

# Commissioning of Heavy-ion Treatment Facility i-ROCK in KANAGAWA

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SAOTOME<sup>2)</sup>, Ryohei TANSHO<sup>2)</sup>, Yuichi SARAYA<sup>2)</sup>, Koji NODA<sup>2)</sup>

**1)KCC, 2)NIRS**

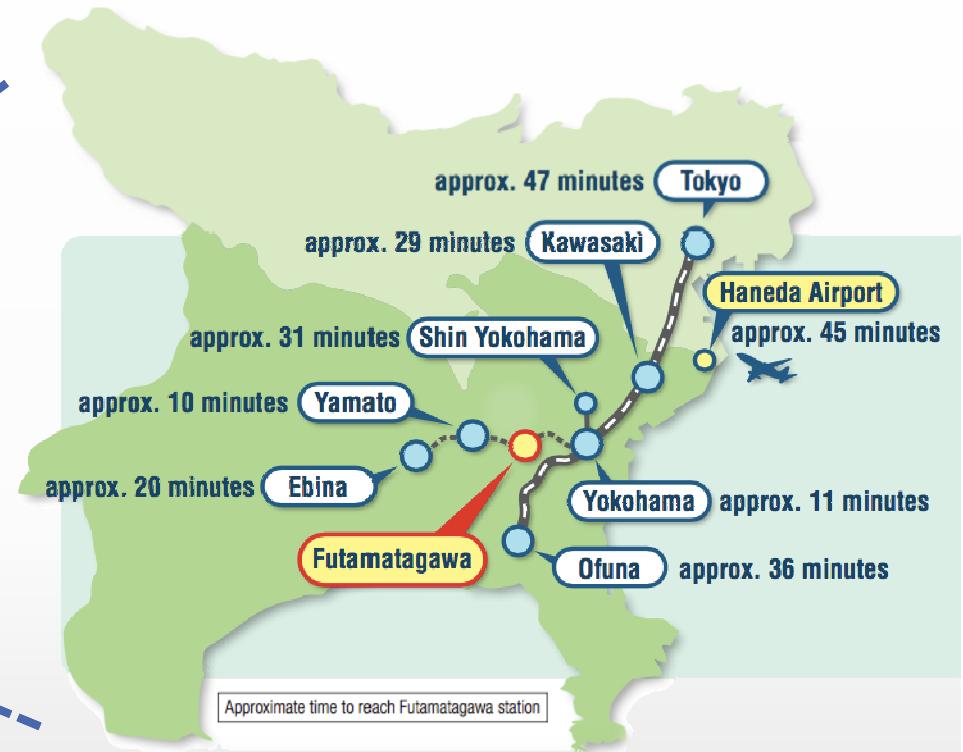


ion-beam Radiation Oncology Center in Kanagawa

# Location of KCC



- ▶ Located in Yokohama
- ▶ Tokyo Station: About 60 min.
- ▶ Tokyo International Airport: About 50 min.



**! Convenient access !**

# Radiation Oncology in KCC

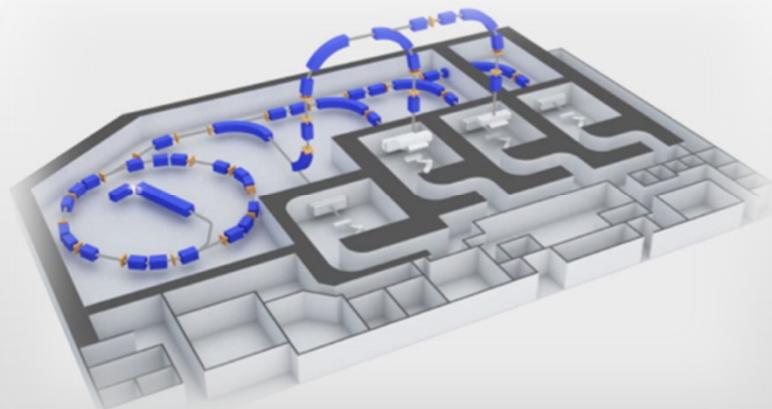
## Photon Therapy

- ▶ 4 Liniac machines (5 in future)
  - ▶ 3D-CRT (3D conformal radiation therapy)
  - ▶ SRT (Stereotactic Radiotherapy)
  - ▶ IMRT (Intensity Modulated Radiation Therapy)
  - ▶ TBI (Total Body Irradiation)
- ▶ RALS with in-room CT
  - ▶ Brachytherapy
- ▶ Radionuclide therapy



## Carbon-ion Therapy

- ▶ 4 Treatment Rooms
  - ▶ 2 rooms for scanning
  - ▶ 2 rooms for extended scanning



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ion-beam Radiation Oncology Center in Kanagawa

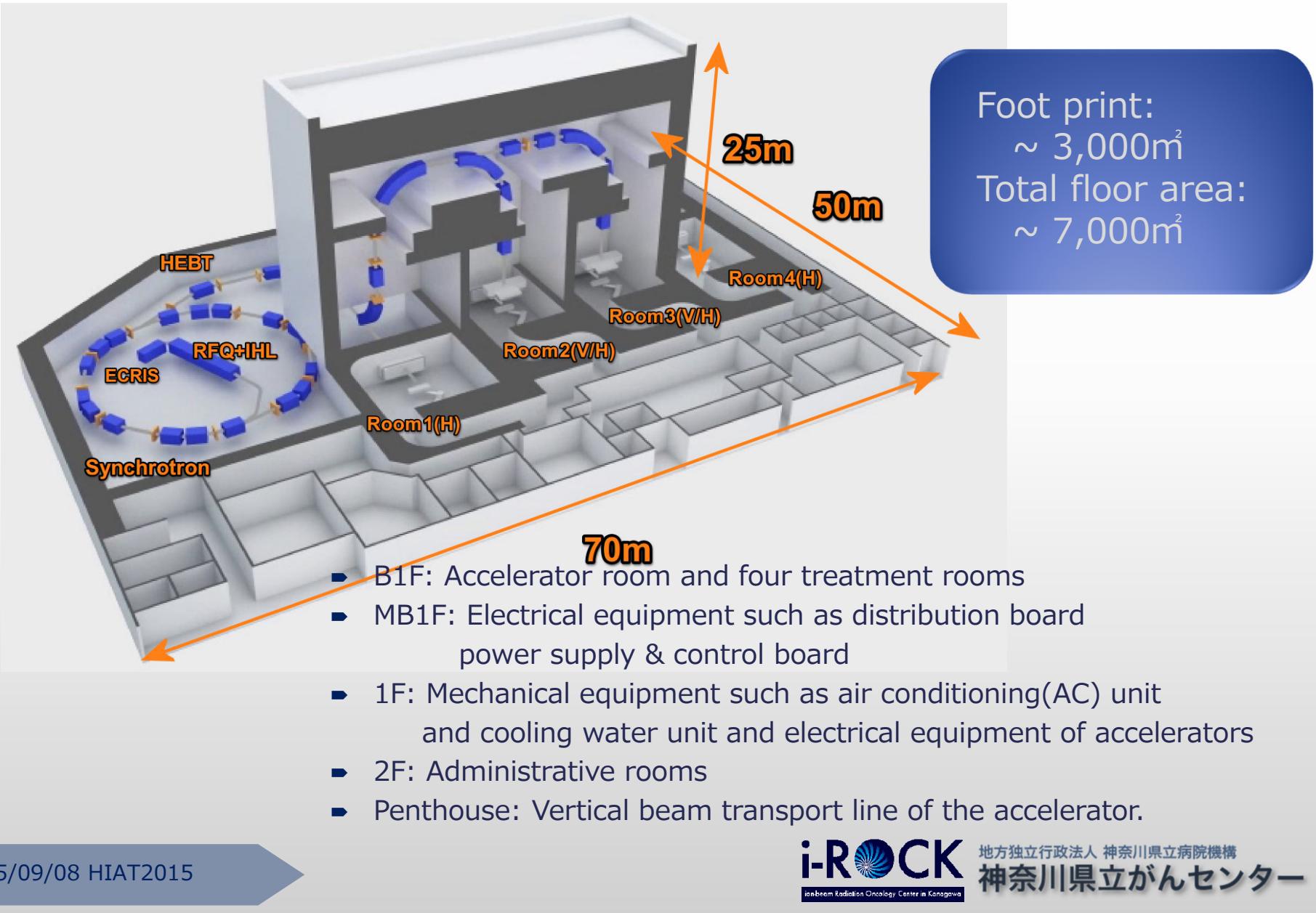
地方独立行政法人 神奈川県立病院機構  
神奈川県立がんセンター

# i-ROCK



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# Floor Design



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# Facility Specification

Treatment Room	1	2	3	4
Beam port	Horizontal	Vertical Horizontal	Vertical Horizontal	Horizontal
3D Pencil-beam scanning				
Irradiation Type	Extend scanning with compensator, collimator and ridge filter			
Energy	(Nominal) 140 - 430 MeV/u in Carbon-ion			
Residual range	(max.) more than 25cm in water			
Range control	Fine range-shifter with multi-step energy			

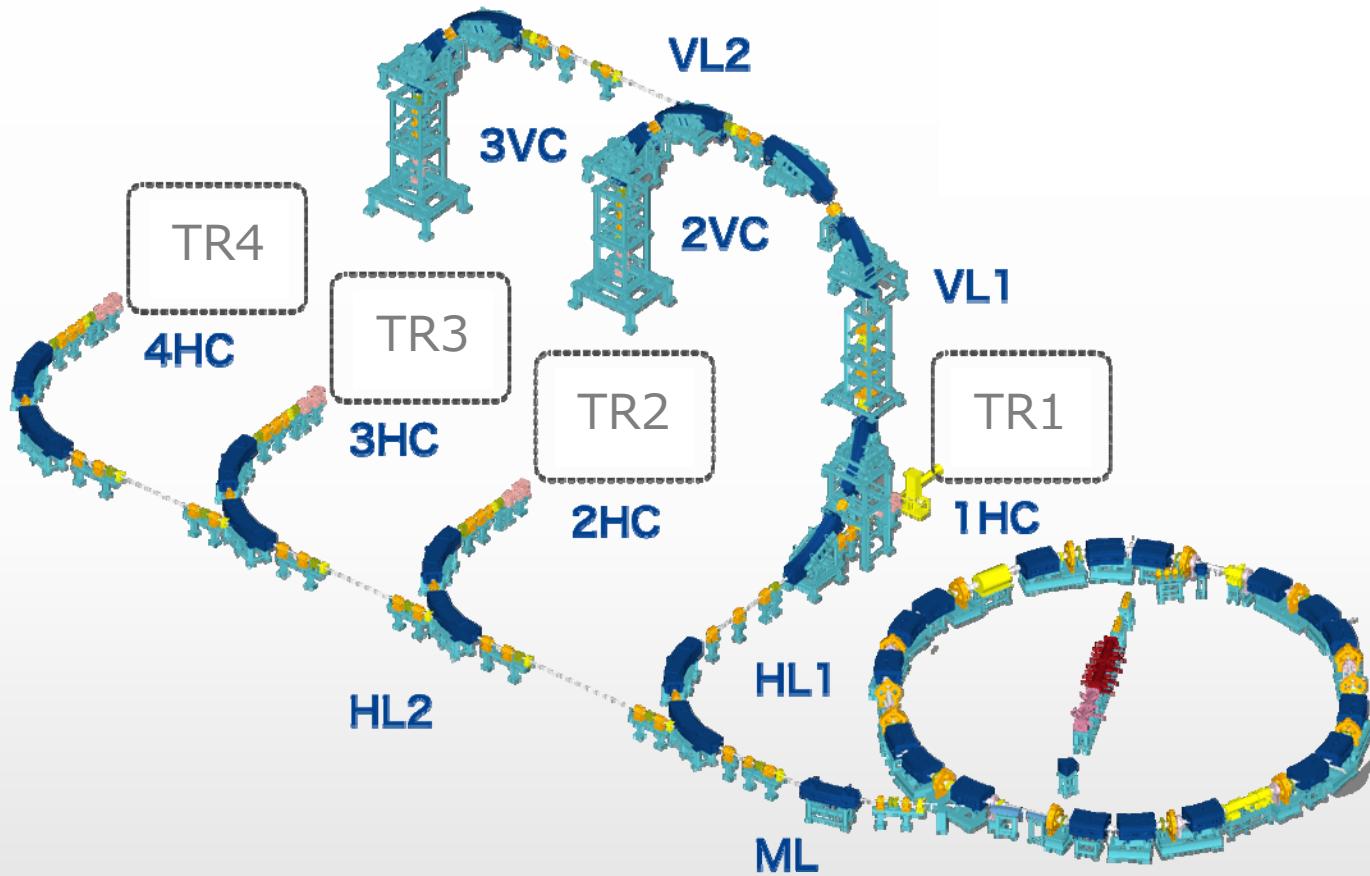
Number of treatment days / year

> 220 days/year  
(4-5 days/week)

