Operation of Pelletron tandem accelerator

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The Pelletron tandem accelerator (5SDH-2) provides ion beams accelerated by up to 1.7 MV for sample irradiation, material analysis, and developments of detectors used in RIBF. This accelerator is registered as a joint-use equipment (ID: WE0429)[1] at the Wako campus and is managed by the Detector Team of RNC. Fig. 1 shows the configuration of the accelerator, four beam lines, and two ion sources. One ion source is the RF charge-exchange type, referred to as Alphatross and is used to generate He^- ions. The other is the Source of Negative Ions by Cesium Sputtering (SNICS), which can generate almost all other negative ions. Till date, ion species of H, He, B, C, O, and Au have been mainly accelerated in the range of 0.5–1.7 MV. For example, the energies of He^{2+} and $^{12}C^{6+}$ are 5.1 and 11.9 MeV, respectively, upon the application of 1.7 MV.

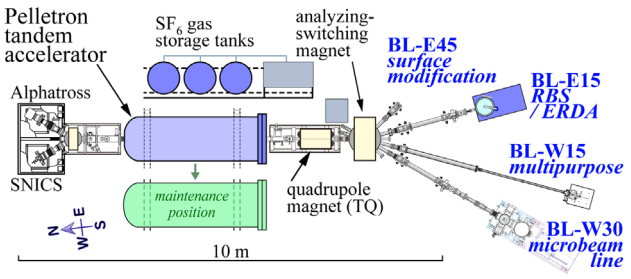

Fig. 1. Pelletron tandem accelerator and beam lines at Nishina R&D Building.

BL-E45 is dedicated to a sub-mm sized beam irradiation for samples in liquid.[2] BL-E15 is used by users in the field of material science to perform Rutherford backscattering (RBS) spectrometry analysis[3,4] and elastic recoil detection analysis (ERDA). The RBS/ERDA apparatus (Charles Evans and Associates Model RBS-400) comprises a goniometer to rotate a sample and particle detectors. Further, the detectors are located at backward and forward positions to measure the energies of backscattered (He^{2+}) ions and recoiled particles from the sample, respectively. The samples and the detectors are inside a vacuum chamber with a vacuum level of the order of 10^{-4} Pa. The intensity of the input He^{2+} beam of 2.28 MeV is greater than 10 nA according to the collimated beam size of 5–10 mm in diameter. On the west side, BL-W15 is employed as a multipurpose line for various equipment. Test systems have been constructed for profile measurements of ion microbeam produced by glass capillary[5] and microbeam irradiation to induce damage in DNA of mammalian cells.[6] The production of γ rays based on proton-induced resonance reactions is available for a cross-section measurement in an international summer school, Nishina School, and for calibration of Ge detectors using high energy γ rays up to 10.8 MeV. Although the 992-keV proton resonance in the reaction of $^{27}Al(p,\gamma)^{28}Si$.[7] BL-W30 was previously used for detector calibration;[8] however, since 2020, it has been dedicated to a new cell irradiation port equipped with a glass capillary microbeam generator[9–11] and an Olympus research microscope. This line has a unique feature to irradiate living cells in liquid medium with a short ion range (<100 μm) and a stopping power (>200 keV/μm), which is sufficiently high to induce double strand breaks of DNA in cell nucleus.

The total machine time (MT) from January 1 to December 31, 2022, was 27 days as presented in Table 1. The MT included a machine study (MS) on acceleration, whereas excluded the conditioning of the ion sources.

Table 1. Beam conditions.

Ion	Energy [MeV]	Beam current [particle nA]	Experiment	Operation time [days]
$^{1}H^{+}$	1.0–3.2	0.05–980	Irradiation	23
$^{4}He^{2+}$	2.28	5–58	RBS	3
$B^{1,2,3+}$	1.0–2.0	7	MS	1

The experiments performed in this facility are listed below, along with the beam lines and number of days of MT. The Nishina School in 2022 was postponed.

(1) Microbeam performance study with H ions using glass capillaries at BL-W15 and -W30 (9 days)
(2) RBS/ERDA experiments at BL-E15 (4 days)
(3) Educational experiment of proton capture by carbon/boron-nucleus for the Nishina School (0 days)
(4) Development of a charged-particle/γ-ray detector to be used for RIBF experiments including MS (14 days)

The fluctuation of the acceleration voltage of the Pelletron improved from 2 to 0.1% following the overhaul from February to March. The achieved stability was the best in the last decade and realized the beam position fluctuation of less than 1 mm (beam size is 10–20 mm) at the samples.

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