ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-WEOXGD3

AN ALTERNATIVE DESIGN FOR BEPCII UPGRADE

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Abstract

The Beijing Electron Positron Collider II (BEPCII) has achieved a series of achievements in high energy physics study. Along with the deepening of the research, more important physcis is expected in higher energy region (> 2.1 GeV). As the upper limit of BEPCII design energy is 2.1 GeV, an urgent upgrade is required.

To achieve a higher luminosity at higher energy, the number of RF cavities is expected to be doubled. In this paper, an alternative lattice design for the upgrade of BEPCII is studied. The survey of the RF region is modified in contrast to the baseline design to accommodate two RF cavities in each ring. The dynamic aperture tracking result show that the lattice could meet the injection requirement of BEPCII beam with reasonable margin.

INTRODUCTION

The Beijing Electron Positron Collider II (BEPCII) [1] is a two-ring eletron positron collider running in the tau-charm energy region. The upper limit of designed beam energy of BEPCII is 2.1 GeV, with an optimized performance at 1.89 GeV. The commissioning of BEPCII started at 2007, and since then, a series of achievements has been achieved in high energy physics study. Along with the deepening of the research, more important physcis is expected in higher energy region (> 2.1 GeV) [2]. An urgent upgrade is required for BEPCII to ensure the competitive advantage in high energy physics study.

To improve the performance at higher energy, BEPCII is expected to upgrade the RF system from one-cavity to two-cavity per ring, so as to dramatically boost the cavity voltage. The arrangement of elements in BEPCII is very compact, so finding enough space for the extra cavity in each ring is not trivial. In this paper, we show one novel layout that successfully provides enough space for two cavites in each ring by shifting the north crossing point to the east by 8 meters in contrast to the baseline design to accommodate two RF cavities in each ring [3]. The lattice design and the dynamic aperture tracking result in the new layout will be shown.

PARAMETER DESIGN

To minimize technical crisis and avoid heavy workload, BEPCII has chosen the classic scheme, which is maintaining the small Pinwinski angle, and raising the beam current and cavity voltage at the same time to achieve a much higher luminosity at higher beam energy.

When optimizing the parameters, the synchrotron radiation power is restricted to 250 kW, the bunch number is limited to 120, the bunch current is kept as low as possible for each cavity voltage. Also, for each cavity voltage, the vertical β function at the IP $\beta_y{}^*$ is chosen according to the bunch length, then the coupling of emittances is then chosen according to the beam beam parameter ξ_{y0}.

The designed parameters and the comparison with the present BEPCII operation parameters at the energy of 2.35 GeV are shown is Table 1.

Table 1: The designed parameters and the comparison with the present BEPCII operation parameters at the energy of 2.35 GeV

	BEPCII	**BEPCII-U**
RF voltage [MV]	1.6	3.3
β_y* [cm]	1.5	1.35
bunch current (mA)	7.1	7.5
bunch number	56	120
SR power (kW)	110	250
$\xi_{y,lum}$	0.029	0.036
ϵ_x [nm·rad]	147	152
coupling %	0.53	0.35
bucket height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.04
σ_z [cm]	*1.10=1.69	1.3
Lum$[10^{32}cm^{-2}s^{-1}]$	3.5	11

MODIFICATION OF THE RF REGION

Current layout of the RF region is shown in Fig. 1 We can see from Fig. 1 that the north crossing point is in the middle of the hall with higher roofing, the two RF cavities which are currently in running in BEPCII are placed at the two ends of the hall. Away from the hall, is the normal tunnel with a height of 3.5 m. The total length of the straight section at RF region is about 20 m.

According to design of present BEPCII RF cavities [4], the height of the RF cavity is 2.75 m, the inner conductor of the coupler is installed upright with a length of about 1 m. To ensure the coupler can be maintained and replaced online, an extra height of 1m is needed for pulling out the inner conductor. Thus, the requirement of tunnel height for installing RF cavities is > 3.75 m. The tunnel height of

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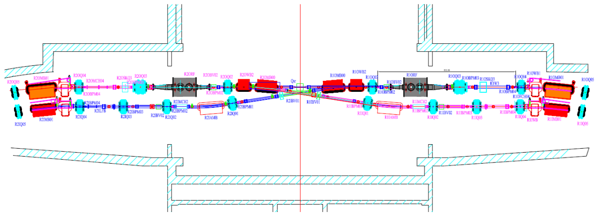

Figure 1: Current layout of the north crossing region.

