Commissioning a Proton Therapy Machine and TPS

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McLaren Cancer Institute

McLaren - Flint

2012 GLC Fall Meeting, 2012.11.09

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- Overview of Proton Beam Therapy
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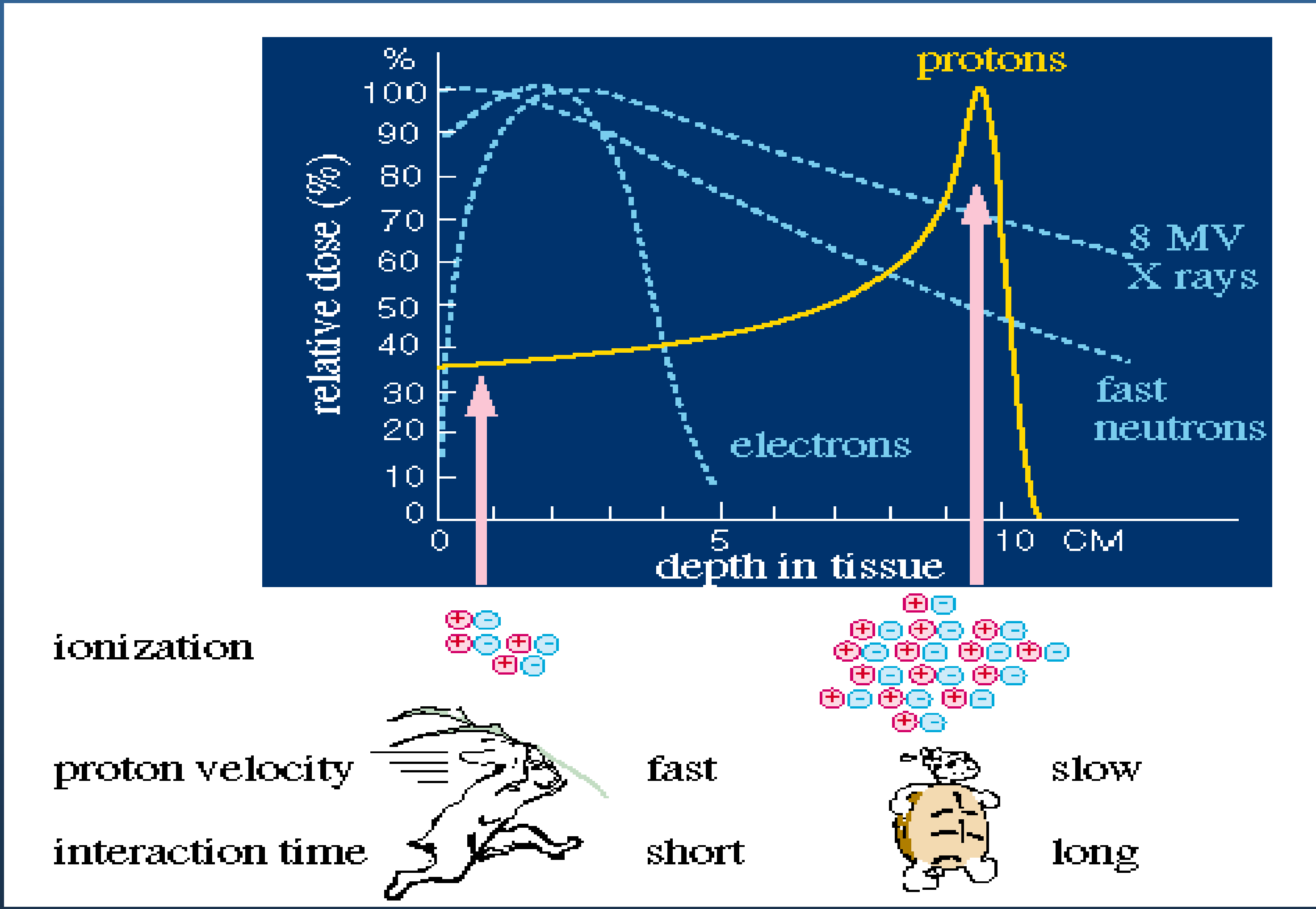
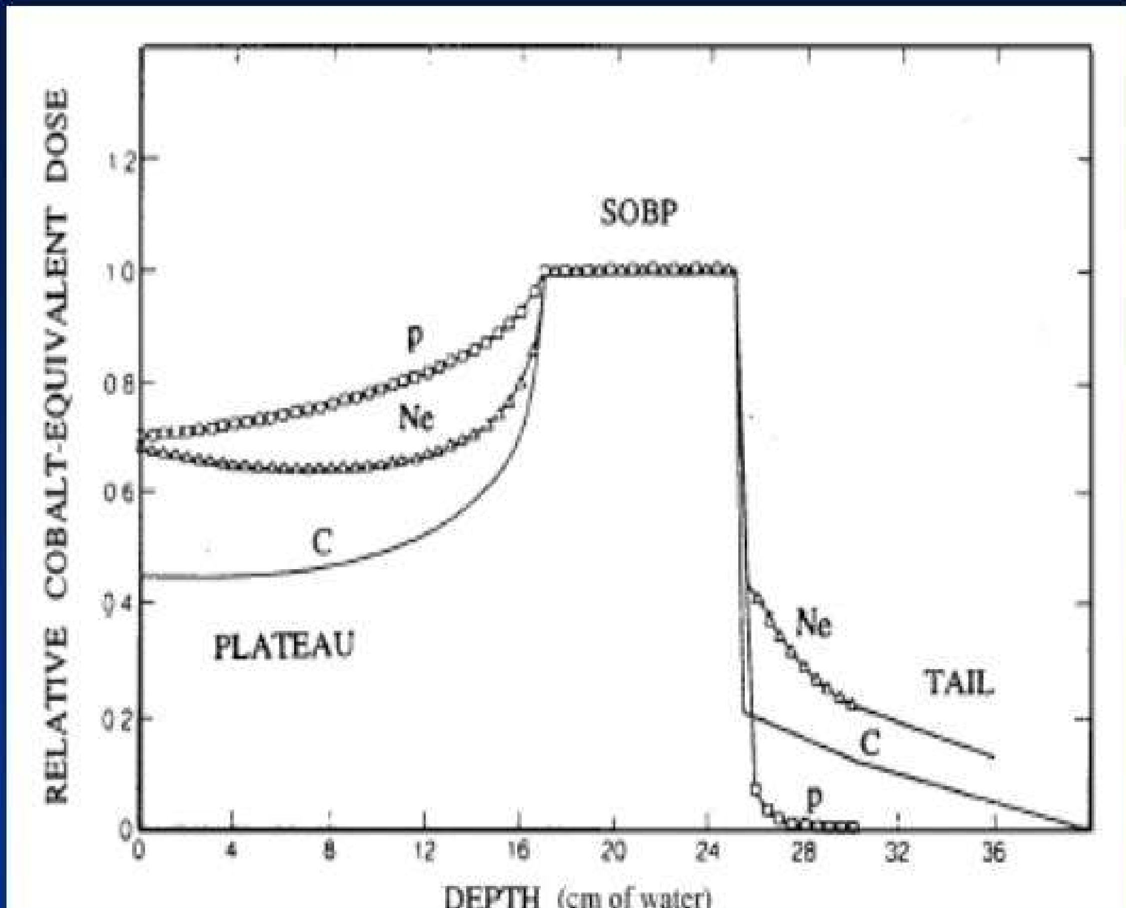
Overview of Proton Beam Therapy

Accelerated proton beams are used for the treatment of cancer





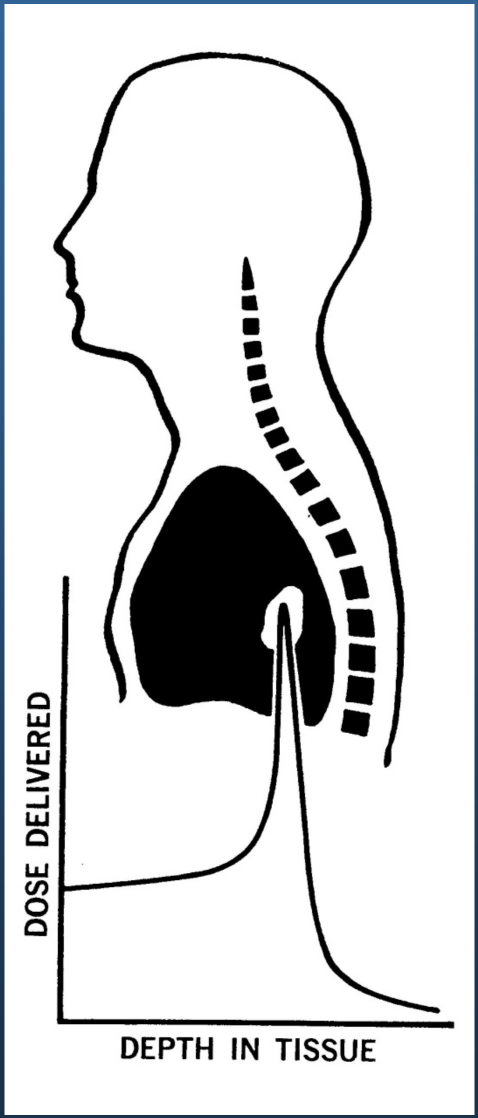
Dose beyond the Bragg peak:

p ~ 1-2 %

C ~ 15 %

Ne ~ 30 %

Rationale of Bragg Peak Therapy



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- Localization is superior
- Lower entrance dose
- No exit dose

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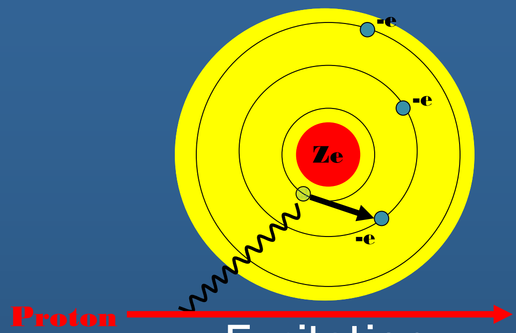
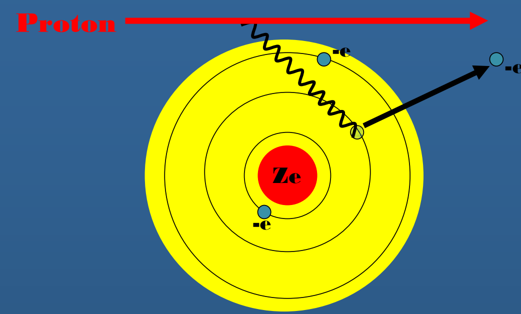
Energy Loss of Proton

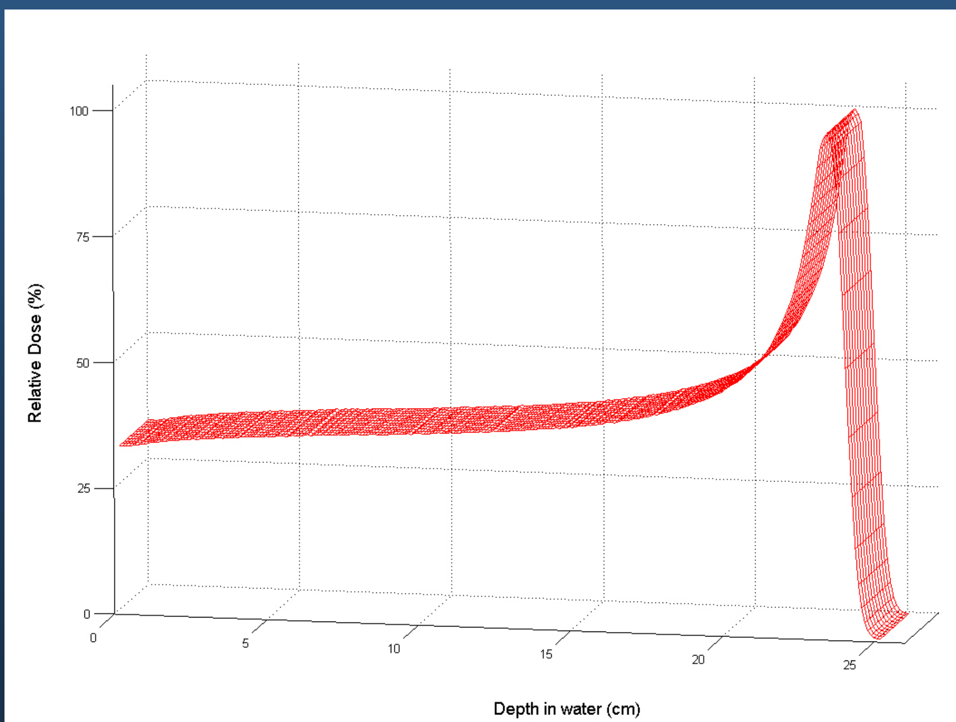
Electromagnetic Interaction with Electrons



Excitation



Ionization



Distal Distribution

Mass electronic stopping power is the energy lost by protons in electronic collision in traversing the distance dx in a material of density ρ.

$$S/\rho = 1/\rho[dE/dx] \propto 1/V^2$$

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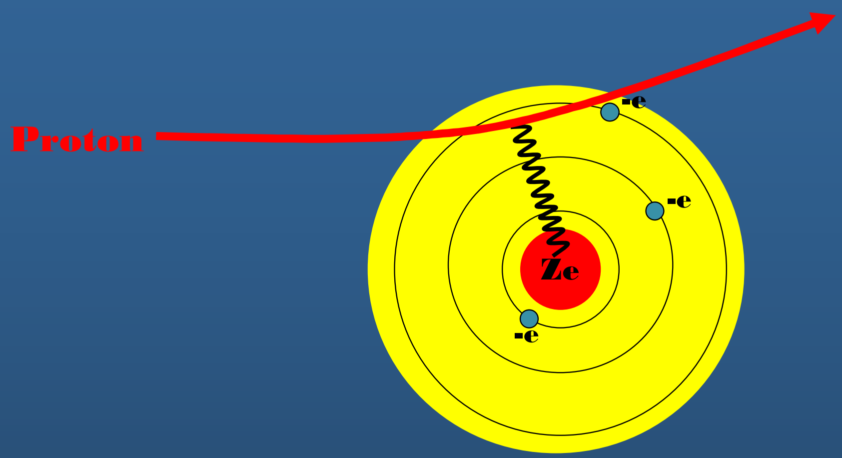
Energy Loss of Protons

Electromagnetic Interaction with Nuclear

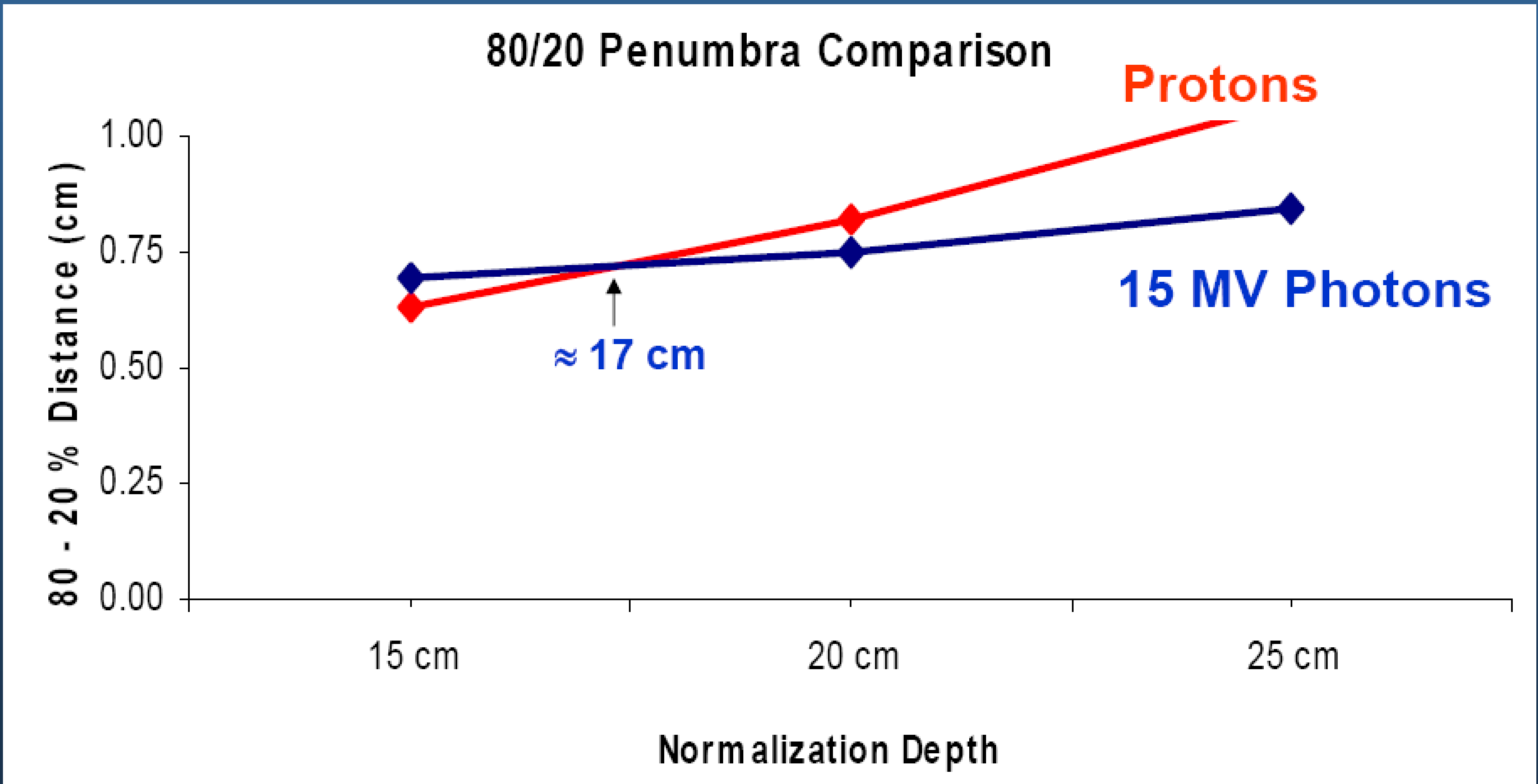


Multiple Coloumb Scattering

- Protons are deflected frequently in the electric field of nuclei.
- Beam broadening can be approximated by a Gaussian distribution.
- Lateral distribution

Energy Loss of Protons

Lateral dose fall-off: Protons vs. Photons



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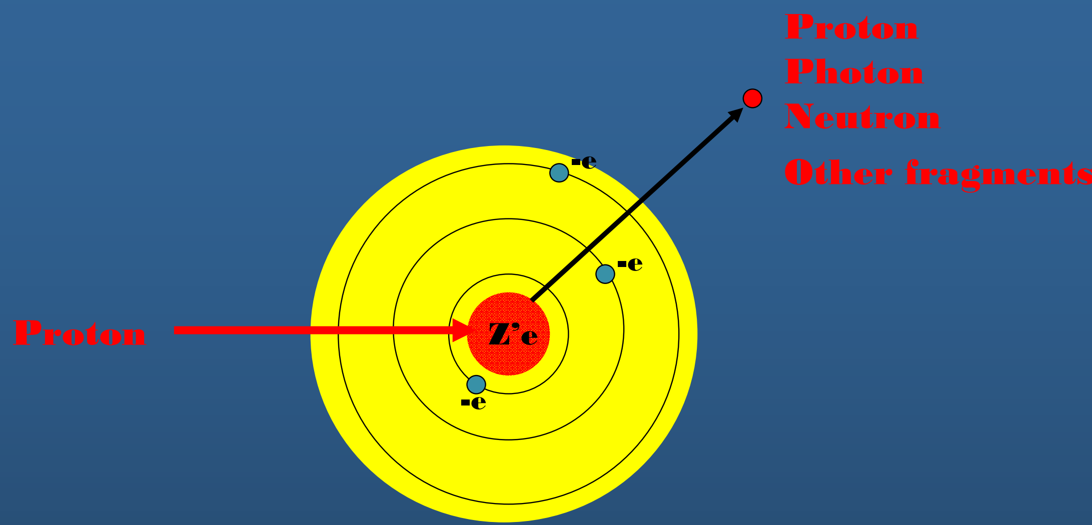
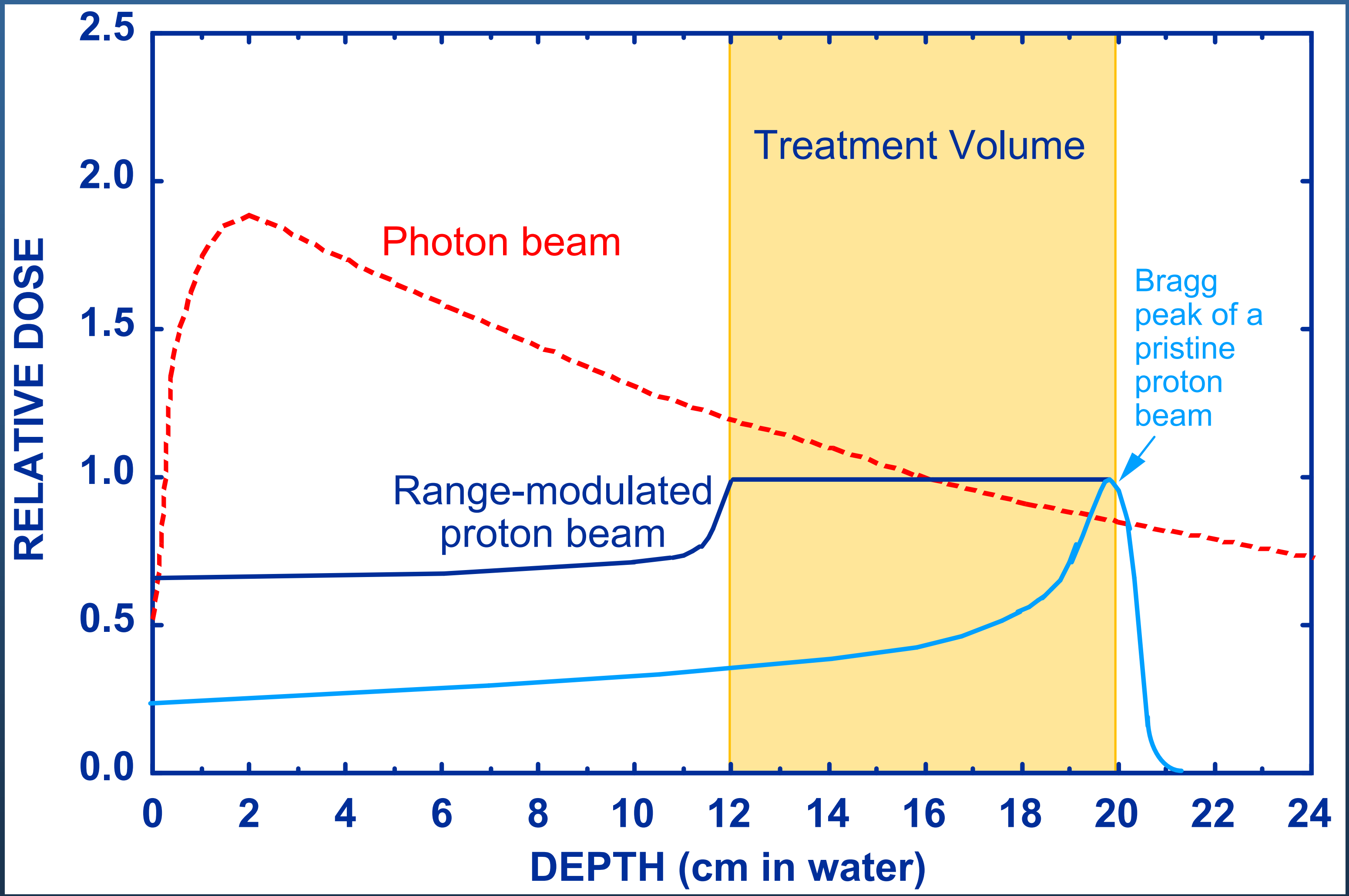
Energy Loss of Protons

Nuclear Interaction



- Hardronic interaction with nuclear
- Bigger transverse momentum transfer than EM interaction
- High LET process – nuclear recoil, fragmentation
- Induced radioactivities – long-lived isotopes

