

# *Monitoring Beam and Position with Cherenkov Imaging*

**David J. Gladstone, Sc.D., FAAPM**

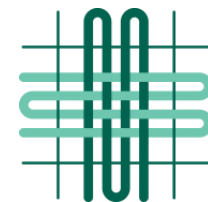
Thayer School of Engineering, Dartmouth College, Hanover, NH  
Geisel School of Medicine at Dartmouth, Hanover, NH



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ENGINEERING**



**Dartmouth  
Health**

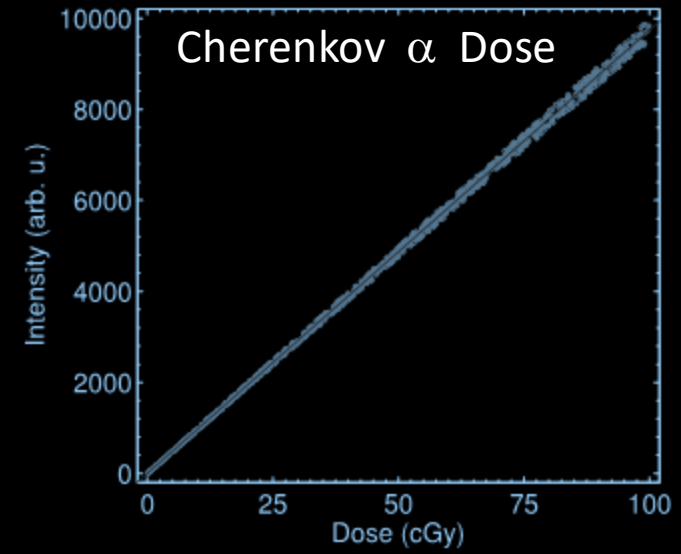
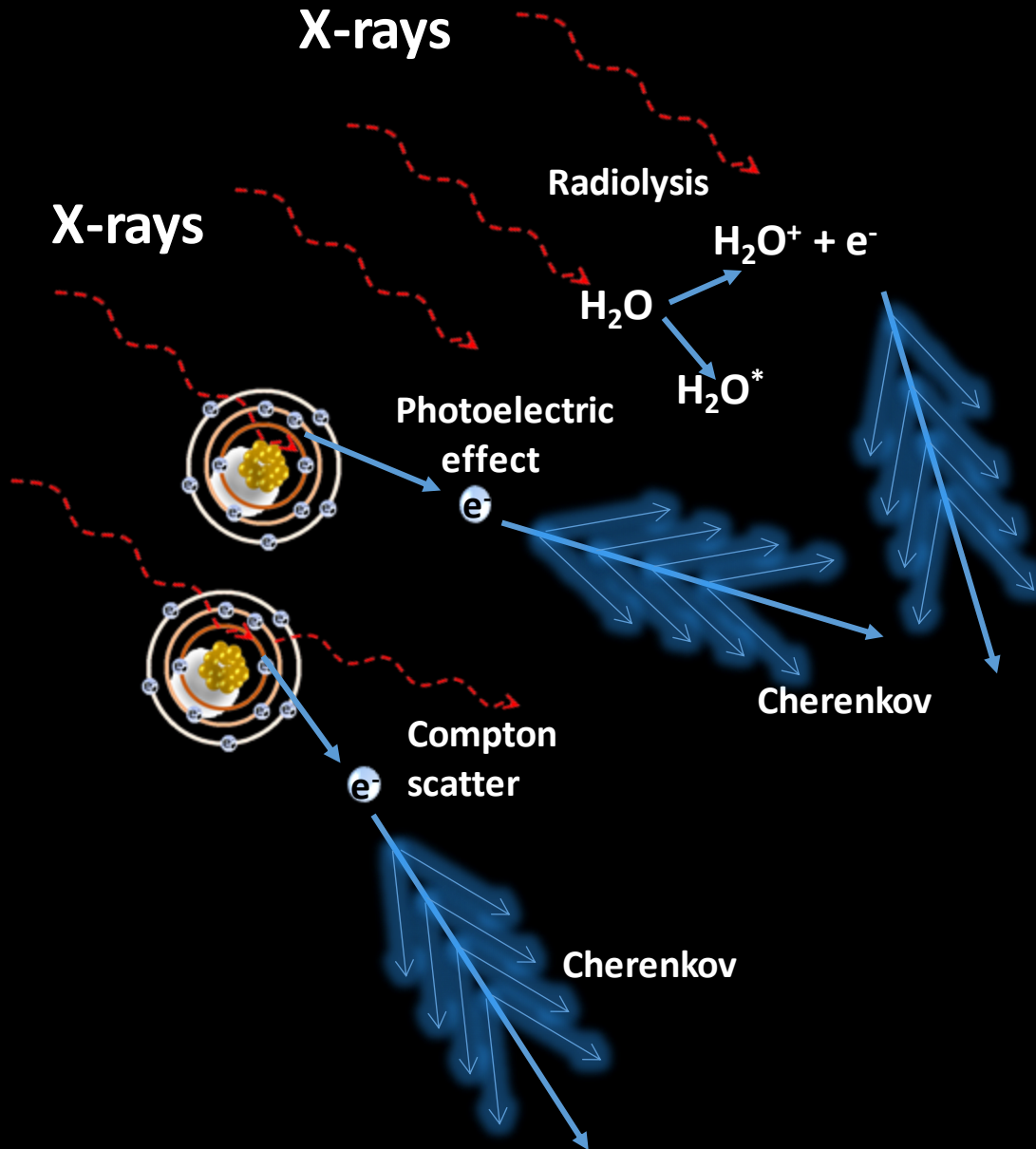
# *Disclosures*

Work is supported by  
NIH R01EB023909  
NIH 5P30 CA023108-41  
DoseOptics, LLC  
VisionRT

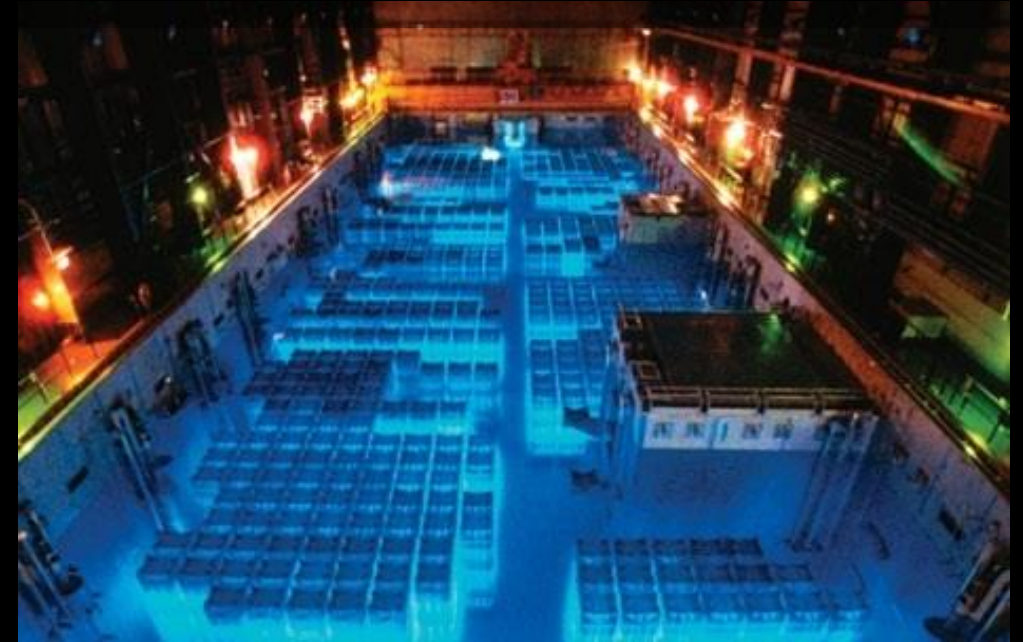
All human studies approved by Dartmouth Health IRB



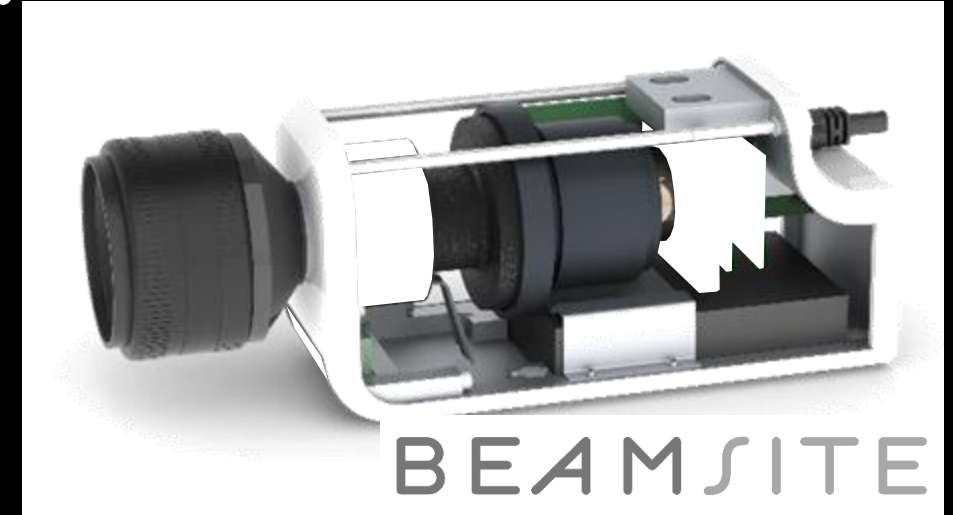
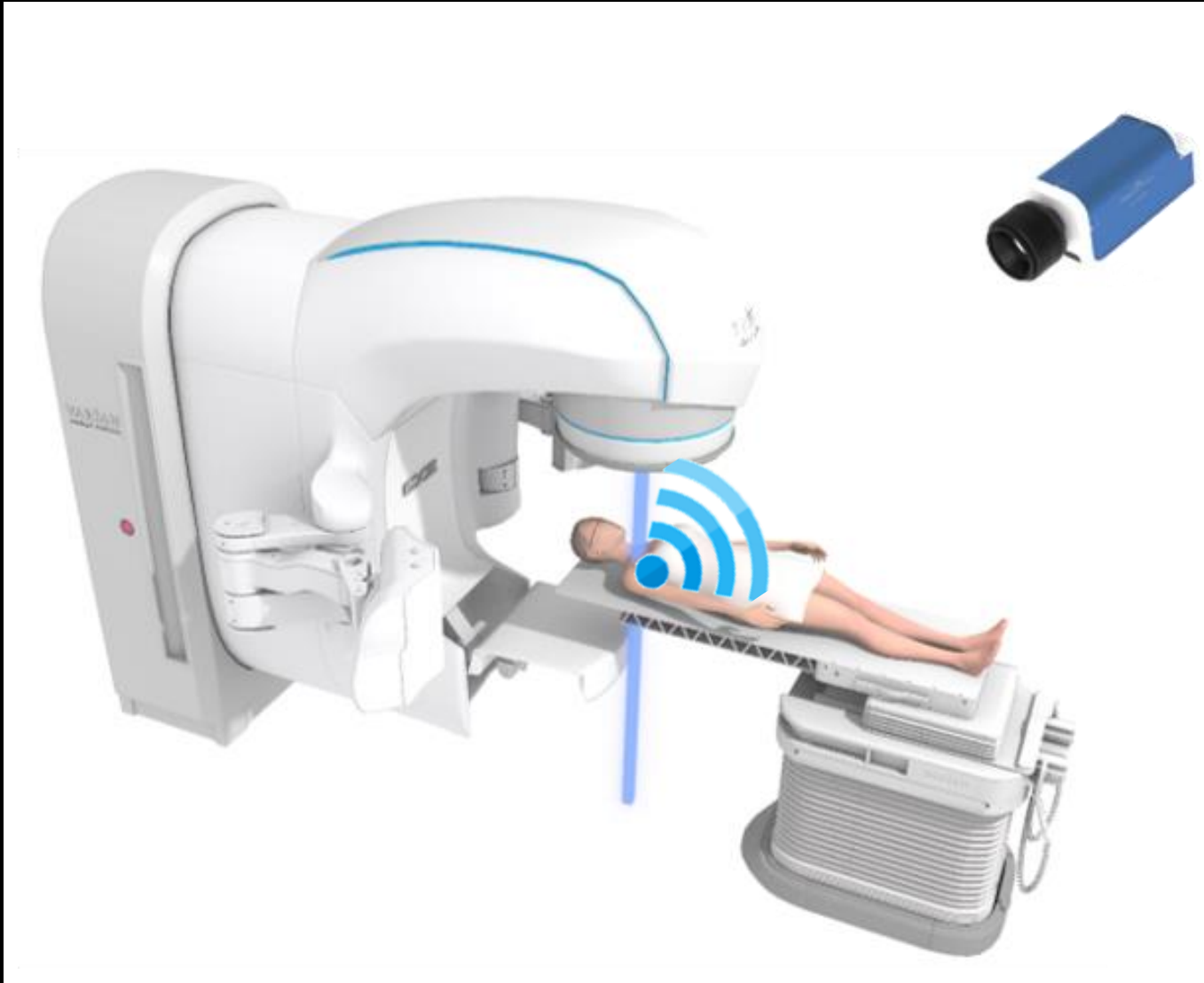
*Cherenkov light* is part of the MV radiation dose



