Flexibility of the Matching Sections in the TI2 and TI8 Transfer Lines

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Abstract

The matching sections at the SPS and LHC ends of TI2 and TI8 were designed several years ago. The magnet positions and powering were optimized to match the constraints existing at that time. For various reasons the boundary conditions at both the start and the end of the line have changed over the past few years.

The downstream matching sections were chosen to house the collimator section foreseen to protect the LHC injection septa and the adjacent regions in the LHC ring. The precise phase constraints at the collimators considerably limit the optical flexibility of these transfer lines. Without these phase constraints the flexibility would be sufficient.

The installation of skew quadrupoles to absorb the tilt mismatch at the end of the line is no longer envisaged.

MATCHING TO SPS AND LHC

Optical requirements

TI2 and TI8 were designed many years ago [1]. The central regions of the two injection lines contain two quadrupole circuits (F and D), each powered in series. Matching sections with individually powered quadrupoles are located at both ends of the lines.

SPS		Q1-6	QF, QD	Q7-16		LHC.B1

Table 1: Schematic layout of the matching quadrupoles 1 to 16 at both ends of TI2

SPS		Q1-7	QF, QD	Q8-17		LHC.B2

Table 2: Schematic layout of the matching quadrupoles 1 to 17 at both ends of TI8

In the regular cells of TI2 the β functions and the dispersion are matched (fig. 1). Matching to SPS is achieved with 6, and matching to LHC with 10 quadrupoles.

In the central part of TI8 the horizontal dispersion function is not matched, its value fluctuates between -1 and -4 m at the F quadrupoles (fig. 2). The β_x and $\beta_y$matching to SPS is achieved with 7, and to LHC with 10 quadrupoles. In TI8 D_x is matched across the entire line, without constraints in the central region.

Two years ago the necessity of skew quadrupole sections at the end of the injection lines to match the tilt of the beam (around its axis) to the value of the LHC was discussed [2],[3],[4]. In the meantime a new calculation [5] has shown that the emittance blow-up due to this effect is smaller than 2 % in TI8 and even smaller in TI2. A skew quadrupole system is therefore no longer considered necessary at present.

