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STUDY OF BACKGROUND AND MDI DESIGN FOR CEPC*

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Abstract

CEPC (circular electron positron collider) is a high energy electron positron collider proposed by IHEP, which is designed to provide e^+e^- collisions at the centre-of-mass energy of 240 GeV and deliver a peak luminosity greater than $1\times10^{34}cm^{-2}s^{-1}$ at each interaction point. The super high energy brings many challenges in machine design, especially in the control of background and protection of detectors. We describe the preliminary research result about background and MDI design.

INTRODUCTION

CEPC is short for circular electron positron collider with 120 GeV beam energy. Now we have just finished the Pre-CDR of it. Based on the lattice and IR design released now, we have made some preliminary research on background and MDI design. The research will be updated with the future lattice design.

MAIN PARAMETERS AND IR DESIGN

The main machine parameters are list in Table1.

Table 1: The Main Parameters of CEPC

Parameter		Unit
Beam energy [E]	120	GeV
Circumference [C]	54.752	Km
Luminosity [L]	2.04E+34	cm-2s-1
Number of IP [NIP]	2	
Bunch number [nB]	50	
betax at IP	0.0012	m
betay at IP	0.8	m

In general, the sensitive region for the detectors is within several meters from IP. For CEPC, we just concern about the region within ±4meters from IP. The layout of IR and MDI design are illustrated in Figure 1. There are four quadrupole magnets in this region, two of them designed for focusing and others for defocusing.

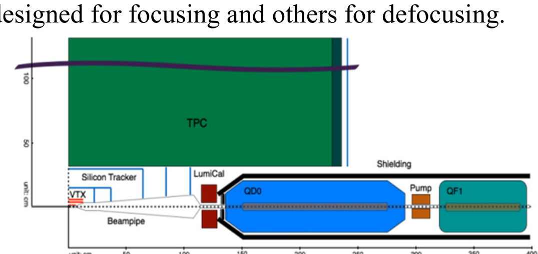

Figure 1: Layout of the MDI of CEPC.

The beam background of CEPC consists of synchrotron radiation background and lost particles background. The synchrotron radiation background has two sources, from the last bending magnets and from the quadrupole magnets in the final focus region. As for the lost particles background, there are many background source for CEPC, but the main source are beamstrahlung and radiative bhabha scattering.

SR BACKGROUND

When the beam passes through the last bending magnets upstream the IP, its orbit will be bended by the magnetic field with a SR fan emitted along the orbit direction. This SR fan will scan the IR region and may make damages on the detectors. In addition, for the beam size effect in horizontal and vertical plane, the particles in the edge of the beam will see the magnetic field of quadrupole magnets because of the displacement. Then it will also emit a SR fan and this SR also need to be analyzed.

The energy spectrum of the SR photons can be characterised by the critical energy [1], which can be calculated by the following formula.

$$E_c = \frac{3}{2}\hbar c\gamma^3 / \rho \qquad (1)$$

For the last bending magnets upstream the IP, the bending radius of it is about 3780m,. Substitute it into the formula 1 with a 120GeV energy, we can get the critical energy of the photons from the last bending magnets is about 938KeV. As a comparison, the SR spectrum in LEP at 45.6GeV is less than 100GeV [2]. As for the SR photons from quadrupole magnets, we can still calculate the critical energy as the formula 1 with a new definited bending radius.

$$(1/\rho)_{quad} = kr^*\sqrt{\varepsilon_x\beta_x + \varepsilon_y\beta_y} \qquad (2)$$

where the term with a square root symbol is the radial RMS beam size. The critical energy of the SR photons from quadrupole magnet is proportion to the beam size. If we assume a 12 times RMS beam size, the corresponding critical energy is about 23MeV which is pretty high.

In order to estimate the photons distribution and power distribution of SR in the IR, We use a code provided by Mike Sullivan to simulate the synchrotron radiation background, the simulation result is showed in Figure 2.

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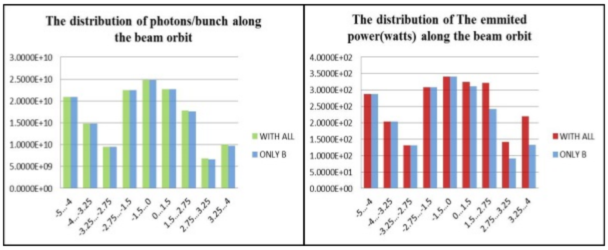

Figure 2: The simulation result of SR.

