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THE CEPC LATTICE DESIGN WITH COMBINED DIPOLE MAGNET*

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Abstract

For the lattice of CEPC collider ring, the combined magnet (dipole + sextupole) scheme has been developed to reduce the power consumption of the stand-alone sextupoles. The power consumption of sextupoles has been decreased by 75% due to 50% reduction of strength. The dynamic aperture for the combined magnet scheme is as good as the original lattice. The magnet design for this kind of combined dipole has been done which provides a good support for this new idea.

INTRODUCTION

For the collider ring of CEPC, the arc section is composed by FODO cells with 90/90 degrees phase advances. Non-interleaved sextupole scheme is adopted to cancel the self non-linearity of the sextupoles [1, 2]. Two rings for electron beam and positron beam are close to each other in order to use twin aperture dipoles and quadrupoles, and hence reduce the machine cost. Only sextupoles are independent for two rings. Due to the strong strength for chromaticity correction, the power consumption of the arc sextupoles is unreasonable which is 16.7 MW with copper coils compared to 6.5 MW for all the dipoles with aluminum coils. According to the relation between power consumption and strength of sextupole in formula (1), reducing the strength of the stand-alone sextupoles can help decrease the power consumption.

$$P_{sex} \propto r^6 k_2^2 L_{sex} \quad (1)$$

In this paper, we considered the combined dipole magnet which is a combination of dipole and sextupole to reduce the strength of sextupoles by a half so that the power consumption of the stand-alone sextupoles is reduced by 75%.

LATTICE WITH COMBINED DIPOLE MAGNETS

In the arc of CEPC collider ring, there are five dipoles between two quadrupoles and the length of each dipole is 5.8 m. The combined sextupoles are located at the first and fifth dipoles [3] where the correction of linear chromaticity is most effective due to the maximum difference of βx and βy as shown in Fig. 1. Our design goal is to correct half of the linear chromaticity by the combined sextupoles and correct the other half linear chromaticity as well as higher order non-linearity by the original independent sextupoles.

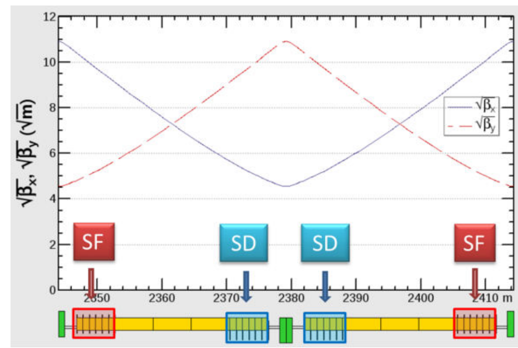


Figure 1: Lattice design with combined dipole magnets.

With this kind of lattice design, we need two kinds of dipole magnet shown in Fig. 2 [4]. One is the special dipole magnet attached sextupole component and the other is the common one in the middle of two quadrupoles. While no additional power sources are needed for SF and SD in the combined dipole magnet.

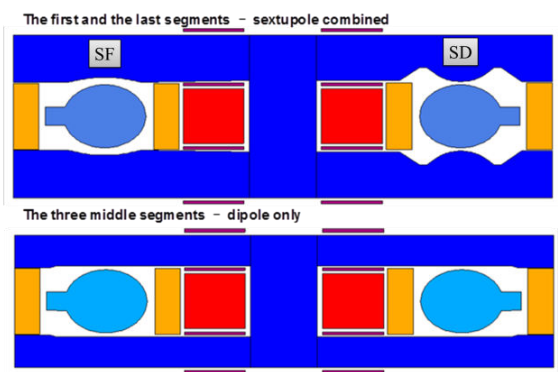
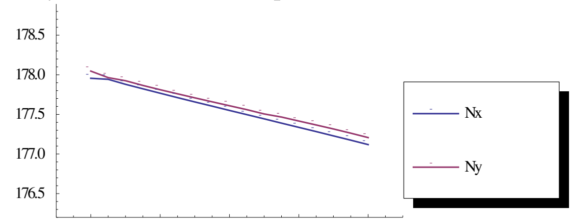


Figure 2: Magnet design for CEPC arc dipoles.

