CHAPTER 13

THE SPS INJECTION CHANNEL

13.1 INTRODUCTION

The SPS injection channel was upgraded during the 2000-2001 machine shutdown. The injection kicker magnets (MKP) were partially replaced and the pulse forming networks were modified to fulfil the requirements of the LHC beams [1,2,3]. The layout in the BA1 surface building, which contains the MKP system power and control electronics, was modified in order to create space for additional kicker units.

With the addition of a kicker tank the kick centre of the injection kickers moved down stream. The small dipole installed after the kicker tanks had to be replaced by a stronger magnet to compensate for the slightly shorter lever arm. This dipole is used to steer the non-injected beam onto the injection dump.

13.2 SYSTEM PARAMETERS AND LAYOUT

The system parameters of the injection kicker system (MKP) are given in Tab.13.1. Originally the LHC ions required a rise time of less than 115ns. This very stringent requirement determined the system design, although after installation the LHC ion scheme was modified and the required rise time became comparable to the one needed for the LHC protons (smaller than 220 ns). The other requirement imposed at the design stage was on the kicker flat-top ripple, which for all LHC beams must be smaller than ±0.5 %. The new design required magnet modifications to reduce the rise time and PFN improvements to reduce the ripple.

The faster rise time was obtained by increasing the impedance of the system from 12.5 Ω to 16.67 Ω and by reducing the kicker magnet length from 22 cells to 17 cells. Adding additional magnets to the system compensated the reduced strength per magnet. The original MKP layout consisted of three magnet tanks with 4 magnets each. The new layout consists of two kicker tanks with 5 high impedance magnets each, one kicker tank with two high impedance magnets and one unmodified kicker tank with four low impedance magnets. A schematic of the system layout, which includes an optional Pulse Forming Line (PFL) for use with the LHC ion injection, is shown in Fig. 13.1. The PFL scheme was devised in order to meet the 115 ns rise time for LHC ions. As this is no longer requested by the LHC, the option of installing the PFL system has been shelved.

Table 13.1: The MKP kicker system requirements for various beams

Beam	**Injection momentum GeV/c/q**	**Rise Time /ns**	**Flat Top /µs**	**Fall Time /µs**	**Ripple /%**
LHC Protons	26	**< 220**	2.1	No Restriction	**< ±0.5**
FT Protons	14	<1000	10.5	1.0	< ±1.0
LHC Ions	17.1	**<220**	0.5	No Restriction	**< ±0.5**
FT Ions	12.9	<1000	2.0	3.8	< ±1/0

13.3 MKP MAGNETS

The new MKP magnets have the following modifications with respect to the original magnets:

- To reduce the rise time of the magnets, the impedance was increased from 12.5 Ω to 16.67 Ω. This was done by reducing the surface area of the high voltage plates of the magnets.
- The number of cells was reduced from 22 to 17, in order to reduce the filling time of the magnet and hence reduce the rise time of the field.
- Damping resistors of 47 Ω were added between the high voltage plates of each cell to damp the magnetic field oscillations.
- The gap between the magnet and the tank was screened to reduce the impedance seen by the beam.
- Capacitive pick-ups were installed on one magnet out of two to measure the magnetic field [4].
- On one magnet two temperature probes were installed on an earth plate to measure the beam induced heating. This temperature is rather close to temperatures of the outside of the ferrites.

- To avoid machining of beryllium, the new return conductors are made of titanium [5].

