

양성자치료기의 방사선 특성 및 현안 (국립암센터)

책임의학물리학자

이 세 병

대형가속기시설의 방사선안전관리 협의회 발족 및 현안발표 Workshop
2017. 10. 25(수), 경주현대호텔

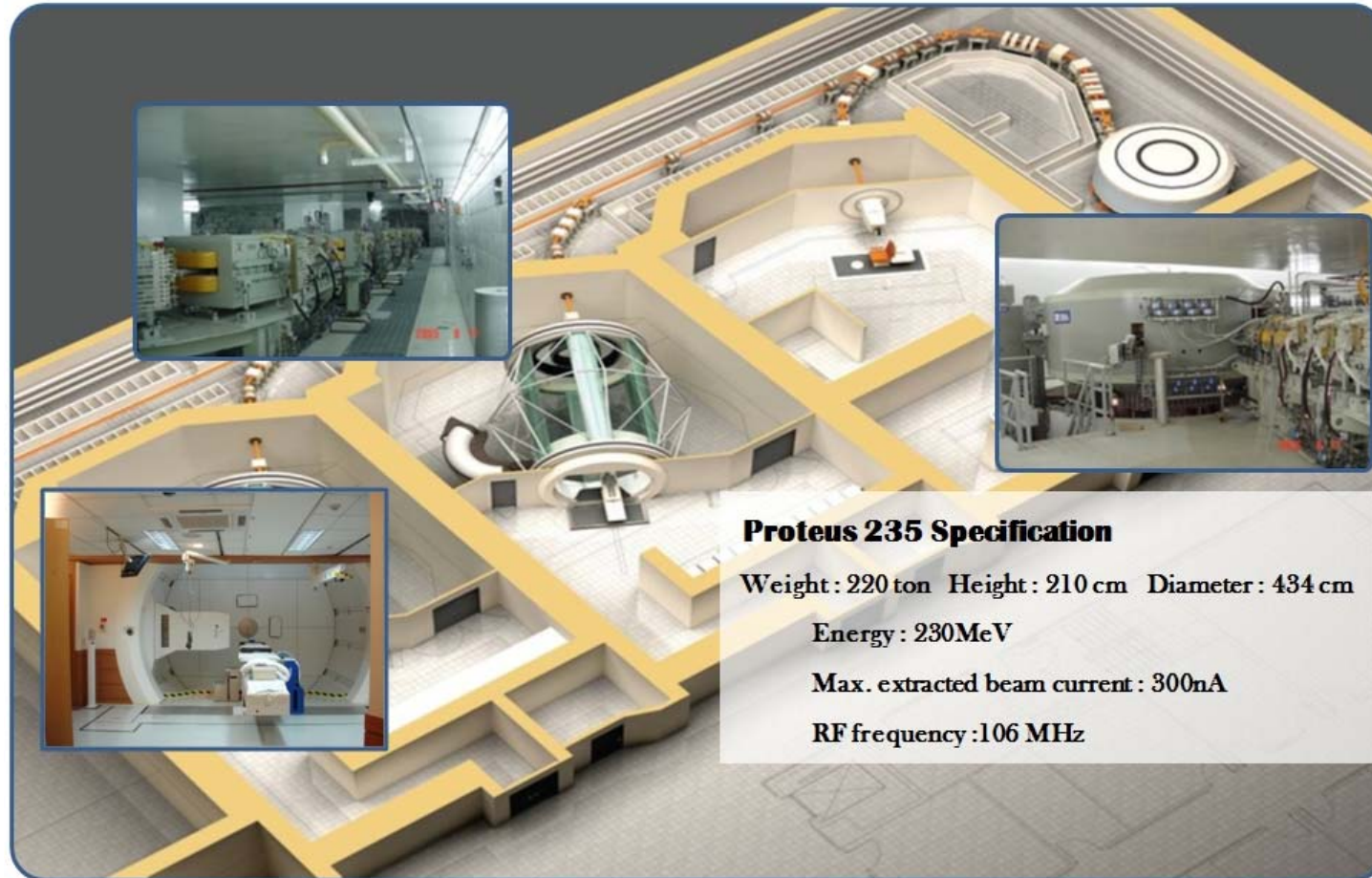


Proton Therapy Facility in NCC, Korea

- | | |
|-----------------------------|--|
| 2005. 02. 15 | IBA Proteus 235 installation start |
| 2005. 10. 21 | First Beam Production |
| 2005. 09.~ 2006. 12. | Beam line tuning & Passive mode beam calibration & Acceptance test (1 Fixed Beam & 2 Gantry Tx. Rooms) |
| 2007. 01.~ 2007. 03. | GTR2 Beam data taking & Commissioning |
| 2007. 03. 19. | First Proton Treatment Start (Double Scattering) |
| 2010. 08. 27. | Wobbling Beam Treatment Start |
| 2015. 09. 22. | PBS Treatment Start |
| 2017. 06. 30 | Over 2250 patients treated in Proton Therapy Facility |

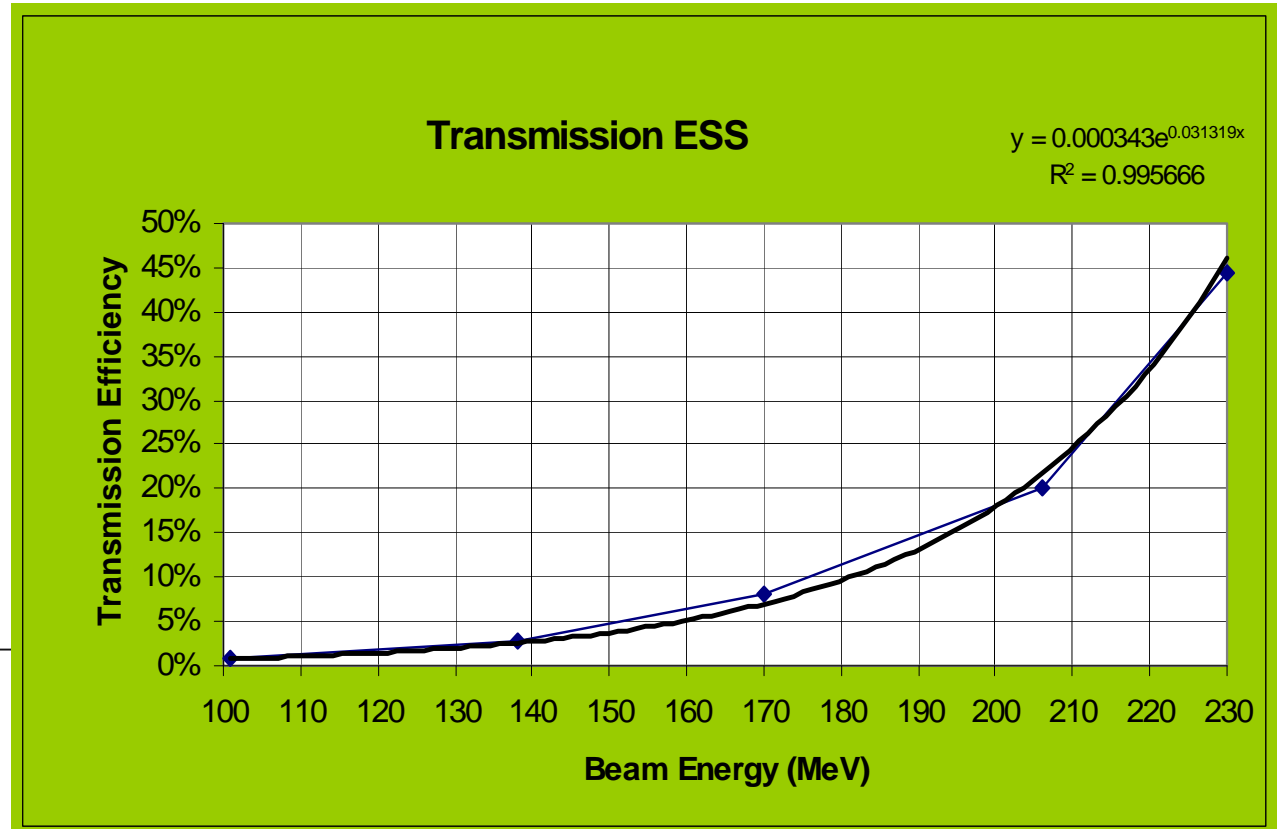
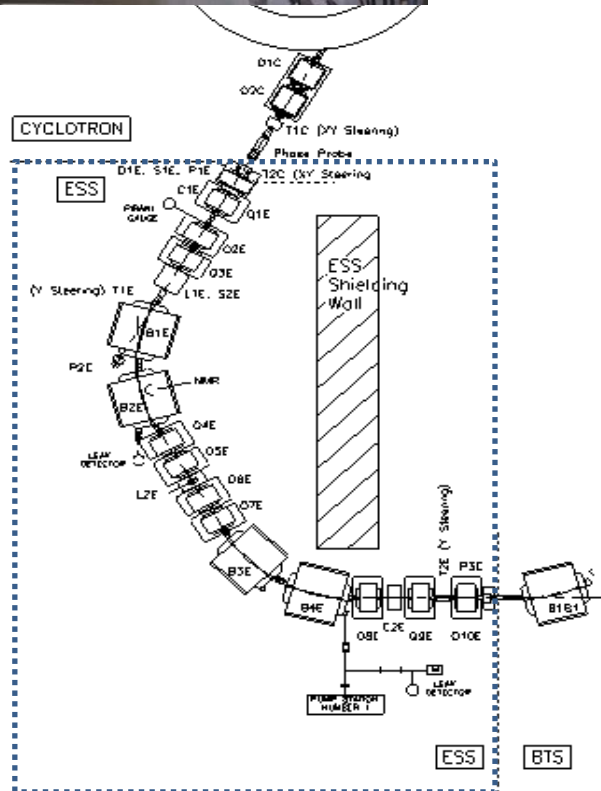