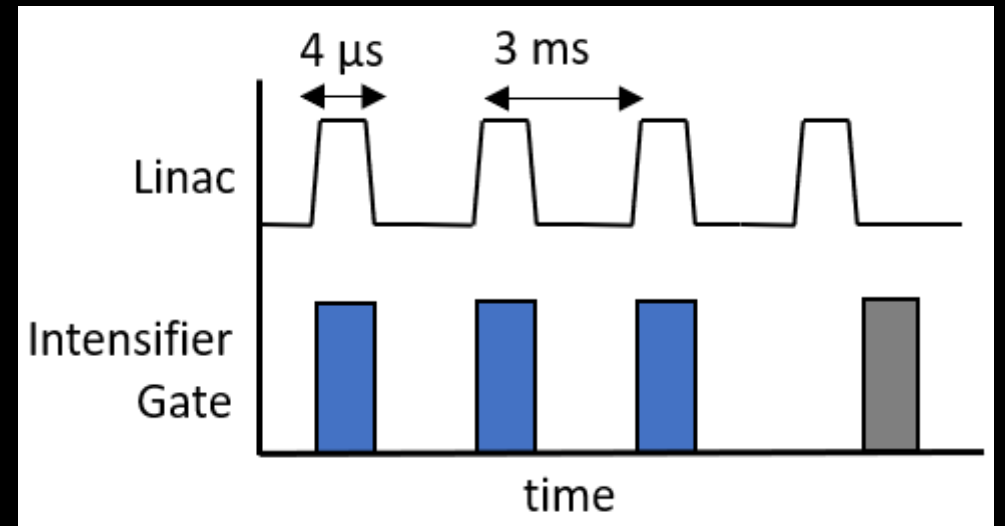
Cherenkov light from fission in nuclear fuel



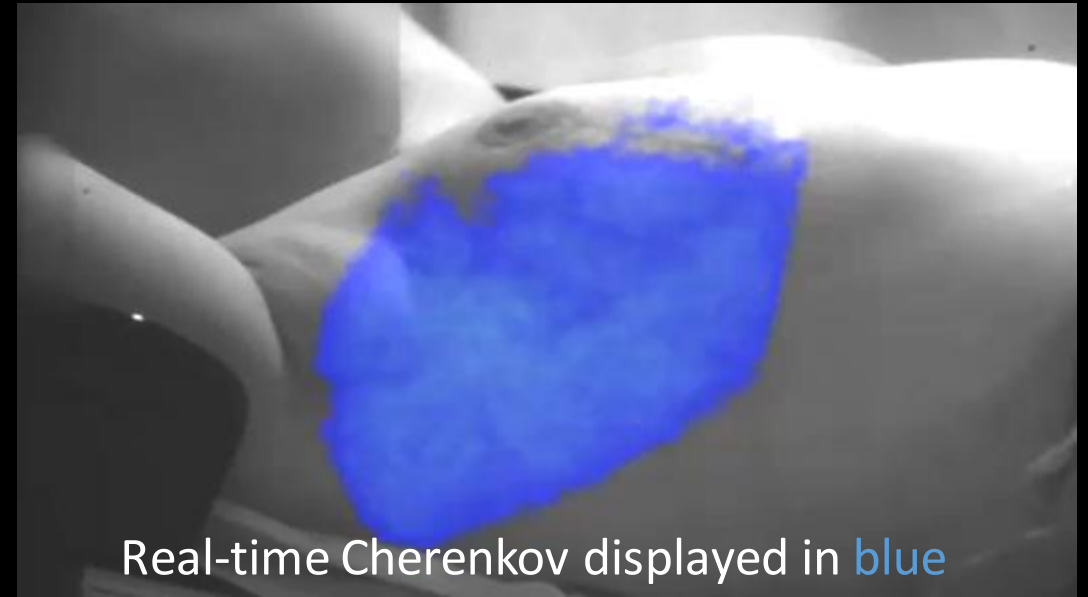
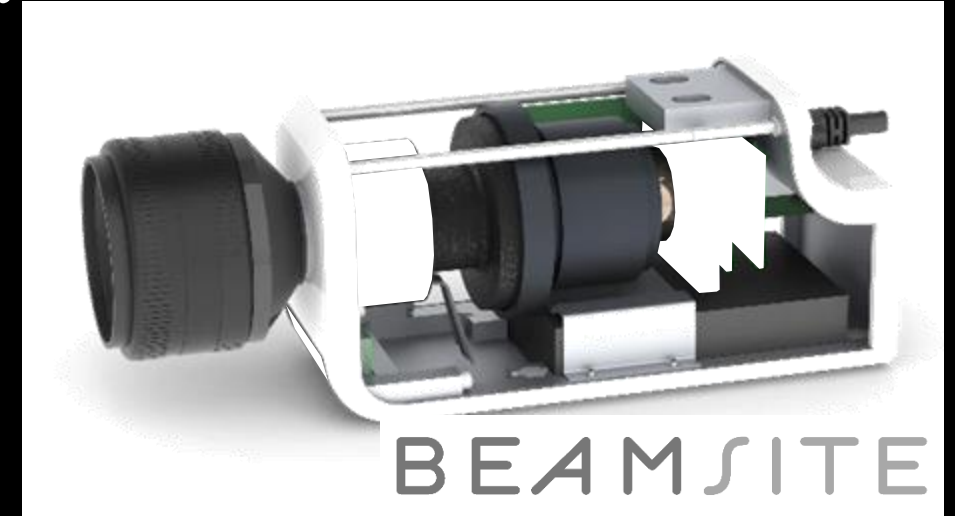
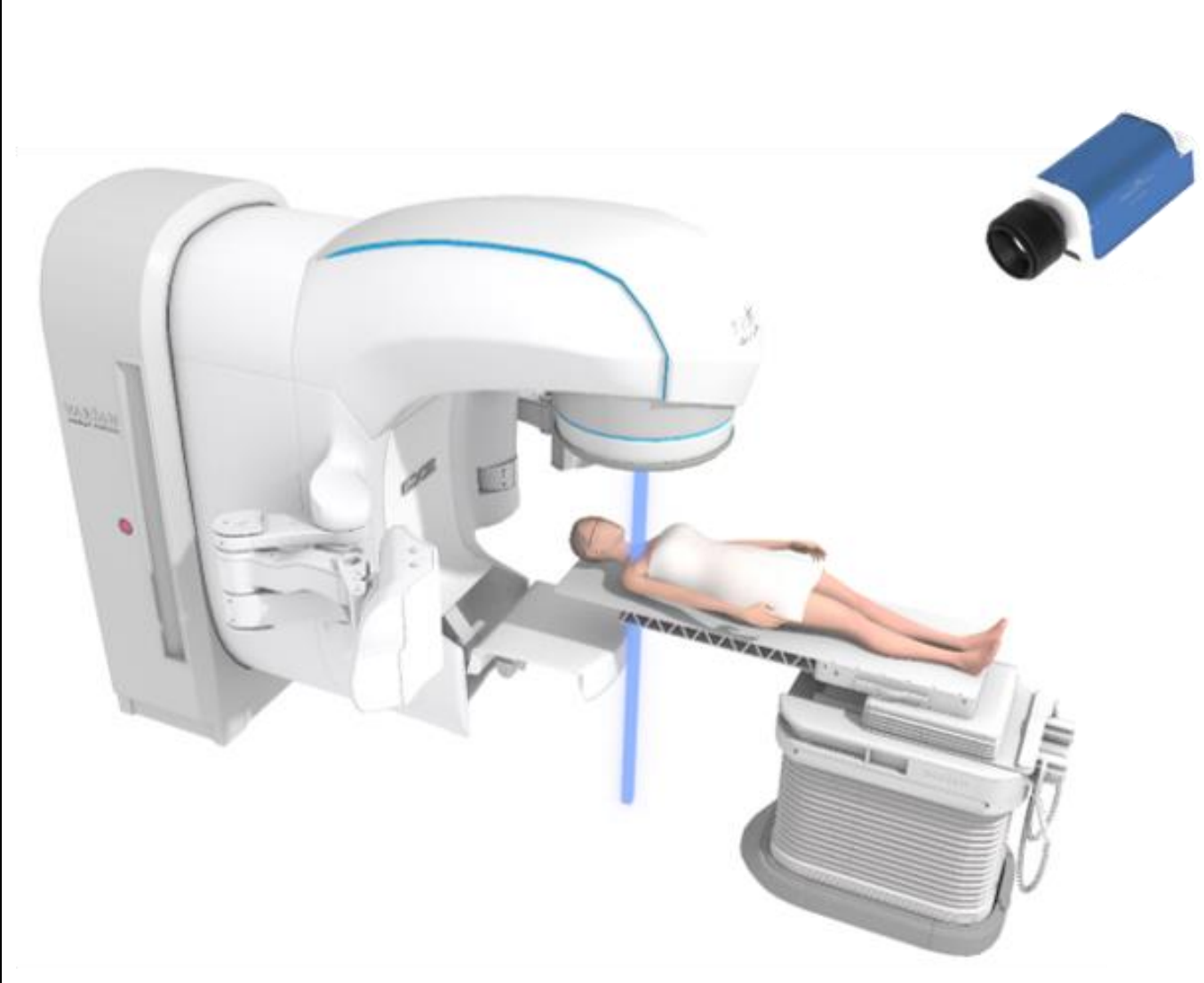
# *Cherenkov imaging from LINAC pulses!*



