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Proposal of a new Optics for the FTA Transfer Line

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Abstract

A new optics for the FTA transfer line, delivering high energy proton beam onto the p-bar production target, is presented and discussed in details. It allows to have the same optical configuration in the TT2 transfer line as that used for the other 26 GeV/c beams.

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1 Introduction

In the last year a big effort has been devoted to the analysis of the TT2 transfer line. Three different lines of activity have been pursued:

- Careful measurement of the optical parameters (Twiss parameters and dispersion function) both at the extraction point of the PS machine and in the beam line itself [1].
- Definition of the transfer line model. The description of the line has been carefully cross-checked against the data from the survey database [2], to verify the geometry, and with a series of kick measurements to verify the optics [3].
- Computation of a series of new optics for the different beams, starting from the measured parameters at the extraction point of the PS machine.

This campaign allowed to define a common, reference optics for both the PS machine and the TT2 transfer lines for all the 26 GeV/c beams. In a first stage, only LHC-type beams were considered, but it is clear that also the p-bar production beam should be taken into account in the same scheme. In fact, to have a unique optical configuration for the whole ensemble of high energy beams would greatly simplify and make more efficient the every-day machine operation.

In this note, the optics for the p-bar production beam is reviewed in details. The first step consists in computing the optical parameters for the nominal configuration, based on the values of the measured initial conditions. Then two different optical configuration have been calculated in order to adapt the FTA transfer line to the new setting of TT2.

2 Optical configurations for the p-bar production beam

2.1 Nominal optics of the TT2/FTA transfer line

Since the beginning of the p-bar operation, the ensemble TT2/FTA had a specific setting. However, over the years the setting of the PS machine at extraction evolved. Therefore, it is not surprising that the overall optics of the FTA transfer line changed with respect to the design specifications.

For the commissioning of the AD machine, it has been decided to keep the same setting of TT2 and FTA as the one used during the operation of the AA/AC complex. The currents used for the quadrupoles are listed in the first column of Table 2.

According to the naming convention and to the sign of the currents used during the last run, the last doublet should have a FD polarity. Optical computations, carried out with the *MAD* program [4], showed that such a configuration would lead to a divergent beam in the horizontal plane. To clarify the situation, it has been decided to measure the actual polarity of the quadrupoles 9050 and 9052. It turned out [5] that the quadrupoles are connected so that they generate a DF configuration. The optical parameters have been computed using as input the initial conditions at the quadrupole F16.QFO105 measured last year. In Fig. 1 both the Twiss parameters (upper part) and the dispersion function (lower part) are shown. The origin is taken at the entry face of the quadrupole F16.QFO105. The p-bar production target is located at the end of the beam line. The beam is now convergent in both planes at the target location. The values of the optical parameters are reported in Table 3.

2.2 Digression: the excitation curve of the last quadrupoles of FTA

The optical computations rely, among other things, on the knowledge of the excitation curves of the different quadrupoles in the transfer line. Such a curve allows to convert the current value into a gradient value, which, in turn, allows to compute the focusing strength of the element. For the last quadrupoles of the FTA line, namely the pulsed elements QFO9050 and QDE9052, some data are available [6]. The coefficients up to order five of a polynomial

