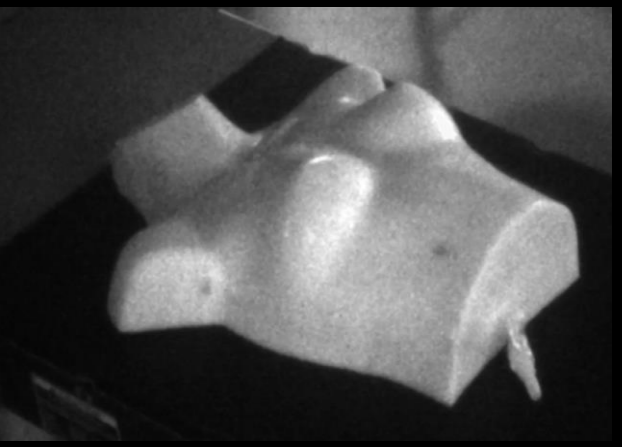
Clinical treatment and process quality improvement due to Cherenkov imaging.



Praise the Lord, I saw the light!

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

Thayer School of Engineering, Dartmouth College, Hanover, NH
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Disclosures

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VisionRT

All human studies approved by Dartmouth Health IRB

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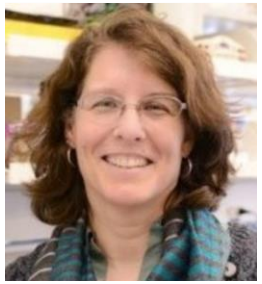
Radiation Oncology & IRB support


Lesley Jarvis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Charles Thomas


Erli Chen


Allison Matous

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Daniel Alexander


Benjamin Williams


Petr Bruza

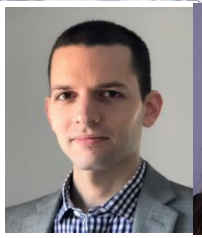
DOSEOPTICS
Visualize radiation therapy


Brian Pogue


Bill Ware


Venkat Krishnaswamy

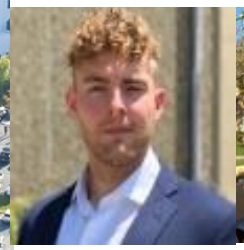

Petr Bruza


Mike Jermyn


Rory Rosselot


Farzeen Christie

Medical Physics Graduate Students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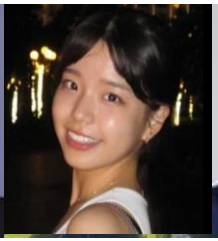
Natasha Mulenga


Kevin Willy


Bomi Lee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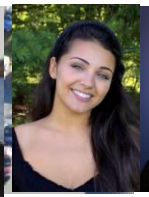
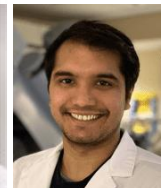
Clark


