

Nuclear Security and Nonproliferation Research in the Applied Nuclear Science Group at the University of Michigan

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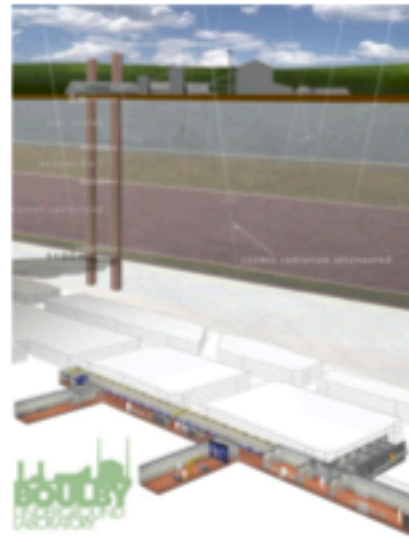
Introduction and Motivation

Advance the technical means for proliferation detection via antineutrino, active interrogation, and optical techniques.

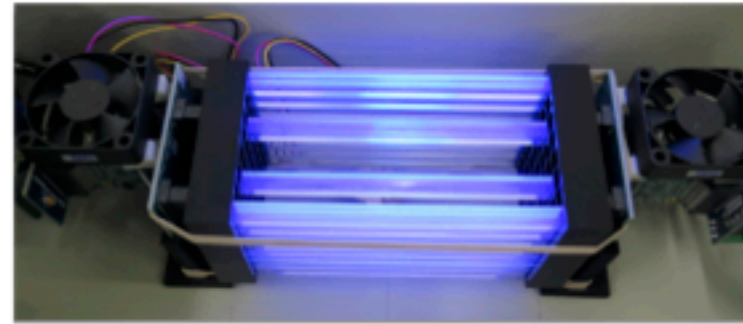
REMOTE DETECTION

PRECISION CHARACTERIZATION

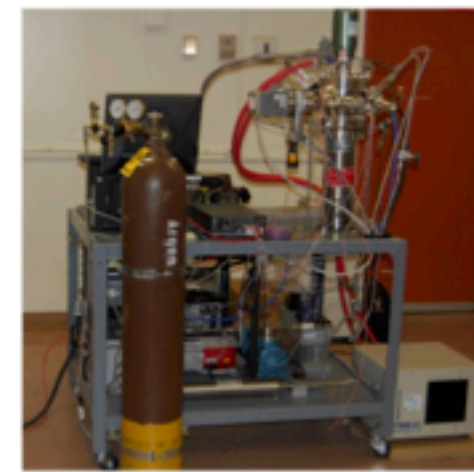
IONIZING RADIATION



Large water-based detectors



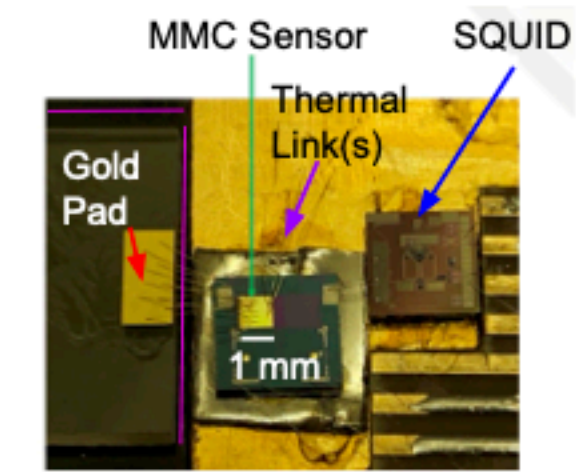
