CYCLOTRON FACILITIES IN JAPAN

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Abstract

In Japan, three classical cyclotron and one synchrocyclotron facilities have been well operating still now.

In a recent few years, four isochronous cyclotron facilities have been established. Two of them, K=120 and 68, are used mainly for nuclear physics. The other two, K=70 and 30, are used mainly for radiology and radiotherapy.

Construction of another facility for multi-purposes, K=50, has been in progress.

1. Classical Cyclotron Facilities

There are three classical cyclotron and one synchrocyclotron facilities. One at Osaka University, has an RF system of a wide frequency range and pole face windings near the maximum radius which allow one to change the accelerated particles and energies. One, at Kyoto University, has also a wide range RF system for the same purpose. These works well still now.

The 160 cm - Synchrocyclotron at INS, University of Tokyo, had been operated in two modes (Frequency Fixed or Frequency Modulated) by changing the RF resonators. This machine has been operated only as the INS-FM Cyclotron, since the start of the construction of the new INS-SF Cyclotron. The INS-FF Cyclotron was one of the oldest variable energy machines and the most stable machines in the world. Almost all researchers of our country used this machine. Now the similar design is took over by the IPCR 160 cm cyclotron which has been improved in every part.

1.1 The IPCR-160 cm Cyclotron

The IPCR-160 cm Cyclotron is intended as a general purpose accelerator which is used in the various fields of research such as chemistry, biology, and solid state physics as well as nuclear physics. Main part of the facility was constructed by Toshiba Electric Co..

The typical features of this machine are B-constant type poles and pole face trimming coils of the main magnet, and a wide frequency range (5 to 13.5 MHz) of the RF system. Performances in the period of 1974 are listed in tables 1 and 2.

Table 1. Accelerated Particles and Intensities by the IPCR Cyclotron

Particle	E(MeV)	Iext(uA)
H^+	4 ~ 17.5	50
D^+	8 ~ 25	30
$^3He^{++}$	12 ~ 45	30
$^4He^{++}$	16 ~ 55	30
C^{4+}	50 ~ 95	3
N^{4+}	60 ~ 95	3
N^{5+}	50 ~120	0.5
O^{5+}	60 ~120	0.5

Table 2. Scheduled Machine time and Subjects of Activity at the IPCR Cyclotron

Subject	Heavy ion	Light ion
Nuclear physics	2110 hr	1812 hr
Nuclear chemistry	0	433
Radiation bislogy	172	13
Solid state physics	131	80
Inner atomic shell excitation study	0	222
Nuclear medicine	0	192
Nuclear fuel study	0	121
RI production	24	17
Development of instrument	45	46
	2506	3020

2. Isochronous Cyclotron Facilities

In a recent few years, four isochronous cyclotron facilities have been established and there are a few facilities under construction or in planning stage, whose details will be given as the contributed papers in this Conference. Some characteristics of the facilities are listed in table 2.

Table 2. I.C. Cyclotron facilities in Japan

	RCNP	INS	IMS	NIRS	Tohoku
Rext(cm)	100	74	42	92	68
Bmax(KG)	16	16	16	14	15
Epmas(MeV)	75	48	26	70	40
K-number(MeV)	120	68	30	70	50
RF system	MOPA	SO	SO	MOPA	MOPA
RF range(MHz)	6~18	7~23	14~26	11~22	20~40
No. of dee	1	1	2	2	2
Width of dee (degree)	180	180	90	86	60
No. of target station	11	11	6	6	8
Beam analyzer	QDDQ	QDDQ	-	-	plan
Mag. spectrograph	QDDQ	QDD	-	-	-
Main purpose	Nucl. Phys.	Nucl. Phys.	Medicine	Medicine	Multi

