Bio-medical Applications of Jefferson Lab's Nuclear Physics Detector Technology

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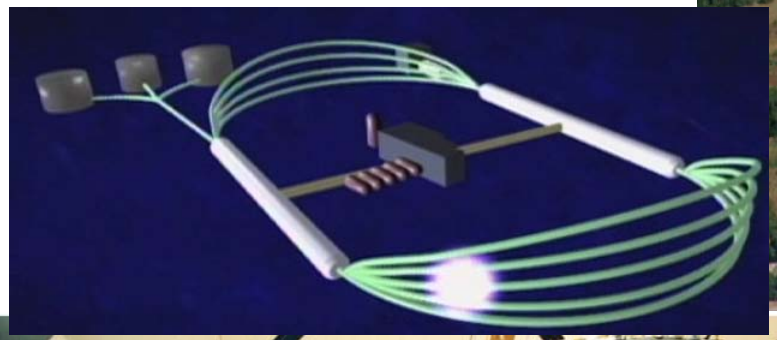
JLab's Continuous Electron Beam Accelerator Facility



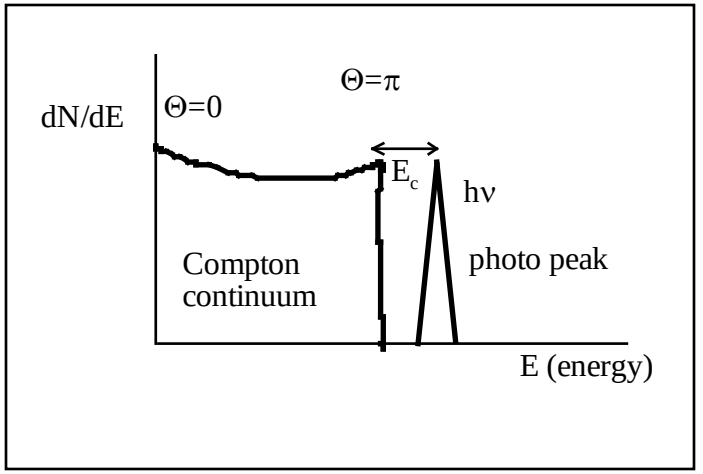
Radiation Detector & Imaging Group

- Support design and construction of new detector systems
- Technical consultants for the lab scientists and users
- Development and use of imaging and non-imaging detector systems
- Expertise in nuclear particle detection
  - gas based detectors
  - silicon photomultiplier (SiPMs)
  - scintillation and light guide techniques
  - standard and position-sensitive photomultiplier tubes (PSPMTs)
  - fast analog readout electronics and data acquisition
  - on-line image formation and analysis
  - image reconstruction algorithms with motion correction
  - compact detectors

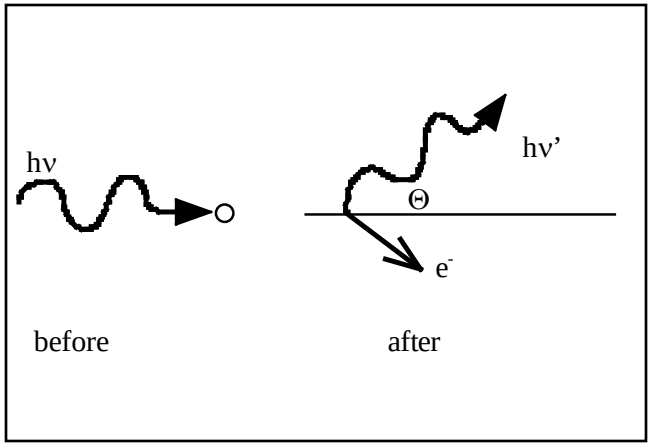
Detecting and Imaging Radioactive Decay (a nuclear process)

Scintillator: transparent material for detecting high energy photons (i.e. x-rays, gamma-rays)

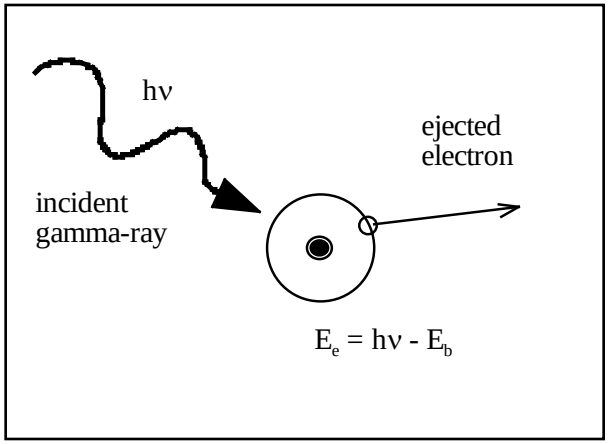
A high energy photon deposits energy in the atoms of the scintillator resulting in the release of lower energy photons that can then be converted to an electrical signal by devices called photomultiplier tubes (PMTs).



Compton Scattering



Photoelectric Absorption



Bio-Medical Imaging Modalities

Structural

Functional

Somatostatin receptors (neuroendocrine tumors)

Nuclear Medicine Imaging Basics

Functional imaging (vs structural): patient injected with a radiopharmaceutical that has a biological function in the body i.e. metabolism.

