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LATTICE OPTIMIZATION OF BEPCII COLLIDER RINGS*

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Abstract

BEPCII is a double ring e+e- collider operating in the tau-charm region. In March 2013, the peak luminosity achieves $7.0 \times 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ with a new lower alphap lattice. The beam-beam parameter also increased from 0.033 to 0.04 with the new lattice. In this paper we'll review the lattice optimization history.

INTRODUCTION

The Beijing Electron-Positron Collider (BEPC) was constructed for both high energy physics and synchrotron radiation (SR) researches. BEPCII is an upgrade project from BEPC. It is a double ring machine. Following the success of KEKB, the crossing scheme was adopted in BEPCII, where two beams collide with a horizontal crossing angle of 2 × 11mrad. The design luminosity of BEPCII is $1.0 \times 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at 1.89GeV, which is about 100 times higher than BEPC [1]. The main design collision parameters are shown in Table 1. In March, 2013, the peak luminosity achieves $7.0 \times 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ with 120 bunches and beam current 730mA, where a lower α_p lattice was used.

Table 1: Design Parameters of BEPCII

E	1.89 GeV	ν_s	0.034
I	910 mA	α_p	0.024
I_b	9.8 mA	σ_{z0}	0.0135 m
n_b	93	σ_z	0.015 m
V_{rf}	1.5 MV	ϵ_x	144 nmrad
β_x^*/β_y^*	1.0/0.015 m	Coupling	1.5%
ν_x/ν_y	6.53/5.58	ξ_y	0.04
θ_c	22 mrad	$\tau_x/\tau_y/\tau_z$	3.0e4/3.0e4/1.5e4

The lattice design is briefly introduced in [2]. There are total 36 sextupoles in the collider ring, but there is a 2-folder symmetry exists in the arrangement, that is to say only 18 indepedent power supplies. In this paper, we'll focused on the lattice optimization for the colliding mode.

LATTICE DESIGN

2009-2010, $Q_x \sim 6.53$

The working point was first choosen at (0.53,0.58), and the simulated luminosity is about 50% of the design [3,4]. The horizontal tune is not very close to half integer , since we worry about if we could move the tune closer to half integer. Fig. 1 shows the performance in 2009 and 2010.

We only use 4 families of sextupoles in the chromaticity correction at that time. Fig. 2 shows the chromaticity. We use the BBWS [6] code to study the chromaticity contribution to the luminosity. It is found there is no luminosity loss when we consider the chromaticity($\frac{d\nu}{d\delta}$, $\frac{d\alpha^*}{d\delta}$, $\frac{d\beta^*}{d\delta}$) to the 3rd order, even though it seems the distortion of β_y^* is not very small.

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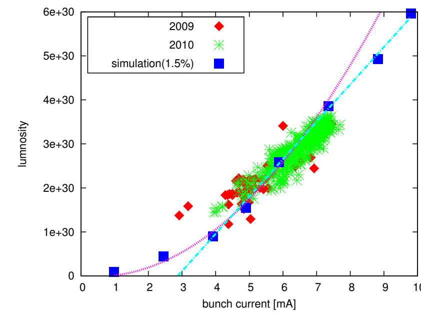

Figure 1: Luminosity performance in 2009 and 2010. The coupling is 1.5% in the simulation.

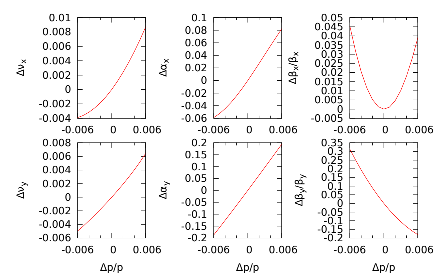

Figure 2: General chromaticity of the lattice in 2009 and 2010.

The dynamic aperture is shown in Fig. 3 The achieved beam-beam parameter is calculated by luminosity,

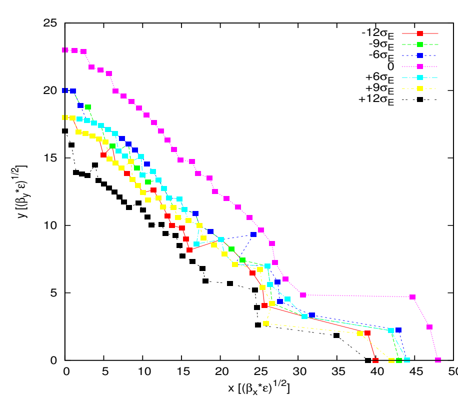

Figure 3: Dynamic aperture of the lattice in 2009 and 2010. The tune is (6.54, 5.59).

$$\xi_y = \frac{2r_e\beta_y^0}{N\gamma}\frac{L}{f_0} \tag{1}$$

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We only achieve 0.02 for ξ_y in the real machine with $Q_x \sim 0.53$, and the maximum simulated is about 0.025 with 1.5% coupling.

