

## 日中科学技術交流協会講演会

# 「中国の粒子線加速器発展状況と我が国のあり方」 北京高能研（IHEP）の概要：2013年11月15日訪問

IHEP側主な出席者

WANG Jiujing 副所長

TANG Jingyu 氏

Beijing HE-Racing Technology DAI Xuwen 社長



# 歴史

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- 1950年：前身である Institute of the Chinese Academy of Science が設立
- 1953年：Institute of Physics, CAS に改名
- 1958年：Institute of Atomic Energy に改組
- 1973年：IAEOの下部組織として IHEP 設立
- 現 Wang Yifang 所長は IHEP 6代目所長
- 多くの著名な物理学者を輩出
- 鄧小平氏～習近平氏まで歴代国家主席来訪
- Carlo Rubbia 氏はじめ多くのノーベル賞受賞者来訪

# 鄧小平国家主席来訪時の写真



No matter past, present or future,  
China must develop its own high  
technology, and must take its place in  
the field of science and technology.

## 組織・施設

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- ・現在、7研究部門含む20部門に1400人が所属内300人が学生 基礎科学研究所として中国1の規模
- ・年間予算は約\$150M?(人件、研究、維持費)
- ・多くの研究施設と将来計画
- ・Machine Shop を持っている  
現在はスピンアウトして会社として経営している。中国内の研究所だけでなく、世界中に機器を供給している。

→ 詳細は以下IHEP側発表資料参照

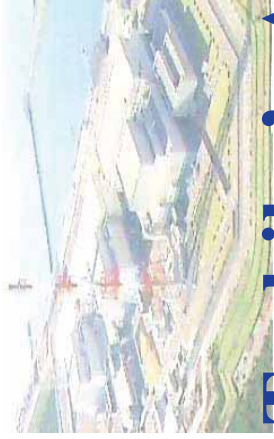
- ① Introduction on IHEP
- ② Introduction on IHEP Machineshop



## まとめ

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- ・訪れた全ての研究所で言えることだが、海外留学経験を持つ若手が活気を持って研究をおこなっている。
- ・若いリーダーが多く、多くの将来計画を同時に走らしており、パワーを感じる。
- ・Machine Shopもレベルが高く(5Sはまだまだ)、世界を相手にビジネスを行っている。
- ・中国に技術を盗まれる、と言っていた時代は終わった。今後コラボレーションが必須。



# Toshiba's Approach to Development of Heavy-Ion Radiotherapy Systems for Cancer Treatment



07 Mar, 2014

**Toshiba Corporation**  
Power Systems Company



# Contents

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- **Toshiba's Accelerator and Superconducting Project**
- **Approach to Heavy-Ion Radiotherapy Systems**
- **Development of Next-generation Accelerator with the aim of downsizing the System**
- **Summary**

