가속기를 이용한 방사선치료 (의학물리)

가속기학교

July 2022

황의중, PhD, DABR
방사선종양학과
충남대학교, 세종충남대학교병원

Contents

Interactions: Radiation to Matter

$$(\mu/\rho) = (\tau/\rho) + (\sigma_{coh}/\rho) + (\sigma/\rho) + (\Pi/\rho)$$

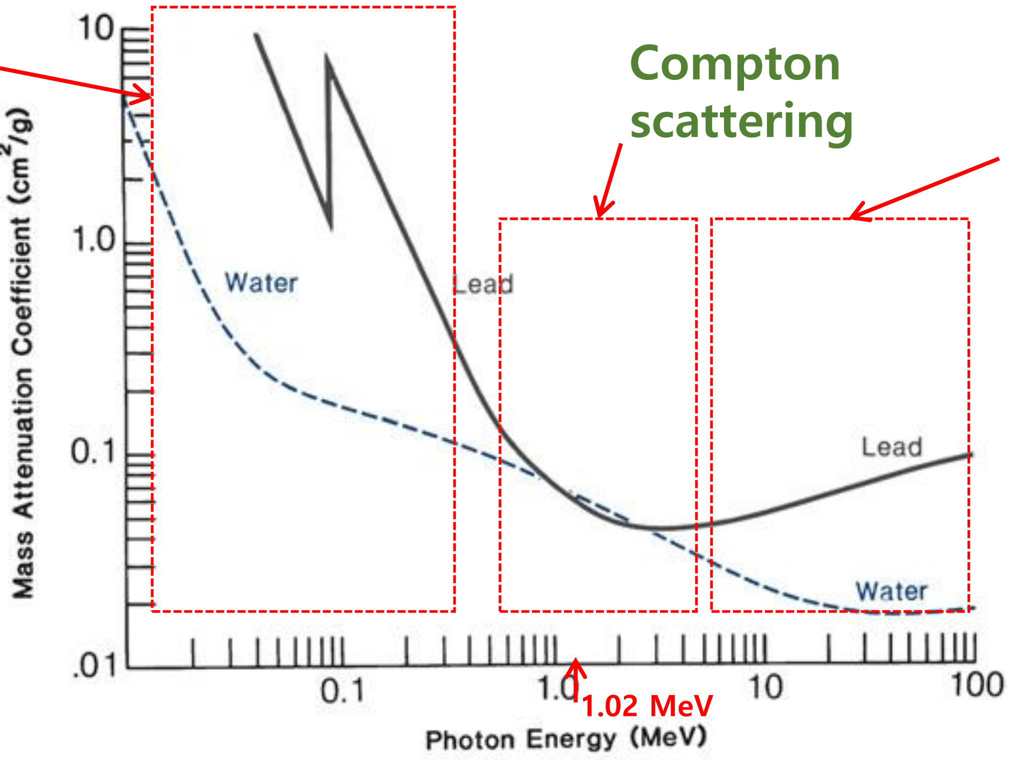
- coherent scattering: for very low photon energies (<10keV) and high Z materials

Photoelectric

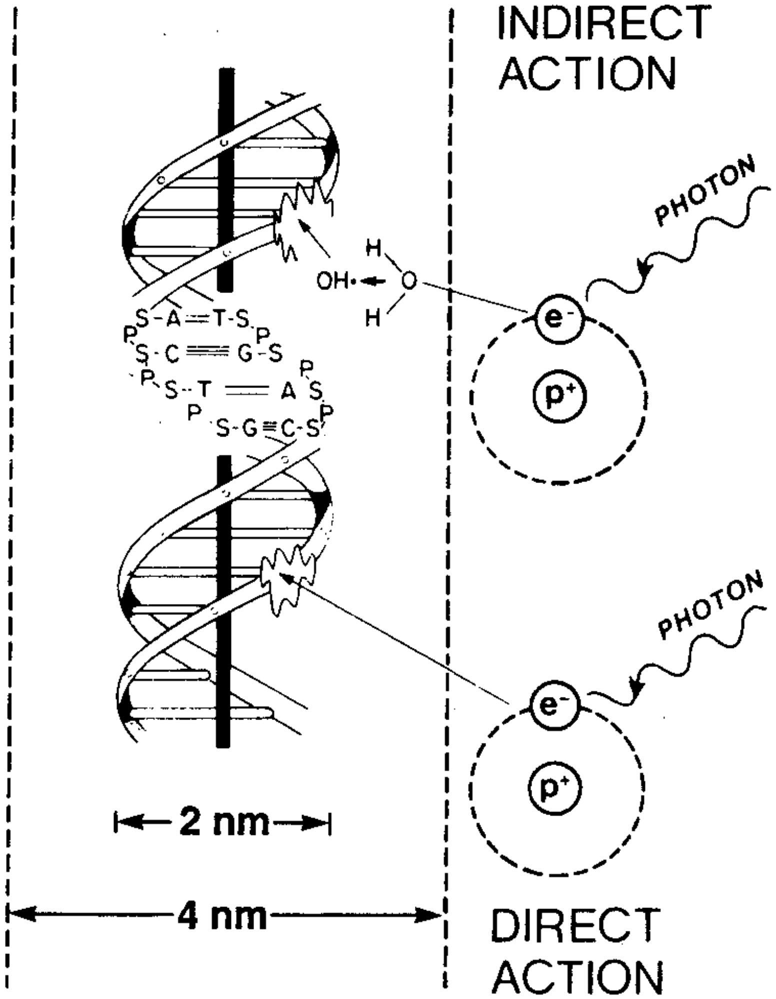
$\tau/\rho \propto Z^3/E^3$

Compton scattering

Pair production



종양세포에 대한 방사선 효과



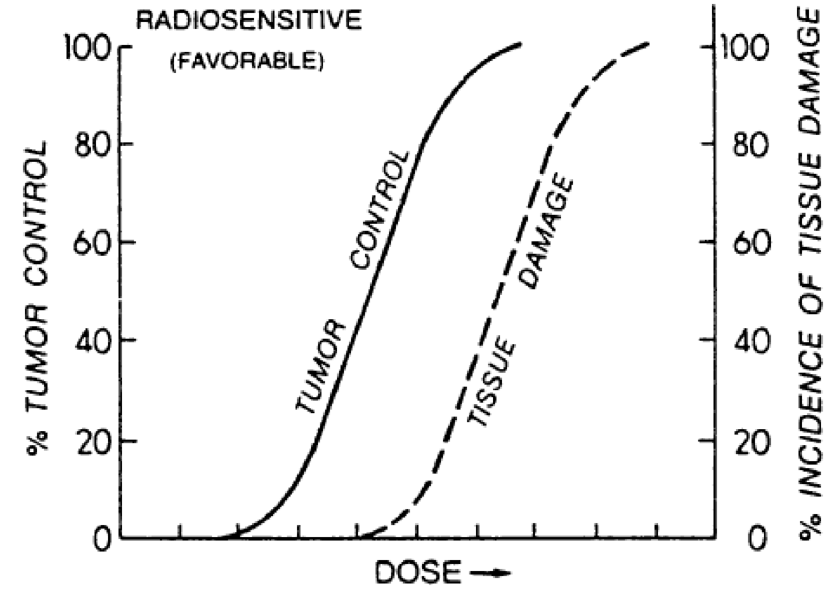
X선, γ선 등 일반 방사선
유리기(free radical, OH^-)가 관여
산소(O_2)에 의해 DNA 손상 고착

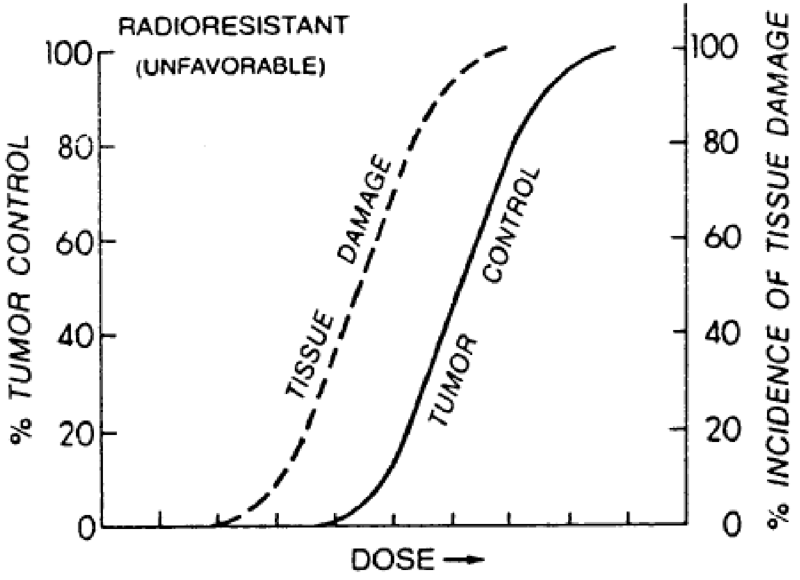
중성자선 등
산소(O_2) 필요없음

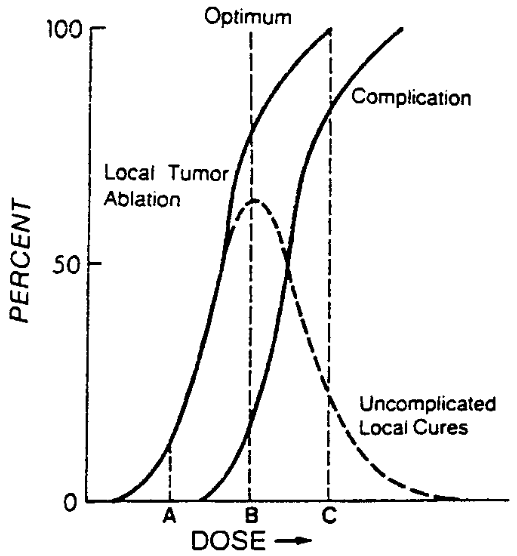
5) 방사선치료의 원리

치료비 (Therapeutic Ratio)

정상조직과 종양의 방사선감수성 (radiation sensitivity) 차이를 이용

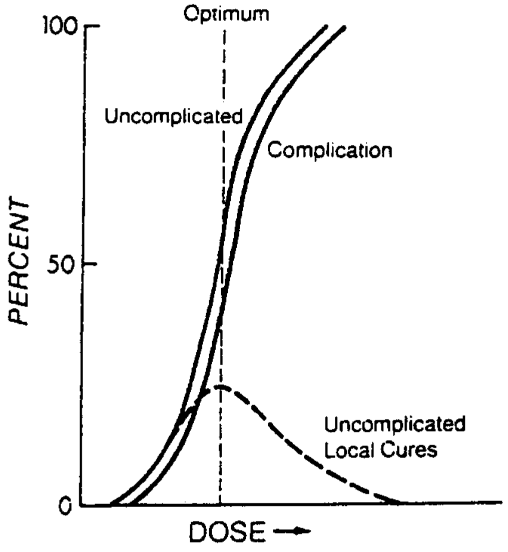






정상조직과 종양간의
치료적 이득 (therapeutic gain)이 있음

	정상조직부작용	종양조절율	치료선
량			
A	(−)	↓	부적합
B	(+)	↑	**적합**
C	↑	최대	부적합



정상조직과 종양간의
치료적 이득 (therapeutic gain)이 거의 없음

1.
Accelerators
for Radiation Therapy

Example of Medical use of Accelerators

1. Radiation Treatment

- **X-ray Radiation Therapy & Electron Therapy**
  (Linear accelerator 4~25 MeV/e)
- **Proton Therapy**
  (Cyclotron, Synchrotron 230 ~ 250MeV/p)
- **Carbon Therapy**
  (Synchrotron 400~430MeV/u Carbon)
- **Born-Neutron Capture Therapy**
  (Linear accelerator, Cyclotron 10~30 MeV/p)

2. Nuclear Medicine

- **Positron Emission Tomography**
  (Cyclotron 5~ 20MeV/p)

X-rays and Electron beam

varian
A Siemens Healthineers Company

iX

Trilogy

VitalBeam

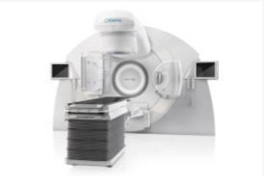
TrueBeam

Halcyon

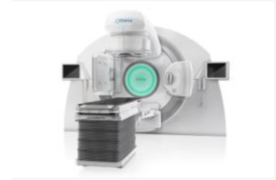
Ethos

Elekta

Synergy



Infinity



VersaHD

Harmony

Unity

ACCURAY

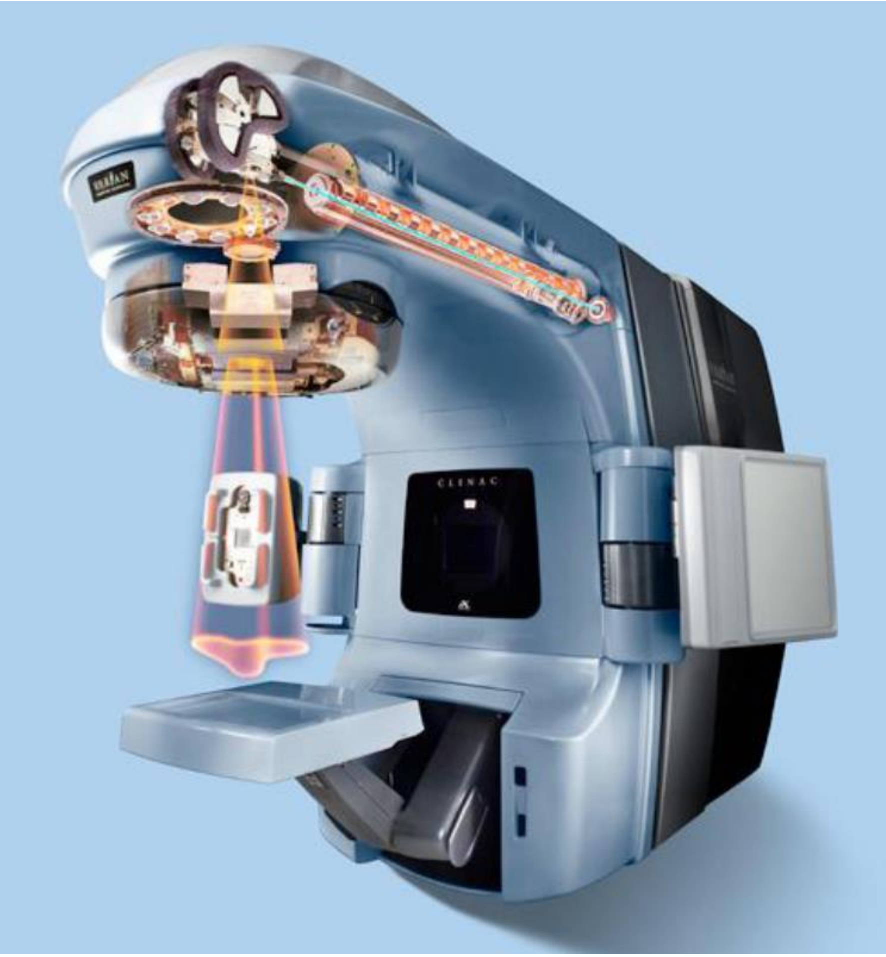
CyberKnife

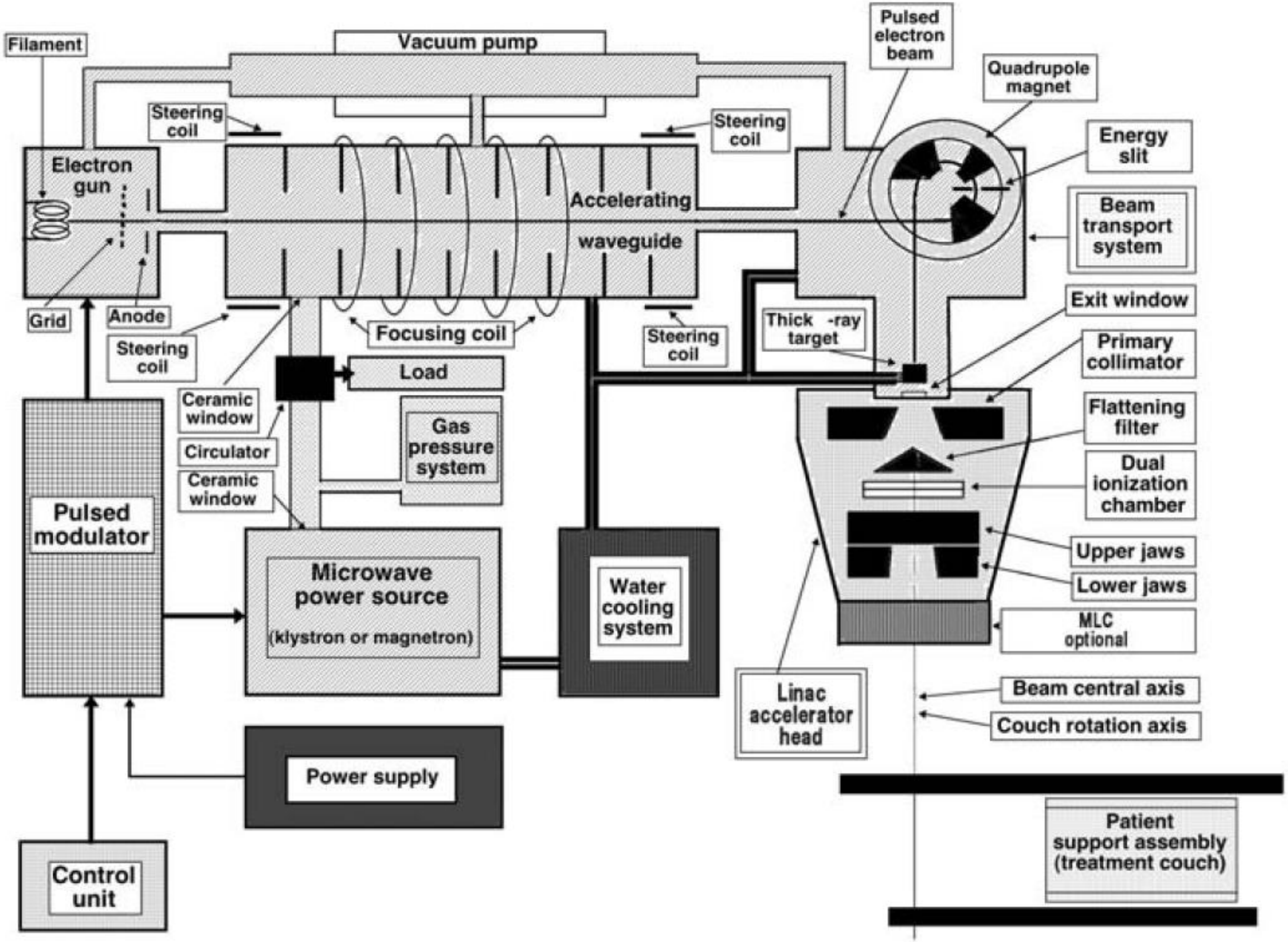
Tomotherapy Hi-Art

Radixact

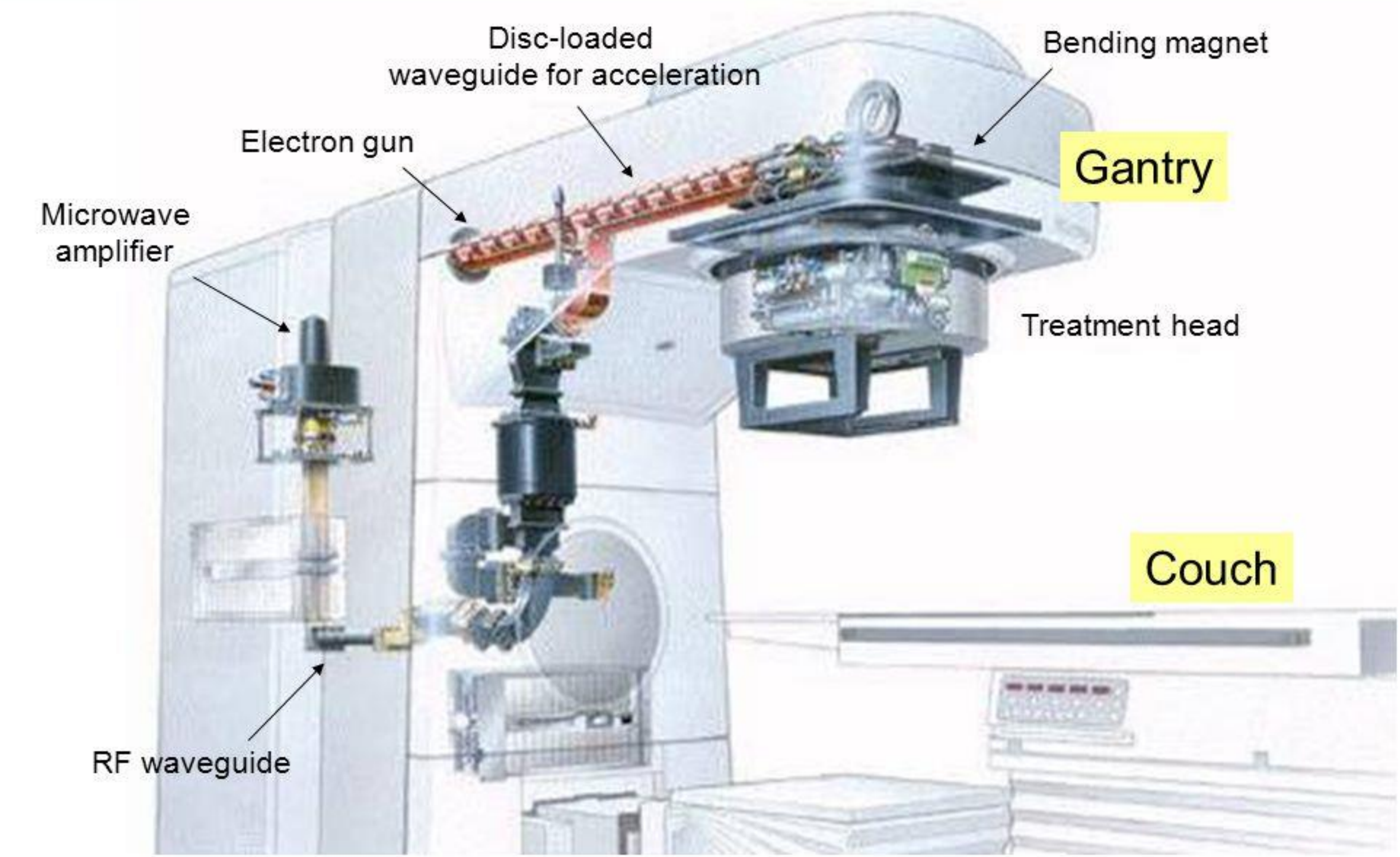
VIEWRAY
VISIBLY BETTER

MRIdian


CLINAC


Filament
Vacuum pump
Pulsed electron beam
Quadrupole magnet
Energy slit
Beam transport system
Steering coil
Steering coil
Electron gun
Accelerating waveguide
Grid
Anode
Steering coil
Focusing coil
Steering coil
Thick -ray target
Exit window
Primary collimator
Load
Ceramic window
Circulator
Ceramic window
Gas pressure system
Flattening filter
Dual ionization chamber
Upper jaws
Lower jaws
MLC optional
Pulsed modulator
Microwave power source
(klystron or magnetron)
Water cooling system
Linac accelerator head
Beam central axis
Couch rotation axis
Power supply
Patient support assembly (treatment couch)
Control unit

