CERN PSB-TO-PS TRANSFER MODIFICATIONS FOR THE 2 GeV UPGRADE

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Abstract

Within the framework of the CERN PS Booster (PSB) energy upgrade from 1.4 to 2 GeV, the PSB-to-PS transfer line will be adapted for pulse-to-pulse modulated operation. A modified lattice is presented including a re-design of the switching dipole between ISOLDE and PS together with a changed focussing structure. Optics solutions optimized for small emittance LHC beams as well as for the large emittance high-intensity (HI) beams are shown.

INTRODUCTION

The upgrade of the PSB energy from 1.4 to 2.0 GeV requires an increase of the operational strength for transfer line (TL) magnets by 30%, see Table 1. In addition it is envisaged to change the focussing structure in the transfer line such that the optics can be matched to the PS injection parameters (the present beams are injected with a dispersion mismatch). The quadrupoles and the switching dipole should provide pulse-to-pulse modulation to allow for dedicated optics solutions for the different requirements of LHC and HI beams between PSB and PS.

Table 1: Beam Characteristics

		Present	Upgrade
Beam rigidity	[T.m]	7.14	9.28
Norm. emittance LHC (h/v)	[μm]	3/3	3/3
Norm. emittance HI SPS	[μm]	9/5	9/5
Norm. emittance HI ISOLDE	[μm]	15/9	15/9

TRANSFER LINE MODIFICATIONS

The PSB to PS transfer line (BT-BTP) is about 70 m long and combines the 4 PSB rings into one line. At 35 m a horizontal dipole (BHZ10) allows to switch into a measurement line (BTM) which has a vertical branch-off to the ISOLDE targets (BTY). The BTM line leads into a dump and can be used for measurements with different optics settings, Fig. 1. To gain flexibility in adapting the optics for the various beam types it is foreseen to add a quadrupole in the BTP line downstream of the wall separating the PSB and PS zones. Two steering magnets and a quadrupole are presently housed in the wall. While the quadrupole location must not be used due to limited accessibility, the two steerers could possibly be replaced by two combined steerers to have redundancy and to reuse the cabling. It is envisaged to install collimators 180º upstream of the PS injection septum to scrape off transverse beam tails and reduce losses while injecting into the PS. Beam position monitors are considered adjacent to each quadrupole and (2n+1)·90º upstream of the septum for injection steering [1].

SWITCHING DIPOLE REDESIGN

The existing BHZ10 has no spare and only few spare parts (1 coil). The combination of the existing magnet and existing power converter is unable to operate with beam energies of 2.0 GeV as the magnet is now operating at the limits of its cooling performance and the existing power converter cannot deliver the required current. A D.C. magnet is ready as emergency spare.

Upgrade Possibilities

Four different scenarios are considered to upgrade the switching dipole:

Longer BHZ10 with existing power converter: This option is technically feasible, although the vacuum chamber stability and integration needs to be studied carefully. The effect on the TL geometry is minimal and can be rematched.

Split C-shaped magnets: It is difficult to provide the same kick angle at 30% higher beam rigidity with even shorter magnets than the present one. To keep the existing power converter the vertical gap would need to be reduced by 6 cm. The effect on the TL geometry is significant due to a different deflection position for at least one line.

Existing BHZ10 and opposite field septum: The option to add an opposite field septum to the existing BHZ10 to provide the extra kick angle is feasible but also here an effect on the TL geometry is expected. As advantage one could immediately start building a spare for the existing BHZ10.

Kicker magnet and two sets of septa: A study done in 2000 [2] aimed at increasing the ISOLDE proton flux by deploying the empty PSB rings in case the PS takes beam from less than four rings. The integration of these elements into the lattice is very difficult.

The option of designing a longer BHZ10 and keeping the existing power converter is both from the technical and cost point of view the preferred solution: itwill be described in detail in the following sections.

Effect on Transfer Line Geometry

The position of the new BHZ10 was optimised within the integration constraints of the lattice such that the geometric effects on the BTM and BTP lines are minimised. Figure 1 shows the line geometries together with a part of the PS ring after rematching the magnet strength. The BTP line can be rematched to the existing

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beam centre by varying the BHZ10 angle only. For the BTM line matching also the downstream bending magnet (BTM.BHZ10) was used.

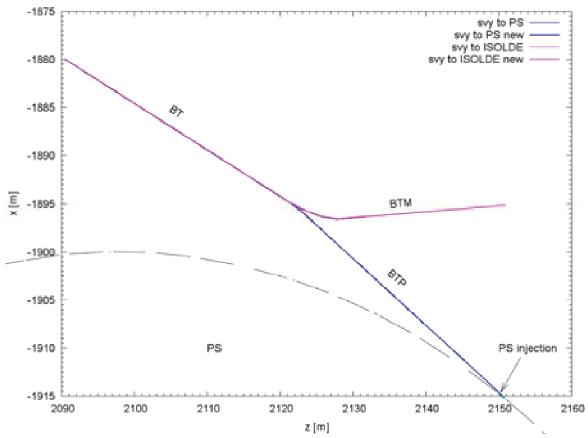

Figure 1: PSB-to-PS TL geometry in MADX survey coordinates. Lines in black show the measured survey data of installed elements. The BTM line (pink) and the BTP line (blue) are plotted on top of it.

