

Technology and Infrastructure Requirements of a Proton Therapy Centre

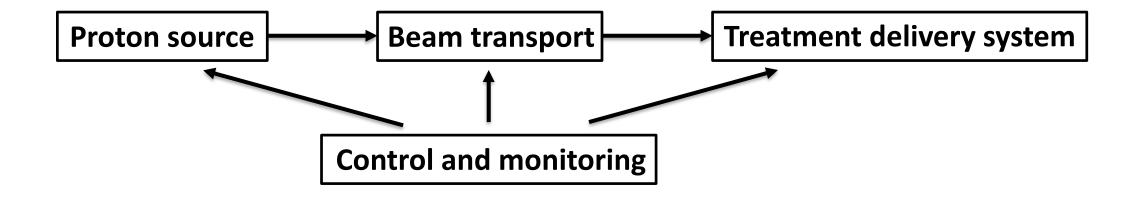
Richard A. Amos, MSc, CPhys, CSci, FIPEM

Hon. Associate Professor of Proton Therapy Research Lead for Clinical Proton Therapy Physics Department of Medical Physics and Biomedical Engineering University College London





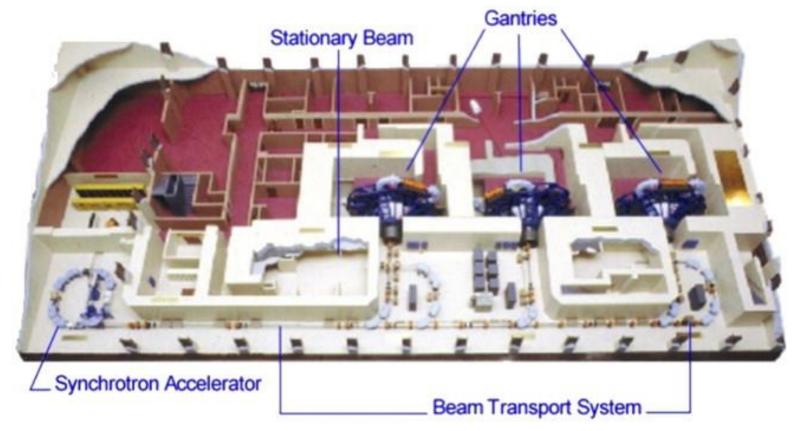




System specifications defined to meet clinical need:

- Specific needs of case mix
 - Paediatrics
 - Moving targets
 - Complex sites
- Patient throughput requirements
- Capital and maintenance costs
- Additional research capacity



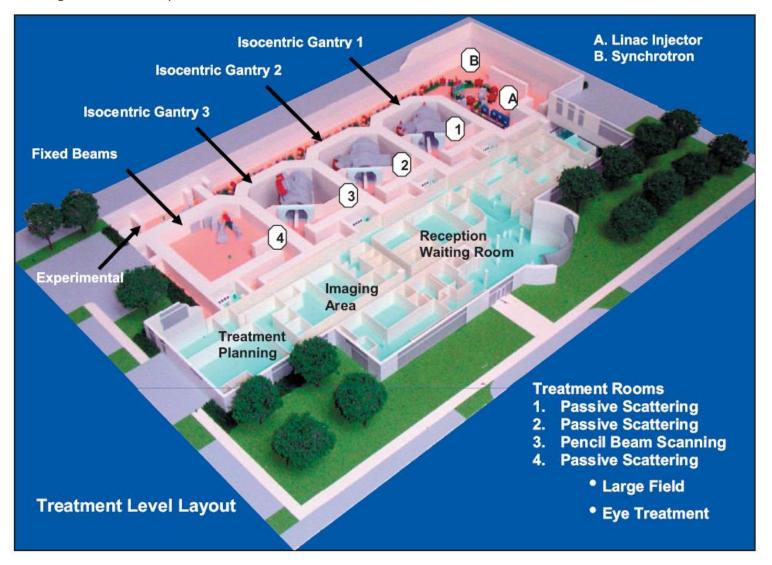


- •250 MeV synchrotron developed in collaboration with Fermi National Accelerator Laboratory
- •3 gantries (passive scattering)
- •1 fixed clinical beamline (passive scattering)
- •1 fixed ocular beamline (passive scattering)
- •1 fixed experimental beamline (passive scattering)

MDAnderson Cancer Center

Making Cancer History®

- •250 MeV synchrotron (Hitachi PROBEAT system)
- •3 gantries (2 passive scattering + 1 pencil beam scanning)
- •1 fixed clinical beamline (passive scattering)
- •1 fixed ocular beamline (passive scattering)
- •1 fixed experimental beamline (passive scattering)