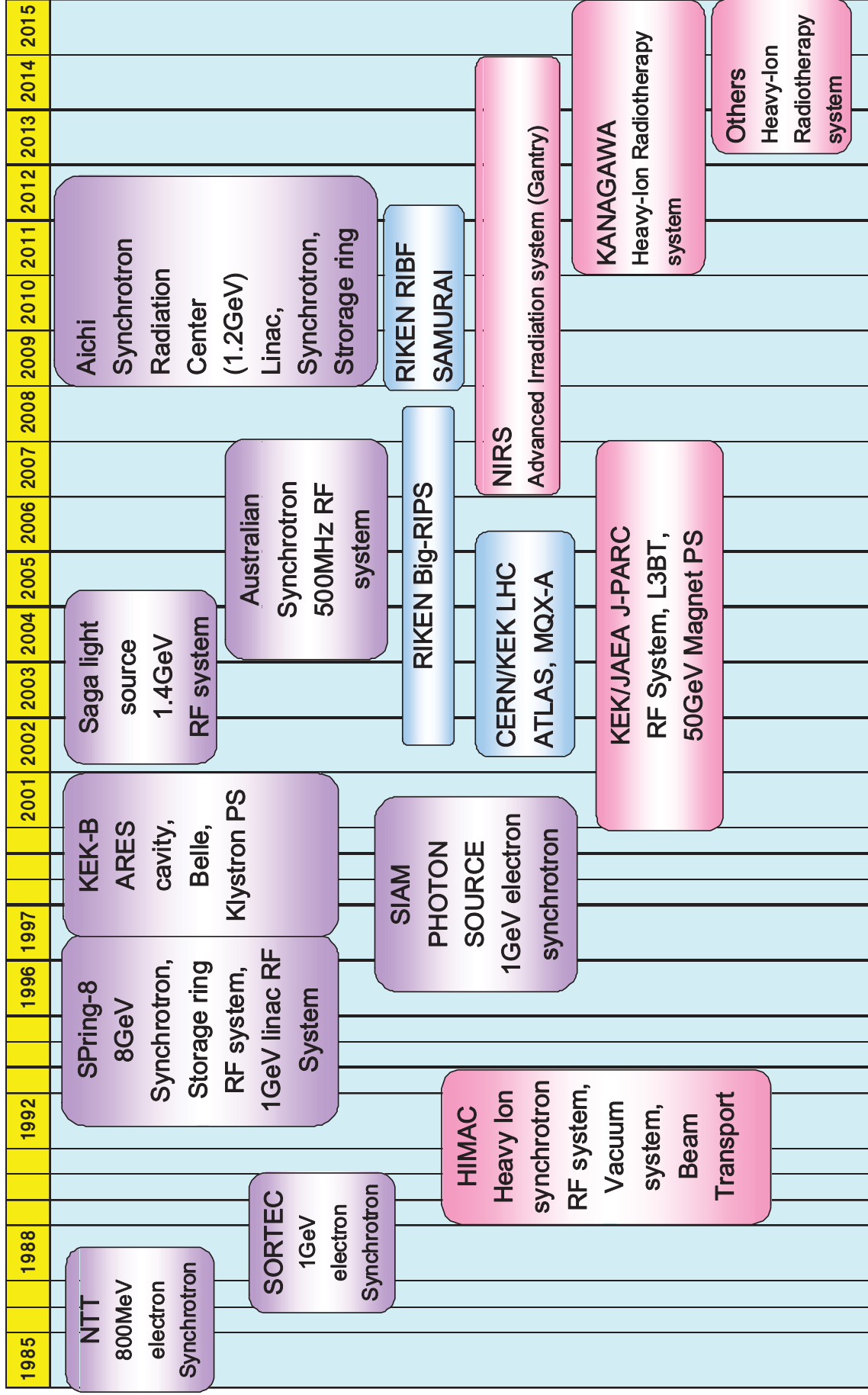


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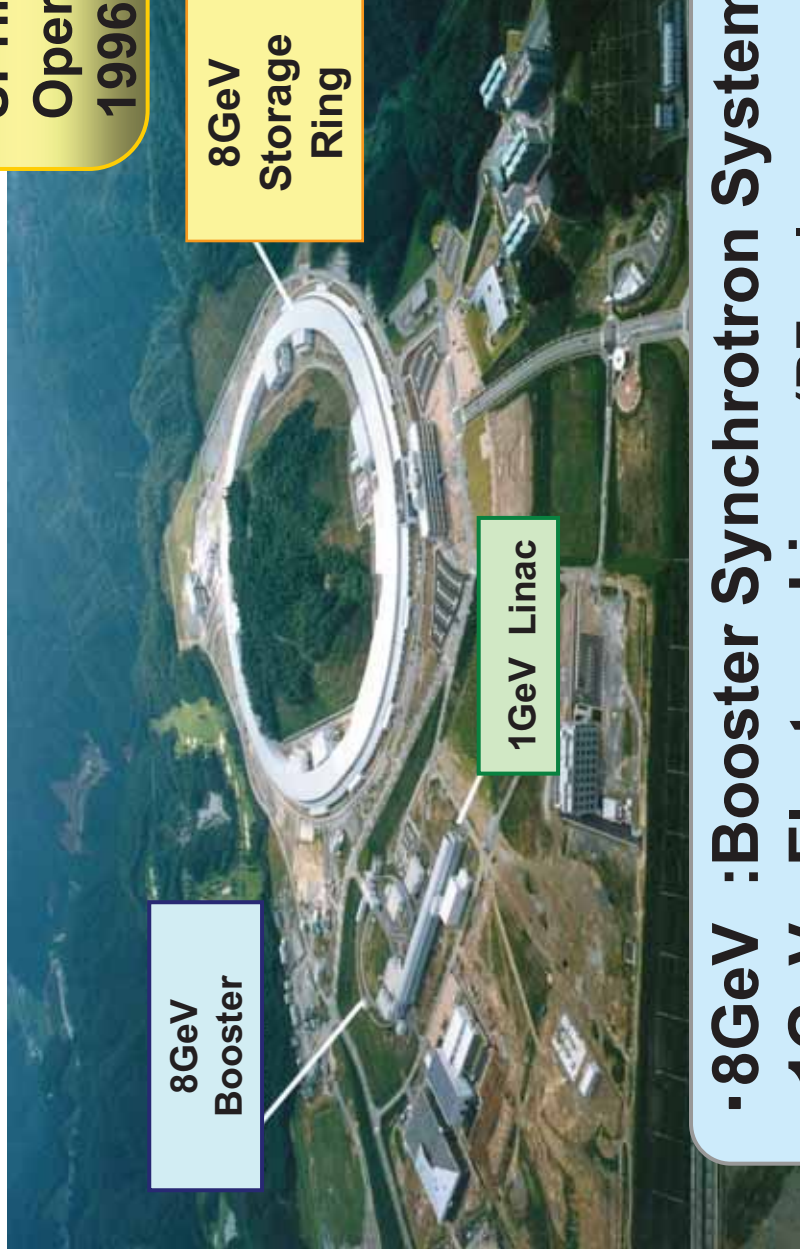
# TOSHIBA Experiences on Accelerator System



# TOSHIBA Accelerator System

## ● Super Photon Ring 8GeV (SPring-8)

JAERI/RIKEN  
SPring-8  
Operation since  
1996



8GeV  
Booster

8GeV  
Storage  
Ring

1GeV Linac

- 8GeV : Booster Synchrotron System
- 1GeV : Electron Linac (RF pulser)
- 8GeV : Storage Ring (RF system)

# Heavy Ion Synchrotron RF System

## RF System for Heavy Ion Synchrotron

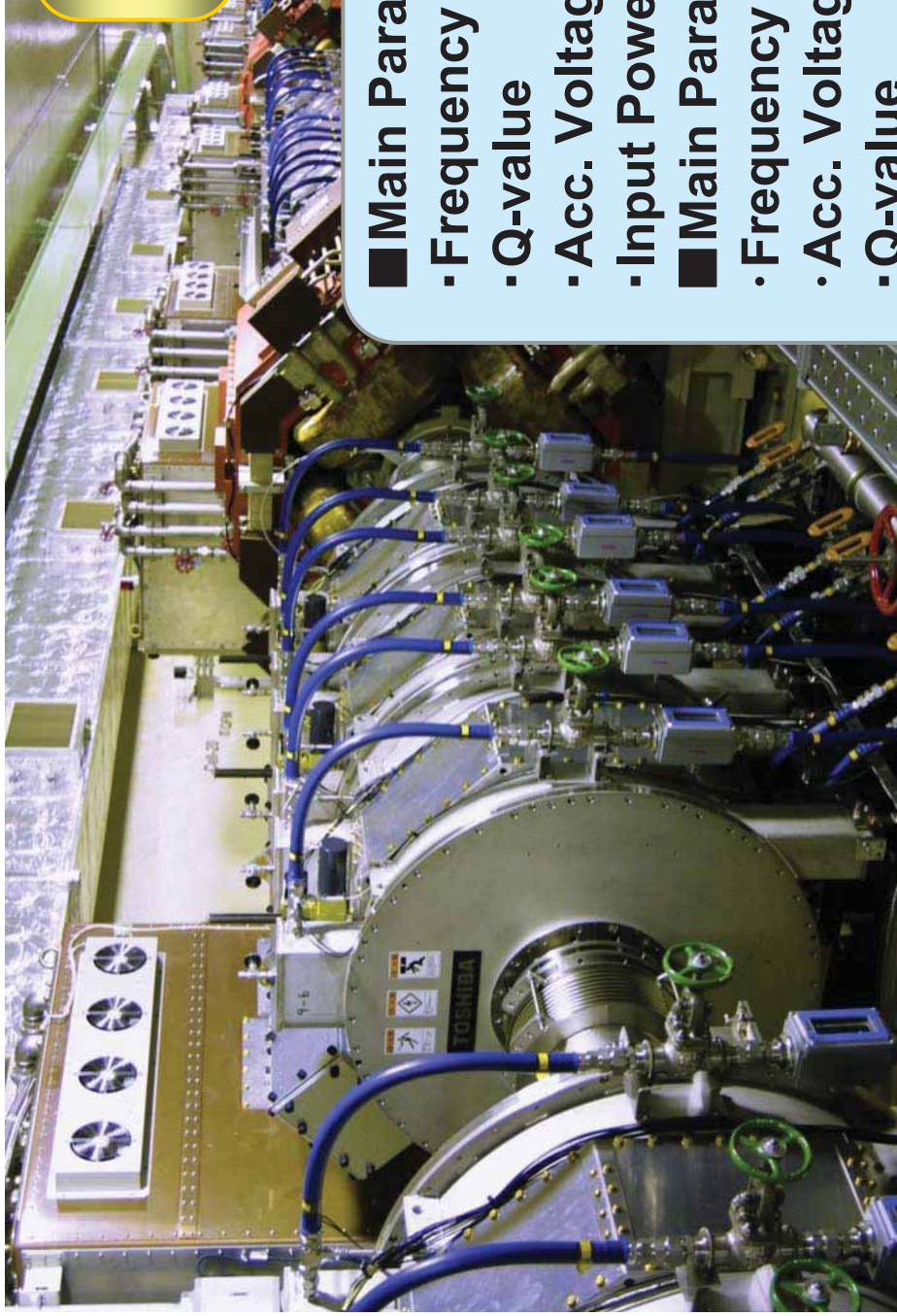
TOKYO UNV. /TARN II  
NIRS/HIMAC  
MELCO/HIBMC  
1986-2000



- Main Parameter :
- RF Frequency 1-8MHz
  - Accelerating Voltage 6kV/Gap
  - Ferrite Type TDK SY6