Depth-Dose Curves for Proton and Photon Beams



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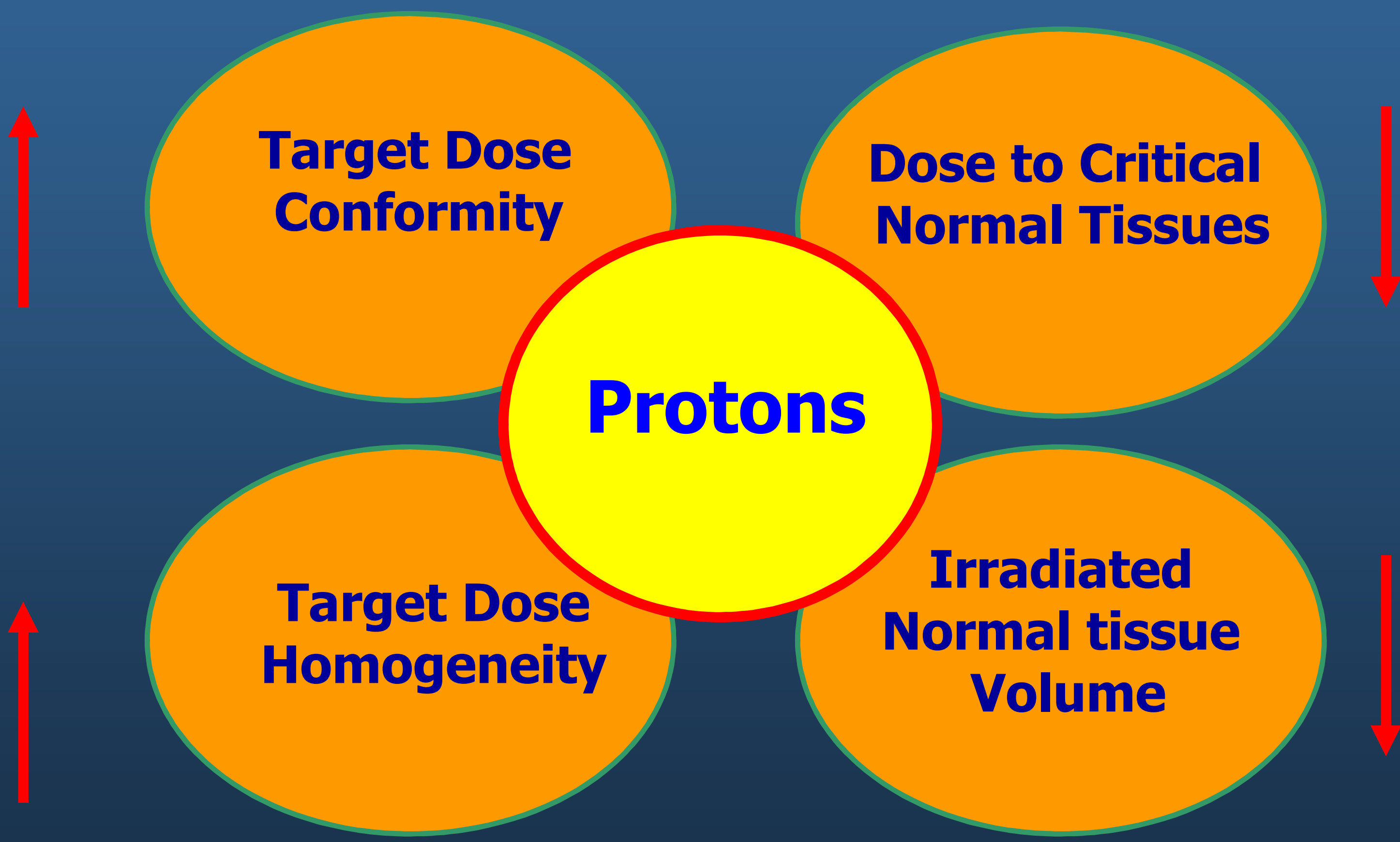
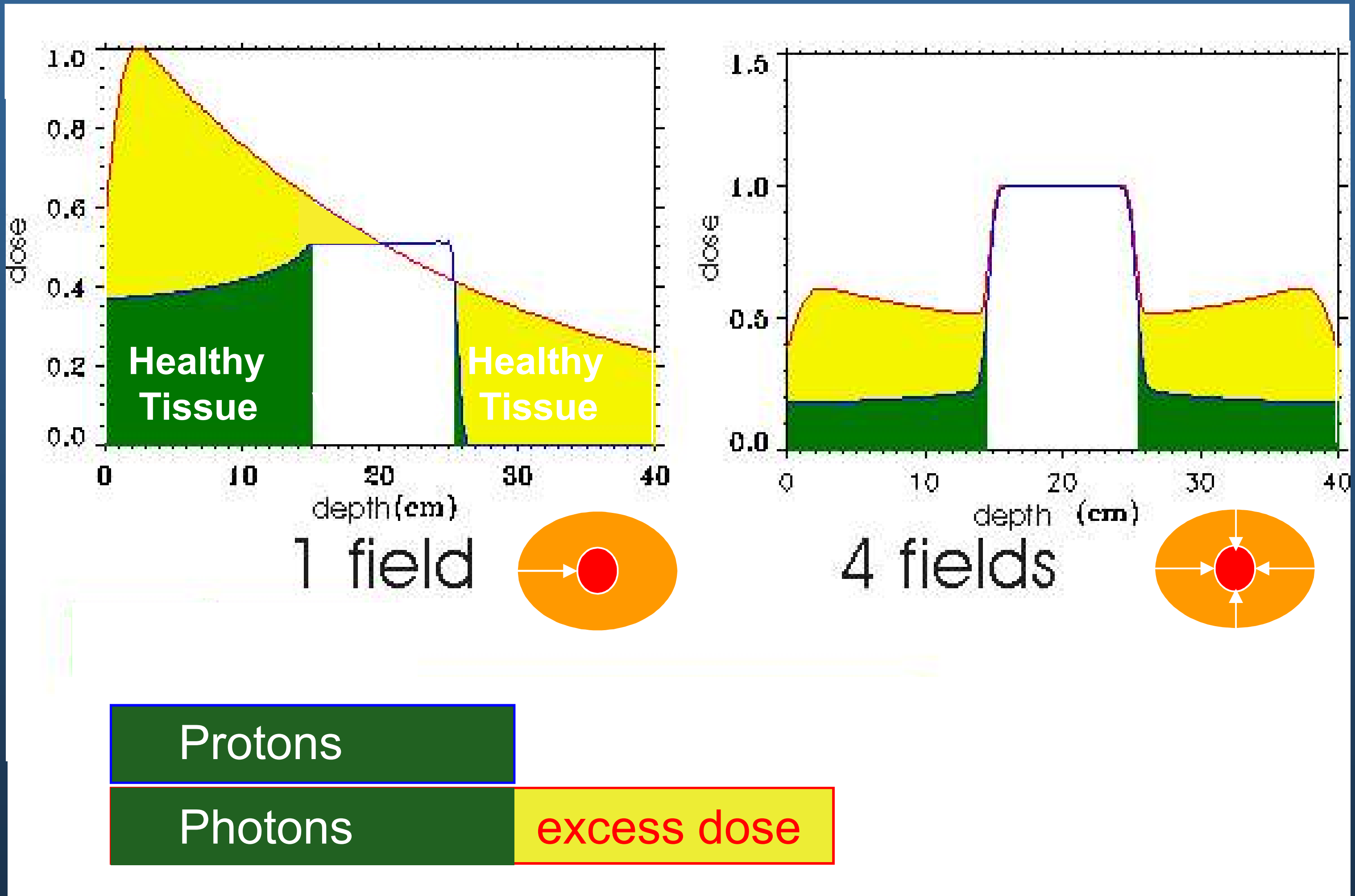
Goals of Radiation Therapy



Dose Sparing: Protons vs. Photons



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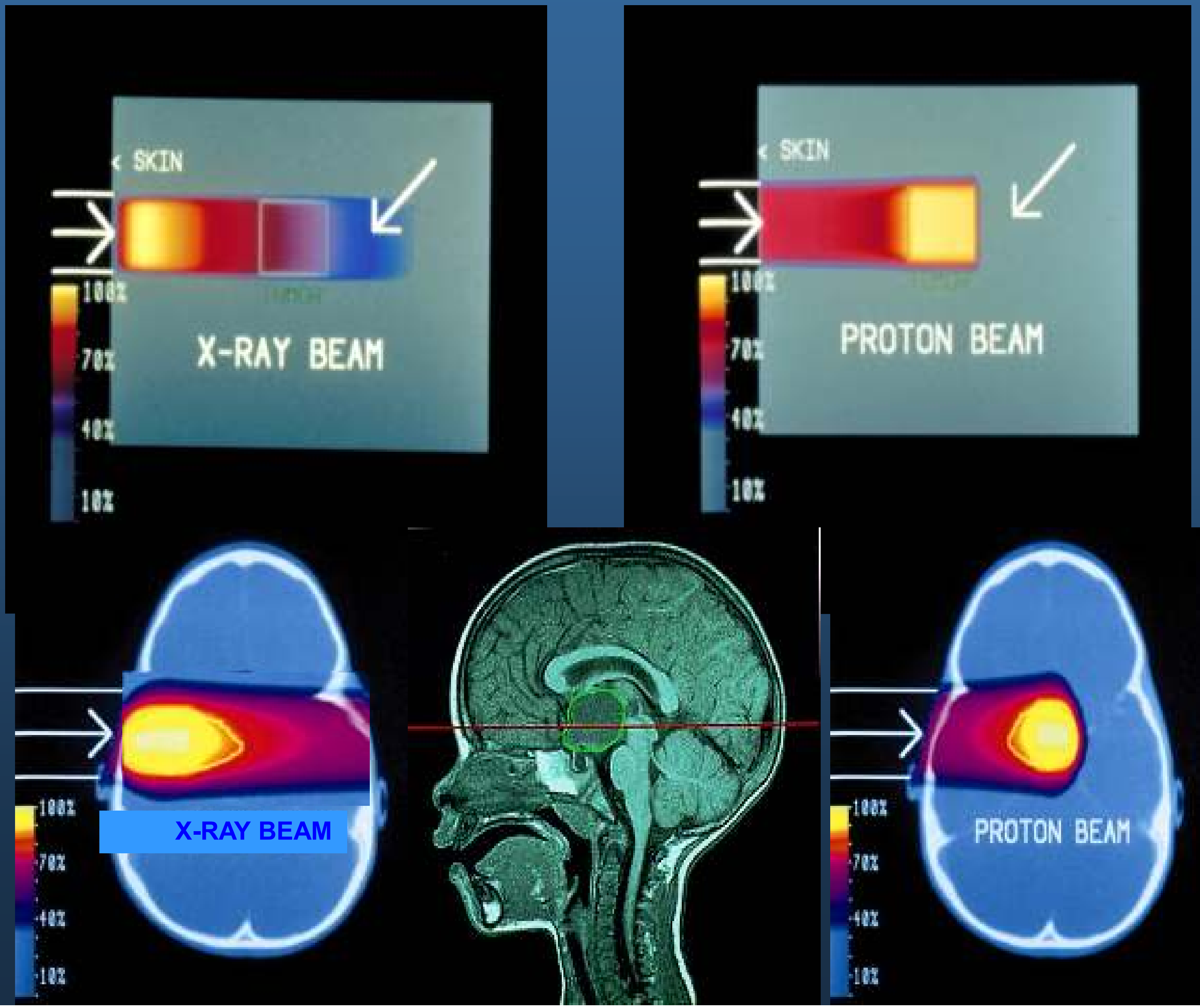
Protons vs. Photons



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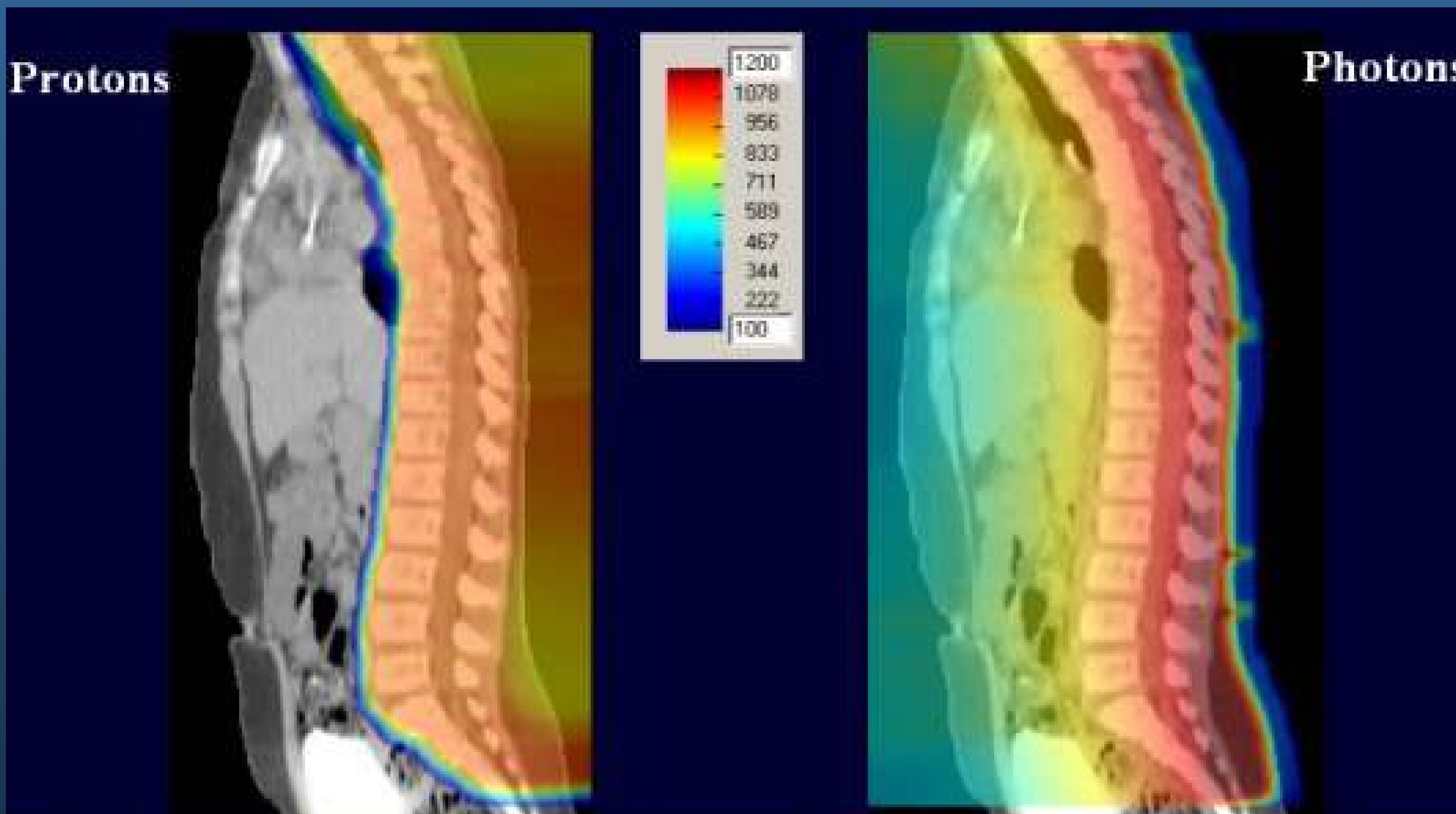
Proton Therapy is highly conformal



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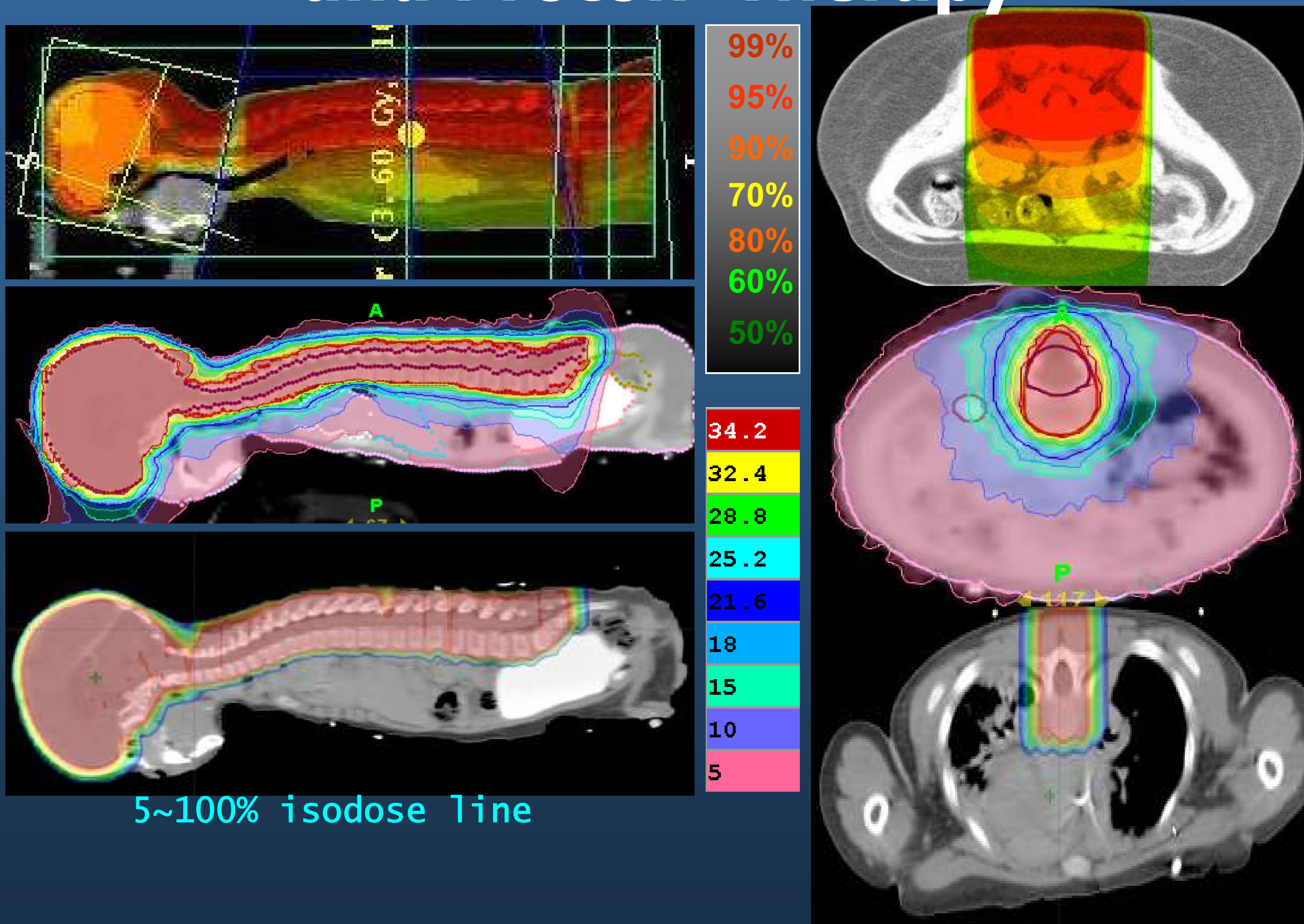
CSI using 3D CRT, Tomotherapy, and Proton Therapy



5~100% isodose line

Yoon MG, Park SY, et al., Int. J. Radiat. Oncol. Biol. Phys., 2011

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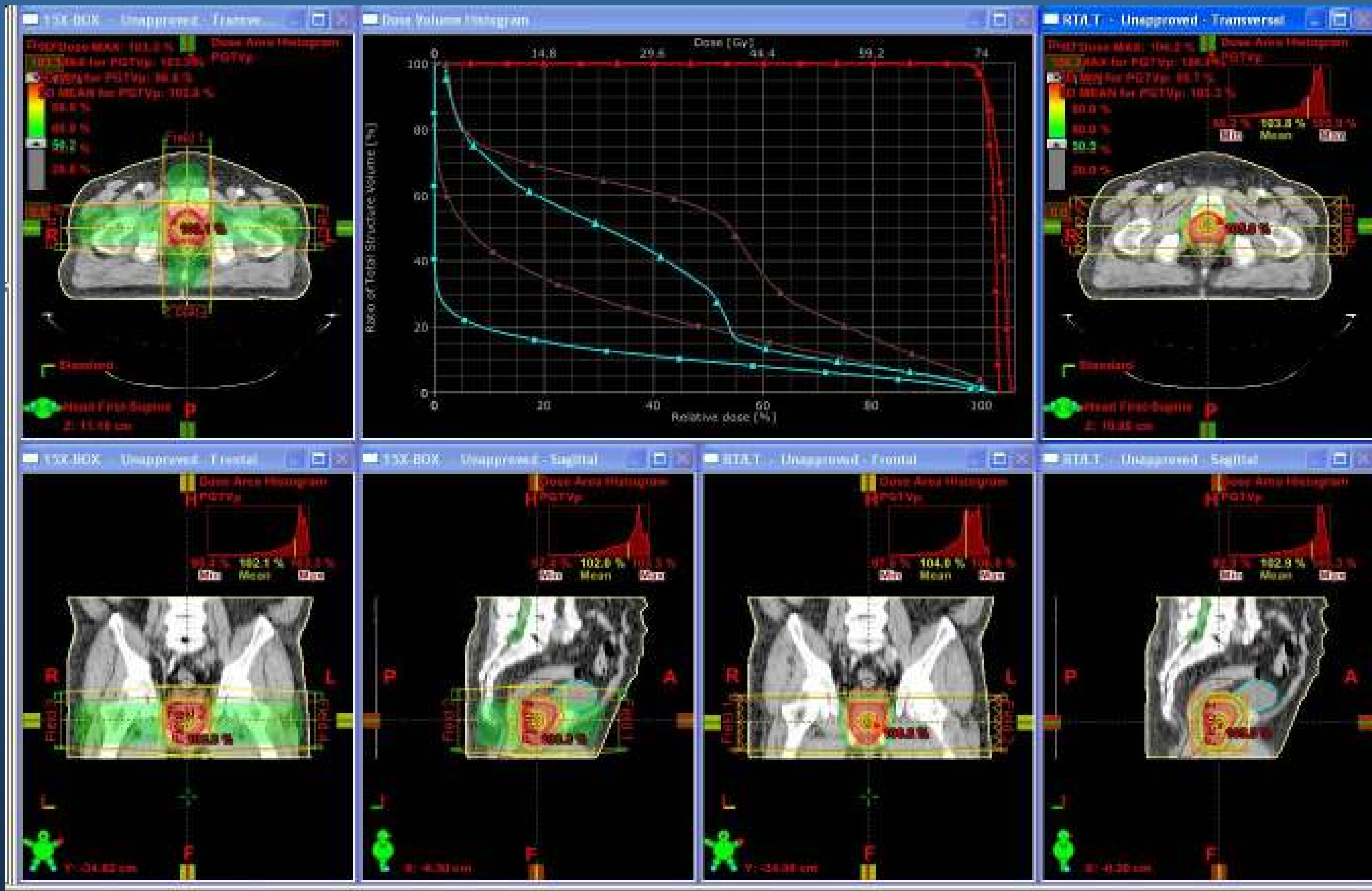
Protons vs. Photons



History of Proton Therapy

- 1919 Rutherford proposed existence of protons
- 1930 E. O. Lawrence built first cyclotron
- 1946 Robert Wilson proposed proton therapy
- 1955 Tobias et al treated patients at LBL
- 1961 Kjellberg et al treated patients at HCL
- 1972 MGH received first NCI grant for proton studies at HCL
- 1983 Tsukuba Univ. in Japan treated patients
- 1985 PTCOG
- 1991 First hospital-based proton facility at LLUMC
- 2009 27 facilities worldwide treating patients;

over 67,000 patients treated with protons.

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Patient Statistics (for the facilities out of operation; end of 2010):

WHERE		PARTICLE	FIRST PATIEN
Belgium	Louvain-la-Neuve	p	1991
Canada	Vancouver (TRIUMF)	π^-	1979
Germany	Darmstadt (GSI)	C-ion	1997
Japan	Tsukuba (PMRC, 1)	p	1983
Japan	Chiba	p	1979
Japan	WERC	p	2002
Russia	Dubna (1)	p	1967
Sweden	Uppsala (1)	p	1957
Switzerland	Villigen PSI (SIN-Piotron)	π^-	1980
Switzerland	Villigen PSI (OPTIS 1)	p	1984
CA., USA	Berkeley 184	p	1954
CA., USA	Berkeley	He	1957
CA., USA	Berkeley	ion	1975
IN., USA	Bloomington (MPRI, 1)	p	1993
MA., USA	Harvard	p	1961
NM., USA	Los Alamos	π^-	1974

t

Patient Statistics (for the facilities in operation end of 2011):