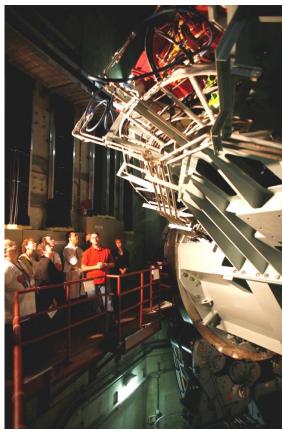




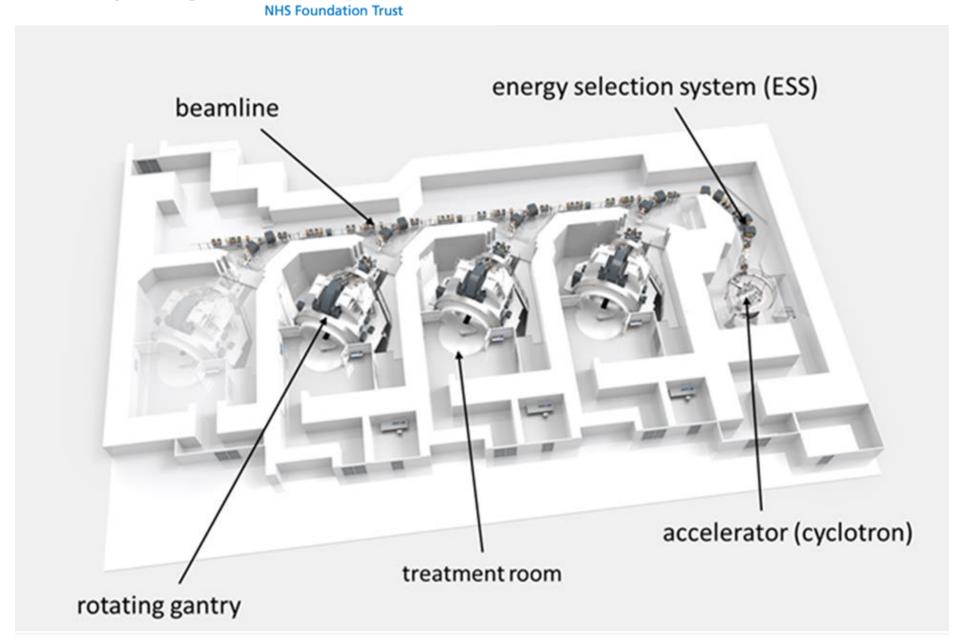




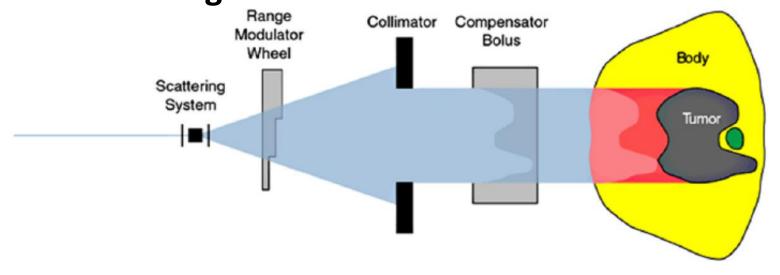




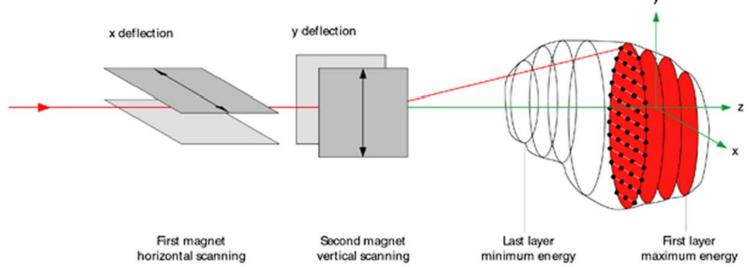




Passive Scattering

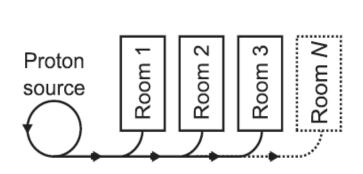


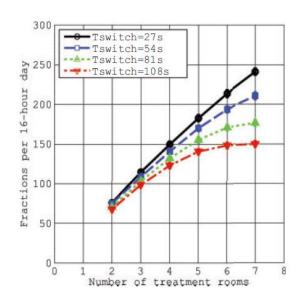
Pencil Beam Scanning (PBS)

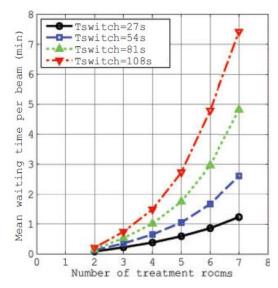


Modelling the throughput capacity of a single-accelerator multitreatment room proton therapy centre