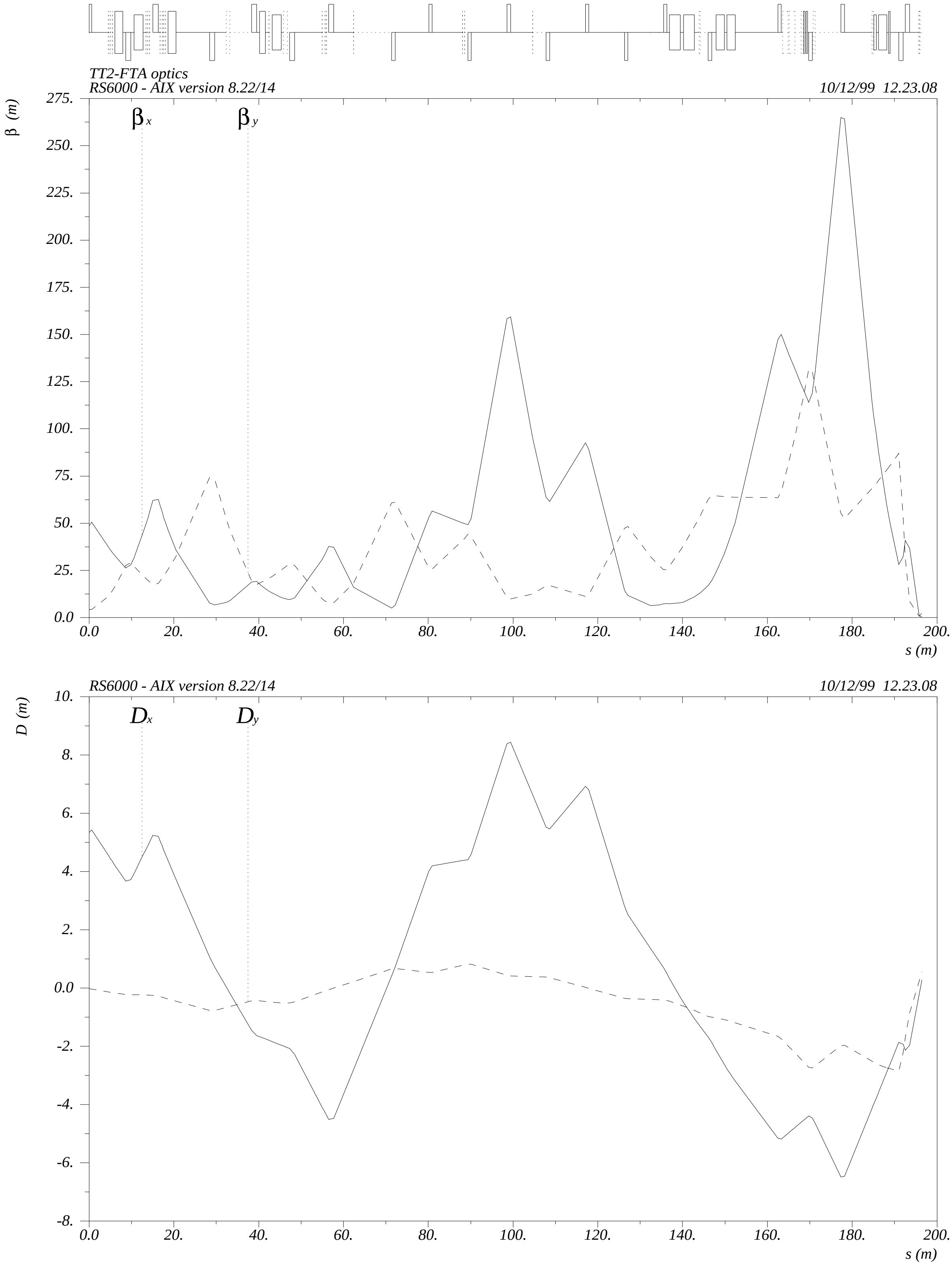

Figure 1: Twiss parameters (upper part) and dispersion function (lower part) for the nominal optics of the `TT2/FTA` transfer line. The origin represents the entry face of the quadrupole F16.QFO105. The last doublet has a setting corresponding to a DF configuration.

giving the integrated gradient versus the current or its inverse function, namely

$$\int G(z)\,dz = f(I) = A_0 + A_1 I + \cdots + A_5 I^5 \tag{1}$$

and

$$I = g\left(\int G(z)\,dz\right) = f^{-1}\left(\int G(z)\,dz\right) = B_0 + B_1\left(\int G(z)\,dz\right) + \cdots + B_5\left(\int G(z)\,dz\right)^5 \tag{2}$$

are given in the range $2000 < I < 4200\mathrm{A}$. As an example the graph of the function f is shown in Fig. 1. The first astonishing property of such a curve is that, within the range of validity of