At the PS injection septum – 35 m downstream of BHZ10 – the new beam line is less than 5 mm off the existing beam centre, Fig. 2. This difference can be corrected with steering magnets in the line. The angle of the injected beam at the septum remains unchanged.

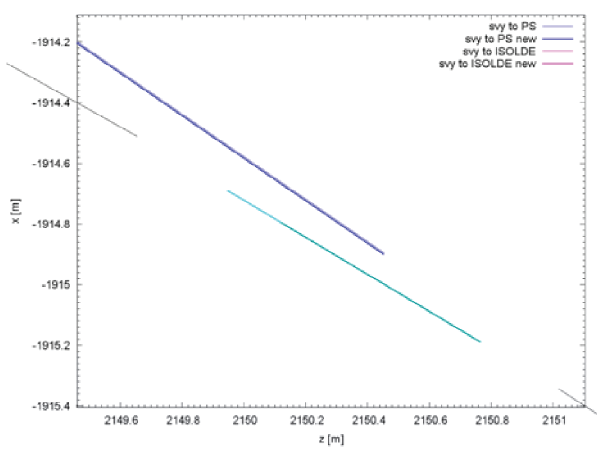

Figure 2: PS injection geometry. The turquoise line shows the increase in septum length for the upgrade with respect to the black line for the existing magnet. The injected and circulating beam centres have a distance of about 95 mm at the septum centre.

Magnet Design

A solution can be achieved by a new magnet designed to match the characteristics of the power converter, capable of providing 450 A at 550 V with a maximum ramp rate of 1500 A/s. The design is based on a 2 m long window-frame dipole providing an integrated field of 1.49 T·m. With respect to the present magnet, the ramp rate is decreased from 1500 A/s to approximately 840 A/s to compensate for the increase in inductance of 400 mH to 540 mH; a flat top and flat bottom of 0.1 seconds is allowed for field stabilisation and changing of the converter polarity, respectively. Due to the change in operation the duty cycle becomes larger and thus the effective current and dissipated power increase. To limit the temperature rise with the available water pressure in the machine, the required cooling flow is achieved with an increase in the cooling channel diameter and putting six cooling circuits in parallel (3 per coil). Doubling the number of cooling circuits to twelve (six per coil) could also be considered to allow D.C. operation of the magnet. This may be required if pulses at 900 ms intervals from the PSB to the PS are used to minimise the waiting time at low energy in PS (two PSB cycles are required for filling the PS). With the same potential for 900 ms in mind the magnet is designed to stay below saturation levels, and uses relatively thin laminations and non-magnetic parts for the welding bars and the end plates. It should be noted, however, that for the 900 ms operation a new power converter with more voltage would be required. The main parameters of the present magnet and the proposed one are shown in Table 2, the 3D model is shown in Fig. 3.

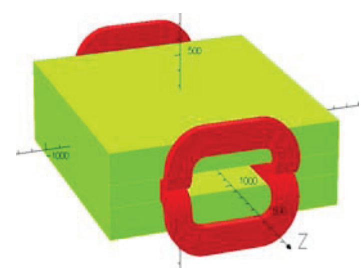

Figure 3: 3D magnet model.

Table 2: Existing and Proposed Magnet Parameters

BHZ10		**Present**	**Upgrade**
Dipole field	[T]	0.728	0.743
Dipole Int.field	[Tm]	1.16	1.486
Gap	[m]	0.14	0.14
Magnetic length	[m]	1.57	2
Aperture width	[m]	0.29-0.49	0.6
Iron length	[m]	1.46	1.8
Current @ 1.4 GeV	[A]	360	418
Max RMS current	[A]	260	418
dI/dt	[A/s]	1500	840
Resistance	[Ω]	0.35	0.385
Inductance	[H]	0.4	0.54
# Turns		2·112	2·102
Cooling @ 11 bars	[l/min]	14.9	32
Weight	[t]	7.8	12

OPTICS

In [3] an optics solution matched to the existing PS injection parameters was shown wich used the quadrupole in the wall as well as an additional one.

For the transversely small LHC beams, see Table 1, the matching to the existing PS injection parameters was refined without the quadrupole in the wall.

