THE INFLUENCE OF STRIP-LINE BPMS' MEASURING RESULTS MADE BY EDGE OF THE ULTRA-RELATIVISTIC ELECTRON BEAM

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Abstract

The edge of the ultra-relativistic electron beam may affect the measuring results of the strip-line beam position monitor (BPM) when we take the transverse size of the beam into account. Simulations have been made by using the Wakefield Solver of CST Particle Studio. The results of this influence at different ratio of beam horizontal width σ_x and the BPM inner diameter a has been obtained. This kind of influence has been observed in the strip-line BPMs in the big dispersion section in transfer line of Beijing Positron Electron Colliders upgraded version II (BEPCII). This research is useful when we design the inner diameter of the strip-line BPMs which will be used in the high dispersion sections for ultra-relativistic electron beam, meanwhile it provides reference to distinguish the invalid ones from the measuring results obtained by the strip-line BPMs in the ultra-relativistic situation.

INTRODUCTION

The theoretical model of the beam position monitor (BPM) [1-3] usually uses the centre of the beam whose size can be ignored instead the beam transverse section. And in the calibration of a BPM, we often use power wire to take the place of the beam [3, 4], where the transverse size can also be regarded as zero. Nevertheless, in the big dispersion section, for example after the bending magnet, there may be a big displacement between the beam centre and the orbit as well as a big envelope because of the energy fluctuation. In this situation, the edge of the beam may strike into the electrode of the BPM, which affects the measuring results. The BPMs installed in the transfer line of BEPCII linear accelerator (LINAC) meet the same problem (see Fig. 1). Those in the big dispersion section are named TEBPM1 and TEBPM3. Their inner diameter a is 26.2 mm while the beam envelope of the horizontal direction σ_x there is nearly 5 mm.

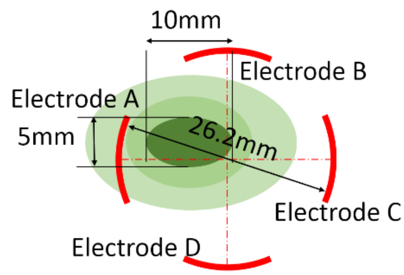

Figure 1: The schematic diagram of the BPM installed in the transfer line of BEPCII LINAC and the beam profile. If the beam centre is deviated far away from the centre of BPM, the edge of the beam may strike into the electrode.

It is necessary to make clear that how big the influence will be by using the model which takes the transverse size of the beam into account.

SIMULATION

We use the Wakefield Solver of CST (short for Computer Simulation Technology) Particle Studio [5] to do the simulation because there is already a case called "Beam Position Monitor" there [6]. But this case is just for the zero size situation. To meet our requirement, we did some modifications.

The Model

In order to take the transverse size of the beam into account, we use 196 particle beams (14 rows and 14 columns) to replace the single one. But the total charge of the 196 particle beams equals to the original single one. The charge each particle beam contains fits two-dimensional normal distribution in the horizontal and vertical directions. For example, the particle beams from row 6 to row 9 contain 68.26% of the total charge. Each of the particle beam is the Gaussian beam with the sigma property 30 mm and the velocity (beta) property 1 (in the transfer line of BEPCII, the beam energy is more than 1.89 GeV). So the double space between column and column equals to the beam horizontal width σ_x and the double space between row and row equals to the beam vertical width σ_y. Figure 2 shows the model used to simulate in CST PS. Its ratio of beam horizontal width σ_x and the BPM inner diameter a is 4:25 and the beam has a displacement of 8 mm to the centre in the horizontal direction.

