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Project 15 Seminar: ‘Bioluminescence Tomography-Guided Radiation Therapy for Preclinical Research’

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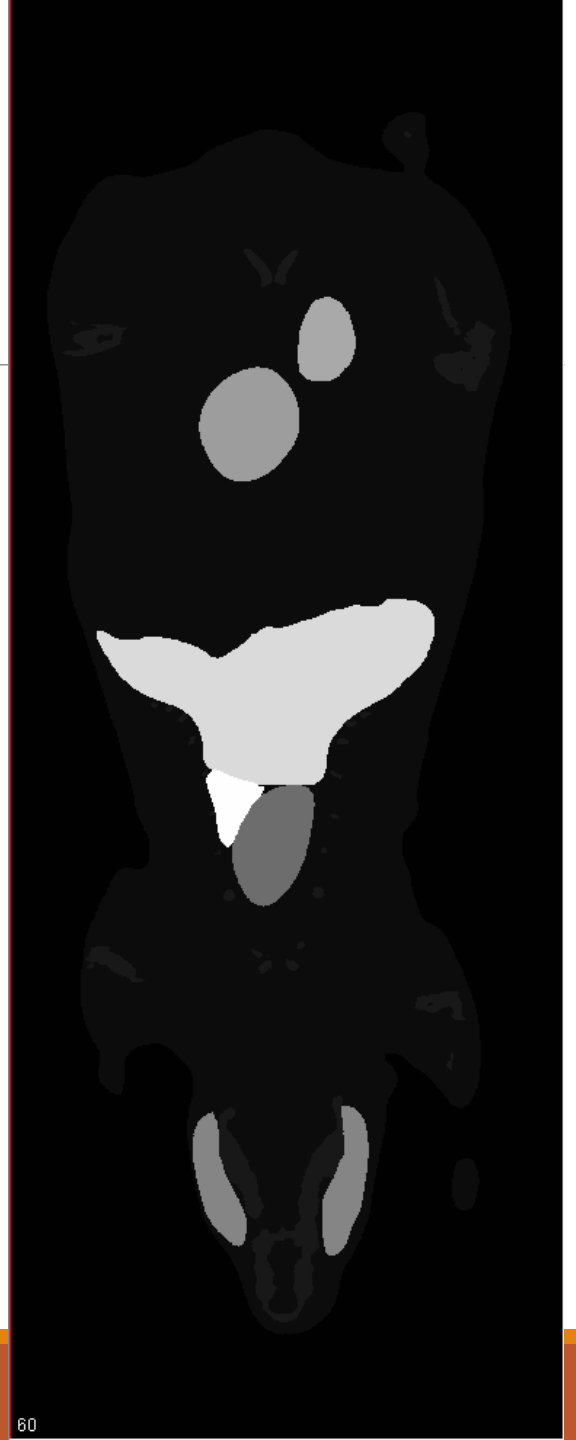
Relation to Project 15

Project 15 Goal(s): Incorporate organ-specific optical information into BLT reconstruction for SARRP

- Mouse segmentation and optical property LUT
- Experiment with virtual and implanted light source

Article Selection:

- Recent prior work on the SARRP
- Describes background/context of Project 15



Problem

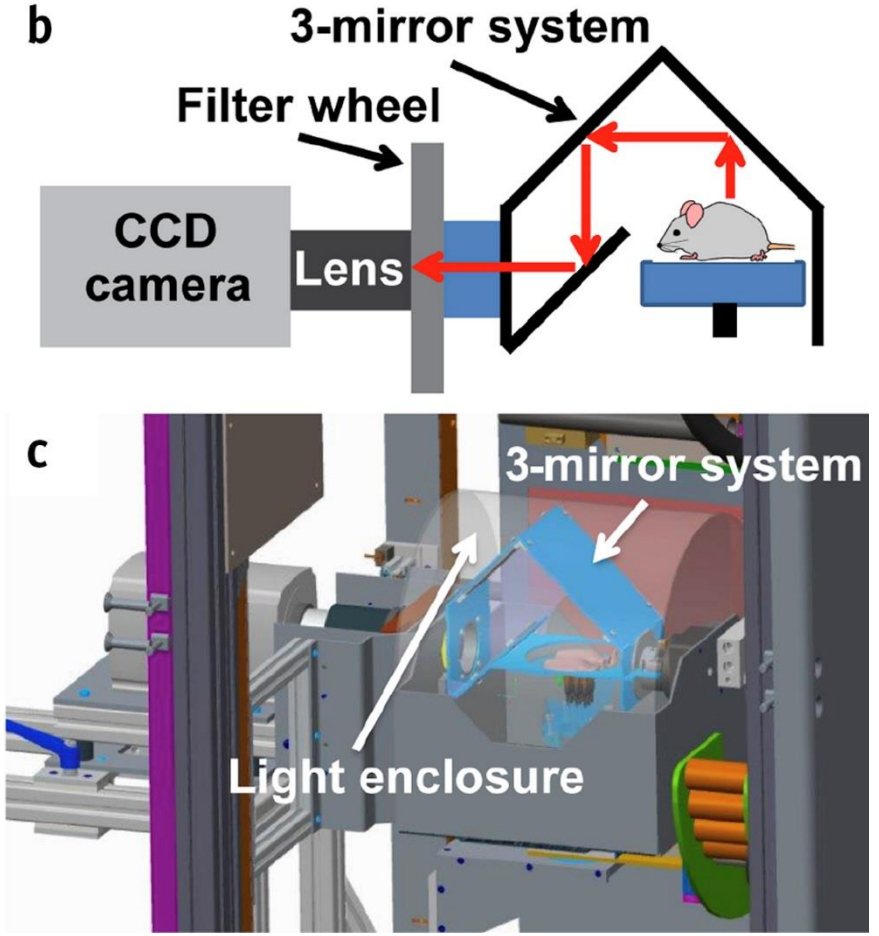
- Need to validate accuracy of BLT reconstruction algorithm
- Need to demonstrate delivery of BLT-guided radiation therapy with SARRP

Key Results

- Phantom experiments:
  - Average 3D offset: **0.6 +/- 0.1 mm**
- Mouse carcass experiments:
  - Average 3D offset: **1.0 +/- 0.6 mm**
- In vivo experiments:
  - Good match between BLI and BLT

