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The Operation of RIKEN Ring Cyclotron

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INTRODUCTION

Almost nine years has passed since the first beam was extracted from the RIKEN Ring Cyclotron (RRC) successfully, and five years since the RIKEN Accelerator Research Facility was fully completed[1)] as shown in fig.1. Since then, the RRC has been supplying a variety of beams with a good stability for a variety of experiments. As many improvements have been made, a machine shut-down due to trouble-shooting decreased and a beam tuning time spent in order to get a high quality beam was shortened .

OPERATION STATUS

All beams, which were accelerated with the RIKEN Ring Cyclotron (RRC) during tments, such as medical science, radio-chemistry, health physics, material science, biology, atomic physics. Although the portion of beam time is so small, a variety of kinds of experiments were behese two years, are listed in table 1, together with their energy range and total time spent for experiments. In this period, totally 23 kinds of particles were accelerated by RRC and used for experiments. Their masses as well as their energies cover a very wide range from 1 to 170. Figure 2 shows the plots of particles accelerated so far in the region of energy-mass space. The plots are ranging almost everywhere in the available region of the space.

As listed in table 2, the total operation time for the last one year (from Sept. 1994 to Aug. 1995) amounted to 259 days. Among them, a total of 70 days were spent for beam tuning. Since a beam was prepared 72 times in this period, it takes 0.97 days on the average to tune one beam. The beam tuning time depends on how much an user requires a high quality beam, for example, a strict single-turn extraction, an extremely small beam spot, a well-separated single-bunched beam and so on. To meet these requirements completely, it takes sometimes longer than 1.5 days.

The beam time, which is used for experiments, is 189 days. Most of the beam time (86.7%) was devoted to nuclear physics experiments and the rest (13.3%) to other field experiing made, since beam time demanded for one experiment in these fields are very short as compared to that of nuclear physics.

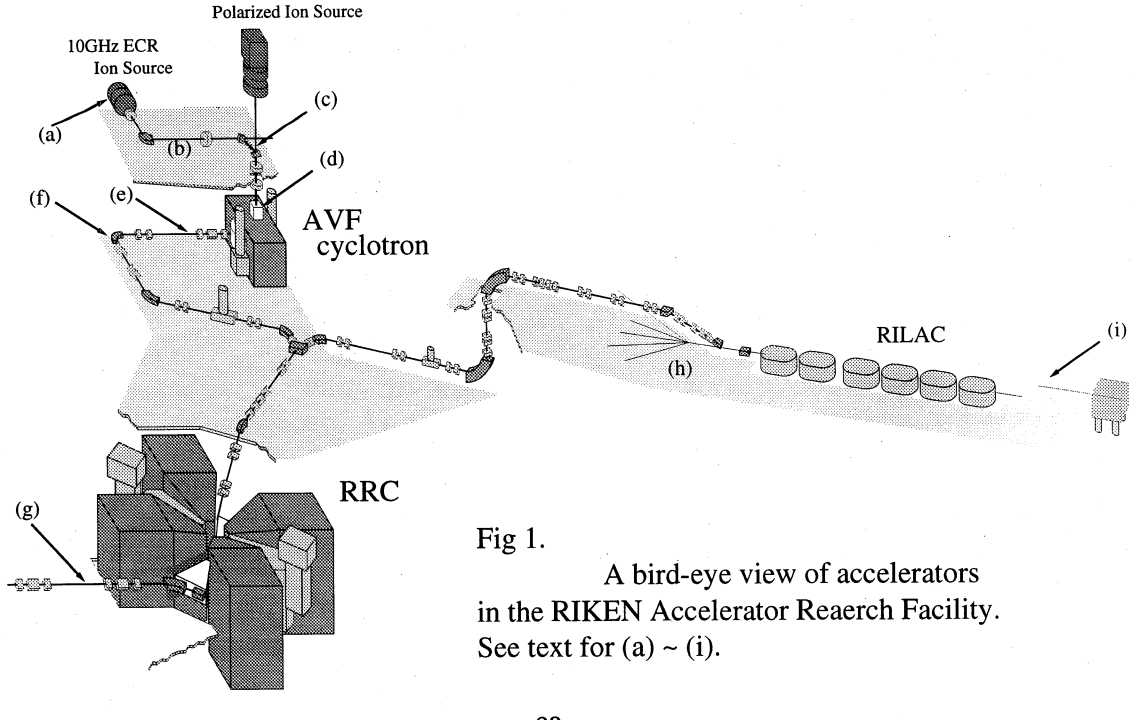

Fig 1.
A bird-eye view of accelerators in the RIKEN Accelerator Reaerch Facility. See text for (a) ~ (i).

