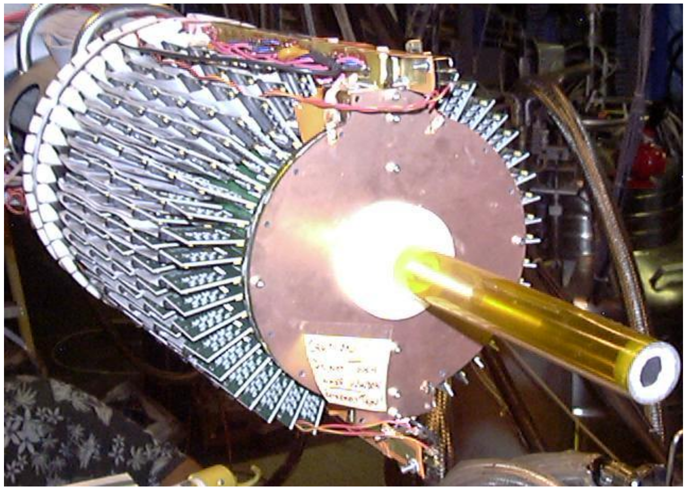
# Applications of Nuclear Physics

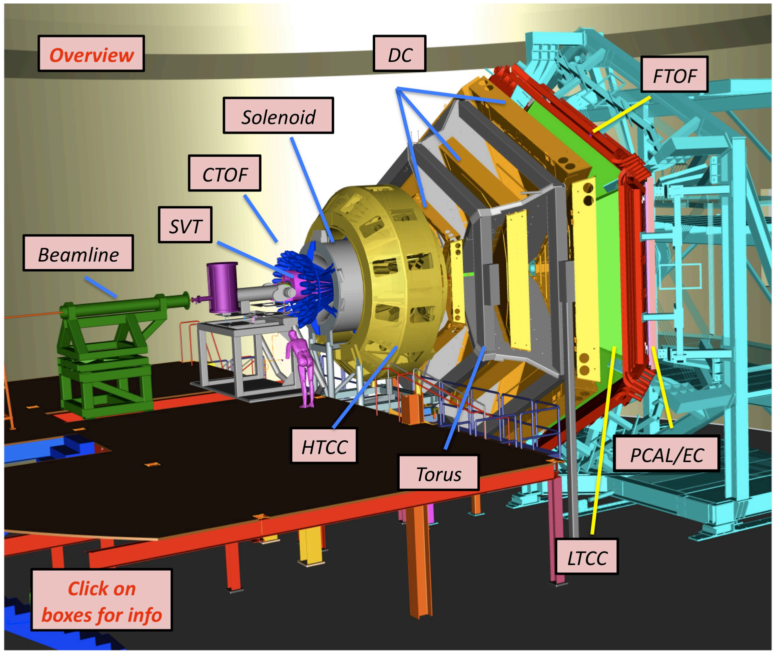

- Radiation Detectors -> Medicine, materials, climate, security
- Accelerators; gamma ray and synchrotron sources, FELS
- Radioactive elements for medicine and industry
- Nuclear Power
- Isotope dating, Forensics
- Radiation protection
- Defense

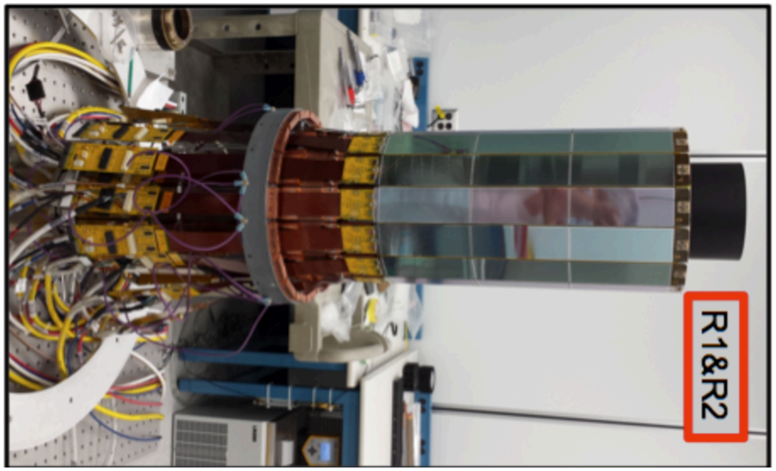
# Tools of fundamental research

We build particle detectors big…

…and small:



