TRANSFER LINES TO AND FROM PS2

C. Hessler, W. Bartmann, M. Benedikt, B. Goddard, M. Meddahi, J. Uythoven
CERN, Geneva, Switzerland

Abstract

Within the scope of the LHC injector upgrade, it is proposed to replace the present injector chain by new accelerators, Linac4, SPL and PS2, for which new beam transfer lines are required. The beam properties and requirements for each of the lines are summarized. The original design of the beam lines has been fully reconsidered due to the very demanding constraints on the beam line layouts at the PS2 injection / extraction regions and a new straight section of the PS2 which led to a much improved beam line geometry. The relevant modifications and optics designs are described.

INTRODUCTION

The planned LHC luminosity upgrade requires reliable high-intensity beams which are limited by the present injector chain. To overcome these limitations it has been proposed by the study group on Proton Accelerators for the Future (PAF) to upgrade the injector chain [1]. Within this upgrade plan it is proposed to replace the present injectors LINAC2, PS Booster and PS by new linear H^- accelerators LINAC4 [2] and SPL [3] and by a new 50 GeV proton synchrotron (PS2 [4]). Important system upgrades are also required for the SPS. In addition to their main purpose – the increase of the beam availability and intensity for the LHC – they should allow their use as drivers for future experimental facilities like e.g. a new neutrino factory. Therefore, a low power (LP-SPL) and a high power (HP-SPL) version of the SPL are under study for PS2 and future facilities, respectively. To connect the PS2 to the different injectors, several new transfer lines are required, whose preliminary designs will be presented in this paper.

BEAM TRANSFER SYSTEMS

For PS2 numerous systems for injection and extraction, beam dumping and beam transfer are required, which result in the following transfer lines with their preliminary names given in brackets:

- SPL-to-PS2 transfer line (TTL1) for multi-turn H^- injection into PS2 using a stripping foil or laser stripping at 4 GeV.
- PS/LEIR-to-PS2 transfer line (TT10) for fast single-turn injection of 1.3 GeV ions or protons for PS2 commissioning.
- PS2-to-SPS transfer line (TT11) for fast single-turn and low loss 5-turns extractions of protons and ions at 20-50 GeV for SPS.
- Beam line from PS2 to a new experimental area (TTEA) for a slow extracted proton beam. This beam line will also transport fast extracted beams to an external beam dump.
- Short beam line from the PS2 injection region to the injection beam dump for unstripped and partially stripped H^0/H^- waste beams (TD1).

The overall layout of PS2 and its transfer lines resulting from these studies is shown in Fig. 1.

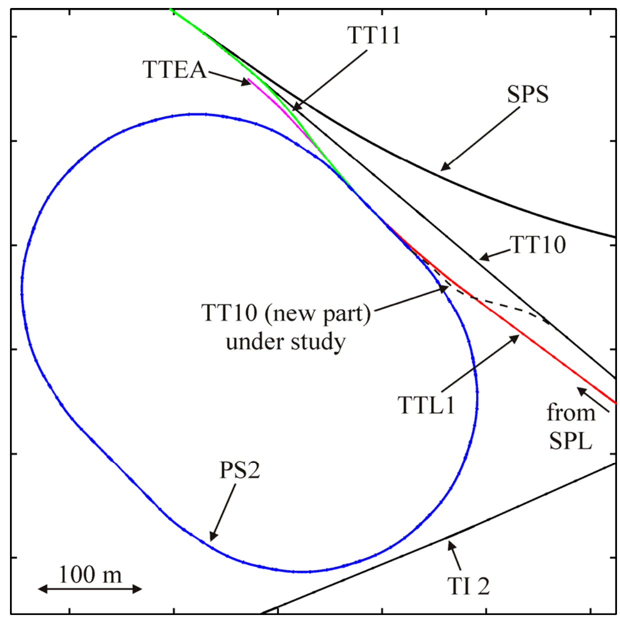

Figure 1: Layout of PS2 and its transfer lines. The dashed line represents the proposed location for the new TT10 transfer line which is currently under study.

REQUIREMENTS

Beam Properties

The beam parameters of the different beams to and from PS2 are listed in Tab. 1 and 2.

Table 1: Parameters of the Beams Injected into the PS2

	TTL1	TT10	
Origin	LP-SPL	LEIR	PS
Particle type	H^-	Pb^{54+}	p
Energy	4 / 5 GeV	1.3 GeV*	1.3 GeV
Norm. emittance H/V	0.35 µm / 0.35 µm	1 µm / 1 µm	1 µm / 1 µm
Injection	slow	fast	fast

* Proton equivalent energy

Table 2: Parameters of the Beams Extracted from the PS2

	TT11		
Destination	SPS/LHC	SPS/LHC	SPS/CNGS
Particle type	p	Pb^{54+}	p
Energy	20-50 GeV	20-50 GeV*	20-50 GeV
Norm. emittance H/V	3 µm / 3 µm	1 µm / 1 µm	9 µm / 7 µm
Extraction	fast	fast	fast 5 turns
	TTEA		**TD1**
Destination	Exp. area	External beam dump	Injection beam dump
Particle type	p	p/Pb^{54+}	p
Energy	20-50 GeV	20-50 GeV*	4/5 GeV
Norm. emittance H/V	0.45 µm / 7 µm	9 µm / 7 µm	1 µm / 1.25 µm
Extraction	slow	fast	slow