Proton therapy Facility





Transmission efficiency ESS



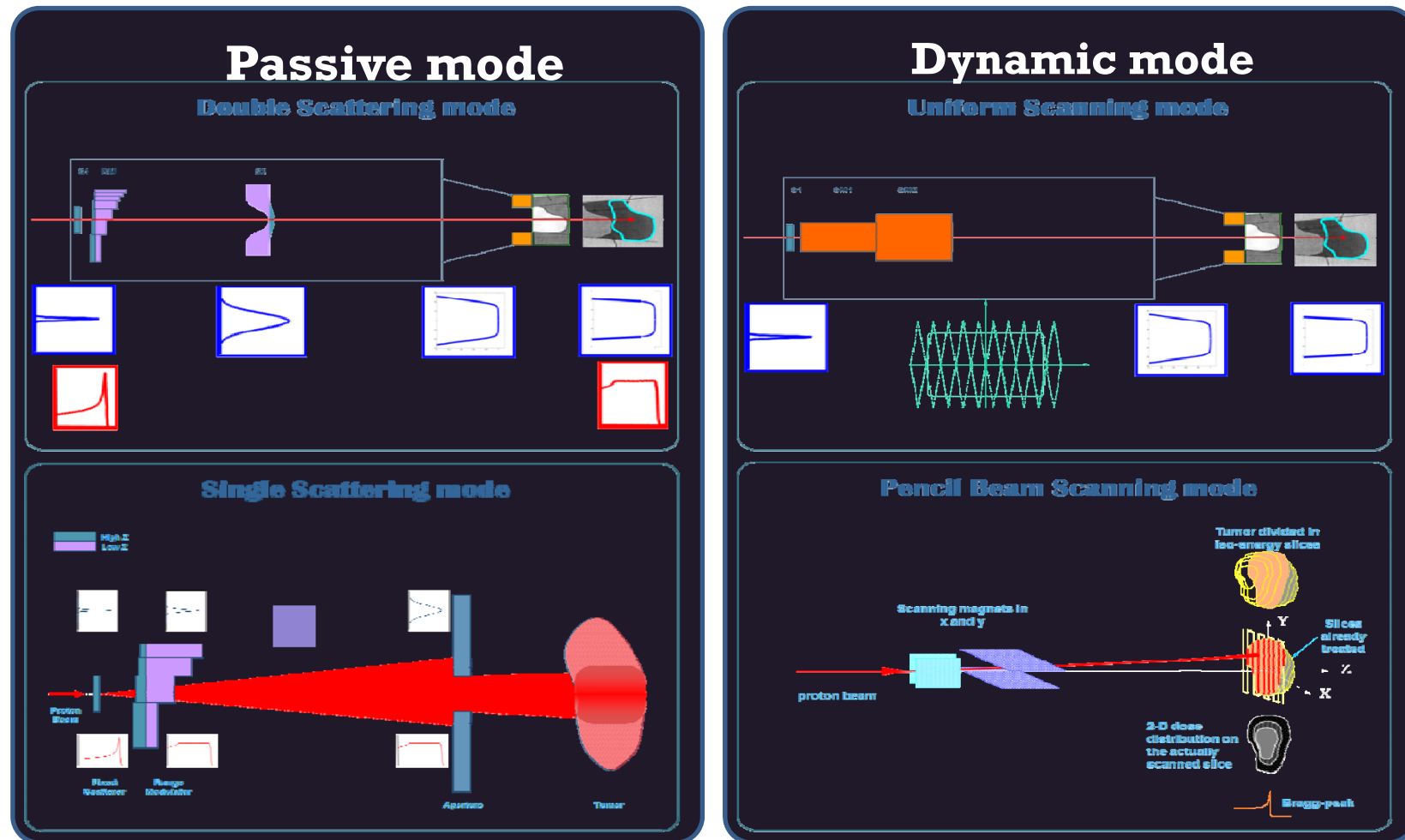
Max Beam current in treatment room = 300 nA x Transmission ESS

* transmission ESS to treatment room = ~100%

* 300 nA = 4.8×10^{12} protons/sec.

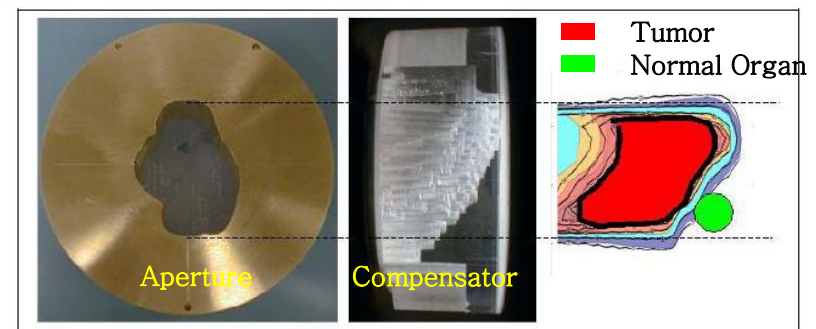
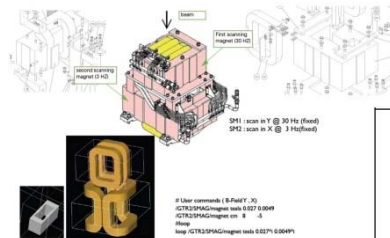
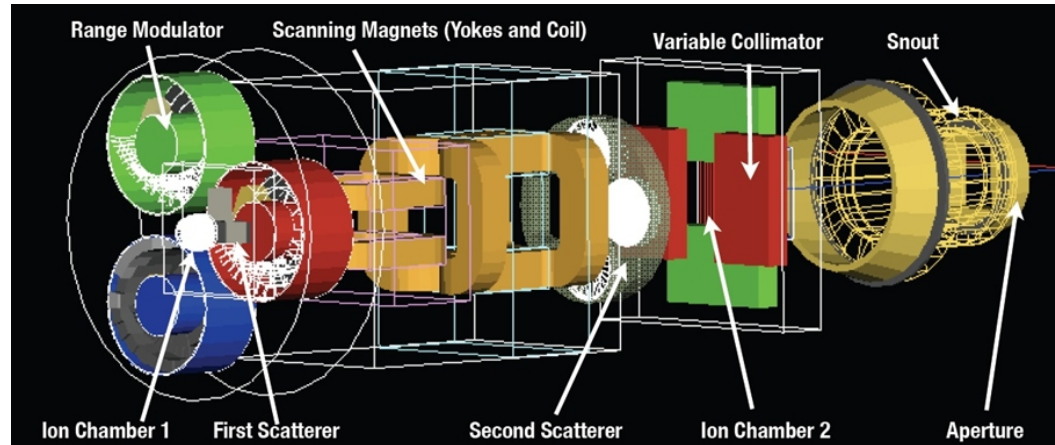
Proton Beam Nozzle