# Proton Synchrotron RF Systems

## RF Systems for J-PARC Proton Synchrotron

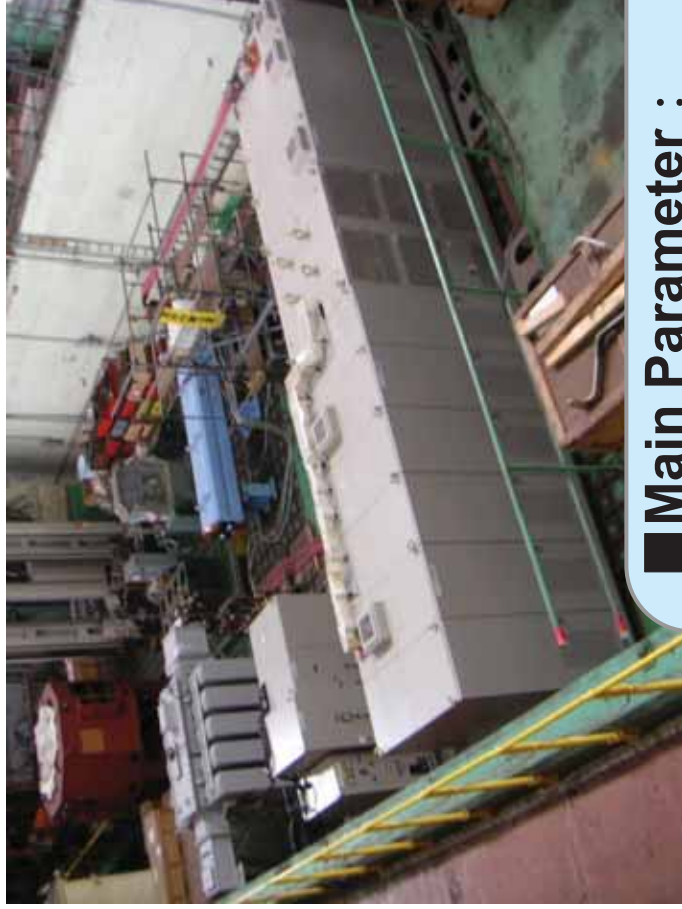


KEK&JAEA  
2000-2007

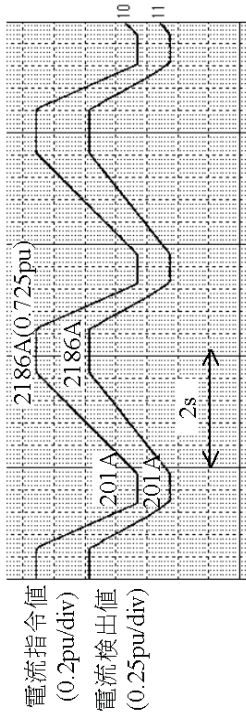
- Main Parameters for RCS
  - Frequency 0.47-5.0MHz
  - Q-value 2
  - Acc. Voltage 40kV
  - Input Power 1MW
- Main Parameters for MR
  - Frequency 1.6-1.7MHz
  - Acc. Voltage 40kV
  - Q-value 25
  - Input Power 1MW

# Proton Synchrotron Magnet Power Supply

- Magnet Power Supply for J-PARC Main Proton Synchrotron



**KEK**  
**2002-2007**

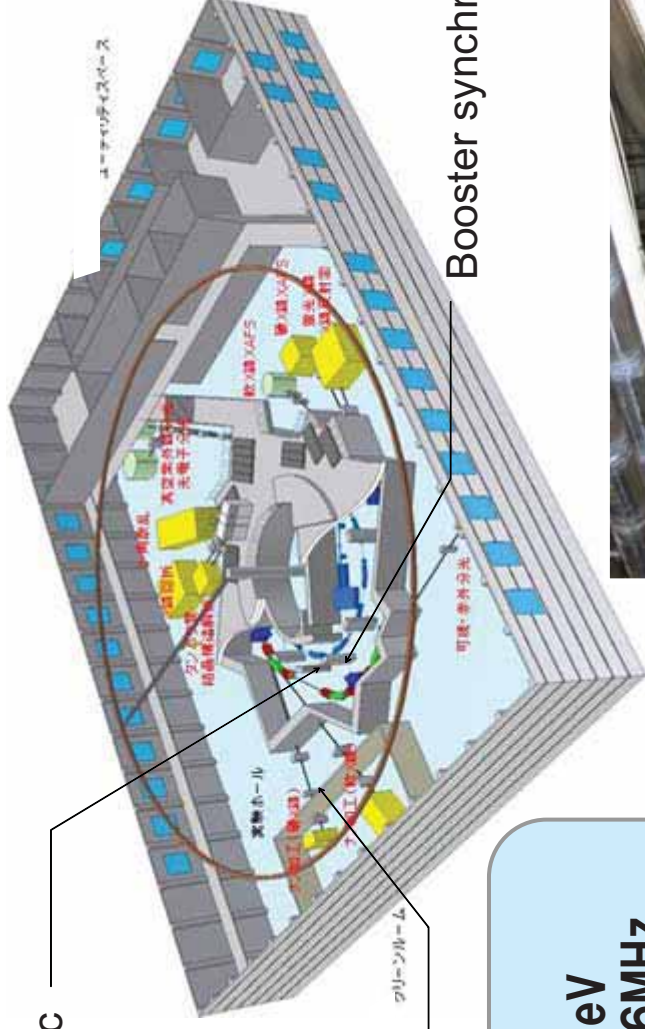


- Main Parameter :
- D Magnet PS : 2186A, 4.2-4.5kV x 6
- Q Magnet PS: 1037A, 2.1-4.2kV x 4
- Q Magnet PS: 1123A, 420-800V x 7
- Sext. Magnet PS: 280A, 370V x 3
- Current Stability:  $\pm 0.5 \times 10^{-4}$  (@Max.Current)

# Aichi Synchrotron Radiation Center

Linac

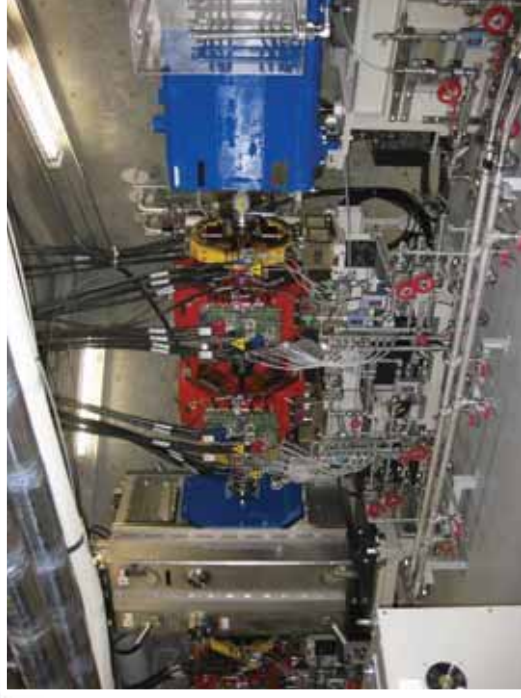
Operation from 2012



Storage ring

Booster synchrotron

- **Injector linac**      **50MeV**
- Electron energy      **2856MHz**
- RF frequency
- **Booster Synchrotron**
- Electron energy      **1.2GeV**
- Circumference      **49.2m**
- Repetition rate      **1Hz**
- **Storage ring**
- Electron energy      **1.2GeV**
- Circumference      **72m**
- Current      **300mA**
- Emittance      **50nmrad**

