

WIRE PROFILE MONITORS IN J-PARC LINAC

H. Akikawa, Z. Igarashi, M. Ikegami, S. Lee,
 High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan
 Y. Kondo, S. Sato, T. Tomisawa, A. Ueno,
 Japan Atomic Energy Agency, 2-4 Shirakata-Shirane, Tokai, Naka, Ibaraki 319-1195, Japan

Abstract

We schedule to install wire scanners for J-PARC (Japan Proton Accelerator Research Complex) linac in order to measure beam profile and emittance. They have been designed to capture electrons in H⁻ beam, and 7μm-diameter carbon wires and are 30μm-diameter tungsten wires are used for 3MeV and 50-181MeV beam, respectively. In this paper, we report the result of the beam test with 3MeV beam performed at KEK and the calculation about signal and wire temperature.

WIRE SCANNER DESIGN

J-PARC linac is being constructed [1]. We have developed wire scanners for the measurement of beam profile. We schedule to install 36 wire scanners at linac in total. Four wire scanners are at MEBT1 between RFQ and DTL where the kinetic energy is 3MeV, other four are at SDTL where the beam energy is 50MeV, and the rest 28 are at where beam dumps where the beam energy is 181MeV [2].

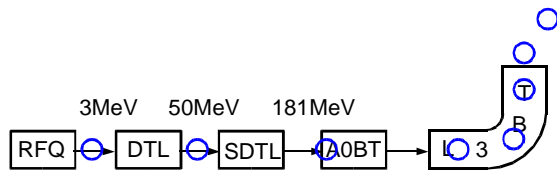


Figure 1: Schematic layout of wire scanners in J-PARC linac.

Each wire scanner has two wires. The frames of wire scanners are inserted into beam line with 45degree against the horizontal axis and move in 0.1mm step. One wire is stretched horizontally and is used for measuring vertical profile. The other wire is stretched vertically and is used for measuring horizontal profile.

SIGNAL GENERATED IN WIRE

H⁻ ions are accelerated in J-PARC linac. There are three sources of the signal generated in a wire by collision of H⁻ beam.

- (1) negative current by the electrons flowing into a wire
- (2) positive current by the protons flowing into a wire
- (3) positive current by secondary electron emission when electrons and protons impact a wire

For thin wire, the both of electrons and protons in H⁻ penetrate the wire and the signals are generated by only above (3). For middle-thick wire, protons penetrate the wire and electrons stop in the wire and the signals are generated by above (1) and (3). For much thin wire, the both of electrons and protons stop in a wire and the signals are generated by above (1), (2), and (3).

We calculated secondary-electron yield (3) using the expression

$$Y = (Pd_s/E_*) dE/dx,$$

where dE/dx is the stopping power, d_s is the average depth from which secondaries arise, E* is the average amount of kinetic energy lost by an ion per ionization produced in the wire, and P is a probability. We use P=1/2, d_s=1nm, E*=25eV [3][4], and calculated stopping power table [5].

We have selected middle-thick wire. Because secondary emission yield is about 1/10 of beam current, the large signal is obtained by the middle thickness wire. In order to stop electrons in 181MeV H⁻ beam, tungsten wire need over 18μm diameter.

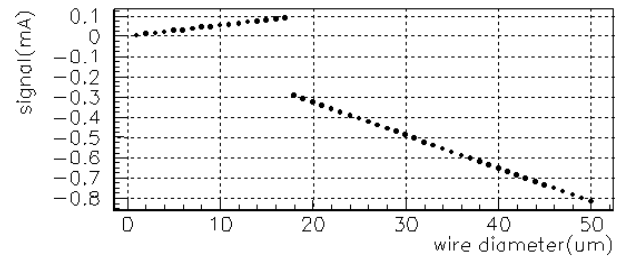


Figure 2: Signal calculation for tungsten wire.

We also performed temperature simulation of the wire. Figure3 shows the results of simulation for tungsten wires. We considered full beam condition for the simulation, 181MeV energy, 50mA current, 50Hz repetition, 500μs length, and 56% duty. Since the melting point of tungsten is 3680K, 30μm tungsten will not be heated up to the limit temperature in the result of this simulation. We have constructed wire scanners at 181MeV point using 30μm tungsten wire.

