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TUNING SIMULATIONS FOR THE CLIC TRADITIONAL BEAM DELIVERY SYSTEM

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Abstract

As the design of the CLIC beam delivery system (BDS) evolves, tuning simulations must be performed on each of the proposed lattice designs to see which system achieves the highest luminosity in the most realistic manner. This work will focus on the tuning simulations performed on the so-called Traditional lattice design for the center-of-mass energy of 3 TeV. The lattice modifications required to target the most important aberrations and the latest tuning results will be presented.

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Abstract

As the design of the CLIC beam delivery system (BDS) evolves, tuning simulations must be performed on each of the proposed lattice designs to see which system achieves the highest luminosity in the most realistic manner. This work will focus on the tuning simulations performed on the so-called Traditional lattice design for the center-of-mass energy of 3 TeV. The lattice modifications required to target the most important aberrations and the latest tuning results will be presented.

INTRODUCTION

The design beam delivery system (BDS) of the Compact Linear Collider (CLIC) is constantly being updated to reflect the most recent developments in both particle physics and accelerator research and development. There are two basic layouts of the final focus section (FFS) under consideration: the local chromaticity correction scheme [1], and the traditional beam delivery system, which separates the chromaticity correction by plane in two sections. Figure 1 shows diagrams of each of these layouts [2]. The most important difference between the two options is that the traditional scheme is 1460 m in length, while the local scheme is only 450 m. Both are able to achieve nearly the same luminosity

This work will investigate the single-beam tuning of the traditional FFS for the 3 TeV CLIC machine using the simulation codes PLACET [3] and GUINEA-PIG [4]. Past tuning efforts will be reviewed briefly, and current efforts will be described.

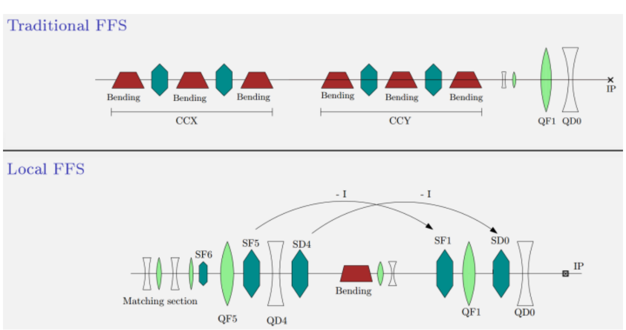

Figure 1: Two final focus system layouts [2].

TUNING PROCESS

There are several general steps which occur during the tuning procedure [5]. In the initial phases, static transverse offsets of up to 10 µm are applied randomly to the beamline elements in the BDS. Then, one-to-one (121) tuning is performed on the uncorrected beam. In order to keep dispersion near design values, dispersion-free steering (DFS1) is performed next. Following this step, in an effort to maximize the luminosity, tuning knobs are used. Another round of dispersion-free steering (DFS2) is subsequently performed. Finally, the simulations then iterate through various tuning knob configurations in order to maximize the luminosity. This general recipe is applied to whichever BDS is under investigation until 90% of seeds reach 110% of the nominal luminosity.

For the early stages, there is an increase in luminosity for each iteration. In time, the luminosity will fail to increase with further iterations, and more specific approaches must be used if the final luminosity goal is not reached.

Generally, these more targeted approaches involve the creation and customization of new tuning knobs which address the specific aberrations present after the many iterations required for tuning.

CUSTOM TUNING KNOBS

As discussed at the Linear Collider Workshop 2016 in Morioka, Japan [6], in order to design custom tuning knobs, one must first identify which aberrations to target. For the 3 TeV CLIC traditional lattice, the increase in luminosity stalled at approximately 9 iterations.

Since luminosity is inversely proportional to the beam size, and since beam size measurements are far faster than luminosity measurements in the simulations, those aberrations that dominate in decreasing the beam size in both planes were identified.

