# COMMISSIONING STUDY OF THE PARASITIC MODE WITH 3W1 WIGGLER MAGNET ON THE BEPC

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### *Abstract*

This paper describes the commissioning study of the parasitic mode with the permanent magnet wiggler 3W1 on the Beijing Electron Positron Collider (BEPC). This mode provides the possibility that during the HEP run the synchrotron radiation users can do experiment using the beamline of 3W1 meantime. The perturbation on the lattice of the collision mode due to the wiggle magnet was studied and a compensation scheme has been designed to keep the beta function at IP and the working point the same as the normal collision mode, thus the luminosity is not degraded. Through heavy commissioning work, the parasitic mode was operated stably during the period for high energy physics experiment at the energies of $\psi''(3770)$ from March to May in 2003, meanwhile served many synchrotron radiation users.


## INTRODUCTION

Beijing Electron Positron Collider (BEPC) is operated not only as an advanced electron-positron collider at τ-charm energy region, but also as a dedicated synchrotron radiation facility with broad X-ray spectrum at the beam energy of 2.2GeV. There are 4 wigglers in the BEPC storage ring. In which three of them are permanent magnet wiggler. The commissioning study of the parasitic mode was aim to taking advantage of one of the permanent wigglers during the HEP experiment, which is named as 3W1. Therefore, the data process of data acquisition of high energy physics and the process of SR application in the biologic molecule beam line and soft X-ray beam line could be carried out at the same time. The commissioning was successful and then the parasitic mode was adopted during the BEPC running. Thus the running efficiency of the BEPC was improved obviously.

## THE PERTURBATION FROM THE WIGGLER 3W1 TO THE LATTICE AND ITS COMPENSATION

3W1 is 5-periods permanent magnet wiggler with a variable gap, which is located in the arc of BEPC, between two quadrupole the magnets R3Q8 and R3Q9. The length of the magnetic period of 3W1 is 29.6mm, and the gap can be adjusted from 39 to 220 mm. The peak magnetic field is 1.6T. During the normal high energy physics run, the gap is set to its maximum value of 220 mm, and the magnetic field is nearly zero to avoid the perturbation to the colliding beam. When the gap is set to 43.2 mm for the dedicated mode of synchrotron radiation, the magnetic field is more than 1.0T. [1]

### *The Influence of the 3W1 on the Beam Parameter*

The edge focusing effect of the wiggler will affect the vertical beta function as well as the vertical tune, while the perturbation to the horizontal beta function and tune is negligible. The additional synchrotron radiation induced by the wiggler will affect the emittance, energy spread, damping time and other beam parameters, but the effects are not so large. Table 1 and 2 [2] show the perturbation of 3W1 to the beam parameters for E=1.89GeV and E=1.55GeV respectively.

Table 1: The perturbation of 3W1 to the beam parameters (E=1.89GeV)

| **B(Tesla)** | **3W1=0** | **3W1=1.0** |
|---|---|---|
| $\beta_y$*(m)(S/N) | 0.050/0.050 | 0.051/0.050 |
| $\beta_y$ max (m) | 97.697 | 97.279 |
| $\Delta \nu_y$ | 0 | 0.004 |
| $\Delta U_0$ (keV/turn) | 0 | 1.687 |
| $\varepsilon_{x0}$ (nm·rad) | 637 | 654 |
| $\sigma_e$ ($\times 10^{-4}$) | 5.036 | 5.046 |

(S/N) stands for the south and north IP respectively.

Table2: The perturbation of 3W1 to the beam parameters (E=1.55GeV)

| **B(Tesla)** | **3W1=0** | **3W1=1.0** |
|---|---|---|
| $\beta_y$*(m)(S/N) | 0.050/0.050 | 0.052/0.050 |
| $\beta_y$ max (m) | 97.643 | 97.157 |
| $\Delta \nu_y$ | 0 | 0.005 |
| $\Delta U_0$ (keV/turn) | 0 | 1.134 |
| $\varepsilon_{x0}$ (nm·rad) | 404 | 425 |
| $\sigma_e$ ($\times 10^{-4}$) | 4.130 | 4.155 |

### *The Compensation for the Beta Function and Tune in the Parasitic Mode*

When the gap of 3W1 is closed to 60mm during the run of the colliding mode, the beta function at the interaction point and tune are perturbed, and the characteristic of symmetry of the storage ring is destroyed. The compensation for beta function at the interaction point and tune is necessary to decrease the effects of the perturbation. The newly designed parasitic mode is based on the wiggler field of 1.0 Tesla. For the limitation of the power supply of the BEPC, only the vertical beta function at the interaction point and the vertical tune is compensated in the newly designed parasitic mode.

