# Proton Therapy


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의학물리학자(교수)

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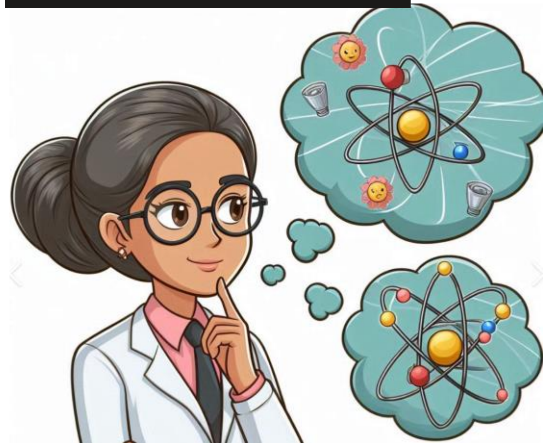
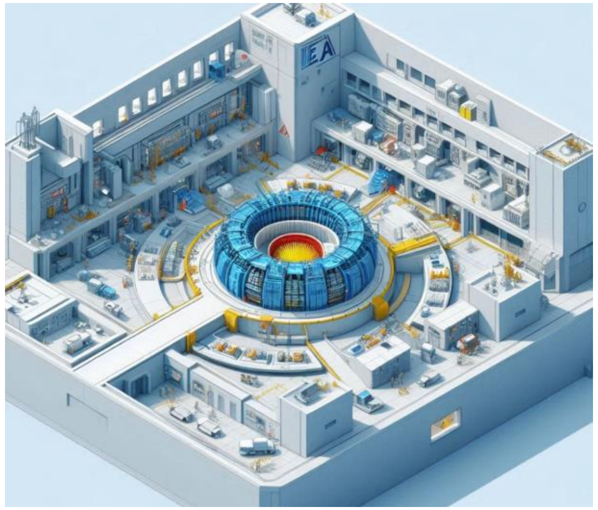
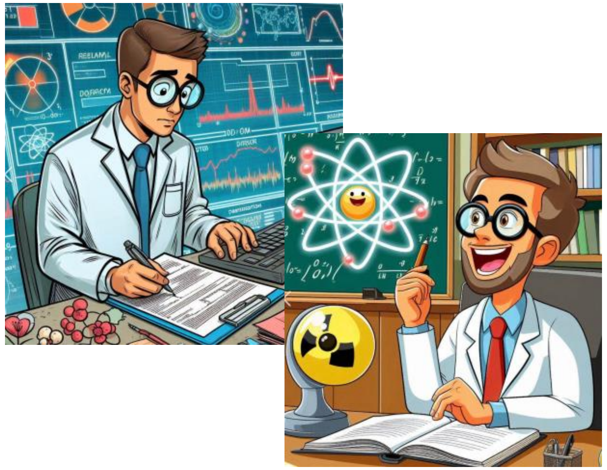
고려대학교 세종캠퍼스

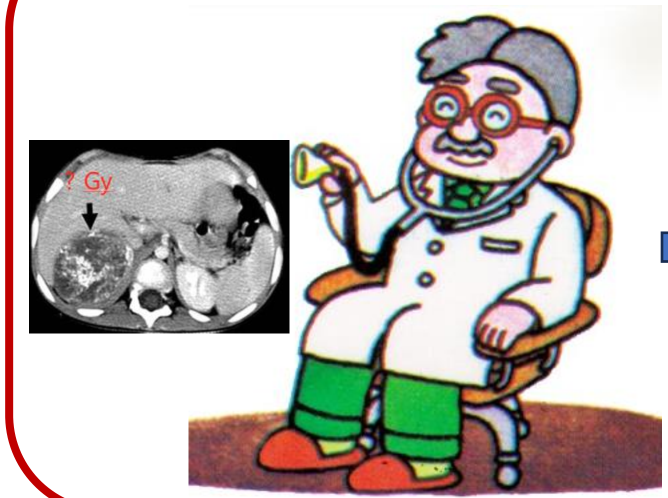
# Accelerator Experiment vs. Radiation Treatment

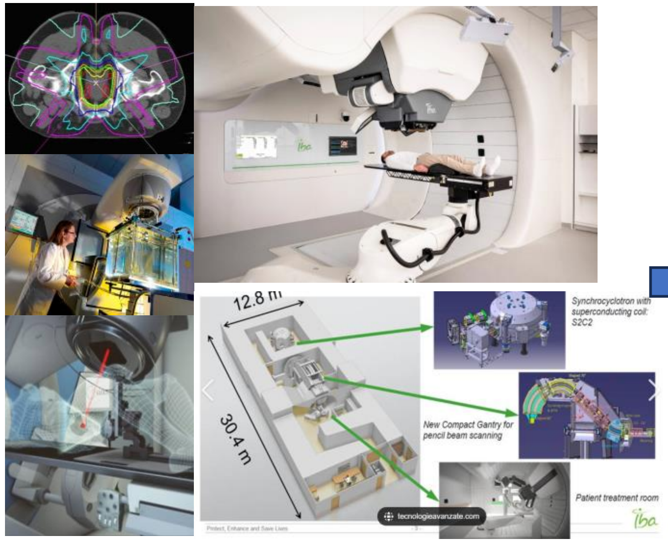
Copilot | Designer

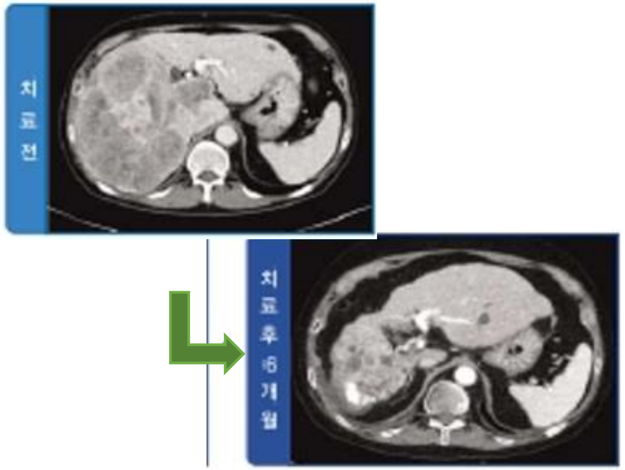




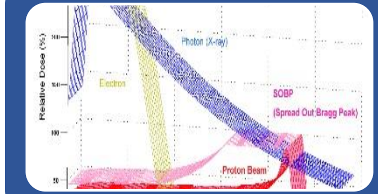




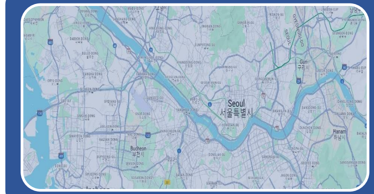



Introduction: NCC Proton Therapy & Particle Therapy



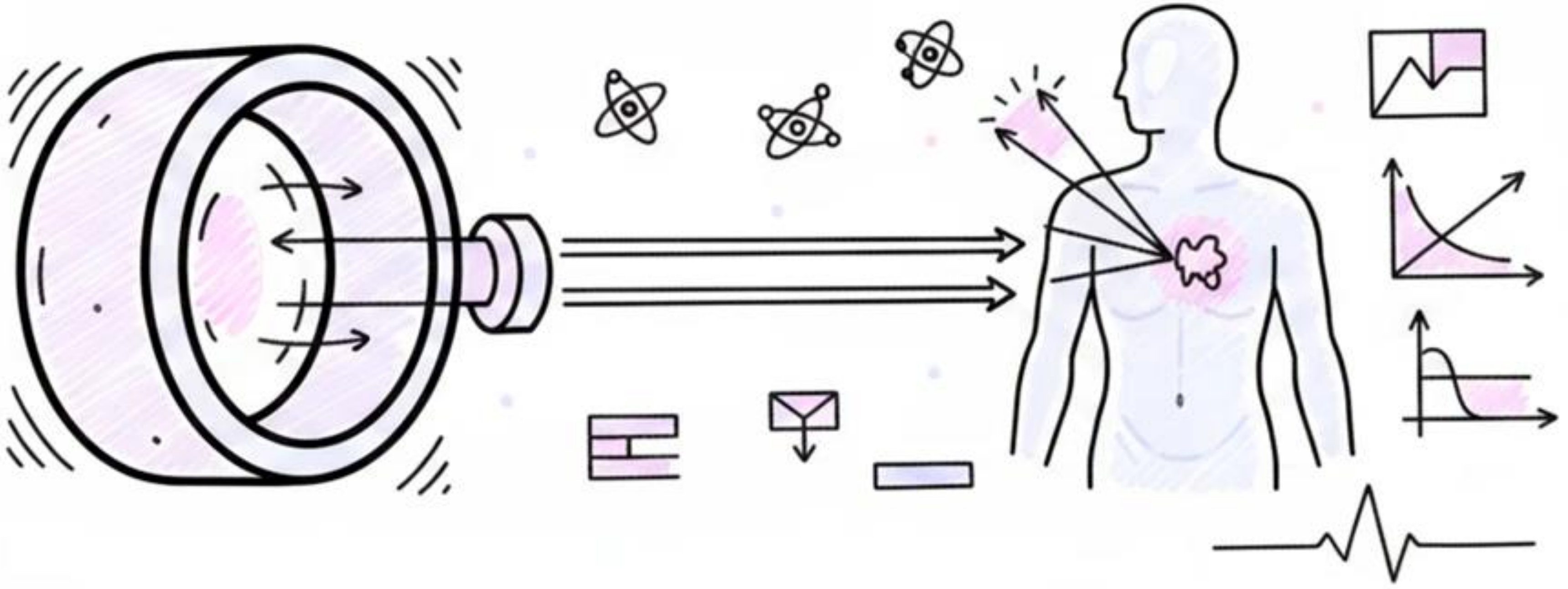

Why we need proton therapy in clinical?

Proton therapy system & techniques

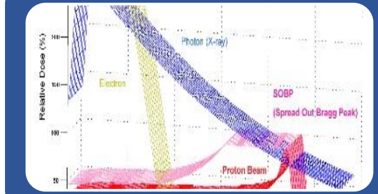


Current Status of Particle therapy in Korea

# 의학 속 가속기: 양성자 치료



Introduction: NCC Proton Therapy & Particle Therapy

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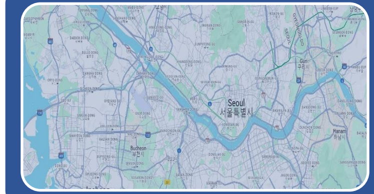



Current Status of Particle therapy in Korea

Hospital

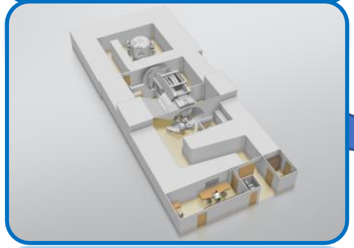
New Hospital

Research Institute

Proton Therapy Center

National Center For
Cancer Prevention
And Early Detection

# History



| | |
|---|---|
| 2000.10 | •NCC Start clinical care service |
| 2001.6 | •NCC Opening ceremony held |
| 2001.12 | •Launch of NCC proton therapy Project |
| 2002.6.29 | •Signing with IBA |
| 2003.3.21 | •Ground Breaking |
| 2003.5-2004.12 | •Building construction |
| 2005.2.15 | •Start of IBA Proteus 235 installation |
| 2005.10.21 | •First Beam Generation |
| 2005.10-2006.12 | •Beam test &tuning for Cyclotron and Beamline |
| 2007.1-2007.2 | •Commissioning and Beam data taking |
| 2007.3.19 | •First Patient Treatment start (GTR2) $27^{th}$ Open in the world, $3^{th}$ IBA System in the world |
| 2007.7.9 | •GTR3 Patient treatment start |
| 2009.5.15 | •First Eye melanoma proton treatment start |
| 2010.8.27 | •First Wobbling mode Tx start (GTR2) |
| 2015.8.27 | •First PBS mode Tx Start(GTR3) |
| 2027 | •Compact Proton Therapy system(IBA Proteus one) install |


## 2001

**Creation of NCC-K**

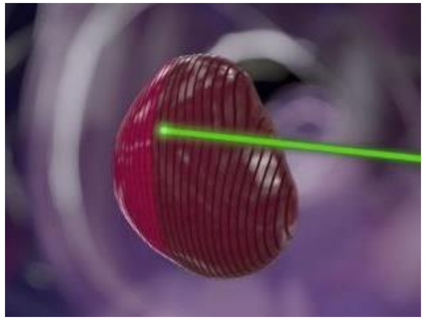
First treatment in PT at **MGH**

## 2002

**NCC-K** purchases its Proteus®**PLUS**

## 2007

First patient treatment at **NCC-K** in passive scattering mode



## 2015

First treatment with pencil beam scanning at **NCC-K**

## 2018

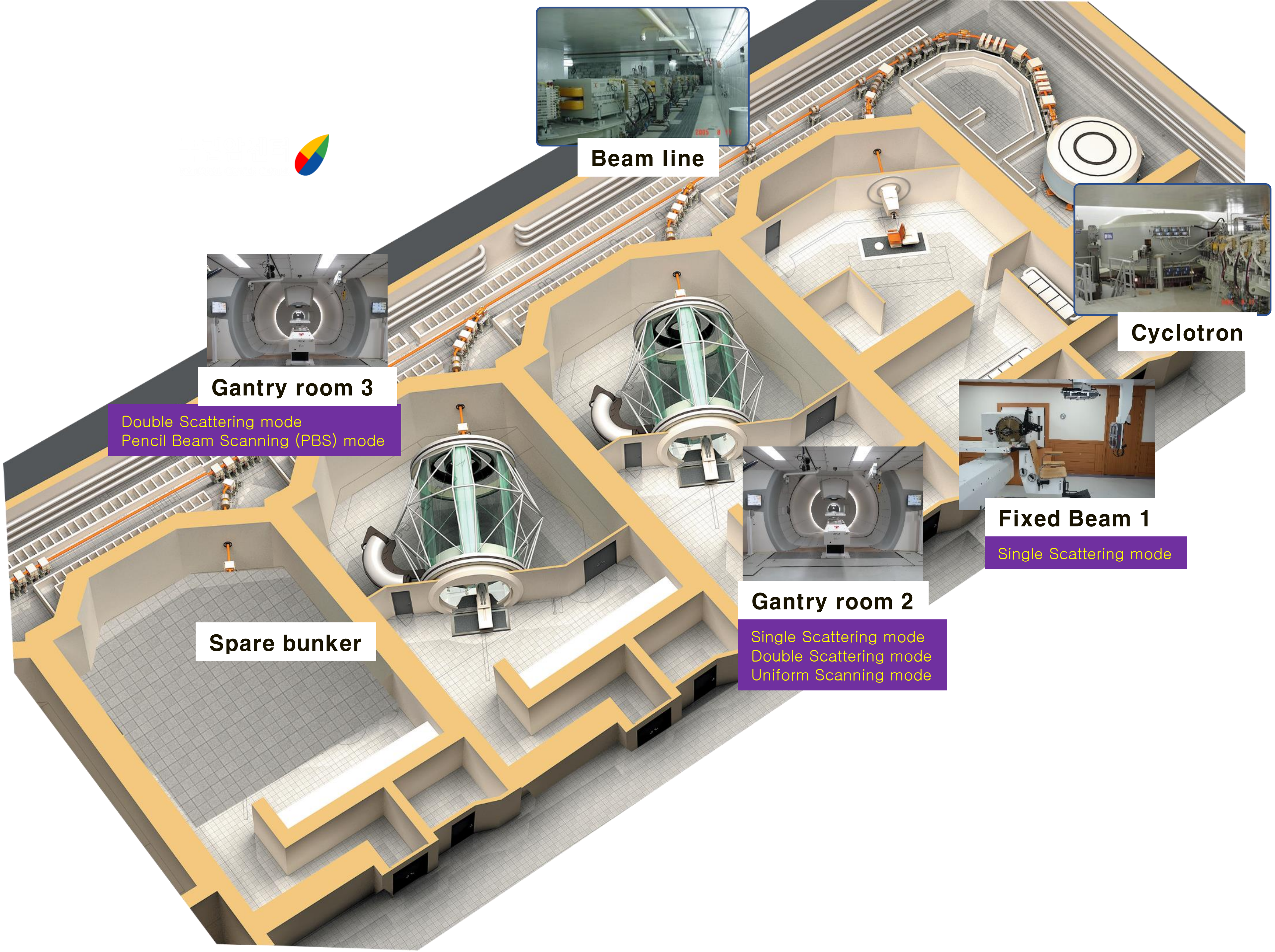
Introduction of Gantry Rolling Floor and Remote Postiionning at **NCC-K**

## 2019

Adapt Insight imaging platform + first clinical use of Cone Beam CT (CBCT) at **NCC-K**

## 2021

NCC-K purchases compact IMPT solution Proteus®**ONE**


Beam line
Cyclotron
Gantry room 3
Double Scattering mode
Pencil Beam Scanning (PBS) mode
Fixed Beam 1
Single Scattering mode
Gantry room 2
Single Scattering mode
Double Scattering mode
Uniform Scanning mode
Spare bunker

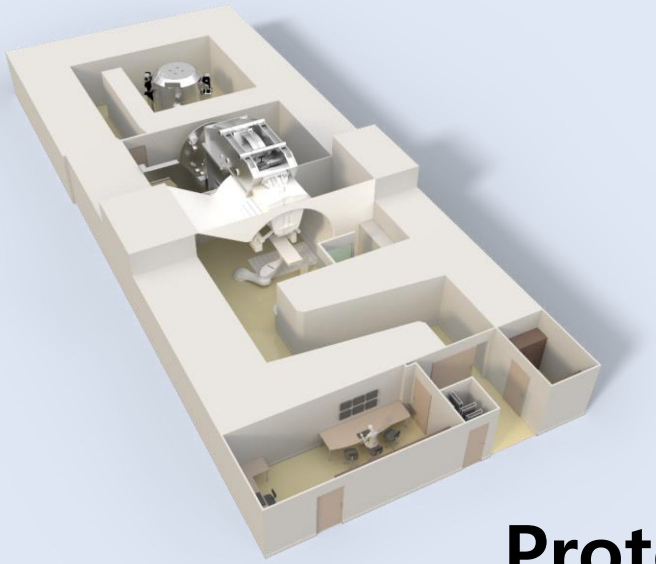
## ❖ People

| | Staff | Fellow(Residency) |
|---|---|---|
| Oncologist | 7 | 1(0) |
| Medical physicist | 6 | 4(4) |
| Therapist | 49 | |
| Nurse | 6 | |
| Proton Engineer | 9 | |
| Office work | 3 | |

## ❖ Facilities

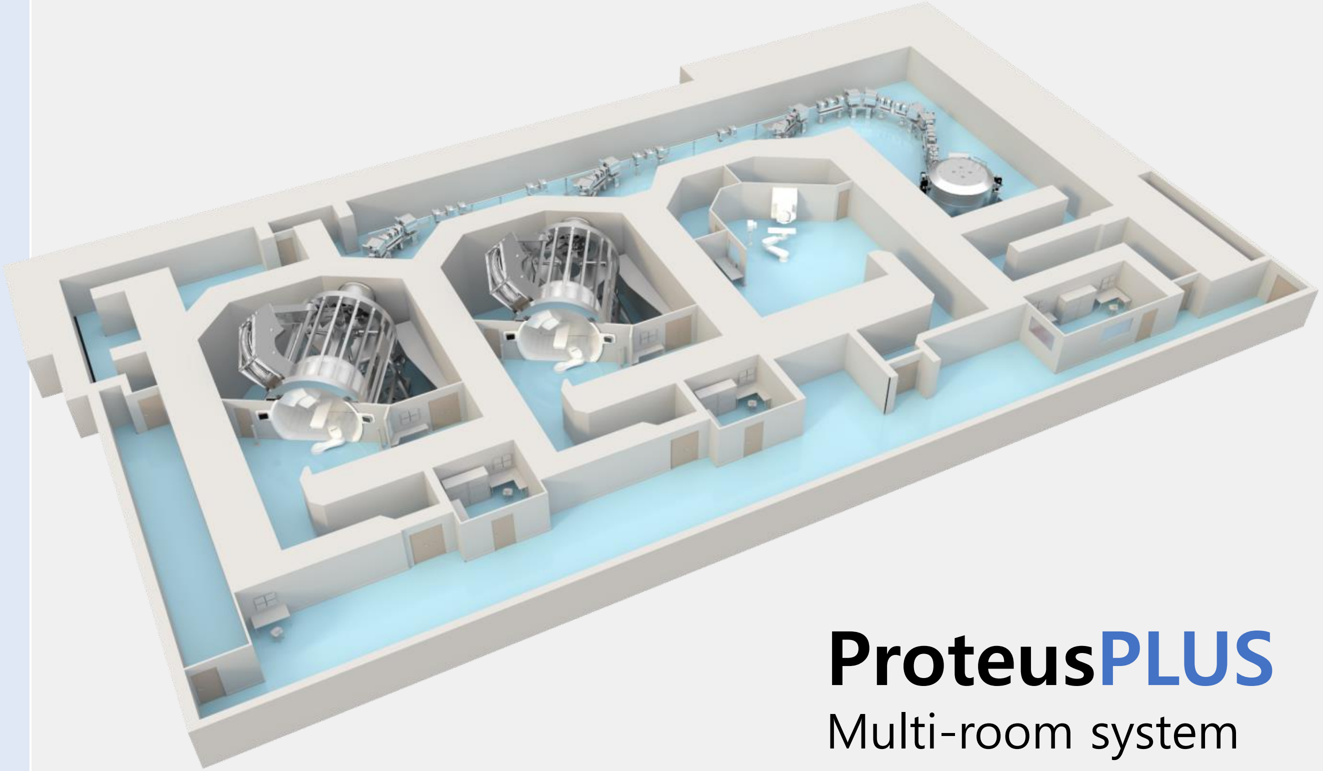
| Treatment room | | |
|---|---|---|
| Proton | 3 | MCR, MMS |
| X-ray LINAC | 3 | |
| TOMO therapy | 2 | |
| CT simulator | 2 | 4D &Dual Energy CT |
| 2D simulator | 1 | |
| HDR | 1 | |

# Addition of a single room system - National Cancer Center



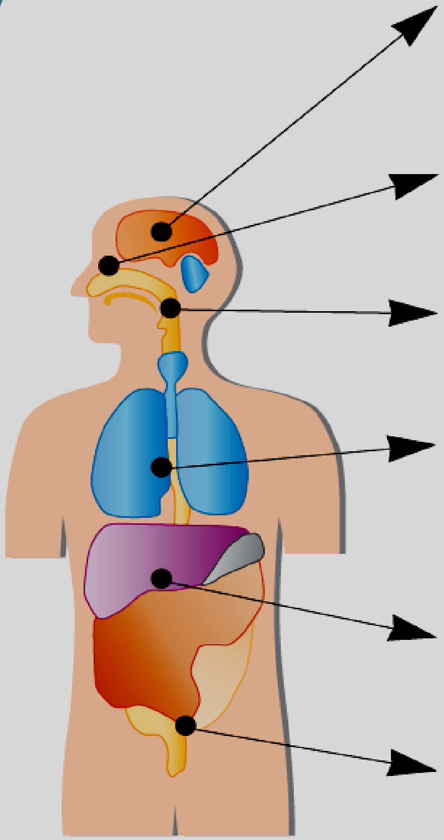
**ProteusONE**
Single-room system
**NEW!**

In **2028**



**ProteusPLUS**
Multi-room system
**FACING OBSOLESCENCE**

# Treatment sites with proton therapy at NCC



**Central Nervous System (Brain & Spinal Cord)**
- glioma
- pituitary adenoma
- chordoma
- vestibular schwannoma
- meningioma
- optic glioma

**Orbit (Eye)**
- choroidal melanoma
- lacrimal gland tumor
- retinoblastoma

**Head & Neck**
- oropharyngeal cancer
- unresectable or recurrent cancer
- nasopharyngeal cancer

**Thorax and Breast**
- lung cancer : selective
- breast cancer : selective
- esophageal cancer
- unresectable or recurrent cancer

**Abdomen**
- liver and pancreas cancer : selective
- unresectable or recurrent cancer

**Pelvis and Extremities**
- prostate cancer
- chordoma
- unresectable or recurrent cancer
- sarcoma
- soft tissue sarcoma

**Pediatric (Child) Tumors**
- Glioma, medulloblastoma and other primitive neuroectodermal tumors, germinoma, sarcoma, retinoblatoma, soft tissue sarcoma, skull base chordoma and chondrosarcoma
- recurrent cancer and others : selective

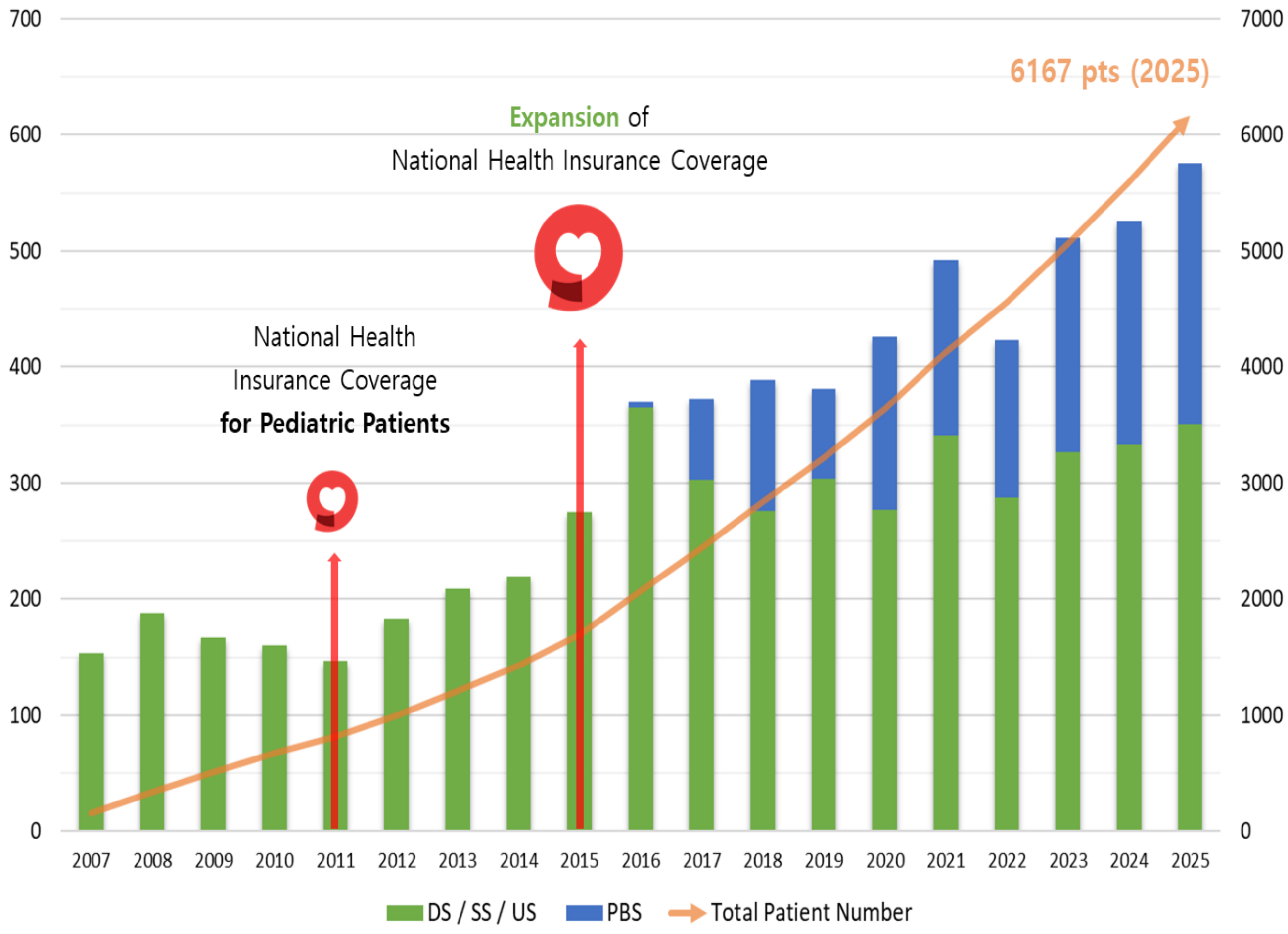
**570+** patients/yr

**6167** patients as per Dec 2025

On **2** shifts (8:00AM – 10:00PM)

NCC-K is at capacity

It calls for expansion




*Slide and data are courtesy of Dr. Tae Hyun Kim, Medical Director at NCC-K*

# PTCOG: Total Number of Patients Treated Globally

**384629**
Cumulative Number of Patients 2024

**429595**
Cumulative Estimated Number 2025

Particle Therapy Co-Operative Group

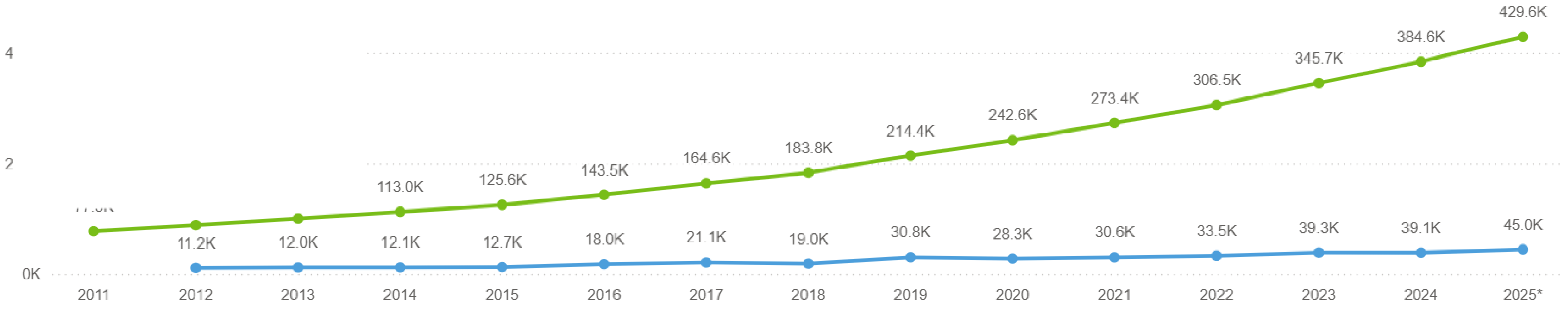
Country
All

Region
All

Vendor
All

## Cumulative and Yearly Number of Patients Treated

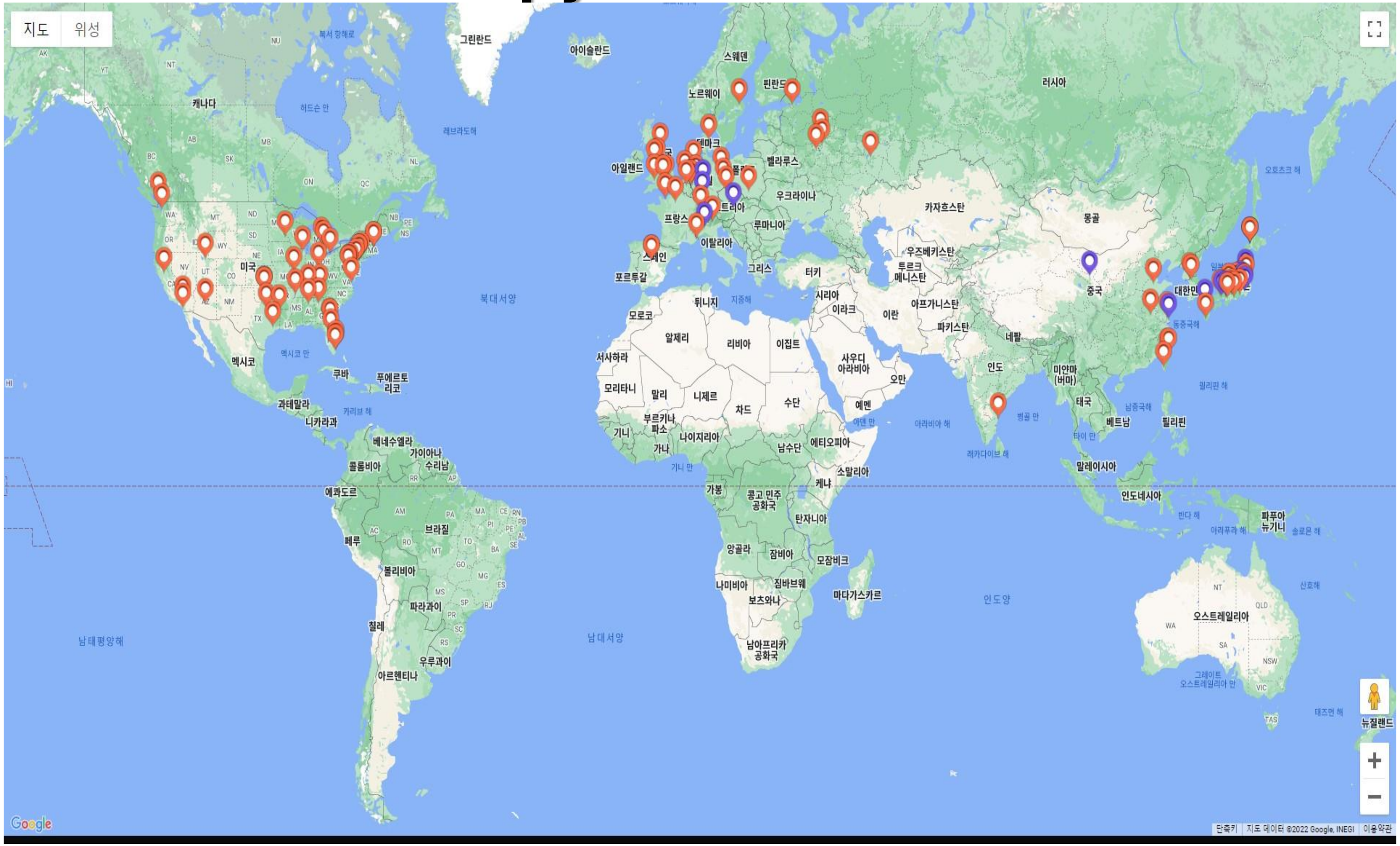
Cumulative Yearly




*The number of patients treated in 2025 is **estimated** using exponential smoothing algorithm. Click for more info.

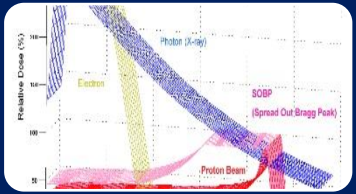
Source: PTCOG statistics (www.ptcog.conline) and IBA internal data

# Particle Therapy Center in the world



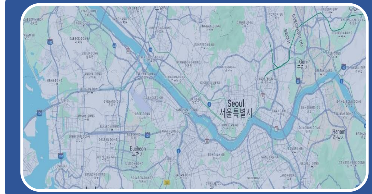

*Last update : July-2022 from PTCOG*

Introduction: NCC Proton Therapy & Particle Therapy




Why we need proton therapy in clinical?

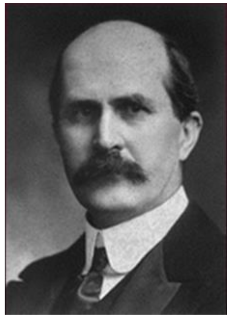
Proton therapy system & techniques

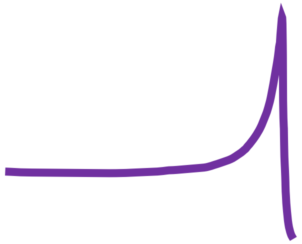



Current Status of Particle therapy in Korea

# History of Proton(Particle) Therapy

- *William Bragg* -1904: Publication of curves for ionization of air by radium alpha particles demonstrating that ionization density increased sharply near the end of range.





