Radiation safety management at RIBF

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In this paper, the results of radiation monitoring at RIBF, conducted at the border of the facility and the radiation-controlled area are reported. In addition, the residual doses along the accelerator setups are presented. In 2018, a ^{238}U beam of approximately 345 MeV/nucleon was provided at an intensity of 70 particle nA during October to December. A ^{18}O beam of approximately 230 MeV/nucleon of 700 particle nA was used in May and June.

The dose rates at the boundary of the radiation-controlled area were monitored. Neutron and γ-ray monitors were used at three locations: the roofs of the RRC, IRC, and BigRIPS. Figure 1 shows the annual neutron dose at these positions. In 2018, 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 2018 was found to be lower than the detection limit after 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 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 started its operation. For AVF, the dose rate increased in 2006 because the radioisotope production was started in that year and thus, the beam intensity increased.

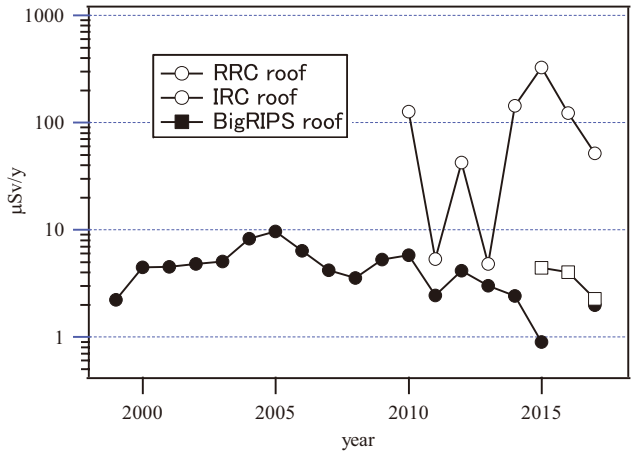

Fig. 1. Radiation dose at the boundary of radiation-controlled area.

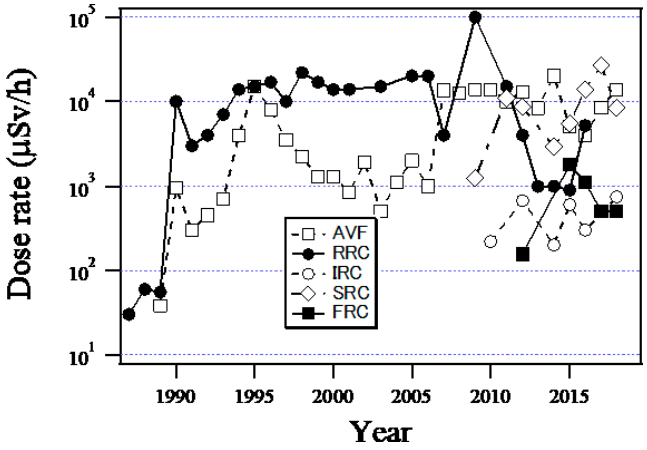

Fig. 2. Dose rates of residual radioactivity at the deflectors of five cyclotrons.

The residual radioactivity along the beam lines was measured after 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 17.8 mSv/h at point 19, which is in the vicinity of beam dump of BigRIPS.

The radioactivity in the closed cooling system at BigRIPS was measured. The water for the F0 target, exit beam dump, and side-wall dump were sampled in June. The water in the closed cooling systems for the F0 target and exit beam dump was replaced in May 2018. Therefore, the detected radioisotopes in the F0 target and exit beam dump were generated during one month of operation in RIBF. For the side-wall beam dump, part of the water was replaced in January 2018, but all the water was replaced in March 2015; the results are presented 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 the γ rays emitted from other radionuclides. The radionuclides, except H-3, were already filtered by an ion exchange resin in the closed cooling systems.

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Although the overall value of contamination was less than the legal limit for drain water, as presented 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.