Camera auto triggers with each pulse

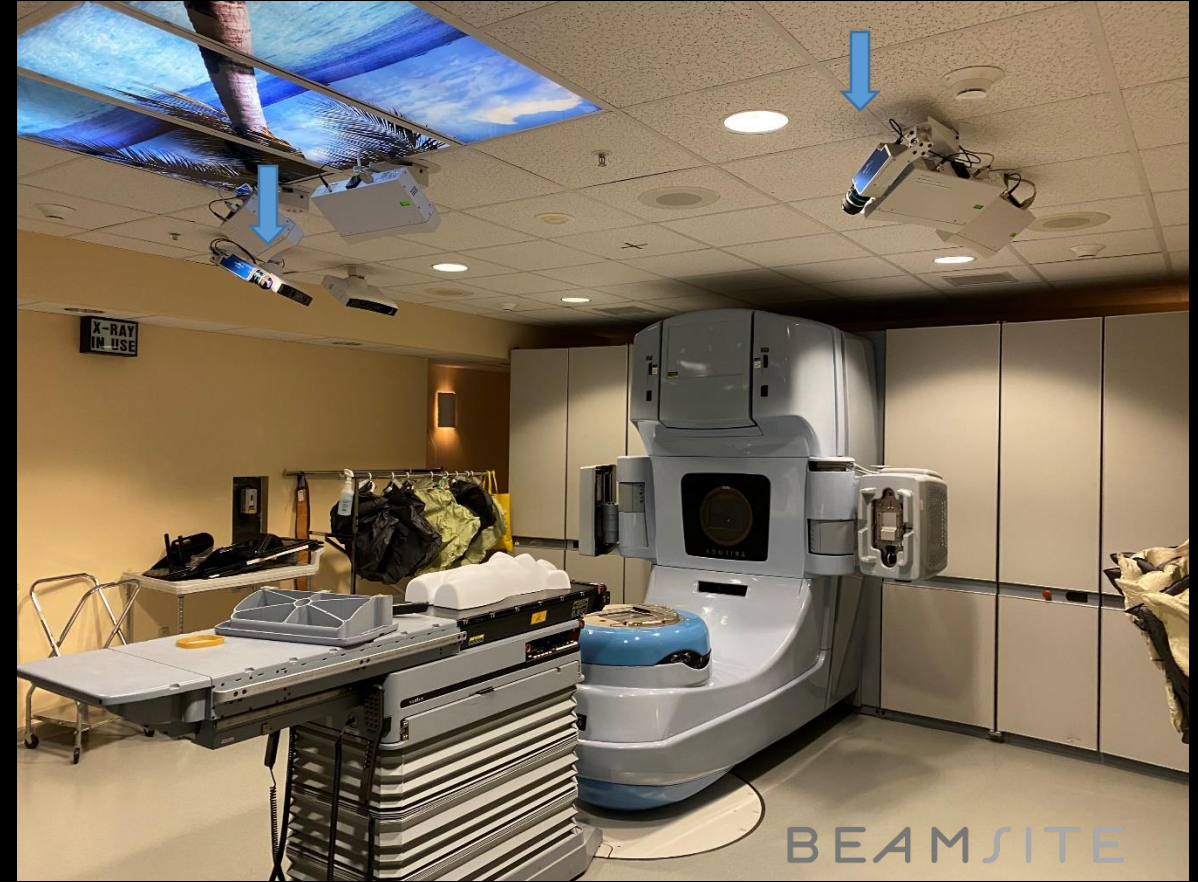


# *Cherenkov imaging from LINAC pulses!*





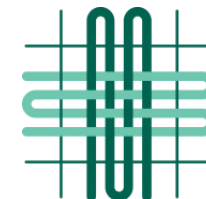
# Dartmouth Cancer Center installations



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# BEAMSITE

BeamSite [Dev] - DoseOptics - Dev M2



LIVE

REVIEW

TOGGLE CUMULATIVE

TAKE SCREENSHOT

VIEW SCREENSHOTS

HELP

\*patient breast treatment: 6MV & 10 MV – field in field



2020-10-27 10:14:24 Cam [19092406]

10:14:24

10:14:33

10:14:49

10:15:10

10:15:32

10:15:44

2020-10-27 10:14:24 Cam [00000105]

10:14:24

10:14:33

10:14:49

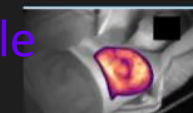
10:15:10

10:15:32

10:15:44

Real-time Cherenkov → blue

Cumulative Cherenkov → yellow-orange-purple





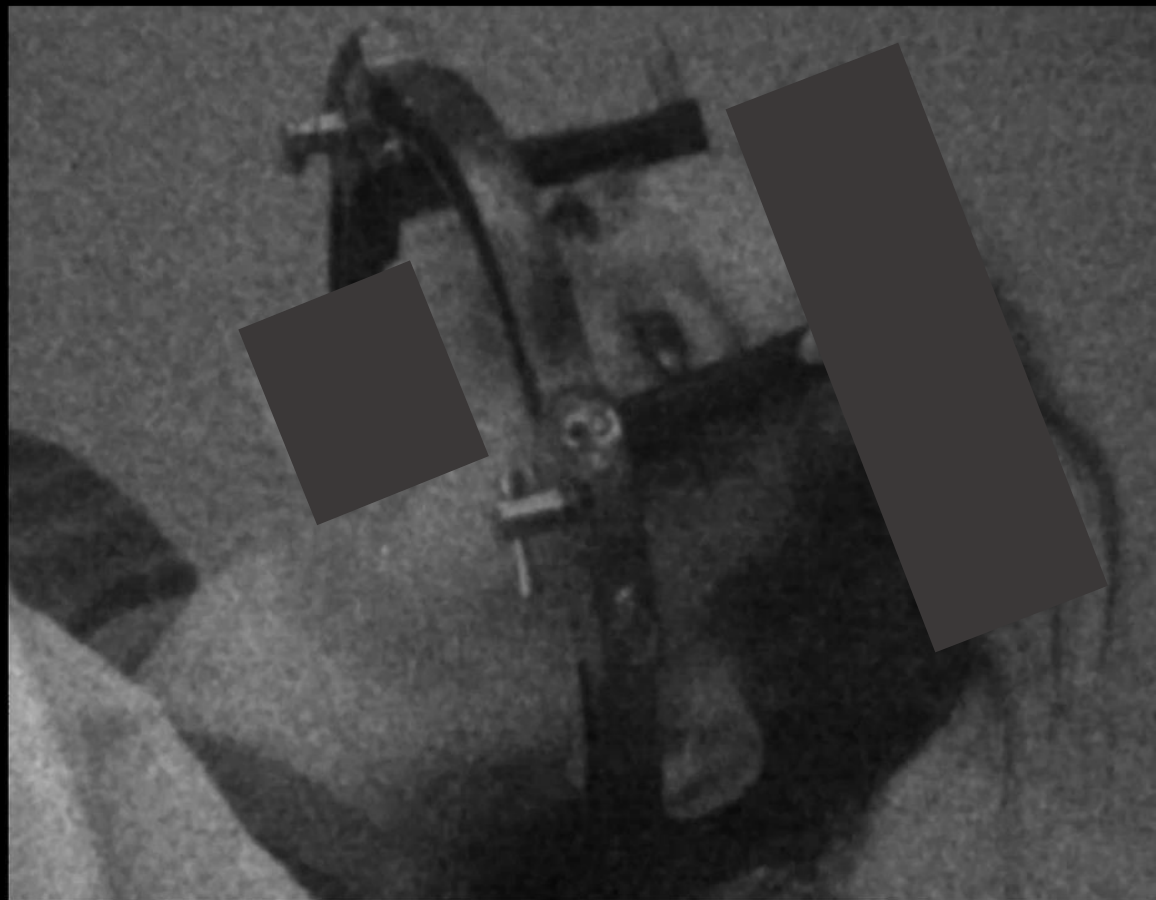
# *Stereotactic Cherenkov:*

INTERNATIONAL JOURNAL OF  
RADIATION ONCOLOGY • BIOLOGY • PHYSICS

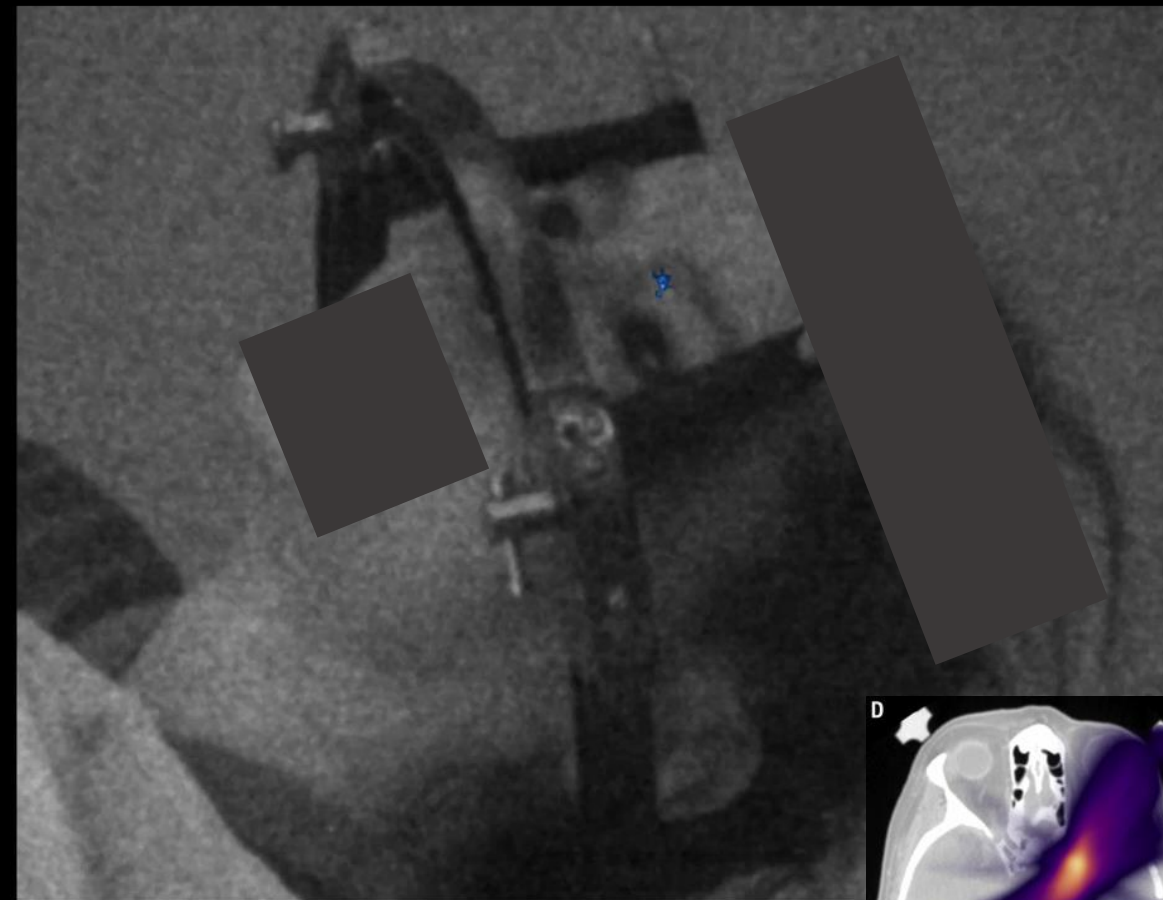
ASTRO

*Top Downloaded paper 2020!*

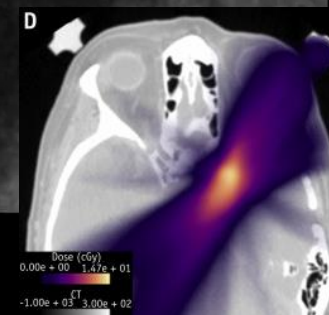
Tendler et al, 2020



Cumulative View



Real-Time View





International Journal of  
**Radiation Oncology • Biology • Physics**



[www.redjournal.org](http://www.redjournal.org)

