Ion Beam Dosimetry

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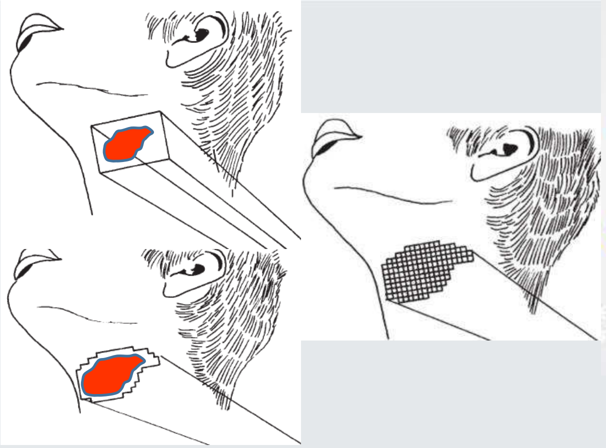
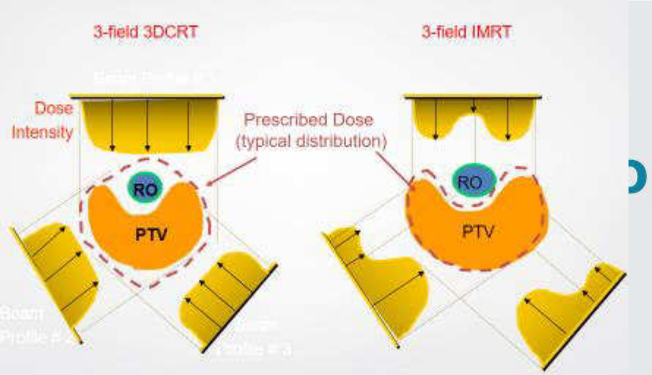
Radiotherapy

- External Radiotherapy
  - Conventional /2DRT
  - 3DCRT
  - IMRT/VMAT (RapidArc)
  - SRS/SRT (Intracranial tumour)
  - SBRT/Ablative RT (Extracranial Tumour)
  - Hadron/PArticle Therapy Proton/Carbon
- Brachytherapy
  - Intracavitary
  - Intraluminal
  - Interstial
  - Intraoperative RT

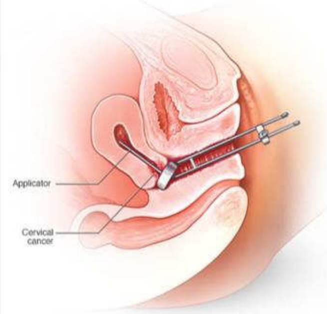


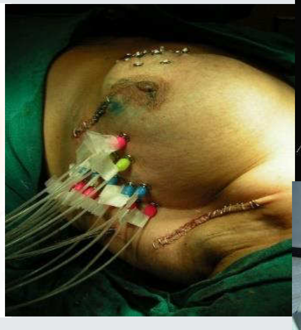


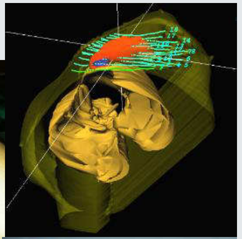
Relatively large tumour
1.8-2.5 Gy/Frs in 20-35 Frs

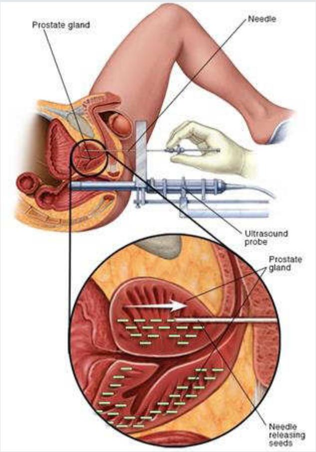
SRS/SRT and SBRT/Ablative RT:
Relatively small tumour
12-80 Gy in single Fr
5-20 Gy/Fr in 3-s

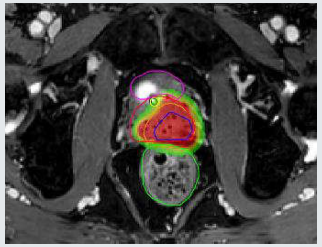
Use as sole modality Or + EXRT; 1-10 Frs

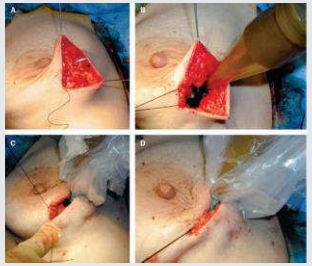






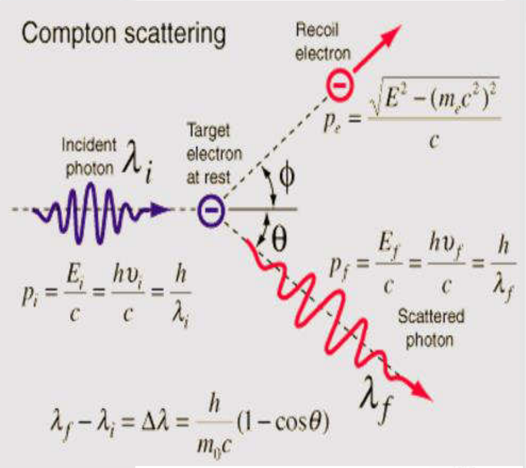


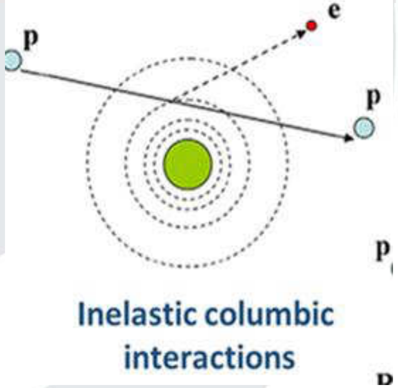




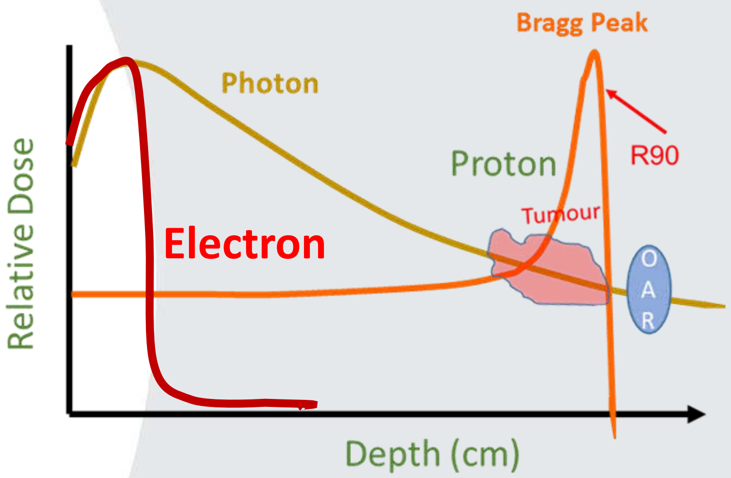
Radiation Delivery System: MeV X-rays

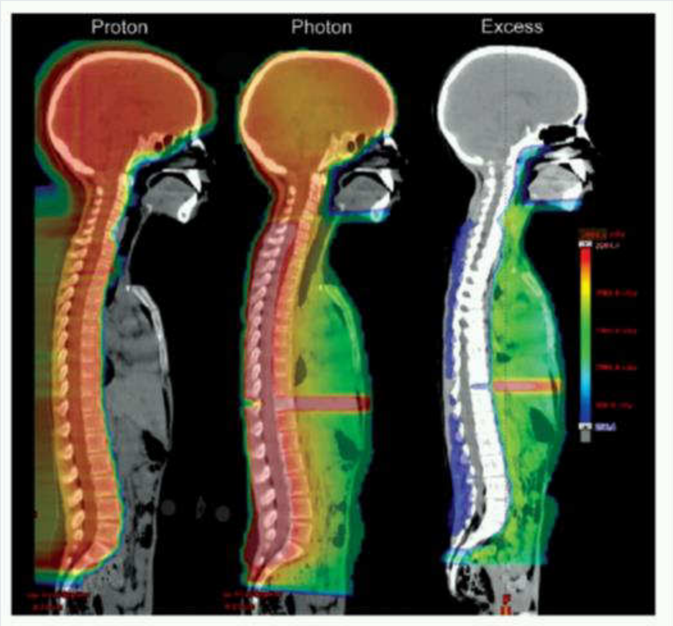
Rational for Proton beam therapy





1. Depth Dose Characteristics

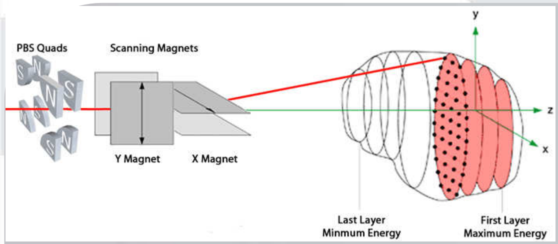


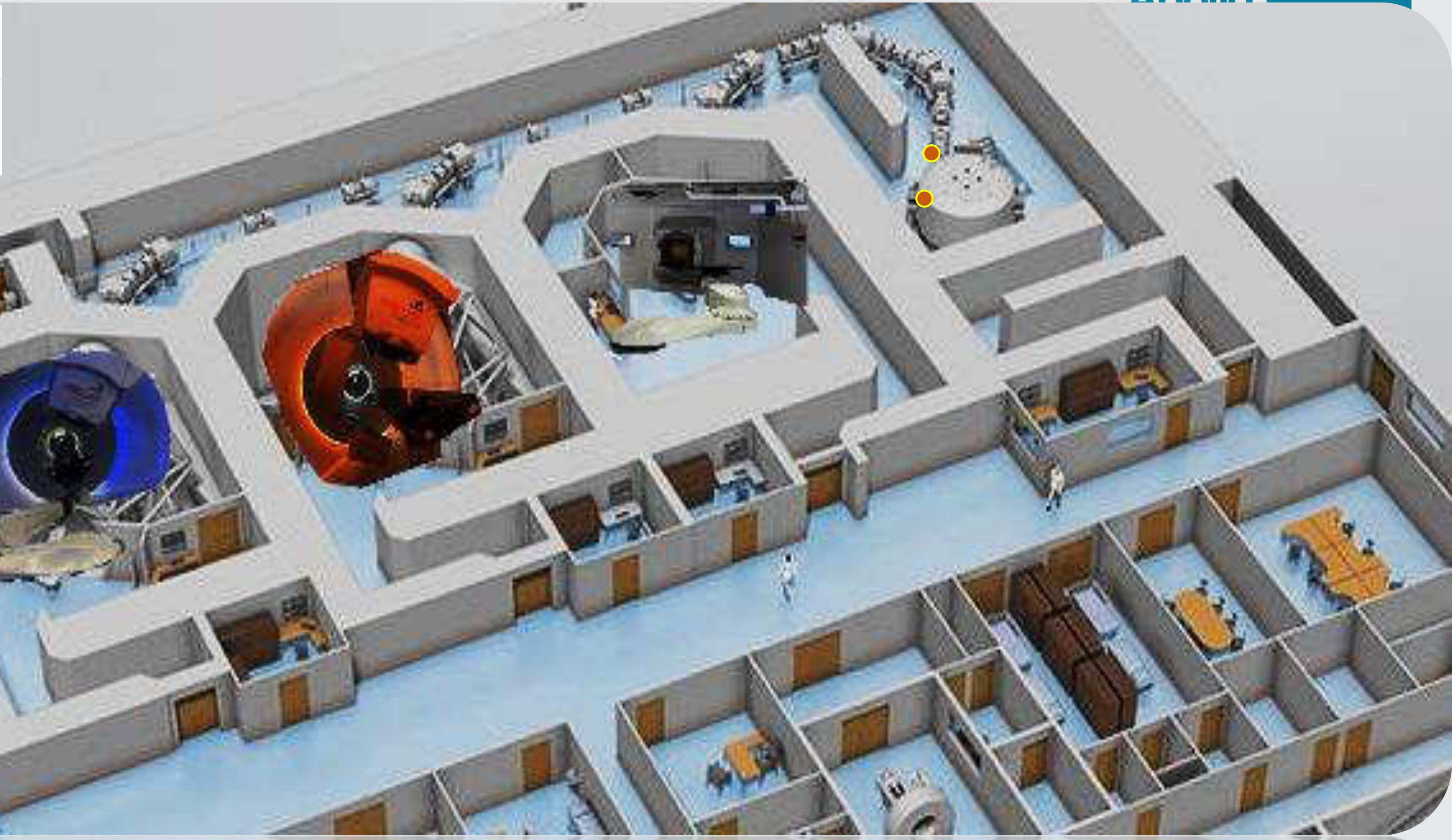


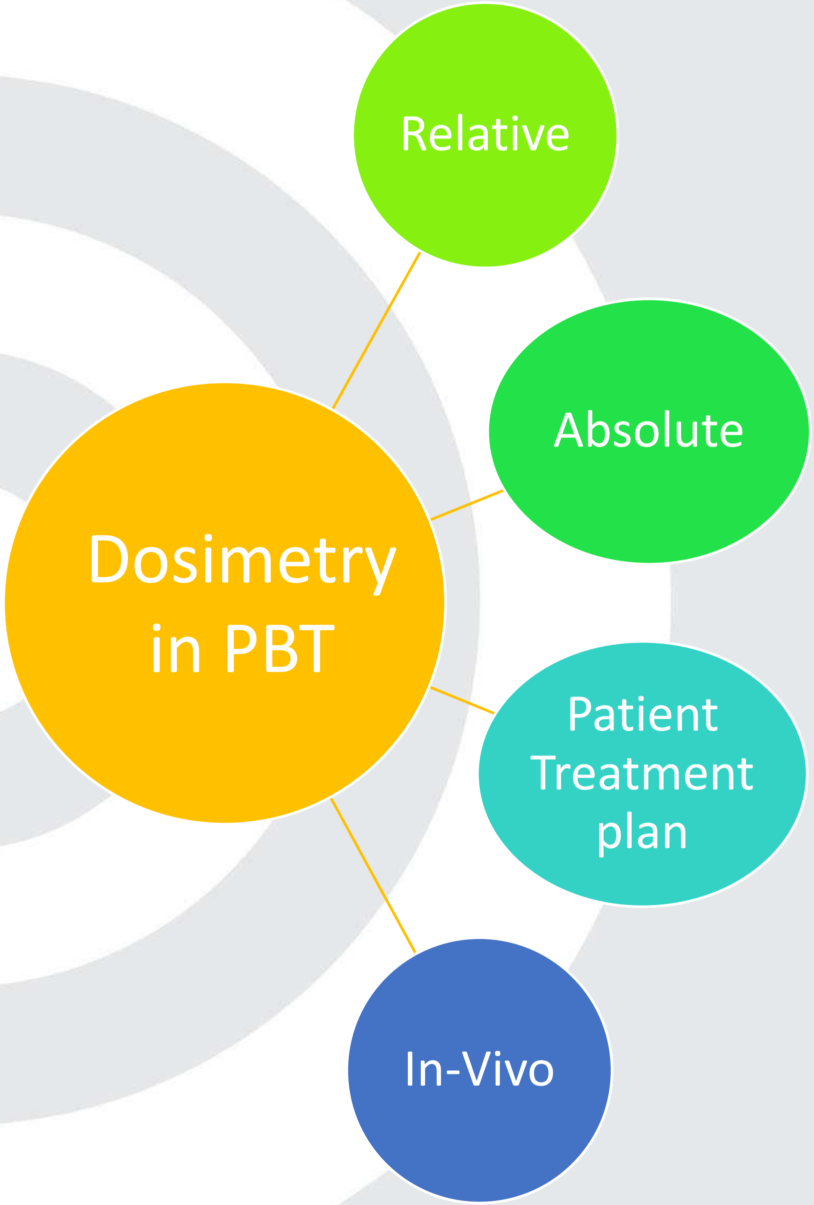
$$\frac{-dE}{dx} = 4\,\pi\, N_A r_e^2 \,\frac{m_e\, c^4}{v^2}\,\frac{Zz^2}{A}\,\rho\left[\frac{1}{2}\ln\left(\frac{2\,\gamma^2\beta^2 m_e c^2 E_{max}}{I_o^2}\right)\right] - \beta^2 - \frac{\varepsilon}{2} - \frac{\delta(\beta\gamma)}{2}$$

- Dosimetric advantage
  - better target conformity
  - reduction of OAR & integral dose
  - Possibility of dose escalation
- Better tumour control
- Reduced acute and late toxicity
- Improve quality of life
- Lower risk of induced disorders (e.g. Secondary cancers or child growth abnormalities etc)

Proton therapy : How it work







- Requirements are specific to beam delivery techniques
  - Double scattering (DS)
  - Uniform scanning (US)
  - Pencil beam scanning (PBS)
- PBS at Apollo Proton Cancer Centre
- Identify vital beam parameters which influence dosimetric properties
- ICRU 78 identified parameters for broad beam pertaining to DS, US & PBS
- AAPM TG-224; 2019
- AAPM TG-185; 2020

IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY
Phys. Med. Biol. 55 (2010) R193–R234 doi:10.1088/0031-9155/55/21/R01

TOPICAL REVIEW

Dosimetry for ion beam radiotherapy

Christian P Karger[1,5], Oliver Jäkel[1,2], Hugo Palmans[3] and Tatsuaki Kanai[4]

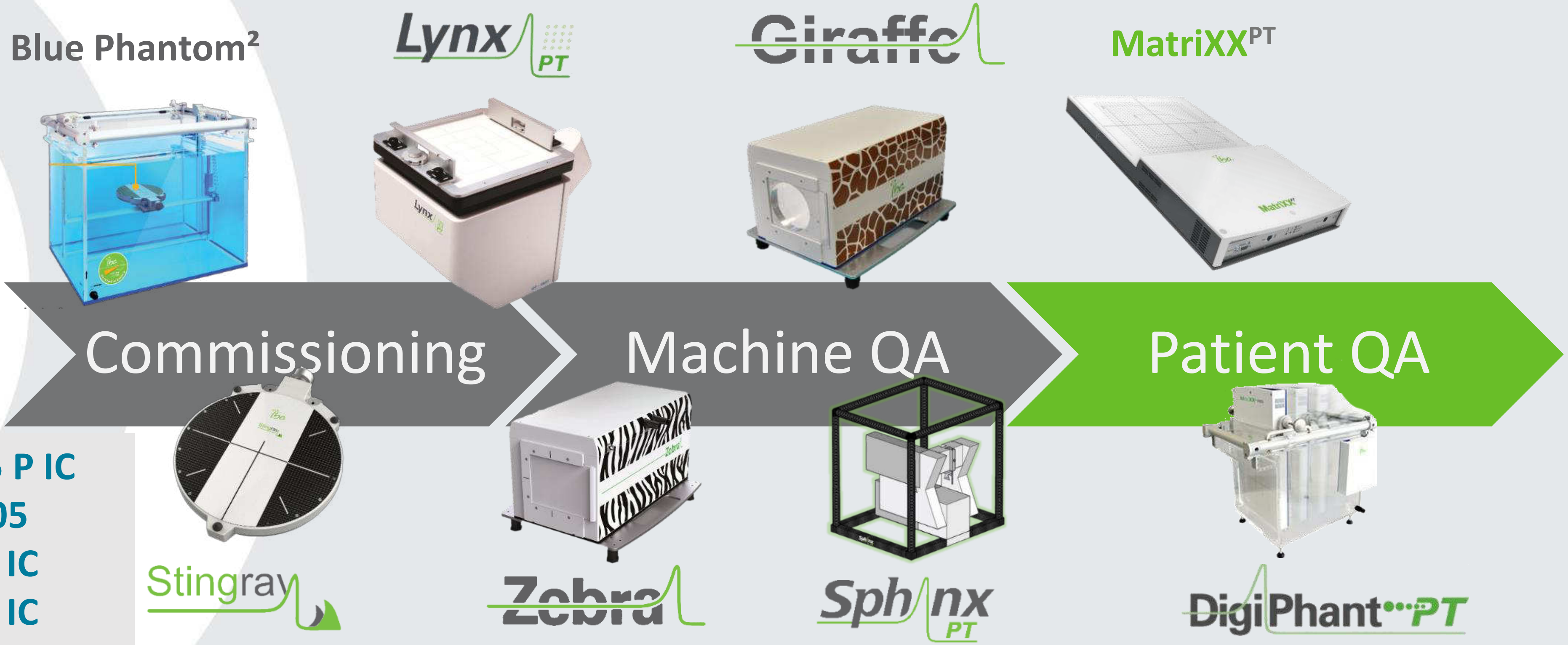
Apollo PROTON Cancer Centres

Table 1. Detectors for absorbed dose applied in ion beam radiotherapy.

