MDI DESIGN IN CEPC PARTIAL DOUBLE RING*

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Abstract

With the discovery of the higgs boson at around 125GeV, a circular higgs factory design with high luminosity (L ~ 10^34 cm^-2 s^-1) is becoming more popular in the accelerator world. The CEPC project in China is one of them. Machine Detector Interface (MDI) is the key research area in electron-positron colliders, especially in CEPC, it is one of the criteria to measure the accelerator and detector design performance. Detector background, collimator and solenoid compensation are the most critical physics problem. Beamstrahlung is the problem which is never gotten into before in the existed electron positron collider of world history. Every kinds of background are bad for detector, and solenoid can make damage to accelerator beam. We will use a Monte Carlo simulation method to calculate and analysis the CEPC detector background and the harm it makes to detector. Anti-solenoid are designed to compensate the strong detector solenoid field of several tesla.

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. MDI is one of the most challenging field in CEPC design, it almost covered all the common problems in accelerator and detector. Background is a crucial link in MDI study. Every kinds of background source will increase the initial particles into detector, producing energy deposition in detector, which will make bad influence on the life of detector. Particles which hit the inner wall of beam pipe or collimators may interact with materials, producing lots of secondary particles into detector. These secondary particles will disturb the experiment and make damage to each layers. So it is necessary to reduce lost particles into detector.

The central field strength of CEPC detector solenoid is about 3.5T, it will introduce strong coupling of horizontal and vertical betatron motion, increasing the vertical emittance and also the vertical orbit. If it is not compensated, the IP beam size will increase, and degrade the luminosity.

In this paper, a monte-carlo simulation method was used to analyse the background of CEPC partial double ring, including beamstrahlung, Radiative Bhabha scattering, and synchrotron radiation. Lost particles information are got for detector simulation. Anti-solenoid are designed to compensate the strong detector solenoid field of several tesla. And the influence of accelerator beam are simulated and reported.

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IR LAYOUT OF CEPC PARTIAL DOUBLE RING

In the CEPC partial double ring scheme [2], positron and electron beam collide with a 30mrad crossing angle, the distance from IP to the last quadrupole (QD0) is 1.5m. Due to the space between the two apertures in QD0 is only 45mm, the QD0 must be a double-aperture magnet. The interaction region (IR) layout in the partial double ring is shown below in figure 1:

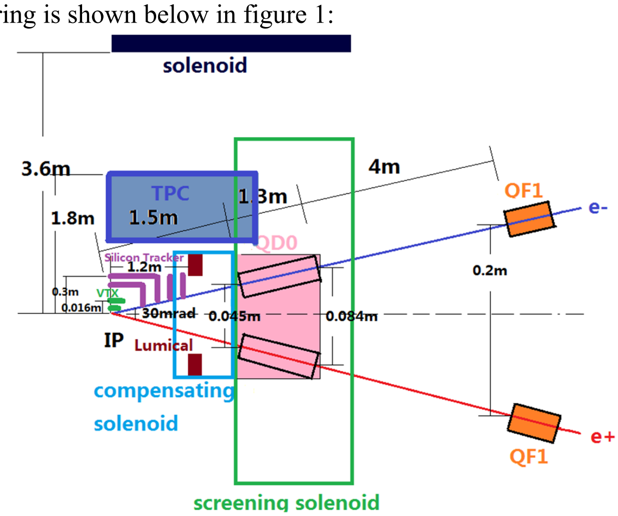

Figure 1: IR layout of CEPC partial double ring.

BACKGROUND STUDY

CEPC has a collision energy 240GeV, for such high energy, Radiative Bhabha scattering and beamstrahlung are the main beam loss. CEPC beam parameters and beam lifetime due to beam loss is shown below in table 1:

Table 1: CEPC Beam Lifetime due to Beam Loss

Loss mechanisms	Lifetime	comment
Quantum effect	＞1000hours	
Touschek effect	＞1000hours	
Beam-gas scattering (Comlomb)	＞400hours	P=1e-7（Pa）
Beam-gas scattering (beamstrahlung)	＞40hours	
Radiative Bhabha	About 51 min	simulated
beamstrahlung	About 47 min	simulated

Beam loss due to quantum effect and Touschek could be ignored, beam-gas, radiative bahabha scattering and beamstrahlung are the main beam loss, especially for Radiative bhabha scattering and beamstrahlung.

Radiative Bhabha Scattering

In the Radiative Bhabha scattering process, photons are

$$e^-(p_1)+e^+(q_1)\rightarrow e^-(p_2)+e^+(q_2)+\gamma(k)$$

generated which will take away some energy, the spent particles will lose energy, causing energy spread, when the energy spread is big enough and out of energy acceptance, beam will loss. Radiative Bhabha scattering is one of the main process of beam loss during collision, by which the beam lifetime decided. It is the main source for small angle range during collision, can be used to measure luminosity.