Physics Contribution

## **Initial Clinical Experience of Cherenkov Imaging in External Beam Radiation Therapy Identifies Opportunities to Improve Treatment Delivery**

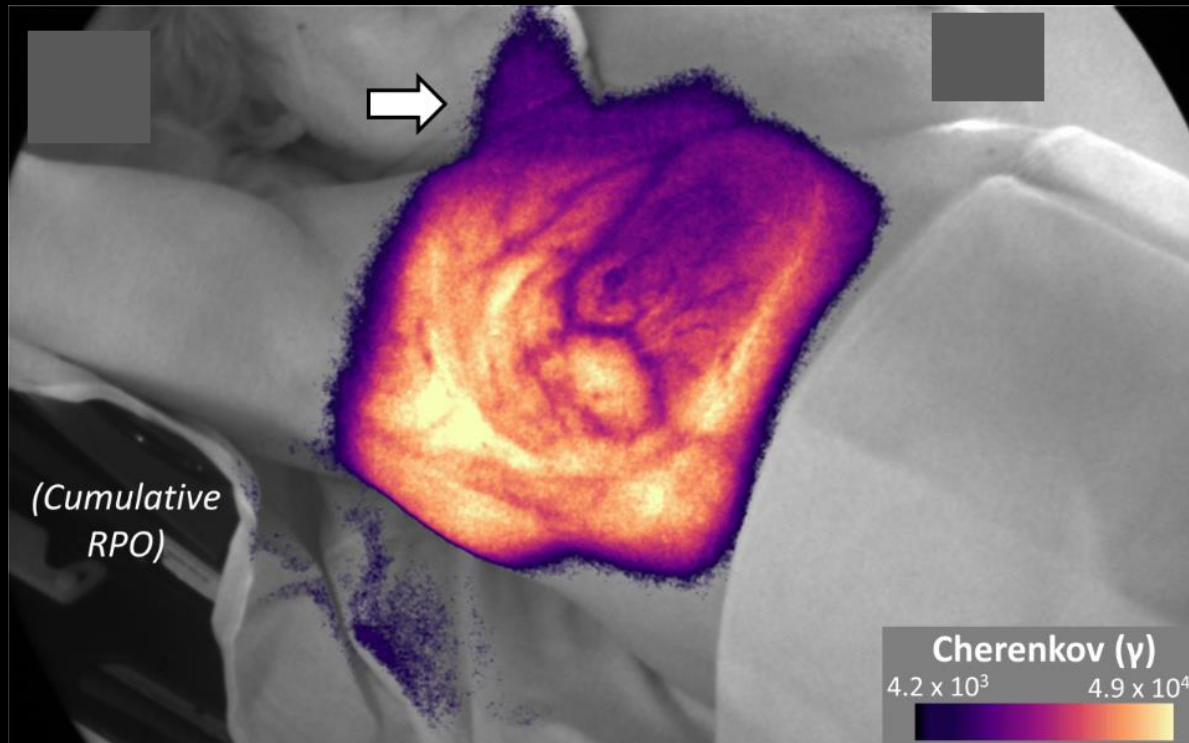
**Lesley A. Jarvis, MD, PhD,\* Rachael L. Hachadorian, MS,<sup>†</sup>  
Michael Jermyn, PhD,<sup>†</sup> Petr Bruza, PhD,<sup>†</sup> Daniel A. Alexander, MS,<sup>†</sup>  
Irwin I. Tendler, PhD,<sup>†</sup> Benjamin B. Williams, PhD,\*<sup>†</sup>  
David J. Gladstone, ScD,\*<sup>†</sup> Philip E. Schaner, MD, PhD,\*  
Bassem I. Zaki, MD,\* and Brian W. Pogue, PhD<sup>†</sup>**

*\*Department of Medicine, Section of Radiation Oncology, Geisel School of Medicine at Dartmouth,  
Hanover, New Hampshire; and <sup>†</sup>Thayer School of Engineering at Dartmouth, Hanover, New Hampshire*

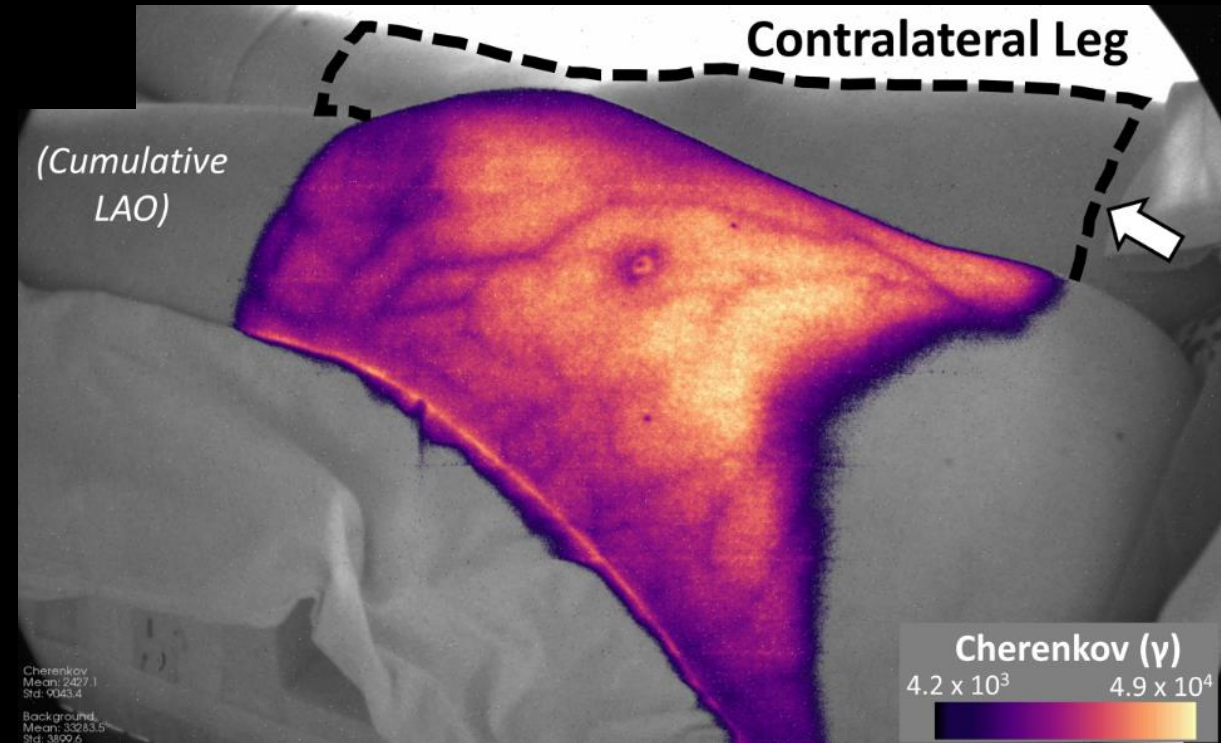
Received Jun 5, 2020. Accepted for publication Nov 5, 2020.

# 1<sup>st</sup> study: Prospective recruitment study

## Case 1 - Patient Motion

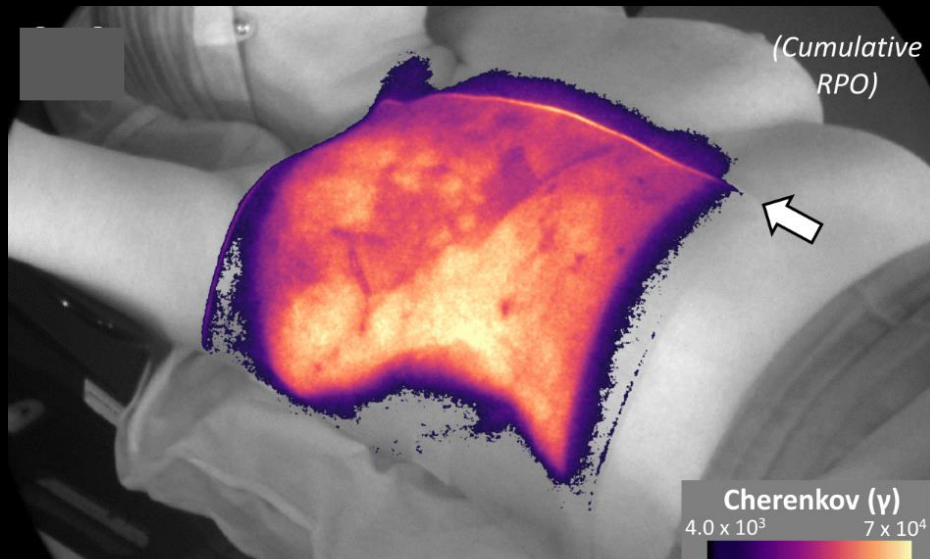
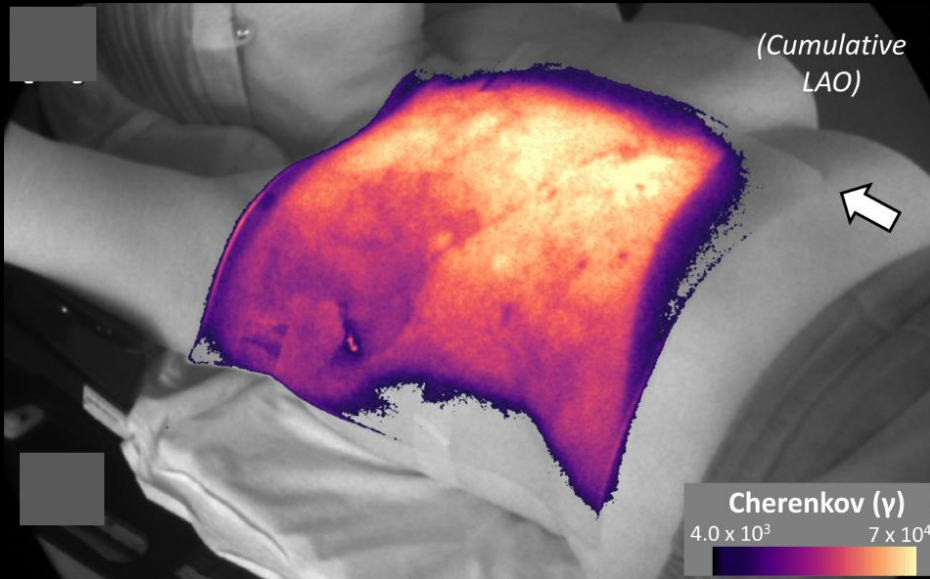