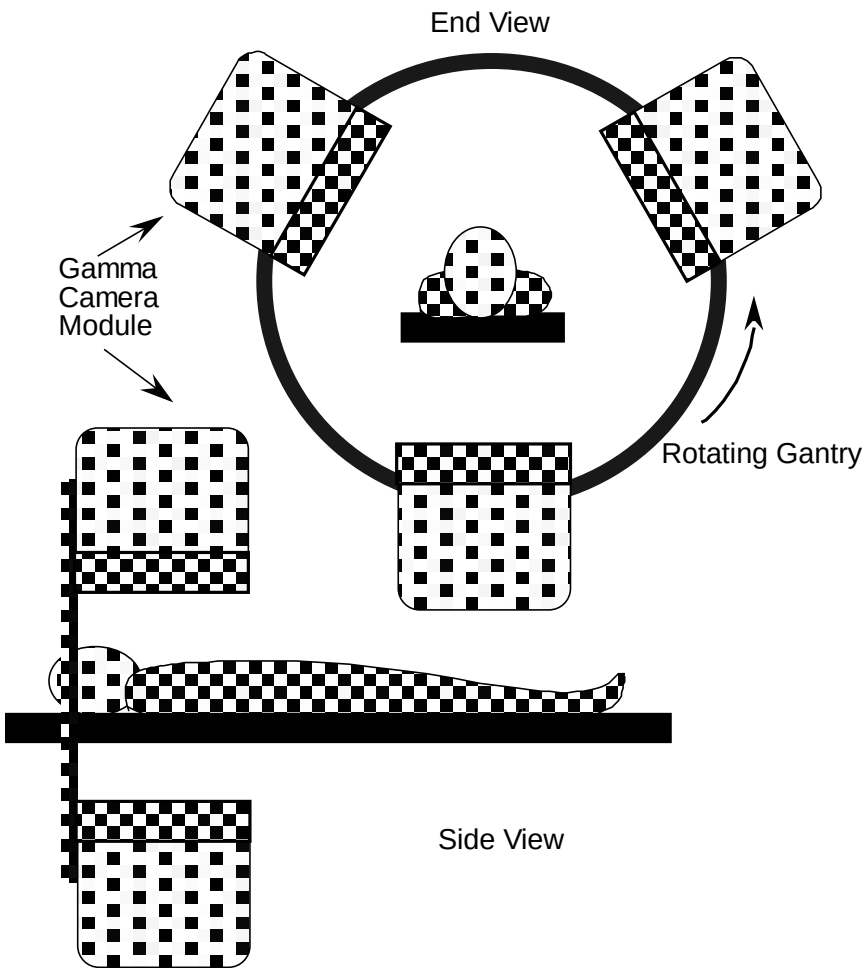
Radiopharmaceutical: radioactive isotope + bioactive tag

Gamma Camera
planar nuclear medicine images (also known as scintigraphy)

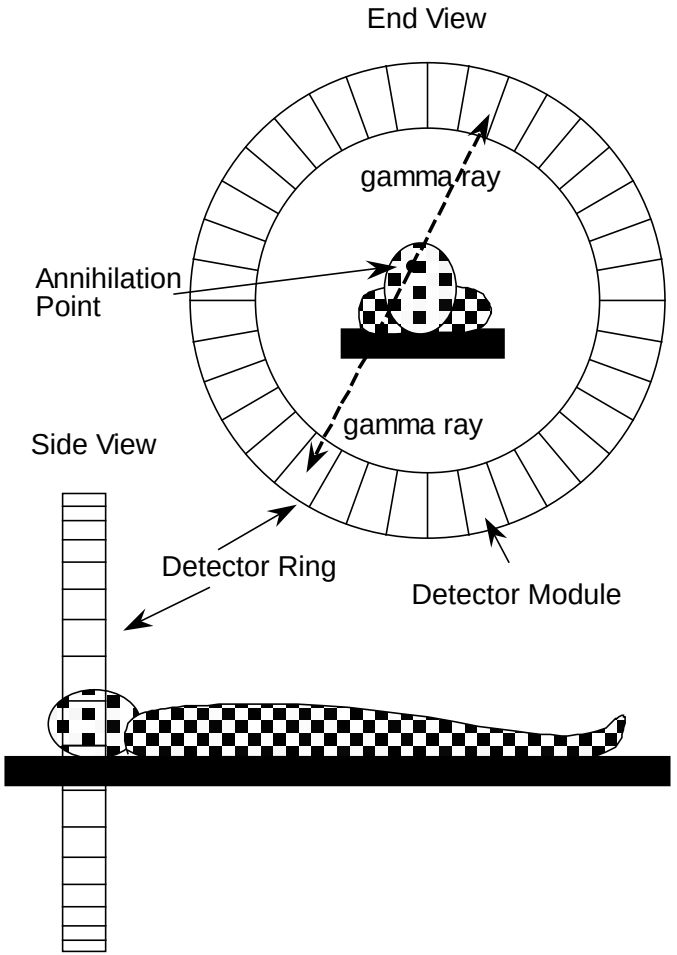
Single-Photon Emission Computed Tomography (SPECT)
technetium-99m (140 keV gamma-ray, 6 hour half-life)

Positron Emission Tomography (PET)
coincident radiation detection through positron-electron interaction
fluorine-18 (positron emitter, 110 minute half-life) two 511 kev annihilation photons