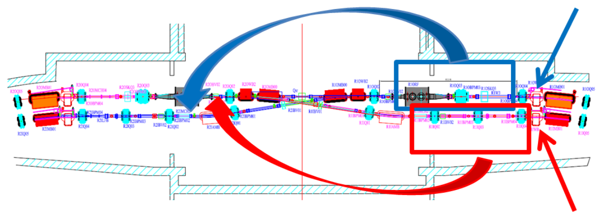

Figure 2: Sketch of how the RF region is modified.

BEPCII is 3 m, thus the cavities must be installed within the hall to guarantee online maintainance. The length of each RF cavity is 3.5 m, the connection section between two cavities is about 0.5 m. So the total longitudinal drift space for installing two cavities is 7.5 m.

To make space for installing two cavities in the hall, we move the RF cavity and part of the straight section downstream, from the outer ring to the inner ring, and rearrange the position of the quadrupoles. For BPR ring, we keep the position of the RF cavity unchanged, and move the same length of straight section as have done in BER from the inner ring to downstream of present cavity, as sketched in Fig. 2.

To ensure the positron bunch have the same distance to the front and back electron bunch when passing through the north crossing point, the time difference between positron and electron bunches passing through the north crossing point has to be $(n + 0.5)T$, namely the distance difference between positron and electron bunch from IP to the north crossing point is $(n + 0.5)\lambda$,with T the period of the RF system and λ the wavelength of the RF system. This condition is already satisfied in current BEPCII layout, so the length of the moved straight section has to be $n\lambda$. Taking into account of the width of the RF cavity is 1.1 m, which is comparable to the transverse distance between BER and BPR, the cavities of the two rings can only be aligned interlaced, so extra spacing will be needed for interlacing the cavities. The RF frequency of BEPCII is 499.8 MHz, here we choose the integer number $n = 14$,i.e., the length of the moved straight section is 8.40 m.

The newlayout with the RF cavities in position is sketched in Fig. 3.

LATTICE DESIGN

To make enough space for the straight section, the weak bend R1OWB and R1IWB in BER and BPR are also removed. The survey change in BER is locally compensated by tuning the neighboring three bends downstream the north crossing point. While the survey change in BPR is compensated by R1IAMB and the two bends downstream the north crossing point. The circumferences of two rings are kept constant during the survey modification.

Table 2: The amplitude comparison of the six bends before and after the survey modification.

	Magnet Name	Current Bending Angle (rad)	New Bending Angle (rad)
BER	R1OMB00	0.13	0.12
	R1OMB01	0.15	0.17
	R1OWB2	0.020	0.043
BPR	R1IAMB	-0.15	-0.13
	R2OMB00	0.13	0.14
	R2OWB2	0.020	0.014

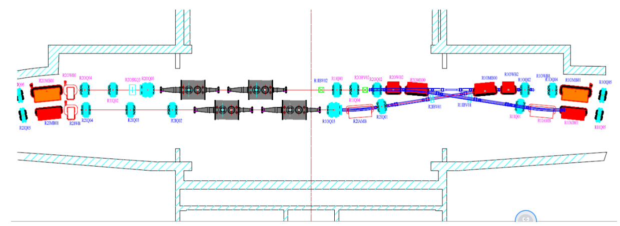

Figure 3: The newlayout after moving the straight sections.

The amplitude change for the six bends are listed in Table 2. We can see from Table 2 that, all the bends except R1OWB2, the strengths are either reduced or increased within 20% of the original strengths,which is within the tunability of the magnets, so these bends do not need to be replaced in the upgradation. For the magnet R1OWB2, the strength is doubled in the new design, this magnet will be upgraded by replacing the excitation coil to have the required strength.

Due to the modification of the RF region, the lattice needs to be rematched.The main matching conditions are: dispersion free at the RF cavities position; the working points kept the same as current BEPCII design; the maximum β functions at the cavites is less than 15 m. The optics functions of BER and BPR after rematching is shown in Fig. 4.

