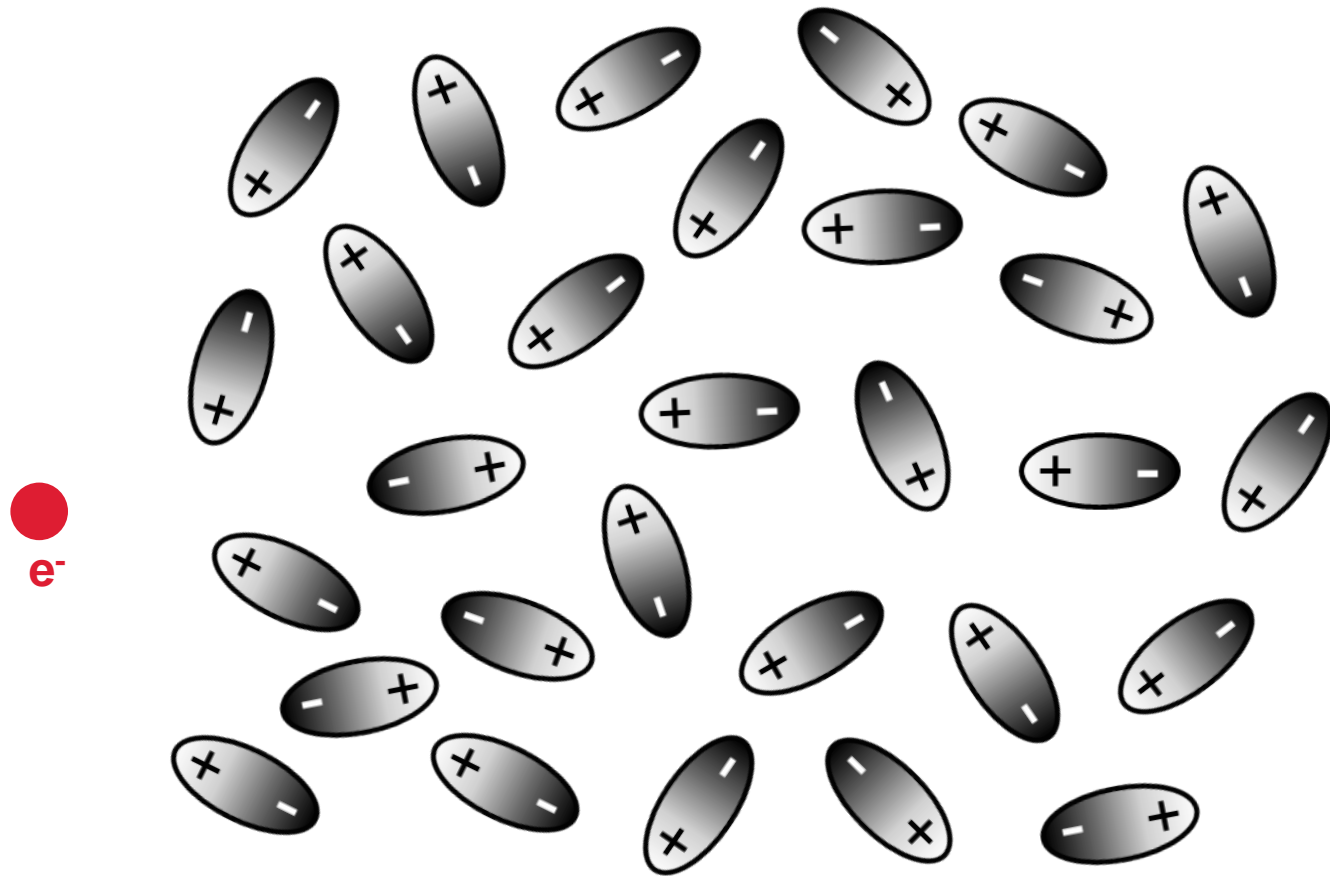


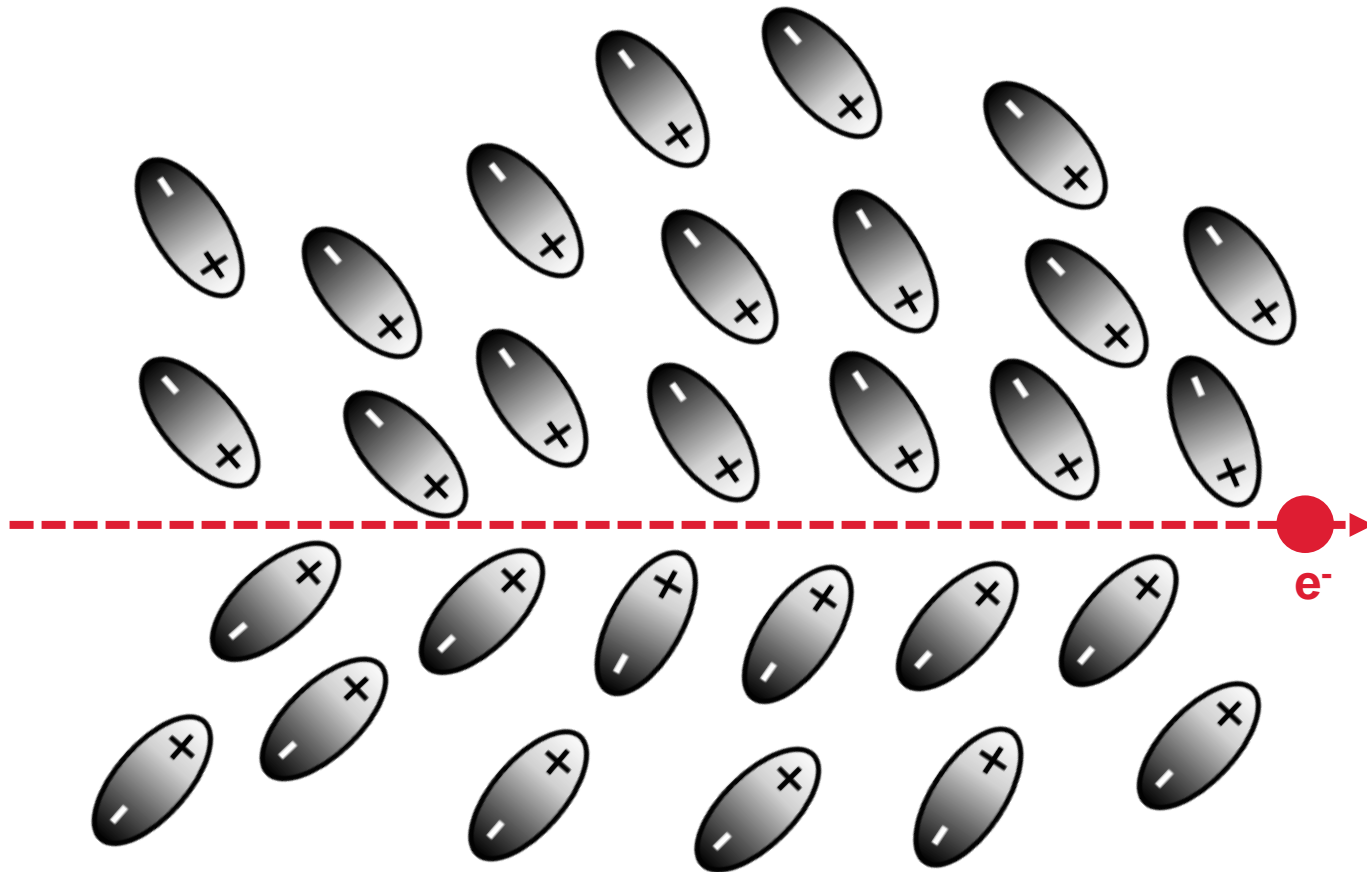
# Method and Application for Spectral Decomposition of Cherenkov Emission for Tissue Characterization and Attenuation Correction in Radiotherapy

Roman Vasylytsiv<sup>1</sup>, Allison Matous<sup>2</sup>, Shiru Wang<sup>1</sup>, Brian Pogue<sup>1</sup>, David Gladstone<sup>1</sup>, Lesley Jarvis<sup>2</sup>, Petr Bruza<sup>1</sup>

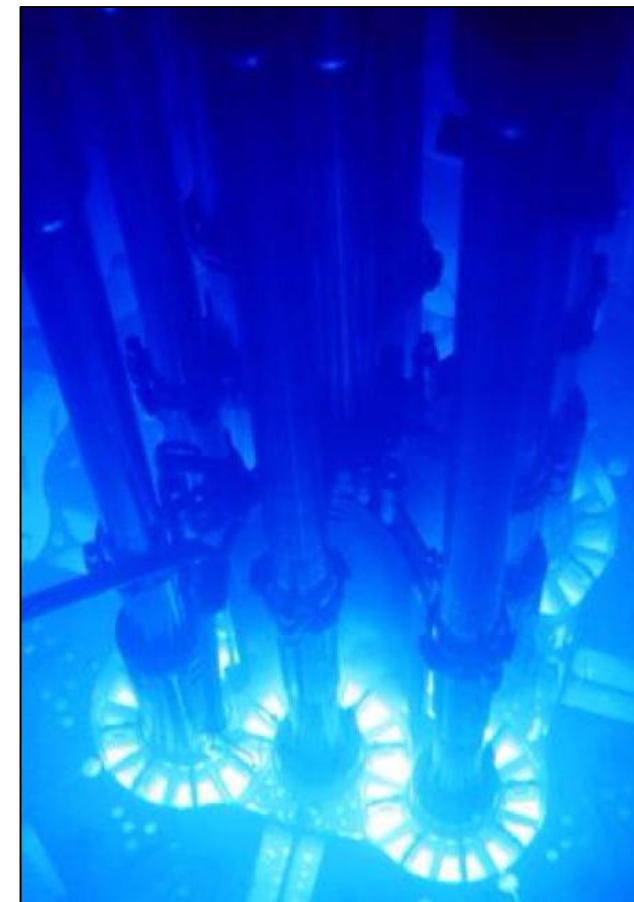
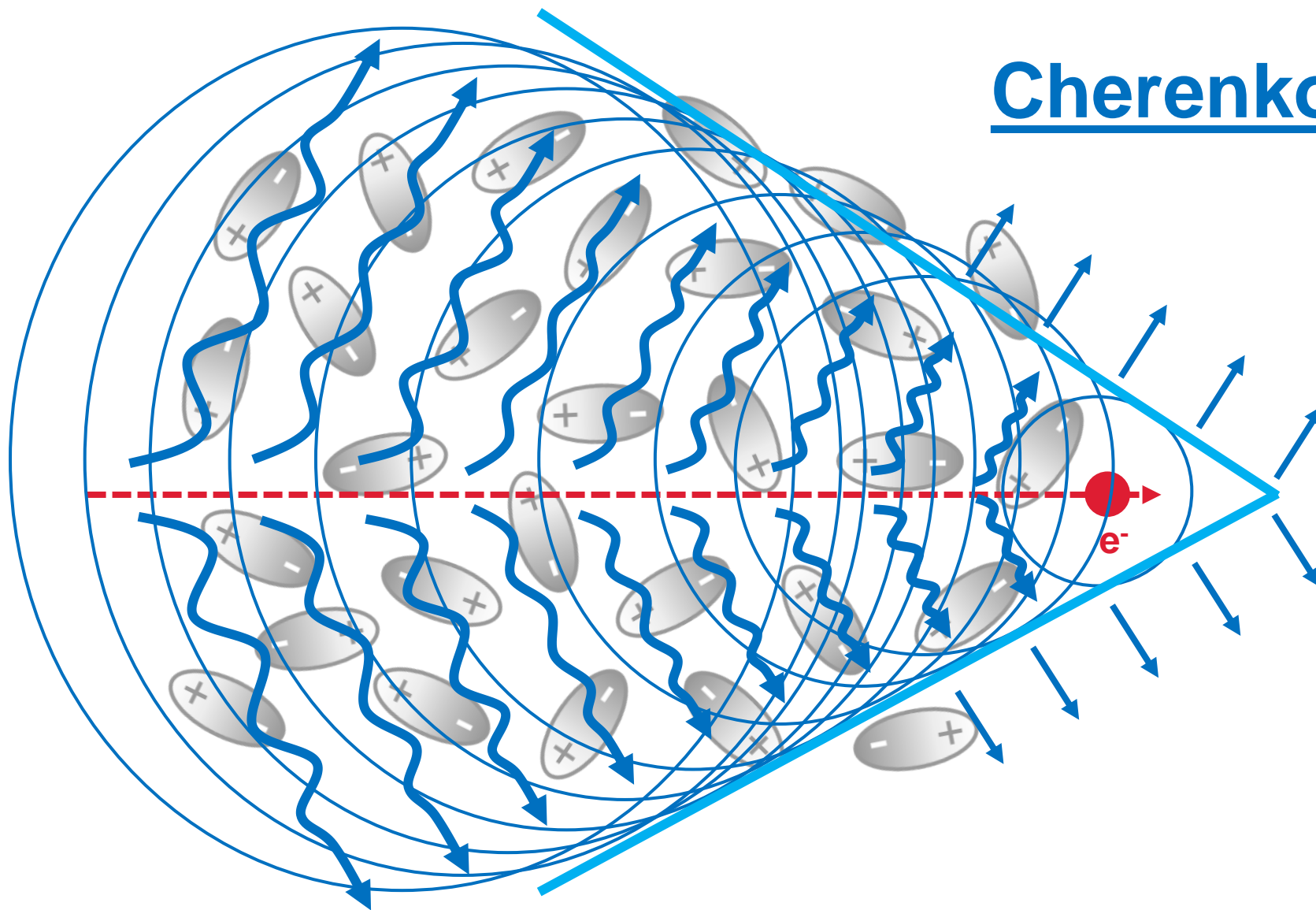
<sup>1</sup>Thayer School of Engineering, Dartmouth College, Hanover, NH    <sup>2</sup>Department of Radiation Oncology, Dartmouth Health, Lebanon, NH

February 5, 2026  
New England AAPM Conference

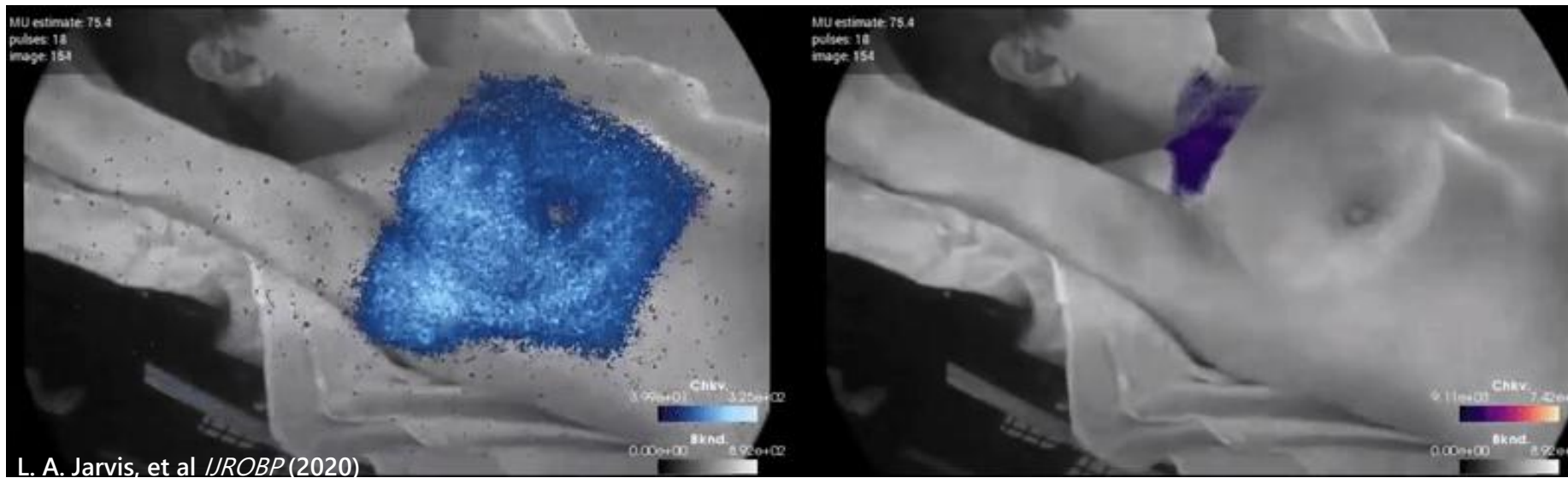




# Cherenkov Radiation



# Clinical Cherenkov Imaging Provides Real Time Dose Visualization for Treatment Field Verification



L. A. Jarvis, et al *IJROBP* (2020)

## Live Cherenkov Video

## Cumulative Cherenkov Image

> *Int J Radiat Oncol Biol Phys.* 2014 Jul 1;89(3):615-22. doi: 10.1016/j.ijrobp.2014.01.046. Epub 2014 Mar 28.

**Cherenkov video imaging allows for the first visualization of radiation therapy in real time**

Lesley A Jarvis<sup>1</sup>, Rongxiao Zhang<sup>2</sup>, David J Gladstone<sup>3</sup>, Shudong Jiang<sup>4</sup>, Whitney Hitchcock<sup>5</sup>, Oscar D Friedman<sup>4</sup>, Adam K Glaser<sup>4</sup>, Michael Jermy<sup>4</sup>, Brian W Pogue<sup>6</sup>

Affiliations + expand  
PMID: 24685442 DOI: 10.1016/j.ijrobp.2014.01.046

> *Int J Radiat Oncol Biol Phys.* 2021 Apr 1;109(5):1627-1637. doi: 10.1016/j.ijrobp.2020.11.013. Epub 2020 Nov 20.

