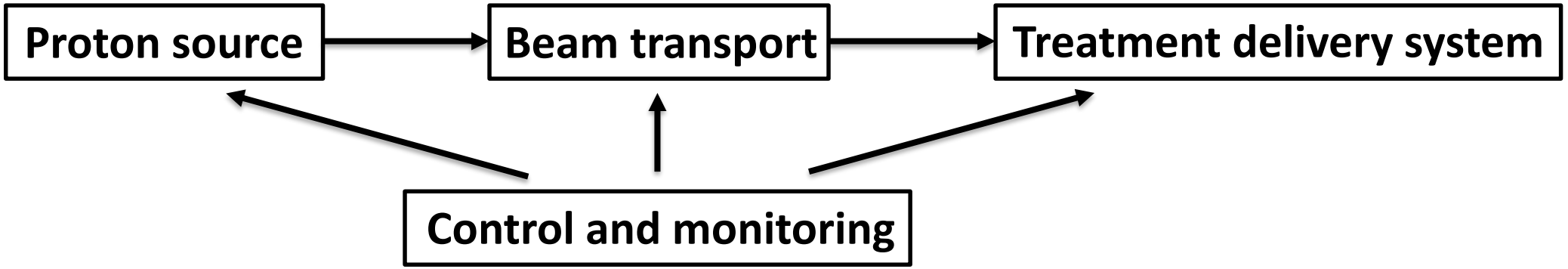
# Technology and Infrastructure Requirements of a Proton Therapy Centre

*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*

ENLIGHT Annual Meeting
UCL, London, UK
June 25-27, 2018

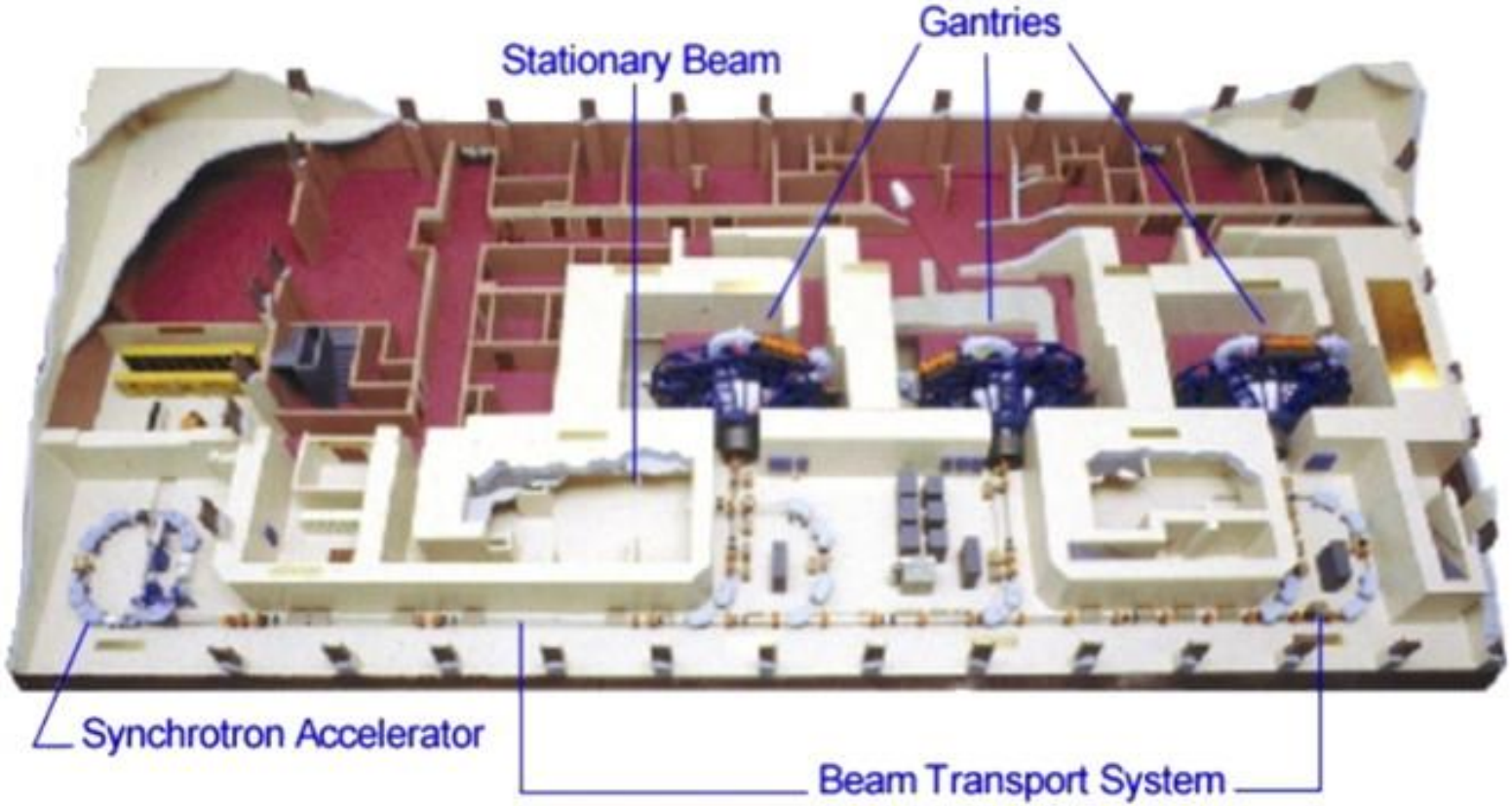
@ProtonAdvanceRT




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

LOMA LINDA UNIVERSITY
MEDICAL CENTER




- 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)

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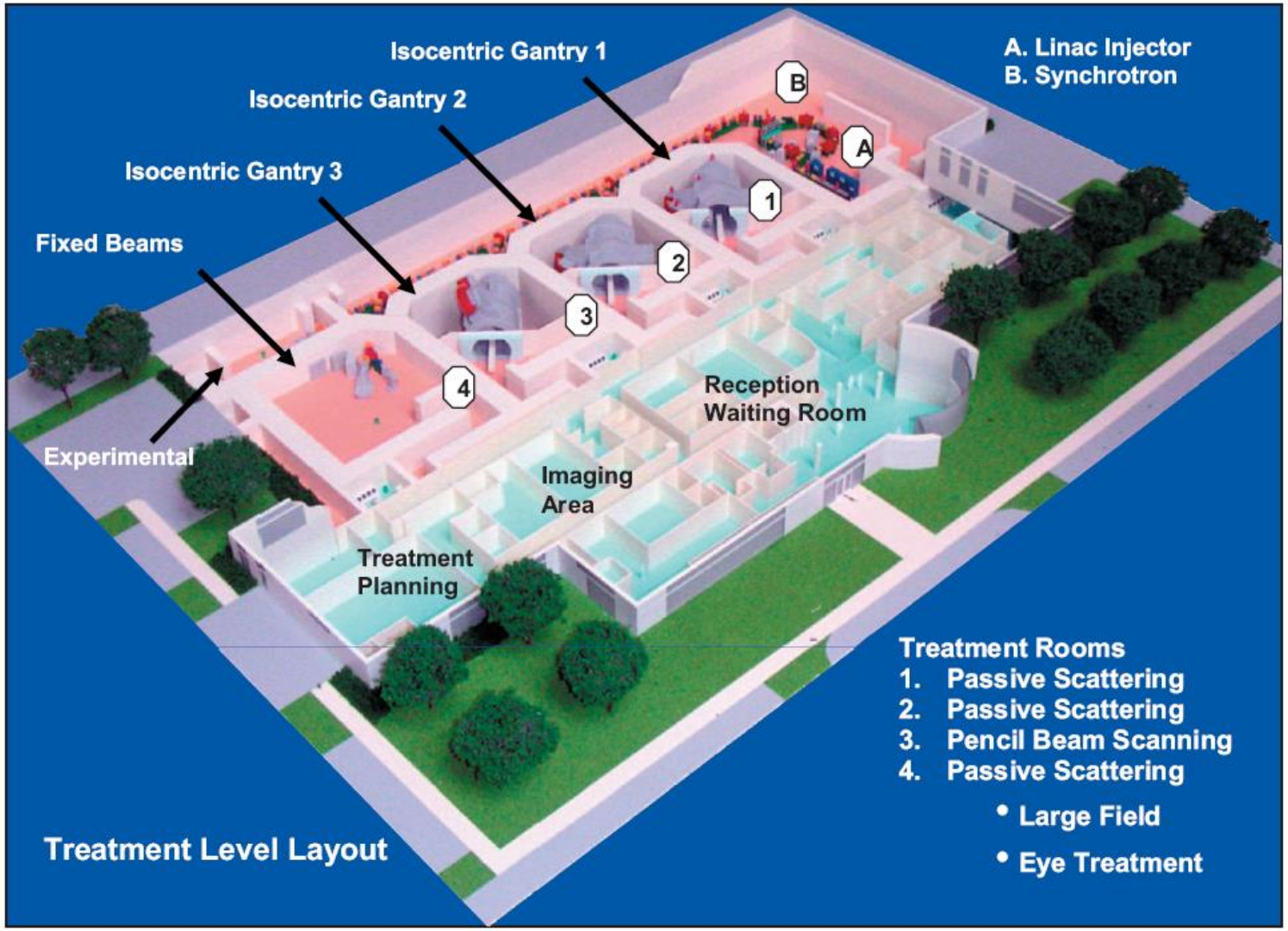
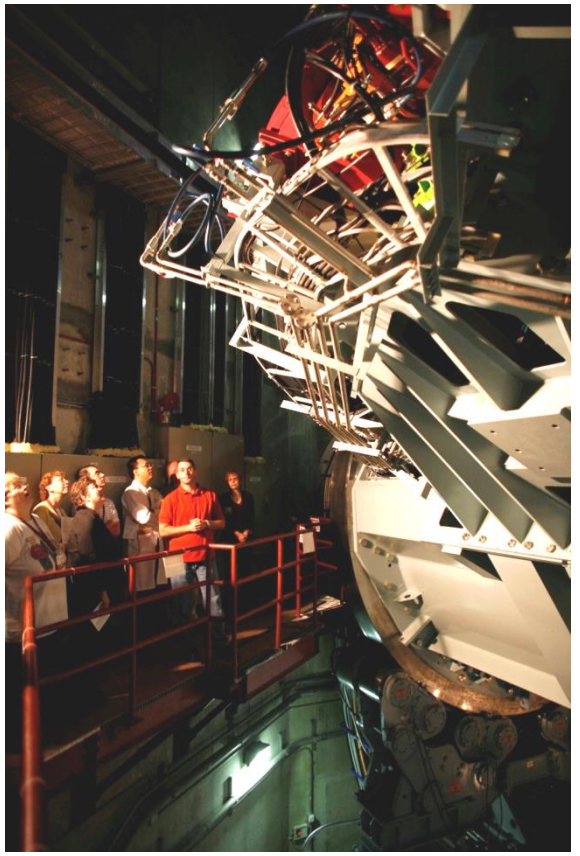
MD Anderson Cancer Center
Making Cancer History®

