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Interaction region design and realization for the Beijing Electron Positron Collider

C.H. Yu *, Y.Z. Wu, Z.S. Yin, J.F. Zhang, M.T. Wang, Q.L. Peng, J.B. Pang, Y. Yang, X.W. Dai, Y.D. Liu

Institute of High Energy Physics, CAS, Beijing 100049, China

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ABSTRACT

The Beijing Electron Positron Collider (BEPC) has been upgraded as a double-ring factory-like collider (BEPCII). A compact interaction region (IR), which is the most complicated region in the BEPCII, has been designed to afford a peak luminosity of $1\times10^{33}\,cm^{-2}\,s^{-1}$ with an equal beam energy of 1.89 GeV, a cross angle of ±11 mrad, 93 bunches and maximum beam current of 0.91 A. All the components of the IR have been fabricated successfully. The design and realization of the interaction region for the BEPCII will be introduced in detail.

1. Layout of the IR

The two new rings of BEPCII have been built in the existing BEPC tunnel while keeping the function as synchrotron radiation source. The interaction region (IR) is restricted within about ±14 m long around the interaction point (IP), in which twenty main magnets, thirty nonstandard vacuum pumps and other accelerator equipments need to be installed [1].

The central part of the BESIII detector is a cylindrical drift chamber surrounded by electromagnetic calorimeters. The geometry of the drift chamber has a direct bearing on the IR design. It requires that the accelerator components inside the detector must fit within a conical space with an opening angle of 21.5°. The first accelerator element can only approach 0.55 m on each side of the IP.

To ensure adequate quantum lifetime, the beam stay clear is defined to accommodate at least $14\sigma+2$ mm in the IR [2]. The beam line layout in the central part of the IR is shown in Fig. 1. On each side of the IP, a doublet of quadrupole is used to provide the focusing optics at the IP. The first vertical focusing quadrupole, SCQ, connects the outer and the inner rings, which are shared by both beams. Two beams collide with a horizontal crossing angle of 22 mrad at the IP. A horizontal bending magnet ISPB, which is located just beyond the vertical focusing quadrupole, enhances the separation between electron and positron beams. ISPB is a septum magnet, which acts on the outgoing beam line only. The second element of the doublet is horizontal focusing quadrupoles Q1a and Q1b. In order to achieve the aims of keeping the symmetrical structure of two rings and saving space, the quadrupoles Q1a and Q1b are designed as a two-in-one type. Two separate beam channels for the incoming and the outgoing beams have same field strength.

2. Superconducting magnets

The superconducting magnet [3] has a multi-function coil pack. As shown in Fig. 1, it consists of independent quadrupole (SCQ), horizontal dipole (SCB), vertical dipole (VDC), skew quadrupole (SKQ) and three anti-solenoid (AS1, AS2 and AS3) windings. The cryostat has a warm bore with an inner diameter of $\varnothing$132 mm and outer diameter of $\varnothing$326 mm. The endcan of cryostat has an outer diameter of $\varnothing$640 mm.

The harmonic requirements for SCB and SCQ at the reference radius are SCB (R = 38 mm) $Bn/B1<5\times10^{-4}$ and SCQ (R = 50 mm) $Bn/B2<3\times10^{-4}$. Field measurement results show that there is a larger sextupole component of 7.0×10^{-4} in the superconducting quadrupole, which is located in the east region. Other components of this quadrupole satisfy the requirements. The field quality of the other superconducting quadrupole and both superconducting bending magnets can satisfy the requirements.

3. Compensation of solenoid field

The detector solenoid has an effective length of ±1.8 m around the IP. The maximum field strength of solenoid is 1.0 T so that the particle motion between the horizontal and the vertical planes will be coupled strongly. It is impossible to meet higher luminosity without the dedicated coupling compensation of solenoid field. According to the requirements of high-energy physics, the collider will be operated at the energy range from 1.0 to 2.1 GeV, so the compensation system should be powerful

* Corresponding author.
E-mail address: yuch@ihep.ac.cn (C.H. Yu).