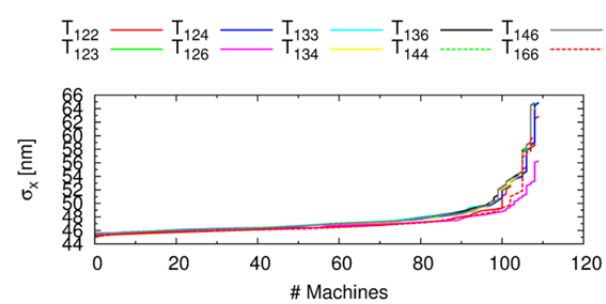

Figure 2: Dominant aberrations in the horizontal plane.

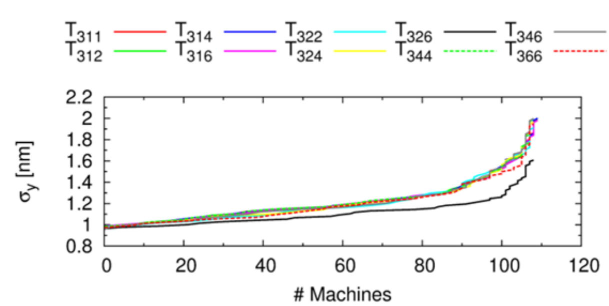

Figure 3: Dominant aberrations in the vertical plane.

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Looking at Figs. 2 and 3, one can identify the most dominant aberrations by finding which will decrease the beam size the most if removed. In the horizontal plane, these were the T_{126}, T_{166}, and T_{122} modes. In the vertical plane, the T_{326} mode was by far the most dominant, and the T_{366} contributed as well.

Since some of these aberrations are of higher-order, additional dimensionless (thin-lens) skew sextupoles were added to the lattice and new knobs were designed.

This method had proven successful for other BDS systems [7]. However, after attempting several iterations, it did not appear that the luminosity was increasing any further for the traditional BDS (see Fig. 4).

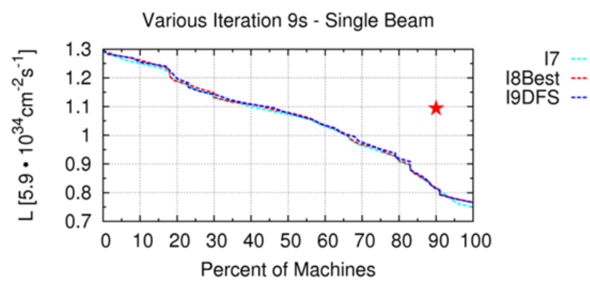

Figure 4: Tuning iterations 7, 8, and 9. Star is goal.

GOING BACK TO THE BEGINNING

At this point, it was decided to return to the very beginning of the tuning procedure and re-evaluate. First, we investigated the weighting parameters used in 121 tuning and DFS1 tuning. For 121 tuning, this parameter is called β, but has no relationship to either the relativistic or twiss parameters. For DFS1, the parameter is called ω_1. During all previous tuning, β was 11 and ω_1 was 73. These values work well for the local scheme, but a series of parameter scans were performed to make sure they work for the traditional scheme (see Figs. 5, 6, 7, and 8).

Simultaneously scanning through values of β and ω_1, the average beam sizes (after 40 seeds) were plotted and the smallest value in each plane was identified. During the first set of scans (Figs. 5 and 6), it was discovered that the smallest beam size in both planes occurred when $\beta = 1$ and $\omega_1 = 0$. Having $\omega_1 = 0$ means that DFS1 is effectively turned off. This result was unexpected, and when the scans for $\omega_1 = 0$ are excluded (Figs. 7 and 8), each plane had different results for β and ω_1. For the horizontal plane, the smallest beam size occurred when $\beta = 118$ and $\omega_1 = -5$. For the vertical plane, the smallest beam size occurred when $\beta = 8$ and $\omega_1 = 1$.

Both of these results are unexpected, and are currently being investigated further. If the results where $\omega_1 = 0$ are correct, it would mean the first stage of DFS tuning either does not help, or may be detrimental to the tuning of the traditional BDS. If the other results are correct and the parameters are dependent upon the plane, this could mean that each plane must be tuned independently rather than simultaneously. Simulations are currently running with each of these conditions to be sure that the results are consistent.

