AAPM Annual Meeting 2016
Invited Review

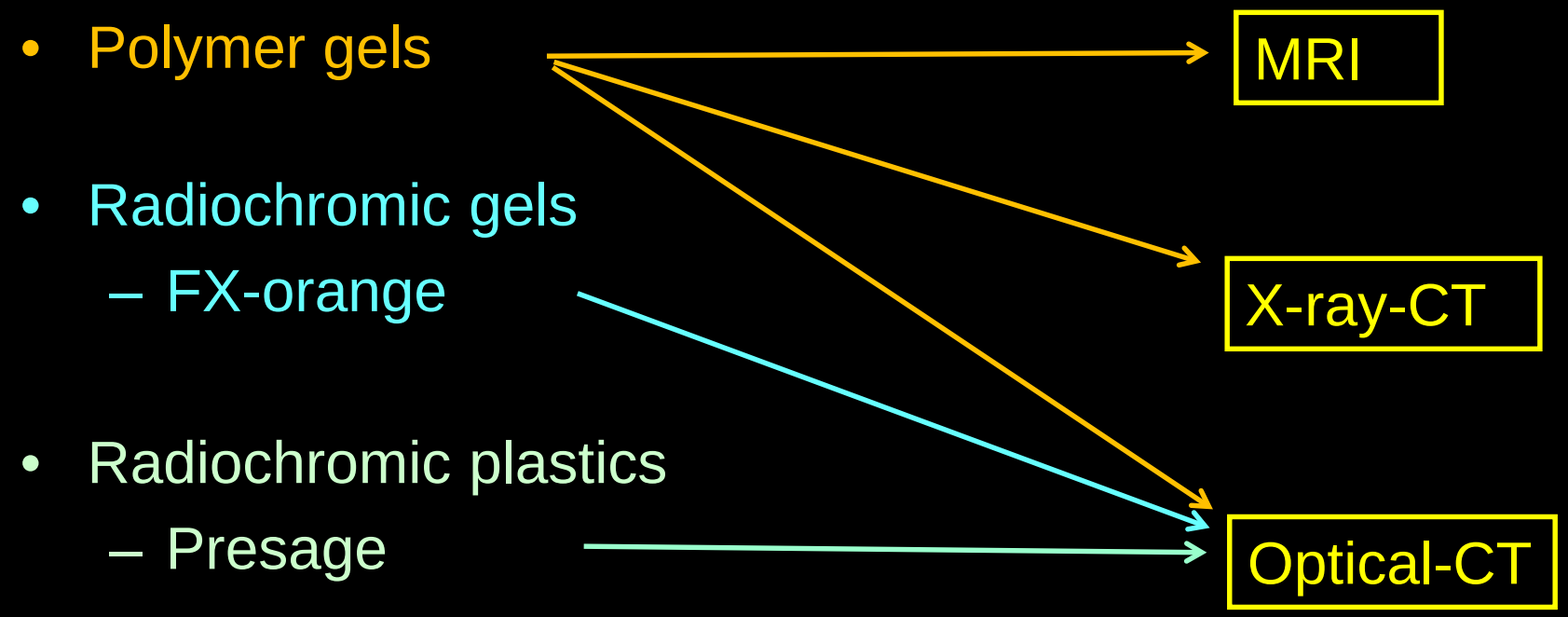
Methods and Applications of 3D Radiochromic Dosimetry

No Financial Disclosures

Mark Oldham PhD,
Professor, Radiation Oncology,
Associate Professor, Biomedical Engineering,
Duke University Medical Center, Durham NC

3D dosimetry systems ?

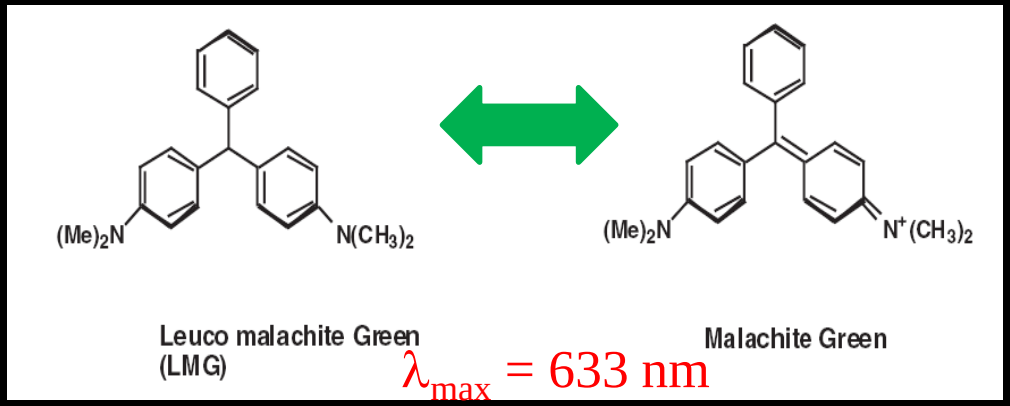
Material	Read-out

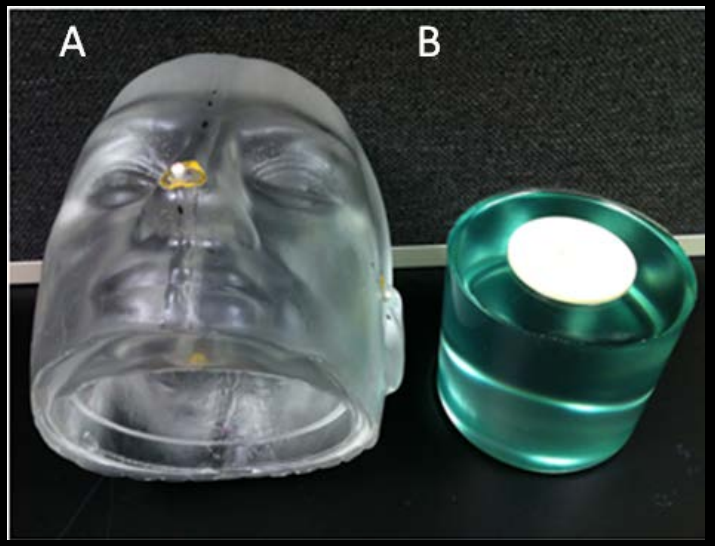


Liquid/solid scintillators
Transit dosimetry - EPIDS
Semi-3D systems - diode arrays

Radiochromic Plastic: Presage

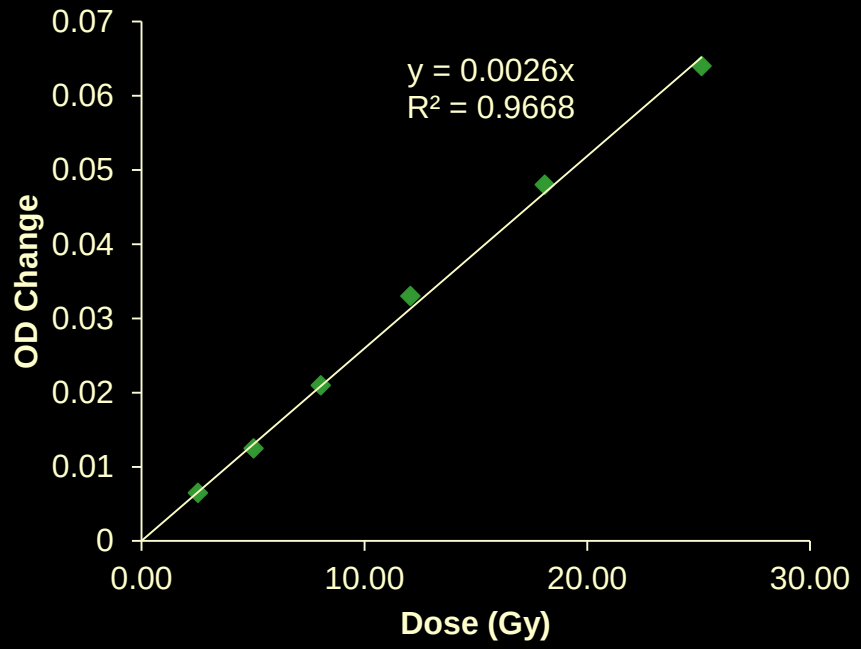
- Contrast: light absorption
- Good dosimetry properties
- Flexible

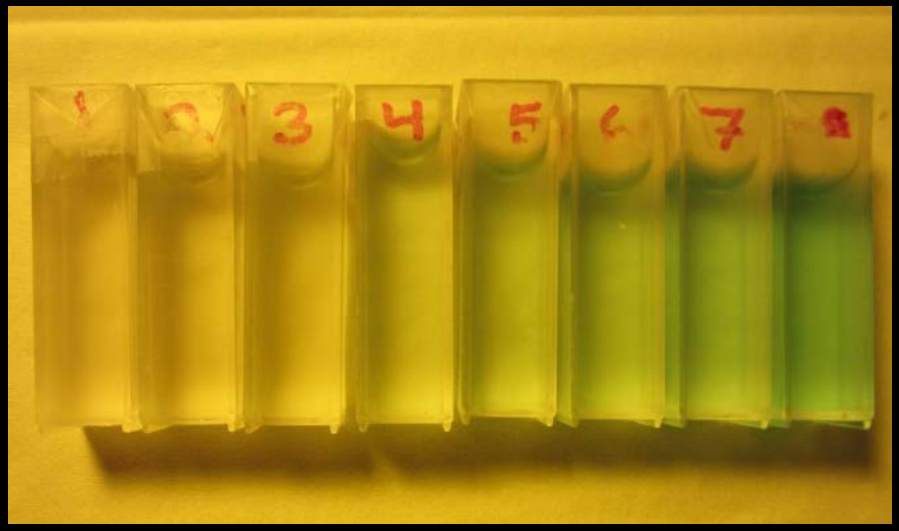




PRESAGE (Heuris Inc)

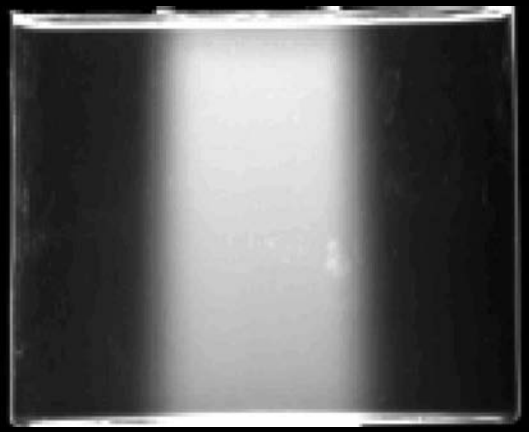
– OD proportional to dose

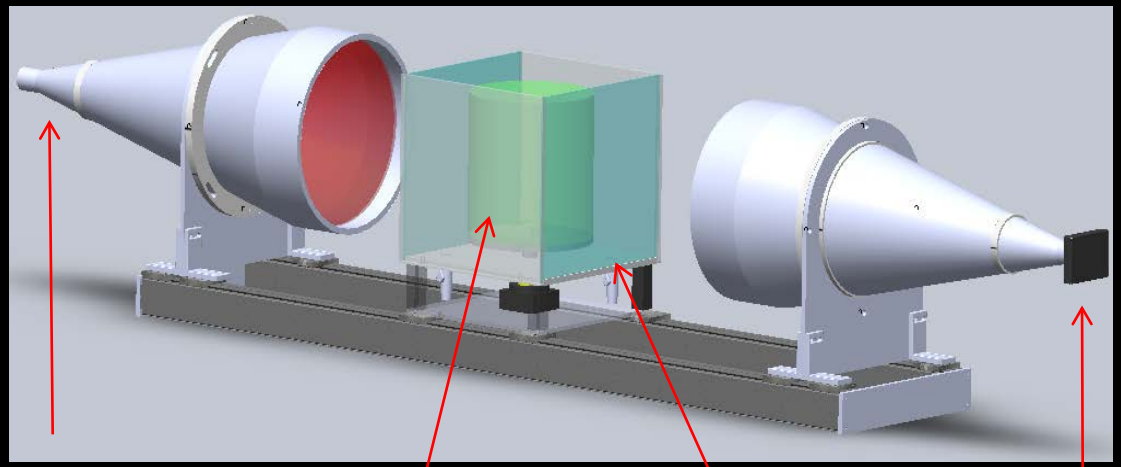


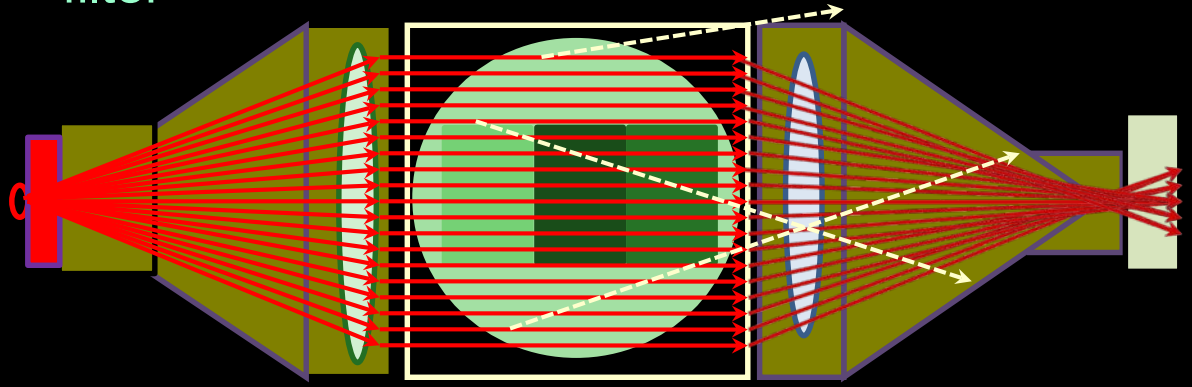


DLOS : Duke Large Field-of-View Optical-CT Scanner

Design Specifications		
FOV	240	mm
esolution	2 - 0.2	mm
Time	10 - 30	mins







Thomas et al. Med Phys, 2011

Key developmental milestones

Commissioning and benchmarking a 3D dosimetry system for clinical use

Andrew Thomas and Joseph Newton
Duke University Medical Center, Durham, North Carolina 27710

John Adamovics
Rider University, Lawrenceville, New Jersey 08648

Mark Oldham[a)]
Duke University Medical Center, Durham, North Carolina 27710

Med. Phys. 38 (8), August 2011

A method to correct for stray light in telecentric optical-CT imaging of radiochromic dosimeters

