A Status Report of the RCNP Cyclotrons

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Abstract

Operation of the RCNP cyclotrons is summarized. In recent years, some light-heavy ions have become to be required and were accelerated. In addition, some improvements for the RCNP cyclotrons in last few years are also reported.

1 Introduction

The RCNP AVF cyclotron and ring cyclotron have been operated to several kinds of high quality beams for the nuclear physics experiment. An emphasis is placed on the design to accelerate high quality beams. Various efforts for the cyclotron operation have been carried out. In this report, we would like to describe improvements of an ECR ion source, a water cooling system, power supplies and a magnetic field monitor of the AVF cyclotron for last two years and to summarize the beam usage and the performance of the cyclotrons.

2 An operation of the RCNP cyclotrons

Table 1 shows a summary of the beam usage of the cyclotrons from 1995 to 1998. Mainly high-quality light-ion beam such as proton, deutron and helium beam have been required. In the past few fiscal years, ~ 70-90 % of the machine time was carried out for the ions.

In recent years, various kinds of light-heavy ions have become to be required such as ^{11}B and ^{18}O in the table. ^{12}C is also requested, the machine time of which is scheduled in October, 1999.

In 1998 and 1999, 1080 MeV $^{18}O^{8+}$ beam was accelerated successfully in the ring cyclotron. $^{18}O^{6+}$ beam was extracted from the NEOMAFIOS ECR ion source reported elsewhere[1] and accelerated to 246.5 MeV by the AVF cyclotron. After that, the beam was stripped to 8+ charge and injected the ring cyclotron. On-target intensity of the $^{18}O^{8+}$ beam was ~ 5 enA in 1998 and was increased to be ~ 50 enA in 1999. Stability of the $^{18}O^{8+}$also becomes better. Mainly, improvement of the NEOMAFIOS ECR ion source and careful adjustment of the trim coil current of the ring cyclotron caused such a good operation.

An acceleration test of $^{11}B^{4+}$ was started by the AVF cyclotron from 1998 and 156.5 MeV $^{11}B^{4+}$ beam of 10 enA was obtained in a preliminary result. Further acceleration test of $^{11}B^{4+}$ is scheduled in October, 1999. 480 MeV $^{12}C^{6+}$ beam is also required and the machine time of the beam also scheduled in October, 1999.

particls	1995	1996	1997	1998
H	926.4hrs	838.5hrs	581.3hrs	911.8hrs
pol H	3210.8	2935	1777.8	1722
D	401.8	11.3	232	41.5
pol D	25.5	81.7	161.7	60.5
^{3}He	743.5	340.8	382.8	539.8
^{4}He	96.2	266.8	0	294
^{6}Li	88.2	177.5	930.8	207.2
^{7}Li	0	572	572	136
^{11}B	0	0	0	25.7
^{14}N	268.8	0	62.2	0
^{18}O	0	0	0	151
Total	5811.5	5223.7	4558.8	4089.5

Table 1: A summary of the beam usage of the cyclotrons

	1995	1996	1997	1998
Beam time	5811.5	5223.7	4558.8	4089.5
Maintenace and set up	1380	1464	1776	1416
Scheduled shutdown	1416	768	1896	3000
Unscheduled shutdown	176.5	1304.3	529.2	254.5
Total	8784	8760	8760	8760

Table 2: A summary of the performance of the cyclotrons

A summary of the performance of the cyclotrons during last four fisical years is given in table 2. A slight decrease of the beam time is mainly due to the financial reason, i.e., saving the running costs. Especially, in the fisical year of 1998, the cyclotron facility was shut down from August to September and from January to March.

3 An improvement of the ECR ion source

As is described above, various kinds of light-heavy ions have become to be required in recent years. The NEOMAFIOS ECR ion source has been operated for the light-heavy ions. Since we do not have enough time for a test operation, we emphasized the test for the operation as an injector rather than that of the ion source itself. Experimentally, stabilization of ion sources have been found to be quite important not only for the stability of the accelerated beam but also for obtaining higher-intensity beam, because we can get enough time to search various kinds of operation parameters of the cyclotrons.

Figure 1 shows a typical ^{18}O ions spectrum optimized for $^{18}O^{6+}$. The extraction voltage is 11.1 kV. The obtained intensity of $^{18}O^{6+}$ is $\sim$ 12 eμA. ^{18}O enriched gas($\sim$ 95%) was used and ^{4}He gas was supplied as buffer gas. We investigated ^{4}He mixing effect using ^{16}O gas. The

