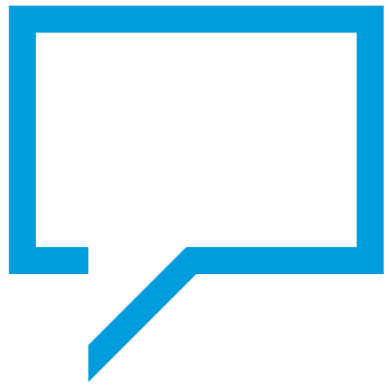
MAYO CLINIC

THE UNIVERSITY OF TEXAS MD Anderson Cancer Center

PROTON RADIOGRAPHY WITH A MONOLITHIC PLASTIC SCINTILLATOR AND DIGITAL CAMERA

PRELIMINARY STUDIES



Daniel Robertson, PhD

7th Annual Loma Linda Workshop on Particle Imaging and Radiation Therapy
2 August 2021

ACKNOWLEDGEDMENTS

Sam Beddar
- Fahed Alsanea
- Chinmay Darne
- Nathaniel Fredette
- Rajesh Panthi
- Luis Perles
- Irwin Tendler

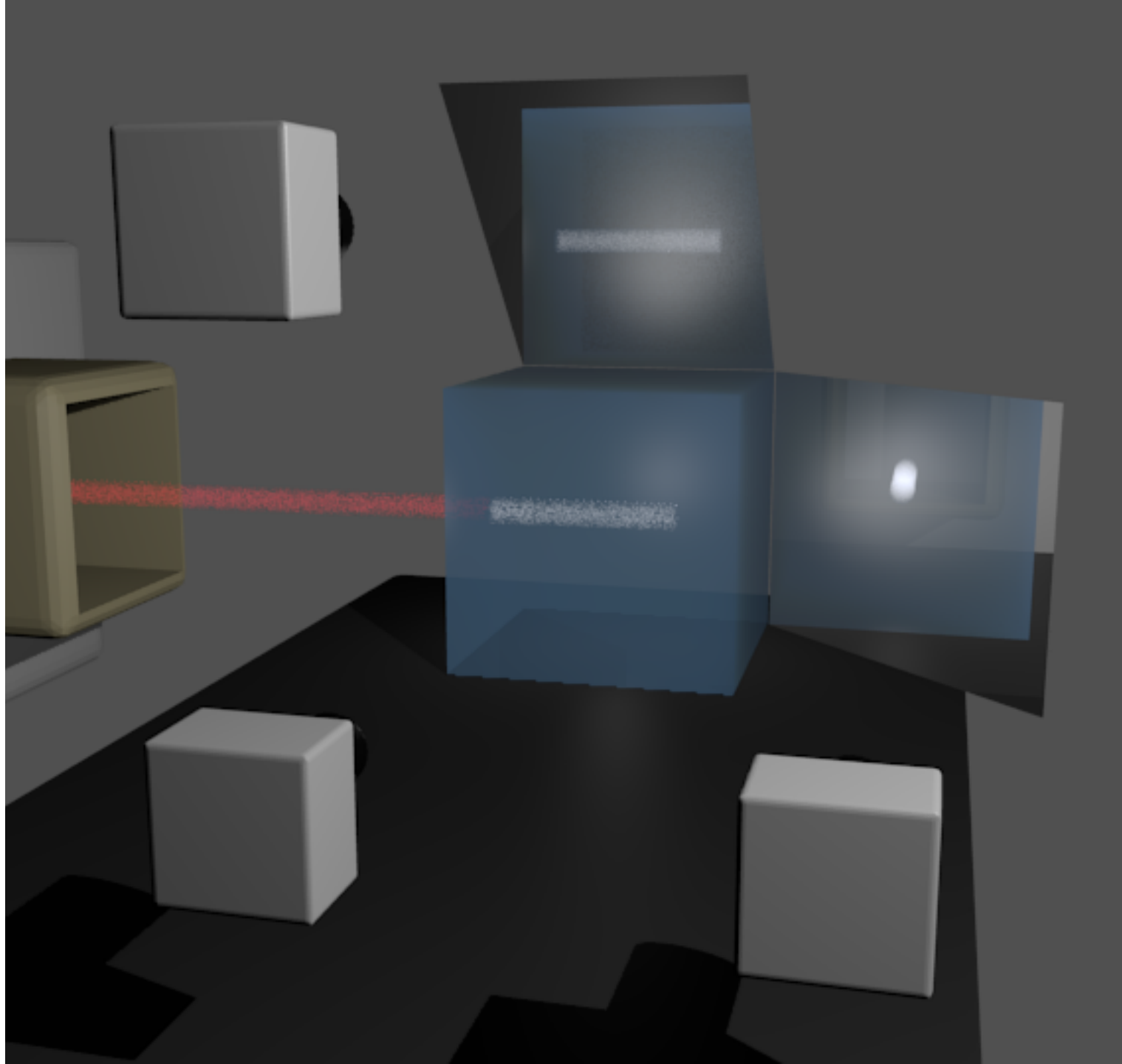
Charles-Antoine Collins Fekete
- Ryan Fullarton
- Mikael Simard

OUTLINE

1. Sources of inspiration
2. Motivation for this approach
3. Detector description
4. Simulation studies
5. Experiments

1

INSPIRATION

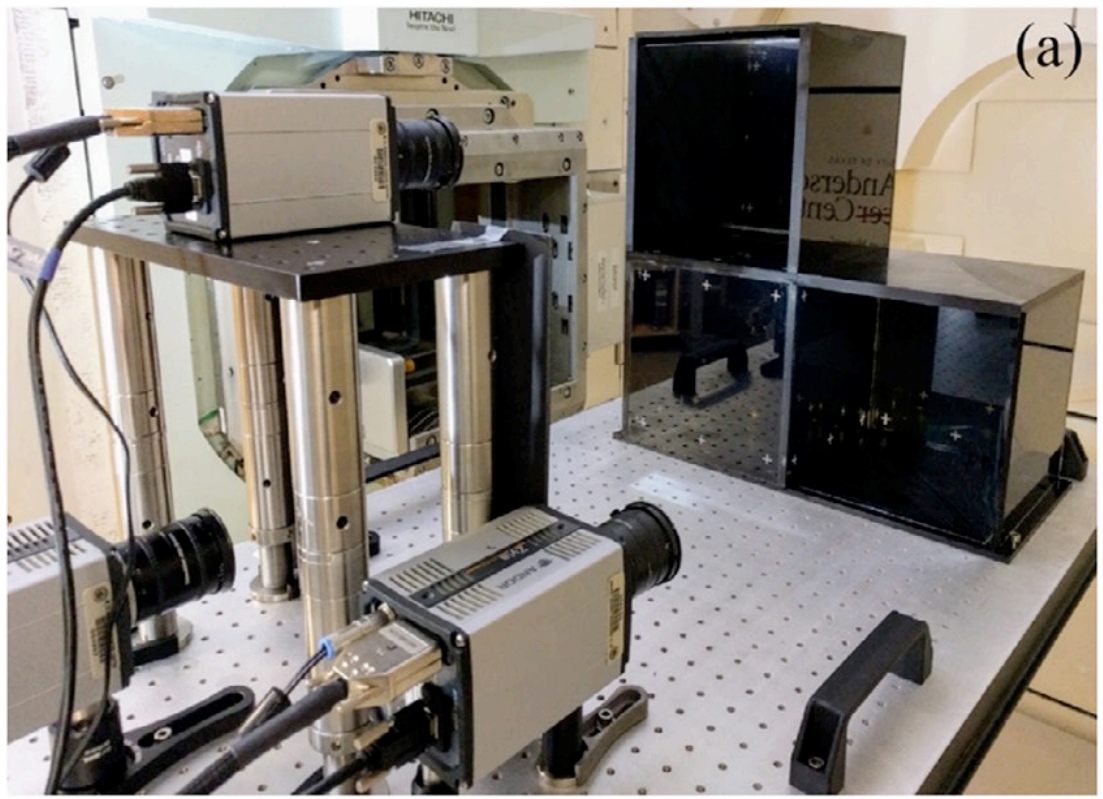


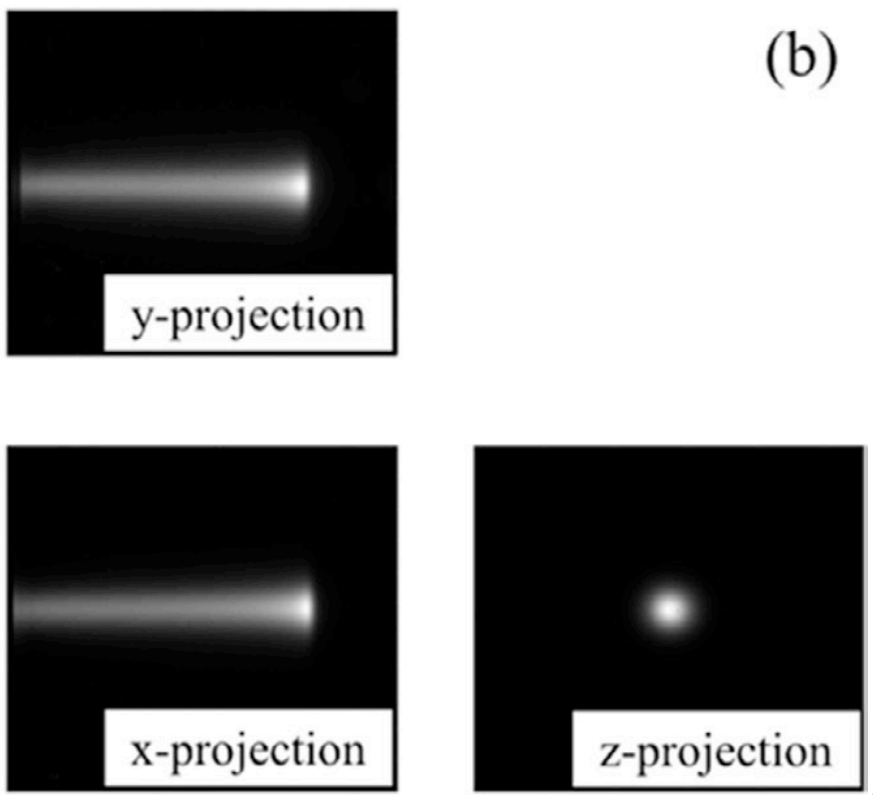
IOP Publishing | Institute of Physics and Engineering in Medicine Physics in Medicine & Biology

Phys. Med. Biol. **62** (2017) 5652–5667 https://doi.org/10.1088/1361-6560/aa780b

Performance characterization of a 3D liquid scintillation detector for discrete spot scanning proton beam systems

Chinmay D Darne[1], Fahed Alsanea[1], Daniel G Robertson[2], Narayan Sahoo[1] and Sam Beddar[1,3]





