Carbon Ion Radiotherapy

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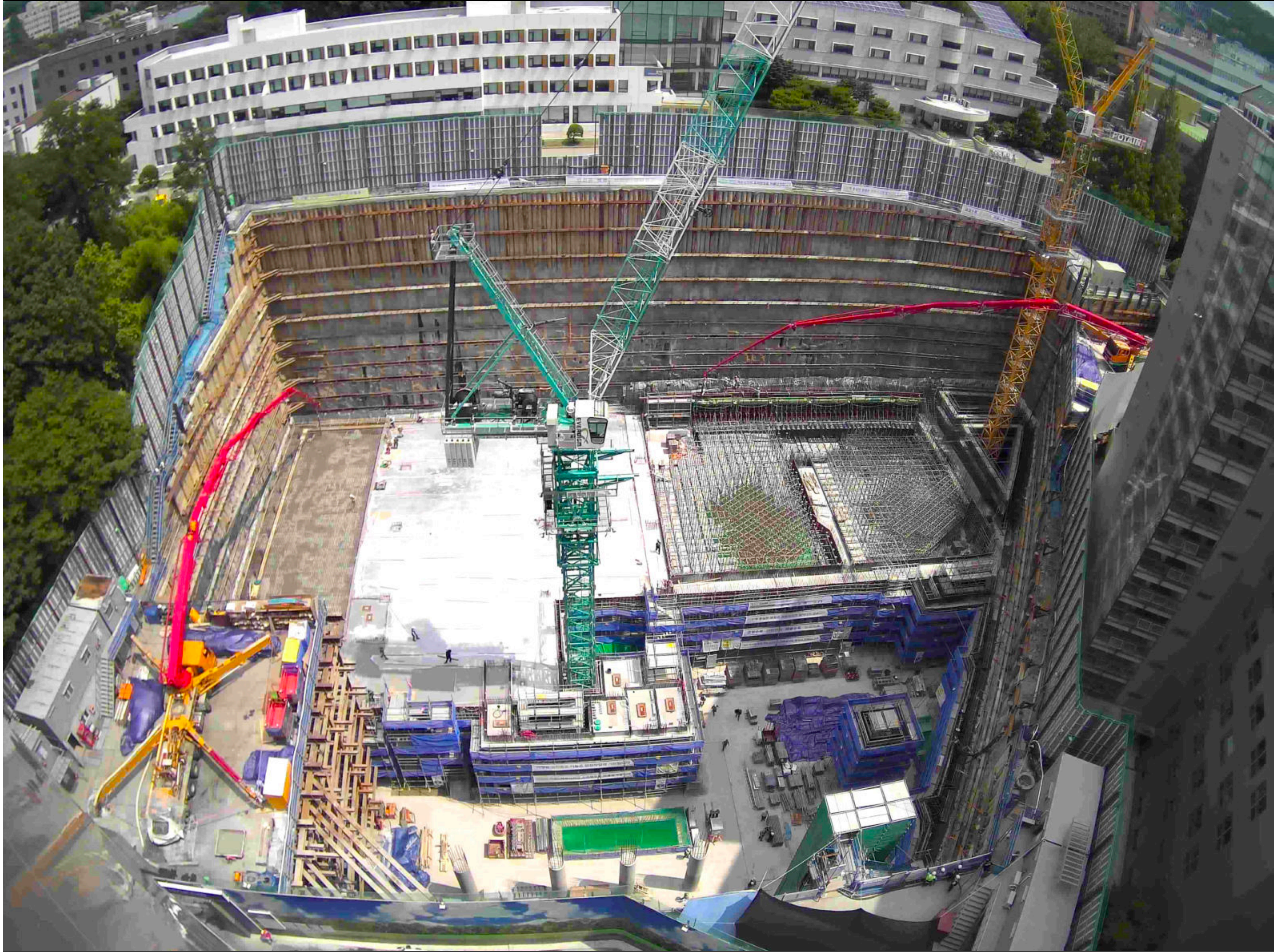

POTAIN

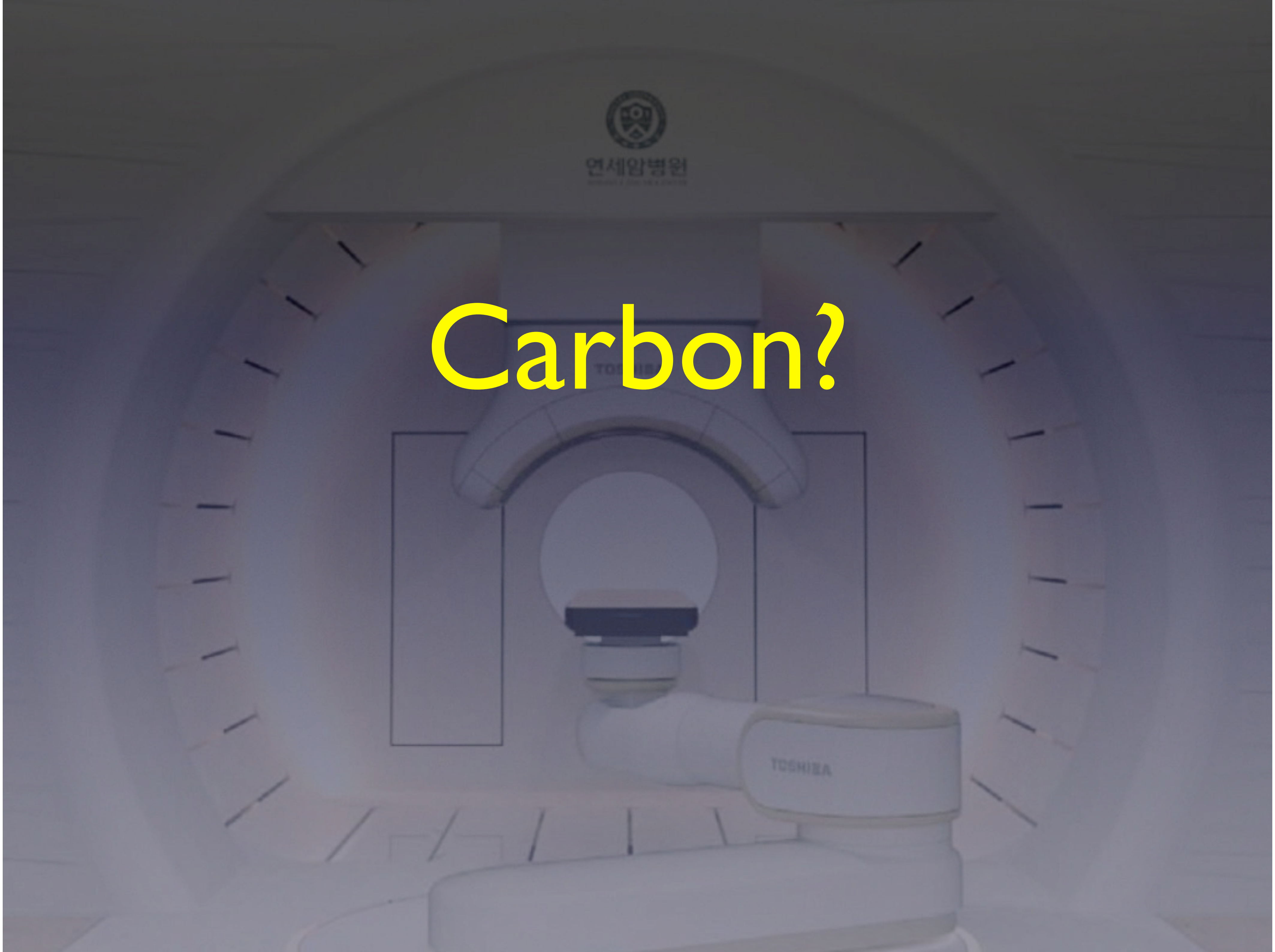
My Life with Particle

- 2007.03-2009.02
  - 국립암센터
  - 양성자치료센터 - Proton, IBA
- 2009.03-2016.02
  - 삼성서울병원
  - 양성자치료센터 - Proton, Sumitomo
- 2016.03-
  - 연세대학교 의과대학
  - 중입자치료기 - Carbon, Toshiba

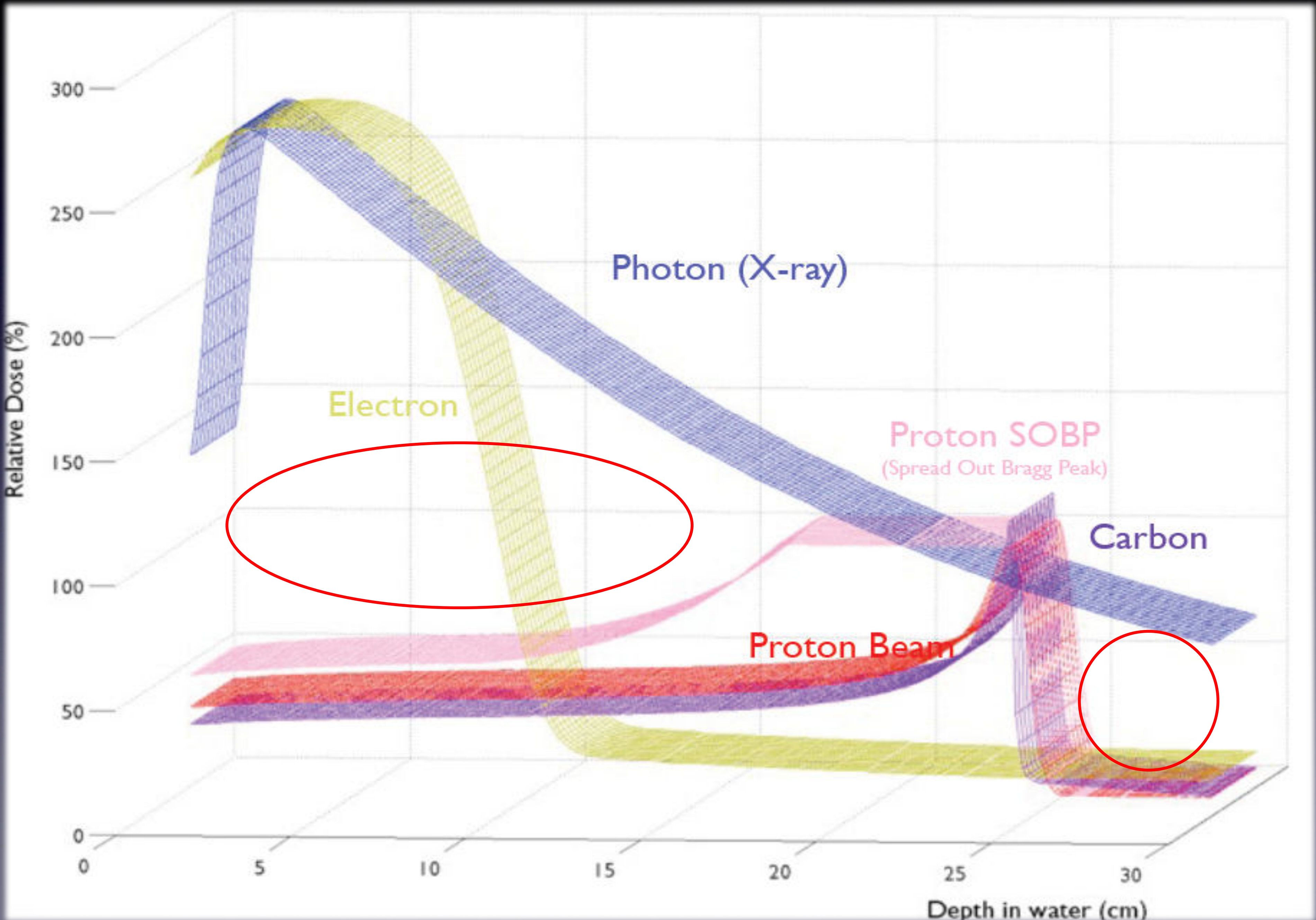
Contents

- Why Particle? and Carbon?
- Why in Yonsei?
- Advanced carbon ion therapy
- Summary

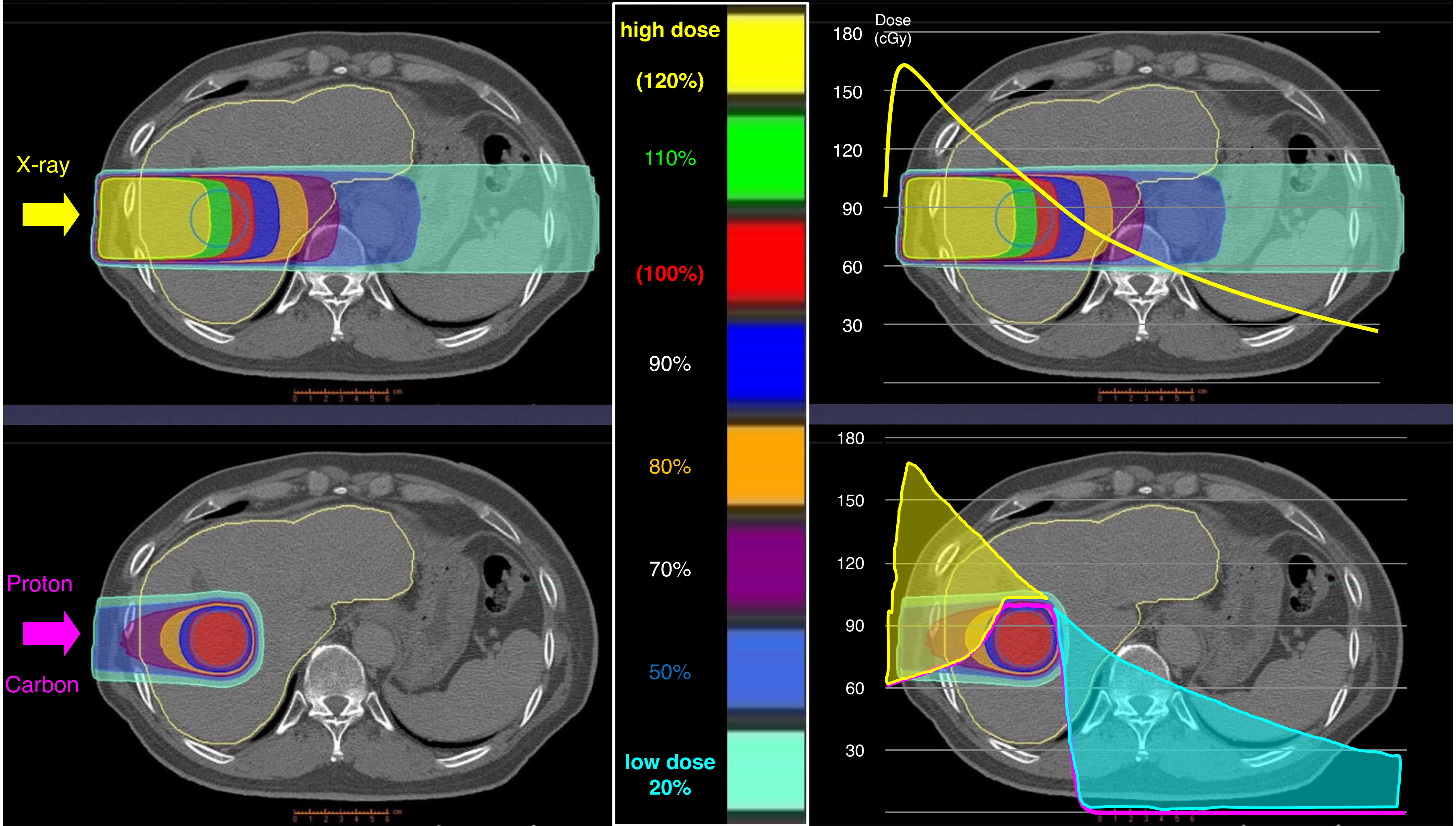
Carbon?



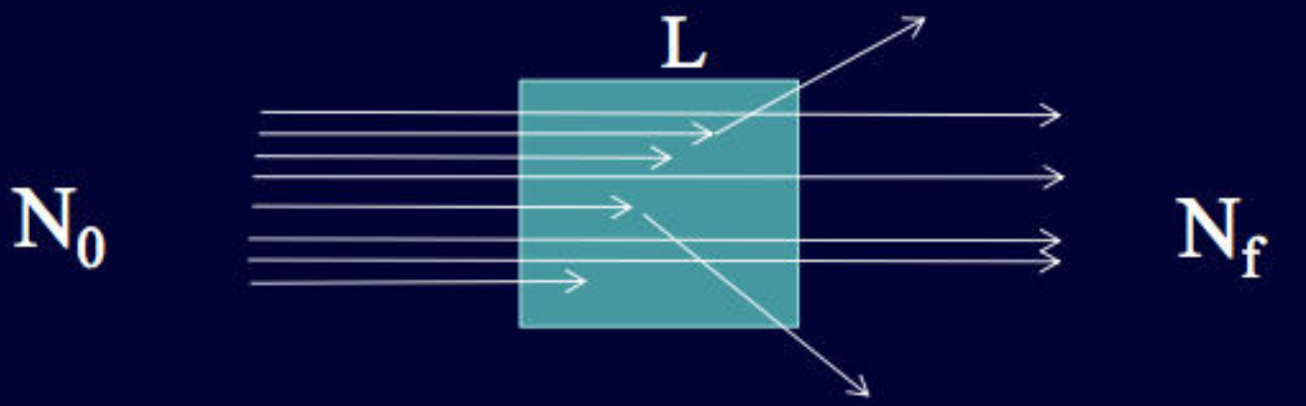
Percent Depth Dose



Why Particle?



X-ray, Photon



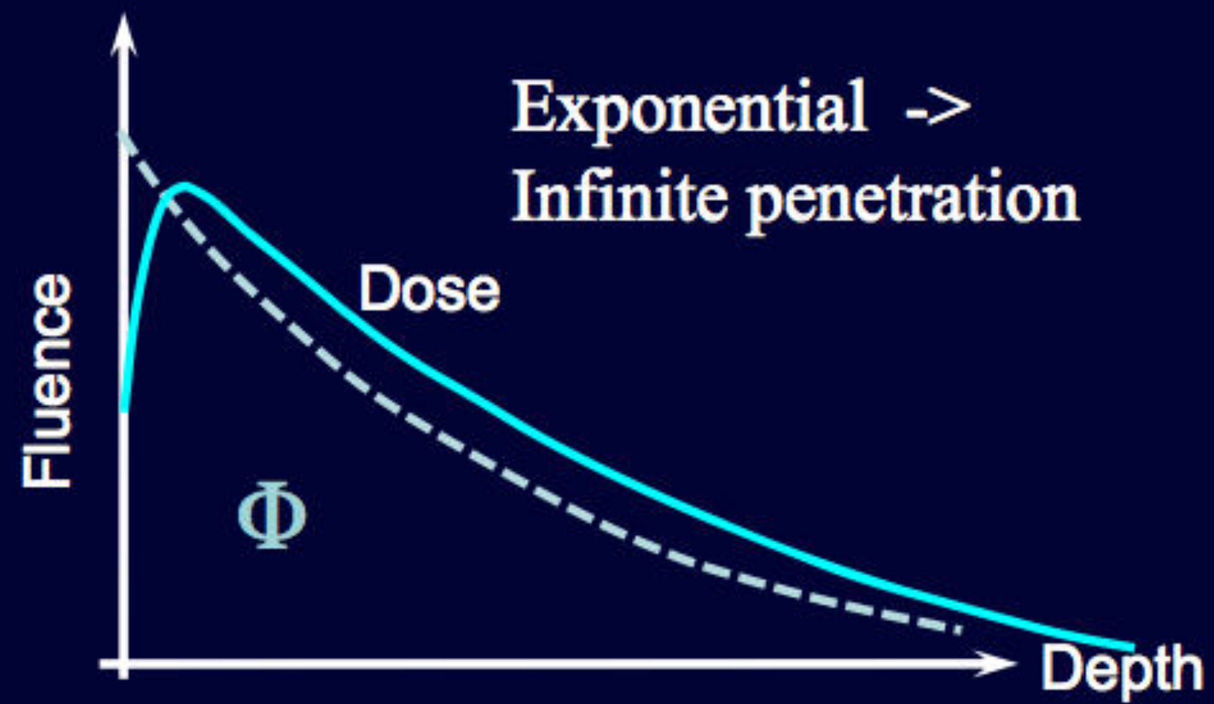
Number of photons decreases exponentially

$$N_f = N_0\, e^{-\mu L}$$

Fluence:

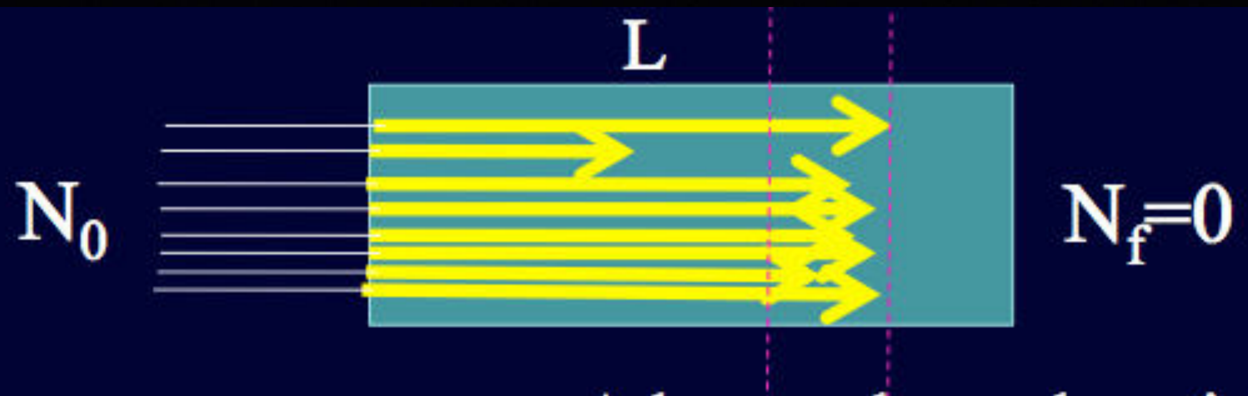
$$\Phi = N / A$$

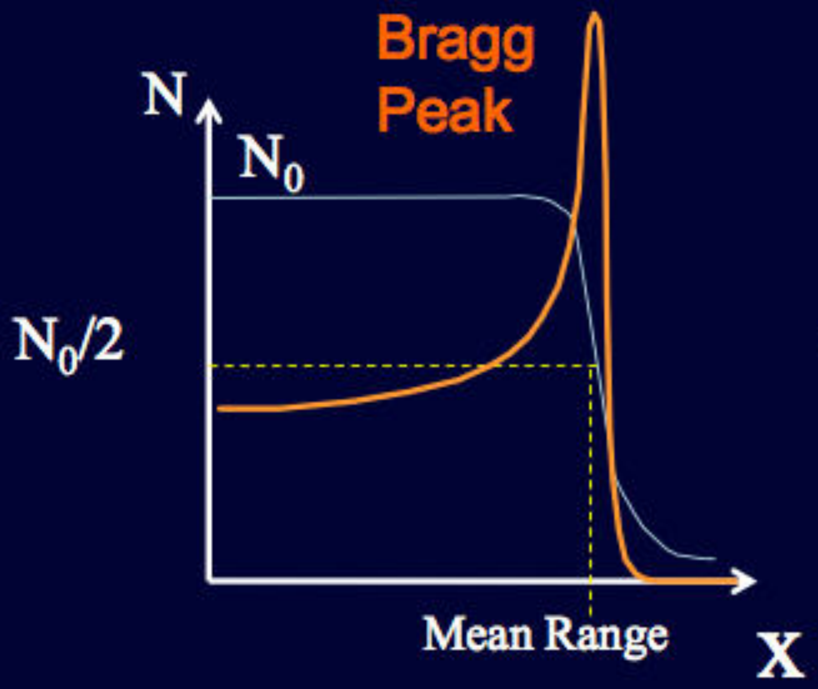
Exponential -> Infinite penetration



Attenuation!

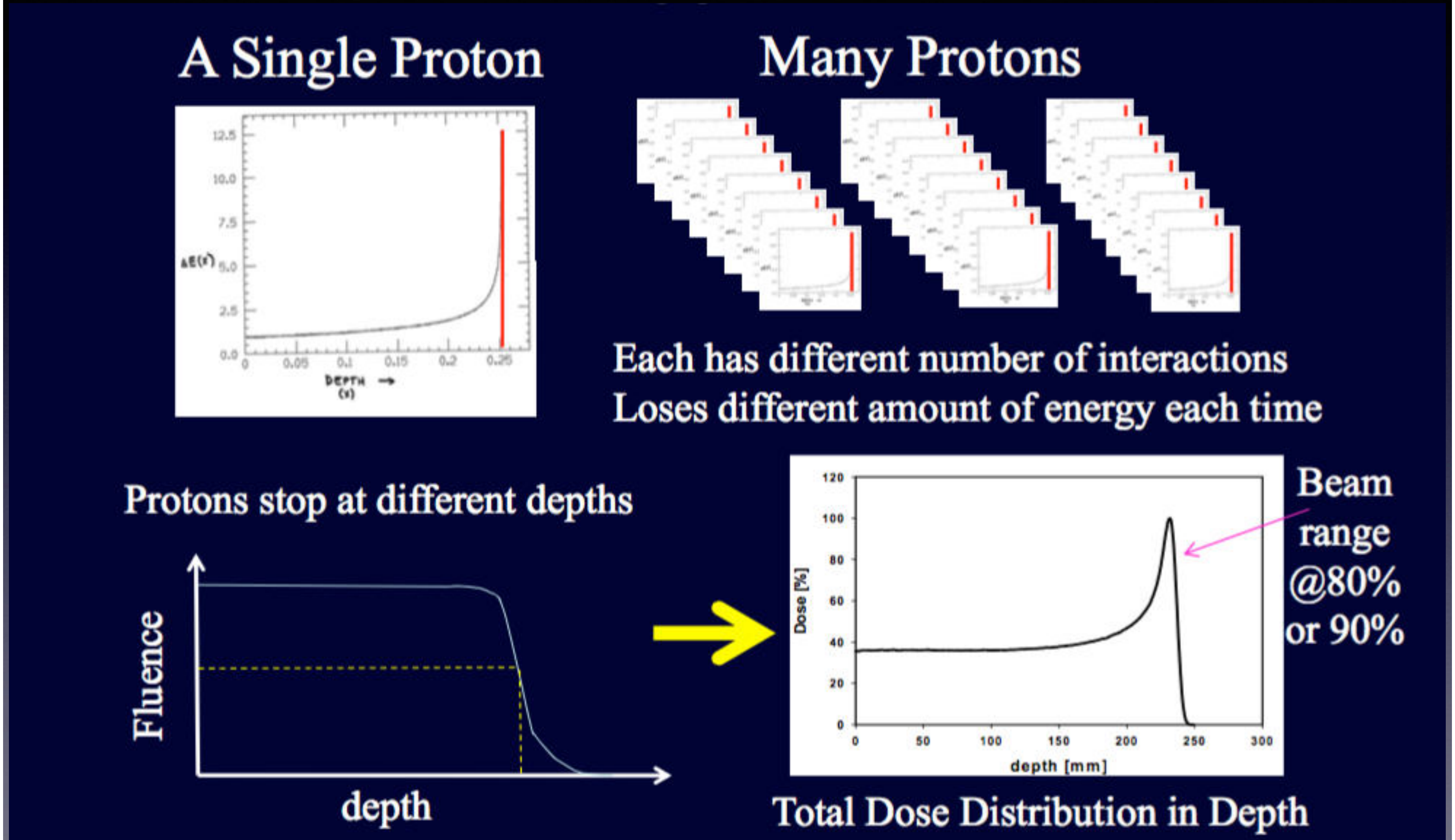
Particle = No attenuation!





