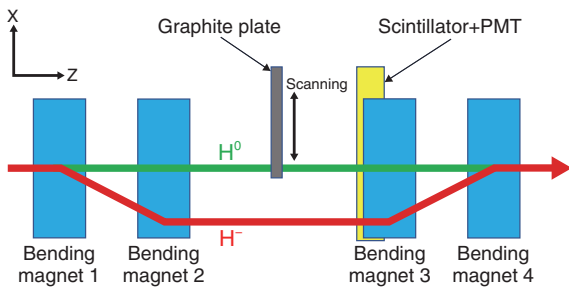
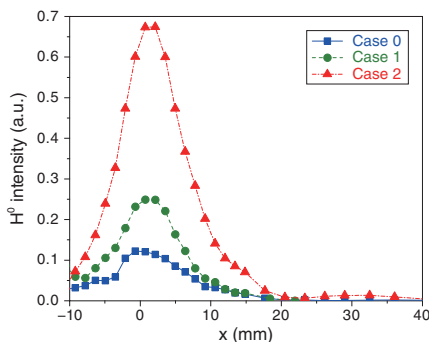


## 5-1 Beam Loss Assessment of High-Intensity Negative Hydrogen Ion Beams — Observation of Neutral Beams Generated by Residual Gas Electron Stripping —



**Fig.1 Diagnostic line for  $H^0$  particles in MEBT2**

$H^0$  particles and  $H^-$  beams are horizontally separated between bending magnets 2 and 3 by forming a chicane orbit of the  $H^-$  beam. A graphite plate is horizontally scanned in the central area where  $H^0$  particles are distributed, and the secondary radiations are detected using a scintillator and photomultiplier tube (PMT).



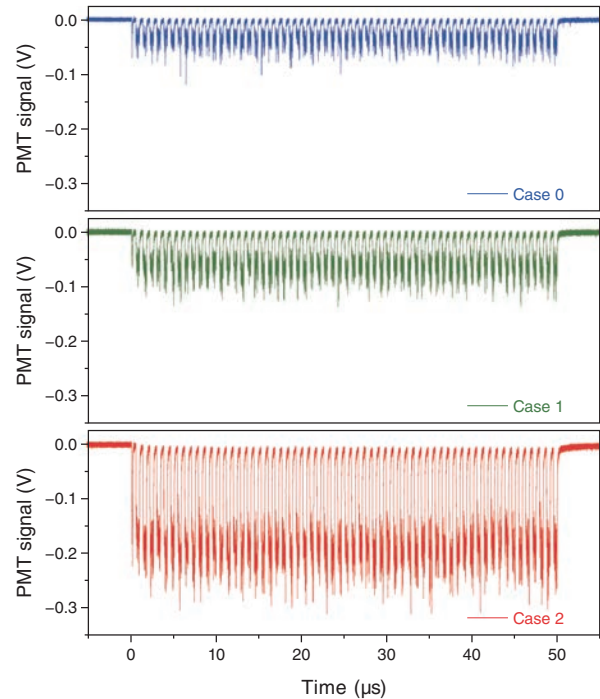
**Fig.3 Horizontal intensity distribution of the  $H^0$  particles in MEBT2**

The horizontal intensity distribution of the  $H^0$  particles are obtained by the time integration of the PMT signal at each position where the horizontal position of the graphite plate is scanned.

Beam loss accompanied by high-intensity beam acceleration, even if it is only a small fraction of the beam, can cause activation of the accelerator components. Therefore, beam loss is a critical issue in high-intensity accelerators from the viewpoint of reducing radiation exposure. In the J-PARC linac, high-intensity negative hydrogen ( $H^-$ ) beams are accelerated to 191 MeV by the separated drift tube linac (SDTL) and then to 400 MeV by the annular-ring coupled structure (ACS). The accelerated  $H^-$  ions can lose their electrons mainly due to the following factors:

- Residual gas stripping caused by the collisions of accelerated  $H^-$  ions with residual gases
  - Intra-beam stripping caused by collisions between  $H^-$  ions in the radiofrequency (RF) bunch
  - Field stripping caused by an external electric or magnetic field
- These electron-stripping phenomena, which generate uncontrollable neutral hydrogen ( $H^0$ ) particles, are characteristic beam loss factors of  $H^-$  linacs. Hence, it is imperative to perform a detailed stripping loss assessment for mitigation of beam loss, but a specific strategy has not yet been established.

To diagnose the  $H^0$  particles at the exit of the SDTL section, we developed a dedicated diagnostic line in the second medium



**Fig.2 Examples of detected PMT signals measured at different gas pressures**

The residual gas pressure in the downstream part of the SDTL section was increased by turning off the ion pumps. Case 0 represents the normal vacuum condition, and the residual gas pressure is increased in the order of Case 1 and Case 2.

energy beam transport (MEBT2) between the SDTL and ACS (Fig.1). In this diagnostic line,  $H^0$  particles are separated from the  $H^-$  beam, and the secondary radiations generated by  $H^0$  particles colliding with the graphite plate are detected using a scintillator and PMT. The beam loss due to residual gas stripping can be evaluated by measuring the relative intensities of the PMT signal. Examples of the detected PMT signals are shown in Fig.2, and the measured intensity profiles of the  $H^0$  particles are shown in Fig.3. The analysis revealed that approximately half of the  $H^0$  particles detected in MEBT2 under the normal vacuum condition were generated by residual gas stripping in the SDTL section. Loss estimation based on the cross-sections of the residual gas stripping and intra-beam stripping showed that the remaining  $H^0$  particles were likely generated mainly by intra-beam stripping. Moreover, for the ACS section, the residual gas pressure in the ACS cavities is an order of magnitude lower than that in the SDTL cavities; accordingly, the stripping loss is mainly attributed to intra-beam stripping.

In this study, we showed that further improvement of the residual pressure in the SDTL section is effective for mitigating beam loss in the J-PARC linac.

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### Reference

Tamura, J. et al., Measurement of  $H^0$  Particles Generated by Residual Gas Stripping in the Japan Proton Accelerator Research Complex Linac, Nuclear Instruments and Methods in Physics Research Section A, vol.1049, 2023, 168033, 7p.