

# Detector and Imaging Applications at Jefferson Lab

**Wenze Xi, Ph.D.**  
**Radiation Detector and Imaging Group**  
**Nuclear Physics Division**



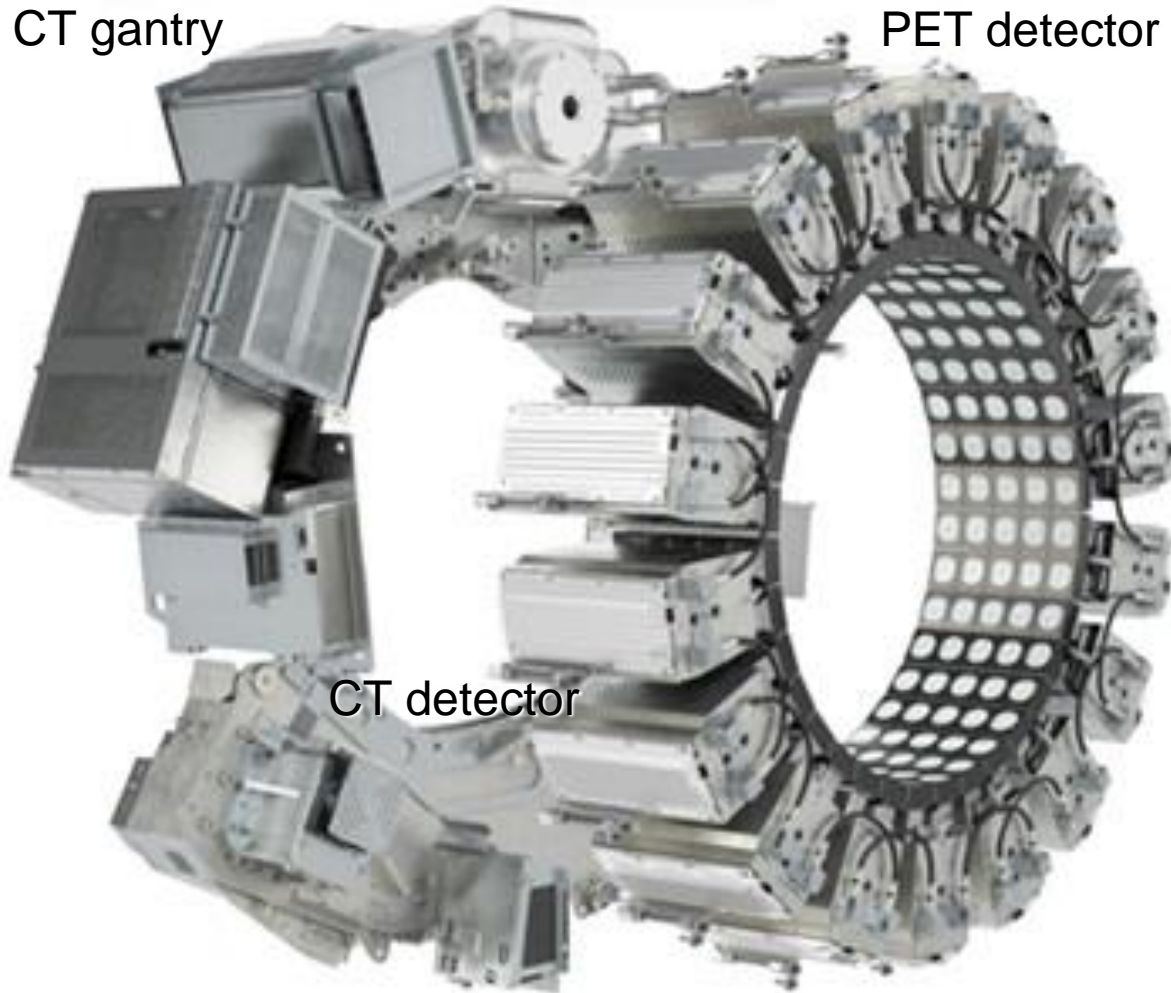
# Outline

- **Clinical medical imaging detector applications**
  - Positron emission tomography (PET)
  - Single photon emission tomography (SPECT)
  - Gamma cameras
    - Breast cancer imaging
    - VASH collimator for tomosynthesis
    - Cancer surgery imaging probe
- **Preclinical imaging system**
  - Awake-animal SPECT
- **Radiation detectors for biological environmental research**
  - PhytoPET plant imaging system
  - RhizoBeta plant root imaging system

