PREPARING THE SECTOR TEST: EXTRACTION, TRANSFER AND INJECTION

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Abstract

In view of the sector test in 2004 the requirements for extraction into TT40, the transfer line TI 8 and the injection near IP8 are reviewed. A brief overview of the systems and their availability is given. Beam requirements and commissioning scenarios are discussed, taking into account the impact on and from access and safety systems and the interference with CNGS construction. The demand on controls for these operations is outlined.

1 INTRODUCTION

Two new transfer lines, TI 2 and TI 8, are under construction to transport beams from SPS to LHC. According to the present draft planning [1] the first of these lines, TI 8, and the injection near IP8 should be installed by 04/2004, to provide beam to the LHC during the following sector test. A necessary prerequisite is the new SPS extraction [2] to be built in LSS4 as part of the SLI Project [3]. To note is that the proton beam line of the future CNGS facility [4], TT41, will branch off from the line leading to the LHC after some 100 meters. From close to the end of TI 8 an access gallery will lead to the CNGS hadron stop and muon detectors.

The overall layout of the LHC transfer lines is given in Figure 1. An overview of the lines can be found in [5, 6]; issues related to injection protection are furthermore discussed in [7, 8]. Comprehensive status information is accessible from the home page of the LTI Project [9].

2 GENERAL CONSIDERATIONS

The new SPS extraction in LSS4, the transfer line TI 8 and the injection near IP8 form, topologically speaking, the last links of a long chain aimed at providing beam for the test of the first LHC sector. Therefore these building blocks are supposed to be completely installed by the time of the LHC sector test, fulfilling the specified performance requirements [5]. This proceeds from the assumption that, after commissioning, beam has to be delivered at the injection kickers, on the LHC orbit, using the nominal optics.

Logistics is probably the dominant challenge until this equipment will be in place. A huge amount of components has to be manufactured (minor parts have still to be specified), received, temporarily stored and prepared for installation. The mounting of services and beam line equipment (comprising over 400 magnets) has to be planned carefully, after evaluation of e.g. the available transport paths, the temporary (underground) storage space, the possible material flow and installation rate and the resulting manpower needs. As the same persons are involved in several work packages (TI 8, CNGS, TI 2), which are time-wise closely interleaved, delays in one activity can quickly and severely impinge on the overall progress. The SPS operation and the need (or desire) to test already installed pieces of equipment, with or without beam, puts constraints on the time available for access to continue installation or perform checks.

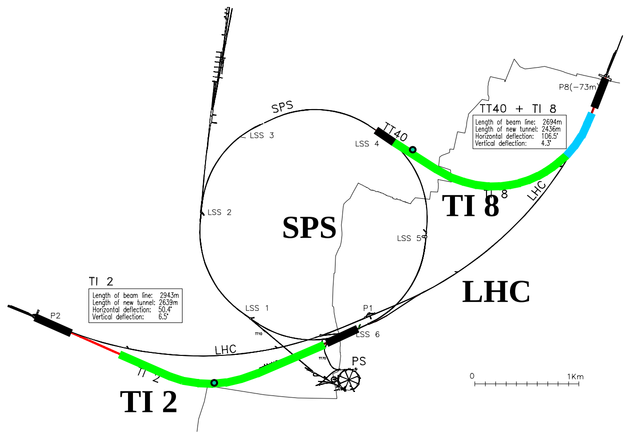

Figure 1: Overall layout of TI 2 and TI 8.

It is obvious that throughout the whole installation phase the rapidly varying and frequently conflicting needs for transport, access, testing with or without beam, etc. put heavy strain on the access system. This must be capable to handle the various conditions safely and efficiently. Personal safety must in fact never be compromised; this implies that safety related components like ventilation, smoke detectors, emergency stops, adequate communication facilities and lighting should become operational as soon as possible.

The time allocated for beam commissioning, which will be deducted from the time available for SPS fixed target operation, must be optimally used, to maximise the possible progress in understanding the behaviour of the new building blocks. This implies that, besides that the basic components like magnets, power converters, vacuum etc. need to be thoroughly tested beforehand; beam instrumentation should also be fully operational by that time (except of any tuning only possible with beam, of course), The same holds for application software, where the mandatory ingredients should be thoroughly debugged before the start of the commissioning.

