A NEW LEAD ION INJECTION SYSTEM FOR THE CERN SPS WITH 50 NS RISE TIME

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Abstract

The LHC High Luminosity upgrade project includes a performance upgrade for heavy ions. One of the present performance limitations is the rise time of the SPS injection kicker system, which imposes a spacing of at least 220 ns between injected bunch trains at the operational rigidity. A reduction of this rise time to 50 ns for lead ions is requested as part of the suite of measures needed to increase the present design performance by a factor three. A new injection system based on a fast pulsed septum and a fast kicker has been proposed to fulfil this rise time requirement, and to meet all the constraints associated with the existing high intensity proton injection in the same region. This paper describes the concept and the required equipment parameters, and explores the implications of such a system for SPS operation.

MOTIVATION

A reduction from the present 225 ns to 50 ns rise time for the injection of Pb ions into the SPS would allow a potential increase of almost 90% in the luminosity reach of the LHC, taken together with the other measures proposed for the ion injectors [1].

Such a change would require extensive modifications to the SPS injection kicker system, which is used in several configurations for different beam species and energies, Table 1. Different options have been explored and the most promising (in terms of technical feasibility, potential performance and minimum impact on the existing SPS injection) is described in the remainder of this paper.

It is assumed that ion species other than Pb^{82+} will not require faster rise times than at present. Attention is drawn to the difference in flat-top requirements for the various beams.

Table 1: Main Parameters for Different Beams to be Injected Into SPS, Including New Request for Pb^{82+} Ions

Parameter	Unit	LHC p+	SPS FT p+	LHC Pb^{82+}
Momentum	GeV/c/u	26.0	14.0	17.1
ε_{xy} (1 σ rms)	mm.mrad	3.5	12.0	1.3
B.ρ	T.m	89.7	49.7	60.0
Rise time	ns	225	1000	225/**50**
Flat-top	μs	2.0	11.0	0.2

INJECTION INTO THE SPS

The SPS injection system occupies two half-cells of the lattice, shown in Fig. 1, and comprises a series of four out-of-vacuum septum magnets MSI and a total of 16 separate travelling wave terminated injection kicker magnets of two types, MKPAC and MKP. There is also a beam dump TBSJ to intercept non-kicked beams, and for transfer-line and injection setting up, and a dedicated horizontal dipole magnet (not shown) which is used to steer the beam further onto the block in case of dumping over many cycles.

The injection for the 17.1 GeV/c/u ion beam is shown in Fig. 2, with ±5 σ beam envelopes, for the kicker off and on. The injection trajectory is at the limit with the kick strength available, and in fact a closed orbit bump of several mm has to be applied in the injection region to increase slightly the aperture.

The characteristics of the existing injection kickers are shown in Table 2.

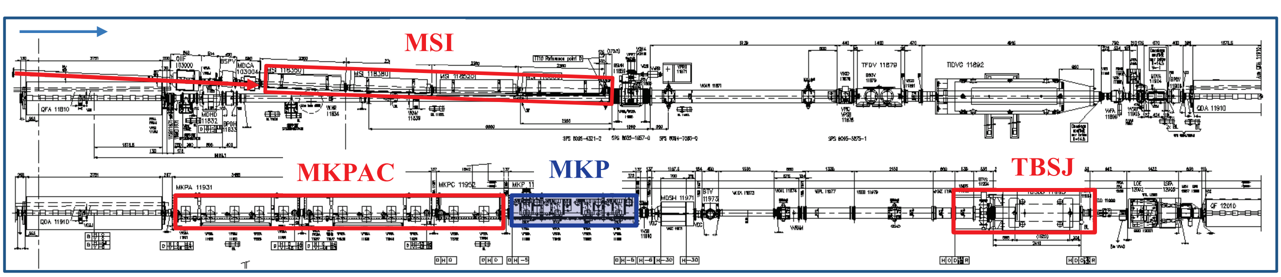

Figure 1: The two half-cells of the present SPS injection system, shown septum MSI, kickers MKPAC and MKP, and beam dump TBSJ.

