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THE FUTURE OF THE SPS INJECTION CHANNEL

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Abstract

The SPS accelerator will be used as injector for the LHC [1] and has to be adapted to the LHC requirements. The tight specification on beam blow-up in the SPS requires a reduction of the magnetic field ripple of the SPS injection kicker magnets to less than ±0.5 %. The bunch spacing of the LHC ion beam requires a reduction of the kicker magnets' rise time from 145 ns to less than 115 ns. To obtain the shorter rise time the existing kicker magnets have to be reduced in length and the characteristic impedance has to be increased. The resulting loss in magnetic field has to be compensated by the installation of additional magnets.

Results of studies on the required kicker strengths and physical apertures for the different types of beam and corresponding operational modes are shown. Changes to the Pulse Forming Network (PFN) and the option of using Pulse Forming Lines (PFL) are presented. Results of first magnet measurements are shown.

1 SYSTEM REQUIREMENTS

In the LHC era four different types of beam will be injected into the SPS. For their injection the MKP kicker magnets in the LSS1 area will be used and a modification of the present system is necessary to fulfil the future needs [2]. Table 1 shows the kicker system requirements for the different types of beam. The most stringent kicker rise time requirement comes from the LHC type ion beam injection. As the PS bunch structure has to be conserved in the SPS, the kicker rise time has to be reduced from the present 145 ns (2 - 98 % rise time) to less than 115 ns (0 - 100 % rise time). The total deflection strength required is determined by the relatively high injection energy of the LHC type proton beam. On top of this, the ripple of the magnetic field has to be reduced for both the LHC proton beam and the LHC ion beam. The present ripple is not critical and is around ± 1 %. For the LHC beams the ripple will have to be less than ± 0.5 %.

2 SYSTEM LAYOUT

To obtain the shorter rise time of the kicker pulse the magnets will be increased in impedance, from 12.5 Ω to 16.67 Ω, and the number of cells will be decreased, from 22 to 17 cells. Both changes decrease the kicker strength and additional magnets have to be added to continue to work with HV values below 50 kV.

The new system layout is shown in figure 1. It shows an additional fourth kicker tank with two magnets placed between the present second and third tank. The magnets in this tank and in the first two tanks have the increased impedance of 16.67 Ω and a reduced length. Because of the reduced magnet length 5 magnets instead of 4 can be placed in each of the first two existing tanks.

In the new layout the magnets in the first three tanks will be used for ion injection and will have the required fast rise time. The four magnets in the last kicker tank, which are at the moment already of a different type, will have an unchanged impedance and length. However, changes have to be made to the magnet and the PFN to meet the specification on the ripple and rise time for the LHC-type proton beam.

Figure 1 also shows a Pulse Forming Line (PFL) in parallel with the PFN (indicated with pulser 0.5 μs). As it is uncertain that the specifications on rise time and ripple can be met by using a PFN, it might be necessary to use PFLs for the LHC ion beam injection. Because the required pulse length for this beam is only 500 ns, a PFL cable length of about 60 m will be sufficient.

Table 1: The different types of beam to be injected with their kicker magnet requirements.

Beam	Injection Energy	Kicker Rise time	Kicker Flat top	Kicker Fall time	Kicker Ripple
LHC protons	26 GeV/c	< 220 ns	2.1 μs	No restriction	**< ± 0.5 %**
Fixed target protons	14 GeV/c	< 1.0 μs	10.5 μs	1.0 μs	< ± 1.0 %
LHC ions	12.9 GeV/c	**< 115 ns**	0.5 μs	No restriction	**< ± 0.5 %**
Fixed target ions	12.9 GeV/c	< 1.0 μs	2.0 μs	3.8 μs	< ± 1.0 %