# Core Technology for Medical Imaging: Radiation Detectors

CT gantry

PET detector ring



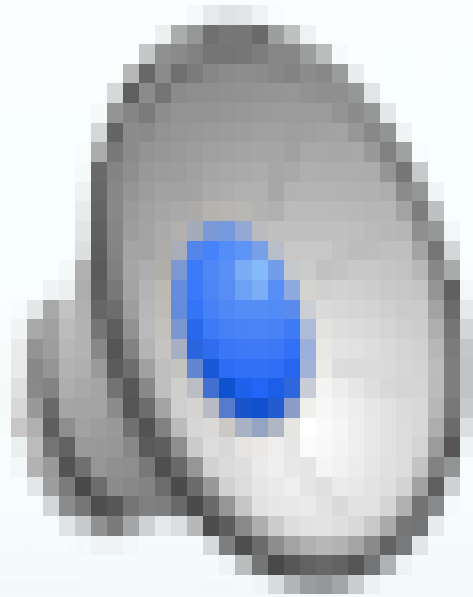
CT detector



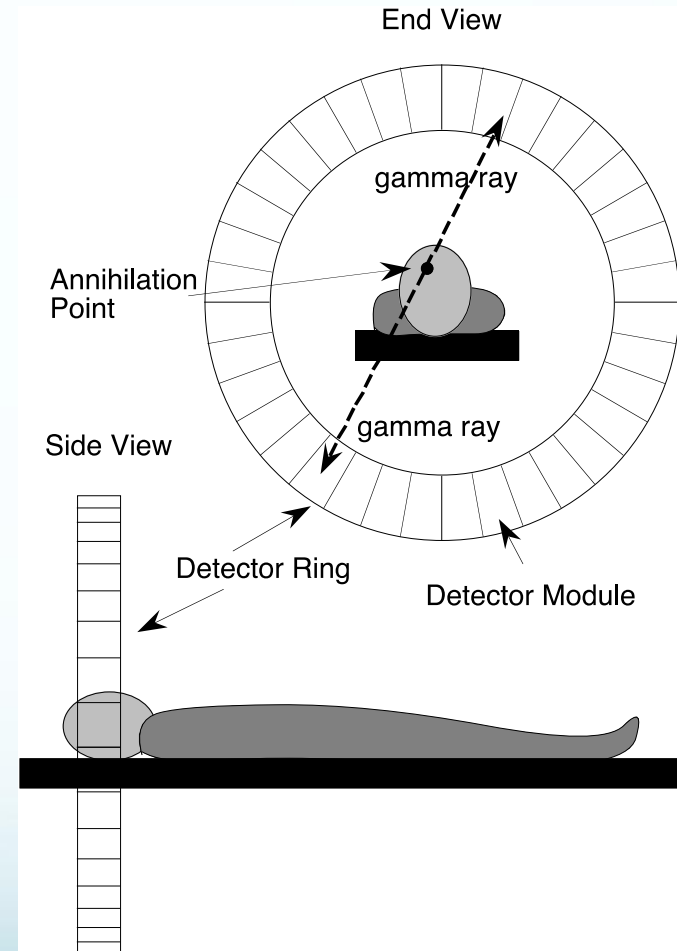
PET detector module

Example: GE PET/CT Discovery IQ

# Medical Imaging Example: PET



# PET Imaging Systems



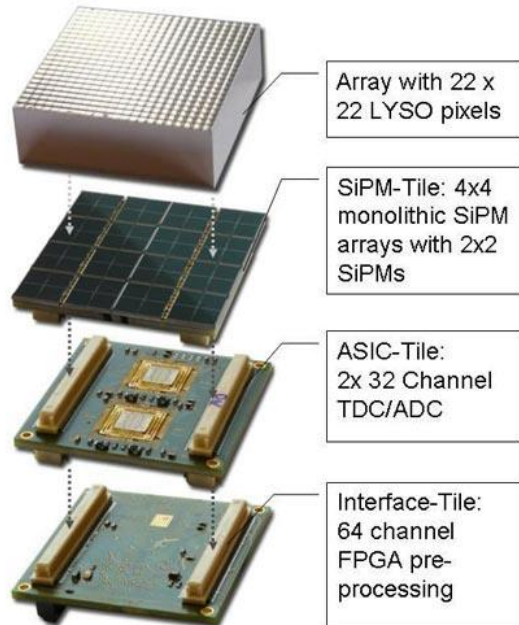
Clinical PET System

Optical

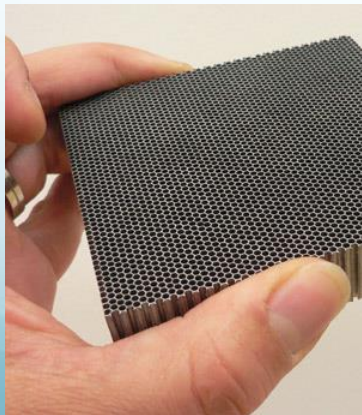
Analog

Analog/  
Digital

Digital



# SPECT Imaging Systems



Collimator

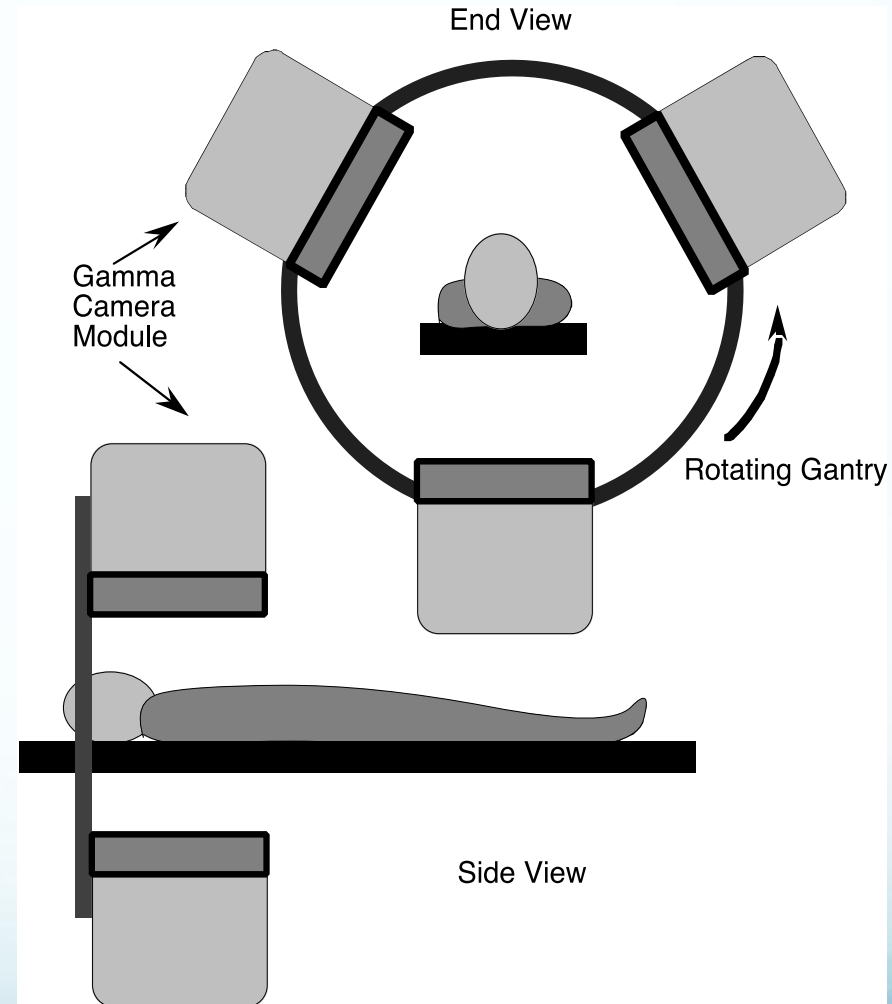
## Single Photon Emitters

Tc-99m\* 140 keV

Iodine-123 159 keV

Iodine-131 364 keV

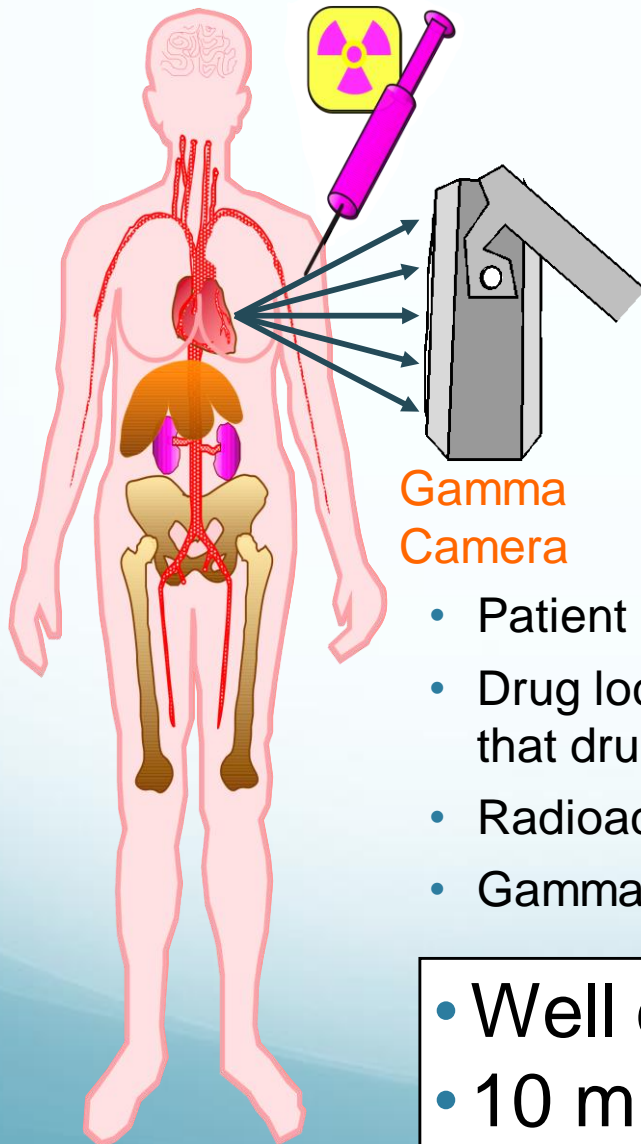
Thallium-201 201keV



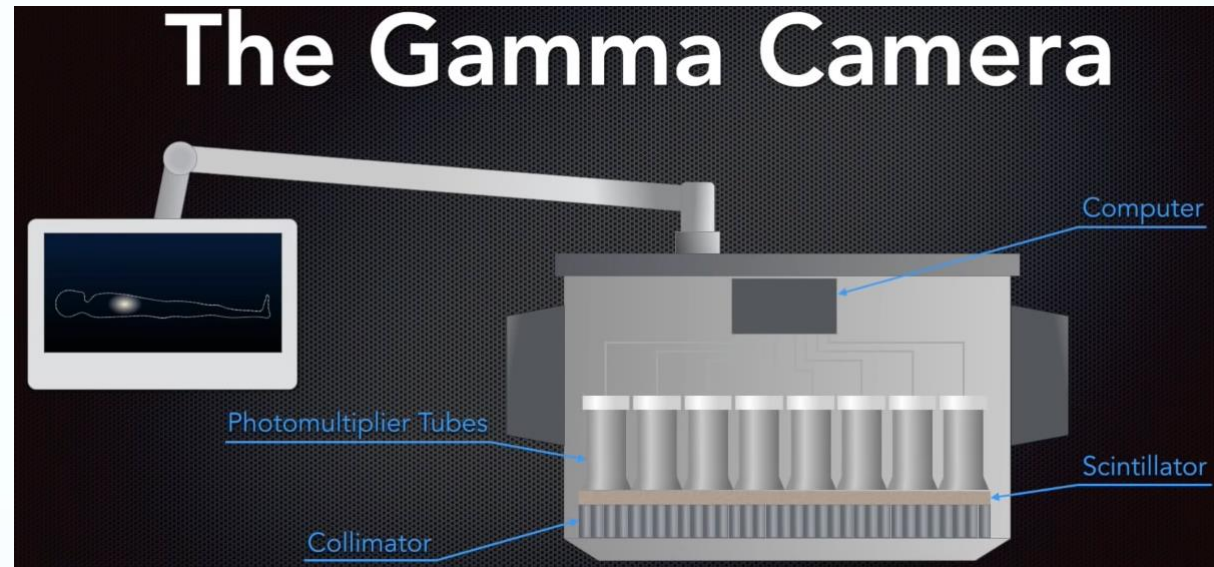
Clinical SPECT System



# Gamma Cameras

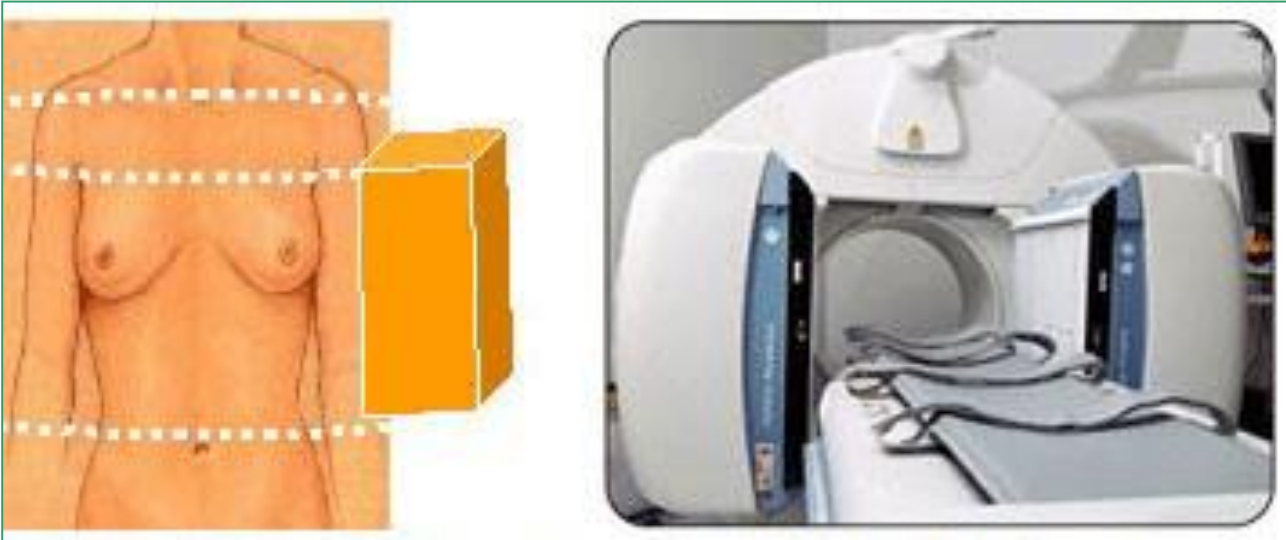


Gamma  
Camera



- Patient injected with *small* amount of radioactive drug
  - Drug localizes in patient according to metabolic properties of that drug
  - Radioactivity decays, emitting gamma rays
  - Gamma rays that exit the patient are imaged
- Well established clinical technique
  - 10 million studies annually

