BEAM OPTIMIZATION IN PARASITIC MODE OF BEPCII DURING *R* MEASUREMENT *

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Abstract

The Beijing Electron Positron Collider II (BEPCII) operated for R measurement from 2013 November to 2014 February in parasitic mode. During R measurement, beam energy shifted from 1.925GeV to 2.3GeV in three month. Meanwhile, in parasitic mode, 8 beamlines including 2 from wigglers could also operate for synchrotron radiation (SR) experiments. Frequent energy change in such wide range and wigglers effect made beam optimization a hard task. This paper will describe the main progresses on the beam optimization of the BEPCII during R measurement in the field of accelerator physics.

INTRODUCTION

BEPCII is an electron-position double-ring collider operating in the tau-charm region, which was constructed for both high energy physics and synchrotron radiation (SR) researches. The accelerator consists of a 200 meter long linac, two transport lines for electron and position respectively, and two storage rings for colliding mode. These two rings are named as BER and BPR. Table 1 shows the main design parameters of BEPC-II.

Table 1: Design Parameters of BEPC-II Colliding Mode[1]

Beam Energy (GeV)	1-2.1GeV
Optimum Energy	1.89GeV
Beta at IP $\beta x^*/\beta y^*$	1/0.015m
Tune υ_x/υ_y	6.53/5.58
Crossing angle at IP ϕc	2*11mrad
Current I	910mA
α_p	0.024
Emittance ε_x	144nmrad
Beam-Beam ξ_y	0.04
Coupling	1.5%

BEPCII has two running modes. One is only for SR experiments called the dedicated mode which connect the two outer half rings of BER and BPR, to form the ring for synchrotron radiation, which is named as BSR. The other is mainly for high energy physics called the parasitic mode, in which some beamlines could also operate for SR experiments. Since 2010, 5 beamlines (4 bending magnets and 1 Wiggler) of Beijing Synchrotron Radiation Facility (BSRF). Started to open to users in the parasitic mode.

New measurements of R value in the energy of 3.85-4.6GeV were completed and caused a strong impact on the search for new physics and Higgs particle in the international high energy physics.

From November 10 2013 to February 4 2014, beam energy of BEPCII shifted from 1.925GeV to 2.3GeV. In total of 105 energy points, the max energy interval was 0.02GeV and the min energy interval was 1MeV. Note that the max design energy of BEPC-II was 2.1GeV, there even was 0.2GeV exceeded the design limit at 2.3GeV, which made the current of some magnets not in the linear region and without magnet measurement result.

At this run, there was some differences compared with default lattice design. Taking into account the 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 fact, our colleagues did some try to reduce α_p but keep the horizontal tune unchanged. But most of the efforts break the injection requirements, the two horizontal kickers need to the advance in horizontal direction. We would have to switch the lattice between injection and collision mode, the feasibility is very bad in a real machine running near half integer tune. The momentum compaction factor of new lattice is about .017, and the old one is 0.024. The reduction of α_p is achieved by increase the horizontal tune from 6.505 to 7.505.

In the new lattice, we use all the 18 sextupole families since there are 18 independent power supplies 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.

In 2014, the wiggler 1W1 in the electron ring was put into parasitic mode, which made the optimization even harder.

The accelerator tools (AT) [2] was used in BEPCII for optics optimization in response matrix method for some years. This program provided corrections of quadrupole magnets, BPM gains, corrector magnets gains, and some beam parameters measurements like twiss parameters. Figure 1 shows that the fudge factors of quadrupole magnets given by AT. More analysis would be given below.

SAD [3] and MADX [4] were also used to take many work like machine control, lattice design and matching in linear or nonlinear, and simulations in many topic.