Segmented detectors



CEvNS



Active interrogation

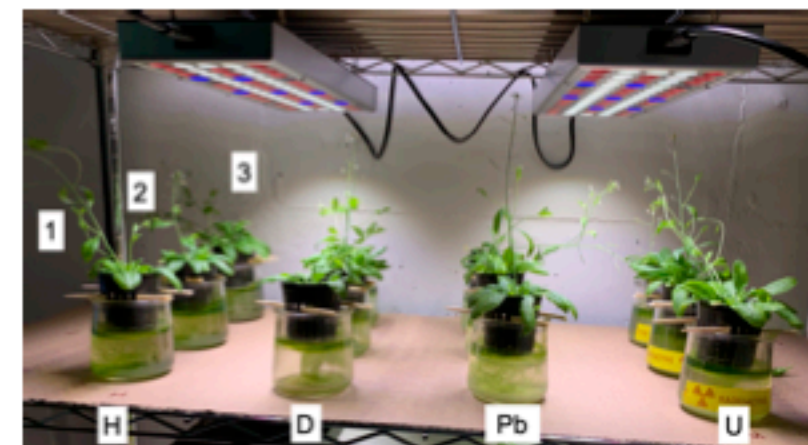


Magnetic microcalorimeters

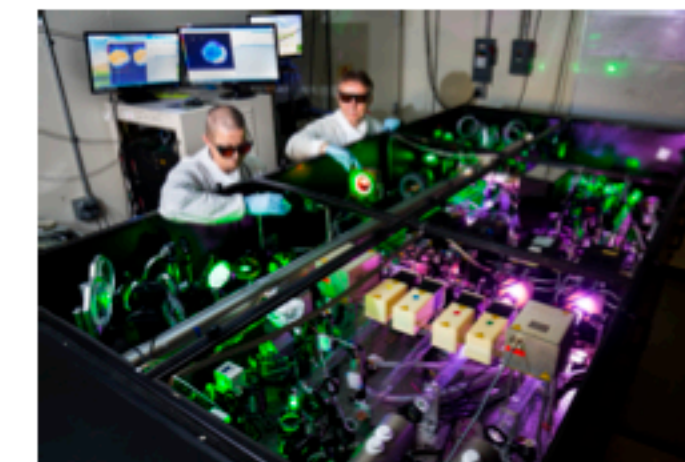
OPTICAL RADIATION



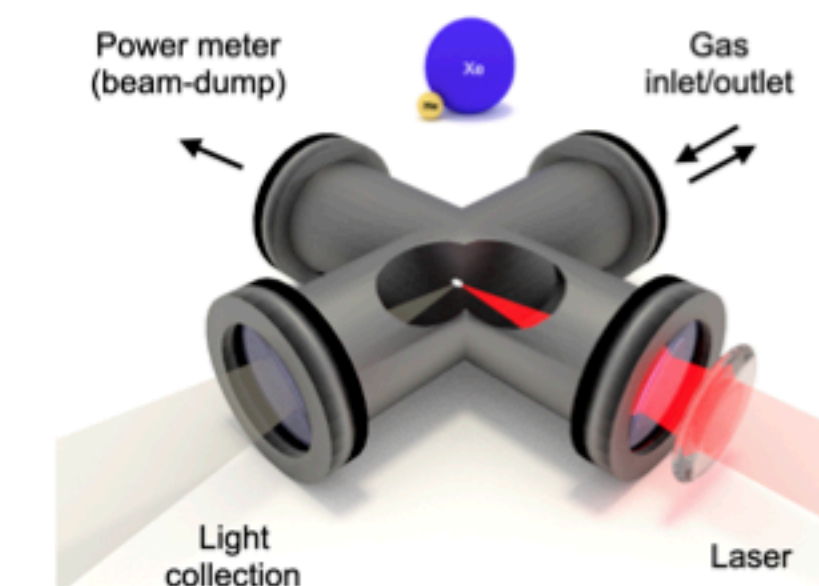
Standoff detection of U



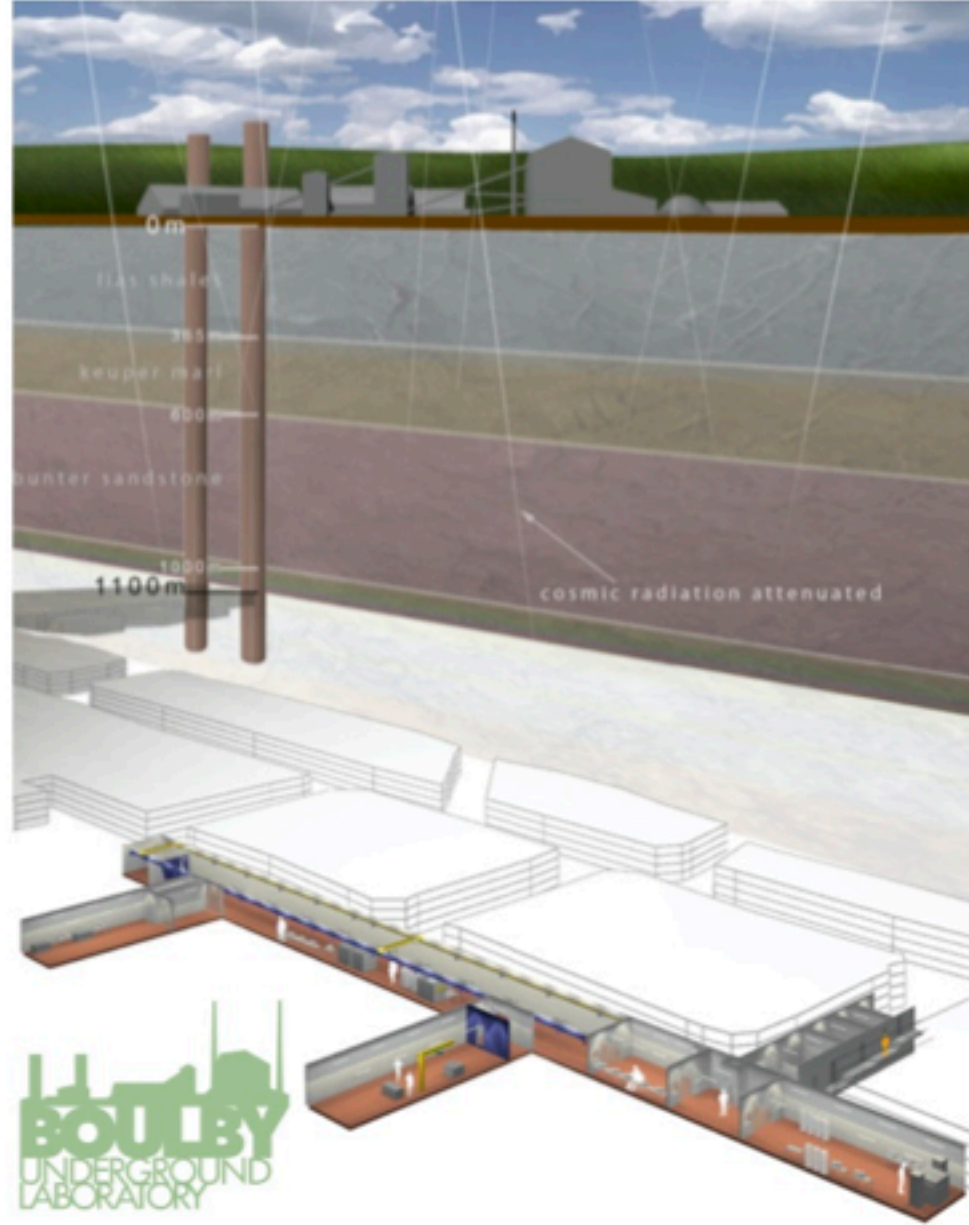
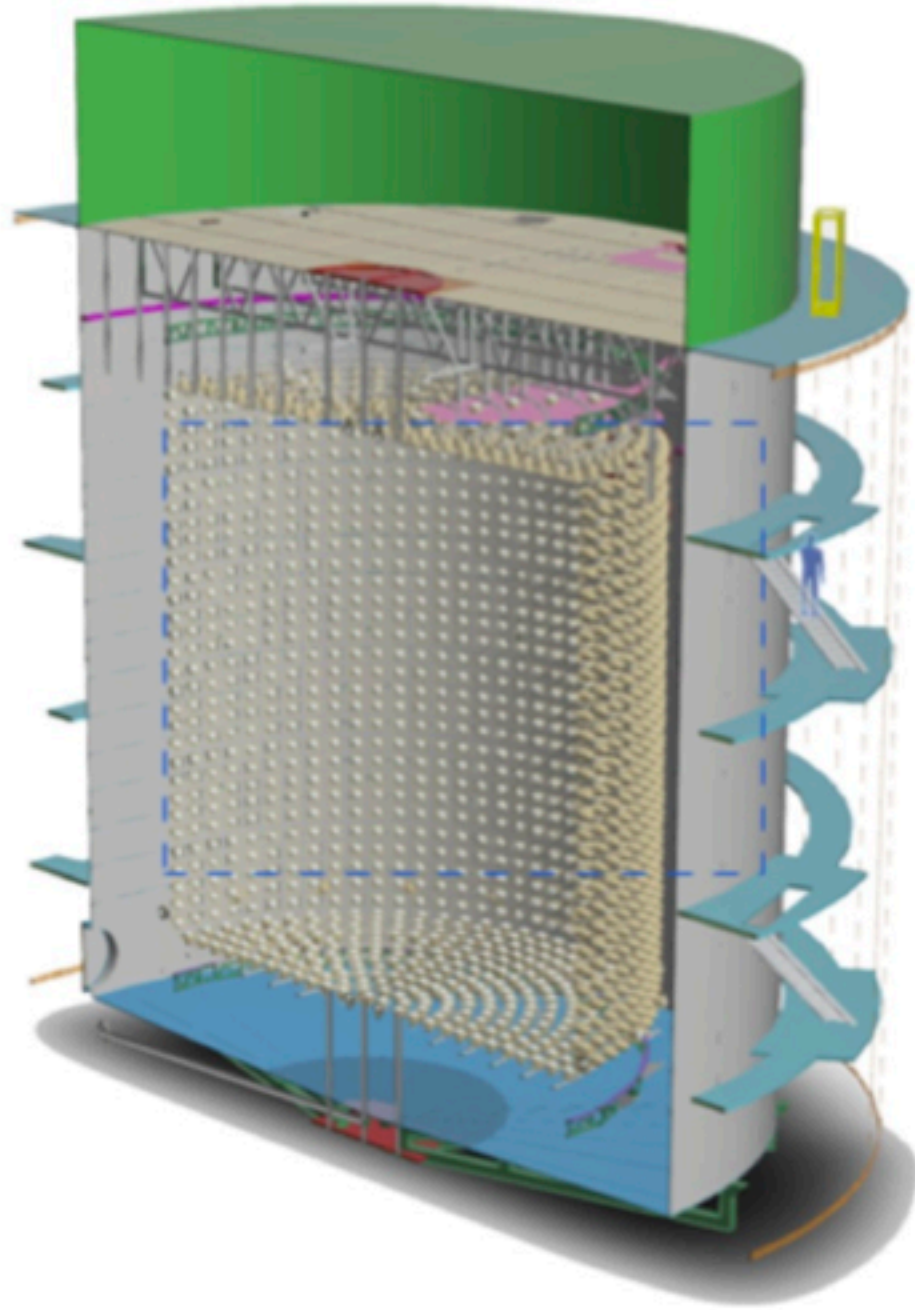
Biota



Nuclear photonics Optical instrumentation for advanced reactors



Large Water-based Antineutrino Detectors

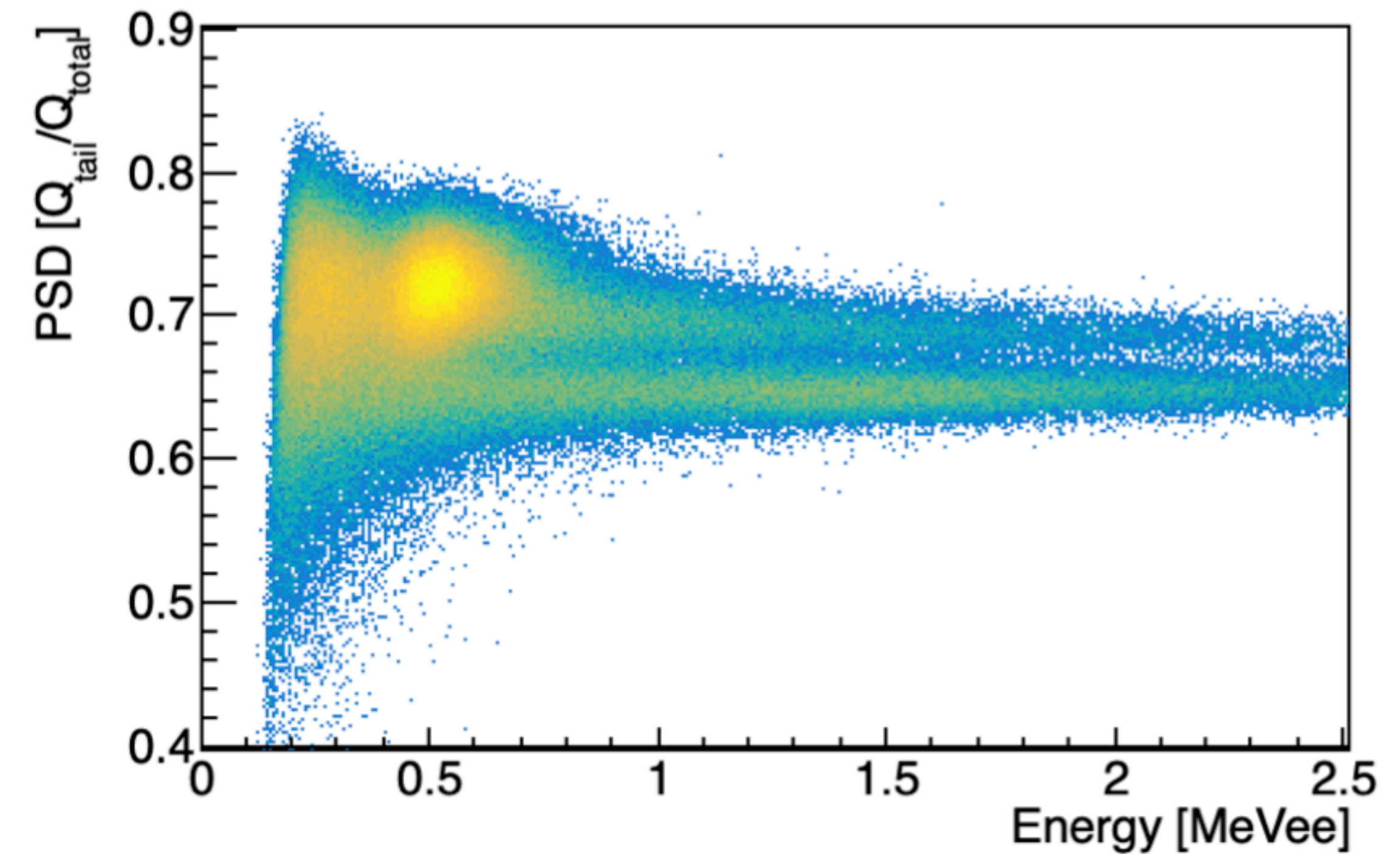
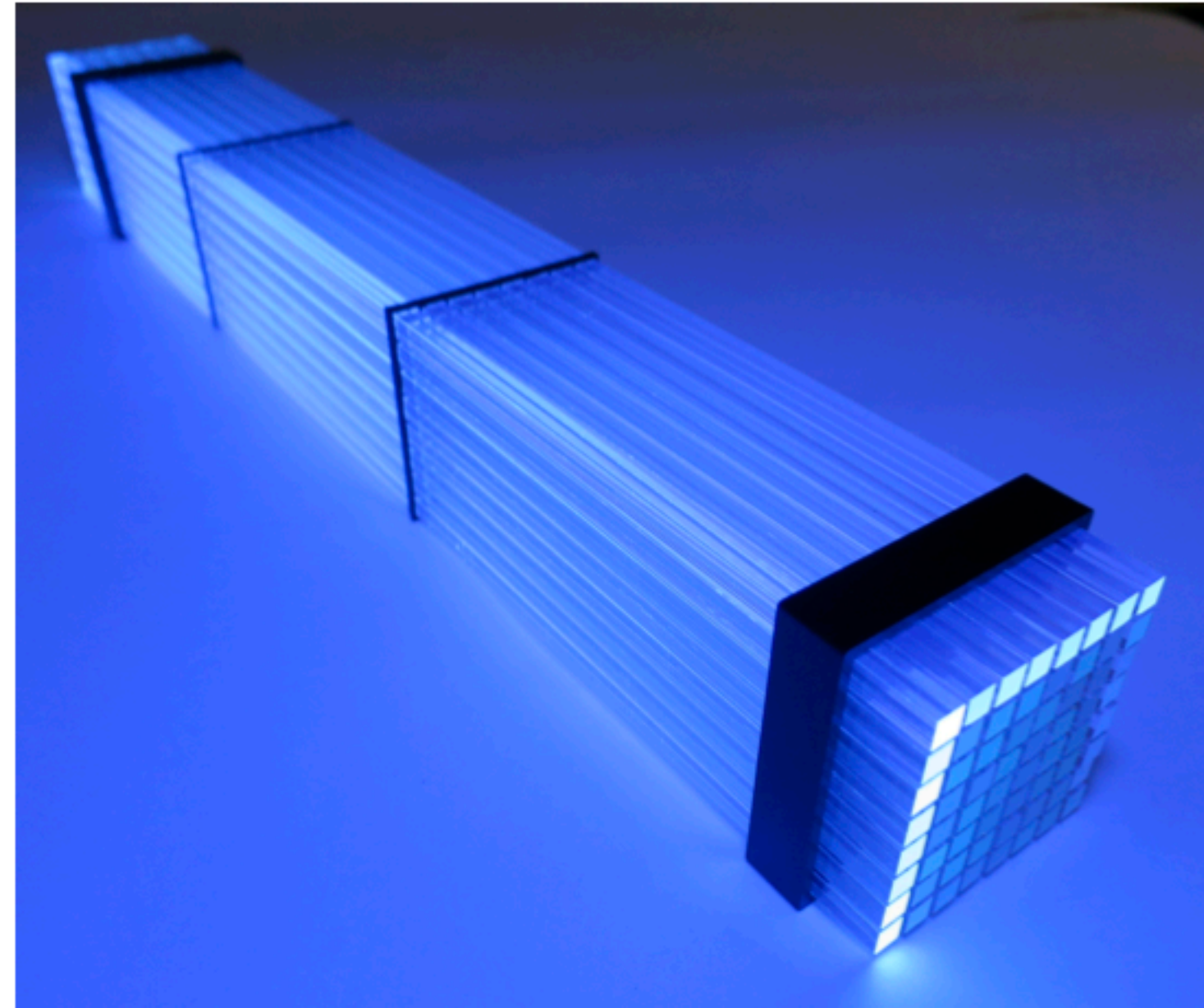
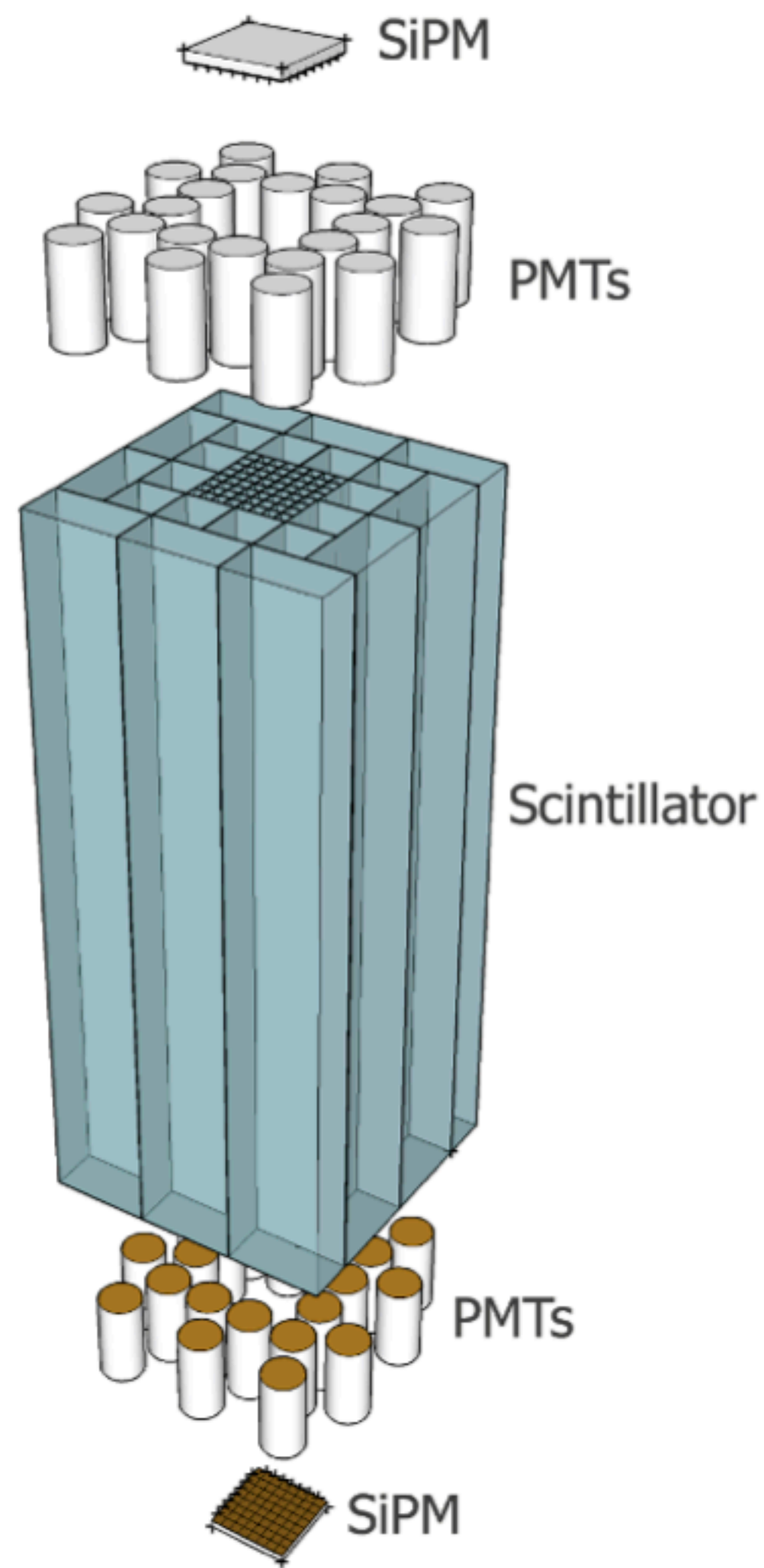