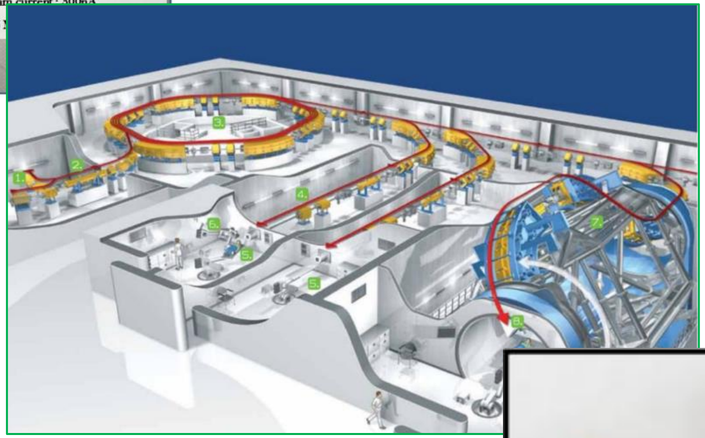
Main components of medical linac



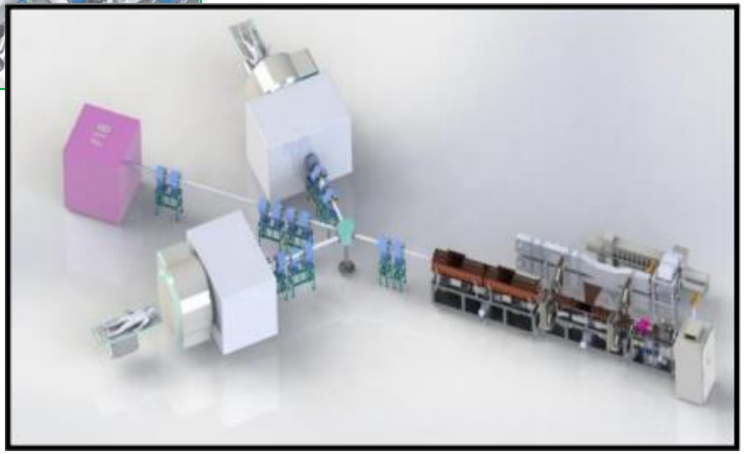
Proton Therapy

Particle Therapy Systems

Proton Therapy

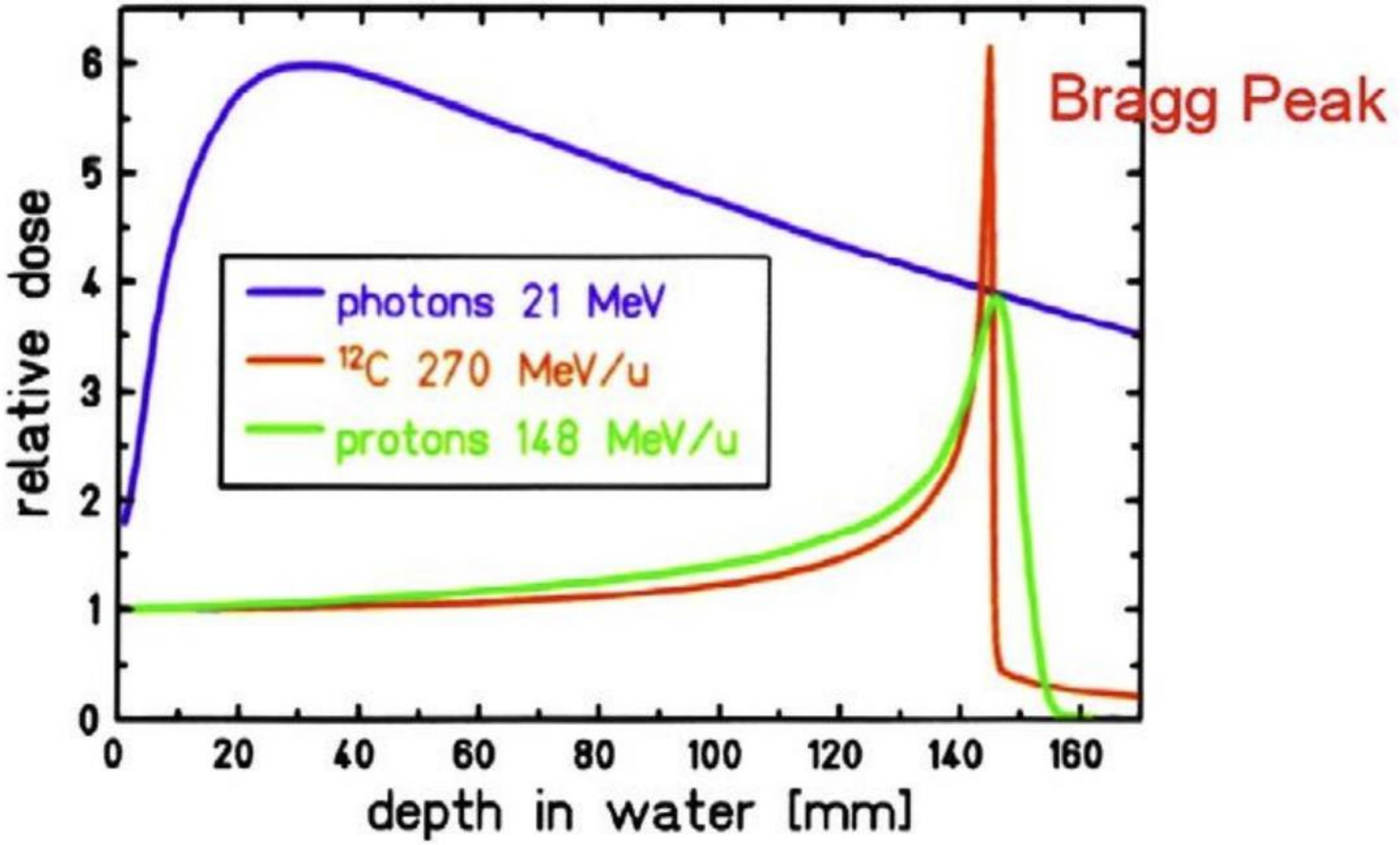


Carbon Therapy

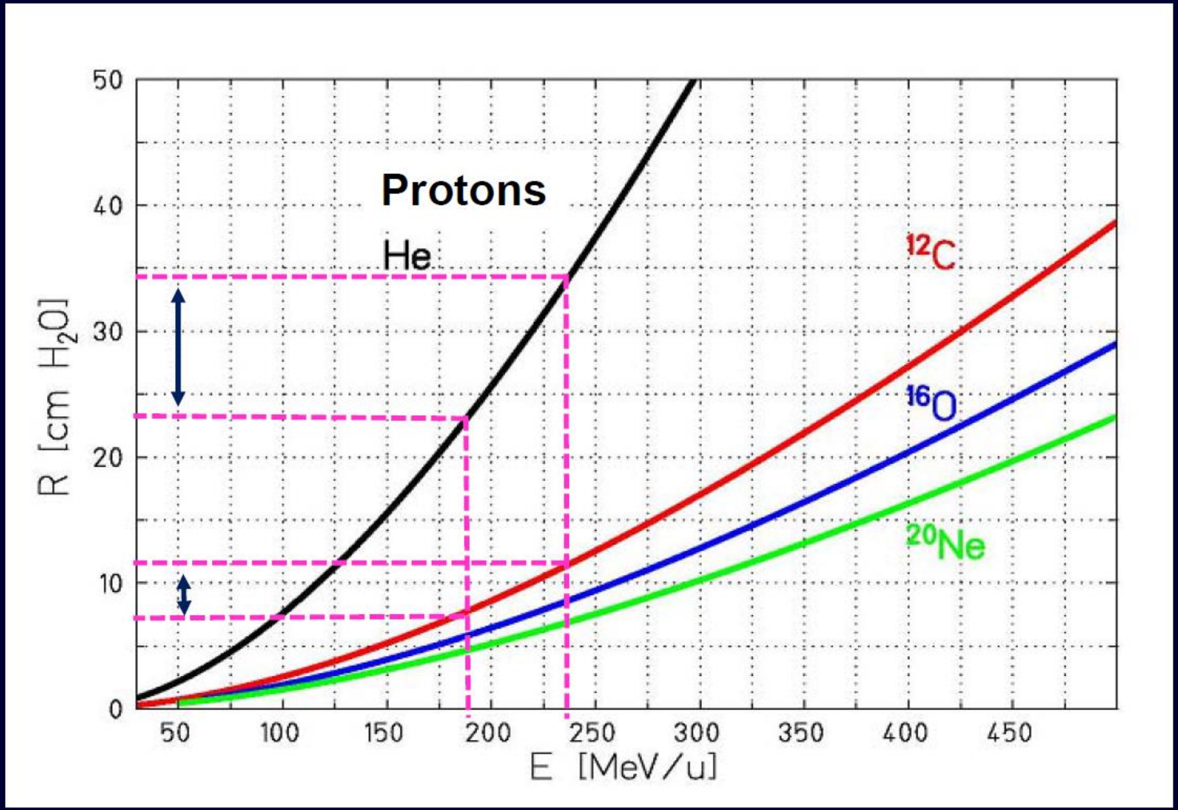


Born Neutron
Capture Therapy

Depth dose curve for radiations



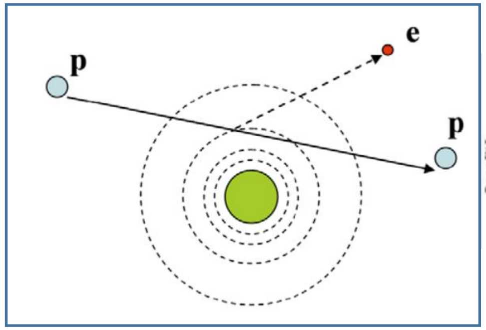
Particle Range vs Energy

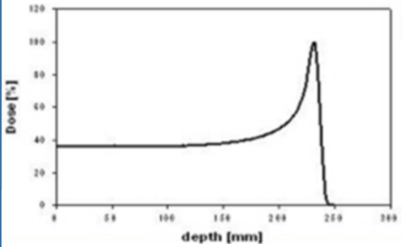


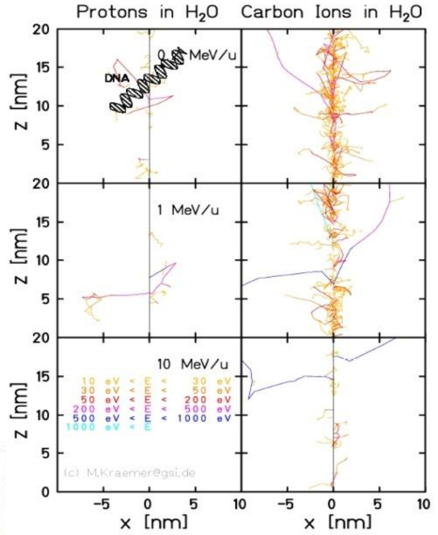
1-2. Physics & Biology of PT

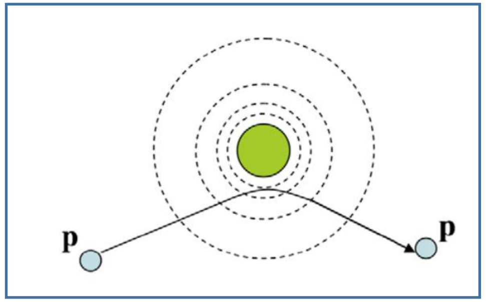
- Electronic Process (Energy Loss)
  - Inelastic collisions
    (Ionization & Excitation)
    : Bragg-Peak & Distal Penumbra

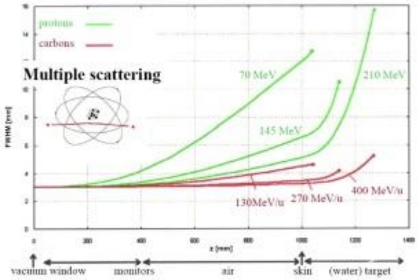
- Nuclear Process (Defrection, E loss)
  - Elastic scattering (MCS, Collision)
    : Lateral Penumbra
  - Nuclear reactions

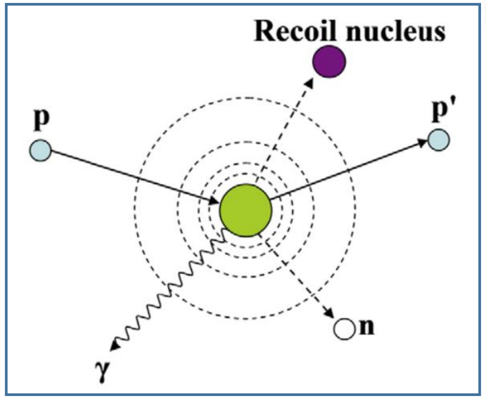




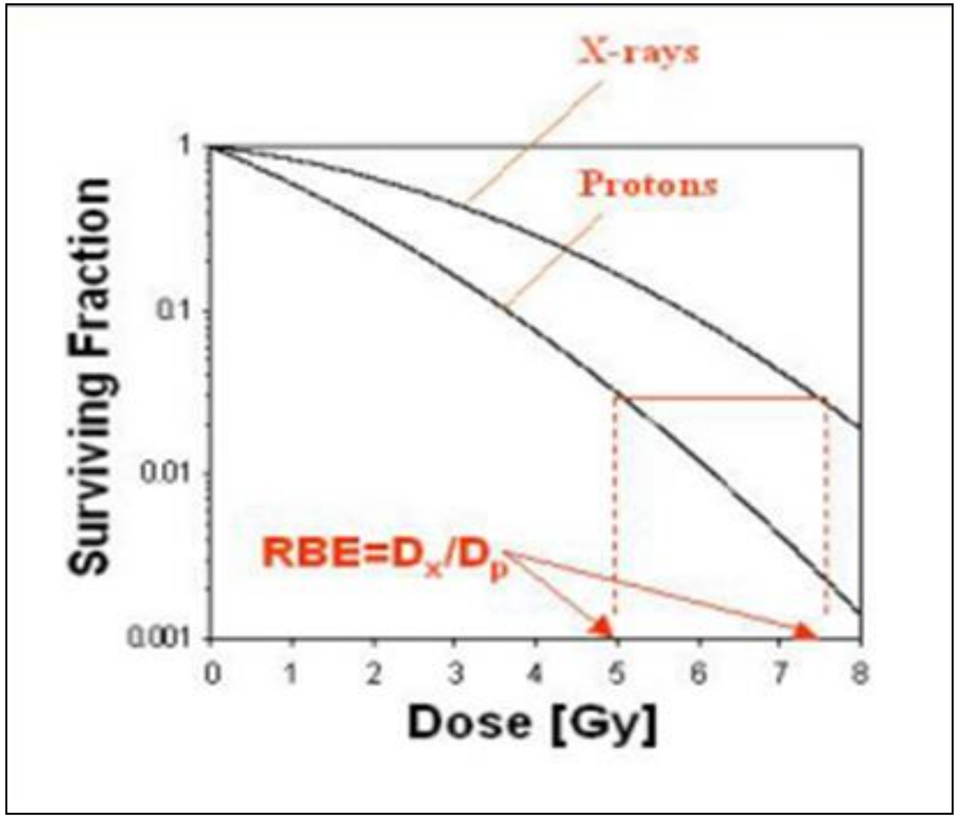




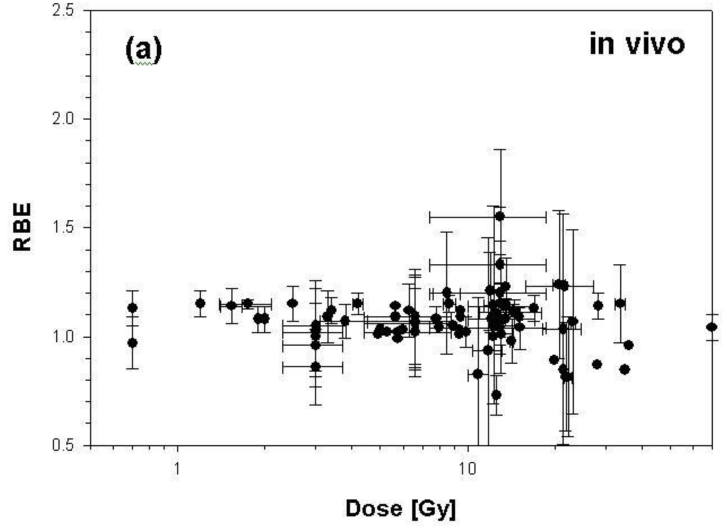




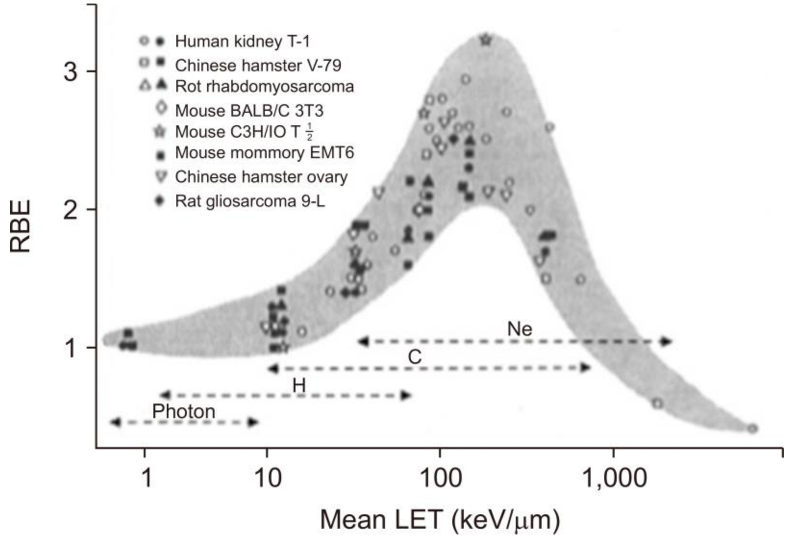
Relative Biological Effectiveness (RBE)



