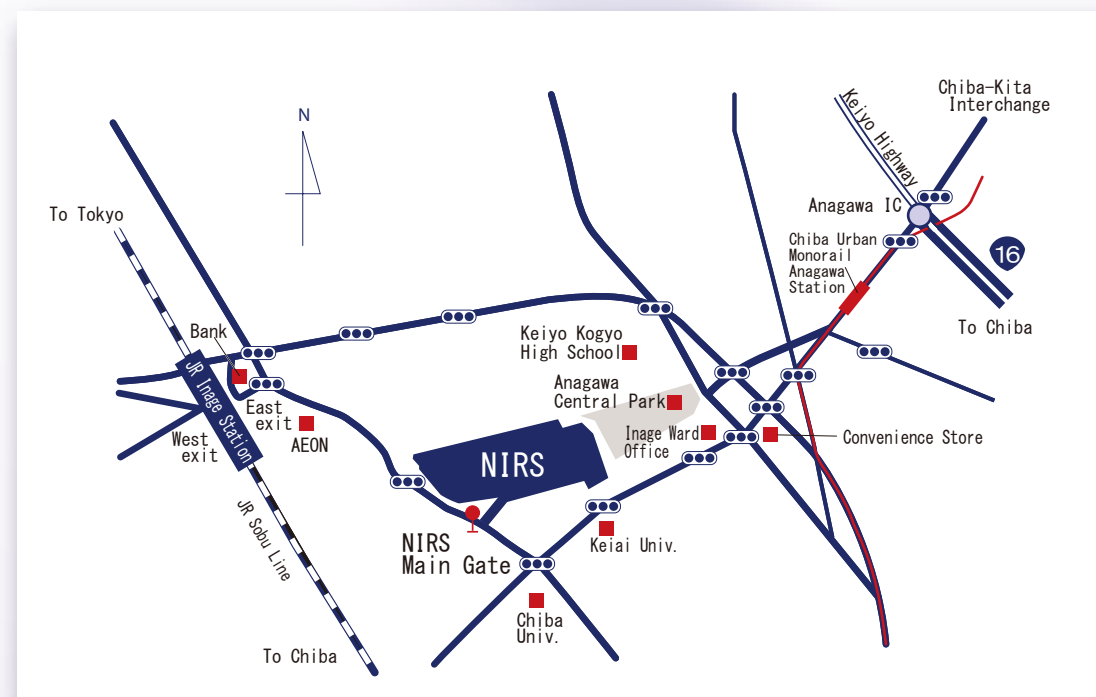


For more information , please contact us:

Research Planning and Promotion Office  
Phone: +81-(0)43-382-3476



- |  |   |
|--|---|
| ● From central Tokyo, Tokyo-Haneda Airport | <by train> Take the JR Sobu line to Inage station.<br>Walk for 10 minutes to NIRS, or take the bus for Sanno-cho from Inage station to Houiken-mae/NIRS's main gate.                  |
|  | <by car> About 1.8 km to NIRS from Anagawa IC on Keiyo Highway.   |
| ● From Tokyo-Narita Airport                | <by train> Take the JR Sobu line in rapid service to Inage station.<br>Walk for 10 minutes to NIRS, or take the bus for Sanno-cho from Inage station to Houiken-mae/NIRS's main gate. |
|  | <by car> About 5.5 km from Chiba-kita IC on Higashi-Kanto Expressway.   |