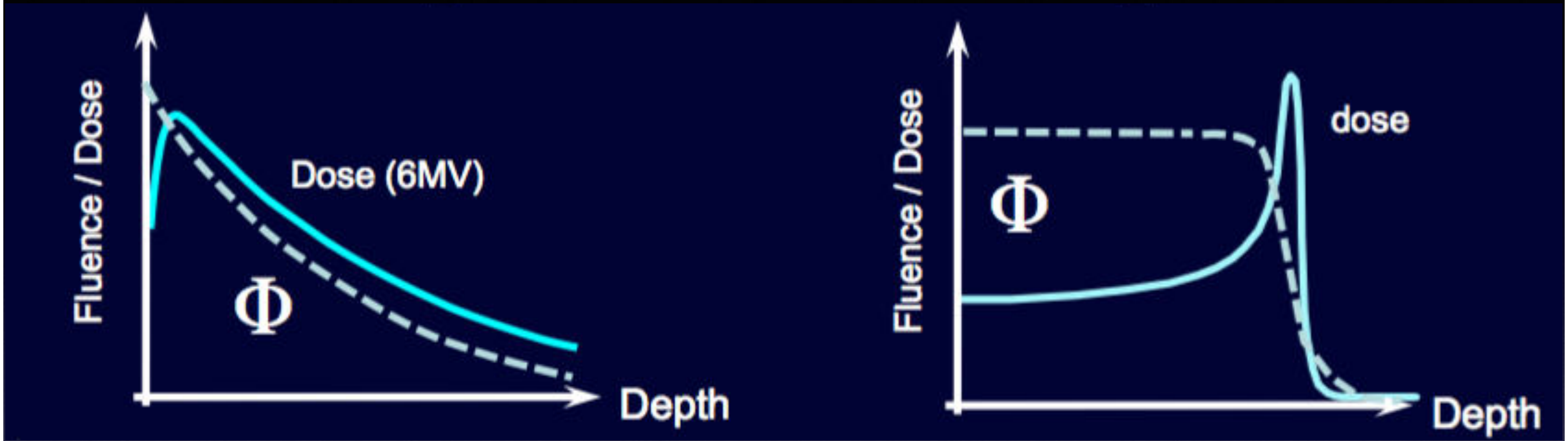
- A heavy charged particle endures multiple interactions through matter, but "stays" in the beam, because it is deflected only slightly.
- It loses only a small fraction of its energy in each interaction (except in "rare" nuclear interactions) until it stops, i.e., continuous slowing down.
- It deposits most energy near the end

example) Proton's Bragg Peak



Slide from Hsiao-Ming Lu, Ph.D @ MGH

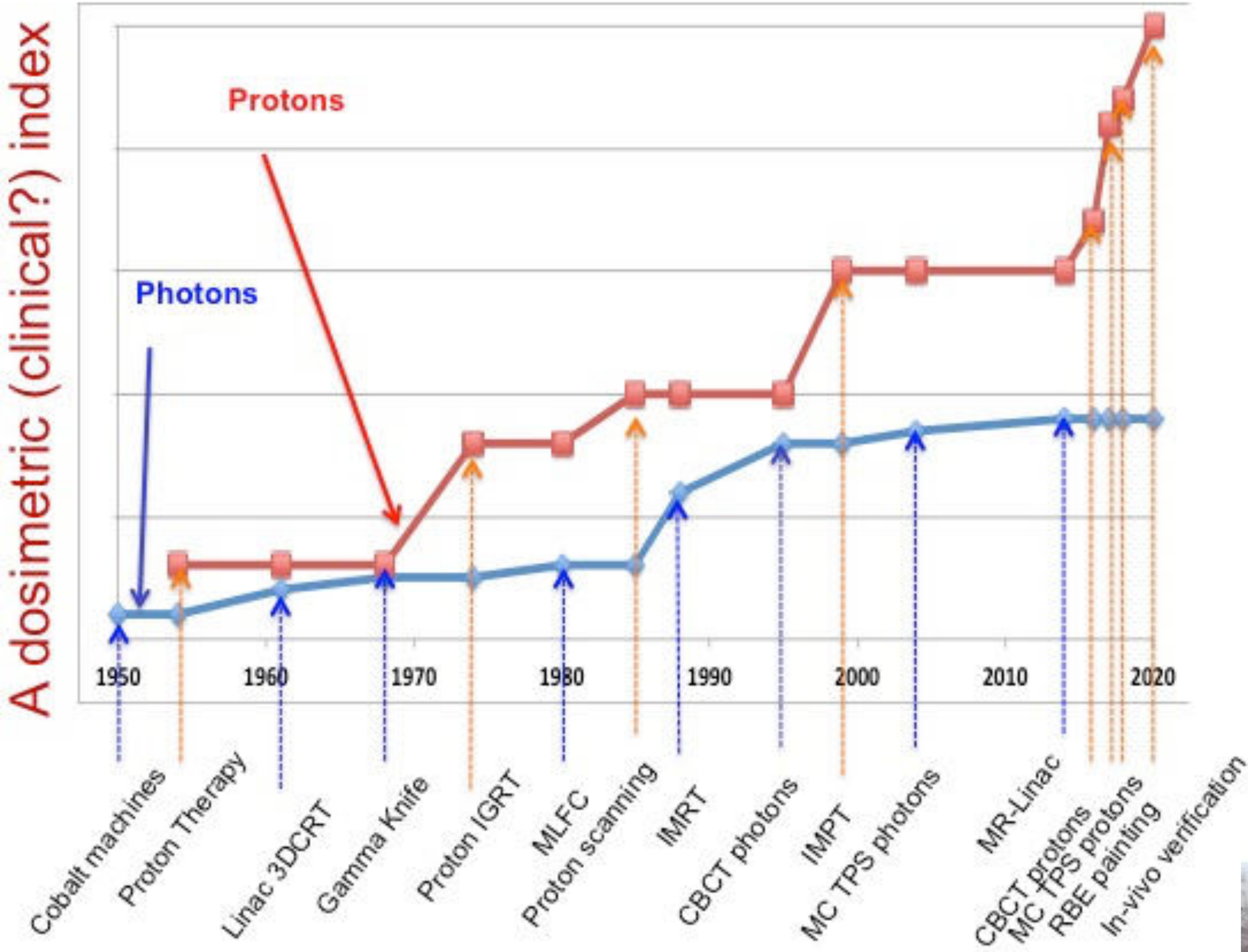
Xray vs Particle



- Attenuation, fluence decreasing
- No substantial change in energy spectrum
- No change in ratio between biological dose and physical dose
- Compton electron E mostly high → dose buildup near surface

- No attenuation, fluence stays constant except near the end
- Particles lose energy gradually
- Energy loss per ion pair stays same
- Increase in LET, and possibly RBE
- Electron energy low ➡ no buildup

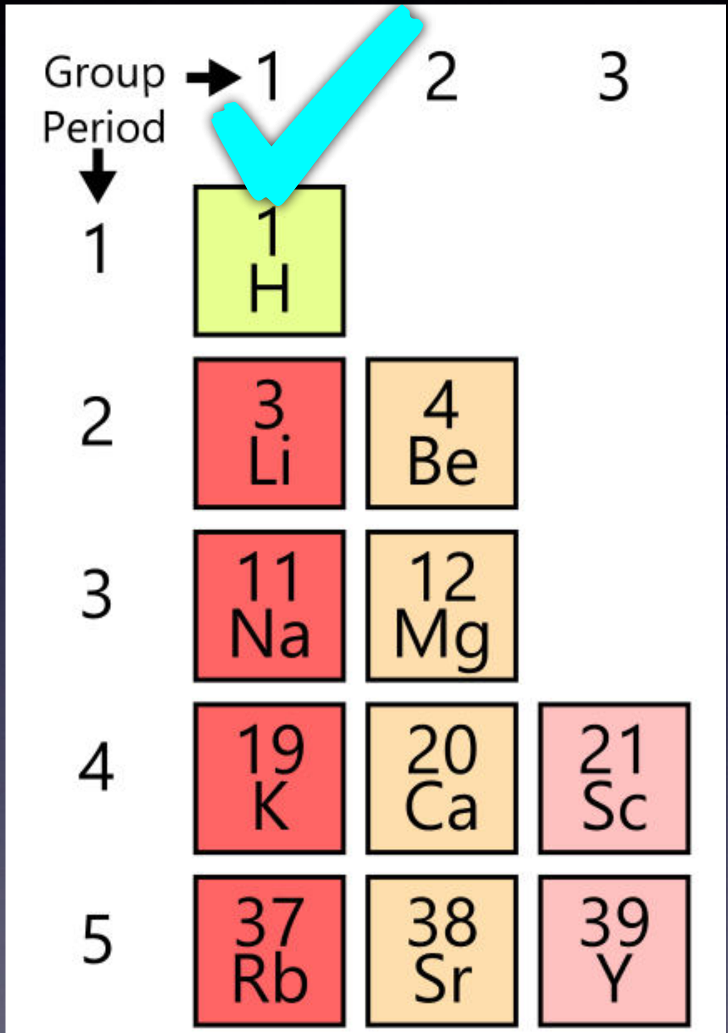
Slide from Hsiao-Ming Lu, Ph.D @ MGH

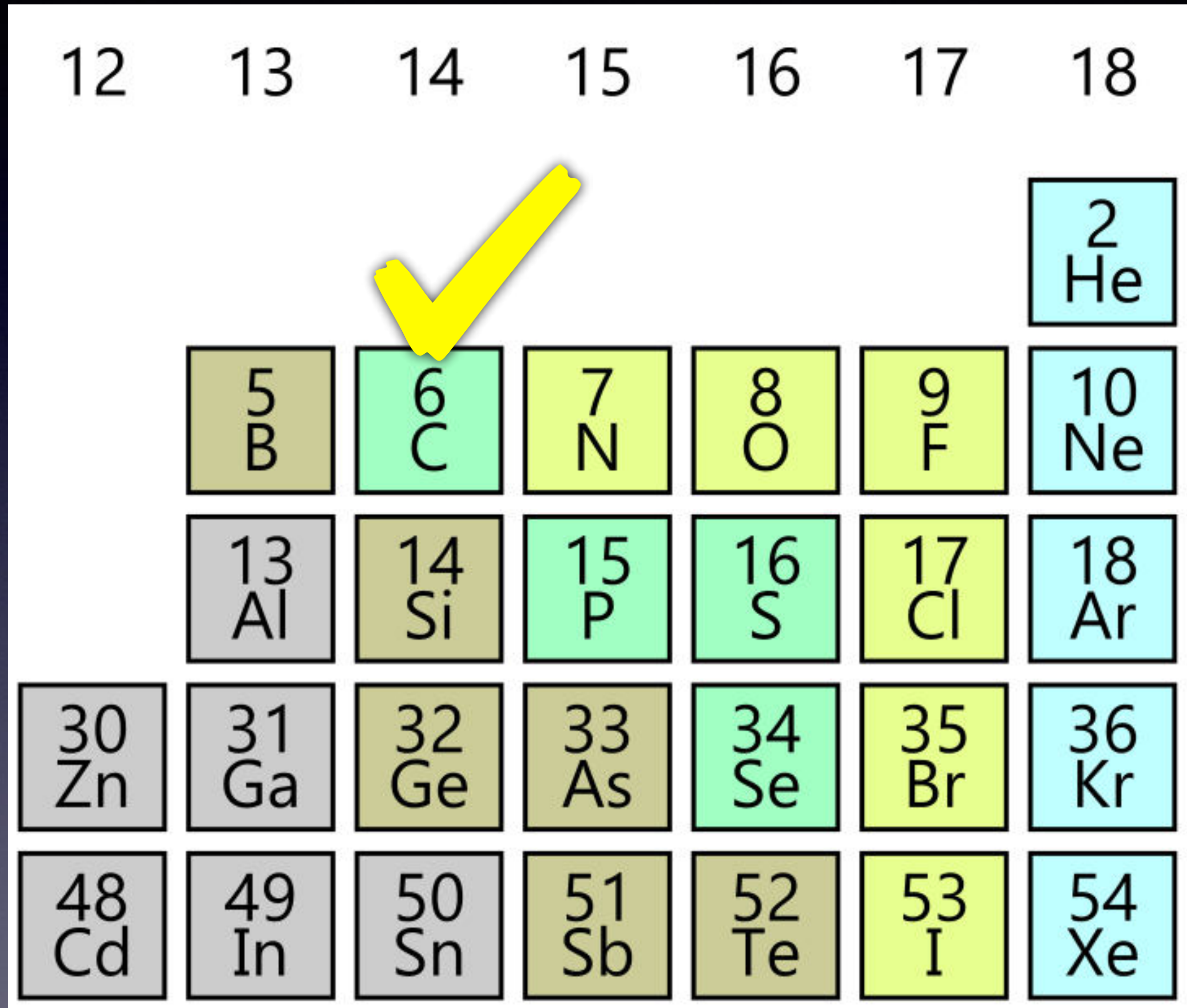


- Generic advances are typically developed first on one side
- Modality specific advancements will influence the gap long term

MASSACHUSETTS GENERAL HOSPITAL
RADIATION ONCOLOGY
HARVARD MEDICAL SCHOOL

Do you remember?



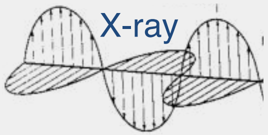


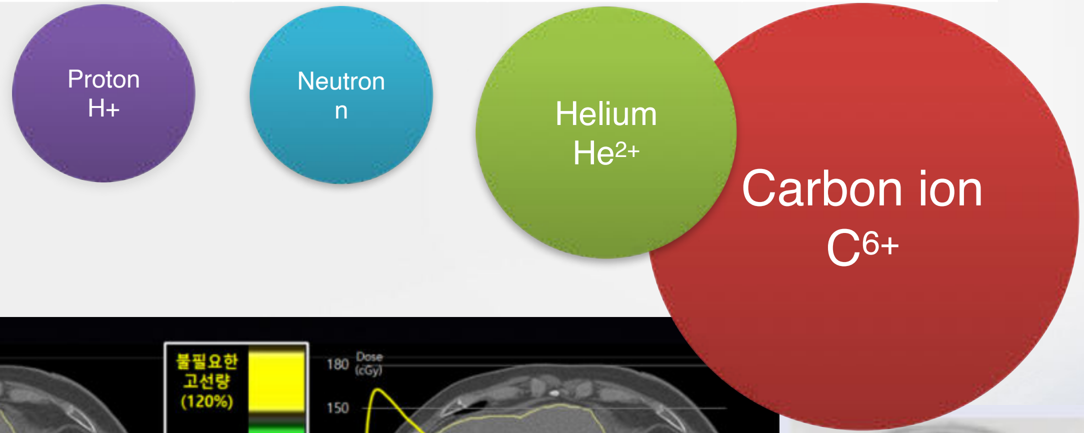
$^{1}_{1}H$ Proton

$^{6}_{12}C$ Carbon

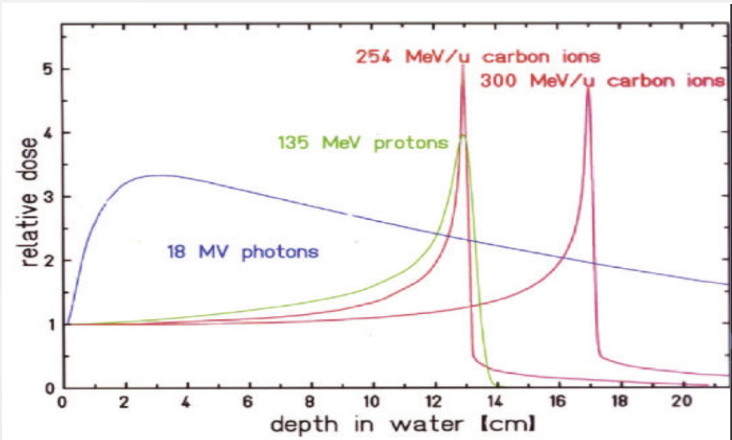
중입자란? 重粒子, Heavy Ion

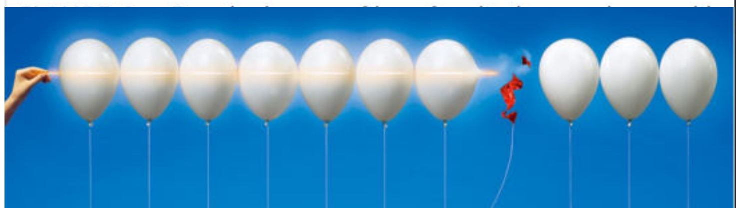
	X-ray	Electron	Proton	Neutron	Helium	Carbon
Mass	X	0.0005	1	1	4	12
Charge	X	-1	+1	0	+2	+6
RBE	1	1	1.1	10~100	1.1~1.3	2~3

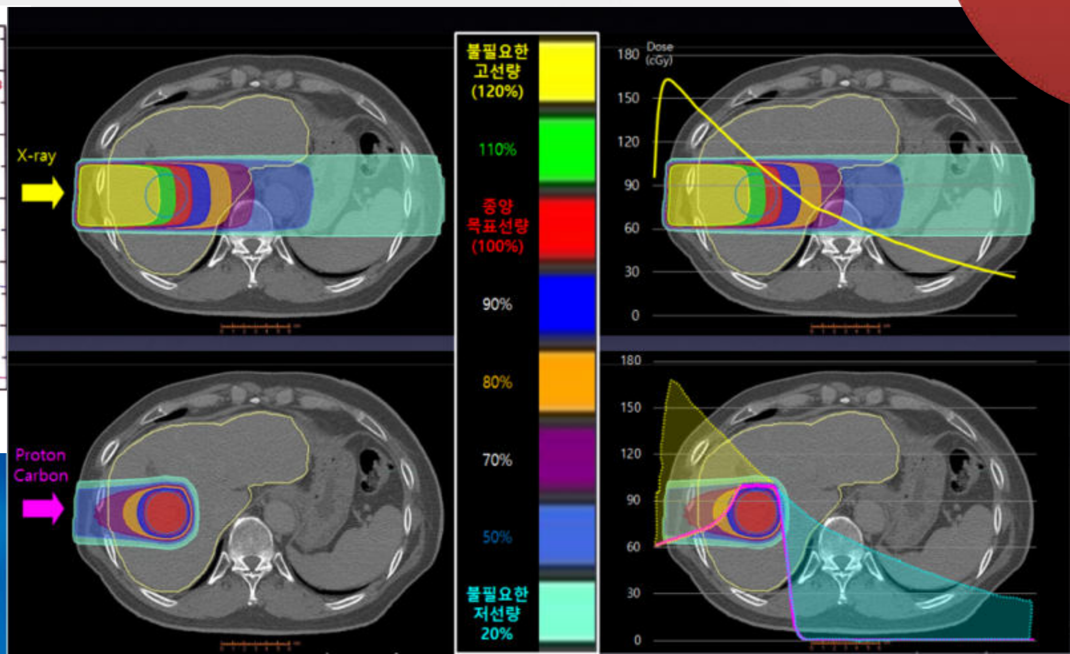




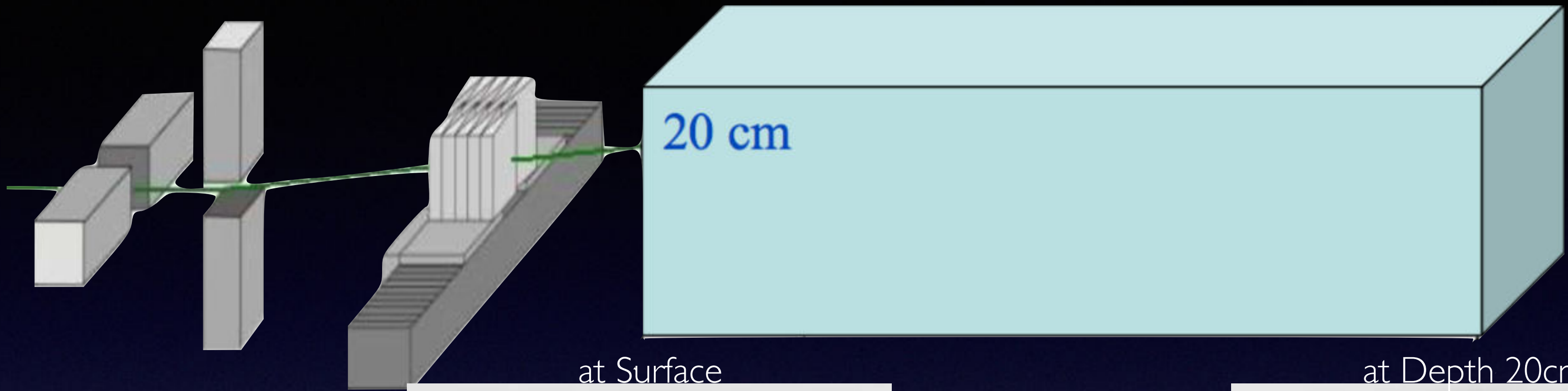
RBE: 2~3 times than x-ray, proton!
but… not sure…







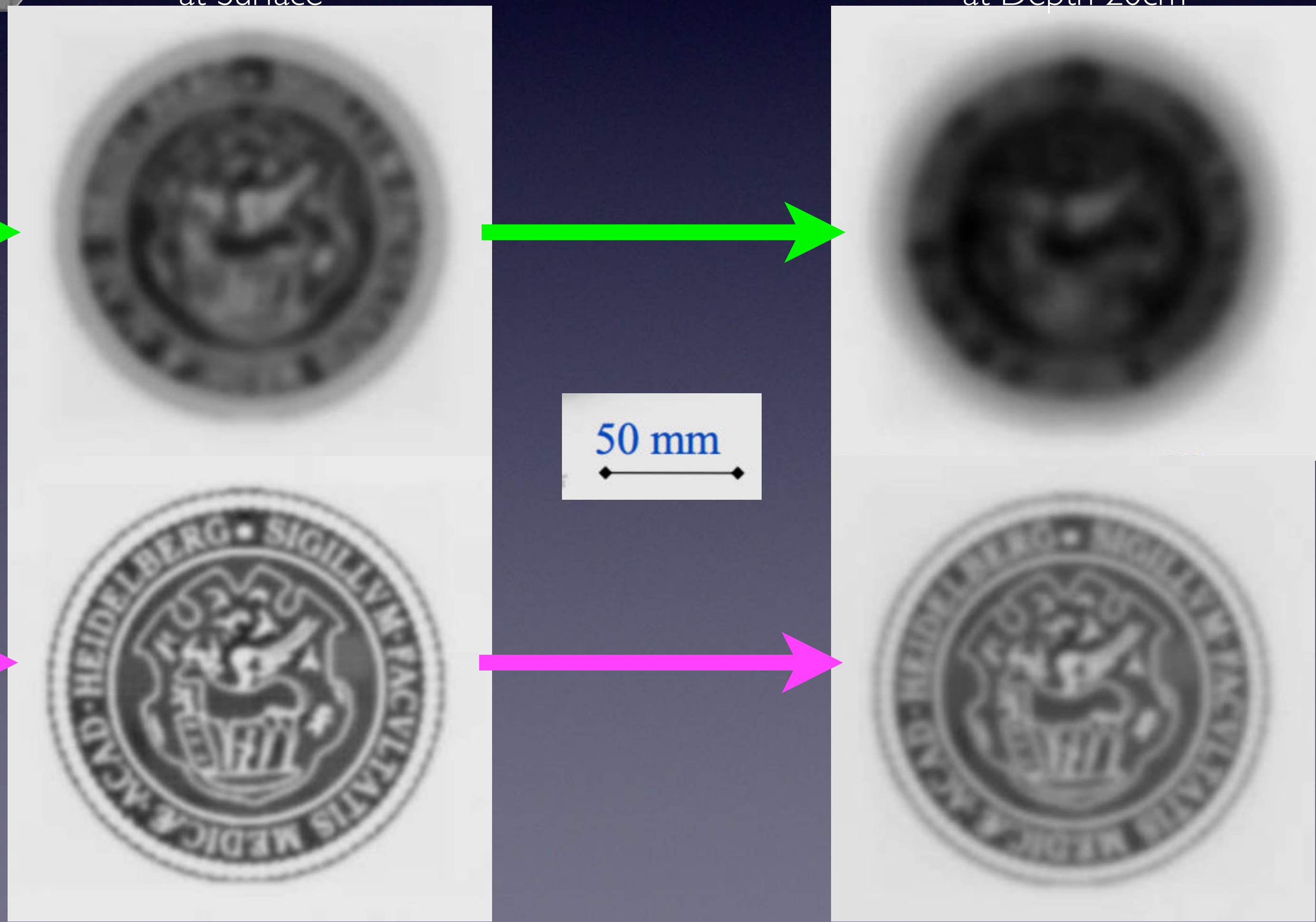
Penumbra in water - Proton vs Carbon



at Surface

at Depth 20cm

Proton
220 MeV



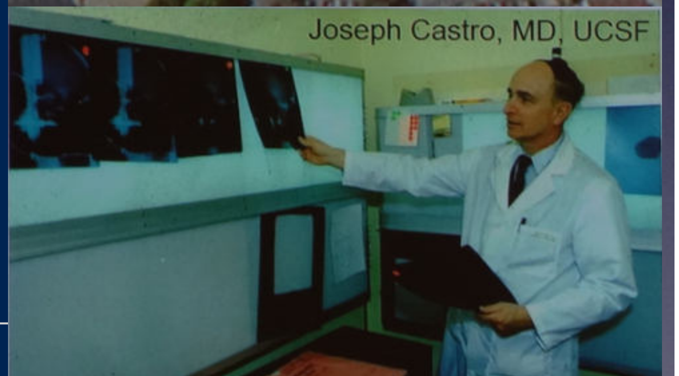
Carbon
380 MeV/u

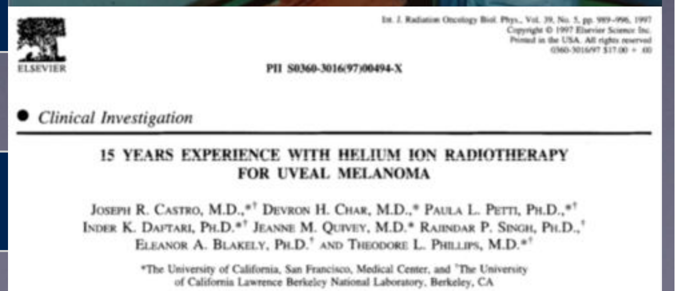
Oliver Jäkel, 2013 AAPM

Various particle therapy in the world

Where	What?	Start	End	No. Patients
Berkeley	**Proton**	1954	1957	30
Uppsala	Proton	1957	1976	73
Berkeley	**He**	1957	1992	2,054
Harvard	Proton	1961	2002	9,116
Los Alamos	**Pion**	1974	1982	230
Berkeley	**Carbon**	1977	1992	433
	Ne	1977		
	Ar	1979		
	Si	1982		
PSI	Pion	1980	1993	503
Tsukuba	Proton	1983	2000	700
Chiba	Carbon	1994	Ongoing	10,486

from PTCOG website




ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. 39, No. 5, pp. 989–996, 1997
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PII S0360-3016(97)00494-X

● *Clinical Investigation*

15 YEARS EXPERIENCE WITH HELIUM ION RADIOTHERAPY FOR UVEAL MELANOMA

Joseph R. Castro, M.D.,*† Devron H. Char, M.D.,* Paula L. Petti, Ph.D.,*† Inder K. Daftari, Ph.D.*† Jeanne M. Quivey, M.D.* Rajindar P. Singh, Ph.D.,† Eleanor A. Blakely, Ph.D.† and Theodore L. Phillips, M.D.*†

*The University of California, San Francisco, Medical Center, and †The University of California Lawrence Berkeley National Laboratory, Berkeley, CA

SEVERANCE

Carbon could be better?

