The 6th Symp. on Accelerator Science and Technology, 1987, Tokyo, Japan (© Ionics, Tokyo, 1987)

ACCELERATORS FOR THE JAPANESE HADRON FACILITY

M. Kihara

National Laboratory for High Energy Physics
Oho, Tsukuba, Ibaraki, 305, Japan

ABSTRACT

The general concept of the accelerator system of the proposed Japanese Hadron Facility (JHF) is reported.

GENERAL DESCRIPTION OF THE JHF ACCELERATORS

The accelerator complex for the Japanese Hadron Facility is composed of the four accelerator sections, as shown in Fig.1.

(1) proton synchrotron (Ring I-A)
(2) stretcher/synchrotron ring (Ring I-B)
(3) proton linac
(4) heavy ion linac

Ring I-A is a 2-GeV rapid cycling synchrotron, which is capable of delivering a 200-μA proton beam. The beam in the synchrotron is bunched in a time of 200 ns and supplied to the experimental facilities of pulsed neutron scattering and pulsed muon experiments.

Ring I-A will also be a GeV-pion facility. This is unique in the world because a high intensity pion beam up to 1.5 GeV is available from the ring.

An injector for Ring I-A is a 1-GeV linac with an intensity capability of more than 200 μA. The reason of adopting such a high energy linac is that the intensity is limited by the space charge effect and the collective instabilities whose threshold currents depend on the injection energy.

The heavy ion accelerators are composed of a linac of a final energy of 8 MeV/u and a slow-cycling synchrotron(Ring I-B) of an energy of 1 GeV/u. One of the design features of the JHF project is coexistence of the proton accelerator and the heavy ion accelerator. Owing to the high intensity proton linac, a high intensity beam of unstable nuclei is available from an Isotope-Separator-On-Line (ISOL) ion source.

Ring I-B acts also as a stretcher for the high intensity proton beam. A continuous beam is required from nuclear physics experiments and the stretcher is a requisite for the GeV-pion facility.

The Japanese Hadron Facility is supposed to be built in the south campus of the KEK Laboratory. The layout of the JHF accelerator system is shown in Fig.2. The 1-GeV proton linac will be a powerful injector for the present KEK-PS and the improvement of KEK-PS will be considered in the project.

PROTON LINAC

The proton linac of the JHF is composed of an ion source, an RFQ linac, a drift-tube linac(DTL) and a coupled-cell linac(CCL). The accelerated beam is a negative hydrogen beam. The JHF linac system is different from those previously constructed in the following respects. One is adoption of the RFQ linac in place of the Cockcroft-Walton accelerator as the preinjector, and the other is that the rf frequency is approximately twice that of most existing linacs. In the present project, the frequency of the RFQ and the DTL is 432 MHz and that of the CCL is 1296 MHz.

Advantages of high frequencies are that (1) klystrons can be used as power amplifiers instead of triodes or tetrodes commonly used in a 200-MHz region, (2) the shunt impedance of the cavity becomes higher as the frequency increases, and (3) the cavity construction cost should be cheaper owing to small size. It is mainly due to adoption of the RFQ as the preinjector that high frequency choice became feasible, because a preinjector energy of 2-3 MeV is practical by using the RFQ.

Table 1 lists the main parameters of the JHF linac. In the following brief descriptions will be given on each linac section.

(1) RFQ linac The RFQ accepts a negative hydrogen beam with an intensity of 20 mA and an emittance of 1 mm·mrad from the ion source and accelerates it to an energy of 3 MeV. Another option is also considered, in which two RFQ's of the frequency of 216 MHz(half of that of the DTL) are used and beams from both RFQ's are injected into the DTL alternately.

(2) DTL This is a post-stabilized drift-tube linac of the frequency of 432 MHz, and accelerates a beam from 3 MeV to 150 MeV. Focusing is made by permanent magnet quadrupoles.

(3) CCL Above 150 MeV where shunt impedance of the DTL cavity decreases, the coupled-cell cavity is used operating at the frequency of 1296 MHz. Choice of the type of structure is still open. Further study will be needed to compare the alternating periodic structure (APS) and the side coupled structure(SCS).

HEAVY ION LINAC

The heavy ion linac accelerates a variety of ions (from hydrogen to uranium) to an energy of 8 MeV/u. The design feature of the JHF accelerator system is acceleration of unstable nuclei which are produced from relevant target materials through the proton-initiated nuclear spallation reaction.

(1) ion sources

Two kinds of ion sources are used.

(a) ECR ion sources These are the ion sources for ordinary stable nuclei.

(b) ISOL ion source In this ion source, target materials like Ta are bombarded with a high-intensity proton beam, and unstable nuclei produced in the target, after ionized, are accelerated to 60 keV and analyzed to get desired species.

