

Operation report on the RIKEN AVF cyclotron for 2018

K. Kobayashi,^{*1} K. Ozeki,^{*2} M. Fujimaki,^{*2} N. Fukunishi,^{*2} S. Fukuzawa,^{*1} A. Goto,^{*2} M. Hamanaka,^{*1} H. Hasebe,^{*2} Y. Higurashi,^{*2} E. Ikezawa,^{*2} H. Imao,^{*2} S. Ishikawa,^{*1} O. Kamigaito,^{*2} K. Kaneko,^{*1} M. Kase,^{*2} M. Kidera,^{*2} M. Komiyama,^{*2} Y. Kotaka,^{*3} R. Koyama,^{*1} K. Kumagai,^{*2} T. Maie,^{*2} M. Nagase,^{*2} T. Nagatomo,^{*2} T. Nakagawa,^{*2} T. Nakamura,^{*1} M. Nishida,^{*1} M. Nishimura,^{*1} J. Ohnishi,^{*2} H. Okuno,^{*2} Y. Oshiro,^{*3} K. Oyamada,^{*1} N. Sakamoto,^{*2} J. Shibata,^{*1} K. Suda,^{*2} M. Tamura,^{*1} N. Tsukiori,^{*1} A. Uchiyama,^{*2} S. Watanabe,^{*2} T. Watanabe,^{*2} Y. Watanabe,^{*2} K. Yadomi,^{*1} K. Yamada,^{*2} and A. Yusa^{*1}

The yearly report on the operation of the RIKEN AVF cyclotron (denoted as AVF hereafter) for the period January–December 2018, is presented. AVF has four beam courses of various ion beams used for stand-alone operations: C01 (machine study), C03 (RI production), E7A (CRIB), and E7B (student experiment). In addition, AVF is used as an injector of RRC. In this mode, beams are delivered to three courses: RRC-RARF, RRC-IRC E5, and RRC-IRC-SRC. The beam courses are shown schematically in Fig. 1.

The yearly operation statistics and beams accelerated using AVF are summarized in Table 1 and 2, respectively. Remarkable operations achieved this year include a development test of C-foil and a demonstration experiment of nuclear transmutation. For C-foil development, an endurance test was performed for 150 h at C03. The experiment to demonstrate nuclear transmutation was carried out at C03. Most of the delivered time to C03 (2067 h, twice as long as that in the usual year) was spent on this experiment. In the RIBF experiment (RRC-IRC-SRC course), the beam was continuously delivered without any break for 600 h, out of a total delivered time of 820 h. In a total operation time of 5042 h, only 7 h was spent for AVF repairs. In the

last experiment in July, a cooling water pipe of PHASE SLIT leaked inside the AVF vacuum. Therefore, the RARF experiment was canceled.

Table 1. Comparison of AVF operation statistics with that of the previous year.

Particle	Energy [MeV/u]	Course
Stand-alone operation		
<i>d</i>	11.00	E7B
<i>d</i>	12.00	C03, E7B
<i>d</i>	14.00	C03
α	6.50	E7B
α	7.16	E7B
α	7.25	C03
α	12.50	C03, E7B
${}^7\text{Li}$	5.60	E7A
${}^7\text{Li}$	6.00	C03, E7A
${}^{11}\text{B}$	7.82	C03
${}^{12}\text{C}$	7.30	C03
${}^{18}\text{O}$	6.08	C03
${}^{18}\text{O}$	7.00	E7A
${}^{40}\text{Ar}$	3.78	C03
Operation as injector of RRC		
${}^{12}\text{C}$	7.00	RRC - RARF
${}^{14}\text{N}$	3.97	RRC - RARF
${}^{18}\text{O}$	4.51	RRC - RIBF
${}^{40}\text{Ar}$	5.19	RRC - RIBF
${}^{40}\text{Ar}$	5.20	RRC - RARF
${}^{56}\text{Fe}$	5.00	RRC - RARF
${}^{84}\text{Kr}$	3.97	RRC - RARF
${}^{86}\text{Kr}$	3.78	RRC - RARF

Table 2. AVF beam list in 2018.

AVF stand-alone operation	2017	2018
Tuning of AVF [h]	742	886
Trouble of AVF [h]	4	6
C01 M.S. [h]	32	0
C03 exp. [h]	1113	2067
E7A exp. [h]	245	262
E7B exp. [h]	597	274
Sub total [h]	2697	3489
AVF operation as injector of RRC	2017	2018
Tuning of AVF [h]	141	132
Trouble of AVF [h]	9	1
RRC-RARF exp. [h]	564	600
RRC-RIBF exp. [h]	549	820
Sub total [h]	1254	1551
Total [h]	3951	5042

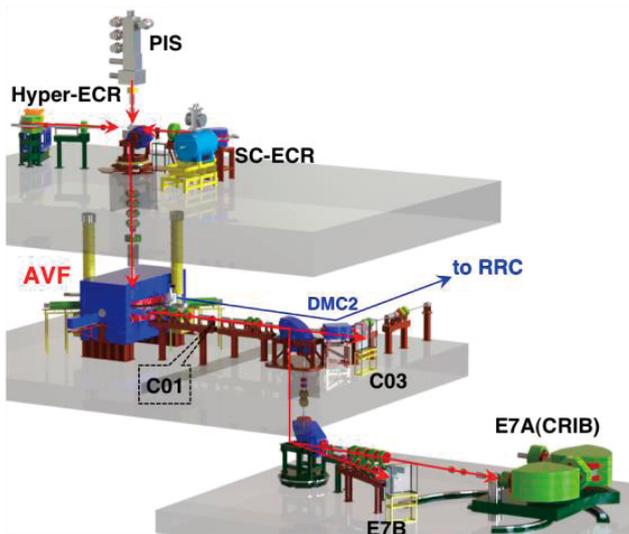


Fig. 1. Overview of AVF cyclotron with ion sources, experimental courses, and beam transport line to RRC.

*1 SHI Accelerator Service Ltd.

*2 RIKEN Nishina Center

*3 Center for Nuclear Study, the University of Tokyo