1. Past, present, and future of radiotherapy for the benefit of patients

Nature Reviews Clinical Oncology **10**, 52-60 (January 2013)

2. Cancer treatment: Sharp shooters

Nature 508, 133–138 (03 April 2014)

3. Carbon ion radiotherapy in Japan: an assessment of 20 years of clinical experience

Lancet Oncol 2015; ***16****: e93–100*

Innovation in Radiation Therapy

We have some history in radiation therapy

- the RT option for prostate is changing from x-ray to particle..

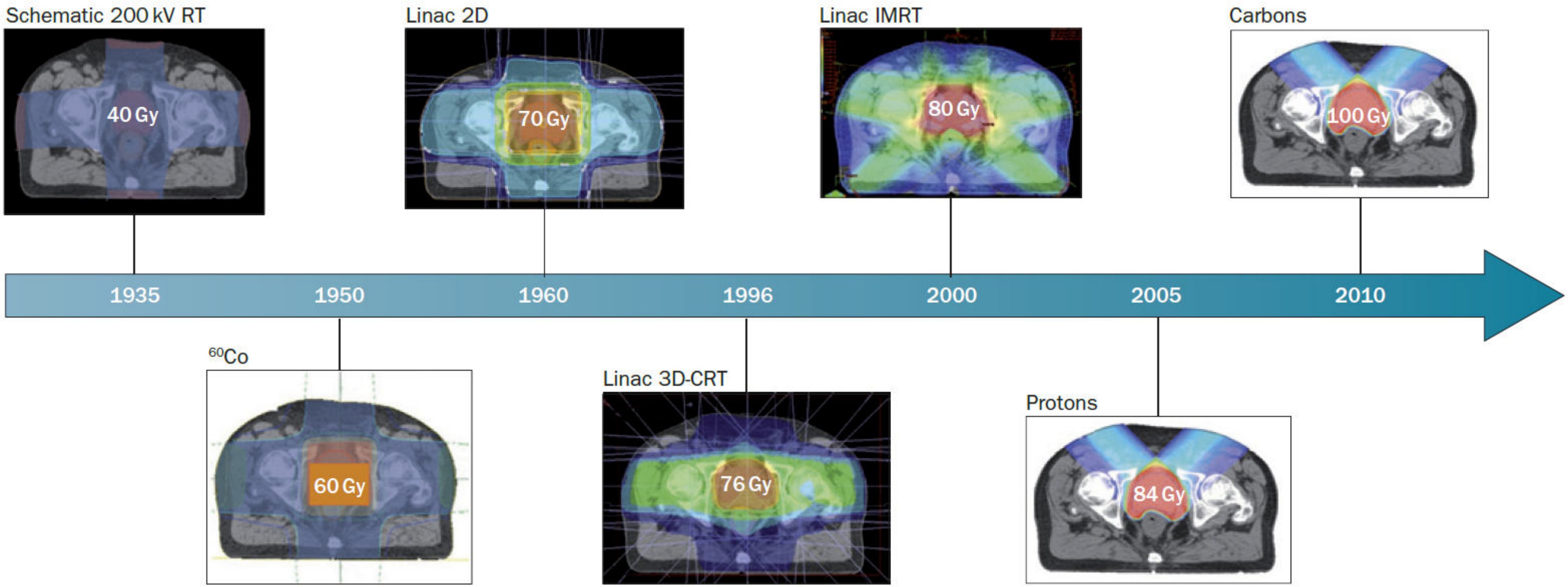


Figure 1 | Prostate cancer radiotherapy 1935–2010. Prostate cancer irradiation is a good example of the improvement of radiotherapy technology over the past decades. By increasing the beam energy and the precision of the targeting, it was possible to escalate the dose to the prostate without exceeding the tolerance dose of healthy tissues; allowing the move from palliative irradiation to curative treatment. Abbreviations: 3D-CRT, 3D conformal radiotherapy; IMRT, intensity modulated radiotherapy; RT, radiotherapy.

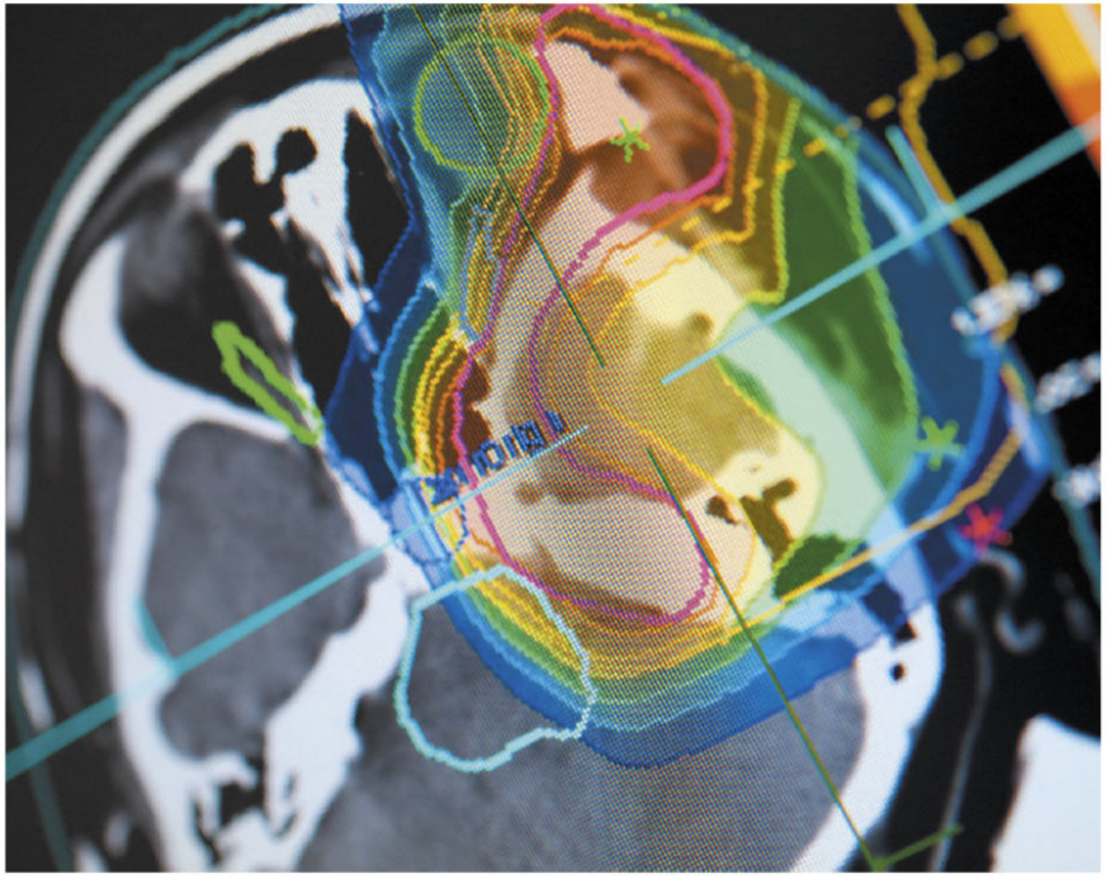
Past, present, and future of radiotherapy for the benefit of patients,
Nature Reviews Clinical Oncology **10**, 52-60 (January 2013)

TECHNOLOGY FEATURE

SHARP SHOOTERS

Beams of charged particles can treat cancer more safely and effectively than X-rays. Physicists and biomedical researchers are working to refine the technology for wider use.

HEIDELBERG UNIV. HOSPITAL



A computed-tomography scan shows a tumour and the ion-beam dosage that will be used to treat it.

BY VIVIEN MARX

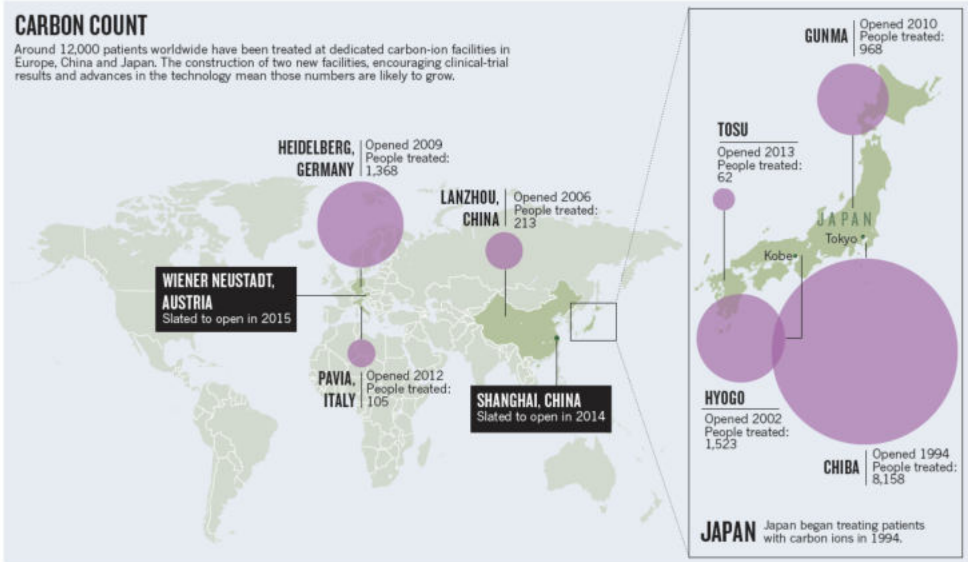
Clinicians attack cancer with many types of weapon, ranging from scalpels to physically remove all or most of a tumour to drugs that kill the tumour cells where they are. In about half of people with cancer, doctors go after the malignant cells with ionizing radiation.

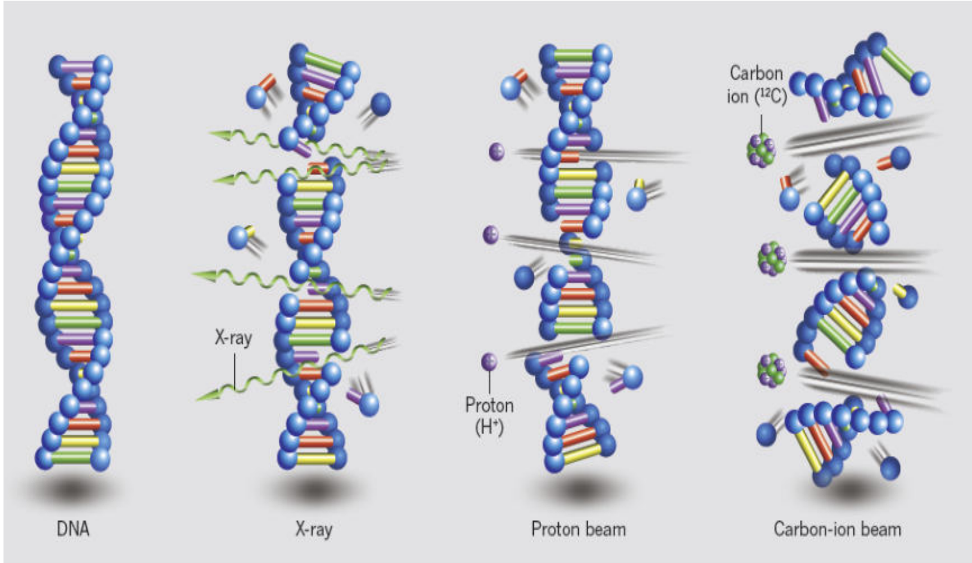
along their path through the body — damaging healthy cells as they go — clinicians and researchers are increasingly paying attention to beams that use charged particles such as protons and carbon ions[1]. Charged particles can deposit most of their lethal energy mainly at the tumour site, largely sparing the healthy tissue. Protons are slightly more lethal to cancer cells than X-rays, and carbon ions seem ... s deadly. ... 00,000 people have

received proton treatments for cancer. Japan, China, Germany and Italy have built ion-beam facilities that have treated some 12,000 patients with carbon ions, the majority in Japan and Germany (see 'Carbon count').

Carbon ions are heavier than protons, so the facilities to deliver them are pricier. The charged-particle facilities in Germany and Japan cost between US$130 million and $200 million each to build. Nonetheless, there has been a spike in research and ▸

Cancer treatment: Sharp shooters,
Nature 508, 133–138 (03 April 2014)





Carbon’s 20 years clinical outcome

- More than 8,000 patients
- Clinical trial only for 9 years
- **<u>Outstanding outcome</u> + Lower toxicities +** Short Tx time

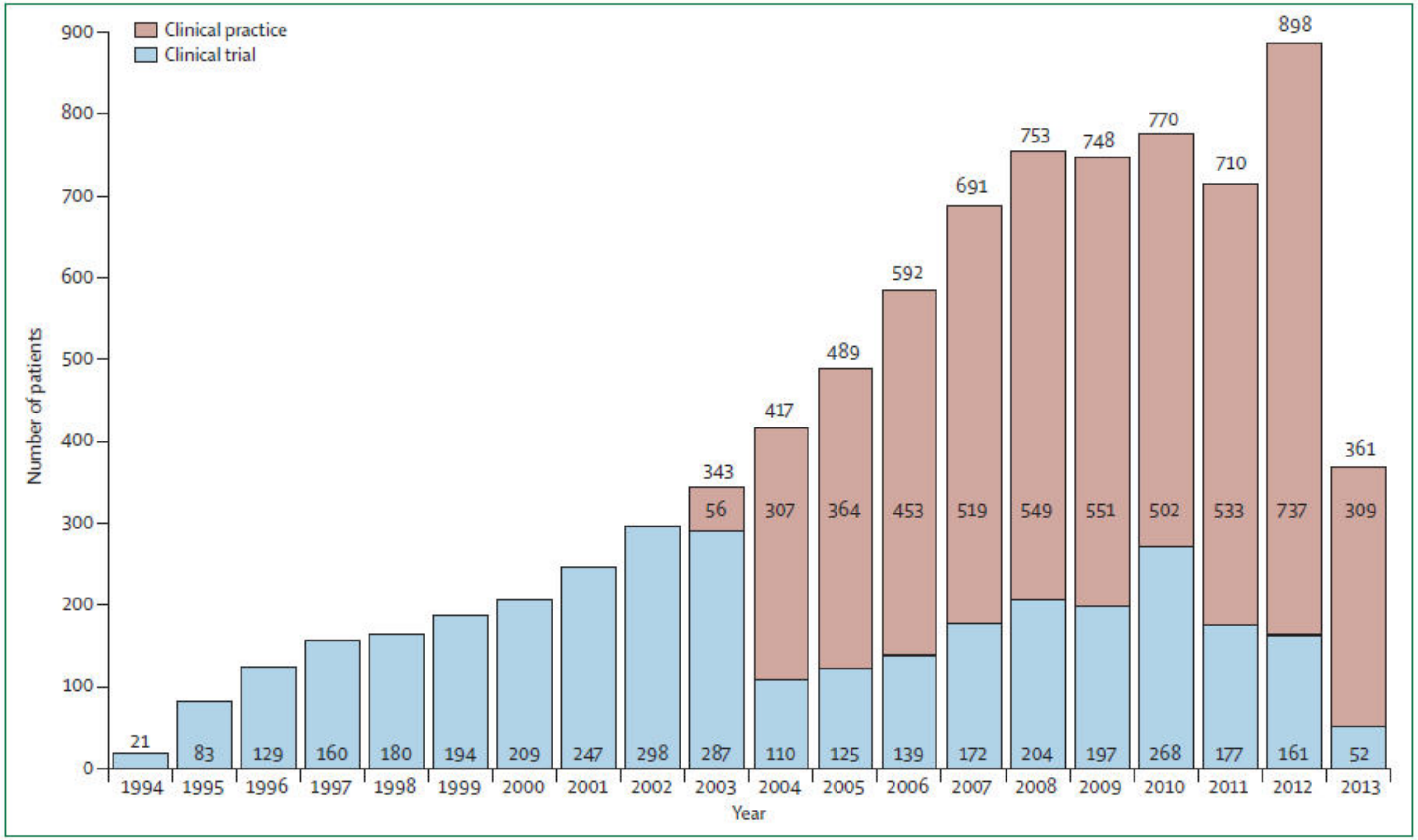


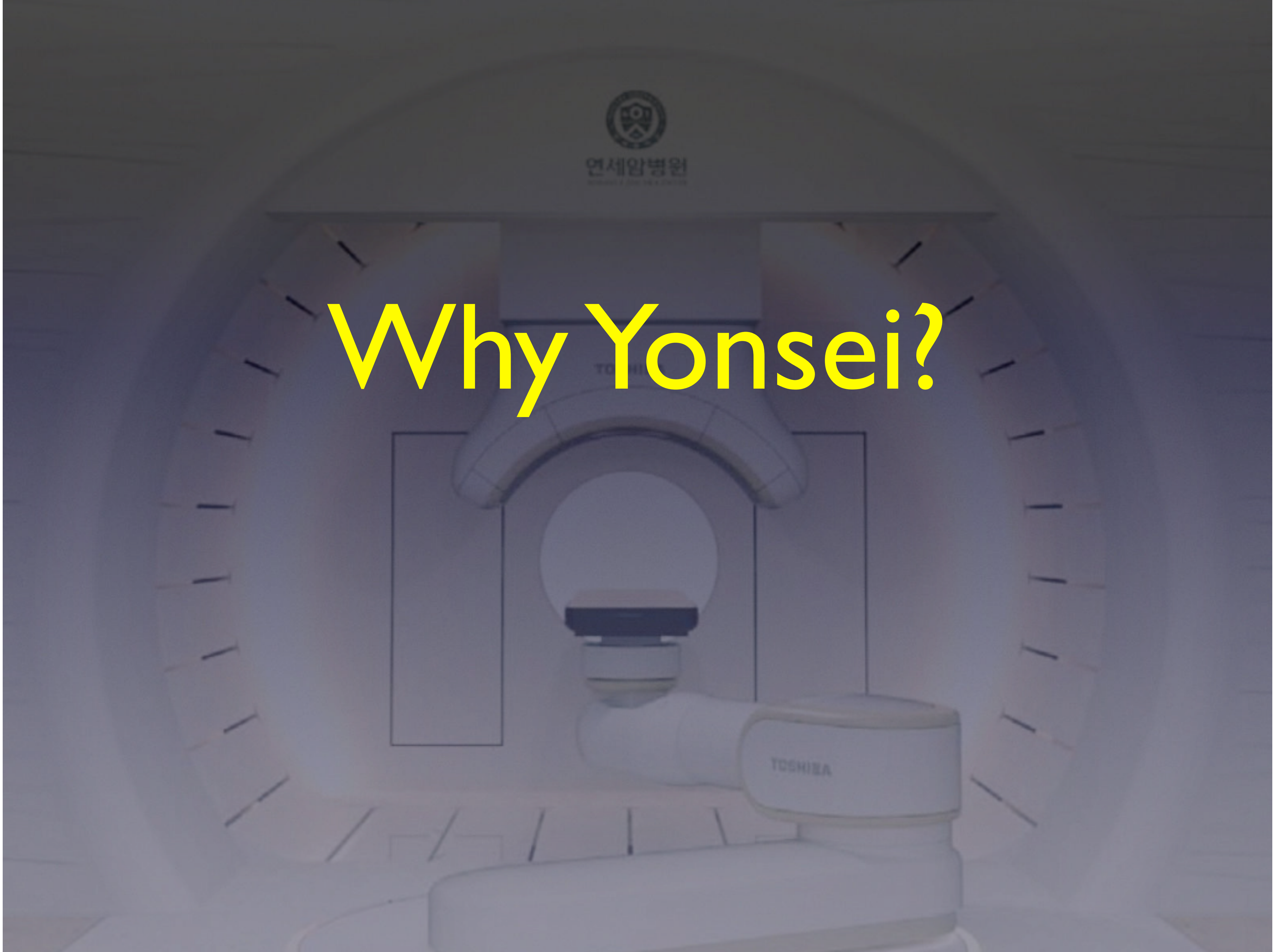
Figure 2: **Number of patients treated at National Institute of Radiological Sciences with carbon ion radiotherapy each year from June, 1994, to August, 2013**

	Total number of patients (%)	Clinical practice
Prostate	1731 (22%)	1399
Bone and soft tissue	1033 (13%)	780
Head and neck	854 (11%)	529
Lung	795 (10%)	207
Liver	485 (6%)	250
Post-operative rectum	408 (5%)	338
Pancreas	353 (4%)	113
Gynaecological	207 (3%)	10
Eye	128 (2%)	86
CNS	106 (1%)	0
Para aortic lymph node	94 (1%)	87
Skull base	85 (1%)	56
Oesophagus	71 (1%)	0
Lacrimal gland	24 (<1%)	1
Scanning	11 (<1%)	0
Miscellaneous	1547 (20%)	715

Table 3: **Distribution of patients treated with carbon ion radiotherapy at the National Institute of Radiological Sciences by tumour type**

Carbon ion radiotherapy in Japan: an assessment of 20 years of clinical experience,
Lancet Oncol 2015; ***16****: e93–100*

Why Yonsei?



