CLIC FFS LATTICE PROPOSALS COMBINING LOCAL AND NON-LOCAL CHROMATICITY CORRECTIONS

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Abstract

The requirements on the Final Focusing System (FFS) for a new linear collider has lead to lattice designs where chromaticity is corrected either locally or non-locally. Here, alternative proposals of lattice design are presented for the current CLIC 500GeV beam parameters, combining the local chromaticity correction on the vertical plane and non-local correction on the horizontal. The tight tolerance on phase advances and beta functions imposed to obtain -I transformation required to cancel the chromatic terms is relaxed by enlarging the system length and using a more general transformation definition, aiming to obtain better results in tuning simulations.

INTRODUCTION

The beam size reduction at the Interaction Point (IP) in linear accelerators is fundamental to obtain designed luminosities [1]. The FFS lattice is conceived to demagnify the beam under a chromaticity correction scheme, whose purpose is to reduce second or higher order contributions by cancelling the focal length dependence with energy spread.

The non-local correction scheme [2] compensates upstream the chromaticity in the Final Doublet (FD). A pair of sextupoles is used in horizontally dispersive regions ($\eta_x \neq 0$) to produce opposite sign chromaticity. In addition, these sextupoles are matched to cancel geometrical aberrations, known as -I transformation. Fig. (1) shows schematically the lattice configuration, where QF1 and QD0 constitute the FD, B0 to B5 are dipole magnets to produce horizontal dispersion, SD and SF sextupoles are used to cancel vertical and horizontal chromaticity respectively.

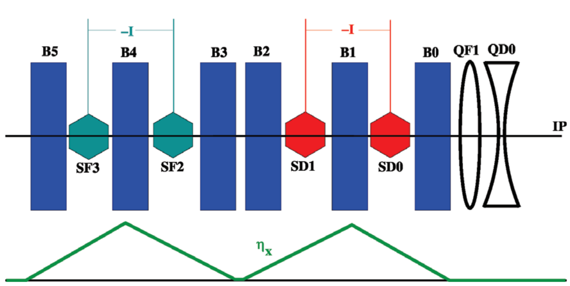

Figure 1: Non-local chromaticity correction.

The local chromaticity correction scheme [3] compensates chromaticity inside the FD. Fig. (2) shows the sextupoles locations. Here, one of the paired sextupoles is outside the horizontally dispersive region to cancel only geometrical contributions to beamsize. Horizontal dispersion angle is different from zero at the IP. This leads to a more compact design.

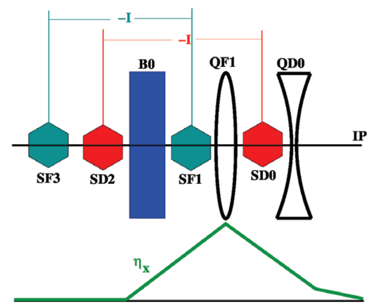

Figure 2: Local chromaticity correction.

Both schemes have been compared for CLIC [4], concluding in smaller lattice length for the local scheme and easier tuning capabilities for the non-local. It has been mainly attributed to knobs orthogonality because the non-local scheme has a separated block per plane, while in the local, the horizontal and vertical correction blocks are interleaved.

THE NON-INTERLEAVED CHROMATICITY CORRECTION LATTICE CONCEPT

In the non-interleaved scheme, the idea is to preserve the knobs orthogonality by putting horizontal and vertical chromatic corrections in different lattice sections while keeping the vertical local correction. One of the paired sextupoles is inside a horizontal dispersive region while the other remains outside to cancel geometric contributions.

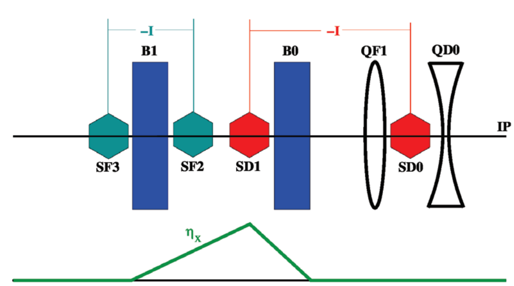

Figure 3: Non-interleaved chromaticity correction.

Horizontal dispersion is generated over a common region and it is cancelled upstream, before the IP. Fig. (3) shows QD0 preceded by a sextupole SD0, which is matched with a second SD1 by the -I transformation. The same configura-

ISBN 978-3-95450-132-8

tion is used to cancel horizontal chromaticity in an upstream section of the lattice, using SF sextupoles.

