Introduction to radiotherapy and recent advanced

Sung Hwan AHN

(Samsung Medical Center)

01 의학물리학이 무엇인가요

물리학을 의학에 적용한 학문이 의학물리학입니다. 현대 의학에 이용되고 있는 대부분의 검사장비 및 치료 장비들은 물리학을 기초로 개발되었습니다. CT, MRI, 방사선 치료 장비와 같이 첨단 과학으로 만들어진 의료 장비들에 대한 물리학의 이해 없이는 높은 수준의 환자 진단 및 치료를 기대하기 어렵습니다.

물리학자 아인슈타인

물리학이 만들어내는
의학의 기적들

→

초음파영상: 전립선암 (사람형상)

암만 죽이는 첨단 방사선암치료

02 의학물리학을 전공한 전문가를 가장 필요로 하는 곳은 어디인가요

의학물리학을 전공한 전문가는 의료계 전체에서 필요로 하지만 크게 영상의학분야, 핵의학분야, 방사선치료분야 3분야에서 요구되고 있습니다.

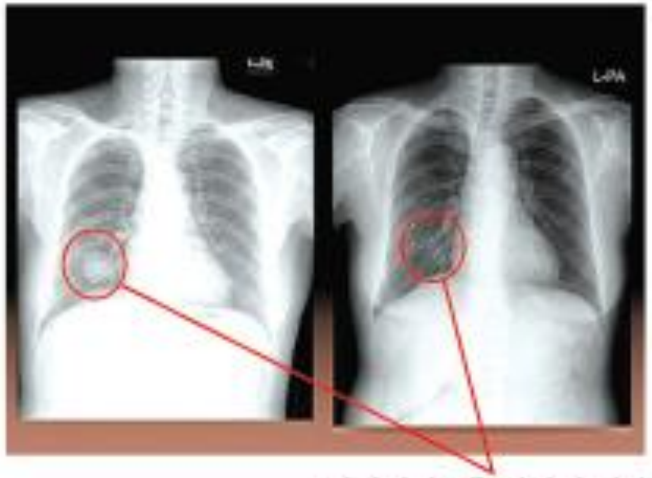
- **영상의학** CT, MRI, 초음파 영상 등 영상 장비 개발, 품질 관리, 동료 의사에게 영상에 대한 자문 제공
- **핵의학** 최신 영상장치인 PET_CT 등의 영상 장치 개발, 품질 관리, 동료 의사에게 영상에 대한 자문 제공
- **방사선치료** 방사선 치료 장비 도입, 운영, 품질 관리, 방사선 치료법 개발, 치료 방법에 대한 자문 제공

03 의학물리사는 누구인가요

물리학 및 물리학 관련 분야를 전공한 사람으로 기초의학(해부학, 종양학, 방사선생물학)을 배우고 병원의 관련 분야에 근무하는 전문가를 의학물리학자 또는 의학물리사라고 합니다. 국내에는 90% 이상이 방사선치료분야에 종사하고 있습니다.

06 방사선치료란 어떤 것인가요

방사선을 사용하여 암세포를 죽이는 치료를 말합니다. 수술은 종양을 제거하기 위해 의사가 수술칼을 사용하지만 방사선 치료는 방사선을 종양에만 집중시키면 수술칼처럼 작용하여 종양을 제거합니다. 또한 방사선치료를 전문으로 하는 "과"를 방사선종양학과라 합니다.



방사선치료후 사라진 폐암

07 방사선종양학과의 인적구성은 어떻게 되나요

방사선종양학과의 인적구성은 방사선종양학 전문의, 의학물리사, 간호사, 방사선사로 이루어져 있습니다.

- **방사선종양학 전문의**
  방사선치료를 요하는
  환자 진료
- **의학물리사**
  방사선 빔을
  종합적으로 관리
- **간호사**
  방사선치료에 대한 전문지식
  보유, 환자 간호 및 관리, 상담
- **방사선사**
  환자가 방사선을 조사(照射) 받을
  수 있도록 준비하고 장비 동작

https://www.ksmp.or.kr/

08 방사선치료에서 의학물리사가 구체적으로 무슨 일을 하나요

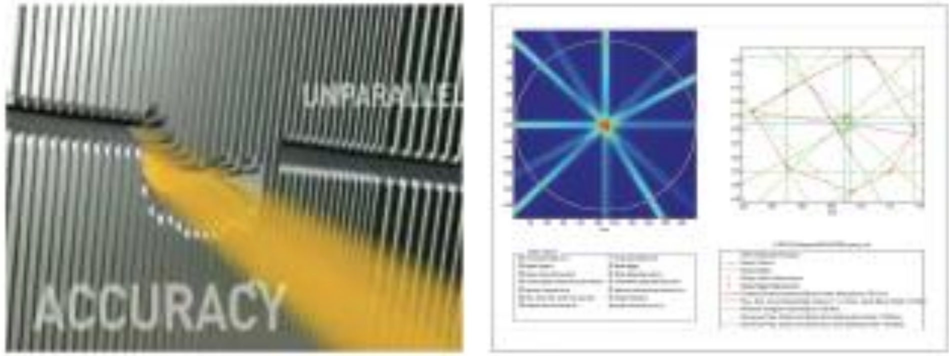
방사선치료의 핵심은 얼마나 정확하고 정밀하게 방사선을 환자에게 투여하느냐에 달려 있습니다. 그 정도에 따라 암치료 효과가 좌우되기 때문에 의학물리사의 주된 역할도 여기에 초점이 맞추어져 있습니다.

❶ 방사선장비의 인수검사

도입된 장비의 규격과 성능이 주문사항과 일치하는지, 설치 엔지니어가 기준에 맞게 설치하였는지 확인 및 점검하는 작업입니다. 이때 얻은 자료가 장비의 품질을 관리하는 기초가 됩니다.

장비설치중 점검

장비설치후 인수검사



인수 정밀 검사

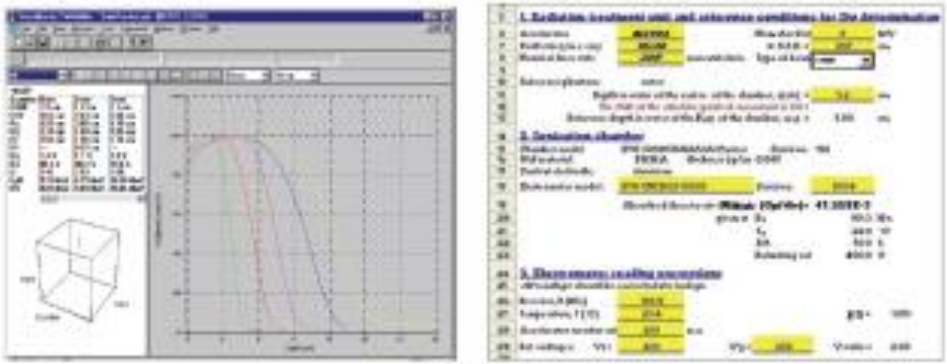
08 방사선치료에서 의학물리사가 구체적으로 무슨 일을 하나요

방사선치료의 핵심은 얼마나 정확하고 정밀하게 방사선을 환자에게 투여하느냐에 달려 있습니다. 그 정도에 따라 암치료 효과가 좌우되기 때문에 의학물리사의 주된 역할도 여기에 초점이 맞추어져 있습니다.

❷ 방사선치료기 사용 준비

방사선치료에는 수백 가지의 관련 자료가 필요합니다. 제작사에서 자료 제공이 되지 않기 때문에 치료기 사용 전에 치료와 관련된 모든 자료를 수집해야 합니다. 방사선선량 분포 및 출력 등이 여기에 포함됩니다.

데이타 수집



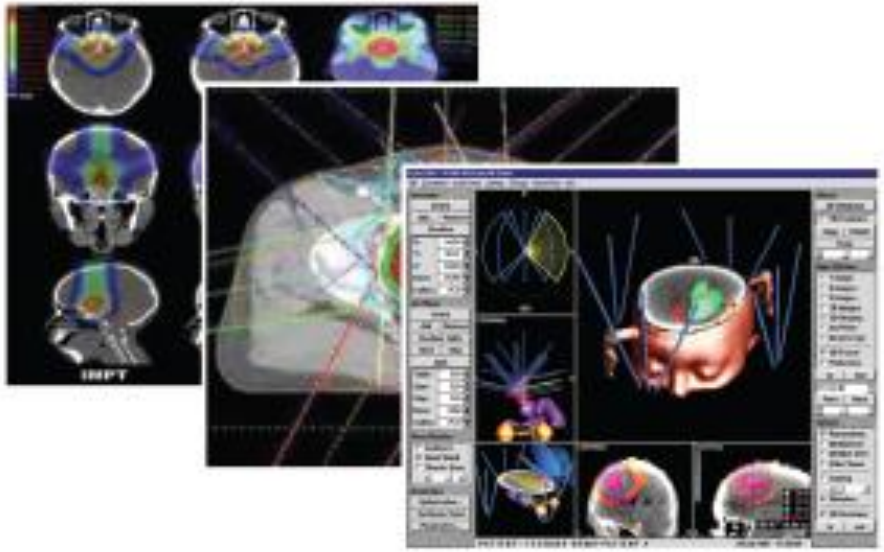
출력교정

08 방사선치료에서 의학물리사가 구체적으로 무슨 일을 하나요

방사선치료의 핵심은 얼마나 정확하고 정밀하게 방사선을 환자에게 투여하느냐에 달려 있습니다. 그 정도에 따라 암치료 효과가 좌우되기 때문에 의학물리사의 주된 역할도 여기에 초점이 맞추어져 있습니다.

❸ 방사선 치료설계 및 치료법 개발, 치료에 대한 전문 자문 제공

환자에게 방사선을 쬐여주는 방식에 따라 암치료 효과가 달라질 수 있기 때문에 의학물리사와 관련 장비회사들이 혁신적인 방법을 개발하는 데 많은 노력들을 기울이고 있습니다. 전반적인 치료방법뿐만 아니라 환자맞춤형 치료방법 개발도 의학물리사의 주된 역할입니다. 동료 의사에게 방사선치료에 대한 전문적인 자문 제공 역시 일상적인 업무입니다.



❹ 정확한 방사선량 측정

방사선 치료는 "방사선"을 환자에 투여하는 것이므로 정확한 방사선량 측정은 방사선치료 성과를 좌우하는 가장 중요한 요소라고 할 수 있습니다. 최첨단화되어 있는 현대의 방사선치료장비는 방사선을 만들어 내는 방식이 아주 정교하고 복잡합니다. 이에 따라 환자에 투여되는 방사선량의 측정도 아주 복잡하여 고도의 전문지식을 갖춘 인력이 정기적으로 수행하지 않으면 안됩니다.

08 방사선치료에서 의학물리사가 구체적으로 무슨 일을 하나요

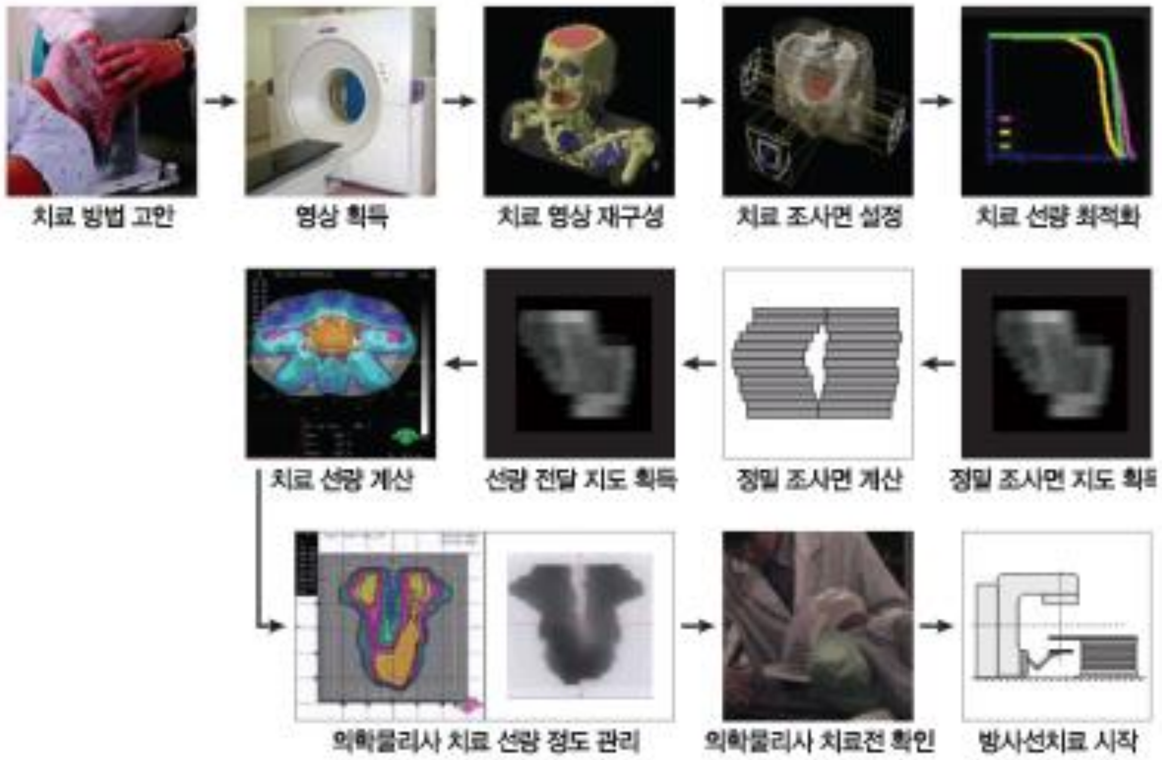
방사선치료의 핵심은 얼마나 정확하고 정밀하게 방사선을 환자에게 투여하느냐에 달려 있습니다. 그 정도에 따라 암치료 효과가 좌우되기 때문에 의학물리사의 주된 역할도 여기에 초점이 맞추어져 있습니다.

❺ 주기적 품질관리

치료장비는 암을 치료하는 데 사용되므로, 항상 최적의 상태로 유지해야 합니다. 앞서 언급했듯이 현대의 방사선치료장비는 최첨단화되어 있어 최상의 상태로 유지 관리하기 위해서는 첨단의 전문지식이 요구됩니다. 의학물리사는 장비 인수 및 사용준비시의 기준 자료를 토대로 정기적으로 품질관리를 수행해야 합니다.

❻ 환자 맞춤 정도관리

방사선치료의 신뢰성 확보를 위해 치료 시작 전에 환자에게 쪼일 방사선 양을 특수 선량측정 장비로 측정하고, 치료설계와 비교평가를 통해 각 환자별 정도관리와 의무기록 확인을 합니다.



이러한 업무의 주기적 활동을 통해 방사선치료의 정확성, 안전성, 객관성을 확보하여 수준 높은 방사선치료라는 신뢰를 쌓고 있습니다.

