DEVELOPMENT OF H^0 BEAM DIAGNOSTIC LINE IN MEBT2 OF J-PARC LINAC

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Abstract

In the Japan Proton Accelerator Research Complex (J-PARC), H^0 particles generated by collisions of accelerated H^- beams with residual gases are considered as one of the key factors of the residual radiation in the high energy accelerating section of the linac. To diagnose the H^0 particles, new beam line for analyzing H^0 and H^- particles was designed. The analysis line consists of four dipole magnets for giving the H^- beam chicane orbit, and a wire scanner monitor (WSM) for measuring the horizontal shift of the H^- beam. In the 2015 summer maintenance period, the new analysis line was installed in the second medium energy beam transport (MEBT2), which is the matching section from separated-type drift tube linac (SDTL) to annular-ring coupled structure linac (ACS). In the beam commissioning, we experimentally confirmed that the accelerated H^- beams are horizontally shifted in the analysis line as designed, and measured the H^0 signal obtained by the WSM plate as H^0 particles penetrating the plate.

INTRODUCTION

In J-PARC linac, H^0 particles generated by collisions of accelerated H^- beams with residual gases are considered as one of the key factors of the residual radiation in the ACS accelerating section [1]. Figure 1 shows the layout of the J-PARC linac accelerating structure. The H^- beam is accelerated to a beam energy of 190 MeV by the SDTL and to 400 MeV by the ACS. Although the lower energy beam has the larger cross section of the electron stripping in the residual gas scattering, the vacuum pressures in the SDTL section and the ACS section are around 10^{-6} Pa and 10^{-7} Pa, respectively. The beam loss at the ACS section was clearly related to the vacuum pressure of the SDTL sections [2].

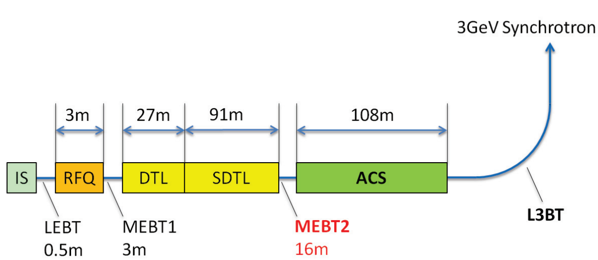

Figure 1: Layout of J-PARC linac accelerating structure.

To diagnose the H^0 particles generated in the SDTL section, we are developing a new diagnostic line in the upstream part of the MEBT2, which is the matching section from the SDTL to the ACS. We call this diagnostic line MEBT2 chicane. In the 2015 summer maintenance period, the new beam line for analyzing H^0 and H^- particles, which is the first stage of the MEBT2 chicane, was installed. In this paper, the configuration of the installed analysis line and the preliminary results of the beam analysis experiment are reported.

DEVELOPMENT OF MEBT2 CHICANE

In the new analysis line of the MEBT2, H^- and H^0 particles are analyzed by the shift bump magnets. The H^- beam is horizontally shifted by the first two dipole magnets (fig. 2) and returned to the original orbit (Z-axis) by the last two dipole magnets. It is noted that the horizontal displacement of $\Delta X \geq 20$mm of the accelerated H^- beam is required because the inner diameter of the beam duct is 37mm before the MEBT2 and is 40mm after the MEBT2. To confirm the horizontal shift of the H^- beam, a WSM and a non-destructive beam position monitor (BPM) are installed between the two sets of the dipole magnets. These components had to be installed within 3m long. The MEBT2 chicane installed in the 2015 summer maintenance period is shown in Fig. 3. The rectangular beam ducts with dimensions of $-50\text{mm} \leq X \leq 50\text{mm}$ and $-20\text{mm} \leq Y \leq 20\text{mm}$ are installed in these dipole magnets. The new beam line is evacuated by a turbo-molecular

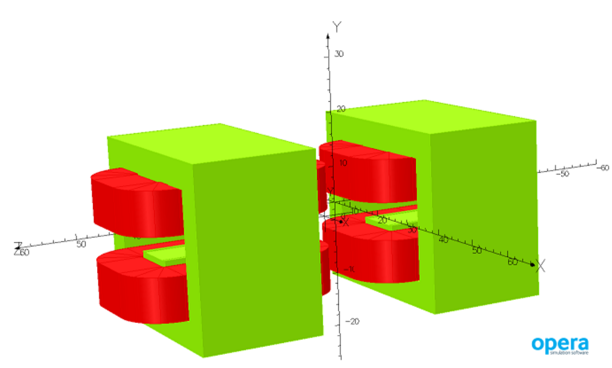

Figure 2: Designed dipole magnets for MEBT2 chicane.