National Institute of Radiological Sciences, Japan

4-9-1 Anagawa, Inage-ku, Chiba City 263-8555, Japan

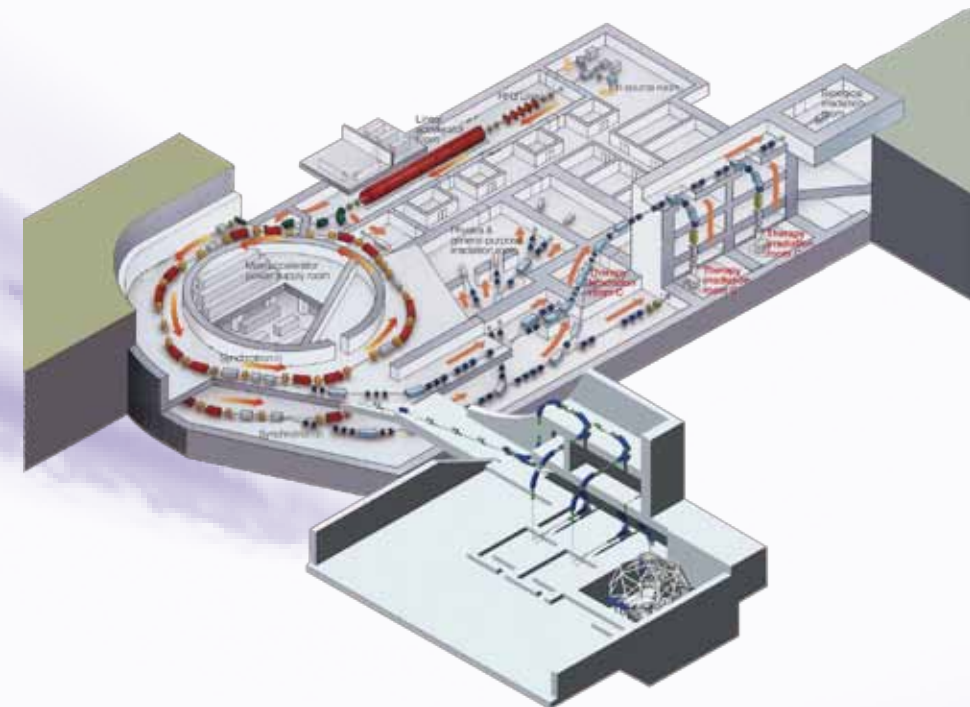
E-mail :nirsinfo@qst.go.jp

Advanced Radiological Sciences  
The World Leader in Radiotherapy for Solid Cancers

# Carbon Ion Radiotherapy

## HIMAC

(Heavy Ion Medical Accelerator in Chiba)

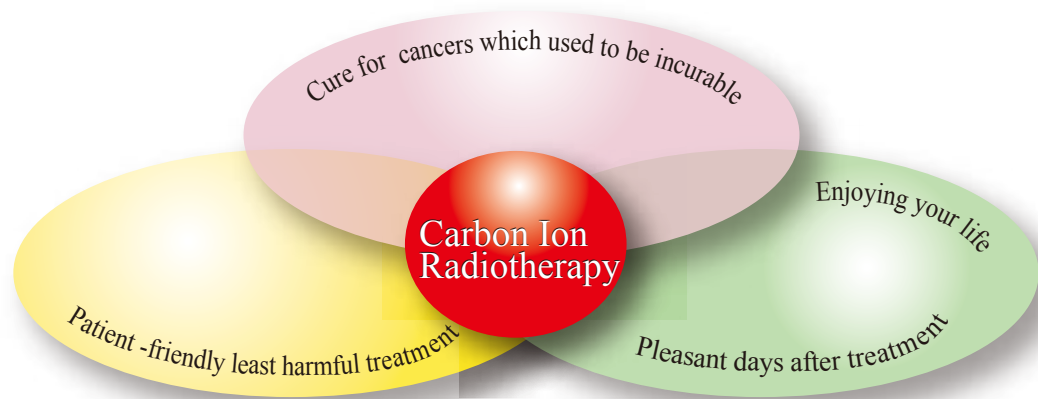


Effective Cure for Intractable Cancers  
Short-Term Treatment  
High Quality of Life

 National Institutes for Quantum and Radiological Science and Technology 

National Institute of Radiological Sciences, Japan

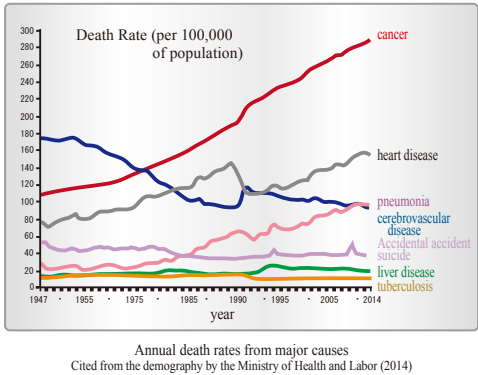
<http://www.qst.go.jp/>



National Institute of Radiological Sciences (NIRS) constructed the first original machine in the world specialized for heavy ion radiotherapy named HIMAC (Heavy Ion Medical Accelerator in Chiba). HIMAC has achieved remarkable results in clinical trials and advanced medicine.