Needs to understand S. Korea

Future life expectancy in 35 industrialised countries: projections with a Bayesian model ensemble

Lancet 2017; 389: 1323–35

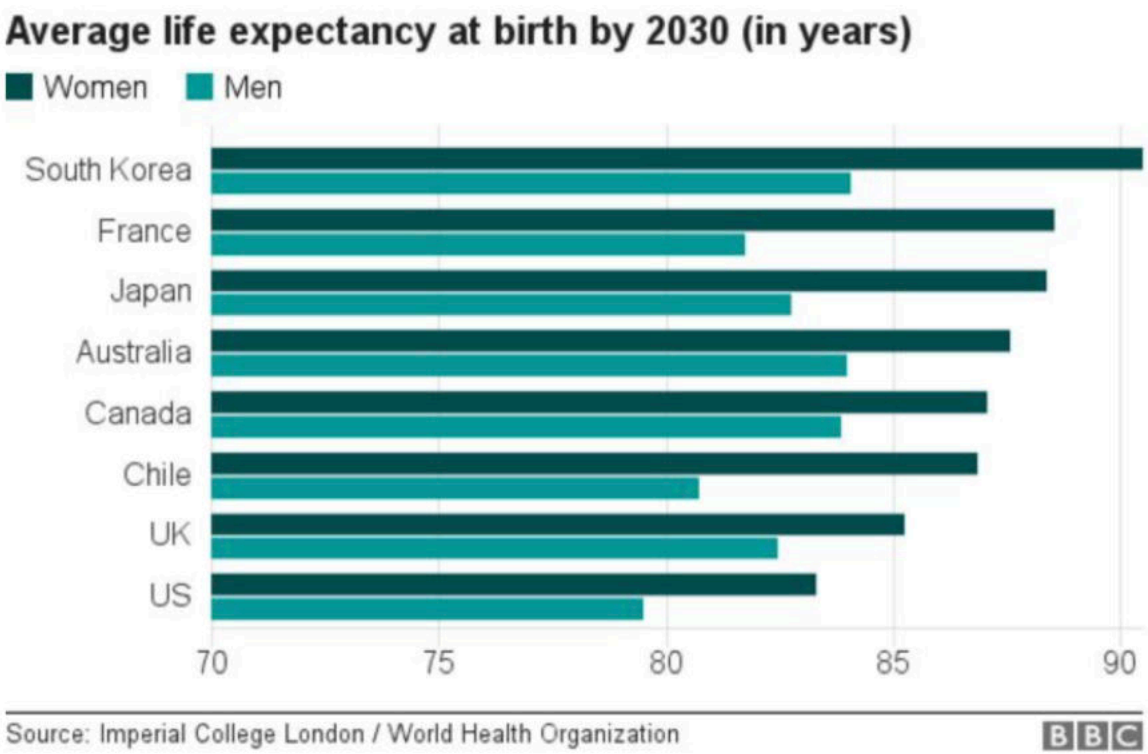
Vasilis Kontis, James E Bennett*, Colin D Mathers, Guangquan Li, Kyle Foreman, Majid Ezzati*

Summary

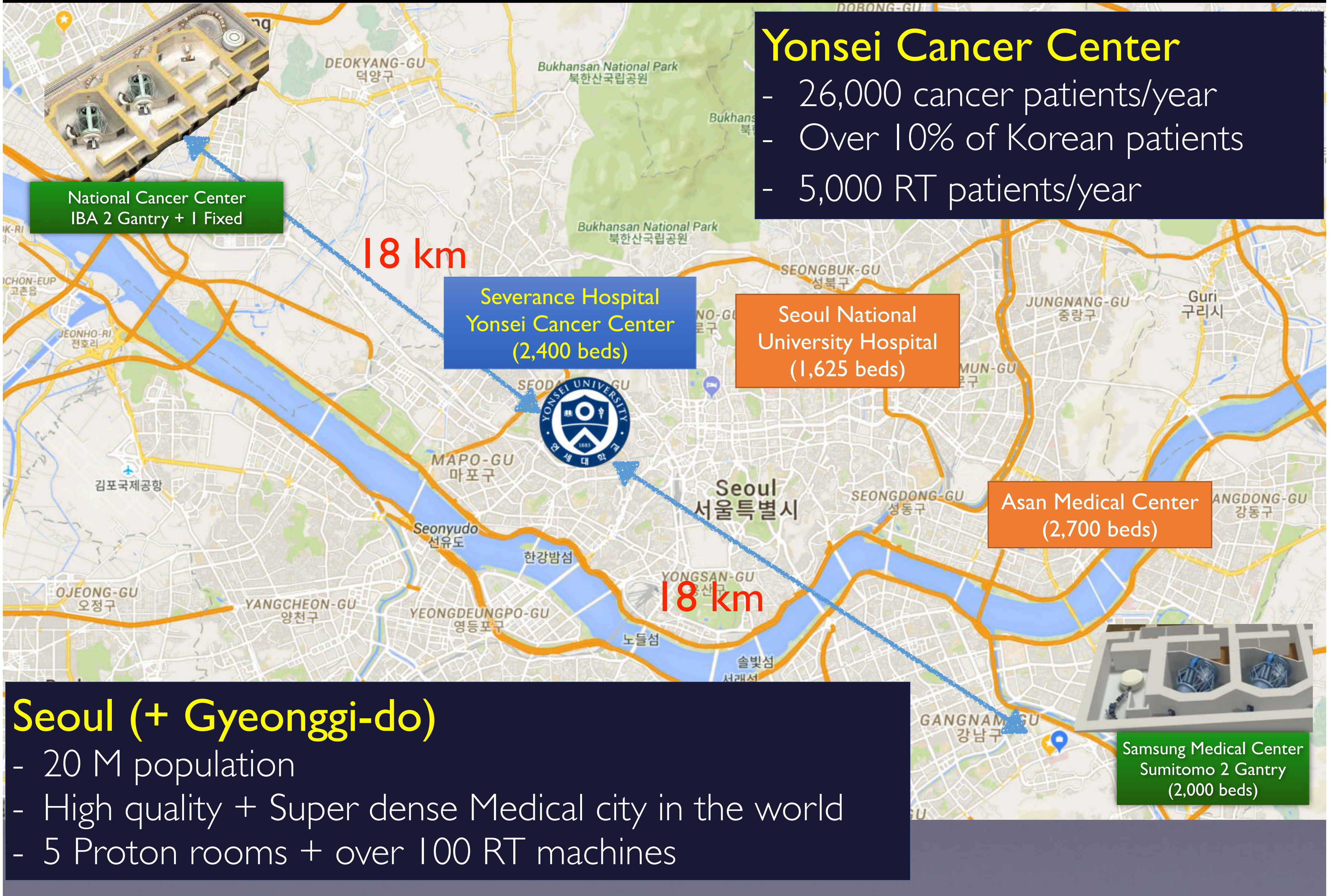
Background Projections of future mortality and life expectancy are needed to plan for health and social services and pensions. Our aim was to forecast national age-specific mortality and life expectancy using an approach that takes into account the uncertainty related to the choice of forecasting model.

Lancet 2017; 389: 1323–35
Published Online
February 21, 2017
http://dx.doi.org/10.1016/

Korea
- 50 M population
- 200,000 cancer patients/year
- Live longer than others @ 2030



Another Understanding for Seoul !



Yonsei Cancer Center
- 26,000 cancer patients/year
- Over 10% of Korean patients
- 5,000 RT patients/year

Seoul (+ Gyeonggi-do)
- 20 M population
- High quality + Super dense Medical city in the world
- 5 Proton rooms + over 100 RT machines

Yonsei; Pioneer of Radiation Oncology in Korea

First Radiotherapy in Korea (1922) ; Dr. Hopkirk, Severance Hospital

Surgical Case Reports. 145

SURGICAL CASE REPORTS; (1) SPINDLE-CELL SARCOMA OF THE NECK; (2) CONGENITAL PAPILLOMA OF BUTTOCK *

A. I. LUDLOW, M.D., F. A. C. S., Seoul, Chosen (Korea).

SPINDLE-CELL SARCOMA OF THE NECK.

China Medical Journal 1923

On waiting for a ship to tape them to Europe, 関東大震災 struck Tokyo (1923). My father helped as many people as he could! After helping to clean up the affected area, the family got on a cruiser and headed to Europe

First Introductions of New Technologies in Korea

LINAC (1972)

HDR Brachytherapy (1979)

TBI (1983)

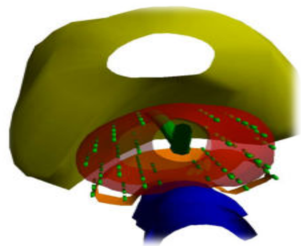
Hyperthermia (1984)

IORT (1986)

LINAC-based RS (1988)

3DCRT (1996)

Eye plaque with Ru (2006)



LDR Brachy (2012)

History of Yonsei Cancer Center

Yonsei Cancer Center 1969

<Korea’s first independent Cancer Special Center>

1969. 11. 10

2 above ground floors, 1 basement floors

Yonsei Cancer Center

1969~2014

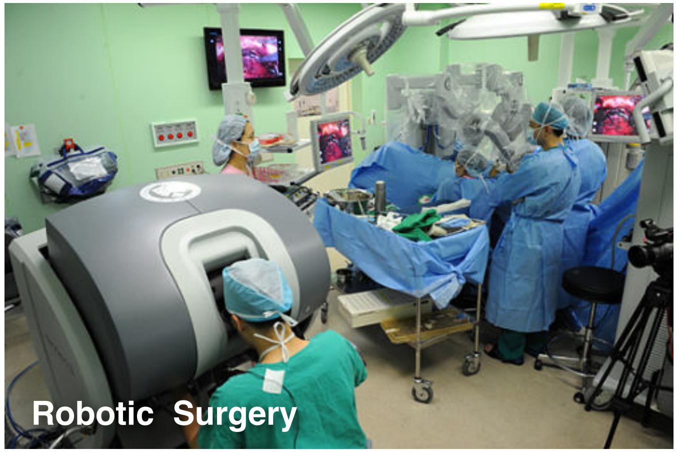
Yonsei Cancer Center 2014

2014. 4. 14

15 above ground floors, 7 basement floors, 508 beds

Portfolio to conquer the cancer of Yonsei Cancer Center


High Precision Radiotherapy


Robotic Surgery


Multidisciplinary team approach

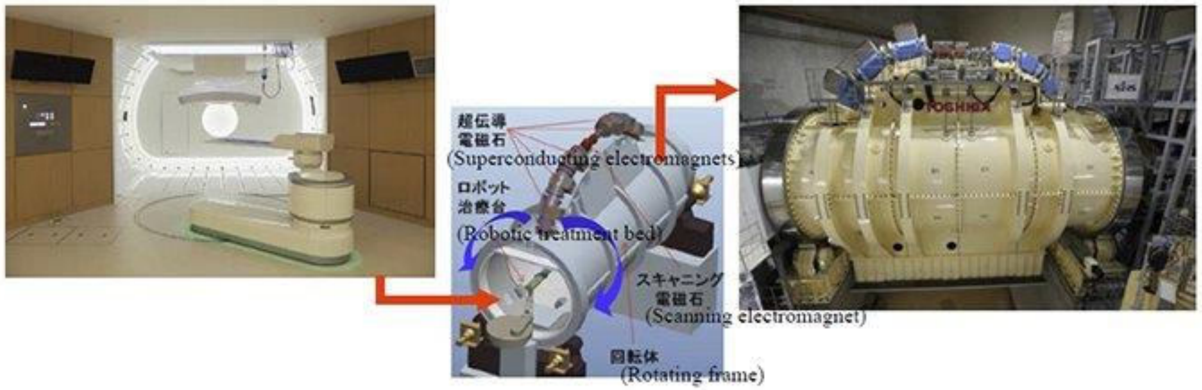
New Patient Experience

Palliative care

Institute for Personalized Cancer Therapy

Cancer Prevention Center

Carbon Ion Therapy



Yonsei RadOnc Tx options

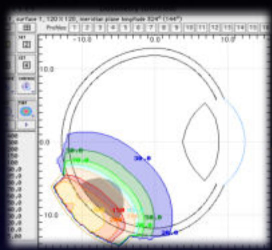
2020.06

400 patients/day (IMRT 80%)

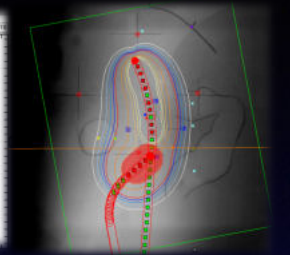
Infinity | VersaHD | Tomotherapy | R-IMRT

IMRT, VMAT	IMRT, VMAT VMAT using FFF	Helical Tomotherapy with Dynamic Jaw	Cone IMRT with MLC
2D XVI, CBCT 4D CBCT	2D XVI, CBCT 4D CBCT	MVCT	2D X-ray Realtime tracking

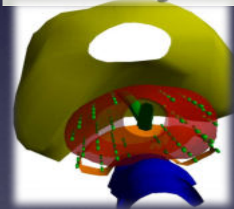
Brachytherapy



Eye plaque (Ru_{106})



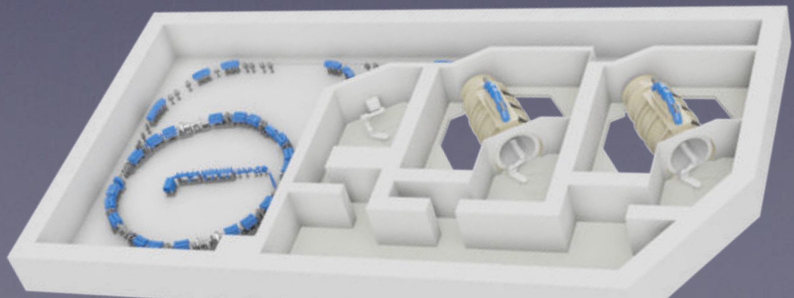
HDR Cervix (Co_{60})



LDR Prostate
with stranded seed
(I_{125})

Hyperthermia Therapy

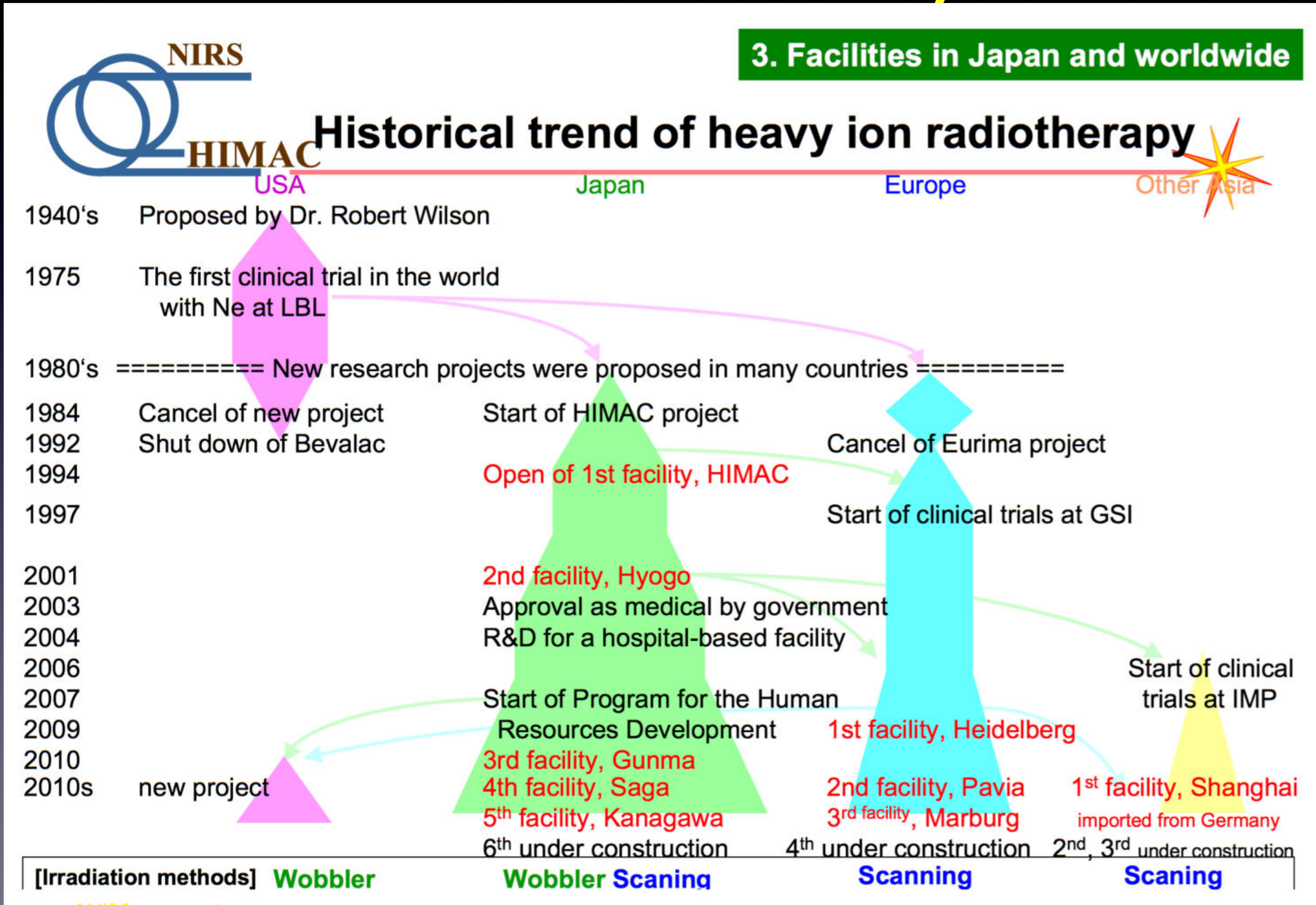
EHY-2000



Carbon Ion Therapy Center in World

Advanced Tech in Carbon

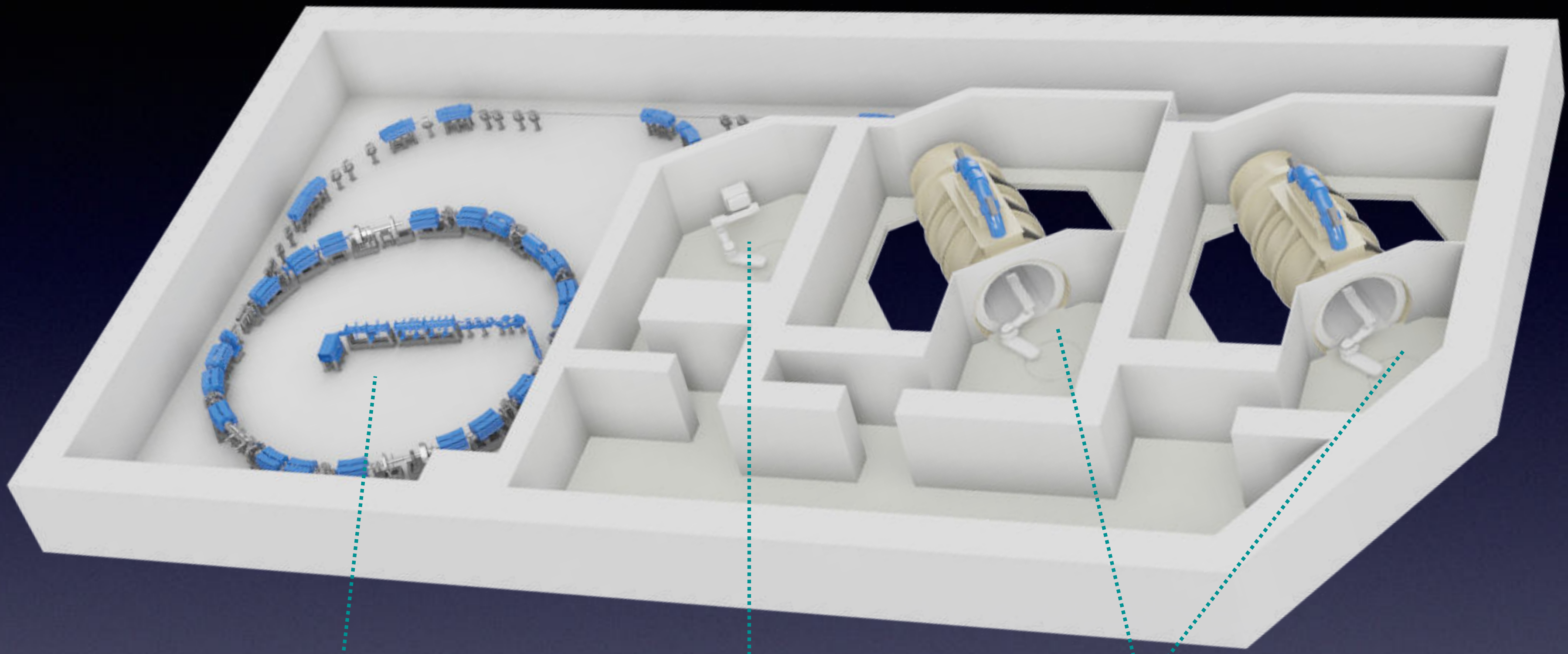
Carbon's History



Courtesy of NIRS presentation

	Site	Start	Tx Room			Vendor	Scat	Scan	Pts.No (~2015)
			Tot	Fixed Room	Gantry				
운영중	HIMAC(NIRS)	1994	3	2(H+V)	1G*	Japan	O	OO	10,486
	HIBMC	2002	2	1H , 1(45)		Mitsubishi	O	X	2,366
	Lanzhou	2006	1	1H		China	O	X	213
	Gunma	2010	3	1H, 1H+V, 1V		Mitsubishi	O	X	1,909
	HIT	2012	3	2H	1G	Siemens	O	O	2,086
	CNAO	2012	4	3H, 1H		Siemens	X	O	591
	SAGA-HIMAT	2013	3	2(H+V),1(45+H)		Mitsubishi	O	X	1,136
	Shanghai	2014	3	3H		Siemens		O	149
	i-Rock	2015	4	2H, 2(H+V)		Toshiba		OO	-
	MIT	2015	4	3H, 1(45)		Siemens		O	-
건설중	Wuwei	2017	4	4 (H+V+45)		China	O	O	-
	MedAustron	2017	2	1H, 1(H+V)		CERN	X	O	-
	Osaka	2019	3	3		Hitachi	X	OO	-
	Yamagata	2020	2	1H+V	1G	Toshiba	X	OO	-
	Yonsei	**2022**	**3**	**1H**	**2G**	**Toshiba**	**X**	**OO**	
계획	Taiwan	2023	3	H+45+V, 45+V, H		Hitachi	X	O	-
	SNUH	2024	2	1H	1G	Toshiba?	X	OO	-
	Mayo	2024?	2	1H	1G	Hitachi?	X	OO	-

Yonsei Carbon ion Therapy Center



Accelerator system

·Advanced Operation
(Extended flat-top operation)

·Ion Beam Injector
·Synchrotron
·Beam Transport Line

Fixed Beam Treatment Room

360° Rotating Gantry Rooms

1 Fixed

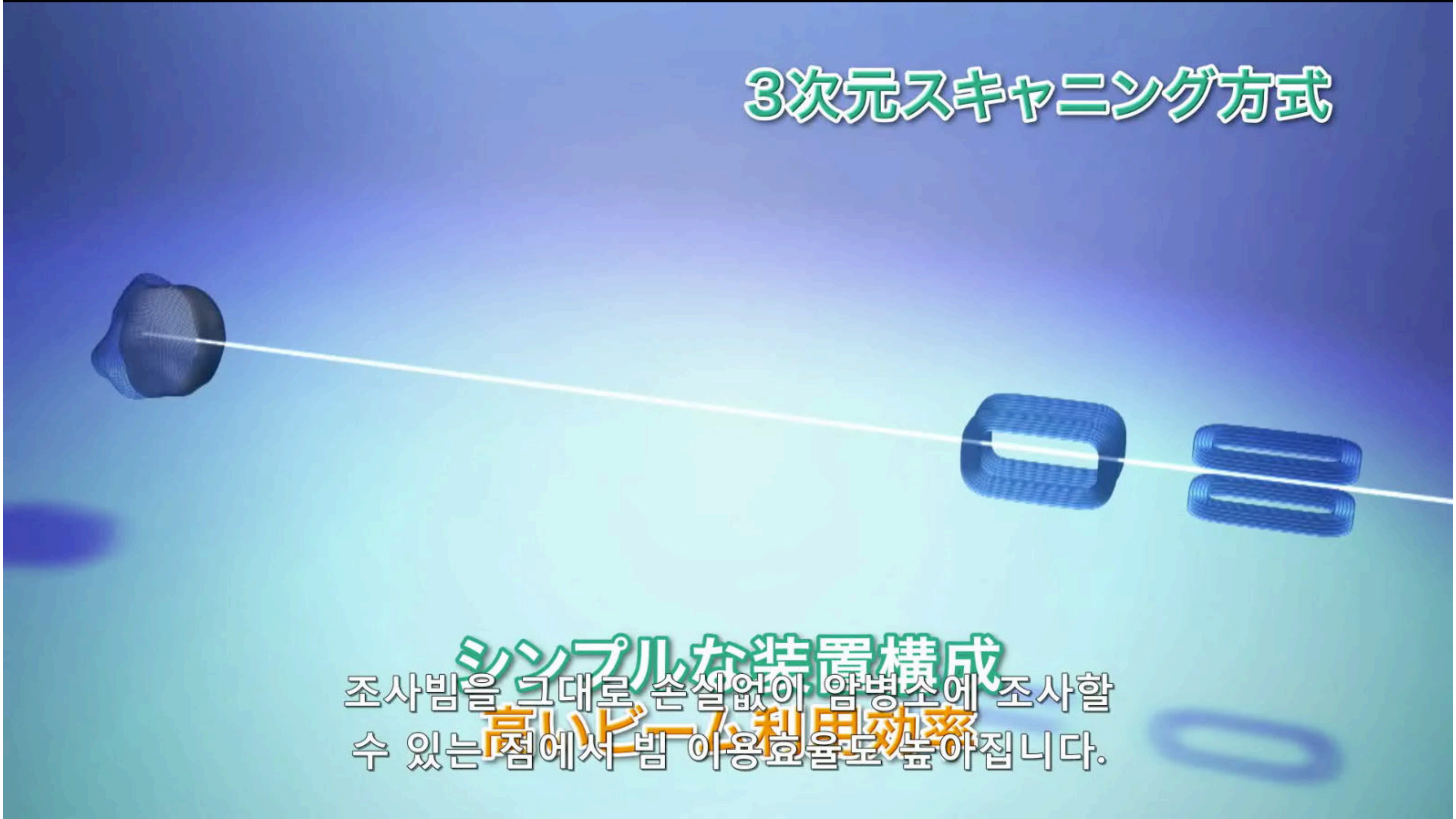
·Automated patient positioning
·3D high-speed scanning
·Respiratory-gated irradiation