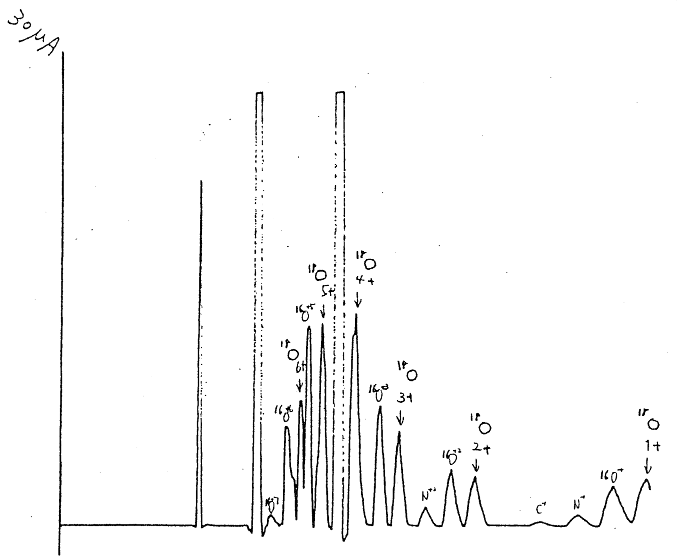

Figure 1: A typical ^{18}O ions spectrum optimized for $^{18}O^{6+}$.

obtained $^{16}O^{6+}$ intensity with He gas was slightly larger than that without He gas. Whereas, the stability of the ion source with He gas was much better than that without He gas. Therefore, in the case of ^{18}O, the mixing He gas method was carried out. Rather large amount of ^{16}O ion fractions in fig. 1 may come from the residual gas due to the test using ^{16}O gas described above.

The obtained $^{18}O^{6+}$ beam of $\sim$ 10eμA was kept over one day. Even though increasing the vacuum level by plasma heating of the chamber wall makes the intensity of the ion changed, the intensity from the ion source was found out to be revived with increasing He gas flow rate and that on the target of the accelerated ions was also revived during a few-day machine time with reappearing total current flowing in high voltage power supply for an extraction.

A typical ^{12}C ions spectrum optimized for $^{12}C^{4+}$ using CO_2 gas is shown in fig. 2. The extraction voltage and the obtained intensity are 11 kV and $\sim$ 25 eμA, respectively.

For $^{11}B^{4+}$ generation, direct insertion of a boron rod to the ECR plasma was adopted. Though $\sim$ 1eμA $^{11}B^{4+}$ was already obtained, the intensity and the stability of $^{11}B^{4+}$ beam was not sufficient and the test of the ion source will be continued.

4 An improvement of the water cooling system

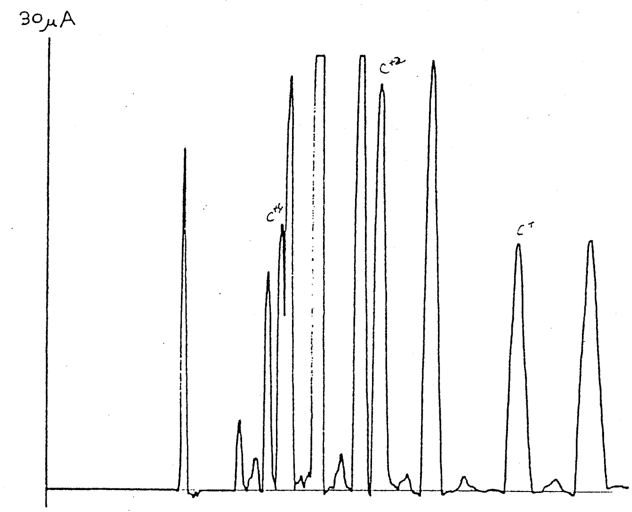

Figure 2: A typical ^{12}C ions spectrum optimized for $^{12}C^{4+}$.

A new water cooling system for the ring cyclotron has been developed. With the improved cooling system, the temperatures of the trim coils, those of the magnetic channels and those of the main coils become to be able to be controlled independently. In addition, dynamic range of the temperature control system was also increased.

The cooling system of the shunt resistors of the power supplies for the main coils was also separeted from other systems. With the new system, temperature of the cooling water for the shunt resistors is kept 25$\pm$0.1 °C.

5 An improvement of the power supplies

Improvements of the power supplies for an AVF main magnet, AVF trim coils, an analizer magnet A1 and a swithcing magnet SW were carried out during past few years. Mainly current detectors(shunt resistors or old DCCTs) of them were replaced with new DCCTs. For the power supply of the AVF main magnet, a new standard voltage generator, FLUKE5440B, is employed as the reference voltage source. After these improvements, the typical current stability of the power supplies is 2.0×10^{-6}/day, 1.0×10^{-5}/8hours, 4.2×10^{-6}/3days and 1.5×10^{-6}/2days for the AVF main magnet, the AVF trim coils, the A1 magnet and the SW magnet, respectively.

6 A magnetic field monitor of the AVF cyclotron

The magnet field of the AVF cyclotron was continuously monitored by a NMR-probe with small field correction coils, which was mounted in a valley sector of the magnet. Carefully choosing the position of the probe and adjusting a current of the correction coils, the field gradient around the NMR-probe may be less than $10^{-4}/cm^3$.

Even though we can not obtain the NMR value at all times for some experimental problems not settled by now, monitoring the NMR value is very useful for a cyclotron operation. Two new NMR probes were installed in the AVF cyclotron in the summer of 1999. Detailed discussions are presented elsewhere[2].

References

[1] K. Takahisa *et al.,* RCNP Annual Report, p.190 (1994).
[2] M. Kibayashi *et al.,* , in this Conf.