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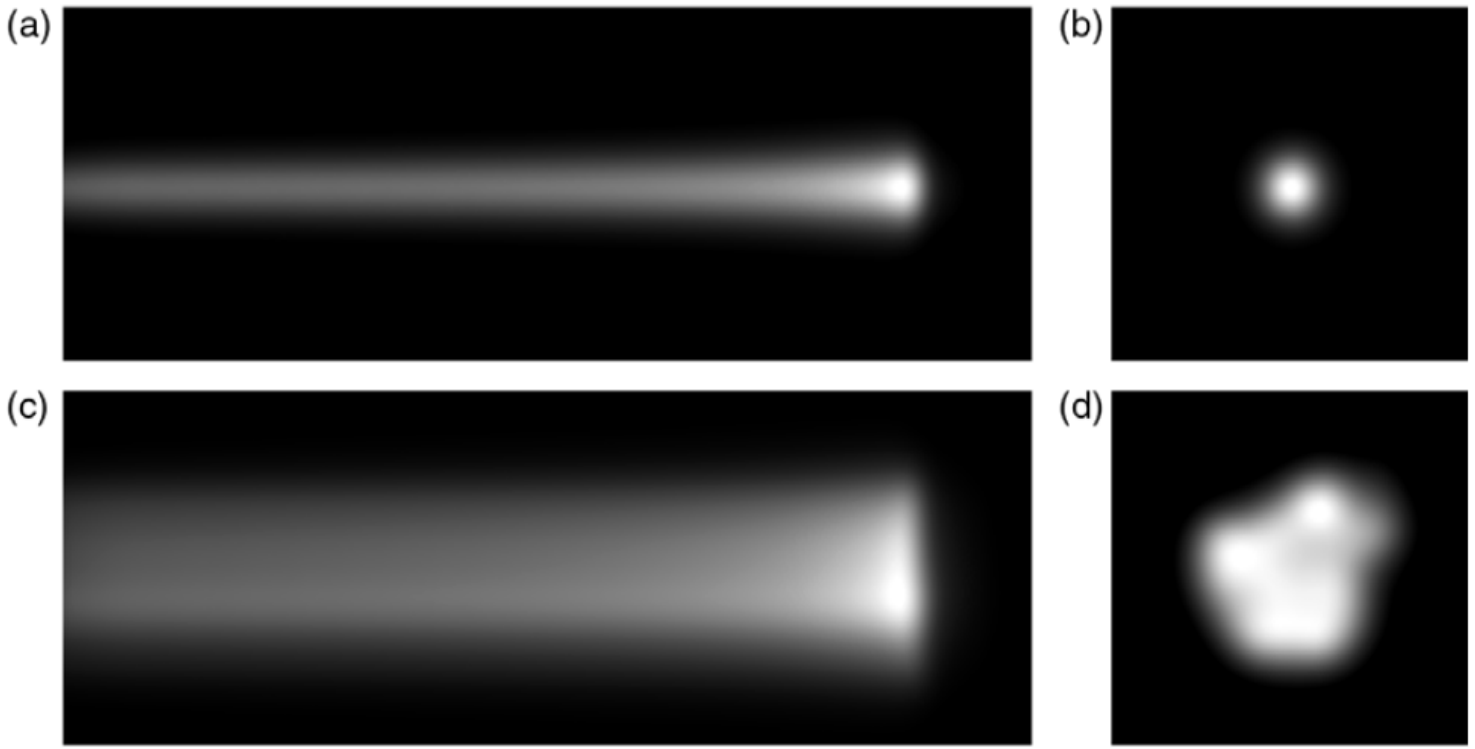
Physics in Medicine & Biology

Phys. Med. Biol. **59** (2014) 4477–4492

doi:10.1088/0031-9155/59/16/4477

3D reconstruction of scintillation light emission from proton pencil beams using limited viewing angles—a simulation study

CheukKai Hui[1], Daniel Robertson[1,2] and Sam Beddar[1,2]



IOP Conf. Series: Journal of Physics: Conf. Series **847** (2017) 012005 doi:10.1088/1742-6596/847/1/012005

Patient-specific quality assurance for spot scanning proton beams using a large-volume liquid scintillator detector

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The Department of Radiation Physics, University of Texas MD Anderson Cancer Center, Houston, TX 77030, USA

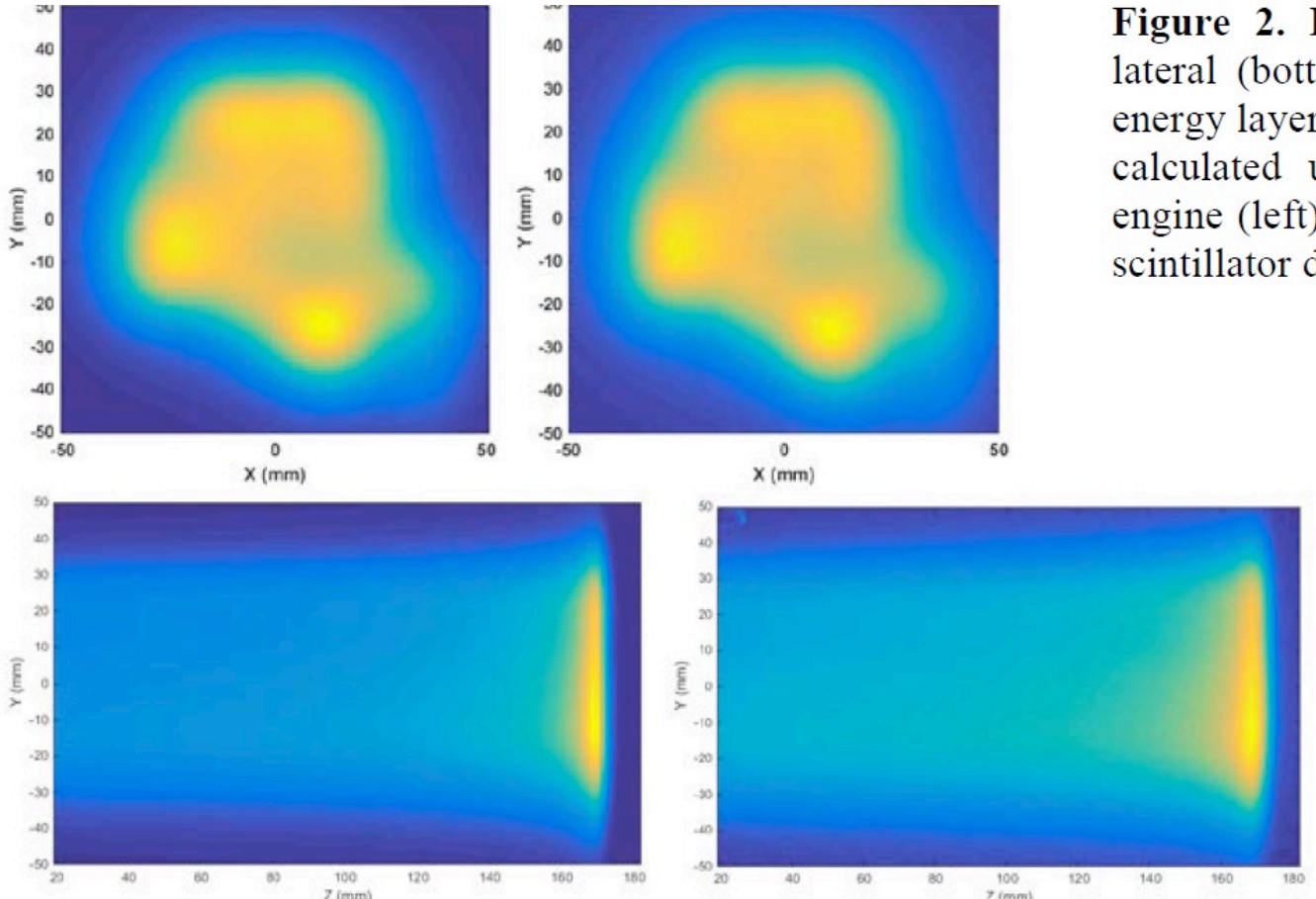

Figure 2. Beam's-eye view (top) and lateral (bottom) projections of a single energy layer of a prostate treatment plan, calculated using a Monte Carlo dose engine (left) and measured with a liquid scintillator detector (right).

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Physics in Medicine & Biology

Phys. Med. Biol. **61** (2016) 4156–4167

doi:10.1088/0031-9155/61/11/4156

Development of proton CT imaging system using plastic scintillator and CCD camera

Sodai Tanaka[1], Teiji Nishio[2,3], Keiichiro Matsushita[2], Masato Tsuneda[4], Shigeto Kabuki[5] and Mitsuru Uesaka[6]

Physics in Medicine & Biology

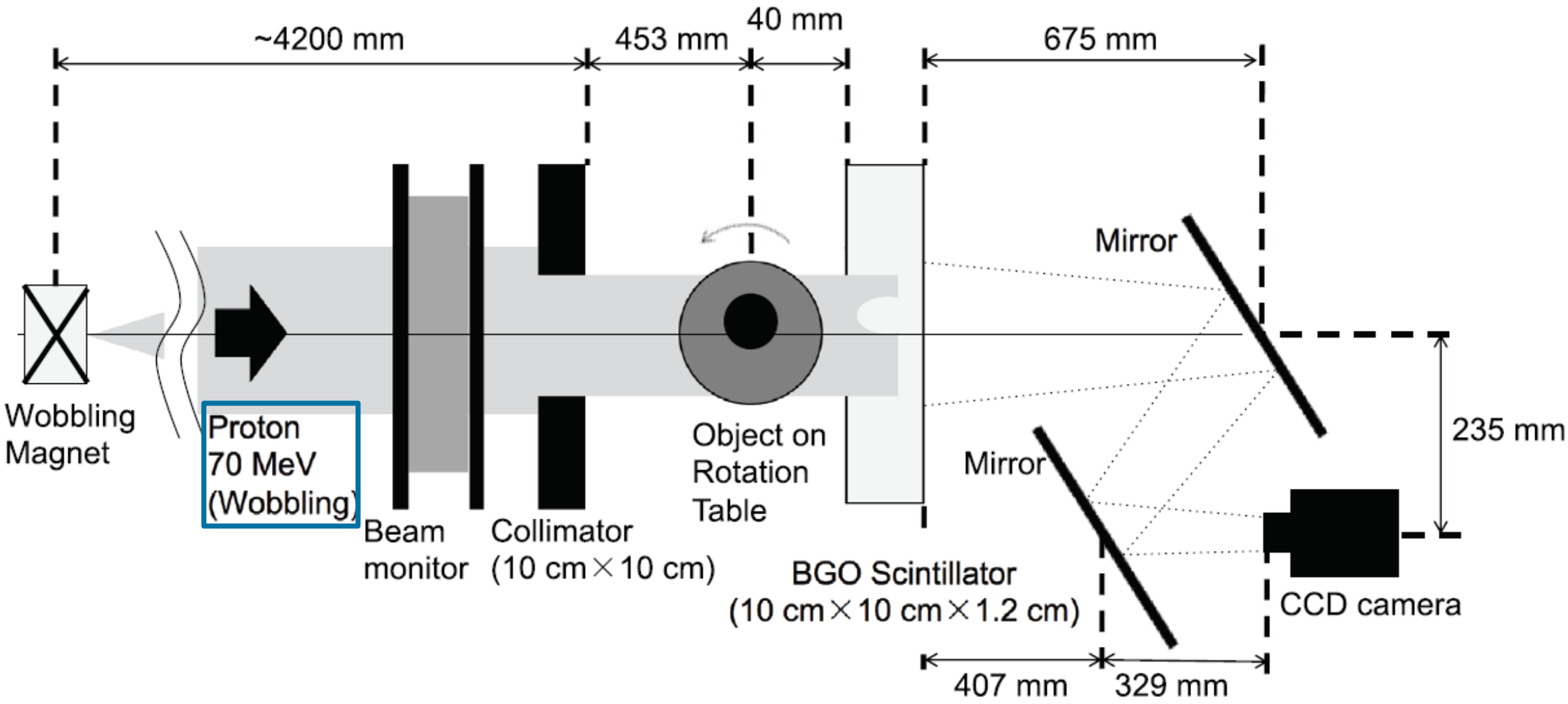
IPEM Institute of Physics and Engineering in Medicine

