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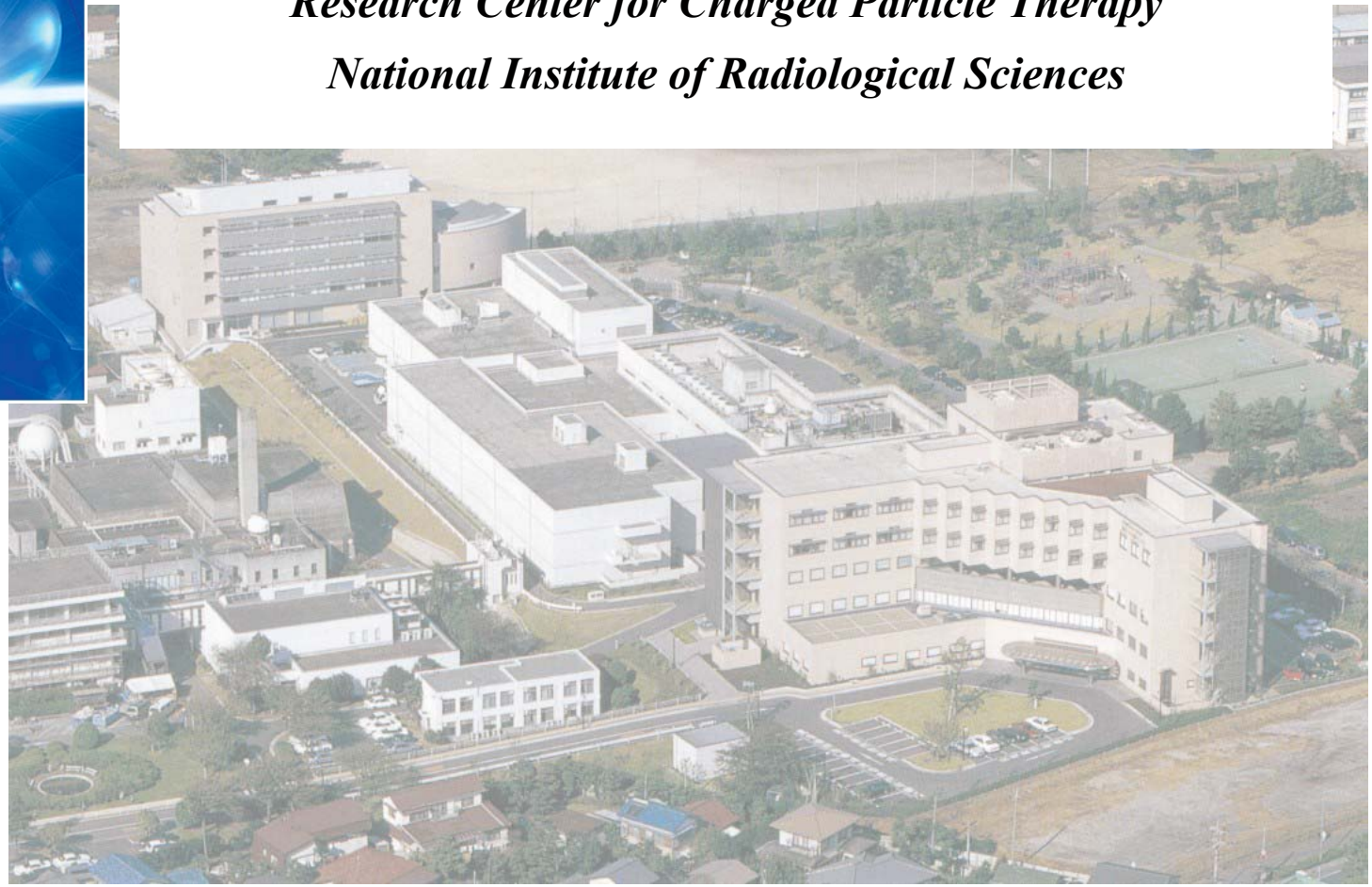
Development of New Carbon Therapy Facility and Future Plan of HIMAC

Koji Noda

Research Center for Charged Particle Therapy

National Institute of Radiological Sciences



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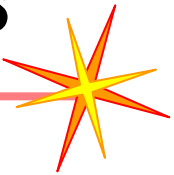
Contents



1. Introduction

2. New Carbon-Therapy Facility (Compact Facility)

3. Future Plan of HIMAC

4. Summary

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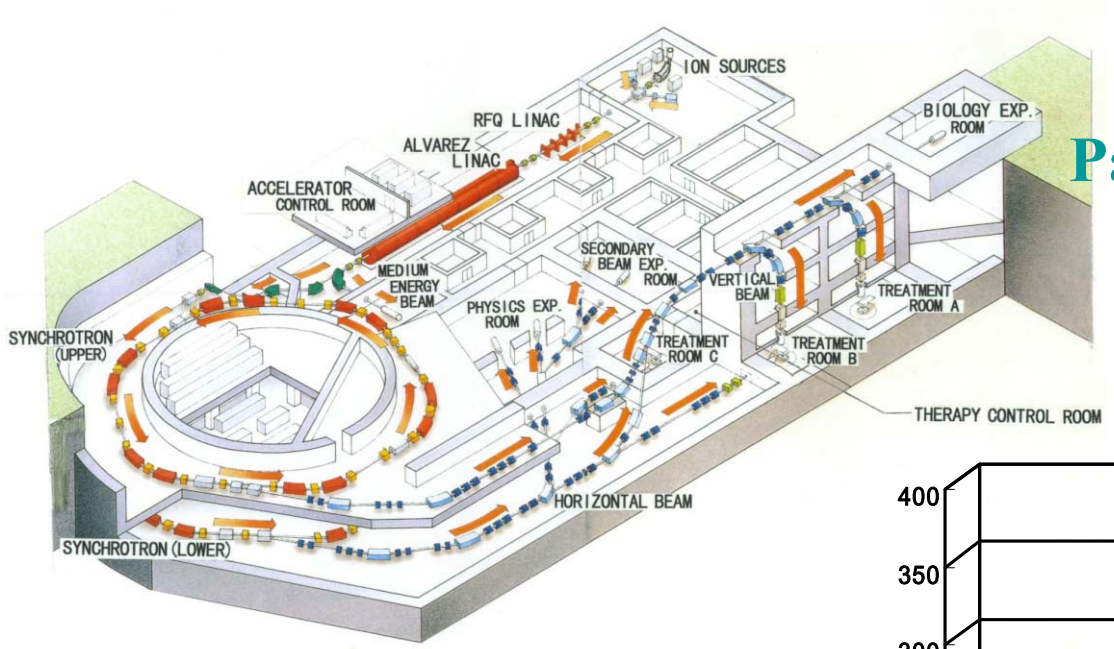
Motivation of Compact Facility

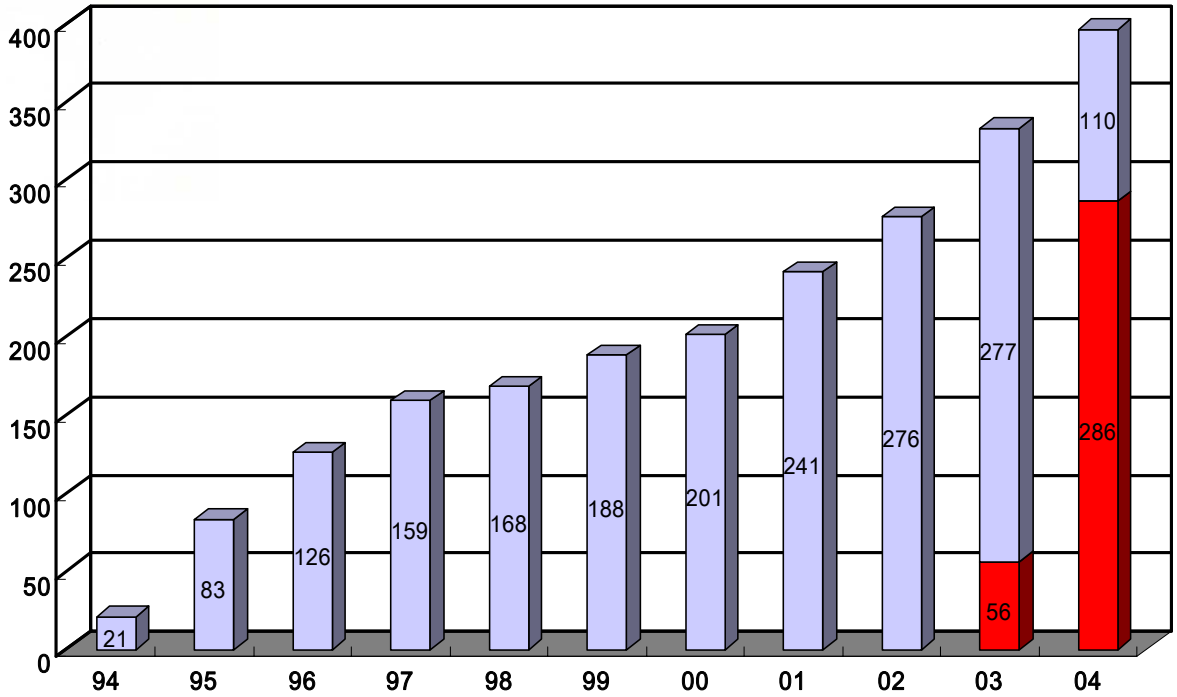


Patients Number of Carbon Therapy

(June '94 ~ Feb. '05)

Highly Advanced Medical Therapy
from Nov. '03

Since 1994, Cancer treatment with HIMAC has been successfully progressed.
Owing to accumulation of treatment number and good result of the clinical trials, the Japanese government approved the HIMAC treatment as the highly advanced medical therapy in Nov. '03.