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

Lesley A Jarvis<sup>1</sup>, Rachael L Hachadorian<sup>2</sup>, Michael Jermy<sup>2</sup>, Petr Bruza<sup>2</sup>, Daniel A Alexander<sup>2</sup>, Irwin I Tendler<sup>2</sup>, Benjamin B Williams<sup>3</sup>, David J Gladstone<sup>3</sup>, Philip E Schaner<sup>4</sup>, Bassem I Zaki<sup>4</sup>, Brian W Pogue<sup>2</sup>

Affiliations + expand  
PMID: 33227443 PMID: PMC10544920 DOI: 10.1016/j.ijrobp.2020.11.013

> *Phys Med Biol.* 2014 Jul 21;59(14):3789-811. doi: 10.1088/0031-9155/59/14/3789. Epub 2014 Jun 18.

**Optical dosimetry of radiotherapy beams using Cherenkov radiation: the relationship between light emission and dose**

Adam K Glaser<sup>1</sup>, Rongxiao Zhang, David J Gladstone, Brian W Pogue

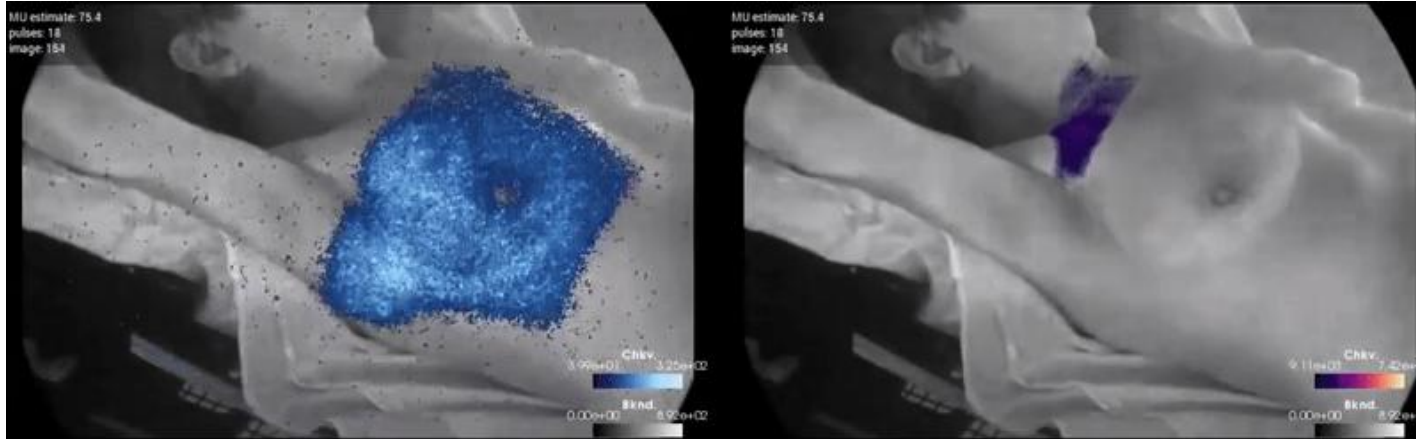
Affiliations + expand  
PMID: 24938928 DOI: 10.1088/0031-9155/59/14/3789

Review > *Pract Radiat Oncol.* 2023 Jan-Feb;13(1):71-81. doi: 10.1016/j.pro.2022.06.009. Epub 2022 Jun 29.

**One Year of Clinic-Wide Cherenkov Imaging for Discovery of Quality Improvement Opportunities in Radiation Therapy**

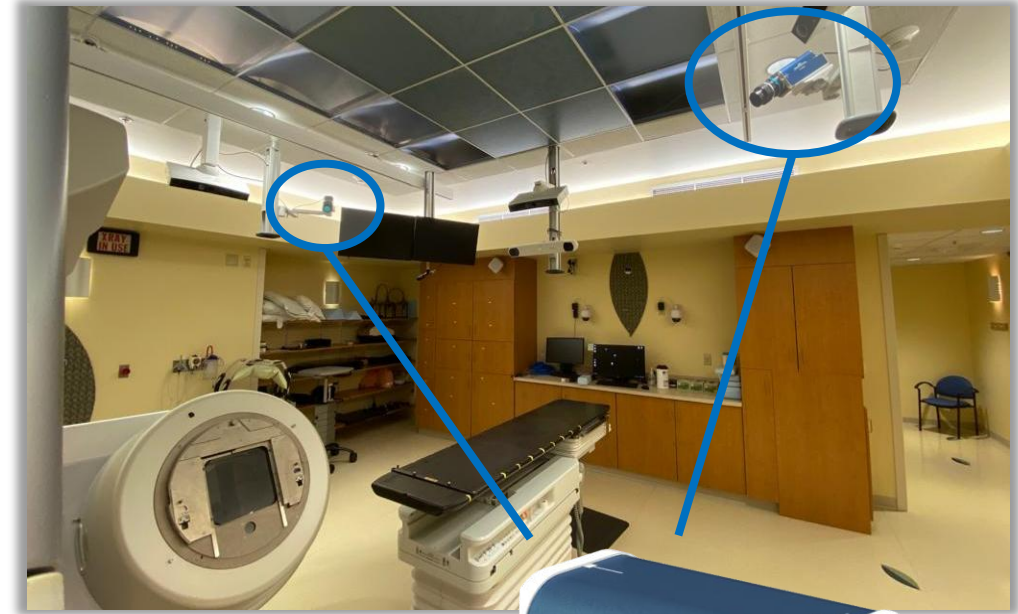
Daniel A Alexander<sup>1</sup>, Savannah M Decker<sup>2</sup>, Michael Jermy<sup>2</sup>, Petr Bruza<sup>2</sup>, Rongxiao Zhang<sup>3</sup>, Erii Chen<sup>4</sup>, Tatum L McGlynn<sup>5</sup>, Rory A Rossetol<sup>5</sup>, Jae Lee<sup>5</sup>, Melanie L Rose<sup>5</sup>, Benjamin B Williams<sup>3</sup>, Brian W Pogue<sup>6</sup>, David J Gladstone<sup>7</sup>, Lesley A Jarvis<sup>8</sup>

Affiliations + expand  
PMID: 35777728 PMID: PMC10984217 DOI: 10.1016/j.pro.2022.06.009



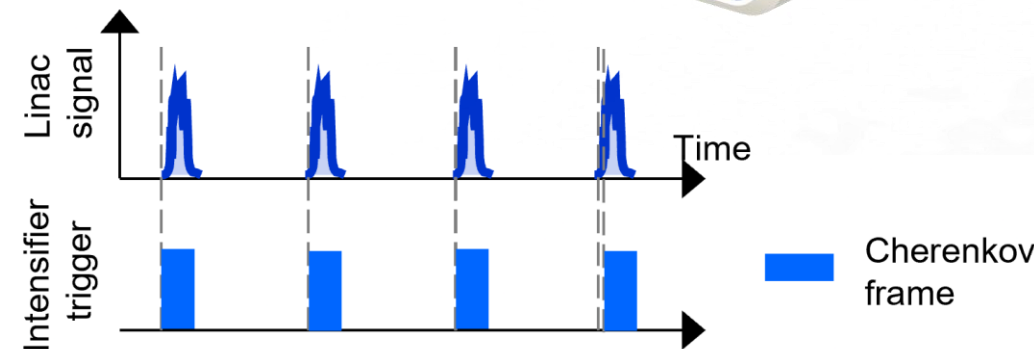
Live Cherenkov Video

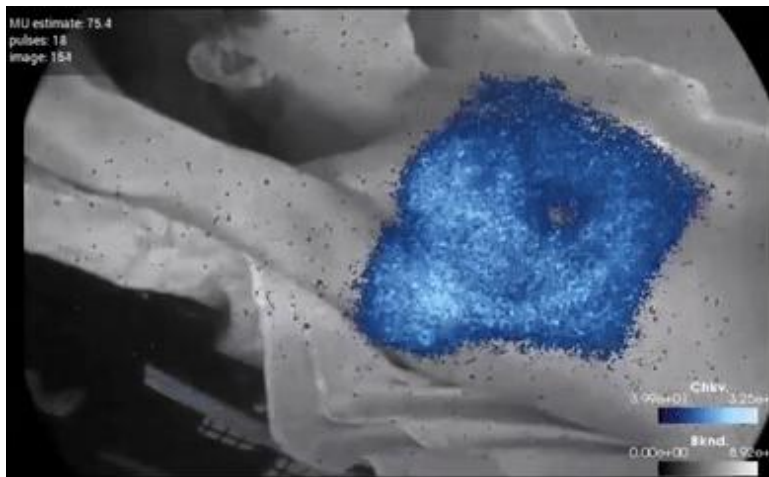
Cumulative Cherenkov Image



### DoseOptics iCMOS Cameras:

- **Gated** acquisition to LINAC pulses
- **Inter-pulse gaps gather background images** and isolate the weak emitted signal
- Cherenkov signal sensitivity increased via **multi-channel plate image intensifier**





Live Cherenkov Video



Cumulative Cherenkov Image

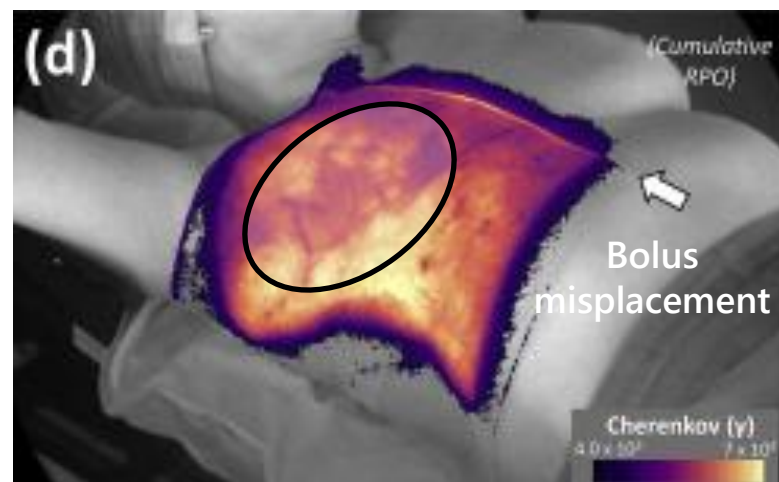
At the point of **generation**  
Cherenkov is linearly  
proportional to dose

**BUT**

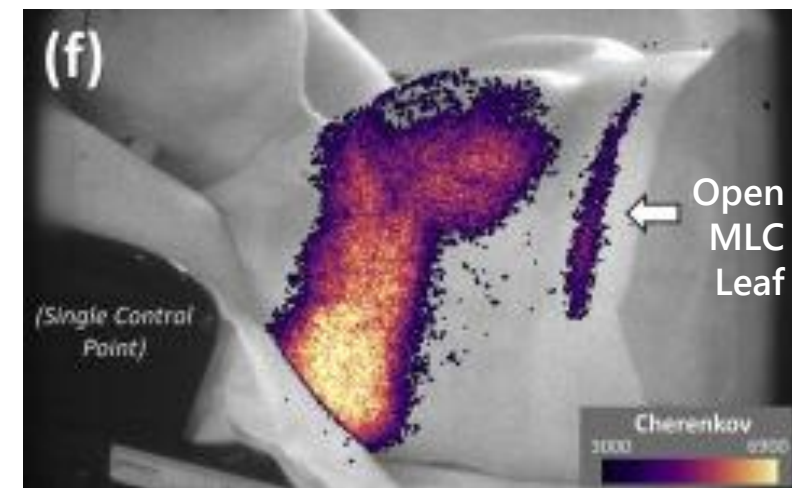
The **imaged** profile loses  
the proportionality due to  
tissue attenuation



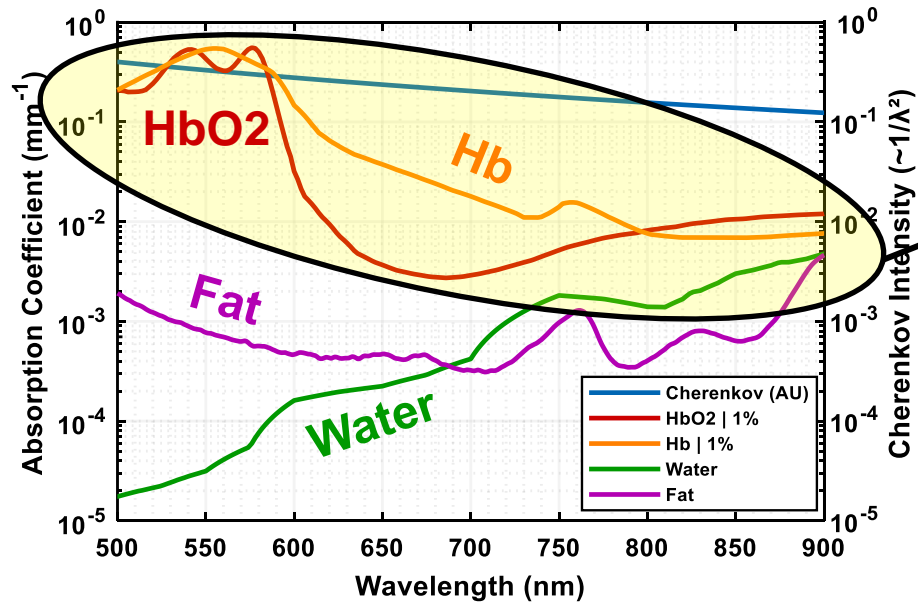
Unplanned anatomy in the beam



Accessory positioning

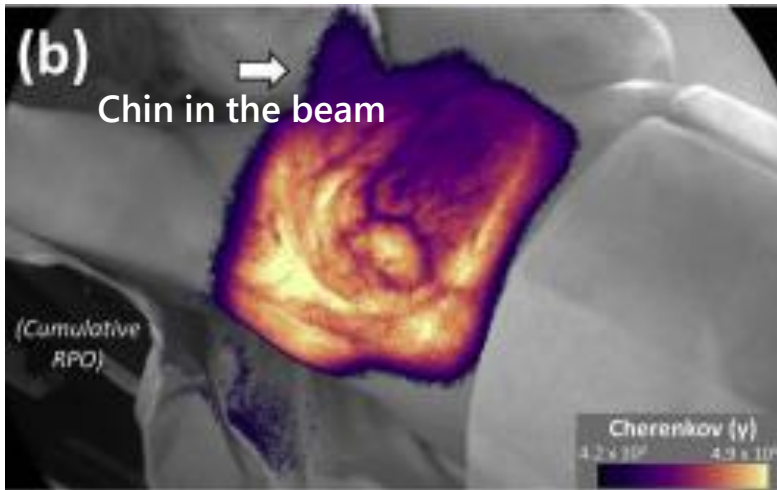


Plan errors

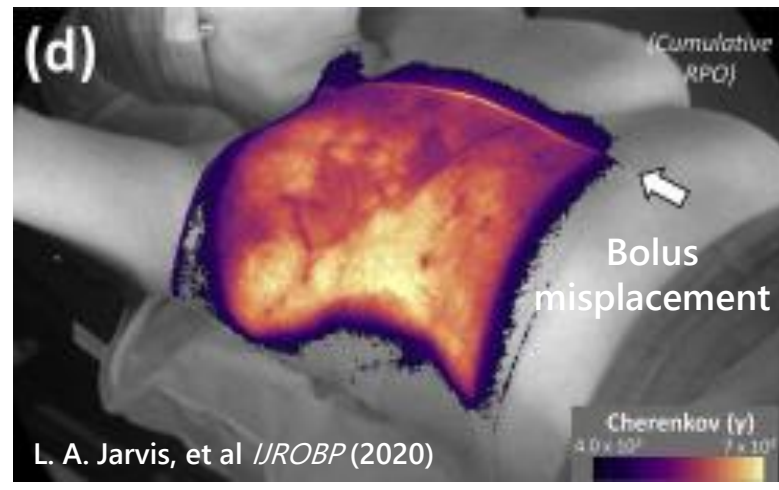


- Locally, the type and quantity of tissue attenuating constituents **cannot be predicted**
- Heterogeneous tissue attenuation is dominated by **blood content** and **variability in hemoglobin oxygenation**

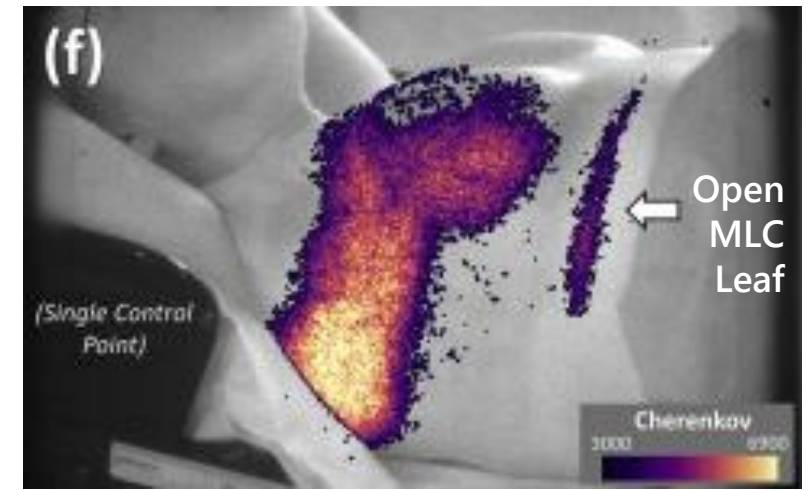
Correlate **Cherenkov spectral variability** with tissue properties to monitor for **physiological development** and **correct the signal attenuation**



