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Non-linear optimatization of the CLIC FFS

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Abstract

The aim of this work is to improve beam size and luminosity of the CLIC FFS using non-linear elements.

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1 Project Targets

The aim of this project was to use MAD - X [1] and PLACET [5] program to optimize beam size and luminosity. Luminosity is defined [2] as :

$$\mathcal{L} = \frac{f_{rep} n_b N_b^2}{4\pi \sigma_x^* \sigma_y^*} H_D, \tag{1}$$

where N_b is colliding bunch population,σ_x^*, σ_y^* are the transverse r.m.s spot sizes at the IP, H_D is luminosity enhancement factor.

2 Procedure

Program for changes in the MAD - X input files was created as well as program for analyzing the output files from PLACET. This allowed automatics scanning of the influence on the luminosity by individual non-linear elements.

The final output is in the figure 1

```
kocttest kdectest -285 14471447 4.52194e+34 1.67292e+34
kocttest kdectest -285 14471547 4.52194e+34 1.67292e+34
.
.
kocttest kdectest -285 14471847 4.52194e+34 1.67292e+34
```

Figure 1: Output of scanning process. First columns contain name of the element, followed by their value and resulting luminosity.

2.1 Used Tools

- MAD - X [1] is a tool for charged-particle optics in alternating-gradient accelerators and beam lines.
- PLACET [5] (Program for Linear Accelerator Correction Efficiency Tests) was developed to simulate the different beam lines in CLIC. In this project it was used to compute luminosity.
- Python [4] is a general-purpose high-level programming language whose design philosophy emphasizes code readability. In this project it was used with combination with IPython and Emacs to automate the process of optimization.
- Git [3] is a distributed revision control system with an emphasis on speed. Git was initially designed and developed by Linus Torvalds for Linux kernel development.
- MAPCLASS [6] MAPCLASS is a code written in PYTHON conceived to optimize the non-linear aberrations of the Final Focus System of CLIC. MAPCLASS calls MADX-PTC to obtain the map coefficients and uses optimization algorithms like the Simplex to compensate the high order aberrations.

3 Results

Two no-linear elements were introduced into the lattice: octupole (kocttest) and decapole (kdectest). The final values after optimization are: -181.13 T/m^3 for kocttest and 14473947.93 T/m^4 for kdectest.

3.1 Magnets strength

In MAD - X[1] coefficients k_x are used instead of physical strength. For octupole Eq.2 and Eq.3 for Decapole. Values in Tesla can be obtained by integrating with respect to x. For octupole we get Eq.4 and Eq.5 for decapole.

$$k_3 = \frac{1}{p/c}\frac{\partial^3 B_y}{\partial^3 x} \quad [\mathrm{T/m^3}], \tag{2}$$

$$k_4 = \frac{1}{p/c}\frac{\partial^4 B_y}{\partial^4 x} \quad [\mathrm{T/m^3}], \tag{3}$$

$$B_{octupole} = k_3 \frac{p}{c}\frac{x^3}{6}, \tag{4}$$

$$B_{decapole} = k_4 \frac{p}{c}\frac{x^4}{24}, \tag{5}$$

Substituting values from [7] we get Eq.6 for octupole and Eq.7 for decapole.

$$B_{octupole} = k_3 \times 3.3 \times 1500 \frac{(10^{-2})^3}{24}, \approx 0.15\mathrm{T}, \tag{6}$$

$$B_{decapole} = k_4 \times 3.3 \times 1500 \frac{(10^{-2})^4}{24}, \approx 29.85\mathrm{T}. \tag{7}$$

Figure 2 shows beam sizes versus order considered in the simulation. Improvement in y-axis is noticeable on right chart. Graphs on figure 3 and 4 shows dependency of the luminosity on strength of individual non-linear elements. These graphs are the result of the optimization process. Dependency on more than one element was tested using Cartesian product of the values of two elements. Results is shown on figure 5

Parameter	Design	Initial	Final	Improvements
Horizontal beam size [nm]	40	41.50	41.50	0
Vertical beam size [nm]	1	1.36	1.20	0.16
Luminosity $[10^{34} cm^{-2} s^{-1}]$	3.69	4.49	4.54	0.04
Luminosity peak $[10^{34} cm^{-2} s^{-1}]$	1.25	1.66	1.68	0.01

Table 1: Parameters summary. Values before, after optimization and designed values for 3 TeV.