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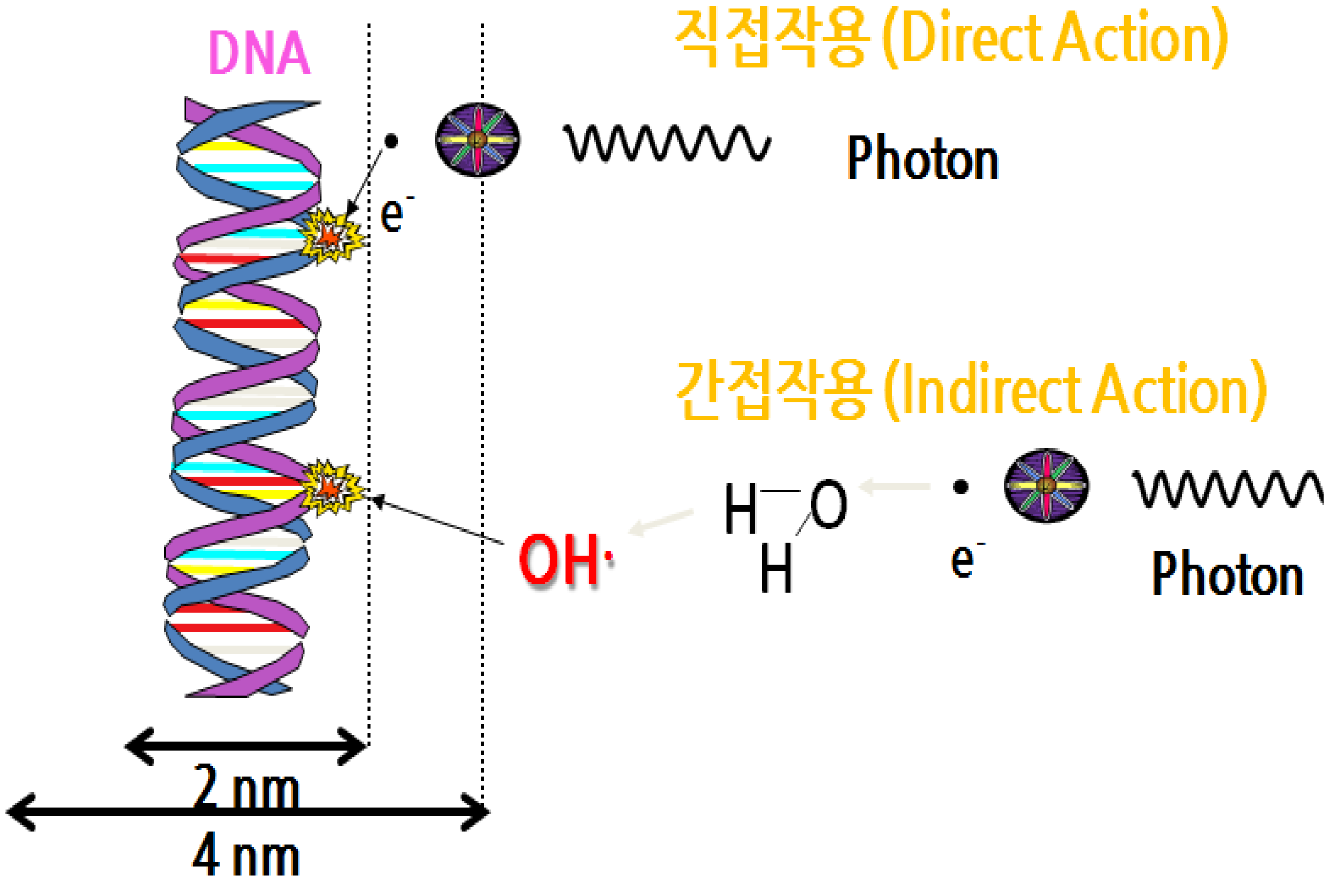
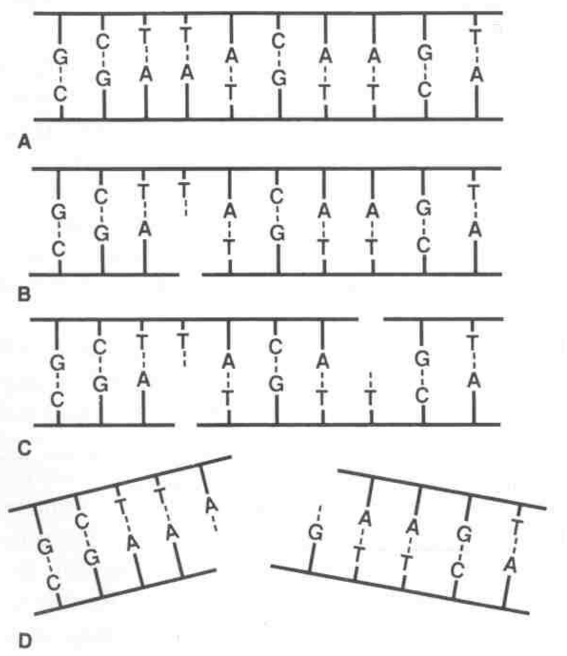
방사선과 세포의 상호작용



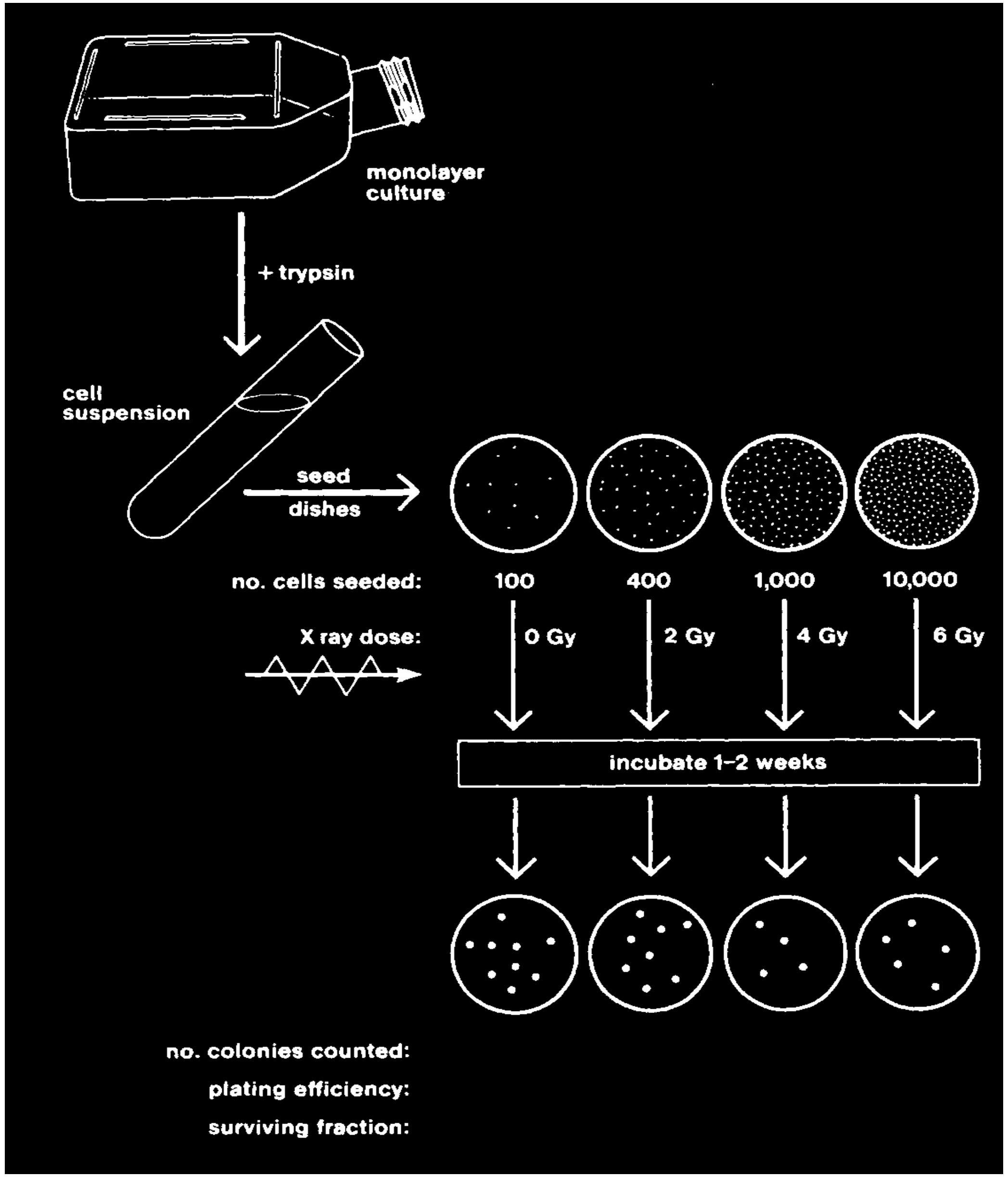
- **직접 작용**
  : DNA손상
- **간접 작용**
  : 체내 유리기 (Free Radical)
  입자의 세포사 유도
  →70%역할
- 손상된 암세포 분열 정지
  → 사멸

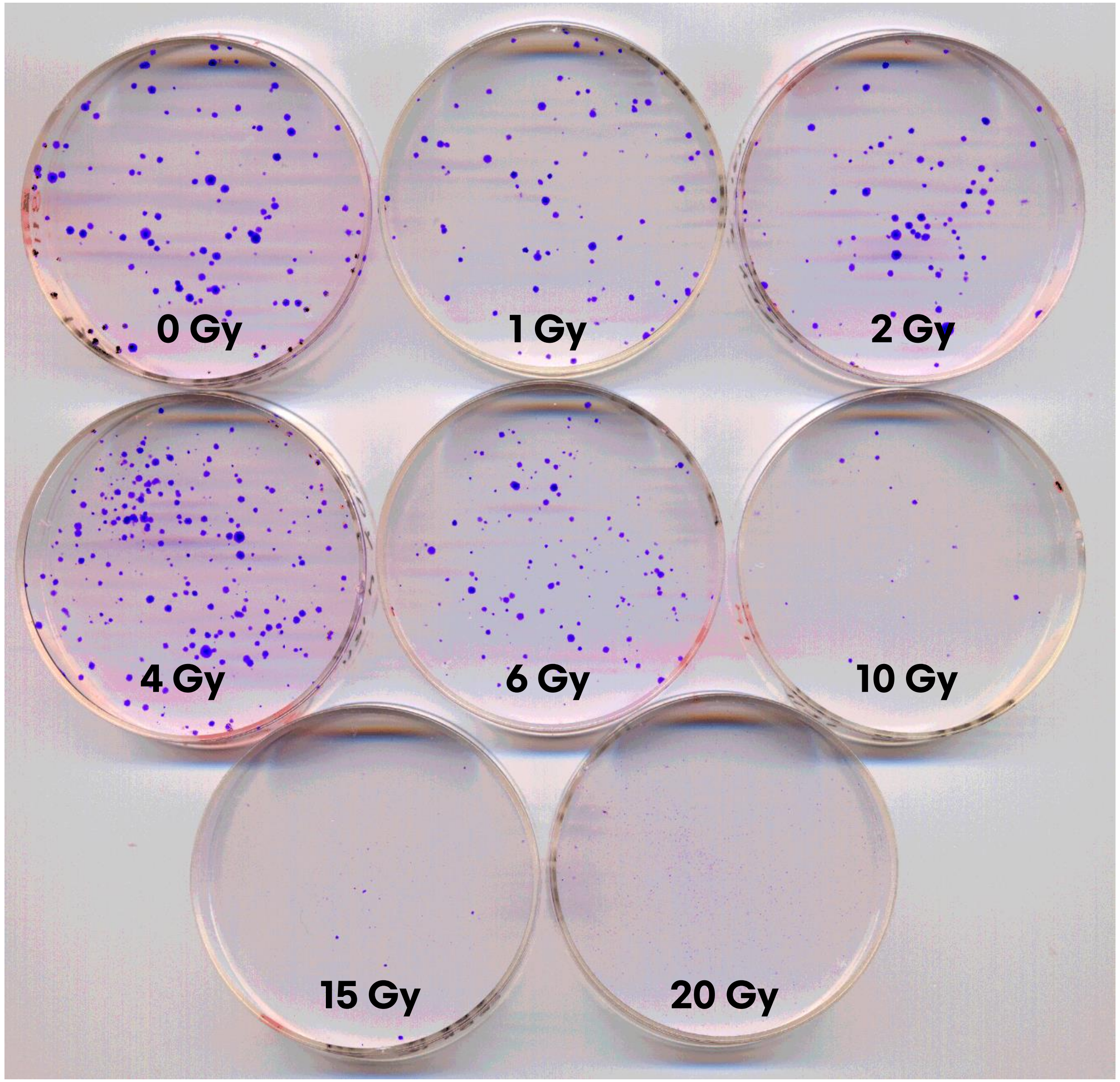
DNA damage from radiation

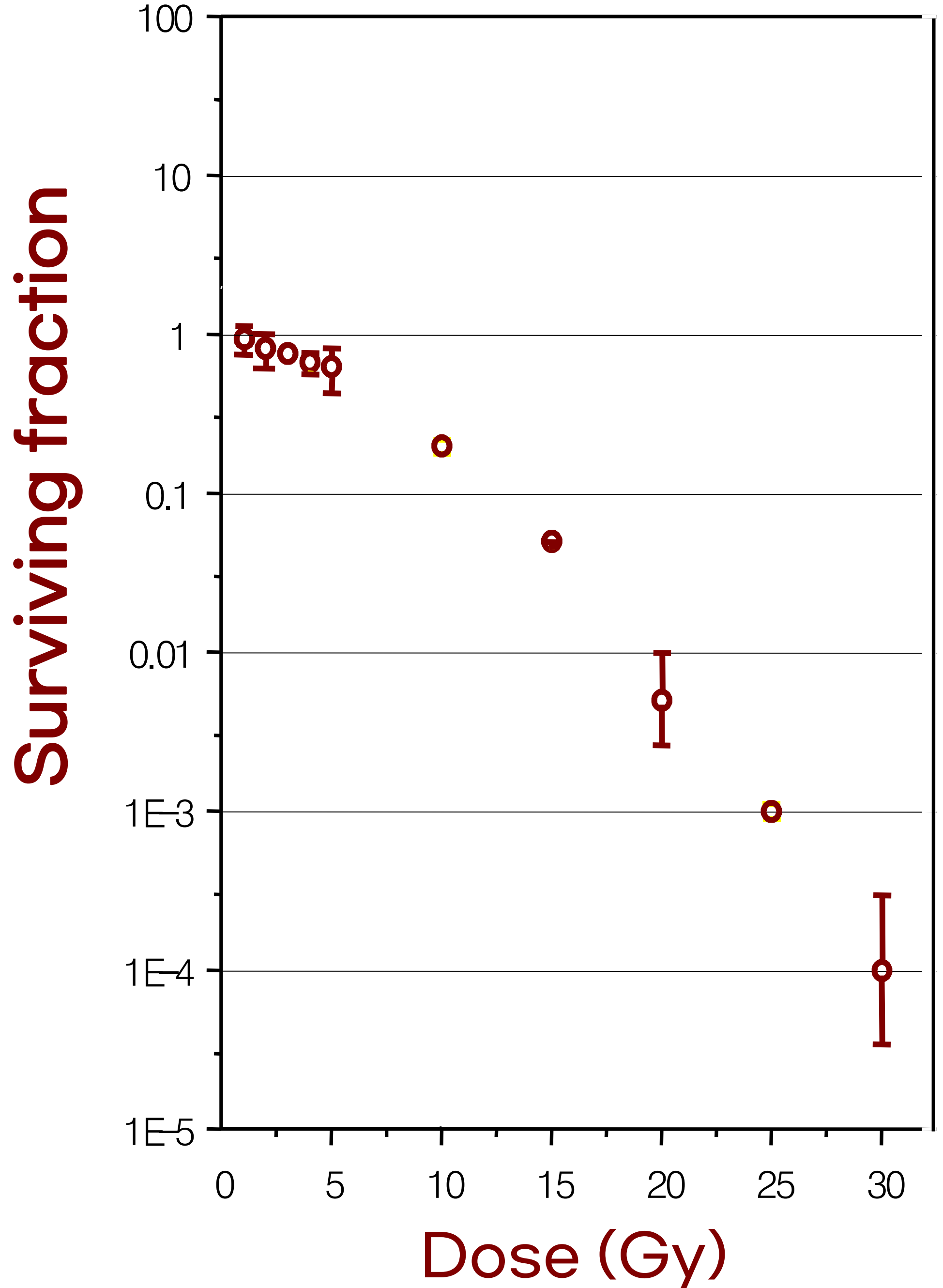
- Base damage
- Single strand breaks (SSB)
- Double strand breaks (DSB)
  - important for radiation induced cell killing



Colony assay: in vitro survival



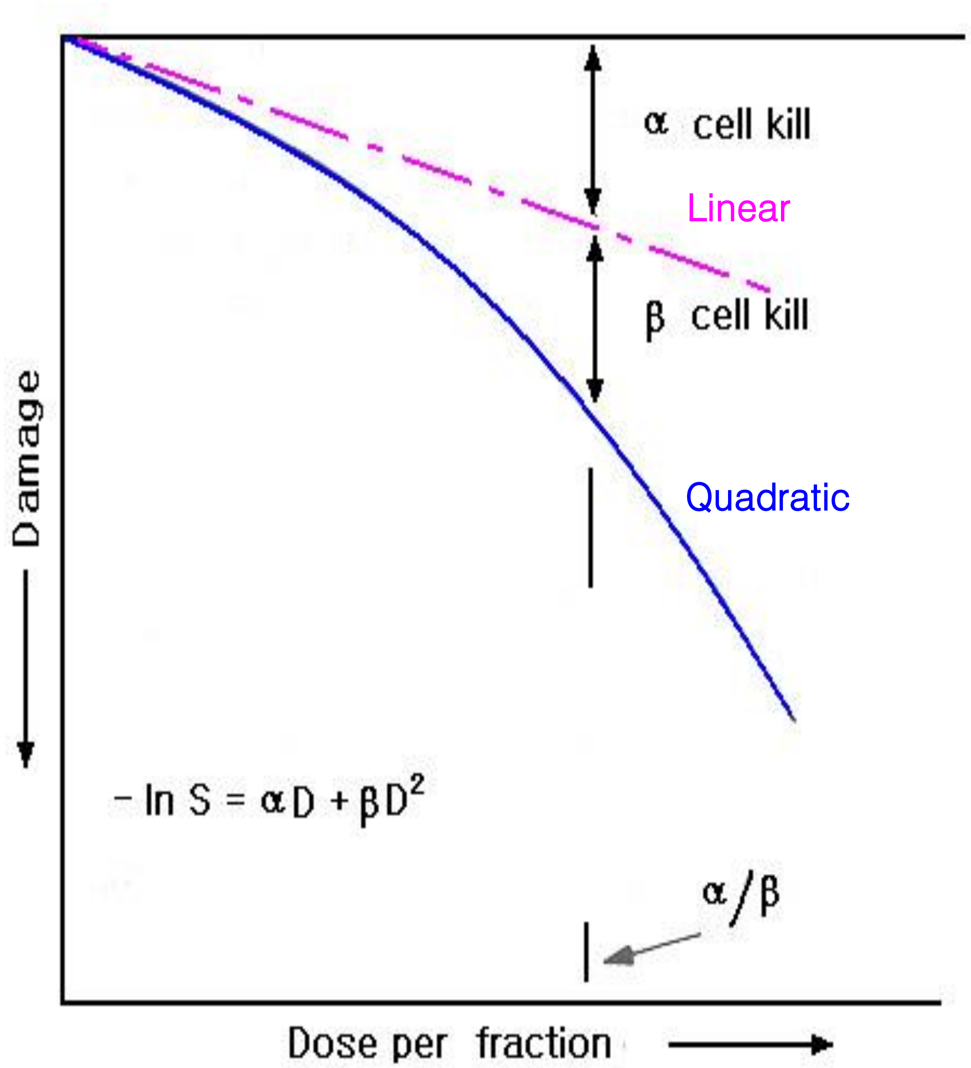


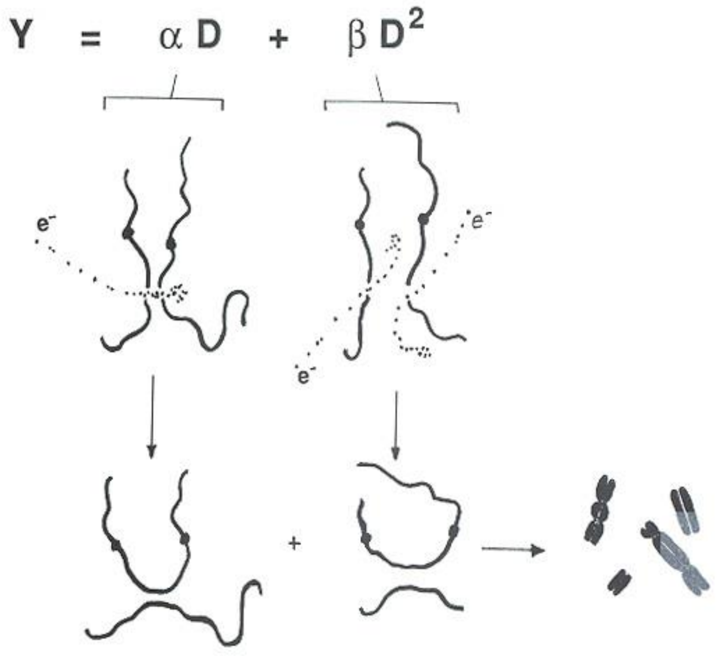


- Typical survival curve for mammalian cells
- What is needed is a m athematical descriptio n

