A Preliminary Lattice Design of a Tau-Charm Factory Storage Ring in Beijing

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ABSTRACT

A preliminary lattice design of a tau-charm factory (τcF) storage ring is described. This storage ring is suggested to be built in the east of the injector, BEL, of BEPC. In addition, some considerations on improving the design will be outlined.

1 INTRODUCTION

Since the initial idea [1] and the machine design [2] of a τcF are proposed, many laboratories have shown great interest in the machine and have studied a lot on it. A τcF is a high performance e^+e^- collider at beam energy range 1-3 GeV with two rings, luminosity reaching up to $1\times10^{33}cm^{-2}s^{-1}$ at 2 GeV. BEPC works at the same energy range as the τcF. In early 1993, we began considering the possibility of upgrading BEPC into a τcF through adding another ring atop the existing one. Unfortunately, the circumference of BEPC tunnel is too short to accommodate the ring of the τcF. Now it is regarded as suitable to construct a τcF storage ring in the east of the injector, BEL, of BEPC, while BEL will be improved as the injector of the τcF. The study of machine feasibility has started up with 5 million RMB yuan investment from the government, which will be finished within one and half year or less. The schematic layout of the τcF is shown in fig.1.

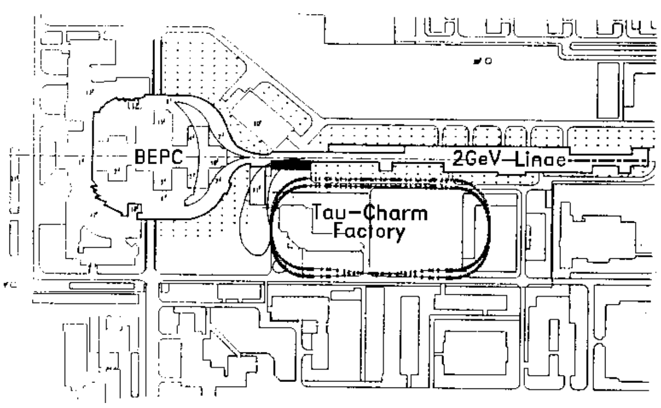

Fig.1: Possible layout of the τcF in Beijing

The preliminary design of the lattice includes both high luminosity scheme (standard scheme) and monochromator scheme. The spread of collision energy is reduced by one order of magnitude in the monochromator scheme, which will be favorable for some physics experiments, especially the study of CP violation at J/ψ resonance. In the monochromator scheme, there must be dispersion functions equal in absolute value but opposite in sign at the IP for electron and positron [3], and the luminosity can be expressed as

$$L=\frac{c}{S_B}\pi\frac{\gamma^2}{r_e^2}\frac{H_y^*}{\beta_x^*}\sigma_\varepsilon^2\,\xi_x\,\xi_y$$

c is light speed, S_B bunch spacing, γ relativistic energy factor, r_e classical electronic radius, H_y^* equal $(D_y^*)^2$ divided by β_y^* (D_y^* is vertical dispersion function at the IP), $\xi_{x,y}$ beam-beam effect parameter, and σ_ε energy spread. To maximize luminosity there need $\beta_x<<\beta_y$ at the IP and low beam emittance [4].

In addition, we expect the lattice could keep the flexibility of transferring to other promising schemes which could further increase luminosity or improve the machine performance.

2 MAGNET LATTICE

The collider includes two rings with one atop the other one respectively for electron and positron except for the only single interaction region where two rings are incorporated in the same vacuum chamber.