Table 2: Parameters of the Existing SPS Injection Kickers

Parameter	Unit	MKPAC	MKP
Rise time	ns	125	225
Flat-top	µs	11.0	2.5
Number of magnets		12	4
Vertical gap	mm	61	54
Magnet impedance	Ω	16.67	12.5
Max. PFN voltage	kV	52	52
Magnetic length	m	0.583	0.709
Peak field	mT	30.9	48.0
∫B.dl per magnet	mT.m	18	34
17.1 GeV/c Pb^{82+} voltage	kV	52	
14 GeV/c p+ voltage	kV	45	45
26 GeV/c p+ voltage	kV	52	52

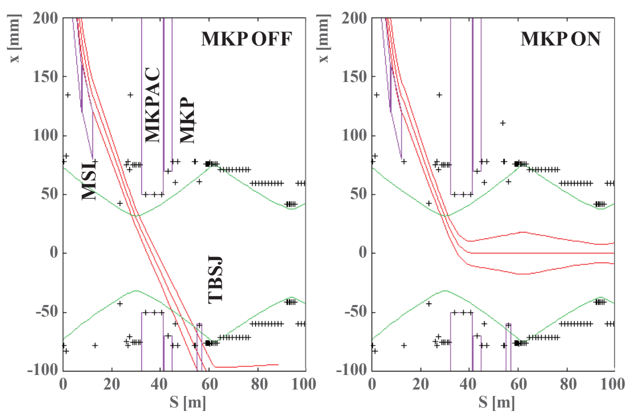

Figure 2: Present 17.1 GeV/u Pb^{82+} ion injection into the SPS with ±5 σ beam envelopes.

CONCEPTS FOR NEW 50 NS ION INJECTION

Various options were examined to reach 50 ns injection. The most promising were a) to keep the injection geometry but rebuild the present system to allow 50 ns rise time, using shorter kickers and more generators, or b) to add a thin pulsed in-vacuum septum to the injection region, plus a new dedicated fast ion kicker and beam dump, adding a separate fast system for ions.

Rebuild of All MKPAC

Option a) to rebuild the existing system could be technically feasible, but would be a heavy upgrade. The present 12 MKPAC magnets each of 583 mm would increase to about 40 magnets of 280 mm long, with an increase of system impedance to 25 Ω. In addition to the resulting high cost and complexity, the lengthening of the kicker system would reduce the aperture for the high intensity FT beam, which might necessitate kickers with significantly larger horizontal aperture. The dumping of the injected 26 GeV LHC beam would be problematic – the core of the beam would miss the dump in case of a kicker missing. Finally, the loss of effective kick strength for 26 GeV/c p+ resulting from the new Q20 optics only adds to the problems with this scheme.

Additional Injection System with Pulsed Septum

Option b) to add a new injection system for ions has been developed in some detail. A thin magnetic septum MSP (assumed to be of 5 mm effective thickness, including alignment errors) is placed downstream of the MSI magnets, to be used for all beams. A new MKPI kicker would be added for ions only, plus a dedicated beam dump. The p+ and Pb^{82+} injection functionalities would then be completely separate, and the p+ injection for 14 and 26 GeV/c would take place exactly as at present.

The injection kicker needs to have an open C-core design, to allow the non-kicked beam to reach the new beam dump. The layout, injection trajectories and beam envelopes are shown in Fig. 3, for the ion beam and 14 GeV/c FT p+ beam.

A small closed orbit bump of about 10 mm amplitude (not shown) could be used to increase the impact parameter on the dump, to ensure that the full beam is absorbed.

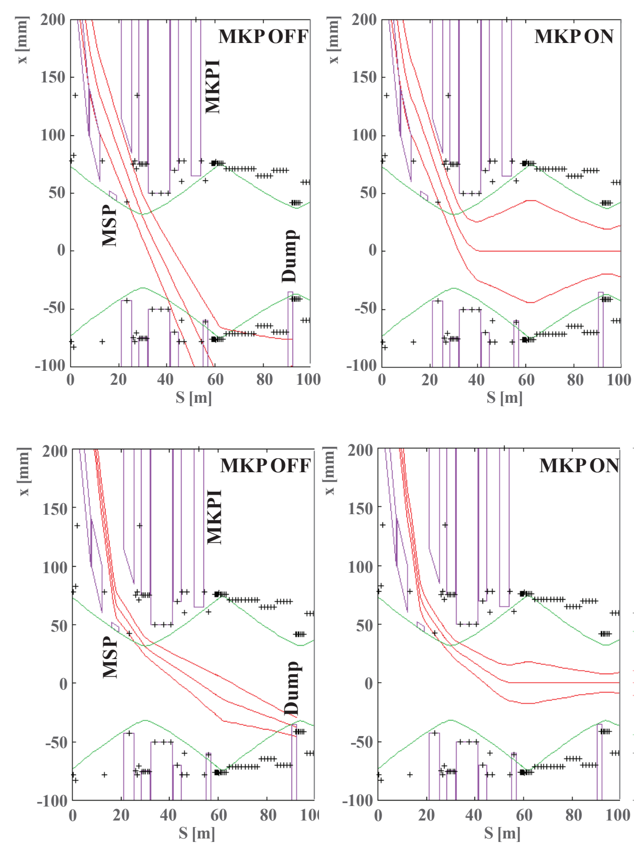

Figure 3: New 17.1 GeV/c/u Pb^{82+} ion injection (top) and 14 GeV/c p+ injection, into the SPS with ±5 σ beam envelopes.