^{1,2}A H AITKENHEAD, PhD, ³D BUGG, BSc, ^{1,2}C G ROWBOTTOM, PhD, ⁴E SMITH, MRCP(UK), FRCR and ^{1,2}R I MACKAY, PhD



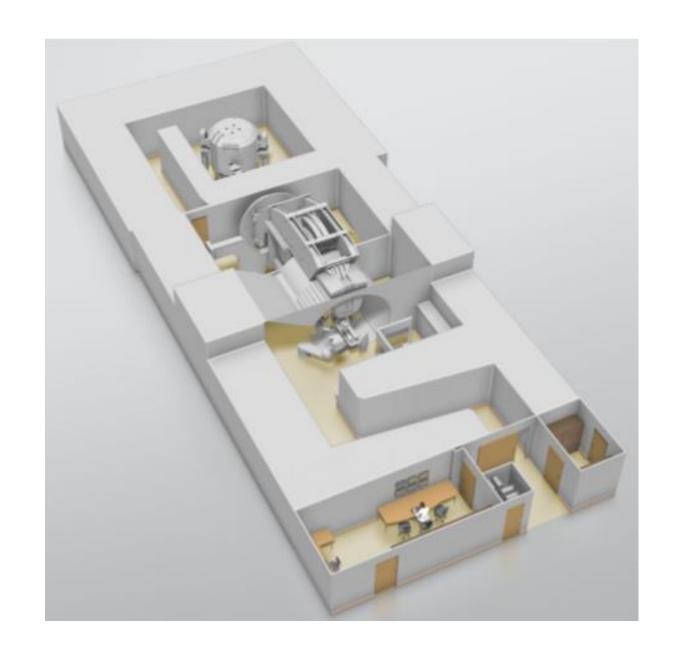




	US caseload			UK caseload		
Number of rooms	t_{fraction} (min)	t _{waiting} (min)	P _{annual} (patients)	t_{fraction} (min)	t _{waiting} (min)	P _{annual} (number of patients)
2	26.6	0.1	546	32.8	0.1	443
3	26.9	0.4	811	33.2	0.4	657
4	27.8	0.7	1046	34.2	0.7	850
5	28.8	1.1	1262	35.5	1.1	1024

Technology evolving:

- Single room facilities
 - Increasing access to wider community
 - Faster construction
 - Efficient
- Partial gantries
 - Space saving
 - Workflow changes
- Accelerator design
 - Higher energy (proton radiography)
 - Cheaper, smaller,....





Proton Beam Therapy Equipment & Services

Document 2

Specification
December 2013

Engineeri and Countries & Malitheaure Service Specification							
Notice: I - for other to provide a compilarit reporse, Didders must provide a response to each section - "I" and "0" have been excluded from the Section numbering sequence i.e. there is no 2.11 or 2.1.0							
Question Number	Response Requirements	Section / Question Weighting (%)	Overall Weighting out of 198%	Overall Weighting out of 72%	Scoring Scale	Grade	En
Section 2.1	Section 2 1 - Conditions of Excels of Engineers						
Notes	Bidders must achieve an overall pass for this section is order to achieve an overall "Pass" for this section Bidders must achieve a "Pass" for each section						
	Countion Children and search that the Equipment proposed has received CE marking or Distinct notice search that the Equipment will achieve CE marking to exact invaluant to commence by the Distinct notice described by the Equipment of Equipment of the Equipment of the Equipment of Equipment of the Equipment of Equipment of Equipment of Equipment of the Equipment of	os.	98	os.	Pass / fail	Pess	The Bidder and any Relevant Organisation(s) warrant that all Equipment or additional provide credible assurance that CE marking will be achieved price
	Bodden has do confirm for C.C. commission was the processor and the state of the confirmation of the state of the confirmation					N	If the Didden Response does not satisfy the orders to achieve a
218	Question: Discussion and warrent that they will comply all applicable UK safety legislation and guidence, including those blood in 2.1.3.	os.	03.	ON.	Page / Fell	Pass	The Bidder and any Relevant Organisation(s) warrants comply blood in 2.13.
	Didden shall notify the Trust in their Response of any non-compliance with these requirements Outdonne Provide statement to warrant compliance.					ret	If the Didders Response does not salisfy the orders to achieve a
21.0	Question field werent that they half and shall maintain throughout the design, manufacture, installation, commissioning and maintenance periods, a quality management systems considered with the ECO 9001 for recognised international equivalently standard and that the Equipment and Services being offered to the Tool which also designed, manufactured, definited, installand, commissioned and maintained in socrations with the standard or manufactured, definited, installand, commissioned and maintained in socrations with the standard programment of the standard programment of the standard of the standard programment of the standard of the standard programment of the	os.	98	os.	Pass / Fall	Pass	The Bidder and any Relevant Organization(s) warrent that they commissioning and maintenance particle, is quality management equivalent) standard and that the Equipment and Services being commissioned and mainteined in accordance with the requirement.
	requirements of their quality management system. Outdomer Provide advisored to werent compliance. Provide Centificate of Accordation where wellable.	ON.		on.	7440/740	NI	Ethe Ekidem Response does not salisfy the criteria to achieve a
210	Question Sides what varient that the Equipment complies with applicable international Standards for Radiation Theoryp Equipment, including the standards label in water 2.1.5. Sides with a roll the Trust in their Response of any non-compliance with these recultements.	25.	0%	ON P	Pass / Fall	Pass	The Didder and any Relevant Organisation(s) warrant that the Therapy Equipment, including the idandards lated in section 2.1.
	Galdanos Povide statement to vernent compliance.		"			Pall	If the Biddens Response does not satisfy the orders to achieve a
212	Question Siddow shall warrant that the control system software complies with the standards and protocols listed in 23.6. Siddow shall notify the Trust in their Response of any non-compliance with these recultements.	ON.	0%	ON.	Pass / Fall	Pass	The Didder and any Relevant Organisation(s) wement that the 21 S.
	Oddance Provide statement to warrant compliance.					rec	If the Bidders Response does not satisfy the orbits to achieve a
10	Question Sidden shall varient that all Equipment image import and export functions and redeck interfaces comply with all applicable international Standards, including those listed in 2.1.7. Sidden shall notify the Trust in their Teleporase of any non-compliance with these requirements.	ON.	09.	cos.	Page / Fall	Passa	The Bidder and any Relevant Organisation(s) warrant that the comply with all applicable international Standards, including those
	Oddance Provide statement to warrant compliance.	"				Tel:	If the Bidders Response does not satisfy the orbits to achieve a
210	Question Sodem shall varent that design of the mechanisal 8 public health services (including any generus supplies) comply with all applicable UK legislation and regulations, including those blade in 2.1.6. Sodiem shall notify the Trust in their Response of any non-compliance with these regularments.	ON.	03.	co.	Pass / Fall	Passa	The Bidder and any Relevant Organisation(s) warrant that de supplies) comply with all applicable UK legislation and regulation
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2.131	Ownton						

