BEAM TESTS OF A WIRE SCANNER FOR THE KEKB INJECTOR LINAC AND BEAM TRANSPORT LINE

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Abstract

Beam tests of a prototype wire scanner which will be used in the KEKB injector linac and in the beam transport line have been successfully conducted. The main purpose of the tests was to investigate effects of beam background on system performance by using electron beams of the injector linac and to prove that the wire scanner does work in an actual beam situation. This report describes results of the beam tests in detail.

1 INTRODUCTION

Since the KEKB is a factory machine, a well-controlled operation of its injector is required for minimizing tuning time and a stable operation. To this end, beam diagnostic and monitoring tools are essentially important. Of those tools, a wire scanner (WS) system is used to measure transverse beam distributions non-destructively and to determine beam emittances and Twiss parameters which are used in optics matching. To determine these parameters without changing magnet strength, at least 3 WS's are needed in a localized area. For redundancy, we plan to install WS's in sets of four. At several critical points of the injector linac and the beam transport (BT) lines, such a set of monitors will be installed.

Wire scanner monitors themselves are well-established and common techniques used in various machines. Empirically, however, performance of WS's is seriously affected by beam background and seriousness of beam background to a detector is rather different from machine to machine. The main motivation of the present beam study was to investigate background situation in our machine. For this purpose, we carried out beam tests three times by using prototypes of WS's.

The first beam test was conducted in July 1997 using a beam of the KEKB injector linac. We used a 2.5GeV electron beam with a beam current of around 0.2nC/bunch. Results were reported elsewhere[1]. Here, we summarize the results very briefly. We found out that seriousness of beam background depends strongly on a beam tuning condition, a detector arrangement and a detector shield condition. A signal to noise (S/N) ratio was easily affected by a very small beam loss in upstream of the monitor and we needed a very careful beam tuning to maximize the S/N ratio. The S/N ratio of the order of 10^2 was finally obtained after sufficient beam tuning. As for a detector arrangement, we compared two cases of (1) a small angle detection (mainly detects Bremsstrahlung photons) and (2) a large angle detection (mainly detects electrons from multiple scattering). Since the latter brought much better S/N ratio than the former, we adopted the large angle method with the detection angle of 65^o.

In the second beam test conducted in December 1997, we investigated beam background in different beam conditions. We used a beam of 1.5GeV with a charge of1∼10 nC/bunch. We also checked out to what extent we can reduce detector shied for saving space. We measured the beam emittance and Twiss parameters using the WS. In this paper, we mainly describe results of this second beam test.

The third beam test is now in progress. In this report, we show very preliminary results very briefly. In the beam test, we employed another prototype of WS, which was redesigned to fit the narrow room for the monitor in the linac[2].

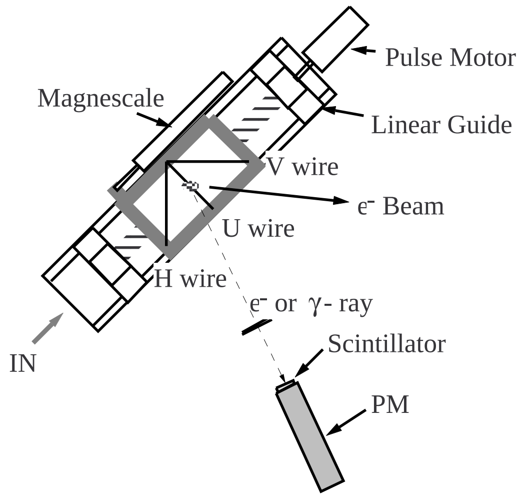

Figure 1: Schematic view of prototype wire scanner.

2 EXPERIMENTAL SETUP

A cross-sectional drawing of the prototype WS used in the second (and first) beam tests is shown in Fig. 1. The WS is composed of a tungsten wire of 300-mm diameter and a driving unit to drive the wire. The driving unit consists of a pulse motor and precise linear guides. Each of 3 wires meets the others at an angle of 45 degree. The three wires are actually different parts of a single wire. The wires, which are called H-,V-, and U-wire, go across the beam horizontally, vertically and in the 45-degree direction by driving a wire holder in the direction perpendicular to U-wire. The motion of the wire holder is constrained by two linear guides installed on both sides of the holder. A small port with a SUS foil of about $100\mu m$ thickness is attached to the vacuum chamber to guide scattered electrons at an angle of 65^o with the beam line. Fig. 2 shows a block diagram of the system. The pulse motor is driven with a step resolution of $1\mu m$ by the motor driver controlled by a pulse-train generator(PTG) at the pulse rate of 512Hz. A tuner controller was used to drive the pulse motor in a bench test. The drive position of the wire is monitored by Magnescale with a resolution of $1\mu m$. The driving unit is controlled by a VME/CAMAC system and a host computer through a network. We used a photomultiplier (PM) tube to which a $40 \times 50 \times 10mm^3$ plastic scintillator was attached. PM signals were directly fed to a CAMAC-based charge ADC(LeCroy 2249W) through a 15m-long coaxial cable. A beam timing signal was used to gate the ADC. A control software has been developed based on the EPICS system.