Clinical SPECT System

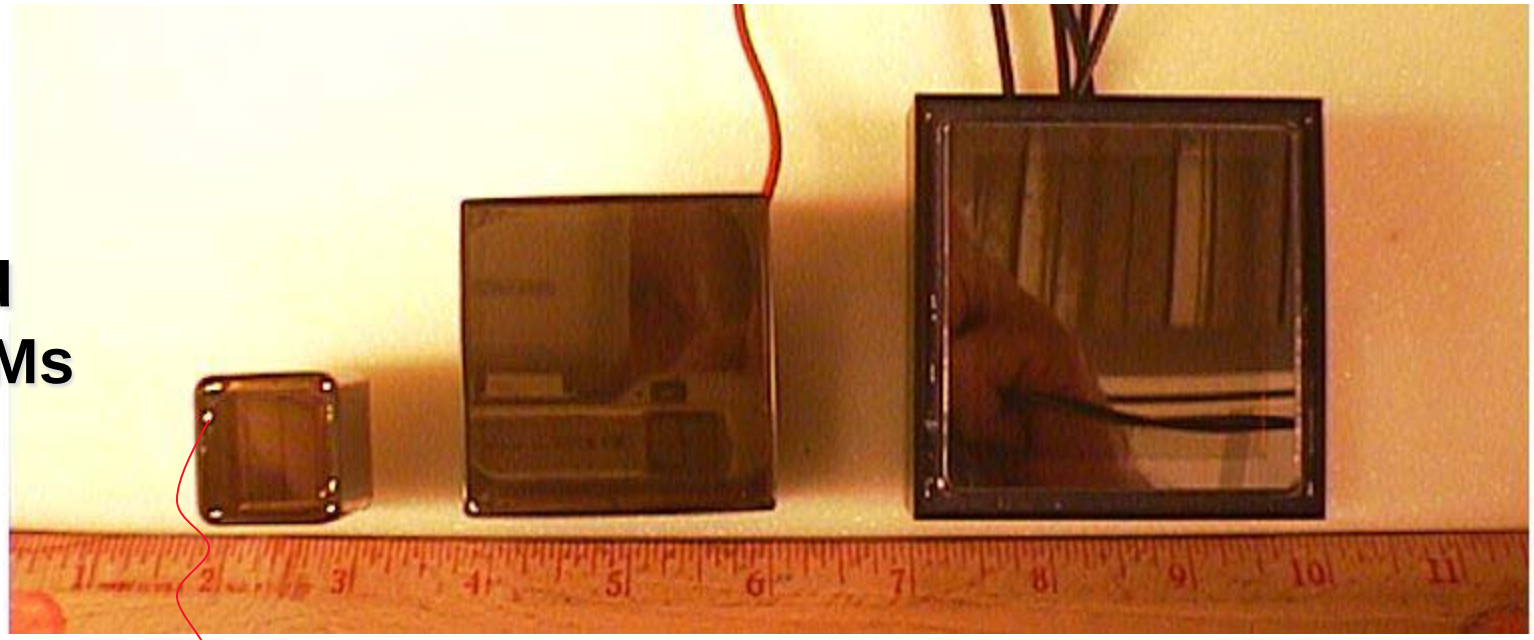


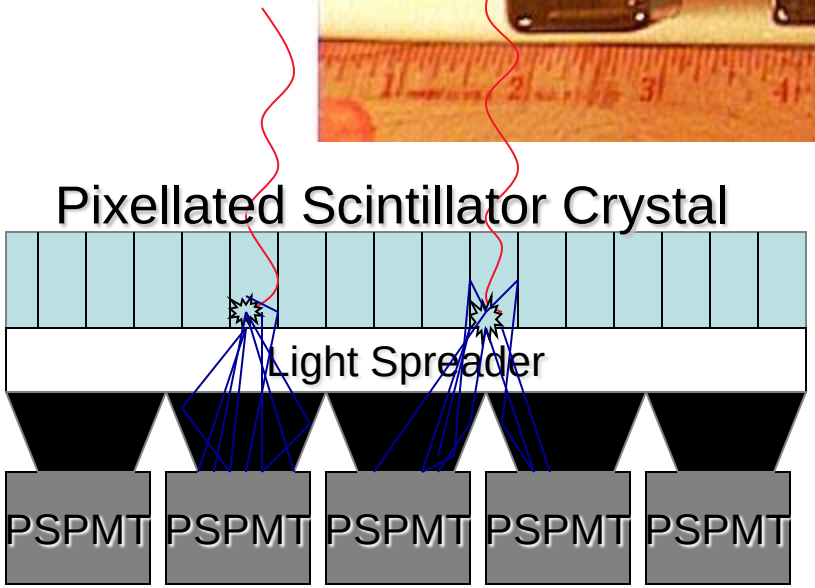
Clinical PET System

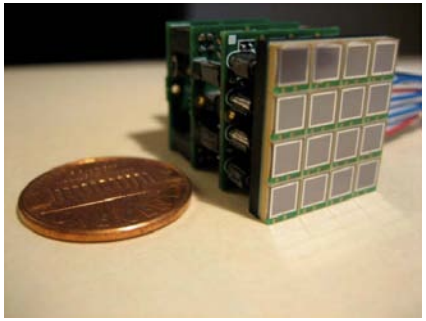


Latest photomultiplier technology allows modular detector construction

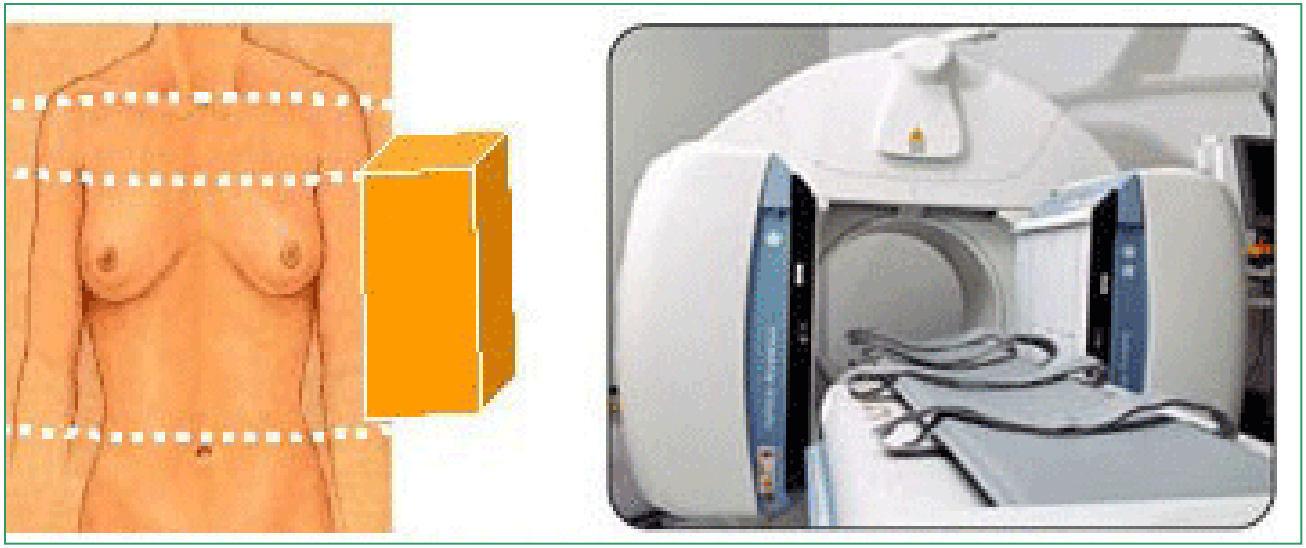
Compact position sensitive PMTs and Silicon PMs







Breast-Specific Gamma Imaging



Need for a Detector Built for the Task

Dilon 6800 Gamma Camera

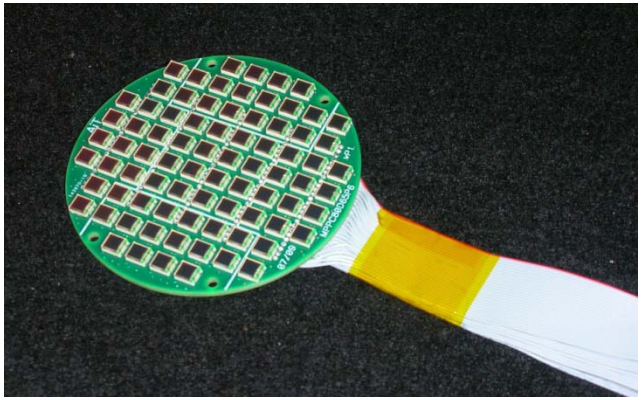
Smart Shield™ immobilizes the breast and prevents shine-through

