INTERACTION REGION DESIGN FOR BEIJING TAU-CHARM FACTORY

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Abstract

Beijing τ-charm factory (BTCF) is compatible with three modes of operation: high luminosity mode, longitudinal polarization mode and monochromator mode. It consists of two rings, one above another, with one interaction point (IP). This paper will describe the overall design of the BTCF interaction region (IR). A cryostat which contains an anti-solenoid (A-S), a shield solenoid (S-S), two focusing quadrupoles (Q1, Q2) will be installed at each side of the IP. Design parameters of these iron free superconducting magnets A-S, S-S, Q1, Q2 and the supporting system for these IR magnetic elements will be described. The IR vacuum chamber, the background issues which related to synchrotron radiation and lost particles will be described also.

1 INTRODUCTION

BTCF is a high luminosity collider with large number of bunches, the design of the IR is inherently difficult since two requirements must be satisfied. The beams must be focused to as small size as possible so that the quadrupoles must therefore be close to the interaction point to reduce chromatic aberrations and sensitivity to magnets position errors. The beams must also be separated as near to the IP as possible to minimize the spacing between successive bunches and still avoid unwanted crossings.

The IR configuration design for BTCF gives both accelerator physics and technology challenges:

- keeping the two beams in collision and separating them as close as possible to the IP.
- compatibility with multi-operation schemes and different phases.
- masking for synchrotron radiation and lost particles backgrounds.
- accommodating required machine elements without violating detector stay-clear region.

The design criteria for BTCF IR include the following:

- The IR configuration provides an effective compensation scheme of the high field(1.0T) of detector solenoid.
- All apertures in the IR must be designed for a beam of at least 14σ (uncoupled in the horizontal plane and full coupled in the vertical plane).
- The levels of synchrotron radiation and lost particles in the detector must be sufficiently low.

2 BEAM SEPARATION SCHEME

The geometry of the central drift chamber of the detector has a direct bearing on the IR design. In the present design of the BTCF detector, it requires the accelerator components must fit within a conical space with an opening angle of 18.2^o. The first accelerator component can only approach to within 600 mm on each side of the IP, which follows the forward detectors. The Schematic side view of the detector and together with the IR accelerator components are shown in Fig 1.

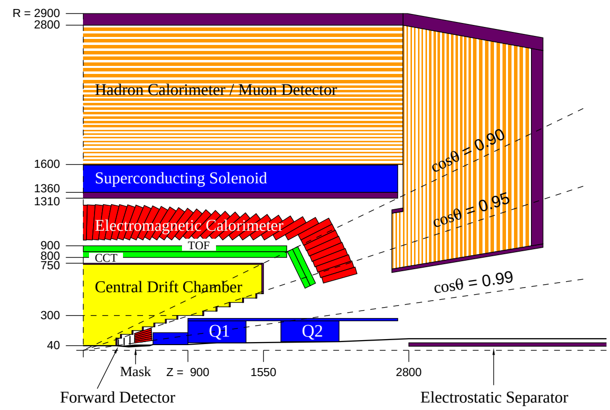

Figure 1: Schematic layout of the detector facility and IR accelerator components.

The IR is designed to be compatible with different modes[1]. Our initial choice is head-on collision or a small crossing angle configuration with flat beams. This configuration is the closest to conventional circular colliders so that the designed luminosity estimates are the most reliable. The monochromator mode will be realized by changing the polarity of the insertion quadrupoles and using additional quadrupoles in the beam separation region.

Figure 2 is the magnet layout of the interaction region. Two iron-free superconducting quadrupoles (Q1, Q2) are used to achieve the micro-beta function at the IP. The maximum field gradients of Q1 and Q2 are respectively 29 T/m and 20 T/m with a length of 0.5 m. An electrostatic separator (ES) with 3.5 m long makes two beams separation about 9 mm at the first parasitic crossing point which is just inside of ES. Two vertical offset quadrupoles QV1 and QV2 are used to further increase beams separation so that a sufficient separation is obtained to install the vertically bending septum magnets while QV1 and QV2 have a function to focus the beams in horizontal plane. Three bending magnets BV1, BV2, and BV3 further finish the beams separation. The last vertical bending magnet BV4 brings the beams back onto horizontal orbit.

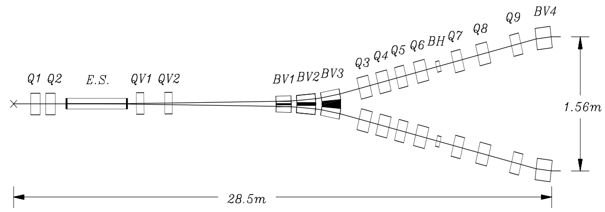

Figure 2: Magnet layout in the interaction region.

