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HITACHI Proton Beam Therapy System

Masumi Umezawa, M.S.
Hitachi, Ltd., Hitachi Research Laboratory

HRL Hitachi Research Laboratory

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3 Outline of HITACHI

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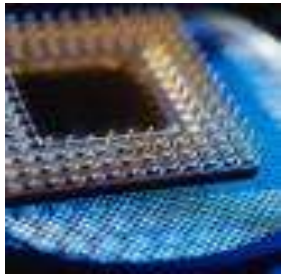
- Founded : 1910
- Consolidated Revenue*: 9,040 Billion Yen ($90.4 Billion, 1USD=100 JPY)
- Employees*: 326,240(*FY 2012)
- Main business activities in :
  - Power and Industrial Systems
  - Electronic Devices
  - Information and telecommunication systems
  - Digital Media & Consumer Products
  - High Functional Materials and Components



4 HITACHI Systems in Medical Society

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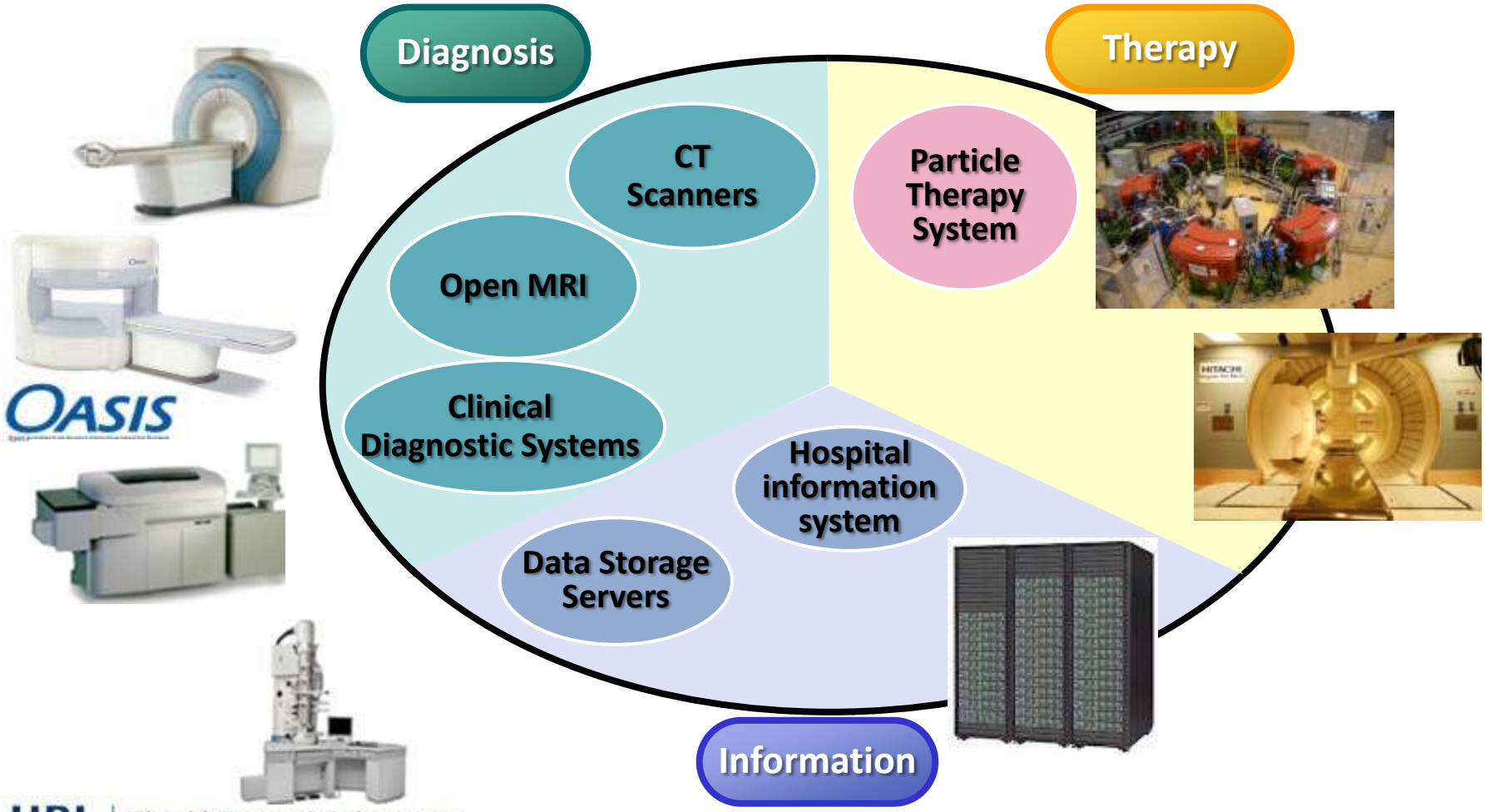
- HITACHI provides healthcare solution to the medical society through diagnosis, therapy and information system and continue to expand as a part of focus to the infrastructure business.



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6 HITACHI Particle Therapy Supply Records

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Proton
Carbon

2012 (2015) — **St. Jude Children Research Hospital, Memphis TN, U.S.A.**

Two half rotating gantry rooms and one fixed beam room. All rooms equipped with scanning system. The c-arm type CBCT. The facility is under construction.

2011 (2015) — **Mayo Clinic Rochester, MN / Phoenix, AZ, U.S.A.**

Four half rotating gantry rooms and one fixed beam room. All rooms equipped with scanning system. The installation in Rochester started in the end of May 2013.