2 Gantry

·Horizontal/
vertical irradiation ports

·Compact gantry
by superconducting magnets

Advanced Carbon ion therapy Technology



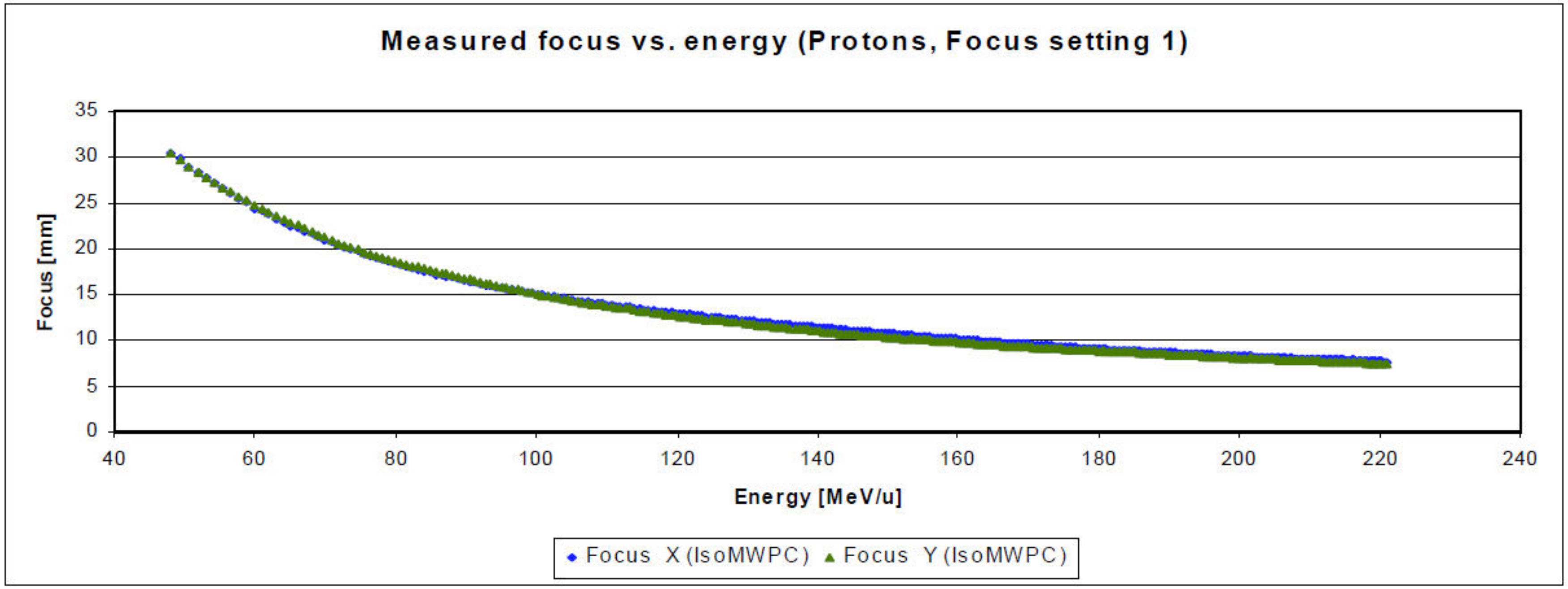
Advanced Carbon Scanning System

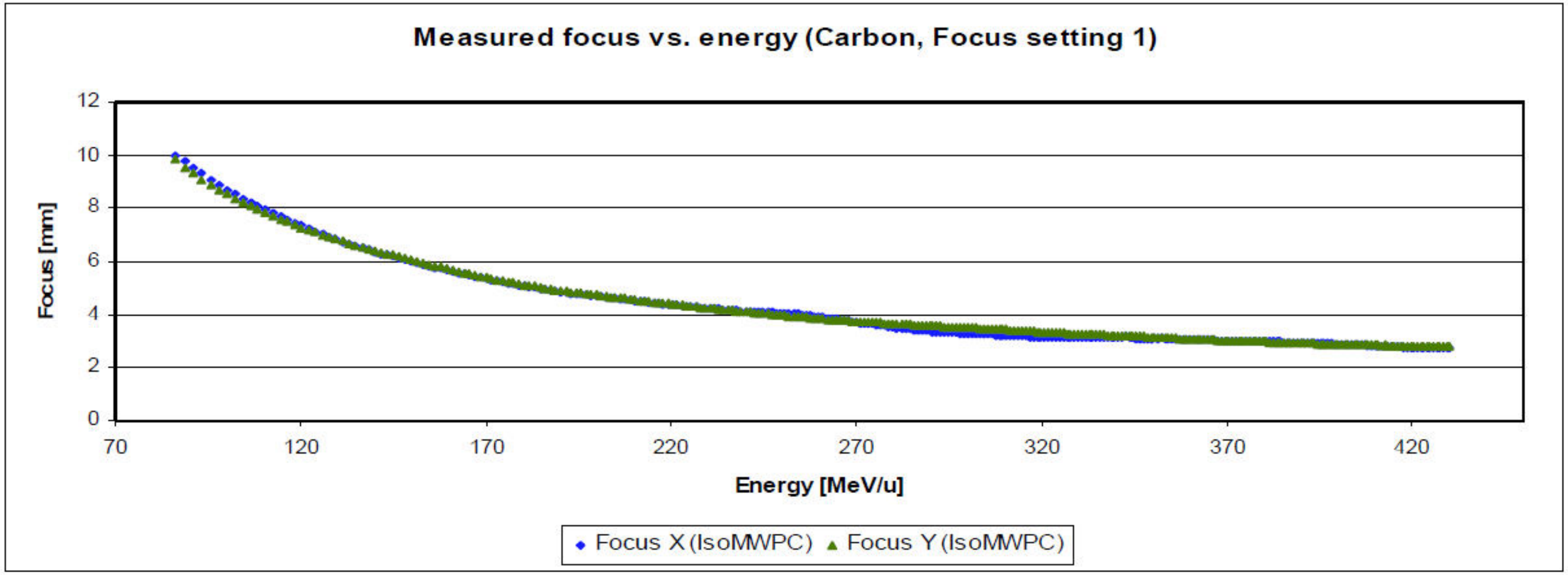
- Small spot size + large field size
- Fast X-Y Scanning speed (rescanning)
- Fast energy switching time
- No. of Energy level without ridge filter
- Rescanning+Gating without fiducial marker
- Automated Integrated QA system

These specs
should be integrated
+
We would like to have
Already proven &
Most advance tech

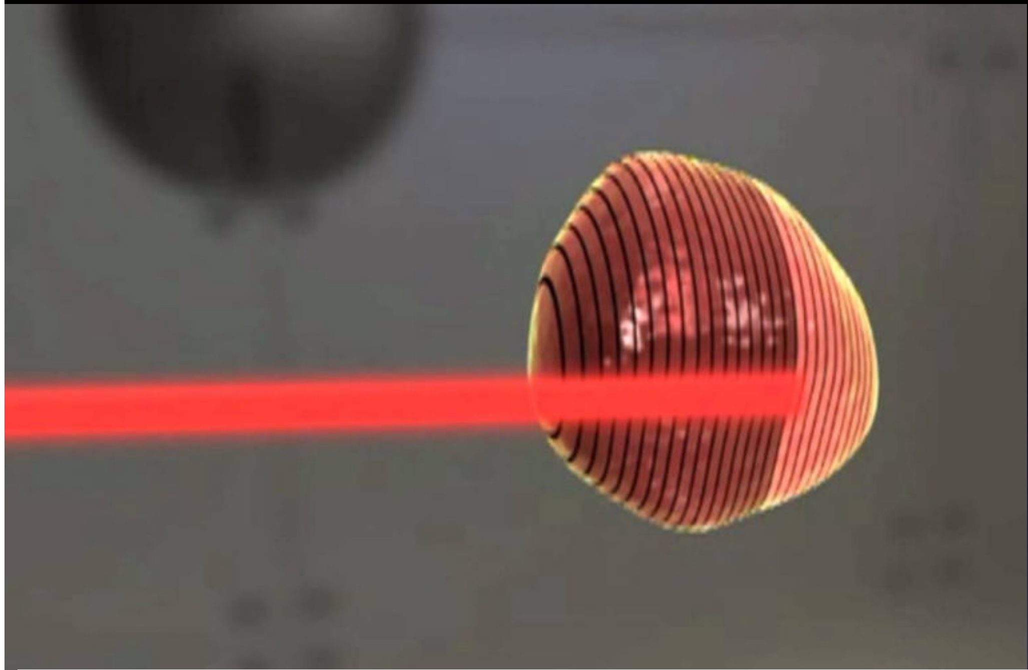
- I need another 2 hours to explain this comparison!
- Vendors offered own techniques based on their experience
  - We need time to understand our vendors before big decision!
- However we prefer Toshiba for our Carbon ion project at 2018

Particle's spot size, penumbra





How many E layer we need for carbon?

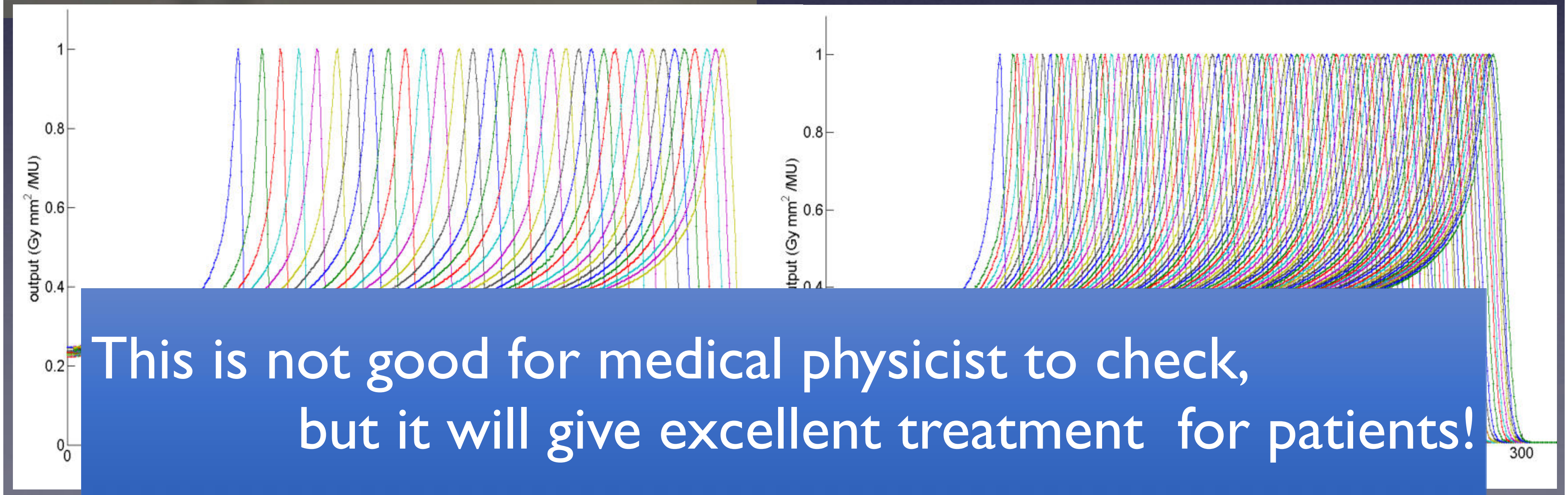


We can have…

1. 11E with Ridge shifter
2. 100 E (2-3mm step)
3. 600 E (0.5mm step)

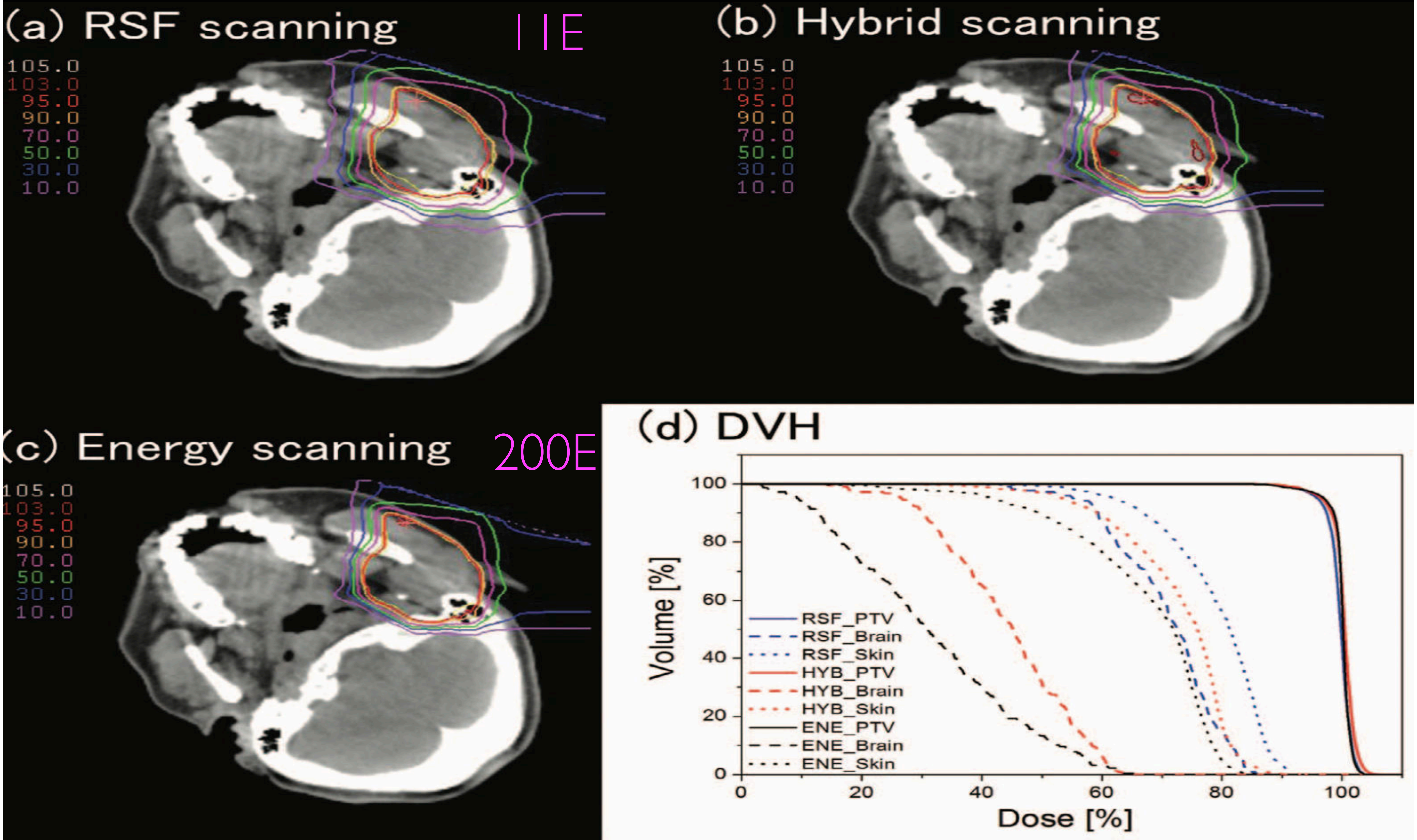
More Important for shallow depth !!!

Need to cover from **0 cm** to 30 cm



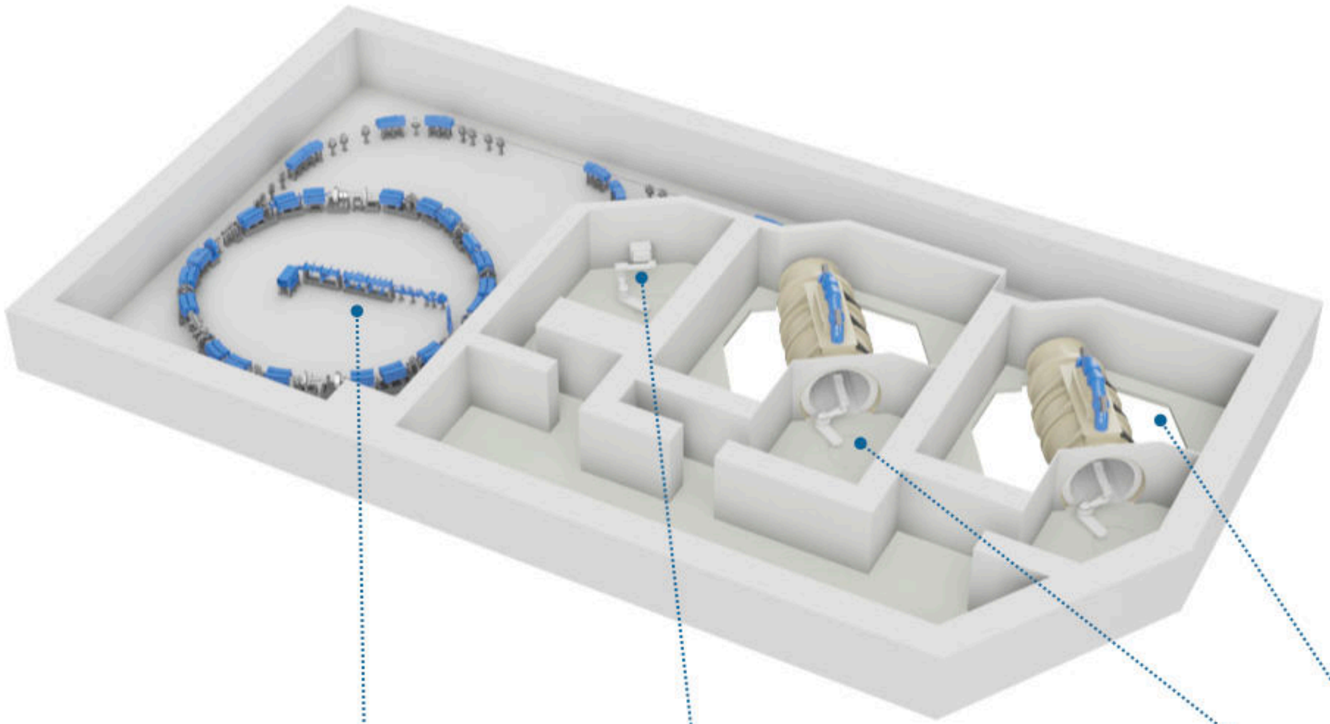
This is not good for medical physicist to check,
but it will give excellent treatment for patients!

How many E layer we need for carbon?



Noda, Koji. "Beam delivery method for carbon-ion radiotherapy with the heavy-ion medical accelerator in Chiba." *International Journal of Particle Therapy* 2.4 (2016): 481-489.

Final decision



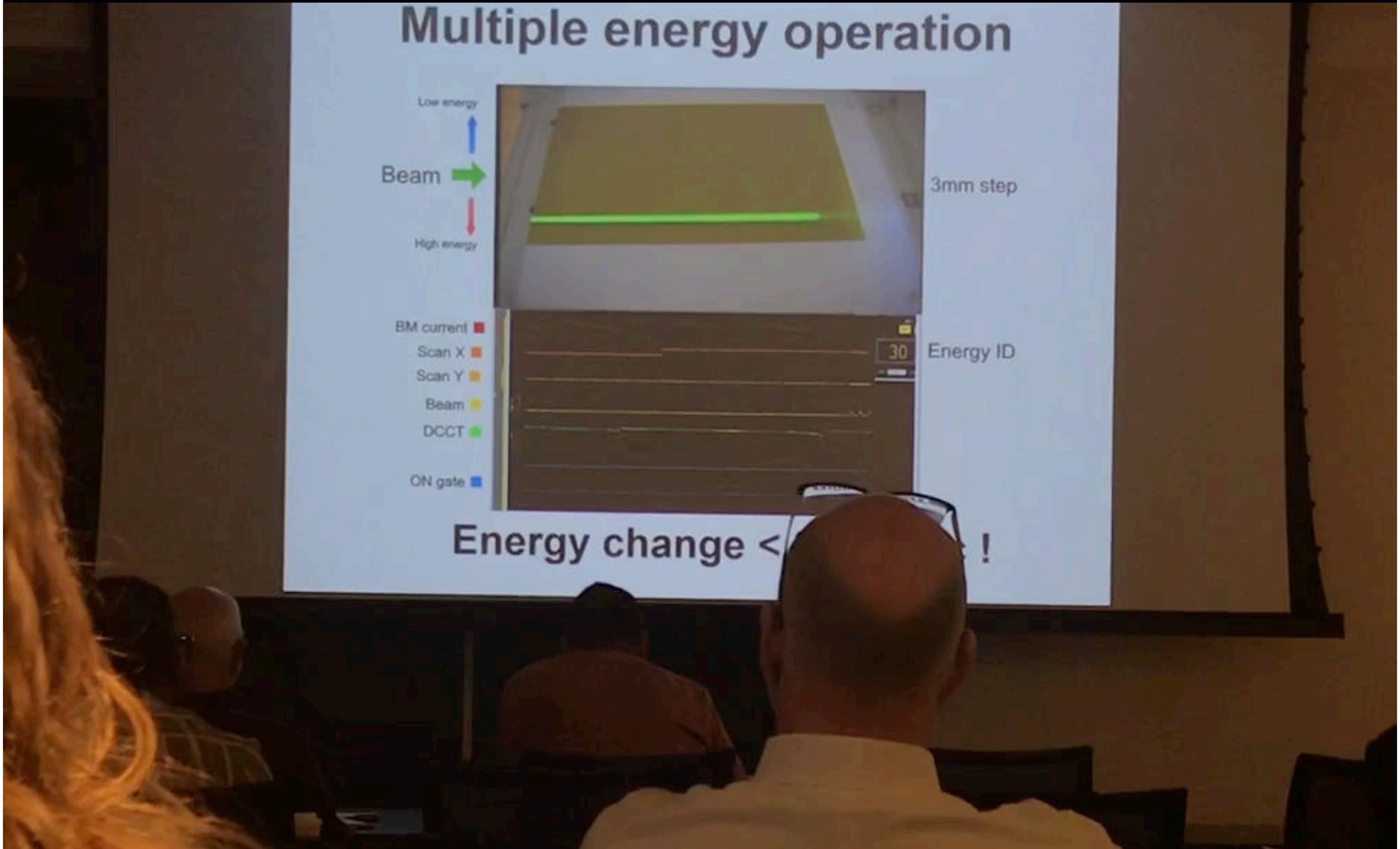
- Carbon only
  - 56 - 430 MeV/u
  - 600 energy level
  - E switching time: 200 ms
- 20 x 20 cm field size
- Spot size
  - Less than 4.0 mm (1sigma)
- 6D robotic couch
- KV imaging alignment
  - <1 mm accuracy

Accelerator system	Fixed Beam Treatment Room	Two 360° Rotating Gantry Rooms
·Advanced Operation (Extended flat-top operation)	·Automated patient positioning ·3D high-speed scanning ·Respiratory-gated irradiation	
·Ion Beam Injector ·Synchrotron ·Beam Transport Line	·Horizontal irradiation ports	·Compact gantry by superconducting magnets

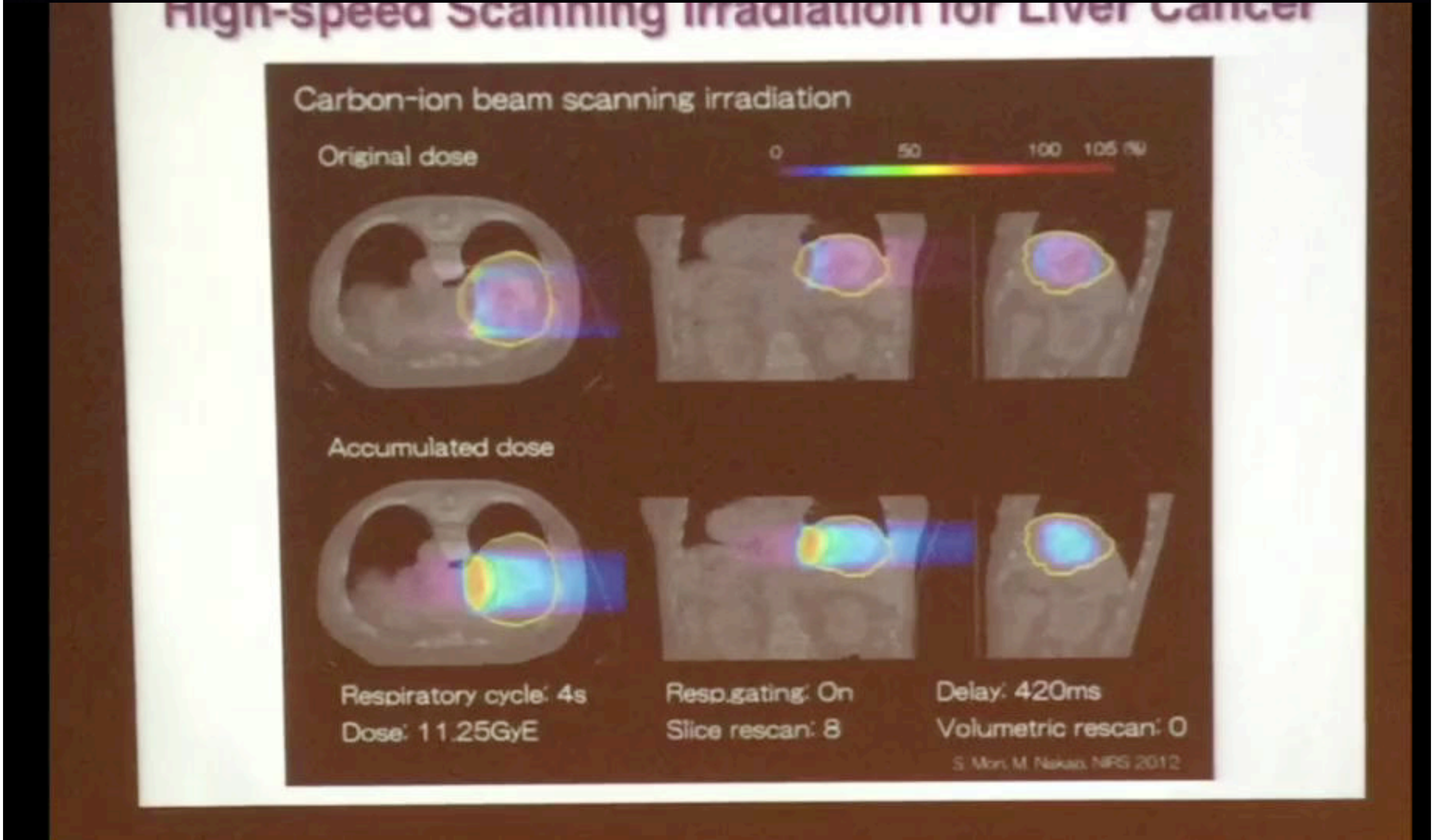
Key specifications

	Item	Specification
1	No of Tx Room	2 Superconducting Gantry + 1 Fixed
2	Accelerator	Synchrotron
3	Ion Species [Max E]	Carbon [430 MeV/u]
4	Field Size	20 cm x 20 cm at isocenter
5	Range (Max, Min)	30 g/cm^2, 4 g/cm^2
6	E switching Time	0.3 sec using Multi Energy Extraction
7	Image guidance	2D X-ray, Real-time monitoring, (InRoom CT)
8	Respiratory Tx system	Rescanning with gating system with/without makers
9	Scanning speed	Fast 3D scanning (over 100 m/s)