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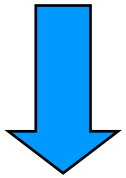
Design Consideration for Compact Facility

- How high Energy ?
- How large Irradiation-Field Size?
- How much Intensity delivered?
- How large Facility?



Based on experience at HIMAC, the specification is determined!!

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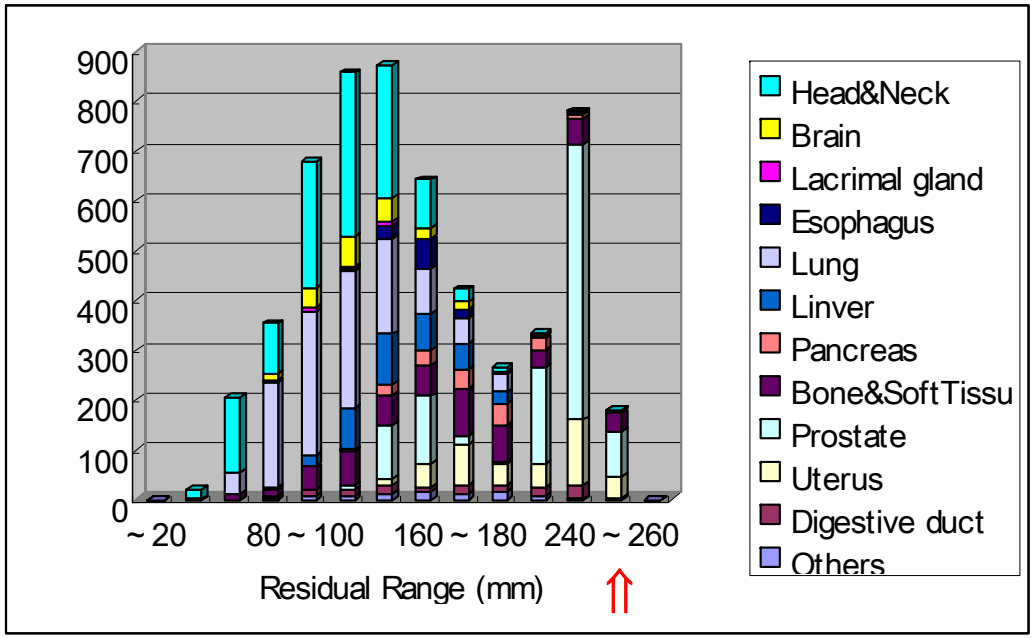
How high beam energy?



Residual range of 250 mm covers almost all treatments at HIMAC.

Required energy: 400 MeV/n, under range loss of 25 mm due to scatterer etc.

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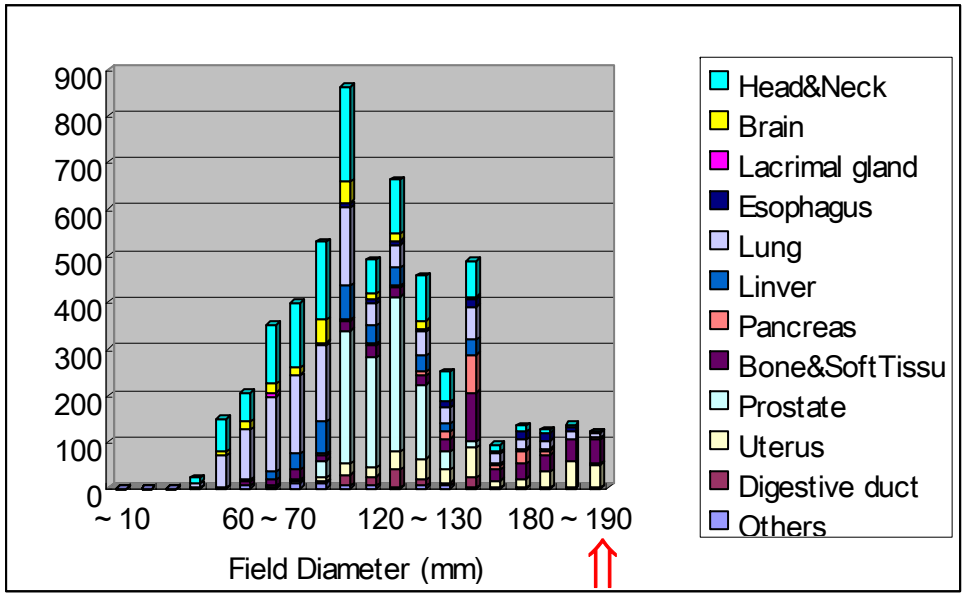
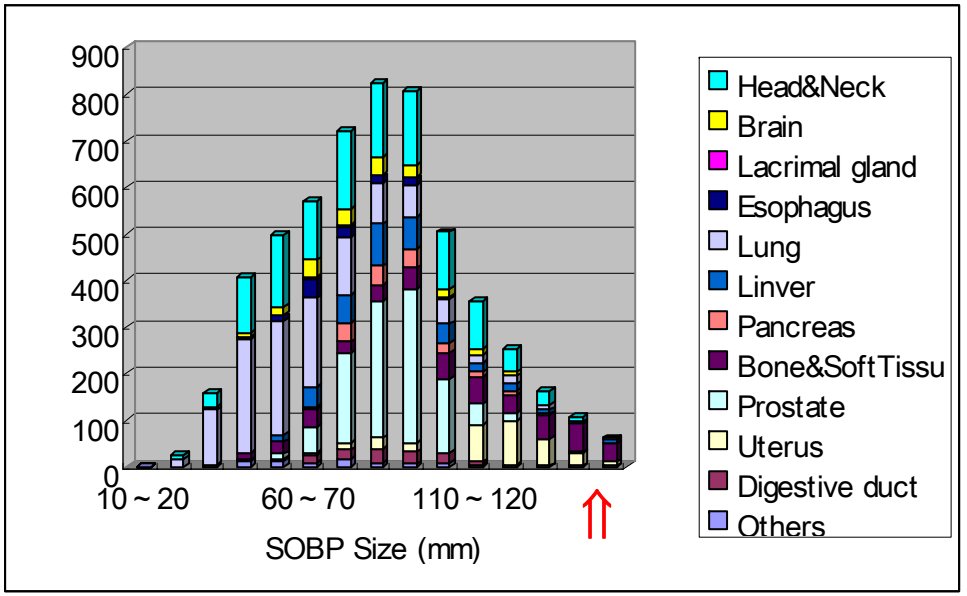
How large field size?





The field diameter more than 200 mm is large enough to cover almost all treatments in HIMAC.

The SOBP more than 150 mm covers treatments more than 95%.

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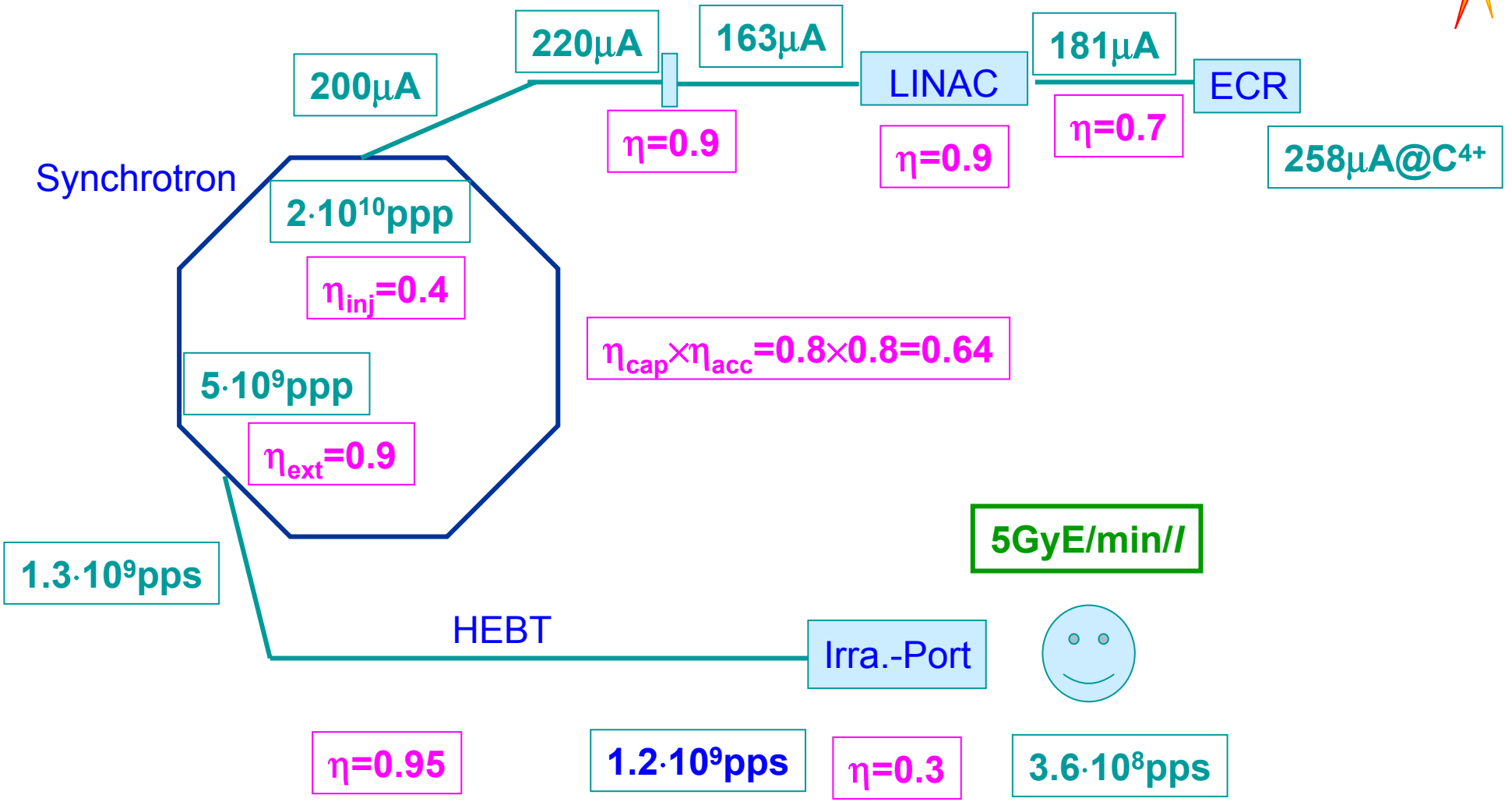
How much intensity?