Compact detector allows imaging close to the chest wall

Several patents licensed from JLab

www.dilon.com

Handheld Gamma Camera for Cancer Surgery

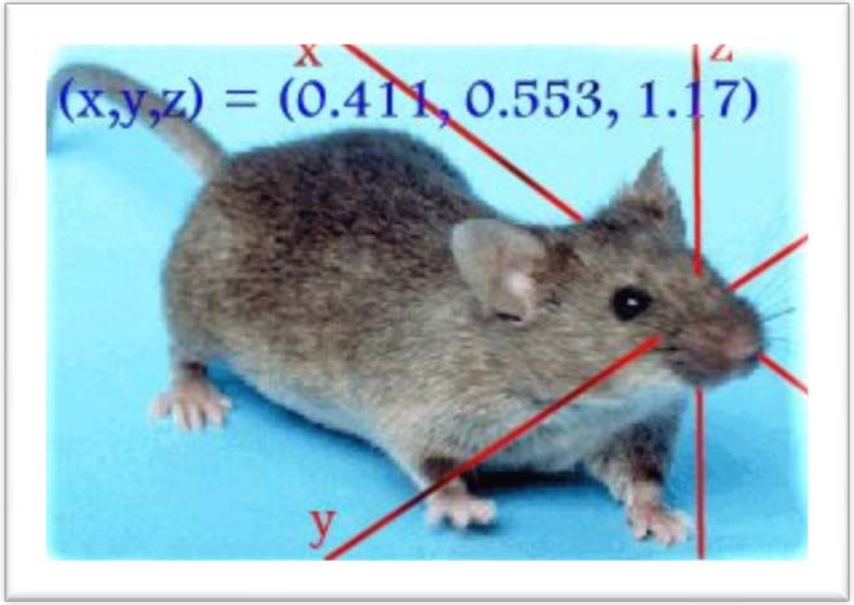


SiPM based would be lighter and hand held.

Imaging lymph nodes before surgery with JLab built **gantry mounted gamma camera**. Right: Imaging during surgery. University of Virginia surgeons.

patents pending

Awake Small Animal Imaging

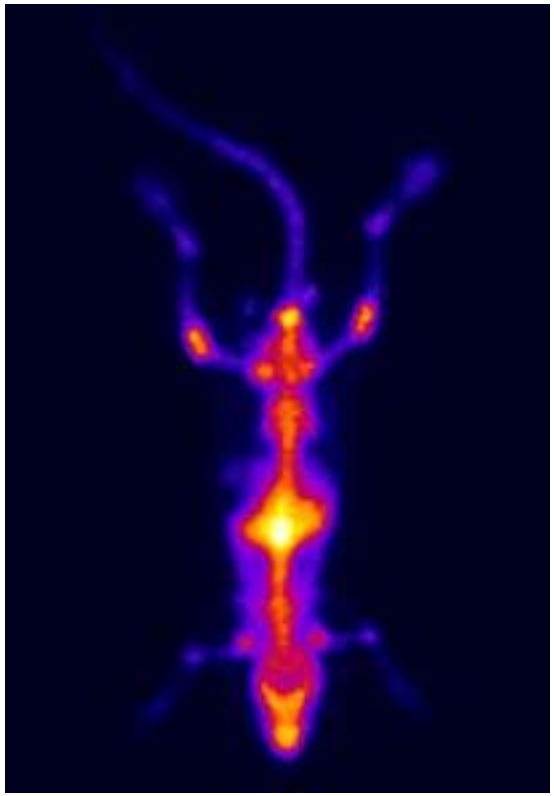


A new tool for biological research under development:

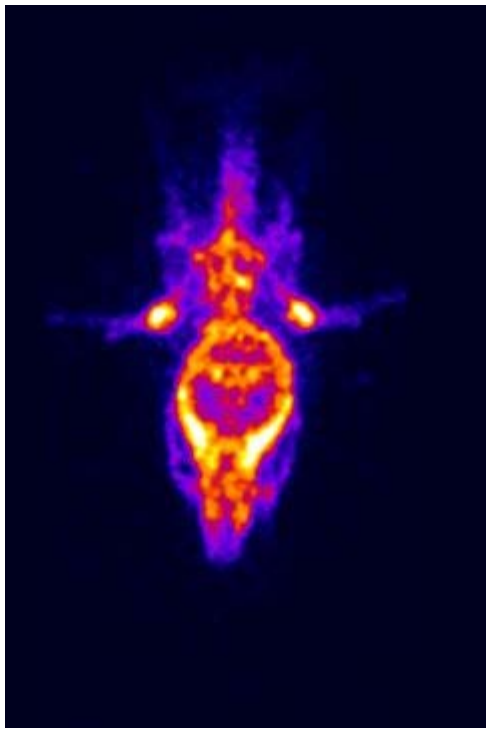
JLab, ORNL and JHU

Several patents awarded and pending

Image of mouse injected with bone marker MDP-Tc99m



Using high resolution parallel hole collimator



Using 1mm pinhole ~2x magnification

Indications for awake animal SPECT imaging

Addiction research

Neuro-degeneration:

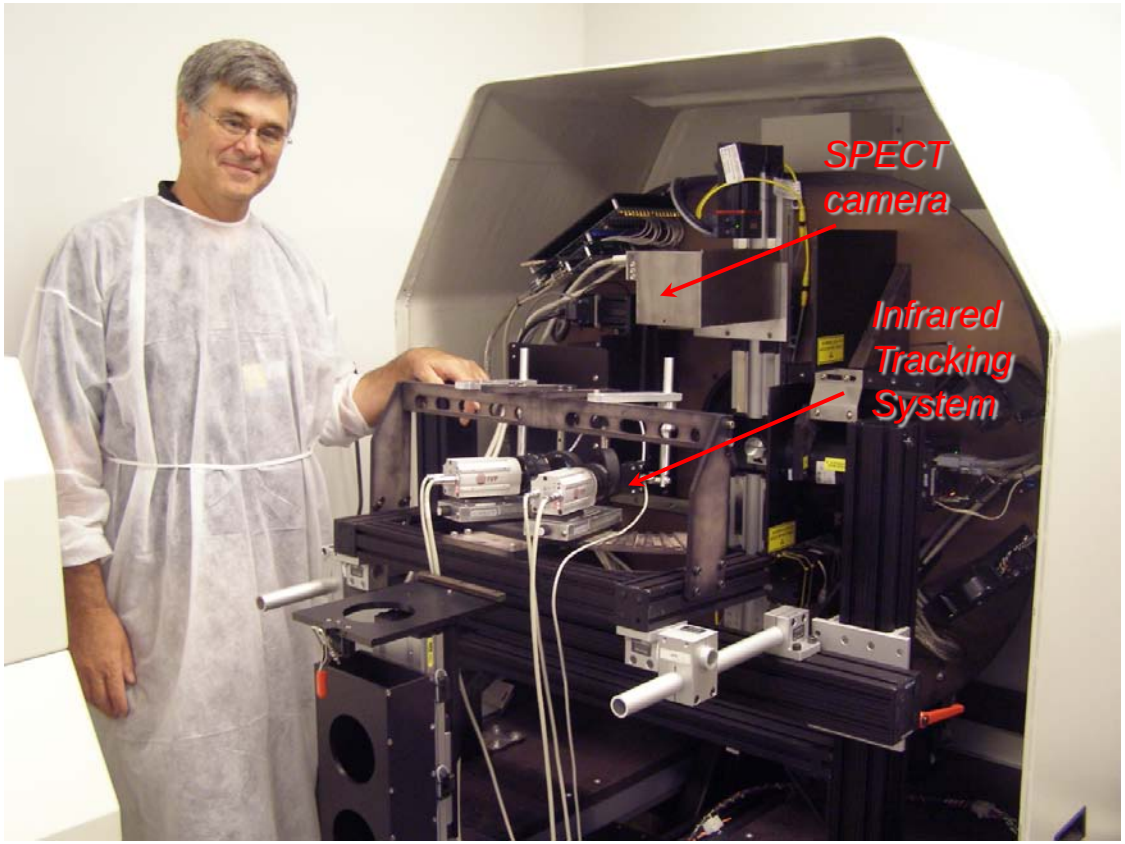
- Alzheimer's Disease
- Parkinson's Disease