Unplanned anatomy in the beam



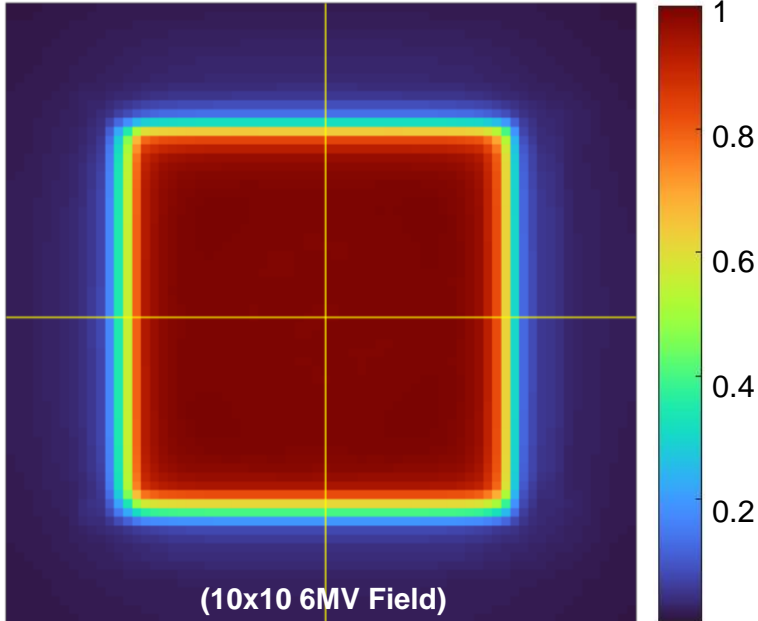
Accessory positioning



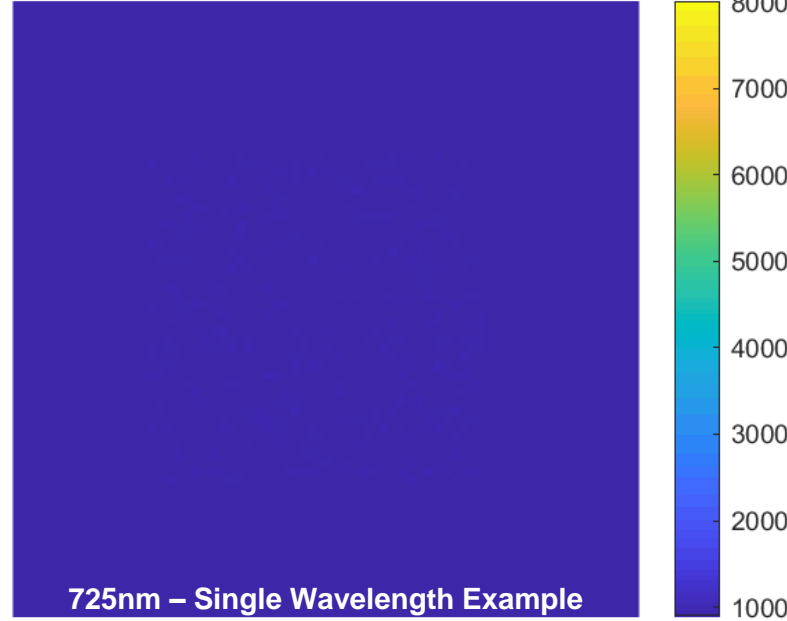
Plan errors

Signal is low so we need to image spectral bands ∴ use simulation to find best ones

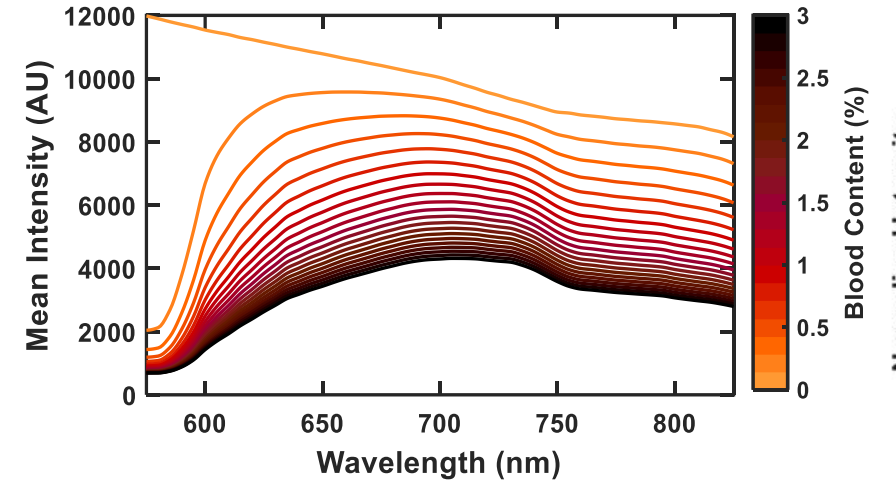
Emitter Profile – XY (Normalized)



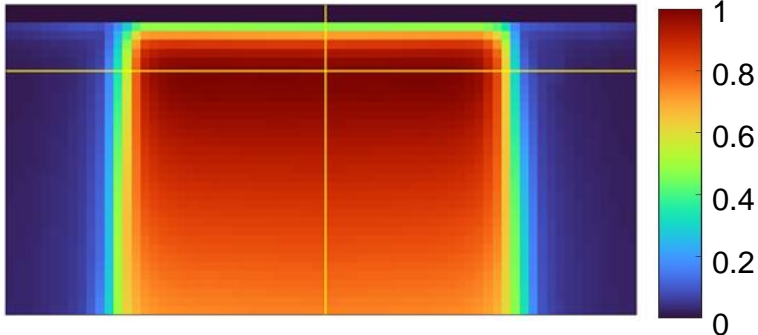
725nm - Cumulative Photons (XY)



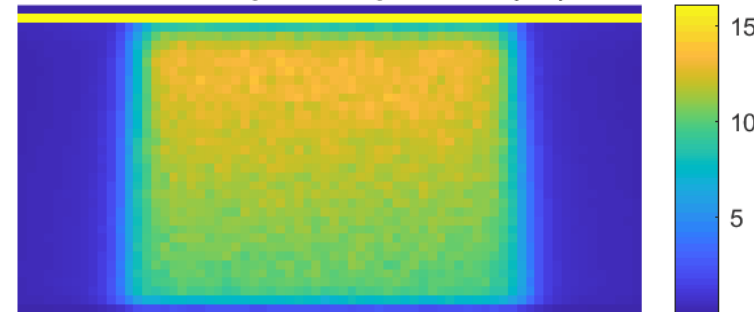
Spectral Response vs Blood Content



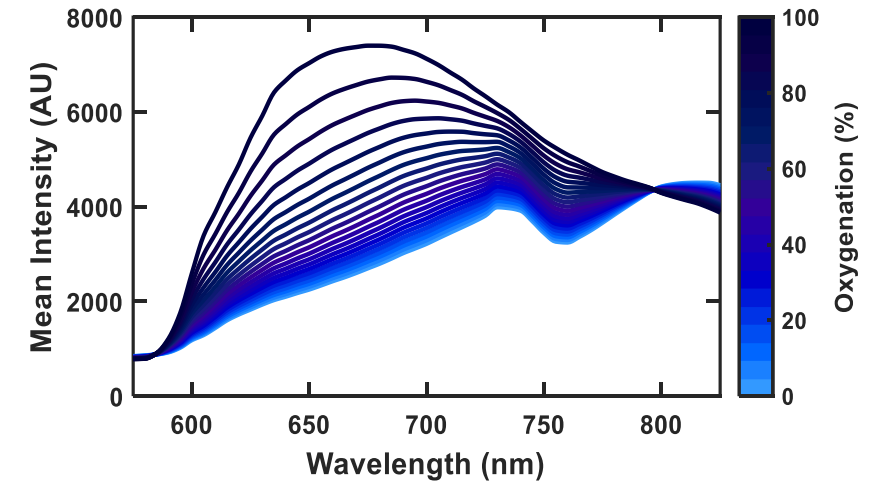
Emitter Profile – XZ (Normalized)



725nm - Deposition per Time (XZ)