Table 1 A list of particles which were accelerated by the RRC from Oct. 1993 to Aug. 1995.

Particle	Energy range (MeV/u)	Total time of operation (days)	Fraction (%)
p*	85 ~ 210	26.6	6.9
d**	135	50.0	13.0
^{12}C	92 ~ 135	32.5	8.4
^{13}C	100	34.3	8.9
^{14}N	35 ~ 135	12.1	3.1
^{15}N	115	11.5	3.0
^{16}O	135	8.7	2.3
^{18}O	42 ~ 100	51.7	13.4
^{20}Ne	135	8.2	2.1
^{22}Ne	70 ~ 110	25.0	6.5
^{24}Mg	100	5.0	1.3
^{28}Si	135	2.3	0.6
^{36}Ar	7.6	9.3	2.4
^{40}Ar	7.5 ~ 95	46.3	12.0
^{48}Ti	7.6	2.9	0.8
^{50}Ti	80	11.9	3.1
^{59}Co	80	1.9	0.5
^{58}Ni	95	5.9	1.5
^{84}Kr	10.5 ~ 36	4.5	1.2
^{130}Te	7.5	16.2	4.2
^{129}Xe	7.5	9.8	2.5
^{136}Xe	26	2.2	0.6
^{170}Er	7	6.5	1.7
total	-	385.0	100.0

* H_2^+ is used for energies lower than 135MeV/u.
** Mostly polarized deuterons.

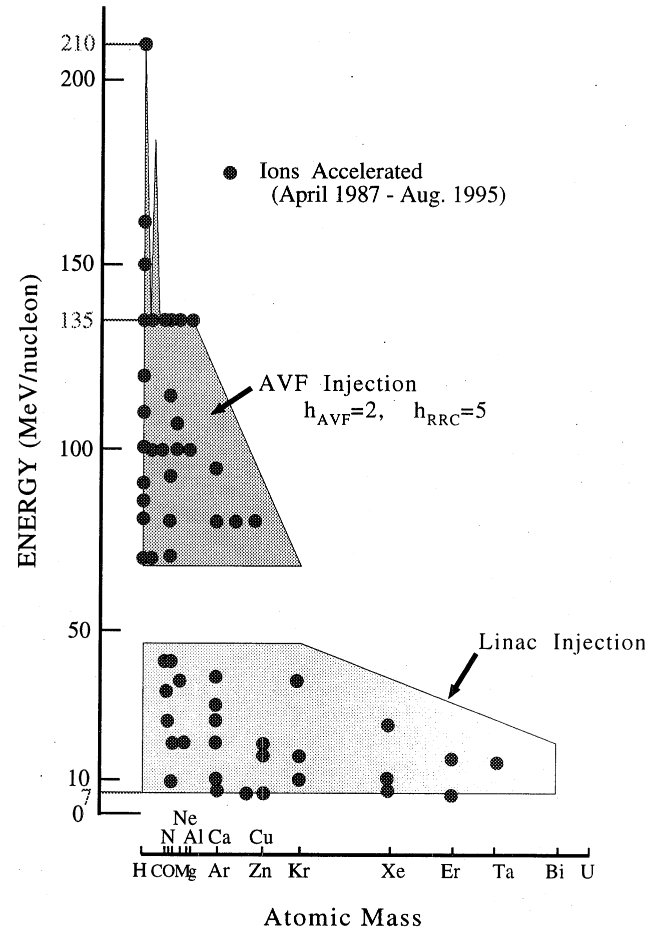

Fig. 2 Plots of ions accelerated so far by RRC on the energy-mass space.