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 76-79

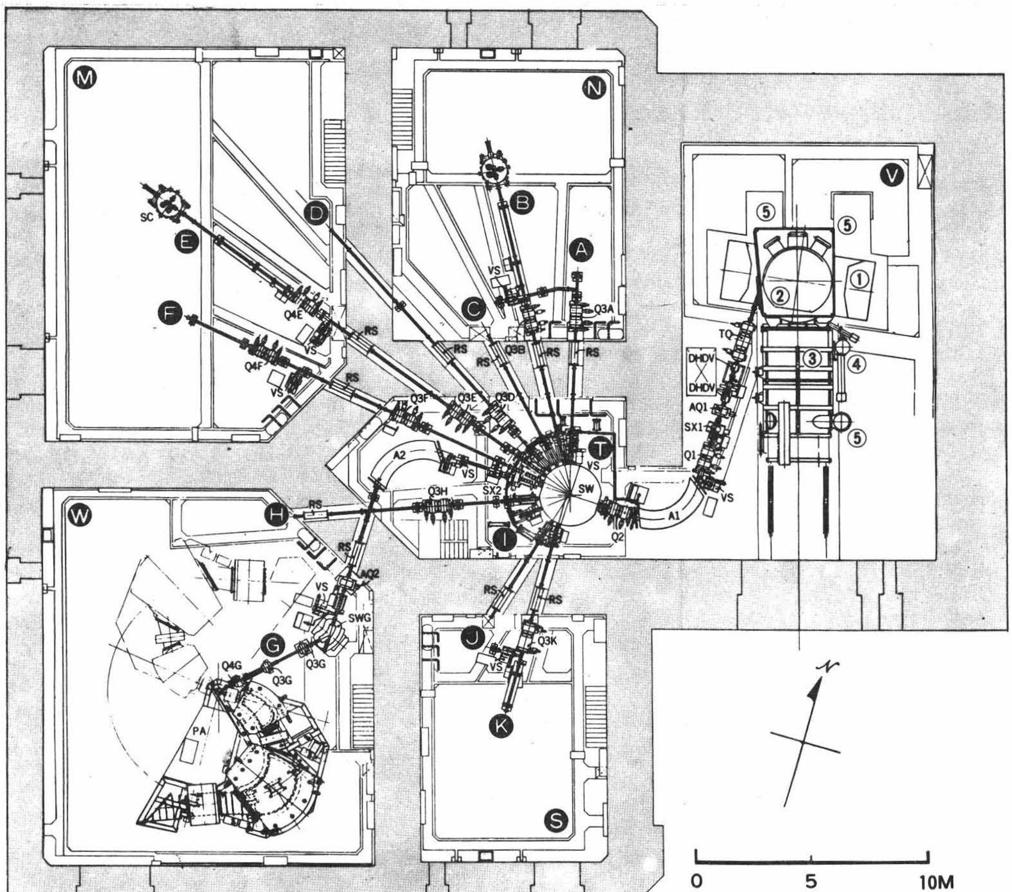

Fig. 1. Plan view of the RCNP Isochronous Cyclotron facility. Number and abbreviation: 1=main magnet, 2=acceleration chamber, 3=coaxial resonator, 4=RF power amplifier, 5=vaccum pump; A-K=beam courses; A1,A2=analyzer magnet, AQ1,AQ2=quadrupole singlet, DHDV=steering magnet, PA=reaction particle analyzer, Q1-Q4=quadrupole doublet, RS=rotary shutter, SC=scattering chamber. SW=switching magnet. SWG=bending magnet. SX1.SX2= sextupole magnet. TQ=quadrupole triplet, VS=molecular pump station; V=cyclotron vault, T=beam switching room, N,M,W,S=experimental room.

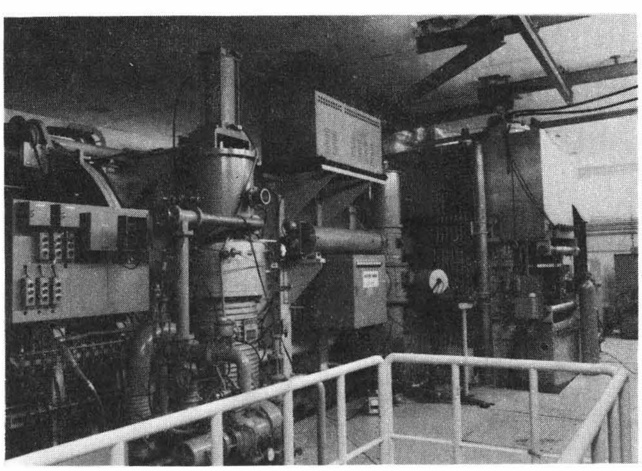

Fig. 2. The RCNP Isochronour Cyclotron. Main magnet, RF power amp, and RF resonator are seen at the right side, center, and left side of the photograph.

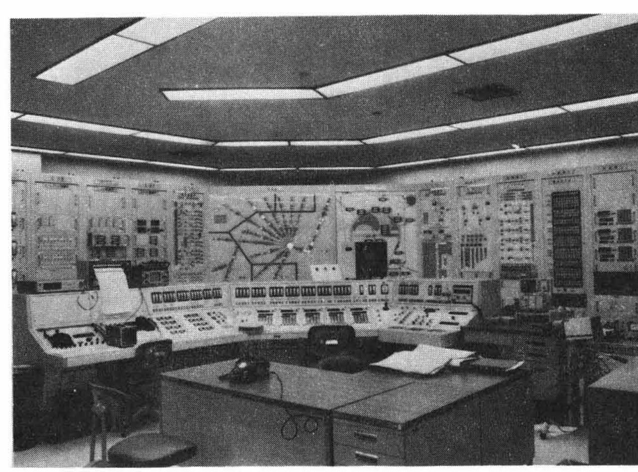

Fig. 3. Control room of the RCNP Isochronous Cyclotron

2.1 Osaka University RCNP Isochronous Cyclotron

This machine was constructed at the Research Center for Nuclear Physics(RCNP) in Osaka University as the biggest and best one in our country. All research facilities are planned for nuclear physics and are open to all nuclear scientists in our country.