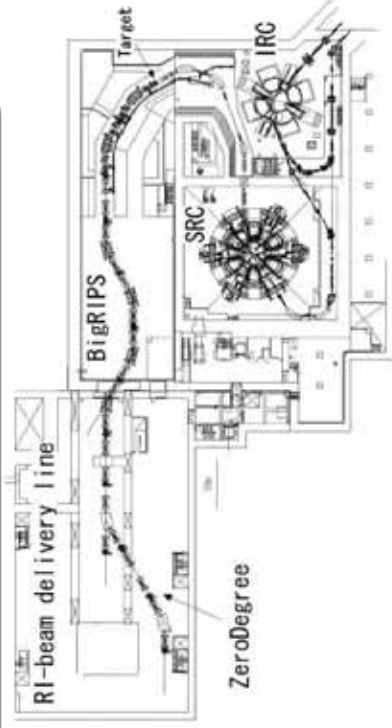


<http://www.nusrc.nagoya-u.ac.jp/>

# RIKEN RI Beam Factory BigRIPS

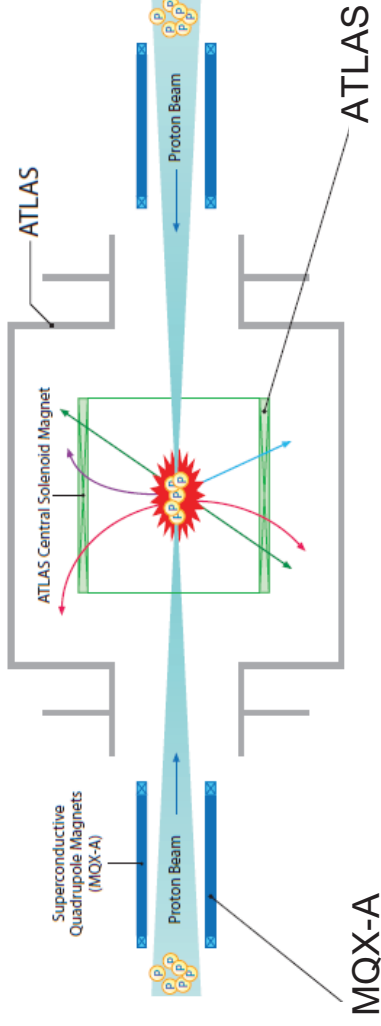
## ● Superconducting Triplet Quadrupole Magnet

- Main Parameter : Superferric
- Type Superferric
- Eff. Length 0.5m/0.8m/0.5m
- Warm Bore Radius 0.14m
- Coil Parameter :
- Nominal Current 135A
- Peak Field(Nominal) 4T
- Winding Race Track
- Cooling Liquid Helium





# CERN/KEK LHC Superconducting Magnet



Operation since 2003



## ATLAS Central Solenoid Magnet

- Coil Inner Radius 1229mm
- Coil Length 5300mm
- Central Magnetic Field 2T

## Quadrupole Magnet for LHC (MQX-A)

- Magnet Length 6.3m
- Coil Inner Radius 35mm
- Peak Field(Nominal) 9.6T

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# System concept

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- Small-sized standard design
- Based on cutting-edge technology

**Advanced Accelerators**

- High-speed scanning irradiation
- Robotic-arm type patient bed
- Treatment management system

**State-of-art treatment room**

**Facility Design for customer**

- Minimizing construction period and cost
- Human friendly design for patients and medical staff

**Based on three strong technologies, we supply the technology of heavy ion radiotherapy system handling 2,000 patients and more annually.**

# Activities in Radiotherapy

- (1) NIRS - Completed New Treatment Facility (operation started)
- (2) KCCCH - Received the order for Ion-Beam Radiation Oncology Center in Kanagawa

## New Treatment Facility at NIRS



( By courtesy of NIRS )

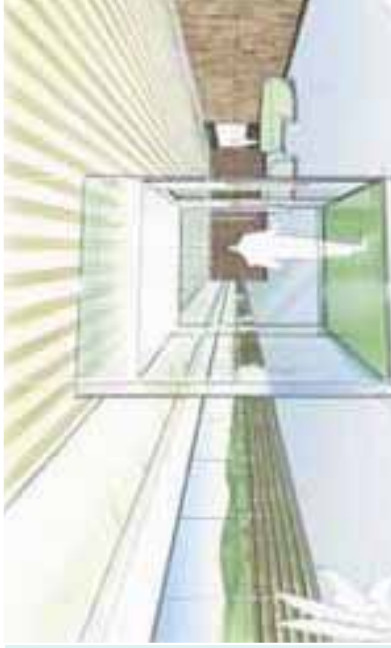
## Ion-Beam Radiation Oncology Center in Kanagawa (i-ROCK) at KCCCH



( By courtesy of KCC )

# Patient load alleviation

**Design alleviating  
mental load**



**Won Good Design Award 2011 (gold award)  
by the treatment room design  
with NIRS and Nihon Sekkei inc.!!**

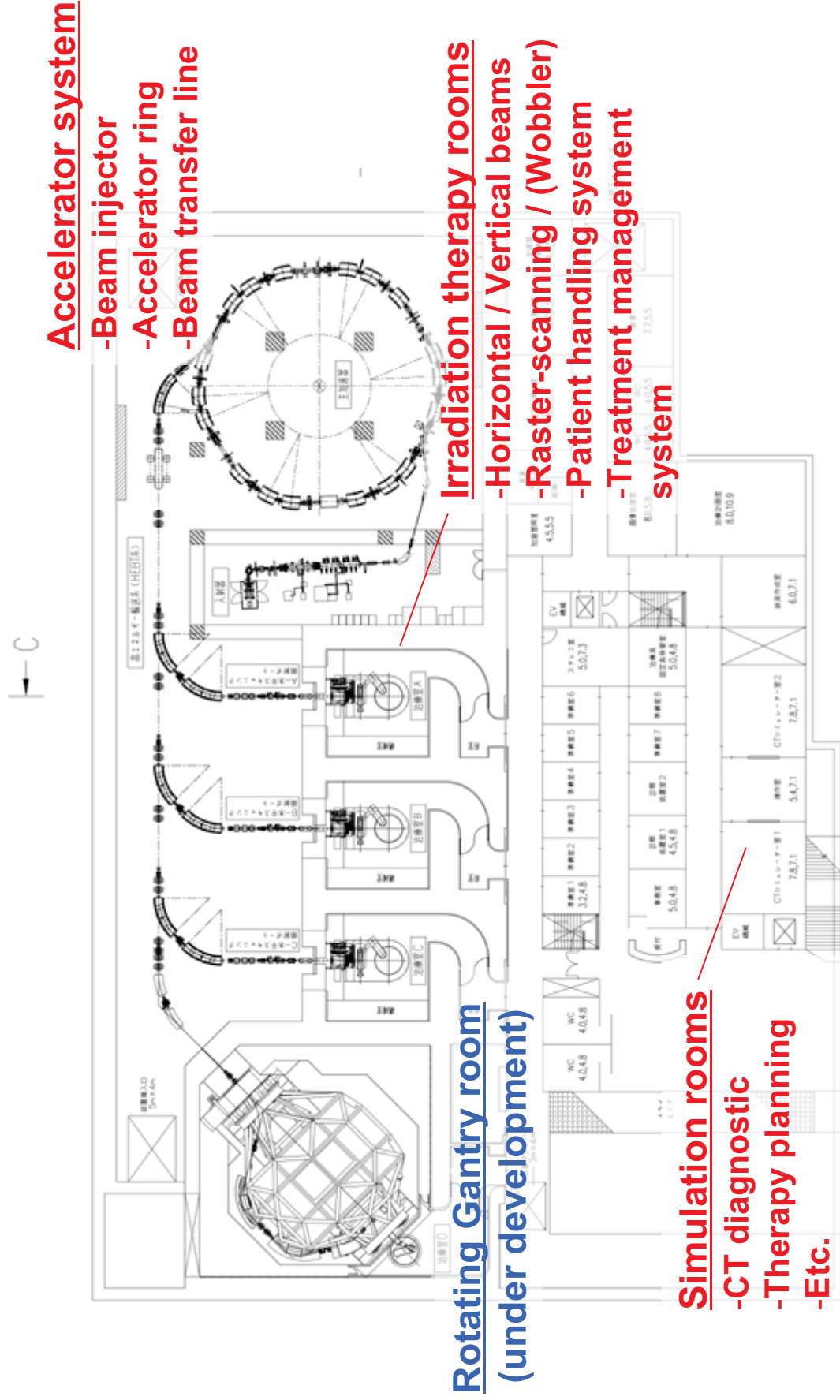
**Technology  
alleviating  
physical load**