Number of patients /year

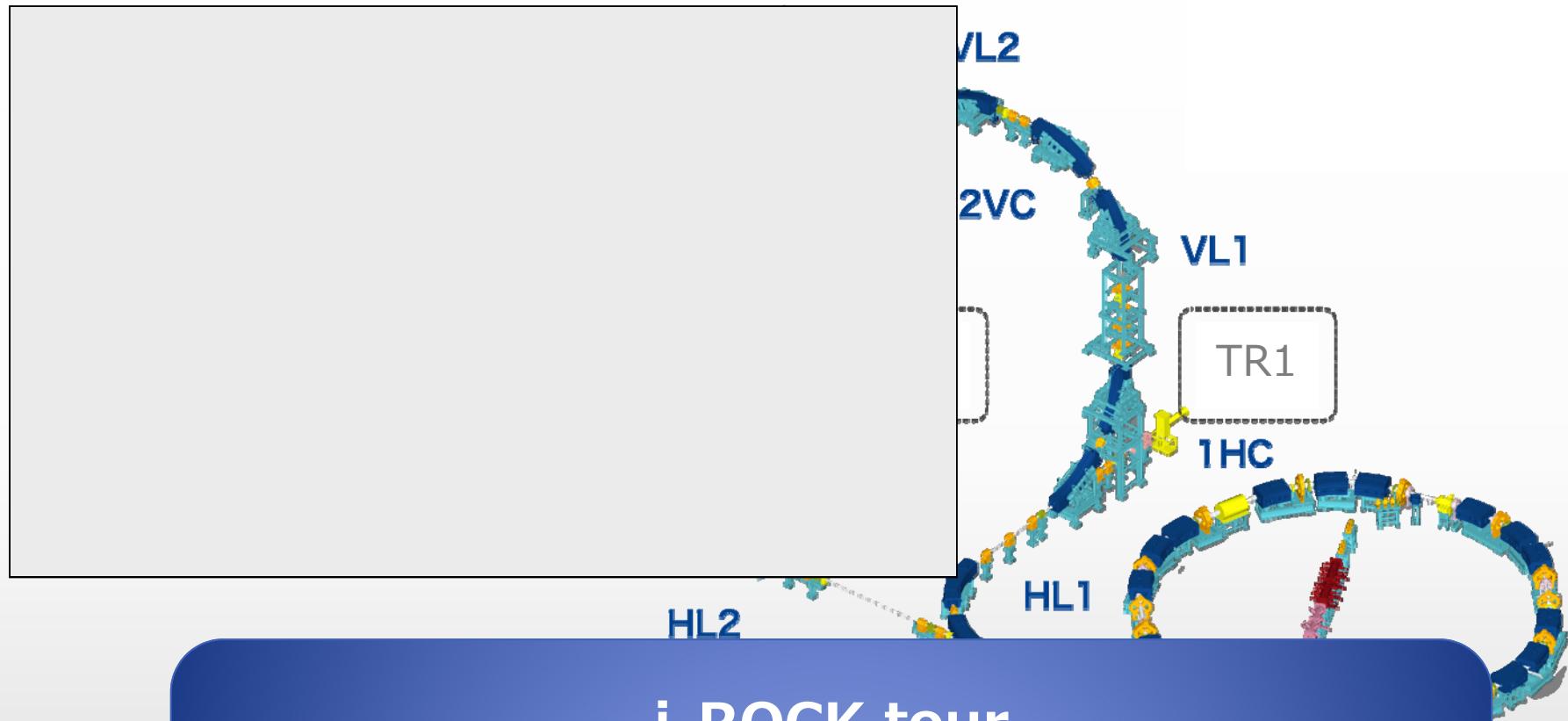
> 880 patients/year  
(500pt at 4 years later)

# Layout of the Beam Line



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# Layout of the Beam Line



i-ROCK tour  
2015/09/08(today!!)  
after the conference 17:10~

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# Schedule

Item	2014												2015		2016	
	4	5	6	7	8	9	10	11	12	1	2	3	A	B	A	B
Building													▼Temporary Air Conditioning Start			
													▼Power Receiving to the Building			
													▼Electric, Air Conditioning & Cooling water in service			
													▼Turning Over			
													▼Remaining work			
Equipment													▼Installation of Magnet Power Supplies & Control Board Start			
													▼Reference Point Setting for the alignment of the accelerator Start			
													▼Installation of Magnets Start			
													▼Installation of Equipment in Treatment Room Start			
													▼Electrical wiring & Piping Start			
													▼Site Test Start			
													▼Beam Commissioning Start			
													▼Facility Radiation Test			
													Submittal of Pharmaceutical Application ▼			
													Start Treatment ▼			

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神奈川県立がんセンター

# Progress for the Building Construction



March, 2013



October, 2013



January, 2014

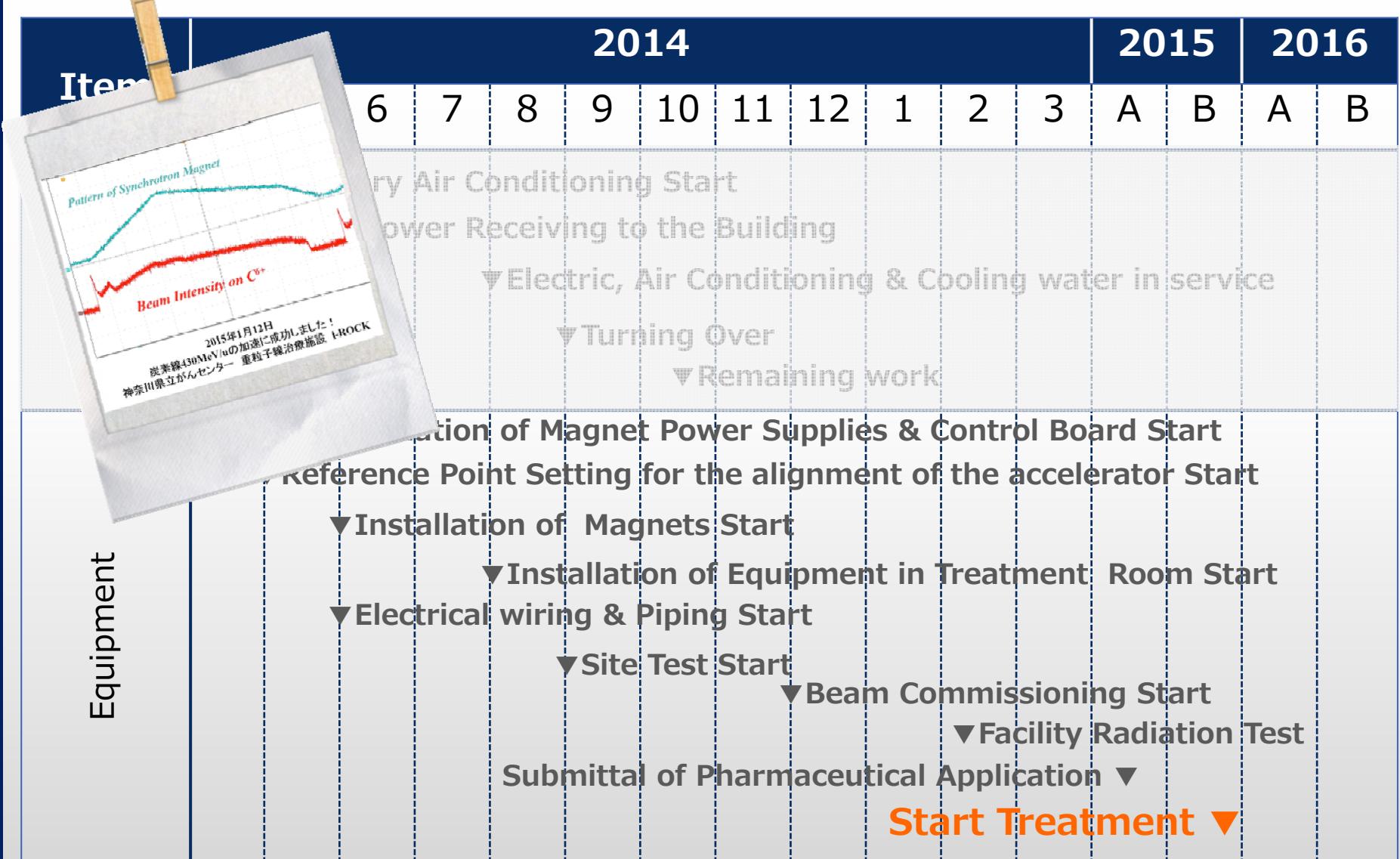


# Schedule

Item	2014												2015	2016	
	4	5	6	7	8	9	10	11	12	1	2	3			
Building															
	<ul style="list-style-type: none"> <li>▼Temporary Air Conditioning Start</li> <li>▼Power Receiving to the Building</li> <li>▼Electric, Air Conditioning &amp; Cooling water in service</li> <li>▼Turning Over</li> <li>▼Remaining work</li> </ul>														
Equipment															
	<ul style="list-style-type: none"> <li>▼Installation of Magnet Power Supplies &amp; Control Board Start</li> <li>▼Reference Point Setting for the alignment of the accelerator Start</li> <li>▼Installation of Magnets Start</li> <li>▼Installation of Equipment in Treatment Room Start</li> <li>▼Electrical wiring &amp; Piping Start</li> <li>▼Site Test Start</li> <li>▼Beam Commissioning Start</li> <li>▼Facility Radiation Test</li> <li>Submittal of Pharmaceutical Application ▼</li> <li><b>Start Treatment ▼</b></li> </ul>														

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# Schedule



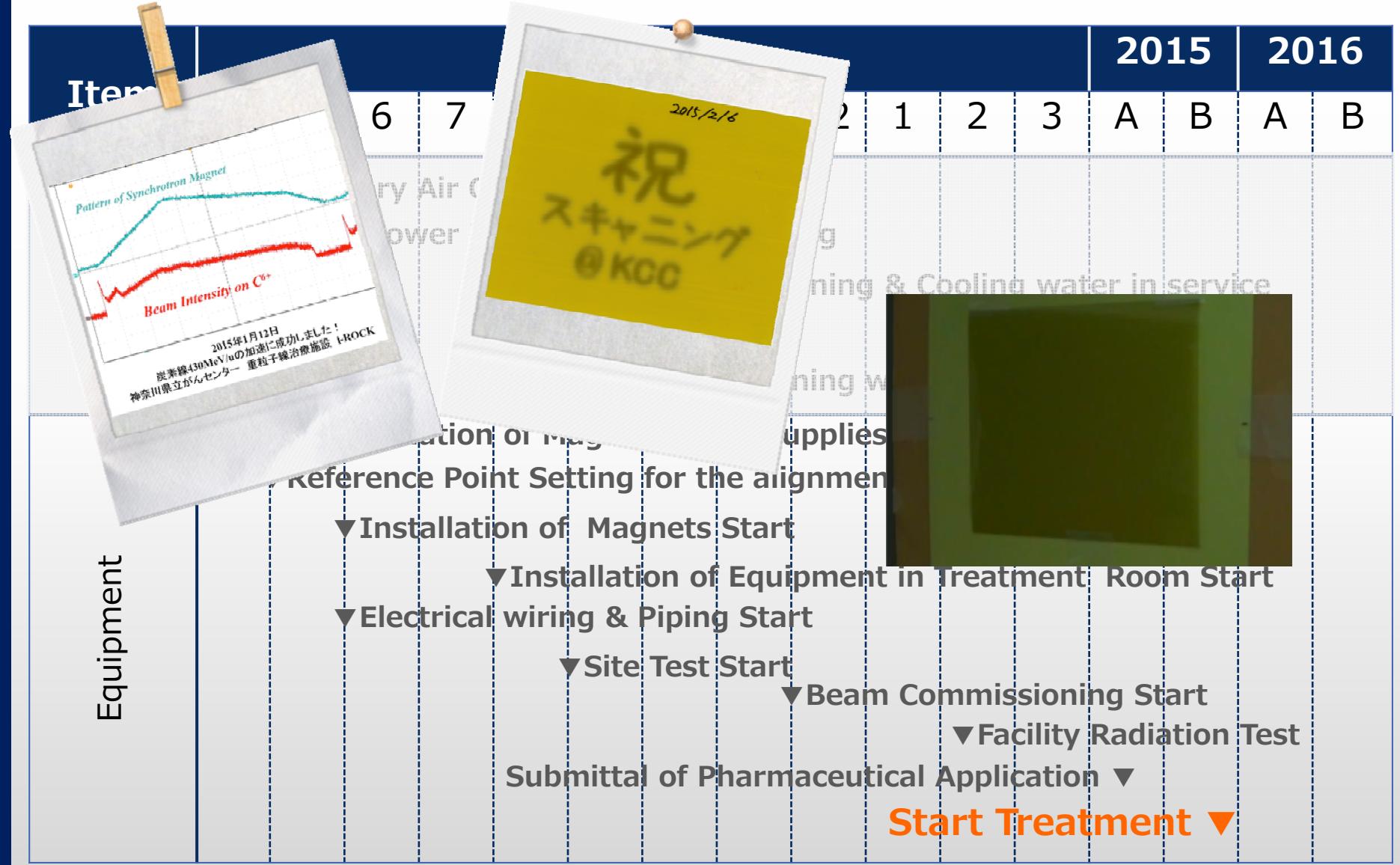
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# Schedule