The left subfigure shows the distribution of photons generated by every bunch along the beam orbit. The right subfigure shows the distribution of emitted power (watts) along the beam orbit. For both of them, we compare the result only with the last bending magnet and the result with all the related magnets. We can get the conclusion that almost all the photons come from the last bending magnet. When it comes to the distribution of power, the main source of the SR power is still the bending magnet except the region downstream of IP. So we need to design a collimators system to prevent the SR background from the last bending magnet to reduce the damage on the detectors. The preliminary design of collimators system is shown in Figure 3.

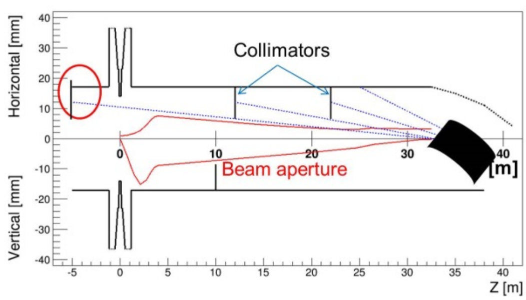

Figure 3: The preliminary collimator system.

In Fig. 3, almost all the SR photons produced by the last bending magnet can be prevented by the collimators and will not hit the IR region. But part of these SR photons will hit the collimators downstream the IP which is circled by a red circle. The backscattering between the photons and collimators will produce many secondary particles and these particles may bring damage on the detectors. The detailed research on this effect is still underway.

LOST PARTICLES BACKGROUND

According to the design parameters of CEPC, we can estimate the beam lifetime cause by different loss mechanisms. The beam lifetimes are show in Table 2. the main source are Beamstrahlung and radiative Bhabha scattering.

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, so beamstrahlung is an important effect in CEPC.

Table 2: The Lifetime of Different Loss Mechanisms

Loss mechanisms	Lifetime	Comment
Quantum effect	>1000 h	
Touschek effect	> 1000 h	
Beam-gas scattering Coulomb)	150 h	The residual gas is CO and the pressure is about 10-7 Pa.
Beam-gasscattering (bremsstrahlung)	14.5 h	
Radiative Bhabha scattering	50 min	simulated
Beamstrahlung	47 min	simulated

The photons emitted in beamstrahlung may generate three different production: Coherent e^+e^- pair production, incoherent e^+e^- pair production and Hadronic background. The Coherent e^+e^- pair production are generated by the photons and the macro filed, the events generated by every bunch crossing can be calculated by formula 3.

$$n_p \approx \frac{2\sqrt{3}}{25\pi}\left(\frac{\alpha\sigma_z}{\gamma\lambda_c}\chi\right)^2 e^{-\frac{16}{3\chi}} \tag{3}$$

With

$$\chi = \frac{5}{6}\frac{Nr_e^2\gamma}{\alpha(\sigma_x+\sigma_y)\sigma_z} \tag{4}$$

The result calculated is close to 0 and this process can be ignored. The incoherent e^+e^- pair production is generated between the emitted photons. This process is the main source of beamstrahlung background. For this effect, we use Guinea-Pig (Generator of Unwanted Interactions of Numerical Experiment Analysis – Program Interfaced to GEANT) as the generator. And make further simulation with GEANT4. The hit number of The incoherent e^+e^- pair simulated in the inner detectors is illustrated in Figure 4 [3].

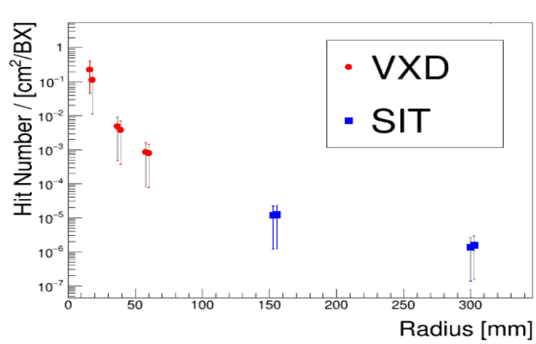

Figure 4: The hit number of The incoherent e+e- pair in the inner detectors.

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According to the simulation, the Hit density caused by the incoherent e+e- pair is about 0.2 hits/cm^2/BX(bunch crossing) at the first layer of the vertex detector and the occupancy is less than 0.001% when the pixel pitch is 20um.