A beam test was performed at the end of the B sector of the linac by using electron beams at a pulse repetition rate of 5Hz. An outline of the linac is described in ref.[3]. The beam energy and beam intensity were 1.5 GeV and 0.7$\sim$10 nC/pulse at the WS. An experimental setup is shown in Fig. 3. The detector was placed in the downstream of the WS and at the same level as the beam line. The detector was sufficiently shielded by using about one-hundred lead blocks against beam background. The detector acceptances were about 1.7×10^{-3} sr.

The third beam test is being done at the Arc section of the linac using another type of WS[2].

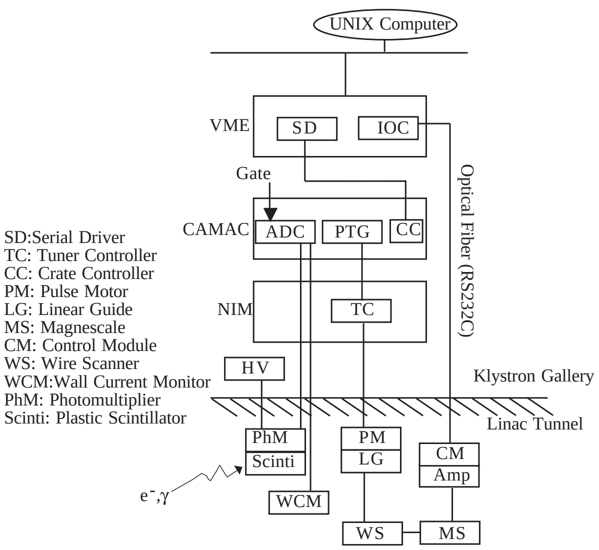

Figure 2: Block diagram of the wire scanner system.

3 PROCEDURE OF BEAM TEST

To obtain an optimum value for high voltage (HV) fed to the PM, we compared signal strength in the case that the beam was on the wire with that off the wire with scanning the HV values. We chose the value of -700V for HV which maximized this ratio. Several parameters were tuned by using the beams before the data taking. The wire holder was driven step by step in units of 0.5mm/step. A whole drive length was set to be 80mm. The number of data points for one whole scan was 160 points/scan (one data point was constructed by a 7-pulses average). As a result, the total measuring time was about ten minutes for one whole scan including waiting time at each drive step before the start of the data taking to avoid any wire vibration. Prior to the beam study, we made a beam orbit correction. An orbit distortion was reduced from 0.5 mm in rms to as much as 0.2 mm in rms for both the horizontal and vertical orbits. This correction was effective to get a better S/N ratio. On the other hand, we did not make any beam tuning on optics for better S/N ratio of the WS. This was because we can not always perform such a tuning for the WS in an actual beam operation. To investigate a beam current dependence of the beam background, we tested three different beam currents; 1nC, 7nC and 10nC/bunch with a beam energy of 1.5GeV. To investigate effectiveness of Pb shield, we intentionally removed some Pb blocks and observed changes of beam background.

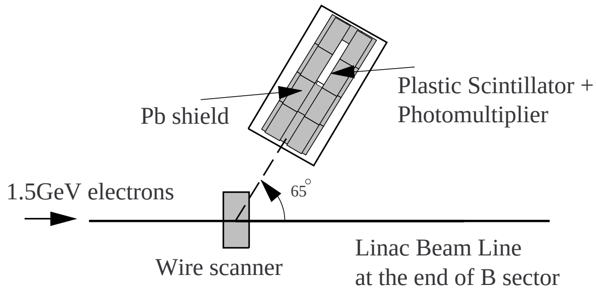

Figure 3: Schematic view of the setup for the second beam test.

In the third beam test, we used the new wire scanner with two different bunch currents of 1nC/bunch and 7nC/bunch so far.

4 RESULTS

In the current dependence measurement in the second beam test, we measured beam profiles with bunch currents of 1nC/bunch, 7nC/bunch and 10nC/bunch. We could measure beam profiles clearly with these current and did not see any significant difference among S/N ratios for these three bunch currents. A typical value of the S/N ratio was around 3/1, although it depended on a beam tuning condition. Fig. 4A shows a typical result for 7nC/bunch. In the figure,the left, middle and right peaks correspond to V-, U- and H-wires, respectively.