PAPER

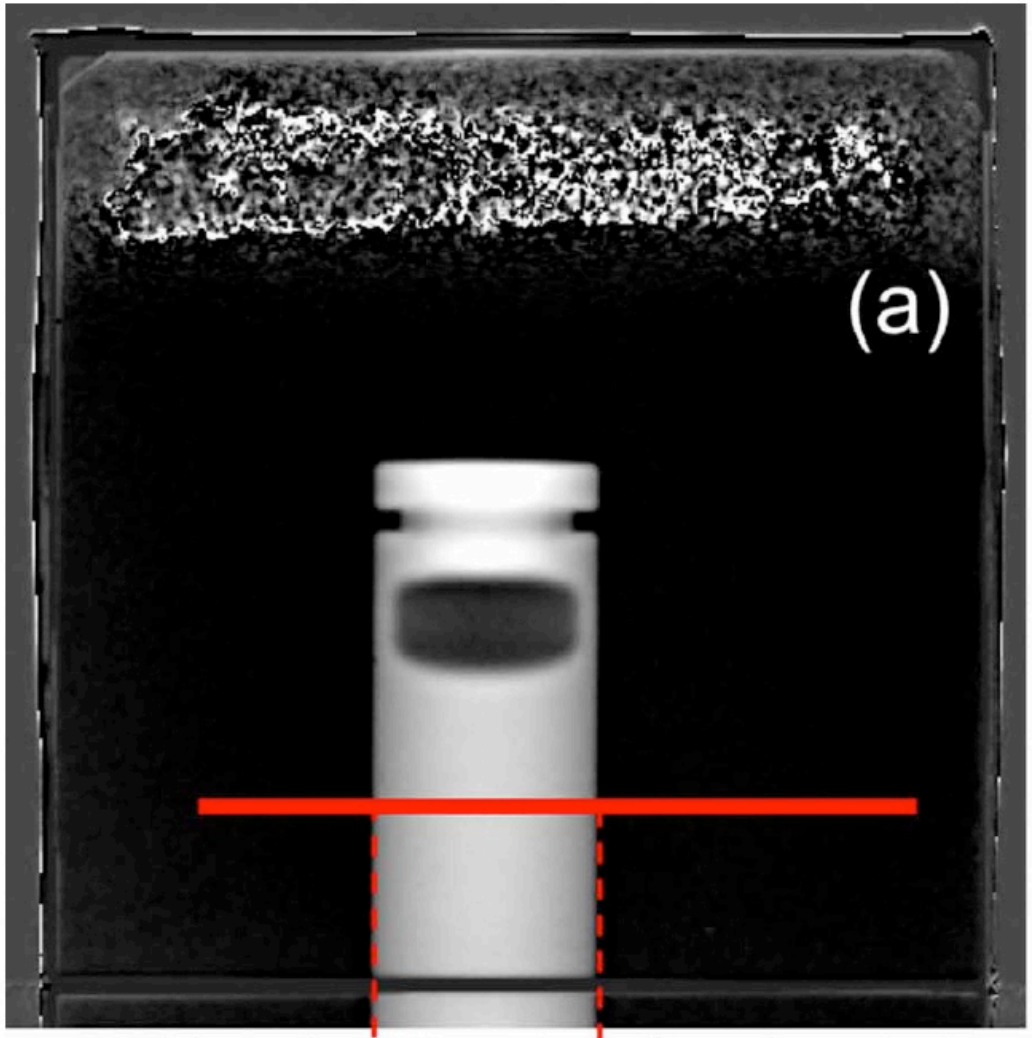
Improved proton CT imaging using a bismuth germanium oxide scintillator

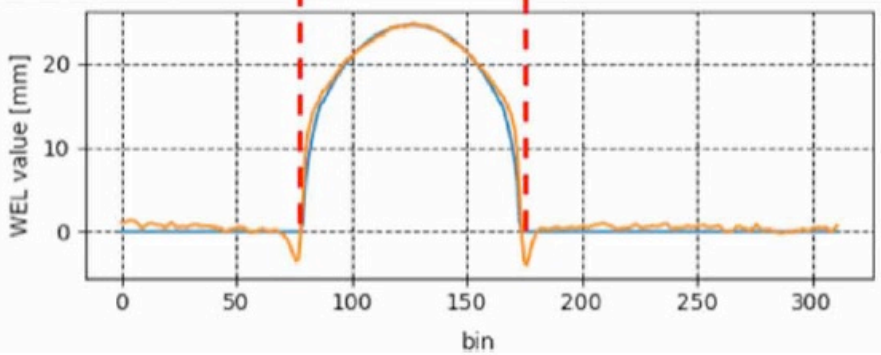
Sodai Tanaka[1], Teiji Nishio[2], Masato Tsuneda[3,4], Keiichiro Matsushita[5], Shigeto Kabuki[6] and Mitsuru Uesaka[7]

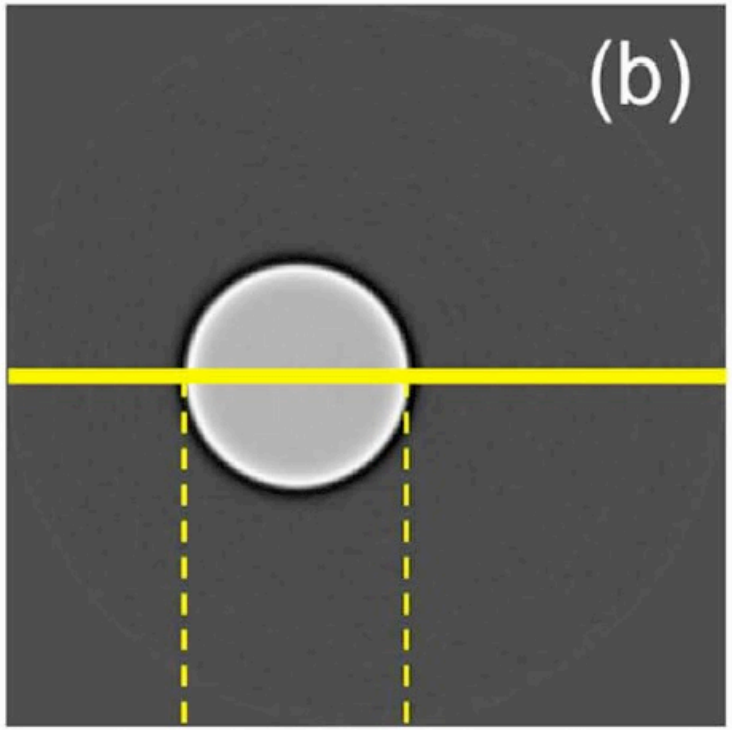
TANAKA ET AL. (2018)

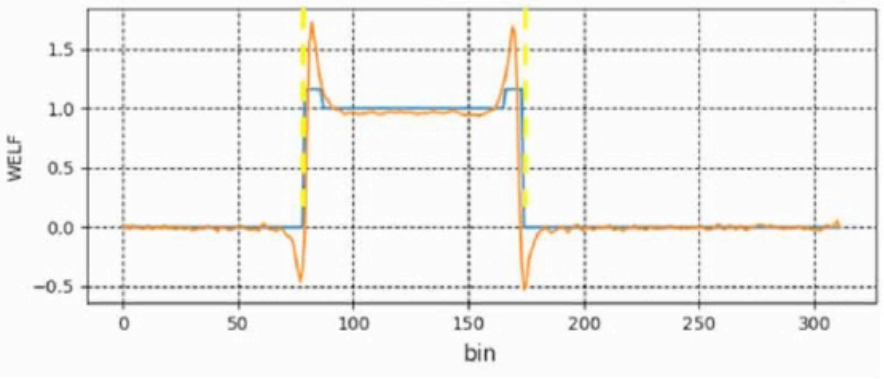


TANAKA ET AL. (2018)





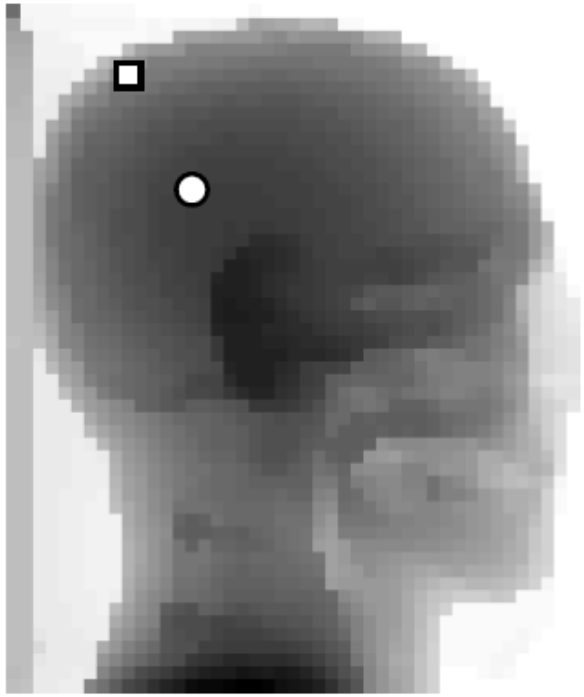




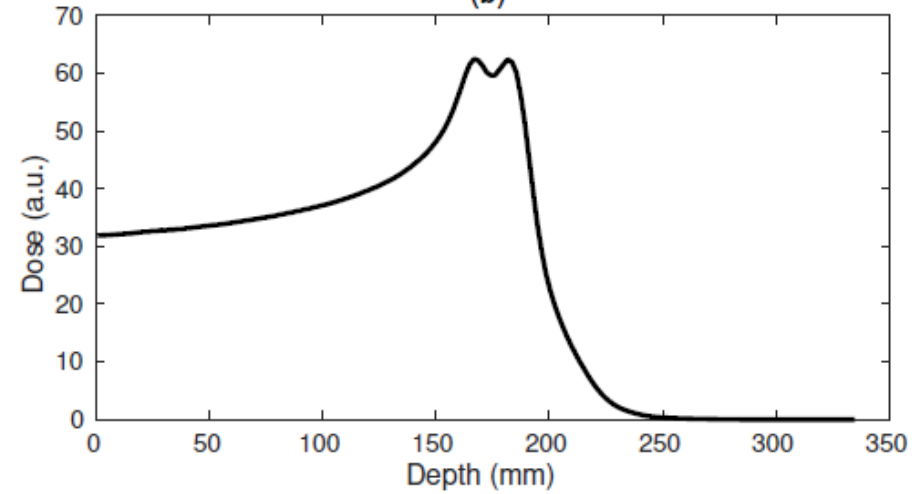
WATER EQUIVALENT THICKNESS ESTIMATION VIA SPARSE DECONVOLUTION OF PROTON RADIOGRAPHY DATA

Sylvain Deffet, Benoît Macq*, François Vander Stappen† and Paolo Farace‡*

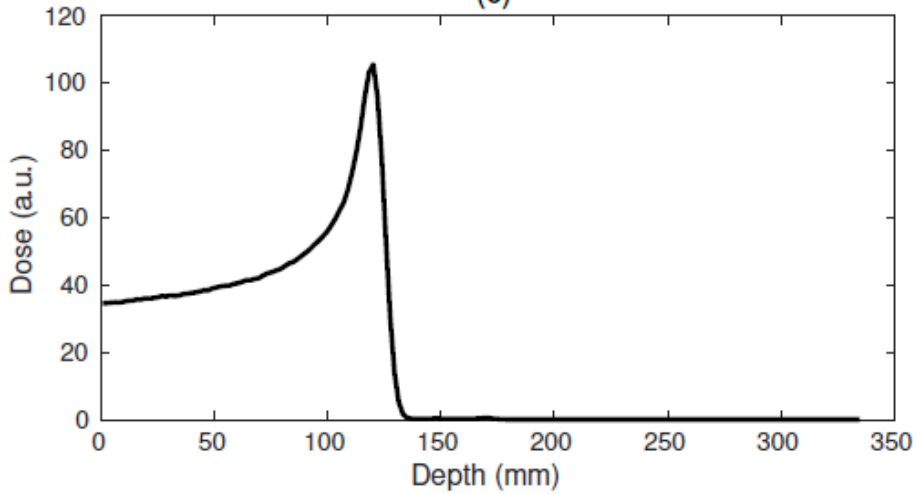
(a)



(b)



(c)