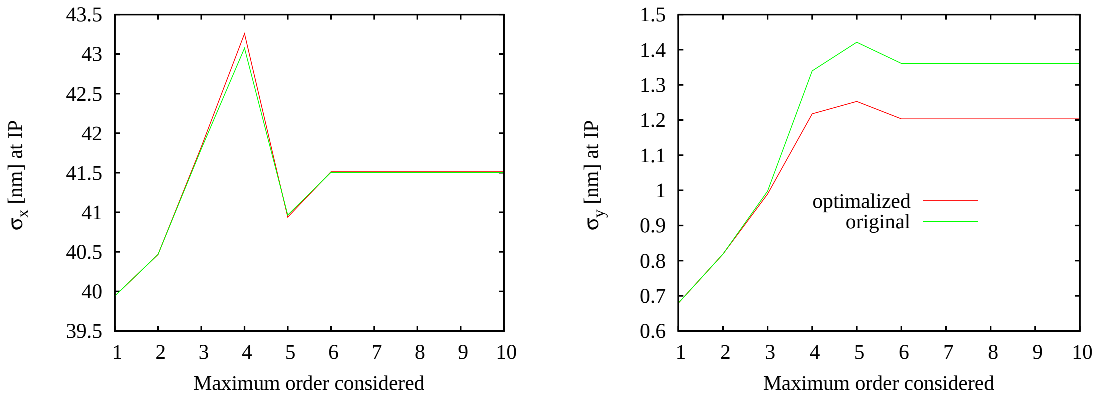

Figure 2: Beam size at the interaction point.

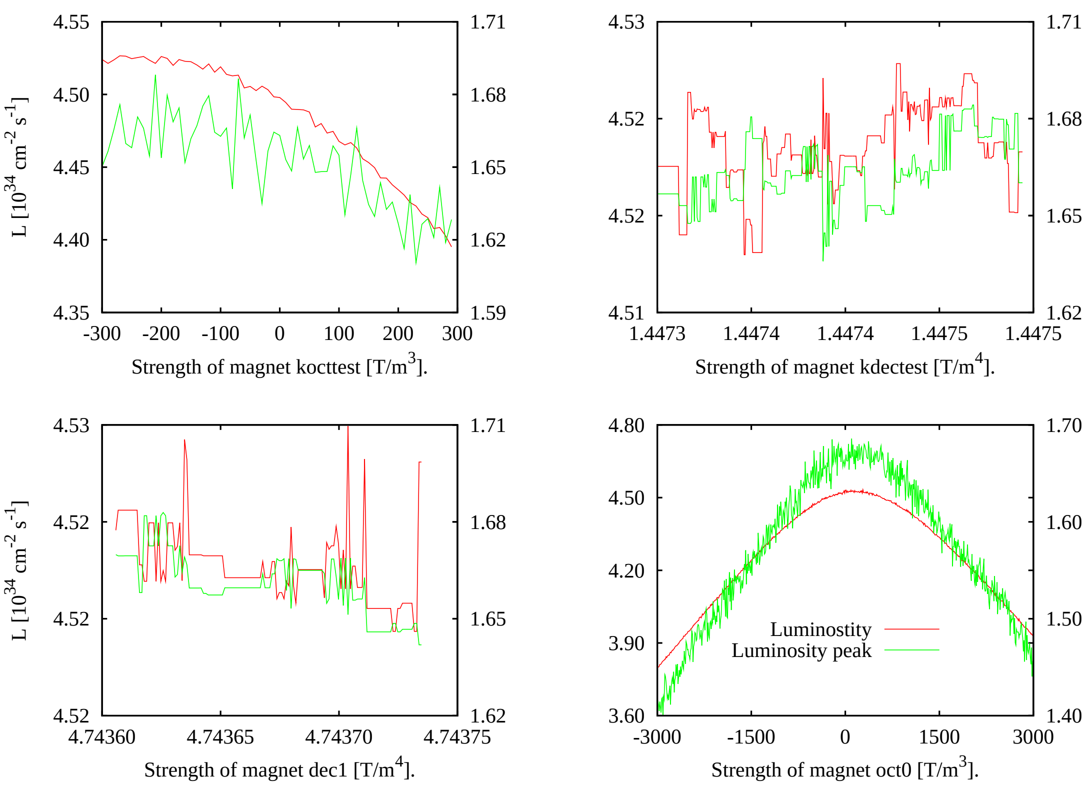

Figure 3: Luminosity dependence on magnet strength.