The first stage of the design was done in 1965. After careful model tests and studies, the construction was started in 1971 and the first internal beam was obtained in 1974. The design studies, model tests, some of engineering designs and operation tests were carried out by the staff members of Osaka University. Studies of beam quality and improvements of the machine have been continued.

A stable and high quality beam is obtained owing to the mechanical accuracies of each part and the high stabilities of 10^{-5} for the main magnetic field and of 10^{-4} for the dee voltage.

All parameters of the cyclotron are controlled with digital switches and stepping motors and will be controlled using PDP 11/40 and interfaces.

The polarized ion source and the injection system are assembled. Many experimental equipments have been installed as shown in Fig. 1. Among those are a tandem beam monochrometer system (ρ=2,000 mm, QD-DQ) and a reaction particle analyzer (ρ= 1,500 mm, QDDQ), whose momentum resolutions should be 32,000 and 20,000, respectively for 1 mm beam spot.[2)]

2.2 The INS-SF Cyclotron, University of Tokyo

This machine was constructed at the Institute for Nuclear Study(INS), University of Tokyo, in order to take over and improve the experimental facilities of the INS-FF Cyclotron as mentioned in section 1.

Design and model tests were started in 1968. The first external beam was obtained in 1974. Most of the machine parts were manufactured by Mitsubishi Electric Co. But almost all the processes, from design to operation test, were performed by the members of INS, as in the case of RCNP. The basic