Item	6	7	2015	2016
Pattern of Synchrotron Magnet Beam Intensity on C <sup>6+</sup>				
2015年1月12日 神奈川県立がんセンター 重粒子線治療施設 i-Rock				
Reference Point Setting for the alignment of the accelerator Start			2	1
▼ Installation of Magnets Start			2	2
▼ Electrical wiring & Piping Start			3	A
▼ Site Test Start			A	B
Submittal of Pharmaceutical Application			B	B
<b>Start Treatment</b>				

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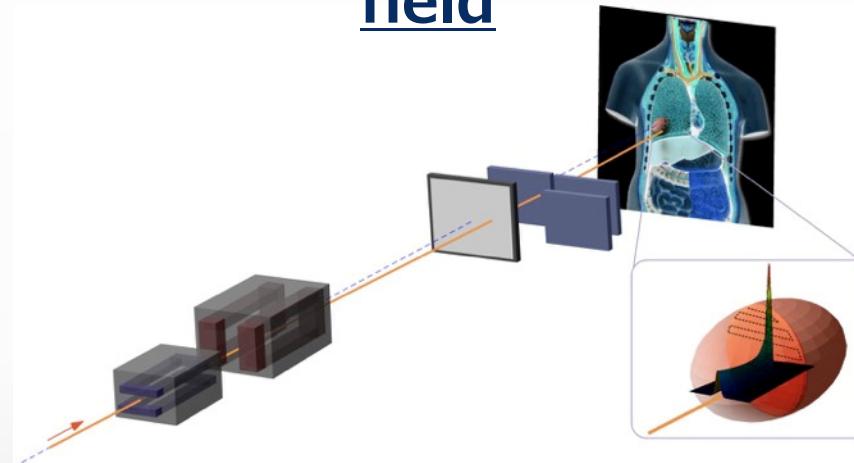
# Schedule



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# Scanning Delivery

Scanning = Superposition of pencil beams for making field

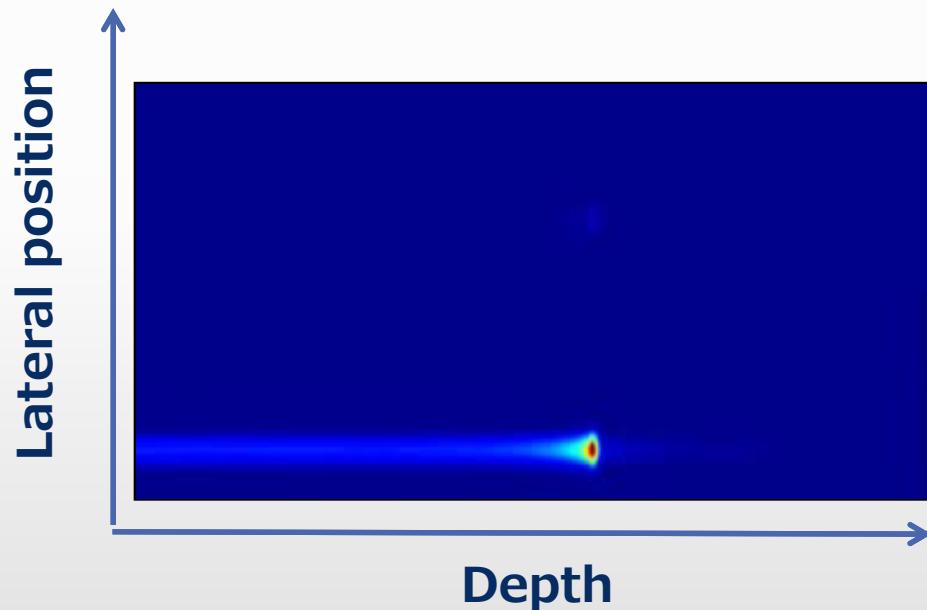


## Advantages

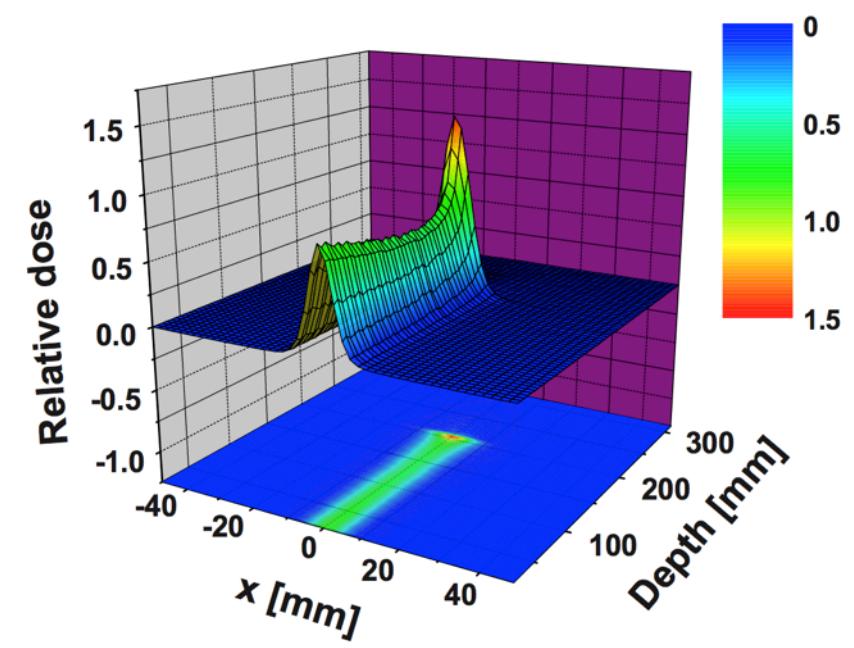
- Good beam utilization efficiency
- Advantage for irregular shaped target
- Elimination of compensator & collimator
- Possibility for adaptive radiotherapy
- IMPT  
(Intensity Modulated Particle Therapy)

