University College London Hospitals NHS
NHS Foundation Trust

uclh

Targeting cancer with proton beams: Developments at UCL Hospital

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Operational Lead for Proton Beam Therapy Physics
Dept. of Radiotherapy Physics, UCLH

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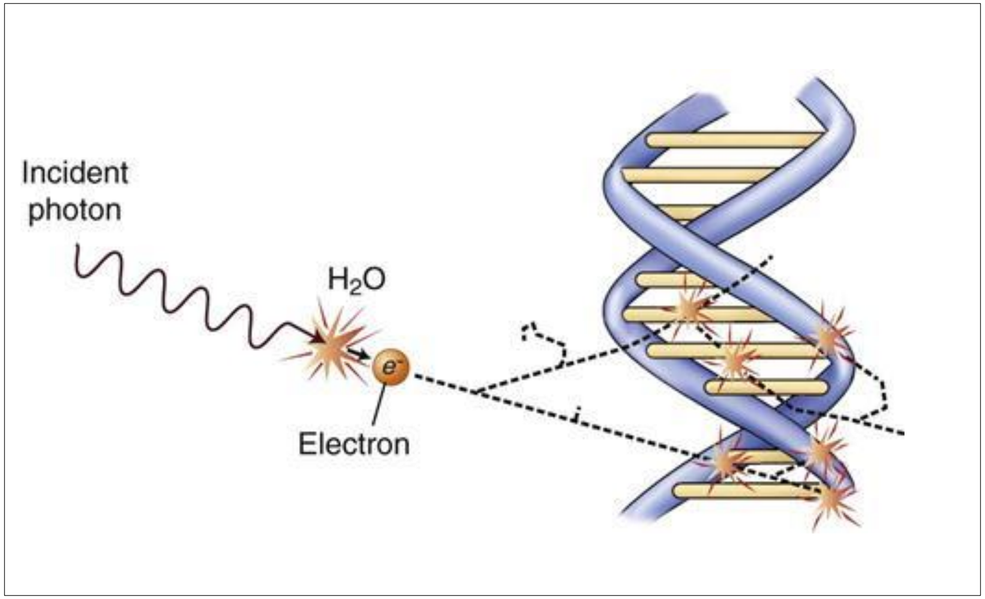
UCL

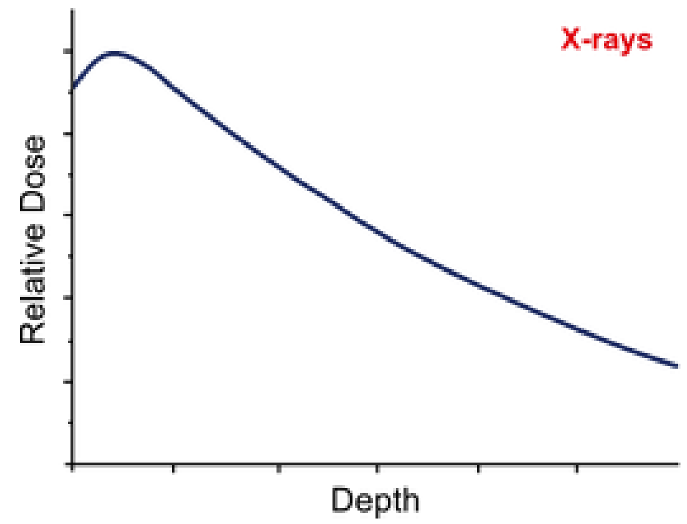
UCL High Energy Physics Group Seminar
Physics and Astronomy, UCL, London, UK
April 15th, 2016

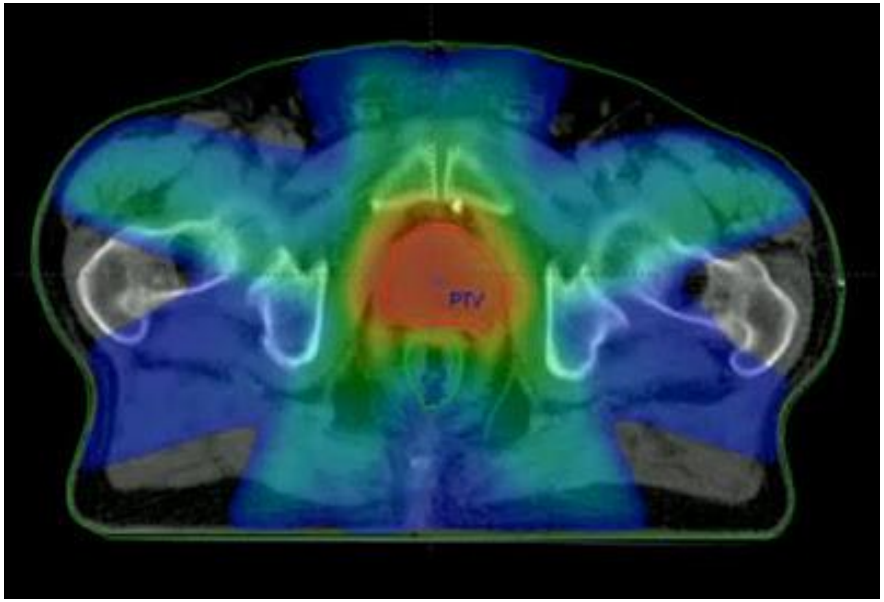
Significance of radiotherapy

The Royal College of Radiologists (RCR) estimates that, of those cancer patients who are cured:

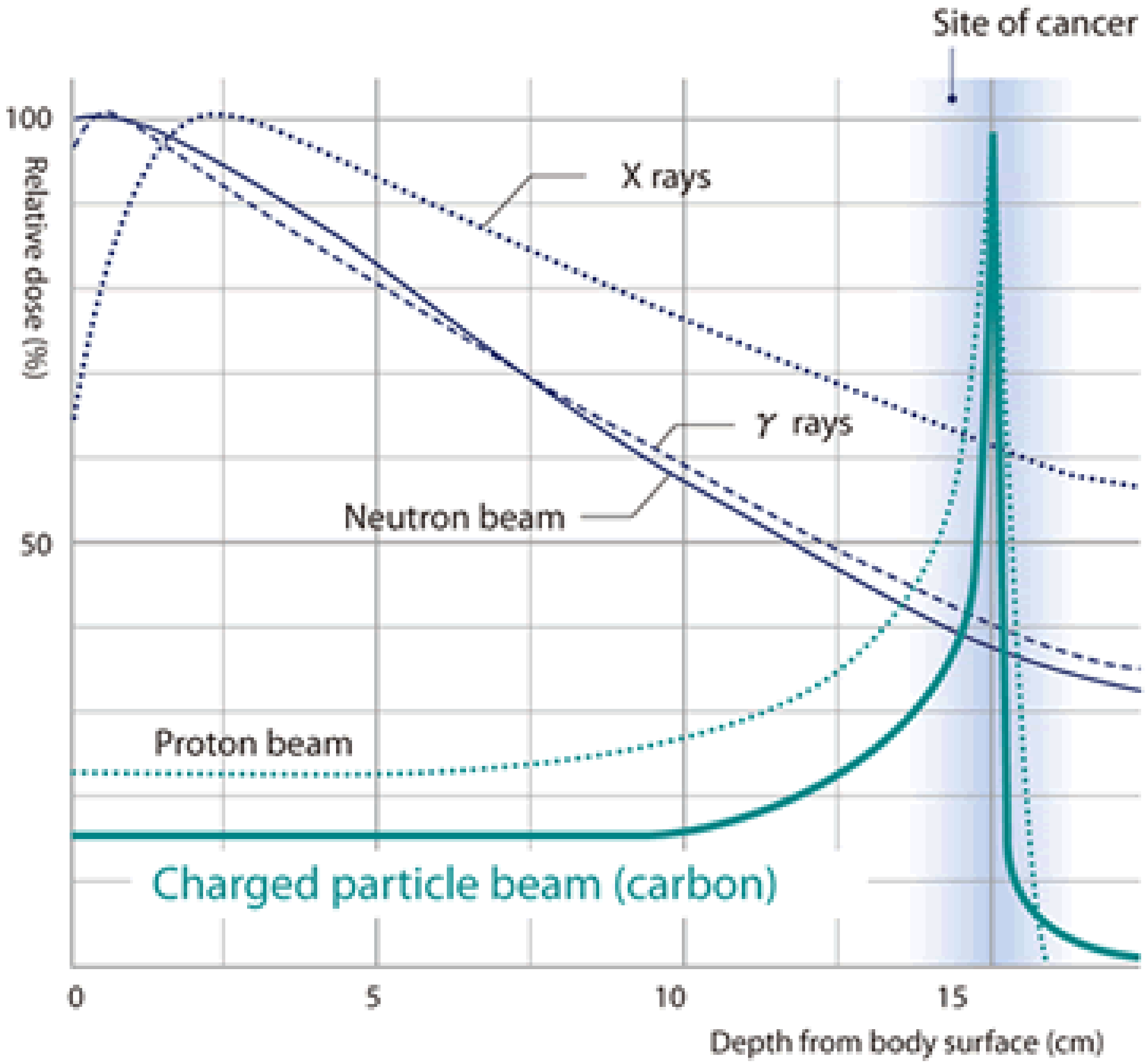
- ⇨ 49% are cured by surgery
- ⇨ 40% are cured by radiotherapy
- ⇨ 11% are cured by chemotherapy

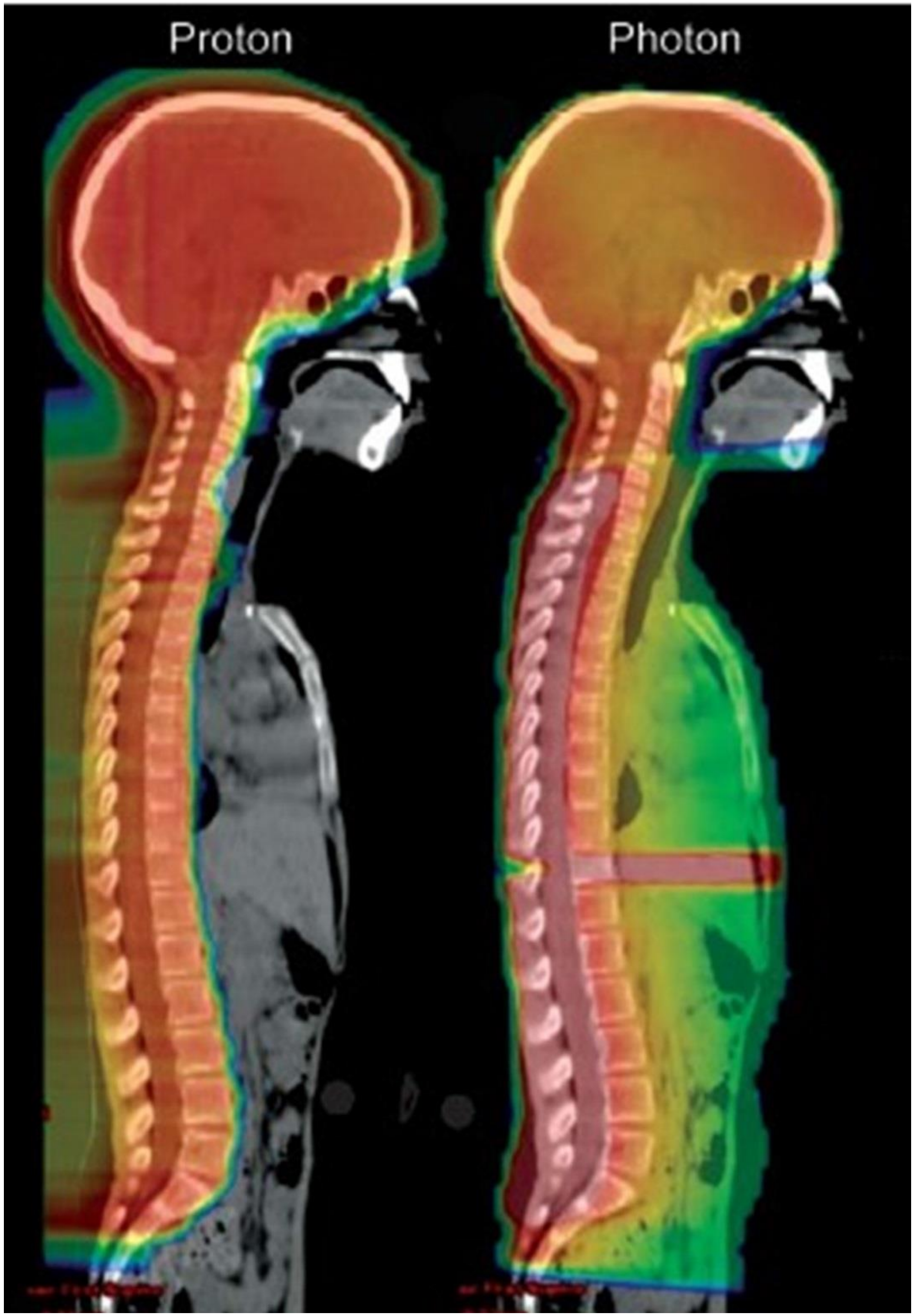

Incident
photon
H_2O
e-
Electron


X-rays
Relative Dose
Depth


PTV

Rationale for hadron beam radiotherapy




Proton
Photon

Brief history of Proton Beam Therapy

1946: Therapeutic use of proton beams first proposed by Robert Wilson[1]

[1]Wilson RR. Radiological use of fast protons. *Radiology.* 1946;47:487-491

1954: First patient treated at the UC Lawrence Berkeley Laboratory (LBL)

– Treated the pituitary gland with beams passing entirely through the brain.

1957: Proton radiosurgical techniques for brain tumors developed at the Gustaf-Werner Institute, Uppsala, Sweden

– First to use range modulation

1961: Radiosurgery of small intercranial targets at the Harvard Cyclotron Laboratory

70s – 80s: Physics facilities worldwide – notably, the Paul Scherrer Institute (PSI) in Switzerland

1989: The world's first hospital-based low-energy ocular proton beam therapy facility opened at Clatterbridge Cancer Centre, UK

1990: The world's first hospital-based high-energy proton beam therapy facility opened at Loma Linda University Medical Center, California

2000s - : Rapid growth in number of proton facilities internationally

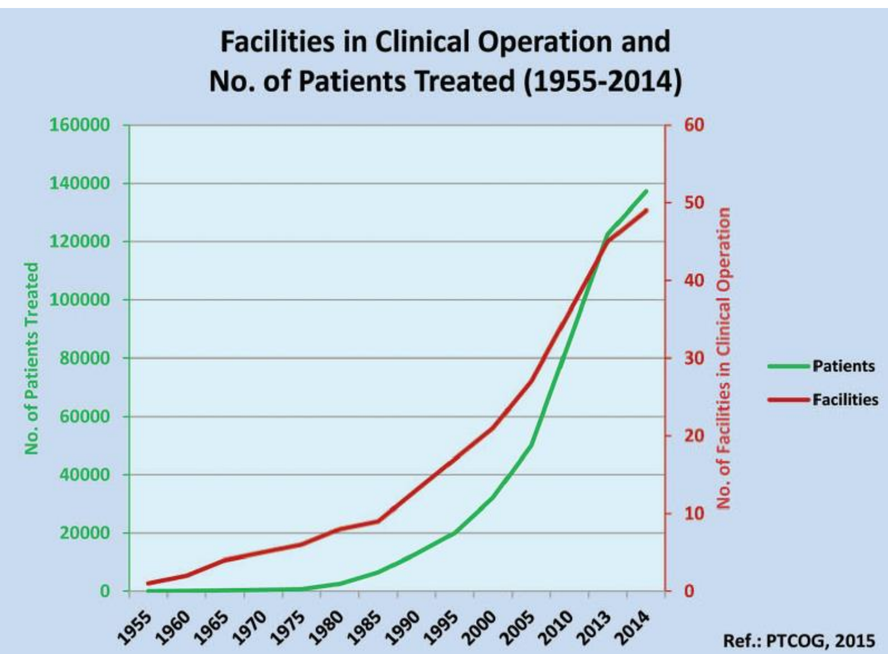
Jermann M. Particle Therapy Statistics in 2014. Int J Particle Ther. 2015;2(1):50–54.

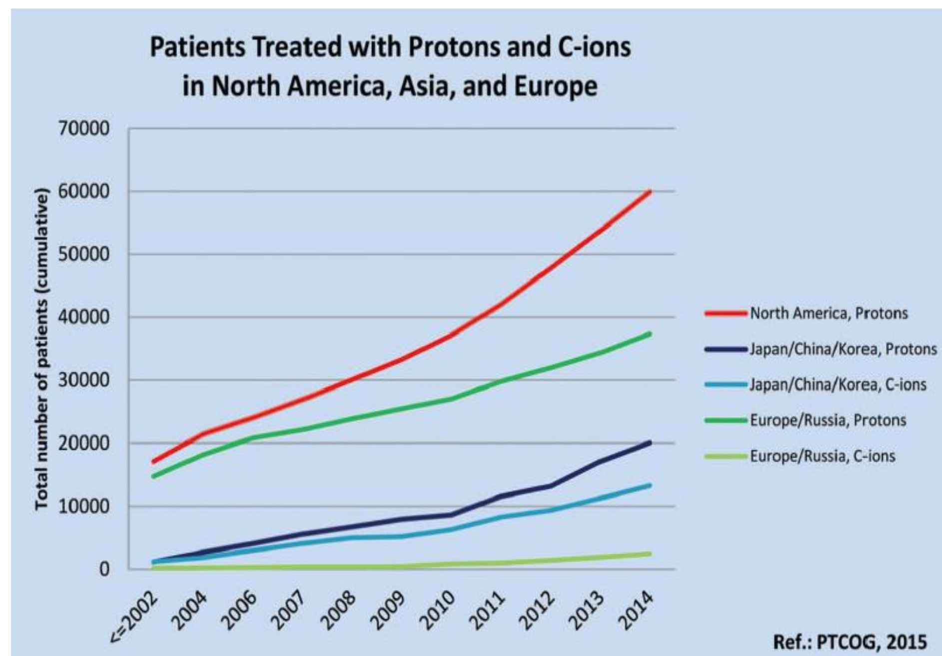
Particle Therapy Statistics in 2014

Martin Jermann, MSc

Secretary of the Particle Therapy Cooperative Group
Paul Scherrer Institute, Villigen, Switzerland

Total of all facilities (in and out of operation):		
He	2054	1957-1992
Pions	1100	1974-1994
C-ions	15736	1994-present
Other ions	433	1975-1992
Protons	118195	1954-present
Grand Total	137179	





Personal experience in proton beam radiotherapy

2002 – 2005:

LOMA LINDA UNIVERSITY
MEDICAL CENTER

- First hospital-based high-energy proton therapy facility in the world.
- First patient treated in 1990
- 18,362 patients treated by end of 2014*

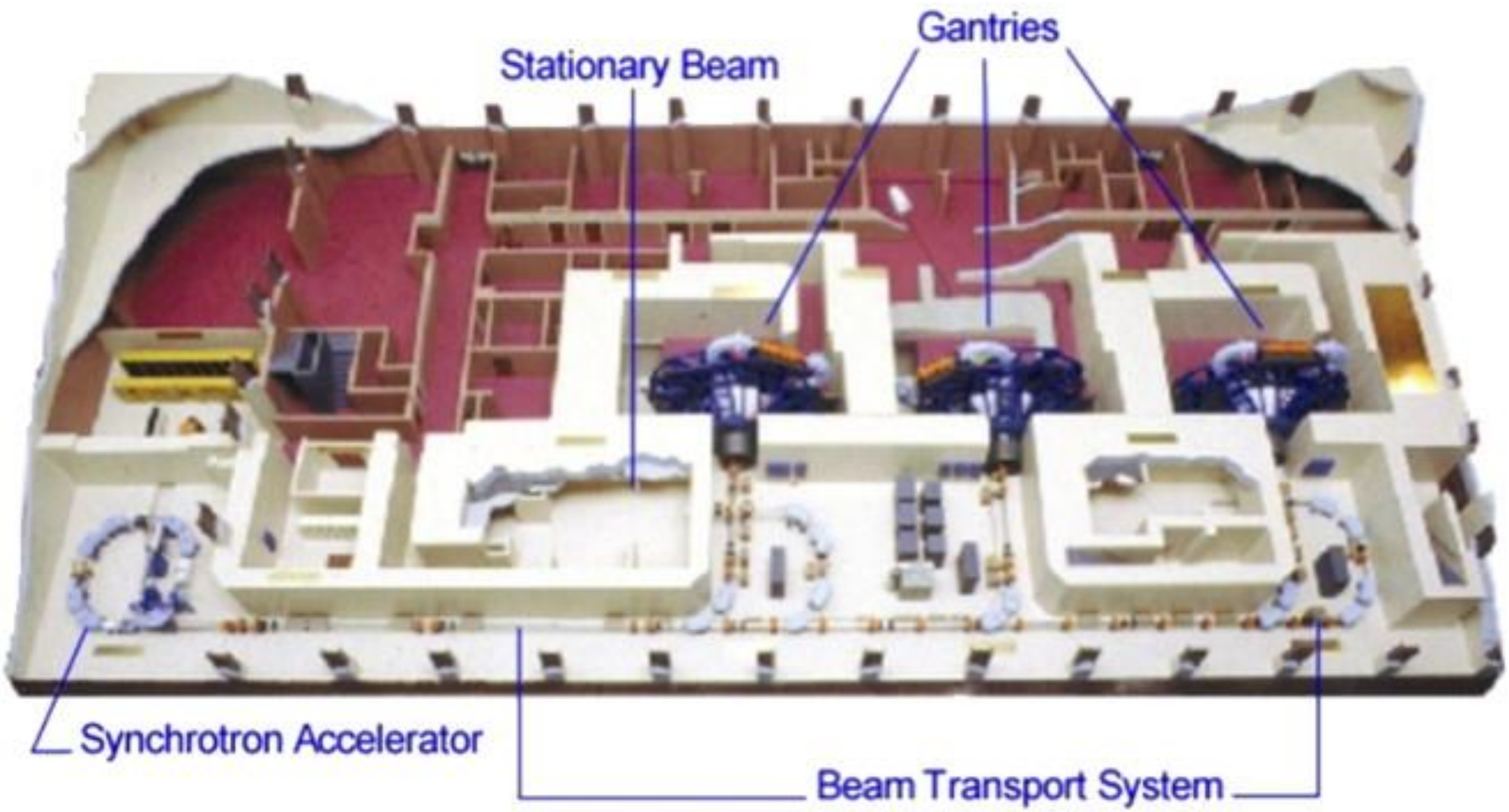
2005 – 2013:

THE UNIVERSITY OF TEXAS
MD Anderson
Cancer Center

- World-leading cancer treatment and research center.
- Proton Therapy Center opened in 2006
- First in the USA to treat with PBS in 2008
- 5,838 patients treated by end of 2014*