A complementary near-field detection program at Hartlepool?



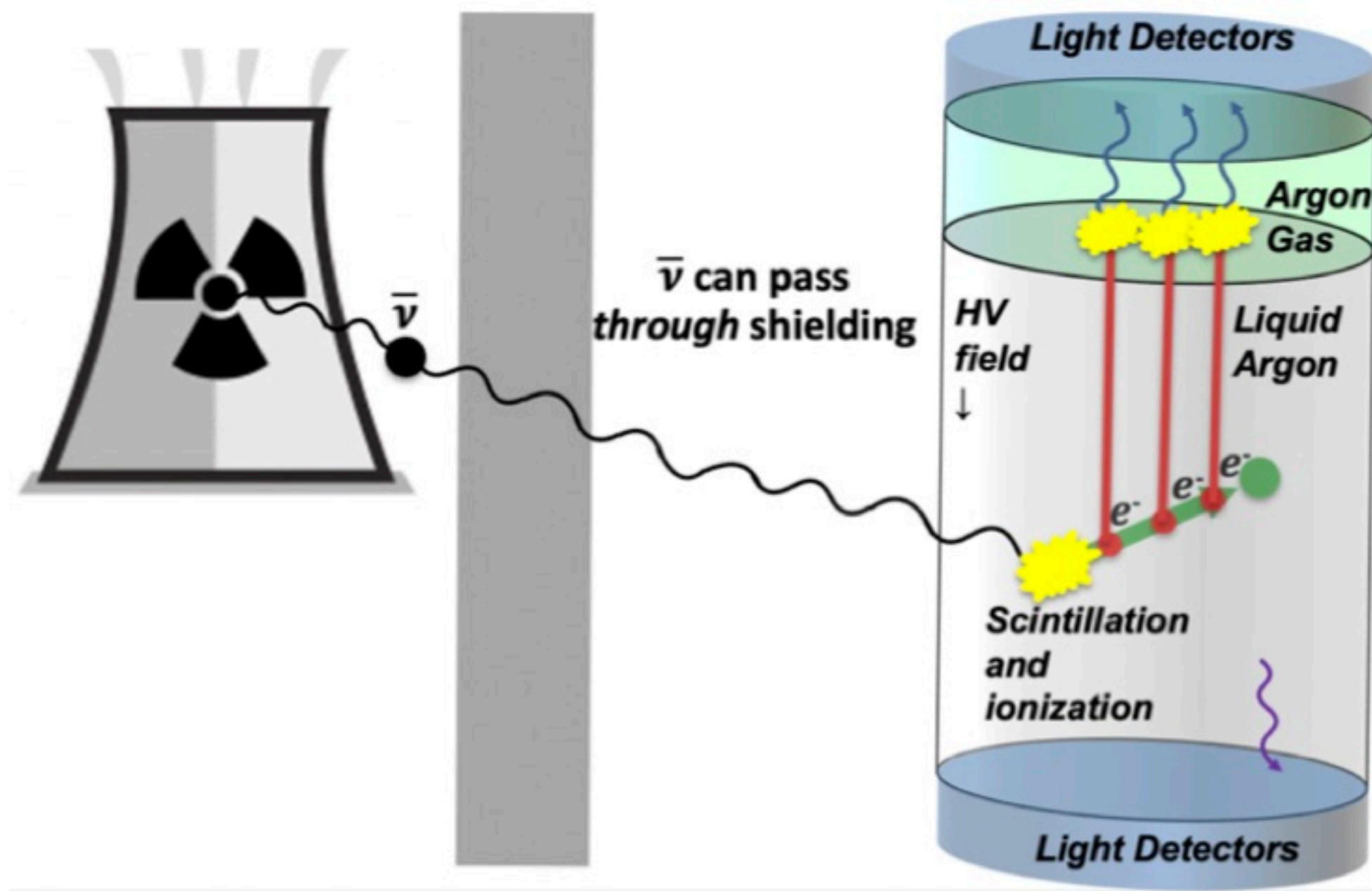
- Advanced Instrumentation Testbed: a joint US-UK initiative
- Members of the WATCHMAN scientific collaboration; currently engaged in Calibrations and Simulations working groups
- Vibrant collaboration with UK colleagues with anticipated extended research visits