* Proton equivalent energy

Injection/Extraction Layout

Previous transfer line studies were based on a long straight section of the PS2 (LSS1) with the extraction elements located upstream of the injection elements [5]. This resulted in a complex layout of the injection/ extraction region with beam lines intersecting with each other at several points, requiring special magnets with coil windows at some locations [6]. To overcome these issues a new LSS1 has been designed with the extraction elements located downstream of the injection elements [7], which is the basis for the transfer line studies presented in this paper. The drawback of this solution is the reduced space available for the transfer lines which will be discussed in the next section.

BEAM LINE OPTICS

TTL1 Transfer Line

The TTL1 transfer line has to overcome an altitude difference of 21 m over its length of ~400 m. Furthermore, the bending strength has to be limited to prevent Lorentz stripping of the H^- beam [6]. This results in a large slope of 8.1% of the beam line.

The beam line layout (Fig. 2) has been evaluated with MAD-X [8] simulations and consists of a FODO lattice

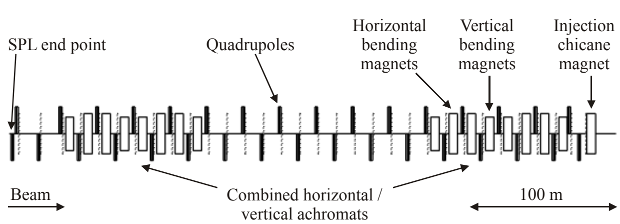

Figure 2: Layout of the TTL1 transfer line.

with 90° phase advance per cell with a cell length of 25 m. The bending is performed with two combined horizontal and vertical achromats which provide a dispersion-free region in between and easy matching to the required beta function and dispersion value at the end of the beam line (Fig. 3).

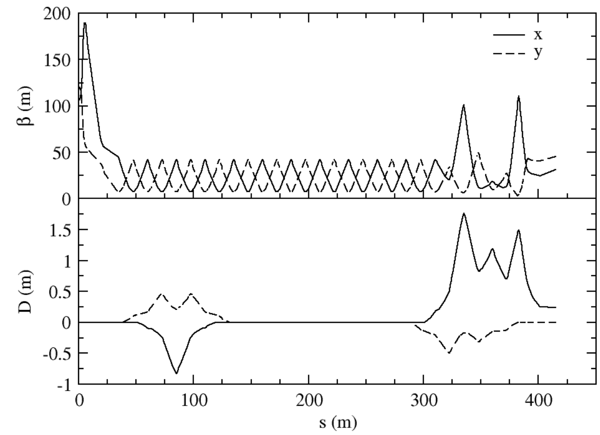

Figure 3: Simulated beta and dispersion functions along the TTL1 transfer line.

TT11 Transfer Line

The TT11 transfer line linking the PS2 with the SPS has also a FODO lattice with 90° phase advance per cell. The cell length is 21 m and adapted gradually to the SPS cell length (Fig. 4). The bending is mainly performed by two horizontal achromats. Due to the same altitude of the PS2 and SPS no vertical bending is required. The end section of the present TT10 beam line and the SPS injection region are kept and reused for TT11 injection into the SPS.

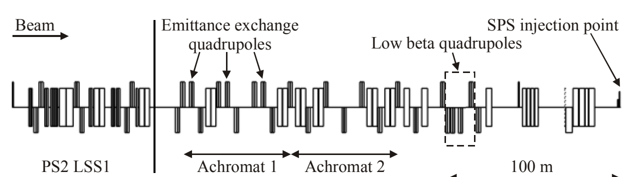

Figure 4: Layout of the TT11 transfer line.

Due to the different kinds of beams which are transported by TT11 special magnet configurations are required in the transfer line:

- Low-beta insertion for lead ion beams, which houses a stripping foil for stripping the Pb^{54+} ions to Pb^{82+}.
- Emittance exchange section for CNGS type beams.

Due to the limited space available for TT11 in the new LSS1 version, no dispersion-free region is available in TT11 for the emittance exchange section. Therefore, no "perfect" emittance exchange section [9] is possible, as it was included in previous versions [6]. Instead, the skew quadrupoles have been placed in the empty half cells of the first achromat resulting in a growth of the vertical normalized emittance of 0.3 µm, which is still acceptable. There is almost no growth of the horizontal emittance.

Detailed optics simulations have been carried out with MAD-X for LHC type proton and ion beams and for CNGS beams (Figs. 5 - 7). The coupled motion due to the emittance exchange required the use of the MAD-X PTC_TWISS module for the CNGS beam optics. The present solution results in more regular beta oscillations than the previous studies [6].