Detector	Advantage	Disadvantage	Application in ion RT
Calorimeter	Direct dose measurement	High effort, knowledge of chemical heat defect and thermal heat conduction required	Potential primary standard in the future, k_Q measurements
Ionization chamber	High accuracy and reproducibility, small LET and energy dependence, easy to handle, many chamber types for different applications	Corrections for deviation from calibration conditions required, incomplete knowledge of corrections (chamber dependent)	Reference dosimetry, commissioning, dosimetric QA, dose verification, beam monitoring
Films	High spatial resolution, 2D measurement	LET and energy dependence, dose cannot be obtained from optical density in mixed fields, off-line analysis required	Measurement of lateral dose profiles, beam widths, field geometry and homogeneity, documentation of beam ports
Radiographic films	Stability after development	Nonlinear response, daylight sensitivity, stable developing conditions required	
Radiochromic films	Linear response, no daylight sensitivity, self-developing, less LET- and energy dependent	Complex evaluation protocols, long term self-development, mechanical sensitivity	

Table 1. Detectors for absorbed dose applied in ion beam radiotherapy.

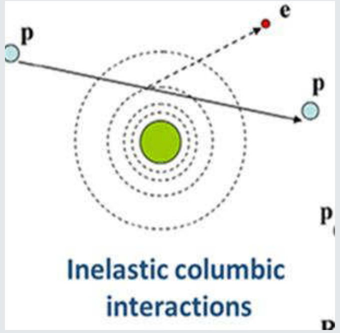
Detector	Advantage	Disadvantage	Application in ion RT
Other detectors			Mostly experimental investigations
Silicon diode and diamond	High spatial resolution, high signal, electronic read-out	LET, dose rate and energy dependence	Lateral profile measurements
TLD	High spatial resolution	LET and energy dependence, off-line evaluation	Point measurements, *in vivo* dosimetry
OSL detector	High spatial resolution, linear response, repeated electronic read-out	LET and energy dependence	Point measurements, profiles
Alanine detector	Nearly water-equivalent, linear response	LET and energy dependence, off-line evaluation with electron spin resonance	Point measurements
Scintillating screen	High 2D spatial resolution, linear intensity-independent response, electronic read-out	LET and energy dependence, large device	1D/2D distributions, field homogeneity, beam width, dose verification
Amorphous silicon detector	High 2D spatial resolution, linear response, electronic read-out	LET and energy dependence, potential radiation damage, expensive	1D/2D distributions, field homogeneity, beam analysis

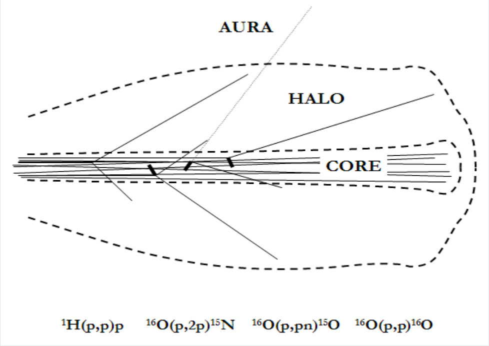


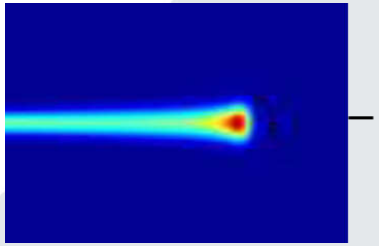
FC 65 P IC
PPC 05
CC13 IC
CC01 IC
SFD

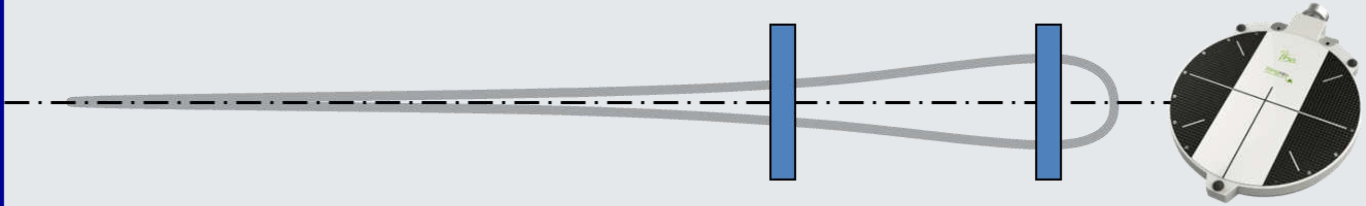
IDD/Pristine Bragg Peak:

- Scanning water Phantom & PPC
- Recommended detector
  - Small chamber in large field
  - Large diameter PPC in pencil beam
  - intercept all primary protons and secondary products in the beam

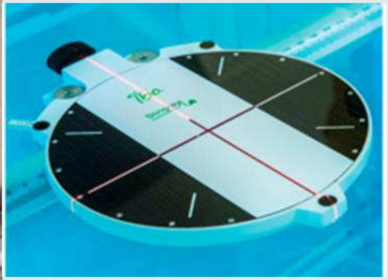


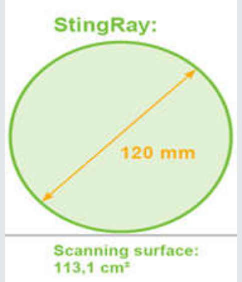


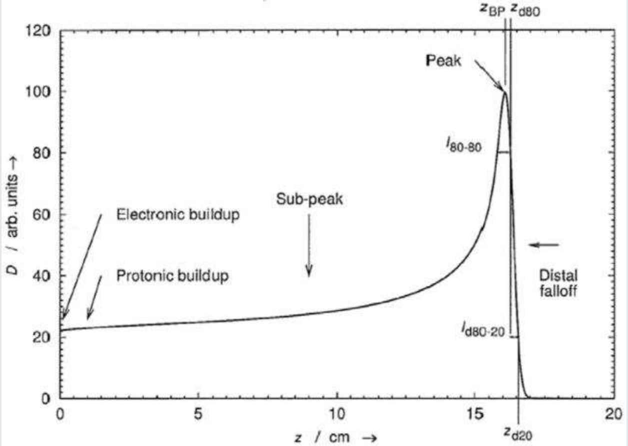




IDD/Pristine Bragg Peak:

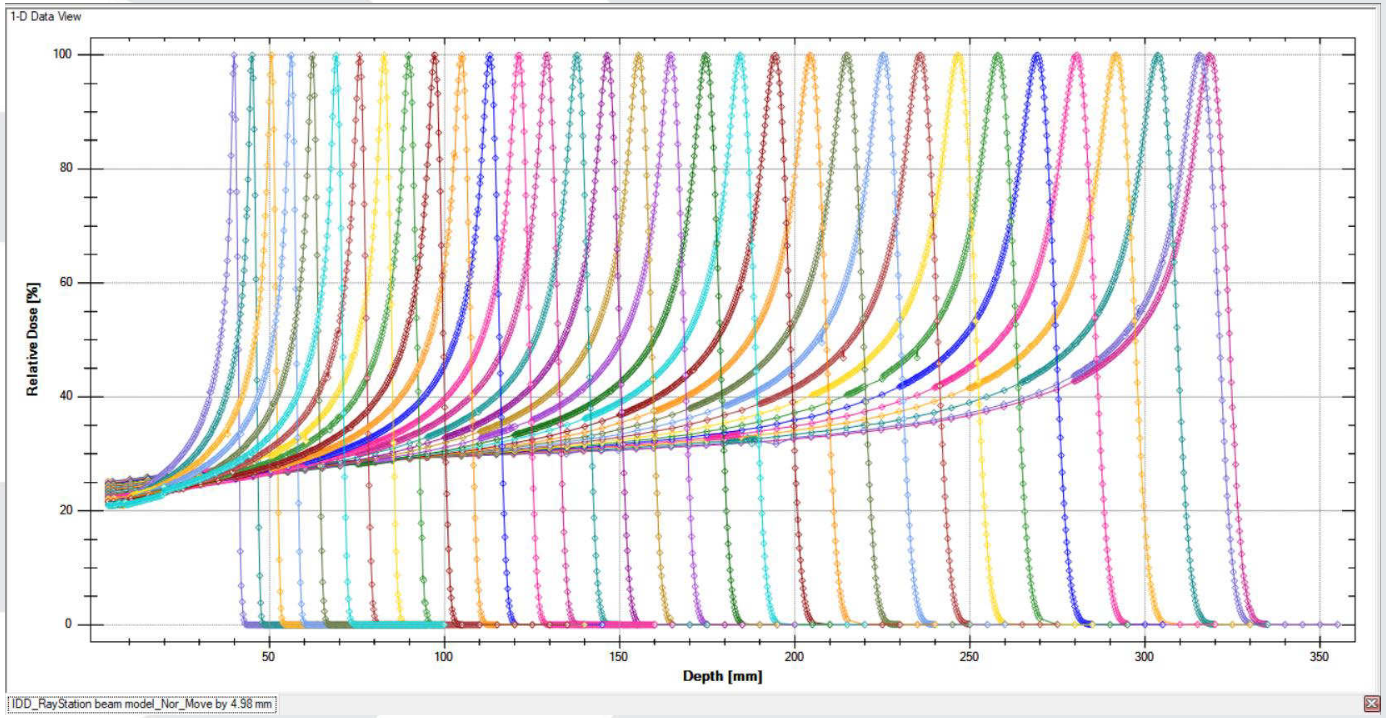




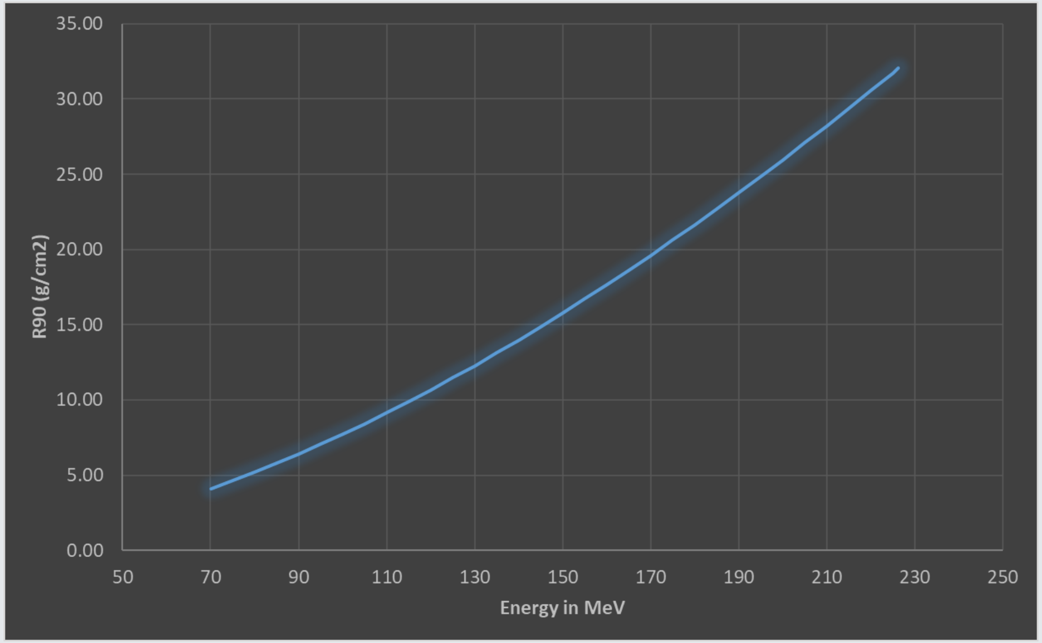


- Range (g/cm2):
  - Distal R90%
  - Proximal R90%
- Pristine Bragg peak width :
  - Distal 80%-proximal 80%
- Distal Fall off
  - Distal (R80-R20)

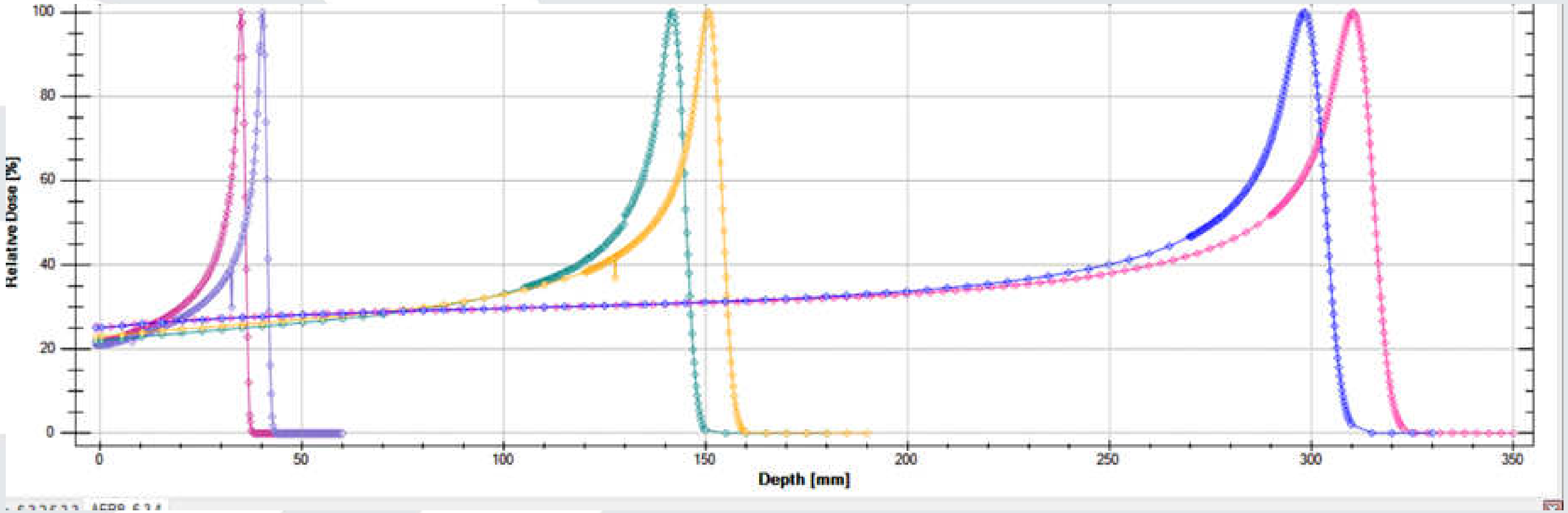
Normalized IDDs : 226 – 70 MeV @ 5 MeV interval

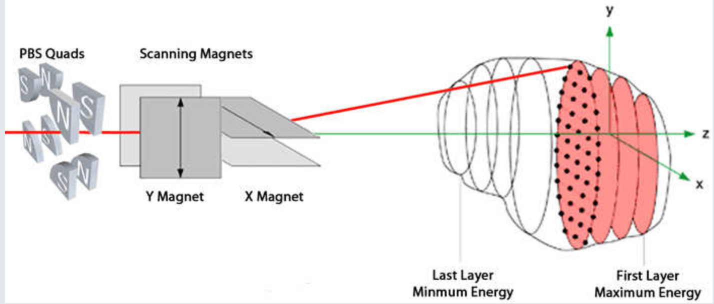


Energy vs Range (R90) in g/cm2



Pull back accuracy





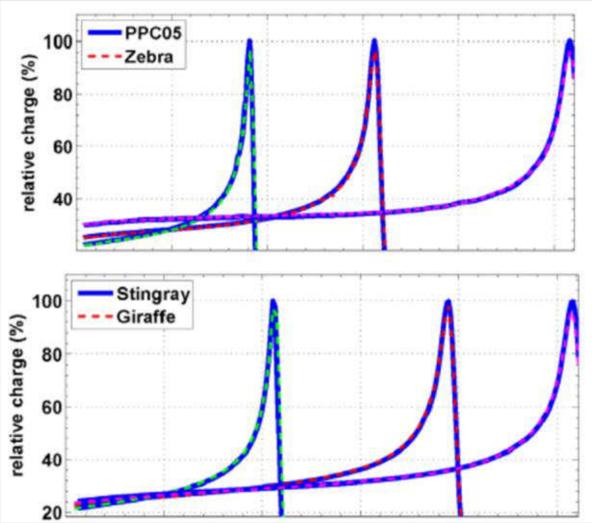
IDD measurement using water Phantom & PPC

- Highly accurate
- Require Extensive time
- Mainly use for commissioning, annual QA & after major intervention

IDD: Multi-layer ionization chambers (MLIC)

Technical Comparison		
	Zebra	**Giraffe**
Application	Broad beam	Single spot
Electrode Diameter	2.5 cm signal pad	12 cm signal pad
Number of chambers	180 chambers	
Pitch	2 mm	
Typical Sensitivity	~14.76 nC/Gy	~247 nC/Gy
Charge Resolution	100 fC/count	200 fC/count
Bias Voltage	- 85V	-150 V
Energy Range	Up to 33cm WET	
Scattering	✔	
Uniform Scanning	✔	
PBS	✔	✔

