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AB-Note-2007-006

Optimization of the CLIC Final Focus dispersion without using extra multipolar components

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Abstract

We optimize the nominal final focus system for CLIC to maximize the luminosity at the IP. We investigate the effect of quadrupole optimization after sextupole optimization for high and low dispersion reductions. Finally we try to improve our optimization further via a small corrective optimization and check that the optimal dispersion reduction also holds for the entire Beam Delivery System (BDS).

Geneva, Switzerland

January 22, 2007

Introduction

The nominal final focus system (FFS) of the CLIC follows the design given by P. Raimondi and A. Seryi in [1]. This design, in its original configuration, contains high order aberrations visible, for instance, in deformations of the phase-space shape. In [3] it was shown that a reduction of the dispersion led to a luminosity increase for a modified version of the FFS with more non-linear elements. It is the scope of this paper to find the optimum dispersion for the nominal FFS and evaluate the luminosity gain.

Optimization Method and Solution Stability

We use the MAPCLASS [2] to maximize the luminosity for different dispersions. The different dispersion levels are obtained by scaling the bending angles of the FFS dipoles. The optimization is done in two steps, first optimizing the sextupole strengths and secondly the quadrupole strengths (the magnet names are given in Table 1). We do the calculations up to sixth order and only introduce synchrotron radiation in the luminosity calculation.

First step	SF6, SF5, SD4, SF1,SD0
Second step	QF8, QD7, QF3a, QF3b, QD2

Table 1: Sextupoles and quadrupoles used in the two steps of the optimization. The numbers appearing in the names are ordered in increasing distance to the IP.

To test the stability of the solution, we started a calculation from zero sextupole strength for all the sextupoles. Even when doing so, the Simplex method still converges to the right solution.

Results

We see from Figure 1, that by decreasing the dispersion, we can achieve a luminosity of $1.04 \pm 0.03 \cdot 10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which is a 28% increase from the nominal FFS. The Figure furthermore shows, that the effect of changes in the quadrupole strength is greatly decreased as the dispersion decreases, as it would be expected. At around 25% reduction of the dispersion, the effect of quadrupole optimization is, within the errorbars, completely negligible.

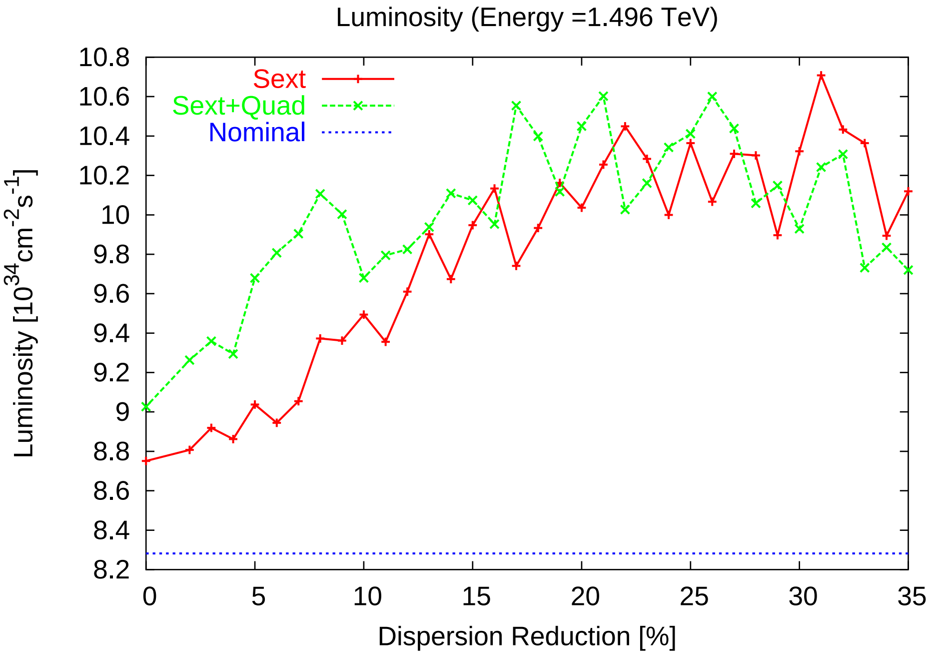

Figure 1: Luminosity versus dispersion reduction through the FFS.