Andrew Thomas, Joseph Newton and Mark Oldham[1]

Duke University Medical Center, Durham, NC, USA

Phys. Med. Biol. **56** (2011) 4433–4451

A method to correct for spectral artifacts in optical-CT dosimetry

Andrew Thomas[1,4], Michael Pierquet[1], Kevin Jordan[2,3] and Mark Oldham[1]

Phys. Med. Biol. **56** (2011) 3403–3416

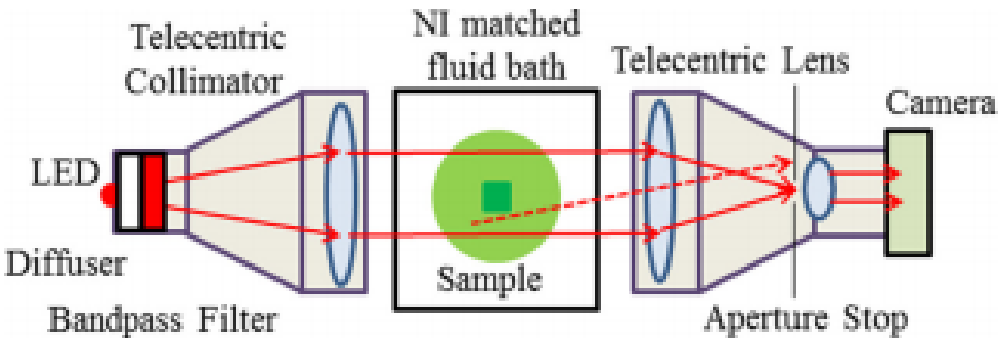
A Quality Assurance Method that Utilizes 3D Dosimetry and Facilitates Clinical Interpretation

Mark Oldham, Ph.D.,* Andrew Thomas, Ph.D.,* Jennifer O'Daniel, Ph.D.,* Titania Juang, B.Sc.,* Geoffrey Ibbott, Ph.D.,† John Adamovics, Ph.D.,‡ and John P. Kirkpatrick, M.D.*

International Journal of Radiation Oncology biology • physics

Aug 2012

3D Dosimeter read-out by optical-CT



DMOS-RPC Recon GUI

Duke 3D Dosimetry Lab, March 2011
Contact mark.oldham@duke.edu

Pre Scan

Load Images

Stray Light Correction
Dynamic Range

Show Dark
Show Flood
Pull Image
Window
Pixel Probe
Line Profile

2_Pre_0001-0001.raw

Post Scan

Load Images

Dynamic Range Images

Show Dark
Show Flood
Pull Image
Window
Pixel Probe
Line Profile

Post_2_0001-0001.raw

Sinogram

Generate

Division

Pull Image
Window
Pixel Probe
Line Profile

Reconstruction

Reconstruct
Load Data Cube
Save

Pull Image
Window
Pixel Probe
Line Profile
Calibrate
Median Filter
Export Cube
Import to CERR

Reconstructed Slice # - 56

Duke Collaborations

Brachytherapy	O Craciunescu, J Chino
4D SBRT	F Yin, J Wu
Radiosurgery	Z Wang J Chang,
Gating.	S Yoo, A Thomas
IMRT, VMAT …	J O'Daniel J Kirkpatrick,
Deformation	S Das

External Collaborations

Credentialing and clinical trials.	Geoff Ibbott, MDACC
Protons	Indra Das Indiana Univ
Neutrons	Anuj Kapadia
Anthropomorphic re-useable	John Adamovics.
deforming dosimeters	(Heuris)

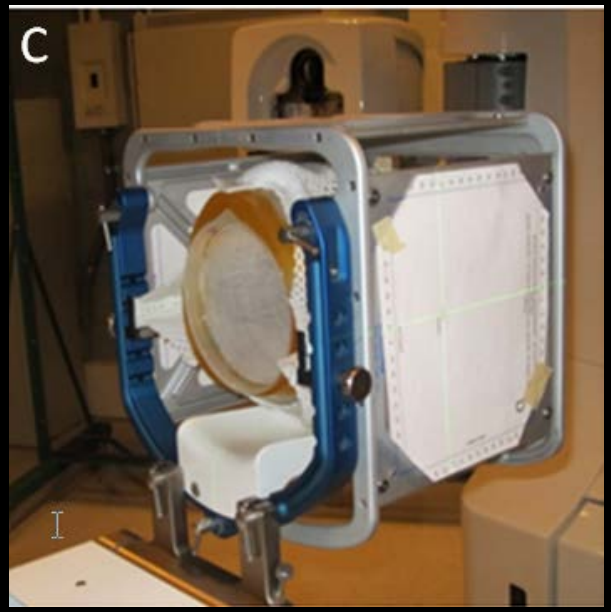
Accuracy of Multifocal single isocenter SRS Treatment ?

5 PTV targets

15 Gy central, 20-24 Gy outer

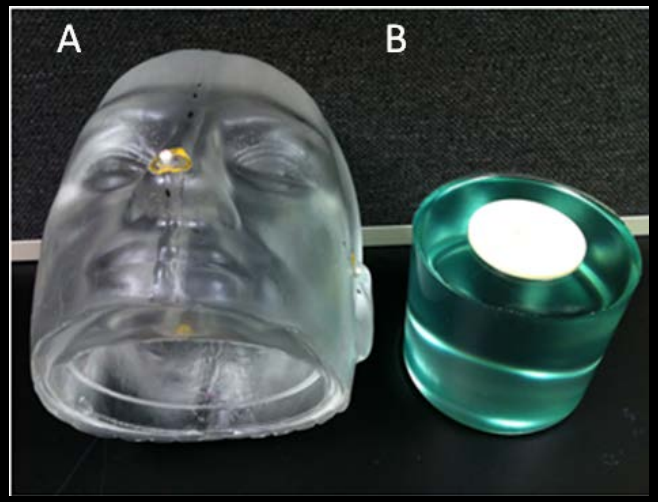
iplan and Eclipse

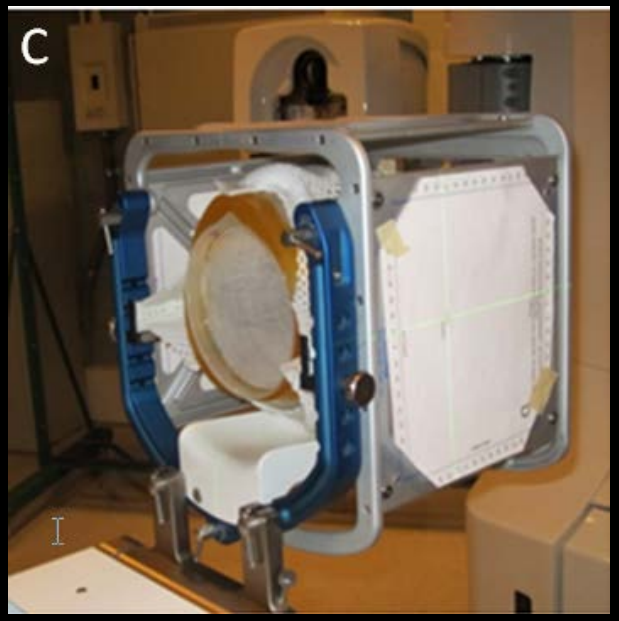
CBCT set-up



Objectives

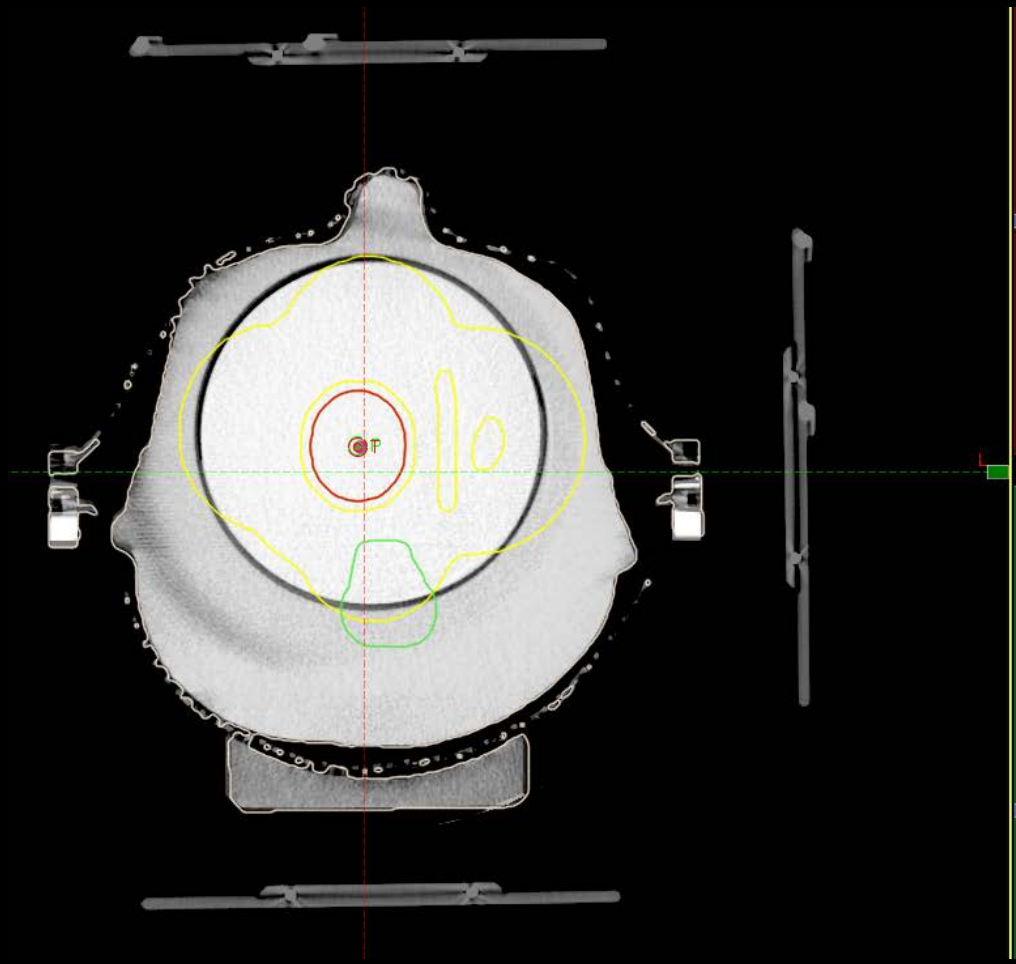
- Evaluate accuracy and reproducibility
  - Novalis Tx delivery
    - 2D kV and CBCT IGRT set-up
- Method/strategy
  - 4 independent deliveries
  - 4 Presage dosimeters
  - Ion-chamber normalised