# Scanning Delivery

Scanning = Superposition of pencil beams

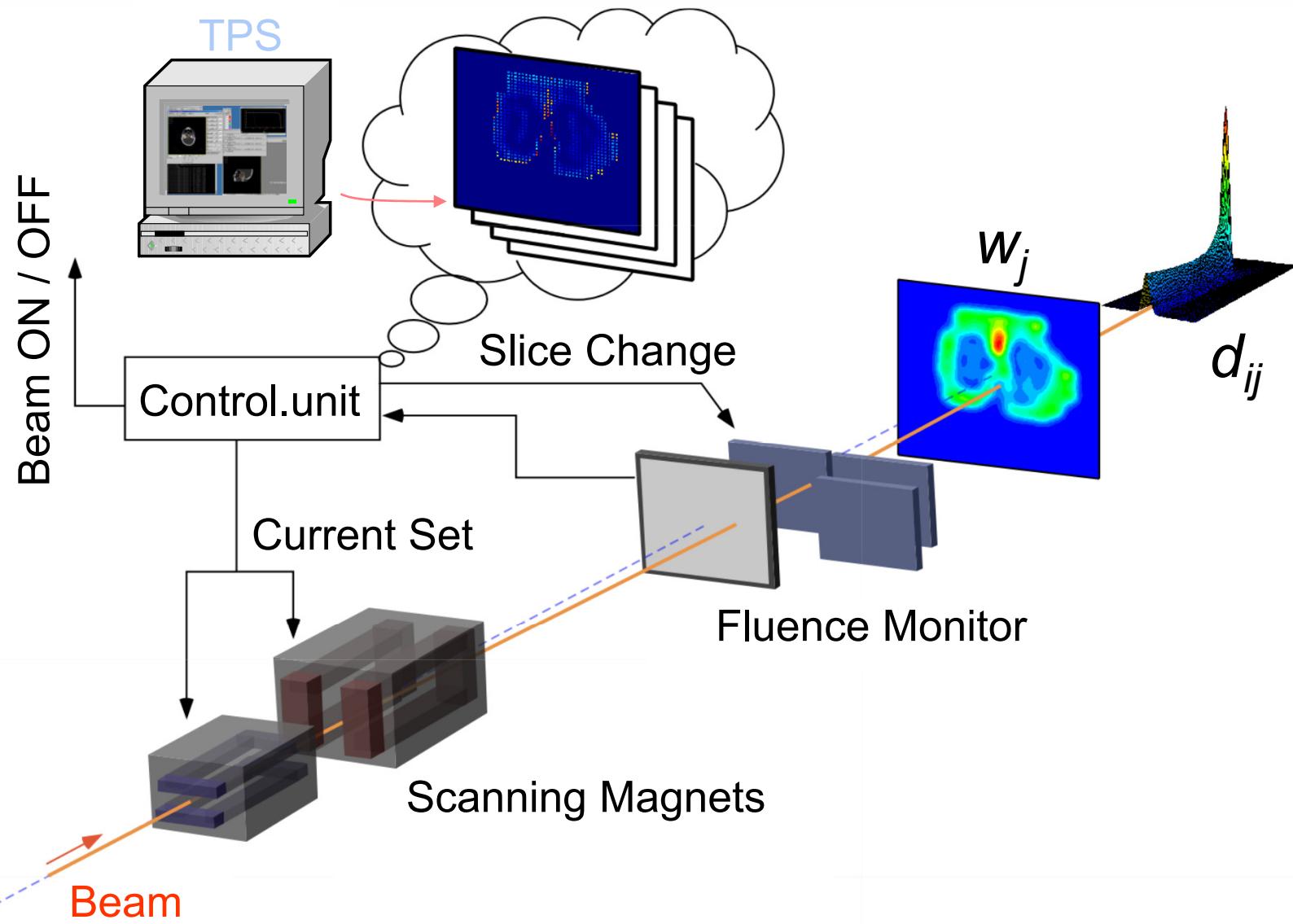


Dose response of pencil beam

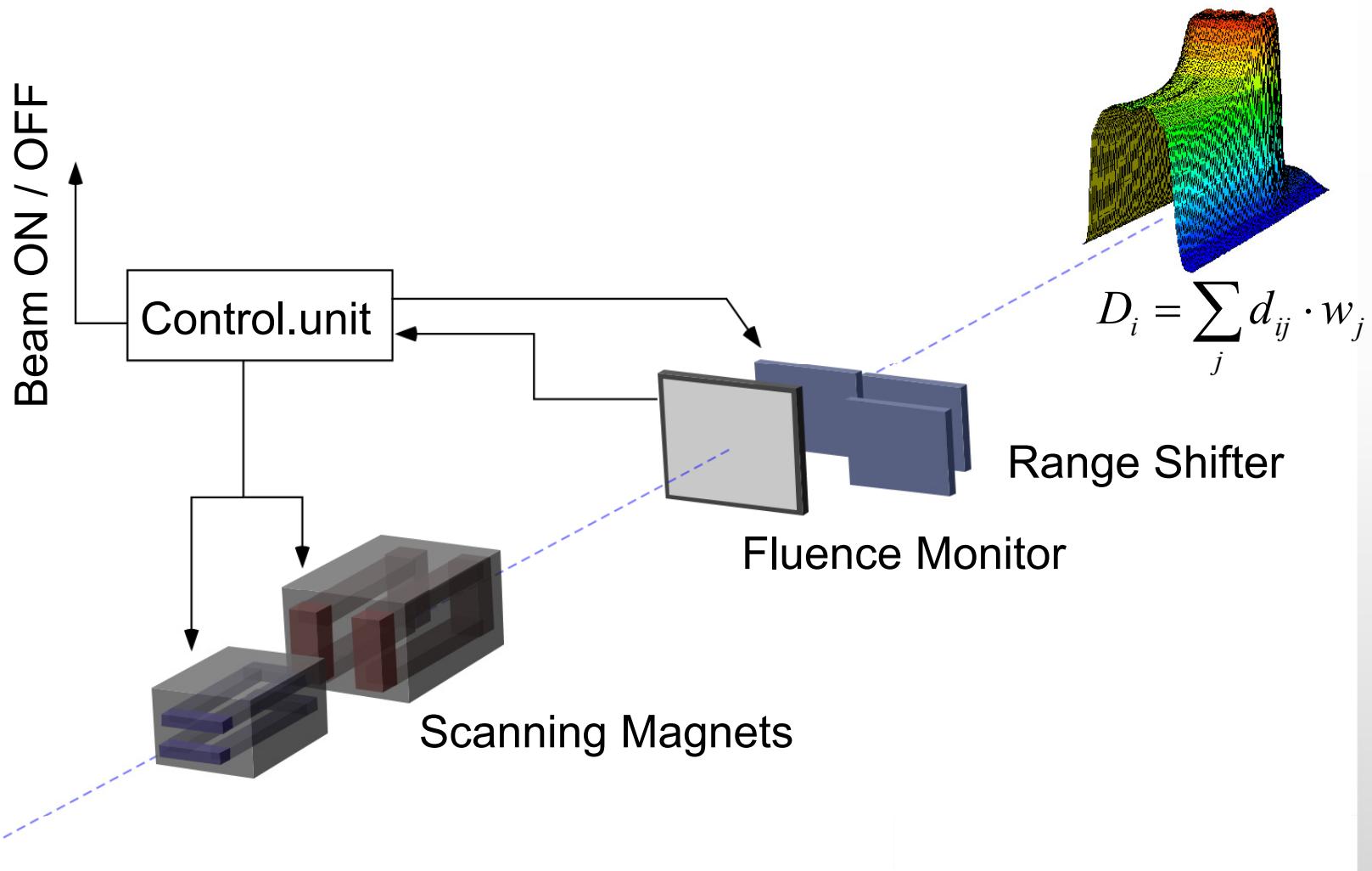


Beam is 3-dimensionally scanned to make desired field

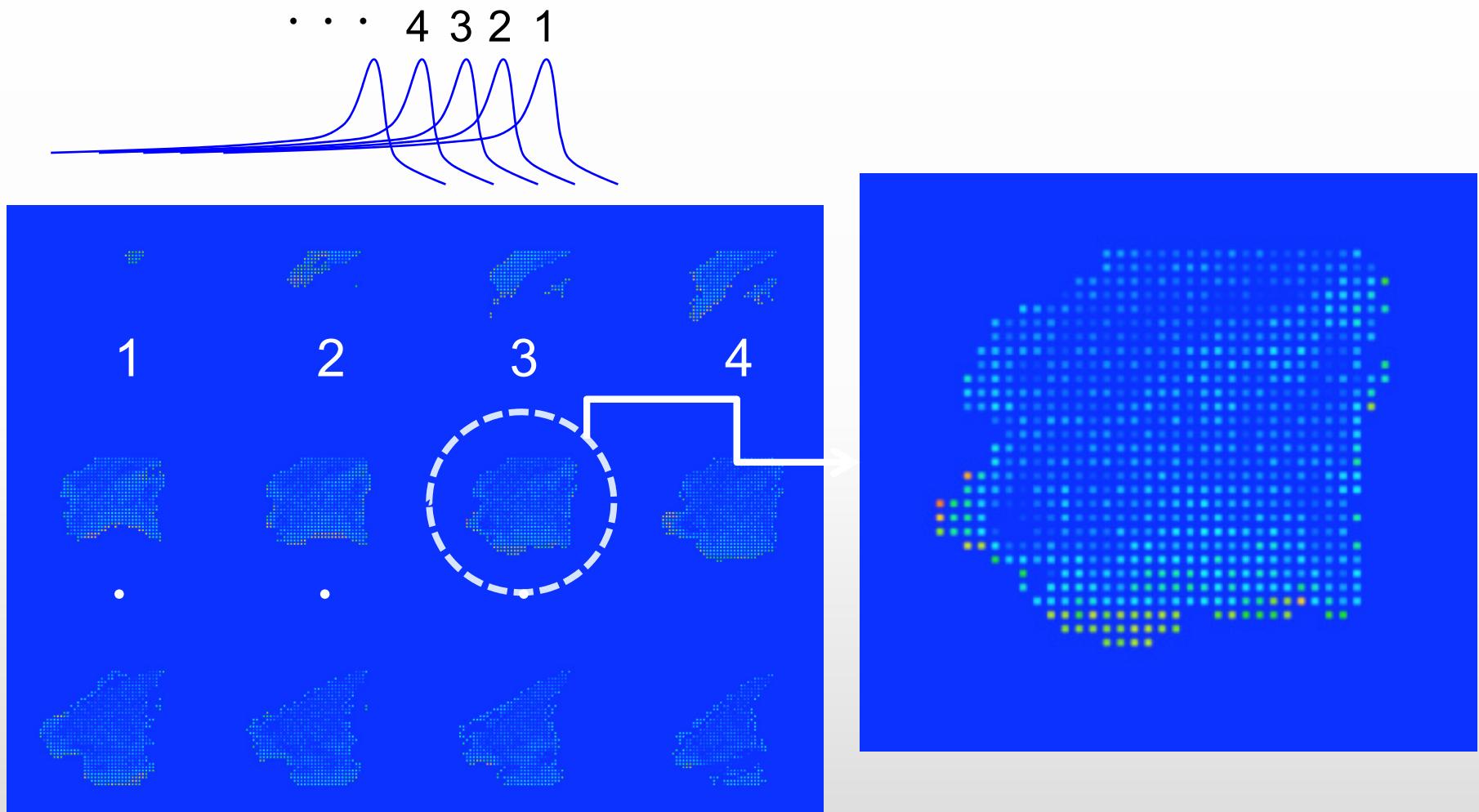
# What is Scanning Delivery??



# What is Scanning Delivery??



# Example of fluence map



Modulation of each point dose is necessary

# Commissioning Results

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# Commissioning for the irradiation system

## Performance test for non-scanned beam

- ▶ Stability check
- ▶ Beam intensity
- ▶ Beam position
- ▶ Beam size

## Performance test for scanned beam

- ▶ Verification of the scanned beam position
- ▶ Reliability confirmation of the dose monitor.
- ▶ Reliability confirmation of the position monitor
- ▶ Overall Verification

# Commissioning for the irradiation system

## Performance test for non-scanned beam

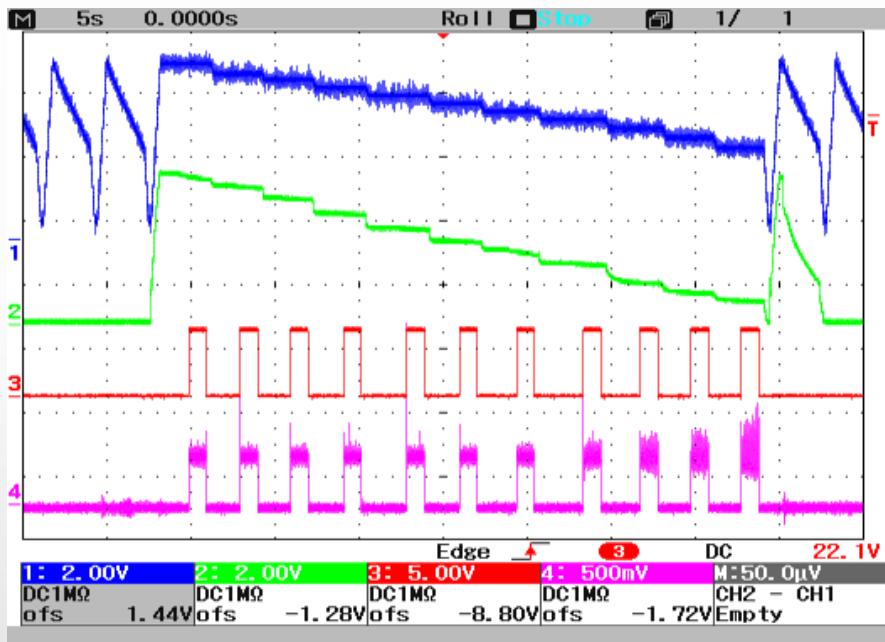
- ▶ Stability check
- ▶ Beam intensity
- ▶ Beam position
- ▶ Beam size

## Performance test for scanned beam

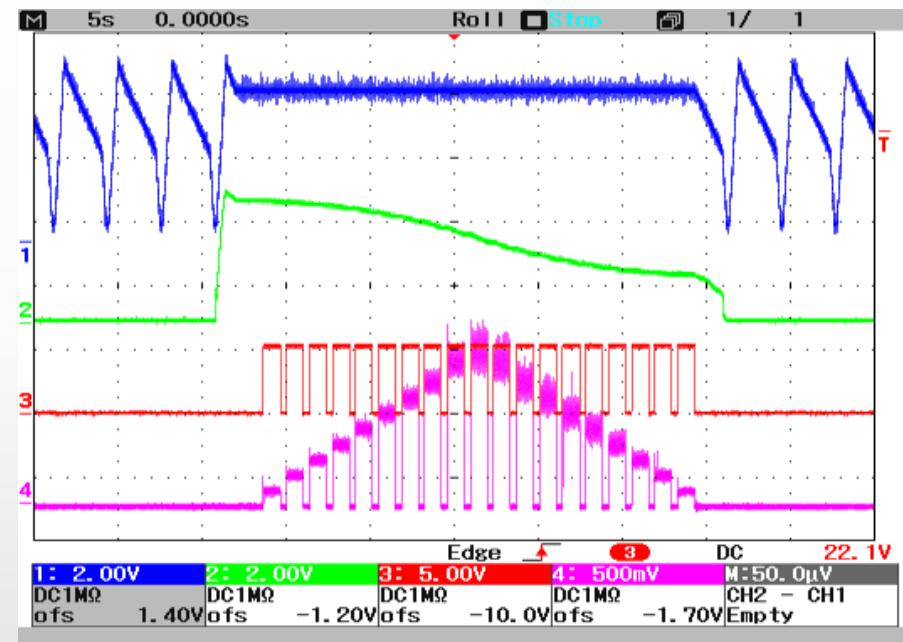
- ▶ Verification of the scanned beam position
- ▶ Reliability confirmation of the dose monitor.
- ▶ Reliability confirmation of the position monitor
- ▶ Overall Verification

