STATUS OF THE RIKEN SSC

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ABSTRACT

Present status of the RIKEN SSC is reported. Construction of the RIKEN separated sector cyclotron is well under way according to schedule. Fabrication of all of sector magnets has already been finished and they were installed in the cyclotron vault in July of 1984. Detailed design of the remaining components of the SSC is almost finished and some of them have already started to be fabricated at the factory.

GENERAL DESCRIPTION

Description of the RIKEN separeted sector cyclotron (SSC) project was given previously[1] and status report presented to the 10th International Conference on Cyclotron and their Applications in 1984.[2] The SSC is a main accelerator of the RIKEN heavy ion accelerator complex having two injectors, one of which is the variable frequency linac (RILAC) and the other an AVF cyclotron with K-value of 65 MeV. RIRAC is principally used for the acceleration of heavy ions with mass-to-charge ratio $A/q \geq 5$ while the AVF cyclotron for light ions with $A/q \leq 5$.

A plan view of the SSC is shown in Fig.1 and its principal parameters are listed in Table 1. The SSC is composed of four sector magnets, two RF resonators, two valley vacuum chambers, injection and extraction elements and beam diagnostic devices. Table 2 lists the characteristics of the beam from the SSC. Energy resolution, emittance and time resolution are estimated by taking the actual quality of the beam from the RILAC into account.[3]

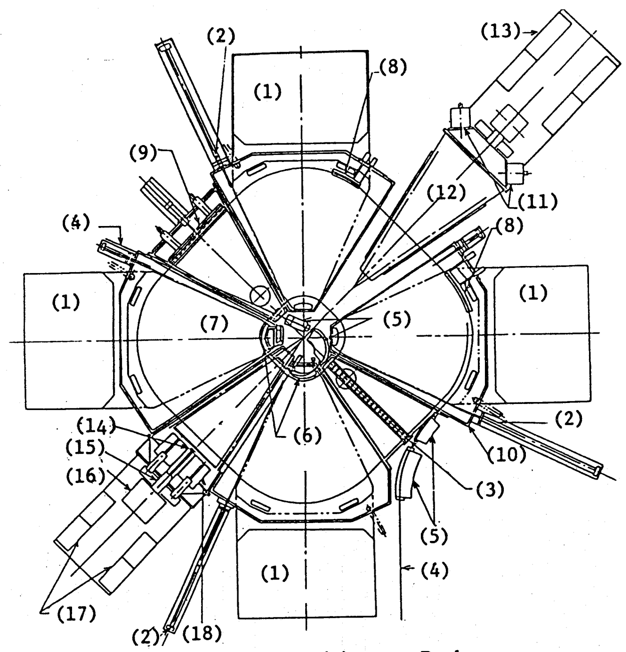
Table 1. Principal characteristics of the RIKEN SSC

Number of sector magnets	4
Sector angle	50°
Gap width	8 cm
Maximum field	16.7 kG
Maximum power	700 kW
Number of trim coils	29 × 4 pairs
Total weight	2100 ton
Number of dees	2 (λ/2 type)
Dee angle	23.5°
RF frequency range	20 - 45 MHz
Frequency tuning	Movable box and Trimmer
Maximum RF voltage	250 kV
Maximum power	600 kW
Main evacuation system	10^4 ℓ/s cryopump × 10 5×10^3 ℓ/s cryopanel × 4
Pressure	$< 1 \times 10^{-7}$ Torr
Control system	Computer network and a number of micro-computers
Dimension of the SSC	
Diameter	12.6 m
Height	6 m
Mean injection radius	0.893 m
Mean extraction radius	3.56 m
Orbit frequency	1.8 - 7.37 MHz
Harmonic number	
RILAC - injected	9, 10, 11
AVF - injected	5

Construction of the SSC started in 1981. Fabrication of all the four sector magnets was finished. Remaining components of the SSC such as RF system, vacuum chambers and vacuum pumps, injection and extraction system, beam transport line between RILAC and the SSC, and the control and beam diagnostic system were already ordered. Some of them have already started to be fabricated.

Construction of the SSC vault was finished and beam transport vault, experimental halls, AVF vault, and control and office building will start to be constructed in this year.

The SSC as well as the building will be completed in 1985 and we expect to have first beam in the middle of 1986. An AVF cyclotron as the second injector will be constructed from 1987.



(1) Sector Magnet
(2) Beam Probe
(3) Phase Probe
(4) Beam Line
(5) Bending Magnet
(6) Magnetic Inflection Channel
(7) Electric Inflection Channel
(8) Magnetic Deflection Channel
(9) Electric Deflection Channel
(10) Vacuum Chamber
(11) Vacuum Pump
(12) Resonator
(13) Platform Car
(14) Coupler
(15) Feeder Line
(16) Final Amplifier
(17) DC Power Supply & Control Panel
(18) Trimmer

Fig. 1. A plan view of the RIKEN SSC.