- 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)*



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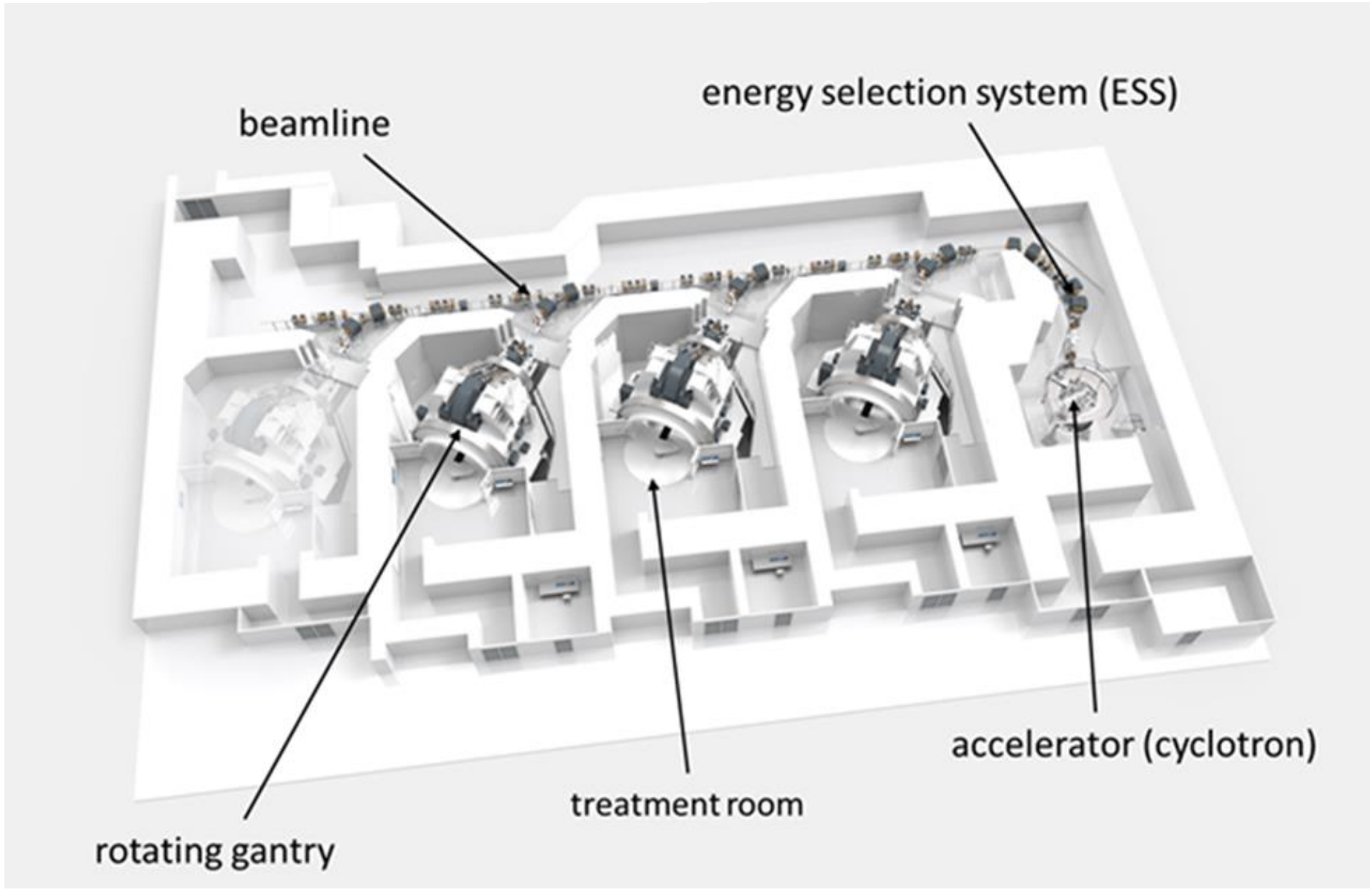
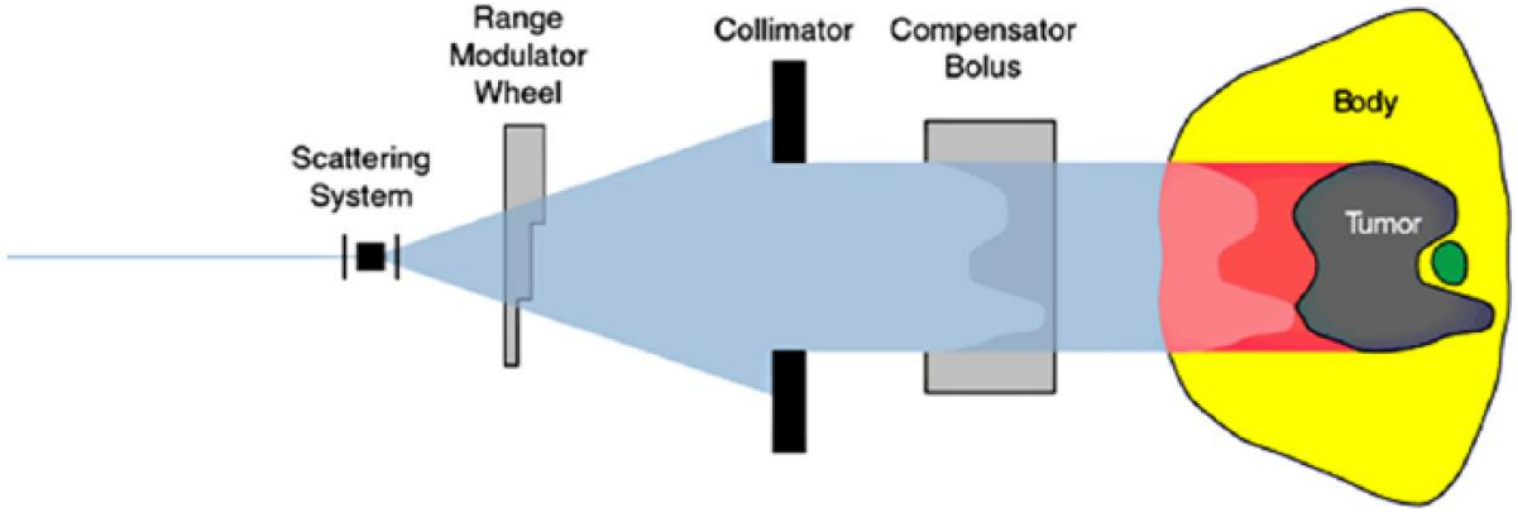
MD Anderson Cancer Center

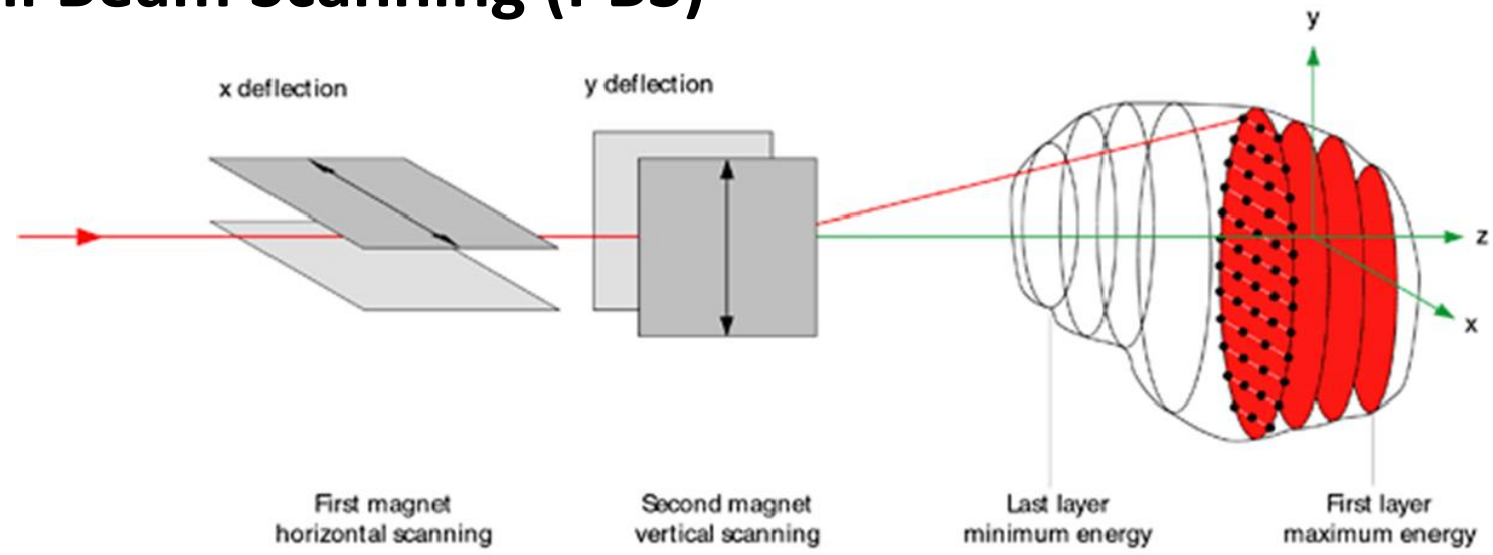
University College London Hospitals NHS
NHS Foundation Trust



# Passive Scattering



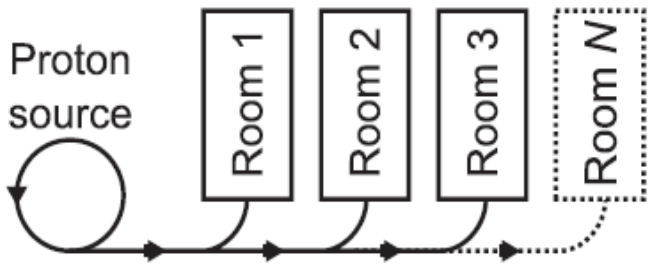

# Pencil Beam Scanning (PBS)

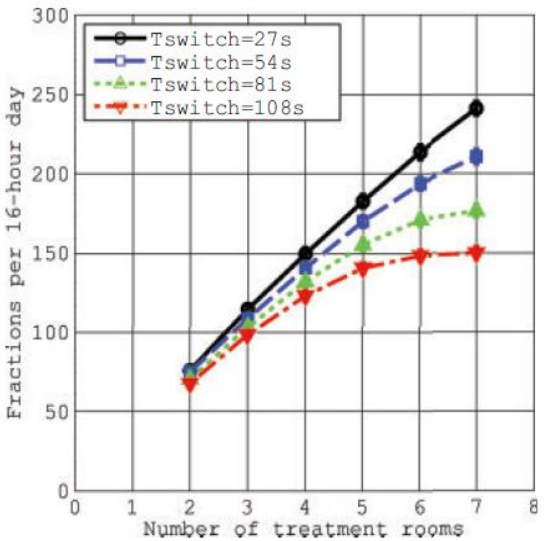


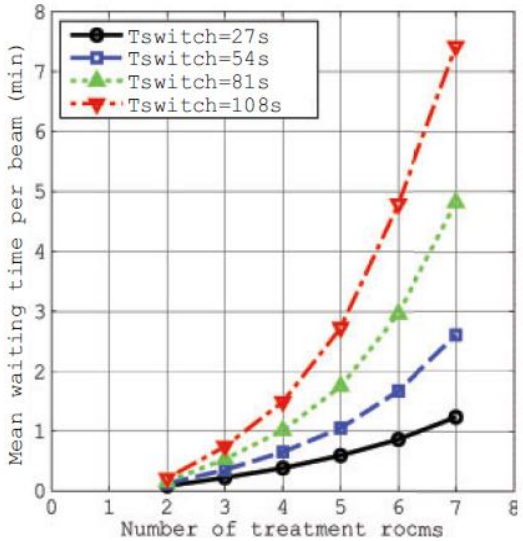
*The British Journal of Radiology, 85* (2012), e1263–e1272