As a test of validity, we ran an optimization of all ten parameters, starting from the optimized values found after the quadrupole optimization. This was done to check for any cross correlations between the two parameter-sets. This attempt did not yield any improvement of the luminosity beyond the error-bars, and we therefore believe, that the two parameter-sets are only weakly correlated.

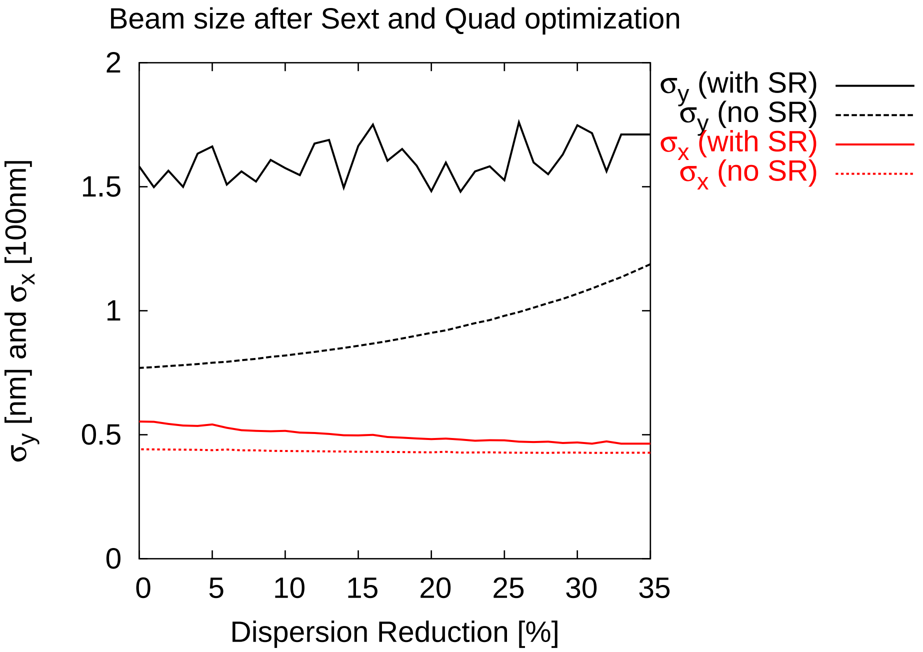

Figure 2: Beam size after optimization of sextupoles and quadrupoles. Values are shown for calculations with and without synchrotron radiation.

We see in Figure 2 that the vertical beam size is roughly constant, when we include the synchrotron radiation, while the horizontal beam size decreases with the dispersion. This means that the general gain we see in the luminosity is contributed by a change in the horizontal size of the beam. We would expect the curves with and without radiation considered to go asymptotically toward each other as the dispersion goes to zero, as the radiation of the beam is mainly due to the dispersion. For the horizontal beam size, this is verified by Figure 2. In the vertical case the dispersion reduction is not investigated to a low enough value for it to be verified, but we do see the two curves approach each other.

Based on these results, a dispersion reduction of 21 % is the best choice. Furthermore, a decrease in dispersion would mean an increase in multipole strength, which would lead to an increased orbit instability. We find for this dispersion reduction, that the multipole values should be increased from the nominal values by the percentage given in Table 2.

Name	Strength Correction [%]	Name	Strength Correction [%]
SD0	27.0	QD2	0.03
SF1	27.4	QF3a	0.08
SD4	26.6	QF3b	-0.26
SF5	24.6	QD7	-0.64
SF6	8.2	QF8	1.10

Table 2: Optimized multipole strengths for a 21 % dispersion reduction.