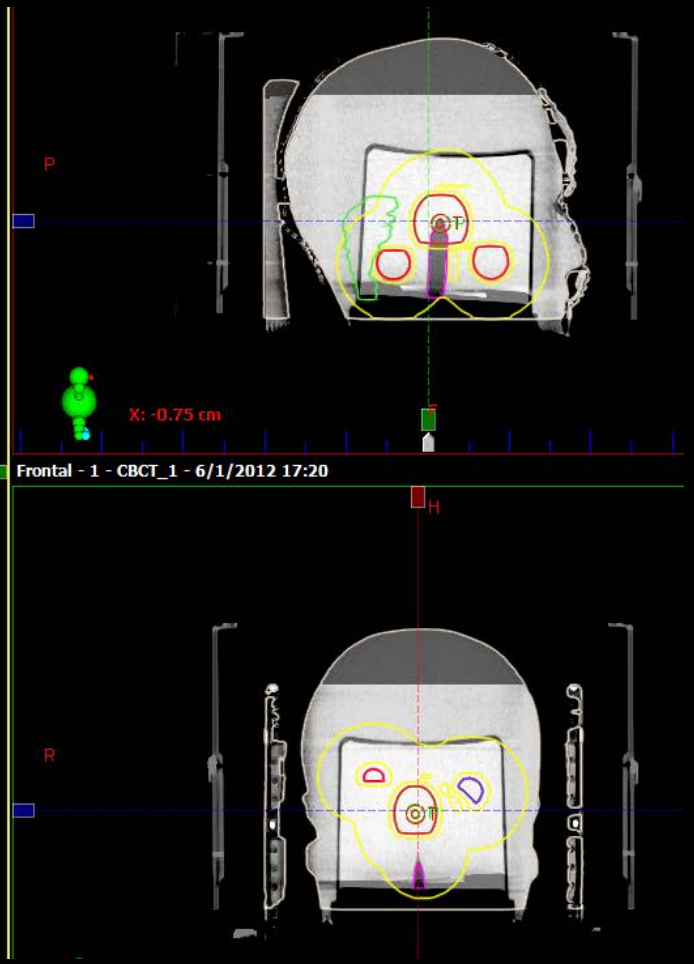




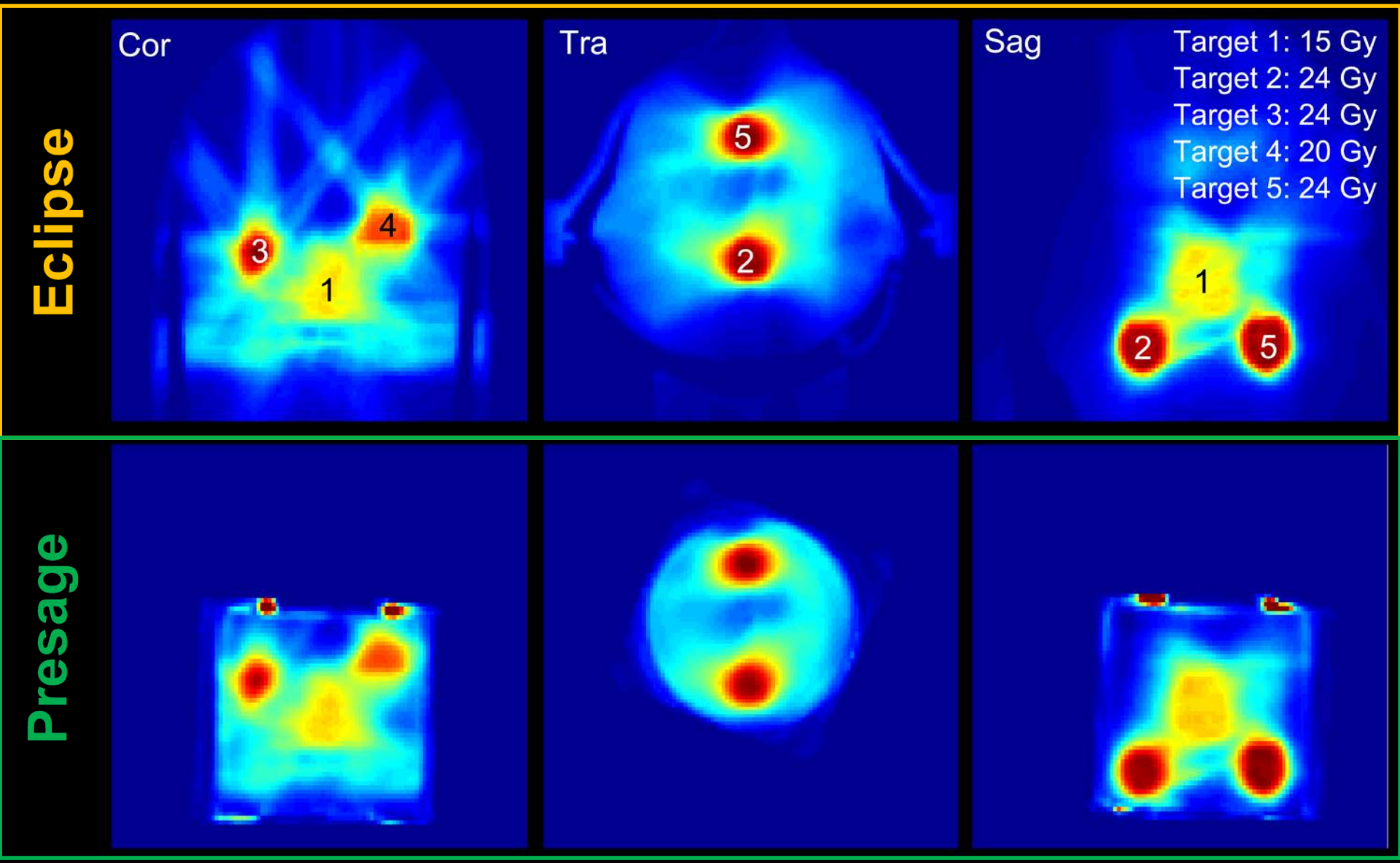
Treatment Delivery

- 4 dosimeters
- 2D KV and CBCT image guidance
- One dosimeter – ion chamber

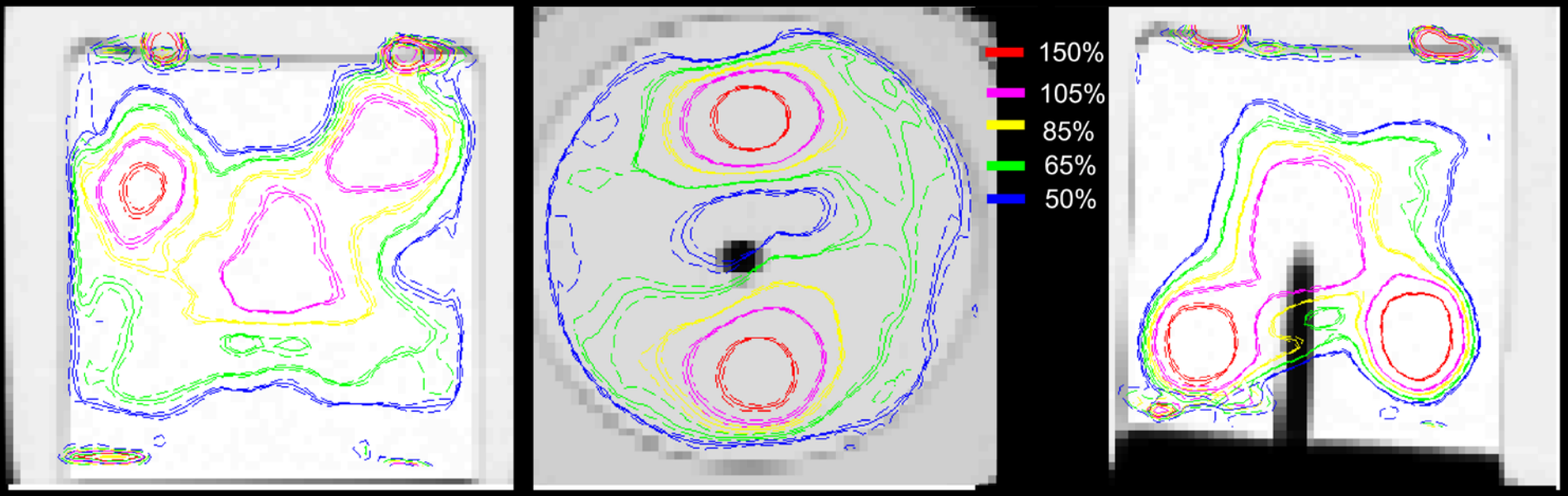




5 lesion VMAT single-iso Radiosurgery



5 VMAT single-iso SRS: accurate and reproducible

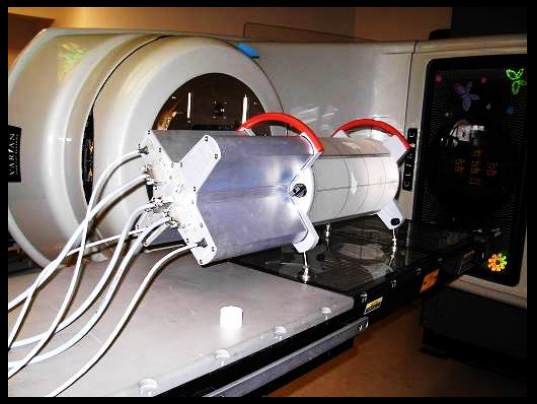


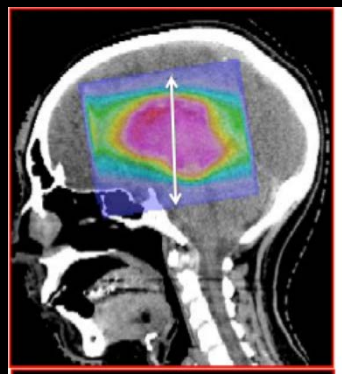
Average (solid lines)

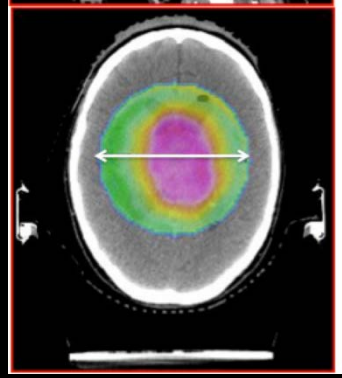
1 StdDev (dashed lines)

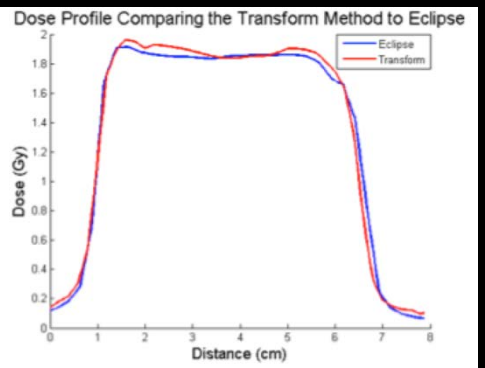
Thomas A , et al. Medical Physics, Dec, 2013

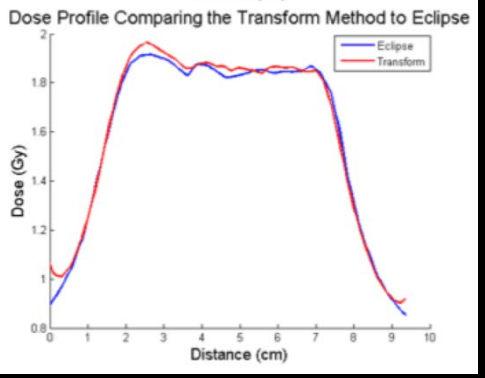
AAPM 2015:

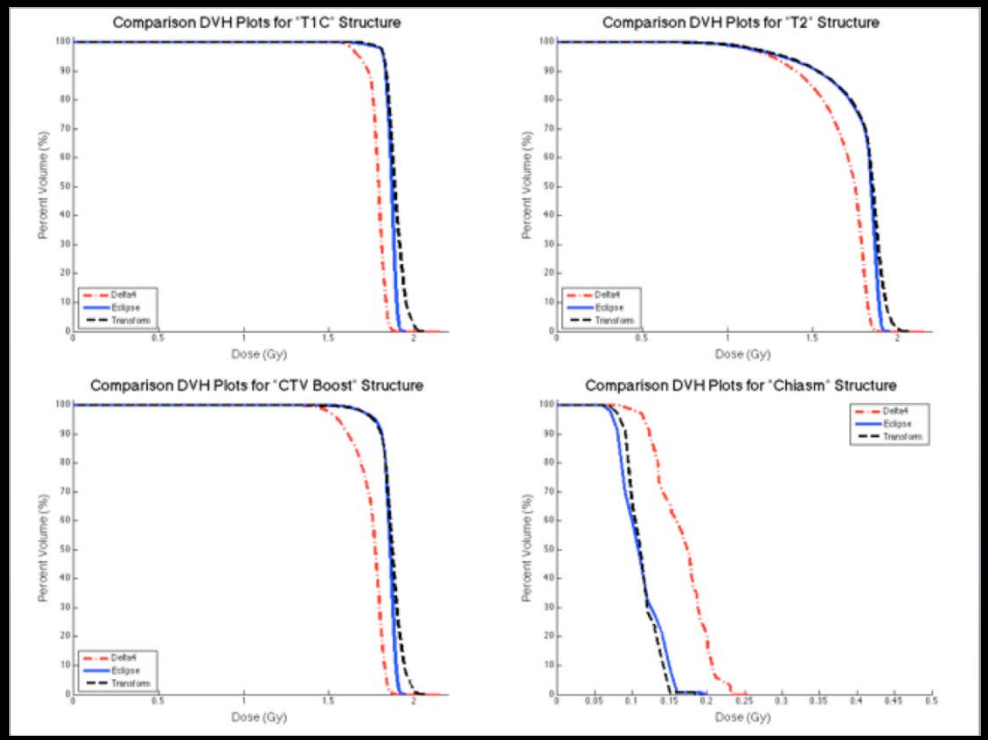








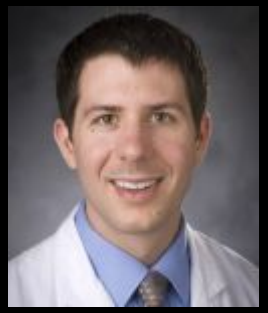


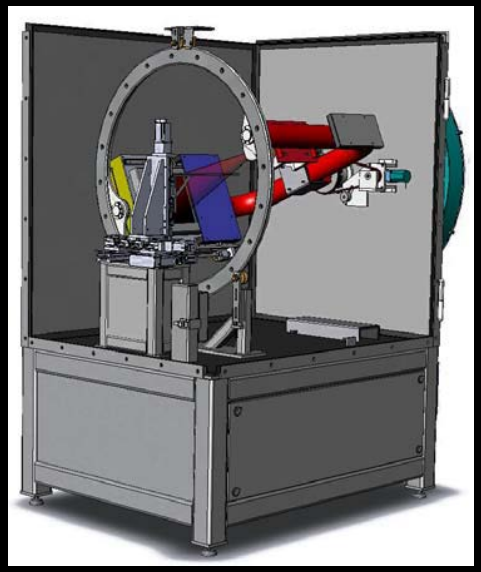


Crockett E, Ren L, Oldham M, AAPM 2015
DVH based Comparison Of True 3D Measurements And Delta4 system

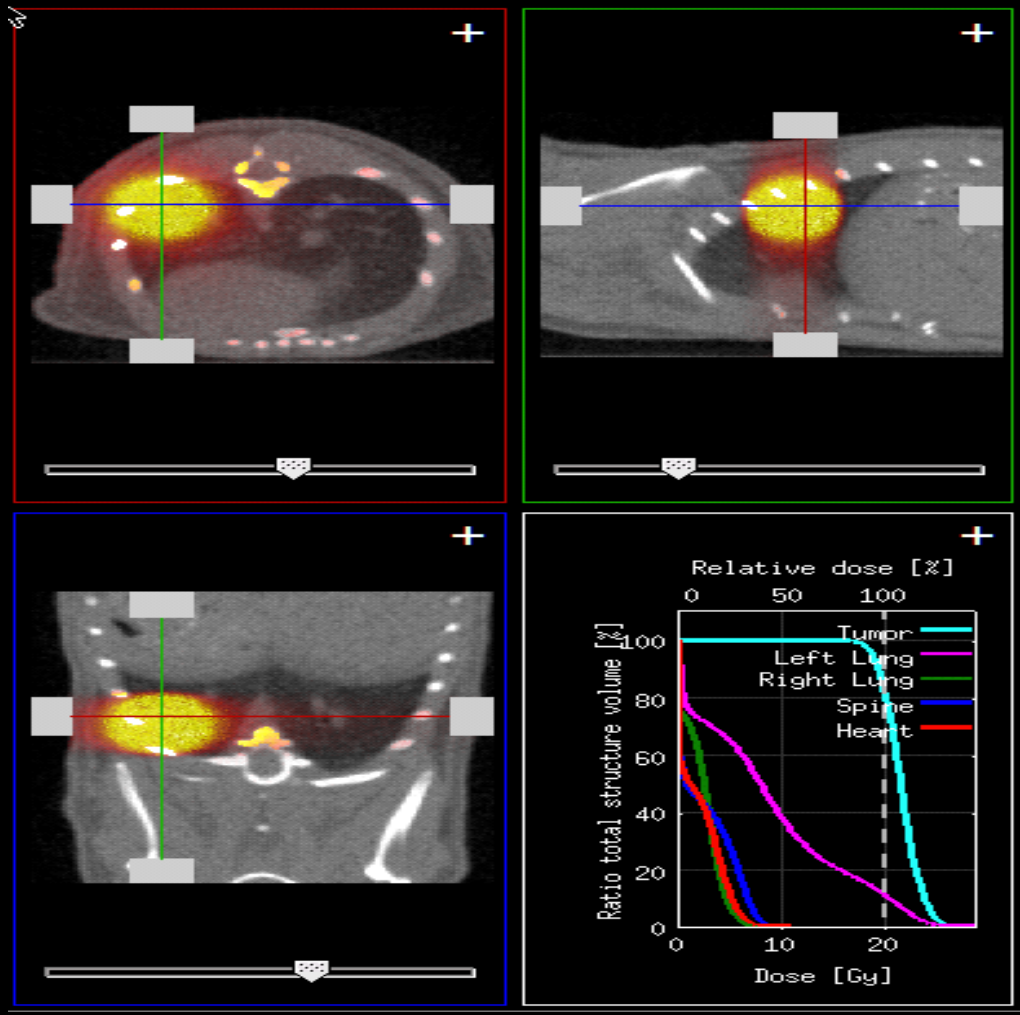
Oldham M , et al. IJROBP, Oct, 2012

Micro-irradiator: Lung SBRT

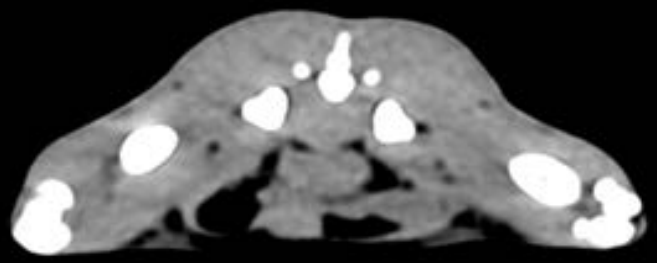


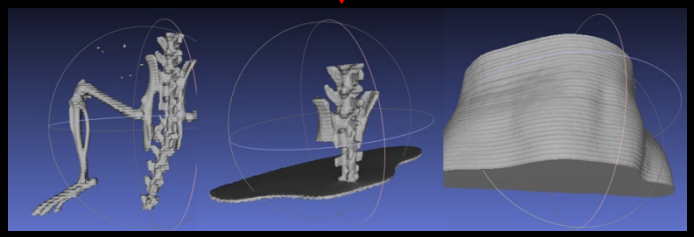


XRAD225Cx from Precision X-Ray Inc.