3 SUPERCONDUCTING SOLENOIDS AND QUADRUPOLES

The detector superconducting solenoid has a maximum field strength of 1.0 T over a distance of ± 2.70 m around the IP. This longitudinal magnetic field causes strong coupling of the betatron oscillations and perturbations of the machine beam optics. To reduce this effect, an A-S and an S-S are used on each side of the IP to compensate the detector field along the beam line[2]. Located at 0.6 m away from IP, A-S with an effective field length of 0.3 m and field strength of 3.0 T compensate the detector field from IP to 0.9 m, and S-S which has a field of 1.0 T and effective length of 1.8 m compensate the detector field from 0.9 m to 2.7 m. Calculation of the magnetic field by combination of these solenoid magnets and the detector solenoid, including effects of iron yoke of the detector, has been done with computer code. The design parameters of the anti-solenoid and the shield solenoid are listed in Table 1.

Table 1: Main parameters of the compensation solenoid.

	A-S	S-S
central field	3.0	1.0 T
current	442.6	86.61 A
max. field on conductor		
with detector field	1.80	1.035 T
no detector field	2.935	1.80 T
store energy	44.58	80.93 KJ
current density	147.5	28.87 A/mm^2
magnetic pressure		
in radial direction	9.8	0.4 MPa
coil IR	100	182 mm
coil OR	120	202 mm
number of turns	1500	11700
effective magnet length	300	1800 mm
body force		
in axial derection	25.42	37.35 KN

Though the strength of the longitudinal attractive forces between the end yoke and the A-S and S-S is somewhat larger, they are within the acceptable level for engineering viewpoints.

Because the S-S screens the Q1 and Q2, the saddle coils of Q1 and Q2 no longer suffer large attractive forces coming from the detector field. The Q1 and Q2 saddle coil end parts should sustain enough radial attractive forces when the S-S does not work. The design parameters of the quadrupoles are listed in Table 2. The design is based on the cos2θ windings that are clamped by stainless collars. The maximum fields of the Q1 and Q2 are all less than 4.0 T, these quadrupoles can be operated in a very wide margin.

Table 2: Main parameters of the quadrupoles.

	Q1	Q2
field gradient	29	20 T/m
effective field length	500	500 mm
current	3096.6	2381.9 A
max field on conductor	3.47	2.98 T
store energy	218.6	150 KJ
induction	22.8	53 mH
coil IR	115	125 mm
coil OR	129	139 mm
number of turns	110	119 /pole

Figure 3 shows the cryostat cross section at the middle of the Q2 quadrupole. Starting with the innermost part, the main components of the cryostat at Q2 are: inner vacuum vessel, inner radiation shield, inner helium vessel (80K), inner helium vessel (4K), Q2 correction coil, Q2 coil, stainless collar, outer helium vessel (4K) for Q2, inner helium vessel (4K) for shield solenoid, shield solenoid correction coil, shield solenoid coil, outer helium vessel (4K), outer helium vessel (80K), outer radiation shield, outer vacuum vessel. The inner and outer diameter of the vacuum vessel of the cryostat at Q2 are 180 mm and 508 mm respectively.

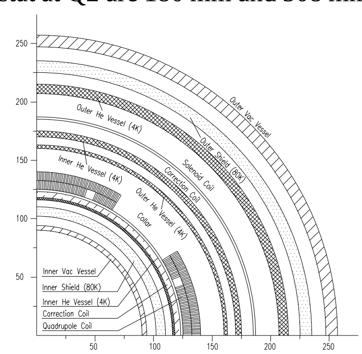

Figure 3: Cryostat cross section at the middle of Q2.

A cryostat will be installed at each side of the IP. They are supplied through a multi-channel transfer line by a comman cryogenic system. Many practical constraints near the IP are considered for designing the cryostat, including small outer diameter, large warm bore, narrow thermal space, sufficient strength to sustain the forces on the magnets, small heat load, easy operation and maintenance.

4 IR VACUUM CHAMBER CONSIDERATION

To ensure adequate quantum life time, the chamber is designed to accommodate at least 14σ. The diameter of the IP vacuum chamber grows up from 80 mm at IP to 120 mm at forward detector, to 140 mm at A-S and at Q1, to 160 mm at Q2.