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

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



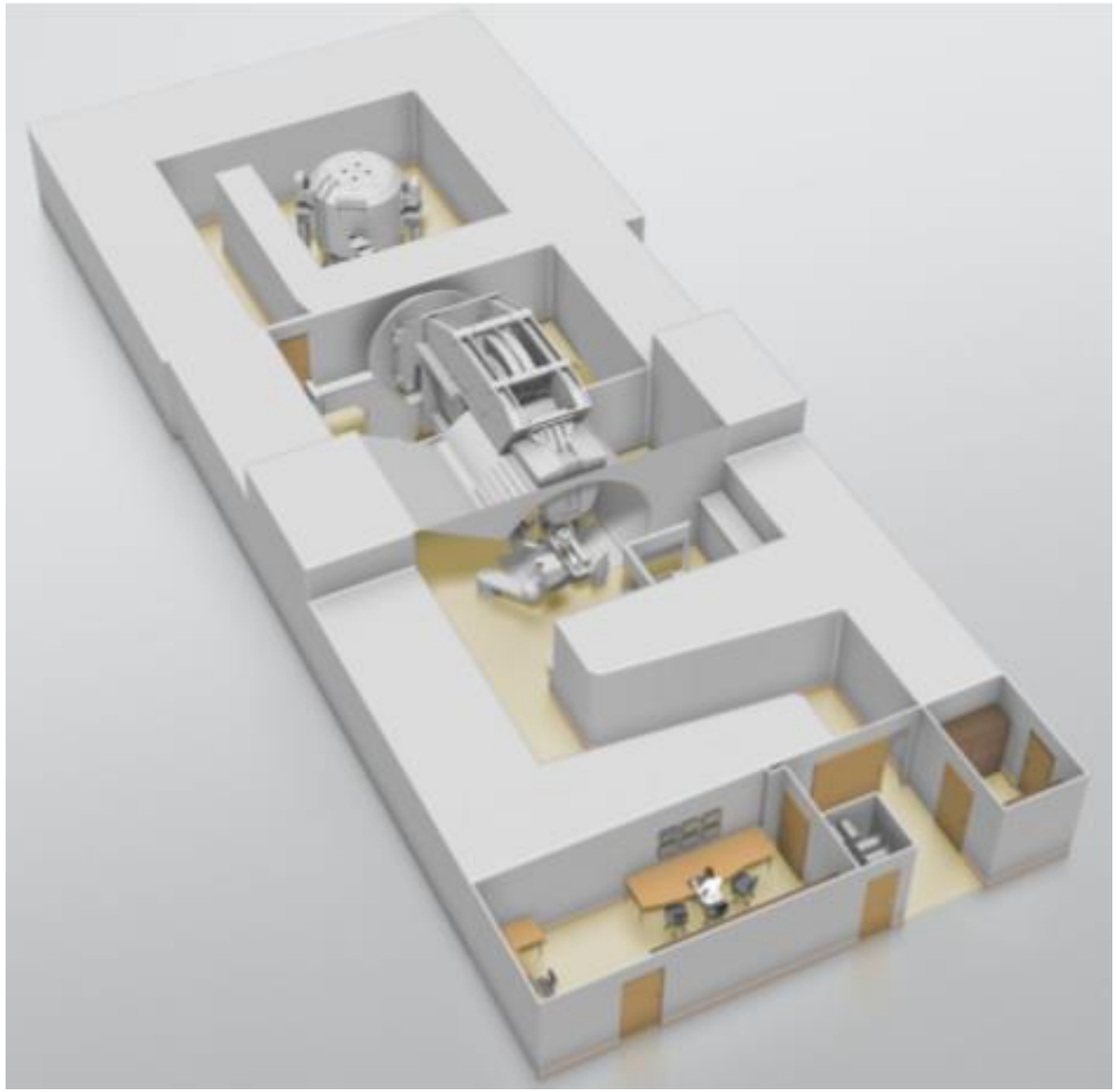



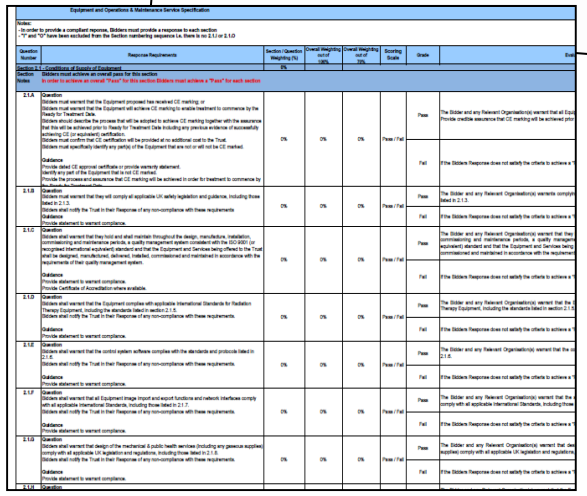




| | US caseload | | | UK caseload | | |
|---|---|---|---|---|---|---|
| Number of rooms | $t_{fraction}$ (min) | $t_{waiting}$ (min) | $P_{annual}$ (patients) | $t_{fraction}$ (min) | $t_{waiting}$ (min) | $P_{annual}$ (number of patients) |
| 2 | 26.6 | 0.1 | 546 | 32.8 | 0.1 | 443 |
| 3 | 26.9 | 0.4 | 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,….



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**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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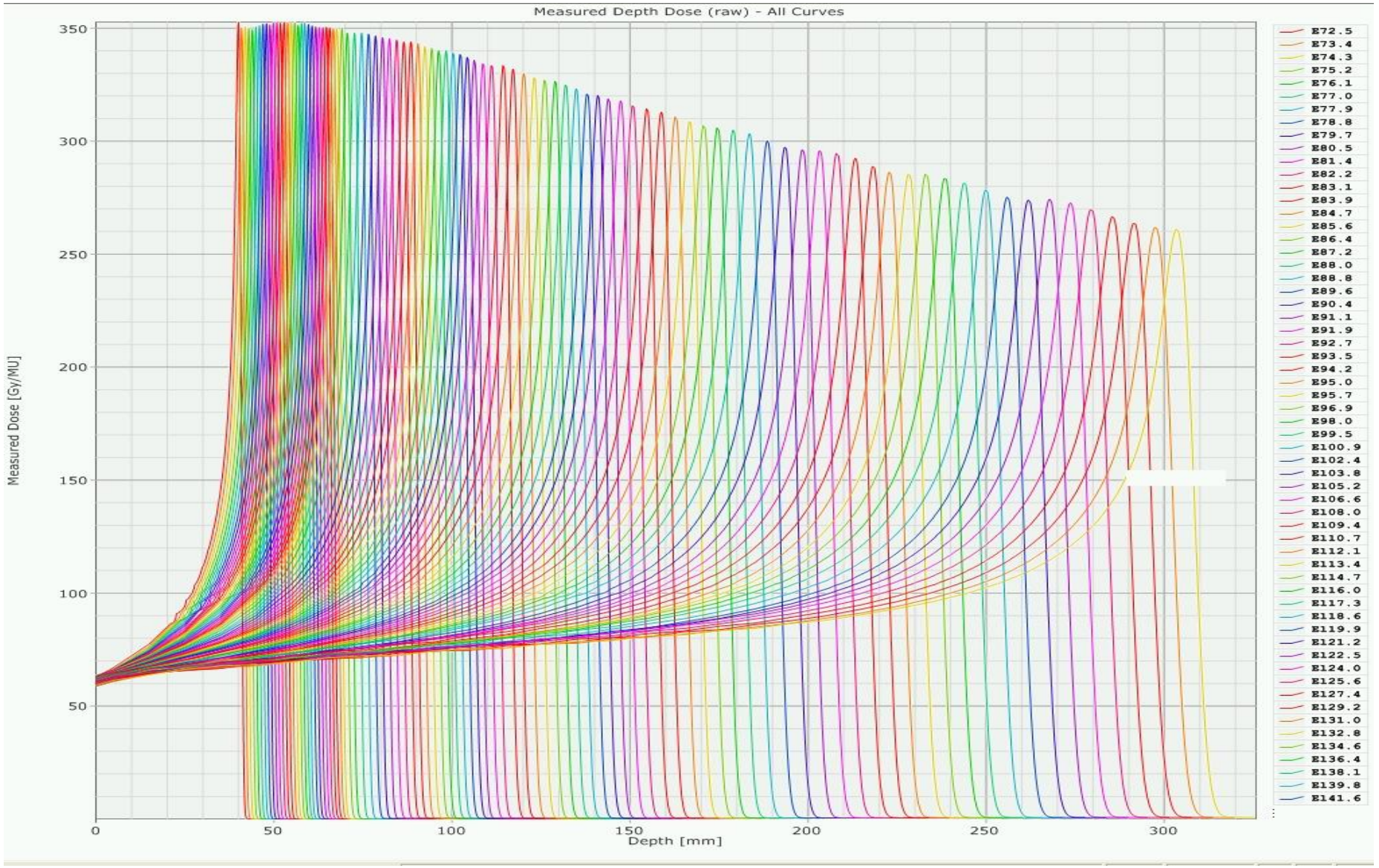
# Monte Carlo generated pre-commissioning data at MD Anderson



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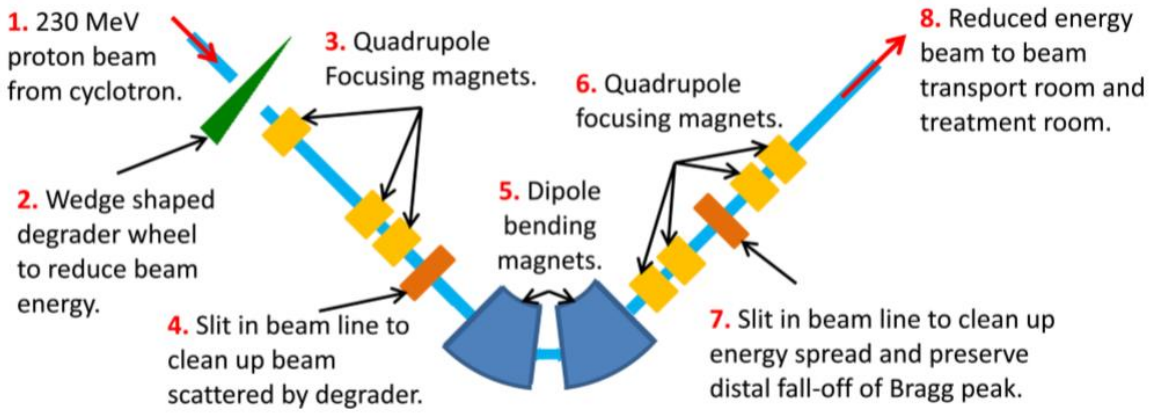
Workload calculations based on estimates of:

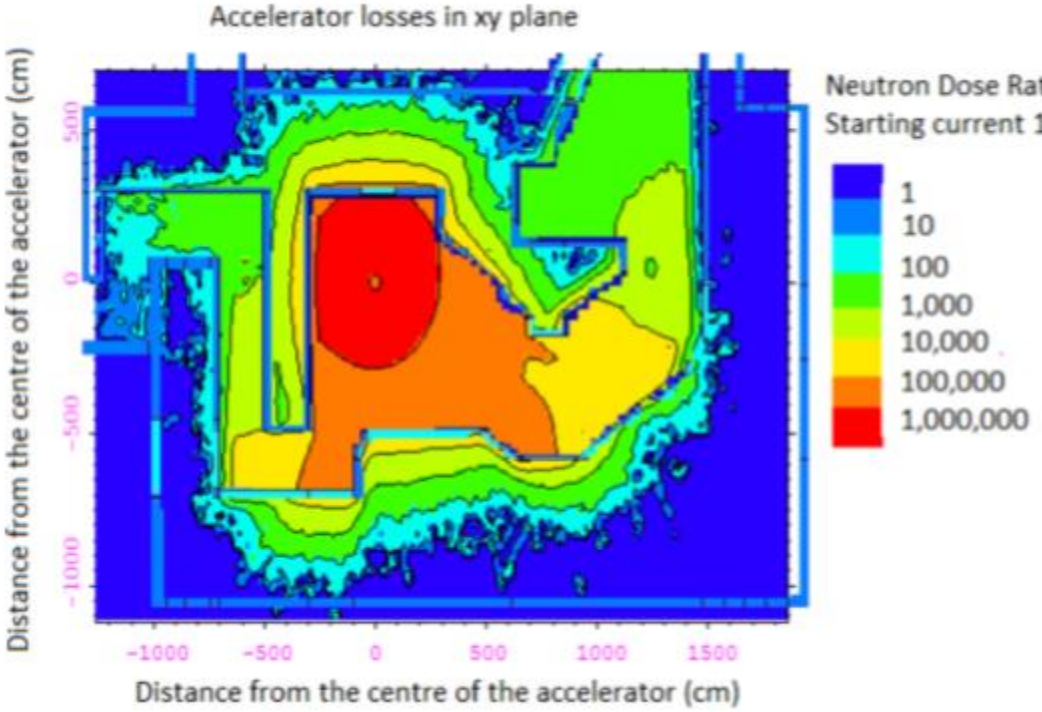
- Patient throughput
- Numbers and angles of beams
- Range of energies used
- Volume of targets

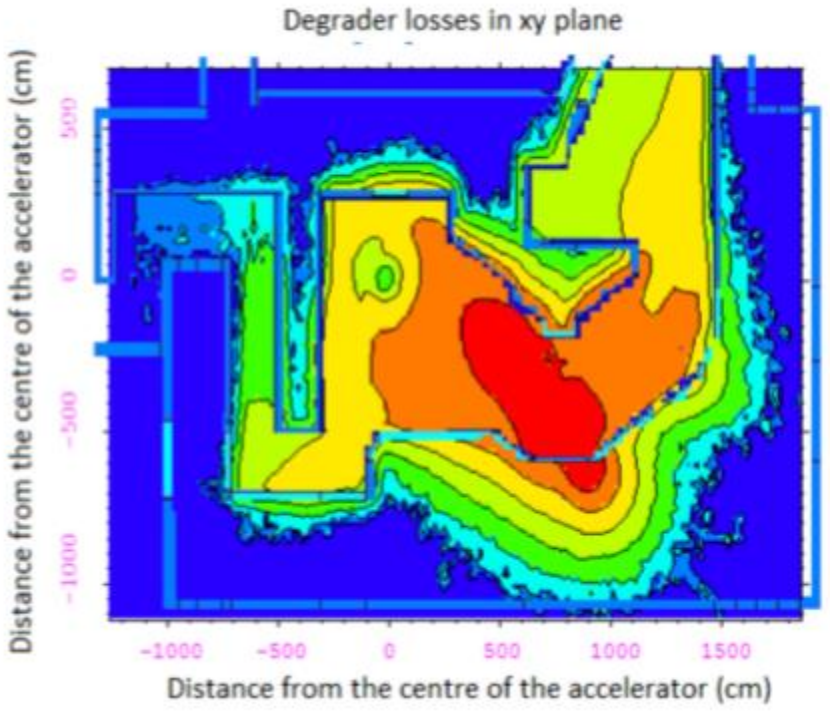
Activation of components, incl. air and water.