Mathematical Modelling of Cell Survival Curve

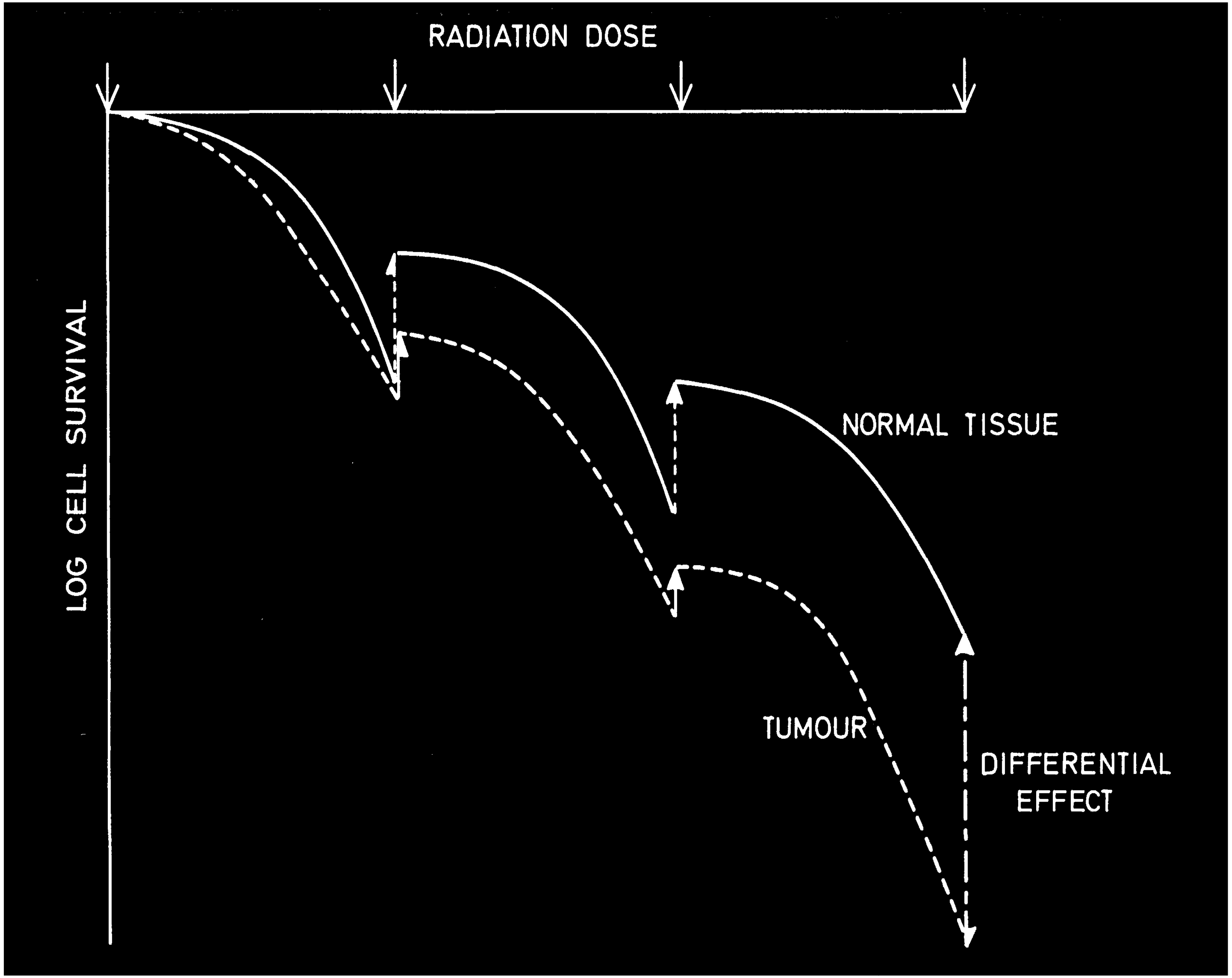
LQ (Linear-Quadratic) model





Y: average yield of chromosomal aberration per cell

Fractionation Sensitivity



Fractionation (분할치료)

Figure 13-1. Conventional multifraction radiotherapy was based on experiments performed in Paris in the 1920s and 1930s. Rams could not be sterilized with a single dose of x-rays without extensive skin damage, whereas if the radiation were delivered in daily fractions over a period of time, sterilization was possible without skin damage. The testes were regarded as a model of a growing tumor and skin as dose-limiting normal tissue.

Regaud, Béclère, Coutard

<u>1920, 1930 Experiment in Paris</u>

Testis : model of growing tumor

Skin : dose limiting normal tissue

- Fractionation of radiation dose in most case, **better tumor control** for given level of normal toxicity than a single large dose

암 치료법들

- **수술 (Surgery)**
- **항암제치료 (Chemotherapy)**
- **방사선치료 (Radiation therapy)**
- 면역치료 (Immunotherapy)
- 유전자치료 (Gene therapy)
- 분자생물학적 표적치료 (Molecular targeting)

…

방사선 치료 과정

1. 환자 및 종양의 상태를 파악 및 검토
   - 종양의 병리적 종류 및 진행 정도 (병기) 파악
   - 방사선 치료 여부, 치료의 목적 결정
   - 방사선 치료의 종류, 범위 및 각 부위별 투여 선량 결정

2. 치료 설계 과정
   - Simulation (모의 계획) : 2D or CT-simulation
   - Patient immobilization and marking on skin
     (환자 고정 및 치료 기준점 표시)
   - 체내 방사선량 분포 계산
   - 차폐물 디자인 및 제작
   - 완성된 치료 설계를 검증 : verification film and 선량 측정

3. 방사선 치료 시행
   - 치료 중 환자의 정기적 관찰 및 지지적 치료
   - 치료 중 필요시 치료 설계 및 선량 변경
   - 정기적으로 치료 설계 재확인 : verification film

방사선 치료의 목적

1. **Curative Radiotherapy**

   -근치적 (완치 목적의) 방사선 치료

   a. Radiotherapy alone

   b. Combination of Radiation and surgery

   가. Pre-operative irradiation

   나. Post-operative irradiation

   다. Organ preservation by radiotherapy following local excision

   c. Combination of chemotherapy and Radiation

2. **Palliative Radiotherapy**

   - 고식적 (완화적) 방사선 치료

방사선 (원자력안전법, 시행령) 정의

원자력안전법

제2조 (정의)

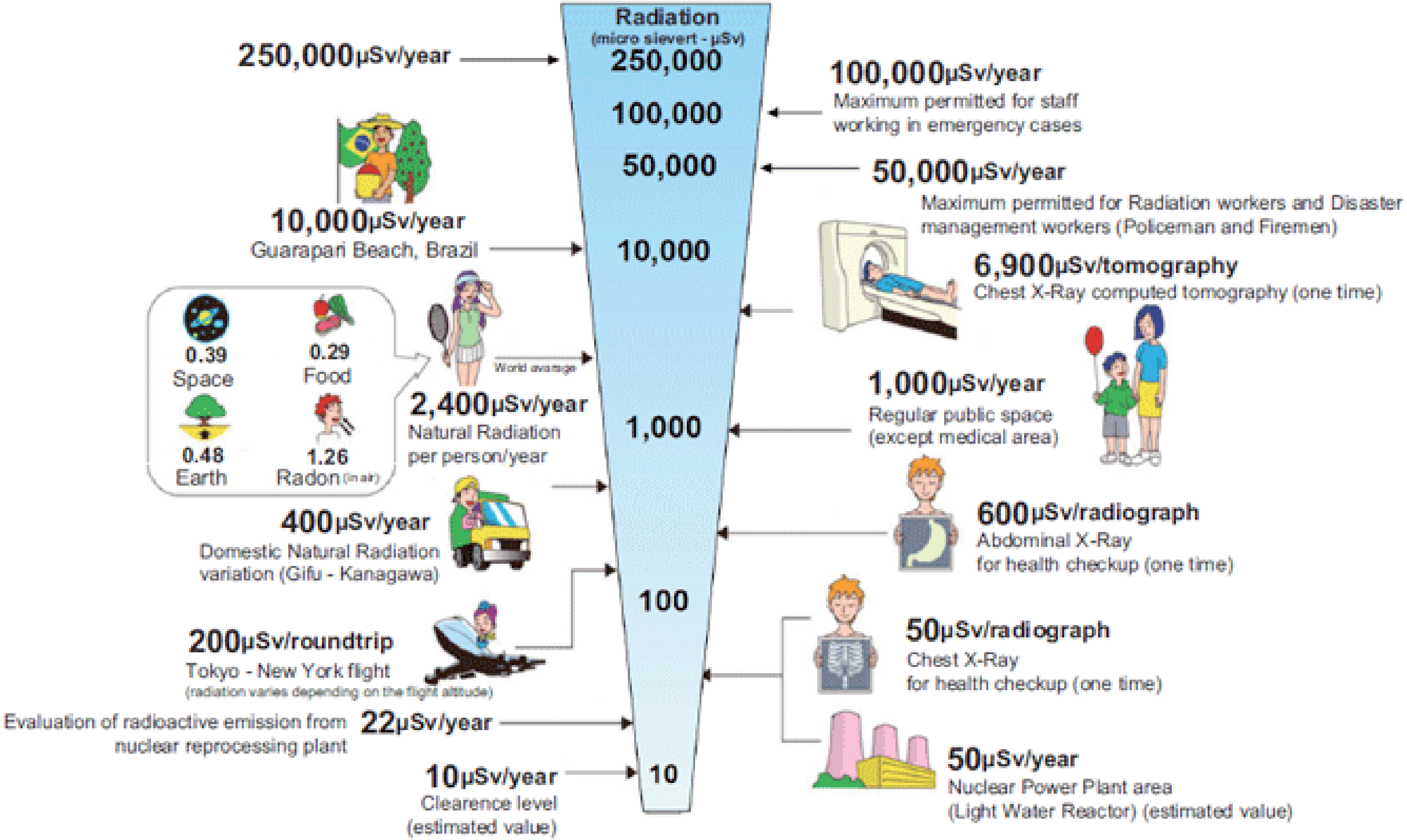
7. **"방사선"이란 전자파 또는 입자선 중 직접 또는 간접으로 공기를 전리(電離)하는 능력을 가진 것**으로서 대통령령으로 정하는 것을 말한다.

원자력안전법 시행령

제6조(방사선) 법 제2조 제7호에서 "대통령령으로 정하는 것"이란 다음 각 호의 것을 말한다.

1. 알파선 · 중양자선 · 양자선 · 베타선 및 그 밖의 중하전입자선
2. 중성자선
3. 감마선 및 엑스선
4. 5만 전자볼트 (50keV) 이상의 에너지를 가진 전자선

RADIATION EXPOSURE IN DAILY LIFE

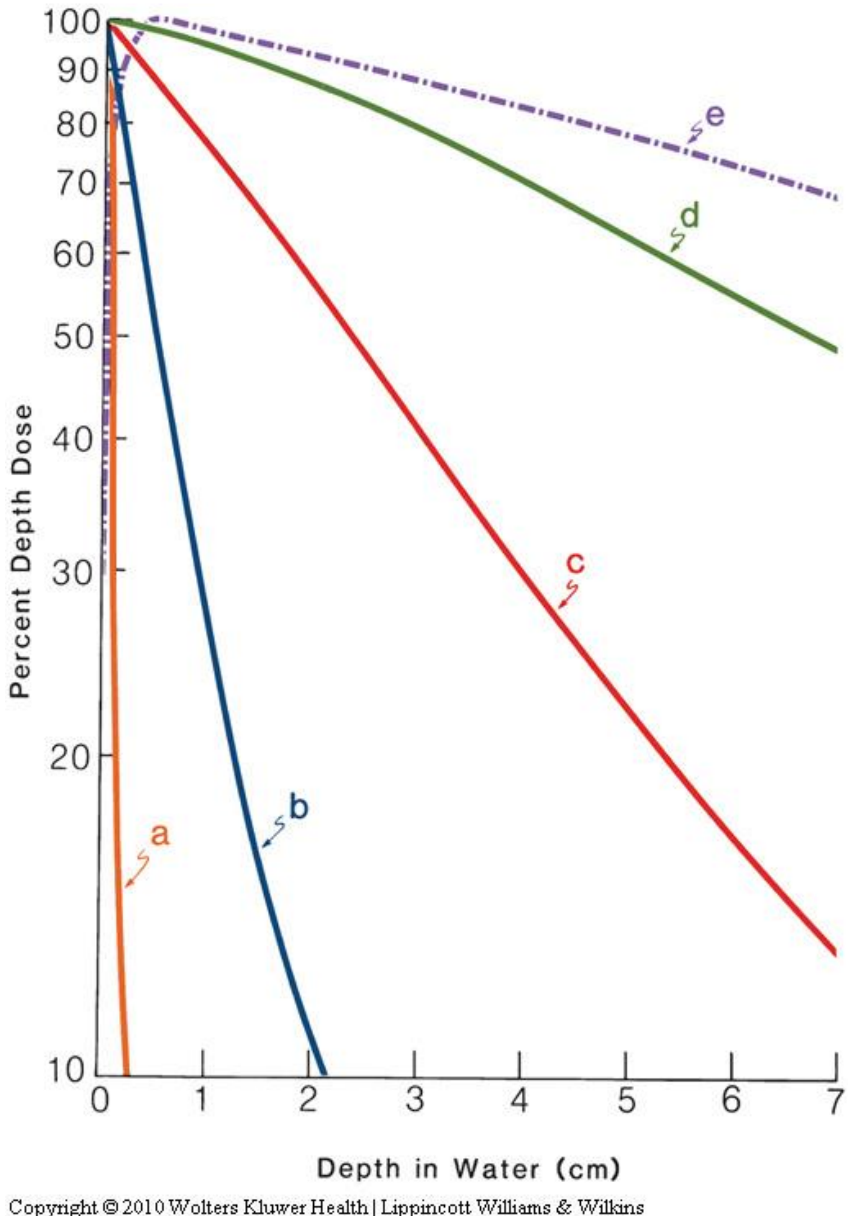


Sv (sievert) = *constant of biological effects of radiation** **x** *Gy (Gray)*

(*) X-Ray, Y-Ray = 1

Source: Ministry of Education, Culture, Sports, Science and Technology of Japan

Percentage Depth Dose (PDD) in water



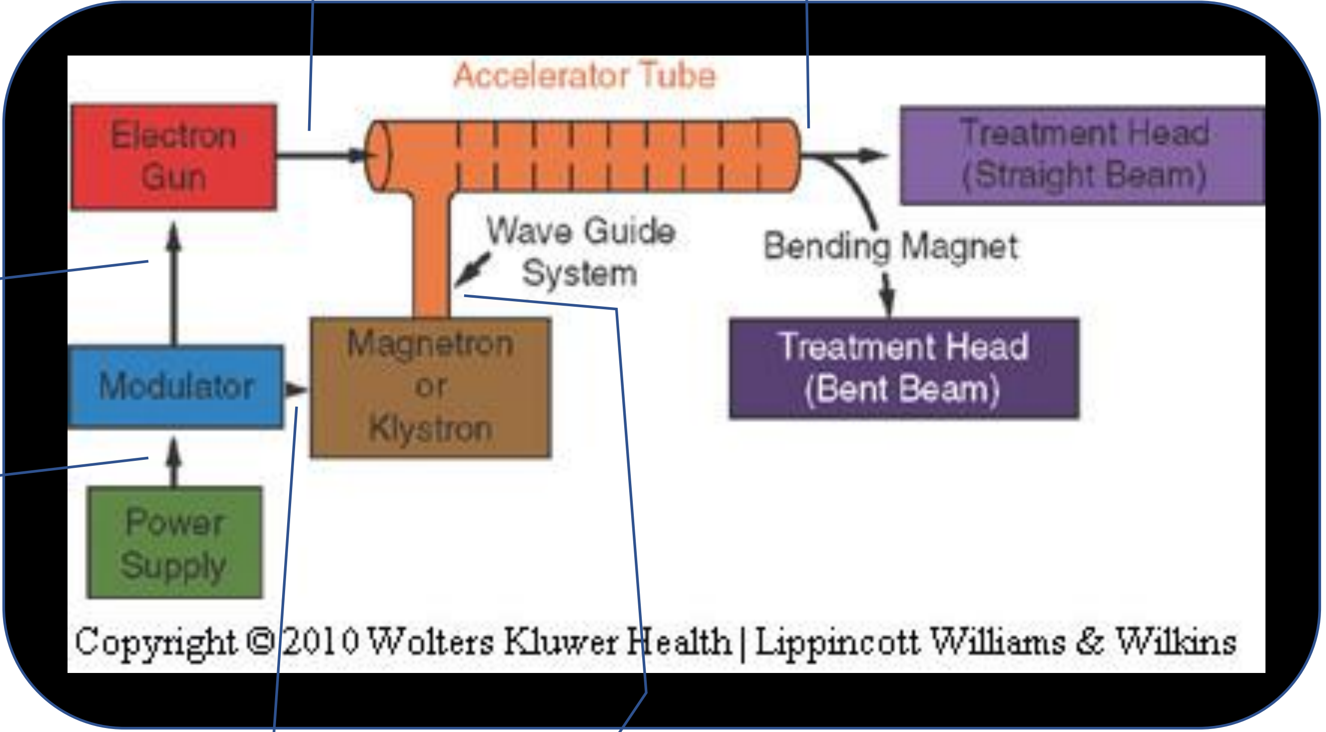
a. Grenz-ray Therapy (<20kV)
b. Contact Therapy (40~50kV)
c. Superficial Therapy (50~150kV)
d. Orthovoltage Therapy (150~500kV)
e. Cobalt-60 Therapy