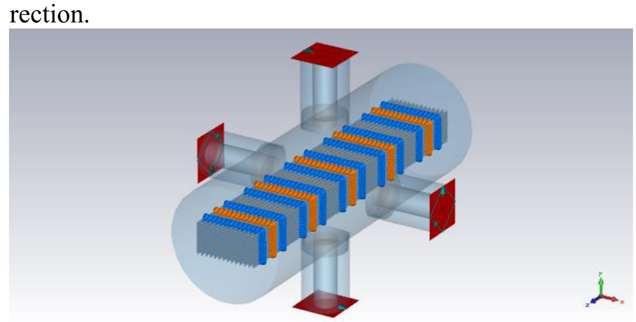

Figure 2: The model used to simulate in the CST PS, whose ratio of beam horizontal width σ_x and the BPM inner diameter a is 4:25 and the beam has a displacement of 8 mm to the centre in the horizontal direction.

When the place of a particle beam is out of the BPM space, we remove this particle beam away and regard it as beam loss in the electrode. This part of beam cannot in-

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duce the induced current in the electrode, instead, it will produce the current in the loss electrode directly. The value of this kind of current equals to the quantity of charge received by the loss electrode per unit time. And the polarity of this current counters to the induced current's, which weakens the current output in fact. Figure 3 gives an example for this situation. When some particle beams lose in the loss electrode, up is the curve of induced current in the loss electrode produced by the other particle beams, middle is the curve of current in the same electrode caused by the beam loss and down is the sum value of the currents above which is regarded as the output current of the loss electrode.

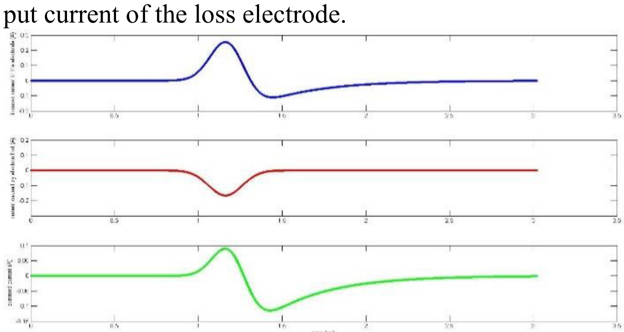

Figure 3: Induced current in the loss electrode (Up); Current caused by the particle beams struck in the loss electrode (Middle); Total current output from the loss electrode (Down).

Simulation Results

Simulations have been done with the displacement to the centre in the horizontal direction set from -24 mm to 24 mm (the displacement to the centre in the vertical direction is always zero) and the ratio of beam horizontal width σ_x and the BPM inner diameter a set 0:25, 2:25, 4:25, 6:25 and 8:25, respectively. We use A to indicate the current output from the electrode A in the horizontal direction and use C to indicate the current output from the electrode C in the horizontal direction. The results of (A-C)/(A+C) vs the beam centre with different values of σ_x:a are shown in Fig. 4.

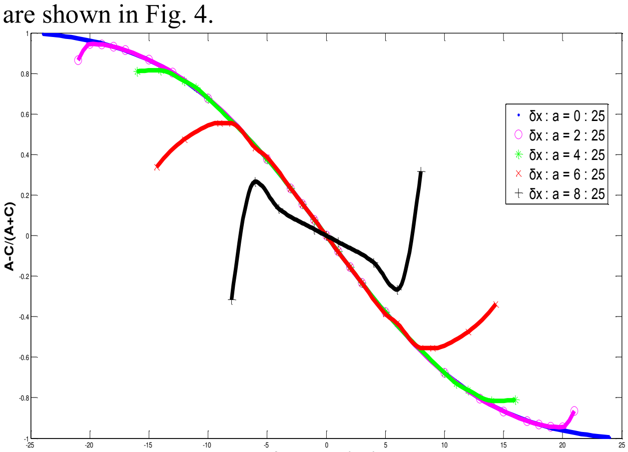

Figure 4: (A-C)/(A+C) vs beam centre at different ratio of beam horizontal width σ_x and the BPM inner diameter a.

From Fig. 4 we can see that when the displacement to the BPM centre is small, the values of (A-C)/(A+C) and the beam centres are linear correlation. As the displacement becomes larger, this kind of relationship is changed. For the situation of big ratio of σ_x and a and at large displacement, the correlation coefficient even changes from negative to positive. Though the BPM will be calibrated before it is installed, the method used doesn't take the transverse size of the beam into account. The simulation results of beam centre measurement with different radio of σ_x and a is shown in Fig. 5. The results have been calibrated so that in the situation of "σ_x:a=0:25", we can get the right beam centre information from the measurement.

