Recent Progress and Future Plan of Heavy-Ion Radiotherapy Facility, HIMAC

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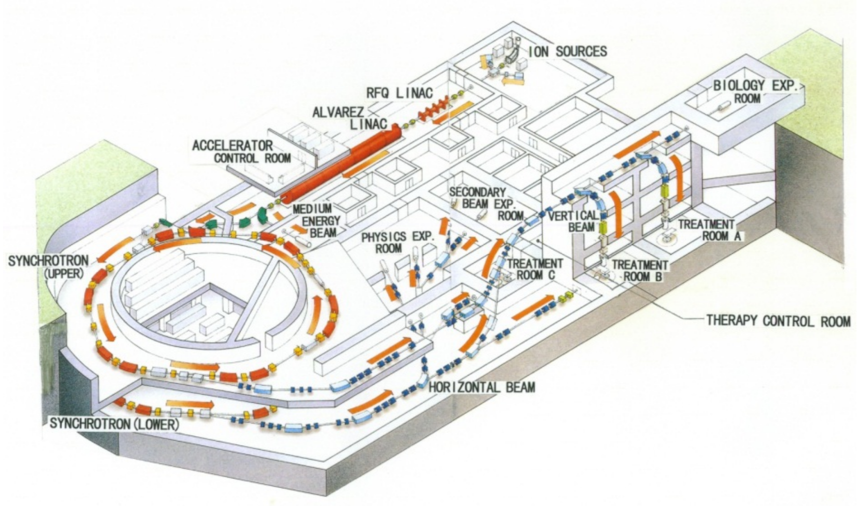
Contents

1. Introduction

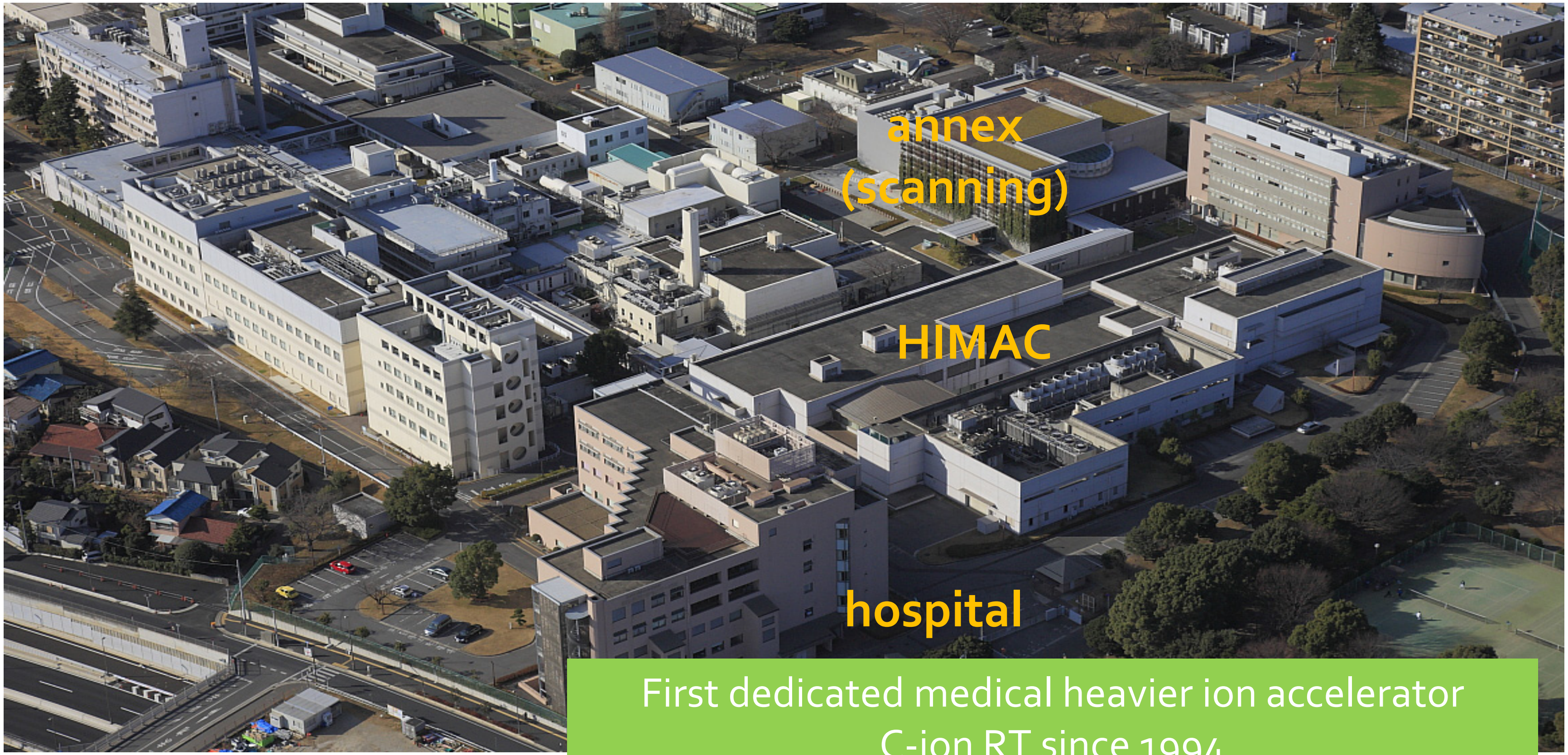
2. 3D Scanning for Static and Moving Targets

3. Superconducting Rotating Gantry

4. Future Plan



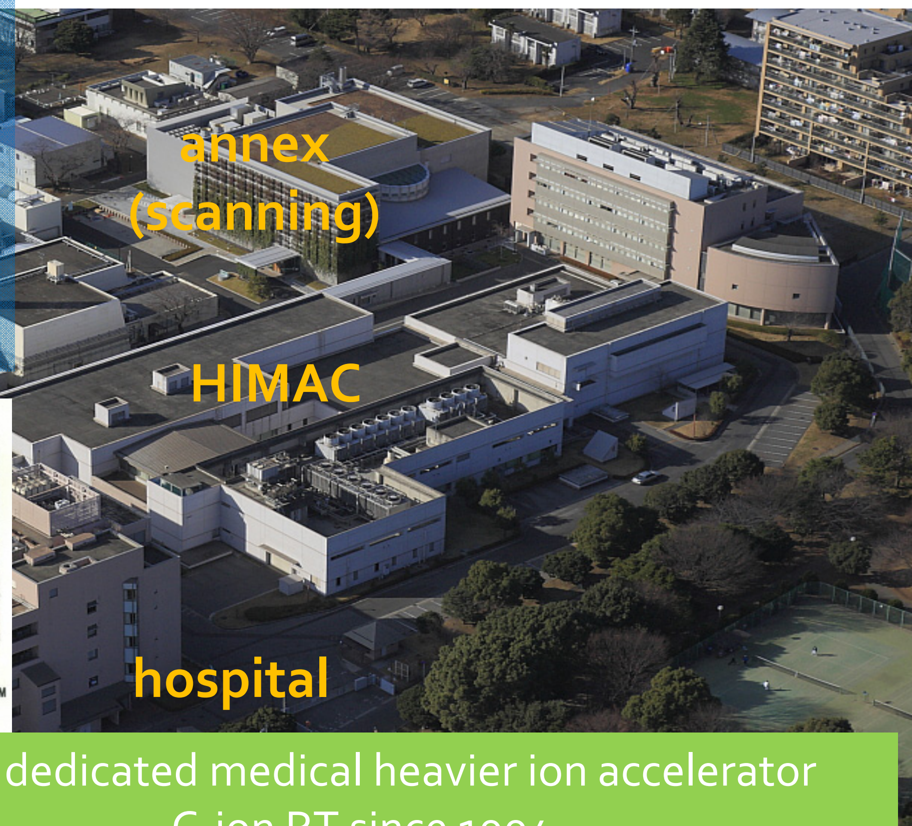
Heavy Ion Medical Accelerator in Chiba, HIMAC



First dedicated medical heavier ion accelerator
C-ion RT since 1994

Heavy Ion Medical Accelerator in Chiba, HIMAC

Ion	H~C~Xe
E_{max}	800 MeV/n
Intensity	$10^0 \sim 10^{10}$ pps
Treatment room	3 (broad beam) 2 (scanning)
Exp. ports	4 (physics), 1 (biology) 1 (injector)



First dedicated medical heavier ion accelerator
C-ion RT since 1994

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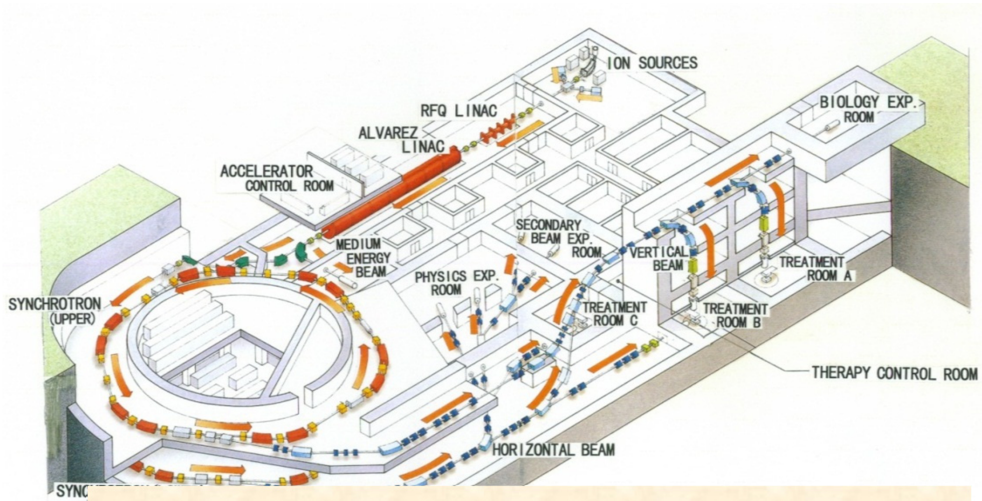
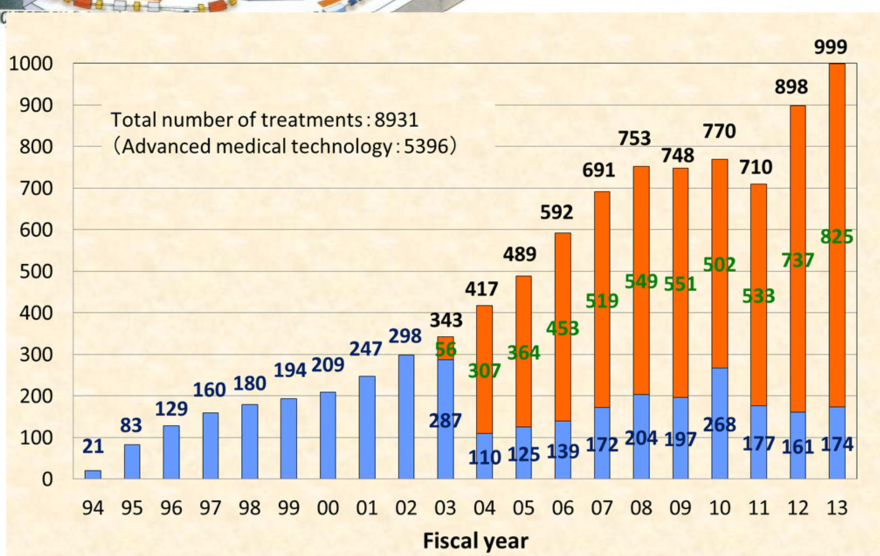
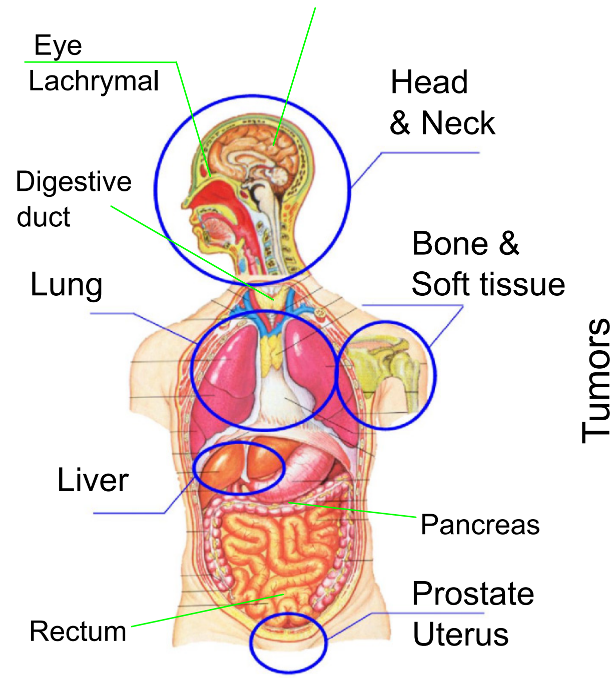
Operation

- ✓ **More than 9 000 pts treated since ‘94.**
- ✓ **≈1 000 pts/y, ≈100 shots/day @180 d/y**
- ✓ **Downtime ration < 0.5%**

