

A DOUBLET-BASED INJECTION-EXTRACTION STRAIGHT SECTION FOR PS2

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Abstract

A new design of the injection-extraction straight section for PS2 has been made, motivated by problematic intersections of the PS2 transfer lines, potential gain in drift length for the beam transfer systems and reduction of the total straight section length. The new straight contains two injection systems with separate beam lines and three extraction systems to the SPS sharing a single beam line, together with an extracted "waste" beam from the H⁻ injection with its line to a beam dump. A symmetric doublet structure was chosen, with a reduced number of cells and quadrupoles. The optics solutions are described and the matching and tuning flexibility investigated. The implications for the different injection and extraction systems and transfer lines will be discussed, together with the specific issues of integration into the overall lattice.

INTRODUCTION

The motivation to revise the triplet insertion concept [1] was driven by minimising the number of physical intersections of transfer lines [2], gaining in drift length for beam transfer elements to avoid coil window designs or passage of the yoke in the doublet quadrupoles, saving in the total long straight section (LSS) length to increase the arc length and improve the change-over optics between dispersion suppressor and LSS. The former insertion concept was built by a central triplet with two FODO cells of 90° phase advance on either side with 14 quadrupoles and a total length of 145 m.

OPTICS AND SCHEME

The new doublet insertion concept contains two pairs of doublets symmetrically arranged around the LSS centre. The doublet spacing is chosen to give values of $\beta_{x,y}$ similar to the arc (see Fig.1). The drift spaces available for beam transfer elements from the centre to the outer ends are 24 m, 18.5 m and 11.85 m. With 8 quadrupoles of 2.4 m length, 2 half-quadrupoles of 0.8 m and a doublet spacing of 0.6 m, the total LSS length amounts to 107.9 m. Figure 2 shows the new arrangement of the injection and extraction systems. The longest drift space in the centre is deployed by the H⁻ injection system. The downstream drift houses the magnetic extraction septum (MS) with a single channel for three different extraction types. A π extraction bump is built by two long kickers (EK1, EK3) around the H⁻ injection whereas the EK1 kicker has 90° phase advance to the MS. A short kicker (EK2) placed next to the MS is used to control the angle of the bump at extraction.

04 Hadron Accelerators

T12 Beam Injection/Extraction and Transport

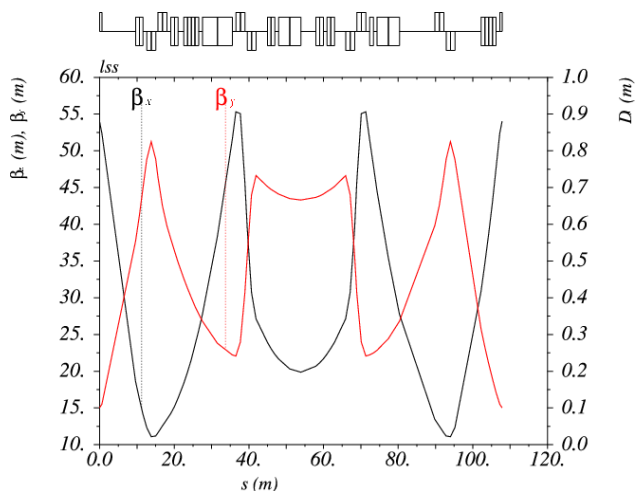


Figure 1: LSS optics for the nominal phase advance of $\mu_x = 0.76$ and $\mu_y = 0.55$.

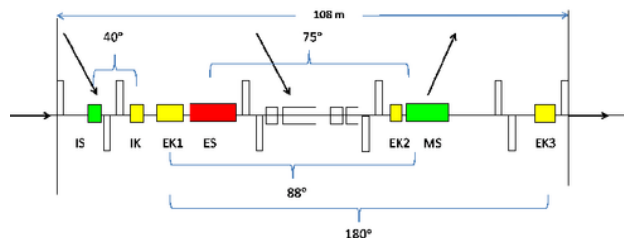


Figure 2: Scheme of the LSS with critical phase advances.