-> Megavoltage Therapy

Khan, The Physics of Radiation Therapy

Linear Accelerator (LINAC)

- Basic Structure



electron

high-energy electron
: pencil beam of 3mm in diameter

high-voltage pulses

direct current power

high-voltage pulses

pulsed microwave

Khan, The Physics of Radiation Therapy

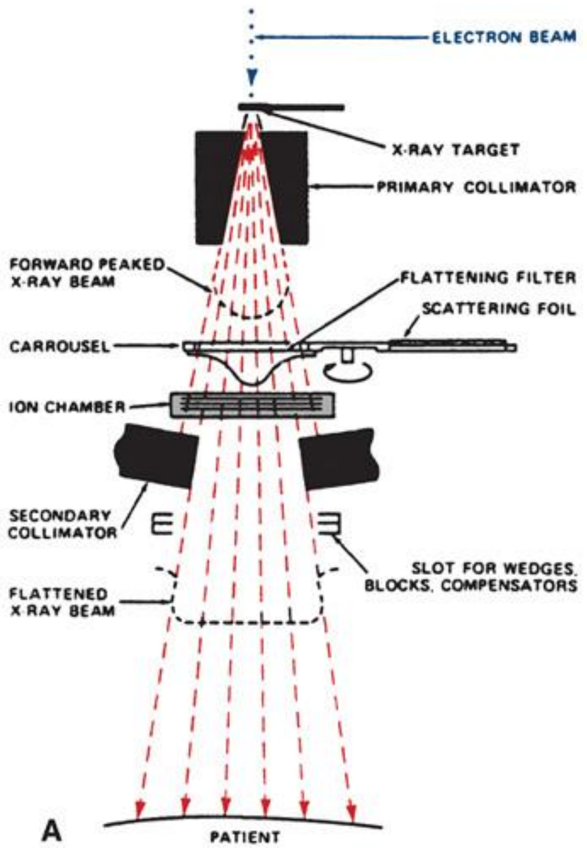
Linear Accelerator (LINAC)

← Low Energy LINAC
(ex : 6EX)

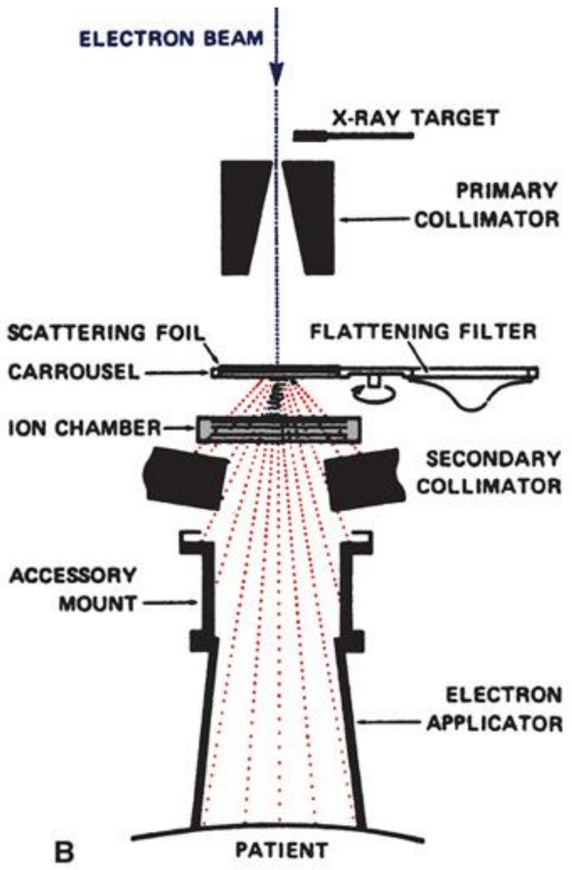
High Energy LINAC →
(ex : 21EX, iX)

Khan, The Physics of Radiation Therapy

Linear Accelerator



X-ray Therapy

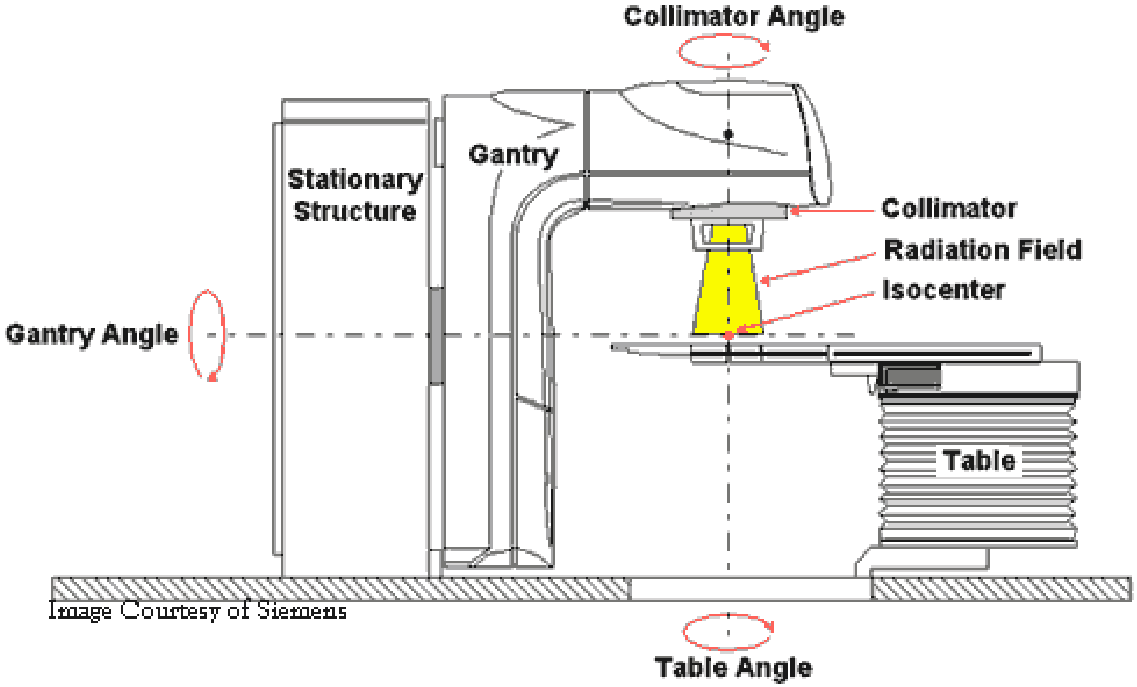


Electron Therapy

Khan, The Physics of Radiation Therapy

Linear Accelerator

Gantry system (isocenter)

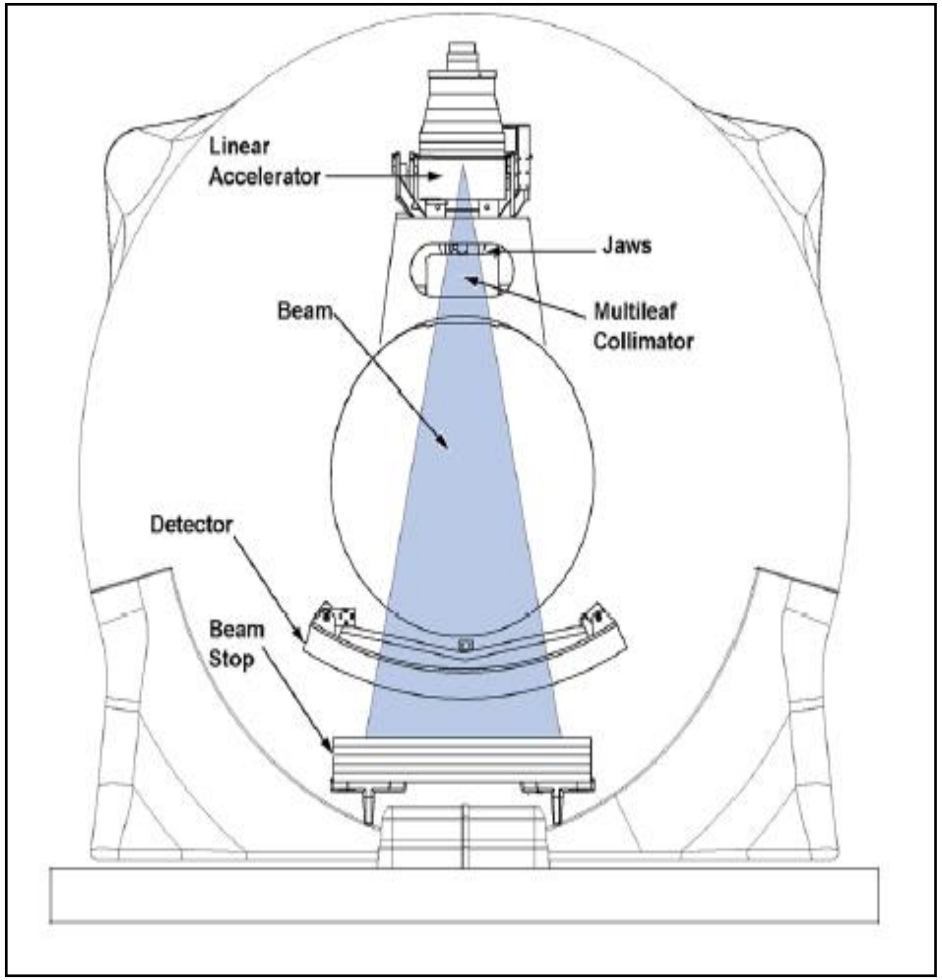


Khan, The Physics of Radiation Therapy

Tomotherapy

1. MVCT
   - Image guided radiation therapy (IGRT)
2. Helical Treatment
   - Intensity modulated radiation therapy (IMRT)
   - Independency with the tumor size
3. Integrated System
4. Adaptive Radiotherapy
   - MVCT

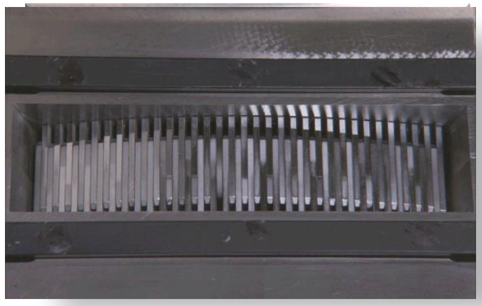
Tomotherapy: exterior & interior



- 85 cm Opening
  - 40 cm X 1.6 m Imaging FOV @ Isocenter

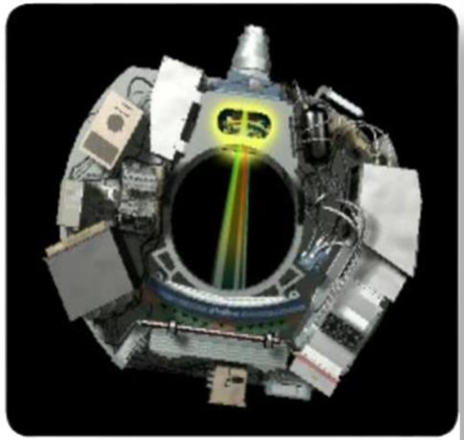
Tomotherapy (IGRT/IMRT)

Fast Binary MLC



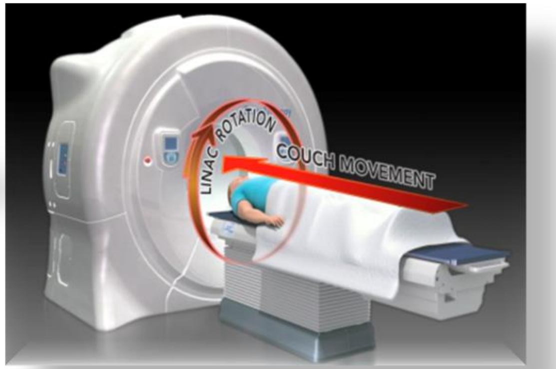
+

Rotating Ring Gantry



+

Continuous Couch Movement



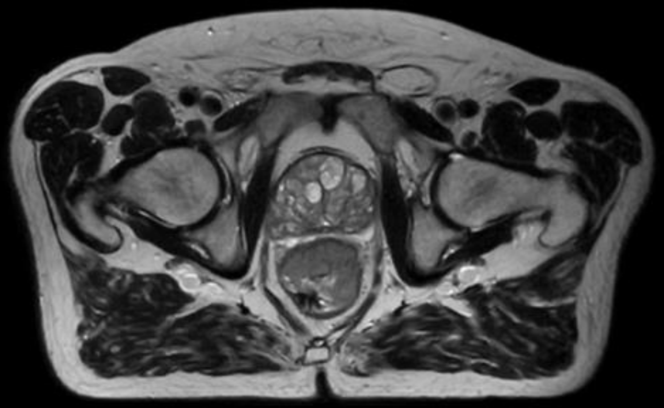
- MLC leaves that move at 250 cm/s to open or shut in ~ 20 milliseconds
- Thousands of beamlets throughout multiple 360 degree rotations
- Coverage of a target extent up to 160 cm in length with no field matching

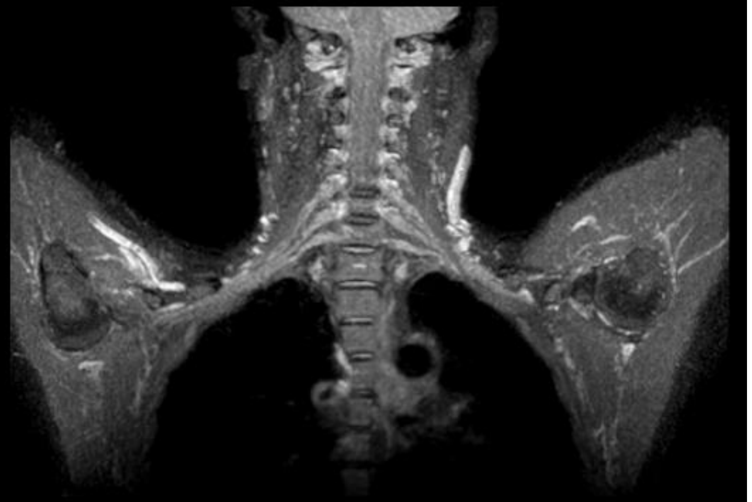
MR-LINAC

https://www.elekta.com/products/radiation-therapy/unity/

MR-LINAC

Examples of Elekta Unity MR images:





Rectum case

MR sequence	2D Turbo Spin Echo T2 weighted
TE	140 ms
Coverage	24 cm C-C
Thickness	3.5 mm
Resolution	1.1 mm x 1.1 mm