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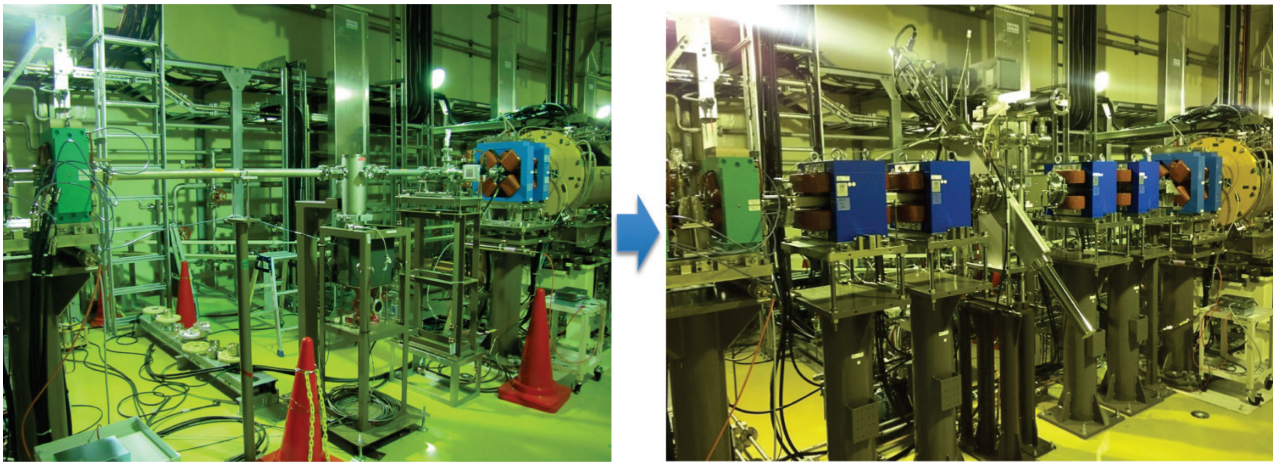

Figure 3: Picture of the upstream part of the MEBT2 beam line before (Left) and after (Right) the installation of the chicane components.

pump (300 L/s) and a NEG pump (SAES Getters, Capaci-Torr D1000) both installed to the WSM chamber. By using these pumps, the vacuum pressure of the beam line was kept around 10^{-6} Pa.

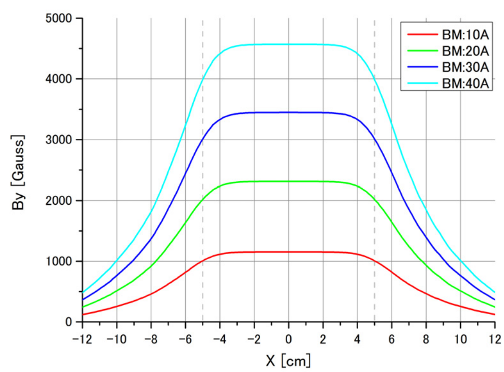

Figure 4: B_y along X-axis at the center of the magnet.

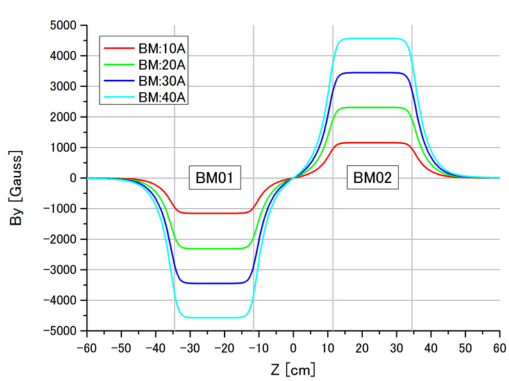

Figure 5: B_y along Z-axis. $Z = 0$ represents the center of the two magnets (BM01 and BM02, or BM03 and BM04).

DIPOLE MAGNETS FOR H$^-$ CHICANE ORBIT

Four dipole magnets are designed and manufactured for the MEBT2 chicane. These four magnets are structurally identical. These magnets are excited by independent power supplies with the same dc current but with the polarity of (BM01, BM02, BM03, BM04) = (+, -, -, +) or (-, +, +, -). The dimension of the iron core is $-50\text{mm} \leq X \leq 50\text{mm}$ with ΔZ of 230mm, and the gap length of the iron core is 53mm. Defining the coordinate of the center of the four dipole magnets as $(X, Y, Z) = (0, 0, 0)$, the center positions of each magnet are aligned as (X, Y, Z) = (0, 0, -1035), (0, 0, -575), (0, 0, 575), and (0, 0, 1035), in mm units. The vertical components of the magnetic flux density, B_y, along X-axis and Z-axis, which were calculated by using TOSCA of COBHAM Opera, are shown in fig. 4 and fig. 5, respectively. It is shown that B_y is flatly distributed within $-25\text{mm} < X < 25\text{mm}$.

