DETECTION OF H^0 PARTICLES IN MEBT2 CHICANE 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, the new analysis line called MEBT2 chicane was installed in the matching section from the separated-type drift tube linac (SDTL) to the annular-ring coupled structure linac (ACS). By horizontally scanning a graphite plate installed in the MEBT2 chicane, we detected H^0 signals around the Z-axis when the H^0 particles are penetrating the plate. We also indirectly detected H^0 signals by using a scintillation detector. We observed that these signals depend on the vacuum condition in the latter part of the SDTL section. This means that we detected H^0 particles generated by the residual gas stripping.

INTRODUCTION

In the 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 a layout of the accelerating structure of the J-PARC linac. The H^- beam is accelerated to a beam energy of 190 MeV by the SDTL and to 400 MeV by the ACS. The vacuum pressures in the SDTL section and in the ACS section are around 10^{-6} Pa and 10^{-7} Pa, respectively, although the lower energy H^- beam has a larger cross section of the residual gas stripping [2]. Therefore, the beam loss at the ACS section is related to the vacuum pressure at the SDTL section [3].

To diagnose the H^0 particles generated in the SDTL section, we installed a new analysis 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.

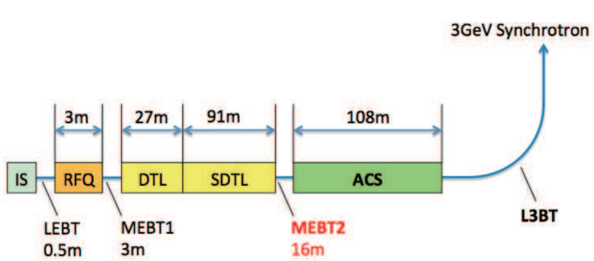

Figure 1: Layout of the J-PARC linac accelerating structure.

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And then, we experimentally confirmed that the 190 MeV H^- beams are horizontally displaced in the MEBT2 chicane as designed [4].

As the next step of the beam diagnostics in the MEBT2 chicane, we focused on the detection of the H^0 particles. In this paper, the preliminary results of the detection experiment using a graphite plate and a scintillation detector are reported.

SCHEME OF MEBT2 CHICANE

In the MEBT2 chicane, H^0 particles are analyzed by giving the H^- beam chicane orbit. Figure 2 shows a schematic view of the chicane. The H^- beam is horizontally displaced by the first two bending magnets (BMs) and returned to the original orbit (Z-axis) by the last BMs. These four BMs are structurally identical and the dimension of the each core is -50 mm $\leq X \leq$ 50 mm with ΔZ of 230 mm. Defining the coordinate of the center of the four BMs as (X, Z) = (0, 0), the center positions of each BM are aligned as (X, Z) = (0, -1035), (0, -575), (0, 575), and (0, 1035), in mm units. To measure the horizontal profile and the horizontal displacement of the H^- beam, a wire scanning monitor (WSM) was installed between the two sets of the BMs (at Z = 99 mm, while Z = 0 represents the center of the BMs). A beam position monitor (BPM) was also installed to check the displacement non-destructively [5].

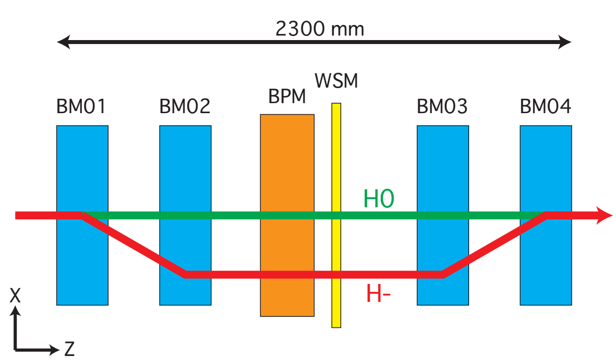

Figure 2: Schematic view of the MEBT2 chicane.

According to the following estimation, the amount of the H^0 particles generated by the Lorentz stripping in the MEBT2 chicane is negligibly small. When an H^- ion traverses in a magnetic flux density: B, the equivalent electric-field in the rest frame of the H^- ion is expressed as $E(B) = \gamma\beta c B$, where β and γ are the relativistic parameters, and c is the speed of light. Then the rest-frame life time of the H^- is given by

$$\tau(B) = \frac{A_1}{E(B)} \exp\left(\frac{A_2}{E(B)}\right) \quad (1)$$

where the constants A_1 and A_2 are determined as 2.47×10^{-6} V·s/m and 4.49×10^9 V/m, respectively [6]. The Lorentz stripping fraction f is derived as

$$f = 1 - \exp\left(-\frac{s}{\gamma\beta c\tau(B)}\right) \quad (2)$$

where s is a distance that the H^- ion traverses in a magnetic field. The electron stripping rate per meter is shown in Fig. 3. The BM current of 10 A produces about 0.11 T of the vertical component of the magnetic flux density (B_y).