Axilla case

MR sequence	3D STIR T2w
Coverage	24 cm A-P
Thickness	1.5 mm
Resolution	1.5 mm x 1.5 mm

https://www.elekta.com/products/radiation-therapy/unity/

PET-LINAC

Biology-guided Radiotherapy

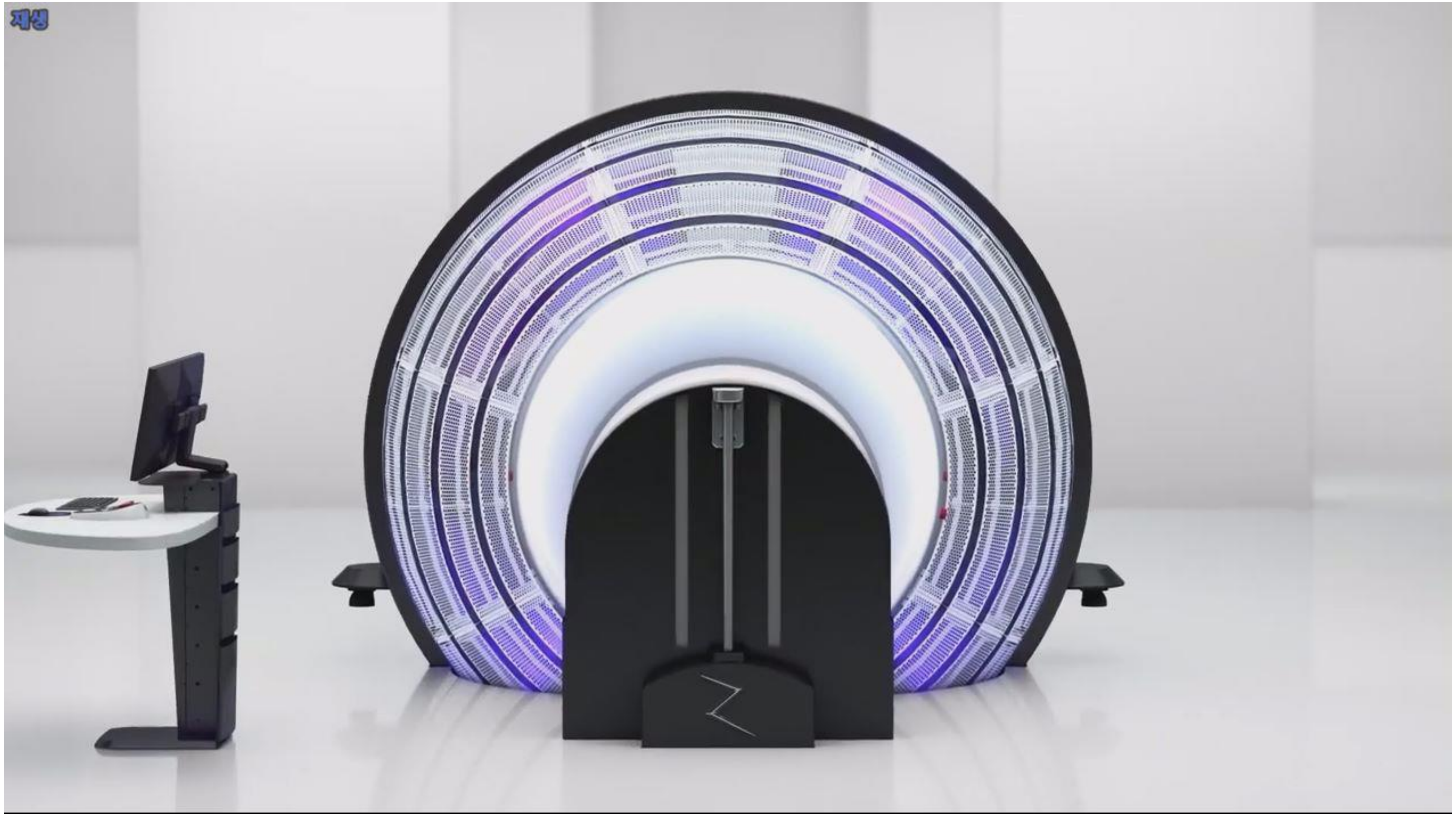
RefleXion's biology-guided radiotherapy (BgRT) is the first to utilize both anatomic (computed tomography) and functional (positron emission tomography) imaging data to guide personalized radiotherapy.

https://reflexion.com/

LINAC-Radiosurgery

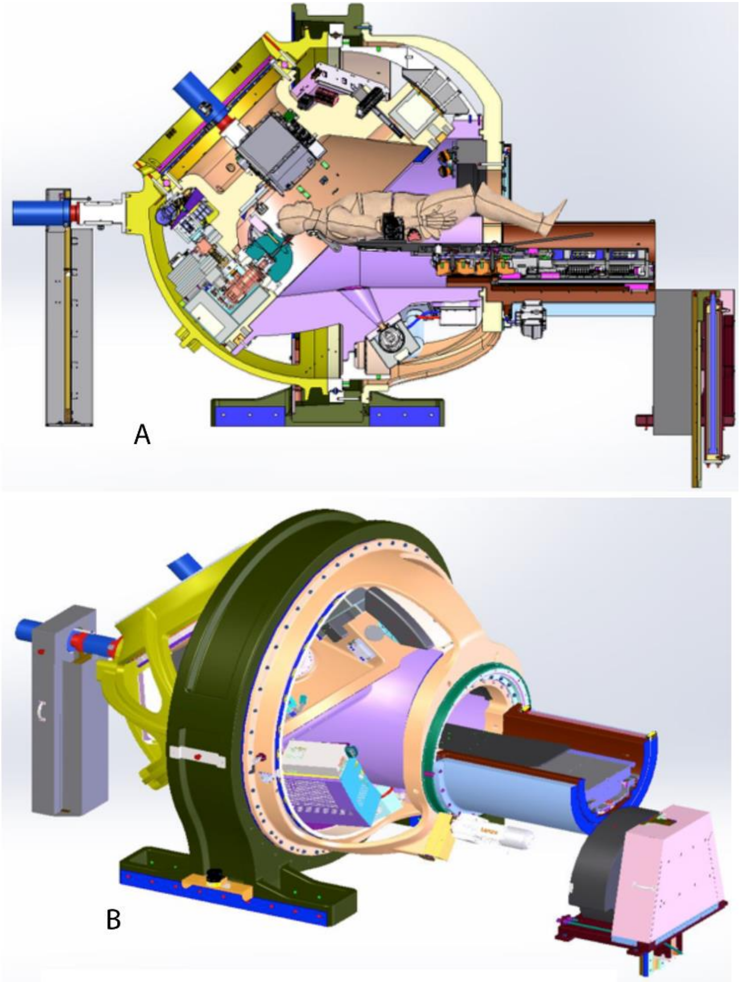
Self-Shielded | LINAC-Based

ZAP-X
GYROSCOPIC RADIOSURGERY™
FOR THE BRAIN



https://zapsurgical.com/

The Zap-X is a self-contained and first-of-its-kind self-shielded therapeutic radiation device dedicated to brain as well as head and neck stereotactic radiosurgery (SRS). By utilizing an S-band linear accelerator (linac) with a 2.7 megavolt (MV) accelerating potential and incorporating radiation-shielded mechanical structures, the Zap-X does not typically require a radiation bunker, thereby saving SRS facilities considerable cost. At the same time, the self-shielded features of the Zap-X are designed for more consistency of radiation protection, reducing the risk to radiation workers and others potentially exposed from a poorly designed or constructed radiotherapy vault. The hypothesis of the present study is that a



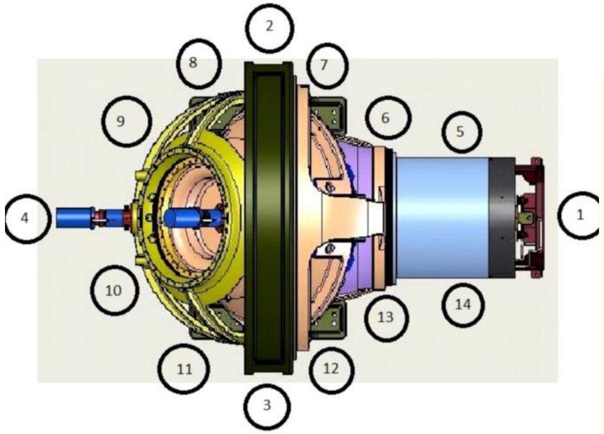


Table 2

Summary of accumulative exposure measurements.

Station	Exposure (microR)	Annual Dose (mSv)
1	31	0.698
2	5	0.113
3	5	0.113
4	29	0.653
5	32	0.720
6	8	0.180
7	4	0.090
8	25	0.563
9	32	0.720
10	30	0.675
11	24	0.540
12	28	0.630
13	0	0
14	30	0.675
15 atop sphere	55	1.238

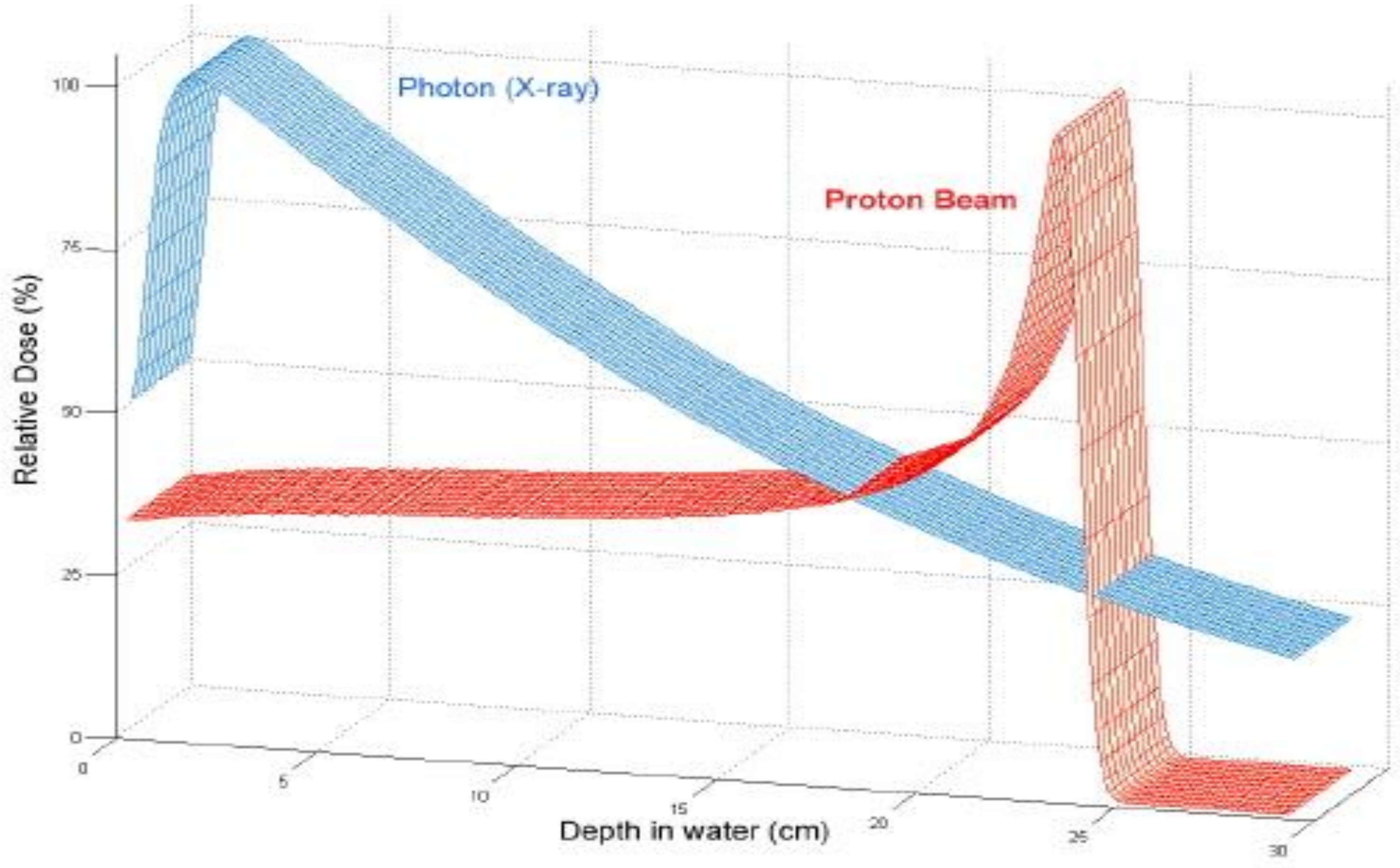
Cureus. 2017 Dec; 9(12): e1917.

Proton Therapy

(양성자 치료)

Photon (X-ray) vs. Proton

- Physics property? (Mass, Charge, etc)
- Dosimetry? (PDD, Penumbra, etc)
- Biology? (RBE, etc)



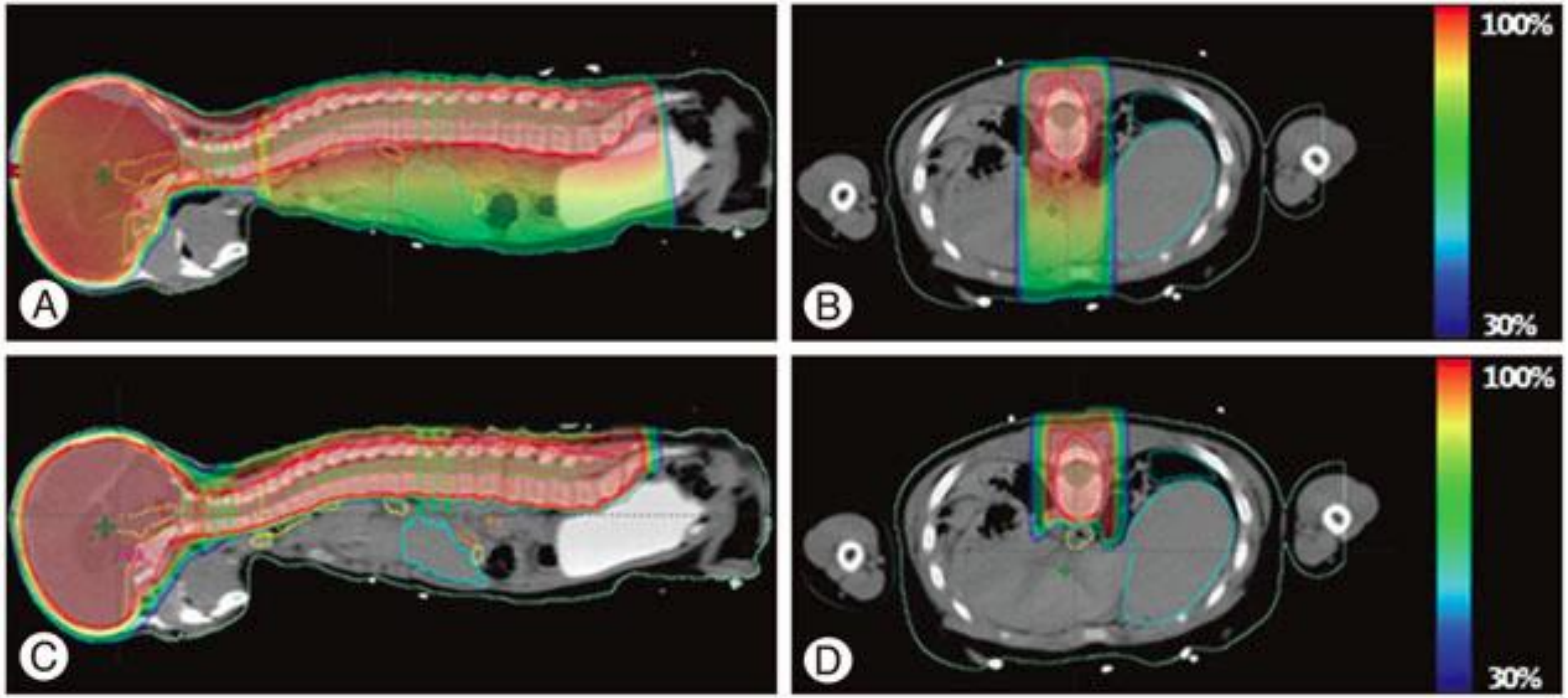
Photon (X-ray) vs. Proton

- Proton has **Bragg-peak** phenomenon.
- Proton enables **less radiation exposure** to the surrounding organs!
- Proton's RBE (relative biologic effectiveness) = 1.1

  → **10% more effective in cell killing** than photons.

