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 2015, on an average, a 345 MeV/u ^{238}U beam was provided at an intensity of 30 particle nA intensity in April, May, October, and November. A ^{78}Kr beam of 300 particle nA was used in May and June, and a ^{48}Ca beam of 400 particle nA in November and December.

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 2015 was found to be smaller 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 dose rates at the boundary of the radiation-controlled area were also monitored. The 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 the RRC and IRC roofs since 1999. The dose in 2015 at the BigRIPS roof is newly plotted because it had been lower than the detection limit of 3 μSv/y before. Even the highest annual dose of 325 μSv/y at the IRC roof is lower than the legal limit of 5.2 mSv/y.

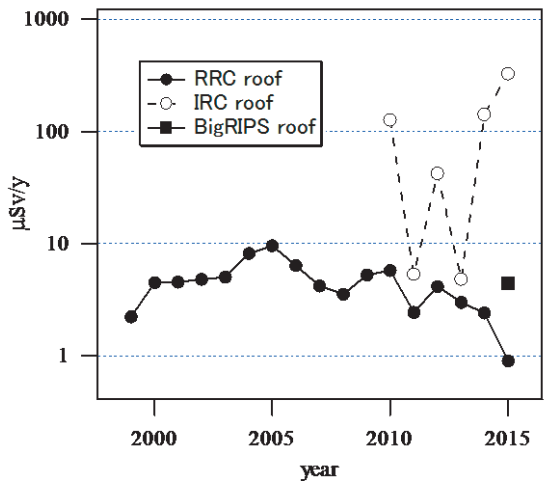

Fig.1 Radiation dose at the boundary of the radiation-controlled area.

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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 after the 2015 operation of RIBF. The results are shown in Table 1. 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 water in the closed cooling systems was replaced in December 2014, therefore it can be said that the detected radioisotopes were generated during 2015. 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 1, 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.

Table 1. 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	7.2	60	0.12
	Be-7	1.1e-2	30	3.3e-3[1)]
			summation	0.12
BigRIPS exit beam dump	H-3	14	60	0.23
	Be-7	1.8e-2	30	6.0e-4
	Co-56	5.7e-4	0.3	1.9e-3
	Co-57	9.6e-4	4	2.4e-4
	Co-58	2.1e-3	1	2.1e-3
	Mn-54	5.2e-3	1	5.2e-3
			summation	0.24
BigRIPS side-wall beam dump	H-3	7.3	60	0.12
	Be-7	1.6e-2	30	5.4e-4
	Mn-54	2.8e-3	1	2.8e-3
			summation	0.12

1) read as 3.3×10^{-3}

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 after the year 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.

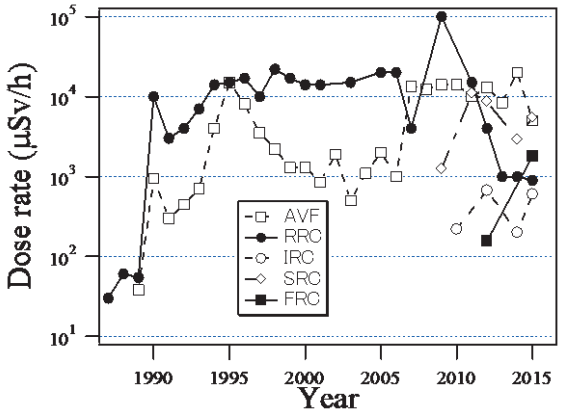

Fig. 2. Dose rates of residual radioactivity at the deflectors of 5 cyclotrons.

Table 2. Dose rates measured at beam lines in 2015. Points 1−26 indicate the locations where measurements were taken as shown in Fig. 3. At point 24-27, the secondary radioactive-isotope beams (RI) were provided whose intensities are limited to 10^7 particle per second.

Point	Dose rate (μSv/h)	Date (M/D)	Particle	Energy (MeV/u)	Intensity (pnA)	Cooling time (h)
1	120	11/18	α	7.25	2750	7
2	85	6/29	Kr-78	10.75	860	158
3	200	7/27	C-12	70	10	165
4	60	6/29	Kr-78	50	530	158
5	1200	12/9	Ca-48	45	715	113
6	1200	12/9	Ca-48	45	715	113
7	80	12/9	Ca-48	45	715	113
8	120	6/29	Kr-78	45	341	159
9	200	12/9	Ca-48	114	650	114
10	130	12/9	Ca-48	114	650	114
11	12000	12/9	Ca-48	345	650	114
12	34000	12/9	Ca-48	345	650	114
13	1100	6/29	Kr-78	345	341	159
14	1600	6/29	Kr-78	345	341	159
15	7000	6/29	Kr-78	345	341	159
16	500	6/29	Kr-78	345	341	159
17	120	6/29	Kr-78	345	341	159
18	180	12/9	Ca-48	345	650	114
19	80	12/9	Ca-48	345	650	114
20	400	12/9	Ca-48	345	650	114
21	32000	12/9	Ca-48	345	650	114
22	5000	12/9	Ca-48	345	650	114
23	23000	12/9	Ca-48	345	650	114
24	400	12/9	RI	<345		114
25	110	12/9	RI	<345		114
26	150	12/9	RI	<345		114
27	500	12/9	RI	<345		114

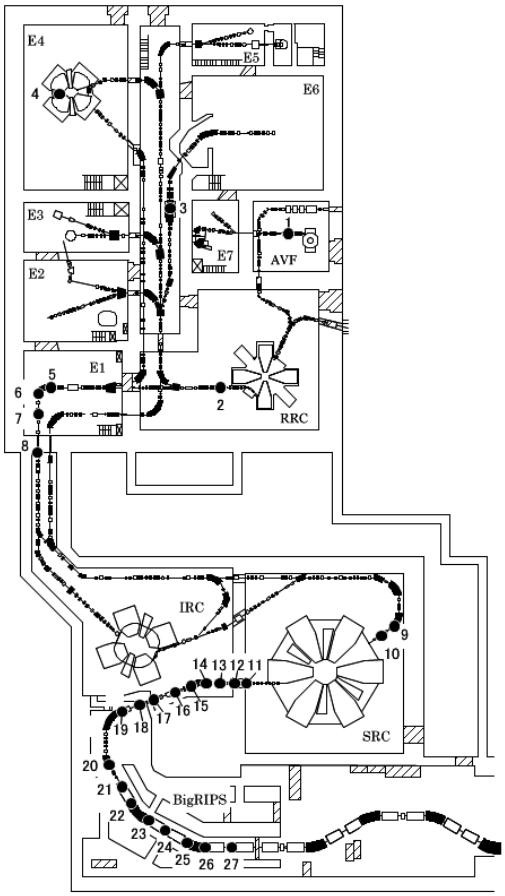

Fig.3. Layout of the beam lines at RIBF. The measurement locations listed in Table 2 are indicated.

The residual radioactivity along the beam lines was measured after almost every experiment. Figure 3 shows locations of measurement points where high residual doses were observed. Table 2 lists the dose rates, beam conditions, and cooling time at the measurement points. The maximum dose was 34 mSv/h at point 12, which is in the vicinity of the G01 faraday cup.

The E-learning module, which can be accessed anytime and from anywhere, even from the outside RIKEN, was newly designed and used for the re-training to the radiation workers at RIBF. About 700 radiation workers have completed the training in 2015.