Cancer, the First Cause of Death  
The ultimate solution for treatment is radiotherapy.

The numbers of patients with cancer, and of deaths resulting from cancer are increasing recently. In 2006, the number of people who died of cancer in Japan amounted to 330,000, which is 33% of the total deaths of the year.



What Is the Radiotherapy?

Radiotherapy = cure without surgery: neither painful, hot, nor scary, and no traces left

Radiotherapy is not a treatment by killing cells with the heat generated by radiation, but a sophisticated method of killing cancer cells with radiation, by making microscopic cuts within the molecules of DNA (deoxyribonucleic acid) in a cell nucleus, and of preventing further cell division.

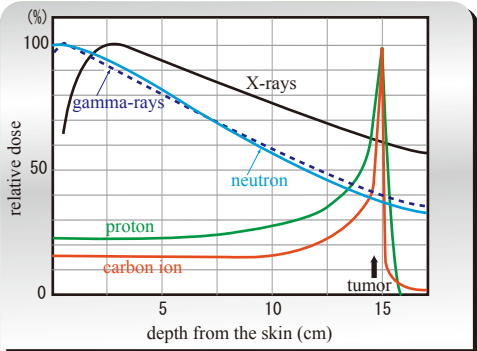
Therapies for Cancers

	surgery	radiotherapy	chemotherapy
case	<ul style="list-style-type: none"><li>early cancer to moderately advanced cancer</li><li>local cancer (not diverged nor scattered)</li></ul>	<ul style="list-style-type: none"><li>early cancer to local advanced cancer</li><li>local cancer</li></ul>	<ul style="list-style-type: none"><li>Leukemia or cancers diffused in the whole body</li></ul>
advantage	<ul style="list-style-type: none"><li>High curability</li></ul>	<ul style="list-style-type: none"><li>minimum loss of form or function</li><li>minimum burden during the treatment</li></ul>	<ul style="list-style-type: none"><li>In some cases, life prolonging effect is remarkable</li></ul>
disadvantage	<ul style="list-style-type: none"><li>It may cause serious loss of form or function</li><li>Unsuitable for elderly patients or patients with physical weakness</li></ul>	<ul style="list-style-type: none"><li>limited side effects left</li></ul>	<ul style="list-style-type: none"><li>In general, side effects are strong.</li><li>Not all patients can complete treatment</li></ul>

Carbon Ion Beam · Physical and Biological Features

Advantages of Carbon Ion Radiotherapy: Cure for intractable cancers, short-term treatment, high quality of life  
Curing cancers not curable by surgery nor conventional radiation

As you can see in the figure on the right, X-rays are not suitable for the treatment of cancers located in a deep region of the body because their effect is gradually decreasing with depth. In comparison, heavy ions are suitable for the treatment of these cancers because they affect cells only weakly until they reach the tumor, and demonstrate an enormous effect at the moment they stop in the tumor.



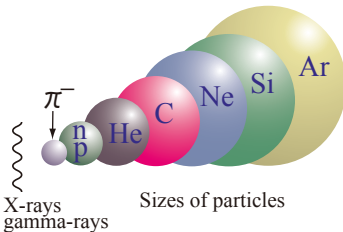
Dose distributions of radiations in the body

What is a heavy ion beam?

heavy ion beam: beam of such ions as carbon(C), neon(Ne), silicon(Si) or argon(Ar), etc. , flying at extraordinarily high speed. NIRS is using a heavy ion (carbon ion) beam for cancer treatment.

Other radiations

proton beam: beam of protons (nuclei of hydrogen) flying at an extraordinarily high speed.  
photon beam: a beam of photons, particles of light . They fly at the speed of light. X-rays and gamma-rays are photon beams at high energy.



※) When these ions are used for the treatment, an extremely large number of flying particles is made up to a bundle (beam) with the same direction for irradiating the tumor.

Physical features of a carbon ion beam

- The depth where the ion stops is exactly predetermined.
- The effect becomes enormous only when the ion stops.

