DESIGN STUDY OF A 100 GeV BEAM TRANSFER LINE FROM THE SPS FOR A SHORT BASELINE NEUTRINO FACILITY

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Abstract

A short baseline neutrino facility at CERN is presently under study. It is considered to extract a 100 GeV beam from the second long straight section of the SPS into the existing transfer channel TT20, which leads to the North Area experimental zone. A new transfer line would branch off the existing TT20 line around 600 m downstream of the extraction, followed by an S-shaped horizontal bending arc to direct the beam with the correct angle onto the defined target location. This paper describes the optimisation of the line geometry with respect to the switch regions in TT20, the integration into the existing facilities and the potential refurbishment of existing magnets. The optics design is shown, and the requirements for the magnets, power converters and instrumentation hardware are discussed.

INTRODUCTION

A design study is on-going at CERN for a short base line neutrino facility (CENF), using a 100 GeV beam non-locally extracted from the SPS [1,2,3]. The primary proton beam will be extracted into the present transfer line TT20 from which the new line TT26 branches off and directs the beam to the neutrino target zone. The relevant beam characteristics are shown in Table 1.

Table 1: Beam Characteristics

Parameter	Unit	Value
Extraction momentum	GeV/c	100
Maximum momentum spread $\delta p/p$ (1 σ rms)		$2 \cdot 10^{-4}$
Maximum intensity per extraction	p+	$2.4 \cdot 10^{13}$
Beam rigidity	T.m	336.6
Normalised horizontal emittance (1 σ rms)	π.mm.mrad	8
Normalised vertical emittance (1 σ rms)	π.mm.mrad	5

SWITCHING FROM TT20

The location of the switch from TT20 is conditioned by several constraints associated with the overall facility geometry, local infrastructure and radioprotection considerations:

- The junction cavern and tunnels should be located within the CERN perimeter to facilitate civil engineering;
- The junction cavern should be well before the splitters to avoid the issues associated with civil engineering in the highly activated splitter zones;
- The performance of the present TT20 line should not be adversely affected, with regard to aperture, optics and other functionality like instrumentation and trajectory correction;
- The amount of disruption to TT20 should be minimised to avoid the need for a dedicated long shutdown of the North Area;
- The magnets used should be existing recuperated spares where possible;
- The switch should allow extraction of a 400 GeV beam for the proposed long baseline LAGUNA-LBNO facility;
- The switch does not necessarily need to provide ‘fast’ switching between TT20 and the new SBLNF line, since in any case the extraction systems are not compatible with rapid beam destination change between the North Area and SBLNF.

A design for a switch has been made which fulfils most of the above constraints. However, the layout is not compatible with the 400 GeV rigidity of 1336.5 Tm and could only be designed for 100 GeV/c p+ beams. The present and modified layouts in the switch region are shown in Fig. 1.

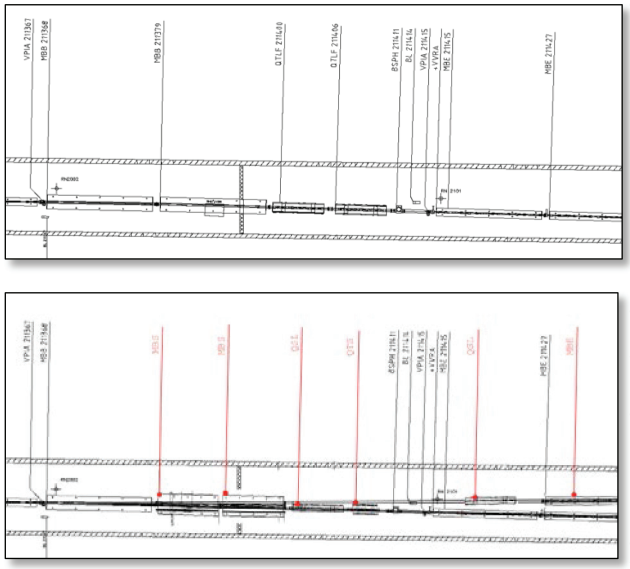

Figure 1: Present layout of MBB.211368 region (top) and layout after modifications for TT20-TT26 switch (bottom). In TT20 the MBB.211379 is replaced by two MBS magnets, and the two QTL magnets are replaced by a QSL and a QTL magnet.

The switch will be located at the last horizontal bend before the splitter magnets. The MBB.211368 will need to be powered with inverted polarity, while the second of the two MBB magnets (MBB.211379) will be replaced by strong open C-core dipoles (type MBS) which are powered to send the beam to the North Area, but which are off when the 100 GeV beam is switched out. These MBS magnets cannot be integrated into the 6.2 m space liberated by the MBB, and require an additional 1.106 m to be found in the lattice. This could be gained by moving the two adjacent quadrupoles downstream. The horizontal beam trajectories and envelopes are shown in Fig. 2.

