Radiation safety management at RIBF

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The results of radiation monitoring at RIBF, conducted at the border of the facility and the radiation-controlled area, are reported. The residual doses along the accelerator setups are also presented. In 2024, an ^{18}O beam approximately 250 MeV/nucleon was provided at an intensity of 500 particle nA on the BigRIPS target in April. Subsequently, a ^{70}Zn beam of about 345 MeV/nucleon of 700 particle nA used in May. A ^{124}Xe beam of the same energy of 150 particle nA was used in June and November. Furthermore, a ^{238}U beam of approximately 345 MeV/nucleon of 70 particle nA was used in November and December.

The dose rates at the boundary of the radiation-controlled area were monitored. Neutron and γ-ray monitors were used at three locations: roofs of the RRC, IRC, and BigRIPS. Figure 1 shows the annual neutron dose at these positions. Because the radiation shield at IRC roof was relatively thin, the dose rate was high before 2016. In 2017, an additional local-concrete shield of 1 m thick was set on a beamline in IRC room. The dose was successfully reduced. The dose at IRC roof is sensitive to IRC and SRC operation time. In 2023, these have not operated owing to a failure of SRC. Therefore, the annual dose of IRC and BigRIPS roof was zero.[1)] In 2024, the radiation dose was recorded because IRC and SRC resumed in April.

The dose rates at the site boundary with Wako city, where the legal limit is 1 mSv/y, were monitored using neutron and γ-ray monitors. The annual dose in 2024 was 17 μSv of neutron after the background correction. The annual dose of the γ-ray was not observed. Therefore, the radiation rate was considerably lower than the legal limit.

The residual radioactivity at the deflectors of the cyclotrons was measured just before the maintenance work. The residual dose depends on factors such as the beam intensity, accelerator operation time, and cooling time. The data were taken at the cyclotrons maintenance works, when the deflectors were accessible. Therefore, the cooling times have not been constant. The dose rates from 1986 are shown in Fig. 2. The dose rates for FRC, IRC, and SRC are shown for years after 2006, when the RIBF operation started. For AVF, the dose rate increased in 2006 because the radioisotope production was started, and the beam intensity increased. In 2024, dose rates except for IRC were measured. Dose rates for IRC were not measured because maintenance work was not performed in this year.

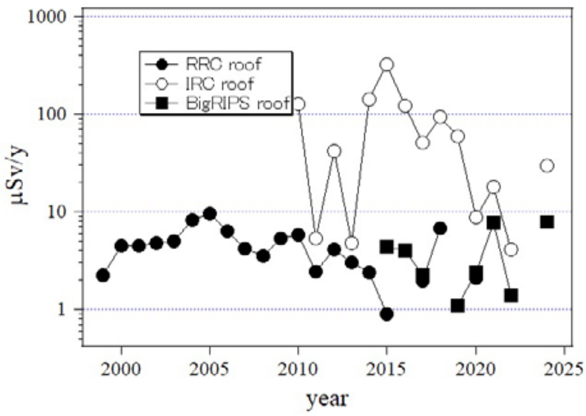

Fig. 1. Radiation dose at the boundary of the radiation-controlled area.

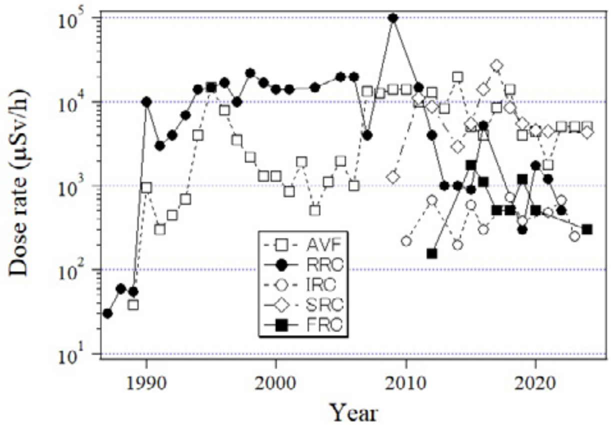

Fig. 2. Dose rates of residual radioactivity at the deflectors of 5 cyclotrons.

The residual radioactivity along the beam lines was measured after almost every experiment. Residual radioactivity reported in 2023 was after a year of cooling because SRC was not operated in the year owing to a failure. A beam was provided in April 2024. The measuring points are the same as the previous report[1)] measured in June 2023 were adopted. Therefore, radiation dose measured in August 2024 increased for several times compared with those in 2023. Figure 3 shows the locations of measurement points where high residual-doses rates more than 70 μSv/h in 2024 were observed. Table 1 lists the dose rates, beam conditions, and cooling time at the measurement points. The max-

