Exploring ultra-low β* values in ATF2 - R&D Programme proposal

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Abstract

We propose to explore the beam sizes and performance of the ATF2 Final Focus System for reduced IP beta functions up to a factor between 2 and 4 below its design. The results will demonstrate the feasibility of the system in a chromaticity regime of interest for CLIC and ILC.

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For the ATF2, CLIC and ILC projects

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Project	Status	β_y^* [mm]	L* [m]	L*/β_y^*	ξ_y
FFTB	Design	0.1	0.4	4000	17000
FFTB	Measured	0.167	0.4	2400	10000
ATF2	Design	0.1	1.0	10000	19000
ATF2 pushed	Proposed	0.05	1.0	20000	38000
CLIC 500GeV	Design	0.2	4.3	21500	35000
CLIC 3TeV	Design	0.09	3.5	39000	63000
ILC	Design	0.4	3.5	8750	15000
ILC pushed	Design	0.2	3.5	17500	30000

Table 1: Relevant parameters of the different projects [3, 4, 5, 6]. ξ_y is a precise computation of natural chromaticity given by $(T_{346}R_{33} - T_{336}R_{34})/\sqrt{\beta_y^*}$. This is shown on the table to verify that the chromaticity of similar FFSs roughly scales with L*/β_y^*, the FFTB being the only FFS having a totally different design.

Introduction

The CLIC parameters at 500GeV have been chosen to be *conservative*, meaning that they ought to be supported by experience in real machines (past or ongoing like ATF2). In particular the 500GeV CLIC IP beta functions are (β_x, β_y)=(10, 0.2)mm with L*=4.3m while the nominal ATF2 IP betas are (β_x, β_y)=(4, 0.1)mm for L*=1m. The chromaticity scales roughly with L*/β^* and therefore the 500GeV CLIC is a factor 2 more chromatic than ATF2. For this reason we propose to test at least a factor 2 reduction in the horizontal and vertical IP beta functions of ATF2. A summary of the relevant parameters of the different projects is given in Table 1 including a more precise computation of chromaticity to confirm the rough scaling law mentioned above for similar FFS. The FFTB had a totally different design, thus its larger chromaticity than the new FFSs. A pushed ATF2 is the only way to prove the feasibility of the CLIC 500GeV chromatic level. The CLIC 3TeV option is more ambitious and has a $\beta_y^* = 0.09$mm. To prove this chromatic level, ATF2 β_y^* should be reduced by another factor of 2 (factor of 4 from nominal). This might require new or modified hardware and instrumentation.

The ILC project would also largely benefit from this test, in particular by gaining experience in exploring lower betas and facing increased tuning difficulties for this pushed machine.

Reference [1] studies a wide range of ATF2 β^* values. The larger β^* are useful during the commissioning period in order to reduce the difficulty of the system. The previous study also shows that there is some margin to lower the vertical IP beta function. Figure 1 shows the vertical sigma versus the vertical beta functions without including radiation effects. A minimum beam size of 20nm seems possible with the magnets and power supplies presently planned in the beam line (not considering potentially increased bremstrahlung background in the Shintake monitor from reducing β_x). Lattice aberrations dominate in the lower betas regime. Codes as MAPCLASS [2] could be used to further investigate the compensation of the lattice aberrations. The nominal ATF2 is just a factor of two away from the 500GeV CLIC in terms of chromatic behavior.

There is another important aspect determining the feasibility of an FFS: the tuning difficulty. By tuning we understand the process of bringing the system to its ideal performance under realistic conditions of lattice errors (misalignments, multipole errors, mispowerings, etc). The tuning difficulty should roughly scale inversely to the beam size at the IP. Achieving the CLIC IP beam sizes in ATF2 is not possible due to the difference in geometrical emittance but the strategy should be reducing the ATF2 betas to the lowest feasible values and experience with the increased tuning difficulty can be extrapolated to both CLIC and ILC.