In 1946 Harvard physicist Robert Wilson(1914-2000) Suggested*

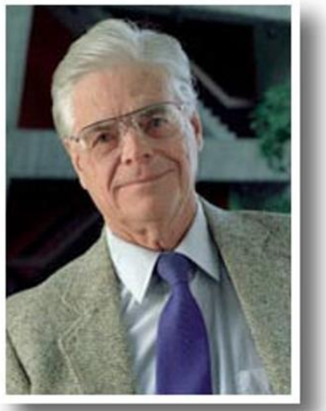
Proton can be used clinically

Accelerators are available

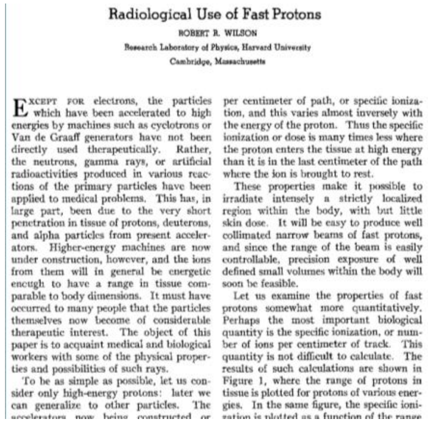
Maximum radiation dose can be placed into the tumor

Proton therapy provides sparing of normal tissues

Modulator wheel can spread narrow Bragg peak



Robert Wilson



Radiological Use of Fast Protons

ROBERT R. WILSON

Research Laboratory of Physics, Harvard University

Cambridge, Massachusetts

EXCEPT FOR electrons, the particles which have been accelerated to high energies by machines such as cyclotrons or Van de Graaff generators have not been directly used therapeutically. Rather, the neutrons, gamma rays, or artificial radioactivities produced in various reactions of the primary particles have been applied to medical problems. This has, in large part, been due to the very short penetration in tissue of protons, deuterons, and alpha particles from present accelerators. Higher-energy machines are now under construction, however, and the ions from them will in general be energetic enough to have a range in tissue comparable to body dimensions. It must have occurred to many people that the particles themselves now become of considerable therapeutic interest. The object of this paper is to acquaint medical and biological workers with some of the physical properties and possibilities of such rays.

To be as simple as possible, let us consider only high-energy protons: later we can generalize to other particles. The

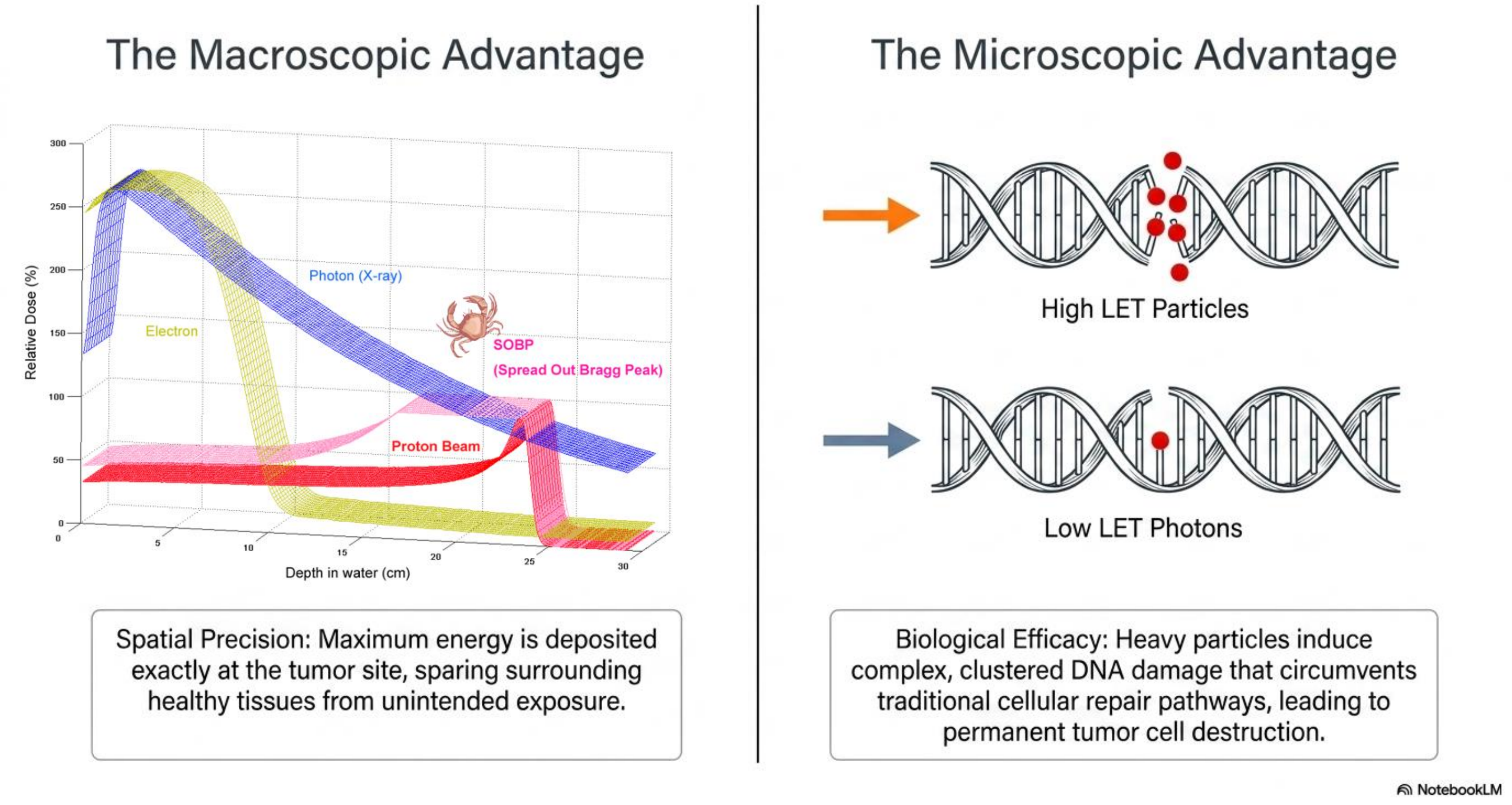
per centimeter of path, or specific ionization, and this varies almost inversely with the energy of the proton. Thus the specific ionization or dose is many times less where the proton enters the tissue at high energy than it is in the last centimeter of the path where the ion is brought to rest.

These properties make it possible to irradiate intensely a strictly localized region within the body, with but little skin dose. It will be easy to produce well collimated narrow beams of fast protons, and since the range of the beam is easily controllable, precision exposure of well defined small volumes within the body will soon be feasible.

Let us examine the properties of fast protons somewhat more quantitatively. Perhaps the most important biological quantity is the specific ionization, or number of ions per centimeter of track. This quantity is not difficult to calculate. The results of such calculations are shown in Figure 1, where the range of protons in tissue is plotted for protons of various energies. In the same figure, the specific ioni-

# Particle Therapy?

**Particle therapy** is an advanced form of external beam radiation therapy used primarily to treat cancer. Instead of using X-rays (photons) like conventional radiation, it utilizes heavier, charged atomic particles—most commonly **protons** or **carbon ions**.

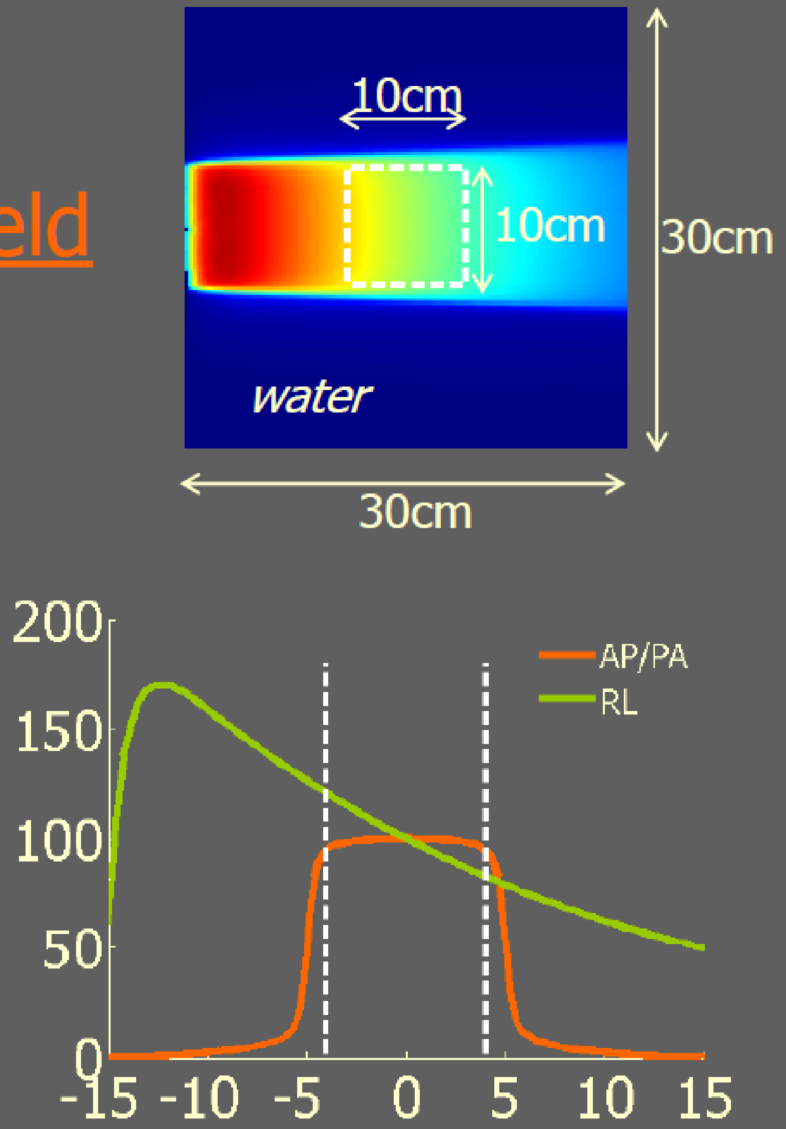


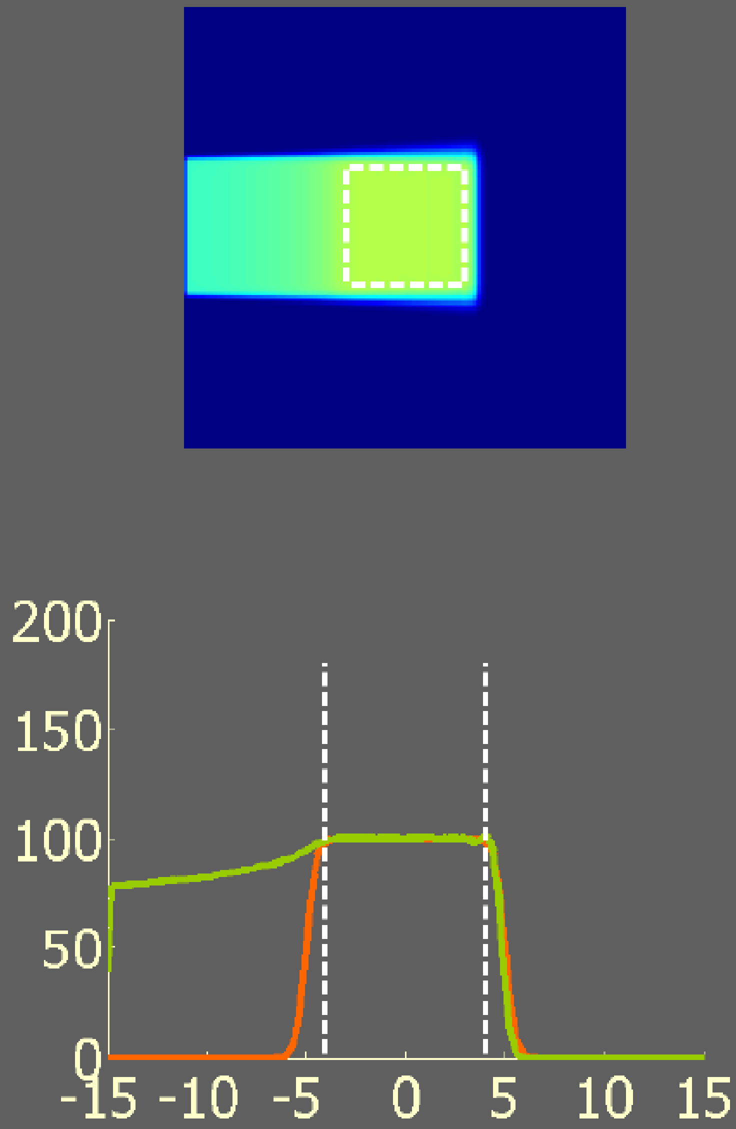
# proton vs. photon pdd

1 field

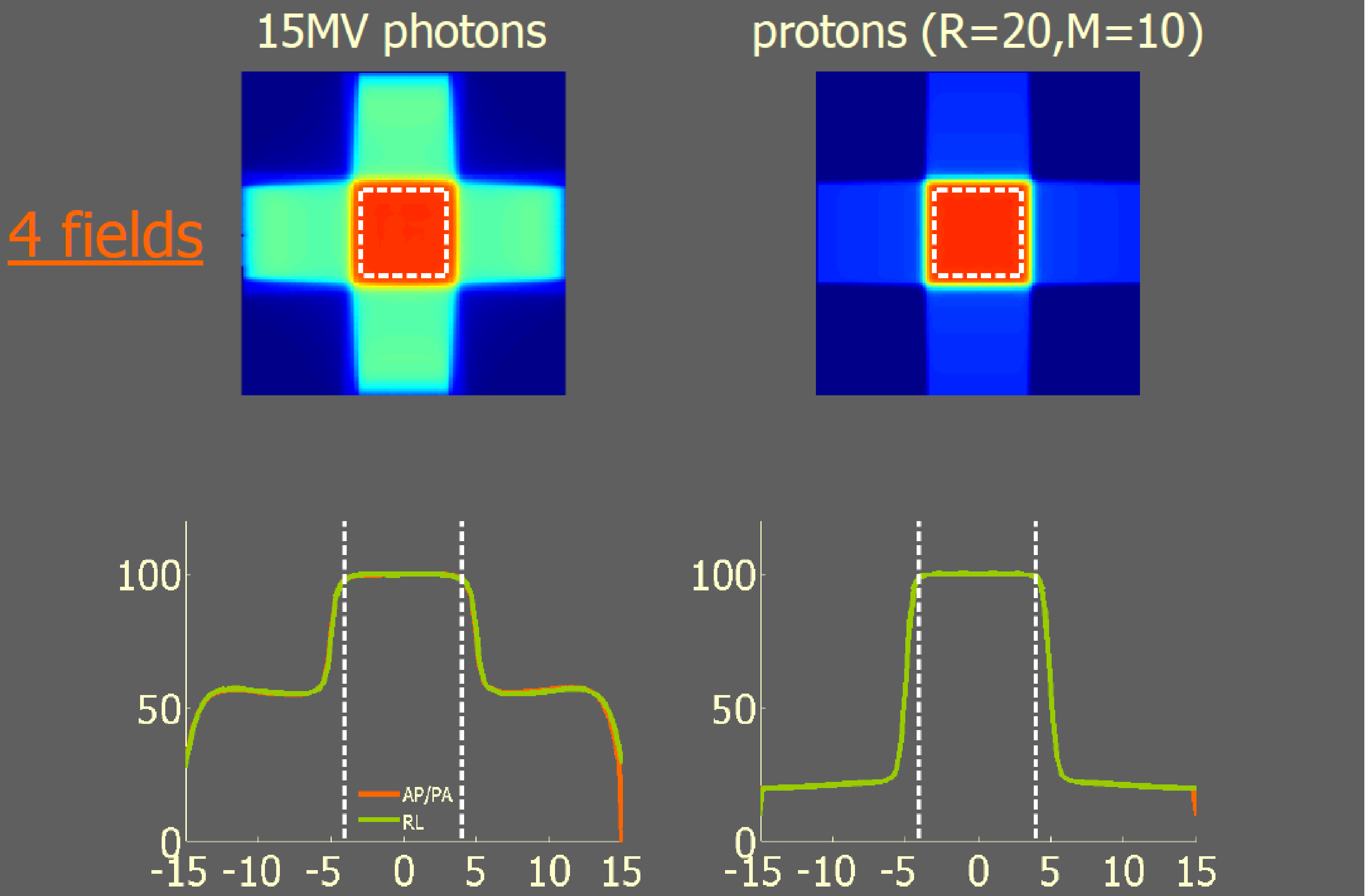
15MV photons

protons (R=20,M=10)

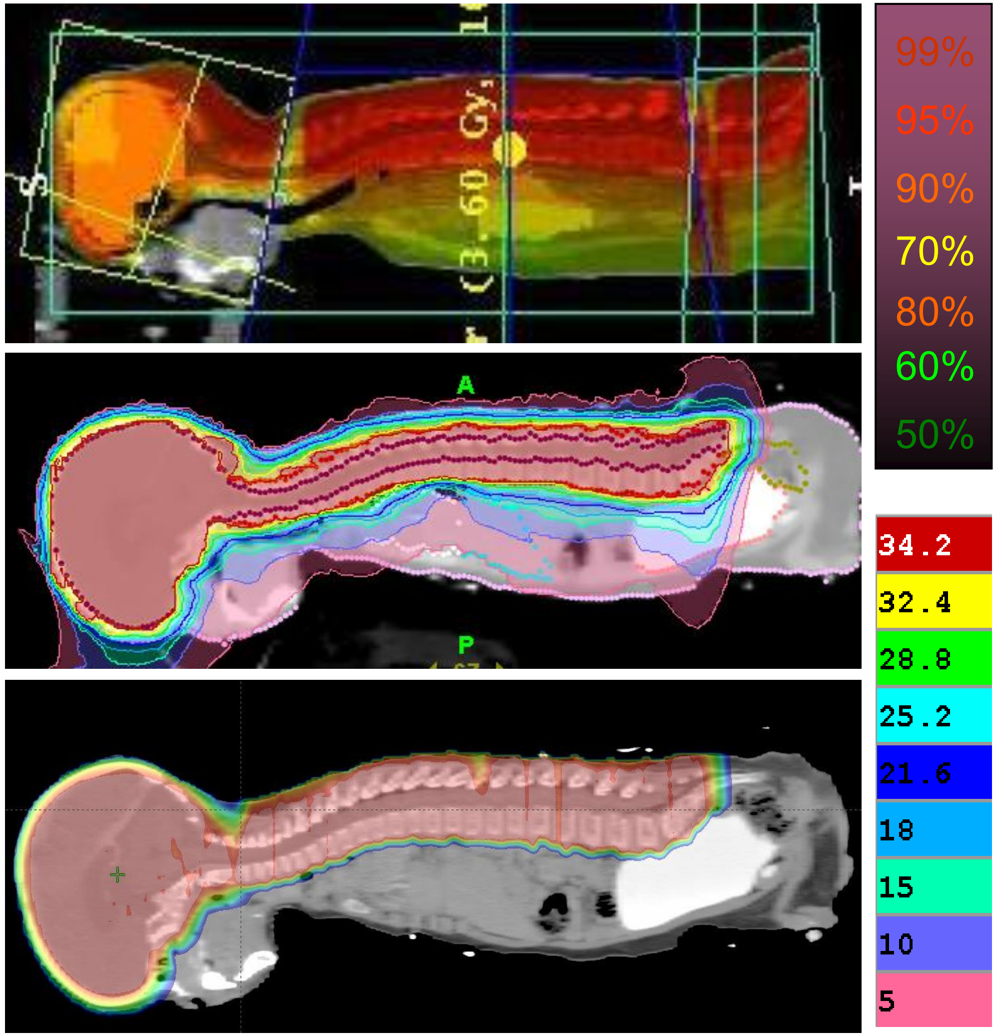


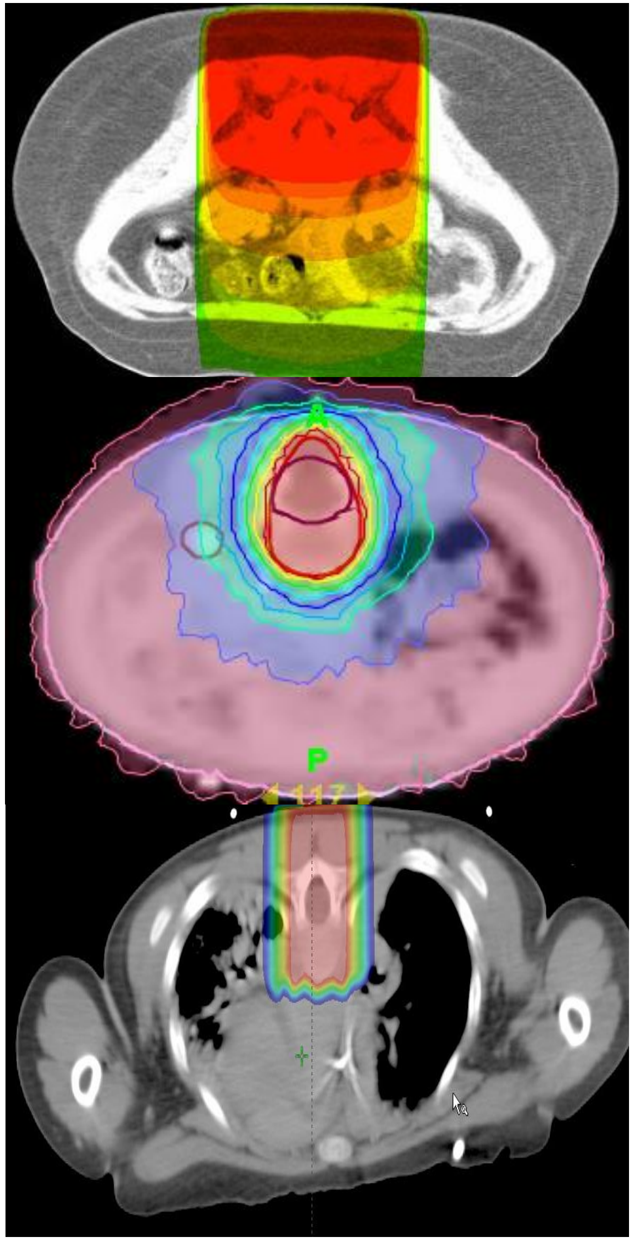



# proton vs. photon pdd

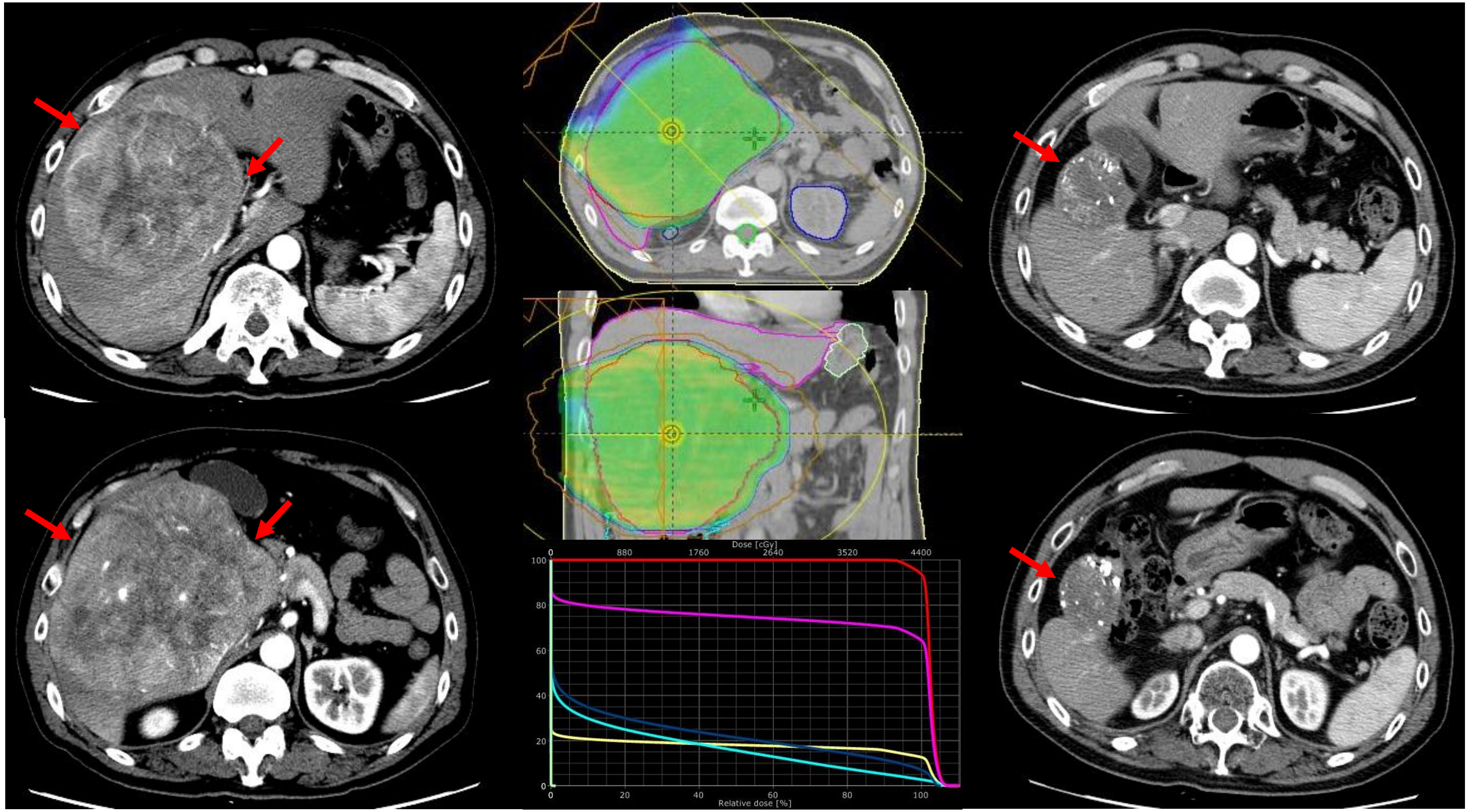


# CSI using 3D CRT, Tomotherapy, and Proton Beam Therapy




5~100% isodose line




치료 전

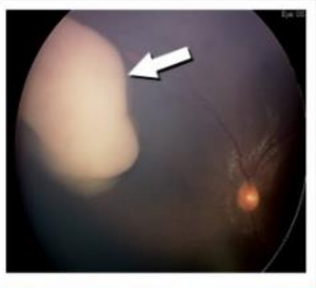
양성자치료 +
경동맥화학색전술

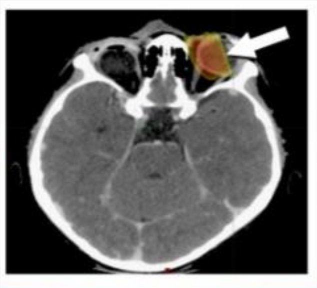
1년 반 후

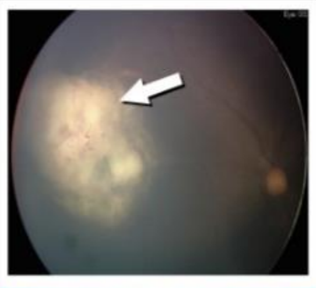
MD. Ph.D. 김태현

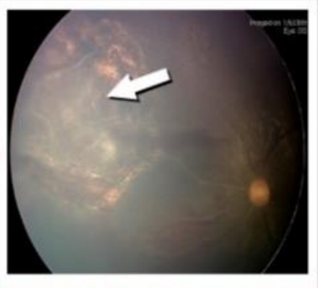
국립암센터
NATIONAL CANCER CENTER

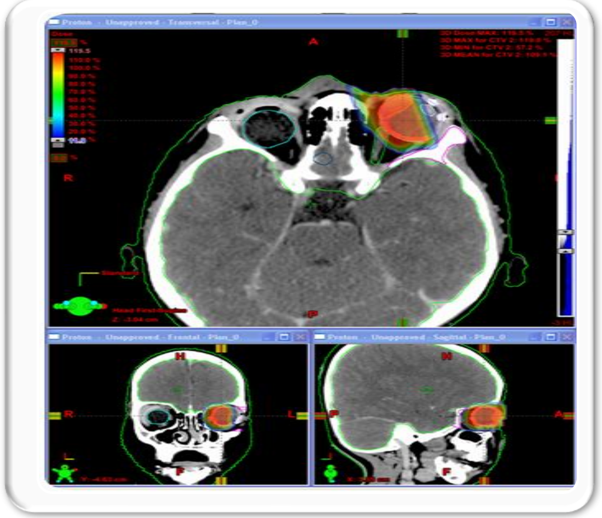
– 망막모세포종 (남아 3세, 오른쪽 눈)
– 눈안의 종양이 양성자 치료 후 안구손상 없이 치료됨

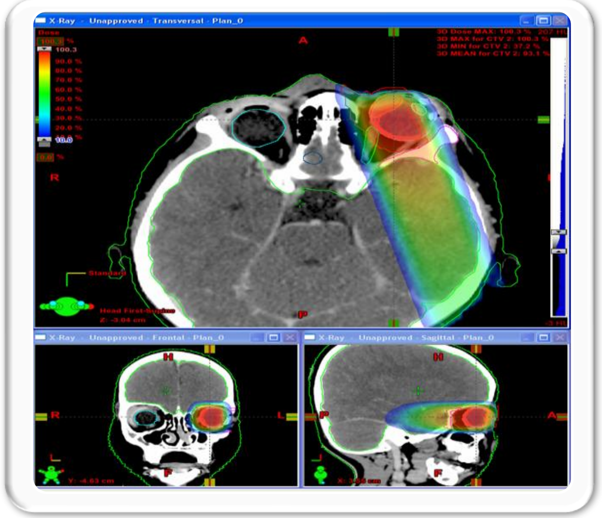

치 료 전


양성자 치료계획

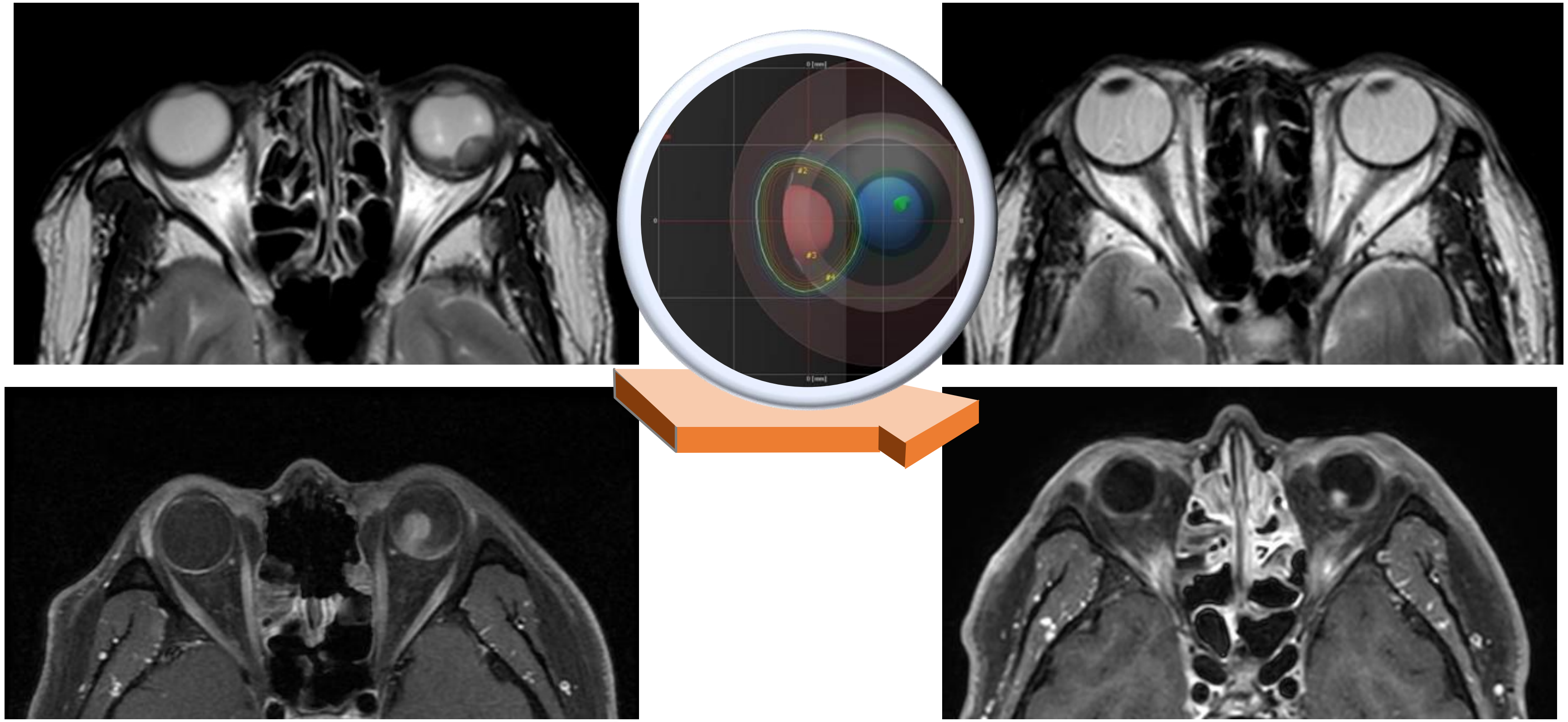

치 료 후 1개월


치 료 후 6개월


**Proton Beam**


**X-Ray**

# 맥락막흑색종 치료 전후 비교



양성자치료 전

양성자치료 후

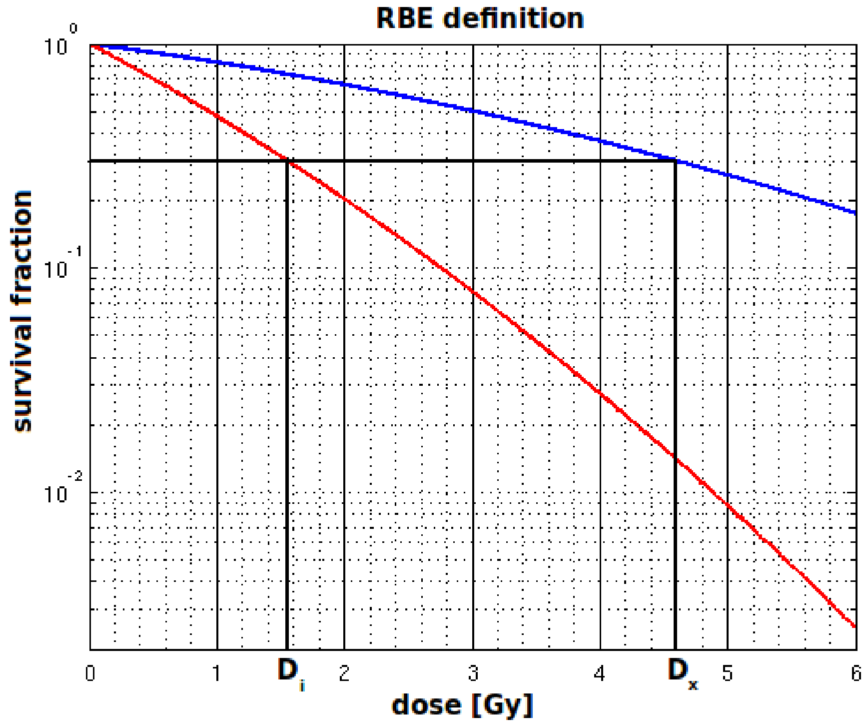
국립암센터
NATIONAL CANCER CENTER

# RBE (Relative Biological Effect)

- The ratio of biological effectiveness of one type of ionizing radiation relative to another, given the same amount of absorbed energy.
- An empirical value that varies depending on the particles, energies involved, and which biological effects are deemed relevant.
- It is a set of experimental measurements.
- Unit of effective dose for charged particle therapy =Gy(RBE) (SI unit)
- RBE depends on
  - Energy/LET
  - Particle species
  - Cell/Tissue type
  - Dose
  - Oxygen status
  - …

$$RBE = \frac{D_x}{D_R}$$

$$D_{eff} = D_{phy} \cdot RBE$$



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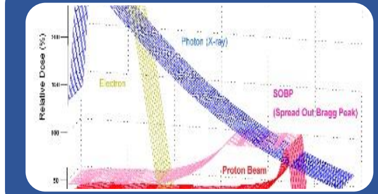


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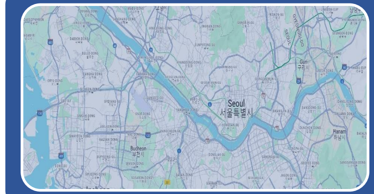



Current Status of Particle therapy in Korea

# Accelerator

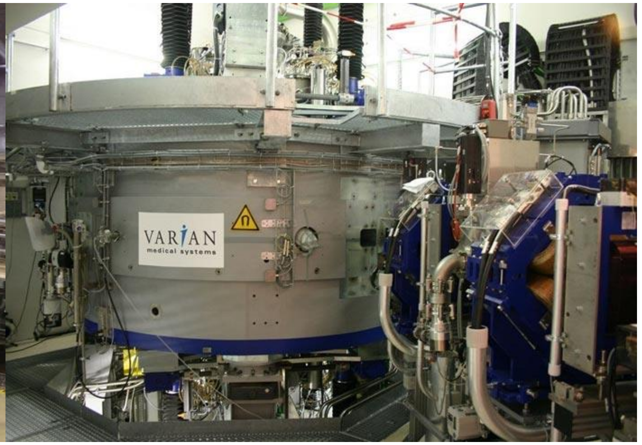

SHI


Synchrotron


IBA

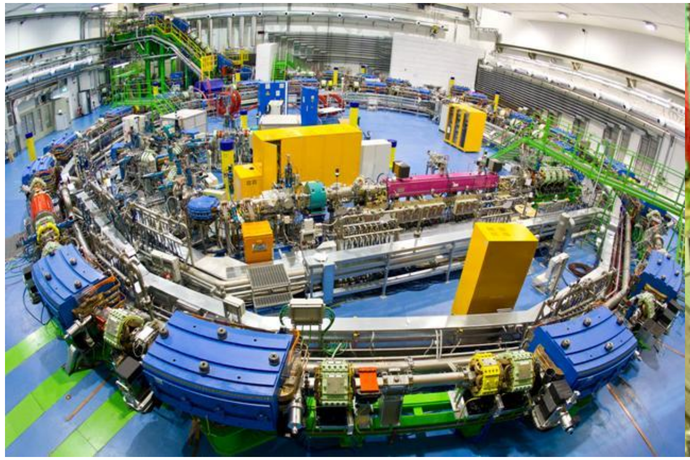
# Cyclotron& Synchrocyclotron






- 1. Fix time/per cycle, with increasing diameter to comply with the increasing speed of particle.
- 2. Continuous beam, not pulse. High output and dose rate.
- 3. Beam at the outlet: fixed energy.
- 4. Adjust energy by beam degrader.
- 5. Relatively more radioactivity of contamination.
- 6. Stable output, more suitable for pencil beam scanning.

