

Operation report on the ring cyclotrons in the RIBF accelerator complex

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The operation report of the ring cyclotrons in the RIBF accelerator complex from Jan. to Dec. 2020 is presented. Table 1 presents a summary of the beams accelerated by these cyclotrons. The availability is defined as the ratio of the actual beam service time to the scheduled beam service time, which is an index of the stable Operation of accelerators. In calculating each availability, for beam service times that were completed earlier than scheduled, the scheduled times are identified with the actual times. Multiple experiments supplying identical beams are treated as one and presented in a row. The total actual beam service time was 1639.1 h. The ratio of the beam service times between the experiments conducted in the old facility (RARF) and the new facility (RIBF) was 54:46.

In the RARF, the actual beam service time was 884.5 h, and the availability was 95.7%. In the RIBF, two beam services were carried out. The actual beam service time was 754.6 h, and the availability was 89.8%. Due to the declaration of a state of emergency in relation to the COVID-19 infection, experiments were cancelled for two months from April. Vacuum leak occurred at the RRC resonator No.1 in May, and weld repair was carried out. Due to the repair, all the beam service times scheduled in June were cancelled.

In the ²³⁸U beam supply for eight experiments, we achieved a maximum beam intensity of 116 particle nA, which is 1.2 times higher than that of the previous beam

service in Nov. 2019. The highest record was obtained due to the upgrade of the RRC resonators^{1,2)} and the change in gap spacing of the RRC-EDC in 2018, and the relocation of the fRC-EIC in 2020. The beam supply was stopped for 8 days due to the repair of the SRC-EDC and SRC-Resonator 2 (RES2). A septum electrode of the EDC was damaged by a loss of the high intensity beams. After the exchange of the EDC, a beam intensity was reduced to 70 particle nA to prevent EDC damage again. RES2 could not be excited because the contact fingers for the coarse tuning plate was partially burned out by a high RF input power. The damaged contact fingers were exchanged. The beam service time was 510.5 h, and the availability was 81.8%.

In the ⁷⁰Zn beam supply for three experiments, we recorded the highest beam intensity of 782 particle nA, which is 3.1 times higher than that of the previous beam service in May 2017. The increase of beam intensity was achieved due to the improvement of the oven in the ion source and of the beam tuning based on the beam supply parameters obtained by a scaling of that for ²³⁸U. The beam service time was 244.2 h, and the availability was 113.1% because the tuning time was shorter than planned and the experiment was started ahead of schedule.

References

- 1) K. Yamada *et al.*, RIKEN Accel. Prog. Rep. **52**, 13 (2019).
- 2) K. Yamada *et al.*, J. Part. Accel. Soc. Jpn. **17**, 159 (2020).

Table 1. Summary of the accelerated beams in 2020.

	Beam particle	Energy (MeV/nucleon)	Acceleration mode	Beam course	Beam intensity (particle nA)		Beam service time (h)		Availability (%)
					Requested	Actual	Scheduled	Actual	
RARF	¹² C	135	AVF-RRC	E5B (Biology)	1	450.0	27.5	9.2	100.0
	¹⁴ N	135		E3B (RI production)	500	571.0	48.0	49.5	103.2
	²⁰ Ne	135		ESB (Biology)	1	270.0	4.0	2.6	100.0
	²² Ne	70		E6 (Material)	250	300.0	108.0	107.9	99.9
	⁴⁰ Ar	95		E5A (Material)	1	26.5	84.0	86.1	102.5
	⁵⁶ Fe	90		ESB (Biology)	1	3.5	6.0	2.1	100.0
	⁸⁴ Kr	70		E5A (Material)	1	9.7	240.0	205.8	85.6
	⁴ He	7.25		RILAC2-RRC	A10 (MS)	18300	590.0	33.6	33.6
¹³⁶ Xe	10.75	E2B (KEK/KISS) /E3A (Material)	250		325.0	381.0	371.5	97.5	
RIBF	⁴⁰ Ar	160	AVF-RRC-IRC	E5B (Biology)	1	23.3	23.5	16.2	100.0
	⁷⁰ Zn	345	RILAC2-RRC	BigRIPS/ZD	>600	782.0	216.0	244.2	113.1
	²³⁸ U	345	-fRC-IRC-SRC	BigRIPS/ZD /Rare-RI Ring	>60	116.3	624.0	510.5	81.8
Total							1795.6	1639.1	92.9

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