Proton Beam Delivery Modes

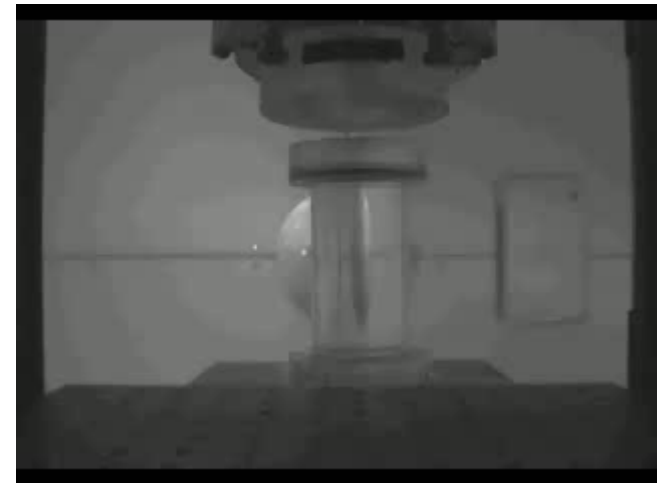
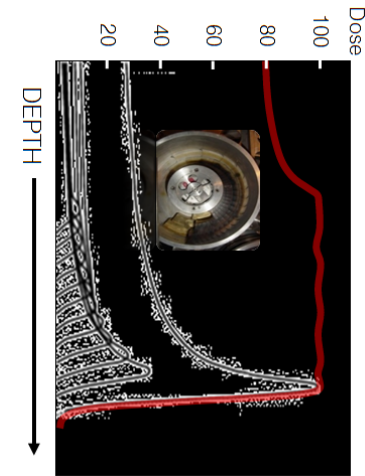
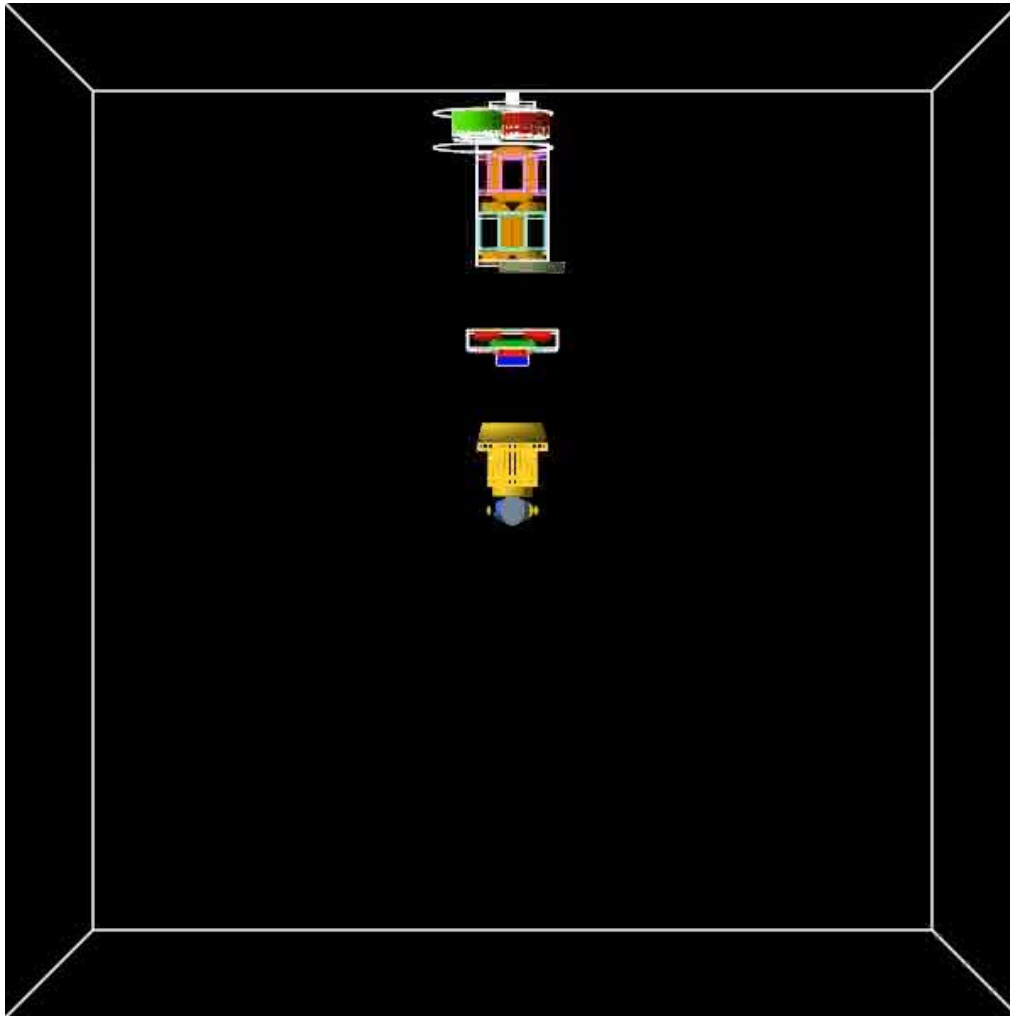


Beam Nozzle System

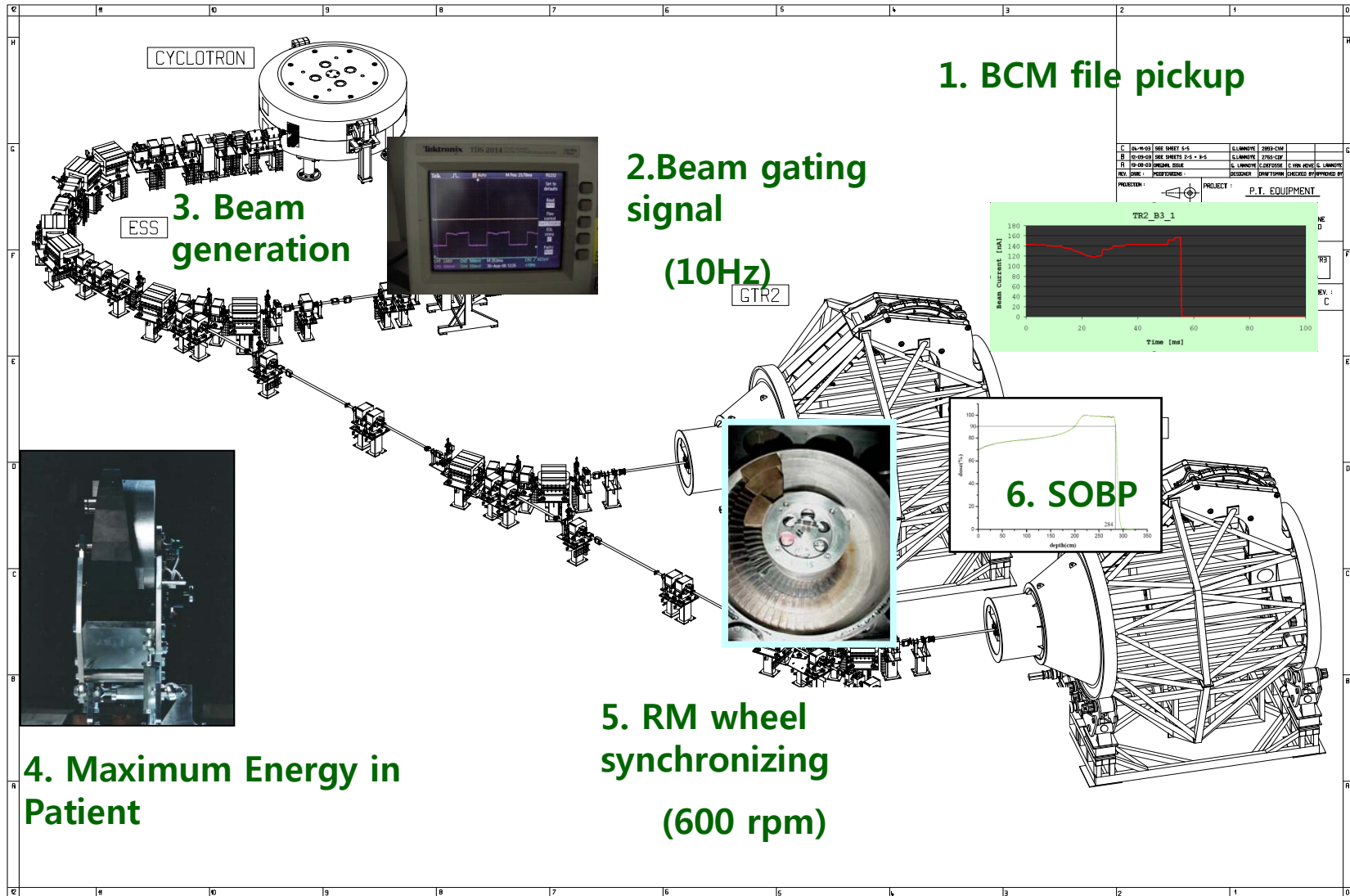
(IBA universal nozzle)



