Radiation safety management at RIBF

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The results of radiation monitoring at RIBF, carried out at the border of the facility and the radiation-controlled area are reported. The residual doses along the accelerator setups are also presented. In 2017, ^{238}U beam of about 345 MeV/u was provided at an intensity of 50 particle nA during May, June, October, and November. A ^{48}Ca beam of 500 particle nA was used in April, a ^{70}Zn beam of 300 particle nA was used in April and May, and a ^{18}O beam of 1000 particle nA was used in June and July.

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. In 2017, even the highest annual dose of 51 μSv/y at the IRC roof was lower than the legal limit of 5.2 mSv/y.

The dose rates at the site boundary, where the legal limit is 1 mSv/y, were monitored. Neutron and γ-ray monitors were used, and the annual dose in 2017 was found to be lower than the detection limit after the background correction. The detection limit of the neutron monitor is 2 μSv/y and that of the γ-ray monitor is 8 μSv/y. Therefore, it was inferred that the annual dose at the boundary was less than 10 μSv/y, which is 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 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.

The residual radioactivity along the beam lines was measured after almost every experiment. Figure 3 shows the locations of measurement points where high residual doses were observed. Table 1 lists the dose rates, beam conditions, and cooling time at the measurement points. The maximum dose was 29 mSv/h at point 14, which is in the vicinity of the G01 faraday cup.

The radioactivity in the closed cooling system at BigRIPS was measured. The water for the F0 target, the exit beam dump, and the sidewall dump were sampled in August. The water in the closed cooling systems was replaced in August 2016; therefore, the detected radioisotopes were generated during one year of operation in RIBF. The results are shown in Table 2. A liquid scintillation counter was used for the low energy β ray of 18 keV from H-3 nuclide. A Ge detector was also used for γ rays emitted from other radionuclides. The radionuclides, except for H-3, were already filtered by an ion exchange resin 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 water leakage.

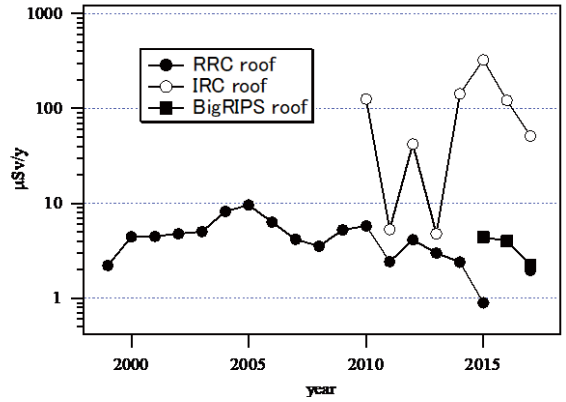

Fig. 1. Radiation dose at the boundary of the radiation-controlled area.

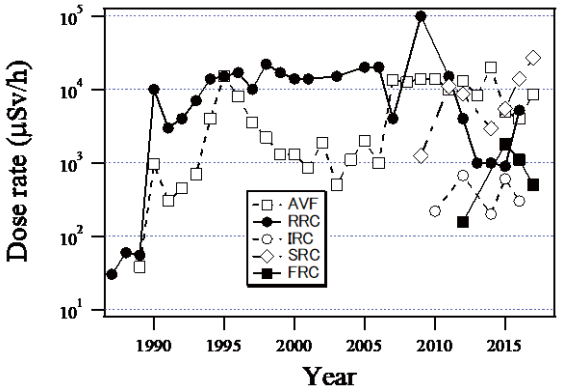

Fig. 2. Dose rates of residual radioactivity at the deflectors of 5 cyclotrons.

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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 660 radiation workers have completed the training in 2017.

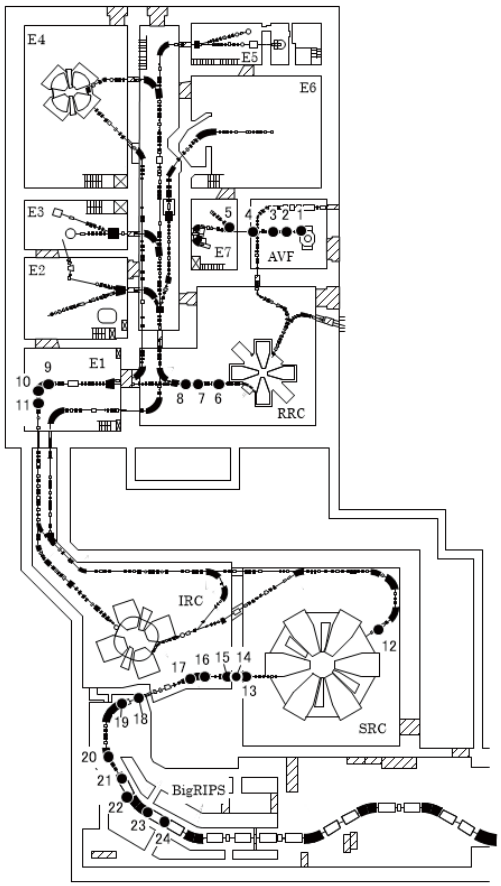

Fig. 3. Layout of the beam lines at RIBF. The measurement locations listed in Table 1 are indicated.

Table 1. Dose rates measured at beam lines in 2017. Points 1–24 indicate the locations where measurements were taken as shown in Fig. 3.

Point	Dose rate (μSv/h)	Date (M/D)	Particle	Energy (MeV/u)	Intensity (pnA)	Cooling time (h)
1	1000	8/4	d	12	10000	97
2	450	8/4	d	12	10000	97
3	500	8/4	d	12	10000	97
4	500	8/4	d	12	10000	97
5	280	12/12	α	6.5	10	291
6	800	8/4	C-12	135	1	186
7	400	8/4	C-12	135	1	186
8	200	12/12	U-238	10.75	1657	283
9	4000	12/12	U-238	50	390	282
10	3000	12/12	U-238	50	390	282
11	400	12/12	U-238	50	390	282
12	170	8/4	O-18	220	550	497
13	8600	8/4	O-18	220	550	497
14	29000	12/8	U-238	345	71	183
15	950	12/8	U-238	345	71	183
16	250	12/8	U-238	345	71	183
17	950	8/4	O-18	220	550	496
18	450	12/8	U-238	345	71	183
19	830	12/8	U-238	345	71	183
20	450	8/8	O-18	220	550	589
21	1780	8/8	O-18	220	550	589
22	1850	8/8	O-18	220	550	589
23	25000	12/8	U-238	345	71	183
24	189	8/8	O-18	220	550	589

Table 2. Concentrations of radionuclide in the cooling water at BigRIPS, the allowable legal limits for drain water, and the 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.	60	0.11
			summation	0.11
BigRIPS exit beam dump	H-3	22.	60	0.37
	Be-7	9.4e-3[1)]	30	3.1e-4
	Co-57	8.1e-4	4	2.0e-4
	Co-58	6.4e-4	1	6.4e-4
	Mn-54	1.4e-3	1	1.4e-3
			summation	0.37
BigRIPS side-wall beam dump	H-3	47.	60	0.79
			summation	0.79

1) read as 9.4× 10^{-3}