CONSTRUCTION AND FIRST OPERATION OF THE RCNP RING CYCLOTRON

I. Miura, T. Yamazaki, A. Shimizu, K. Hosono,
T. Itahashi, T. Saito, A. Ando, K. Tamura,
H. Ogata, M. Kondo and H. Ikegami

Research Center for Nuclear Physics, Osaka University,
Ibaraki, Osaka 567, Japan

and

J. Abe

Quantum Equipment Division, Sumitomo Heavy Industries, Ltd.
Soubiraki 5-2, Niihama, Ehime 792, Japan

Abstract

The RCNP Ring Cyclotron is being commissioned for acceleration of 300 MeV proton. Proton beam of 53 MeV accelerated by the RCNP AVF cyclotron was transported to Ring Cyclotron Hall through new beam transport system in Beam Injection Hall. On October 12th the first beam was injected in to the ring cyclotron and successfuly pass through various injection elements to beam stopper following the flat-topping cavity. The acceleration test of the ring cyclotron is being made.

Introduction

In August 1986, the Ministry of Education authorized the cyclotron Cascade project to start in the spring of 1987. The main components of the new facility are a six separated spiral sector cyclotron (ring cyclotron), a beam circulation ring linked to a high precision dual magnetic spectrograph, a neutron TOF facility with a 100 m neutron flight tunnel and a heavy ion secondary beam facility[1]. The beams extracted from the AVF cyclotron are transported through the old facility and injected into the ring cyclotron. With this ring cyclotron, beam of p, d, ^{3}He, alpha and light-heavy ions will be made available in the wide rage of energies of up to 400, 200, 510, 400 and $400 \cdot Q^2/A$ MeV, respectively. An emphasis is placed on the production of high quality beams to enable precise experiments.

In August 1987, RCNP made a four years contract with Sumitomo Heavy Industries Ltd., to construct the RCNP Ring Cyclotron. Table 1 shows the time schedule of delivery of various components of the ring cyclotron.

Construction of buildings for the ring cyclotron facility was started in November 1987. The radiation shield of facility is made with heavy structure of concrete. The ring cyclotron vault has concrete shield wall 4.5 m in thickness. The building was finished in March 1990. Installation of the ring cyclotron system was started in February 1990, immediately after the finish of Ring Cyclotron Hall. Fig. 1. shows the layout of the cyclotron facilities.

On April 9, 1991 accumulation of the magnetic field data of the RCNP ring cyclotron during the past 4 months was performed. Installation and test of the ring cyclotron components, experimental apparatuses and utilities for the new facilities was done in 1990 simultaneously with finishing of the new building. Fig. 2. shows the photograph of the ring cyclotron.

The RCNP ring cyclotron building has whole base structure and no concrete pile. The every bases of the Hall of the building form thick solid honeycomb structure. The initial sinkage of the building through 1989 was about 3 cm and the sinkage of the main magnet system in the following year was about 2 mm. After removal of the magnetic field mapping system, reassembly and readjustment of the ring cyclotron system were done. Commisioning of the ring cyclotron system is being made.