CHROMATICITY CORRECTION AND DYNAMIC APERTURE

Chromaticity Correction

We try to use the combined sextupoles to correct half of the linear chromaticity. Figure 3 shows that the linear chromaticity of CEPC collider ring can be corrected very well by the combined sextupoles.



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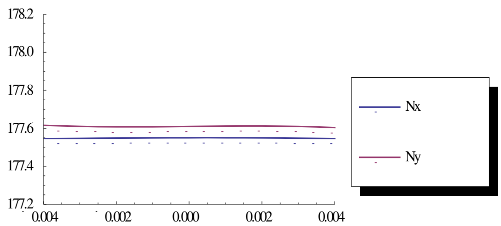


Figure 3: Chromaticity plot of half ring with 50% reduction of the stand-alone sextupoles (top: close combined sextupoles, bottom: open combined sextupoles).

Dynamic Aperture with Multi-sextupole Optimization

After linear chromaticity correction, we use all the stand-alone sextupoles to optimize the off-momentum DA with downhill method [3]. The effects of synchrotron oscillation, damping sawtooth, tampering and quantum fluctuation are included in the optimize process and 50 seeds are used to assess the random effect of synchrotron radiation. To show the DA results, we track 200 turns for Higgs and 3000 turns for Z by SAD [5]. From Fig. 4 to Fig. 9, we can see that the combined magnet scheme will not lose DA compared to the common dipole scheme.

1. DA @ Higgs (crab=1)

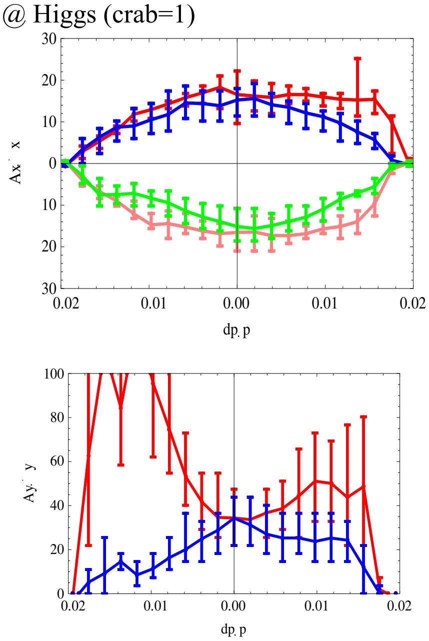
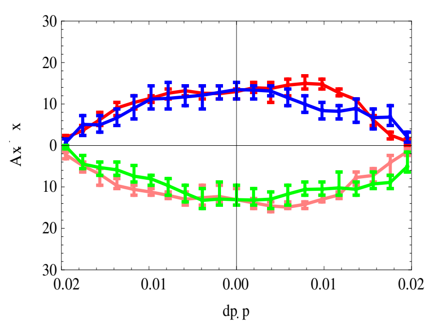


Figure 4: DA without D+S scheme (βx*=0.36m, βy*=2mm).



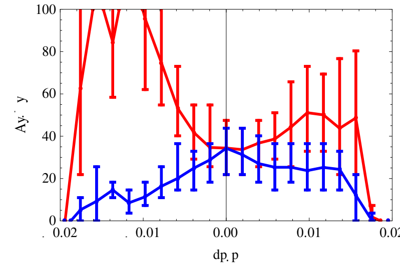


Figure 5: DA with D+S scheme (βx*=0.36m, βy*=2mm).