In order to easily assemble the SC cryostat, the beam pipe is divided into three parts at its different cross section. The first part is over a distance of ± 0.60 m around the IP, which ends at the forward of the A-S. The second part begins at the forward of A-S and ends at the backward of Q1 with the length of 0.8 m. The third part begins at the backward of Q1 and ends at the backward of S-S with the length of 1.3 m. The central section of the first part is a double-walled pipe of pure beryllium with the length of 400∼600 mm around IP. The inside wall and outside wall are all 0.5 mm thick with a space of 1 mm between the two walls for helium cooling. The beryllium section around IP is brazed directly to the copper beam pipe that extends outside.

After the first part of the beam pipe has been pushed in and assembled onto the inner surface of the central drift chamber by support pillars at 0.6 m from IP, the forward detector, which has been divided into four sectors(each sector 90^o) in order to assemble easily, is then assembled onto the beam pipe at 300-600 mm from IP. Next the second part is assembled on the first part, then the SC cryostat is pushed in along the beam line through a movable table, at last the third part is assembled on the second part through a special flange.

The average pressure of the vacuum chamber will be maintained below 5×10^{-10} Torr by the distributed NEGPs at the upstream of Q1 and Q2. Ti-sublimation pumps(TSP) surrounding the beam pipe at A-S will absorb the large SR power.

5 SUPPORTING SYSTEM

Design of IP suport system is based on these cosiderations: sufficient rigid strength, easy assembly, easy maintenance, and easy alignment. For the accelerator requirement, the whole cryostat of the SC component should be completely buried inside the detector. So the cryostat assembly can only go along the beam line.

The SC cryostat at each side of the IP is supported by a precise table. Controlled by a host computer, the table can be moved along the beam line (Z direction), horizontally (X direction), vertically (Y direction), and can also be rotated around the X and Y axises. During the operation, the mass center of the cryostat is nearly 1.8 m off from the support table which has to remain outside of the detector, so enough rigid strength is needed for cryostat and joints that connect the cryostat and the support table to prevent the shake of the cryostat from earthquake.

Each cryostat has its position monitors for detecting the cryostat X, Y position and its tilt meters for detecting the tilt of the cryostat. For easy alignment of the two cryostats along the beam line, each cryostat has a set of hair cross targets stationed on its top surface. On each endplate of the detector central drift chamber, two glass windows will be installed to allow the surveyors looking through left and right of hair targets on the SC cryostats.

In order to easily access into the inner detector, the detector end yoke is designed to split into two same doors along its central vertical line. When the left and right door of the detector end yoke are opened and moved along X in opposite direction, the support table that loads the 3.5 m long ES is receded about 1.2 m along the beam line and then moved along X direction about 2 m, next disassembled the third part of the beam pipe in order to easily pull out the SC cryostat, then the SC cryostat table can be receded along the beam line.

6 BACKGROUND ISSUES

IR beam-related background includes synchrotron radiation (SR) photons and lost beam particles. SR is produced when beam particles experience transverse accelerations in the magnetic fields of quadrupoles and dipoles. Lost particles are created through Bremsstrahlung and Coulomb scattering on the residual gas molecules inside the vacuum chamber.

According to the computer simulation[3], the SR fans generated from the bending magnet BV1, BV2, BV3, offset quadrupoles QV1, QV2, and electrostatic separator ES mainly strike on the central part of the beam pipe and on the end part of the ES. Lost particles through Bremsstrahlung hit the vacuum chamber between the two ES. Two half-circle shaped masks, made of high Z material such as tantalum and installed inside at upstream of the copper vacuum chamber, are designed to prevent the SR fans from directly striking on the beam pipe. They also are used as masks to intercept the lost particles. A vertically movable mask should be placed between QV1 and QV2 to intercept parts of SR fans from hitting on the ES's. In order to reduce the rate of lost particles, two more movable masks are arranged in vertical direction, one is placed at upstream of BV3 at 17.7 m from IP, another is at 46.55 m from IP. With these masks and movable masks, the IR background can reach better condition than the two B factories[4].

7 SUMMARY

The interaction region of BTCF is described. The beam separation scheme is initiated by two electrostatic separators, two offset quadrupoles and several vertical bending magnets further finish the beam separation. The SC cryostat at 0.9m from IP must be stayed within a limited angle(18.2^o) in order to provide maximum amount of the detector solid angle. The SC cryostat that contains superconducting magnets is supported by a movable table which can be moved along the beam line easily. In order to assemble the IR beam pipe easily, it is divided into several parts at its different cross sections. IR background can be reached a relatively better condition by using several masks.

8 REFERENCES

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