Document 4 - Technical Questionnaire

- 2.1 Conditions of Supply of Equipment
- 2.2 Support & Training
- 2.3 General Facility Environmental Specifications
- 2.4 Electricity and power & Building Infrastructure
- 2.5 Equipment Reliability, Efficiency and Uptime Specifications
- 2.6 Installation & Beam Transport Commissioning
- 2.7 Radiation Protection
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- 2.18 Upgrades, Innovations and Retrofits
- 2.19 Fourth Room Option and Research

130 Questions:

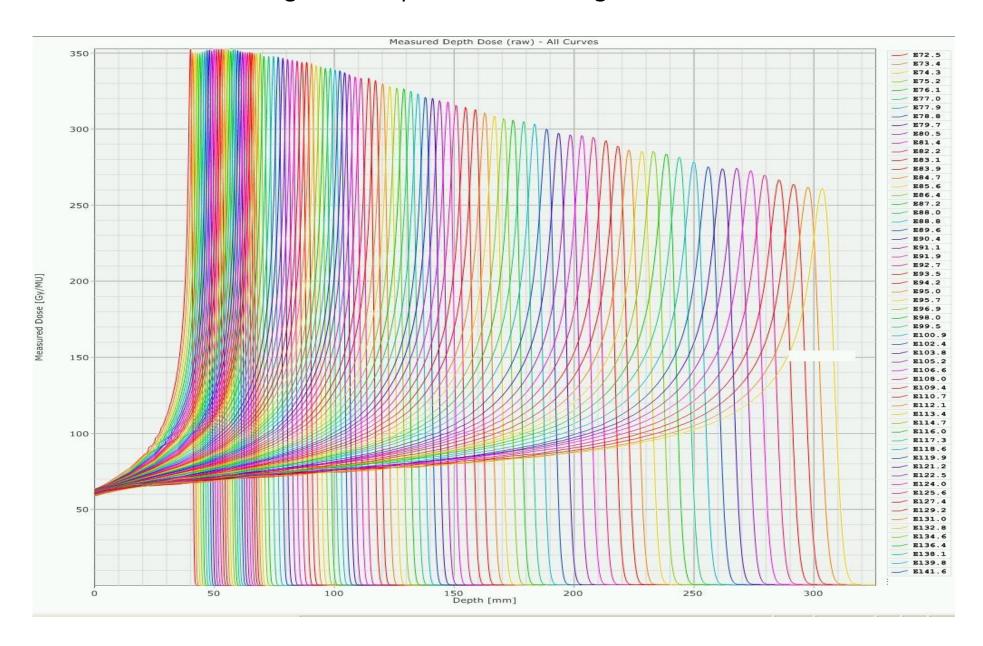
- 31 Pass/Fail
- 35 For information only (needed for compliant bid)
- 64 Scored
 - 4 Excellent confidence
 - 3 Very good confidence
 - 2 Good confidence
 - 1 Minor concerns
 - 0 Major concerns

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Monte Carlo generated pre-commissioning data at MD Anderson

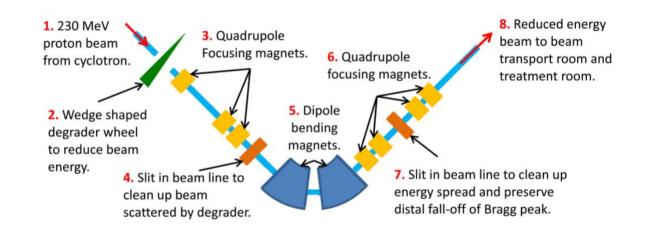


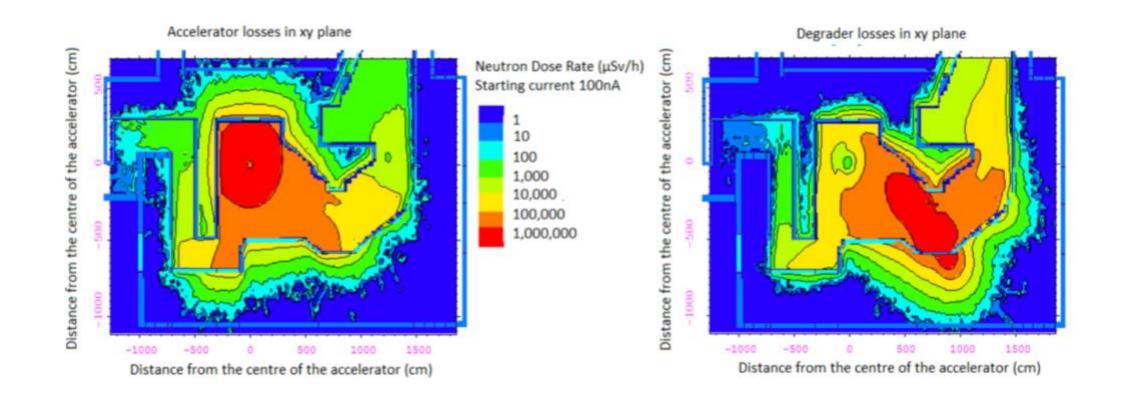
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Workload calculations based on estimates of:

- Patient throughput
- Numbers and angles of beams
- Range of energies used
- Volume of targets

Activation of components, incl. air and water. Ducting in shielding walls – BIM. Monte Carlo modelling of losses....





Particle
Therapy
CoOperative
Group

PTCOG Report 1

PTCOG Publications Sub-Committee Task Group on Shielding Design and Radiation Safety of Charged Particle Therapy Facilities

Series in Physics and Engineering in Medicine and Biology



Design and Shielding of Radiotherapy Treatment Facilities

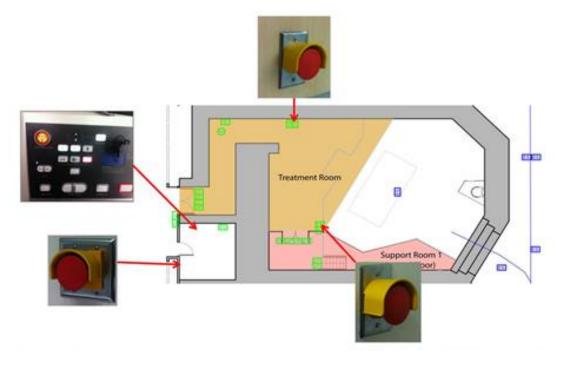
IPEM Report 75

Chapter 11

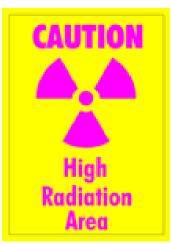
Radiation shielding and safety for particle therapy facilities

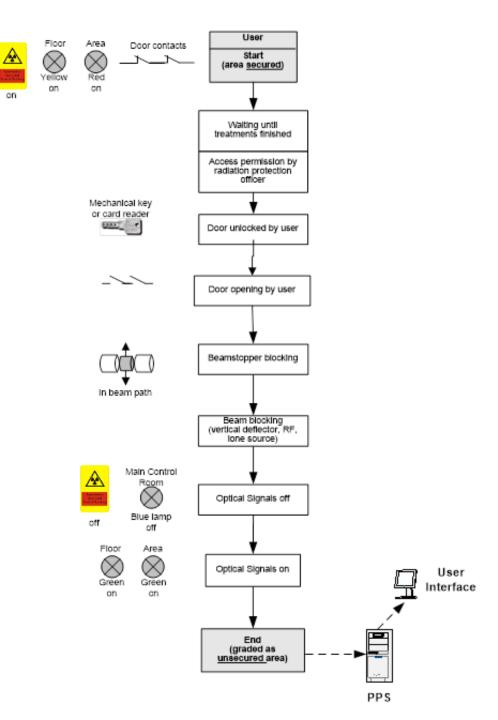
R L Maughan, M J Hardy, M J Taylor, J Reay and R Amos