Table 2. Characteristics of beam from the RIKEN SSC

Maximum energy per nucleon	
proton	210 MeV
^{3}He	185 MeV/u
deuteron, alpha	135 MeV/u
Heavy ion	$540\ (q/A)^2$ MeV/u
Energy resolution	0.05 %
Emittance	1.25π mm·mrad
Time resolution	200 ps

SECTOR MAGNETS

Main characteristics of the sector magnet are also given in Table 1. Each sector magnet is 5.64m in radial length and 5.24m in height. It weighs 526 tons. The ratio of cross sectional area of the yoke to that of the pole base is 0.94. This ratio is minimum allowable value to achieve the required strength of the field. The yoke is divided into 28 sheets of slabs for convenience of transportation and construction.

The pole is made of homogeniously forged steel with carbon contents of 0.1%. Radial edges of the pole have a profile of an approximated B-constant shape. A flange for a vacuum chamber is welded on the pole side. Twenty nine trim coils are directly mounted on the pole face. Each trim coil is made of copper plate of 6mm thick and has a curved shape along equilibrium orbit. A hollow conductor is welded to the copper plate to feed DC current and cooling water. For narrow trim coils, only hollow conductors with curved shape are used. Trim coils as well as pole faces are separated from the main vacuum chamber and are kept under low vacuum.

Preliminary measurements of quantities of the basic performance such as the excitation characteristics and field distributions were done at the factory when two of four sector magnets were completed.[4] Magnetic field produced by each trim coil was also measured and the results were used for trim coil current optimization to produce the isochronous field distribution.[5] The sector magnets have good performance in accordance with the design.

Two power supplies are used for main coils and nine power supplies having fifty six out put terminals are used for trim coils.

The whole sector magnets and power supplies were installed in the cyclotron vault in July of this year. The detailed field mapping will be started in this October. Figure 2 shows a photograph of the sector magnets which were installed in the SSC vault.

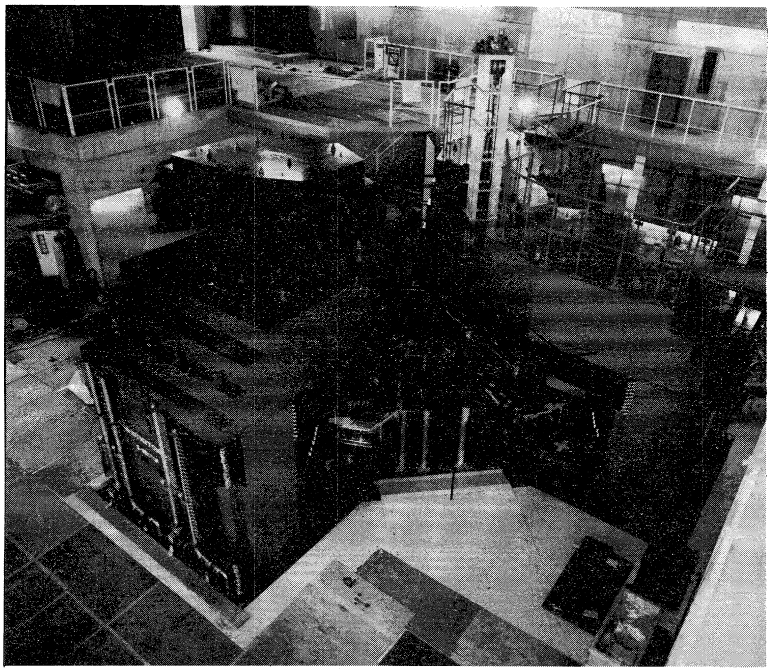


Fig. 2. A photograph of the sector magnets which were installed at right position in the SSC vault.

RF SYSTEM

The RF system for the SSC is required to satisfy the conditions as the frequency range is 20 to 45 MHz and energy gain per turn per unit charge is 1 MeV. Radial length of accelerating gap is 2.7m. The voltage distribution along the accelerating gap should be radially increasing to realize the phase compression. After design studies with several types of models for resonator cavities, the resonator having a movable box as a frequency changing device was adopted.