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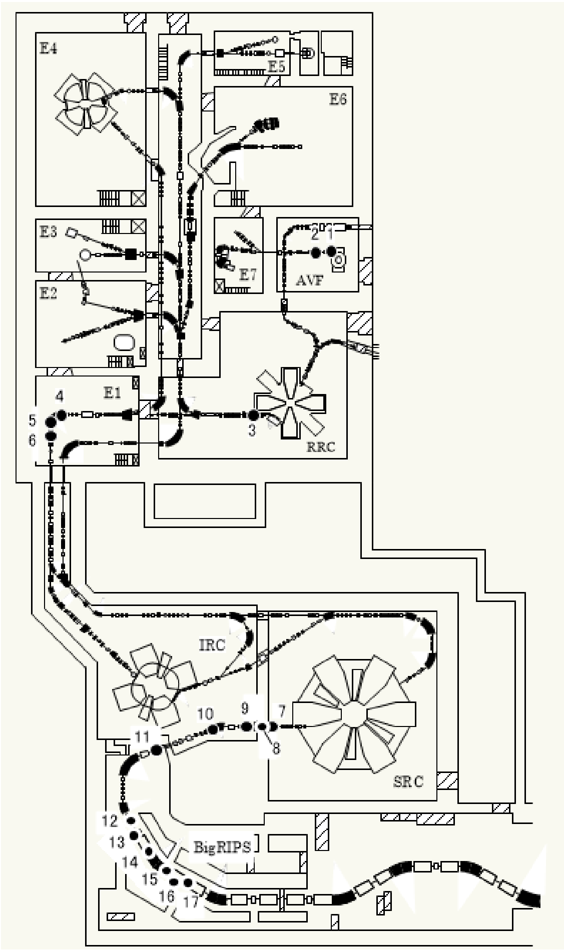

Fig. 3. Layout of the beam lines at RIBF. Themeasurement locations listed in Table 1 are indicated.

imum dose was 32 mSv/h at point 15, which is in the vicinity of the beam dump of BigRIPS. The second highest dose level at point 7 was around the faraday-cup downstream SRC. After the previous measurement in 2023, a beam of 345 MeV/nucleon ^{70}Zn and ^{124}Xe, whose maximum intensities were 500 and 150 particle μA, respectively.

The water radioactivity in the closed cooling system at BigRIPS was measured. It was not performed in 2023 because of the SRC failure. The results are shown in Table 2. A liquid scintillation counter (LSC-7400, Hitachi Co. Ltd.) was used for the low energy β ray of 18 keV from H-3 nuclide. A Ge detector (GC2019, Canbbera Co. Ltd.) was also used for γ rays emitted from other radionuclides. However, the radionuclides, except for H-3, were already filtered using an ion exchange resin set in the closed cooling systems. Although the overall value of contamination was less than the legal limit for drain water, as shown in Table 2, the water from the closed cooling system will be dumped into the drain tank before the next operation to prevent contamination in the room in case of a

Table 1. Dose rates measured at beam lines in 2024. Points 1–17 indicate the locations where measurements were taken as shown in Fig. 3.

Poi nt	Dose rate (µSv/h	Date (M/ D)	Particle	Energ y (Me u)	Intensity (pnA)	Decay Period (h)
1	500	8/7	α	7.3	43	29
2	160	8/7	α	7.3	43	29
3	150	8/7	Xe-136	8.6	0.5	28
4	800	8/7	Xe-124	50	38	268
5	150	8/7	Xe-124	50	38	268
6	130	8/7	Xe-124	50	38	268
7	2300	8/6	Xe-124	345	—	—
8	1000	8/6	Xe-124	345	818	9114
9	75	8/6	Xe-124	345	818	9114
10	500	8/6	Xe-124	345	818	9114
11	70	8/6	Xe-124	345	818	9115
12	930	8/6	Xe-124	345	818	9115
13	1500	8/6	Xe-124	345	818	9115
14	1740	8/6	Xe-124	345	818	9115
15	32000	8/6	Xe-124	345	818	9115
16	320	8/6	Xe-124	345	818	9115
17	460	8/6	Xe-124	345	818	9115

Table 2. Concentrations of radionuclide in the cooling water at BigRIPS, allowable legal limits for drain water, and ratios of concentration to the allowable limit.

Cooling water	Nuclide	Concentration[a] (Bq/cm^3)	Limit[b] (Bq/cm^3)	Ratio to limit [a/b]
BigRIPS F0 target	H-3	6.1	60	0.10
			summation	0.10
BigRIPS exit beam dump	H-3	28	60	0.46
	Be-7	3.3e-3[1)]	30	1.1e-4
	Mn-54	4,3e-3	1	4.3e-3
	Co-56	7.0e-4	0.3	2.3e-3
	Co-57	3.2e-3	4	8.1e-4
	Co-58	3.6e-3	1	3.6e-3
	Co-60	1.6e-3	0.2	7.8e-3
			summation	0.48
BigRIPS side-wall beam dump	H-3	43	60	0.72
	Be-7	9.1e-4	30	1.2e-4
	Mn-54	1.6e-4	1.0	1.1e-4
			summation	0.72

1) read as 4.3×10^{-3}

water leakage.

The entire air in the radiation-controlled area is exhausted through radiation exhaust vent with filter. Because of aging, there were high risks of radioactive air leakage from the two large airtight filter boxes in the Nishina building. One of the filter boxes is connected to the hot-lab experimental room where unsealed radioactive isotopes are operated. The hot lab filter box was renewed. Another filter box, which is applied for whole radiation-controlled area in the Nishina building except for the hot lab, was repaired by replacing parts and adding rust-proofing paint on the surface. The radiation monitoring system with outdated communication standards was also updated because the system could not be repaired if failure occurred.

The E-learning module, which can be accessed anytime and from anywhere (even from the outside RIKEN), has been used for the re-training to the radiation workers at RIBF. About 804 radiation workers completed the training in 2024.

Reference

1) K. Tanaka *et al.*, RIKEN Accel. Prog. Rep. **57**, 205 (2024).