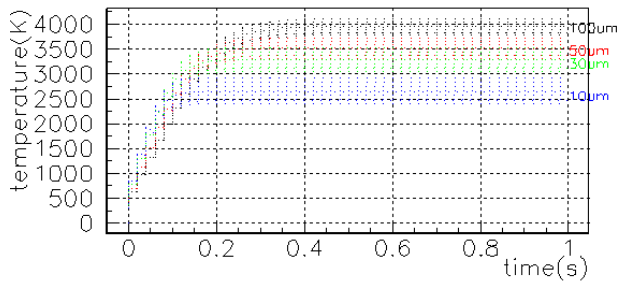


Figure 3: Temperature calculation for 30-mm-diameter tungsten wire for 181MeV H- beam.

BEAM TEST

The beam tests and the R&D of the monitors for the J-PARC linac have been performed at KEK. We installed four wire scanners in the MEBT1 between RFQ and DTL. The kinetic energy of H⁻ is 3MeV. The wire scanners have two 7µm-diameter carbon wires which stop electrons in H⁻.

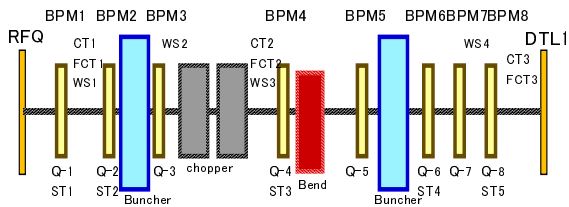


Figure 4: Schematic layout of MEBT1 in beam test. Four wire scanners were installed.

We added bias voltage on wires. Figure 5 shows the measured profiles. The black dots show the profile for non-bias, red dots show profiles for positive voltages from +60V to +240V, and blue dots show profiles for negative voltages from -60V to -240V. The polarity of signal varied according to bias voltage. In the case of positive bias, we observed that higher bias made larger signal. It is because of positive bias suppress secondary electron emission. In the other hand, since negative bias increase the yield of secondary electron emission, positive current by secondary emission exceeds negative current by stopped electron and the total of signal is positive.

We studied a dependence on the position and the intensity of beam changing bias voltage. We measured horizontal profile when changing vertical position of the beam. If measured profile has no dependence on position, horizontal profile should not vary. Figure 6 shows measured profiles for the bias voltage of -240V, 0V, and +240V. It results that negative bias causes position dependence and the measured profile is not correct.

Figure 7 shows the signal efficiency which is defined as the ratio of integrated signal and beam intensity for the bias voltage of from 0V to +60V. In comparison of low (4mA) and high (26mA) beam intensity, for from +20V to +60V bias voltage, the efficiency for low and high

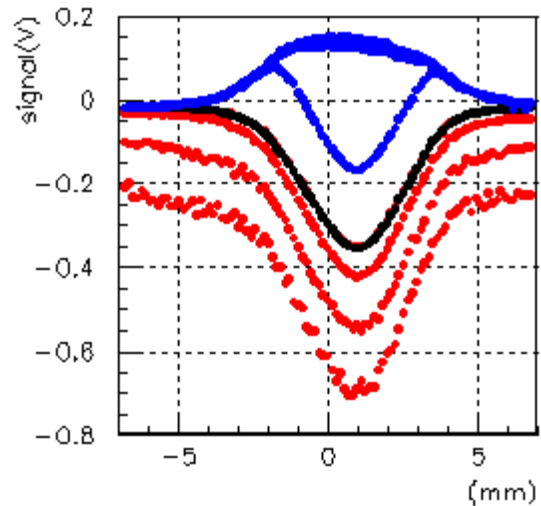


Figure 5: Measured profiles when positive voltage (red), negative voltage (blue), and neutral voltage (black) were added on wire.