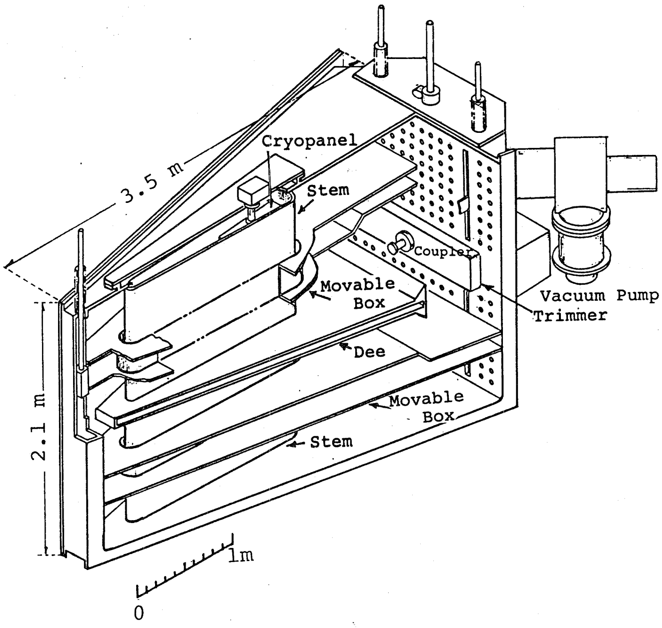


Fig. 3. A bird's-eye view of the new RF resonator cavity for the SSC.

The one fourth scale model resonator was made and the resonant frequency, Q-values and radial distribution of RF electric field were measured on it. Results of the measurement were very satisfactory. Figure 3 shows a bird's-eye view of the new RF resonator.[6] Total height of the present resonator is 2.1m and travelling distance of the box is 0.7m. RF power will be fed through a coupler. Fine tuning of the frequency can be done using a trimmer. Outside plate and the stem are made of copper cladded stainless steel. Two cryopumps and a turbomolecular pump will be equipped backside to evacuate inside of cavity.

Detailed design of the resonator cavity is almost finished and some parts of it are under construction.

Master oscillator and power amplifier system is to be employed for an RF oscillator system. High stability of RF voltage as well as its phase is also required. The maximum output power is larger than 250 kW. An RCA 4648 tetrode is to be used as a grounded cathode amplifier. A plate tuning circuit is a $\lambda/4$ type stub and tuned by changing the length of the stub. The grid tuning circuit is also a $\lambda/4$ type stub and tuned by a variable capacitor. Preliminary study is in progress using the model amplifier.[6]

VACUUM SYSTEM

The vacuum chamber of the SSC is divided into eight sections, that is, four magnet chambers, two RF resonator chambers and two valley chambers. Because of very limited space in the central region, it is so difficult to apply usual metal seals that the flanges between these chambers will be sealed with double elastomer O-rings.

The pressure in the chambers must be kept as low as possible in order to reduce beam loss due to ion scattering by residual gas molecules. If the beam loss is to be kept less than 10 %, the pressure inside the chamber must be lower than 10^{-7} Torr. Total volume of the vacuum chamber is estimated to be $25m^3$ and its inside surface area $310m^2$. Then total outgassing rate from the chamber can be estimated as $7.7x10^{-3}$Torr•ℓ/sec. An additional gas load of about $3x10^{-3}$Torr•ℓ/sec will be caused by evolution from various components inserted in the vacuum chamber and also by permeation through the sealing elastomer.[7] Then the total pumping speed of $12x10^4$ ℓ/sec is required to achieve a pressure lower than $1x10^{-7}$ Torr inside the chamber. To guarantee this pumping speed, ten cryopumps with speed of 10,000 ℓ/sec and four cryopanels with 5000 ℓ/sec will be equipped to the chamber.

In order to reduce the gas load, electron cyclotron resonance (ECR) discharge cleaning technique is to be applied to the magnet chambers. An experimental apparatus for ECR discharge cleaning was built at the model magnet of the old cyclotron and tested. The results showed that the impurity molecules of about $7.2x10^{18}/cm^2$ were tranformed from the surface into gas and thus the surface was cleaned considerably.[8]

The design of the vacuum system is now in its final stage and fabrication of the vacuum chambers will soon be started.

INJECTION AND EXTRACTION SYSTEM

Design study of the injection and extraction system has already been finished. Each system consists of two dipole magnets, two magnetic channels and an electrostatic channel.[9] To obtain a high quality beam, some conditions imposed upon the beam at the injection point must be satisfied. The present system is so designed that this matching can be done. In designing the extraction system, realization of single turn extraction was taken into account. Detailed mechanical design of the elements is now in its final stage.