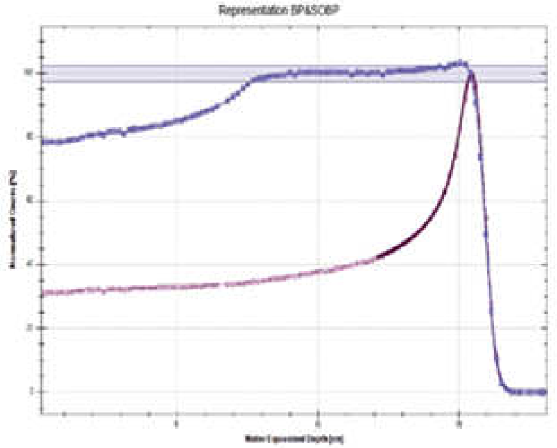
Zebra Vs Giraffe



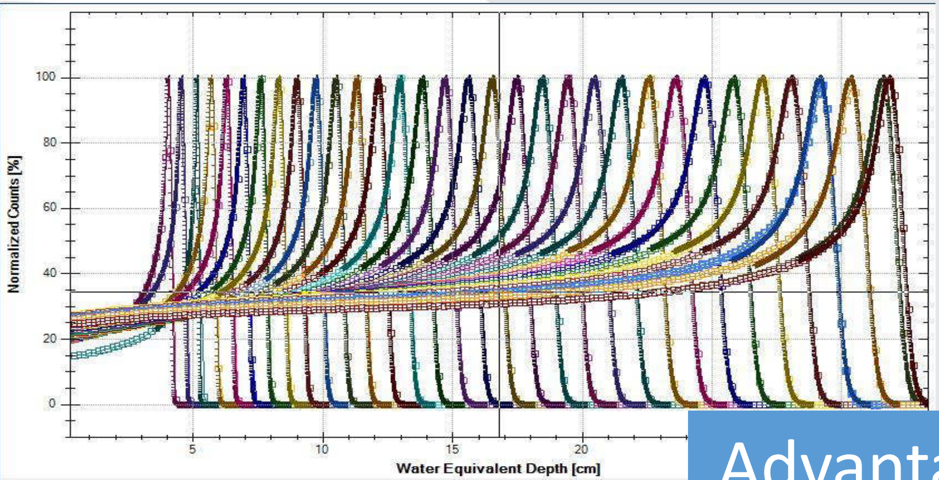
JACMP 16 (6) 2016

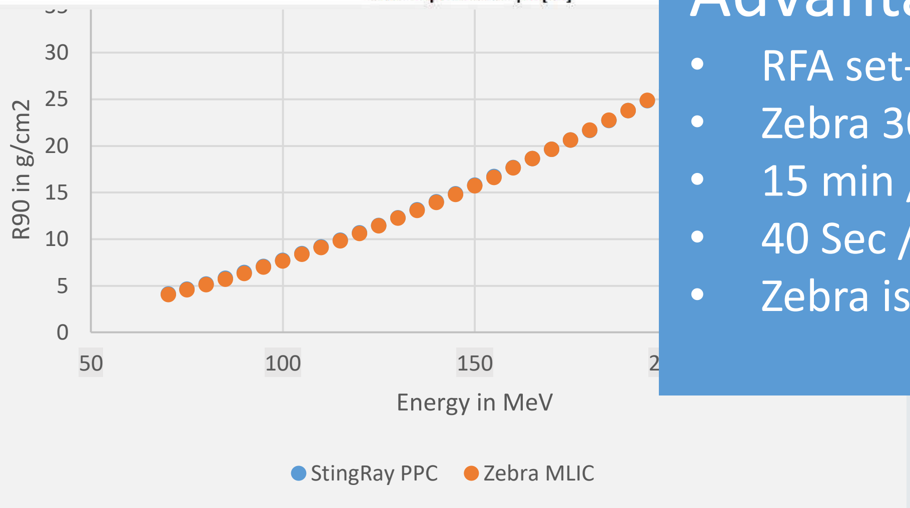
IDD : Zebra

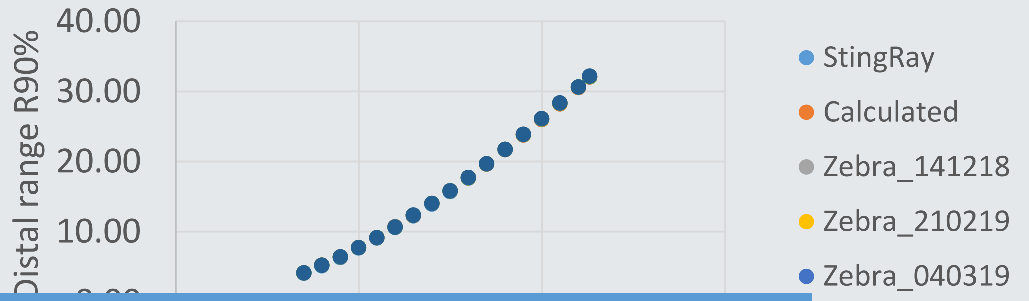
- Calibration wrt to
  - water phantom measured IDD for maximum proton energy using PPC05
  - IDD measurement with Zebra for 4 arbitrarily chosen energy
- Range
- SOBP
  - Distal R80-ProximalR80



Accuracy of Zebra for range measurement:







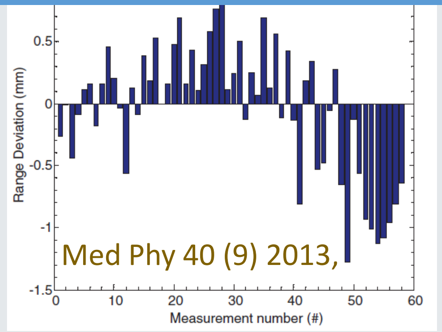
rement

er mean

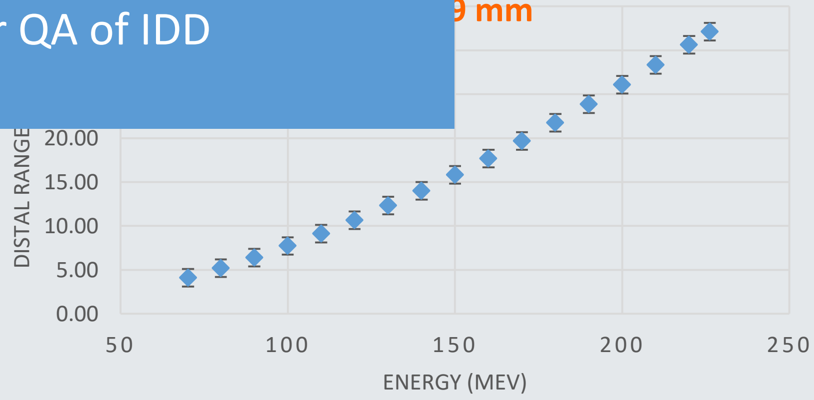
9 mm

Advantage of MLIC

- RFA set-up & dismantle time 1.5 hr
- Zebra 30 min
- 15 min / PDD in RFA
- 40 Sec / PDD in Zebra
- Zebra is a fast and accurate device for QA of IDD



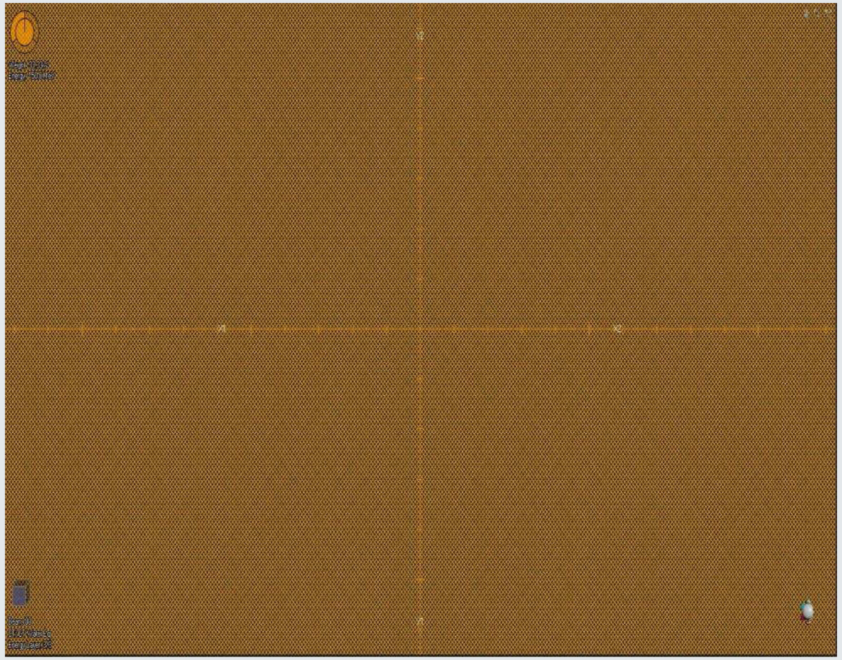
Med Phy 40 (9) 2013,



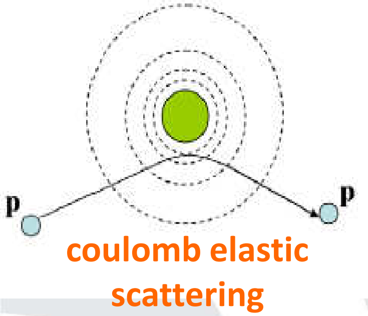
Accuracy

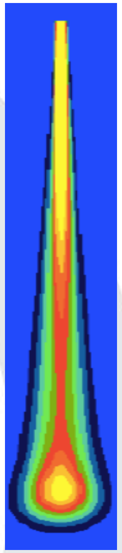
- Max Range deviation between Zebra & StingRay : 1.1 mm
- In agreement with published data

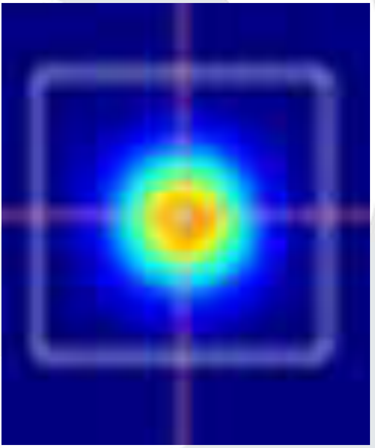
- Small filed in nature
- Smallest field size : 1 spot (Spot sigma 3 mm)
- Maximum field size : 35X40 cm2
- Dosimetry
  - Relative
  - Absolute

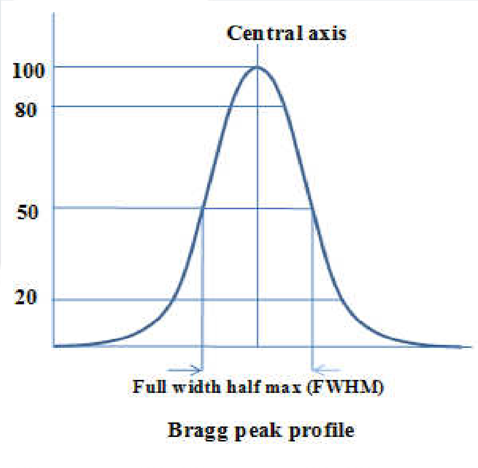


Spot Characteristic | Position | Size | Profiles | Symmetry





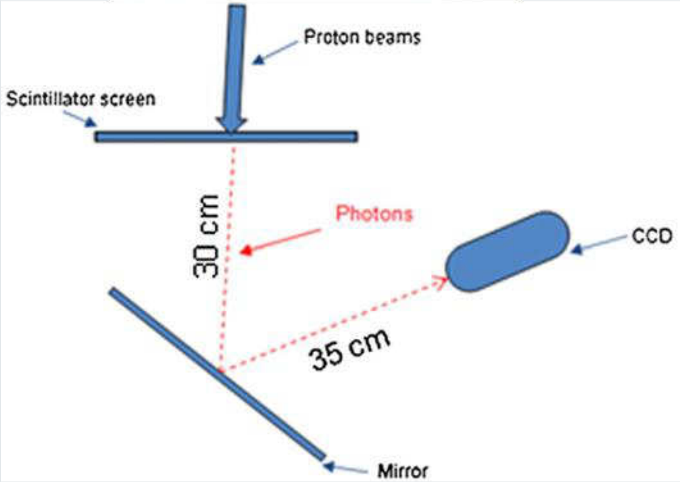




- Spot position
- Spot size (FWHM/Spot sigma as 67%)
- Lateral penumbra (80%-20%)
- Recommend high resolution detector
    - Small volume ionization chamber (≈0.1 cc)
    - Silicon Diodes
    - Gafchromic EBT Film
    - Time and labour intensive
    - Energy dependence specially for diodes & EBT film
- 2D linear detector Array
    - IMatrixx
    - Limited spatial resolution

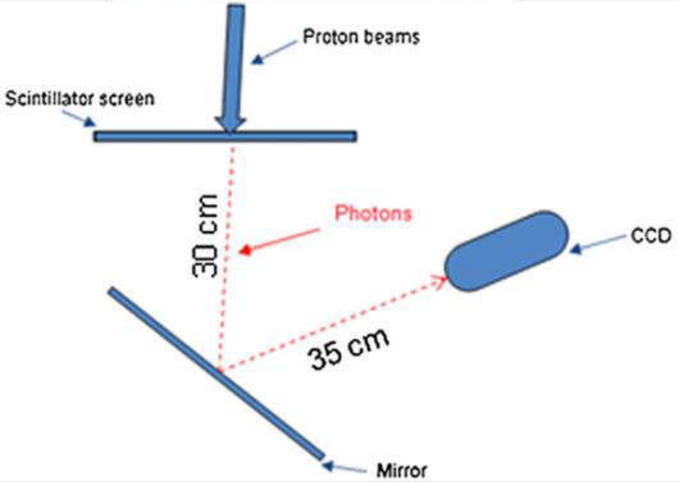
Scintillation detector (Lynx)

- 2-D high-resolution scintillation based system
- Consists of a
  - scintillating screen of gadolinium-based plastic material (0.4 mm thickness), coupled with
  - CCD camera, in a compact light-tight box.
- Detector active surface area of 30 × 30 cm^2
- Effective spatial resolution of 0.5 mm.
- Iris setting 0-100. Recommended >20
- Acquires data in 10-bit format



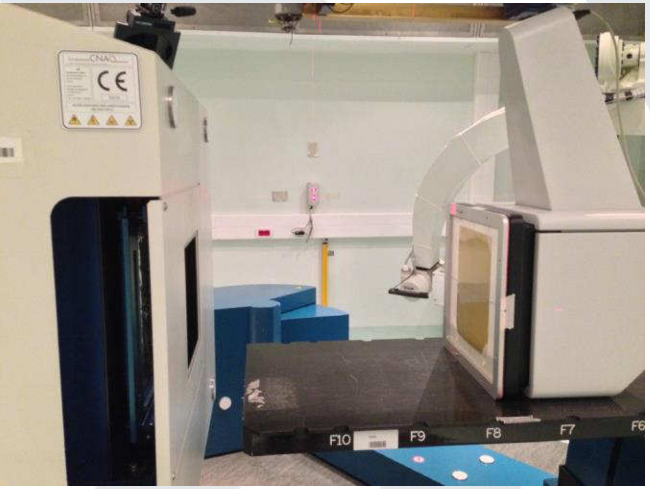
Scintillation detector (Lynx)

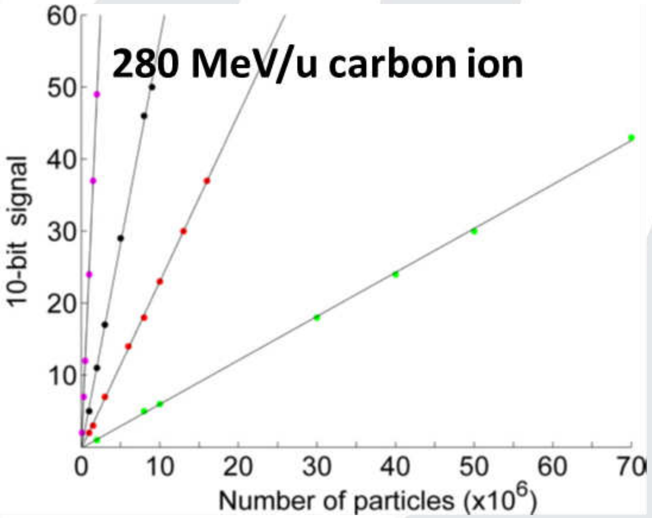
- Principal: Scintillating screen converts the energy lost by the incoming radiation into photons (green light, 540 nm wavelength) which are reflected by a mirror and collected by the photodiodes of the CCD camera.
- Raw data from CCD is corrected for
  - Image deformation
  - Background
    - thermal &
    - communication noises of the camera
- Non-uniform pixels intensity response
- Median filter to reduce intensity variation between each pixel and neighbour