Photon (X-ray) vs. Proton

Craniospinal Irradiation (CSI) – (뇌척수조사)



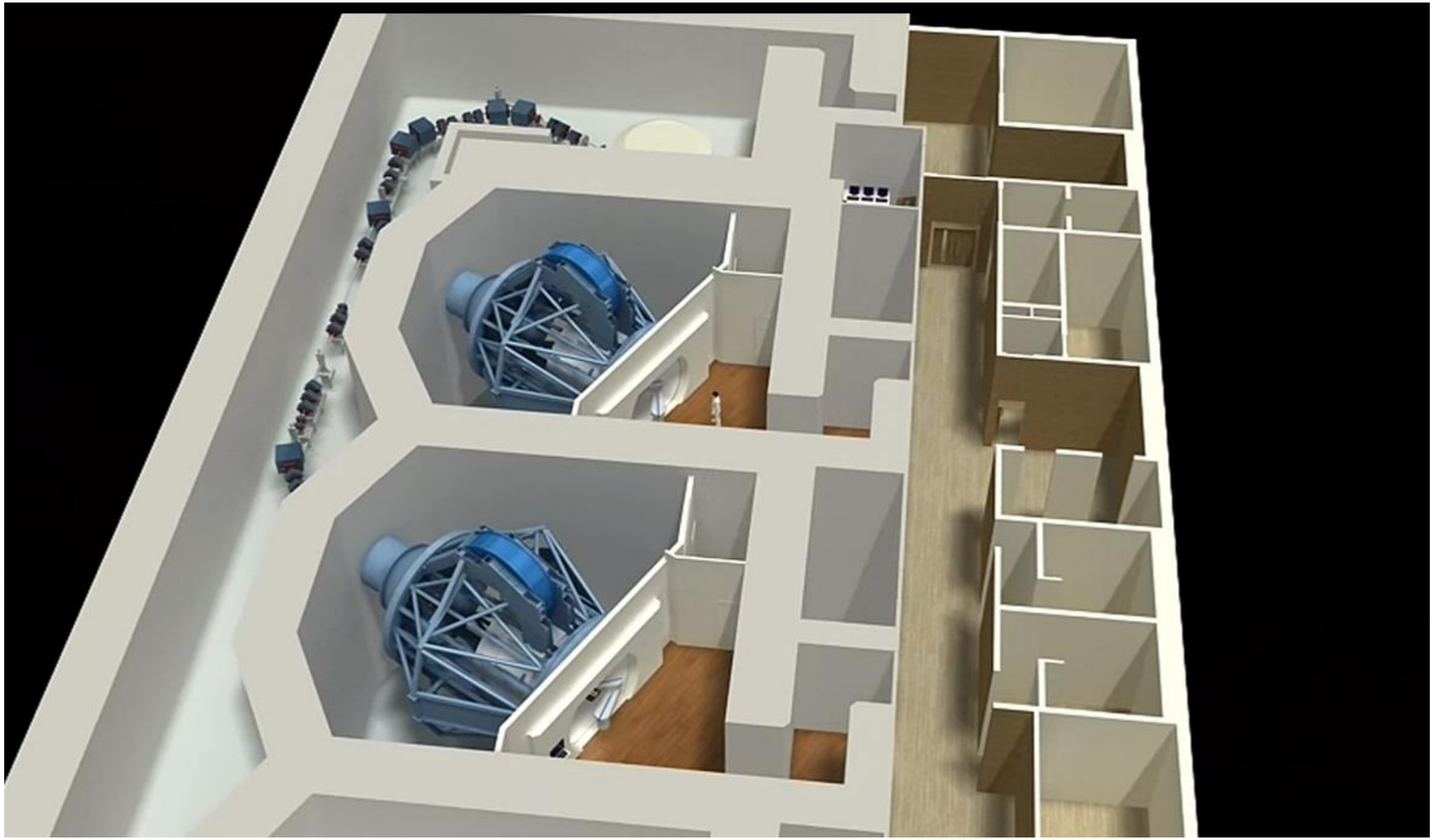
J.Kim, J Korean Neurosurg Soc. 2015 May;57(5):315-322

삼성서울병원

양성자 치료센터 소개

SMC Proton Therapy Center

양성자센터 장비, 치료실 조감도



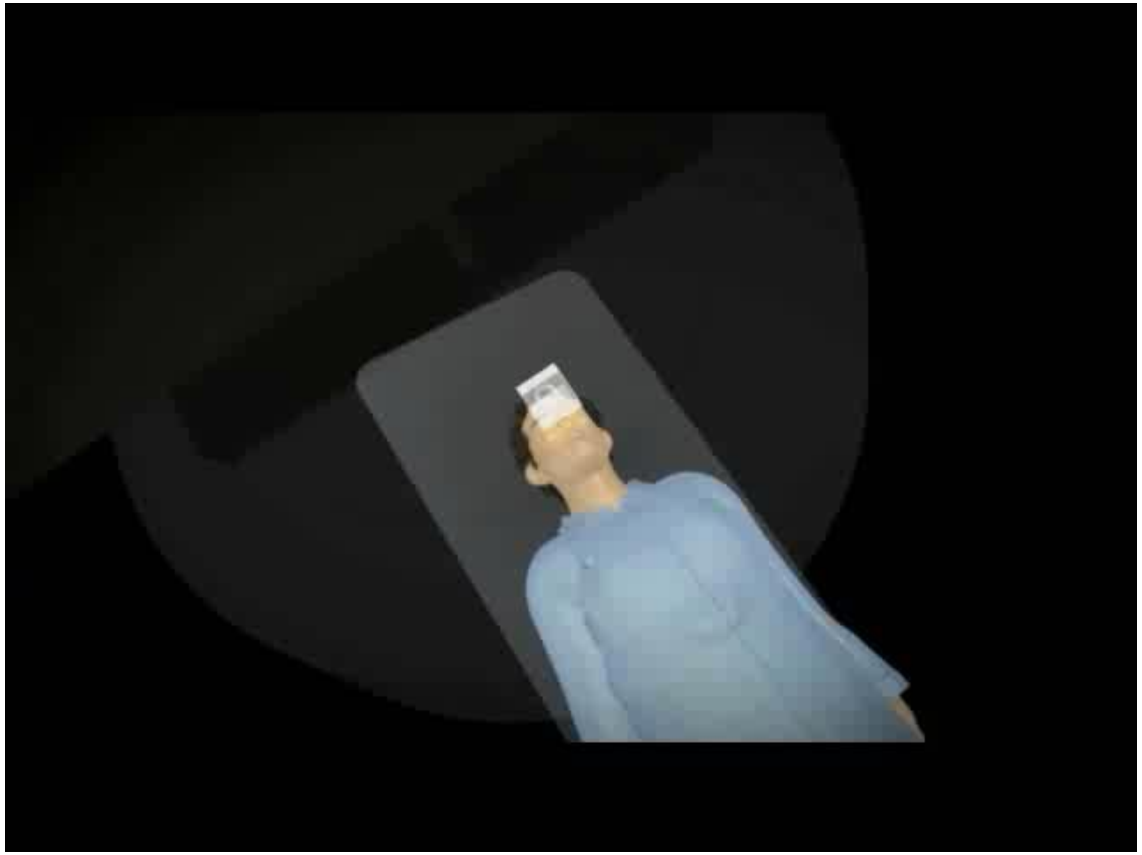
양성자센터 회전식 치료실

Particle Beam production

	Cyclotron	Synchrotron
Energy	Fixed	Variable
Spill Structure	Continuous	Pulse
Beam extract efficacy	Low (high radiation activity)	High
Temperature stability	Variable ->beam position, angle & energy (magnetic permeability > thermal expansion)	Stable
Beam current	High	Low
Beam quality (momentum spread)	Low (large)	High (small)

Gantry, Couch and Nozzle

치료 기법 (Treatment Technique)



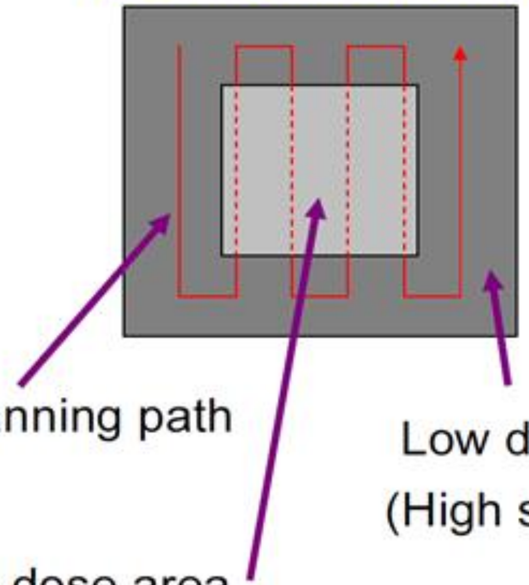
Wobbling Treatment

Line Scanning Treatment

Sumitomo Heavy Industries, Ltd.

Line Scanning

Intensity modulation



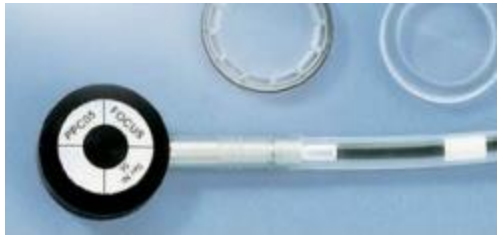
Scanning path

Low dose area
(High speed scanning)

High dose area
(Low speed scanning)

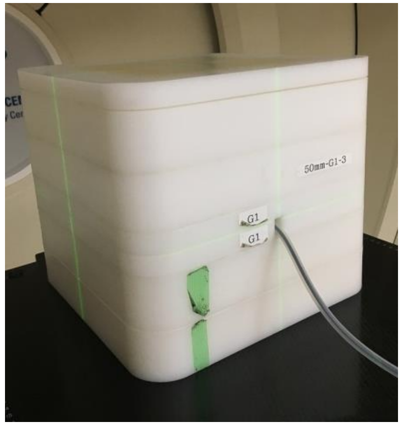
Example of scanning radiation fields

Dosimetry tools




Ion chambers ; Absolute (Relative) dose:
PPC05 (IBA), CC13 (IBA), Pinpoint3D (PTW), Bragg Peak (PTW)

Gafchromic film (EBT3);
Relative dose,
mechanical verification



Solid Phantom :
Material: High Density Polyethylene
Density = 0.950 g/cm^2
Composition
Carbon(C): 85.6% ,Hydrogen(H) : 14.3%

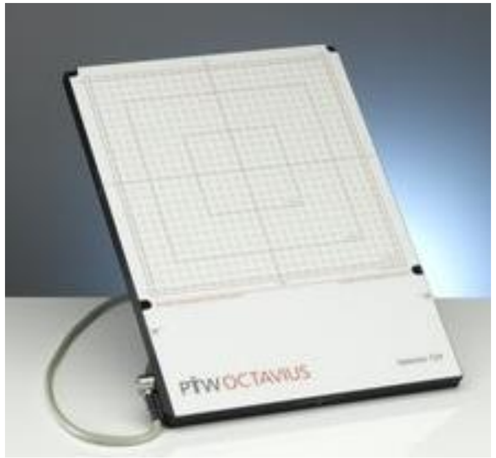
Dosimetry tools

Water Phantom

WP1D, IBA

Blue Phantom^2 , IBA

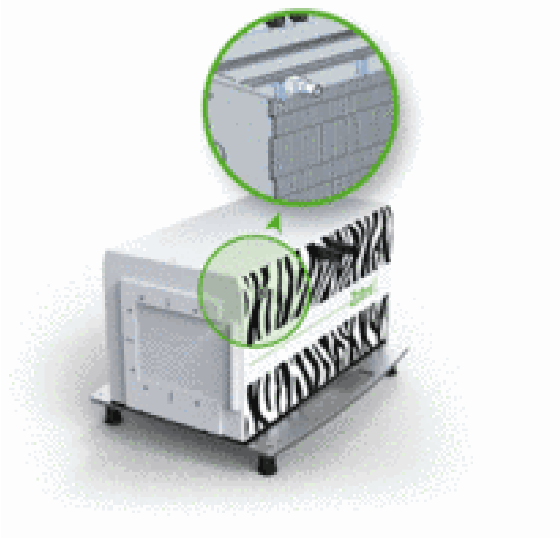
2D Array Detector



Octavius 729^{XDR}, PTW

729 vented ion chambers on 27x27 cm^2 with 1 cm resolution

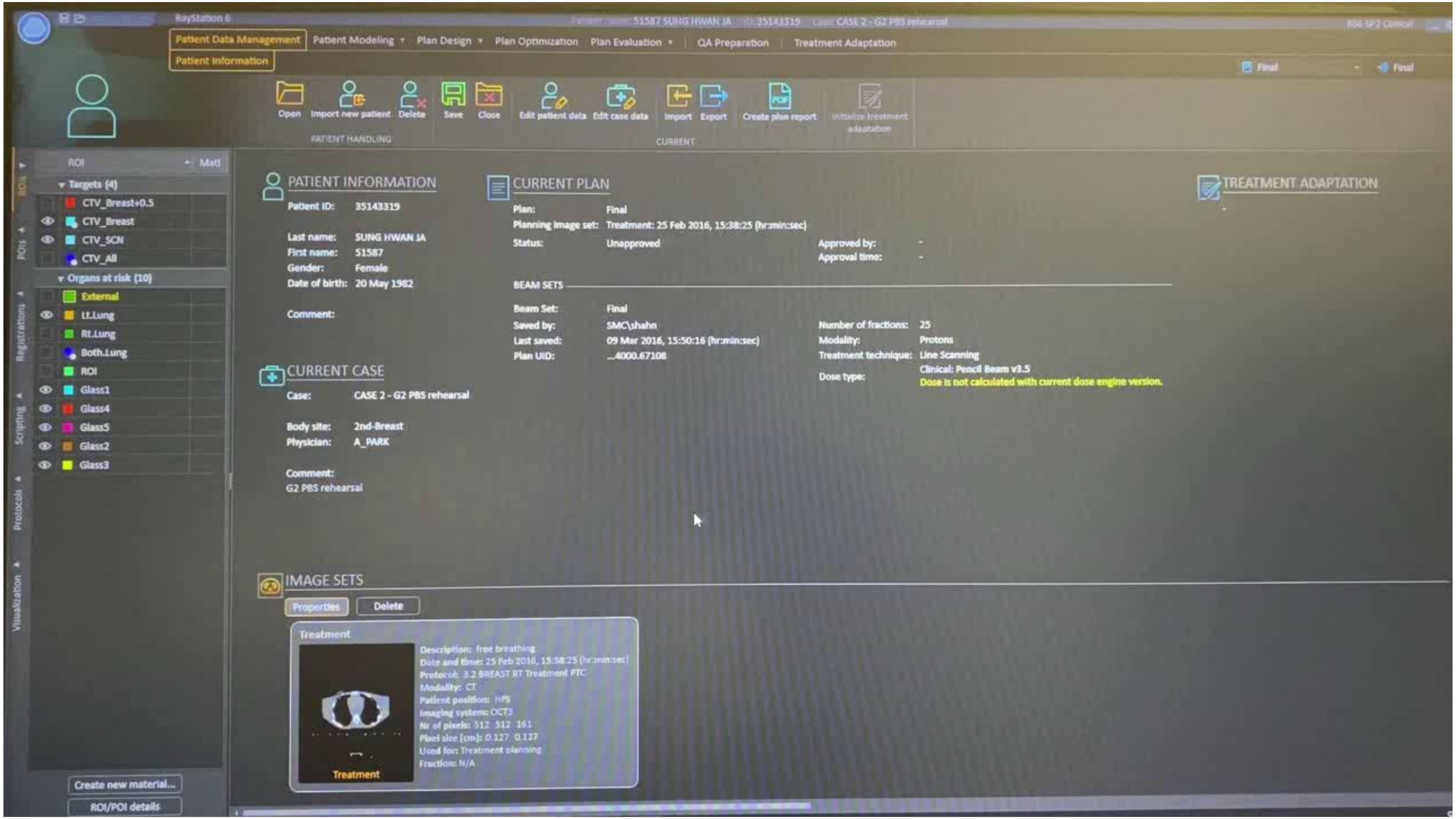
Multi Layer Ionization Chamber (MLIC)



ZEBRA, IBA

180 parallel plate chambers with 2 mm detector spacing

Treatment Planning System (TPS) : Raystation



Carbon Therapy

(중입자 치료)

THE HEIDELBERG ION THERAPY (HIT) - Carbon Gantry

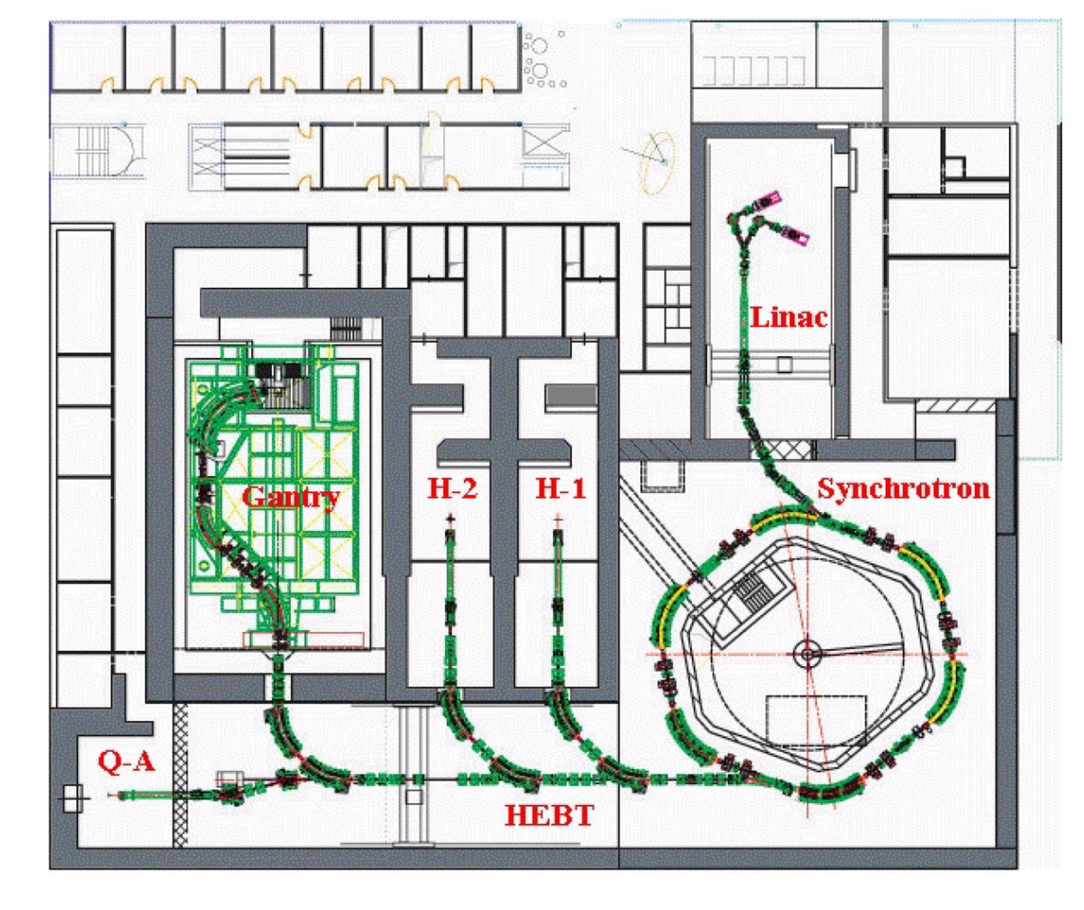


Figure 1: Layout of the first underground level housing the accelerator complex.

