Operation report on the ring-cyclotrons in the RIBF accelerator complex

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In this report, the operation of the ring-cyclotrons in the RIBF accelerator complex from January to December 2015 is presented. Table 1 summarizes the accelerated beams in these cyclotrons. The availability is defined by the ratio of the actual beam time to the scheduled beam time, which is an index of the reliability of beam supply. The delivered beam time in 2015 was 3173.1 h. The ratio of experiments that used the beam extracted from the SRC and the other accelerators was 75% (2388.6 h) and 25%.

The ^{238}U beam was supplied for three periods as follows:

1) Mar. 25th to Apr. 17th for five experiments
2) Apr. 27th to May 8th for two experiments
3) Oct. 19th to Nov. 14th for eight experiments.

A maximum beam intensity of 48.8 particle nA was achieved owing to several factors, such as the increase of the beam current in the ion source, conversion of the injection buncher from the mesh type to cavity type, adoption of a new carbon material for the rotating charge stripper,[1)] improvement of the transmission efficiency in the cyclotrons, and improvement of the vacuum in the RRC.

The polarized deuteron beam was supplied from May 11th to 16th. Although the energy (190 MeV/u) was lower than the certified energy according to the design of SRC (250 MeV/u for M/q = 2 ions), a single-turn extraction was achieved at the acceleration test before the experiment.

The ^{78}Kr beam was supplied in six experiments with a maximum intensity of 310 particle nA, in the RILAC2-RRC-fRC-IRC-SRC mode for the first time (May 23rd to Jun. 22nd). The high-intensity beam production test was performed using an exit beam dump in the BigRIPS, and a beam power of 13.1 kW (486 particle nA) was obtained, which was the power record in the RIBF.

The ^{48}Ca beam was supplied in four experiments (Nov. 17th to Dec. 4th). The maximum intensity reached 689 particle nA owing to the improvement in the ion source and transmission efficiency by the refinement of the rotating charge stripper.

For the machine study, a test to transport the beam extracted from the IRC to E5B was performed. The ^{40}Ar beam was successfully accelerated up to 160 MeV/u in the AVF-RRC-IRC mode and transported to the E5B. In addition, ^{4}He was accelerated in the RILAC2-RRC mode for the first time to be extracted from the RRC. The beam current shown in the table is the converted value to a duty of 100% (the measured current was 0.86 particle μA with a duty of 0.9%).

For the experiments that used a beam extracted from the RRC, ^{48}Ca and ^{12}C (RIPS), ^{84}Kr for industrial use (E5A), ^{86}Kr for the JAXA group (E3A), and ^{136}Xe for the KEK/KISS group (E2A) were supplied. In addition, biological experiments (E5B) were conducted as usual.

Table 1. Summary of the accelerated beams in 2015

Beam particle	Energy (MeV/u)	Acceleration mode	Beam course	Beam current (particle nA)		Beam time (h)		Down time (h)	Availability (%)
				Requested	Actual	Scheduled	Actual		
^{12}C	70	AVF-RRC	E6 (RIPS)	400.0	583.3	108.0	115.8	0.4	106.9
^{12}C	135		E5B (Biology)	1.0	583.3	38.0	38.0	0.0	100.0
^{40}Ar	95		E5B (Biology)/E5A (MS)	1.0	76.5	70.0	70.0	0.0	100.0
^{56}Fe	90		E5B (Biology)	1.0	6.3	22.0	22.0	0.0	100.0
^{84}Kr	70		E5A (Industry)	0.1	5.6	72.0	72.0	0.0	100.0
^{86}Kr	36	RILAC-RRC	E3A (JAXA)	1.0	8.8	12.0	12.0	0.0	100.0
^{48}Ca	63		E6 (RIPS)	300.0	417.6	216.0	212.8	3.3	97.0
^{4}He	7.3	RILAC2-RRC	A02 (MS)	N/A	95000.0	24.0	24.0	0.0	100.0
^{136}Xe	10.75		E2B (KEK/KISS)	50.0	750.0	96.0	95.9	0.3	99.6
^{238}U	10.75		A01 (MS)/A11 (MS)/E5A (Material)	2.0	2500.0	72.0	72.0	0.0	100.0
^{40}Ar	160	AVF-RRC-IRC	E5B (MS/Biology)	N/A	30.0	54.0	54.0	0.0	100.0
pol. *d*	190	AVF-RRC-SRC	BigD-pol	10.0	290.0	96.0	123.9	22.5	105.6
^{48}Ca	345	RILAC-RRC-IRC-SRC	BigRIPS/SAMURAI/ZDS	400.0	689.0	396.0	396.0	19.5	95.1
^{78}Kr	345	RILAC2-RRC-fRC-IRC-SRC	BigRIPS/ZDS/EURICA/Rare-RI Ring	30.0	486.1	732.0	732.0	72.2	90.1
^{238}U (1st)	345		BigRIPS/ZDS	15.0	31.4	552.0	553.0	47.9	91.5
^{238}U (2nd)	345		BigRIPS/ZDS	20.0	39.5	228.0	252.0	25.3	99.5
^{238}U (3rd)	345		BigRIPS/SAMURAI/ZDS	15.0	48.8	588.0	605.7	86.6	88.3

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Reference

1) H. Hasebe et al.: in this report.