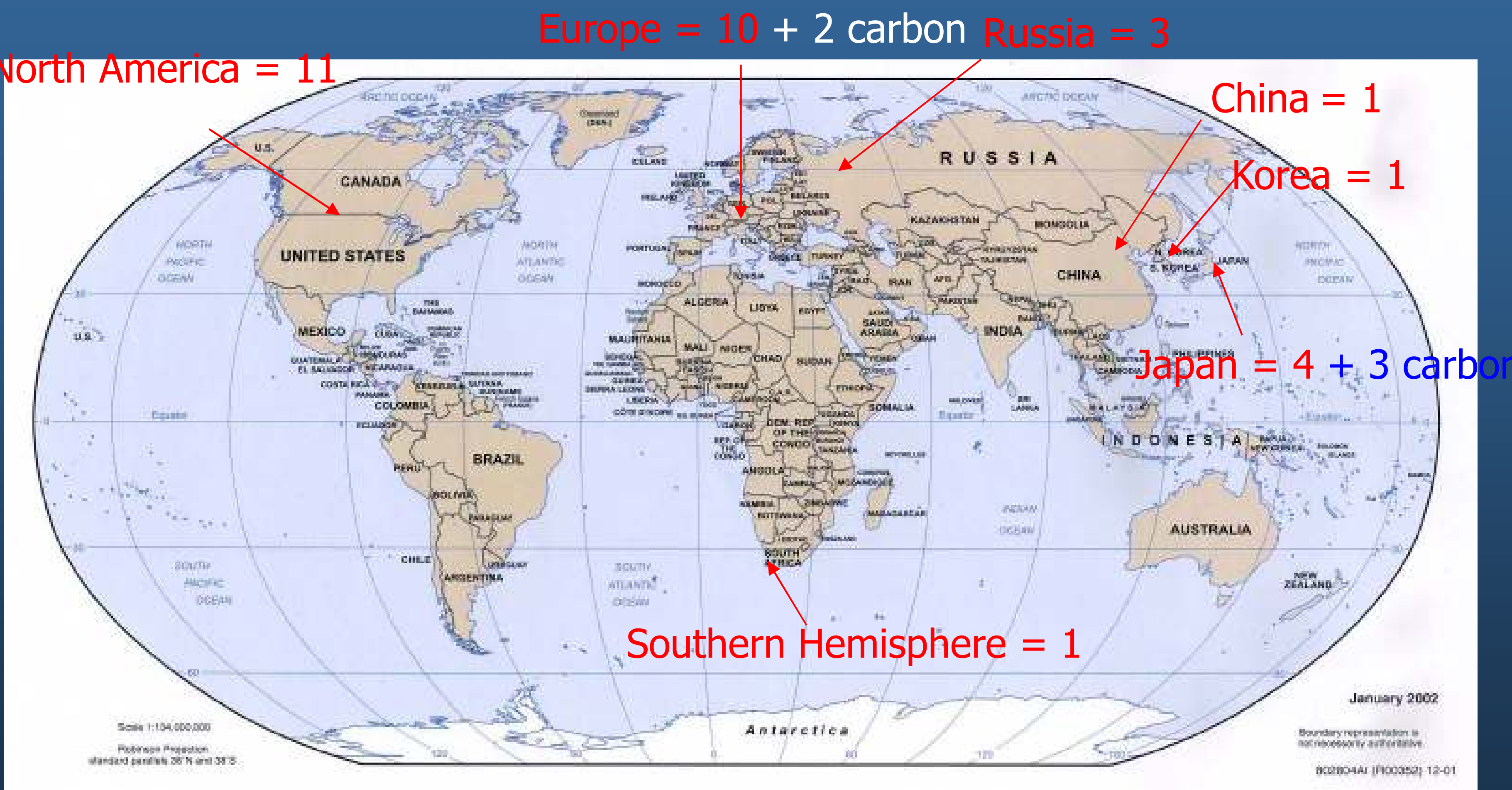
WHERE		PARTICLE	FIRST PATIENT	PATIENT TOTAL	DATE OF TOTAL	
Canada	Vancouver (TRIUMF)	p	1995	161	Dec-11	ocular tumors only
China	Wanjie (WPTC)	p	2004	1078	Dec-11	no patients in 2011
China	Lanzhou	C ion	2006	159	Dec-11	
England	Clatterbridge	p	1989	2151	Dec-11	ocular tumors only
France	Nice (CAL)	p	1991	4417	Dec-11	ocular tumors
France	Orsay (CPO)	p	1991	5634	Dec-11	4540 ocular tumors
Germany	Berlin (HMI)	p	1998	1859	Dec-11	ocular tumors only
Germany	Munich (RPTC)	p	2009	895	Dec-11	
Germany	HIT, Heidelberg	C ion	2010	568	Dec-11	
Germany	HIT, Heidelberg	p	2010	94	Dec-11	
Italy	Catania (INFN-LNS)	p	2002	290	Dec-11	ocular tumors only
Italy	Pavia (CNAO)	C ion	2011	5	Dec-11	
Japan	Chiba (HIMAC)	C ion	1994	6569	Dec-11	11 with scanning
Japan	Kashiwa (NCC)	p	1998	870	Dec-11	estimated
Japan	Hyogo (HIBMC)	p	2001	3198	Dec-11	
Japan	Hyogo (HIBMC)	C ion	2002	1271	Dec-11	
Japan	Tsukuba (PMRC, 2)	p	2001	2166	Dec-11	
Japan	Shizuoka	p	2003	1175	Dec-11	
Japan	Koriyama-City	p	2008	1378	Dec-11	
Japan	Gunma	C ion	2010	271	Dec-11	
Japan	Ibusuki (MMRI)	p	2011	180	Dec-11	
Korea	Ilsan, Seoul	p	2007	810	Dec-11	
Poland	Krakow	p	2011	11	Dec-11	ocular tumors only
Russia	Moscow (ITEP)	p	1969	4300	Dec-11	estimated
Russia	St. Petersburg	p	1975	1372	Dec-11	
Russia	Dubna (JINR, 2)	p	1999	828	Dec-11	
South Africa	iThemba LABS	p	1993	521	Dec-11	
Sweden	Uppsala (2)	p	1989	1185	Dec-11	
Switzerland	Villigen PSI, incl OPTIS2	p	1996	1107	Dec-11	277 ocular tumors
USA, CA.	UCSF - CNL	p	1994	1391	Dec-11	ocular tumors only
USA, CA.	Loma Linda (LLUMC)	p	1990	16000	Dec-11	estimated
USA, IN.	Bloomington (IU Health PTC)	p	2004	1431	Dec-11	
USA, MA.	Boston (NPTC)	p	2001	5562	Oct-11	
USA, TX.	Houston (MD Anderson)	p	2006	3400	Feb-12	
USA, FL	Jacksonville (UFPTI)	p	2006	3461	Dec-11	
USA, OK.	Oklahoma City (ProCure PTC)	p	2009	623	Dec-11	
USA, PA.	Philadelphia Upenn)	p	2010	433	Dec-11	
USA, IL.	CDH Warrenville	p	2010	367	Dec-11	
USA, VA.	Hampton (HUPTI)	p	2010			no data available
				77191	Total	
			thereof	8843 C-ions		
				67904 protons		

Total for all facilities (in operation and out of operation):

2054 He
1100 pions
9283 C-ions
433 other ions
83667 protons
96537 Grand Total

Worldwide Particle Therapy Facilities

31 PROTON AND 5 CARBON ION THERAPY FACILITIES IN 2011



25 additional institutions are planning to have a charged particle therapy.

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Cyclotron

Synchrotron

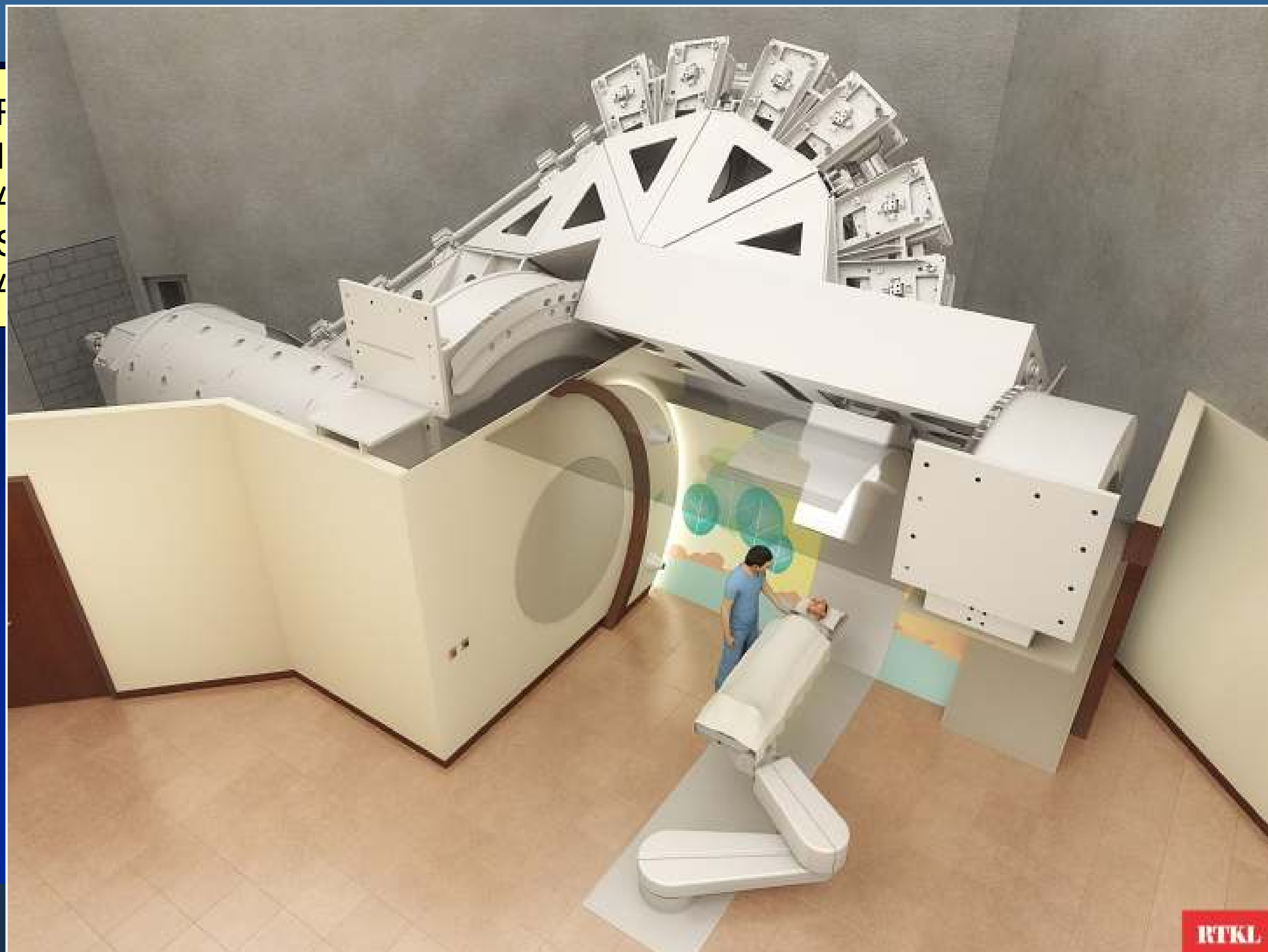
Cyclotron vs. Synchrotron

	Cyclotron	Synchrotron
Energy	Fixed	Variable
Spill Structure	Continuous	Pulse
Beam extract efficacy	Low (high radiation activity)	High
Temperature stability	Variable	Stable
Beam current	High	Low
Beam quality (momentum spread)	Low (large)	High (small)

Beam Transport System

Positioning System

- F
- I
- A
- S
- A



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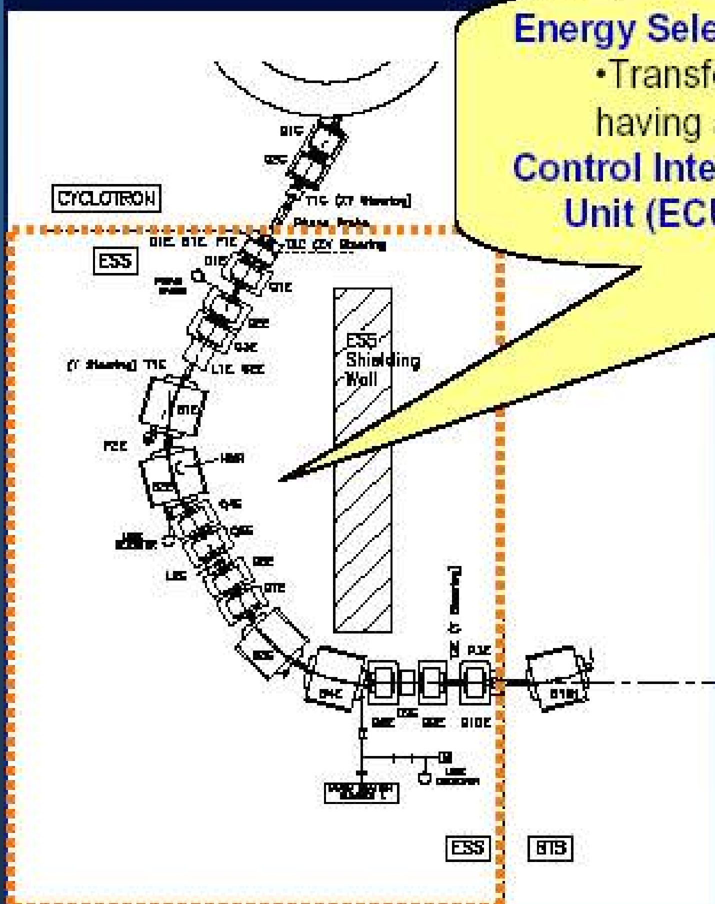
Energy Selection System

Energy Selection System:

- Transform fixed energy beam extracted into a beam having a variable energy [230 MeV - 70 MeV]

Control Interface: Energy & Beam Transport Control Unit (ECUBTCU)

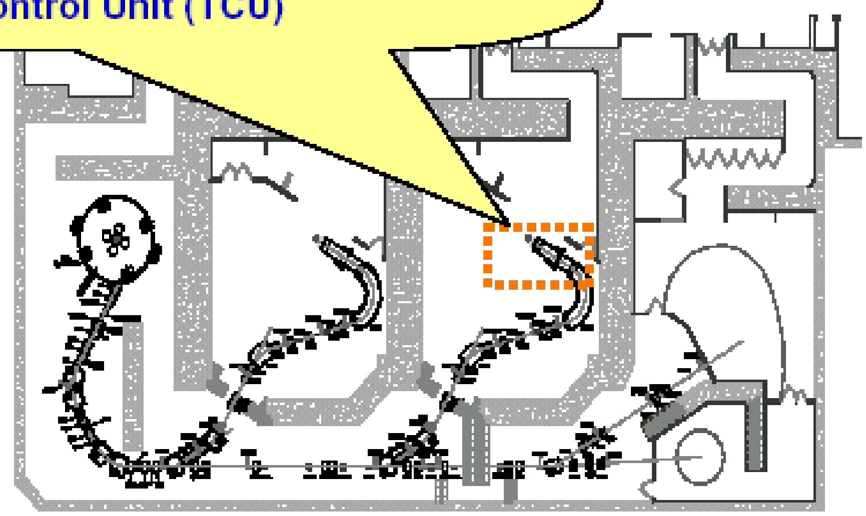


Beam Shaping Components

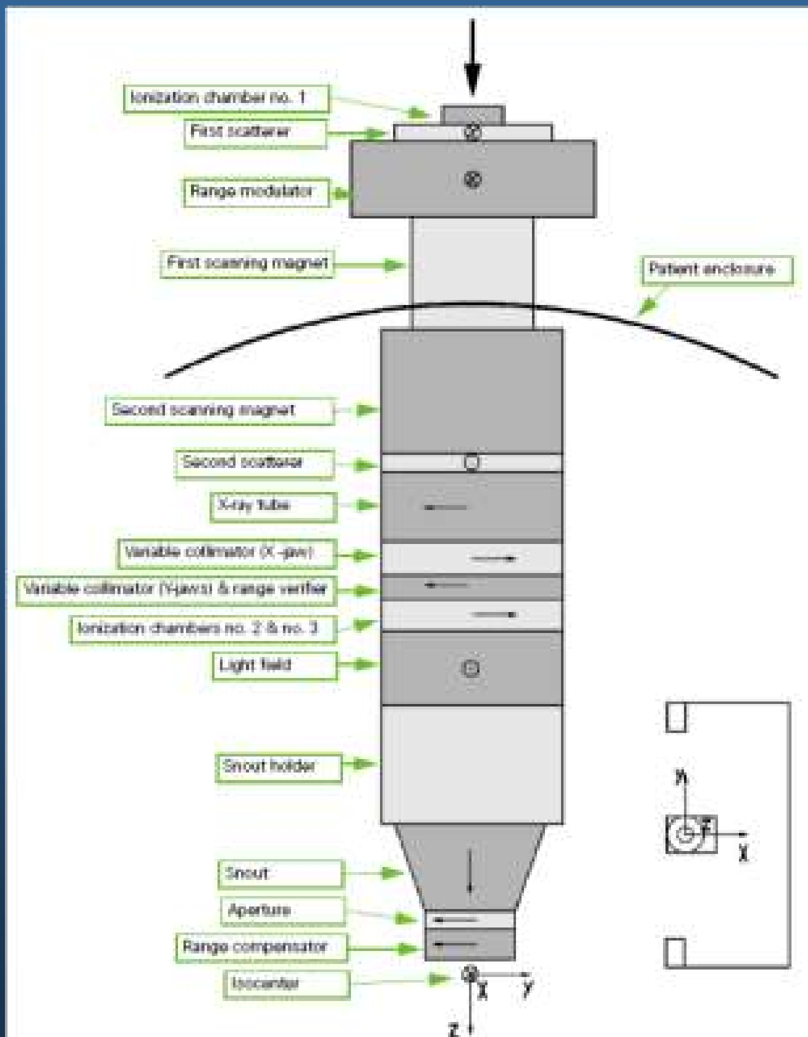
Nozzle:

- To spread the proton beam to obtain a uniform dose distribution in a large volume
- To measure accurately the dose delivered to the patient
- To help the alignment of the patient with the proton field

Control Interface: Treatment Control Unit (TCU)



Nozzle Beam Delivery Modes



- Double Scattering
  - Field diameter < 25 cm
  - “Large” Penumbra
- Single Scattering
  - Field diameter < 8 cm
  - “Sharp” Penumbra
- Wobbling
  - Field 30x40
- Pencil-Beam Scanning
  - IMPT

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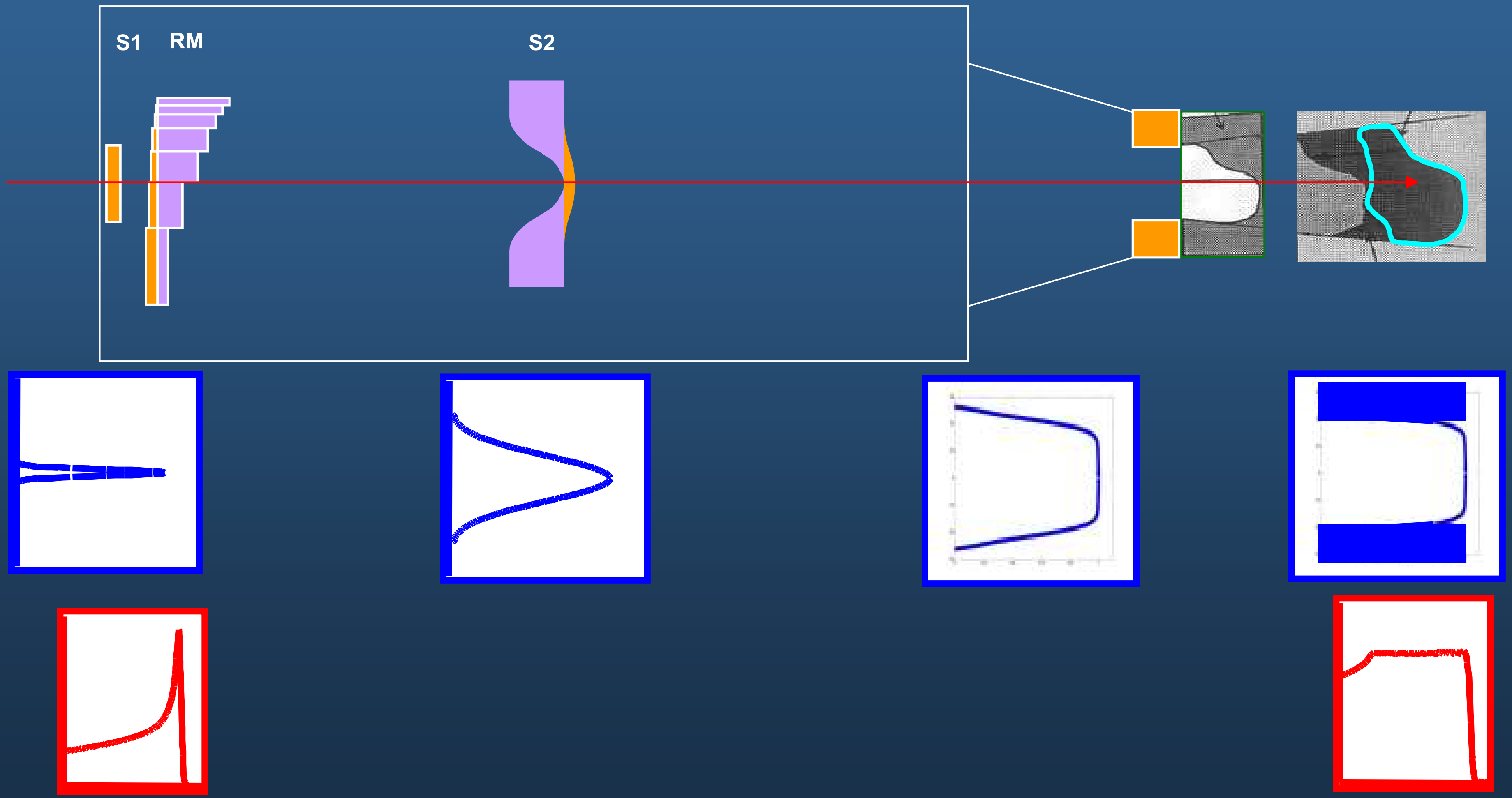
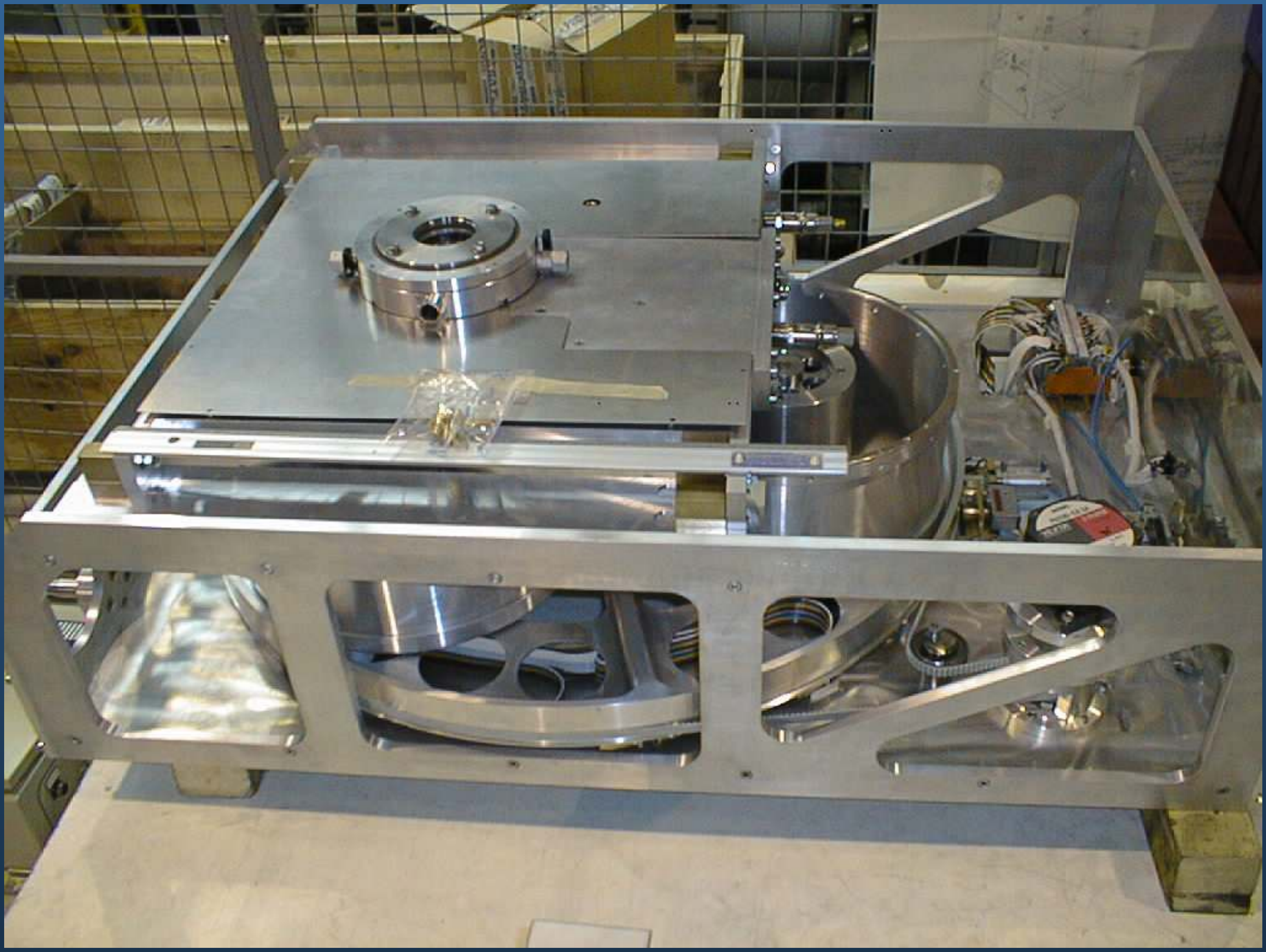
Double scattering principle



RM + FS + IC set A



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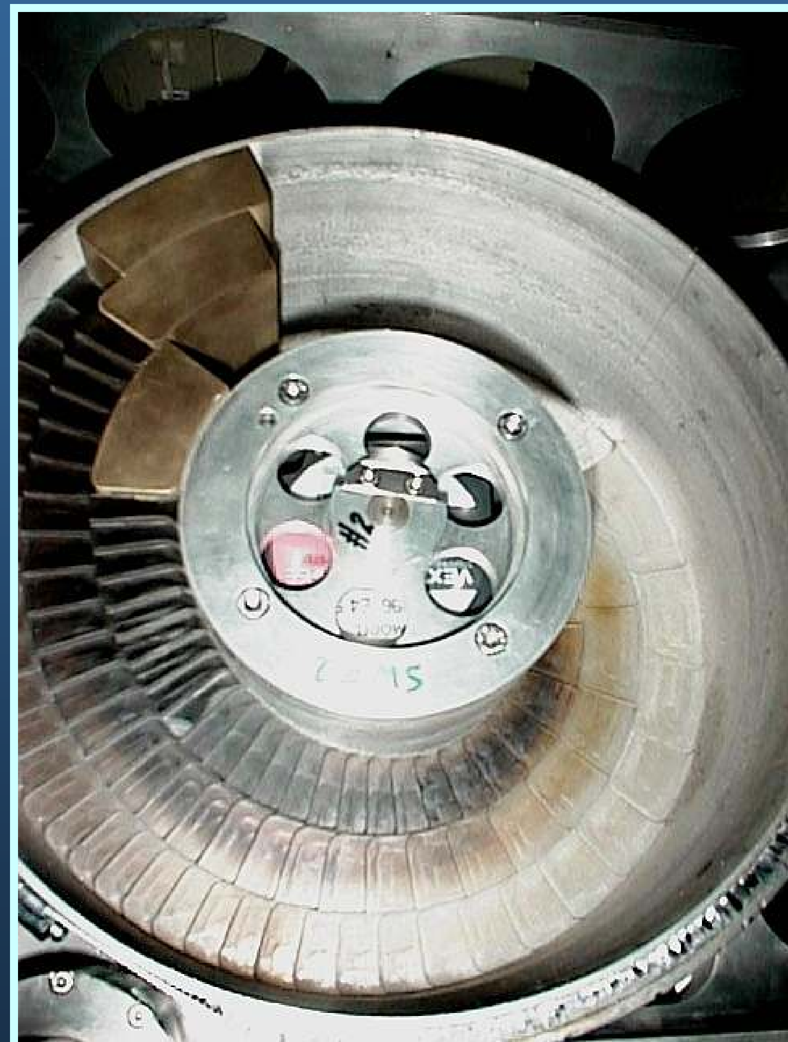
Range Modulator System