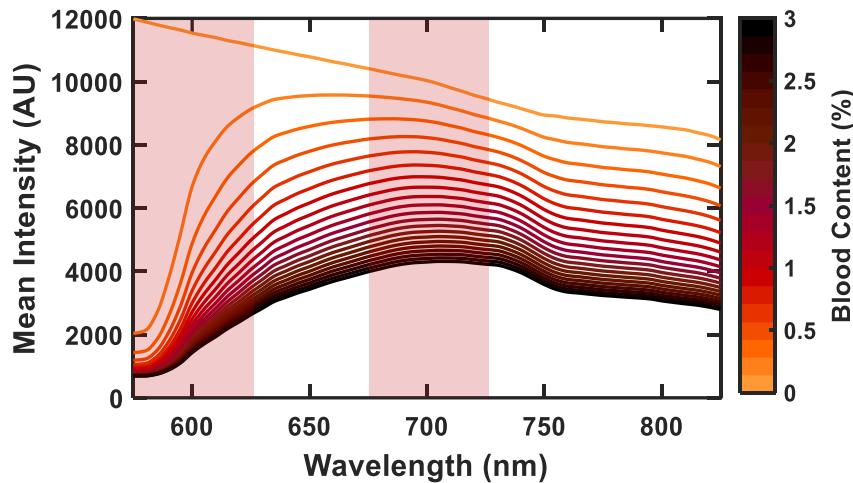


Spectral Response vs Oxygenation

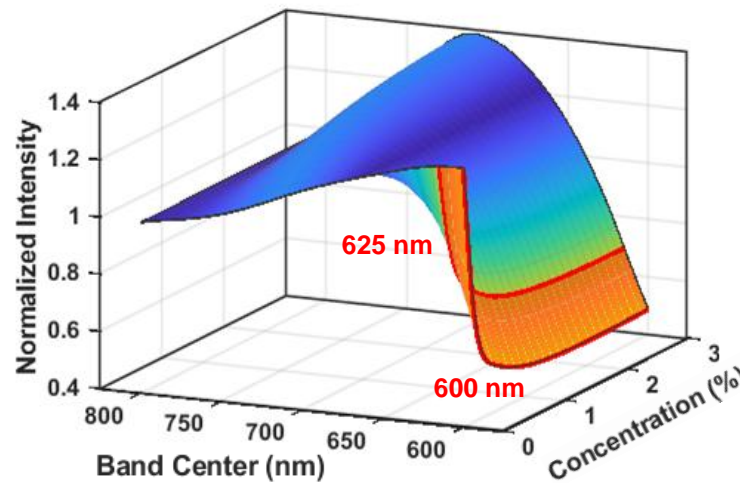


# Best bands = highest dynamic range and greatest rate of change

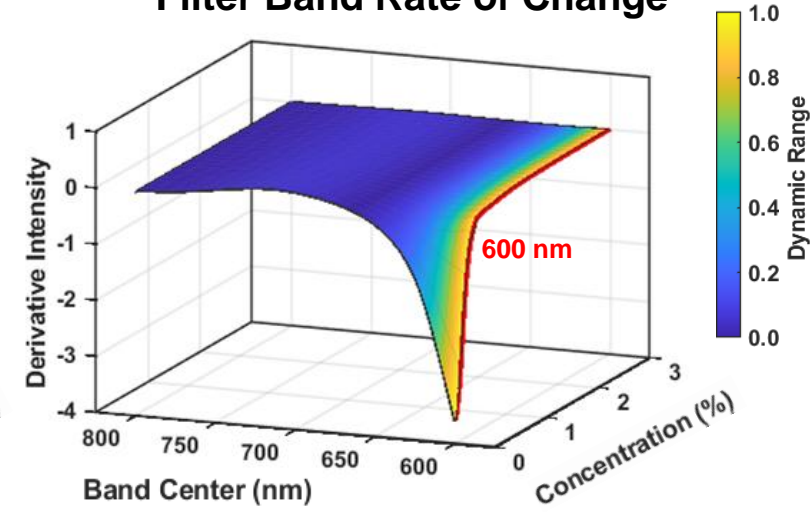
Spectral Response vs Blood Content



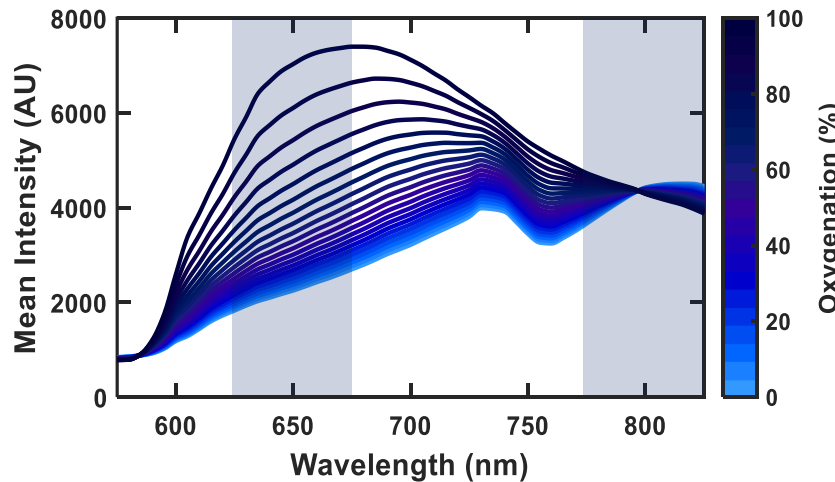
Filter Band Dynamic Range



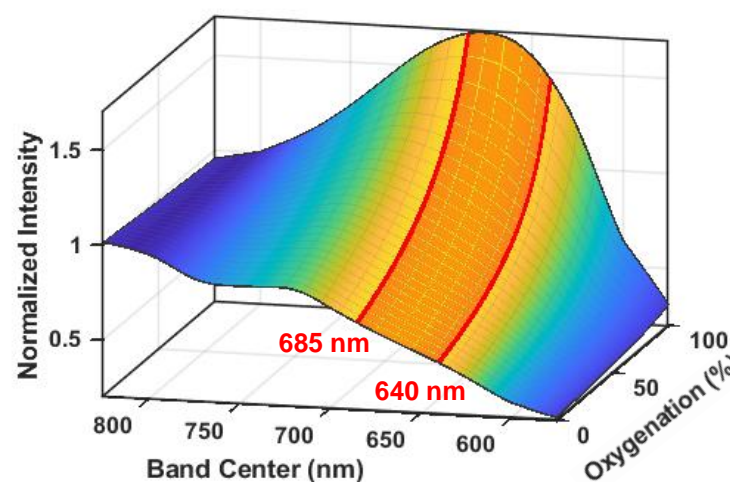
Filter Band Rate of Change



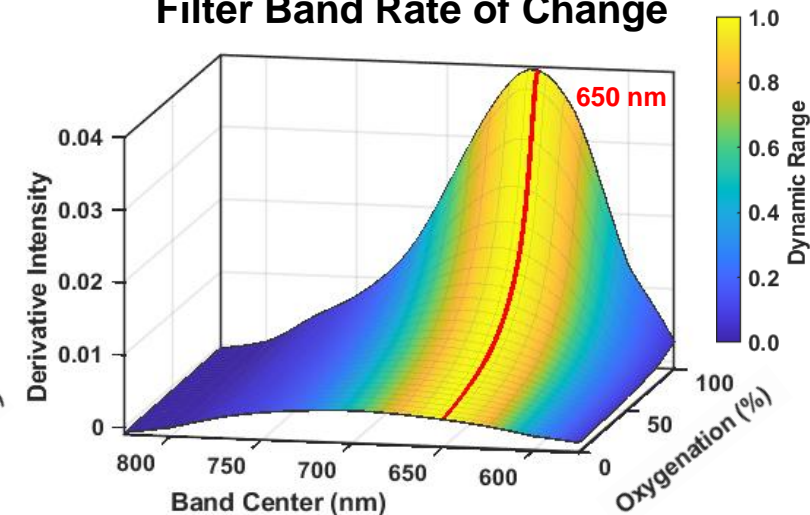
Spectral Response vs Oxygenation



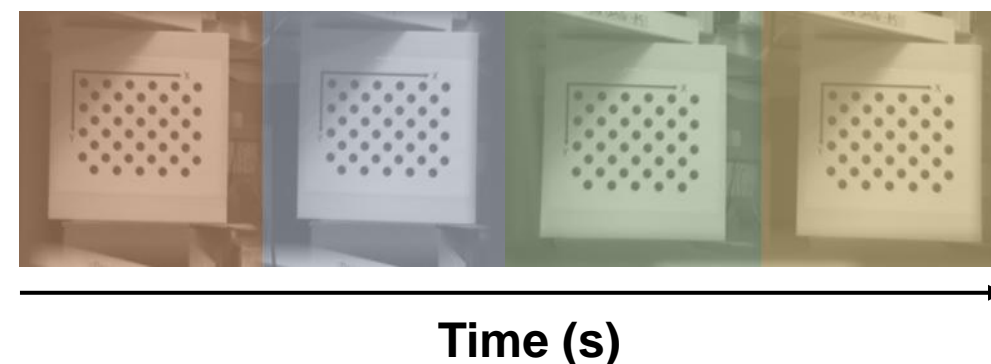
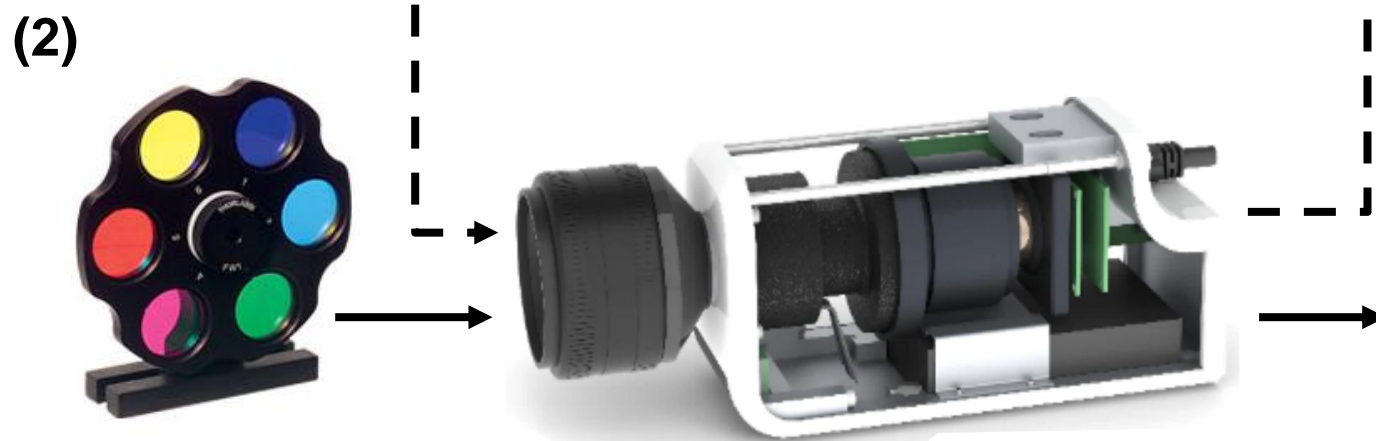
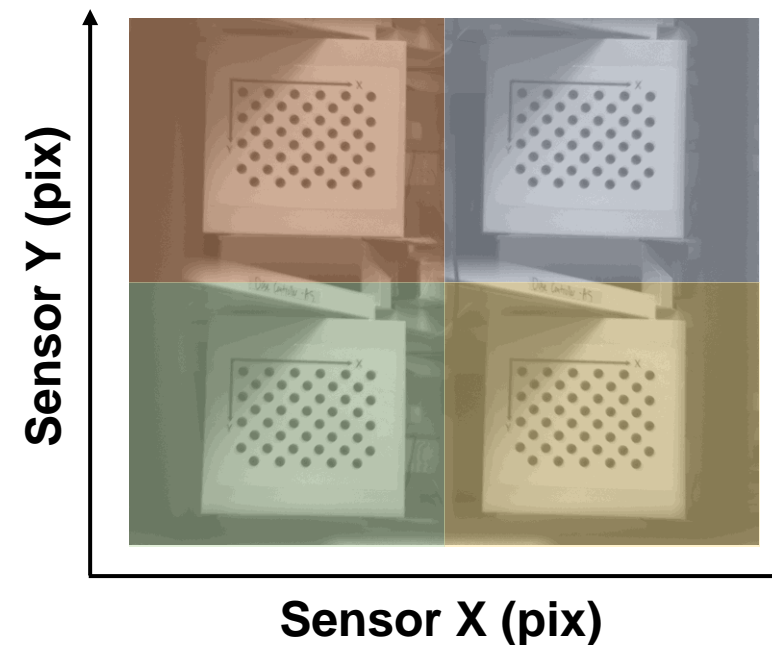
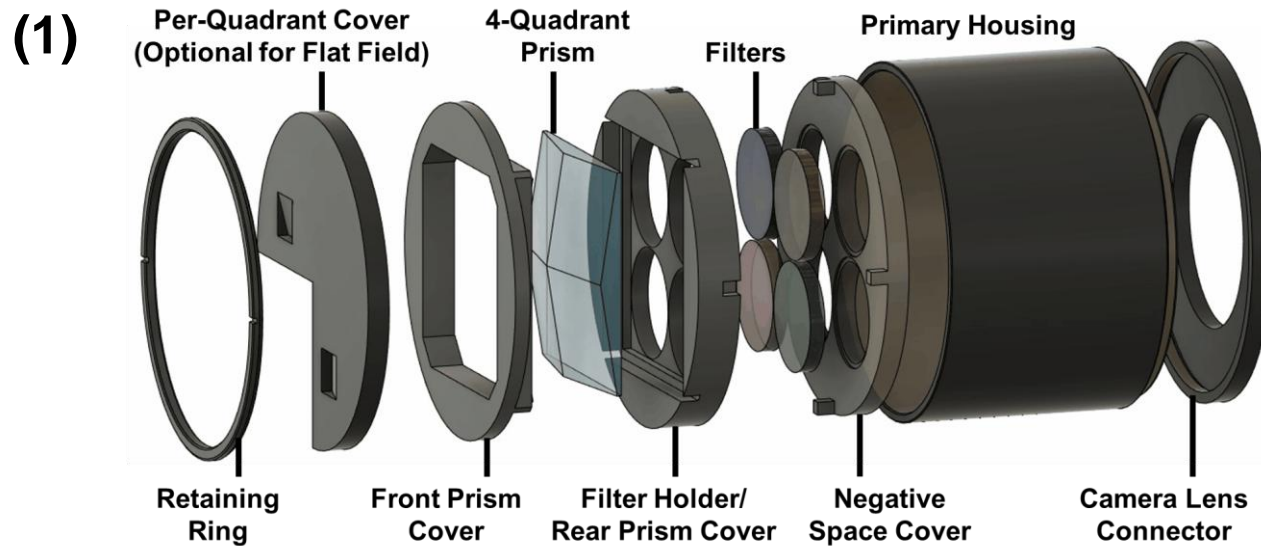
Filter Band Dynamic Range



Filter Band Rate of Change

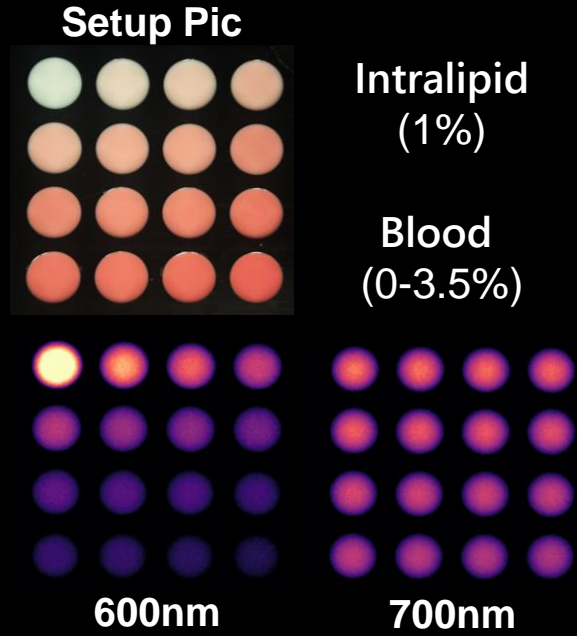


# Methods for collecting spectral Cherenkov images

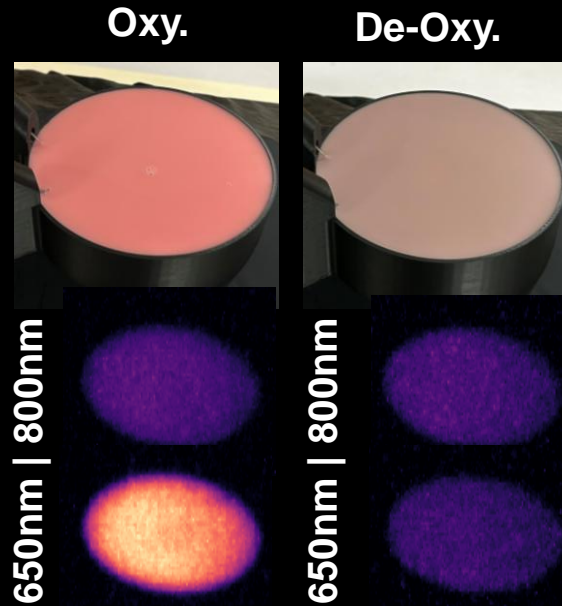


# Incorporating Simulation Results – Blood and Oxygenation Phantom Analysis

Blood Phantom Testing

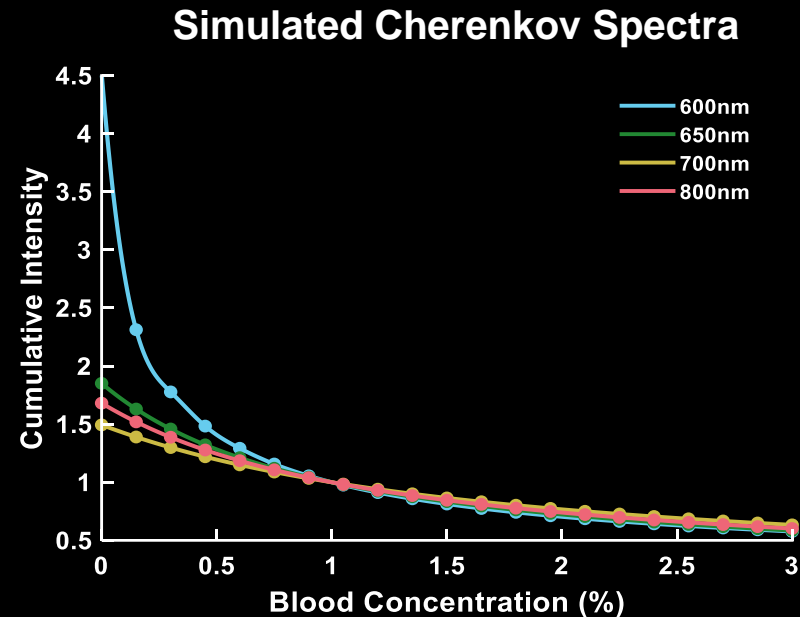
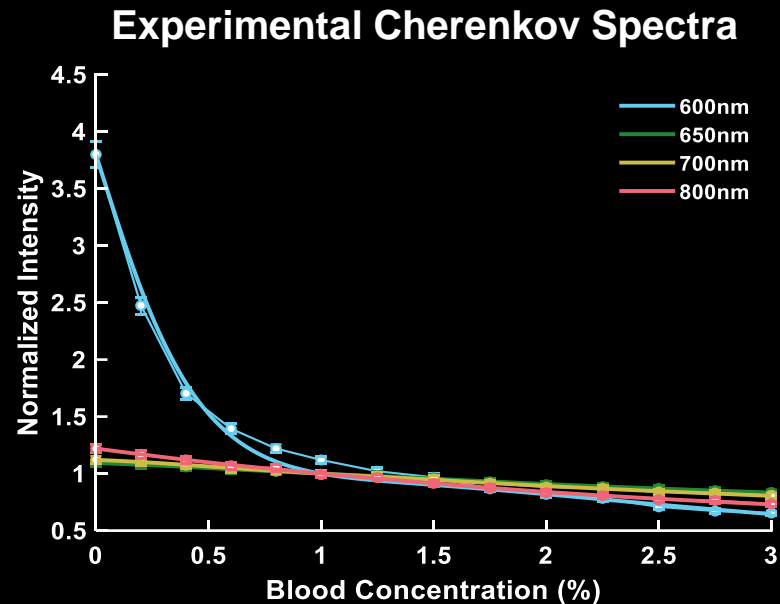
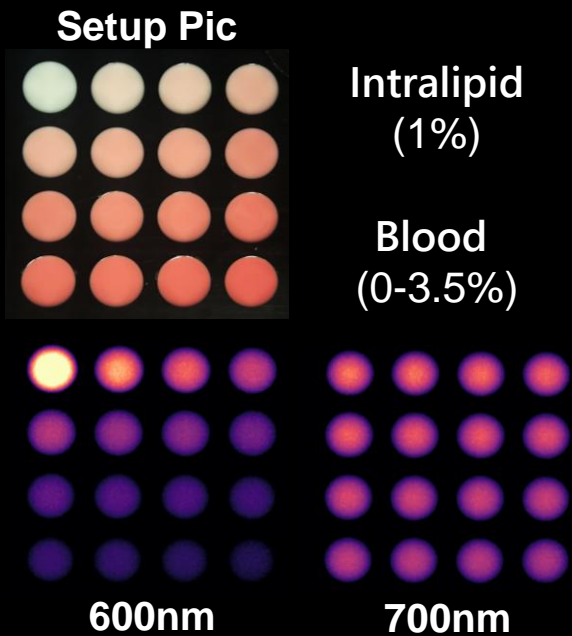


Oxygen Phantom Testing

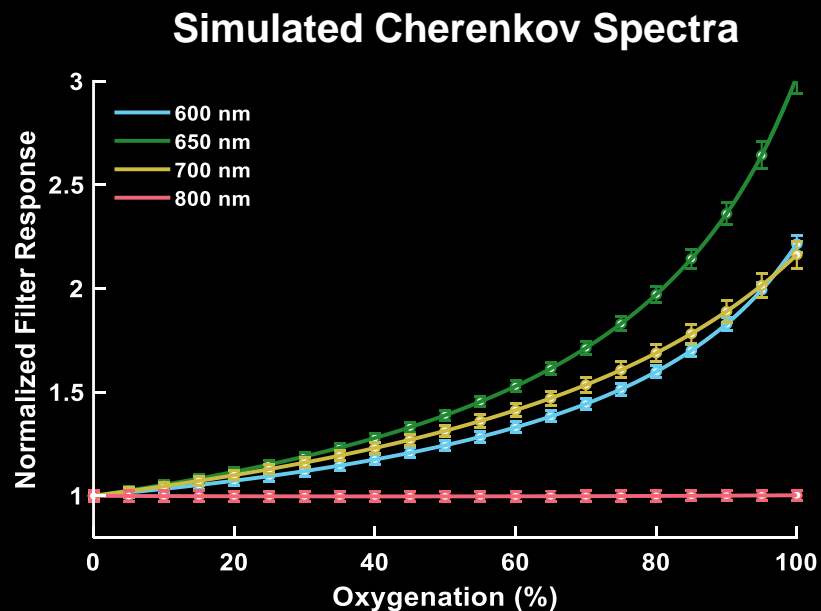
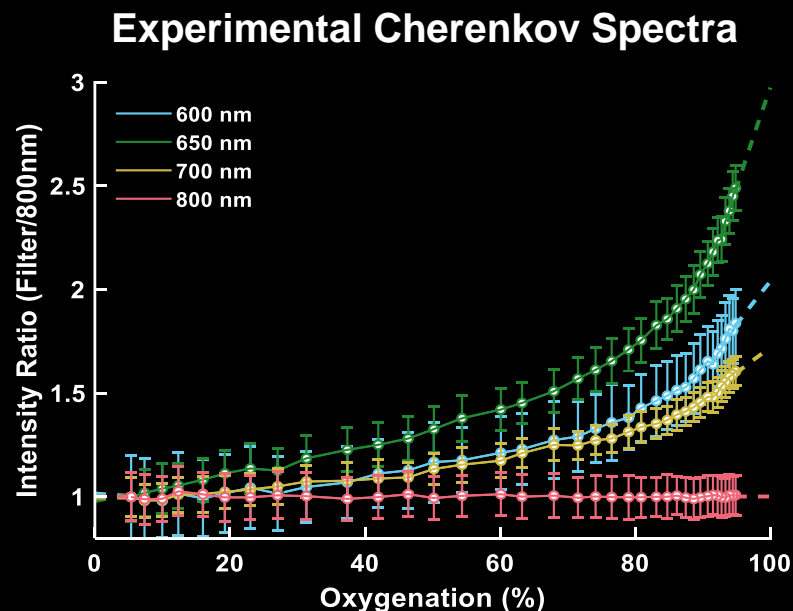
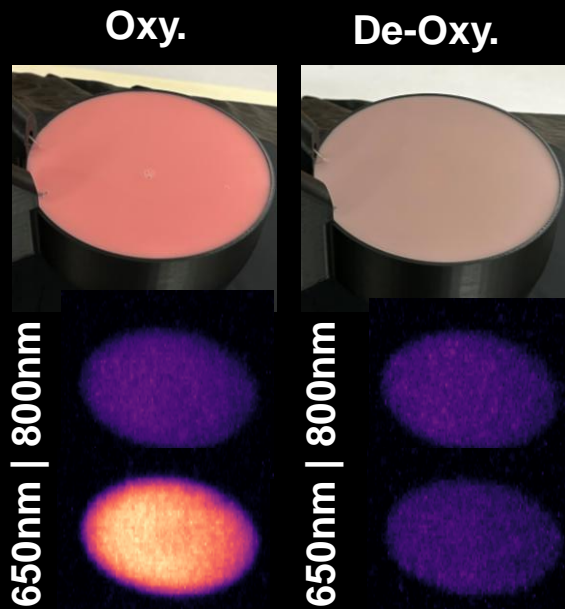