Table 2 An operation statistics of the RRC from Sep. 1994 to Aug. 1995

Total Operation time	259 days	
Beam tunning		70 days
Experiment		189 days
Nuclear Physics		(86.7%)
Other fields		(13.3%)
RILAC injection		(20.4%)
AVF injection		(79.6%)
Unscheduled shut-down	14 days	
Highvoltage trouble		8 days
AVF magnetic channel		5 days
Other reasons		1 day
Maintenance or holiday	92 days	
Total	365 days	

The AVF-RRC operation was performed for 150days (79.6%) and the RILAC-RRC operation for 38.5 days (20.4%). Stand-alone uses of the two injector have routinely been made during a time when the other injector is coupled with RRC. (f, h in fig. 1)

TROUBLE SHOOTING

In this one year, a total of 14 days of the scheduled machine time had to be canceled. Main reasons for these unexpected shut-downs were relating to deflectors of both the AVF cyclotron and the RRC. They sometimes did not work sufficiently due to their unendurable leak currents. A periodic maintenance with an open of a vacuum chamber is necessary in both cases.

Recently, a casing of a magnetic channel in the AVF cyclotron had small holes due to beam hitting and a serious vacuum leak occurred twice. The beam has tendency to go lower side in the extraction region. Though the reason for it is not clear at present, the magnetic channel installed at a vertical position by 2mm lower than the prescribed one.

In the rf system of the AVF, a part of the slide contacts of the movable shorting plate was melted and burned. and the vacuum leak occurred from the magnetic channel due to beam hitting. In the RRC rf, the vacuum leak occurred between the aluminum gasket and the ceramics that are used in the coaxial rf power feeder.

NEW TOPICS

^{50}Ti Beam

Recently a beam of ^{50}Ti was accelerated and used for an experiment. To get an enough intensity, we had to use an enriched-material, which is extremely expensive. To save the quantity of it, when it is charged to the 10 GHz ECR source (a in Fig. 1), a thin alumina (Al_2O_3) pipe, a hole of which was filled with a small amount of powder of enriched (50%) Ti O, was used in stead of a normal ceramic rod. It could supply a 80MeV/u ^{50}Ti beam with an intensity of 8pnA on a target for a week at least.

Parasite-mode operation

We have routinely begun to make use of parasite-mode operation. A sub experiment, such as a detector test, normally demands several times of short-term irradiation of a faint beam. On the other hand, a main experiment needs a long-term irradiation of a very intense beam, like a RIPS's experiment in E6 room. The beam is sent to the sub user as long as they need, normally for several ten minutes. Switching the beam delivery could be made in a second each time.

Monitor of single turn extraction

A combination of beam chopper on the injection beam line of the AVF cyclotron and the two beam detectors (e, g in fig. 1) using a micro-channel plate (MCP) has routinely been used both as phase monitors for stabilizing the magnetic fields of the cyclotrons and as monitors for single-turn extraction[2].

Single bunch selector

A single-bunched beam is sometimes required by users as a time trigger for the measurement of time spectrum. A very compact single-bunch selector, which consists of a fast beam chopper (b, c in fig.1) and a sub-harmonic buncher (d in fig.1), has been successfully developed. Both the devices are installed in a low-energy injection line of the AVF cyclotron. As long as a single-turn extraction is strictly achieved in each cyclotron, a pure single bunched beam with a repetition rate of as high as 1 MHz is available[3].

NEAR-FUTURE PROGRAM

An acceleration test of a new injector system of the RILAC is now under way in a provisional site. It consists of a single-stage 18GHz ECR ion source and a variable frequency RFQ linac.[4] It will be installed at the injection line of RILAC in next spring, being the first-step improvement of the accelerators in aim of the new project, RI beam factory[5].

REFERENCES

1) Y. Yano, "Status Report on RIKEN Ring Cyclotron", Proceedings of 12th Int. Conf. on Cyclotrons and their Applications. Berlin, 1989. pp. 13
2) M. Kase, N. Inabe, I. Yokoyama, and T. Kawama. "A Beam Phase Monitor with Use of a Micro -Channel Plate for the RIKEN Ring Cyclotron" Proceedings of Beam Instrumentation Workshop, Vancouver 1994. pp. 459.
3) N. Inabe et al. in this proceedings.
4) A. Goto et al. in this proceedings.
5) Y. Yano et al. in this proceedings.