THE SIMULATION OF BEAM-BEAM INTERACTION IN BEPCII

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Abstract

BEPCII is a proposed project in IHEP, Beijing. It will be a two-ring electron-positron collider. After upgrading the BEPC (Beijing Electron-Positron Collider), the luminosity will be increased about 100 times. The beam intensity will reach 910 mA. So the beam-beam interaction is very important in the BEPCII. The result of the simulation of the beam-beam interaction is shown in the paper.

1 INTRODUCTION

BEPCII is the upgrade project of BEPC. A new ring will be installed into the existed BEPC tunnel. So BEPCII is a two-ring machine. Electron beam and positron beam will accumulate in the two rings and collide at the south interaction point (IP) with a horizontal crossing angle of 2 × 11 mrad. The lattice of the two rings is ready. In order to estimate the luminosity, the beam-beam simulation is made in the paper. We used K. Hirata's code to make the simulation.

2 SIMULATION OF THE WEAK-STRONG INTERACTION

2.1 Choice of the Number of Slices

The code of beam-beam interaction is the weak-strong mode. The distribution of bunch is supposed to be Gaussian. The strong bunch is cut into several slices along the longitudinal direction. The number of slices influences the result directly. So we need to decide the number firstly. The luminosity per bunch versus the slice number is shown in the Fig. 1.
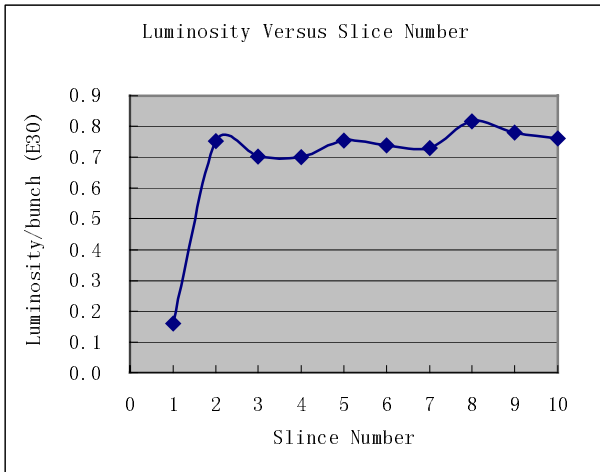

Figure 1: Luminosity vs. slice number

It can be seen that 5 slices are reasonable for the simulation. The larger number will not bring distinct difference, and it will take much more CPU time. Hence in the all following simulation, the number of the slices will be chosen as 5.

The main parameters of the BEPCII are given in the table 1.

Table 1: Main Parameters of BEPCII

Circumference	237.53 m
Emittance $\varepsilon_x / \varepsilon_y$	144/2.2 nm•rad
Damping time $\tau_x / \tau_y / \tau_z$	25/25/12.5 ms
Betatron tune $\nu_x / \nu_y / \nu_z$	6.57/7.61/0.034
β^*_x / β^*_y at IP	1 m/0.015 m
Beam current	0.91 A
Bunch number	93
Number of particles per bunch	4.8×10^{10}
Horizontal crossing angle at IP	2×11 mrad
Optimised beam energy	1.89 GeV
Design luminosity	1.0×10^{33} cm^{-2}s^{-1}

2.2 Result of the Simulation

The tune scan with the code is made in a small region. The horizontal tune is from 6.45 to 6.75 and the vertical tune is from 7.5 to 7.7. The result of the simulation is shown in the Fig. 2.
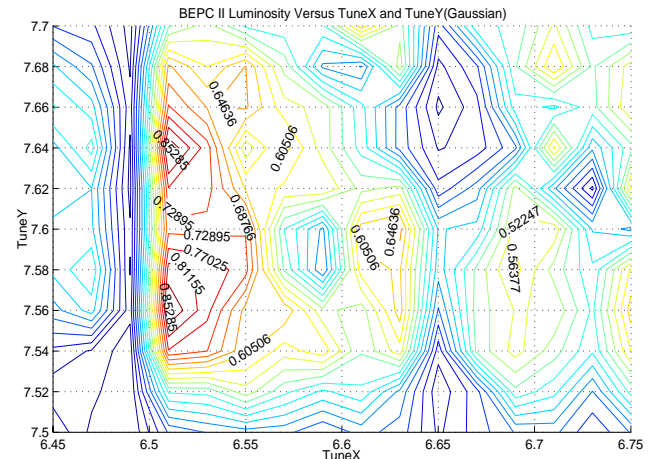

Figure 2: The result of the tune scan with the code

We can see that the region of the higher luminosity is near the horizontal half integer. This region is not very narrow. We can choose tunes for BEPCII near this area.

The tune of the present lattice is not in the high luminosity area. But the lattice is quite flexible, and the tunes can be moved to the region easily. According to the simulation, we suggest the tune should be 6.51/7.56. The peak luminosity per bunch is about 0.9×10^{30} cm^{-2}s^{-1}. In fact, the tunes of other storage rings of electron-positron colliders are all near this value (See table 2).

Table 2: Tunes of other machines

	LER (ν_x/ν_y)	HER (ν_x/ν_y)
KEKB	45.51 / 43.57	44.52/41.59
PEP-II	38.57 / 36.64	24.62/23.64
CESR	10.53 / 9.60	

This means the region of the higher luminosity with the simulation is almost same as the other machines. We choose tunes of ν_x/ν_y = 6.51/7.56 to study the effect with the horizontal crossing angle.

There are also several regions in which the luminosities are much lower. So the BEPCII should avoid to work near these regions.