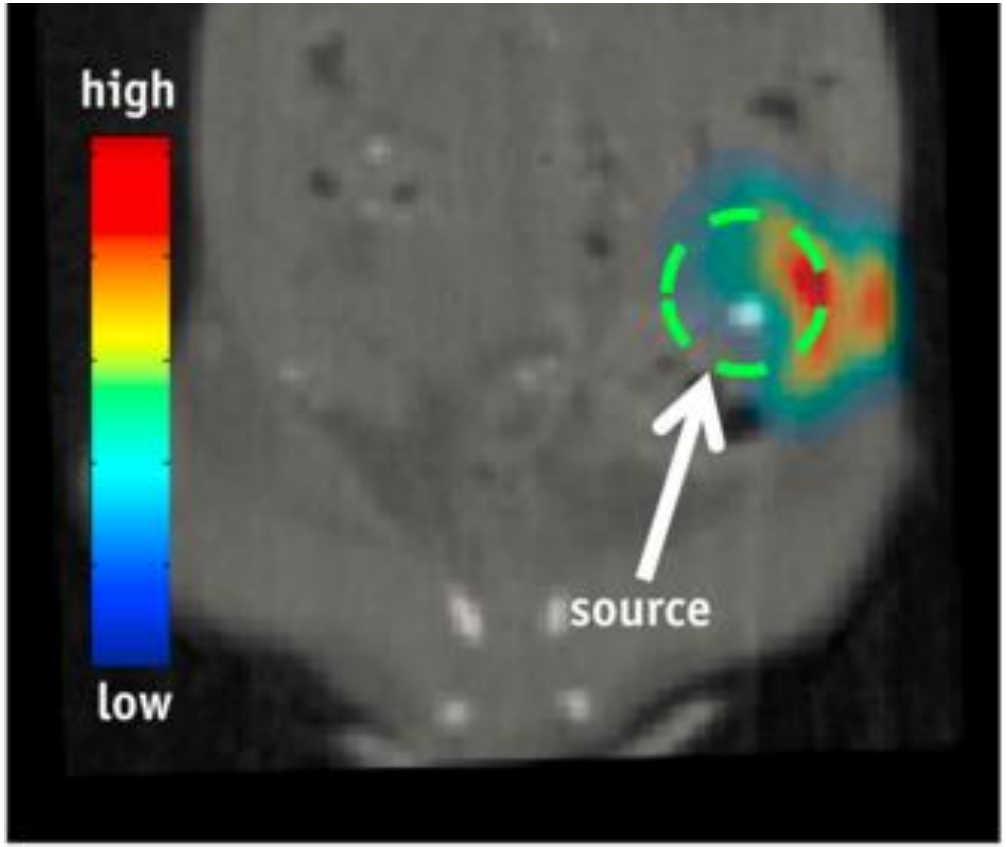
Background: SARRP

- Preclinical research tool
- Scaled down imaging and radiotherapy for small animal models:
  - CBCT to guide radiation therapy
- Hard to localize small/low contrast targets
  - Cost/Bulk Considerations $\Longrightarrow$ BLT
  - Applicable to genetically engineered mouse models
  - Dock into existing SARRP

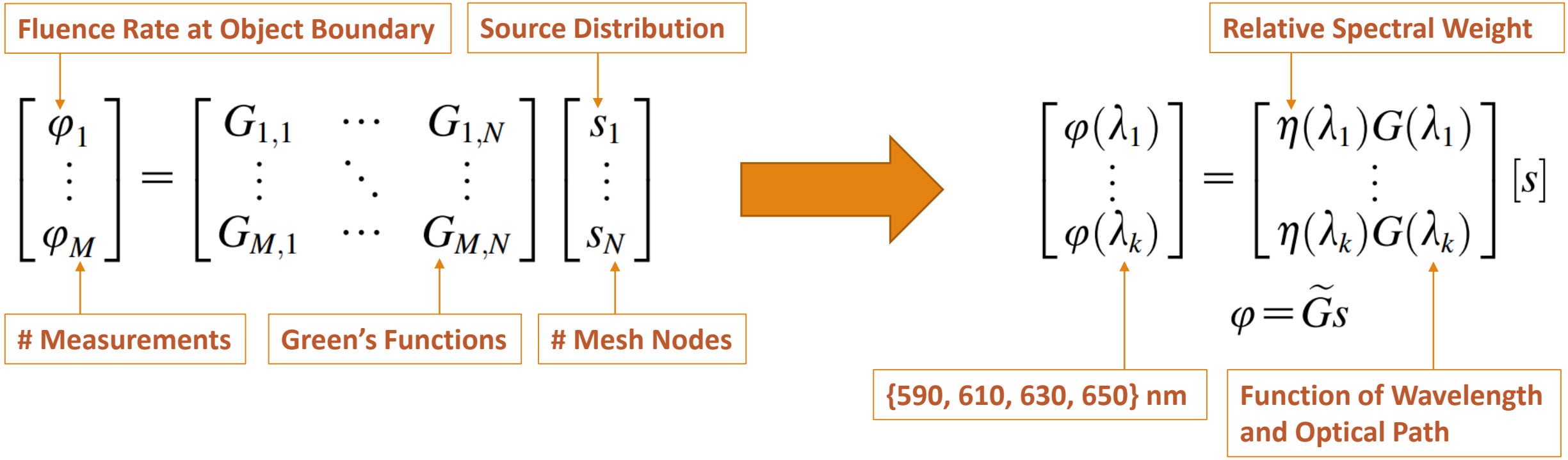


Background: BLT

- ‘Bioluminescence Tomography’
- True source position not evident in BLI AP view
  - No depth information
- Reconstruct 3D bioluminescent source distribution from 2D BLI
- Used in conjunction with 3D mesh from CBCT