2

MOTIVATION

CLINICAL AND TECHNICAL

CLINICAL MOTIVATION

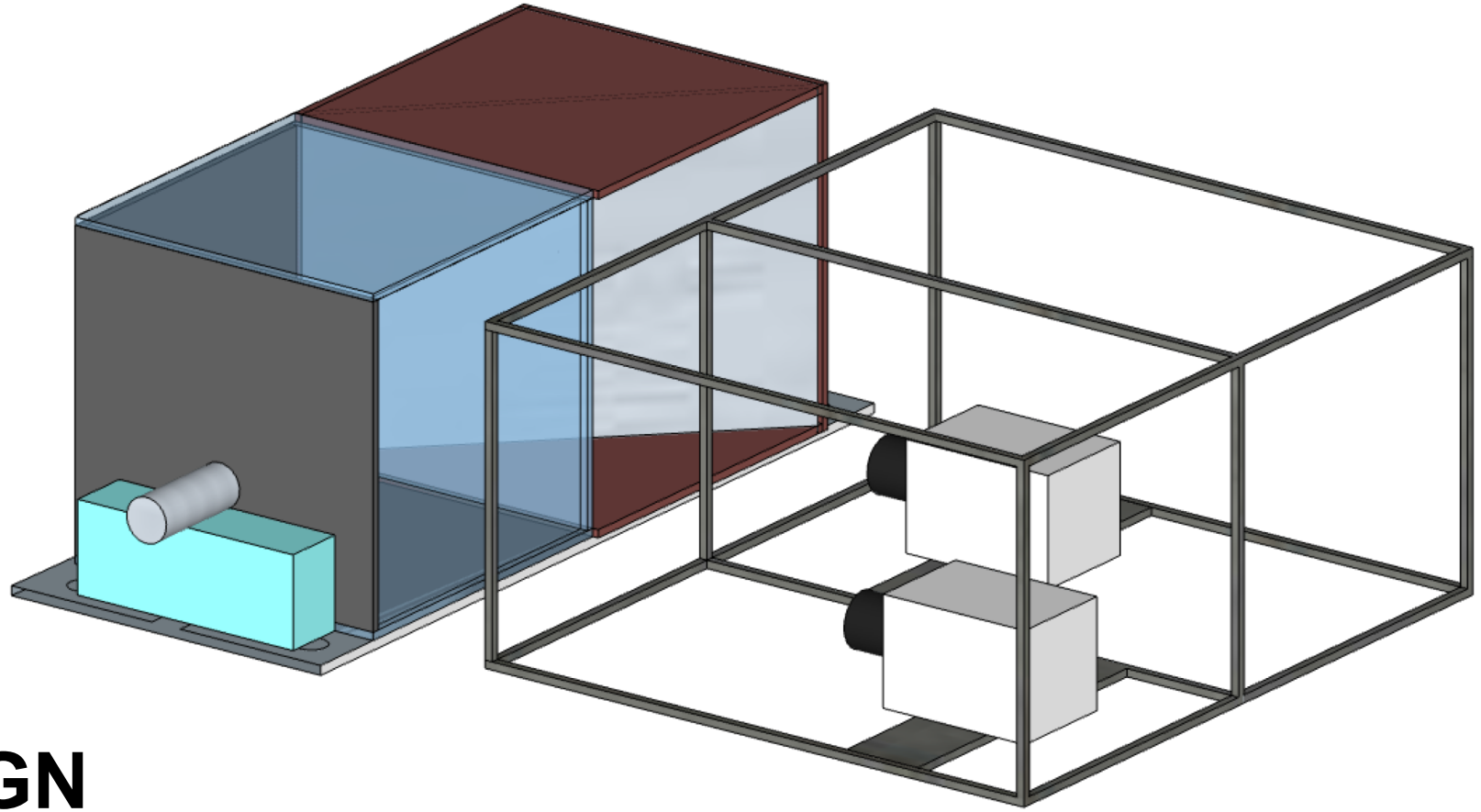
- Stopping power uncertainty
  - Decrease range uncertainty margins
  - Utilize distal edge of Bragg peak for organ sparing
- Image guidance
  - Beam's-eye-view image
  - Volumetric imaging at isocenter
- Adaptive radiation therapy
  - Detect changes in patient/tumor anatomy over the course of treatment

TECHNICAL MOTIVATION

WHY SCINTILLATORS AND DIGITAL CAMERAS?

- **It's what we know**
- **Simplicity and cost**
  - "Off-the-shelf" electronics
  - Few components
  - Simple assembly and operation
- **Clinical integration**
  - Clinical beam delivery mode (no beam tuning for low fluence)
  - Fewer detector elements (distal only)