# synchrotron




1. Fix diameter, with increasing the speed of changes of magnetic field to
comply with the increasing speed of particle.
2. Pulse beam, not continuous. lower output and dose rate.
3. Beam at the outlet: variable energy.
4. Relatively more less radioactivity of contamination.
5. Relatively not stable within a pulse, more difficult in pencil beam scan.

# Cyclotron VS. Synchrotron

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

# Requirement Specifications for Proton therapy

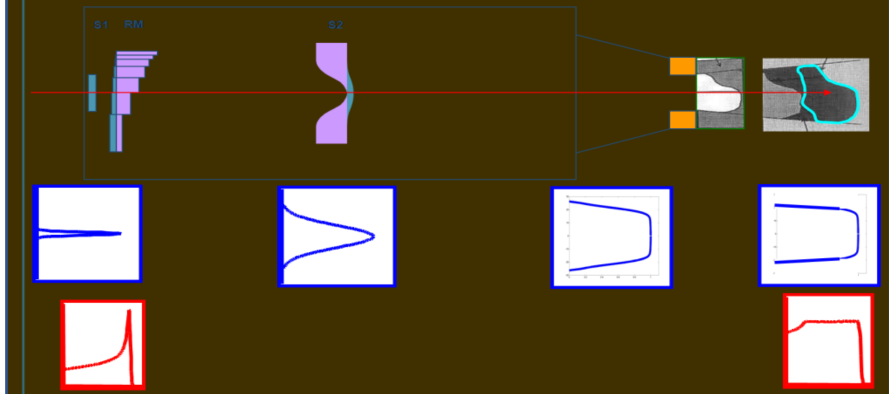
- Accelerator energy : ≥ 230 MeV
- Beam current: greater than 10 nA
- Range in water: 4.1 g/cm$^2$ ~ 32 g/cm$^2$
- Range Adjustment : continuous or ≤ 0.21 g/cm$^2$
- Range Accuracy : ≤ 0.1 g/cm$^2$
- Energy layer switching time :≤ 1.0 sec.
- Field size : 40x40 cm$^2$, (compact 20x20 cm$^2$)
- Dose rate : ≥ 2 Gy/min/liter
- Spot size(@iso, air, 1$\sigma$ )
  - ✓Max energy : ≤ 4 mm
  - ✓Min energy : ≤ 8 mm

# Beam Delivery Technique

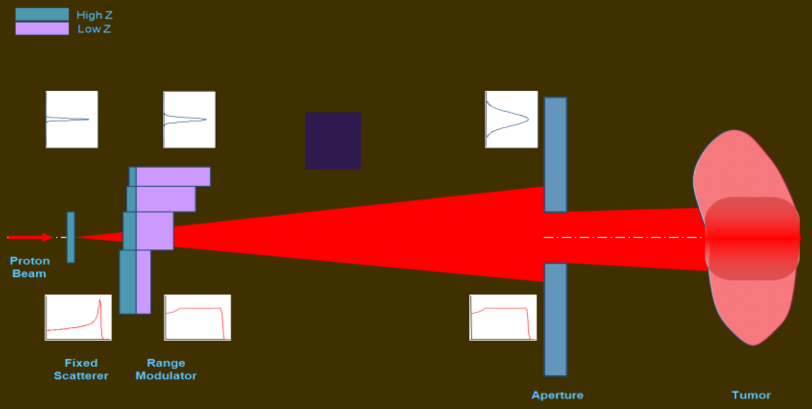
# Proton Beam modes

## Passive mode

### Double Scattering mode

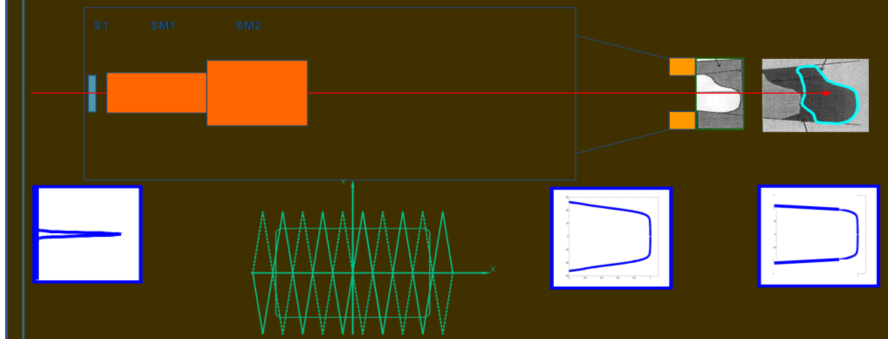


### Single Scattering mode

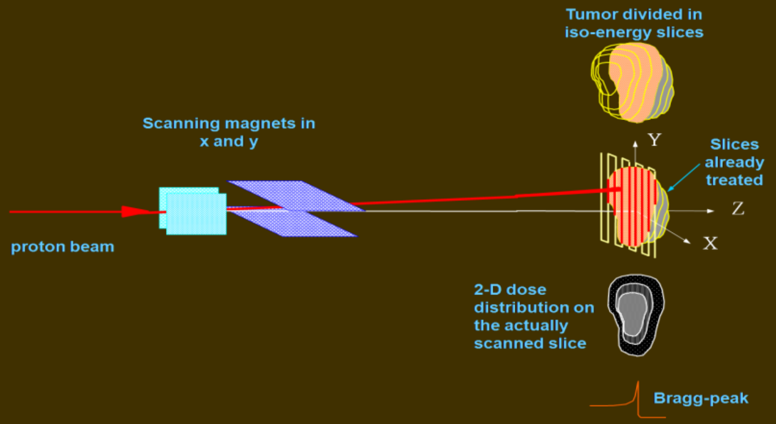



## Dynamic mode

### Uniform Scanning mode

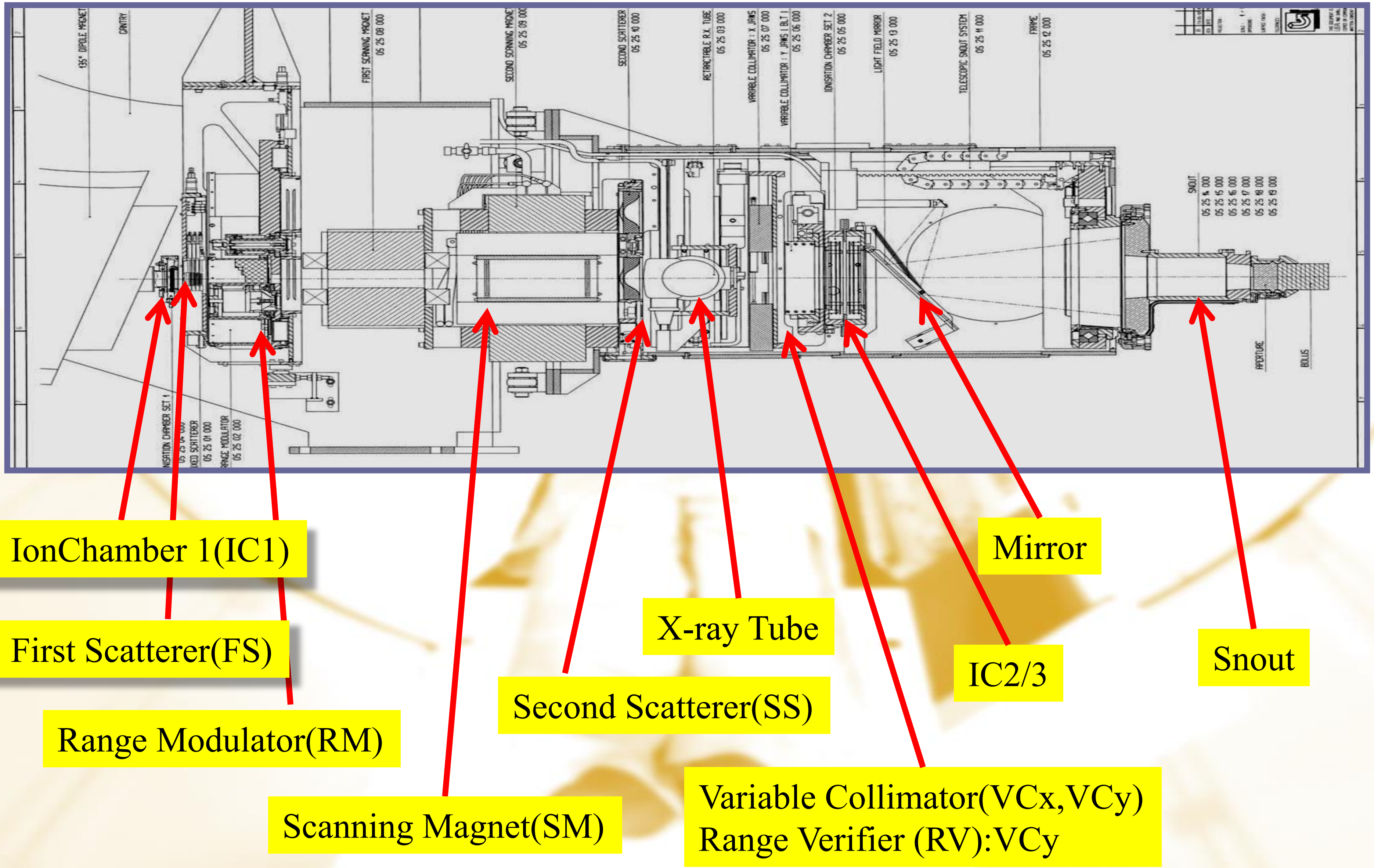


### Pencil Beam Scanning mode

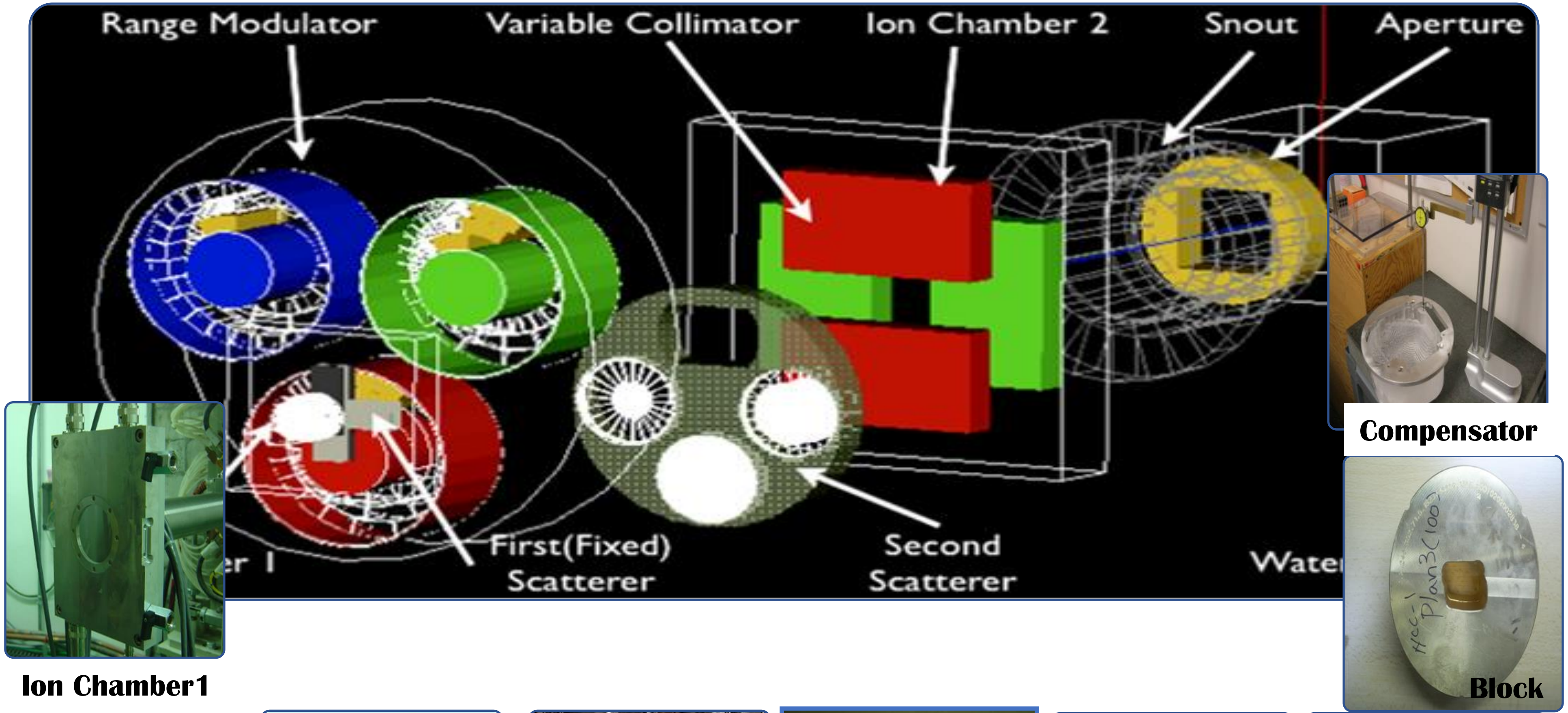


# Passive Mode

# IBA Universal Nozzle



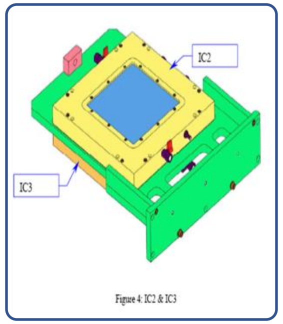
# Nozzle components



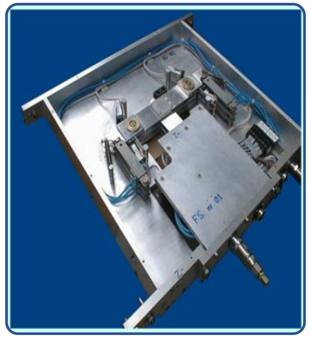

Ion Chamber1

Compensator

Block

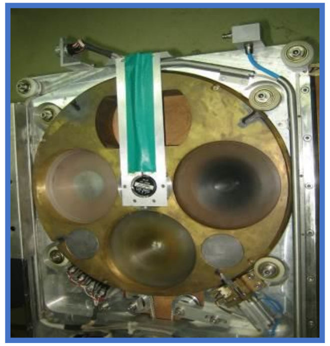



Ion Chamber2,3

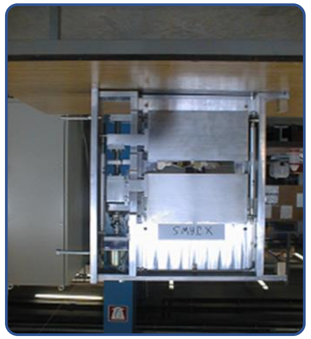


First Scatterer

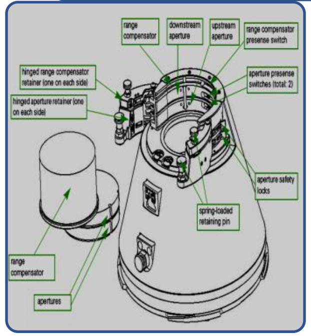
Range modulator



Second Scatterer

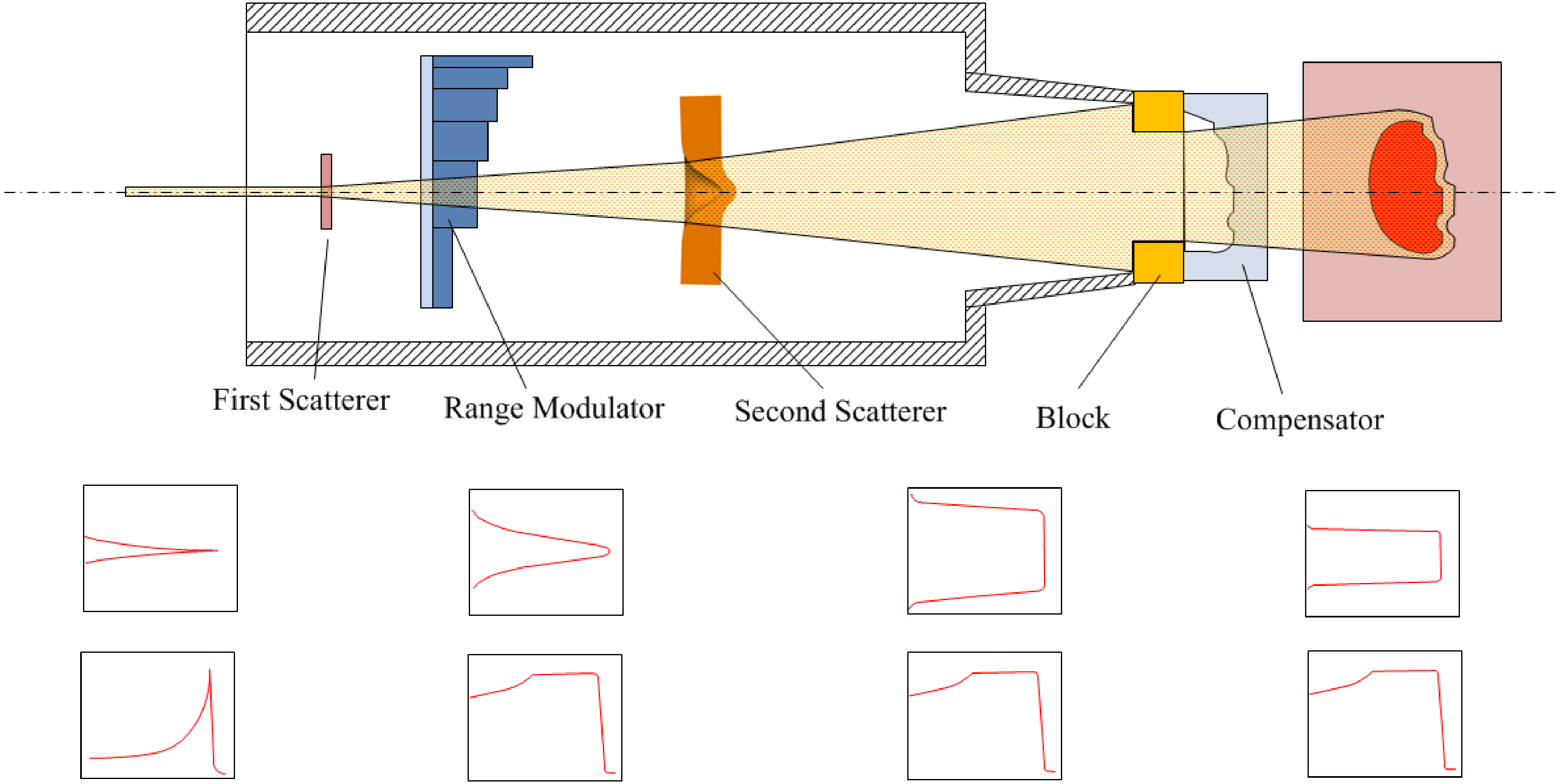


Variable collimator



Snout

# Double Scattering



# Passively scattered proton beam

- Pencil beam

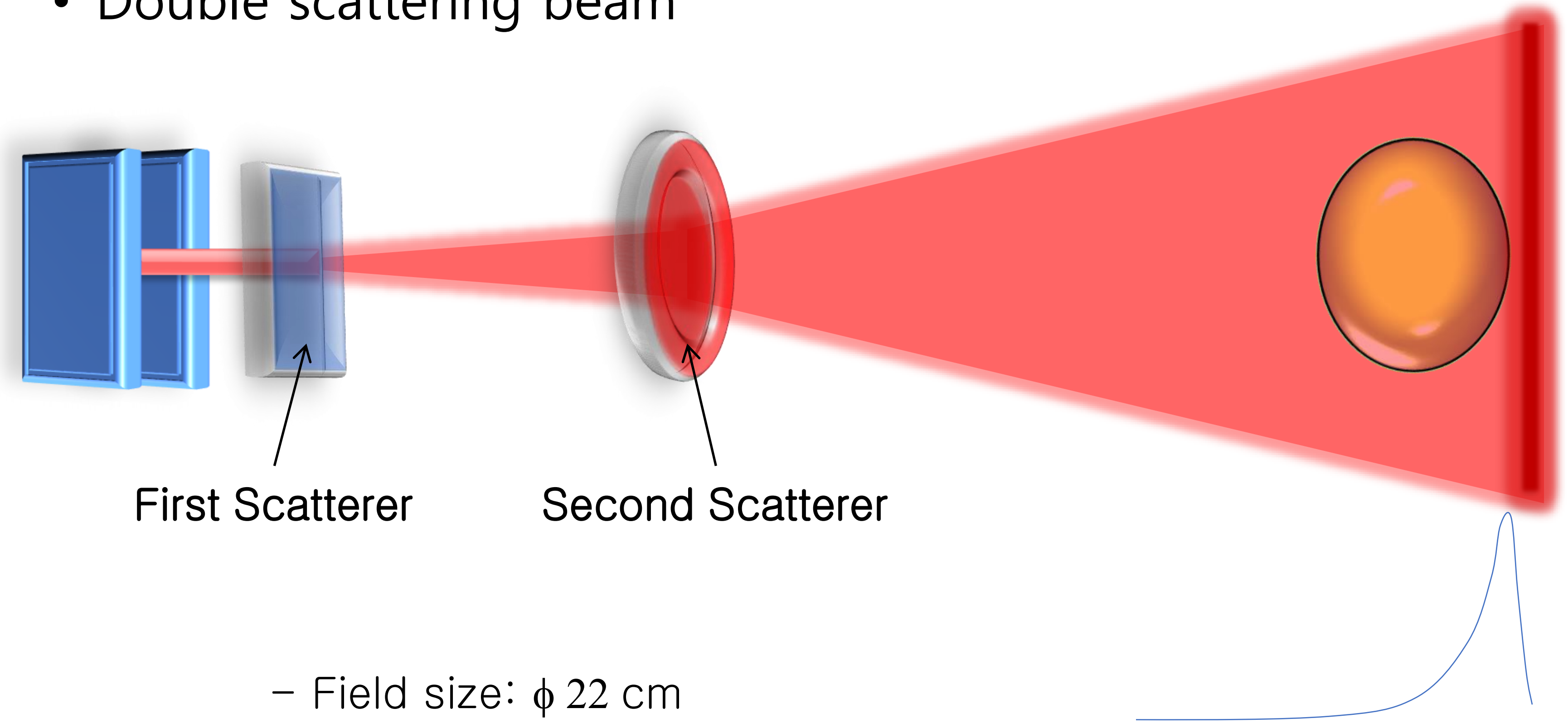
# Passively scattered proton beam

- Single scattering beam


-Field size: $\phi$ 6-7 cm
-Eye treatment
-Brain SRS

# Passively scattered proton beam

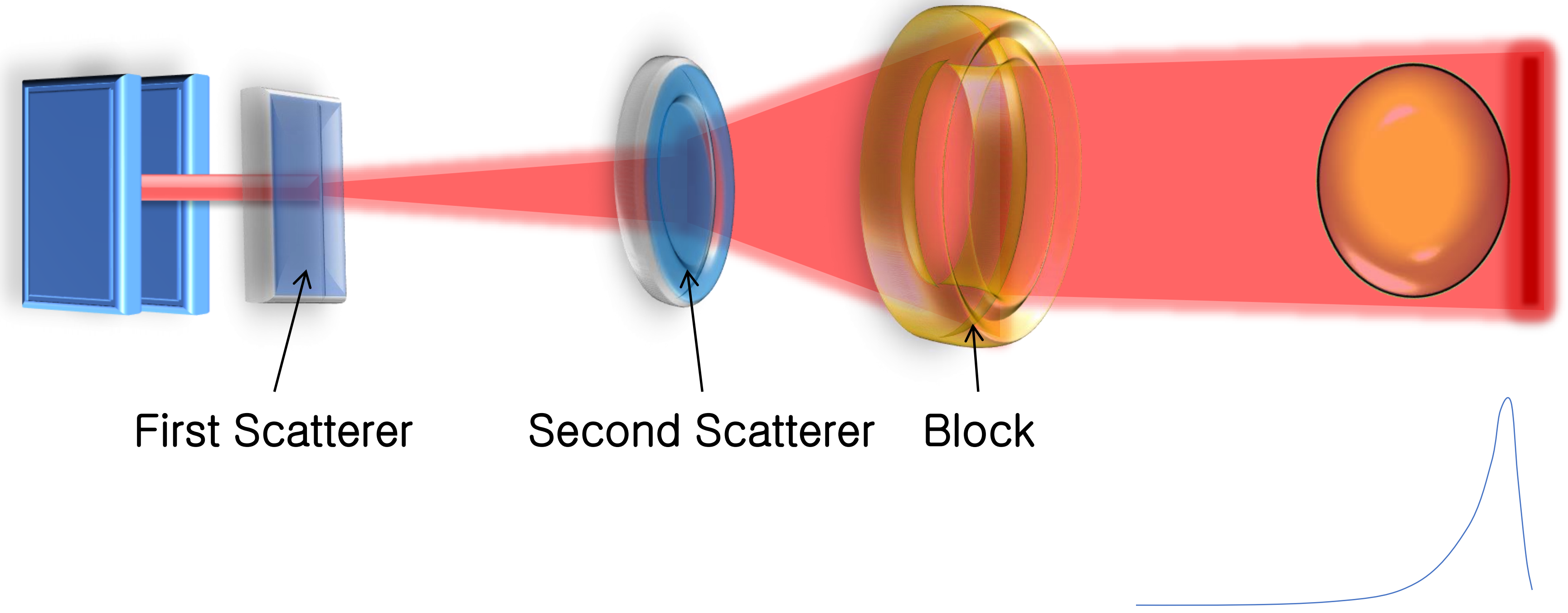
- Double scattering beam




- Field size: ϕ 22 cm
-All treatment
- prostate, brain, lung, breast, CSI….