Decker


Hachadorian

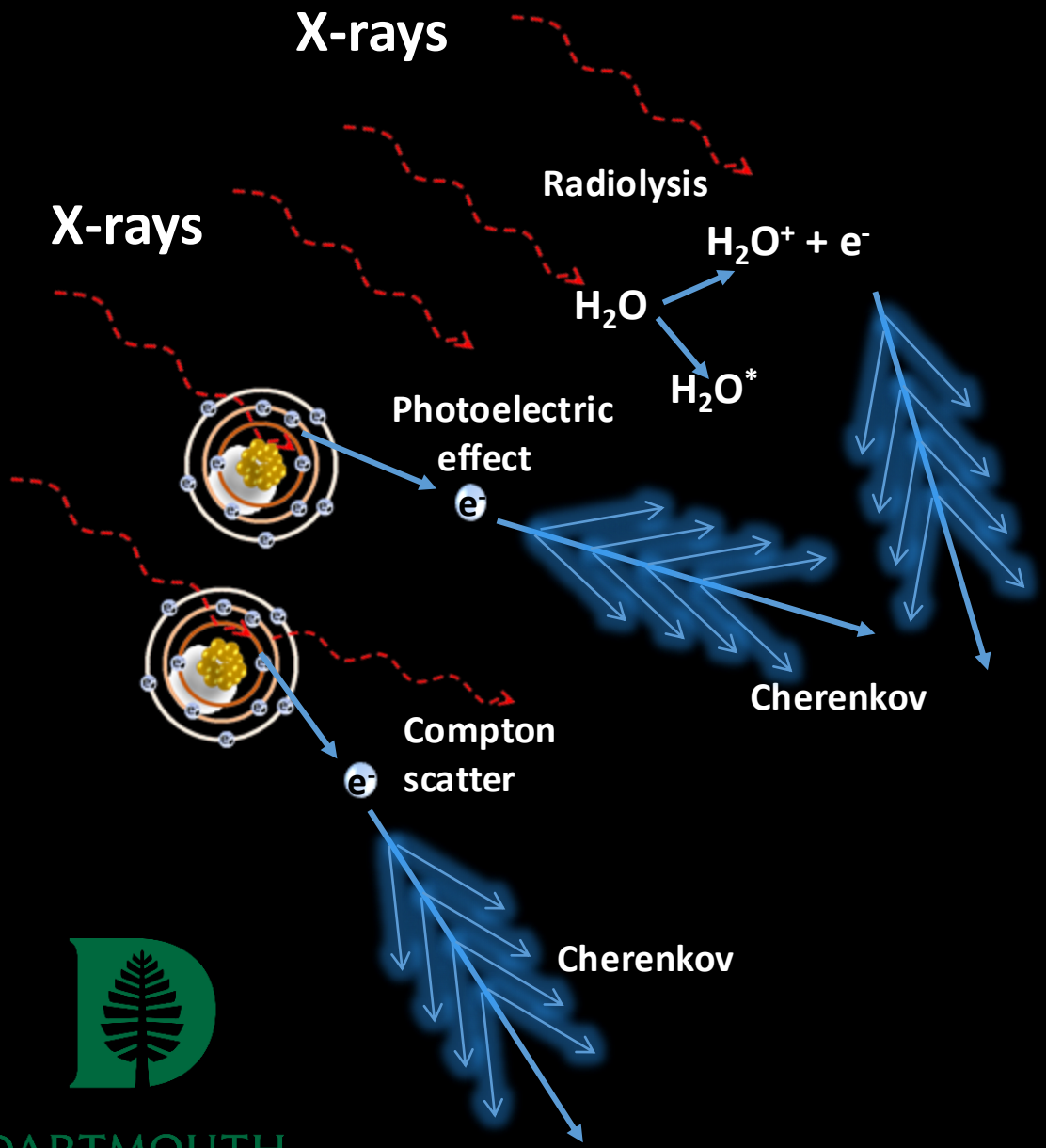

Zhang

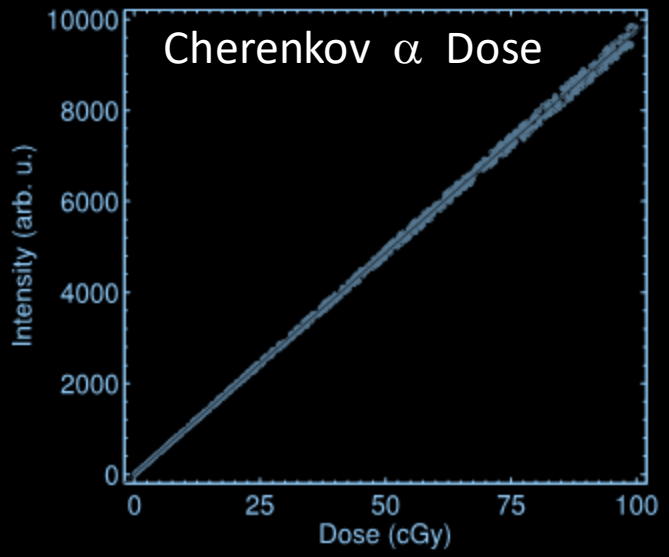

Rahman


Miao


Andreozzi

Cherenkov light is part of the MV radiation dose





Phantom with night vision glasses

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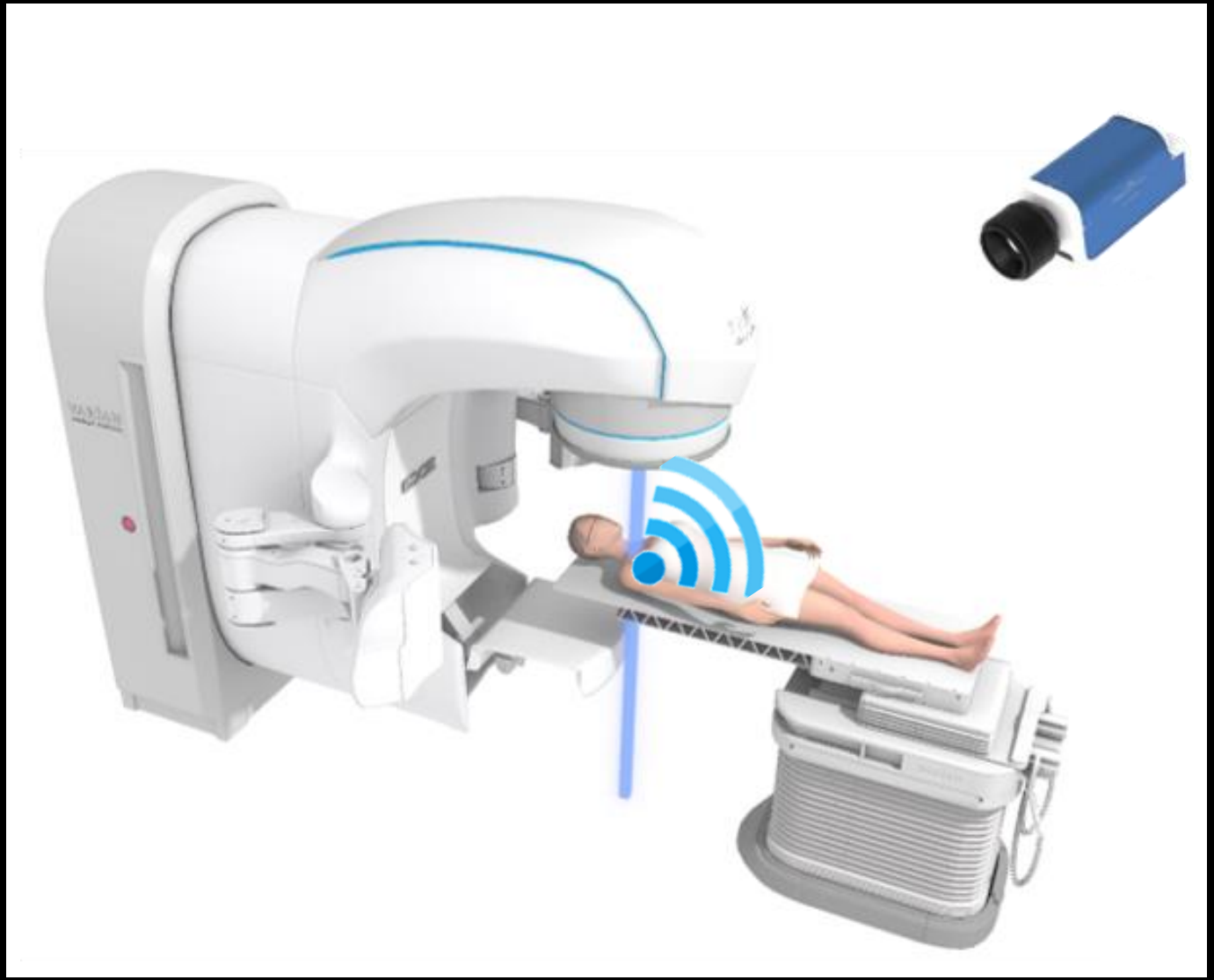
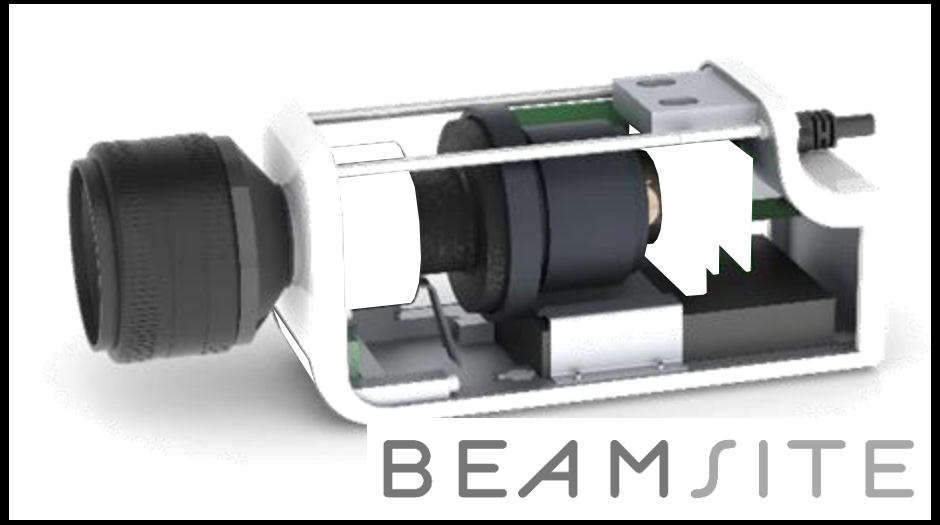
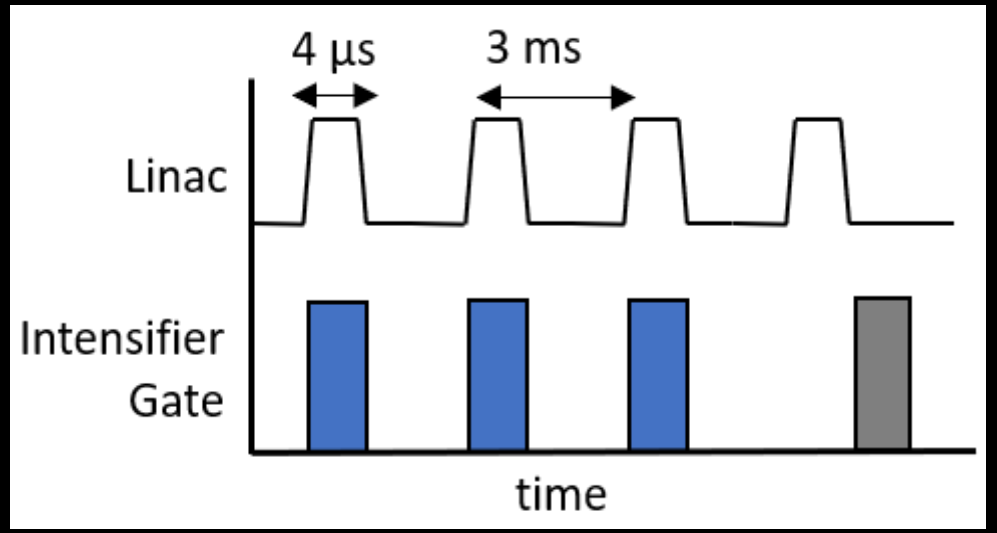
LINAC pulses trigger the camera