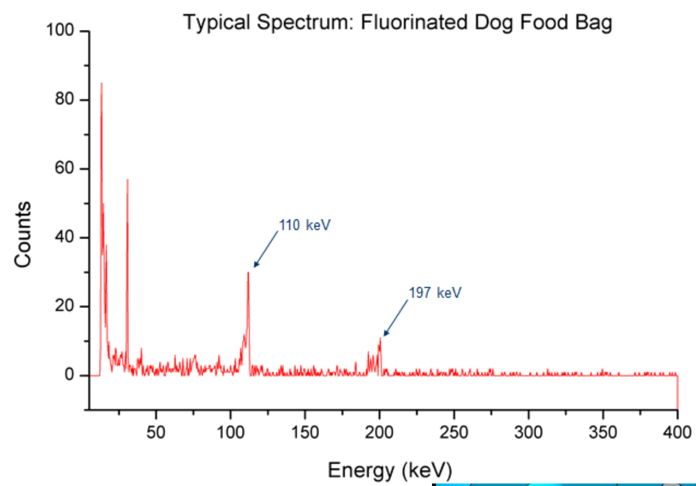


## …that can be used for a wide variety of applications:

# Ion Beam Analysis of Consumer Products

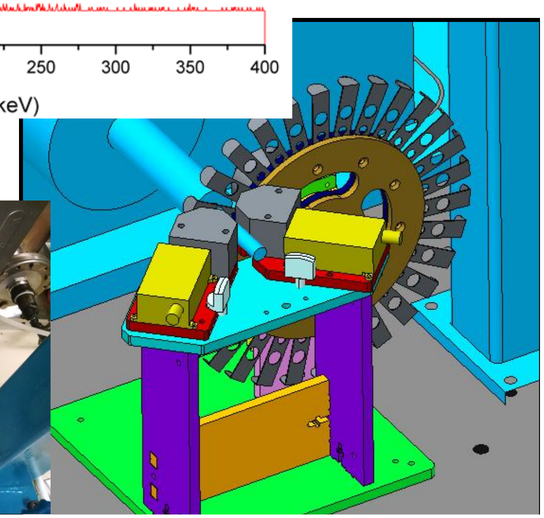
- **Perfluorinated compounds (PFCs)**: fluorine-containing chemicals with unique properties to make materials stain- and stick-resistant. Some PFCs are incredibly resistant to breakdown and are turning up in unexpected places.
- PFOA is a likely human carcinogen.











# Large Field of View Positron Emission Mammography Imaging Devices

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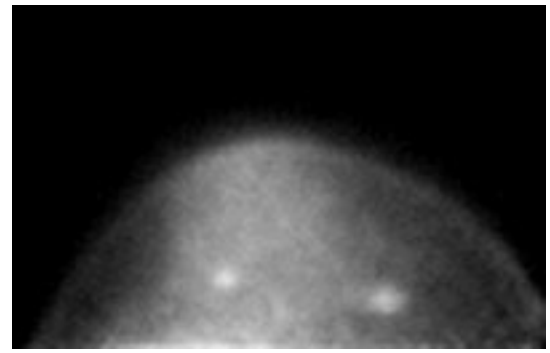
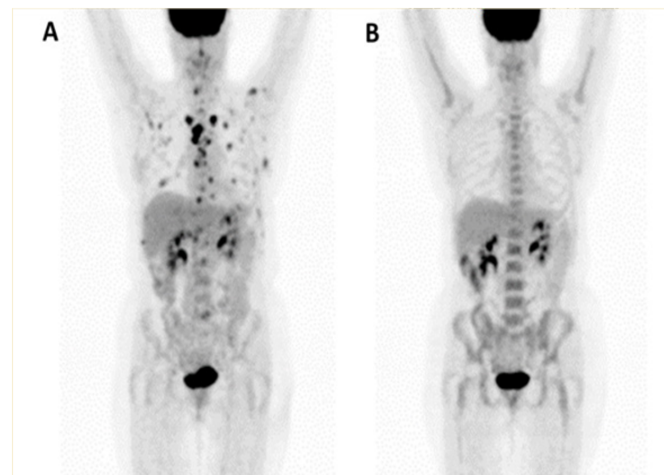


