

TRADITIONAL FINAL FOCUS SYSTEM FOR CLIC

H.Garcia*, A.Latina, R.Tomas, CERN, Geneva 1211, Switzerland

Abstract

A traditional Final Focus System based on dedicated chromaticity correction sections is presented as an alternative for CLIC Final Focus. The Scheme of the lattice is shown and the luminosity bandwidth is calculated. A systematic tuning using Beam Based Alignment and septupole knobs is performed. The complete comparison to the Local Chromaticity correction scheme is presented.

INTRODUCTION

The main task of a linear collider Final Focus System (FFS) [1] is to focus the beam to the small sizes required at the interaction point (IP). To achieve this, the FFS forms a large and almost parallel beam at the entrance of the Final Doublet (FD), which contains two strong quadrupole lenses. For the nominal energy, the beam size at the IP is $\sigma = \sqrt{\beta^* \epsilon}$, where ϵ is the beam emittance and β^* is the betatron function at the IP. However, a beam with an energy spread σ_δ , the beam size is diluted by the chromaticity of these strong lenses.

The chromaticity scales approximately like $\xi \sim \frac{L^* + L_q/2}{\beta^*}$, where L^* is the distance from the IP to the last quadrupole and L_q is the quadrupole length. Thus the chromatic dilution of the beam size $\sigma_\delta \frac{L^* + L_q/2}{\beta^*}$ may be very large. The design of the Final Focus is driven primarily by the necessity of compensating the chromaticity of the FD.

There are two different approaches in order to compensate the chromatic effect, the traditional scheme, based on dedicated chromatic correction sections for each plane; and the local correction scheme, based on the local correction of the chromaticity. Here we are focused on the dedicated scheme.

LATTICE LAYOUT

In the Traditional FFS, used in the SLC and FFTB in SLAC, the chromaticity is compensated in dedicated chromatic correction sections (CCX and CCY) by sextupoles placed in high dispersion and high beta regions. The geometric aberrations generated by sextupoles are canceled by using them in pairs with a minus identity transformation between them. The advantage of this scheme is its separated optics with strictly defined functions and straightforward cancellation of geometrical aberrations. This makes the system relatively simple for design and analysis. The most important disadvantage is that the chromaticity is not

Table 1: Key parameters of the CLIC Final Focus at the IP

Parameter	Units	Value
Beam energy	TeV	1.5
Last drift L^*	m	3.5
Nominal beam size σ_x/σ_y	nm	40/1
Nominal beta function β_x/β_y	mm	10/0.07
Nominal bunch length σ_z	μm	44
Bunch population		$3.7 \cdot 10^9$

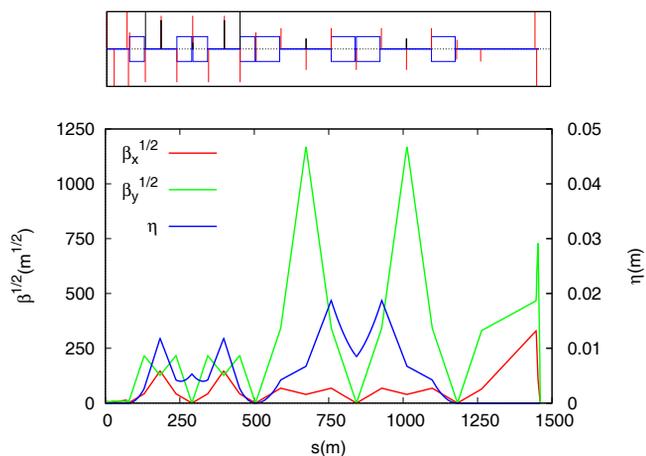


Figure 1: Layout of the FFS with dedicated chromatic correction sections.

locally corrected. The consequence is an intrinsic limitation on the bandwidth of the system due to the unavoidable breakdown of the proper relations between the sextupoles and the FD for different energies. Moreover the system is very sensitive to any disturbance of the beam energy due to synchrotron radiation. The bending magnets have to be large and weak enough to minimize the additional energy spread due to synchrotron radiation. As a result the Beam Delivery System becomes a significant fraction of the length of the accelerator.

Using FFADA (Final Focus Automatic Design and Analysis) [5] we can generate a lattice for a Final Focus with the desired parameters. The lattice layout for the 1.5 km long FFS is shown in Fig. 1. We compare this lattice with two other different lattices: the current lattice of the CLIC FFS with local chromaticity correction scheme and a 3 km long lattice proposed in [3]. The lattice shown in Fig. 1 takes the same parameters for the beam size at the IP and are shown in Table 1.

* hector.garcia.morales@cern.ch

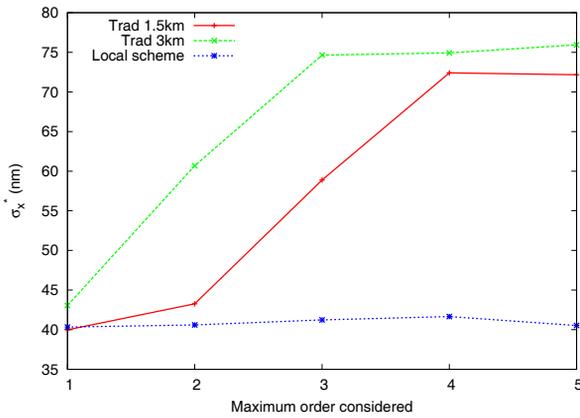


Figure 2: Horizontal beam size for order considered computed by MAPCLASS.