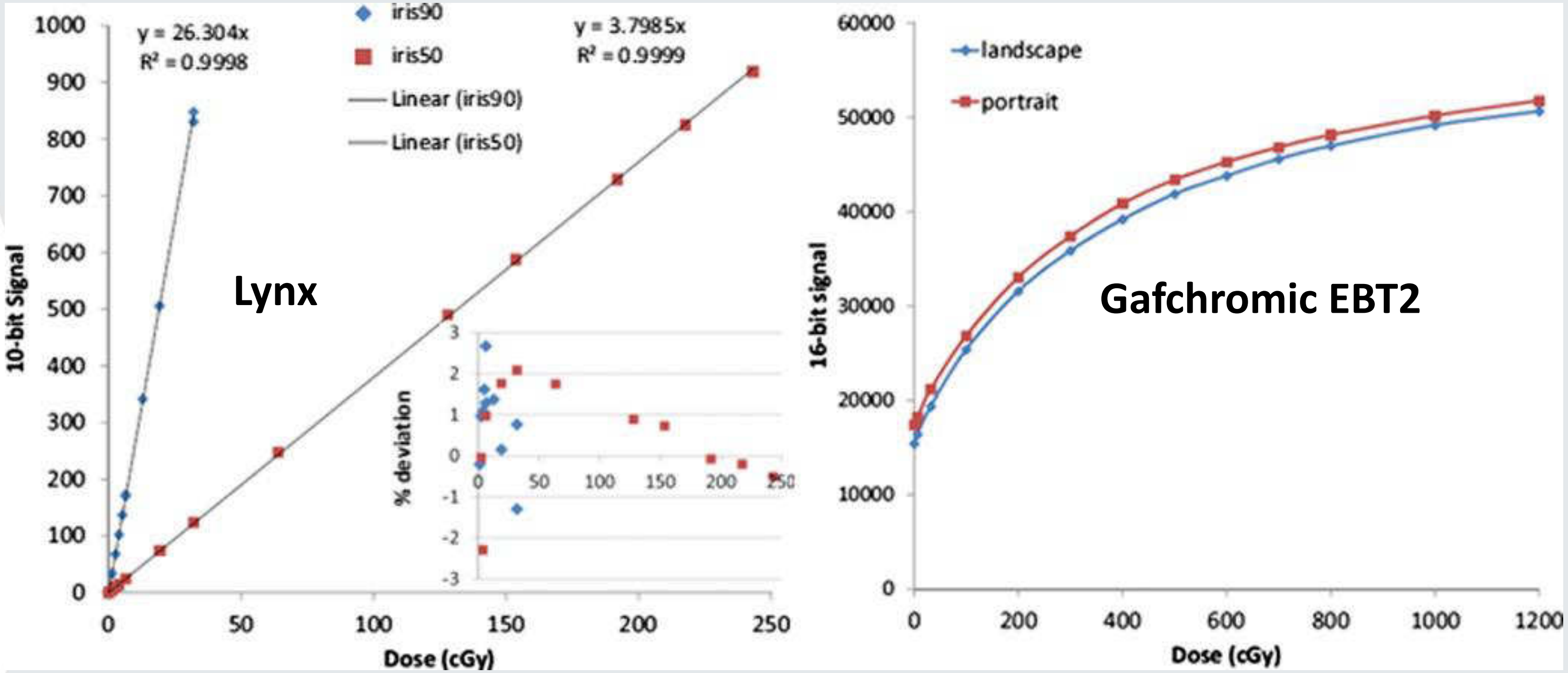


Characterization of Lynx for PBS

115 MeV Proton beam



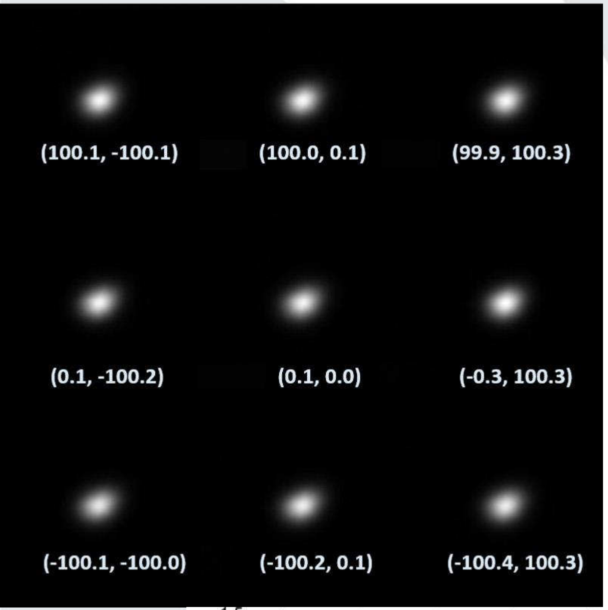


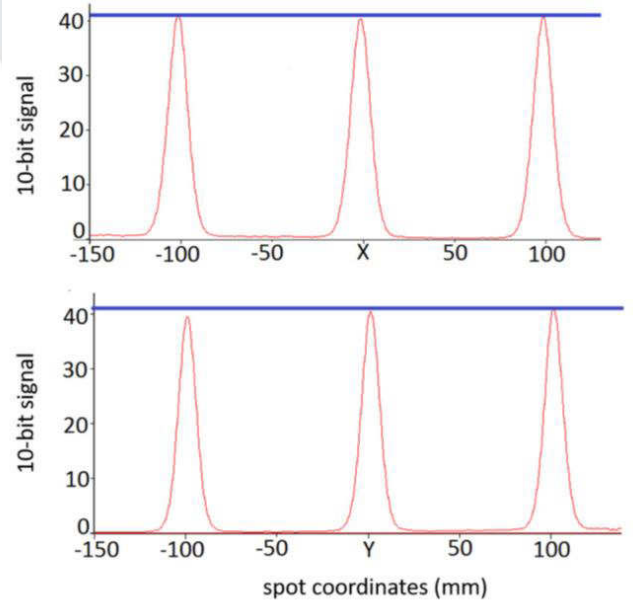


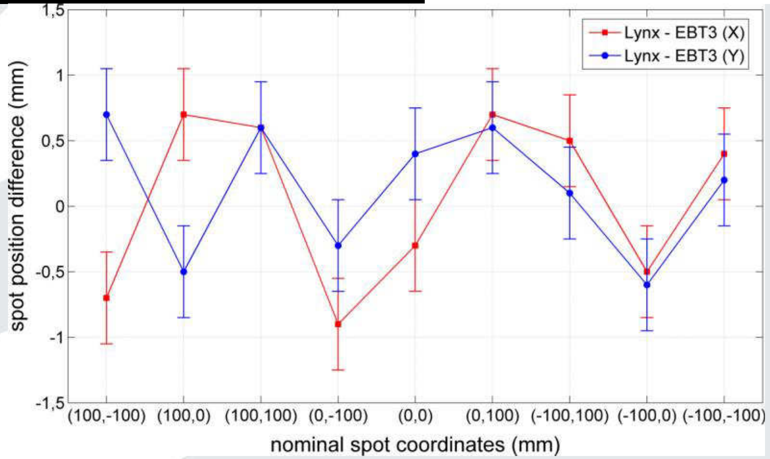
- Signal linearity with MU is better 3% even in the lowest dose
- Iris 90 is 7 times sensitive than iris 50

Phy Med Bio 58; 2013
Physica Medica 2017

Characterization of Lynx for PBS





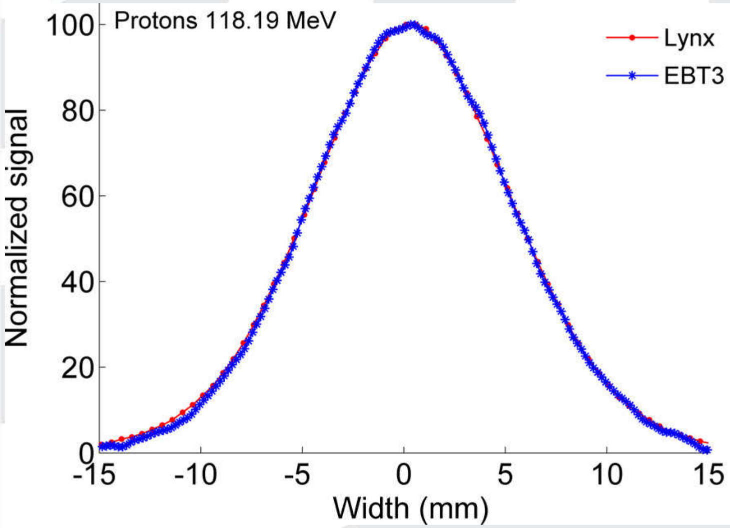


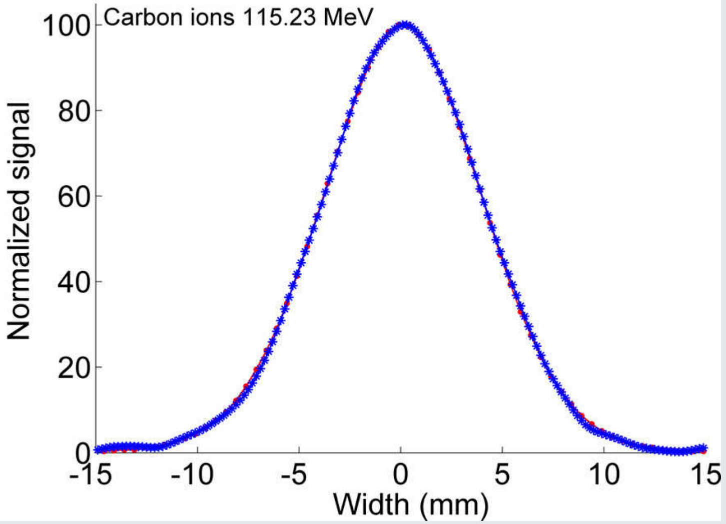
- Coefficient of variation of the mean signal in the investigated ROIs centred around the nine spots was less than 2%
- Indicating a good image uniformity
- No evident of image geometrical distortion
- Spot position accuracy within ±1mm

Physica Medica 2017

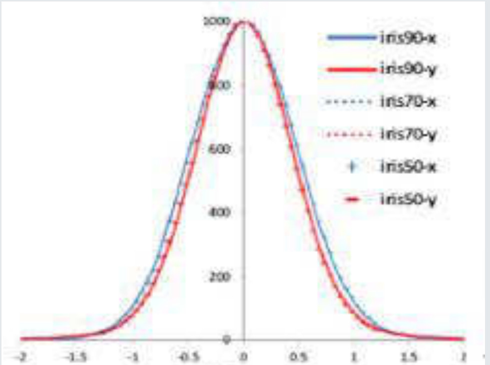
Characterization of Lynx

- Spot profile independent of iris setting & MU
- No observable difference in spot profile between Lynx & EBT2
- Spot size difference (FWHM): <0.5 mm

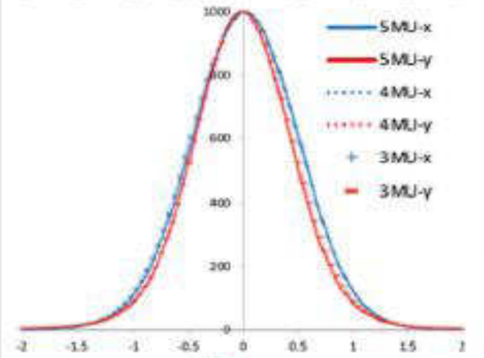




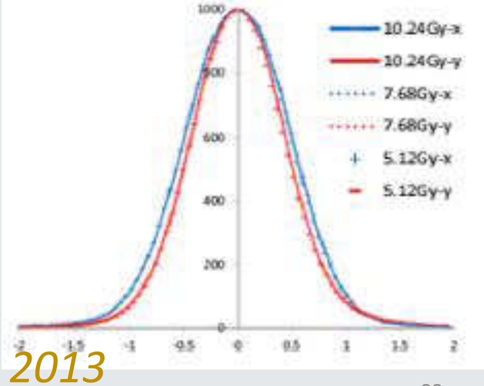
Lynx : Different iris setting
with same MU 5



Lynx : Same iris setting (90) different MU

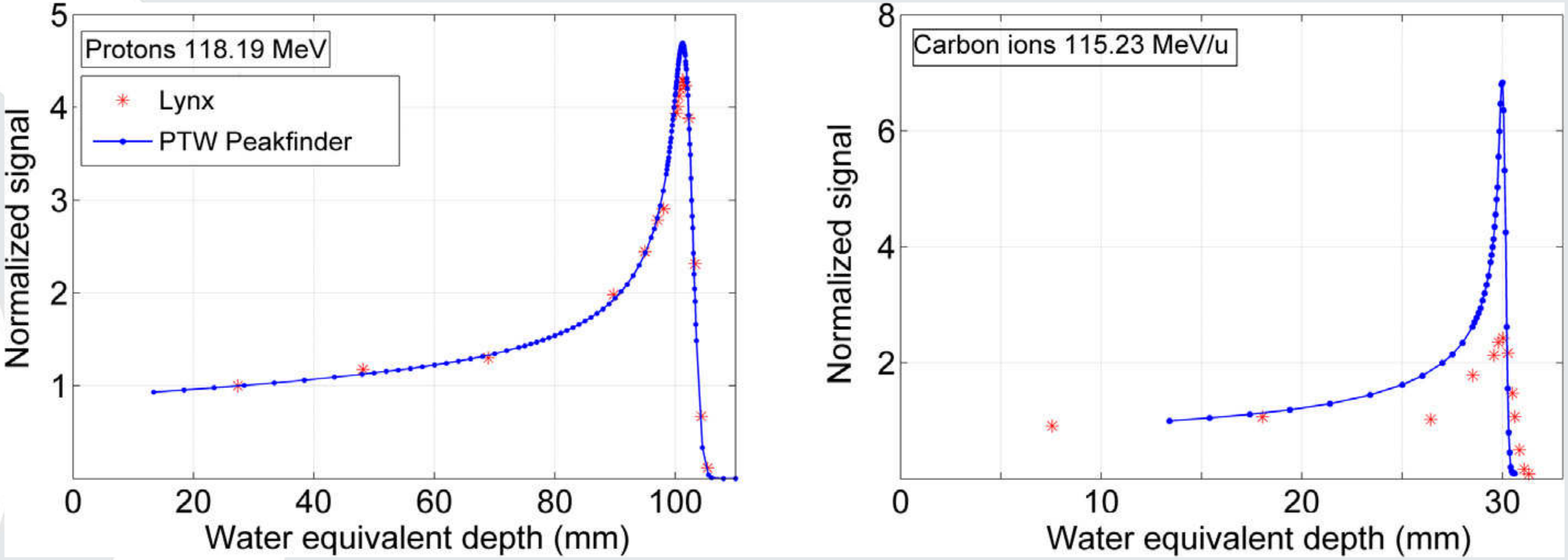


EBT2 : different MU



Phy Med Bio 58; 2013
Physica Medica 2017 in Press

Characterization of Lynx for PBS: LET dependence



Lynx is therefore suitable to replace EBT3 films, allowing real-time less time-consuming **beam commissioning, Validation** and **periodic constancy tests** for Proton. Not suitable for 3D dosimetry measurements, unless quenching is modelled

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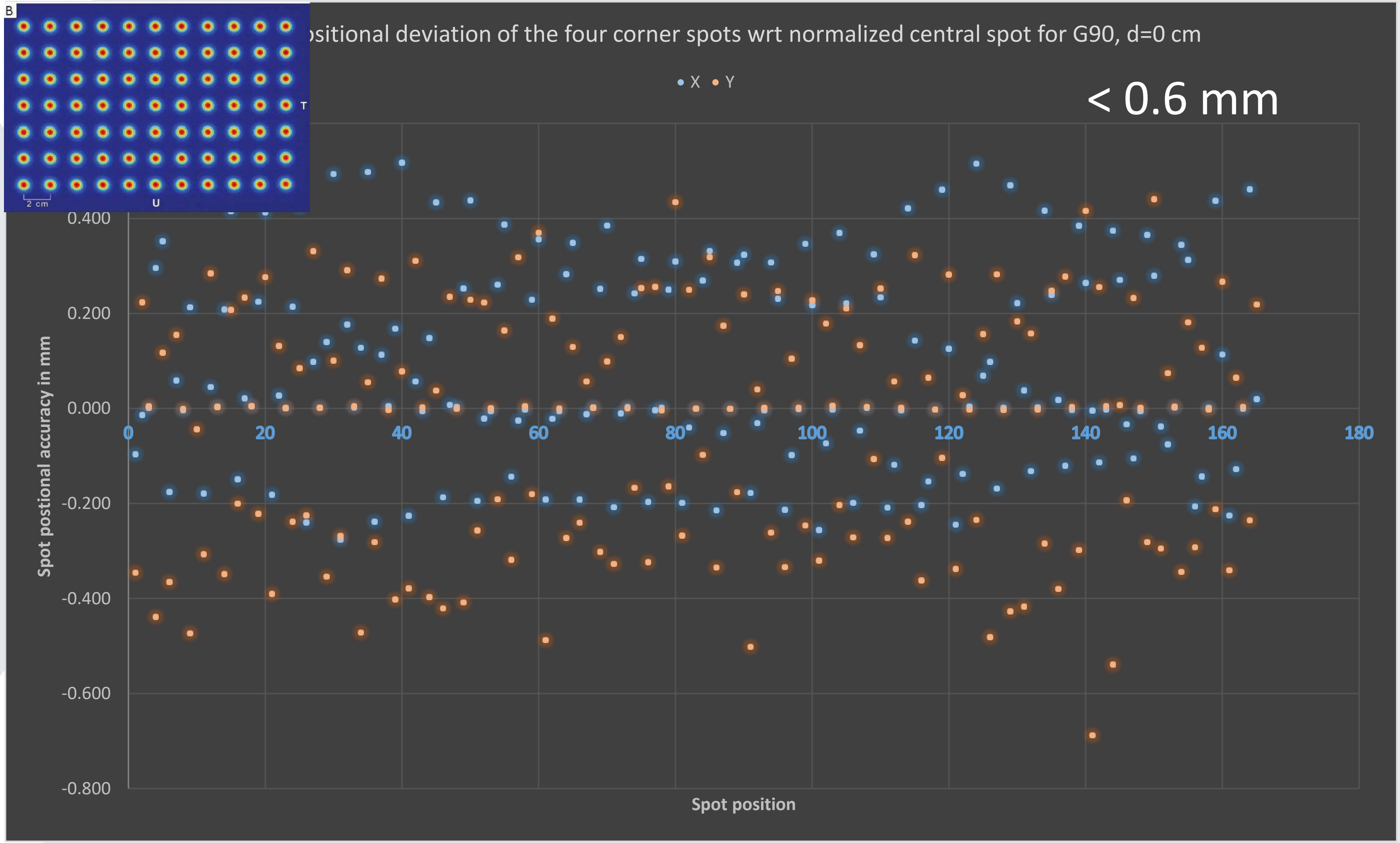
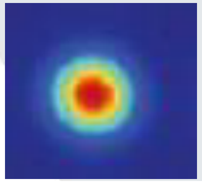
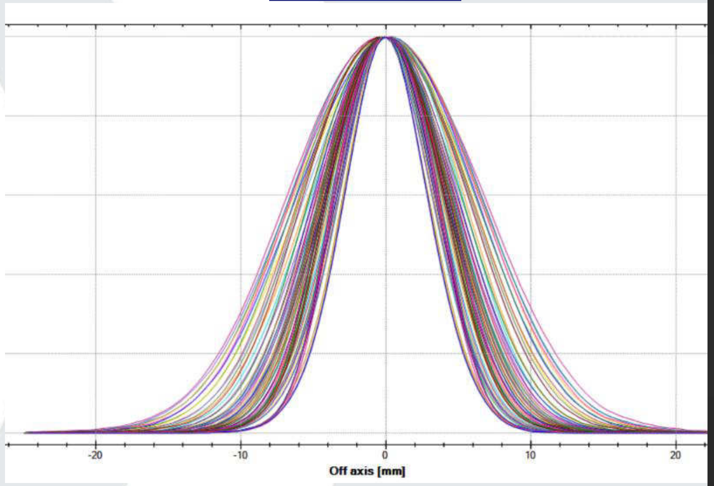
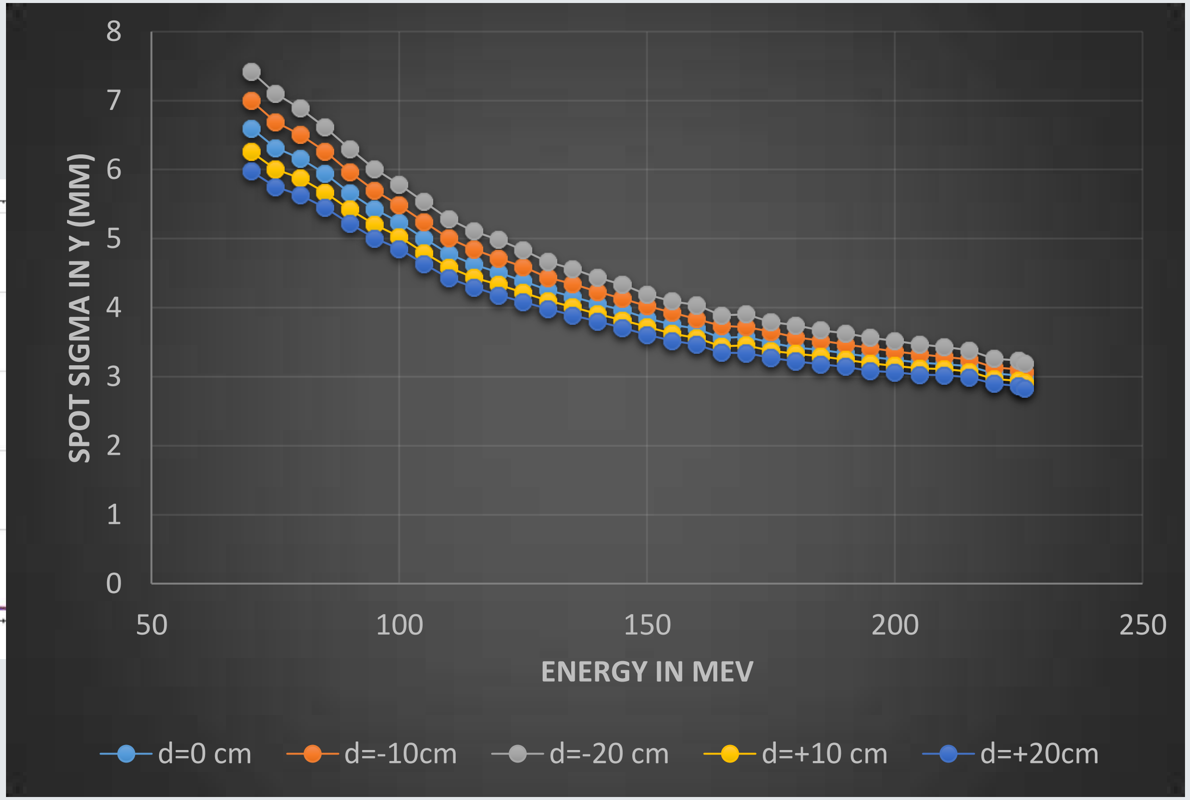
Relative spot positioning error