Radiative Bhabha Scattering

The electron and positron that collide can emit a photon. The process can illustrated by the formula 5.

$$e_1^+ + e_1^- = e_2^+ + e_2^- + \gamma \tag{5}$$

If the energy of the emitted photon is large enough, the final electron and positron may be outside the energy acceptance of the machine and result in beam loss. The cross-section and lifetime of radiative bhabha scattering can be calculated by formulas or by the simulation using the code BBBREM [4]. The formula 6 is used to calculate the cross-section for radiative bhabha scattering.

$$\sigma_{ee} = \frac{16\alpha r_e^2}{3}((\ln\frac{1}{\eta}+\eta-\frac{3}{8}\eta^2-\frac{5}{8})[\ln(\sqrt{2}\frac{a}{\lambda_p})+\frac{\gamma_E}{2}]+\frac{1}{4}(\frac{13}{3}\ln\frac{1}{\eta}+\frac{13\eta}{3}-\frac{3}{2}\eta^2-\frac{17}{6})),$$
$$a=\sqrt{2}\frac{\sigma_x\sigma_y}{\sigma_x+\sigma_y}. \tag{6}$$

And the lifetime of radiative Bhabha scattering is expressed by:

$$\tau_{RBB} = \frac{I}{eLn_{IP}\sigma_{RBB}f_0} \tag{7}$$

The cailculated lifetime of radiative Bhabha scattering is about 52min, which is very close to the result simulated by BBBREM(50min).

In addition, we can also output the radiative bhabha scattering events from the BBBREM to do some further simulation in the accelerator and detectors.

The process of the simulation on Radiative bhabha scattering can be summarized as Figure 5.

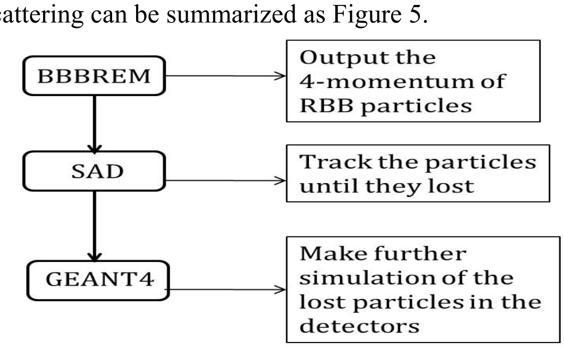

Figure 5: the process of the simulation on radiative Bhabha scattering.

At first, output the momentum coordinates of the events from BBBREM, secondly, combine the gauss distribution and coordinates the code read in together to generate the initial beam parameter. thirdly make tracking in the accelerators(here we use SAD [5] to do the tracking) until the particles lost. Then we record the position and momentum information of the particle lost in the IR and make further simulation in the detectors (we use GEANT4 to finish this simulation). The events number and energy deposition in the IR is illustrated in Figure 6.

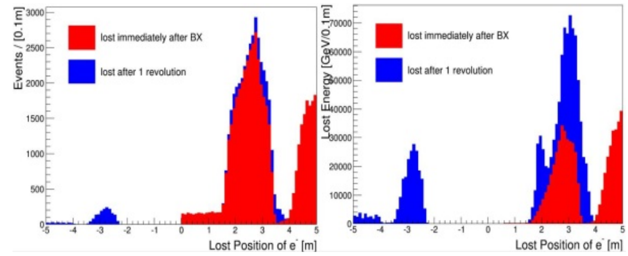

Figure 6: The events number and energy deposition in the IR.

From the Figure 6, we can make the conclusion that most of the particles lost in the detector immediately after the collision for their large energy loss. Few particles with high energy will lost near the IP after 1 revolution for a small energy loss. The hit number of radiative bhabha scattering in the inner detectors is illustrated in Figure 7.

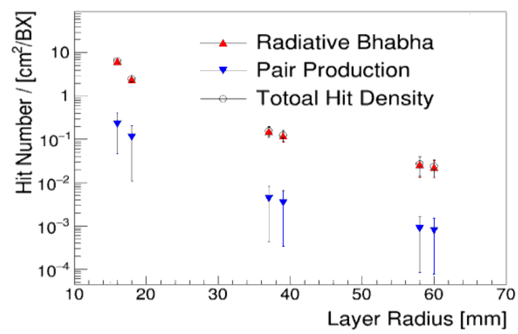

Figure 7: The hit number of Radiative bhabha scattering in the inner detectors.

According to Figure7, the average hit density caused by Radiative bhabha scattering is about 6.6 hits/cm2/BX at the first layer of the vertex detector and the Occupancy is about 0.00264% when the pixel pitch is 20um.

CONCLUSION

Based on the preliminary research of background on CEPC, the lever of different background source is under the tolerance range. But more detailed analysis still need to be done. At the same time, research will be updated with the future lattice and IR design.

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