WSM INSTALLED IN MEBT2 CHICANE

To observe the horizontal shift of the accelerated H$^-$ beam, WSM was installed between the two sets of the

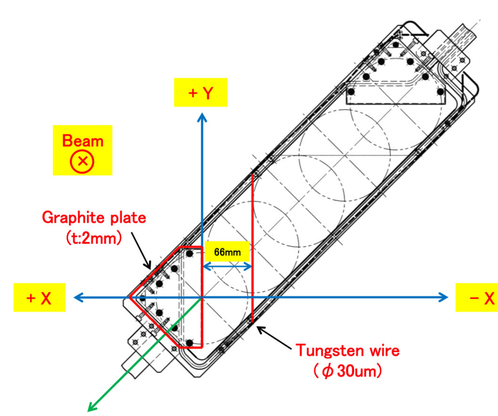

Figure 6: WSM sensor frame installed in MEBT2 chicane.

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dipole magnets (at $Z = 99$mm, while $Z = 0$ is the center of the four magnets). The configuration of the WSM sensor frame is shown in fig. 6. The tungsten wire with a diameter of $\phi 30\mu$m set vertically to the frame is scanned horizontally with the frame to measure the horizontal shift and the horizontal profile of the H^- beam. The graphite plate with a thickness of 2mm is also installed to the WSM frame. This plate is for detecting the H^0 signal when it is located at the Z-axis position where H^0 particles are distributed and expanding.

BEAM ANALYSIS EXPERIMENT

After the installation of the MEBT2 chicane to the beam line in the summer of 2015, we performed the beam analysis experiment. Figure 7 shows the horizontal shift of the H^- beam with a beam energy of 190 MeV measured by using the WSM. Negative signals are obtained by the electrons stripped from H^- beams due to collisions to the tungsten wire. The 190 MeV H^- beams are shifted to the horizontal direction about 7.5mm per 10 A of bending magnet current. It shows good agreement with the prediction of the trajectory calculation of the 190 MeV single proton obtained by the OPERA post-processor as shown in fig. 8.

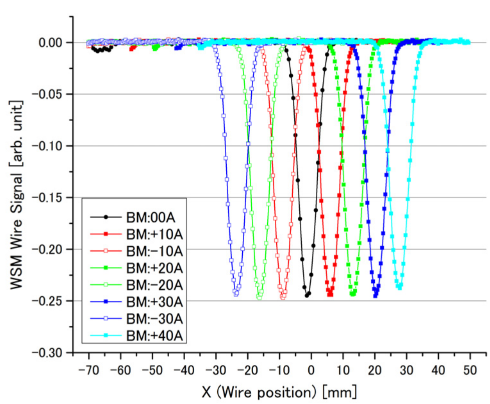

Figure 7: WSM wire signal changing the magnet current.

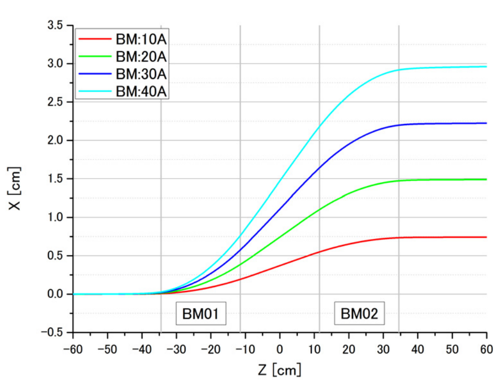

Figure 8: 190 MeV single proton trajectory shifted by the first two dipole magnets.

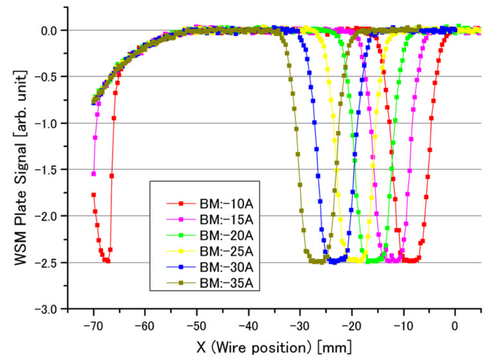

Figure 9: WSM plate signal changing the magnet current.

We also scanned the graphite plate set to the WSM frame. Figure 9 shows the WSM plate signal. When the H^- beams are hitting the WSM wire, secondary electrons from the wire reach the plate. These produce different peaks by changing the magnet current. When the plate is located around the Z-axis, $-70\text{mm} < X < -50\text{mm}$ of wire position, there are same signal slopes independent of magnet current. These are considered as signals from electrons stripped from H^0 particles penetrating the plate. Red signal (-10A of magnet current) and pink signal (-15A of magnet current) would be due to the beam halo of the accelerated H^- beams.

SUMMARY

To analyze the H^0 and the accelerated H^- particles, the bump magnet system was designed and manufactured. In the 2015 summer maintenance period, we installed the new analysis line which consists of the four dipole magnets and the WSM in MEBT2. In the beam commissioning, we experimentally confirmed that the accelerated 190 MeV H^- beams are horizontally shifted as designed. We also observed the H^0 signals obtained by the graphite plate. For the next stage of this diagnostic, we are proceeding to perform quantitative investigation of the H^0 particles.

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