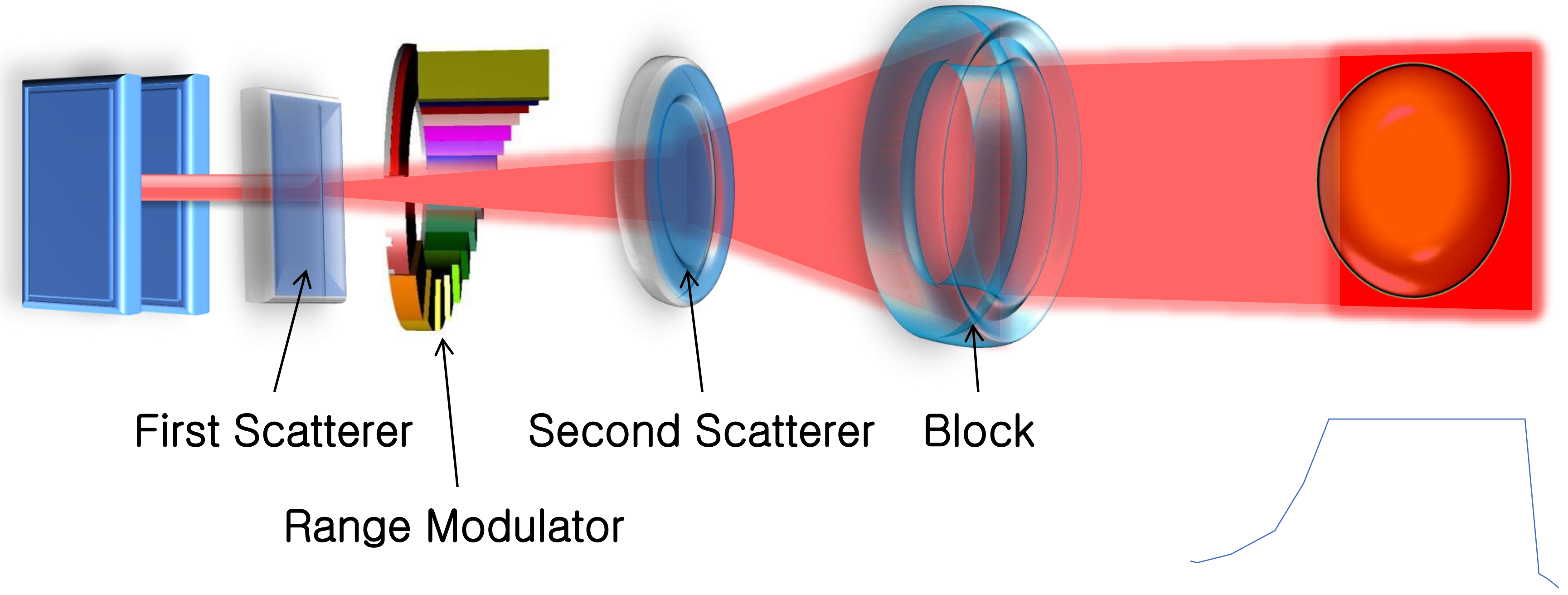
# Passively scattered proton beam

- Double scattering beam



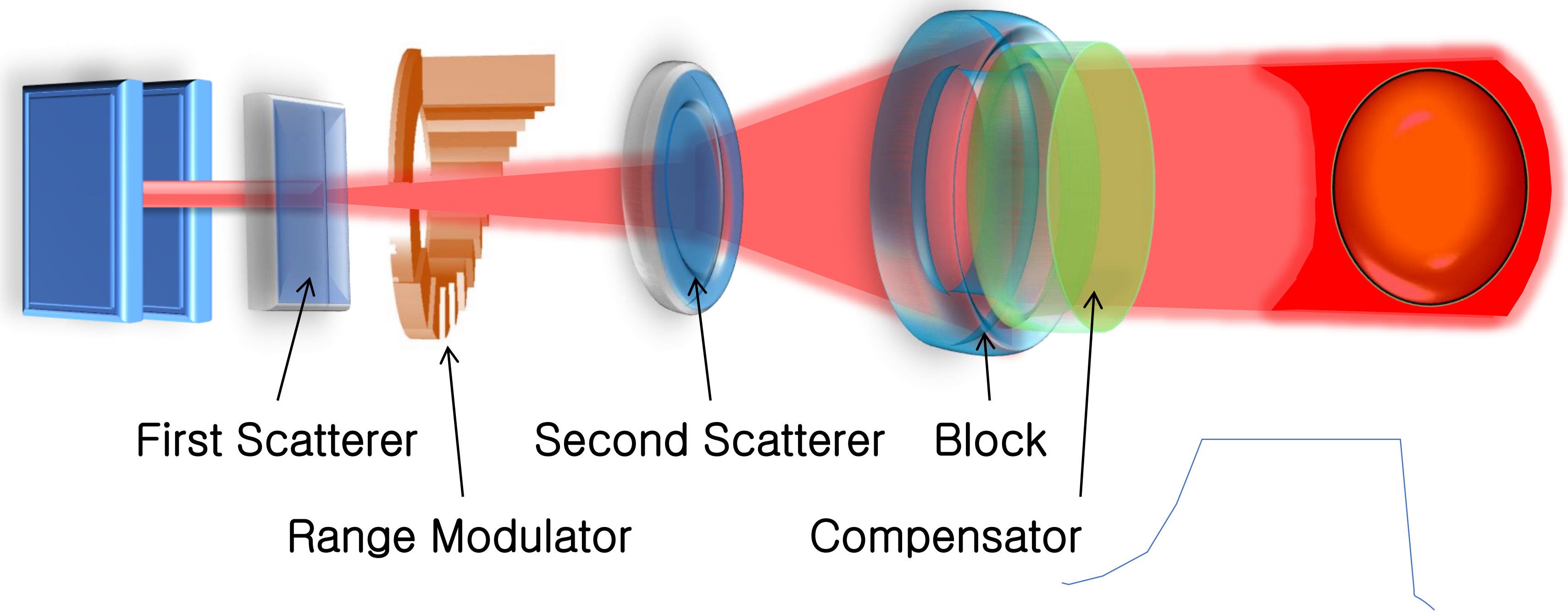
# Passively scattered proton beam

- Double scattering beam

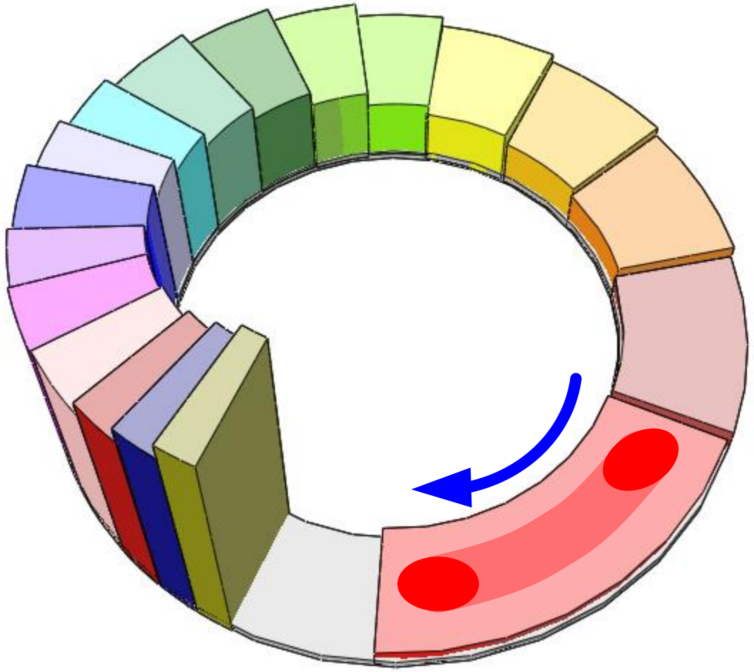


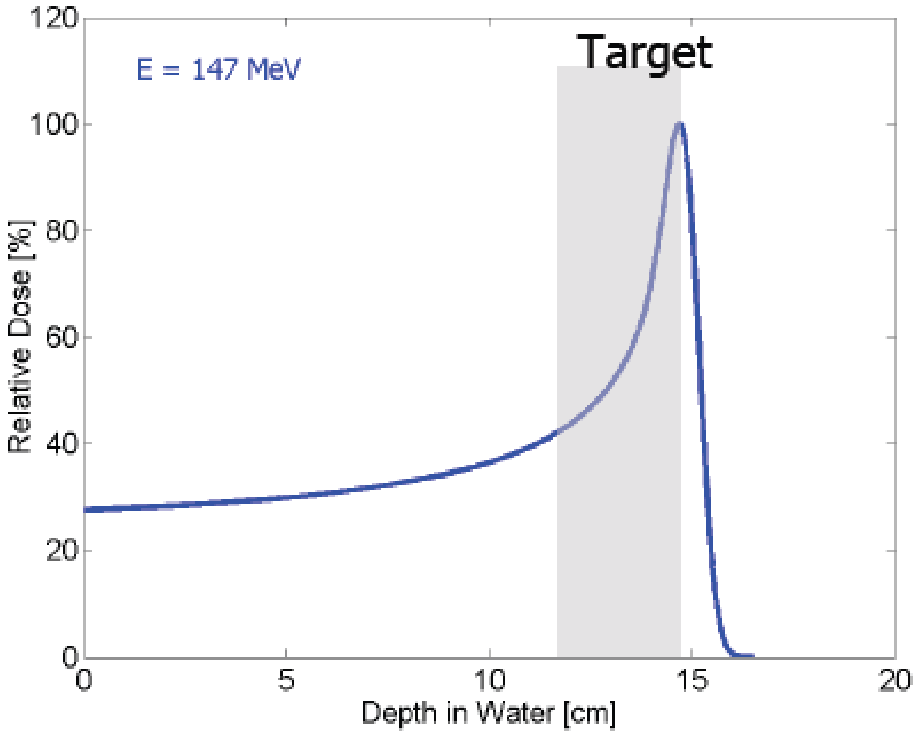
# Passively scattered proton beam

- Double scattering beam



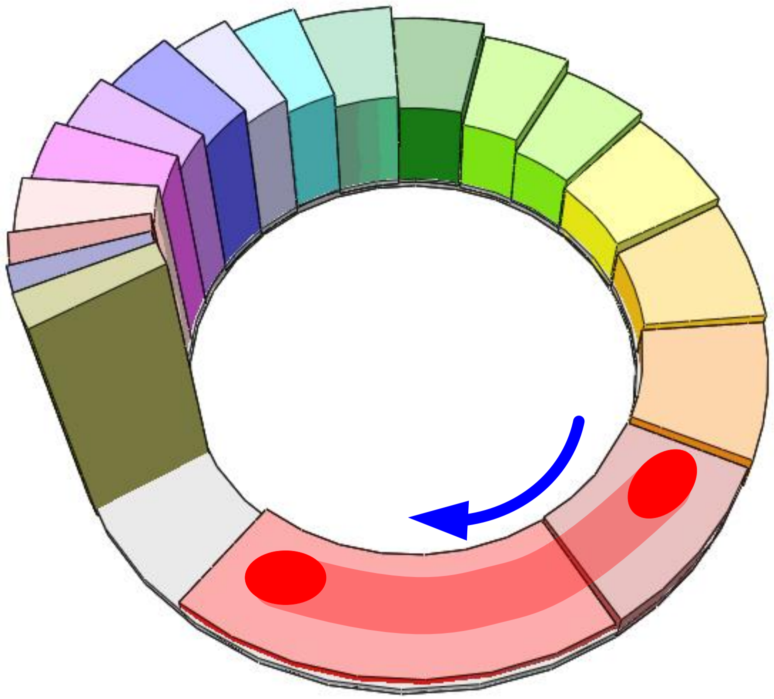
# Range Modulation

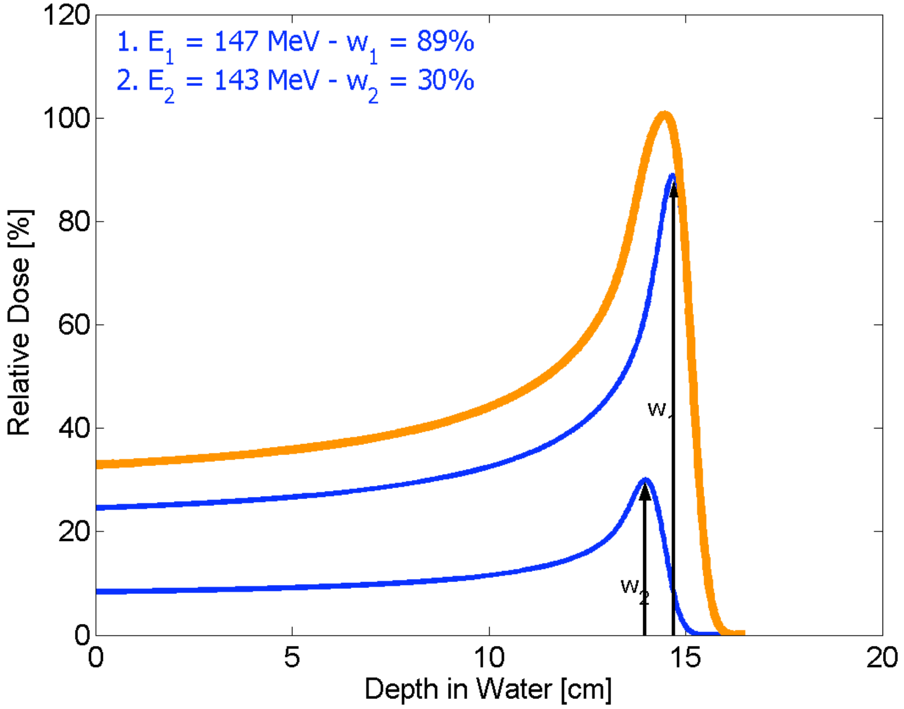





Roelf Slopsema, "Proton Beam Delivery Techniques and Commissioning Issues: Scattered Proton Beams", 19 May 2008 – PTCOG Educational Workshop

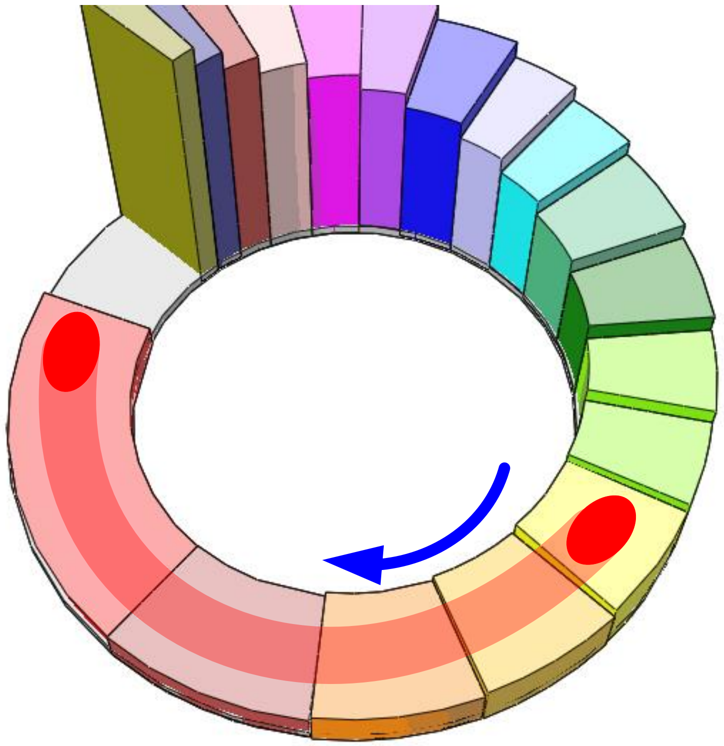
# Range Modulation

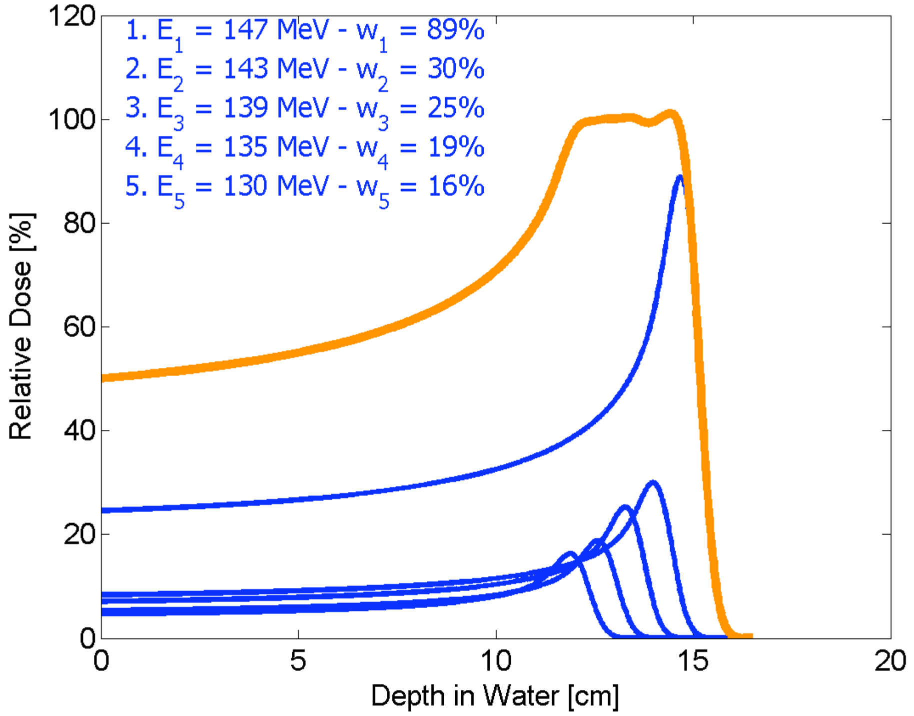





Roelf Slopsema, “Proton Beam Delivery Techniques and Commissioning Issues: Scattered Proton Beams”, 19 May 2008 – PTCOG Educational Workshop

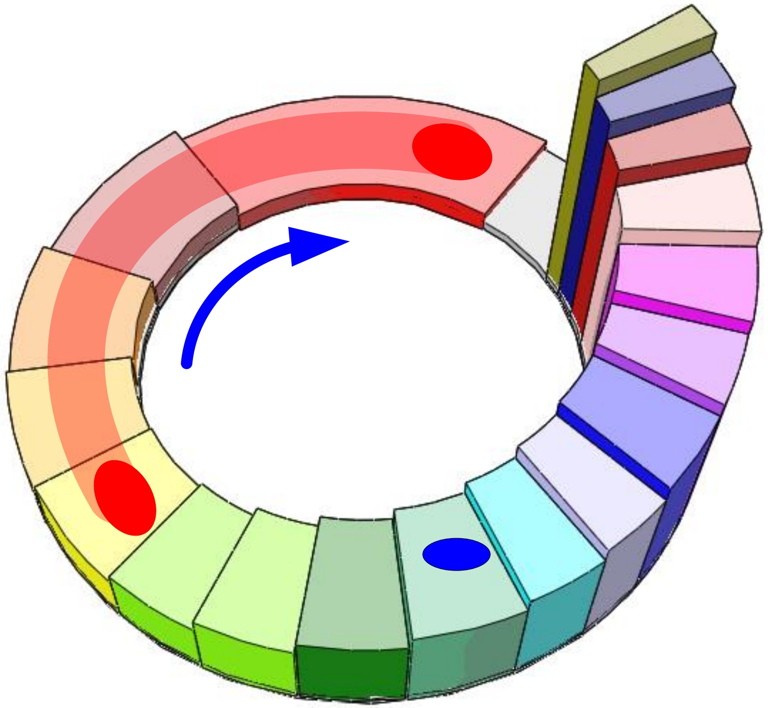
# Range Modulation

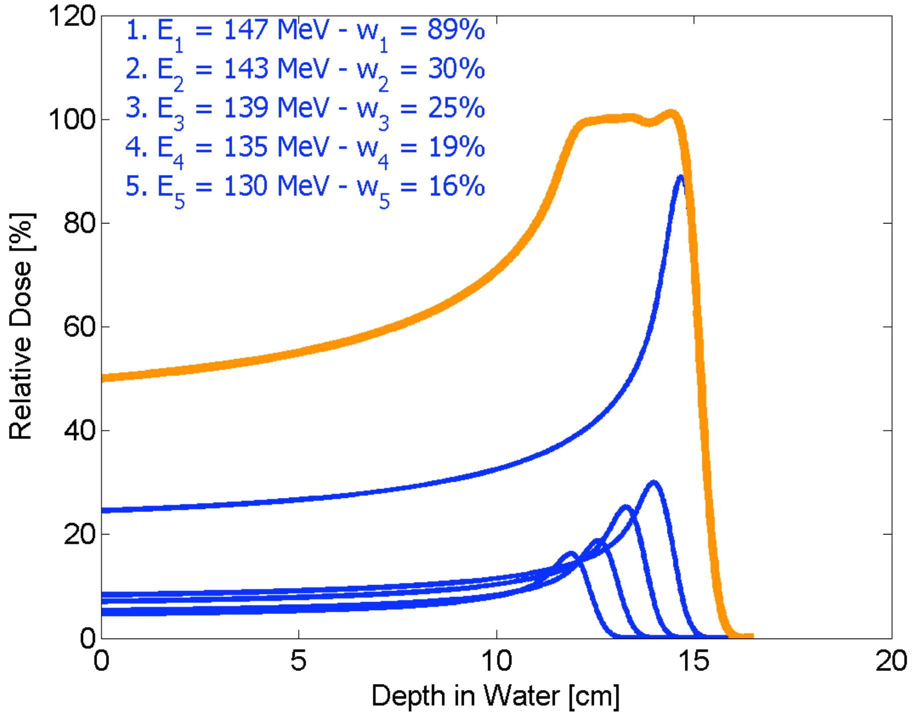





Roelf Slopsema, “Proton Beam Delivery Techniques and Commissioning Issues: Scattered Proton Beams”, 19 May 2008 – PTCOG Educational Workshop

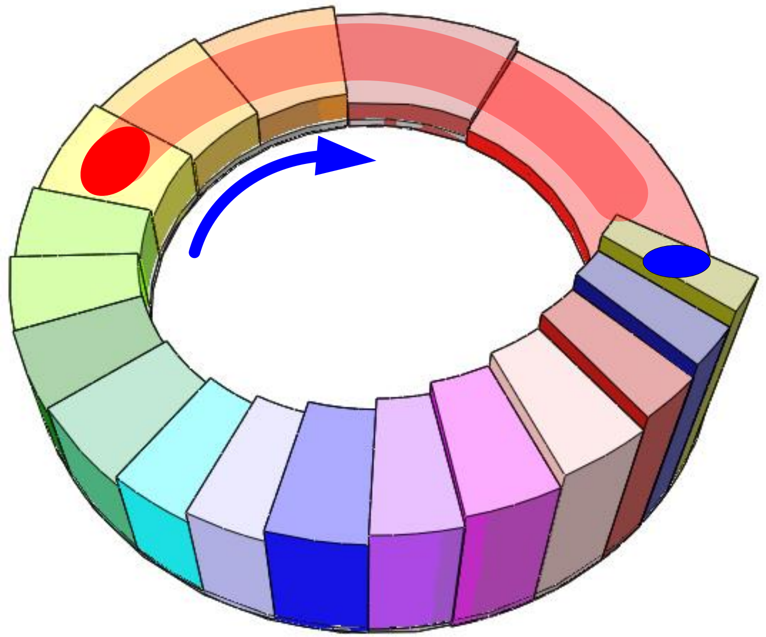
# Range Modulation

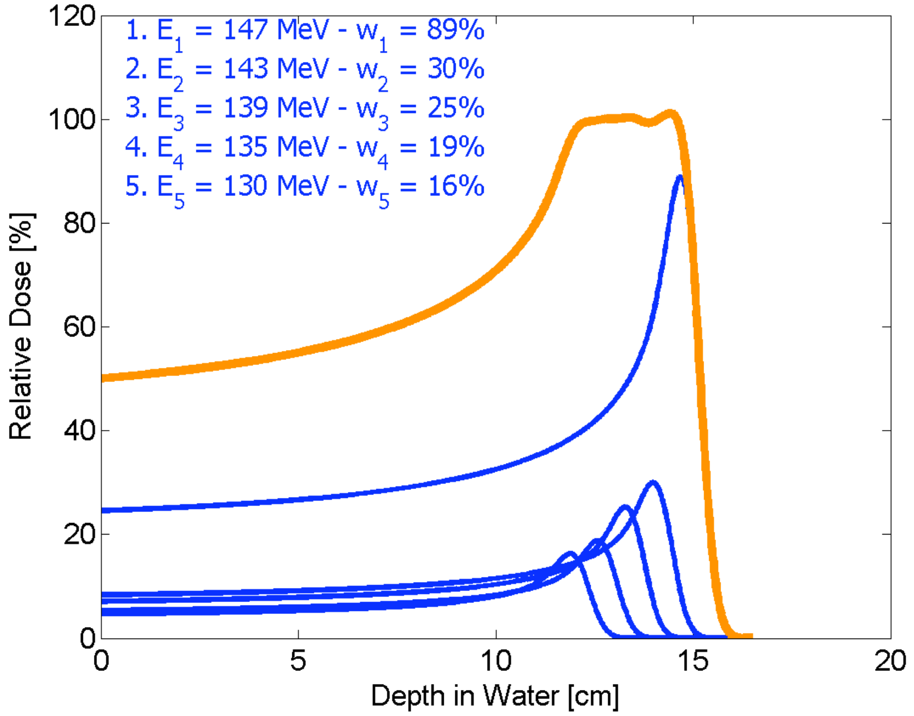





Roelf Slopsema, "Proton Beam Delivery Techniques and Commissioning Issues: Scattered Proton Beams", 19 May 2008 – PTCOG Educational Workshop

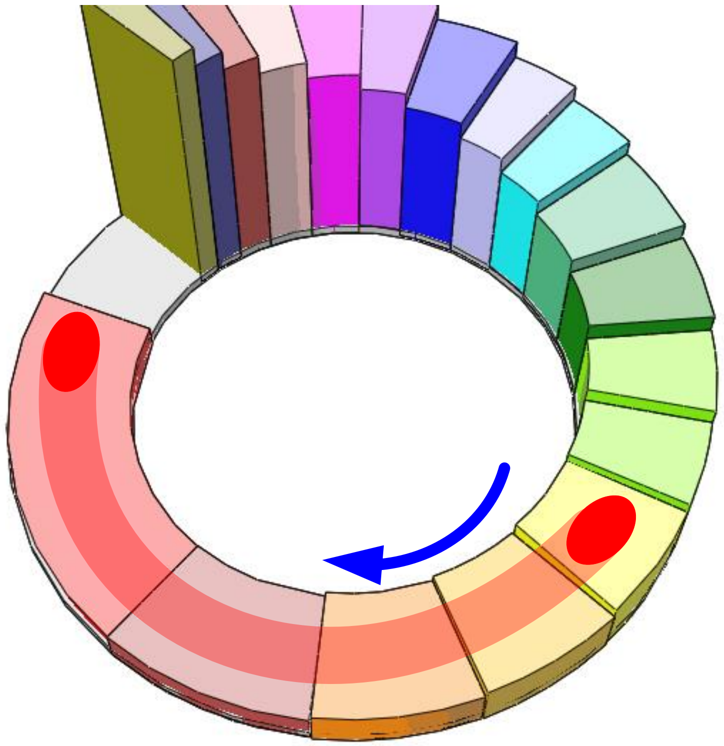
# Range Modulation

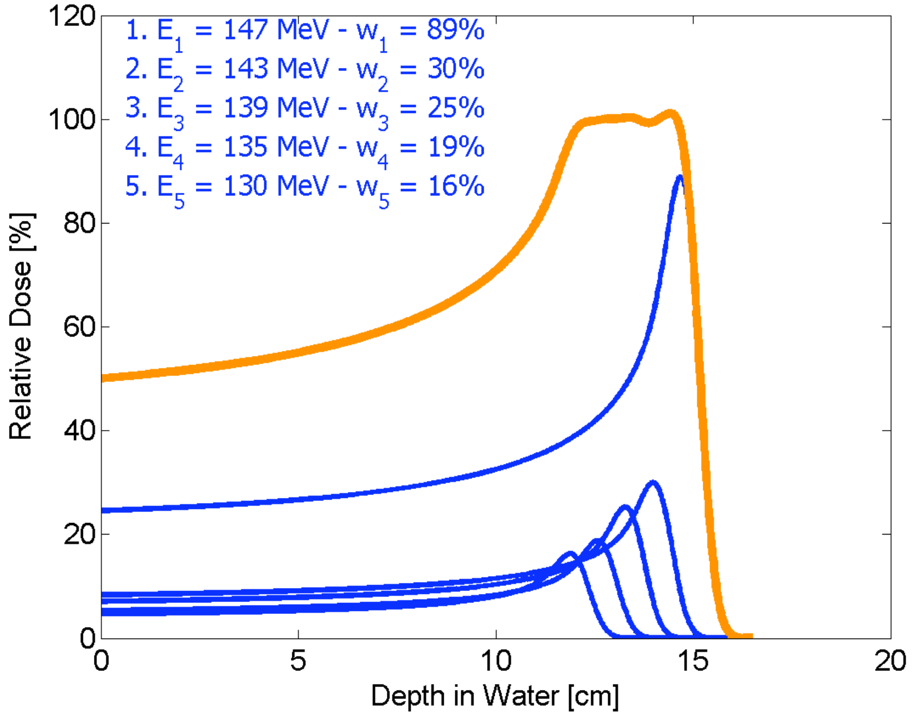





Roelf Slopsema, "Proton Beam Delivery Techniques and Commissioning Issues: Scattered Proton Beams", 19 May 2008 – PTCOG Educational Workshop

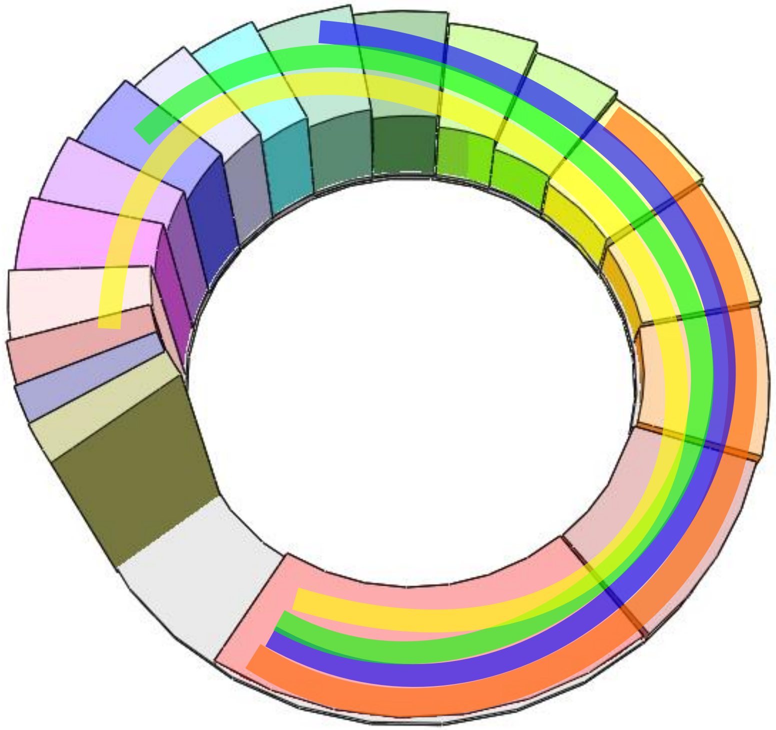
# Range Modulation

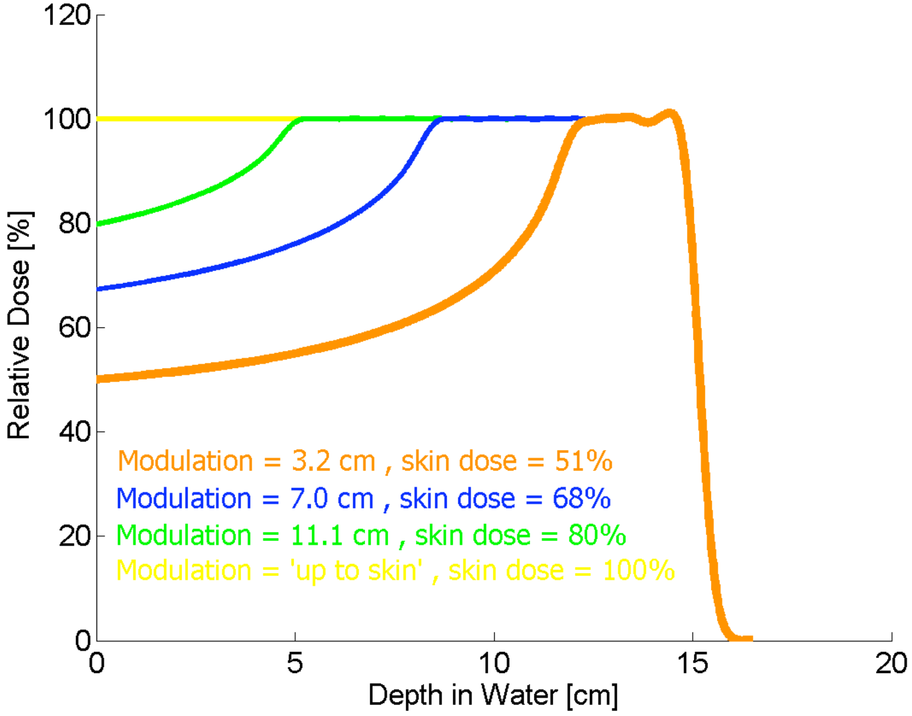





Roelf Slopsema, "Proton Beam Delivery Techniques and Commissioning Issues: Scattered Proton Beams", 19 May 2008 – PTCOG Educational Workshop

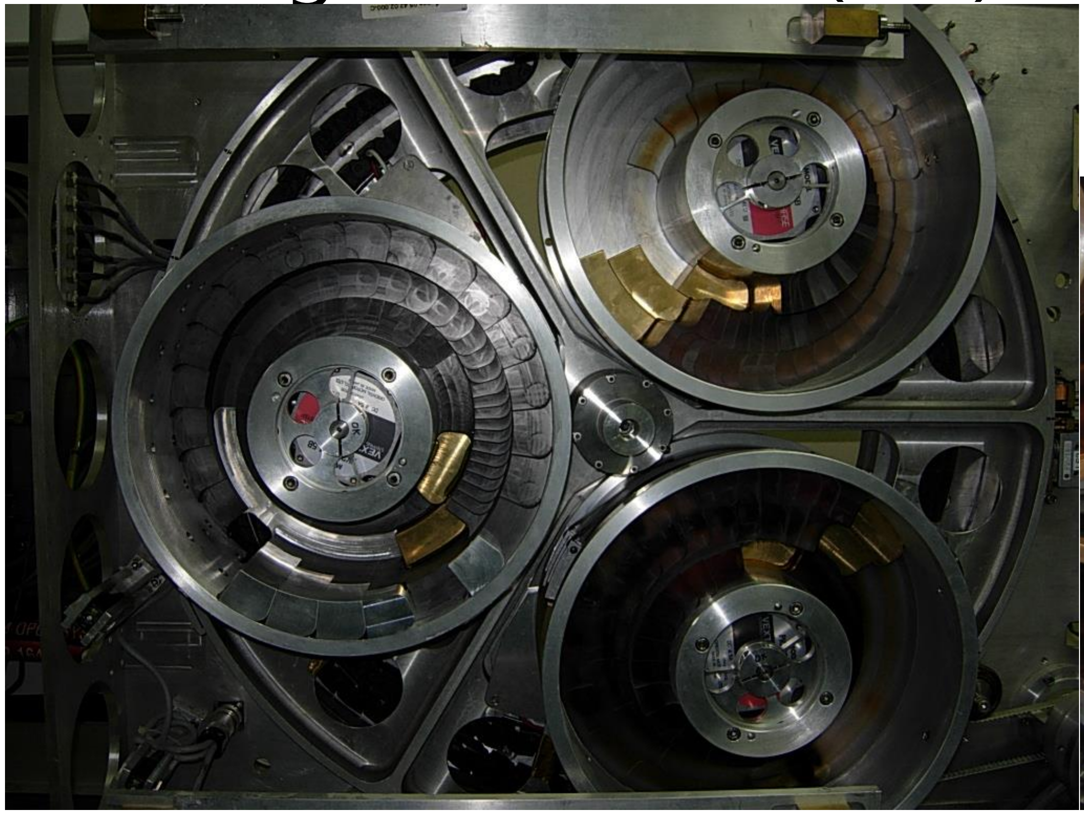
# Range Modulation

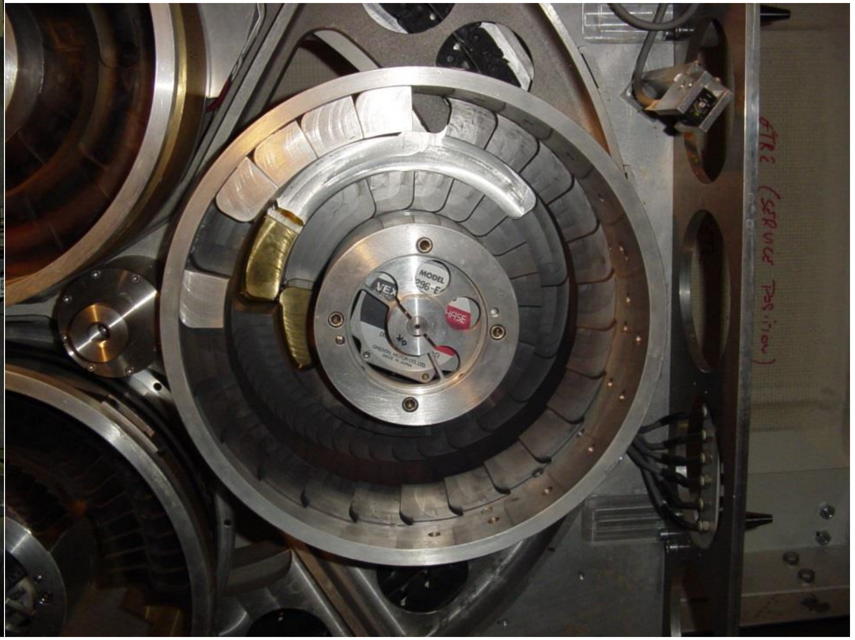





Roelf Slopsema, "Proton Beam Delivery Techniques and Commissioning Issues: Scattered Proton Beams", 19 May 2008 – PTCOG Educational Workshop

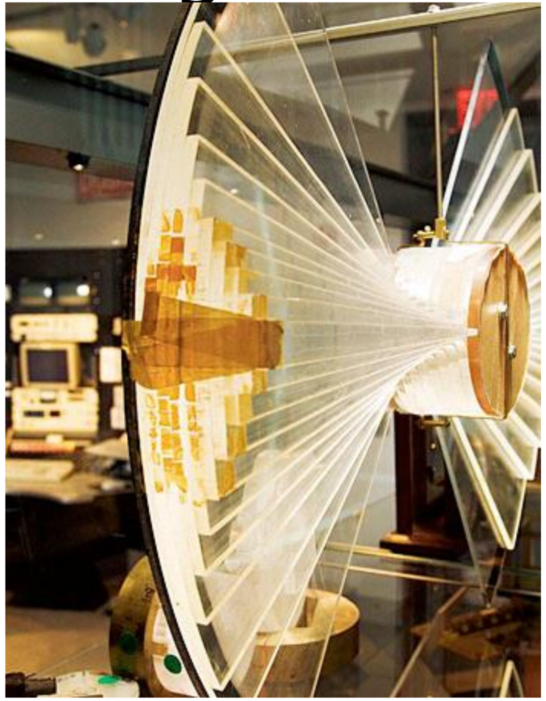
# Range Modulator(IBA)



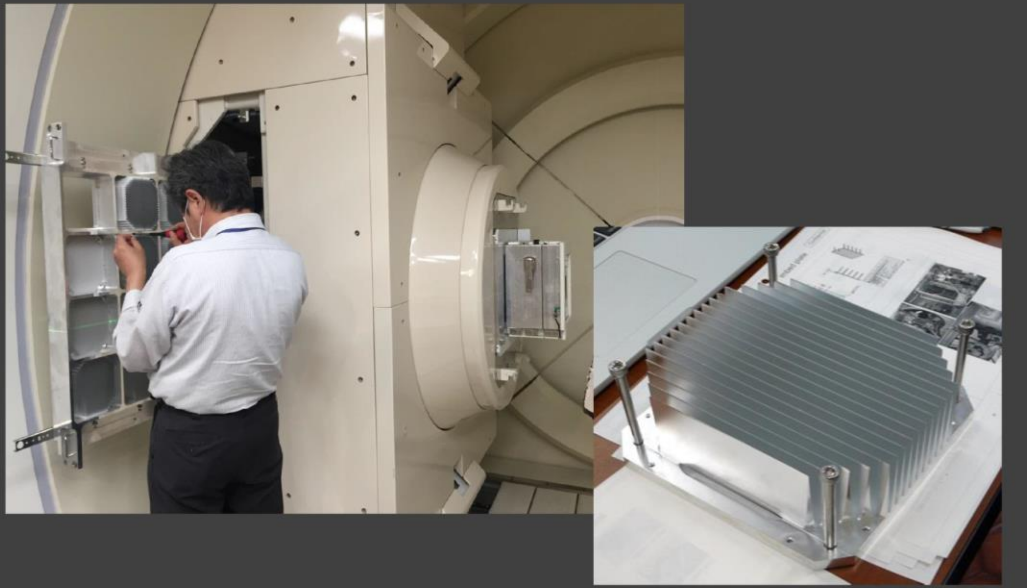


IBA design (3 tracks on single wheel, gating used to adjust modulation)