Cell survival curves to X-ray & P

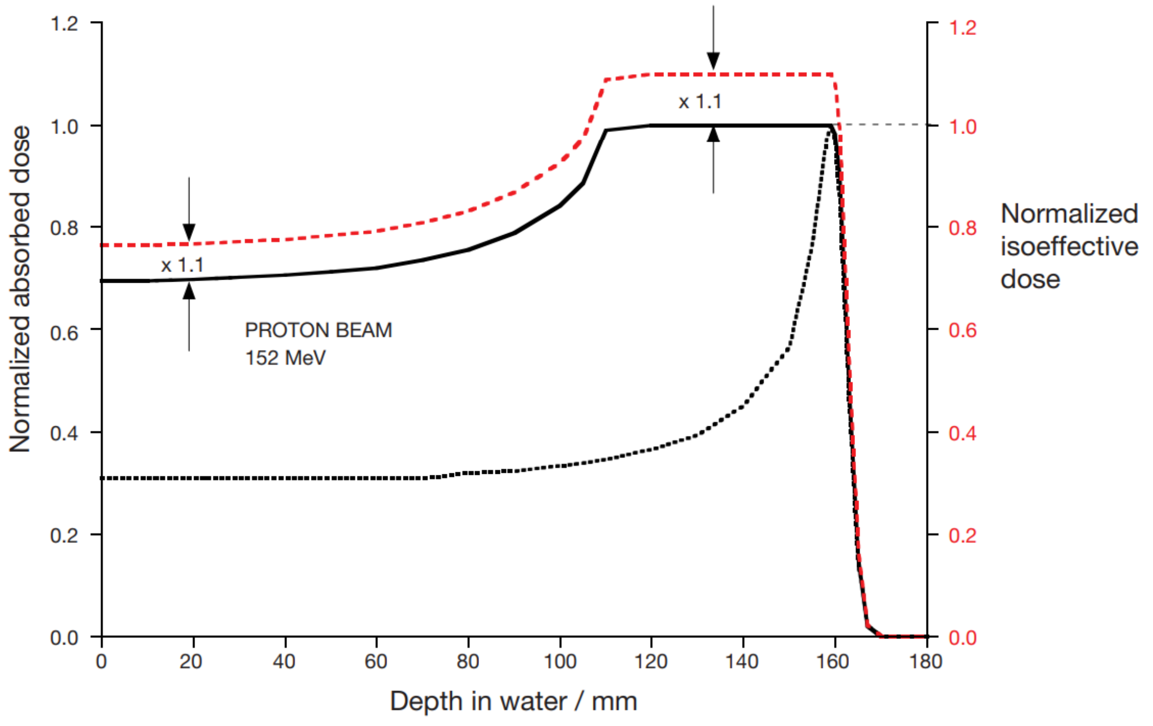


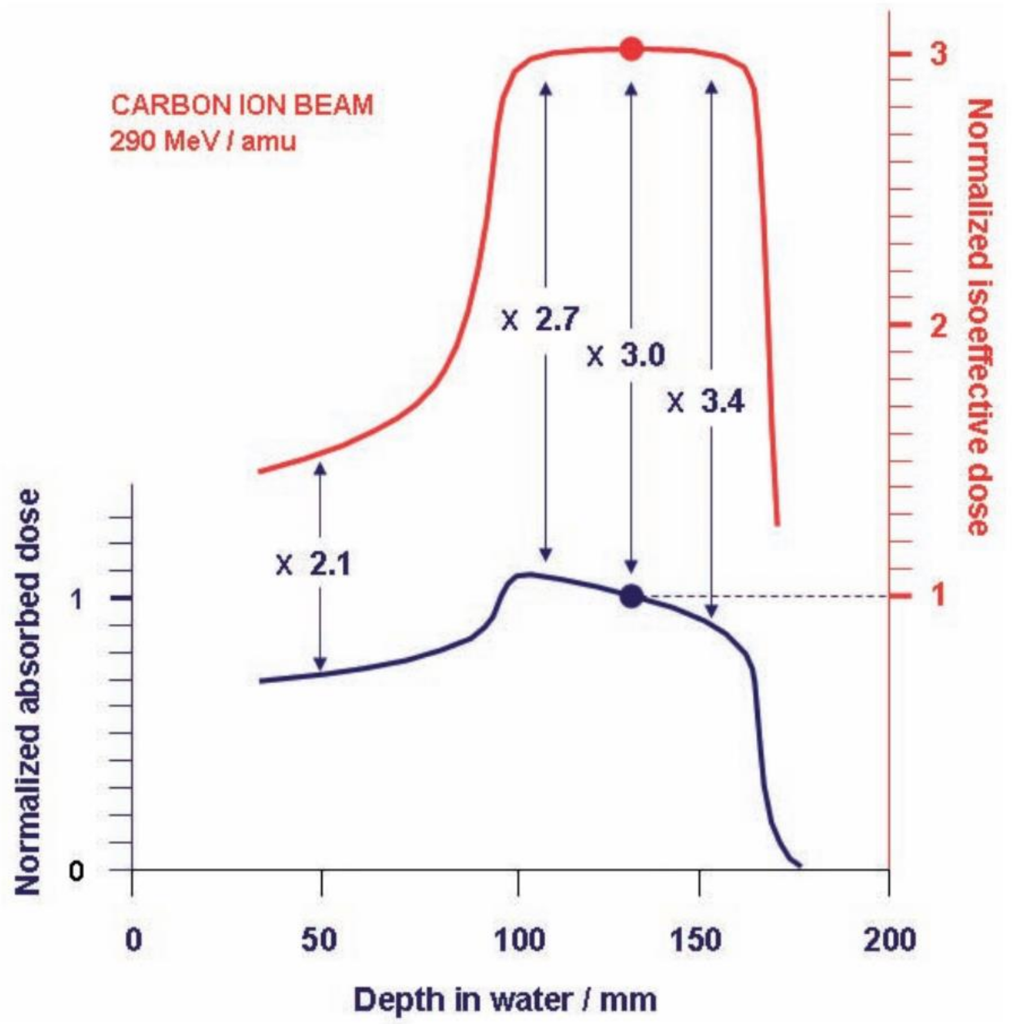
RBE
X-ray: 1.0
Proton: 1.1



RBE of proton and carbon ion beam

Proton beam

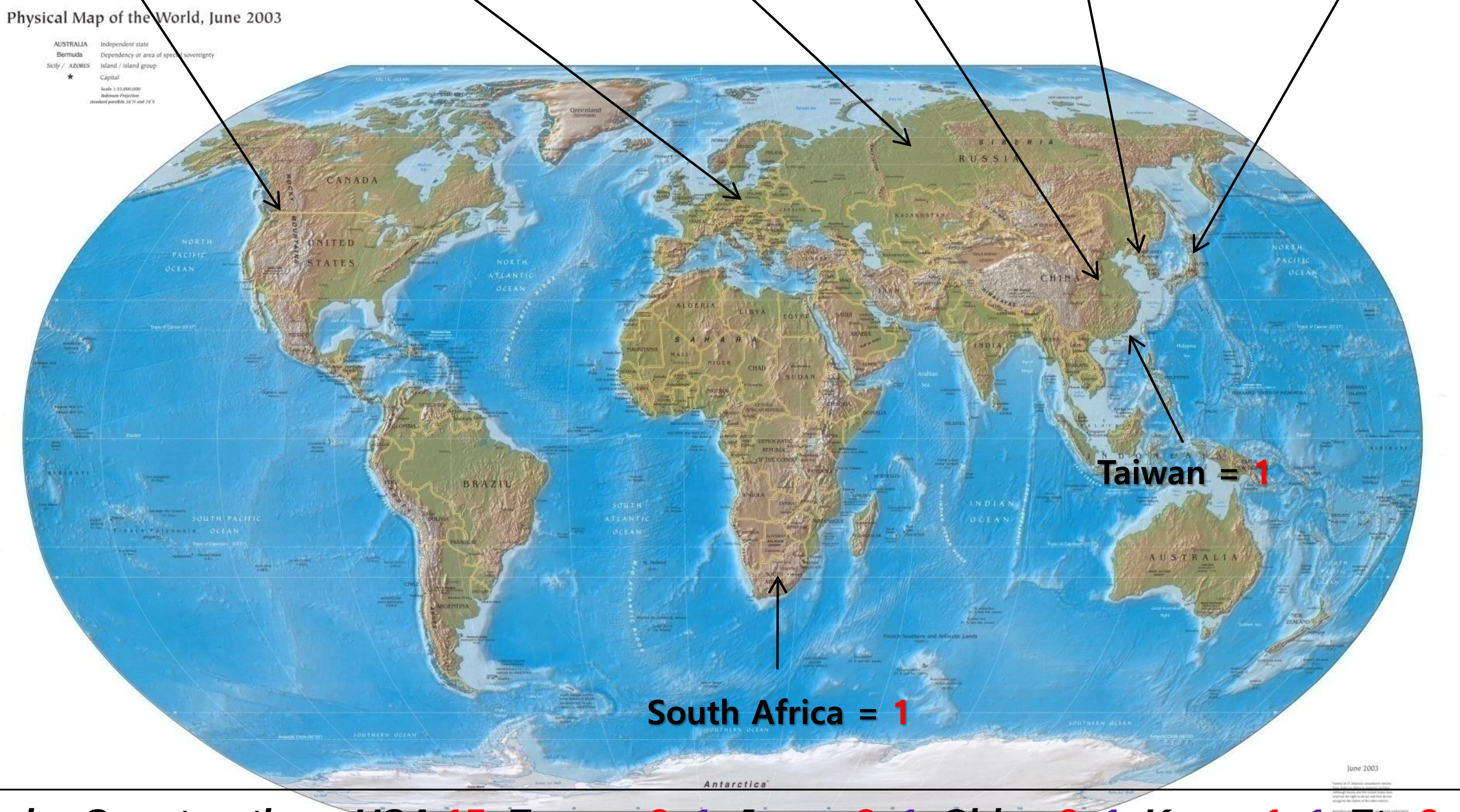




1-3. Worldwide particle therapy facilities

48 Proton and 9 Carbon Ion Therapy Facilities in Operation(2015.09)

North America = 18 Europe = 15+3 Russia = 3 China = 2+2 Korea = 1 Japan = 9+4

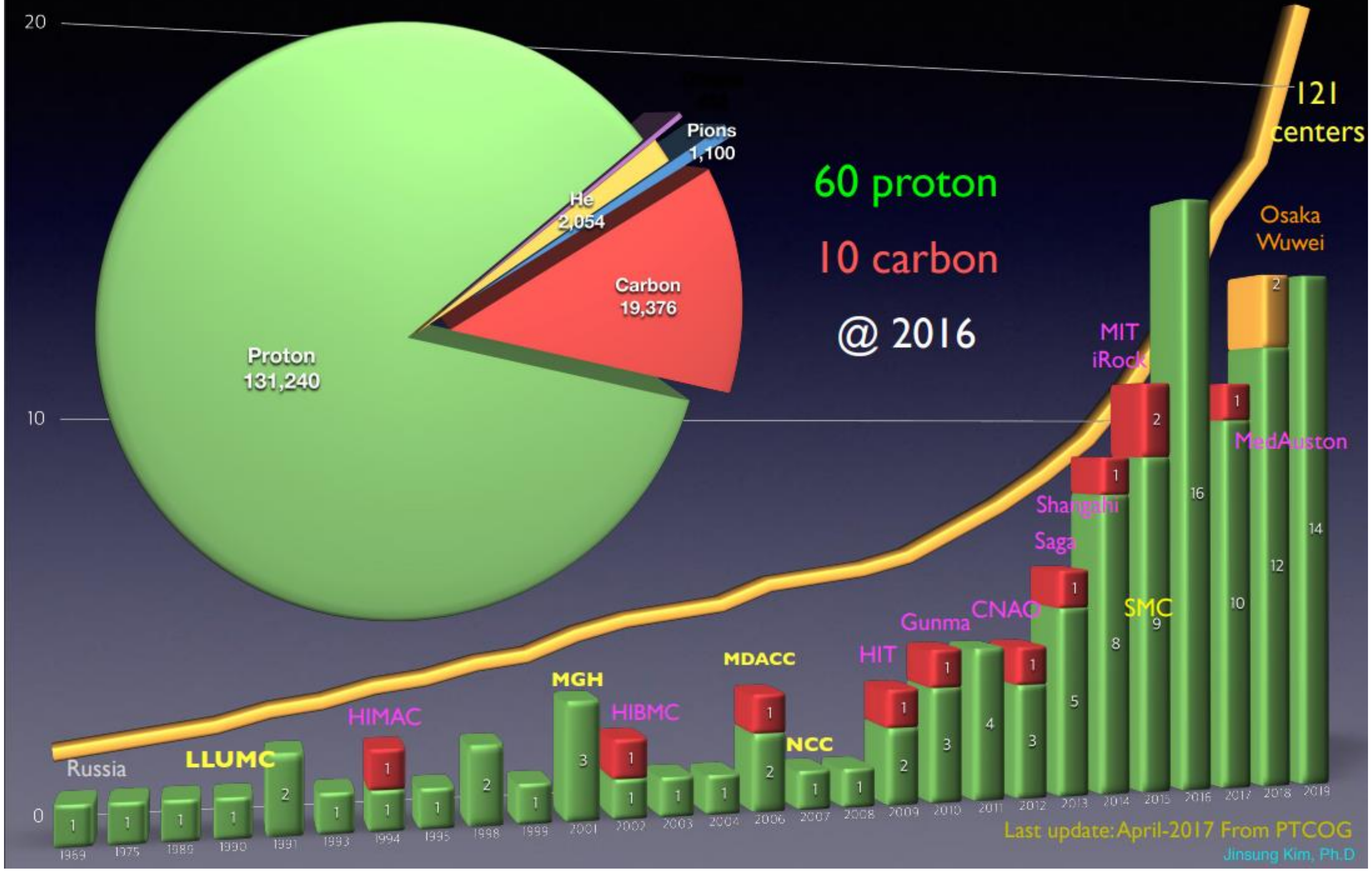


Taiwan = 1

South Africa = 1

Under Construction : USA 15, Europe 8+1, Japan 3+1, China 2+1, Korea 1+1, Etc 3.
Planning stage : Worldwide 15 ** Total : Proton 47 + Carbon 3*

Particle Therapy Center in the world



1-4. Providers for Proton Therapy

varian
A Siemens Healthineers Company

ProBeam

ProBeam

Compact

Multi Room

ProBeam360

Single Room

Multi Room

iba

Proteus

Proteus ONE

Proteus PLUS

HITACHI
Inspire the Next

ProBEAT (proton)

HyBEAT (carbon ion)

Sumitomo
Heavy Industries, Ltd.

TOSHIBA

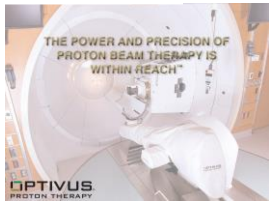
MEVION
medical systems

S250

S250mx

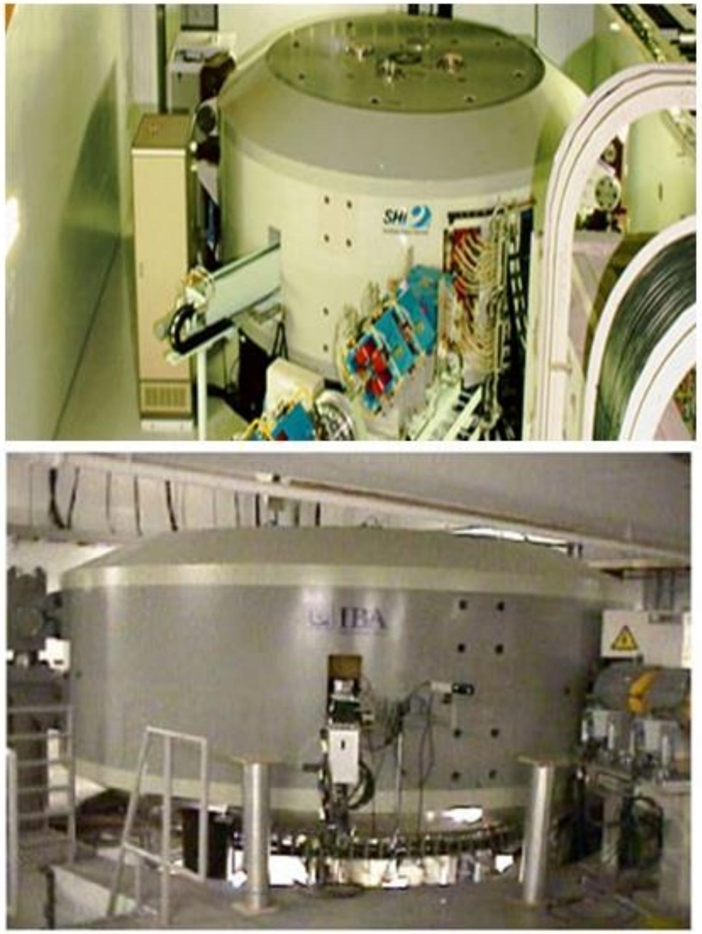
PROTOM
proton therapy technologies

OPTIVUS
PROTON THERAPY



ProNova SC360

2-1. Accelerators (1)



Cyclotron

Synchrotron

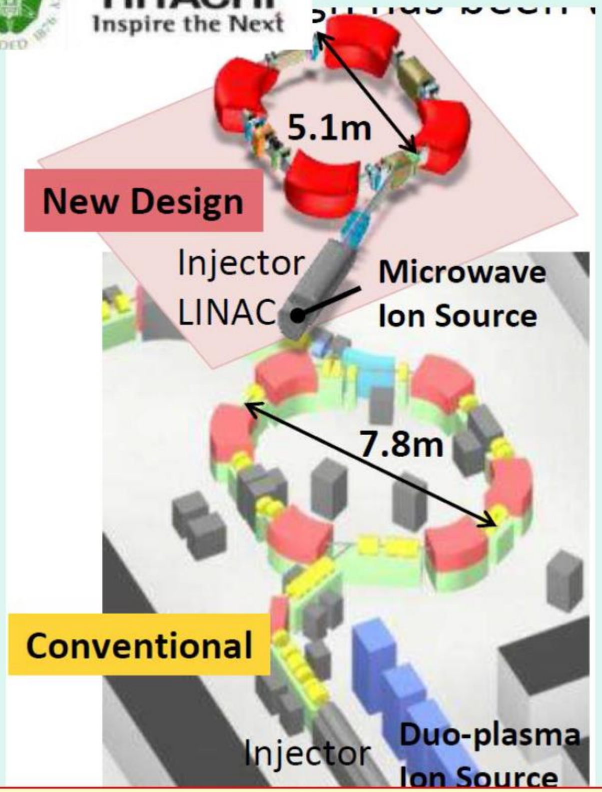
2-1. Accelerators (2)

Compact synchrotron

ProTom 330 MeV

2012: Installation at:
McLaren, Flint (Mi)
MGH Boston (Ma)

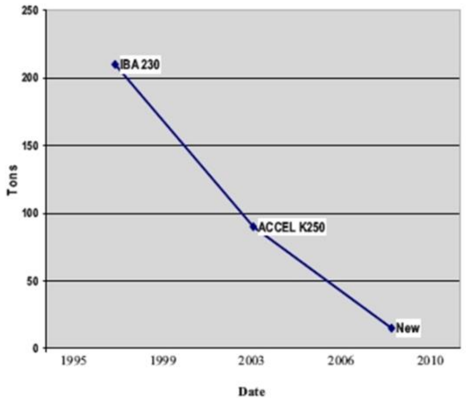
- Fully variable beam energy of 30-330 MeV ± 0.15%
- Time of acceleration up to 330 MeV - 1 sec
- Efficiency of the beam extraction ~ 80%
- Total weight - 15 tons



- 220 MeV
- First facility in Hokkaido started 2013

2-1. Accelerators (3)

Synchro-Cyclotron



Cyclotron → Synchro-Cyclotron
Diameter : 4m → 1.8m
Weight : 220tons → 40tons

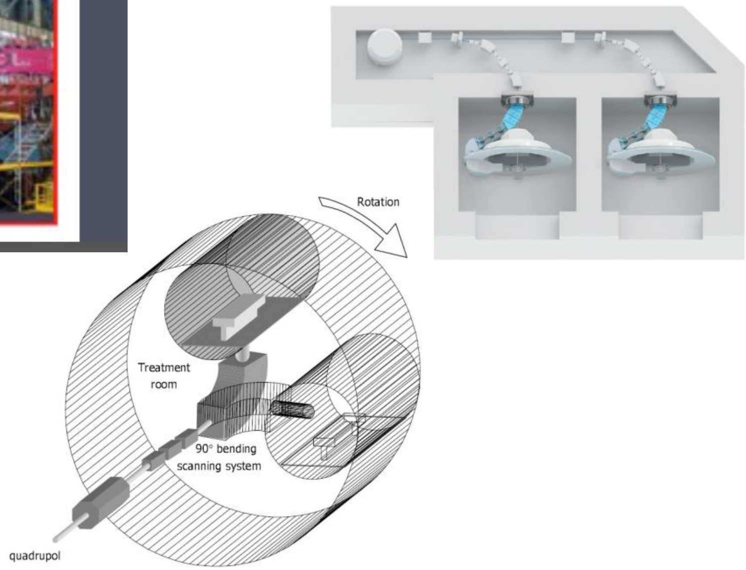
First beam extracted in May 2010

First beam at IBA in 2013

2~5 nA @ nozzle
10~20 nA @ Accelerator ⟷ 2 Gy/min

2-3. Gantry

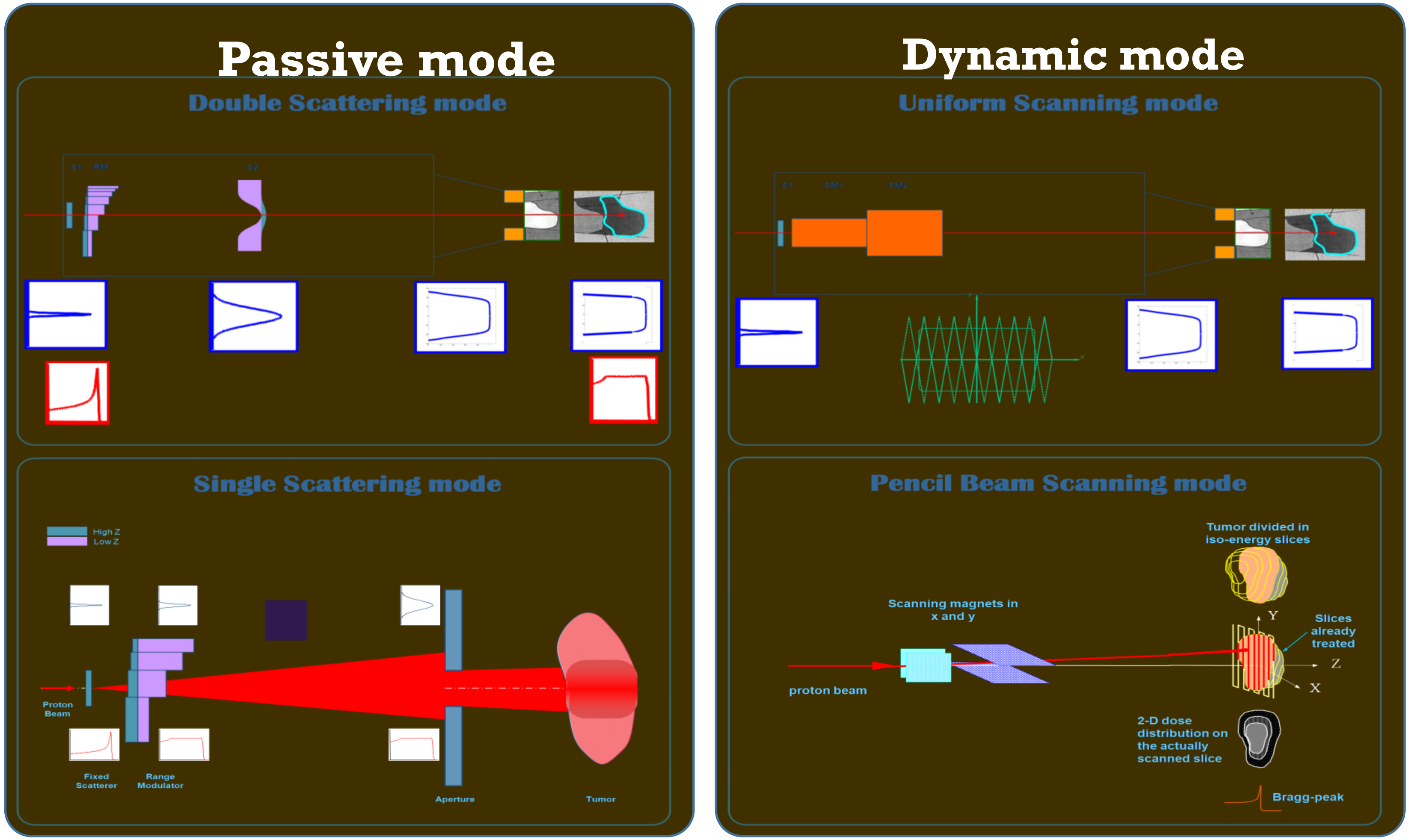
Various Gantry Systems

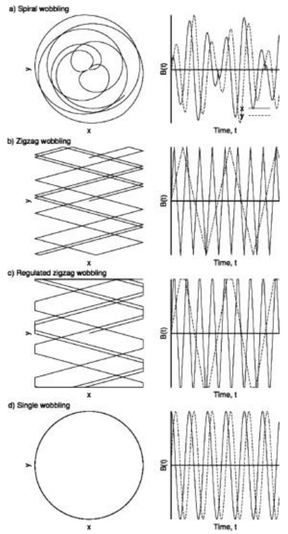


Large & Heavy ➔
Compact & Light Design
Still expensive..

2-2. Beam Nozzle (1)

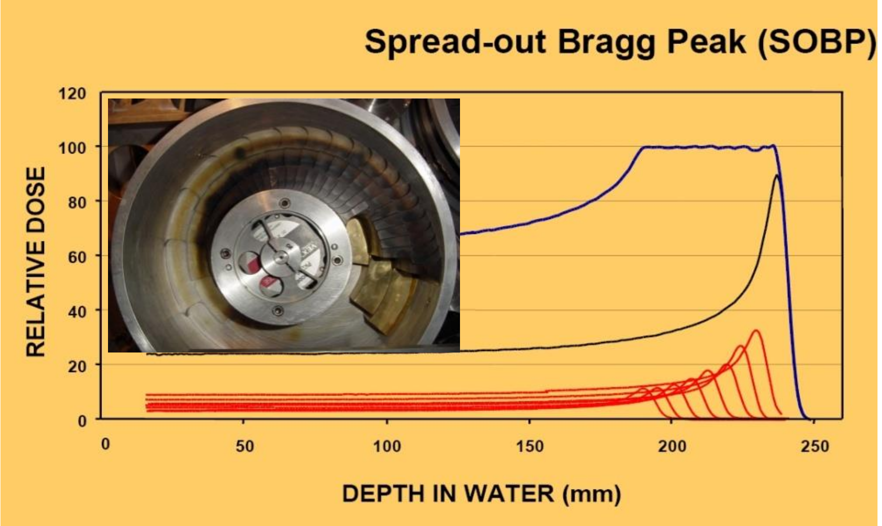
Proton Beam Delivery Modes

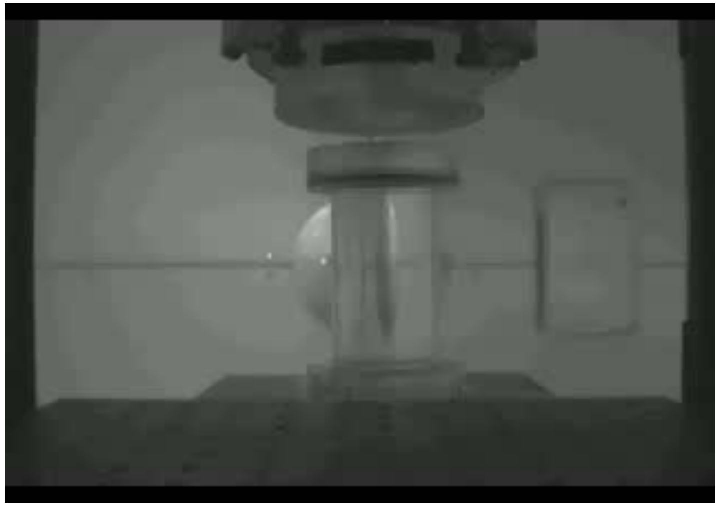


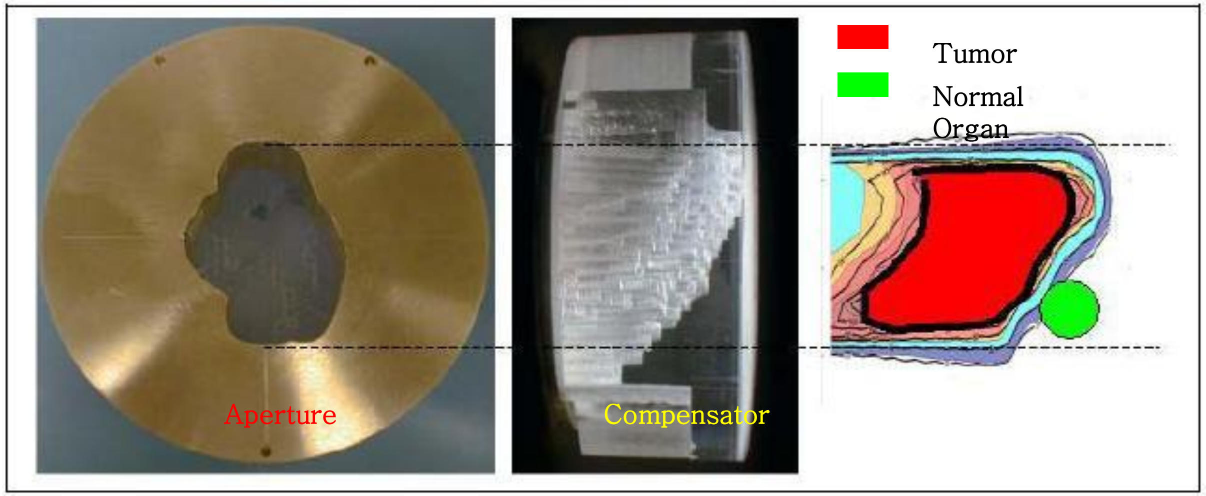


2-2. Beam Nozzle (2)