Ducting in shielding walls – BIM.

Monte Carlo modelling of losses….



Particle Therapy Co-Operative Group

# PTCOG Report 1

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

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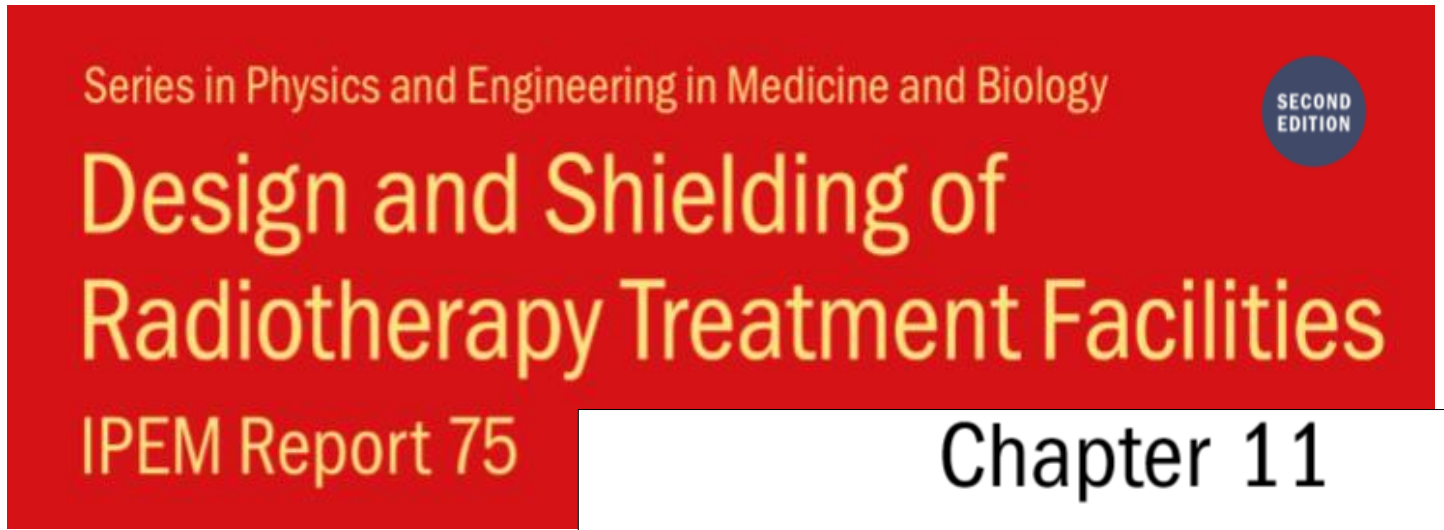
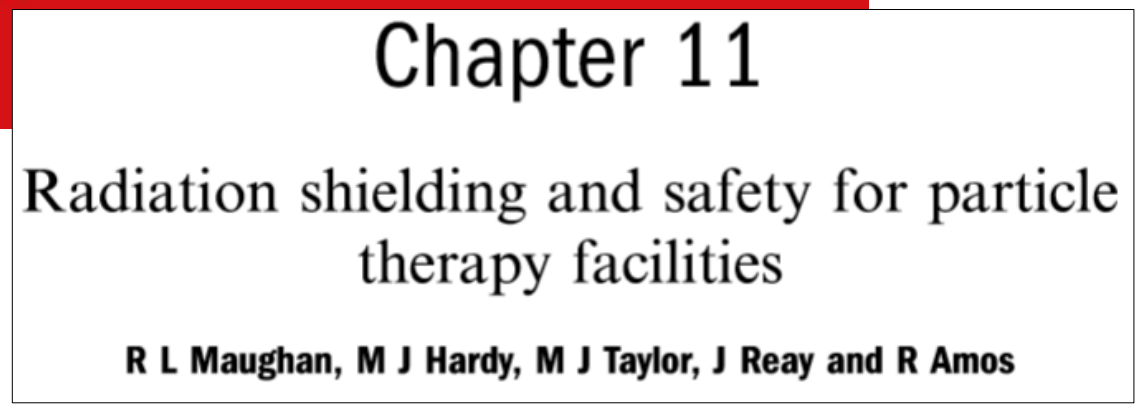
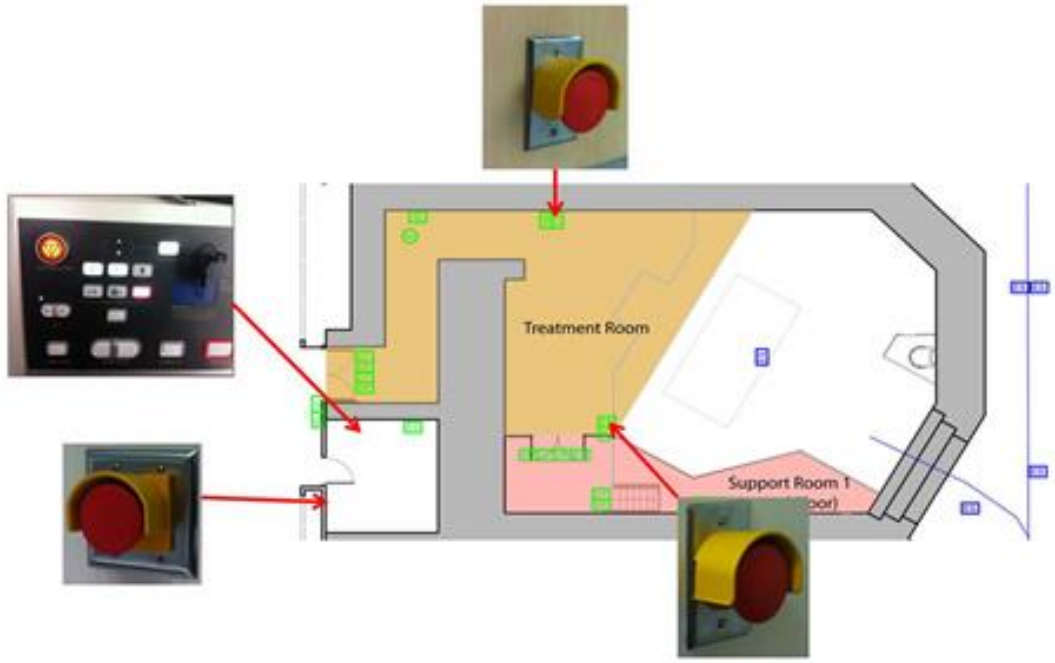
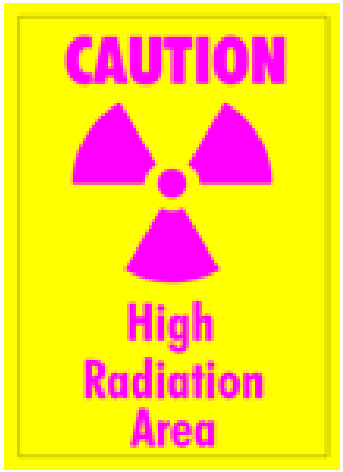


