ATF2 ULTRA-LOW IP BETAS PROPOSAL

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**ATF2 ULTRA-LOW IP BETAS PROPOSAL**

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**Abstract**

The CLIC Final Focus System has considerably larger chromaticity than those of ILC and its scaled test machine ATF2. We propose to reduce the IP betas of ATF2 to reach a CLIC-like chromaticity. This would also allow to study the FFS tuning difficulty as function of the IP beam spot size. Both the ILC and CLIC projects will largely benefit from the ATF2 experience at these ultra-low IP betas.

**INTRODUCTION**

ATF2 is a test facility with the aim of testing the FFS design that has been proposed in [5]. To prove the CLIC 3TeV chromatic level, ATF2 \( \beta_y \) should be reduced by a factor of 4, see Table 1. After the original proposal [1] there are some open questions: tuning difficulty, impact of the known magnetic errors and the compatibility of the Shintake monitor with a probably enlarged halo.

The ILC project and the ILC low-power [2], would also largely benefit from this test, in particular by gaining experience in exploring larger chromaticities and facing increased tuning difficulties for this smaller beam size.

Reference [3] studies a wide range of ATF2 \( \beta_y \) values.

![Variable ATF2 beam size](image)

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 \( \beta_y \) is marked on the plot together with the corresponding ideal vertical sigma.

**Table 1:** Relevant parameters of the different projects [8, 9, 10, 11]. \( \xi_y \) 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 \( L^*\beta_y^* \), the FFTB being the only FFS having a totally different design.

<table>
<thead>
<tr>
<th>Project</th>
<th>Status</th>
<th>( \beta_y^* ) [mm]</th>
<th>L* [m]</th>
<th>( \xi_y )</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFTB</td>
<td>Design</td>
<td>0.1</td>
<td>0.4</td>
<td>17000</td>
</tr>
<tr>
<td>FFTB</td>
<td>Measured</td>
<td>0.167</td>
<td>0.4</td>
<td>10000</td>
</tr>
<tr>
<td>ATF2</td>
<td>Design</td>
<td>0.1</td>
<td>1.0</td>
<td>19000</td>
</tr>
<tr>
<td>ATF2 ultra-low</td>
<td>Proposed</td>
<td>0.025</td>
<td>1.0</td>
<td>76000</td>
</tr>
<tr>
<td>CLIC 3TeV</td>
<td>Design</td>
<td>0.09</td>
<td>3.5</td>
<td>63000</td>
</tr>
<tr>
<td>ILC</td>
<td>Design</td>
<td>0.4</td>
<td>3.5</td>
<td>15000</td>
</tr>
<tr>
<td>ILC low power</td>
<td>Proposed</td>
<td>0.2</td>
<td>3.5</td>
<td>30000</td>
</tr>
</tbody>
</table>

The larger \( \beta^* \) 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 bremsstrahlung background in the Shintake monitor from reducing \( \beta_x \)). Lattice aberrations dominate the beam size in the lower betas regime. MAPCLASS [4] has been used to achieve the minimum beam size. 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. This procedure leads us to experience with another important aspect: the tuning difficulty of the FFS. By tuning, we understand the process of bringing the system to its ideal performance under realistic conditions of lattice errors. The experience learned can be extrapolated to both CLIC and ILC.

**TUNING PERFORMANCE VS \( \beta^* \)**

It is expected that the tuning difficulty should roughly scale inversely to the beam size at the IP. Tuning simulations have been performed for three different IP vertical beta functions of ATF2. The simulation takes into account ground motion, H & V displacements, transverse rolls and mispowerings of the magnets. The Simplex-Nelder algorithm [7] is used to minimize the IP beam sizes. The results...
Table 2: Tuning performance of the ATF2 ideal lattice for decreasing values of the vertical IP beta function.

<table>
<thead>
<tr>
<th>case</th>
<th>Max. tuning time</th>
<th>Ratio of success</th>
</tr>
</thead>
<tbody>
<tr>
<td>β₀₃=0.1mm</td>
<td>5.5 days</td>
<td>100%</td>
</tr>
<tr>
<td>β₀₅=0.05mm</td>
<td>8 days</td>
<td>90%</td>
</tr>
<tr>
<td>β₀₇=0.025mm</td>
<td>10 days</td>
<td>80%</td>
</tr>
</tbody>
</table>

Figure 2: Nominal βₓ, βᵧ and horizontal Dispersion Dx functions for the ATF2 ultra-low β proposal. It should be noted the present symmetry around 70m concerning βᵧ.

obtained are summarized in Table 2. Clearly, lower betas require more tuning time and show a lower success ratio. Improved algorithms will be used in the future in order to reach a better performance.