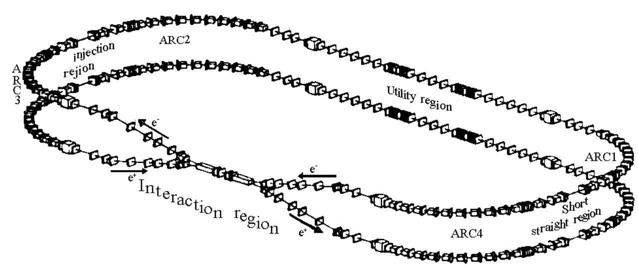

Fig.2: Schematic of the τcF storage ring in Beijing

As shown in fig.2, the circumference is 367.5m with 61.42m wide and 143.49m long, and the two rings are vertically separated 1.46m. There are 32 bunches circulating in each ring. Each ring can be divided into four main parts, including one interaction region, one utility region, four arc regions and two short straight regions one of which is used as the injection region. The main parameters of the machine including monochromator scheme are listed in table.1.

2.1 INTERACTION REGION

The interaction region includes a micro-β insertion, two e^+e^- orbits separation sections and two β-function matching sections, which are symmetrically placed on each side of the IP with a length of 95.26m, as show in fig.3.

Table.1: Principal parameters of the τcF in Beijing

Scheme	Standard	Monochr.	Crossing angle
Nominal energy E(GeV)	2.0	1.5	2.0
Ring circumference C(m)	367.5	367.5	367.5
Crossing angle at IP θ (mrad)	0.0	0.0	2.5~4.0
β-function at IP β_x^* / β_y^* (m)	0.2/0.01	0.01/0.15	0.5/0.01
Dispersion at IP D_y^* (m)	0.00	0.35	0.00
Momentum compaction α_p	0.022	0.008	0.022
Natural emittance ε_x (nm·rad)	251	20	251
Emittance with wiggler		10 (J_x=2)	
Vertical emittance ε_{yc}	12	2	4.8
Energy spread σ_ε	5.4×10^{-4}	8×10^{-4}	5.4×10^{-4}
Energy loss per turn U (KeV)	142.6	45.0	427.8
Damping time $\tau_x/\tau_y/\tau_\varepsilon$ (ms)	34/34/17	41/80/80	34/34/17
RF frequency (MHz)	500	500	500
RF voltage (MV)	9.00	9	9.00
Numbers of bunches k_B	32	32	32×3
Bunch spacing s_B	11.48	11.48	11.48/3
Total current per beam (A)	0.55	0.215	1.65
Particles per bunch	1.32×10^{11}	5.14×10^{10}	1.32×10^{11}
Natural bunch length (cm)	1.0	0.78	1.0
Impedance $\vert Z/n\vert_{\parallel}(\Omega)$	0.32	>0.32	0.32
Beam-Beam effect ξ_x/ξ_y	.04/.04	.031/.015	.04/.04
Beam life time τ (hours)	4.8	1.5	
Transverse tune Q_x/ Q_y	11.192/ 10.192	13.18/ 9.24	11.15/ 10.18
Synchrotron tune Q_s	0.098	0.068	0.098
Natural chromaticity Q'_x / Q'_y	-26.6/ -32.0	-35.9/ -44.5	-20.0/ -35.09
Luminosity L ($cm^{-2}s^{-1}$)	1×10^{33}	2.2×10^{32}	3×10^{33}
CM energy spread σ_W (MeV)	1.53	0.105	1.53

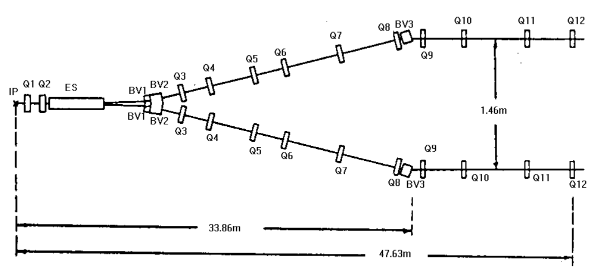

Fig.3: Interaction region of the τcF storage ring

Doublet focusing is used to achieve low β function at the IP with two superconducting quadrupoles distanced 0.8m from each other which are protruded into the detector with their outer radius no greater than 20cm due to the limitation of the detector. Their field gradients are less than 25.4T/m. Q1 is 0.8m away from the IP. The polarities of Q1 and Q2 are adverse in the monochromator scheme and the standard scheme.