# Incorporating Simulation Results – Blood and Oxygenation Phantom Analysis

## Blood Phantom Testing

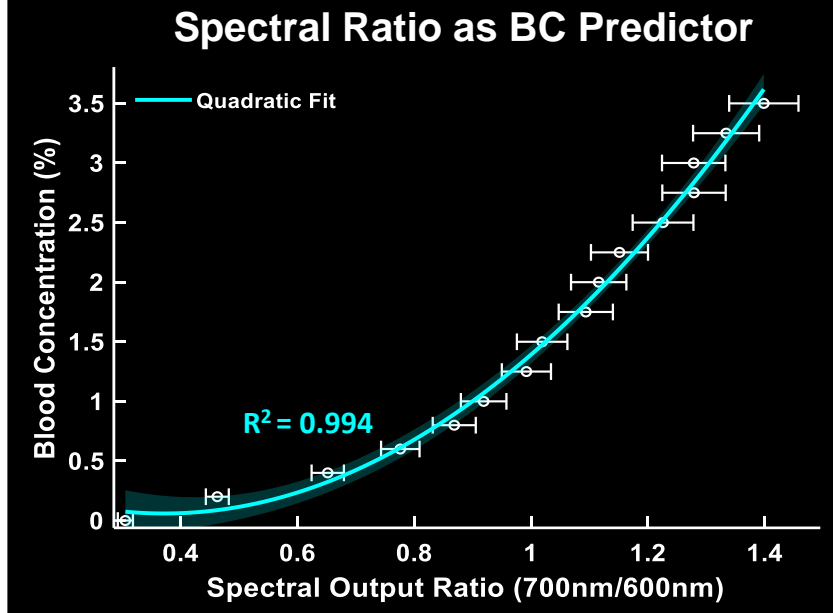
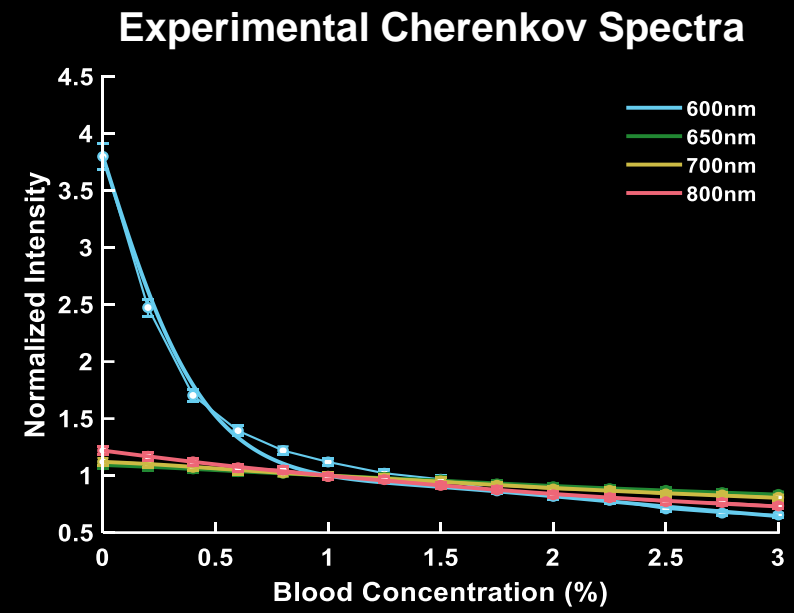
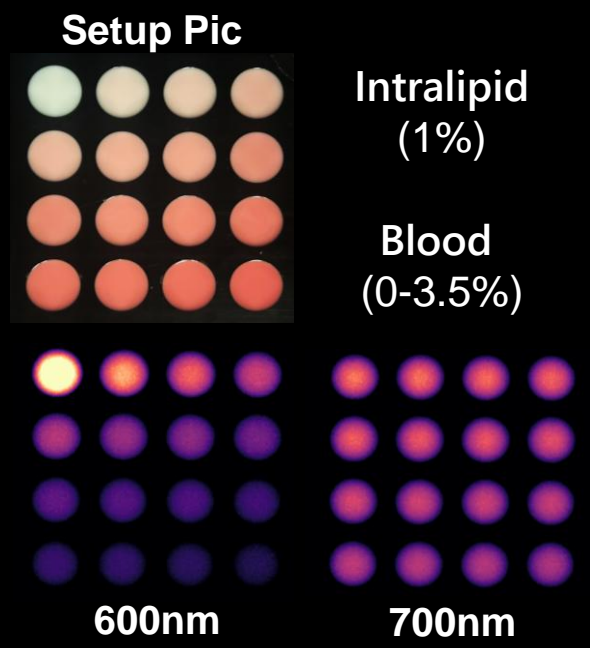


## Oxygen Phantom Testing

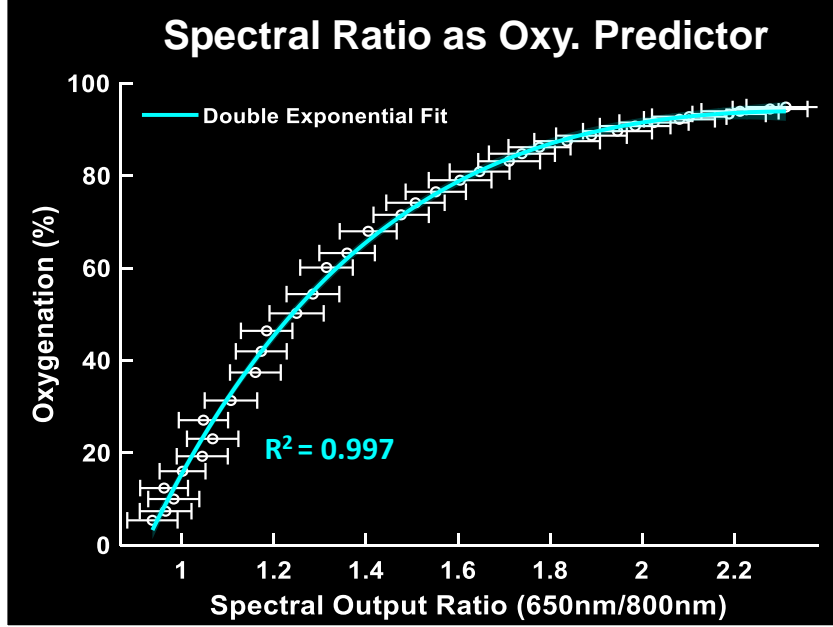
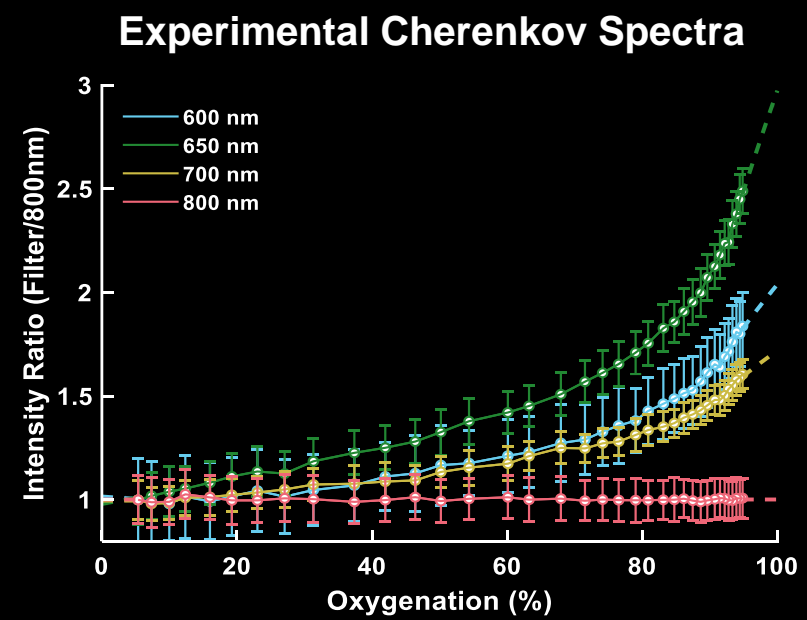
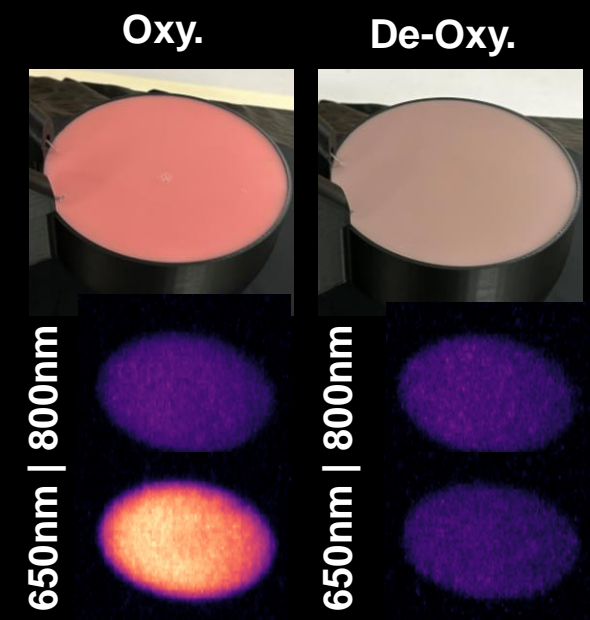


# Cherenkov Spectral Comparison as a Predictor for Single Factor Tissue Constituents

Blood Phantom Testing

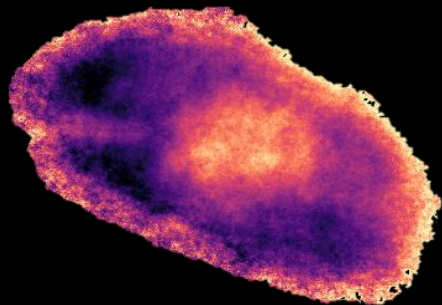
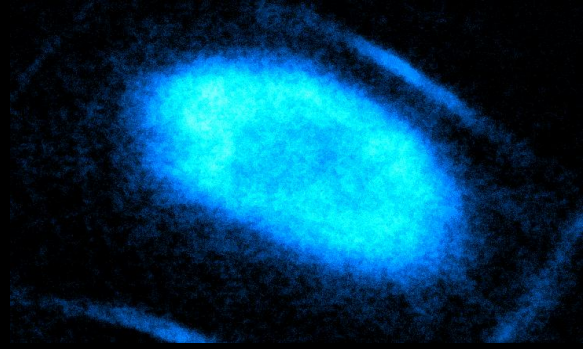


Oxygen Phantom Testing

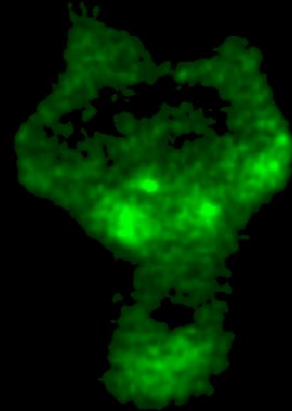
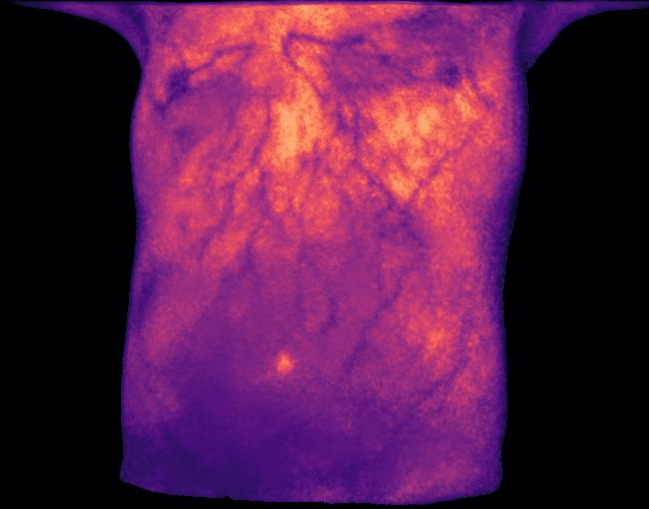


# First Multispectral Cherenkov Clinical Imaging

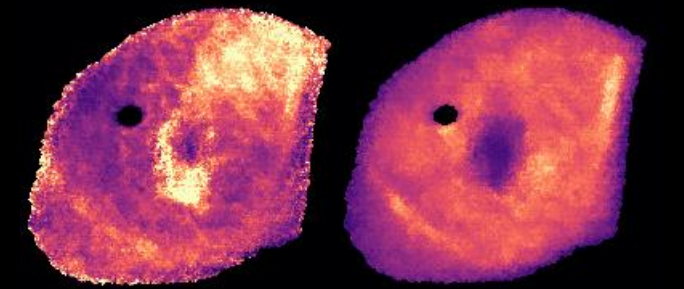
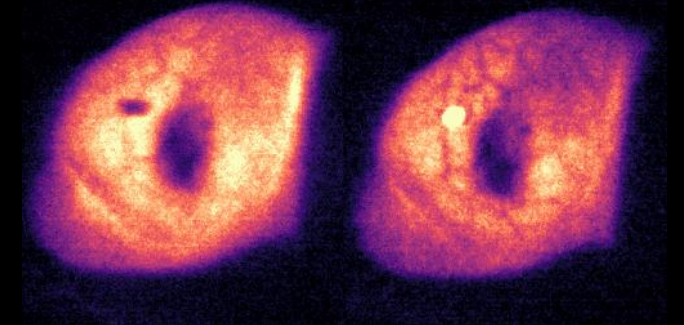
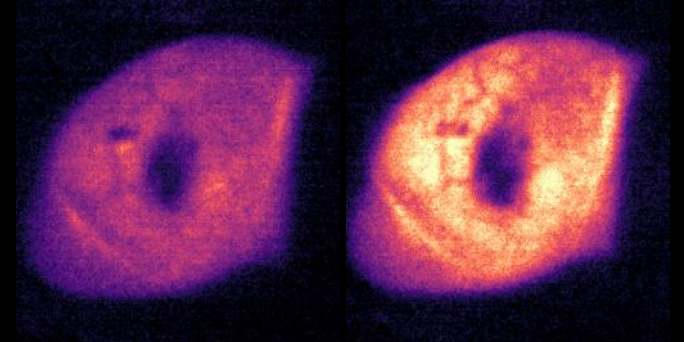
## MCL Imaging