3 THE EFFECT OF CROSSING ANGLE ON LUMINOSITY

3.1 Calculation With formulae

For a collider with a half horizontal crossing angle θ, if the beam size $\sigma_y^* \ll \sigma_x^*$, its luminosity can be described as following:

$$\frac{L}{L_0} = \sqrt{\frac{2}{\pi}} a e^b K_0(b)$$

where L_0 is the luminosity that the geometry parameters are not taken into account, K_0 is the modified Bessel function, a and b are given as follows respectively:

$$a = \frac{\beta_y^*}{\sqrt{2}\sigma_z} ; \quad b = a^2 \left[1 + \left(\frac{\sigma_z}{\sigma_x^*} \tan\theta \right)^2 \right]$$

where β_y^* is the vertical beta-function at IP, σ_z is the bunch length. If $\sigma_z \ll \beta_y^*$, we can use the following formula:

$$\frac{L}{L_0} \approx \left[1 + (\frac{\sigma_z}{\sigma_x^*} \tan\theta)^2 \right]^{-\frac{1}{2}}$$

The parameters of BEPCII are as follows: σ_z = 1.3 cm, σ_x^* = 0.38 mm, β_y^* = 1.5 cm, ε_x =144×10^{-9} mrad, particle number/bunch = 4.84×10^{10}.

We can calculate the luminosity versus the horizontal crossing angle (shown in the table 3 and figure 3).

Table 3: Calculation of the luminosity vs. the angle

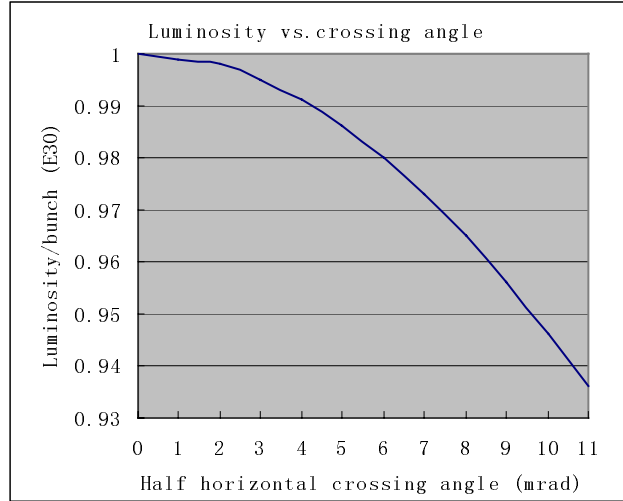| Crossing angle (mrad)	0	1	5	11
L_{angle}/L_0	1	0.999	0.986	0.936

Figure 3: Calculation result of luminosity vs. the horizontal crossing angle

3.2 Computer Simulation

The result of the simulation with the code for the luminosity versus the angle is shown in the Fig. 4.
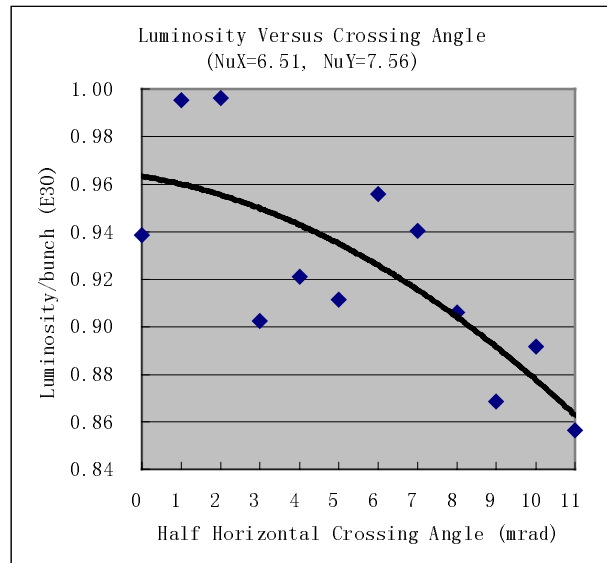

Figure 4: Simulation result of the luminosity vs. the angle

3.3 Effects of Horizontal Crossing Angle on Luminosity

The luminosities versus the horizontal crossing angles are shown in Fig. 3 and Fig. 4 where the angles vary from 1 mrad to 11 mrad. The luminosity decreases gradually with the increment of the crossing angle. We should consider the effect of the angle or else we shall not gain the luminosity of 1.0×10^{33} cm^{-2}s^{-1}.

There will give rise to some instabilities because of the crossing angle at IP, such as betatron-synchrotron coupling instability. It can cause beam blow up when the beam intensity is high. We must pay more attention to the phenomenon. We shall study this in the future.

4 SUMARRY

According to the simulation, we have found the good region of the tunes where the peak luminosity is higher. The tunes of BEPCII should be near $\nu_x/\nu_y = 6.51/7.56$.

The peak luminosity reduces with the increment of the horizontal crossing angle. It can't be neglected.

We shall use Hirata's code and other codes to check the storage ring of BEPC. This will be helpful for us to choose the tunes. From the simulation, we can conclude:

- The betatron tunes should be chosen in the area where $\nu_x = 6.51 \sim 6.53$ and $\nu_y = 7.56 \sim 7.64$.
- According to the calculation and simulation, the luminosity of BEPCII decreases with the horizontal crossing angle. We must consider the effect of the angle.
- From the simulation, we get the peak luminosity of BEPCII is $9 \times 93 = 8.4$ ($\times 10^{32}$ cm^{-1}s^{-1}). It is close to the design value 10×10^{32} cm^{-1}s^{-1}.

- According to the simulation result, we can conclude that the luminosity of the design is reasonable.
- It is possible to induce the synchrotron-betatron instability for the large crossing angle. We must study this phenomenon in detail.

5 REFERENCES

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