Beam Modulation (Range) & Patient dedicated Devices

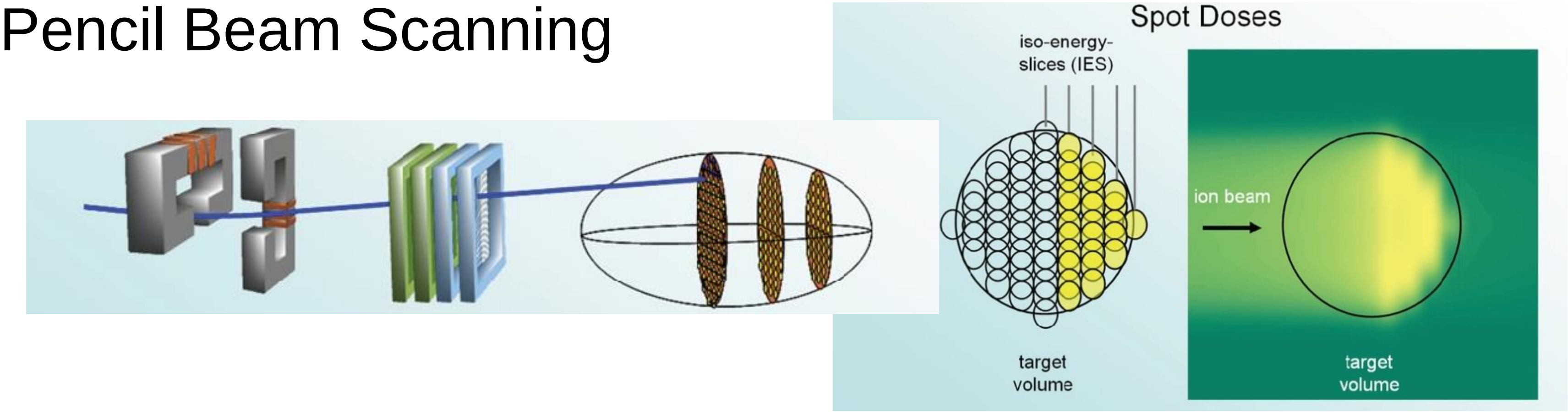


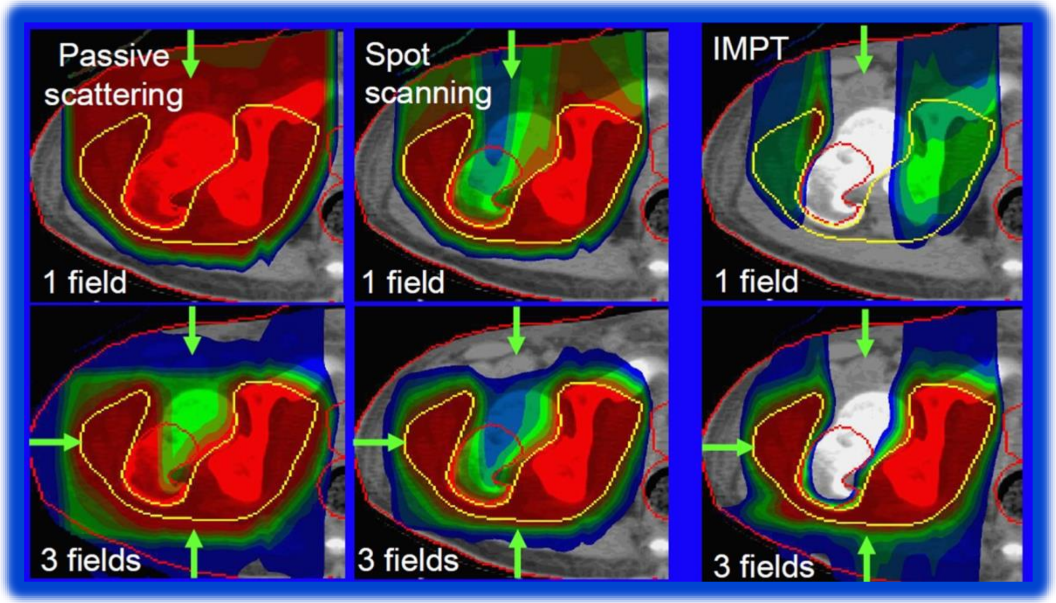




2-2. Beam Nozzle (3)

Pencil Beam Scanning



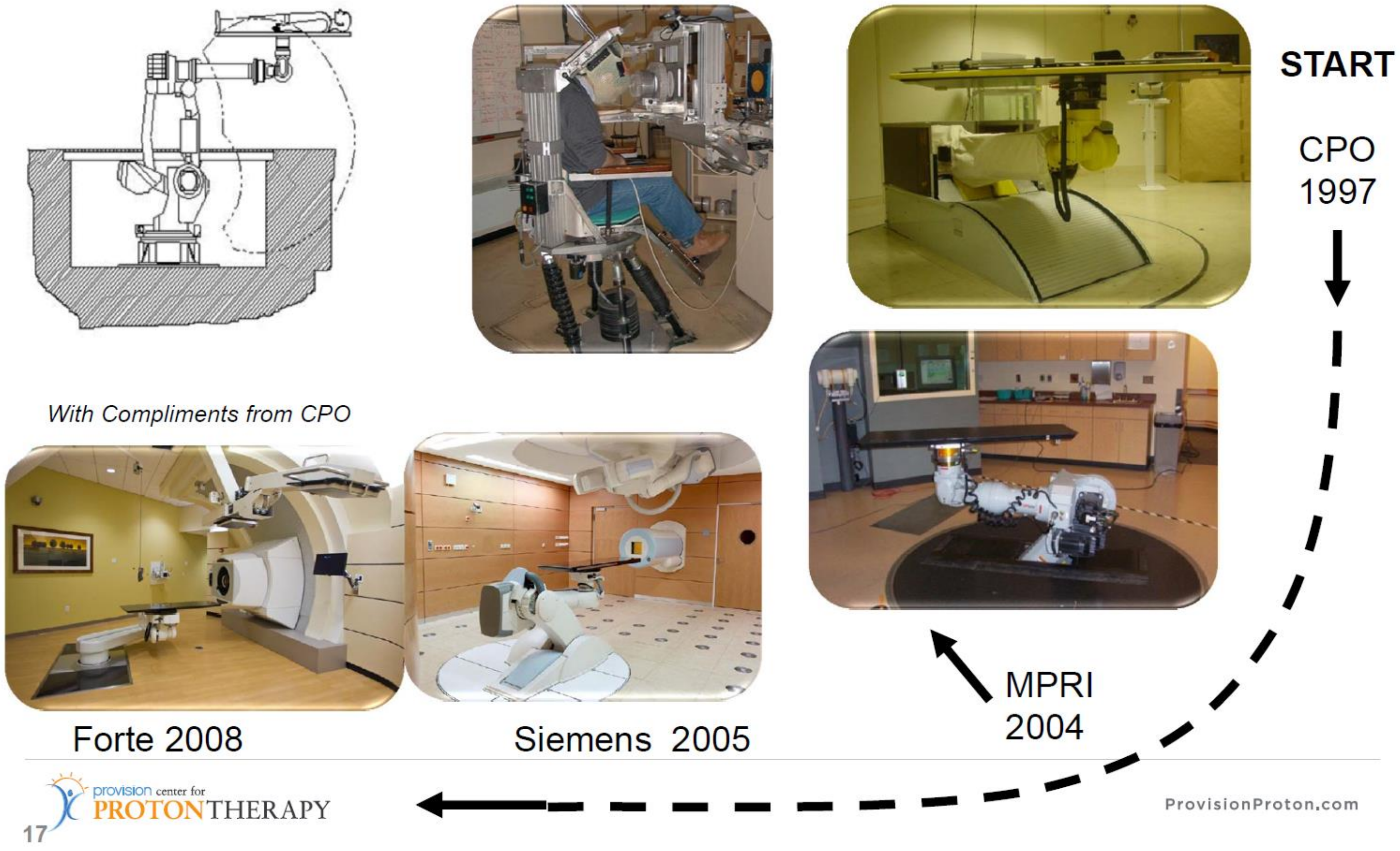


Comparison of Dose Distribution

- Passive vs. Spot scanning vs. IMPT
- 1field vs. 3fields

2-4. Patient Positioning System (1)

Robotic Couch



2-4. Patient Positioning System (2)

Next Steps – Robotic PPS

- **Smarter uses of the Robotic positioners**
  - ✓ Haptic motions
  - ✓ Smart trajectories
  - ✓ Vision guidance
- **Add tracking software to enlarge useable work envelopes**
- **Improved calibration methods**
- **Integrate the PPS better with PAS and Control systems**

2-4. Patient Positioning System (3)

Volumetric Image Registration (CBCT)

Med-Photon

2-5. Trend of Proton Therapy Facility

- Particle therapy is **in the midst of a remarkable transition**

- During the next decade, important advances in **proton therapy treatment delivery, treatment planning, and quality assurance systems** will be made.

- **IMPT** is becoming **routine treatment** in PT facilities

- **More hospital-based, state-of-art of proton facilities** will be built and increasing PT patients.

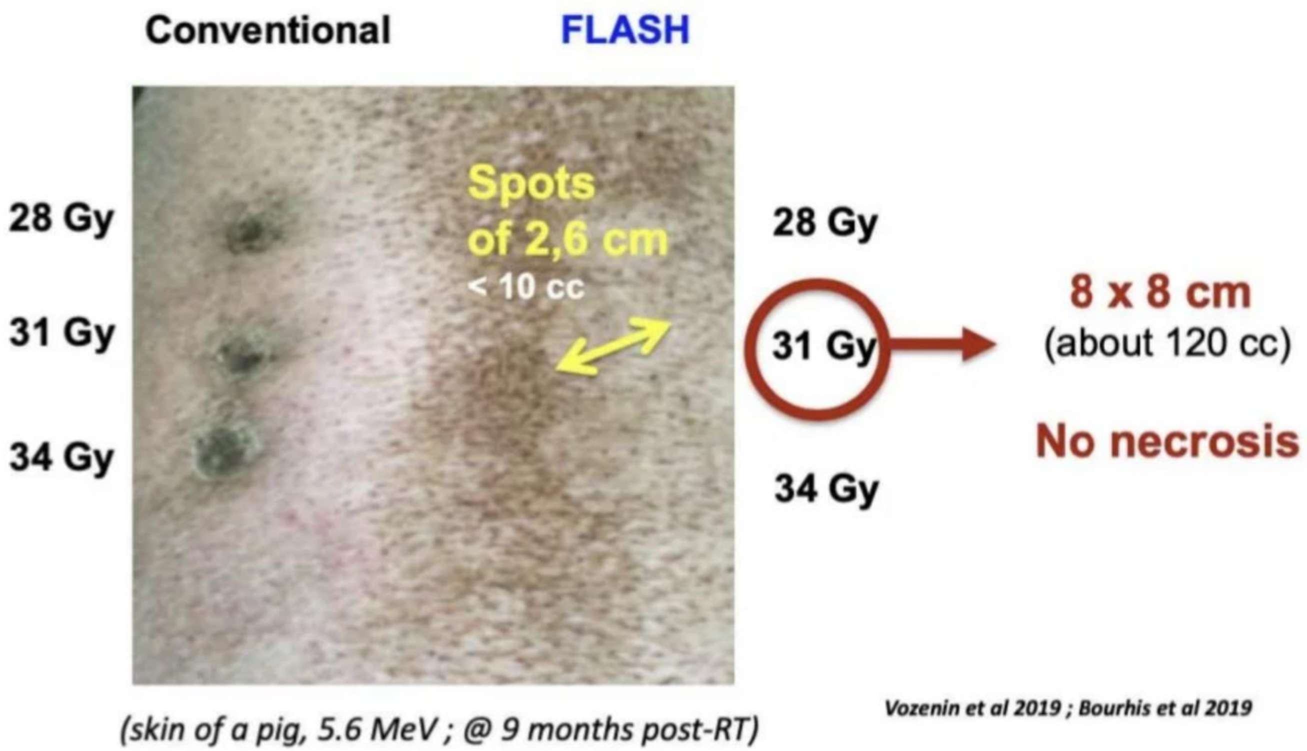
On going technique of Proton therapy

Flash therapy; Ultra high dose rate (~40 Gy/s)

Spatially Fractionated RT

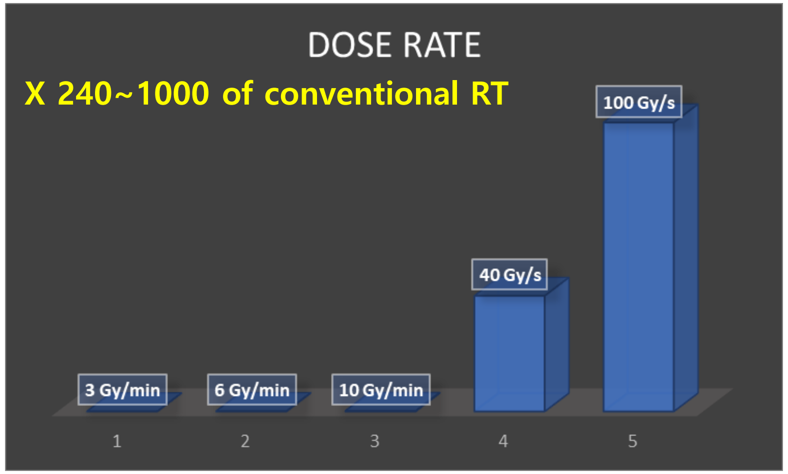
Flash therapy

❖ Described by Town et al. (1967) first
❖ Applied to tumors first (Favaudon & Vozenin eta al. 2015)
❖ Bourhis et al. (2019): first patient treatment



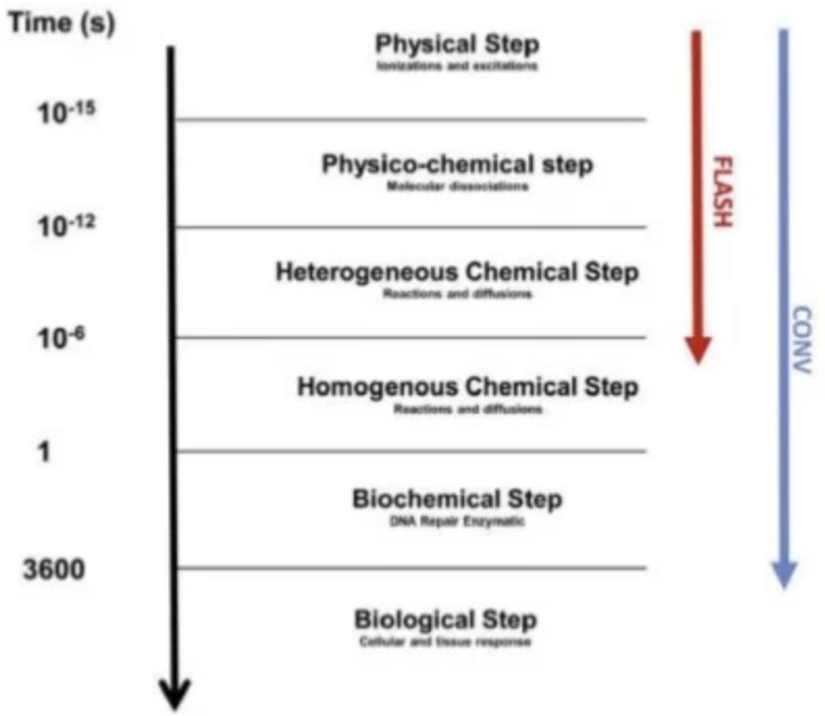
Physical parameters: FLASH Effects

- Dose rate: >40 Gray/sec (possible); >100-150 Gray/sec (likely)
- Reproducible effect
  - Dose / pulse (> 1.5 Gy & few pulses)
  - Dose rate in the pulse (>= 10^6 Gy /s)
  - Overall time (< 100 ms)
- Dose/fraction
  - Begins to show up at >10 Gray/fraction
  - No dose limiting effect observed in animal models between 25-41 Gray
- Radiation type
  - Most reproducible with electrons
  - Ongoing work on X-rays and protons



Biological effect

- Complete oxygen depletion in cells: well oxygenated normal tissues are spared
- Difference in redox biology of the oxygen metabolism
- Different immune effect (less cytokine release: less normal tissue damage)
- Differential gene expression induced by FLASH



Spatially Fractionated therapy

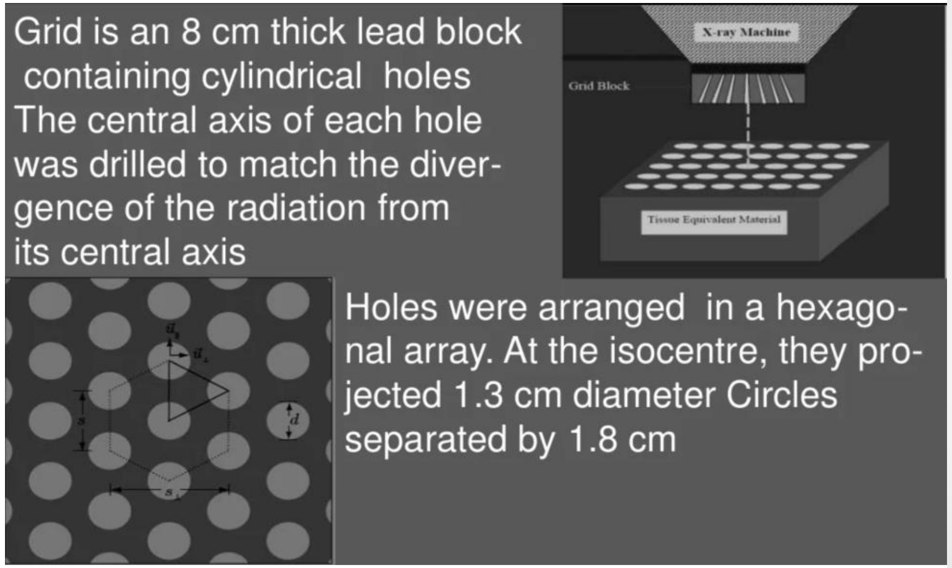
(Grid, Microbeam, Minibeam …)

- ❖ Kohler (2909): radiation through a “perforated screen” creating an effect similar to treatment with multiple small pencil beam
- ❖ Liverson (1933): used this technique for the successful treatment of deep seated cancers

SFRT

Delivery of radiation in clusters of small areas without producing prohibitive normal tissue damage to the skin and subcutaneous tissue

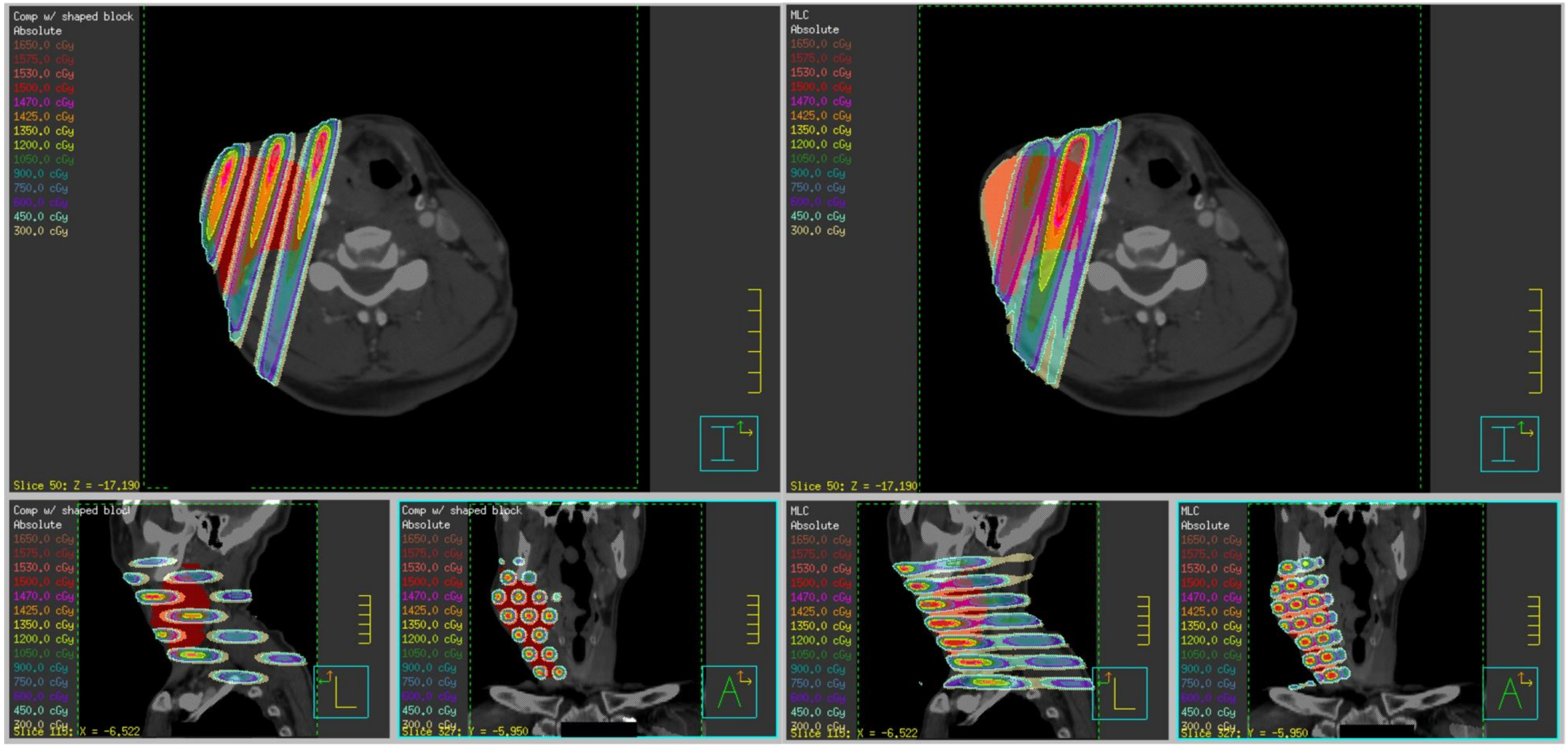
Small volume of skin could safely tolerate high doses of radiation



SFRT

- Exact biological response is not fully known
- Believed that high single GRID dose incites reoxygenation with a high tumor cell kill
- Reoxygenation can then begin more rapid tumor response and higher efficiency of a traditional external beam fractionation following GRID
- Bystander effect may also contribute to effectiveness of GRID
- High direct cell kill
- Can cause indirect cell kill of nearby cells due to excretion of cytokines upon death of the nearby cells