BEAM TRANSPORT SYSTEM AND EXPERIMENTAL ROOMS

This facility will be devoted to research works in various fields. Layout of the beam transport lines and the experimental rooms is shown in Fig.4 and the main characteristics of the beam transport lines are listed in Table 3.[10]

Sometimes it will be beneficial for two experimental groups to share the beam. For that purpose, every 90° bending magnet in Fig.4 will be divided into two pieces, one of which deflects the beam by an angle of 25° and the other 65°. It has been confirmed by an ion optical calculation that the beam conditions obtained from the previous analysis with 90° bending magnets are satisfactorily well reproduced by this modified configuration. The dipole magnet which deflects the beam by an angle of 25° will be operated in a pulse mode and two users can share the beam. The pole gap is 6 cm.[11]

Table 3. Characteristics of beam on targets

Dispersive transport	
Energy resolution	0.01 %
Achromatic transport	
Energy resolution	0.02 %
Isochronous transport	
Time resolution	300 ps

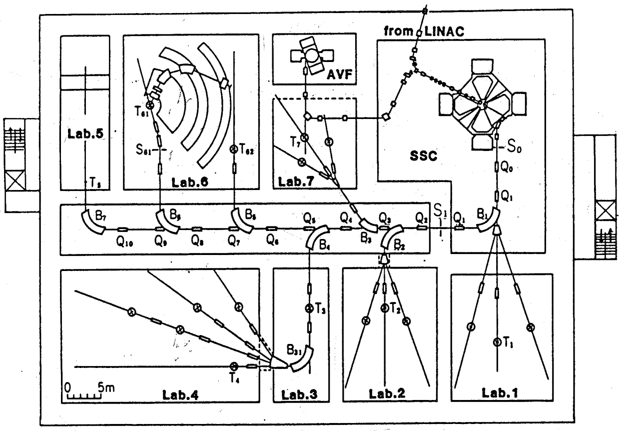


Fig. 4. Plan view of the beam handling system for the RIKEN SSC. S_0 is object point of the system.

CONTROL AND BEAM DIAGNOSTIC SYSTEM

A computer aided control system will be introduced for the SSC. The system is composed of a network of three computers and CAMAC system. The computer is MELCOM350-60/500 and its word length is 32 bits. Among them one is used for control of the SSC, the second for control of the RILAC and the last will be used for program development and data file. These three computers are equivalent to each other and can be supported by each other through the network.[12]

All the devices will be controlled through the CAMAC by the computer. To decrease necessary number of CAMAC crates, modules and signal cables, new CAMAC modules named CIM(Communication Interface Module) and DIM(Device Interface Module) are developed.[13] They have the following functions: 1) Execution of macro programs for a sequential control and a data acquisition. 2) Periodic logging and storage of status information independently of the computer. 3) Block transfer of information from/to the control computer. 4) Automatic alarm to the control computer at an apparatus failure. These intelligent interface modules can control the devices locally and ensure high speed sequential control and measurements without any aid of the control computer.

Both the CIM and DIM consist of micro processors and memories. The CIM can be linked with eleven DIM's. Informations between CIM and DIM are transmitted through Receiver/Transmitter equipped to the CIM and DIM and optical fiber.

We have a plan to optimize the operation of the SSC using the computer. In order to realize this successfully, it is necessary to equip enough number of beam diagnostic devices of various types measuring the current distribution, beam emittance and its phase relative to the RF voltage. Preliminary tests will be done using the RILAC in the near future.

BUILDING

Construction of the SSC vault (the phase 1 of the building program) was completed in March of this year. The SSC vault is seen in the right of the photograph shown in Fig.5. Building of the RILAC can be seen in the left. Negotiation for construction of beam transport vault, experimental halls, AVF vault, and control and office buildings is now in final stage and construction of them will start in this year.

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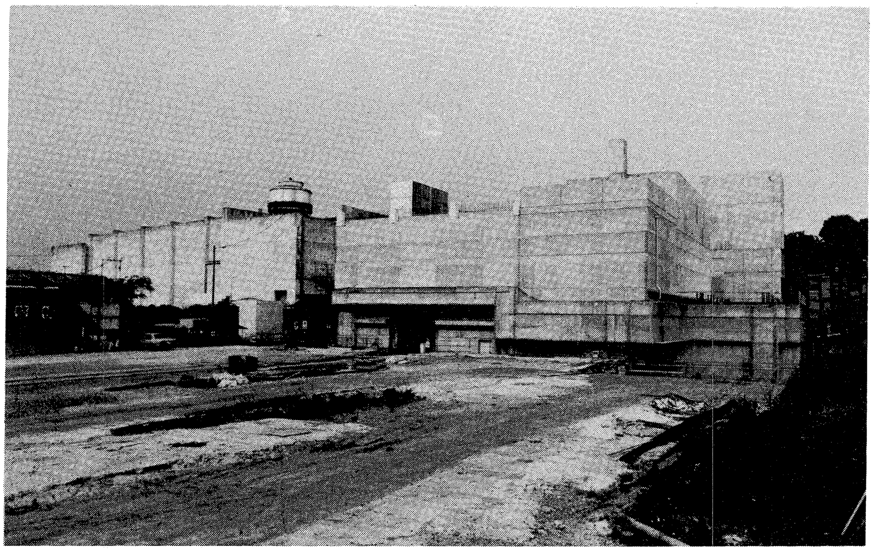

Fig. 5. A photograph of the buildings for the SSC vault(right) and RILAC(left).