BEIJING TAU-CHARM FACTORY DESIGN STUDY

BTCF Design Group, Presented by Y.Z. Wu
IHEP, Chinese Academy of Sciences, P.O. Box 918-9, Beijing 100039, P.R. of China

Abstract

This paper describes recent progress of the design of the Beijing Tau-Charm Factory (BTCF). The main machine goals, parameters, various operation modes, and some hardware systems are reviewed here.

1 INTRODUCTION

A Tau-Charm Factory (TCF) is a high luminosity e^+ e^- collider operating near the J/ψ and τ production threshold, which requires center of mass about 3 to 6 GeV. It has been considered as an unique facility to research some areas of particle physics by the worldwide communities of the high energy physics [1].

The feasibility study of the BTCF was approved in Feb. of 1995. Since then the design study activities have mainly focused on the optimization of the lattice and a preliminary study of key components and systems. The experiences from the existing e^+e^- storage ring colliders, specially from CESR and BEPC provide a firm foundation for BTCF design. Also there is a lot experience that we can use from previous designs of TCF, B-factory and ϕ-factory. Considerable economies can be achieved by siting BTCF nearby BEPC site. The injector system (linac) of BEPC can be used for the injector of the BTCF and there are substantial opportunities to use the hardwares and existing buildings and the other infrastructure for BEPC [2]. The layout of general BTCF is shown in Figure 1.

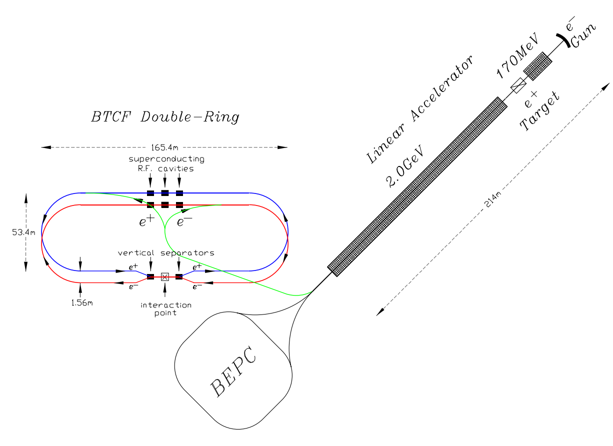

Figure 1: General layout of the Beijing tau-charm factory.

2 GOALS AND PARAMETERS

The BTCF is planned, ultimately, to have three modes of operation. In priority order, they are the high luminosity mode, longitudinal polarization mode and monochromator mode respectively. Accordingly, this design focuses primarily on the high luminosity mode. Preliminary designs for providing polarization and monochromatic operation are included to assure that the basic design is compatible with eventual operation in these modes. The main machine parameters for the high luminosity mode and the monochromator mode are listed in Table 1. The design goals are listed as follows:

- Achieving a peak luminosity $L = 1 \times 10^{33}$ cm^{-2}s^{-1} in a high luminosity mode at a beam energy E = 2.0 GeV.
- Beam energy being adjustable from 1.5 GeV to 2.5 GeV with the potential up to 3.0 GeV being kept.
- Providing the possibility of the operation of the polarization mode and the monochromator mode in the future.
- Maintaining the detector background at acceptable level.
- Keeping high injection efficiency and reliable operation.

3 DESCRIPTION OF THREE MODES

The collider consists of two rings, one above the other, with one IP. Each ring is 53 m wide and 165 m long with a circumference of 385.4 m. The two rings are vertically separated 1.56 m. Each ring can be divided into four main parts: one interaction region (IR) with a beam separation section at each side, the spin rotator sections for the polarization mode, two arcs and an utility region with the injection section at one side. Detailed design of the optics for the operation modes has been discussed in Ref. [3]. The design about IR and background issues can be referred to in Ref. [5]. The beam-beam issue is discussed in [6]. The following is general description for the three operation modes.

3.1 High Luminosity Mode

Electron and positron beams collide at a small horizontal crossing angle which is refered to the crossing angle scheme. This scheme has the advantages that more bunches can be stored and the particles per bunch can be reduced

Table 1: Machine parameters for BTCF including the high luminosity mode and the monochromator mode.