2010 (2014) — **Hokkaido University, Japan**

One gantry room with scanning system. Real-Time Tumor tracking System, Robotic Couch and Gantry Mounted CBCT. The 220 MeV beam is extracted and transported to Icocenter.

2008 (2013) — **Nagoya city Quality Life 21 Jouhoku, Japan**

Two gantry rooms with one passive and one scanning system and one Fixed room
Treatment started on Feb. 25th 2013. The scanning port is under commissioning.

2006 — **Heidelberg Ion Therapy Center , Germany**

HITACHI supplied the RF acceleration system.

2002 (2006) — **MD Anderson Cancer Center / PROTON THERAPY CENTER, Houston, TX, U.S.A.**

Three gantry room with two passive and one scanning system, Fixed room and Experimental room.
PTC-H has treated total 4,564 patients and 980 patients with spot scanning till June 2013.

1998 (2000) — **Tsukuba University Proton Medical Research Center（PMRC), Japan**

Two gantry rooms with passive system. PMRC treats many cases of Lung, Liver with respiratory gating.
PMRC have treated 2,641 patients till July 2013.

1996 (2000) — **Wakasa-bay Energy Research Center（W-MAST）, Japan**

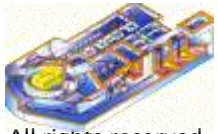
Multi-purpose system. Acceleration of proton, Helium and Carbon and is used for physics, biology and medicine. Medical research was shutdown on November 2009.

1995 — **National Cancer Center, Japan**

HITACHI designed and constructed Gantry Room 1 and Fixed Room.

1994 — **National Institute for Radiology Science（HIMAC), Japan**

HITACHI supplied the synchrotron, power supplies and control system



7 Overview of HITACHI Proton beam therapy system

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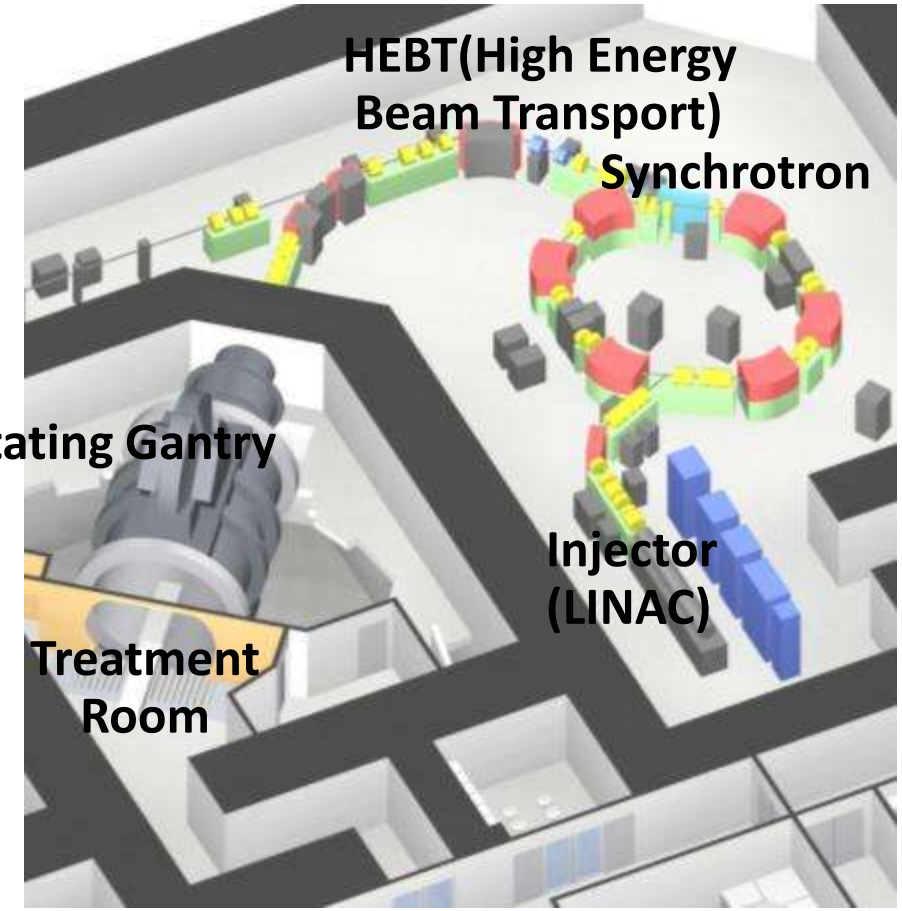
■ HITACHI PBT System
-Synchrotron accelerator with Injector LINAC
-High Energy Beam Transport lines
-Rotating Gantry and patient couch



Key Features

Synchrotron
with RF-driven Extraction Technology
Energy : 70 - 250MeV(for Passive)
: 70 - 220MeV(for Scanning)

HEBT
Course switching time < 45sec.