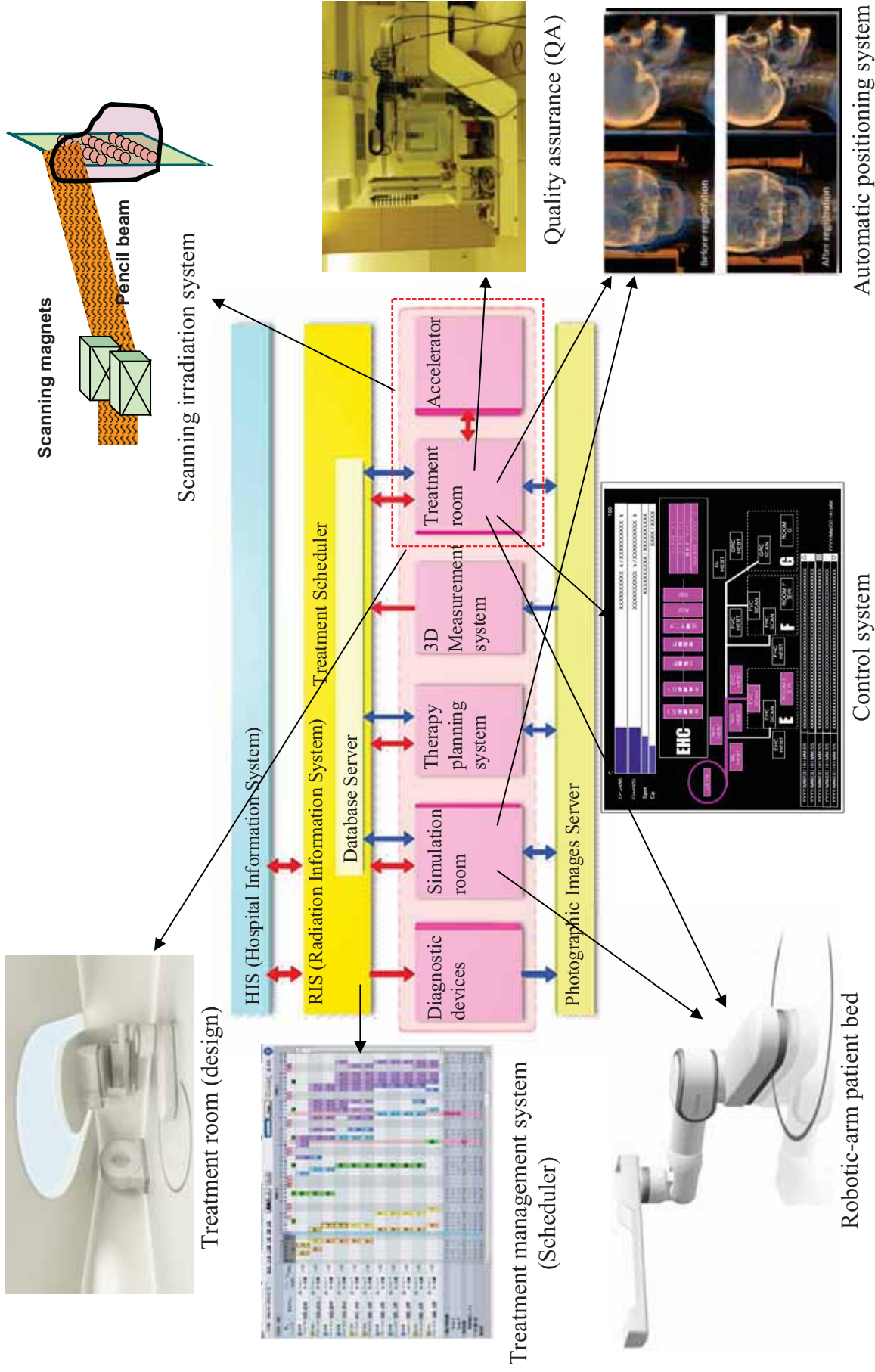
Robotic arm bed



# Example of a facility



# Technical Items supporting System Configuration



# Treatment Management System



Home page



Monthly schedule



Individual patient schedule

TMS is a web application. As it is accessible from anywhere in the facility, real-time information sharing is possible among staff members.

( By courtesy of NIRS )