*Int J Particle Ther. 2015;2(1):50-54

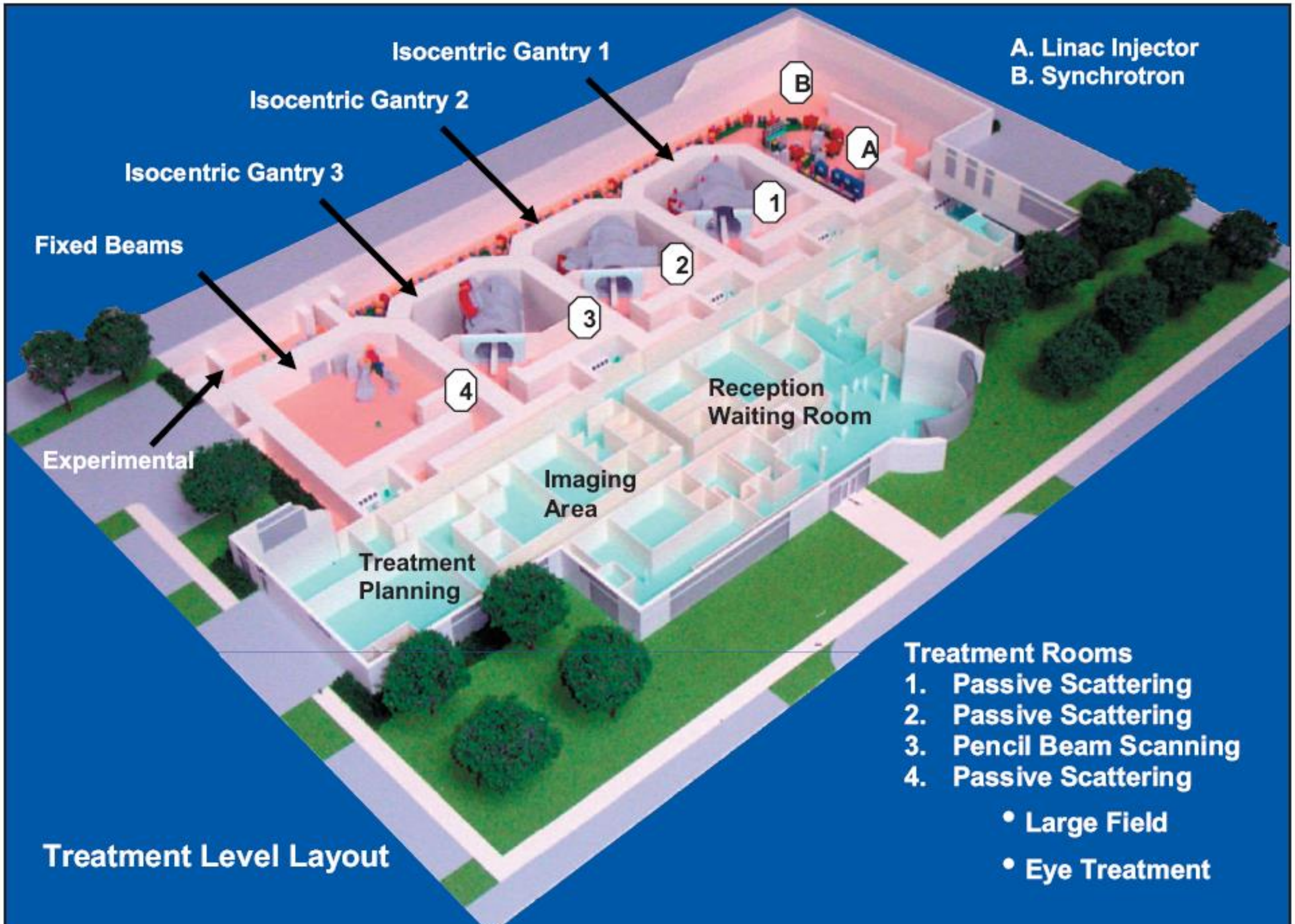
LOMA LINDA UNIVERSITY
MEDICAL CENTER

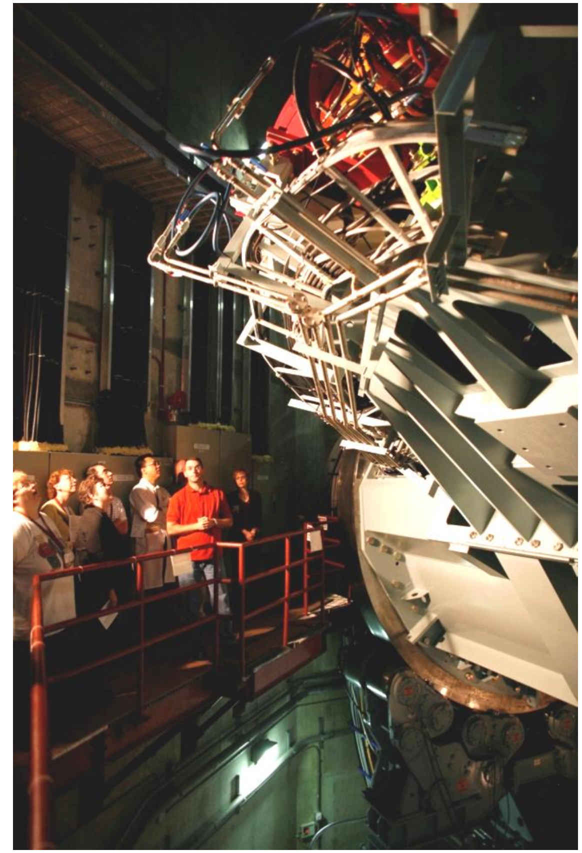


- 250 MeV synchrotron developed in collaboration with Fermi National Accelerator Laboratory
- 3 gantries (passive scattering)
- 1 fixed clinical beamline (passive scattering)
- 1 fixed ocular beamline (passive scattering)
- 1 fixed experimental beamline (passive scattering)

THE UNIVERSITY OF TEXAS
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)*





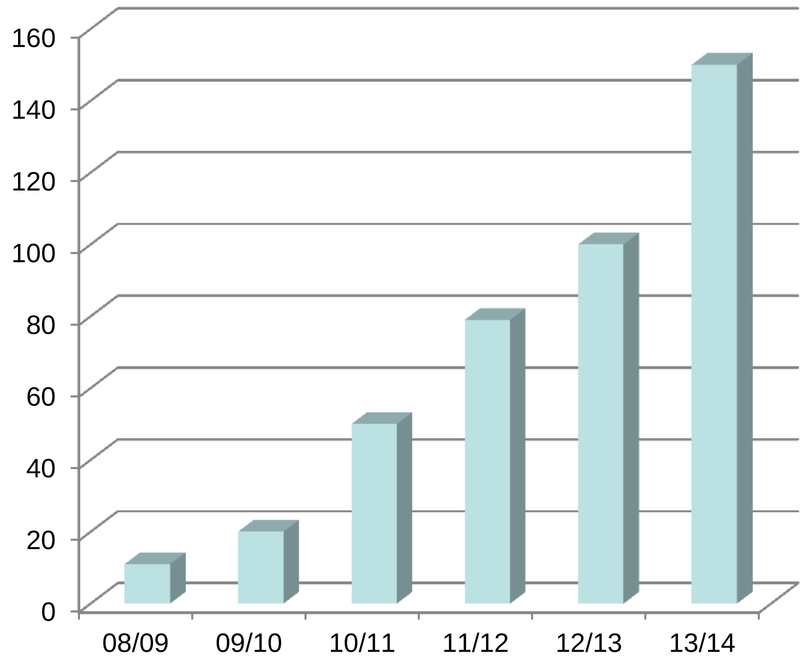
THE UNIVERSITY OF TEXAS

MD Anderson

~~Cancer~~ Center

Current Indications for NHS Patients Travelling Abroad for PBT

- **Adult**
- Base of Skull & Spinal Chordoma
- Base of Skull Chondrosarcoma
- Spinal & Paraspinal Bone and Soft Tissue Sarcomas (Non Ewing's)



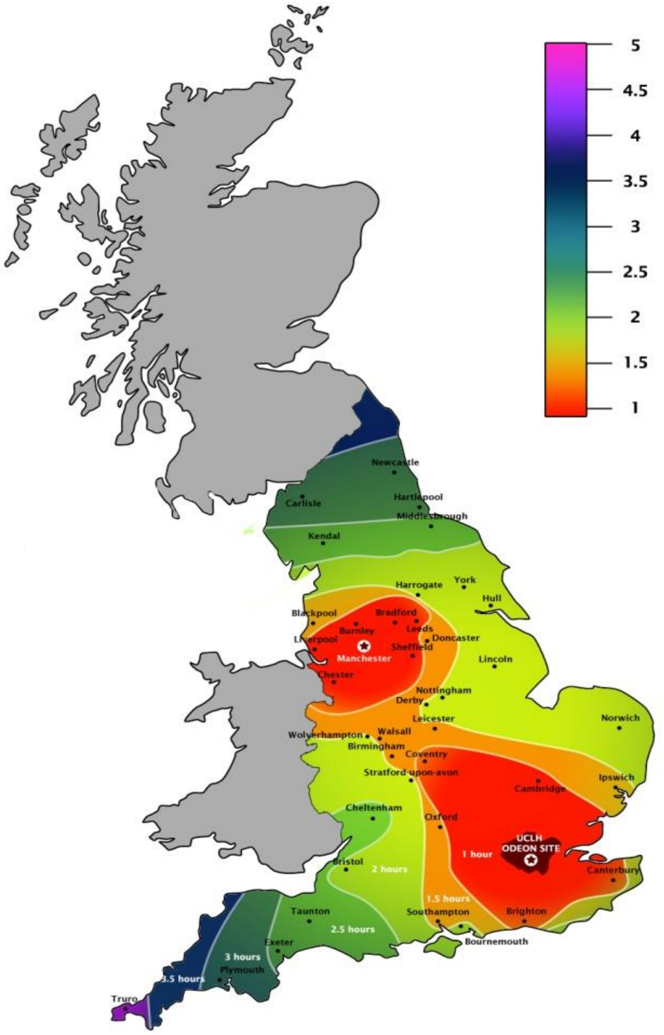
- **Paediatric**
- Base of Skull & Spinal Chordoma
- Base of Skull Chondrosarcoma
- Spinal & Paraspinal 'adult type' Bone and Soft Tissue Sarcomas
- Rhabdomyosarcoma
- Orbit
- Parameningeal & Head & Neck
- Pelvis
- Ependymoma
- Ewing's Sarcoma
- Retinoblastoma
- Pelvic Sarcoma
- Optic Pathway and other selected Low Grade Glioma
- Craniopharyngioma
- Pineal Parenchymal Tumours (not Pineoblastoma)
- Esthesioneuroblastoma

Paediatric			Adult		
Indication	**2009 Framework assumption**	**2012 Updated assumption**	**Indication**	**2009 Framework assumption**	**2012 Updated assumption**
Chordoma/ Chondrosacoma	15		Ocular/Orbital	2	25
Rhabdomyosarcoma (Orbit)	5		Chordoma	60	60
Rhabdomyosarcoma (Parameningeal and H&N)	15		Chondrosarcoma	30	30
Rhabdomyosarcoma(Pelvis)	10		Para- Spinal / Spinal Sarcoma	180	180
Osteosarcoma	3		Meningioma	100	100
Ewings	9		Acoustic Neuroma	100	100
PPNET	5		Craniospinal NOS (Pineal)	10	10
Ependymoma	25		Head & Neck & Paranasal Sinuses	300	300
Low Grade Glioma	5		PNET(medulloblastoma)	30	30
Optic Pathway Glioma	12		Difficult cases	300	123
Craniopharyngioma	15		TYA		200
Medulloblastoma (PNET)	70				
Hodgkins	5				
Retinoblastoma	5				
Meningioma	3				
Intracranial germinoma	10				
Nasopharynx (H&N)	15				
Difficult Cases-Esthe/Neuro/Liver	5				
Very Young Age	20				
Total	**252**	330	**Total**	**1,110**	1157

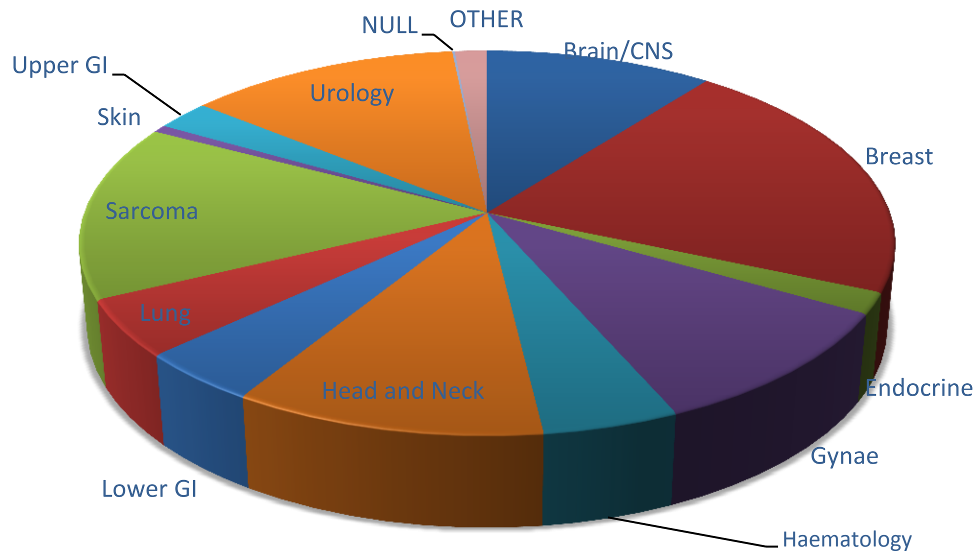
What will UK service look like?

- 2 sites selected
  - The Christie (Manchester)
  - UCLH (London)

- 2 Sites, 1 Service
  - Integrated clinically within the hospital setting
  - Integrated with existing conventional photon facilities
  - Collaboration across all areas
    - Referral
    - Protocol Development
    - Technology
    - Research
  - Due to open in 2018/2019



Why UCLH?



- Geographical access
- Viable centre size
- Integrated radiotherapy department
- High quality and recognised complex case mix
  - Largest paediatric practice in Europe

University College London Hospitals NHS
NHS Foundation Trust

Green light for proton beam therapy centre

11 Mar 2015

The Department of Health has announced the preferred contractors for the building and supply of equipment for the proton beam therapy (PBT) service which will treat hundreds of patients each year at University College Hospital from 2018.

The Christie NHS
NHS Foundation Trust

Green light for proton beam therapy centre

Press Release Posted 11 March 2015

The Department of Health has announced the preferred contractors for the building and supply of equipment for the proton beam therapy (PBT) service which will treat hundreds of patients each year at The Christie from 2018.

VARIAN
medical systems

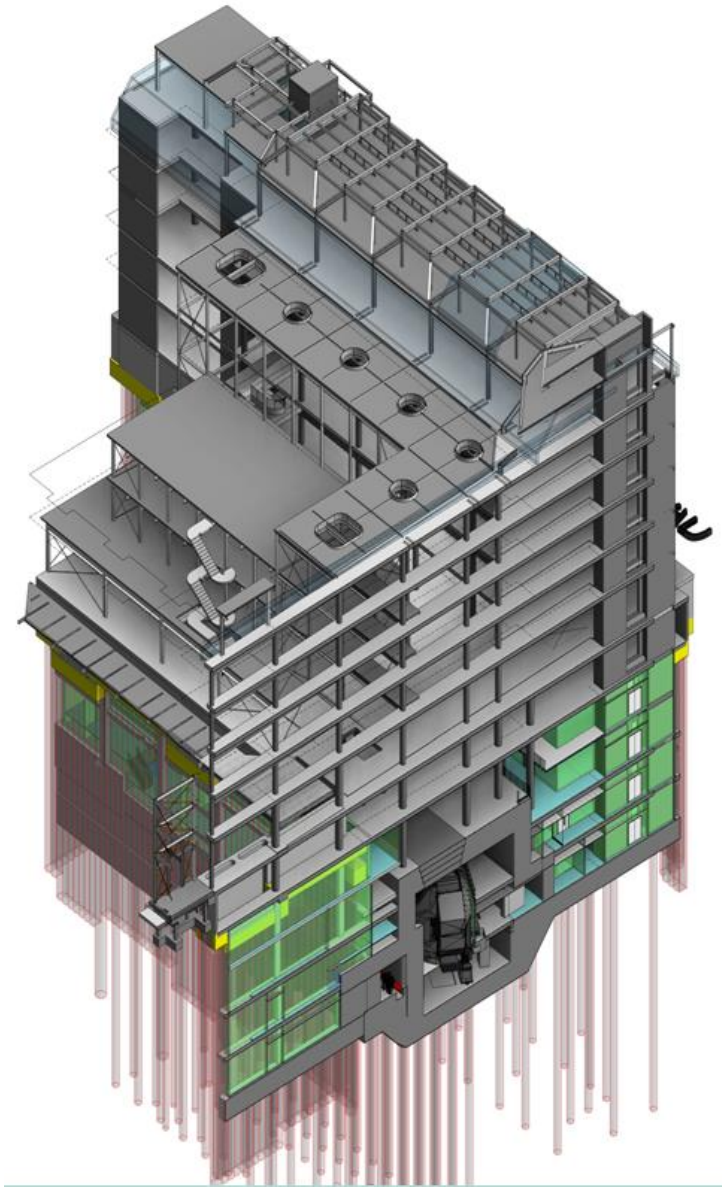
VARIAN MEDICAL SYSTEMS SELECTED TO EQUIP TWO NATIONAL PROTON THERAPY CENTERS IN ENGLAND

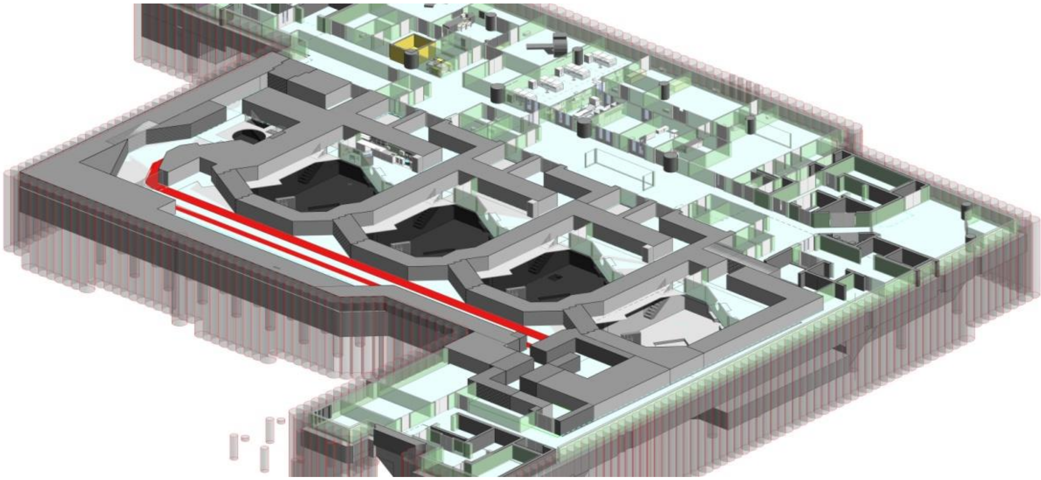
Mar 11, 2015

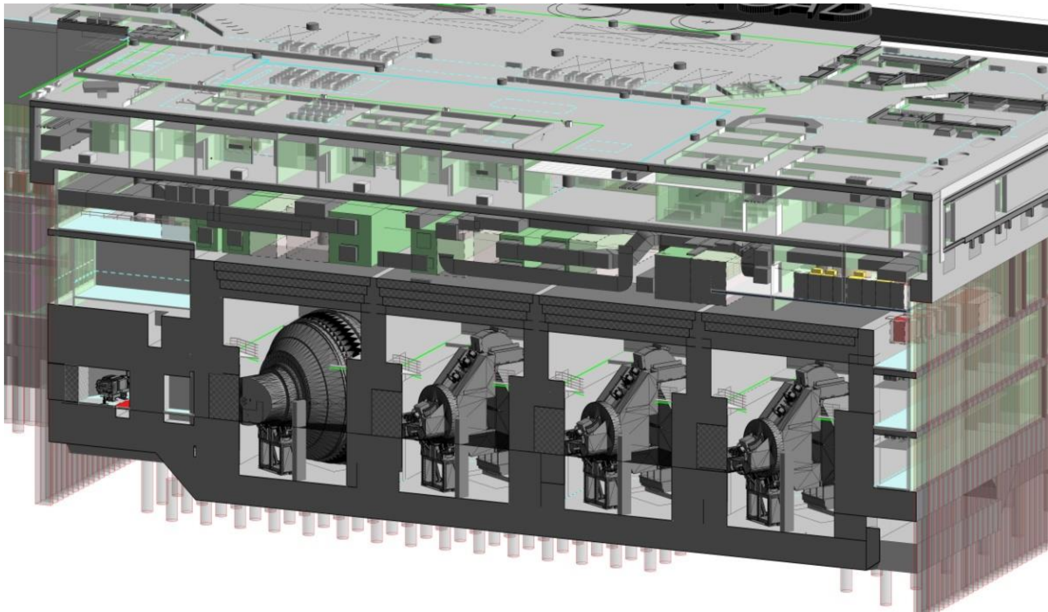
Zakrzewska P, Pitt M, **Amos RA**, D'Souza D & Ahmed T.

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








proBEAM


VARIAN

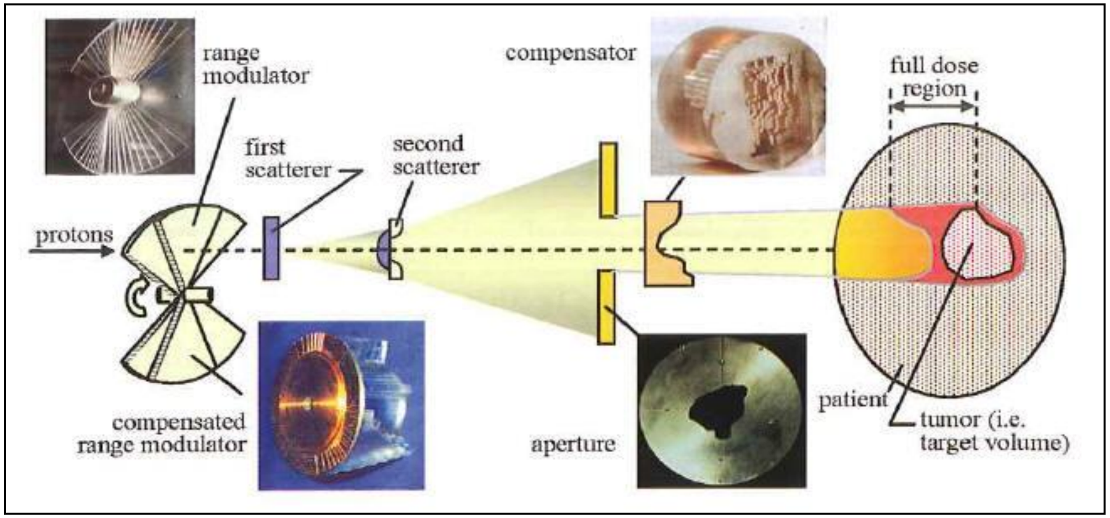

VARIAN
medical systems
proBEAM

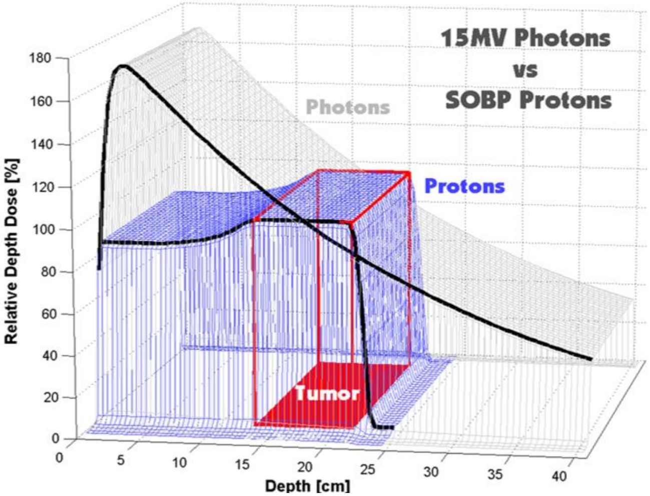
Operational Expectations

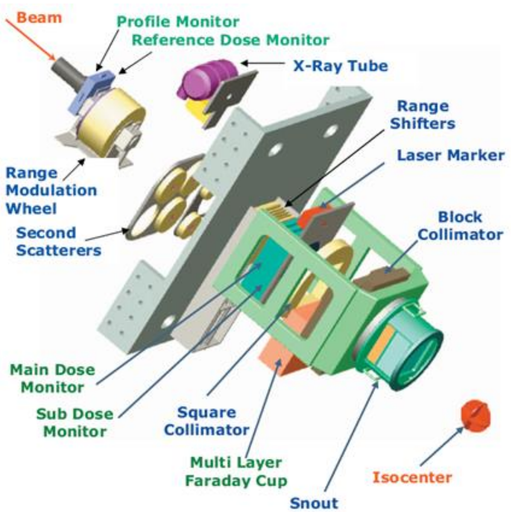
Facility opening times:

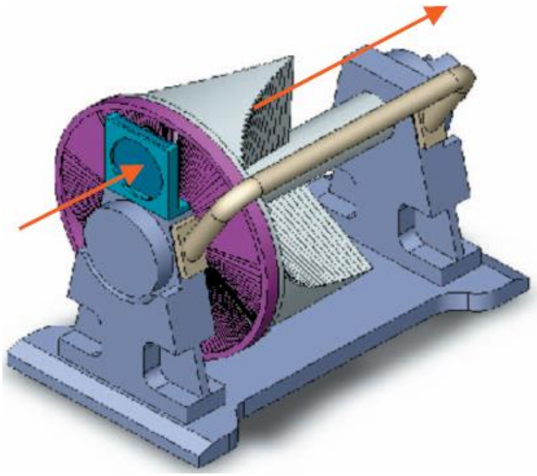
- 24Hour/day
- Clinical time:
  - 5 days per week
  - 14 Hours per day
- Quality Assurance Checks
- Maintenance Requirements
- Research