The detailed planning for the installation of services has been launched recently. It is hoped to start the equipment planning shortly. These plannings have to be fitted within the framework defined by the upcoming revised master planning. Inversely, the master planning must be confirmed and backed up by the various kinds of resources available for installation, taking also the time needed for tests into account during which certain areas will be inaccessible.

To advance more rapidly in the task of bringing beam from SPS to LHC it seems natural to break it up into three work segments, to be built and tested one after the other: the SPS extraction into the beam line TT40 (later to be shared between LHC filling and CNGS operation), the transfer line TI 8, and the injection near IP8. This allows to concentrate on one segment at a time and to build upon previous experience when setting up the next one. These three work segments will now be discussed in turn in terms of availability and requirements of their components, main aims and possible commissioning scenarios.

3 SPS EXTRACTION INTO TT40

The future SPS extraction in LSS4 has been described, e.g., in [2]. Four horizontal bumper magnets are used to deform the closed orbit prior to extraction. To extract the full SPS beam in a single turn a series of five kicker magnets (MKE) is pulsed deflecting the beam into the field of six magnetic septa (MSE). The extracted beam then leaves the SPS tunnel and enters TT40 where a full beam dump (TED400353), equipped with a graphite core, will be able to receive and stop repetitively full intensity beams. A sketch of the area downstream of the extraction is given in Figure 2.

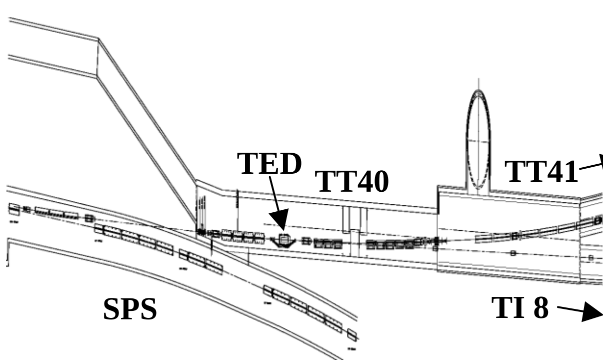

Figure 2: Layout of TT40 and the adjacent area.

All equipment up to the TED is intended to be operational after the 2002/2003 shutdown (albeit certain ingredients are not strictly mandatory). Tests could then be carried out during the 2003 running period, permitting to set up the extraction equipment and to study the characteristics of the extracted beam (bunch-to-bunch variations, pulse-to-pulse reproducibility, long-term stability, etc.), much before beam really has to be transported the long way to the injection point.

These tests would also form a good test bed for practically all types of components to be used in a much larger scale later on, like magnets, power supplies, instrumentation, vacuum equipment (including associated electronics and controls equipment and low-level software), and the controls infrastructure like network related ingredients and field buses. This is in principle also true for application software, where it would be preferable to dispose already at this moment of the close-to-definitive suite of tools (note that TT40 will already comprise LHC-type beam instrumentation). However, in view of the relatively small amount of equipment involved and its use purely during tests it would be acceptable to start off with some existing software, e.g. copied from other extractions.

The necessary parts of the access system must of course be operational, as well as the interlocks involved so far. To note is that all pipework and cables leading to TI 8 and TT41 will pass through TT40, and need therefore to be installed before the beam line is put in place. The chicane downstream of the TED is needed to permit access to the downstream areas when the SPS operates. It needs to be opened whenever equipment has to be transported through the access gallery, which anyway excludes SPS operation. The realisation of a bypass tunnel from the neutrino access gallery, as presently discussed, would provide much more freedom in organising these accesses.

This phase does not yet put particular requirements on the beam. The goal should be to maximise progress in extraction commissioning with the minimum effort to be put in beam preparation. In fact, apart from an LHC-type beam any kind of low intensity beam with small enough emittance and compatible with the pulse shape of the extraction kickers and the beam instrumentation could be used to start off. A beam with standard 200 MHz structure (as later be used for CNGS) would require to use the second set of beam position monitors. A beam diluter will protect the MSE magnets. Once the extraction is properly set up one could go up in intensity (time permitting), but the TED should not be unnecessarily activated. One might also want to proceed by measuring the optical properties of this part of the line.