2011-2012, $Q_x \sim 6.505$

According to the simulation [3,4], the best working point is near 0.505.

In May, 2009, Horizonatal tune was moved to 0.51 from 0.53. Luminosity reached $3 \times 10^{32} cm^{-2} s^{-1}$ with beam current 600mA . The design goal of the government funding agency was achieved! But the detector dark current is too high to take data.

In December, 2010. Detector background was reduced when Q_x is 0.51 by aligning the detector in the summer shutdown and tuning the closed orbit. The physics people could take data with the working point more closer to half integer. In April, 2011, 6.5e32 was achieved with beam current 720mA, and ξ_y achieves 0.033.

Fig. 4 shows the beam-beam performance with the horizontal tune near 6.505. We use SAD [5] to do the weak-strong beam-beam simulation with the real lattice element. Fig. 6 shows the luminosity loss coming from the real lattice. The weak-strong result shows that loss is about 6%. It shoud be mentioned that the tune is (6.508, 5.570) in the simulation. The loss could boost to about 20% (10mA) with tune (6.505, 5.575). Fig. 7 shows the general chromaticity at (6.508,5.570) We also use BBWS [6] to study the chromatic effect on luminosity. But it's strange that the chromaticity does not reduce the luminosity in the weak-strong simulation.

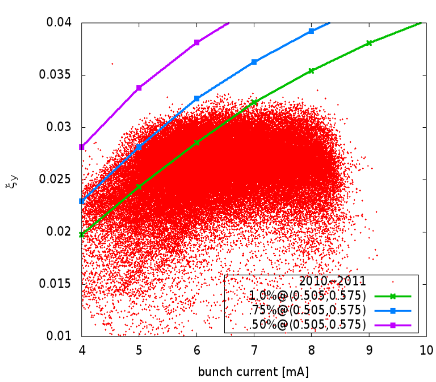

Figure 4: Beam-beam performance achieved in 2011. Different lines show simulation result with different coupling.

The dynamic aperture is shown in Fig. 5. It is not very good for off-momentum particles.

2013-now, $Q_x \sim 7.505$

Since lower α_p could reduce the bunch length and increase the luminosity. The momentum compaction factor is proportional to the inverse of square horizontal tune. We succeeded in increasing the integer part of horizontal tune from 6 to 7 in 2013.

In fact, our colleagues did some try to reduce α_p but keep the horizontal tune unchanged [8]. But most of the efforts

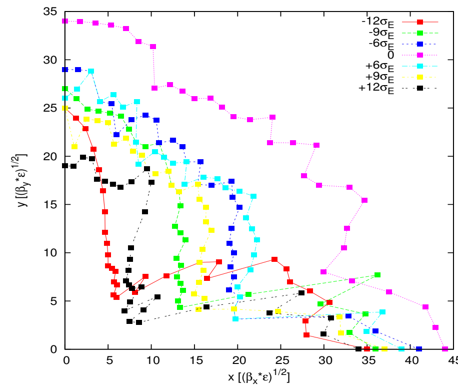

Figure 5: Dynamic aperture of the lattice in 2011. The tune is (6.508, 5.570).

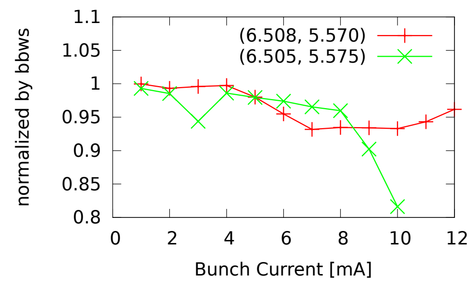

Figure 6: The luminosity calculated by SAD is normalized by the result obtained with BBWS. The sextupole configuration is same, we only knob the tune from (6.508, 5.570) to (6.505, 5.575).

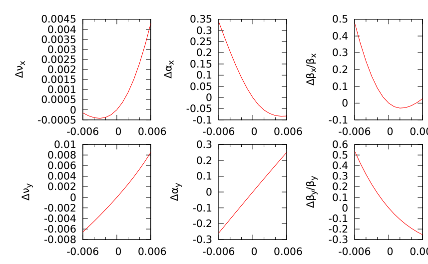

Figure 7: General chromaticity of the lattice in 2011. The tune is (6.508, 5.570).

break the injection requirements, the two horizontal kickers need to the π advance in horizontal direction. We would have to switch the lattice between injection and collission mode, the fesibility is very bad in a real machine running near half integer tune.