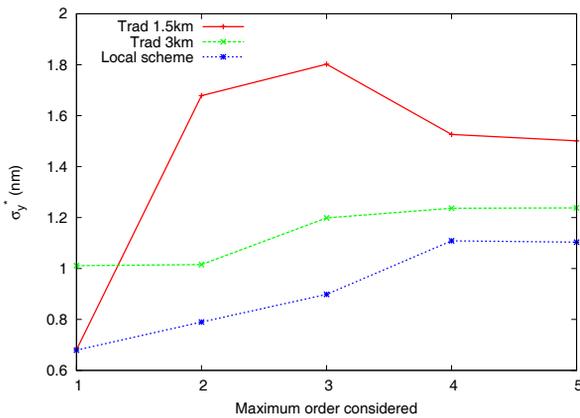


Figure 3: Vertical beam size for order considered computed by MAPCLASS.

BEAM SIZES

The most important parameter that determines the final luminosity of a collider is the beam size at the IP. Due to strong nonlinearities, the beam size might be augmented considerably. In Fig.2 and 3 we see the beam size order by order computed in MAPCLASS [6]. The nonlinearities are better corrected in the local scheme yielding to a smaller final beam size at the IP. We can compare the MAPCLASS results to the beam sizes obtained after tracking using PLACET. Table 2 shows the results for both cases, with and without synchrotron radiation effect. The agreement is complete with the results obtained before.

LUMINOSITY

The luminosity in a linear collider can be expressed as

$$\mathcal{L} = \frac{f_{rep} n_b N^2}{4\pi \sigma_x^* \sigma_y^*} H_D \quad (1)$$

where f_{rep} is the repetition frequency, n_b the number of bunches per pulse, N the number of particles per bunch and $\sigma_{x,y}$ the RMS horizontal and vertical spot size

Table 2: Beam sizes in nm and peak Luminosity for 1% energy offset in units 10^{34}cm^{-2} per BC.

		Trad. 1.5km	Trad 3.0km	Local
rms	σ_x	69.80	76.05	40.39
w/o sync.	σ_y	1.39	1.24	1.11
rms	σ_x	71.62	78.85	48.46
w sync.	σ_y	3.22	1.47	2.69
w/o sync.	$\mathcal{L}_{1\%}^{\text{peak}}$	1.51	1.52	2.24
w sync.	$\mathcal{L}_{1\%}^{\text{peak}}$	1.25	1.37	1.71

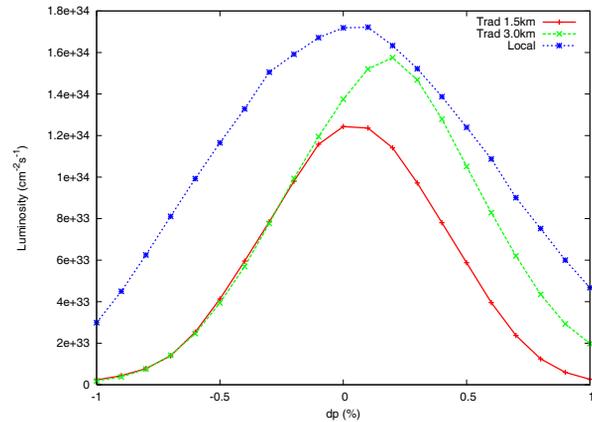


Figure 4: Absolute luminosity for three different schemes: Local scheme, 1.5km and 3.0km traditional schemes.

respectively. Finally, H_D is the enhancement factor due to the pinch effect, the mutual attraction of both beams close to the IP.

In Fig. 4 we see the luminosity as a function of the relative momentum deviation $dp = \frac{dE}{E}$. The local scheme presents a higher peak luminosity due to the better compensation of the nonlinearities. In Fig. 5 are represented the normalized luminosities according to the peak luminosities given in 4. In this case we can compare the bandwidth of both schemes giving again a better performance of the local scheme over both traditional schemes. The length of the system seems to have no influence in the luminosity.

FFS TUNING

The biggest challenge faced by the BDS is the demonstration of the performance assuming realistic static and dynamic imperfections [7]. The diagnostics and the collimation sections have been demonstrated to be robust against a prealignment of $10 \mu\text{m}$ over 500 m. Standard orbit correction techniques, as the 1:1 correction and dispersion free steering, guarantee the beam transport without blow-up in these regions. However this techniques fail at the FFS due to the very non-linear behavior of the system.

