DYNAMIC APERTURE STUDY ON BEIJING τ-CHARM FACTORY DESIGN

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1 INTRODUCTION

The Beijing τ-Charm Factory (BTCF) is a two-ring collider, with the beam energy of 2 GeV, including both crossing-angle and monochromator schemes. Some brief parameters of the ring are shown in table 1. The dynamic aperture behaves as a crucial role in the design of collider, especially the particle factories. The arrangement of chromaticity sextupoles, which influence the dynamic aperture mainly as considered, is illustrated in the following section. The 6-dimensional simulations were done with MAD code mainly, while SIXTRACK was also used for comparison and cross-checking. High order multipolar components for magnets were assigned in the tracking. To improve the dynamic aperture of the machine, the lattice has been made some progress, and the mono-chromator scheme has also been upgraded as well. In this paper, only the dynamic aperture simulations on the crossing-angle scheme are described.

Table 1: Main parameters of the BTCF storage ring[1]

Beam energy (GeV)	2.0
Circumference (m)	385.447
Crossing angle at IP (mrad)	5.2
β-function at IP (m/m)	0.65/0.01
Betatron tunes Q_x/Q_y	11.8/12.6
Momentum compaction	0.014
Natural chromaticity Q'_x/Q'_y	-20/-36
Natural emittance (nm)	153
Energy spread	5.84×10^{-4}
Synchrotron tune	0.068
Total current per beam (A)	0.57
Number of bunches	86
Luminosity ($cm^{-2}s^{-1}$)	1×10^{33}

2 SEXTUPOLE INSTALLATION AND LATTICE EVOLUTION

In the design of Preliminary Lattice (PL) for BTCF storage ring[1], two families of chromaticity sextupoles have been set. They are interleaved with different phase advance between the SD's and the SF's (SD stands for the defocusing sextupole, while SF the focusing one.). The phase advance of each cell in the arc is around 60°. This brings about the diminishing of the dynamic aperture of the storage ring, as shown in the following sections. To overcome the shortcoming of the lattice and increase the dynamic aperture, an Improved Lattice (IL) with different sextupoles array has been developed[2]. In the IL, we arranged the sextupoles again according to the theory of W vector proposed by B.Montague[3] and changed the phase advance of cell to exact 60°. The sextupoles are still interleaved, but with same phase advance between SD's and SF's. At last, the tunes have been changed to near 11.25 in horizontal and 12.25 in vertical. This Improved Lattice has a better dynamic aperture compared with the Preliminary Lattice, even with the effects of multipolar components of magnets.

3 ERROR ASSIGNMENT

The stable area in phase space is affected by the non-linear fields introduced by magnet imperfections or by the beam-beam effect. The non-linearities are measured in terms of the high-order coefficients a_n and b_n of the complex field expansion (European convention)

$$B_y + iB_x = B_1 \sum_n (b_n + ia_n)(z/R_r)^{n-1} \qquad (1)$$

where B_1 is the nominal vertical magnetic field, B_y and B_x are the actual components of the field in the vertical and horizontal planes, R_r is the reference radius, and $z = x + iy$.

In the light of the experience of BEPC and other machine, such as PEP[4], only random or rms. errors with Gaussian distribution for dipoles and normal quadrupoles are given to the simulations. Both systematic and random errors for the superconducting insertion quadrupoles near the collision point are introduced in the tracking program. Table 2 shows the expected field pertubations of dipoles and quadrupoles.

Neither field strength error, nor roll error, nor misalignment has been put into simulation because we don't install any correctors except for chromaticity sextupoles. All the three kinds of above errors could be compensated by dipolar or skew quadrupolar correctors. The parallel studies are still under way.