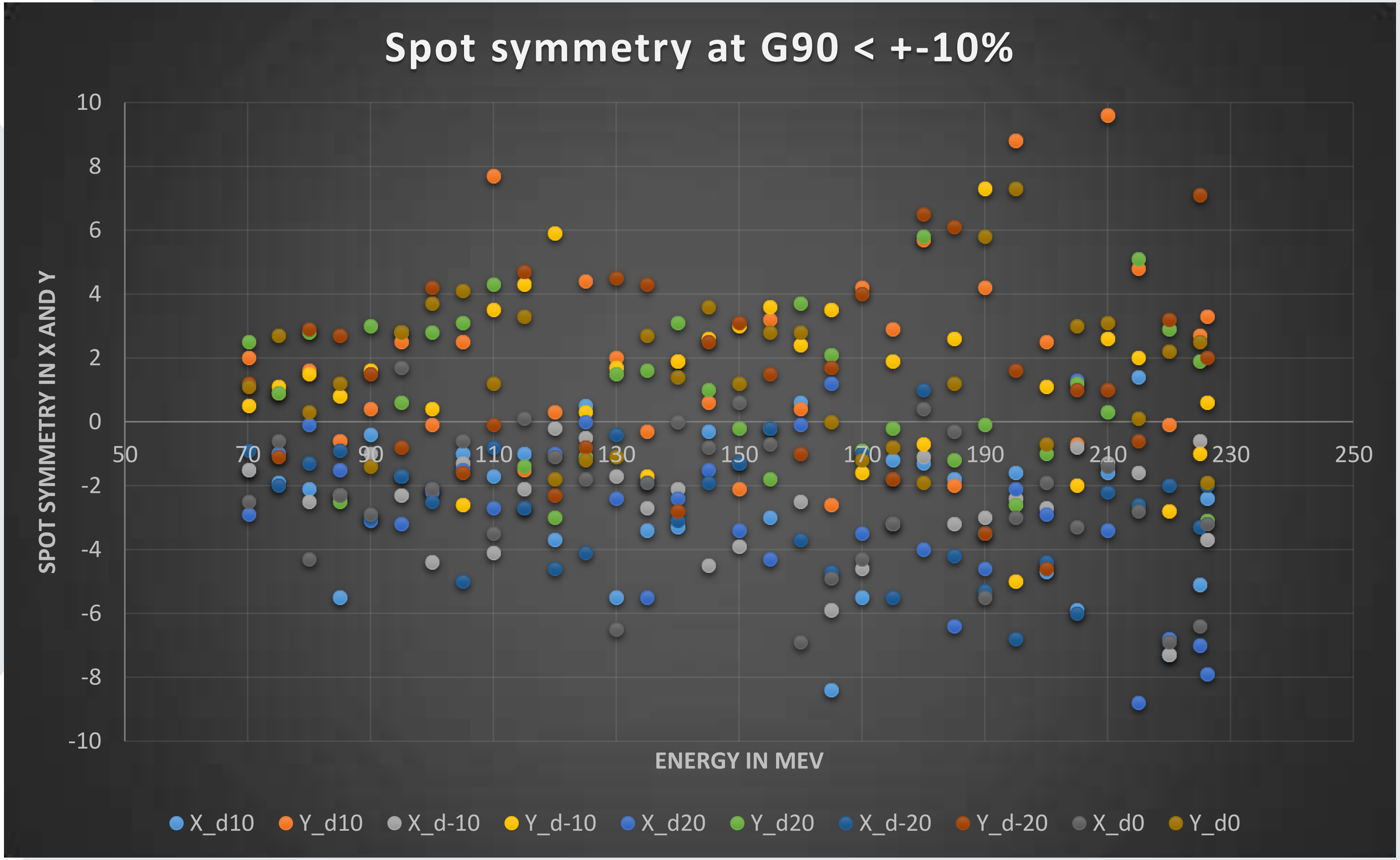
Average Spot sigma at different air gap



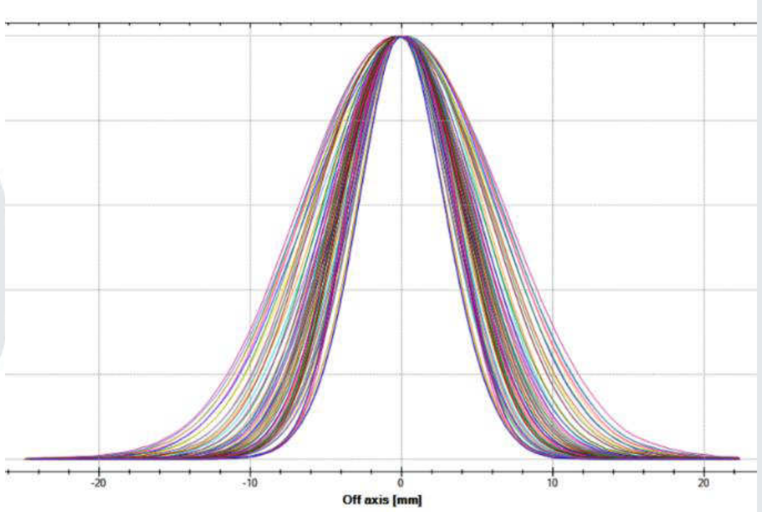


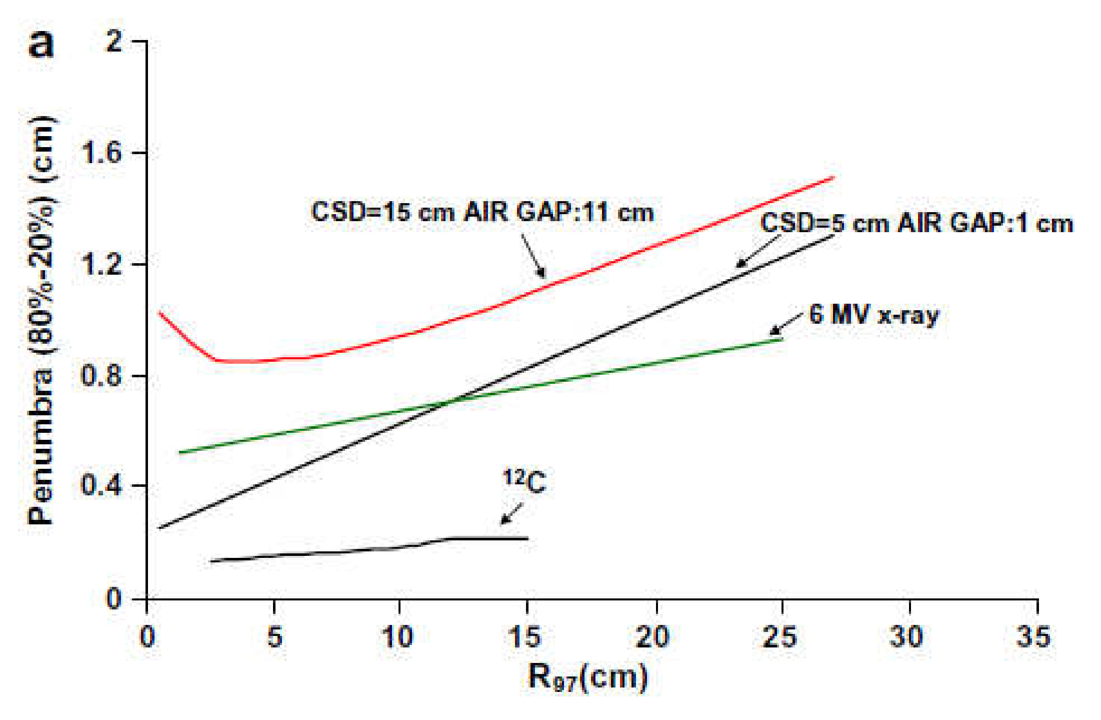


Spot symmetry



Lateral Penumbra





Absolute dosimetry

- Different code of practice
  - AAPM) report 16 (Lyman et al 1986)
  - European Clinical Heavy Particle Dosimetry Group (ECHED) code (Vynckier et al 1991, 1994)
  - International commission on radiation unit (ICRU) report 59 (ICRU 1998).
- All these codes recommend the use of thimble ionization chamber calibrated in a ^{60}Co beam in terms of air kerma (or exposure) (Lyman et al 1986, Vynckier et al 1991, 1994) or absorbed dose to water (ICRU 1998).
- IAEA TRS-398 (IAEA 2000, 2003) is the latest and most widely used
  - based on standards of absorbed dose to water.
- Recommended calibrated chambers
  - Thimble ionization chamber
  - Parallel plate chamber

