

Operation report on ring cyclotrons in the RIBF accelerator complex

K. Kobayashi,^{*1} K. Suda,^{*2} T. Adachi,^{*2} T. Dantsuka,^{*2} M. Fujimaki,^{*2} T. Fujinawa,^{*2} N. Fukunishi,^{*2} S. Fukuzawa,^{*1} M. Hamanaka,^{*1} H. Hasebe,^{*2} Y. Higurashi,^{*2} E. Ikezawa,^{*2} H. Imao,^{*2} S. Ishikawa,^{*1} O. Kamigaito,^{*2} Y. Kanai,^{*2} M. Kidera,^{*2} M. Komiyama,^{*2} R. Koyama,^{*1} K. Kumagai,^{*2} T. Maie,^{*2} Y. Miyake,^{*2} R. Moteki,^{*1} T. Nagatomo,^{*2} T. Nakagawa,^{*2} M. Nakamura,^{*2} T. Nakamura,^{*1} M. Nishida,^{*1} M. Nishimura,^{*1} J. Ohnishi,^{*2} H. Okuno,^{*2} K. Ozeki,^{*2} N. Sakamoto,^{*2} J. Shibata,^{*1} N. Tsukiori,^{*1} A. Uchiyama,^{*2} S. Watanabe,^{*2} T. Watanabe,^{*2} Y. Watanabe,^{*2} K. Yadomi,^{*1} and K. Yamada^{*2}

This paper presents an operation report on ring cyclotrons in the RIBF accelerator complex from January to December 2022. Table 1 summarizes the beams accelerated by these cyclotrons. Availability can be defined as the ratio of the actual beam service time to the scheduled beam service time, which is an index of stable operation of accelerators. When calculating each availability for beam service times completed earlier than scheduled, we regarded scheduled times as actual times. The total actual beam service time was 2403.2 hours. The ratio of the beam service time between the experiments conducted in the old (RARF) and new (RIBF) facilities was 49 : 51. In the RARF, the actual beam service time was 1178.8 hours with an availability of 99.1%.

In the RIBF, three beam services were conducted. The actual beam service time was 1224.4 hours with an availability of 96.3%. The beam services of ²³⁸U 345 MeV/nucleon were conducted primarily to compensate the beam supply suspended owing to the issue of BigRIPS in December 2021. No major problem occurred during the experiment. The maximum beam intensity was 82.6 particle nA, and the availability was 97.8%.

In the ⁷⁸Kr beam supply, we recorded the highest ever beam intensity of 690 particle nA. The power supply of the IRC main coil failed twice because the flow meter malfunctioned. It took three hours for recovery. As the beam tuning time was shorter than the expected time and the beam service for 20 days started earlier than scheduled, the availability was 103.0%.

In the ⁷⁰Zn beam service conducted in December 2022, severe failures occurred. The fRC-W plate power supply failed to generate 12 kV DC owing to the ground fault of the high-voltage transformer. It took 15 hours to replace the transformer. A beam supply was unstable overnight because a fluctuation in the receiving voltage in the Nishina memorial building affected the RF systems of RRC and fRC. To protect equipments, the beam intensity was reduced to 2/3 of the maximum value using a slit placed after the ion source. However, the beam service was suspended owing to a vacuum leakage in SRC-MDC3 caused by beam loss. The beam service time was only 148.5 hours, and the availability was 77.4%.

The total availability in the RARF and RIBF was 97.6%.

Table 1. Summary of accelerated beams in 2022.

Beam particle	Energy (MeV/nucleon)	Acceleration mode	Beam course	Beam intensity (particle nA)		Beam service time (h)		Availability (%)	
				Requested	Actual	Scheduled	Actual		
¹² C	135	AVF-RRC	E5B (Biology)	2	550.0	24.5	12.9	100.0	
¹⁴ N	70		E3B (RI Production)	100	111.0	6.0	5.9	100.0	
²⁰ Ne	135		E5B (Biology)	2	120.0	3.0	1.2	100.0	
²² Ne	70		E6 (RIPS)	500	530.0	120.0	119.3	99.4	
⁴⁰ Ar	95		E5A (Industry)	1	85.3	192.0	143.8	100.0	
⁵⁶ Fe	90		E5B (Biology)	2	6.3	12.0	3.7	100.0	
⁸⁴ Kr	70		E3A (Industry)	1	7.4	30.0	30.0	100.0	
			E5A (Industry)	1	9.8	336.0	269.9	100.0	
RARF ¹³⁶ Xe	35.7		E5A (MS)	1	0.1	0.0	0.0	0.0	
⁴ He	7.25		RILAC2-RRC	E3B (RI Production)	10000	10000.0	24.0	19.0	100.0
⁵¹ V	6	E6 (KEK/MRTOF)		5000	3306.0	288.0	284.1	100.0	
		E2B (KEK/KISS)		200	240.0	108.0	107.9	99.9	
¹³⁶ Xe	10.75	E3A (JAXA)		100	125.0	36.0	35.0	100.0	
		E5A (Industry)		1	100.0	48.0	46.1	100.0	
²³⁸ U	10.75	E2B (KEK/KISS)	2	314.3	96.0	89.5	93.2		
⁴⁰ Ar	160	AVF-RRC-IRC	E5B (Biology)	2	29.4	28.5	10.7	100.0	
				Subtotal		1352.0	1178.8	99.1	
RIBF	⁷⁰ Zn	RILAC2-RRC-fRC-IRC-SRC	BigRIPS/ZDS/SHARAQ	1000	818.0	192.0	148.5	77.4	
	⁷⁸ Kr		345	BigRIPS/ZDS/SHARAQ	700	690.0	384.0	395.4	103.0
	²³⁸ U		BigRIPS/ZDS/F12/SLOWRI/SHARAQ	120	82.6	696.0	680.4	97.8	
				Subtotal		1272.0	1224.4	96.3	
				Total		2624.0	2403.2	97.6	

*1 SHI Accelerator Service Ltd.

*2 RIKEN Nishina Center