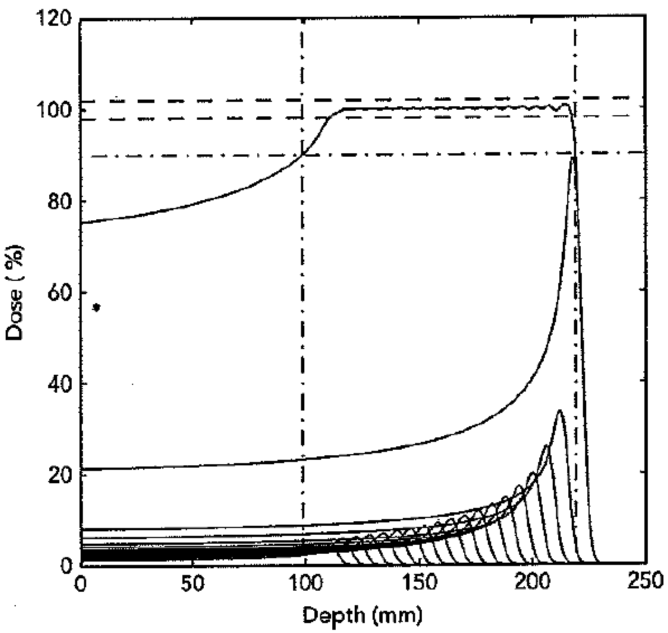
Beam delivery system: Passive scattering





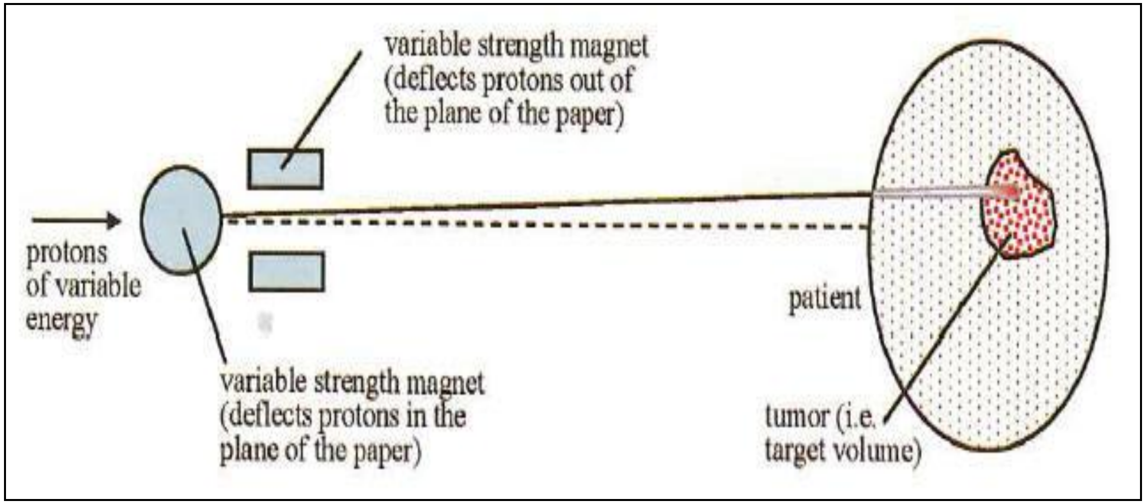


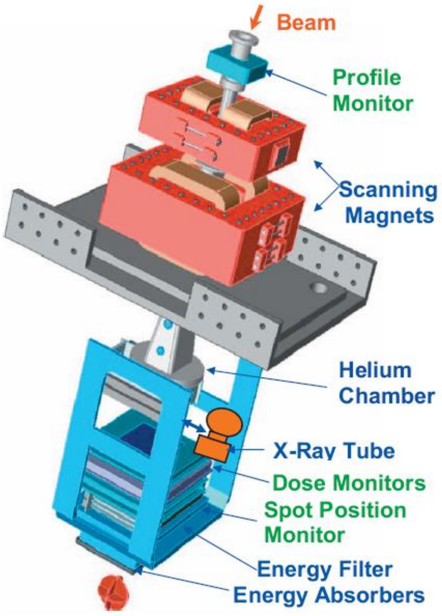


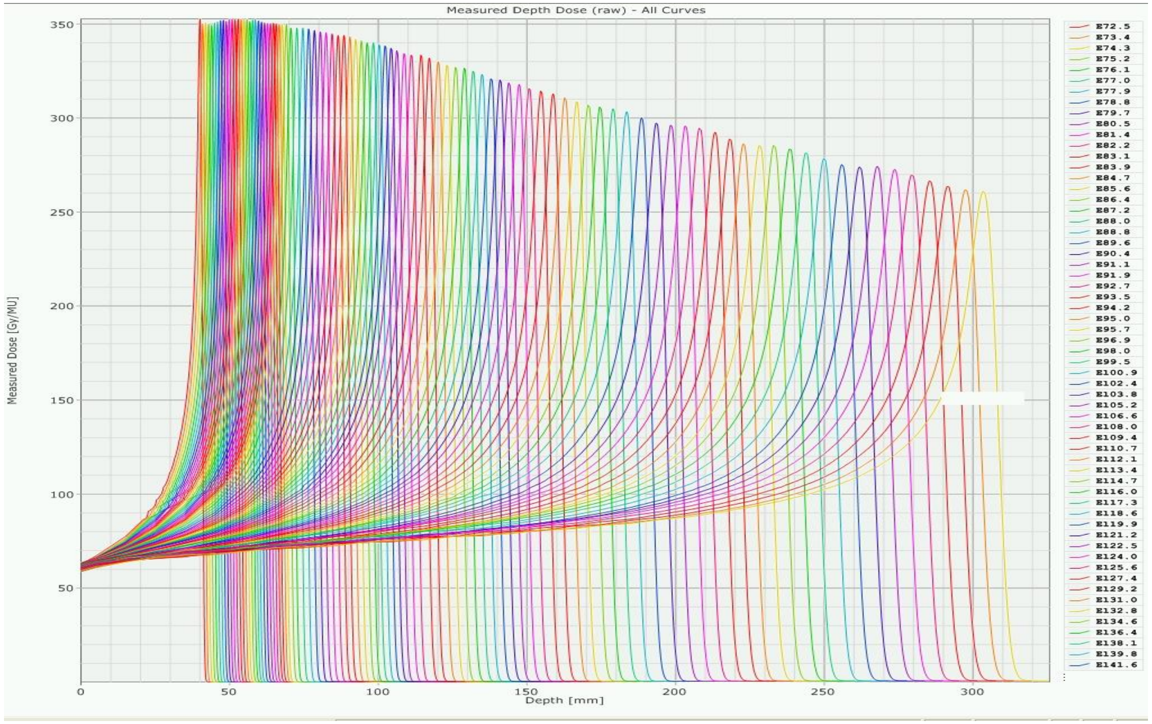


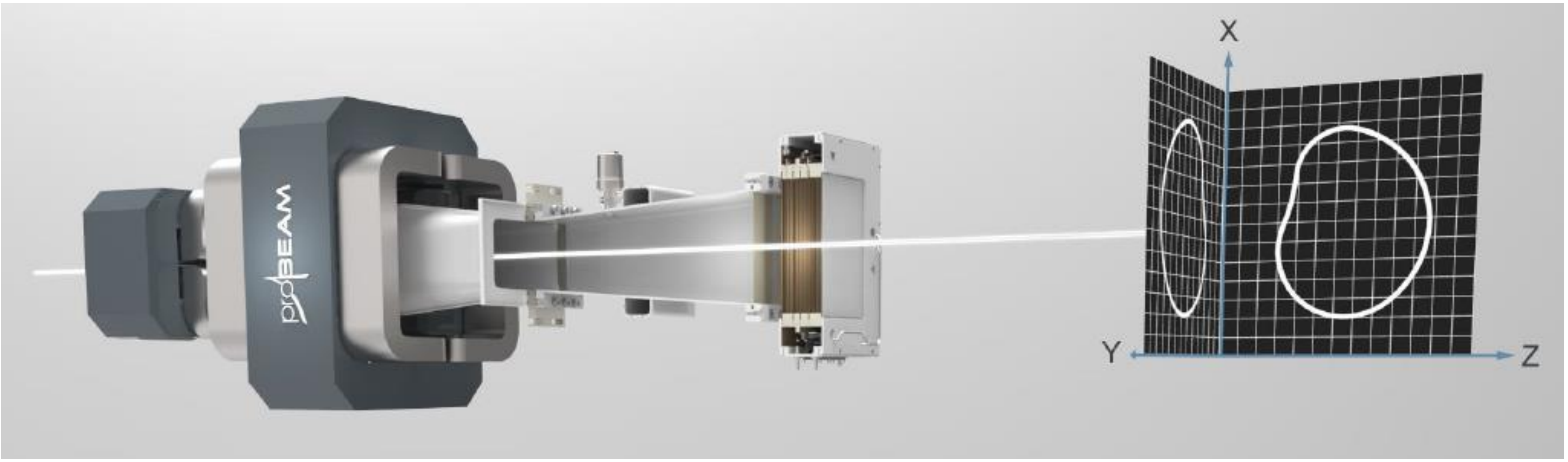
Beam delivery system: Pencil beam scanning

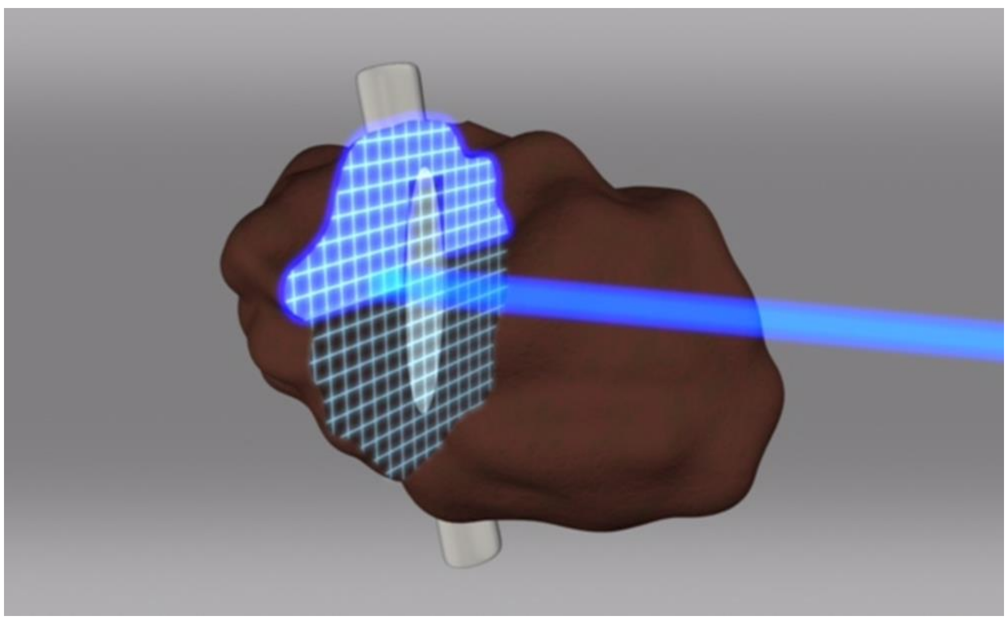
- 94 Energies: 72.5 - 221.8 MeV
- Range: 4.0 – 30.6 cm
- Adjustability: 0.1 cm
- Max field size: 30x30 cm^2
- Beam size: 5 - 14 mm σ (air)
- Energy absorber (*range shifter*)

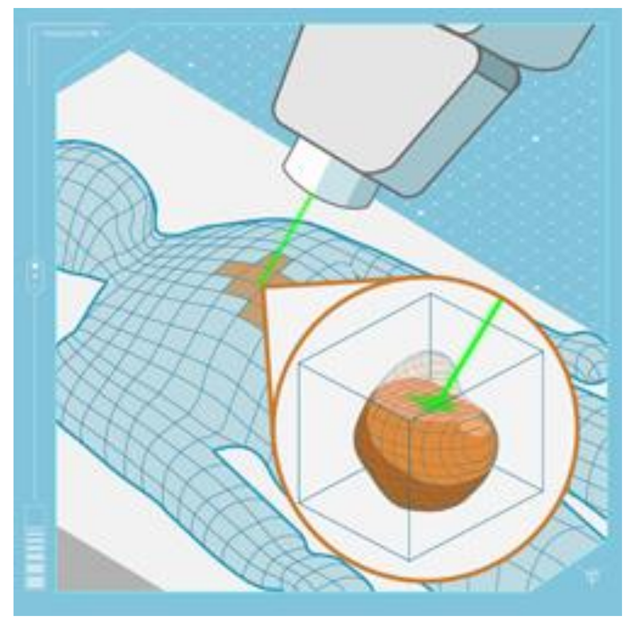







proBEAM
X
Y
Z





Advantages of scanned beam delivery

1. Can "paint" any physically possible dose distribution.
2. Uses protons very efficiently as compared to passive scattering in which more than 50% of protons have to be "thrown away".
3. Generally requires no patient-specific hardware.
4. The neutron background is substantially reduced as a result of points (2) and (3).
5. Allows the implementation of IMRT with protons – termed *intensity-modulated proton therapy (IMPT)*

Disadvantages of scanned beam delivery

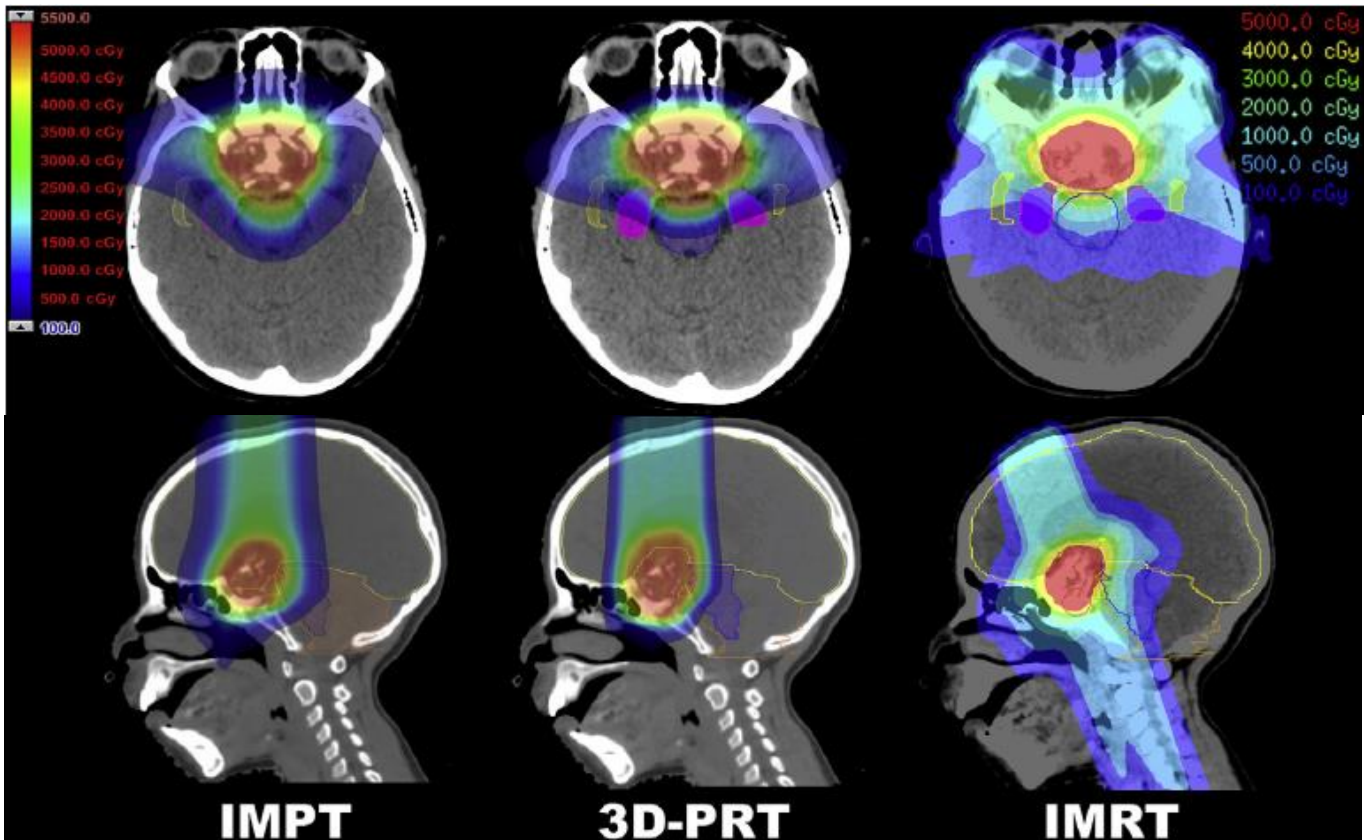
1. The need to overcome *"interplay effects"* (Bortfeld, 2002)* induced by organ motion.

**Bortfeld T et al. (2002) Effects of intra-fraction motion on IMRT dose delivery: Statistical analysis and simulation. Phys Med Biol 47:2203-2220*

DOSIMETRIC COMPARISON OF THREE-DIMENSIONAL CONFORMAL PROTON RADIOTHERAPY, INTENSITY-MODULATED PROTON THERAPY, AND INTENSITY-MODULATED RADIOTHERAPY FOR TREATMENT OF PEDIATRIC CRANIOPHARYNGIOMAS

NICHOLAS S. BOEHLING, B.A.,* DAVID R. GROSSHANS, M.D., PH.D.,* JAQUES B. BLUETT, C.M.D., M.S.,† MATTHEW T. PALMER, C.M.D., M.B.A.,* XIAOFEI SONG, PH.D.,† RICHARD A. AMOS, M.SC.,† NARAYAN SAHOO, PH.D.,† JEFFREY J. MEYER, M.D.,* ANITA MAHAJAN, M.D.,* AND SHIAO Y. WOO, M.D.*

Departments of *Radiation Oncology and †Radiation Physics, The University of Texas M. D. Anderson Cancer Center, Houston, TX



Int. J. Radiation Oncology Biol. Phys., Vol. 82, No. 2, pp. 643–652, 2012

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Medical Dosimetry, Vol. 35, No. 3, pp. 179-194, 2010

0958-3947/10/$–see front matter

ELSEVIER

doi:10.1016/j.meddos.2009.05.004

ION STOPPING POWERS AND CT NUMBERS

MICHAEL F. MOYERS, PH.D., MILIND SARDESAI, PH.D., SEAN SUN, M.S., and DANIEL W. MILLER, PH.D.

Proton Therapy, Inc., Colton, CA; Long Beach Memorial Medical Center, Long Beach, CA; City of Hope National Medical Center, Duarte, CA; and Loma Linda University Medical Center, Loma Linda, CA

IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY

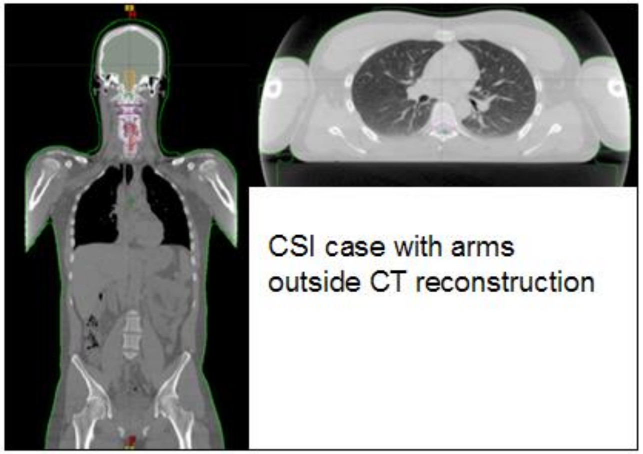
Phys. Med. Biol. **57** (2012) 4095–4115 doi:10.1088/0031-9155/57/13/4095

Comprehensive analysis of proton range uncertainties related to patient stopping-power-ratio estimation using the stoichiometric calibration

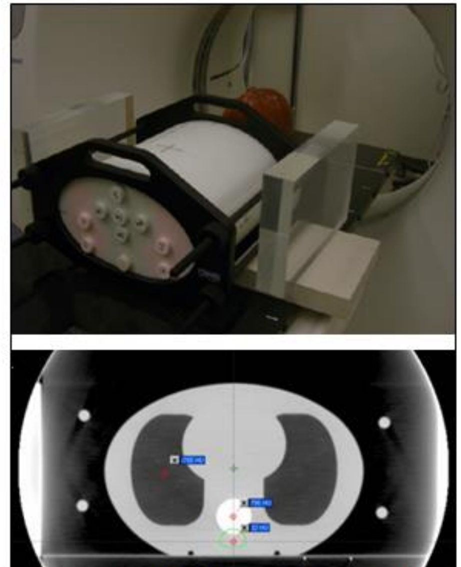
Ming Yang[1,2], X Ronald Zhu[1,2], Peter C Park[1,2], Uwe Titt[1,2], Radhe Mohan[1,2], Gary Virshup[3], James E Clayton[3] and Lei Dong[1,2,4]

[1] Department of Radiation Physics, Unit 94, The University of Texas MD Anderson Cancer Center, 1515 Holcombe Blvd., Houston, TX 77030, USA
[2] Medical Physics Program, Graduate School of Biomedical Sciences, The University of Texas Health Science Center at Houston, 7000 Fannin St, Houston, TX 77030, USA
[3] Ginzton Technology Center, Varian Medical Systems, 3120 Hansen Way, Palo Alto, CA 94303, USA

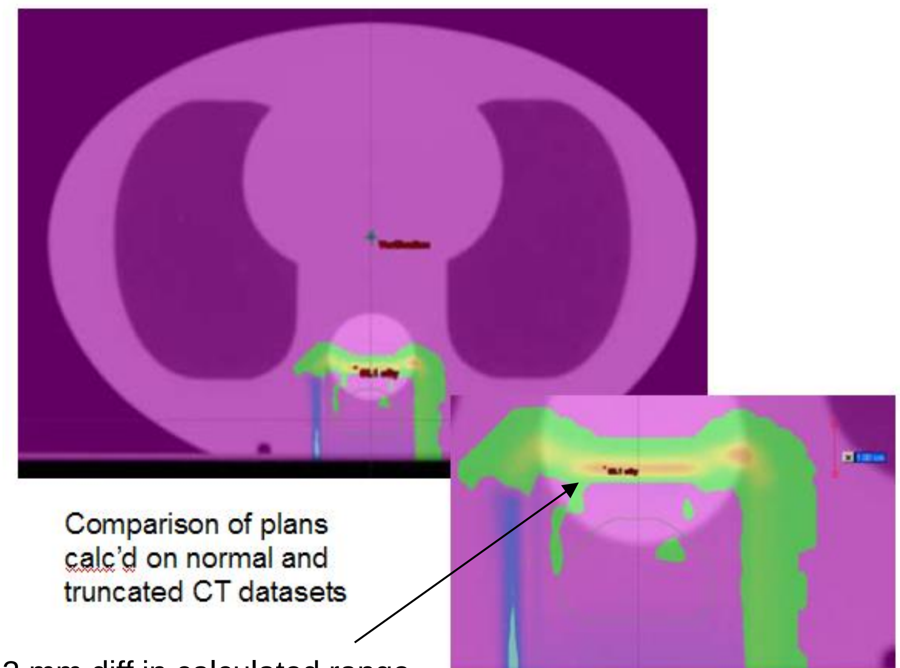
Wu R, **Amos RA**, *et al.* Effect of CT truncation artifacts on proton dose calculation. (Abstract) *Med Phys* **35**, 2697 (2008)