Output : cGy/MU calibration

IAEA TRS 398

Calibrated ionization chamber

Water Phantom measurement

Reference depth : 3 cm

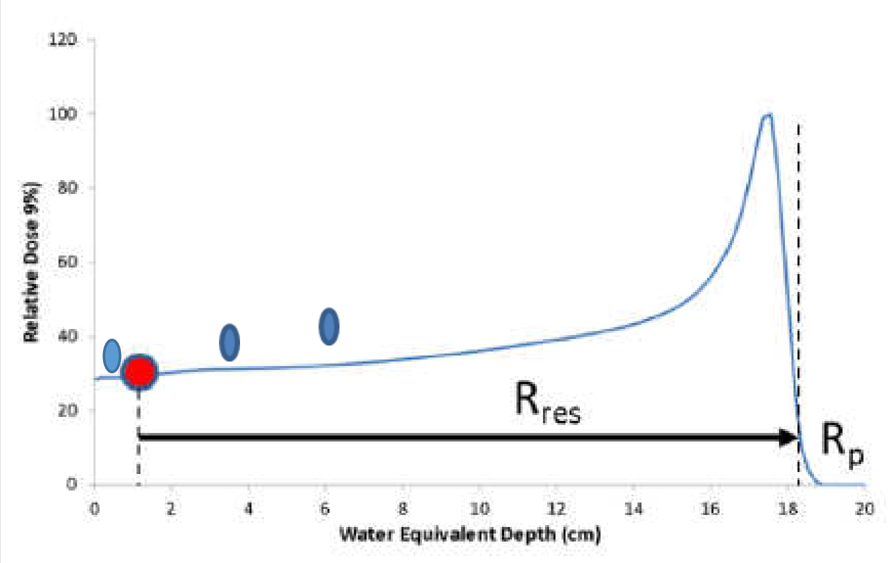
: variable depth

: TPS requirement

Water Phantom

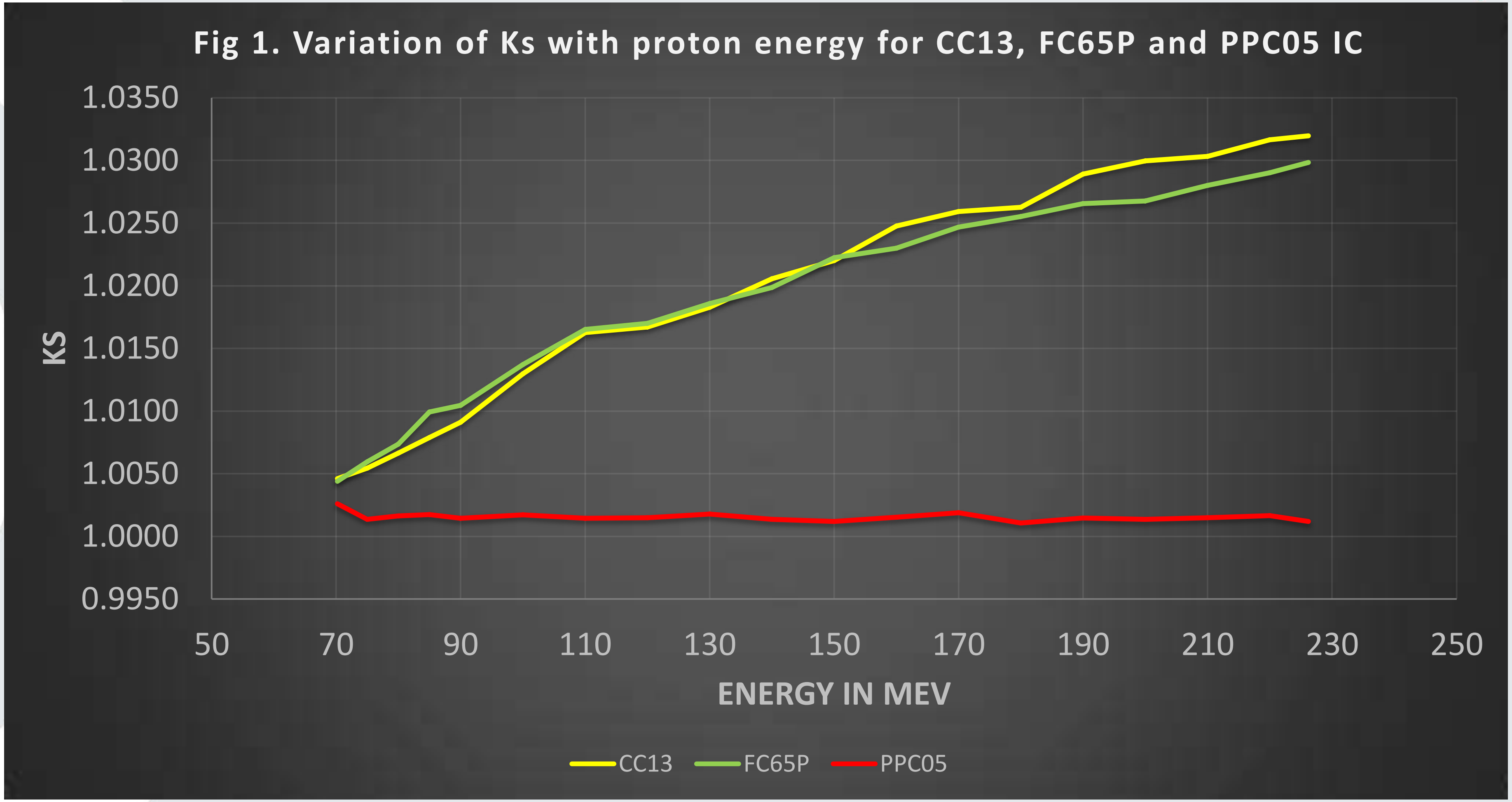
Calibrated PP05 Parallel plate chamber

$$D_{w,Q} = M_Q N_{D,w,Q_o} k_{Q,Q_o}$$



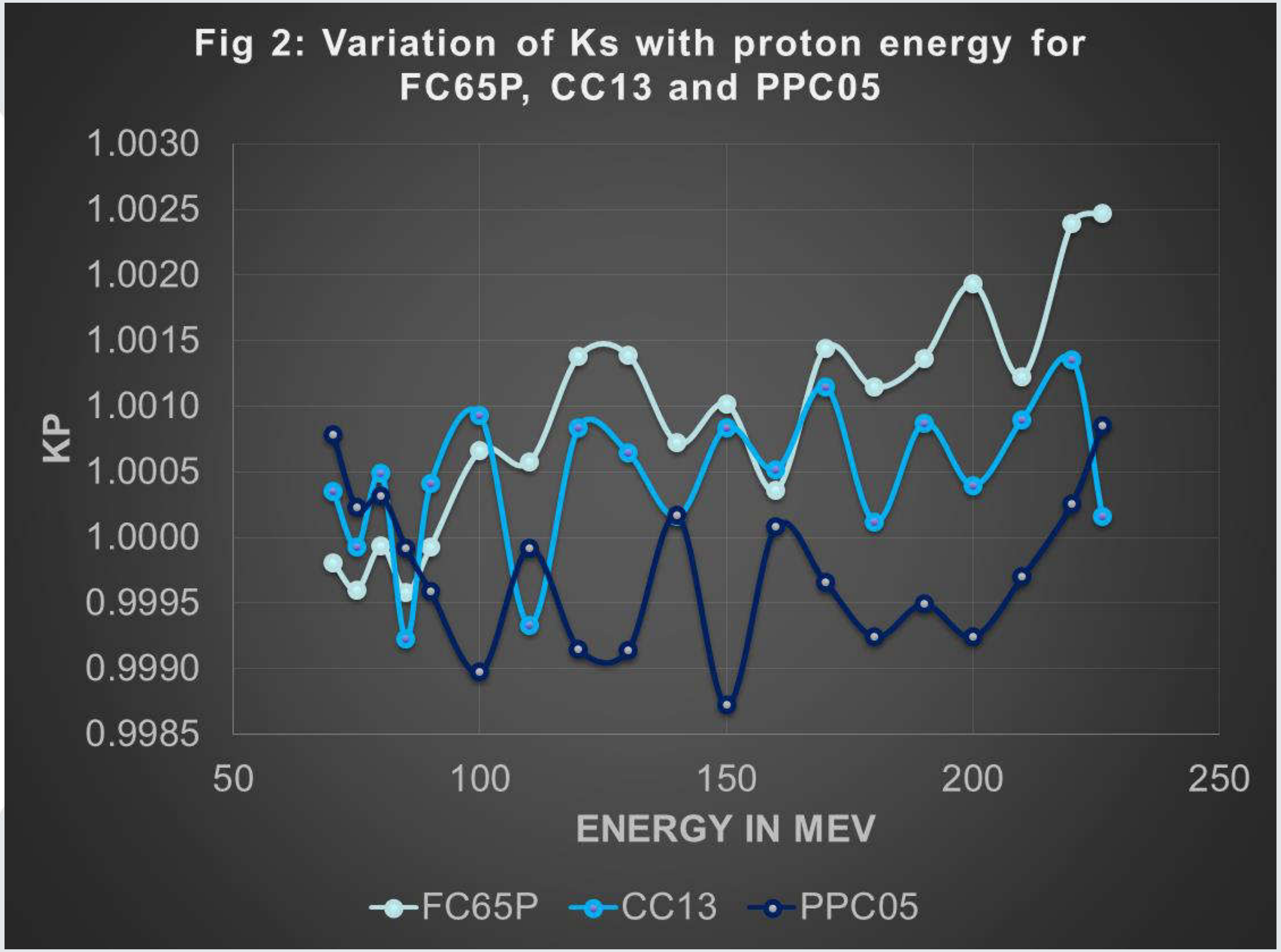
IAEA, TRS 398

Ion recombination



Dayananda et al PTCOG 2019, Manchester

Polarity correction



Dayananda et al PTCOG 2019, Manchester

Absolute Dosimetry

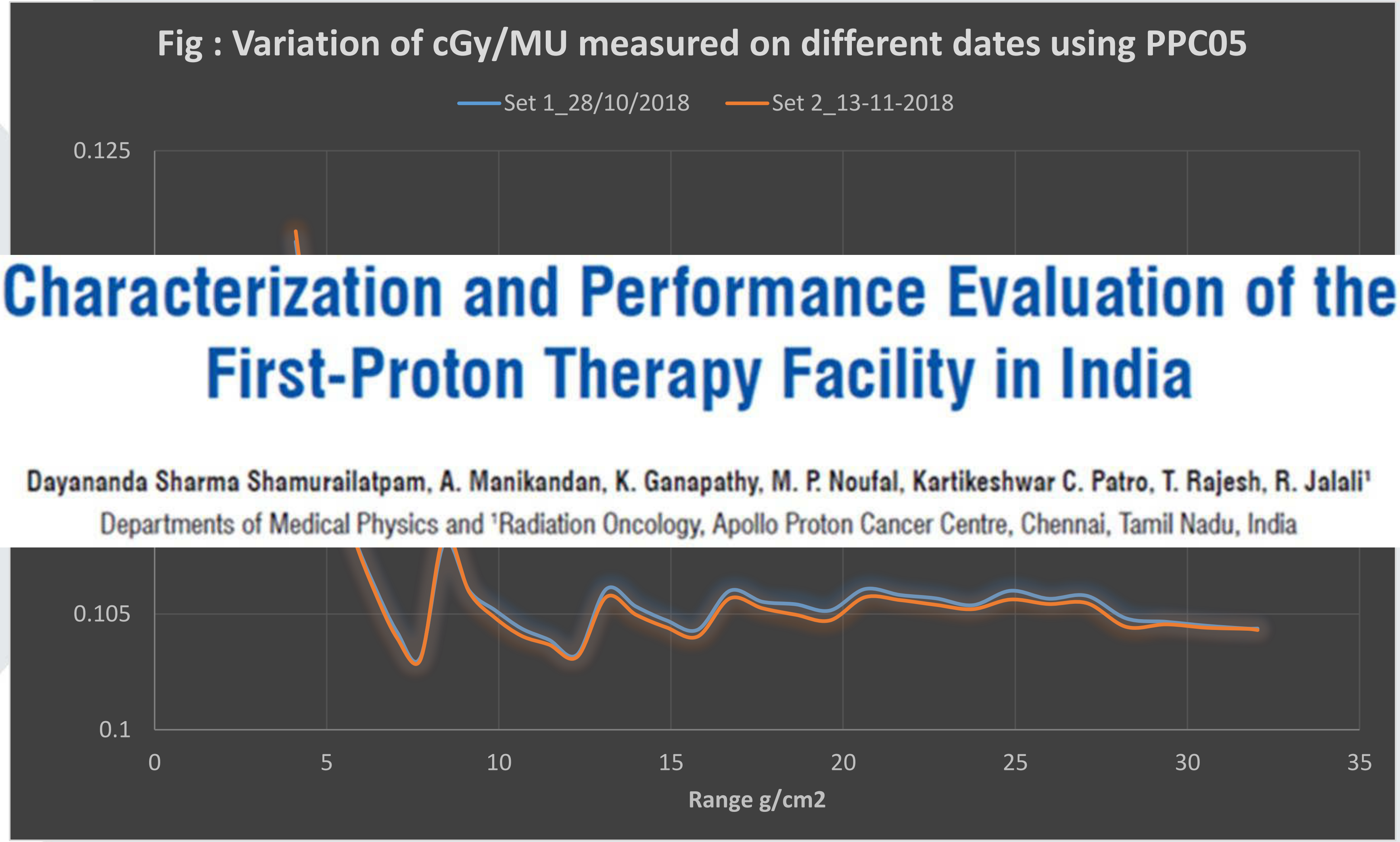
- Chamber perturbation correction factor
- Combines many corrections into one factor based on beam quality (Rres)

TABLE V. CALCULATED VALUES OF k_Q FOR PROTON BEAMS, FOR VARIOUS CYLINDRICAL AND PLANE-PARALLEL IONIZATION CHAMBERS AS A FUNCTION OF BEAM QUALITY R_{res}

Ionization chamber type	Beam quality R_{res} (g cm^{-2})															
	0.25	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	7.5	10	15	20	30
Cylindrical chambers																
Scdx-Wellhöfer CC01		1.042	1.040	1.040	1.040	1.039	1.039	1.039	1.039	1.039	1.039	1.039	1.039	1.038	1.038	1.038
Scdx-Wellhöfer CC04/IC04		1.037	1.035	1.035	1.034	1.034	1.034	1.034	1.034	1.034	1.034	1.034	1.033	1.033	1.033	1.032
Scdx-Wellhöfer CC08/IC05/IC06	-	1.041	1.039	1.039	1.039	1.038	1.038	1.038	1.038	1.038	1.038	1.038	1.038	1.037	1.037	1.037
Scdx-Wellhöfer CC13/IC10/IC15	-	1.041	1.039	1.039	1.039	1.038	1.038	1.038	1.038	1.038	1.038	1.038	1.038	1.037	1.037	1.037
Scdx-Wellhöfer CC25/IC25	-	1.041	1.039	1.039	1.039	1.038	1.038	1.038	1.038	1.038	1.038	1.038	1.038	1.037	1.037	1.037
Scdx-Wellhöfer FC23-C/IC28 Farmer shortened	-	1.042	1.040	1.039	1.039	1.039	1.039	1.039	1.038	1.038	1.038	1.038	1.038	1.038	1.038	1.037
Scdx-Wellhöfer FC65-P/IC69 Farmer	-	1.037	1.036	1.035	1.035	1.035	1.035	1.034	1.034	1.034	1.034	1.034	1.034	1.034	1.033	1.033
Scdx-Wellhöfer FC65-G/IC70 Farmer	-	1.044	1.042	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.040	1.040	1.040	1.040	1.040	1.039
Plane-parallel chambers																
NACP	0.994	0.991	0.989	0.989	0.988	0.988	0.988	0.988	0.988	0.988	0.988	0.987	0.987	0.987	0.987	0.986
PPC05 Markus-type	1.009	1.005	1.004	1.003	1.003	1.003	1.003	1.003	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.001
PPC35/40 Roos-type	1.008	1.004	1.003	1.002	1.002	1.002	1.002	1.002	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.000

IAEA, TRS 398

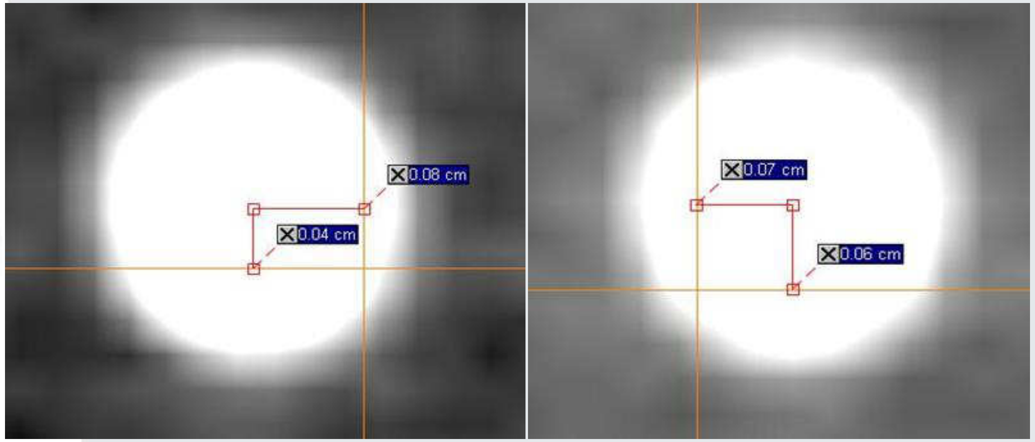
Output measurement



Characterization and Performance Evaluation of the First-Proton Therapy Facility in India

Dayananda Sharma Shamurailatpam, A. Manikandan, K. Ganapathy, M. P. Noufal, Kartikeshwar C. Patro, T. Rajesh, R. Jalali[1]
Departments of Medical Physics and [1]Radiation Oncology, Apollo Proton Cancer Centre, Chennai, Tamil Nadu, India

Imaging QA :
Alignment of X-ray iso with laser & Proton Iso



Geometrical QA

Alignment of X-ray iso with lasers & Proton Isocenter

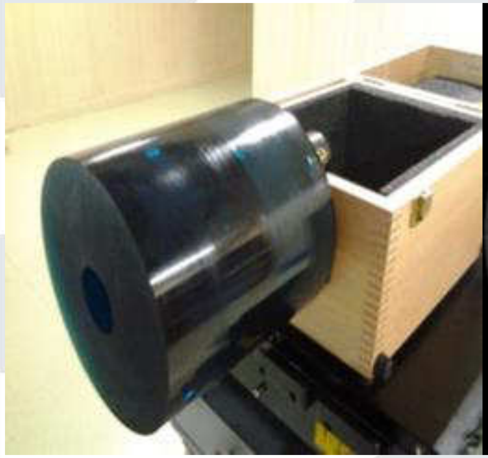
Image quality

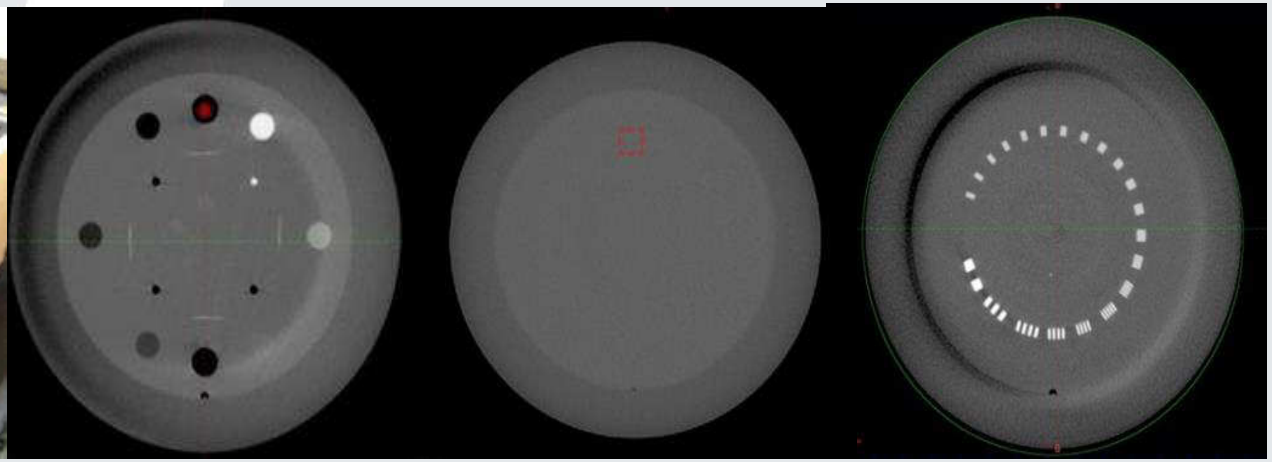
Uniformity

Linearity of CT number

Spatial resolution

Imaging Dose





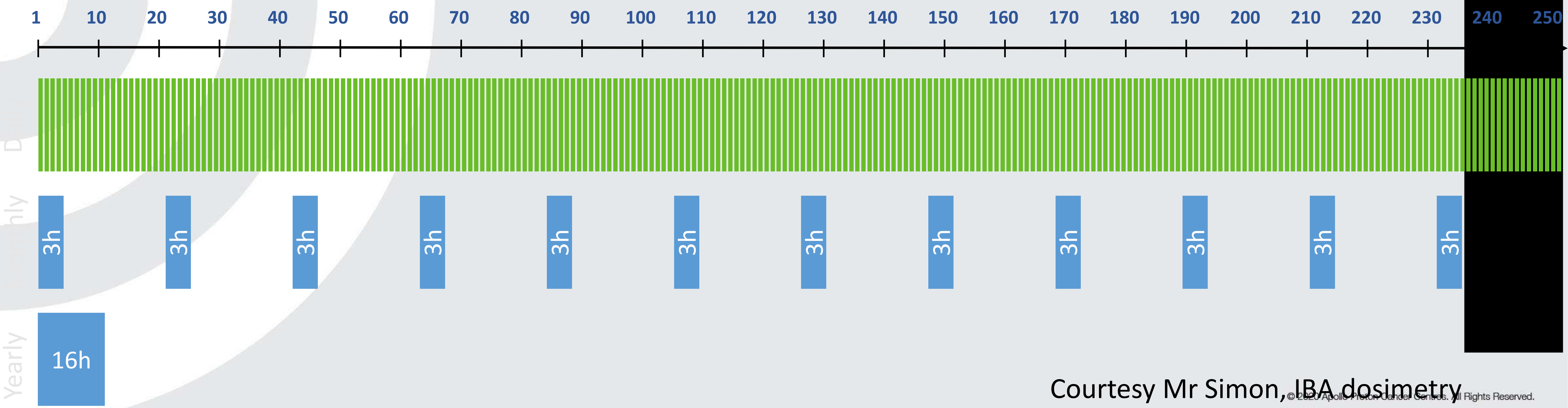
What does it mean practically ?

Different Proton centres

- Check different parameters
- Use different QA device (commercial/In-house)
- Time Spend varies widely

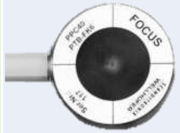
QA Test	Min	Max	Average
Daily	20 min	60 min	**≈ 30 min**
Monthly	2 hours	5 hours	**≈ 3 hours**
Yearly	1 day	3 days	**≈ 2 days**

Yearly Working Days



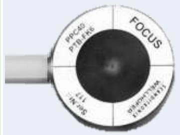
Courtesy Mr Simon, IBA dosimetry

Devices Summary

		Energy	Spots Positions	Spots Sizes	Spots Symmetry	Output	Imaging System	Beam vs X-ray
Zebra or MLFC		✓	✗	✗	✗	✗	✗	✗
Lynx or films		✗	✓	✓	✓	≈	≈	≈
MatriXX or equivalent		≈	≈	≈	✗	✓	≈	≈
PPC05 + water equivalent		≈	✗	✗	✗	✓	✗	✗
Stringray + Blue Phantom		✓	✗	✗	✗	✗	✗	✗
…								

Today's current practices:  +  +  **OR** 

Devices Summary

		Energy	Spots Position	Spots Size	Spots Symmetry	Output	Imaging System	Beam vs X-ray
Zebra or MLFC		✓	✗	✗	✗	✗	✗	✗
Lynx or films		✗	✓	✓	✓	≈	≈	≈
MatriXX or equivalent		≈	≈	≈	✗	✓	≈	≈
PPC05 + water equivalent		≈	✗	✗	✗	✓	✗	✗
Stringray + Blue Phantom		✓	✗	✗	✗	✗	✗	✗
…								
Objective		✓	✓	✓	✓	✓	✓	✓

Courtesy Mr Simon, IBA dosimetry

How to improve the efficiency

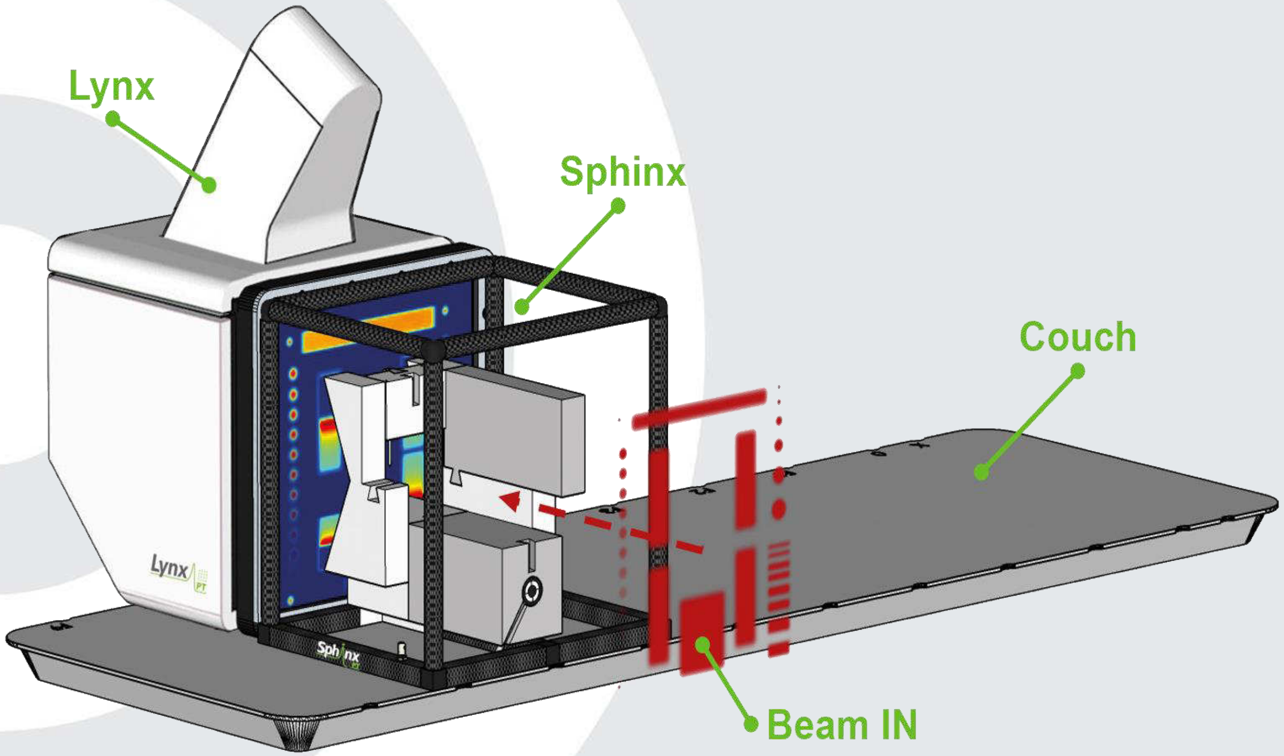
- What can we eliminate?
  - Entire steps or part
  - conditions within a step of a type of measurement
- What can we automate?
- What can we combine?
- PTCOG Subcommittee report on Particle Therapy Efficiency: Aspects of Quality Assurance, May 2016
- Proposed to develop and adopt good tools & methods to integrate the measurements