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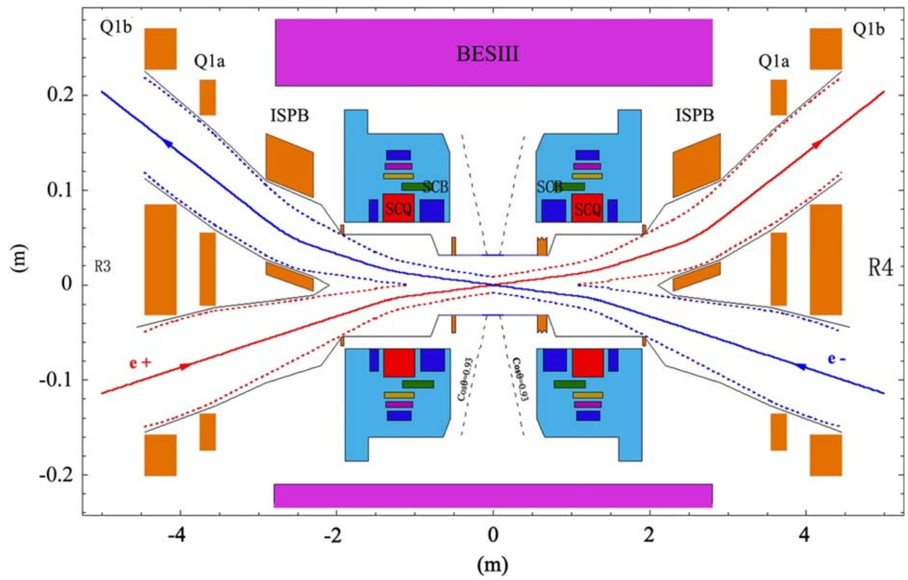

Fig. 1. The layout and beam separation in the IR.

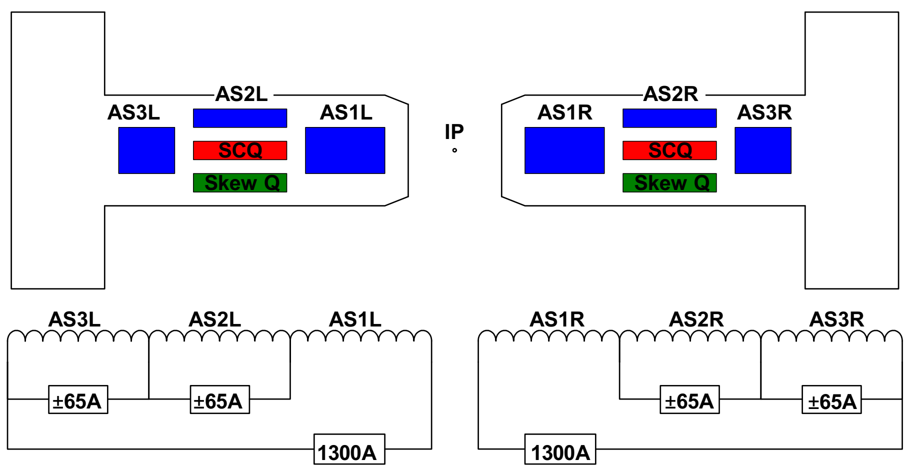

Fig. 2. The wiring schematic diagram of anti-solenoids.

enough to work perfectly for particles within the relevant momentum range. For this purpose a special anti-solenoid system has been designed to realize the local compensation of solenoid.

This system consists of three anti-solenoids AS1, AS2 and AS3 and a skew quadrupole SCSKQ, which are all inside the superconducting cryostat. AS1 locates between the IP and the superconducting quadrupole (SCQ). AS2 and the skew quadrupole SCSKQ overlap the SCQ, while AS3 locates after the SCQ.

The local compensation layout of BEPCII and wiring schematic diagram are shown in Fig. 2. AS2 and AS3, which have their own independent trim circuits to allow fine-tuning of the anti-solenoid compensation scheme, are in series with AS1. Since the compensation of longitudinal field within the SCQ region is a key to control the vertical beam size at the IP, the skew quadrupole SCSKQ is used to make fine tuning of longitudinal field over the SCQ region instead of the mechanical rotation method.

With this local coupling compensation scheme, the integral field $\int B_z\,ds$ between the IP and the SCQ is zero. The longitudinal field over the SCQ is nearly zero and the integral field $\int B_z\,ds$ between the SCQ and the first horizontal focusing quadrupole is zero too. The field measurements of the detector solenoid, anti-solenoid and the combination field have been finished. The distribution of the combination magnetic field B_z along the axis of the BESIII detector after compensation is shown in Fig. 3.

4. Septum bending magnet ISPB

Two ISPB [4] magnets shown in Fig. 4 have been successfully fabricated. The field measurements show that its performance meets the requirements of beam dynamics with $B_n/B_1 < 5 \times 10^{-4}$.

5. Special quadrupoles Q1a and Q1b

The separation between two beams is about 185 mm at the inboard face of Q1a [4] and 231 mm for Q1b while the beam stay clear is 95 and 102 mm, respectively. The space for the design of septum is very limited. The following accelerator elements are quadrupoles Q2, Q3 and Q4 where the separation of two beams is large enough to allow them to be installed side by side into the two rings.