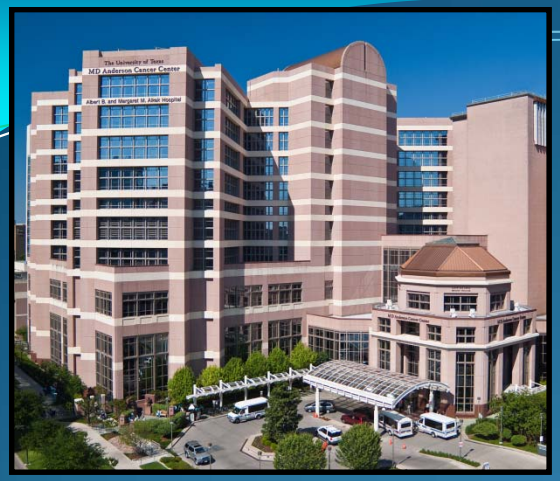


Investigation of PRESAGE® as a 3-D dosimetric tool for therapy by measurement of proton-activated positron emission

IROC™
IMAGING AND RADIATION ONCOLOGY CORE
Global Leaders in Clinical Trial Quality Assurance

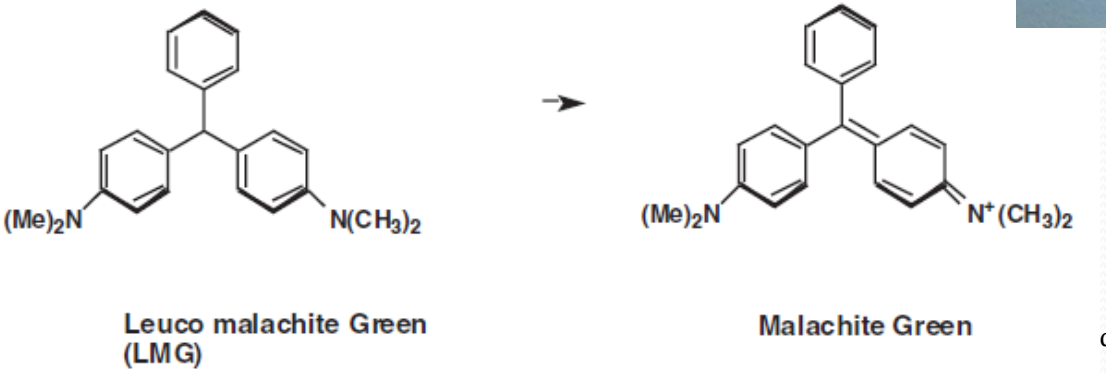
THE UNIVERSITY OF TEXAS
MD Anderson Cancer Center
Making Cancer History®

M. Carroll, G. Ibbott, J. Adamovics

CIRMS 2015 April 27th, 2015

PRESAGE®

- Supplied by Heuris Pharma
- Polyurethane matrix housing leuco malachite dye which responds to ionizing radiation.
  - Optical-density (ΔOD) exhibits a linear change to dose
- Different formulations:
  - Proton LMG
  - O-MeO LMG (photon)
- Compared to gel dosimeters:
  - Does not require a container
  - Cannot be manufactured in-house
  - Limited imaging options
  - Similar costs



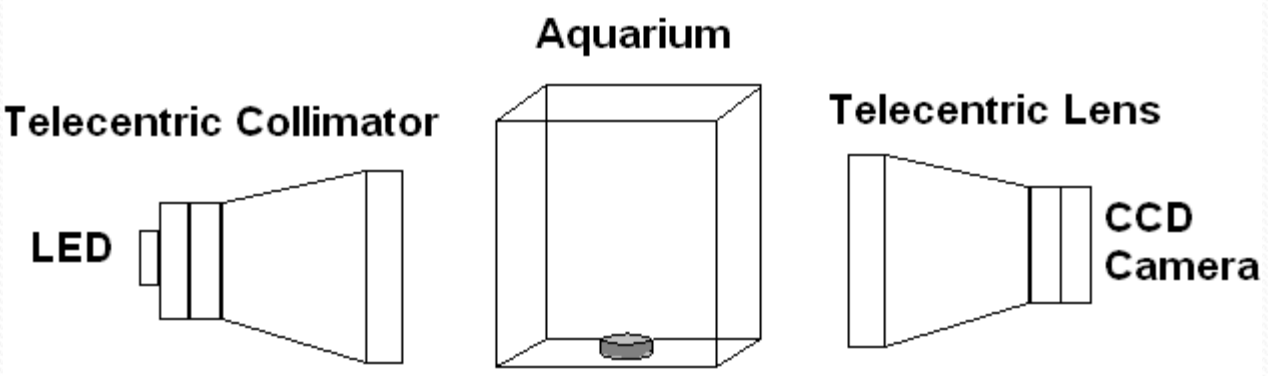
α

α: J. Adamovics and M. J. Maryanski, Radiation Protection Dosimetry 120 (2006) 107.