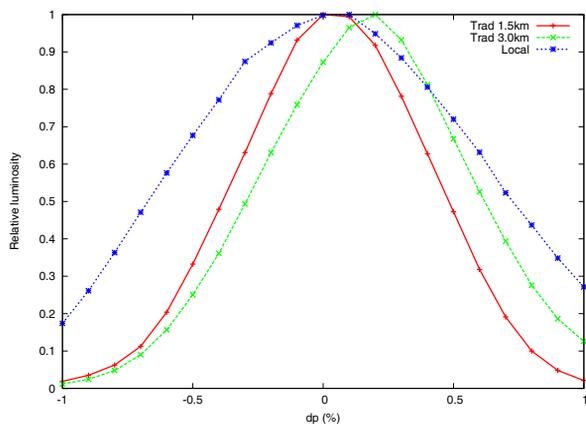


Figure 5: Normalized luminescence for three different schemes: Local scheme, 1.5 km and 3.0 km traditional schemes.

One-to-one correction (1:1)

The most straightforward beam-based alignment method is one-to-one steering. The aim of this alignment procedure is to steer the beam such that the transverse displacements measured by the BPMs are minimized. The beam is steered by using dipole correctors or by using quadrupole displacements. A matrix describing the response of the trajectory to corrector changes may be used to simultaneously adjust all correctors, sometimes called few-to-few steering.

Dispersion Free Steering (DFS)

The principle of DFS consists of a simultaneous correction of the orbit and the dispersion using one of the standard orbit correction algorithms. This guarantees that the beam orbit is flat while at the same time minimizing the residual dispersion. The beam position is measured with a set of N BPMs. The orbit is corrected with a set of M dipole magnets (correctors).

Multiknobs

A knob is a linear combination of variables that are able to modify one property of the beam without changing the others but this is only ensured if the knobs are orthogonal. We use 10 different knobs corresponding to 5 sextupole position in x and y .

Tuning simulation

We simulate the tuning process using an algorithm developed in [8]. We use 110 different seeds with an initial random misalignment of $10\mu\text{m}$ in all the elements of the line and a BPM resolution of 10nm . The tracking simulations are done in PLACET and luminosity is measured with Guinea-Pig, being the luminosity the figure of merit of the optimization.

The tuning simulation results are shown in Fig. for both the local and traditional FFS. The performance of the traditional scheme is clearly better. Almost all the machines keep half of the luminosity and 80% of them are above the 80% of the luminosity.

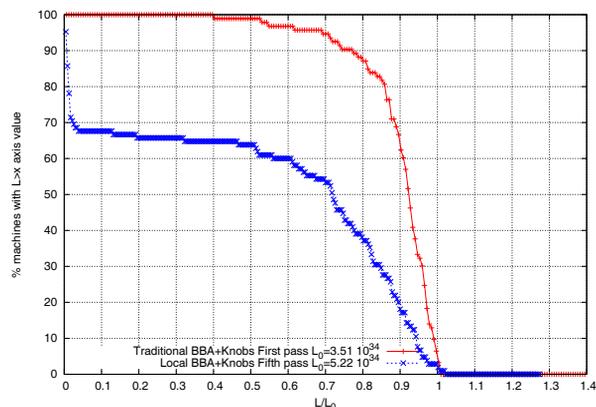


Figure 6: Luminosity performance for 100 statistical realizations of the Traditional and local CLIC FFS after tuning using BBA+Knobs algorithm.

CONCLUSIONS

We have presented an alternative Final Focus System for CLIC at $\sqrt{s} = 3\text{ TeV}$. We have reduced in a factor two the length of the previous traditional system without any significant luminosity loss. We have seen that the general performance is far from the performance of the current local chromaticity correction scheme. Despite of the bad performance we have demonstrated that the tuning process seems to work much better for the traditional scheme due mainly to the orthogonality of the knobs. An optimization of a $\sqrt{s} = 500\text{ GeV}$ lattice is ongoing expecting even better results due to more relaxed energy constraints that imposes a multi-TeV collider.

ACKNOWLEDGMENTS

I want to thank Andrea Latina for his constant support and help in the tuning process and Daniel Schulte for providing us the FFADA code.

REFERENCES

- [1] T.O. Raubenheimer, F.Zimmermann, "Final Focus systems in linear colliders", *Rev.Mod.Phys.* **77**, 1, (2000).
- [2] P.Raimondi, A.Seryi, "Novel Final Focus Design for Future Linear Colliders", *Phys.Rev.Lett.* **86**, 7, (2001)
- [3] F.Zimmermann, R.Helm, J.Irwin, "Optimization of the NLC Final Focus System", (1996)
- [4] R.Brinkmann, "Optimization of the Final Focus System for Large Momentum Bandwidth", DESY-M-90-14, (1990).
- [5] O.Napoly, B.Dunham, "FFADA: Computer Design of Final Focus Systems for Linear Colliders", EPAC'94 (1994).
- [6] R.Tomàs, "Nonlinear optimization of beam lines", *Phys.Rev. STAB*, **9**, 081001, (2006).
- [7] Y.Nosochkov, P.Raimondi, T.O.Raubenheimer, A.Seryi, M.Woodley, "Tuning Knobs for the NLC Final Focus", EPAC'02 Paris (2002).
- [8] A.Latina, "A Novel Alignment Procedure for the Final Focus of Future Linear Colliders", LINAC10, (2010)