4 TRACKING ON DYNAMIC APERTURE

The dynamic aperture is defined as the maximum initial amplitude of particles which have to survive for suitable time in electron ring. Above a certain oscillation amplitude the particle motion becomes unstable. A large dynamic aperture is required for a reliable lattice of storage

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Table 2: Field errors expected for tracking (in units of 10^{-4} at R_r=1cm)

Random errors in dipole				Random errors in quadrupole			
b_1	0.000	a_1	0.000	b_1	0.000	a_1	0.000
b_2	0.000	a_2	0.000	b_2	0.000	a_2	0.000
b_3	0.174	a_3	0.000	b_3	0.220	a_3	0.000
b_4	0.008	a_4	0.000	b_4	0.013	a_4	0.000
b_5	0.003	a_5	0.000	b_5	1.46E-3	a_5	0.000
b_6	0.000	a_6	0.000	b_6	5.73E-4	a_6	0.000
b_7	0.000	a_7	0.000	b_7	0.000	a_7	0.000
b_8	0.000	a_8	0.000	b_8	0.000	a_8	0.000
b_9	0.000	a_9	0.000	b_9	0.000	a_9	0.000
b_{10}	0.000	a_{10}	0.000	b_{10}	9.216E-7	a_{10}	0.000
b_{11}	0.000	a_{11}	0.000	b_{11}	0.000	a_{11}	0.000
b_{12}	0.000	a_{12}	0.000	b_{12}	0.000	a_{12}	0.000
b_{13}	0.000	a_{13}	0.000	b_{13}	0.000	a_{13}	0.000
b_{14}	0.000	a_{14}	0.000	b_{14}	5.734E-10	a_{14}	0.000

Field errors in superconducting quadrupole Q1							
Systematic errors				Random errors			
b_2	0.000	a_2	0.000	b_2	0.000	a_2	0.000
b_3	0.000	a_3	0.000	b_3	2.64E-2	a_3	0.000
b_4	0.000	a_4	0.000	b_4	3.04E-3	a_4	0.000
b_5	0.000	a_5	0.000	b_5	3.49E-4	a_5	0.000
b_6	0.000	a_6	0.000	b_6	4.01E-5	a_6	0.000
b_7	0.000	a_7	0.000	b_7	4.61E-6	a_7	0.000
b_8	0.000	a_8	0.000	b_8	5.30E-7	a_8	0.000
b_9	0.000	a_9	0.000	b_9	6.09E-8	a_9	0.000
b_{10}	0.000	a_{10}	0.000	b_{10}	7.00E-9	a_{10}	0.000
b_{11}	0.000	a_{11}	0.000	b_{11}	8.05E-10	a_{11}	0.000
b_{12}	0.000	a_{12}	0.000	b_{12}	9.25E-11	a_{12}	0.000
b_{13}	0.000	a_{13}	0.000	b_{13}	1.06E-11	a_{13}	0.000
b_{14}	0.000	a_{14}	0.000	b_{14}	1.22E-12	a_{14}	0.000
b_{15}	0.000	a_{15}	0.000	b_{15}	1.41E-13	a_{15}	0.000
b_{18}	-8.54E-14	a_{18}	0.000	b_{18}	0.000	a_{18}	0.000

Field errors in superconducting quadrupole Q2							
Systematic errors				Random errors			
b_2	0.000	a_2	0.000	b_2	0.000	a_2	0.000
b_3	-6.20E-2	a_3	0.000	b_3	5.59E-2	a_3	0.000
b_4	2.41E-2	a_4	0.000	b_4	1.32E-2	a_4	0.000
b_5	1.97E-3	a_5	0.000	b_5	3.12E-3	a_5	0.000
b_6	-3.69E-4	a_6	0.000	b_6	7.38E-4	a_6	0.000
b_7	0.000	a_7	0.000	b_7	1.75E-4	a_7	0.000
b_8	0.000	a_8	0.000	b_8	4.13E-5	a_8	0.000
b_9	0.000	a_9	0.000	b_9	9.76E-6	a_9	0.000
b_{10}	0.000	a_{10}	0.000	b_{10}	2.31E-6	a_{10}	0.000
b_{11}	0.000	a_{11}	0.000	b_{11}	5.45E-7	a_{11}	0.000
b_{12}	0.000	a_{12}	0.000	b_{12}	1.29E-7	a_{12}	0.000
b_{13}	0.000	a_{13}	0.000	b_{13}	3.05E-7	a_{13}	0.000
b_{14}	0.000	a_{14}	0.000	b_{14}	7.20E-8	a_{14}	0.000
b_{15}	0.000	a_{15}	0.000	b_{15}	1.70E-9	a_{15}	0.000
b_{18}	0.000	a_{18}	0.000	b_{18}	0.000	a_{18}	0.000