Plotting the horizontal phase-space distribution (Figure 3) and beam profile (Figure 4) for the 21 % dispersion reduction, we see that there are still a few particles in the far outer rims of the beam, but this is only about 0.1 % of the particles. This could probably be improved by adding higher order multipolar correctors.

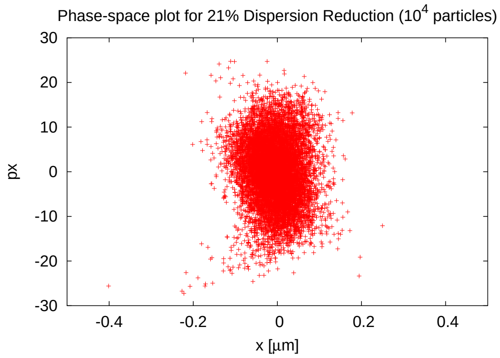

Figure 3: Phase-space plot of the (x,p_x)-plane for 21% dispersion reduction.

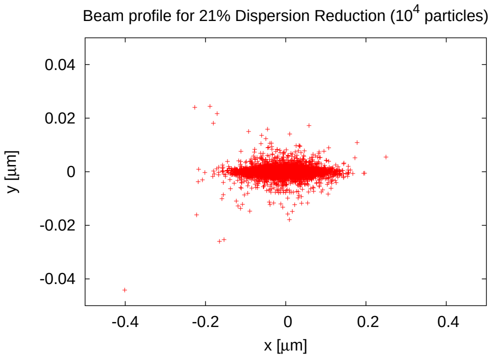

Figure 4: Beam-profile at the IP for 21% dispersion reduction.

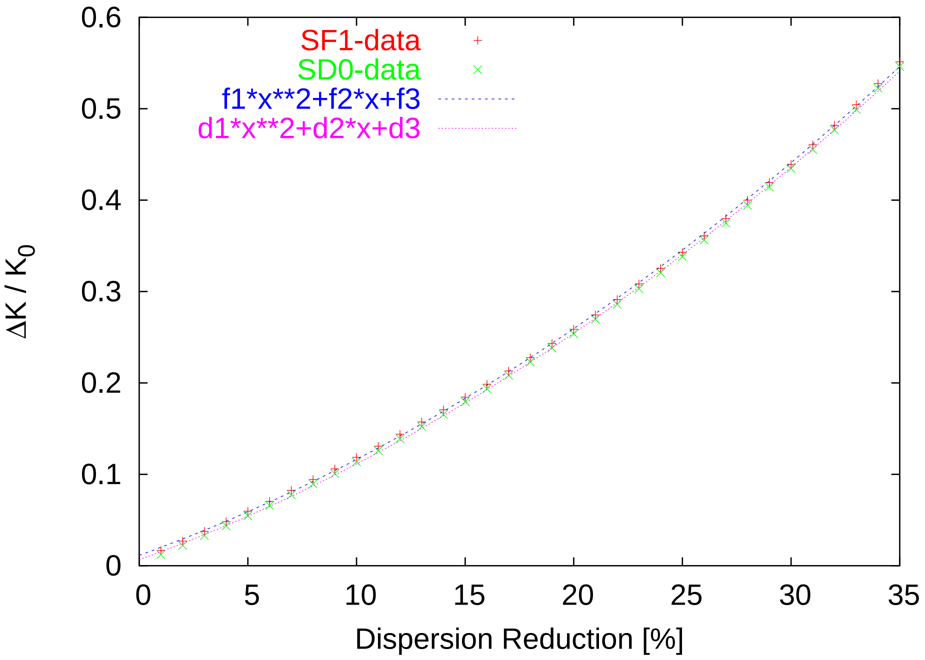

Figure 5: Relative increase in the sextupole strength.