Example of Proton Beam Irradiation



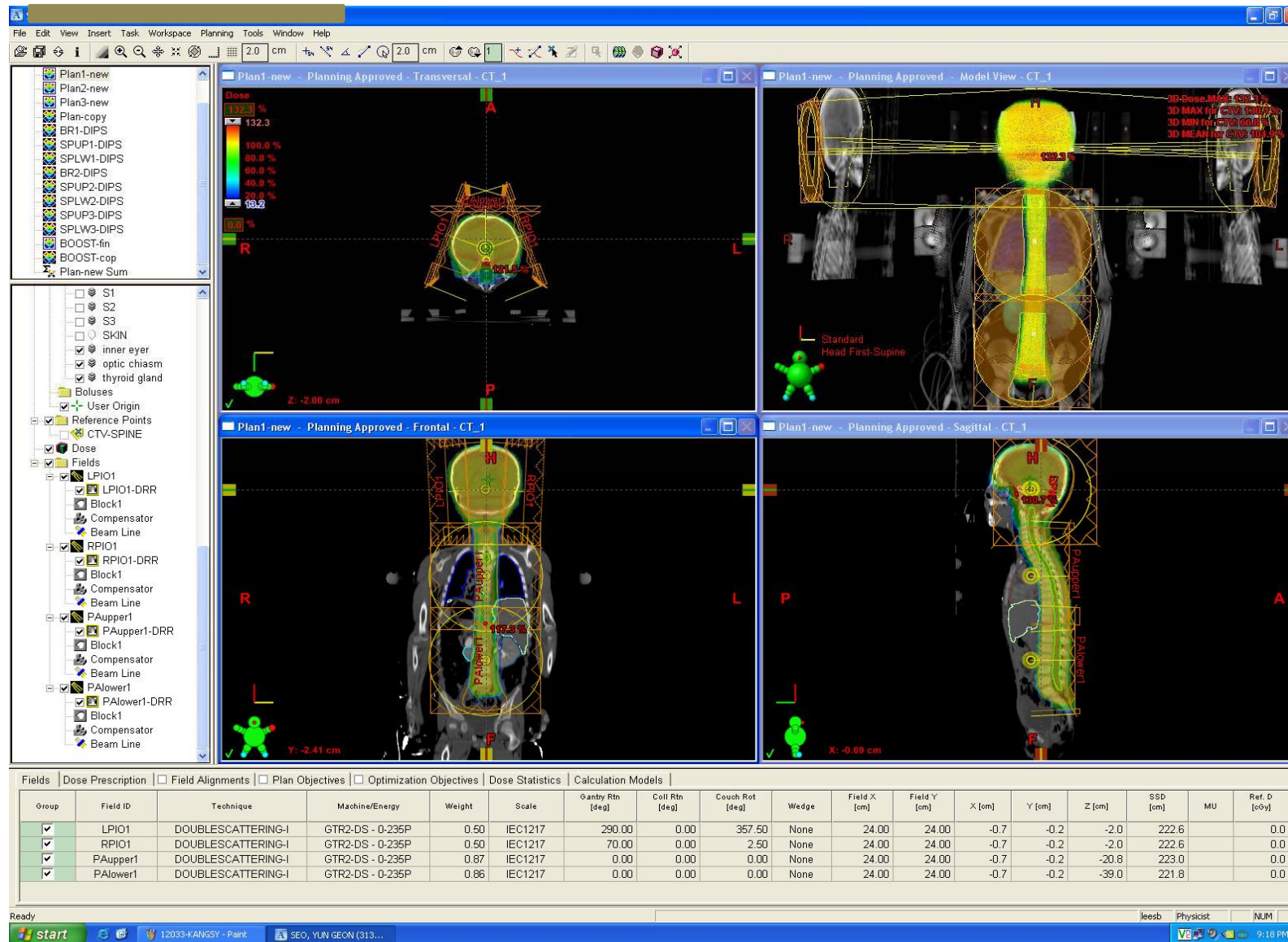
SOBP on Passive mode



Specifications of Modulated Proton Beam

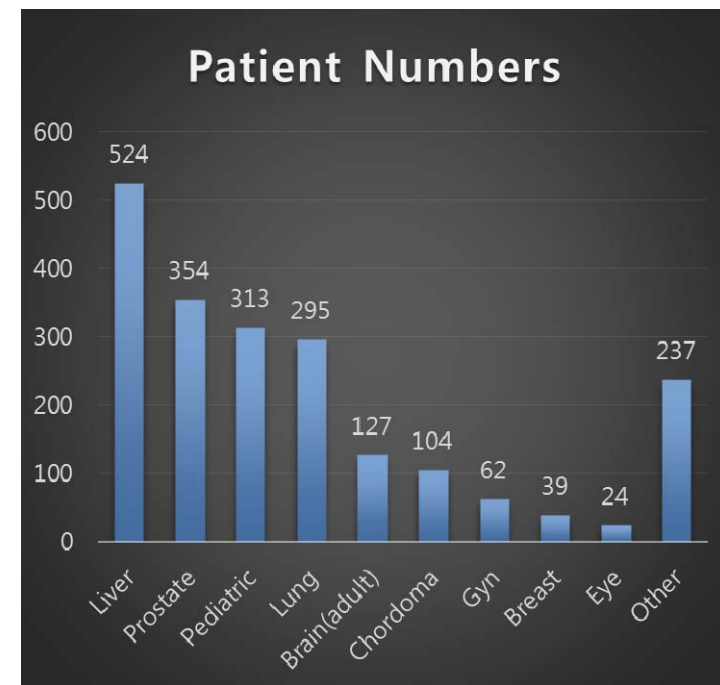
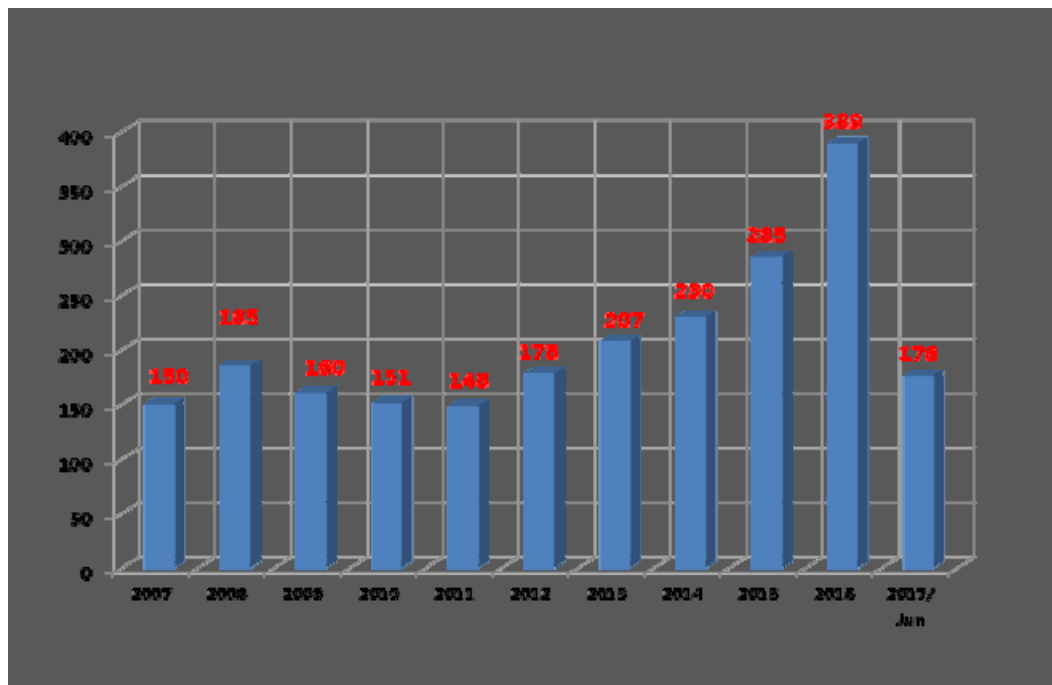
Item	Singles Scattering	Double Scattering	Uniform Scanning	Pencil Beam Scanning
Range in Patient (g/cm ²)	3.35–20.4	4.51–28.42	3.42–32.1	7.5–32
Range mod. Adjustment, max. modulation (g/cm ²)	0.4(R>6), 0.17 9.2	0.2 20.75	0.5 Full	0.4 24
Range adjustment(g/cm ²)	0.09(R>6),0.05	0.1	0.1	0.4
Ave. dose rate (Gy/min)	5.93	3	1.15	–
Max. Field Size (cm)	4 (D)	24.3 (D)	40X30	22.5X22.5 At 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)	0.17	0.48	0.30(y), 0.22(x)	4.9mm@R32cm 10.4mm@R8cm
	H&N, RS	General	Large Size	IMPT