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Specification

1. Ion species: high LET (100keV/μm) charged particle - Carbon
2. Range: Max. 25cm in water
3. Maximum irradiation area: 15cm square
4. Dose rate: 5GyE/min// ⟶ 1.2×10^{9}pps (C ions)
5. Irradiation direction : horizontal, vertical
6. Treatment rooms: 3 (H&V, H, V)
7. Irradiation technique: gating & layer stacking irradiation

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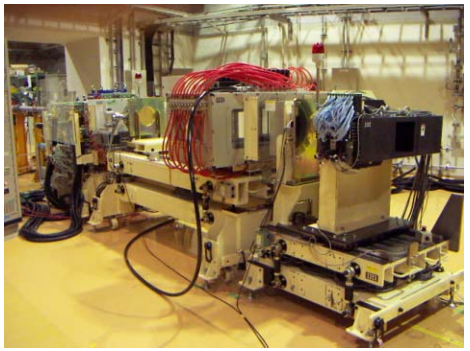
Design and R&D for Compact Facility

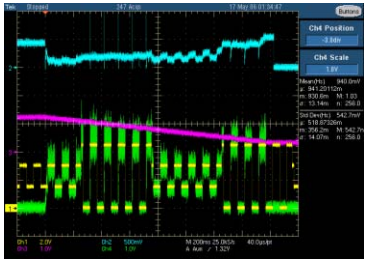
Compact RF-cavity

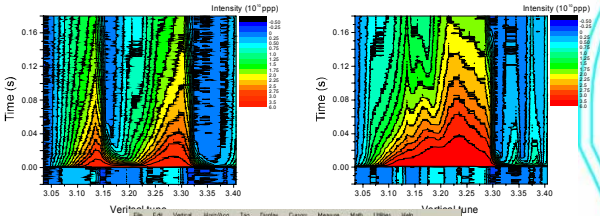
Compact Injector
RFQ + APF-IH

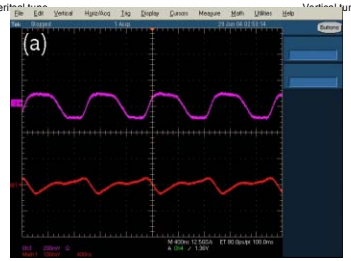


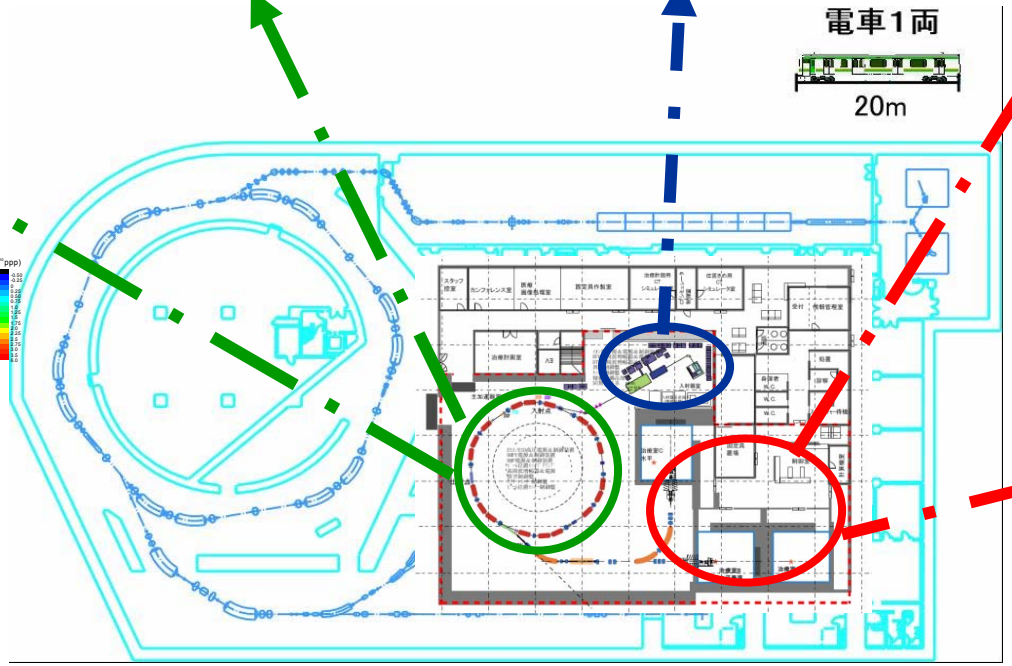
Development Irrad. Tech.

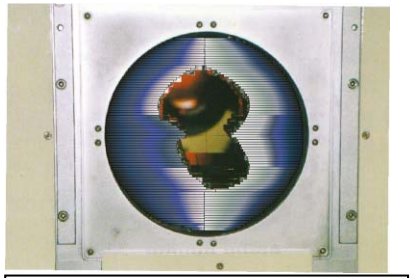
Beam Study











High-Precision MLC

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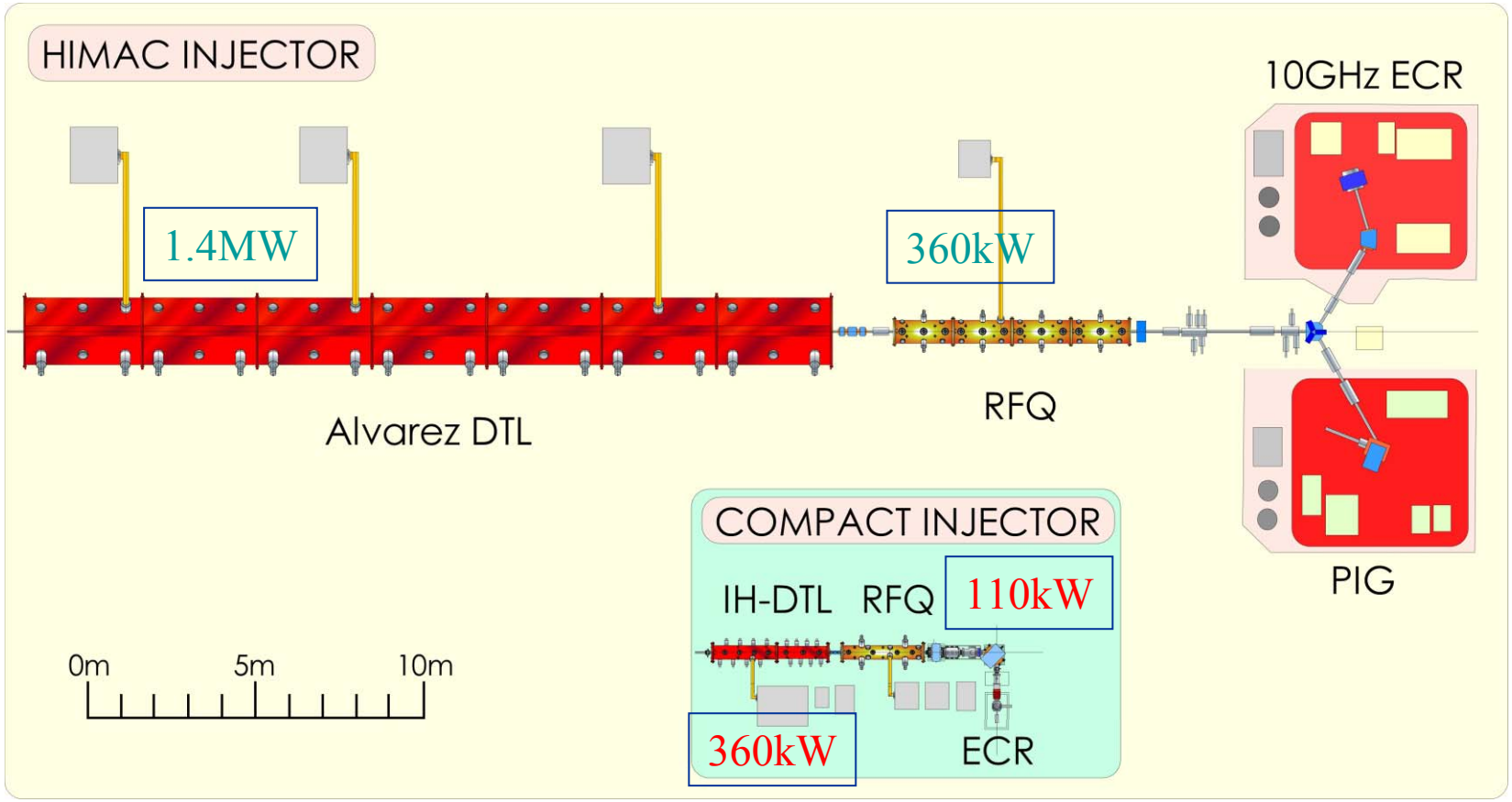
Compact Injector Linac Cascade



The injector linac cascade consists of RFQ and APH-IH linac. The RFQ accelerates C^{4+} ions from 10 to 600 keV/n. The APF-IH accelerates them to 4 MeV/n. Both the operation frequencies are 200 MHz.