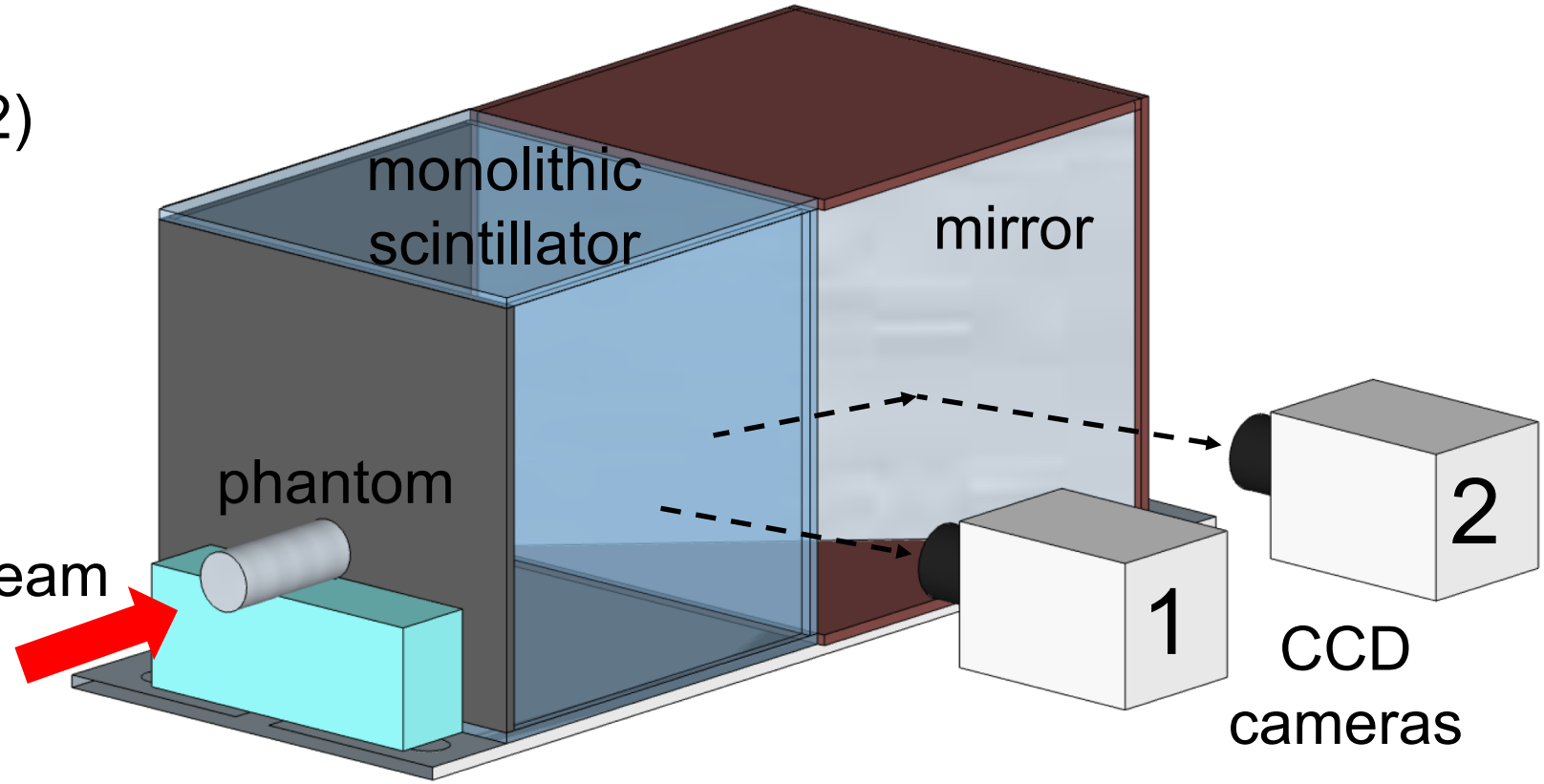
3



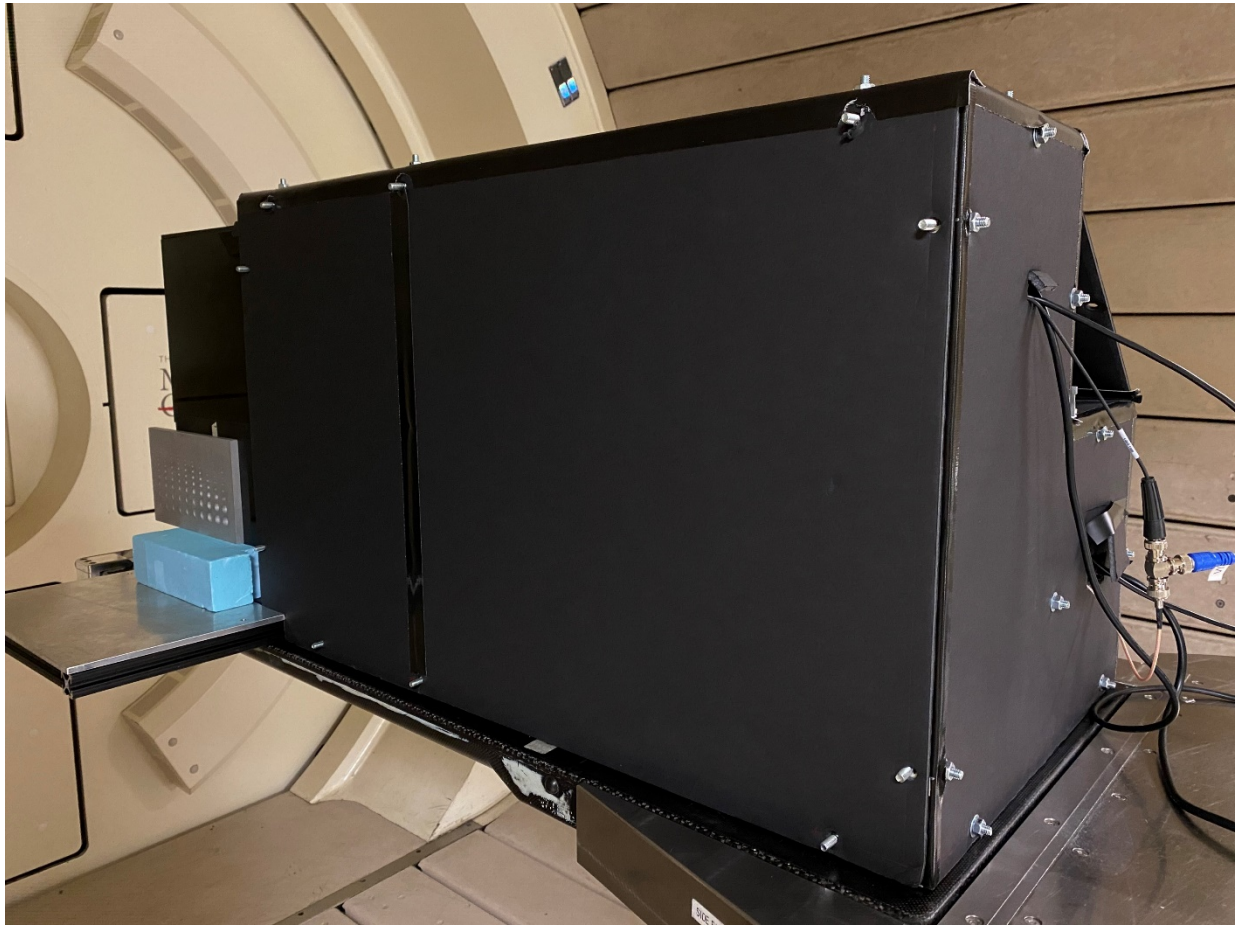
DETECTOR DESIGN

DETECTOR DESIGN

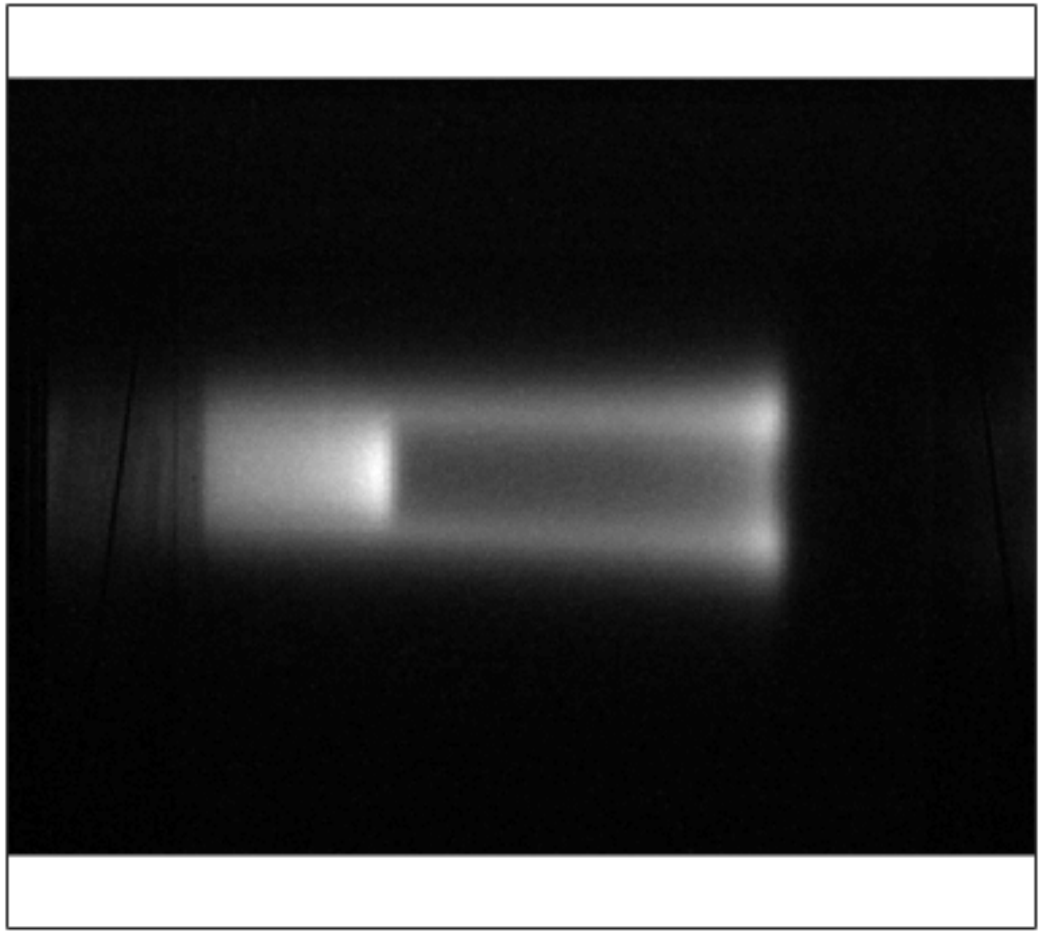
- Plastic scintillator
  - Green color to match camera spectral sensitivity
  - 20x20x20 cm^3
- Andor CCD cameras (2)
  - Beam's-eye-view
  - Lateral view (PDD)