Biological features of a carbon ion beam

- The effect is stronger than X-rays for the same dose.

Difference between X-ray and carbon ion beam treatments

**Cancer treatment with conventional radiation**

The conventional radiation (photon beam) has the strongest effect in shallow regions of the body and its effect is gradually decreasing with depth; in addition, it does not stop at a finite depth but is penetrating furthermore. Therefore, it causes damage to normal tissue before and after the tumor.

※1 highly radiosensitive organs to which irradiation should be avoided.  
※2 cancer cells strongly resistant to conventional radiation (X-rays, gamma-rays) because they have low radiosensitivity.

**Cancer treatment with carbon ion beams**

Carbon ions stop at the exact depth given by the injection energy. In addition, they have the advantage that enormous effect on killing cells is shown only at the point where they stop. Therefore, one can concentrate the damage to cancer cells by adjusting the stopping point for them.

※1 highly radiosensitive organs to which irradiation should be avoided.  
※2 cancer cells strongly resistant to conventional radiation (X-rays, gamma-rays) because they have low radiosensitivity.  
※3 compensating matter for adjusting the dose distribution to the shape of the cancer.



# Instruments for Carbon Ion Radiotherapy

## HIMAC, the first machine for heavy ion radiotherapy in the world

HIMAC is the first machine in the world specially constructed for researches on heavy ion radiotherapy. The mission of HIMAC is to verify the effectiveness and safety of carbon ion radiotherapy and to develop new medical technologies. HIMAC consists of various instruments shown below.



③ Alvarez Linac

Linear accelerator for medium speed ions. Length: 24 m / up to 11% of the light speed



② RFQ Linac

Linear accelerator for low speed ions. Length: 7.3 m / up to 4% of the light speed



① ECR Ion Source

This type of ion source produces highly charged ions.



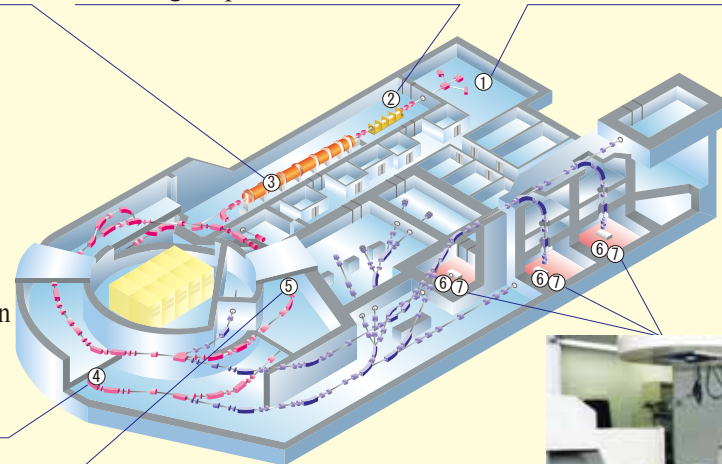
④ Bending Magnet of Synchrotron

These alternating current electromagnets form the orbit of ions.



⑤ RF Cavity

Radio frequency gradually accelerates ions up to 84% of the light speed.



⑥ Irradiation Instruments

For example, a multi-leaf collimator forms the irradiation field of an ion beam adjusted to the shape of the cross section of a tumor.