Background: BLT



Background: BLT

Avoid Biasing toward Longer Wavelengths

$$\begin{cases} \overline{\varphi}(\lambda_k) = \varphi(\lambda_k)/\max(\varphi(\lambda_k)) \\ \overline{G}(\lambda_k) = \widetilde{G}(\lambda_k)/\max(\varphi(\lambda_k)) \end{cases}$$

BLT Minimization Problem

$$\min_s \frac{1}{2}\left\|\overline{G}s - \overline{\varphi}\right\|_2^2 + \tau\|s\|_1$$

Regularization Term

Iterative Region Shrinking Strategy

Initial Nodes

Iterations = 20

$$\beta = (N_1/N_f)^{1/(N_{it}-1)}$$

Permissible Region Reduction Factor

Final Nodes = 1

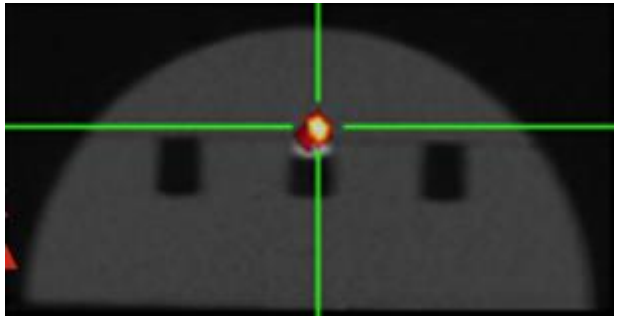
Objective Function to Choose Solution

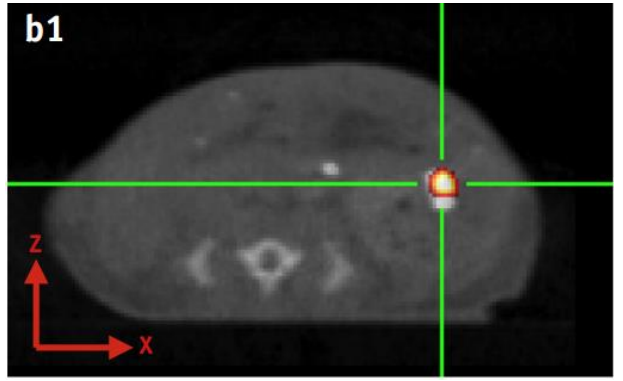
$$f_i = \sum \left\|\overline{G}s^{(i)} - \overline{\varphi}\right\|_1$$