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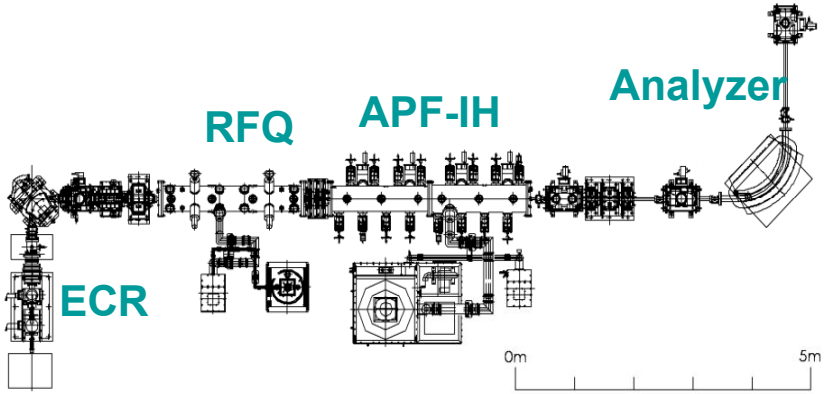
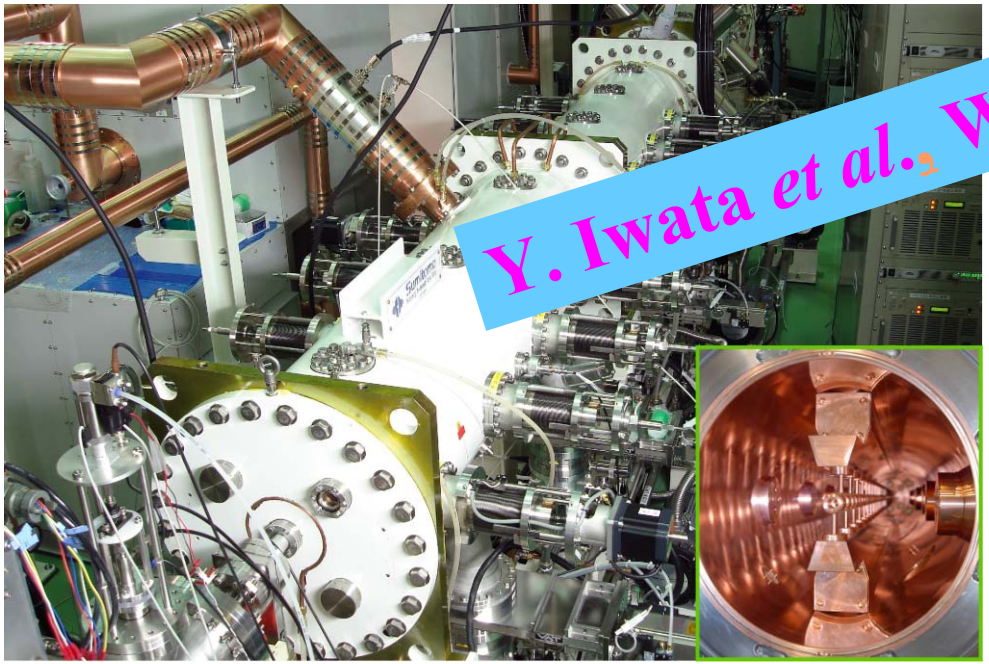
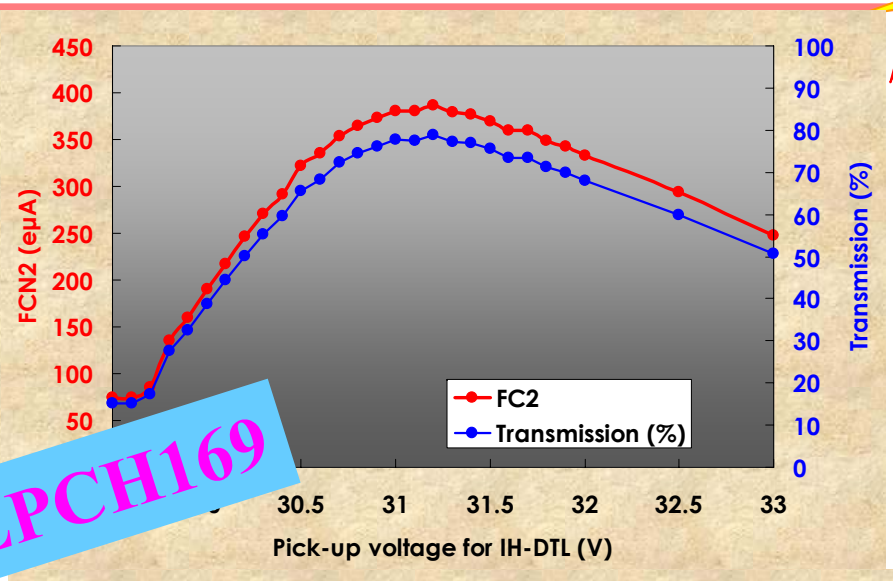
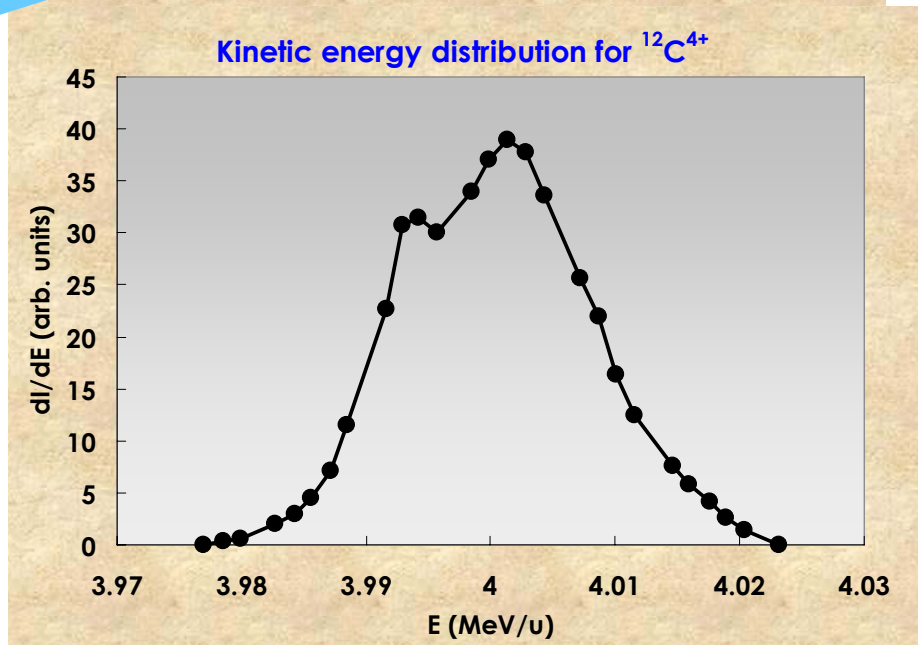
Beam Test of Compact Injector





Y. Iwata *et al.*, WEPCH169





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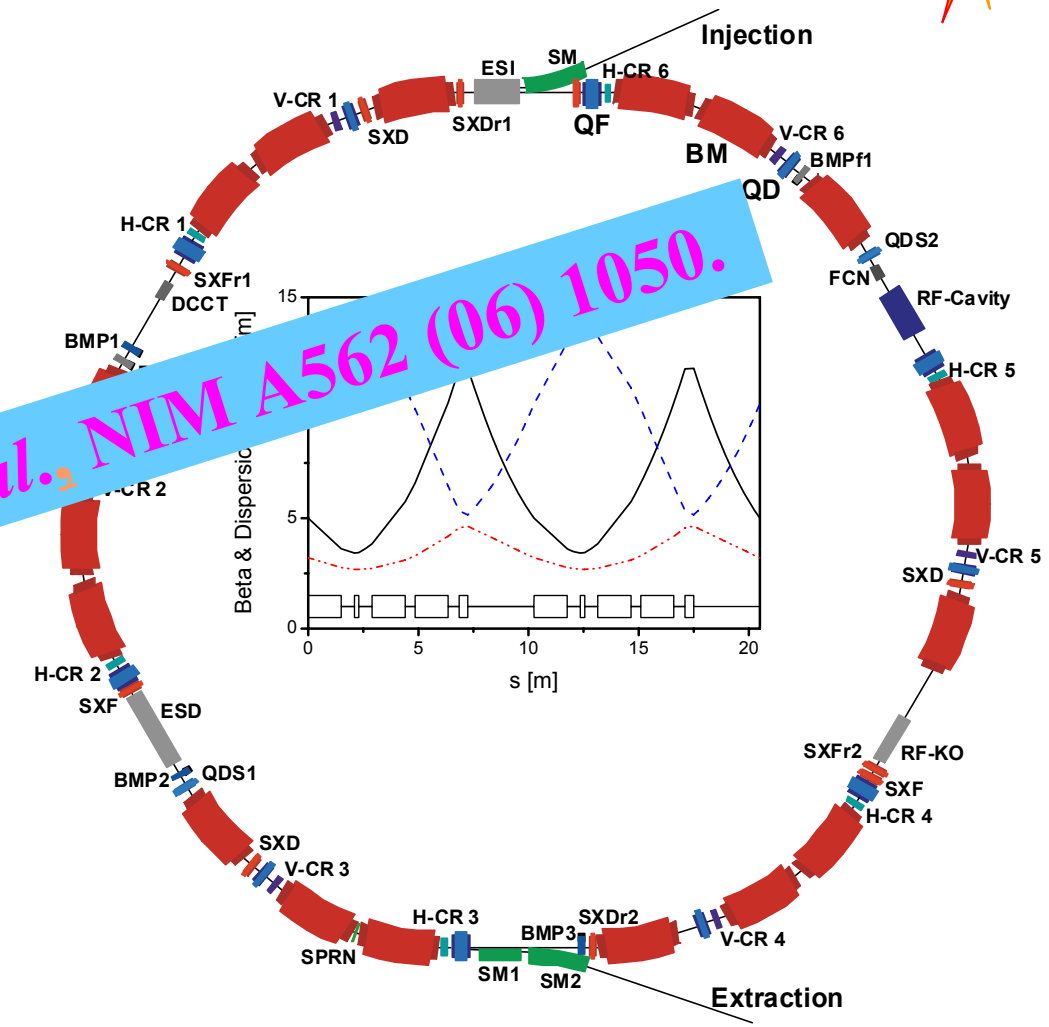
Synchrotron

Main parameters of the synchrotron.

