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CCT Type Coil Design for CEPC Twin Aperture Superconducting Quadrupole

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Abstract

Iron free twin aperture superconducting quadrupole in the interaction region is a key technology to increase the luminosity for the high energy particle collider. CEPC that China plan to build in the next 10 years, has the center-of-mass energy of 240 GeV and the cross angle 33 of mrad in the interaction regions. At the final focusing quadrupole QD0, which is 2.2 m away from the interaction point (IP), the beam separation space, is only 72 mm. The QD0 will select Canted Cosine Theta（CCT) coil type, where the coil can be wound on the coil former in a fix angle. In real case, a bundle of thin superconducting wires will be put into the pre-machined slot on the former. The coils can also be designed with the combination of the several function magnets, or can be used to cancel out the unwanted harmonics. For QD0 magnet in CEPC, the coils in the two apertures are nearly contacted, high order harmonics produced by field crosstalk can be calculated in precision. This paper will present the 400mm prototype design for the QD0 magnet, and the coil optimizition by added several opposite harmonics to cancel out the unwanted harmonics from the crosstalk. Two 400 mm CCT coil prototypes will be fabricated and test both at room temperature and at 4.2K as the similar position to QD0 to verified the harmonic introduced and correction scheme.

I. Introduction

The layout of the CEPC Collider is shown in Figure 1, where proton and anti-proton beams collided at the interaction point with 33 mrad. The final focusing quadrupole QD0 is begun with 2.2m from the IP.

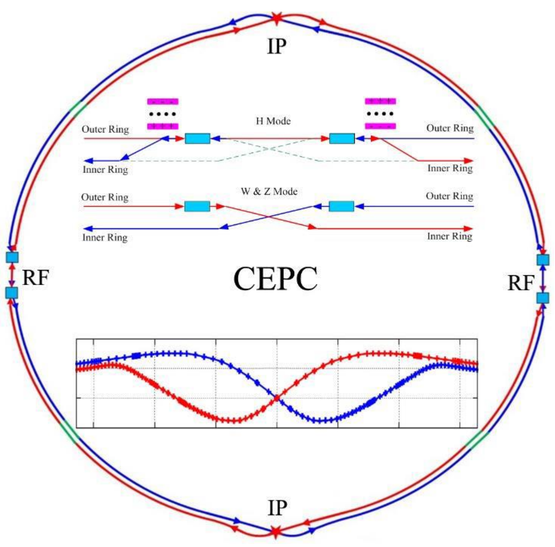

Figure 1 layout of the CEPC Collider

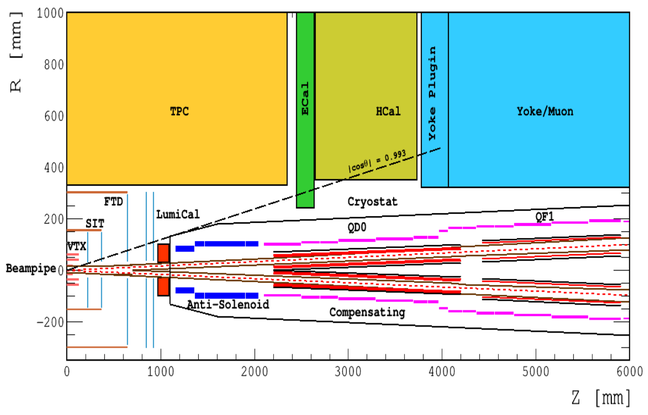

Figure 2 layout of the central part of the interaction region

II. Coil Design for single aperture CCT quadrupole

CCT type coil are selected for the coil design. 8 strands with daimeter of 0.82mm NbTi wires are bounded with a 2X4 shape to put into the slot of the Al former.

The slot are machined according to the spatial function as Eq. 1. where θ is the space angle for each turn, ω is the twist pitch for each turn, α is coil winding angle with respect to the former axial. Figure 3 shows the 400mm CCT quadrupole coil prototype of the inner coil, the outer coil coils and the one set of the CCT coils. Figure 4 shows the harmonic distribution for the 400mm coil model. As can be seen, each harmonic can be canceled by in each coil end or canceled by both coil end.

$$x = R\cos\theta$$
$$y = R\sin\theta$$
$$z = \left(\frac{R\sin(2\theta)}{2\tan\alpha} + \frac{\omega\theta}{2\pi}\right) \quad (1)$$

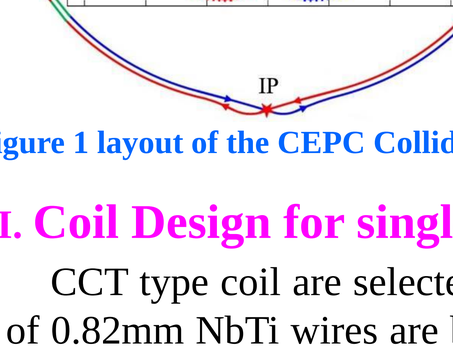

Figure 3 CCT quadrupole coil prototype. Upper: inner coil; middle: the outer coils, lower: one set of the coils

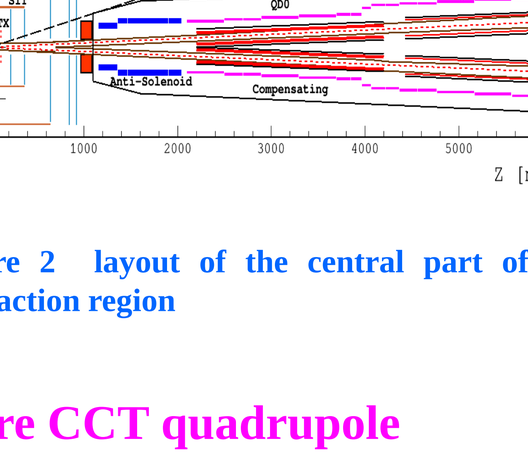

Figure 4. Harmonic distribution for the 400mm coil prototype

III Harmonic generated by coil crosstalk

For QD0, coils in the two apertures are is very close, magnetic field in one aperture will go to another aperture and arise high order harmonics. Fig. 5 shows the two set of CCT coil calculation model. Fig. 6 and Fig. 7 show the harmonic distribution in each aperture, the reference radius is 13 mm.