GEOMETRIC TERMS CANCELLATION

All chromatic correction schemes use a pair of matched sextupoles to cancel one another geometrical components. It is generally noted as the -I transformation. However, calculations in [5] show that the -I transformation is one particular solution, and having a pair sextupoles as in Fig. (4) joined by a transport matrix T_{12}, the general solution is $t_{12} = 0$, $t_{34} = 0$, $t_{11}t_{22} = 1$, $t_{33}t_{44} = 1$, $k_{s1} = -k_{s2}t_{11}$ and $t_{11} = \pm t_{33}$, where, t_{ij} are the matrix elements and k_{s1}, k_{s2} are the sextupole gradients. This general solution is used to generate different lattice versions, one with -I transformation and others where the general cancellation is achieved.

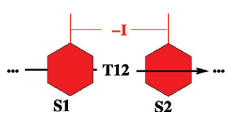

Figure 4: Sextupoles joined by the transport matrix T_{12}.

Tolerances

Previous general expressions set restrictions over the optic lattice parameters and tolerances should be set during the lattice design stage. In order to evaluate those tolerances, $\Delta\phi_x, \Delta\phi_y, r_x, r_y$ have been defined as $\phi_{x12}+\Delta\phi_x = \pi$, $\phi_{y12}+\Delta\phi_y = \pi$, $k_{s1}\beta_{x1}^{3/2} - k_{s2}\beta_{x2}^{3/2} + r_x = 0$ and $k_{s1}\beta_{y1}^{3/2} - k_{s2}\beta_{y2}^{3/2} + r_y = 0$ respectively, where $\Delta\phi$ is the phase advance error, r is the residual after subtractions and ϕ, β are the optical parameters in horizontal x and vertical y planes for both sextupoles $S1$ or $S2$.

Factors $\alpha_{x1}\Delta\phi_x$, $\alpha_{x2}\Delta\phi_x$, $\alpha_{y1}\Delta\phi_y$, $\alpha_{y2}\Delta\phi_y \ll 1$, with α the optic parameter, are conditions to achieve geometrical terms cancellation. The FD requires phase advances finely matched because α and β are high. β_y/β_x ratio can be chosen to match sextupole strengths.

CHROMATICITY

Following the properties of telescopic systems [6], a FD as in Fig. (5), where $r = L/L_{IP}$ and $r_{im} = L_{IM}/L_{IP}$, the β functions can be written as $\beta_{\substack{x\\y}0} = \frac{L_{IP}^2}{\beta^*_{\substack{x\\y}}}$ for $QD0$ and $\beta_{\substack{x\\y}1} = \beta_{\substack{x\\y}0}\left(1 + r \pm \sqrt{\frac{r}{r_{im}} + r + \frac{r^2}{r_{im}}}\sqrt{\frac{1+r}{1+r/r_{im}}}\right)^2$ for $QF1$, using $\left(\frac{\beta^*}{L_{IP}}\right)^2 \ll 1$. Chromaticity ξ can be evaluated as

$$\xi_{\substack{x\\y}} = \mp\frac{1}{4\pi}\left(\beta_{\substack{x\\y}1}k_1 l_1 - \beta_{\substack{x\\y}0}k_0 l_0\right) = \frac{1}{4\pi}\frac{L_{IP}}{\beta^*_{\substack{x\\y}}}\Xi_{\substack{x\\y}}(r, r_{im}),$$

where β^* is the β function at the IP and

$$\Xi_{\substack{x\\y}}(r, r_{im}) = \mp\sqrt{\frac{1}{r r_{im}} + \frac{1}{r} + \frac{1}{r_{im}}}\sqrt{\frac{1 + r/r_{im}}{1+r}} \left[\left(1 + r \pm \sqrt{\frac{r}{r_{im}} + r + \frac{r^2}{r_{im}}}\sqrt{\frac{1+r}{1+r/r_{im}}}\right)^2 - \left(\frac{1+r}{1+r/r_{im}}\right)\right].$$

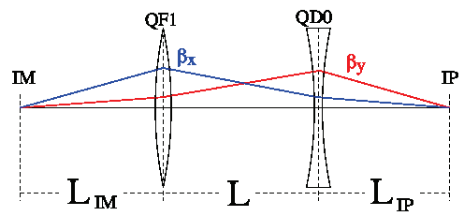

Figure 5: FD with focal points IM and IP at different distances.

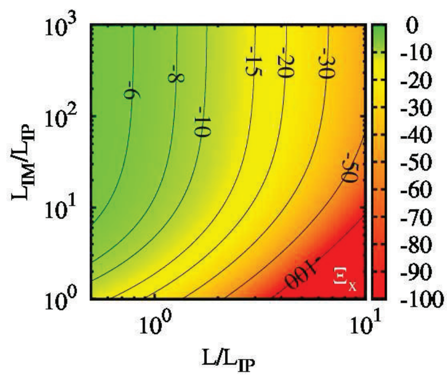

Figure 6: Horizontal normalized chromaticity.

