ATF2 variable β_IP parameters

M. Thorey, P. Bambade

LAL/RT 07-05
CARE/ELAN Document-2007-005
October 2007

Laboratoire de l'Accélérateur Linéaire

ATF2 variable β_{IP} parameters

M. Thorey, P. Bambade
LAL, Univ Paris-Sud, IN2P3/CNRS, Orsay, France

U.M.R
de
l'Université Paris-Sud

Institut National de
Physique Nucléaire et de
Physique des Particules du CNRS

LAL ~ Bât. 200 ~ B.P. 34 ~ 91898 Orsay Cedex ~ France

LAL/RT 07-05
CARE/ELAN Document-2007-005
October 2007

ATF2 variable β_{IP} parameters

Marie THOREY, Philip BAMBADE
LAL, Univ Paris-Sud, IN2P3/CNRS, Orsay, France

Abstract

Optical configurations with variable β_{IP} parameters can be useful during the commissioning of the ATF2 beam line and for the perfomance optimisation, to limit the beam sensitivity to displacements and energy errors. Such configurations are calculated, and the resulting tolerances studied.

1 Introduction

The aim of this work is to obtain a set of variable β_{IP} parameters for the ATF2 line commissioning and the performance optimisation. This is achieved by matching some quadrupoles and sextupoles in the beam line. A study of the tolerance of the beam in these configurations is also performed. Increasing the β_{IP} parameters reduces the beam sensitivity to the energy spread and magnet displacements for the commissioning. Decreasing them can also be considered for the final optimisation.

2 Optical configurations

2.1 Matching procedure

The ATF2 line transports electrons with an energy of 1.3 GeV. To obtain and study the intermediate parameters, the MAD tracking module [1] is used. Both β functions at the interaction point are increased by successively applying the following fitting conditions :
-fit QM12, QM13, QM14, QM15, QM16 to obtain the wanted $\beta_{x,y}$ and to maintain $\alpha_{x,y} = 0$ and $D_x = 0$ at the interaction point,
-fit the sextupoles SD0, SF1, SD4, SF5, SF6 to cancel T_{122}, T_{126}, T_{166}, T_{342} and T_{346}, which are the largest second order terms.

2.2 Matched quadrupoles and sextupoles

The nominal parameters are $\beta_x = 0.004$m and $\beta_y = 0.0001$m. New configurations with these nominal parameters, increased simultaneously by factors of 2 to 8, are obtained with the magnet strengths listed in Table 1 :

β	x1	x2	x4	x6	x8
σ_x (μm)	2.878	4.022	5.682	6.955	8.032
σ_y (nm)	34.64	48.56	68.68	84.45	97.55
KLQM12 (m^{-2})	0.386	0.374	0.380	0.380	0.378
KLQM13 (m^{-2})	0.990	0.959	0.925	0.898	0.873
KLQM14 (m^{-2})	-1.64	-1.46	-1.52	-1.47	-1.39
KLQM15 (m^{-2})	-0.108	0.228	0.544	0.616	0.644
KLQM16 (m^{-2})	-0.0561	-0.200	-0.425	-0.473	-0.487
KLSD0 (m^{-3})	4.47	4.48	4.50	4.51	4.51
KLSF1 (m^{-3})	-2.64	-2.65	-2.66	-2.67	-2.67
KLSD4 (m^{-3})	14.5	14.6	14.7	15.0	15.2
KLSF5 (m^{-3})	-0.873	-0.944	-1.07	-1.16	-1.24
KLSF6 (m^{-3})	7.84	7.81	7.74	7.68	7.64

Table 1: Magnet strength for the variable β_{IP}.

New configurations can also similarly be obtained changing only the vertical β_{IP} parameter and leaving the horizontal one unchanged. This is shown in Table 2 :