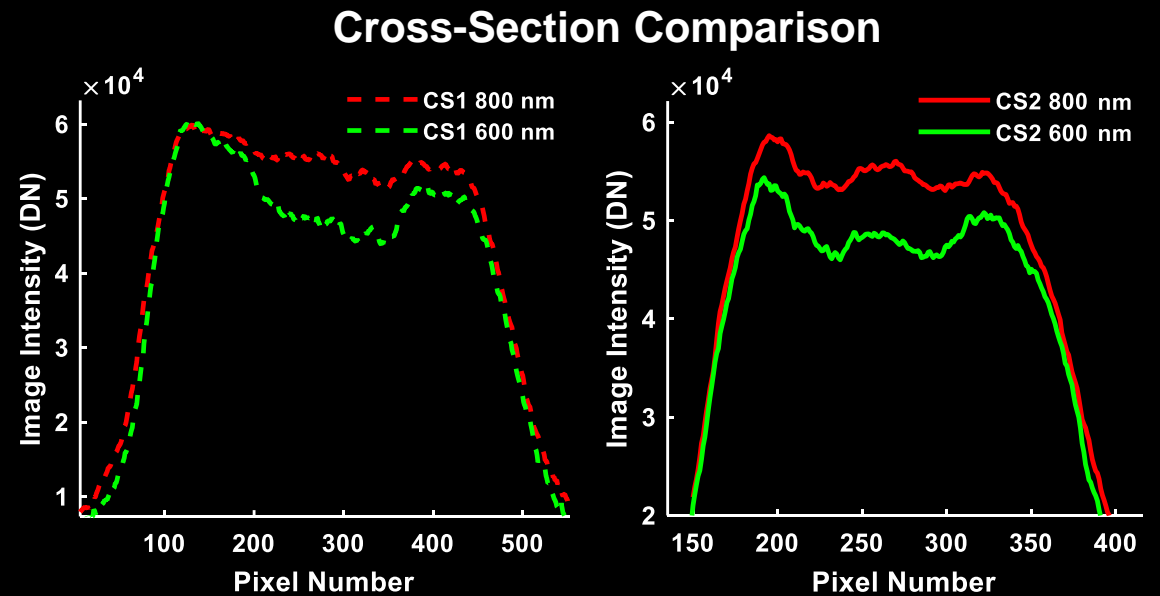
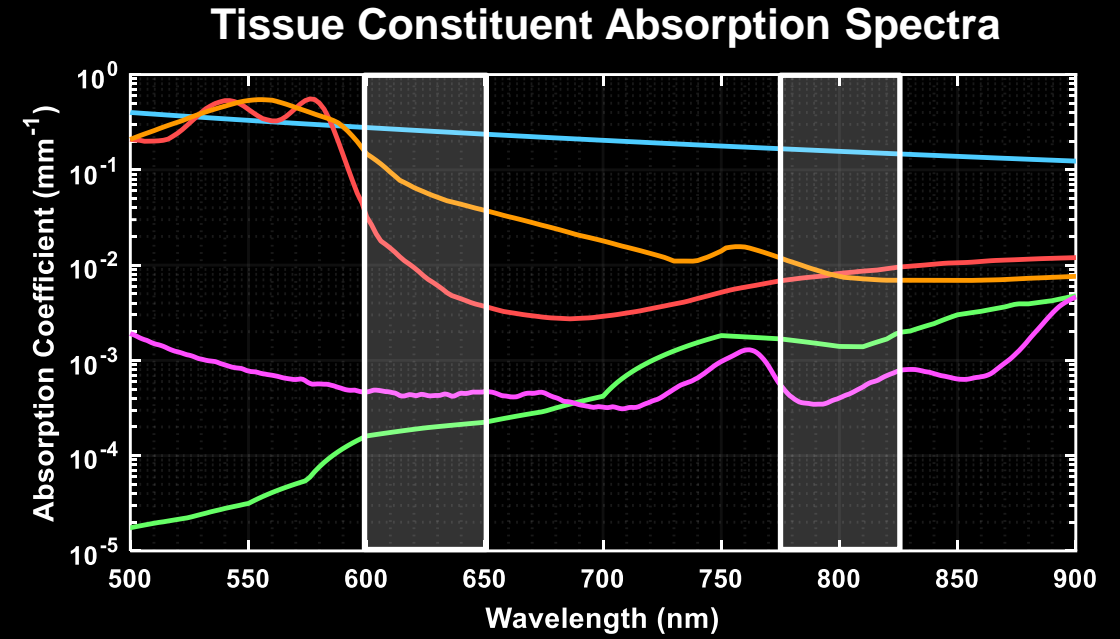
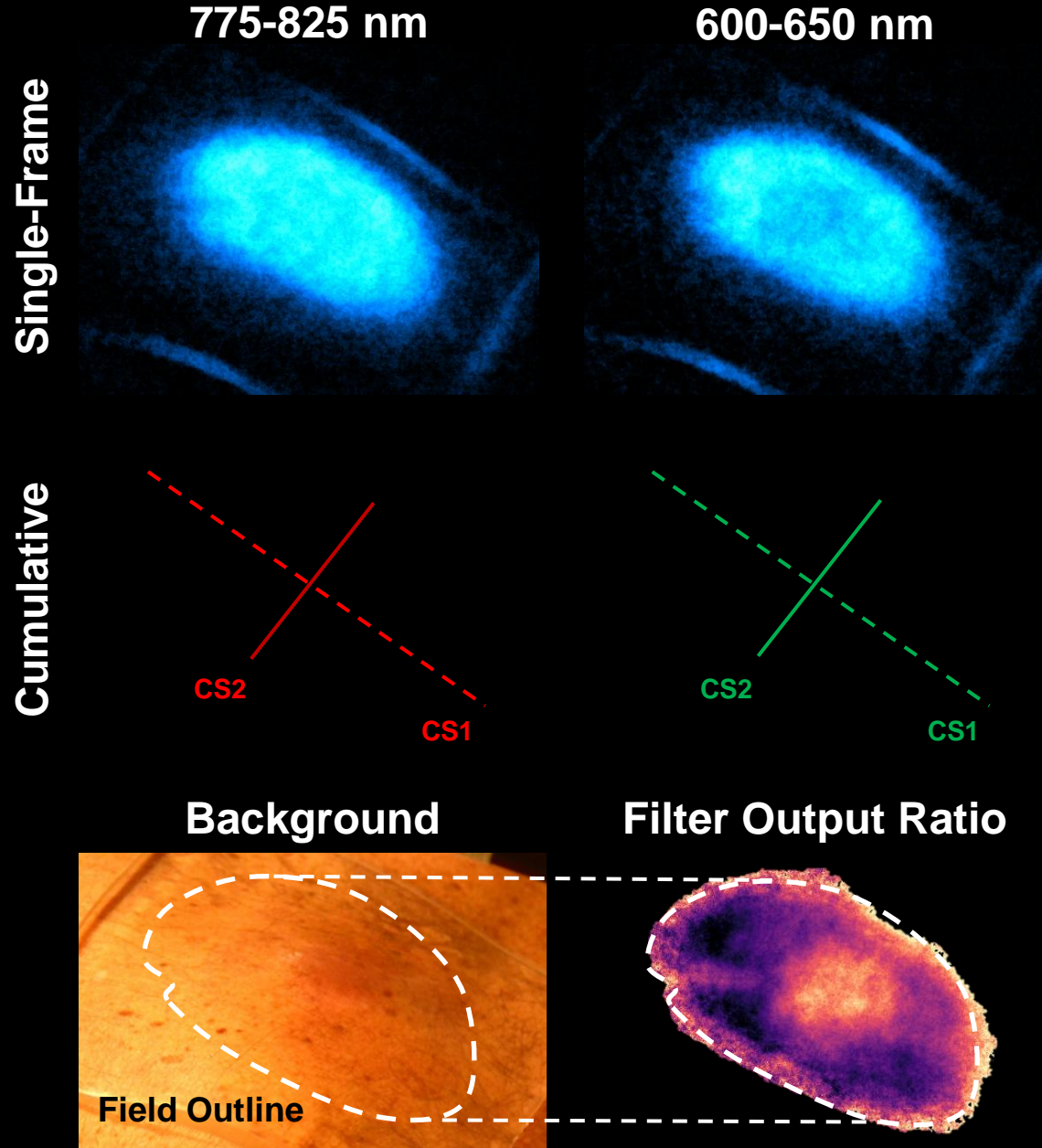
## TSET Imaging



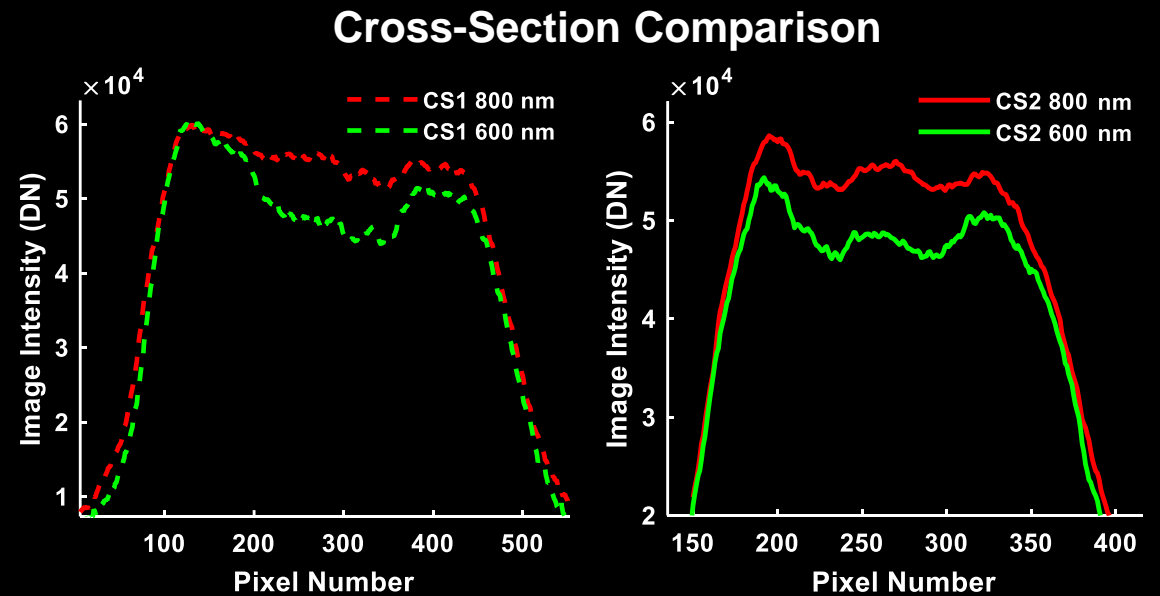
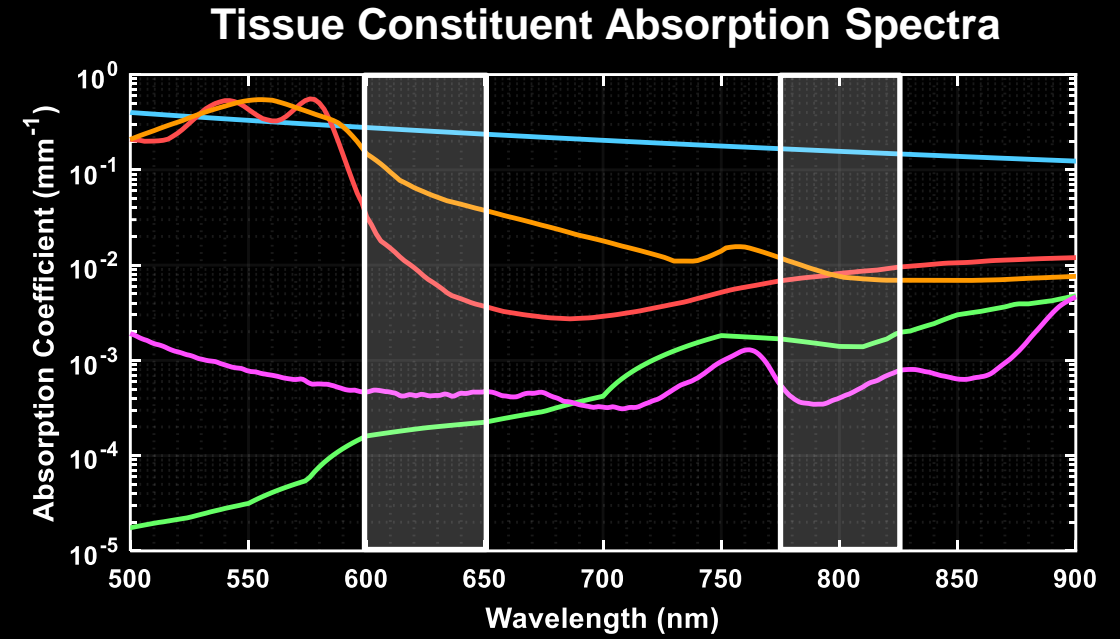
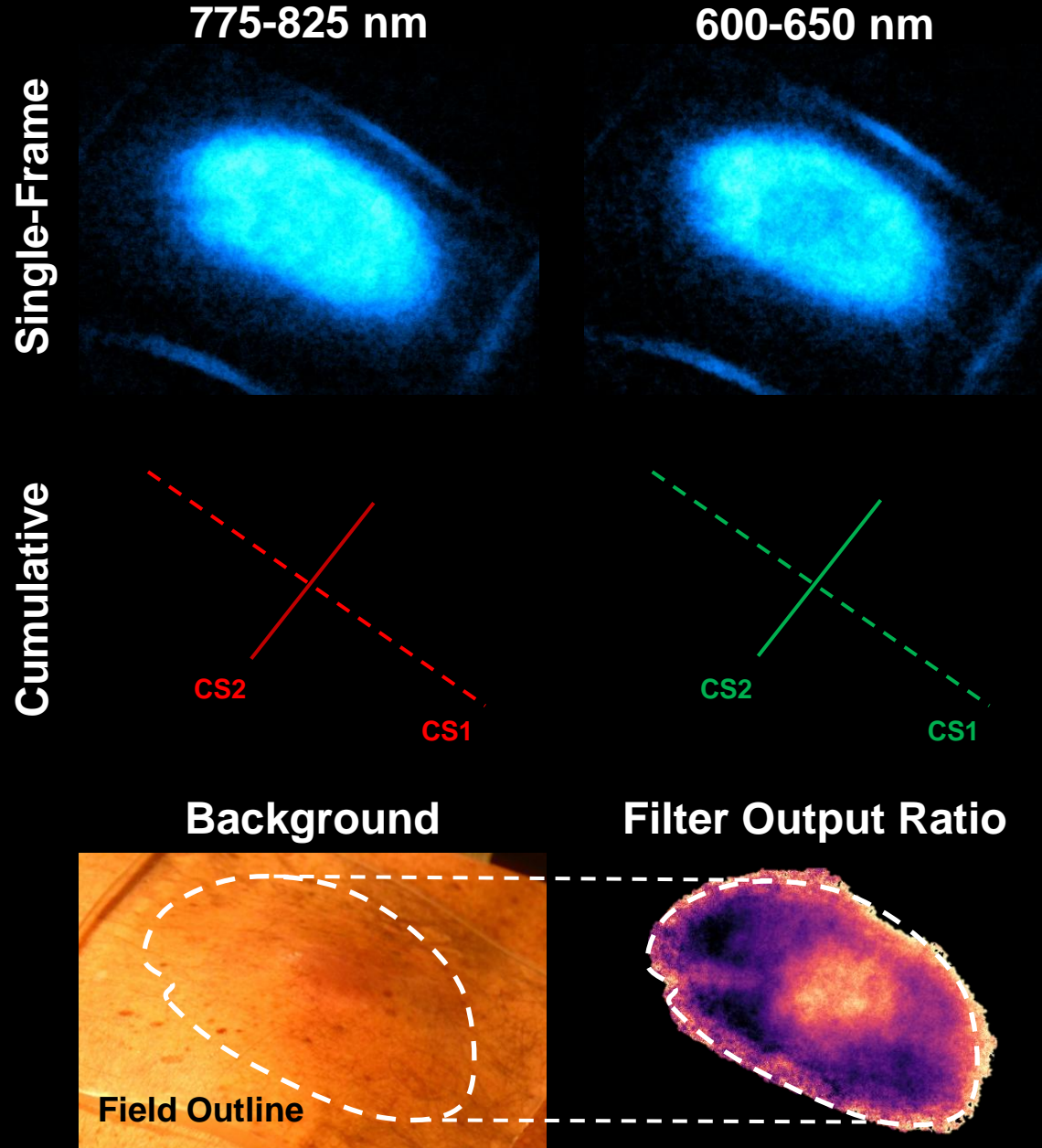
## Breast RT Imaging



# Mantle Cell Lymphoma Surface Imaging – Hypoxic Core Correlation

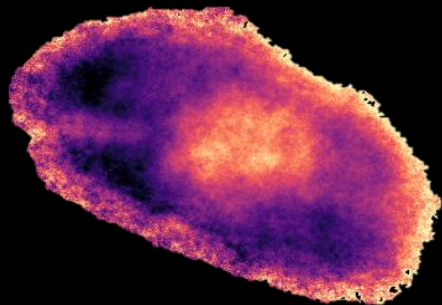
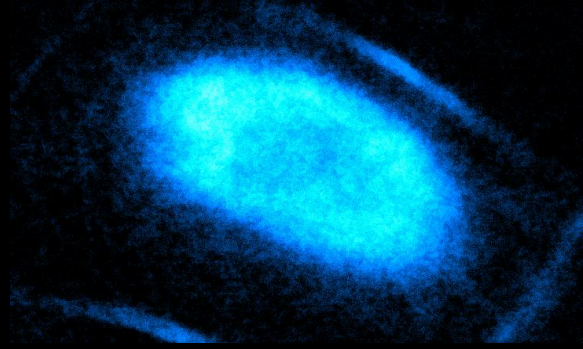


# Mantle Cell Lymphoma Surface Imaging – Hypoxic Core Correlation

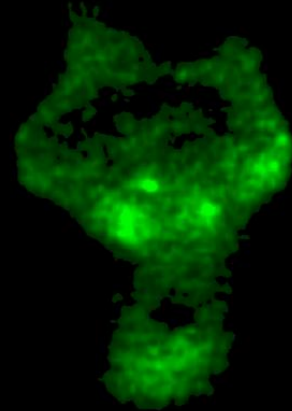
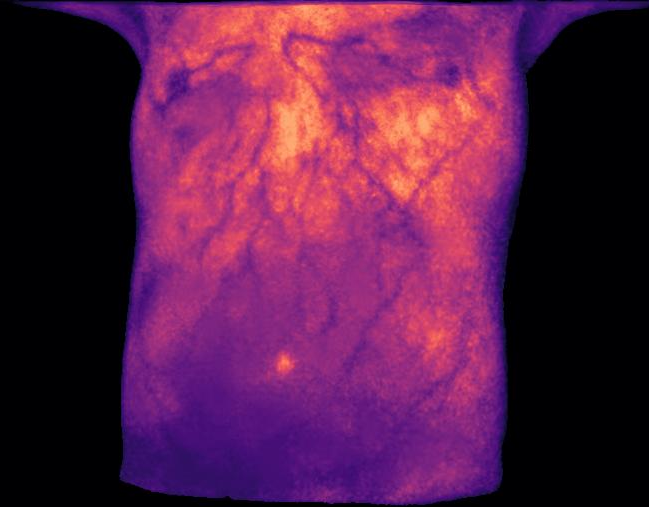


# First Multispectral Cherenkov Clinical Imaging

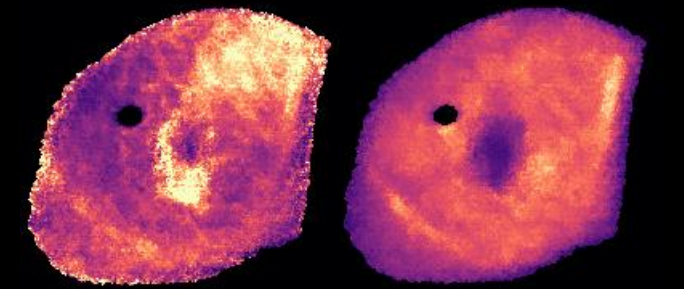
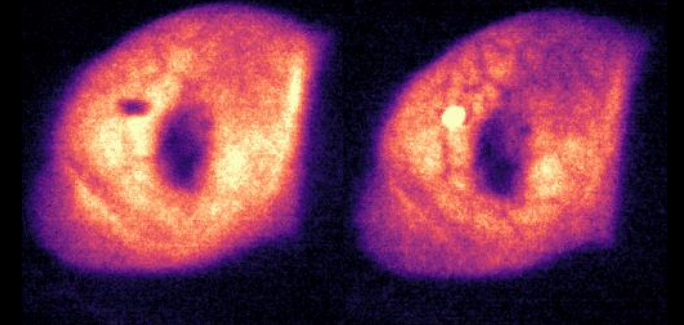
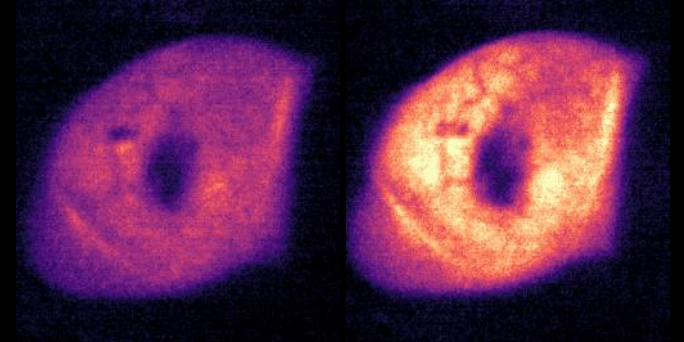
## MCL Imaging