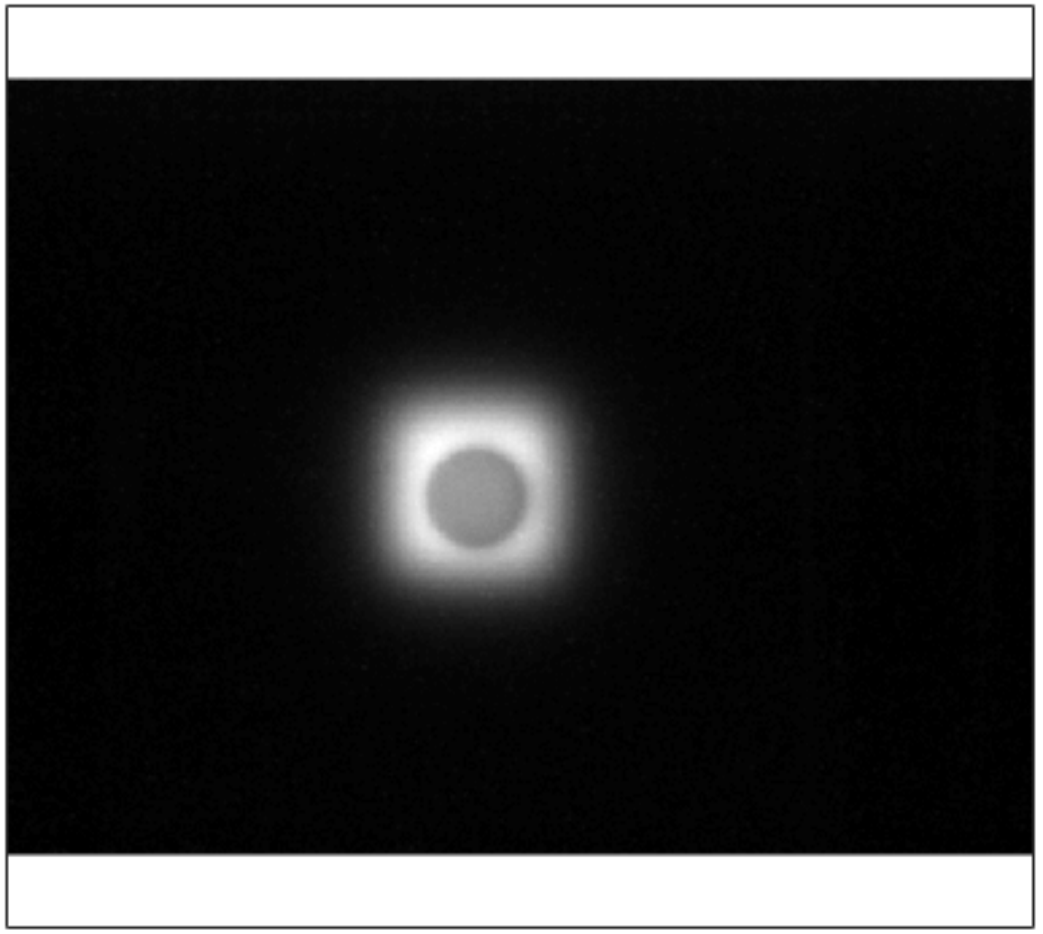


DETECTOR DESIGN

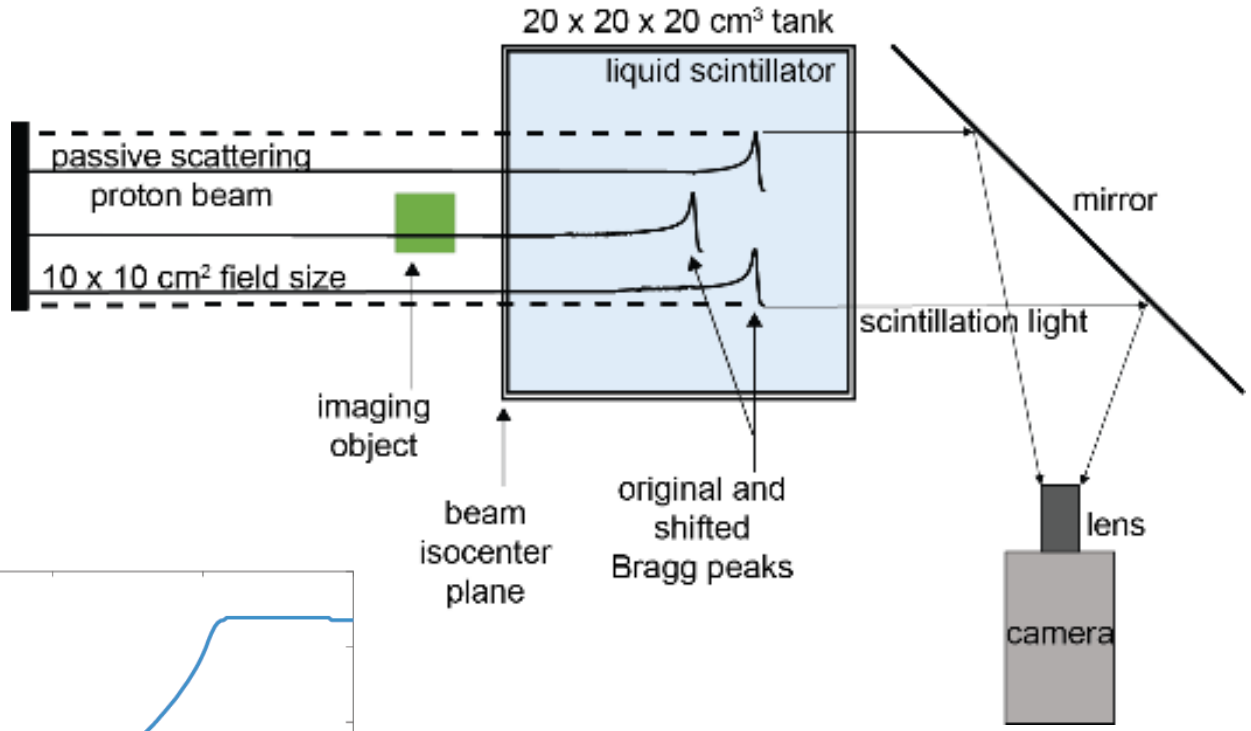


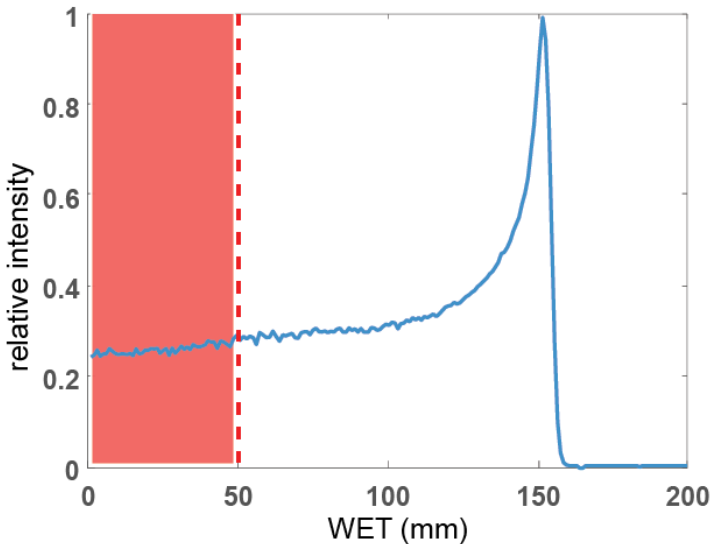
SAMPLE RAW DATA

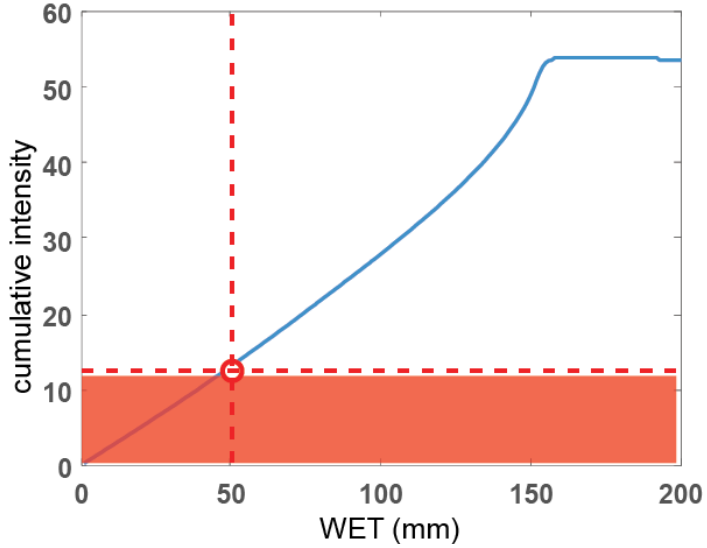




RADIOGRAPH RECONSTRUCTION METHOD







4

SIMULATION STUDIES

Physics in Medicine & Biology

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31 October 2020

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16 June 2021

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9 July 2021

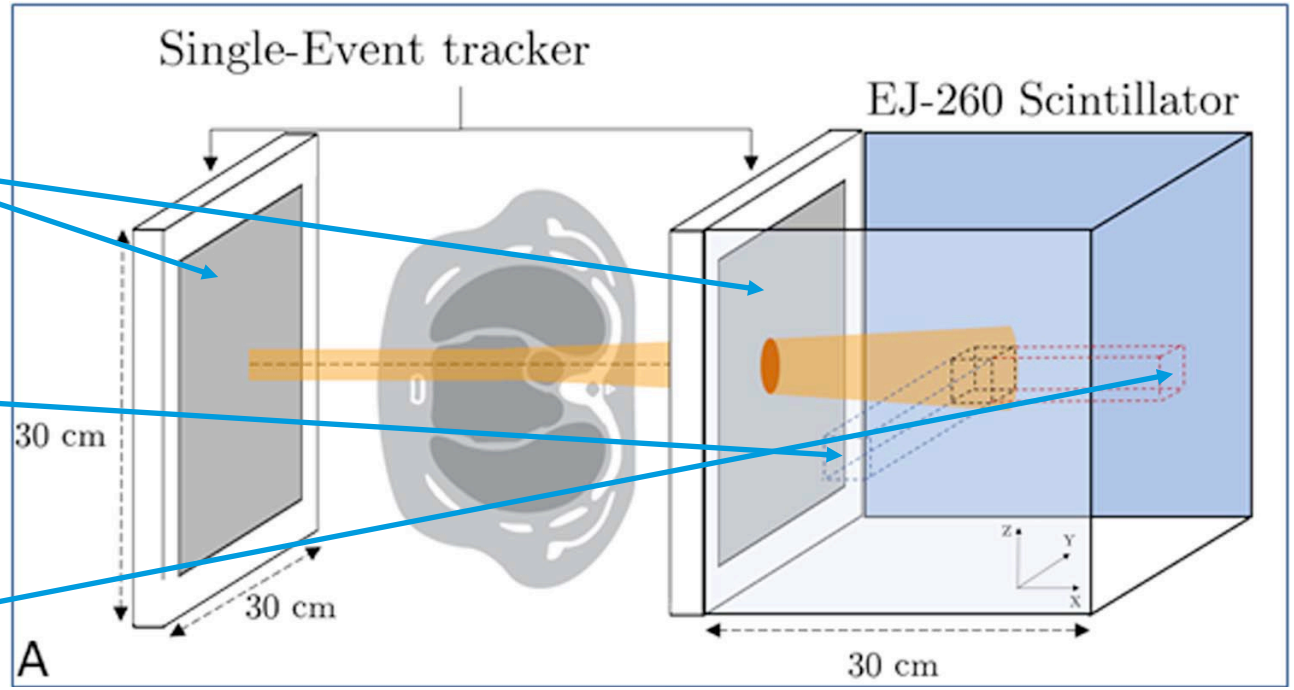
PAPER

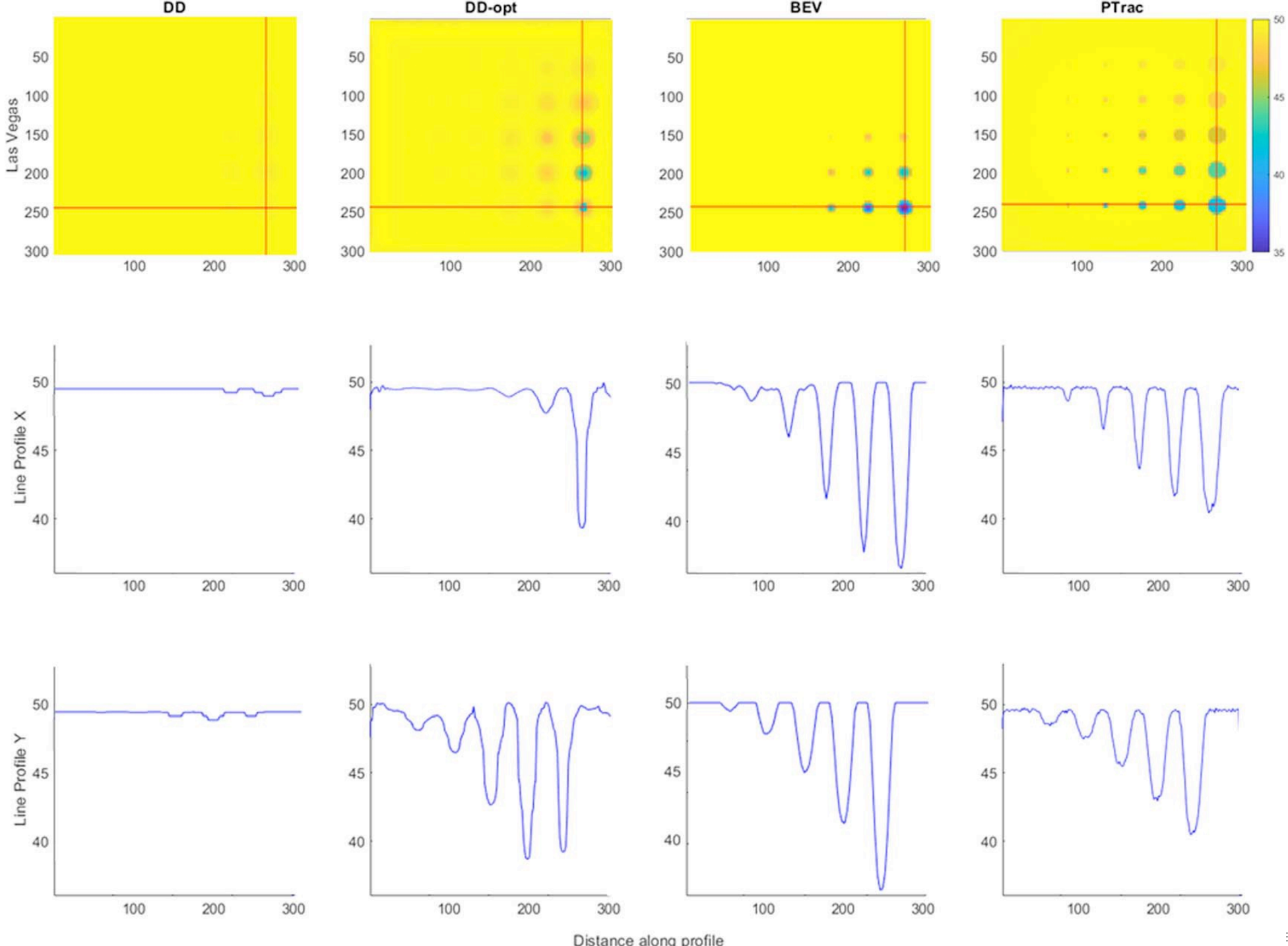
Image quality evaluation of projection- and depth dose-based approaches to integrating proton radiography using a monolithic scintillator detector

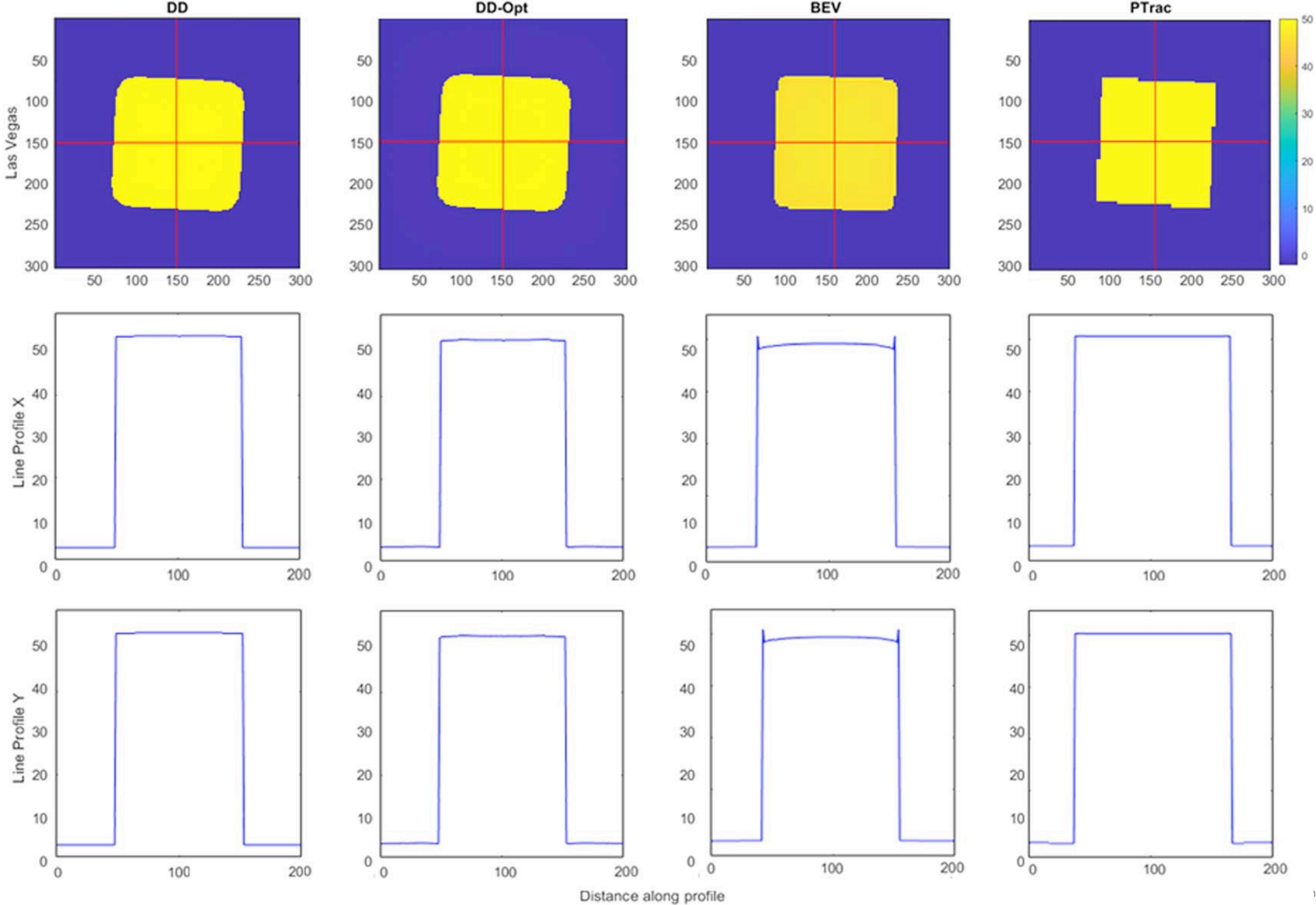
Irwin Tendler[1], Daniel Robertson[2], Chinmay Darne[1], Rajesh Panthi[1], Fahed Alsanea[1], Charles-Antoine Collins-Fekete[3] and Sam Beddar[1,4,*]