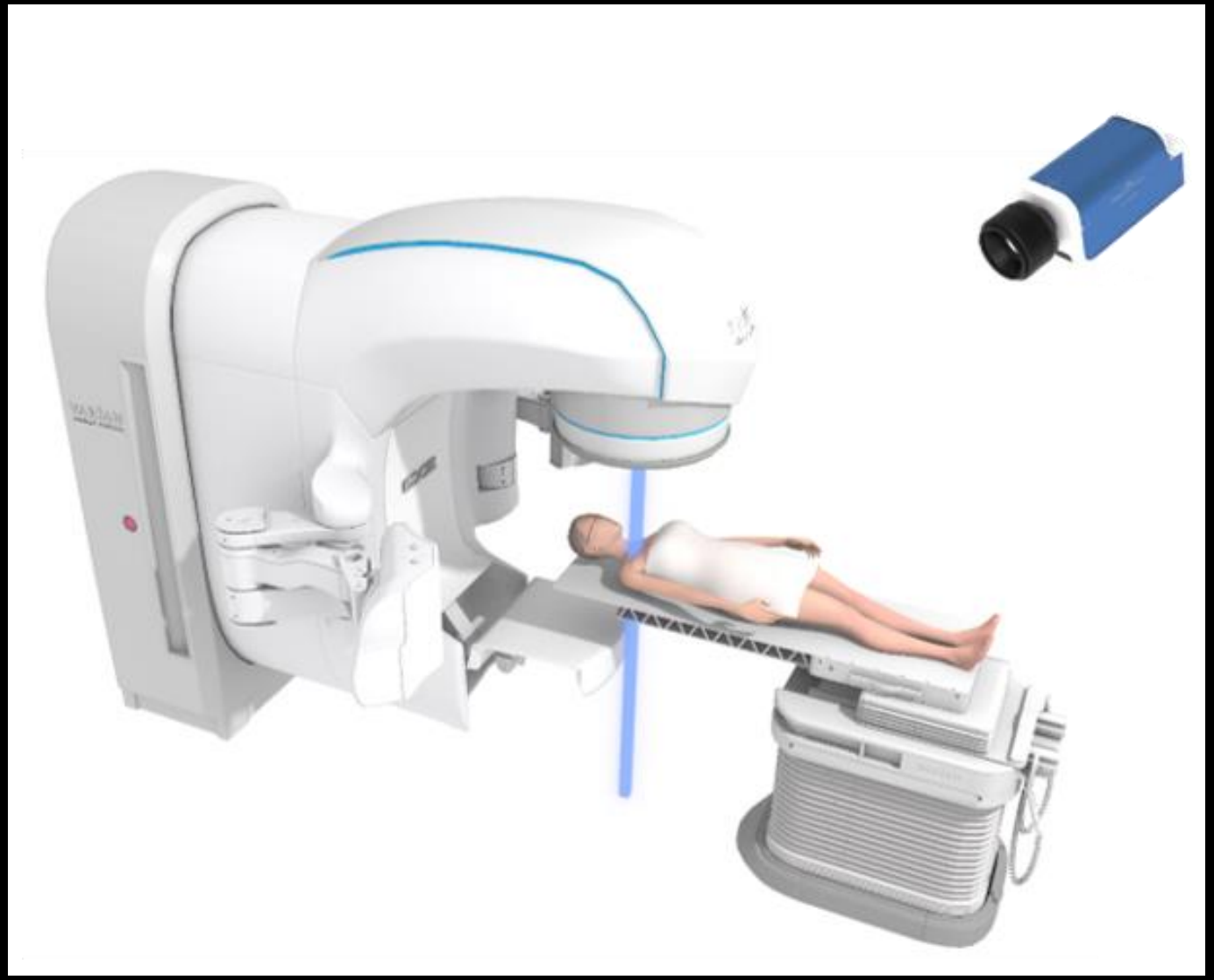


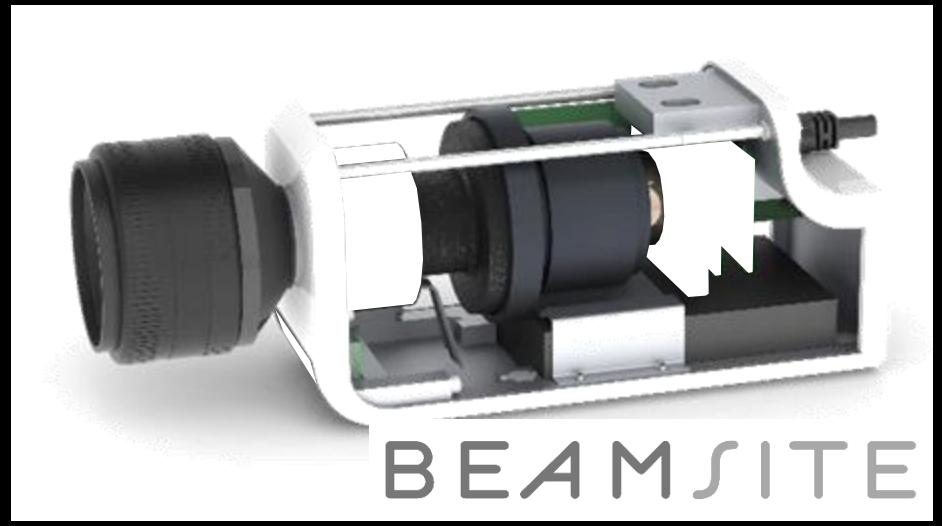


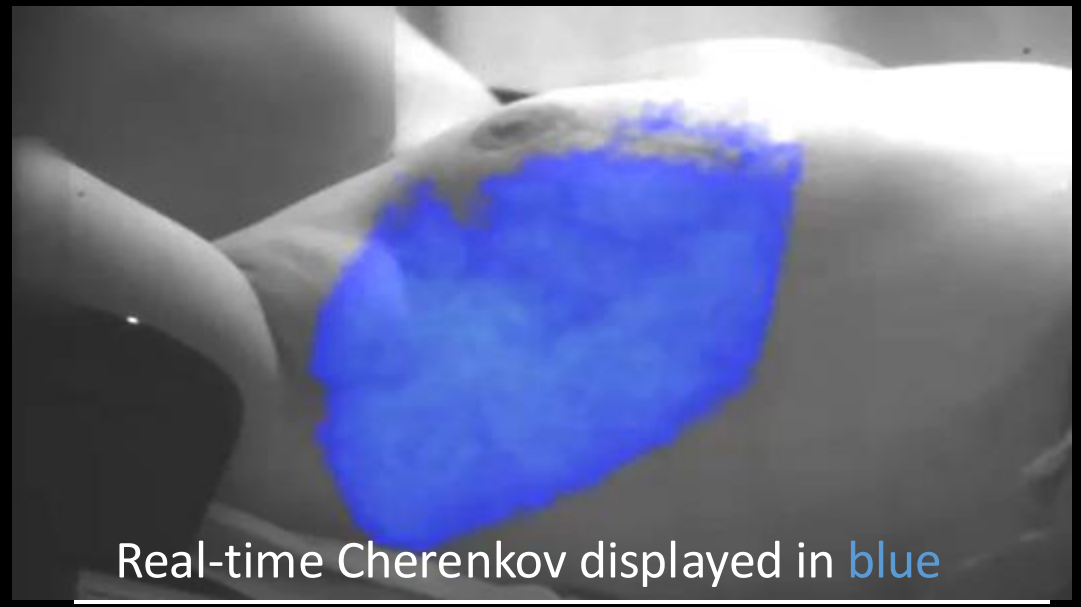
Camera auto triggers with each pulse



Cherenkov imaging from LINAC pulses!

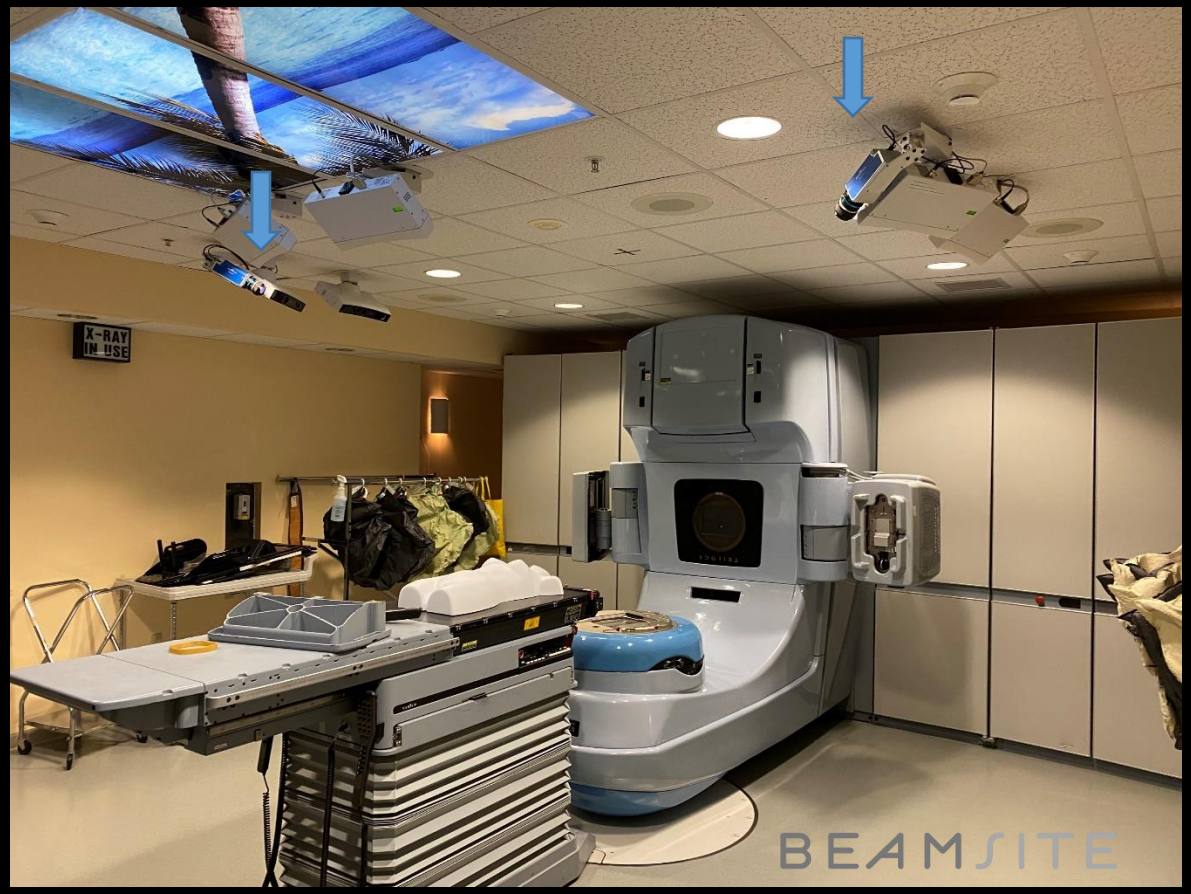






Dartmouth Cancer Center installations

Linac pulses turn off the room lights



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BEAMSITE

BeamSite [Dev] - DoseOptics - Dev M2

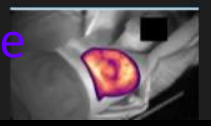
LIVE | REVIEW

TOGGLE CUMULATIVE | TAKE SCREENSHOT | VIEW SCREENSHOTS | HELP

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

Real-time Cherenkov → blue

Cumulative Cherenkov → yellow-orange-purple

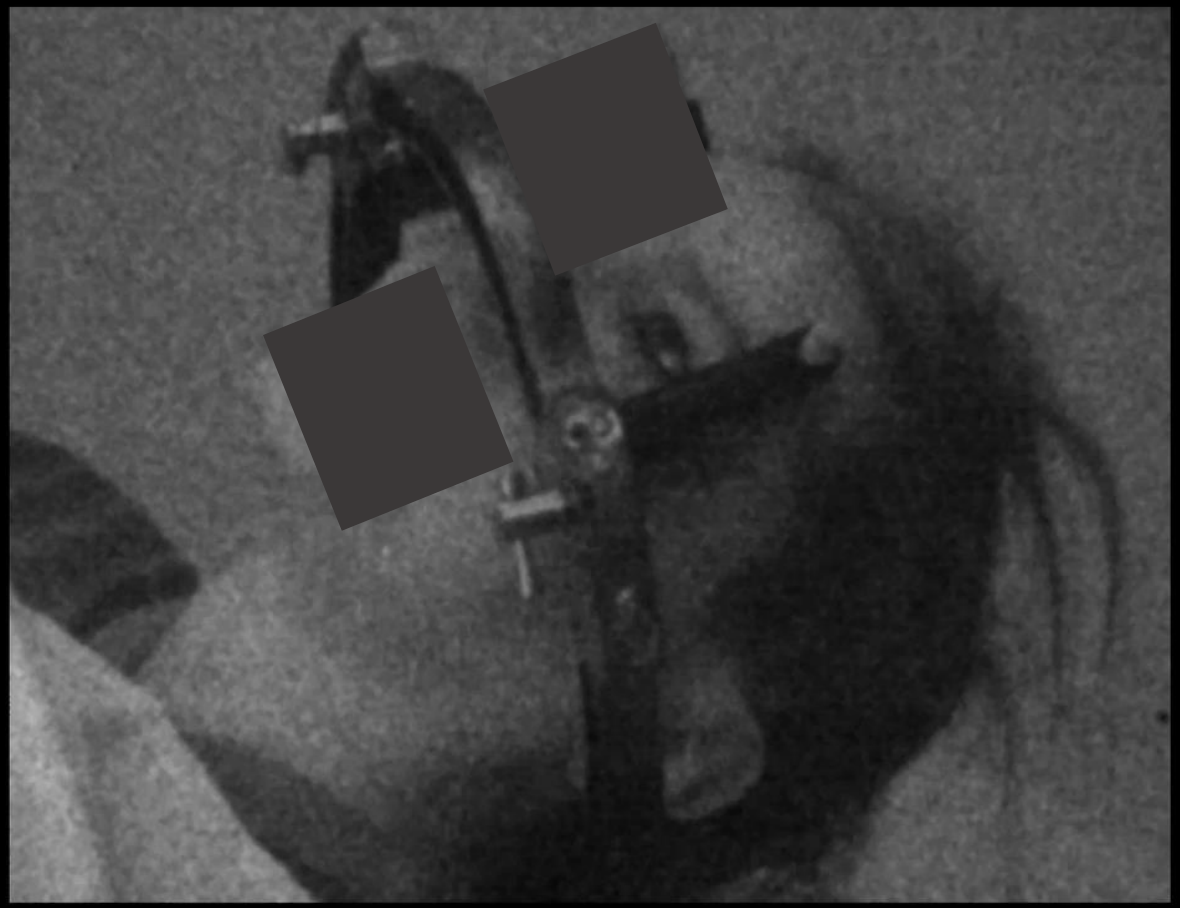


Stereotactic Cherenkov:

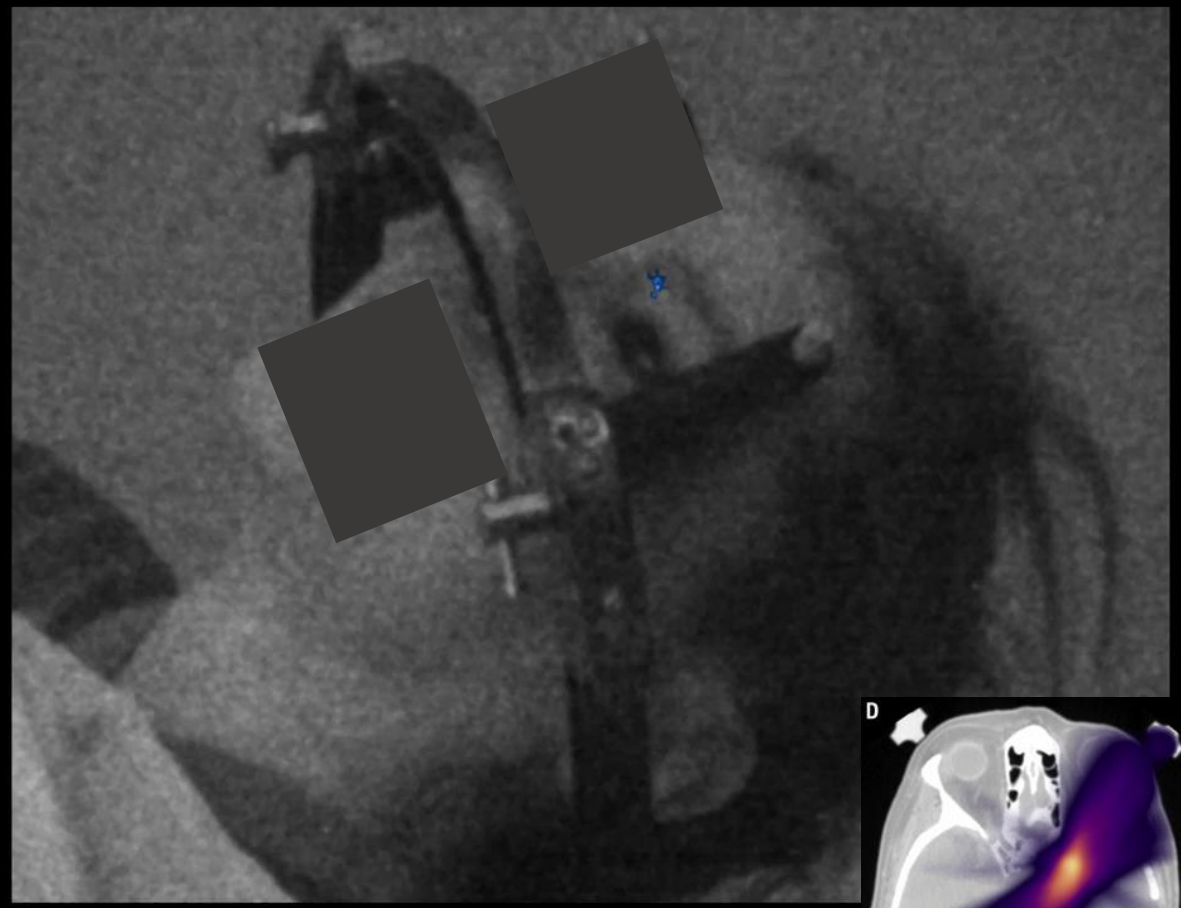
INTERNATIONAL JOURNAL OF
RADIATION ONCOLOGY · BIOLOGY · PHYSICS
ASTRO

Top Downloaded paper 2020!

Tendler et al, 2020



Cumulative View



Real-Time View

Four Key Areas for Radiotherapy Improvement:

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

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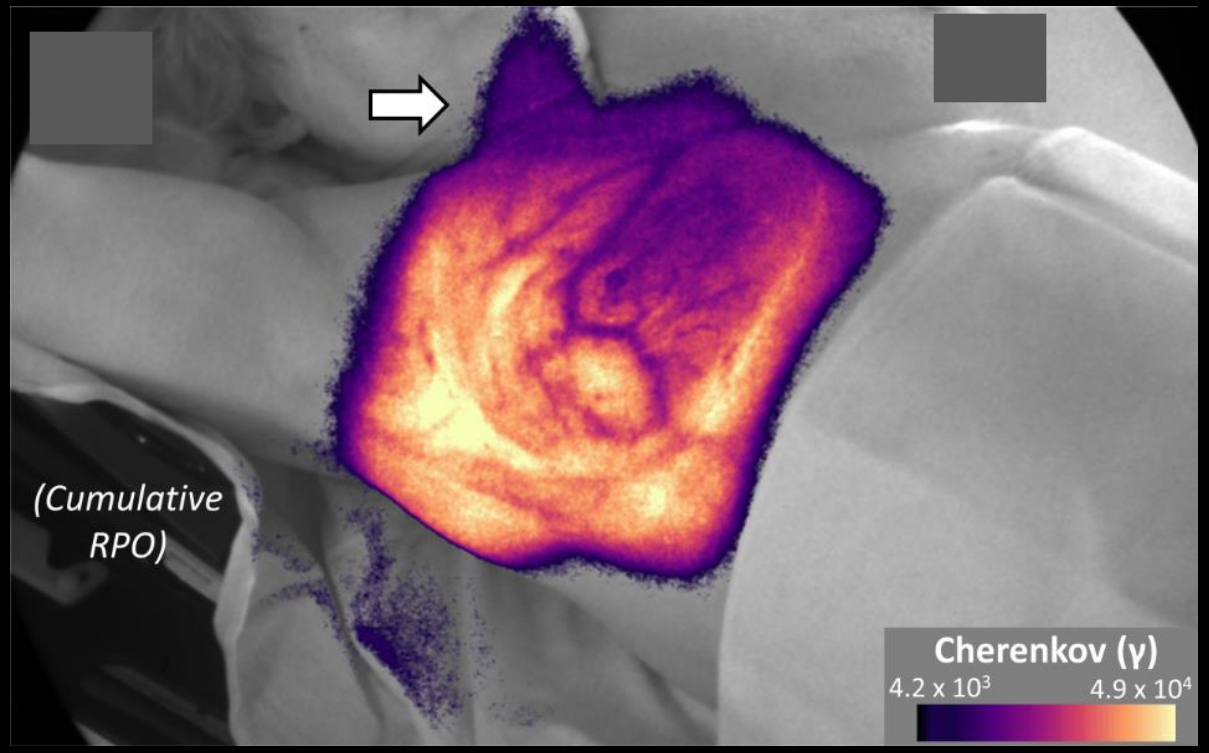
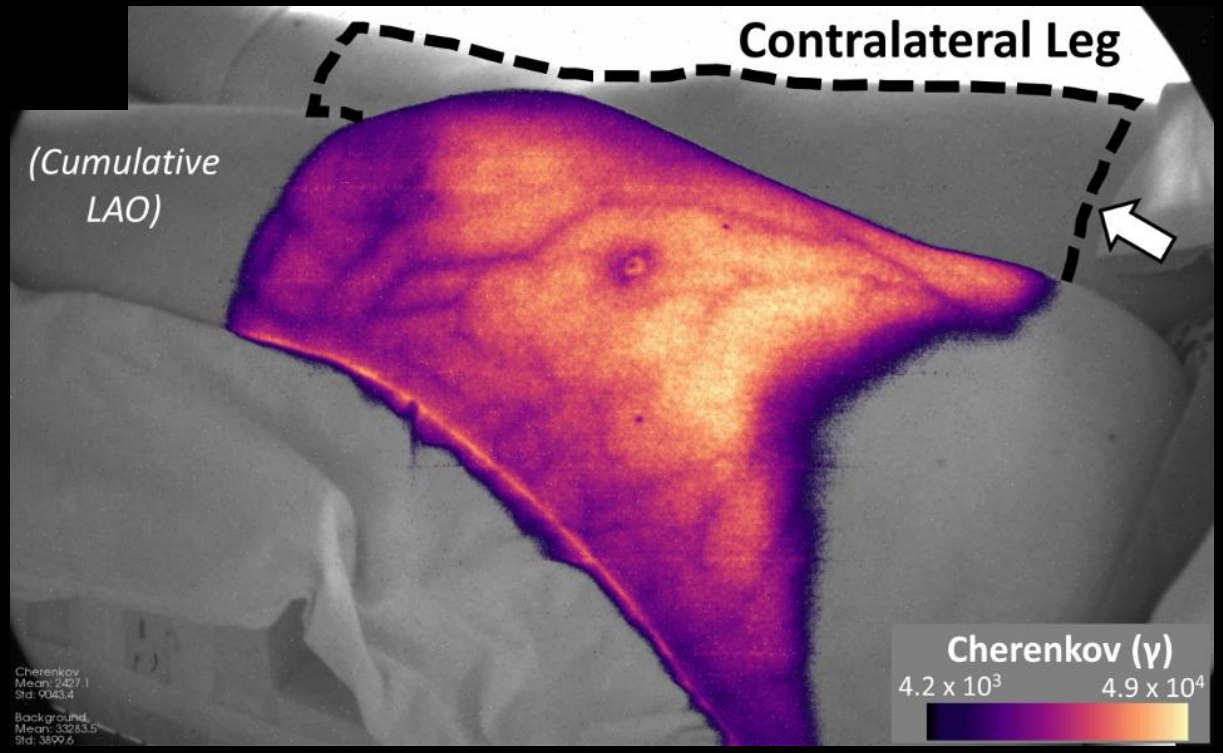
1st study: Prospective recruitment study