## TSET Imaging

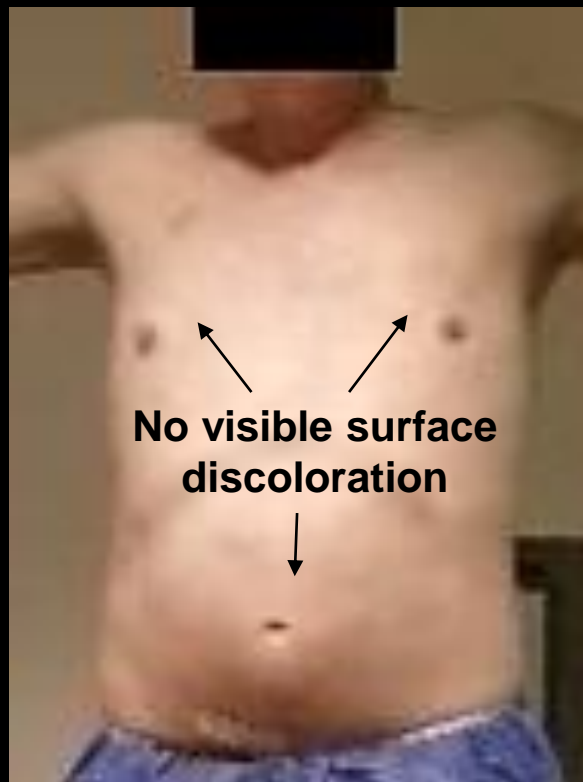


## Breast RT Imaging

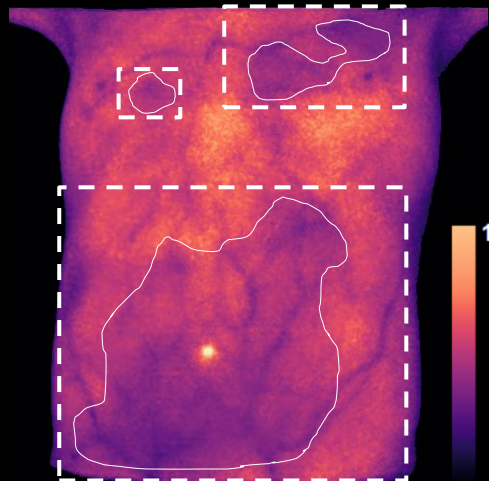


# Total Skin Electron Therapy Imaging – Disease Correlation

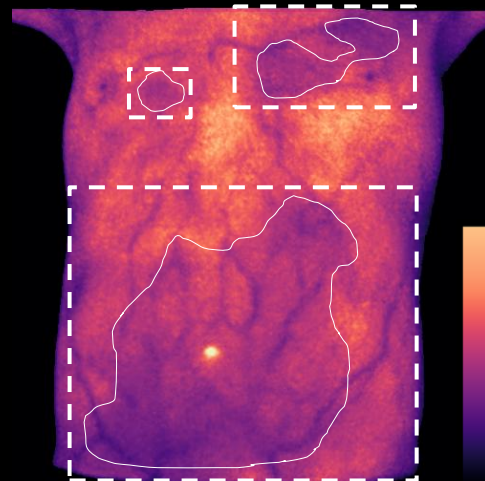
**Clinical  
Surface Image**



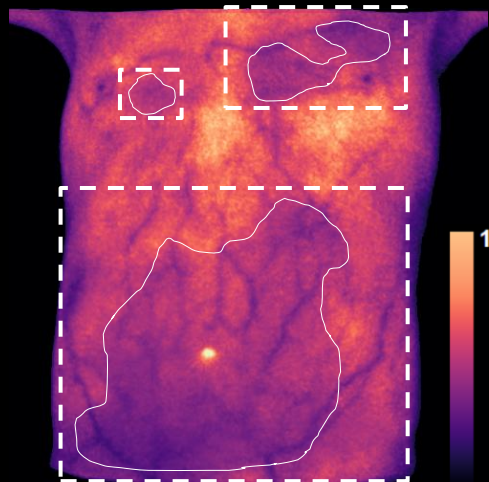
**Filter 1**  
800 (775-825) nm



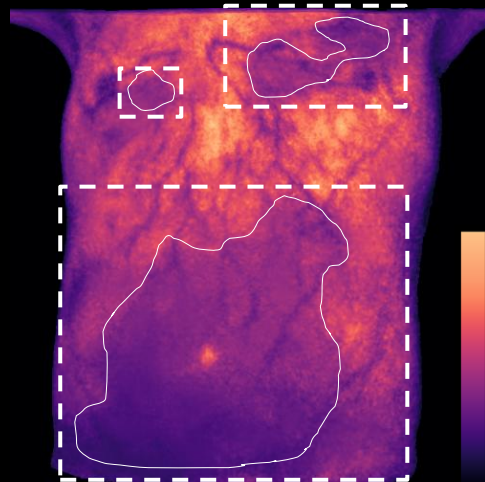
**Filter 2**  
700 (675-725) nm



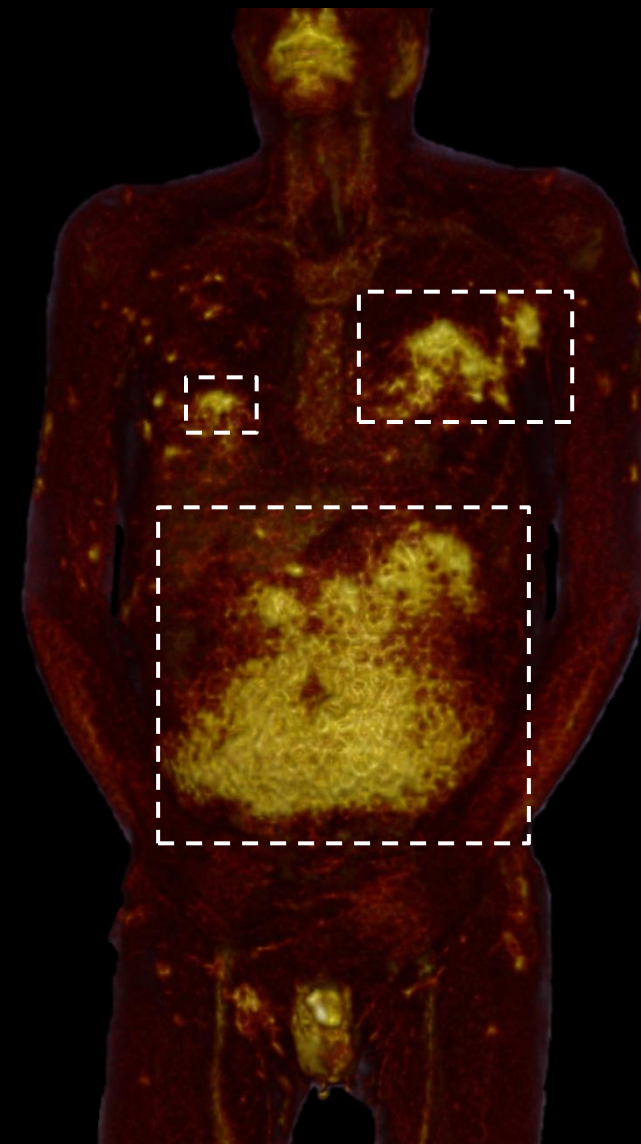
**Filter 3**  
650 (625-675) nm



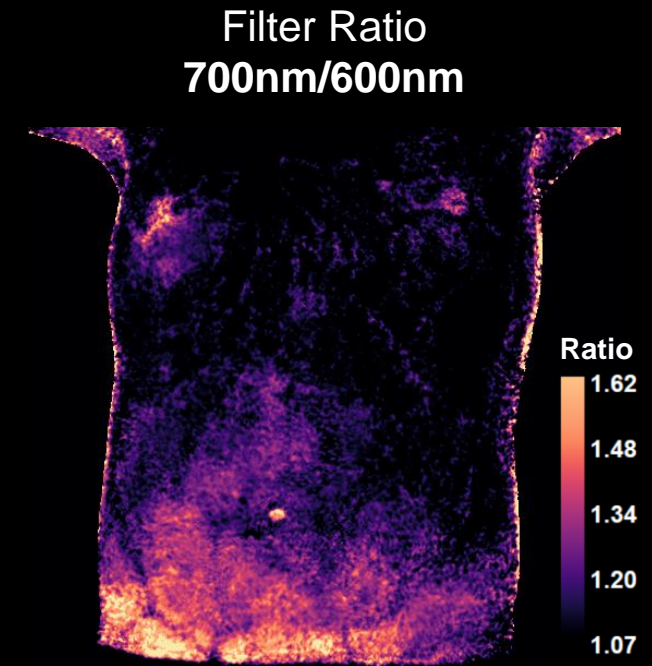
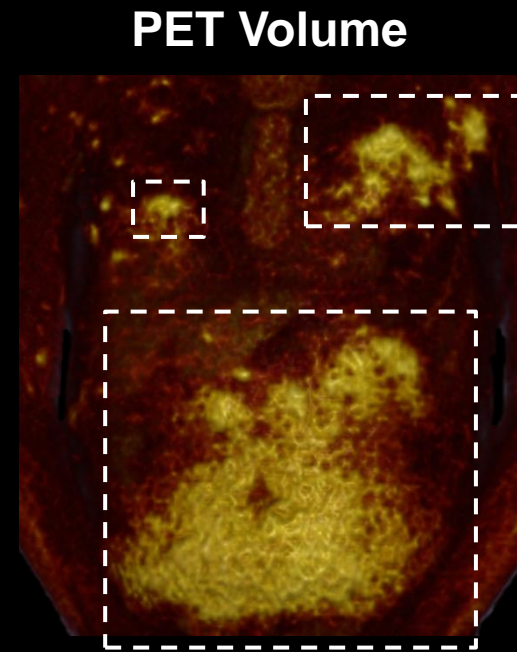
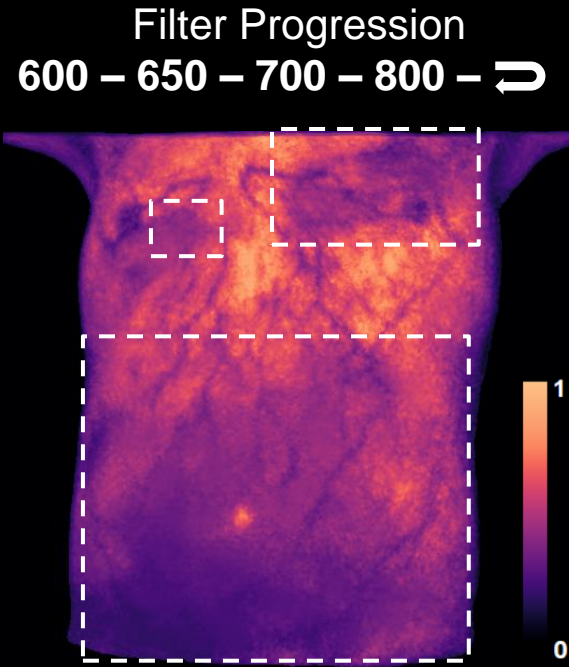
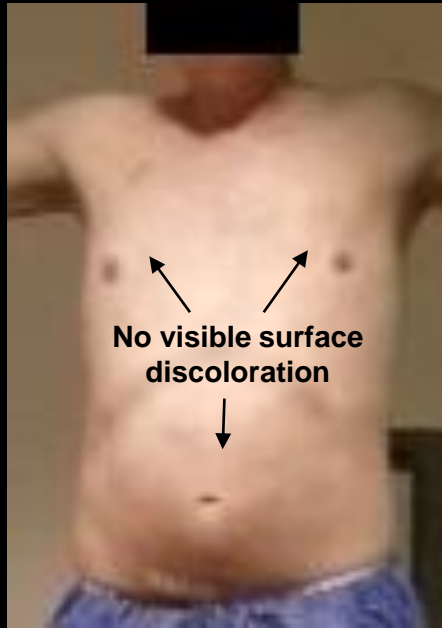
**Filter 4**  
600 (575-625) nm



**PET Volume**

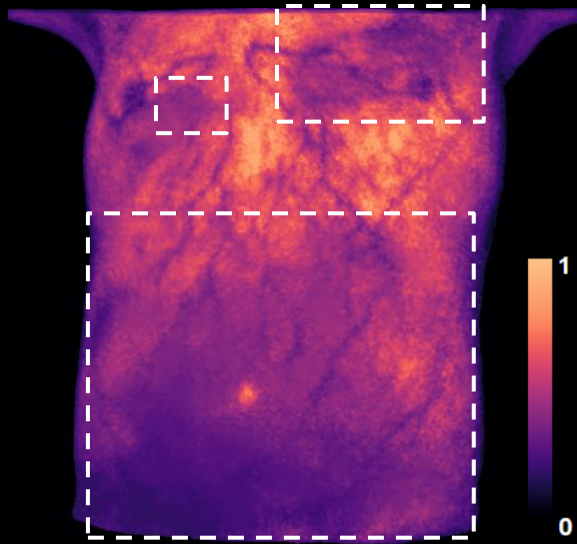


# Total Skin Electron Therapy Imaging – Depth Correlation

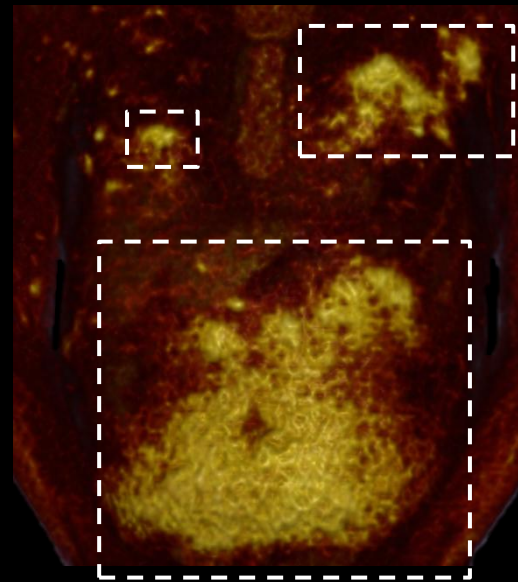


# Total Skin Electron Therapy Imaging – Depth Correlation

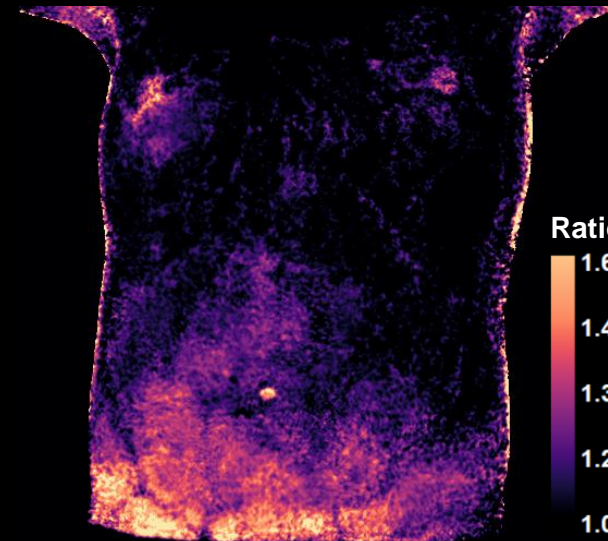
Filter Progression  
600 – 650 – 700 – 800 – ↷



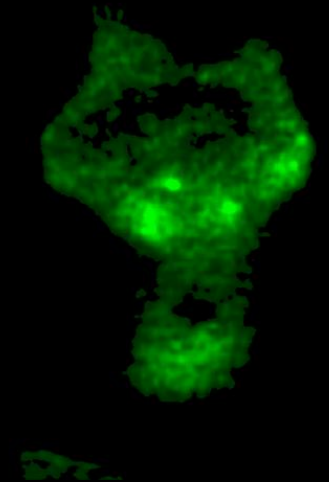
PET Volume



Filter Ratio  
700nm/600nm

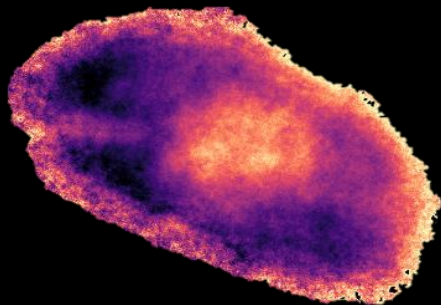
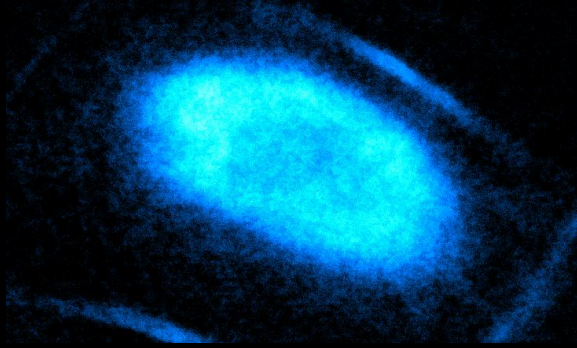


