LATTICE DESIGN OF BTCF STORAGE RING

N. Huang, L.H. Jin, W.B. Liu, D. Wang, Z.T. Wei, C.H. Yu
IHEP, Chinese Academy of Sciences, P.O. Box 918-9, Beijing 100039, P.R. of China

Abstract

This paper will describe the latest improved optics design of Beijing Tau-Charm Factory (BTCF). It has larger dynamic aperture for the high luminosity mode, higher luminosity with longer Touschek lifetime for the monochromator mode, compared with previous design[2]. Some study results of spin matching of polarization mode will be presented here.

1 INTRODUCTION

In terms of the goals of the machine [1], the lattice is designed to take the high luminosity mode as the first priority, meantime to be compatible with the polarized beam collision mode and monochromator mode.

2 OPTICS

The BTCF consists of two rings , one above the other, with one interaction point (IP). Each ring is 53 m wide and 165 m long with a circumference of 385.4 m. The two rings are vertically separated about 1.67m. Each ring can be divided into four main parts: The interaction region (IR), two polarization insertions, two arcs and a utility region with injection section. (see Figure 1). The main lattice parameters for the high luminosity mode and monochromator scheme are listed in Table 1. The lattice functions of the whole ring for the high luminosity mode are shown in Figure 2.

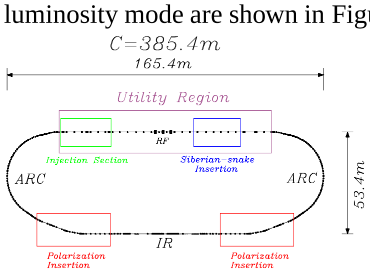

Figure 1: Schematic diagram of the BTCF storage ring.

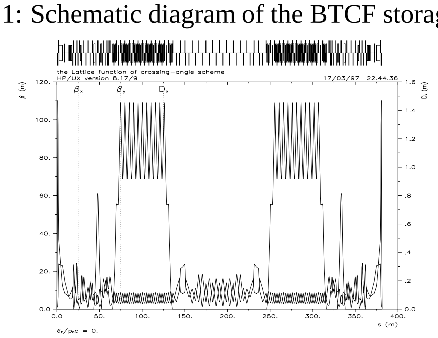

Figure 2: Twiss parameters of the high luminosity mode.

3 INTERACTION REGION

At each side of the IP there are a micro-beta insertion and a vertical separation insertion. Figure 3 shows the magnet layout in the region.

Table 1: Main lattice parameters for the high luminosity mode.

Mode	High Lumi.	Monochr.
Circumference (m)	385.4	385.4
Normal Energy (GeV)	2.0	1.55
Crossing angle at IP (mrad)	2.6×2	0.0
Bending radius (m)	8.33	8.33
Beta-functions at IP (m) Hori./Verti.	0.66/0.01	0.01/0.15
Dispersion-functions at IP (m) Hori./Verti.	0.0/0.0	0.0/0.45
Natural horizontal emittance (nmrad)	138	83 36(with wig.)
Vertical emittance (nmrad)	2.1	5.3
Tunes,Hori./vert.	11.75/11.76	12.21/12.23
Natural chromaticity, H/V	-17/-35	-36/-31
Momentum compaction	0.014	0.014
Momentum spread (10^{-4})	6	7.8(with wig.)
Damping time,H/V/Longi.(ms)	30/30/15	26/61/90
Number of benches	86	29
Particle per bench (10^{10})	5.4	9.3
Beam-beam parameters ξ_x/ξ_y	0.044/0.04	0.018/0.015
Luminosity ($10^{33}cm^{-2}s^{-1}$)	1.0	0.2
Energy spread at CM (MeV)	1.7	0.14

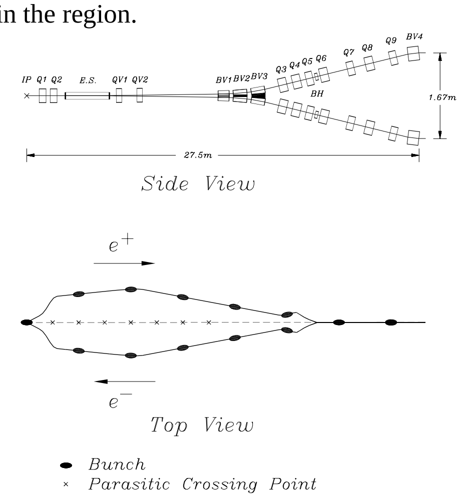

Figure 3: Magnet layout in the interaction region.