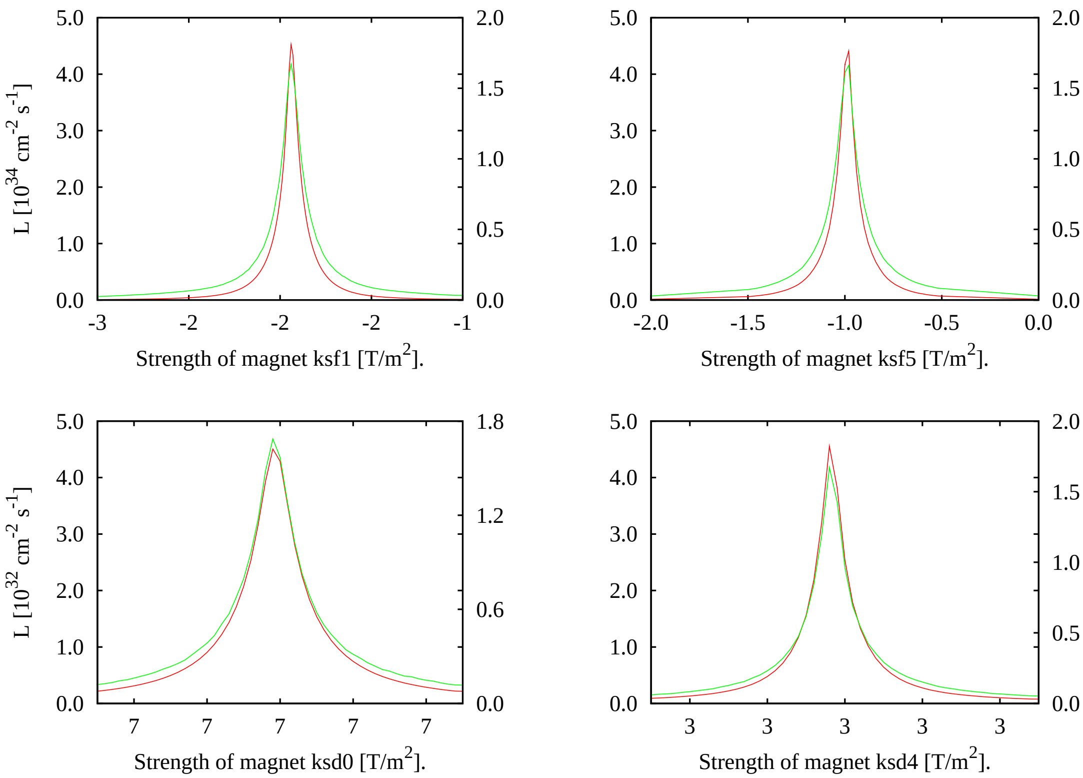

Figure 4: Luminosity dependence on magnet strength.

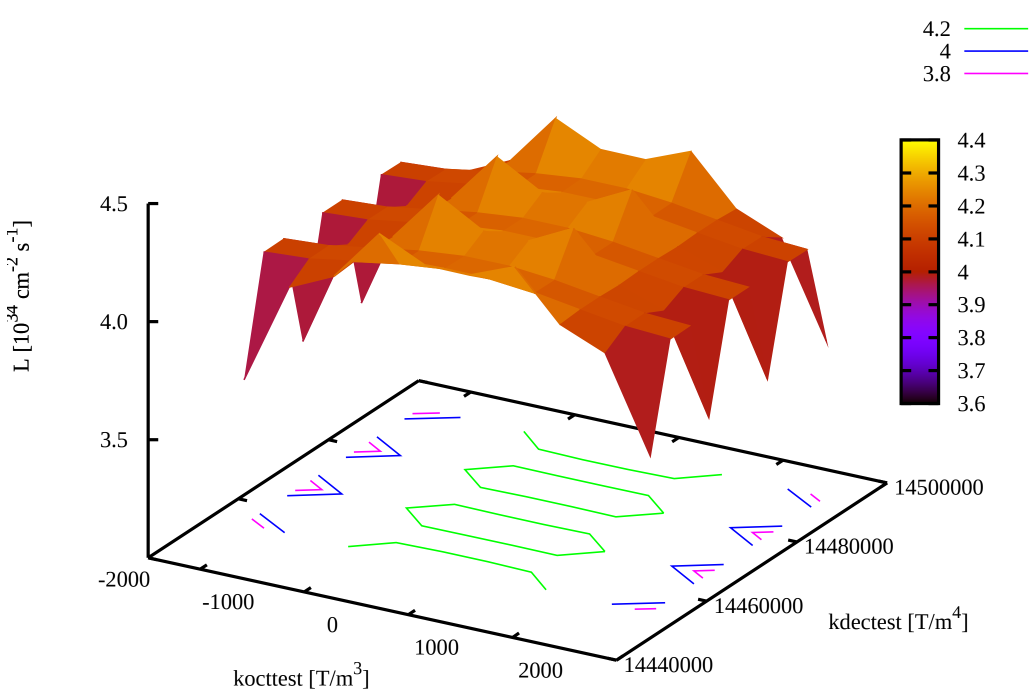

Figure 5: Luminosity dependence on two elements.

4 Conclusion

Automatization of the optimization process led to some improvements in the luminosity and beam size. Individual tests takes 35 seconds on lxplus4 computer. Graph 3 and 4 contains 50 points. Graph 5 contains 1600 points and the stimulation takes 14 hours.

Acknowledgments

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References

[1] Herr, Werner ; Schmidt, F, A MAD - X Primer, 2004

[2] Neil, M., CERN Accelerator School, fifth general accelerator physics course, 1992

[3] GIT, `http://git-scm.com/`

[4] PYTHON, `http://www.python.org/`

[5] PLACET,`http://dschulte.home.cern.ch/dschulte/placet.html`

[6] R. Tomás, MAPCLASS : a code to optimize high order aberrations,CERN-AB-Note-2006-017 `http://cdsweb.cern.ch/record/944769`

[7] R. Mutzner et al., Multi-Bunch eect of resistive wall in the beam delivery system of the Compact Linear Collider, CLIC-note-818, (2010).