Commissioning of the RI production line for the mass production of astatine-211 using SRILAC

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At RIKEN, research has been conducted to enable the large-scale production of astatine-211 (^{211}At) as a medical radioisotope.[1,2] Recently, a new ^{211}At production beamline, called the RI production line, was constructed downstream the superconducting linear accelerator (SRILAC)[3] to enhance production capacity. The RI production line was constructed near the GARIS-III beamline. The target system was designed to accommodate high-intensity He^{2+} beams exceeding 100 electric μA (eμA). For radiation safety, the beam is injected vertically down to the target. To ensure sufficient shielding between the target and floor, the beamline is structured to first direct the beam upward by 12.5°, and direct it vertically downward onto the target, as illustrated in Fig. 1.

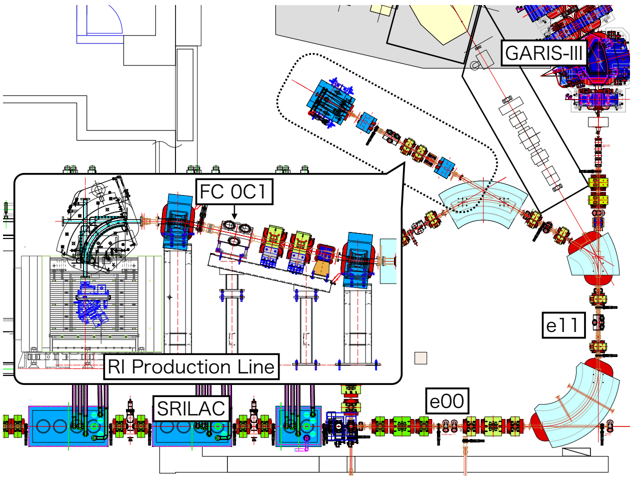

Fig. 1. Overview of the beamline from SRILAC to newly constructed RI production line for ^{211}At.

At the end of December 2024, a commissioning experiment was conducted to accelerate He^{2+} beams using SRILAC for the first time and transport them to the constructed beamline. He^{2+} beams were supplied by 28-GHz superconducting ECR ion source.[4] The 4 rms emittance of the beam was reduced to several tens of π mm·mrad, approximately 1/5 to 1/6 of its initial value, using slit triplet before RFQ to make the emittance comparable to the previously established $^{51}\mathrm{V}^{13+}$ beam values. Subsequently, the He^{2+} beam was accelerated to 3.78 MeV/nucleon using the RFQ and normal-conducting accelerating cavities of RILAC before being injected into SRILAC. Within SRILAC, the beam was further accelerated to the required 7.25 MeV/nucleon for ^{211}At production using 10 superconducting cavities. Typically, the acceleration phase for each cavity is set around $-25°$ to ensure longitudinal convergence; however, in this experiment, the first four cavities were set to $-20°$ to suppress the transverse envelope. The acceleration phase was precisely adjusted based on energy measurements using Beam Energy Profile Monitors,[5] and the accelerating voltage was tuned to achieve the target energy. The final adjustments were consistent with simulations within ±10° for the acceleration phase and within 5% for voltage. Measurements of the phase ellipses downstream SRLAC, called e00, indicate that both horizontal and vertical emittances were approximately 4 to 5 π mm·mrad (4 rms), which were consistent with those of $^{51}\mathrm{V}^{13+}$ beams. Finally, He^{2+} beams were transported to the Faraday cup (FC) in the RI production line, called FC-0C1. The ion optics was designed to have zero horizontal dispersion at the RI production line, and optics adjustments were performed to maximize beam current at FC-0C1 preserving this condition. As a result, approximately 100% transmission efficiency was achieved from the middle of the transport beamline, called e11, to FC-0C1. However, the maximum beam intensity was limited to approximately 170 electric nA (enA) since the beam was stopped at the FC without radiation shield. Phase ellipses were also analyzed just before FC-0C1, and the results were found to be consistent with those obtained at e00.

In conclusion, the commissioning of He^{2+} beam acceleration using SRILAC and transport to the recently constructed ^{211}At production beamline was performed successfully. Future efforts will focus on the development of the target system and conducting tests at higher beam intensities. This research was partially supported by research funds provided by F-REI (JPFR23040201 and 24040201).

References

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