After the head-on collision at the IP, the orbits of e^+ e^- are orderly separated by an electrostatic separator ES (0.006rad) with length of 4.7m, two vertical septum bending magnets BV1 (0.006rad) and BV2 (0.02rad) with length respectively 0.5m and 1.0m. The full gap of ES is 48mm and maximum electric field is 3.2MV/m. The magnetic field of BV1 and BV2 are respectively 0.1T and 0.17T and their septum thickness respectively less than 2.3cm and 2.7cm, which seems no difficulty in making. After a 0.8m long vertical bending magnet BV3 (-0.032rad), the orbit is returned to horizon. The vertical separation of e^+ e^- bunches gets 2.5σ_x for the standard scheme, and 20σ_y for the monochromator scheme at the parasitic crossing point which is 5.74m away from the IP. There are totally six quadrupoles to finish focusing and vertical dispersion suppressing between BV2 and BV3. In the monochromator scheme, Q7 will be switched off and Q8 changed polarity. The lattice functions in this region is shown in fig.4a and fig.4b.

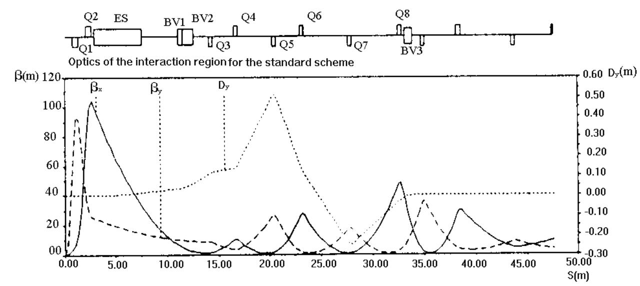

Fig.4a: Lattice functions of the standard scheme in the interaction region

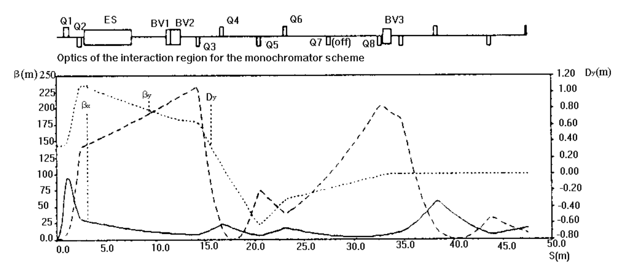

Fig.4b: Lattice functions of the monochromator scheme in the interaction region

2.2 ARC REGION AND UTILITY REGION

Each arc region consists of seven irregular FODO cells in which almost every quadupole has its own independent power supply in order to get more flexibilities. Every bending magnet give the beam bending angle of 7.5°. One magnet is missed in the sixth cell and replaced by a Robinson wiggler. Through the change of the phase advance per cell and adjusting maximum dispersion function in the region, emittance can be varied from maximum 550nm (2.0GeV) to minimum 20nm (1.5GeV). Robinson wiggler can redistribute the damping partition number J_x and J_ε [5,6] ,and so can change emittance. Four Robinson wigglers in arc regions combined with four damping wigglers in the utility region are used to reduce the emittance to 10nm (1.5GeV) in the monochromator scheme, meanwhile concomitant increasing of beam energy spread is good at maximizing luminosity which can be seen from the formula in the introduction.

The utility region consists of ten FOOD cells with a β-function matching section in each side. Some RF cavities as well as necessary instruments can be installed in this region, and working point also can be adjusted through this region. Fig.5a and fig.5b are lattice functions in half a ring.