## Case 2 - Limb Monitoring

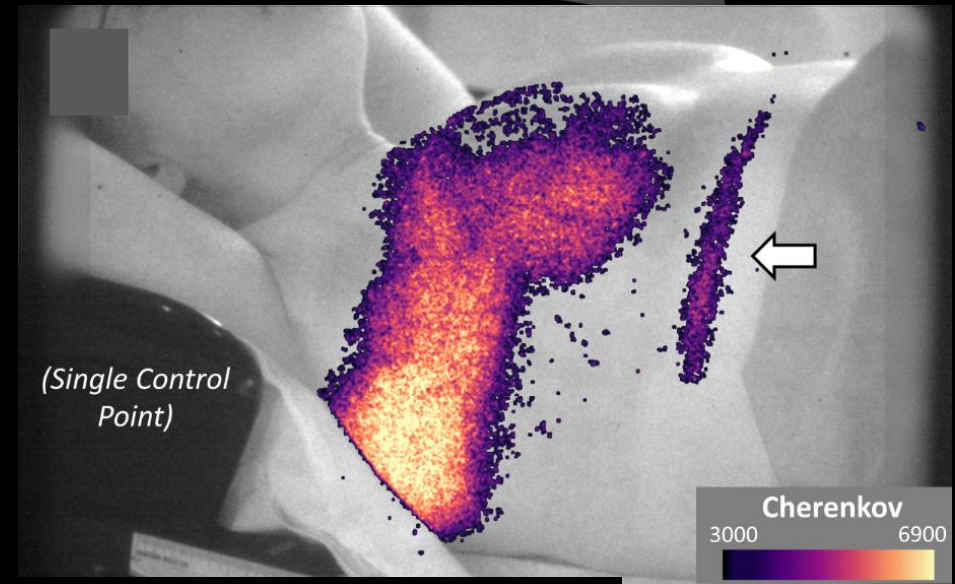
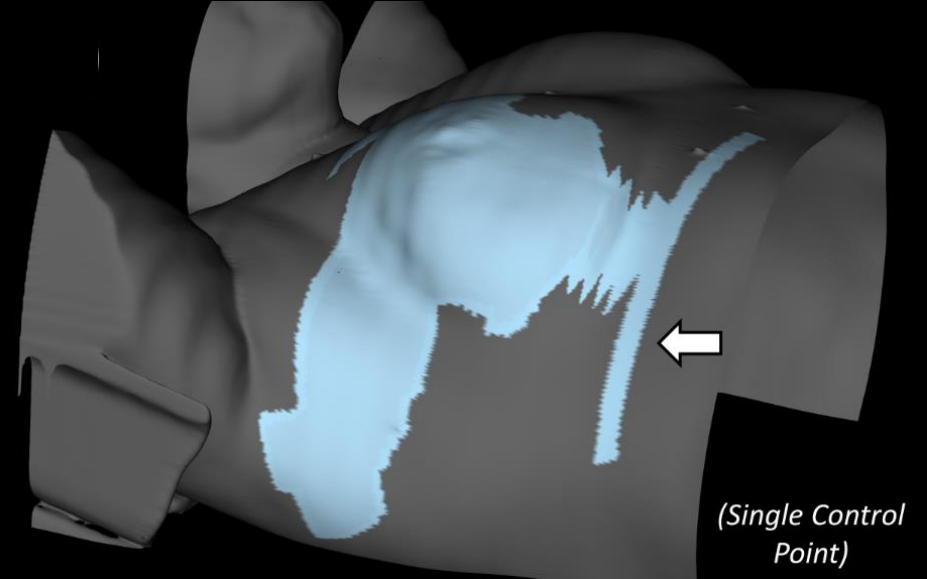


# 1<sup>st</sup> study: Prospective recruitment study

## Case 3 – Bolus alignment



## Case 4 – Open MLC in plan



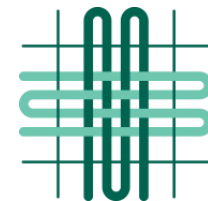
*2<sup>nd</sup> study:* 1 year retrospective of 12,000 fractions



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# Four Key Areas for Radiotherapy Improvement:

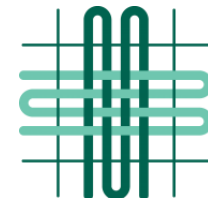
1. Patient Setup
2. Planning
3. Accessories
4. Compliance



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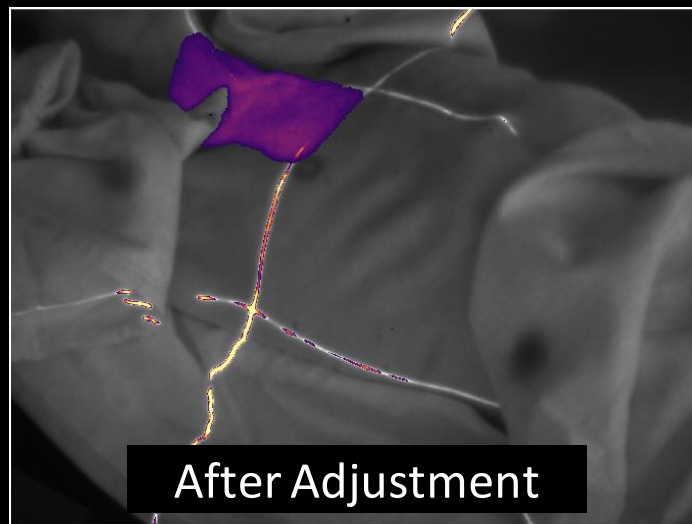
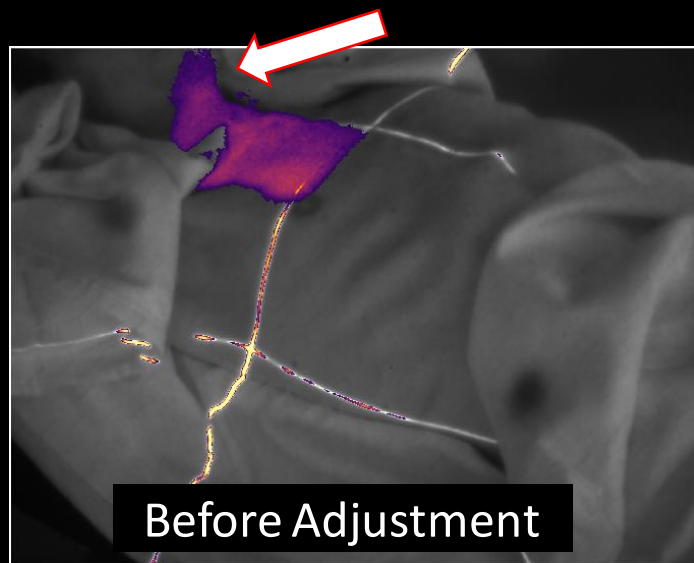


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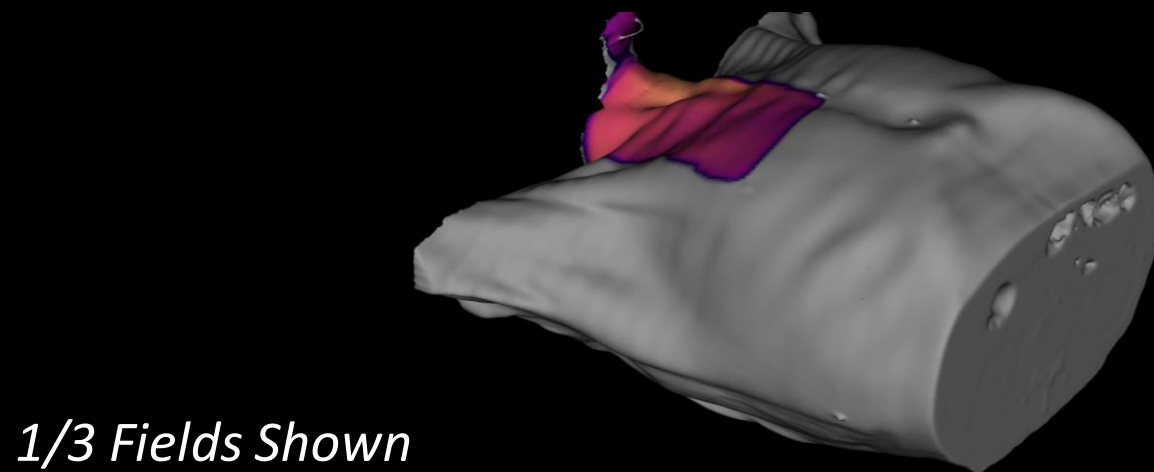
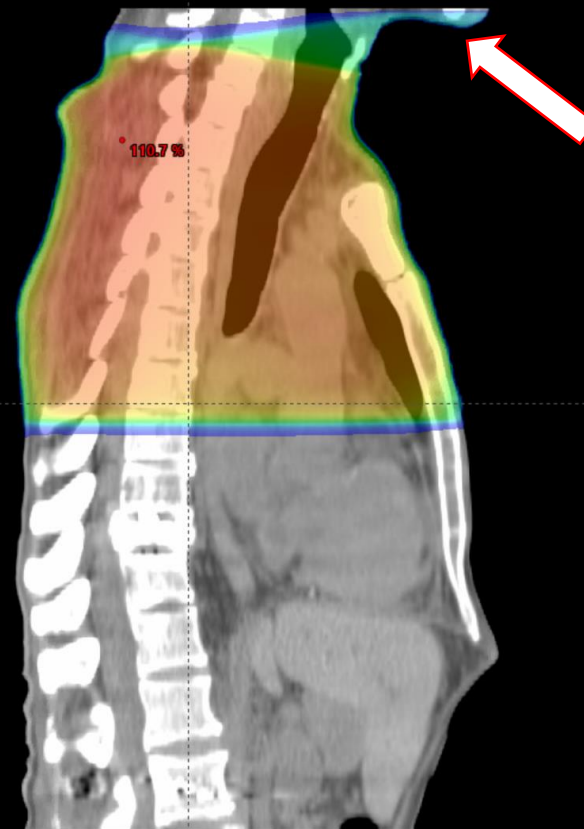


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# Set up & Planning: Real Time & Discovery of Issues