Case 1 - Patient Motion

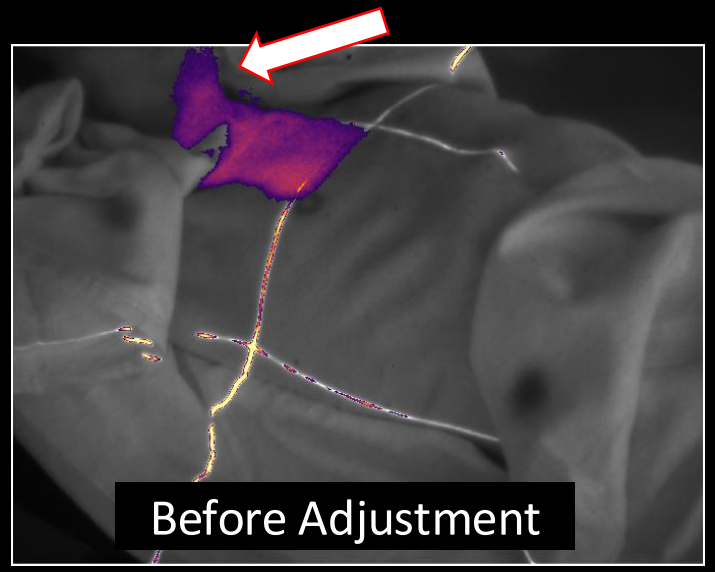


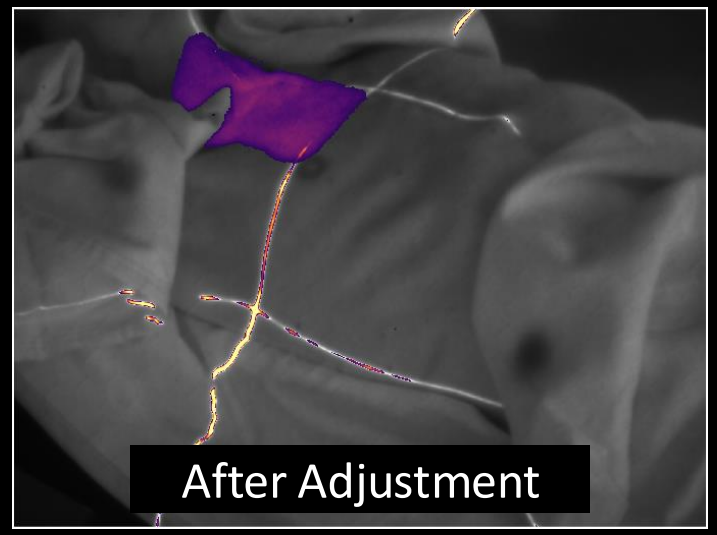
Case 2 - Limb Monitoring



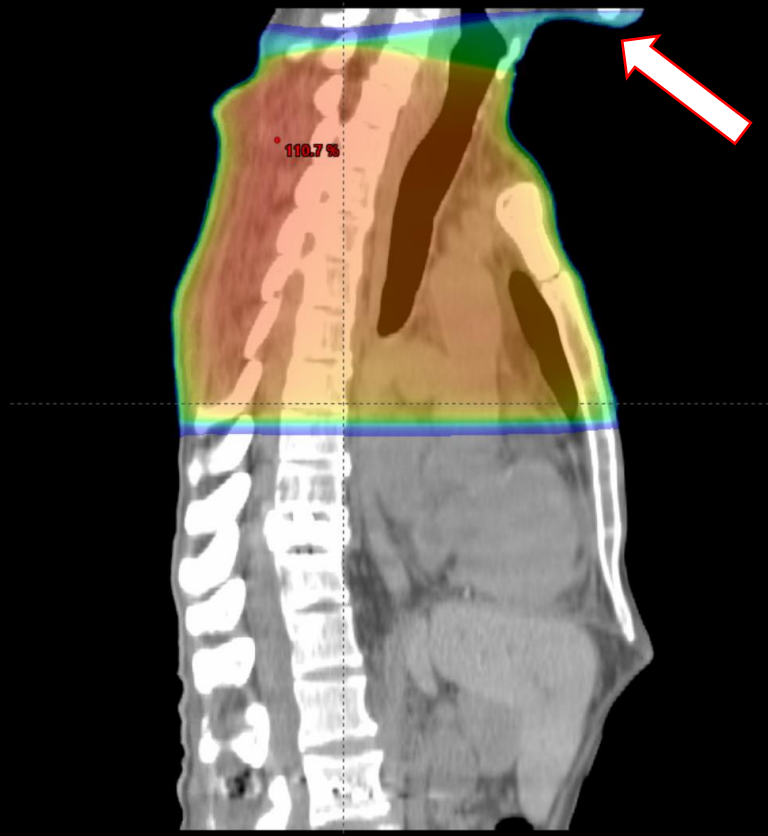
L. A. Jarvis, et al. *International Journal of Radiation Oncology*Biology*Physics* **(2020), doi:**10.1016/j.ijrobp.2020.11.013.

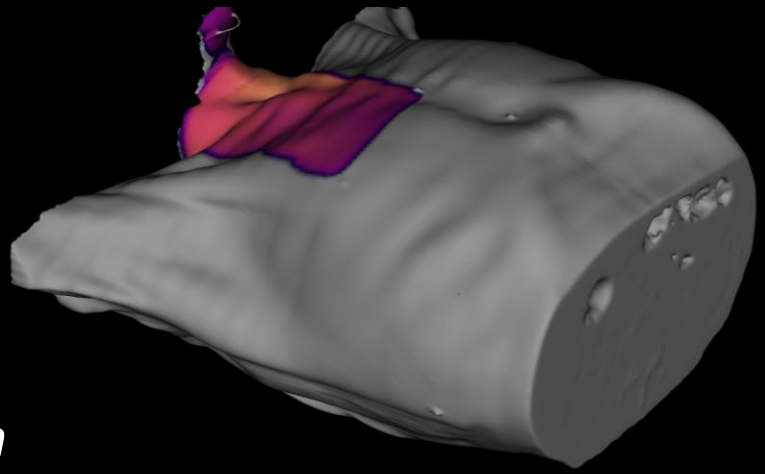
Set up & Planning: Real Time & Discovery of Issues





Treatment Plan,
central sagittal slice



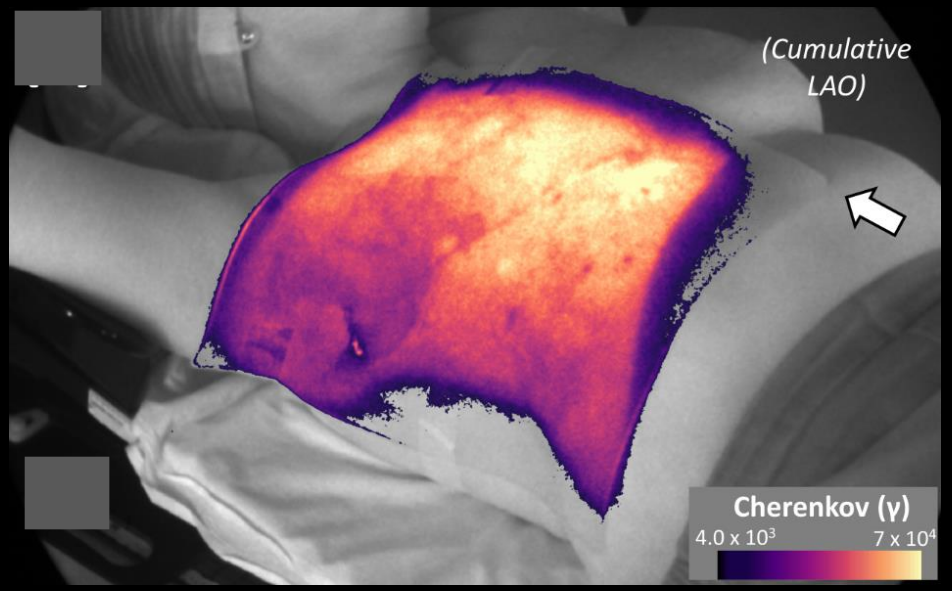


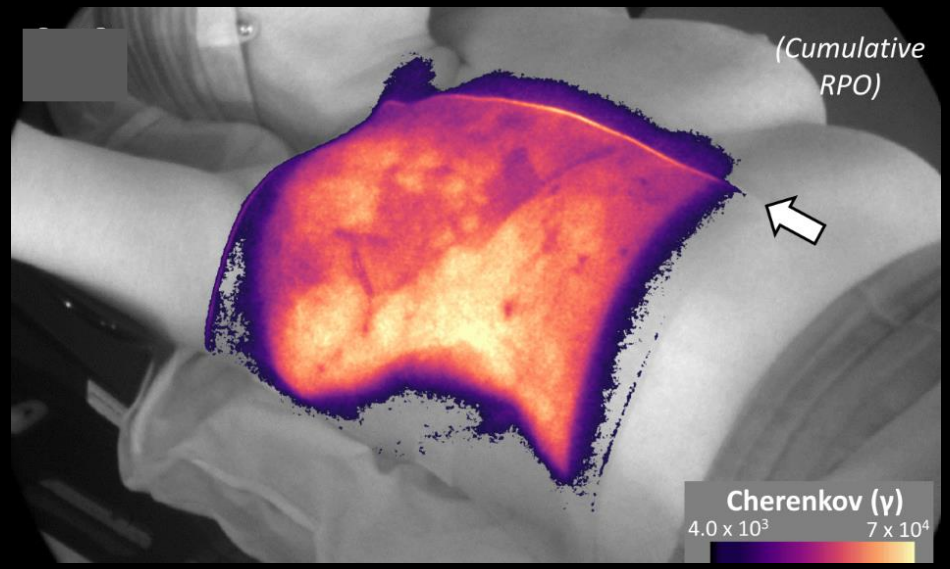
1/3 Fields Shown

Planned Surface Dose

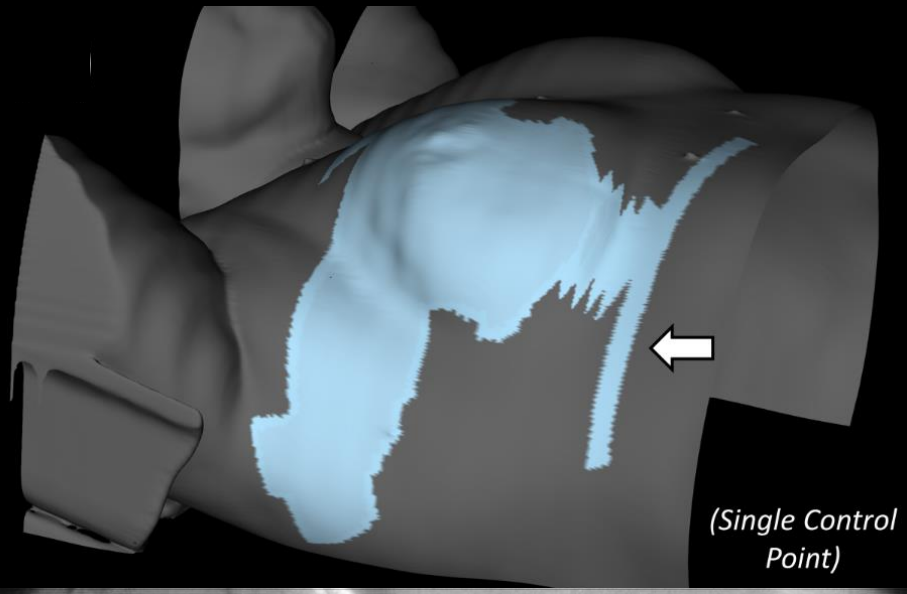
1st study: Prospective recruitment study