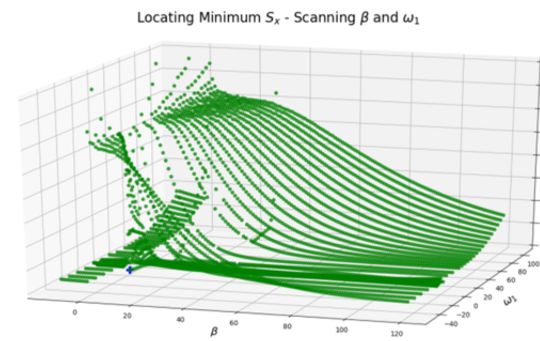

Figure 5: Plotting β vs. ω_1 vs. average beam size, including ω_1=0 data. Each point is the average of 40 seeds.

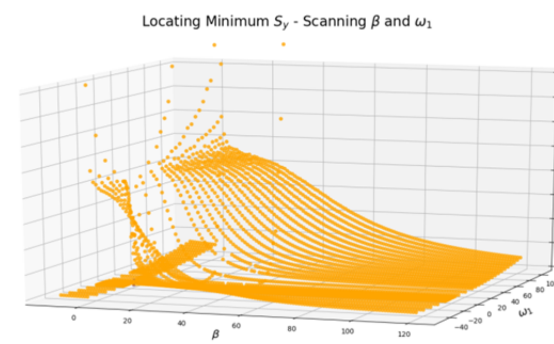

Figure 6: Plotting β vs. ω_1 vs. average beam size, including ω1=0 data. Each point is the average of 40 seeds.

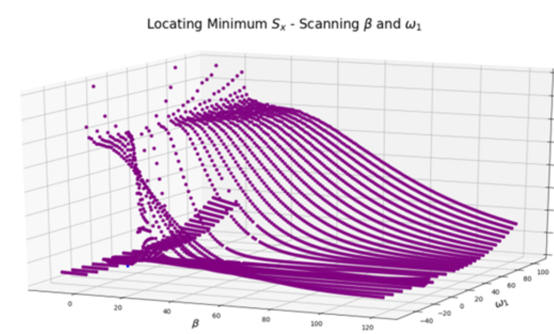

Figure 7: Plotting β vs. ω_1 vs. average beam size, excluding ω1=0 data. Each point is the average of 40 seeds.

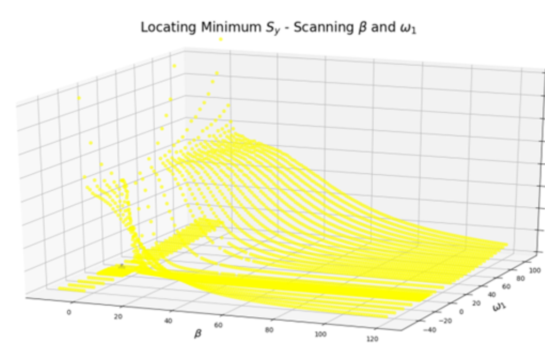

Figure 8: Plotting β vs. ω_1 vs. average beam size, excluding ω1=0 data. Each point is the average of 40 seeds.

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MOVING FORWARD

Due to such unexpected results, a more in-depth investigation is necessary to be sure not only that they are accurate, but also what repercussions may arise.

If the DFS1 tuning stage is not required, or is detrimental to the tuning process, it is simple enough to remove. However, this may have unexpected consequences related to the dispersion being far from nominal. It will likely take several tuning iterations to see if these effects are present.

If each plane must be tuned independently, this would constitute a new tuning method, and would need to be fully investigated from the ground up. It would require brand new codes and procedures to be written. It is unclear if tuning in this manner will succeed in increasing the luminosity, but if these results are confirmed it would warrant further investigation.

The initial findings are already under investigation, though no meaningful results have been acquired at this point. Simulations are running which use these new parameters in the regular tuning procedure so that comparisons to previous studies can be made. Once these results are analysed, the path forward will be made apparent.

CONCLUSION

Contrary to expectations, tuning of the traditional FFS of the CLIC 3 TeV beam delivery system has proven to be more problematic than the local scheme. Thus far, it has not succeeded in reaching the goal of 90% of machines reaching 110% of the nominal luminosity. However, the recent weighting parameter scans indicate that there may be a new direction to take in the tuning procedure. Forthcoming analysis will provide further insight.

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