Lattice Type	FODO
Maximum intensity of C^{6+}	2×10^9 pps
Cell number	6
Long straight section	3.0m×6
Circumference	61.5m
Injection energy	4 MeV/u
Extraction energy	140-400 MeV/u
Revolution frequency	0.450
Emittance and Δp/p of injection beam	.2%
Acceptance (after COD correction)	240/30 π mm mrad
Momentum acceptance	±0.4%
Qx /Qy	1.68-1.72/1.13
Maximum β function	11.5/13.4
transition gamma	1.72
ξx/ξy	-0.5/-1.5



T. Furukawa *et al.*, NIM A562 (06) 1050.

BM filling factor of 43% is much larger than that of 31% in HIMAC, which brings a compact synchrotron.

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Compact RF Cavity

Un-tuned RF cavity with Co-based MA

M. Kanazawa *et al.*, TUOCFI03
A. Sugiura *et al.*, TUPCH124

Comparison between HIMAC cavity

	HIMAC	New cavity
[illegible]	1 ~ 8	0.4 ~ 7
[illegible] [kV]	6	4.5
Power [kW]	15	8
Cavity size [cm]	277×89	150×140
Size of PS etc	Amp. with Tetrode 70×40×60 250×150×250 70×70×90 Bias PS 100×100×200	Transister Amp. 60×85×220

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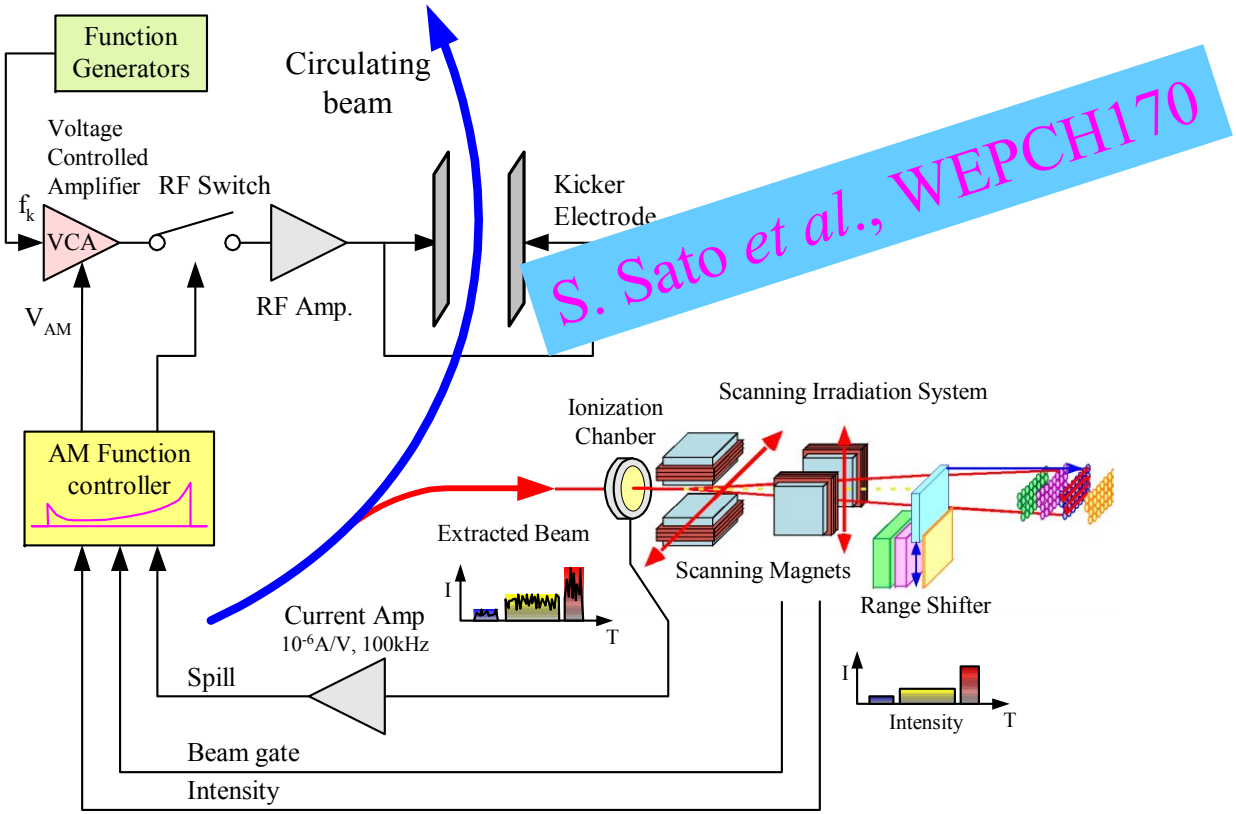
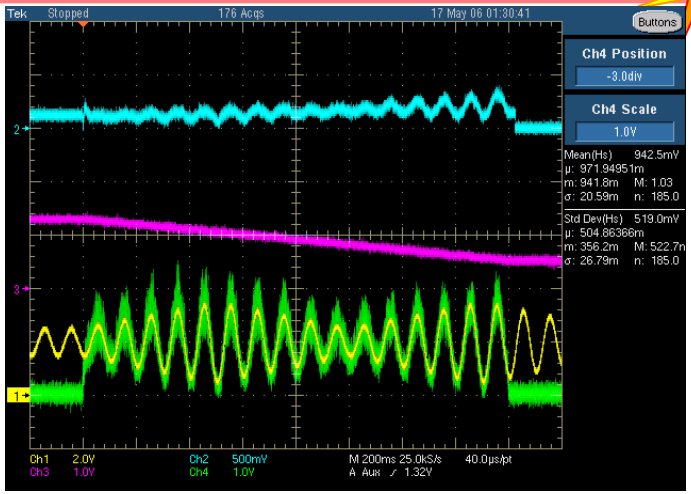
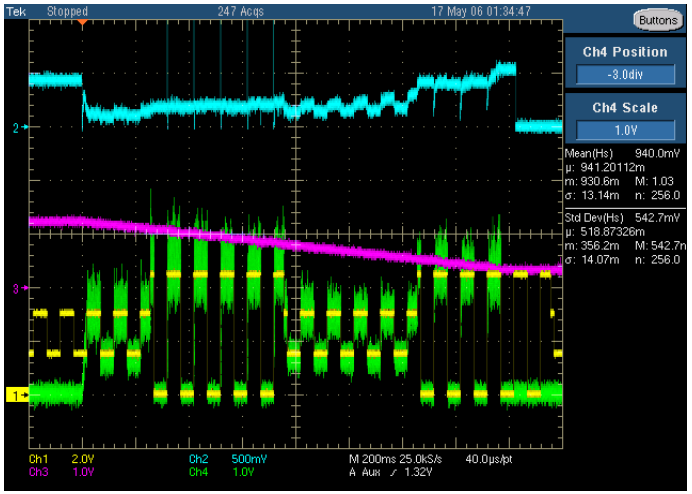
Intensity Modulation







The spot scanning and layer stacking methods require an intensity modulation. Therefore, we have studied the dynamically intensity control. This figure shows three intensity steps during 50 ms. This figure shows sinusoidal intensity wave.