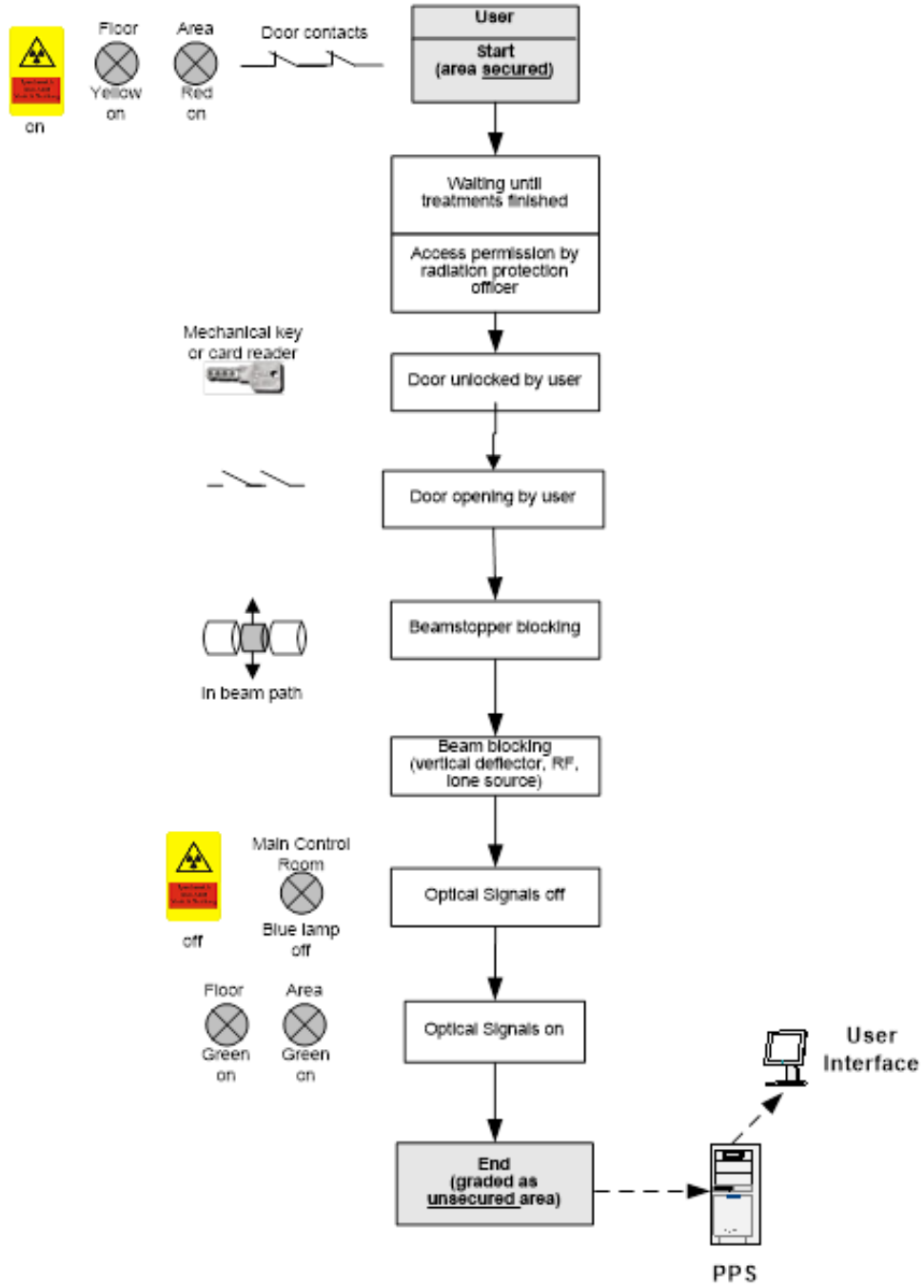



# Radiation and general safety interlock system







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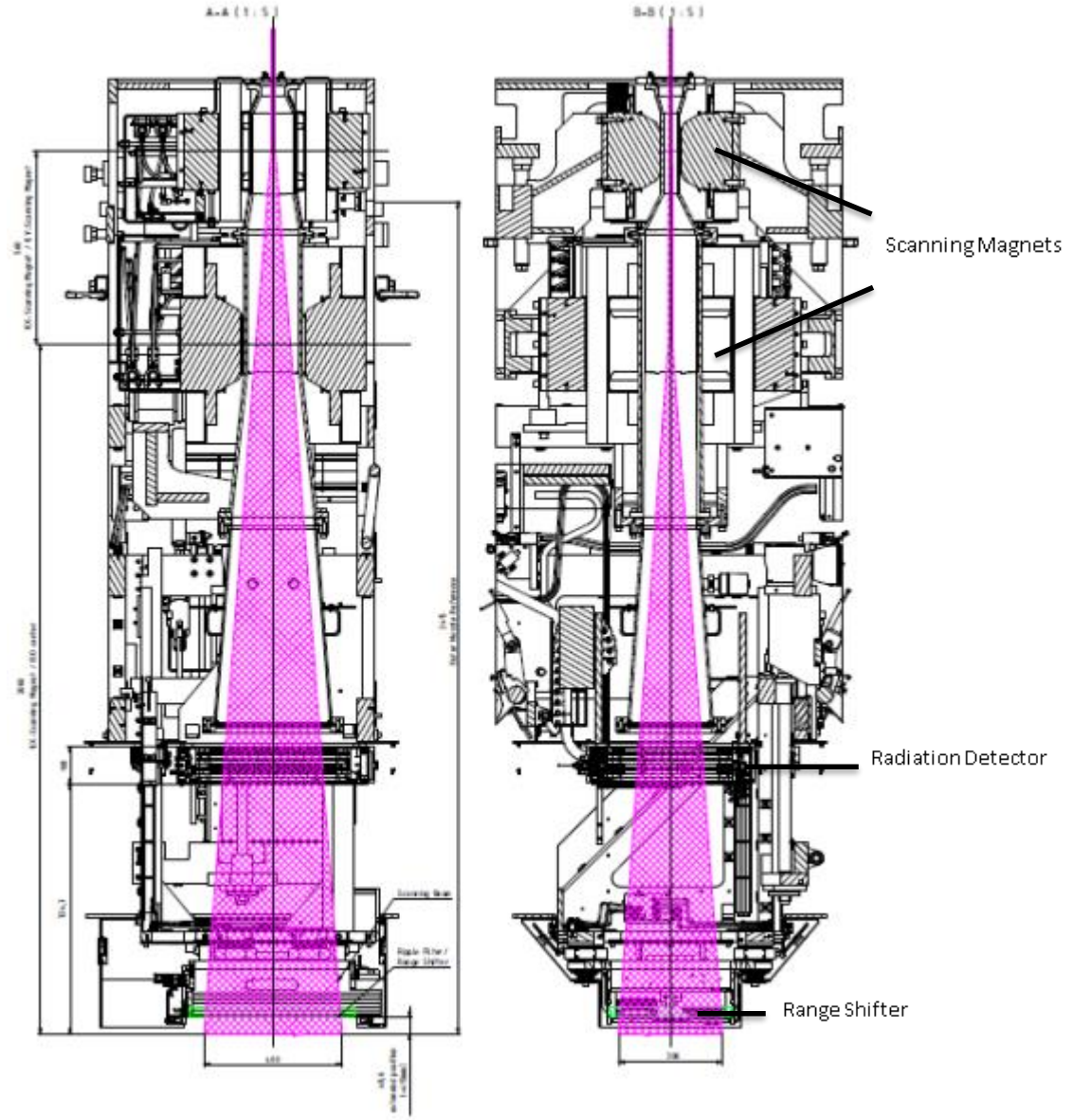
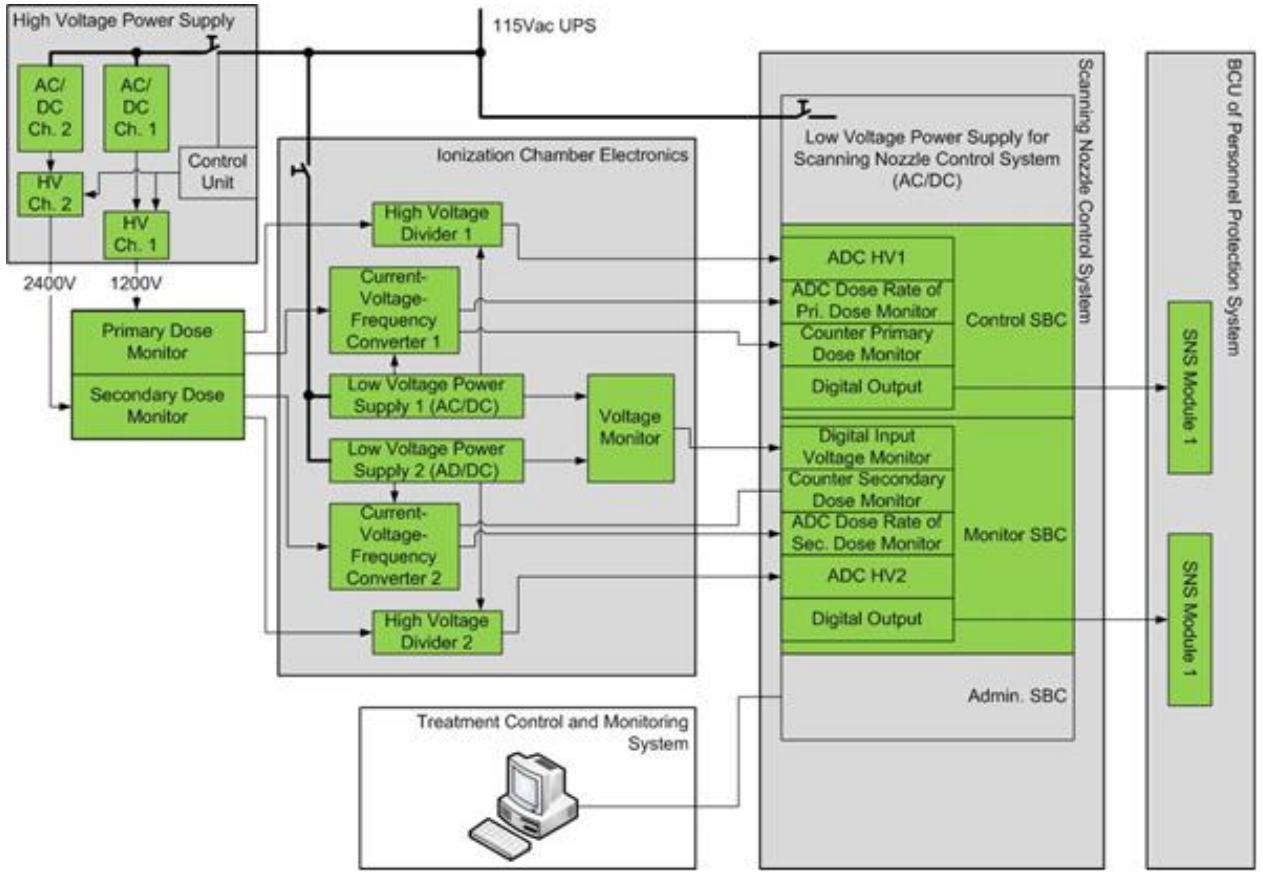
# Dosimetry, telemetry, and beam control systems



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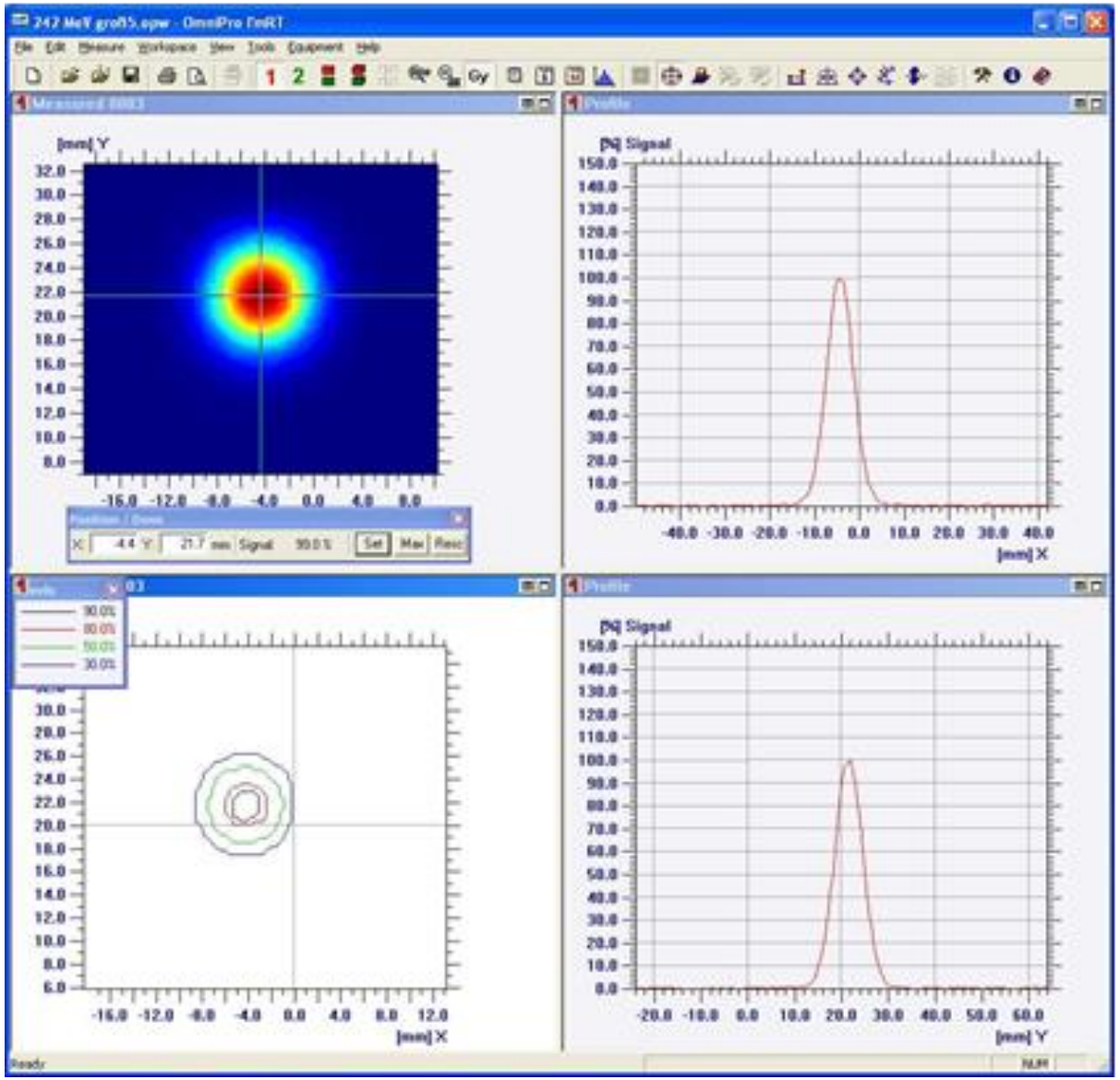
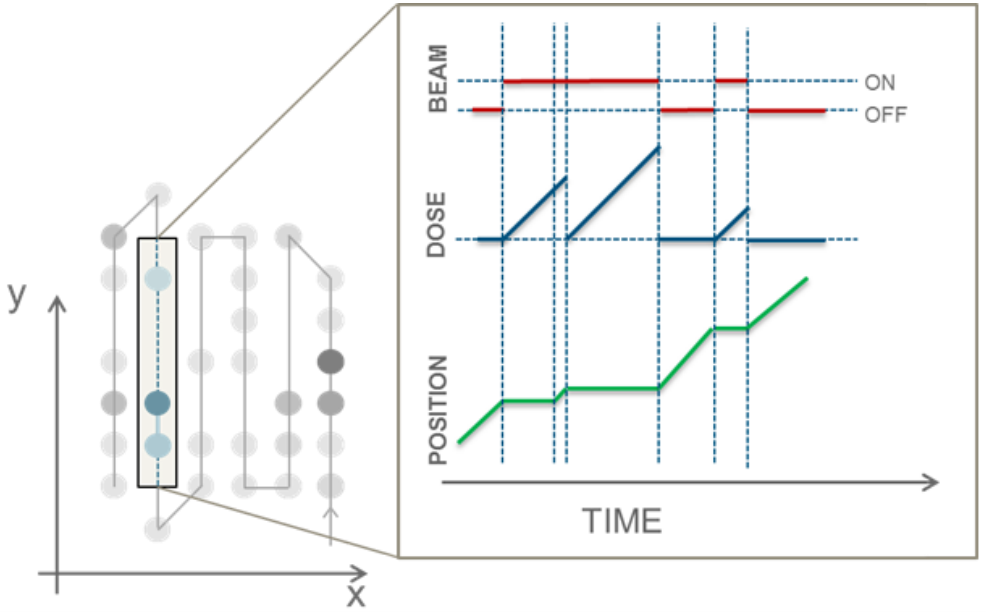
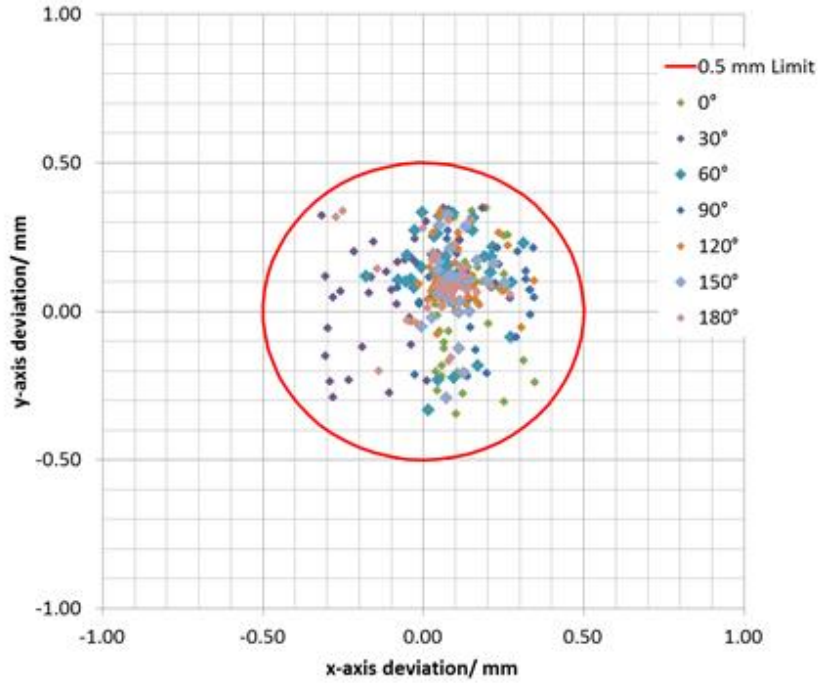
# Clinical beam characteristics