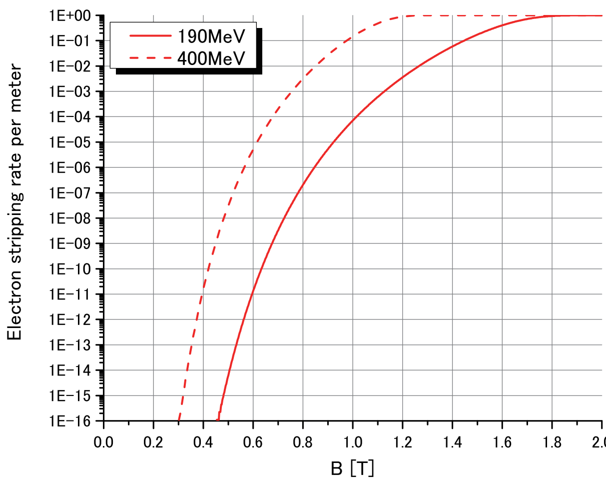

Figure 3: Electron stripping rate per meter by Lorentz stripping.

DETECTION OF H^- PARTICLES

To detect H^0 particles, we used a graphite plate installed to the WSM in the MEBT2 chicane. The configuration of the WSM sensor frame including the graphite plate with a thickness of 2 mm is shown in Fig. 4. The plate is penetrated by H^0 particles when it is located around the Z-axis position where H^0 particles are distributed and expanding. Also, the tungsten wires with a diameter of ϕ30 µm and with a diameter of ϕ200 µm are set vertically to the frame to measure the horizontal displacement and the horizontal profile of the H^- beam.

By scanning the graphite plate horizontally, we detected signals of H^0 particles. Figure 5 shows the signals obtained by using the plate with different BM currents. There are a signal slope around the Z-axis ($X < -15$ mm) and a signal peak per a scan. The former is independent of the BM current, whereas the position of the latter depends on the BM current. The intensity of these signals depend on a beam duty adjusted by an operation of the chopper cavity in MEBT1. The negative peak signals are caused by collisions of the 190 MeV H^- beams, which are horizontally displaced about 7.5 mm per 10 A of the BM current, with the ϕ30 µm wire 66 mm far from the plate edge. It is considered that the slope signals are produced from electrons stripped from H^0 particles penetrating the plate. By differentiating the slope signals by X, these will give horizontal profiles of the H^- particles.

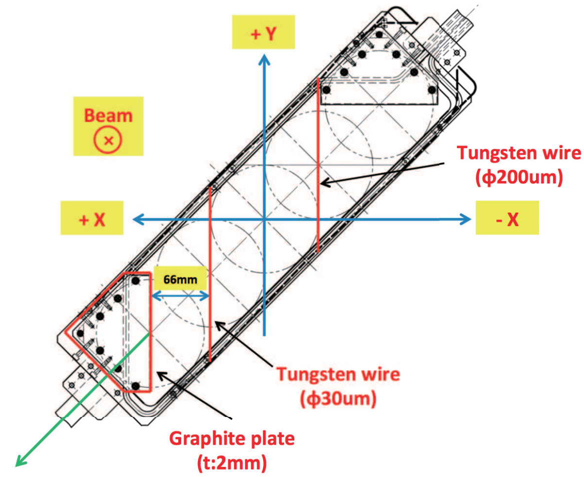

Figure 4: Graphite plate and tungsten wires installed to the WSM in the MEBT2 chicane.

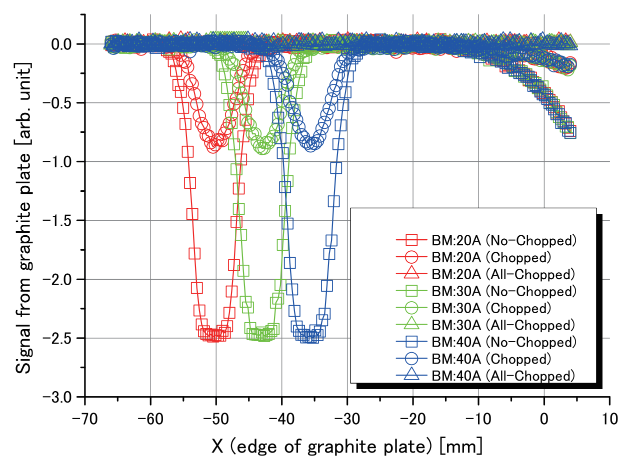

Figure 5: Signals obtained by scanning the graphite plate horizontally with different BM currents.