The Radiative Bhabha scattering generator use a Monte-Carlo random point method: randomly generate a two-dimension coordinate, x/y without any correlation. 10^5 particles energy spread are generated as shown below in figure 2:

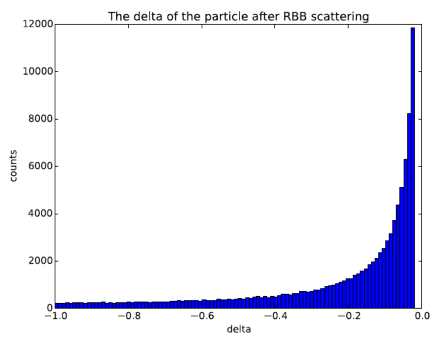

Figure 2: Energy spread distribution of lost particles due to RBB scattering.

Radiative Bhabha scattering events are generated at IP1, and tracking one turn in SAD [3], in which the aperture in Final doublet is set to 1.7cm in radius. Lost particles statistic is shown in figure 3:

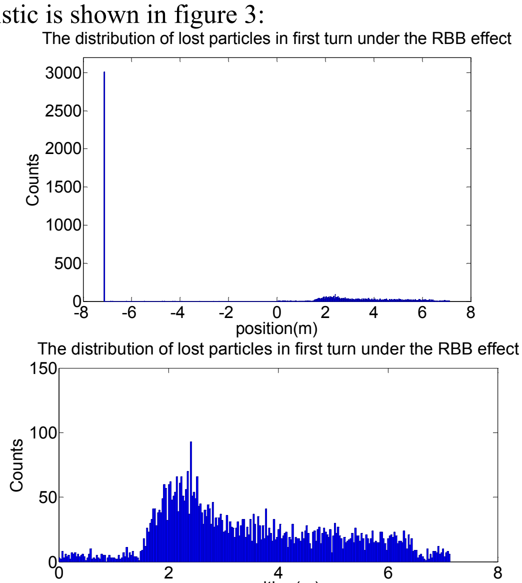

Figure 3: Lost particles statistic due to RBB.

The number of particle lost in the downstream of the first turn is 5153, while the number of particles lost in the upstream of the first turn is 5651.

Beamstrahlung

Beamstrahlung is synchrotron radiation from a particle being deflected by the collective electromagnetic field of the opposing bunch. This effect will increase the energy spread and limit the lifetime of the beams. Its importance increases considerably with energy, especially in a high beam energy machine, such as CEPC.

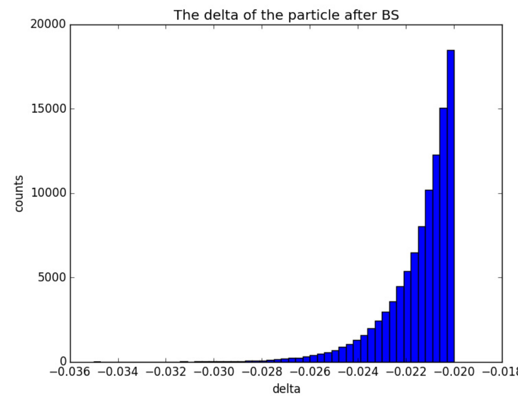

Figure 4: Energy spread distribution of lost particles due to Beamstrahlung.

Compared with the particles energy spread from Radiative Bhabha scattering, beamstrahlung effect grows exponentially. So most of the energy spread of particles are distributed in a region a little bit bigger than 2%.

Beamstrahlung events are generated at IP1, and tracking in one turn in SAD, in which the aperture in Final doublet is set to 1.7cm in radius. Lost particles statistic is shown in figure 5:

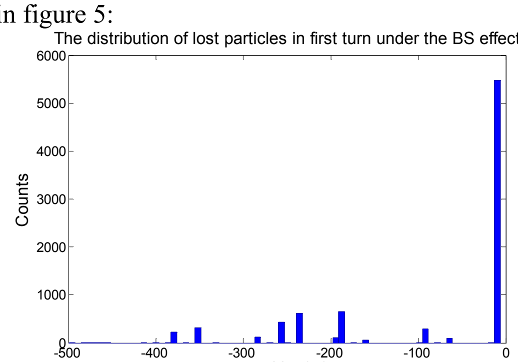

Figure 5: Lost particles statistic due to Beamstrahlung.

The number of particles lost in the downstream of the first turn is zero, while the number of particles lost in the upstream of the first turn is 8728.

Synchrotron Radiation

The high beam energy 120GeV of CEPC may cause the synchrotron radiation critical energy large, which makes damage to the detector and also the radiation protection could be difficult. The main source of the IR synchrotron radiation is from the bending magnet in the IR.