The QTLF.211400 will be replaced by a physically thinner QSL quadrupole, and the QTLF.211406 quadrupole will be replaced by a shorter QTS quadrupole, to minimise the perturbation to the lattice by the change of focussing centre.

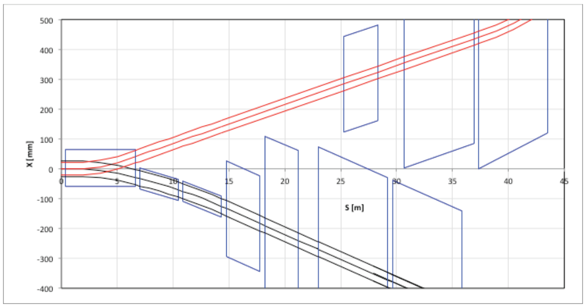

Figure 2: Switch layout. Horizontal beam envelopes for TT26 (red) branching off from the TT20 line (black).

TT26 GEOMETRY

The coordinates of the neutrino target and of the near detector define the primary beamline delivery location and orientation. 16 recuperated dipoles (MBN type) powered in 4 different families are used to match the line geometry in both planes to reach the target coordinates.

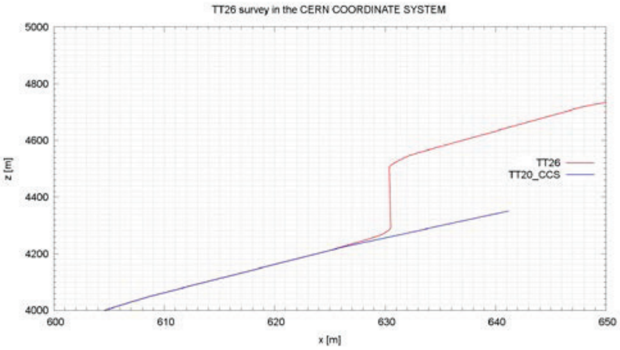

Figure 3: Geometry of TT20 and TT26 in the horizontal plane in the CERN coordinate system.

In the horizontal plane it is required to separate the two beam lines as early as possible to facilitate access to the junction cavern while in the vertical plane the distance to the ground level has to be at least 10 m. To meet both constraints, tilted dipoles are used in the area downstream of the switch. In addition the maximum slope of the beam line has to be limited due to transport reasons, and the minimum bending radius of the first arc is defined by the limits of existing magnets to be more than 600 m per cell.

Figures 3 and 4 show the geometry of the new beam line (red) in the horizontal and vertical plane, respectively. In Table 2 the main geometric bends of TT26 are listed.

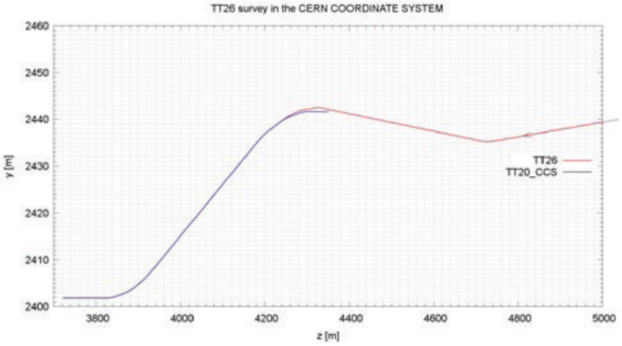

Figure 4: Geometry of TT20 and TT26 in the vertical plane in the CERN coordinate system.

Table 2: Main (geometric) Bends for TT26, Including Switch Dipoles

Type	PC family	Plane	#	Total angle [mrad]
MBE		V	1	-13.00
MBB		H	2	-13.00
MBNT	I	H/V	4	-21.24
MBNT	II	H/V	4	16.06
MBNT	III	H	4	15.00
MBNT	IV	H/V	4	24.75

TT20 AND TT26 OPTICS

The present TT20 line is designed for a slow extracted 450 GeV beam. Rematching of its optics was necessary to accommodate a 5σ beam size in the available aperture, Fig. 5. The aperture bottleneck is in the horizontal plane the first vertical bending magnet of MBE type in the switch area. Replacing this magnet by an MBN type with 80 mm wider aperture should be considered.

The focussing structure of TT26 is a 90° FODO lattice with the same cell length as in TT20, to limit the beta functions between 20 and 120 m. In the switch area 8 individually powered quadrupoles are used to match from the regular TT20 optics to the TT26 lattice. The maximum beta functions in TT20 amount to (H/V) 257/232 m, in TT26 they reach 189/181 m.