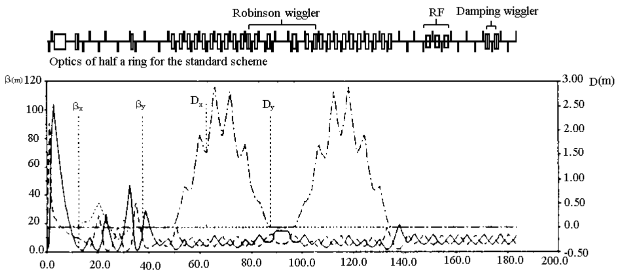

Fig.5a: Lattice functions in half a ring for the standard scheme

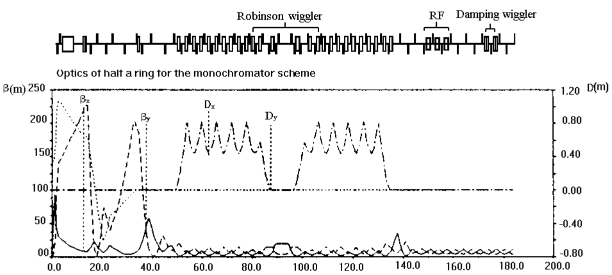

Fig.5b: Lattice functions in half a ring for the monochromator scheme

3 DYNAMIC APERTURE

Six families of sextupoles with total number of 48 are distributed in the arc regions of each ring for chromaticity correction. As to standard scheme, it seems there are no problems about dynamic aperture from the result of tracking studies as shown fig.6. Three different lines correspond to three initial energy oscillation amplitudes. In the range of energy deviation equal $10\sigma_\varepsilon$, β-function deviation at the IP is not greater than 25% and the deviation of working points (Q_x, Q_y) is 0.01.

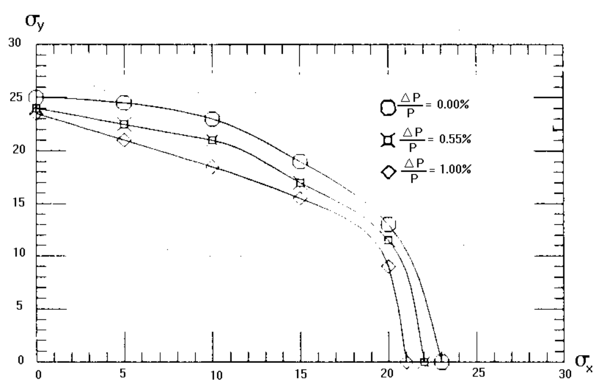

Fig.6: Dynamic aperture with three different initial energy oscillation amplitudes in standard scheme ($\varepsilon_{yc}/\varepsilon_x$=20%)

For the monochromator scheme, the result of tracking studies shows dynamic aperture is 20mm in horizontal direction and 15mm in vertical direction with 0.3% energy deviation at the injection point, which maybe is not sufficient, especially for energy acceptance. However due to existence of vertical dispersion function in the interaction region, additional two sextupoles (electrostatic and 90° rotated) could be installed this region for local chromaticity correction, one between Q1 and Q2 for horizontal chromaticity correction, the other one between BV2 and Q3. The studies on it are under way.

4 FUTURE CONSIDERATIONS

Now a collision scheme with a small horizontal crossing angle (2.5~4mrad) at the IP, which one assumes is too small to drive the synchro-betatron resonance [7] , is being studied on the basis of above design. The crossing angle can be caused by a pair of horizontal deflection dipoles which are symmetrically located just where the phase advance is π or 2π from the IP. To get the two beams are horizontally separated $10\sigma_x$ at the parasitic crossing point, β-function at the IP has to be increased to over 0.5m. The initial study shows bunch spacing can be decreased by three times and so numbers of bunches increased by three times. Obviously luminosity could be expected to close to $3\times10^{33}cm^{-2}s^{-1}$.

Several other versatile lattice designs have been being studied to provided more flexibility in IR and ARC. A complete polarization scheme is also being studied aiming at producing longitudinal polarized colliding beams at 1.55 GeV or 2.087GeV.

5 CONCLUSION

The preliminary lattice design could meet requirements of both standard scheme and monochromator scheme, and keep a possibility of transferring to a crossing angle collision scheme.

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