Imaging

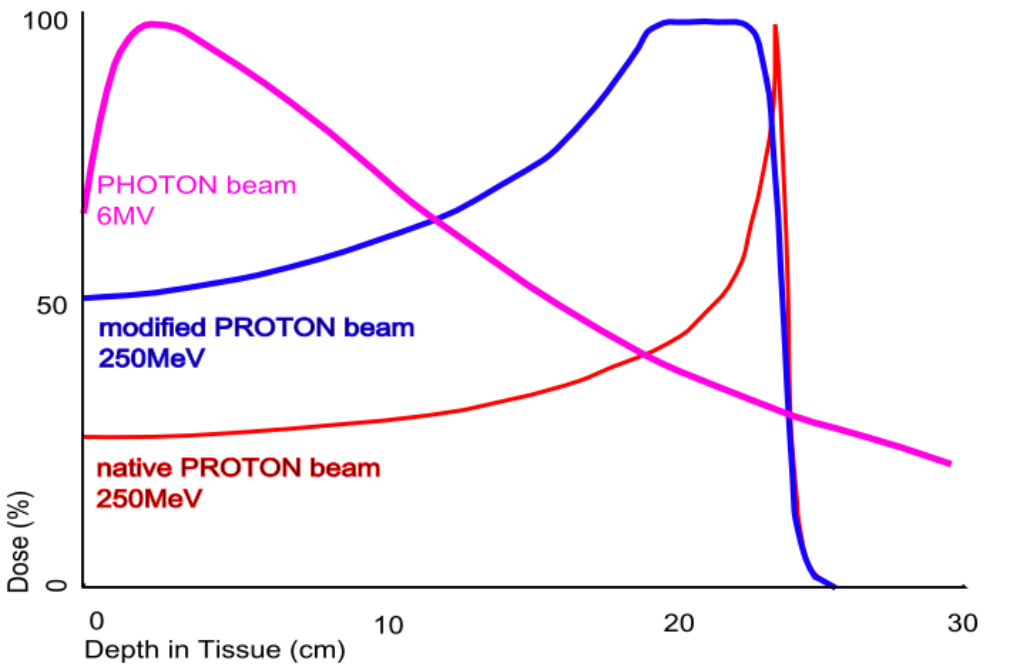
- Duke medium-field-of-view optical-CT scanner (DMOS)
  - Measures light absorbance in 3D using a telecentric LED.
  - Dose = image subtractions
  - Dose reconstruction analyzed using CERR
- Scanning procedure:
  - Prescan (same day)
  - Irradiation
  - Postscan (24 hours later)

632 nm LED



The advantage of proton therapy

- Proton therapy allows for highly conformal irradiations while sparing healthy tissue outside of the PTV
  - Less entrance dose than electrons
  - Less distal dose than photons
- Bragg peak
- <u>Excellent sparing of critical structures!!</u>



Proton therapy uncertainties

- Machine and treatment planning:
  - Beam energies (depths)
  - Beam penumbra
  - CT number – stopping power conversions
  - Relative biological effectiveness (RBE)
- Patient:
  - Patient setup
  - Muscle and organ motion
  - Changes in anatomy

Positrons

- Inelastic collisions with a nucleus can produce positron emitters in the target.
- The interaction cross sections have a minimal threshold and dependent on incident proton energy.
- Enough signal is produced in clinical doses to be imaged with a PET scanner.[1]

Reaction	Threshold energy (MeV)	Half life (min)	Positron energy (MeV)
$^{16}O(p, pn)^{15}O$	16.79	2.037	1.72
$^{16}O(p, \alpha)^{13}N$	5.66	9.965	1.19
$^{14}N(p, pn)^{13}N$	11.44	9.965	1.19
$^{12}C(p, pn)^{11}C$	20.61	20.390	0.96
$^{14}N(p, \alpha)^{11}C$	3.22	20.390	0.96
$^{16}O(p, \alpha pn)^{11}C$	59.64	20.390	0.96