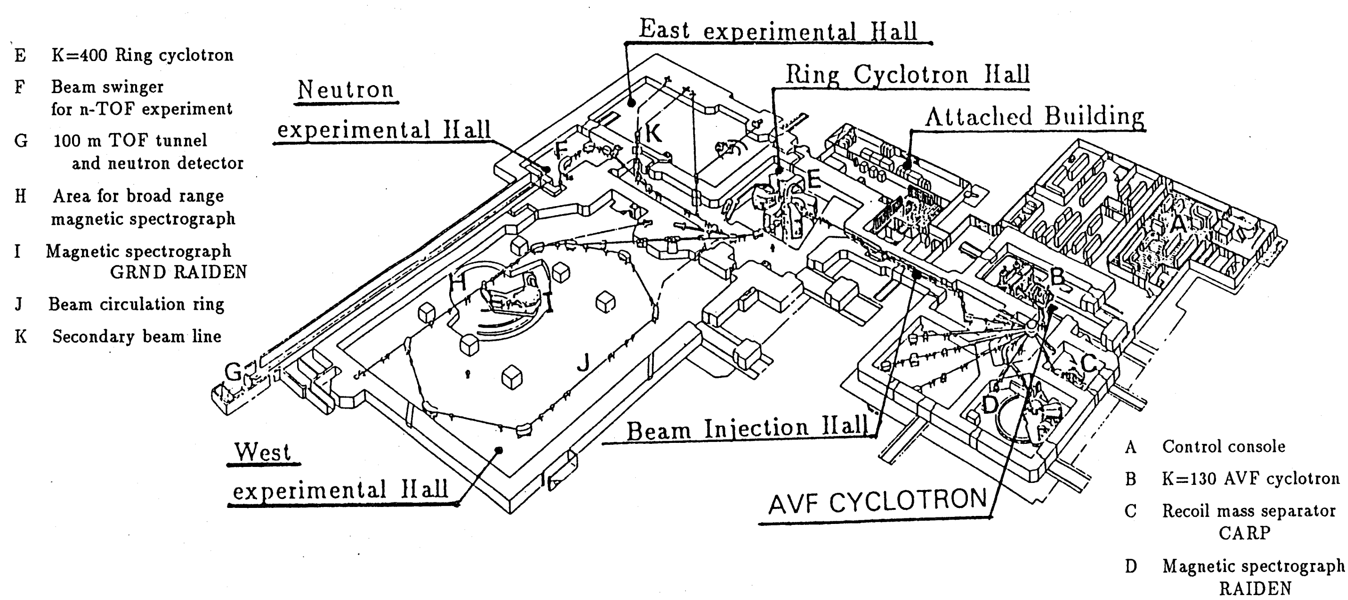

Fig. 1 Layout of the cyclotron facilities.

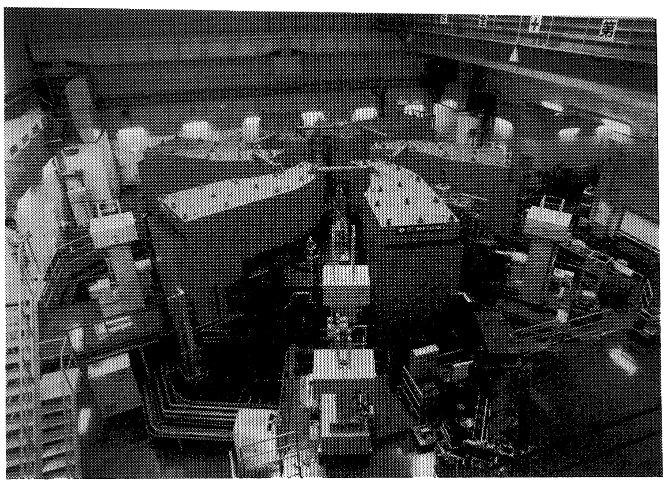

Fig. 2 Photograph of the RCNP ring cyclotron.

Outline of the ring cyclotron

The ring cyclotron[2] is energy quadrupler of the RCNP AVF cyclotron[3] and has phase acceptance of 20° with beam energy width 10^{-4}. Plan view of the ring cyclotron is shown in Fig. 3. Three single gap acceleration cavities are used in the ring cyclotron. Frequency range of the cavity is 30~52 MHz and harmonic numbers of acceleration is 6, 10, 12 and 18. An additional single gap cavity is used for flat-topping with 3rd harmonic of acceleration frequency to get good energy resolution and wide phase acceptance.

A 180°-single-dee acceleration cavity is used in the RCNP AVF cyclotron. The frequency range of the cavity is 5.5~19.5 MHz, and fundamental and 3rd harmonic acceleration modes are used. Fig. 4 shows relation between orbital frequencies and acceleration frequencies in the AVF cyclotron and the ring cyclotron for various ions and energies. The characteristics of the cyclotrons are given in Table 2.

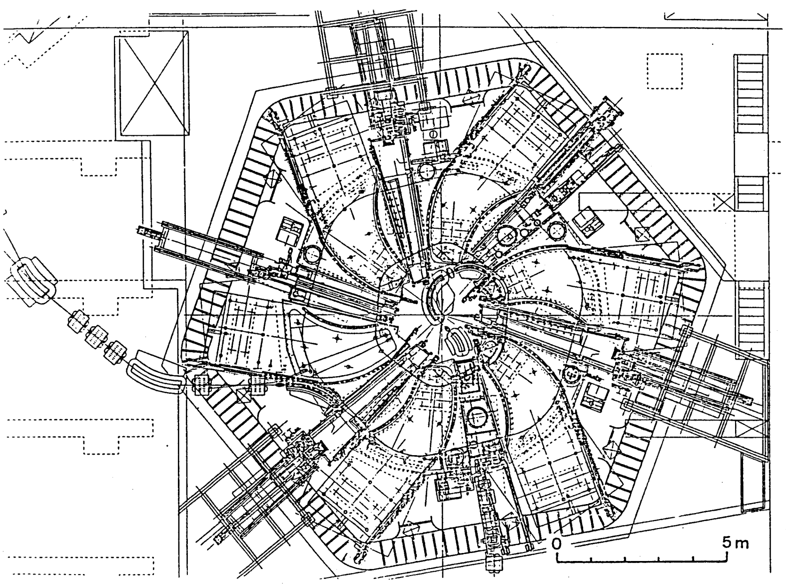

Fig. 3 Plan view of the ring cyclotron.