Example of Patient Treatment

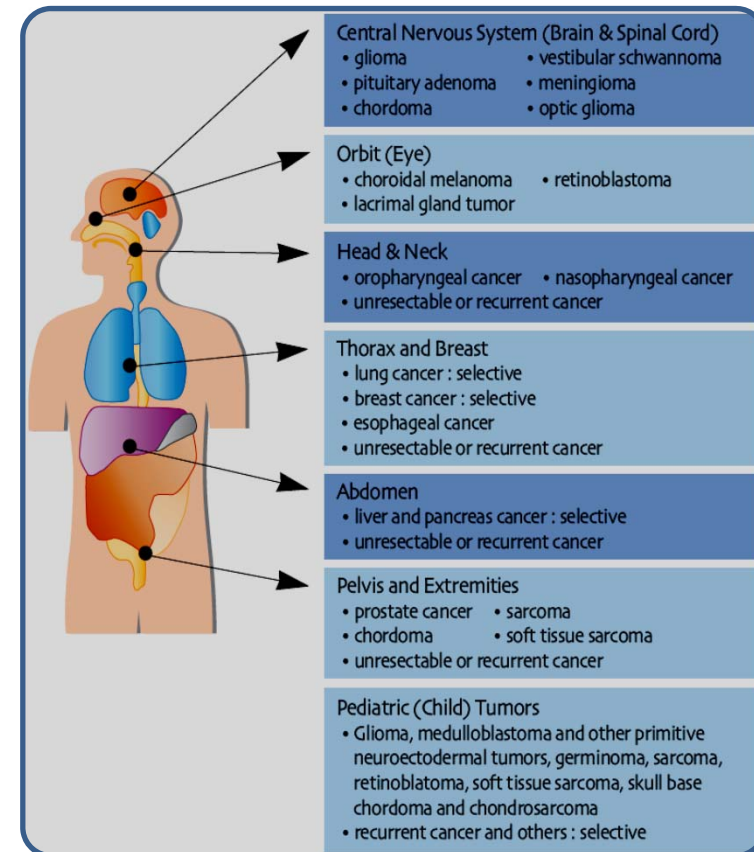
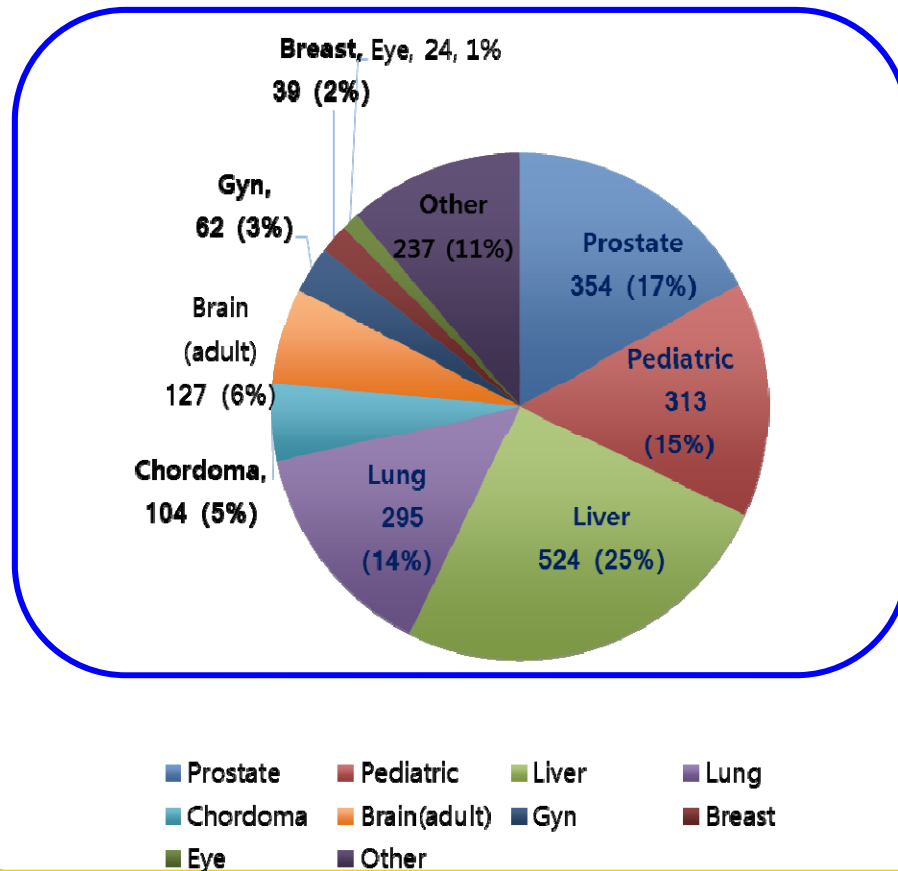


Number of Patients treated in KNCC

(2007. 3 ~ 2016. 12 / 2,079명)



Treatment sites with proton therapy at NCC



Proton Therapy Facility Running Schedule

time	Mon	Tue	Wed	Thu	Fri	Sat	Sun
6	Morning QA work for daily Patient Treatment					Machine QA & PM	Reserved for Research & PM
7							
8	Patient Treatment						
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21	Patient QA & PM	Patient QA & PM	Patient QA & PM	Patient QA & PM	Patient QA & PM		
22							
23							
24							

Maintenance Team

- **Biomedical Engineers : 8 man/year**

- 1 RF & PT system Engineer
- 1.5 Electronics Engineer
- 1.5 Mechanics Engineer
- 1 Software Engineer
- 3 Cyclotron OP

