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ALIGNMENT OF THE CLIC BDS*

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Abstract

Aligning the CLIC Beam Delivery System faces two major challenges, the tight tolerances for the emittance preservation and its strong non-linear beam dynamics. For these reasons conventional beam-based alignment techniques, like dispersion free steering, are only partially successful and need to be followed by optimization algorithms based on other observables, like beam sizes.

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Aligning the CLIC Beam Delivery System faces two major challenges, the tight tolerances for the emittance preservation and its strong non-linear beam dynamics. For these reasons conventional beam-based alignment techniques, like dispersion free steering, are only partially successful and need to be followed by optimization algorithms based on other observables, like beam sizes.

INTRODUCTION

The CLIC Final Focus System is based on the local chromaticity correction scheme presented in [1] which uses strong sextupoles near the final doublet quadrupoles for the chromatic correction. Extra non-linear elements have been added to the CLIC FFS to cancel residual aberrations of octupolar and decapolar order [2, 3]. The intrinsic non-linear behavior of this system is illustrated in Fig. 1 where three vertical BPM readings are plotted versus energy deviation with and without radiation using the simulation code PLACET [5]. Even though linear dispersion is zero the BPMs measure linear and non-linear dispersion due to the non-linearities and the bunch density distributions. A random effect of similar order of magnitude is observed when synchrotron radiation effects are included in the simulation. It has been verified that this effect scales with the square root of the number of particles used in the simulation which typically is 5 orders of magnitude smaller than in the CLIC nominal bunch.

TRADITIONAL ALGORITHMS

Dispersion Free Steering (DFS) [6] is an extended beam-based alignment method that minimizes the dispersion at the BPMs by using beams with different energies and linear response matrices. Applying this method to the full CLIC BDS improves the emittance but does not reach a satisfactory correction, Fig. 2. However this method proves successful if applied to the collimation section only, which is the first part of the BDS, Fig. 3. We conclude that the non-linear behavior of the FFS limits the use of DFS in this final section of the BDS. Other methods using the beam size at the IP, luminosity and a non-linear version of the DFS are studied below with first applications to the ATF2 for testing and code verification purposes.

USING ATF2 AS A TEST BENCH FOR CLIC ALIGNMENT ALGORITHMS

ATF2 is a test facility with the aim of proving the FFS design proposed in [1]. Therefore this is an ideal test

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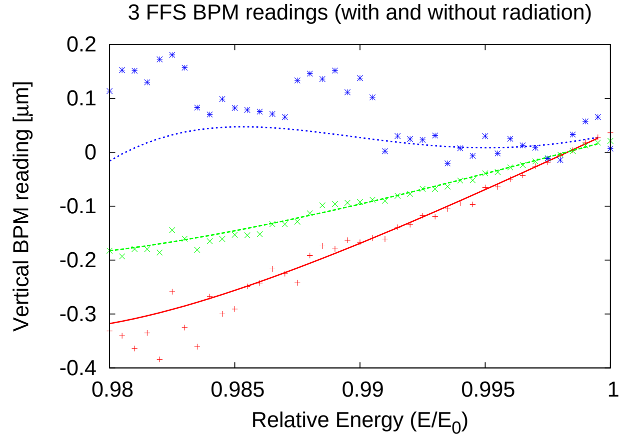

Figure 1: Simulation of three vertical FFS BPM readings versus beam relative energy including radiation effects (points) and without radiation (lines). Apparent linear and non-linear dispersion is observed plus an important numerical effect of the stochastic nature of radiation.

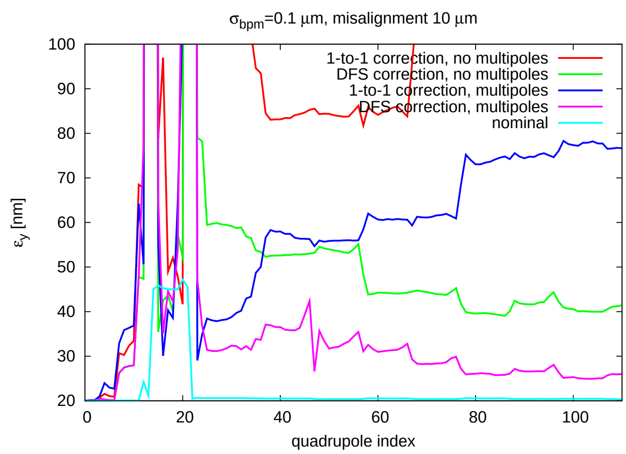

Figure 2: Vertical emittance versus longitudinal location after attempting the alignment of the full CLIC BDS by one-to-one steering and dispersion free steering.