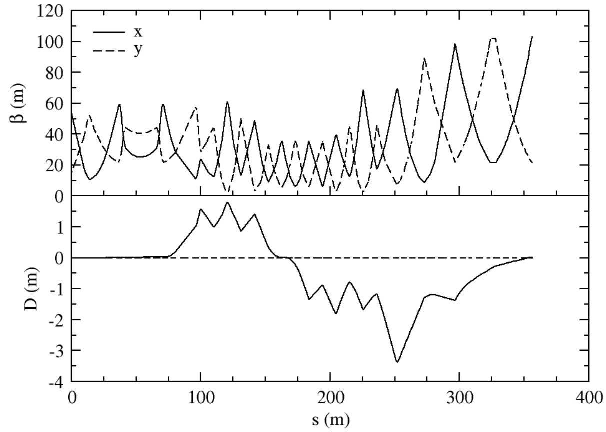

Figure 5: Simulated beta and dispersion functions along the TT11 transfer line for an LHC type proton beam.

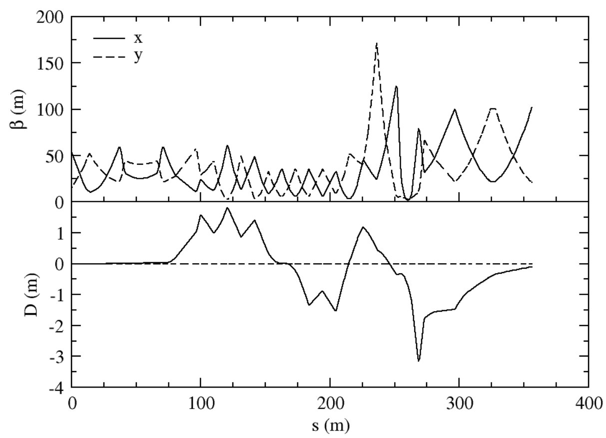

Figure 6: Simulated beta and dispersion functions along the TT11 transfer line for an LHC type lead ion beam.

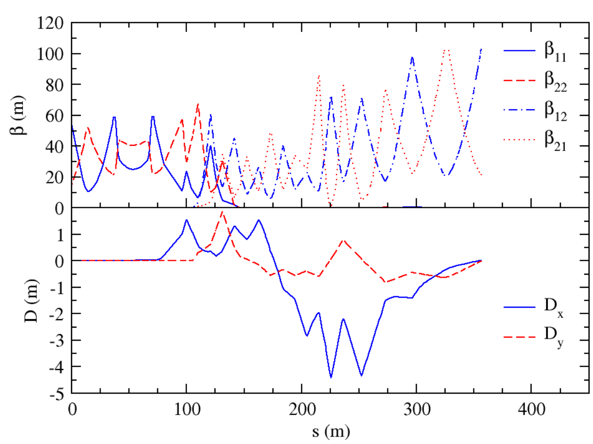

Figure 7: Simulated Ripken optics parameters and dispersion functions along the TT11 transfer line for a CNGS type beam with the skew quadrupoles powered.

TTEA, TT10 and TD1 Transfer Lines

The layout and the optics of the TTEA beam line is similar to the solution presented in [6] and is therefore not discussed in detail. It branches off from TT11 at an empty half cell of the first achromat. The end point is not yet defined, waiting for a layout of the experimental area.

The new part of TT10 will connect the existing TT10 beam line to the PS2 and is currently under study. Since the fast injection kicker is located upstream the stripping foil, TT10 will intersect TTL1. This will be the only intersection between beam lines in this new injection/extraction layout and can be placed in an empty half cell of TTL1.

TD1 will have a similar design as presented in [6].

CONCLUSION AND OUTLOOK

The new injection/extraction region geometry has been much improved. The number of intersections between beam lines has been reduced from four to one with respect to the previous layout [6]. The feasibility of the TTL1 and TT11 beam lines with reduced lengths and still including all features (emittance exchange, low-beta insertion) has been demonstrated. Further work has to be carried out on the TT10/TD1 beam lines and the magnet design.

ACKNOWLEDGEMENTS

The authors would like to thank the PS2 project team members and all contributors for fruitful discussions.

REFERENCES

[1] R. Garoby, "Plans for Upgrading the CERN Proton Accelerator Complex", J. Phys.: Conf. Ser. 110 (2008) 112003.

[2] L. Arnaudon et al., "Linac4 Technical Design Report", CERN-AB-2006-084 (2006).

[3] O. Brunner et al., "Plans for a Superconducting H^- LINAC (SPL) at CERN", CERN-AB-2008-066 BI (2008).

[4] M. Benedikt, "Design Optimization of PS2", Proc. PAC'09, Vancouver, in press.

[5] W. Bartmann et al., "A Triplet Insertion Concept for the PS2 H^- Injection", Proc. ICFA Advanced Beam Dynamics Workshop on High-Intensity, High-Brightness Hadron Beams 2008, Nashville, p. 326.

[6] C. Hessler et al., "PS2 Transfer Lines", sLHC Project Note 0013 (2010).

[7] W. Bartmann et al., "A Doublet-based Injection-extraction Straight Section for PS2", these proceedings.

[8] www.cern.ch/mad.

[9] L. R. Evans, "A Phase Plane Exchange Section for the SPS Antiproton Injection Beam-Line", CERN-SPS-DI-MST 80-2 (1980).