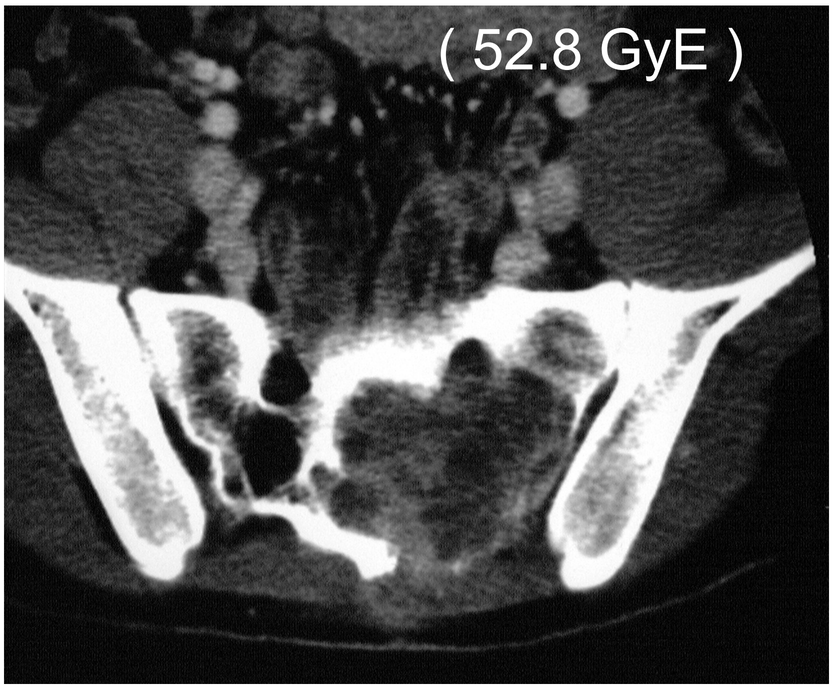






Clinical Results

Treatment against Radio-Resistive tumor



Before treatment

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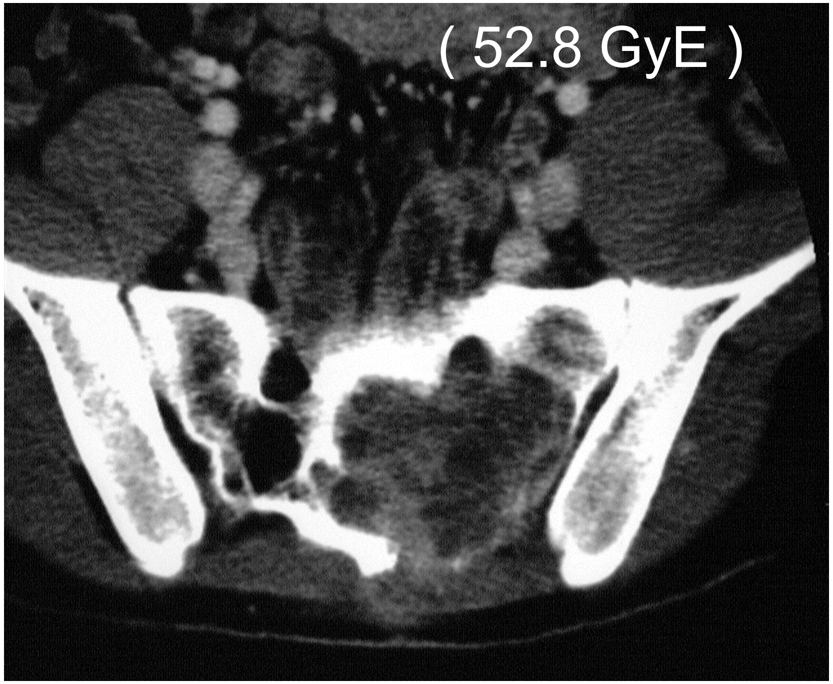
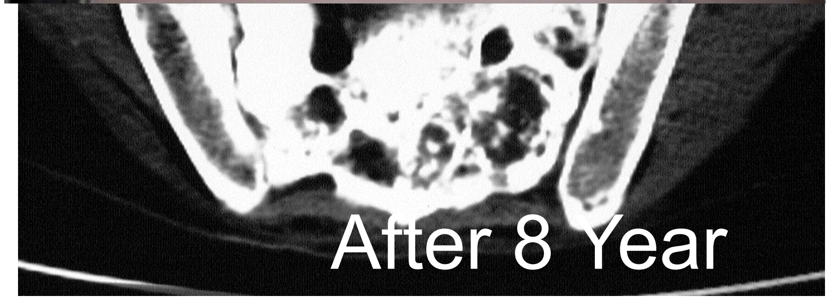
Clinical Results

Treatment against Radio-Resistive tumor



Before treatment



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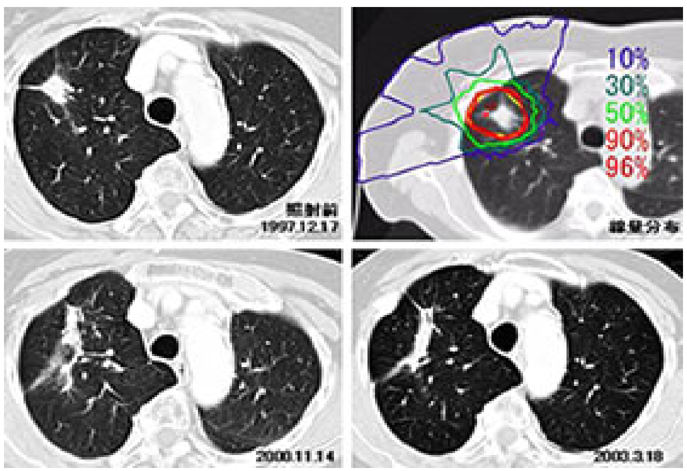
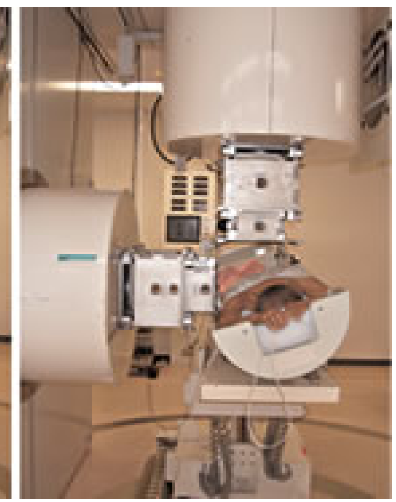
Clinical Results

Single Fraction Treatment with Respiratory Gated Irradiation

LCR > 95%, a 5 year OSR ~ 50-60% and a cause-specific SR ~ 70-80%. These results correspond to those obtained with surgery. The treatment period and the number of fractions have been successively reduced from 18 fractions over 6 weeks to single fraction in one day. It has been carried out since April 2003.





59.4 – 95.4GyE (18 fraction)
94/10 ~ 97/8

54 – 79.2GyE (9 fraction)
97/9 ~ 00/12

52.8 - 60GyE (4 fraction)
00/12 ~ 03/11

28 - 32GyE (1 fraction)
03/4 ~ 06/3

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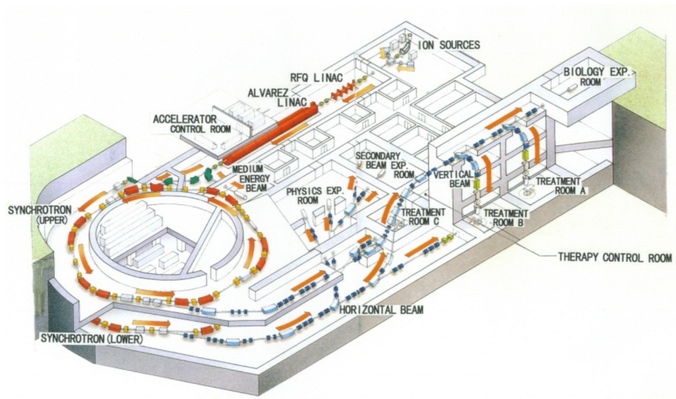
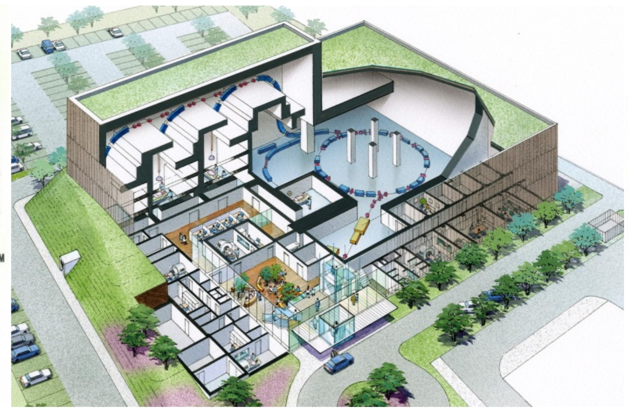
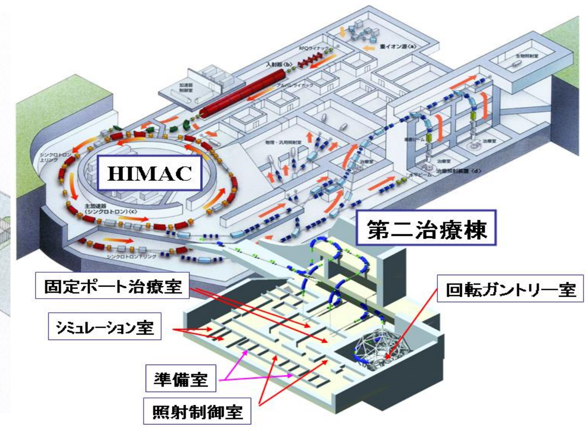
Technology Development

HIMAC	Standard-version@Gunma	New Treatment System







He〜Ar
Max.800MeV/n
Beam-Woblling Method.
Respiratory-Gated Irrad.
Layer Stacking Irrad.

1984~1994

C
Max. 400MeV/n
Spiral Wobling Method
Respiratory-Gated Irrad.
Layer Stacking Irrad.

2004~

C, O,(^{11}C, ^{15}O)
Max. 430MeV/n
Fast 3D-Scanning
Respiratory-Gated Irrad.
Rotaing Gantry

2006~

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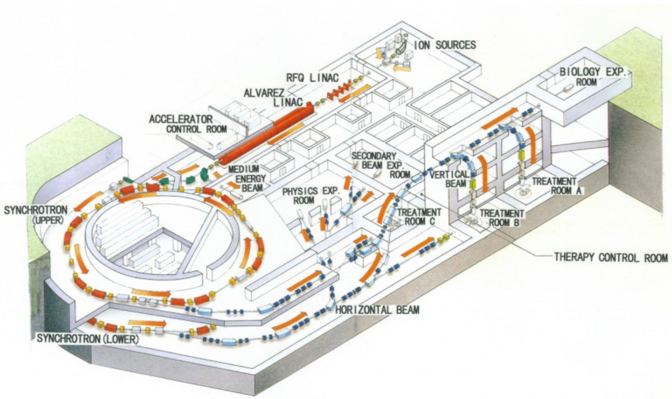
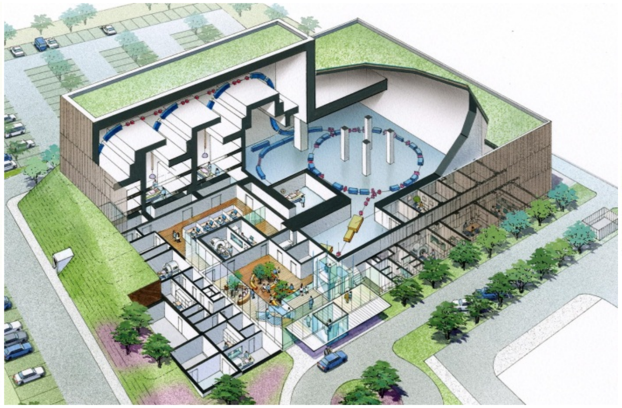
Technology Development

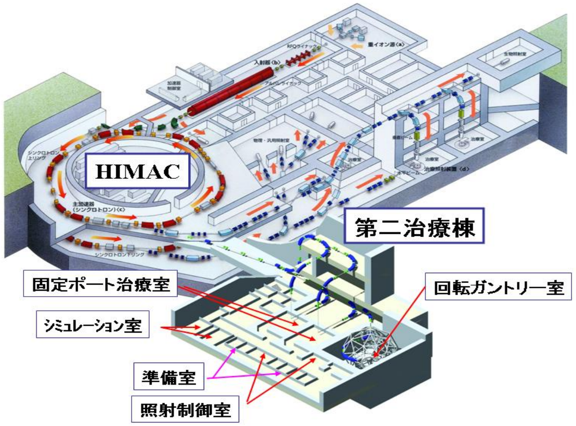
HIMAC



Standard-version@Gunma



New Treatment System



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Max.800MeV/n
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+

C, O,(^{11}C, ^{15}O)
Max. 430MeV/n
Fast 3D-Scanning
Respiratory-Gated Irrad.
Rotaing Gantry

Advanced Standard Version

NIRS
HIMAC

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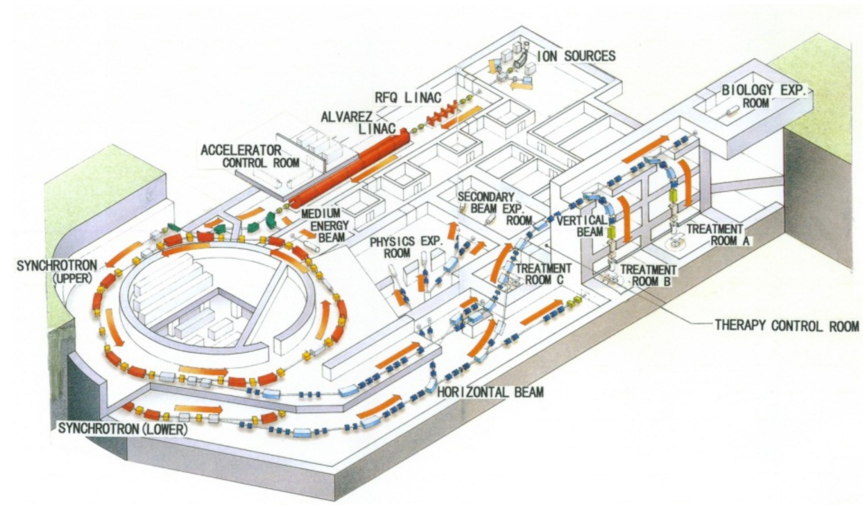
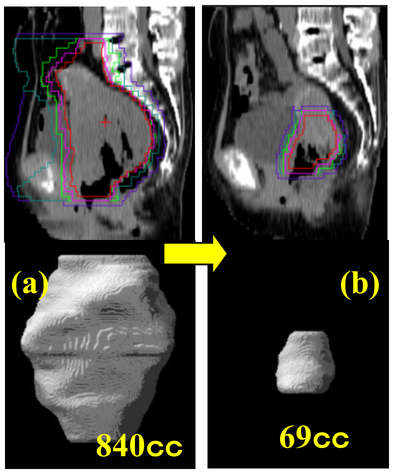
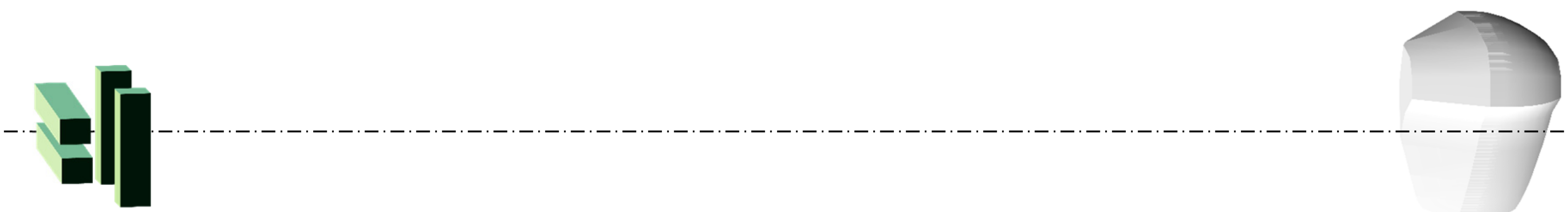