The e-learning module, which can be accessed anytime from anywhere (even from outside RIKEN), has been used to the re-train the radiation workers at RIBF. Approximately 630 radiation workers have completed the training in 2018.

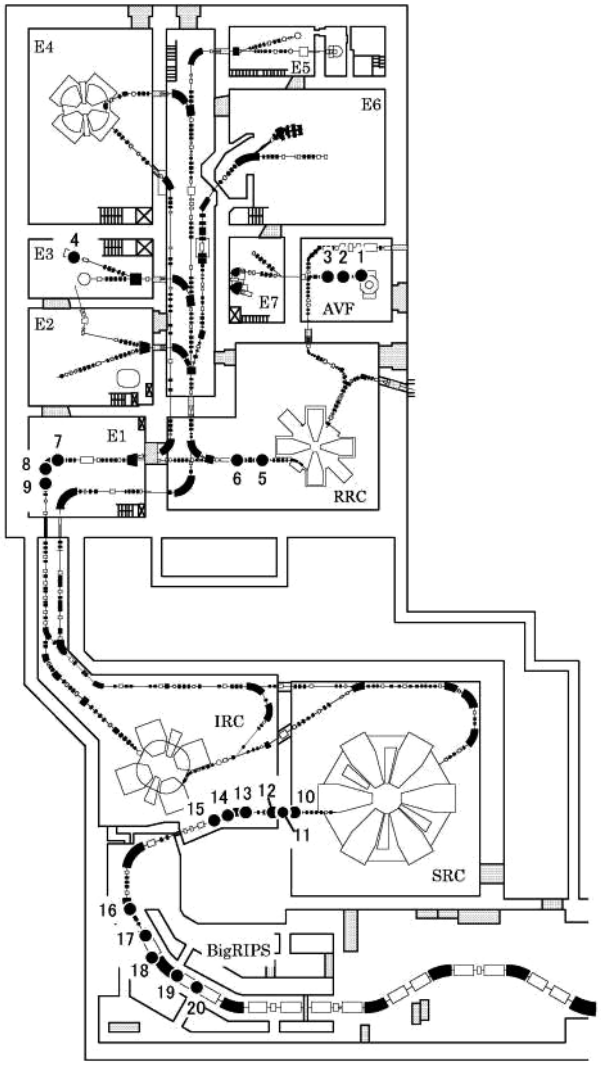

Fig. 3. Layout of the beam lines at RIBF. The measurement locations listed in Table 1 are indicated.

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	200	8/24	Ar-40	5.2	40	573
2	400	8/24	Ar-40	5.2	40	573
3	170	8/24	Ar-40	5.2	40	573
4	1000	10/10	N-14	135	357	120
5	250	8/24	Ar-40	95	1	571
6	150	8/24	Ar-40	95	1	571
7	5500	12/17	U-238	50	342	159
8	1800	12/17	U-238	50	342	159
9	700	12/17	U-238	50	342	159
10	100	12/20	U-238	345	72	231
11	9600	12/20	U-238	345	72	231
12	140	12/20	U-238	345	72	231
13	350	12/20	U-238	345	72	231
14	1600	7/25	Ar-40	160	1	983
15	400	7/25	Ar-40	160	1	983
16	200	7/25	O-18	230	600	1133
17	1430	12/20	U-238	345	72	231
18	3450	12/20	U-238	345	72	231
19	17800	12/20	U-238	345	72	231
20	241	12/20	U-238	345	72	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	H-3	3.4	60	5.8e-2
F0 target			summation	5.8e-2
BigRIPS	H-3	3.8	60	6.4e-2
exit	Mn-54	1.3e-3[1)]	1	1.3e-3
beam			summation	6.4e-2
dump				
BigRIPS	H-3	53.	60	0.89
side-wall	Be-7	8.6e-2	30	2.9e-3
beam	Mn-54	1.2e-3	1	1.2e-3
dump			summation	0.89

1) read as 1.3×10^{-3}