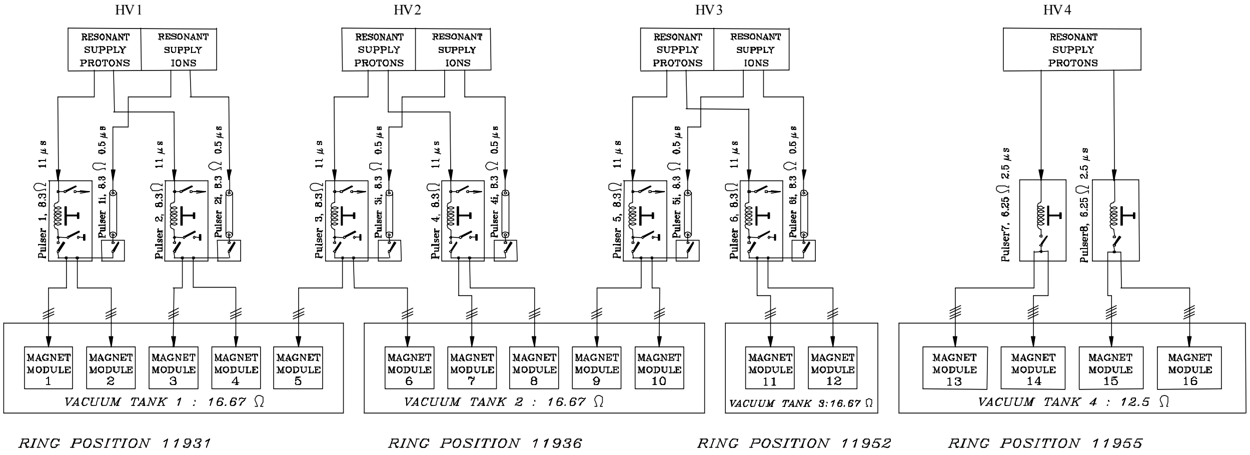

Figure 13.1: MKP system layout, which the option of the Pulse Forming Line (PFL) for the LHC ion injection.

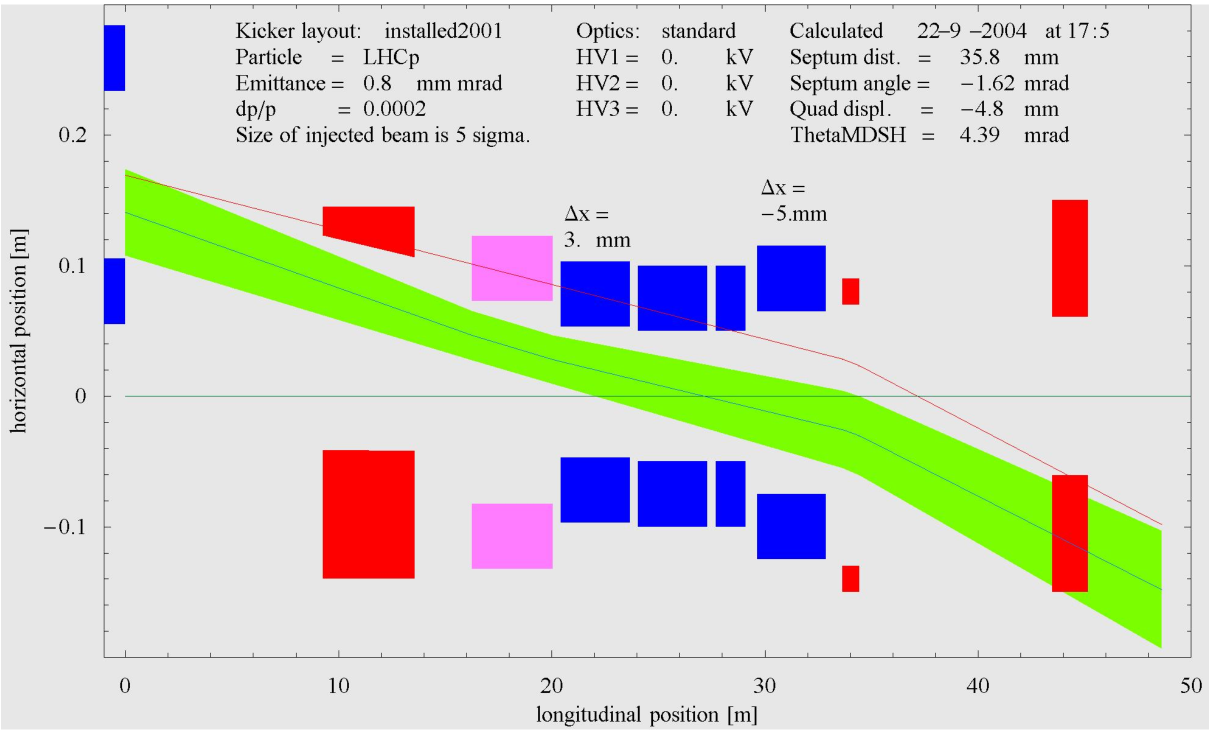

Figure 13.2: Horizontal apertures for the injected LHC beam.