Segmented Scintillation Detectors



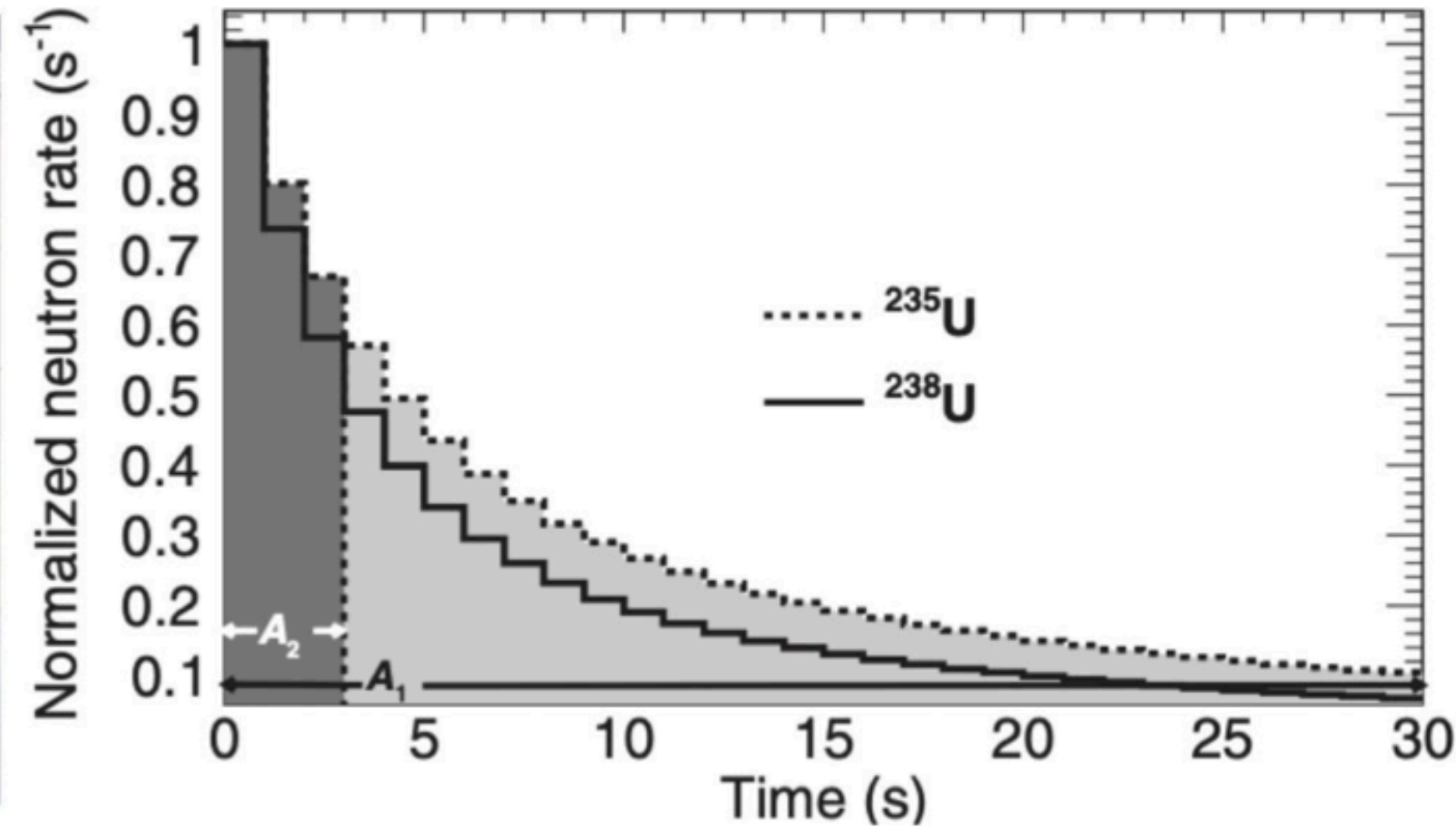
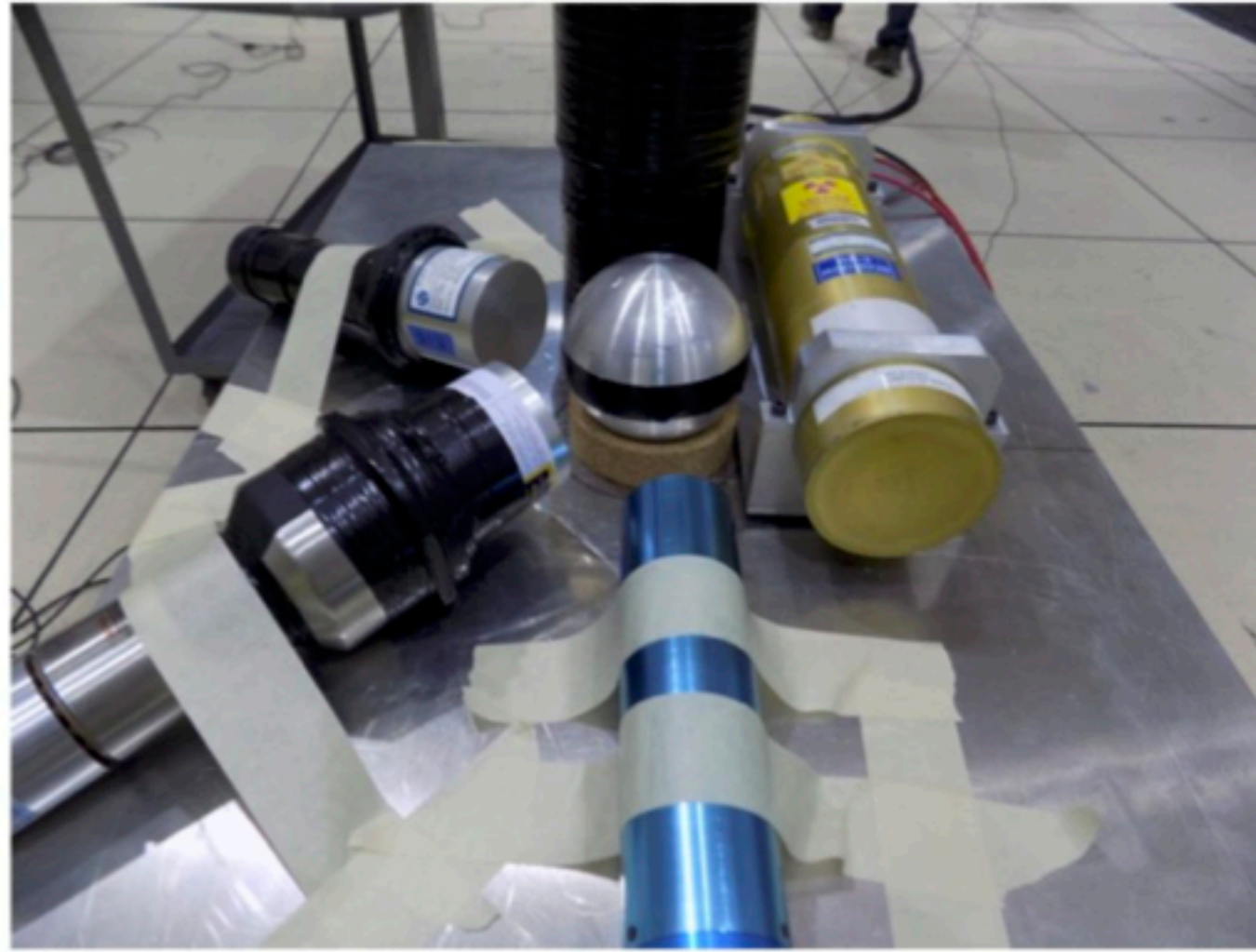
- PSD plastic with ^6Li doping
- Fine position reconstruction for antineutrino detection and predicted limited antineutrino directionality
- Large channel count DAQ development and assessment
- Platform suitable for neutron scatter camera development

Coherent Neutrino-Nucleus Scattering

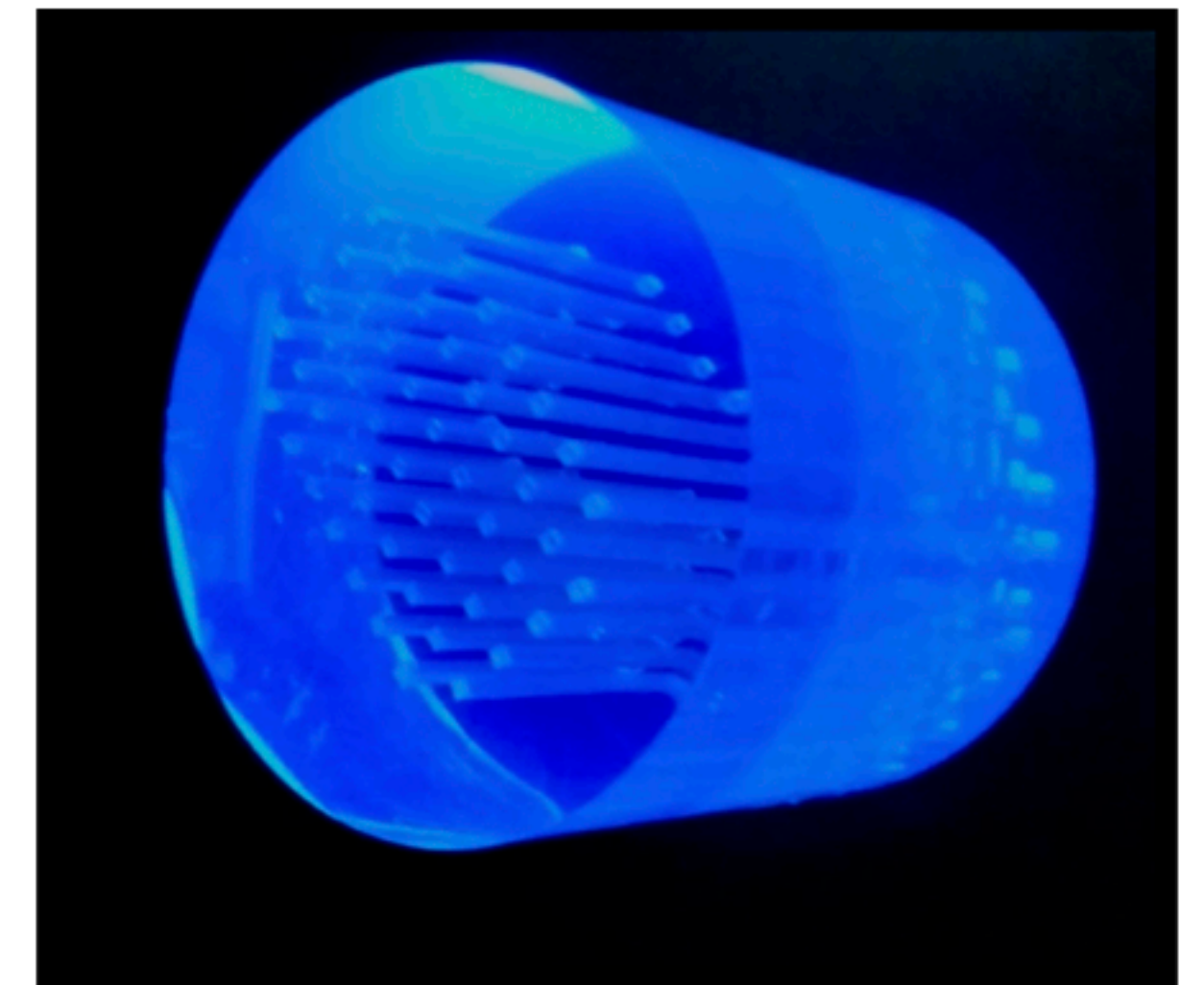


- Scalable noble element detectors (liquid argon)
- Wavelength shifting and improved light collection
- Assessing the nonproliferation potential of CEvNS in LAr