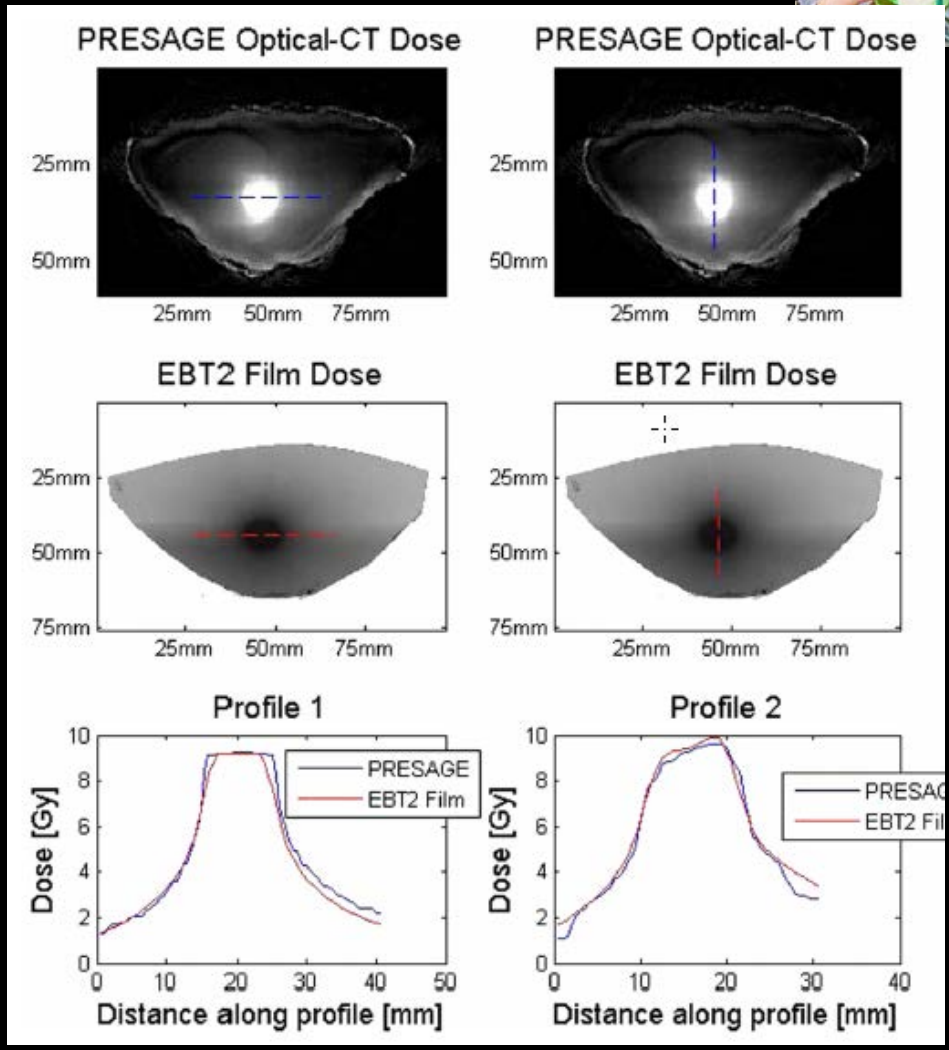


- MC planning
- 2-40mm fields
- Lung SBRT



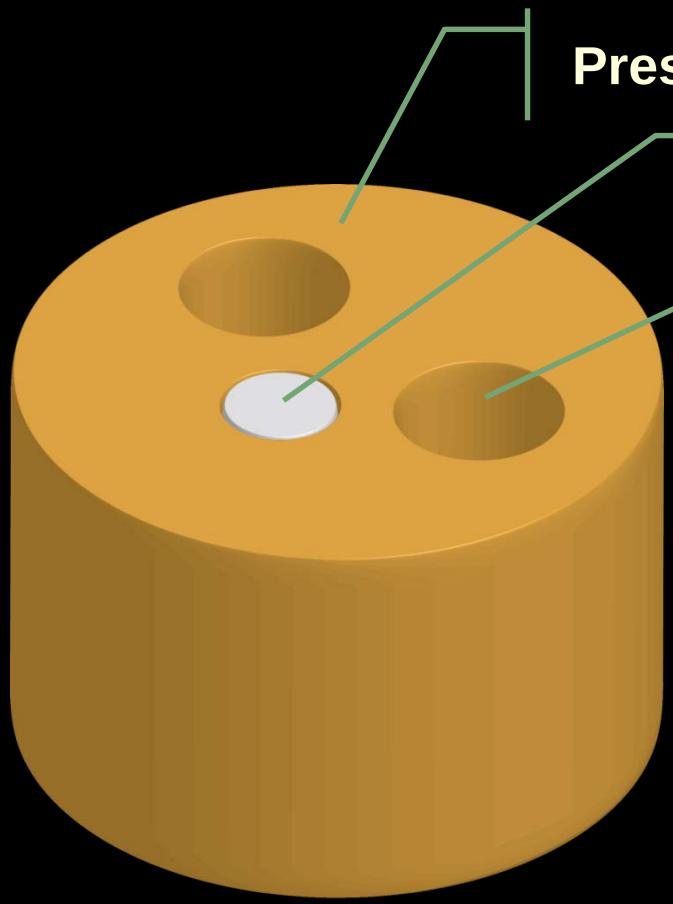


3D micro-dosimetry:
3D Printing:

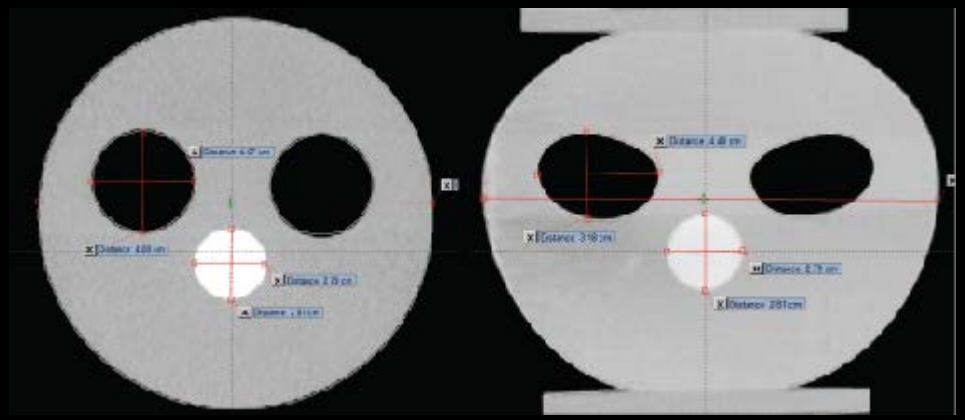


Bache S, et al. Med Phys, 2015

Can SmartAdapt/Velocity enable next generation gynecological treatments combining IG brachytherapy with RT

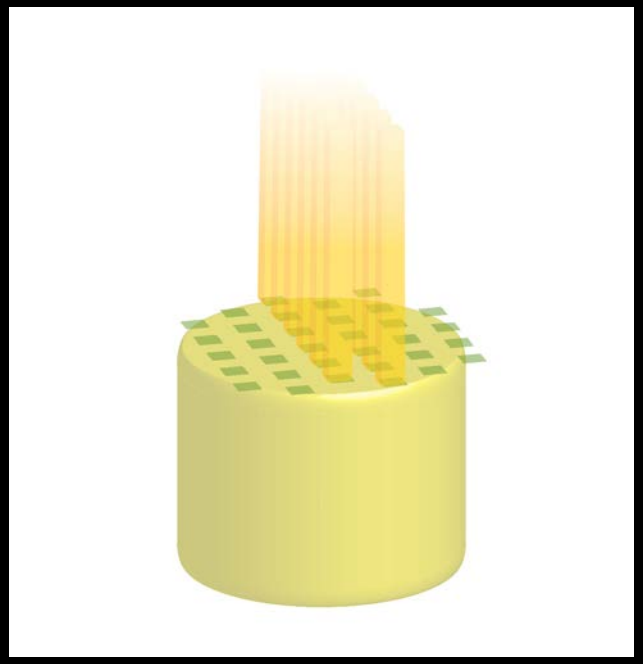


Complex, Non-Uniform Deformation

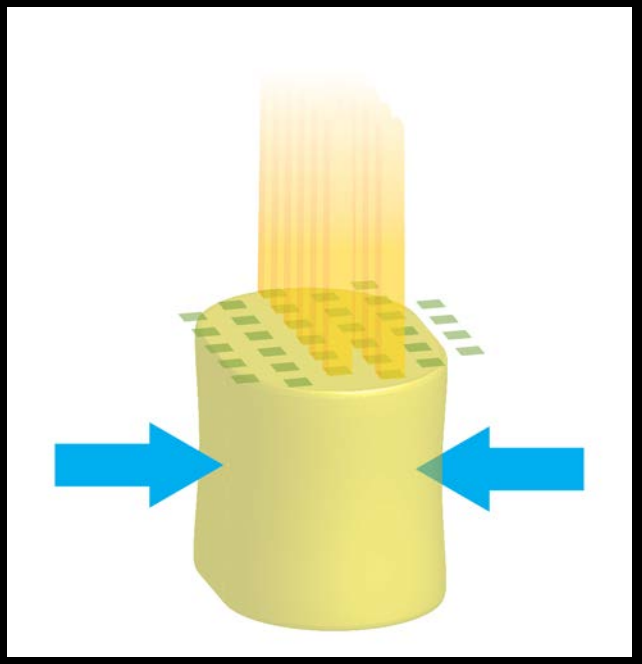


“On the need for validation of deformable dose accumulation (DIR) with a novel 3D dosimeter.”

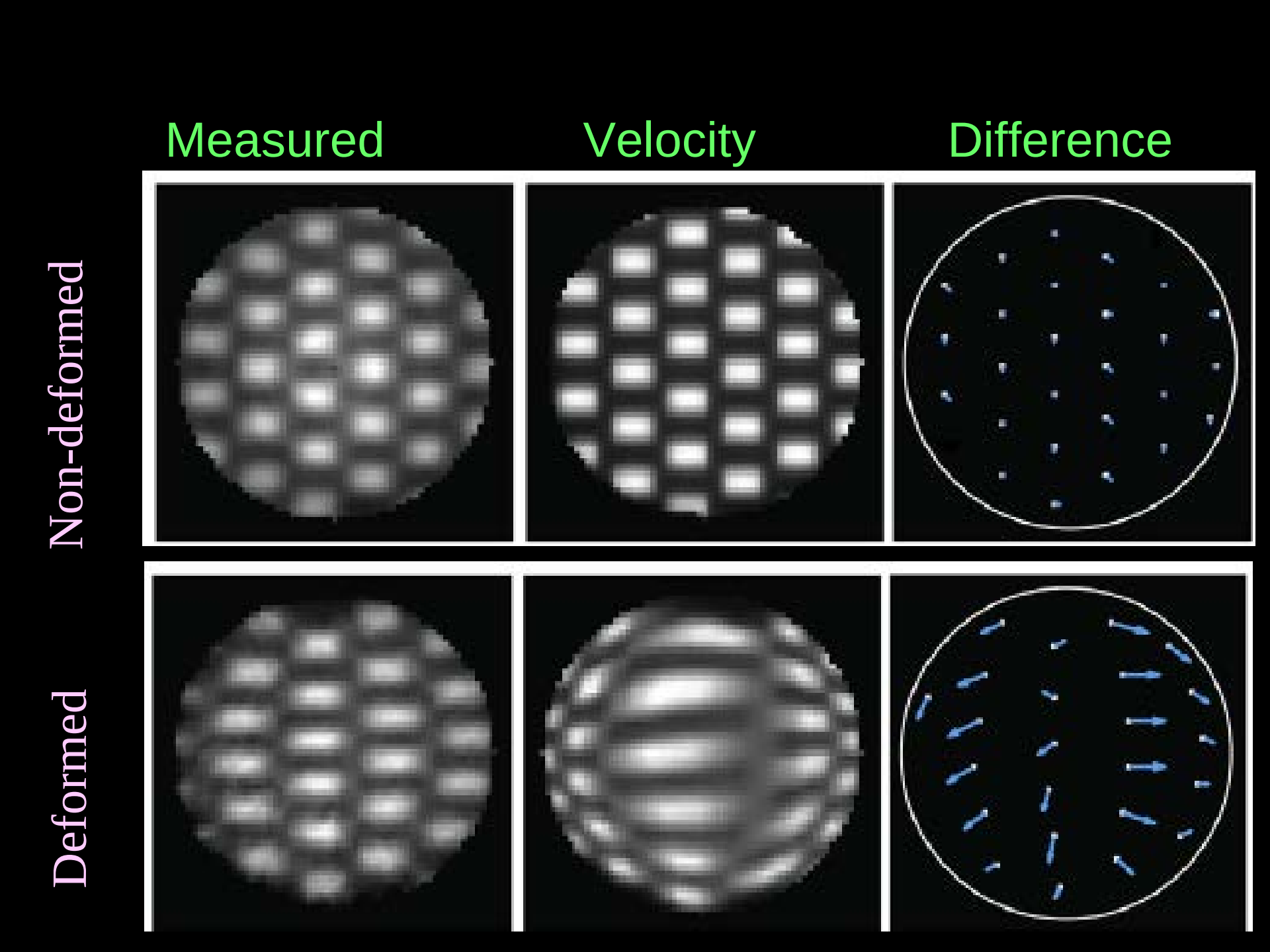
Juang et al. IJROBP, 2013



Control
(No Deformation)



