CHAPTER 11

INTRODUCTION

The SPS will form the final link in the injector chain for the LHC, accelerating 26 GeV protons from the PS to 450 GeV before extraction via two specially built transfer lines connecting the SPS and the LHC ring tunnels. The first report detailing the upgrades needed for the SPS was published in 1993 [1]. This study was based on the use of superconducting magnets for the transfer lines. The report was later revised and incorporated into the LHC conceptual design report [2] once the decision to use room temperature magnets for the two transfer lines had been taken. A more detailed study was launched in 1996 and a comprehensive conceptual design report for the SPS as LHC injector was published in 1997 [3].

Since then, many changes have been made to the technical details of the SPS upgrade in preparation for the LHC. Many of these changes have come about as a result of changes, or additions, to the requirements. Most notably, major modifications have come about as a result of the following:

- The approval of the CNGS facility which will share the new SPS east extraction channel with the anti-clockwise LHC ring
- The final decision to shield impedance sources in the SPS and not to install a higher harmonic RF system in the SPS
- The decision to close the west experimental area, allowing a significant simplification to the west extraction channel
- Modifications to the bunch patterns and schemes for both protons and ions

In addition, an active machine development programme has been undertaken in the SPS to study the very bright beams required by the LHC. These studies have lead to considerable changes in both the technical details of the installed equipment and the operational procedures used to produce the LHC beam [4].

Chap.12 describes the LHC beam parameters and requirements in the SPS, together with the SPS cycles needed to produce the beam. As well as the nominal 25ns beam for LHC, other beams requested by the LHC are detailed: these include the pilot bunch, the 75ns beam and special schemes for early commissioning or TOTEM operation. The beam parameters in the SPS for the ultimate beam are also described.

One of the major challenges for the SPS is the conservation of the transverse emittance during the transfer through the SPS and its beam lines. Any transverse emittance growth in the SPS will directly affect the luminosity performance of the LHC. One of the major contributions to the emittance growth is the transfer and injection process. In order to stay within a very tight emittance growth budget, careful matching between the PS and SPS machines is required. Careful measurements are required to reach to required level of matching. In addition, the injection equipment in the SPS has been upgraded to pulse the kickers with a shorter rise time and substantially smaller ripple. The injection channel upgrades are described in Chap. 13. Any remaining injection errors will have to be damped by powerful transverse dampers, see Chap 14. The overall procedures for emittance preservation throughout the transfer, injection, acceleration and extraction processes are described in Chap. 15.

Some of the major hardware modifications and additions which are needed to transform the SPS into LHC injector are described in Chaps. 16-20. The existing 200 MHz travelling wave RF system is undergoing a major upgrade. This includes new power plant, circulators and cavity coupler modifications to cope with the increased beam loading. New low-level controls and synchronisation systems will also be put in place for the LHC beam. While the 400 MHz system described in [3] has been dropped, the 800 MHz RF system, already installed in the SPS ring, will play a vital role in stabilising the beam during acceleration. Considerable new hardware is required to make the 800 MHz system routinely operational.

The long straight section in LSS4 houses the new extraction channel and the first part of the transfer line TT40 towards both the LHC anti-clockwise ring (via TI 8) and CNGS (via TT41). This channel has been installed and commissioned successfully. The clockwise LHC ring will be filled from the existing west extraction via TI 2. The decision to definitively close the west experimental area of the SPS makes the LHC the only user of this channel and has allowed the layout in LSS6 to be simplified considerably. This channel will be modified during the coming long shutdown of the SPS in 2005.

The impedance reduction programme in the SPS has made a major contribution to the ability of the SPS to produce the LHC beam. Two major activities have taken place: Firstly the shielding of specific equipment, such as the magnetic septa, identified as an impedance source, secondly, the shielding of some 900 inter-magnet pumping ports has reduced significantly the resonant impedance in the machine and increased the stability of the LHC beam, even at the highest intensities. Some open questions remain, notably the impedance of the new extraction kickers installed in both LSS6 and LSS4.

The key to maintaining the very high quality beam demanded by the LHC in the SPS is the quality of the beam instrumentation. Many changes, additions and upgrades to the beam diagnostics have been made. This includes bunch-by-bunch measurements of intensity and position, additional transfer line monitors, matching measurement systems for the injection line and high quality, continuous emittance measurements throughout the acceleration cycle. Additional instrumentation has also been provided in the extraction channels. A set of scrapers will be needed to remove the tails of the particle distribution before transfer to the LHC. Finally the very bright LHC beam, compressed into 30% of the machine circumference has required an upgrade to the high energy internal beam dump. A completely new dump core has been designed and installed in the machine.

With many of the major upgrades already completed the SPS has demonstrated its ability to meet the stringent requirements of the LHC. Beam matching the requirements for LHC nominal operation has successfully been accelerated to 450 GeV. This is in spite of the discovery that the electron cloud effect is a major issue for the SPS [5]. Continued machine development to understand and cure the phenomena in the SPS has been accompanied by additional studies using the SPS as a test-bed for the LHC. Periods of beam conditioning are now routinely used to “scrub” the surface of the vacuum chambers, reduce the secondary electron yield and minimise the vacuum pressure rise. For the future, in addition to completing the hardware modifications, continued studies will be required to allow routine operation of the SPS as injector for LHC while still delivering high quality beams to the other SPS users in the periods when beam is not required by the LHC.

REFERENCES

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