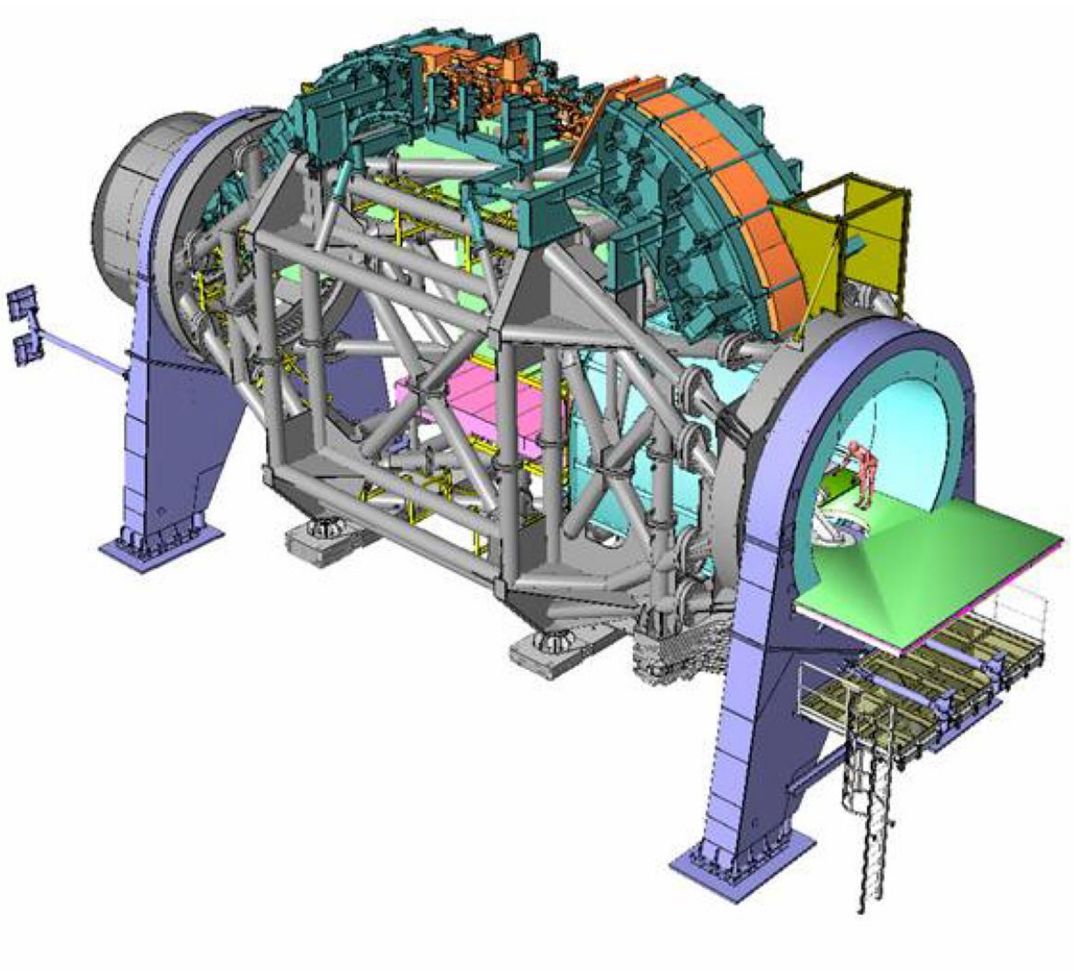
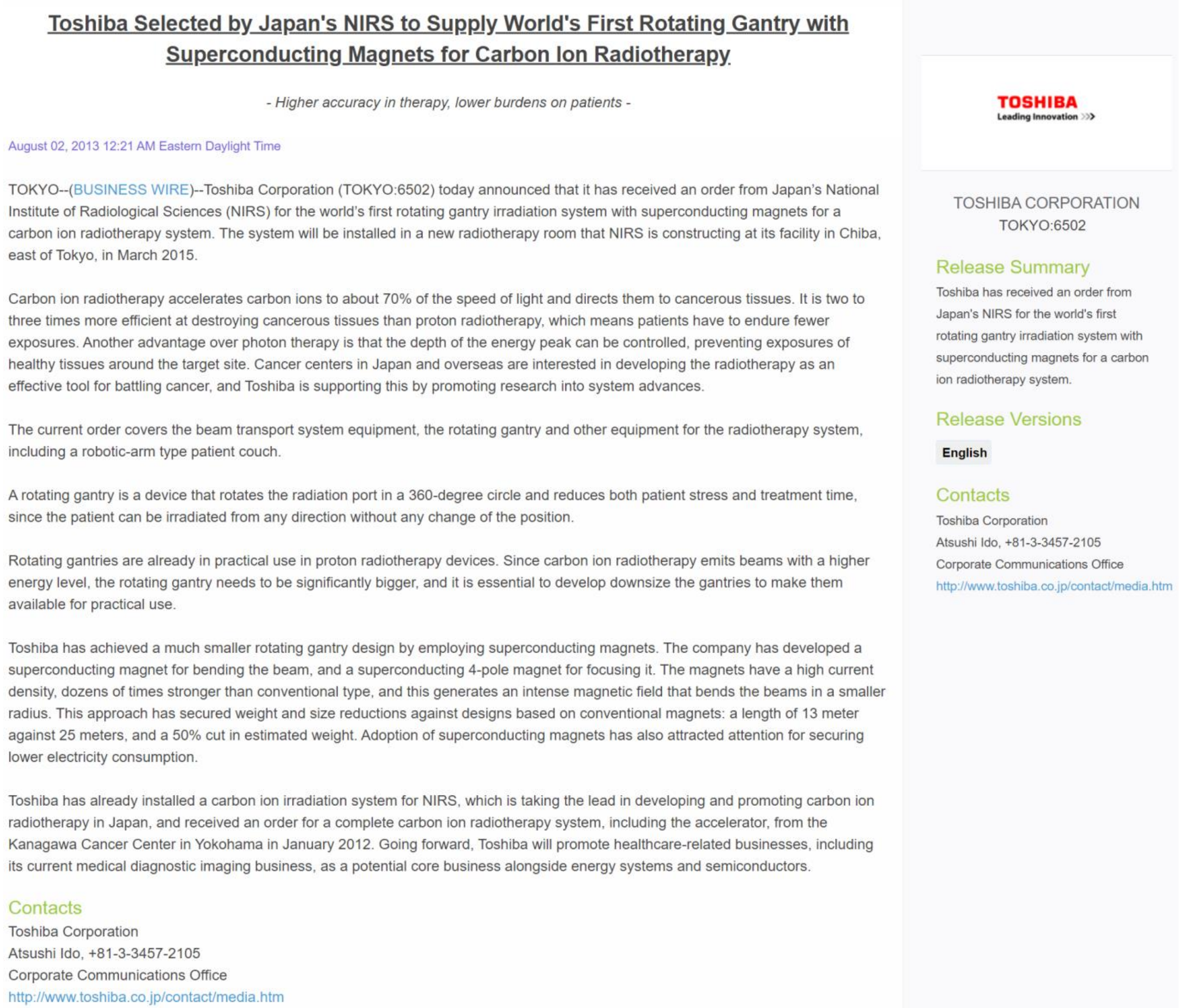


Figure 2: Overview of the isocentric ion gantry.

R. Fuchs et al, ASSEMBLY OF THE CARBON BEAM GANTRY AT THE HEIDELBERG ION THERAPY (HIT) ACCELERATOR, Proceedings of EPAC08, Genoa, Italy

Superconducting Carbon Gantry (TOSHIBA, NIRS)



Toshiba Selected by Japan's NIRS to Supply World's First Rotating Gantry with Superconducting Magnets for Carbon Ion Radiotherapy

- Higher accuracy in therapy, lower burdens on patients -

August 02, 2013 12:21 AM Eastern Daylight Time

TOKYO--(BUSINESS WIRE)--Toshiba Corporation (TOKYO:6502) today announced that it has received an order from Japan's National Institute of Radiological Sciences (NIRS) for the world's first rotating gantry irradiation system with superconducting magnets for a carbon ion radiotherapy system. The system will be installed in a new radiotherapy room that NIRS is constructing at its facility in Chiba, east of Tokyo, in March 2015.

Carbon ion radiotherapy accelerates carbon ions to about 70% of the speed of light and directs them to cancerous tissues. It is two to three times more efficient at destroying cancerous tissues than proton radiotherapy, which means patients have to endure fewer exposures. Another advantage over photon therapy is that the depth of the energy peak can be controlled, preventing exposures of healthy tissues around the target site. Cancer centers in Japan and overseas are interested in developing the radiotherapy as an effective tool for battling cancer, and Toshiba is supporting this by promoting research into system advances.

The current order covers the beam transport system equipment, the rotating gantry and other equipment for the radiotherapy system, including a robotic-arm type patient couch.

A rotating gantry is a device that rotates the radiation port in a 360-degree circle and reduces both patient stress and treatment time, since the patient can be irradiated from any direction without any change of the position.

Rotating gantries are already in practical use in proton radiotherapy devices. Since carbon ion radiotherapy emits beams with a higher energy level, the rotating gantry needs to be significantly bigger, and it is essential to develop downsize the gantries to make them available for practical use.

Toshiba has achieved a much smaller rotating gantry design by employing superconducting magnets. The company has developed a superconducting magnet for bending the beam, and a superconducting 4-pole magnet for focusing it. The magnets have a high current density, dozens of times stronger than conventional type, and this generates an intense magnetic field that bends the beams in a smaller radius. This approach has secured weight and size reductions against designs based on conventional magnets: a length of 13 meter against 25 meters, and a 50% cut in estimated weight. Adoption of superconducting magnets has also attracted attention for securing lower electricity consumption.

Toshiba has already installed a carbon ion irradiation system for NIRS, which is taking the lead in developing and promoting carbon ion radiotherapy in Japan, and received an order for a complete carbon ion radiotherapy system, including the accelerator, from the Kanagawa Cancer Center in Yokohama in January 2012. Going forward, Toshiba will promote healthcare-related businesses, including its current medical diagnostic imaging business, as a potential core business alongside energy systems and semiconductors.

Contacts
Toshiba Corporation
Atsushi Ido, +81-3-3457-2105
Corporate Communications Office
http://www.toshiba.co.jp/contact/media.htm

TOSHIBA Leading Innovation

TOSHIBA CORPORATION
TOKYO:6502

Release Summary
Toshiba has received an order from Japan's NIRS for the world's first rotating gantry irradiation system with superconducting magnets for a carbon ion radiotherapy system.

Release Versions
English

Contacts
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Atsushi Ido, +81-3-3457-2105
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http://www.toshiba.co.jp/contact/media.htm

https://www.businesswire.com/news/home/20130801006999/en/Toshiba-Selected-by-Japans-NIRS-to-Supply-Worlds-First-Rotating-Gantry-with-Superconducting-Magnets-for-Carbon-Ion-Radiotherapy

SUPERCONDUCTING GANTRY FOR CARBON-ION RADIOTHERAPY

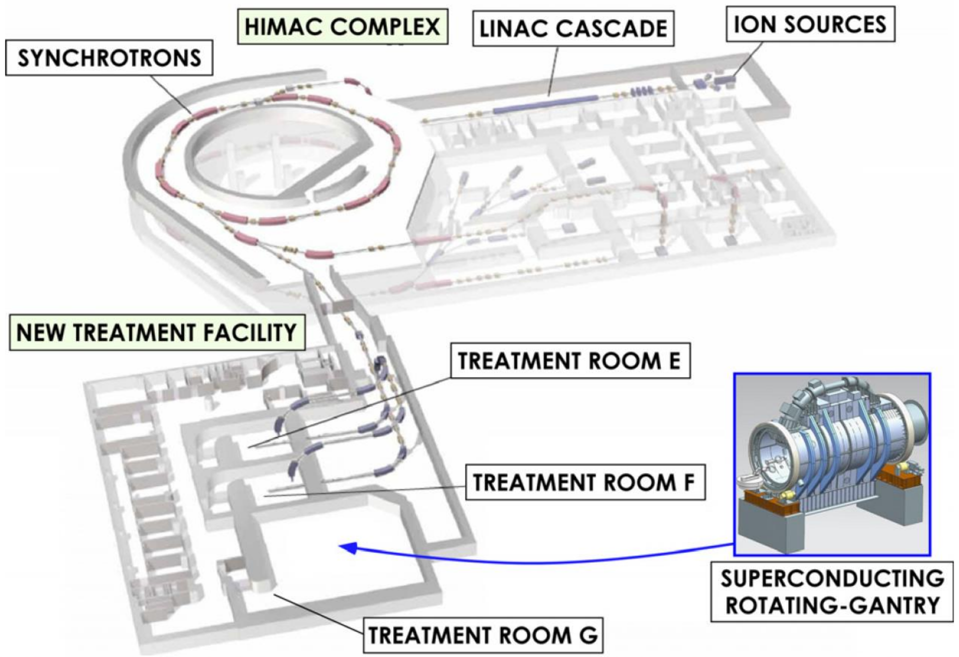


Figure 1: Bird's eye view of the HIMAC complex. The HIMAC complex consists of three ion sources, one linac cascade, two synchrotron rings, and three treatment rooms. The new treatment facility was constructed in conjunction with the HIMAC complex, and has the three treatment rooms.

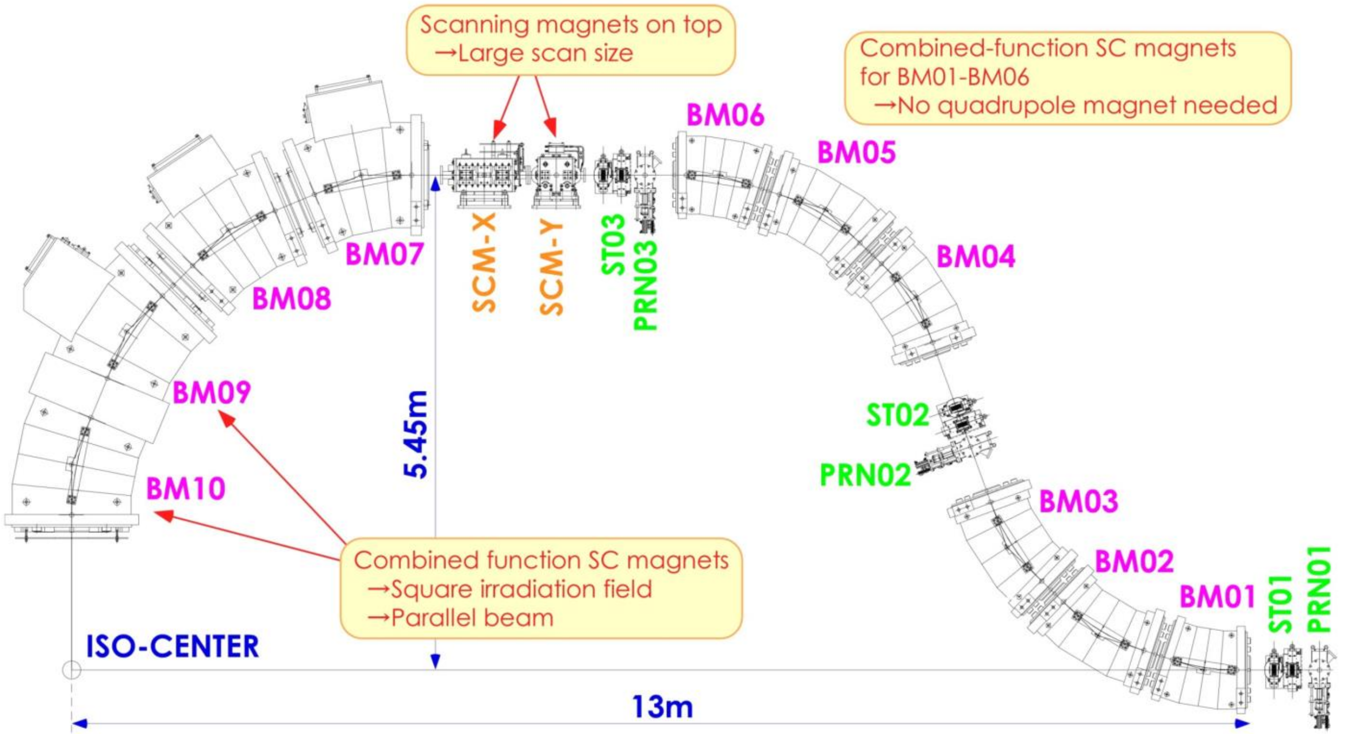


Figure 2: Layout of the superconducting rotating-gantry. The gantry consists of the ten superconducting magnets (BM01-BM10), the three pairs of the steering magnets (ST01-ST03) and profile monitors (PRN01-PRN03), and a pair of the scanning magnets (SCM-X and SCM-Y).