# Stability of the Beam Intensity

Extended FT + Multiple Energy Operation



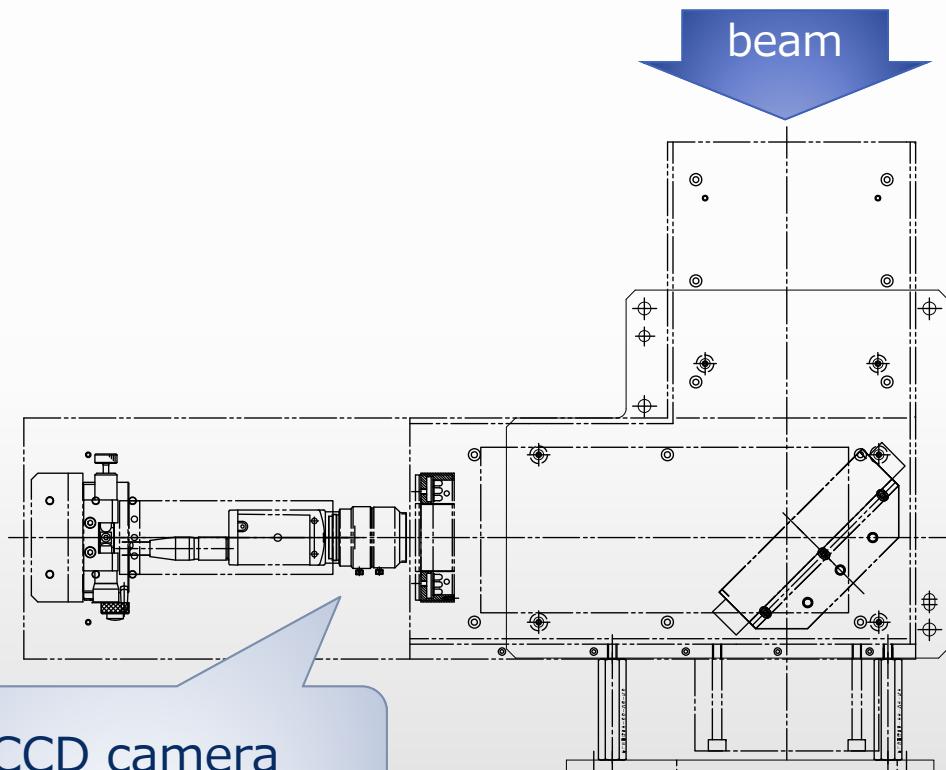
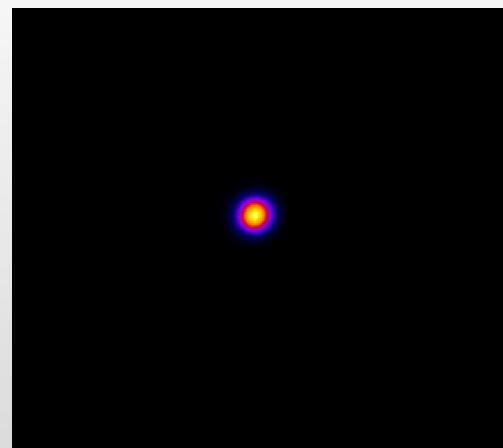
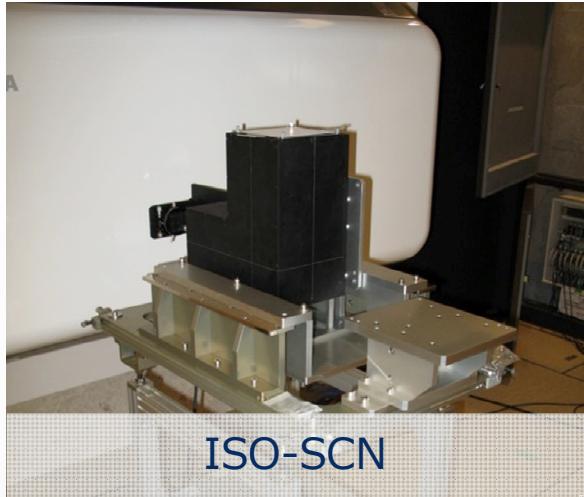
Extended FT + Intensity Modulation Operation



Blue: BM current, Green: DCCT, Red: Enable signal of extraction, Pink: Dose monitor

**Constancy of the intensity and the ripples  
are suppressed within 20%**

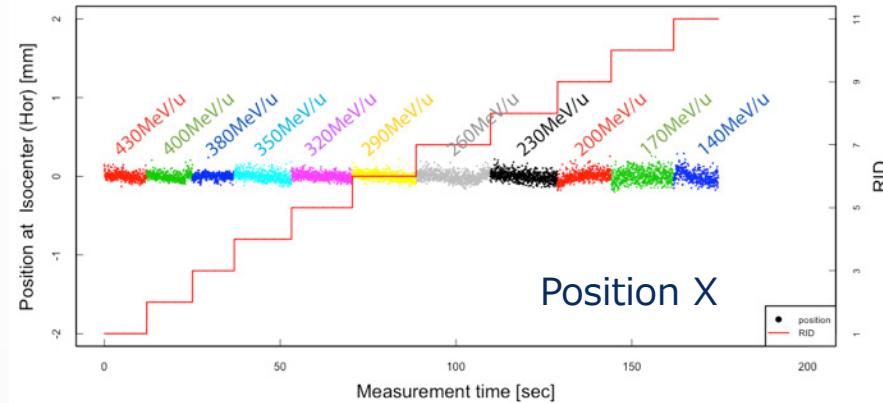
# QA Tool for Beam Position & Size



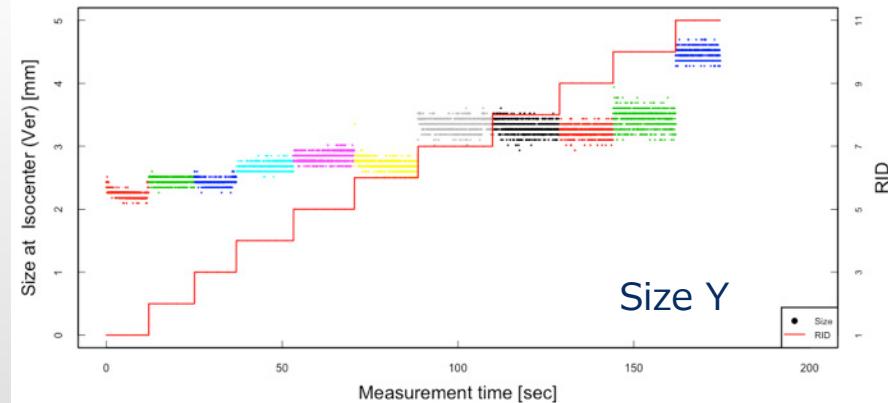
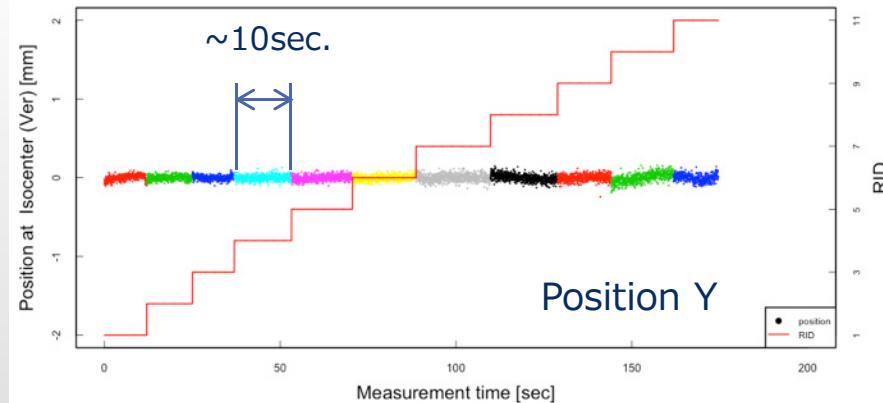
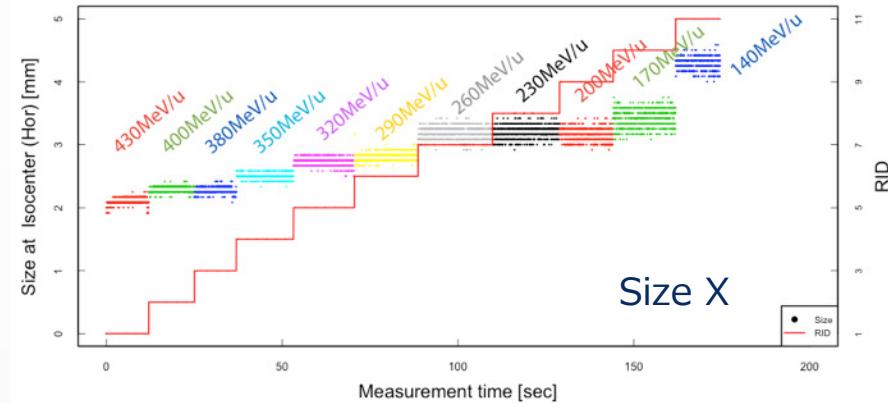
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# Stability of the Beam Position and Size

Beam position (2VC)



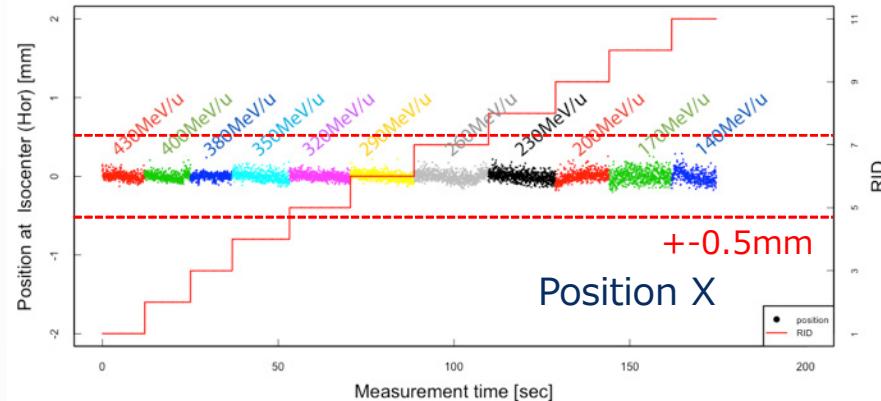
Beam size (2VC)



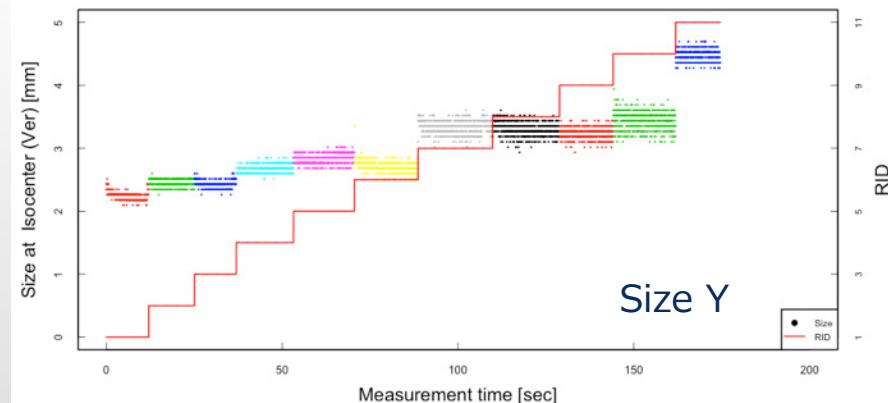
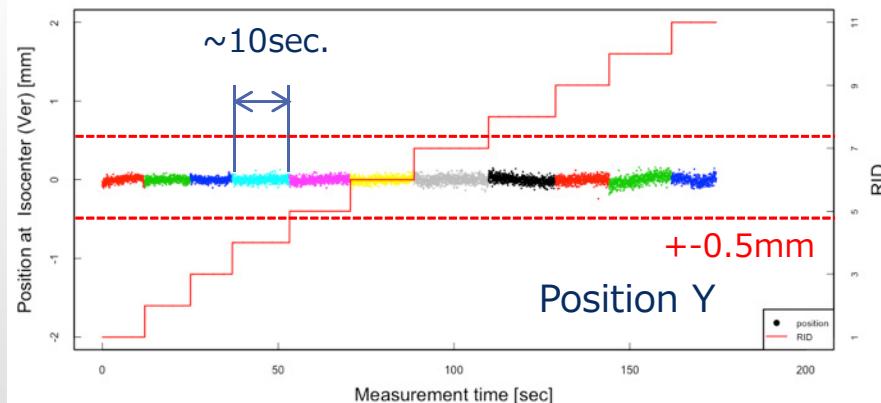
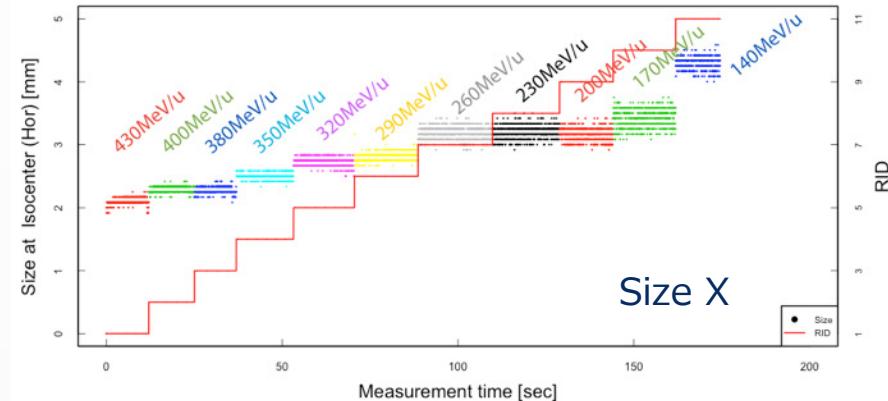
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# Stability of the Beam Position and Size