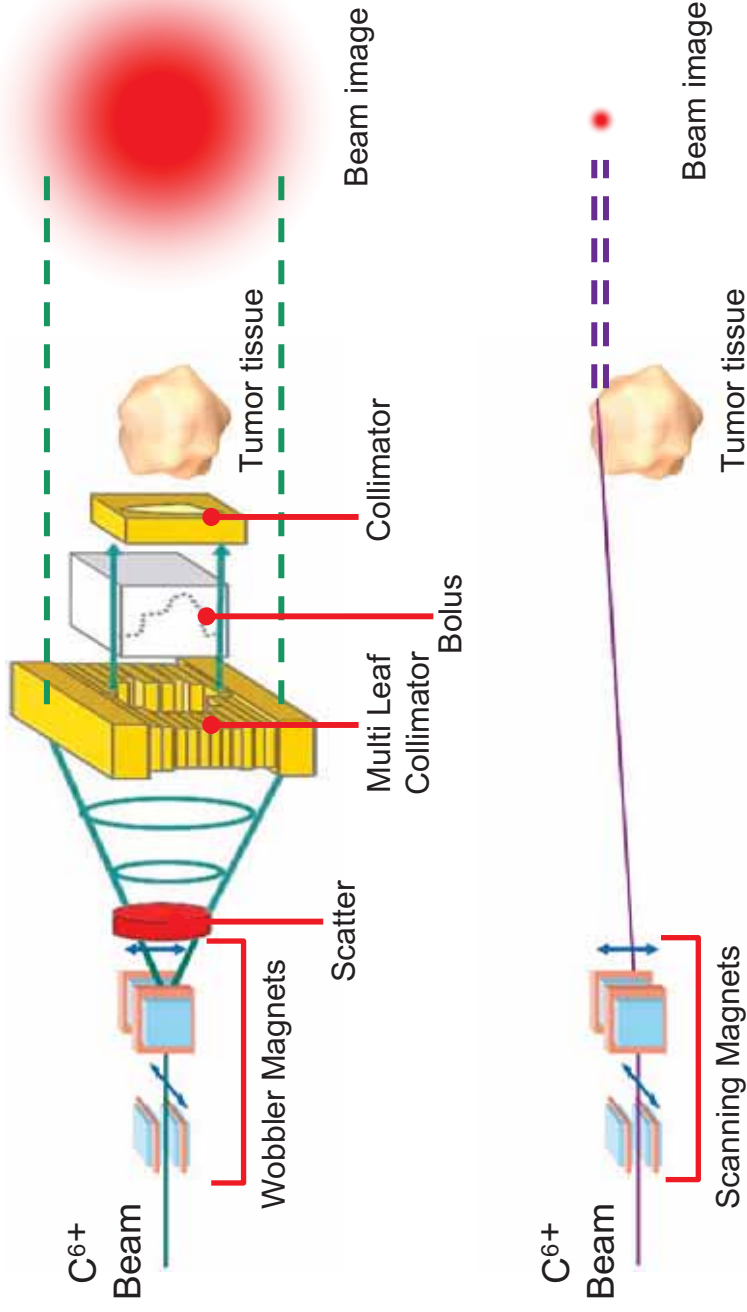
# Auto Scheduling



 Immobilizer production  
 Rehearsal  
 CT simulation  
 Irradiation

 Patients (Color represents protocol)

# Raster-scanning system



## Wobler method

## Scanning method

**Merits** (in comparison with wobler method)

- (1) High beam efficiency
- (2) Dose controllable on complexly-shaped tumor tissue
- (3) Dose controllable on tumor tissue daily changing in shape and location
- (4) Dose minimized on normal tissue, especially in proximal end
- (5) Unnecessary bolus nor collimators

# Patient positioning with robot-arm type bed

Automatic setting of positioning data

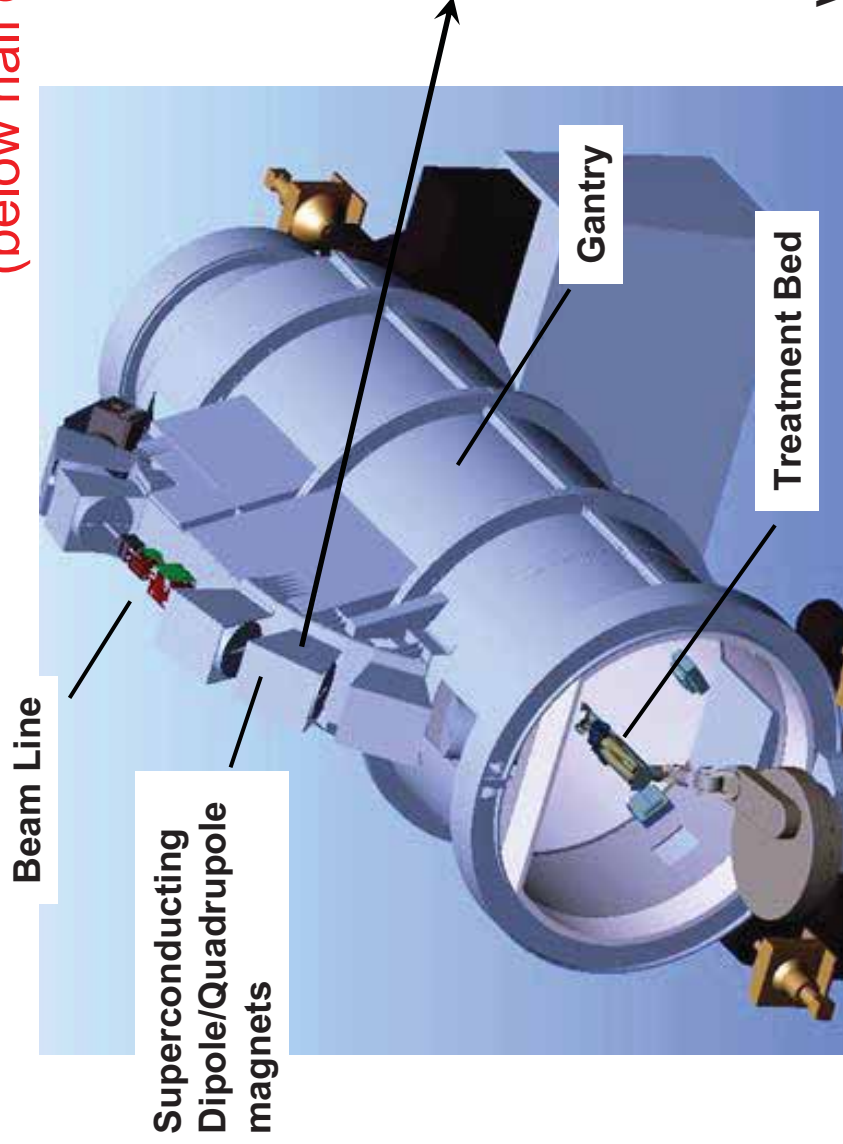
False operation protection by lightening buttons



Positioning time : ~8min in average, ~3min in minimum.

# Superconducting Rotating Gantry

Superconducting technology is applied to reduce the total weight of the gantry.  
(below half of HICAT gantry at Heidelberg)



Refrigerators directly cooling SCM



Vacuum Vessel containing SCM

Superconducting magnets will be directly cooled by refrigerators, which eliminates the annoying troublesome liquid helium handling.

# Superconducting Rotating Gantry

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**Manufacturing Technique for Compact Supercond. Magnet**