Deformed
(27% Lateral Compression)


Measured
Velocity
Difference
Non-deformed
Deformed

Results

No Deformation

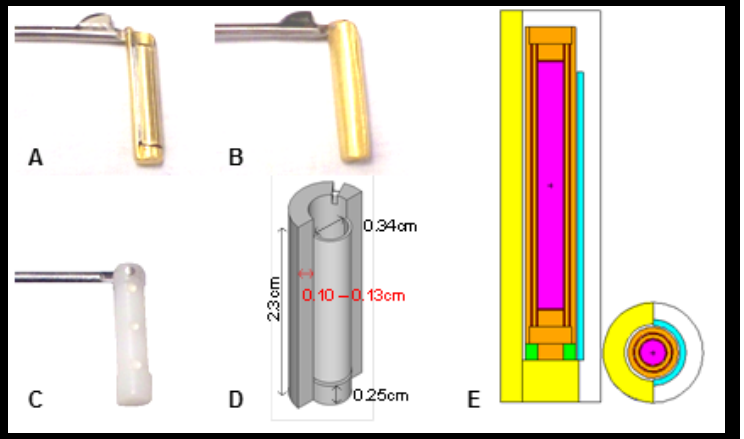
Deformed

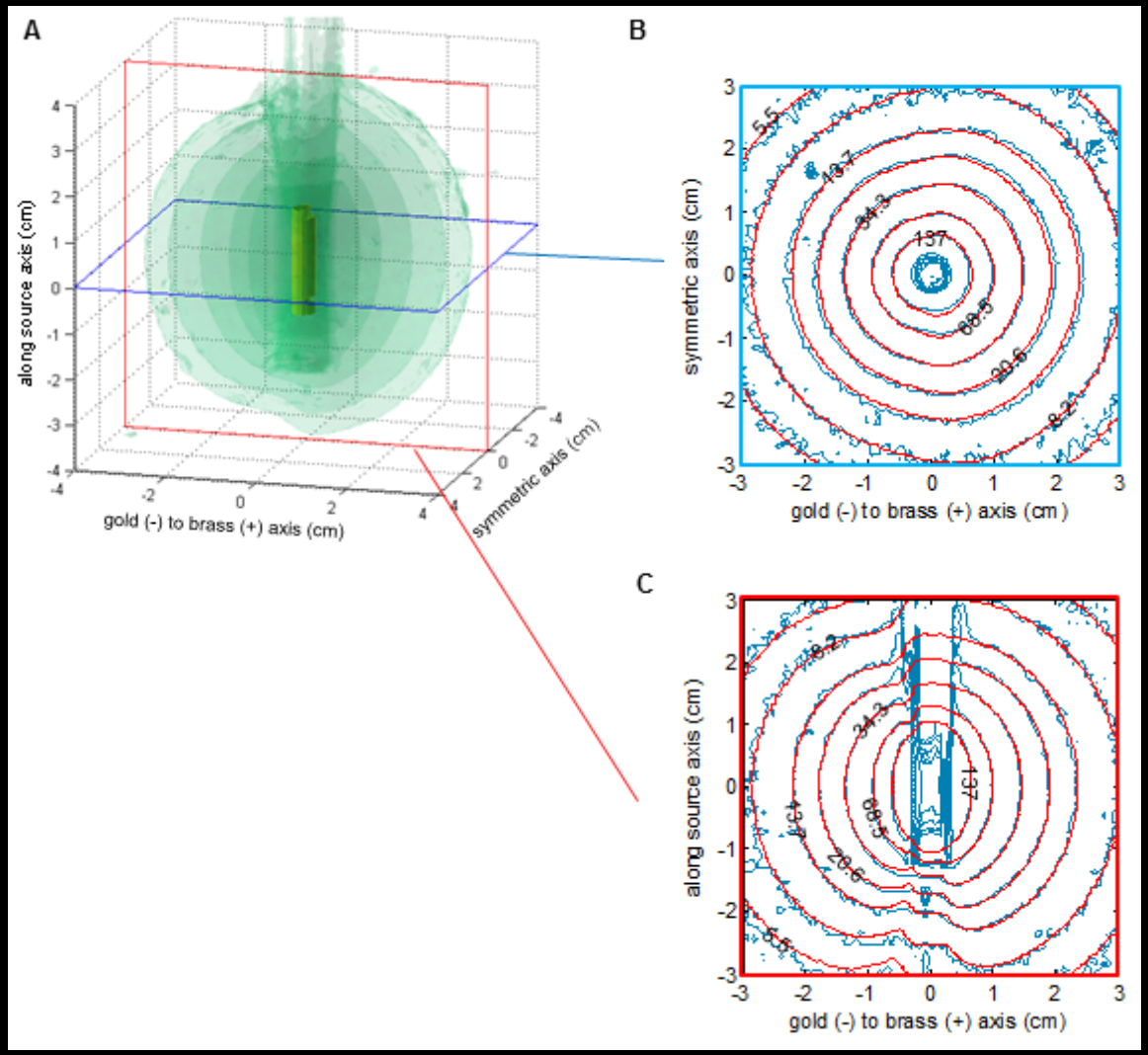
VelocityAI

MEASURED **CALCULATED**

Brachytherapy

^{137}Cs source in shielded bucket

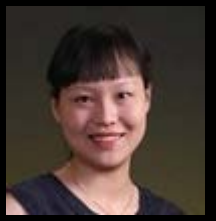




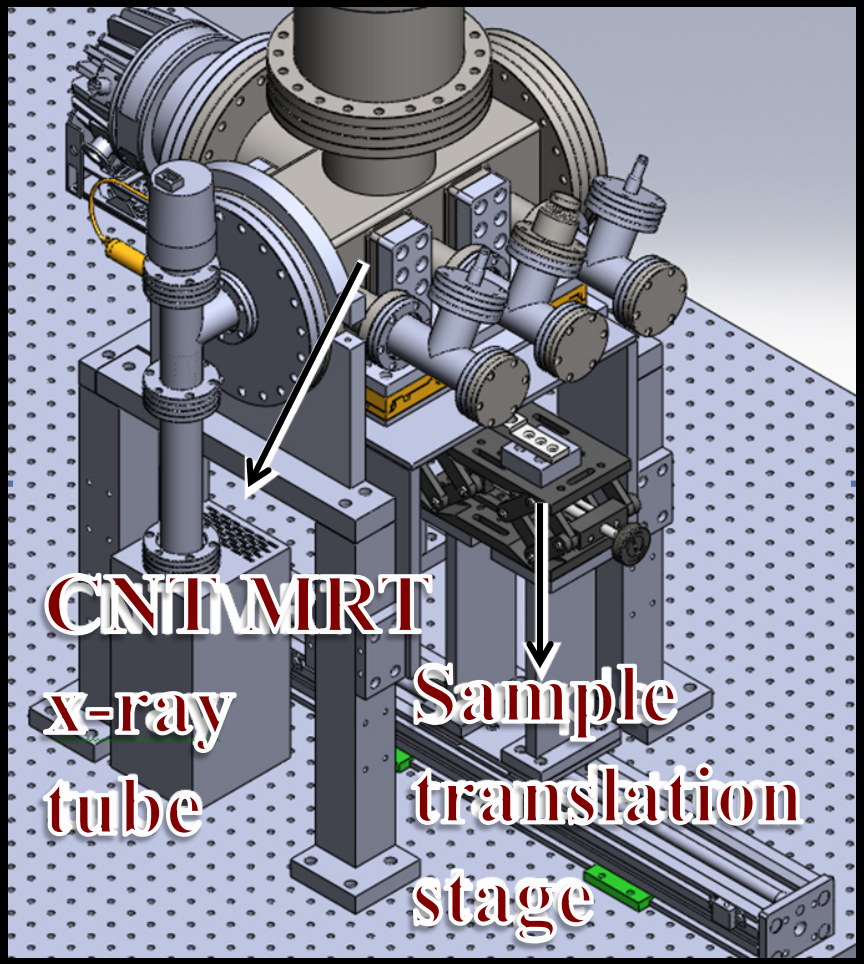
$0.5mm^3$ voxels !

Adamson J et al,
Med Phys 2012

Micro-radiation therapy (MRT - UNC)



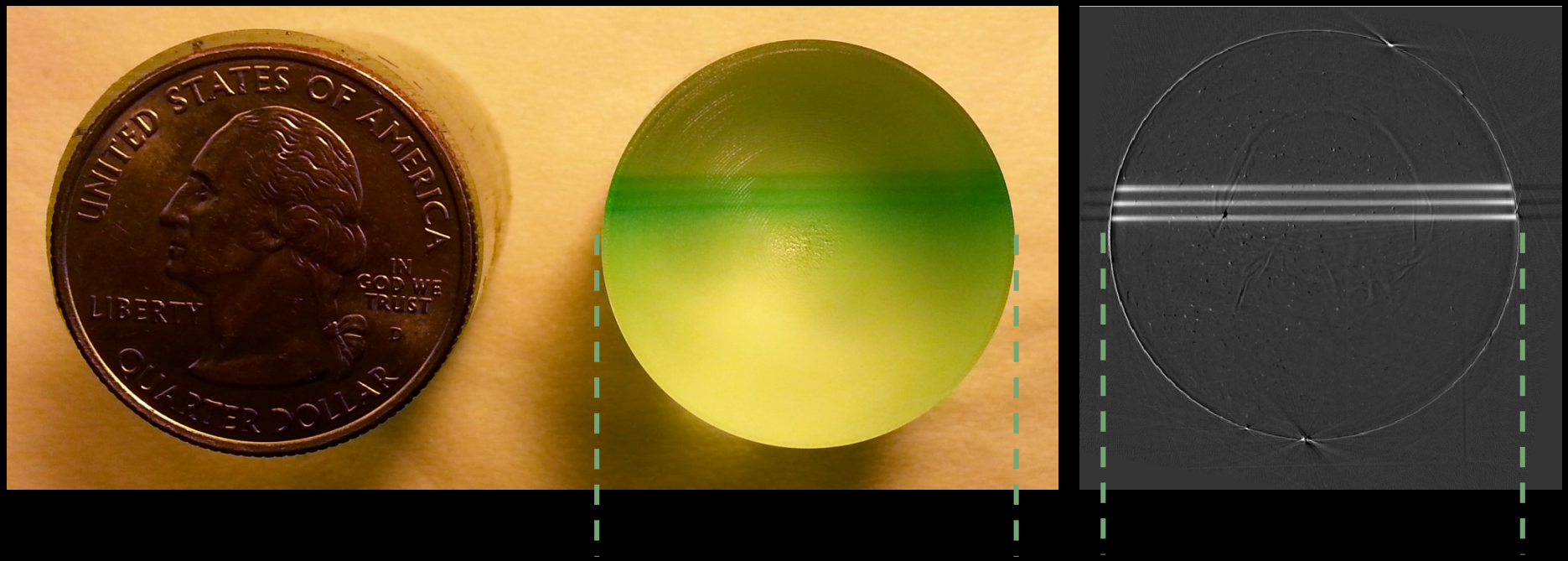
Qiongge Li



- 3 parallel beams
  - ▸ 300-400 μm width
  - ▸ 909 μm spacing
- 32 Gy entrance dose

Optical-CT Dosimetry

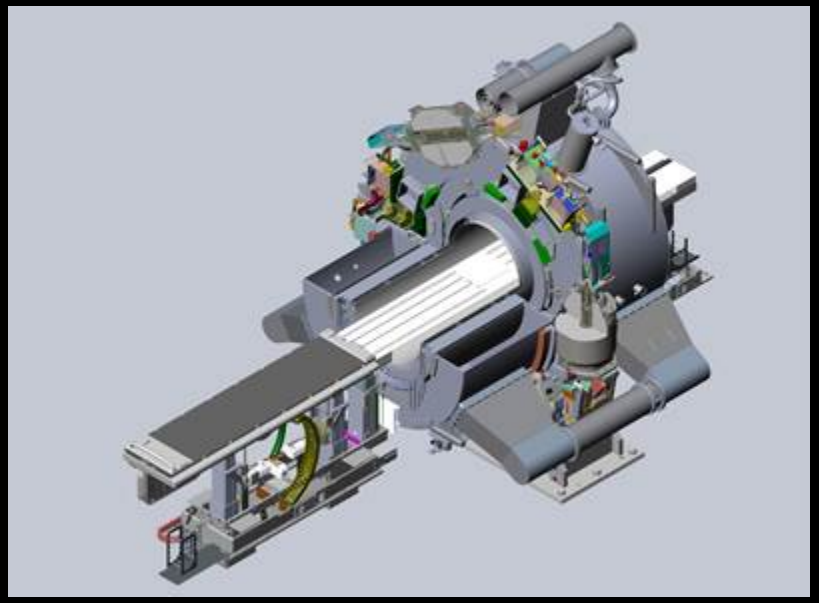
Scanned in Optical-CT Scanner
Reconstructed at 50 µm isotropic resolution