Radiation and general safety interlock system



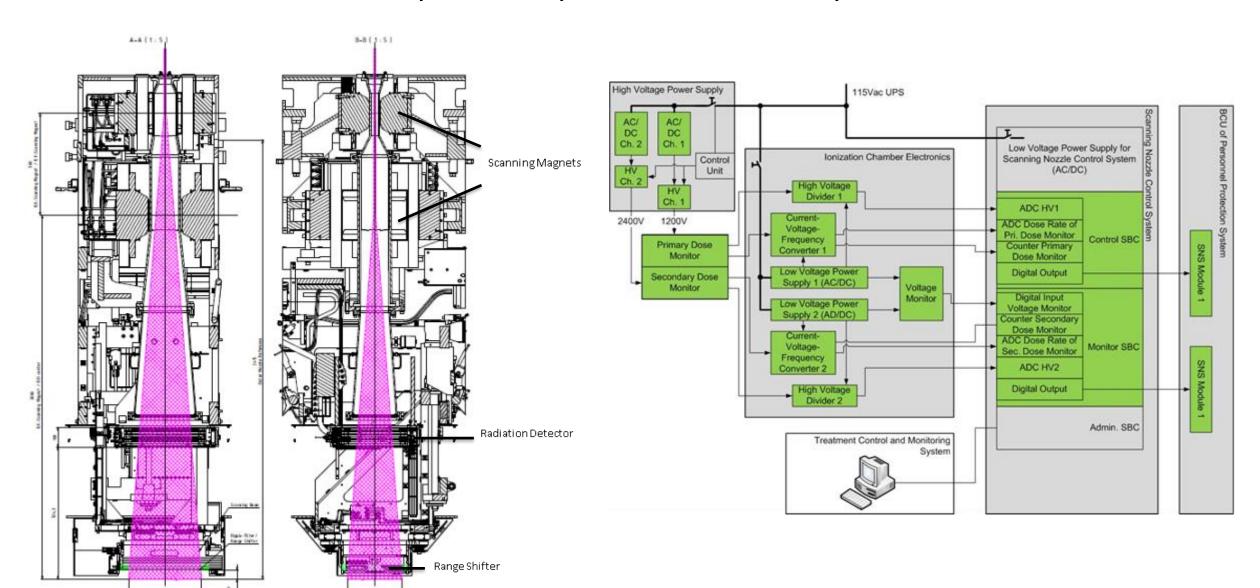






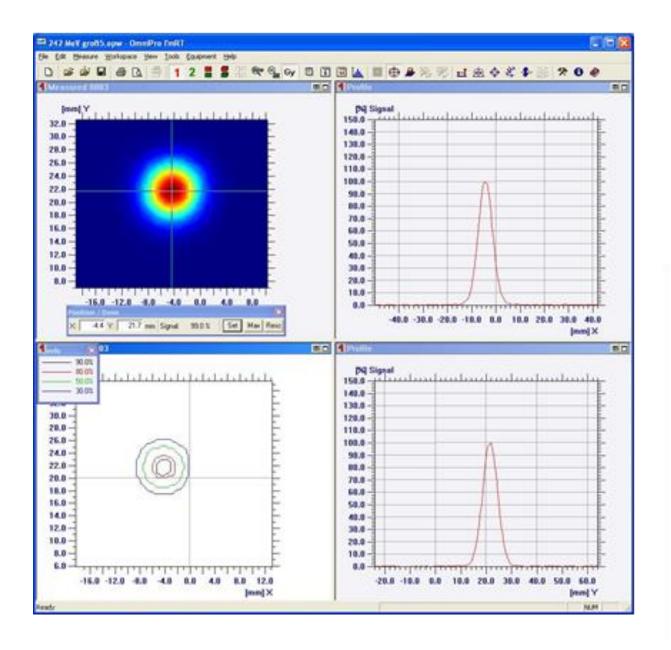
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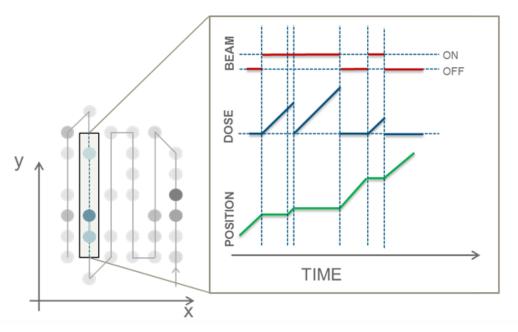
Dosimetry, telemetry, and beam control systems

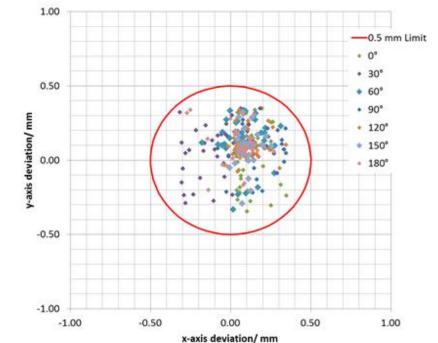


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Clinical beam characteristics







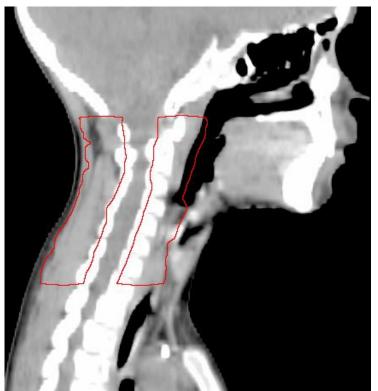
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Clinical Case # 1



Ewing Sarcoma Right C-Spine

- •Rx: 54 Gy (RBE) / 30 fx to C-spine and right neck (*PTV ED*)
- •IMPT with component of SFUD (at least 20% IMPT)
- •RPO, gantry angle $^{\sim}$ 200 210 deg
- •LPO, gantry angle ~ 130 140 deg
- •Rt Lat, gantry angle 90 deg
- •Same angles for SFUD and IMPT components

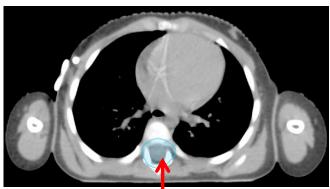


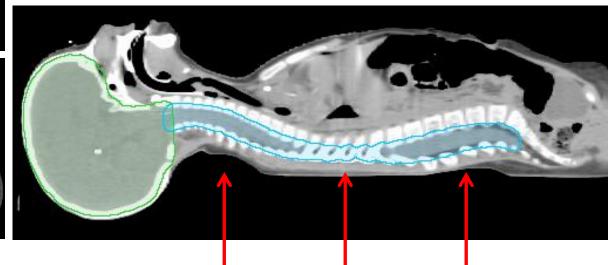
Clinical Case # 2 (Phase 1)