In February 2013. Lower alphap mode was first tested at 2.18GeV, which help us break the ξ_y record of 0.033. We also did some machine development in order to increase the peak luminosity at 1.89GeV. The achieved beam-beam paramter with different bunch pattern is shown in Fig. 8. ξ_y is above 0.04 at 1.89GeV with lower alphap lattice.

In the new lattice, we use all the 18 sextupole families since there are 18 independent power supplies. In fact in the end of 2012, with the old linear lattice, it is found that the dark current of the detector is too high to take data. We've

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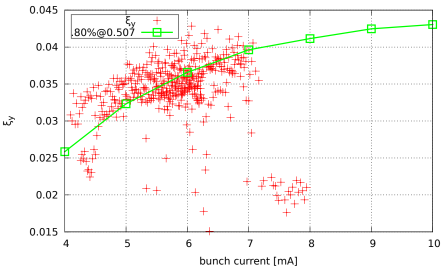

Figure 8: Achieved beam-beam parameter at 1.89GeV with new lattice in 2013.

begun to use 18 families since then instead of only 4. Better control of twiss@IP chromatic distortion (β/α and waist position) seems could also help us reduce the detector background.

The momentum compaction factor of new lattice is about 0.017, and the old one is 0.024. The reduction of α_p is achieved by increase the horizontal tune from 6.5 to 7.5. The general chromaticity of the new lattice is shown in Fig. 9. Besides the chromataic aberrations, we also try to control some nonlinear resonance driving terms, especially GNFU(1,0,2,0), (1,0,1,1), (2,0,2,0), (2,0,1,1) and (1,1,2,0) (definition in MADX) are optimized, since the horizontal oscillation will be coupled to vertical by them. However we still not establish a so-called "standard" that could tell us the lattice is good enough.

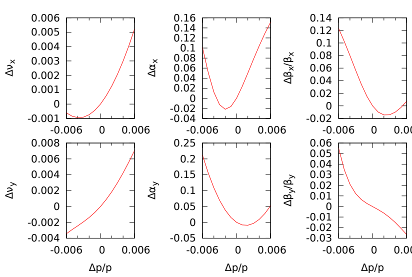

Figure 9: General chromaticity of the lattice in 2013. The tune is (7.505, 5.575).

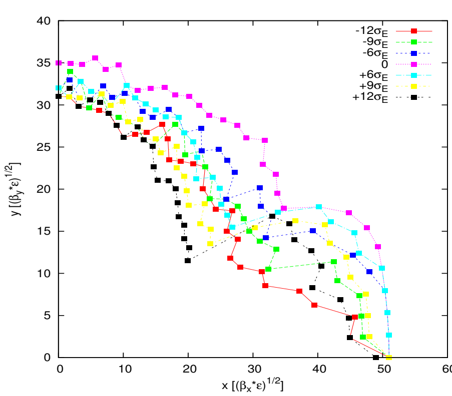

Figure 10: Dynamic aperture of the lattice in 2013. The tune is (7.505, 5.575).

In 2014, the wiggler 1W2 in the electron ring is put into use. At the very beginning we only rematch the linear optics and keep the sextupoles unchanged. But the horizontal chromatcitiy is only about 0.1, and the optimized luminosity is lower than history. So we think maybe too small positive chromaticity is the cause, and change the sextupole configuration to increase the horizontal chromaticity to 0.8. And the luminosity increase from 3.4e32 to 3.8e32 with 430mA(2.21GeV). But it is very insteresting that in the simulation taking int count the general chromaticity, the luminosity of new configuration is lower about 10% than the old one. It seems that the suppression of head-tail instabiltiy maybe helps in the new configuration.

In May, 2014, we begin to knob the chromaticity online in order to suppress the resonance $2\nu_x + \nu_s = N$, since the resonance strength is determined by the first order chromaticity($\frac{d\nu}{d\delta}$, $\frac{d\alpha^*}{d\delta}$, $\frac{d\beta^*}{d\delta}$) and we've many enough sextupoles. This knob help us increase the luminosity by about 10%. And the BBWS simulation with up to 3rd order chromaticity coincides very well with the real machine.

We've done some machine study specifically to optimize the peak luminosity at 1.89GeV, since our design goal is 10e32 at the energy and only achieve 7e32 till now. According to the tuning experience, the collision with less bunch number is stable but not so stable and very hard to do the optimization with many bunches (> 100 bunch). The available beam diagnositics system (streak camera, bunch-by-bunch bpm, spectrum analyzer and etc.) does not tell us what is the cause. It is suspected that the tune chromaticity is too small (only ~ 0.8). In the near future we'll try to larger vertical chromaticity in the machine development.

SUMMARY

During the optimization of luminosity, we've changed the horizontal tune from 6.5 to 7.5, and use more sextupole families to control the chromaticity and nonlinear resonance driving terms. Some luminosity optimization could be explained by simulation and others need further study.

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