

Operation report on the RIKEN AVF cyclotron for 2020

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The yearly report on the operation of the RIKEN AVF cyclotron (denoted as AVF hereafter) for the period January-December 2020 is presented. AVF delivered beams to five courses for stand-alone operations: C01 (machine study), C03 (radioactive isotope (RI) production), C12 (CNS, RI production), E7A (CRIB), and E7B (RI production, student experiment). On the other hand, when AVF was used as an injector of the RIKEN Ring Cyclotron (RRC), beams were delivered to two courses: RRC-RARF and RRC-IRC-E5. Figure 1 shows the experimental apparatuses around AVF.

Thus far, AVF was equipped with three ion sources to deliver various ion beams: the superconducting electron cyclotron resonance ion source (SC ECRIS), Hyper ECRIS, and polarized ion source (PIS, only used for polarized deuterons). However, a GM refrigerator used for cooling the superconducting mirror coils in SC ECRIS had become too old. Therefore, SC ECRIS was replaced with the 18 GHz ECRIS that had been used at RILAC, and beam deliveries from the 18 GHz ECRIS commenced in January.

The yearly operation statistics are presented in Tables 1 and 2. In a total operation time of 2702 h, 1520 h was spent for stand-alone operation, and 1182 h was spent for injection to RRC. Because of the declaration of a state of emergency due to the COVID-19 outbreak, all beam times scheduled for April and May were canceled.

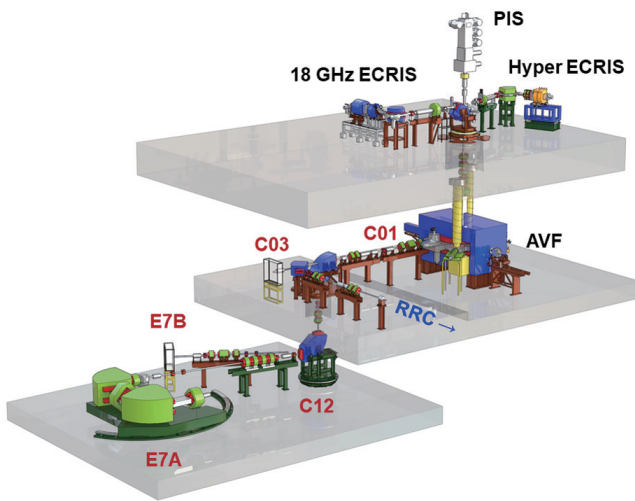


Fig. 1. Overview of the AVF cyclotron with ion sources, each experimental course, and beam transport line to RRC.

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This is a main reason why the operation time for stand-alone operation in this year is considerably less than that in the previous year. In addition, an RI production experiment using 30-MeV protons was conducted for the first time in June.

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

AVF stand-alone operation		2019	2020
Tuning of AVF	[h]	1314	744
Trouble of AVF	[h]	0	1
C01 M. S.	[h]	0	12
C03 exp.	[h]	873	631
C12 exp.	[h]	36	18
E7A exp.	[h]	789	12
E7B exp.	[h]	152	101
Sub total	[h]	3166	1520
AVF operation as injector of RRC		2019	2020
Tuning of AVF	[h]	117	178
Trouble of AVF	[h]	0	5
RRC-RARF exp.	[h]	320	999
RRC-RIBF exp.	[h]	0	0
Sub total	[h]	437	1182
Total	[h]	3603	2702

Table 2. AVF beam list in 2020.

Particle	Energy (MeV/nucleon)	Course
Stand-alone operation		
p	12.00	C03
p	19.00	C12
p	30.00	C01, C03
d	12.00	C03
α	6.50	E7B
α	7.25	C03, E7B
α	12.50	C03
${}^7\text{Li}$	6.00	C03
${}^{16}\text{O}$	6.80	E7A
${}^{18}\text{O}$	7.00	C12
${}^{19}\text{F}$	6.30	C03
Operation as injector of RRC		
${}^{12}\text{C}$	7.00	RRC-RARF
${}^{14}\text{N}$	7.00	RRC-RARF
${}^{20}\text{Ne}$	7.00	RRC-RARF
${}^{22}\text{Ne}$	3.97	RRC-RARF
${}^{40}\text{Ar}$	3.80	RRC-IRC-RARF
${}^{40}\text{Ar}$	5.20	RRC-RARF
${}^{56}\text{Fe}$	5.00	RRC-RARF
${}^{84}\text{Kr}$	3.97	RRC-RARF