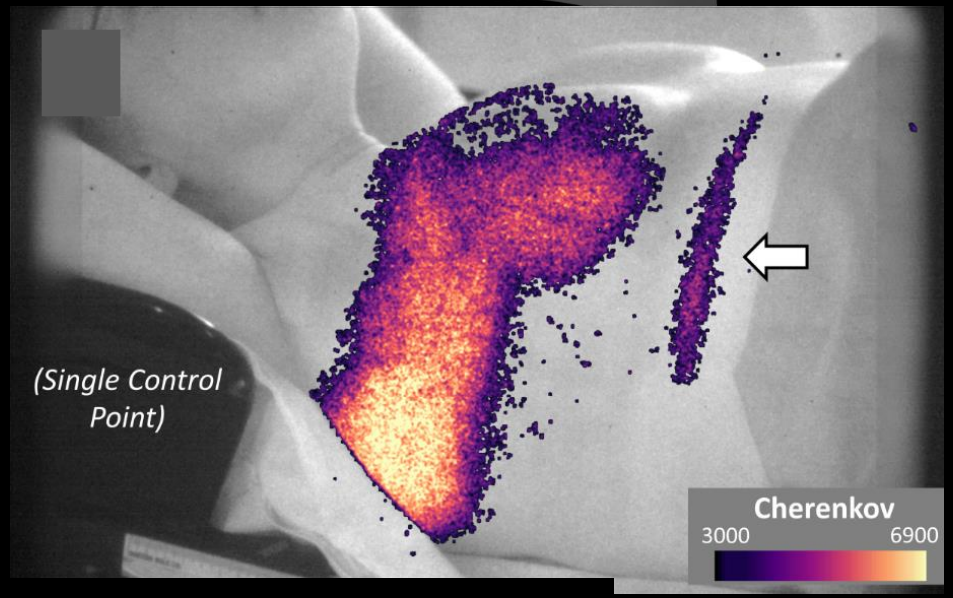
Case 3 – Bolus alignment





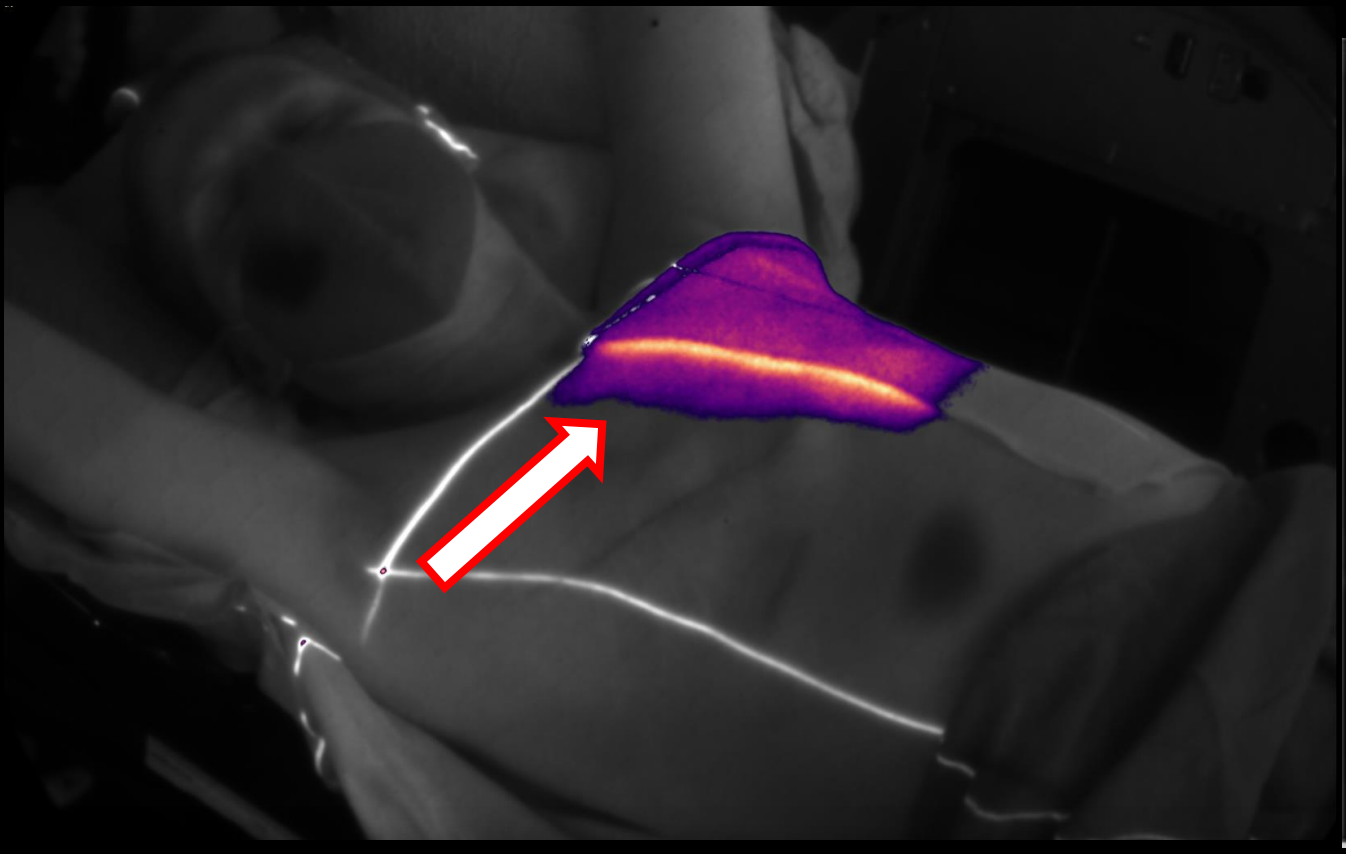
Case 4 – Open MLC in plan

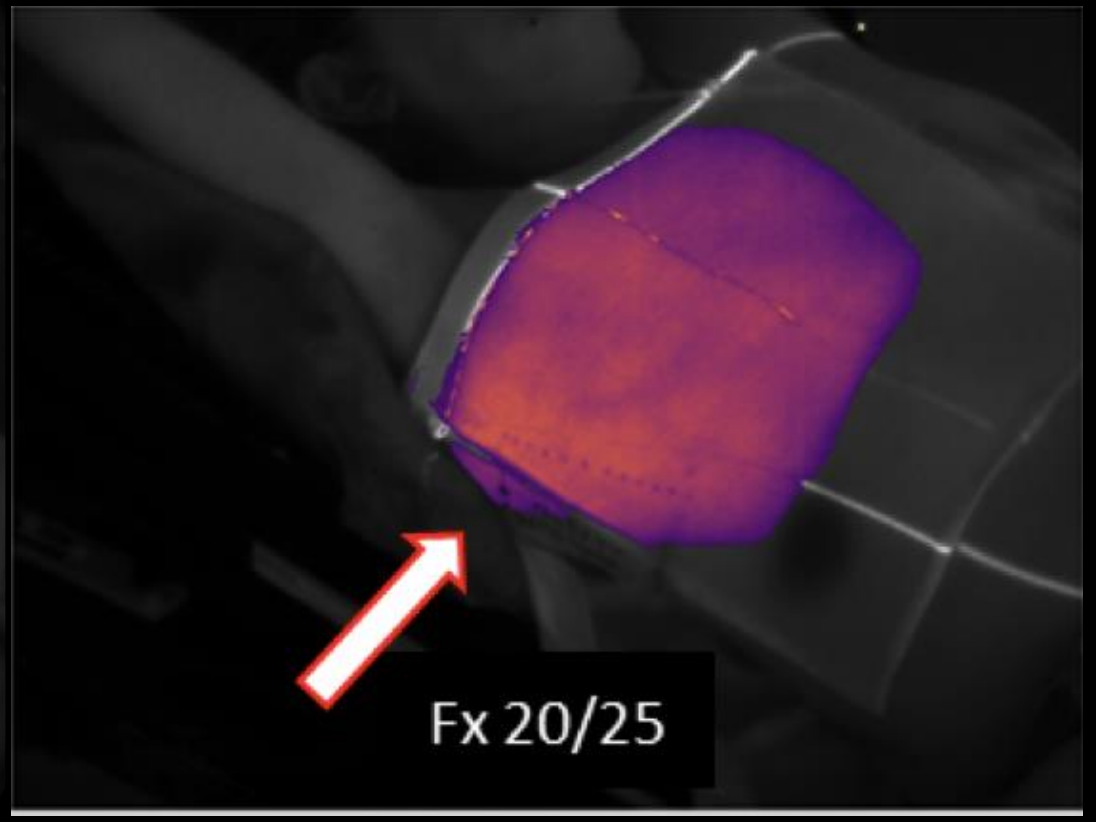




L. A. Jarvis, et al. *International Journal of Radiation Oncology*Biology*Physics* **109** (5). **2021**

Bolus placement variations are visible





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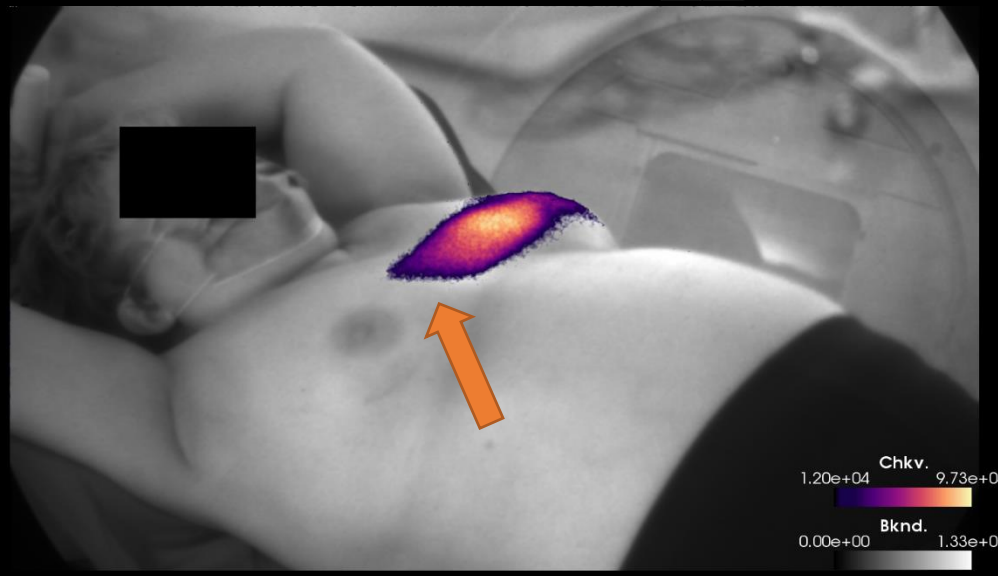
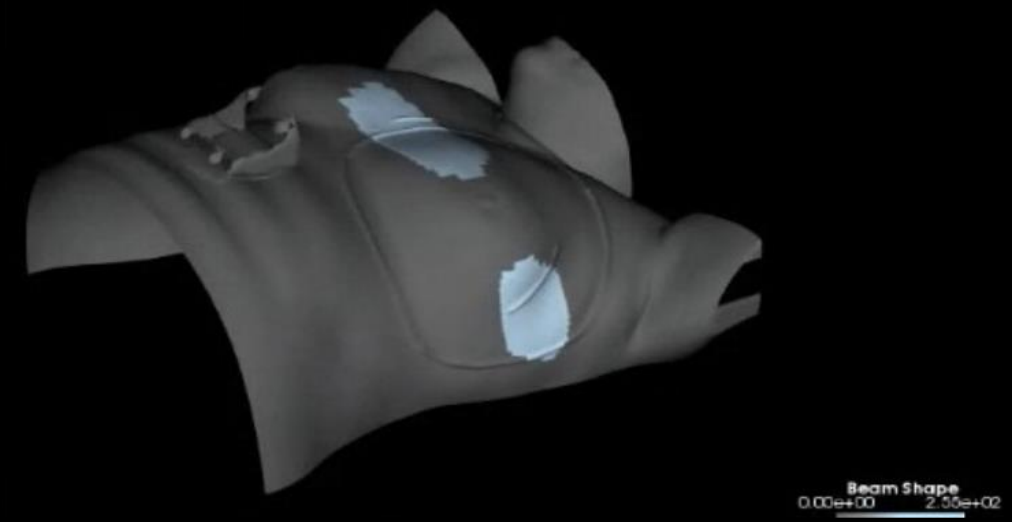
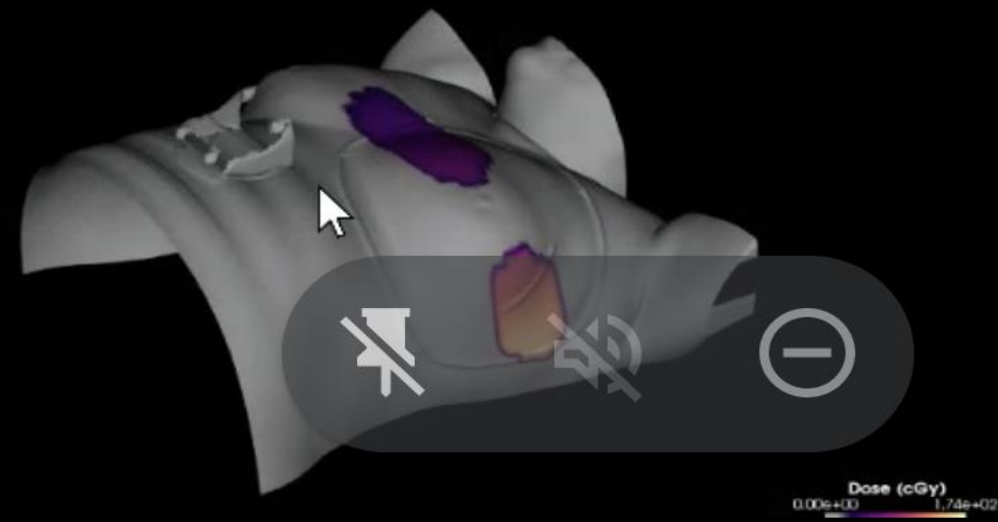
Patient setup & Compliance: exposure to extremities

D A Alexander, et al, "Retrospective Evaluation of an Always-on Cherenkov Imaging System for Radiotherapy Quality Improvement" **arXiv**: 2110.07494 [physics.med-ph]

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







Evaluating ***D***ose ***U***sing ***C***herenkov ***A***nd scintillation ***TE***chnolgy

The EDUCATE trial

Limiting contralateral breast dose (CBD) is a critical goal in the planning & delivery of breast RT

- Why do **WECARE**? CBD in excess of 1 Gy in young patients is associated with elevated risk of a subsequent contralateral breast cancer