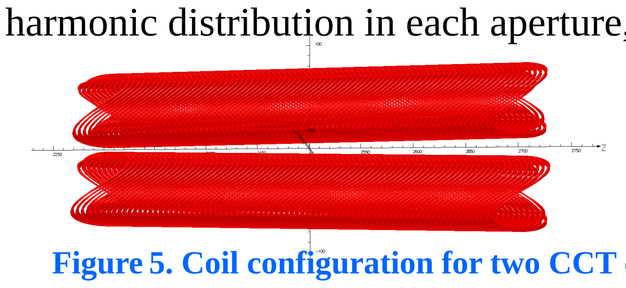

Figure 5. Coil configuration for two CCT coils in both aperture

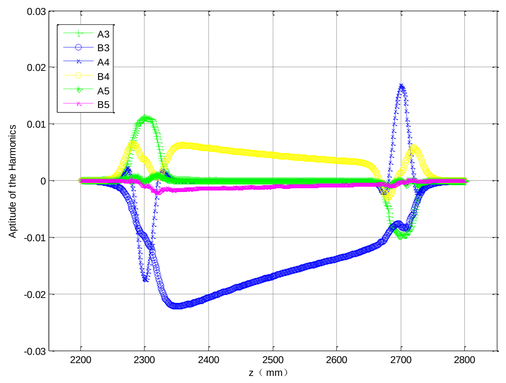

Figure 6. Harmonic distribution in AP. 1.

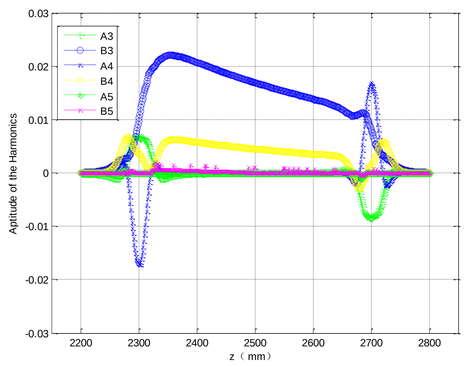

Figure 7. Harmonic distribution in AP 2.

IV. Introduced opposite harmonics in the CCT coil

In order to cancel the harmonics generated by crosstalk, some extra opposite harmonic as show in Eq. 1 will introduced in each coil according to the calculations in Fig 6 and Figure 7. Fig. 8 and Fig. 9 shows the harmonic distribution when a opposite harmonic are added.

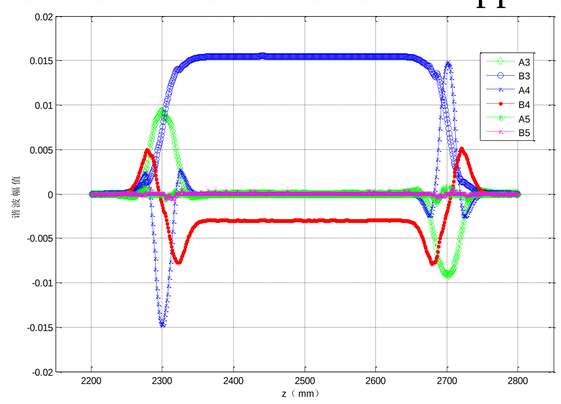

Figure. 8. An extra opposite harmonic are added in AP. 1.

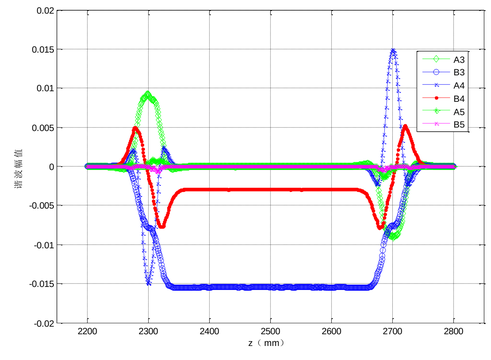

Figure. 9. An extra opposite harmonic are added in AP. 2.

V. Co-Field calculation after harmonics correction

With the new coil configuration as the introduced harmonics in IV, co-field calculation are done by OPERA-3d, the new harmonic distribution are shown in Fig. 8 and Fig. 9 respectively. As it seen, the harmonics are all reduced in an accepted level. In the future, a set of 400 mm CCT Quadrupole coil will be designed, fabricated and test both at room temperature and at 4.2K to verify the coil design and harmonic correction method for the iron free twin aperture CCT quadrupole.

Figure. 10. Harmonic distribution after harmonic correction in AP. 1.

Figure. 11. Harmonic distribution after harmonic correction in AP. 2.

VI. Conclusion

A set of 400 mm long CCT coil model is designed to verify the possibility to machined an iron free twin aperture quadrupole. The harmonic correction method in the paper will give some direction for other kind of magnet design.