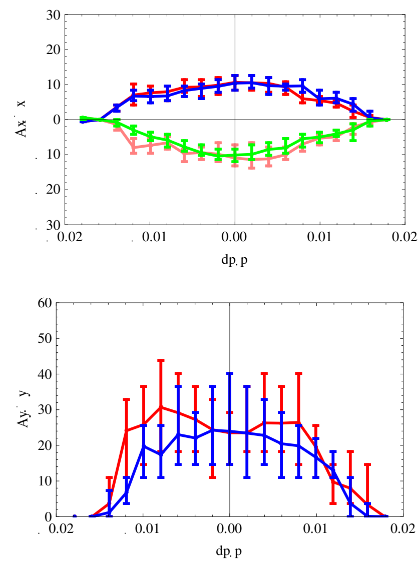


Figure 6: DA without D+S scheme (βx*=0.36m, βy*=1.5mm).

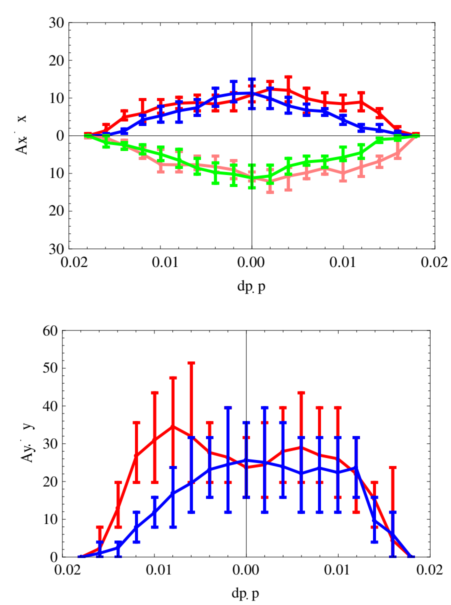


Figure 7: DA with D+S scheme (βx*=0.36m, βy*=1.5mm).

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2. DA @ Z (crab=1)

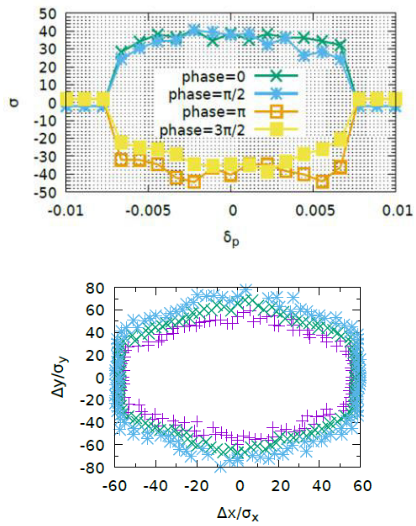

Figure 8: DA without D+S scheme (βx*=0.2m, βy*=2mm).

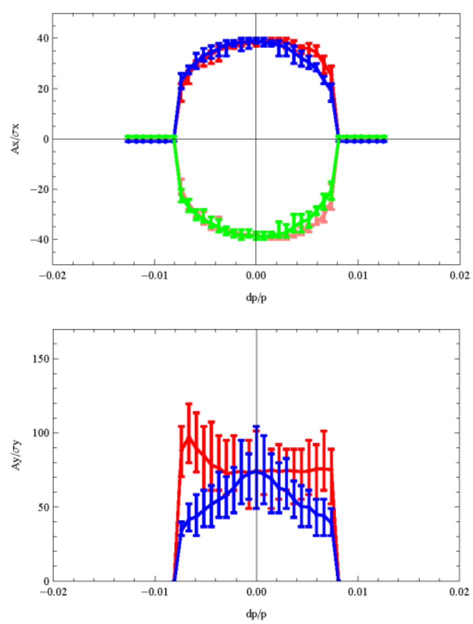

Figure 9: DA with D+S scheme (βx*=0.2m, βy*=2mm).

Figure 10 shows that the strength of the stand-alone sextupole has been reduced by a half thanks to the combined magnet scheme. Accordingly, the power consumption of stand-alone sextupoles has been reduced from 16.7MW to 4.4MW.

