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CHALLENGES AND STATUS OF TUNING SIMULATIONS FOR CLIC TRADITIONAL BEAM DELIVERY SYSTEM

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Abstract

The beam delivery system (BDS) for the 3 TeV version of the Compact Linear Collider (CLIC) has two main design types. One type is referred to as the local scheme, as it is approximately one kilometer shorter and corrects the chromaticity in both planes. The other type is referred to as the traditional scheme, and separates the chromaticity correction of each plane into different areas. The expectation early in the studies is that the traditional scheme would be easier to tune. However, it appears that this is not the case. Previous proceedings have shown the complications in tuning the traditional scheme. This work will address the problems experienced in tuning simulations for the traditional BDS and describe the current state of these simulation.

INTRODUCTION

The design of the Compact Linear Collider (CLIC) [1] has evolved to reflect progress in accelerator research and development as well as recent developments in particle physics. The final focus section (FFS) of CLIC's beam delivery system (BDS) has gone through several design iterations. All of these iterations fall under two basic layouts: the local chromaticity correction scheme [2], which simultaneously corrects the chromaticity of both planes, and the traditional chromaticity correction scheme, which separates the correction of each plane into two different regions of the FFS [3]. The basic layouts of the two designs can be seen in Fig. 1. One of the most important differences between these designs is that the local scheme is over 1 km shorter than the traditional scheme for the 3 TeV machine, measuring 450 m and 1460 m, respectively. This influences the construction costs, as a longer machine would cost more to build. Despite the large difference in overall length, both FFSs are capable of achieving approximately the same luminosity in ideal conditions.

The focus of this work is a continuation of the work presented in [4], which involved the single-beam tuning of the CLIC 3 TeV traditional FFS. There will be a very brief review of the tuning process, as well as previous tuning efforts for this lattice. The discussion will then focus on the most recent efforts, and will conclude with what the current results mean, especially when compared to other FFSs.

TUNING SIMULATION RECIPE

Due to the very small beam size at the interaction point (IP) and the one-shot nature of the collisions in linear colliders, the requirements placed on controlling the beam are

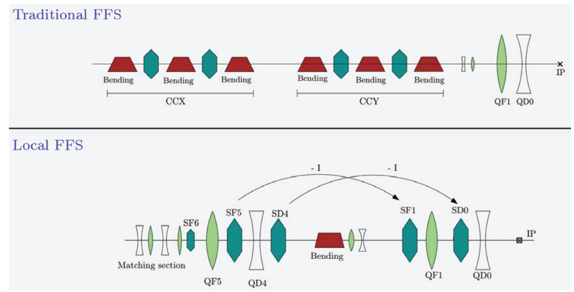

Figure 1: General layouts of two FFS systems [3].

very stringent. The BDS, and specifically the FFS, provides the last opportunity to control the beam prior to collision. Therefore, the BDS must be tuned carefully to maximize the luminosity achieved by the machine. For these tuning simulations, the programs PLACET [5] and GUINEA-PIG [6] are used [7].

The first step in the tuning simulation process [8] is to misalign the components of the beamline. For the studies presented in this work, only transverse static offsets of up to 10 μm were applied randomly to each component. One-to-one (121) tuning is then performed, which uses dipoles to steer the beam back toward its nominal trajectory. Upon completion of 121 tuning, a first stage of dispersion free steering (DFS) is performed to bring the dispersion back toward the design values. The next step is to adjust linear knobs which help to minimize first-order aberrations and maximize the luminosity. Then, after applying the linear knobs, some of the random seeds will need to go through a second stage of dispersion-free steering, while others will have to go through another set of hybrid DFS knobs which minimize dispersion growth while maximizing luminosity [9]. Then, the machines will go through a series of iterations which apply linear knobs, non-linear (2nd and higher-order) knobs, and dispersion free steering. For single beam tuning with only static transverse offsets, the goal of the tuning is to have 90% of random seeds reach 110% of the nominal luminosity.

In general, this approach works for the early stages of tuning. However, after some time this procedure no longer shows improvement. At this point, custom tuning knobs are required to make further improvements. The process of designing and applying these custom tuning knobs is discussed in [4] for the traditional FFS. To summarize briefly, higher-order aberrations in each plane are identified, and knobs are designed to address these aberrations. Once these knobs are applied, and several iterations of various knobs are performed, new aberrations are identified and more custom knobs are created.