Sphinx phantom

IBA IN COLLABORATION WITH

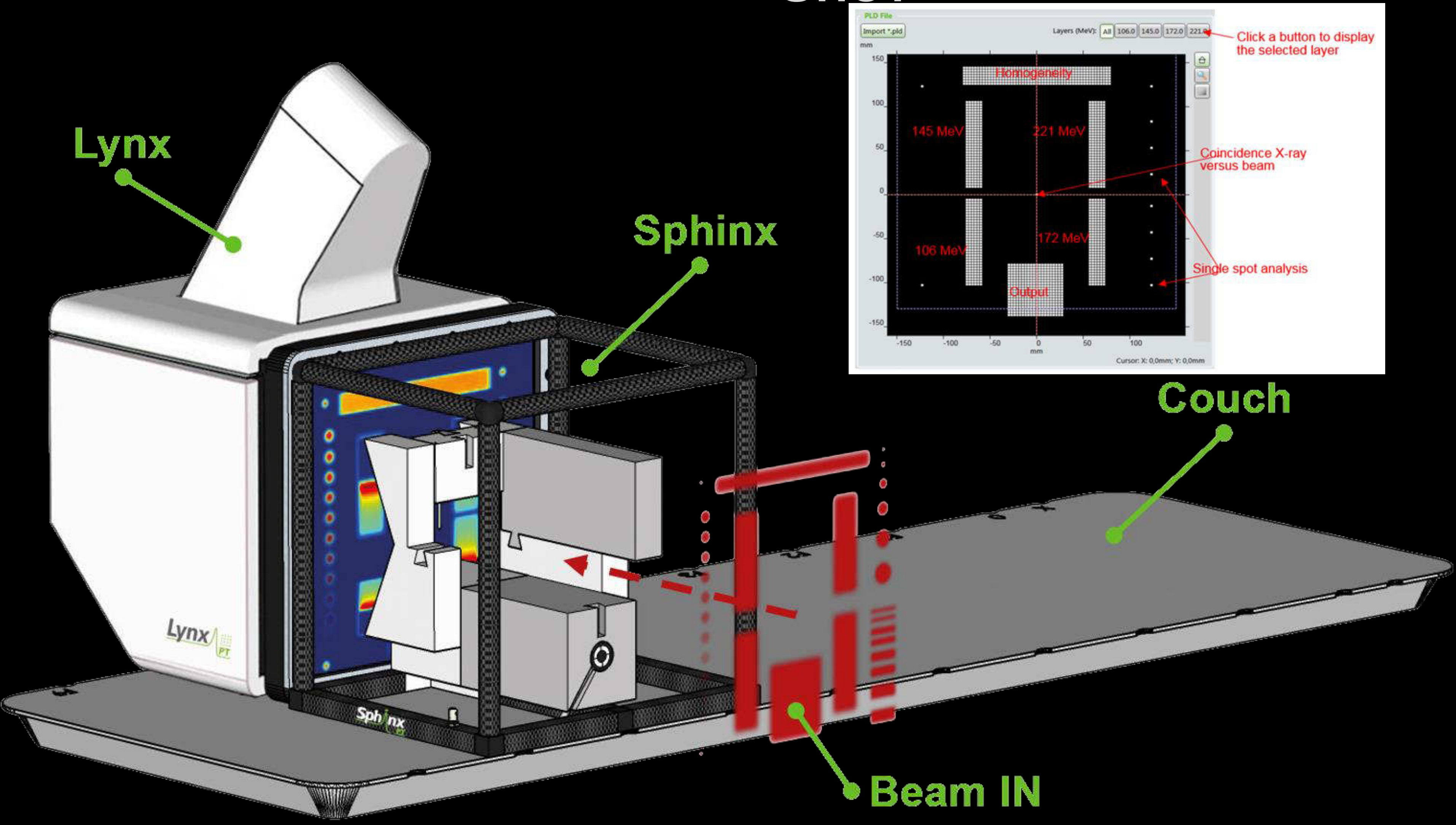
- 4 wedges blocks of RW3 of varying thickness for range verification
- Corresponding energy of 120,150,180 and 230 MeV.
- Fiducials inserted in to the RW3 blocks
- Opening to hold a PPC 05 (0.5 cc) parallel plate IC for absolute dose measurement
- A small radiopaque ball mounted on the centre of the imaging system

Integrated efficient daily QA tool for PBS



- CCD camera (Lynx) integrated to Sphinx wedge phantom using carbon fibre frame
- Segregated regions for testing different aspects of proton beams
- Software :
    - Lynx software for data acquisition and
    - myQA for data analysis
- PPC 05 parallel plate chamber
- Dose 1 Electrometer

Integrated Efficient daily QA in one Shot



- ✓ Energy
- ✓ Spots Size
- ✓ Spots Position
- ✓ Spots Symmetry
- ✓ Absolute dose
- ✓ X-ray vs Proton
- ✓ Lasers
- ✓ Uniformity
- ✓ Imaging system
- ✓ Couch translation
- ✓ …

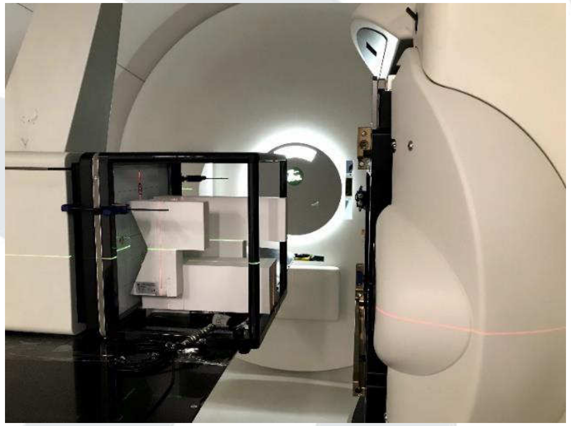
+ *AAPM TG Compliant*

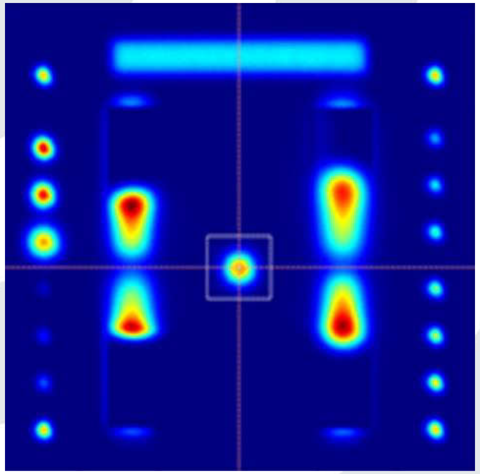
Daily Machine QA

AAPM task group 224: Comprehensive proton therapy machine quality assurance

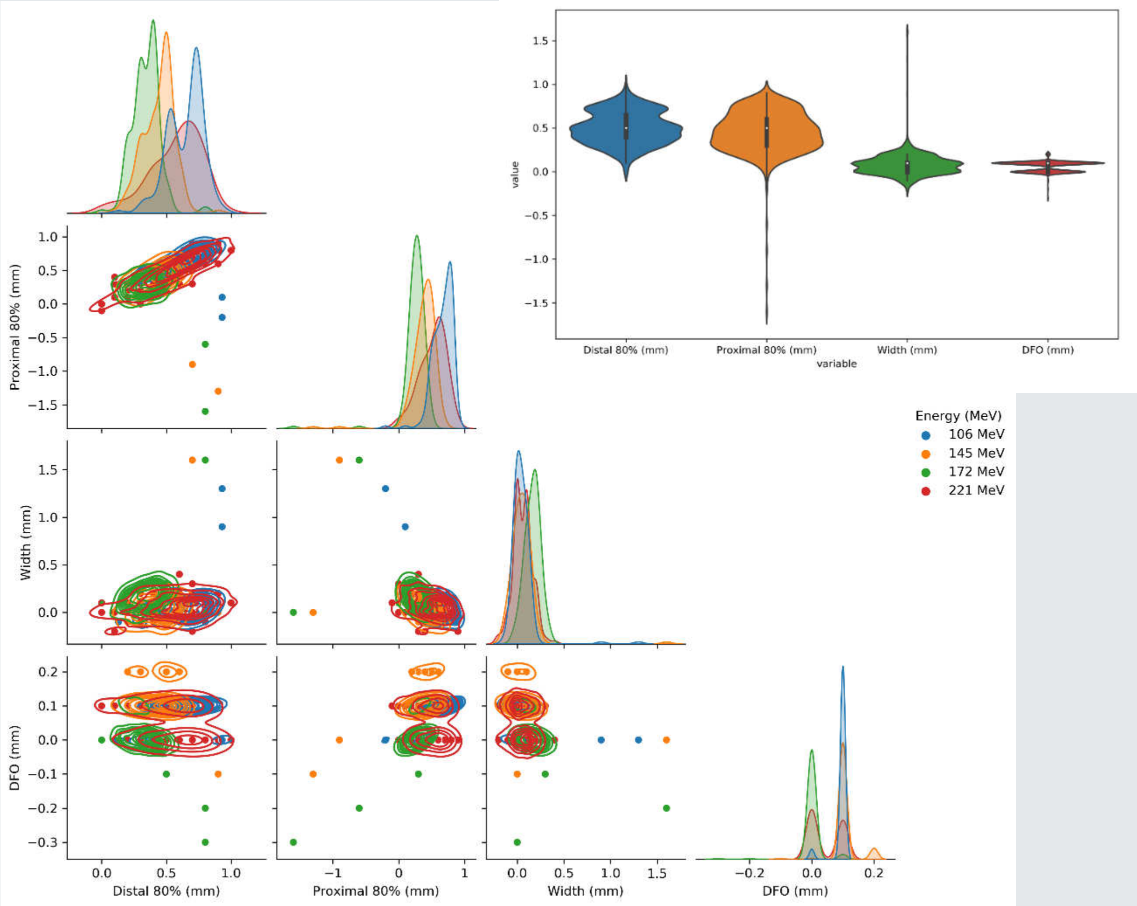
Bijan Arjomandy[a)]
Karmanos Cancer Institute at McLaren-Flint, McLaren Proton Therapy Center, Flint, MI, USA

Paige Taylor
Imaging and Radiation Oncology Core (IROC) Houston, University of Texas MD Anderson Cancer Center, Houston, TX, USA





- Energy
- Spots Size
- Spots Position
- Spots Symmetry
- Absolute dose
- X-ray vs Proton
- Lasers
- Uniformity
- Imaging system
- Couch translation



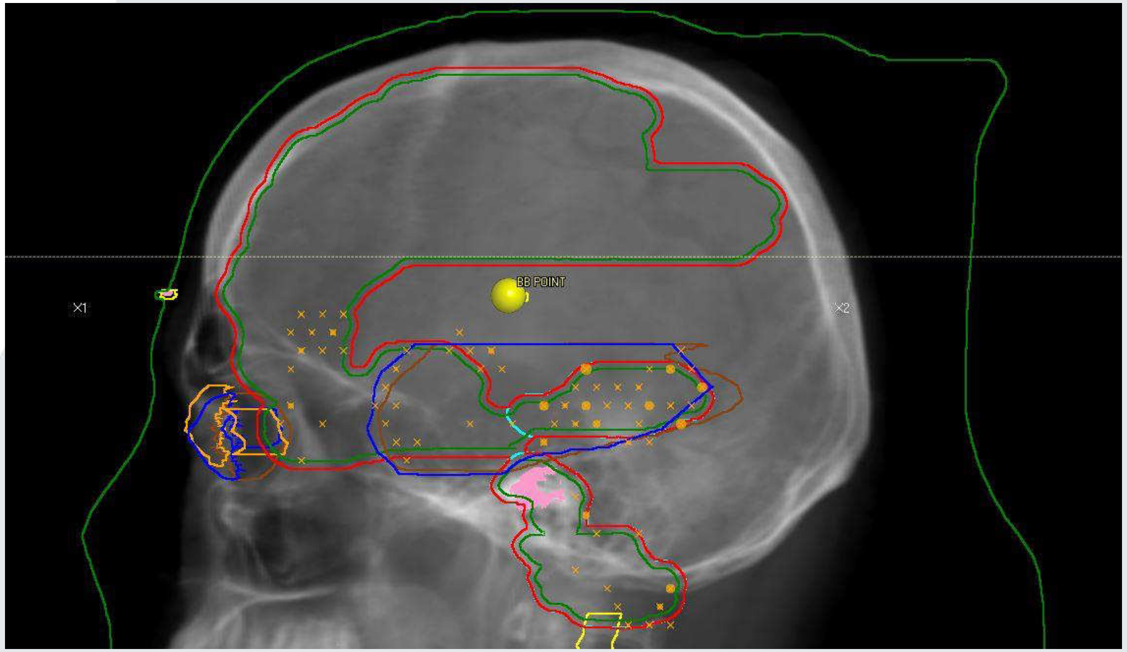
Do we really need a QA for each treatment plan?

1. High degree of complexity involved in IMPT plans

Do we really need a QA for each treatment plan?

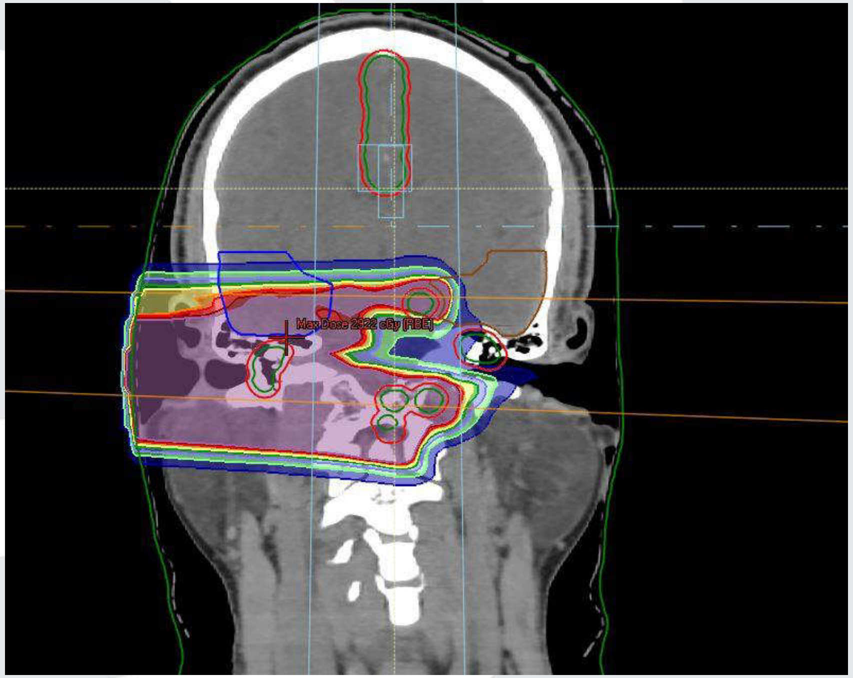
1. High degree of complexity involved in IMPT plans

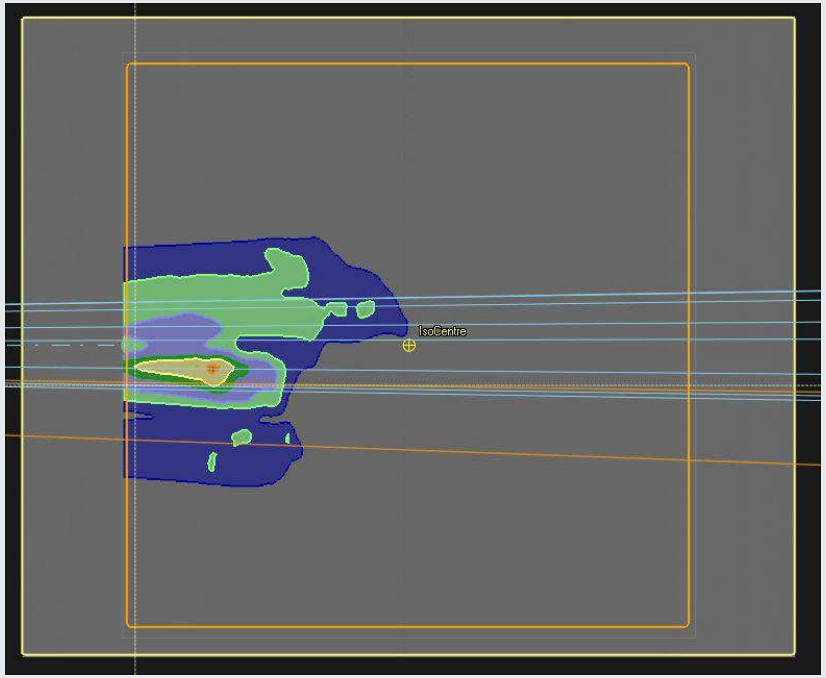
- Multiple proton beams staked over one another (SOBP)
- Thousands of spots distributed in a complex pattern in each layer
- Spot positions, spot spacing and weights
- Intricacy of this spot intensity map becomes complex (SFO – MFO)



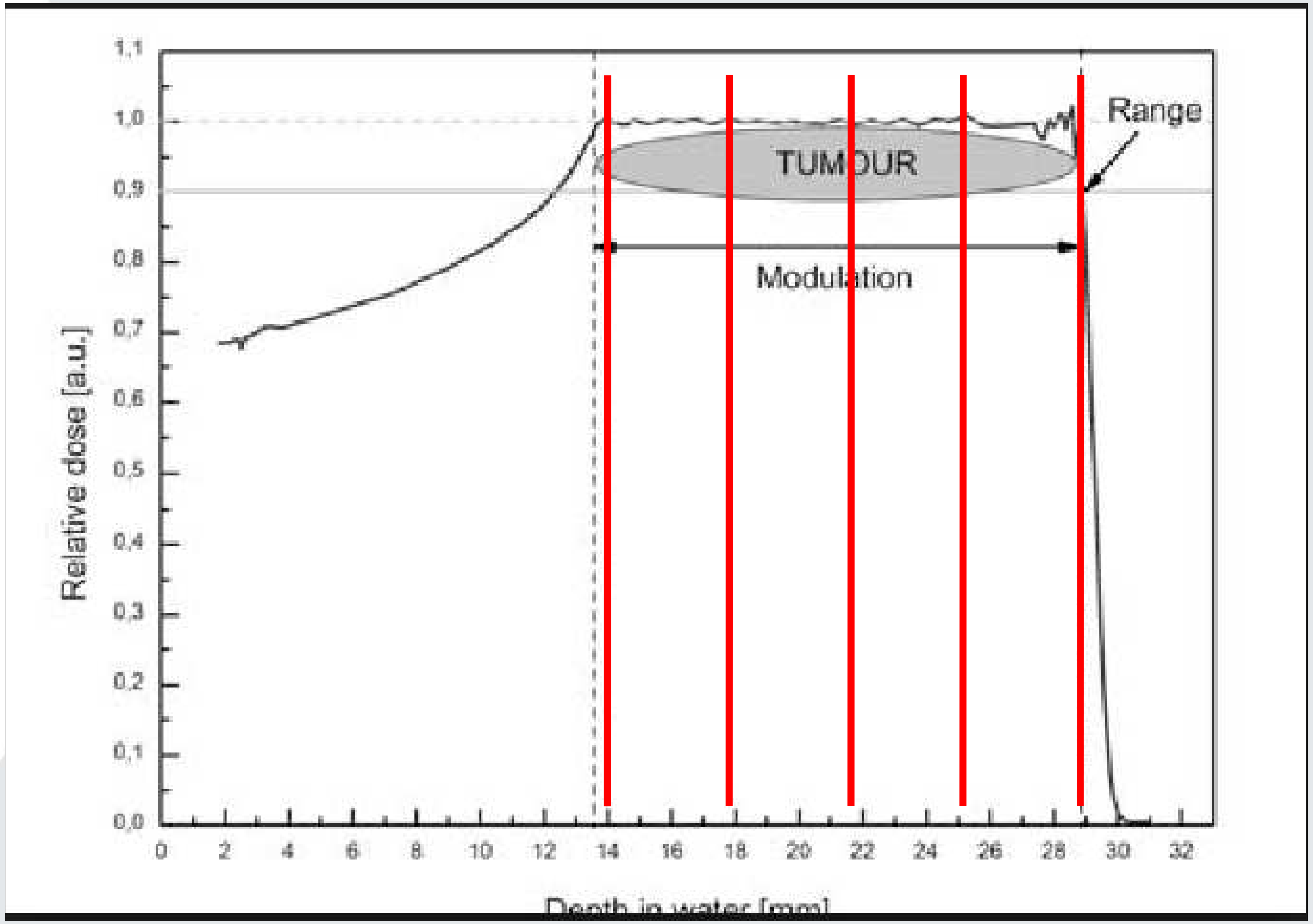
PSQA – Work flow

Treatment Planning room		Treatment room
Dose distribution in patient	Dose distribution in phantom	Plan delivery & measurement





