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OPTIMIZATION OF THE MOMENTUM BANDWIDTH FOR FINAL FOCUS SYSTEM IN CEPC*

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Abstract

With the discovery of the higgs boson at around 125GeV, a circular higgs factory design with high luminosity ($L \sim 10^{34}\ cm^{-2}s^{-1}$) is becoming more popular in the accelerator world. To achieve such high luminosity, a final focus system in non-local chromaticity correction scheme with very low β functions at the interaction point is designed. The narrow momentum bandwidth is a crucial problem of this kind of design. It is shown that by introducing additional sextupoles the momentum acceptance of the CEPC final focus system can be increased by about a factor of four.

INTRODUCTION

With the discovery of a Higgs boson at about 125 GeV, the world high-energy physics community is investigating the feasibility of a Higgs Factory, a complement to the LHC for studying the Higgs [1]. There are two ideas now in the world to design a future higgs factory, a linear 125 × 125 GeV e^+e^- collider and a circular 125 GeV e^+e^- collider. From the accelerator point of view, the circular 125 GeV e^+e^- collider, due to its low budget and mature technology, is becoming the preferred choice to the accelerator group in China. In order to achieve high luminosity ($L \sim 10^{34}\ cm^{-2}s^{-1}$), the beam dimensions at the interaction point have to be extremely small, typically $\sigma_x^* \sigma_y^* \sim 10^{-11}\ cm^2$. This requires, in addition to small beam emittances, a beam-optical system which produces very low β functions at the interaction point. Unavoidably, the natural chromaticity of such a system becomes very large and its compensation difficult. On the other hand, high luminosity and overall efficiency of the collider calls for a high bunch intensity which in turn increases the momentum spread within a bunch due to the longitudinal wakefields in the linac. It is therefore clear that a large momentum acceptance of the final focus system (usually defined as the range of δp/p for which the spot size at the interaction point varies by less than a factor of two) is highly desirable.

In this paper, the limitation of the momentum bandwidth is first analyzed. An improved chromaticity correction section is achieved by adding Brinkmann sextupoles. The momentum bandwidth of the final focus system is then increased by a factor of four. The performance of the optimized system is investigated with particle tracking simulations.

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-I TRANSFORMATION MATRIX BREAKDOWN

The CEPC final focus system are designed that the chromatic aberrations caused by the final focus doublet are compensated with a two-family non-interleaved sextupole distribution (Fig. 1). Each family consists of two identical sextupoles connected by a $-I$ transformer. The non-interleaved scheme of the sextupoles almost cancels the pure geometric aberrations from the sextupoles except for the aberrations produced by the finite thickness of the sextupoles.

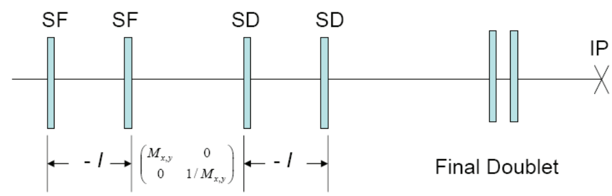

Figure 1: Sextupole families.

The increase of the vertical beam size due to the thickness l_s of the sextupole is written as [2]:

$$\Delta_y \equiv \frac{\Delta\sigma_y^{*2}}{\sigma_y^{*2}} = \frac{5}{12}\frac{k'^4 \beta_y^4 \varepsilon_{Ny}^2 l_s^2}{\gamma^2} \quad (1)$$

Where k', l_s and β_y are the strength, thickness of the SD sextupole and the vertical β function at the sextupole.

HIGH ORDER ANALYSIS IN CEPC FFS

Due to the breakdown of the $-I$, the non-linear kicks for off-momentum particles are no longer cancelled. The aberrations which caused by this will degrade the momentum acceptance for off-momentum particles. We analyzed the high-order aberrations of CEPC final focus system with different energy spread using a code called MAPCLASS [3] which is developed in CERN.