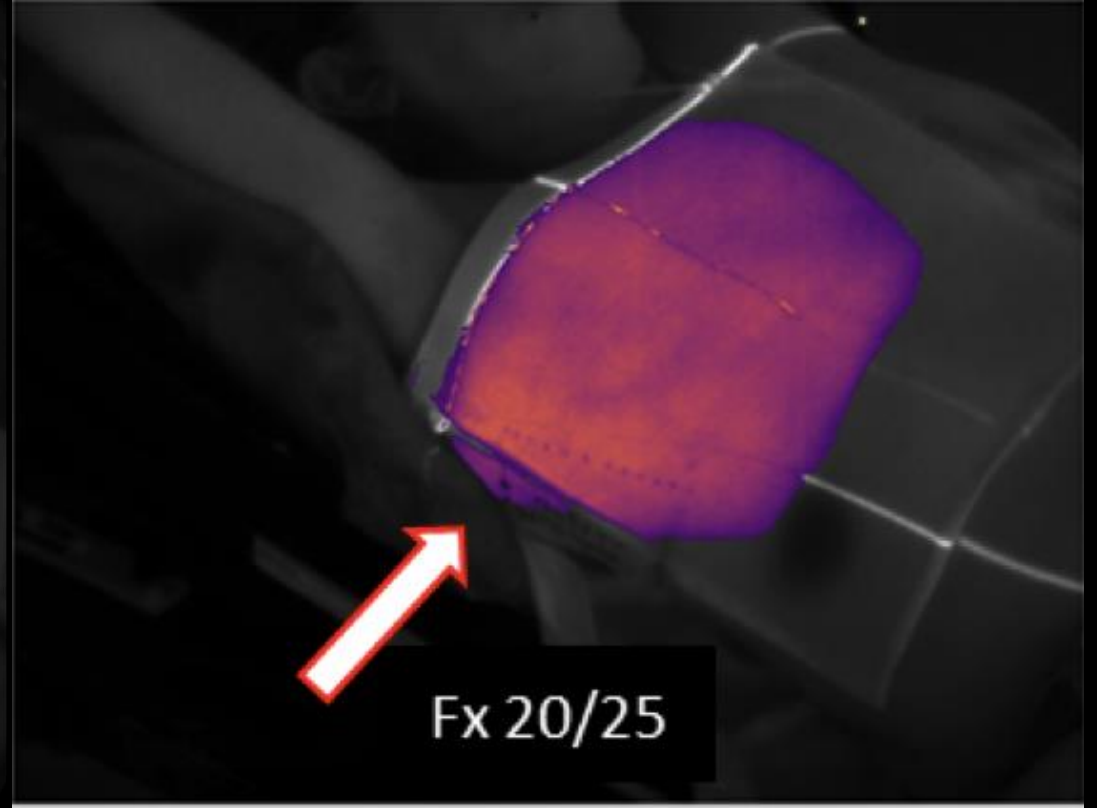
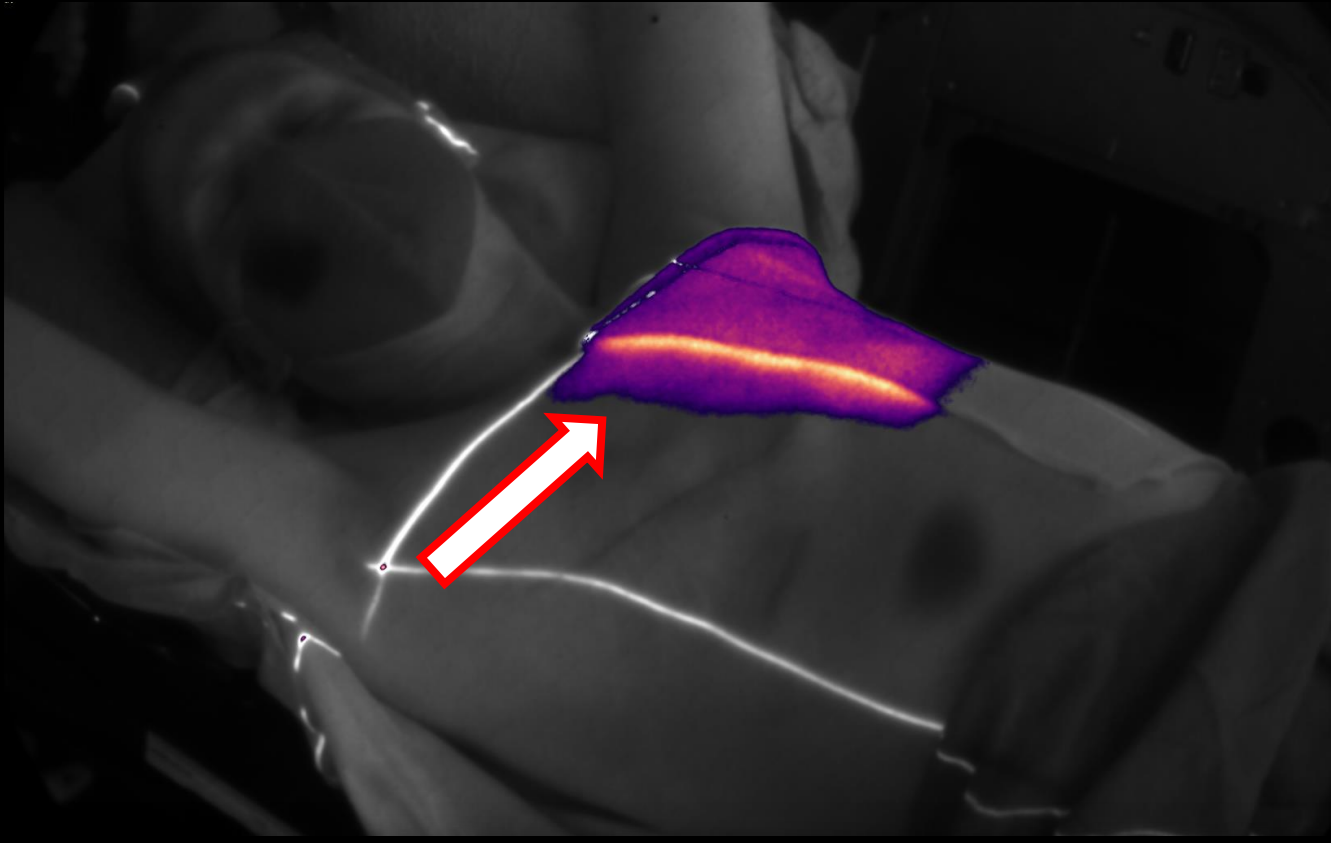


Treatment Plan,  
central sagittal slice



Planned Surface Dose

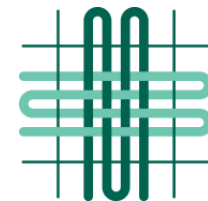
*Bolus placement variations are visible*



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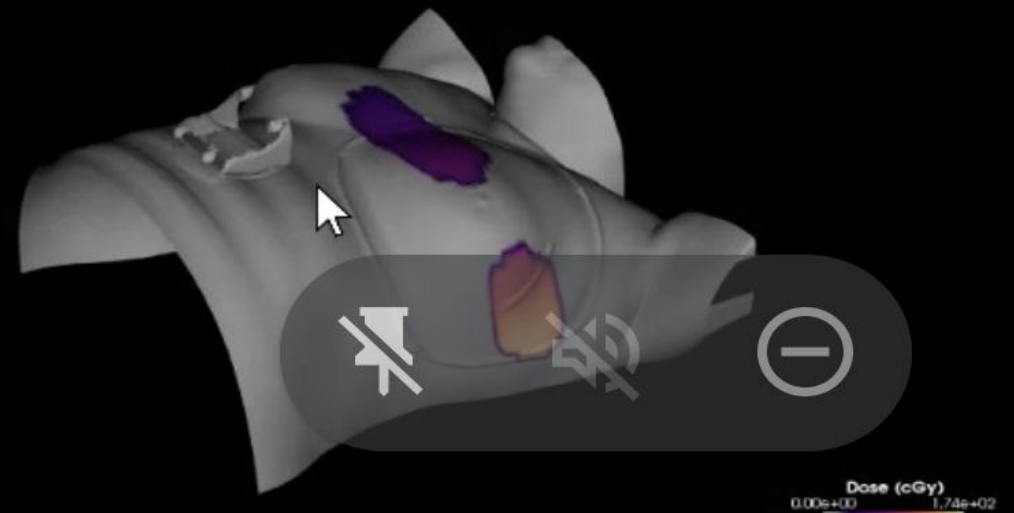
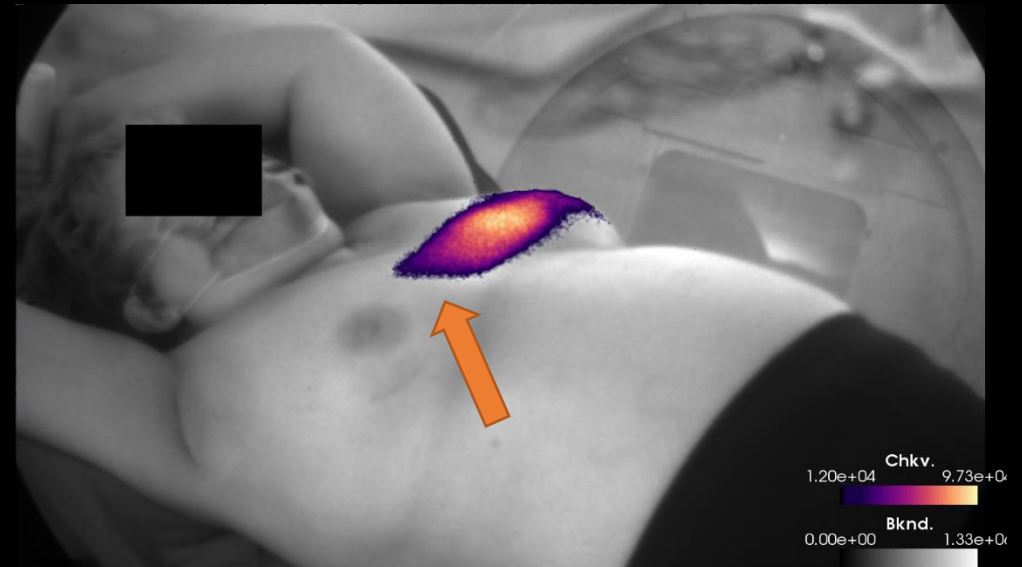
# *Patient setup & Compliance:* exposure to extremities