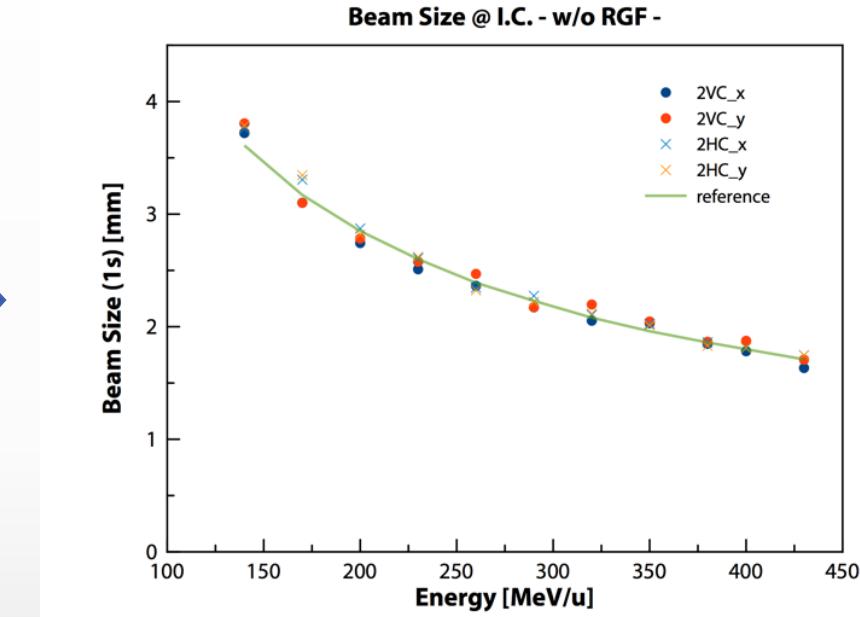
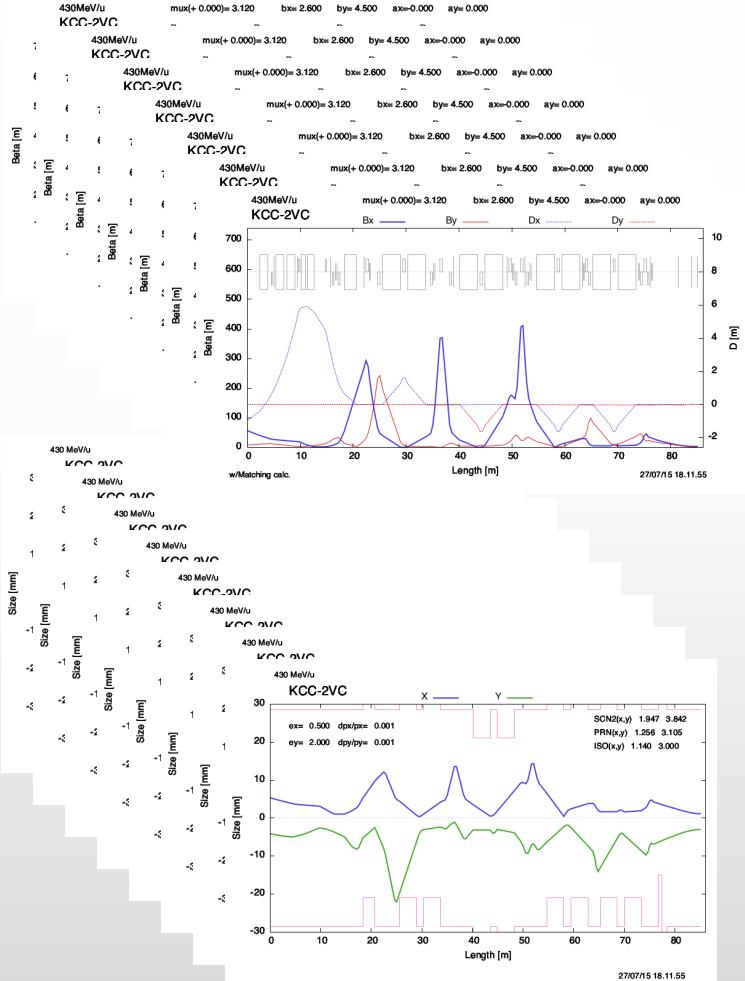
Beam position (2VC)



Beam size (2VC)



# Adjust of the Beam Size



## Symmetric Profile with

- ✓ X and Y
  - ✓ Every energy
  - ✓ All irradiation port

# Commissioning for the irradiation system

## Performance test for non-scanned beam

- ▶ Stability check
- ▶ Beam intensity
- ▶ Beam position
- ▶ Beam size

## Performance test for scanned beam

- ▶ Verification of the scanned beam position
- ▶ Reliability confirmation of the dose monitor.
- ▶ Reliability confirmation of the position monitor
- ▶ Overall Verification

# QA Tool for the irradiation field

Fluence

CCD camera  
+  
Fluorescence Screen



Dose

Ionization chamber  
+  
Electro meter

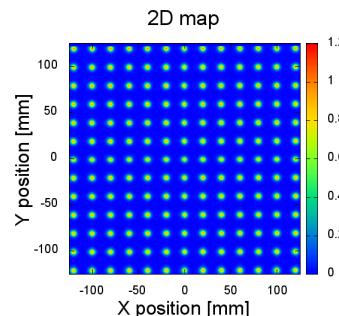


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ionbeam Radiation Oncology Center in Kanagawa

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神奈川県立がんセンター

# Adjust the Scanned Beam Position

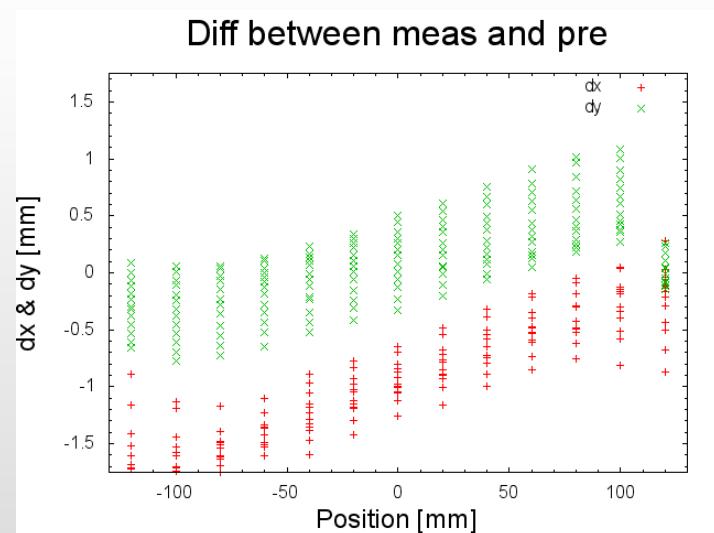


Spot field

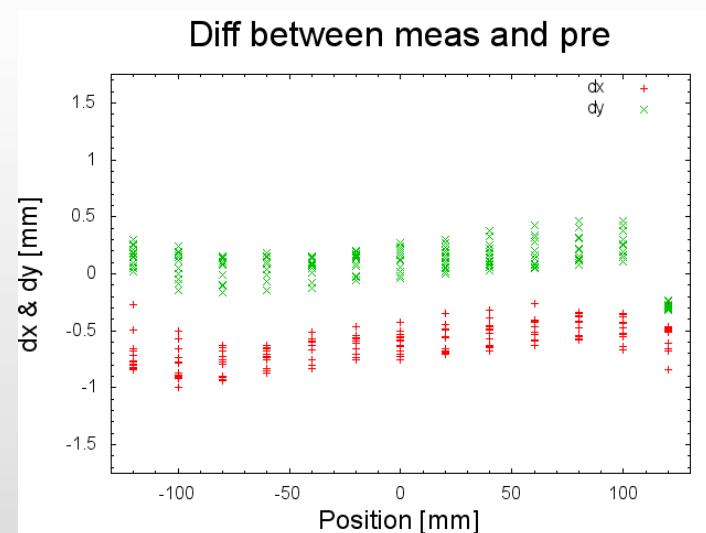
- ✓ 290 MeV/u
- ✓ 20 mm pitch

Image processing  
+  
COG calculation

Position of scanned beam



Before correction

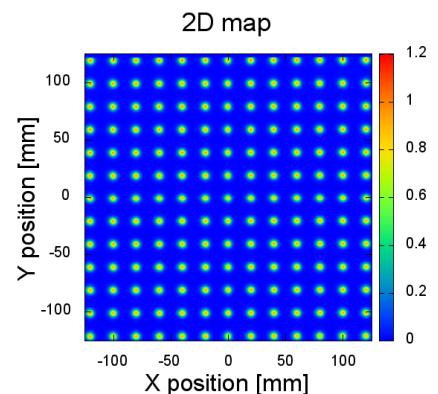


After correction

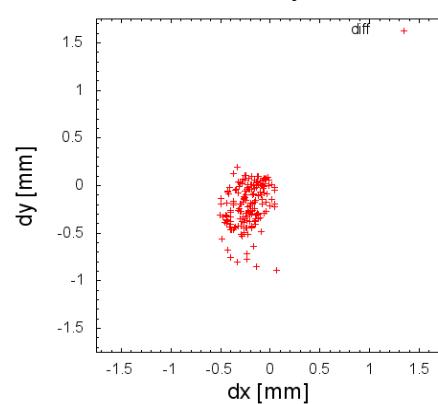
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# Check the Scanned Beam Position

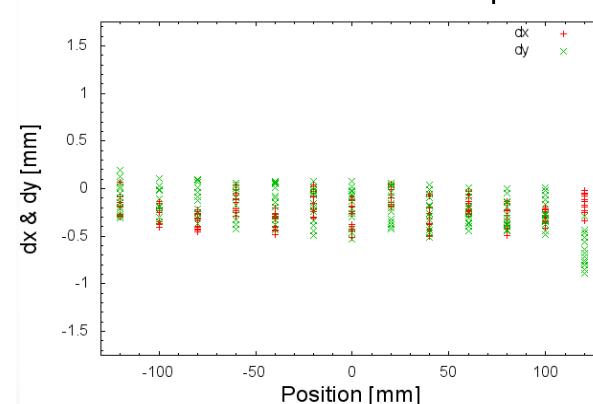
430MeV/u



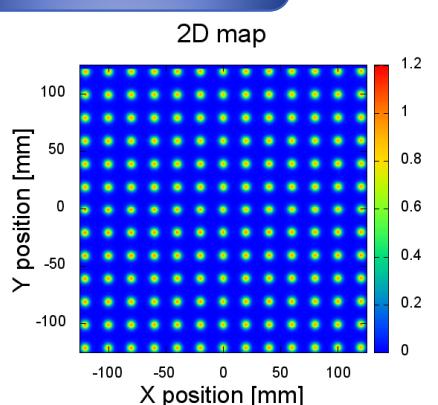
dx-dy



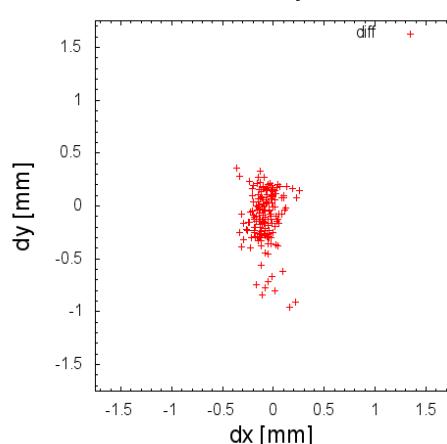
Diff between meas and pre



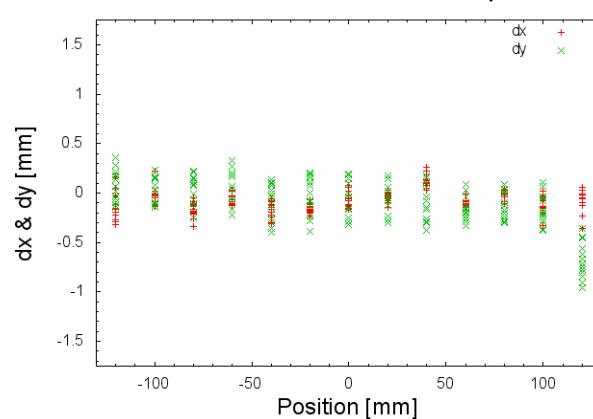
380MeV/u



dx-dy



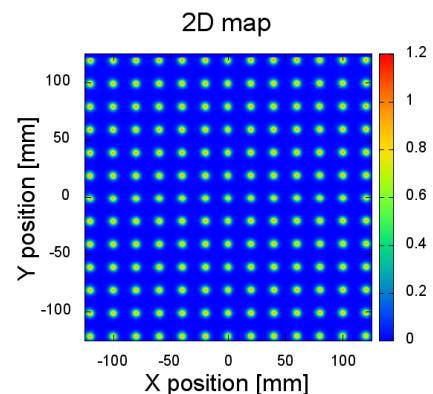
Diff between meas and pre



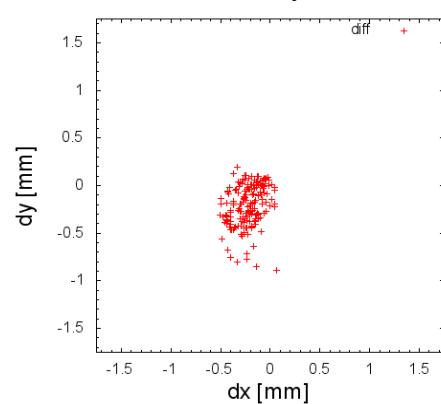
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# Check the Scanned Beam Position