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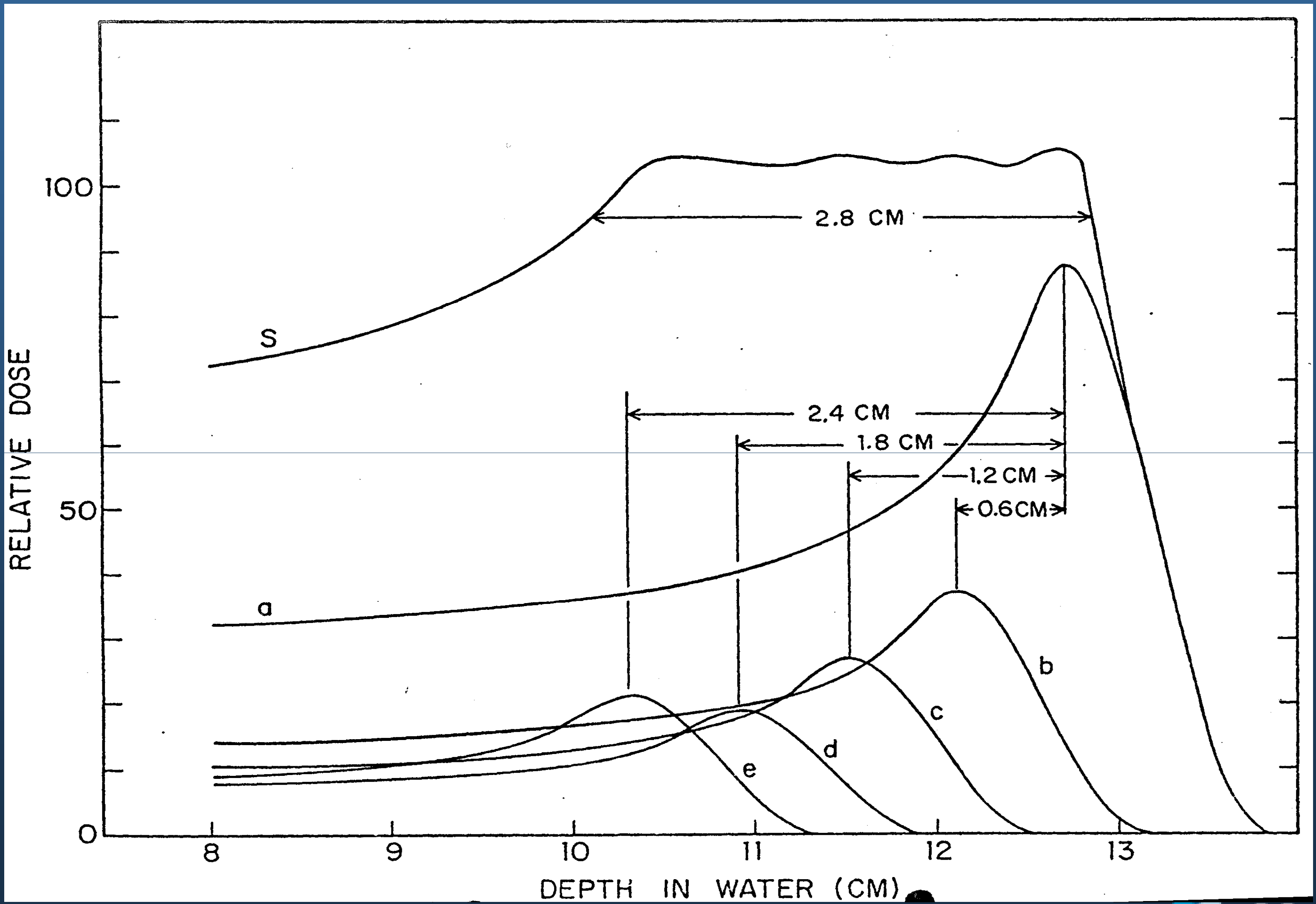
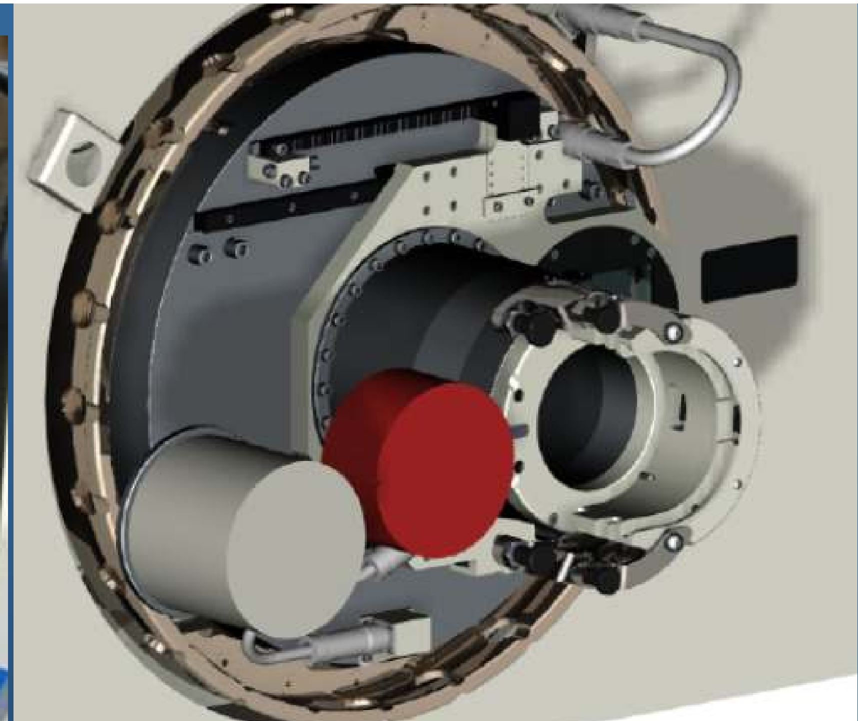
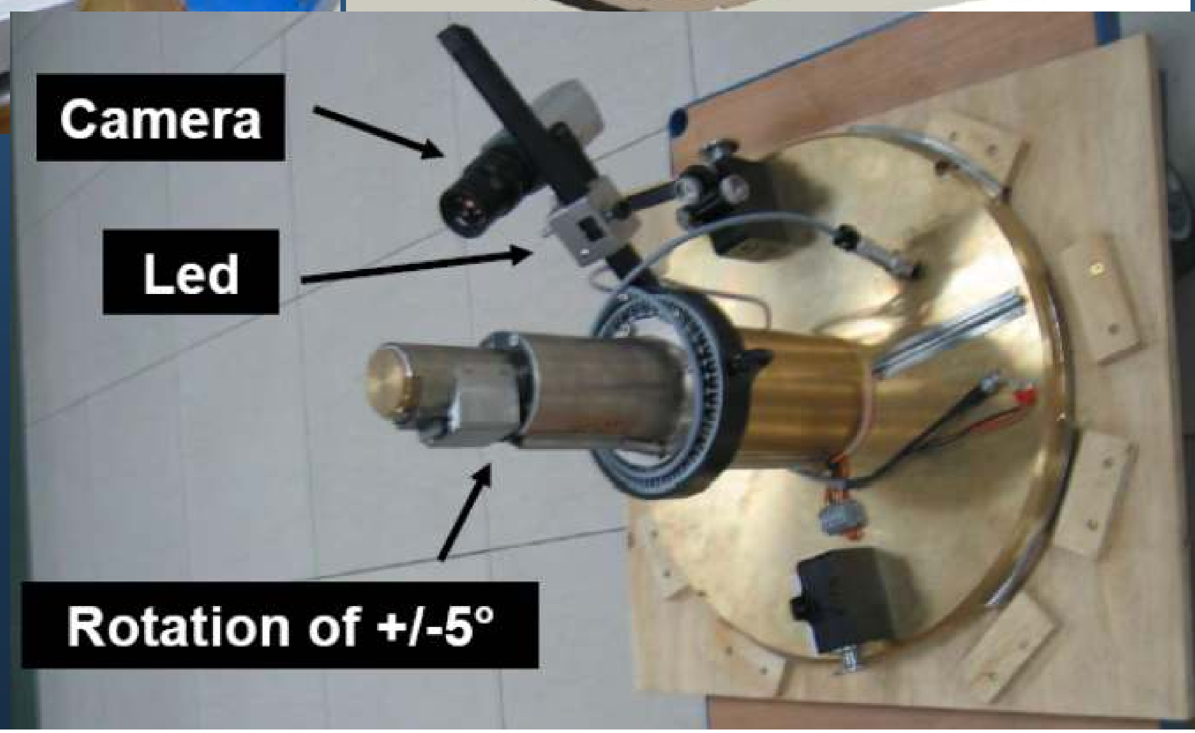
Range Modulation



Second Scatterer System



Snout



Aperture and Range Compensator

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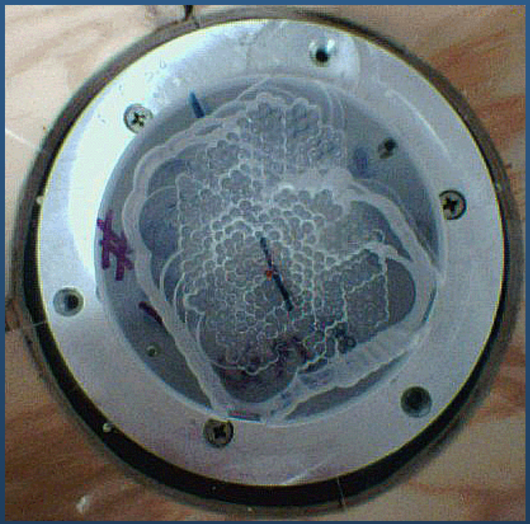

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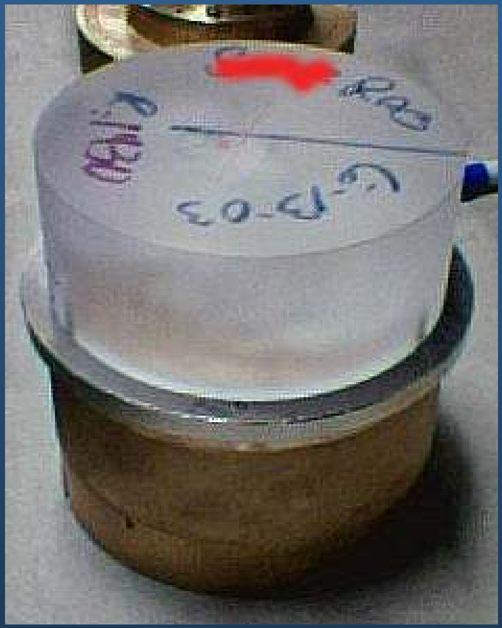

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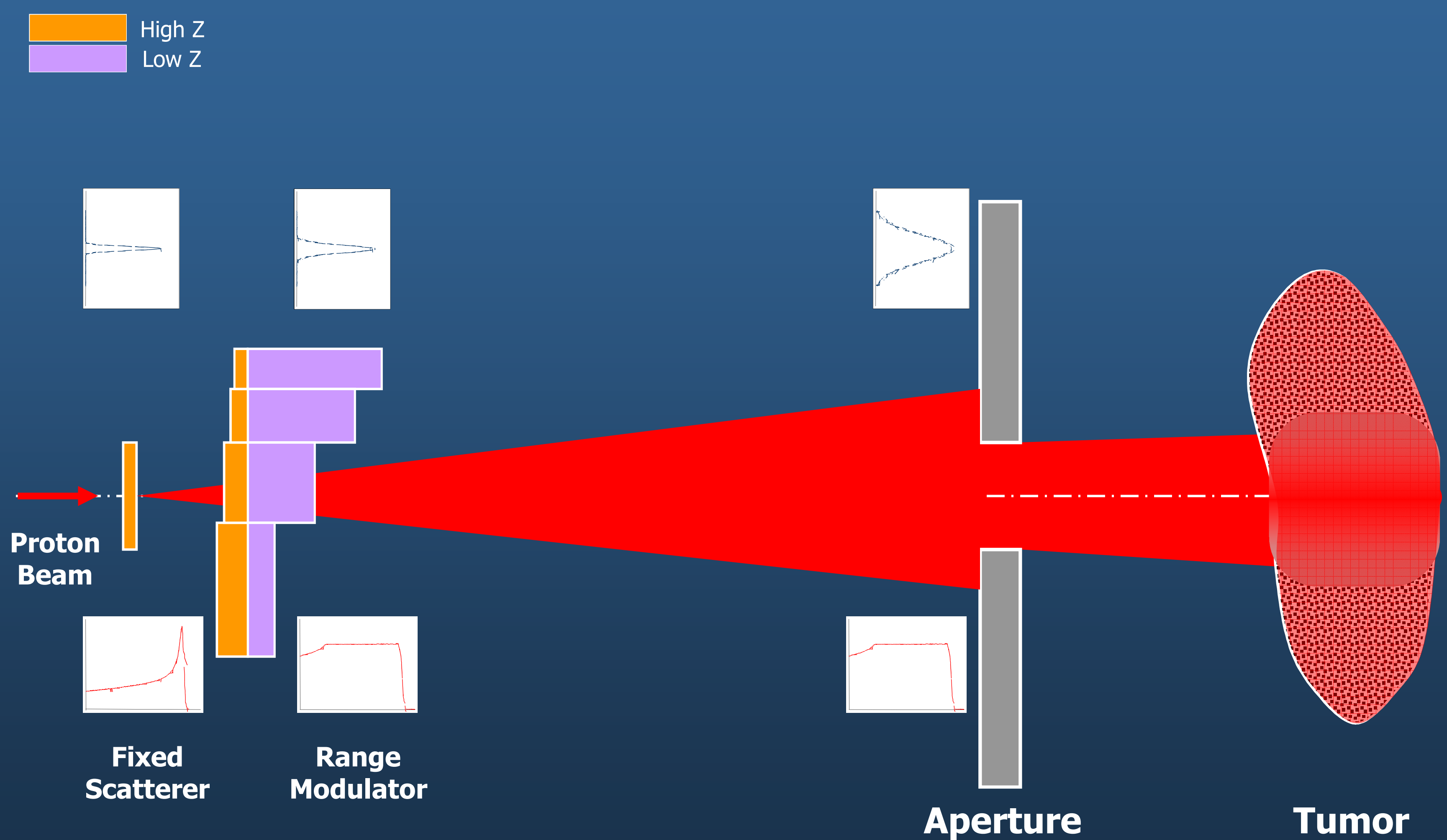
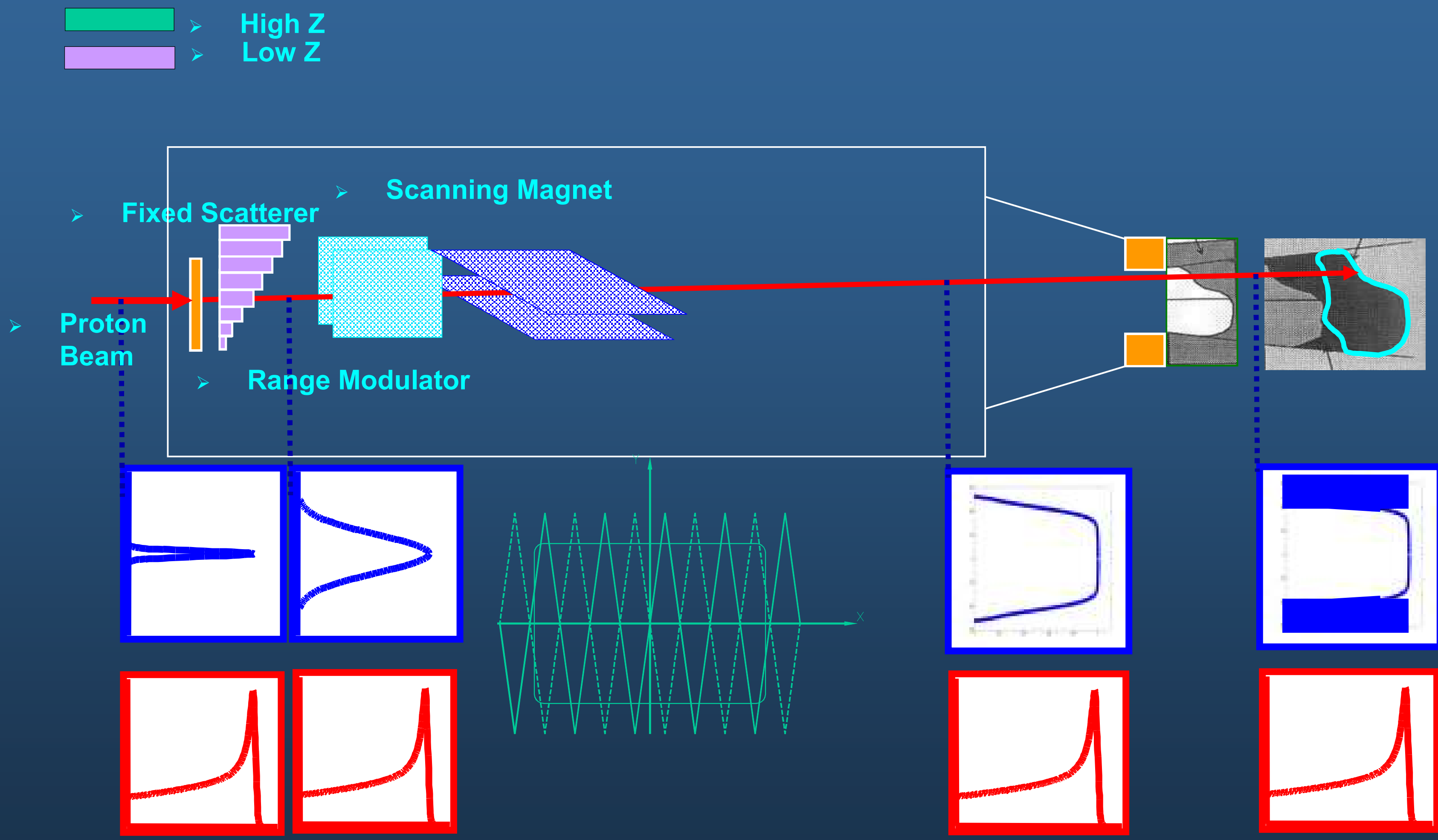
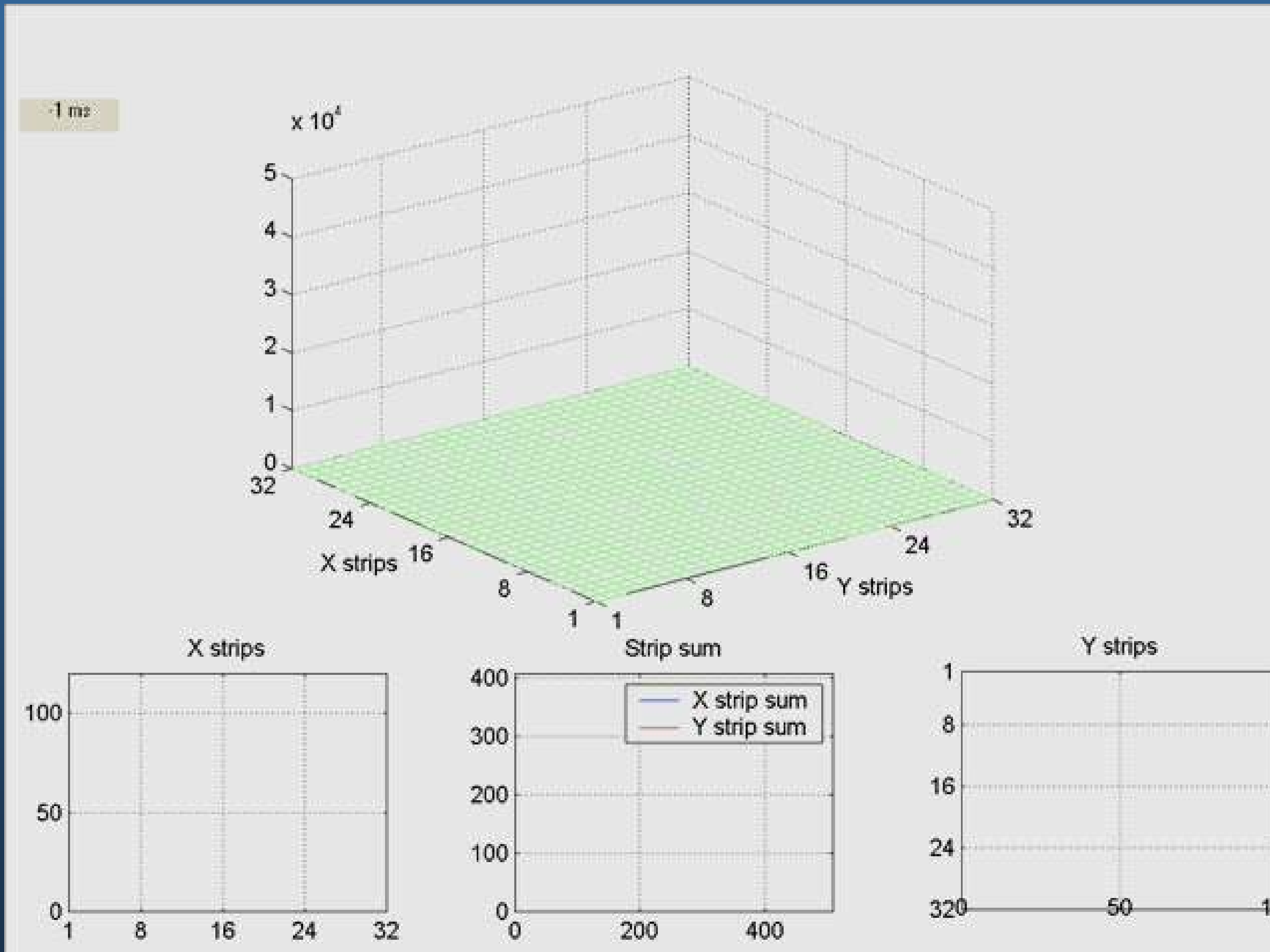
Single Scattering



Uniform scanning principle



Painting a Layer



Courtesy by H. Benteffour, IBA Physics Dept.

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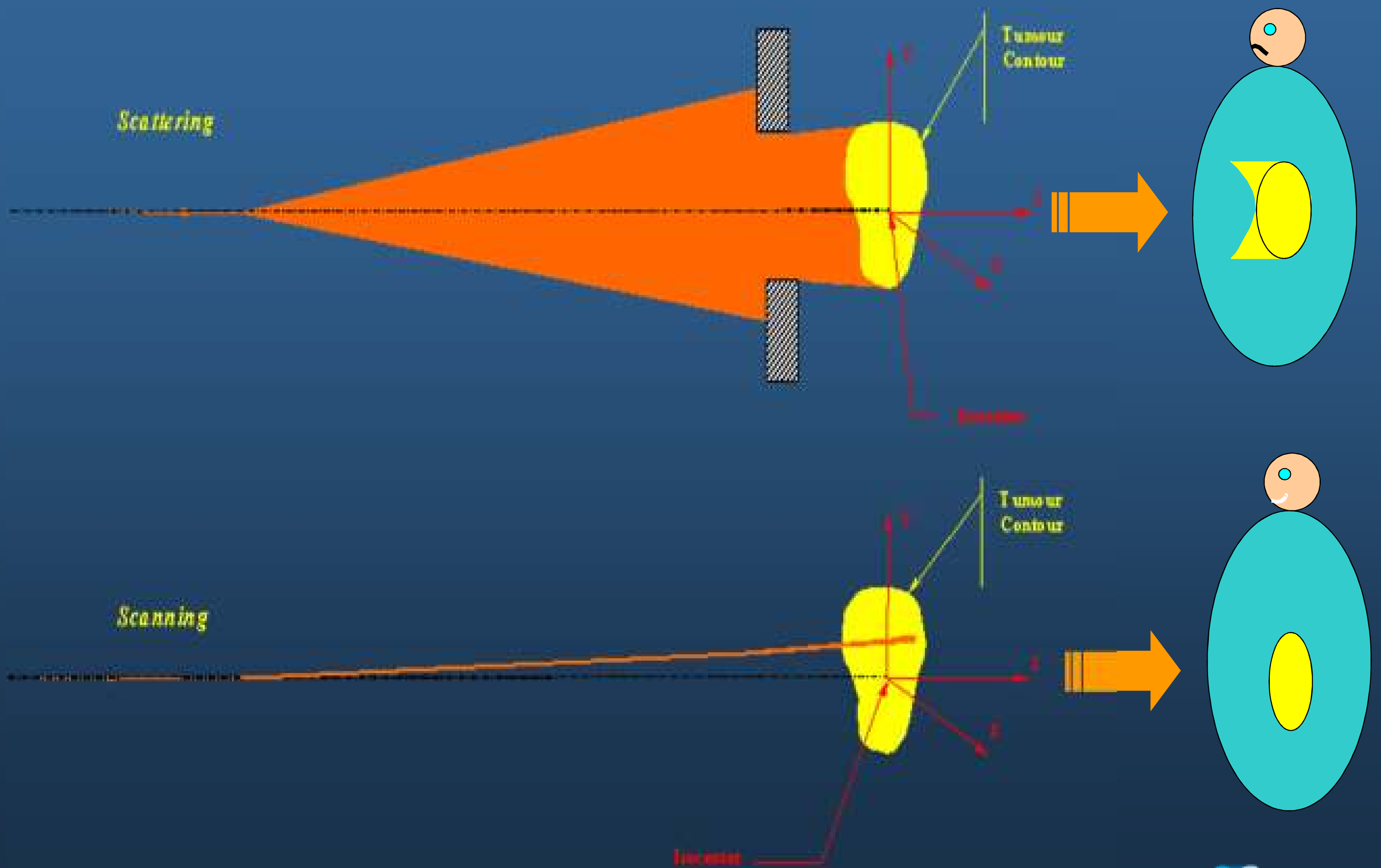
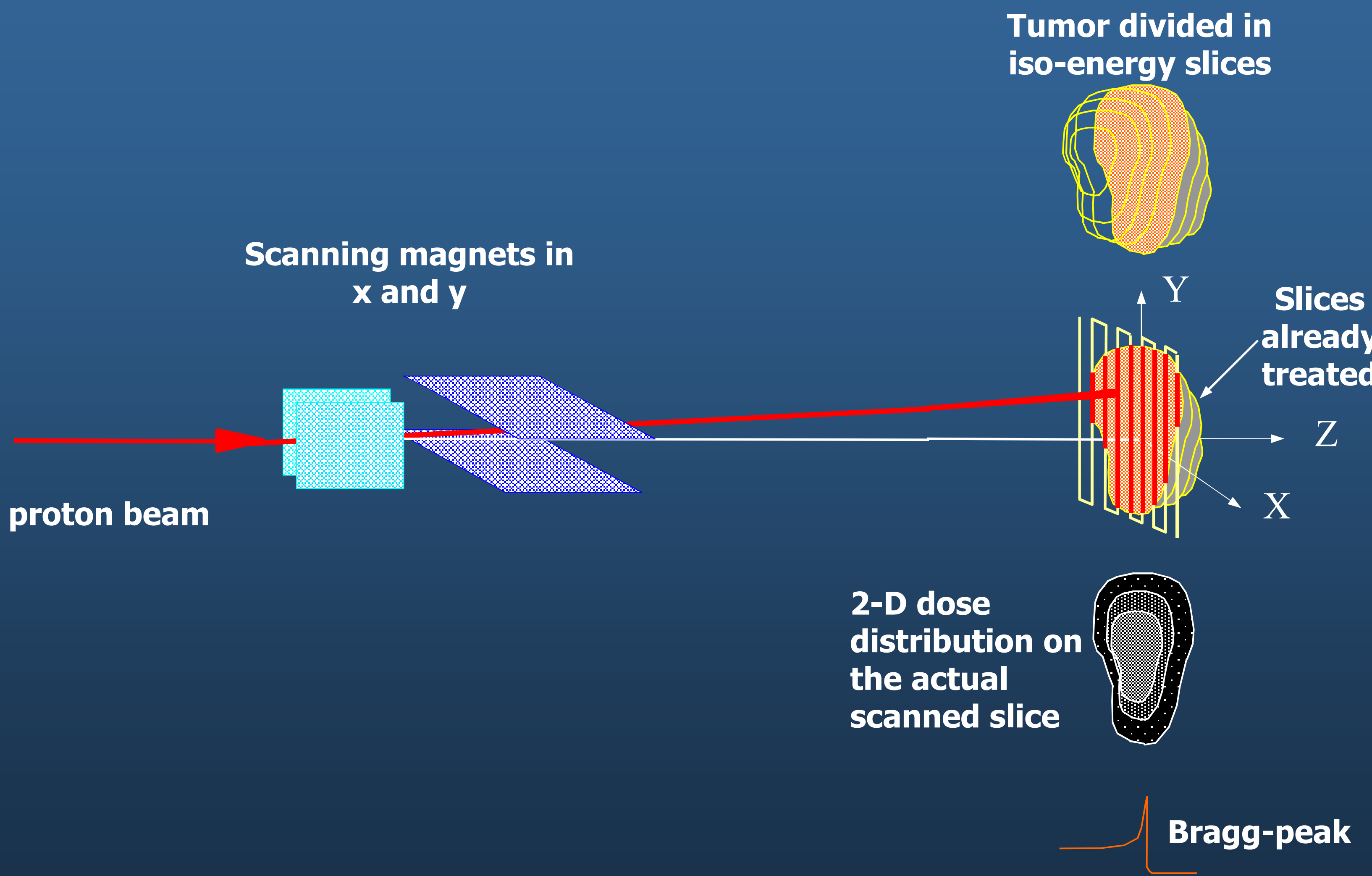
Comparison between scattering and scanning