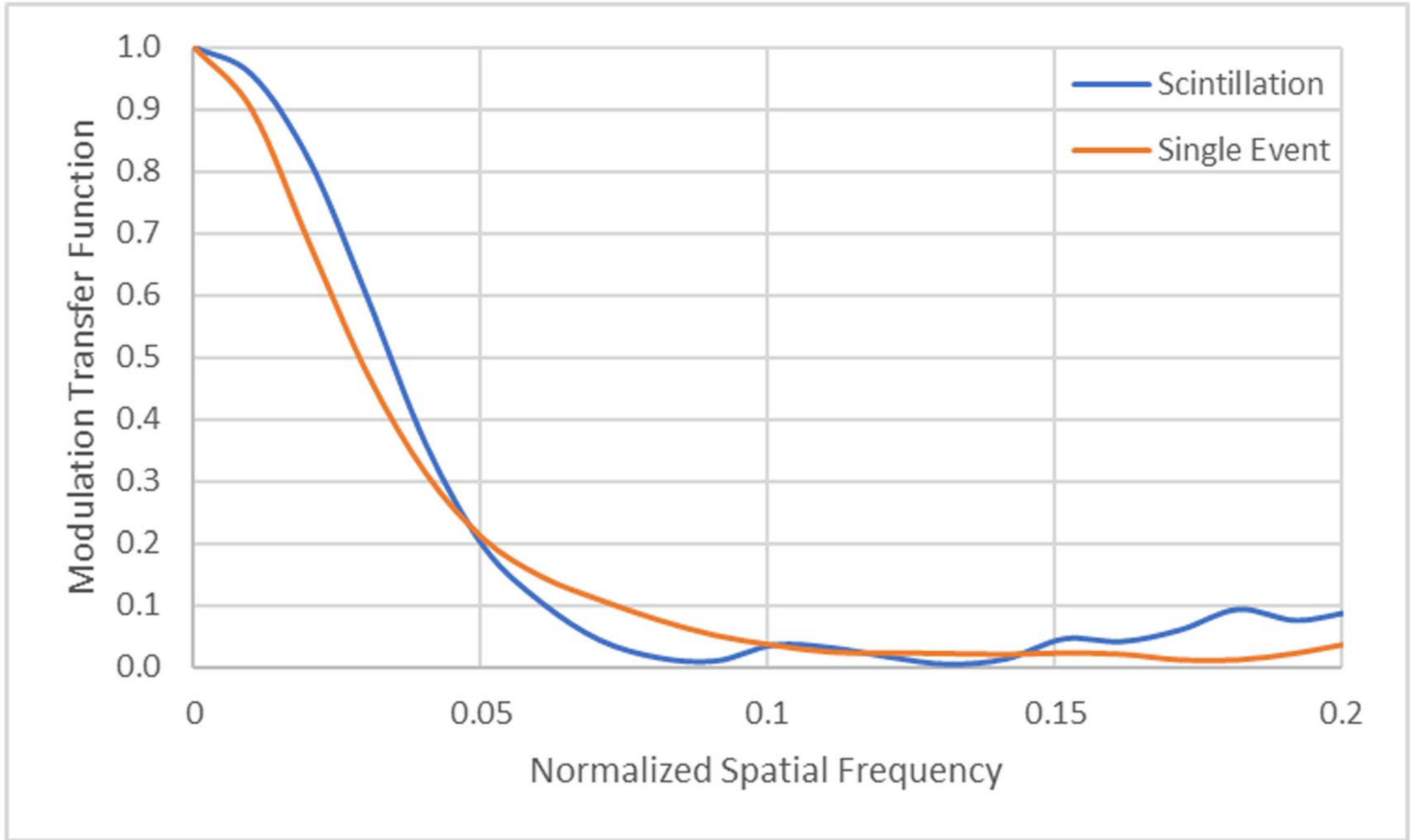
MONTE CARLO SIMULATION STUDY

- Geant4
  - 30x30x30 cm^3 scintillator
- 4 image reconstruction methods:
  - List-mode PR binned at the rear tracker
    - Collins-Fekete et al 2016, 2020
  - Depth dose profile ranging
    - Naive (no optimization)
    - Curvelet minimization (Deffet et al 2020)
  - Distal projection




DD
DD-opt
BEV
PTrac
Las Vegas
Line Profile X
Line Profile Y
Distance along profile


DD
DD-Opt
BEV
PTrac
Las Vegas
Line Profile X
Line Profile Y
Distance along profile



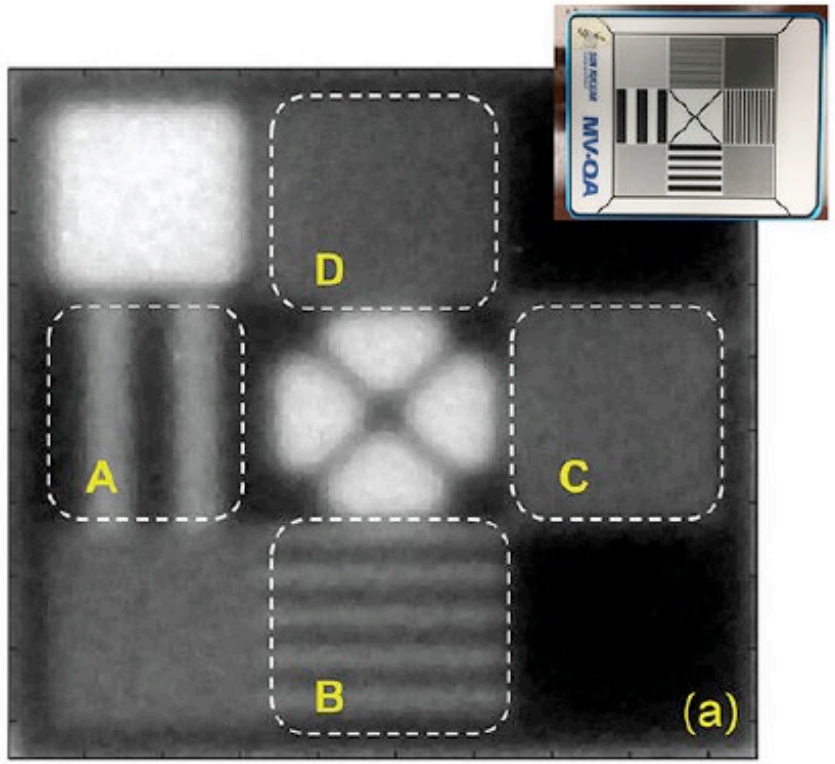
5

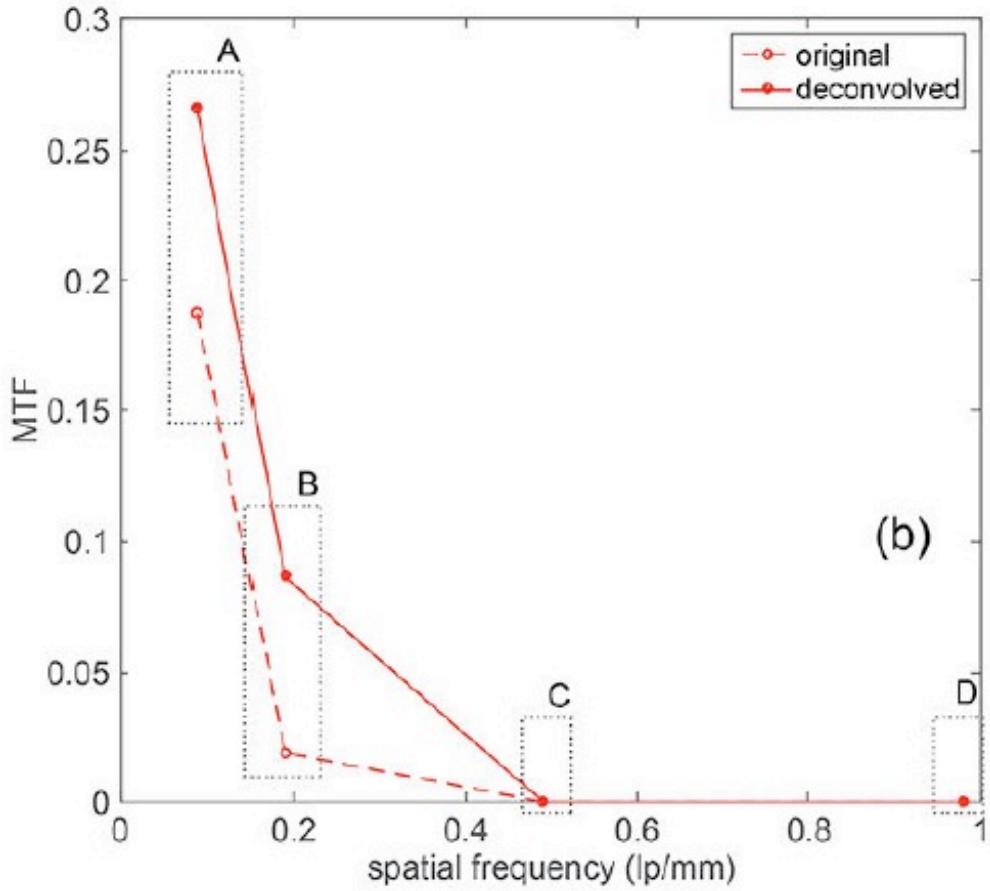
EXPERIMENTAL STUDIES

Published in final edited form as:
Biomed Phys Eng Express. 2019 July ; 5(4): . doi:10.1088/2057-1976/ab2e4a.

A proton imaging system using a volumetric liquid scintillator: a preliminary study

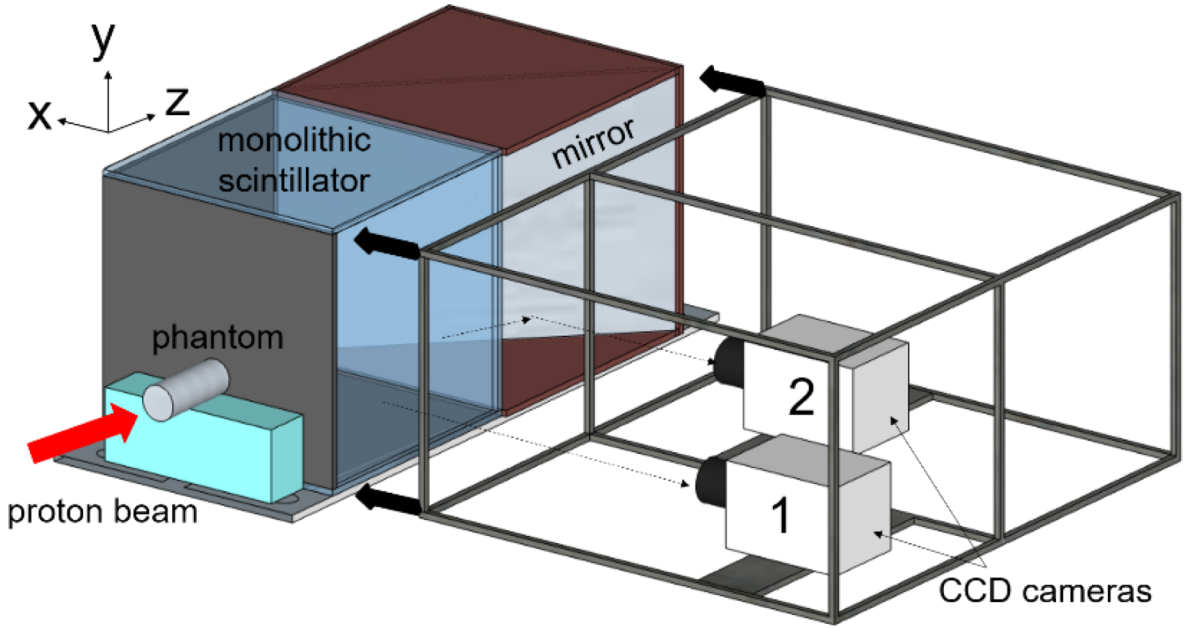
Chinmay D Darne[1], **Fahed Alsanea**[1,2], **Daniel G Robertson**[3], **Fada Guan**[1], **Tinsu Pan**[2,4], **David Grosshans**[5], **Sam Beddar**[1,2]





EXPERIMENTAL STUDIES

- Detector setup:
  - 20x20x20 cm3 plastic scintillator
  - 2 CCD cameras (lateral and beam's-eye-view)
- Scanning proton beam
  - MD Anderson G3 (large spot size)
  - Clinical beam mode
- CIRS Hounsfield Unit phantom plugs
  - Solid water, adipose, cortical bone, lucite
- Image reconstruction methods
  - PDD range with curvelet optimization
  - Distal projection