ISBN 978-3-95450-122-9

The trajectory for the beam dump with the orbit bump allows the beam to be centred on the block, which would be immediately upstream of QDA.12110. A 10 mm inwards displacement of the dipoles MBB.12070 and 90 would help to provide about 30 mm opening for the dumped beam.

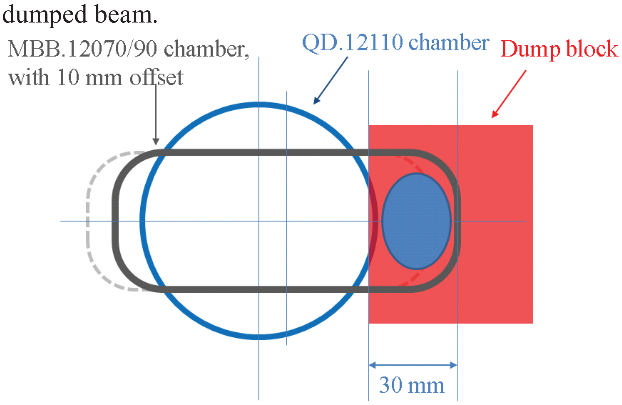

Figure 4: Dump block upstream of Q.12110, and downstream of the offset dipoles MBB.12070 and 90.

IMPLEMENTATION DISCUSSION

MKPI Injection Kicker

The kicker needs to be open towards the inside of the machine, with a C-shaped yoke, to allow the non-kicked beam to be dumped. The system could be based on a short-circuited 50 Ω travelling wave system, with 8 separate magnets and a total magnetic length of 2.8 m. The main parameters of such a system are shown in Table 3. The rise time can be achieved, although probably not for 1-99% of the kick strength, which has obvious implications for the transverse damper for the resulting injection oscillations and kicks to the circulating bunches. The short flat-top length means that pulse-forming lines can be used, which will improve the flat-top ripple. The vertical gap of 44 mm is possible because of the location next to the QD, where the vertical beta function is small. The total installed length would be about 4.5 m, probably in two separate tanks for ease of handling.

Table 3: Parameters of New 50 ns MKPI Injection Kicker

Parameter	Unit	MKPI
Filling time	ns	42
Flat-top	ns	200
Number of magnets		8
Vertical gap	mm	44
Magnet impedance (short-circuit)	Ω	50
Max. PFL voltage	kV	50
Magnetic length per magnet	m	0.35
Peak field	mT	28.6
∫B.dl per magnet	mT.m	10

MSP Fast Pulsed Injection Septum

The injection septum is based on the existing PSB recombination septa, which can be recovered when the PSB extraction energy is upgraded to 2 GeV. Two septa of 1060 mm length would be installed into a single 2.5 m long tank. The 0.54 T field gives a sufficient maximum deflection of 18 mrad at 17.1 GeV/c/u, and the device has a 5 mm septum thickness and 60.4 mm vertical gap.

Septum powering would be with a ~3 ms length half-sine capacitor discharge, with 3rd harmonic. A new supply needs to be developed but should not pose major issues.

Beam Dump

A ~1 m long space for a beam dump block exists in the lattice. Detailed studies are needed to define the material composition and length, and also for the physical integration of the block in the short space available. The short stopping distances for Pb^{82+} ions and low intensities mean that 1 m longitudinal length should be sufficient.

Instrumentation

A new screen or XY SEM grids should be integrated with the beam dump to allow accurate determination of the dumped beam location. One or two BLMs should also be added at the dump and septum tanks. Otherwise no additional beam instrumentation is required.

Kicker Impedance

The addition of 2.8 m (magnetic) of kicker to the SPS will certainly increase somewhat the overall machine impedance. The short magnets mean that serigraphy is not a realistic option – detailed simulations are needed to evaluate the impact on the SPS, and also on the power expected to be deposited in the kicker ferrites.

Injection Region Aperture

The addition of a septum in the injection region needs careful attention with regard to the aperture for the other injection beams, especially the high intensity, large emittance Fixed Target beam. All possible operational configurations will need to be carefully analysed, with all the failure modes of the injection system and upstream transfer line considered.

CONCLUSION

The requirements for 50 ns ion injection can be met, provided an open C-core kicker of specified performance can be built. The kicker system is rather compact with 8 0.35 m magnets. The septa exist and can be adapted, and the ion beam can also be dumped with the addition of a new dump block. The rise time of the kicker is still critical and the implications for the damper need to be checked. Limitations from kicker impedance and restricted aperture in the injection region need careful evaluation prior to the start of any detailed design.

REFERENCES

[1] D. Manglunki et al., WEPEA060, these proceedings.