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Heavy Ion Medical Accelerator Project by Hyogo Prefectural Government

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Abstract

A project to construct a heavy ion medical accelerator facility for cancer therapy in five years is expected to start from 1996 by Hyogo prefectural government. The site will be located near SPring-8 synchrotron radiation facility in Harima Science Garden City, about 75 km north-west of Kobe city, Japan. Beam particles include proton, helium and carbon. Beam energy ranges are 70 - 230 MeV/u for proton and helium, and 70 - 320 MeV/u for carbon. The beam intensities are required to satisfy the dose rate of 5 Gy/min. for treatment volumes of 15 cmϕ field size and of fully extended spread out Bragg peak (SOBP) over the maximum beam range. The facility will have a horizontal line, a vertical line and an oblique (45°) line for proton, helium and carbon beams, and two isocentric gantry lines for proton beam.

Hyogo prefectural government have been engaged in a construction of Harima Science Garden City, which has about 2000 ha surface and is located about 75 km north-west of Kobe city. The location is shown in Fig. 1. A synchrotron radiation facility SPring-8 and a charged particle therapy facility had been planned as the major facilities in the city. The SPring-8 is now under construction by the Institute of Physical and Chemical Research (RIKEN) and the Japan Atomic Energy Research Institute (JAERI) of the Science and Technology Agency (STA). As a Heavy Ion Medical Accelerator in Chiba (HIMAC) of the National Institute of Radiological Sciences (NIRS) was commissioned [1]-[3] and the clinical trials were successfully started [4] from June in 1994, the Hyogo prefectural government has decided to start the construction of a charged particle therapy facility. This is the first charged particle therapy facility in Japan that is constructed by a non-national but a prefectural government level. This year a basic design study of the facility starts under a financial support by the government.

Beam particles include proton, helium and carbon. Beam energy ranges are 70 - 230 MeV/u for proton and helium, and 70 - 320 MeV/u for carbon. The beam intensities are required to satisfy the dose rate of 5 Gy/min. for treatment volumes of 15 cmϕ field size and of fully extended spread out Bragg peak (SOBP) over the maximum beam range. The facility consists of injector, synchrotron, high energy beam transport lines and treatment system. The injector has two 10 GHz ECR ion sources with 35 keV/u output energy, 1 MeV/u RFQ linac, two-staged Alvarez linacs and debuncher. The first stage linac accelerates proton, helium and carbon up to 5 MeV/u. The second stage linac accelerates only proton from 5 MeV up to 10 MeV. Operation rf frequency of the linacs is 200 MHz. Synchrotron ring is of a separated function type with a strong FODO structure and its super periodicity is 6. Maximum rigidity of the ring is 5.58 Tm. The beam is extracted by the third-order resonance scheme. The beam transport system will have a horizontal line, a vertical line and an oblique (45°) line for proton, helium and carbon beams, and two isocentric gantry lines for proton beam. One of the gantry lines is for future extension. One beam line for physical and/or biological experiments is also anticipated. Table I summarizes the clinical requirement and physical specifications of the charged particle beams.

From the results of the basic design, some reconsideration of the requirements on beam intensities and field size may be done to bring about a simpler and more compact design of the facility. Some options for

future extensions and upgrades will be studied. Compensation of a tune shift due to the space charge effect during multi-turn injection, irradiation synchronized with patient's breathing, beam spill control to have a flat beam structure in time, energy variability during one treatment and raster scanning system are anticipated. In the next year a detailed design study of the accelerator and the buildings will start.

Clinical trials are expected to start in the year 2001. The project will be executed in close collaboration with NIRS. Medical imaging using the synchrotron radiation light from SPring-8 for the diagnosis is anticipated. Table II shows the time schedule of the construction. This schedule has one year delay from an initial one [5] because of an earthquake in Kobe area on January 1995.