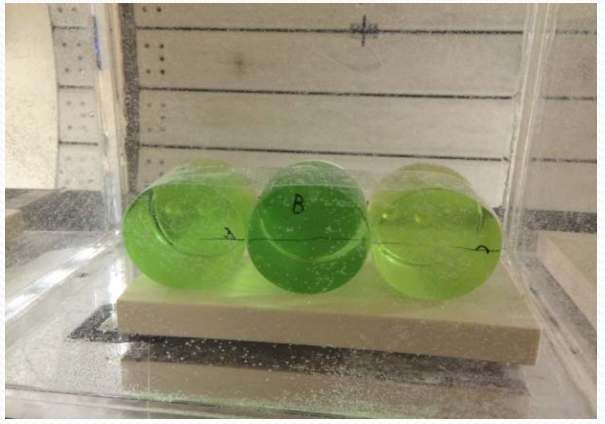
1. Studenski, Matthew T., and Ying Xiao. "Proton therapy dosimetry using positron emission tomography." World journal of radiology 2.4 (2010): 135.

Irradiation

- Cylindrical dosimeters were irradiated with a 180-MeV proton beam in a single, wide-beam shot.
  - Irradiated to 500 cGy

- Immediately after, dosimeters were rushed to nearby GE Discovery 690 FX PET scanner
  - Three hour acquisition

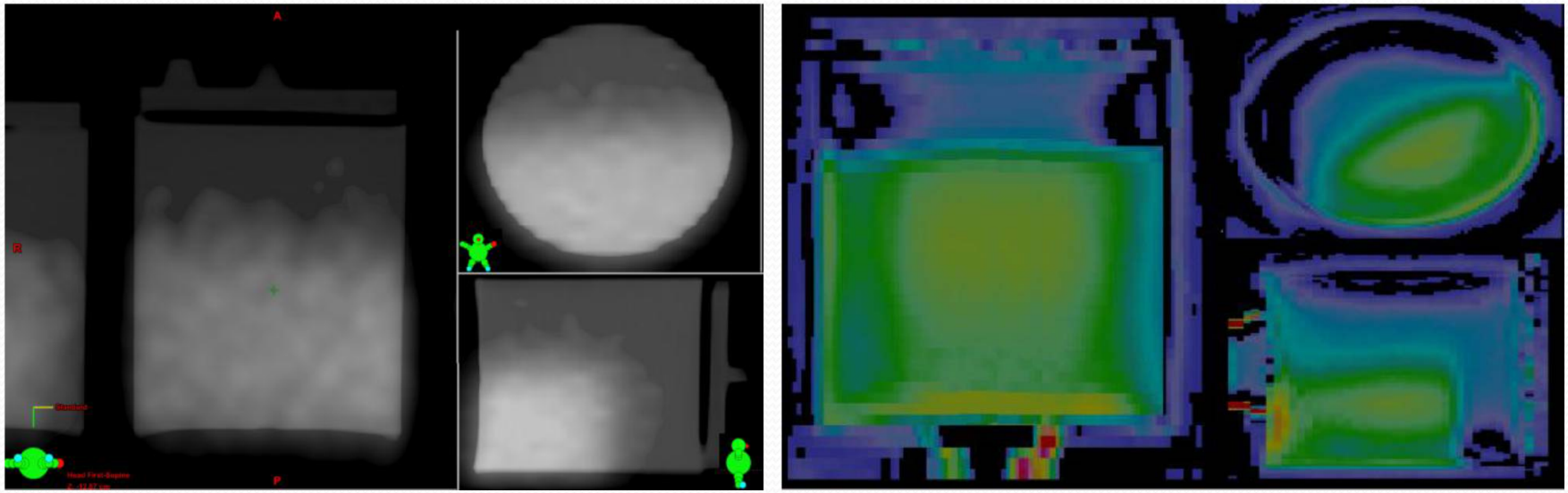
- Following PET scan, dosimetry was readout using the DMOS