  - Dose constraint of Dmax ≤ 2 Gy may be accepted for older patients
- Since the WECARE data have been published, we've seen some changes in breast RT
  - Expanded indications for irradiation of the IMNs
  - Adoption of VMAT techniques
- Plus, Cherenkov imaging has shown us that there are times where CBD is present, but we just can't detect or appreciate the magnitude using standard methods

Hypothesis: Incidence of CBD in modern clinical practice may be underappreciated

Stovall et al., *IJROBP.* 2008.

EDUCATE objectives

1. To establish the incidence of CBD in routine clinical practice
2. To quantify CBD using Cherenkov-image-guided *in vivo* dosimetry
3. To determine the root causes of CBD
   - Distinguish between planned vs unplanned CBD
   - Minimize CBD in future treatments, when possible

METHODS

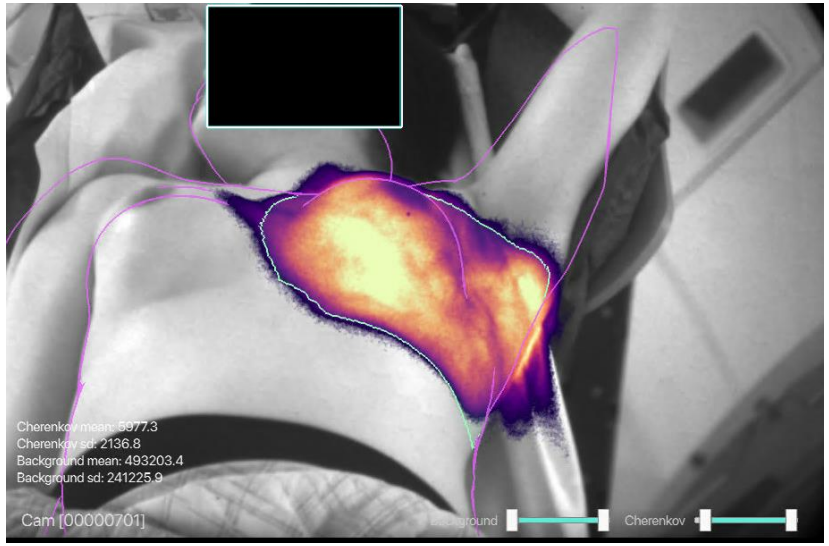
- Daily Cherenkov image review of all breast treatments at an academic & community medical center to identify CBD
- Measure CBD with *in vivo* dosimetry when identified

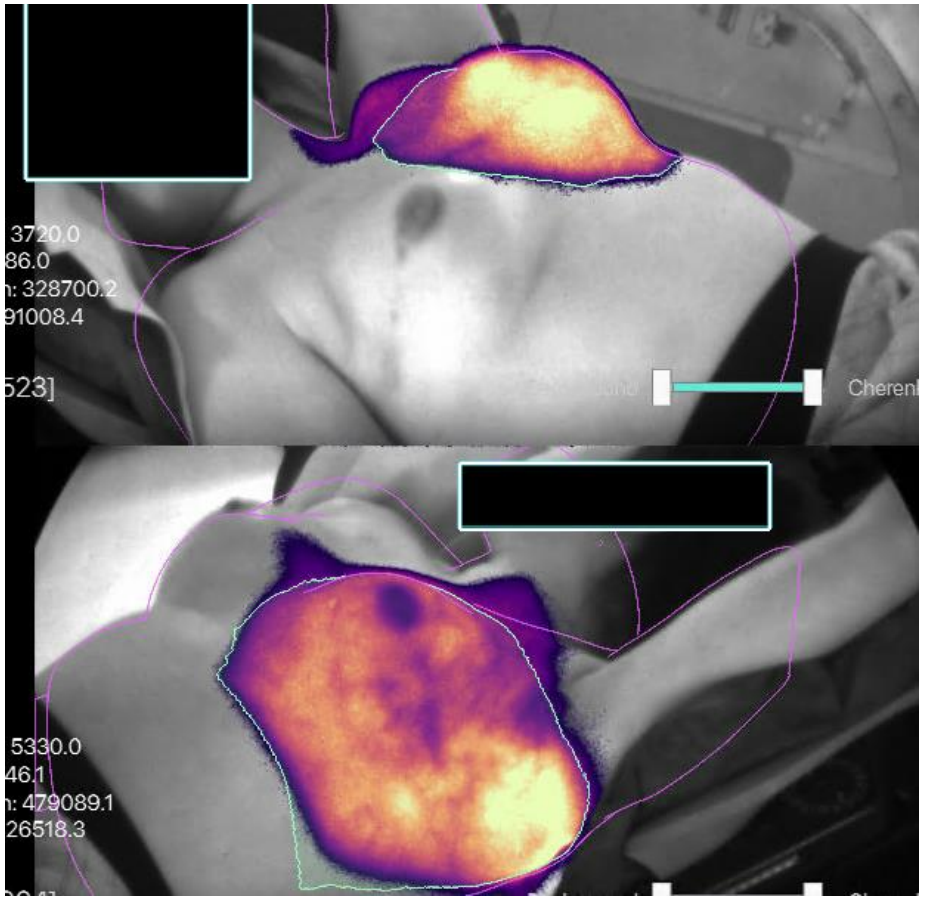
Over 40% of breast treatments show CBD on Cherenkov imaging!