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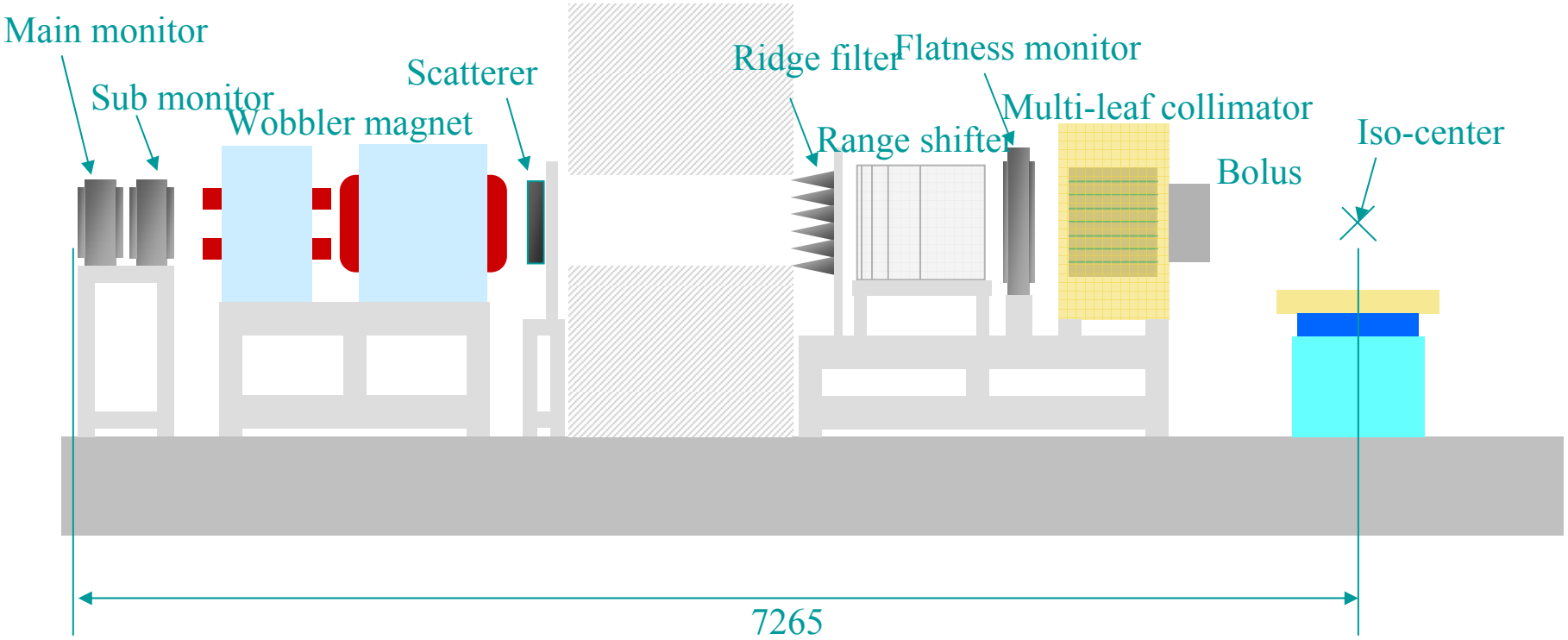
Beam Delivery System



Komori M. et al; J Jpn Appl Phys.

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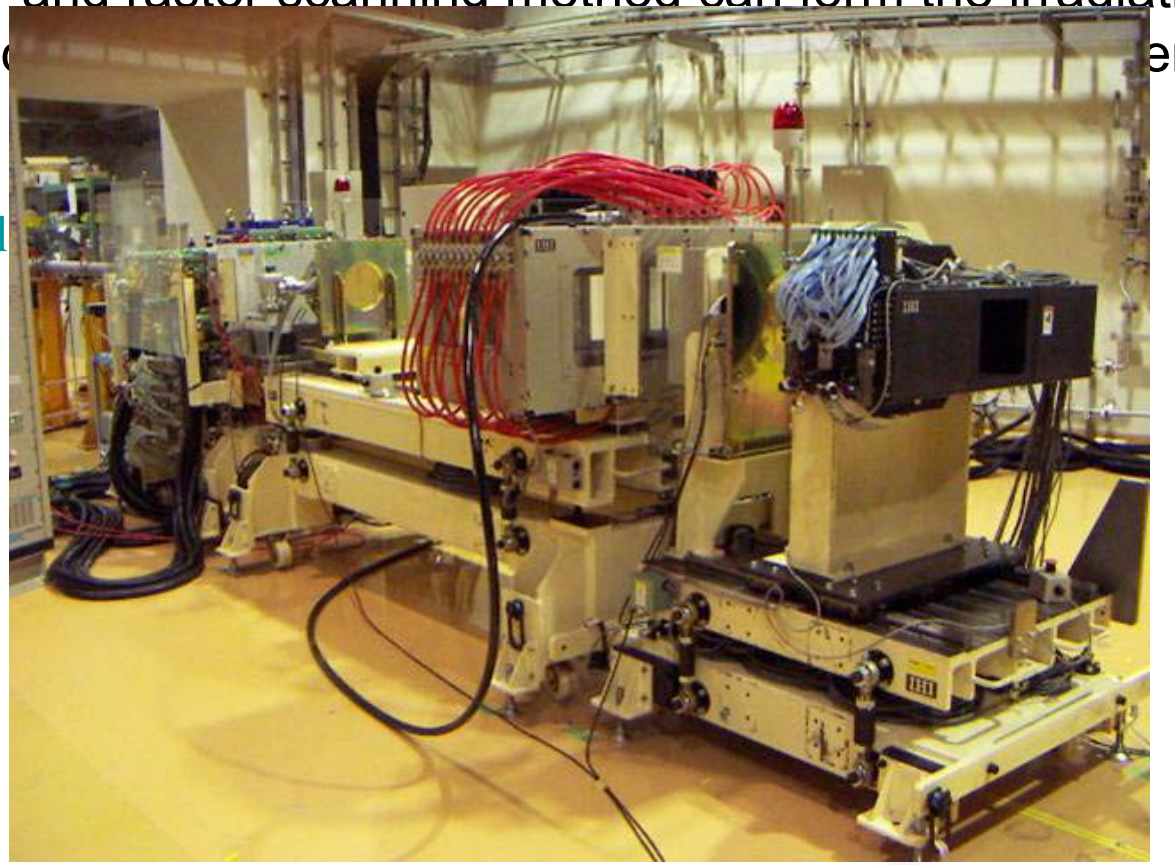
Spiral Wobbler & Raster Scanning

The spiral wobbler and raster scanning method can form the irradiation field by thin scatterer compare[illegible]er residual range in patient.

Conventional Wobbl

Spiral Wobbler

Raster Scanning



The spiral wobbler and raster scanning can be available a larger field even under thin scatterer.

→ Longer residual range

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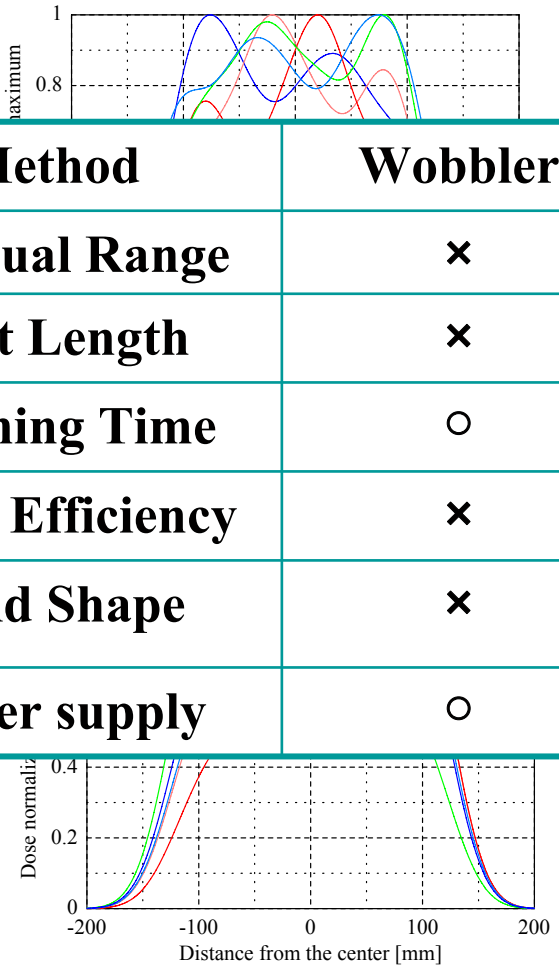
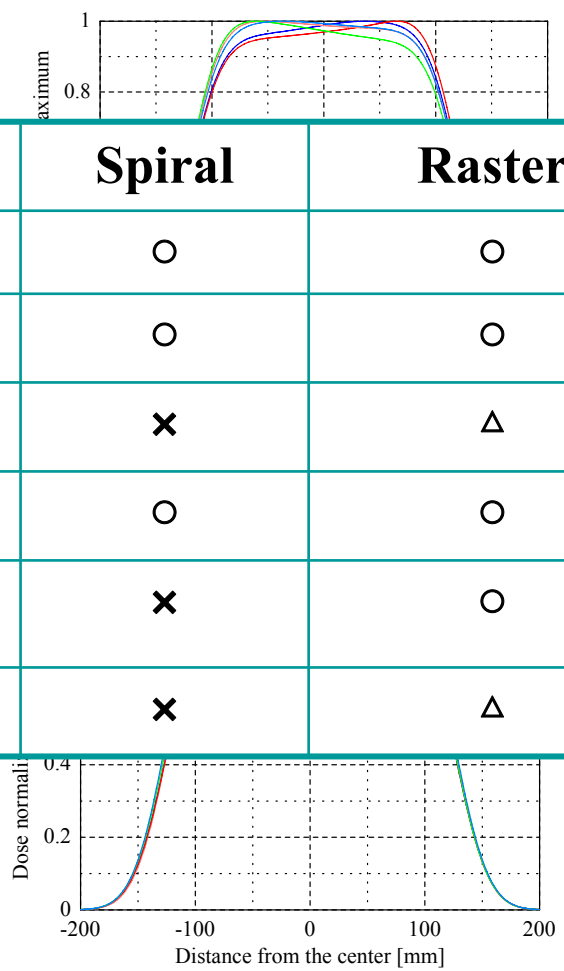
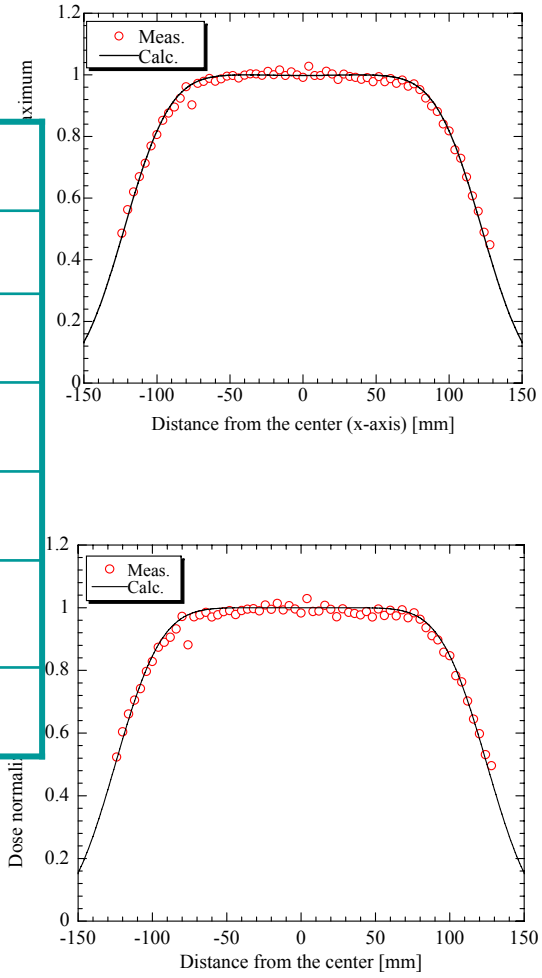
Beam-Test Result