Pencil-Beam 3D Scanning



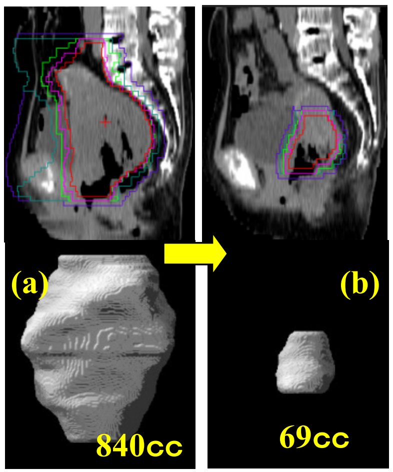
We should modify a treatment planning corresponding to change of target during treatment,

⇒ Adaptive Cancer Treatment



Scanning Magnet

Pencil-Beam 3D Scanning



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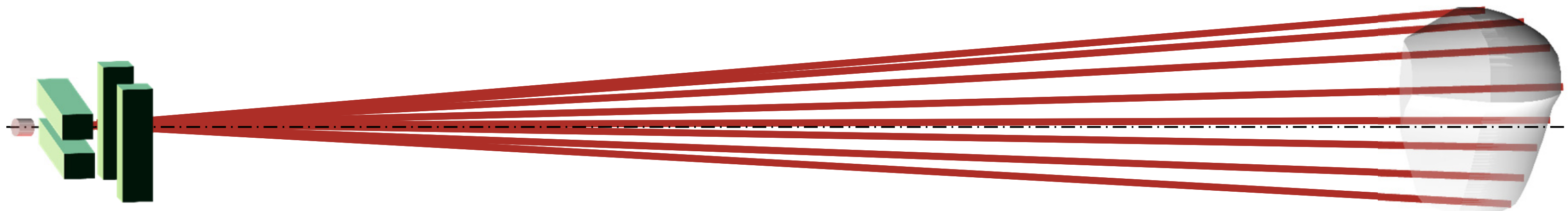

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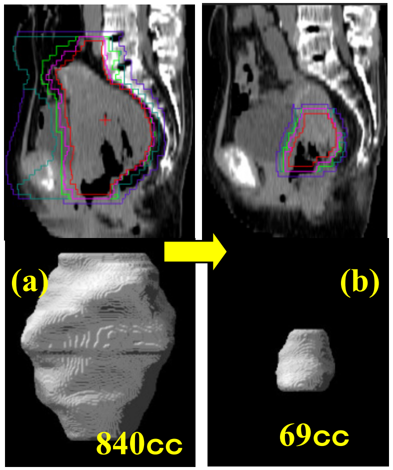

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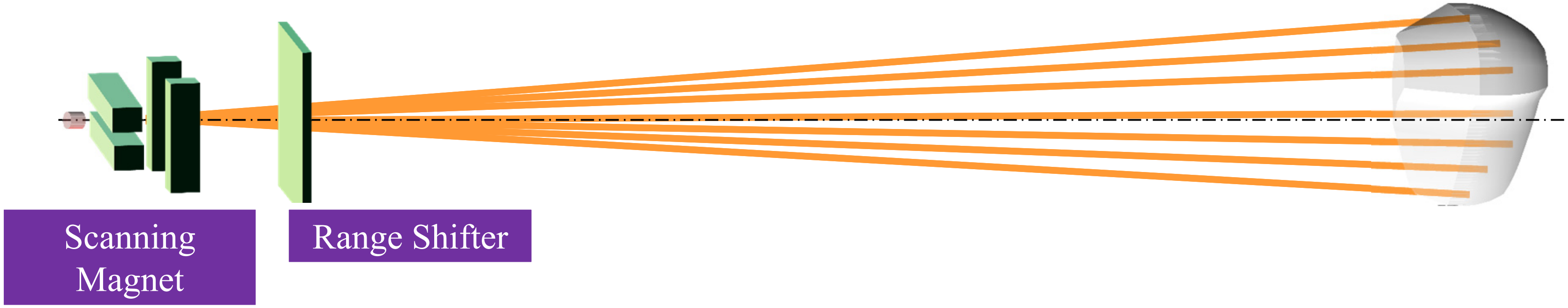

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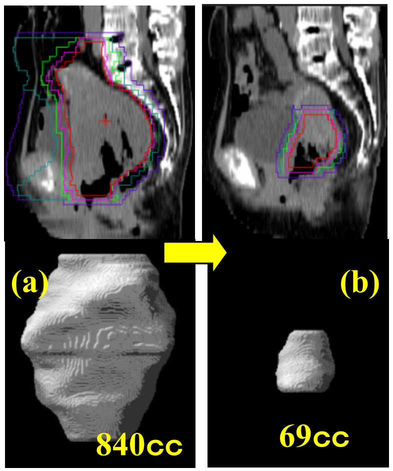

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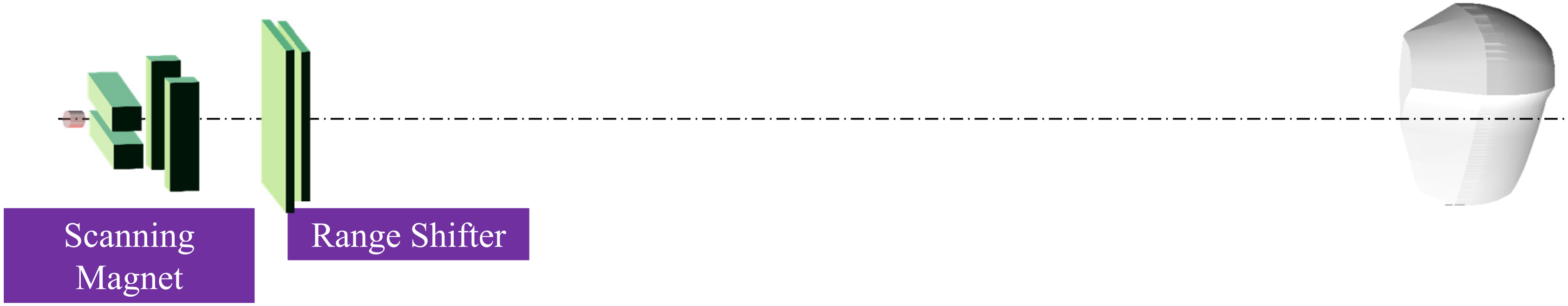

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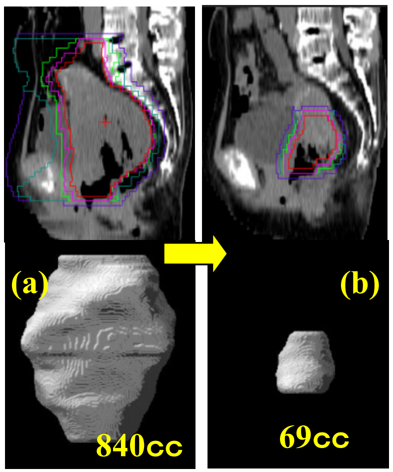

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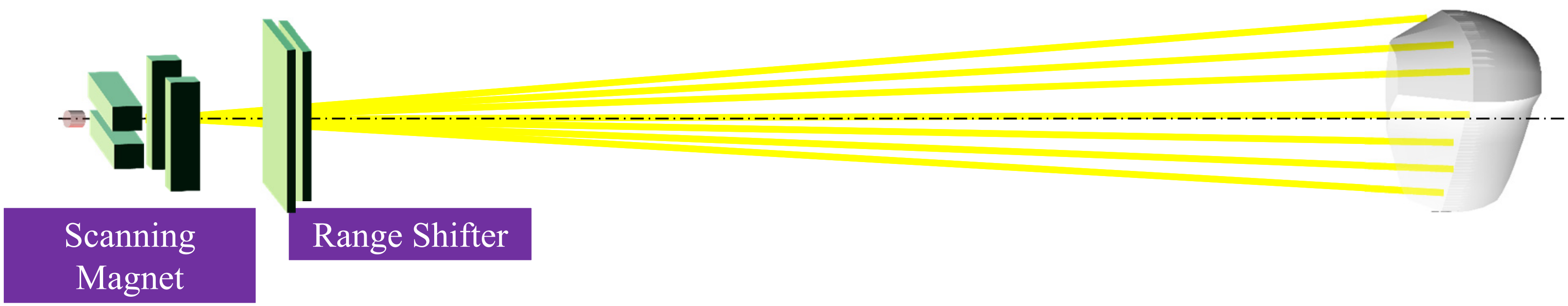

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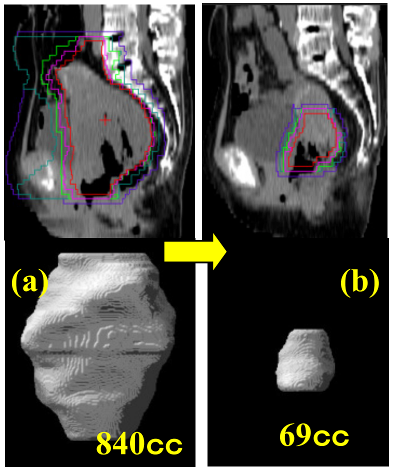

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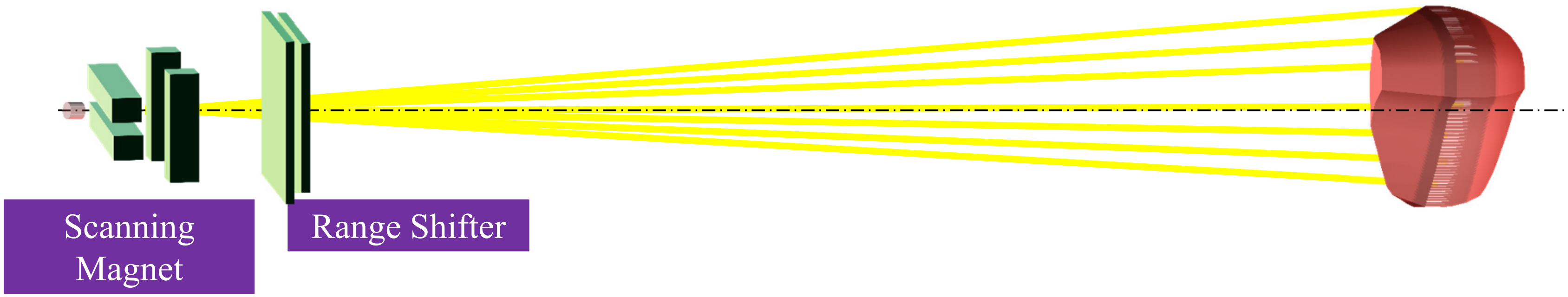

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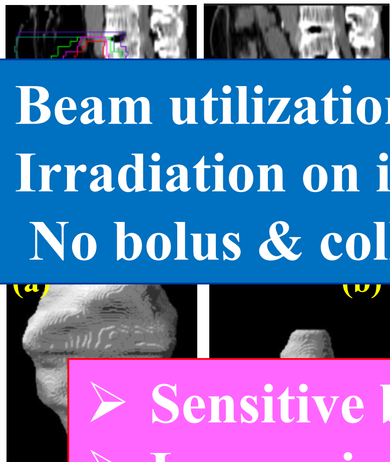


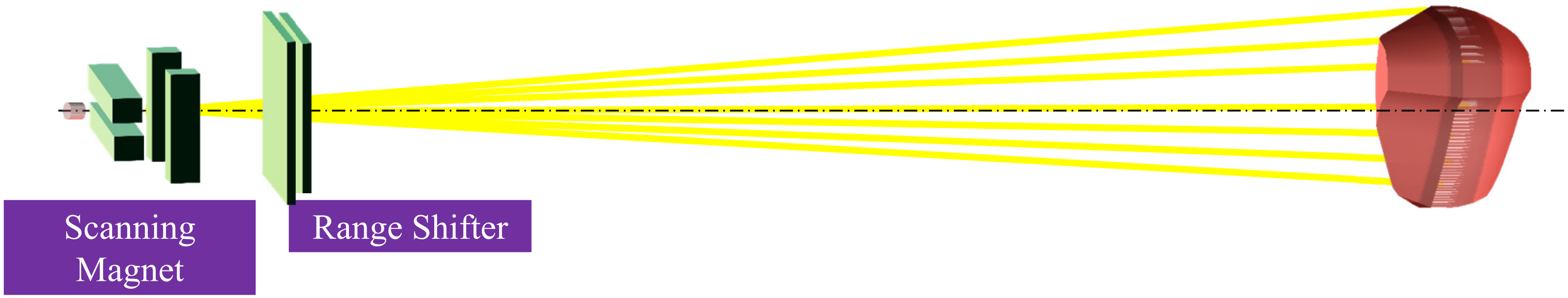
- Beam utilization efficiency ~100%
- Irradiation on irregular shape target
- No bolus & collimator

ment planning

nge of target during treatment,

reatment

- Sensitive beam error
- Longer irradiation time



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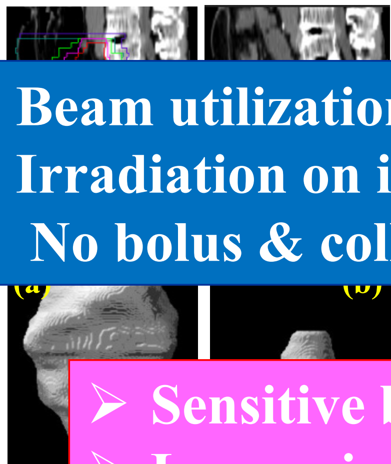
3D Scan

Pencil-Beam 3D Scanning



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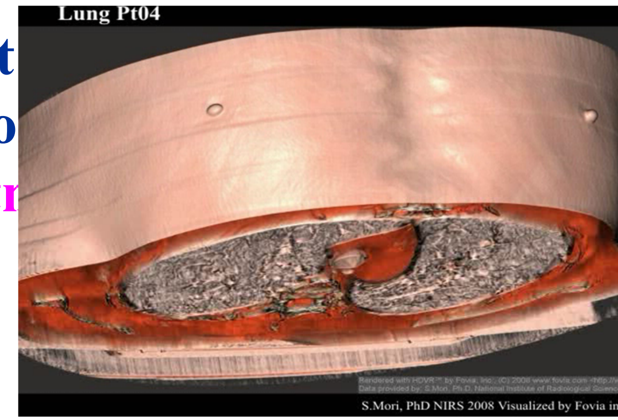

- Sensitive beam error
- Longer irradiation time

Especially sensitive organ motion

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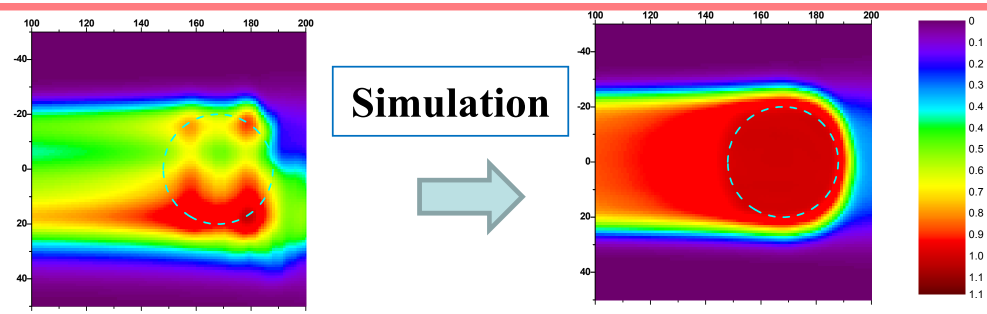
Fast scanning for moving target



Rescan with respiratory-gating

100-times speed up !!