CSI case with arms outside CT reconstruction

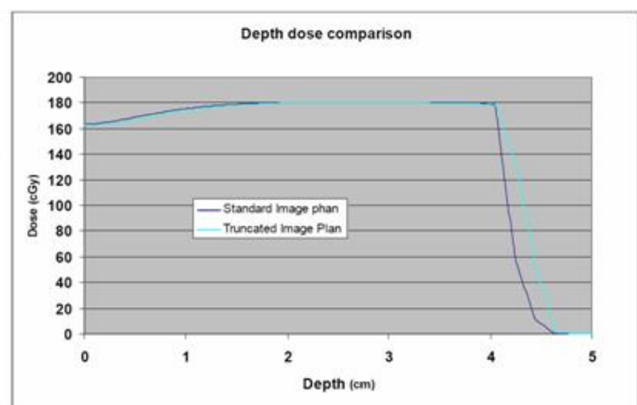


Thoracic phantom scanned with tissue equiv. material truncated



Comparison of plans calc'd on normal and truncated CT datasets

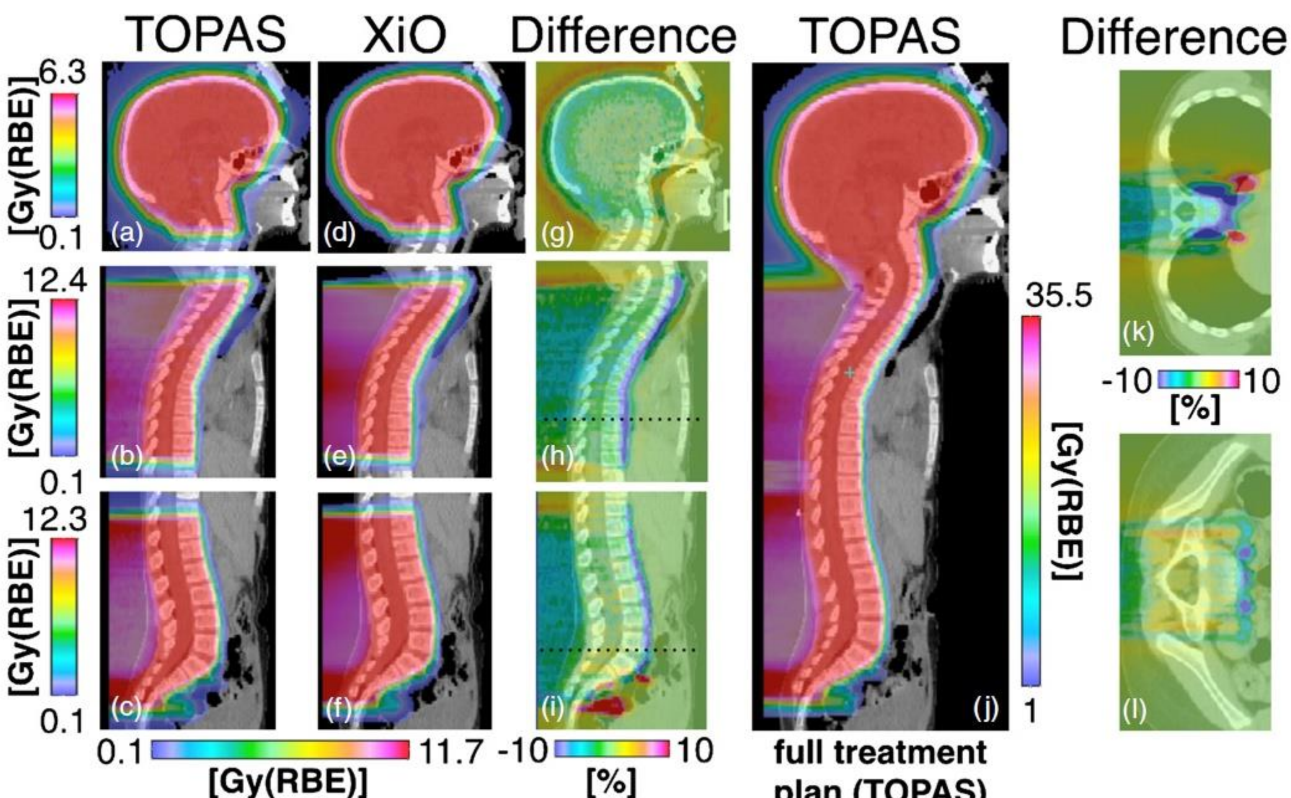
2-3 mm diff in calculated range



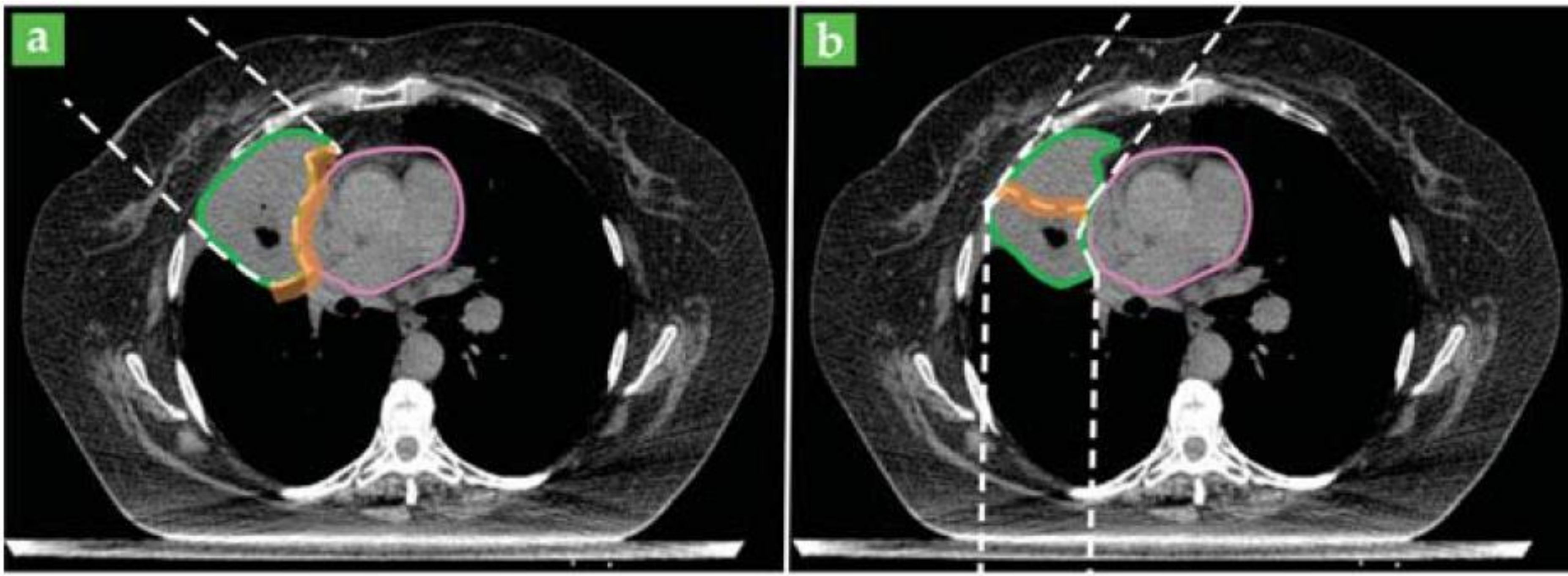
Site-specific range uncertainties caused by dose calculation algorithms for proton therapy

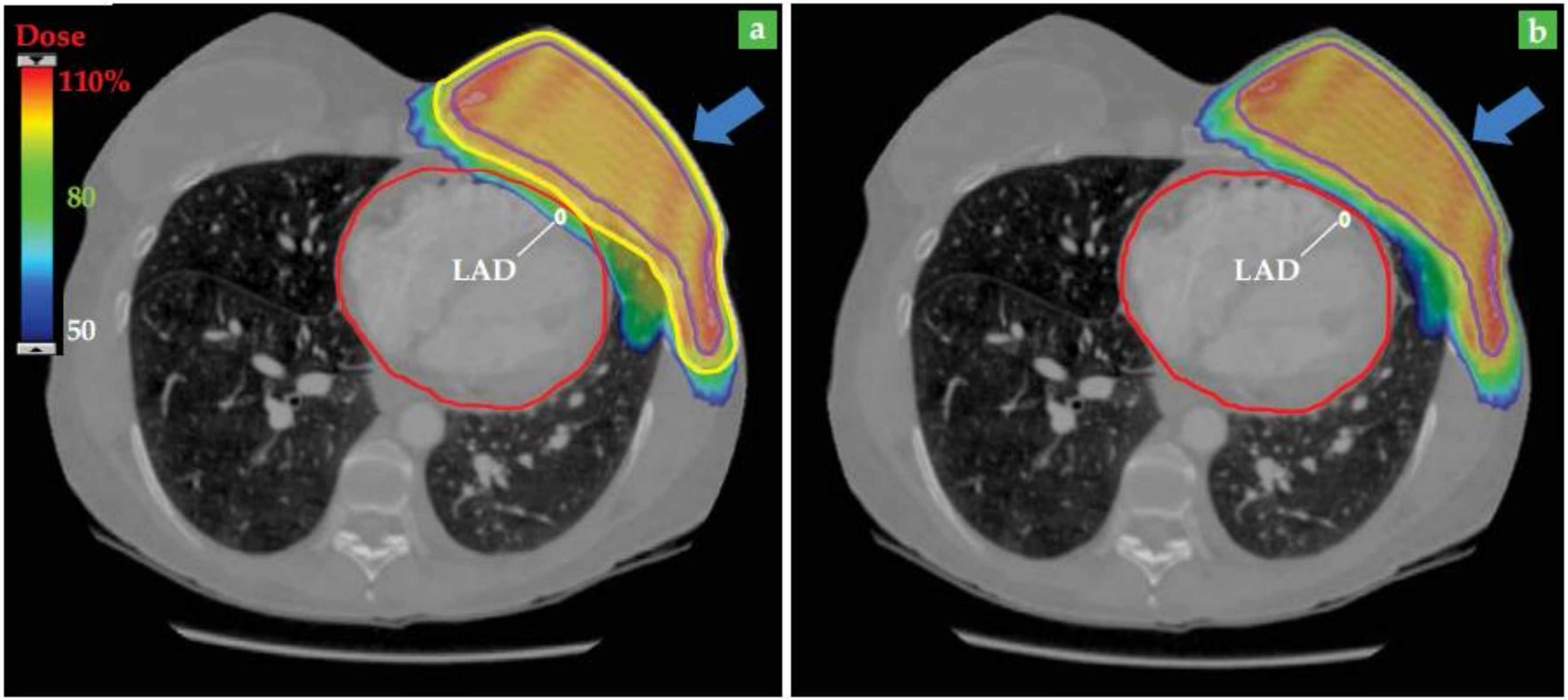
J Schuemann, S Dowdell[1], C Grassberger, C H Min[2] and H Paganetti

Department of Radiation Oncology, Massachusetts General Hospital and Harvard Medical School, Boston, MA 02114, USA



Phys. Med. Biol. **59** (2014) 4007–4031


a
b

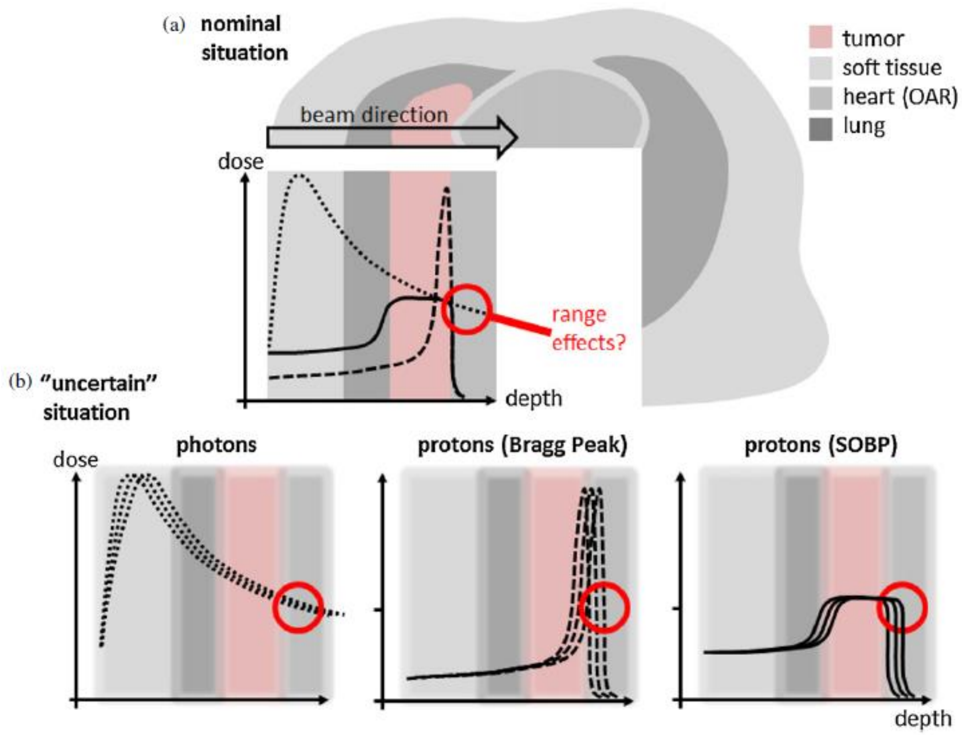


LAD: Left Anterior Descending artery

In vivo proton range verification: a review

Antje-Christin Knopf and Antony Lomax

Center for Proton Therapy, Paul Scherrer Institut, Villigen, Switzerland



Phys. Med. Biol. **58** (2013) R131–R160

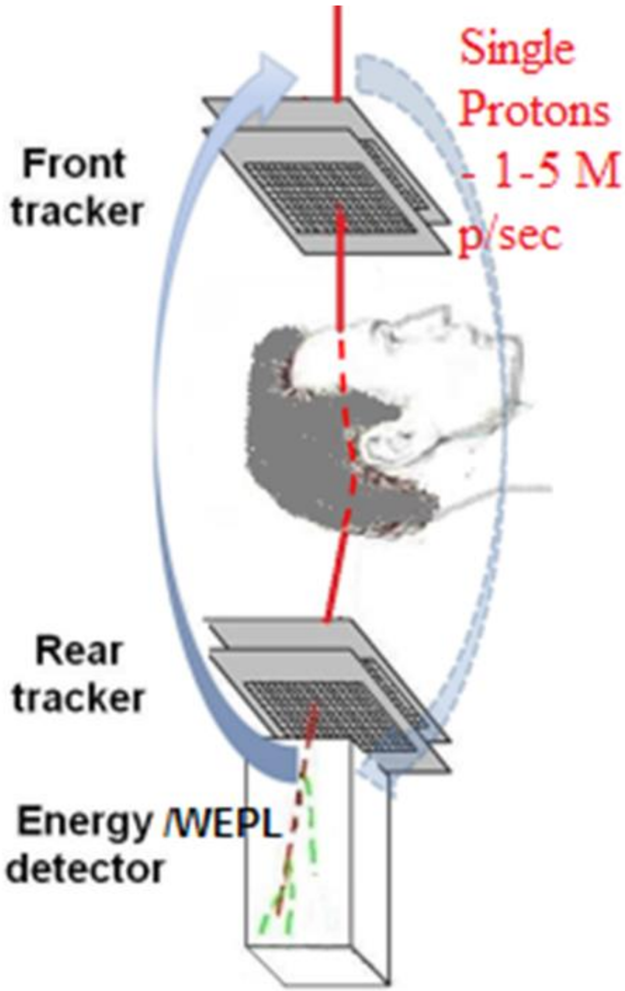
Range probe / proton radiography
•Possible prior, during and after field delivery
•pCT only possible pre- or post-delivery

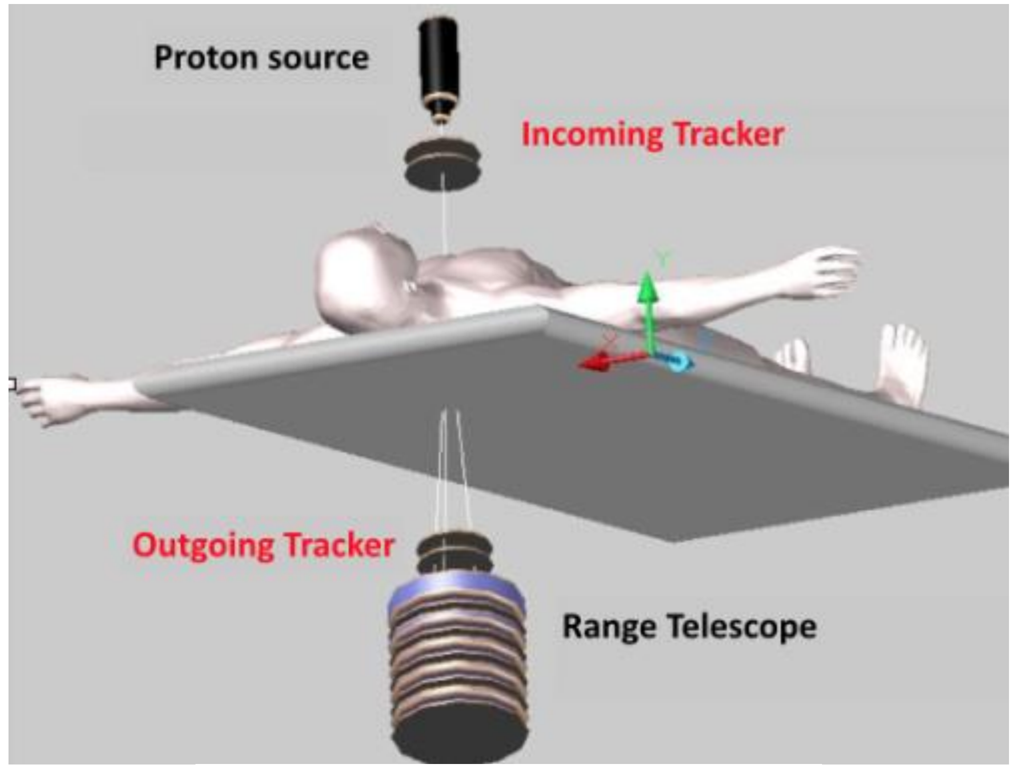
Prompt gamma
•Prompt γ emission within nanoseconds
•Only applicable for on-line range verification

PET
•Possible on-line, or short time after irradiation
•Biological wash-out can be an issue

MRI
•Retrospective range verification as a function of tissue change.

Proton CT

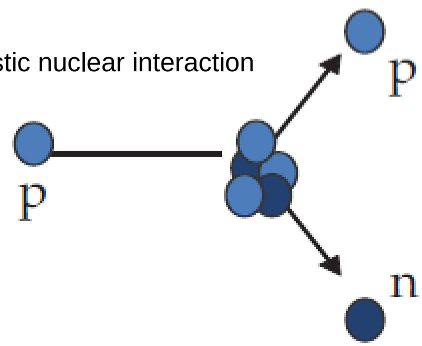




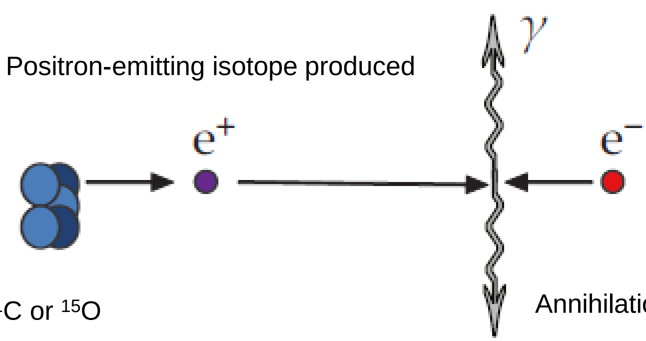
PRaVDA
Proton Radiotherapy Verification and Dosimetry Applications

Positron-annihilation gammas

Inelastic nuclear interaction



Positron-emitting isotope produced

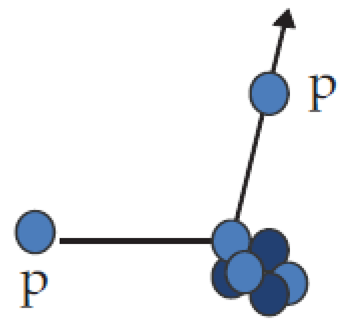


^{11}C or ^{15}O

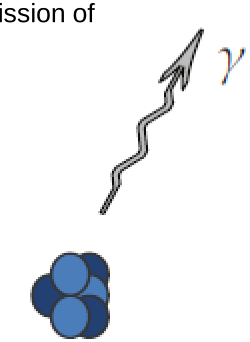
Annihilation

511 keV gammas

Prompt gammas

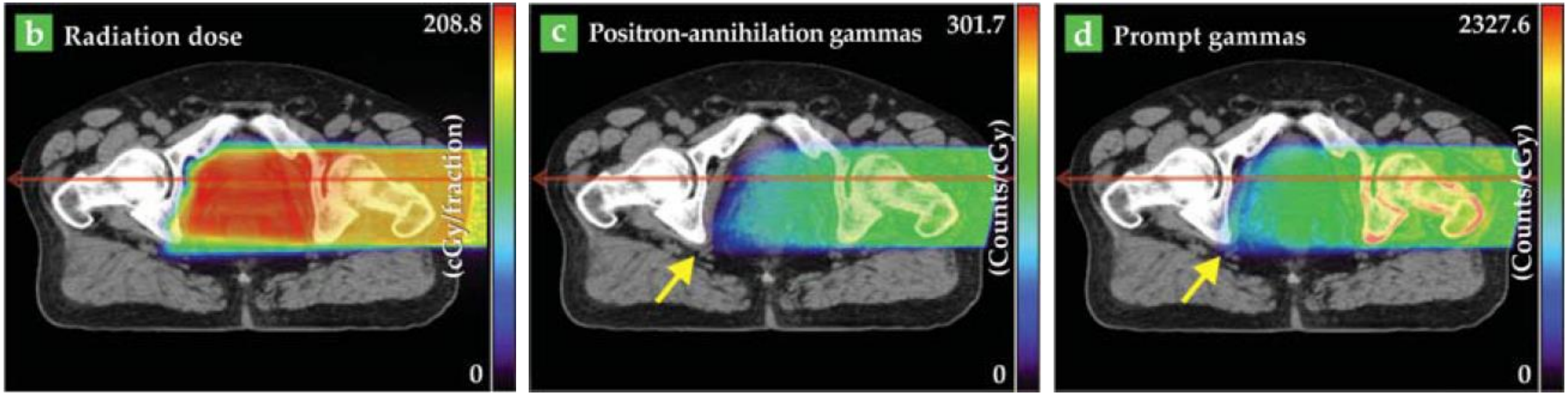


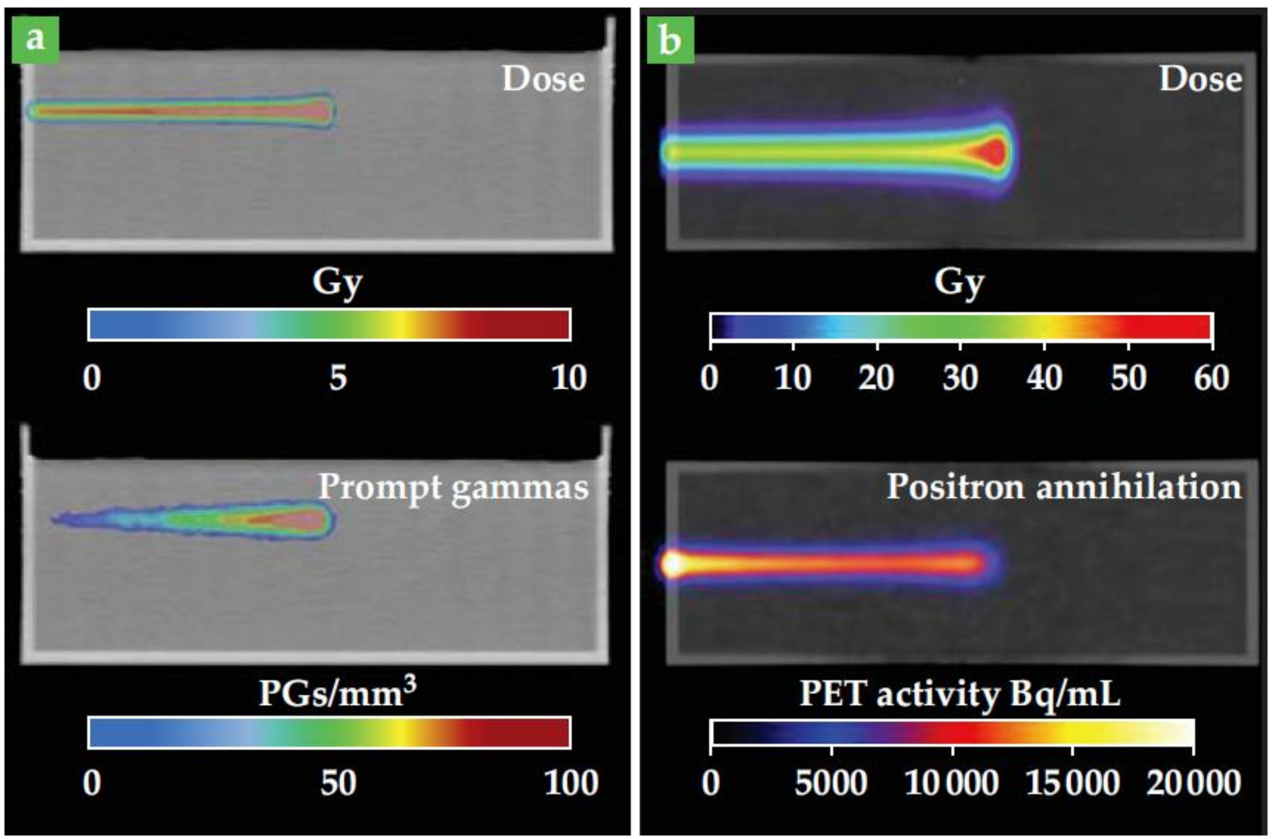
Nuclear scatter promote nuclei to excited states that decay through emission of single gamma



2 – 15 MeV gammas

(Existing imaging systems designed for gamma energies of a few hunded keV)


b
Radiation dose
208.8
(cGy/fraction)
0
c
Positron-annihilation gammas
301.7
(Counts/cGy)
0
d
Prompt gammas
2327.6
(Counts/cGy)
0


a
Dose
Gy
0
5
10
Prompt gammas
PGs/mm^3
0
50
100
b
Dose
Gy
0
10
20
30
40
50
60
Positron annihilation
PET activity Bq/mL
0
5000
10 000
15 000
20 000

Proton Beam Range Verification using Off-site PET by Imaging Novel Proton-Activated Markers

Jongmin Cho, Geoffrey Ibbott, Matthew Kerr, Richard Amos, and Osama Mawlawi

Proceedings: 2013 IEEE Nuclear Science Symposium & Medical Imaging Conference, Seoul, Korea.