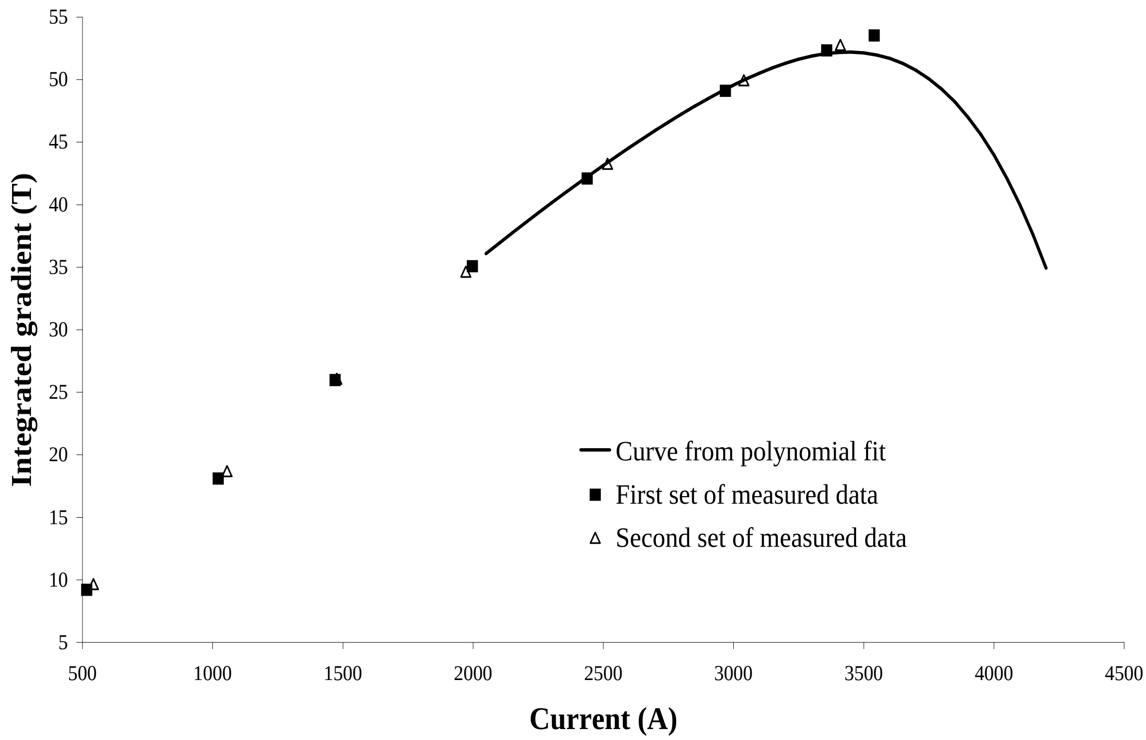

Figure 2: Excitation data for the last two quadrupoles of the FTA line. The continuous curve refer to the polynomial fit [6]. The markers correspond to two sets of measurement data.

the fit, the graph has a maximum. Therefore, the function is not invertible and the validity of the set of data quoted in [6] is questionable.

To try solving this puzzle, additional data have been looked for. Fortunately, it was possible to retrieve two sets of measurements [7] concerning the two quadrupoles under consideration. The two data sets are also reported in Fig. 1 using two different types of markers. The measured values are in rather good agreement with the curve and, furthermore, they have the nice property of extending the range towards low current values and to define an invertible function in the range of the measurement, namely for $500 < I < 3500\mathrm{A}$.

A fit of a polynomial curve of degree three has been carried out on this data set using the standard approach based on chi-square minimisation. The results are reported in Table 1. The errors on the fitted parameters are obtained in the standard way. In the rest of the note, all the optical configurations have been computed by using that fitted polynomial to evaluate the gradient of the last quadrupole doublet from the current value.

α_0	α_1	α_2	α_3
(1.42 ± 0.41)	$(1.372 \pm 0.081) \times 10^{-2}$	$(3.29 \pm 0.45) \times 10^{-6}$	$(-8.51 \pm 0.73) \times 10^{-10}$

Table 1: Parameters of the fitted polynomial curve through the measured data. The error terms are obtained by the fitting algorithm.