Rotating Gantry
with High precision < ±1mm

Irradiation Technique Capability
-Passive(Wobbler+RF, DS+RF, DS+RMW)+MLC
-Spot Scanning(Discrete)

RF: Ridge Filter, DS: Double Scattering,
RMW: Range Modulation Wheel

8 Spot Scanning Irradiation Nozzle

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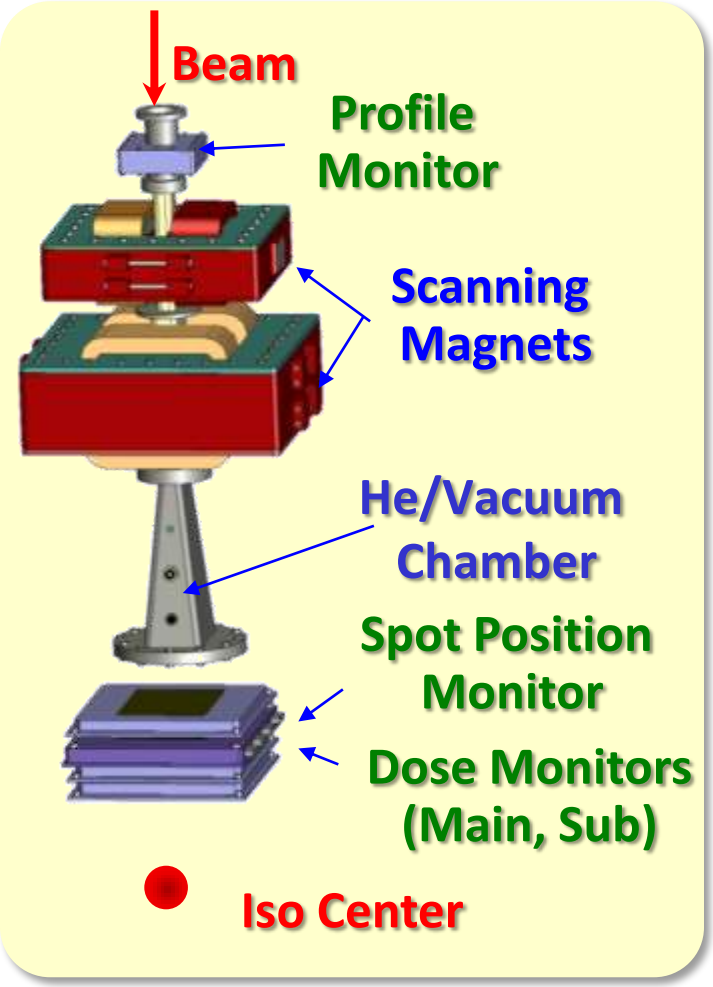
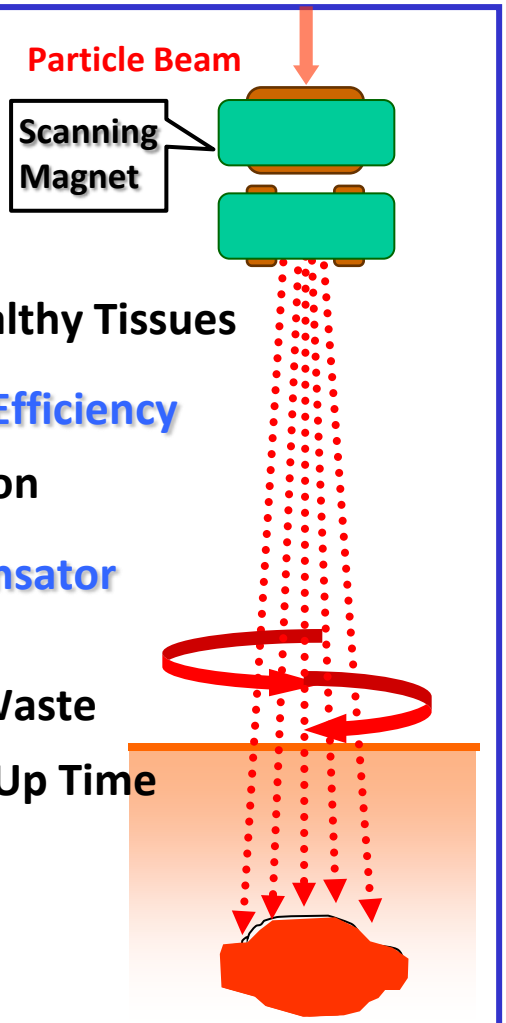
- HITACHI provides spot scanning dedicated nozzle.
- Smaller spot size is achieved by He/Vaccum chamber.