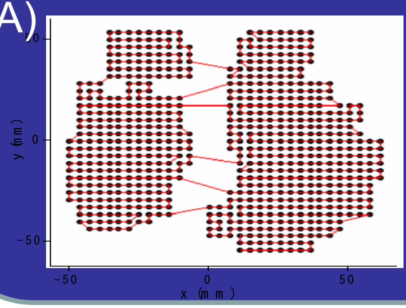
Key Technoly ⇒ Fast 3D Scanning within Torelable Time for moving target

A) TPS for Fast Scanning ⇒ ×5

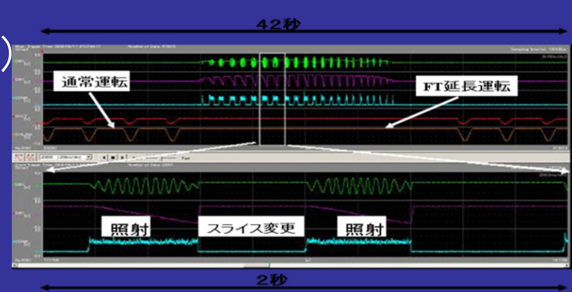
B) Extended Flattop Operation ⇒ ×2

C) Fast Scanning Magnet ⇒ ×10

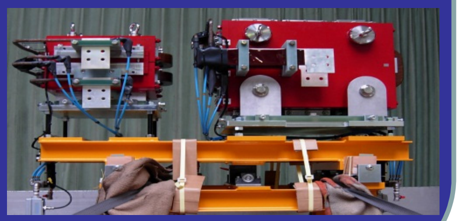
(A)



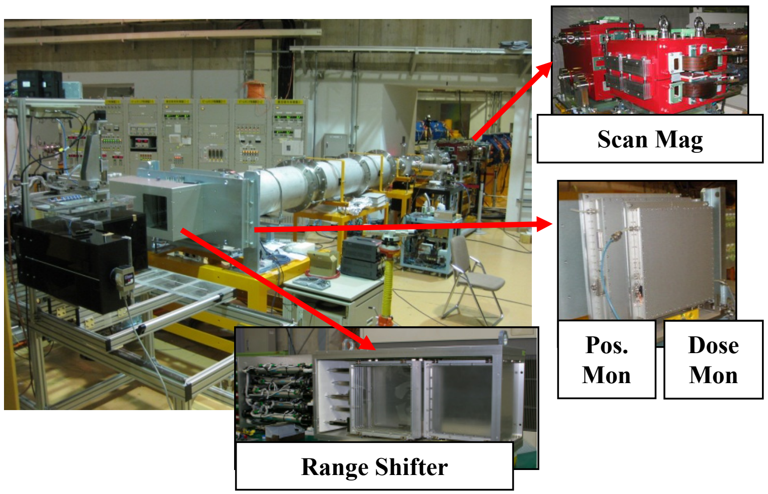
(B)



(C)

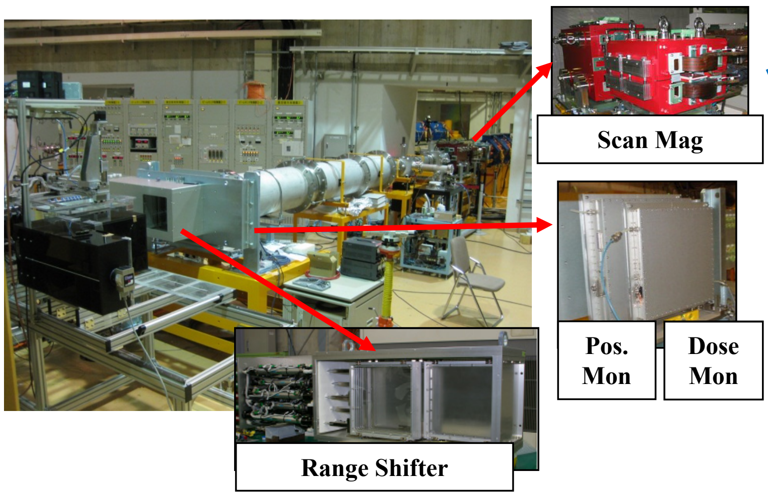


Verification



Test Port for Fast 3D scanning Test Port

Verification



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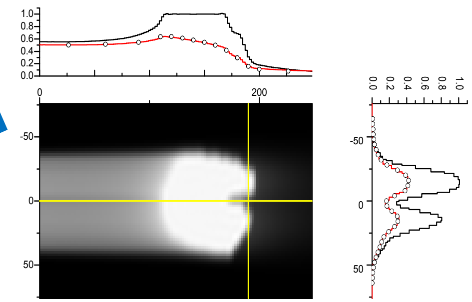
Phys. Dose Dist.



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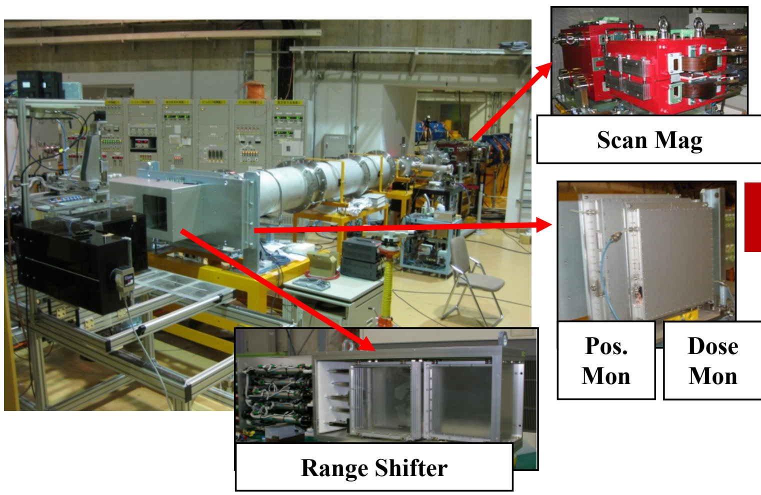

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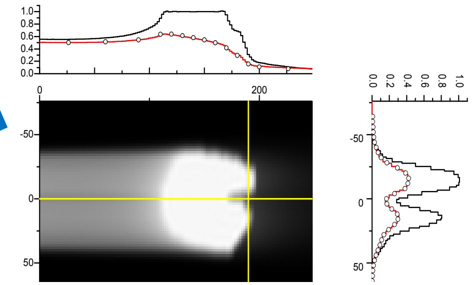
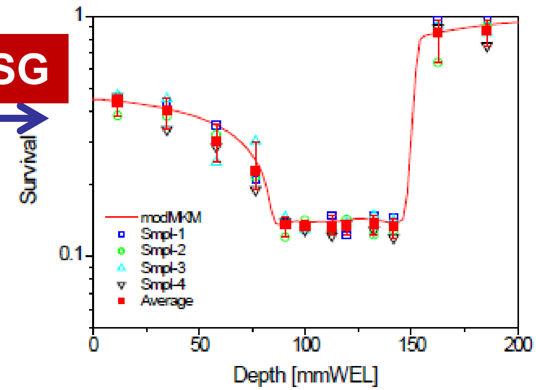


Survival of HSG



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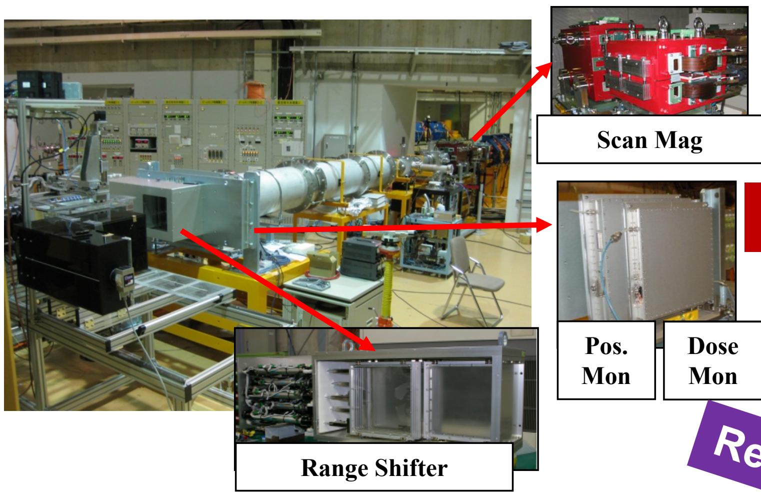

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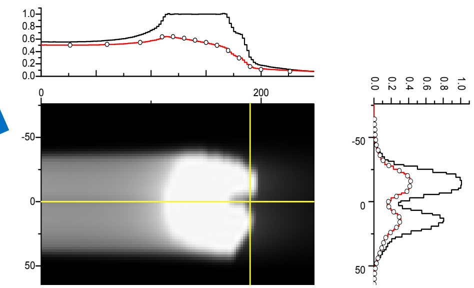

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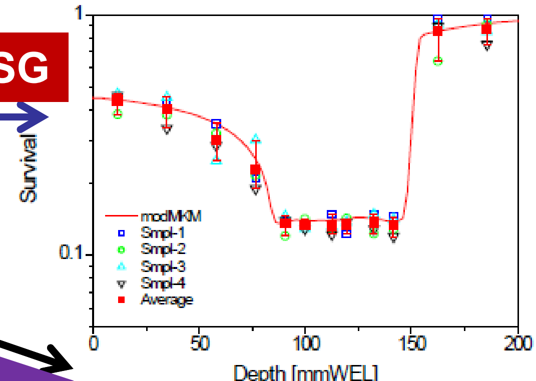
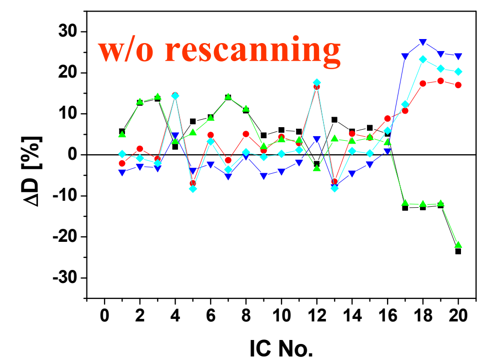


Respiratory Gating



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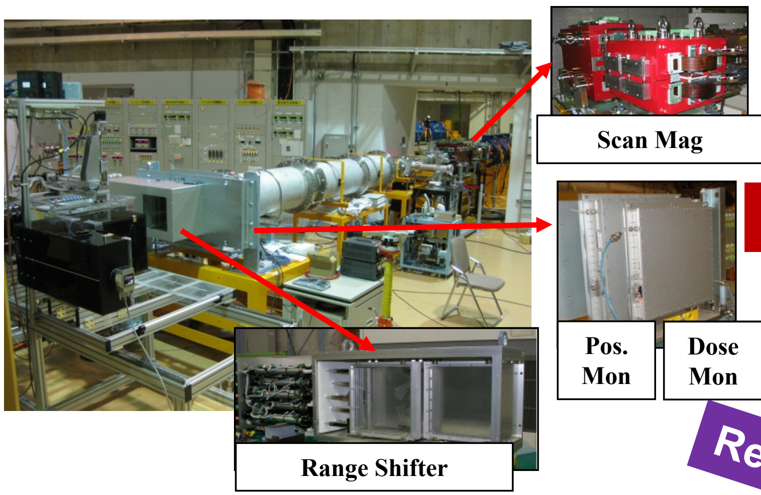
3D Scan

Verification



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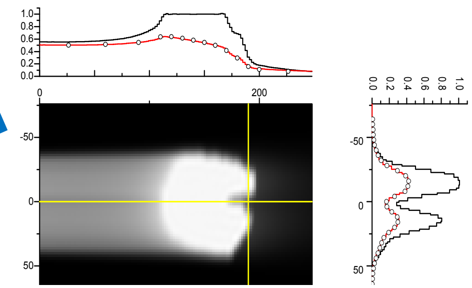

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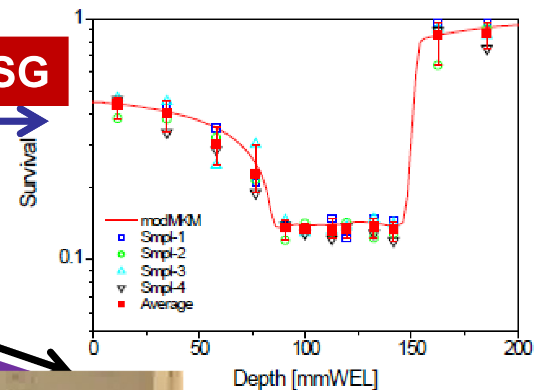
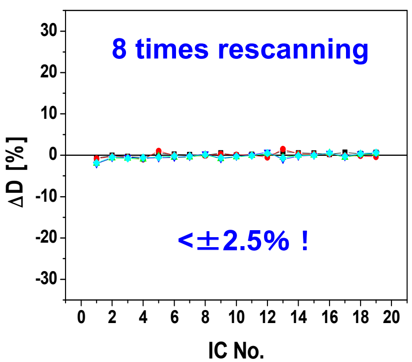
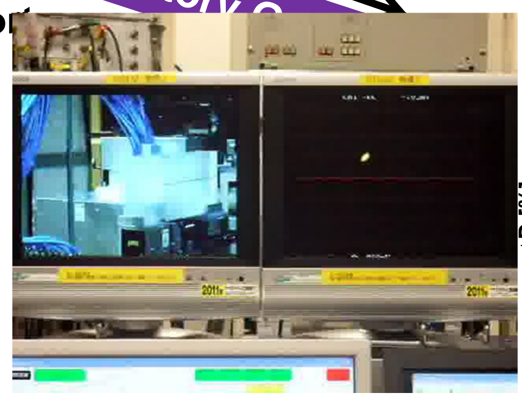
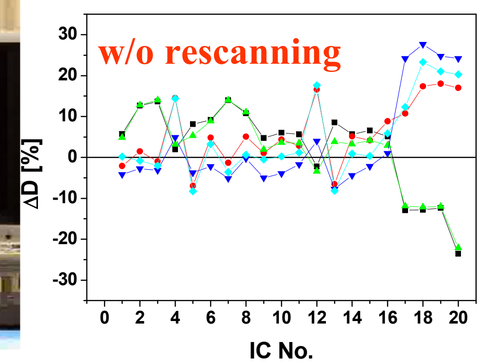