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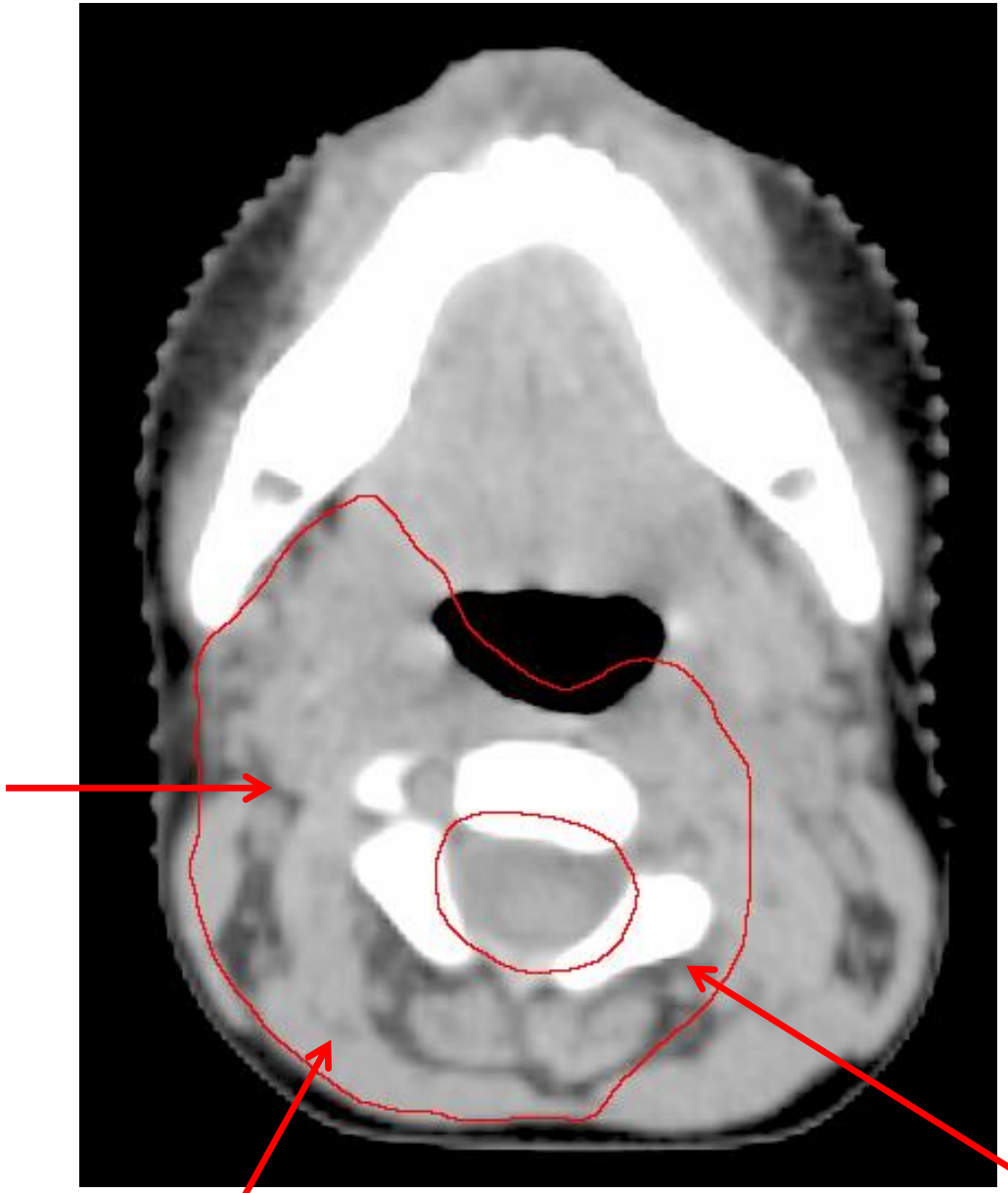
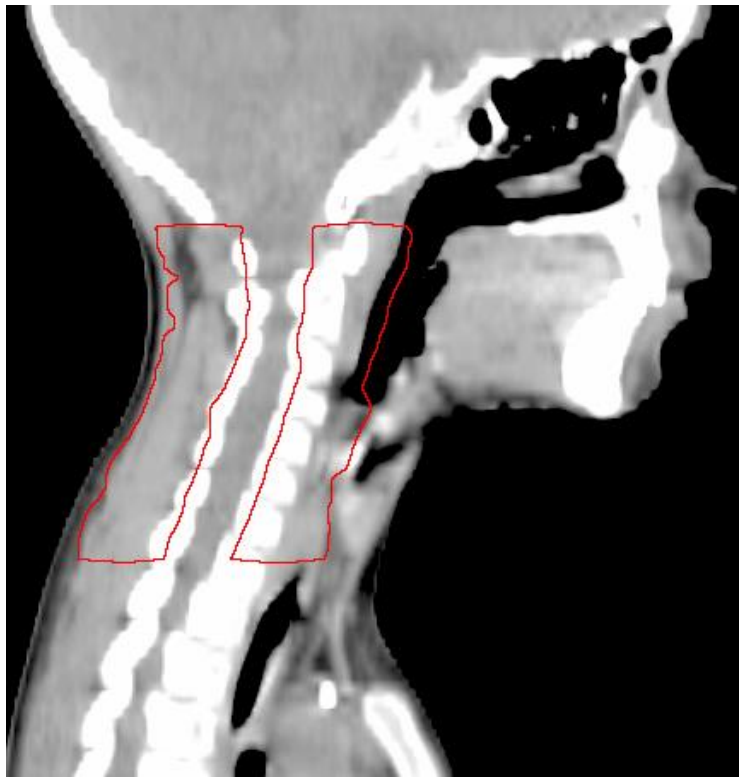
# Clinical Case # 1

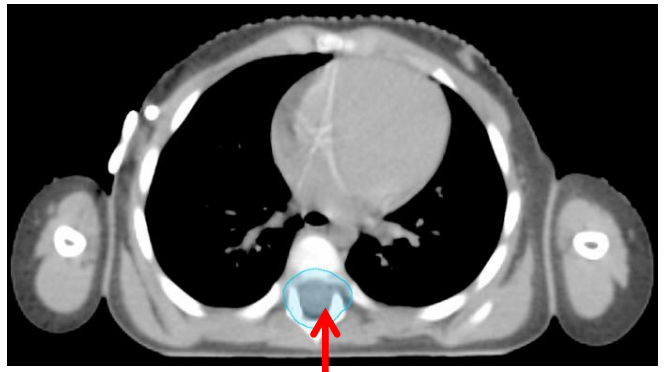
Ewing Sarcoma Right C-Spine



- 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 ~ 200 – 210 deg
- LPO, gantry angle ~ 130 – 140 deg
- Rt Lat, gantry angle 90 deg
- Same angles for SFUD and IMPT components



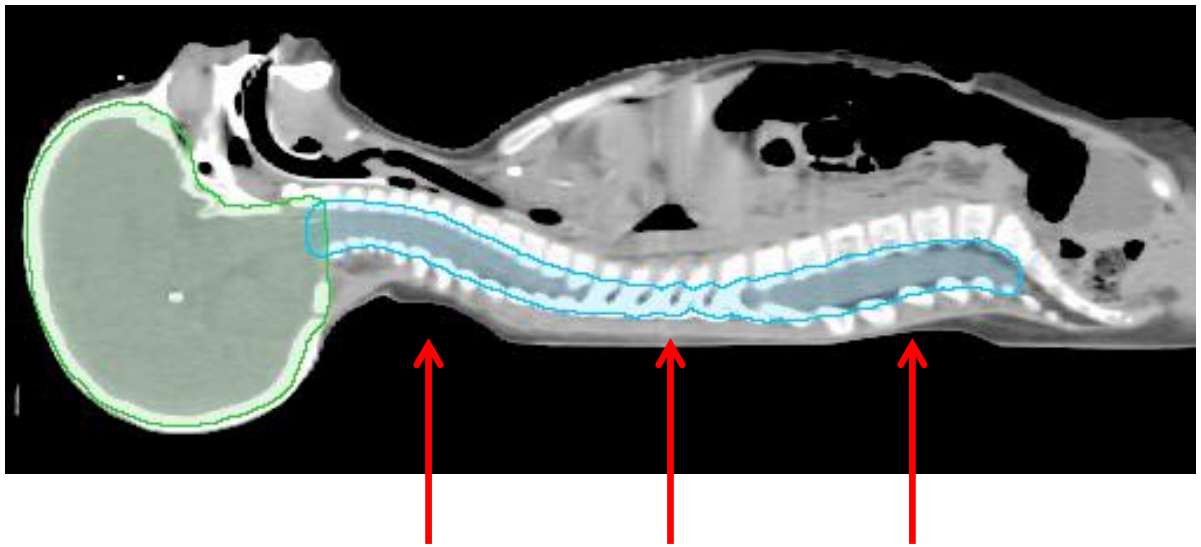
# **Clinical Case # 2** (Phase 1)



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 ~ 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