Mode	High Lumi.	Monochr.
Beam energy E (GeV)	2.0	1.55
Circumference C (m)	385.447	385.447
Revolution frequency f_0 (MHz)	0.778	0.778
Crossing angle at IP $2\phi_c$ (mrad)	5.2	0.0
β-function at IP $\beta_x^*/\beta_y^*(m)$	0.66/0.01	0.01/0.15
Dispersion at IP D_x^*/D_y^* (m)	0.00 /0.00	0.00/0.45
Betatron tunes Q_x/Q_y	11.75/11.76	12.21/11.23
Momentum compaction α_p	0.014	0.014
Synch. rad. loss/turn U_0 (keV)	174	67
Damping time $\tau_x/\tau_y/\tau_\epsilon$ (ms)	30/30/15	26/61/90
Natural emittance ϵ_{x0} (nm)	138	36
Vertical emittance ϵ_y (nm)	2.1	5.3
Momentum spread σ_ϵ	5.9×10^{-4}	7.8×10^{-4}
Synchrotron tune Q_s	0.069	0.067
Natural chromaticity Q_x'/Q_y'	-17/-35	-36/-31
Total current per beam I (A)	0.57	0.33
Number of bunches k_b	86	29
Particles per bunch $N_b(10^{11})$	0.54	0.93
Bunch space (m)	3.78	11.97
RF frequency f_{rf} (MHz)	476	476
RF voltage V_{rf} (MV)	6.8	5.0
Natural bunch length σ_l (cm)	0.76	1.0
Beam-beam effect ξ_x/ξ_y	0.044/0.04	0.018/0.015
Luminosity L (cm^{-2}s^{-1})	1×10^{33}	2×10^{32}
CM energy spread σ_ω (MeV)	1.7	0.14

compared to the head-on collision at the certain luminosity. There are 86 bunches spaced 3.78 m in each ring for this scheme with the gap of about 15% leaving for ion-clearing. The crossing angle ϕ_c at the interaction point (IP) is chosen as $2\phi_c \leq 0.16\sigma_x^*/\sigma_l$ to avoid the excitation of synchro-betatron resonance according to the CESR experience [4]. This angle is produced by a pair of horizontal bending magnets BHs, each located symmetrically in one side of the IP. The horizontal phase advance between the BH and the IP is π so that the orbit distortion is defined between this two BHs. Certainly, head-on collisions can be obtained if needed and the way is to turn off the BHs.

3.2 Polarization Mode

The major energy range of the longitudinal polarized beam required by physics side is around 2.0 GeV and 1.55 GeV. In case of BTCF, the polarization time due to Sokolov-Ternov effect is too long [2] compare to the beam lifetime. The use of asymmetric wiggler to shorten the polarization time causes the significant increase in energy spread. Consequently, the beams must be prepolarized before they are filled into the ring. It is planned that only e$^-$ is prepolarized at begin ing for the design.

The spin rotation scheme(s) is certainly needed to ensure the longitudinally polarization at the interaction point. Three kinds of spin rotator, say, HERA-type mini-rotator, symmetric solenoid spin rotator and Siberian snake, are studied to seek the proper scheme on the BTCF. Briefly, the main difficulty for the mini-rotators each consisting of 3 vertical and 3 horizontal bends is that the vertical emittance produced by vertical bends can not be neglected owing to the large bending angle (about 20° at 2.0 GeV) needed. The vertical emittance can hardly be controlled lower then 10 nm with general arrangement. The more sophisticated arrangement aiming to minimize the vertical emittance needs to split the large dipoles to 2-3 small pieces and to insert quadrupoles in between therefore longer space is required. The Siberian snake is the candidate for low energy polarization scheme on BTCF. However it suffers from the short depolarization time, i.e., about 26 minutes at 1.55 GeV.

The scheme adopted in current BTCF design is symmetric solenoid spin rotator. The rotator in each side of the IR consists of a pair of superconducting solenoid and 2 horizontal dipoles to rotate the spin direction and many quadrupoles for the local coupling compensation and other matching. To reach an applicable polarization level the spin-matching must be applied to suppress the strong depolarization effects even for the perfectly aligned machine. The 'partial' spin-matching by adjusting 25 quadrupole strengthes results in remarkable enhancement in depolarization time (100 minutes) and equilibrium polarization level. Change in helicity can easily be achieved by reversing the field direction of solenoid.

Generally speaking, up to now, the consideration for the longitudinal polarization has significantly changed the layout and lattice of BTCF. The detailed studies [7] suggest that more modifications in ring design are necessary to optimize the performance of polarization operation mode. For instance, a larger circumference(420-450m) is much preferable.

3.3 Monochromator Mode

The monochromator mode has been incorporated into design at normal energy of 1.55 GeV with 29 bunches in each ring. The bunch space is 11.97 m with the gap of about 10% for ion-clearing. This mode doesn't affect the layout of the storage ring. Only small variation is needed. In the IR, some qaudrupoles are required to change polarity, and some are required to turn on or turn off. In arc, eight Robinson wigglers are arranged to reduce beam emittance and increase beam energy spread.