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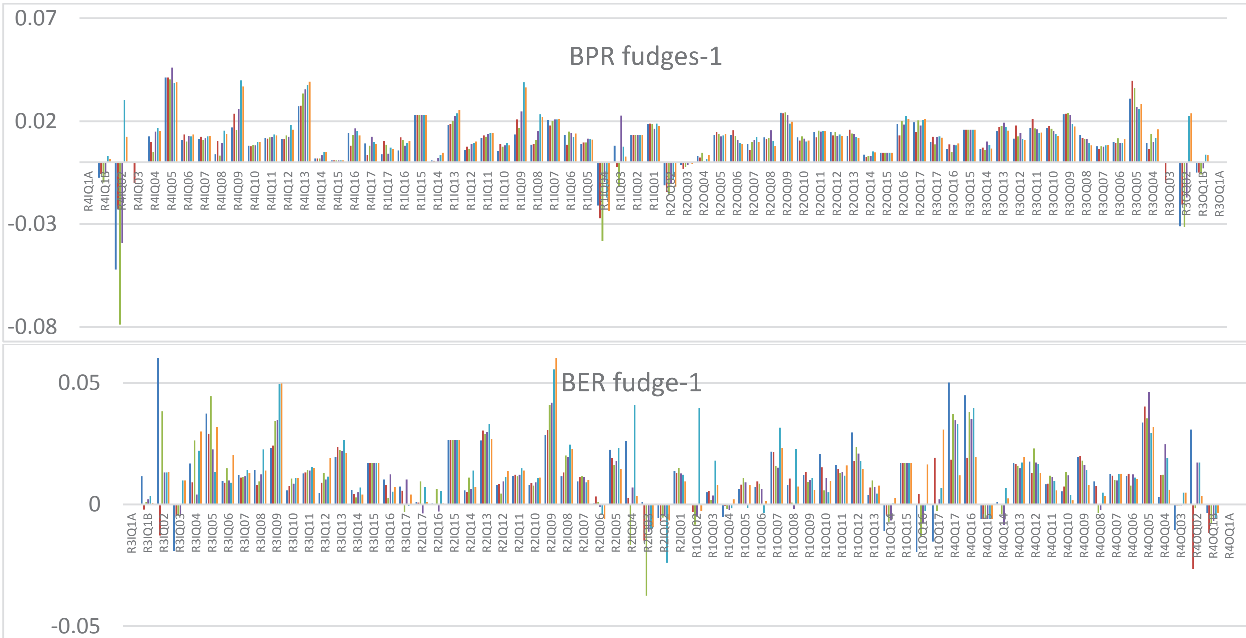

Figure 1: Quadrupole magnet fudge factor by AT. Upper: BPR. Lower:BER.

OPTICS CORRECTION

Energy Shift

For measurement of R value, beam energy shifted from 1.925GeV to 2.3GeV in total of 105 energy points. Sharply energy change pointed out that more corrections were needed to keep luminosity and beam stability acceptable. But that took a lot of machine time, as Figure 2 shown. Because of some breakdown caused by cryogenic, RF cavity and some other reasons, 38.27% of the machine time supplied for BESIII, about 849 hours. Including optics correction, the machine study took 6.59% machine time (146 hours), about 1/6 of BESIII machine time.

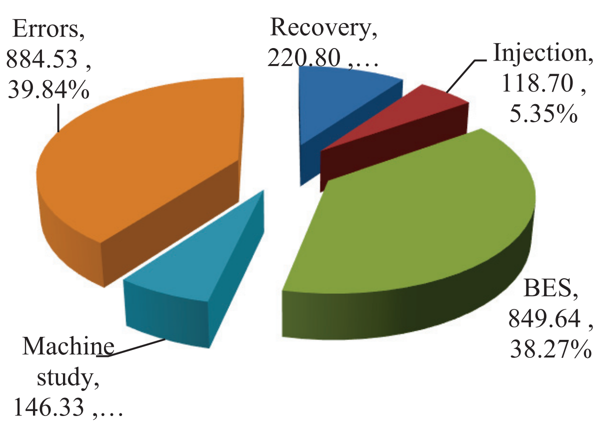

Figure 2: Machine time count.

During the measurements of R value, BPR and BER had corrected optics parameters 5 times respectively in different energy shown in Figure 3 with black dots. Each took more than 4 hours. Linear optics was corrected with fudge factors of quadrupole magnets by response matrix method as Figure 1 shown. From the result of BPR, most of magnet were stable when energy changed, but a few of them which work current was closed to lower or upper limits showed energy influence in nonlinear region. The BER results were not so clean because when the 1W1 wiggler took in the default lattice model was changed.

Despite so much time was spent to correct optics, the interval of beam energy between corrections was about 0.1GeV average, which was enough to cause big impact.to a collider whose work point near 0.5. Figure 3 show the luminosity curve in blue and which energy the optics correction took on in black. That pointed out that each correction improve the luminosity effective. But luminosity descended rapidly with energy. Obviously at 2.1GeV which was design limit energy of BEPCII, the luminosity dropped sharply and irreversibly. On the one hand, lack of effective magnet measurement made it deviate from design lattice and hard to correct. On the other hand, beam current and many other beam parameters had been worsen because of RF system limit or other reason. Some shown in Table 2.