Method	Wobbler	Spiral	Raster
Residual Range	×	○	○
Port Length	×	○	○
Forming Time	○	×	△
Beam Efficiency	×	○	○
Field Shape	×	×	○
Power supply	○	×	△







Raster Scann

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Future Plan of HIMAC (1)

♥For High Accurate Treatment

3D scanning on a moving target

for reducing the margin of 5 - 10 mm

♣ Repainting with Raster Scan & Layer Stacking Method

3D scanning on a fixed target

for fitting irregular shape

♣ Spot Scanning or Raster Scanning Method

♥For Flexible Treatment and One-day Treatment

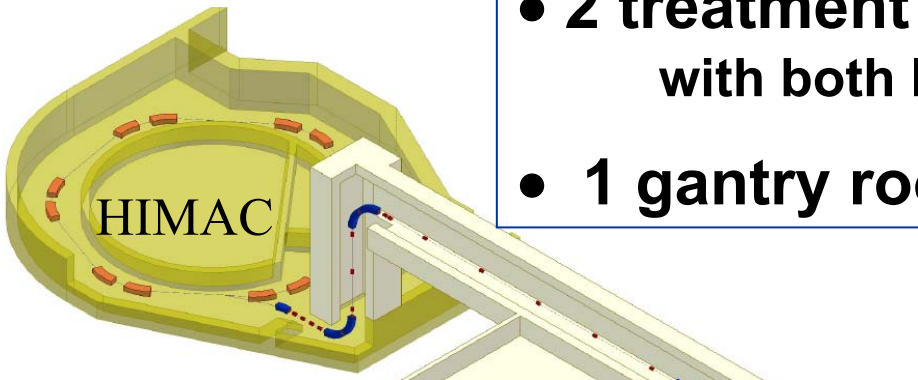
Rotating Gantry

♣ Repainting with Raster Scan & Layer Stacking Method

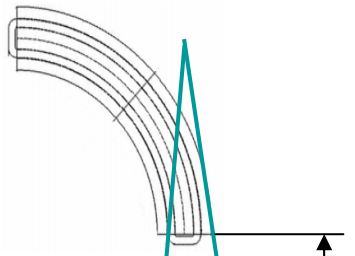
NIRS HIMAC

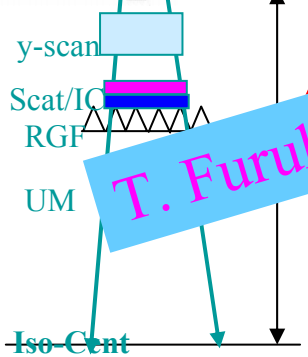
Future Plan of HIMAC (2)

- **2 treatment rooms (H&V)**
  with both broad beam & 3D scanning system
- **1 gantry room**



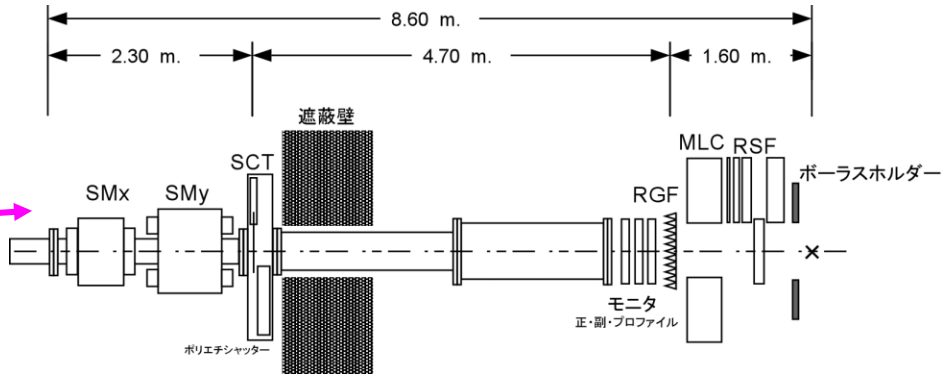
New Treatment Facility





T. Furukawa *et al.*, WEPCH167

Broad-beam Raster & Layer Stacking



- Broad-beam Raster & Layer Stacking
- Spot Scanning

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Summary

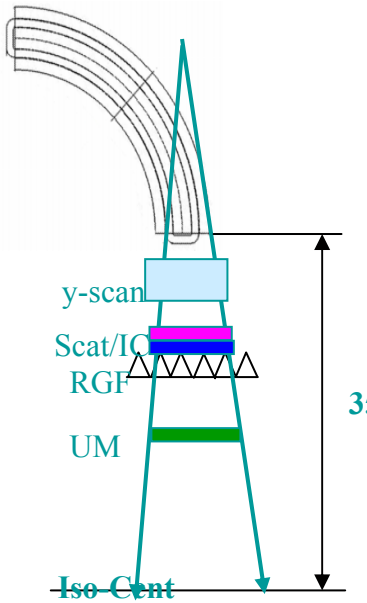
- **Compact carbon-therapy facility was initiated at Gunma University from April 2006: 3 years project**

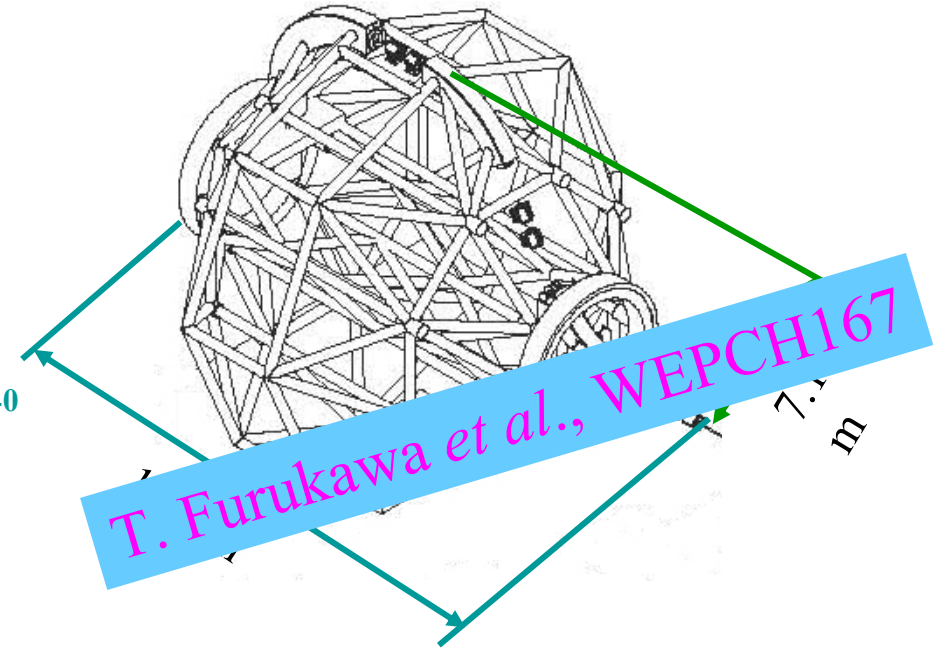
- **New treatment facility with HIMAC was also initiated at NIRS from April 2006: 7 years project**

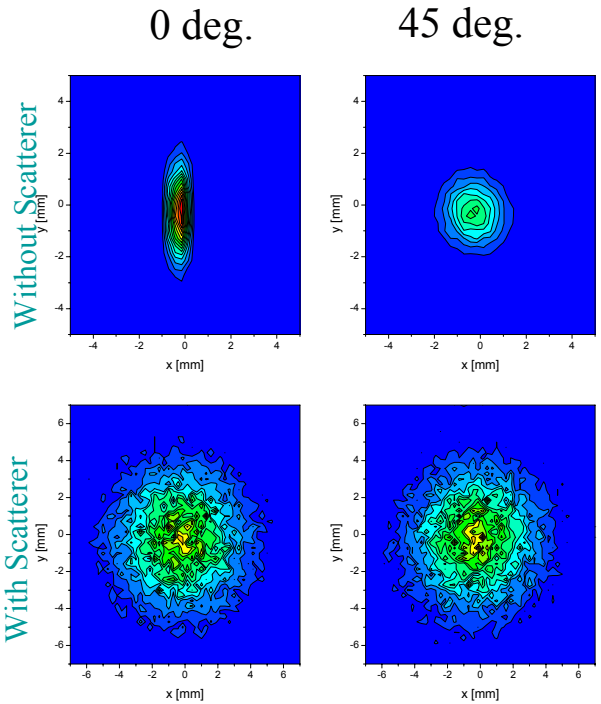
Thank you for your attention !!