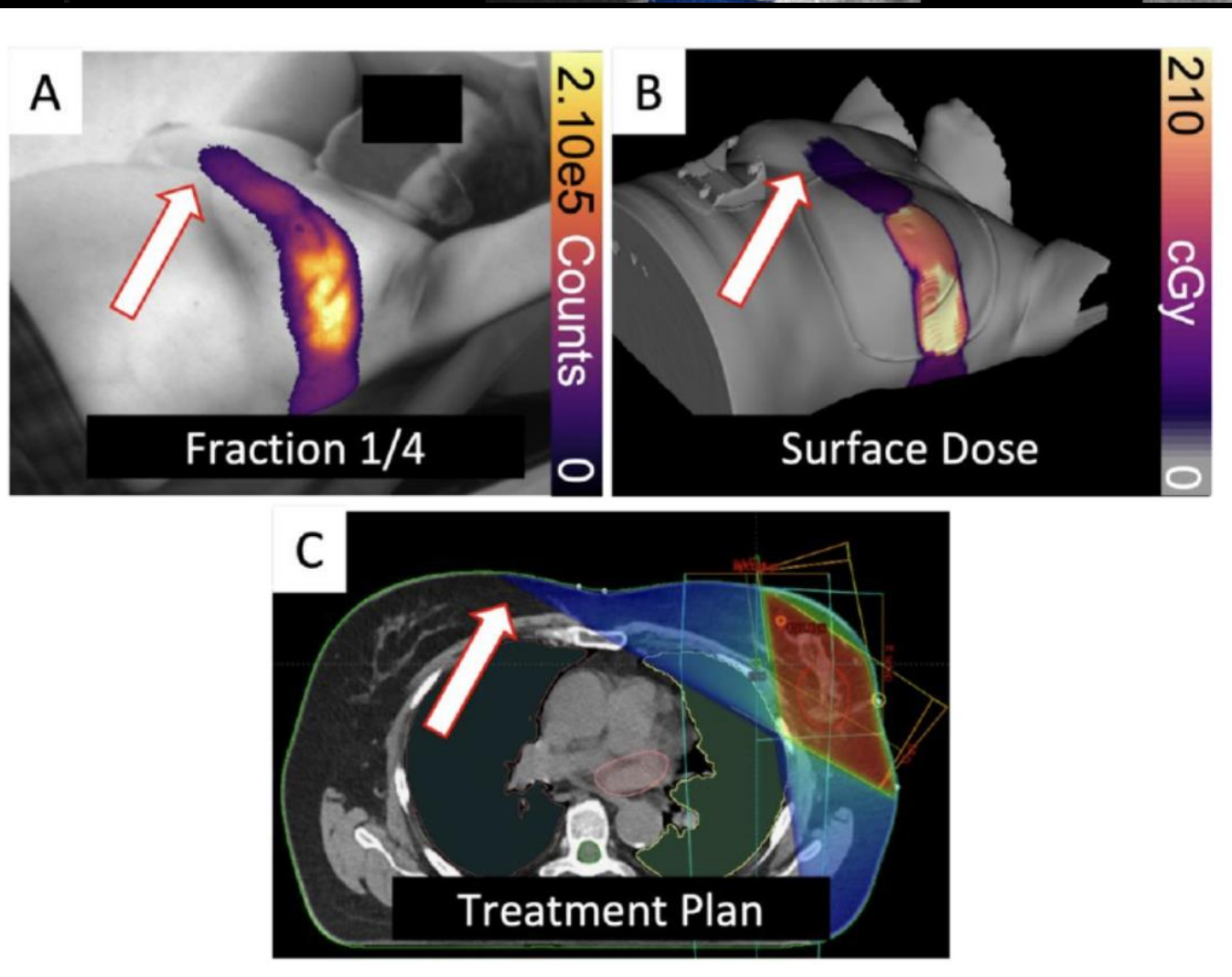
D A Alexander, et al, "Retrospective Evaluation of an Always-on Cherenkov Imaging System for Radiotherapy Quality Improvement" [arXiv](https://arxiv.org/abs/2110.07494): 2110.07494 [physics.med-ph]



# First patient at new site - Dose to Contralateral Breast – non-optimal treatment plan



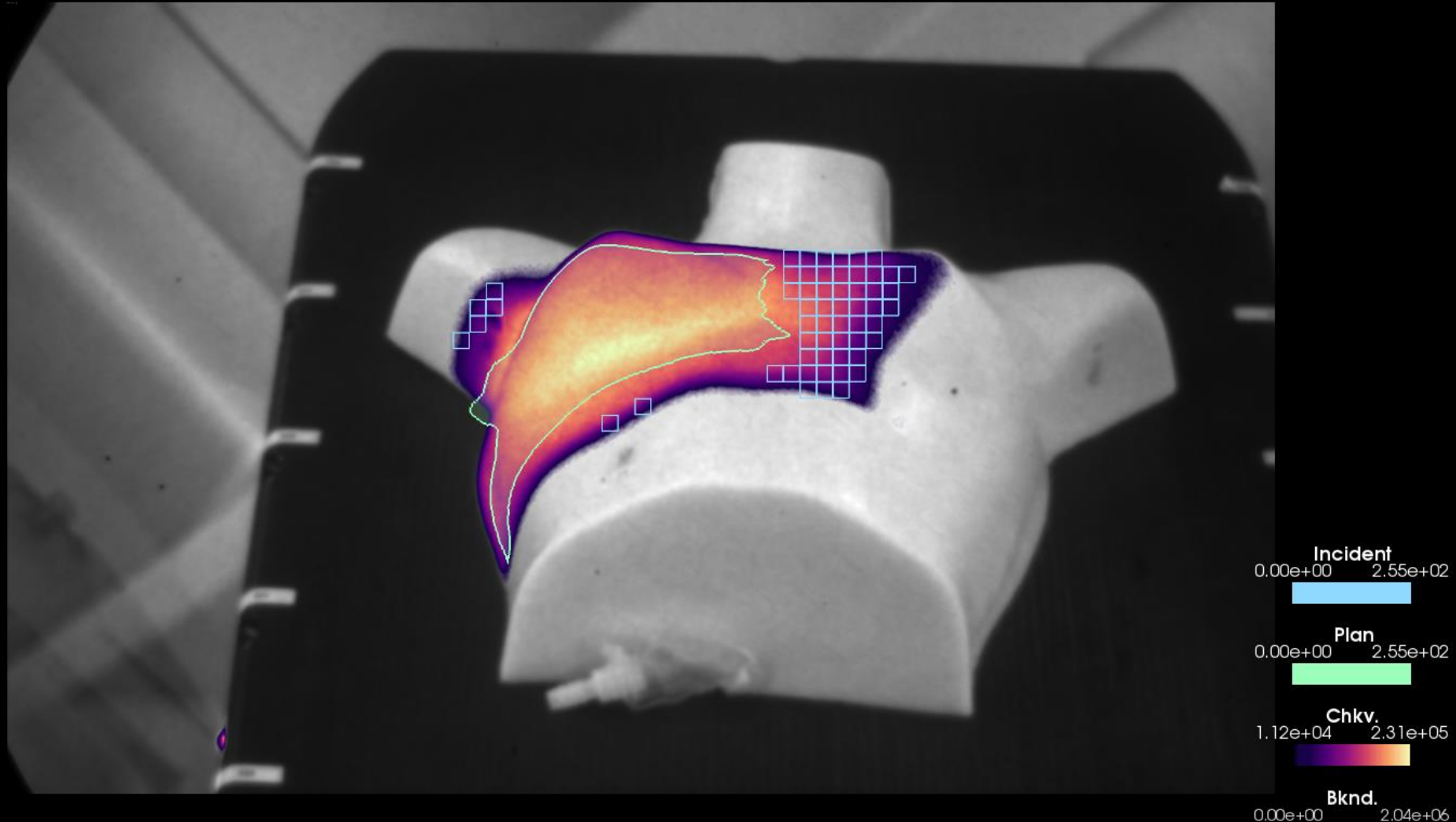
# Visualization of dose delivery to contralateral breast



- Motivated an updated dosimetry treatment plan isodose display policy
- If plan includes CB exit dose → required display of 10% isodose line before sending to physician for plan evaluation

(Chen et al. 2022)

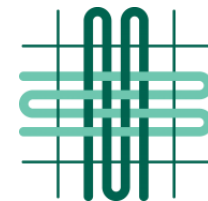
# *Future:* Automatic Incident Detection Software



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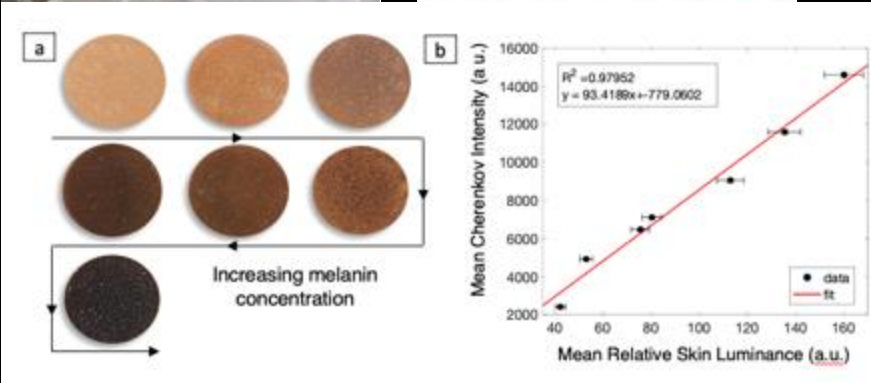
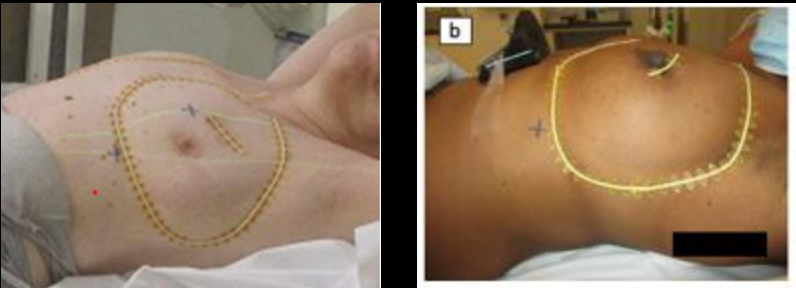


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# Future: Patient Dosimetry

## Melanin attenuates Cherenkov light



13 March 2023

**Color-resolved Cherenkov imaging allows for differential signal detection in blood and melanin content**

Vihan A. Wickramasinghe, Savannah M. Decker, Samuel S. Streeter, Austin M. Sloop, Arthur F. Petusseau, Daniel A. Alexander, Petr Bruza, David J. Gladstone, Rongxiao Zhang, Brian W. Pogue

Savannah Decker (unpublished)

## Blood content (tissue type) attenuates Cherenkov light

Nat Commun 2020; 11: 2298.  
Published online 2020 May 8. doi: [10.1038/s41467-020-16031-z](https://doi.org/10.1038/s41467-020-16031-z)