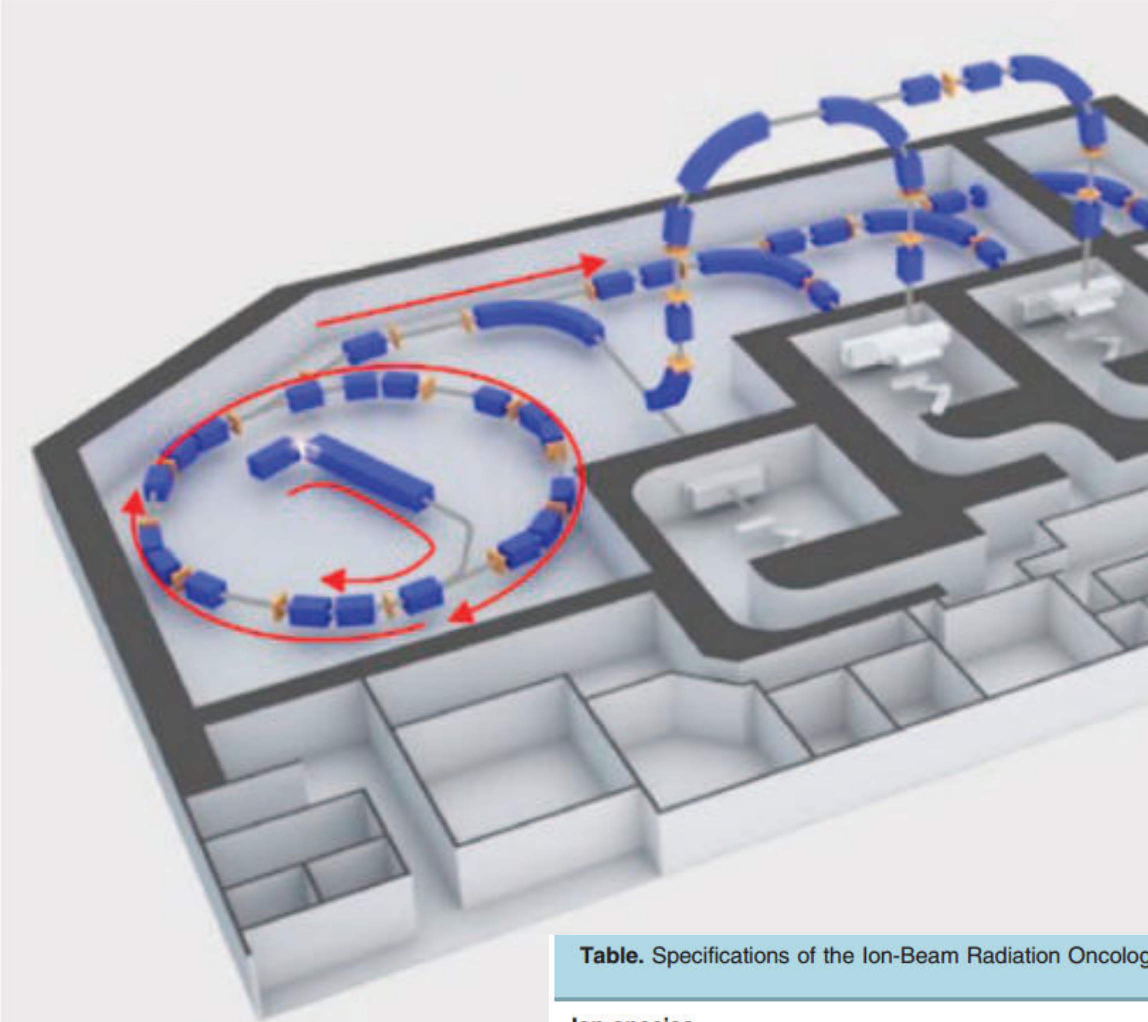
Energy switching (with 600 Energy)



Rescanning, Gating without markers



Do we need a carbon gantry?



If you don't have gantry,

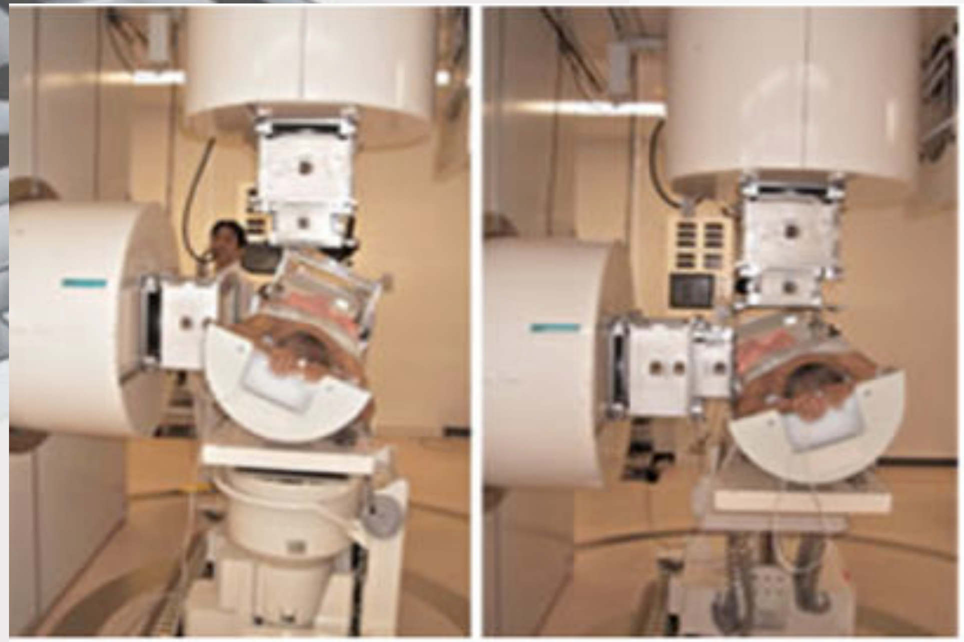


Table. Specifications of the Ion-Beam Radiation Oncology Center in Kanagawa.

Ion species	**Carbon ion**
Maximum energy	430 MeV/u; Residual range > 25 cm in water
Range control	0.2 mm step; fine-range shifters with multistep variable energy
Beam delivery	3-dimensional pencil beam fast scanning
	Irradiation field; 200 × 200 mm
Number of treatment rooms	4 rooms with fixed beam port; 2 with horizontal and vertical beam ports, 2 with horizontal beam port
Treatment couch	Robotic couch with 7 degrees of freedom
Patient positioning	Orthogonal x-ray flat panel detector imaging system
	Rail-on in-room computed tomography

Gantry

- Do we really need a Gantry for Carbon?

Technological Advances

International Journal of Radiation Oncology biology • physics

www.redjournal.org

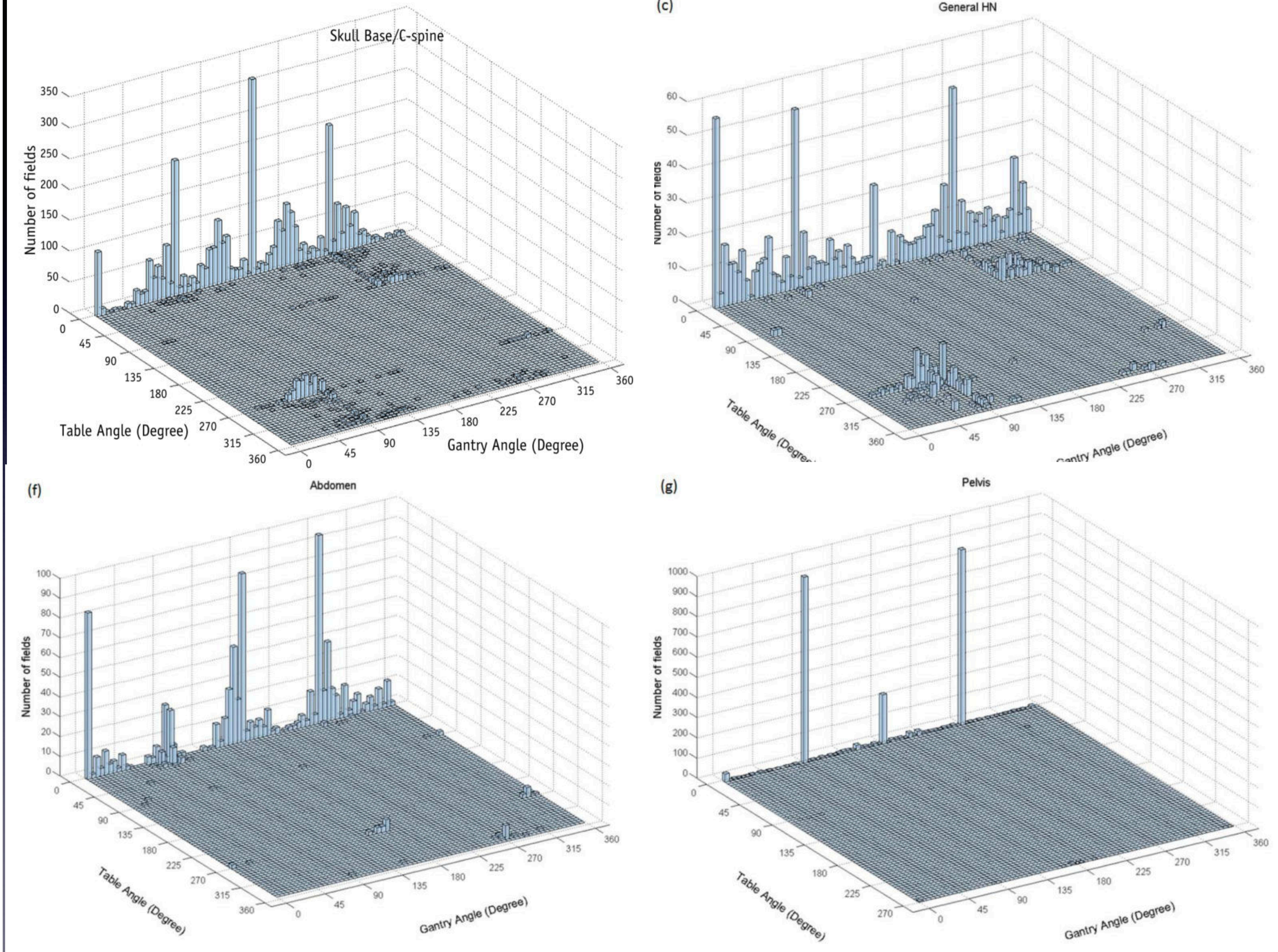
Reassessment of the Necessity of the Proton Gantry: Analysis of Beam Orientations From 4332 Treatments at the Massachusetts General Hospital Proton Center Over the Past 10 Years

Susu Yan, PhD, Hsiao-Ming Lu, PhD, Jay Flanz, PhD, Judith Adams, CMD, Alexei Trofimov, PhD, and Thomas Bortfeld, PhD

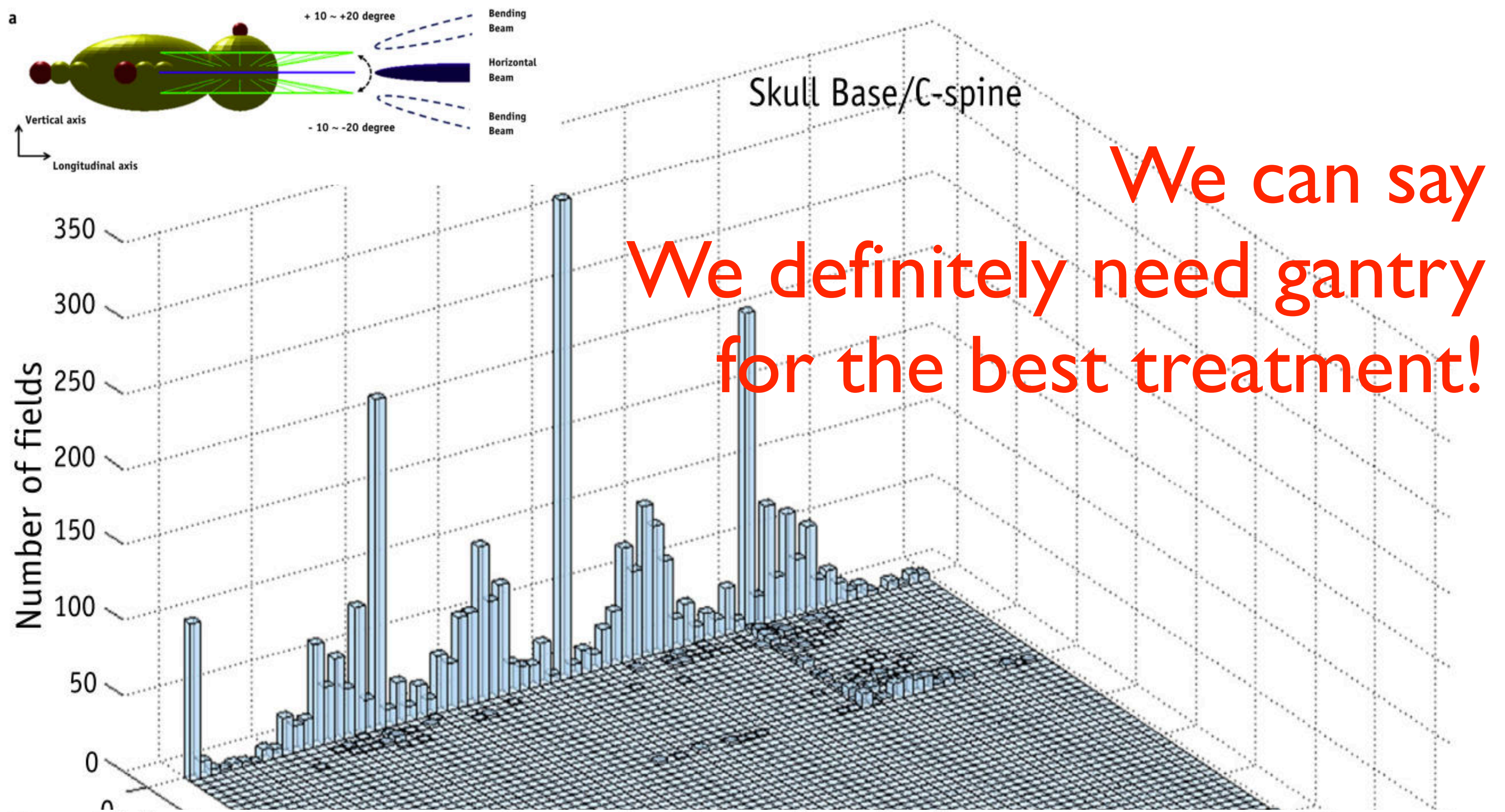
Department of Radiation Oncology, Massachusetts General Hospital, Boston, Massachusetts

Received Feb 9, 2015, and in revised form Aug 14, 2015. Accepted for publication Sep 21, 2015.

Conclusions: The majority of practical beam approaches can be realized with gantry-less delivery, aided by limited beam bending and patient movements. Practical limitations of the MOVE geometry, and treatments requiring a combination of lying and sitting positions, may lower the percentage of head and neck patients who could be treated without a gantry. Further investigation into planning, immobilization, and imaging is needed to remove the practical limitations and to facilitate proton treatment without a gantry.

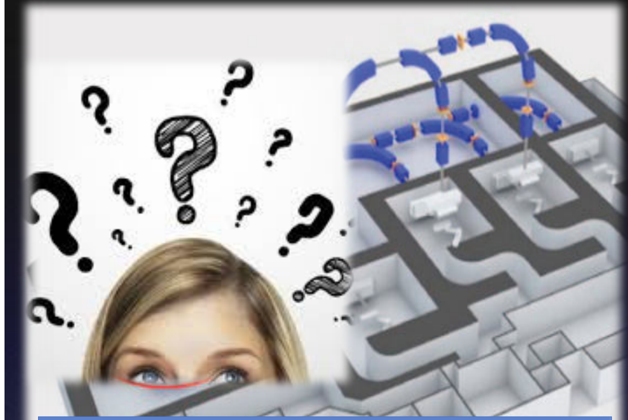


Skull Base/C-spine
Number of fields
Table Angle (Degree)
Gantry Angle (Degree)
(c)
General HN
Number of fields
Table Angle (Degree)
Gantry Angle (Degree)
(f)
Abdomen
Number of fields
Table Angle (Degree)
Gantry Angle (Degree)
(g)
Pelvis
Number of fields
Table Angle (Degree)
Gantry Angle (Degree)



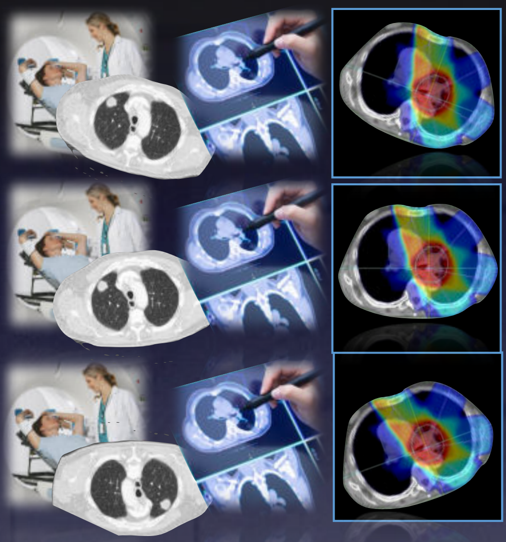
Conclusions: The majority of practical beam approaches can be realized with gantry-less delivery, aided by limited beam bending and patient movements. Practical limitations of the MOVE geometry, and treatments requiring a combination of lying and sitting positions, may lower the percentage of head and neck patients who could be treated without a gantry. Further investigation into planning, immobilization, and imaging is needed to remove the practical limitations and to facilitate proton treatment without a gantry.

If you don't have a Gantry,

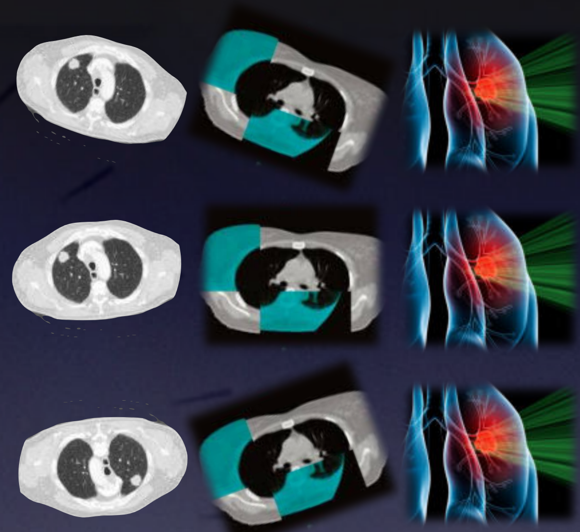


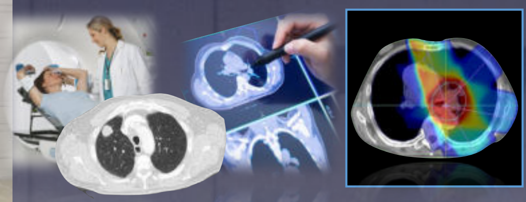
We need to think about the plan for the angle before CT simulation!

CT | Contour | Plan | | Setup | IGRT | Beam!!

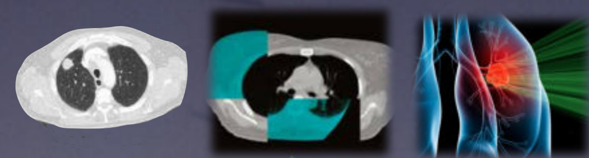


SFUD
Summation
+
Confirm
-
Difficult
to make
IMCT plan





Simple
Workflow
with IMCT



Gantry can make everyone happy!

- Doctors, Physicist, Dosimetrist, RTT, Nurse and Patient!!!!
- Even hospital !!!! to get high patients number!

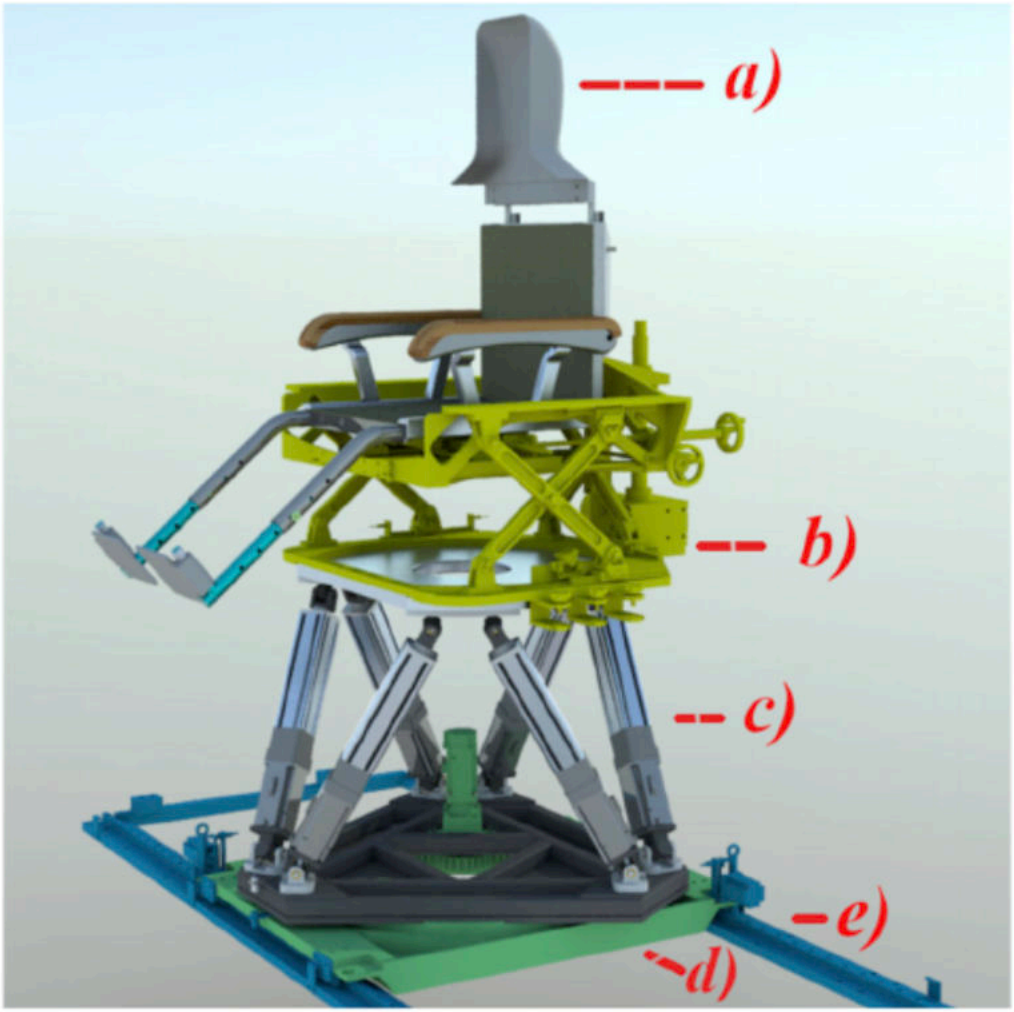
MEDICAL PHYSICS
The International Journal of Medical Physics Research and Practice