Fig. 4 shows a result of a study on effectiveness of Pb shields performed in the second beam test. The bunch current was 7nC/bunch in this measurement. In the study, we intentionally removed some Pb shield. Before removal, a detector (a plastic scintillator and a photomultiplier) was shielded closely with Pb blocks of 20cm in effective thickness on every side except for a path through which signal particles can reach the detector from the wire. We removed

Pb blocks on one side which faced the upstream. As is seen in Fig. 4, the S/N ratio got worth when we reduced the shield thickness from 20cm(a) to 10cm(b). The shield thicknesses of 10cm(b) and 5cm(c) gave almost the same result. Here, we noticed that a large crevice in front of the detector was made unintentionally when we removed the Pb blocks. When we narrowed this crevice in the case of a thickness of 5cm, the S/N ratio was improved(d). Although the S/N ratio was not recovered to the level of the 20cm-shield, this may be due to a residual crevice. In a restricted machine time, we could not fill the crevice sufficiently. From these observation, we concluded that the 5cm-thickness may be enough but we should pay close attention not to make unnecessary crevice. The WS system was used to measure beam emittance. Results were well consistent with those by using a screen monitor near to the WS.

In the third beam test, we prepared a Pb shield structure with the thickness of 5cm based on the result of the second beam test. With the bunch current of 1nC, the S/N ratio was at a practical level. However, in the case of 7nC/bunch, we could not measure the beam profile at all, owing to a bad S/N ratio. This was because we could not cure a heavy beam loss which amounted to 20% of the whole beam in the Arc section where the WS was installed. A further study with additional shield blocks showed that we need a shield with a thickness of 10cm in that case.

5 SUMMARY

A prototype system of the wire scanner worked well with a detector shield of 5cm-lead in effective thickness in the range of bunch current of 1nC∼10nC/bunch, unless the beam loss is heavy. When the beam loss is such that it amounts to several tens percent of the whole beam around the monitor system, we need thicker lead, say, of 10cm-thickness for suppressing the background.

6 ACKNOWLEDGMENTS

The authors gratefully acknowledge S. Yoshida in Kanto Information Service for his help on the software development using EPICS. Thanks are also devoted to the KEKB commissioning group who helped the preparation of this experiment.

7 REFERENCES

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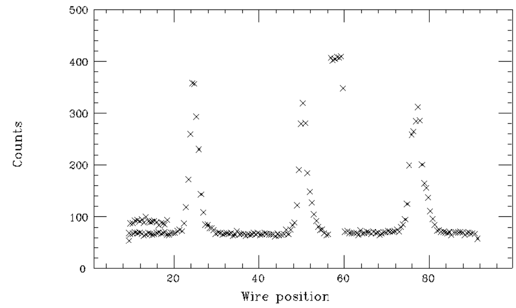
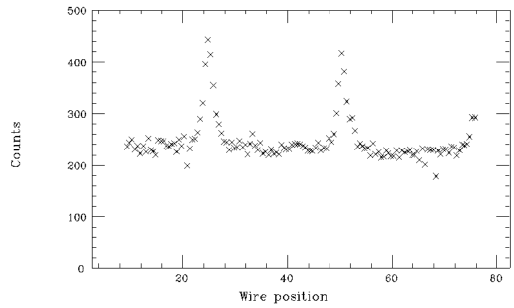
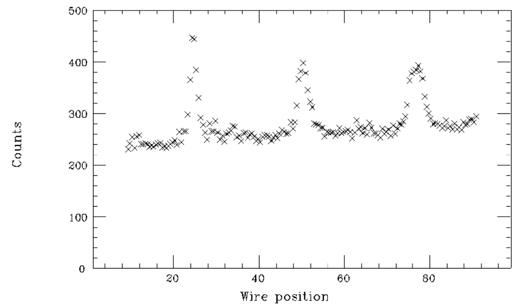


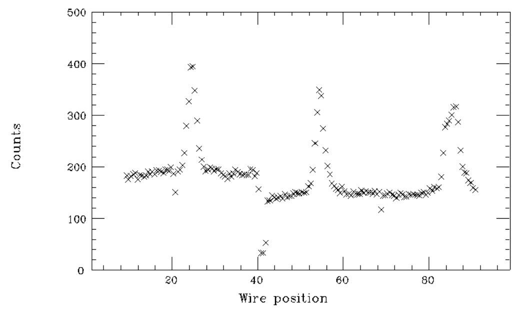
(a) 20cm-lead shield



(b) 10cm-lead shield



(c) 5cm-lead shield



(d) 5cm-lead shield (narrowed crevice)

Figure 4: Results of study on effectiveness of Pb shield with a bunch current of 7nC/bunch. The abscissa and ordinate denote wire positions in units of mm and ADC counts, respectively.