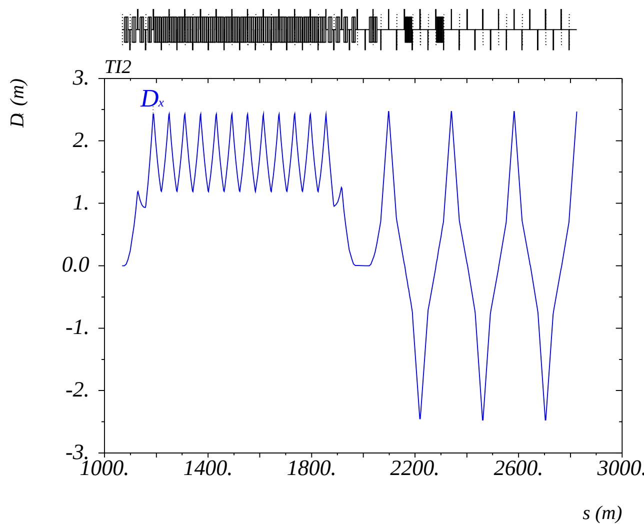

Figure 1: Dispersion function in the central part of TI2

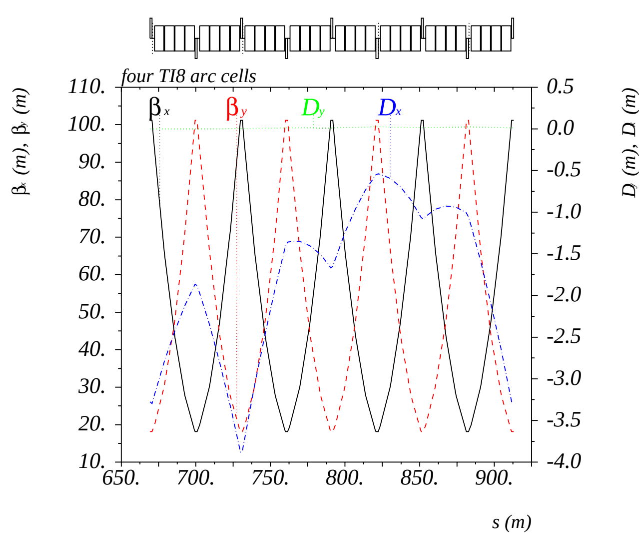

Figure 2: Dispersion beating in four TI8 arc cells

Collimation requirements

However, another candidate had by then entered the competition for the available space at the end of the injection lines: locations had to be found for a system of collimators (TCDI) protecting the LHC injection septa (MSI) and the adjacent LHC regions.

A layout with collimators separated by phase advances of $45°$ was first designed for TI8 [6]. In this line space is only available at the end, i.e. in the matching section. Optically the proposed solution could be matched to SPS and LHC without any problem.

The design of the collimation in TI2 (not completed) is expected to be easier as there is more available space.

REMATCHING

LHC changes to version 6.5

No important layout changes are expected in the SPS extraction regions. Small changes in the upstream matching conditions for TI2 and TI8 recently resulted from tune shifts in the SPS ring, and from improvements in the modeling of the extraction elements.

On the downstream side the injection lines end in the LHC matching sections (Q4 to Q7) between the low-β triplet and the Dispersion Suppressor. The optical conditions in the middle of these matching sections are by construction less stable then the conditions at their ends, where the constraints are applied. For example, the 30 cm displacement of Q3 between LHC versions 6.4 and 6.5 resulted in a non-negligible change of the LHC lattice functions at the TI8-LHC matching point between Q4 and Q5. Other possible future changes in matching conditions are listed in [6].

In turn, rematching TI8 to this new LHC version considerably changed the betatron phases of the selected TCDI locations. Attempts to recover the ideal phases at these collimator locations strongly modified the dispersion function, and TI8 could no longer be matched to the SPS without exceeding I_{max} for Q7.

A new collimator layout

Recently cost considerations initiated a study of schemes with fewer collimators ($60°$ between collimators instead of $45°$). The required betatron phases were obtained wherever possible by moving the collimators, rather than by constraining their phase values, at the expense of moving one or two quadrupoles. Matching at both ends of TI8 could now be achieved without exceeding I_{max}.

If yet more flexibility is needed

The above mentioned developments of the TI8 design show that the matching sections are no longer flexible once the collimator locations have been chosen. Future changes in optical conditions in the SPS or the LHC may thus require collimator displacements.

A possible solution is to keep the collimation at the end of the line and move the matching section upstream of the collimation. In this case the collimators remain close to the MSI septum. The betatron transfer matrices between the collimators and the septum (and also some particular phase advances like $0°$, $180°$ and $360°$) become independent of the matching conditions at the ends of the line, which is important for collimation performance. Equally, several matching quadrupoles will then be located at larger D_x and thus be more efficient for dispersion matching. On the other hand, some 6 quadrupoles upstream of the collimation will have to be disconnected from the main QF-QD circuits in TI8 and extra power converters will have to be installed to power these matching quadrupoles.

The cost of these modifications will have to be compared to the cost of increasing the number of installed collimators. With a larger number of collimators their performance will be less dependent on their betatron phase advances and thus the flexibility will be better.

CONCLUSION

The TI2 and TI8 lines were designed with a large degree of flexibility so as to be able to absorb future changes in optical conditions in the SPS and the LHC.

More recently this design was completed by a proposal to install protection collimators (TCDI) in the matching sections at the ends of these lines. Unfortunately, the recent history of the TI8 design shows that these matching sections are no longer flexible once the collimator locations have been fixed.

The present TI2/TI8 matching sections can accommodate small changes in SPS or LHC optics, while still keeping the ideal betatron phases at the collimators.

However, with the present numbers of collimators and matching quadrupoles it will not be possible to absorb larger changes (like from LHC V6.4 to V6.5) while keeping the locations of quadrupoles and collimators fixed, and layout changes may become unavoidable in the future. To eliminate this risk either more individually powered quadrupoles, or a larger number of installed collimators are required.

REFERENCES

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