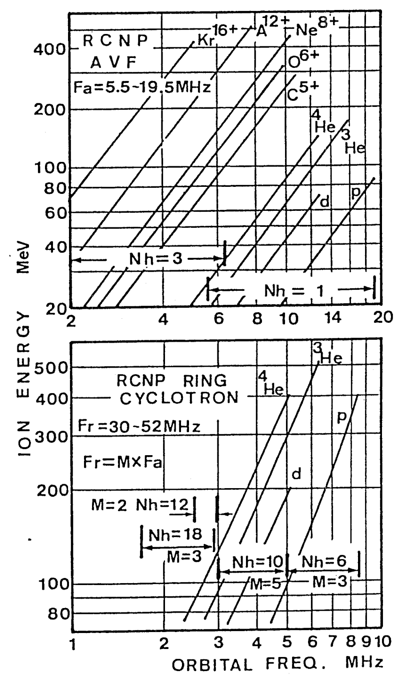

Fig. 4 Orbital frequencies, acceleration frequencies and harmonic numbers of acceleration in the AVF cyclotron and the RCNP ring cyclotron. M is ratio of the RF frequency of the ring cyclotron to the AVF cyclotron.

Table 1
Time schedule of delivery

	FY'87	FY'88	FY'89	FY'90
Main magnet system				
Sector magnet			4 set	2 set
Power supply			1 set	
Field mapper			1 set	
Field data				1 set
Injection and extraction system	1set			
Acceleration system				
Acceleration cavity		1 set	2 set	
RF Power amplifier	1 set	2 set		
Flat-topping cavity		1 set		
RF power amplifier			1 set	
RF driving signal				1 set
Valley chamber			2 set	
Vacuum system				
Roughing system			1 set	
Diffusion pump			6 set	
Cryogenic pump		2 set	4 set	3 set
Turbo-molecular Pump				3 set
Auxiliary				1 set
Beam diagnostic system			1 set	
Cooling system			1 set	
Control system				
Hardware			1 set	
Software				1 set

Table 2

Characteristic of cyclotrons

	Injector Cyclotron	Ring Cyclotron
No. of sector magnets	3	6
Sector angle	max 52°	22~27.5°
Injection radius(cm)		200
Extraction radius(cm)	100	404
Magnet gap(cm)	20.7 min	6.0
Max. Magnetic field(kG)	19.5	17.5
Proton max. energy(MeV)	84	400
Alpha particle energy(MeV)	130	400
^{3}He energy(MeV)	160	510
Weight of magnet(ton)	400	2100
Main coil magnet(kW)	450	440
No. of trim coils	16	36
Trim coil power(kW)	265	350
No. of cavities	1	3(Acc.) 1(FT)
RF frequency(MHz)	5.5~19.5	30~52 90~155
RF power(kW)	120	250×3 45

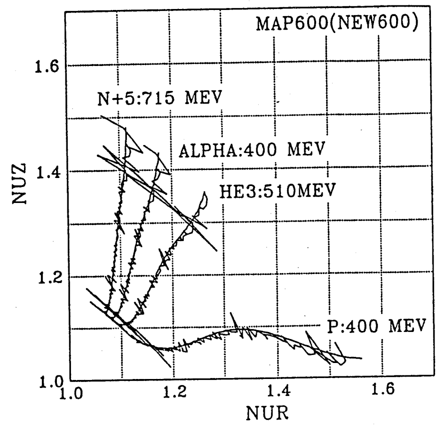

Fig. 5 Comparison between betatron frequencies calculated from the measured field and the designed one.

Magnets of the ring

The magnet of the six spiral sector cyclotron was designed by using computer code FIGER and the results of model magnet study of the previous proposal[4]. The results of the measurements of the magnetic field distribution are quite satisfactory[5]. Fig. 5 shows comparison between belatron frequencies calculated from the measured magnetic field and the designed one.