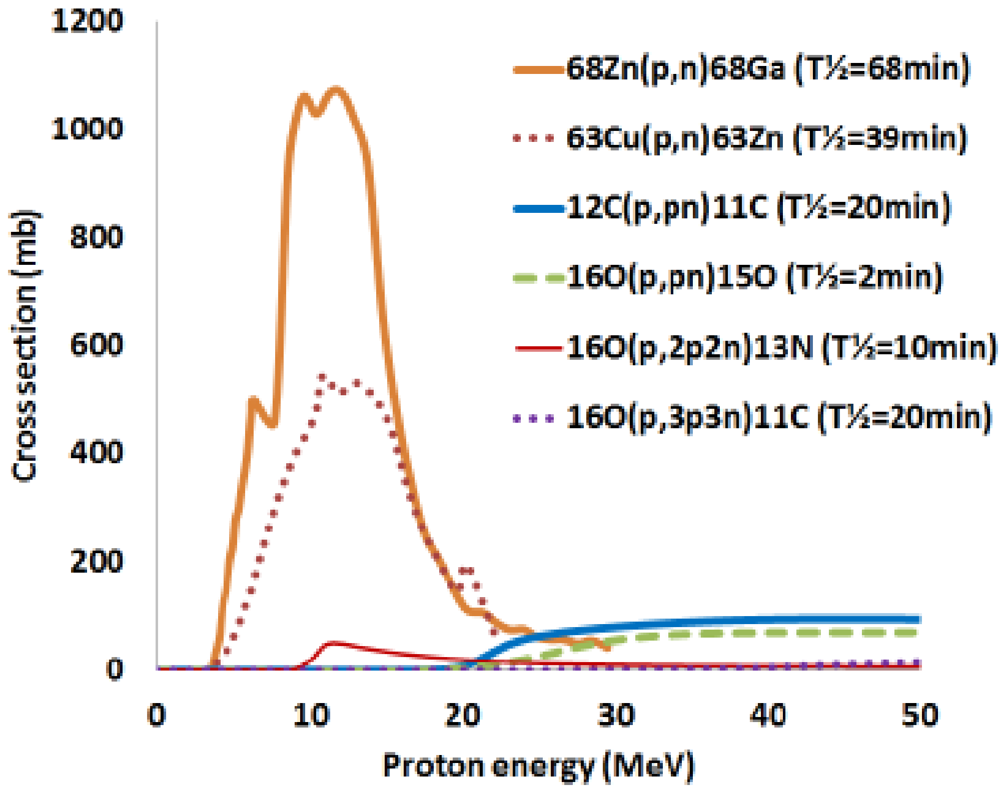


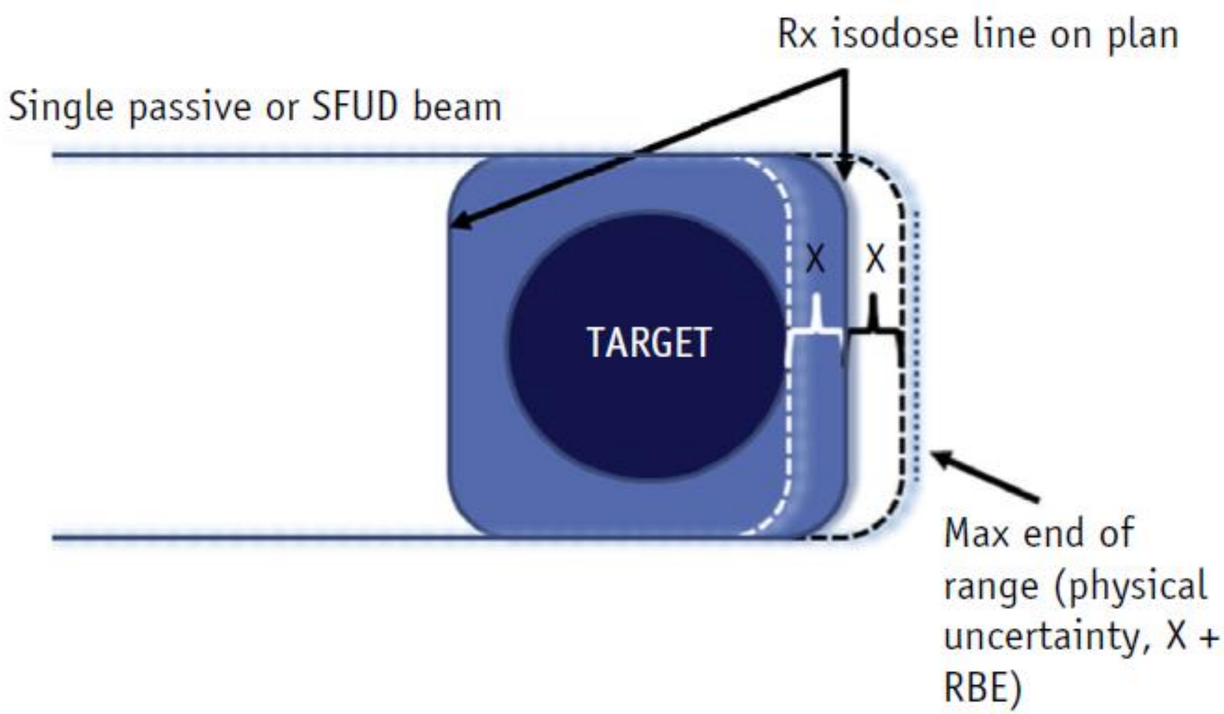
Fig. 1. Proton nuclear interaction cross sections of ^{63}Cu and ^{68}Zn in comparison with tissue endogenous elements – ^{12}C and ^{16}O.

Int J Radiation Oncol Biol Phys, Vol. 95, No. 1, pp. 59–61, 2016

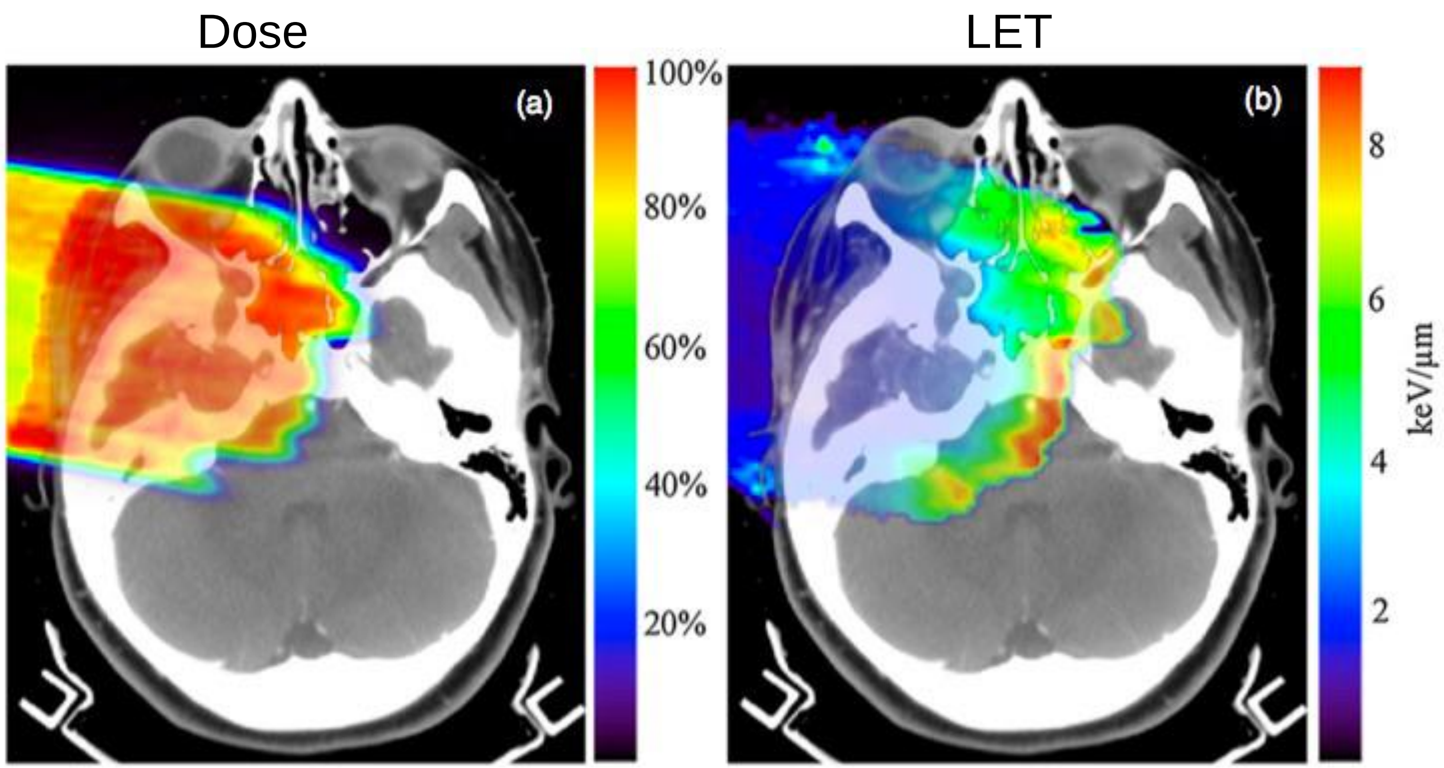
Proton Radiation Biology Considerations for Radiation Oncologists

Wendy A. Woodward, MD, PhD,* and Richard A. Amos, MSc, FIPEM[†,‡]

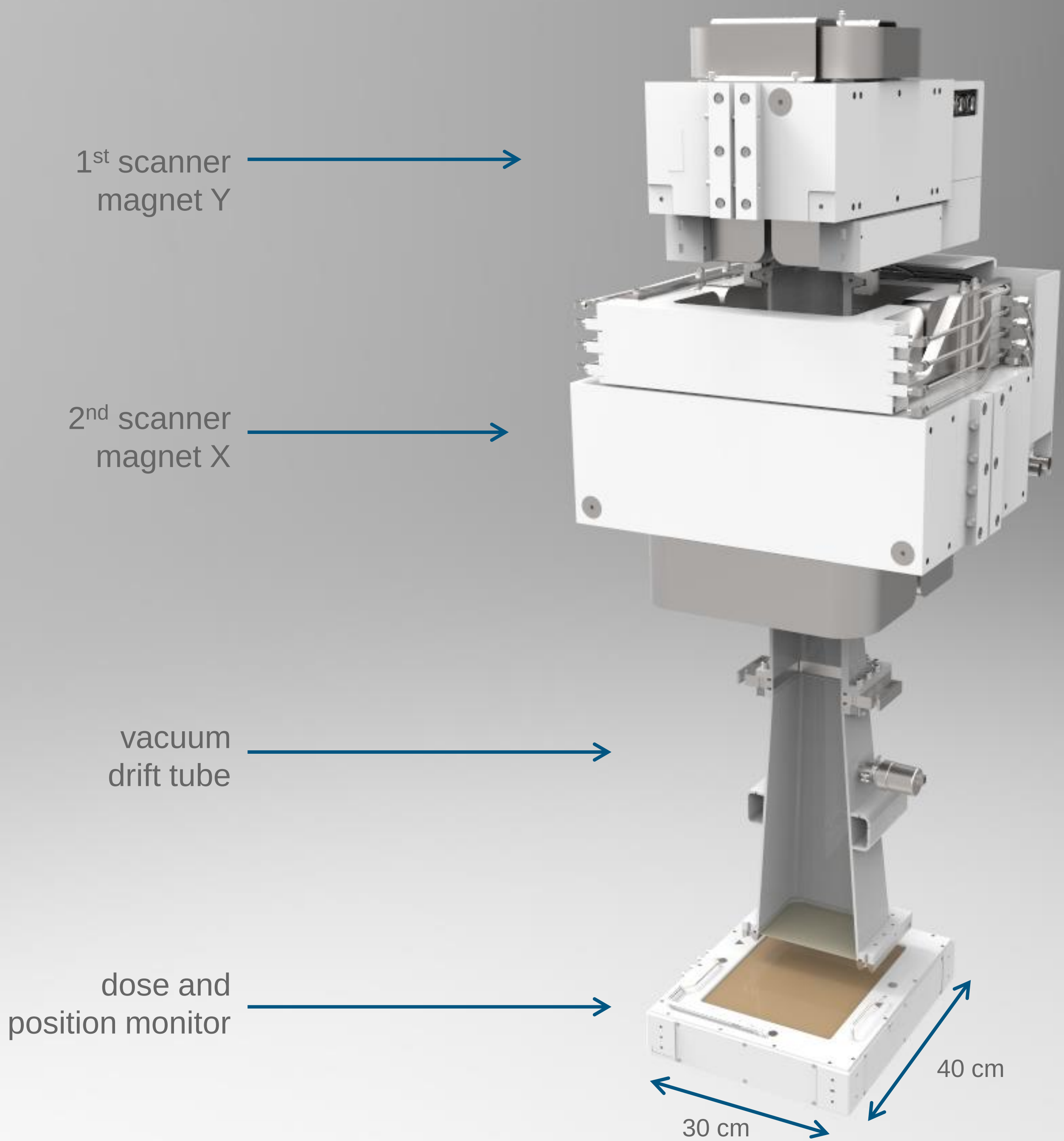
*Department of Radiation Oncology, University of Texas MD Anderson Cancer Center, Houston, Texas; [†]Department of Radiotherapy Physics, University College London Hospitals NHS Foundation Trust, London, United Kingdom; and [‡]Department of Medical Physics and Biomedical Engineering, University College London, London, United Kingdom



Biological effect: Biology based planning



What is the most important metric for proton planning?


1st scanner
magnet Y
2nd scanner
magnet X
vacuum
drift tube
dose and
position monitor
40 cm
30 cm

Parallel plate ion-chamber

“Peakfinder” system

Multi-layer ion chamber (MLIC)

2D scintillation detector

Desirable:

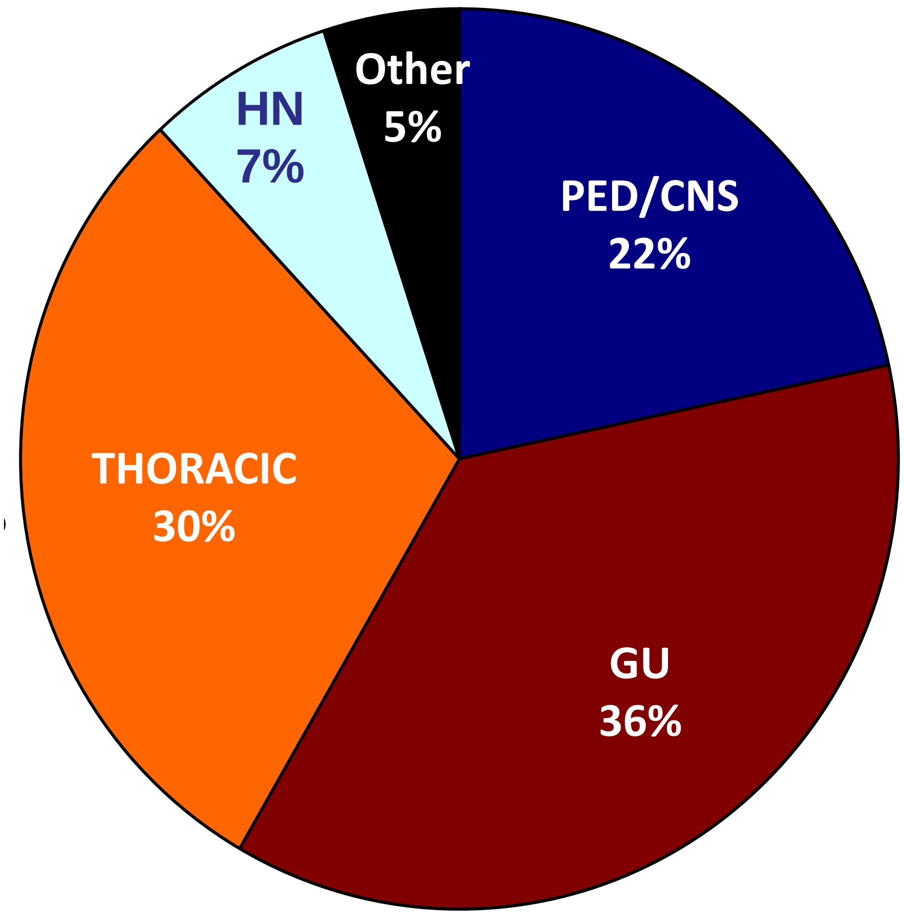
- Fast and accurate 3D dosimetry for treatment plan verification and machine QA

Holy Grail:

- *In vivo* range verification and on-the-fly adaptive PBS delivery:
  - On-board image-guidance (*CBCT, MRI);*
  - Pre-treatment WEPL verification (*pCT, p-radiograph*);
  - Fast detection during treatment (*prompt gamma*);
  - Fast comparison with daily on-board imaging of anatomy;
  - Fast adjustment to spot delivery pattern;
  - Self-verification of pencil beam trajectories and energies;
  - Repeat *in vivo* verification.

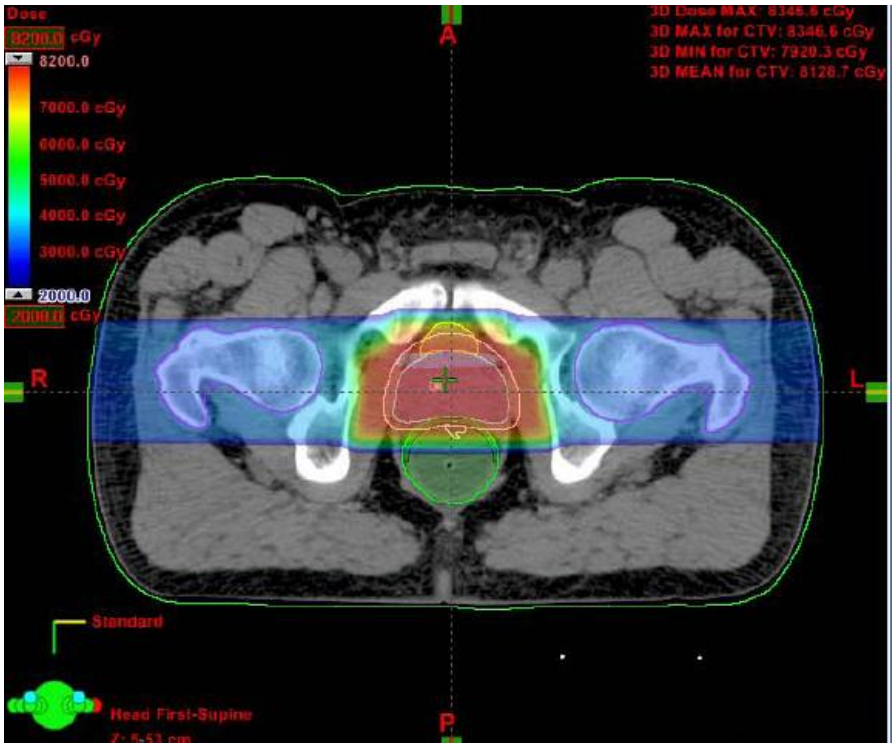
THE UNIVERSITY OF TEXAS
MD Anderson Cancer Center
Making Cancer History®

PBT patient mix (2012)



	FY'12 Annualized
PEDI/CNS	191
GU	311
THORACIC	261
HN	63
OTHER	32
TOTAL	857

Prostate

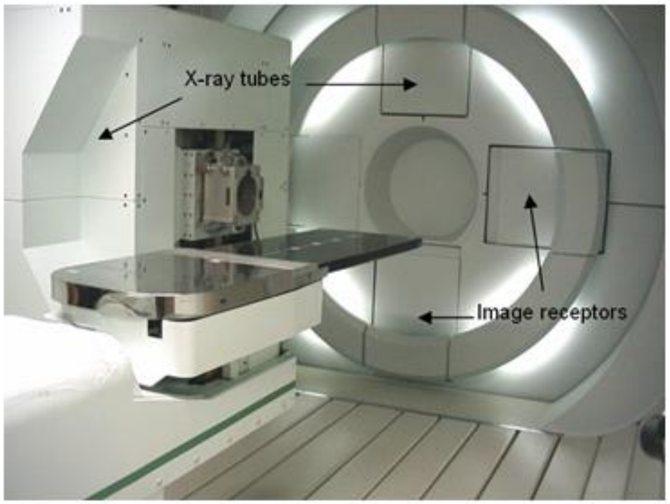


Proton therapy

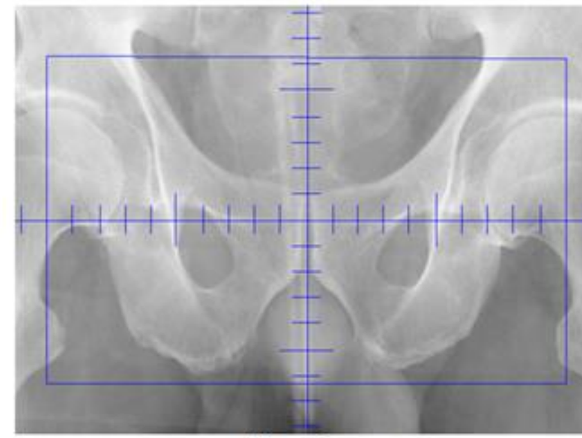
IMRT

Image-guidance

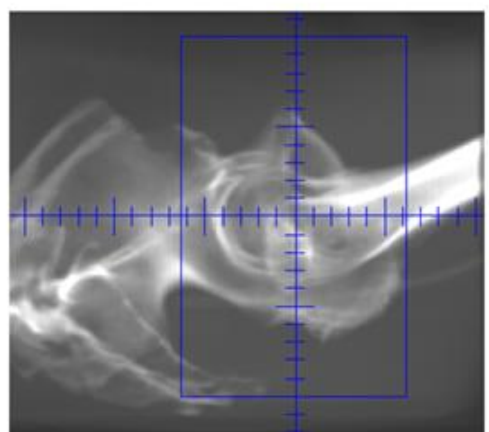
- Daily orthogonal kV x-rays taken to align anatomy with reference DRR's using 2-D matching



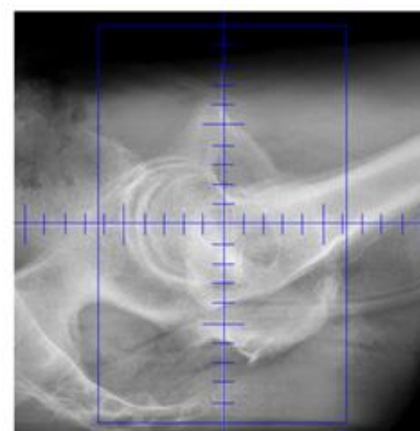
AP DRR



AP x-ray image



Rt Lat DRR

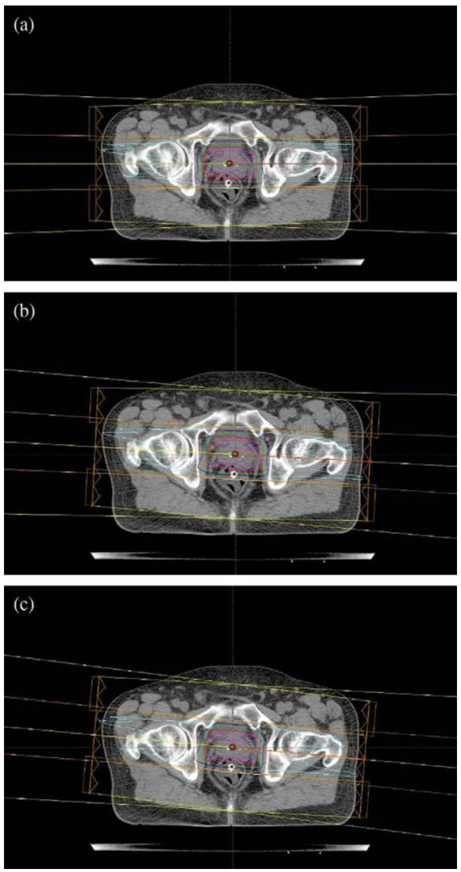


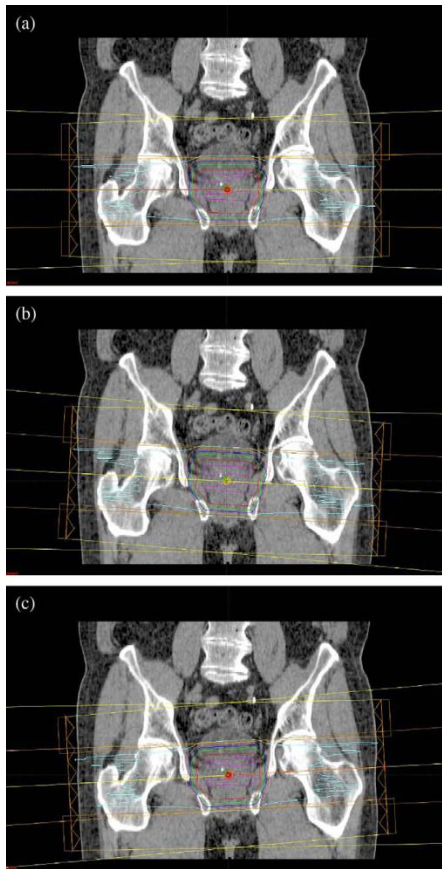
Rt Lat x-ray image

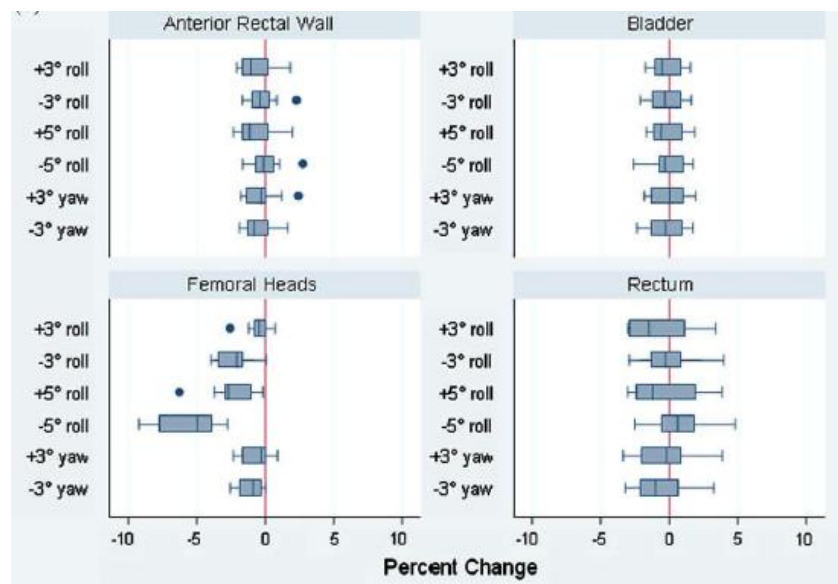
DOSIMETRIC CHANGES RESULTING FROM PATIENT ROTATIONAL SETUP ERRORS IN PROTON THERAPY PROSTATE PLANS