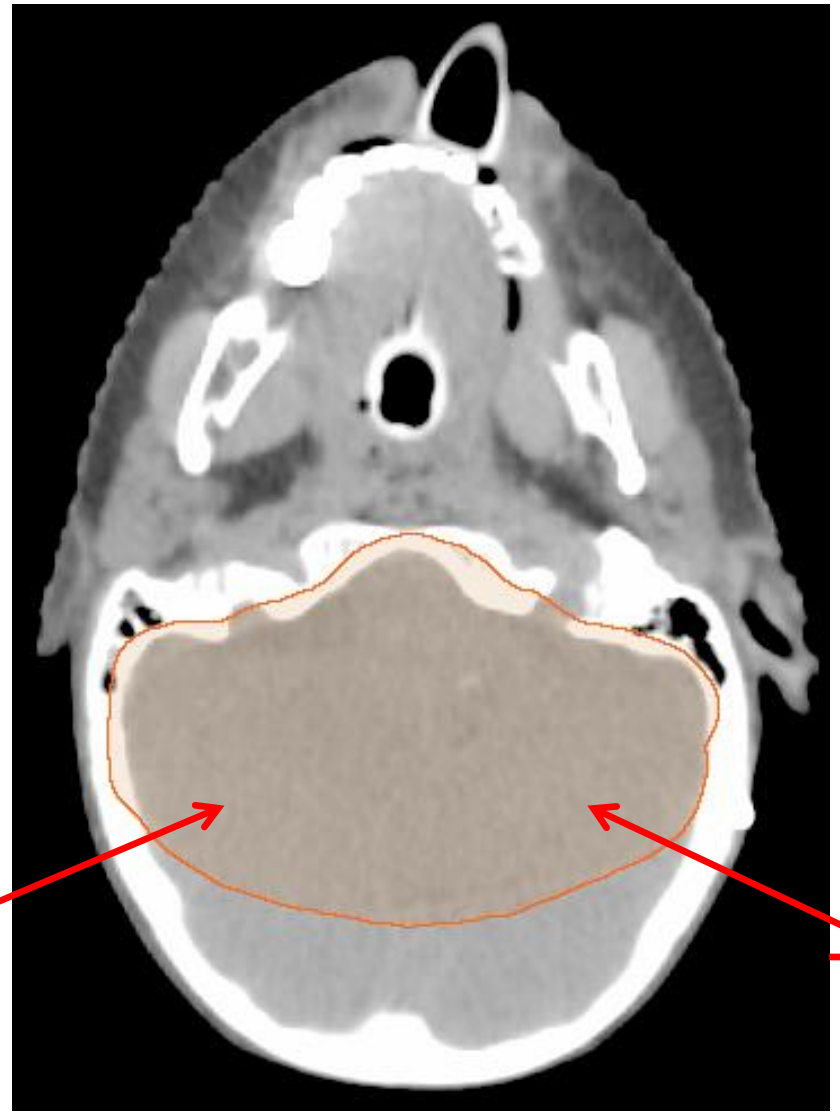
## **Clinical Case # 2** (Phases 2 & 3)

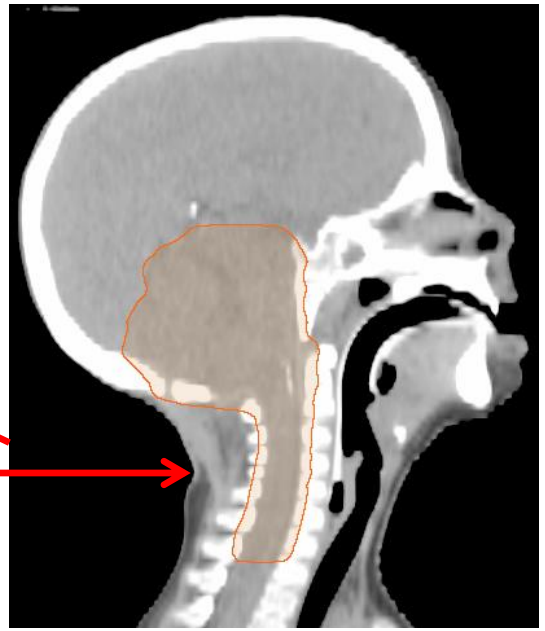
Metastatic Ependymoma

•IMPT with component of SFUD (*at least 20% IMPT*)
•**Patient under GA in supine position**

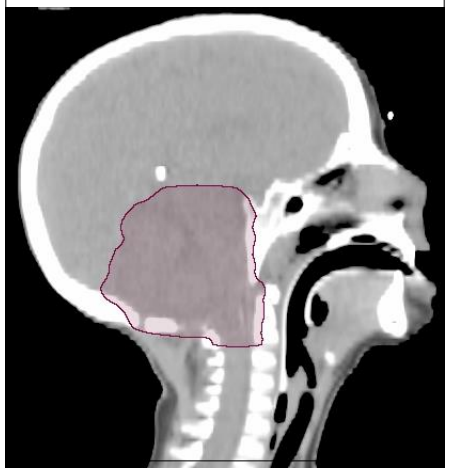
•Phase 2 Rx: 9 Gy (RBE) / 5 fx to C-spine and post fossa (*PTVPh2*)
•LPO, gantry angle ~ 120 – 130 deg
•RPO, gantry angle ~ 230 – 240 deg
•PA, gantry angle = 180 deg
•IMPT – eg, contribution of PA only at C-spine level

•Phase 3 Rx: 9 Gy (RBE) / 5 fx to post fossa (*PTVPh3*)
•Repeat LPO and RPO IMPT fields
•Omit PA component

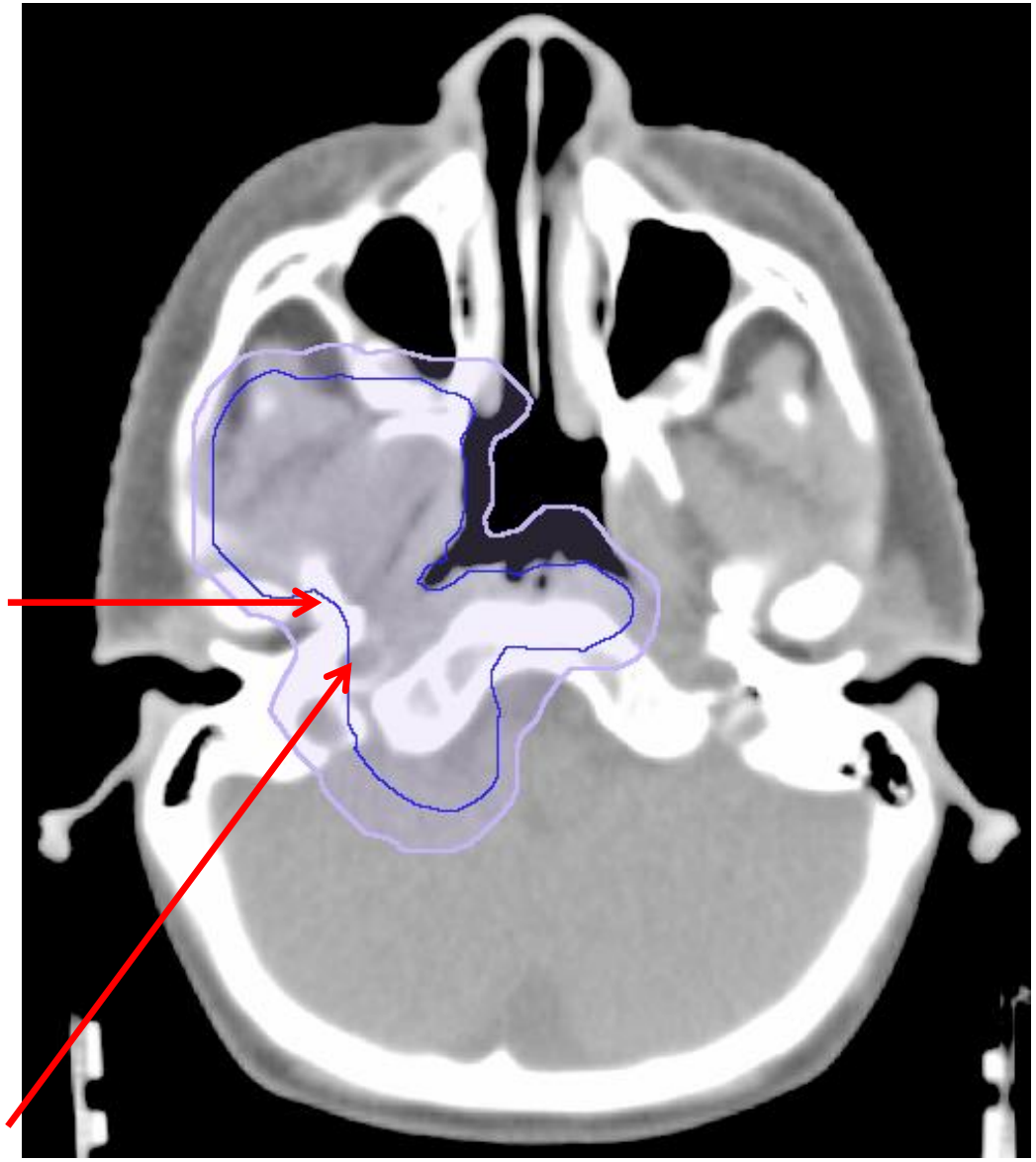




(Phase 3)

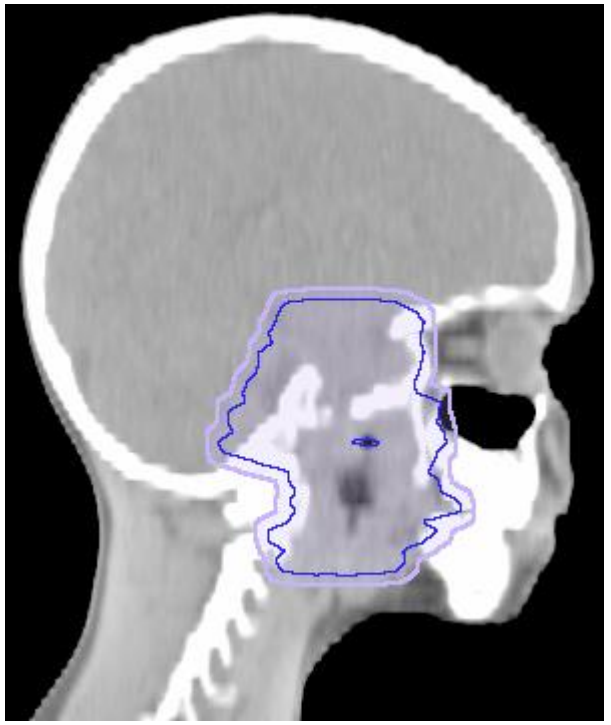


# Clinical Case # 3



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<br>(volume NOT PRV) | 24 Gy (RBE) max; 18 Gy (RBE) mean |
| PharynConstrictors<br>(Volume NOT PRV) | 50 Gy (RBE) mean but do not compromise PTV dose |
| Mandible | Either: < 10 Gy (RBE) whole structure<br>OR: > 10 Gy (RBE) but < 30 Gy (RBE) uniformly over whole structure. |