Vacuum system

The vacuum chamber of the ring cyclotron consists of six magnet chambers. Three acceleration cavity chambers, a flat-topping cavity chamber and two valley chambers as shown Fig. 3. The gaps between these chambers are sealed by punenmatic expansion seals[6]. These seals are working quite well. The ring cyclotron is evacuated down to about 1×10^{-6} Torr by six diffusion pumps with double chevron baffles (2.500 ℓ/sec eq.) and three 16 inch cryopumpus (6.500 ℓ/sec each) with gate valve. After final test of Vacuum system six 20 inch cryopumps (10.000 ℓ/sec each) without gate valve will be installed.

Acceleration system

The acceleration cavities, the flat-topping cavity and their RF power amplifiers were tested individually in last year. The side walls of the cavity chamber can not with stand atmospheric pressure under evacuation, so these walls are supported by the magnet chambers. After full assembly of the ring cyclotron, full power test of the RF system and baking of the cavities are being made[7].

Injection and extraction system

The injection and extraction systems satisfy dispersion matching for any energy. The injection system worked satisfactory as designed[8].

Buncher

The 20° phase acceptance of the ring cyclotron correspond to beam phase width of 7° or 4° for the AVF cyclotron, since the ratio of acceleration frequencies of the ring cyclotron to the AVF cyclotron is 3 or 5, respectively. A beam bancher system operated in 2nd harmonic of acceleration frequencies of the ring cyclotron is used to preper ideal injection beams for the ring cyclotron[9].

AVF cyclotron

Neomafios and ECR ionizer for polarized ion source will be installed in 1992. The phase acceptance of the AVF cyclotron for axial injection mode is very wide and it is difficult to make narrow phase beam with phase slits. A new beam phase selector for axial injection mode was designed[10]. The beam phase width can be limited down to ±5° by using radial deflection with the RF field.

Beam diagnostic system

The commissioning of the ring cyclotron is being made with various kind of beam diagnostic elements. Efforts to get good S/N ratio for weak beam 10nA are being made. Fig. 6 shows the results of the measurements[11].

Control system

The old control system of the AVF cyclotron is used without any modification. For the ring cyclotron, new computer control system is used[12].

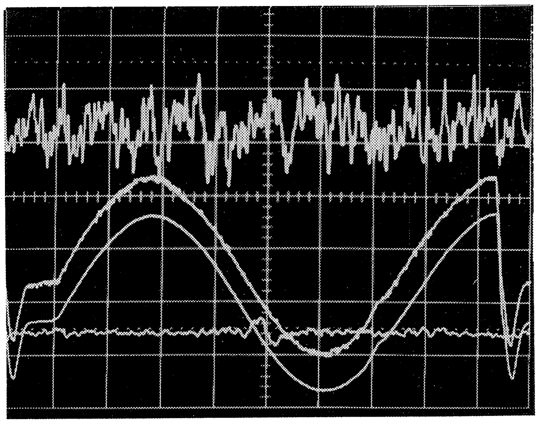

Fig. 6 Beam phase profile measured with phase probe for 50 nA beam. The beam signals from the probe were measured with a sampling oscilloscope and averaged 100 times with digital oscilloscope.

References

1. H. Ikegami, Proc. of the 12th Conf. on Cyc. and Their Aple. Berliln (Germany) 1989, p. 30.
2. I. Miura, et al., Proc. of the 11th Conf. on Cyc. and Their Appl., Tokyo (Japan) 1986, p. 207., Proc. of the Third Japan-China Joint Symposium on Accelerators for Nuclear Science and Their Appl., RIKEN (Japan) 1987, p.13.

3) M. Kondo, IEEE Trans NS-26, 2, 1904-1911

4) I. Miura, et al., Proc. of the 4th Symposium on Acc. Science and Technology, RIKEN (Japan) 1982, p. 97, K. Hosono, et al., Spiral Sector Magnet of RCNP Ring Cyclotron Project, RCNP Annual Report 1984.

5) K. Hosono, et al., Presented at this symposium.

6) A. Shimizu, et al., Vacuum System of the RCNP Ring Cyclotron, RCNP Annual Report 1990.

7) T. Saito, et al., Presented at this symposium.

8) A. Ando, et al., Proc. of the 12th Conf. on Cyc. and their Appl. Berlin (Germany) 1989, p .346.

9) A. Shimizu, et al., Presented at this symposium.

10) I. Miura, et al., Construction of the RNCP Ring Cyclotron, RCNP Annual Report 1990.

11) T. Itahashi, et al., Proc. of the Workshop on Advanced Beam Instrumentation, KEK, Tsukuba (Japan) 1991, KEK Proceedings 91-2, June 1991, A, Volume 1 p. 30.

12) T. Yamazaki, et al., Presented at this symposium.