Y. Iwata et al, SUPERCONDUCTING GANTRY FOR CARBON-ION RADIOTHERAPY, 9th International Particle Accelerator Conference, IPAC2018, Vancouver, BC, Canada

SUPERCONDUCTING GANTRY FOR CARBON-ION RADIOTHERAPY

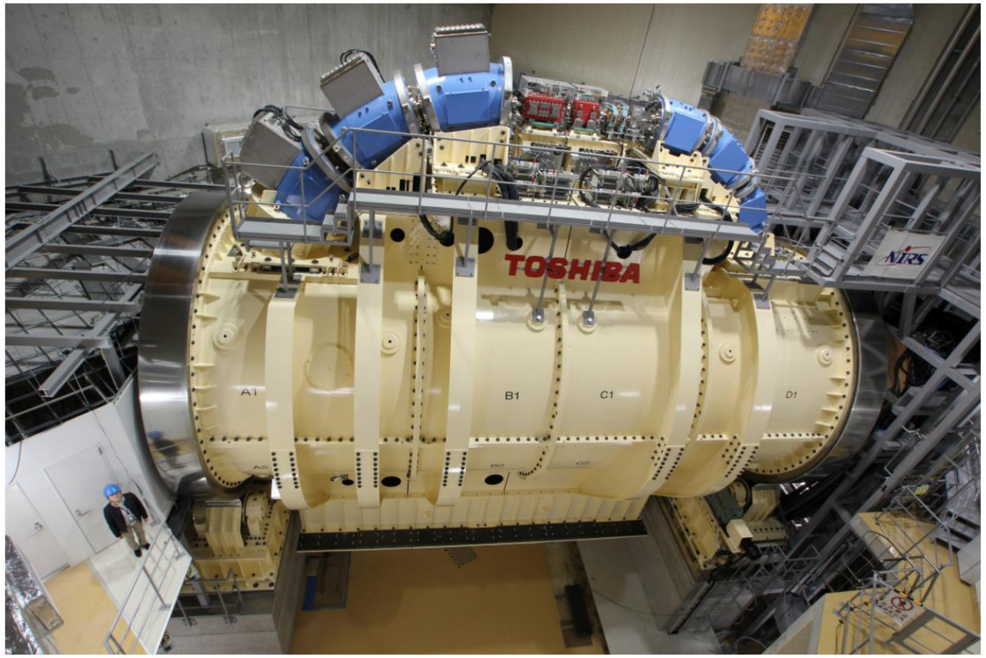


Figure 3: Picture of the superconducting rotating-gantry, as taken at the end of September 2015. The superconducting magnets and the scanning magnets are colored in blue and red, respectively.

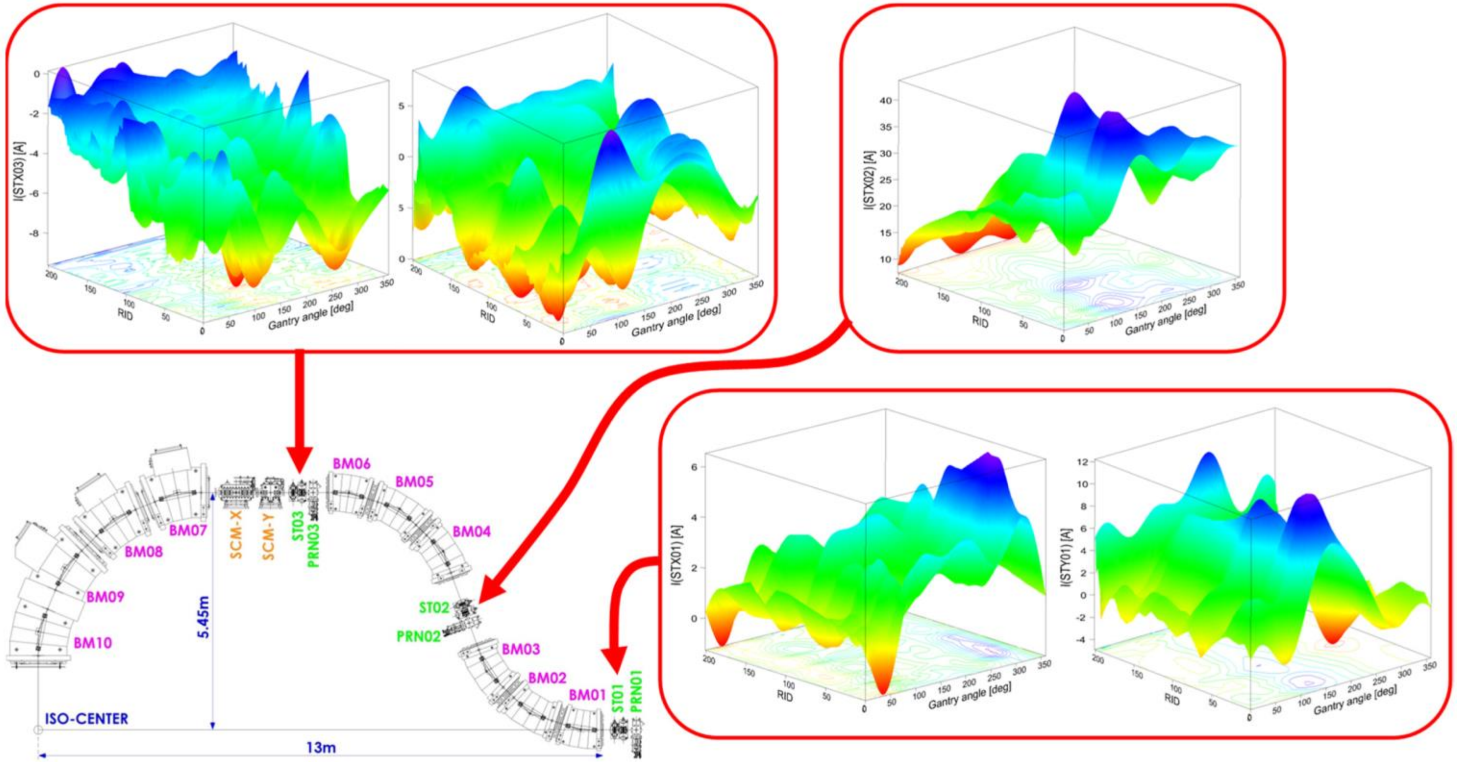
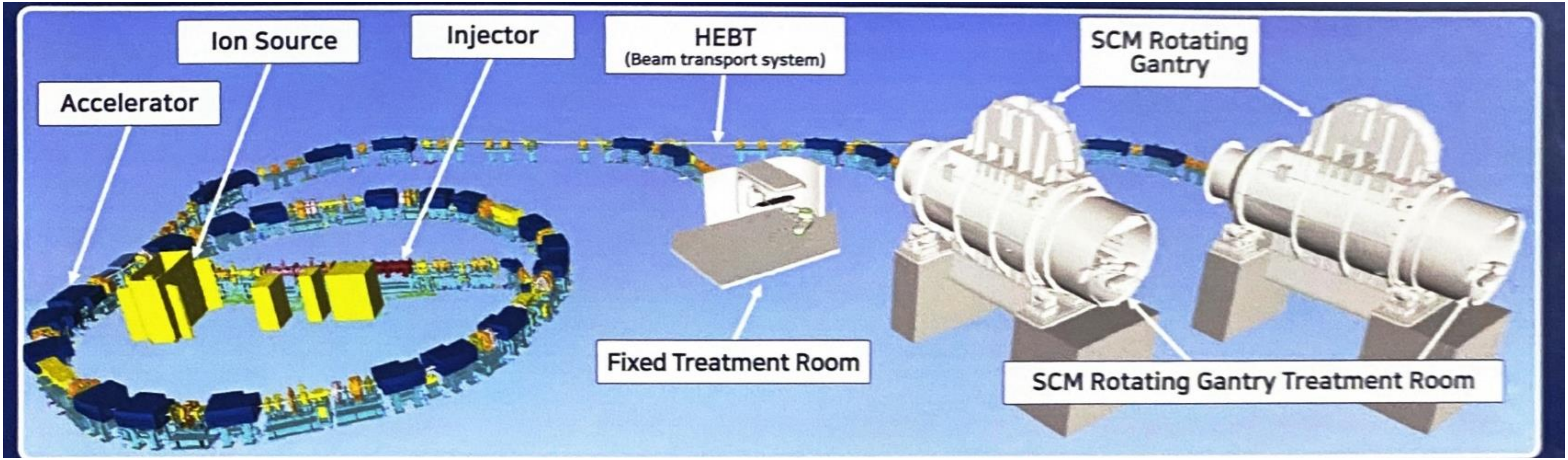


Figure 7: Coil currents for the horizontal steering magnets of STX01-STX03 and the vertical steering magnets of STY01-STY03 as functions of the gantry angle and RID. The steering magnets were turned so as to center the beam spot at the profile monitors as well as the isocenter.

Y. Iwata et al, SUPERCONDUCTING GANTRY FOR CARBON-ION RADIOTHERAPY, 9th International Particle Accelerator Conference, IPAC2018, Vancouver, BC, Canada

연세암병원 중입자치료센터
- 가속기 시스템 (Accelerator)



https://cancer.severance.healthcare/cancer/department/center-clinic/therapy.do

연세암병원 중입자치료센터
- 가속기 시스템 (Accelerator)

Ion source

◈ Prouduct ion : $^{12}C^{4+}$

◈ Acceleration Voltage : 30 kV

◈ Acceleration Current : 200 eμA

◈ Gas type : CH_4

Injector system

◈ Components : RFQ linear accelerator, Drift Tube linear accelerator(DTL), Medium low beam transport system, charge converter devices

◈ RFQ linear accelerator
- ▶ Length : 2.5 m
- ▶ Incident energy : 10 keV/u
- ▶ Exit energy : 600 keV/u
- ▶ RF frequency, power : 200 MHz, 100 kW

◈ Drift Tube linear accelerator
- ▶ Length : 2.5 m
- ▶ Incident energy : 600 keV/u
- ▶ Exit energy : 4 MeV/u
- ▶ RF frequency, power : 200 MHz, Max 400 kW

Accelerator (Synchrotron)

◈ Components: beam injection devices, bending magnets, quadrupole magnets, vacuum ducts, RF accelerating cavity, beam extraction devices, accelerator control devices

◈ Accelerated ions : $^{12}C^{6+}$

◈ Accelerated particle number : 3 x 10^9 particles / pulse or more

◈ Incident energy : about 4.0 MeV/u

◈ Outgoing energy : 55.6 to 430 MeV/u

◈ Outgoing beam intensity 3 x 10^7 to 1 x 10^9 pieces / sec

◈ Circumference : 63.3 m (Diameter : approx. 20 m)

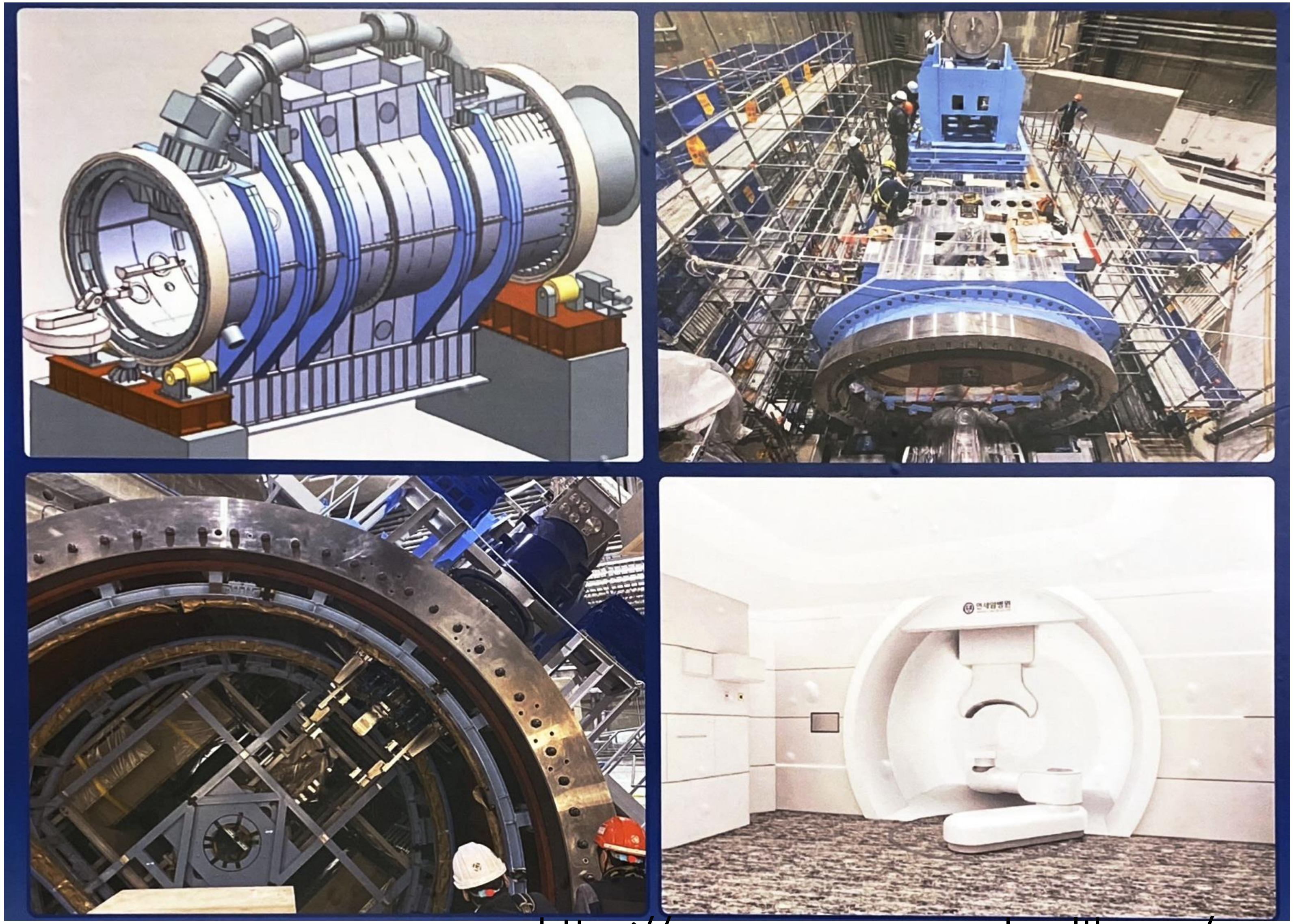
HEBT
(High Energy Beam Transport)

◈ Components : vacuum ducts, bending magnets, quadrupole magnets, beam control devices

The carbon ions accelerated to the energy required by the main accelerator is transported along the transport route by magnets, and is guided to the irradiation system of the designated treatment room

https://cancer.severance.healthcare/cancer/department/center-clinic/therapy.do

연세암병원 중입자치료센터
-갠트리 치료실 (Rotational Gantry)



General

- ◈ Field size: 20 × 20 cm^2
- ◈ Spot size: Less than 4 mm (1 sigma)
- ◈ 6D robotic couch
- ◈ 3D high-speed scanning
- ◈ Respiratory-gated irradiation

Specific

- ◈ Compact gantry design
  - ▶ Diameter : ~6 m
  - ▶ Length : ~8 m
  - ▶ Weight : ~200 tons
- ◈ Components
  - ▶ Ten superconducting magnet
  - ▶ A pair of scanning magnets
  - ▶ Three pairs of steering magnets
  - ▶ Beam profile monitors

https://cancer.severance.healthcare/cancer/department/center-clinic/therapy.do

Artificial Intelligence in Radiation Oncology

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Review

Artificial intelligence in radiation oncology: A specialty-wide disruptive transformation?

Reid F. Thompson [a,b,*], Gilmer Valdes [c], Clifton D. Fuller [d], Colin M. Carpenter [e], Olivier Morin [c], Sanjay Aneja [f], William D. Lindsay [g], Hugo J.W.L. Aerts [h,i], Barbara Agrimson [a], Curtiland Deville Jr. [j], Seth A. Rosenthal [k], James B. Yu [f], Charles R. Thomas Jr [a]

[a] Oregon Health & Science University, Portland; [b] VA Portland Health Care System, Portland; [c] University of California San Francisco, San Francisco; [d] MD Anderson Cancer Center, Houston; [e] Siris Medical, Inc, Redwood City; [f] Yale University, New Haven; [g] Oncora Medical, Philadelphia; [h] Brigham and Women's Hospital, Boston; [i] Dana Farber Cancer Institute, Boston; [j] Johns Hopkins University School of Medicine, Baltimore; and [k] Sutter Medical Group and Suttter Cancer Center, Sacramento, USA

The current state of AI in radiation oncology

- Image segmentation
- Radiotherapy dose optimization
- Clinical decision support and outcomes prediction
- Quality assurance (QA)

Summary

- 의학물리학, 의학물리사
- 방사선생물 (Radiobiology)
- 방사선종양 (Radiation Oncology)
- 방사선물리 (Radiation Phsics)
- Photon (X-ray) Therapy vs. Proton Therapy
- 양성자치료 (Proton Therapy)
- 양성자치료기 개발 및 증가추세
- Superconducting 기술로 인해 기존에 비해 작고 가벼운 중입자치료기 Gantry 개발
- 그리고, 방사선치료에서도 인공지능기술 적용으로 계속된 발전 진행중…