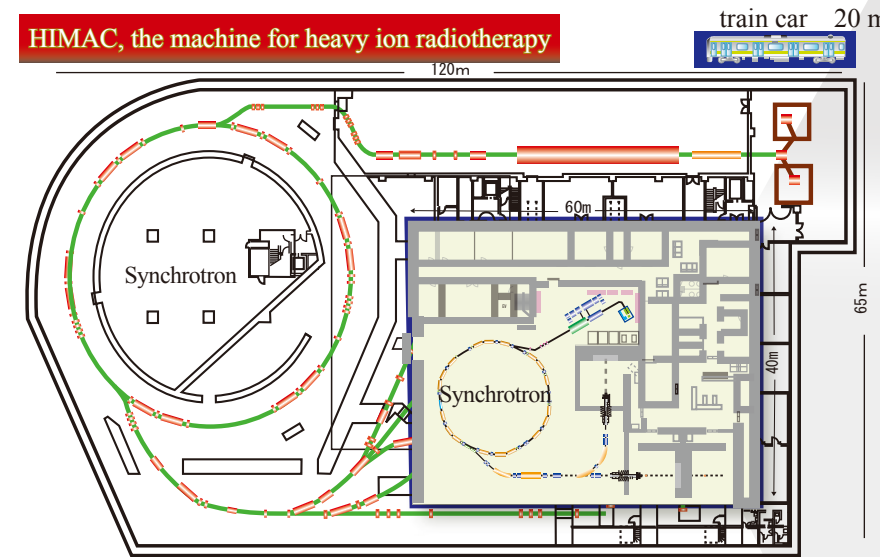
⑦ Treatment Room

HIMAC has three treatment rooms.  
Treatment Room A : Vertical beam  
Treatment Room B : Vertical and horizontal beams  
Treatment Room C : Horizontal beam

HIMAC was designed by NIRS and constructed by Japanese makers.

## Research on Down Sizing for the Standard Type of Facility

HIMAC, the machine for heavy ion radiotherapy



Compact Machine for Carbon Ion Radiotherapy

Since HIMAC was constructed for the research, it has a scale of football court. The optimized type for the treatment becomes one third in scale and in cost because of the optimization of ion species and energy and of down-sized machines. The optimized type facilities work at Gunma University in Saga Prefecture and in Kanagawa Prefecture.



Gunma University Heavy Ion Medical Center  
Carbon Ion Radiotherapy



Kanagawa Cancer Center  
Carbon Ion Radiotherapy



SAGA Heavy ion medical accelerator in Tosu (SAGA HIMAT)  
Carbon Ion Radiotherapy

## Research and Development of Next Generation Irradiation System

### 【Development of Three-dimensional Beam Scanning Irradiation system】

- In order to reduce damages to normal cells, this aims at realizing higher precision irradiation of the tumor which changes its form and size every moment.
- For clinical study, we have started the treatment since 17 May 2011.

### 【Development of Rotating Gantry】

- In comparison with the irradiation from a fixed port, this greatly reduces the burden of a patient in positioning and treatment time, because the direction of irradiation can be freely selected.
- For clinical study, we have started the treatment since 9 May 2017.



New Particle Therapy Research Facilities



Rotating Gantry  
(irradiation from any direction of 360 degrees is available)

## History of Carbon Ion Radiotherapy

1957	1984	1986	1988	1993	1994	2001	2003	2004	2006	2010	2011	2017
• NIRS was established	• National project of HIMAC started under the first 10-year comprehensive strategy against cancer by the Japanese government.	• Basic design of HIMAC started.	• Construction of HIMAC started.	• Construction of HIMAC was accomplished. • Research Center of Charged Particle Therapy was established.	• Clinical trial of carbon ion radiotherapy started. • Research on upgrading of HIMAC started.	• Total number of treated patients exceeded 1000. • Research Center for Charged Particle Therapy was established.	• Carbon ion radiotherapy was approved as advanced medicine by the Minister of Health, Japan.	• Total number of treated patients exceeded 2000. • Research on down sizing of standard type of facility started.	• Research and development of Next Generation Irradiation System started.	• An optimized type for the treatment was constructed At Gunma University and commissione	Clinical trials of the next-generation scanning system were started.	Clinical trials of a rotational gantry were started.

# Frequently Asked Questions

## Fundamental Features

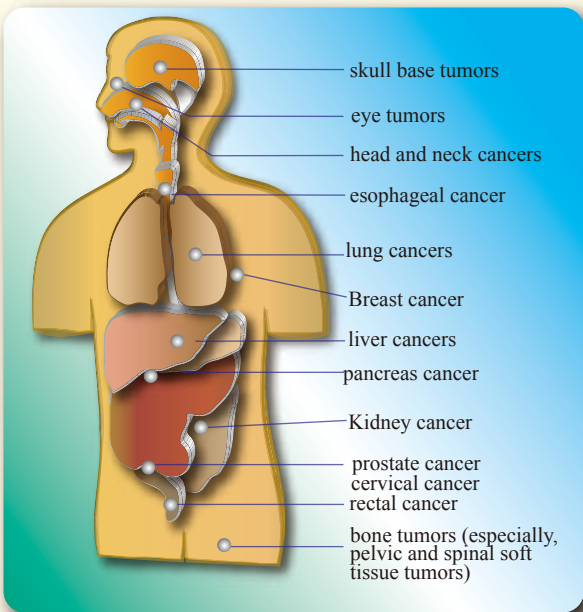
Q1. What is the most important difference of carbon ion radiotherapy from proton radiotherapy?