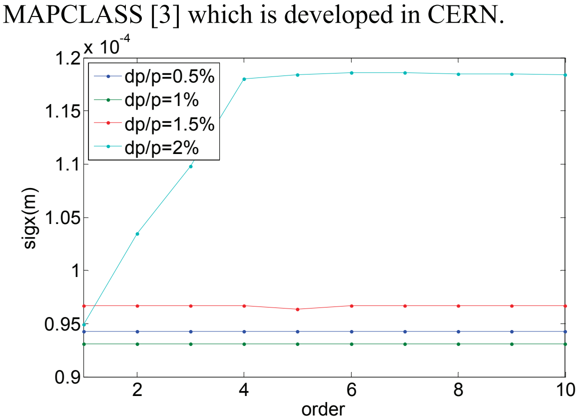

Figure 2: Order analysis of horizontal in CEPC FFS.

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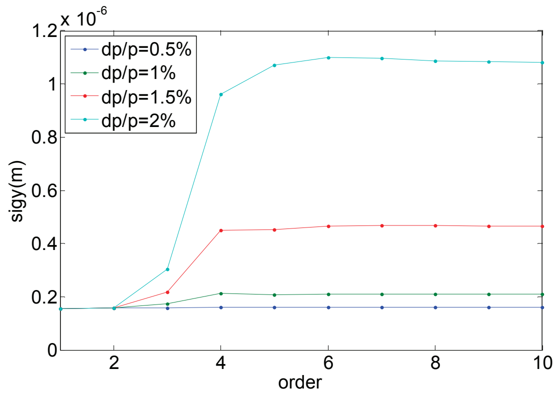

Figure 3: Order analysis of vertical in CEPC FFS.

As can be seen in Fig. 2 and Fig. 3, the third order aberrations may contribute a lot to the final beam size at IP, but the 4th order may be the dominant.

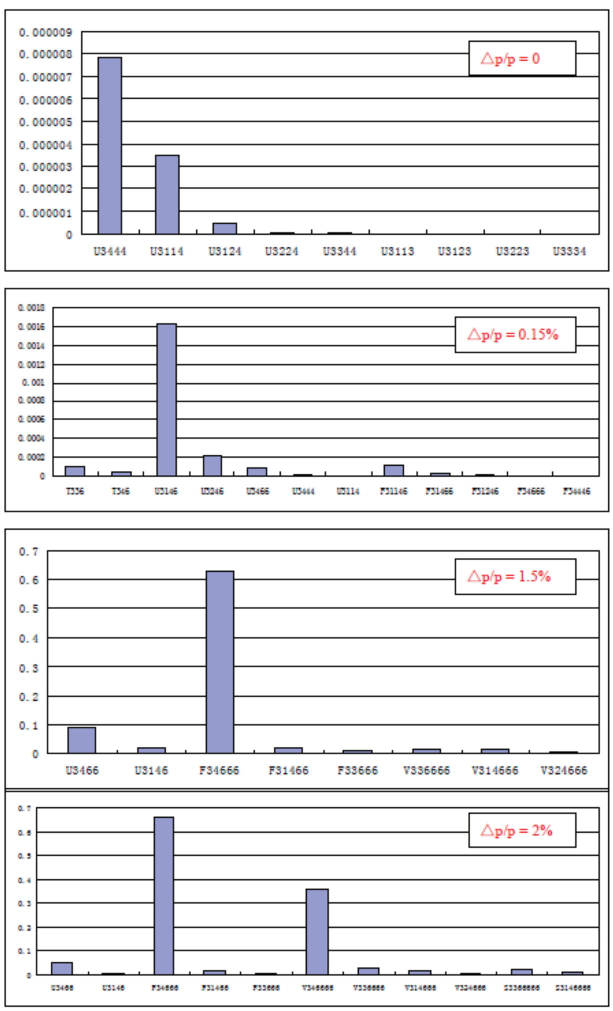

Figure 4: Aberrations in CEPC FFS with different energy spread.

In Fig. 4, after analyzing the high order aberrations in the CEPC FFS, the main contribution comes from the four order term F34666 which is shown in the fourth plot δp/p=2% case. And the third order term U3466 also contributes a lot. Compared with the magnitude of the aberrations in the δp/p=0 case, in which the magnitude of the aberrations is much smaller than the ones of 0.15%, 1.5%, and 2%, It tells us that the dominant aberrations are chromatic.