(2) linac

The layout of the heavy ion linac is shown in Fig. 3. Charge-to-mass ratio(q/A) ranges from 1 to 1/60, so that three low-β linacs (indicated as 1,2,4 in Fig. 3) are needed just behind ion sources. Afterwards two different linacs are used. Charge strippers will be used between linac sections to improve acceleration efficiency in the subsequent accelerator.

Table 2 lists the principal parameters of the heavy ion linacs. Since the velocity of ions from heavy ion sources is smaller than that of protons, RFQ's with high efficiency at low-β are used. The split-coaxial RFQ is effective for acceleration of ions with low q/A ratio, and the four-vane type RFQ is effective for ions with relatively high q/A ratio. IH stands for Inter-digital H-type, and effective for acceleration medium-β ions. The final accelerator section is of Alvarez-type which has advantage of easy construction, although it is inferior to the IH type accelerator in respect of shunt impedance.

RING I-A

Ring I-A is a rapid-cycling synchrotron of an energy of 2 GeV. Principal parameters of the ring are listed in Table 3.

Two bunches of protons circulate in the ring, and each bunch is extracted at a rate of 50 Hz in the neutron and the muon laboratories, respectively. The rf frequency is 3.3 MHz at the extraction time, and the bunch length is approximately 200 ns. This bunch length is short enough for the neutron scattering experiments, but much shorter bunch is desirable for a kind of experiments using mesons.

As pointed, reducing beam loss is the most important requirement for the high intensity accelerator like the present one. The intensity will be far beyond that of the KEK booster synchrotron, which has already suffered from radiation problems. To achieve a low-loss operation, the following countermeasures will be considered:
(1) Acceptance of the ring should be 4 times larger in the transverse space and 2 times larger in the longitudinal space than emittance of the circulating beam.
(2) The beam from the linac is chopped at the ring frequency to mate the linac beam with the ring rf bucket.
(3) The rf cavity should have low impedance to work under the heavy beam loading condition.
Secondarily, beam loss must be localized by virtue of collimators. Accelerator components around collimators will be designed to be handled easily by introducing remote-handling techniques, in the maintenance work.

RING I-B

Ring I-B is a slow-cycling synchrotron for acceleration of heavy ions. The ring diameter is the same as that of Ring I-A. Ring I-B has the maximum guide field strength of 1.8 T and the bending radius of 7.5 m. Then it can accelerate proton to 3.2 GeV, 1.3 GeV/u for a particle with q/A = 1/2 and 0.57 GeV/u for uranium. The principal parameters of Ring I-B are shown in Table 4. The magnet system is based on the separated-function design in which bending and focusing actions are provided separately by dipole and quadrupole magnets. As the repetition frequency is 0.5 Hz, their power supplies will be of rectifier type using thyristers. The rf system of Ring I-B is composed of ferrite-loaded coaxial cavities. The design feature is that the frequency modulation range is wide from 0.69 to 4.81 MHz, which is needed for acceleration of particles of q/A = 1/2.

Table 1 Main parameters of proton linac.

(1) General	
Energy	1 GeV
Total length	600 m
Peak current	10 mA
Repetition rate	50 Hz
Beam pulse length	400 μs
Rf duty factor	3 %
(2) Ion source	
Type	volume production
Beam current	20 mA
Norm'd emittance	1 mm·mrad
(3) RFQ	
Energy	3 MeV
Length	2.8 m
(4) DTL	
Energy	150 MeV
Tank diameter	45 cm
Beam hole diameter	15 mm
Accelerating field	3 MV/m
Rf peak power	10 MW
No. of klystrons	4
Length	72 m
(5) CCL	
Structure	APS or SCS
Accelerating field	4 MV/m
No. of tanks	152
Rf peak power	86 MW
No. of klystrons	25
Length	435 m

Table 2 Parameters of the heavy ion linacs

	(1)	(2)	(3)
Linac type	Split-coaxial RFQ	IH (π−3π)	IH (π−π)
Frequency (MHz)	12.5	25	25
Energy (keV/u)			
In	4.2	19	170
Out	170	170	1400
Charge/mass ratio			
Minimum	2/238	9/238	9/238
Maximum	9/239	1/6	1/6
Length (m)	53	6	29
Z_{sh} (MΩ/m)	13	40	150

	(4)	(5)	(6)
Linac type	Four-vane RFQ	IH (π−π)	Alvarez
Frequency (MHz)	100	100	100
Energy (keV/u)			
In	8	800	1400
Out	800	1400	8000
Charge/mass ratio			
Minimum	1/7	1/7	2/17
Maximum	1	1	1
Length (m)	7	4	43
Z_{sh} (MΩ/m)	34	150	40

Table 3 Main parameters of Ring I-A.