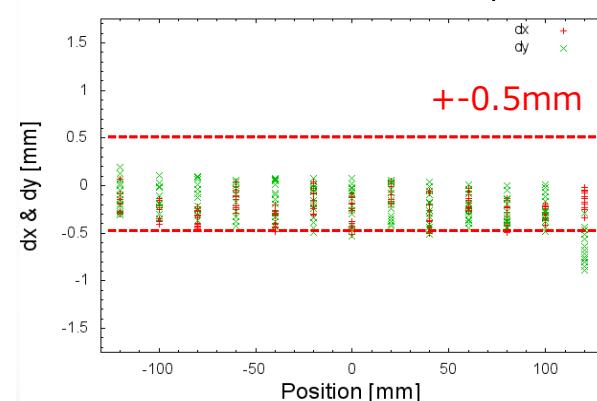
430MeV/u



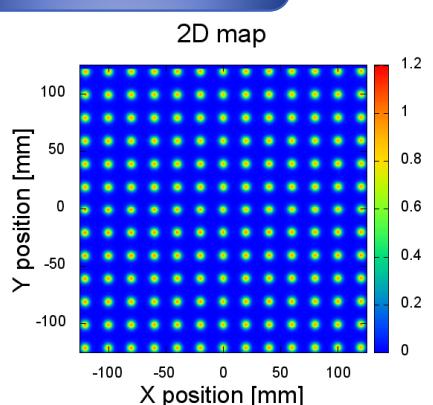
dx-dy



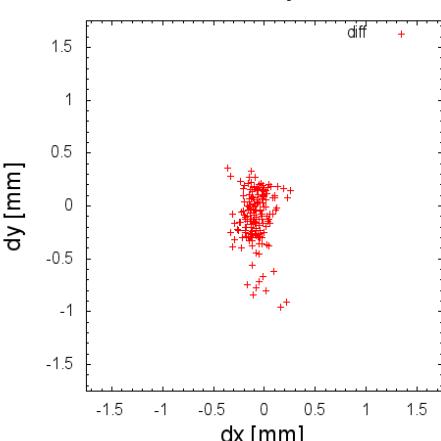
Diff between meas and pre



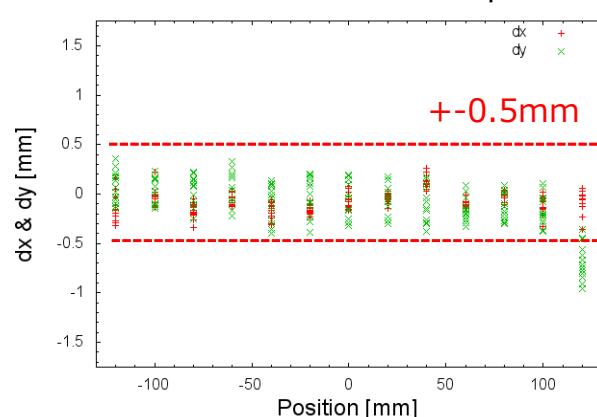
380MeV/u



dx-dy



Diff between meas and pre

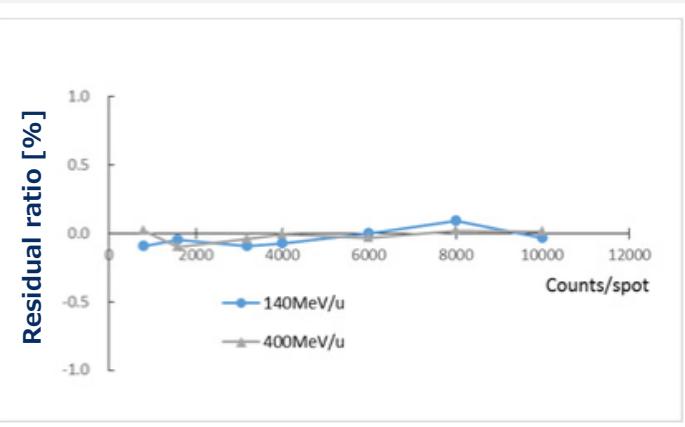
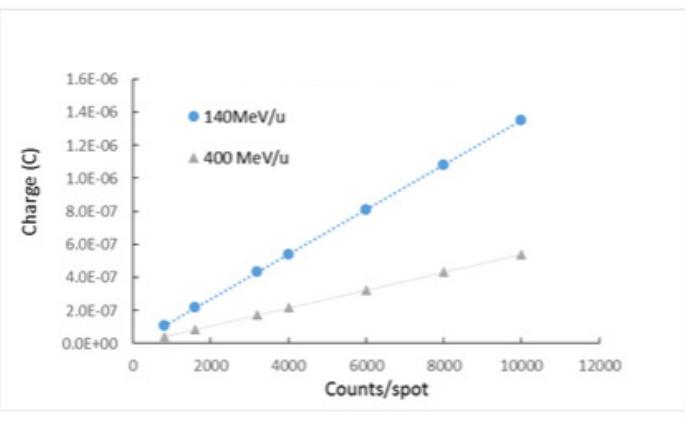


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# Check the Dose Monitor

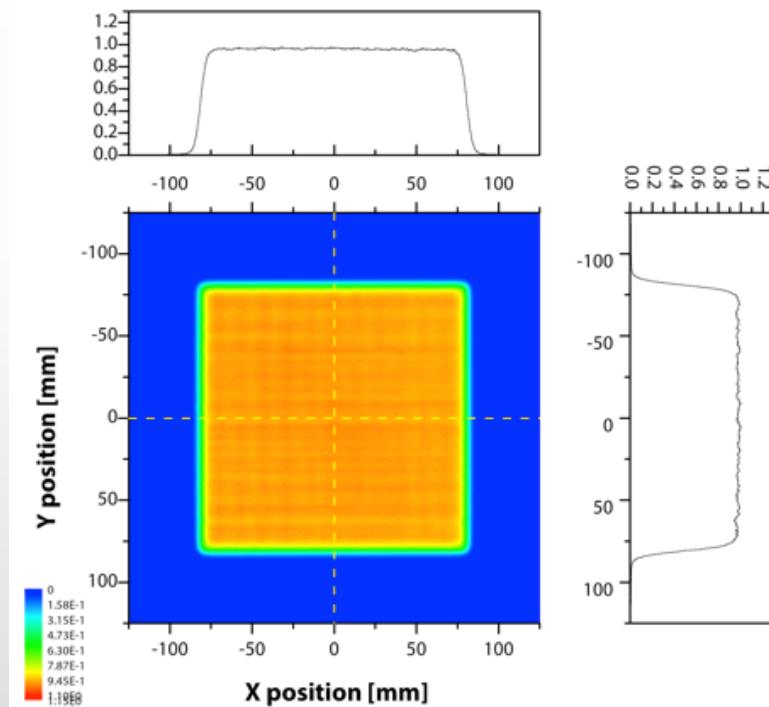
## Linearity

Beam Intensity =  $1.0 \times 10^9$  pps



## Uniformity

290MeV/u, 150x150mm<sup>2</sup>, 2mm pitch

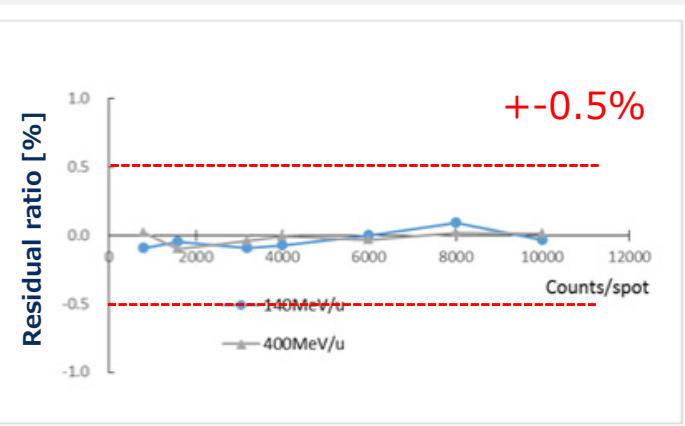
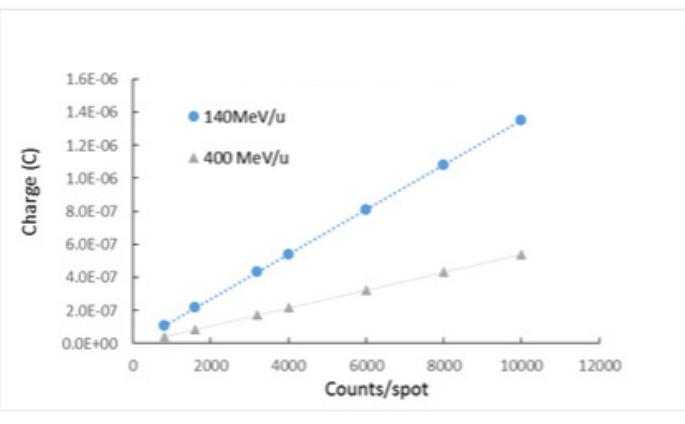


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# Check the Dose Monitor

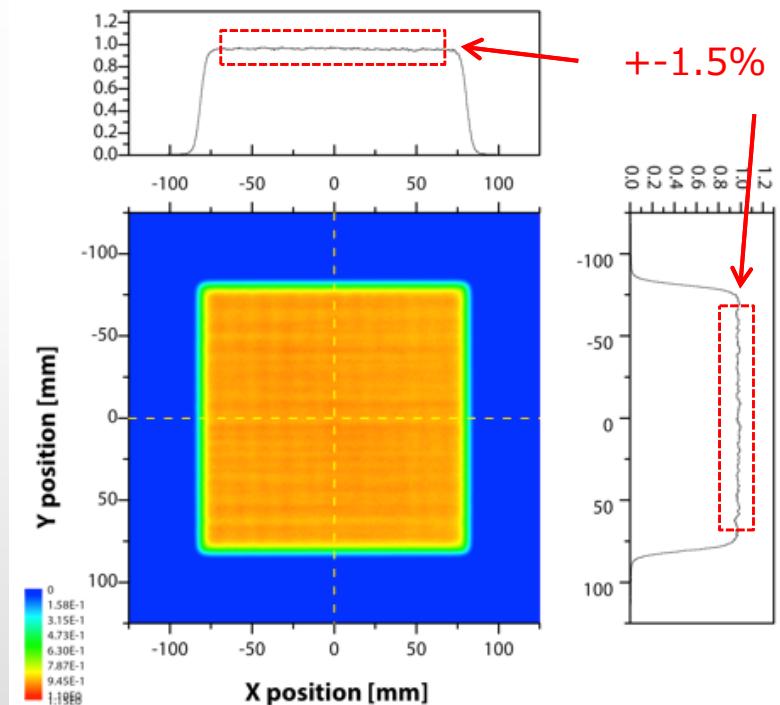
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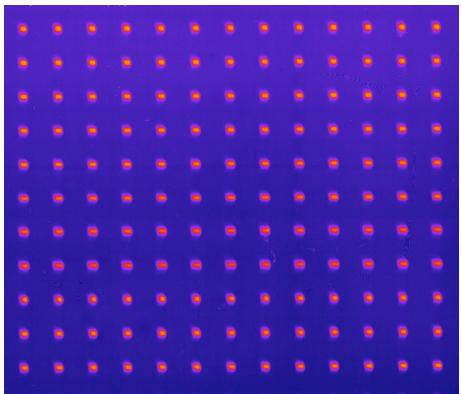
## Uniformity