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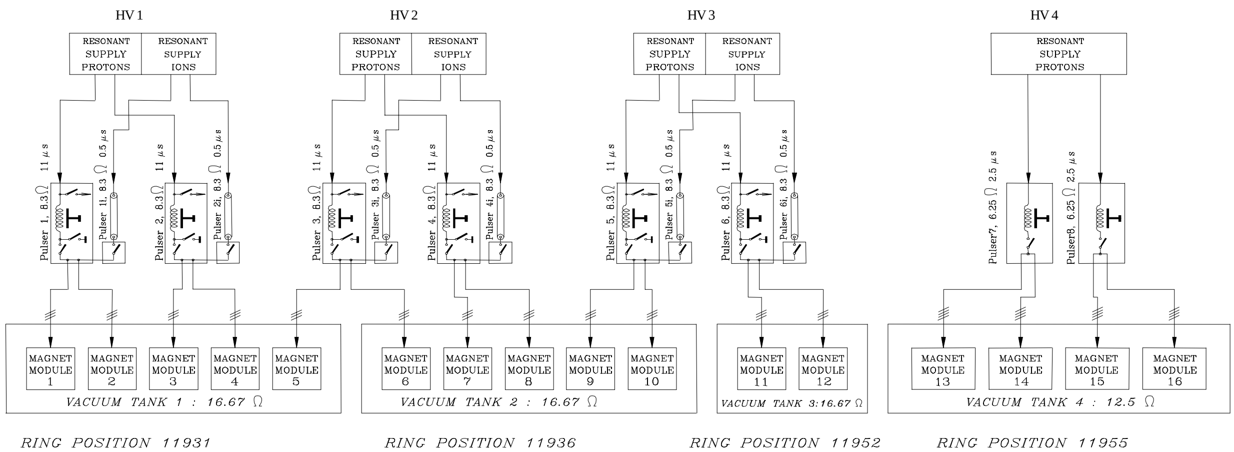

Figure 1: New kicker system layout.

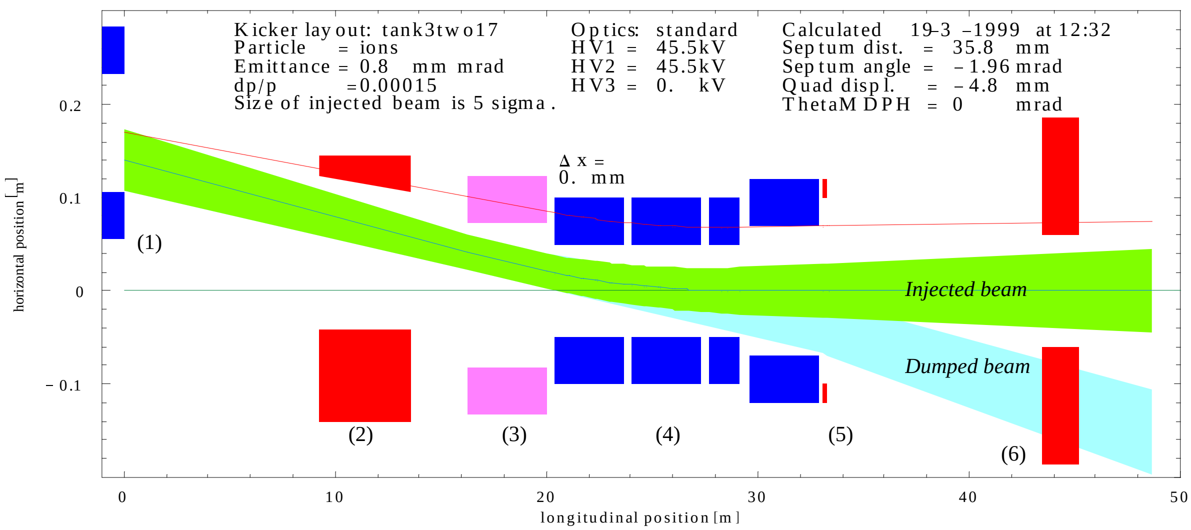

Figure 2: Model of injection of the fixed target ion beam for the horizontal plane. This is the type of beam with the smallest physical aperture in the kicker area, but still more than 5σ. The numbers in the figure correspond to the following elements: (1) Injection septum magnet; (2) High-energy beam dump; (3) Quadrupole magnet; (4) Kicker magnet vacuum tanks; (5) Dump magnet for the injected beam; (6) Beam dump for the injected beam.

2 PHYSICAL APERTURES AND REQUIRED KICKER STRENGTH

A computer model of the injection system has been made. The model is used to calculate the required kicker strengths and to examine the physical apertures available in the kicker region for the old and for the new system layout.

To calculate the beam size, the standard values for the emittance and energy spread are taken [3], together with the standard optical functions of the transfer line [4].

An overview of the physical apertures and the required kicker strengths for the different types of beam is given in table 2. The voltages HV1 to HV4 correspond to the charging voltages, also indicated in figure 1.

From table 2 it can be concluded that with the new layout all required kicker voltages are below 50 kV which is within the capabilities of the present hardware. The physical aperture is ample for the future LHC beams. For the future fixed target beams the physical aperture is slightly reduced for the new system relative to the present situation, but is still well over 5 σ. The smallest physical apertures occur for the fixed target ion beam, see also figure 2.