bench for the alignment algorithms to be used at CLIC. A first simulation campaign of ATF2 alignment and tuning has been carried out taking into account: H & V Gaussian misalignments with $\sigma = 30\mu$m, transverse rolls with $\sigma = 30\mu$rad, relative strength error with $\sigma = 10^{-4}$, measurement error of σ_y with σ=2nm and a model of ground motion based on measurements at the ATF site.

All magnet H & V displacements, their roll and their strengths are used to minimize the transverse beam sizes at

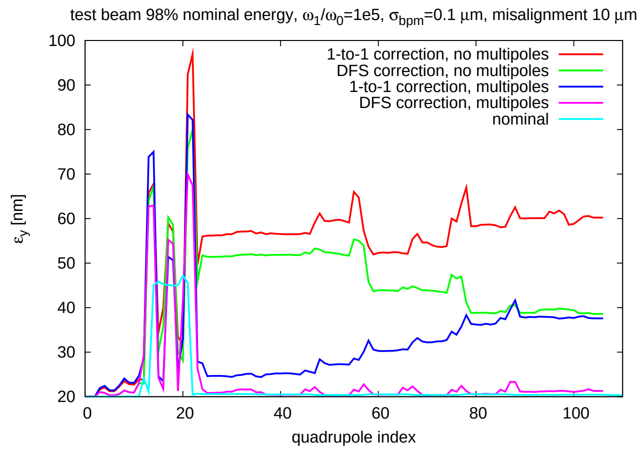

Figure 3: Vertical emittance versus longitudinal location after successfully aligning only the collimation section of the CLIC BDS.

the IP using the Simplex-Nelder algorithm [4]. The tuning stops when the target beam size is reached or when the maximum number of iterations is exceeded. Fig. 4 show the initial beam sizes of the uncorrected FFS, the required number of iterations for convergence and the final beam sizes. Initial vertical IP beam sizes up to 4μm are reduced below 44nm with less than 8000 iterations (equivalent to $\approx$6 days of ATF2 operation). This performance is similar to other studies using different approaches and different simulation codes [7]. Once this simple algorithm has been verified in ATF2 it is applied to the CLIC FFS.

TESTING ALGORITHMS FOR CLIC

Applying the exact same algorithm to the CLIC FFS than to the ATF2 machine we obtain the results shown in Fig. 5. This is unrealistic since CLIC will not be equipped with a beam size monitor at the IP. However we observe that the convergence of the algorithm is not as good as for the ATF2 case, some seeds fail to reach the nominal beam size $\approx 2.4nm$ even though the number of iterations doubled to 16000. A possible improvement to this approach consists in matching the non-linear dispersion to the predicted by the model, basically a non-linear dispersion free steering. This is achieved by adding the quadratic deviations of the measured non-linear dispersion at the BPMs to the figure of merit used by the Simplex. The results of this approach are shown in Fig. 6 without improving the previous, and simpler, approach. Moreover the number of required iterations largely increases due to the need of specific extra measurements with off-energy beams. The complexity of the CLIC FFS requires the development of more sophisticated algorithms than for the ATF2.