Samir V. Sejpal, M.D., M.P.H.,* Richard A. Amos, M.S.,* Jaques B. Bluett, M.S.,* Lawrence B. Levy, M.S.,* Rajat J. Kudchadker, Ph.D.,* Jennifer Johnson, M.S.,* Seungtaek Choi, M.D.,* and Andrew K. Lee, M.D., M.P.H.*

*Division of Radiation Oncology, University of Texas M. D. Anderson Cancer Center, Houston, TX







Int. J. Radiation Oncology Biol. Phys., Vol. 75, No. 1, pp. 40–48, 2009

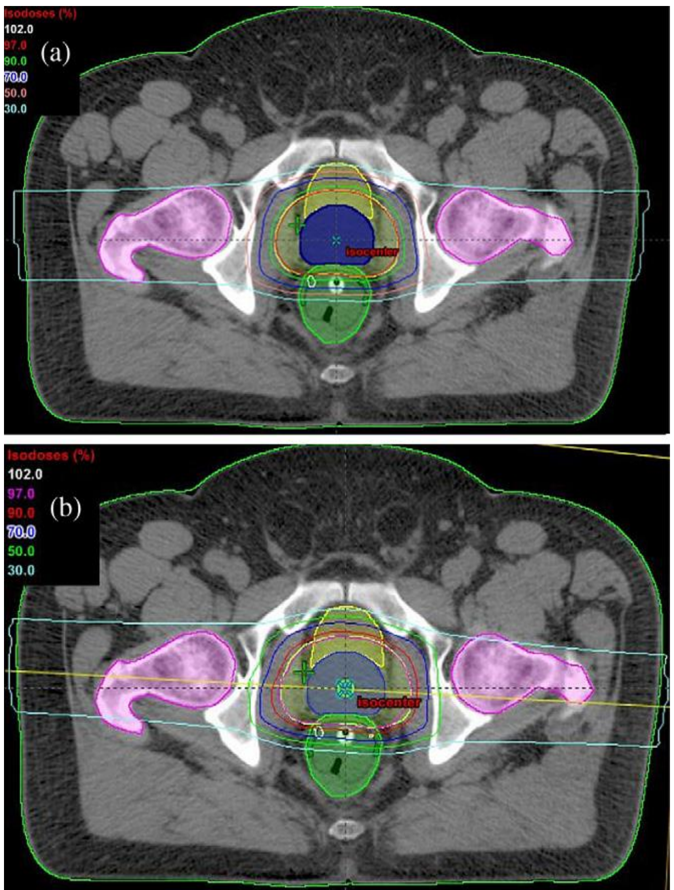
CONCLUSION

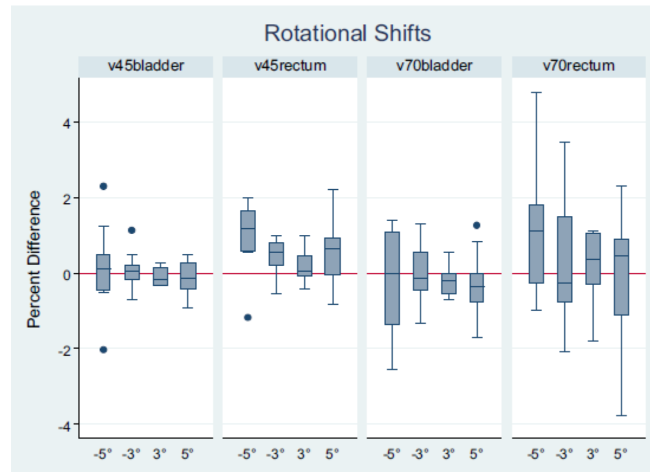
Protons are sensitive to changes in density along their path because of their physical characteristics of a finite range. Setup errors could lead to shifts in the Bragg peak, which could affect the dose delivered to target volume and adjacent structures of interest. Systematic rotational setup errors of ≤5° or horizontal couch shifts of 3° rendered clinically insignificant dose changes to the target volume and critical structures. These findings suggest that field margins such as were used in the design of these plans are sufficient to ensure target coverage in the event of rotational setup errors of ≤5°.

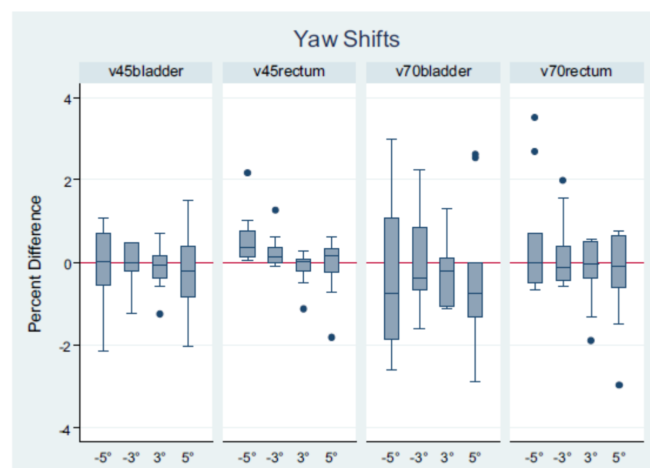
SPOT SCANNING PROTON BEAM THERAPY FOR PROSTATE CANCER: TREATMENT PLANNING TECHNIQUE AND ANALYSIS OF CONSEQUENCES OF ROTATIONAL AND TRANSLATIONAL ALIGNMENT ERRORS

JEFF MEYER, M.D.,* JAQUES BLUETT, M.S.,* RICHARD AMOS, M.S.,* LARRY LEVY, M.S.,* SEUNGTAEK CHOI, M.D.,* QUYNH-NHU NGUYEN, M.D.,* X. RON ZHU, PH.D.,* MICHAEL GILLIN, PH.D.,* AND ANDREW LEE, M.D., M.P.H.*

From the *University of Texas-M.D. Anderson Cancer Center, Houston, TX





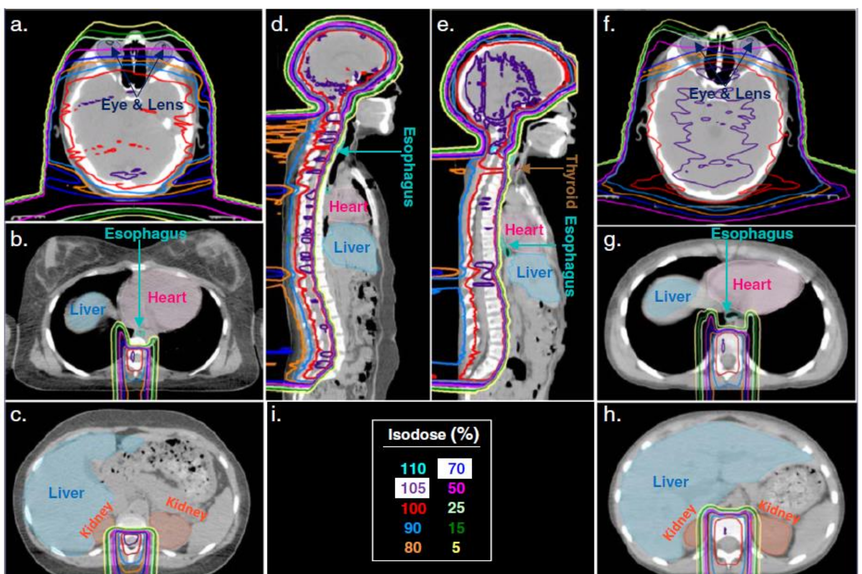


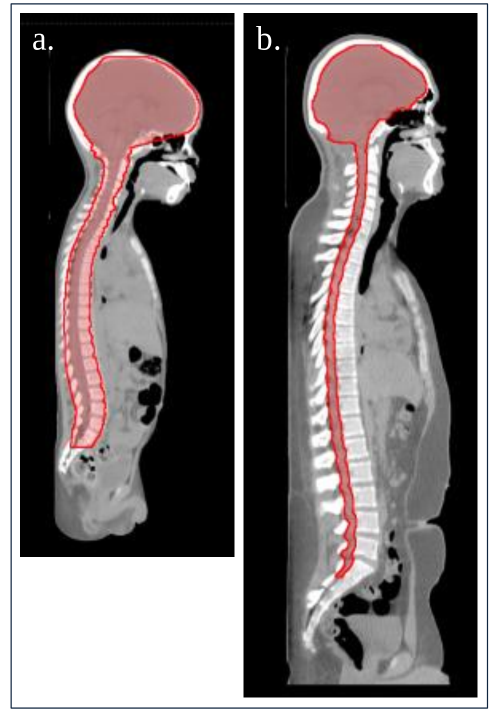
Int. J. Radiation Oncology Biol. Phys., Vol. 78, No. 2, pp. 428–434, 2010

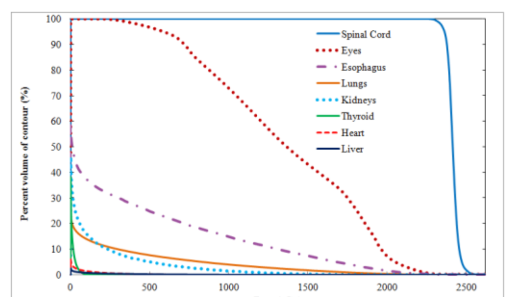
Standardized treatment planning methodology for passively scattered proton craniospinal irradiation

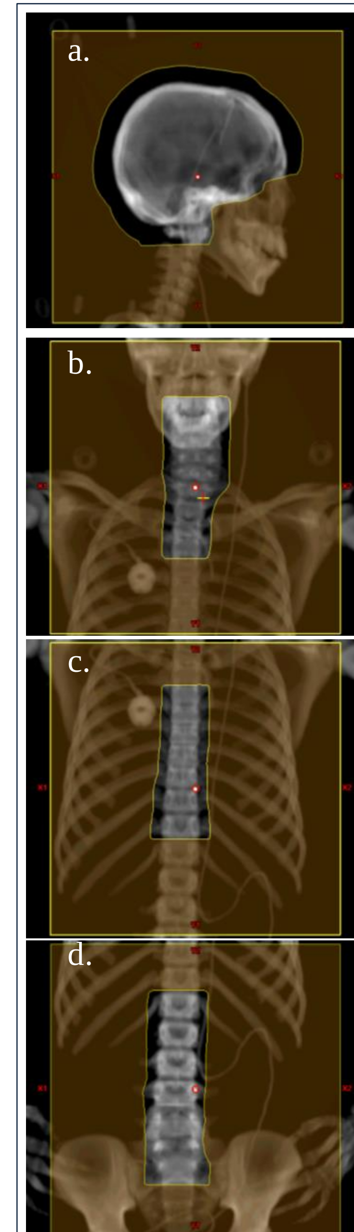
Annelise Giebeler[1,2,4], Wayne D Newhauser[1,2,5], Richard A Amos[1,2], Anita Mahajan[3], Kenneth Homann[1,2] and Rebecca M Howell[1,2*]

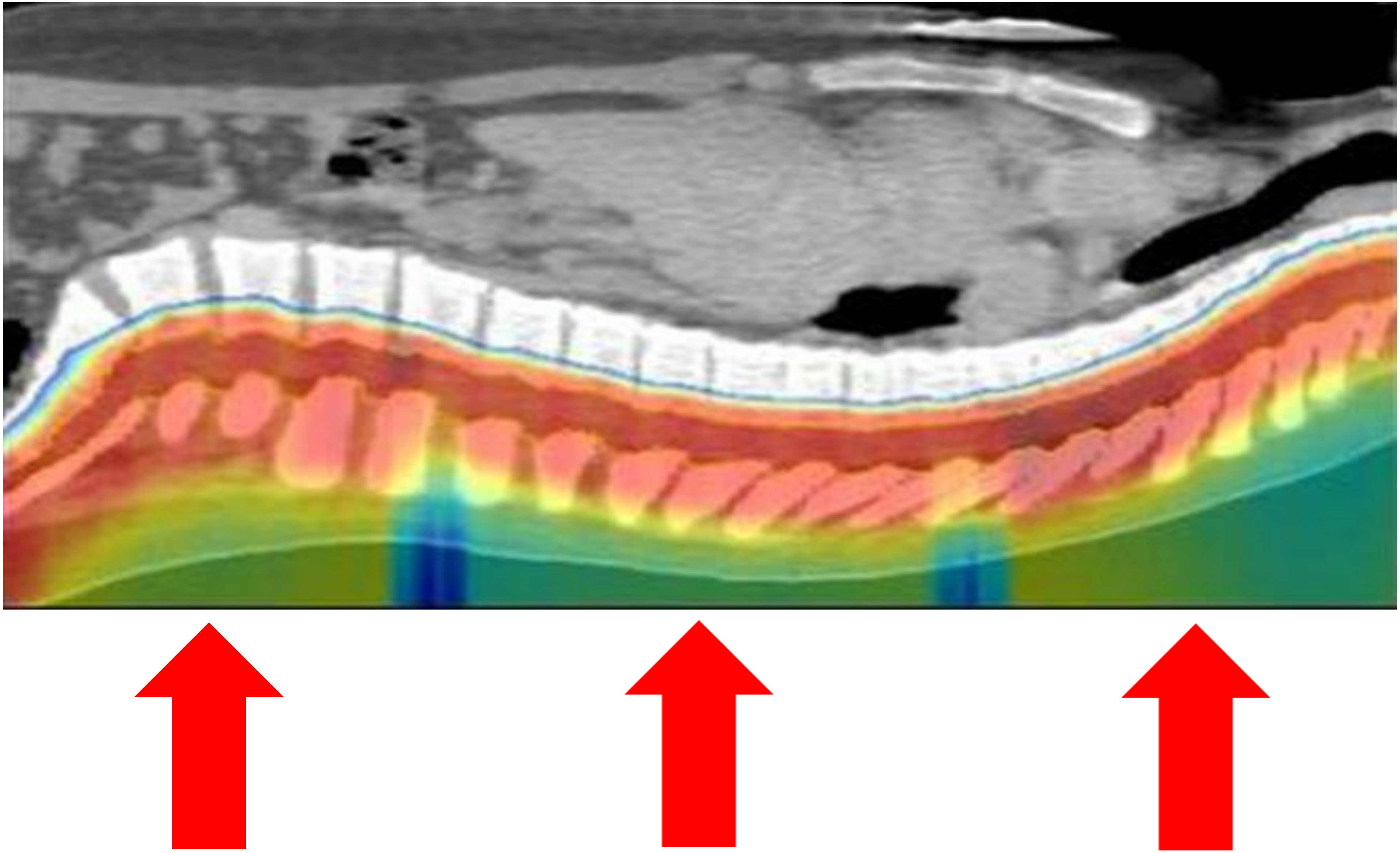
Giebeler *et al. Radiation Oncology* 2013, **8**:32
http://www.ro-journal.com/content/8/1/32









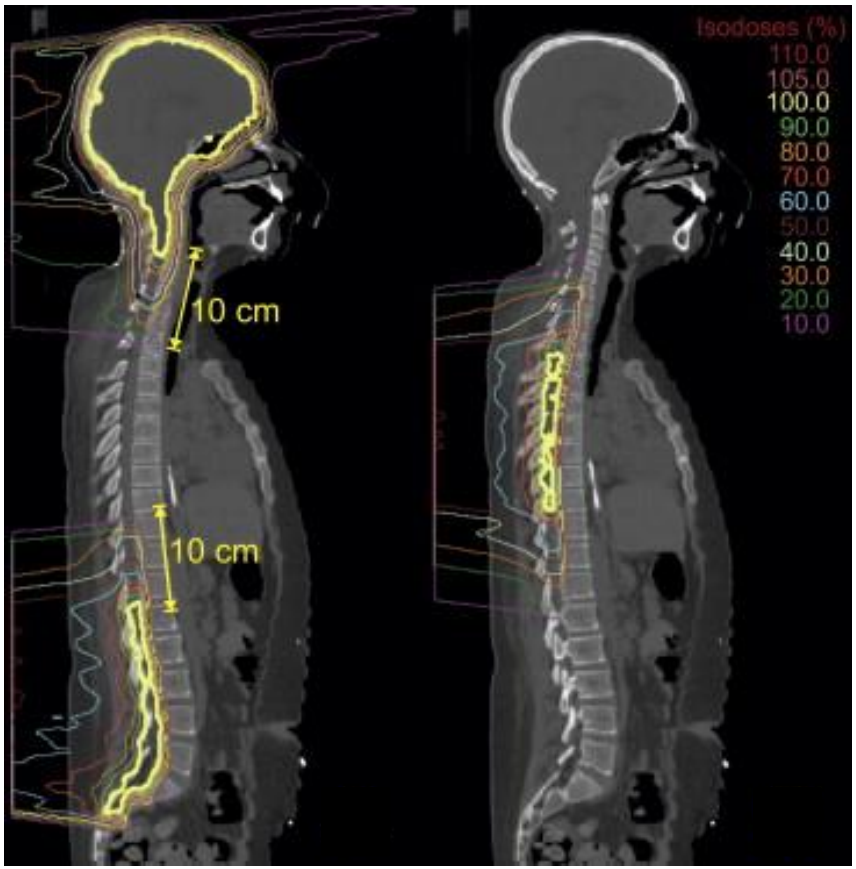


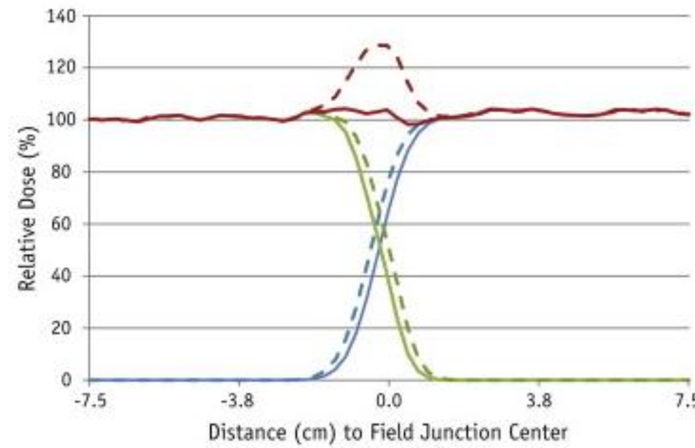
Comparison of Discrete Spot Scanning and Passive Scattering Craniospinal Proton Irradiation

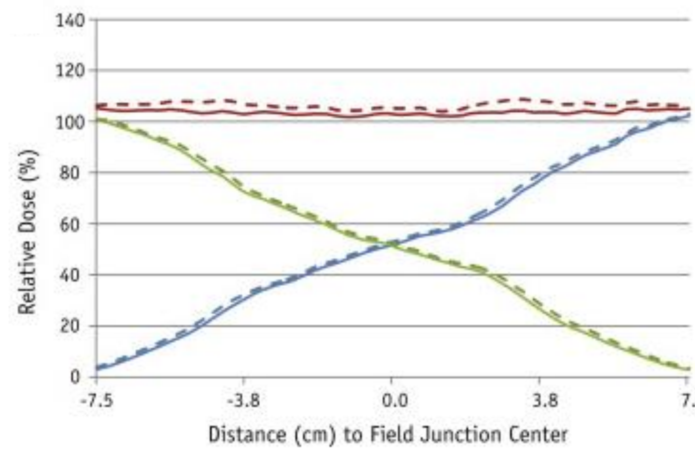
J Stoker*, R Amos, Y Li, W Liu, P Park, N Sahoo, X Zhang, X Zhu, M Gillin, MD Anderson Cancer Center, Houston, TX

Conclusion:

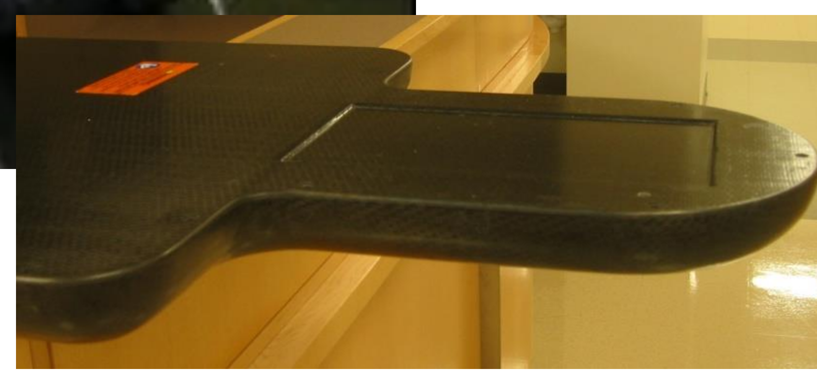
This work demonstrates the potential for improved robustness of proton craniospinal irradiations using a DSS delivery method, as well as significant decreases in clinic expenses. The use of apertures to define the sagittal plane field edge for DSS delivery improves the dose to target.