A1. Carbon ion radiotherapy shows greater effect in attacking tumor for the same dose. As a result, it can remarkably reduce the number of sessions for treatment. For radioresistant cancers such as osteosarcoma, carbon ion radiotherapy is especially powerful because of its higher dose convergence and biological effectiveness compared with X-ray or proton beam.

## Applicable Cases and Clinical Results

Q2. What cases the carbon ion radiotherapy can be applied at NIRS?

A2. Major cancers are as follows.



### 【Cancers for clinical trials】

malignant melanoma (choroid in the eye, etc.)

### 【Cancers for public health insurance】

- **bone and soft tissue sarcoma**  
surgery not applicable cases . . . . . 4-week treatment

### 【Cancers for advanced therapy (partially insured)】

- **head and neck cancers**  
nose, paranasal sinus, salivary gland . . . 4-week treatment
- **lung cancers (non-small-cell cancers)**  
local advanced cancer . . . . . 3~4-week treatment  
stage I 1 day or 3-week treatment
- **liver cancers** . . . . . 2-day treatment
- **pancreas cancer** . . . . . 3-week treatment
- **prostate cancer** . . . . . 3-week treatment
- **cervical cancer** . . . . . 5-week treatment
- **rectal cancer (Postoperative recurrence)**  
surgery not applicable cases . . . . . 4-week treatment

Q3. What are the cases the treatment at NIRS is not applicable?

- A3. ■ In case of metastasis
- In principle, carbon ion radiotherapy is not applicable to metastasis to the lung etc., far from the primary region (distant metastasis). In the case of wide spread metastases in the whole body, carbon ion radiotherapy is not applicable for individual metastases either.
- In case of post-radiotherapy
- Since irradiation of carbon ions on to the lesion already irradiated in the past risks serious side effects, the patient with the present lesion already irradiated is, in principle, out of application.
- In case of cancers in bag-shaped hollow organs or the cases for which the therapies have been established by other methods
- stomach cancer, duodenum cancer, ovary cancer, etc.



Q4. Is heavy-ion radiotherapy really effective?

A4. In radiotherapy, it takes a long time to evaluate the effects of treatment in radiotherapy. Because the tumor does not immediately disappear. Any obvious change is not observed right after the irradiation even with a sufficient dose. On the other hand, inside the cell nuclei, so serious change has happened that DNA, the record of genetic information, has been received an unrecoverable damage. Since the tumor cells lose their ability to proliferate, the tumor shrinks or disappears. It takes from one month to one year or two years, depending on the kind of a tumor. The follow-up with the indices of 3 year- or 5 year-local control rate and survival rate is carried out to evaluate the clinical result.

Local control rate is the rate that a tumor disappears or a shrunk tumor does not repopulate. On the other hand, there is a possibility that an advanced cancer causes metastasis. Local control rate takes account of only irradiated tumors except for metastasis.

Survival rates are classified into several indices like cause-specific survival rate, total survival rate, etc. Total survival rate is mainly used for the evaluation result of a treatment. Cause-specific survival rate is the survival rate due to the original cancer, excluding other causes; other disease, accident, etc. Total survival rate includes the deaths by other causes. The criteria for local control rate and survival rate are exactly defined by the protocol which precisely provides how to treat a cancer of what kind, like a recipe of treatment. The effectiveness and the safety can be evaluated. These clinical results are published not only in academic papers for specialists but also in public lectures or in our home pages in a style easy to understand for non-specialists.

## Medical Cost

Q5. How much is the expense of a patient from abroad?

A5. In the case of a patient from abroad, being not covered by the Japanese National Health insurance, the technical fee for the carbon ion radiotherapy is 4,500,000 yen. Additional expenses for traveling, staying, hospital, etc. are necessary.