- Images for **129 unique patients** over 1854 fractions reviewed over 6 months
  - **94 patients (1305 fractions) treated with supine techniques**
- CBD was identified during treatment delivery for **43%** (N = 40) unique patients!

Rates of CBD vary by technique

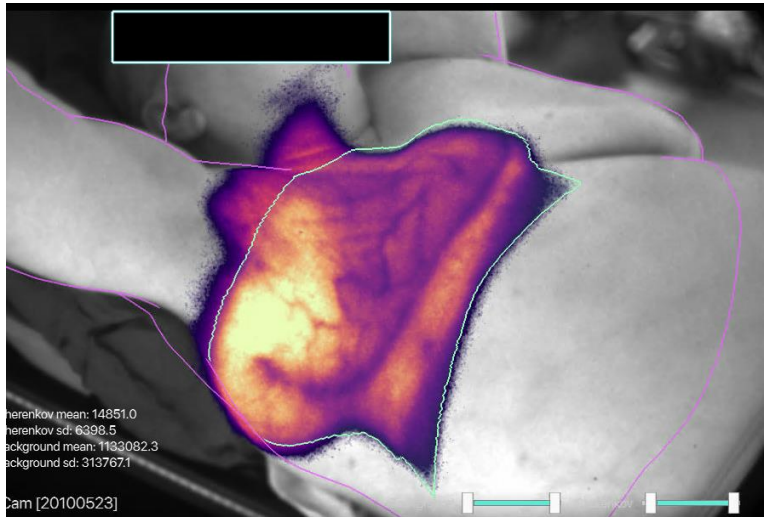
- Tangents **11%** (6/56)
- Wide tangents **93%** (13/14)
- Tangents with medial electrons **100%** (2/2)
- aPBI with VMAT **100%** (17/17)
- Chest wall with VMAT **100%** (2/2)



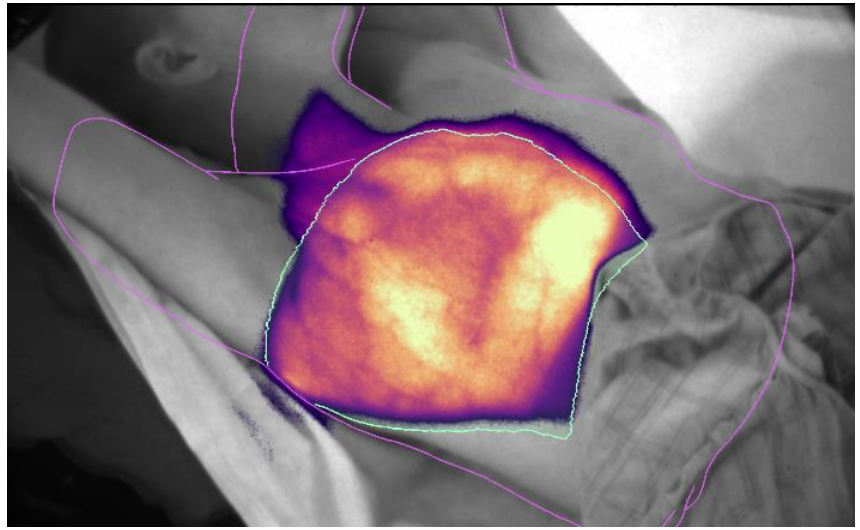


"Lines are experimental and not approved for clinical use by the FDA"

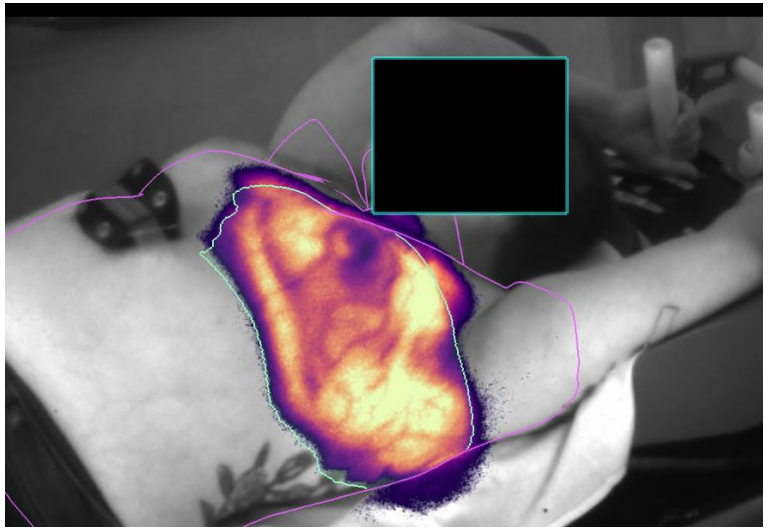
CBD was unplanned in 10% of cases!



Planned CBD



Unplanned CBD



Combination of planned & unplanned CBD

"Lines are experimental and not approved for clinical use by the FDA"

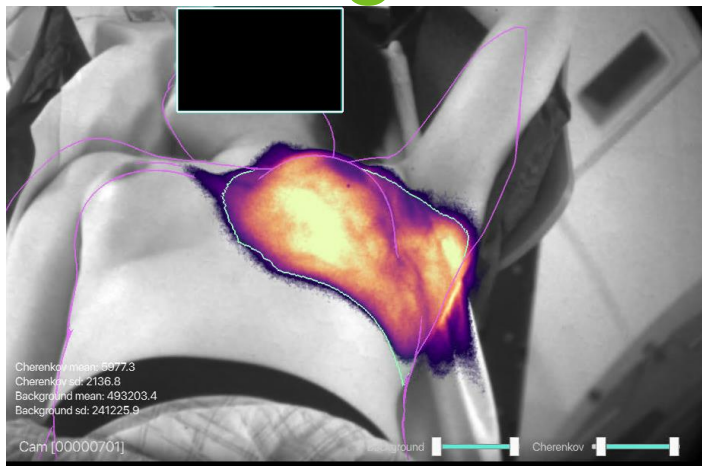
Measured dose to contralateral breast exceeds dose constraints for 3D treatments

	Wide Tangents 7 patients	Tangents + Medial Electrons 1 patient	aPBI with VMAT 15 patients
TLD measured dose (Gy) to CB over 1 fraction	0.256 – 2.16	1.71 – 1.94	0.07 – 0.63
Total dose (Gy) to CB if summed across all fractions	6.38 - 34.5	42.8 - 48.5	0.35 – 3.15
Number of treatment courses that have CBD in excess of the 2 Gy dose constraint	100%	100%	7%

*CB = contralateral breast

CB dose constraint: Dmax $\leq$ 2 Gy

17% (22) of patients in this cohort are age 50 or younger!



- Of these patients, **27%** (6/22) had **CBD** on imaging
- 2 of these patients underwent dose measurement

Patients under 50 had CBD in excess of this dose constraint!

- Future work includes monitoring every young patient with Cherenkov imaging to eliminate unplanned dose

Goal: Reduce the 10% rate of unplanned CBD to 0%!

"Lines are experimental and not approved for clinical use by the FDA"

Summary: Clinical Cherenkov Imaging Provides a Visualization of Dose for Treatment Field Verification

Clinical incidents identified *only* by use of Cherenkov imaging

Sub-optimal planning

Patient motion / imperfect setup

Inconsistent bolus placement

Alexander†, Decker†, et al. PRO (2022)

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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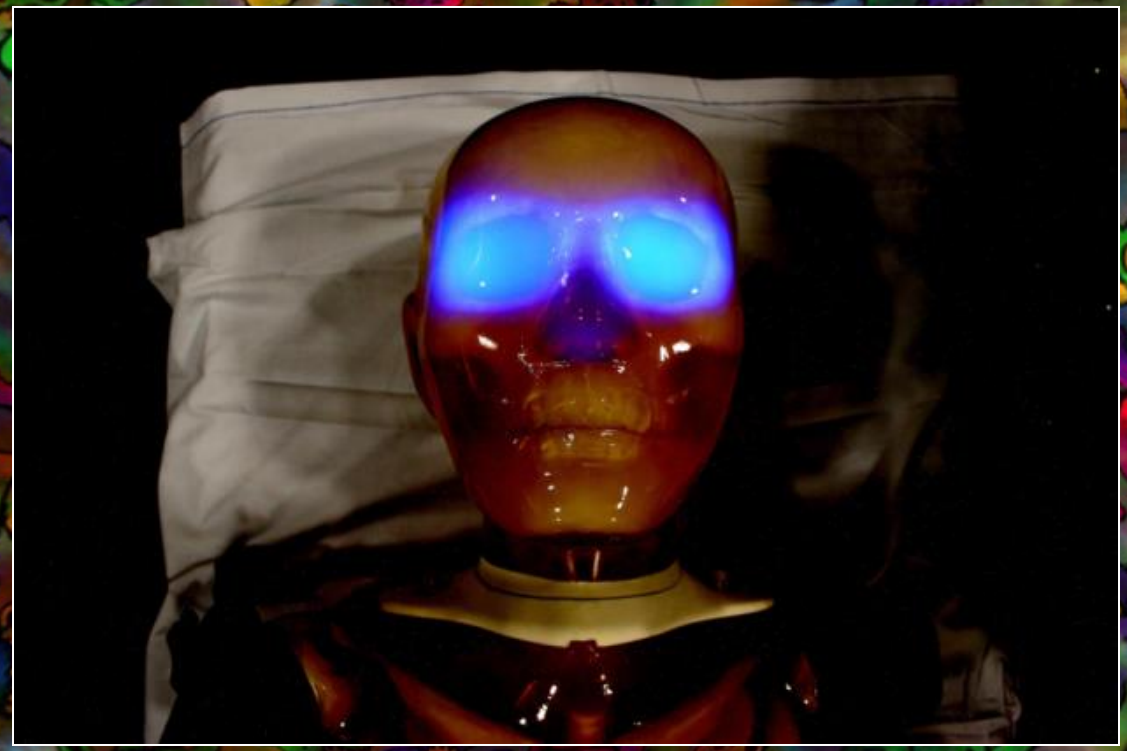
QUESTIONS ?



"Once in a while you can get shown the light in the strangest of places if you look at it right."

J. Garcia, R. Hunter

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