20 mm **400 px**

Magnetic Resonance Imaging guided Radiation Therapy (MRIgRT

- Remote 3D dosimetry protocol
- Duke and WashU
- Advantages
  - MR independent



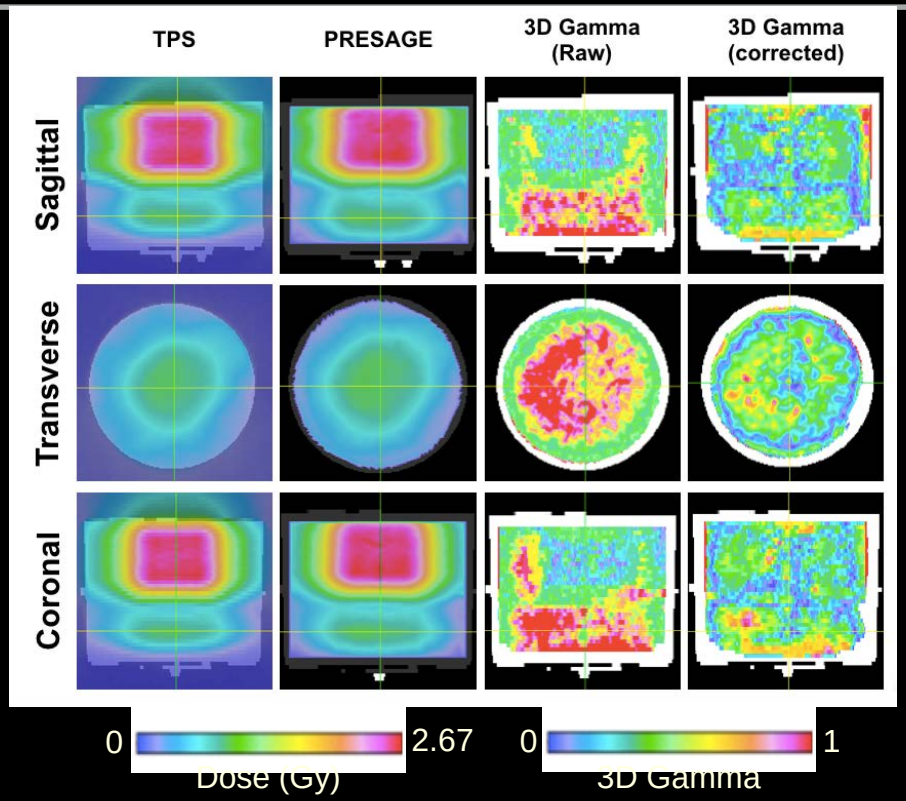
- Stage I
  - TG119 irradiations

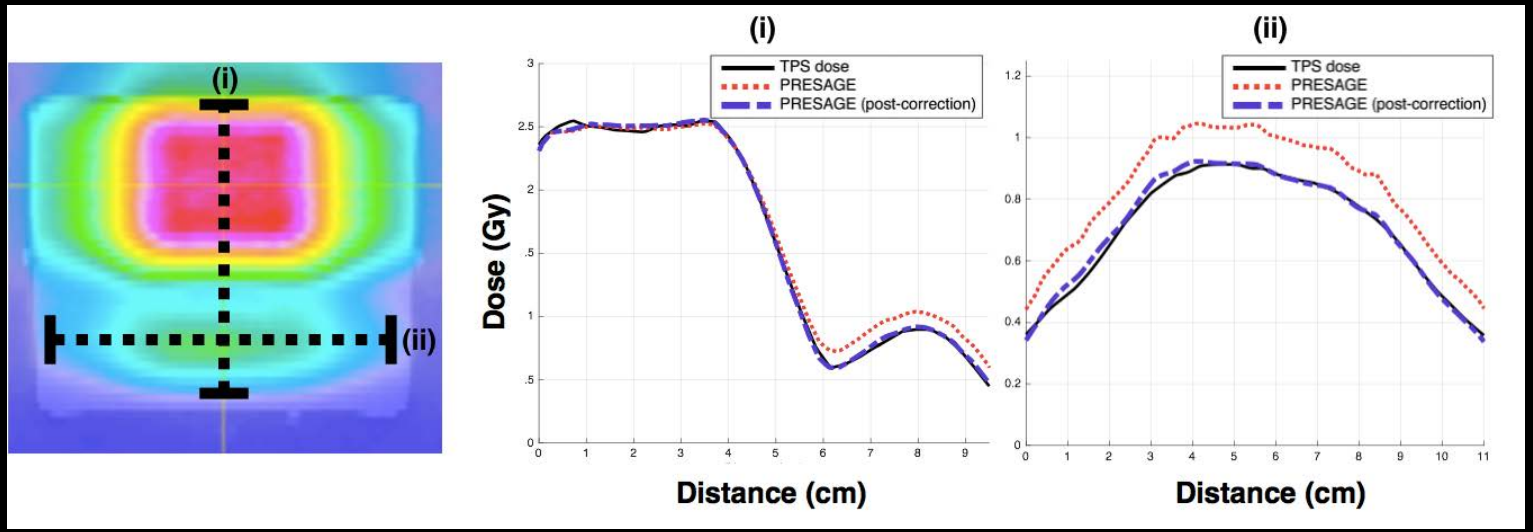
MULTI-TARGET (TG119)

Passing Rate (3%/3mm):

Raw	Corrected
91.6%	→ 98.5%

TH-CD-BRA-11





Conclusions so far !

- Hi-res 3D dosimetry is feasible
- Remaining challenges
  - Dosimeter development
  - Scanner Development
  - Applications: Many
    - Advanced Tx
    - Pre-clinical
    - Deformable, IG procedures
    - New devices and techniques

Radiochromic Dosimetry at CCSEO

Based on change of optical attenuation coefficients in irradiated dosimeter

- *Fricke and Radiochromic dosimeters*
  - Absorption changes

Fricke Gels

Leucodye MicelleGels

Modus QA

Prepare

Image

Plan

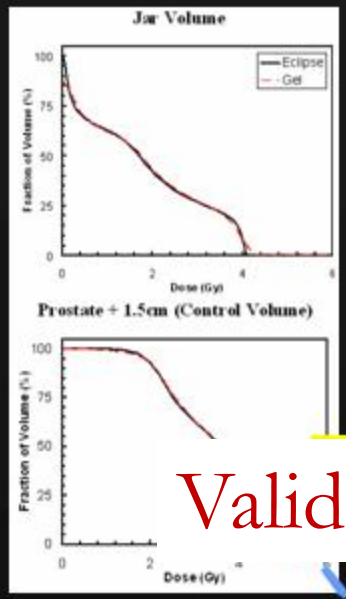
CBCT

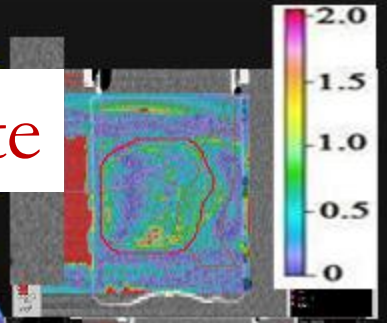
Set up

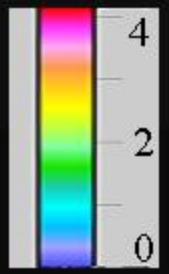
“ Treat ”

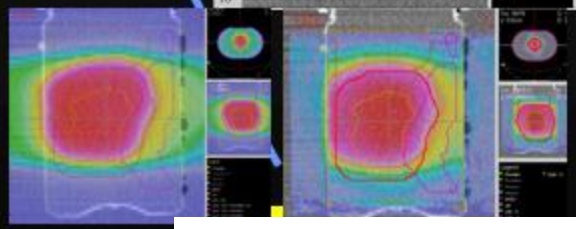
3D Readout

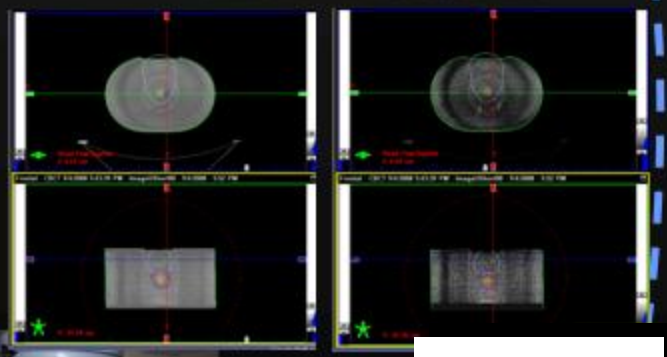
Validate









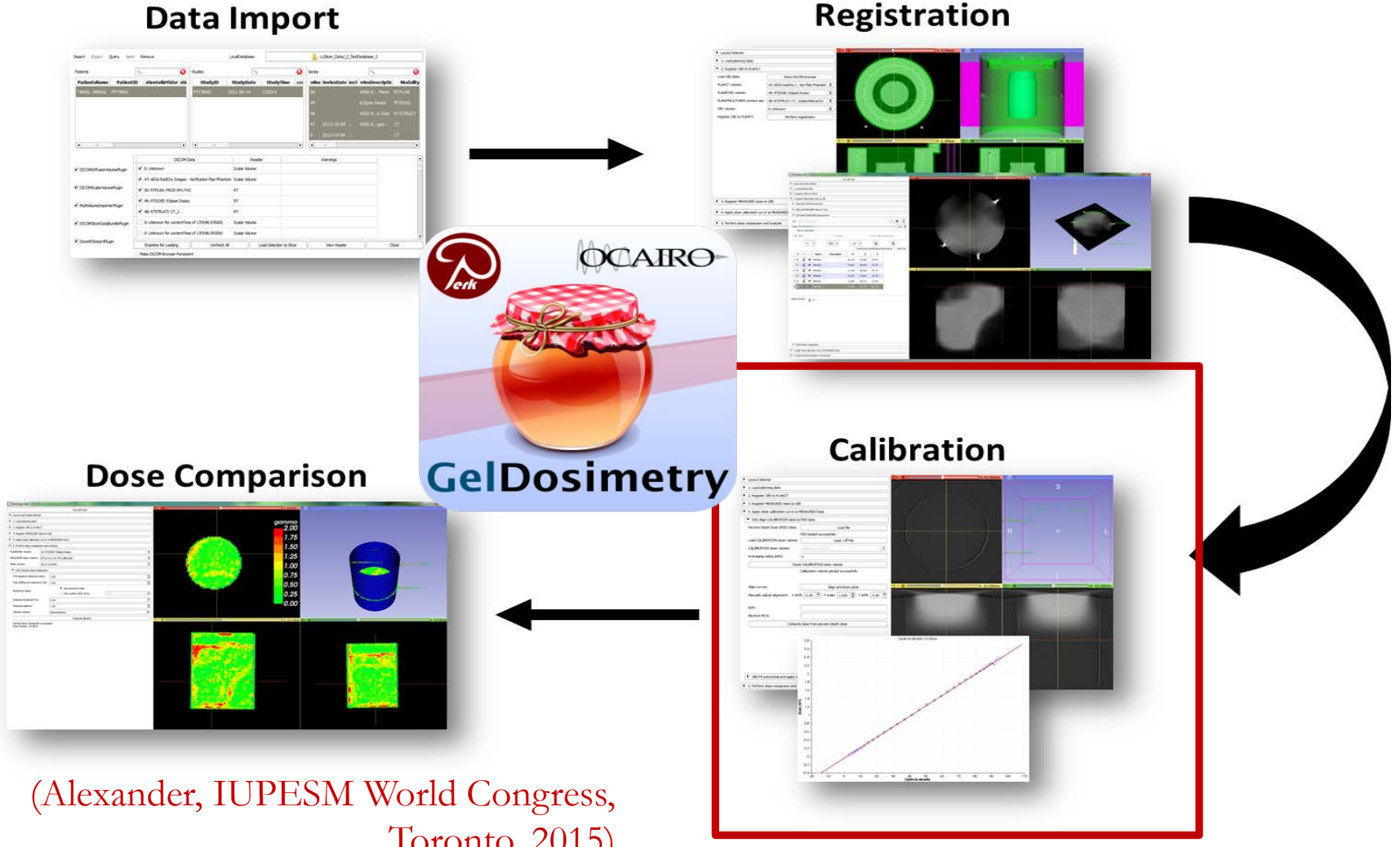


CCSEO

LJS 2008

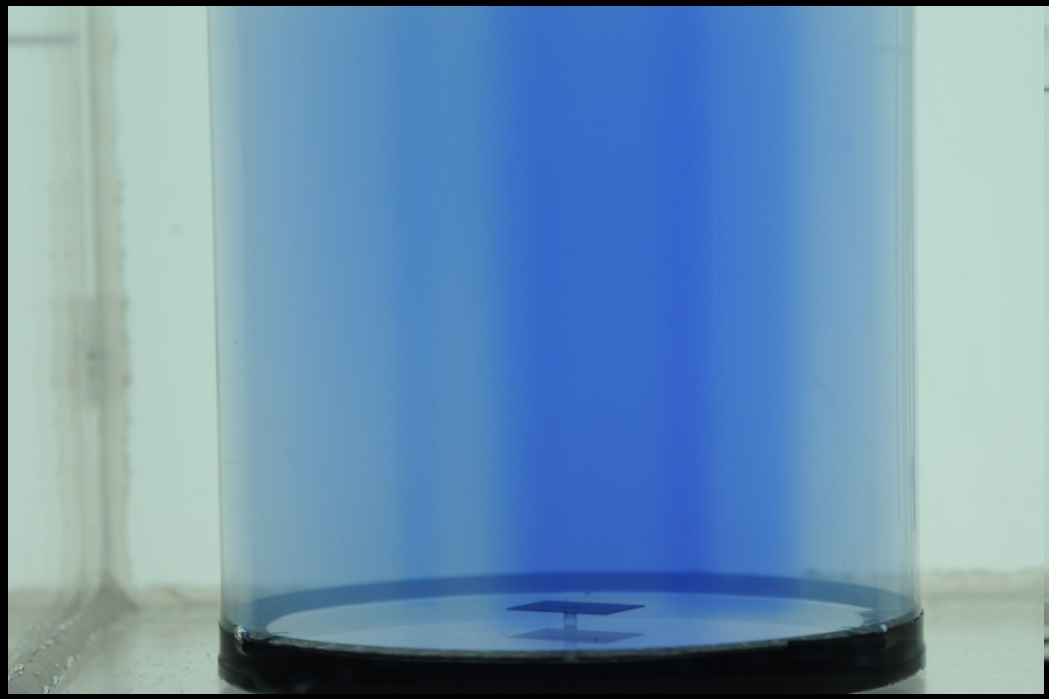
Data analysis

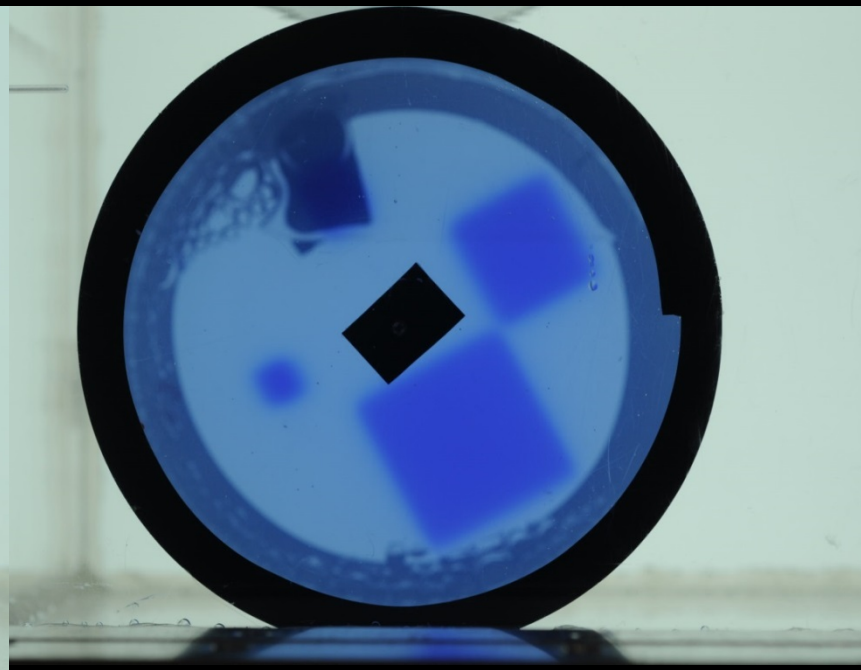
We work in SLICER-RT open source environment