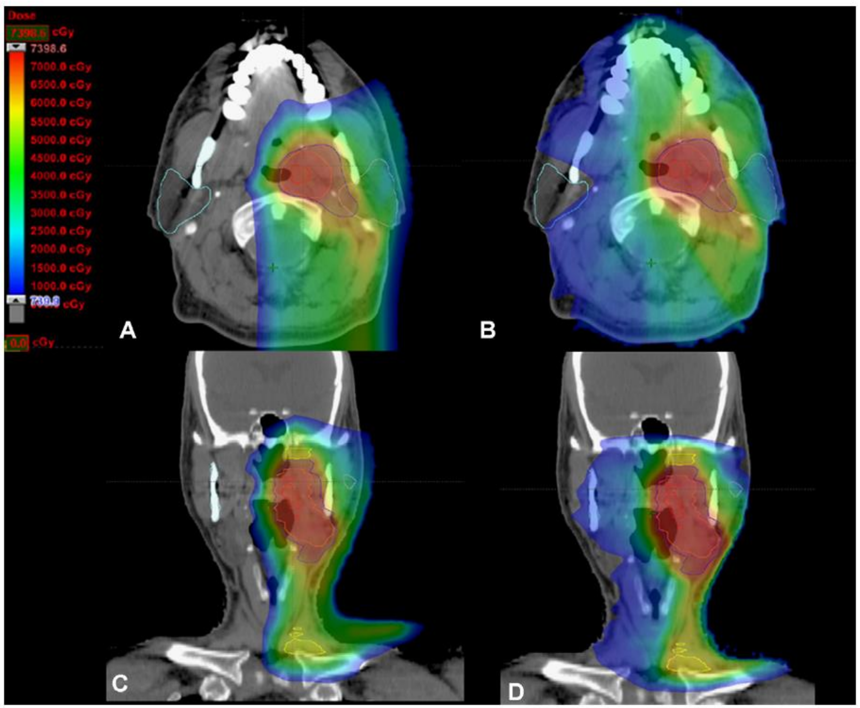
Head & Neck

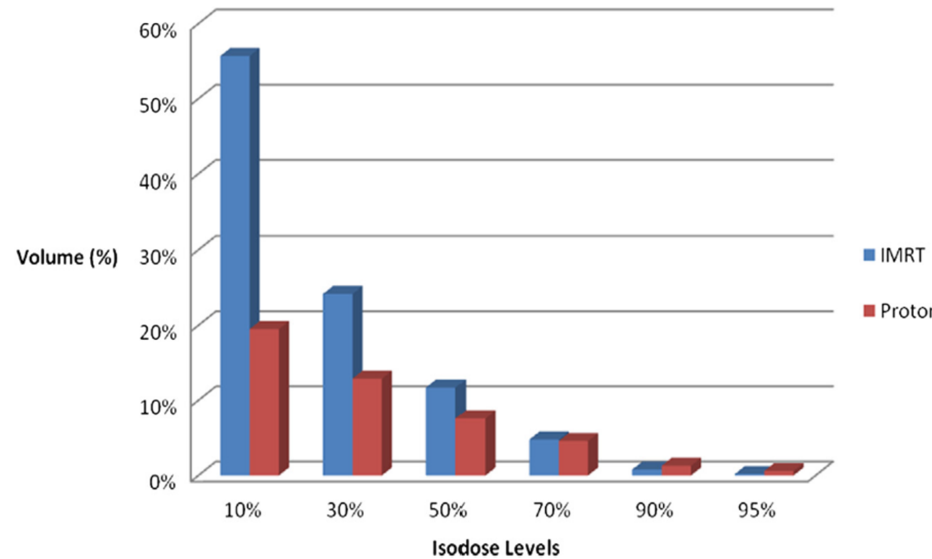


Spot-scanning beam proton therapy *vs* intensity-modulated radiation therapy for ipsilateral head and neck malignancies: A treatment planning comparison

Shravan Kandula, M.D.,* Xiaorong Zhu, Ph.D.,† Adam S. Garden, M.D.,* Michael Gillin, Ph.D.,† David I. Rosenthal, M.D.,* Kie-Kian Ang, M.D., Ph.D.,* Radhe Mohan, Ph.D.,† Mayankkumar V. Amin, C.M.D.,* John A. Garcia, C.M.D.,* Richard Wu, Ph.D.,† Narayan Sahoo, Ph.D.,† and Steven J. Frank, M.D.*

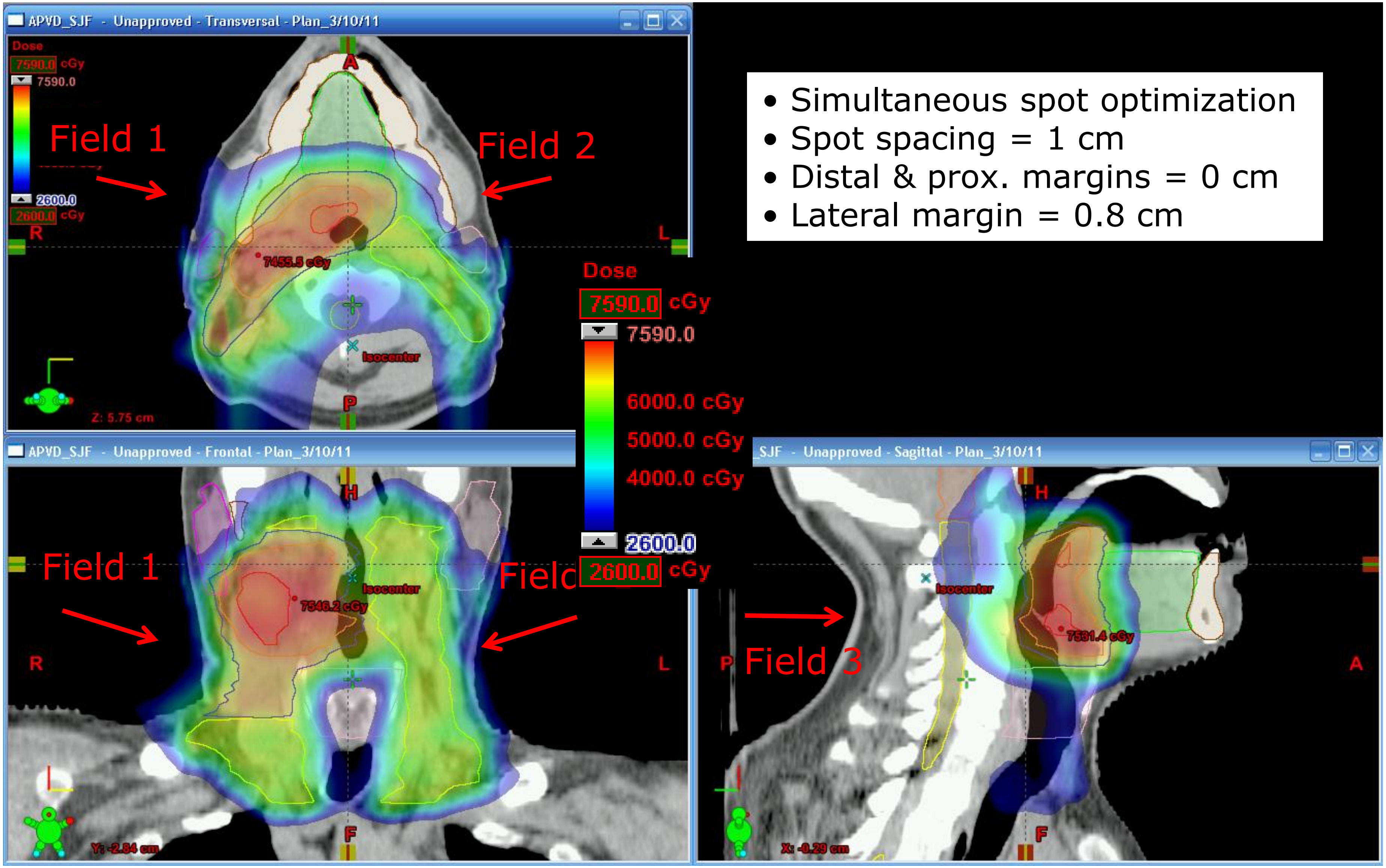
*Department of Radiation Oncology, The University of Texas MD Anderson Cancer Center, Houston, TX; and †Department of Radiation Physics, The University of Texas MD Anderson Cancer Center, Houston, TX





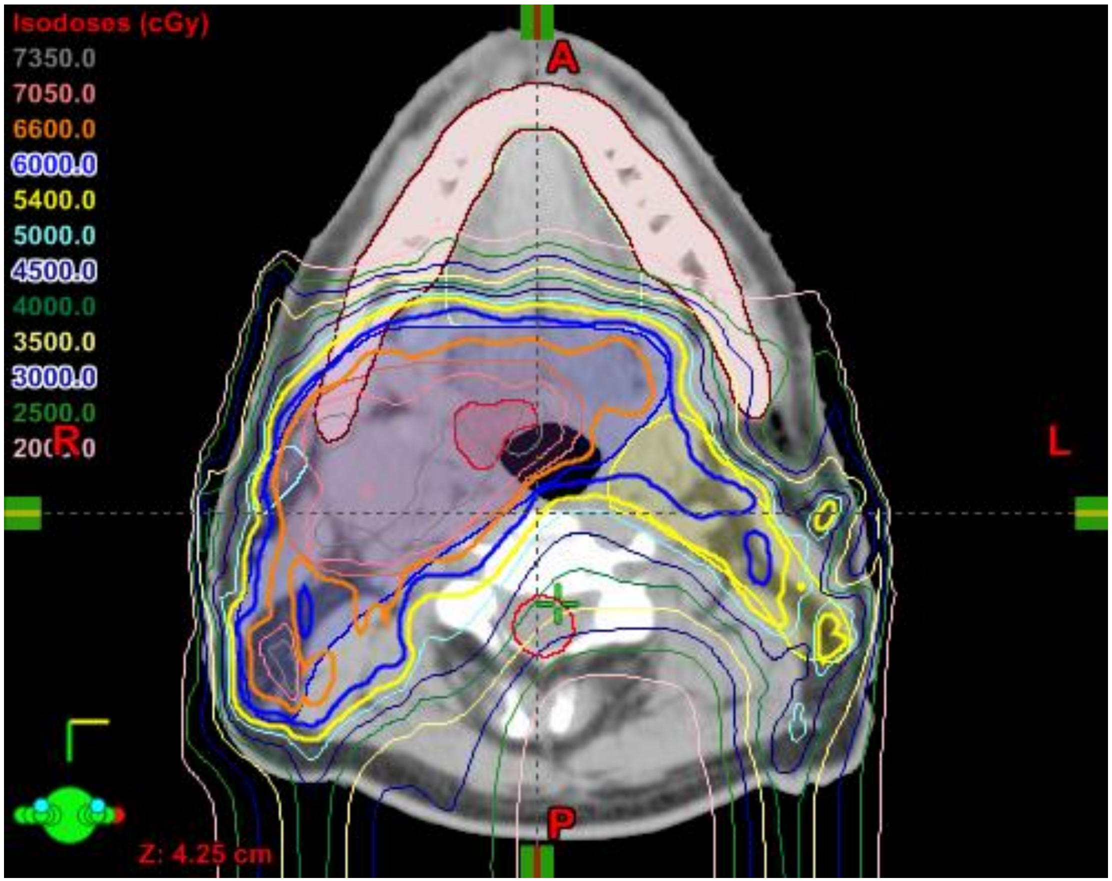
Medical Dosimetry 38 (2013) 390–394

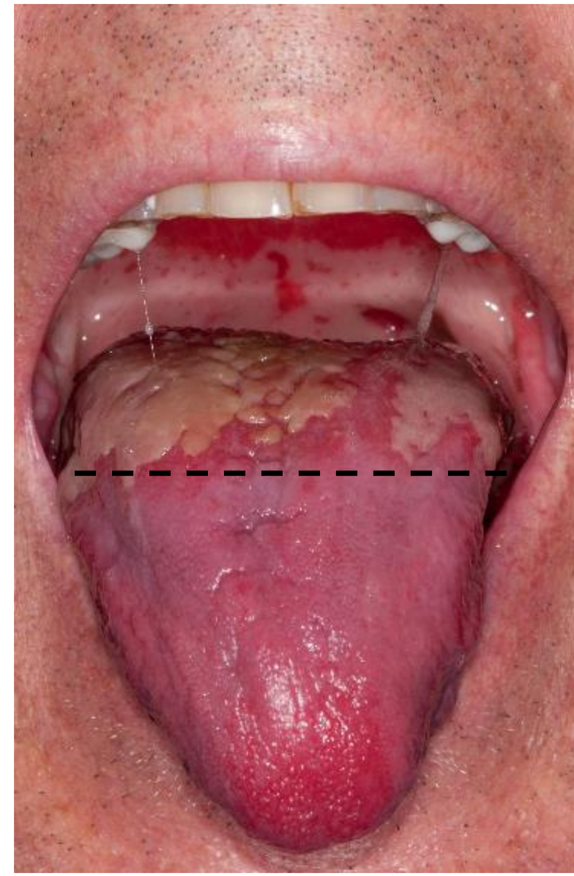
IMPT H&N - Example



- Simultaneous spot optimization
- Spot spacing = 1 cm
- Distal & prox. margins = 0 cm
- Lateral margin = 0.8 cm

Post-irradiation photography!





Cone-Beam Computed Tomography and Deformable Registration-Based “Dose of the Day” Calculations for Adaptive Proton Therapy

Catarina Veiga, MSc[1]; Jailan Alshaikhi, MSc[1,2]; Richard Amos, MSc[2]; Ana Mónica Lourenço, MSc[1,3]; Marc Modat, PhD[4]; Sebastien Ourselin, PhD[4]; Gary Royle, PhD[1]; Jamie R. McClelland, PhD[4]

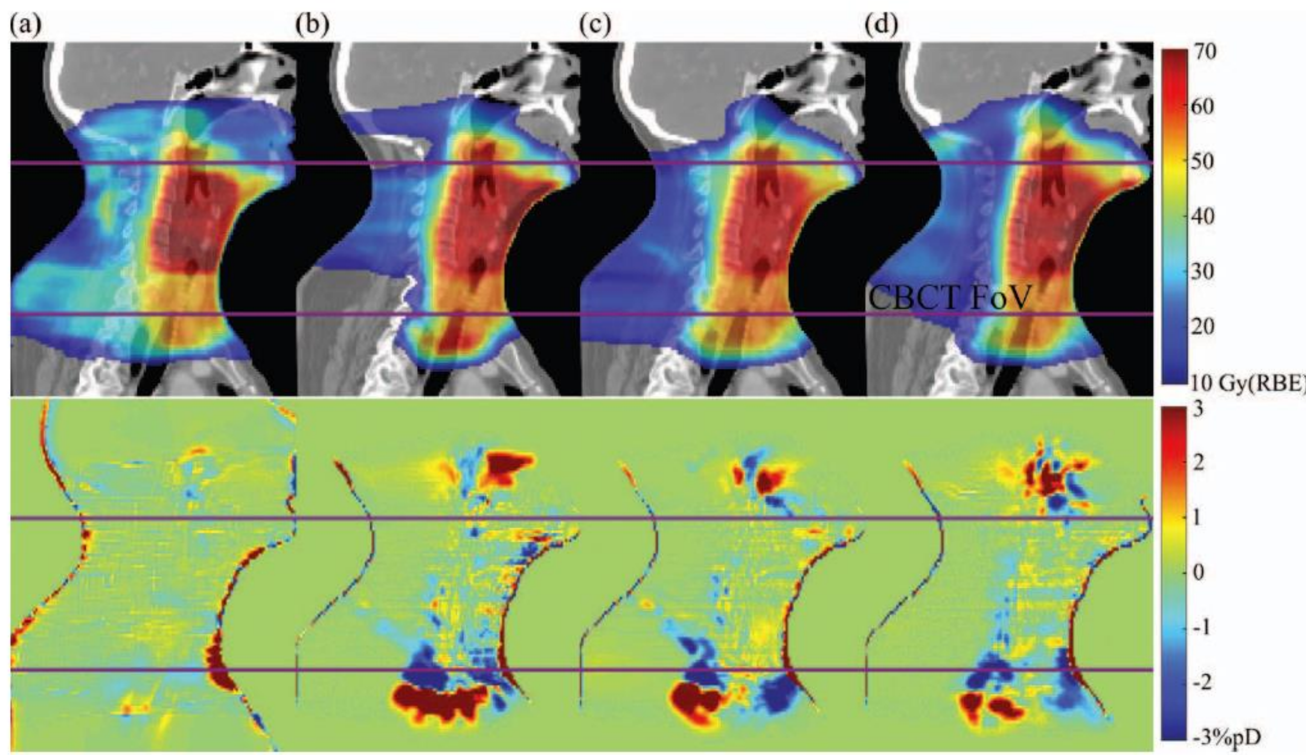
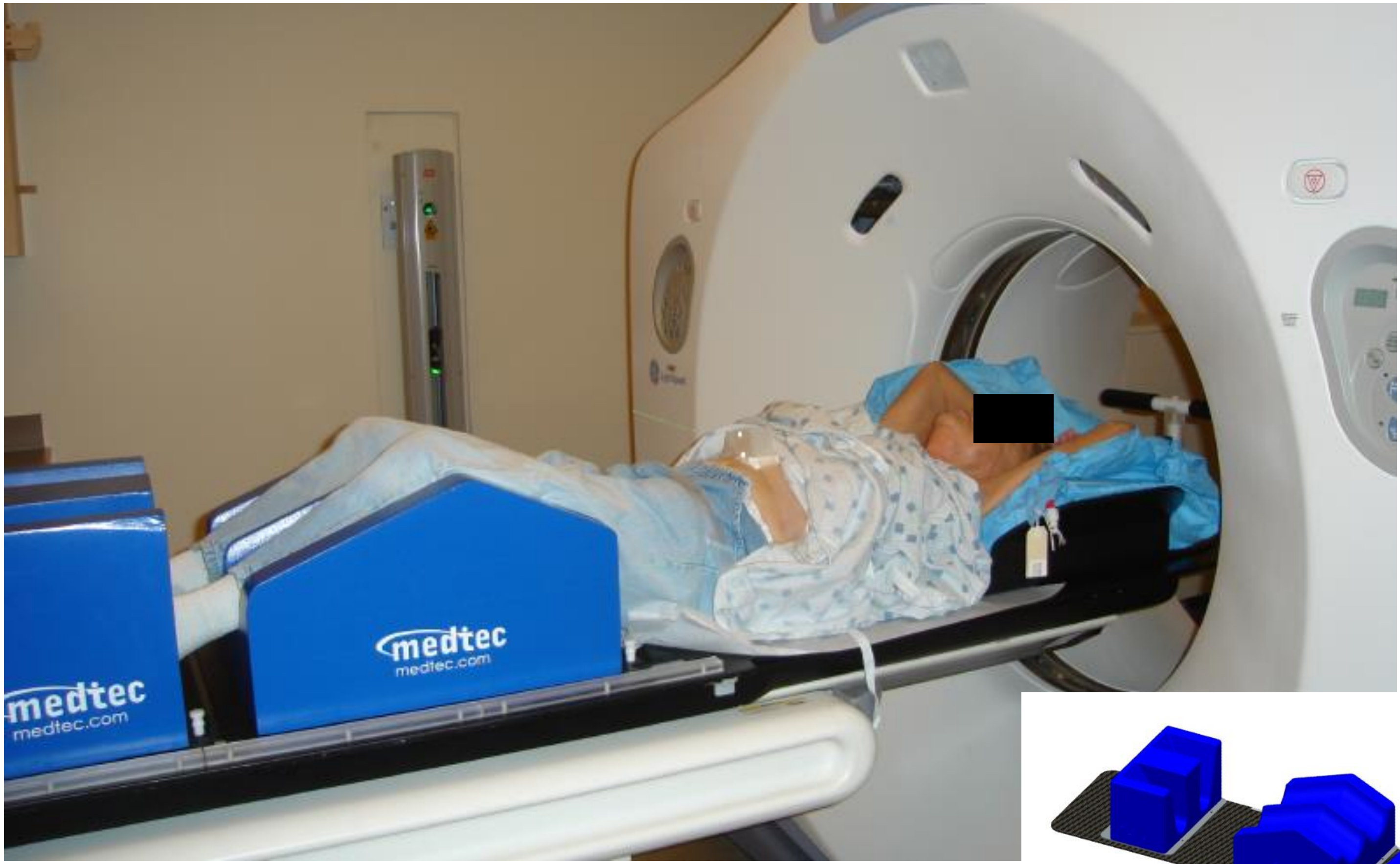
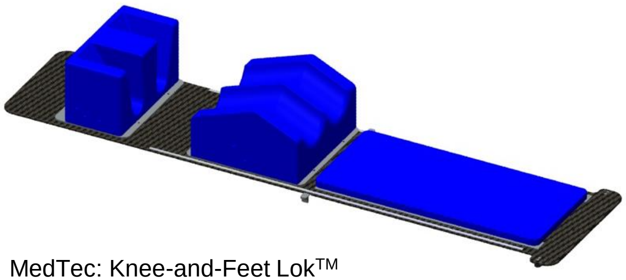


Figure 3. Dose color wash overlayed on the replan CT (top row) and difference in dose between replan CT and deformed CT (bottom row) for (A) the IMRT plan, (B) the $IMPT_{3B}$ plan, (C) the $SFUD_{3B}$ plan, and (D) the $IMPT_{5B}$ plan for one of the patients included in this study. The horizontal purple lines indicate the length of the CBCT FoV. Abbreviations: CBCT, cone-beam computed tomography; CT, computed tomography; FoV, field of view; IMPT, intensity-modulated radiation therapy; IMRT, intensity-modulated radiation therapy; SFUD, single-field uniform dose.

Thoracic

Obtain 4D-CT data

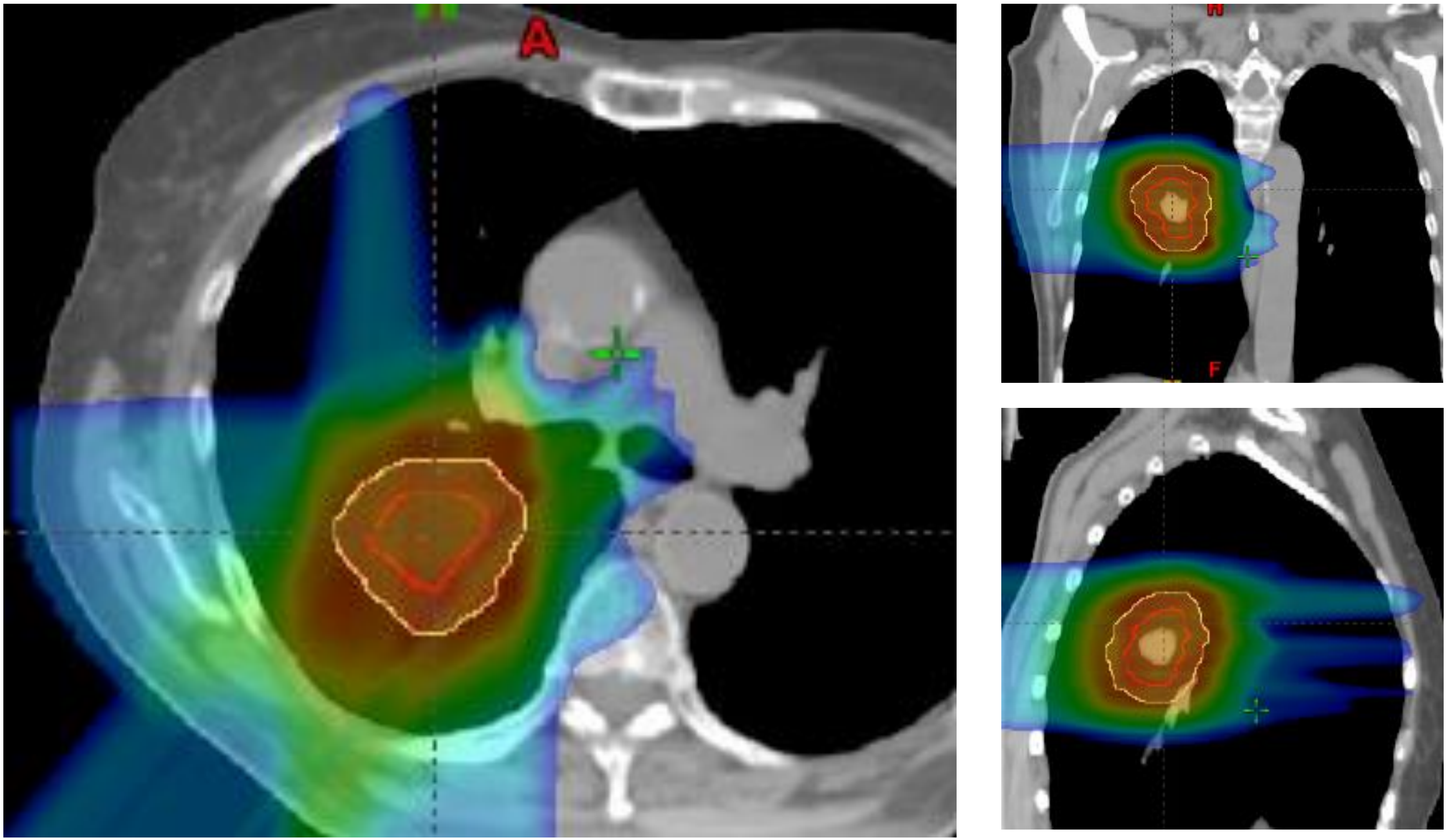




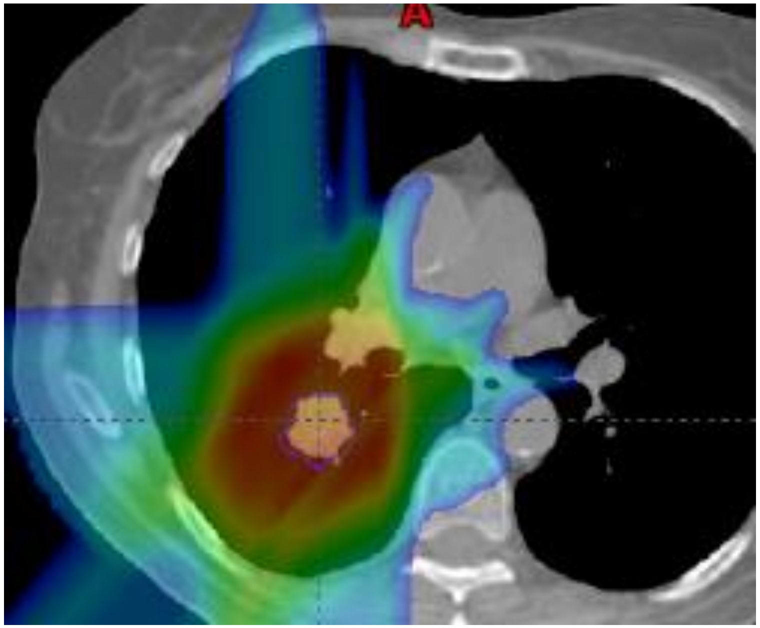
Avg, MIP, and breathing phase data sets transferred to Eclipse TPS, and all registered to the Avg. CT.