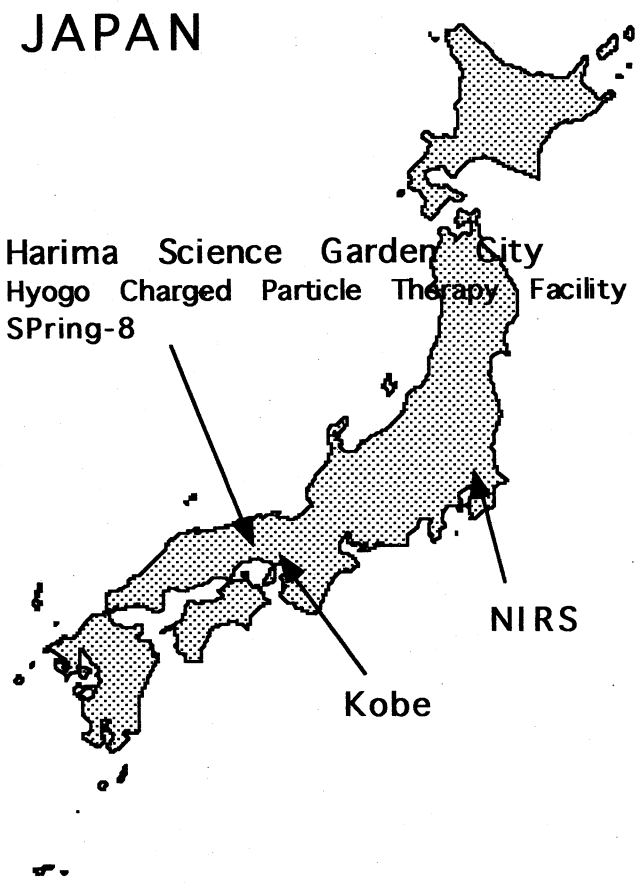

Fig. 1. Location of the Harima science garden city in Hyogo prefecture.

Table I
Clinical Requirement and Physical Specifications of Charged Particle Beams.

Particles	Proton, Helium and Carbon
Energy Range	70 - 230 MeV/u for p & He 70 - 320 MeV/u for C
Beam Intensity	7.2×10^{10} pps for p 1.8×10^{10} pps for He 1.2×10^{9} pps for C
Dose Rate	5 Gy/min for treatment volumes of 15 cmϕ field size and of fully extended Spread Out Bragg Peak (SOBP)
Beam Range	40 - 300 mm for p and He 13 - 200 mm for C
Field homogeneity	± 2% (over treatment field)
Field size	30 cm x 15 cm by magnetic wobbling 15 cm x 15 cm by double scattering method 15 cm x 15 cm for gantry
Displacement of beam axis	± 2 mm (from isocentre)
Irradiation rooms	One horizontal line One vertical line One oblique line (45°) Two gantries for proton
Beam spill length	400 ms
Repetition rate	0.5 Hz for He and C 1 Hz for proton

References

[1] S. Yamada, "HIMAC Accelerator -- Performance and Feature.", Proceedings of NIRS International Seminar on the Application of Heavy Ion Accelerator to Radiation Therapy of Cancer in connection with XXI PTCOG Meeting, Editor T. Kanai and E. Takada, NIRS, Chiba, Japan, November 1994, NIRS-M-103 and HIMAC-008.

[2] K.Sato *et al.*, "Performance of HIMAC", Nucl. Phy. A588(1995)229c-234c.

[3] S. Yamada *et al.*, "Present status of the medical accelerator HIMAC." These proceedings.

[4] H. Tsujii, "Commencing heavy-ion clinical trial at HIMAC.", Proceedings of NIRS International Seminar on the Application of Heavy Ion Accelerator to Radiation Therapy of Cancer in connection with XXI PTCOG

Meeting, Editor T. Kanai and E. Takada, NIRS, Chiba, Japan, November 1994, NIRS-M-103 and HIMAC-008.

[5] A.Itano *et al.*, "Heavy Ion Medical Accelerator Project by Hyogo Prefecture Government.", *ibid.*

Table II

Construction Time Schedule of Hyogo Heavy Ion Medical Accelerator Project.

Budget year	Accelerator, beam delivery and instrumentation	Accelerator building and conventional plants	Hospital	Service utilitiy (hotel,dwelling)
1995	Basic design			
1996	Detailed design and Construction	Design		
1997	Construction	Construction	Design	Design
1998			Construction	Construction
1999	Installation	Commissioning	Commissioning	
2000	Commssioning		Pre-test	Commissioning
2001	Routine Beam Operation		Clinical trial	