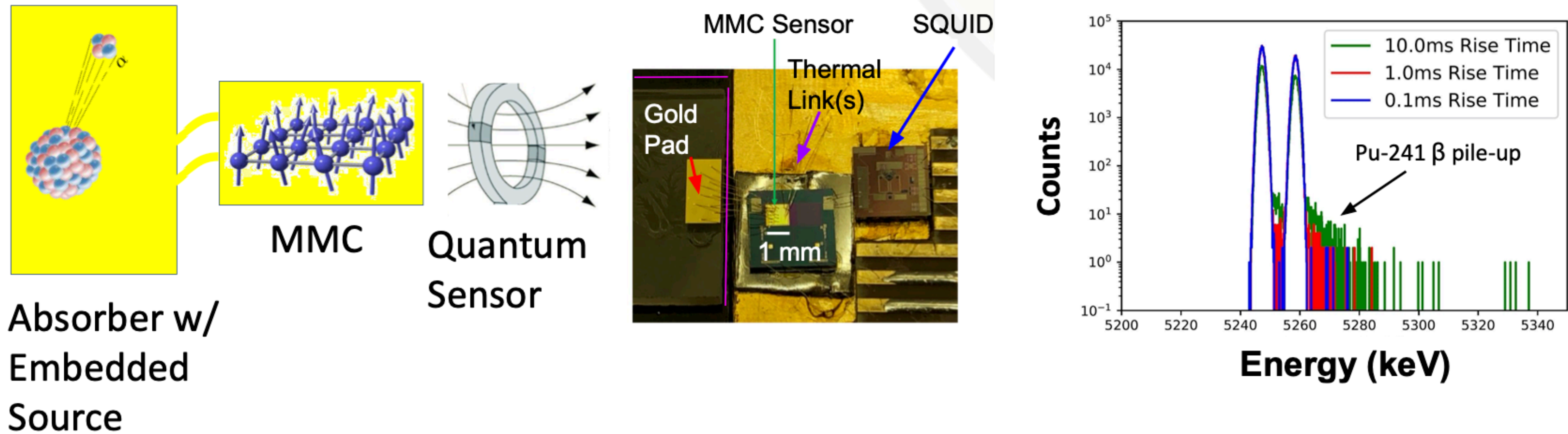
Active Interrogation



- Ion-driven nuclear reaction sources for gamma radiography
- Gamma and neutron spectroscopic radiography with data fusion
- Delayed neutrons for calibration-free enrichment measurements insensitive to shielding
- Heterogeneous composite scintillators for neutron measurements in harsh AI environments

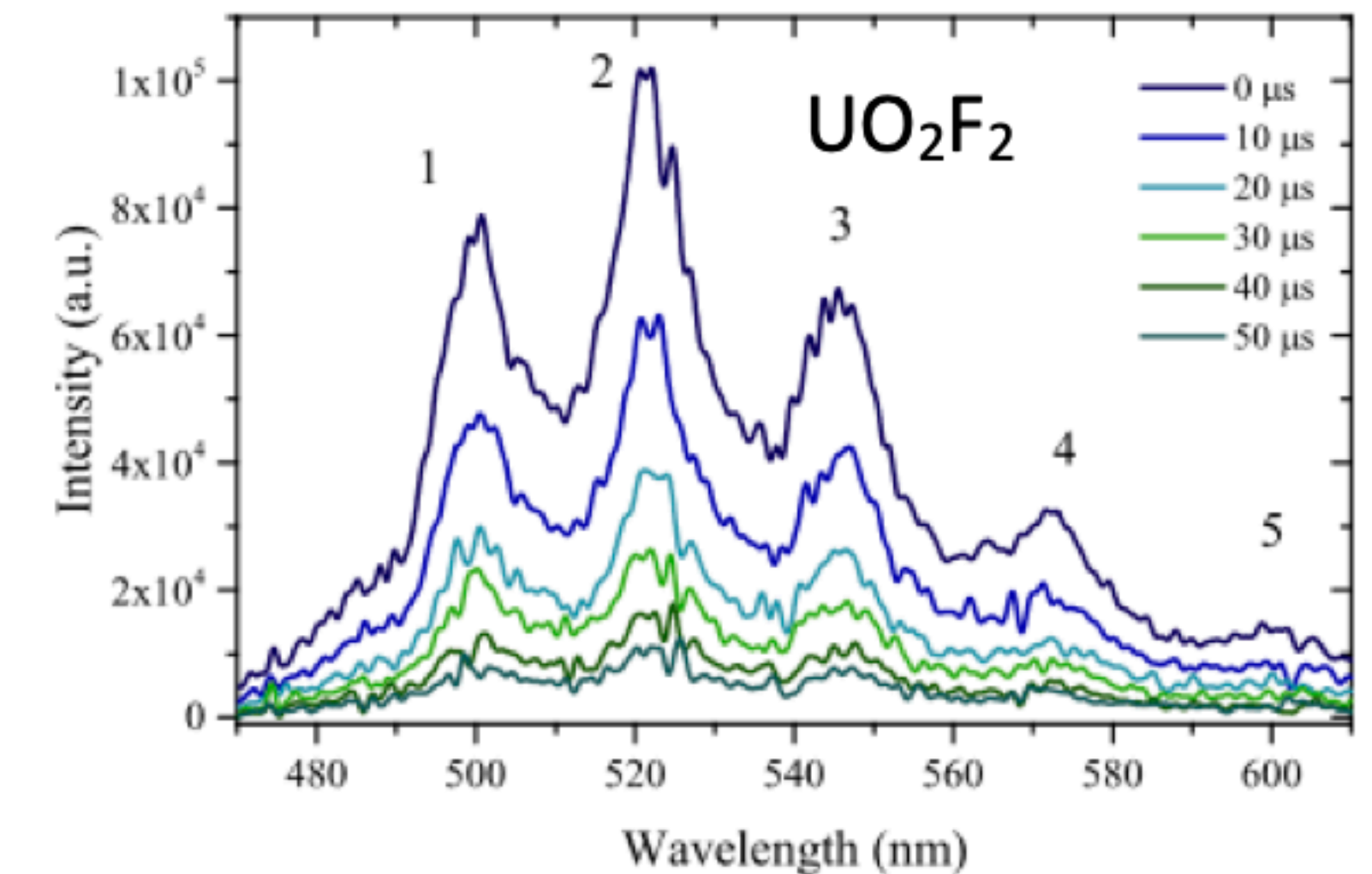
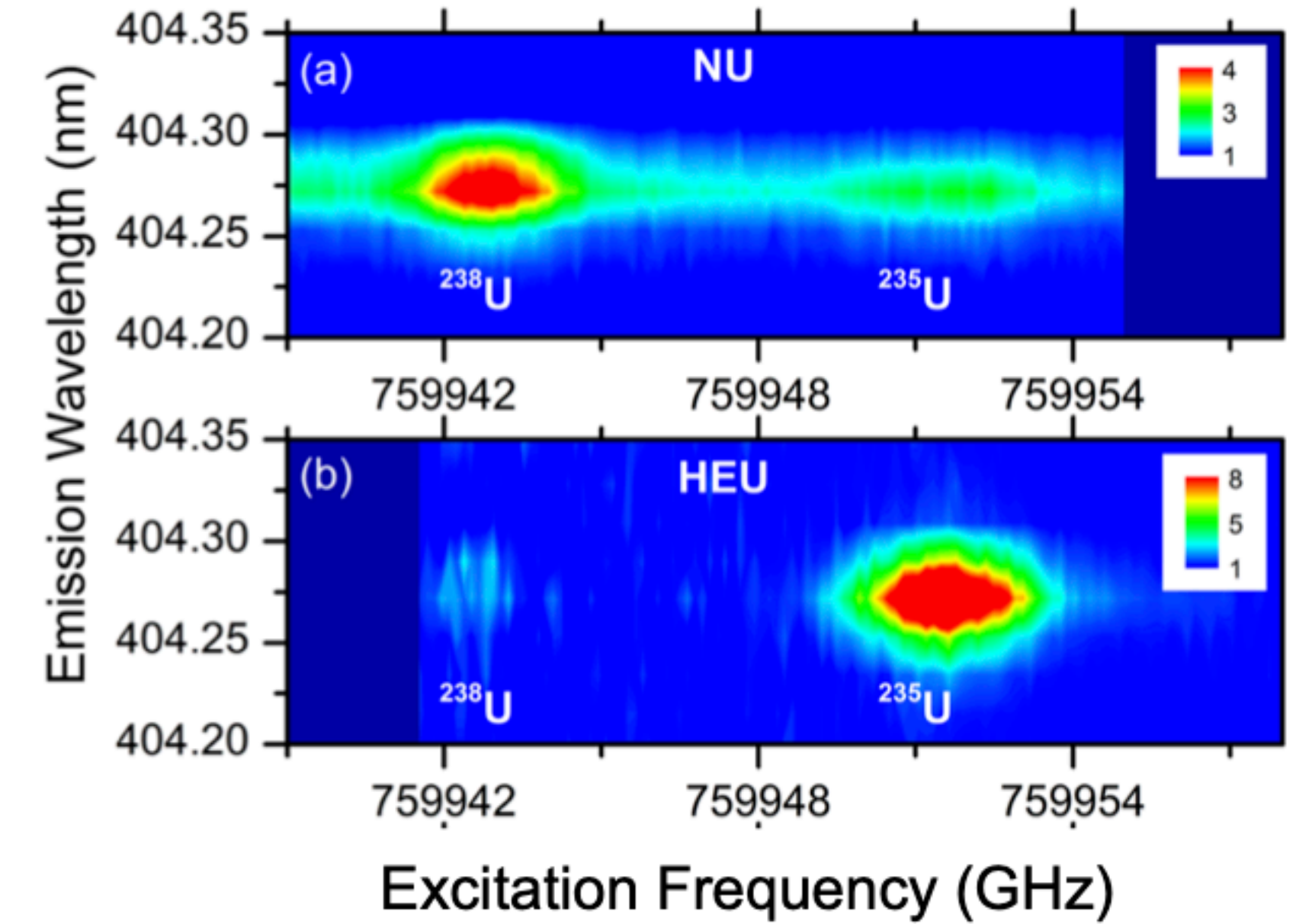
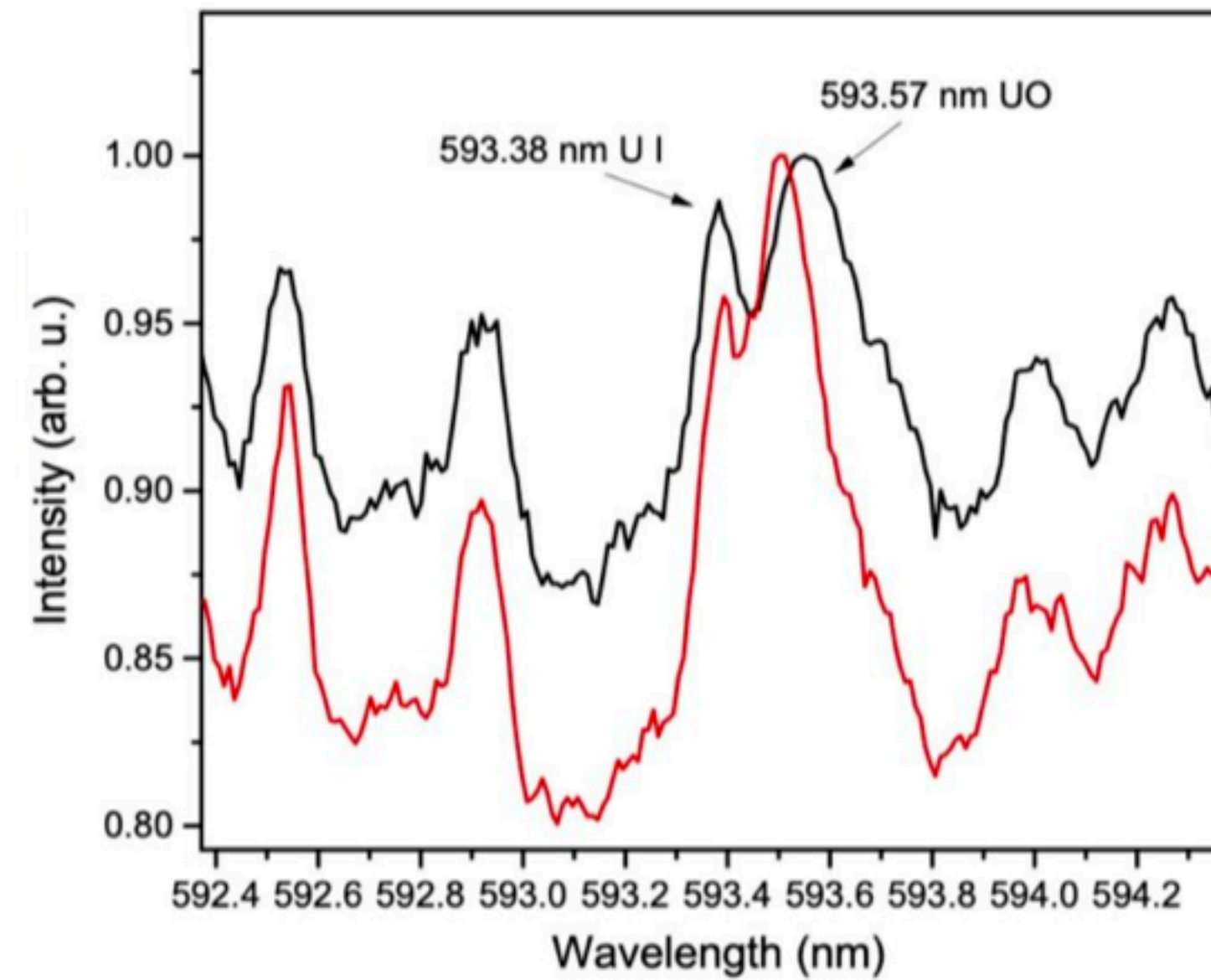
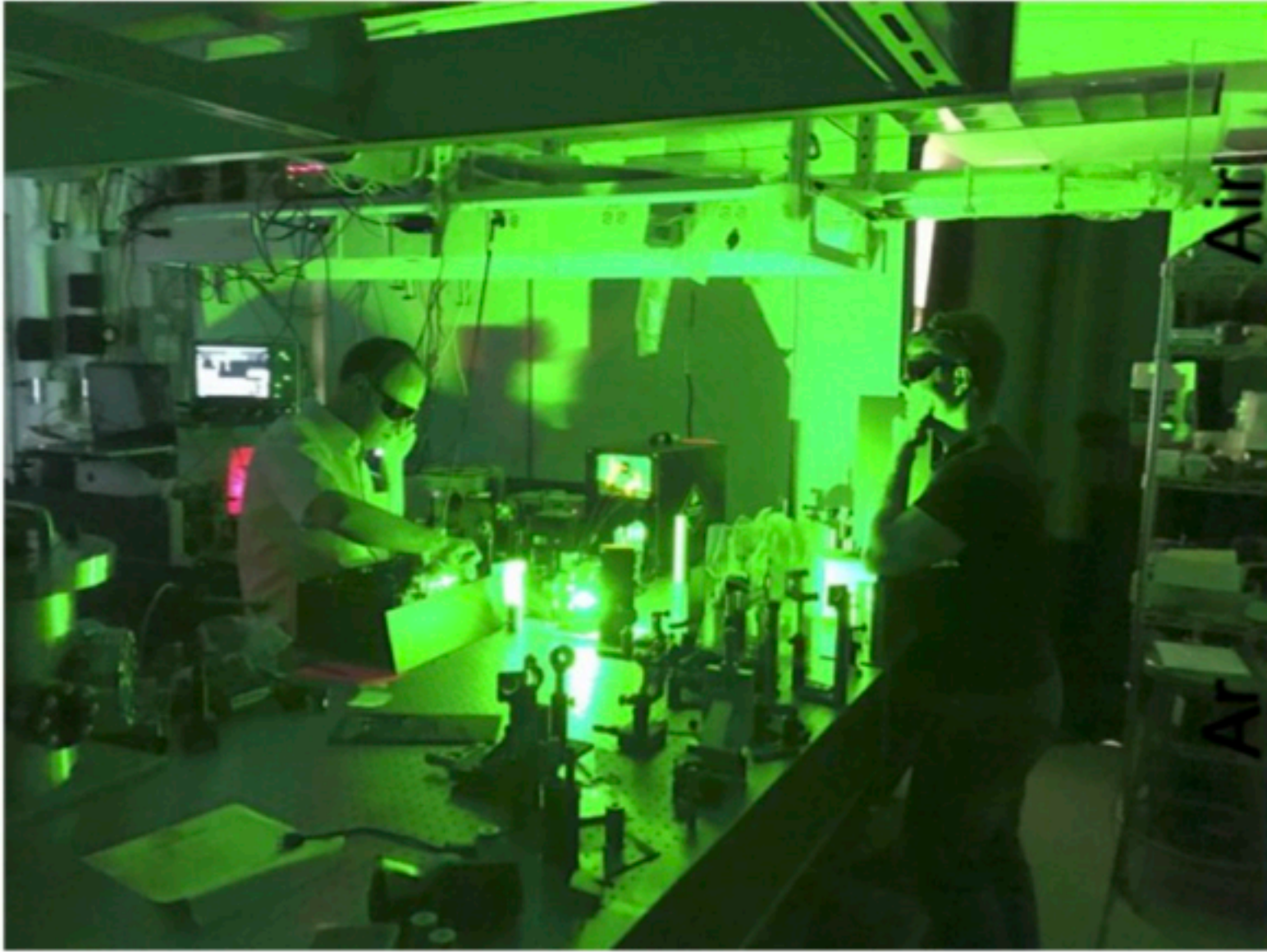