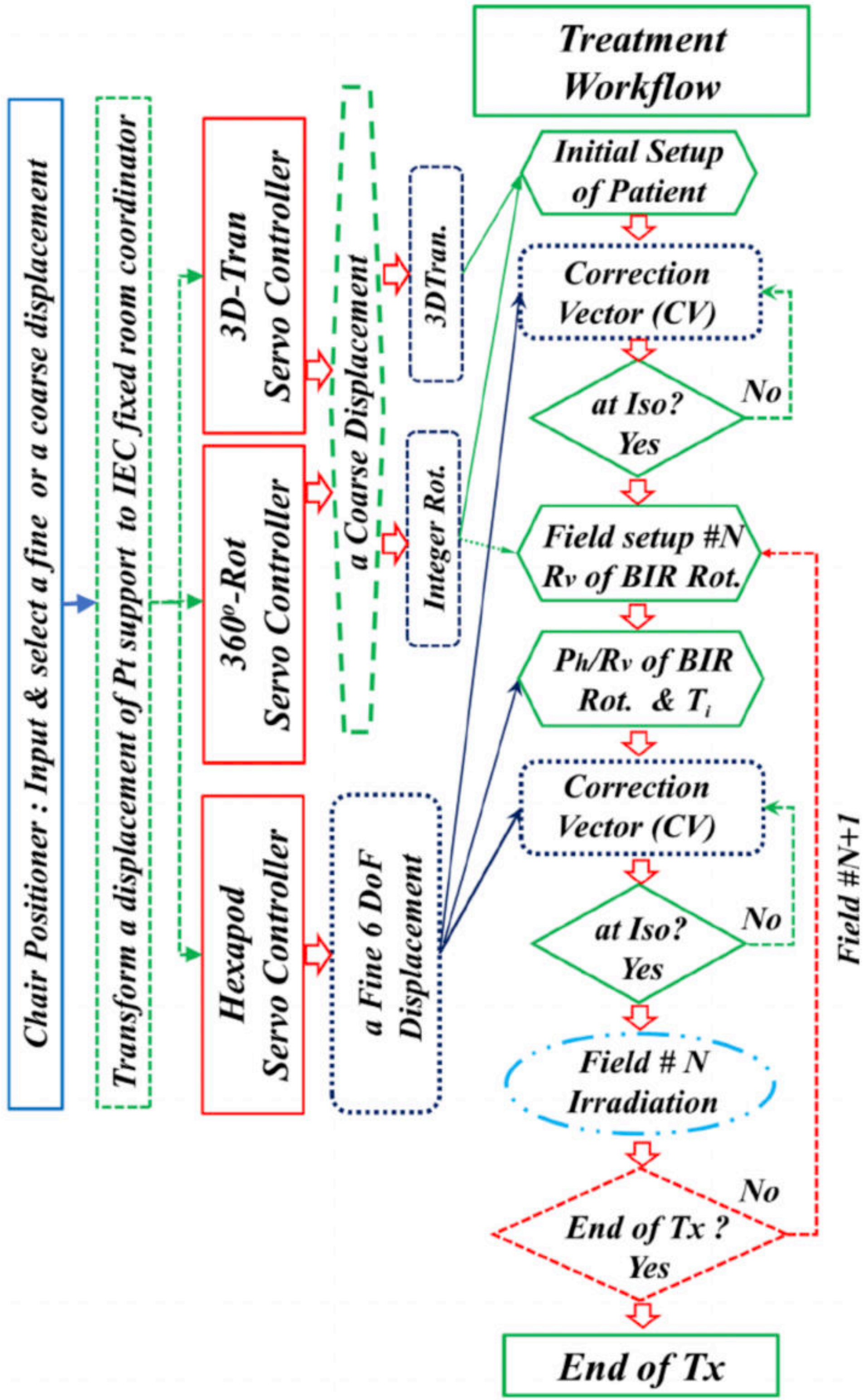
Research Article | Free Access

Development of an isocentric rotating chair positioner to treat patients of head and neck cancer at upright seated position with multiple nonplanar fields in a fixed carbon-ion beamline

Xiang Zhang, Wen Chien Hsi, Feng Yang, Zhonghai Wang, Yinxiangzi Sheng, Jiayao Sun, Chaowen Yang, Rong Zhou ... See fewer authors

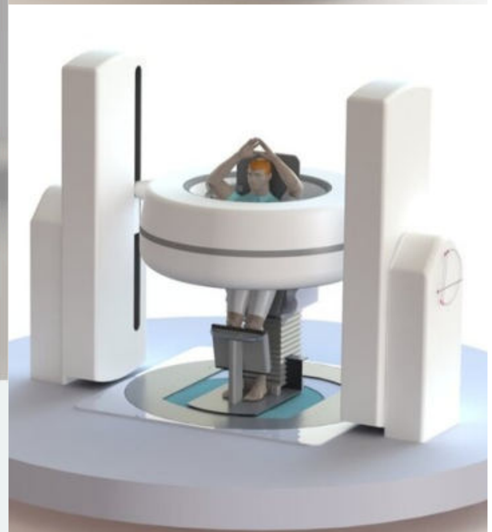
First published:05 March 2020 | https://doi.org/10.1002/mp.14115





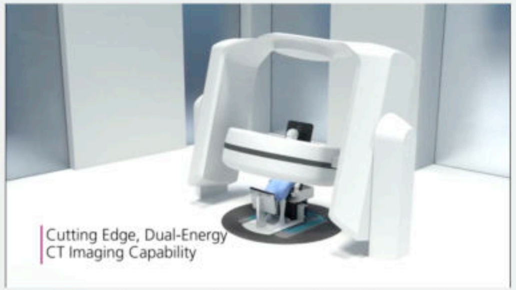
LEO
Cancer Care

HOME PRODUCTS CLINICAL TEAM HISTORY NEWS CAREERS CONTACT

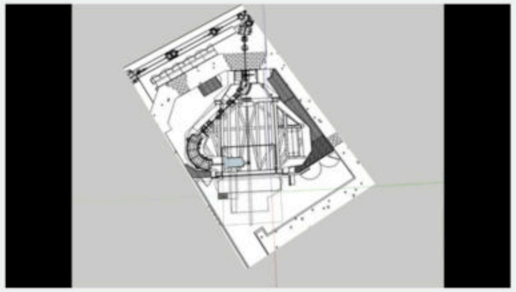


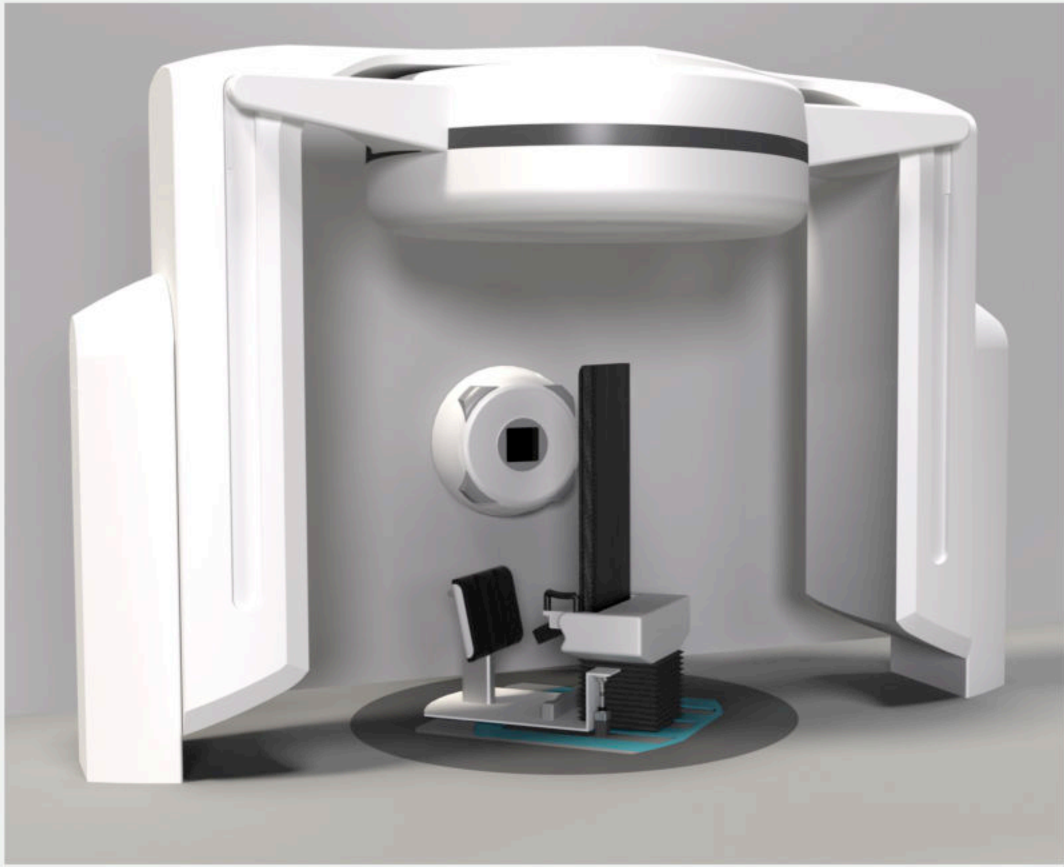
IT'S TIME TO STOP FACING CANCER LYING DOWN

Video Gallery



This video shows the flexibility of LEO Cancer Care's family of upright radiotherapy positioning and imaging devices. LEO products enable streamlined and eff...



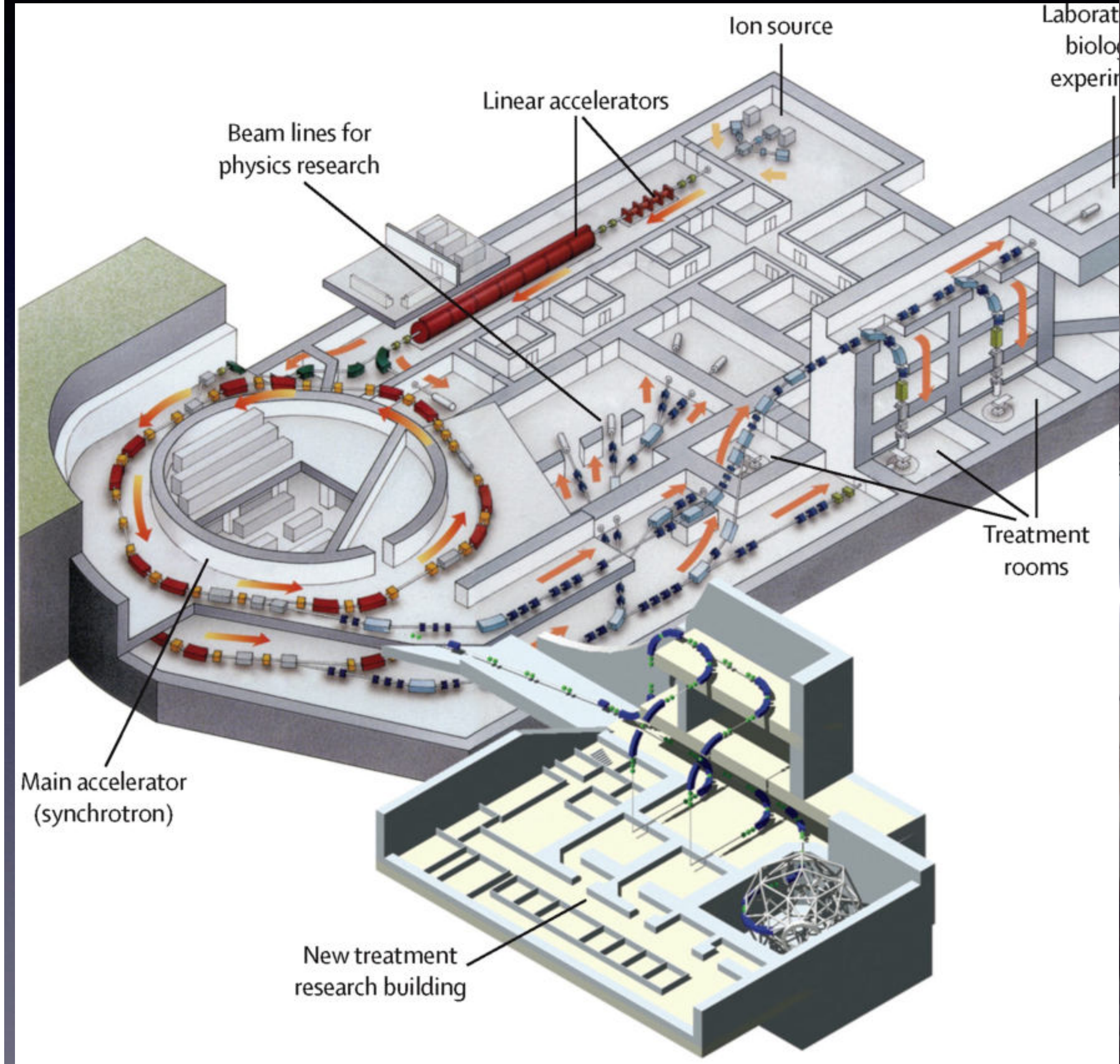


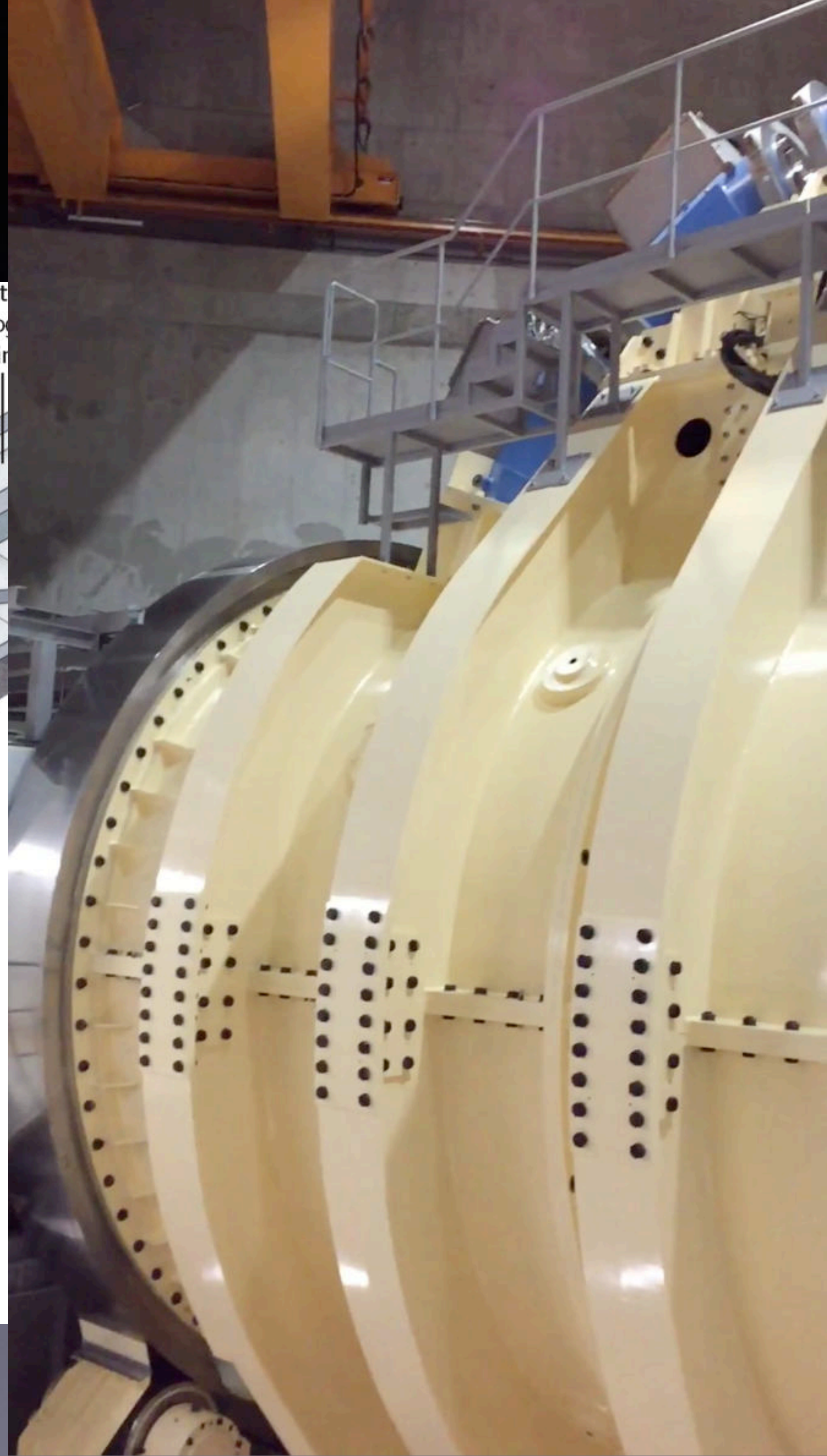
Upright ion beam treatment room

HIT - World 1st Carbon Gantry

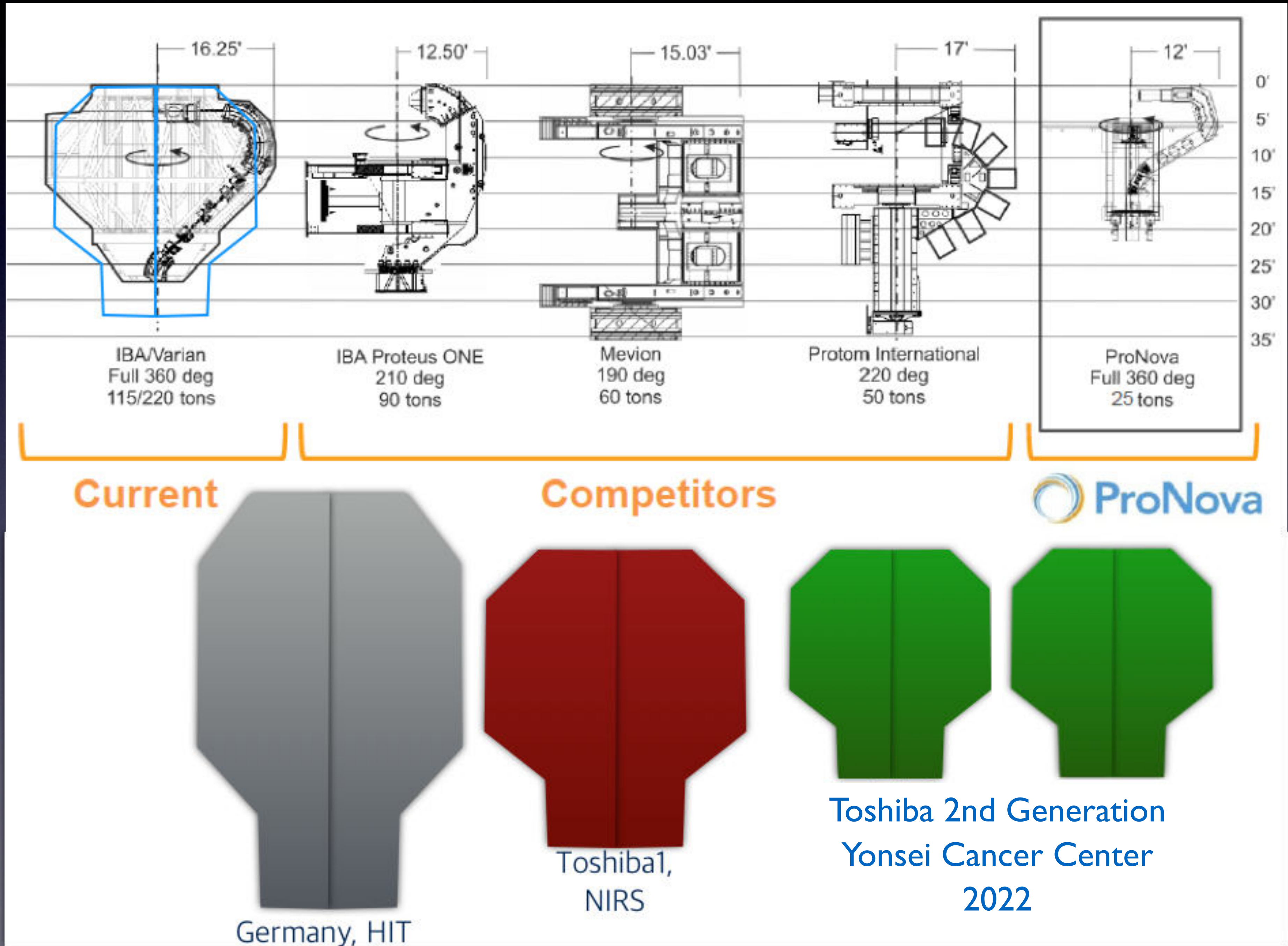
600 ton

NIRS Gantry


Ion source
Linear accelerators
Beam lines for
physics research
Treatment
rooms
Main accelerator
(synchrotron)
New treatment
research building

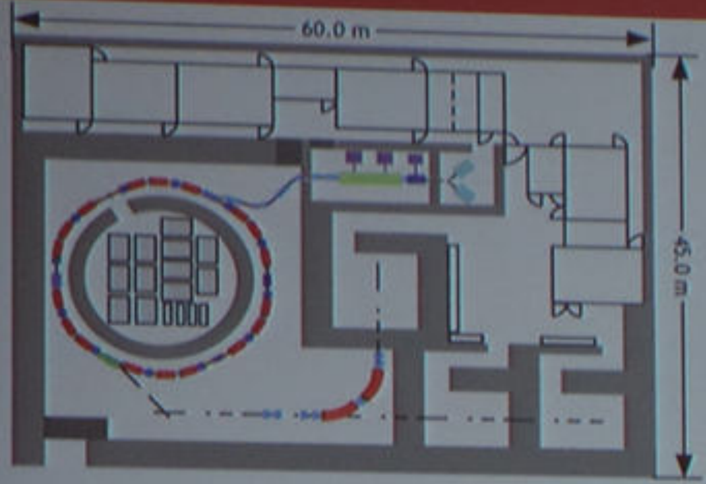


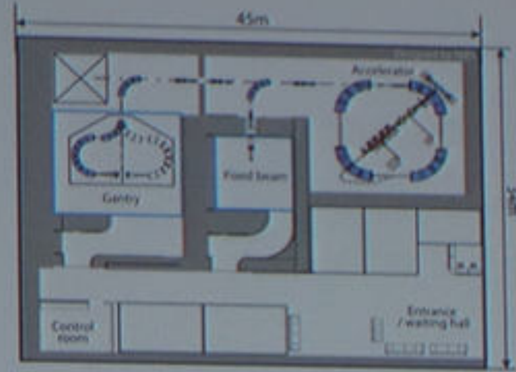
Particle's gantry (proton,carbon)



Next generation's carbon

Future Ion beam Facility R/D Plan





3rd generation

Present
Synchrotron: diameter20m
Foot print: 60m x 45m
Beam delivery:
Fixed port wobbler type
Fixed port scanning
Gantry scanning (SCM:2.9T)

4th generation

Near future
synchrotron: diameter10m
(SCDM synchrotron)
Foot print45m x 34m
Beam delivery:
Fixed port scanning
Gantry scanning (SCM:2.9T)

5th generation

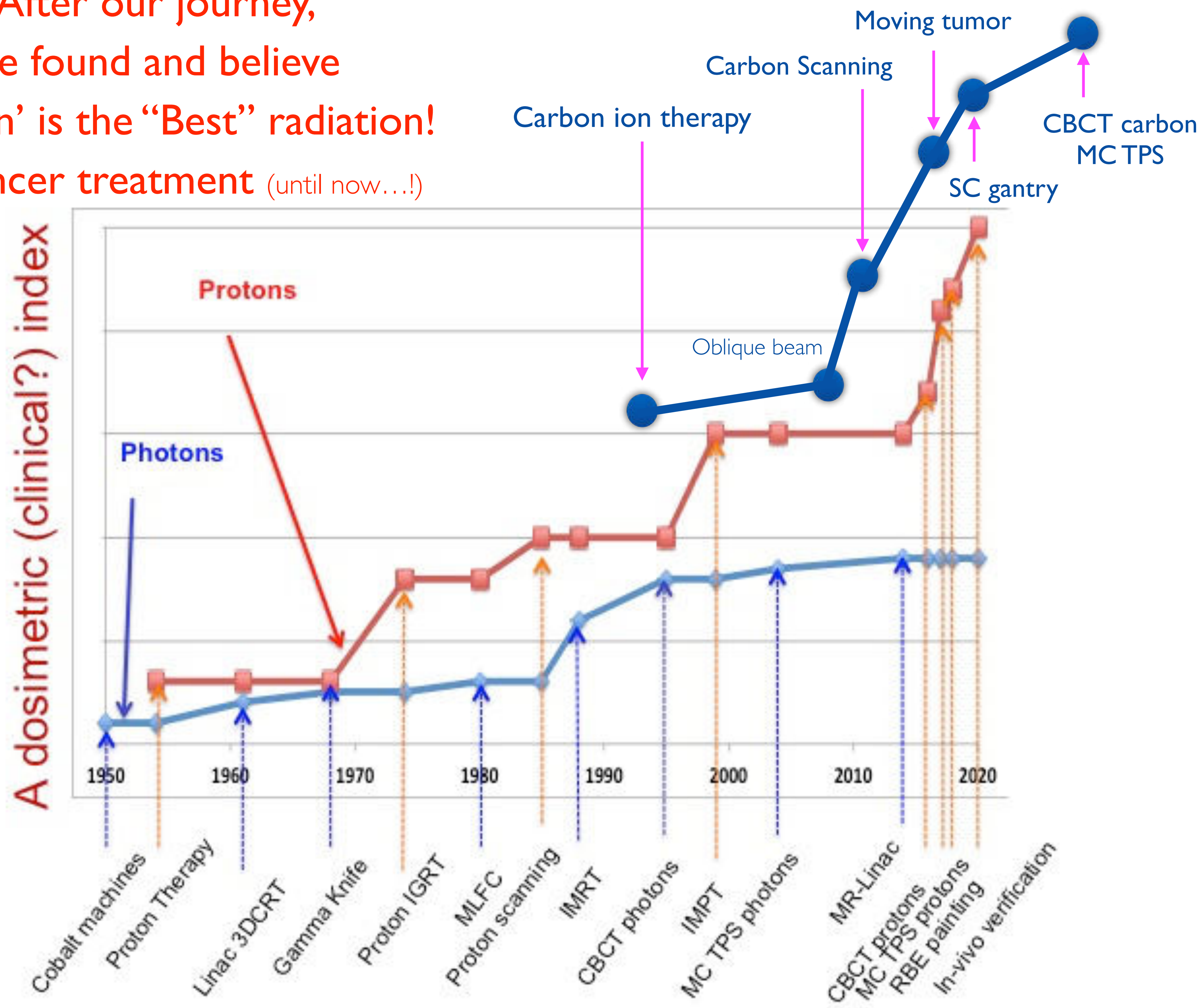
2030~
synchrotron: diameter7m
(HMFSCDM synchrotron)
Injector: length 2m
(Laser acceleration)
Foot print 20m x 10m
(in house installing)
Beam delivery:
Gantry scanning
(HMFSCM: 4T)

SCM : super conducting magnet
HMF : High magnetic field

2030?

http://www.japantimes.co.jp

After our journey,
we found and believe
'Carbon' is the "Best" radiation!
for cancer treatment (until now…!)