β_y	0.00003	0.00005	0.0001	0.0002	0.0004	0.0008
σ_y (nm)	21.76	28.91	34.6	48.62	68.67	97.1
KLQM12 (m^{-2})	0.392	0.388	0.386	0.382	0.380	0.383
KLQM13 (m^{-2})	1.02	1.00	0.989	0.971	0.954	0.934
KLQM14 (m^{-2})	-2.08	-1.78	-1.64	-1.45	-1.32	−1.16
KLQM15 (m^{-2})	-0.186	-0.135	-0.108	-0.0299	0.0681	0.105
KLQM16 (m^{-2})	0.138	-0.0000015	-0.0560	-0.168	-0.288	-0.374
KLSD0 (m^{-3})	4.46	4.47	4.47	4.48	4.49	4.51
KLSF1 (m^{-3})	-2.63	-2.64	-2.64	-2.65	-2.65	-2.65
KLSD4 (m^{-3})	14.5	14.6	14.6	14.6	14.6	14.7
KLSF5 (m^{-3})	-0.804	-0.885	-0.899	-0.917	-0.930	-0.939
KLSF6 (m^{-3})	7.89	7.84	7.84	7.82	7.82	7.81

Table 2: Magnet strength for the variable $\beta_{y,IP}$

Obtaining smaller $\beta_{y,IP}$ parameters for the ATF2 line was also tried. Since only a few quadrupoles are adjusted at the beginning of the line, without a reoptimisation of the entire final focus, there is only limited scope for this. However, as it can be seen in Table 2, it is still possible to achieve such a reduction, down to a factor of $\frac{1}{3}$ with respect to the nominal $\beta_{y,IP}$ value, without becoming dominated by higher order terms.

Figure 1 shows the second order term contributions relative to the beam size for $\beta_{y,IP} = 0.00002$m, corresponding to a reduction of a factor 5. In this case, a vertical beam size of 54 nm at the interaction point is obtained as both second and (predominantly) third order terms are enhanced.

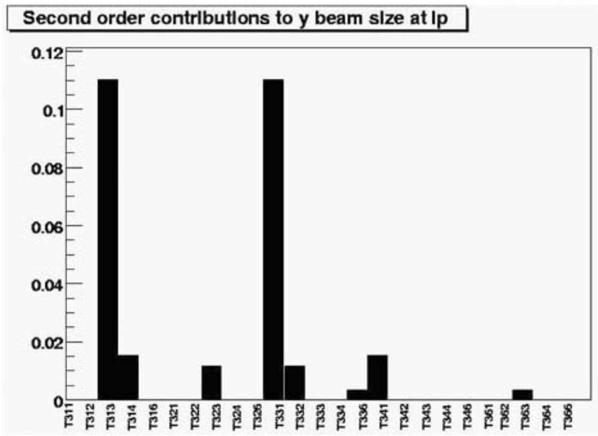

Figure 1: Relative contributions of second order terms to the vertical beam size at the interaction point

Moreover, it has been checked whether the matching module can be constrained to maintain the signs of the quadrupole strengths. This was shown to be easily achieved for the bigger parameters, but not for the smaller ones. This may need to be taken into account in the decision whether to upgrade to bipolar power supplies for these quadrupoles. An additional consideration relevant in this context is the optical tuning strategy, in the presence of matching errors, which may also require adjustments of these quadrupoles. This also need to be studied further.

3 Simulation Results

3.1 Energy spread

Figure 2 shows the ATF2 optical bandwidth for the variable parameters. The leading order contribution from the energy spread can be written as $\sigma = \sqrt{\epsilon}\sqrt{\beta + \frac{(l\delta)^2}{\beta}}$ with l the effective focal length of the final doublet, and δ the fractional energy spread. So, the bigger the β function is, the less influence the energy spread has on the beam size. The energy spread was simulated as a Gaussian with RMS $\delta = 0.001$.