Scanning



Conformal Irradiation

- Minimized Dose to Healthy Tissues

Almost 100 % of Beam Efficiency

- Low Neutron Generation

No Collimator / Compensator Necessary

- Reduced Radioactive Waste
- Shortened Patient Set Up Time

Less Mechanical Parts

- Less spare parts

9 Discrete Spot Scanning Irradiation Scheme

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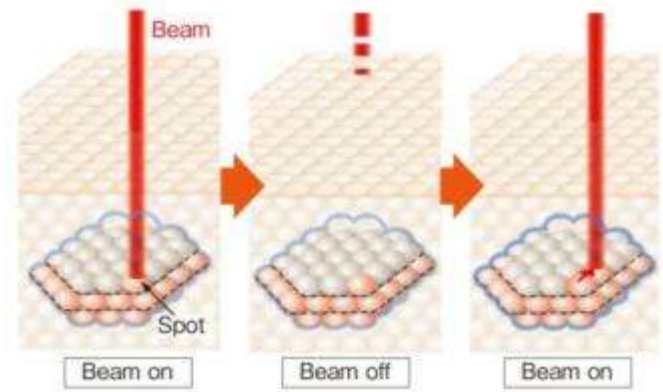
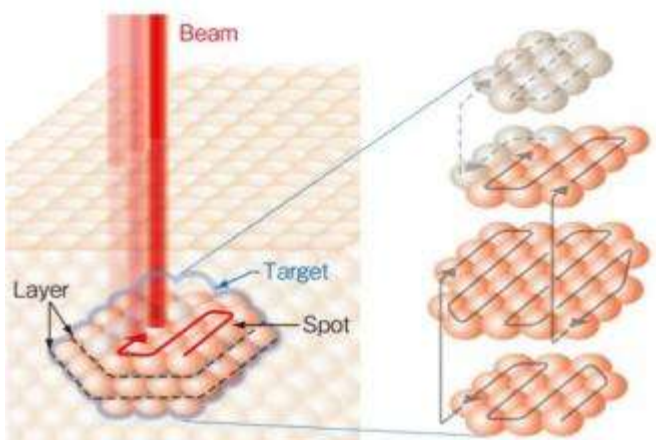
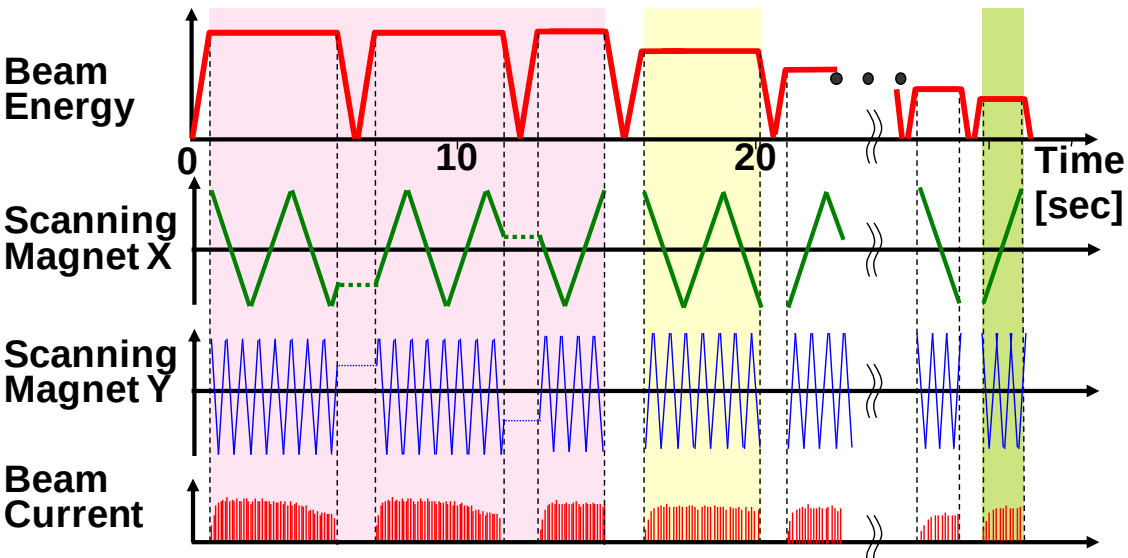
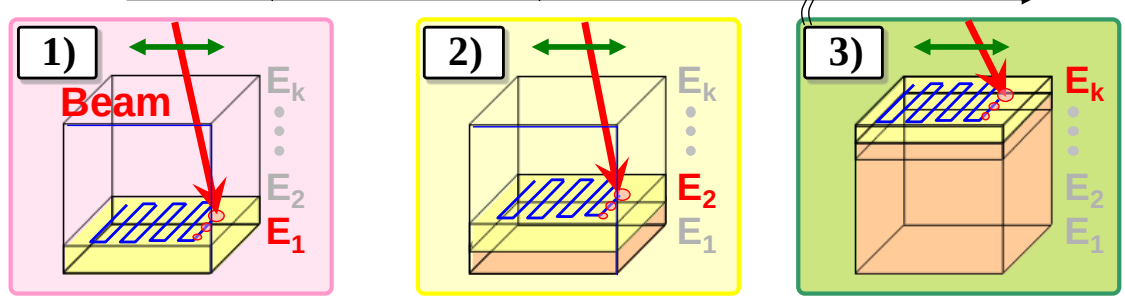
- Beam turn on till spot dose attain to prescription.
- Beam switch off during spot scan.
- Energy change layer by layer with switching synchrotron operation pattern without degrader.