Pencil Beam Scanning principle



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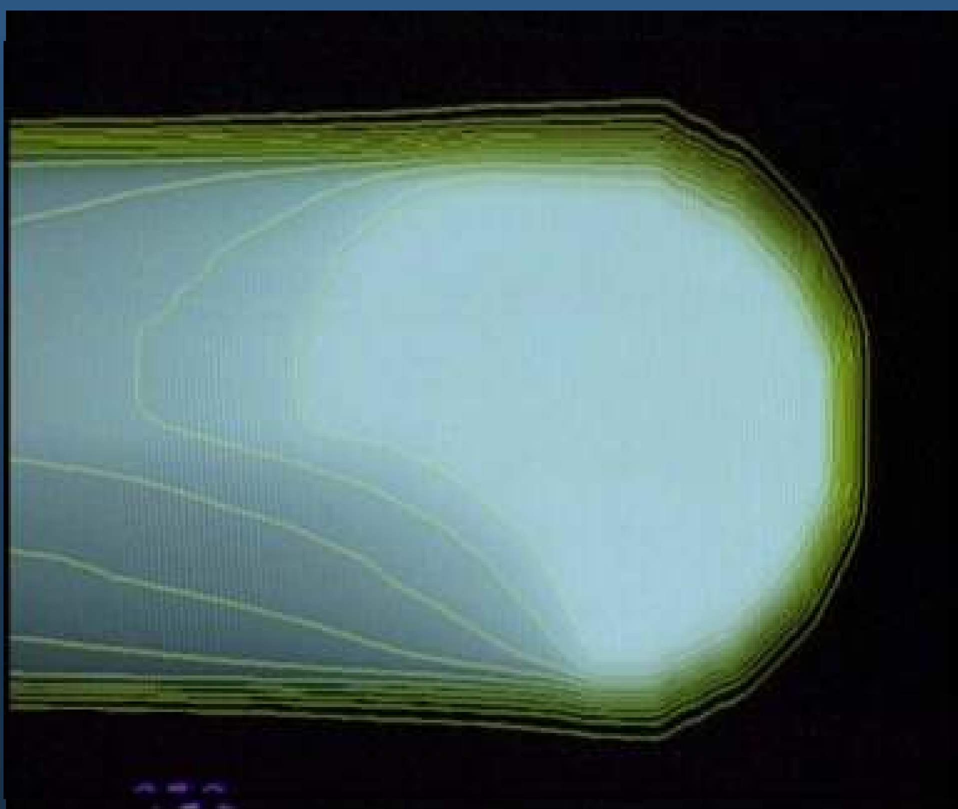
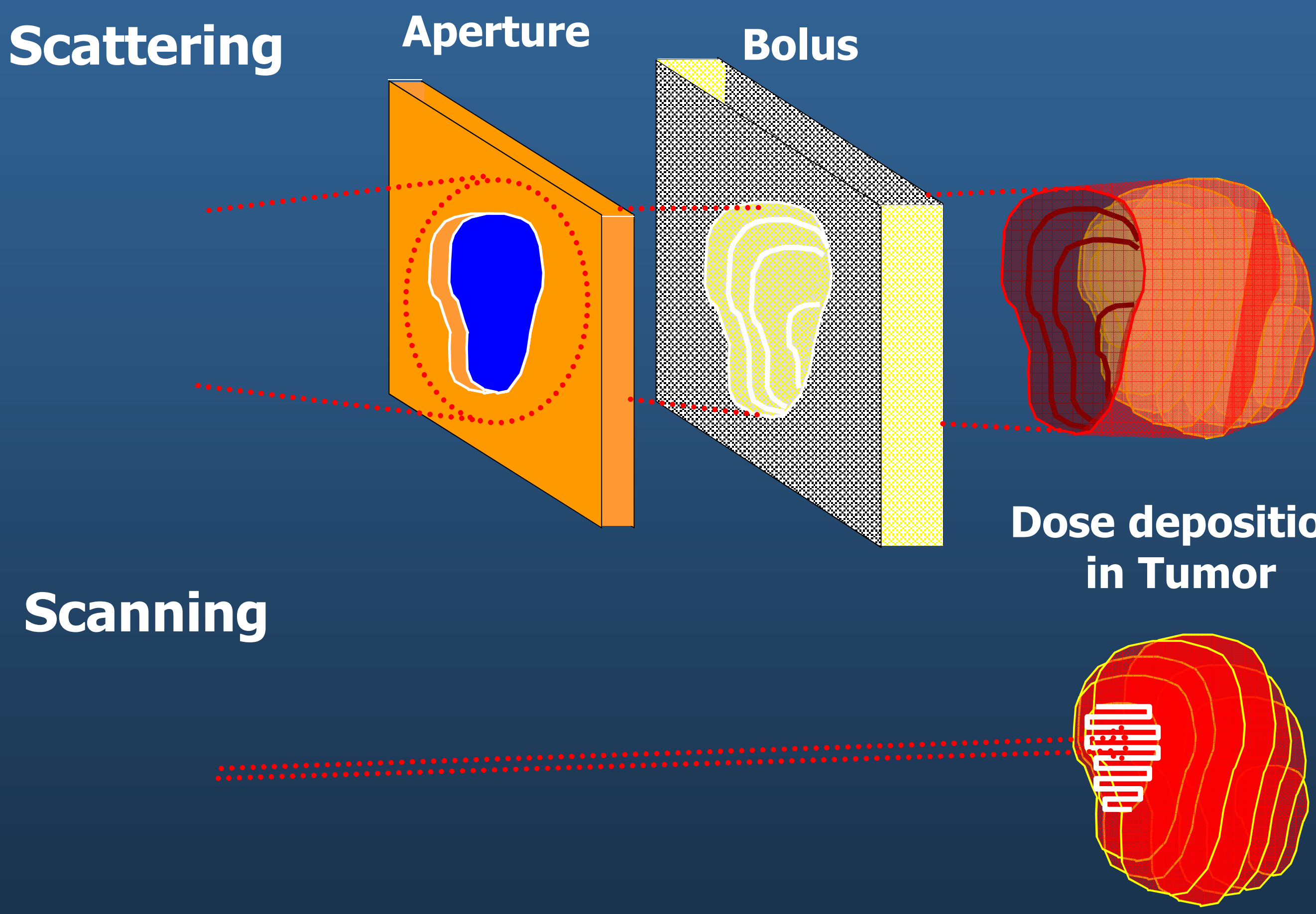
- **Deliver many small beams to a tumor using magnetic beam deflection.**
- **Energy is changed in accelerator to scan each successive layer.**



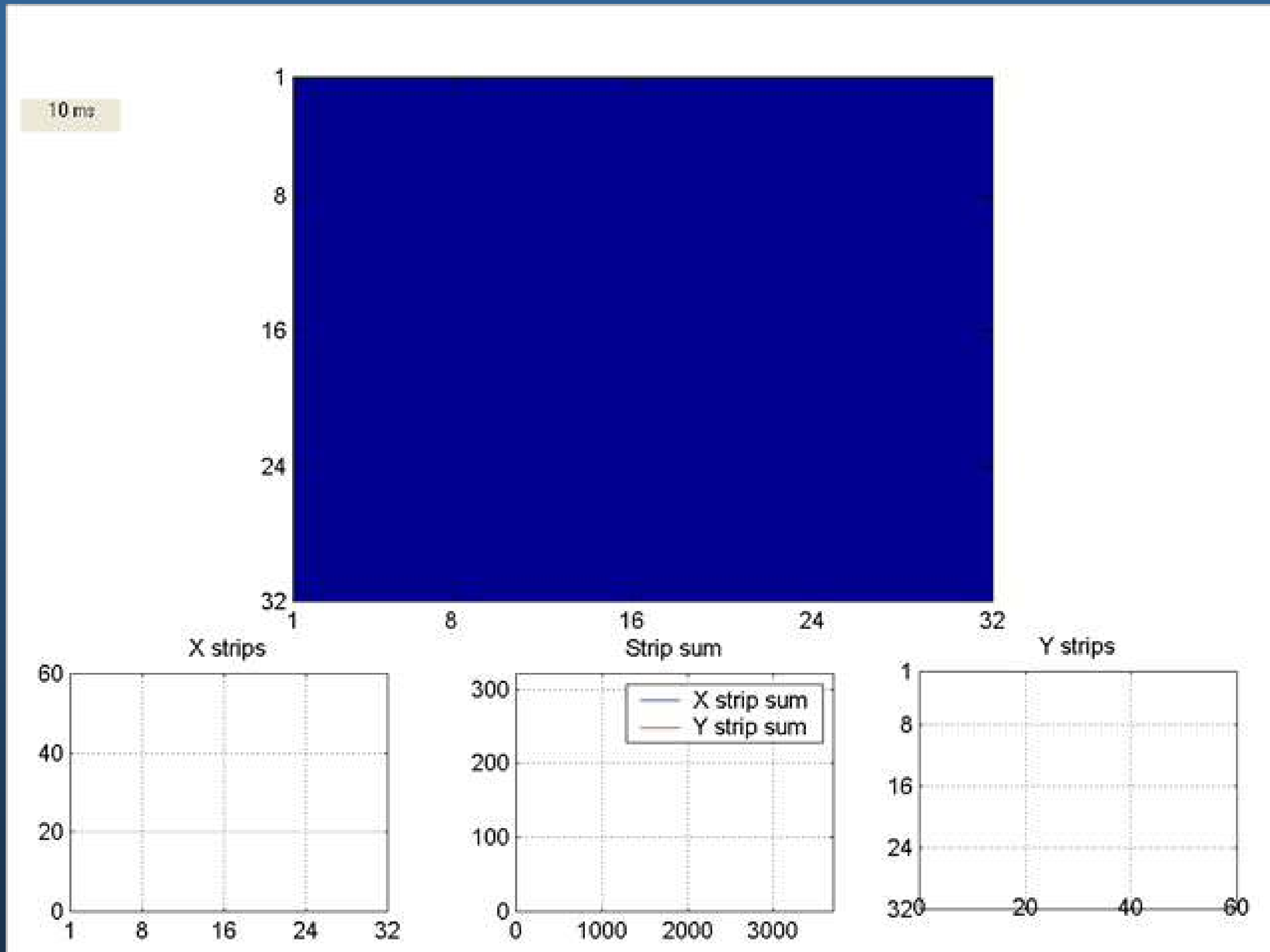
A full set, with a homogenous dose conformed distally *and* proximally

Pedroni, PSI

Advantages of PBS



Pure PBS nozzle status



Courtesy of H. Bentefour, *PBS physicist in MGH*

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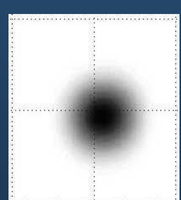
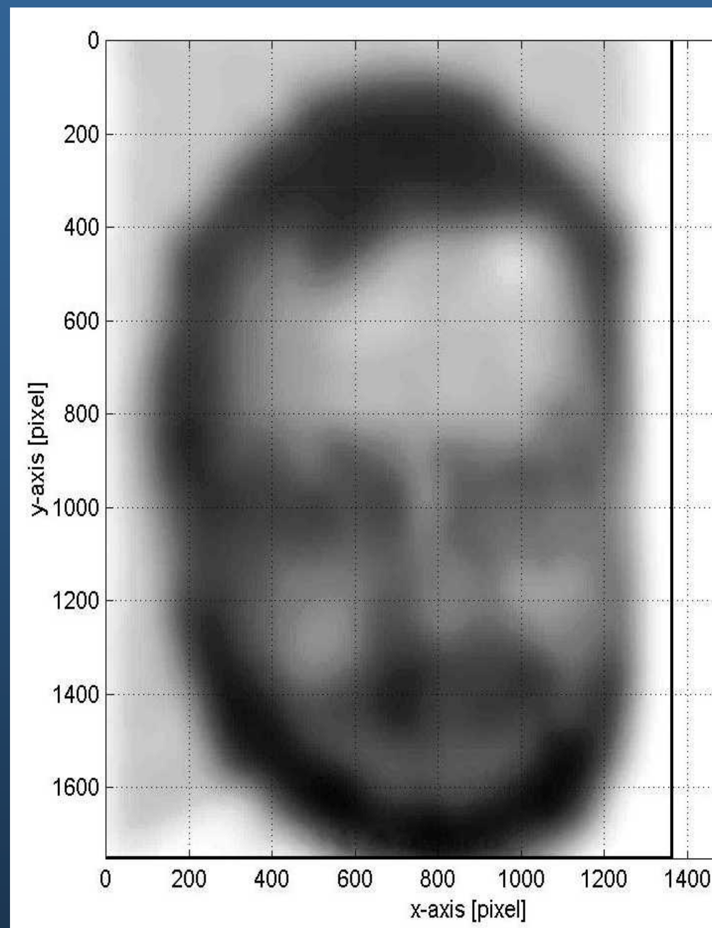
Scanning a Non-Uniform Dose Distribution

Spot size:



(σ = 10 mm)



- *# of passes: 1*
- *# lines: 50*
- ***irr. time: 4.5 sec***
- ***23 x 30 cm***
- *V = 250 cm/sec*

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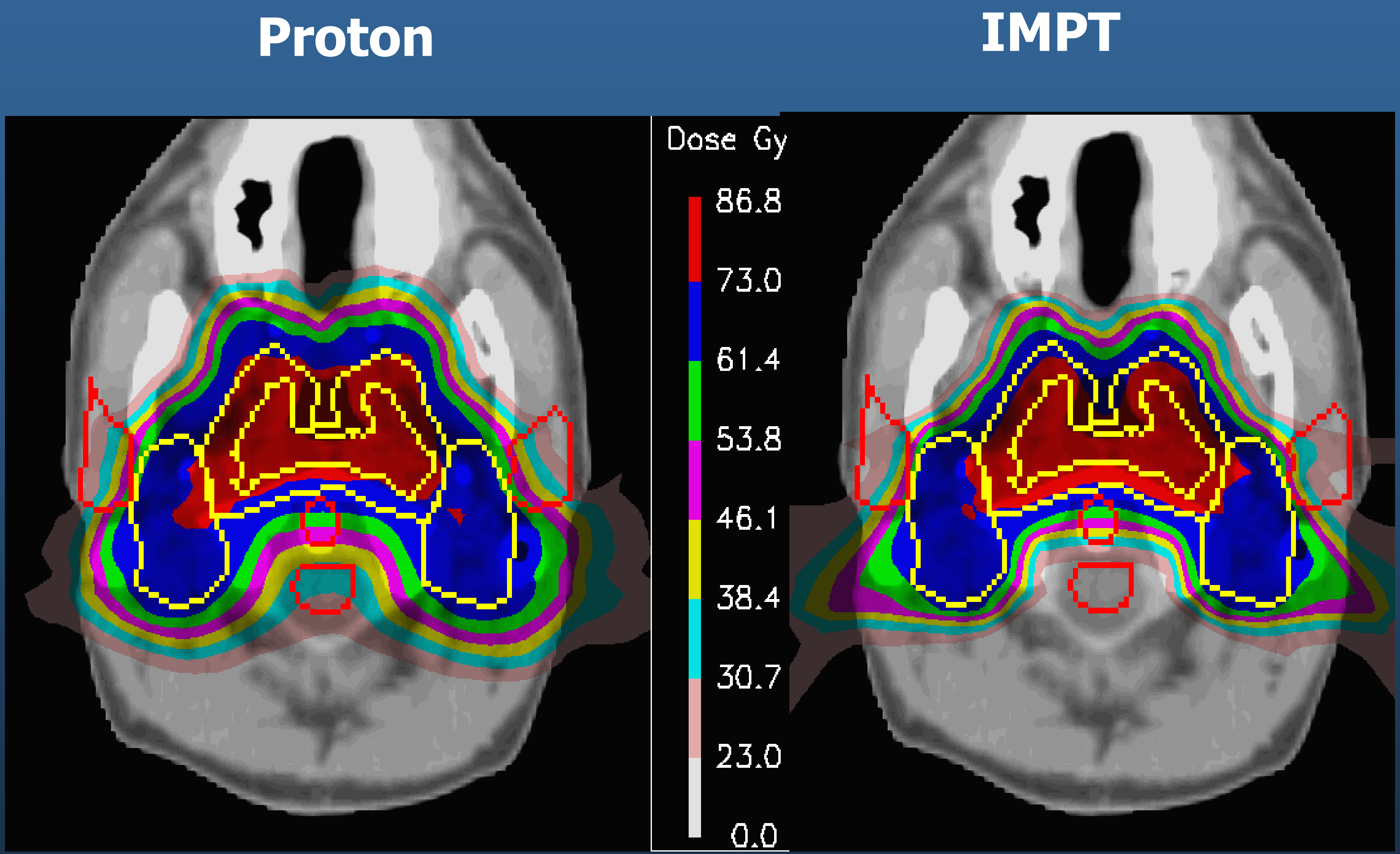
Improved Dose Distribution with IMPT



Lomax, PSI

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Commissioning

Commissioning?

- Refers to the process whereby the needed machine-specific beam data are acquired, and operational procedures are defined.: beam data acquisition, entry of beam data into an RTP system and testing of its accuracy, development of operational procedures, and training of all concerned with the operation of the new machine. (AAPM Report No. 47)

=> has strong dependency on beam delivery system and treatment planning system.

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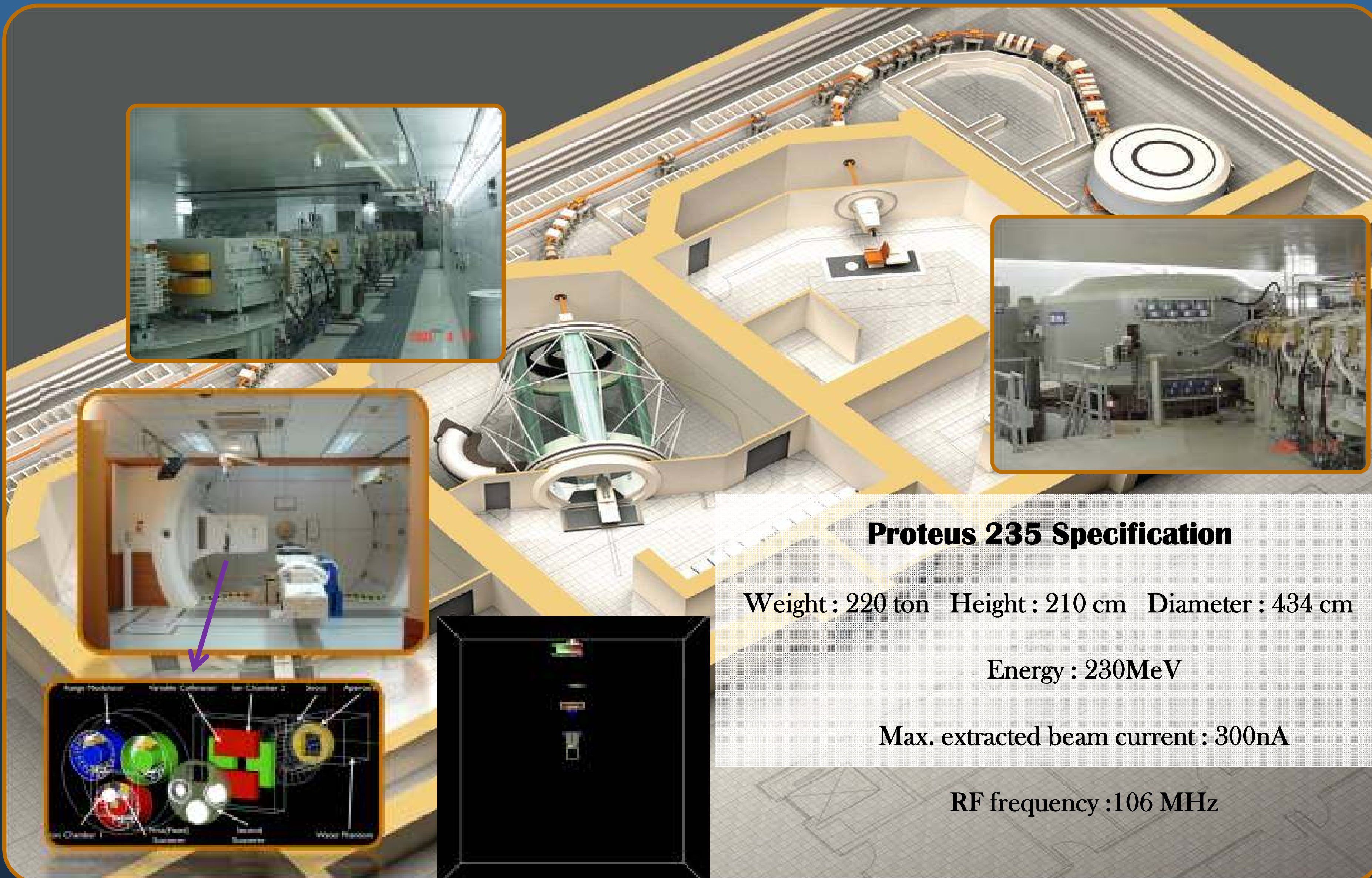
Proton Commissioning

- Safety Interlocks
- Dosimetric Calibration
- Mechanical
- CT HU to Stopping Power Calibration
- TPS Commissioning
- Imaging System Commissioning
- R&V System
- Beam Modifying Accessories
- Integration Testing
- Clinical Procedures

NCC Proton Therapy Center (IBA, Belgium)



Proteus 235 Specification

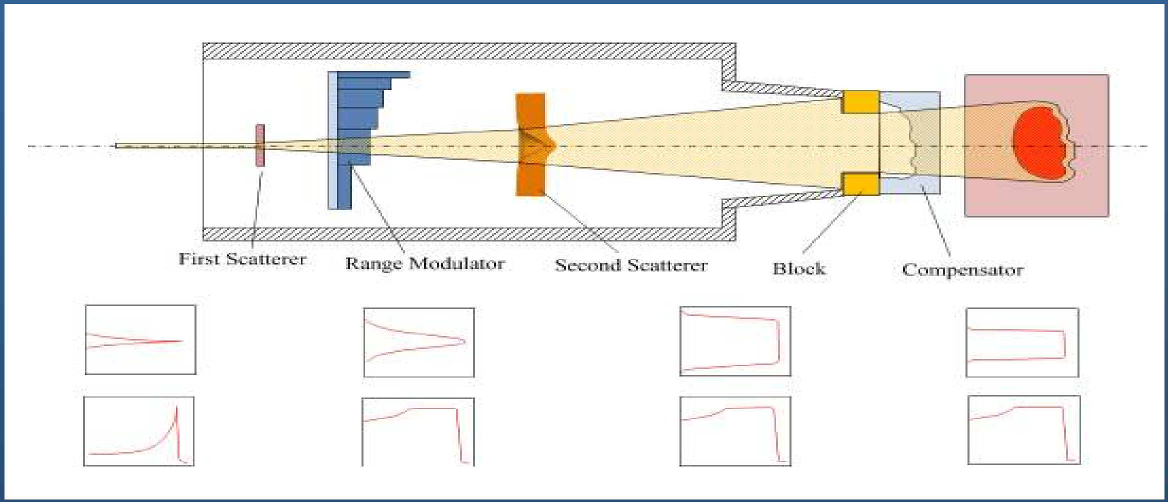
Weight : 220 ton Height : 210 cm Diameter : 434 cm