- **Medical Physicist**

- 1 Beam Calibration & Dosimetry support

- **IBA On-site Engineer**

- 1 General technical support

**** Preventive Maintenance : 320 items per day, week, month, year**

가속기 운영 통계



Proteus 235 Specification

Weight : 220 ton Height : 210 cm Diameter : 434 cm

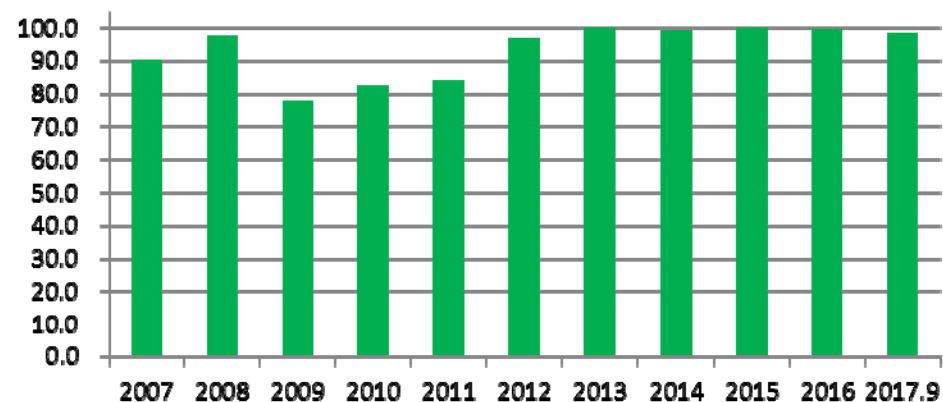
Energy : 230MeV

Max. extracted beam current : 300nA

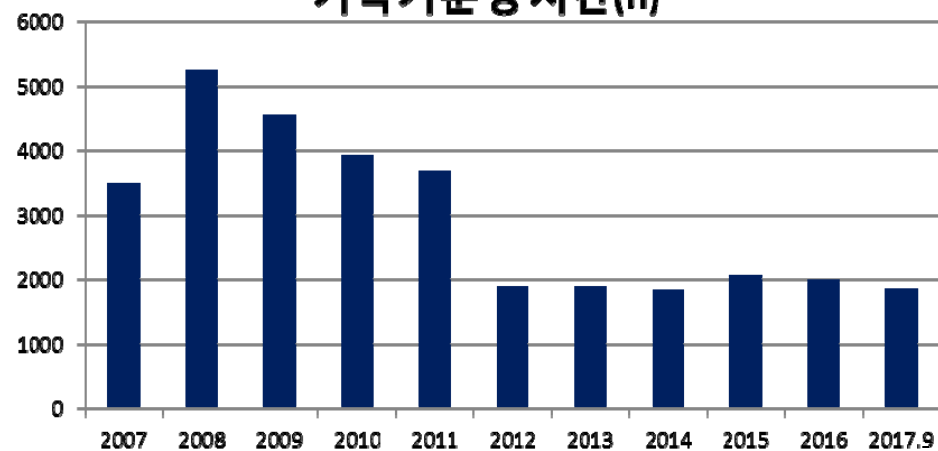
RF frequency : 106 MHz

총 운영시간 32,429h
(2007.1 ~ 2017.9)

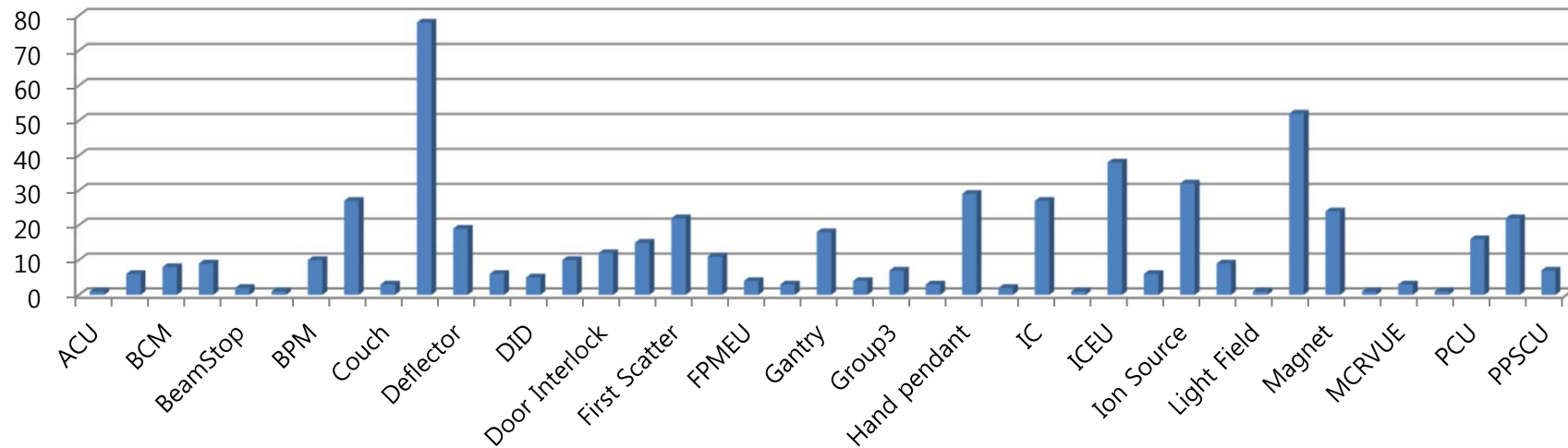
가속기 가동율(%)



가속기 운영 시간(h)



Example of Statistics of trouble parts (2007. 03 – 2010. 05)



방사선 안전 관련 사항

1. 양성자시설의 방사선 차폐 및 안전장치 설계

- 장비 제조사가 표준설계 제시
- 차폐대상 빔의 종류(중성자) 및 조사량 고려
- 차폐적인 차폐계산 및 검증 필요.
- FMEA를 통한 시설의 안전장치 구비

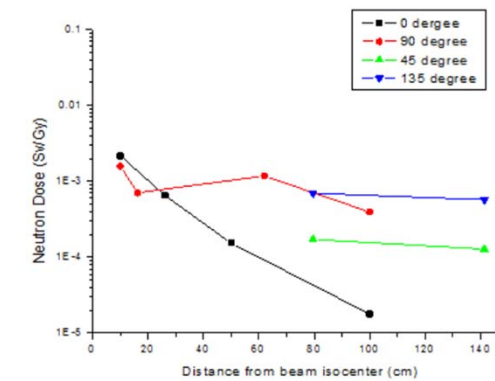
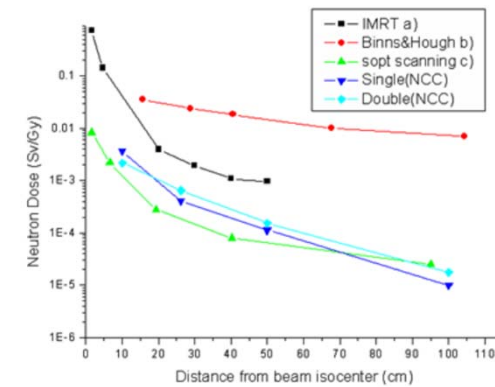
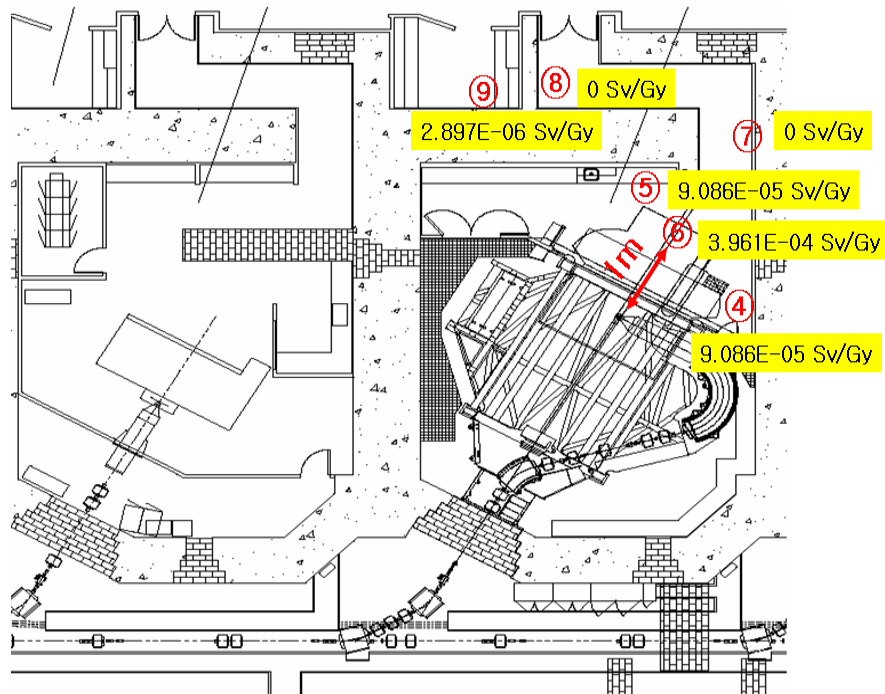
2. 방사선 관리구역의 인원 통제 및 관리

- 방사선 작업자 관리(기술자, 방사선사, 의학물리학자, 의사 등)
- 일반인의 통제(환자 보호자, 방문자 및 일반 작업자)
- 환자의 치료외적 방사선 노출관리(정상장기의 노출 제한)