Brain inflammation (i.e. HIV, MS).

Stem cell trafficking

- ❑ avoid influence of anesthesia on: blood flow, metabolism, neural-vascular coupling
- ❑ elucidate disease pathophysiology
- ❑ drug/radiopharmaceutical development
- ❑ mimic the human state

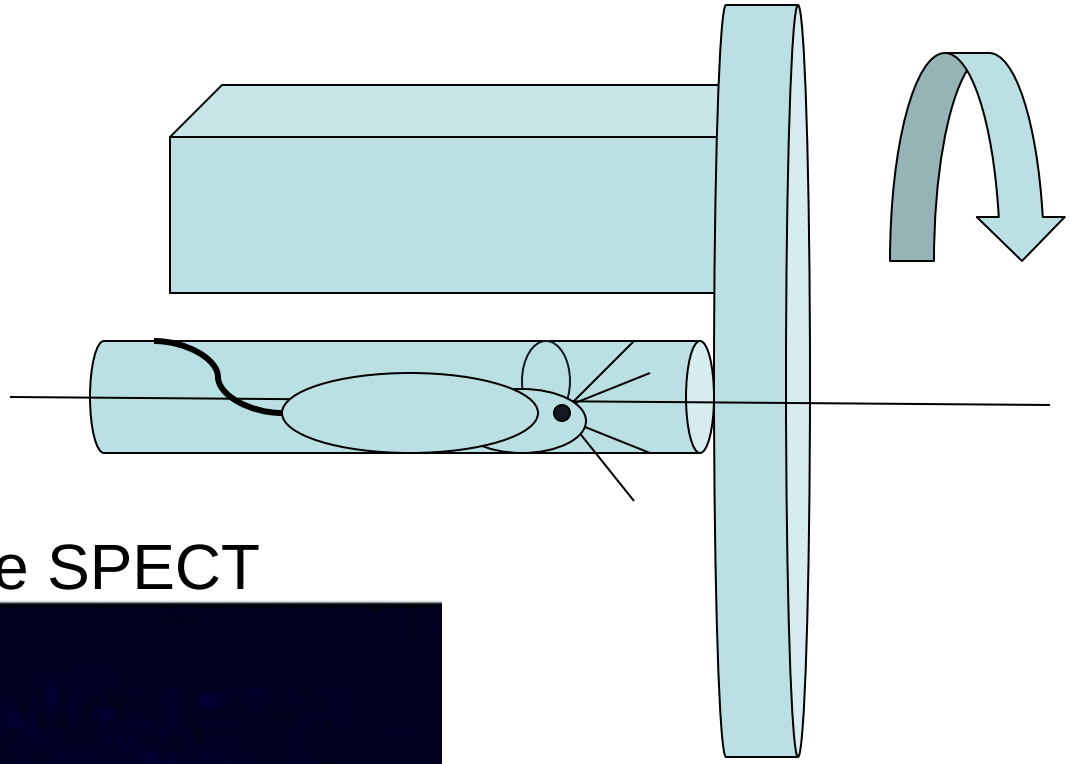
Awake Animal SPECT-CT Imaging System



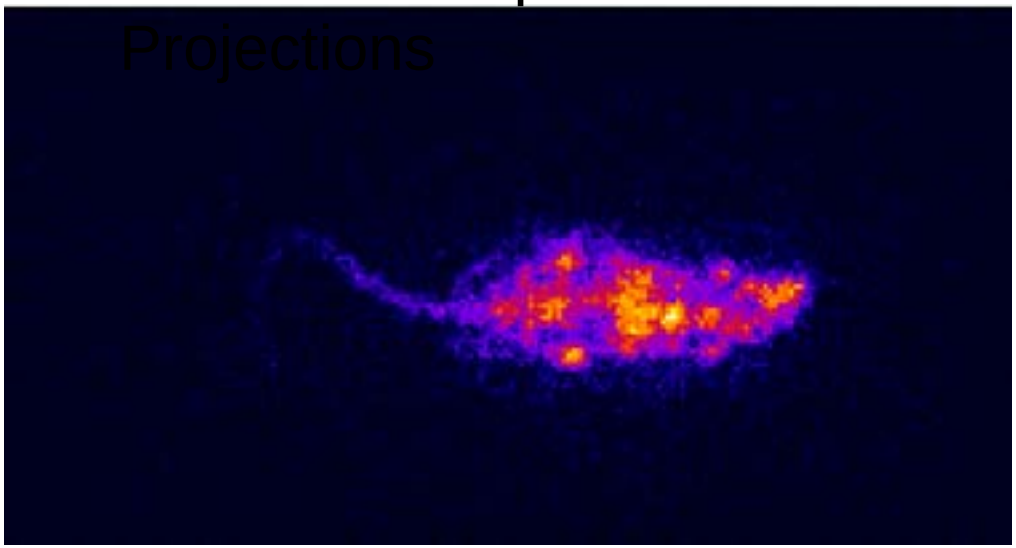
An awake mouse with infrared reflectors for head tracking shown in imaging burrow.