2.3 New optical configurations of the TT2/FTA transfer line

The goal of this study is to find out an acceptable optical configuration of the FTA line, with the TT2 line having the same setting as for the other 26 GeV/c beams.

Two different solutions have been found:

- In the first configuration, the two quadrupoles FTA.QDE9010 and FTA.QFO9020 have been set to zero. Then, the elements QDE9030 and QFO9040 have been used to match the optics onto the target. The current of the last two quadrupoles is the same as for the nominal optics. Their optical configuration is DF. The results are shown in Fig. 3.
- In the second configuration, the four quadrupoles FTA.QDE9010, FTA.QFO9020, QDE9030 and QFO9040 have been used to match the optics onto the target. Also in this case, the current of the last two quadrupoles is the same as for the nominal optics. Their optical configuration is DF. The results are shown in Fig. 4.

The values of the current for the quadrupoles in the different configurations are summarised in Table 2. The optical parameters are listed in Table 3

Element name	Nominal Optics (DF) [A]	Conf. 1 [A]	Conf. 2 [A]
F16.QFO105	533.39	520.40	520.40
F16.QDE120	230.59	248.60	248.60
F16.QFO135	204.60	184.60	184.60
F16.QDE150	168.15	145.15	145.15
F16.QFO165	214.50	102.50	102.50
F16.QDE180	174.90	144.90	144.90
F16.QFO205	236.40	126.40	126.40
F16.QDE210S	234.49	219.12	219.12
F16.QFO215S	232.39	242.91	242.91
FTA.QDE9010	97.40	0.00	40.00
FTA.QFO9020	149.20	0.00	40.00
FTA.QDE9030	233.80	204.77	184.00
FTA.QFO9040	245.80	304.58	302.58
FTA.QFO9050	-2222.10	-2222.10	-2222.10
FTA.QDE9052	-2930.00	-2930.00	-2930.00

Table 2: Setting of the quadrupoles of the TT2 and FTA transfer lines for the four configurations presented in this note.