Using the luminosity instead of the beam size as the figure of merit is more realistic for the CLIC case since CLIC will not be equipped with a beam size monitor at the IP. The results are shown in Fig. 6 with a performance similar

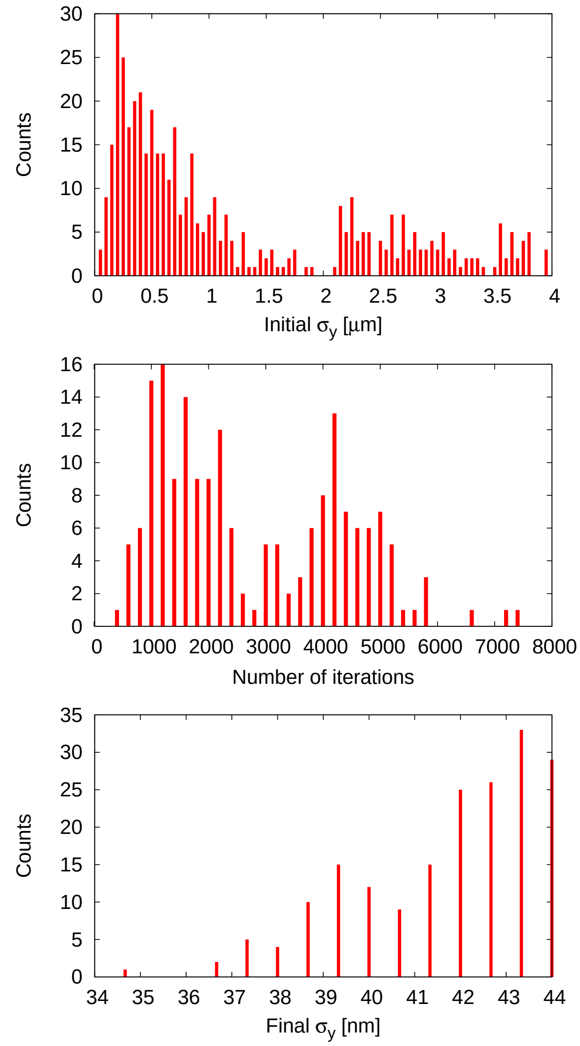

Figure 4: ATF2 simulations: histograms of initial and final vertical beam sizes (top and bottom) and number of correction iterations (medium) using the Simplex algorithm.

or better than when plainly using the beam size. Basically 80% of the seeds end with a luminosity above 80% of the design luminosity in less than 18000 iterations.

CONCLUSIONS

It has been proved via realistic simulations that dispersion free steering can be used to align the CLIC collimation section with an emittance growth below 5%. These pure alignment techniques fail in the FFS and more general tuning algorithms have to be used for this more complex CLIC system. A simple tuning algorithm that works succesfully in the ATF2 is not satisfactory for all the CLIC seeds. This and other reasons have triggered a proposal to reduce the ATF2 β^* by at least a factor 2, increasing thus its chromaticity and also the tuning difficulty [8]. This increased tuning difficulty may lay closer to that of the CLIC case, being one step closer to experimentally validate the CLIC FFS in the frame of the ATF2 project. A more refined version of the CLIC tuning algorithm including non-linear dispersion free steering does not improve the situation. The