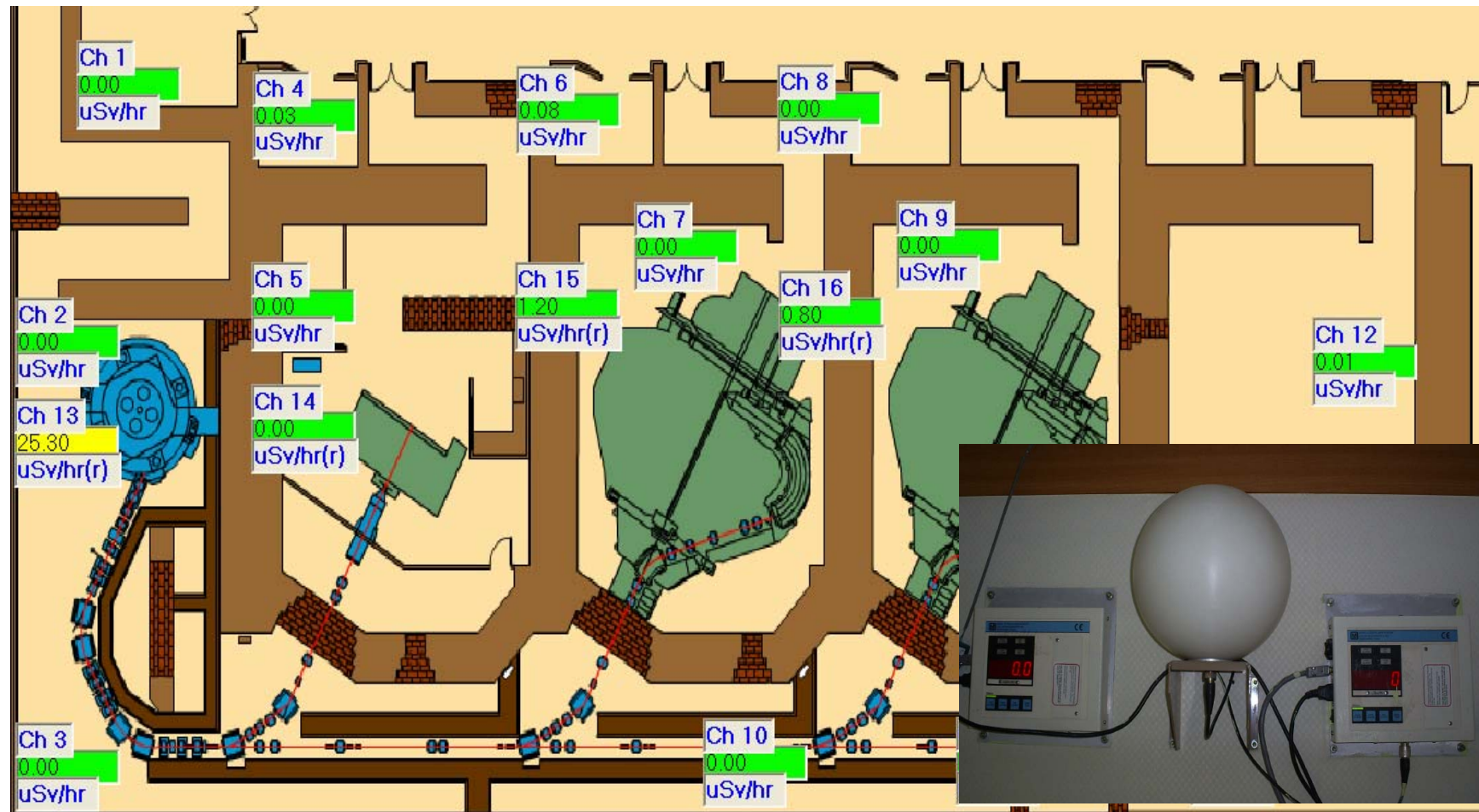
3. 양성자 빔에 의해 발생한 방사성 폐기물의 관리

- 가속기 장치 및 시설의 방사화(냉각수 및 공기 포함)
- 개별 환자치료에 필요한 장치들의 방사화

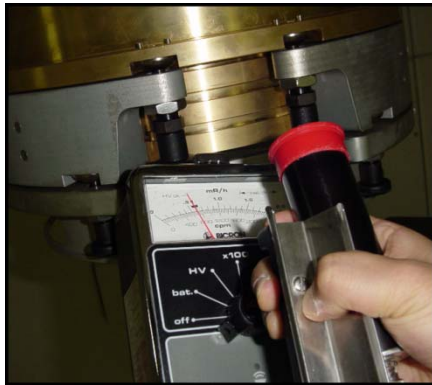
치료실의 선량분포



Radiation level monitor & area detector



양성자 치료 환자용 블록 예



일반적인 폐기물에 대한 정의를 살펴볼 때,

1. 개인에 대해 10mSv/year (1.25×10^{-2} mR/h) 이상 나오거나,
2. 과기부장관이 정하는 핵종별 농도 이상일 때

이 두 가지 조건을 모두 만족해야 폐기물로 정의합니다. 이 조건에 block의 값들이 해당되지 않는다면 폐기물에 들어가지 않는다고 할 수 있음.

한국원자력연구원

우305-353 대전광역시 유성구 대덕대로 1045
(Tel: 042 868 2443-2444, Fax: 042 868 4506)

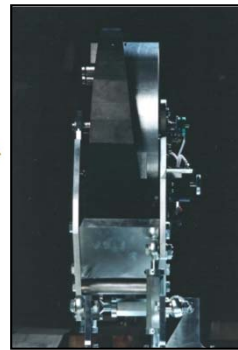
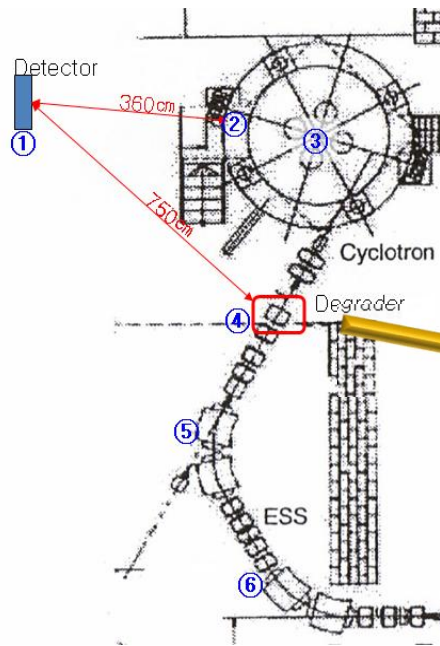
성적서 번호 :
CT-CA-14-0317

페이지 (2) / (총 2)

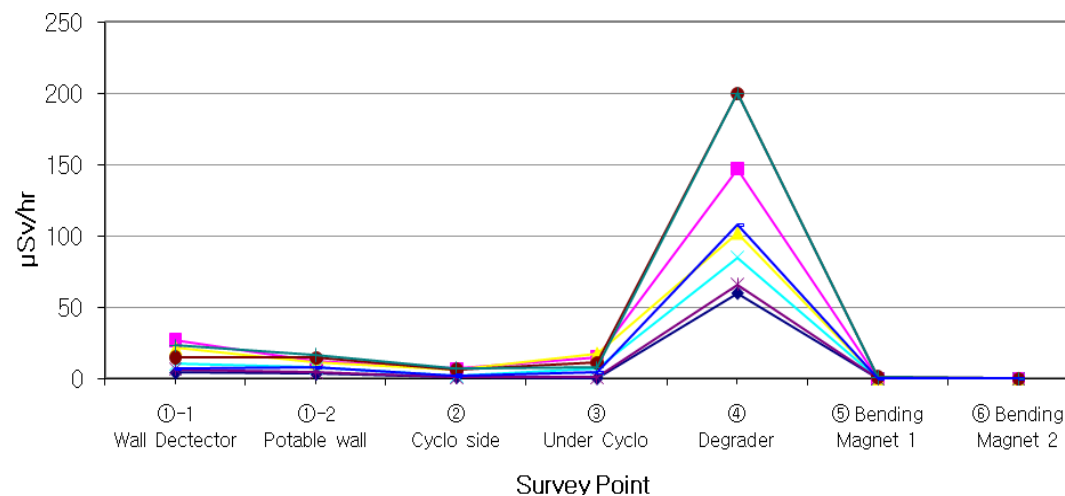
I. X선 핵종 분석결과

시 료 명	방 사 능		계 측 일
	핵 종	측정값(Bq/g) ± 불확도*	
조사된 황동	Mn-54	1.89E-01 ± 2.77E-02	2014-12-16
	Co-56	5.17E-01 ± 4.41E-02	
	Co-57	8.56E-01 ± 2.12E-02	
	Co-58	5.09E+00 ± 7.00E-02	
	Fe-59	4.63E-01 ± 4.19E-02	
	Zn-65	4.32E+00 ± 1.06E-01	
조사된 구리	Mn-54	< 6.34E-01	2014-12-19
	Co-56	< 6.57E-01	
	Co-57	3.16E+00 ± 5.53E-01	
	Co-58	1.62E+01 ± 1.44E+00	
	Fe-59	< 3.50E+00	
	Zn-65	< 1.93E+00	