Respiratory G

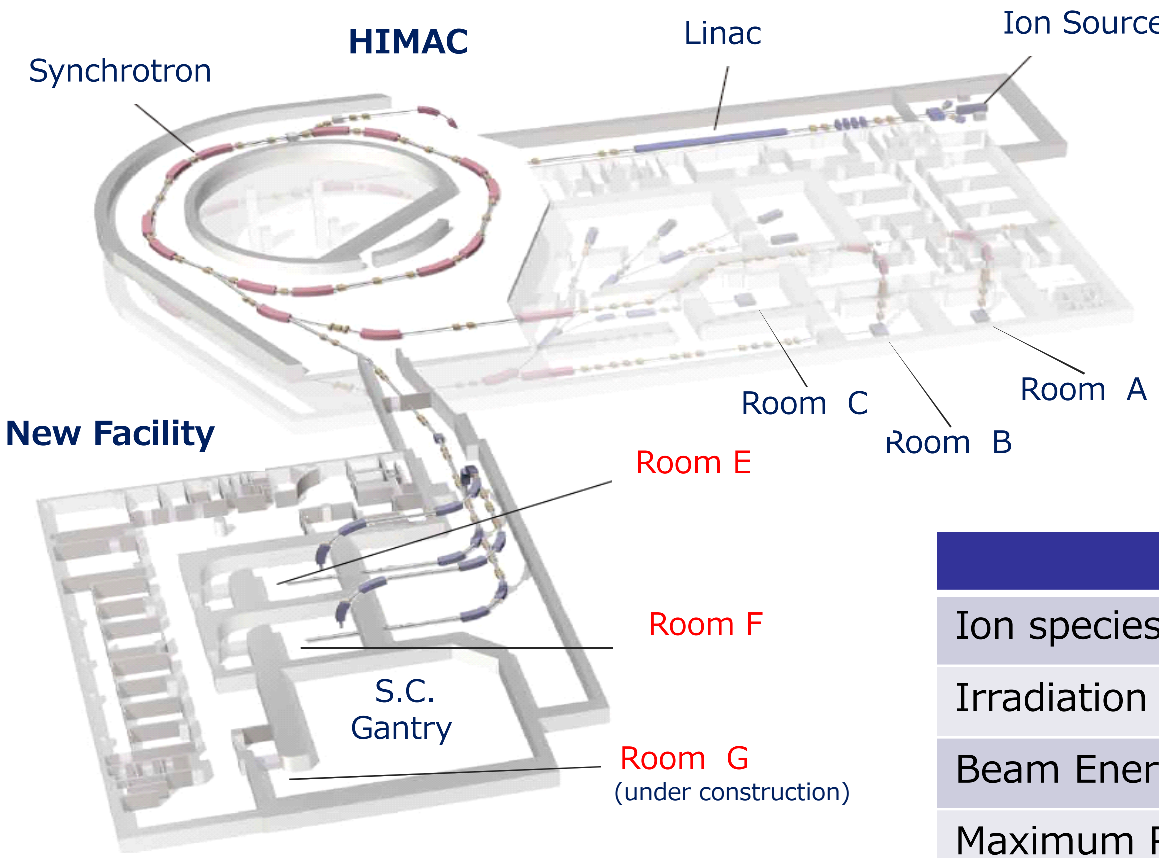
Test Port for Fast 3D scanning Test Por







HIMAC and New Facility



Room E with H/V scanning ports is in service since May 2011.

Room F with H/V scanning ports is in service since Sep.2012

Room G with rotating gantry is under development.

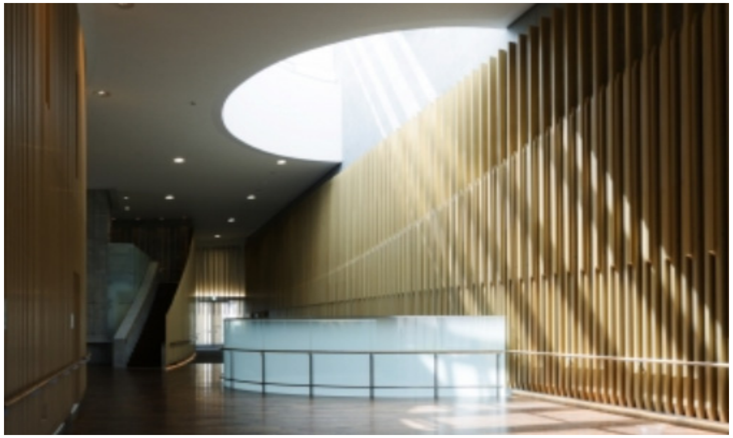
Main specifications	
Ion species	^{12}C
Irradiation method	3D Scanning
Beam Energy	430 MeV/n (max.)
Maximum Range	30cm in water
Maximum Field	22×22 cm^2 (E, F)

NIRS
HIMAC

3D Scan

Photograph of New Facility

Building facade with green curtain



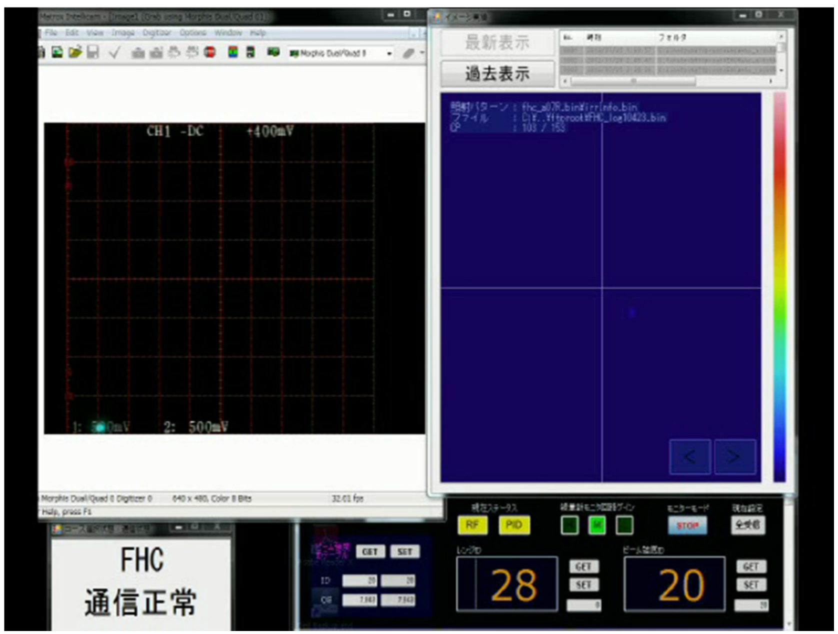
Entrance hall (1F)

Waiting hall (B2F)

Treatment Room E (B2F)

Operation

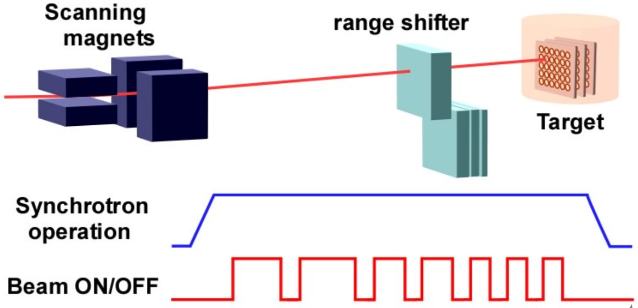
- **Operation**
  - Daily QA (MU calibration, range check etc) ～ 15min/course
  - Treatment irradiation (except positioning) ～ 2min
  - 30 patients/day



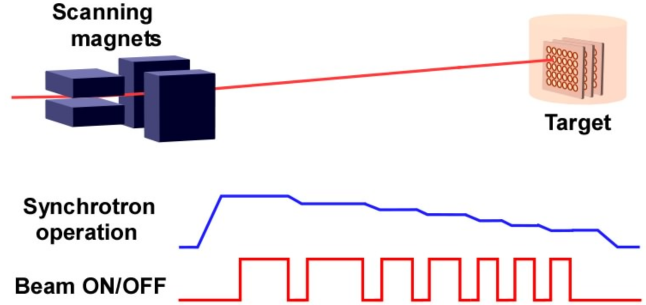
NIRS HIMAC

Improvement of Depth Scan

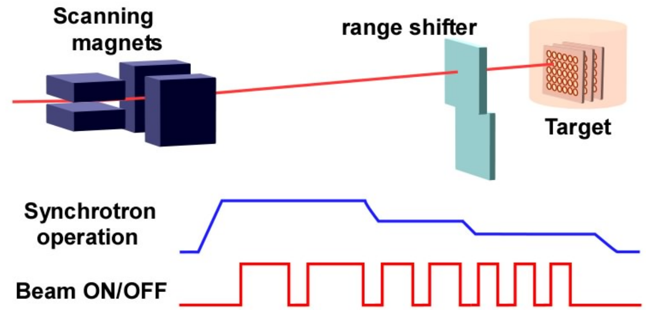
RSF scanning



Energy scanning



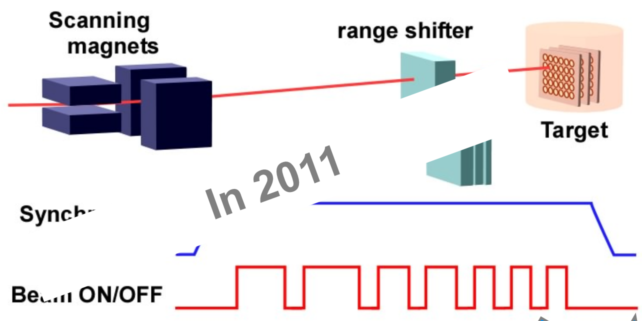
Hybrid scanning



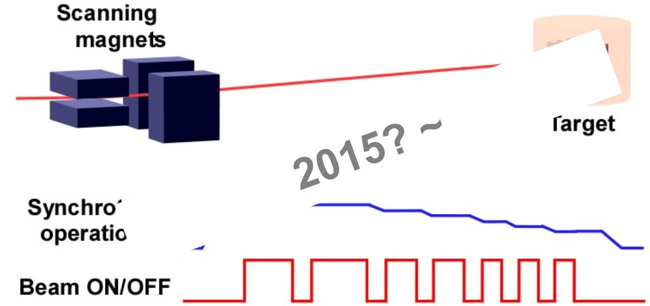
11 energy-steps + RSF

Improvement of Depth Scan

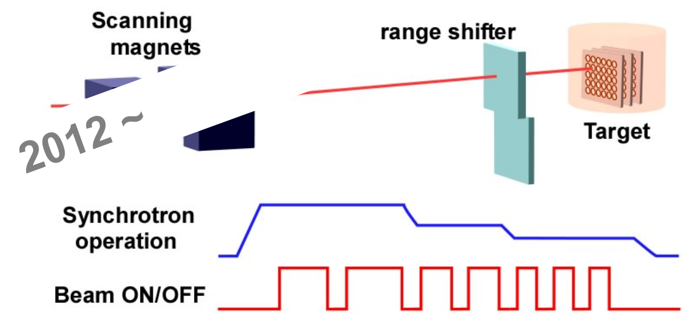
RSF scanning



Energy scanning



Hybrid scanning

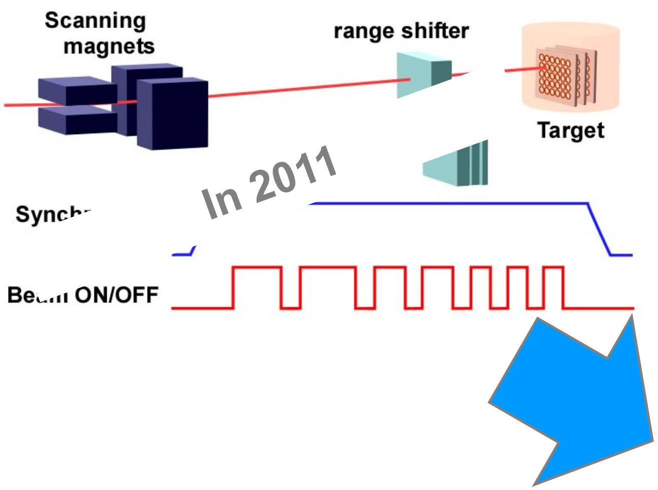


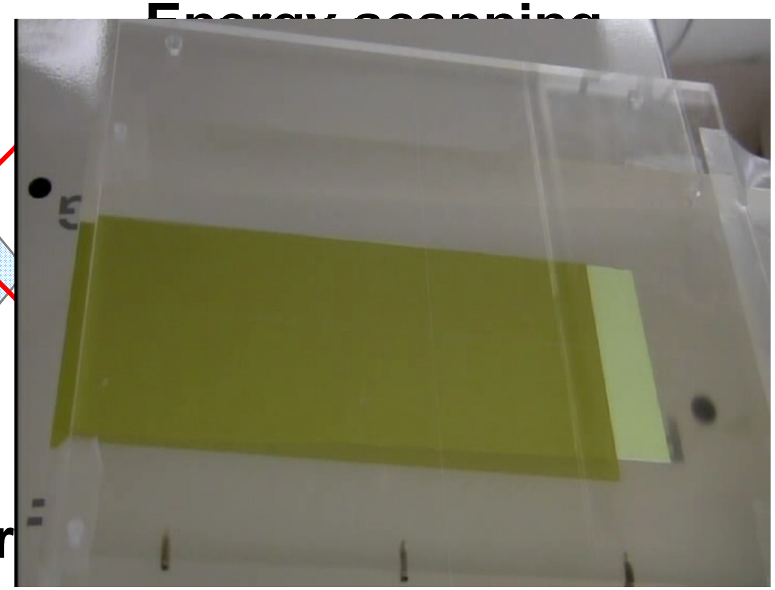
11 energy-steps + RSF

NIRS HIMAC

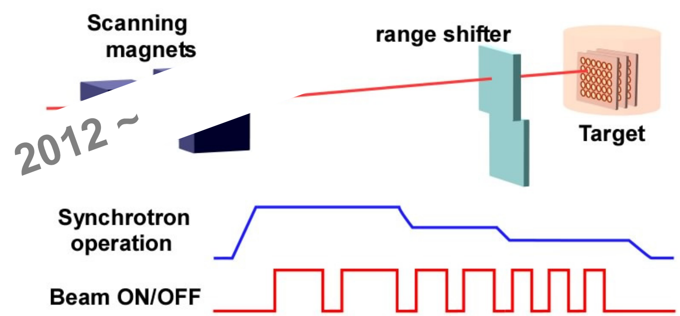
Improvement of Depth Scan

RSF scanning





Hybr



Variable-Energy Operation

- High speed slice change
- Suppressing beam-size growth
- Reduction of 2^{nd} neutron