10 Beam Position Accuracy

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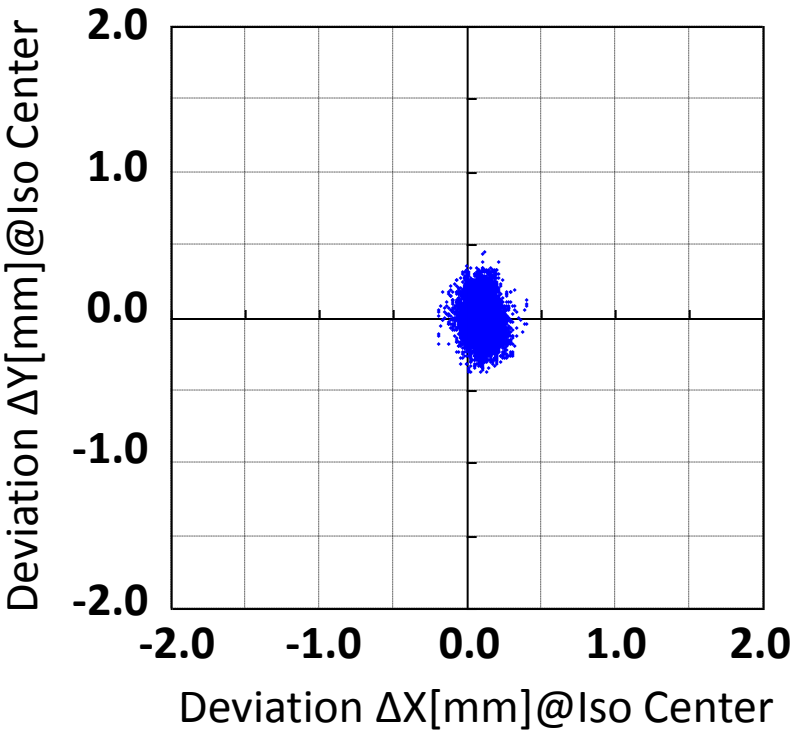
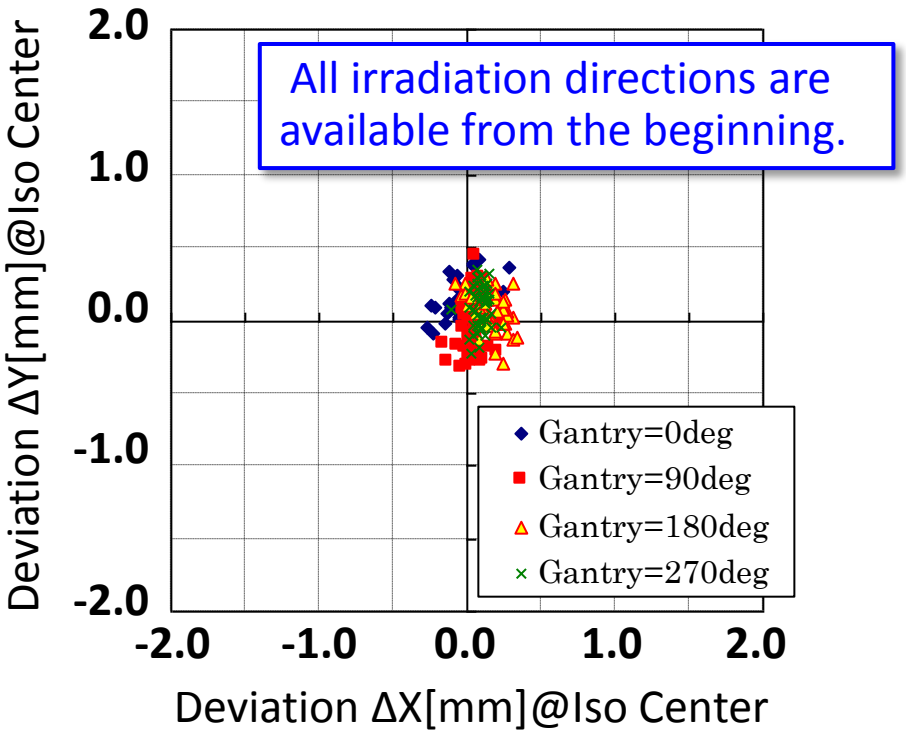
- Synchrotron and HEBT parameters can be changed every cycle.
- Beam position is accurate and stable after Energy Change.



Deviation of spot position for a lateral 2D scanning (30cm x 30cm, 10,000spots)



Deviation of beam center for consecutive energy scanning operation for 47 energy levels and 4 directions

HITACHI Scanning Irradiation Technology

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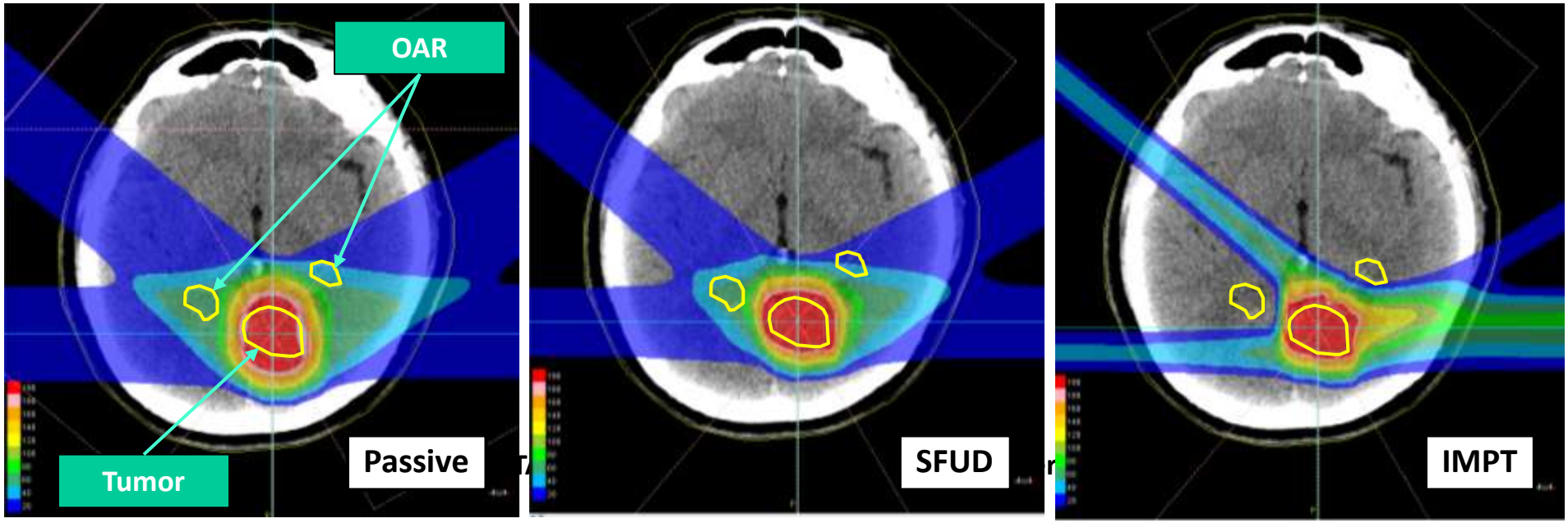
- The first company that received FDA clearance for Pencil Beam Scanning in U. S. and started Spot Scanning Treatment in Commercial Based Hospital in the world.
- The first system in the world started Spot Scanning Treatment and started **IMPT** irradiation in the commercial based hospital.
- MDA has been treating patients for 5 years and completed about 1000 patients treatments with Spot Scanning.