The apertures of the 12 new S-type magnets are identical to the 8 magnets which were removed (full aperture H x V = 101 mm x 61 mm). The aperture of the 4 magnets which were not changed is larger in the horizontal plane, but smaller in the vertical (141 mm x 54 mm). These apertures are sufficiently large, as illustrated in Fig 13.2. The 5σ beam is shown together with the horizontal displacements of the kicker tanks. All kicker tanks were installed with zero vertical displacement.

The integrated magnetic field of the non-modified L-magnets in the fourth tank is 32.9 mT.m/magnet for the LHC HV setting of 48.4 kV. For the same setting the modified S-Type magnets have an integrated dipole field of 17.4 mT.m/magnet. Fig. 13.3 shows the four MKP kicker tanks as installed in half cell 119 of LSS1. In the foreground the MDSH magnet, described in Sec. 13.5 can be seen.

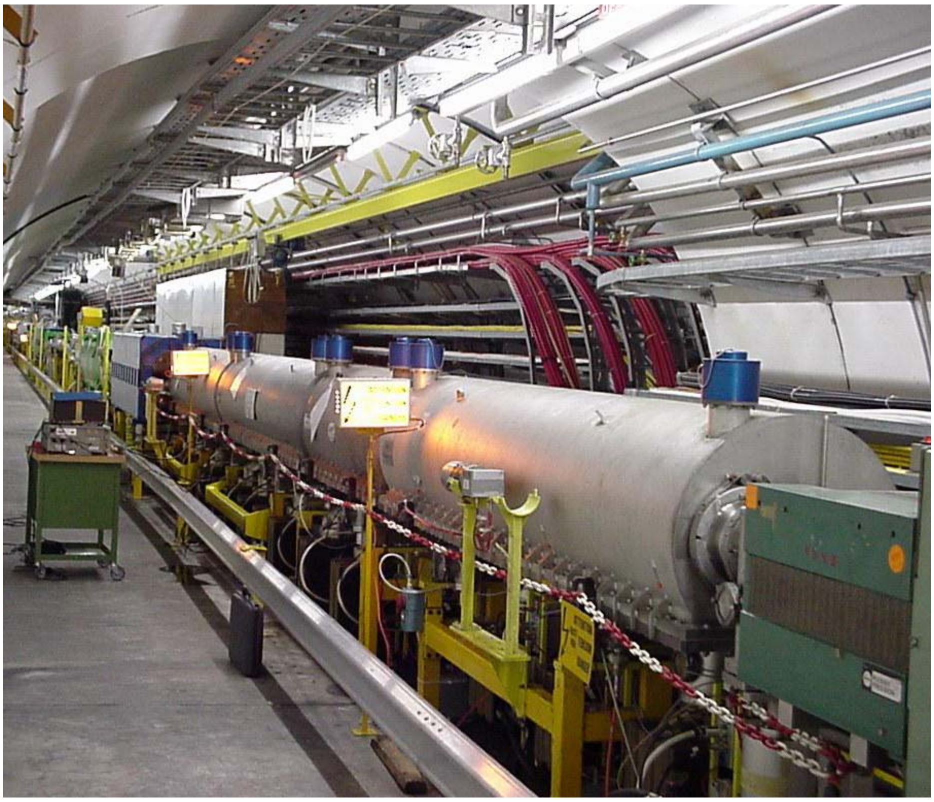

Figure 13.3: The MKP as installed in the tunnel.

Figure 13.4: Modified PFN tank for the S-Type MKP Kickers

13.4 MKP PULSE FORMING NETWORKS

The Pulse Forming Networks (PFN) at position 1 to 6 in Fig. 13.1 underwent the following modifications with respect to their original design:

- The impedance was increased from 6.25 Ω to 8.33 Ω to match two modified magnets in parallel.
- Continuous coils have replaced the small coils between each PFN cell in order to reduce the ripple of the magnetic field.
- Resistors of 50 Ω were added between each PFN cell to reduce the field ripple.
- The components of the PFN front cells were adjusted to obtain the required pulse shape.