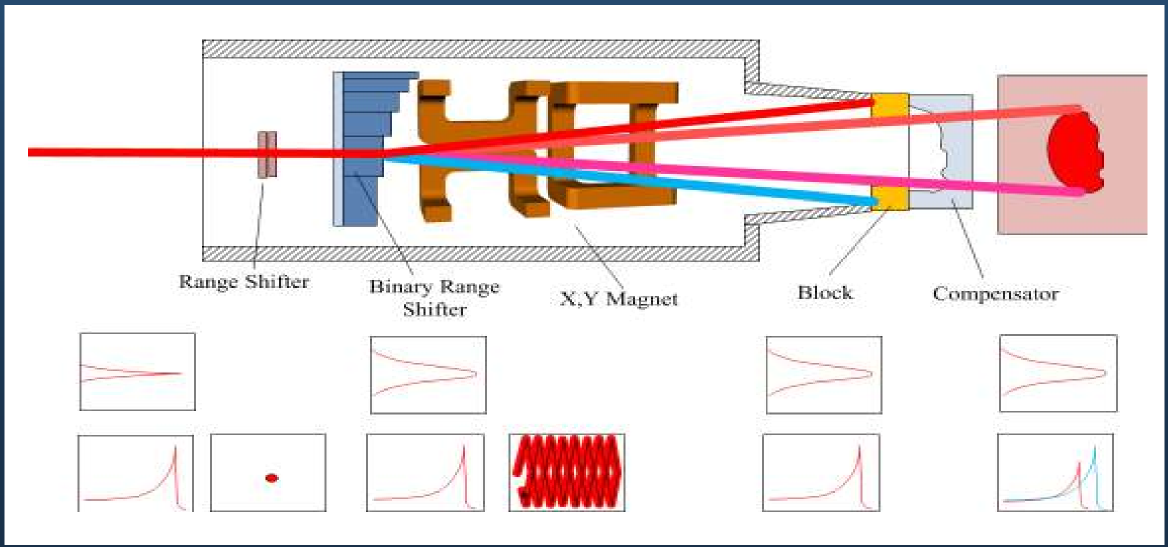
Energy : 230MeV

Max. extracted beam current : 300nA

RF frequency :106 MHz

Treatment Beam Modes





Universal nozzle

-Passive mode

Double Scattering

Single Scattering

-Dynamic mode

Uniform Scanning

Pencil Beam Scanning

Clinical Specifications of Proton Beam

Item	Single Scattering	Double Scattering	Uniform Scanning
Range in Patient (g/cm^2)	3.35-20.4	4.51-28.42	3.42-32.1
Range modulation (g/cm^2) adjustment & Size	0.4(R>6), 0.17 9.2	0.2 20.75	0.5 Full
Range adjustment (g/cm^2)	0.09(R>6),0.05	0.1	0.1
Average dose rate (Gy/min)	5.93	3	1.15
Max. Field Size (cm)	4 (D)	24.3 (D)	40X30
Dose Uniformity (%)	1.25	1.05	1.5(R), 2.6(L)
Effective SAD (m)	2.55	2.19	2.12
Distal Penumbra (cm)	0.21	0.23	0.13
Lateral Penumbra (cm)	0.17	0.48	0.30(y), 0.22(x)
	H&N, RS	Conventional	Large Size

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Schedule for Beam Data Taking and Commissioning

Room No.	Procedure	2006		2007											
		11	12	1	2	3	4	5	6	7	8	9	10	11	12
GTR2	Beam data library measurement														
	Commissioning & validation														
	Patient treatment														
GTR3	Treatment room Acceptance test														
	Beam data library measurement														
	Commissioning & validation														
	Patient treatment														
FBRT	Treatment room Acceptance test														
	Beam data library measurement														
	Commissioning & validation														

Treatment Planning System Issue

- Limited vendors and just enough support for a proton treatment planning
- Proton Therapy system has a complicated beam nozzle configuration and delivery option (Too many machine dedicated parameters on TPS).
- Compatibility issues among TPS, OIS and TCS. (Treatment beam parameters, Patient setup images, Aperture & Compensator data).

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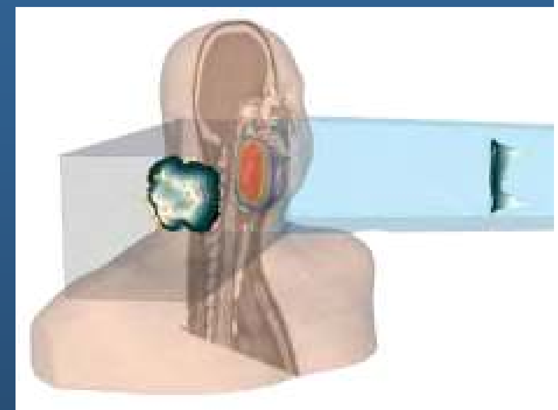
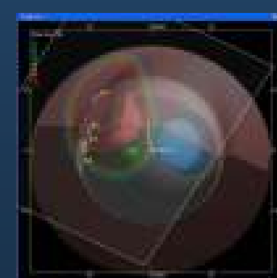
Proton Treatment Planning Systems

1. Varian, Eclipse (version 10.x, OIS - ARIA)
   : Scattering mode / Scanning mode



2. Elekta, XIO (v4.64, OIS-MOSAIQ)
   : Scattering mode/ Scanning mode

3. Ray Search Laboratories, RayStation
   : Scattering mode/ Scanning mode
   (under development)



4. Home made TPS for eye treatment

5. Etc..

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Prerequisites and Necessary tools for Beam Commissioning

Prerequisites

- The beam calibration is done by the machine vendor.
- The treatment control system is configured with the accurate beam parameters
- The dose monitoring system is calibrated to deliver one cGy per Monitor Unit (MU) in the reference field conditions. This task is the responsibility of a medical physicist.
- The treatment Room acceptance tests are passed by a medical physicist.

Necessary Tools

- Dosimetry tools
  - The 3D Water phantom and its associated software.
  - Ion chambers (parallel plate IC & Cylindrical IC) or diode detector
  - Multi-layer Ionization chamber
  - Electrometer.
  - Film
- Treatment beam parameter converting sheet for the treatment room (ex. ConValgo/WobAlgo for IBA PT system)
- Apertures with various sizes
- Spirit level, Ruler, Barometer & Thermometer.

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Beam modeling on Eclipse TPS

- Beam data required
  1. Depth dose curve → Depth dose
  2. Half beam block profile → Lateral penumbra
  3. Beam fluence along Z axis → Effective SAD
  4. Open field cross profiles → Virtual SAD
  5. Depth dose and Z fluence → MU calculation
  6. Cross profiles of spot fluence → Phase space

- Nozzle Stucture (Water Equivalent Thickness)
  1. Scatterers
  2. Range modulators
  3. Other parts on the beam path way

- Field size, Range option, Aperture & Comensator, etc.

McLaren

Example of Range Option

Double Scattering

Option	B1	B2	B3	B4	B5	B6	B7	B8
Range (cm)	4.6–5.87	5.78–7.49	7.49–9.55	9.55–11.65	11.65–15.54	15.54–19.83	19.83–23.91	22.8–28.2
SOBP (cm)	5.87	7.49	9.55	11.65	15.54	15.6	18	20.75
Field size (Φ cm)	12	12	11	11	11	11	11	7

Uniform Scanning

Option	Option1	OPtion2	Option3	Option4
Range (cm)	3.5–12	12–18	18–26	26–32.5
SOBP (cm)	0.35–12	0.45–18	0.55–26	0.6–32.5
Field size	30X40			

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Example of Beam Data Measurement

Per Option the following curves need to be measured				
Type	# Energies	# Position	# NET	Total
Depth dose curves (in water)	5	1 (Central axis)	1	5
Z Fluences (in air)	5	1 (Central axis)	3-5	15-25
X Profiles (in air)	5	4 (Z=+150mm,0mm,-150mm and 300mm)	1	20
Half blocked profile (in air)	5	4 (Z=+150mm,0mm,-150mm and 300mm)	3-5	60-100
			Total	100-150

150 measurement/option * (DS:8+SS:6+US:4) options = 2,700 measurements

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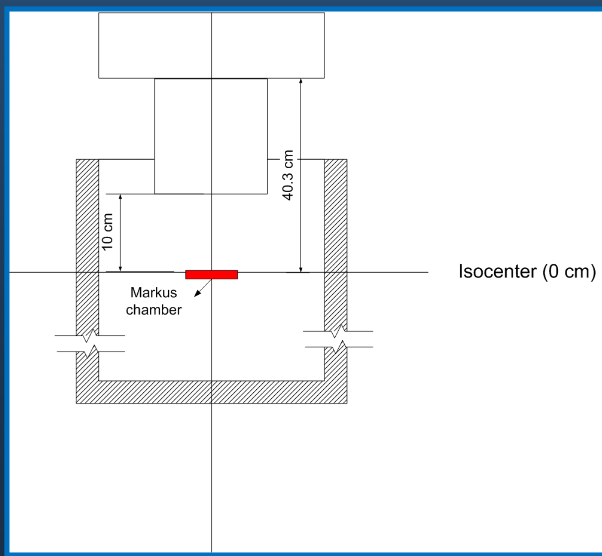
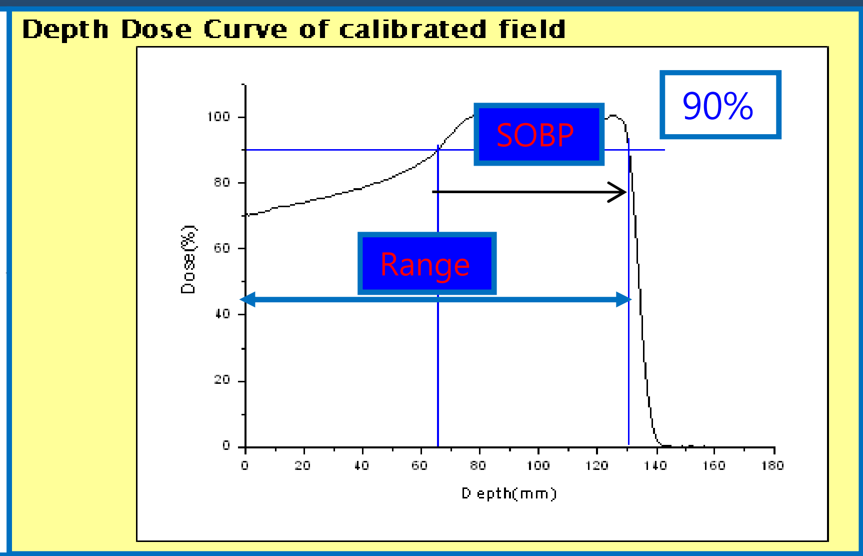
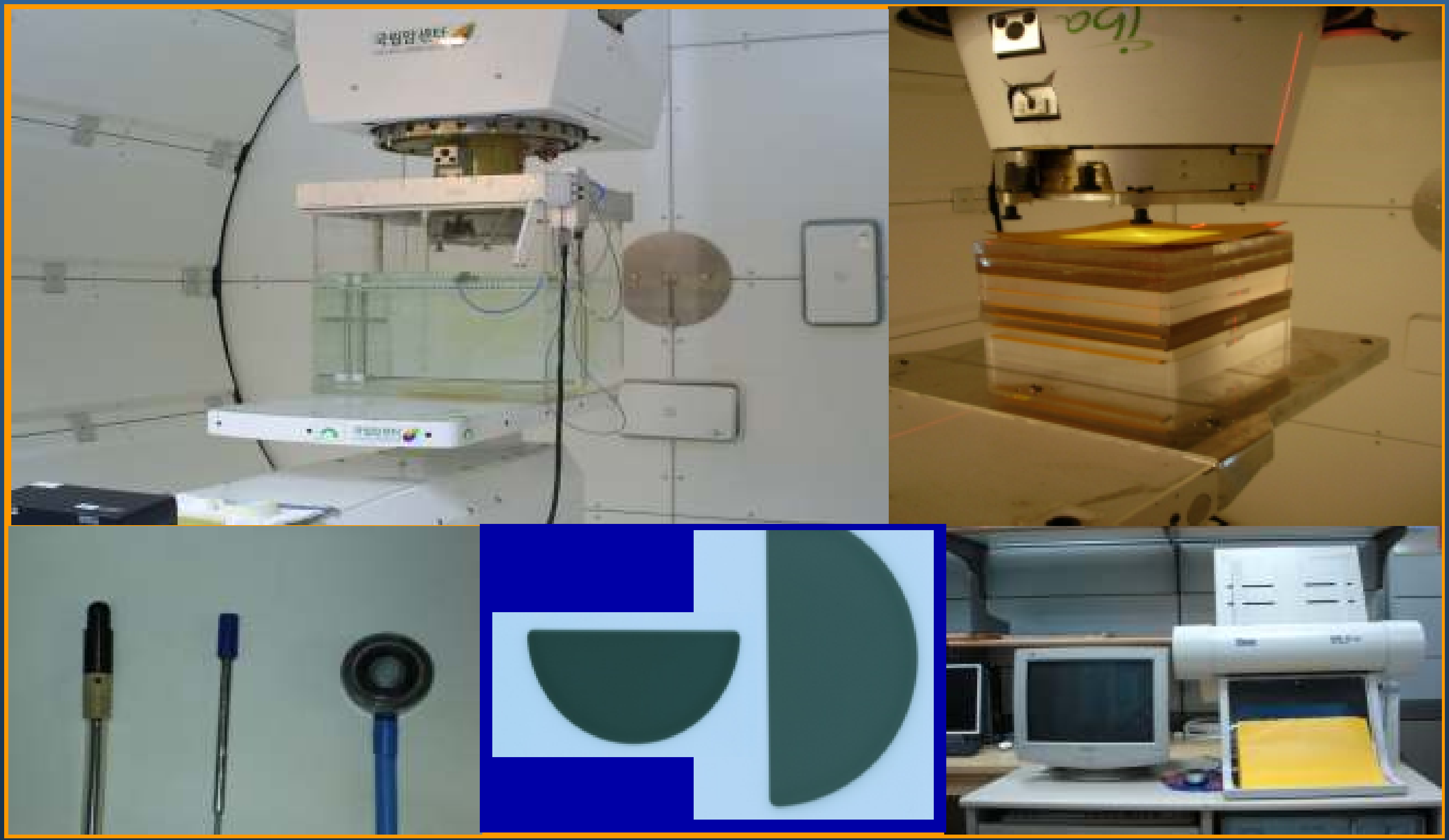
Proton Beam Measurements

- Output measurement (TRS 398)
  - Reference chamber : Farmer type
  - Small Field size : Pinpoint chamber
- Profile measurement
  - PDD, Distal Penumbra : Markus Chamber, MLIC
  - Lateral Penumbra : Pinpoint Chamber, Diode detector, Film (X-Omat, EDR2, and EBT)





Dosimetry Devices I



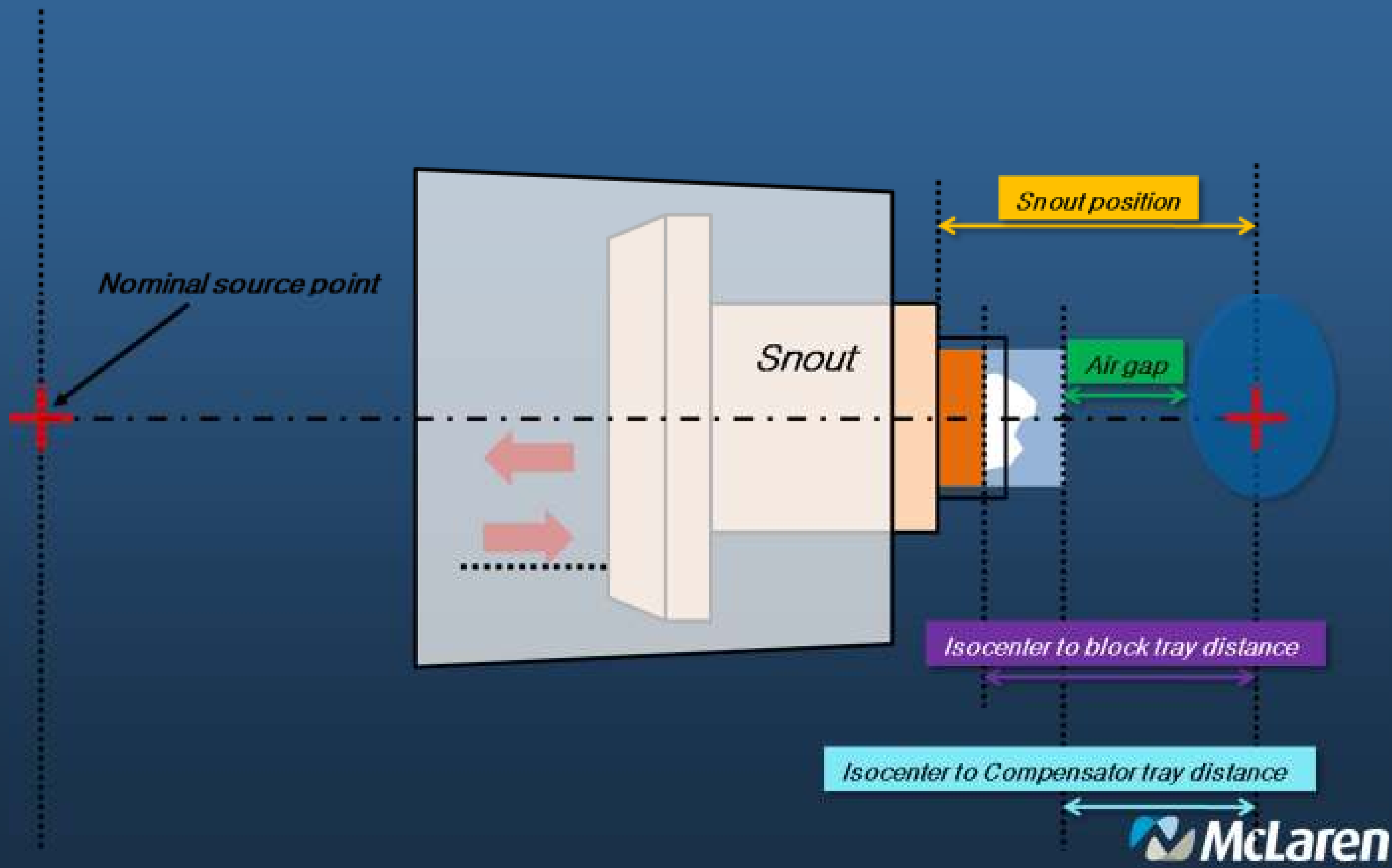
Dosimetry Devices II

There are several tools, useful for scanning beam.

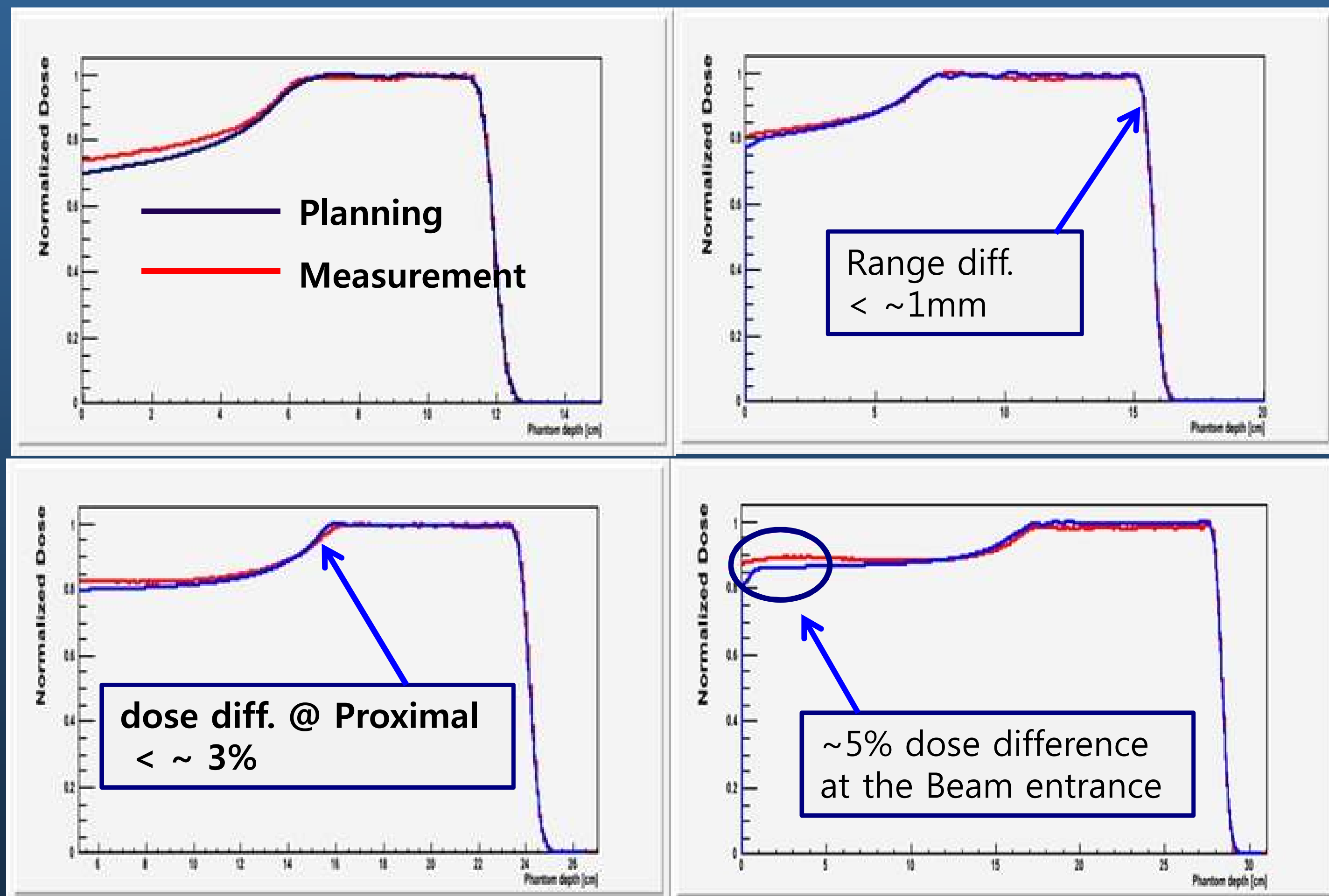
Some of them are essential and others can save your beam data measurement time.

Ex.) MLIC, Scintillation Plate type detector, 2D Array type Ionization Chamber, Large size PP type chamber, etc.