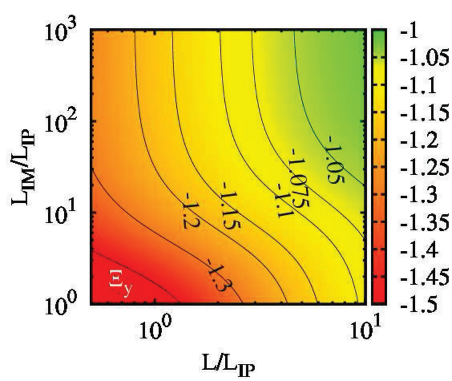

Figure 7: Vertical normalized chromaticity.

Figures (6-7) show the functions Ξ_x and Ξ_y normalized to L_{IP}/β^* units. Adding up the horizontal and vertical terms,

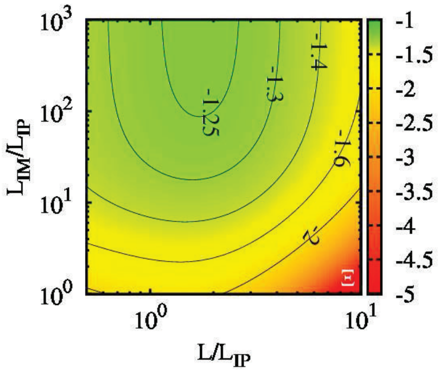

Figure 8: Added horizontal and vertical chromaticit CLIC 500 GeV.

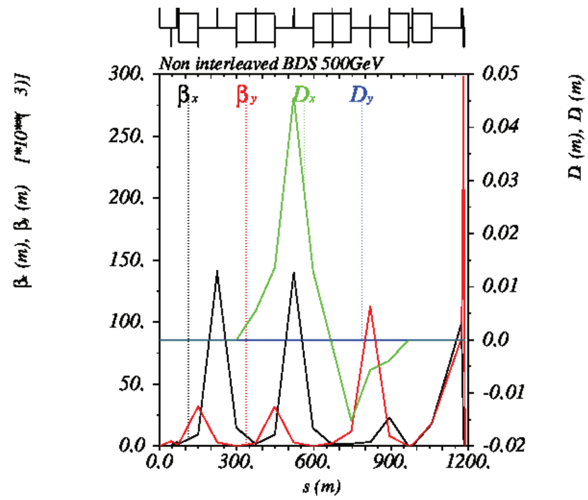

Figure 9: Non-interleaved lattice design for CLIC 500 GeV.

$$\xi = \xi_x + \xi_y = \frac{1}{4\pi}\frac{L_{IP}}{\beta_y^*}\left(\frac{\Xi_x(r,r_{im})}{\beta_x^*/\beta_y^*} + \Xi_y(r,r_{im})\right)$$
$$= \frac{1}{4\pi}\frac{L_{IP}}{\beta_y^*}\Xi(\beta_x^*/\beta_y^*,r,r_{im}).$$

Figure (8) corresponds to ξ for CLIC 500 GeV [7], $\beta_x^*/\beta_y^* = 8.0\text{mm}/0.1\text{mm} = 80$. For a given L_{IM}, the minimum added chromaticity in the FD is found when L is one or two times the distance to the IP.

THE LATTICE

Using the CLIC 500 GeV parameters, new lattices were designed in MAD-X [8] following the previous considerations and those in [9]. Fig. (9) is an example. It is worth to note the change of sign in the horizontal dispersion function D_x from the horizontal chrom correction to the vertical. Phase advances have been matched to 10^{-6} precision due to high α values in the FD. MAPCLASS2 [10–13] has been used to calculate the beamsize giving a linear vertical beam size of 1.86nm and 3.08nm to the second order.

CONCLUSION

Chromaticity in the FD has been theoretically addressed. FD length between one and two times the distance to the IP minimizes the added vertical and horizontal chromaticity. Tolerance in geometrical terms cancellation has been analyzed, where the product of the alfa lattice function and the phase advance mismatch should be much lower than 1. In addition, β lattice functions do not need to be identical in the paired sextupoles.

These conclusions and the non-interleaved chromatic correction scheme have been used to design lattice in MAD-X for CLIC 500 GeV. Beam size has been calculated using MAPCLASS2.

This work will continue with a final design and tuning capabilities analysis.

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ISBN 978-3-95450-132-8