**Surface winding technology  
(One stroke drawing)**

- Automatic and precise NC winding
- Suitable for complicated configuration

**Curved Coil manufactured by  
surface winding technology**

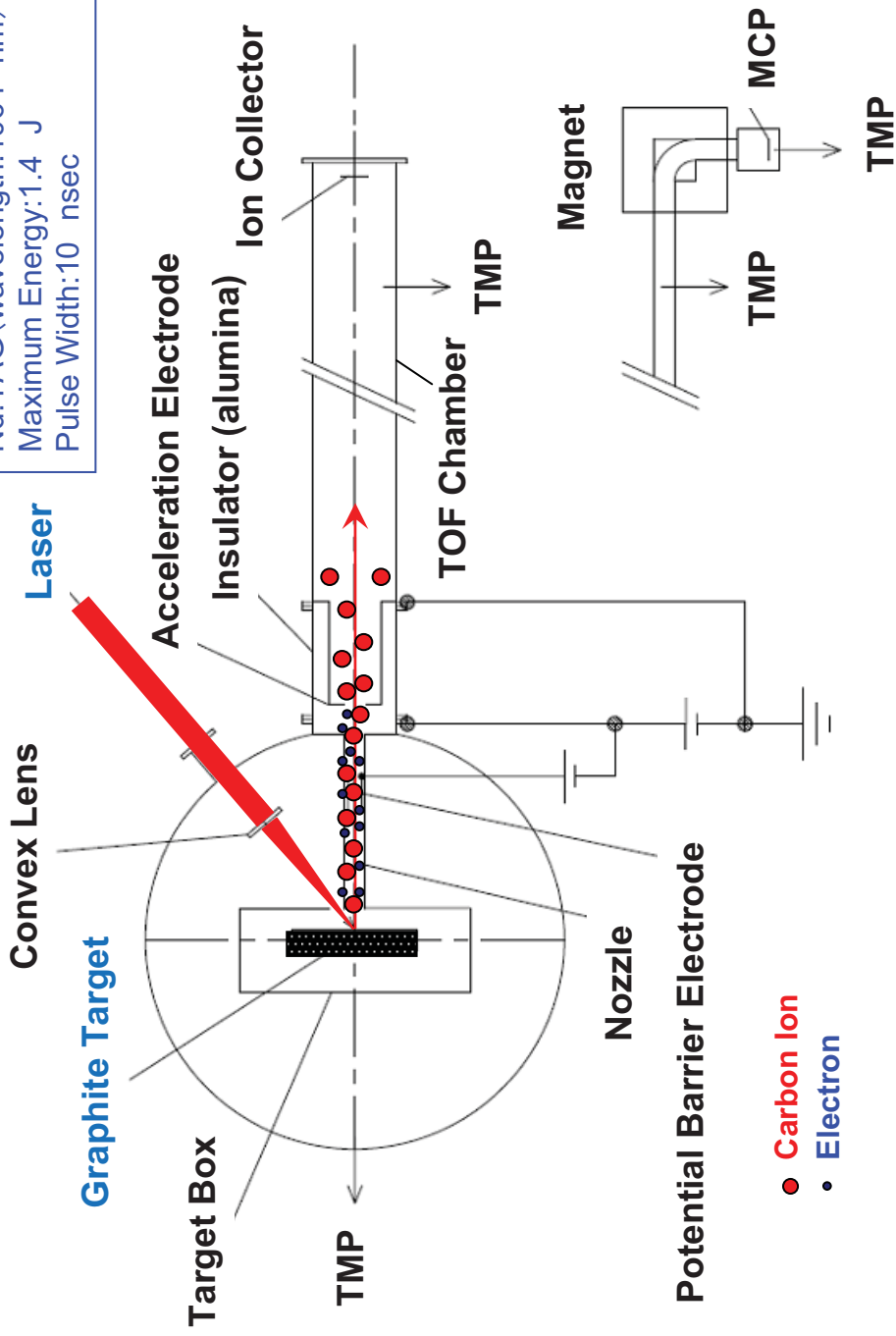
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# Operating Principle of LIS

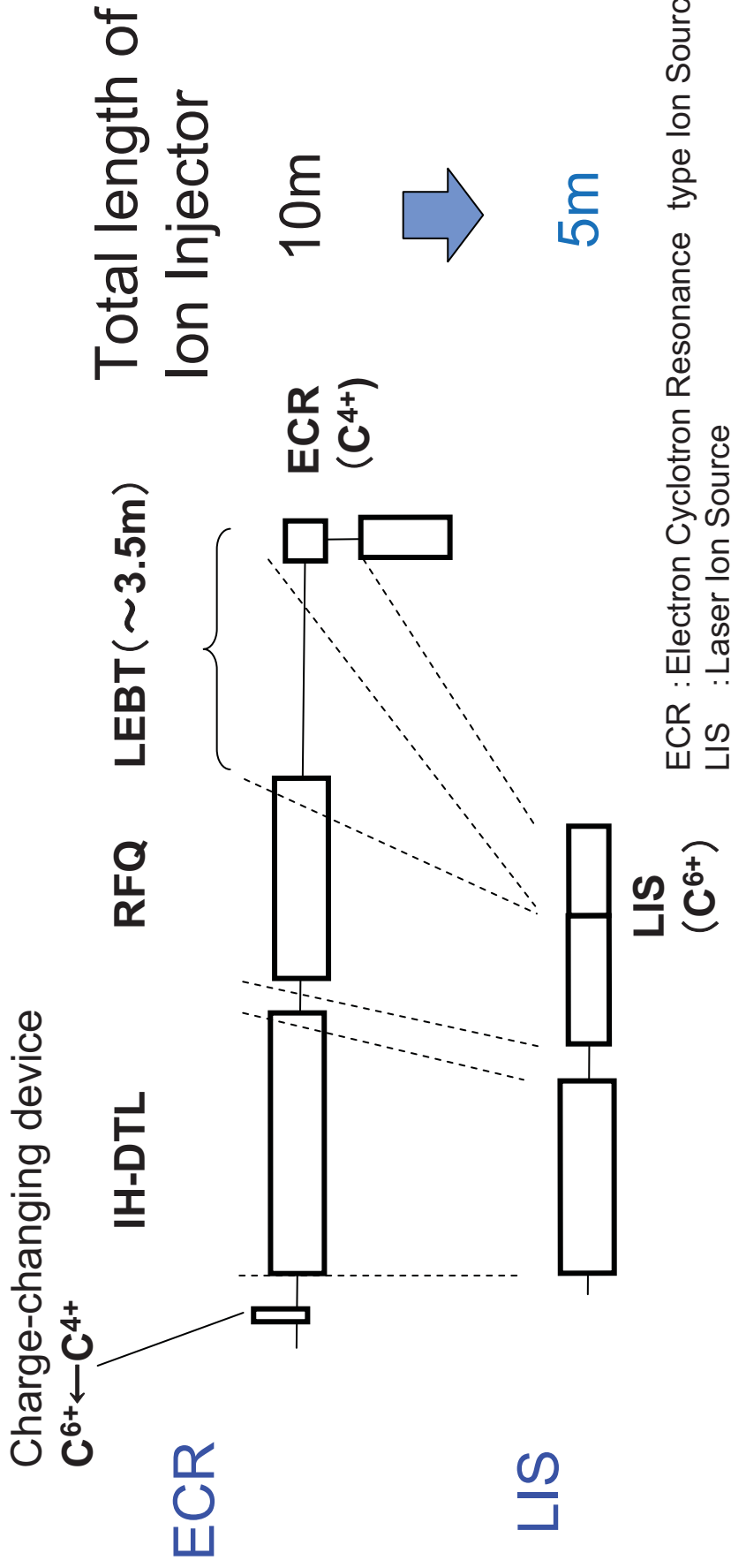
Nd:YAG (wavelength:1064 nm)  
Maximum Energy:1.4 J  
Pulse Width:10 nsec



Irradiating a carbon target with a laser, C6+ ions are generated. They are accelerated by acceleration electrodes.