Snout Position and Tray Distances



TPS Validation Test: PDD Comparison (DS)



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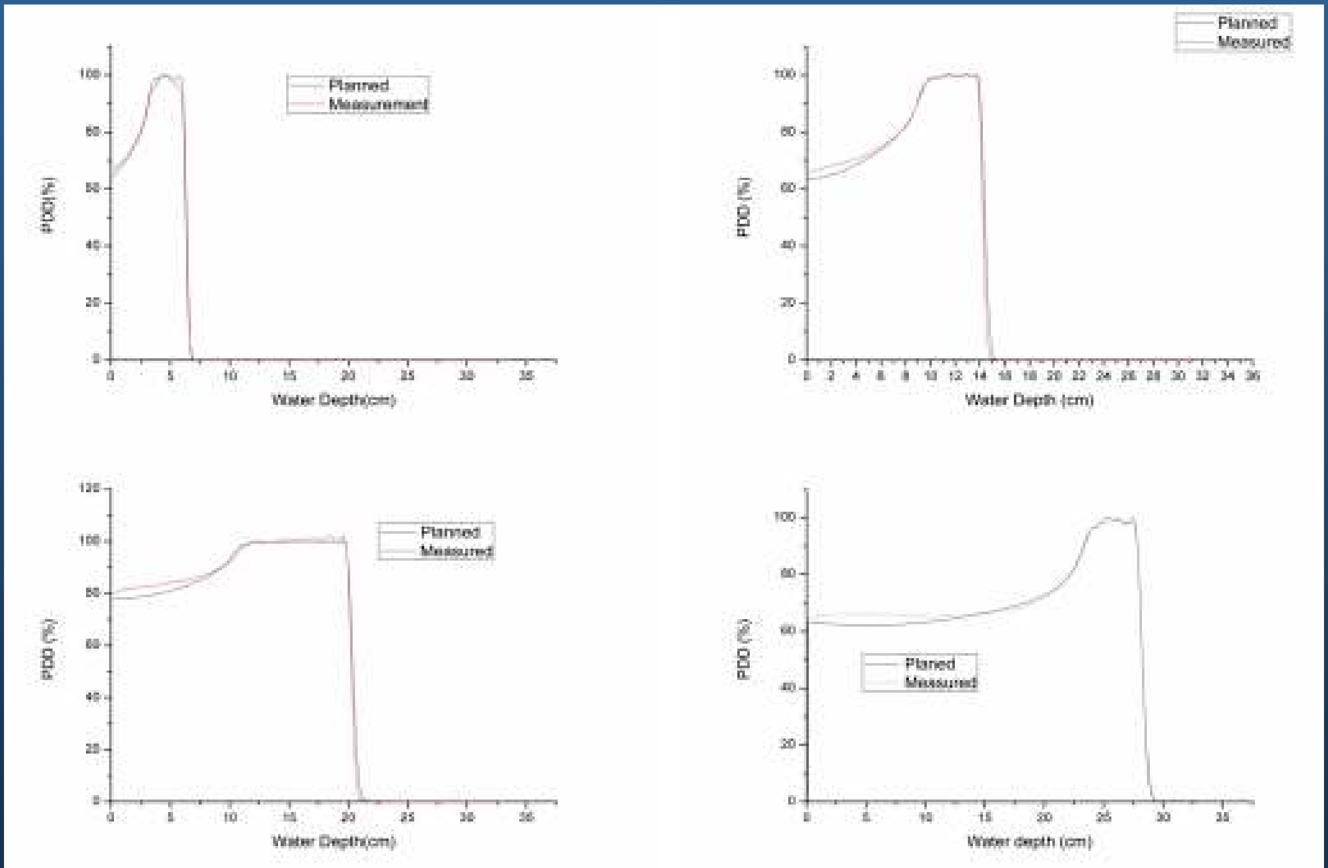
TPS Validation Test: PDD Comparison (US)



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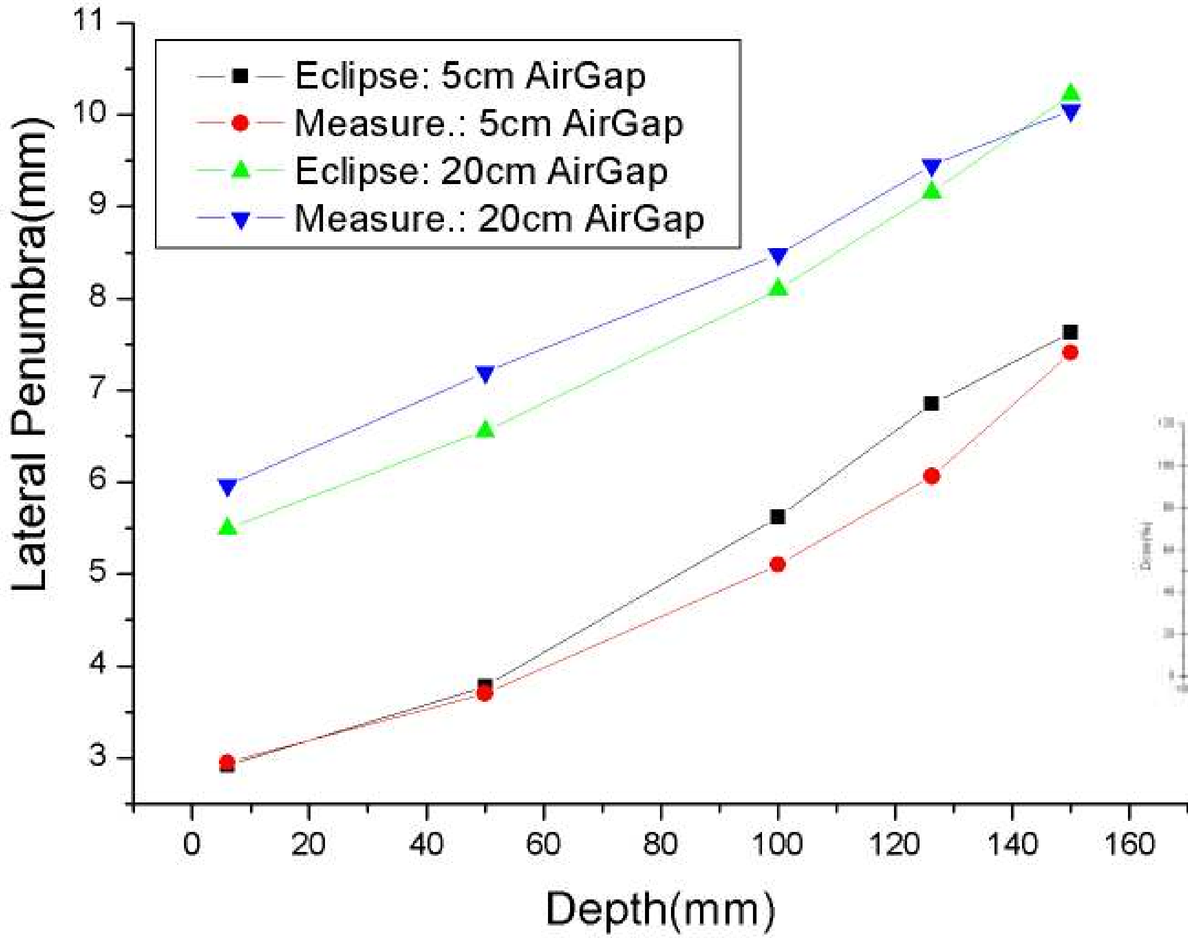
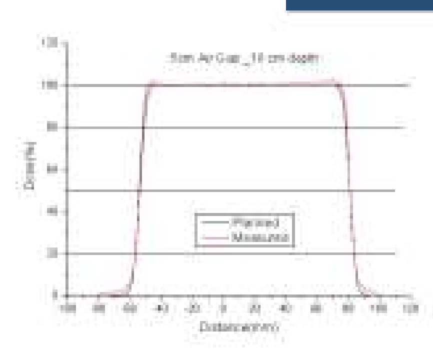
TPS Validation Test: Lateral Penumbra





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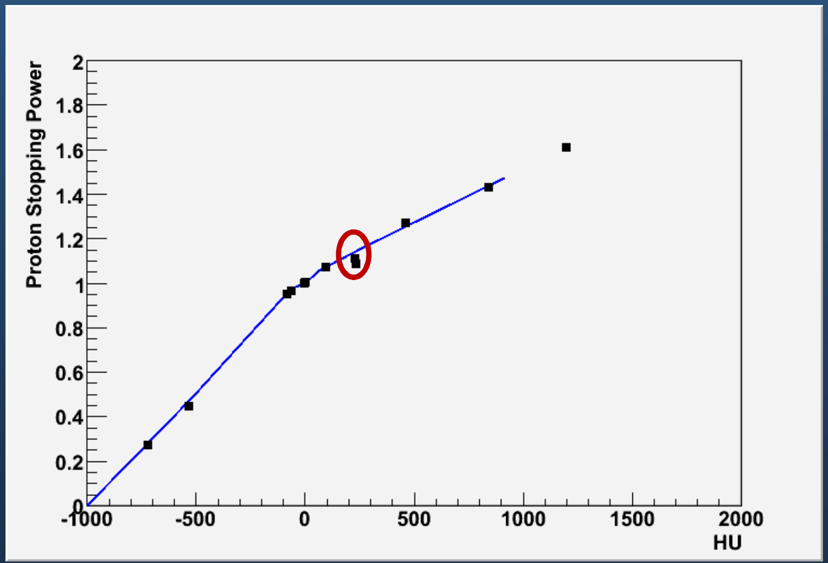
Dose Uncertainties in Proton Therapy

- Conversion from Hounsfield numbers to electron density does not exactly match with proton stopping power.
- Materials with different relative stopping power can have the same CT numbers.

Phantom	Density	Electron Density	Proton SP
CB2−50	1.560	1.470	1.431
LN−300	0.280	0.273	0.273
Adipose	0.941	0.924	0.949
LN−450	0.450	0.437	0.445
B−200	1.153	1.105	1.110
CB2−30	1.334	1.279	1.267
water	1.000	1.000	1.000
Brain	1.053	1.049	1.061
Breast	0.979	0.956	0.963
Solid water	1.017	0.988	1.004
Liver	1.094	1.062	1.070
Inner Bone	1.144	1.097	1.084
Cortical Bone	1.824	1.696	1.610



Ex.) CT number vs. Proton (SP)

Daily Morning QA with PMMA Phantom

Snout 100, Snout 180

PTW30013 type ion chamber
- Located at 10cm depth

Relative SP 1.158

Optimize Beam condition
Range : 14.07 cm
SOBP : 5 cm

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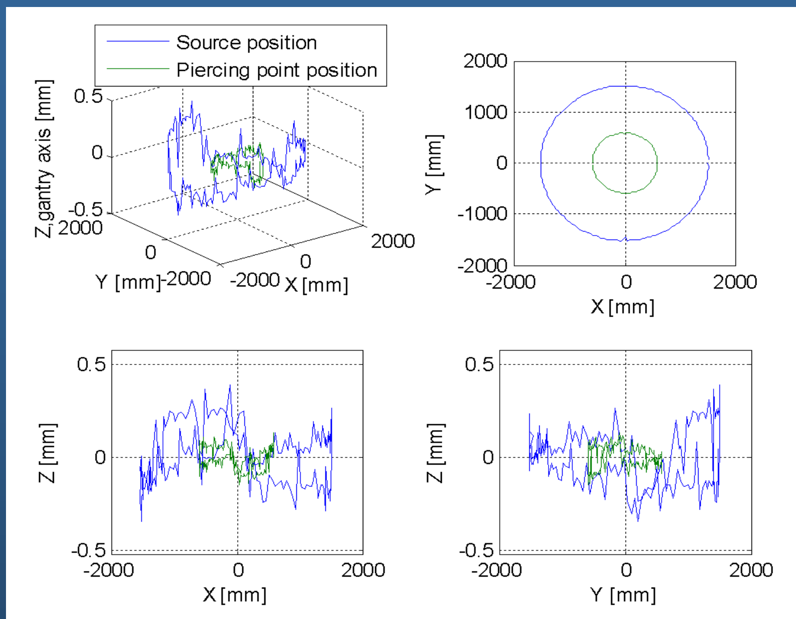
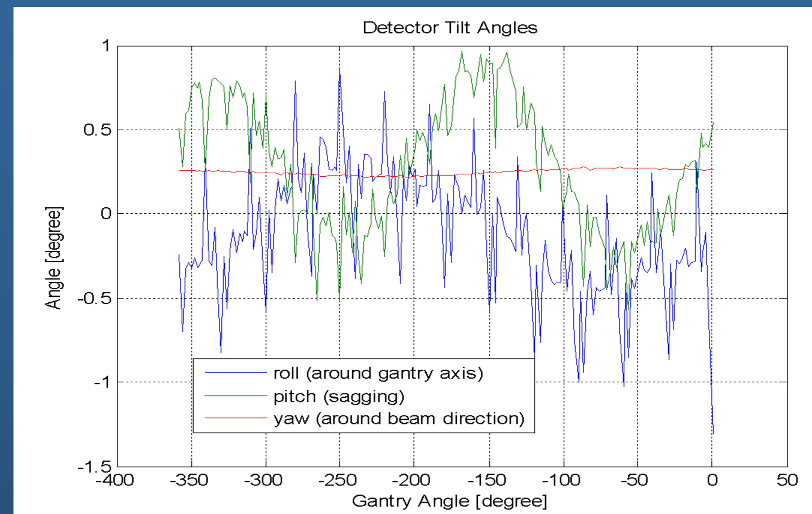
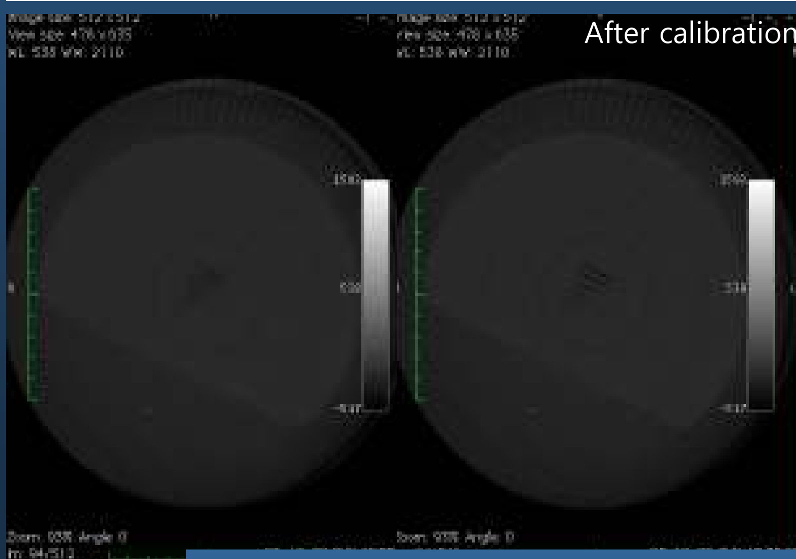
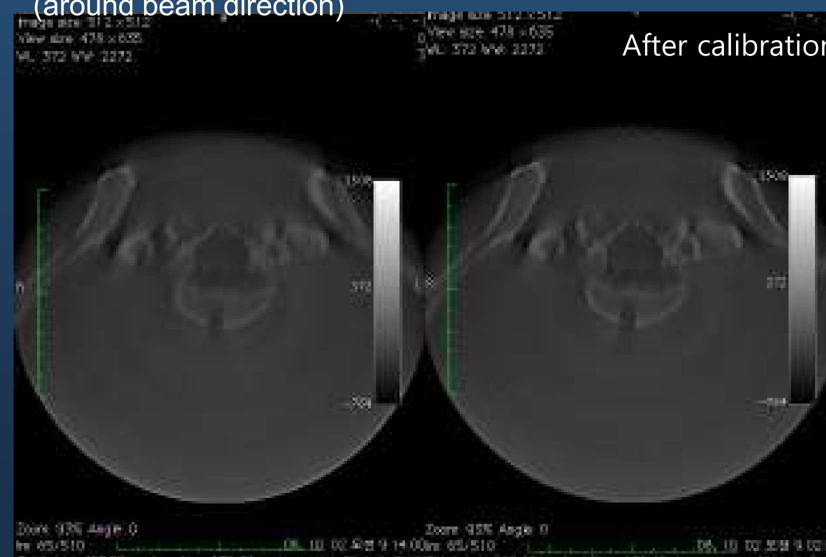
Calibration Results





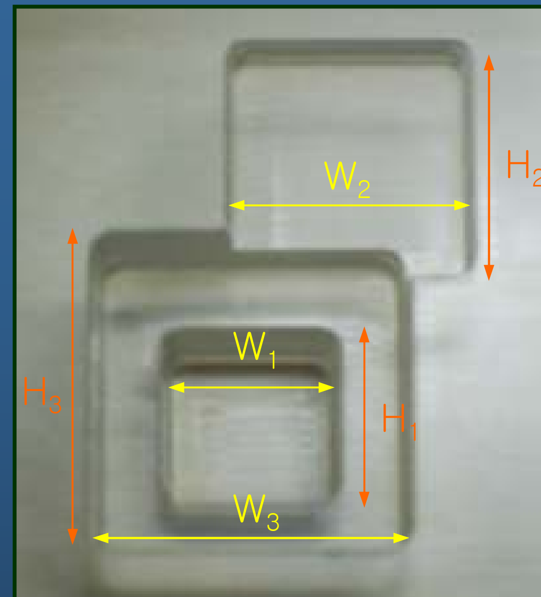
- Results from PMH.
- We need to calibrate the detector with 0.25 rotation yaw (around beam direction)





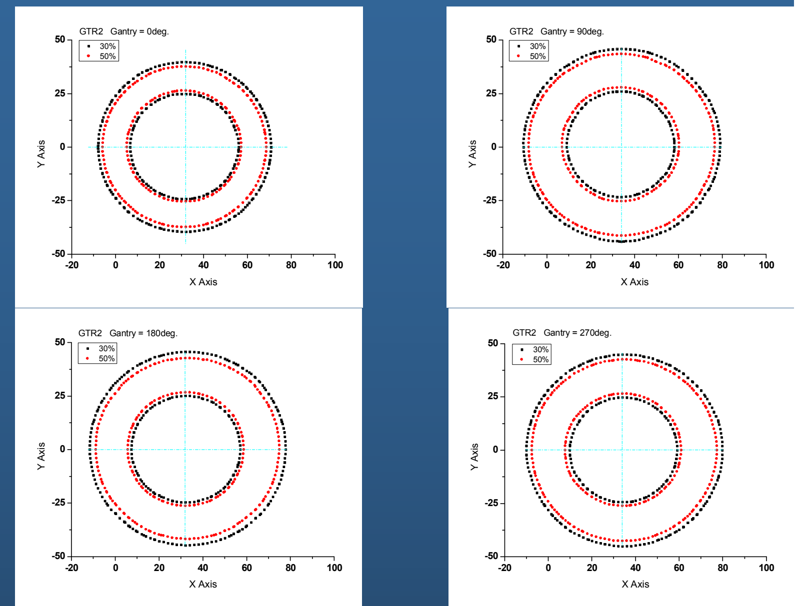
Kim JS, Park SY, et al., Korean J. Med. Phys., Vol. 19(4), pp. 209-18, 2008

Monthly QA Compensator Accuracy



	Plan				Machine data			Compensator			
	@220.5 (cm)	@230.0 (cm)	Norm. Diverg.	Design (mm)	Excl. Tool	Incl. Tool	Diff. (mm)	Upper	Lower	Diff. (mm)	Diverg. (deg.)
W1	24.2	25.3	1.0022727	20	19.2	24.2	0.0	24.7	23.8	−0.4	1.43
W2	33.7	35.1	0.9985228	30	28.8	33.8	−0.1	35.0	33.8	0.0	3.55
W3	43.2	45.2	1.0030797	40	38.3	43.3	−0.1	45.4	43.0	−0.3	3.42
H1	24.3	25.3	0.9981481	20	19.2	24.2	0.1	25.0	23.5	−0.7	2.39
H2	33.5	35.0	1.0016223	30	28.8	33.8	−0.3	34.8	33.0	−0.7	4.89
H3	43.3	45.1	0.9985491	40	38.3	43.3	0.0	45.5	43.0	−0.3	3.60
										공구 경사각	3.00

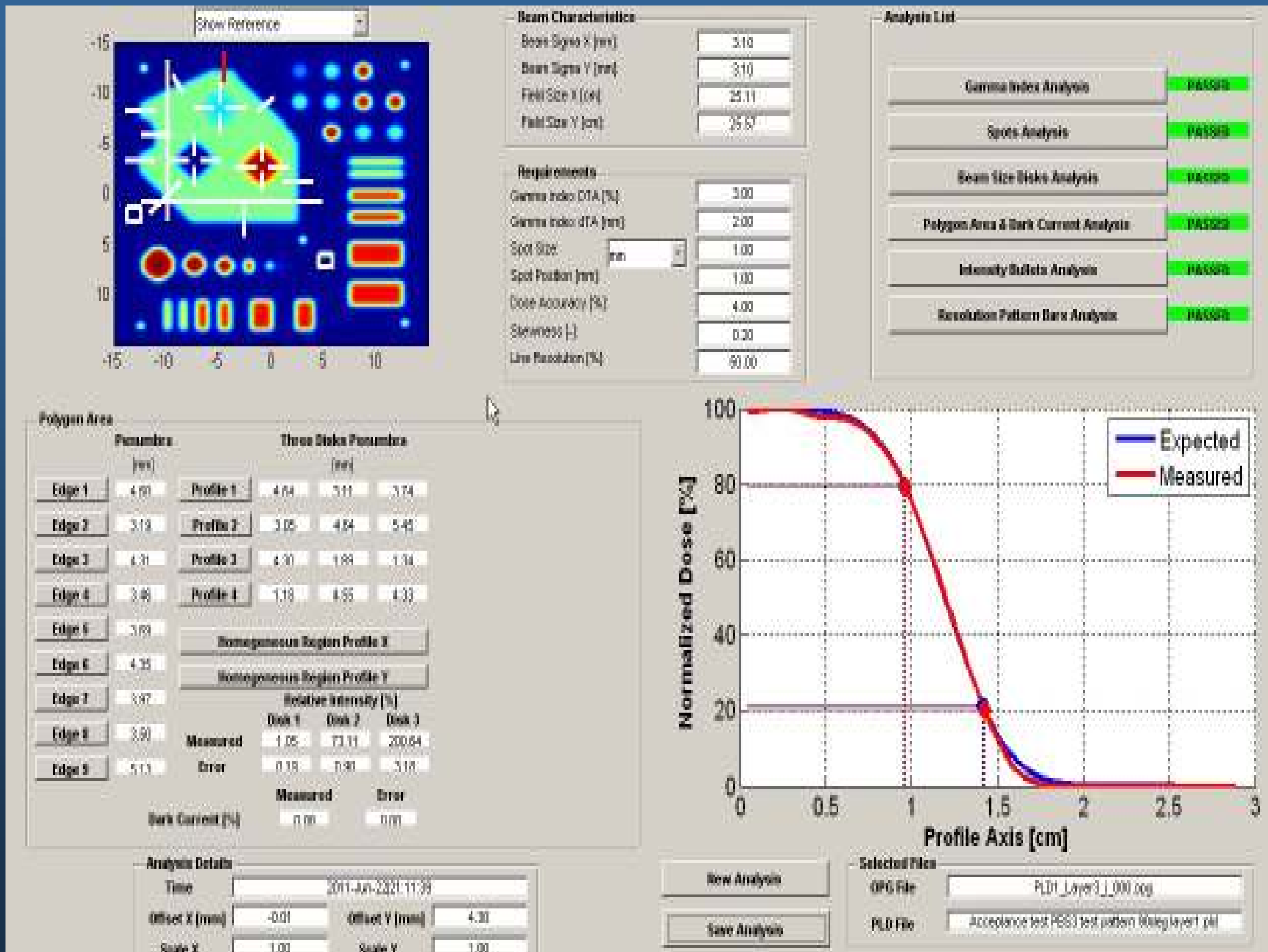
Monthly QA: X-ray alignment GTR1



Gantry angle	Coord.	DIPS (Rad A)	Isodose = 30%			Isodose = 50%		
			Field	Metal Ball	Diff.(mm)	Field	Metal Ball	Diff.(mm)
0	Xo	−0.046	31.35	31.35	0	31.4	31.2	−0.2
	Yo	0	0.15	0.35	0.2	0.15	0.5	0.35
90	Xo	0.046	34.15	33.55	−0.6	34.15	33.65	−0.5
	Yo	0	0.9	1.4	0.5	1.1	1.3	0.2
180	Xo	−0.046	33.05	32.2	−0.85	33.05	32.2	−0.85
	Yo	−0.046	0.5	0.25	−0.25	0.45	0.2	−0.25
270	Xo	0	34.9	34.45	−0.45	35	34.4	−0.6
	Yo	0.046	−0.1	0.25	0.35	−0.05	0.2	0.25

Test Pattern

Initiated by Jay Flanz. Developed originally as an acceptance test pattern via a collaboration between IBA, MGH, ProCure, Florida, Orsay, Essen, and Penn.



J. McDonough, 2012

Patient Treatment QA

- Field Calibration
  - Range & SOBP: Water Phantom, MLIC
  - Output: TRS398, Farmer Chamber

- 2D dose distribution comparison:
  - Measurement in 3D water phantom & TPS Dose calculation

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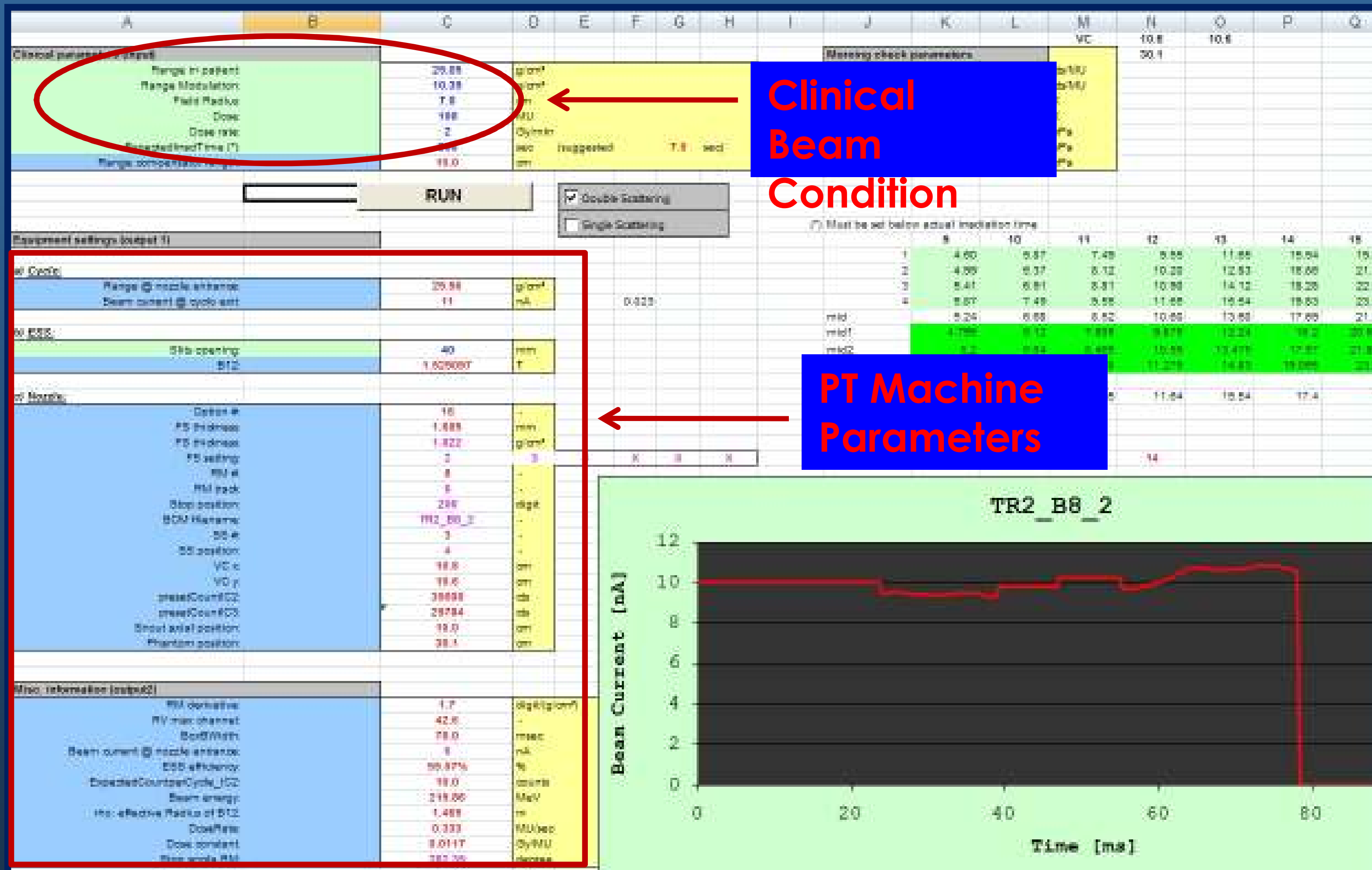
Beam Parameter Converting Algorithm (Convalgo)



- IBA provides the converting Algorithm for a beam delivery conditions
- However, it is not enough for our clinical beam delivery tolerance!