(Alexander, IUPESM World Congress, Toronto, 2015)

Non-diffusing leuco crystal violet gelatin hydrogel (see IC3DDose16)
~20 Gy per beam, jaw size=3x3, 2x2, 1x1 & 0.6x0.6 cm
AP, 6 MV, 400 MU/min,
“POP bottle vessel”, 11 cm diameter



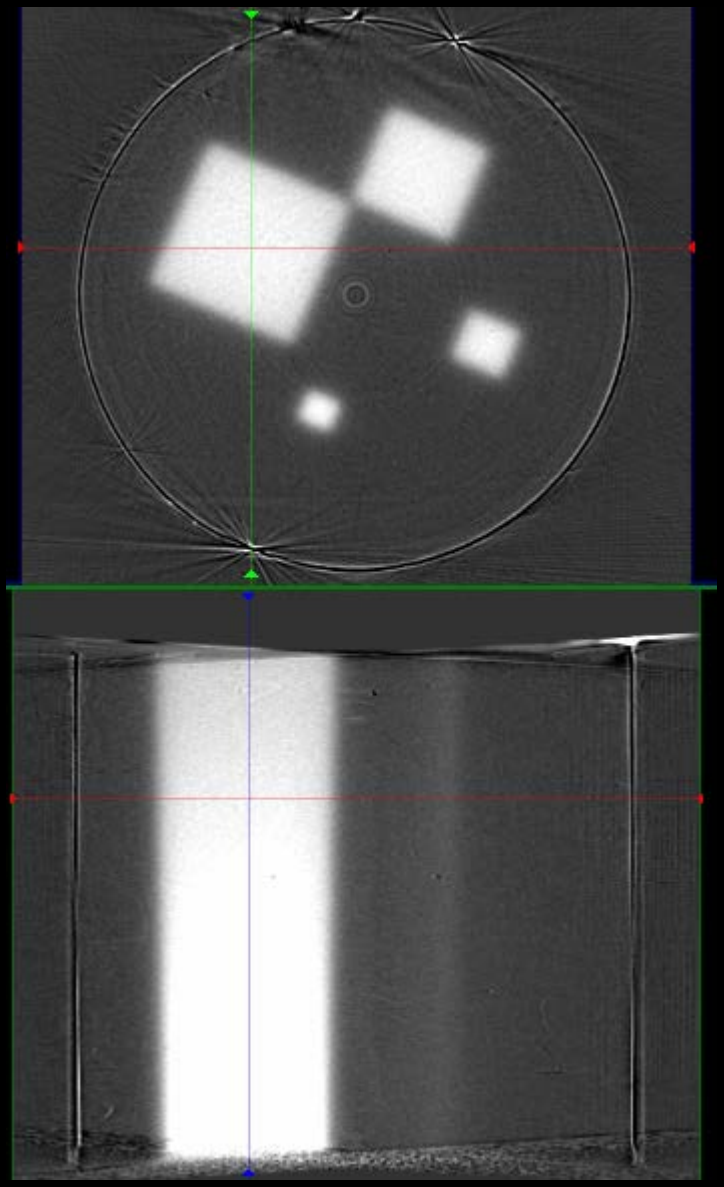


K Jordan, London Regional Cancer Program

Reconstruction

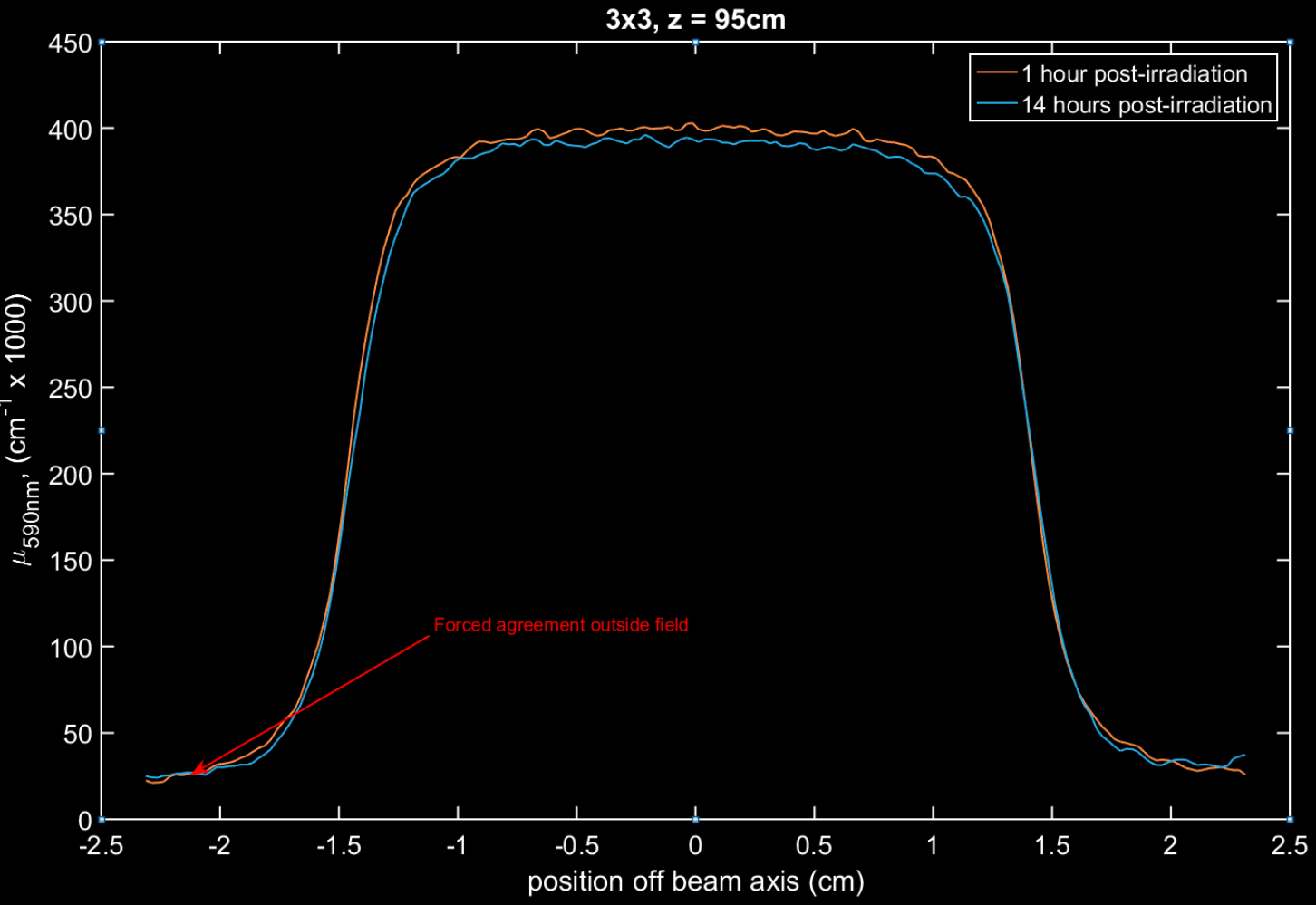
- 512 projections, 0.25mm voxels, 10 minute scan time, FDK reconstruction, hamming filter (Modus VistaRecon.exe)

- Vista optical CBCT scanner, custom source (Fresnel lens + LED)



K Jordan, London Regional Cancer Program

- diffusion is not a problem over ~14h



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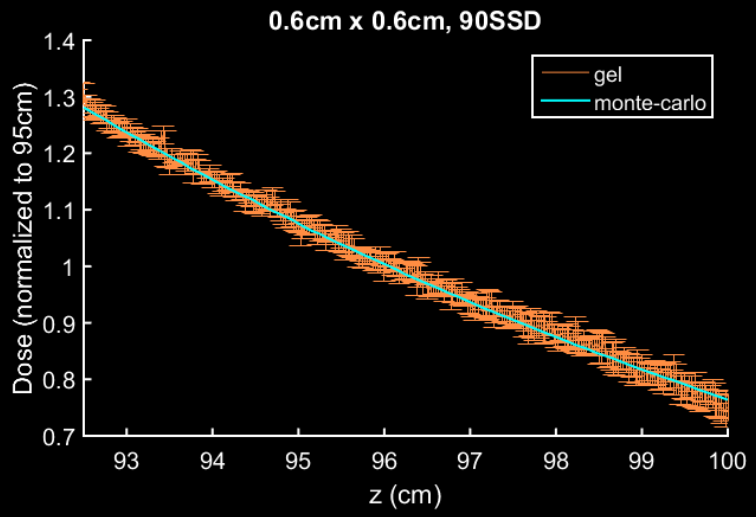
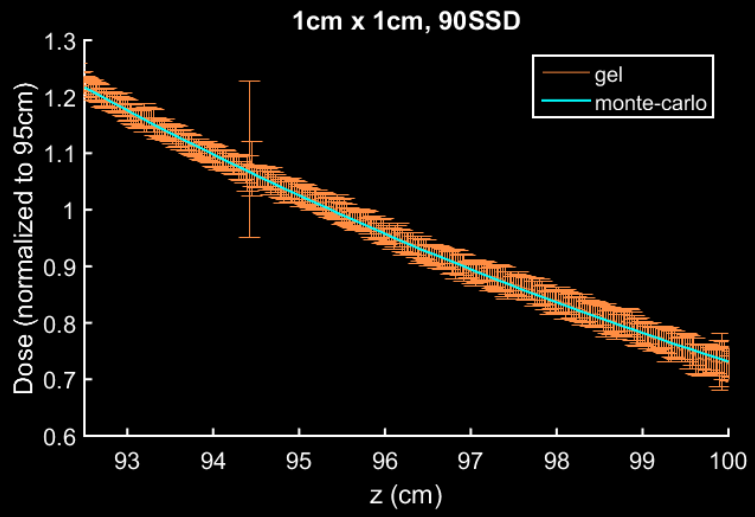
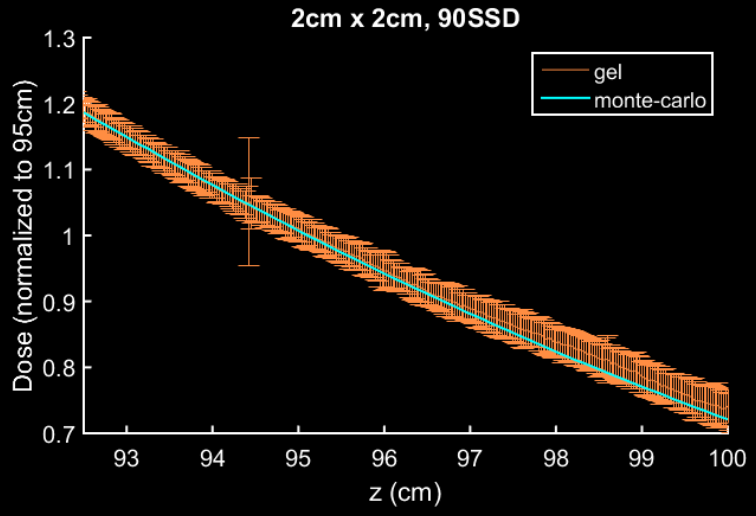
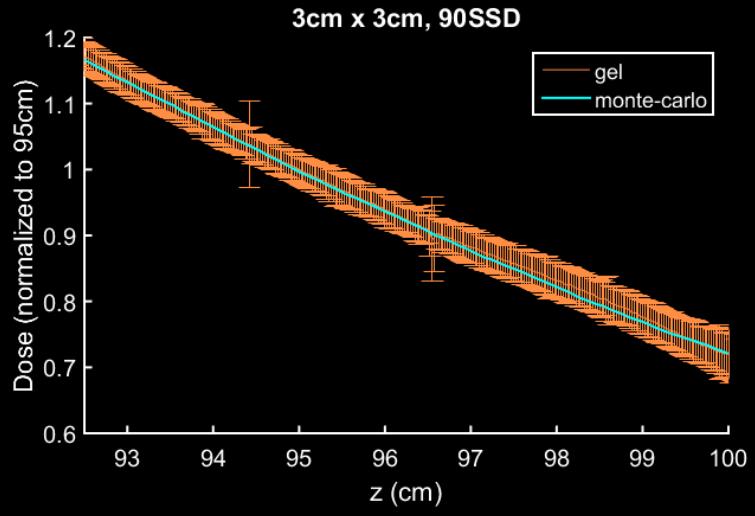
Background-Corrected, Depth Dose Curves