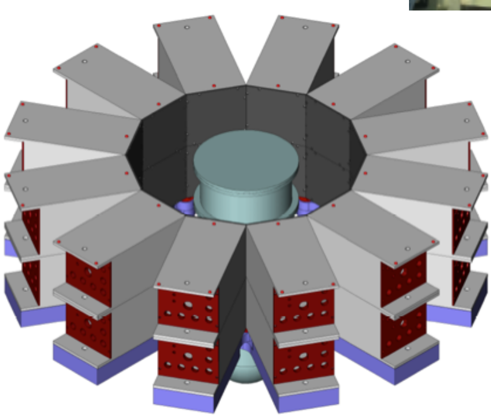


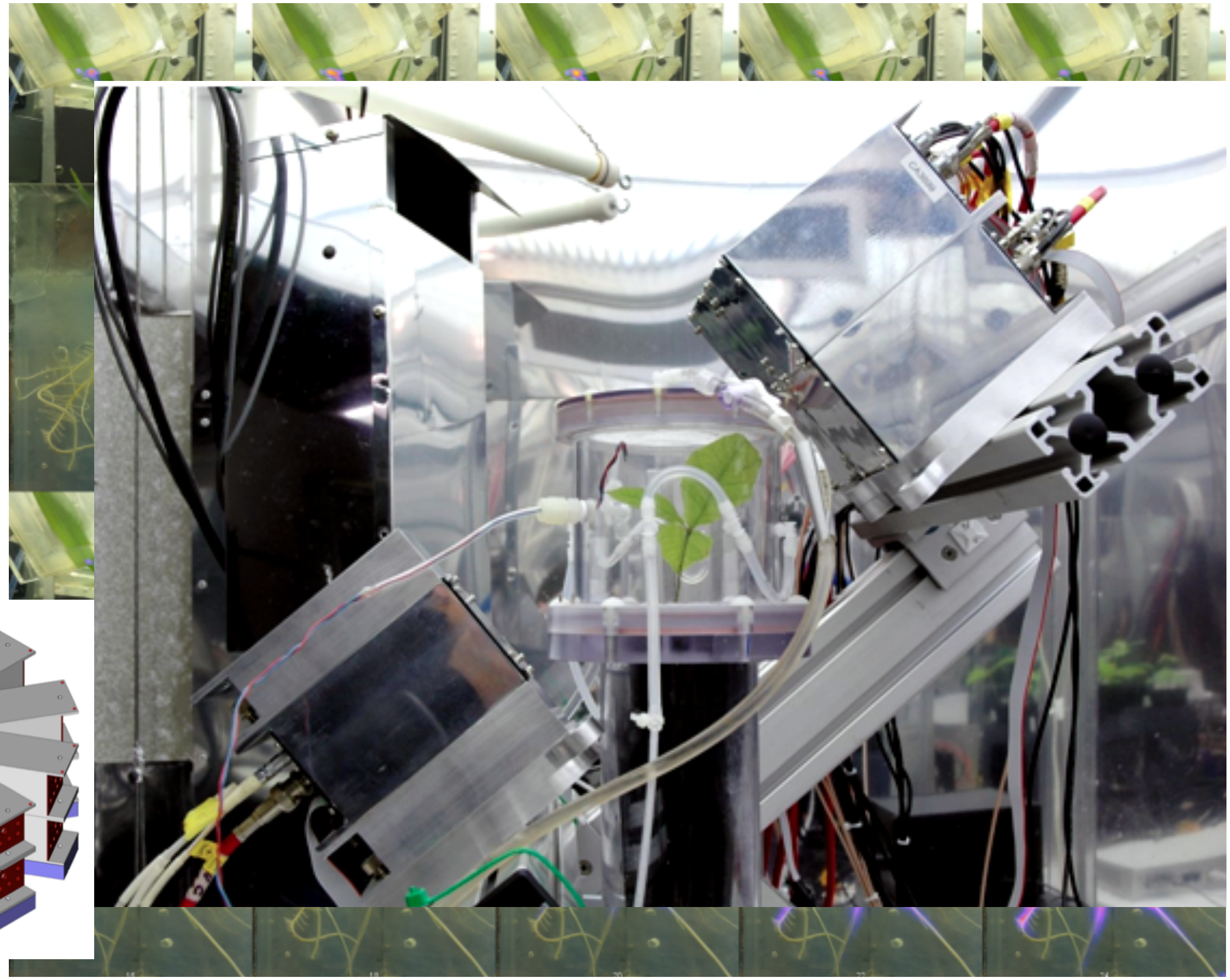

*[$^{18}$F] fluorodeoxyglucose scan of a woman diagnosed with T cell lymphoma. (A) At diagnosis, which shows uptake in extensive disease sites along with normal signal in the brain and bladder. (B) Following four months of chemotherapy, which shows the dramatic decrease in signal in the cancer sites, indicating that this patient is responding well to therapy. Image credit: J. McConathy.*

# Plant Biology Imaging

$^{11}CO_2$ (half life = 20 min.)