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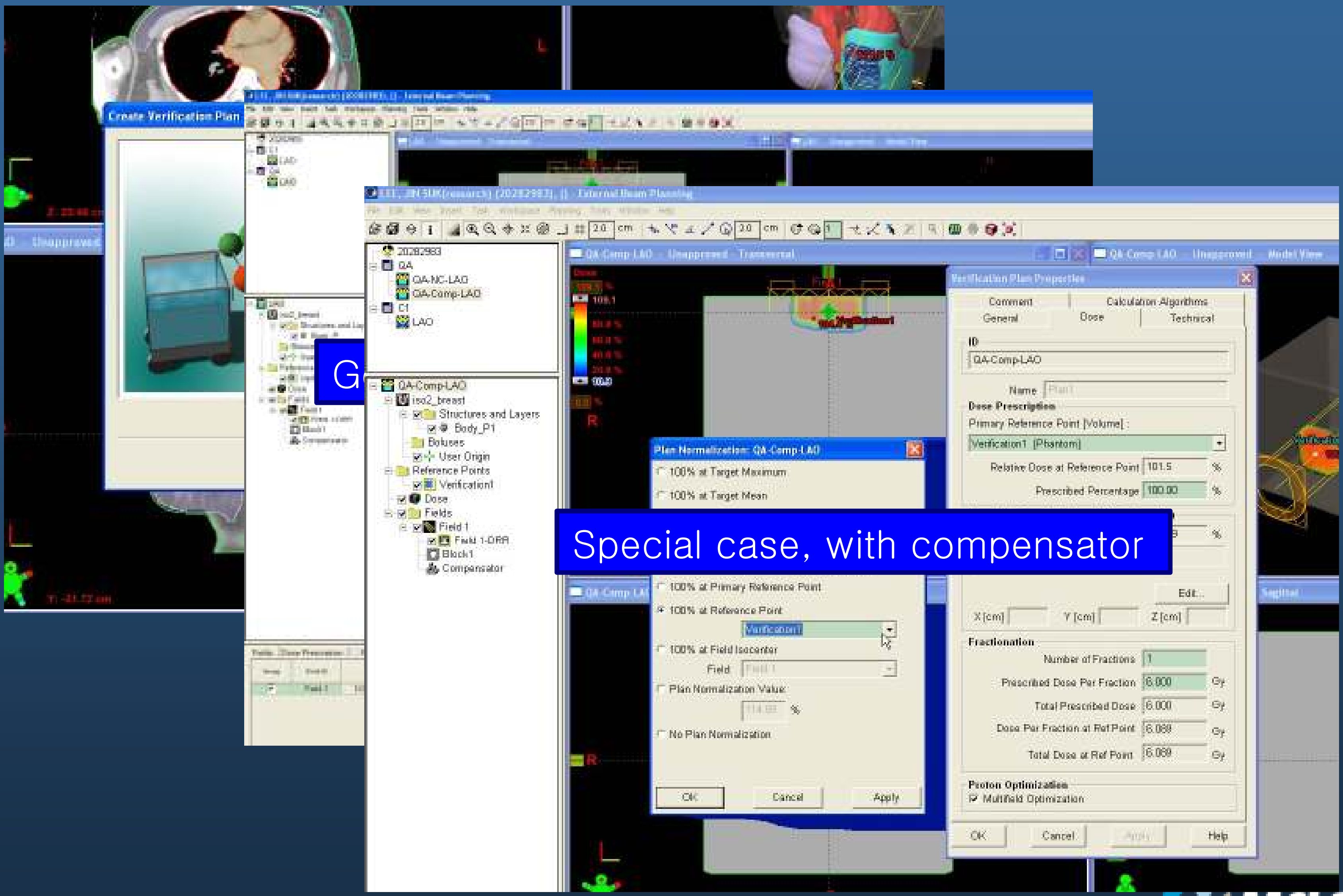
Example of Patient QA Plan



1. RTP parameter

Eclips GTR2-DS Proton_803

	Plan		Verification		Dose dist.	
Prescription Dose :	235	CcGE				
Range in patient :	25.05	g/cm^2			25.07	g/cm^2
SOBP width :	10.39	g/cm^2			10.27	g/cm^2
Snout position :	27.9	cm				
Air Gap :	2.0	cm	12	cm		
Gantry Angle :	270	°				
Couch Angle :	0	°	Option :		B8_2	
Setup SSD :	223.4	cm	Reference depth :		20.4	g/cm^2
Snout Size :	180		Range Modulator :		RM_8	

2. Range/SOBP calibration

Convalgo ver. GTR2 - 6.0_3.3.1

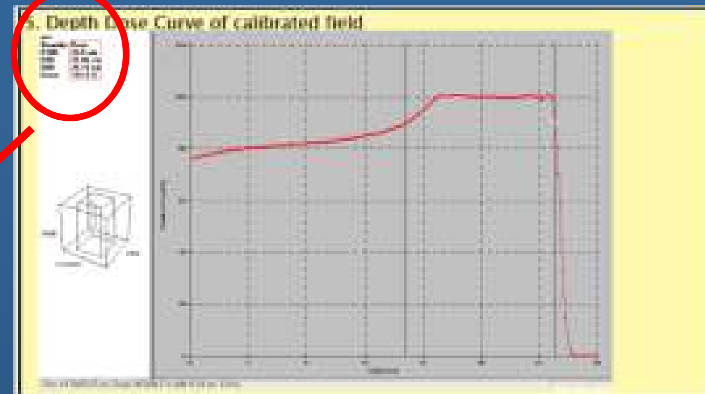
	Convalgo		Measurement			
	Range	SOBP	Range	SOBP	dRange	dSOBP
1	25.05	10.39	25.16	10.27	0.09	0
2	24.96	10.39	25.07	10.3	0	0.03
3						
4						
5						
final	24.96	10.39	25.07	10.3	0	0.03

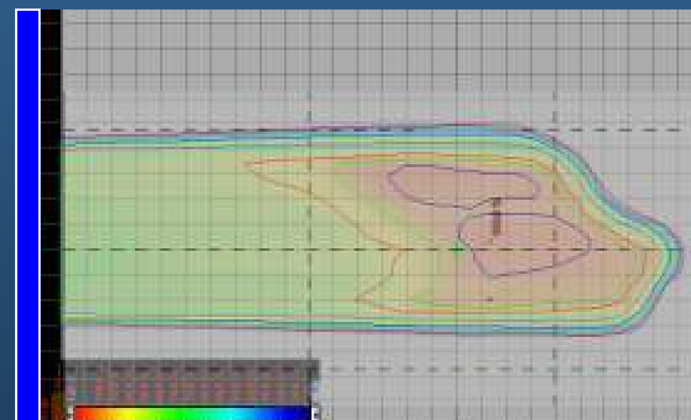
3. OutPut Calibration

PTW30006-04073 Ks = 1.002, Kpol = 1.000, Ndw = 0.05424

Range in patient :	25.07	g/cm^2	Temperature :	22.84	°C
SOBP width :	10.3	g/cm^2	Pressure :	1019.2	hPa
Reference depth :	20.4	g/cm^2	Dose at V.P. :	209.8	CcGE
Practical Range :	25.88	g/cm^2	RBE Correction :	1.1	CcGE/cGy
Dosimeter output :	50.8	50.7	50.7	Average : 50.73	nC/200MU
Beam quality factor :	1.030		Calibration MU :	200	MU
Output Factor :	1.416	cGy/MU	PT factor :	0.997	
Expected :	1.387	cGy/MU	Physical Dose :	190.73	cGy
Difference :	2.08	%	Treatment MU :	134.69	MU

item	CRange	CSOBP	MRange	MSOBP	Output
DB	24.96	10.39	25.07	10.30	1.4164
Meas. – DB	0.00	0.00	0.00	0.00	-0.0003





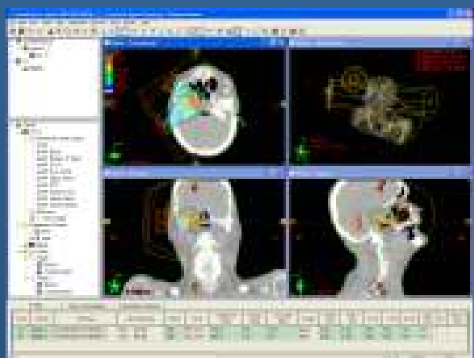
Patient QA working Sheet in NCC :

Range, SOBP, Output

(& 2D dose distribution)

Patient QA Procedure

TPS

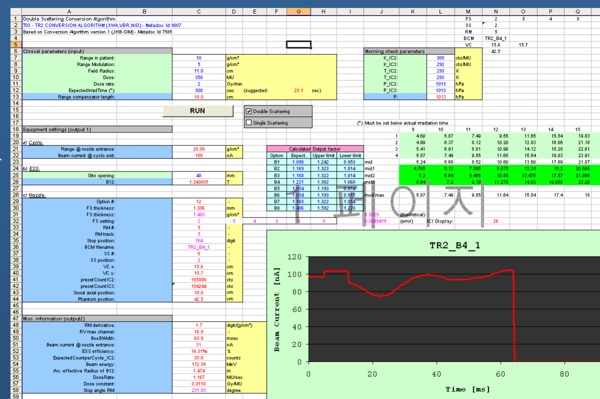


Treatment Planning

→ Range, SOBP, Dose calculation

→ MU calculation accuracy (??)

Conv. Algorithm



Beam Parameter Generation

Beam Measurement

Fine-tuning the beam parameters to give the planned beam conditions

Tolerances for Tx.
- Range : 1~2 mm
- Output : 3%

Time consuming job : ~ 2hrs/patient

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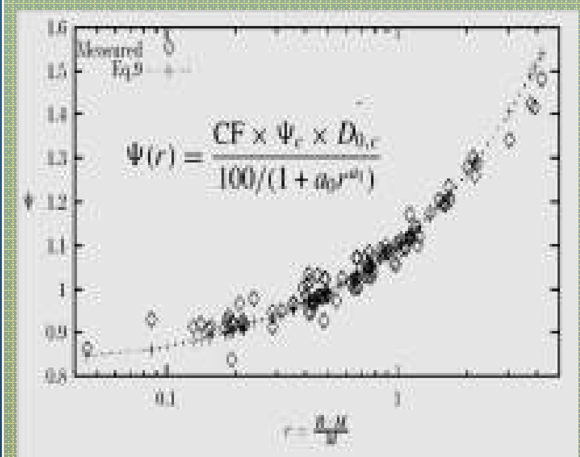
DB based Prediction for Output Factor, Range, and SOBP

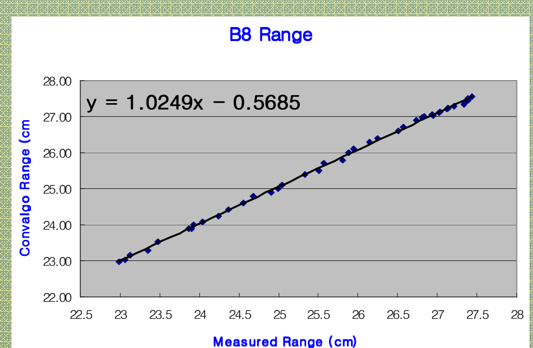
Output

* Hanne Kooy's paper(MGH)



Ψ : Output factor
Ψ_c : Output factor (calib)
CF : Constant related RM opt.
$D_{0,c}$: Entrance Dose (calib)
r : r = (R-SOBP) / SOBP
a_0, a_1 : theoretical values

Range

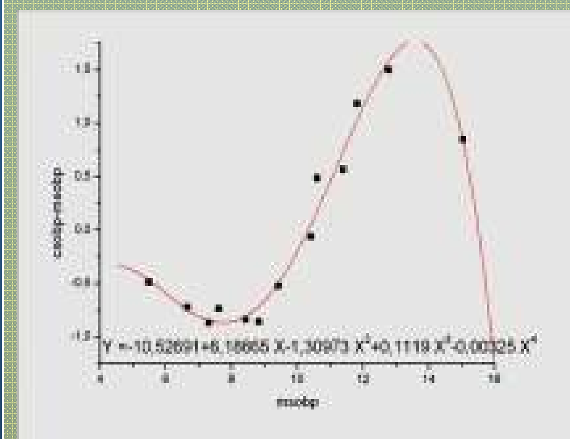


ConvAlgo vs. Measurement data

Linear Func. Fitting Method

→ Y = P1*X + P2

SOBP



ConvAlgo vs. Measurement data
4 degree Func. Fitting Method

→ $Y = P1*X^4 + P2*X^3 + P3*X^2 + P4*X + P5$

* PMB, 50 (2005), p5847-5856

→ Patient QA can be covered by the DB based prediction methods.
→ used for the independent check of QA.

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McLaren Proton Therapy Project

Architectural rendering for MPTC and MCI

Total Construction = 52,434 SF
MPTC new construction = 42,093SF
MCI renovations = 10,341 SF

en

Space Layout for the MPTC

- Compact synchrotron and three 180° isocentric gantries
- IGRT using CBCT, CT-Sim and PET-CT imaging modalities
- Treatment set-up room external to the treatment rooms

McLaren Project schedule

- Contract signing with Equipment Vendor: 3/12/10
- Contract signing with Design-Build Team: 7/6/10
- Building ready for Equipment Installation: 7/1/11
- Major equipment Installation Complete: 7/20/12
- Technical Commissioning Completed: 11/30/12
- Acceptance Tests Complete: 12/16/12
- Clinical Commissioning Completed and First Treatment Begins: 3/12/2013

~ *3 yrs*

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Selected McLaren Specifications

- Pencil beam scanning for IMPT and SFUD
- $\Delta E/E$ of beam at extraction: $\leq 0.2\%$
- Maximum treatment field size: 40 cm x 30 cm
- Beam penetration: 4 – 37 g/cm^2
- Spot sizes in air at isocenter (1 σ): 3 mm to 7 mm
- Beam spill length (flat top): 0.1 to 5 s
- Time between beam spills: ~ 1 s
- Beam intensity: variable within spill. DR ~10:1
- Time to treat 0.5 liter volume to 2 Gy: $\leq$ 1.5 m
- CBCT for image-guided setup and verification
- Proton Tomography to be developed

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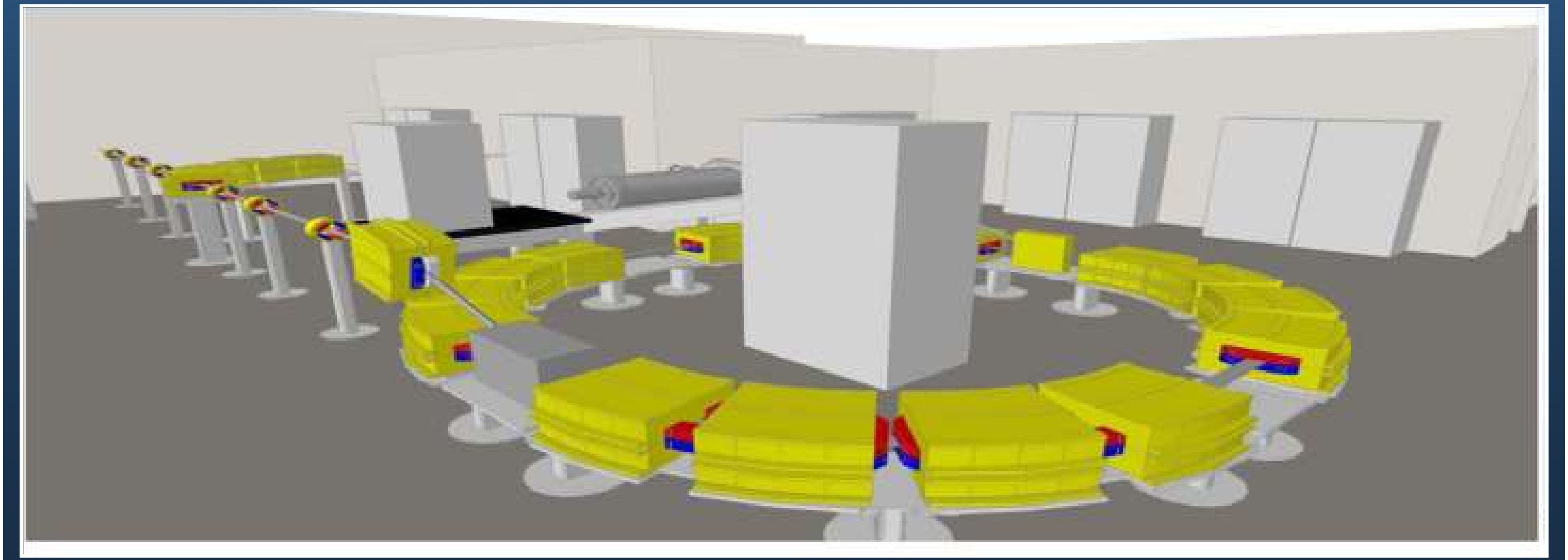
ProTom International
Scanning Optimized Synchrotron

Total weight = 15 tons
4.9 m diameter

70 – 250 MeV for treatments
330 MeV for Proton tomography
Variable extraction sequence
Variable intensity




PHOTON
PHOTON
PHOTON

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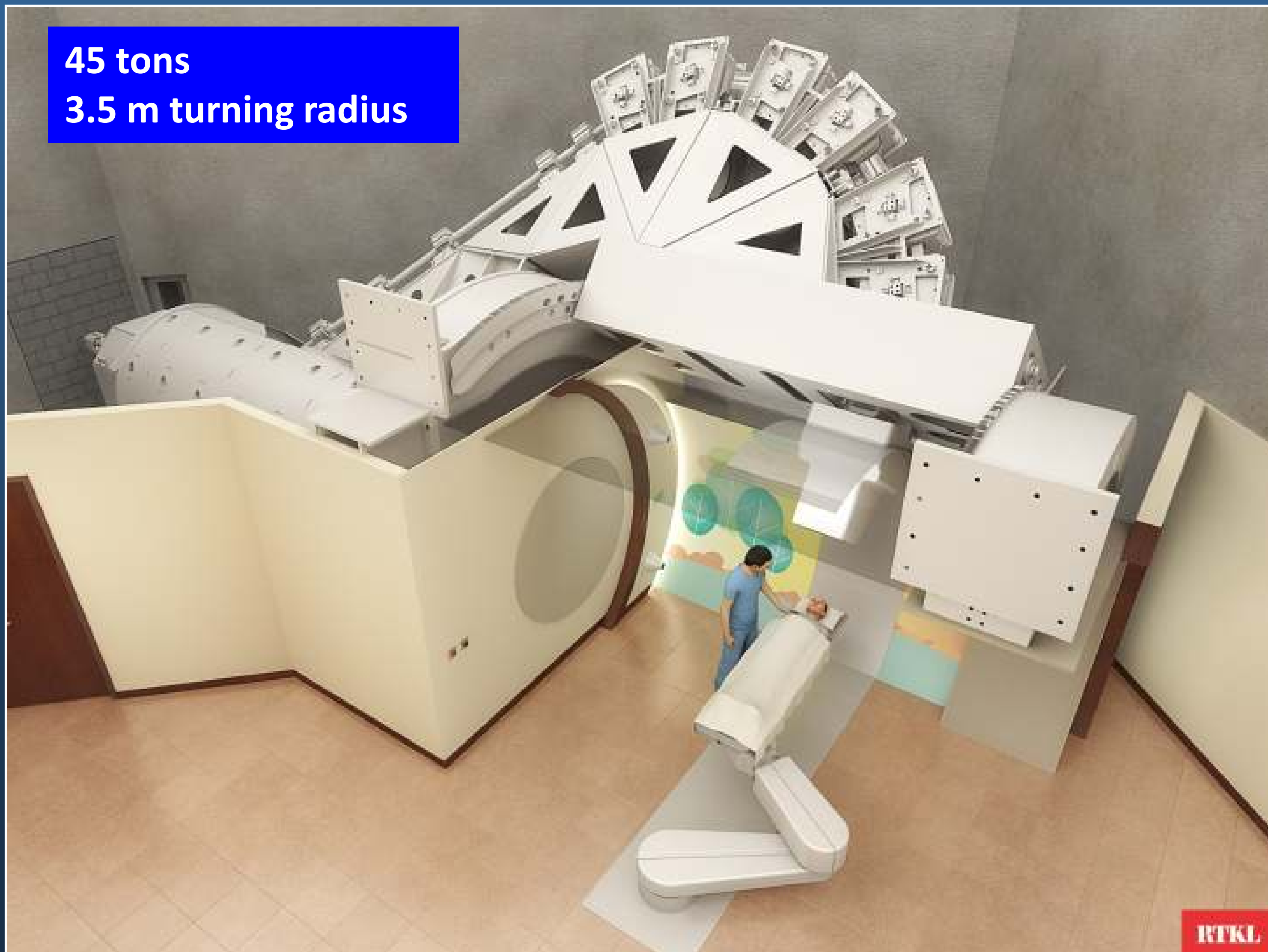
ProTom International Isocentric Gantry

180 degree rotation coupled with robotic patient positioner provides complete 360 degree treatment beam entry angles for patient treatments.



McLaren Proton Therapy Center Flint, MI

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McLaren Proton Therapy Center Front Lobby

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Hospitality House

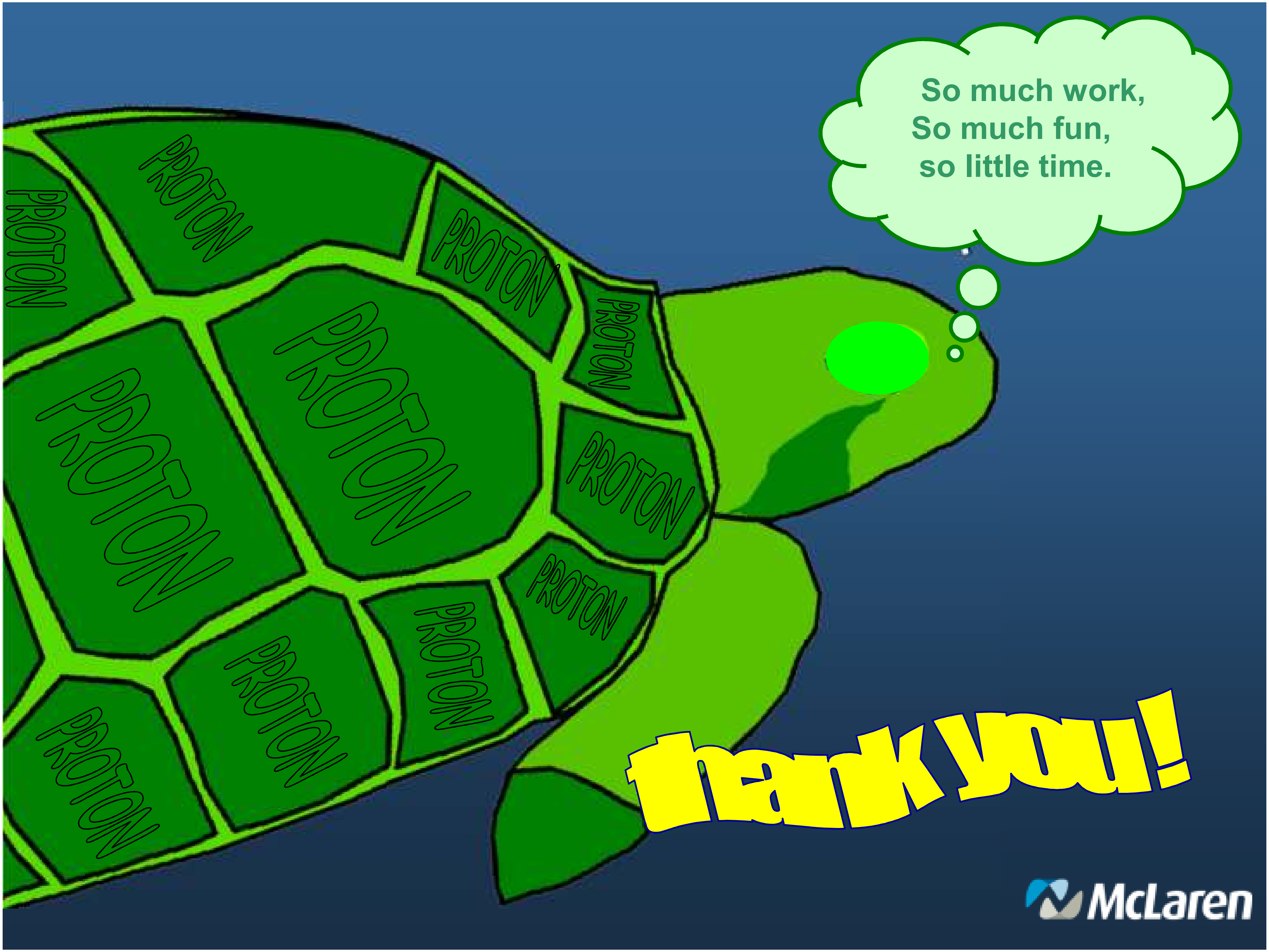
- Designed for Patients and Caregivers
- Most patients will travel an hour or more to Flint for Proton Therapy
- Long-term stays, typically 6 – 8 weeks
- The Hospitality House will be a non-profit
  - Room fees would be in the form of suggested donation ($35 per night)
- 20 – 30 guest rooms
- About 38,000 square feet

McLaren

Summary

Summary

- The commissioning of a Proton therapy system is very time consuming work and requires good understanding of the system.
- It is a big issue to deal with the limited beam time and man-power (other room beam calibration, maintenance, patient treatment and machine/patient QA, etc.).
- There is a need to develop the standard QA program for proton therapy. => AAPM TG 224



PROTON
PROTON
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PROTON
PROTON
PROTON
PROTON
PROTON
So much work,
So much fun,
so little time.
thank you!
McLaren