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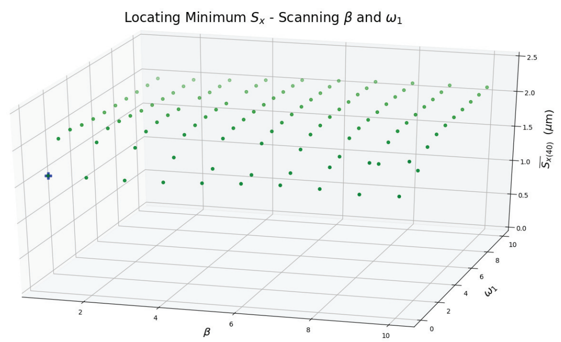

Figure 2: β vs. ω_1 vs. horizontal beam size averaged over 40 seeds. Minimum indicated by blue cross.

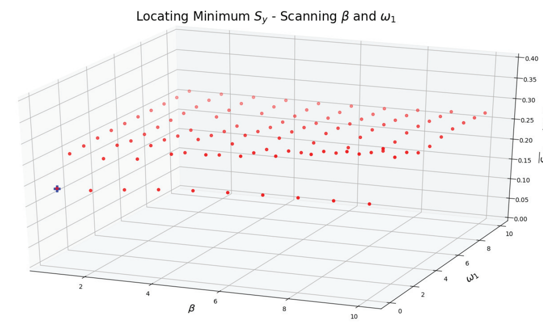

Figure 3: β vs. ω_1 vs. vertical beam size averaged over 40 seeds. Minimum indicated by blue cross.

This method was shown to be successful for the local FFS [10, 11], but only achieved minor improvements in the traditional FFS [4].

REVISITING THE FIRST STAGES

Last year [4], we started an investigation into why the traditional FFS did not appear to improve after several iterations, especially when compared to the local FFS. It was decided to start at the beginning and re-examine basic functions and formulas used during the early stages of the tuning process, which are described in detail in [8].

Two weighting parameters used for the 121 and first stage dispersion free steering steps were suspected to be less than optimal. To check them, parameter scans were performed. These weighting functions (β for 121 tuning and ω_1 for DFS) were scanned to see which would minimize the overall beam size (thus maximizing luminosity) after the first stage DFS but before any tuning knobs were applied. The beam size scans included scanning the values of $\beta = 0$ and $\omega_1 = 0$. If $\beta = 0$, this means that 121 tuning and the first stage DFS would not occur. If $\omega_1 = 0$, 121 tuning can still take place, but the first stage DFS tuning will not occur. During the analysis, the smallest beam sizes were recorded with the corresponding weighting parameters. When including all of the data acquired, the smallest beam size occurred when $\omega_1 = 0$ and $\beta = 1$ for both planes. If the data where the weighting parameters equalled 0 is omitted from the analysis, then the smallest beam sizes in each plane occurred for different values; $\beta = 2$ and $\omega_1 = 5$ for the horizontal plane and $\beta = 8$ and $\omega_1 = 1$ for the vertical plane. However, the beam sizes for both planes were far smaller when $\omega_1 = 0$ and $\beta = 1$ for both planes. the results of these scans can be found in [4].

Before restarting the tuning procedure with the new parameters, a series of new scans were performed where the tuning process was allowed to continue past the stage with linear knobs. These results are shown in Figs. 2 and 3 for the x and y planes, respectively. Similarly to the previous scans, the minimum beam size occurred when $\omega_1 = 0$. This indicates that the first stage of DFS may be detrimental to the overall tuning procedure for the traditional FFS.

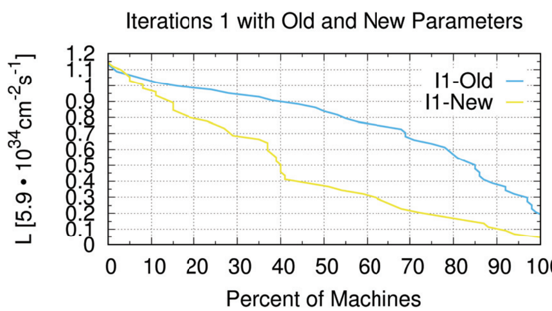

Figure 4: Comparing the results for the first tuning iteration using the old weighting parameters and the new.