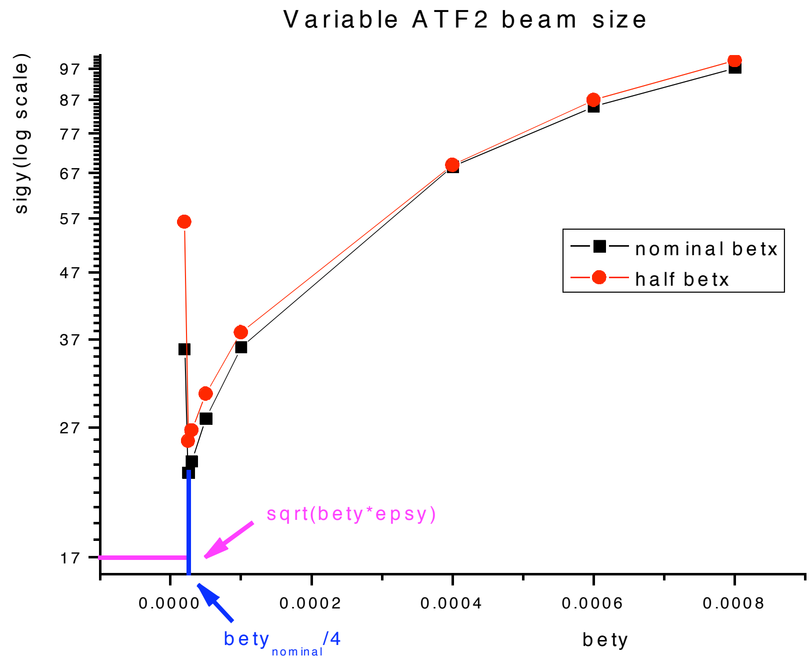

Figure 1: Vertical beam size (in [nm]) at the IP versus vertical beta function (in [m]) for two cases: nominal and half horizontal beta functions. Aberrations change the ideal trend of this curve for the very low betas and they are larger for the case with half the nominal horizontal beta. The quarter of β_y is marked on the plot together with the corresponding ideal vertical sigma.

Preparation

- An ATF2 lattice with IP betas (β_x, β_y)=(2, 0.05)mm should be prepared being compatible with hardware, aperture and instrumentation constraints. In particular:
  - If final doublet apertures are not sufficient, collimation and/or the option of superconducting magnets [7] should be pursued.
  - The Shintake monitor should be compatible with the smaller beam size and possibly enlarged halo. The present measurement range is between 20nm and 5μm [8].
- The minimum achievable ATF2 IP betas should be found, again compatible with the above constraints. The limiting elements should be identified in order to assess the feasibility of an upgrade of ATF2 to even lower IP betas. As an example Figure 2 shows the vertical beam distribution at the IP for a preliminary optics with β_y=0.025mm. Aberrations and/or optics still need optimization for this pushed option [2].
- Tuning studies and simulations should establish the best tuning algorithms for the different focusing stages. They should show the increasing difficulty as the beam size is reduced.

Experimental Goal

- ATF2 operation at lower IP betas for a period long enough to prove the optics design and the tuning algorithms.

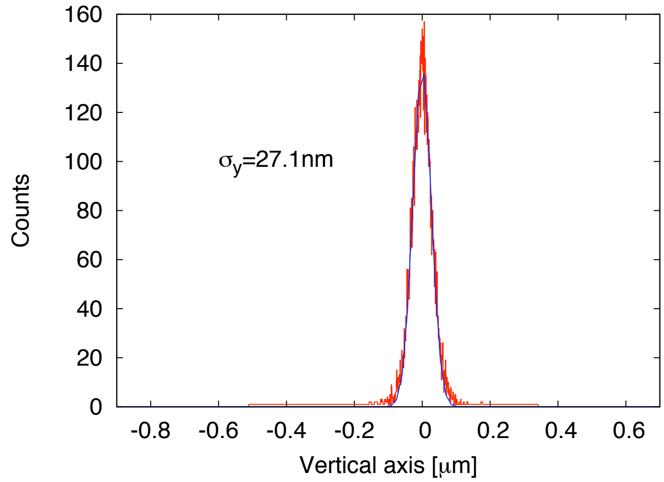

Figure 2: Vertical beam distribution at the IP for a preliminary optics with a factor 4 reduction in β_y. Aberrations and/or optics still need optimization for this pushed option since the ideal beam size would be $\sigma_y = 17$nm.

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