Computer display illustrating real-time pose tracking via the stereo infrared CCD cameras.

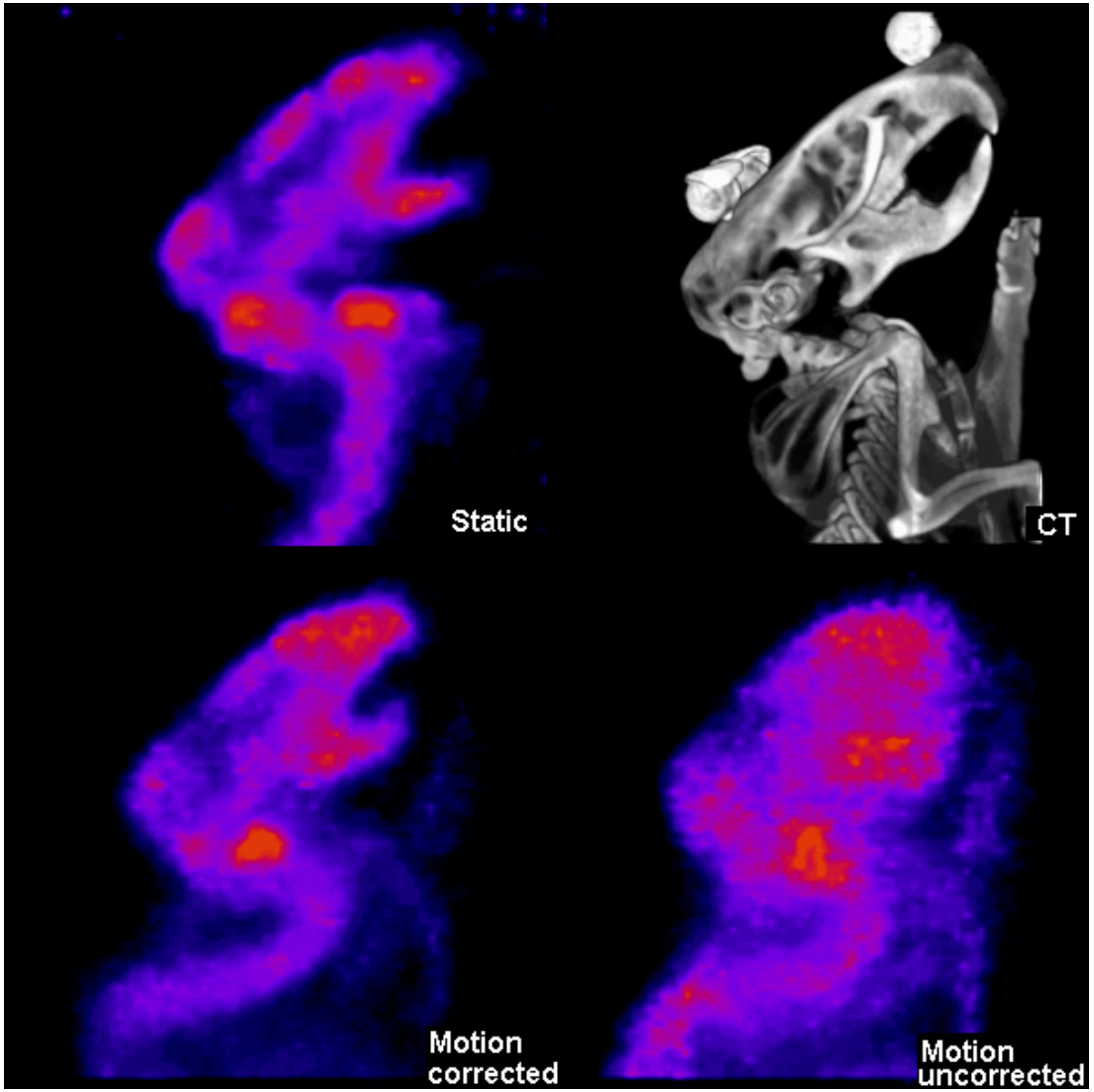
SPECT Scan of Awake Mouse



Movie of Multiple SPECT Projections

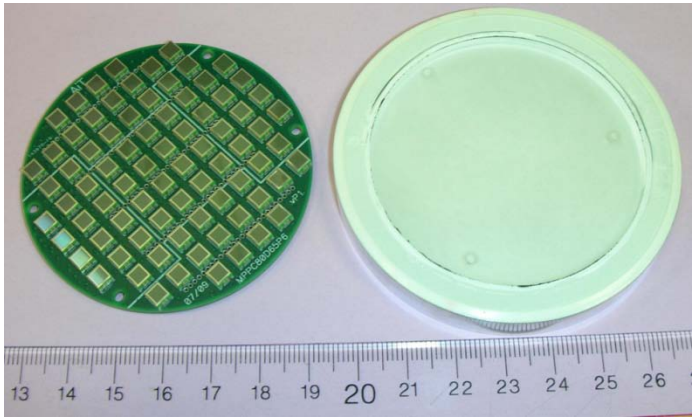


Tc99m-MDP


Static
CT
Motion corrected
Motion uncorrected

Handheld Imaging Gamma Detector Development

Hand held gamma cameras for field work
SiPM based with tracking



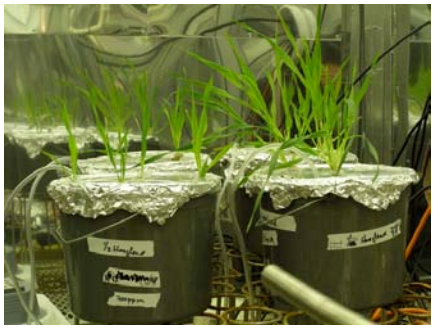
Handheld detector with tungsten shell and tungsten collimators

Plant Biology Specific PET Detector Development

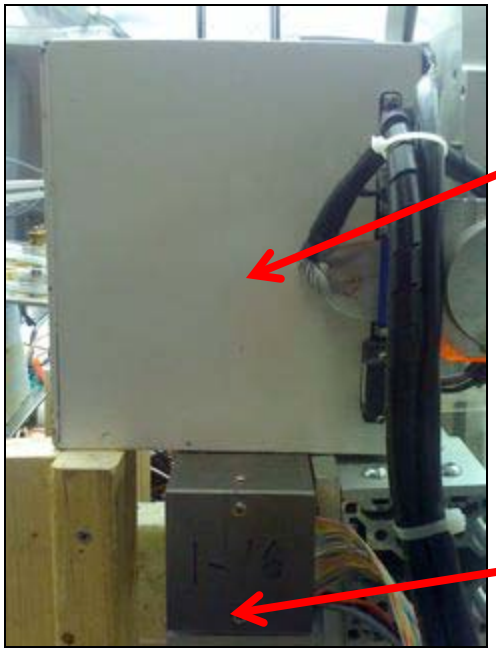
- Crop Pathogen
- Bio-fuels
- Photosynthesis Studies
- Subsurface radiation contamination to crops
- Carbon sequestration