290MeV/u, 150x150mm<sup>2</sup>, 2mm pitch



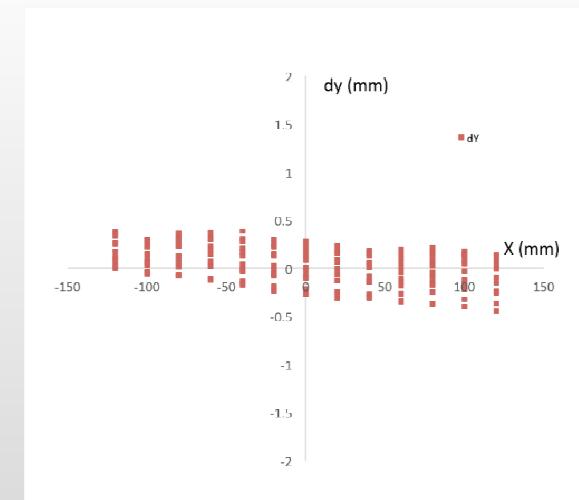
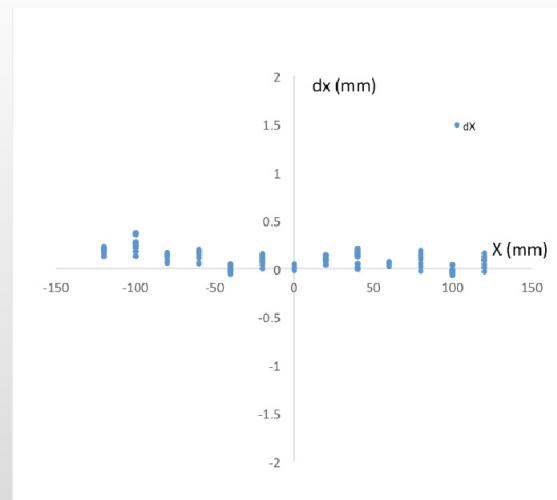
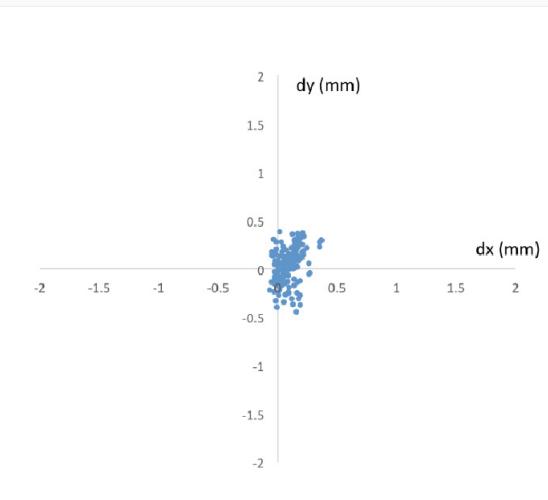
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# Check the measurement position by PRN



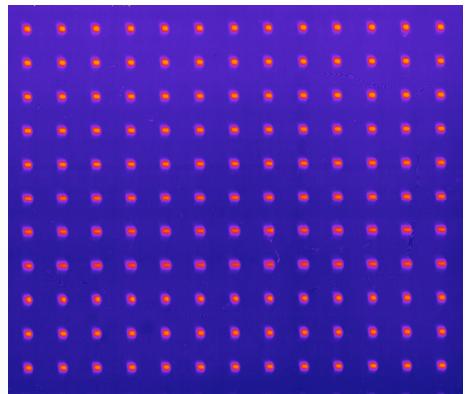
## Compare with measurement

- ✓ Gafchromic film
- ✓ Position monitor to survey  
the beam position during the irradiatio



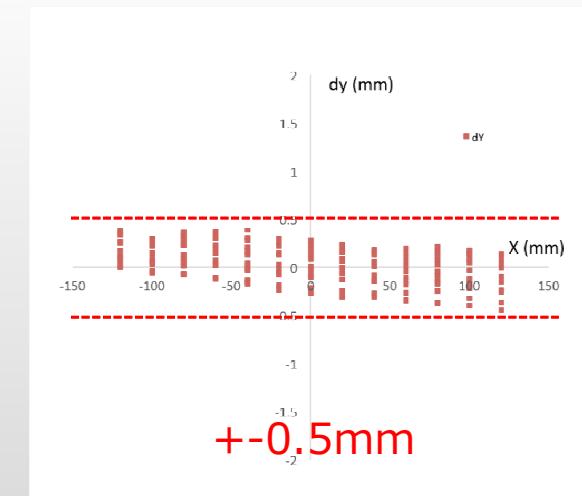
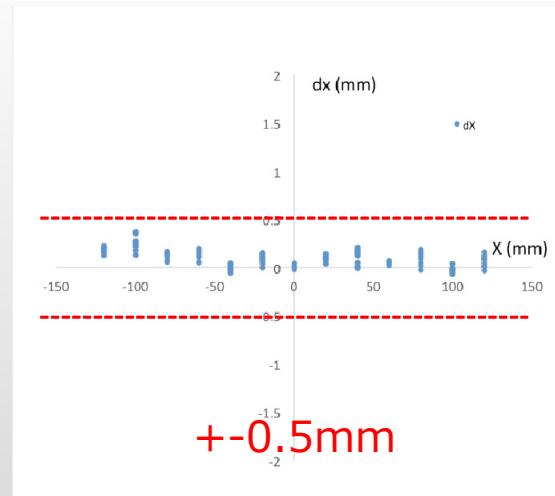
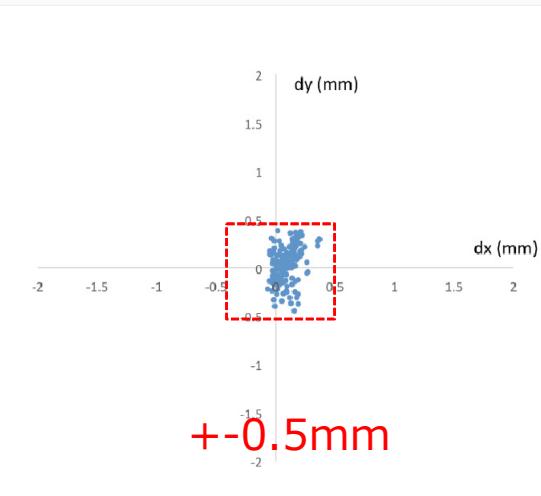
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# Check the measurement position by PRN



## Compare with measurement

- ✓ Gafchromic film
- ✓ Position monitor to survey  
the beam position during the irradiatio



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# Overall verification

QA pattern



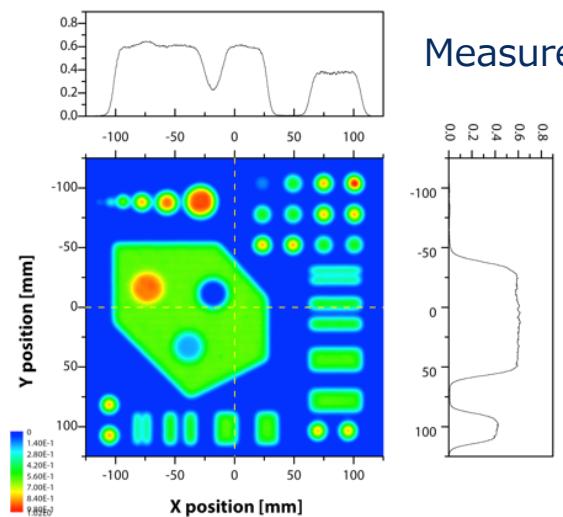
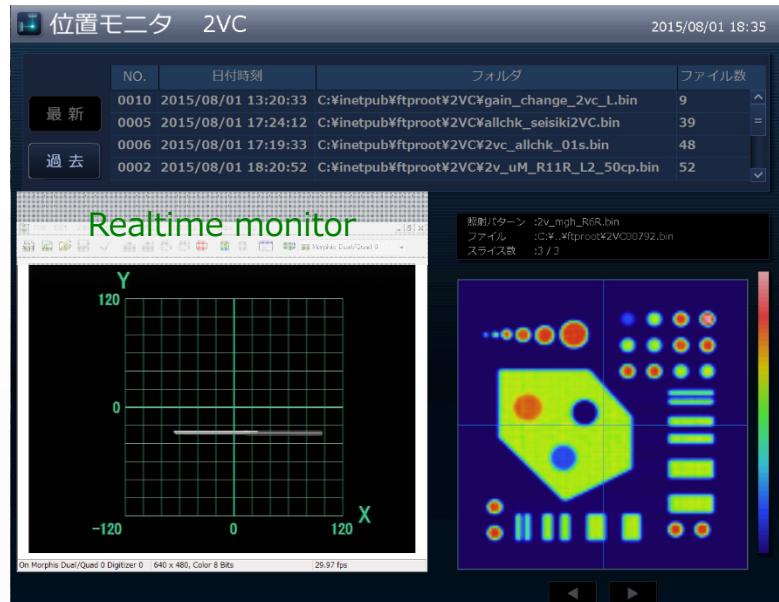
ID	X, Y, Z	Preset Count
1	50,60,198	1807
2	48,60,198	2096
3	46,60,198	4404
4	44,60,198	1467
.	.	.
17247	-24,-32,114	467
17248	-26,-32,114	1017
17249	-28,-32,114	226

Transfer to irradiation system



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Position monitor system



# Summary

## Performance test for non-scanned beam

- ▶ Beam intensity → suppressed within 20%
- ▶ Beam position → stability within +-0.5mm
- ▶ Beam size → keep symmetric shape with all energy and port

## Performance test for scanned beam

- ▶ Scanned beam position → within +-0.5mm
- ▶ Dose monitor → Linearity=+-0.5%, Uniformity=+-3%
- ▶ Position monitor → accuracy=+-0.5mm
- ▶ Overall verification → Good!!!

# Summary

## Performance test for non-scanned beam

- ▶ Beam intensity → suppressed within 20%
- ▶ Beam position → stability within +-0.5mm
- ▶ Beam size → keep symmetric shape with all energy and port

## Performance test for scanned beam

- ▶ Scanned beam position → within +-0.5mm
- ▶ Dose monitor → Linearity=+-0.5%, Uniformity=+-3%
- ▶ Position monitor → accuracy=+-0.5mm
- ▶ Overall verification → Good!!!

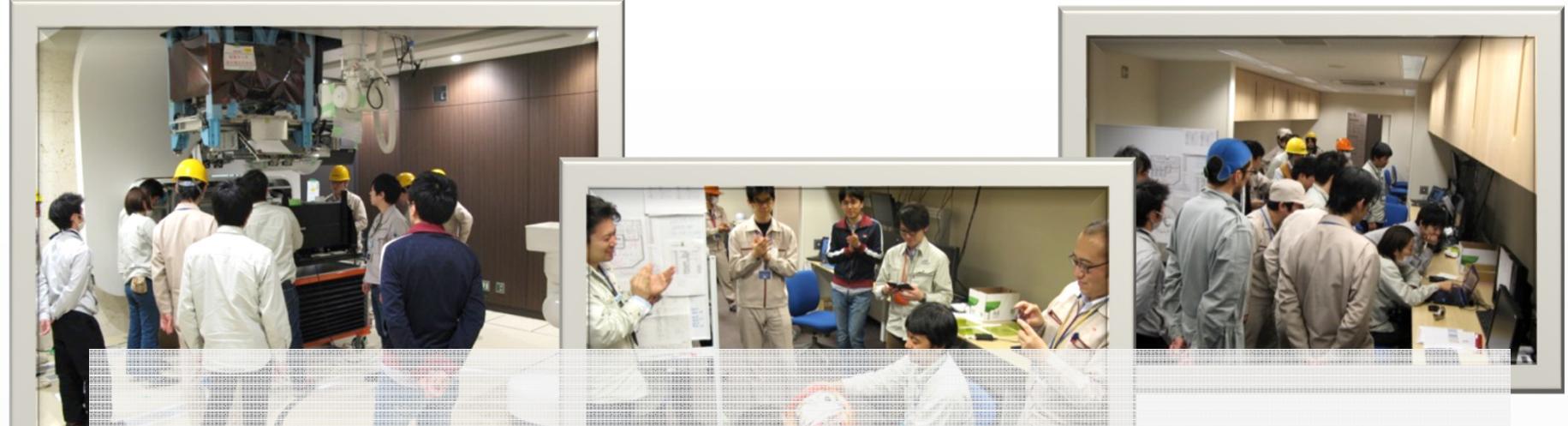
! First treatment in December 2015 !



2015/09/08 HIAT2015



地方独立行政法人 神奈川県立病院機構  
**神奈川県立がんセンター**



Thank you for your attention  
&

Thank to all of commissioning members ☺



2015/09/08 HIAT2015



地方独立行政法人 神奈川県立病院機構  
神奈川県立がんセンター

# Specification in the Treatment Room

Treatment couch	Robotic couch (7 degree of freedom) based on the SCARA (Selective Compliance Assembly Robot Arm)
Image Verification for patient setup	Orthogonal X-ray FPD images <ul style="list-style-type: none"><li>• 3 D automatic image registration tool</li><li>• Manual registration tool using multipoint</li></ul>
Respiratory Gating	Internal marker tracking using X-ray fluoroscopic images  External respiration sensor on the body surface
Target Verification	In-room CT (all treatment rooms) Verification of the target position based on the dose distribution, and in future for adaptive radiotherapy