IMPT: Measure at as many depths as possible

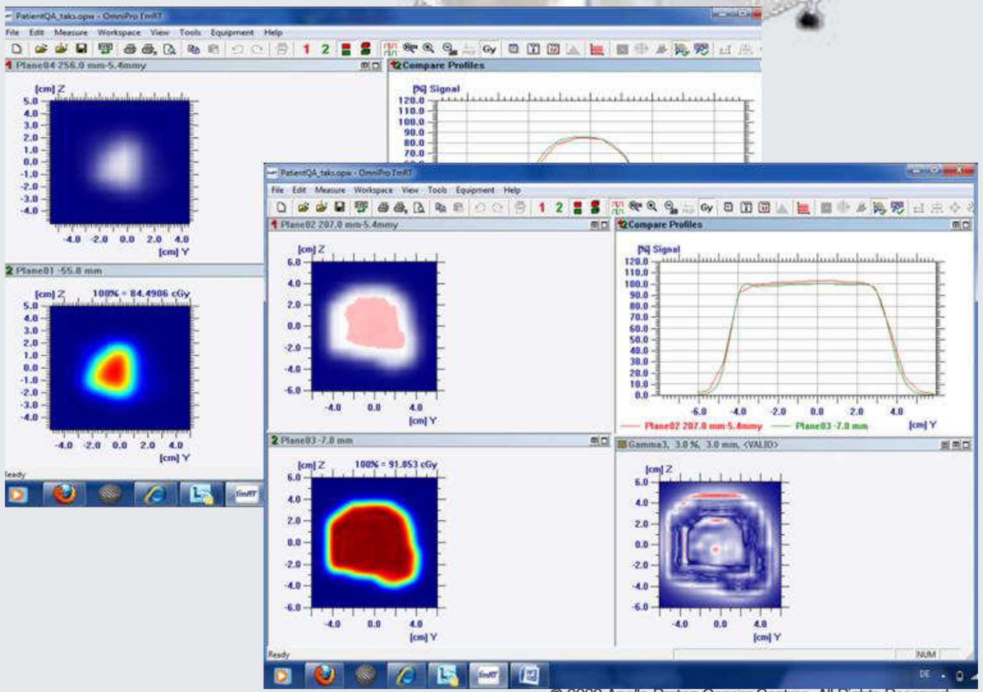


MatriXX PT for patient specific QA

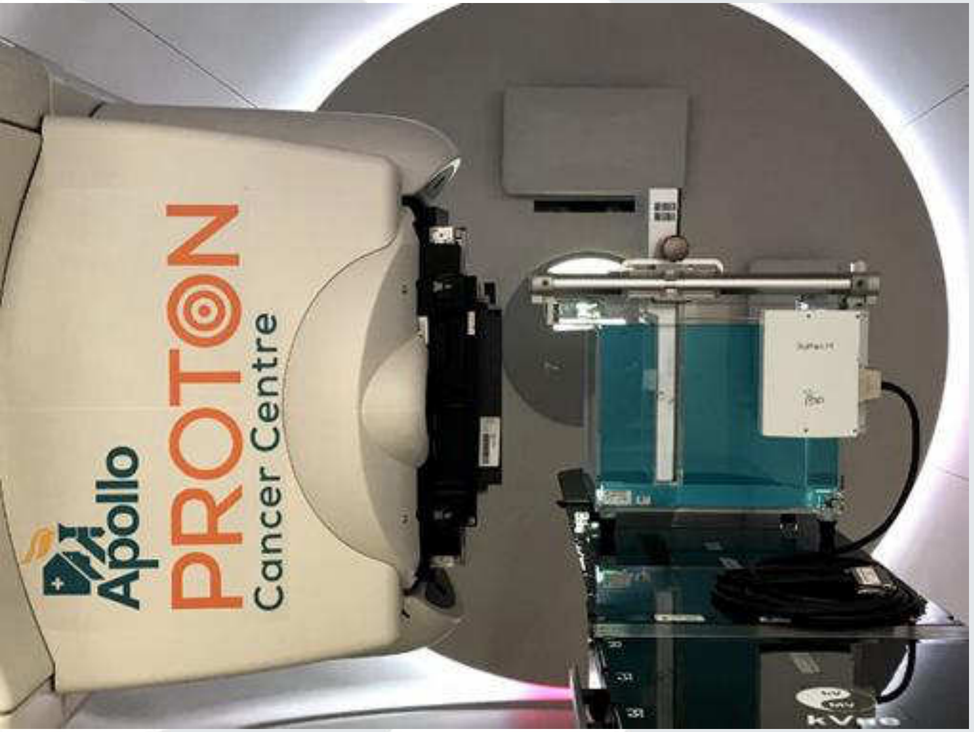
- Specially designed to handle PBS high dose rate
- 1020 ICs covering area of 24.4x24.4 cm^2
- Distance between ICs = 7.6 mm
- ICs size: 4mm diameter over 2 mm of active gap (instead of 5 mm for standard MatriXX)
- Sigma of 3mm: Typical collection efficiency for various bias voltage (Jaffe's protocol)
  - 100V -- 93.9%
  - 250V -- 98.9%
  - 500V – 99.8%
- 500V polarizing voltage

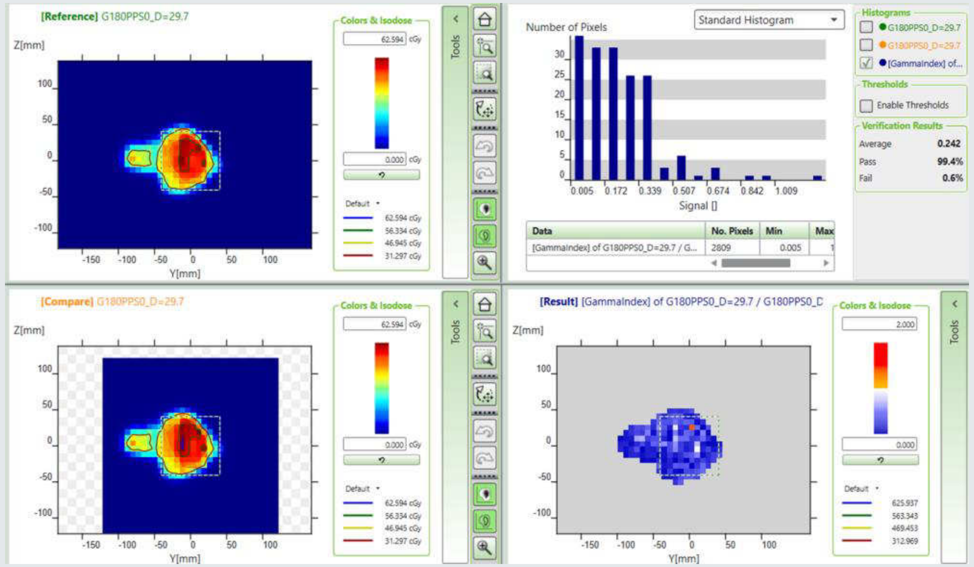
Patient specific QA using DigiMatriXX PT for

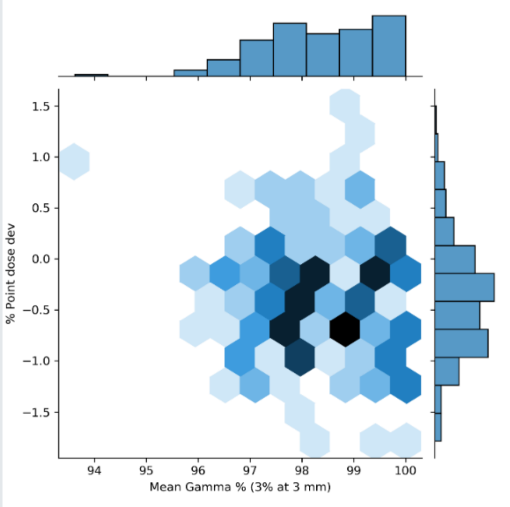
- Create patient verification plan by calculating patient dose on phantom (MatriXX PT or DigiPhant)
- Export each layer of SOBP from TPS and import to software
- Measure 2-3 layers for each patient plan
- Deliver patient dose for all fields MatriXX PT.
- Verify delivered dose vs planned dose in myQA Patient software.
- **3D plan verification**

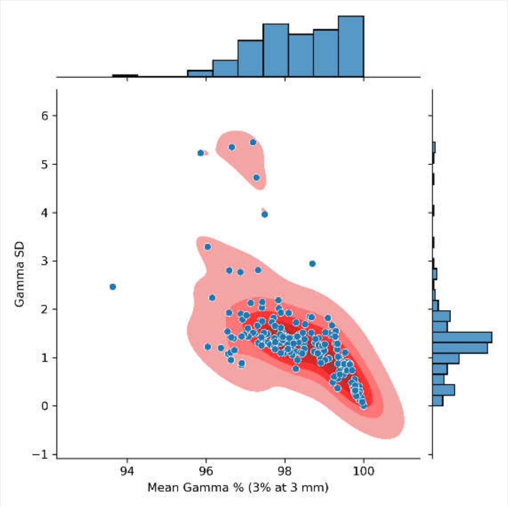


Pre-treatment PSQA of PBT

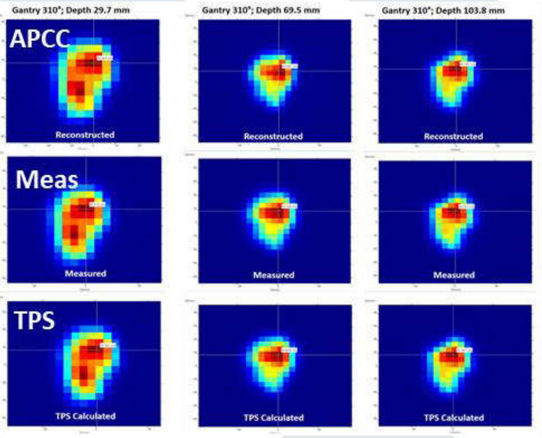


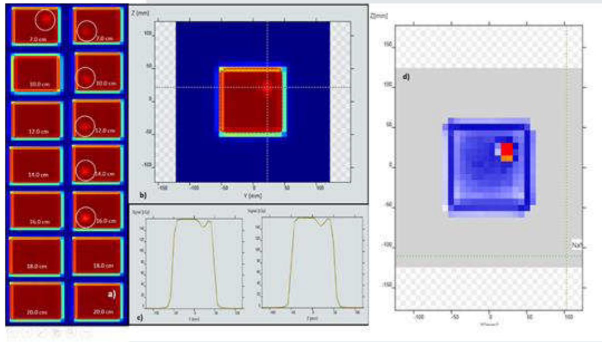






APCC Proposal – to simplify the PSQA





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Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

PAPER

A novel hybrid 3D dose reconstruction approach for pre-treatment verification of intensity modulated proton therapy plans

Manikandan Arjunan[1], Dayananda Shamurailatpam Sharma[1], Suryakant Kaushik[1], Ganapathy Krishnan[1], Kartikeshwar C Patro[1], Noufal Mandala Padanthaiyil[1], T Rajesh[1] and R Jalali[2]

[1] Department of Medical Physics, Apollo Proton Cancer Centre, 100 Feet Road Taramani, Chennai, Tamil Nadu, India

[2] Department of Radiation Oncology, Apollo Proton Cancer Centre, 100 Feet Road Taramani, Chennai, Tamil Nadu, India

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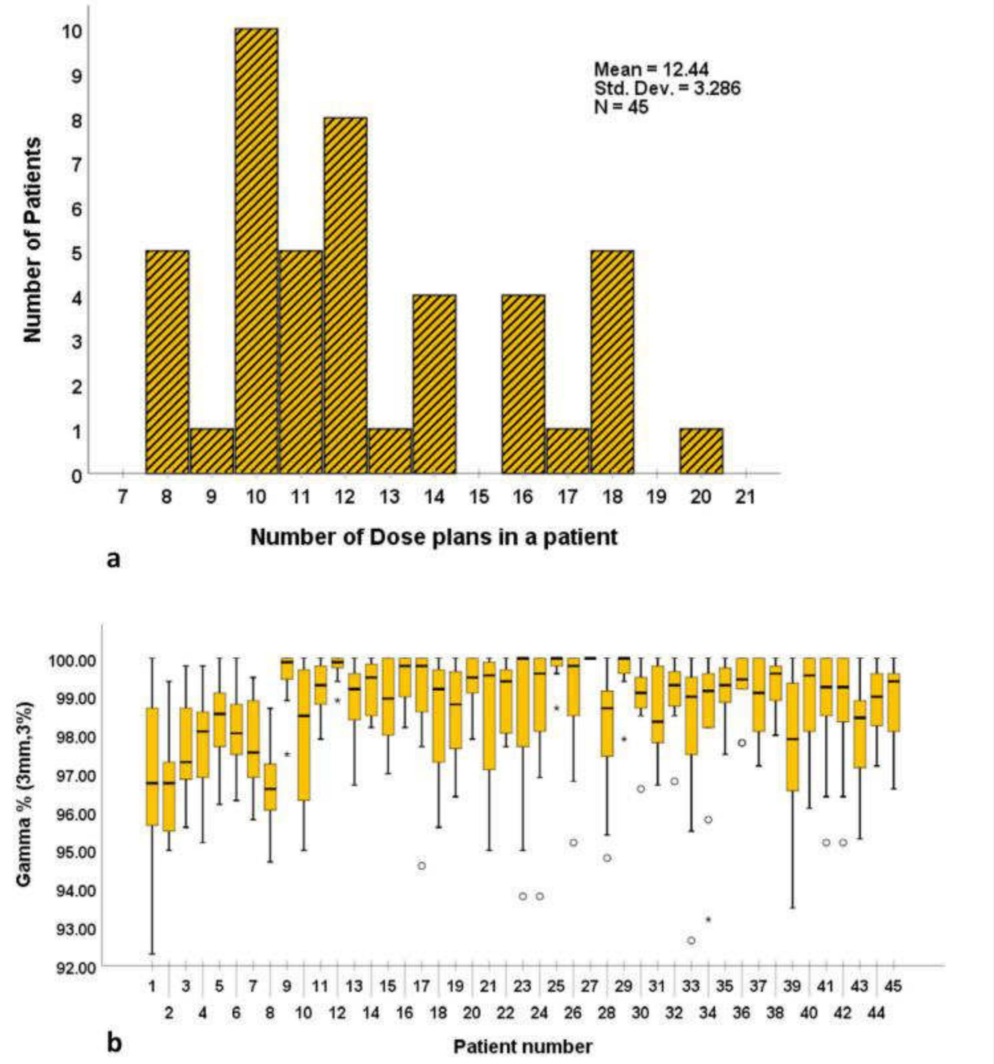
Original Article

Critical Appraisal of Paediatric Embryonal Cancers Treated with Image-guided Intensity-modulated Proton Therapy

D.S. Sharma [*], N.M. Padanthaiyil [*], G. Krishnan [*], M. Arjunan [*], A.K. Reddy [†], S. Mahammood [*], S. Gayen [*], R. Thiyagarajan [*], U. Gaikwad [†], R.T. Sudarsan [†], S. Chilukuri [†], R. Jalali [†]

[*] *Department of Medical Physics, Apollo Proton Cancer Centre, Chennai, Tamil Nadu, India*
[†] *Department of Radiation Oncology, Apollo Proton Cancer Centre, Chennai, Tamil Nadu, India*



The Value of On-Site Proton Audits

Paige A. Taylor, MS, Jessica Lowenstein, MS, David Followill, PhD, and Stephen F. Kry, PhD

The University of Texas, MD Anderson Cancer Center, Houston, Texas

Received Jun 25, 2021; Accepted for publication Oct 22, 2021

Summery : Water tank measurement with ICs

Chamber type

- Small volume chamber
- Parallel plate chamber
- Large diameter PPC
- Farmer chamber
- + computerized Water tank

Measurement type

- Beam profile measurement
- Absolute dose calibration
- Beam range and modulation measurement
- Relative dose output
- Patient specific QA output

Generally use during commissioning, quarterly and annual QA

Summery : Linx

Measurement types

- Alignment check
- Alignment check with gantry mount
- Spot alignment
- Spot distribution characteristics

Applications

- Commissioning
- Validation
- Daily QA
- Monthly QA
- Annual QA

Summery: Sphinx phantom with Linx

Measurement type

- Energy
- Spots Size
- Spots Position
- Spots Symmetry
- Absolute dose
- X-ray vs Proton
- Lasers
- Uniformity
- Imaging system
- Couch translation

Application

- Daily QA
- Monthly QA
- Annual QA

Zebra MLIC

Measurement type

- Range
- Modulation
- Pristine Bragg Peak
- SOBP

Application

- Commissioning
- Validation
- Monthly QA
- Annual QA

MatriXX-PT / DigiMatrixxPT

Measurement type
- Output
- Beam profile analysis
- Planar dose distribution
- Comparison of measurements to other measurement to calculated dose distribution

Application
- Patient specific QA
- Monthly QA

Conclusion

- Proton therapy provides superior sparing of OAR and reduce integral dose to normal tissue significantly due to its physical Bragg's peak characteristic
- PBS technique is highly flexible & have the potential of treating very complex cases using IMPT.
- Dosimetry of pencil beam proton requires different type of dosimetric equipment different than photon
- Accurate measurement of PBS beam data requires good knowledge of proton characteristic, dosimetric equipment toll
- Proton beam characteristic parameters are quite reproducible

1. **Sharma DS**, Padanthaiyil NM, Krishnan G, Arjunan M, Reddy AK, Mahammood S, Gayen S, Thiyagarajan R, Gaikwad U, Sudarsan RT, Chilukuri S, Jalali R. Critical Appraisal of Paediatric Embryonal Cancers Treated with Image-guided Intensity-modulated Proton Therapy. Clin Oncol (R Coll Radiol). 2023 Jan 4:S0936-6555(22)00580-5. doi: 10.1016/j.clon.2022.12.003. Epub ahead of print. PMID: 36609026.

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The Team
Thank You