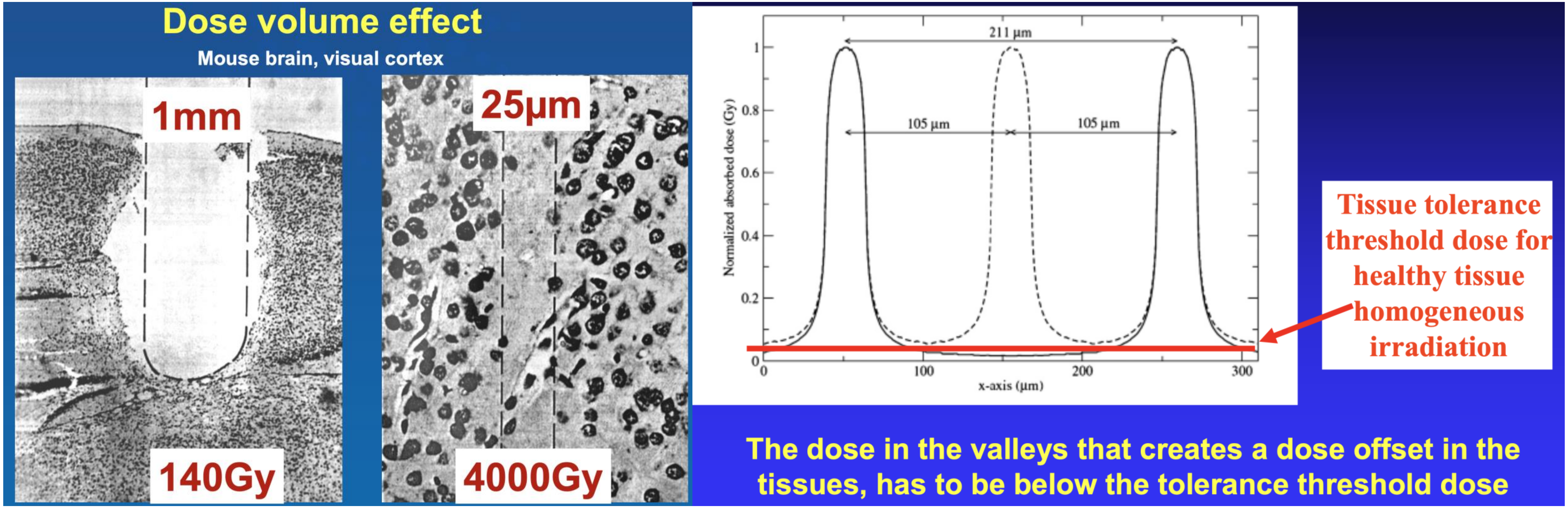
SFRT



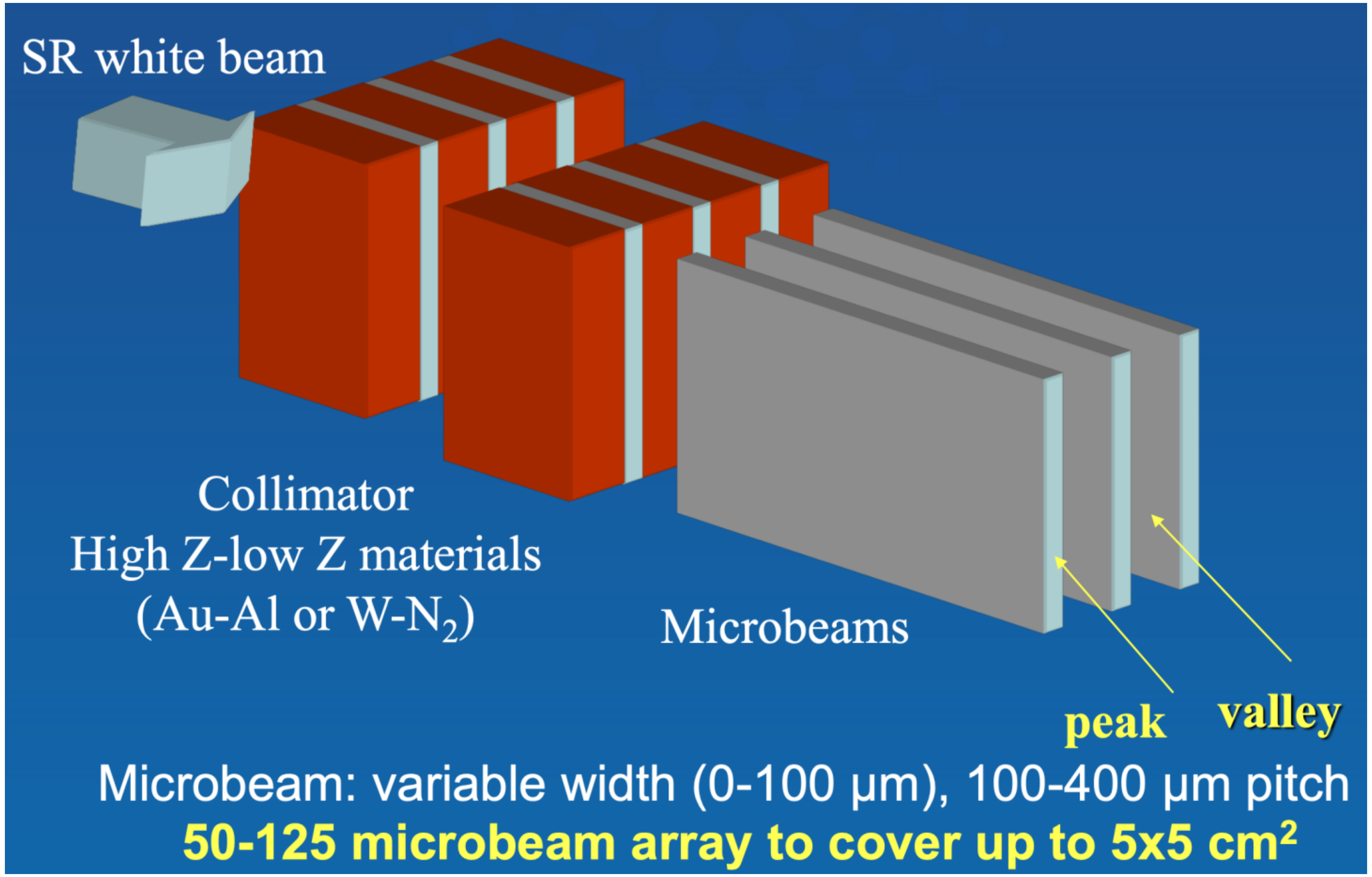
Grid Compensator | MLC based

(4) Buckey, Courtney et al. Evaluation of a commercially-available block for spatially fractionated radiation therapy. **Journal of Applied Clinical Medical Physics**, [S.l.], v. 11, n. 3, apr. 2010. ISSN 15269914.

SFRT, micro-beam



SFRT, micro → mini-beam

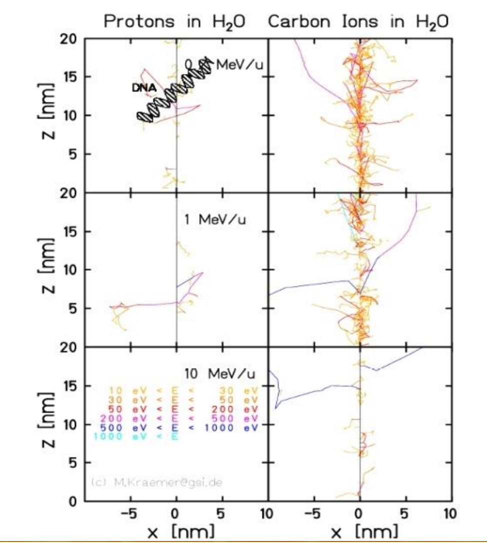


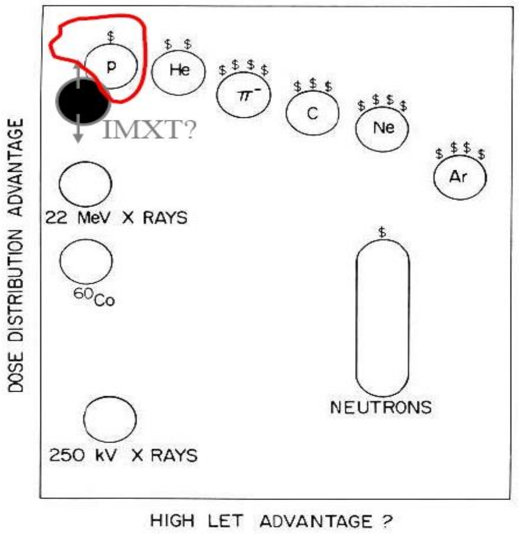
~ mm

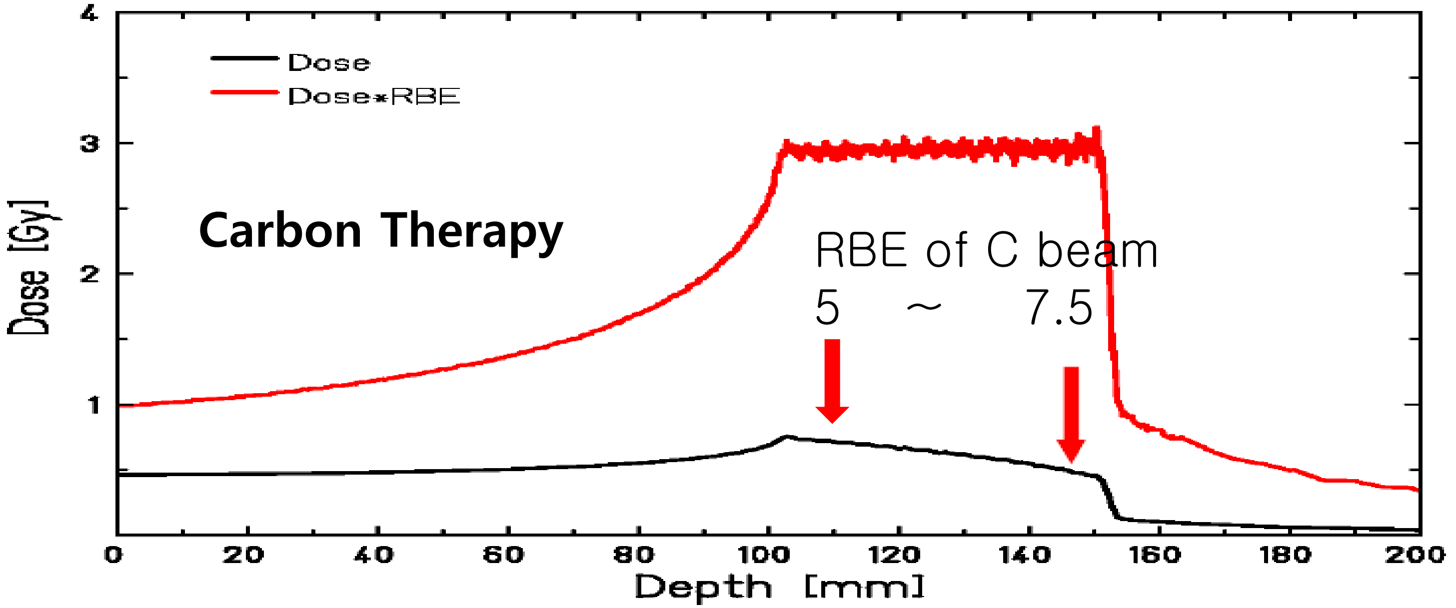
Mini-beam

Carbon Therapy

RBE consideration for heavy ions



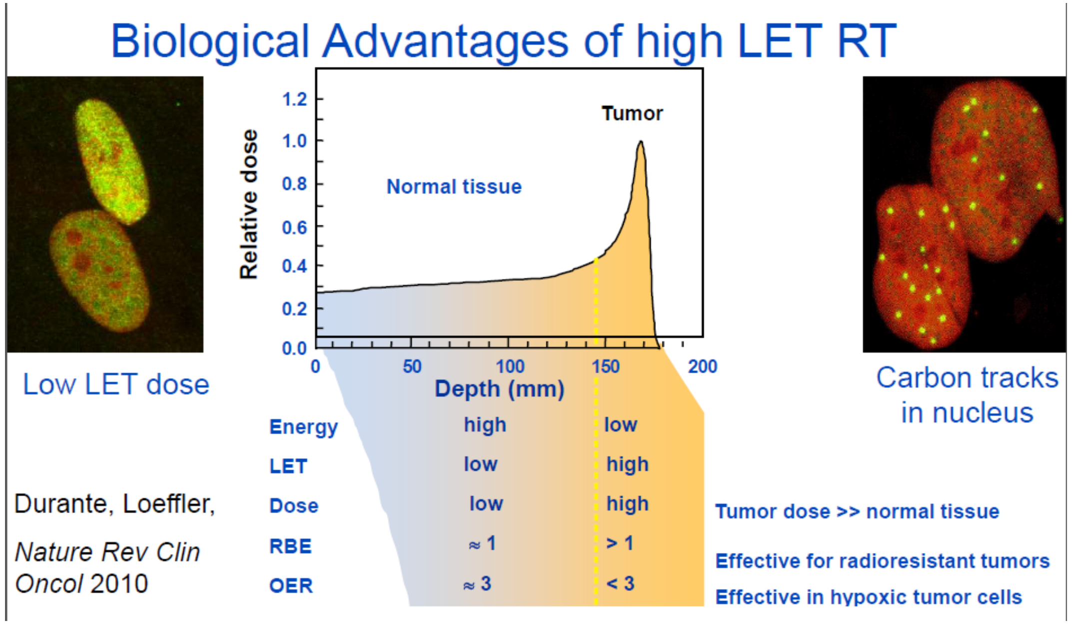




Carbon Therapy Advantages

Physical advantages
of heavier ions vs. protons

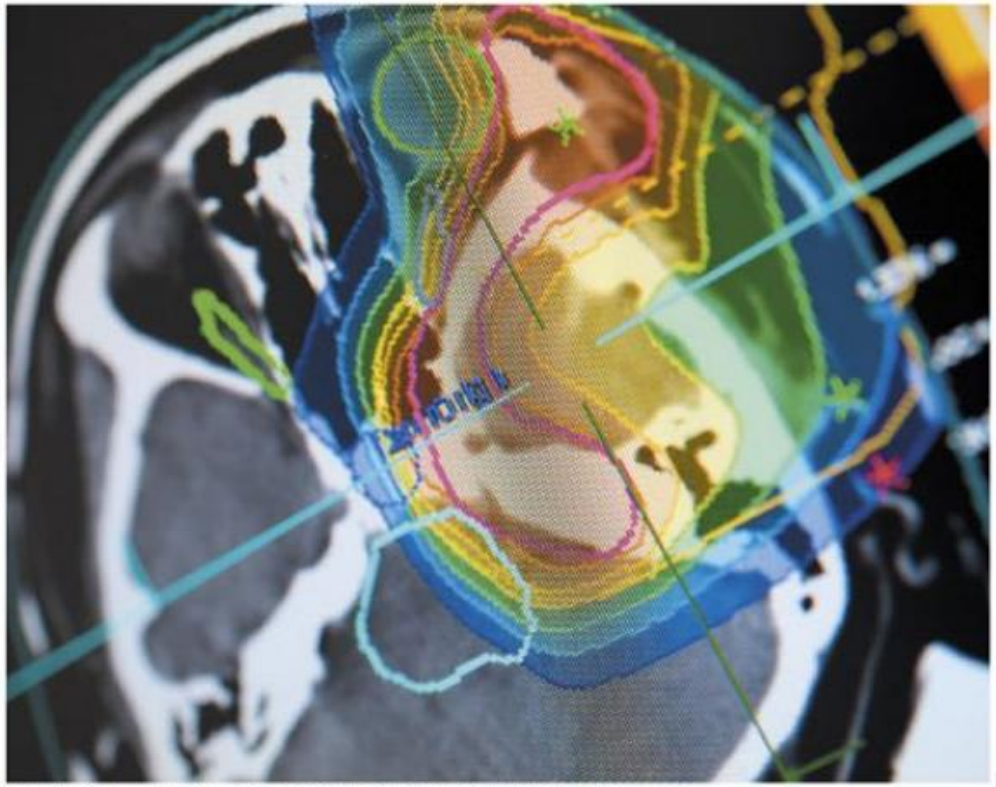
- Reduced angular scattering: sharper penumbra
- Reduced range straggling: sharper distal fall-off
- Better targeting due to better in-vivo monitoring
- There is a whole variety of heavy ions



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.



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

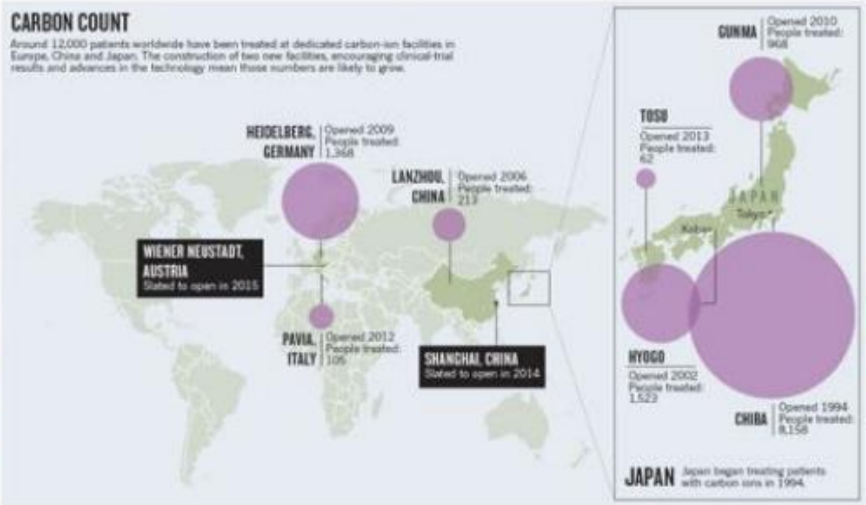
BY VIVIEN MARX

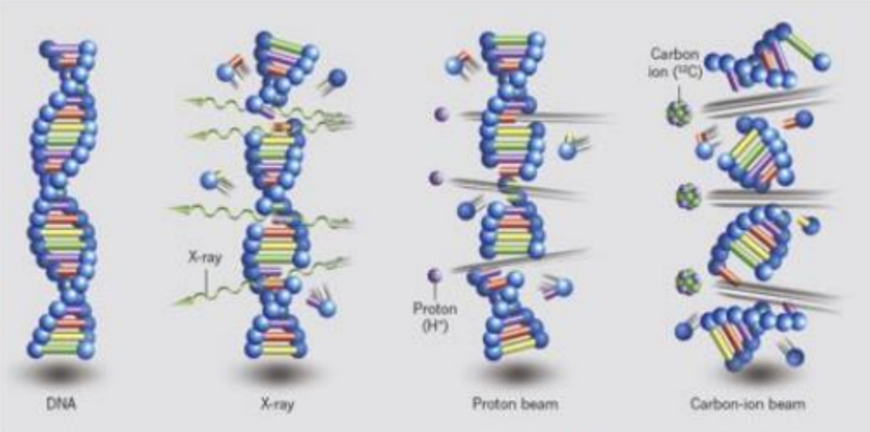
Clinicians attack cancer with many types of weapon, ranging from scalpels to physically remove all or most of a tumour to drugs that kill the tumour cells where they are. In about half of people with cancer, doctors go after the malignant cells with ionizing radiation.

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. ... 100,000 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 ▶

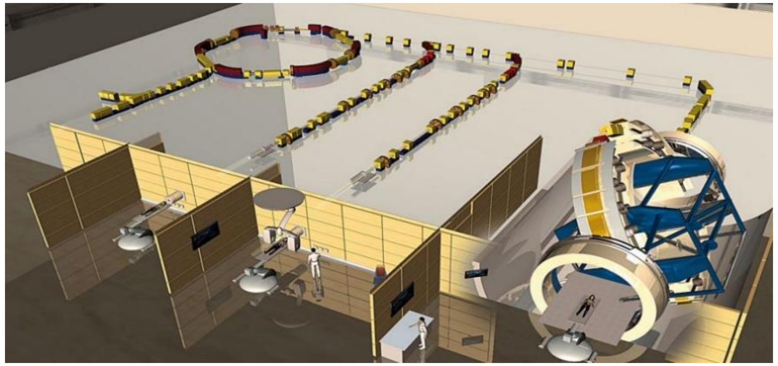
Cancer treatment: Sharp shooters,
Nature 508, 133–138 (03 April 2014)



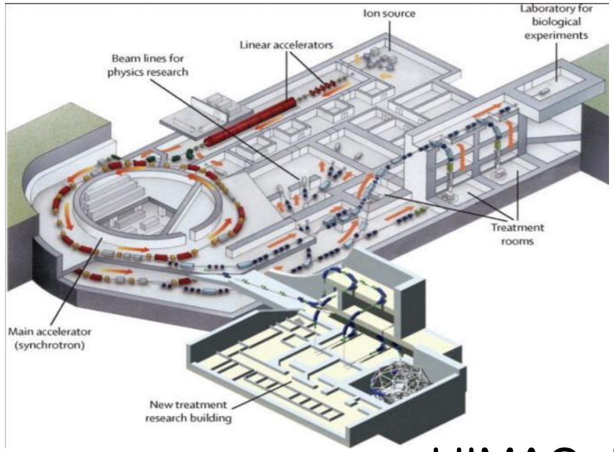


Radiation can kill cancer cells by damaging their DNA.
X-rays can hit or miss.
Protons are slightly more lethal to cancer cells than X-rays.
Carbon ions are around 2–3 times as damaging as X-rays.

Example of Carbon-Beam Therapy Center



HIT



HIMAC-NIRS

HIBMC

MedAustron

World Carbon-Beam Therapy Center

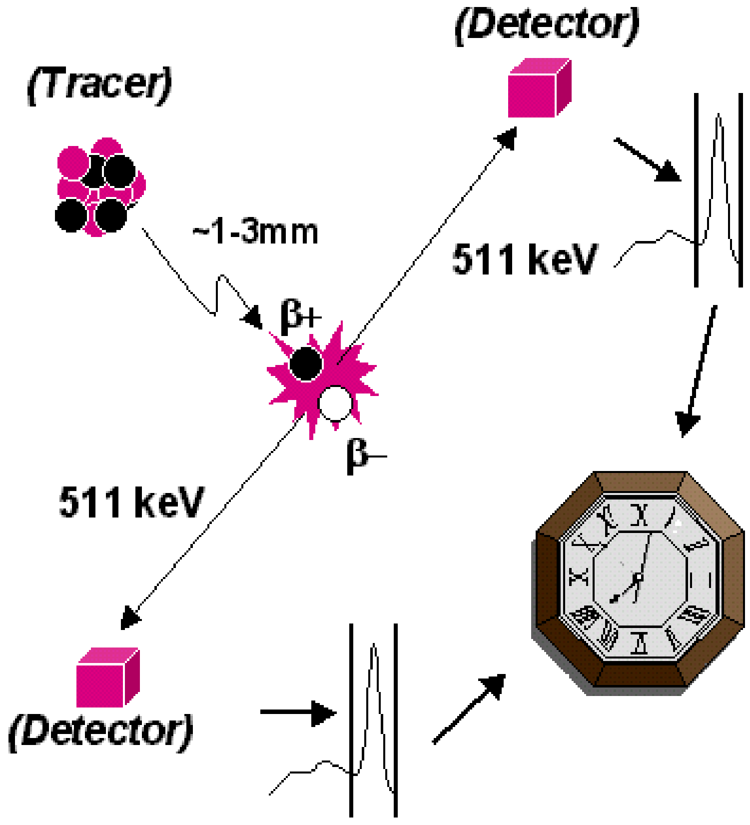
	COUNTRY	WHO, WHERE	PARTICLE	S/C/SC* MAX. ENERGY (MeV)	BEAM DIRECTIONS	START OF TREATMENT
1	Austria	MedAustron, Wiener Neustadt	C-ion	S 403/u	2 horiz. and 1 verticalfixed beam**	2019
2	China	SPHIC, Shanghai	C-ion	S 430/u	3 fixed beams**	2014
	China	Heavy Ion Cancer Treatment Center,	C-ion	S 400/u	4 fixed beams**	2019
2	Germany	HIT, Heidelberg	C-ion	S 430/u	2 fixed beams, 1 gantry**	2009, 2012
	Germany	MIT, Marburg	C-ion	S 430/u	3 horiz., 1 45deg. fixed beams**	2015
1	Italy	CNAO, Pavia	C-ion	S 480/u	3 horiz., 1 vertical, fixed beams	2012
7	Japan	HIMAC, QST, Chiba	C-ion	S 800/u	horiz.***, vertical***, fixed beams, 1 gantry	1994, 2017
	Japan	HIBMC, Hyogo	C-ion	S 320/u	horiz.,vertical, fixed beams	2002
	Japan	GHMC, Gunma	C-ion	S 400/u	3 horiz., 1 vertical, fixed beams	2010
	Japan	SAGA-HIMAT, Tosu	C-ion	S 400/u	3 horiz., vertical, 45 deg., fixed beams	2013
	Japan	i-Rock Kanagawa Cancer Center, Yokohama	C-ion	S 430/u	4 horiz., 2 vertical, fixed beams	2015
	Japan	Osaka Heavy Ion Therapy Center, Osaka	C-ion	S 430/u	3 fixed beams, 6 ports**	2018
	Japan	East Japan HIC,Yamagata University Hospital, Yamagata	C-ion	S 430/u	1 SC gantry**, 1 horiz. & vertical fixed beam	2021

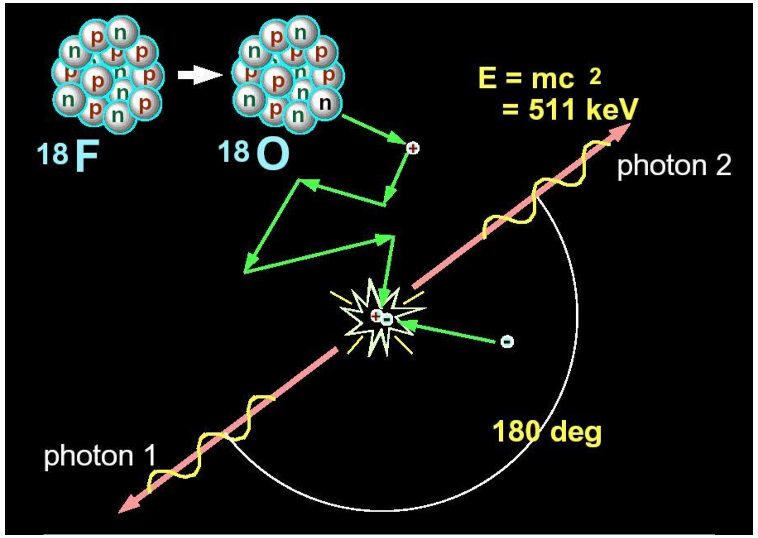
World Carbon-Beam Therapy Center (under construction)

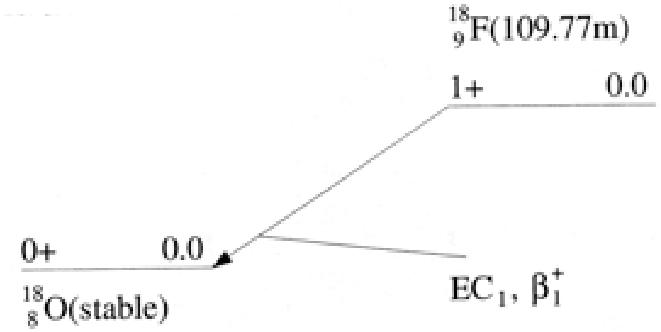
COUNTRY	WHO, WHERE	PARTICLE(S)	MAX. ENERGY (MeV) ACCELERATOR TYPE (VENDOR)*	BEAM DIRECTIONS	NO. OF TREATMENT ROOMS	START OF TREATMENT PLANNED
China	HITFil at IMP, Lanzhou, Gansu	C-ion	400/u synchrotron (?)	4 horiz, vertical, oblique, fixed beams	4	2022?
France	ARCHADE, Caen	C-ion	400/u cyclotron (IBA)	1 fixed beam (r&d)	1	2023
South Korea	Seoul National University Hospital, Busan	C-ion, He-ion	430/u for C, 230 MeV/u for He synchrotron (Toshiba)	1 gantry, 1 horiz. fixed beam	2	2025
South Korea	Yonsei University Hospital, Seoul	C-ion	430/u, synchrotron (Toshiba)	2 gantries, 1 horiz. fixed beam	3	2022
Taiwan	Taipei Veterans General Hospital, Taipei	C-ion	430/u synchrotron (Hitachi)	2 vertical and 2 horizontal fixed beams	2	2021/2022
USA	Mayo Carbon Ion Therapy Center, Jacksonville, FL.	p, C-ion	250, 430/u, synchrotron (Hitachi)	1 gantry (p), 2-3 fixed beams (C-ion)	3-4	2025+

Positron Emission Tomography?