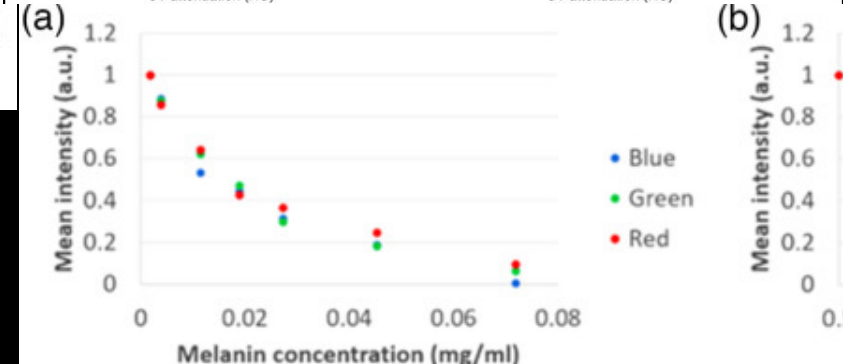
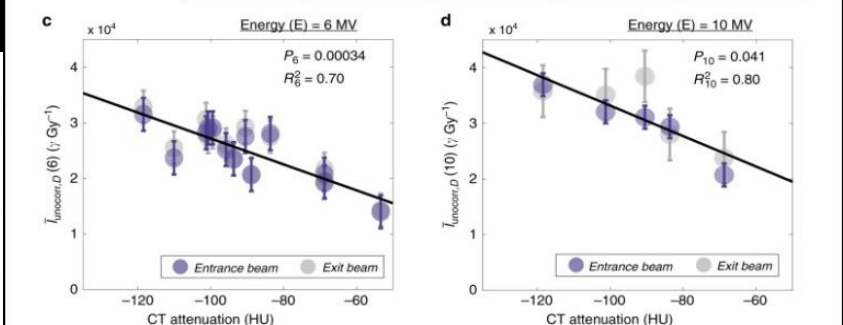
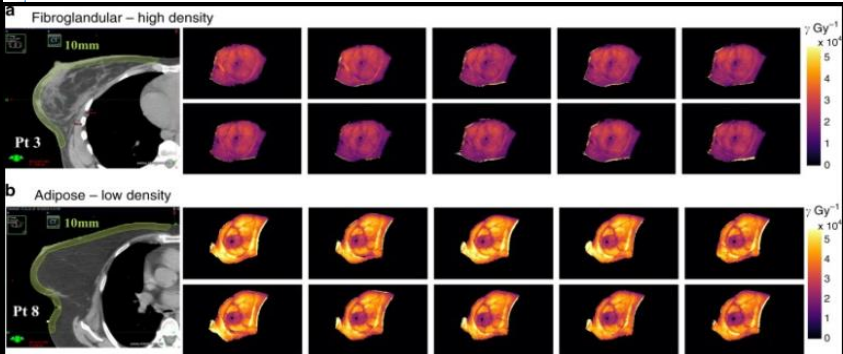
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PMID: [3238523](https://pubmed.ncbi.nlm.nih.gov/3238523/)

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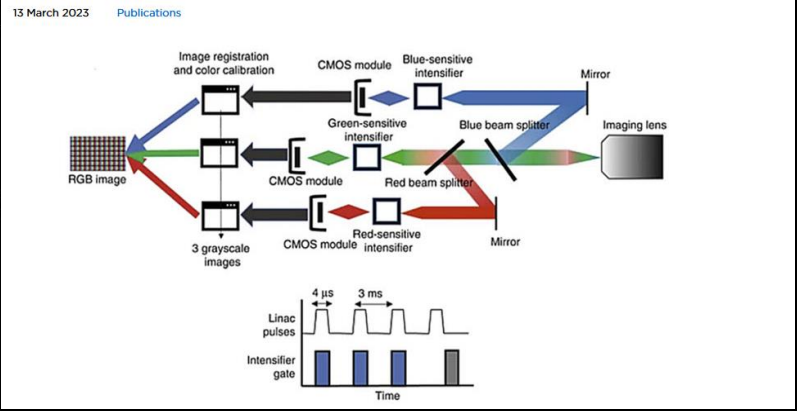
### Imaging radiation dose in breast radiotherapy by X-ray CT calibration of Cherenkov light

R. L. Hachadorian,<sup>1</sup> P. Bruza,<sup>1</sup> M. Jermyn,<sup>1,2</sup> D. J. Gladstone,<sup>1,3,4</sup> B. W. Pogue,<sup>1,2,3,4</sup> and L. A. Jarvis<sup>2,3,4</sup>



### Cherenkov color imaging shows promise in enhancing radiation therapy effectiveness

Researchers examine how melanin and blood levels in tissues affect Cherenkov emission, opening possibilities for better radiation dosage determination





# Summary

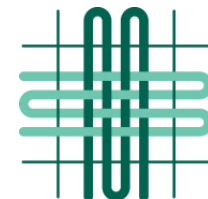
- Cherenkov imaging allows real-time visual of dose delivery & records for later review by team
- Images show daily variations
- Non-ideal delivery can occur due to:
  - Patient non-compliance (movements)
  - Accessory placement (bolus)
  - Set up variation (chin, breast, neck)
  - Sub-optimal plans (contralateral breast)
- dosert™ seamlessly integrates Cherenkov into SGRT



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# Acknowledgements



## Radiation Oncology & IRB support



Jarvis



Mansur



Thomas

## Medical Physics Faculty



Gladstone



Zhang



Williams



Chen



Bruza



Brian Pogue



Bill Ware



Venkat Krishnaswamy



Petr Bruza



Mike Jermyn



Dan Alexander



Fardeen Christie



## Medical Physics Graduate Students



Wickramasinghe



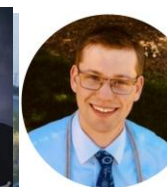
Clark



Decker



Sunnerberg



Sloop



Thomas



Niver



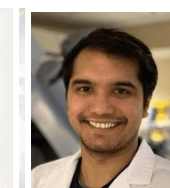
## Medical Physics PhD Alumni



Hachadorian



Alexander



Rahman



Miao



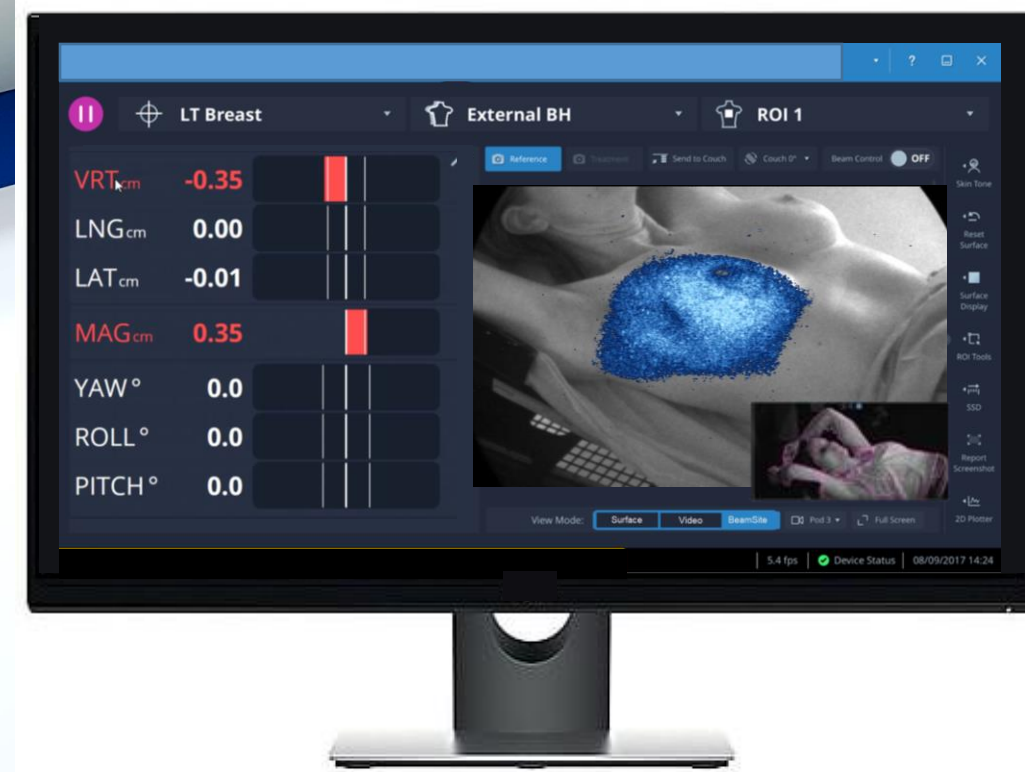
Andreozzi



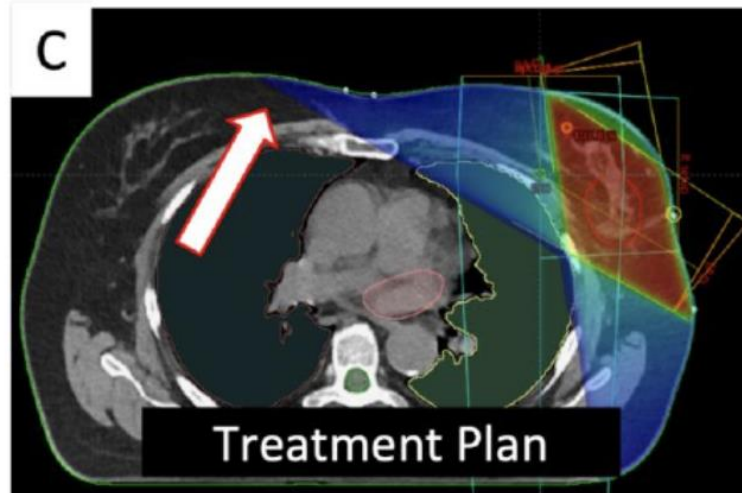
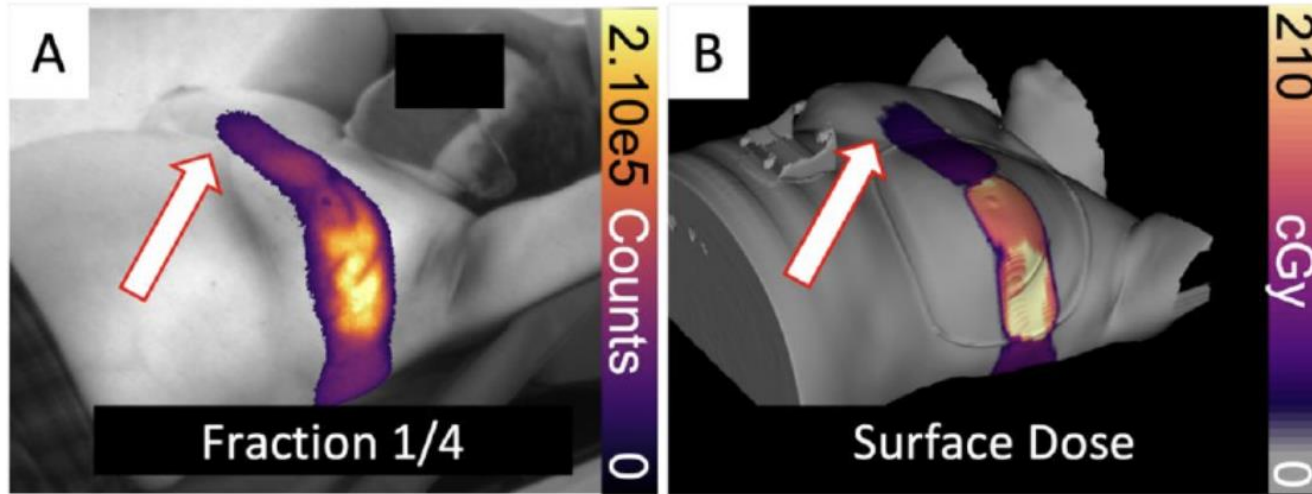


**Every Patient  
Every Fraction**

***Watch the Patient  
and the Beam***



# Background / Motivation



Alexander\*, Decker\*, et al. 2022

Planned Dose

- Motivated an updated dosimetry treatment plan isodose display policy
- If plan includes CB exit dose → required display of 10% isodose line before sending to physician for plan evaluation

(Chen et al. 2022)

0

352

Cumu

0

Counts

9e4