Aligned PRESAGE® dosimeters

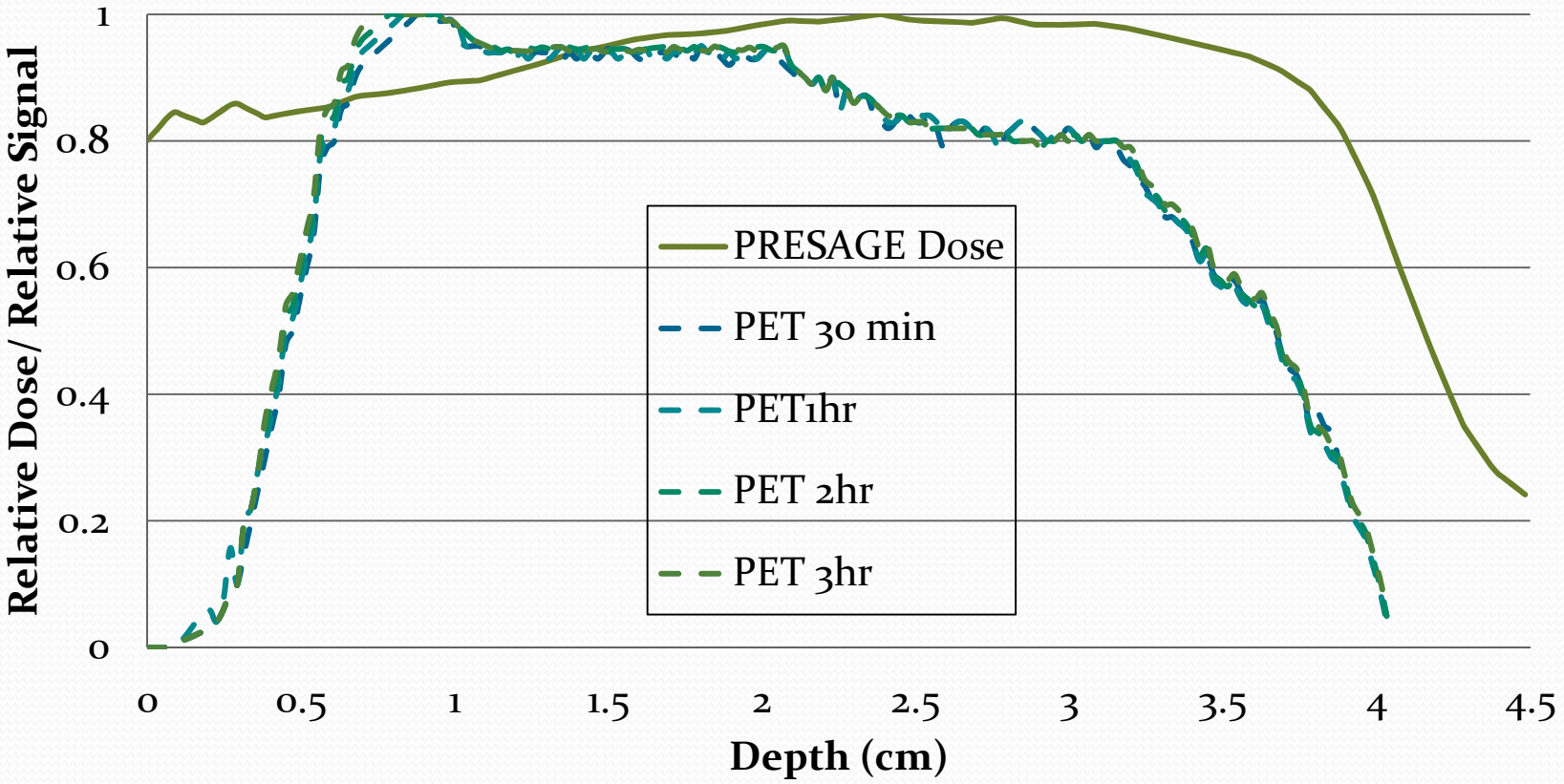
Results

- PET scans were reconstructed for 30 minutes, 1 hour, 2 hours, and 3 hours measurement times



Co-registered PET/CT cross-section with three hour reconstruction (left) and PRESAGE® optical-CT image cross-section (right).