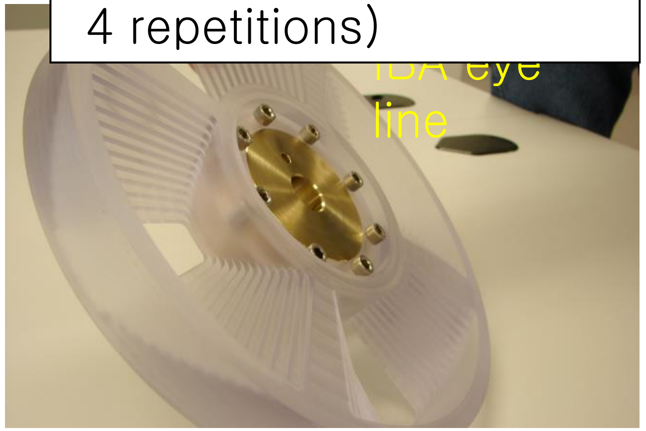
# Range Modulator

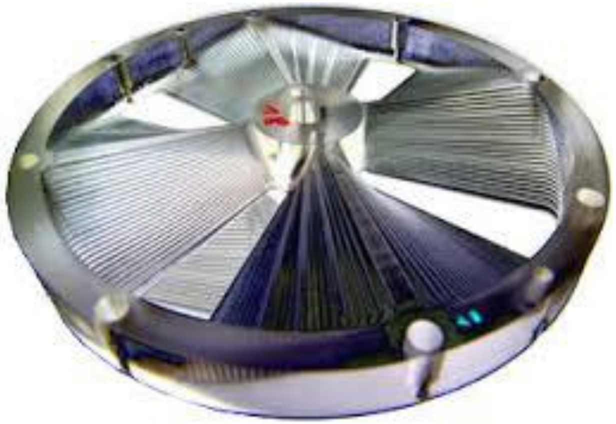


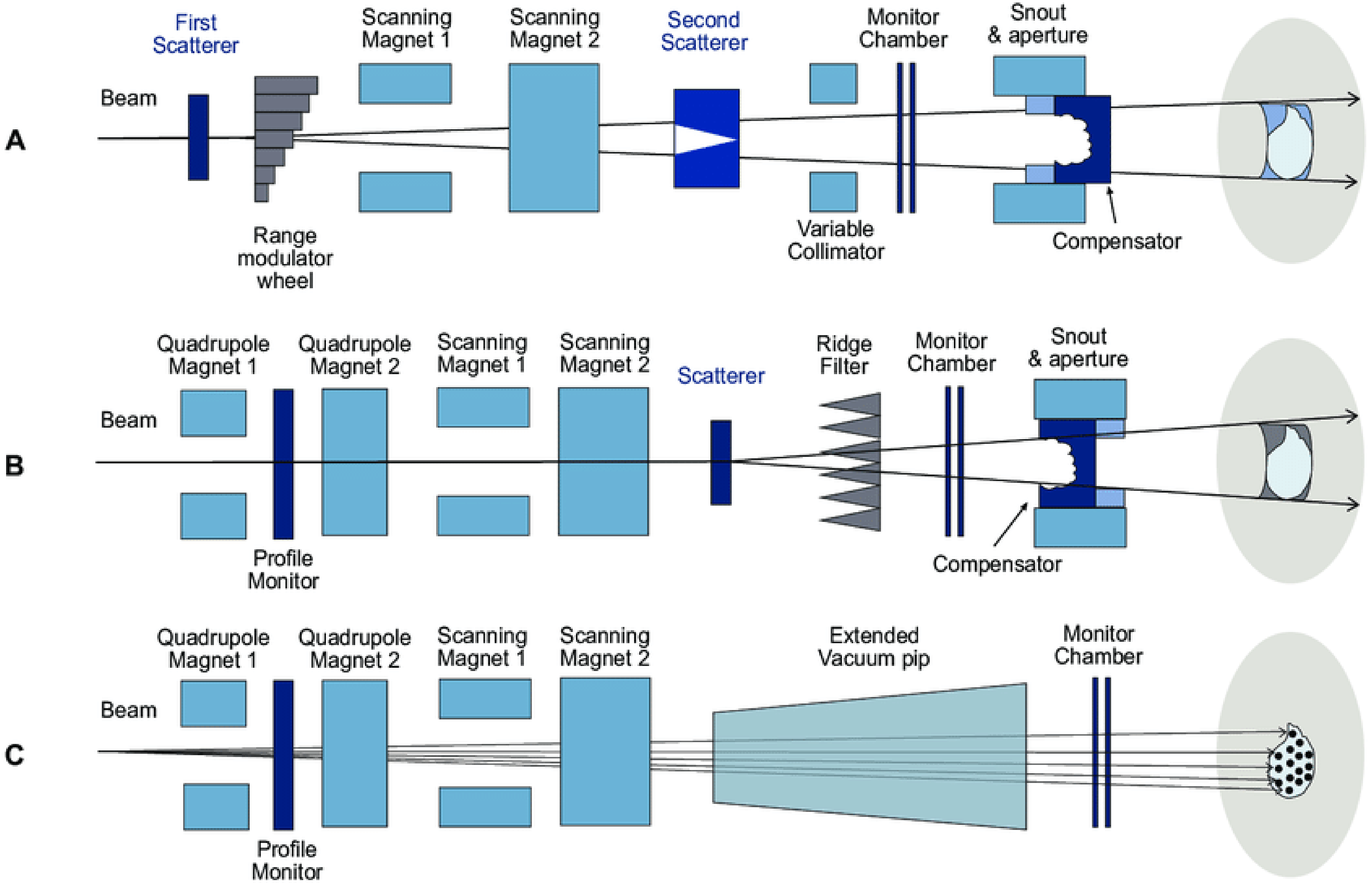
Ridge Filter



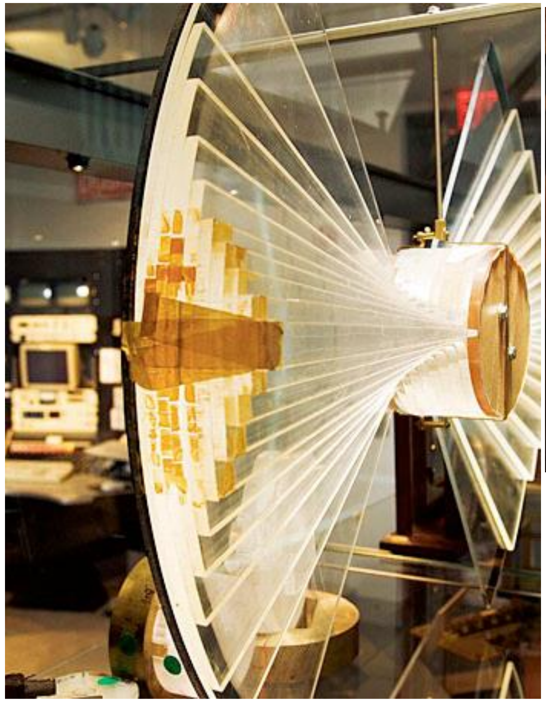
HCL design (single modulation,
4 repetitions)



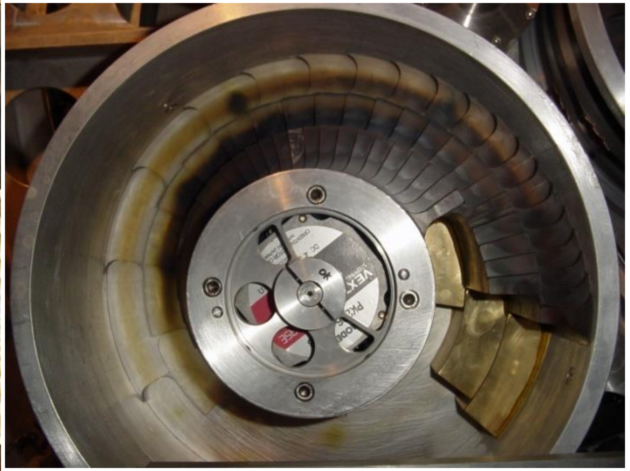




A
First Scatterer
Scanning Magnet 1
Scanning Magnet 2
Second Scatterer
Monitor Chamber
Snout & aperture
Beam
Range modulator wheel
Variable Collimator
Compensator
B
Quadrupole Magnet 1
Quadrupole Magnet 2
Scanning Magnet 1
Scanning Magnet 2
Scatterer
Ridge Filter
Monitor Chamber
Snout & aperture
Beam
Profile Monitor
Compensator
C
Quadrupole Magnet 1
Quadrupole Magnet 2
Scanning Magnet 1
Scanning Magnet 2
Extended Vacuum pip
Monitor Chamber
Beam
Profile Monitor

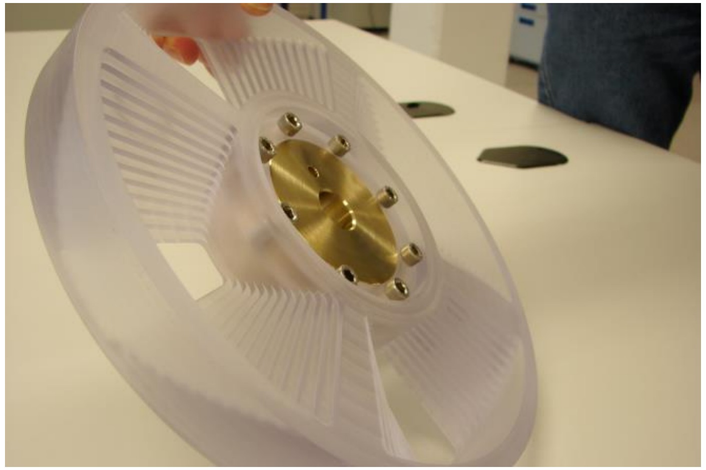
# Range Modulator



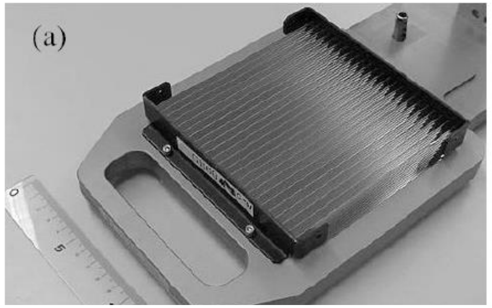
HCL design (single modulation,
4 repetitions)



IBA design (3 tracks on single wheel,
gating used to adjust modulation)



IBA eye-line



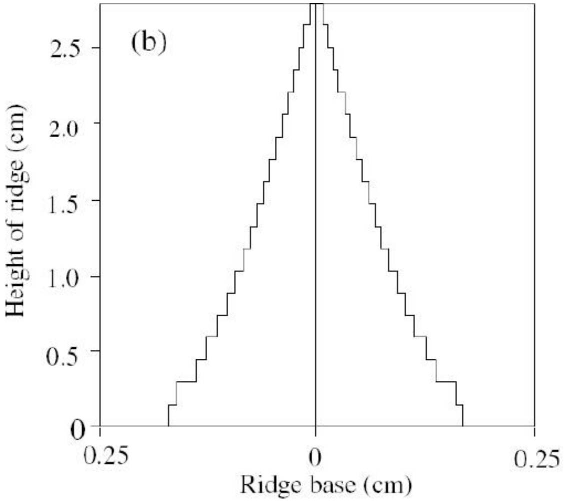
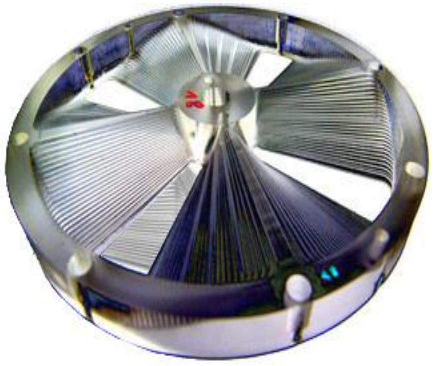



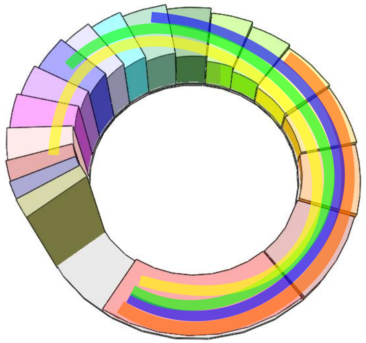

**Figure 2.** A bar ridge filter for the proton beam in the gantry nozzle (a), the cross-sectional shapes of the ridge for 6 cm SOBP (b).

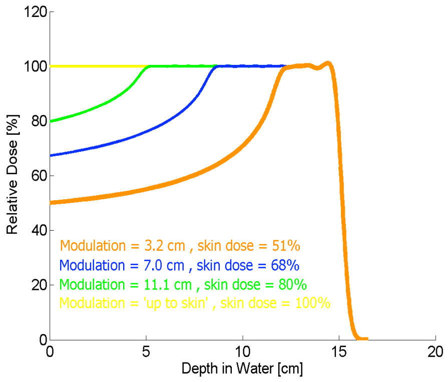
Ridge filter design for proton therapy at Hyogo Ion Beam Medical Center, T.Akagi et al, Phys. Med. Biol. 48 No 22 (21 November 2003) N301-N312

# Range Modulation Methods

## 1. Range Modulation Wheel

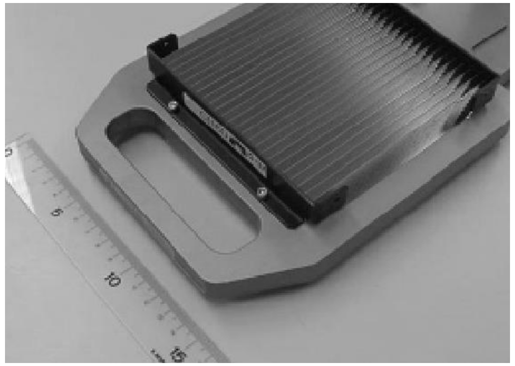


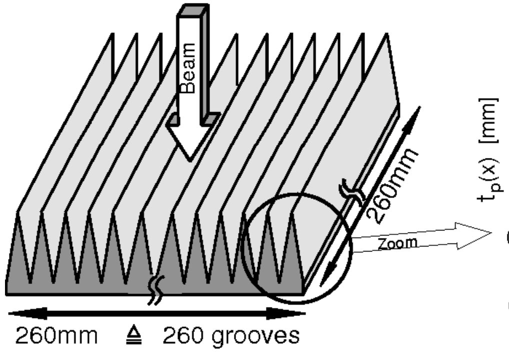


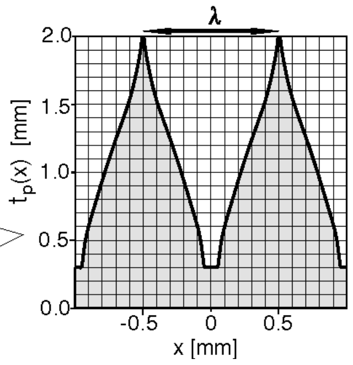


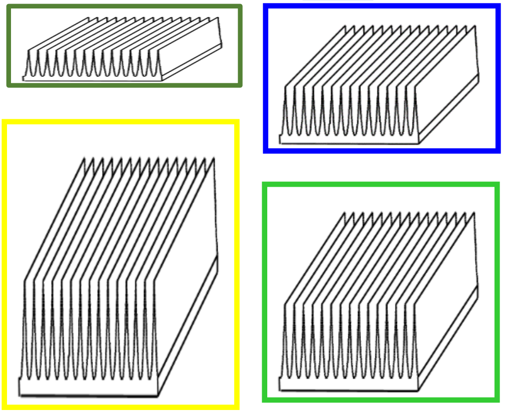

mm 단위로 SOBP 조절, Flatness 좋음, 고장이 잦음. Rotating timing 중요

## 2. Ridge Filter



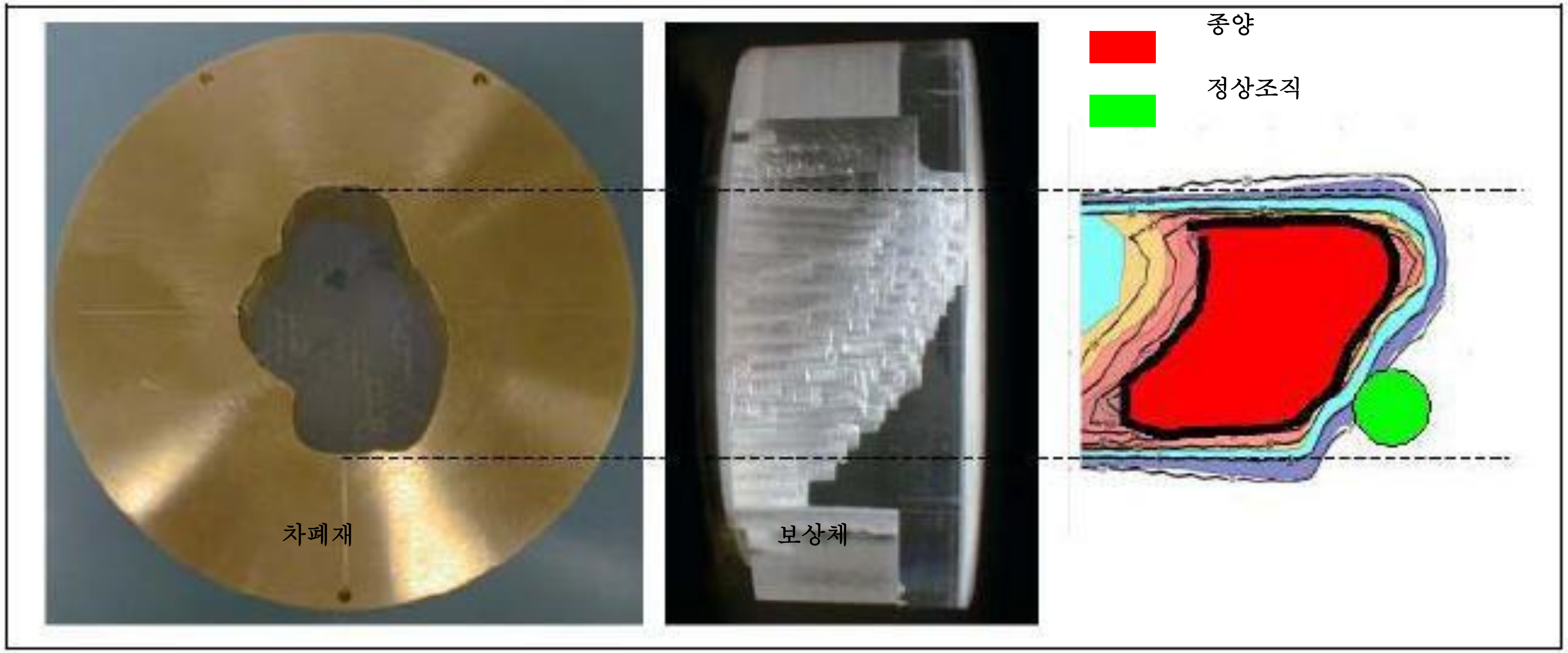


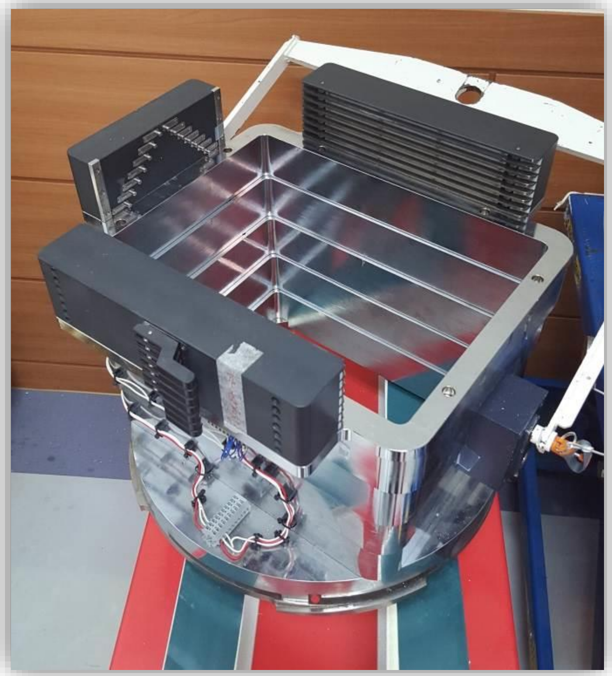



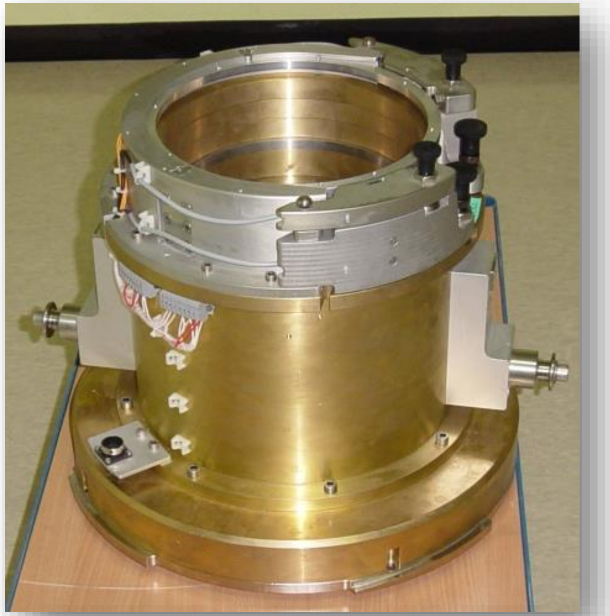
cm 단위로 SOBP 조절, 경우에 따라 Tilted 됨. 고장의 우려가 적음.

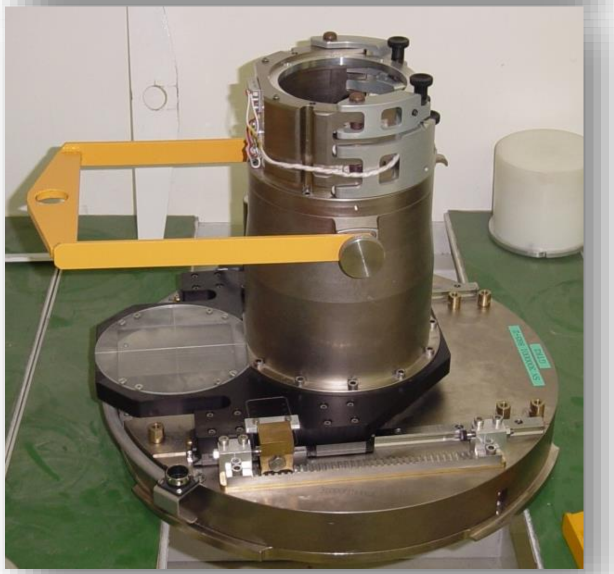
# Aperture and Bolus

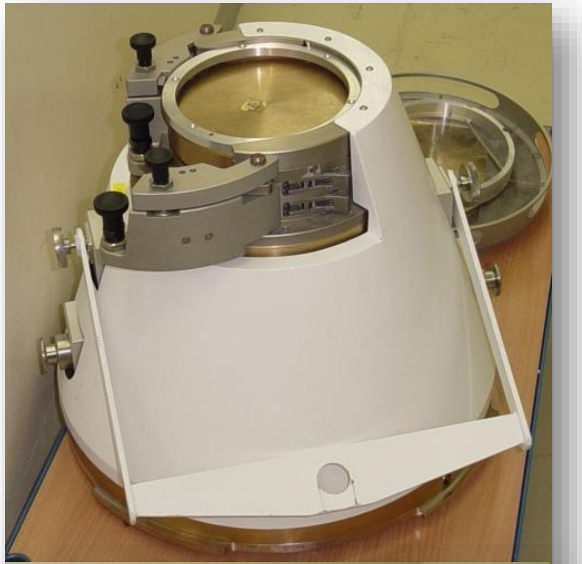


# Snouts 30X40, 250, 180, 100 & Eye

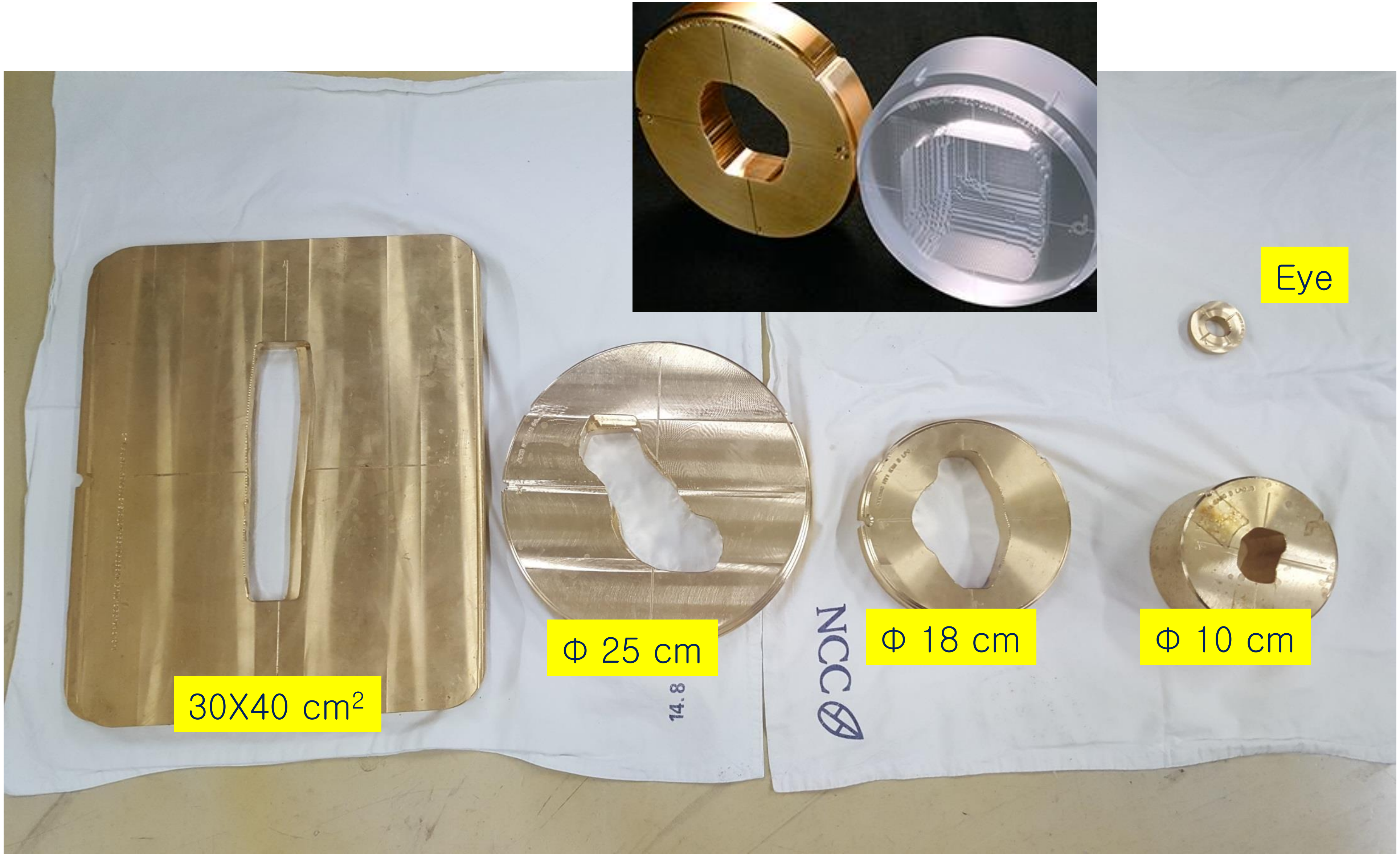


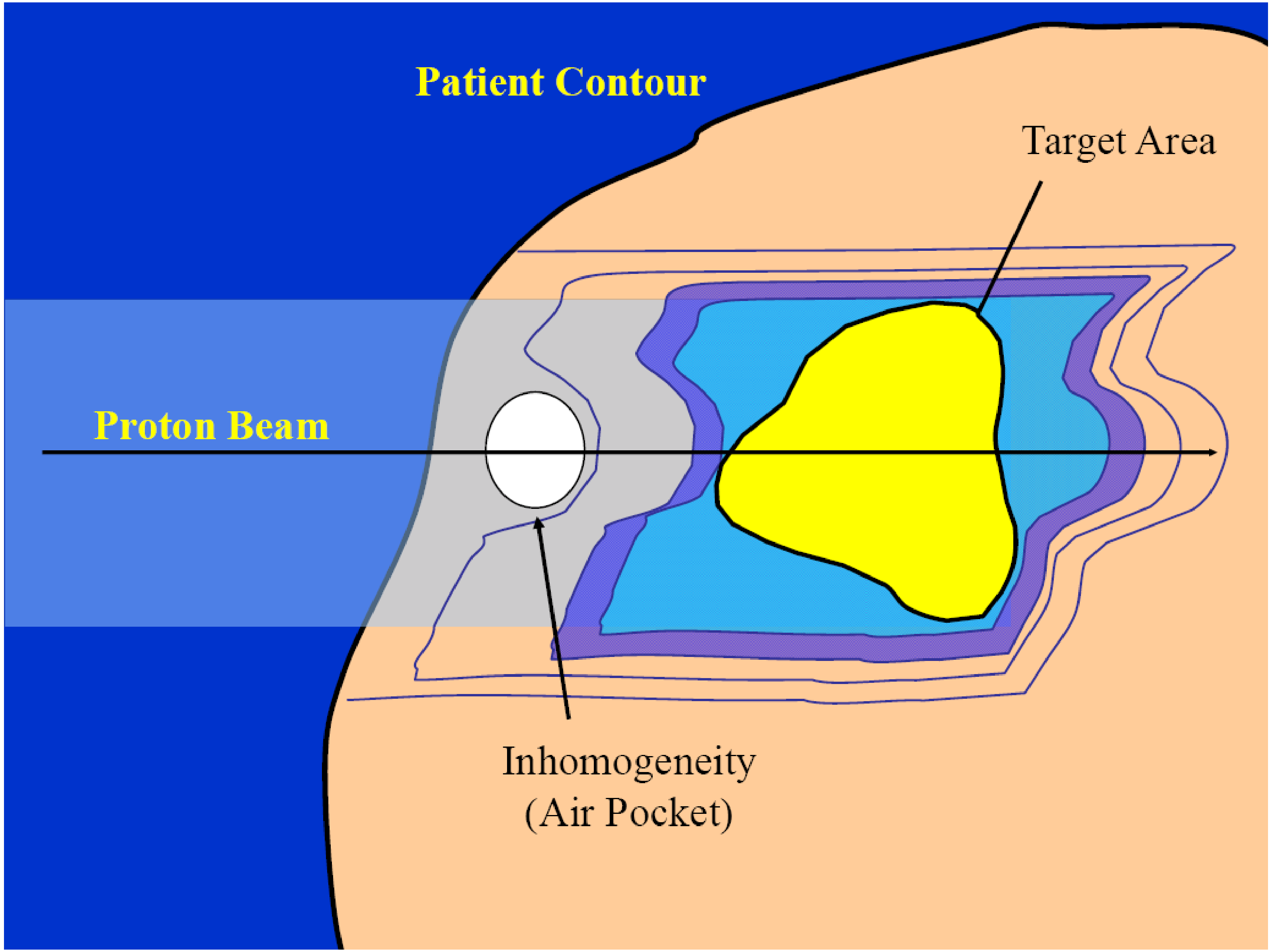


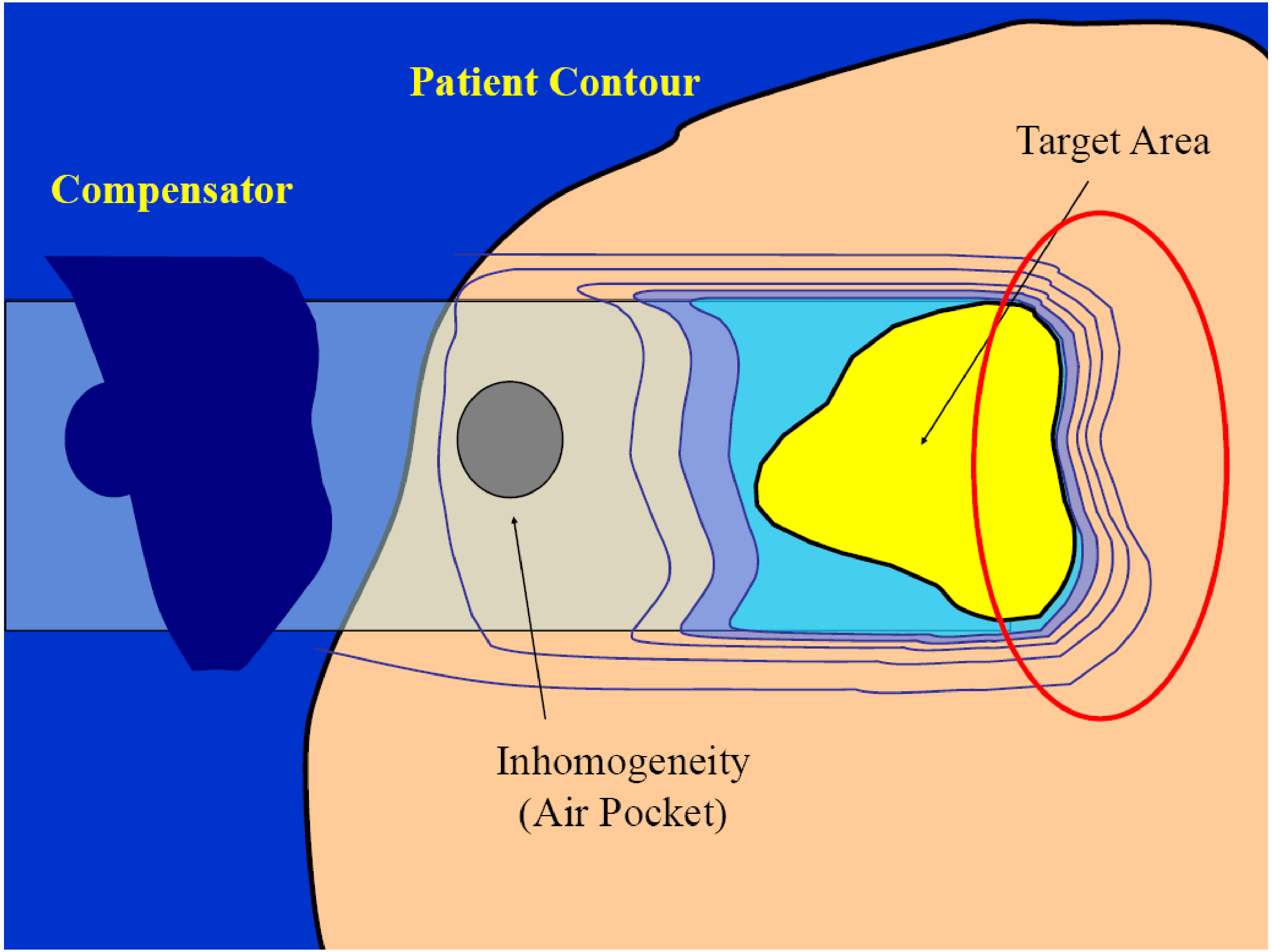




# Brass Block

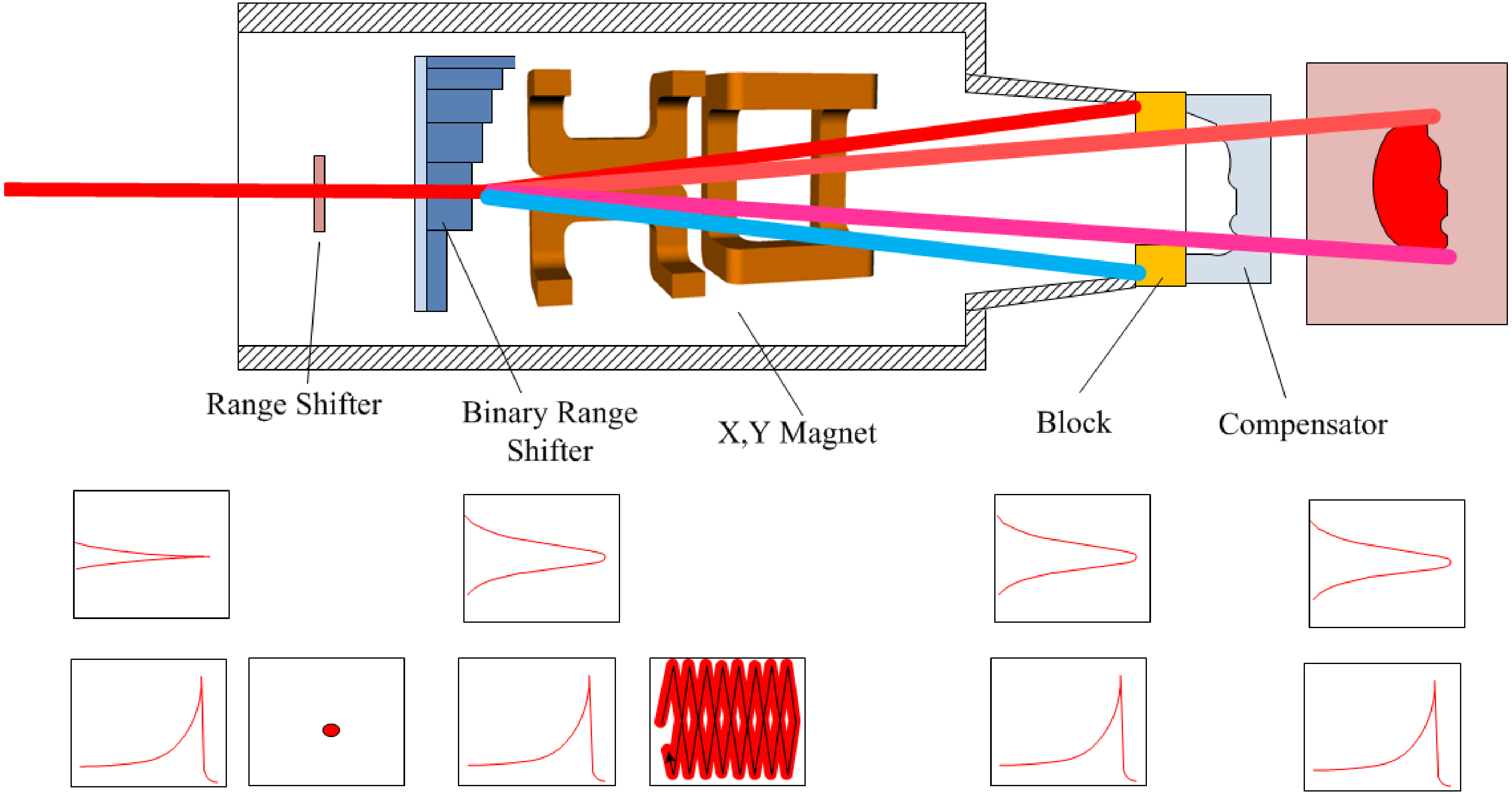



Patient Contour
Target Area
Proton Beam
Inhomogeneity
(Air Pocket)