The most difficult part of the optics design is to limit the maximum dispersion through both lines. To reduce the dispersion in TT20, the regular FODO lattice was detuned from 90° to 72° which improves the phase advance between the dipoles in TT20 and the dipoles in the switch region, neither of which can be moved. An iterative optimisation of placing the TT26 dipoles in an

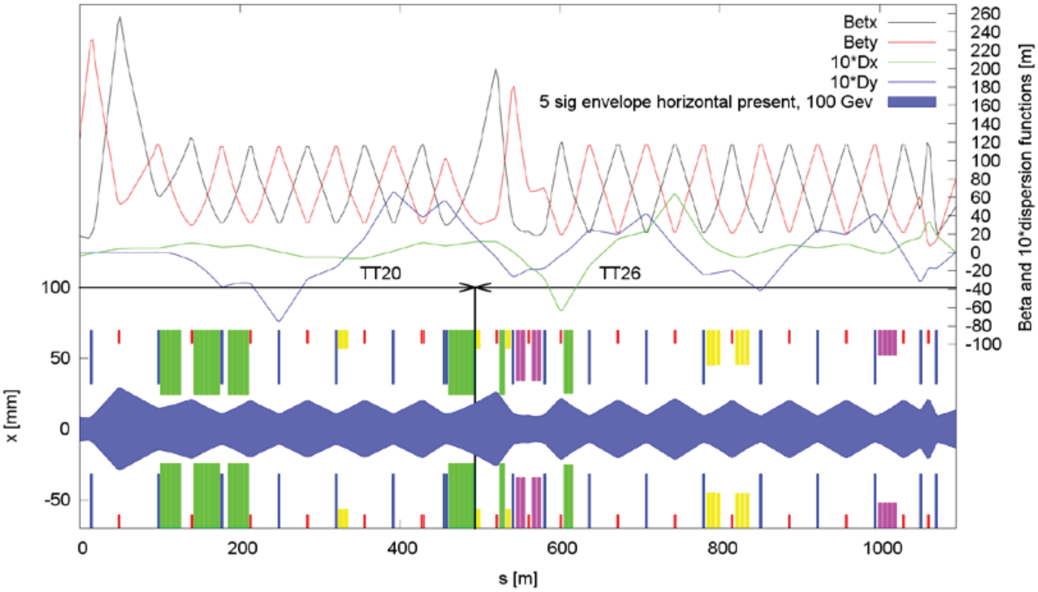

Figure 5: Optics functions (top) and horizontal 5σ beam envelope in TT20 and TT26.

achromatic way together with matching the line geometry had to be done to limit the maximum dispersion. The maximum dispersion in TT20 amounts to 1.1/7.5 m, in TT26 up to 6.34/4.1 m, in H/V respectively.

Tilting some of the dipoles for geometric reasons worsens the optics matching significantly. As shown in Fig. 5 the effective available aperture of tilted dipoles has to be taken into account. Horizontal magnet apertures are indicated in yellow, vertical apertures in green and tilted magnet apertures in magenta.

For the focussing structure, a total of 20 QNL type quadrupoles will be recuperated, 6 for the matching section between TT20 and TT26 (also 2 existing quadrupoles from TT20 will be individually powered), 11 FODO quadrupoles and 3 triplet quadrupoles. Their gradients are shown in Table 3.

Table 3: Quadrupole Gradients

Location	Gradient [T/m]	I/I_{max} [%]
TT20	2 - 4.14	8 - 17
TT26	3.77 - 6	15 - 25
Triplet	5.58 - 12.38	23 - 52

The required 1σ rms beam size at the target is 2.1 mm, the maximum 1σ rms beam divergence is 1 mrad for both planes. The final focussing triplet allows ±30% adjustment of the beam size on the target while keeping the dispersion limited to ±1m. 20 m are reserved between the last quadrupole and the target for steering and instrumentation.

UPGRADE OF TT20

The present TT20 beamline needs to be equipped to accept high-intensity fast extracted beams. The powering scheme for the line will basically remain unchanged to the switch region, but a significant extension to the present beam instrumentation is needed, together with a new optics. Also the interlocking of the line needs to be upgraded with the addition of a Warm Magnet Interlock (WIC) and Beam Interlock (BIC) system.

New beam position and loss monitors will be needed at each quadrupole (~15). The two existing BTV screens need upgrading with the addition of interlocking on the screen positions, and the addition of OTR screens for accurate profile measurements. An additional BTV screen will be needed in the early part of TT20, upstream of the extraction dump (TED). A new fast Beam Current Transformer will be needed at the start of TT20, before the TED.

CONCLUSIONS

The geometry of the primary beam line can be matched to the constraints of target position and angle, radiation protection, civil engineering and transport deploying recuperated magnets.

The presented optics allows the transport of at least 5σ of the 100 GeV high-intensity beam extracted from the SPS and tuning of the beam size at the target.

The most critical part is the switch from the present beam line which does not facilitate extracting also a 400 GeV beam. Also a part of the existing magnets has to be rearranged and its effect on the present optics needs to be investigated in detail.

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