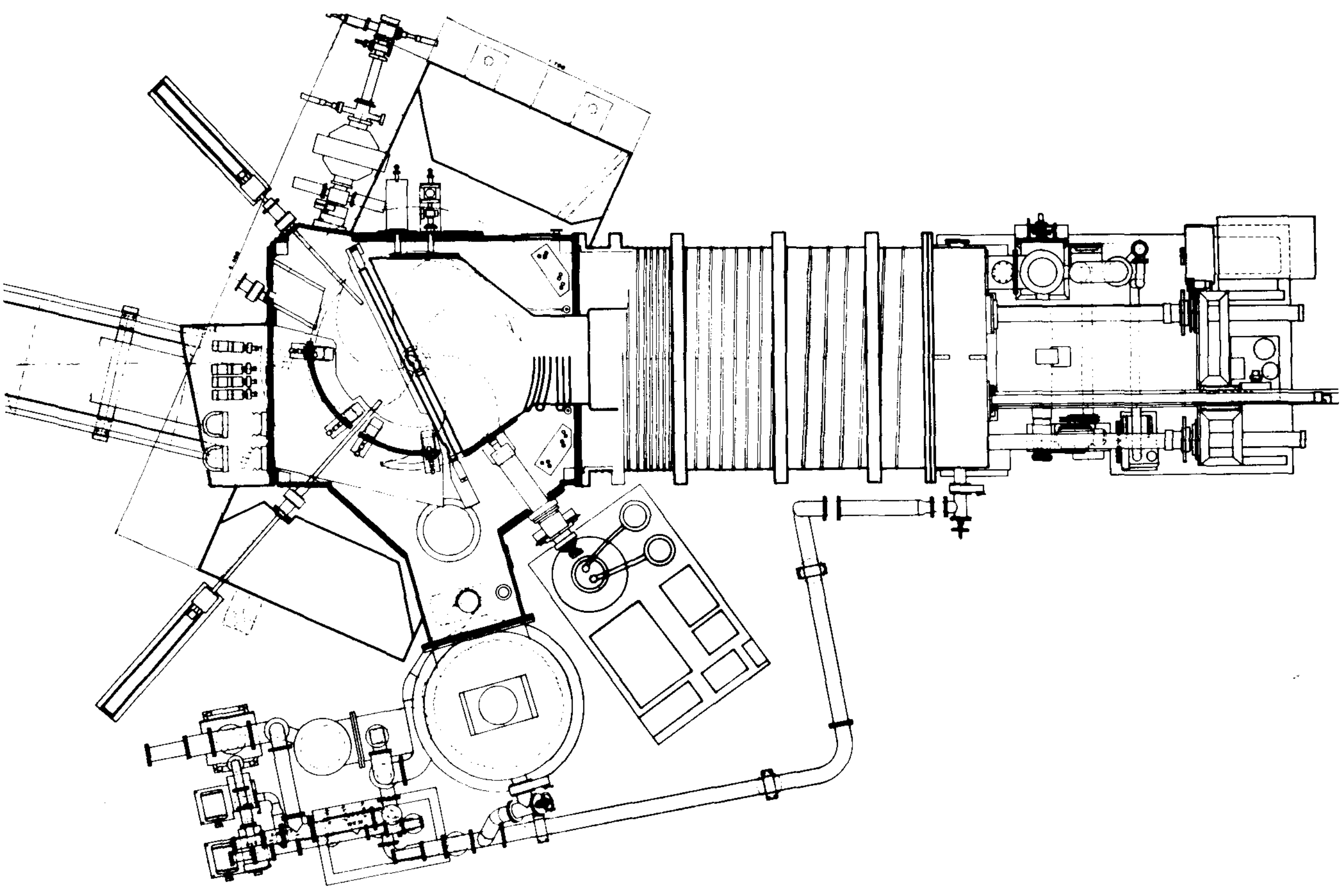

Fig. 4 Plan view of the INS-SF Cyclotron

design is somewhat similar to that of RCNP, but the scale is smaller than that.

Tests of polarized ion source and axial injection system are in progress. Beam transport system was completed, including a beam analyzer of QD-DQ type. Several research projects, such as the isotope separation on-line (ISOL), in-beam spectroscopy, particle-γ correlation etc., are in porgress. Construction of a particle spectrograph of QDD type is just before assembly.

2.3 The IMS Cyclotron, University of Tokyo

This facility was built at the Institute of Medical Science, University of Tokyo, and aimed mainly for RI production for medicine, neutron therapy and biology, and partly for nuclear physics. Because of easy handling and maintenance, TCC Model CS-30 was chosen.

External beam pulsing system are installed. Using horizontal and vertical RF deflector system, beam period can be selected from 160 ns (H^+), 200 ns ($^3He^{++}$) and 280 ns (D^+, $^4He^{++}$) to infinite. This system is used for in-beam γray spectroscopy and studies of hyperfine interaction.

For medical and biological studies, a target and collimator system of neutron generation are installed.

2.4 NIRS Isochronous Cyclotron in Chiba

The main purposes of this facility is the neutron therapy and the short-lived isotope production for nuclear medicine.

This machine is similar to the design of that at the Catholic University of Louvain. Engineering, construction, adjustment and operation test are carried out by the CGR-MeV, France. But several parts such as RF resonator tank, magnet yoke, vacuum chamber and D.C. power supplies were manufactured in our country under the supervision of CGR-MeV.

The completion of the machine including beam transport was in 1974. This machine has an internal beam chopper for neutron time of flight experiment. The single turn extraction study was done as a necessary condition for this purpose. It was found that the adjustment of parameters, especially of trimming coils and phase slit, are critical for the single turn extraction.

Dose measurement for biological and medical studies, and neutron therapy are to be started in near future.

2.5 The Tohoku University Cyclotron Project

The aim of this project is to build a cyclotron facility which meet requirements from different fields of research at the University: nuclear and radiation chemistry, isotope production, activation analysis, radiation damage, radiation biology and medicine, solid state physics, atomic and molecular physics, and nuclear physics.

The type of the machine was decided as the CGR-MeV 's Orleans type. It is constructed by Sumitomo Heavy Industries Ltd., under guidance of the CGR-MeV, according to a technical collaboration between the companies.

The cyclotron will be installed in 1976 and RI production will be started at first. Installation of the beam lines and experimental equipments for the various fields is expected in 1977.

3.3 Future trends

Most of the present and planned cyclotron facilities become not only those for nuclear physics but also for various fields of science in Japan, as in many countries.

On the other hand, heavier ions and higher energy are called for in several fields of research. For such requirements, design studies of an heavy ion synchrotron and proto-type model tests of a sector magnet for a ring cyclotron are started. Which kind of machine is preferable should depend on the cases, how heavy or how much energetic are the expected ions.

The construction of the heavy ion linac (E~20q) has been in progress in IPCR, which has some possibility to become an injector to a ring cyclotron.

References

1) M. Inoue et al., paper A. 32, this Conference
2) H. Ikegami et al., to be published in RCNP Annual Report (1975) and Nucl. Instr. and Methods.
3) Y. Hirao et al., paper A. 34 and D.44 this Conference.