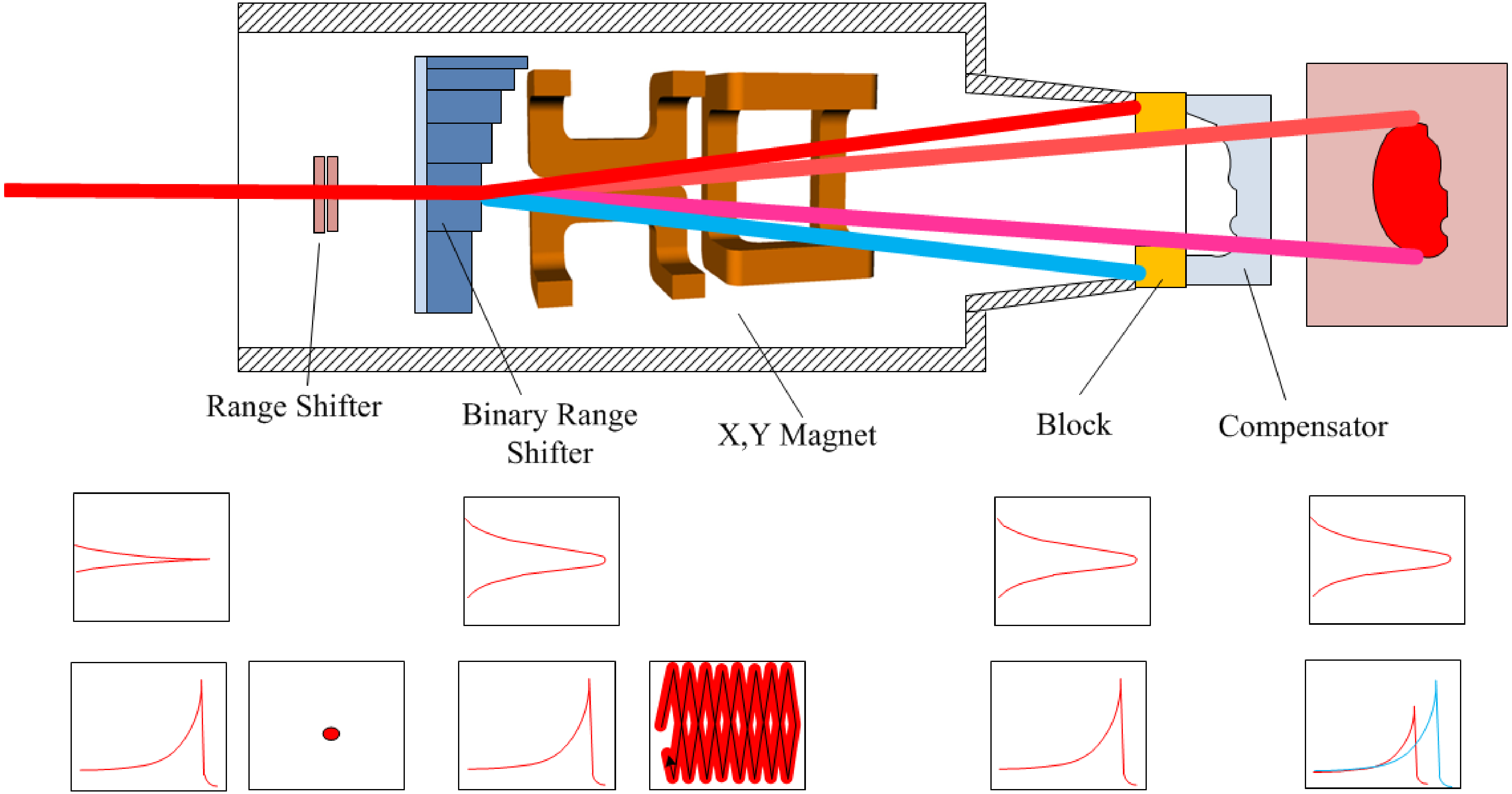

Patient Contour
Compensator
Target Area
Inhomogeneity
(Air Pocket)

# Dynamic Mode

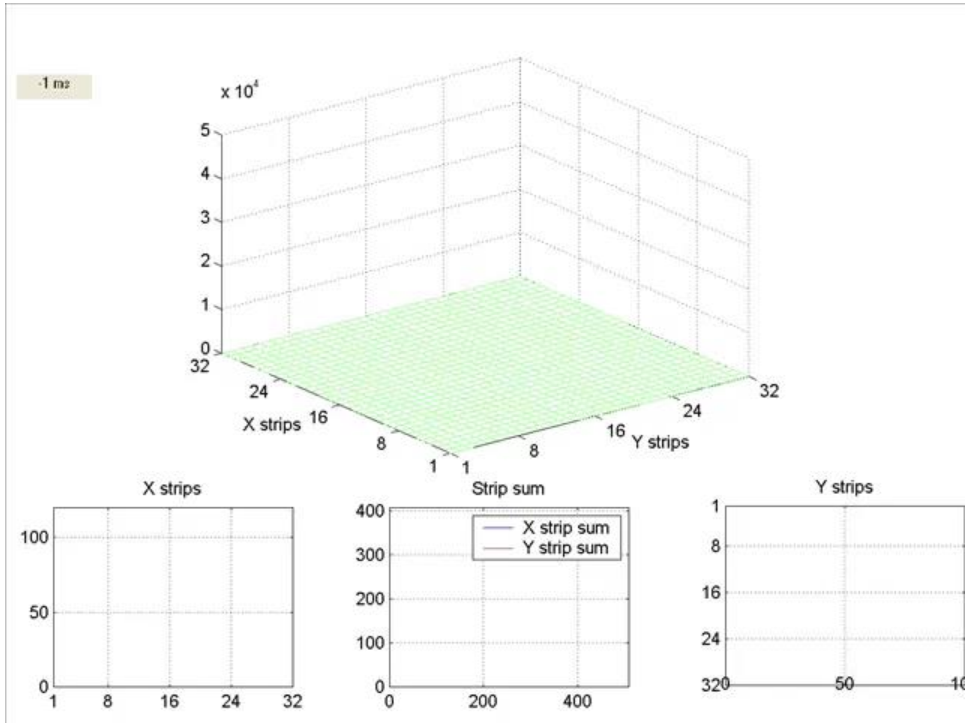
# Uniform Scanning

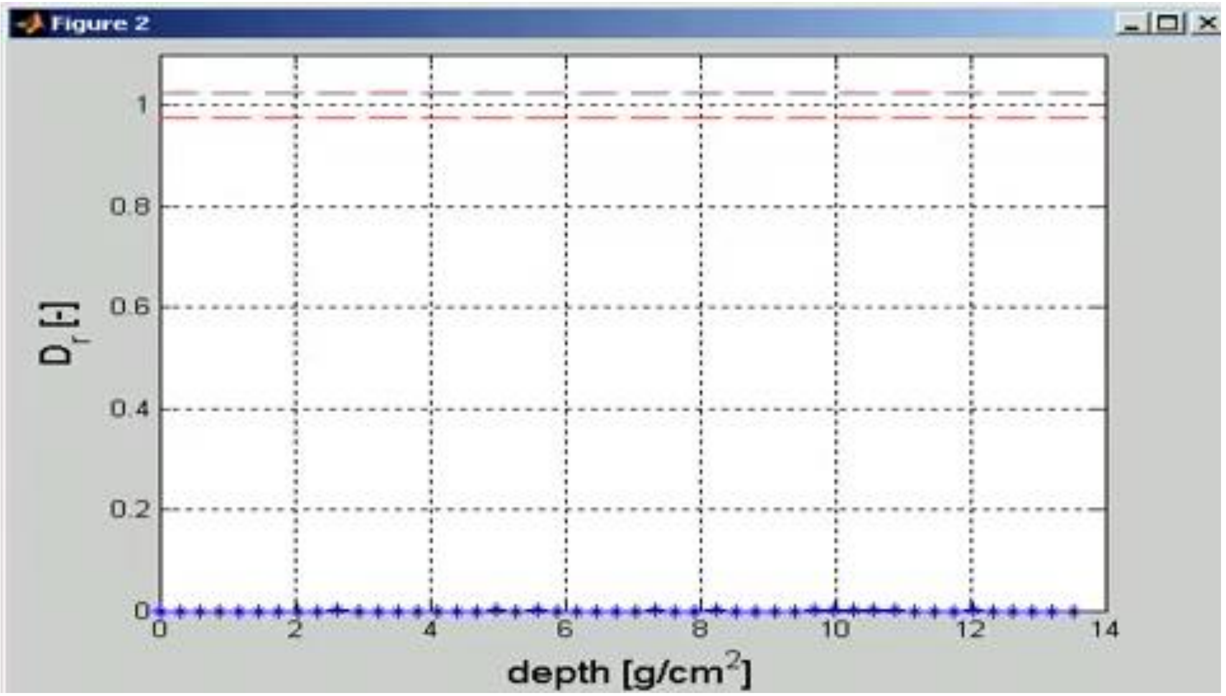


# Uniform Scanning



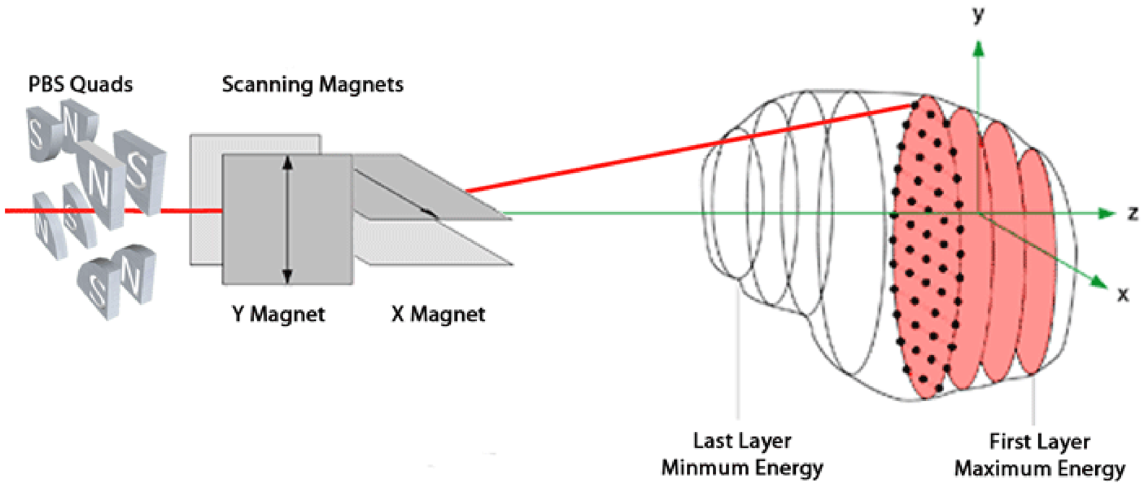
# Uniform Scanning

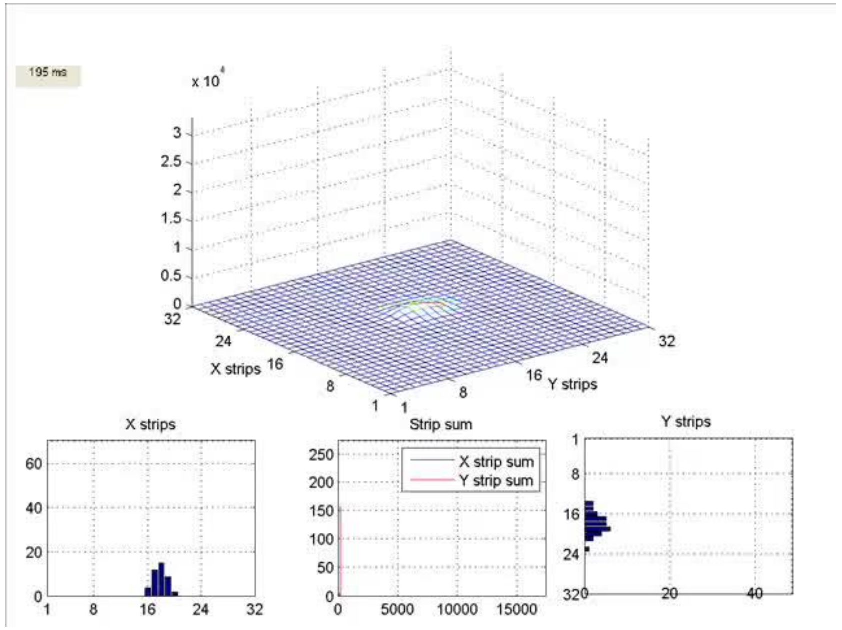



IBA-Hicham Yang- 17 MARCH 2008

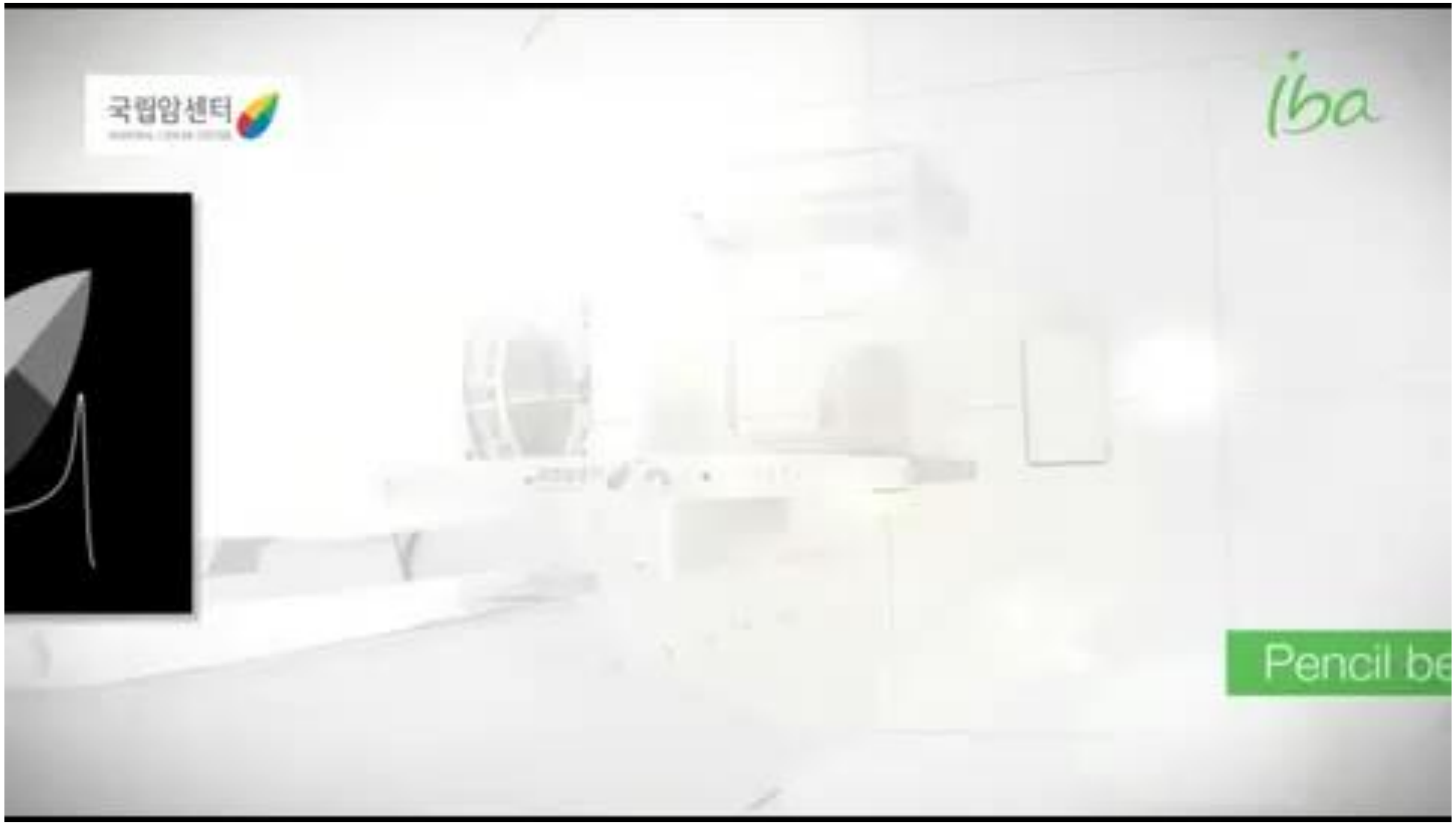
# Pencil Beam Scanning (PBS)



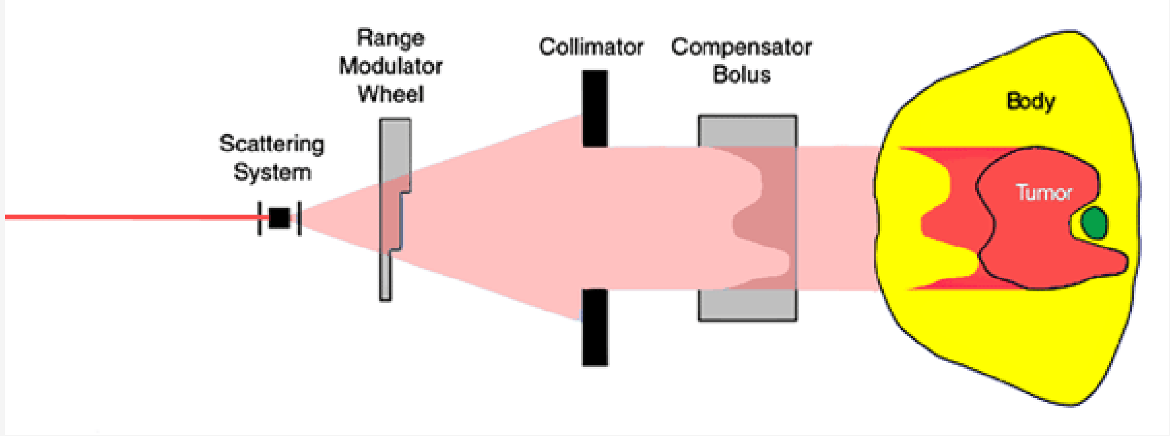
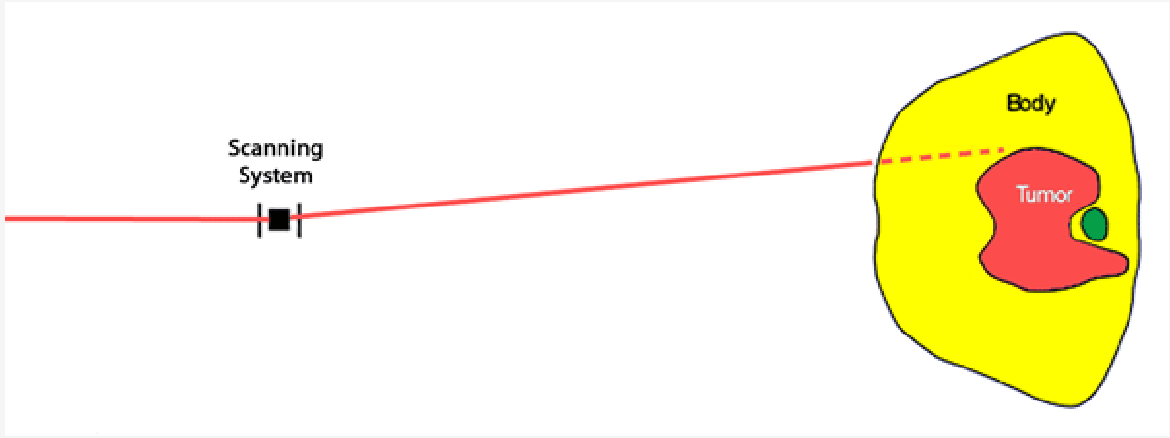




IBA-Hicham Yang- 17 MARCH 2008

# NCC Pencil Beam Scanning (PBS)



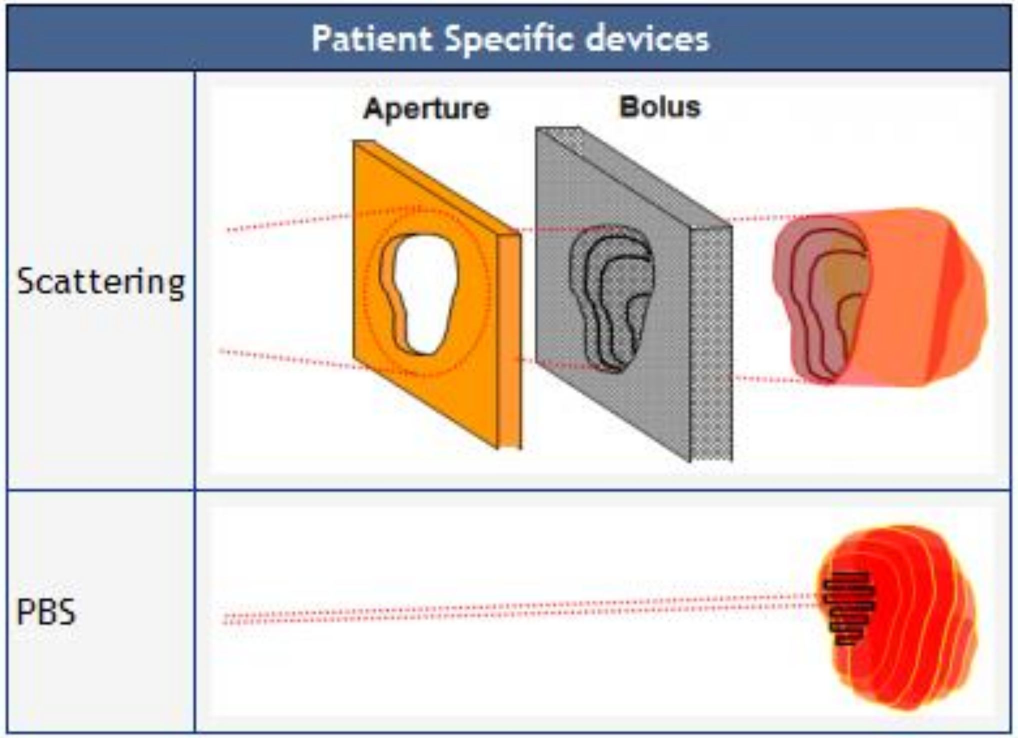
# Comparison Dose Conformity

| Scattering vs PBS dose Conformity | |
|---|---|
| Scattering |   |
| PBS |   |

IBA-Yong Liang CAI-2012

# Comparison Patient Specific Devices

- PBS doesn't require patient specific compensators and bolus
  - Less neutrons close from the patient
  - Less expensive (apertures and bolis cost a lot!)
  - No more snout changes ☺




IBA-Yong Liang CAI-2012

# Specifications of Modulated Proton Beam(NCC)

| Item | Singles Scattering | Double Scattering | Uniform Scanning | Pencil Beam Scanning |
|---|---|---|---|---|
| Range in Patient ($g/cm^2$) | 3.35-20.4 | 4.51-28.42 | 3.42-32.1 | 7.5-35<br>(0.5-32) |
| Range modulation ($g/cm^2$)<br>adjustment & Size | 0.4(R>6), 0.17<br>9.2 | 0.2<br>20.75 | 0.5<br>Full | 0.4<br>24 |
| Range adjustment($g/cm^2$) | 0.09(R>6),0.05 | 0.1 | 0.1 | 0.4 |
| Average dose rate (Gy/min) | 5.93 | 3 | 1.15 | - |
| Max. Field Size (cm) | 4 (Dia) | 24.3 (Dia) | 40 X30 | 22.5 X25<br>@ High E |
| Dose Uniformity (%) | 1.25 | 1.05 | 1.5(R), 2.6(L) | 3 |
| Effective SAD (m) | 2.55 | 2.19 | 2.12 | 2.12 |
| Distal Penumbra ($g/cm^2$) | 0.21 | 0.23 | 0.13 | Beam sigma |
| Lateral Penumbra(cm)<br>/ Spot size (PBS) | 0.17 | 0.48 | 0.30(y), 0.22(x) | 4.9 mm @32 cm<br>10.4 mm@ R8 cm |
| Clinical Use | H&N, Eye | Conventional | Large Size | IMPT |

# Proton ARC therapy

Rah et al. Radiation Oncology (2016) 11:140
DOI 10.1186/s13014-016-0717-4

Radiation Oncology

RESEARCH Open Access

# A treatment planning study of proton arc therapy for para-aortic lymph node tumors: dosimetric evaluation of conventional proton therapy, proton arc therapy, and intensity modulated radiotherapy

Jeong-Eun Rah[1], Gwe-Ya Kim[2], Do Hoon Oh[1], Tae Hyun Kim[3], Jong Won Kim[4], Dae Yong Kim[3], Sung Yong Park[5] and Dongho Shin[3*]

## Abstract

**Background:** The purpose of this study is to evaluate the dosimetric benefits of a proton arc technique for treating tumors of the para-aortic lymph nodes (PALN).

**Method:** In nine patients, a proton arc therapy (PAT) technique was compared with intensity modulated radiation therapy (IMRT) and proton beam therapy (PBT) techniques with respect to the planning target volume (PTV) and organs at risk (OAR). PTV coverage, conformity index (CI), homogeneity index (HI) and OAR doses were compared. Organ-specific radiation induced cancer risks were estimated by applying organ equivalent dose (OED) and normal tissue complication probability (NTCP).

**Results:** The PAT techniques showed better PTV coverage than IMRT and PBT plans. The CI obtained with PAT was 1.19 ± 0.02, which was significantly better than that for the IMRT techniques. The HI was lowest for the PAT plan and highest for IMRT. The dose to the OARs was always below the acceptable limits and comparable for all three techniques. OED results calculated based on a plateau dose–response model showed that the risk of secondary cancers in organs was much higher when IMRT or PBT were employed than when PAT was used. NTCPs of PAT to the stomach (0.29 %), small bowel (0.69 %) and liver (0.38 %) were substantially lower than those of IMRT and PBT.

**Conclusion:** This study demonstrates that there is a potential role for PAT as a commercialized instrument in the future to proton therapy.

**Keywords:** Proton arc therapy (PAT), Proton beam therapy (RBT), Intensity modulated radiation therapy (IMRT), Organ equivalent doses (OED), Normal tissue complication probability (NTCP)

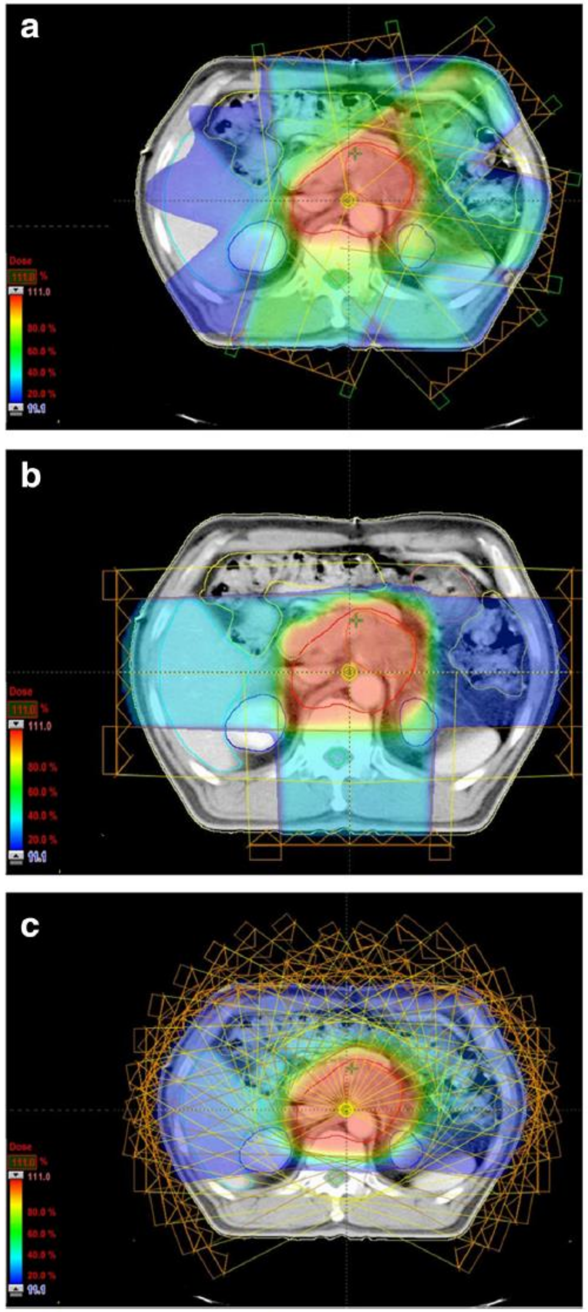
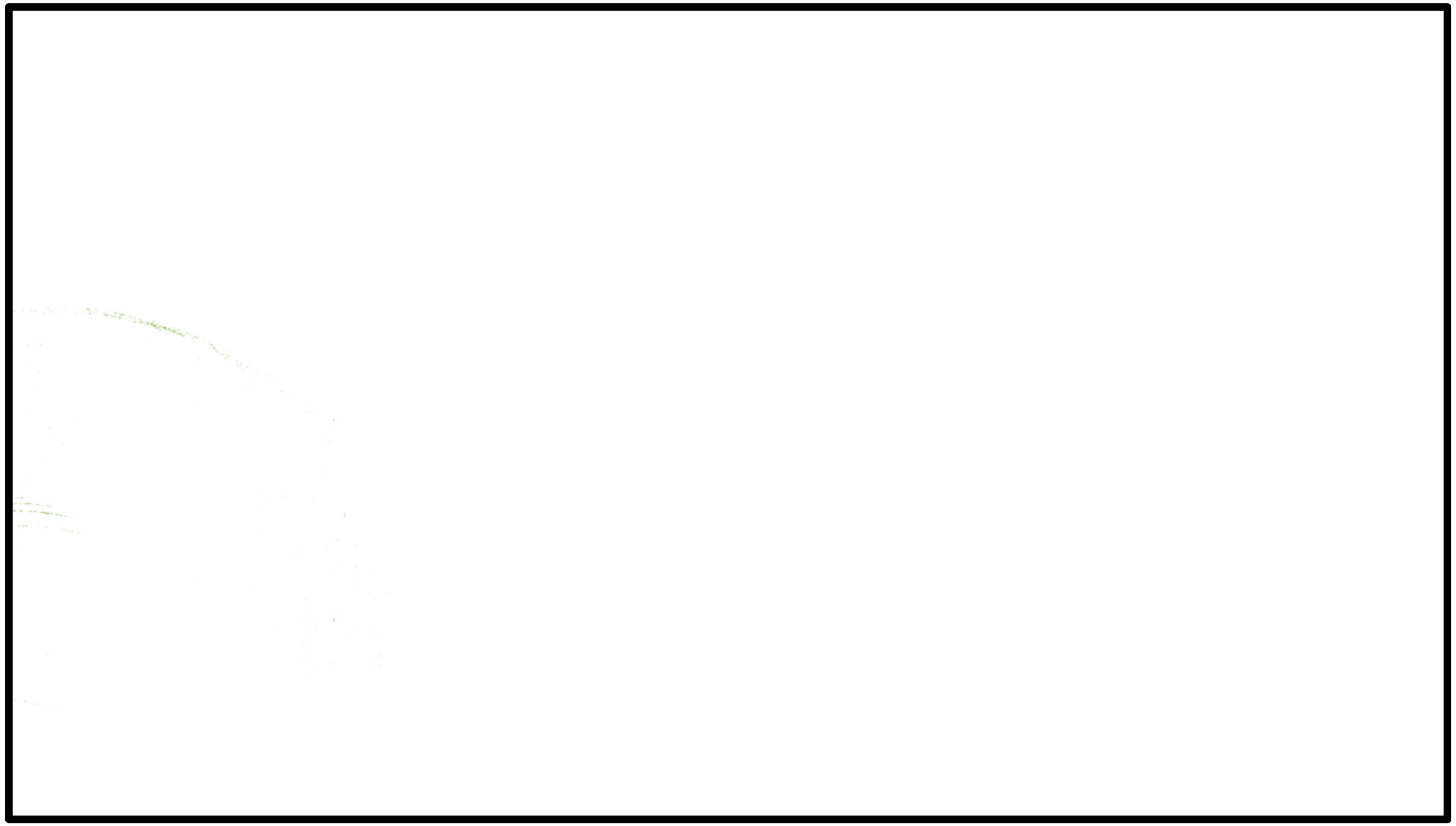



**Fig. 1** Dose distribution of (**a**) IMRT, (**b**) PBT, and (**c**) PAT technique in axial plane. Color wash banding is restricted to relative dose range of 11–110 %

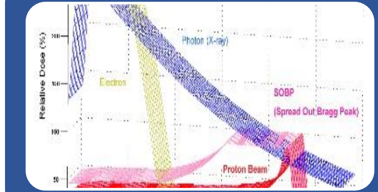
# Arc Therapy: streamlining your proton therapy center


IBA CONFIDENTIAL    Feature in development

# IBA Proton Arc therapy

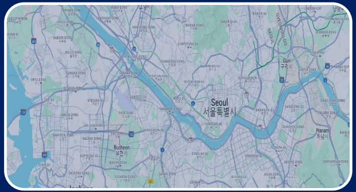


Introduction: NCC Proton Therapy & Particle Therapy



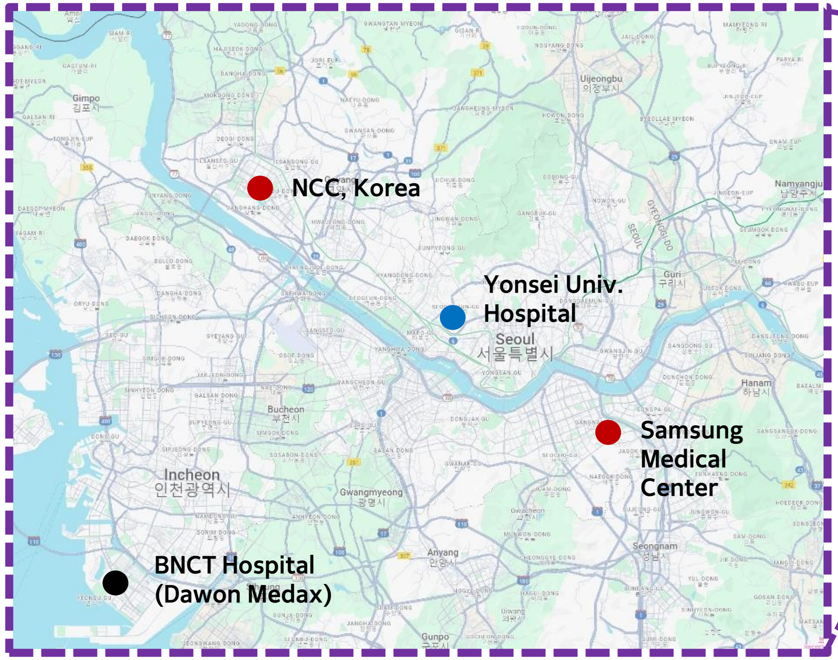

Why we need proton therapy in clinical?