The two iron-free superconducting quadrupoles (Q1 and Q2) are used to achieve the micro-beta function at the IP. Q1 is 0.9 m away from the IP. Q1 and Q2 are protruded into the detector. The distance between Q1 and Q2 is kept 0.3 m. The maximum field gradients of Q1 and Q2 are respectively 29 T/m and 20 T/m with a length of 0.5 m. After colliding at the IP, the two beams are initially separated by an electrostatic separator ES, located 0.6 m away from Q2, with a length of 3.2 m. The ES field is limited below 1.5 MV/m to avoid the risk of sparking due to a significant quantity of synchrotron radiation. The vertical off-set quadrupole QV1 (0.5 m away from the ES) is used to further increase beam separation so that a sufficient separation is obtained to install the vertically bending septum magnets. Three vertical bending septum magnets BV1, BV2, and BV3 further finish the beam separation. The bending angle of BV3 is increased by 10 mrad and the length of IR is 1 m shorter than the previous design [2]. The last vertical bending magnet BV4 brings the beam back onto horizontal orbit.

Six quadrupoles are arranged to finish focusing and vertical dispersion matching between BV3 and BV4. The length of Q3, Q4, Q6 and Q8 is 0.6 m, while the length of Q7, Q9 is 0.5 m. Owing to the insufficient separation of the two beams, the outer radii of Q3, Q4 have to be strictly confined in one direction as 160 mm and 230 mm respectively. The maximum gradient of these quadrupoles is 15 T/m.

For the high luminosity mode, a pair of horizontal deflecting dipoles (BH), symmetrically placed just where the horizontal phase advance from the IP is π, produces a closed orbit distortion between the two BHs and makes the two beams collide at a small horizontal crossing angle (referred to the crossing angle scheme). As Figure 3 shows, the BH lies in between Q5 and Q6 and the maximum field of 0.06 T. The phase advance between ES and BV4 is about 2π so that the vertical dispersion produced by the ES, BV1, BV2 and BV3 can be suppressed. The maximum vertical dispersion function is about 0.2 m in this region.

For the monochromator mode, the polarity of Q1, Q2, Q6 has to be changed, and Q4, Q8 and BHs are switched off. The lattice functions of this region are shown in Figure 4.

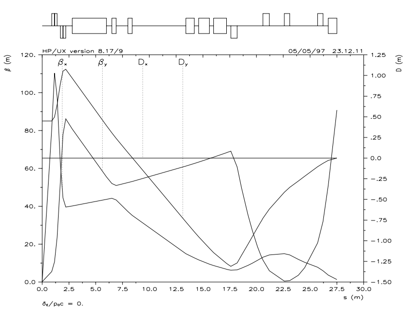

Figure 4: Lattice functions of the IR for the monochromator mode.

This mode requires that there be vertical dispersions opposite in sign and equal in value at the IP for the electron and positron. The dispersion value is changed from 0.35m to 0.45m comparing with the previous design [2] in order to increase luminosity.

The opposite dispersions can be produced by the vertical deflecting components (ES, BV1, BV2, BV3 and BV4), which make the electron and the positron into different directions. The central particle trajectory between ES and BV3 in this mode differs from the crossing angle scheme due to larger deflecting angle of ES at the strength (1.5 MV/m). The difference is canceled after BV3 by adjusting the magnitude of off-set quadrupoles QV1 and vertical septums BV1, BV2 and BV3. The phase advance between ES and BV4 is close to π in order to suppress the vertical dispersion.

Behind BV4 is the polarization insertion which only does matching to arc except polarization mode. There are beta-function matching section and spin rotator section.

3.1 Arc

Each arc consists of 14 FODO cells, including 10 normal cells with 60° phase advance and one dispersion suppressor at each end of an arc, one of which contains two FODO cells with 2 normal bending magnets missed. Each dispersion superessors close to the IR has a special bending magnet with independent power supply. The length of each normal bending magnet is 0.96m with the bending angle of 6.605°. The length of each cell is 5.12 m. The drift space of 0.6 m is provided for hardware between the dipole and the quadrupole. In this fashion, the emittance can be controlled easily by adjusting wigglers in this region.

For the monochromator mode, the lattice is almost the same as above except eight Robinson wigglers in each ring are used for redistributing the damping partition number between J_x and J_ϵ [3, 4]. For this mode, the luminosity increases as the beam energy spread increases. When the Robinson wigglers decrease the emittance, it happens to increase the energy spread. Choosing the parameters of each Robinson wiggler (4 blocks) as the effective length of 0.84 m (total length is 1.32 m) with the dipole bending radius 14m and the gradient strength 1.2 m^{-2}, J_x increases from 1 to 2.34 and J_ϵ reduces from 2 to 0.66. As a result the emittance gets to about 36 nmrad and the energy spread increases to 8×10^{-4} from natural energy spread 4.6×10^{-4} at 1.55GeV. Figure 5 shows the lattice functions in the arc.

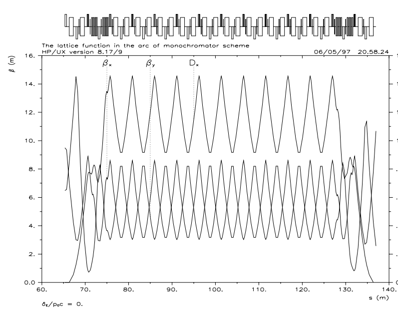

Figure 5: Lattice functions in arc for the monochromator mode.