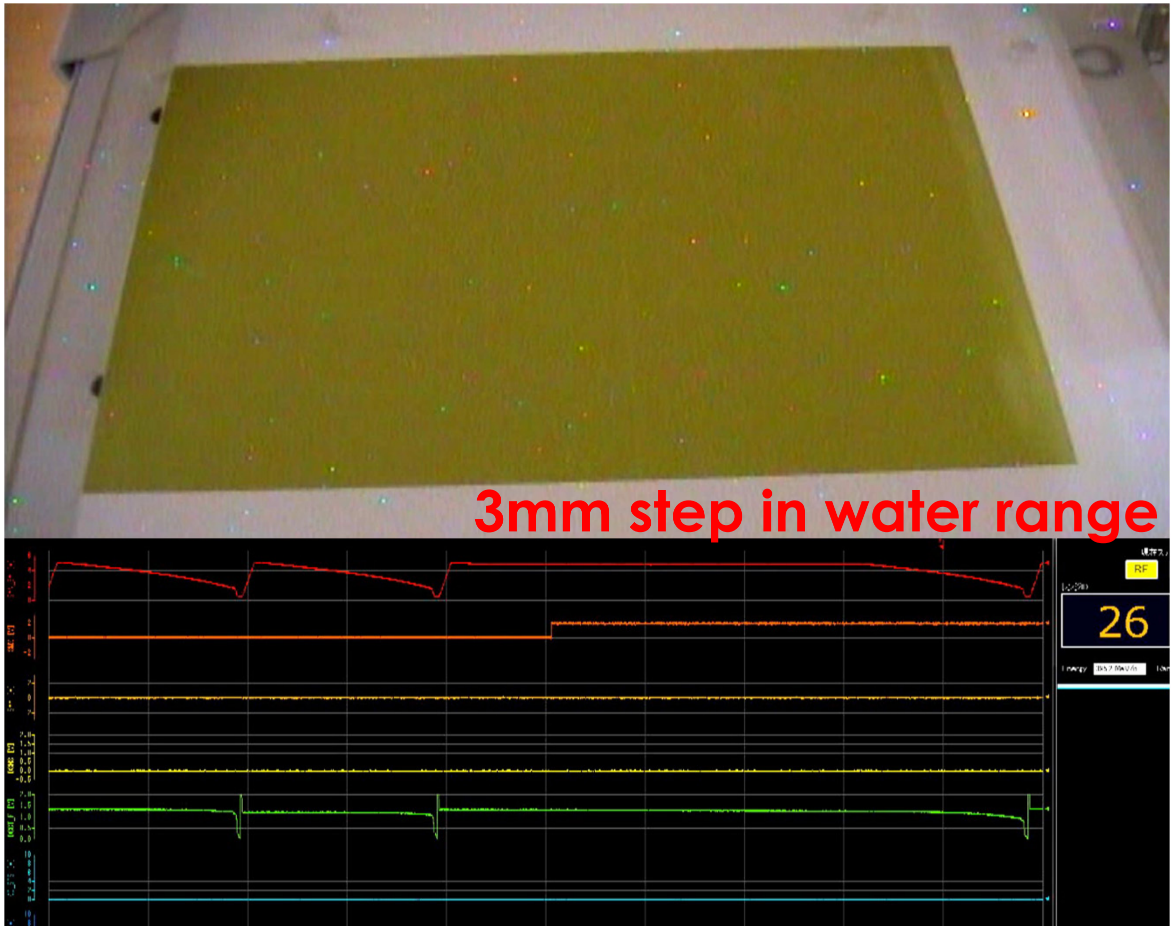
11 energy-steps + RSF

Full Energy Depth Scan

Lower energy

Beam direction

Higher energy



Current pattern of BM

Scanning magnet (X)

Scanning magnet (Y)

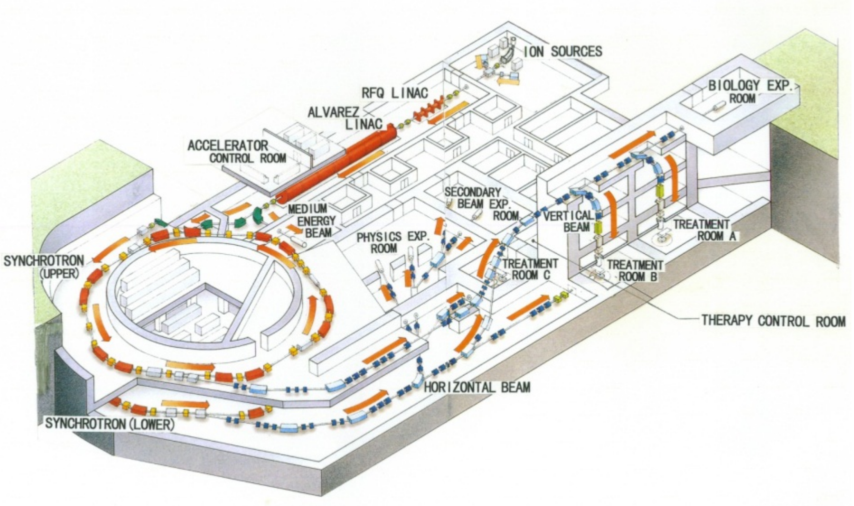
Extracted beam

Beam current in ring

Irradiation gate

Energy ID

Contents

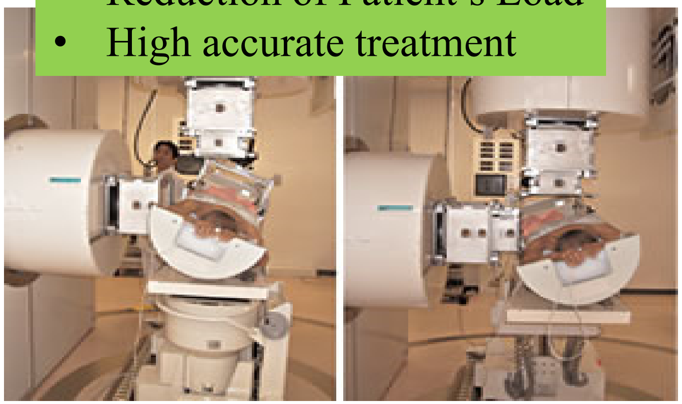


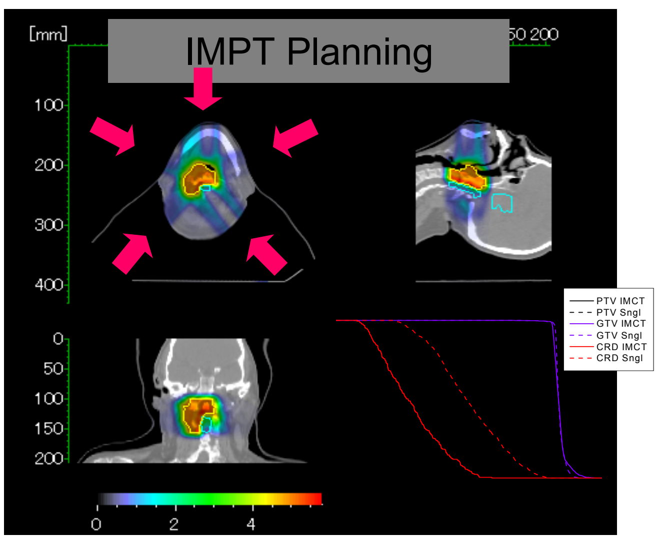
ION SOURCES
BIOLOGY EXP. ROOM
RFQ LINAC
ALVAREZ LINAC
ACCELERATOR CONTROL ROOM
SECONDARY BEAM EXP. ROOM
MEDIUM ENERGY BEAM
VERTICAL BEAM
TREATMENT ROOM A
PHYSICS EXP. ROOM
SYNCHROTRON (UPPER)
TREATMENT ROOM C
TREATMENT ROOM B
THERAPY CONTROL ROOM
HORIZONTAL BEAM
SYNCHROTRON (LOWER)

NIRS HIMAC

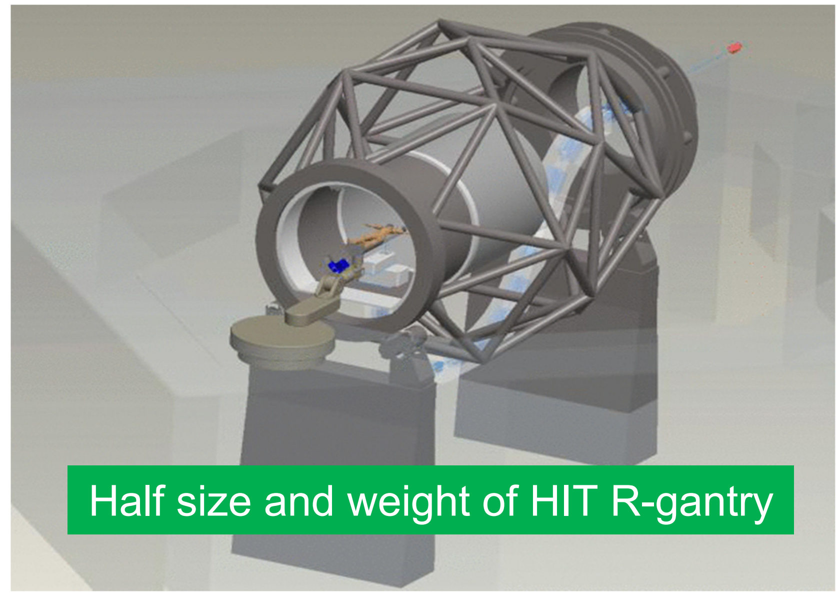
Rotating Gantry

3D Scanning + R-Gantry
- Reduction of Patient's Load
- High accurate treatment





Shorter Course Treatment



Field	: 1.8T
Weight	: 400t
Diameter	: 14 m
Length	: 15m

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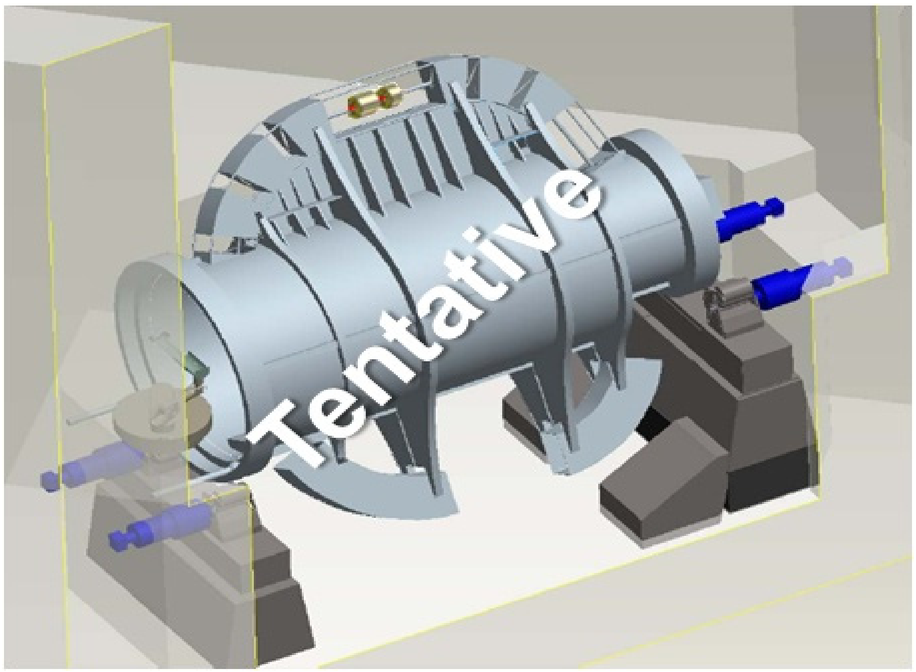
Superconducting R-Gantry

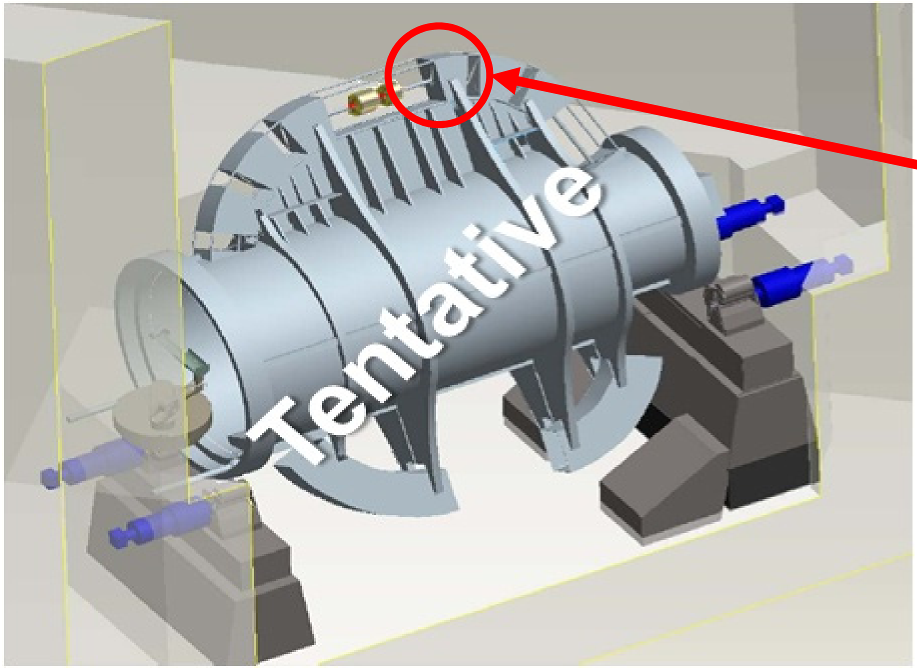


Max. field: ~3T

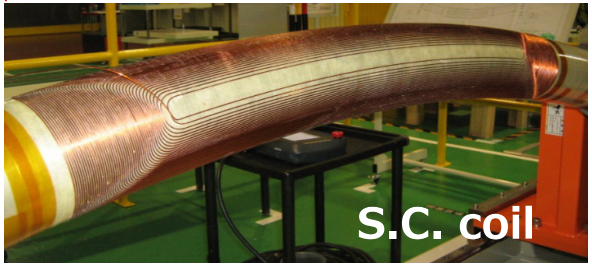
Rotating Gantry

Ion species	^{12}C
Irradiation meth.	Scanning
Beam energy	430 MeV/n (max.)
Max. Field	18×18 cm^2 (tent.)
Magnet	Superconducting Combined function
Num. of magnets	10 (6+4)
Magnetic field	2.4 ~ 2.9 T
Gantry radius	5.5 m
Gantry weight	280 t (tent.)