SFUD: Single Field Uniform Dose, IMPT: Intensity Modulation Proton Therapy

HITACHI System Status in M.D. Anderson

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- 100-110 patients are treated per day in 4 treatment rooms
- G3 Room (Scanning) is the busiest with 35 patients/day.
- HITACHI realizes **more than 97% availability** for six year avg.,(From 12/2011 to now: **99%**)

Ground breaking	**– May 2003**
Passive scattering	**– May 2006**
Spot Scanning	**– May 2008**
Patients	**(05/2006 – 05/2013)**
Total patients	**~4600**
Spot scanning	**~988**
	(05/2008-05/2013)

SFO Patients:
Single field integrated boost (SFIB) ~ 82
Single field uniform dose (SFUD) ~810

IMPT Patients ~ 95
First one: 11/01/2010
H&N 66, CNS 16, Others 13

X R Zhu, et al., " Current Status of Scanning Beam Treatments at M. D. Anderson PTCH ", HITACHI Proton Beam Therapy User Meeting, 6/4/2013, Essen, Germany

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14 Treatment Room and IGRT Device Layout

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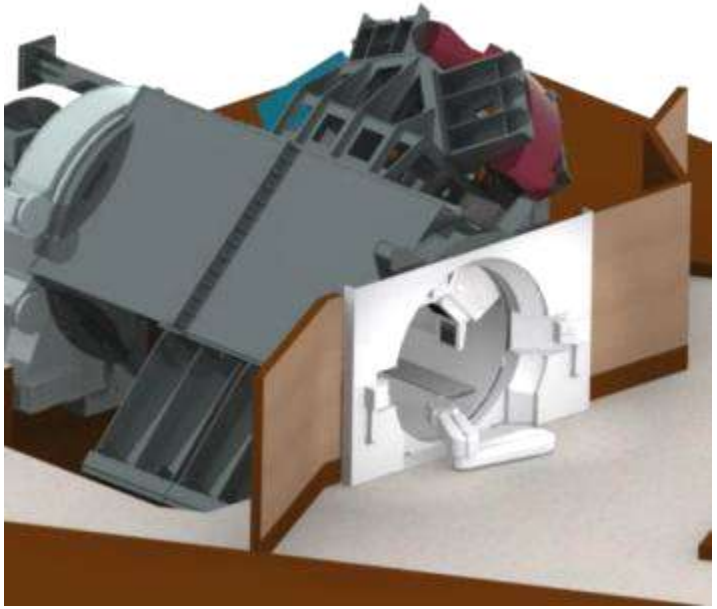
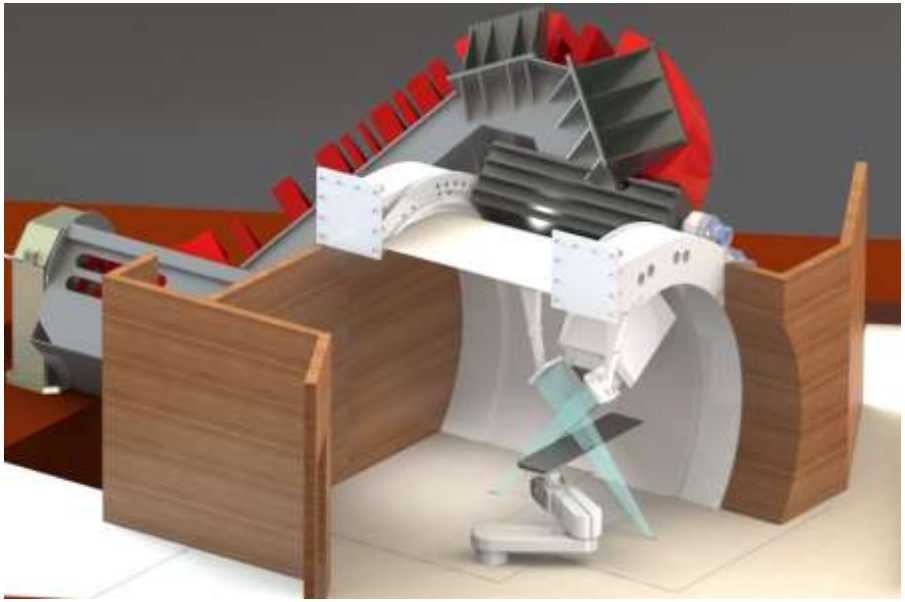
- Hitachi provides various type of Treatment Room Layout to meet the customer's requirement.
  - Full Rotating Gantry with CBCT Capability
  - Half Rotating Gantry with Orthogonal FPD and X-ray
  - Half Rotating Gantry with C-arm CBCT/ in room CT



Full Rotating Gantry With CBCT Capabiliy(*)