How this test programme will be organised and carried out in detail will certainly be one of the subjects of the upcoming Commissioning Committee. One could imagine that the major part is done, dispersed in time, during fixed periods (MDs). As the “SPS-2001” software is intended to be fully implemented by mid 2003 [9], one might also envisage to carry out at least a part parasitically, e.g. by using (during a certain time) one LSS4 extraction per, say, 20 fixed target cycles, which would allow to advance the extraction commissioning without disturbing significantly the normal operation. However, it remains to be seen how difficult it will be to vary the intensity and the number of bunches on a cycle-to-cycle basis.

4 TRANSFER LINE TI 8

The new transfer line TI 8 has already been described in [5]. A synoptic view of the sequence of elements is given in Figure 3, together with graphs of the betatron and dispersion functions.

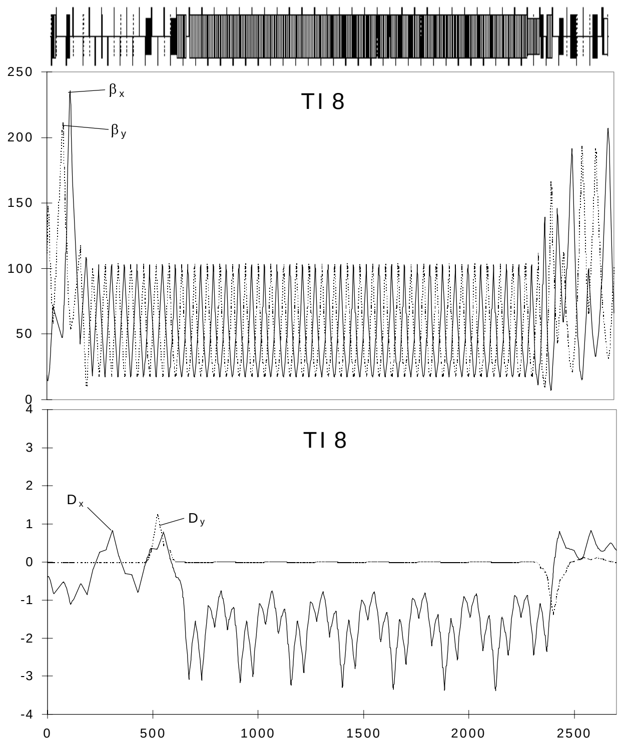

Figure 3: Sequence of elements and graphs of the betatron and dispersion functions of TI 8 (incl. TT40).

According to the present draft planning [1] it has to be fully installed, including the injection system, at the beginning of the sector test, i.e. by 04/2004. As by then a lot of preparation work still needs to be done before beam can be reasonably accepted by the LHC (cool down, check of the machine protection system, etc.) this time could be used to already test the transfer line. In fact, the part up to the TED87765 could already be tested once all elements up to the TED are in place (i.e. before the injection system is installed). Clearly such tests must be safety- and time-wise carefully co-ordinated in order not to compromise any remaining installation work.

The main advantage of such advance testing would be that by the time beam is welcome in the LHC sector the injection tests could be performed under optimum conditions, permitting to use the allocated beam time to its best. This, in turn, proceeds from the assumption that the extraction has been successfully set up and any equipment or controls problems have been cured in the course of 2003.

The main goals during this phase would be to debug the full-size installation, set up the trajectory correction, understand the behaviour of the line (e.g. check for time-dependent effects) and to measure its optical properties. Like for the extraction tests it is assumed that all beam instrumentation is operational (a review of its present layout is given in [11]). Concerning software tools temporary solutions should, at the latest by that time, be replaced by the debugged basic constituents of the definitive system, to be able to concentrate on the understanding of the line. The complete access system must now be in place, as it it the case for safety devices and all interlocks.

To achieve all described goals will certainly take a significant amount of time, depending how many shifts are allotted. One has to see how this can best be interleaved with access to the LHC sector, which should by the start of the sector test per definition be completely installed. It should be pointed out that there will be a real need for tuning the line. Surely, one can try a “shot in the dark” with low intensity. However (even presuming that everything has been correctly set up), considering the number of sources for alignment errors, the length of the line and the remaining physical aperture, the probability to receive significant beam at the end without careful tuning is not big. Even after having “threaded” beam through there remains still a long way to go until the full programme is completed and the beam properly prepared for the next phase.