Superconducting R-Gantry



Max. field: ~3T



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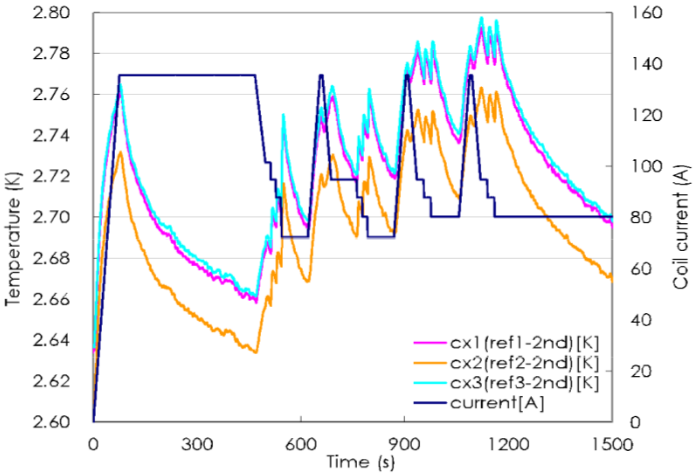
R-Gantry

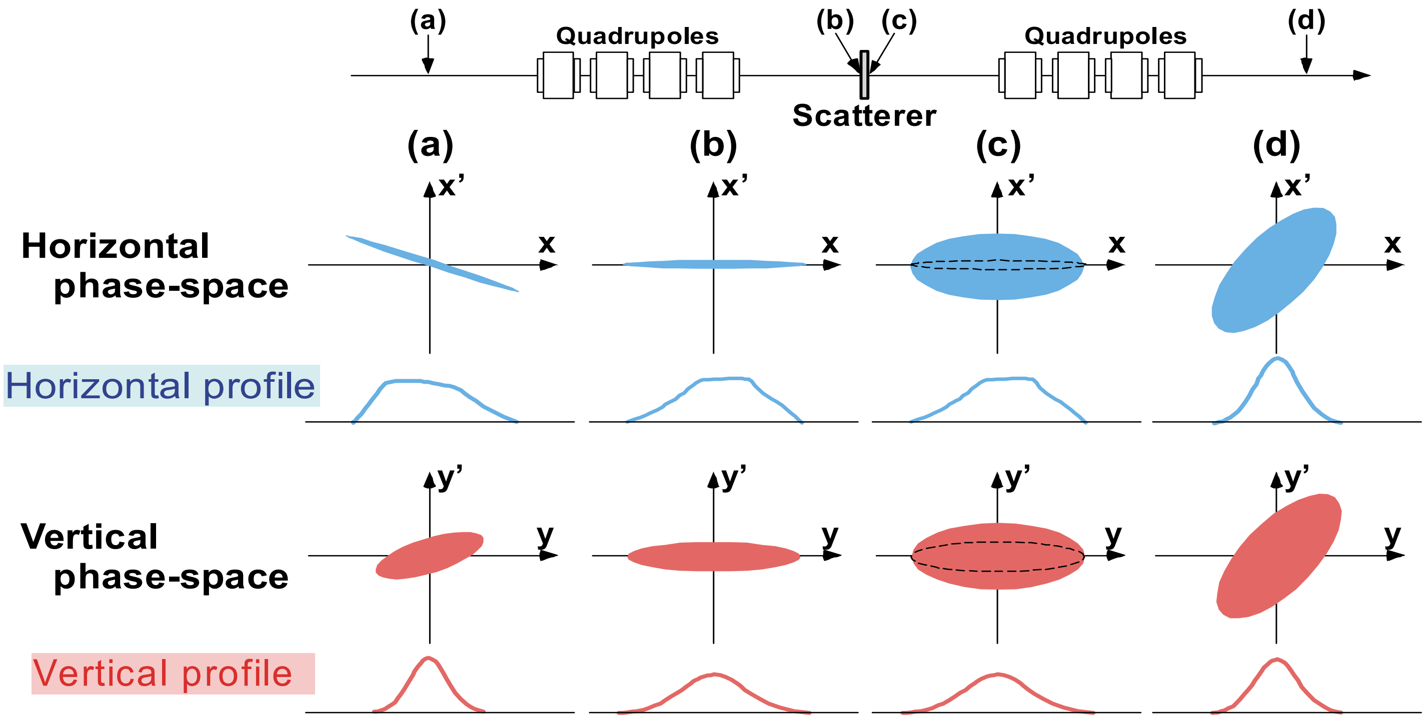
NIRS HIMAC

Tests of SC Magnets for Gantry



- **Field uniformity in wide effective area**
  - TOSCA 3D magnetic field calculation
  - Field measurements in progress
- **Stability of the superconducting magnet**
  - Liquid He free conduction cooled SC magnet
  - Rotating test of the magnet **No quench!**
- **Fast excitation of the magnets**
  - Optimization of the AC loss and Cooling
  - Excitation test of the magnet **No quench!**

Compensation of asymmetric profile



T. Furukawa, K. Noda, NIM A565 ('06) 430

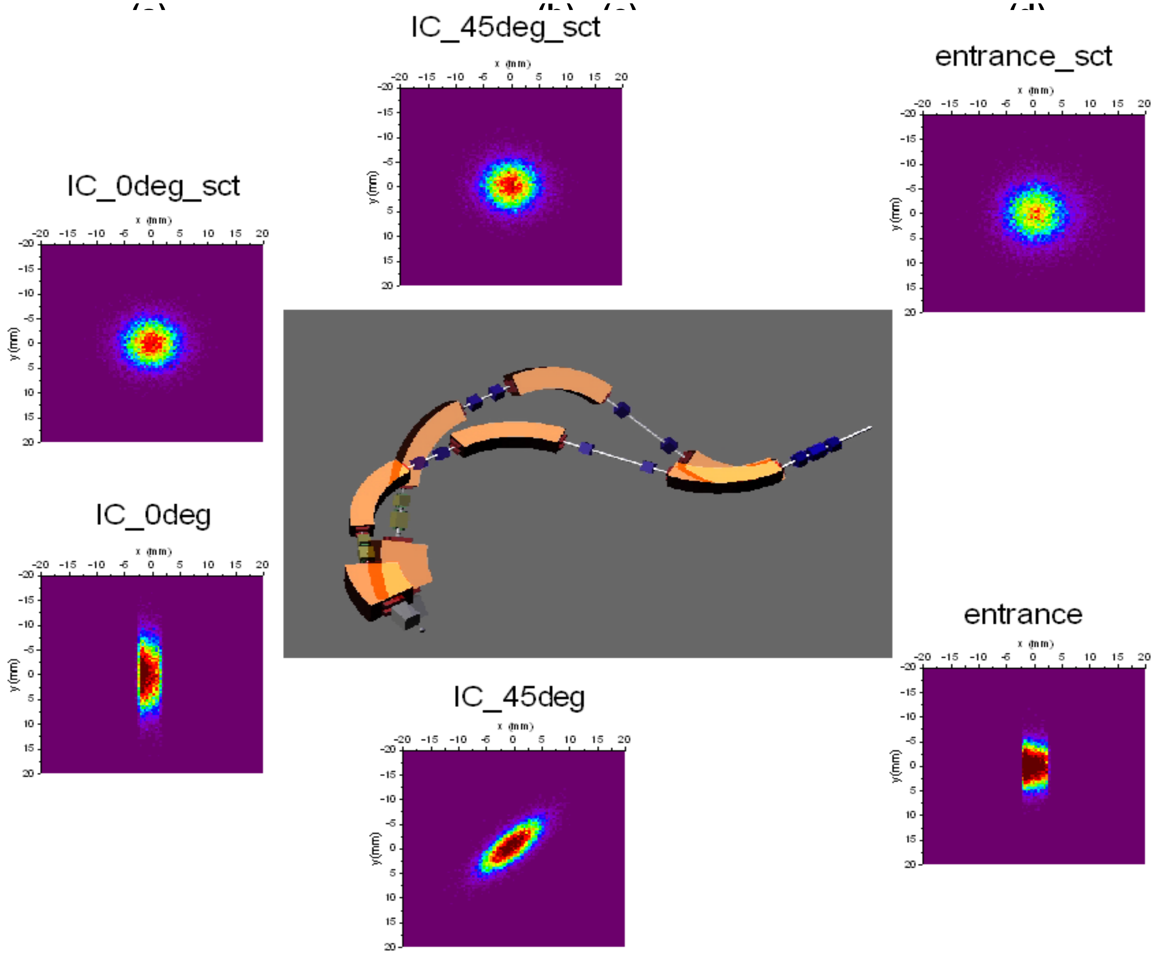
Compensation of asymmetric profile

Horizontal phase-spac

Horizontal pro

Vertical phase-spac

Vertical profi



T. Furukawa, K. Noda, NIM A565 ('06) 430

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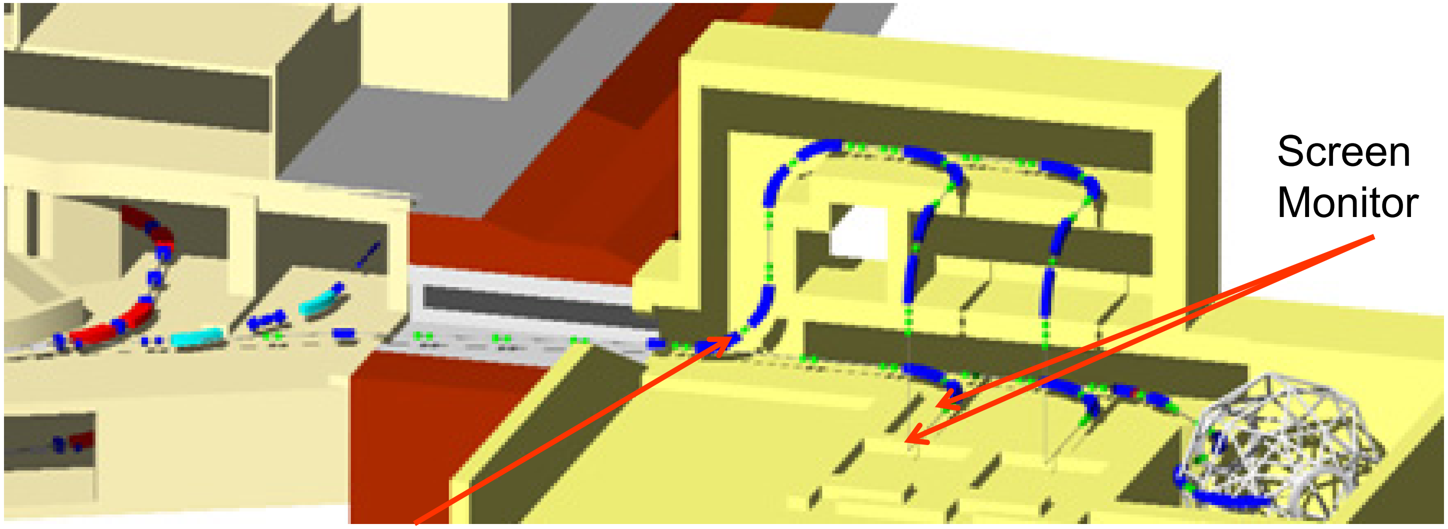
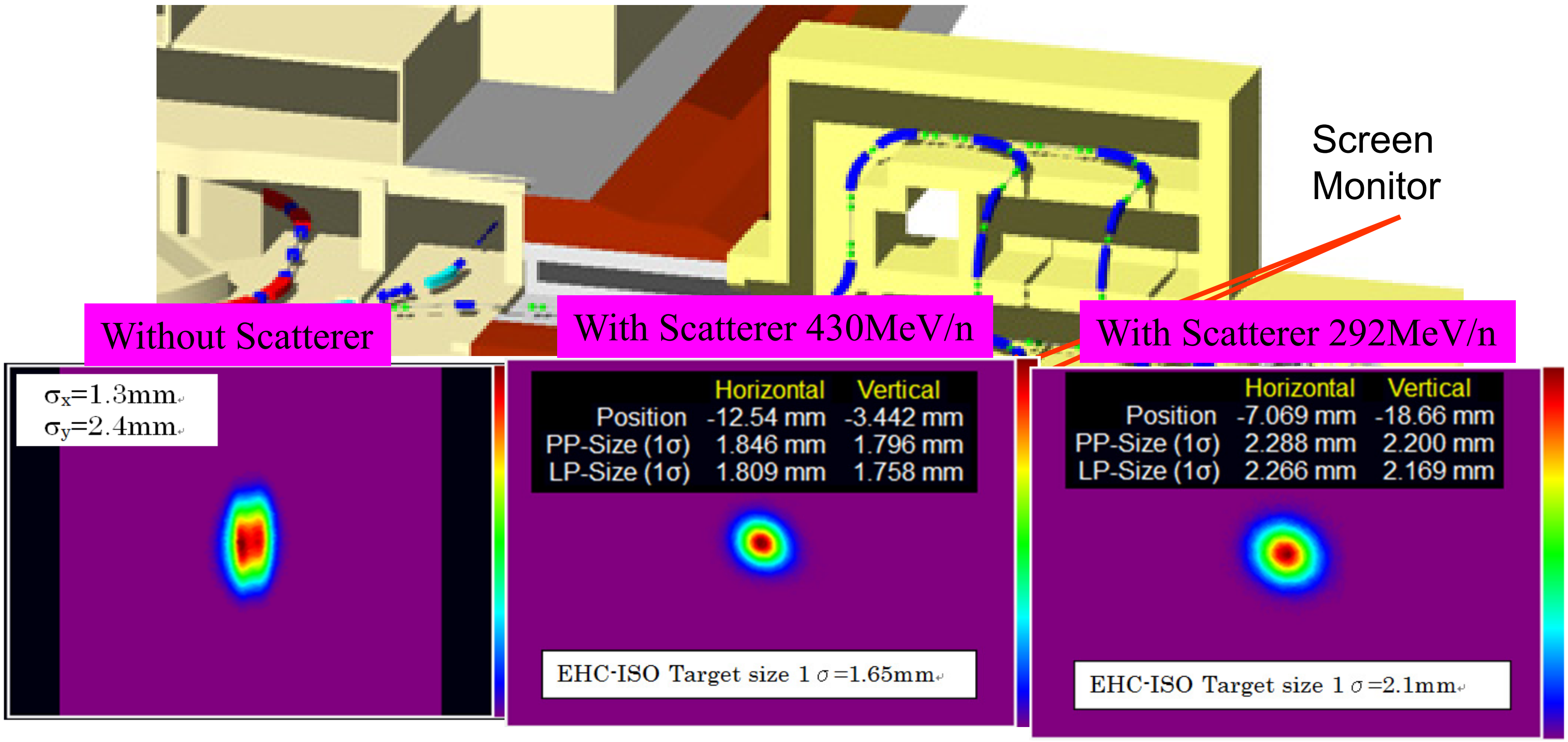
Asymmetric Distribution Compensation

