# THE EXPERIMENT OF THE SINGLE INTERACTION POINT SCHEME IN BEPC

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*Abstract*

In order to increase the luminosity of Beijing Electron-Positron Collider (BEPC), the single interaction point (SIP) schemes were adopted. Then the electron and positron beams were separated at the north IP and collided at the south IP. Some experiments were done during these years. The results are given in the paper.


## 1 INTRODUCTION

There are two interaction points in the storage ring of BEPC. Only one detector BES (BEijing Spectrometer) has been used at the south IP since BEPC was built [1]. The higher luminosity is needed so that BES can acquire data efficiently. One of way to increase the luminosity is to adopt SIP collision scheme. As the beam current already reached the limit by the beam-beam interaction for the double IPs (DIP) scheme, reducing the number of the IP is one of the way to increase the beam current. Then the luminosity can be enhanced. Some experiments were done with several kinds of SIP schemes during these years. The current and luminosity were increased compared with DIP scheme in 1998.

## 2 SIP SCHEMES

Several SIP schemes were used according to the different hardware and the lattices of the BEPC storage ring. But we couldn't try each of them in detail as there was no enough time for the machine study of the SIP schemes. Two typical modes were used.

### *2.1 SIP scheme with the original lattice*

The vertical phase advance between the two close separators (SP) is not π degree in the DIP lattice, and there is no space or independent power supplies of the quadrupoles to change them to π. This produces a small separation between electron and positron beams at the south IP after turning off the south SP. So the south SP must be given a little value in order to make electron and positron beams collide exactly at the south IP. The two auxiliary power supplies of SP were installed in the BEPC storage ring in 1993. Some experiments were done with adjusting the two auxiliary power supplies in the year. We got some good results [2]. But the luminosity was less than that of DIP. And the beam current was not increased compared with the DIP scheme.

During the beam collision, the coherent oscillation was observed from the synchrotron radiation monitor. This is because there was a large closed orbit distortion (COD) in the whole ring. The electron and positron beams passed different orbits in the ring. And there was a large COD in RF cavities and other magnets. The nonlinear effects gave rise some instabilities to the beams. So it is better to make the COD outside the north two SP eliminate.

### *2.2 Lattice modification*

The BEPC storage ring is 4-fold symmetric. Normally one power supply should control four quadrupoles. It is impossible to change the vertical phase advance between the two SP to π. In the luminosity upgrade project of BEPC, four power supplies of the insertion qradrupoles were prepared in order to adopt mini-β scheme. We used these four power supplies to calculate the lattice again so that the vertical phase advance between the north two SP was π. Then after turning off the south SP, the COD outside the north SP is zero. So the beams should be stable. Figure 1 shows the COD in which the north SP was on and the south SP was off.

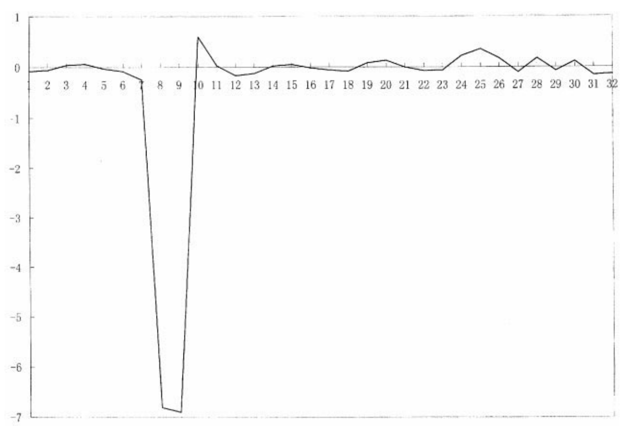

Figure 1: COD of the SIP scheme

Of course, the power supplies of the north SP can be used to adjust the colliding angle ($Y'_s$) between the electron and positron beams in order to realize head-on collision.

$$Y_s' = \frac{\theta_{spn1} - \theta_{spn2}}{2\sin \pi\nu_y}\sqrt{\frac{\beta_{spn}}{\beta^*_{ys}}} \qquad (1)$$

$\theta_{spn1}$, $\theta_{spn1}$ express the bending angle by the two north SP, $\beta_{spn}$, $\beta^*_{ys}$ the β-function of the north SP and the south IP.