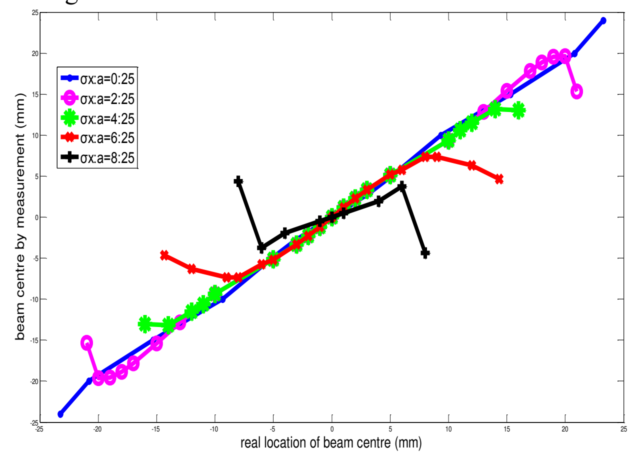

Figure 5: After calibrating, the simulation results of beam centre measurement with different radio of σ_x and a.

In Fig. 5, it indicates that in the situation of big radio of σ_x and a, we may get the wrong measurement results of the beam centre at the large displacement. That is, when the displacement of the beam centre gets larger, the location we measured becomes smaller.

OBSERVATION IN BEPCII TRANSFER LINE

The radio of σ_x and a in the big dispersion section of BEPCII transfer line where there are BPMs named TEBPM1 and TEBPM3, is between 6:25 and 10:25, which means the phenomenon discussed above can be observed in TEBPM1 or TEBPM3.

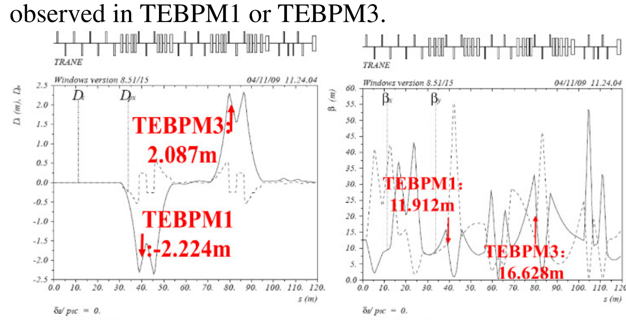

Figure 6: The dispersion curve of the electron transfer line of BEPCII made by MAD code (left) and the beta function curve made by MAD code (right).

Figure 6 (right) shows that the value of beta function in TEBPM1 is 11.912 m and in TEBPM3 is 16.628 m. If we ignore the little difference of beam emittance in this two places, the beam envelope in TEBPM3 will be larger than it in TEBPM1, which means the phenomenon will be first observed in TEBPM3. We made the beam go through the

BPMs and recorded the measurement results of them at the same time. Figure 7 is the results of the record. The coordinate of each spot in this plot represents the values measured by TEBPM1 (x axis) and TEBPM3 (y axis) at the same time.

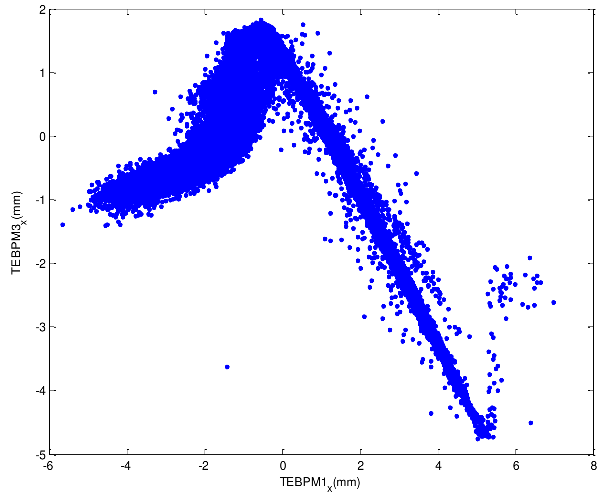

Figure 7: The coordinate of each spot in this plot represents the values measured by TEBPM1 (x axis) and TEBPM3 (y axis) at the same time.