Half Rotating Gantry With Fixed FPD and X-ray

*:developed with Hokkaido University

15 Positioning Image Analysis System

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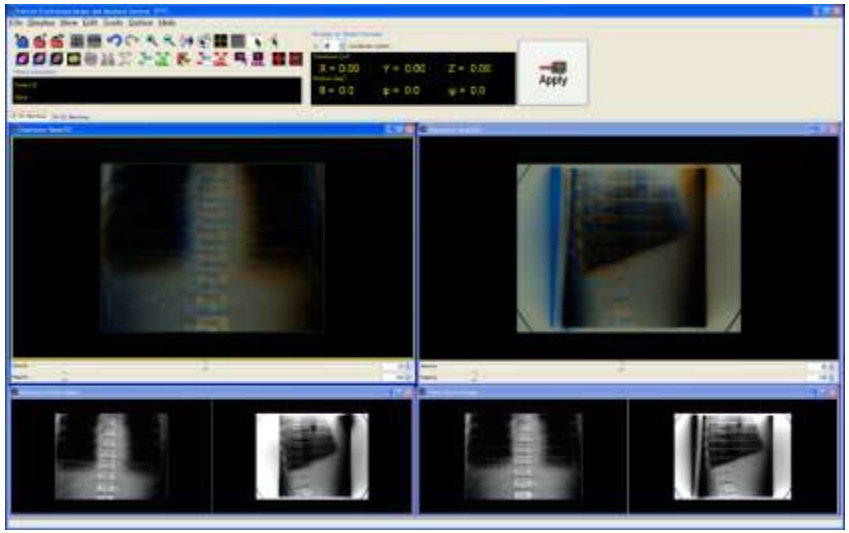
- Positioning Image Analysis System provides the function to calculate the couch deviation (displacement from planned position) by comparing X-ray images, and supports the image guided proton therapy.



Item	Design Specification
Positioning Technique	- 2D/2D matching - 3D/2D matching - 3D/3D matching
Image Interface	DICOM RT compliance
Couch Interface	On-line communication with control system

16 Motion Management with Tracking

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- To realize precise treatment in moving organs by developing a Gated Spot Scanning Proton Therapy with Real-Time Tumor-Tracking system

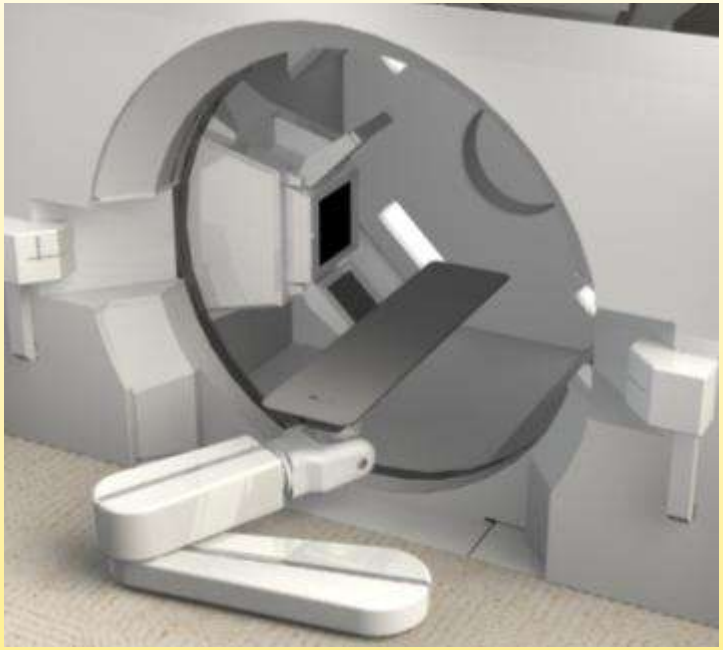
Real-time Tumor-tracking Radiotherapy

Developed by Hokkaido University

Spot scanning Proton Beam Therapy

Developed by Hitachi, Ltd.

Integration



The Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST Program)

Advanced Radiation Therapy Project

- Real-time Tumor-tracking with Molecular Imaging Technique -

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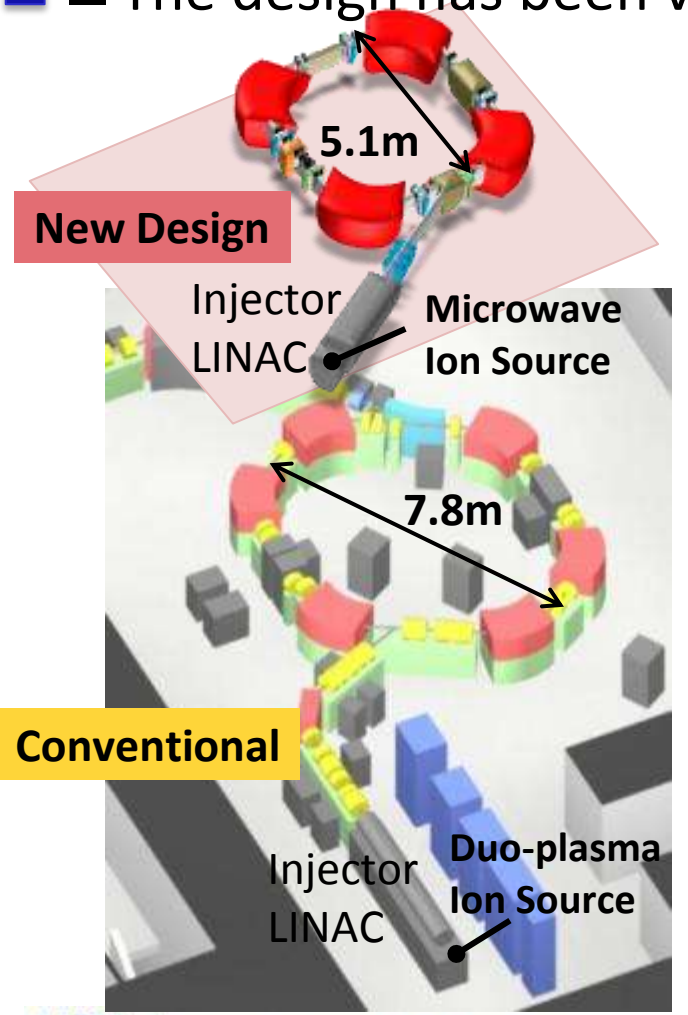
Compact Proton Synchrotron