In the vertical plane the physical aperture is just below 5 σ and is limited by the high energy dump. This is also the case for the present system.

3 MAGNET DEVELOPMENT

Low voltage measurements on the first modified short magnet have been performed. The magnet was equipped with 47 Ω resistors in parallel with the cell inductance, to damp the field oscillations. Standard low voltage coaxial cables were used as a PFL. The rise time of the low power switch was adjusted to be 45 ns. The results of the measurements are shown in figure 3. The rise time of the pulse is just within the specification, but the field ripple is slightly too large (about 1.3 % and 1.0 % required). At the moment the surface of the high voltage plates is further reduced by 4 % to increase the actual magnet impedance from 16.03 Ω to 16.33 Ω (the PFN/PFL and magnet impedance are designed to be slightly below the transmission line impedance). Simulations have shown that this should bring the field ripple within specification.

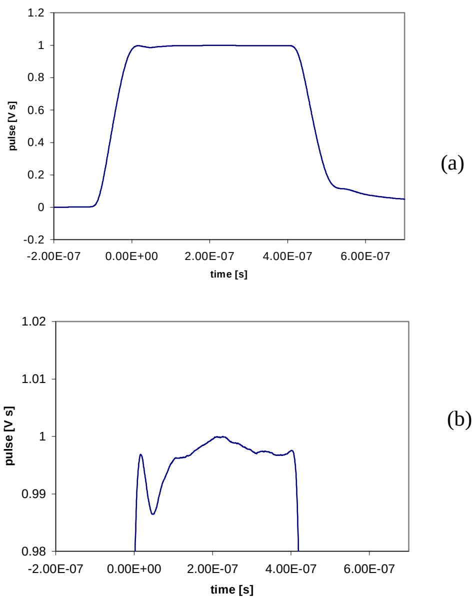

Figure 3:Measured pulse of a modified kicker magnet (a). The lower graph shows the field ripple in more detail (b).

3 GENERATOR DEVELOPMENT

The modified PFN used for the longer kicker pulses will be equipped with a 3.5 m long coil. Having a single coil which spans many capacitors should reduce the pulse ripple and improve stability. It has been verified that for a test coil with a diameter of 70 mm and a length of 1.5 m the PFN impedance increases from 6.25 Ω to about 8.2 Ω. New PFN front cells are being manufactured.

An existing thyratron switch is being modified with 'speed-up cells' to obtain the required fast switching characteristics. The cells will be adapted to the PFL cable, transmission cable and modified magnet.

5 CONCLUSIONS

The LHC-type ion beam that will be injected in the SPS requires an injection kicker rise time of less than 115 ns. On top of this, both LHC type beams require a field ripple of less than ±0.5 %. To fulfil the rise time condition two third of the present magnets will have to be shortened and have their impedance increased. The loss in kick strength will be compensated by the installation of an additional four magnets. Two of those magnets will be installed in an additional vacuum tank, the other two can be added to the present first two tanks.

As it is not certain that the required kicker magnet rise time can be obtained with PFNs, the option to use a Pulse Forming Line instead of a PFN is being studied simultaneously.

In the new set-up all required kicker voltages for the different types of beam are calculated to be below 50 kV. The physical apertures are sufficient, with a 5 σ + 3.5 mm being the smallest aperture, calculated for the dumped fixed target ion beam.

Low voltage measurements of the modified magnet have shown that the required kicker pulse rise time can be obtained with a switch rise time of about 45 ns. The measured field ripple is presently too large, but should be within the specifications after a slight increase of the magnet impedance.

Table 2: Calculated charging HV values and physical apertures in the horizontal plane for the different beams.

Beam	**Layout**	**Operational HV values**		**Smallest physical aperture**
		HV1 to HV3 [kV]	**HV4 [kV]**	
Fixed target protons	Present layout	26.1	-	5.0 σ + 8.3 mm
Fixed target ions	Present layout	24.2	-	5.0 σ + 7.9 mm
LHC protons	New layout	48.4	48.4	5.0 σ + 14.1 mm
Fixed target protons,	New layout	49.2	0	5.0 σ + 4.4 mm (dump side)
LHC ions	New layout	45.5	0	5.0 σ + 16.5 mm (dump side)
Fixed target ions	New layout	45.5	0	5.0 σ + 3.5 mm (dump side)

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