# Breast-specific Gamma Camera



Need for a specialized detector built for the imaging task



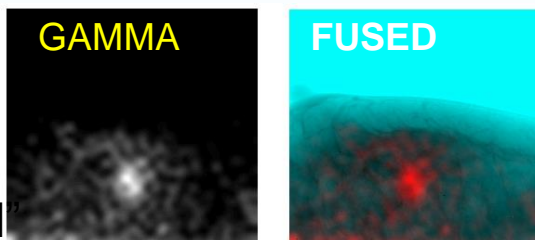


# Jefferson Lab: Breast Cancer Imaging

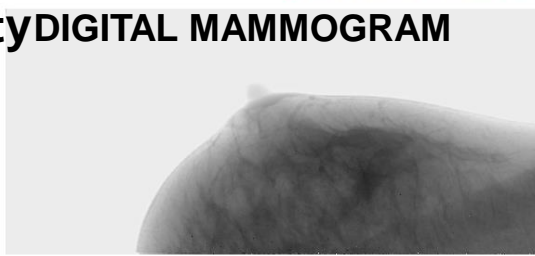


GAMMA

FUSED



Early clinical trials with “GEM” at the **University of Virginia**.



Development Team led by Stan Majewski:  
Jefferson Lab: Brian Kross, Vladimir Popov,  
Drew Weisenberger, Randy Wojcik, Daniela  
Steinbach, Carl Zorn. Dilon Technologies: Doug  
Kieper, Ben Welch

# Technology Transfer: Dilon Technologies

## Dilon 6800 Gamma Camera



**Dilon Technologies, Inc.**

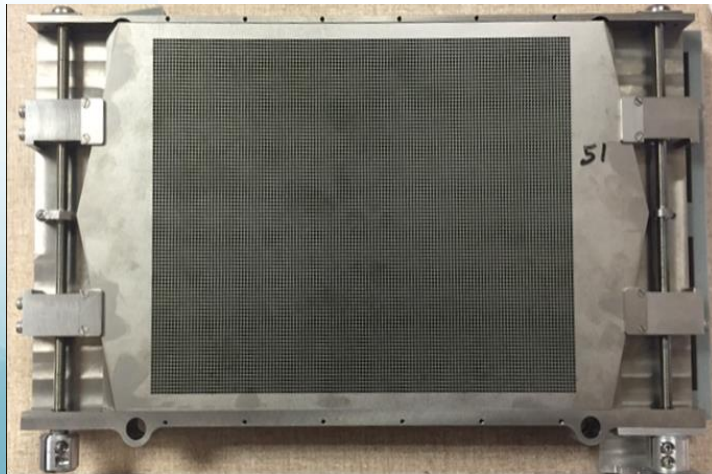
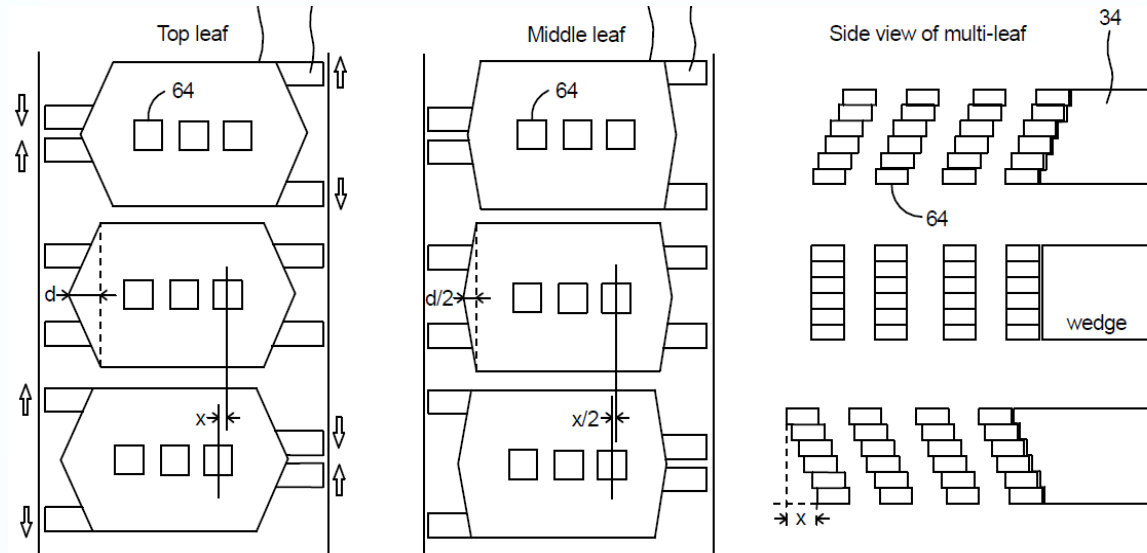
Newport News, Virginia

~30 employees

Several patents licensed from Jefferson Lab



# VASH Collimator for Tomosynthesis

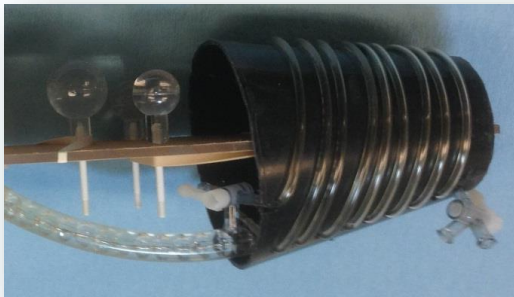


**Top view of actual VASH collimator made of tungsten housing and 48 tungsten leaves. The size of housing is 328 mm x 180 mm x 20 mm**

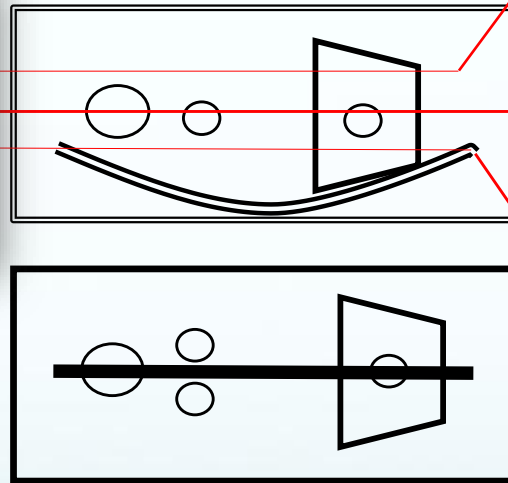


# VASH Collimator for Pediatric Phantom

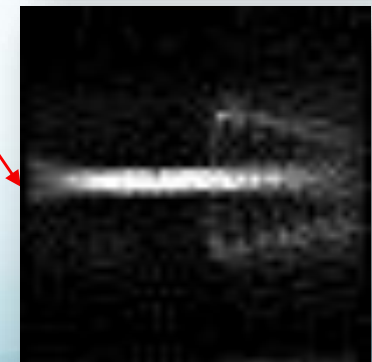
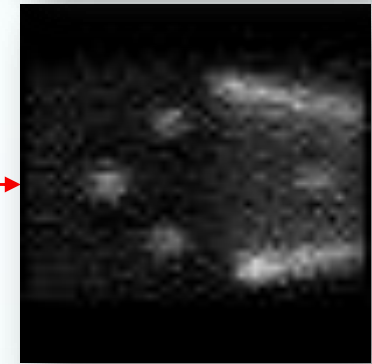
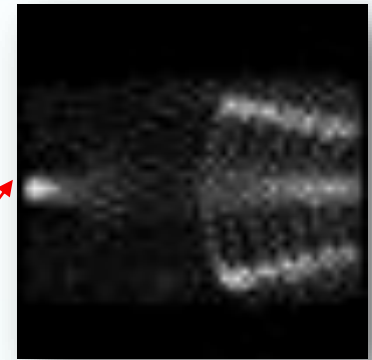
With VASH collimator,  
three depth of the phantom viewing  
became possible!