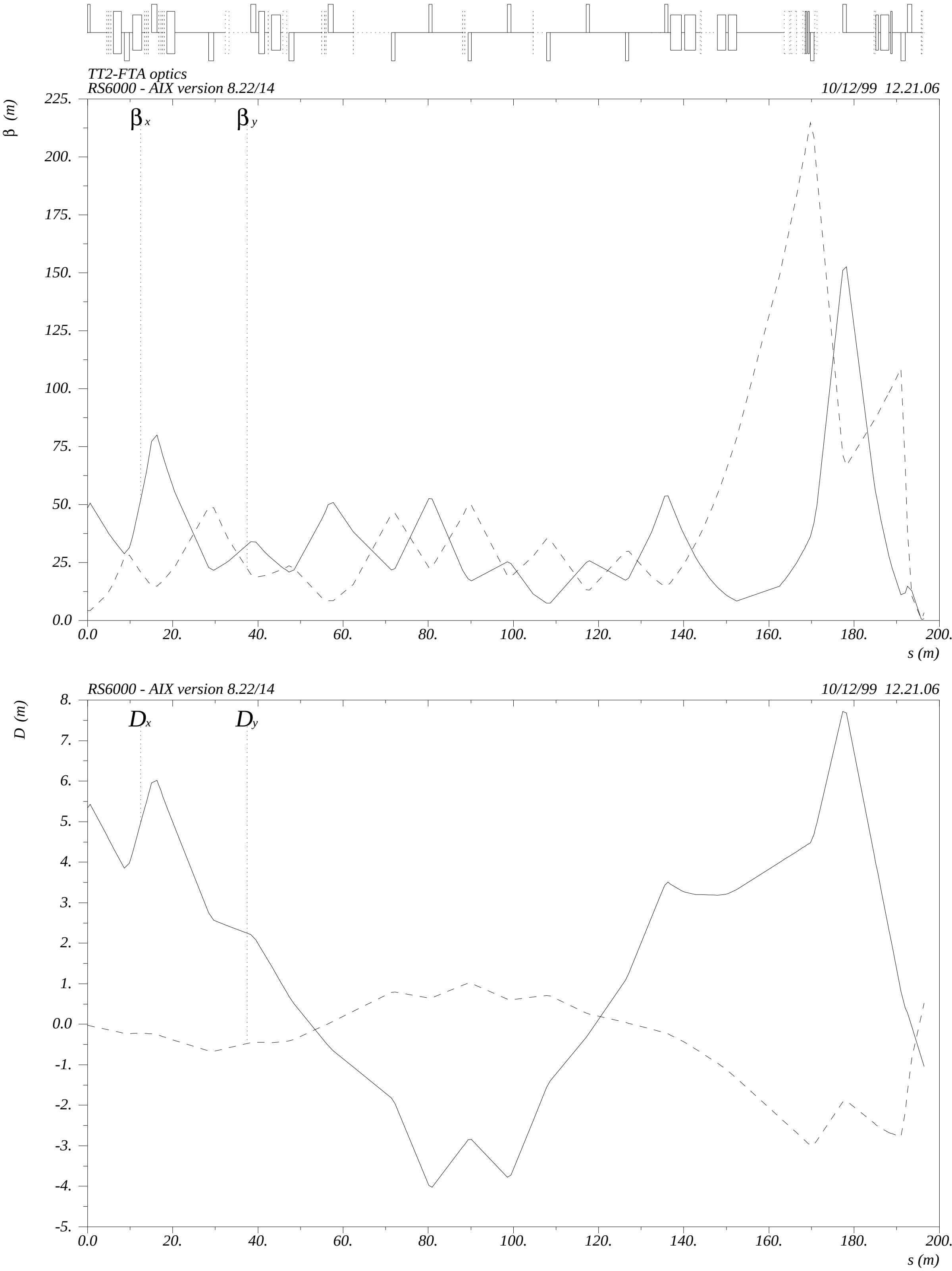

Figure 3: Twiss parameters (upper part) and dispersion function (lower part) for the first optical configuration of the `TT2/FTA` transfer line. The origin represents the entry face of the quadrupole F16.QFO105. The last doublet has a setting corresponding to a DF configuration.