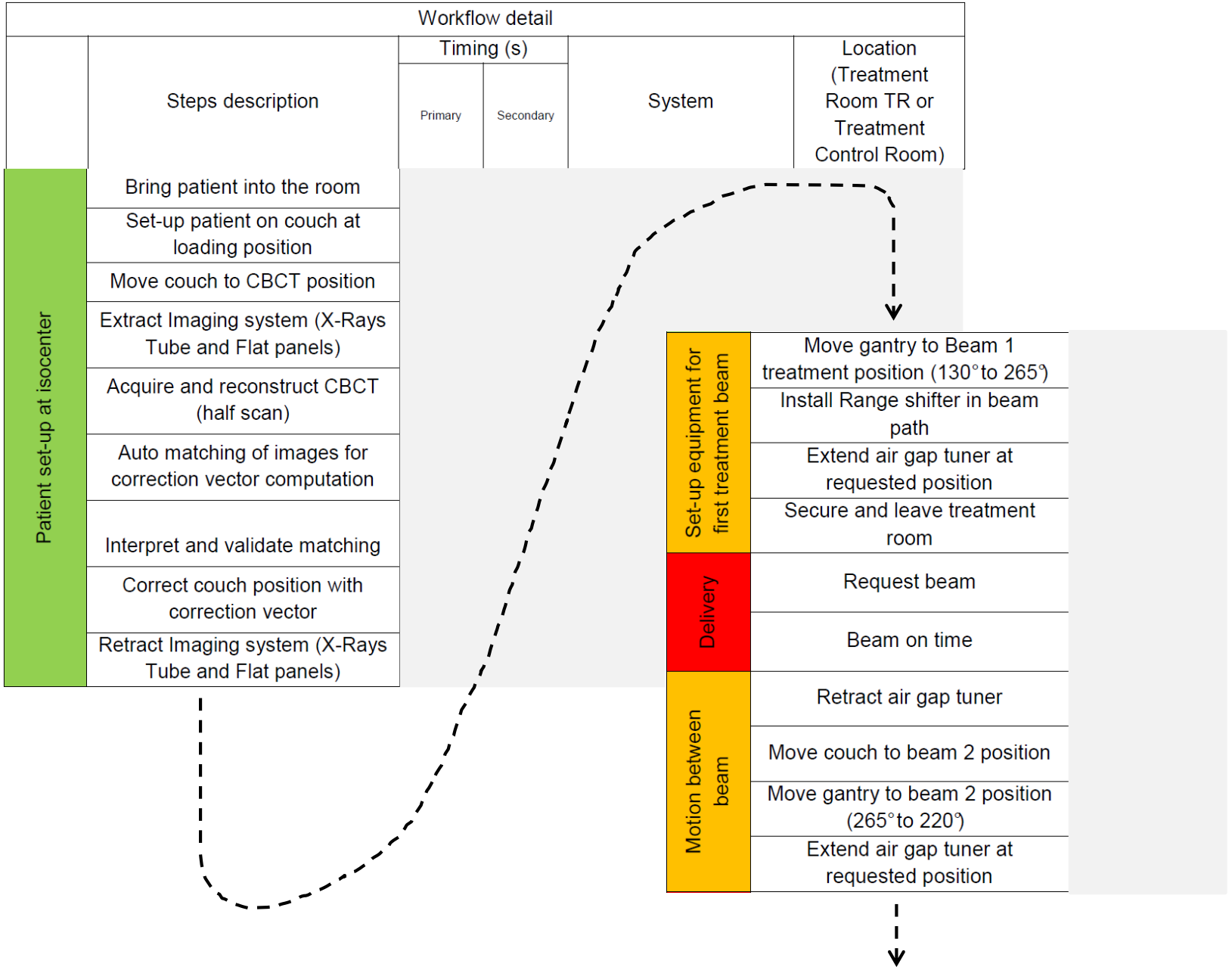
## Clinical Case # 2

| 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<br>OR: > 10 Gy (RBE) but < 30 Gy (RBE) uniformly over whole structure. |

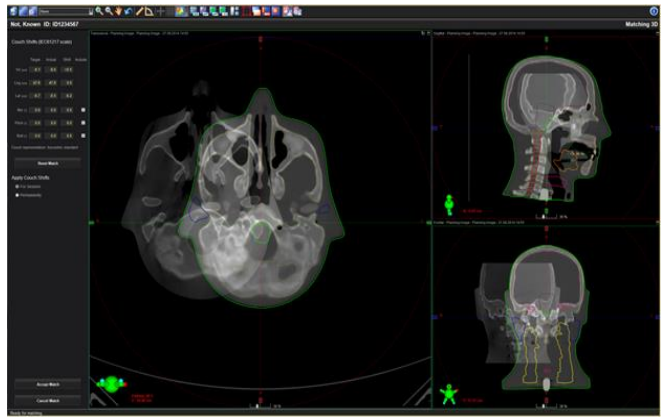
## Clinical Case # 3

| 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<br>OR: > 10 Gy (RBE) but < 30 Gy (RBE) uniformly over whole structure. |

Plans returned as DICOM files and evaluated for clinical acceptability


Workflow detail
Steps description
Timing (s)
Primary
Secondary
System
Location (Treatment Room TR or Treatment Control Room)
Patient set-up at isocenter
Bring patient into the room
Set-up patient on couch at loading position
Move couch to CBCT position
Extract Imaging system (X-Rays Tube and Flat panels)
Acquire and reconstruct CBCT (half scan)
Auto matching of images for correction vector computation
Interpret and validate matching
Correct couch position with correction vector
Retract Imaging system (X-Rays Tube and Flat panels)
Set-up equipment for first treatment beam
Move gantry to Beam 1 treatment position (130° to 265°)
Install Range shifter in beam path
Extend air gap tuner at requested position
Secure and leave treatment room
Delivery
Request beam
Beam on time
Motion between beam
Retract air gap tuner
Move couch to beam 2 position
Move gantry to beam 2 position (265° to 220°)
Extend air gap tuner at requested position

| 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 |
| 2.8 General Safety / Interlocks |
| 2.9 Control and Monitoring Systems |
| 2.10 Operations, Maintenance and Quality Assurance |
| 2.11 Proton Accelerator and Beamline Parameters |
| 2.12 Clinical Beam Characteristics |
| 2.13 Clinical Cases |
| 2.14 Dosimetry |
| 2.15 Treatment Room Specifications |
| 2.16 In-Room Image Guidance Systems |
| 2.17 Treatment Planning, Verification and Oncology Management Systems |
| 2.18 Upgrades, Innovations and Retrofits |
| 2.19 Fourth Room Option and Research |

## 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
- ……

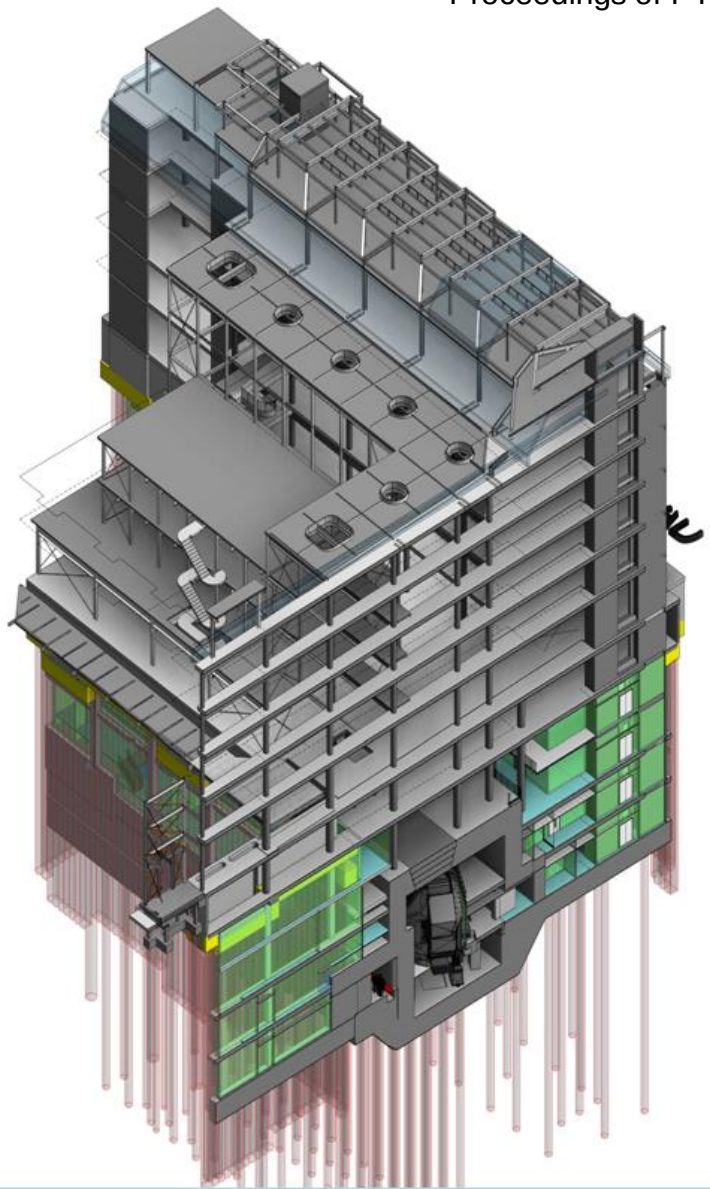
## Other infrastructure

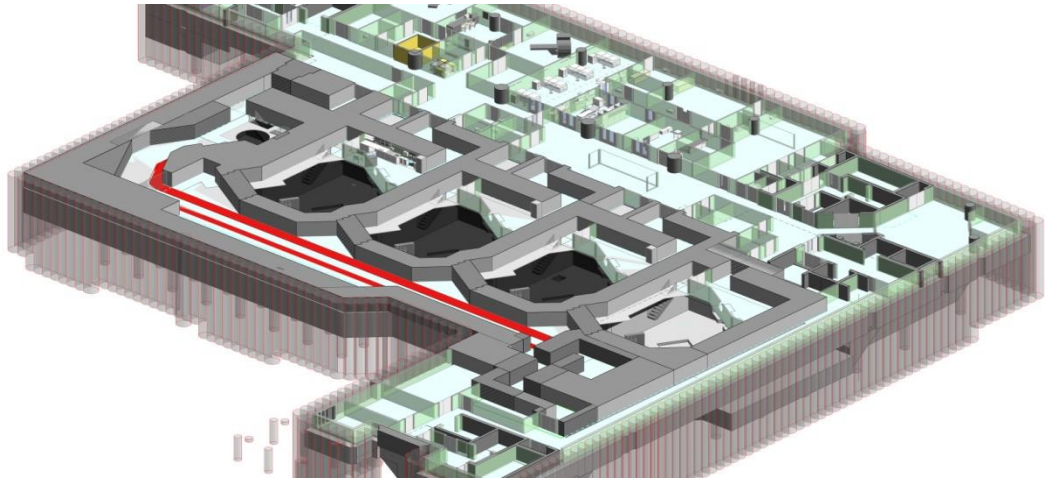
- Workforce – numbers and training
- Education of referrers and public
- Referral pathways
- Outcomes data collection and storage
- Academic and industrial partnerships
- ……..

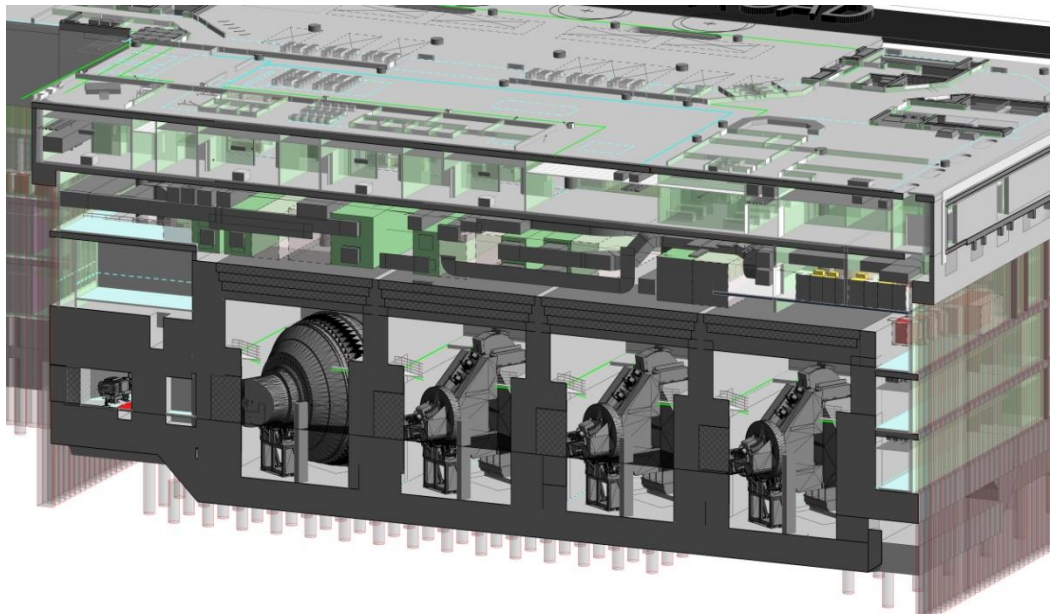
Have people involved who have experience and understand of clinical radiotherapy

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.

Proceedings of PTCOG 54. *Int J Particle Ther*. 2015;**2**(1):331-332







# Thank you!