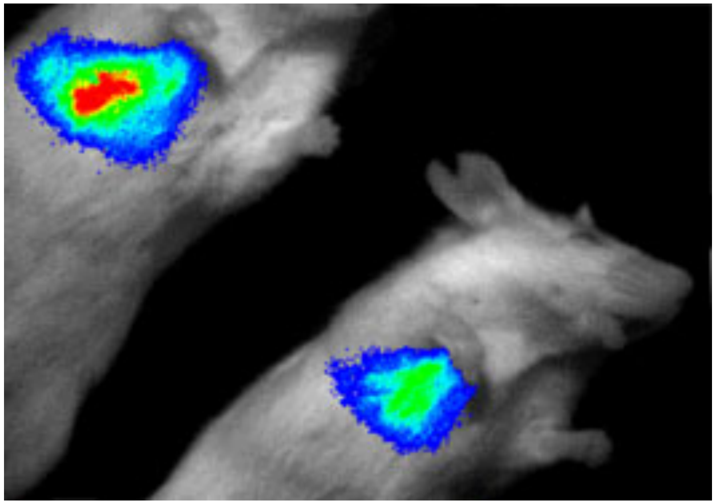
Translocation of sugars in corn – indicator of environmental conditions





# Awake Animal SPECT Project

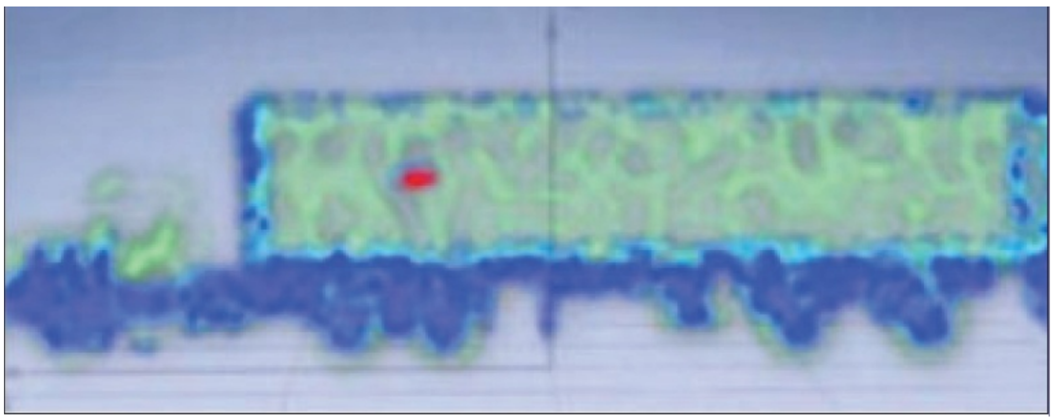
The Jefferson Lab Detector and Imaging Group in collaboration with Oak Ridge National Laboratory (Dr. Justin Baba), Johns Hopkins University (Dr. Martin Pomper) and the University of Sydney (Dr. Steve Meikle) is developing an imaging methodology that utilizes SPECT and X-ray CT for small animal research. The primary challenging task of this project is to develop a SPECT imaging system to allow molecular imaging of unrestrained and un-anesthetized mice. Present methods of performing SPECT imaging with mice require the animals to be anesthetized or physically restrained during image acquisition. Both methods of restraint have the potential to interfere with the physiological and neurological processes being investigated. In the initial focus of the project, tracking of the orientation and location of the mouse's head during SPECT imaging is accomplished through a pair of CMOS optical cameras that image IR retro-reflectors attached to the mouse's head. The gamma-ray projection data is reconstructed into a fixed small animal reference frame based on the time-varying animal orientation data. The goal is to develop instrumentation to acquire high-resolution volumetric SPECT images of the head region of an unrestrained, un-anesthetized mouse and to register these image volumes with microCT data sets of the same mouse acquired before or after the SPECT scan. The animal will be anesthetized during the microCT scan. Jefferson Lab is coordinating the entire effort and is developing high spatial resolution gamma cameras 10 cm x 20 cm in size for the SPECT system. The system is installed in the animal research facility at Johns Hopkins University where it is being tested with awake mice.