Duke Forest FACE

Reach in EGC



Hordeum distichum L

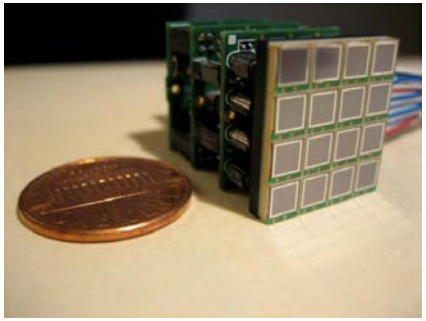


Dual 15 cm x 20 cm Planar PET system

- ◆3.03 mm step pixellated, 10 mm thick LGSO (90% LSO, 10% GSO) array
- ◆ 6x8 array of Hamamatsu R7600-00-C8 PSPMTs

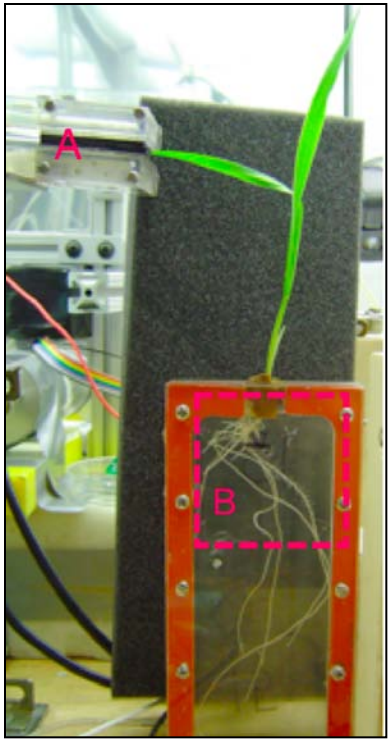
Dual 5 cm x 5 cm Planar PET system

- ◆1.5 mm step pixellated, 10 mm thick, LYSO array using 4ch PEM readout
- ◆Single Hamamatsu H8500 PSPMT

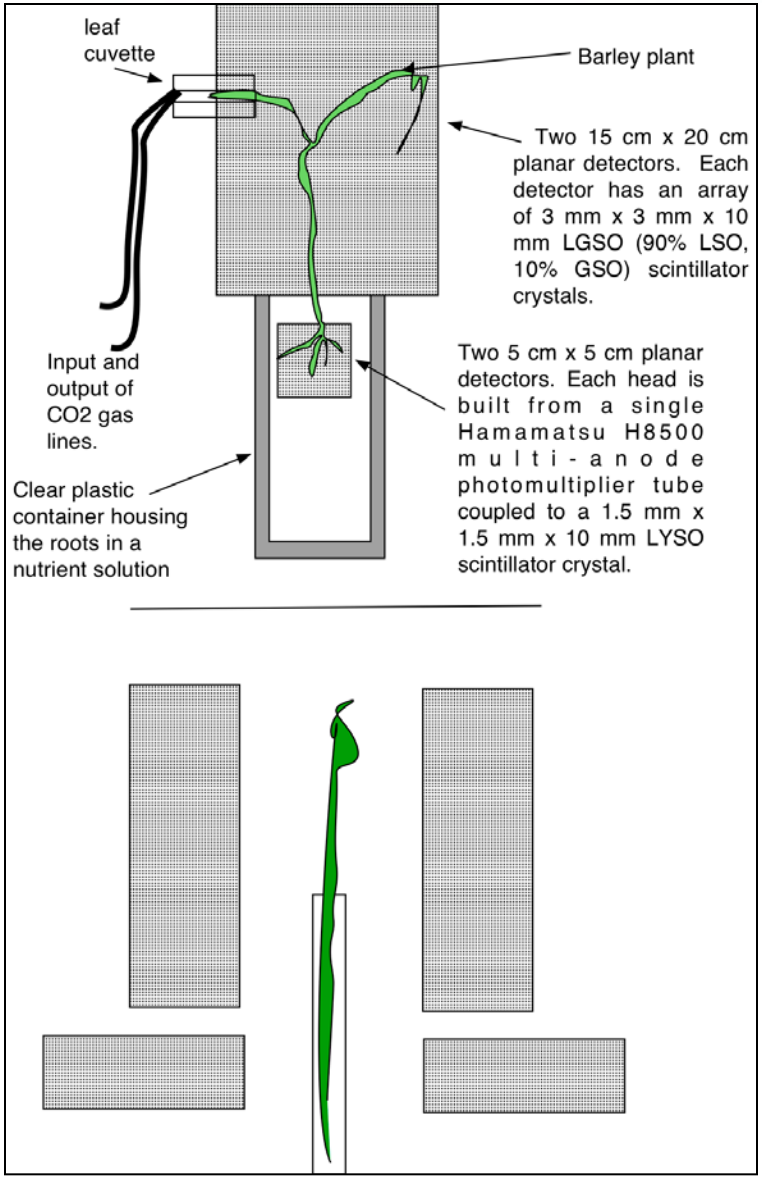


Silicon Photomultplier (SiPM)

