

Operation report of 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. 2019 is presented here. Table 1 presents a summary of the beams accelerated by these cyclotrons. The availability in the table is defined by the ratio of the actual beam time to the scheduled beam time, which is an index of the stable operation of accelerators. In calculating each availability, for beam times that were completed earlier than scheduled, the scheduled times are identified with the actual times. Multiple experiments supplying identical beams are shown as a block.

The total beam supply time (actual beam time) was 1581.8 h. The ratio of beam times between the experiments conducted in the old facility (RARF) and those conducted in the new facility (RIBF) was 8% and 92%.

In the RARF, the actual beam time was 128.0 h, and the availability was 105.6%. Beams were stably supplied as usual. In addition to the beams listed in Table 1, experiments for synthesizing the 119th element using a ⁵¹V beam were conducted as a closed beam time under the Nishina Center Director.

In the RIBF, three beam services were conducted. The total beam time was 1453.8 h, and the availability was 92.2%. For the supply of ²³⁸U beams, a maximum beam intensity of 94.2 particle nA was achieved, which was 1.3 times higher than the value of 72.0 particle nA in a previous beam time in Oct. 2018. A second high-temperature oven¹⁾ was added in the 28-GHz superconducting electron cyclotron resonance ion source, which has contributed to an increase in intensity and the stabilization of the uranium beam. Furthermore, the stabilization of the magnetic field of the IRC has also contributed to a stable beam intensity and an improvement in the transmission efficiencies for RRC and fRC.²⁾ For

the supply of ¹²⁴Xe beams, a maximum beam intensity of 173 particle nA was achieved, which was 1.7 times higher than the value of 102 particle nA in a previous beam time in Apr. 2016.

The improvement of the acceleration voltage by the upgrade of the RRC resonators³⁾ performed in 2018 has contributed to the remarkable enhancement in the intensity of beams delivered to the RIBF. In 18.25-MHz operations, both resonators were operated with an acceleration voltage of over 138 kV. Owing to an improvement of the shunt impedance, a significant reduction was achieved in the frequencies of the voltage breakdown by discharge and in the high-voltage trips of the vacuum tube. After all beam times scheduled in the first half of this fiscal year had been finished, a high-power test was performed. Both resonators achieved an acceleration voltage of 160 kV, which was twice that before the upgrade.

However, after the resonator upgrade of RRC, water leakages occurred in cooling water channels of the stems several times in 2018 and once in 2019. We spent 4–5 days repairing the leakage point by welding. Water leakage is a very serious problem that hinders the stable operation of RIBF. Therefore, during this summer maintenance period, an intensive investigation to find tiny leaks and the treatment of all the leaks found in the investigation were conducted. Since then, no degradations of vacuum occurred due to water leakage from the stems.

References

- 1) J. Ohnishi *et al.*, RIKEN Accel. Prog. Rep. **52**, 109 (2019).
- 2) R. Koyama *et al.*, in this report.
- 3) K. Yamada *et al.*, RIKEN Accel. Prog. Rep. **52**, 13 (2019).

Table 1. Summary of the accelerated beams in 2019.

Beam particle	Energy (MeV/nucleon)	Acceleration mode	Beam course	Beam intensity (particle nA)		Beam time (h)		Availability (%)
				Requested	Actual	Scheduled	Actual	
RARF								
¹² C	135	AVF-RRC	E5B (Biology)	1	483.3	39.0	28.5	100.0
¹⁴ N	135		E3B (RI production)	500	571.0	72.0	78.7	109.4
⁵⁶ Fe	90		E5B (Biology)	1	7.9	12.0	9.2	100.0
⁴⁰ Ar	160	AVF-RRC-IRC	E5B (Biology)	1	18.3	17.5	11.6	100.0
RIBF								
⁷⁸ Kr	345	RILAC2-RRC-fRC-IRC-SRC	BigRIPS/SAMURAI	> 300	272.2	672.0	649.0	96.6
¹²⁴ Xe			BigRIPS/ZDS	>80	165.4	516.0	372.6	72.2
²³⁸ U			BigRIPS/ZDS/F12	>60	94.2	388.9	432.2	111.1
Total						1717.4	1581.8	93.1

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