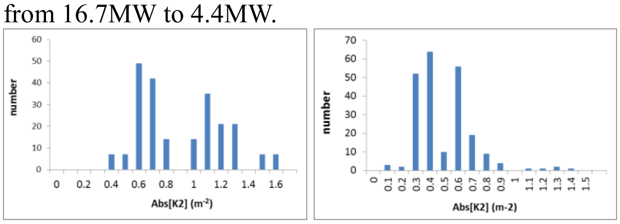

Figure 10: Distribution of sextupole strength (left: ordinary dipole, right: D+S).

Frequency Map Analysis

FMA is done by AT on CEPC collider ring for both ordinary dipole scheme and D+S scheme in order to check the non-linearity and make a comparison of two schemes. For both cases, particles are tracking by 200 turns at 120GeV without the effect of synchrotron oscillation, radiation damping and fluctuation. The Fig. 11 shows the plot of frequency map for the two cases. And the tune dependence on the transverse amplitude is shown in Fig. 12 and Fig. 13. We don't find additional unstable resonance for the D+S scheme.

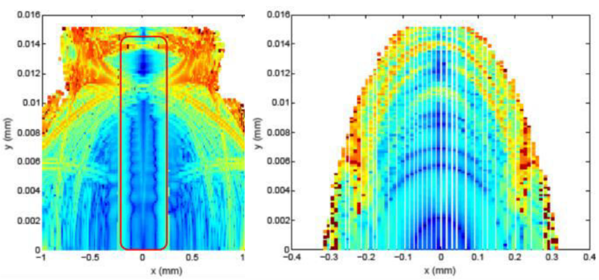

Figure 11: Frequency map (left: ordinary dipole, right: D+S).

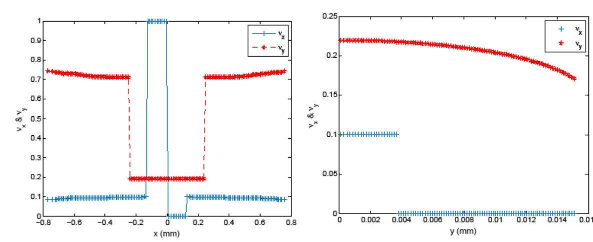

Figure 12: Tune dependence on horizontal/vertical amplitude without D+S scheme.

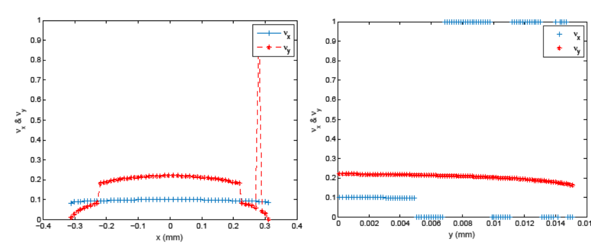

Figure 13: Tune dependence on horizontal/vertical amplitude with D+S scheme.

CONCLUSION

A lattice of CEPC collider ring with combined dipole magnet is designed recently. With the help of combined sextupole component on the dipole, the power consumption of stand-alone sextupoles can be decreased by 75% with about half reduction of sextupole strength. DA of the new scheme is same as the original one without combined dipole magnets. According magnet design for this kind of special dipole is done to make sure this scheme can work.

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REFERENCES

[1] Y. Wang *et al.*, "Beam Optics Design of CEPC Collider Ring for the Concept Design Report", presented at IPAC'18, Vancouver, Canada, Apr. 29-May 4 2018, paper MOPMF082.

[2] K. Oide *et al.*, "Design of beam optics for the FCC-ee collider rings", Phys. Rev. ST Accel. Beams, 19, 111005 (2016).

[3] D. Wang *et al.*, "DA studies in CEPC by downhill method", ICFA Mini-Workshop on Dynamic Apertures of Circular Accelerators, IHEP, Beijing, China, Nov. 2017.

[4] The CEPC-SPPC Study Group, "CEPC Conceptual Design Report", to be published.

[5] SAD, https://hep-project-sad.web.cern.ch/SADHelp/SADHelp.html