**EFFECT OF MULTIPOLAR ERRORS**

The ATF2 ultra-low initial β and dispersion functions, are presented in Fig. 2. The recently measured magnetic errors in (mainly in QF1 and QDO) have been added to the MAD model. This has considerably deteriorated the IP beam sizes. The size of the beam at the IP is computed using MAPCLASS [4] code. This code performs an order by order analysis allowing the identification of the most important contributions to the beam size. The horizontal normalized emittance ϵₓ,n is varied within the range [2.8μm, 6.0μm], while the vertical normalized emittance ϵᵧ,n is fixed at 3nm. From the results presented in Fig. 3 (top), it is clear that the fifth order (dodecapole error) is responsible of blowing up the beam size at higher emittances. In addition, a non-negligible contribution from the third order (octupole error) is present. A less important contribution comes from the second order, not shown on the graph. From the results presented in Fig. 3 (bottom), again the dodecapole error rises up considerably the σₓ as the horizontal emittance increases. And a negligible contribution from the rest of the orders is observed. This emittance blow-up is mostly due to the multipolar errors in QF1, where the

MINIMIZING THE ERROR

Two possible solutions are proposed in this section. The first one is inserting a dodecapole in front of QF1. A scan over seven different strength values of the dodecapole magnet has been performed. The beam size versus the strength is presented in Fig. 4. The study is presented for two different horizontal emittances: ϵₓ,n=3.14μm and ϵₓ,n=6.0μm. Parabolic curves fit the results allowing to obtain the minimum vertical beam size at the optimum dodecapole strength=1.6 × 10⁶ m⁻⁵. At this strength, for

Figure 3: (top): Vertical beam size σᵧ at the IP versus horizontal emittance for three different orders: first, third and fifth. Clearly the fifth order amplify dramatically the beam size. (bottom): Horizontal beam size σₓ at the IP versus horizontal emittance

horizontal beam size is maximum. In order to reduce this growth either a new optics could be developed or a dodecapole magnet could be inserted nearby QF1.

Figure 4: Qualitative study for the optimization of the dodecapole strength at lower and higher ϵₓ. Keeping the ultra-low beta lattice design unmodified. The black solid points mark the minimum σᵧ at the IP for both cases.
The vertical beam size is increased for smaller IP beam sizes. The measured multipolar errors considerably increase the IP beam sizes. 

The most satisfactory solution to minimize the effect from the multipolar errors is to change the IP beta functions to the quadrupolar, octupolar and dodecapolar. Therefore an octupole magnet would also be required to better cancel the aberrations.

The second solution consists in reducing the beam size at QF1 by modifying the optics. MADX and MAPCLASS allow a matching for the quadrupoles and sextupoles strengths, in order to reduce the $\sigma_y$ at the IP. For this purpose no constraints are given to the horizontal $\beta$ functions. The results obtained are presented in Fig. 7, with the new $\beta_x^*=8.3\text{mm}$, and $\beta_y^*=31.6\text{µm}$. Approximately $\sigma_y$ has been reduced 3.5 times and it is worth mentioning that also the octupolar component has been reduced. On the contrary, $\sigma_x$ has increased a factor of $\sqrt{2}$ due to the increase of $\beta_x^*$. The $\beta$ functions and the dispersion along the FFS for the new lattice are plotted in Fig. 6. It is important to notice the symmetry breaking of $\beta_y$ around 70m with respect to the nominal $\beta_y$ plotted in Fig. 2.

**CONCLUSIONS**

The progress on the ultra-low $\beta$ proposal has been presented. It has been shown through simulations that the tuning time increases for smaller IP beam sizes. The measured multipolar errors considerably increase the IP beam sizes.

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**REFERENCES**


[2] A. Seryi et al "POWER SAVING OPTIMIZATION FOR LINEAR COLLIDER INTERACTION REGION PARAMETERS”, these proceedings.