Coronal views

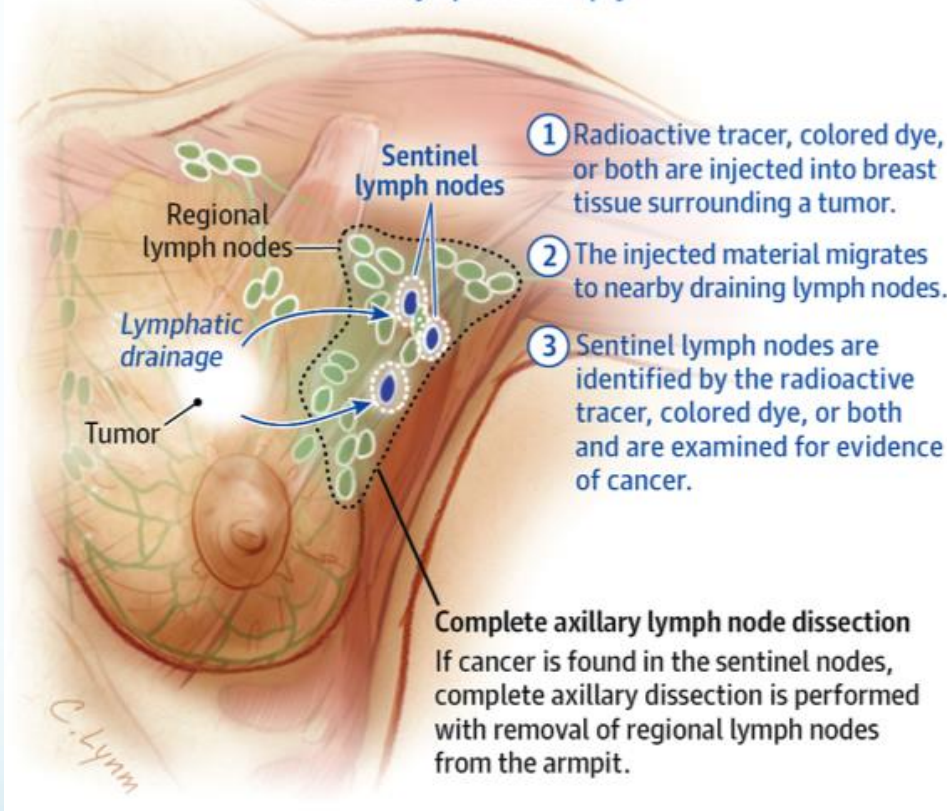


Implication of tomosynthesis: multiple projection  
images are reconstructed allowing visual review of  
thin sections, it offers the potential to unmask cancers  
obscured by normal tissue located above and below  
the lesion.



# Clinical Application: Cancer Surgery

Sentinel lymph node biopsy



**Problem:** Need for compact handheld imaging gamma-ray detector to do lymphoscintigraphy for use in cancer surgery

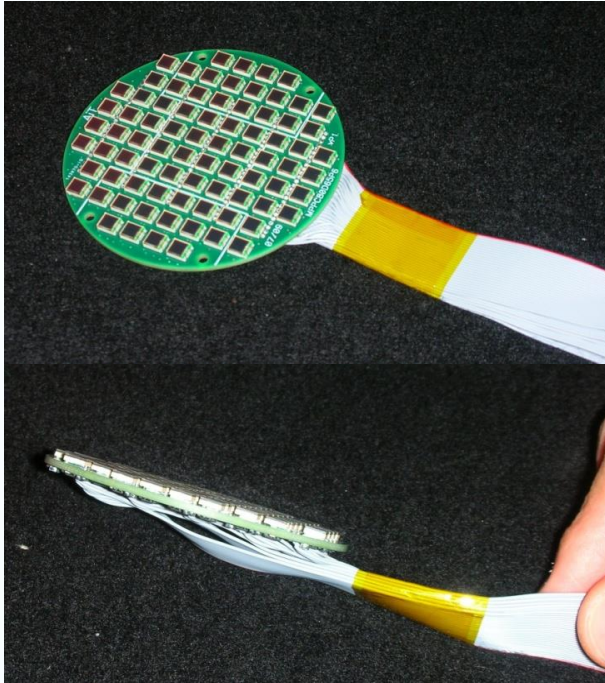
**Solution:** Use array of 80 SiPMs to develop a compact “Gamma Puck” detector with  $\text{LaBr}_3$  (5 cm diam, 6 mm thick) scintillator and custom tungsten-polymer composite two-part collimator

“Gamma Puck”: Handheld detector with tungsten shell and tungsten collimators

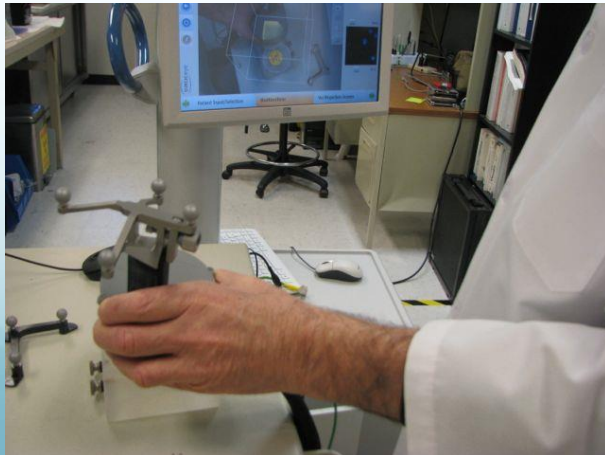




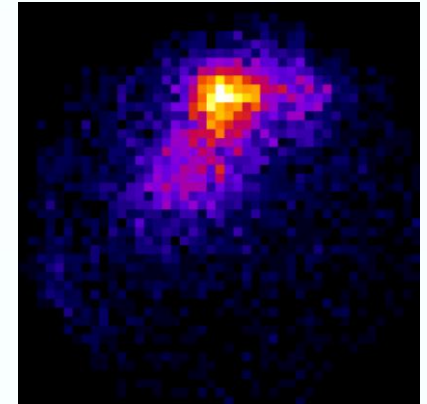
# Clinical Gamma Puck by JLab/UVA/Dilon



SiPMs mounted to PCB



Real-time tracking: Free hand SPECT



~ 3cm lymph node



Radiopharmaceutical used to identify sentinel lymph nodes with cancer involvement during breast cancer surgery

# Pre-clinical Application: Awake Small Animal Imaging for Brain Disease Research

**A novel research tool by JLab, ORNL, JHU (patents) :**

Drug addiction

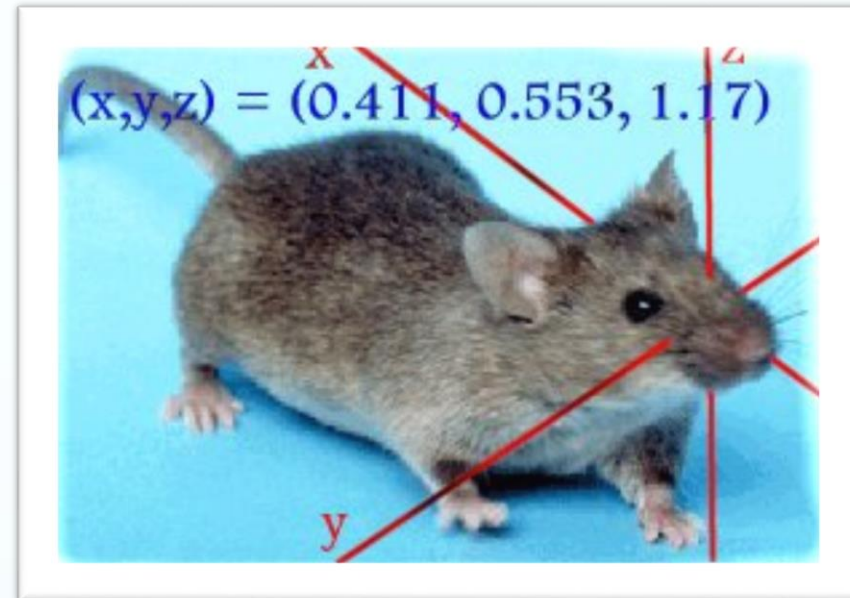
Neuro-degeneration:

*Alzheimer's Disease*

*Parkinson's Disease*

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

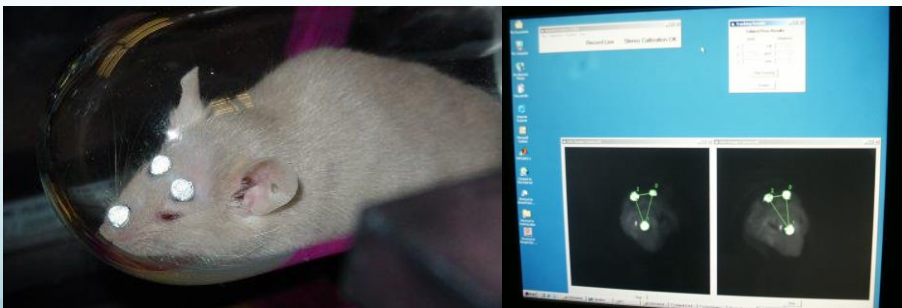
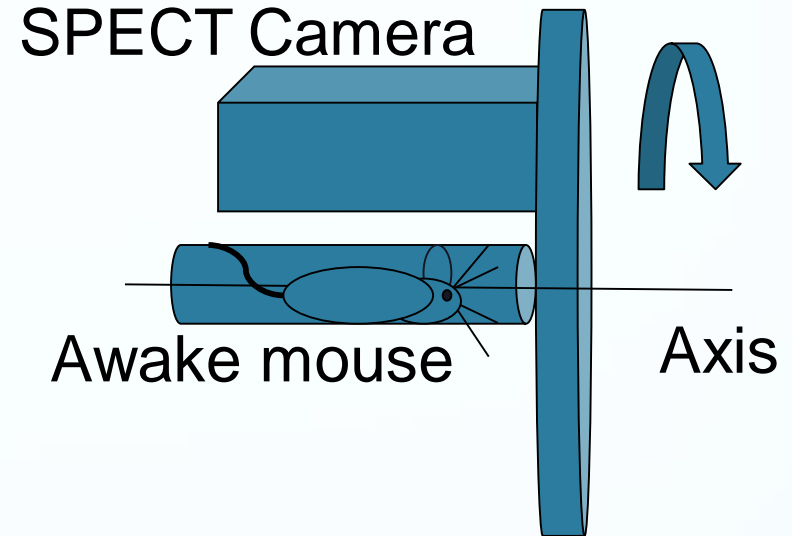
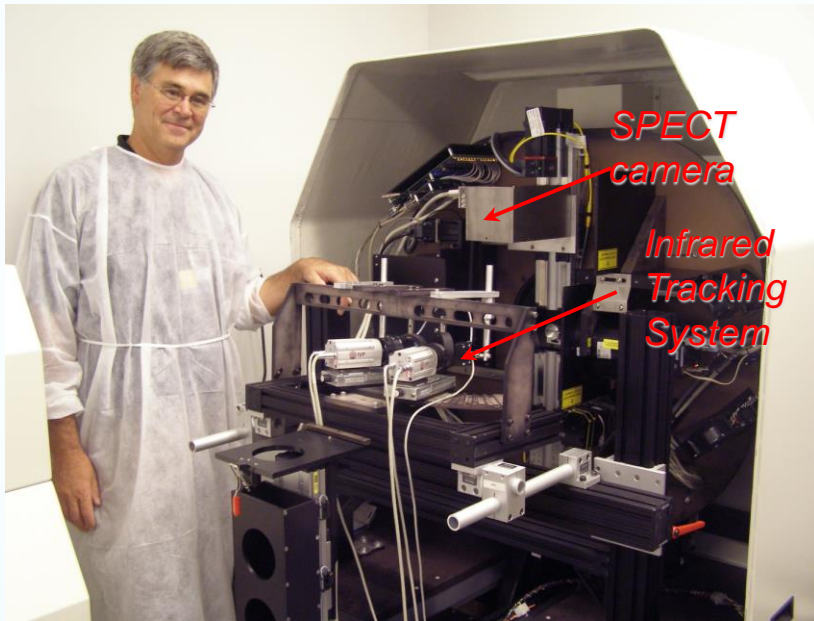
Stem cell trafficking