3.2 Utility Region

A long straight region lies on the side opposite from the IR. It consists of the injection insertion and four regular FODO cells as well as two beta-function matching sections. Figure 6 gives the lattice functions in this region. The Each quadrupole here is 0.4 m long with the maximum gradient of 15 T/m. The kickers and Lambertson magnet are arranged in one injection insertion. The RF cavities are located in the regular cells which can provide over 3.2 m long drift spaces. The working points can be adjusted in this region.

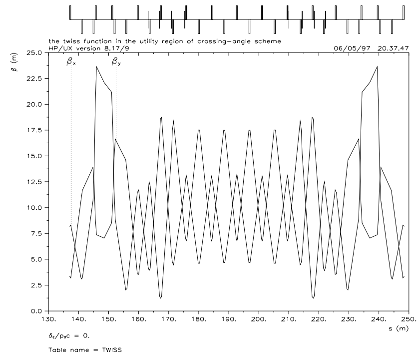

Figure 6: Lattice functions in the utility region for the high luminosity mode, (for the monochromator mode is almost the same).

3.3 Spin Rotator Section

The longitudinal polarization scheme at around 2.0 GeV adopted in current BTCF design is symmetric solenoid spin rotator.

The rotator in each side of IR consists of one Double Bend Achromat section ($19.8^\circ \sim 21.5^\circ$), and two superconducting solenoids (9.63 T) which are switched off in non-polarization mode, 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 strengths results in remarkable enhancement in depolarization time (100 minutes, see Figure 7) and equilibrium polarization level. Change in helicity can easily be achieved by reversing the field direction of solenoid. However the detailed studies show that more modifications in lattice design are needed to optimize the performance of polarization operation mode [5].

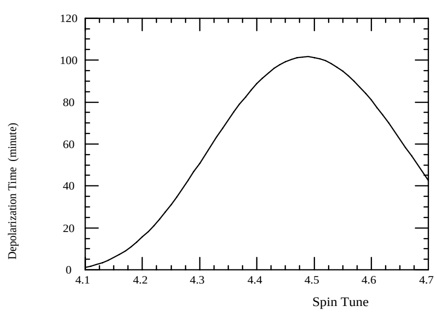

Figure 7: Depolarization time with spin-matching at 2.0 GeV.

4 TRACKING STUDIES

The tracking and simulations (without imperfections) are evaluated with the code MAD [6]. Except for the chromaticity sextupoles, no other correctors have been installed into the linear lattice. Simulations in six dimension are done for 2000 turns which corresponds to 1/12 damping time. Chromaticities in both transverse planes are corrected to a slightly positive value.

For the high luminosity mode, 48 sextupoles with five families are distributed in the arcs of each ring. Without any errors considered, the dynamic aperture of $20\sigma_x \times 15\sigma_y$ is obtained at the energy spread of $\pm 0.6\%$ with fully-coupled situation. Figure 8 gives the dynamic aperture of the high luminosity mode (without errors).

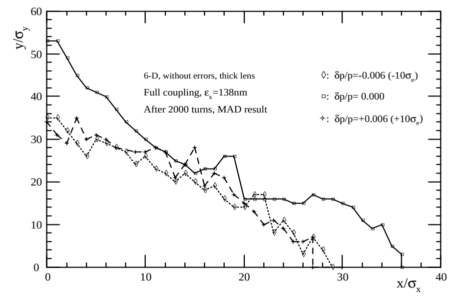

Figure 8: The dynamic aperture of the high lumi. mode.

5 TOUSCHEK LIFETIME AND DYNAMIC APERTURE OF MONOCHROMATOR MODE

5.1 Touschek Lifetime

In order to increase Touschek lifetimeτ_T large beam size and energy acceptance(E_{acc}) is necessary. So the normal cell with 60° phase advance is used in the arc to increase the dynamic aperture and energy acceptance and emittance (ϵ_x=35 nmrad with wigglers).

The results calculated by the code ZAP [7] show: when ϵ_x=13nm, ϵ_y=2nm, E_{acc}=8e-3, it has τ_T=0.5hrs . when ϵ_x=35nm, ϵ_y=5.3nm, E_{acc}=8e-3,9e-3,10e-3,11,e-3, it has τ_T=1.0hrs,1.3hrs, 1.7hrs, 2.1hrs respectively .

5.2 Dynamic Aperture

For the monochromator mode, 48 sextupoles of nine families are distributed in the arcs of each ring.The initial tracking results in six dimensions with full coupling is shown that dynamic aperture is $15\sigma_x \times 11\sigma_y$ with $\delta p = \pm 0.008$

6 CONCLUSION

The current lattice design is feasible to meet the requirement of the BTCF. The three operation modes have been compatible in one magnet lattice. Obviously, more detailed work is still needed on the aspects of the dynamic aperture and polarization.

7 REFERENCES

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