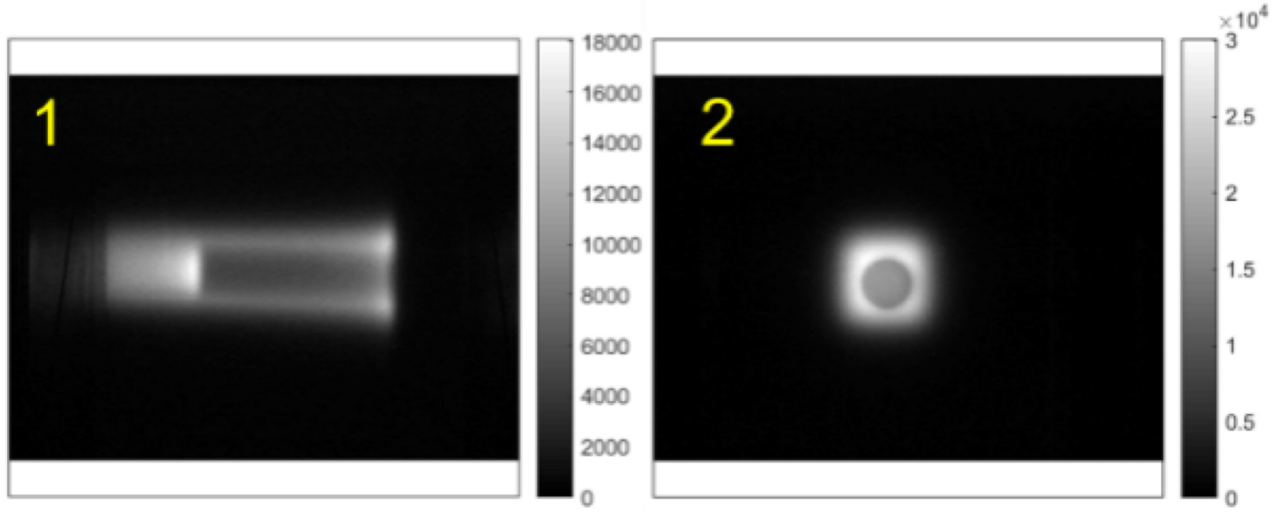
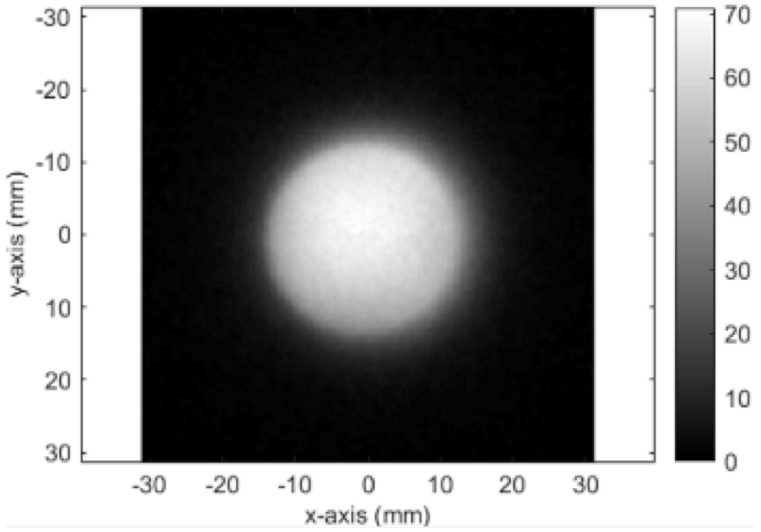
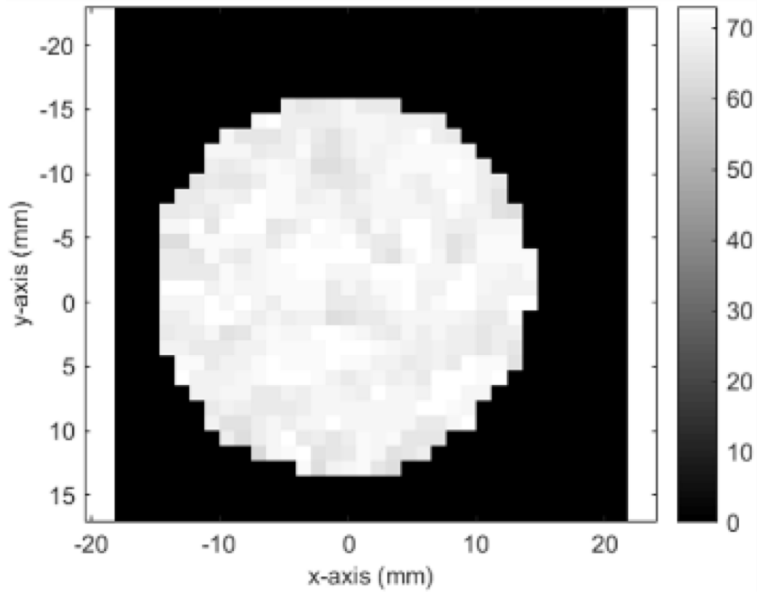


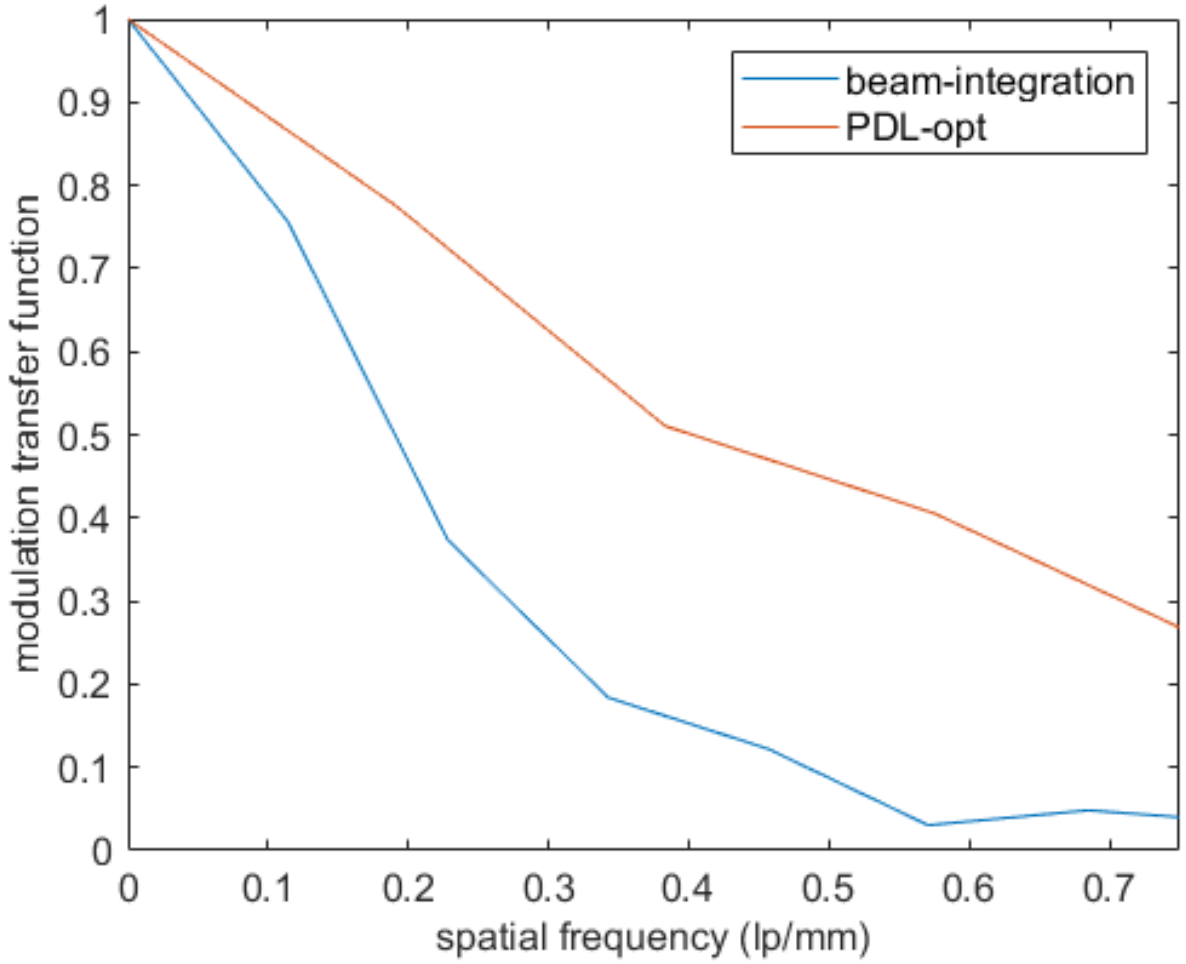
IMAGE QUALITY COMPARISON

Distal Projection

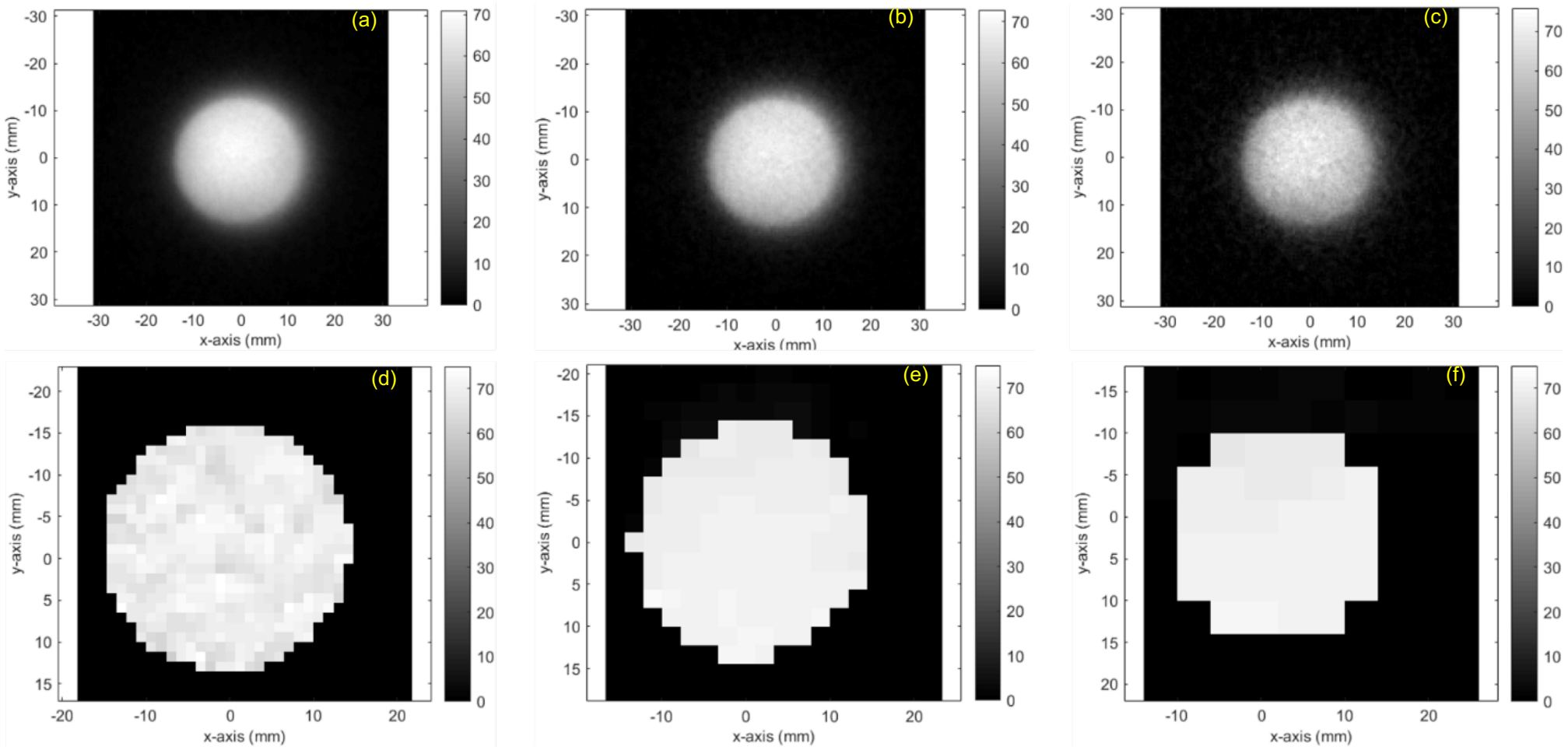


PDD range with curvelet optimization





PROTON BEAM SPACING



2.5 mm

5 mm

10 mm

WET ACCURACY

Material	Distal Projection	PDD Range w/ Optimization
Solid water	-0.18 (±0.35) %	-0.29 (±3.11) %
Adipose	-0.11 (±0.51) %	-0.15 (±2.64) %
Cortical bone	-2.94 (±1.20) %	-0.75 (±6.11) %
Lucite	-1.65 (±0.35) %	0.36 (±3.93) %

Beam Spacing (mm)	Distal Projection	PDD Range w/ Optimization
2.5	0.02 %	-0.2 %
5	-0.75 %	0.45 %
10	1.43 %	0.44 %

QUESTIONS & ANSWERS