Final energy	2.0 GeV
Injection energy	1.0 GeV
Average current	200 μA
Particles per pulse	2.5×10^{13} ppp
Repetition rate	50 Hz
No. of bunches	2
Mean radius	27 m

Table 4 Main parameters of Ring I-B.

Maximum energy	3.2 GeV(proton) 1.3 GeV/u(q/A=1/2) 0.56 GeV/u(uranium,q=69)
Injection energy	2 GeV(proton) 8 MeV/u(heavy ion)
Intensity	1 μA(proton) 0.1 pnA(uranium,q=69)
Intensity of stretched protons	100 μA
Mean radius	27 m
Repetition rate	0.5 Hz

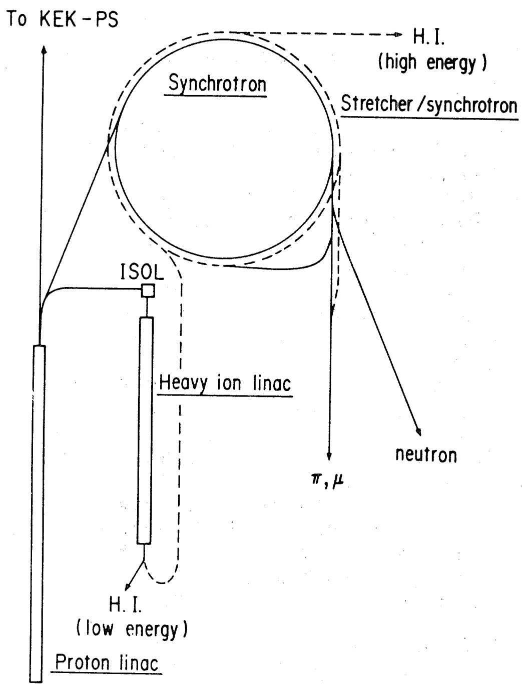

Fig. 1 Layout of the JHF accelerators.

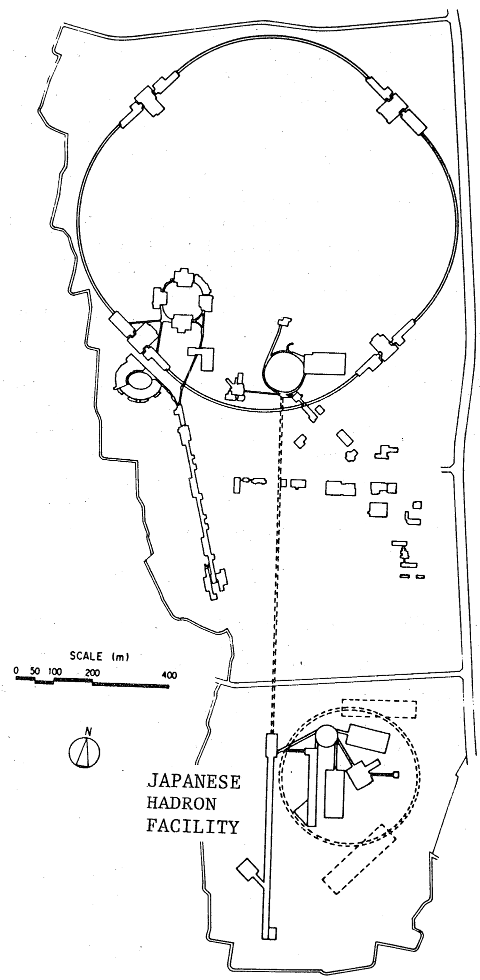

Fig. 2 Proposed site of the Japanese Hadron Facility.

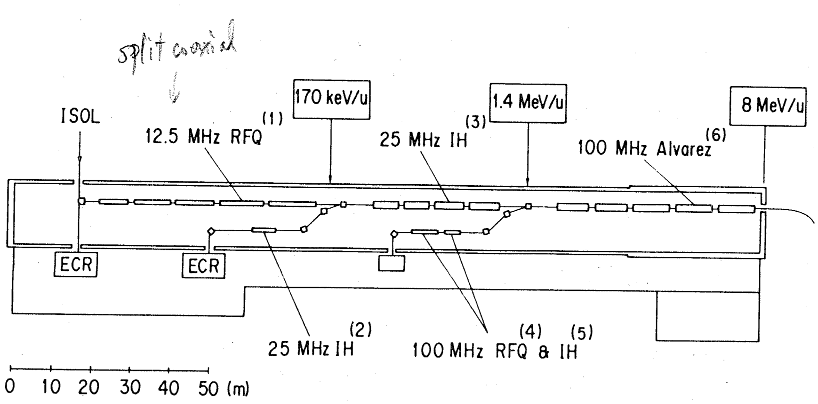

Fig. 3 Scheme of the heavy ion linacs.