OPTIMIZATION OF THE MOMENTUM BANDWIDTH IN CEPC FFS

It has been demonstrated by Brinkmann [4] that by optimizing the chromatic properties of a final focus system with the help of additional sextupoles, a large momentum acceptance can be achieved. Since the dominant aberrations comes from the chromatic, we put ten additional sextupoles close to the quadrupoles in the dispersive region. Figure 5 is the twiss figure of the 170 m CEPC FFS, in which the red arrows show the location of the Brinkmann sextupoles.

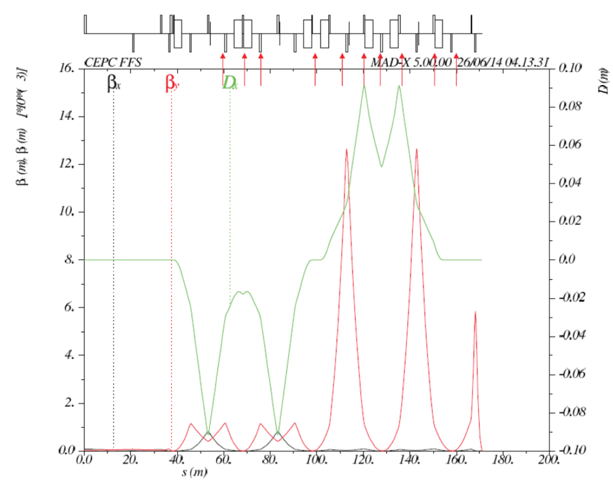

Figure 5: Brinkmann sextupoles in CEPC FFS.

By optimizing the locations and strengths of the sextupoles in MAPCLASS, which allows following an ensemble of trajectories through the beamline, to determine the spotsize at the interaction point, a better momentum bandwidth is achieved in the CEPC FFS. The simulations are done for a Gaussian initial distribution of the transverse coordinates and a Gaussian distribution of δp/p which is cut at 3σ. 10000 particles are tracked and at the interaction point the rms beam size is got to the transverse distributions. The results of the β function bandwidths optimization is shown in Fig. 6, and the beam size bandwidth in Fig. 7.

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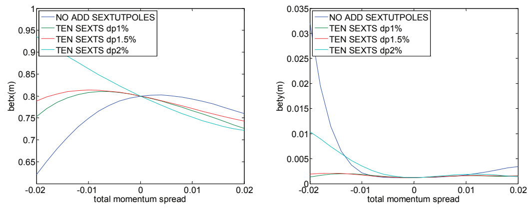

Figure 6: β function bandwidth for optimization in CEPC FFS.

The chromatic variation of the β-function for the system before optimization is shown in blue line. The momentum bandwidth is limited to less than 0.4%. For energy spread 1% and 1.5%, the β_x is more flat than the one without adding ten Brinkmann sextupoles. The variance ratio of β_y is much more flat with ten sextupoles than without the sextupoles.

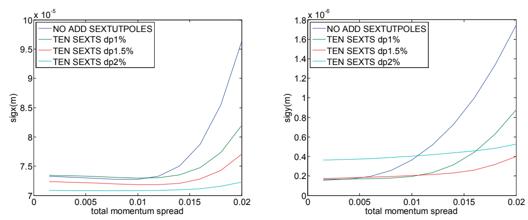

Figure 7: Beam size bandwidth for optimization in CEPC FFS.

For the horizontal beam size, the bandwidth seems improved obviously with ten Brinkmann sextupoles than without. For the vertical beam size, when the energy spread smaller than 1.5%, the bandwidth is more flat than the initial without ten sextupoles. But beyond 1.5%, this will become worse.

CONCLUSION

The narrow bandwidth is a common disadvantage of the non-local type Final focus system with non-interleaved sextupoles chromatic correction scheme. This is caused by the –I transformation matrix breakdown coming from the finite thickness sextupoles, which is demonstrated firstly in this paper. We analyzed the aberrations of CEPC FFS in different energy spread cases, and found that the dominant one is the fourth order. It has been pointed out by Brinkmann that the momentum bandwidth of the final focus system can be optimized by introducing additional sextupoles. We validate this method and enlarged the momentum bandwidth of CEPC FFS by a factor of four.

ACKNOWLEDGMENT

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