As is shown in Fig. 7, the beam centre measured by TEBPM1 and TEBPM3 is negative linear correlation from about -1 mm to 5 mm, while the absolute values received by TEBPM3 become smaller beyond this area. We can deduce that the edge of the beam may affect the measurement in TEBPM3. Because of exist of BPM offset, the normal area is not centred on zero. To verify our surmise, we have also recorded their ADC converted data, respectively. Results are shown in Fig. 8.

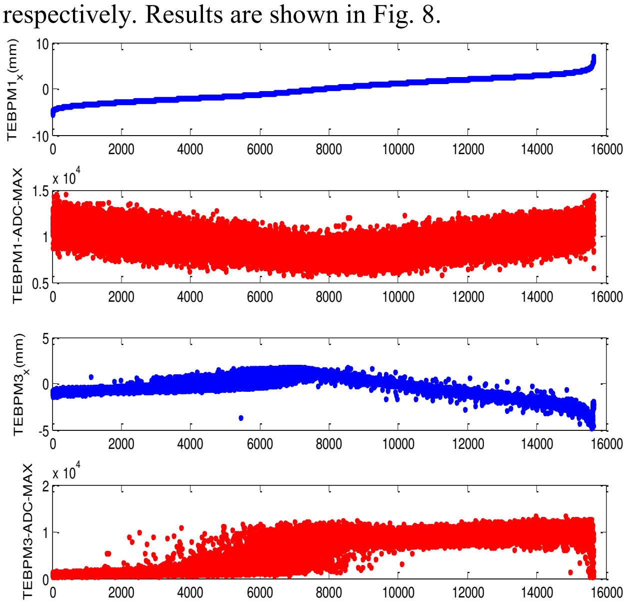

Figure 8: Top set is values measured by TEBPM1 (sorted from the lowest to the highest). Second set from top is the ADC converted data of TEBPM1. Third set from top is values measured by TEBPM3. Bottom set is the ADC converted data of TEBPM3.

The top set of spots in Fig. 8 are the values measured by TEBPM1. They are sorted from the lowest to the highest. The second set of spots from top are the ADC converted data of TEBPM1 which correspond one to one to their measurement values. The ADC data of TEBPM1 are smaller in the middle area and bigger in two heads, which fits the theory well for smaller distance leading to the higher induced current. The third set of spots are the values measured by TEBPM3 which also correspond one to one to TEBPM1 values in the time. The bottom set of spots are the ADC converted data of TEBPM3. We can see clearly that for the problem data measured by TEBPM3, the ADC converted data of them also have abnormal drops. This means the output current of the electrode at that time became lower even more than them in the middle. This record support our deduction that the edge of the beam affected the measurement in TEBPM3 in a way we discussed above.

CONCLUSION

From the simulation of the BPM which taken the transverse size of the beam into account, we find that the edge of the beam may affect the measurement results of the BPMs in some situations. To avoid using the problem data to make wrong decisions, we should record the converted data from the ADCs or the current output from the electrodes directly at the same time and take care of those values with ADC numbers or current values dropping down suddenly. If the measurement values of the BPM are not very big, but their ADC numbers are rather small, it is quite possible that the edge of the beam has lost in one of the electrode and affected the measurement.

What's more, we are ought to take care of the radio of beam horizontal width σ_x and the BPM inner diameter a when we design BPMs for transfer line of high energy electrons or positrons especially in the big dispersion sections. If it is possible, the radio σ_x:a should be as large as it can and the offset of the BPM should be zero to prevent this problem from happening.

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