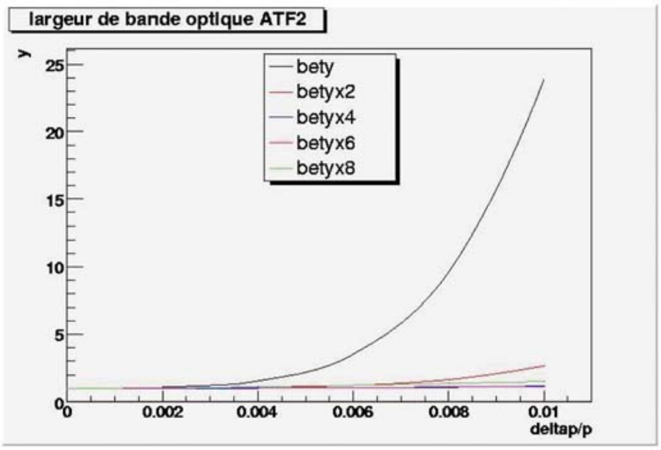

Figure 2: Optical bandwidth for different β_y^*, from 0.0001 to 0.0008m

3.2 Tolerance to magnet displacements

The magnet displacements are calculated using the simulator PLACET [2], which generates the beam and models the displacements. Magnet displacements cause deviations to the beam, which can change its size and its position at the interaction point. Figure 3 shows the relative increase in vertical beam size at the interaction point when moving each of the magnets one at the time by one micron. The beam size along the line is smaller when the IP β functions increase, so the magnet displacements have less influence in this case. Moreover, the beam size at the IP also becomes larger, so the relative beam size variations are also reduced. The contrary is true for both effects, if reduced $\beta_{y,IP}$ are used. Note that whatever parameters are used, the beam size varies in a similar way, but with a different amplitude. The biggest size effects occur when the last quadrupole before the final doublet is moved. In fact, the beam size is the largest in the final doublet, so if the beam is not well steered into it, the misalignements in the final focus sextupoles will defocus the beam at the interaction point.

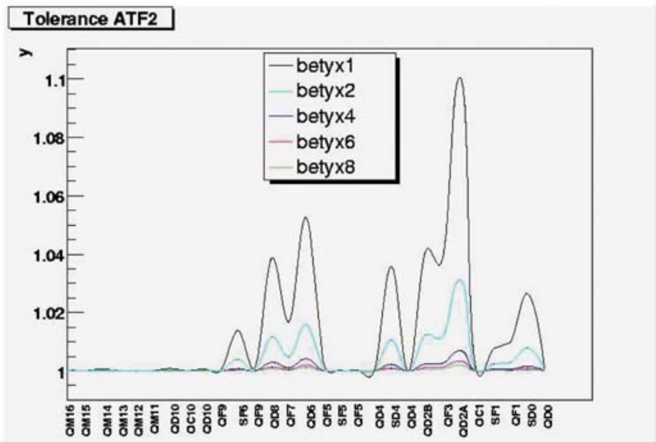

Figure 3: Relative increase in vertical beam size at the IP for 1 micron displacements of the magnets, moved one at the time, for different β_y^*, from 0.0001 to 0.0008m

The magnet displacements also change the beam position at the interaction point, which is shown in Figure 4. However the beam displacement is independant of the choice of β_{IP} parameters, since the relative optical transfer functions are unchanged. Nonetheless, the displacements relative to the beam size are reduced when β_{IP} is increased.

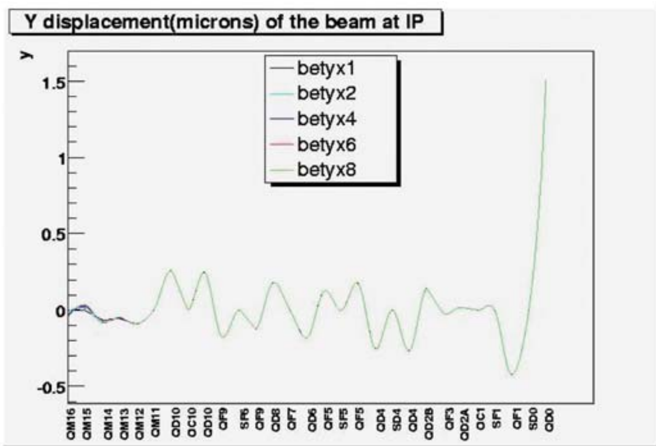

Figure 4: Vertical shift of the beam at the IP for 1 micron displacements of the magnets, moved one at the time, for different β_y^*, from 0.0001 to 0.0008m

4 Conclusion

In this note, quadrupoles and sextupoles have been fitted to get intermediate parameters for the ATF2 line commissioning. Vertical β functions from 0.00003 to 0.008m were obtained. For larger than the nominal $\beta_{y,IP}$ values, more relaxed tolerances result, as well as broader optical bandwidths. Both can be useful for the commissioning. A reduction of $\beta_{y,IP}$ down by a factor up to $\frac{1}{3}$ is also possible, but getting even smaller parameters would require using another matching method, fitting the whole line.

5 Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395)

References

[1] H. Grote and F.C.Iselin, *The MAD Program, User's Reference Manual*, 1996

[2] D. Schulte and A.Latina and N.Leros and P.Eliasson and E.D'Amica, *The tracking Code PLACET https://savannah.cern.ch/projects/placet*