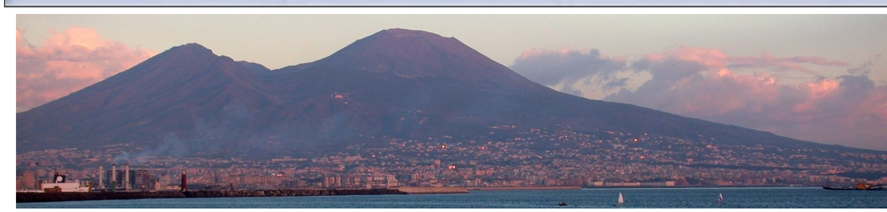


…and oil exploration, fluid dynamics, material imaging, climate model testing, nuclear reactor monitoring, radioactive element detection, space radiation mapping, CT, PET, …

…and even **NMRI**!

Looking for dangerous cargo…





…or monitoring a dangerous volcano (Vesuvius)…

# Scanning with muons

**Using cosmic muons to search for cavities in the Pyramid of the Sun, Teotihuacan: preliminary results.**

S. Aguilar[1], R. Alfaro[1], E. Belmont[1], V. Grabski[1], T. Ibarra[1], V. Lemus[1], L. Manzanilla[2], A. Martínez-Dávalos[1], M. Moreno[1], R. Núñez[1], A. Sandoval[1] , and A. Menchaca-Rocha[1].
[1]Instituto de Física, Universidad Nacional Autónoma de México, México
[2]Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México, México

Over the last two years the Pyramid of the Sun, at Teotihuacan, Mexico, has been searched for possible hidden chambers by means of muon attenuation measurements inside the monument's volume. The experimental method is based on the use of a muon tracker [1] placed in a chamber at the end of a tunnel, which runs below the base, and ends close to the symmetry axis of the pyramid. The accumulated experimental data, when compared to physics simulations using GEANT4 [2], already show identifiable known features of the external shape of the pyramid. Experimental results of the relative density distribution inside the pyramid are presented and compared to the aforementioned Monte Carlo simulations.

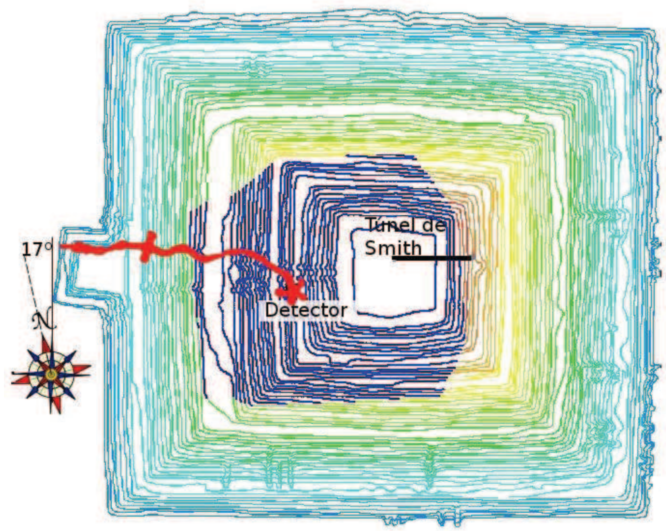



Fig 1. External shape of the Pyramid of the Sun. Outlined in dark blue is the projected detector field of view. The prehispanic tunnel location is shown in red.

…or finding hidden chambers in pyramids!