ring, not only due to efficient injection, but long lifetime under collision conditions and other reasons.

A modified thin lens model has been applied in the simulation on dynamic aperture for BTCF. In this model, each thick lens quadrupole is separated into two pieces of thin lens with a space of 2/3 length of the thick lens between two thin lenses. This makes the thin lens model approach the real machine with smaller beta-beatings and closer quadrupole strengths[5].

In BTCF, the injection takes place in the horizontal plane for both rings. To evaluate the injection aperture we launch particles at the injection point and determine the aperture in terms of transverse position coordinates measured from the central orbit. In injection, the vertical beam size is taken from the fully-coupled emittances. An aperture, including 16 rms horizontal beam sizes and 7 rms vertical beam sizes within nearly $10\sigma_e$ of the nominal injection energy, i.e., $16\sigma_x \times 7\sigma_y \times 10\sigma_e$, is required for injection.

In the colliding-beam conditions, particles are launched at the interaction point. The dynamic aperture of 10σ in both transverse planes and $10\sigma_e$ in energy deviation is taken into account. The fully-coupled emittances are also considered.

All the tracking and simulations (with or without imperfections) were evaluated with the code MAD[6] in 6D, and cross-checked with SIXTRACK[7]. Except for chromaticity sextupoles, no any other correctors have been installed into the linear lattice. Simulations are done for 2000 turns, which corresponds to 1/12 damping time, at several amplitudes. Chromaticities in both transverse planes are corrected to a slightly positive value.

Figure 1 and 2 depict the β functions and tunes as functions of energy deviation in the crossing-angle scheme in PL, while figure 3 and 4 show the same parameters in IL. The dynamic aperture in transverse planes with or without energy deviation and multipolar errors is plotted in figures 5 and 6 for both PL and IL lattices, while figure 7 compares the results from MAD and SIXTRACK under the same conditions of tracking. The magnetic multipolar imperfection causes the decrease of dynamic aperture, especially in the vertical plane. The results obtained from MAD and SIXTRACK could be considered similar in tracking to a certain extent. The simulation for 24000 turns, i.e., one damping time, has also been studied. The dynamic aperture only reduces reasonably 1 or 2 σ in both transverse planes.

5 CONCLUSION

The chromaticity sextupoles remain the key reason in dynamic aperture, from the changing of the sextupoles arrangement and the evolution of the lattice. The improved lattice of BTCF gives a larger dynamic aperture than the preliminary lattice. With the multipolar imperfections of magnets, the dynamic aperture decreases about 10σ in vertical plane, but still satisfies the needs of injection and collision. Compared with the results from SIXTRACK, MAD gives similar outcome in the simulation.

6 ACKNOWLEDGEMENTS

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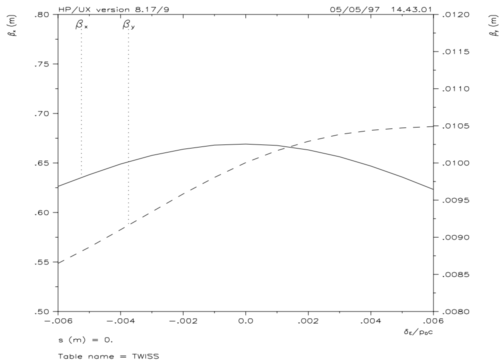