Magnetic Microcalorimeters



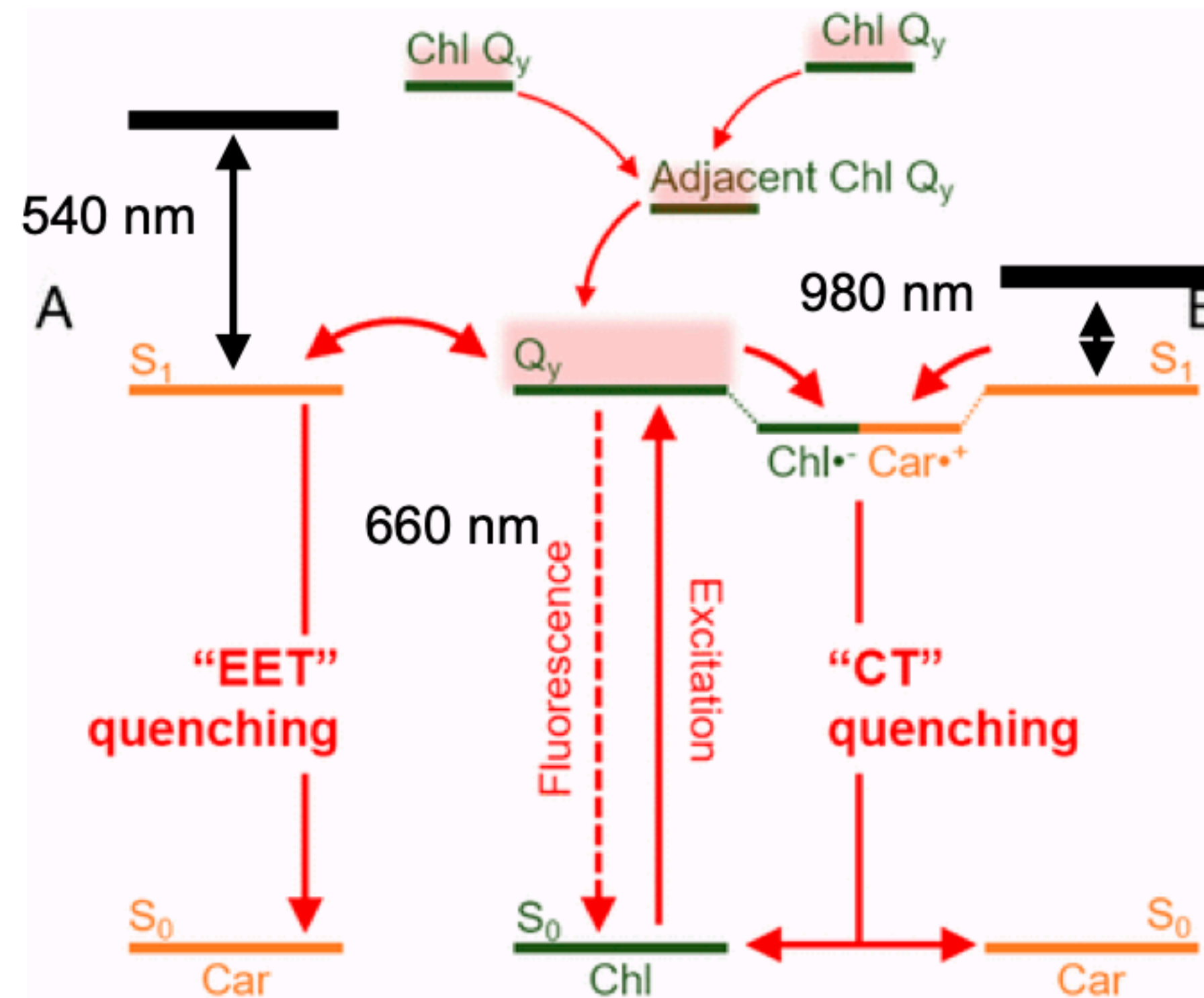
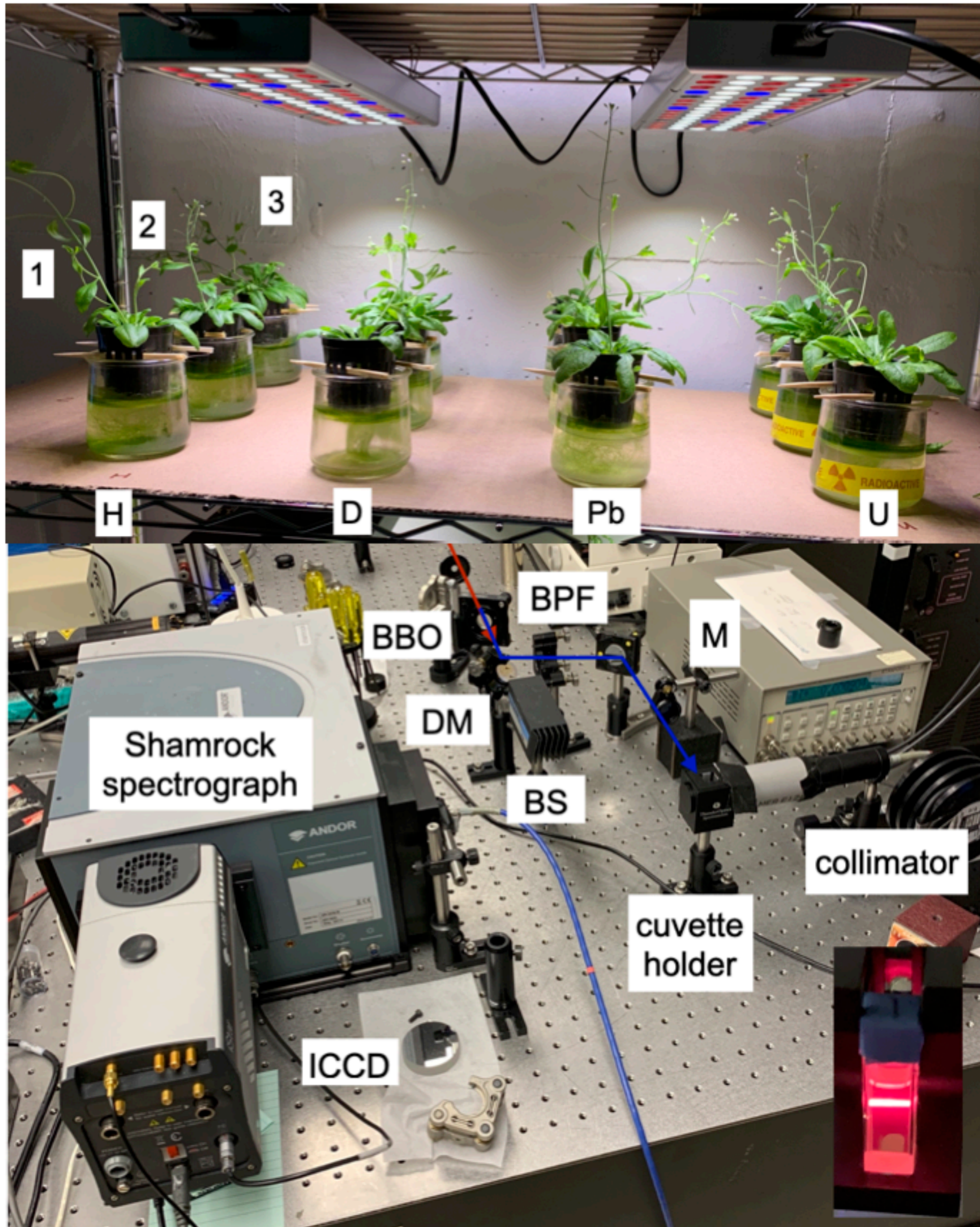
- Decay Energy (Q)-Spectroscopy: embed actinides within detectors \rightarrow entire decay energy measured in a single peak
- Magnetic microcalorimeters (MMCs) – cryogenic detectors with ultrahigh energy resolution: few keV at MeV scale.
- High-accuracy radioactive material analysis for nuclear safeguards and forensics.
- Challenge: rise-times on the order of milliseconds \rightarrow pile-up could introduce systematic bias in isotopic ratio analysis – must be accounted for in simulation or by trading off detector speed for resolution