# Nuclear Science in Art and Archaeology

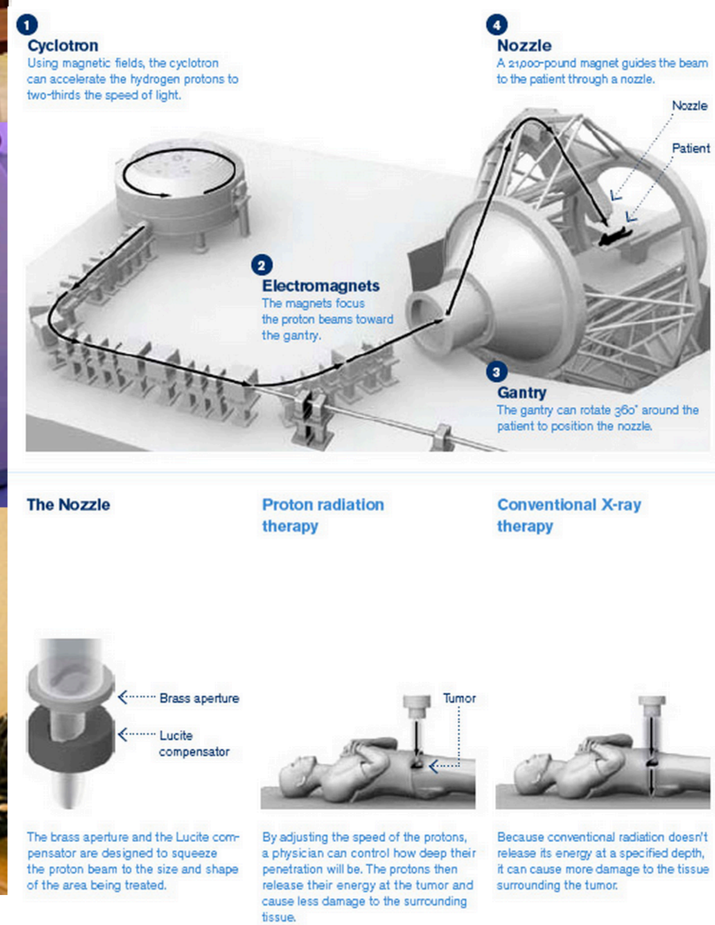
luminescence dating, and methods of archeometry.

***Figure 1:*** *A University of Missouri researcher characterizing an ancient Roman artifact (photo credit Nic Brenner, University of Missouri).*

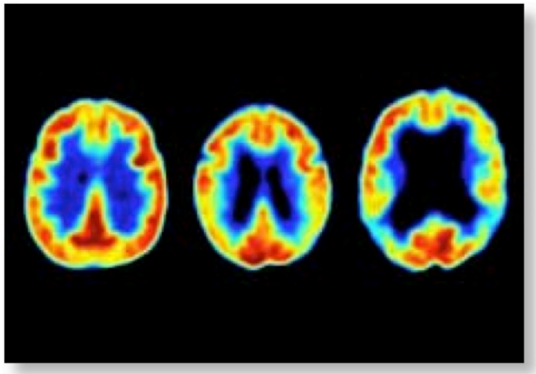
***Figure 2:*** *Figurine found in Mesoamerican burial grounds and currently housed at the University of Notre Dame's Snite Museum of Art. The figurine is mounted on the proton-induced X-ray emission (PIXE) beam line at Notre Dame's 11-MV electrostatic accelerator to obtain quantitative details of the pigment composition; in particular, PIXE reveals the iron and manganese content of the paint.*

# Accelerators in Industry and Medicine

Hampton University
Proton Therapy Institute



# …even more examples

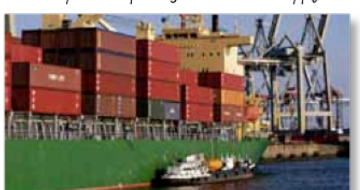


PET scans reveal reduced brain activity in people with Alzheimer's disease (right) and cognitive impairment (center).

Advances in accelerator physics have led to more effective cancer-killing beams.

The Cassini spacecraft gets power from plutonium, a nuclear isotope.

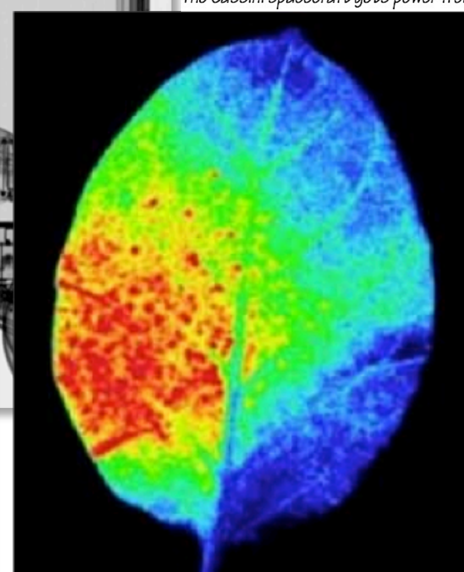
Techniques developed by nuclear physicists eliminate potential pathogens in our food supply.



Developing innovative detectors is crucial to identifying hazardous materials in shipping containers.

Nuclear ph

Next-generation nuclear reactors will operate with increased safety and flexibility.



PET scans reveal how plants respond to rising $CO_2$

Archaeologists used accelerator-based studies to more accurately date 12,000-year-old cave paintings.