Figure 1: β-fuction vs energy deviation in PL

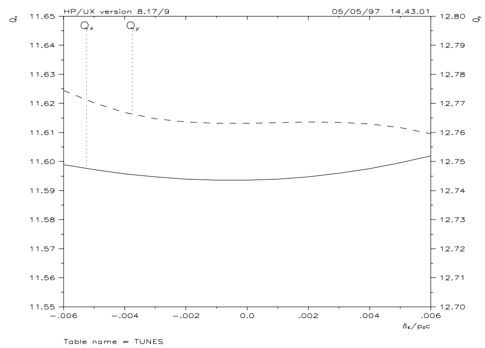

Figure 2: Tunes vs energy deviation in PL

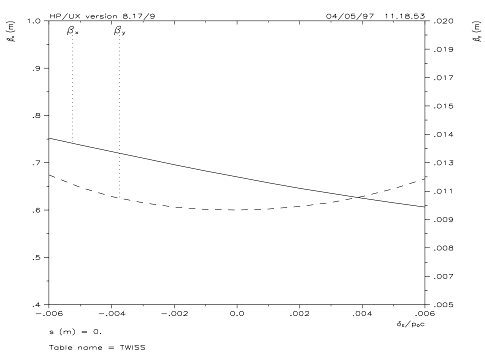

Figure 3: β-fuction vs energy deviation in IL

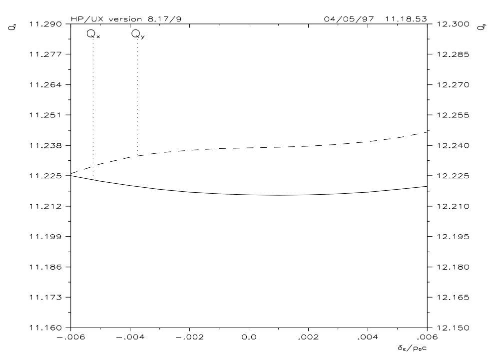

Figure 4: Tunes vs energy deviation in IL

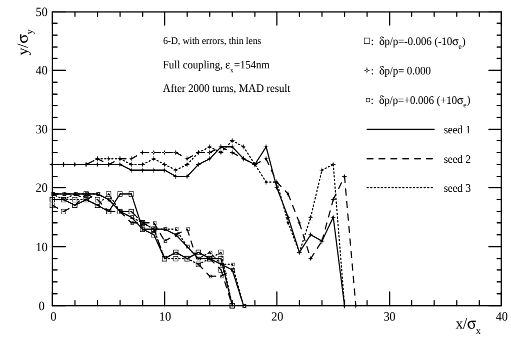

Figure 5: Dynamic aperture with errors of PL

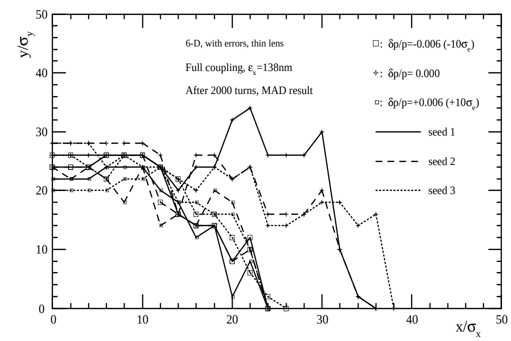

Figure 6: Dynamic aperture with errors of IL

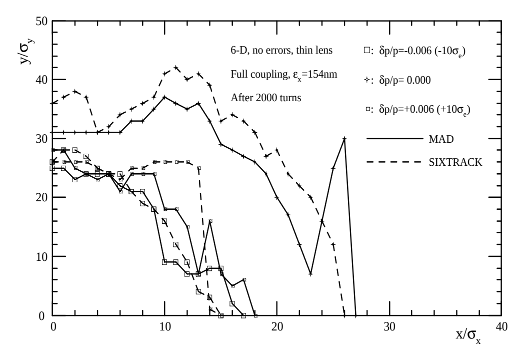

Figure 7: Comparison of results from MAD and SIX-TRACK