Assessment of potential advantages of relevant ions for particle therapy: A model based study

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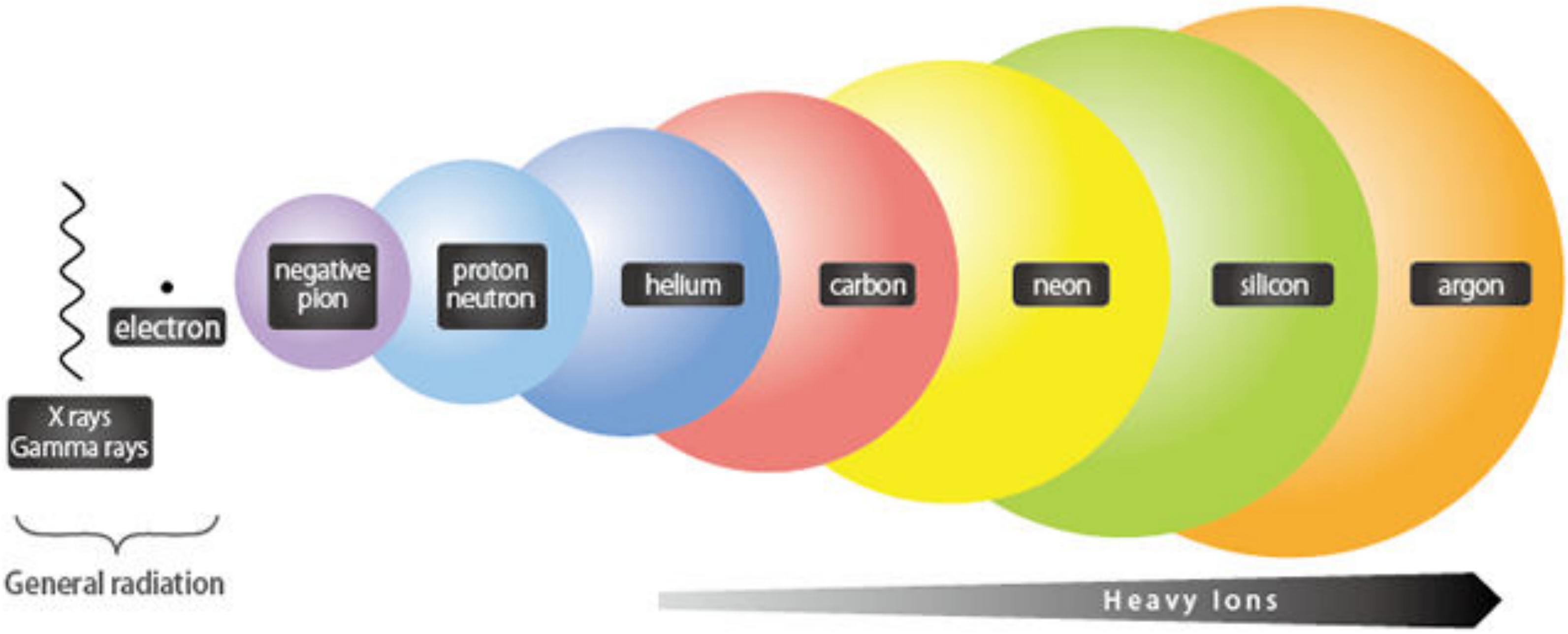
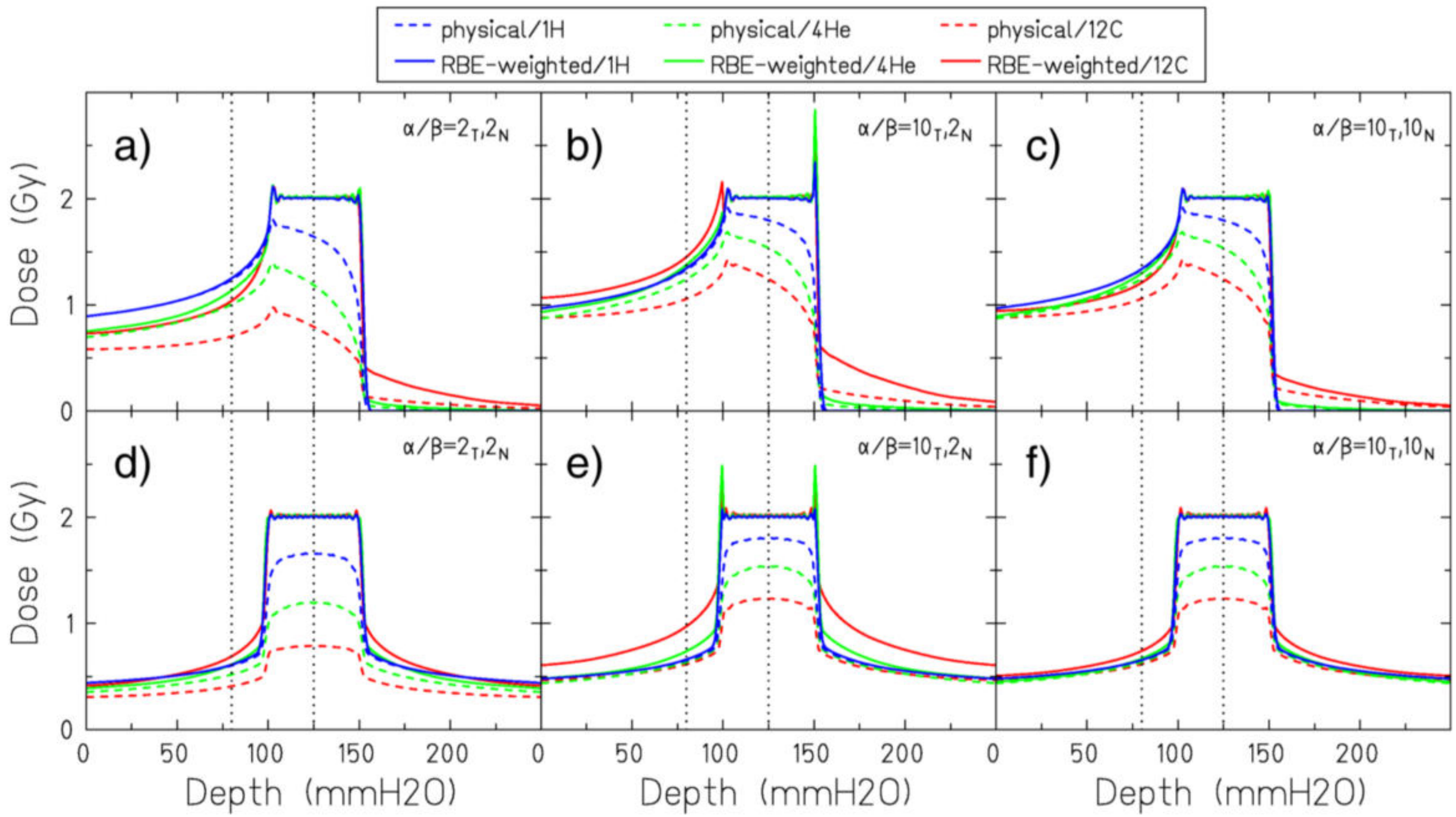
Med. Phys. 42 (2), February 2015 **0094-2405/2015/42(2)/1037/11/$30.00**



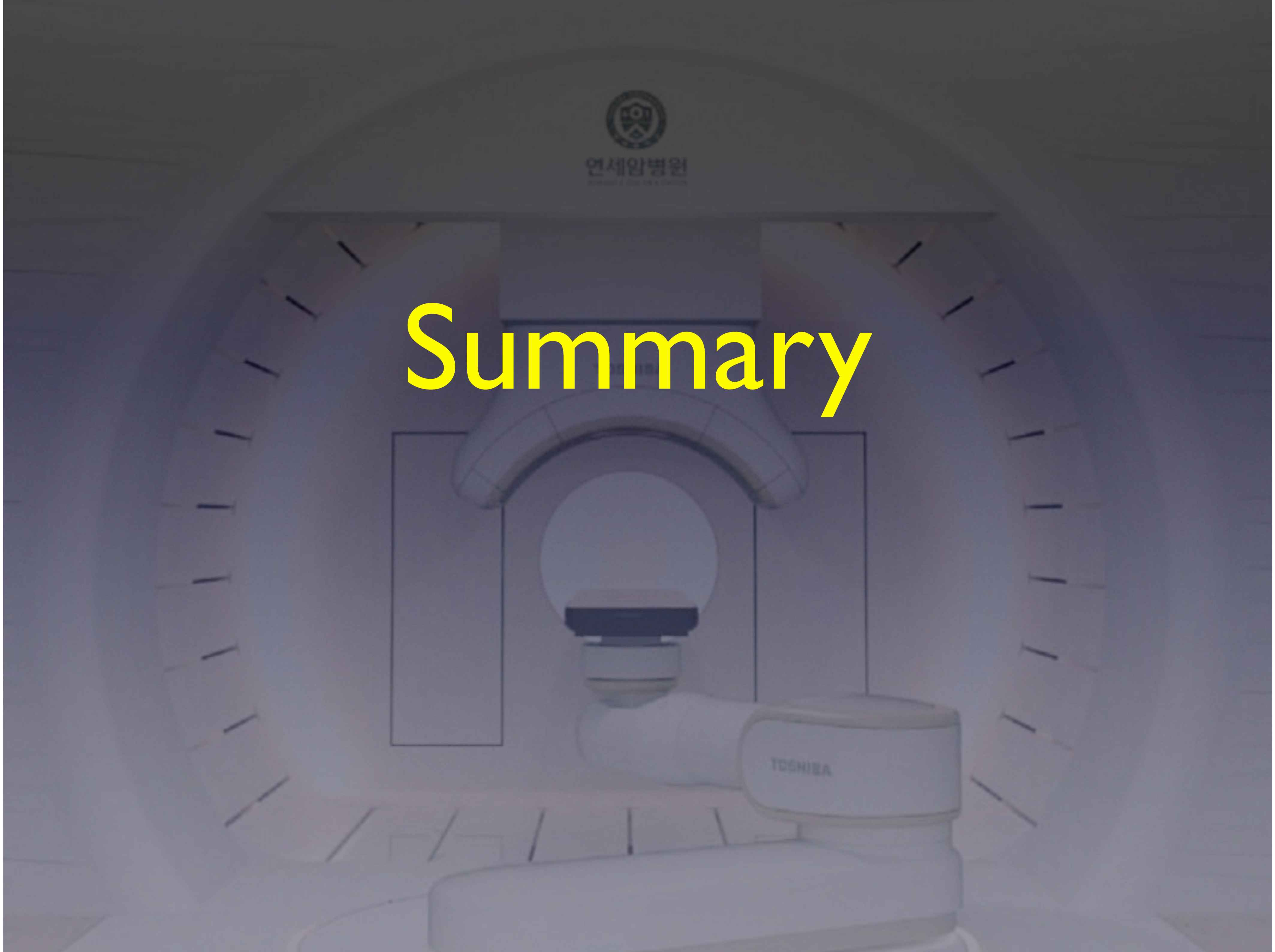


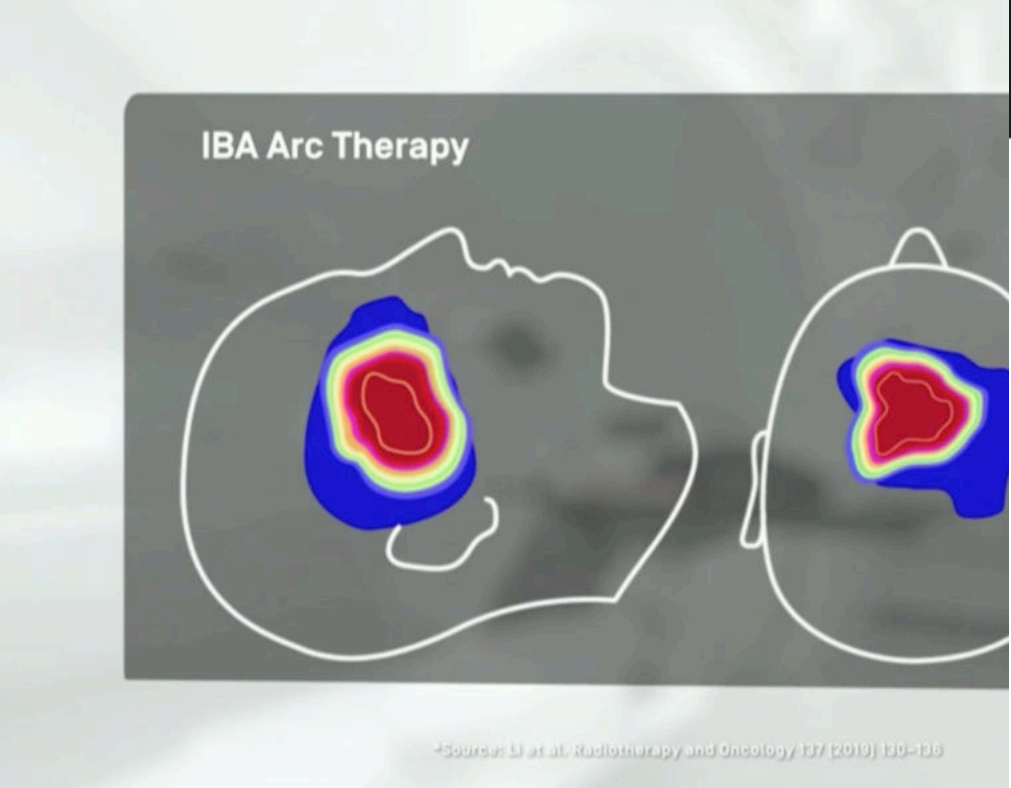
Assessment of potential advantages of relevant ions for particle therapy: A model based study

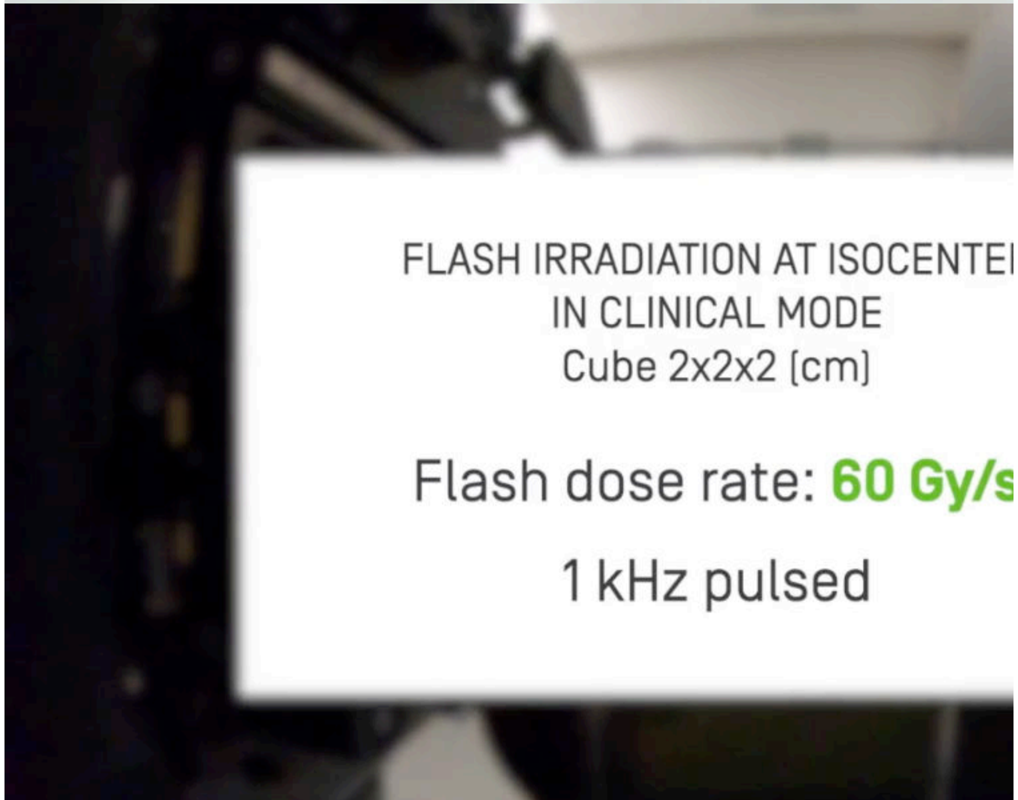
Med. Phys. **42**, 1037 (2015)

Helium ions are thus expected to represent a promising alternative to protons and carbon ions overcoming the weakness of both with an intermediate effectiveness.

Summary







June 15, 2020

Germany's Heidelberg University Hospital will become the world's first cancer center to use RayStation for helium ion therapy planning

PDF

RaySearch Laboratories AB (publ) and Heidelberg University Hospital's Ion Beam Therapy Center announce the world's first clinical release with support for helium ion therapy in treatment planning system RayStation®*.

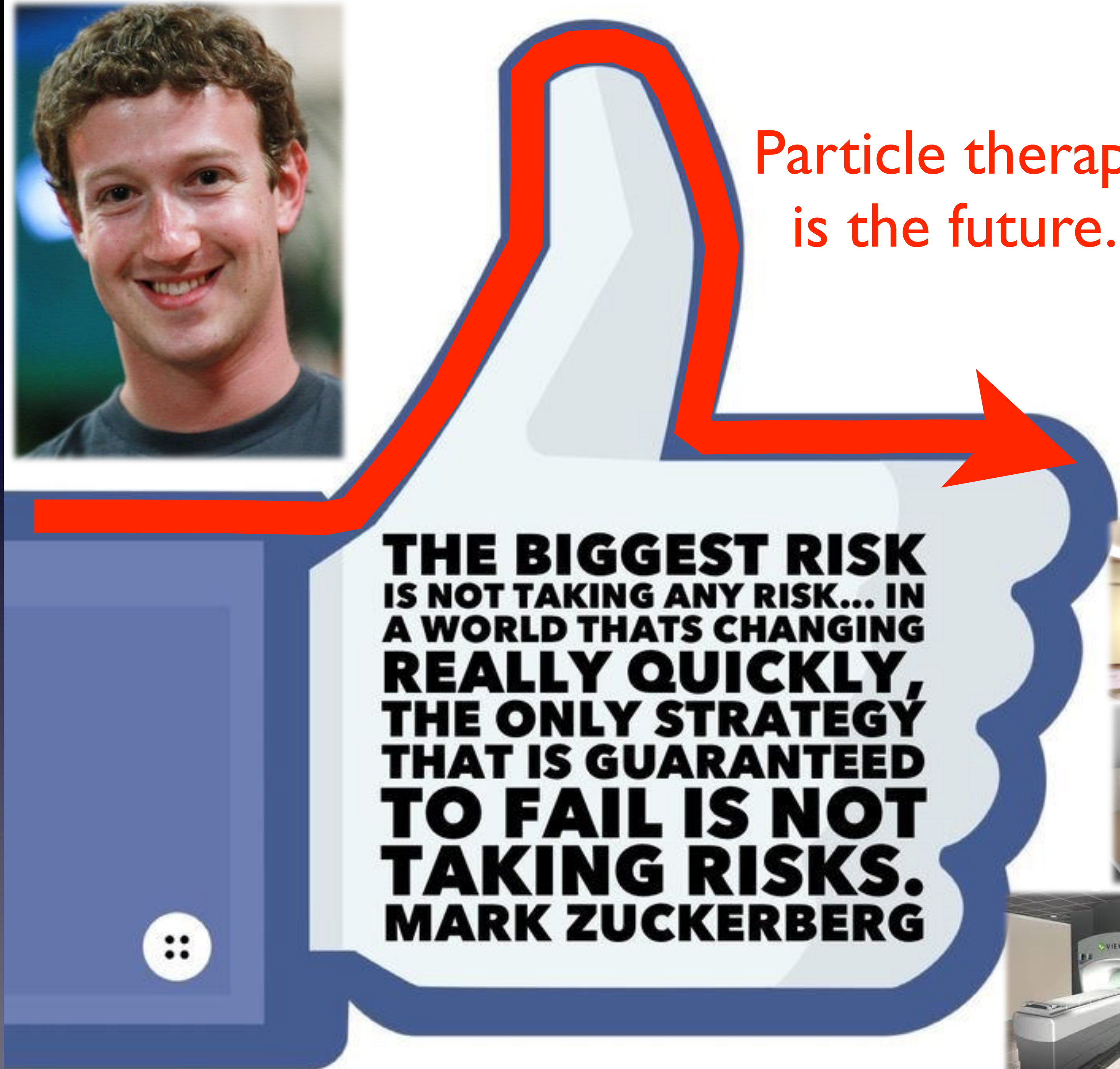
RayStation is the first commercial treatment planning system in the world to support helium ion therapy. Heidelberg University Hospital's Ion Beam Therapy Center will become the first in Europe with helium, and first in the world with pencil-beam scanning (PBS) delivery.

The leading oncology center in Heidelberg, Germany, bought licenses from RaySearch for helium PBS in March 2018 and intends to conduct a clinical study of 20-50 patients starting 2021 to demonstrate the effectiveness of helium ion therapy on cancer patients.

RayStation offers support for robust optimization and evaluation, dose tracking and everything else that is already supported for proton and carbon ion therapy. Physical dose calculation is performed using a pencil beam dose algorithm implemented on the graphic processing unit, and the relative biological effective dose is determined using either the local effect model or microdosimetric kinetics model.

Prof. Dr. Dr. Juergen Debus, chairman of the department of radiation oncology at Heidelberg and director of the national center of tumor diseases, says: "It will now be possible to integrate helium treatment planning into our precision radiotherapy program including modern photon and particle beams on the RayStation platform and seamlessly optimize the treatment for every patient."

Johan Löf, founder and CEO, RaySearch, says: "Heidelberg has been an important clinical partner for RaySearch for several years, and it's exciting to enter clinic trials for helium ion therapy with the esteemed team in Germany. Collaboration on this level is the drive force of innovation within precision health care and a cornerstone of our approach to innovation."



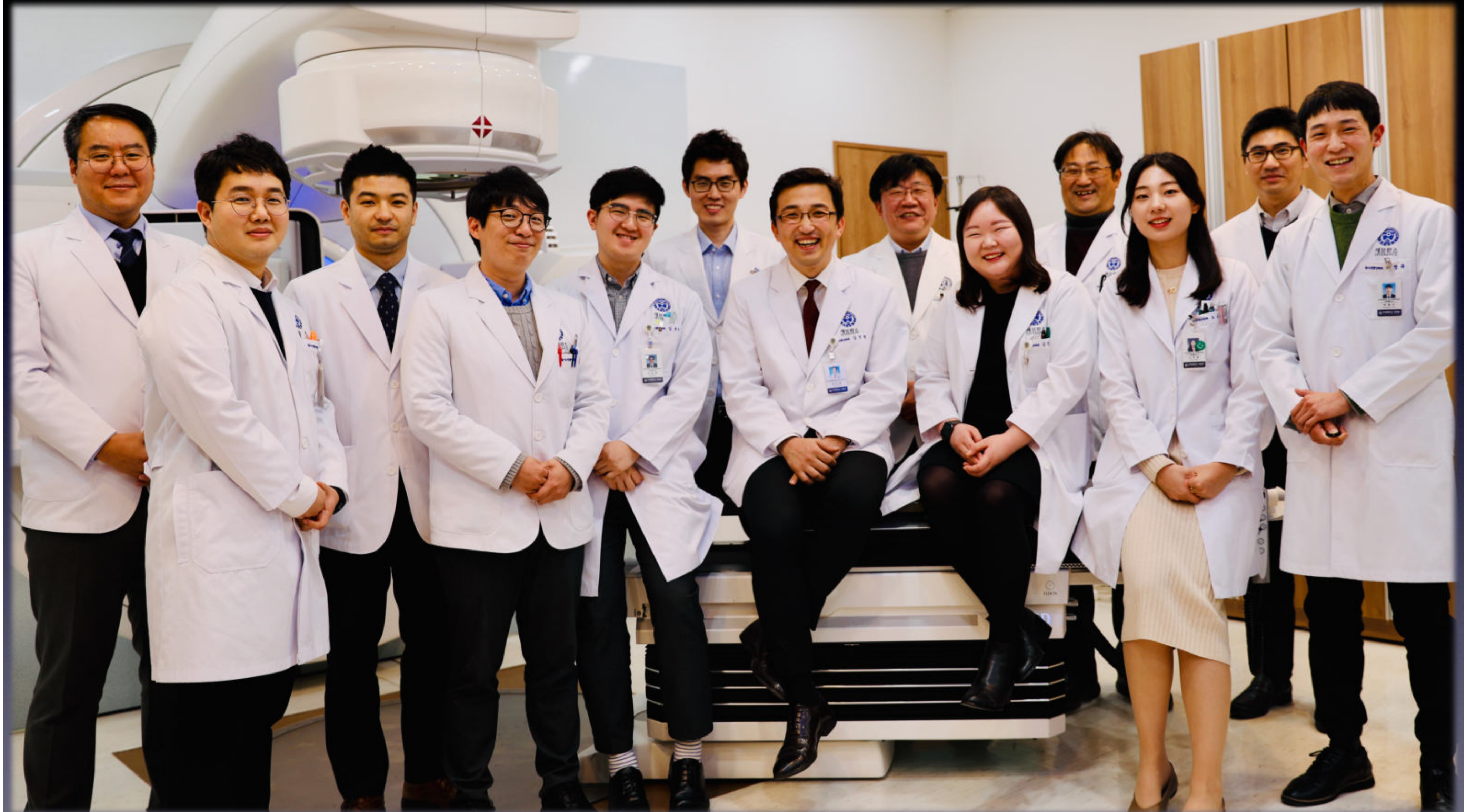
Particle therapy is the future.

Ongoing in Yonsei

- Full Maintenance
- KINS approval - 2020
  - RIST(Research Organization for Information Science and Technology)
    - performed radiation shielding calculations for all carbon ion centers
- Staffing
  - 0 Professors
  - 00 Medical Physicists
    - medical physicists, operators, planners

- Research
  - Clinical research, Medical physics, Biological, Translational research

Thank you for attention!



세브란스 SEVERANCE | 연세암병원

Physics
Yonsei Medical Physics

MPBEL 의학물리 및 의공학 연구실
Medical Physics and Biomedical Engineering Lab