Standoff Detection of Uranium



- Remote, rapid detection using ultrafast laser filaments
- Elemental, isotopic, and compound detection (oxides and fluorides)
- Single-shot detection of uranium demonstrated at 10 meters → readily scalable to longer distances
- Optimization of detection via wavefront control
- Air waveguiding of optical signal for improved collection

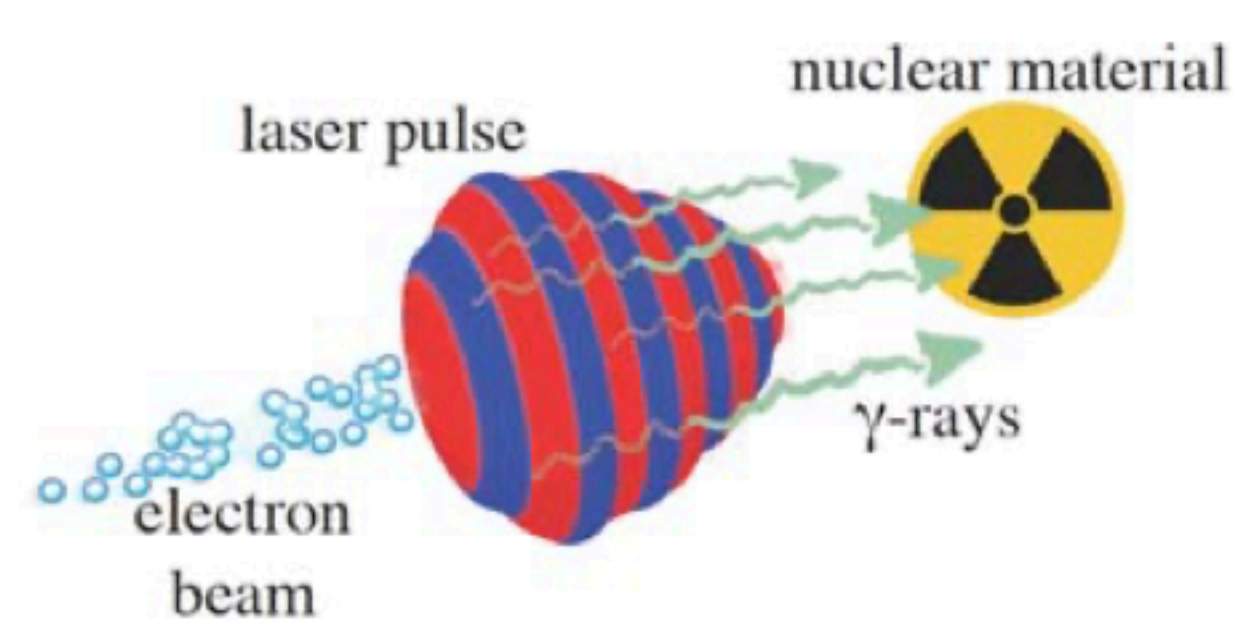
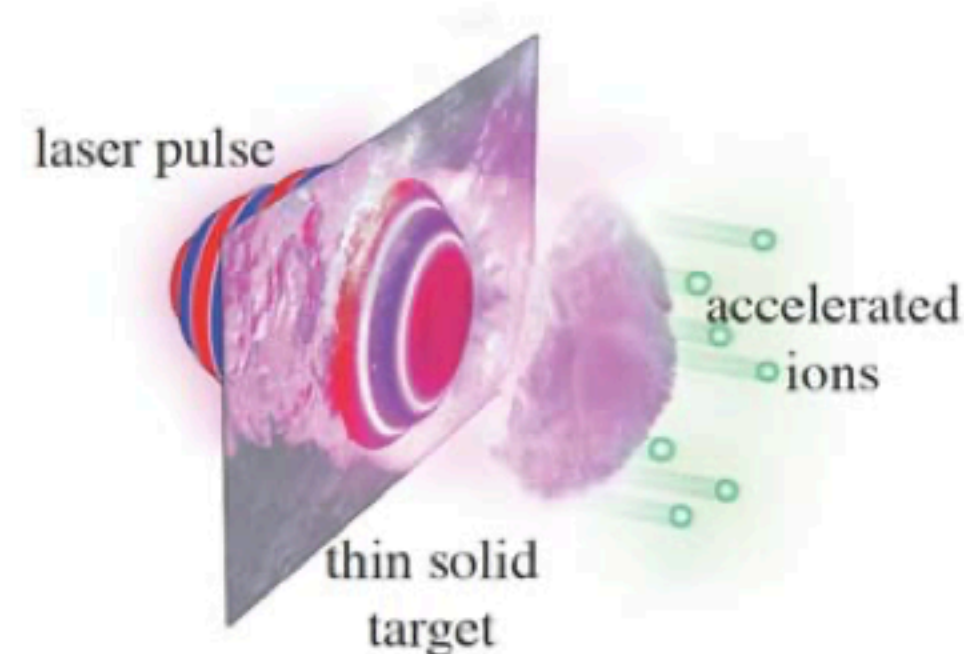
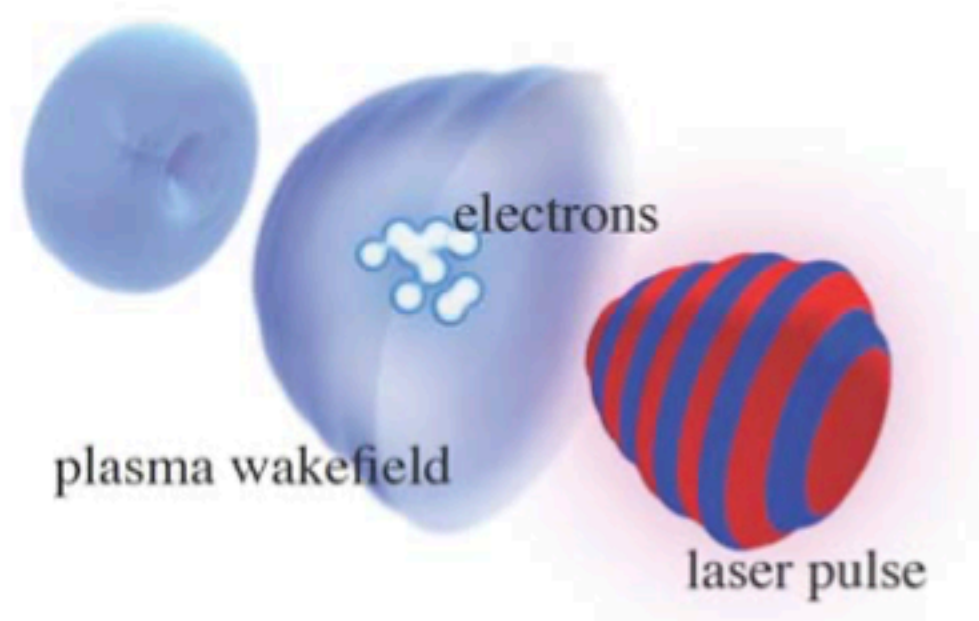
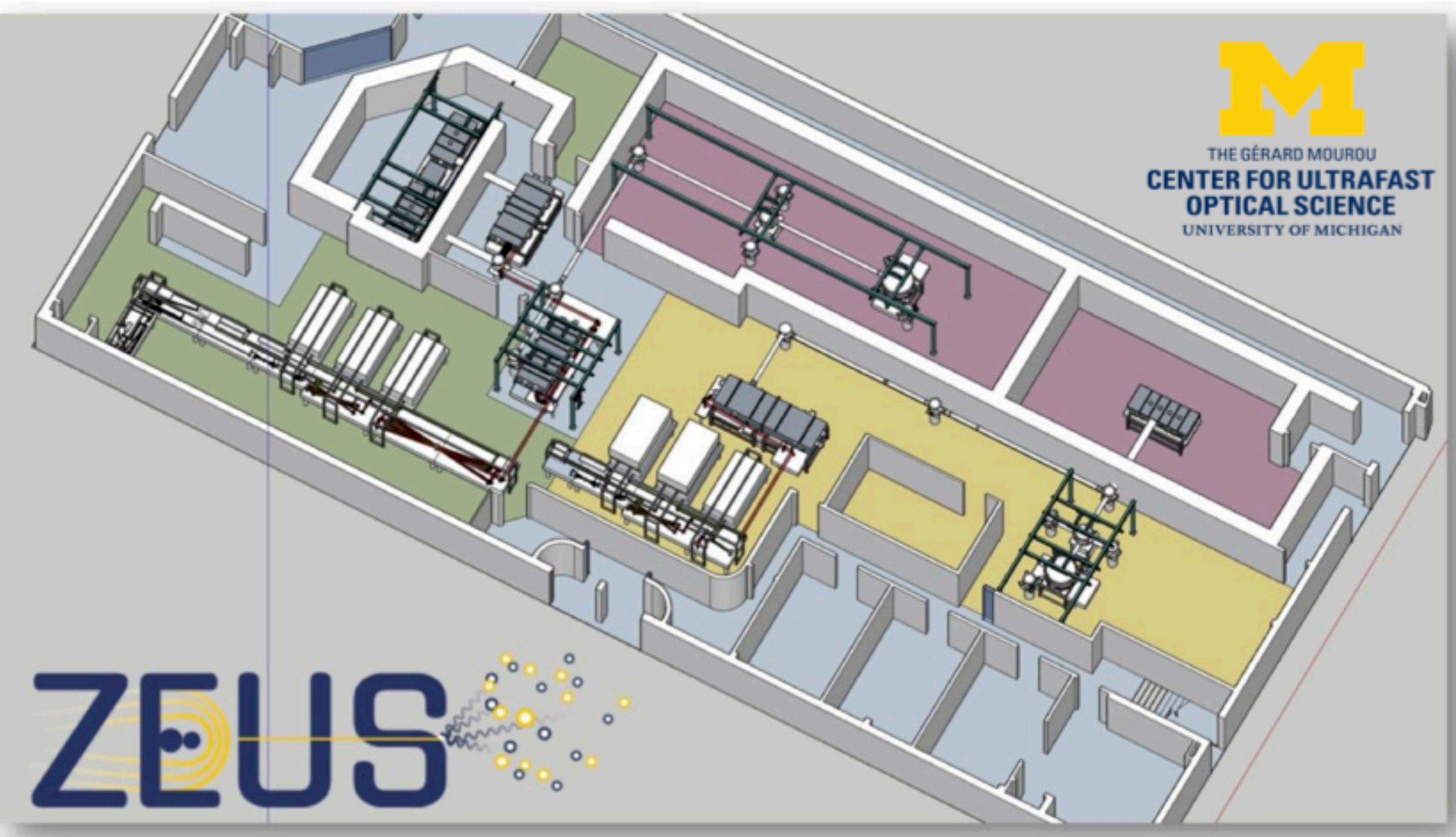
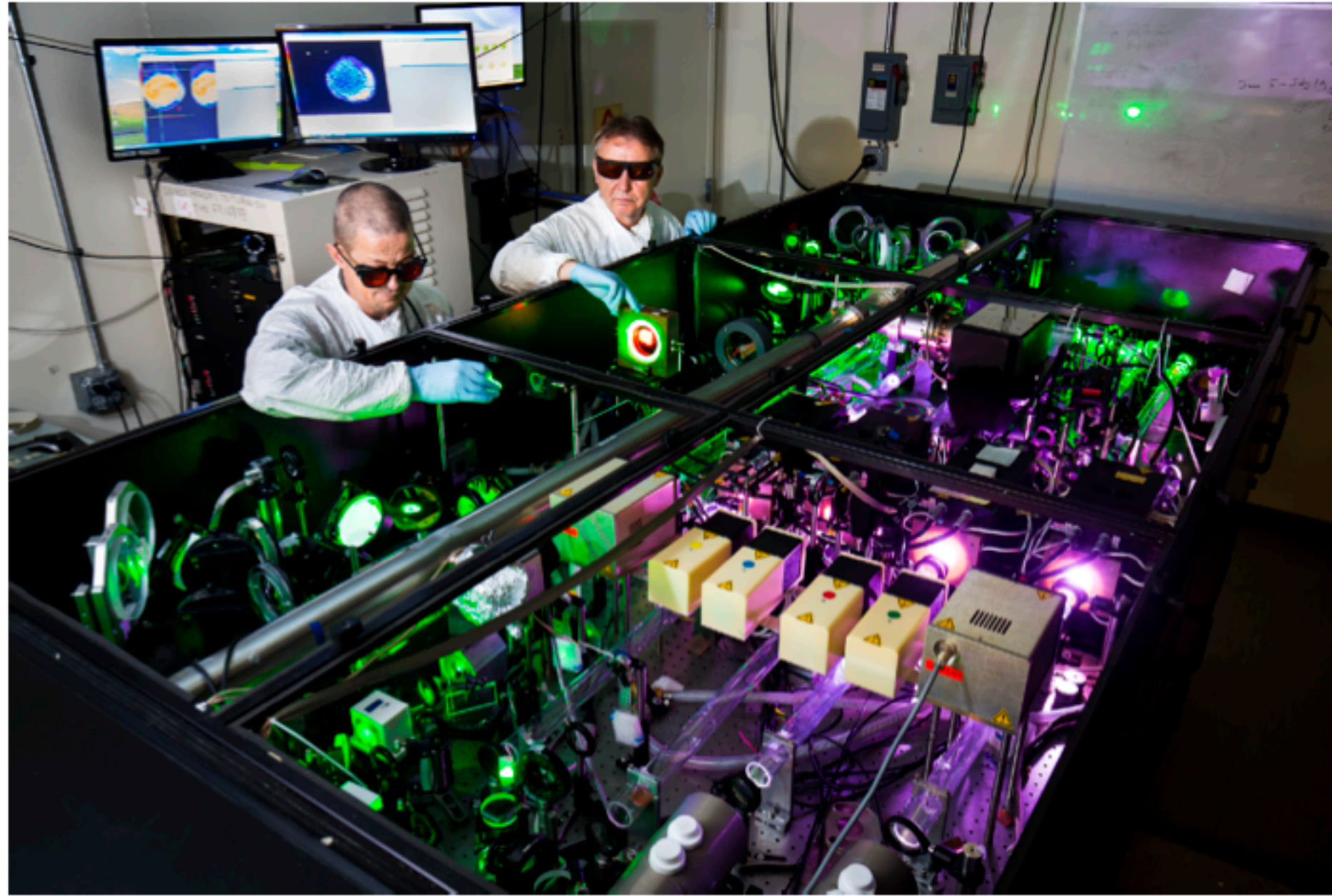
Biota: Proliferation Detection via Plant Stress