We calculated the two kinds of lattices with adding the four power supplies. The emittances were kept nearly unchanged:

1. We modified the DIP lattice so that the optics parameters outside the north SP were same as DIP. But the vertical phase advance between the north SP was $\pi$. So the tunes were changed lot which were just above integer and half integer for the horizontal and vertical ones respectively, $\nu_x/\nu_y = 6.12/6.60$;
2. The tunes were nearly same as that of DIP, $\nu_x/\nu_y = 5.58/6.70$. But the parameters in the whole ring were quite different from that of DIP. The coupling correction is not same either.

## 3 RESULTS OF THE EXPERIMENTS

We mainly studied the first SIP scheme that was easy to be operated as the most of part of the ring is same as DIP. Table 1 gives the parameters of the SIP and DIP schemes.

Table 1: Parameters of SIP (1) and DIP lattices

| | SIP (1) | DIP |
|---|---|---|
| Energy | 1.548 GeV | 1.548 GeV |
| South $\beta_y^*$ | 0.05 m | 0.05 m |
| North $\beta_y^*$ | 5 m | 0.05 m |
| $\nu_x/\nu_y$ | 6.12/6.60 | 5.79/6.78 |
| Phase advance of north SP | $\pm 0.250\times 2\pi$ | $\pm 0.267\times 2\pi$ |

Some good results were gained in the first half of 1998. Figure 2 shows the luminosity comparison between the DIP and SIP.

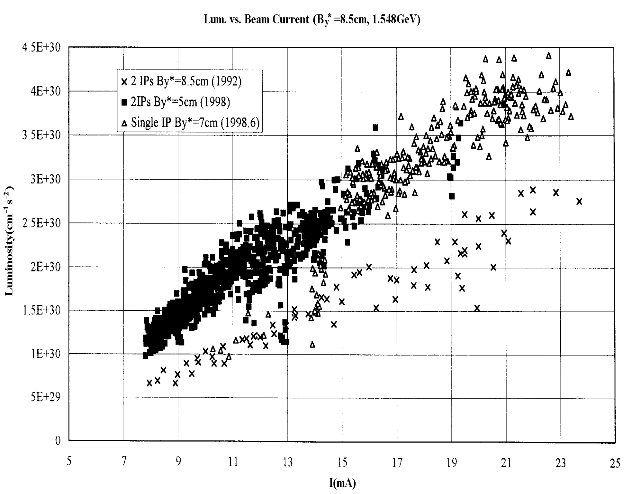


Figure 2: Luminosity comparison between the DIP and SIP schemes

The maximum current was 49.3 mA, and the peak luminosity was $4.4\times10^{30}$ $cm^{-2}s^{-1}$. At that time, the maximum current and the peak luminosity of DIP scheme were 39.5 mA and $3.6\times10^{30}$ $cm^{-2}s^{-1}$ respectively. So both the beam current and the luminosity were increased significantly with the SIP scheme. From the detector of BES, the hadron events were enhanced obviously. This will be benefit for the BES to take data efficiently.

## 4 BETA-FUNCTION AT IP

The nominated $\beta$-function at the south IP ($\beta_y^*$) of SIP scheme is 7 cm instead of 5 cm which was used in the DIP lattice. We measured the $\beta_y^*$ of SIP with colliding beams. The value was less than 7 cm. According to the linear theory, the beta function should be changed as the equation 2:

$$\beta^*_{y0} \sin \nu_{y0} = \beta^*_y \sin(\nu_{y0} + \Delta\nu) \qquad (2)$$

Here $\beta^*_{y0}$ is the undisturbed vertical beta function at the south IP, $\nu_y$ the vertical tune, $\Delta\nu$ the vertical tune shift.

We choose $\Delta\nu=0.035$, then the calculated beta function $\beta_y^* = 5.4$ cm. So the operation $\beta_y^*$ was reduced because the tunes were just above the integer and half integer which were quite different from the DIP scheme.

We tried to reduce the $\beta_y^*$ to 5 cm, but it's difficult to get high current. The maximum one was about 22 mA. We need time to enlarge it.

For the second kind of SIP scheme, the parameters are shown in the table 2.

Table 2: Parameters of SIP (2) and DIP lattices

| | SIP (2) | DIP |
|---|---|---|
| Energy | 1.548 GeV | 1.548 GeV |
| South $\beta_y^*$ | 0.05 m | 0.05 m |
| north $\beta_y^*$ | 4 m | 0.05 m |
| $\nu_x/\nu_y$ | 5.57/6.70 | 5.79/6.78 |
| Phase advance of north SP | $\pm 0.250\times 2\pi$ | $\pm 0.267\times 2\pi$ |

The maximum current was about 33 mA at $\beta_y^* = 5$ cm. The disturbed beta function was about 5.4 cm with the equation 2. But the luminosity reduced lot. The reason is not clear now. We also need time to improve it.