What beam is best for this phase remains to be seen and will certainly again be dealt with by the Commissioning Committee. For the beginning every low intensity beam with reasonable emittance and “near-LHC” type structure would do, in other words anything which is easy to produce. Single bunches would surely be interesting. At some time “pencil beams” (with low Δp/p) are required to measure the dispersion. Towards the end of this phase pilot pulses have to be ready for injection.

5 INJECTION

An overview of the injection system has been given in [5]; special information on injection protection is contained in [7, 8]. Additional protection issues are discussed in [12]. A schematic view of the injection zone (in IP2, a

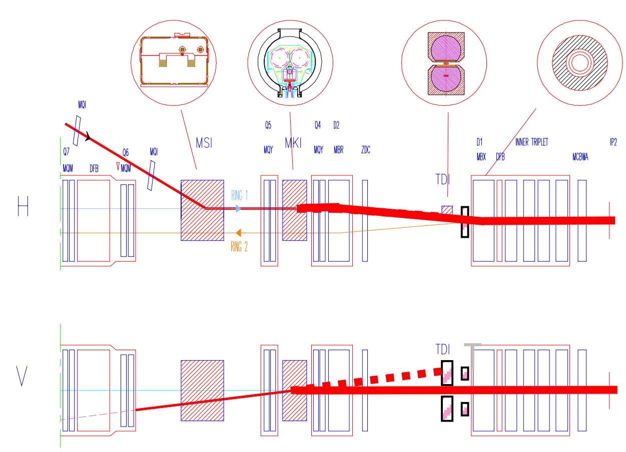

Figure 4: Schematic view of an LHC injection.

mirror-image of IP8) is given in Figure 4.

Once TI 8 is sufficiently tuned and the sector is ready (around mid 2004 ?) one can retract the TED at the end of TI 8 and let the beam continue up to the injection beam stopper (TDI), with the injection kickers still off. Now one needs first to tune the remaining part of the line. Once the sector (and the INB authorities) give green light, the kickers can be turned on and the beam brought onto the LHC orbit.

To state it again, this operation could certainly be more quickly and properly be done if the upstream segments would already be fully tuned by that time. The beam would then finally continue up to a temporary dump, of which the placement still needs to be defined. To layout the dump correctly it needs to be specified how much integrated and how much instantaneous intensity it has to absorb.

Above all requirements already listed in the previous chapters a seamless integration between the transfer line software tools and those of the LHC (especially for beam instrumentation and steering) becomes now essential. The correct functioning of all injection related interlocks is primordial.

Beam-wise one should start with pilot bunches, just intense enough to see them reliably with the beam instrumentation, but safely away from the quench limit. As confidence builds up one can move on to full batches (time permitting). Since this phase is still much ahead trying to go deeper would mean pure speculation. Instead, the interested reader is once more referred to the future Commissioning Committee.

6 CONCLUSIONS

In getting the SPS extraction, the transfer line TI 8 and the injection near IP8 ready for the sector test it seems natural to proceed in 3 distinct phases, namely to build and tune one of these sub-systems after the other. This should help to disentangle potential problems and to build upon the experience gained in the previous phase, thus speeding up the overall progress. The present baseline planning is to have the full beam line, including the injection and the foreseen injection protection devices, installed and hardware-wise tested by 04/2004. After commissioning and tuning with beam it shall be prepared to deliver beam within the specified precision, with nominal optics, on the LHC orbit, at the place of the injection kickers.

Since the same persons are involved in several subsequent activities one must stick throughout the whole project to the predefined planning to avoid affecting other work packages. The start of operation of the CNGS facility, planned for 05/2005, will put a severe constraint on further accesses to TI 8.

Apart from the challenges from the logistics and planning a lot of work has still to go into the design and realization of the access system, the machine protection system both for LHC and SPS (interlocks related to extraction, transfer and injection with link up to both) and the necessary application software. Many details concerning beam requirements, commissioning scenarios etc. will be worked out in the framework of the upcoming Commissioning Committee.

ACKNOWLEDGEMENT

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