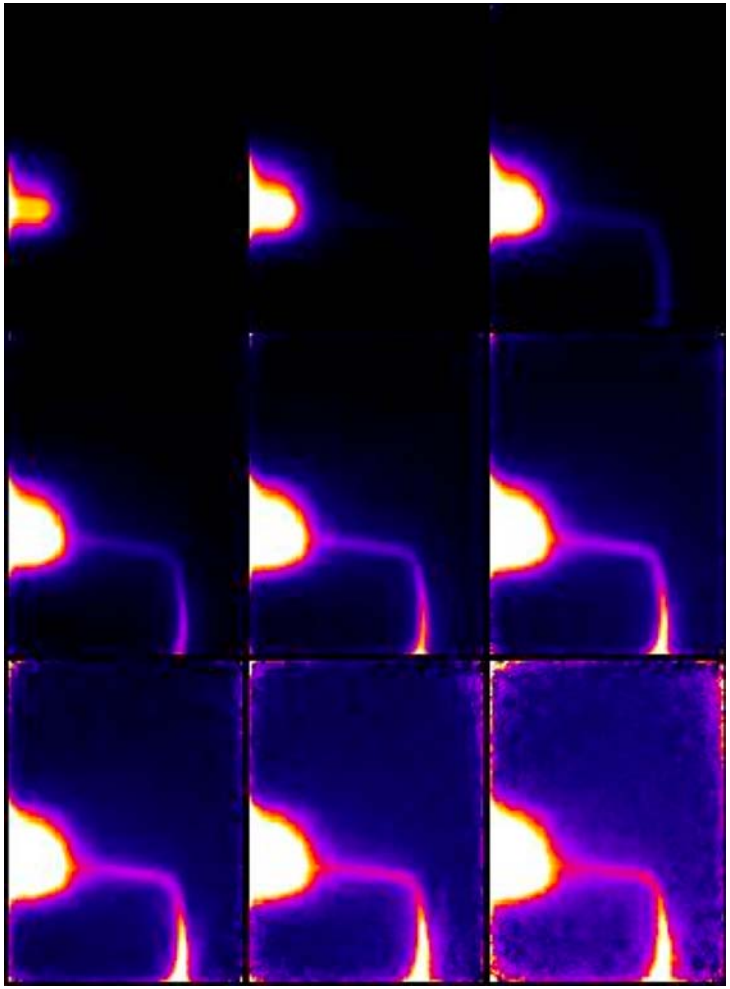
- ◆Compact
- ◆MRI compatible



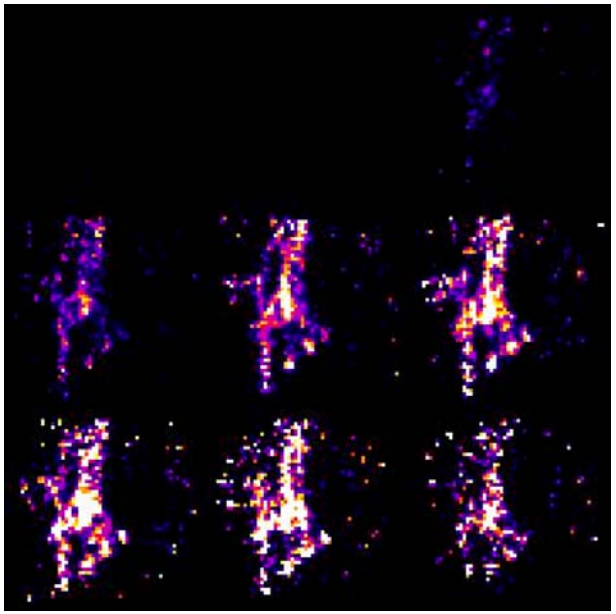
The model plant used for the experiment was barley (*Hordeum distichum L.*) grown in hydroponic fluid



PET Imaging of Carbon Dioxide Utilization in Plant

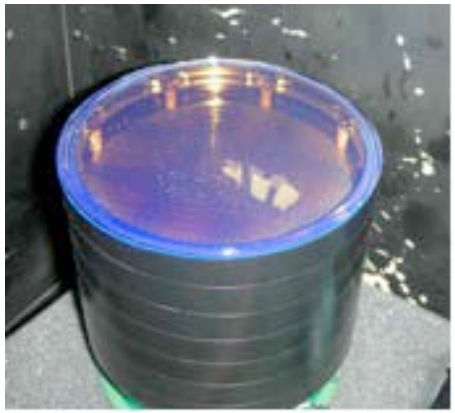


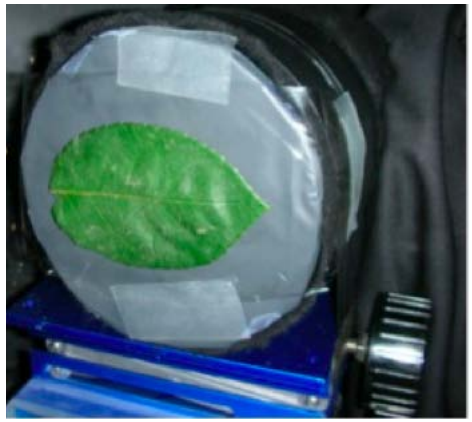
Reconstruction montage of the leaf area of the image data obtained using a Plexiglass positron trap. Enhanced sensitivity is observed.

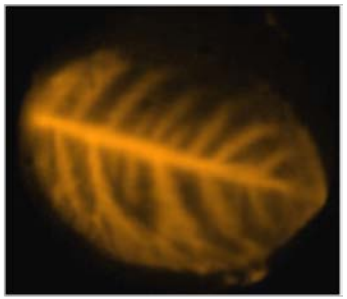


Montage of root area reconstructed images. Time bin for each image was 20 minutes. Images are decay corrected for the half-life of ^{11}C. Time bin was 20 minutes, images are decay corrected for the half-life of ^{11}C

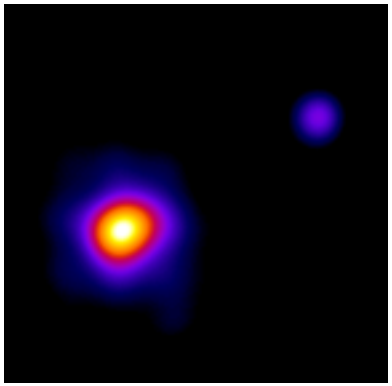
Plant Biology Specific Direct β+ Imaging Detector Development







R3292 110mm diam. Hamamatsu PSPMT coupled to BC400 0.5mm thick plastic scintillator, 15 microns Mylar film and 25 micron Tedlar film were applied on top of the scintillating plastic. Detector ~600X more sensitive that dual planar PET.



"Detector on a stick"

H8500 Hamamatsu 5cm x 5cm PSPMT – 2 mm thick BC408 plastic scintillator Cs137 & Cd109 electron sources

Gamma-ray Imaging for Biological Systems

Partners:

- Oak Ridge National Laboratory (ORNL)
- Triangle Universities Nuclear Laboratory (TUNL)
- Los Alamos National Laboratory (LANL)
- West Virginia University
- Hampton University Proton Therapy Institute
- University of Virginia
- Johns Hopkins University
- Case Western Reserve University
- College of William and Mary
- Duke University
- Columbia University
- Dilon Technologies, Inc.

Detector Group Spin-Off Companies

Dilon Technologies

Ray Visions, Inc

Adaptive I/O

NeoMed

JLab CTO: Roy Whitney

757-269-7536

https://www.jlab.org/exp_prog/techtransfer/