- 
- Avoid influence of anesthesia on: blood flow, metabolism, neural-vascular coupling
  - Elucidate disease pathophysiology
  - Radiopharmaceutical development
  - Mimic the human state

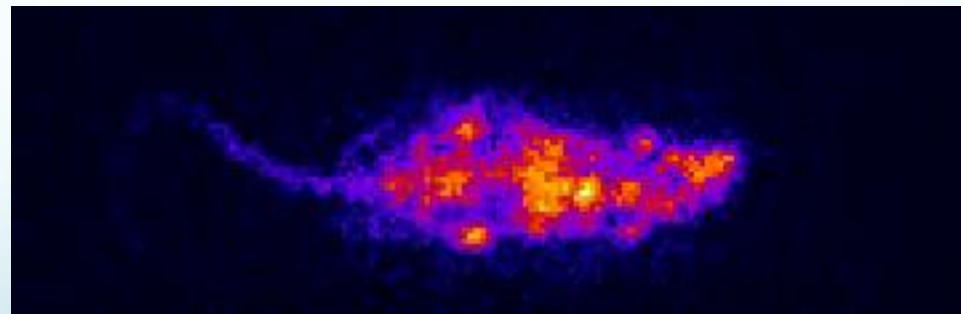


# Pre-clinical Application: Awake SPECT



Right: An awake mouse with infrared reflectors for head tracking

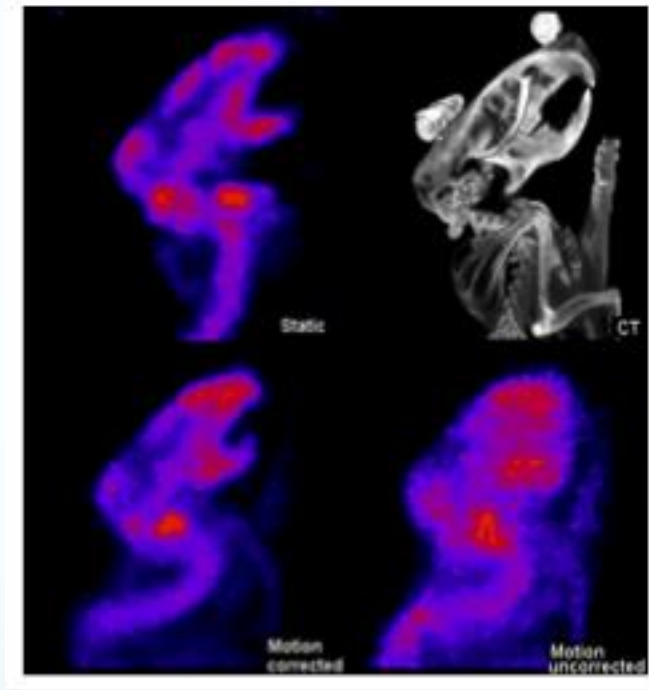
Real-time pose tracking via the stereo infrared CCD cameras.



Multiple SPECT Projections

# Motion Correction Applied to Moving Mice

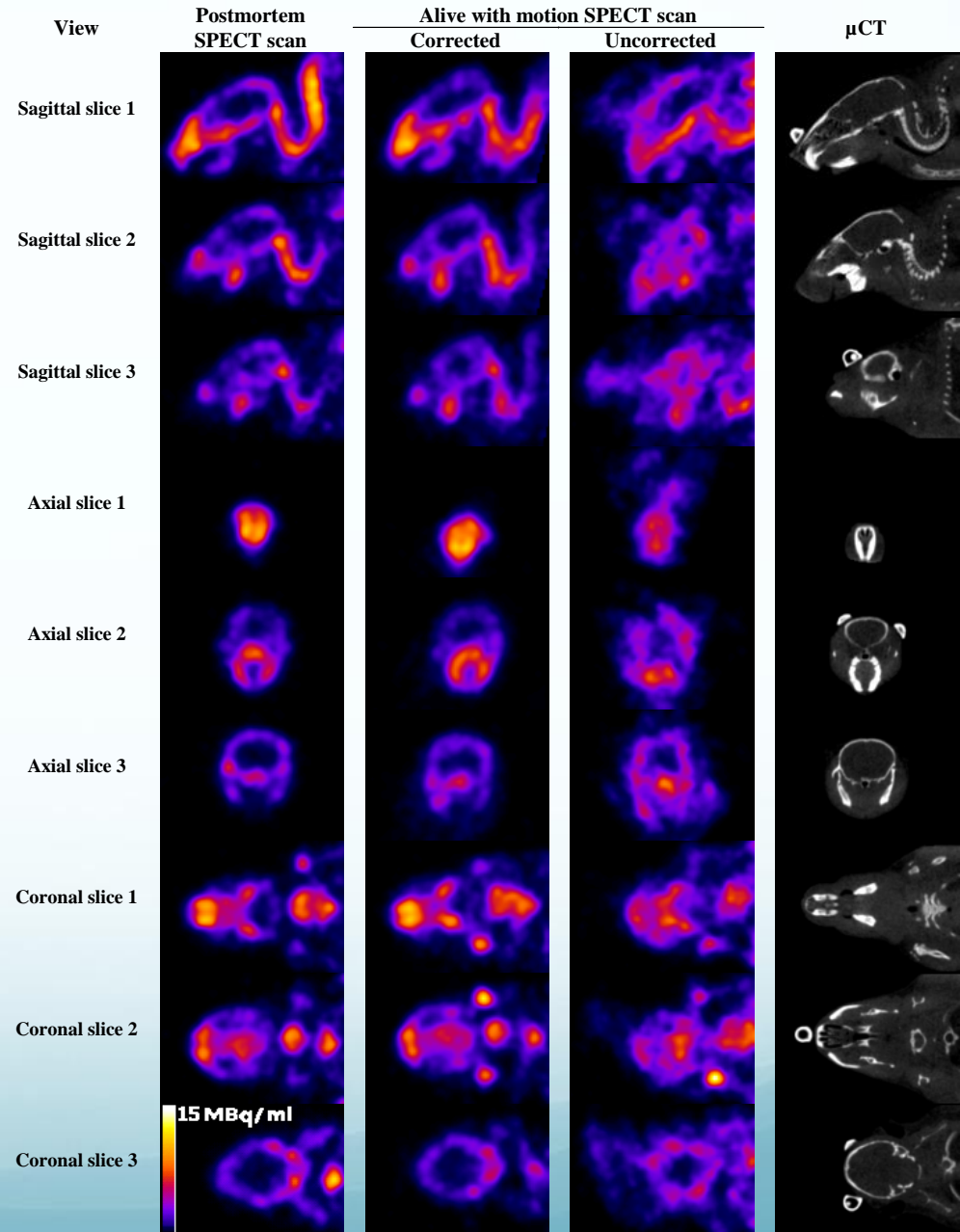
Bone Imaging:  
99mTc-methylene Diphosphonate