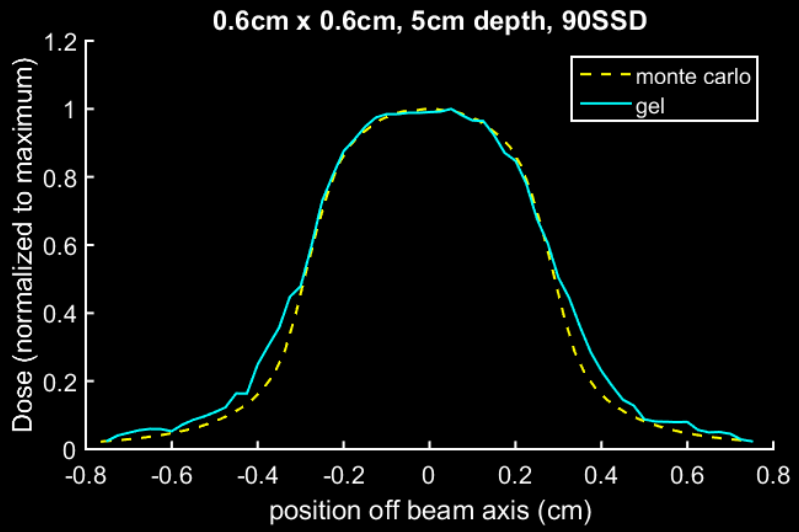


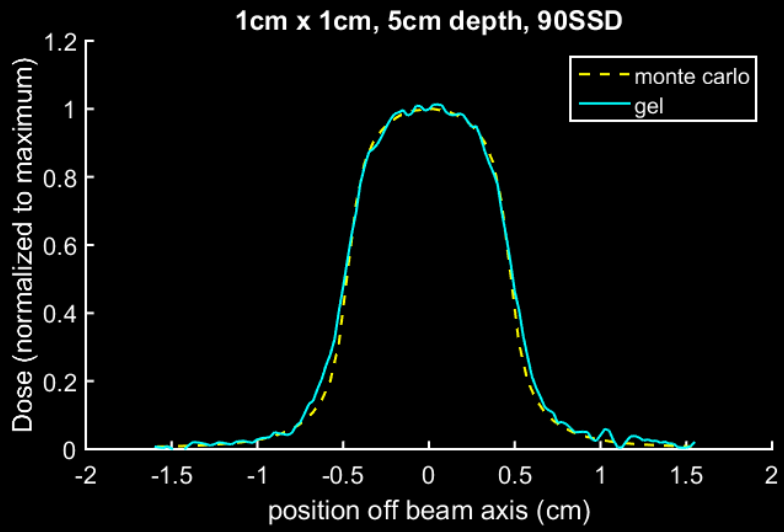


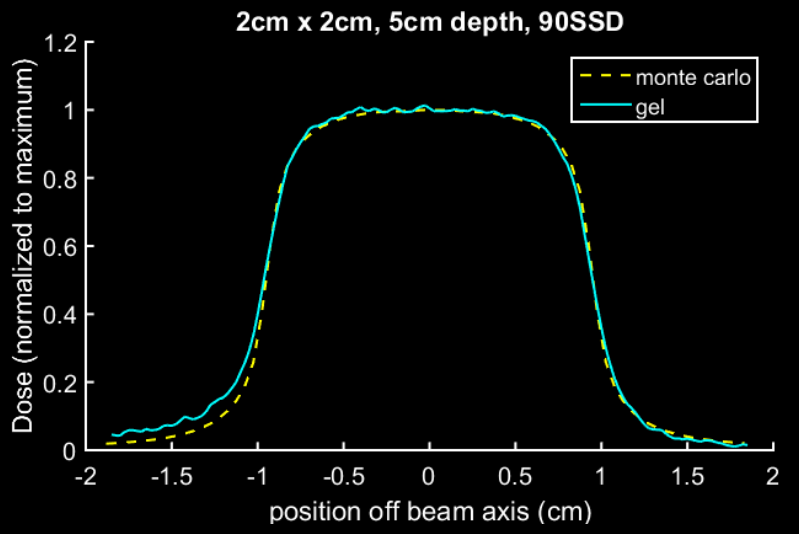


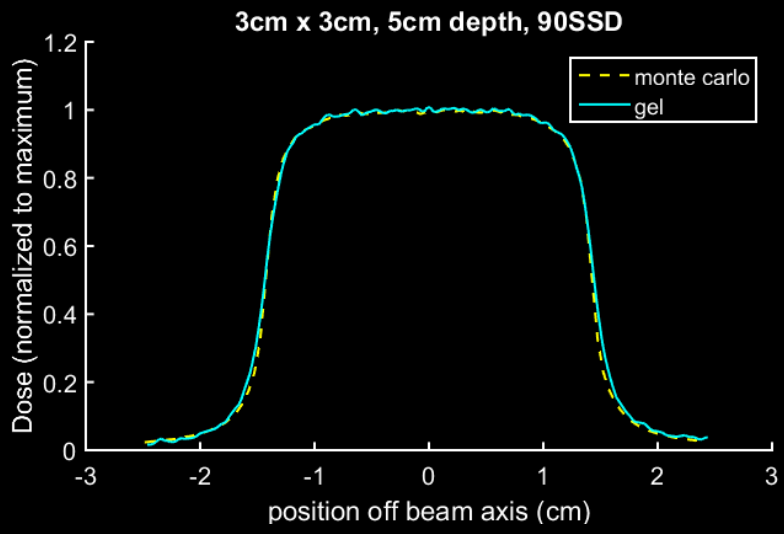
K Jordan, London Regional Cancer Program

Background-Corrected Beam Profiles



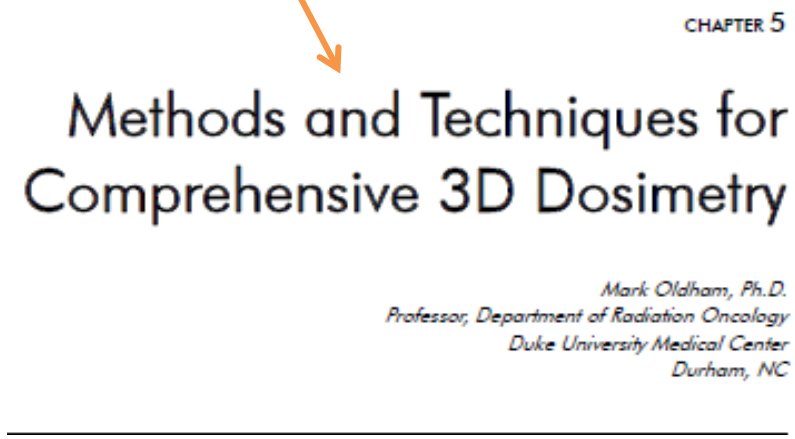






Resources for future reading

Oldham M 2014
in: Advances in Medical Physics
Godfrey D et al (ed)
(Medical Physics Publishing, Madison WI)



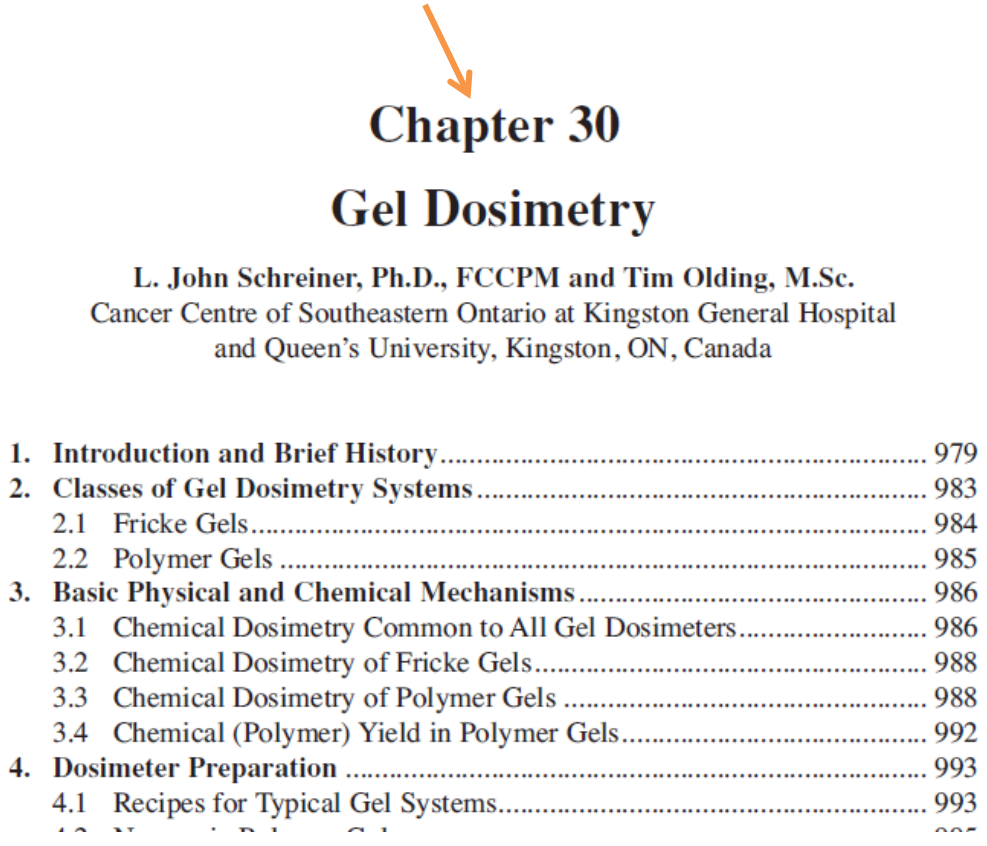
CHAPTER 5

Methods and Techniques for Comprehensive 3D Dosimetry

Mark Oldham, Ph.D.
Professor, Department of Radiation Oncology
Duke University Medical Center
Durham, NC

Schreiner LJ and Olding T 2009 Gel dosimetry
in: Clinical Dosimetry Measurements in Radiotherapy

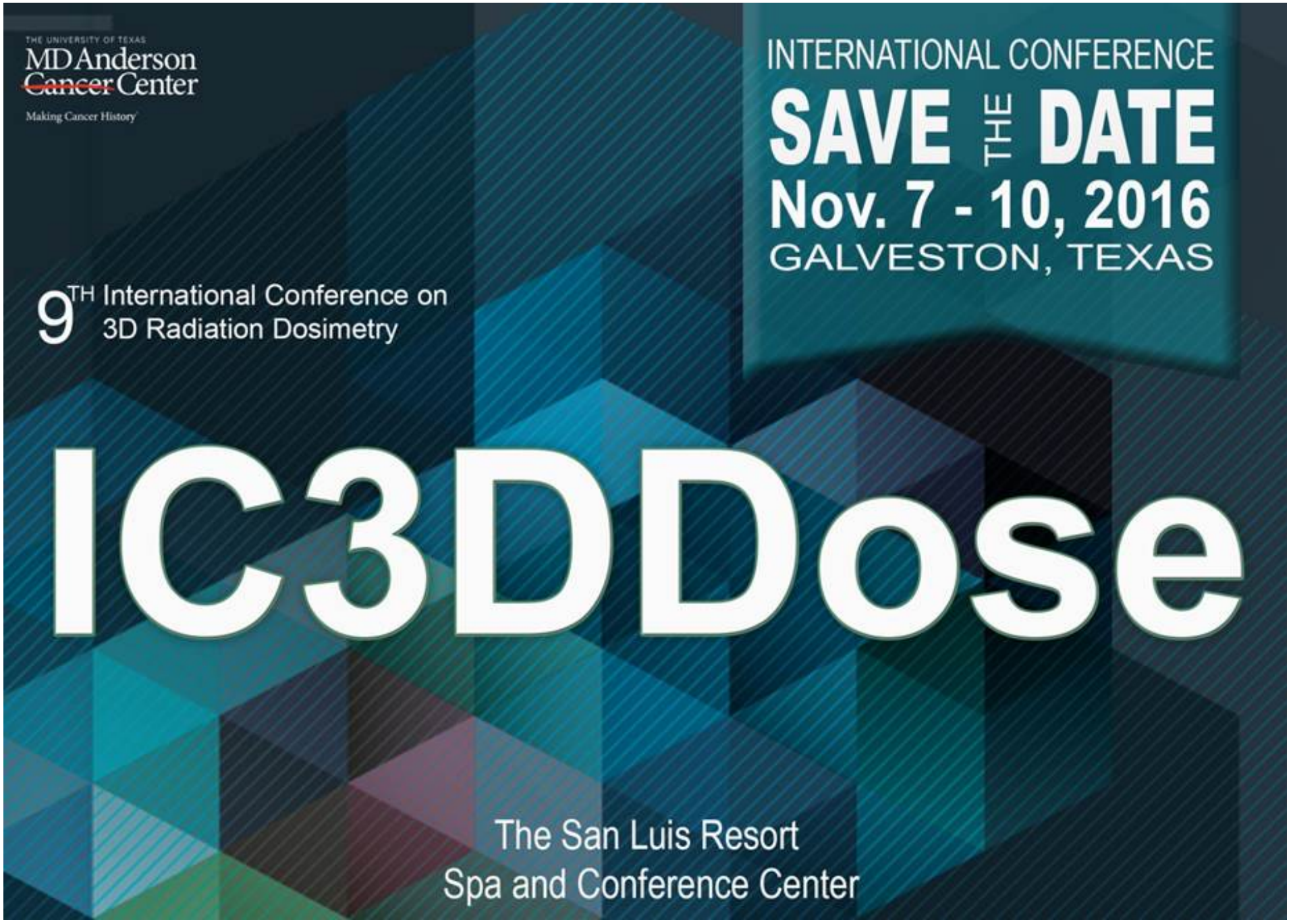
(AAPM Medical Physics Monograph No. 34)
Rogers D and Cygler J (ed.),
(Medical Physics Publishing, Madison WI)



Chapter 30

Gel Dosimetry

L. John Schreiner, Ph.D., FCCPM and Tim Olding, M.Sc.
Cancer Centre of Southeastern Ontario at Kingston General Hospital
and Queen's University, Kingston, ON, Canada


THE UNIVERSITY OF TEXAS
MD Anderson Cancer Center
Making Cancer History
INTERNATIONAL CONFERENCE
SAVE THE DATE
Nov. 7 - 10, 2016
GALVESTON, TEXAS
9TH International Conference on 3D Radiation Dosimetry
IC3DDose
The San Luis Resort
Spa and Conference Center

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Duke Faculty and 3D Dosimetry Lab Members
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