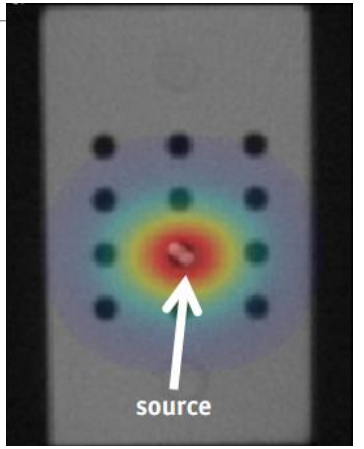
Experiments: Phantom and Carcass

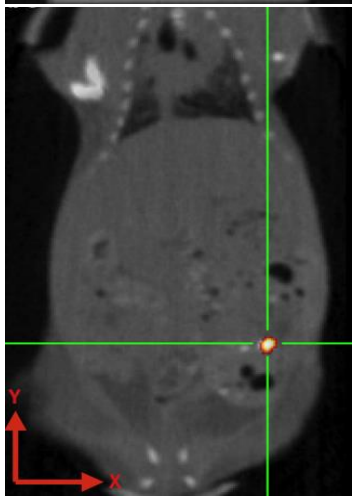
Purpose: Assess BLT targeting accuracy

.9x2 mm
High CBCT Contrast:
Treat as Ground Truth

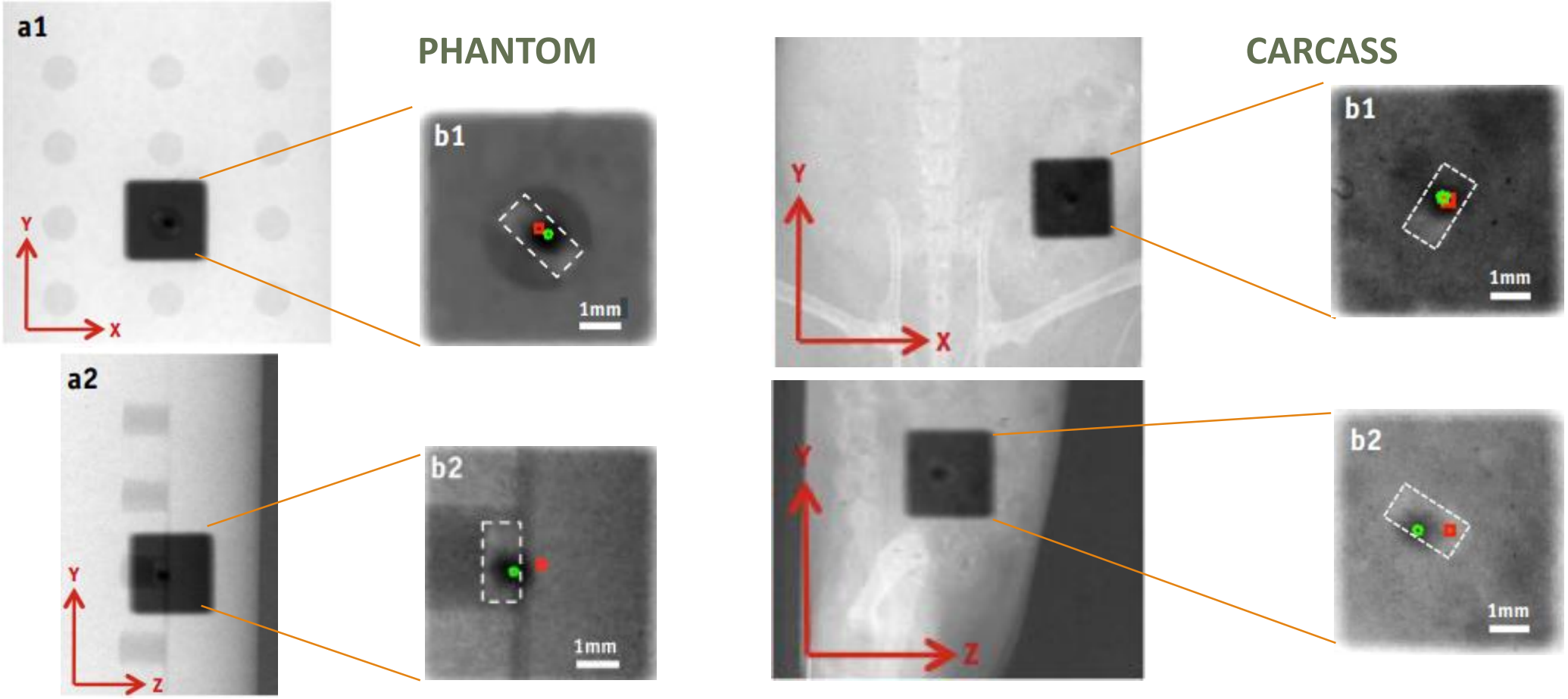








Results: Phantom and Carcass



Results: Phantom and Carcass

PHANTOM

4 independent experiments

Reconstruction:

- Largest COM deviation between BLT and CT results along z-axis: **0.6 mm**
- Average 3D offset **0.6 +/- 0.1 mm**

Irradiation:

- Centers of BLT and CBCT x-y offset < **0.2 mm**
- Largest offset along z-axis: **0.6 mm**

CARCASS

3 independent carcass experiments

Reconstruction:

- Largest COM deviation between BLT and CT results along z-axis: **0.8 mm**
- Average 3D offset: **1.0 +/- 0.6 mm**

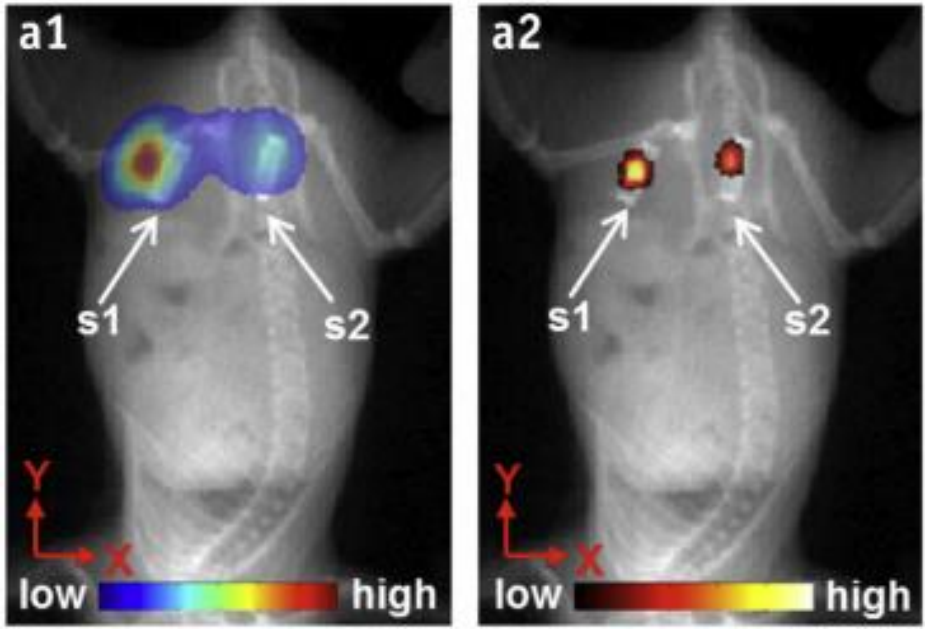
Irradiation:

- Centers of BLT and CBCT x-y offset < **0.2 mm**
- Largest offset along z-axis: **0.8 mm**

Experiment: In Vivo

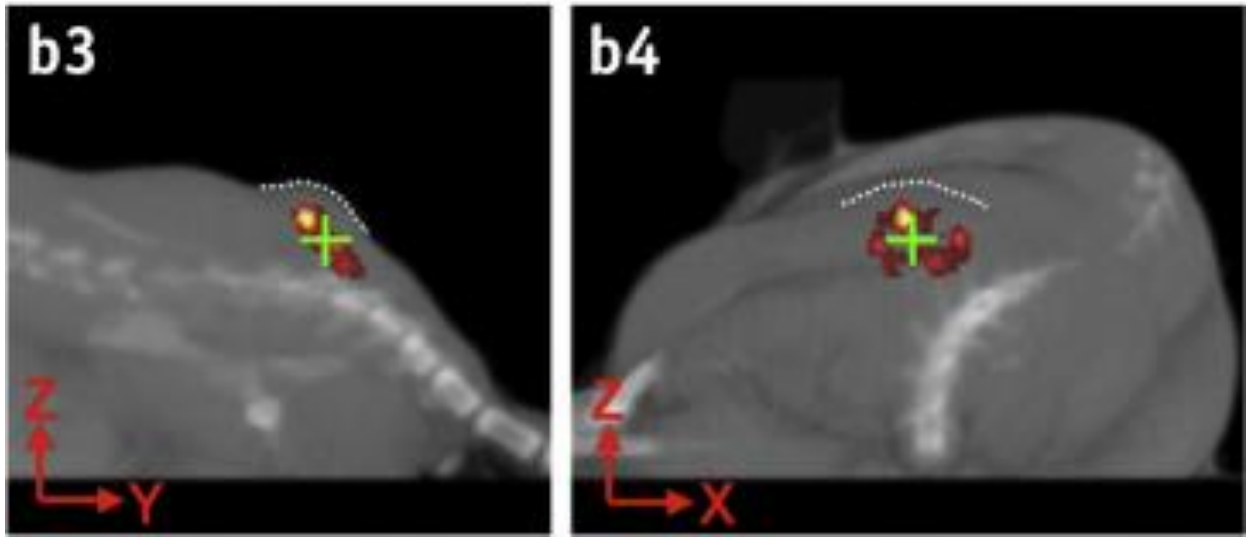
EXPERIMENT 1:

Two 2x6 mm Trigalight sources in abdomen



EXPERIMENT 2:

Subcutaneous tumor, firefly PC3-Luc



Results: In Vivo

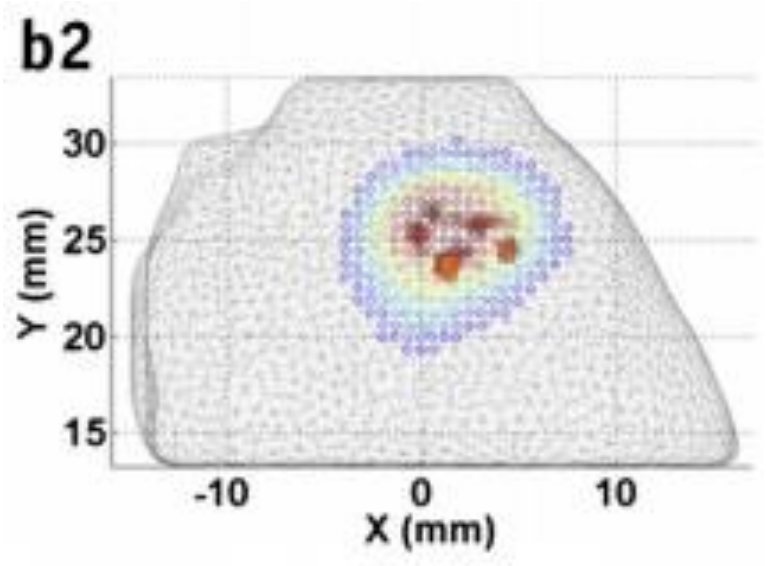
EXPERIMENT 1:

Deviations of BLT-reconstructed COM:

- Source 1: **0.8 mm**
- Source 2: **0.9 mm**

EXPERIMENT 2:

2D BLI believed to represent true location, since tumor is subcutaneous and palpable



Assessment/Concluding Thoughts

Good and Bad

- COM metric for accuracy
  - Additional assessment for in vivo experiment
- Optical homogeneity (phantom vs carcass)
  - Abdomen
- 1 mm targeting accuracy in phantom and carcass models
- Same properties for all carcasses
- Covered some variation in source materials, geometries, number

Possible Next Steps

- Different source geometries
- Different source placements
- Diffuse optical tomography or organ specific properties to address heterogeneity

Reference

Bin Zhang, Ken Kang-Hsin Wang, Jingjing Yu, Sohrab Eslami, Iulian Iordachita, Juvenal Reyes, Reem Malek, Phuoc T. Tran, Michael S. Patterson, and John W. Wong. “Bioluminescence Tomography-Guided Radiation Therapy for Preclinical Research”. International Journal of Radiation Oncology*Biology*Physics.