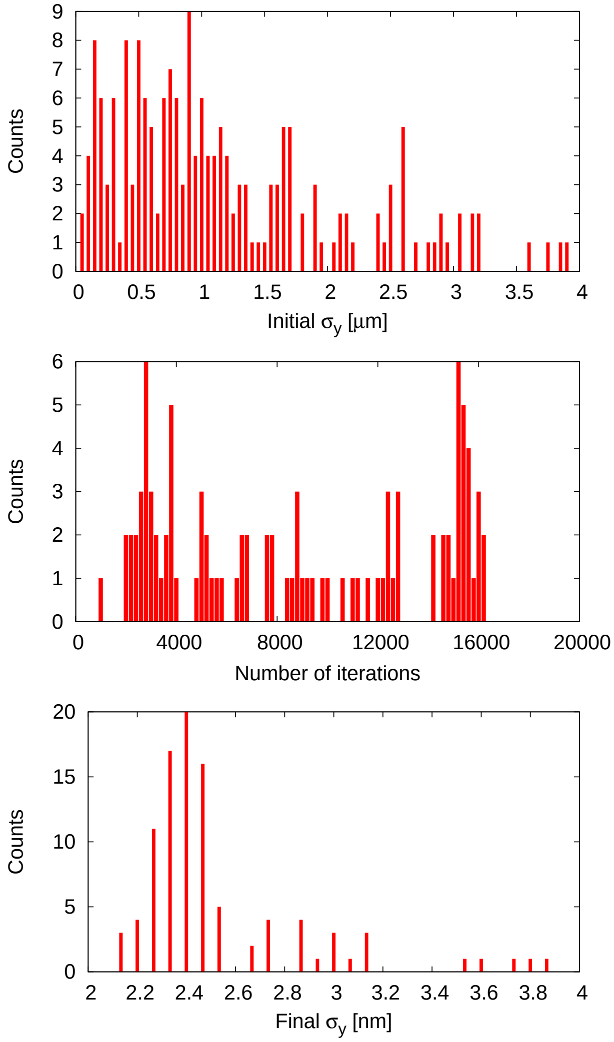

Figure 5: Histograms of vertical beam sizes (before and after correction) and iterations taken by the optimization for the CLIC FFS. Beam size only as figure of merit. Knobs: H&V displacements.

current conclussion is that 80% of the seeds converge to a luminosity above 80% of the design case and that algorithms need to be improved to reach 100% success.

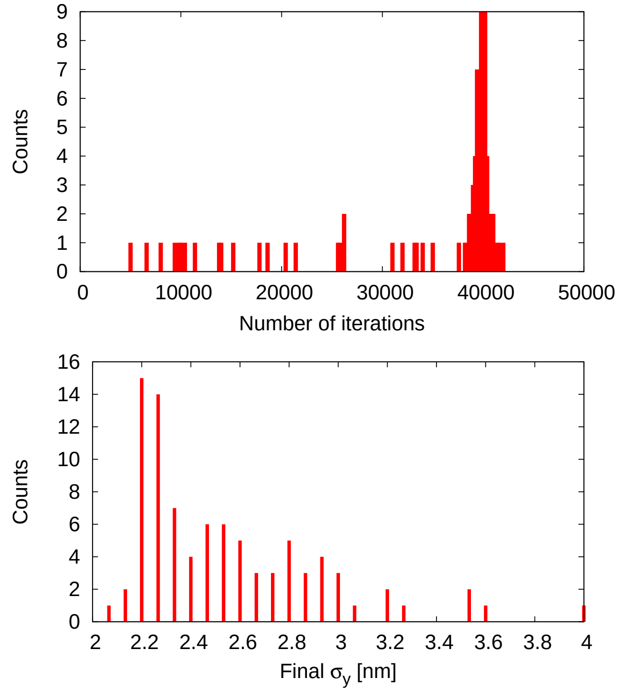

Figure 6: Histograms of vertical beam sizes (before and after correction) and iterations taken by the optimization for the CLIC FFS. Figure of merit: Beam size plus non-linear dispersion. knobs: H&V displacements plus strengths

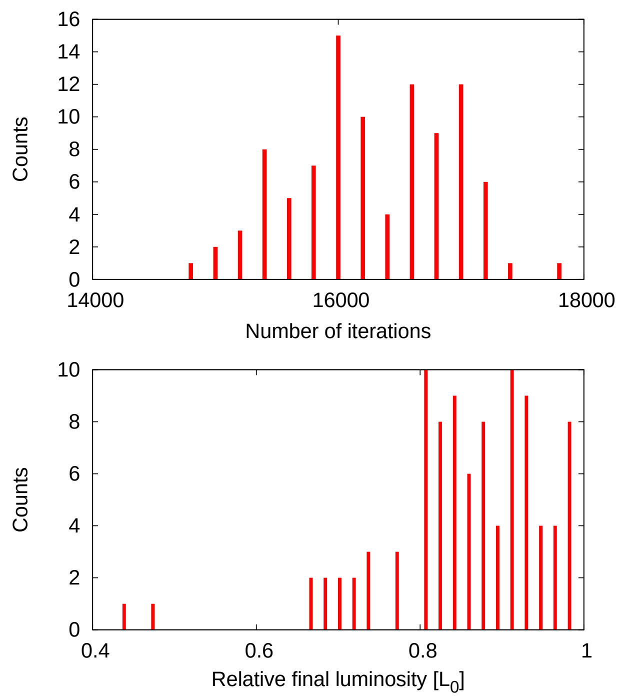

Figure 7: Histograms of number of iterations (top) and relative final luminosities (bottom) for the tunning of the CLIC FFS. knobs: H&V displacements plus strengths

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