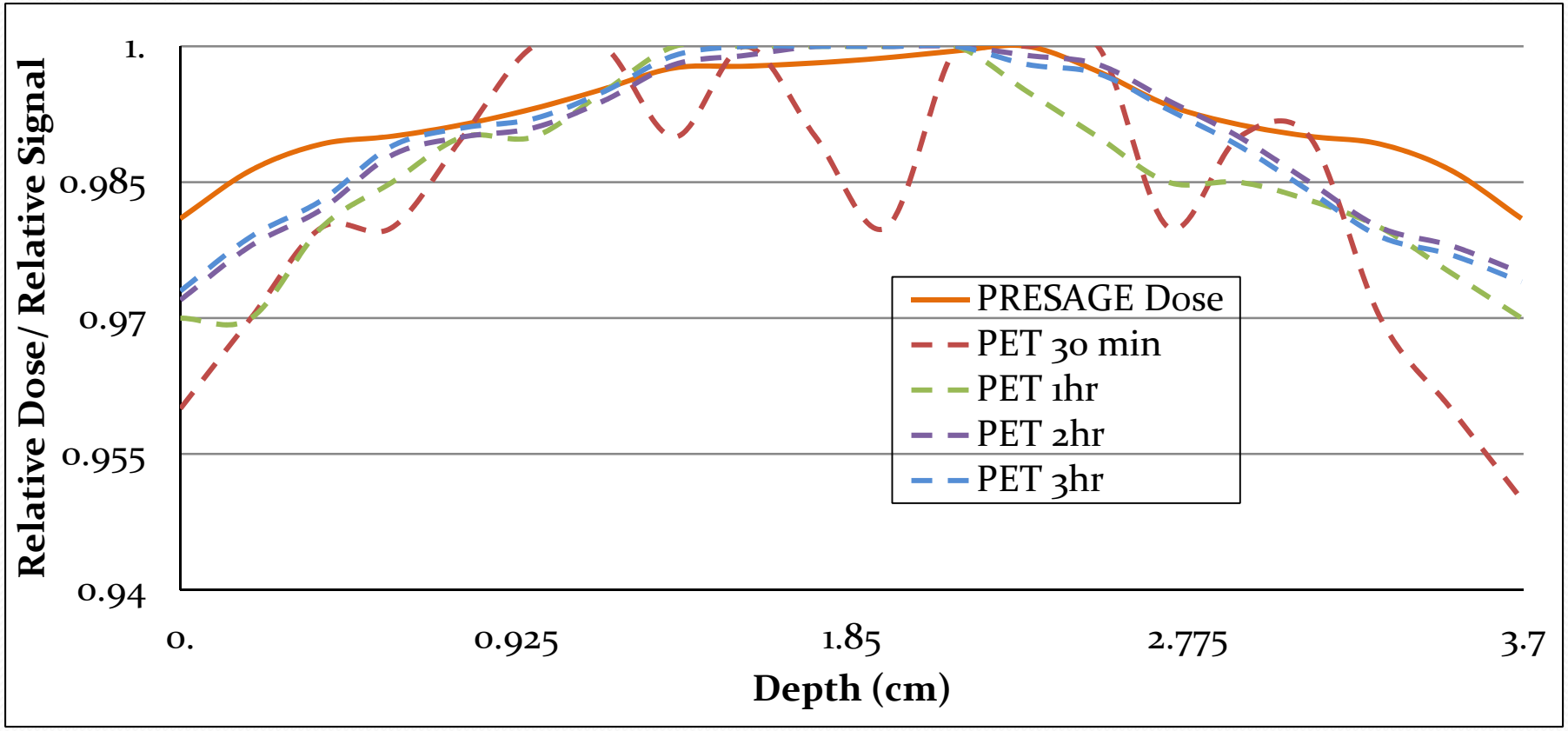
Signal through central axis



Analysis

- At the distal-80% of the field, a 1 cm discrepancy between the measured dose and the PET activity was found.
- A 1 cm discrepancy between the measured dose and the PET activity was foud.
- Further along the distal region, in which the beam energy has significantly decreased, shows no PET signal as proton energies have fallen below the carbon activation thresholds.

Signal along lateral axis



Analysis

- A lateral axis profile comparison shows another cross-section of relative uniformly measured dose which demonstrates the positrons activity across a monoenergetic profile.

- PET measurements showed minor improvements in stability for scans beyond 60 minutes with all additional durations agreeing to within 2%.

Summary

- PET activation offers a unique opportunity for *in vivo* treatment verification.
  - PET signal shift makes dosimetry difficult, but allows approximation of Bragg peak
- PRESAGE® offers the unique potential to correlate dosimetric and positron activation information in a realistic time window for off-line PET studies.
- Further studies will demonstrate PET to Bragg peak correlations in multiple complex treatment fields.

THANK YOU!