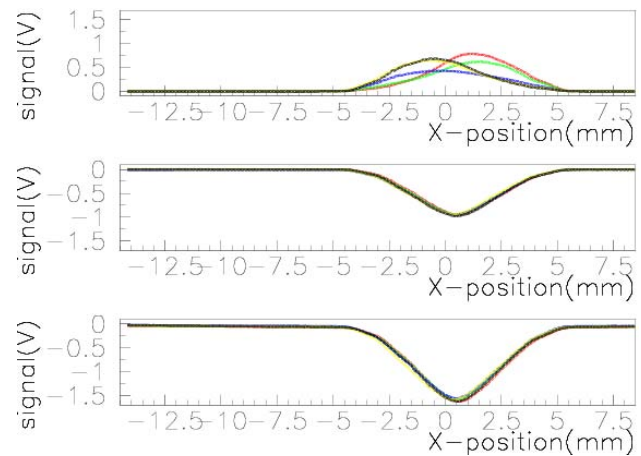


Figure 6: Dependence on position for the bias voltages of -240V, 0V, and +240V.

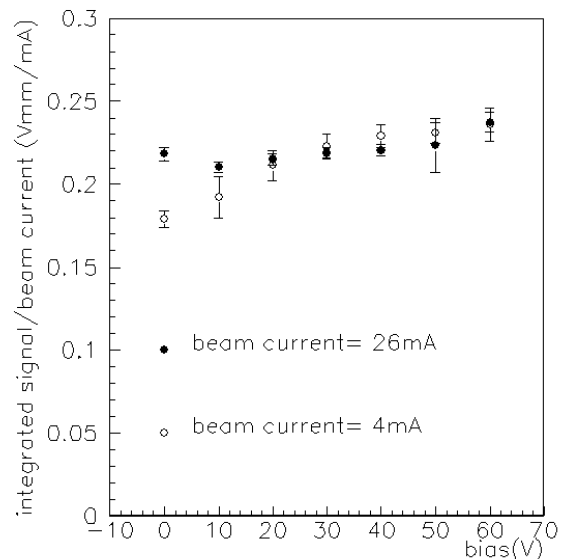


Figure 7: Dependence of signal efficiency on beam intensity.

intensity have same value. In the other hand, the efficiency under +20V depend upon beam intensity, which causes distortion of measured profiles.

Figure8 shows the difference of the measured profiles between the bias voltage of 0V and +20V. In the case of 0V, since low intensity beam causes low signal efficiency, the edge part is underestimated.

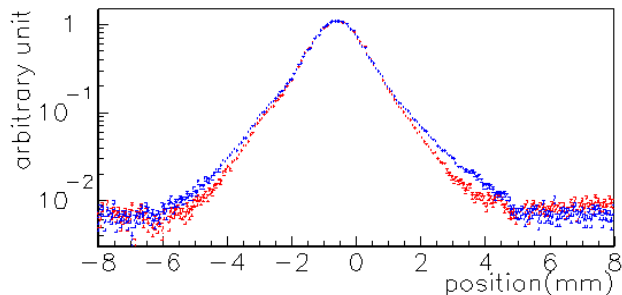


Figure 8: The difference of measured profiles between the bias voltages of 0 (red) and 20V (blue).

SUMMARY

We have developed wire scanners for J-PARC linac.in order to measure beam profile. 7μm-diameter carbon wire was selected for 3MeV beam and 30μm-diameter tungsten wire was selected for 181MeV for catching electrons in H⁻ beam. We performed beam test at MEBT1 where the beam energy is 3MeV and we have concluded that the proper bias is 20-60V.

REFERENCES

- [1] Y. Yamazaki (eds), “Accelerator Technical Design Report for J-PARC”,KEK-Report 2002-13; JAERI-Tech 2003-044
- [2] E. J. Sternglass, Phys. Rev. 108, 1 (1957)
- [3] J.E. Borovsky and D.M. Suszeysky, Phys. Rev. A43, 1416 (1991)
- [4] S. Lee *et al.*, “The Beam Diagnostics System in The J-PARC Linac”, Proc. of LINAC2004, TUP74.
- [5] Stopping-Power and Range Tables for Electrons, Protons, and Helium Ions, <http://physics.nist.gov/PhysRefData/Star/Text/contents.html>