We observed that the slope signals obtained by the graphite plate were affected by the vacuum condition at the SDTL section. To investigate the dependence property on the residual gas pressure, the vacuum pressure at the latter part of the SDTL section were increased by turning off the ion pumps installed to the SDTL cavities from S08-S16. The vacuum pressure in the SDTL section and the plate signal with different vacuum conditions are shown in Fig. 6 and Fig. 7, respectively. The slope signal around the Z-axis is strongly affected by the vacuum pressure increase, whereas the signal peak caused by the 190 MeV H^- beam hitting the ϕ30 µm wire looks independent of the vacuum condition. This means that the enlargement of the slope signal

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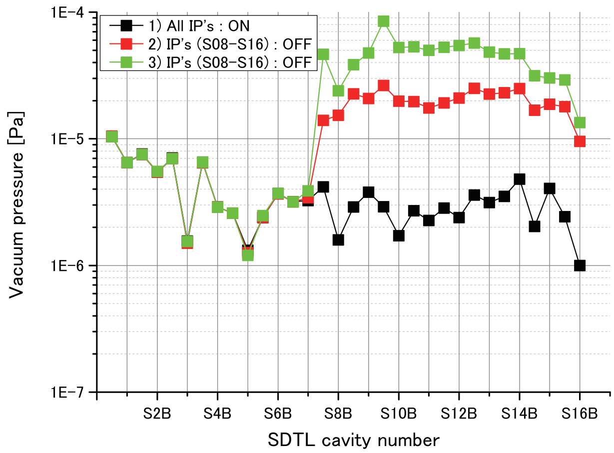

Figure 6: Vacuum pressure in the SDTL section (from S01 cavity to S16 cavity). 1): All ion pumps (S01-S16) are ON. 2): Ion pumps (S08-S16) were turned OFF. 3): Time passed from 2).

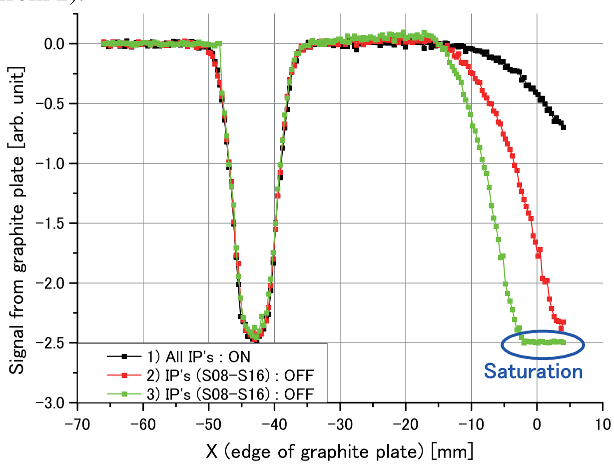

Figure 7: The WSM plate signal with different vacuum conditions at the SDTL section. The plot colors are corresponding to the Fig. 6.

represents the increase of the H^0 particles generated by the residual gas stripping.

We also indirectly detected the H^0 signals by using a scintillation detector. The scintillator detector was installed below the iron core of the BM03 at the downstream of the WSM. When the accelerated H^- beams travel in a chicane orbit and the $\phi 200$ µm wire is located at the H^0 position ($X \simeq 0$), the scintillator reacts with the secondary radiations generated by the collisions of H^0 particles with the wire. As shown in Fig. 8, we observed that the scintillator signal was amplified by increasing the vacuum pressure at the last part of the SDTL section. The vacuum pressure was increased by turning off the ion pumps installed to the SDTL cavities from S14-S16.

SUMMARY

To detect H^0 particles in the MEBT2 chicane, we used a graphite plate. By scanning the plate horizontally, we detected the H^0 signals around the Z-axis where the H^0

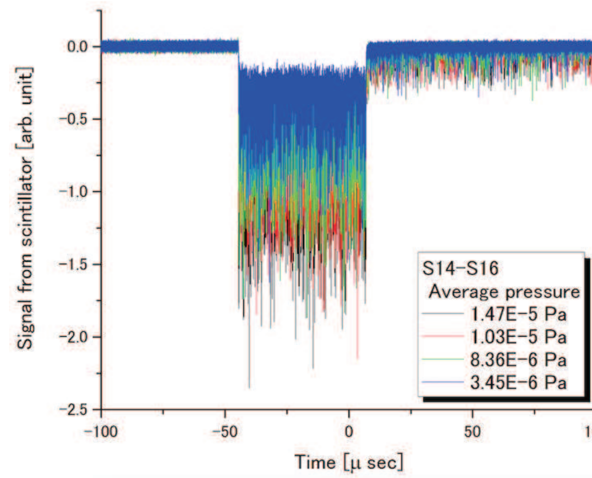

Figure 8: Scintillator signal, 16-times averaged by an oscilloscope, with a PMT voltage of -1.6 kV. The representative pressures are obtained by averaging the pressure at S14, 15, and S16.

particles are penetrating the plate. The slope of the signal was independent of the BM currents, and its intensity changes with a beam duty. The slope signal was enlarged by increasing the vacuum pressure at the latter part of the SDTL section. Also, a signal obtained by using a scintillator detector was enlarged by increasing the vacuum pressure at the last part of the SDTL section. These means that we detected H^0 particles generated by a residual gas stripping. For the next stage of this diagnostic, we are proceeding to perform a more detailed investigation of the H^0 particles.

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