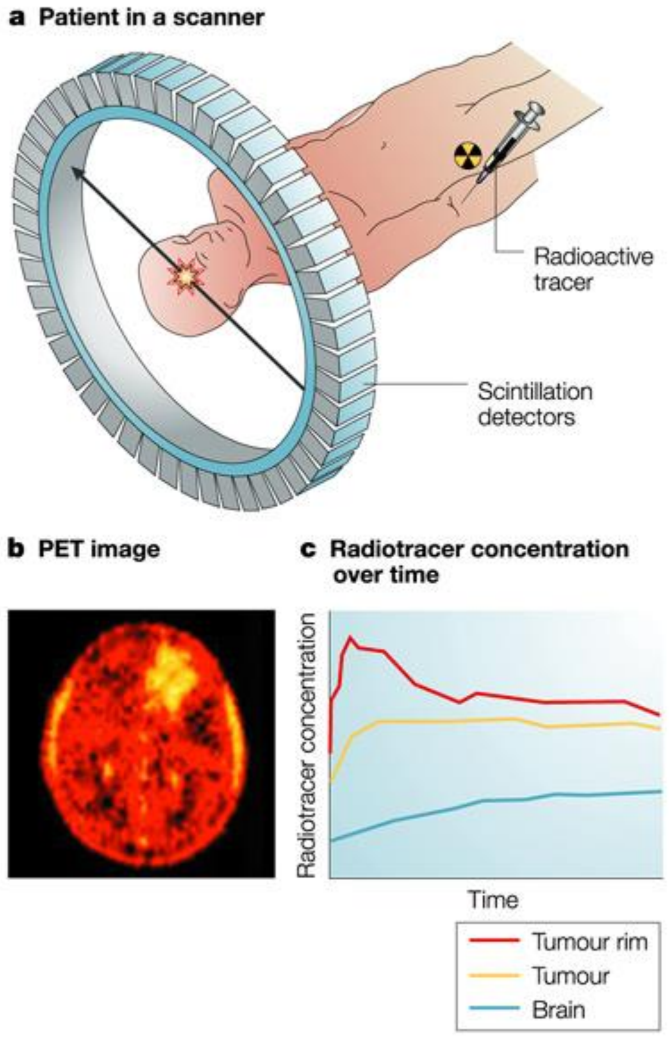
Positron Annihilation





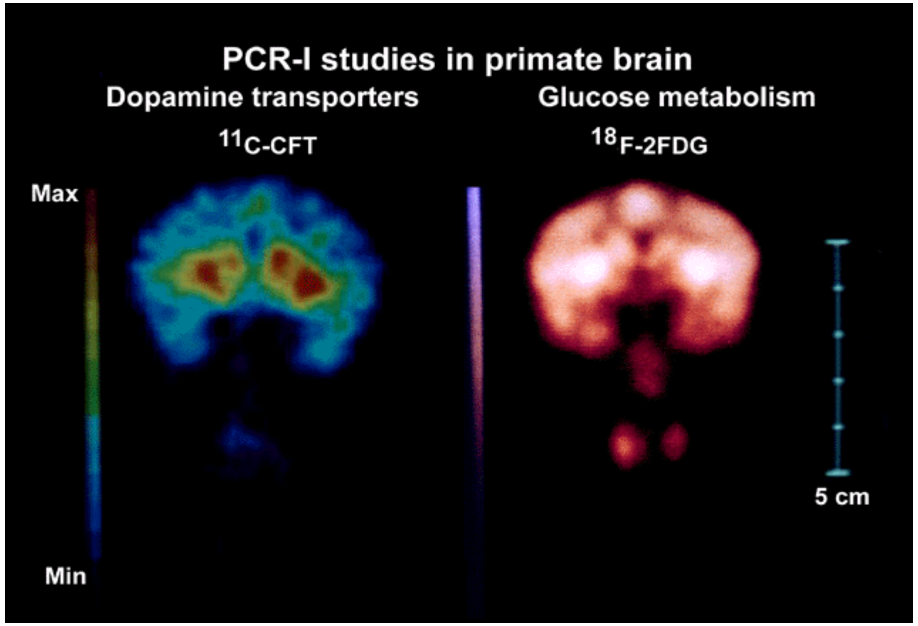


Clinical Use of PET – Functional Imaging

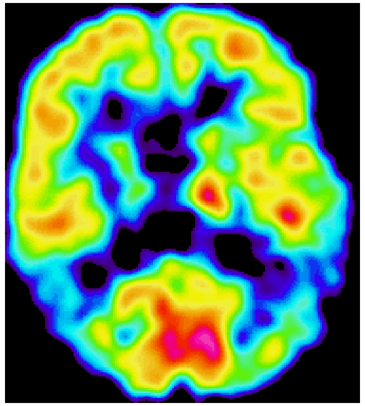


Nature Reviews | Cancer

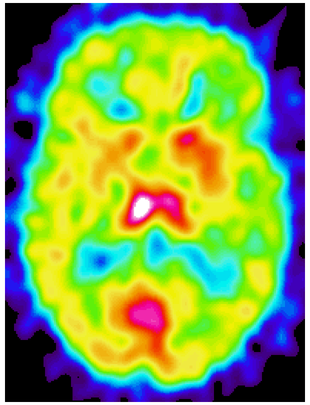
Single ring positron emission tomography (1985)



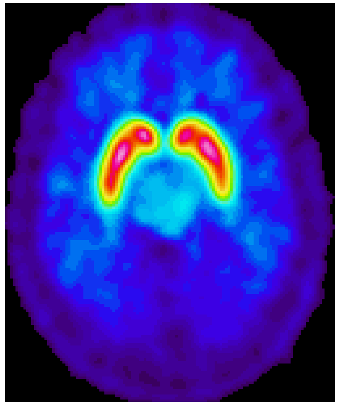
Example of PET imaging



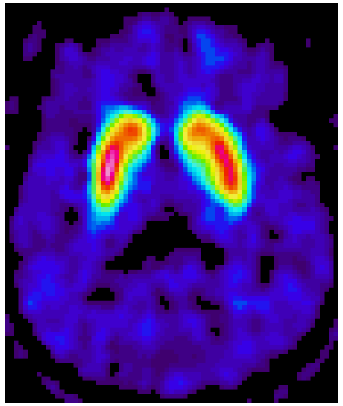
Glucose metabolism
^{18}F Fluorodeoxyglucose



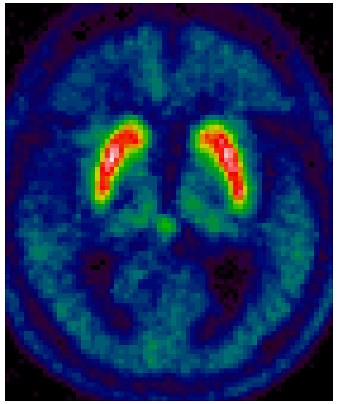
Inflammation
^{11}C D-Deprenyl



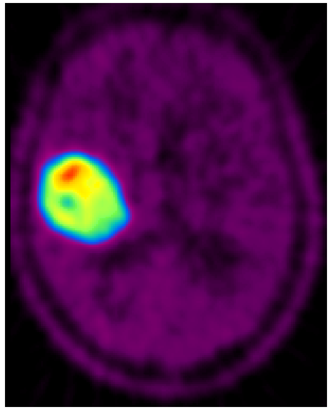
Dopamine reuptake
^{11}C BCIT



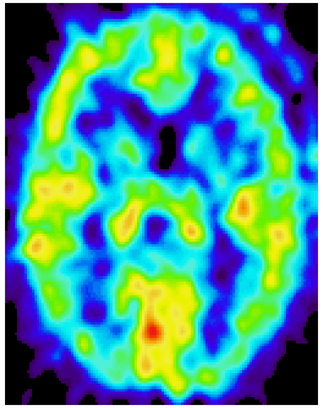
D2-receptors
^{11}C Raclopride



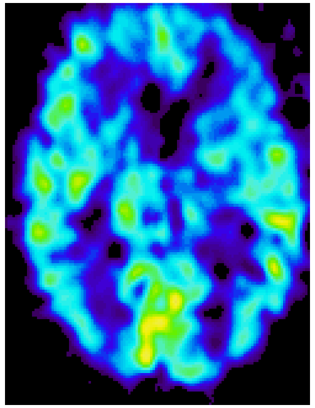
Dopamine synthesis
^{18}F Dopa



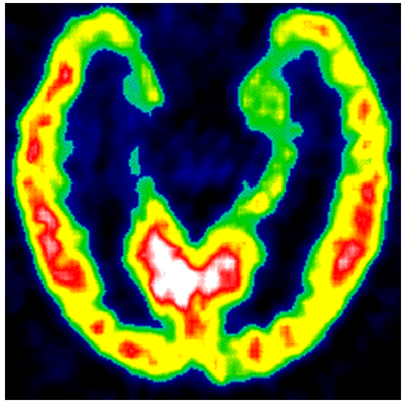
Amino acid uptake
^{11}C Methionin



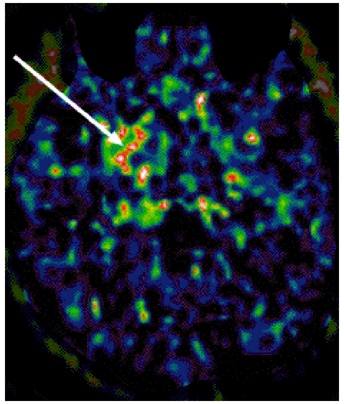
Blood flow
^{15}O Water



Oxygen Consumption
^{15}O Oxygen



Central BZ-receptors
^{11}C Flumazenil

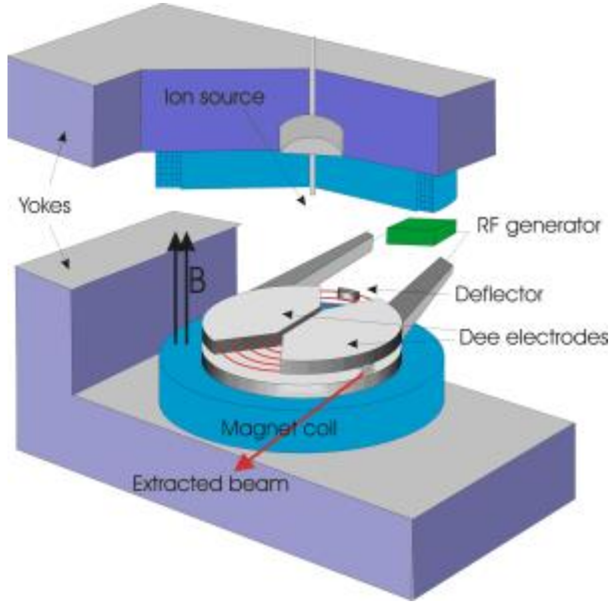


Microglia activation
^{11}C PK11195

Radio-nuclides Production using Particle Accelerators

Nuclide	Half-life
C-11	20.3 min.
N-13	10 min.
O-15	124 sec.
F-18	**110 min.**
Rb-82	75 sec.

Cyclotron



A Course of Radiation Therapy

Radiography

- In 1895, Wilhelm Conrad Röentgen discovered new kinds of ray emitted by a gas discharge tube that could blacken photographic film.
- The first radiograph.

Rontgen Museum, Germany

2) 방사선치료의 역사

1895 Roentgen – X-ray

1898 Curie – Radium (brachytherapy)

1900 Becquerel – radiobiology

1922 Clinical approach(larynx cancer)

1934 Fractionated radiation therapy

1970- Computer Treatment Planning System

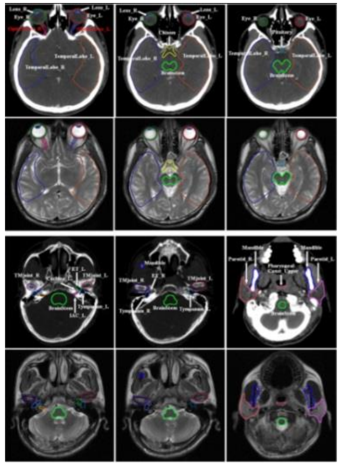
1980- 3D Conformal Radiation Therapy (CRT)

1990- Intensity Modulated Radiation Therapy (IMRT)

2000- Image Guided Radiation Therapy (IGRT)

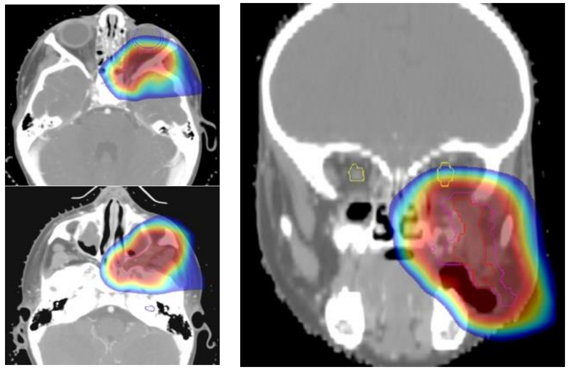
Radiation Treatment

CT simulation



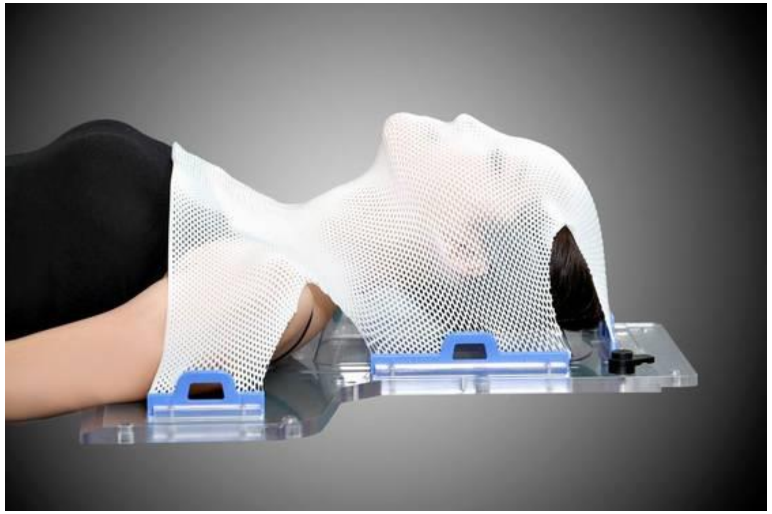
Organs & Tumors Segmentation

Treatment Planning



Radiation Treatment & Radiation Dose Distribution on Patient Body

CT simulation



US, MR, PET, …

❖ Usefulness of CT

(a) delineation of target volume and the surrounding structures in relation to the external contour → most important

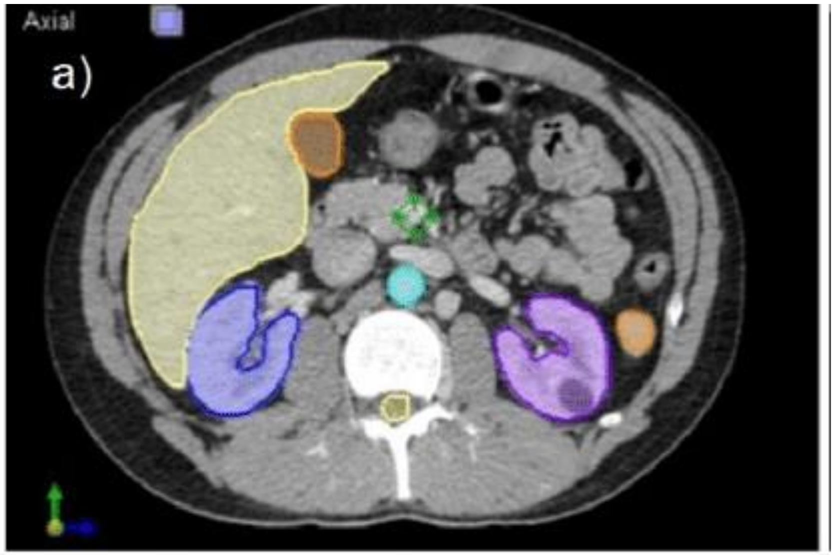
- not only crucial for optimizing a treatment technique
- but also necessary for accurate calculation of dose distribution

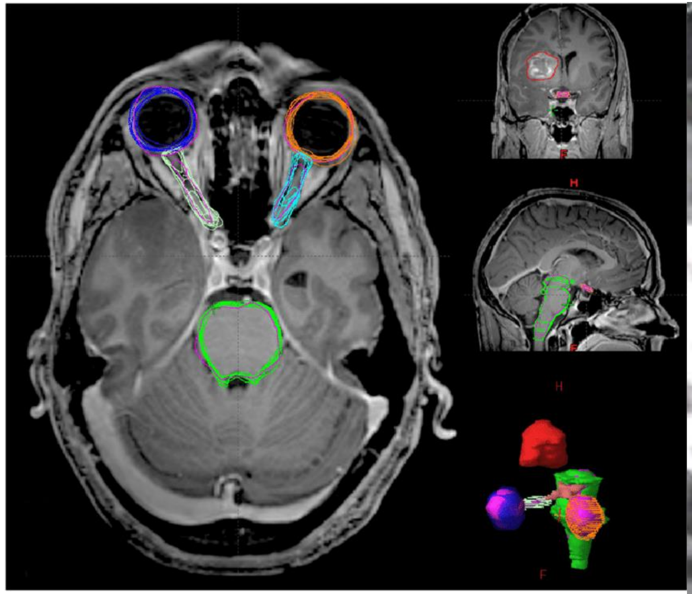
(b) providing quantitative data for tissue heterogeneity corrections

❖ The most severe errors in computing the dose distribution are caused by inaccurate delineation of the geometric outlines of tissue inhomogeneities rather than inaccurate relative electron density for the inhomogeneity

- However, severe dose gradient region in the direction of the beam → greater precision in the inhomogeneity outline and electron density are required
- For electron beam therapy, and in regions where electronic equilibrium is not established in high-energy photon beam
  → Pixel-by-pixel correction method
- In the case of lung correction, dose calculation algorithms based on electron transport (convolution/superposition or Monte Carlo) are necessary to provide accuracy of better than 5%

Segmentation





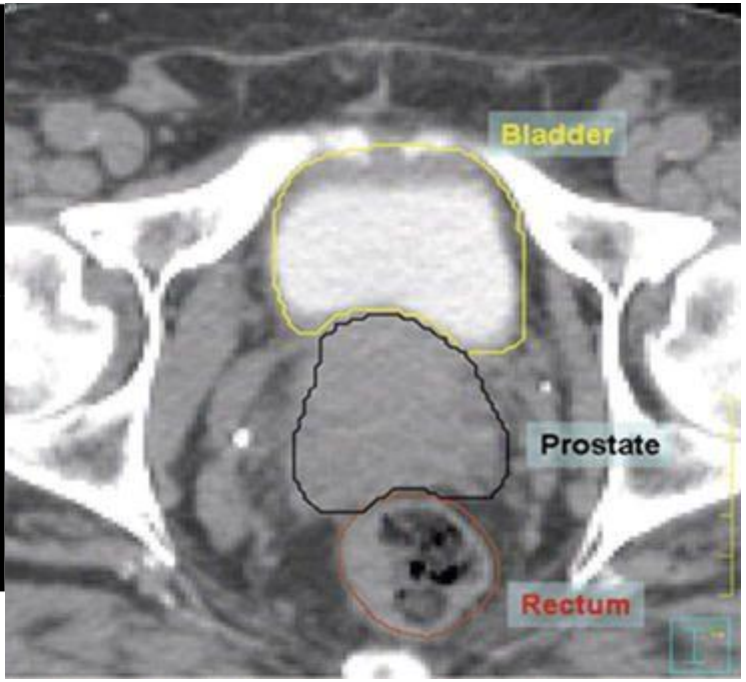
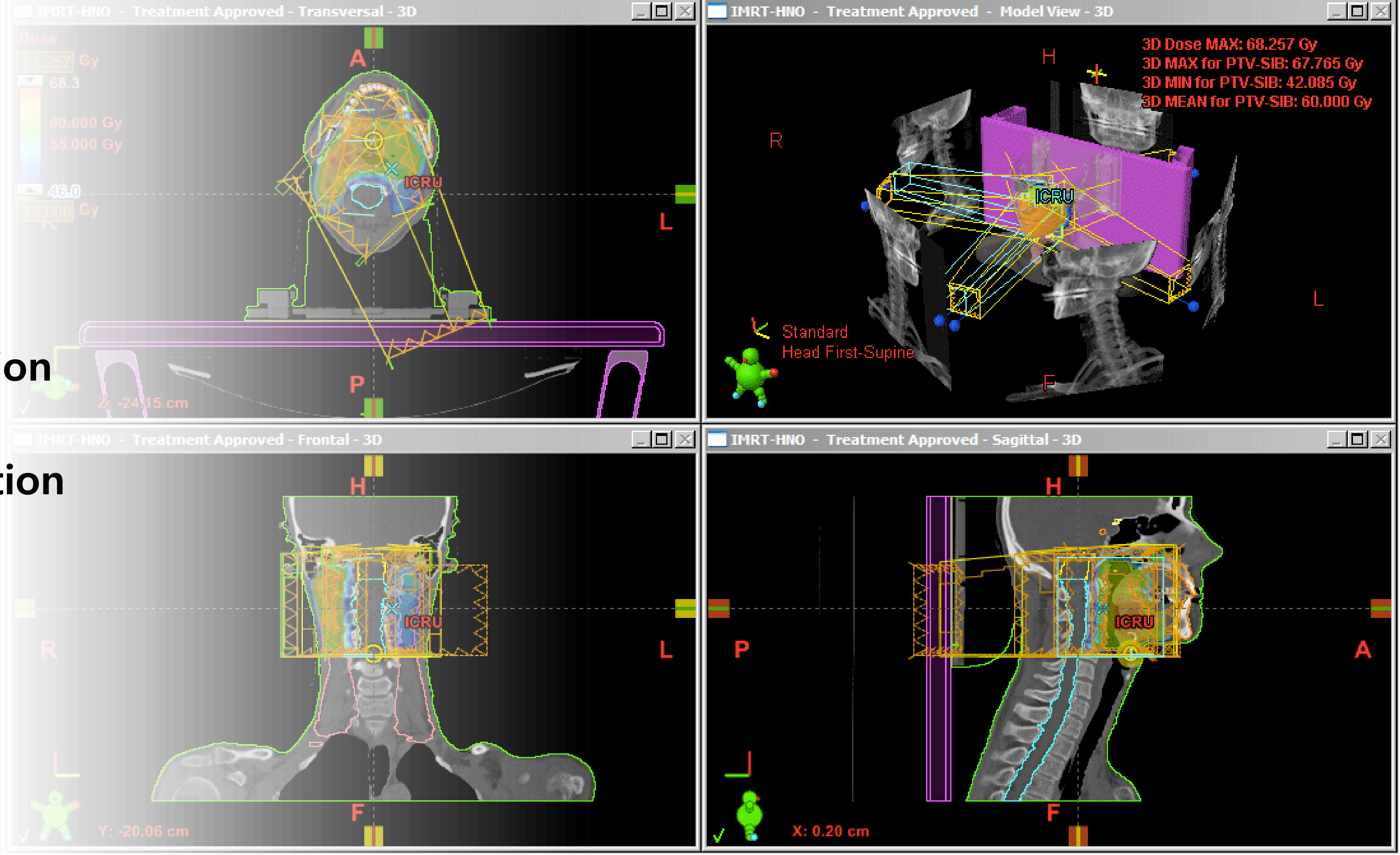