Experimental Setup



Asymmetric Distribution Compensation

Experimental Setup



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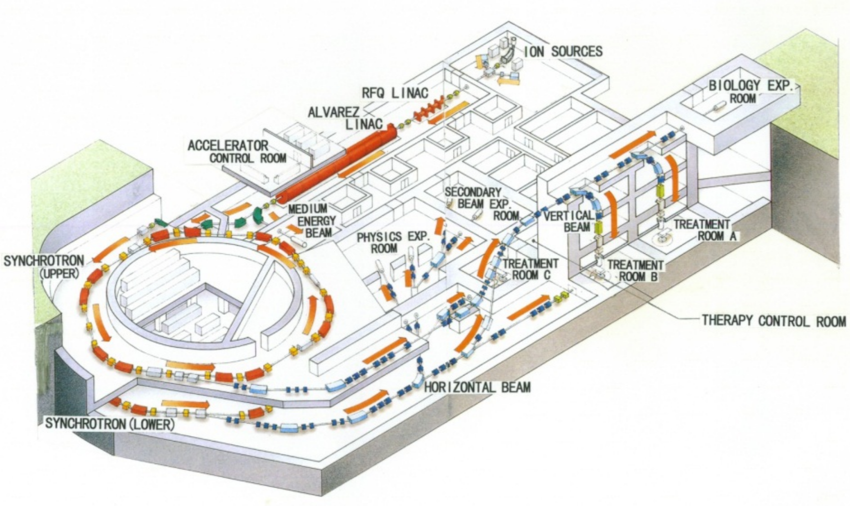

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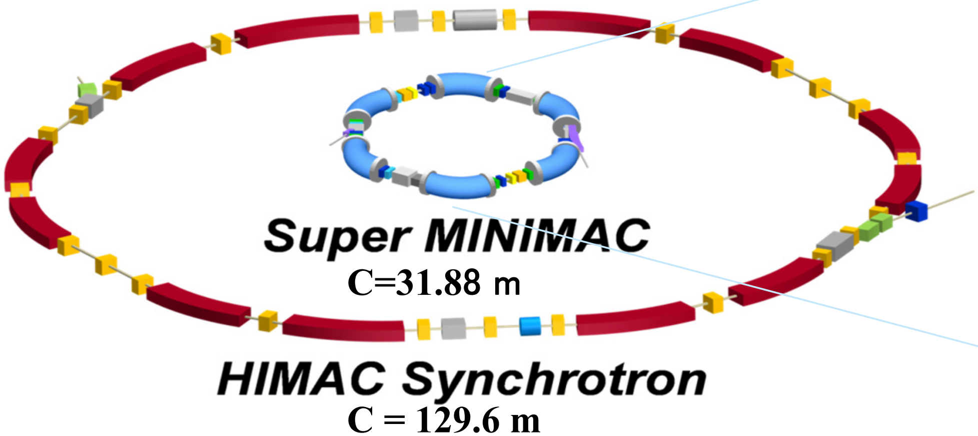
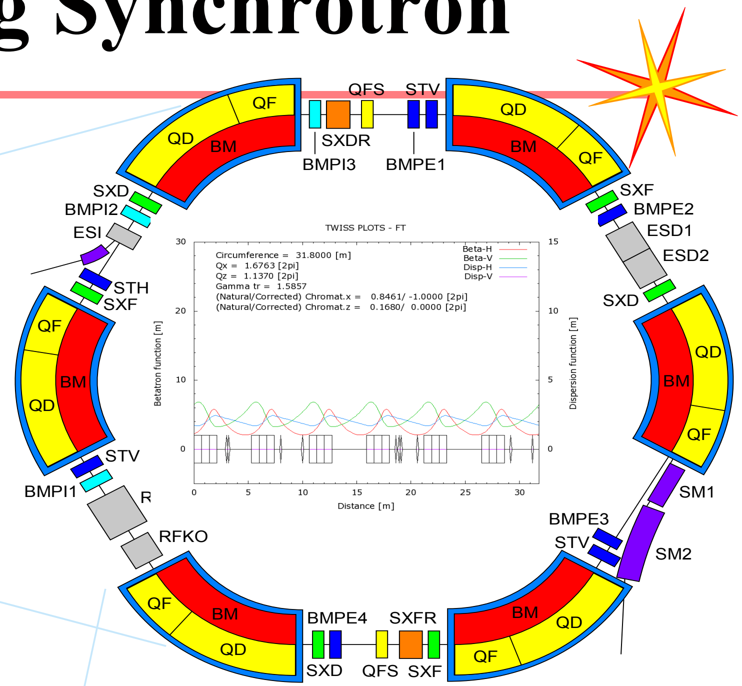
SYNCHROTRON (LOWER)

Superconducting Synchrotron

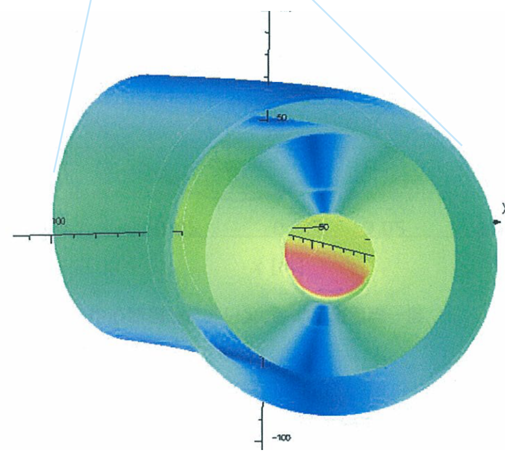
NIRS HIMAC

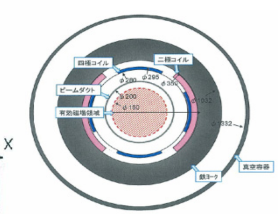
Design Study



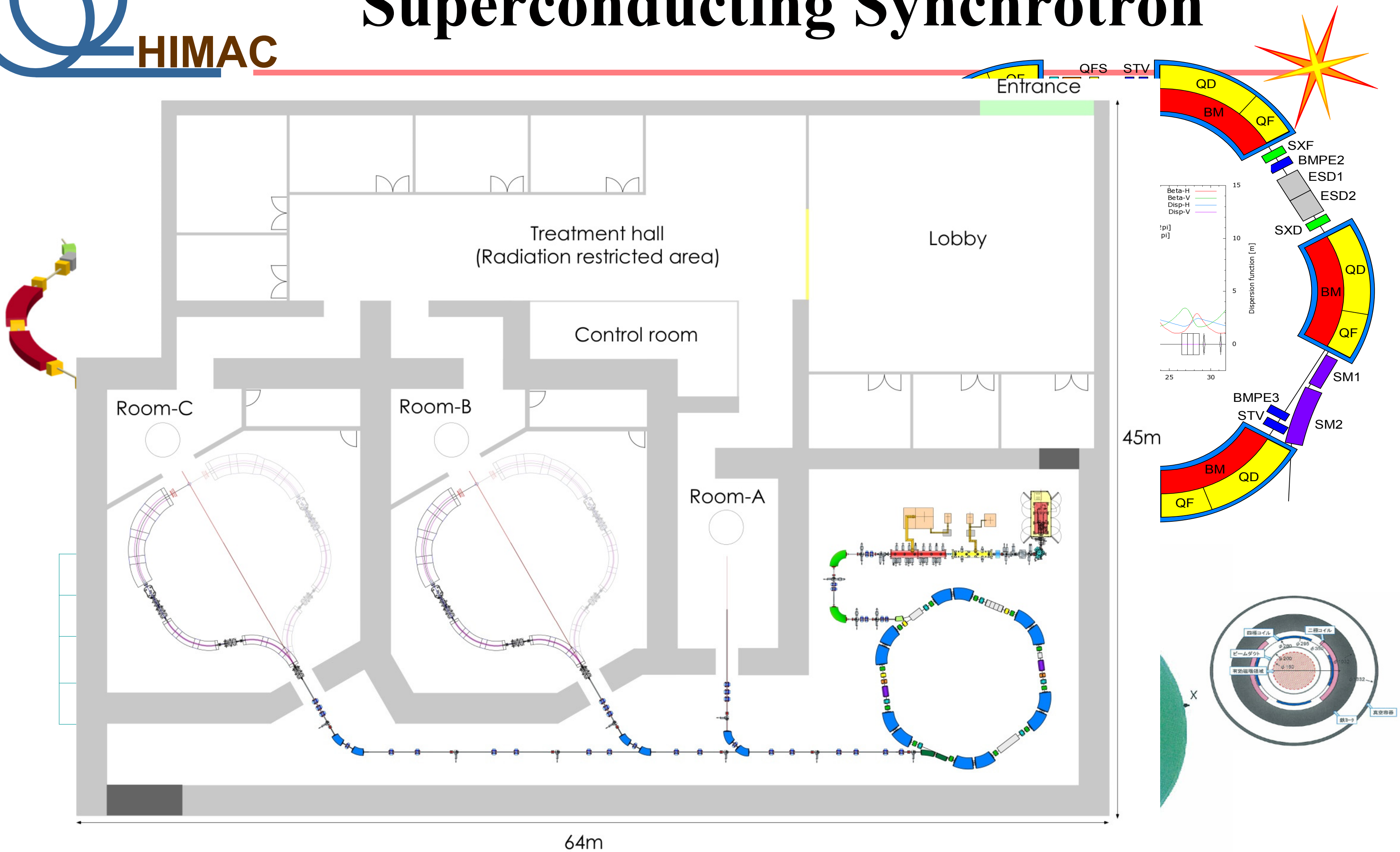


Injection Energy	4 – 8 MeV/n
Extraction Energy	430–60 MeV/n
Tune(Q_x ,Q_y)	(1.68, 1.13)
Field Strength	~3.4 T



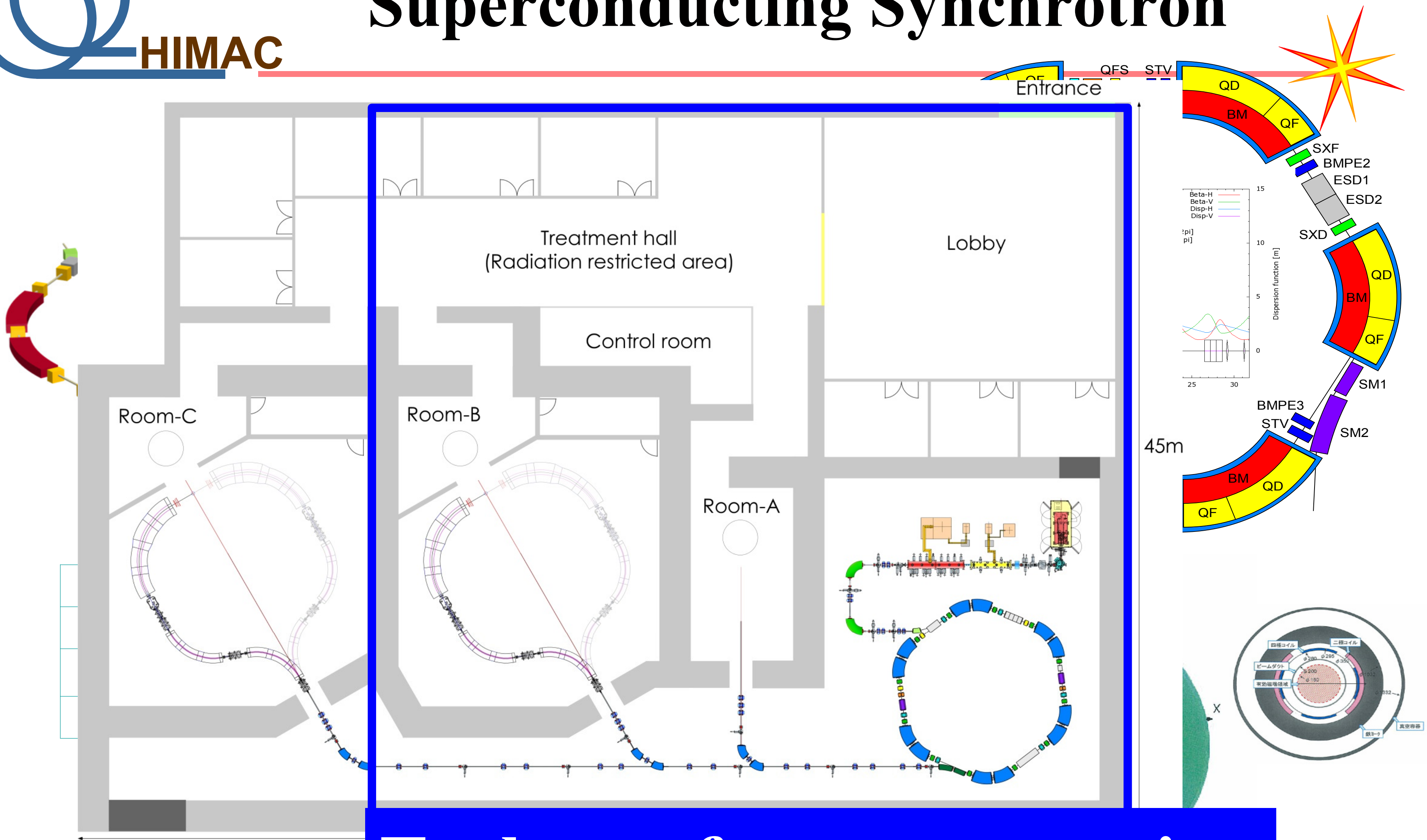


Superconducting Synchrotron



Super-MINIMAC

Superconducting Synchrotron



Tank you for your attention