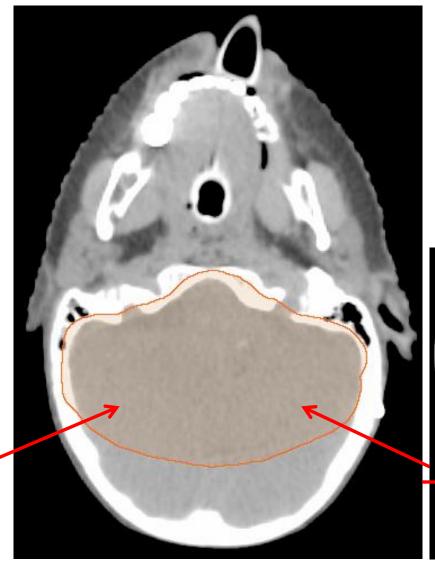
Metastatic Ependymoma

- •IMPT with component of SFUD (at least 20% IMPT)
- Patient under GA in supine position
- •Phase 1 Rx: 36 Gy (RBE) / 20 fx to whole CNS (brain + spine PTV)
- Multiple isocenters
- •RPO and LPO fields to the brain, gantry angles $^{\sim}$ 255 and 105 deg respectively
- •Multiple PA fields to spine (number of fields depends on field size limitations)
- •IMPT component to taper field matches to improve plan robustness



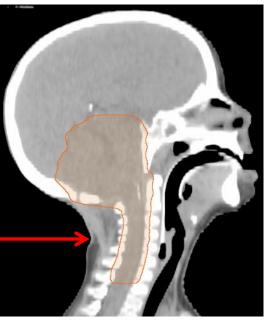


Clinical Case # 2 (Phases 2 & 3)

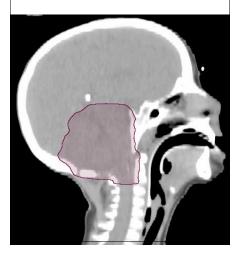


Metastatic Ependymoma

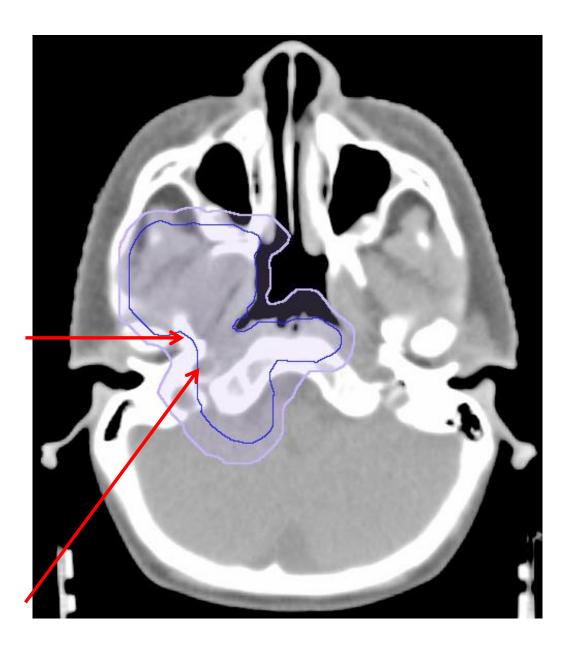
- •IMPT with component of SFUD (at least 20% IMPT)
- Patient under GA in supine position
- •Phase 2 Rx: 9 Gy (RBE) / 5 fx to C-spine and post fossa (PTVPh2)
- •LPO, gantry angle ~ 120 130 deg
- •RPO, gantry angle ~ 230 240 deg
- •PA, gantry angle = 180 deg
- •IMPT eg, contribution of PA only at C-spine level
- •Phase 3 Rx: 9 Gy (RBE) / 5 fx to post fossa (*PTVPh3*)
- •Repeat LPO and RPO IMPT fields
- •Omit PA component





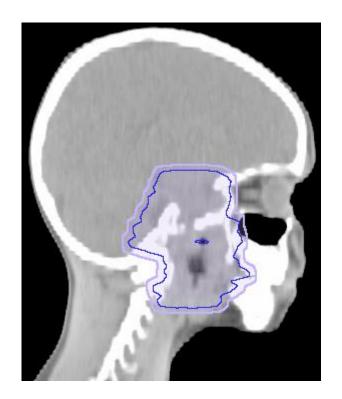


Clinical Case # 3



Alveolar Rhabdomyosarcoma (Post nasal space)

- •Rx: 50.4 Gy (RBE) / 28 fx to PTV
- •IMPT with component of SFUD (at least 20% IMPT)
- •RPO, gantry angle ~ 220 deg
- •Rt Lat, (or very slight RPO)
- •SFUD up to a dose of approx. 40 Gy (RBE), then IMPT to better spare the OARs. Same gantry angles for SFUD and IMPT



Clinical Case # 1

CRITICAL ORGAN LABEL	DOSE CONSTRAINT [Gy (RBE)]		
Canal (PRV)	50 Gy (RBE)		
Parotid (volume NOT PRV)	24 Gy (RBE) max; 18 Gy (RBE) mean		
PharynConstrictors (Volume NOT PRV)	50 Gy (RBE) mean but do not compromise PTV dose		
Mandible	Either: < 10 Gy (RBE) whole structure OR: > 10 Gy (RBE) but < 30 Gy (RBE) uniformly over whole structure.		