Radiation level after beam stop



Emergency Maintenance work

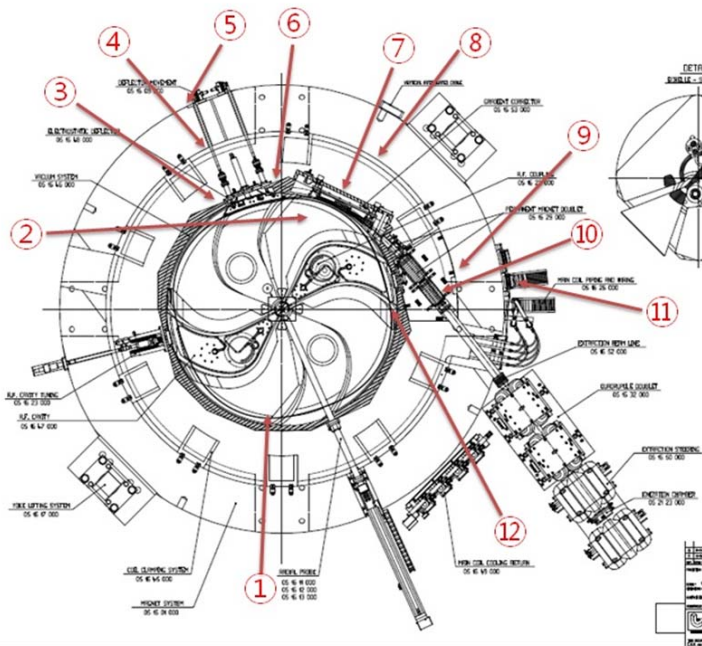


A level of radiation around cyclotron and energy selection system area through random measurements after accelerator operation.

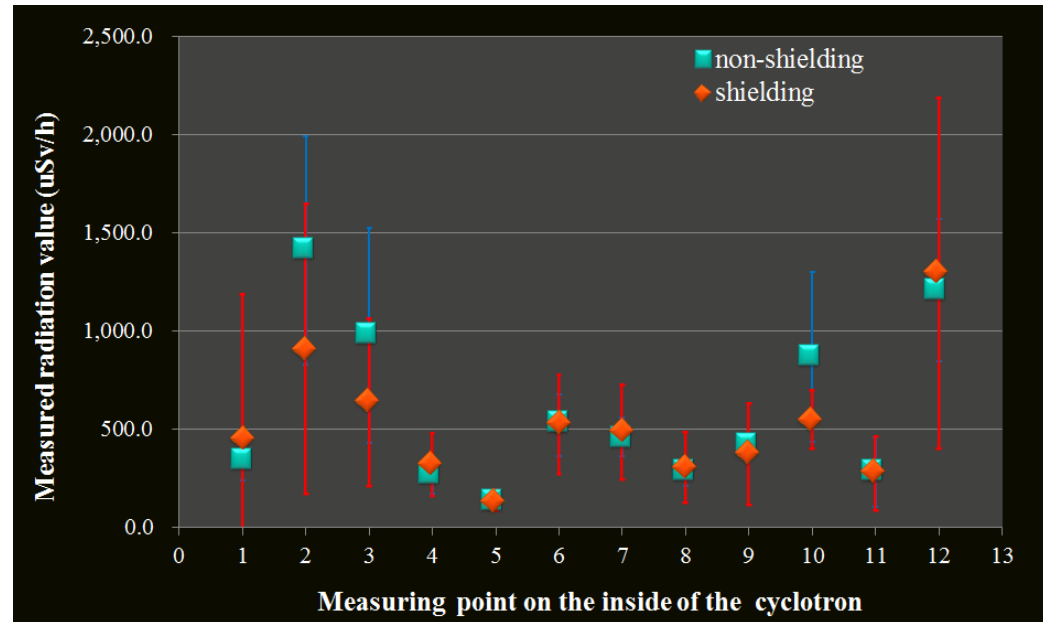
Radiation Exposure statistics for workers

Category	Exposure Dose in 2009
Therapists	< 1 mSv
Medical Physicists	< 1 mSv
MCR Operators	0.7 ~ 2.5 mSv
Maintenance Engineers	4.5 ~ 7.0 mSv

Radiation Activity Distribution during Cyclotron PM

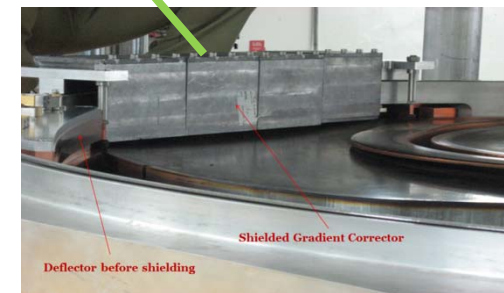
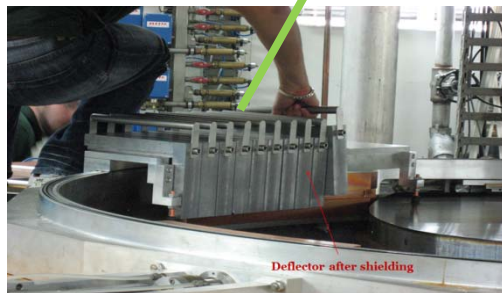
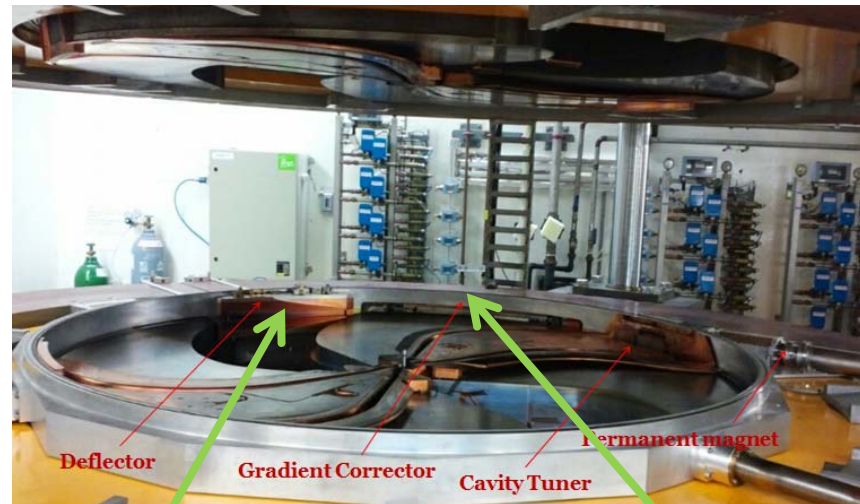


No.	Description	No.	Description
1	Opposite side of deflector	7	Rear end of gradient corrector
2	Front of Gradient corrector	8	Boundary of main coil back Gradient corrector
3	Right rear end of deflector	9	Boundary of main coil back permanent magnet
4	Boundary of main coil back deflector	10	Permanent magnet
5	Boundary of yoke back deflector	11	Boundary of yoke near permanent magnet
6	Left rear end of deflector	12	Front of fixed cavity tuner



- 2014. 4~ 2017. 4 까지 6회 측정
- 빔 생산 중단 후 하루 뒤 개봉, 차폐체 설치 전후에 방사능 세기 측정 (survey meter: 450B-DE-SI, VICTOREEN & FH40 G-10, THERMO)
- 12개의 부분을 지정 모니터 및 차폐체 설치

Example of Hot Points on Cyclotron & Shielding Caps



Thank you for your attention!