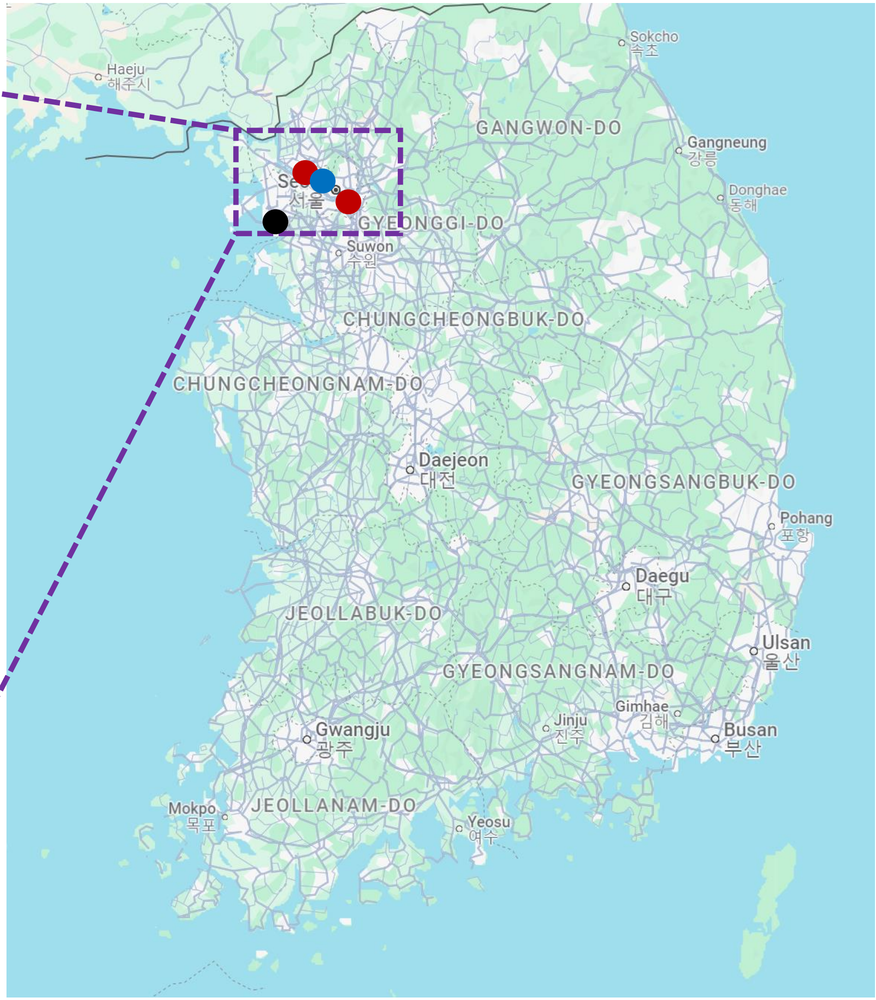
Proton therapy system & techniques




Current Status of Particle therapy in Korea

# Particle Therapy Centers in Korea



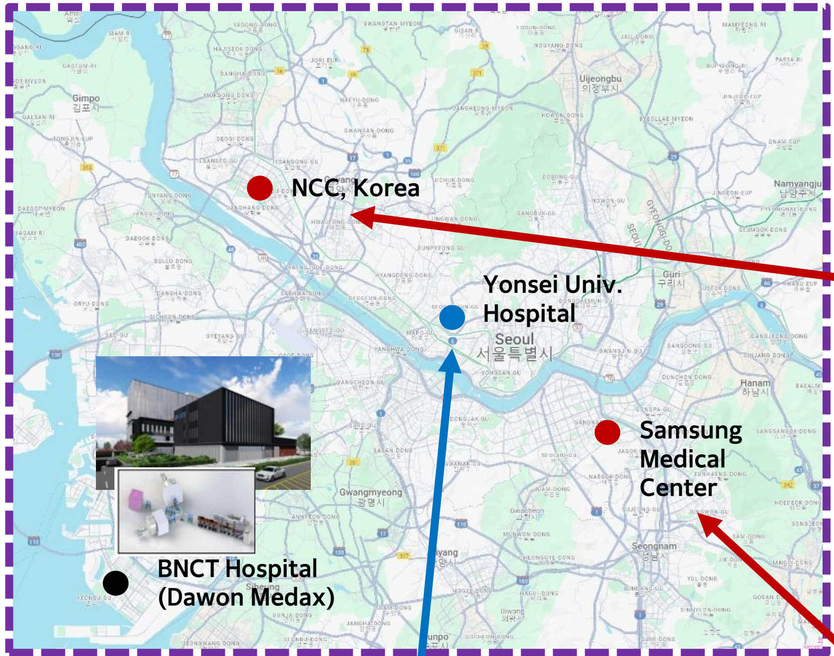




Facility in Operation

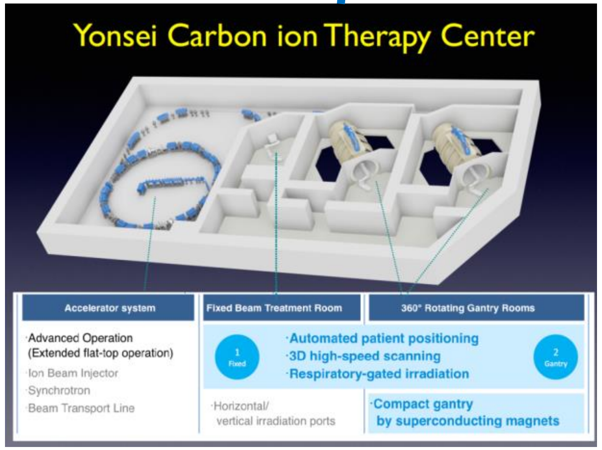
● Proton ● Carbon ● BNCT*

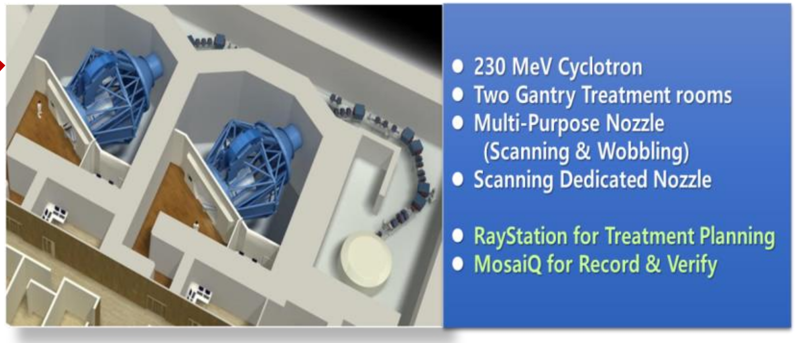
**Under Clinical Trial*

# Facility in Operation in Korea







# ❖ National Cancer Center, Korea

| | |
|---|---|
| 2000.10 | •NCC Start clinical care service |
| 2001.6 | •NCC Opening ceremony held |
| 2001.12 | •Launch of NCC proton therapy Project |
| 2002.6.29 | •Signing with IBA |
| 2003.3.21 | •Ground Breaking |
| 2003.5-2004.12 | •Building construction |
| 2005.2.15 | •Start of IBA Proteus 235 installation |
| 2005.10.21 | •First Beam Generation |
| 2005.10-2006.12 | •Beam test &tuning for Cyclotron and Beamline |
| 2007.1-2007.2 | •Commissioning and Beam data taking |
| 2007.3.19 | •First Patient Treatment start (GTR2) $27^{th}$ Open in the world, $3^{th}$ IBA System in the world |
| 2007.7.9 | •GTR3 Patient treatment start |
| 2009.5.15 | •First Eye melanoma proton treatment start |
| 2010.8.27 | •First Wobbling mode Tx start (GTR2) |
| 2015.8.27 | •First PBS mode Tx Start(GTR3) |
| 2026 | •Compact Proton Therapy system(IBA Proteus one) install |

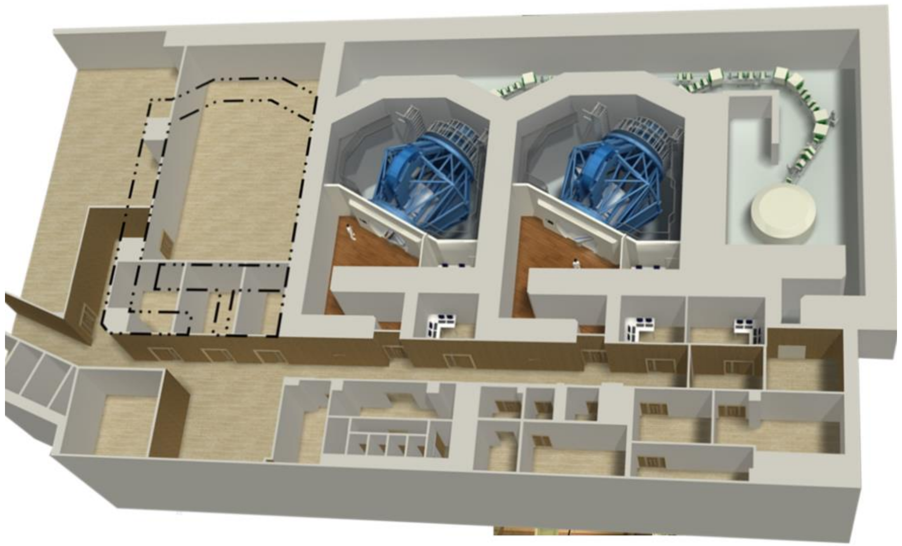
Proton Therapy Facility

# ❖ Yonsei Univ. Cancer Center

## Progress of YONSEI HIT Center

YONSEI CANCER CENTER

- February 2013 — Start Particle Therapy Review
- April 2016 — Approve HITS in board of directors
- March 2018 — Contract for Heavy Ion Therapy System
- April 2023 — Permit MFDS

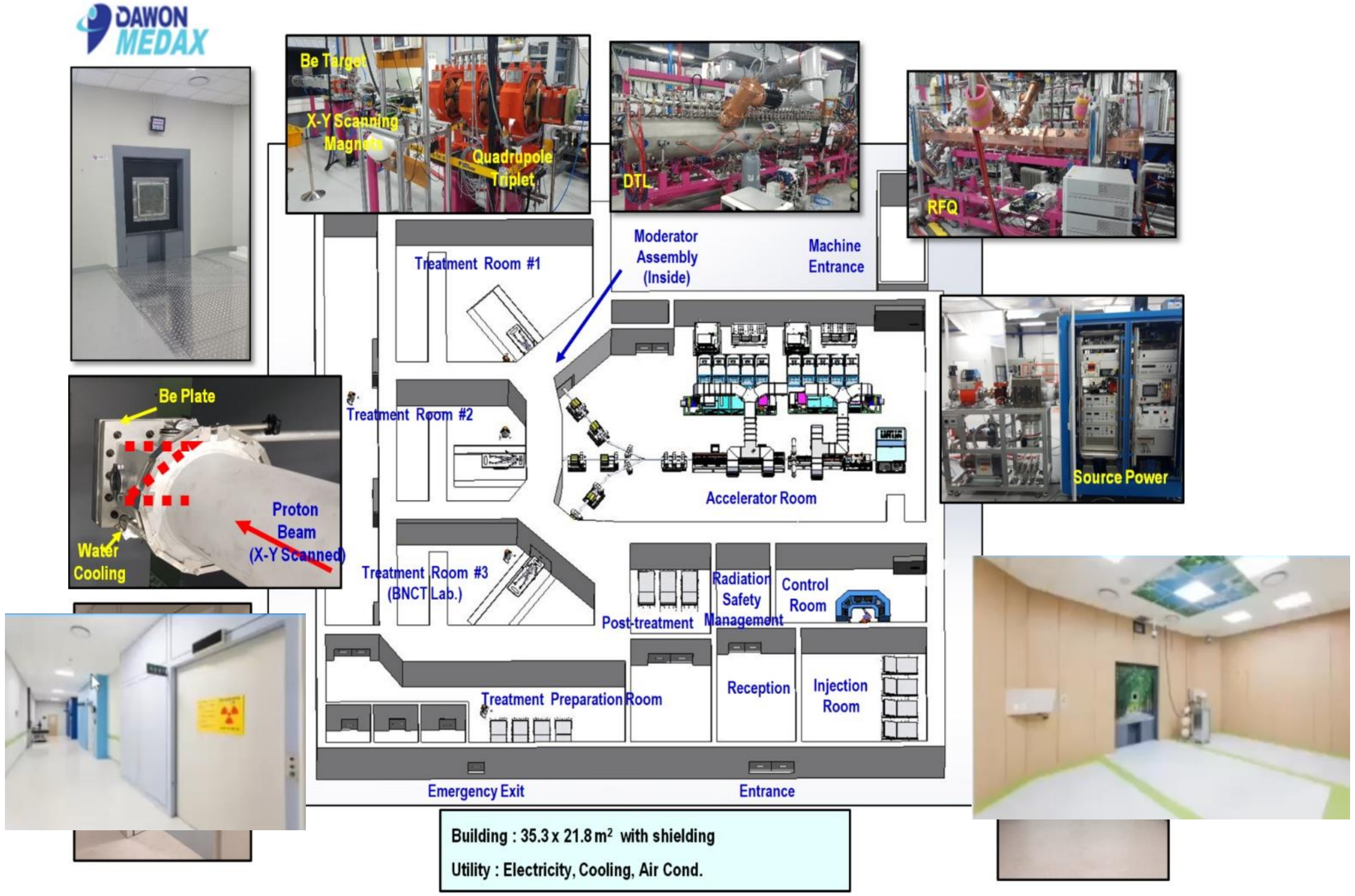


## Construction

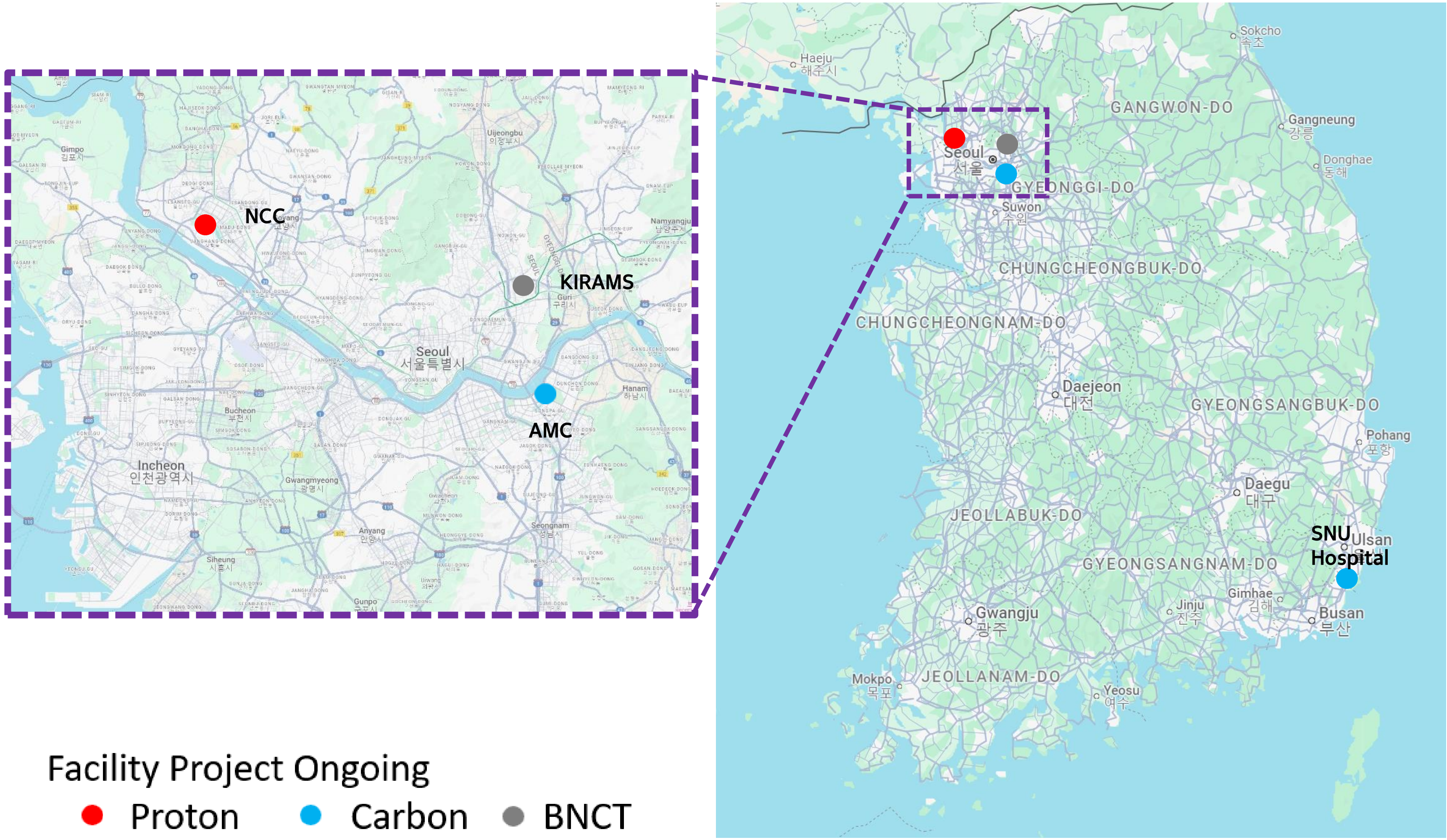
YONSEI CANCER CENTER

# ❖ A-BNCT in Gil Medical Center (Dawon Medax)

- Sept. 2015. Establish DAWONMEDAX
- Nov. 2015. BNCT development MOU with Gil Hospital



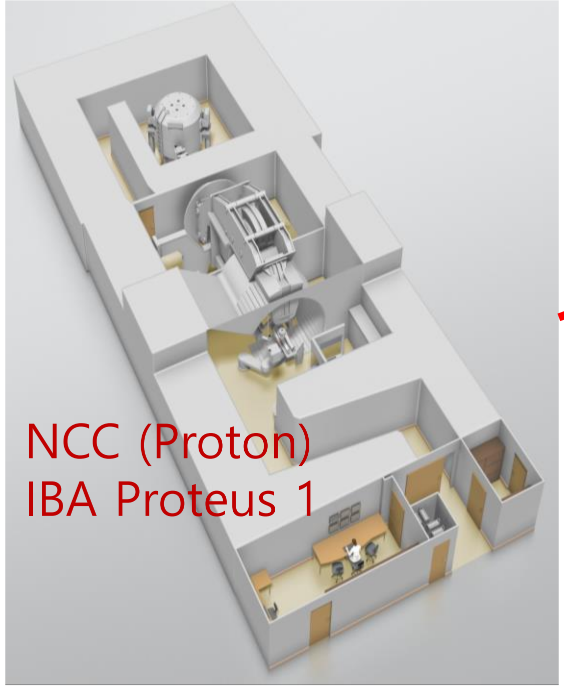
# Particle Therapy Centers in Korea




Facility Project Ongoing

● Proton ● Carbon ● BNCT

# Facility Project Ongoing in Korea



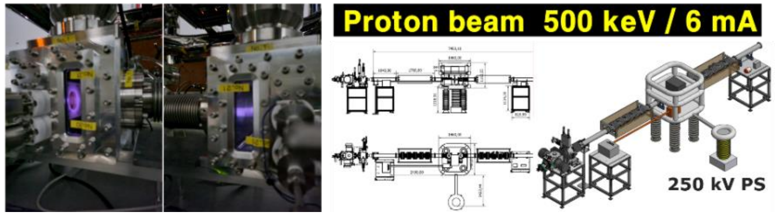


# ❖ Korea Institution of Radiological & Medical Science

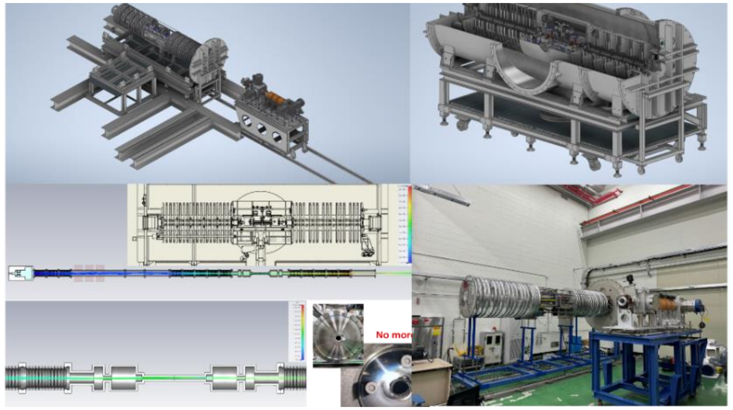
## Devloping tandem accelerator prototype

한국원자력의학원
KOREA INSTITUTE OF RADIOLOGICAL & MEDICAL SCIENCES

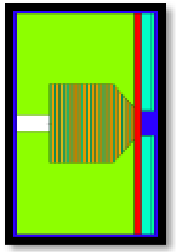
Development of Korea's first high-current
500 keV proton tandem accelerator in 2022

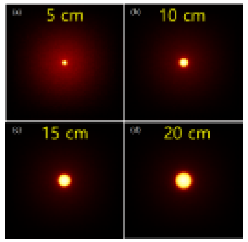



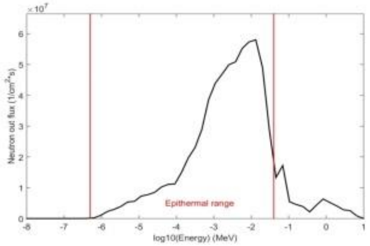

2023-current:
Design and fabrication of a high-current 2.4 MeV proton tandem accelerator under construction.

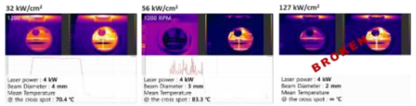


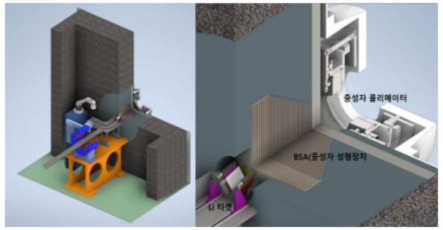
Successful development of Korea's first 1200 kV DC power supply in 2024



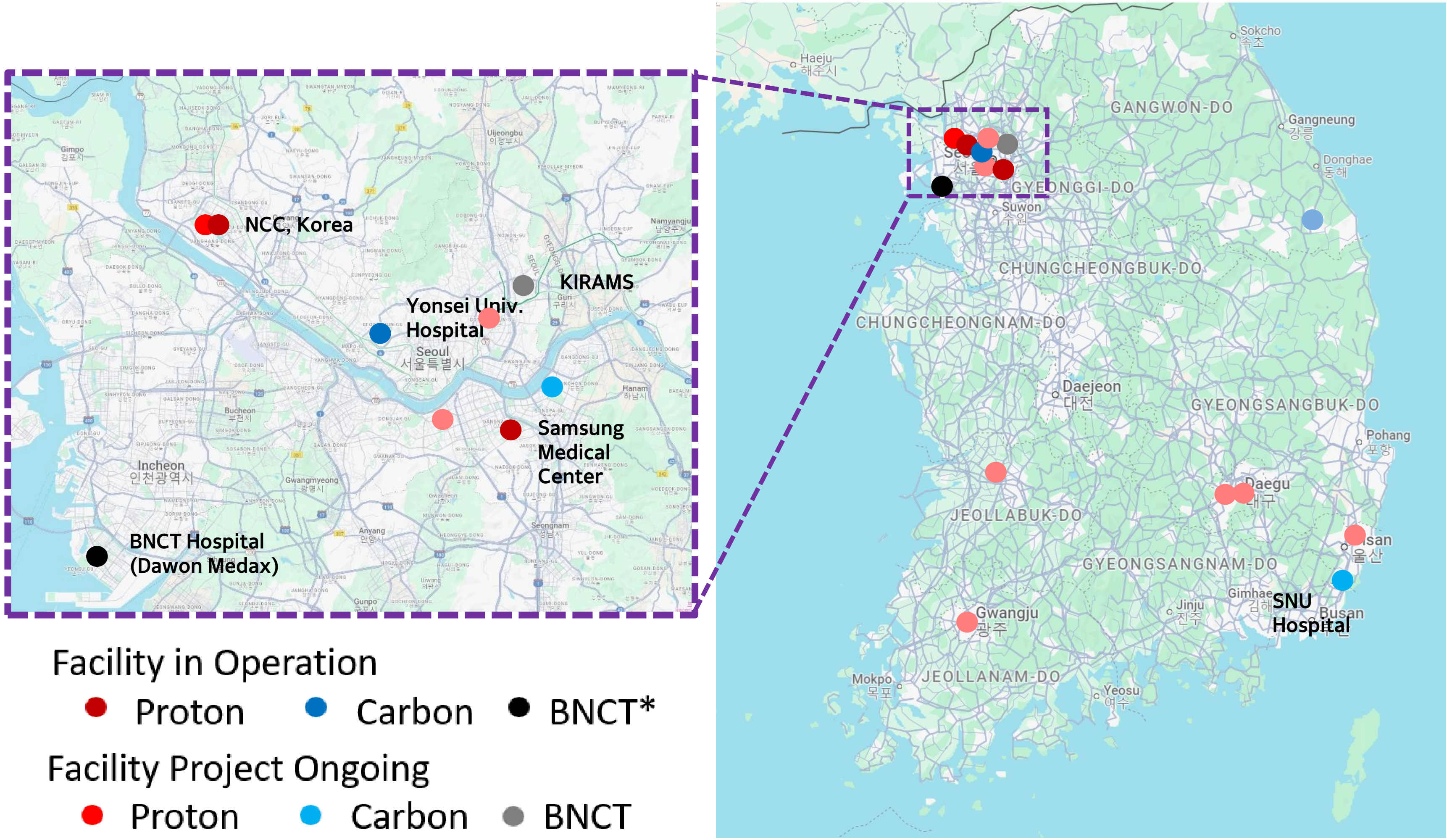




# Particle Therapy Centers in Korea




Facility in Operation

- Proton
- Carbon
- BNCT*

Facility Project Ongoing

- Proton
- Carbon
- BNCT

Facility under Consideration

- Proton
- Carbon

**Under Clinical Trial*

# Future Outlook of Particle Therapy in Korea

National Cancer Center, Proton Therapy
Treatment Started (Since 2007)

Yonsei Cancer Hospital, Heavy Ion Therapy
Treatment Started (Since 2023)

Seoul ST. Mary's Hospital, Proton Therapy
Contracted (2025.11)

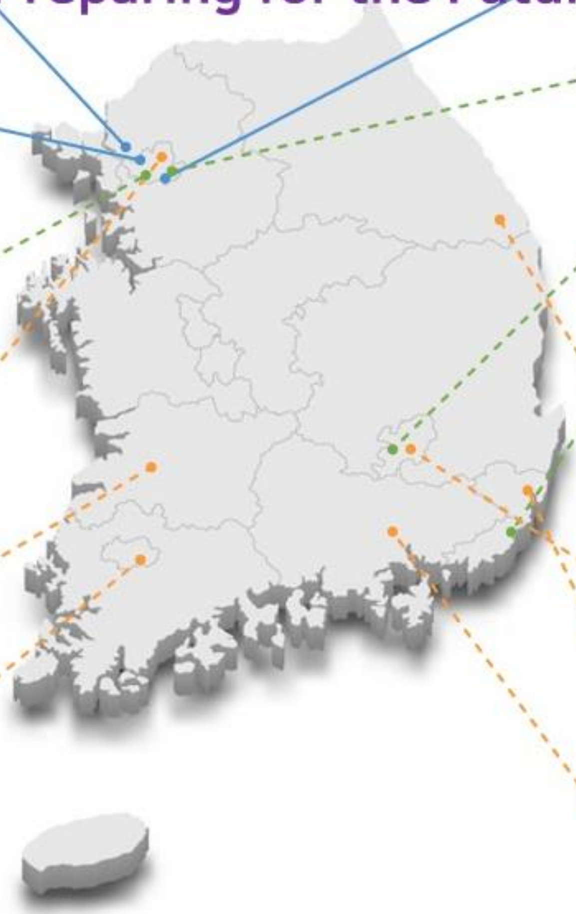
Korea Univ. Anam Hospital, Proton Therapy
(in Planning)

Wonkwang Univ. Hospital, Proton Therapy
(in Planning)

Chonnam Univ. Hospital, Proton Therapy
(in Planning)

Needs

**Preparing for the Future**



Samsung Medical Center, Proton Therapy
Treatment Started (Since 2015)

Seoul Asan Medical Center, Heavy Ion Therapy
Contracted (Expected in 2031)

Keimyung Univ. Dongsan Hospital, Proton Therapy
Contracted (2025.08)

Seoul NUH (Gijang), Heavy Ion Therapy
under Installation (Expected in 2027)

Samcheok, Heavy Ion Therapy
in the Investigation Stage (Approved in 2025)

Kyungpook NUH, Proton Therapy
(in Planning)

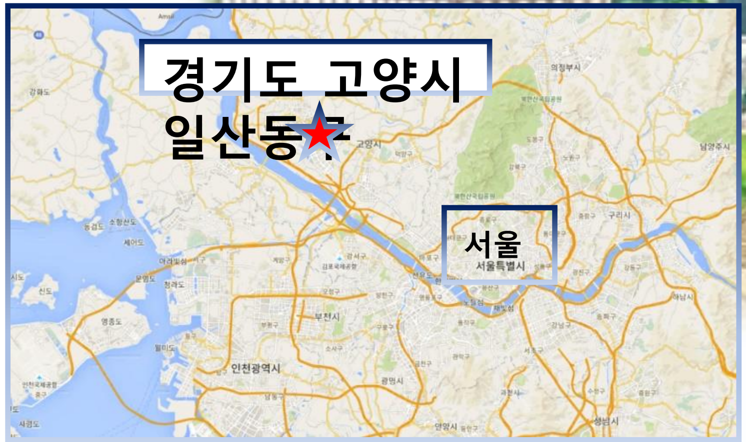
Ulsan Univ. Hospital, Proton Therapy
(in Planning)

Hanmaeum Medical Center, Proton Therapy
(in Planning)

국립암센터
NATIONAL CANCER CENTER
암 정복의 리더, 최초에서 최고로

https://www.ncc.re.kr

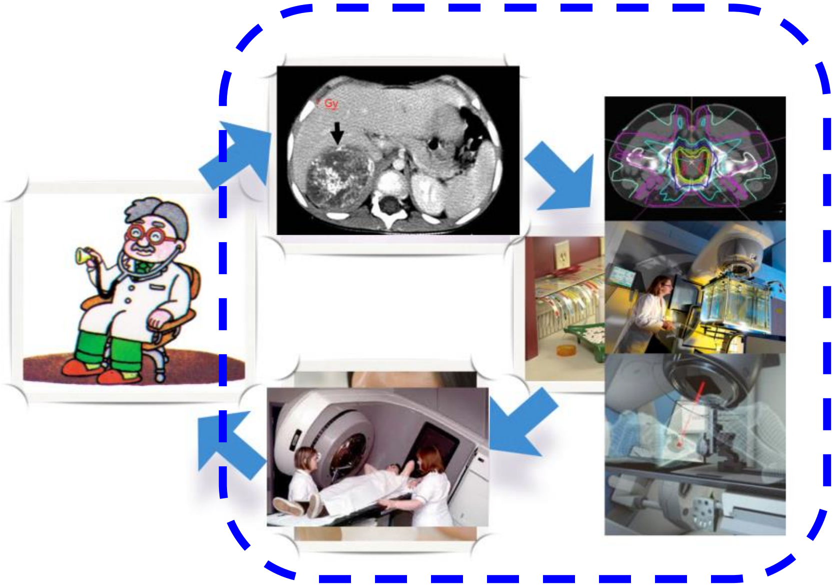
# 감사합니다.