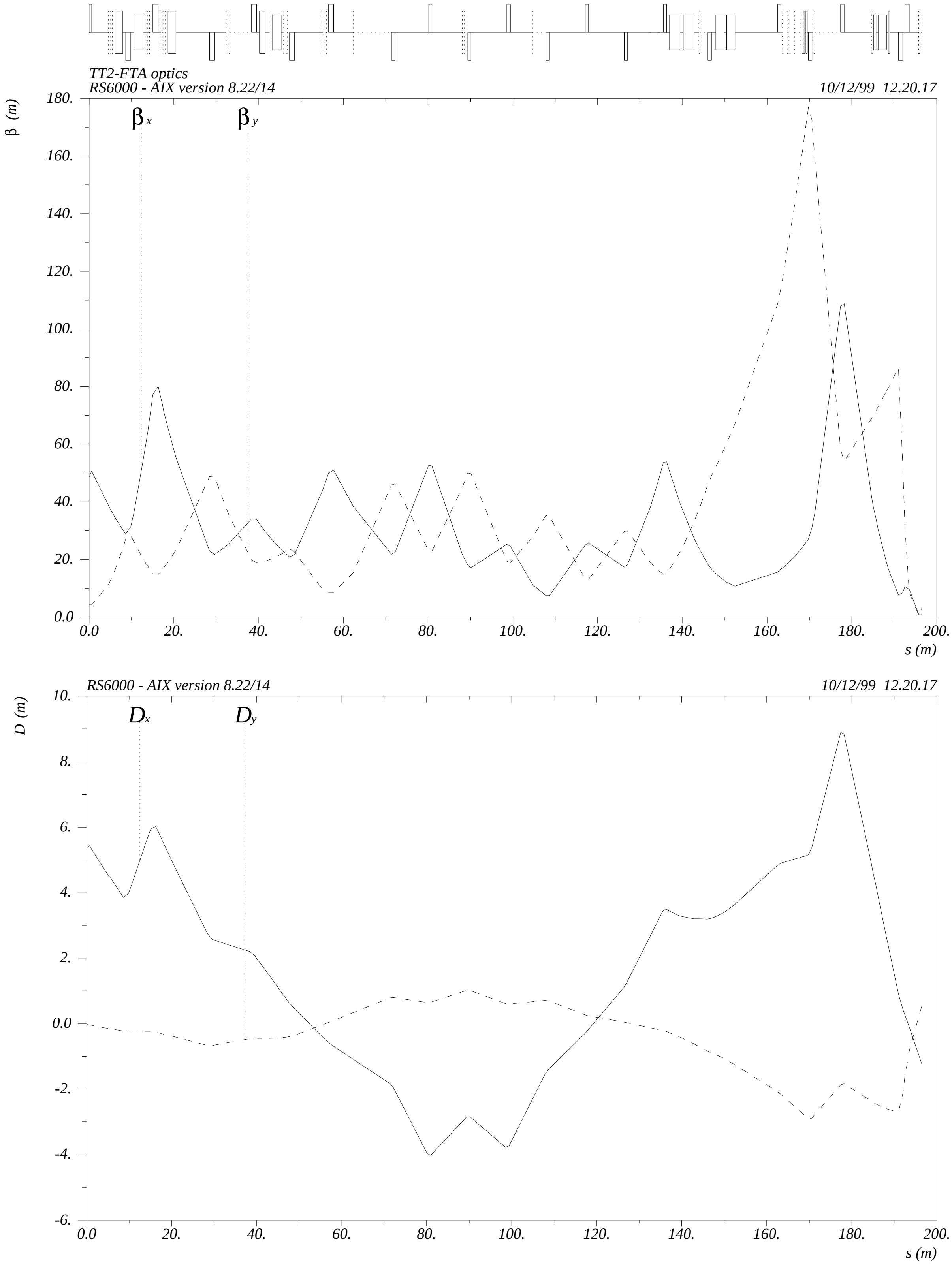

Figure 4: Twiss parameters (upper part) and dispersion function (lower part) for the second optical configuration of the `TT2/FTA` transfer line. The origin represents the entry face of the quadrupole F16.QFO105. The last doublet has a setting corresponding to a DF configuration.

	Nominal Optics (DF)	Conf. 1	Conf. 2
$\beta_{\rm H}$ [m]	1.29	0.68	0.91
$\beta_{\rm H}^{\rm max}$ [m]	265.03	152.55	108.82
$D_{\rm H}$ [m]	-0.22	-0.81	-0.96
$D_{\rm H}^{\rm max}$ [m]	8.44	7.72	8.90
$\beta_{\rm V}$ [m]	1.31	0.49	0.53
$\beta_{\rm V}^{\rm max}$ [m]	131.54	214.77	176.88
$D_{\rm V}$ [m]	0.37	0.23	0.24
$D_{\rm V}^{\rm max}$ [m]	2.85	2.99	2.90

Table 3: Summary of the optical parameters at the target location, for the configurations reported in the note.

3 Conclusions

From the discussion carried out in the previous sections, it seems clear that, during the forthcoming shut-down period, the name of the last two quadrupoles in the FTA should be changed to be in agreement with their polarity. Therefore, the element QFO9050 should become QDE9050 and the quadrupole QDE9052 should be named QFO9052.

Furthermore, it seems feasible to replace the nominal optics used since the operation of the AA/AC complex with one of the two solutions presented in the previous section. As far as the optical parameters are concerned, the two solutions are at least comparable when not superior to the nominal optics. They both have a smaller value of the β-functions and smaller $\beta^{\rm max}$. An additional advantage will be a more efficient and simplified operation of the whole ensemble of the 26 GeV/c beams delivered by the PS machine.

Acknowledgements

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