The evolution of the strengths of SD0 and SF1 as a function of the dispersion reduction in the FFS are shown in Figure 5. The coefficients of parabolic fits are given in the Table 3

Coefficients: $ax^2 + bx + c$			
SF1		SD0	
a	$1.92 \cdot 10^{-4}$	a	$1.92 \cdot 10^{-4}$
b	$8.57 \cdot 10^{-3}$	b	$8.56 \cdot 10^{-3}$
c	$1.14 \cdot 10^{-2}$	c	$6.61 \cdot 10^{-3}$

Table 3: Fitting parameters for SDF1 and SD0.

Verification of dispersion reduction

Performing the same optimization to the entire BDS, we get Figure 6 by doing the optimization described in Table 4.

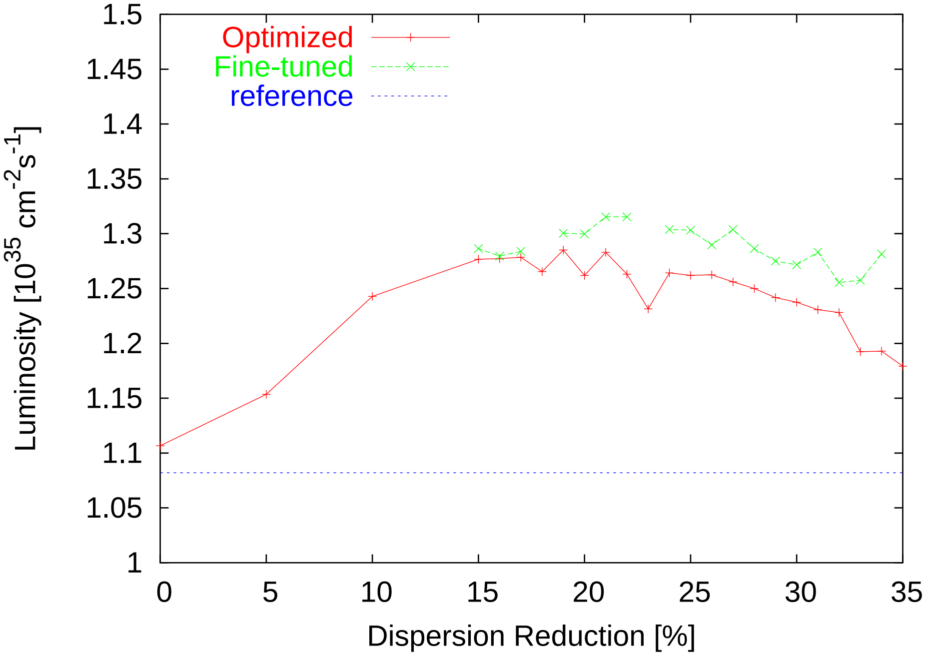

Figure 6: Luminosity versus dispersion reduction through the BDS.

First step	SF6, SF5, SD4, SF1,SD0
Second step	OF1, OD0, OF4, OD4
Third step	DD0, DF0, DF4
Fourth step	QF8, QD7, QF3a, QF3b, QD2
Fine-tuning	All of the above

Table 4: Sequence for adjusting the relevant circuits.

This shows that the optimum of 21% dispersion reduction also holds for the entire BDS. We see that the luminosity increase is reduced from the previous 28% to 18%, when the entire BDS is taken into consideration.

Conclusion

We have found that a 21 % reduction in the final focus dispersion of CLIC, increases the luminosity by 18 %. This reduction also gives a more Gaussian shape of the beam.

References

[1] P. Raimondi and A. Seryi, “Novel Final Focus Design for Future Linear Colliders”Phys. Rev. Lett. **86**, 3779-3782, 2001.

[2] R. Tomás, “MAPCLASS: A code to optimize high order aberrations”, CERN-AB-Note-017 ABP, 2006.

[3] R. Tomás, “Non-Linear Optimization of Beam Lines”, CLIC Note 659, 2006.