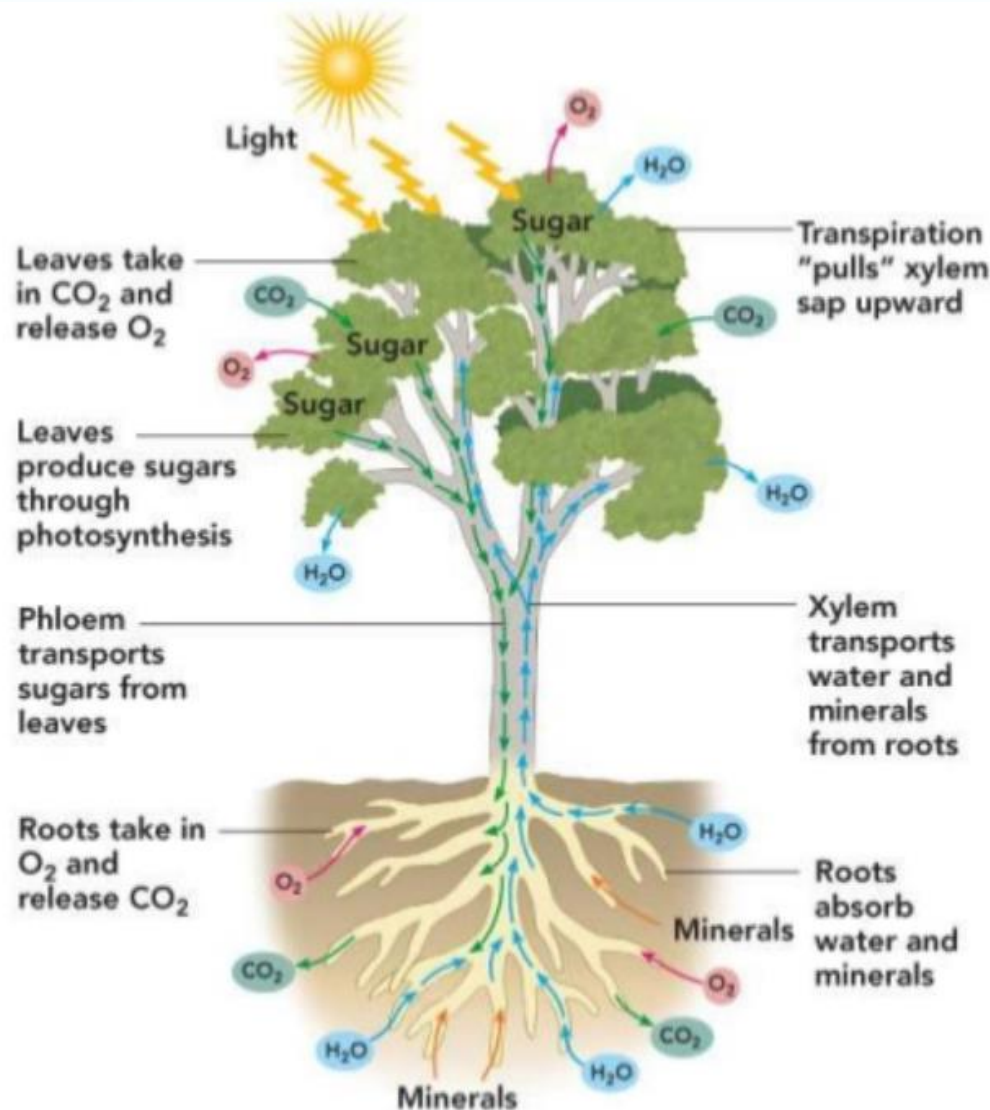
## System Parameters:

**Hardware:** Pinhole diameter: 1.5 mm  
focal length (pinhole to detector): 111.1 mm  
pinhole to AOR distance: 49.3 mm magnification:  
2.25

**Software:** MLEM recon algorithm with 40  
iterations, a 0.5 mm voxel size and post-filtering  
with a 3-D, 0.6 mm FWHM Gaussian function.



# Biological & Environmental Applications



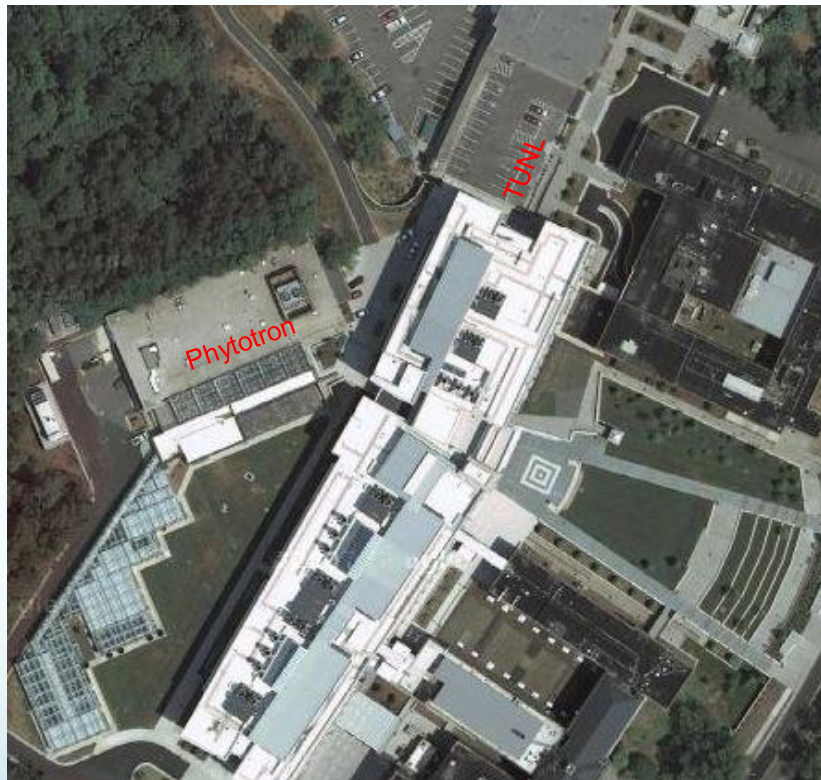
DOE basic ecological research to understand the direct impacts of enhanced atmospheric  $\text{CO}_2$

Questions to be answered:

- ◆ How can the initial enhanced plant productivity with increased  $\text{CO}_2$  be maintained?
- ◆ What is the role of enhanced plant photosynthate production to the short-term microbial activity that could stimulate nutrient turnover?
- ◆ Are there ways to stimulate plants to sequester more  $\text{CO}_2$ ?

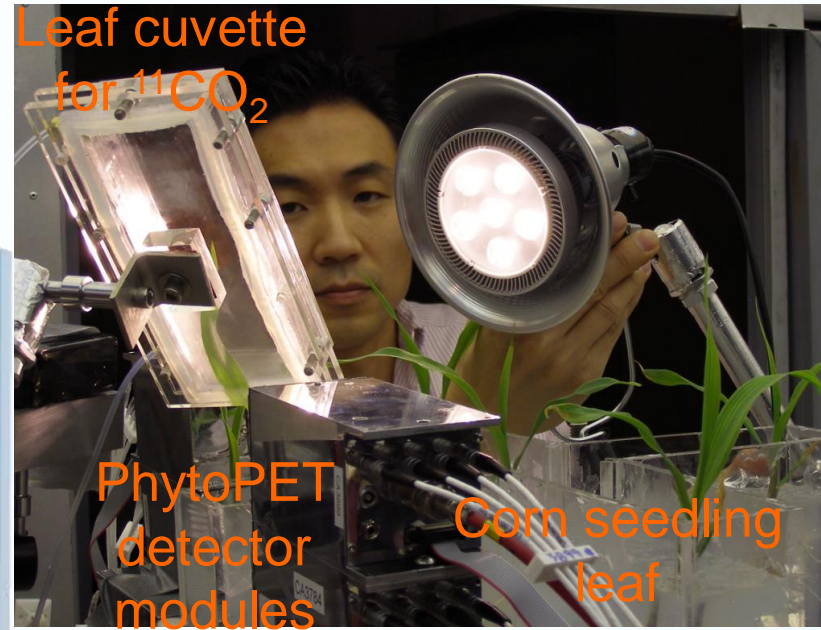
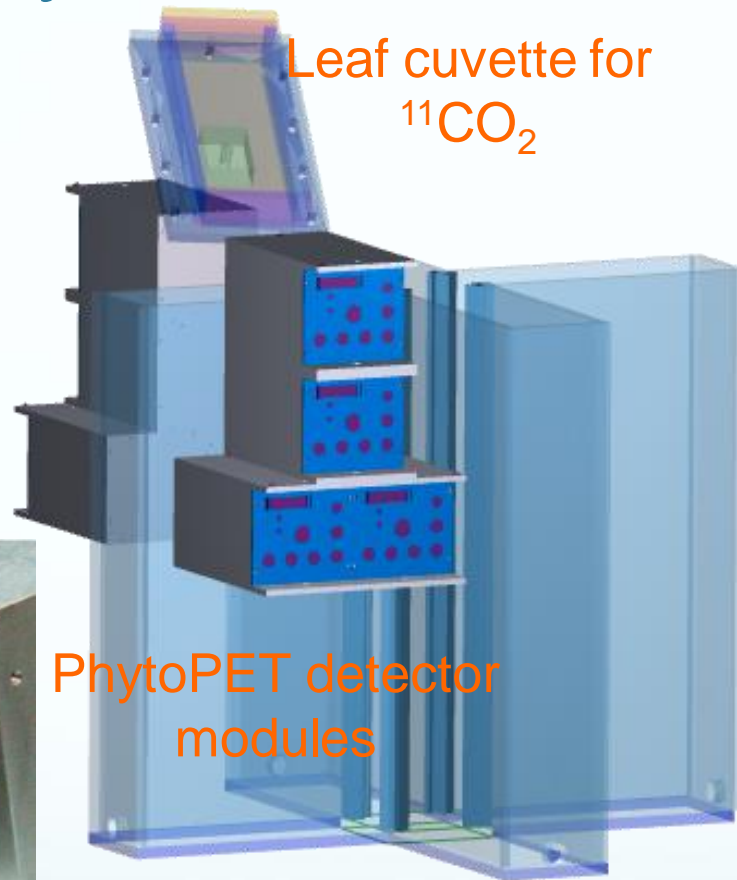