## 5 COMPARISON OF BEAM-BEAM EFFECT VERSUS BEAM CURRENT

Figure 3 and figure 4 show the comparison of the luminosity and beam-beam effect ($\xi_y$) vs. beam currents at $\beta_y^*$ =8.5 cm.

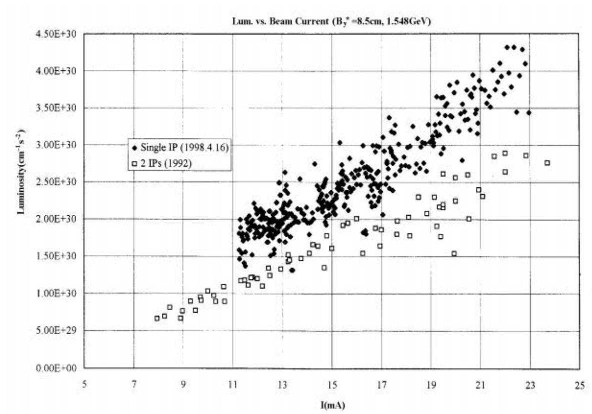


Figure 3: Comparison of the luminosity vs. beam currents at $\beta_y^*$ =8.5 cm

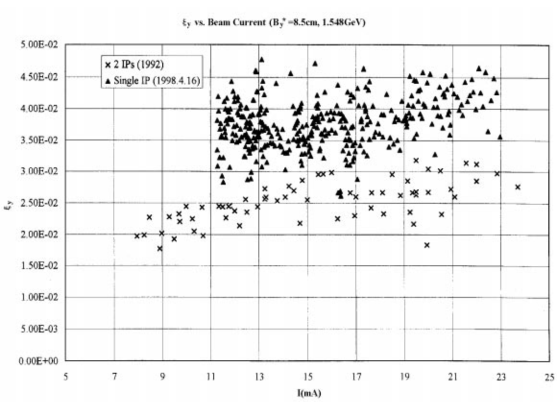


Figure 4: Comparison of the beam-beam effects ($\xi_y$) vs. beam currents at $\beta_y^*$ =8.5 cm

From the figure 3 and figure 4, we can see the luminosity and $\xi_y$ of SIP was increased about 50% compared with DIP at the same currents.

Figure 2 and figure 5 show the comparison of the luminosity and $\xi_y$ vs. beam currents at $\beta_y^*$ =7 cm for SIP scheme and DIP scheme at $\beta_y^*$ =8.5 and 5 cm.

It is obviously that the luminosity and $\xi_y$ were increased with the SIP scheme. This is reason why we try to use the SIP scheme in the BEPC storage ring. Of course, the background will be studied carefully.

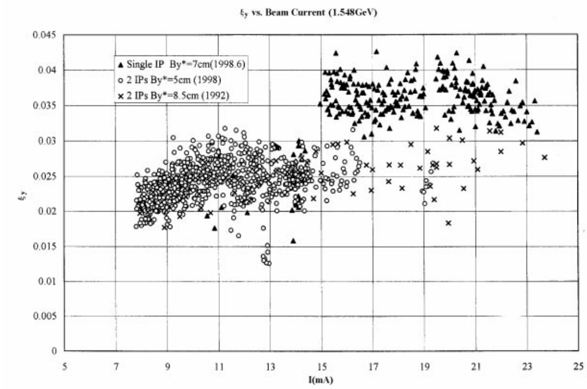


Figure 5: Comparison of the $\xi_y$ vs. beam current

It took us about 15 days to adjust the SIP scheme in 1998. The time was too short to do more detail study as the most of beam time were used for BES and the synchrotron radiation facility.

There are still many problems for the SIP schemes. When the beam current was increased more, such as larger than 50 mA, the beam blow-up always happened. Sometimes changing the coupling or the chromaticity could eliminate the blow-up. But it is not always useful. For the next step, we shall spend more time to adjust the tunes, closed orbit and other parameters carefully in order to enhance the luminosity further.

We would like to thank all persons of the accelerator physics group. They gave many good suggestions and contributed lot during the commissioning of the SIP scheme. We also acknowledge the support by the hardware group.

## 5 REFERENCES

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