# Advantages of Laser Ion Source

## Downsizing RFQ and IH-DTL of linear accelerator

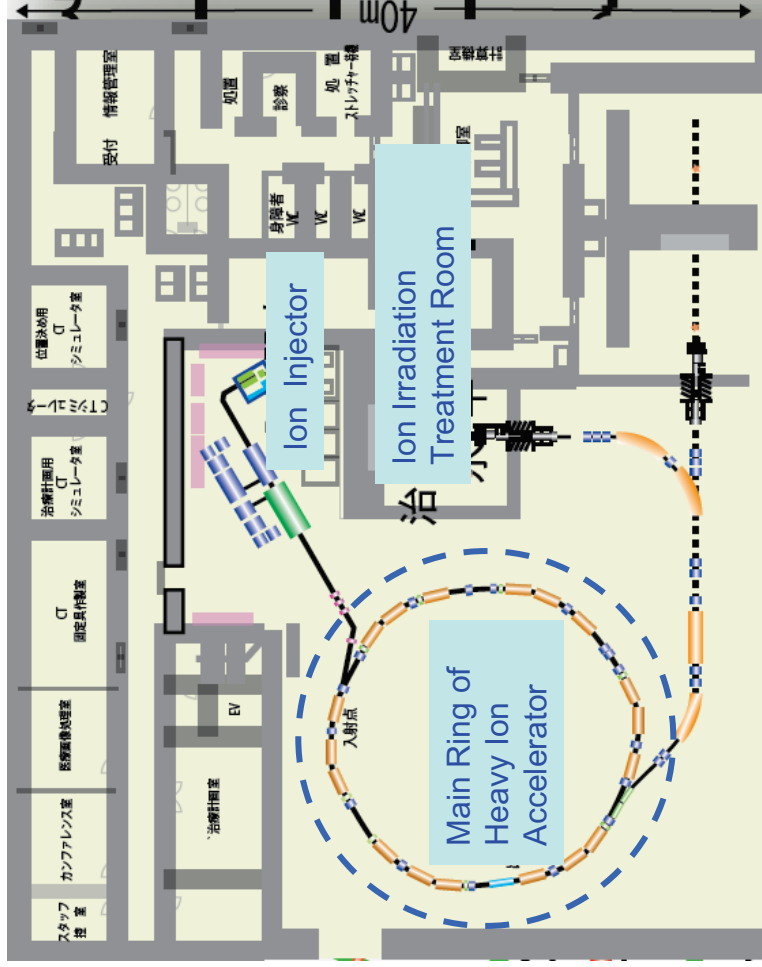


Since  $C^{6+}$  ions are generated in an LIS, energy gains are higher compared with an ECR in which  $C^{4+}$  ions are accelerated. Therefore RFQ and IH-DTL are downsized.

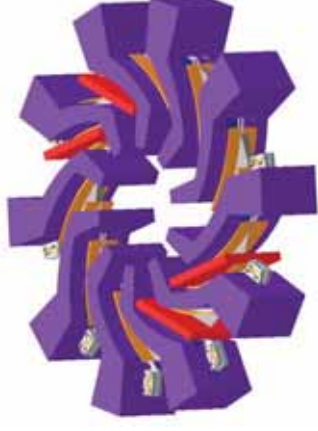


# Miniaturization of Main Ring

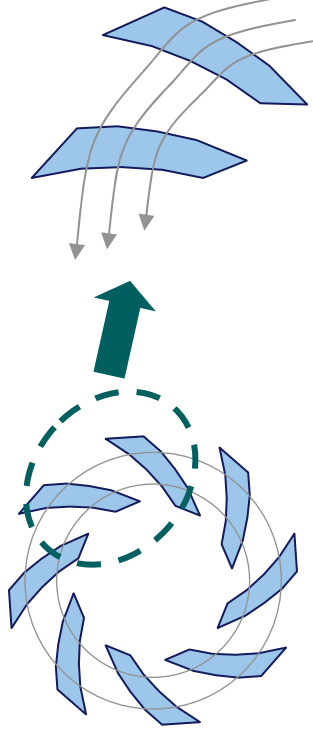
We have been developing high-temperature superconducting magnets aiming to miniaturization of a main ring.



Schematic View of Heavy Ion Cancer Treatment Device



Schematic View of Main Ring



High magnetic field  
↓  
Possible to reduce curvature radius of main ring  
(Ring radius: 10m→5m)

Superconducting magnet is suitable for miniaturization of main ring.

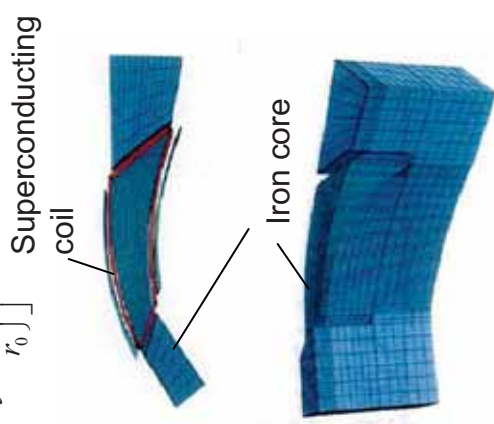
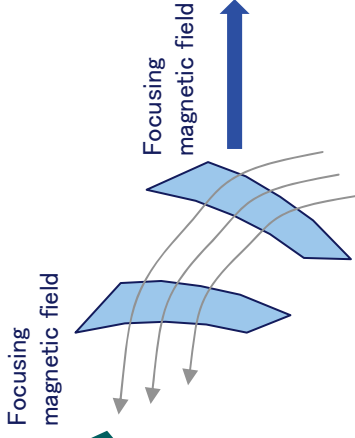
※This work was partially supported by Japan Science and Technology Agency under Strategic Promotion of Innovative Research and Development Program.  
© 2013 Toshiba Corporation

# Magnets for FFAG accelerator

Spiral-sector Type



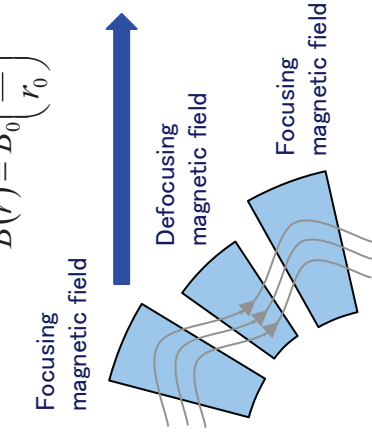
$$B(r, \theta) = B_0 \left( \frac{r}{r_0} \right)^k \left[ 1 + \sin \left\{ N\theta - N \tan \xi \ln \frac{r}{r_0} \right\} \right]$$



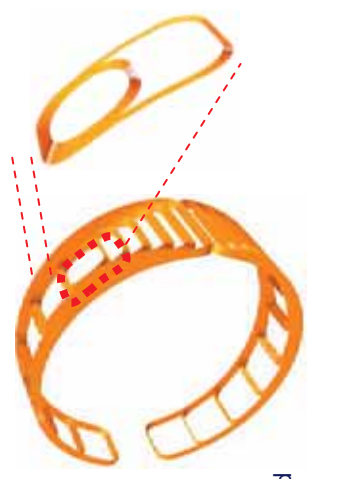
Radial-sector Type



$$B(r) = B_0 \left( \frac{r}{r_0} \right)^k$$



Negative-bend-shaped coil



Saddle-shaped coil

Complicated shaped coils are needed for FFAG in order to ensure a precise magnetic field distribution.

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## Summary

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- **Toshiba anticipate that, because of its high efficacy and QOL, demand for heavy-ion radiotherapy will increase.**
- **Toshiba will continue our activities to disseminate this excellent heavy-ion radiotherapy so that more cancer patients can receive it.**
- **In accordance with these concept, Toshiba will provide advanced heavy-ion radiotherapy systems contribute to the best quality cancer treatment with all Toshiba group's strength.**

**TOSHIBA**

**Leading Innovation >>>**