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Synchrotron radiation from bending magnets is shown in table 2:

Table 2: Synchrotron Radiation from Bending Magnets

Element	Weight	Critical Energy (keV)	Number of Photons	Distance to IP (m)	Bending Angle (mrad)
BMHFFS_L	10	96.6616	5.31E-11	54.8886	0.58
BMHFFS_L	10	96.6616	5.31E-11	126.889	0.58
BMHFFS_L	10	96.6616	5.31E-11	150.889	0.58
BMHFFS_L	2	96.6616	5.31E-11	222.889	0.58
BMHFFS_L	4	96.6616	5.31E-11	246.789	-0.58
BMHFFS_L	10	96.6616	5.31E-11	318.789	-0.58
BMHFFS_L	10	96.6616	5.31E-11	342.789	-0.58
BMHFFS_L	2	96.6616	5.31E-11	414.789	-0.58
B3	5	423.73	1.98E-12	482.833	2.16667

The critical energy of bending magnets in the final focus beam line are calculated to be about 100keV, which could be accepted by detector and radiation protection.

SOLENOID COMPENSATION

CEPC detector solenoid central field is about 3.5T, and the effective length is about 7.6m [4].

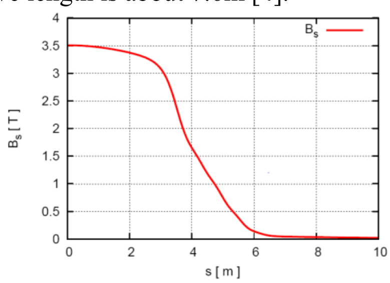

Figure 6: CEPC detector solenoid.

The detector solenoid is longitudinal field, it introduces x-y coupling, increases the vertical emittance, and also has bad influence on vertical orbit. If without compensation, the beam size at IP will increase so as to degrade luminosity.

In CEPC partial double ring scheme, the last superconducting magnet QD0 is in the detector solenoid, so the solenoid compensating method is (which is shown in figure 1): designing compensating solenoid to cancel the solenoid field from IP to the entrance of QD0, and screening solenoid to cancel the solenoid field in QD0.

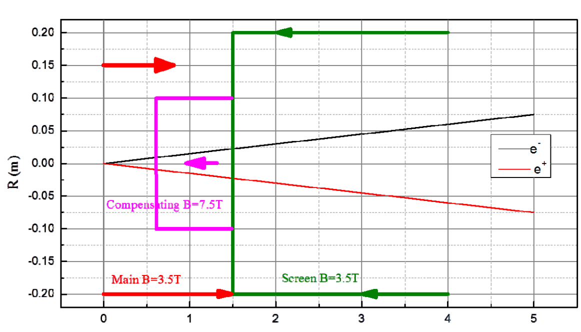

Figure 7: Solenoid compensating layout.

The compensating solenoid and screening solenoid design parameters are listed in table 3:

Table 3: Compensating and Screening Solenoid Design Parameters

Item	Compensating Solenoid	Screening-Solenoid(QD0)
Central field (T)	7.5	3.5
Length (m)	0.7	2.4
Conductor Type	NbTi-Cu Conductor 4×2mm	
Coil turns	2450	6000
Current density (A/mm	220	137.5
Coil inner diameter (mm)	200	300
Coil out diameter (mm)	256	340

The compensating solenoid has a length of 0.7m, starting from 0.8m distance of IP, the central field is 7.5T, of which its coils can be made of round NbTi-Cu conductor using direct winding technology. The strength of compensating solenoid is inverse proportional to the length, the known record is about 11.7T, but needs lower temperature.

CONCLUSION

The main background level of Radiative Bhabha scattering, Beamstrahlung and Synchrotron radiation is analysed for CEPC partial double ring, lost particles information are got. The pressure of suppressing background level in detector is much higher, although synchrotron radiation level could be accepted by detector at this stage. There are two methods to suppress background, one is shielding with collimators; the other is by well designing the beam orbit to make the synchrotron photons pass through the IR. The space for beam pipe and QD0 at L* is much tighter. Anti-solenoid is designed to compensate the detector solenoid longitudinal field, and the length of the compensating solenoid could be optimized to be shorter in order to give more space for detector, but needs lower temperature.

ACKNOWLEDGMENT

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REFERENCES

[1] Accelerators for a Higgs Factory: linear vs circular (HF2012). https://indico.fnal.gov/conferenceDisplay.py?confId=5775

[2] Dou Wang, "CEPC Partial Double Ring Scheme and Crab-waist Parameters", Presentation in IAS Program on High Energy Physics, Conference: 18-21 Jan 2016.

[3] SAD, http://acc-physics.kek.jp/SAD/

[4] CEPC-SppC Preliminary Conceptual Design Report, Volume I- Physics & Detector, IHEP-CEPC-DR-2015-01.