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Table3: The compare of the beam parameters between parasitic mode and colliding mode

| Energy(GeV) | E=1.55 | E=1.89 |
|---|---|---|
| $\beta_y$*(m)(S/N) | 0.050/0.048 | 0.051/0.050 |
| $\beta_y$ max (m) | 100.84 | 97.238 |
| $\Delta\nu_y$ | 0 | 0.001 |
| $\Delta U_0$ (keV/turn) | 1.134 | 1.687 |
| $\varepsilon_{x0}$ (nm·rad) | 424 | 652 |
| $\sigma_e$ ($\times10^{-4}$) | 4.155 | 5.046 |

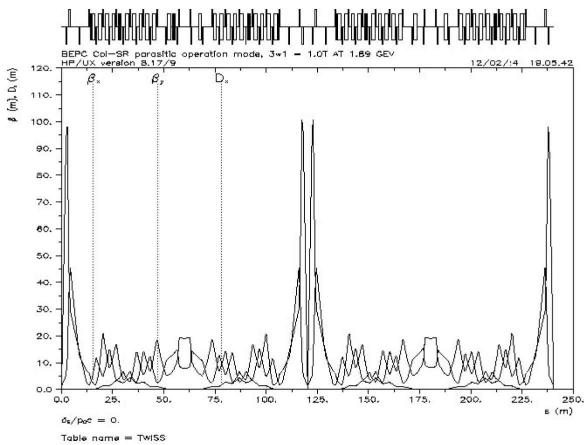

Figure 1: The lattice of the parasitic mode.

### *The Effect of the 3W1 on the Energy Spread in Parasitic Mode*

As shown in the table 1, 2 and table 3, the increase of the energy spread due to 3W1 is less than 1% for both case of E=1.55GeV and E=1.89GeV. The bunch current is 20 mA and 50 mA for ψ(2S) run and ψ″ run respectively, and the threshold of the microwave instability is about 10 mA, so the bunch length and energy spread are increased with bunch current [3]. The scaling law of the bunch lengthening obtained by experiments on BEPC is [4][5],

$$\sigma_l(cm) = 0.651\times\left(\frac{I_b(mA)\,\alpha_p}{E(GeV)\nu_s^2}\right)^{\frac{1}{3.49}} \tag{1}$$

$$\frac{\sigma_E}{\sigma_{E0}} = [1+\frac{(Z/n)_{pot}}{(Z/n)_{crit}}]^{-1/2}\,\frac{\sigma_l}{\sigma_{l0}} \propto \frac{\sigma_l}{\sigma_{l0}} \tag{2}$$

and the relation between energy spread and bunch current can be expressed as:

$$\frac{\sigma_E}{\sigma_{E0}} \propto (\frac{I_b}{I_{b0}})^{1/3.49} \tag{3}$$

The ratio of the energy spread between 45 mA bunch and 20 mA bunch is:

$$\frac{\sigma_E @ 45mA}{\sigma_E @ 20mA} = (\frac{45}{20})^{1/3.49} = 1.26 \tag{4}$$

From above discussion, one can find that the increasing of the energy spread induced by 3W1 is much smaller than that by bunch lengthening above the microwave instability.

### *The Effect of the 3W1 on the Energy in Parasitic Mode*

In the ideal case, the integral magnetic field along the axis of insertion component is zero, but the error of the integral magnetic field always exists, and beam orbit then will be disturbed and the beam energy will be changed [6].

- The beam energy deviation caused by the error of integral magnetic field is:

$$\frac{\Delta E}{E} = \frac{\int \Delta B ds}{2\pi B\rho} \tag{5}$$

where, E is the beam energy, Bρ is magnetic rigidity, ∫ΔBds is the error of integral magnetic field. The value ∫ΔBds is 5G·m when $B_{3w1}$=1.0Tesla. For the parasitic mode, the beam energy is 1.89GeV, the energy deviation is ΔE=0.024MeV.

- Due to the length difference between arc and bowstring, the actual beam orbit will be increased while the wigglers are switched on. The change of beam orbit can be expressed as:

$$\Delta L = N\cdot[2\rho\sin^{-1}(\frac{l}{2\rho}) - l] \tag{6}$$

where l and N are the periodic length and number of the wiggler respectively. ρ is the radius of orbit curve, and the energy deviation caused by the change of orbit length can be expressed as:

$$\frac{\Delta E}{E} = \frac{\Delta C}{\alpha_p C} \tag{7}$$

where, $\alpha_p$ is momentum compact factor and C is the circumference of storage ring. Just considering the change of orbit length inside wiggler, then ΔC=ΔL and:

$$\frac{\Delta E}{E} = \frac{N\cdot[2\rho\sin^{-1}(\frac{l}{2\rho}) - l]}{\alpha_p C} \tag{8}$$

For the parasitic mode, the energy deviation is ΔE=0.026MeV, while $B_{3w1}$=1.0Tesla, N=5, ρ=6.3m, $\alpha_p$ =0.043, C=240.4m.