# Medical Physics 의 소개

한국에서의 의학물리학자 & 관련연구분야 소개

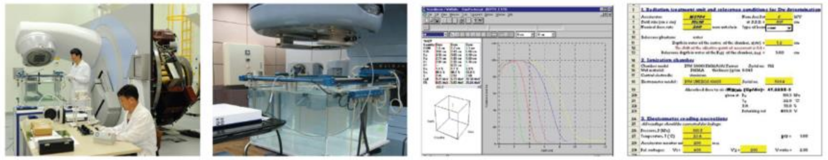
# 의학물리학자의 업무



(1) 방사선 장비의 인수검사

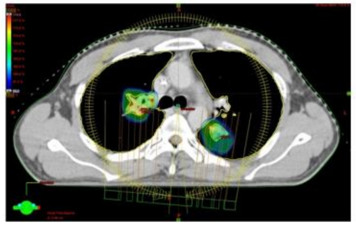

장비설치중 점검 장비설치후 인수검사 인수 정밀 검사

(2) 방사선 치료기의 사용준비

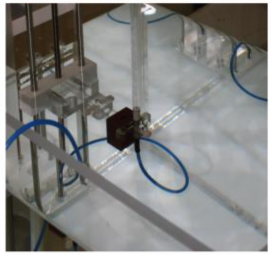


데이타 수집 출력교정

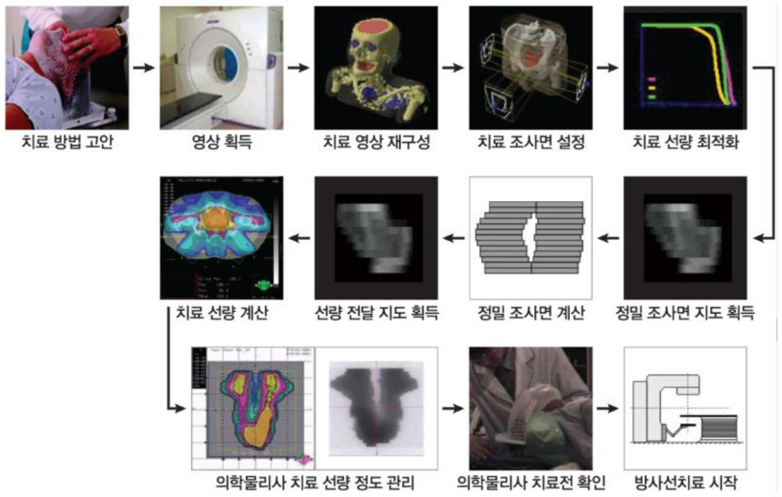
(3) 방사선 치료설계 및 치료법 개발, 치료에 대한 자문 제공



(4) 정확한 방사선량 측정, 품질관리

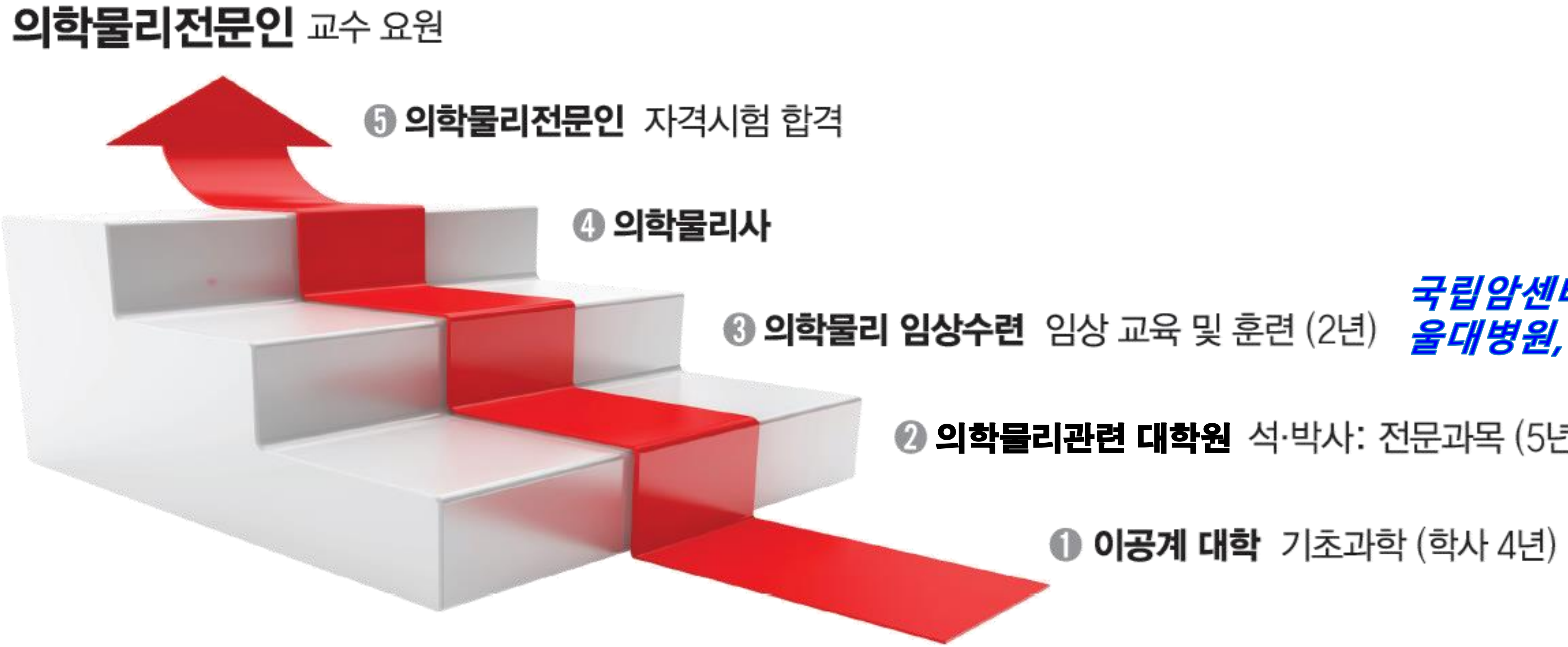


(5) 환자맞춤 정도관리



# 의학물리학자가 되는 과정

- **병원**: 방사선종양학과 의학물리학자
- **학계**: 방사선 관련 학과 교수
- **기업**: 의료기기, 방사선치료기기 회사
- **연구소**: KINS, KAERI, KRISS …



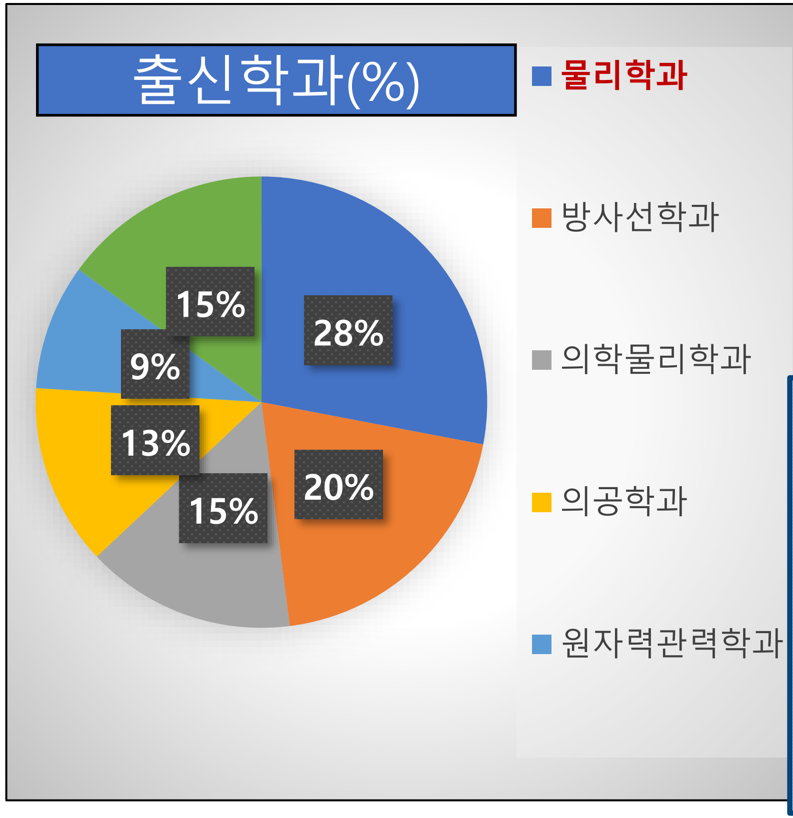

***국립암센터, 서울아산병원, 서울대병원, 세브란스병원***

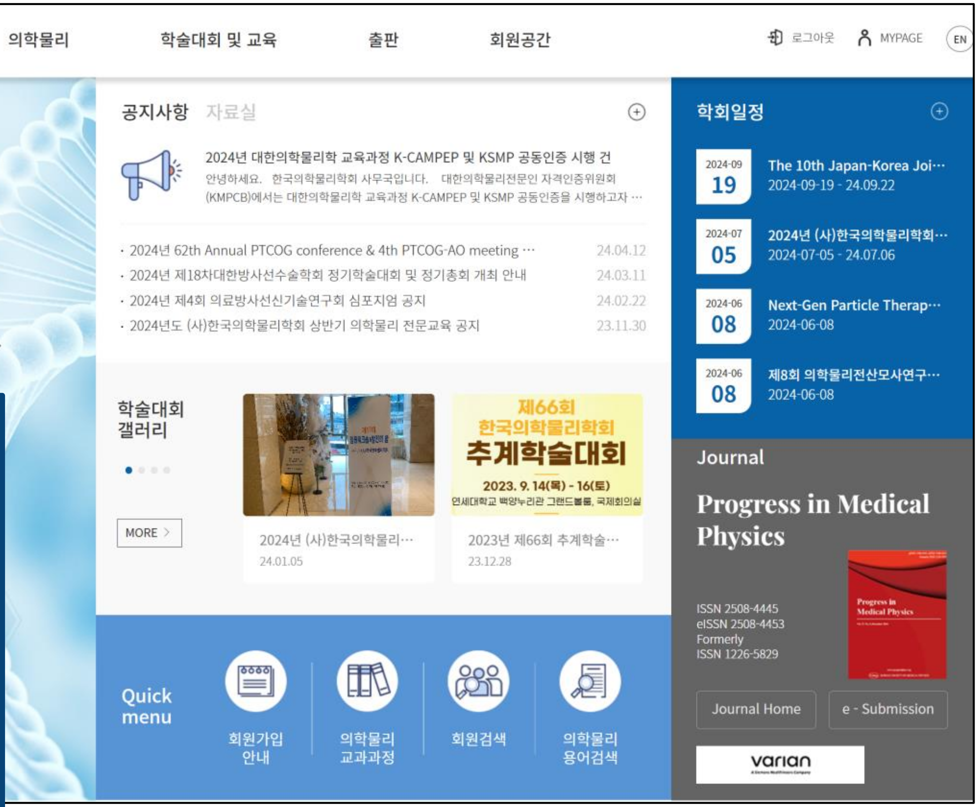
***의학물리학, 방사선학, 물리학, 원자력공학 등***

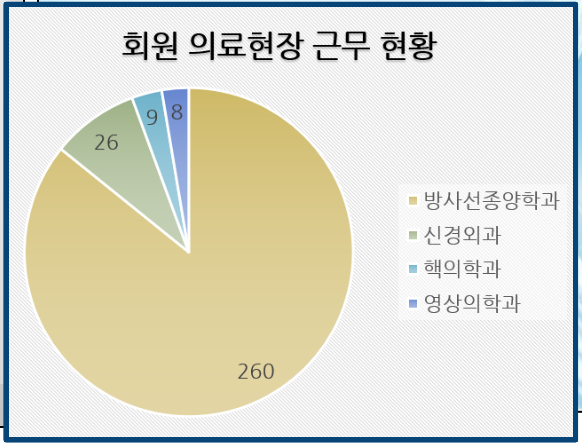
# (사)한국의학물리학회 (http://www.ksmp.or.kr/)

한국의학물리학회
Korean Society of Medical Physics

## 의학물리학회 회원수: 764명 (2024년 6월 현재)

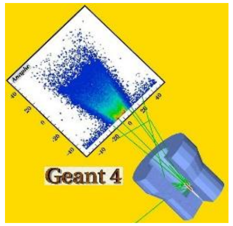


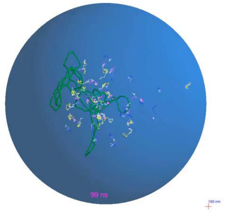



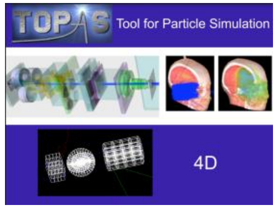



# Research Tools in Medical Physics

- **Monte Carlo Simulation (Geant4, MCNP, FLUKA, EGSnrc, etc.)**

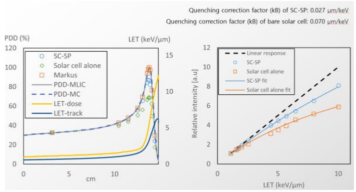


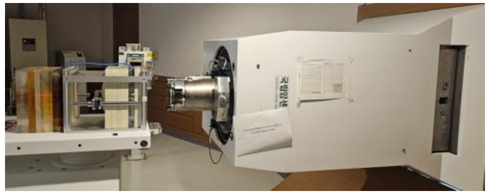



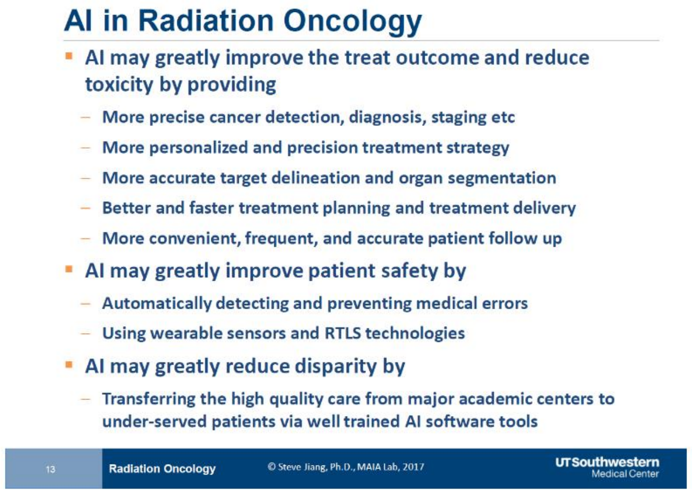



~ 45% of Adv. Example of Geant4 Toolkit is the Medical Physics Topics

- **Experiment Setup & DATA Measurement/Analysis**



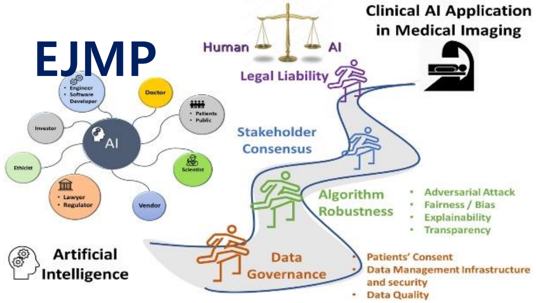


## AI in Radiation Oncology

- AI may greatly improve the treat outcome and reduce toxicity by providing
  - More precise cancer detection, diagnosis, staging etc
  - More personalized and precision treatment strategy
  - More accurate target delineation and organ segmentation
  - Better and faster treatment planning and treatment delivery
  - More convenient, frequent, and accurate patient follow up
- AI may greatly improve patient safety by
  - Automatically detecting and preventing medical errors
  - Using wearable sensors and RTLS technologies
- AI may greatly reduce disparity by
  - Transferring the high quality care from major academic centers to under-served patients via well trained AI software tools

13 Radiation Oncology © Steve Jiang, Ph.D., MAIA Lab, 2017 UTSouthwestern Medical Center

- **Artificial Intelligence(Machine Learning) & Big Data**




# Medical Physics Research Area in RT

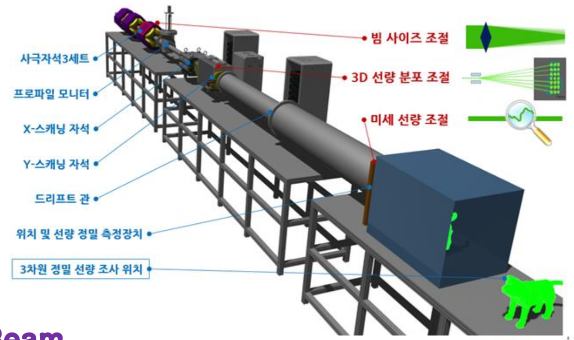
1. Treatment Device: Accelerator, Beam Nozzle (Collimator & Monitor), Gantry, Patient Setup Device, Etc.

2. Treatment Planning System: Absorbed Dose Calculation Algorithm, Human Organs & Cancer Tumor Volume Contouring(Target Region Decision), Optimal Beam Delivery Algorithm, Etc.

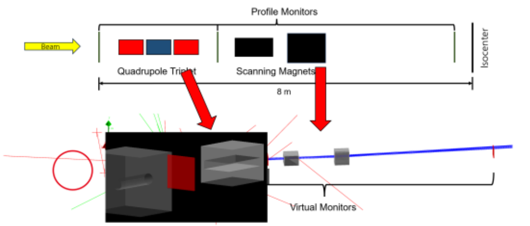
3. Monitoring and  Measurement of Treatment Dose: Beam Delivery Monitor, Treatment Beam Dose Measurement Detector, Etc.

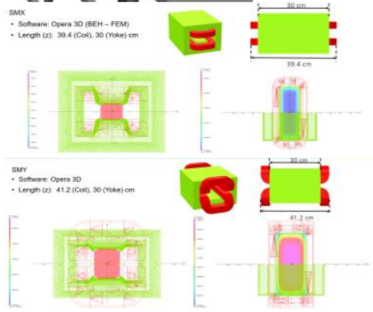
4. Radiation Safety: Secondary Particle Measurement, Radiation Shielding Evaluation & Design, Radioactive Waste produced by treatment beam, Etc.

# 1. Treatment Device

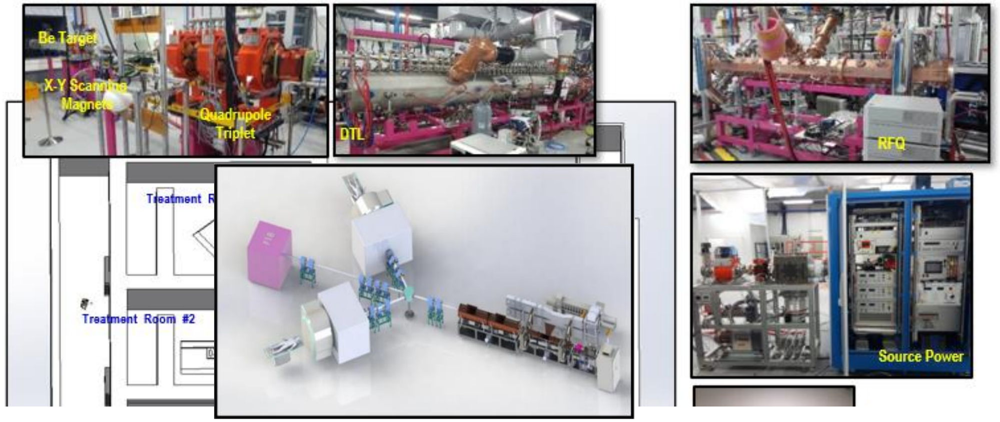



**Flash Proton Beam Nozzle Design**

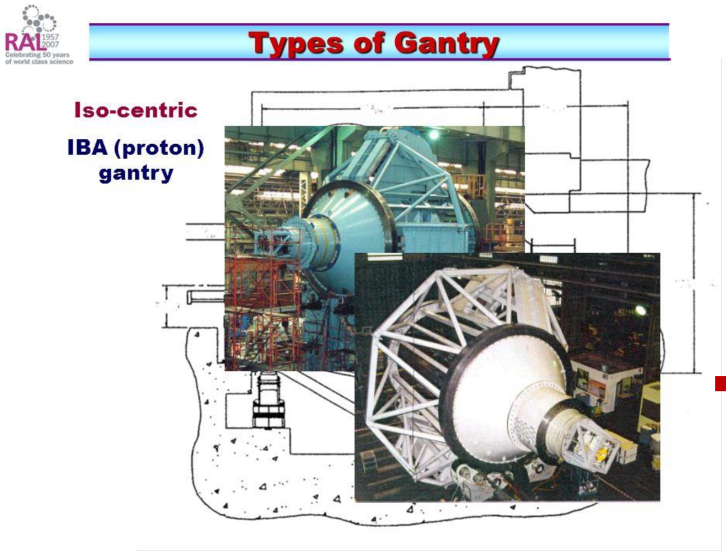


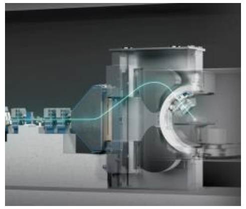




**BNCT System Develpoment**



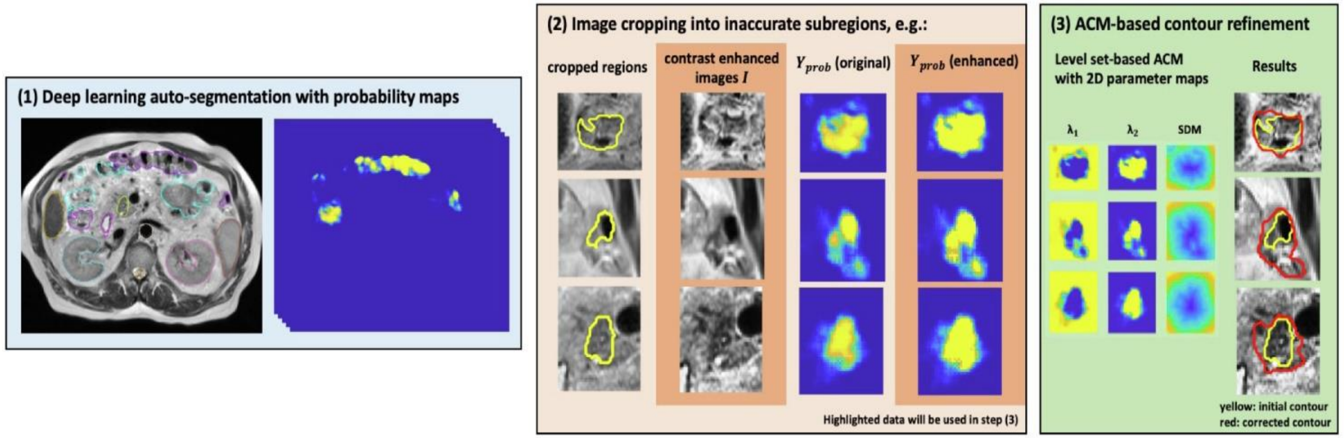

**Compact Accelerator**

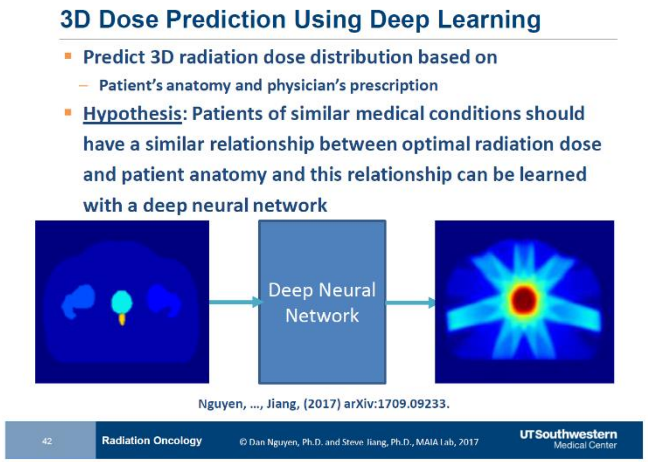


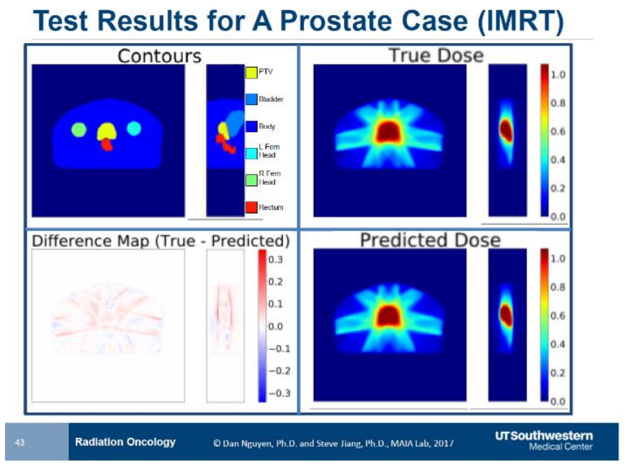



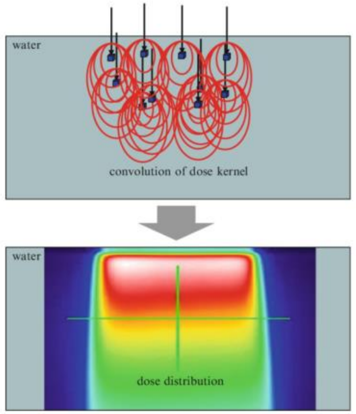
**Compact Gantry**

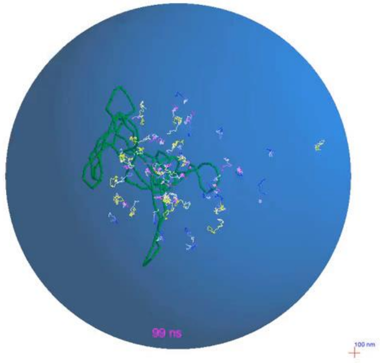
# 2. Treatment Planning System

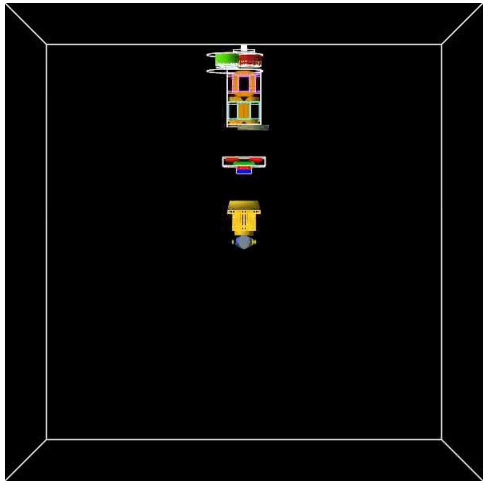


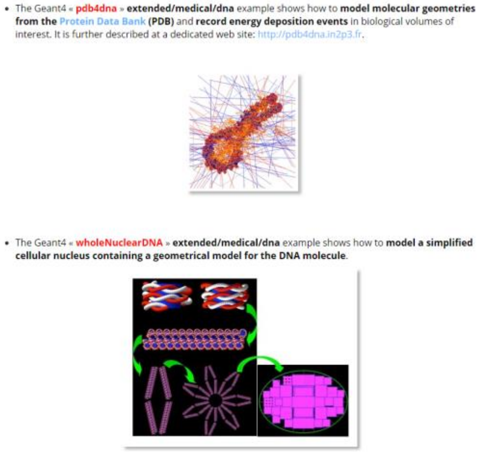



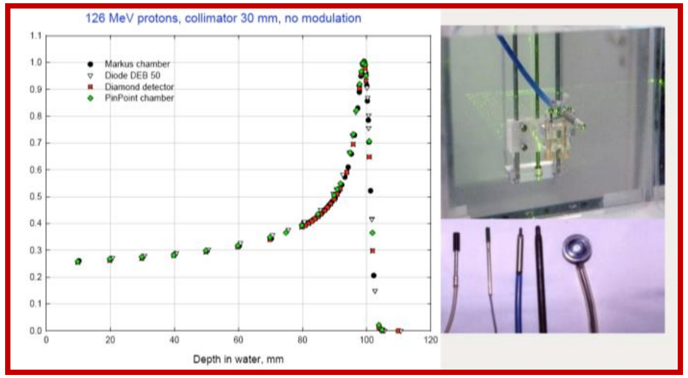



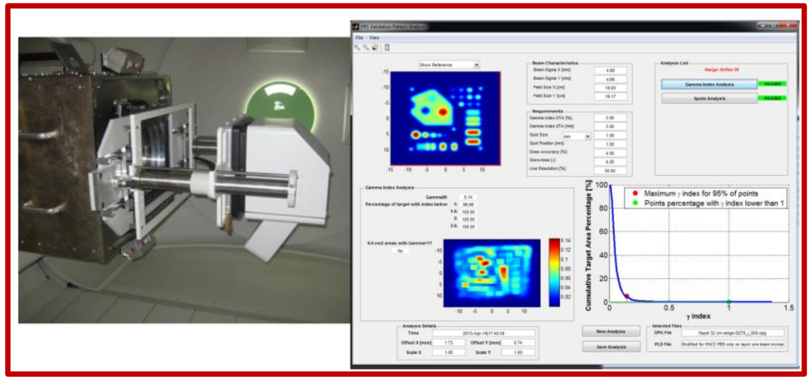



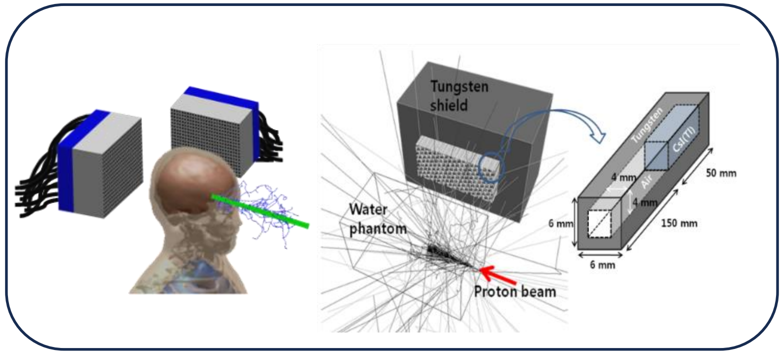


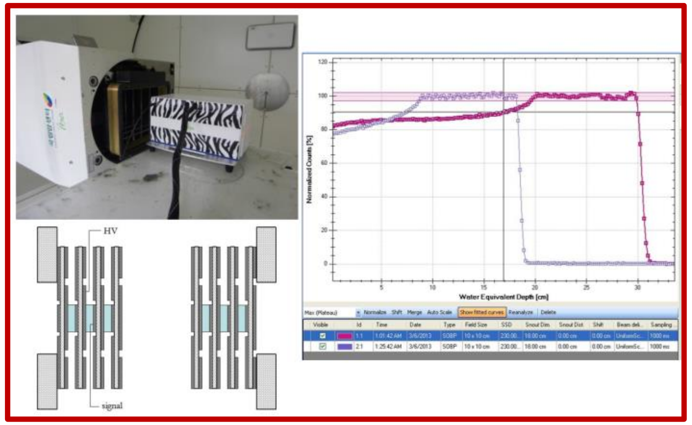


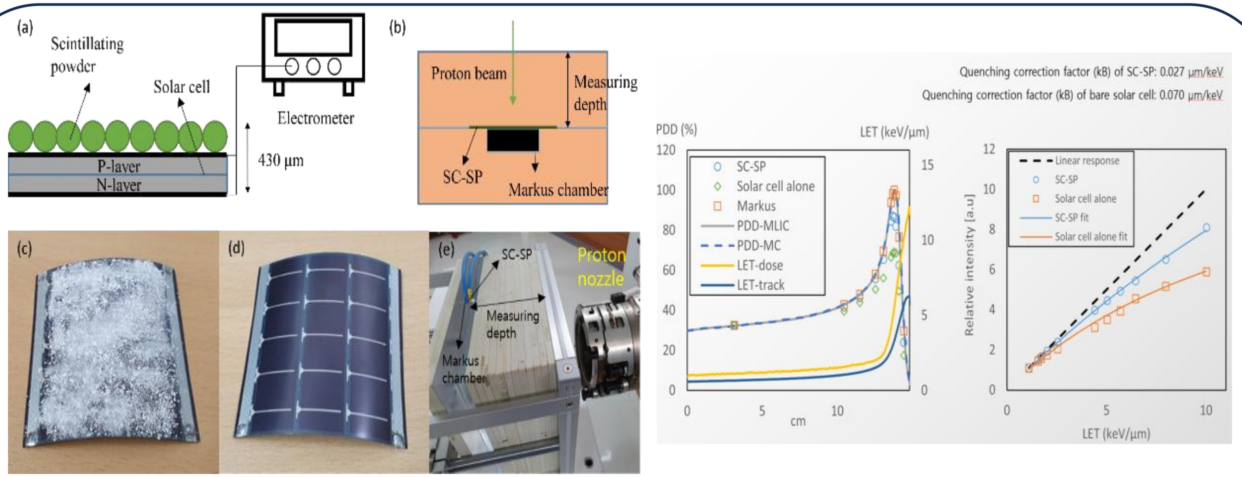
# 3. Monitoring and  Measurement of Treatment Dose



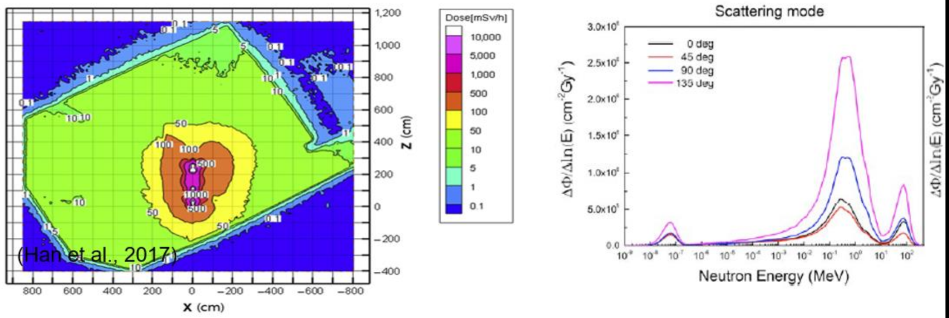





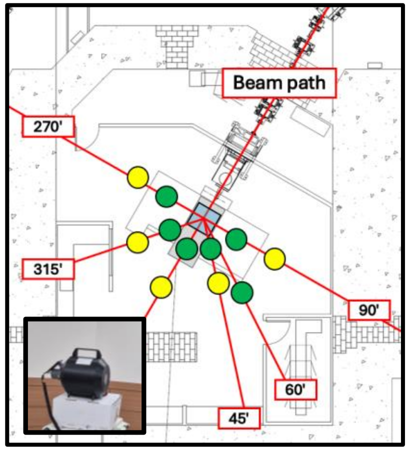



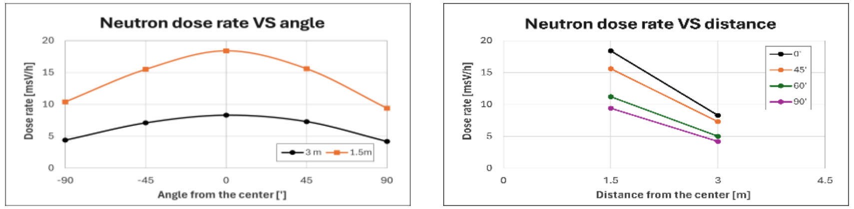



# 4. Radiation Safety

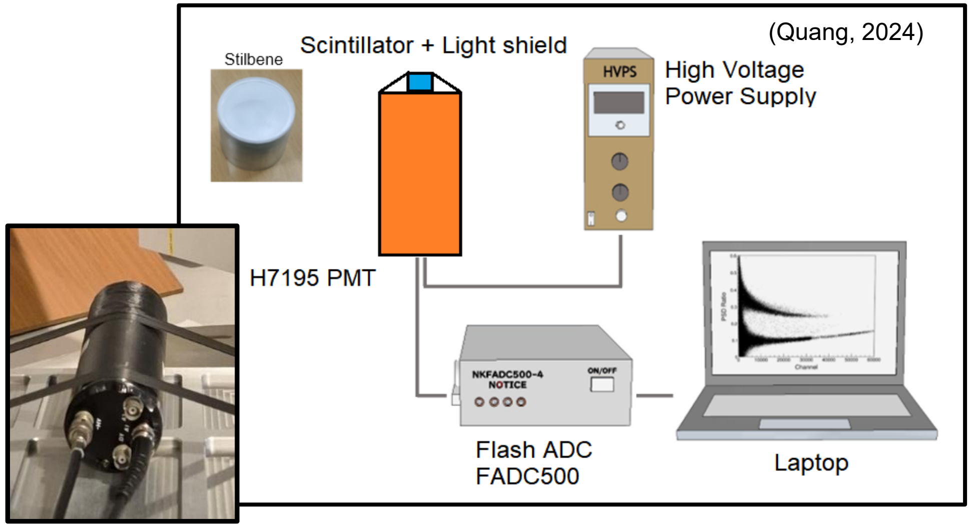


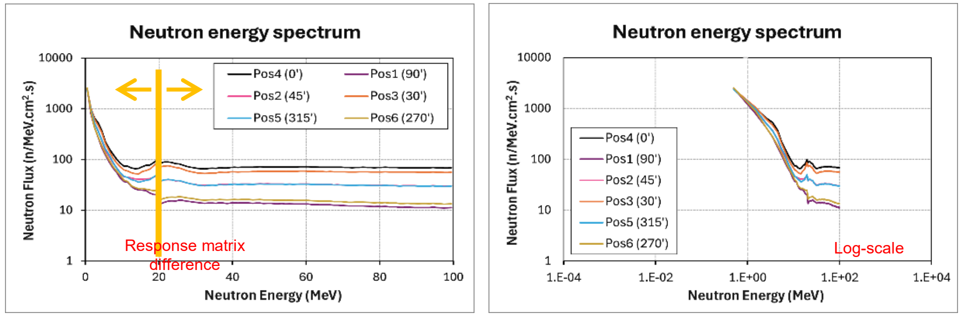

<Neutron dose distribution and neutron spectrum in CONV proton therapy treatment room>




<Neutron dose rate variation with angle and distance from beam center>




<Neutron energy spectrum at various position (pos1 to 6) original (left) log-scale (right)>

# Summary

- The knowledge backgrounds for Radiation Therapy Research are Physics, Biology, and Radiation Oncology.
- Artificial Intelligence technology become one of the necessary elements in medical physics research and medical physicists' roles.
- Experimental Nuclear Physics, Experimental Particle Physics, and Biophysics are pure physics fields close to medical physics.
- To do good research and produce practical results in medical physics, one must understand the medical doctor's needs and clinical procedures.