The quadrupoles in the arcs adjacent to the RF section are used to match the RF section to the ring. The optics functions which are changed in the matching is circled with dashed line in Fig. 4. We can see that the optics functions of BER and BPR become asymmetric in the new layout. In order not to cause emittance growth, the $\mathcal{H}$ function has to be handled with care during the matching process.

We use the code SAD [5] to do the chromatic correction and dynamic aperture tracking. The multi-objective code MODE [6] is used for the optimization. In each ring, 36 sextupoles, which are independently powered with 18 power supplies are used for the chromatic correction and DA op-

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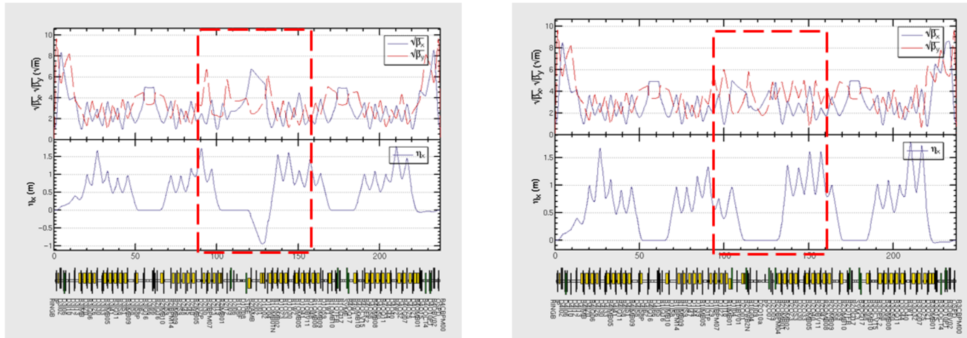

Figure 4: Optics functions of BER (left) and BPR(right) after rematching.

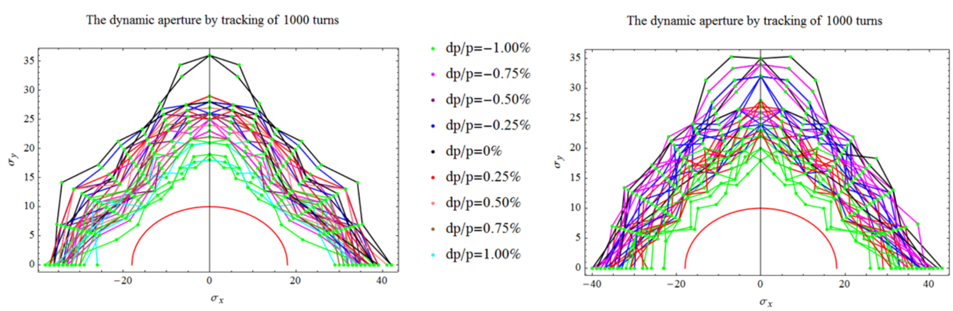

Figure 5: Dynamic aperture of BER (left) and BPR(right) after optimization.

timization. For a beam energy of 2.35GeV and a cavity voltage of 3.3MV, the optimization result is shown in Fig. 5. The result is calculated by tracking 126 particles 1000 turns around the ring. The vertical emittance used to calculate the vertical beam size here is taken to be the same as the horizontal emittance.

SUMMARY

We can see from Fig. 5 that, the DA of BER and BPR are $27\sigma_x \cdot 20\sigma_y$ and $27\sigma_x \cdot 20\sigma_y$, respectively, within a momentum spread of 1% or $15\sigma_e$. The DA of BER and BPR are both much larger than the injection requirement of the ring (shown by the elliptical lines in Fig. 5).

Other constraints applied during the DA optimizations are: within 1% energy spread, a) the tune at the horizontal plane should not be less than 7.504 in order to stay away from the half integer resonance lines, while the variation of the tune at the vertical plane should not exceed 20%; b) the aberration of β^* should be less than 20% and c) the strength of all sextupoles should be within the range of the measurement data.

A detailed lattice design has been performed for the upgrade of BEPCII. The survey is changed to accommodate two cavities in each ring. New lattices have been designed accordingly. The emittances are kept in new lattices. The dynamic aperture tracking result show that the lattice could meet the injection requirement of BEPCII beam with reasonable margin. A much higher luminosity could be foreseen at higher energy of 2.35 GeV with the new design.

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