Shallow – Deep

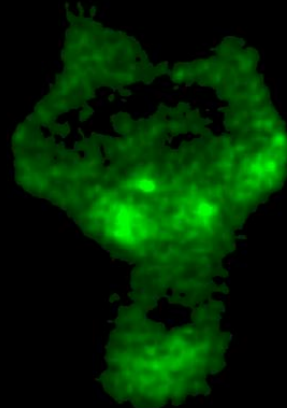
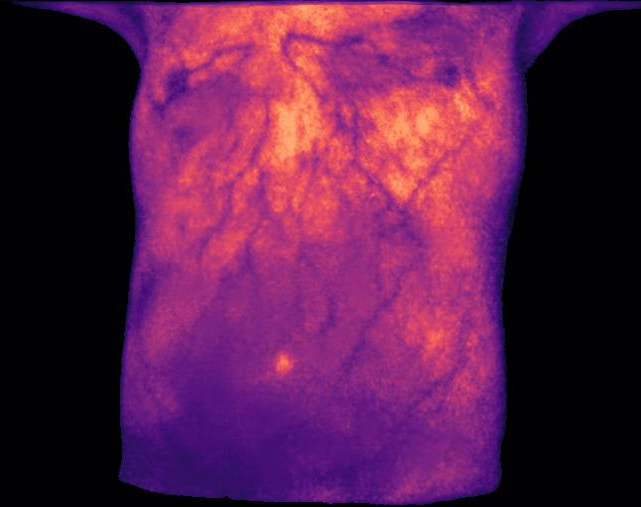


# First Multispectral Cherenkov Clinical Imaging

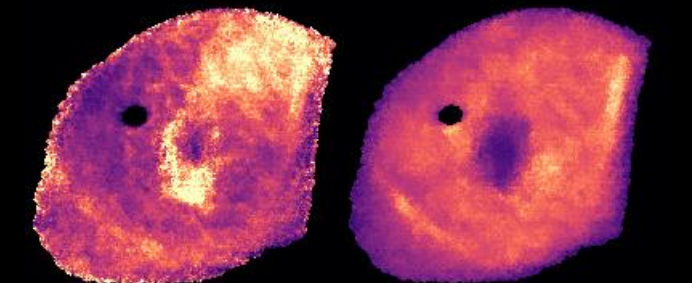
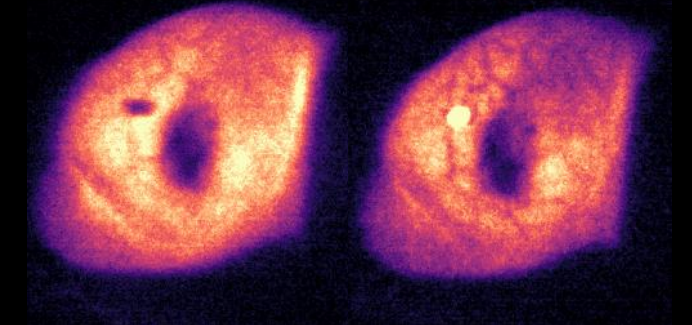
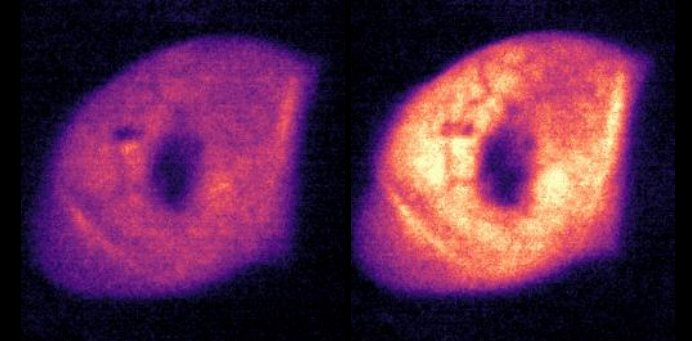
## MCL Imaging



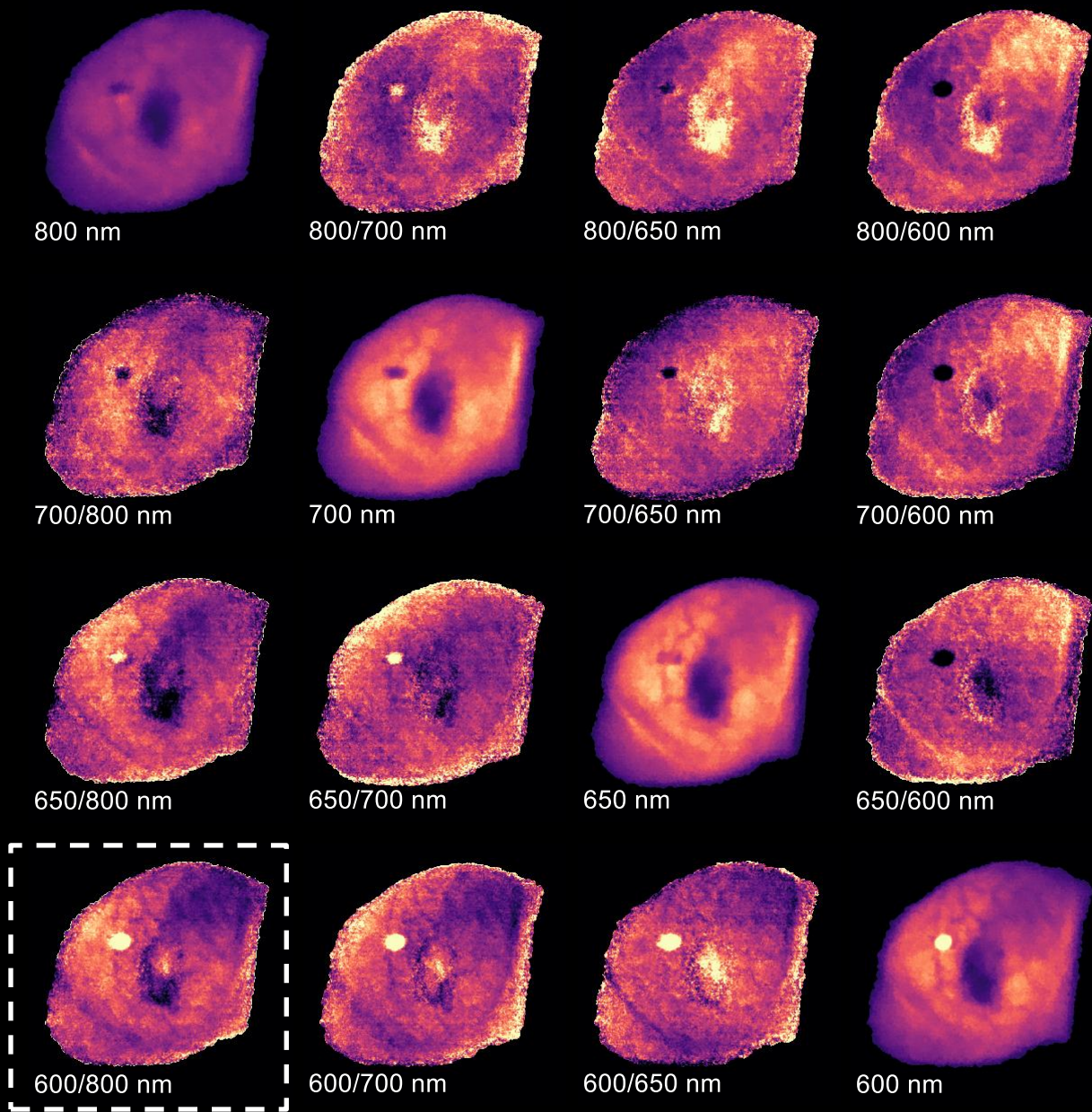
## TSET Imaging



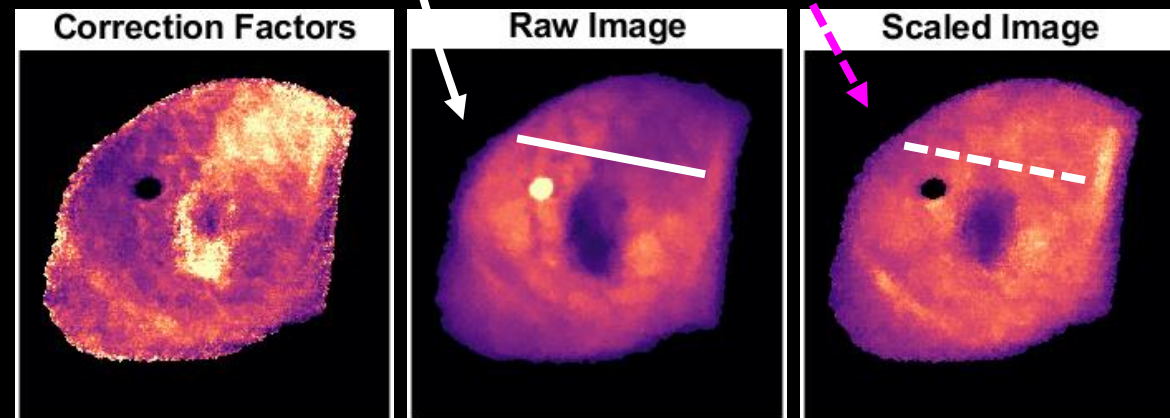
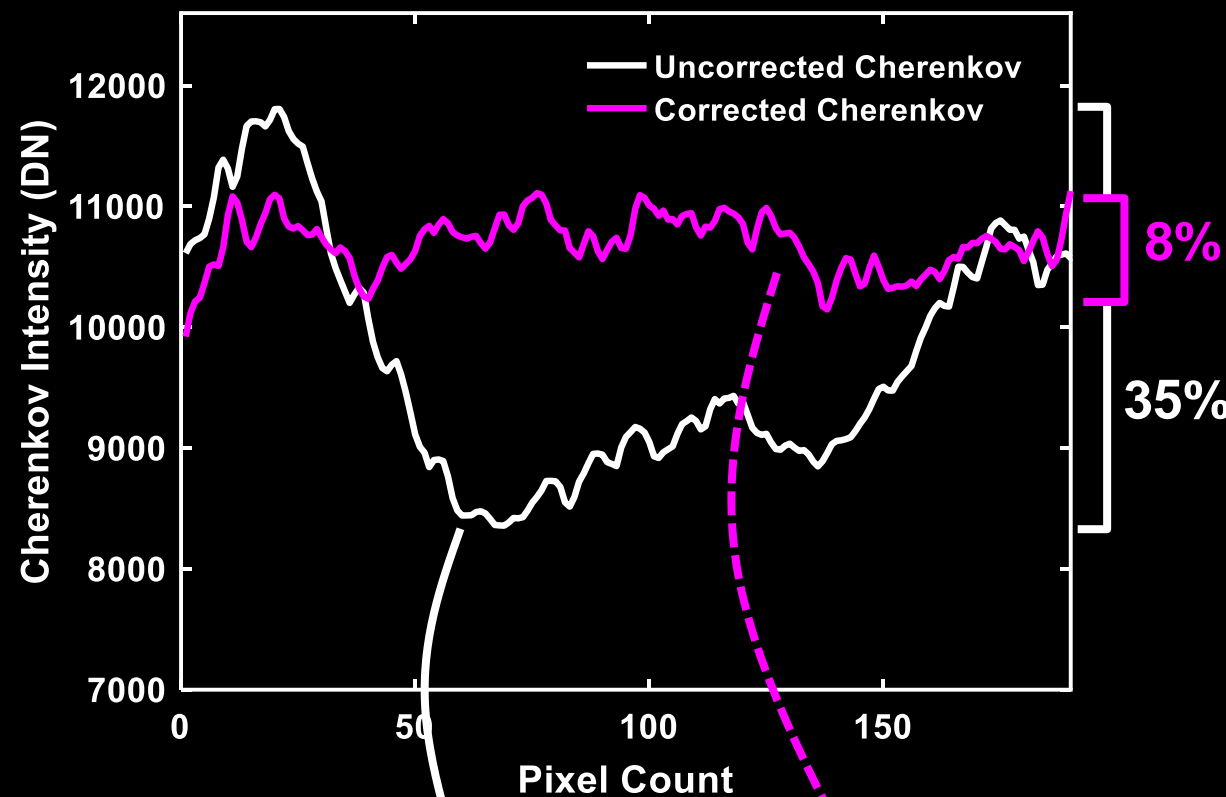
## Breast RT Imaging



# Breast RT Spectral Imaging and Correction

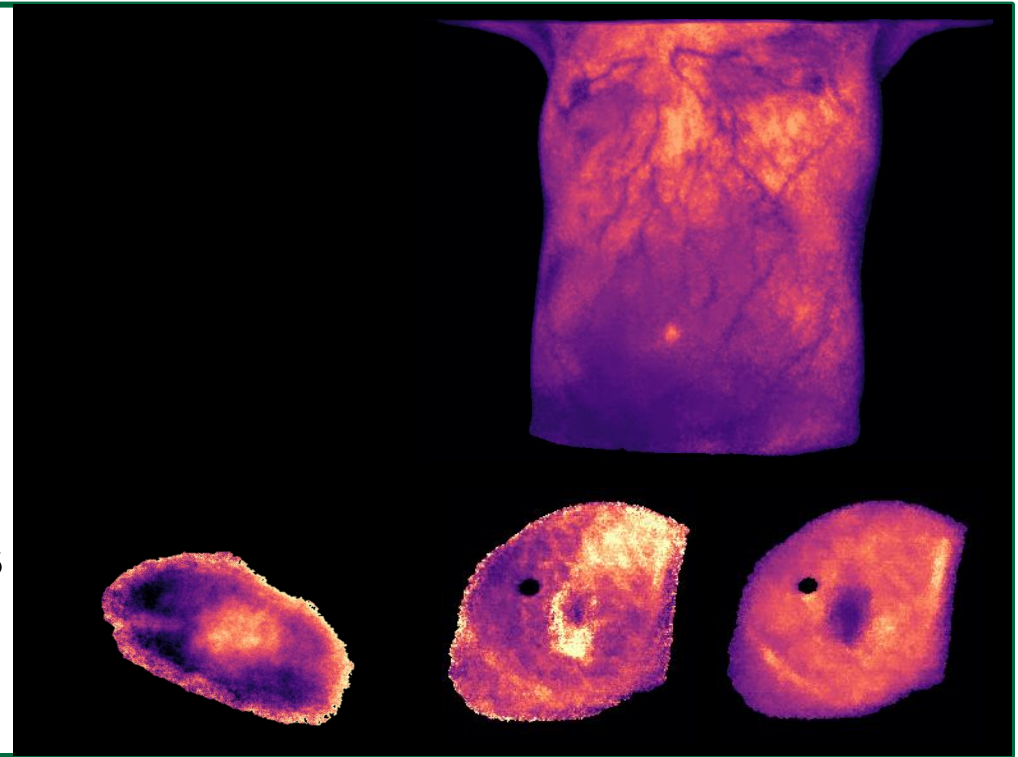


## Cherenkov Image Line Profiles



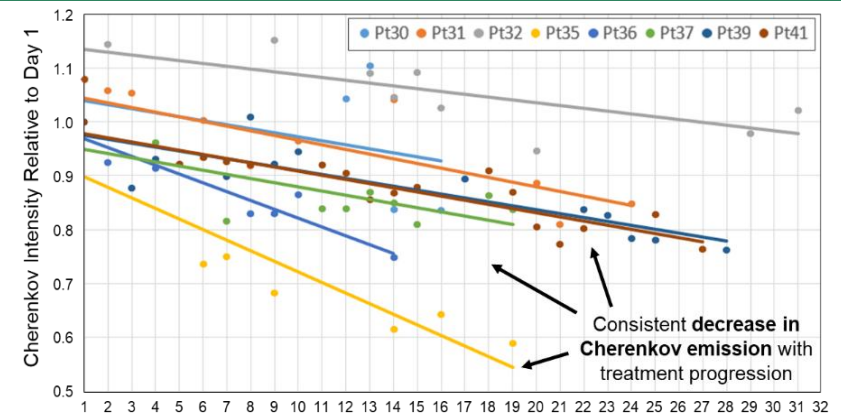
## Conclusions

1. Developed an approach for **spectrally analyzing Cherenkov signal** during treatment delivery
2. Simulated and validated spectral variations with **blood content and tissue oxygenation** using **physical phantoms**
3. Clinically tested hardware, correlating spectral ratios to **disease progression, oxygenation** differences and **attenuation correction**



## Future Directions

- Expand attenuation **correction to multiple factors** such as oxygenation, melanin, fat, and water
- Long term monitoring of treatment delivery and spectral correlation for **early prediction of skin effects/toxicity**



# Thank You!



# DARTMOUTH



**Petr Bruza,  
PhD**



**David Gladstone,  
ScD**



**Leslie Jarvis,  
MD PhD**



**Brian Pogue,  
PhD**



**Charles Thomas,  
MD**



**Allison Matous,  
MD**



**Daniel Alexander,  
PhD**



**Megan Clark,  
PhD**



**Shiru Wang,  
MS**



**Xander Geiersbach,  
MS**



**Kevin Willy,  
BS**



**Natasha Mulenga,  
BS**



**Rafael Carballeira,  
BS**



**Rongxiao Zhang,  
PhD**



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