Image registration

Auto segmentation

RT Planning

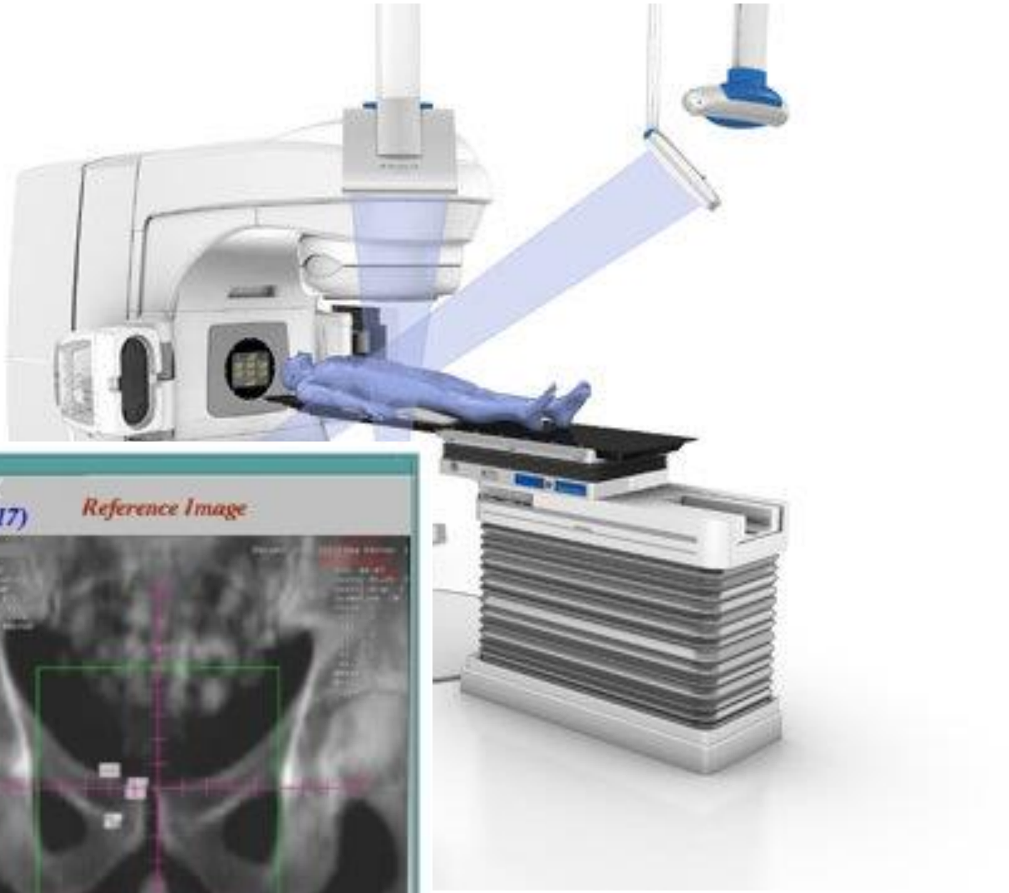
- Energy fluence Optimization
- MLC movement optimization
- Dose calculation
- Plan Evaluation
- Machine data interface
- Patient Specific Plan QA



Field Alignments | Plan Objectives | Optimization Objectives | Dose Statistics | Calculation Models | Plan Sum

que	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	SSD [cm]	MU	Ref. D [Gy]
C-I	Clinac BLAU - 6X		0.00	Varian IEC	0.0	90.0	0.0	None	8.6	+0.2	+8.4	10.0	+5.0	+5.0	0.2	-24.8	-28.4	99.0		
C-I	Clinac BLAU - 6X		0.00	Varian IEC	270.0	90.0	0.0	None	9.0	+0.2	+8.8	9.6	+2.9	+6.7	0.2	-24.8	-28.4	98.1		
C-I	Clinac BLAU - 6X	Dose Dynamic	1.00	Varian IEC	283.9	90.0	0.0	None	10.2	+0.2	+10.0	11.8	+3.8	+8.0	0.2	-24.8	-28.4	98.5	112	
C-I	Clinac BLAU - 6X	Dose Dynamic	1.00	Varian IEC	223.1	90.0	0.0	None	10.2	+0.2	+10.0	11.3	+4.0	+7.3	0.2	-24.8	-28.4	92.8	145	
C-I	Clinac BLAU - 6X	Dose Dynamic	1.00	Varian IEC	5.1	90.0	0.0	None	10.0	+0.2	+9.8	10.0	+5.0	+5.0	0.2	-24.8	-28.4	99.0	114	
C-I	Clinac BLAU - 6X	Dose Dynamic	1.00	Varian IEC	76.1	90.0	0.0	None	10.2	+0.2	+10.0	11.0	+7.0	+4.0	0.2	-24.8	-28.4	98.1	121	
C-I	Clinac BLAU - 6X	Dose Dynamic	1.00	Varian IEC	157.2	90.0	0.0	None	10.2	+0.2	+10.0	12.0	+8.0	+4.0	0.2	-24.8	-28.4	82.4	141	

Patient Setup



DRR construction

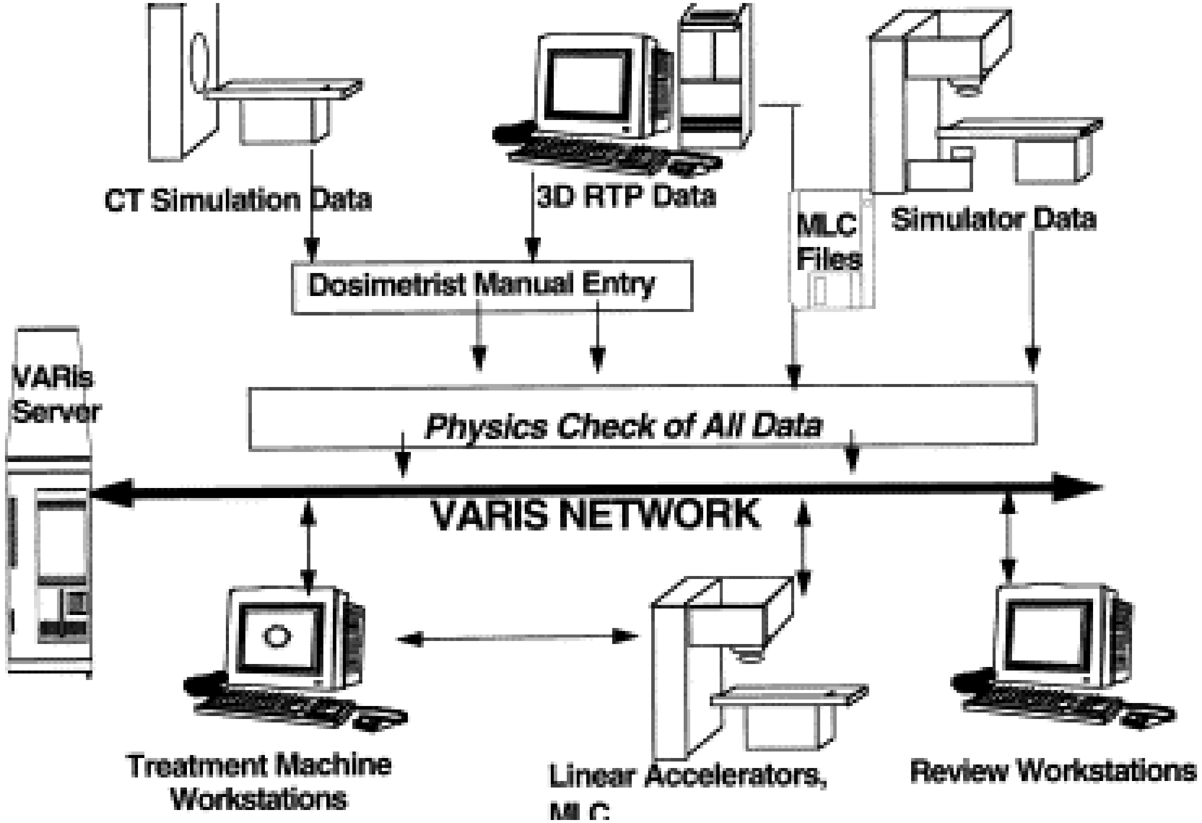
Patient positioning

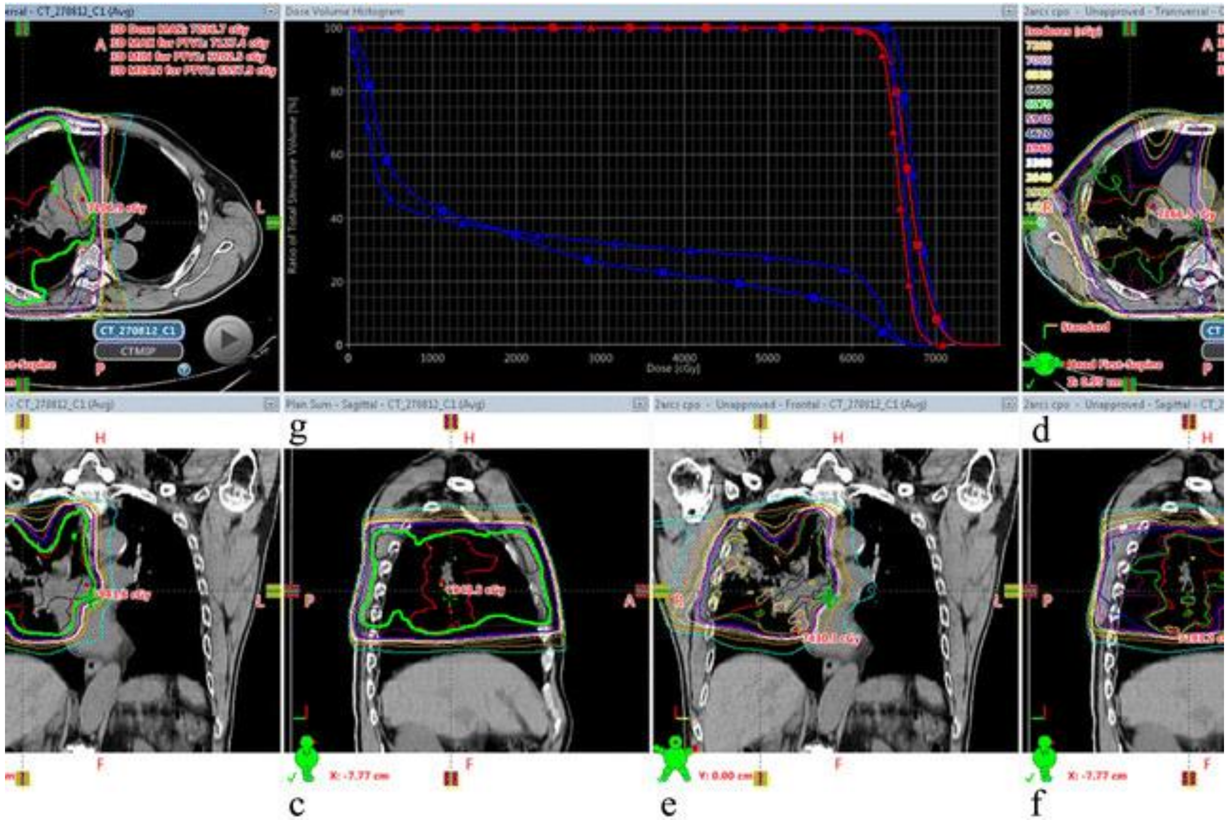
Patient Immobilization

RT Treatment

- Image guidance
- Tumor tracking
- Patient monitoring
- Patient shielding

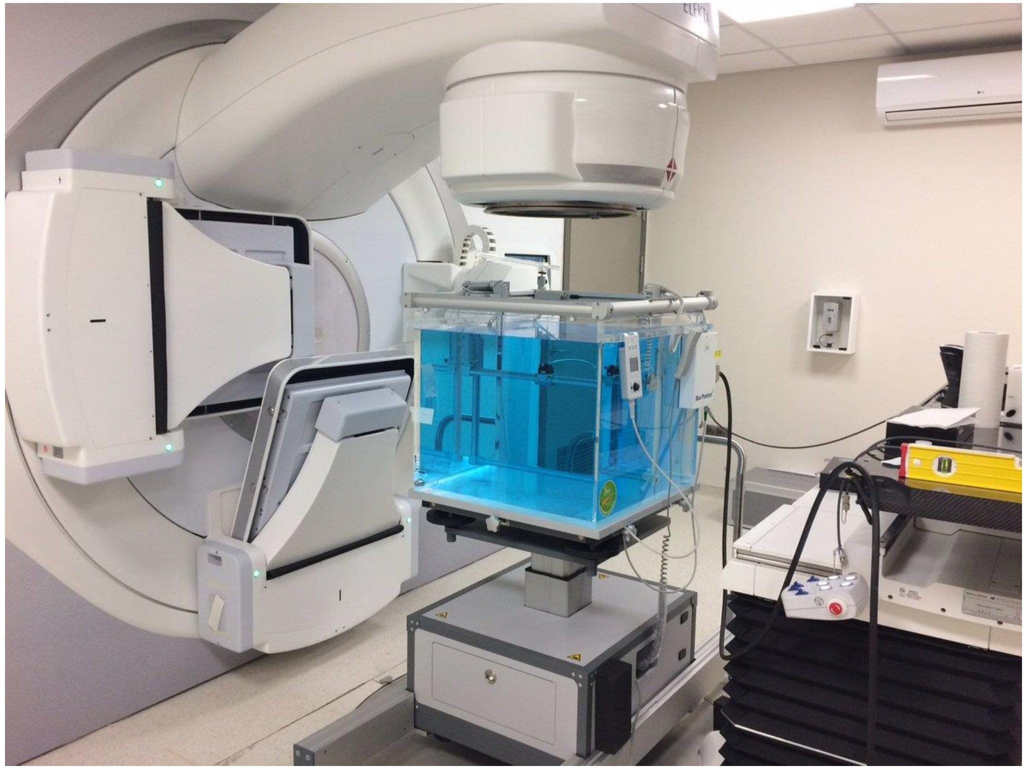
RT Record and Verify





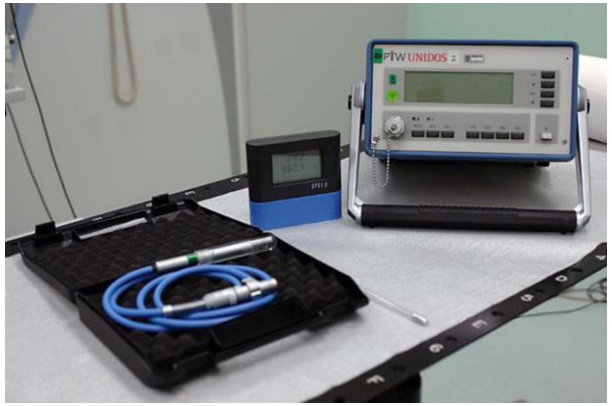
Quality Assurance

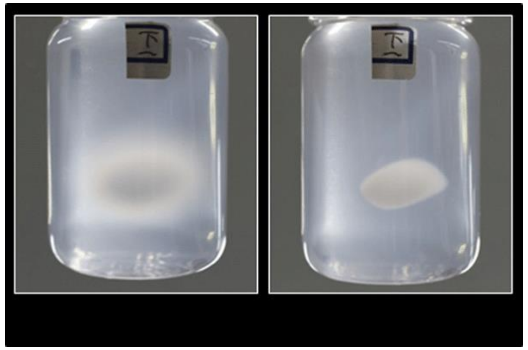
Machine QA



Patient QA

Radiation Dosimetry





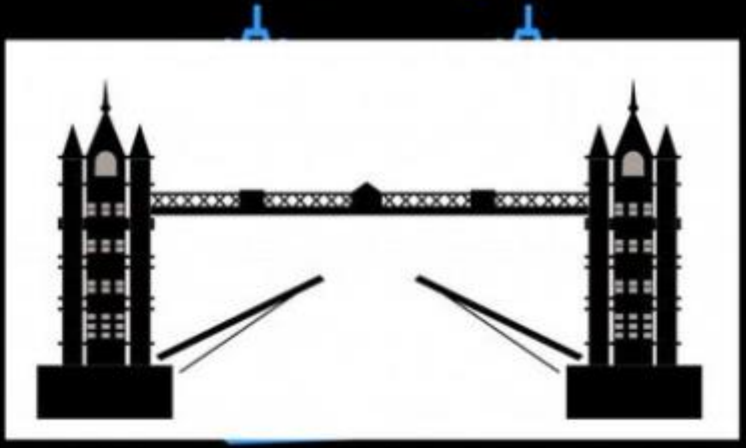
Medical Physics

What is Medical Physics?

Application of the concepts and methods of physics to the diagnosis and treatment of human disease

Medical Physicist

Physics



Medicine

Slide adapted from AAPM Medical Physics Education Presentation

International Labour Organization

Promoting jobs, protecting people

Medical Physicists (Revised definition provided by International Organisation for Medical Physicists)

Medical Physicists apply knowledge and methodology of science of physics to all aspects of medicine, to conduct research, develop or improve theories and address problems related to diagnosis, treatment, and rehabilitation of human disease. They are directly involved with patients and people with disabilities.

Tasks include –

(a) Conducting research into human disorders, illnesses and disabilities; investigating biophysical techniques associated with any branch of medicine.

(b) Conducting specialised examinations of patients and the disabled, improving patient care and clinical services, developing innovative imaging and non-imaging diagnostic

What Medical Physics Covers

Medical Physics is a branch of Applied Physics, pursued by medical physicists, that uses physics principles, methods and techniques in practice and research for the **prevention**, **diagnosis** and **treatment** of human diseases with a specific goal of improving human health and well-being.

Medical physics may further be classified into a number of sub-fields (specialties), including **Radiation Oncology Physics**, **Medical Imaging Physics**, **Nuclear Medicine Physics**, **Medical Health Physics** (Radiation Protection in Medicine), **Non-ionizing Medical Radiation Physics**, and **Physiological Measurement**.

It is also closely linked to neighboring sciences such as Biophysics, Biological Physics, and Health Physics.

University of Cincinnati College of Medicine CAMPEP

First Year		
Semester 1	**Course Title**	**Credit Hrs.**
MP-9001	Professional Aspects of Medical Physics	2
BE-7022	Introduction to Biostatistics	3
MP-9041	Radiobiology I	2
MP-9044	Radiation Physics and Dosimetry I	3
MP-9050	Diagnostic Radiological Imaging Physics I	3
MP-9005	Introduction to Clinical Oncology I	1
MP-9092	Seminar: Current Research Topics in Radiological Sciences	1
	Total: 15	
Semester 2	**Course Title**	**Credit Hrs.**
MP-9041	Radiobiology II	2
MP-9045	Radiation Physics and Dosimetry II	3
MP-9051	Diagnostic Radiological Imaging Physics II	3
MP-9095	Anatomy and Physiology for Radiation Therapy Treatment Planning	3
MP-9072	Radiological Sciences Lab I	2
MP-9011	Clinical Radiation Dosimetry	3
MP-9092	Seminar: Current Research Topics in Radiological Science	1
Total: 17		

Second Year		
Semester 1	**Course Title**	**Credit Hrs.**
MP-9096	Radiotherapy Treatment Planning I	2
MP-9013	Hospital Radiation Protection	3
MP-9073	Radiological Sciences Lab II	2
MP-9093	Clinical Medical Physics	4
MP-9092	Seminar: Current Research Topics in Radiological Sciences	1
MP-9099	Research in Radiological Sciences	4
Total 16		
Semester 2	**Course Title**	**Credit Hrs.**
MP-9097	Radiotherapy Treatment Planning II	2
MP-9093	Clinical Medical Physics	5
MP-9093	Seminar: Current Research Topics in Radiological Sciences	1
MP-9099	Research in Radiological Sciences	5
Total 15		

Third Year		
Semester 1	**Course Title**	**Credit Hrs.**
MP-9015	Clinical Radiation Oncology	1
MP-9061	Clinical Practicum - 3D-CRT	5
MP-9081	QA in Radiation Therapy - Treatment Planning Devices	5
MP-9092	Seminar: Current Research Topics in Radiological Sciences	1
MP-9094	Journal Club	1
MP-9098	Clinical Research in Medical Physics	2
Total 15		
Semester 2	**Course Title**	**Credit Hrs.**
MP-9015	Clinical Radiation Oncology	1
MP-9061	Clinical Practicum - IMRT	5
MP-9082	QA in Radiation Therapy - Treatment Delivery Devices	5
MP-9092	Seminar: Current Research Topics in Radiological Sciences	1
MP-9094	Journal Club	1
MP-9098	Clinical Research in Medical Physics	2
Total 15		

Fourth Year		
Semester 1	**Course Title**	**Credit Hrs.**
MP-9015	Clinical Radiation Oncology	1
MP-9063	Clinical Practicum - SRS and SBRT	5
MP-9083	QA in Radiation Therapy - Imaging Devices	5
MP-9092	Seminar: Current Research Topics in Radiological Sciences	1
MP-9094	Journal Club	1
MP-9098	Clinical Research in Medical Physics	2
MP-9099	Special Topics in Medical Physics (Elective)	0-2
Total 15-17		
Semester 2	**Course Title**	**Credit Hrs.**
MP-9015	Clinical Radiation Oncology	1
MP-9064	Clinical Practicum - Brachytherapy	5
MP-9084	QA in Radiation Therapy - Patient Specific Dosimetry	5
MP-9092	Seminar: Current Research Topics in Radiological Sciences	1
MP-9094	Journal Club	1
MP-9098	Clinical Research in Medical Physics	2
MP-9099	Special Topics in Medical Physics (Elective)	0-2
Total 15-17		

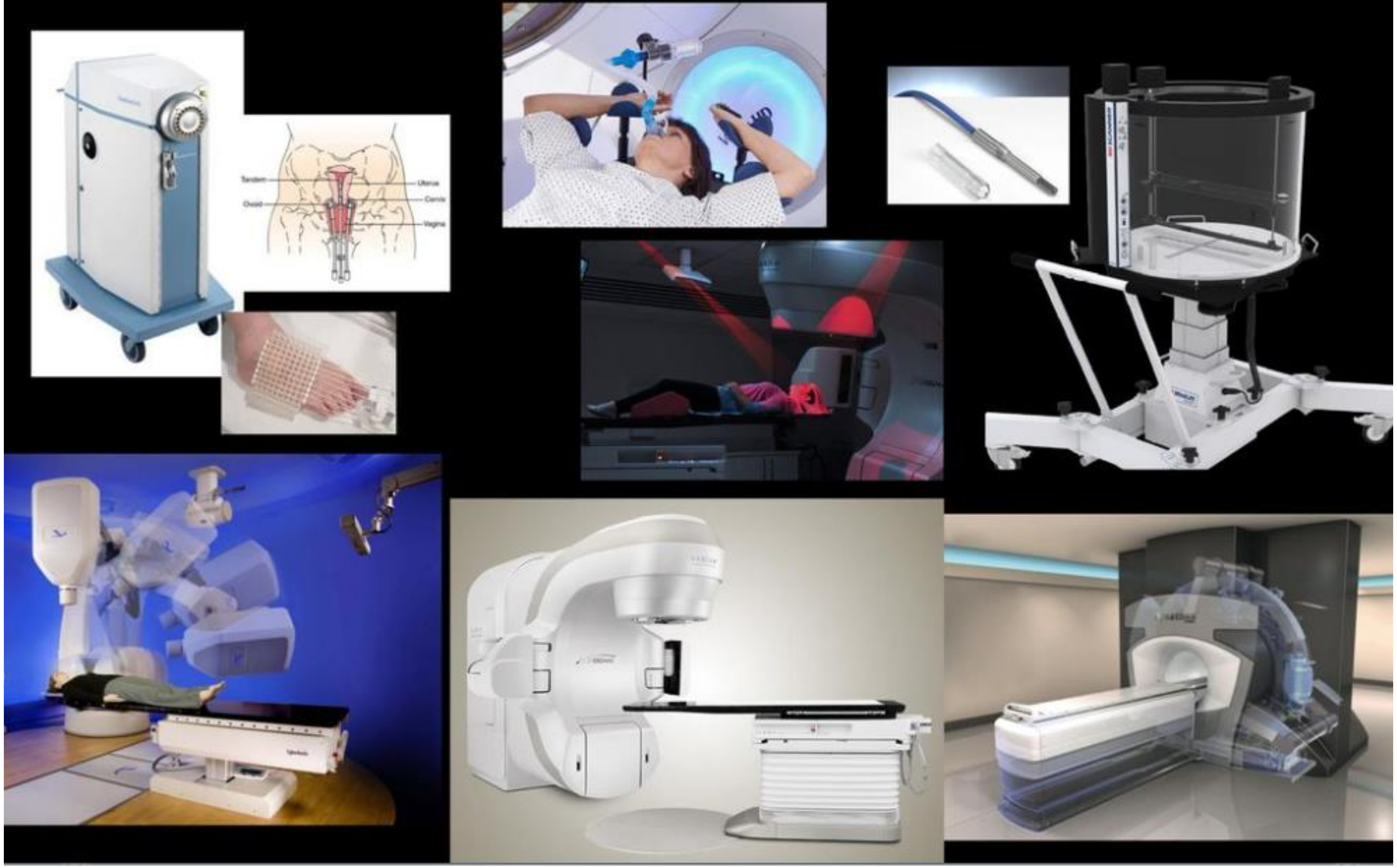
General Areas of Responsibility for Medical Physicist