Take both the above effects into consideration, for the parasitic mode the energy deviation is about $3\times10^{-5}$ at the beam energy of 1.89GeV. It's about factor of 10 smaller than the beam energy spread ($5.1\times10^{-4}$). So the effect of the energy deviation caused by wiggler can be negligible.

## THE LUMINOSITY EFFECT IN THE PARASITIC MODE

During the operation of parasitic mode, the process of data acquisition of high energy physics and the process of SR application could be carried out at the same time. The running comparison of luminosity with various 3W1 magnetic field is shown in figure 2 [7]. The luminosity of parasitic mode and normal colliding mode are displayed in figure 3 and figure 4 respectively. Figure 5 is the hadron events rate in the parasitic mode and normal colliding mode. From these figures, no obvious degradation on the luminosity and the hadron events rate were shown with the parasitic mode, compared to the normal mode. So the efficiency of the BEPC running was significantly improved.

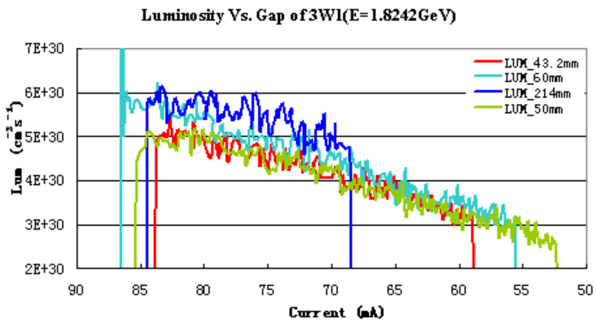


Figure 2: The luminosity vs. different 3W1 field.

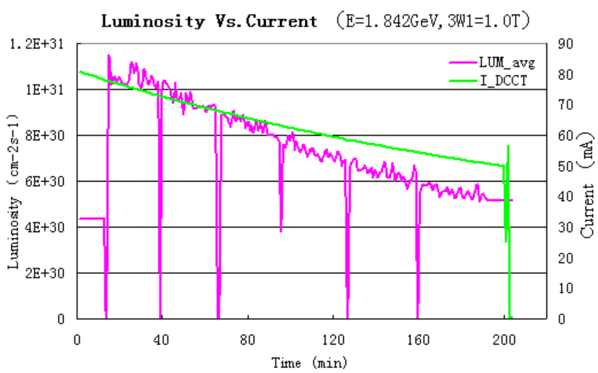


Figure 3: The luminosity vs. beam current for the parasitic mode (E=1.842GeV).

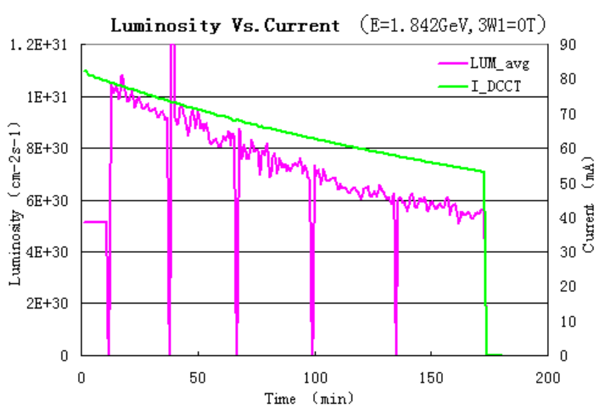


Figure 4: The luminosity vs. beam current for the colliding mode (E=1.842GeV).

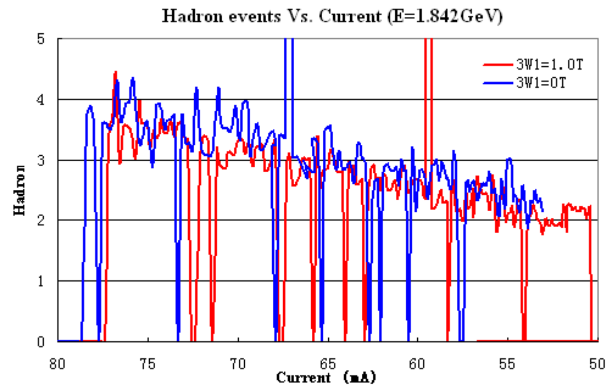


Figure 5: The hadron events rate vs. beam current in the parasitic mode and normal colliding mode.

## CONCLUSIONS

- The perturbation of beam parameter due to the 3W1 wiggler can be compensated very well in BEPC.
- The influence of parasitic mode on the collision luminosity and hadron events is very weak, according to the operation data.
- Due to the well compensation and successful commission, the parasitic mode is runned in BEPC, and the running efficiency is increase in BEPC.

## ACKNOWLEDGMENTS

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