# Research Facility: The Duke University Phytotron



Tools for Environmental Research

# PhytoPET Plant Imaging System

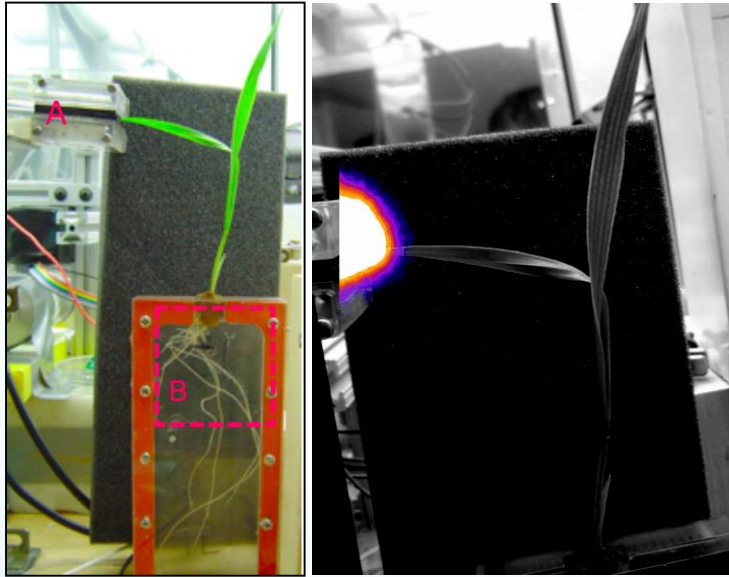


PET detector systems to image the process of carbon transport through plants during photosynthesis, using the positron emission radioisotope carbon-11 .

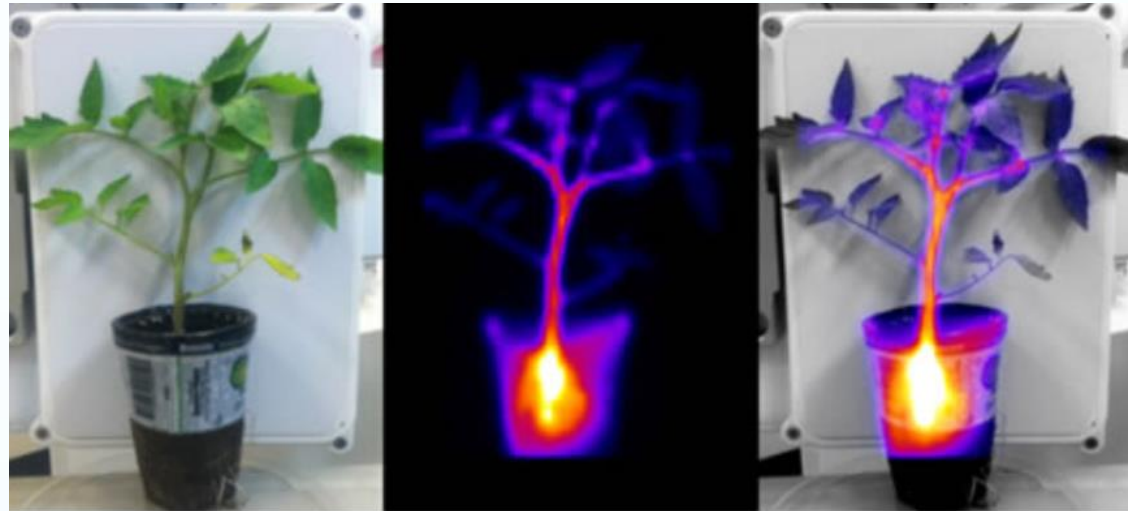




# Plant Imaging Research



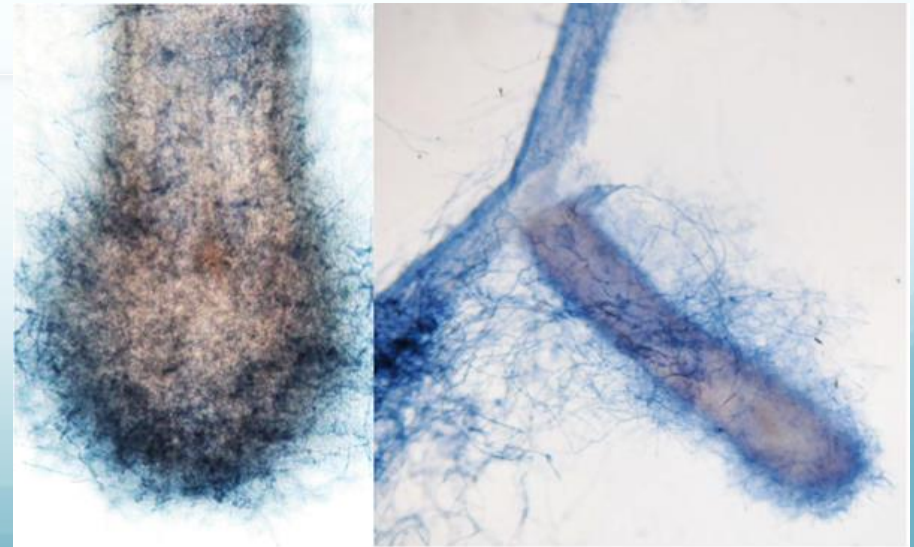
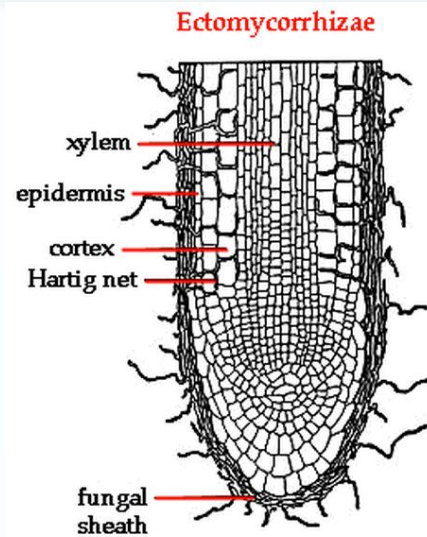
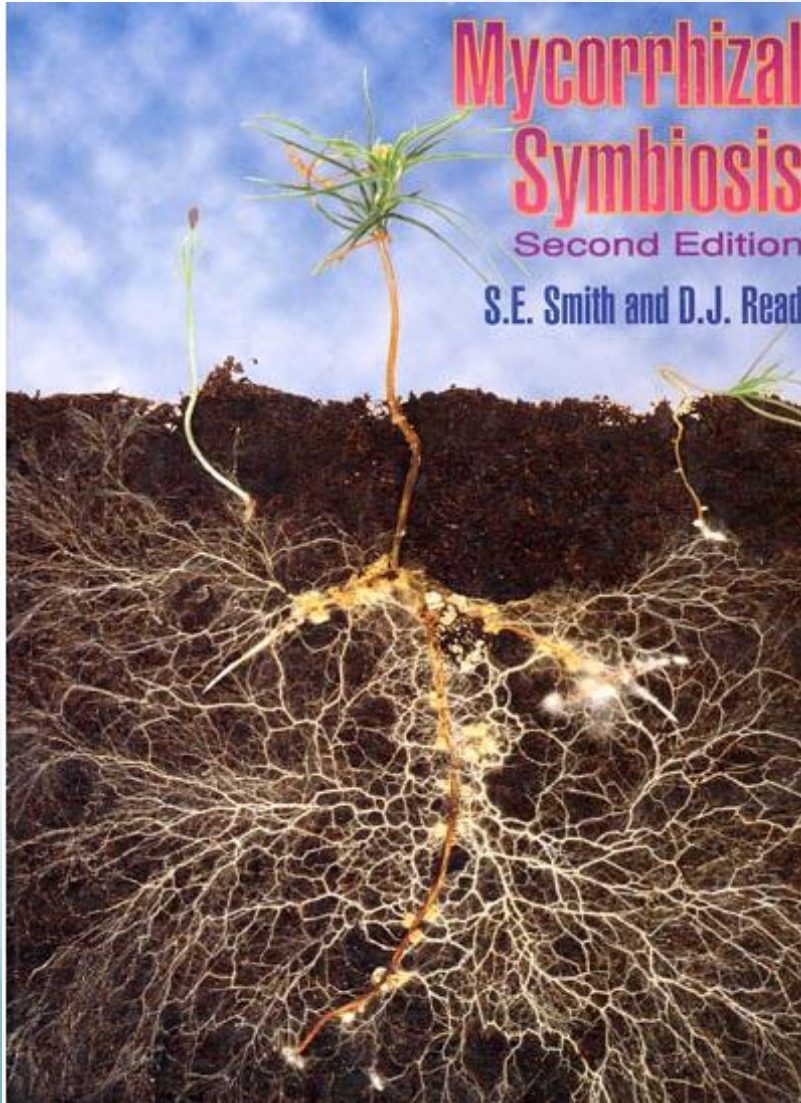
**Barley:** (A)  $^{11}\text{CO}_2$  introduce to leaf  
(B) of plant grown in hydroponic fluid