- Clinical
- Research
- Education
- Regulatory Compliance

Medical Physics Disciplines

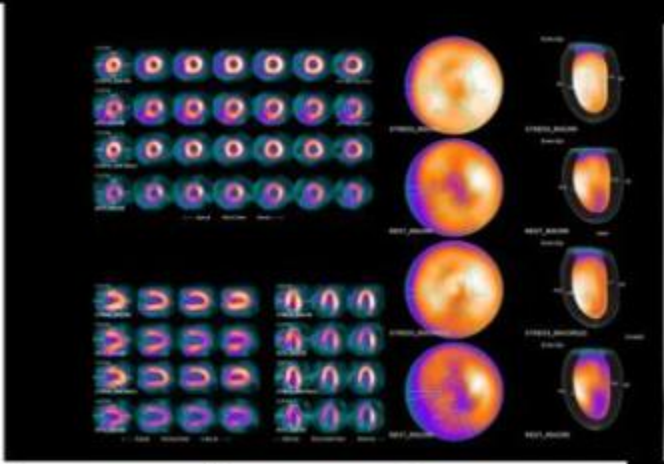
- Therapeutic Medical Physics — Radiation Oncology
- Diagnostic Medical Physics — Radiology
- Nuclear Medical Physics — Radiology
- Medical Health Physics — Radiation Safety

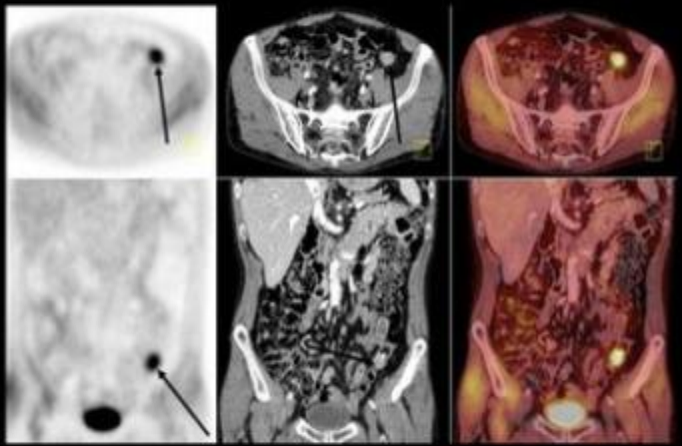
Therapeutic Medical Physics

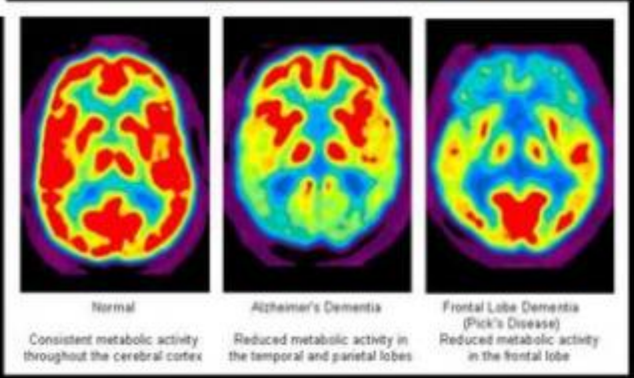


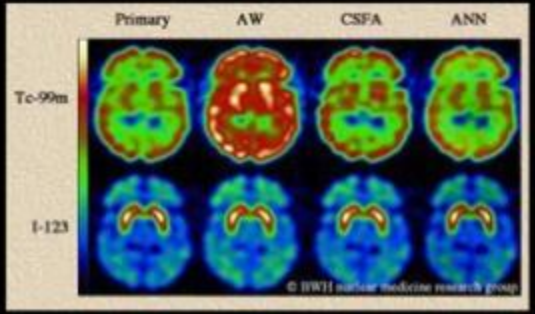
Diagnostic Medical Physics

Nuclear Medical Physics



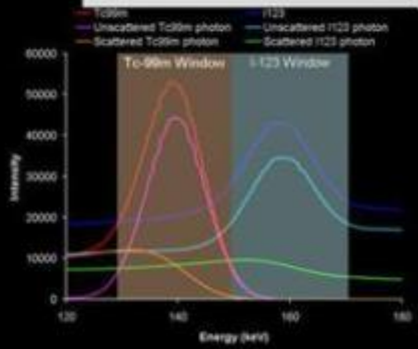






Brain perfusion

neurotransmission



Medical Health Physics

Radiation Protection
Radiation Safety Officer

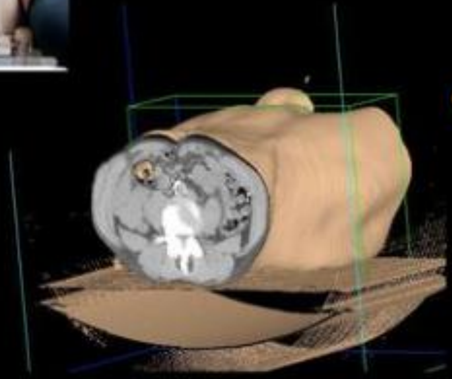
Therapeutic Medical Physicist

Radiation Therapy Process

- Diagnosis, staging, consultation
- Simulation
  - *Decide patient position*
  - *Take images*
- Planning
  - *Design the treatment*
- Treatment Delivery
  - *Implement your plan*
- Response Assessment

Safe and Efficient Treatment Delivery

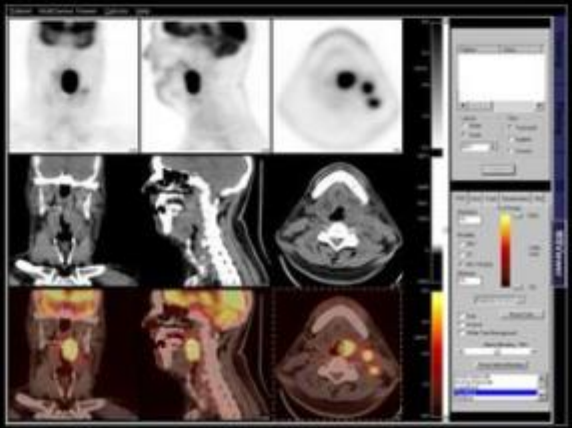
Simulation → Planning → Treatment

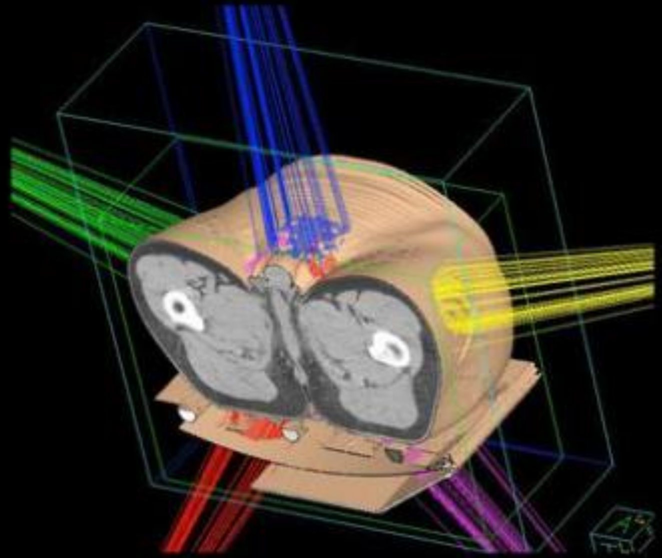


- Process
  - Immobilization
    - for patient positioning and reproducibility
  - Localization
    - establish a fixed coordinate system in relation to a reference point (Isocenter)
  - Modeling
    - 2D or 3D model of patient constructed through imaging
- Physicist:
  - CT scanner quality assurance
  - HU vs electron density table
  - Immobilization device assessment

Safe and Efficient Treatment Delivery

Simulation → **Planning** → Treatment



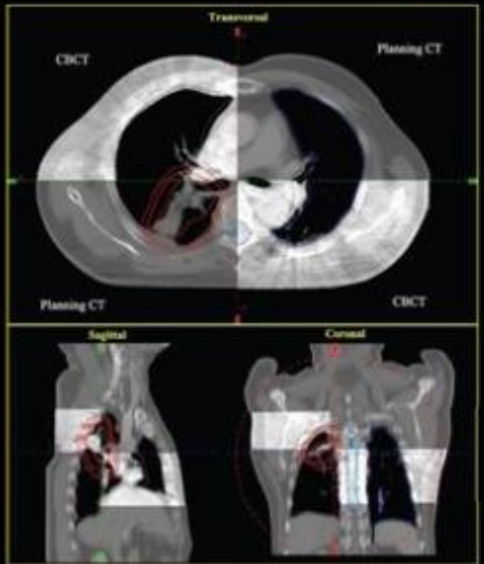


- Process
  - Define target / critical structures
  - Prescribe dose / dose limits
  - Establish field portals
  - Calculate dose
- Physicist:
  - Machine modeling
  - Dose algorithm
  - Image registration
  - Feasibility of treatment

Safe and Efficient Treatment Delivery

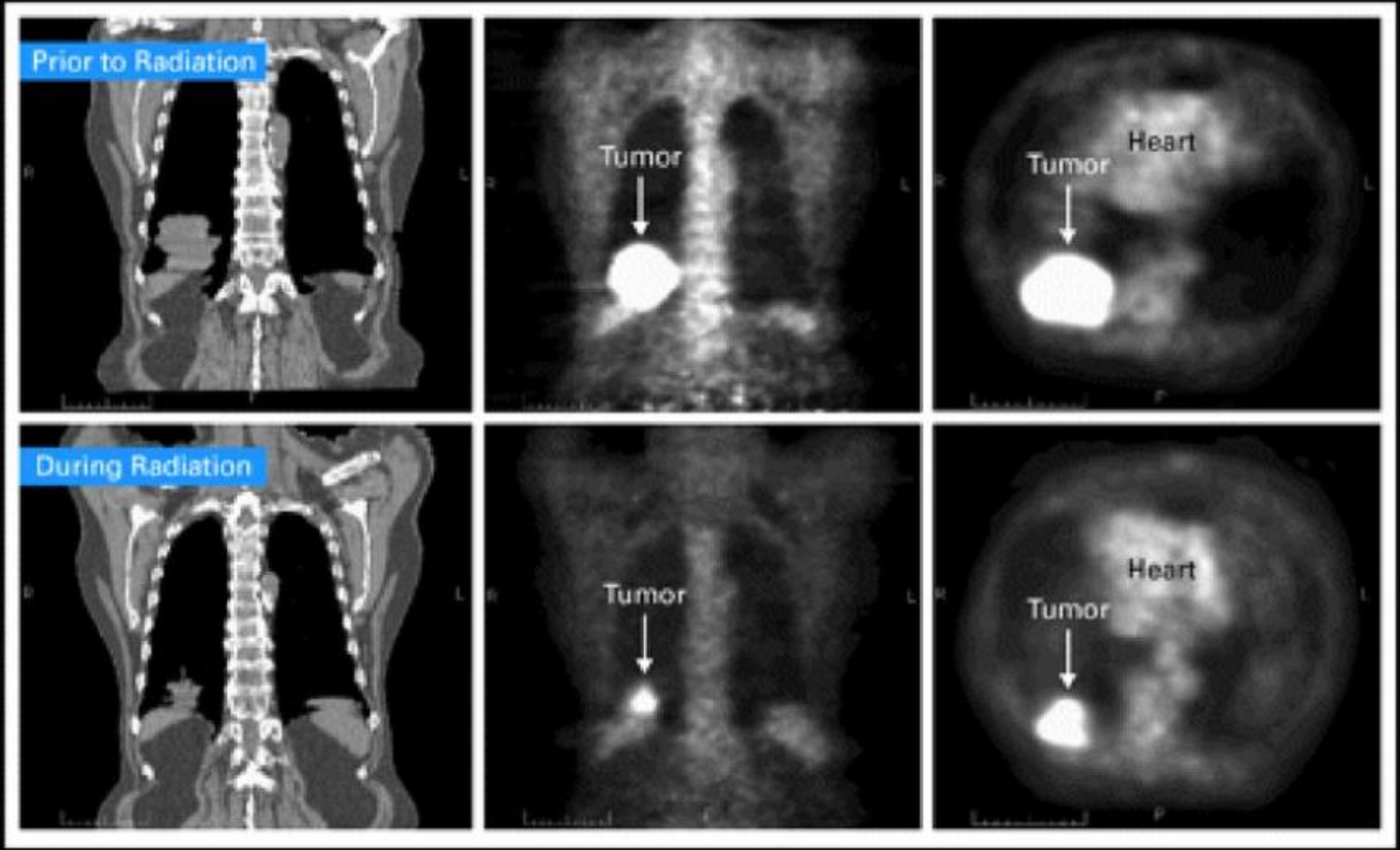
Simulation → Planning → **Treatment**

- Process
  - Setup patient
  - Localization
    - External beam: Set the reference point in patient to the linac isocenter
  - Delivery
    - Safety checks (right patient, site, plan etc.)
    - Equipment functionality (interlocks)
    - Clearance

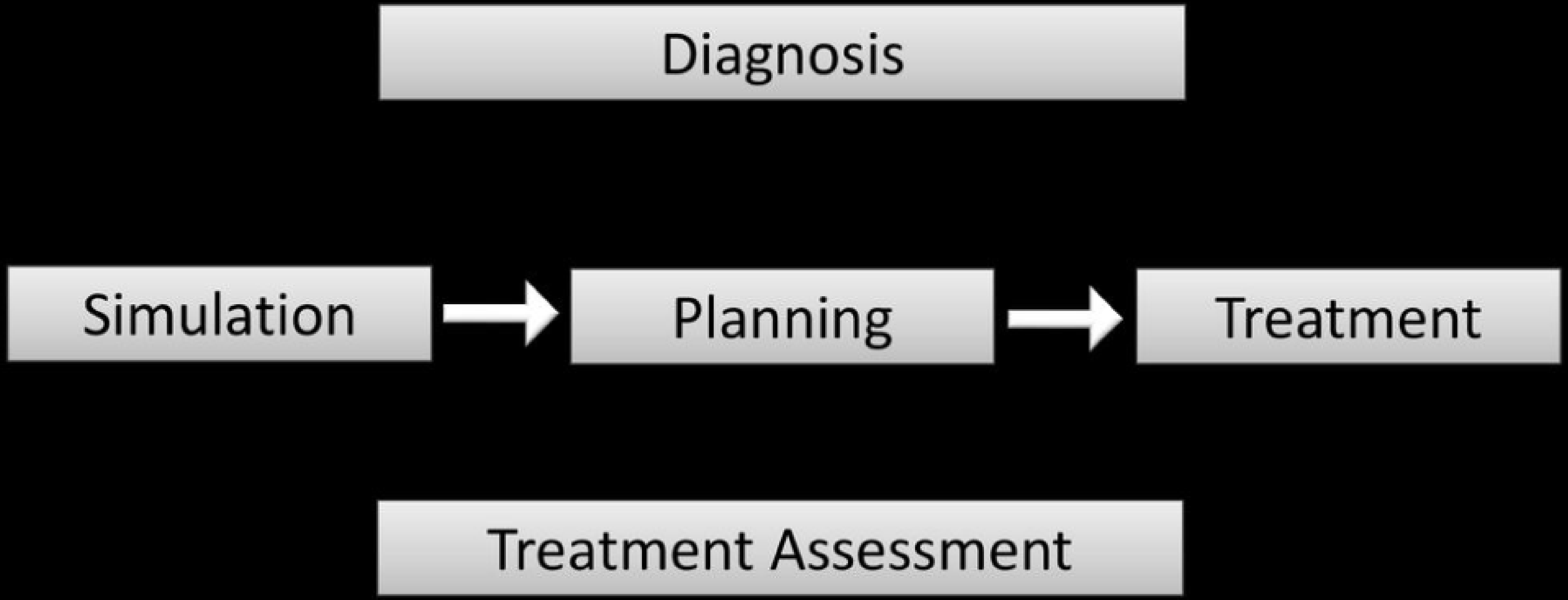


- Physicist:
  - Machine quality assurance and calibration
  - Fidelity of treatment process
  - Implementation of new technologies
  - Workflow efficiency

Treatment Assessment



Safe and Efficient Treatment Delivery



What possible issues do you see?

anatomical changes   visibility of disease   radiosensitivity/radioresistance   patient comfort

setup uncertainty   validity of assumptions during dose calcs   reliable response assessment

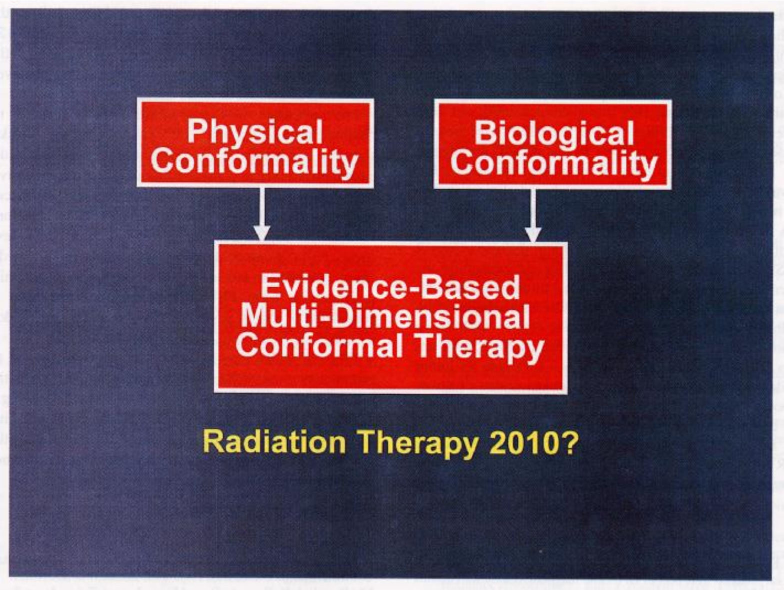
treatment speed   image registration errors   normal tissue toxicity   multimodality treatments

Research Area

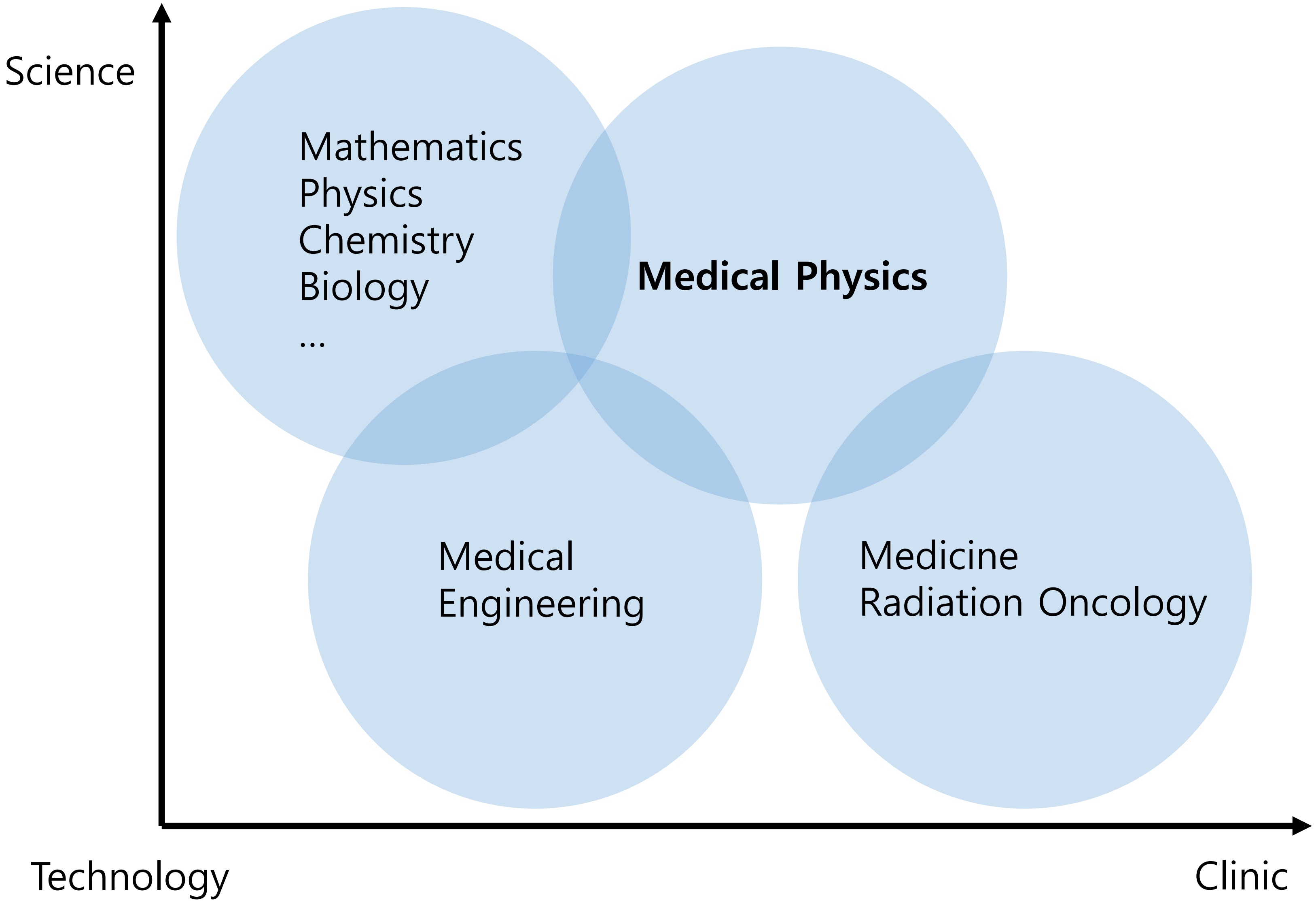
- Imaging: X-ray, CT, MRI, PET, US, …, new imaging modality
- Image reconstruction algorithm, noise reduction, deformable image reconstruction, image processing,
- MR sequence
- RT technology1: photon, electron, proton, helium, carbon, …, Brachytherapy
- Scattering, pensile beam scanning, …
- RT technology2: IMRT, VMAT, Gating, IGRT, ART
- RTP: optimization, dose calculation
- Immobilization technology,
- Quality Assurance: Dosimetry technology, application, QA protocol
- Patient Safety: collision detection/avoidance, surface imaging
- Clinical research: clinical outcome,

Tools: Statistics, Programming, MC, AI (DL)

Physics meets biology :
from physical to biological conformality



Ling Red J 47 p557 2000


Science
Mathematics
Physics
Chemistry
Biology
...
Medical Physics
Medical
Engineering
Medicine
Radiation Oncology
Technology
Clinic