4 INJECTION

The BEPC linac system will be upgraded to a full energy injector which will provide the ability to finish the injection in 5 minutes. To this end, the following measures will be taken: (1) upgrading linac energy. An accelerating unit (12 m long) will be added in the end of the existing linac, and meantime 14 new klystrons (65 MW) replace the present 14 klystrons (30 MW); Another option is to use recirculating scheme. (2) Increasing the positron yield rate. A high current electron gun(10 A) would be developed to increase the electron strength on the e^+ target and the positron target are moved to next station to enhance the bombarding energy of electrons; (3) Increasing the repetition rate from current 12.5 Hz to 25 Hz; (4) adopting the bunch train injection mode.

5 INSTABILITY CONTROL

The beam current limitation and its stabilities are very important issues for the BTCF. To reach the high luminosity, there is high current in storage ring. A great attention must be paid on the effects which the strong current maybe cause.

The criterion of microwave instability gives an impedance threshold requirement at single bunch current of 6.7 mA as $|Z/N|_{eff} \leq 0.51\Omega$. The present estimation for the impedance of ring components including RF cavities, kickers, separators and vacuum chambers indicates that $|Z/N|_0 \sim 0.24\ \Omega$. It seems that a good control of ring impedance can be realized. The bunch lengthening effect due to the longitudinal wakefield has also been investigated with a code [8] developed in KEK. The results show that the bunch length increases about 6%.

The important means to control multibunch instability is to reduce the number and impedance of the high-Q resonant structures in the rings, so that the superconducting cavities would be adpoted. Using of the HOM dampers would reduce external Q value less than 100. Great progress has been made in the design and test of fast feedback system at PEP-II and other labs, which makes it feasible to develop a system for the BTCF to suppress instability as required.

For the Transient Ion Trapping and Beam-Photoelectron Interaction, their mechanisms are being investigated with simulation program developed in KEK, and related machine studies are in progress in the BEPC and other laboratories. Due to the factor that the BTCF has a large beam emittance and less bunch numbers than B factory, it would be expected that these instabilities in BTCF should be much weaker than that in a B-factory.

6 RF SYSTEM

The design requirements of the RF system are mainly based on following considerations: maintaining a short bunch length of less than 1 cm; minimizing the contribution of RF system to the machine impedance.

Single-cell and deeply damped superconducting (SC) cavity with a frequency of 476 MHz is selected in terms of following reasons. First, it has large gradient$\sim$ 10 MV/m. Second, it has large beam pipe and small impedance. The RF voltage is designed at 9 MV in maximum and operated at 6.8 MV with 3 SC cavities per ring. Each cavity delivers 50 KW to the beam.

7 VACUUM

The BTCF storage ring requires that the operating pressure should be $\leq$1x10^{-9} Torr in the arc region and $\leq$5x10^{-10} Torr in the IR.

Total pumping speed of 5.8x10^4 L/s with 58 sets of sputter ion pumps and NEG pumps is needed per ring to deal with high thermal load and minimize the photo desorbed gas load. A test with NEG pumps to get the pressure of lower than 10^{-10} Torr has been done, which provides experience to the design of the IR vacuum.

The vacuum chamber will be made of extruded aluminum in the arc and stainless steel in the straight section with the following inner dimensions: 90 mm$\times$60 mm in arc region (H$\times$V); 90 mm$\times$90 mm in utility section; 130 mm $\times$ 130 mm in Q1 and 150 mm $\times$ 150 mm in Q2; The vacuum pipes at bending magnet region consist of two parts: the beam chamber and antechamber in which the copper absorbers are installed to intercept the synchrotron radiation flux. The great attentions has been paid to smoothness of the chamber.

The vacuum system of the BTCF is similar to B-factories and ϕ-factory but not quite as much of a challenge with that of other factories. So their experiences will be incorporated to the BTCF design.

8 SUMMARY

The BTCF with a luminosity of 10^{33}cm^{-2}s^{-1} at the energy of 2.0 GeV is feasible on a rather conventional basis of multibunch and small crossing angle collision scheme together with a micro-β insertion. To reach such a goal, it is essential to incorporate the advanced experience and the technological achievements of the existing e^+e^- storage ring collider. However, some challenging work for the BTCF still needs to be studied further in optimizing the lattice, the IR design, impedance control, RF design, vacuum design and some problems related to the engineering.

9 REFERENCES

1. Memorandum on the Tau-Charm Factory in the era of B-Factories and CESR, SLAC, Aug. 15-16, 1994.
2. Feasibility Study Report on Beijing Tau-Charm Factory, IHEP-BTCF, Report-02.
3. N. Huang, L.H. Jin, et al, “Lattice Design of BTCF Storage Ring”, this proceedings.
4. M. Tigner, Private communication.
5. Y.Z. Wu, Q.L. Peng, “Interaction Region Design for Beijing Tau-Charm Factory”, this proceedings.
6. C. Zhang, et al, this proceedings.
7. D.Wang, to be published.
8. K. Oide and K. Yokoya, KEK Preprint 90-10, 1990