**Tomato:** Tc99m imaging of plant

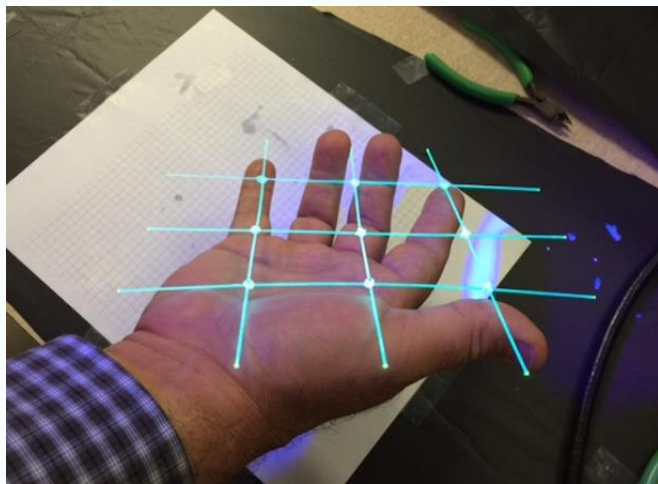
# Symbiotic root associated fungi form a physical network linking soils & plants

Relevant to carbon and nutrient cycling in terrestrial ecosystems

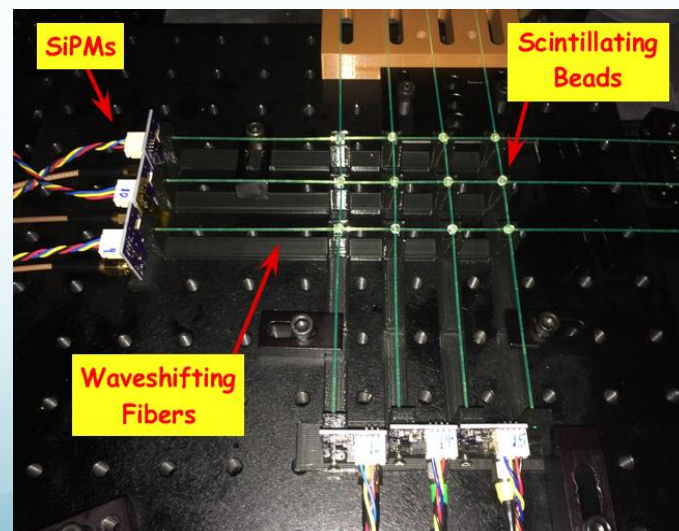
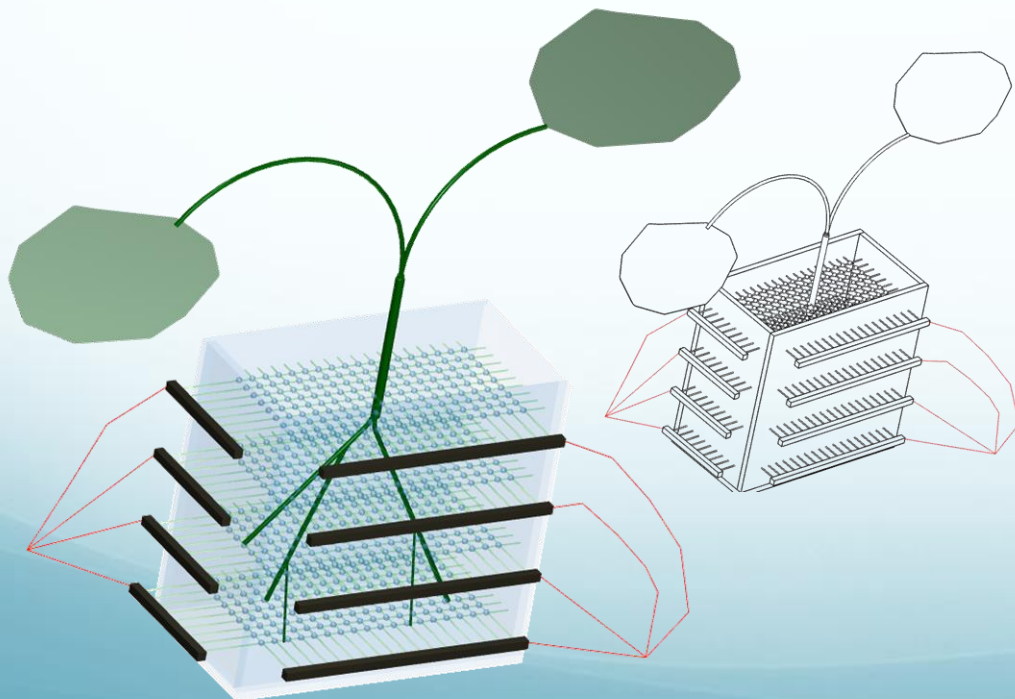
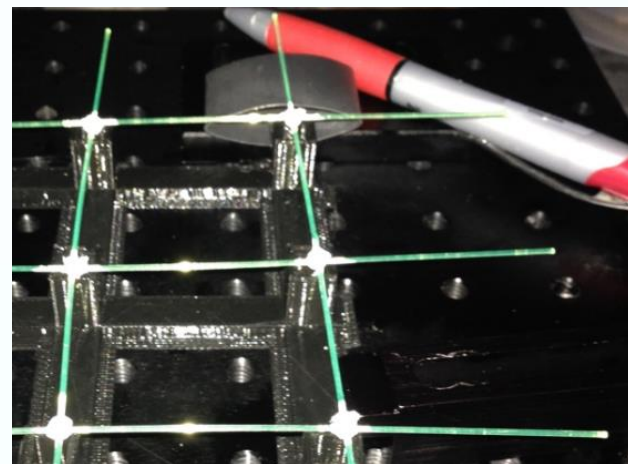




# RhizoBeta Concept for Phosphorus-32/33 Detection

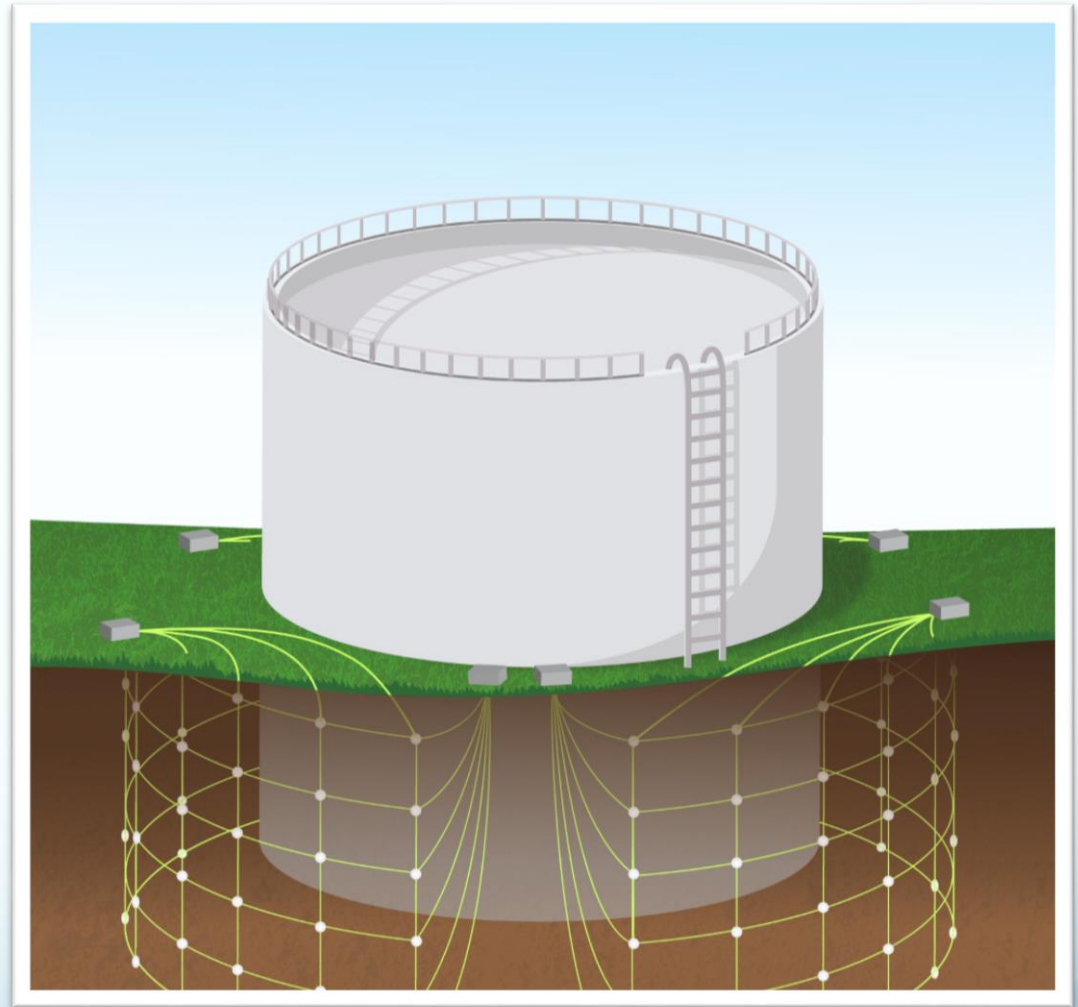


- Plastic scintillator balls
- Wavelength shifting fiber
- Silicon photomultipliers





# RhizoBeta Concept for Phosphorus-32/33 Detection



# Summary

- **Radiation Detector and Imaging Group (Detector Group) in Jefferson lab has a long history on radiation detector applications for preclinical and clinical medical imaging, and for bio-environmental research**

**Thank you!**