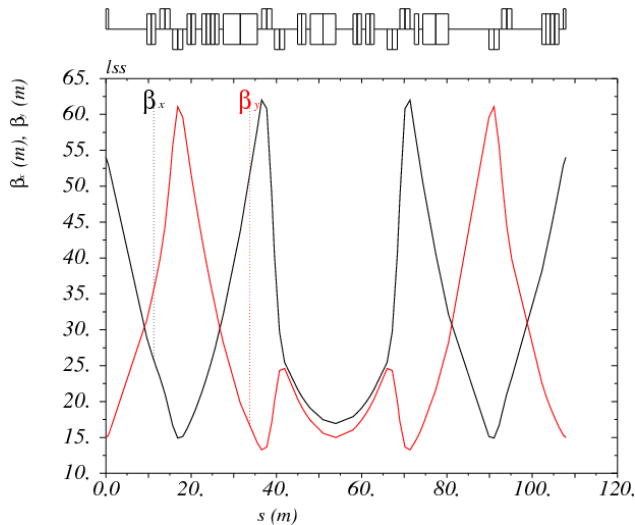
The electrostatic septum (ES) has 75° phase advance to the MS and is placed next to EK1. This drift space also houses the kicker for the fast injection and thus, for the limited space the phase advances for these elements have little margin. The most upstream drift is used to place the injection septum for ions. This arrangement of injection and extraction systems allowed to reduce the beam line intersections to the one of TTL1 (H⁻ injection) and the new TT10 (fast ion injection) which can be located far enough from the LSS to avoid the beam lines passing magnet yokes [3].

Laser Optics

The baseline for the LSS optics is dominated by the constraints for foil injection and extraction. An optics variant fulfilling those constraints is shown in Fig.1. The third set of constraints is given by the H⁻ injection with laser-stripping [4]. In this option (see Fig.3), β_y is lowered as much as possible in the centre while keeping a reasonable value of maximum beta functions. Since this optics has to

Table 1: Injection/Extraction Elements' Specification for the Nominal Working Point

Element	Magnetic length [m]	Strength [mrad]
IS	0.8	60.0
IK	0.9	6.8
EK1	3.1	1.2
ES	3.8	0.8
EK2	-	-
MS	7.5	53.1
EK3	1.7	0.7

Figure 3: Optics variant for the H⁻ laser injection.

be detuned to the extraction optics shown in Fig.1, a steady tuning path was chosen. During this path, the first doublet flips its sign and thus, implications on the magnet design need to be studied.

CONSTRAINTS

The compact arrangement of 5 different beam transfer systems in the LSS implies strict constraints on the optics:

- μ_x between MTE extraction bumpers (EK1, EK3): $k \cdot 180^\circ \pm 20^\circ$
- μ_x between ES and MS: $90^\circ + k \cdot 180^\circ \pm 20^\circ$
- μ_x between MTE extraction bumper (EK1) and MS: $90^\circ + k \cdot 180^\circ \pm 10^\circ$
- $\beta_{x,y}$ below 60 m
- Dispersion-free

For the H⁻ injection two different sets of constraints have to be considered. The foil option demands a minimum value of $\beta_{x,y}$ at the foil of ~ 20 m due to betatron mismatch and foil heating [1]. The lower value compared to 22.5 m for the triplet insertion scheme comes from a change in the

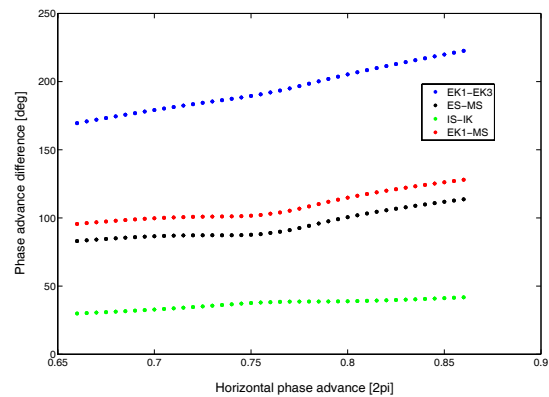


Figure 4: Phase advance between injection/extraction elements for horizontal detuning of the LSS.

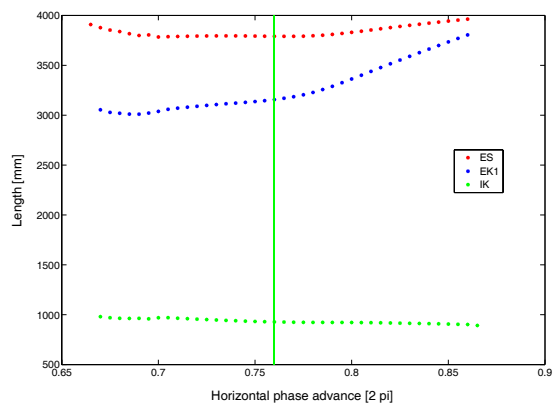


Figure 5: Evolution of length of the injection kicker (IK), the extraction bumper (EK1) and the electrostatic septum (ES).

emittances that will be delivered in the PS2 for the high-intensity fixed-target beam. The optimum ratio of injected-to-ring emittance can be kept also for higher values of $\beta_{x,y}$ with detuning the transfer line. However, lower values would consequently decrease the injected beam size and thus, foil damage due to heating sets the lower limit. The laser option demands the vertical beta function to be as low as possible to reduce the required laser power. Both H⁻ injections are placed at the waist of the betatron function, i.e. the centre of the LSS.