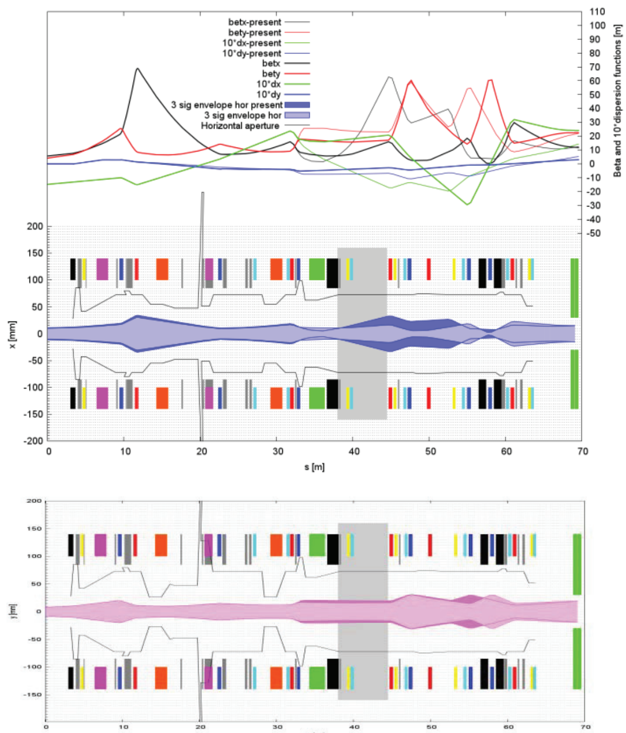

Figure 4: The top part of the plot shows the TL optics matched to existing PS injection parameters. In the lower part the horizontal (blue) and vertical (pink) 3 σ LHC beam sizes are plotted for the present (dark) and upgrade (light) situation.

For the transversely large HI beams the optics parameters at PS injection have been revisited in view of reducing the transverse beam size and, consequently, losses at critical aperture locations at the septum and the excursions of the injection bump. Deploying existing quadrupoles in the PS allows improving the injection optics at the expense of a global ring optics distortion. A locally contained perturbation can only be provided by installing new quadrupoles in the PS.

A TL optics solution – taking into account only existing hardware – was matched to PS injection settings with the global perturbation. This optics will be used to perform measurements this year in order to distinguish the loss origin between injected and circulating beam and decide on the necessity of installing new quadrupoles in the PS ring for the upgrade. Further measurements are foreseen to define the required rise and fall times of the two TL recombination kickers and the PS injection kicker, both for the existing situation and also for potential upgrade scenarios with higher harmonics (in the PS) resulting in shorter bunch spacing.

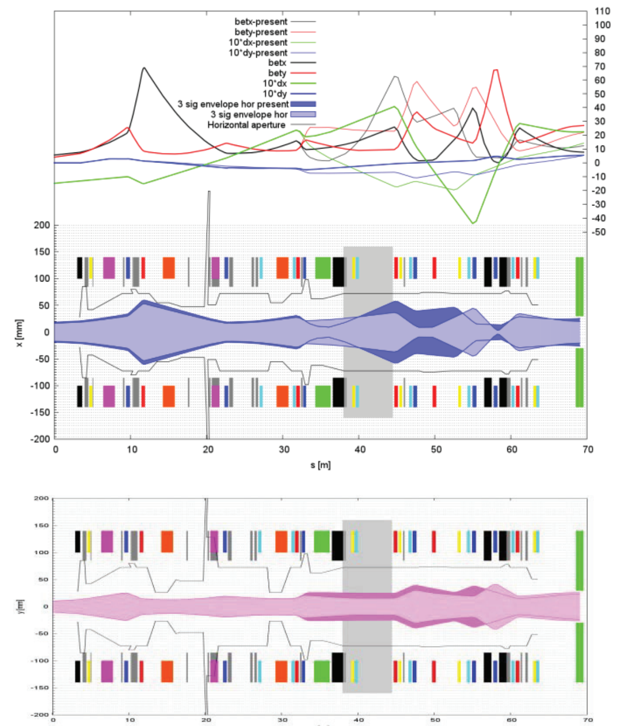

Figure 5: Optics matched to foreseen upgrade optics for HI beams with only local perturbation at PS injection.

CONCLUSION

The proposed redesign of the PSB to PS TL is adapted for increased dipole and quadrupole strength to cope with the energy upgrade, laminated quadrupoles for pulse-to-pulse modulation capability and collimation for beam tail scraping at the end of the line.

Among different variants to upgrade the switching dipole BHZ10, the option with a longer magnet and keeping the existing power converter is most promising from the technical as well as the cost point of view. The proposed magnet design allows to keep the existing power converter in case of a cycle length of 1.2 s and can be operated in D.C. for 900 ms. The magnet is designed to be compatible with an effective 900 ms operation, but this would require a new power converter. The change in the TL geometry was minimised by keeping the centre of the magnetic deflection unchanged and is rematched for both lines. A realignment of the lines is not necessary and the angle at the PS injection septum remains unchanged.

The TL optics can be matched to all different PS injection parameter sets which are demanded by the different constraints of LHC and HI beams.

REFERENCES

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