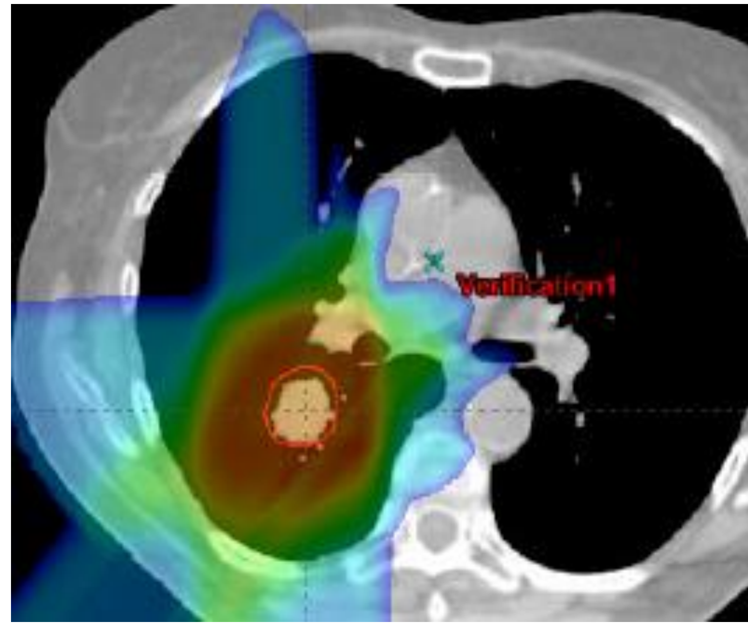
MedTec: Knee-and-Feet Lok™

Dose calculated on Avg CT



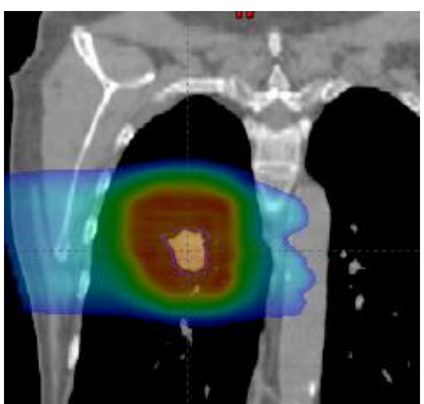
Verification plans are calculated on at least T_0 and T_{50}, using original compensator and aperture designs, to evaluate coverage in extreme phases

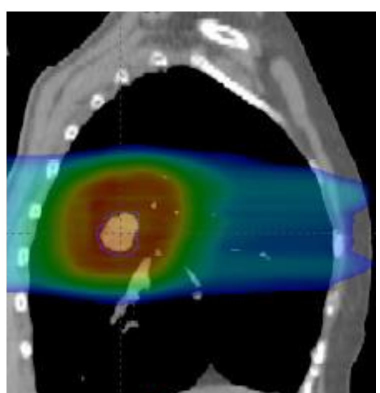


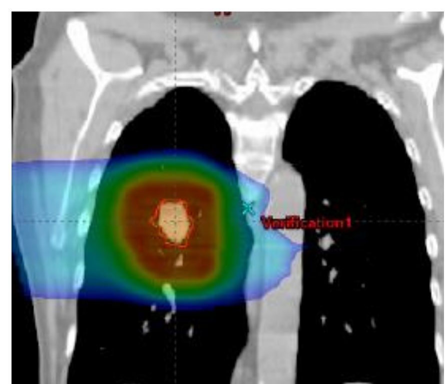


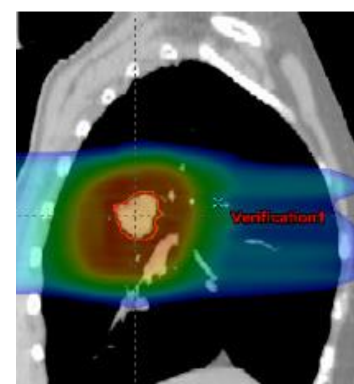
T_0 (end inspiration phase)

T_{50} (end expiration phase)









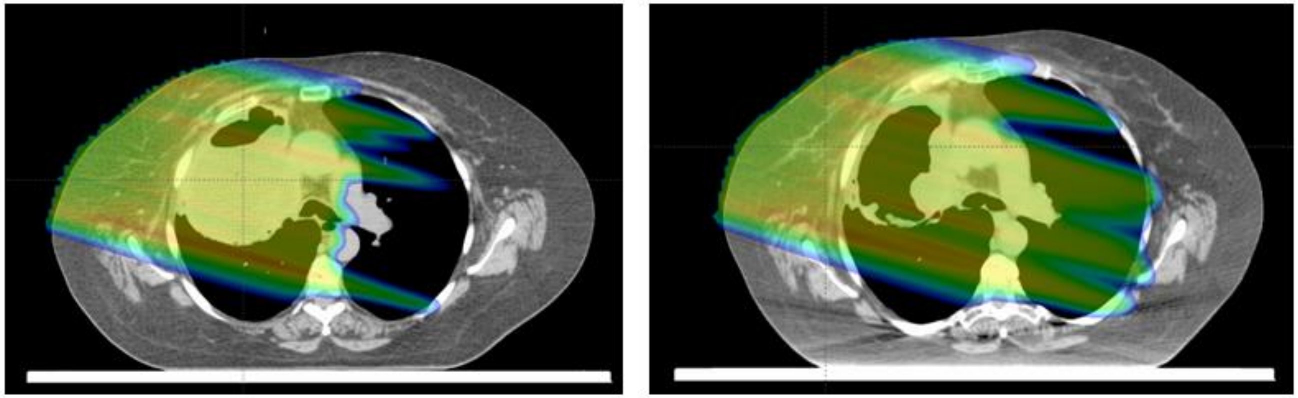


Fig.2 Comparison of dose distribution from single RAO field before and after tumor shrinkage as detected during third week of treatment. (This patient experienced the most dramatic tumor shrinkage).

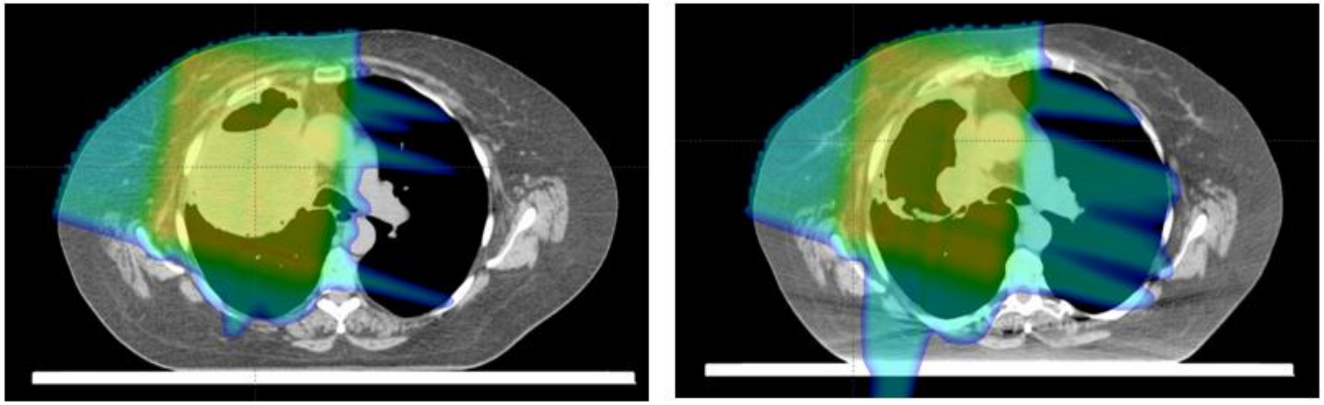


Fig.3 Comparison of total dose distribution before and after tumor shrinkage. (Same patient as Fig.2)

Amos R, *et al.* Variation in dose distribution with tumor shrinkage for proton therapy of lung cancer. Proceedings of PTCOG 46, Zibo, Shandong, China, 2007

International Journal of
Radiation Oncology
biology • physics

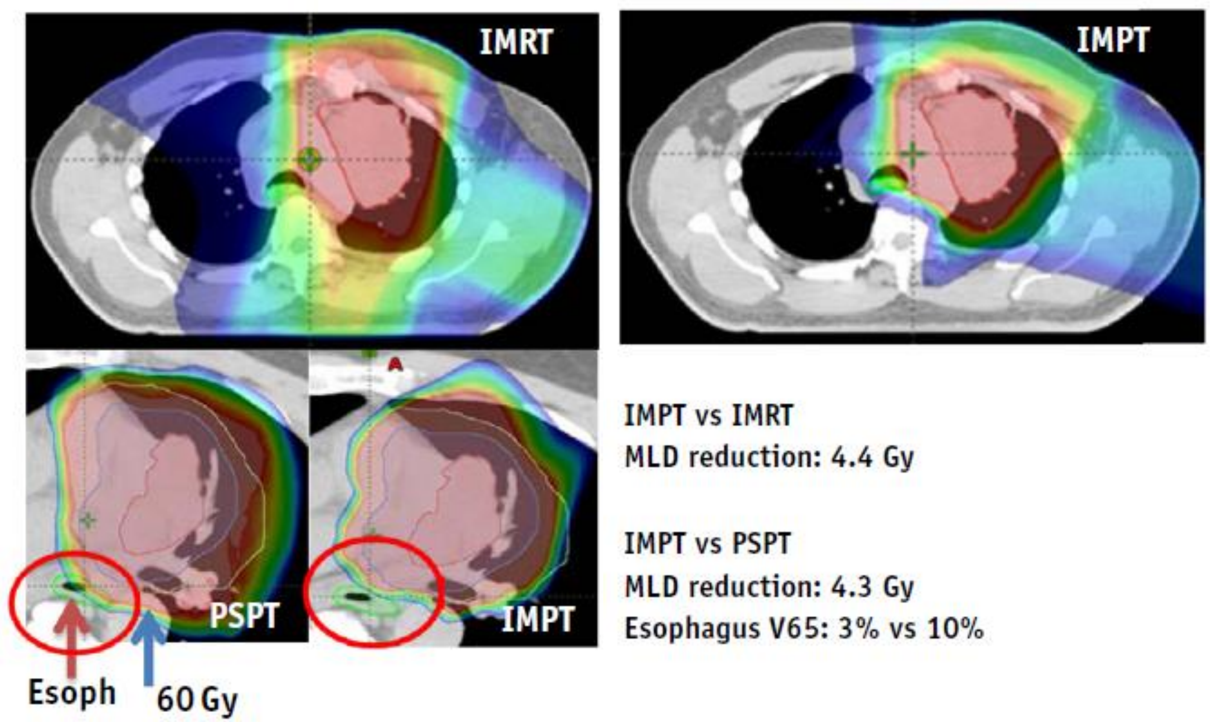
Clinical Implementation of Intensity Modulated Proton Therapy for Thoracic Malignancies

Joe Y. Chang, MD, PhD,* Heng Li, PhD,[†] X. Ronald Zhu, PhD,[†] Zhongxing Liao, MD,* Lina Zhao, MD,* Amy Liu, MS,[†] Yupeng Li, PhD,[†,‡] Narayan Sahoo, PhD,[†] Falk Poenisch, PhD,[†] Daniel R. Gomez, MD,* Richard Wu, MS,[†] Michael Gillin, PhD,[†] and Xiaodong Zhang, PhD[†]

*Department of Radiation Oncology and [†]Department of Radiation Physics, The University of Texas MD Anderson Cancer Center, Houston, Texas; and [‡]Applied Research, Varian Medical Systems, Palo Alto, California

Summary

Intensity modulated proton therapy (IMPT) can offer improved dose conformality but also has increased uncertainties, particularly when used to treat moving targets. We report here our preliminary experience with the clinical implementation of IMPT for thoracic cancer and describe clinical indications, motion analysis and management, plan optimization and robustness analysis, and quality assurance. Our data indicate that IMPT treatment for thoracic cancer with tumor motion <5 mm is safe with use of the approach developed at our institution.



The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MARCH 14, 2013 VOL. 368 NO. 11

Risk of Ischemic Heart Disease in Women after Radiotherapy for Breast Cancer

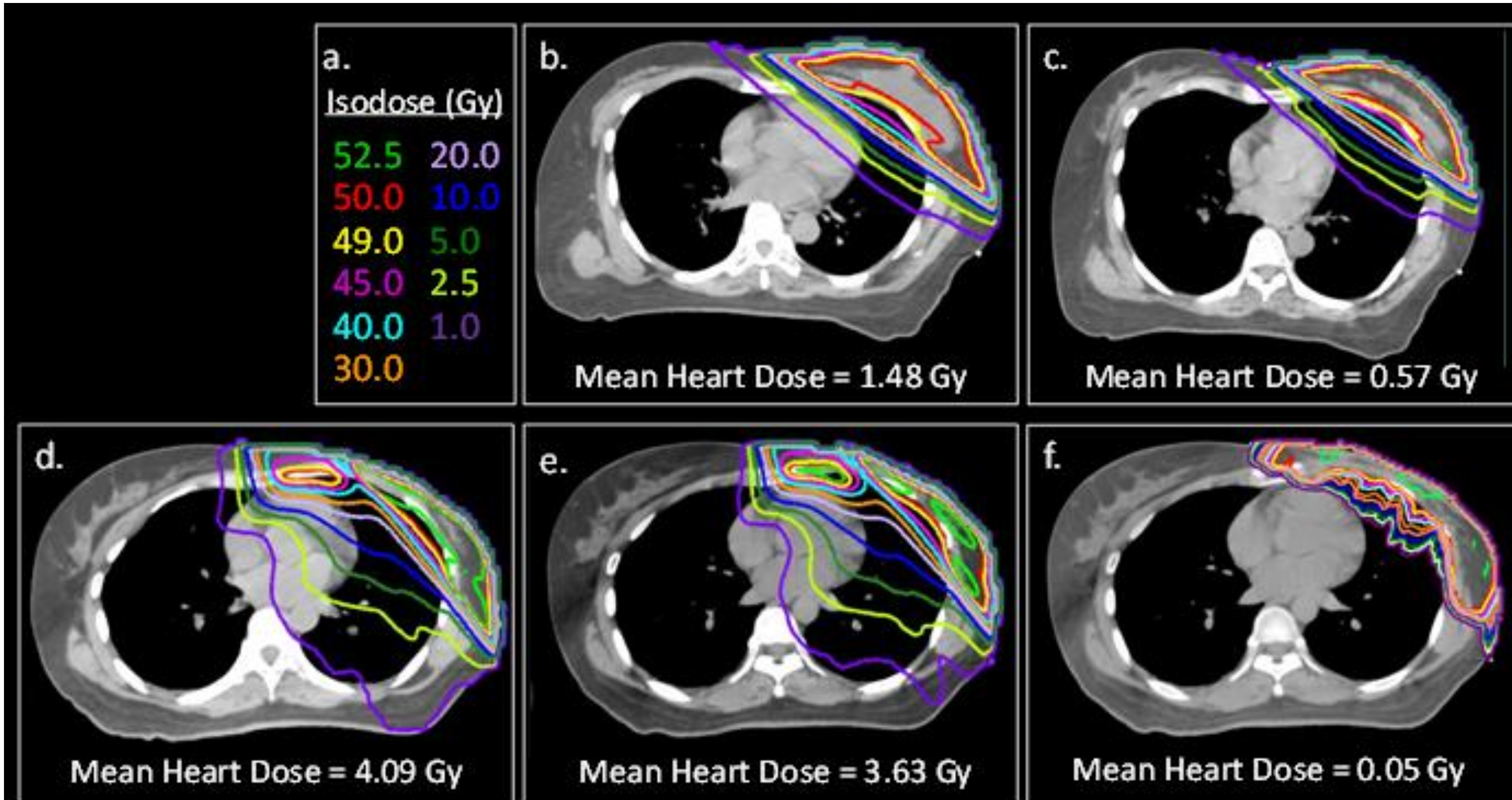
Sarah C. Darby, Ph.D., Marianne Ewertz, D.M.Sc., Paul McGale, Ph.D., Anna M. Bennet, Ph.D., Ulla Blom-Goldman, M.D., Dorthe Brønnum, R.N., Candace Correa, M.D., David Cutter, F.R.C.R., Giovanna Gagliardi, Ph.D., Bruna Gigante, Ph.D., Maj-Britt Jensen, M.Sc., Andrew Nisbet, Ph.D., Richard Peto, F.R.S., Kazem Rahimi, D.M., Carolyn Taylor, D.Phil., and Per Hall, Ph.D.

CONCLUSIONS

Exposure of the heart to ionizing radiation during radiotherapy for breast cancer increases the subsequent rate of ischemic heart disease. The increase is proportional to the mean dose to the heart, begins within a few years after exposure, and continues for at least 20 years. Women with preexisting cardiac risk factors have greater absolute increases in risk from radiotherapy than other women. (Funded by Cancer Research UK and others.)

Howell R, **Amos R**, Kanke J, *et al.*
Predicted risk of cardiac effects with modern cardiac-sparing radiation therapy techniques

Proceedings of PTCOG 53. *Int J Particle Ther*. 2014;**1**(2):617-618

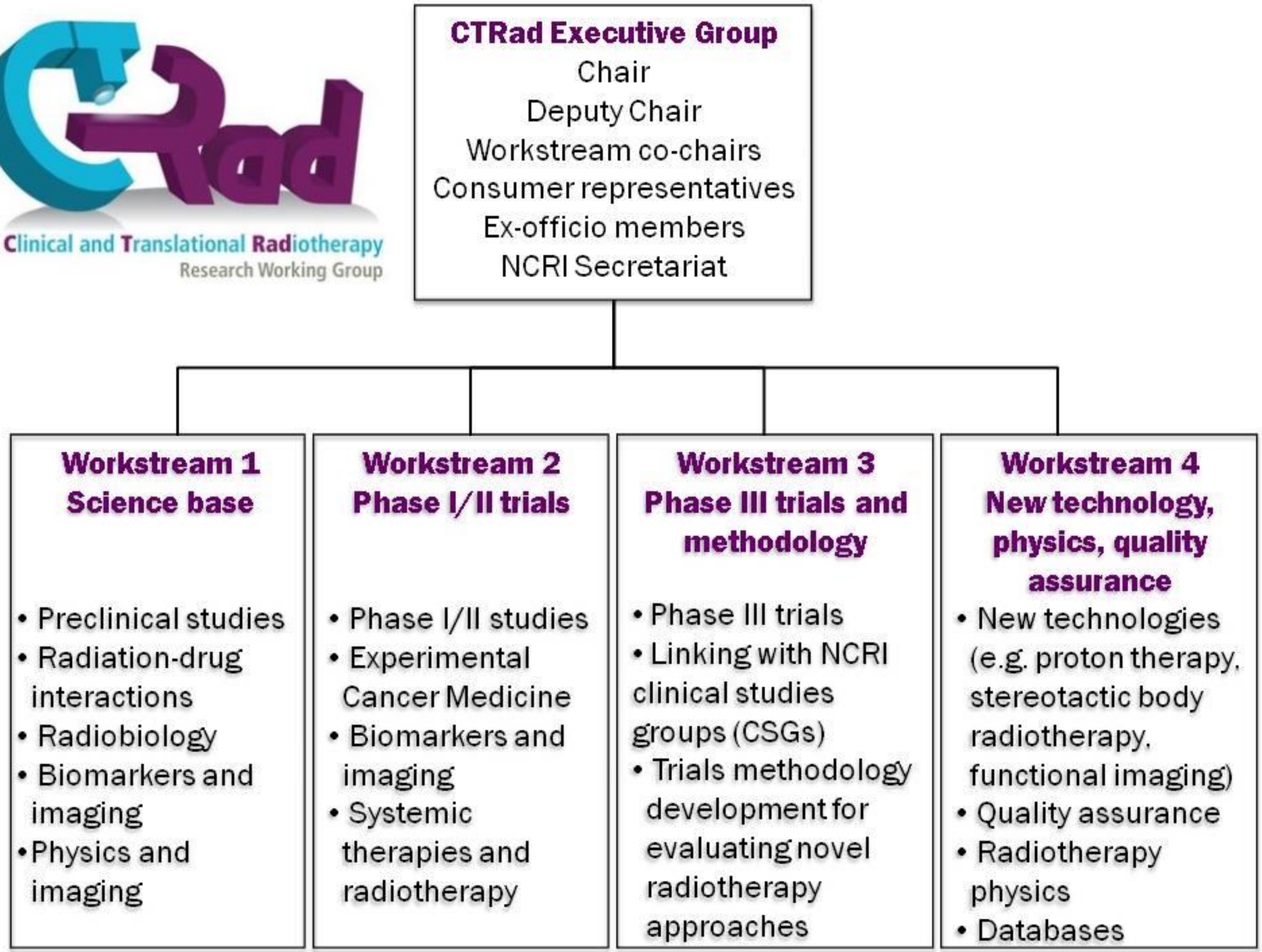


g.

EBRT left breast (1/2013-2/2013)	n	% DIBH	HD (Gy)	RR	RRR
All	58	83 %	2.33 (2.15)	1.17 (0.16)	0.8 (0.14)
Tangents€	28	83 %	0.65 (0.31)	1.05 (0.02)	0.73 (0.15)
Comprehensive£	30	82 %	3.91 (1.93)	1.29 (0.14)	0.87 (0.10)

NCRI
National
Cancer
Research
Institute

CTRad
Clinical and Translational Radiotherapy
Research Working Group



Proton Physics Research & Implementation Group

http://www.pprig.co.uk/pprig/

National Physical Laboratory
http://www.npl.co.uk

The Clatterbridge Cancer Centre
http://www.clatterbridgecc.org.uk/

University College London Hospitals
http://www.uclh.nhs.uk

University Hospitals Birmingham
http://www.uhb.nhs.uk/

The Christie NHS Foundation Trust

The St James's Institute of Oncology
http://www.leedsth.nhs.uk/patients-and-visitors/our-hospitals/st-james-university-hospital

University College London
http://www.ucl.ac.uk/

University of Surrey
http://www.surrey.ac.uk/

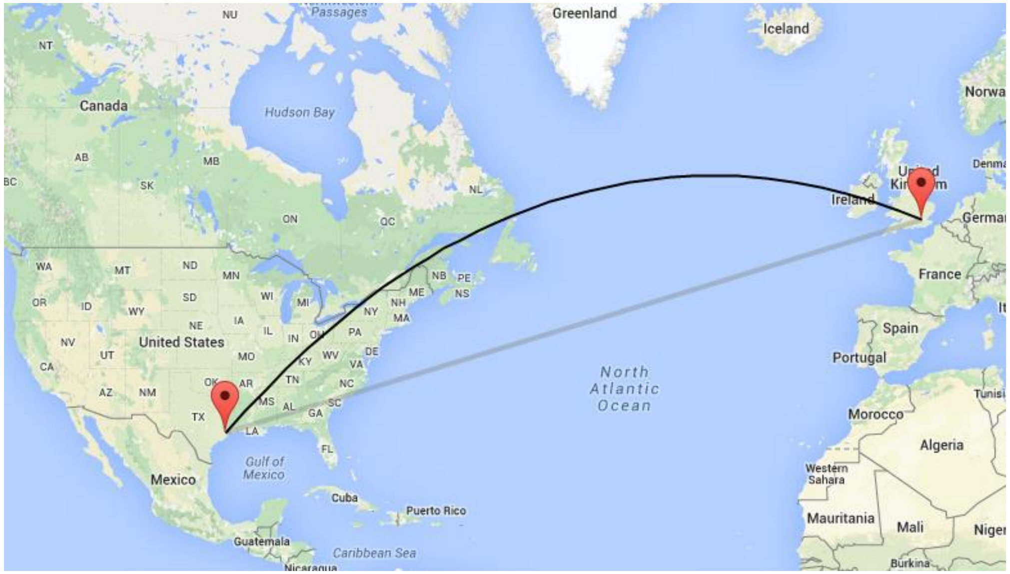
The University of Manchester
http://www.manchester.ac.uk/

University of Oxford
http://www.ox.ac.uk/

PRT
Proton and Advanced Radiotherapy

UCL Proton Therapy Research Group

5,000 mile commute!



Higgs

Boson


Thank you!