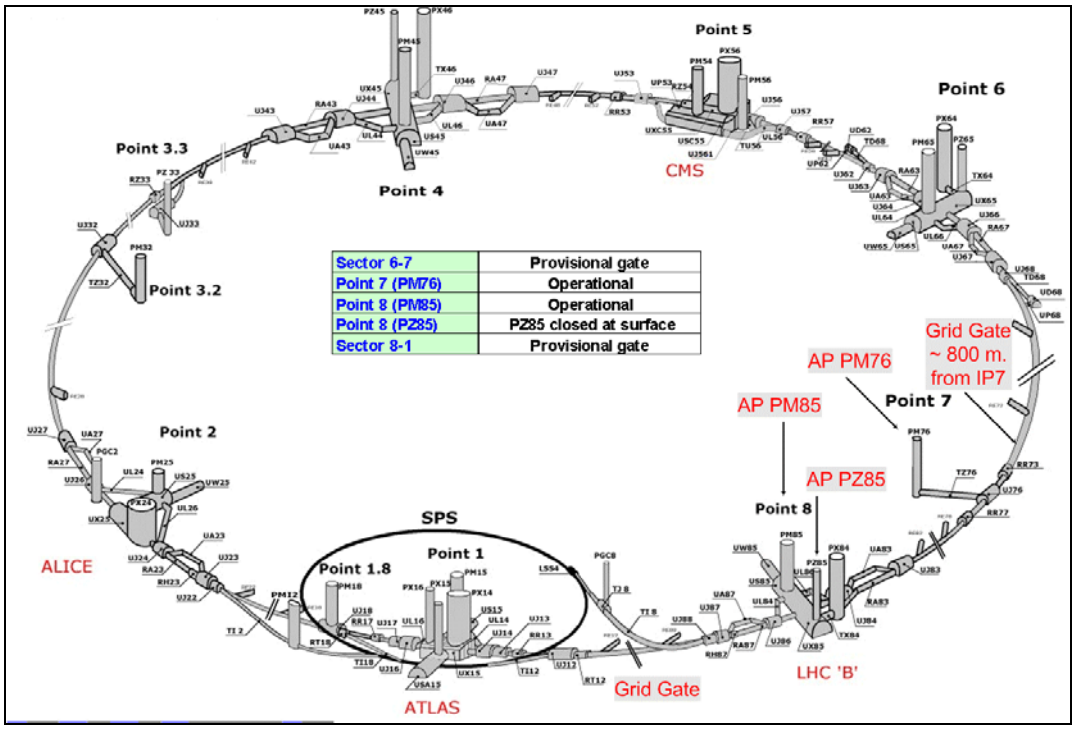

Figure 2: Proposed access restrictions during injection test

[1] As defined in CERN's Safety Code F, 1996

- For sector 6-7, a gate must be installed and interlocked at 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 [3]. The infrastructure would be temporary and would need to be removed 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 access point must be placed at the top of PZ85.
- The gate in sector 1-8 must be operational & interlocked.

Gates are not required to delimit the boundaries of any Simple Controlled Radiation Areas after the test – the zones will be marked by panels and where necessary by mobile fencing.

Transfer line interlocks will be in place to prevent extraction from the SPS in case of equipment fault together with an intensity transfer veto.

6. LHCb

The injection test falls in the period where the installation of the LHCb detector is still ongoing. The LHCb installation sequence and schedule have been adapted to accommodate this injection test. Nevertheless, LHCb would like to point out that:

- It has to be ensured that the experimental cavern at point 8 will be treated as a supervised area[1] after the injection test and not as a controlled area[1].
- Likewise, it has to be ensured that no part of the beam pipe or nearby detector will receive a radiation dose that would leave either activated after the test.

Several measures are anticipated to reduce the risk of irradiating the LHCb installation. With the un-squeezed optics there is reasonable aperture in this region, neither a crossing angle bump nor separation bump will be required. The injection dump (TDI) can be closed as far as possible during injection optimisation. On-line monitoring of the region will also be in place.

7. Ongoing Installation

The test will necessitate the closing of sector 7-8 and part of 6-7 and 8-1. Installation is planned to be ongoing in sectors 3-4, 5-6 and in the open part of 6-7 at the time of test.

At present sectors 7-8 and 8-1 are classified as non-radiation controlled areas and consequently no special radiation protection requirements are asked from the companies supplying contract workers. After the test a part of the LHC tunnel might have to be classified as simple controlled radiation area[1]. In this case the work site conditions will change.

The workers that need to pass through these areas there have to belong to a category of Radiation Worker. Contractors will need to be informed and the fact included in their contract specification. The numbers of workers potentially impacted is at present under study along with the appropriate measures that need to be taken.

8. Conclusions

Injection of beam into sector 7-8 of the partially completed LHC accelerator is planned for May 2006. The tests are foreseen to last two weeks. The beam used will be low intensity single bunch of protons at 450 GeV. Appropriate access restrictions are planned. Activation

will be low, however, Simple Controlled Radiation area will be declared where appropriate. Careful monitoring of radiation levels will take place during and after the test.

9. References

1. M. Lamont, http://cern.ch/lhc-injection-test/
2. 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.
3. G.R. Stevenson, private communication.