TUNABILITY

The working point of the LSS was chosen to $\mu_x = 0.76$ and $\mu_y = 0.55$. The LSS was tuned using all available quadrupoles to the limit of the above mentioned constraints. Figure 4 shows the phase advance between injection/extraction elements for a tune range of ± 0.1 . For this range the start values of β_x and β_y can be slightly changed by ± 1.5 m to adapt for changes in the optics functions coming from the dispersion suppressor. Figure 5 shows the

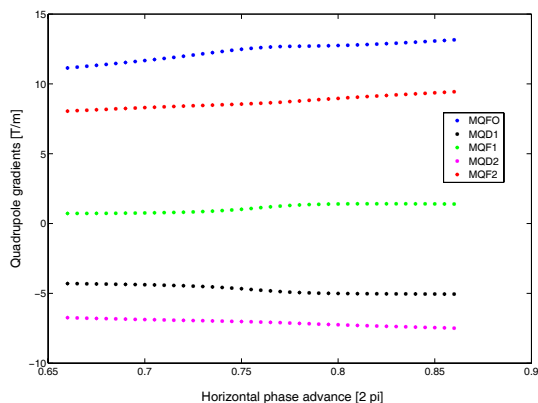


Figure 6: Quadrupole gradients for horizontal LSS tuning with fixed μ_y of 0.55. MQF0 denotes the change-over quadrupoles.

change in length for the injection kicker (IK), the extraction bumper (EK1) and the electrostatic septum (ES) for horizontal detuning. The maximum field has been fixed and the change in phase advance was translated into the minimum length required for these elements at the respective LSS phase advance. The physical length of these three elements is critical since they are placed in the same drift space. The phase advance between the elements for the fast injection is rather insensitive to the LSS tuning, while the phase advances for the extraction bump and between electrostatic and magnetic septum vary considerably which affects the minimum required lengths of the elements.

MAGNETS

In total 10 quadrupoles are used to make the LSS optics. Two quadrupoles, 1.6 m long with the arc aperture of 65 mm, form the change-over to the dispersion suppressor and are limited to a gradient of 16 T/m [5]. Eight 2.4 m long and 1.3 m wide quadrupoles form the doublets. They have an enlarged aperture of 78 mm and are limited to a gradient of 15 T/m. Figure 6 shows the gradients of all quadrupoles for fixed vertical phase advance of 0.55 and horizontal detuning. The evolution of the gradient of the inner-doublet defocusing quadrupole over the whole tuning range in the horizontal and vertical plane is shown in Fig.7.

CONCLUSION

Departing from a considerable reduction of the total LSS length the triplet optics was replaced by doublets. The total length was reduced from 145 to 108 m together with a reduction of the number of quadrupoles from 14 to 10. Fewer, but longer drift spaces allow for a more compact placement of beam transfer elements. This re-arrangement avoids having the problematic beam line intersections except one, which is crossing not too close to the LSS.

An optics version for foil injection and extraction to-

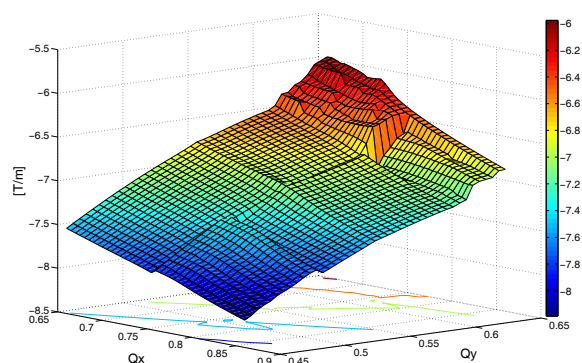


Figure 7: Gradient evolution of MQD2 for horizontal and vertical LSS tuning.

gether and a version for laser injection are shown. The path between the two versions includes a change in the magnet polarities whose implications have to be studied. The constraints on the optics given mainly by the injection/extraction systems but also from considerations on injection mismatch, foil heating and laser power are presented.

The tunability for the foil injection optics was studied. The limitations of the beam transfer systems concerning field strengths and element length specify the margins of the presented constraints. While optics solutions can be found for a tuning range of at least ± 0.125 , the phase advance constraints limit the LSS tunability to ± 0.1 .

Two types of quadrupole lengths have been used of which one is homogenized with the arc types. All magnets are individually powered. The change-over quadrupole with arc aperture stays below 15 T/m gradient, the doublet quadrupoles below 10 T/m which is well within the constraints from magnet design.

In general this new LSS concept can be used for studies of a two-fold and three-fold PS2 lattice. In case of a resonant arc, the demand on the LSS tunability has to be quantified and the reconcilability with the LSS constraints iterated.

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