A modified PFN of this type is shown in Fig. 13.4.

13.5 MKP CONTROL SYSTEM

The MKP controls architecture has been totally renewed [6]. It consists of two essentially independent entities: one for the control of the equipment state (e.g. ON, OFF, STANDBY) and one for the control of the operational settings for the equipment (e.g. kick strength, kick delay, kick length). Typically, the equipment state control requires a response time in the order of 25 ms and is independent of the running machine cycle. This allows the use of industrial components, such as programmable logic controllers (PLC), to implement the required functionality. On the other hand, the MKP operational settings are tightly linked with the running machine cycle. Their control requires a software response time better than 1 ms and timing delays set with a resolution of 5 ns. For these reasons, a real-time operating system and dedicated hardware electronics modules must be used.

For safety reasons, all time critical actions, such as personal protection, are still performed directly at the hardware level with software only being involved for status acquisition.

The MKP state control is based on a SIEMENS S7-400 master PLC driving 4 different controllers through identical PROFIBUS-DP segments. These controllers are either connected as deported I/Os, or as decentralised I/Os when low-level intelligence is required. A fifth PROFIBUS-DP segment is implemented to interface the resources common to the four generators, such as the magnet temperature and vacuum monitoring systems. The PLC master is connected to the machine Ethernet TCP/IP network for communication with the application software layer.

The MKP settings control system consists of 13, G-64 crates connected trough a MIL-1553 field bus to a LynxOS VME PowerPC. Synchronisation is provided to the machine timing system through a TG8 VME module. Each G-64 crate is composed of a set of either programmable modules, or passive signal conditioning modules. In order to limit the total number of modules, the same set of modules are used for each injection attached to a different running machine cycle. The operational functionality of the complete system is obtained through individual settings linked to each injection.

The management of the operational settings is based on a real time task implemented at the front-end level. Upon reception of an injection warning timing event, the TG8 module detects and decodes the event and interrupts a server thread that is in a blocking read state. Recognised interrupts make the thread reload the G-64 modules with voltage and timing parameters from a preloaded local table. This table is structured in terms of SPS cycle types and injection numbers and in each case contains the associated voltage and timing parameters.

Remote control of both systems is implemented through independent SPS2001 compliant device servers. For the settings control the device server runs on a LynxOS front-end computer, while for the state control the device server runs on a dedicated HP-UX workstation. In this scheme, the server processes are aware of the actual elementary SPS running cycle. Client programs can be automatically informed of data changes in servers through a data publish/subscribe mechanism. State management, setting and measurement contracts have been implemented through call-back routines at the server level. Expert actions have also been implemented in order to allow specialists access to an in-depth analysis of the complete system.

13.6 REPLACEMENT OF INJECTION DUMP MAGNET

A small dipole magnet just behind the kicker magnets is used to dump the injected beam on the centre of the target TBSJB when the kickers are switched off. The original magnet of the MDPH type was not strong enough to deflect the 26 GeV/c LHC beam on the target. The magnet and the corresponding power converter have been replaced. The new magnet is of the MDSH type which is sufficiently strong.

13.7 OPERATIONAL ISSUES

The HV settings of the different PFNs and the settings of the MDSH magnet to properly dump the beam with the injection kicker off for both the fixed target and the LHC beams are summarised in Tab. 13.2.

The timing of the system is critical for LHC operation as the rise time of the non-modified kicker magnets are well outside the 220 ns window. When the timing of the different PFNs is set, it is important to include in the analysis the filling time of the magnets (which is different for each of the different magnet types) and not just to consider the TMR signals [7]. A modification of the MKP PFNs number 7 and 8 is foreseen, which should reduce the magnetic field overshoot of the magnets in the unmodified tank and make the timing adjustment less critical.

Table 13.2: Reference settings of the MKP system for the different beams.

	HV generator 1 – 3	**HV generator 4**	**MDSH setting**
Fixed target, 14 GeV/c	49.2 kV	Off	2.08 mrad
LHC beam, 26 GeV/c	48.4 kV	48.4 kV	4.4 mrad

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