NIRS HIMAC

Future Plan of HIMAC (3)







Compensation of asymmetry distribution

400 MeV/n Rotating Gantry

- Field size: 15cm x 15cm
- SOBP : 15cm
- Range : 25cm
- Repainting raster scan with layer stacking

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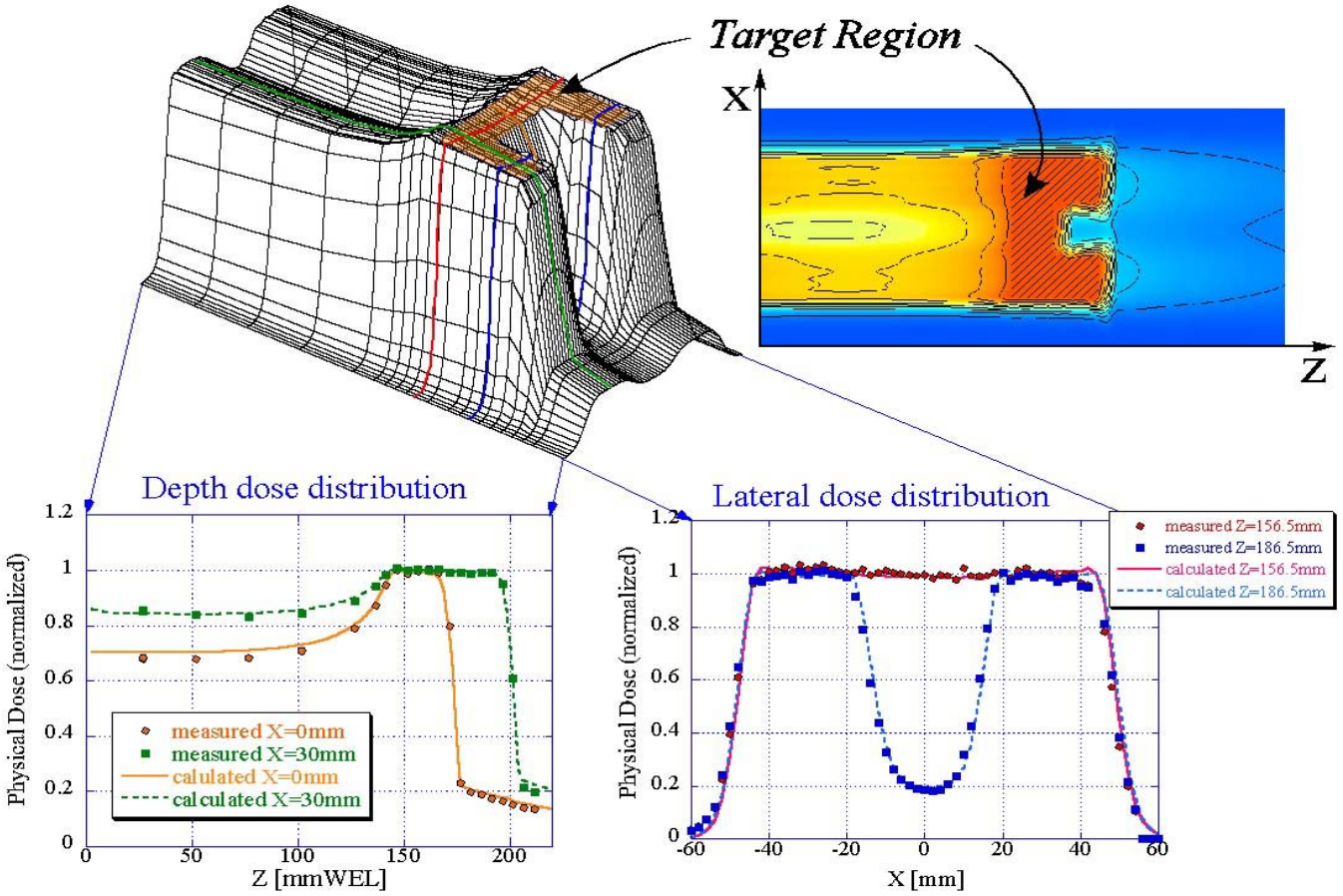
Future Plan of HIMAC (2)



Experiment of spot scan for irregular shape target

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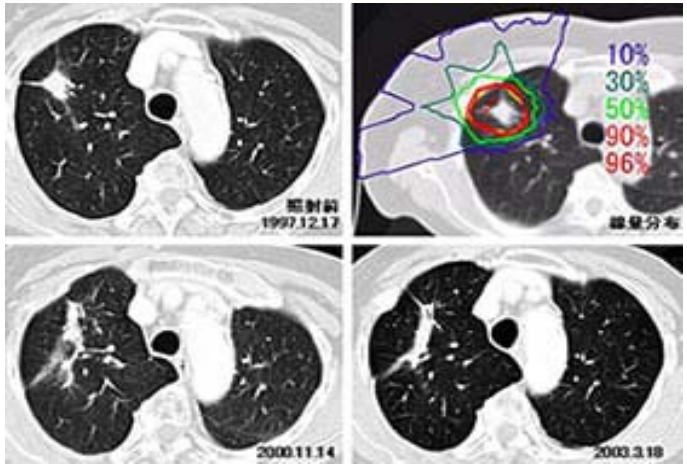
One fraction irradiation on lung cancer

The treatment period and the number of fractions have been successively reduced from 18 fractions over 6 weeks to 9 fractions over 3 weeks and further 4 fractions over one week. The end-point is single fraction. 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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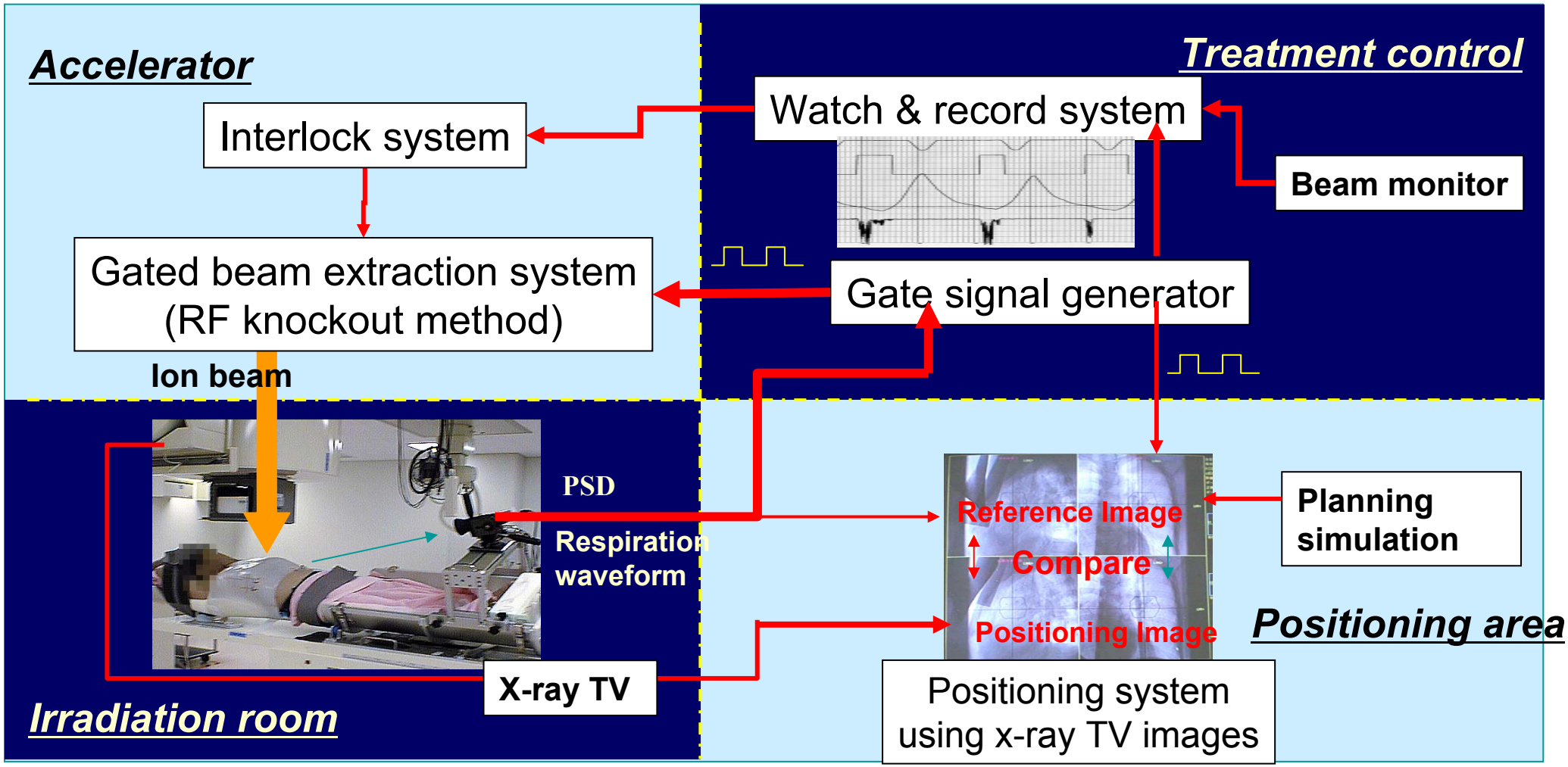
Gated irradiation with respiration

- Irradiation system of coincident with a patient's respiratory motion -



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Layer stacking irradiation

Improvement of the irradiation accuracy

Procedure

1. **Mini SOBP is produced by ridge filter.**
2. **The target volume is longitudinally divided into slices.**
3. **The mini SOBP is longitudinally scanned over the target volume in stepwise manner by using range shifter.**
4. **At same time, the lateral field is shaped by MLC in each slice.**