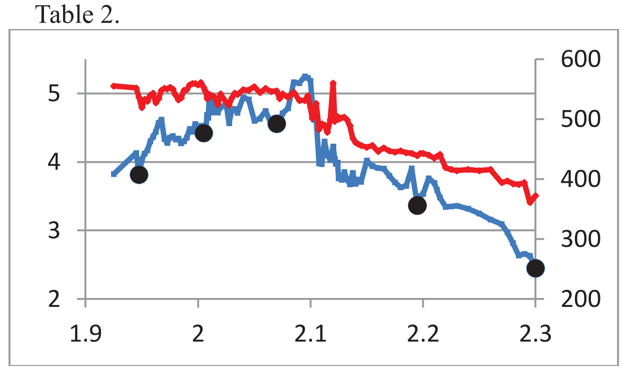

Figure 3: Luminosity and current during R measurement. Blue: peak luminosity; Red: current; Black: correction.

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Table 2: Some Beam Parameters on Different Energy

Energy (GeV)	Emittance e+ (nm)	Emittance e- (nm)	Bunch length (cm)
1.89	98	121	1.15@1.5MV
2.12	123	144	1.37@1.5MV
2.3	145	164	1.62@1.4MV 1.47@1.7MV

Wiggler Effect

In 2014, the wiggler 1W1 and 1W2 in the electron ring was put into use. At the very beginning we tried to fix the optics to original model without wiggler, but luminosity and lifetime decline obviously. So a new model matched with wigglers was used in the linear optics correction. In the process of energy shift, wiggler effect changed relative to beam energy. Figure 4 show the simulation of BER vertical tune shift by 1W2 with beam energy. Figure 5 show BER measured tune deviation in which vertical tune changed much more than horizontal obviously, and the bigger dot was when we take wiggler 1W1 into our model.

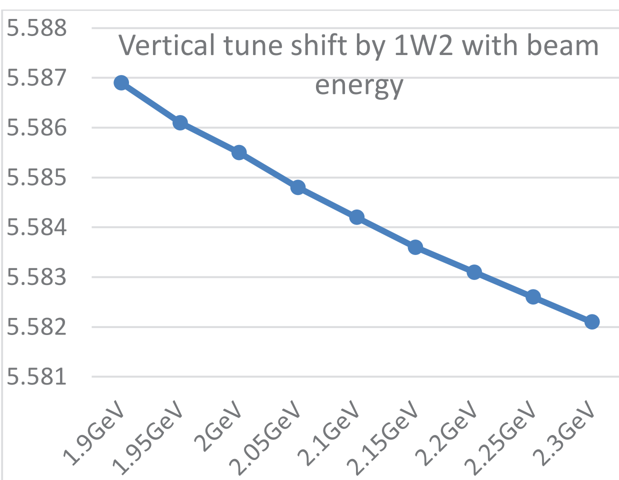

Figure 4: Simulation of BER Vertical tune shift by 1W2.

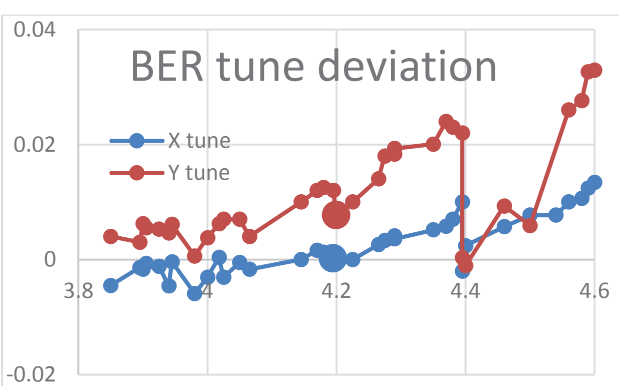

Figure 5: BER measured tune deviation.

Another influence of wiggler is the horizontal chromaticity [5]. The measured chromaticity was only about 0.1. So we think maybe too small positive chromaticity was the cause of the lower luminosity, and changed 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 interesting that in the simulation taking into 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 instability maybe helps in the new configuration.

SUMMARY

BEPCII has finished new measurement of R value from 3.85GeV to 4.6GeV. At same time, 1W1 and 1W2 wigglers were taken into use. Lattice correction and improvement make luminosity and life time acceptable and stable with frequently energy chang.

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