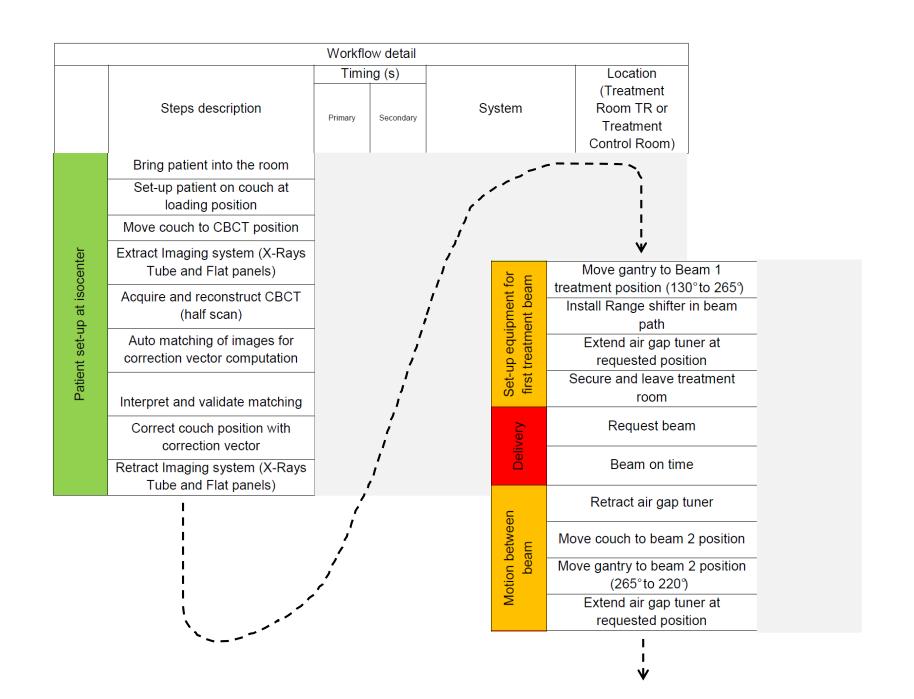
Clinical Case # 2

CRITICAL ORGAN LABEL	DOSE CONSTRAINT [Gy (RBE)]		
Pituitary	For record only		
Eyes	54 Gy (RBE)		
Chiasm	55 Gy (RBE)		
Brainstem	55 Gy (RBE)		
Optic Nerves	45 Gy (RBE)		
Lens	5 Gy (RBE)		
Parotid	Mean dose 24 Gy (RBE) to organ		
Facial bones	Either: < 10 Gy (RBE) whole structure OR: > 10 Gy (RBE) but < 30 Gy (RBE) uniformly over whole structure.		

Clinical Case # 3

CRITICAL ORGAN LABEL	DOSE CONSTRAINT [Gy (RBE)]
RIGHT EYE	Maximum Dose <45 Gy (RBE) to organ
RIGHT LENS	Maximum Dose <5 Gy (RBE) to organ
RIGHT OPTIC NERVE	Maximum Dose <50 Gy (RBE) to organ PRV
LEFT EYE	Maximum Dose <45 Gy (RBE) to organ
LEFT LENS	Maximum Dose <5 Gy (RBE) to organ
LEFT OPTIC NERVE	Maximum Dose <50 Gy (RBE) to organ PRV
OPTIC CHIASM	Maximum Dose <55 Gy (RBE) to organ PRV
BRAINSTEM	Maximum Dose <55 Gy (RBE) to organ PRV
LEFT PAROTID	Maximum Mean dose 24 Gy (RBE) to organ
Mandible	Either: < 10 Gy (RBE) whole structure OR: > 10 Gy (RBE) but < 30 Gy (RBE) uniformly over whole structure.

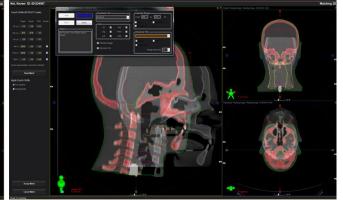
Plans returned as DICOM files and evaluated for clinical acceptability



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Treatment room specs:

- Patient positioner specs
 - Compatibility with immobilization
- In-room telemetry/audio
- Collision detection system
- Anesthetic gases
- Functionality/workflow
-

Image-guidance:

- Laser alignment sytems
- 2D/3D/4D imaging
- Acquisition and reconstruction speeds
- Image quality
- Connectivity to auxiliary systems
 - Optical surface imaging
 - Tracking

Accommodations

- Patient pathway through facility
- Waiting area
- Consultation rooms
- Anaesthesia recovery
- Imaging suite CT (DECT), MRI, PET/CT,...
- Staff accommodations
- Teleconference rooms
- Storage e.g. physics QA equipment
-

Other infrastructure

- Workforce numbers and training
- Education of referrers and public
- Referral pathways
- Outcomes data collection and storage
- Academic and industrial partnerships
- •

Have people involved who have experience and understand of clinical radiotherapy

Zakrzewska P, Pitt M, Amos RA, D'Souza D & Ahmed T.

Application of building information modelling (BIM) in the design, construction, and operations management of a complex proton beam therapy facility in central London.