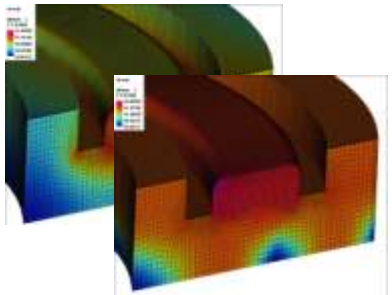
- From Hokkaido System, HITACHI re-designed synchrotron to reduce cost and size with keeping required beam spec. for spot scanning
- The design has been verified based on our experience



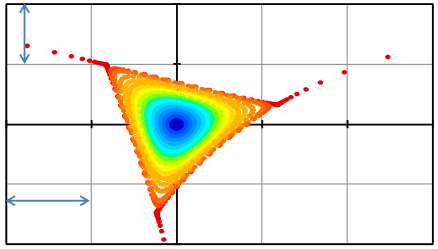
	Conventional	New Design
Circumference	23m	18m
Footprint	42.5m^2	27m^2
# of Magnets (Dipoles, Quads)	(6,10)	(4,4)
Ion Source Type	With Filament	Without Filament

Cost and Size Reduction

Easy Maintenance



3D Magnetic Field Calculation



Particle Tracking Simulation

Design Verification

Recent Progress in Hokkaido Project.

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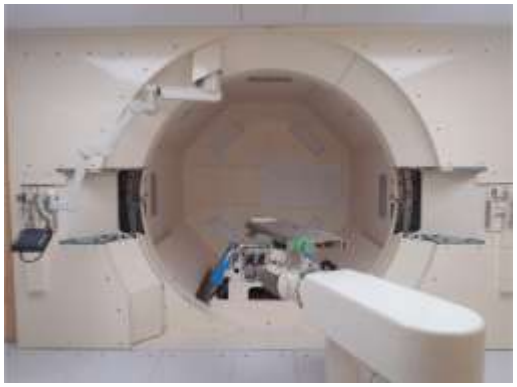
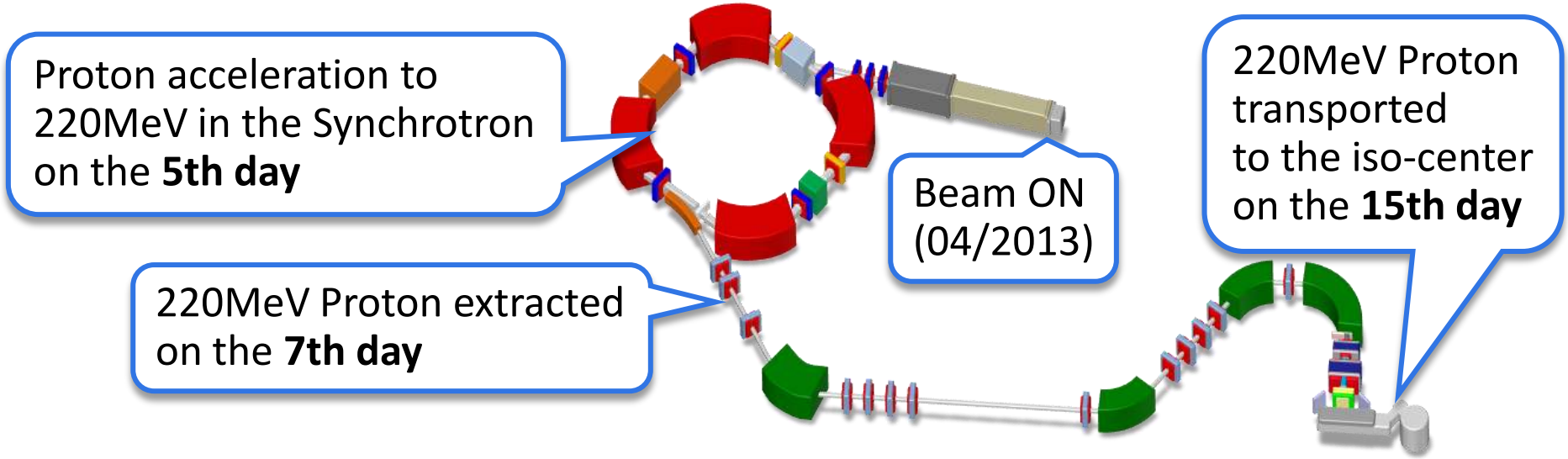
■Beam commissioning has been started on-schedule and the basic performance of newly designed synchrotron system have been confirmed in the short period.





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