RESTARTING THE TUNING

Using the results from the parameter scans, the tuning procedure was restarted in the same manner which gave the best results previously. The only change from the previous tuning efforts was the use of the new weighting parameters found from the scans, which meant that the first stage DFS tuning was effectively turned off.

Figure 4 shows an apples-to-apples comparison of the first iteration of tuning using the old and new parameters. Despite the parameter scans finding the smallest beam size at the new parameters, the tuning performed far worse.

To be sure that the new parameters were detrimental to the tuning, a second iteration was performed in the same manner as previous studies. Using the saved machine status from the first iteration, the second iteration cycles through linear knobs, second-stage DFS (or knobs) and non-linear knobs. No custom knobs are used at this point. As can be seen in Fig. 5, this actually results in decreasing the overall luminosity for most machines. This behavior is similar to that described previously at the Linear Collider Workshop in Morioka [12]. Prior to the development of the second stage, hybrid DFS tuning described in [9], each tuning iteration for the traditional lattice unexpectedly decreased the luminosity achieved. This was previously remedied with the use of the hybrid DFS knobs, but it appears that this is no longer the case.

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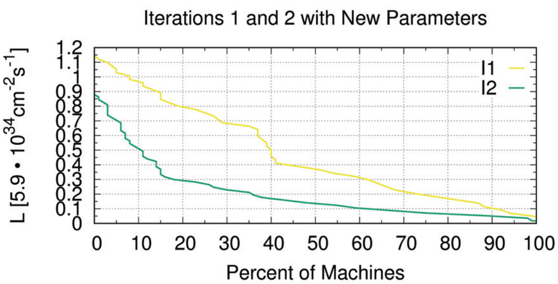

Figure 5: Comparison of iterations 1 and 2 using the new weighting parameters.

DISCUSSION AND COMPARISON

The procedures tested in this study have failed to improve the luminosity to an adequate level. Even in the simplest case of single-beam tuning with static transverse offsets, the traditional FFS has failed to reach the goal of 90% of machines reaching 110% of the nominal luminosity. The best results have accomplished approximately 45% of machines reaching 110% of the nominal luminosity and 100% of machines reaching ≥ 75% [4, 12]. Attempts to address this have thus far been detrimental to the progress made previously. Furthermore, attempts to understand why this lattice fails to respond to the methods that have been so successful elsewhere [10, 11] have been unfruitful. One possible explanation is the existence of Brinkmann sextupoles [13] in the traditional FFS which do not exist in the local FFS. Creating new tuning knobs which use these sextupoles may be necessary, but this has yet to be studied.

Meanwhile, the local FFS has had much more success [11]. For single-beam tuning with only static misalignments, 90% of machines achieved 102% of the nominal luminosity for the local FFS, which is reasonably close to the goal. Furthermore, [11] also shows that it is capable of meeting the more difficult goals of two-beam tuning under more realistic conditions. For two-beam tuning with only static imperfections, the local FFS reaches 97% of the nominal luminosity with 90% of machines. When including dynamic imperfections in addition to the static, two-beam tuning for the local FFS achieves 89% of the nominal luminosity with 90% of machines.

CONCLUSION

These studies have been performed in an attempt to find the most feasible and cost-friendly design for the CLIC beam delivery system. Initially, the longer, traditional FFS for the CLIC BDS was thought to have been more feasible (albeit more expensive to construct). However, these studies, along with others for the local FFS, have shown this to not be the case.

The local chromaticity correction FFS is not only more feasible to tune using the standard methods [11], but it is also less expensive to construct due to its shorter length.

The only way in which the traditional chromaticity correction scheme would be favorable to the local scheme is if it is capable of reaching a significantly higher overall luminosity on average or could tune significantly more quickly. However, this work shows that, under the same conditions and general methods of tuning, the traditional FFS is incapable of reaching the same luminosity as the local FFS. It is possible that new and different tuning procedures could improve the traditional FFS's luminosity, but the current methods and procedures have failed in this. More study would be required for tuning the traditional FFS to form any definite conclusions.

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