- Detect exposure to uranium-containing compounds emanating from enrichment facilities
- Chlorophyll to carotenoid ratio as a signature

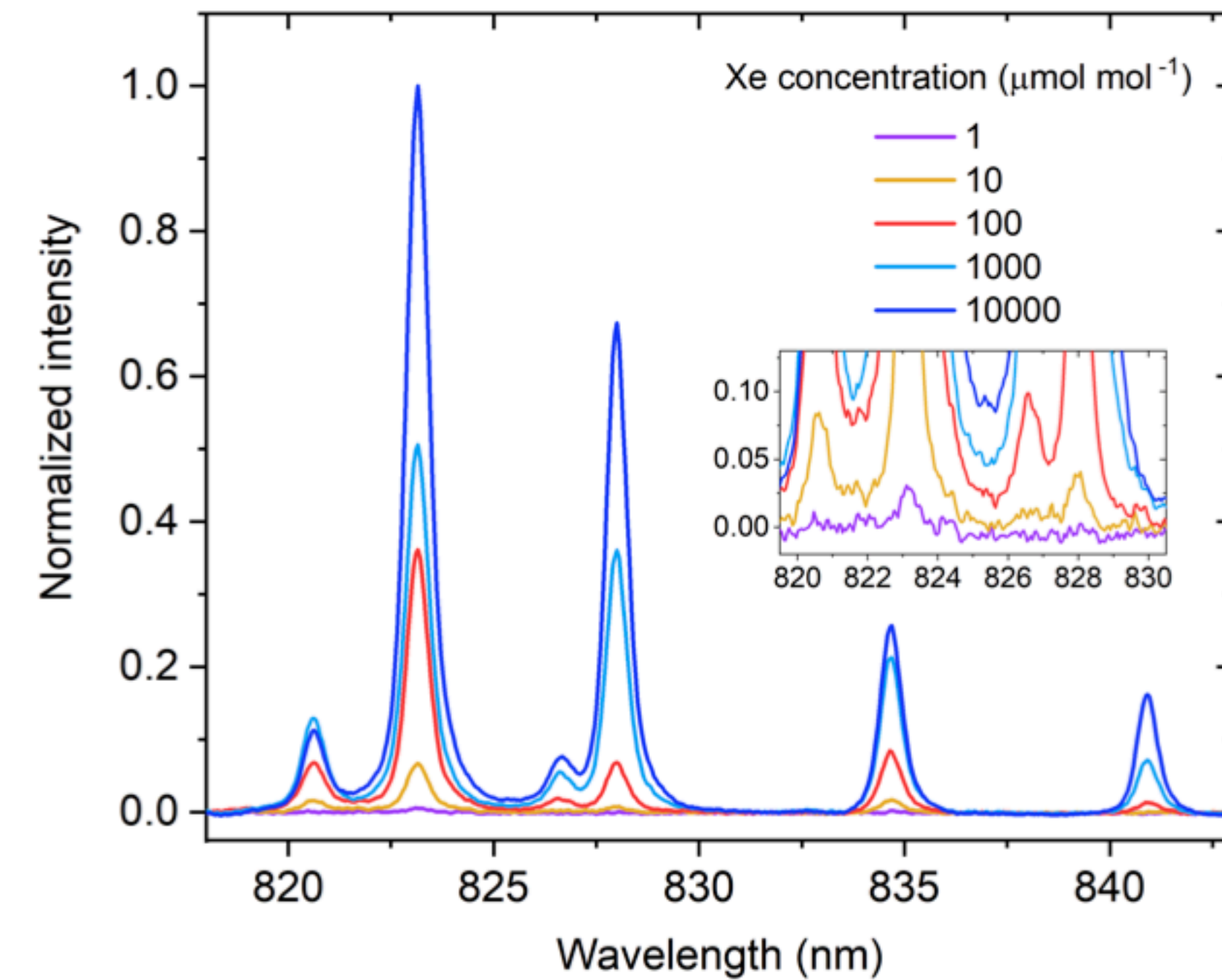
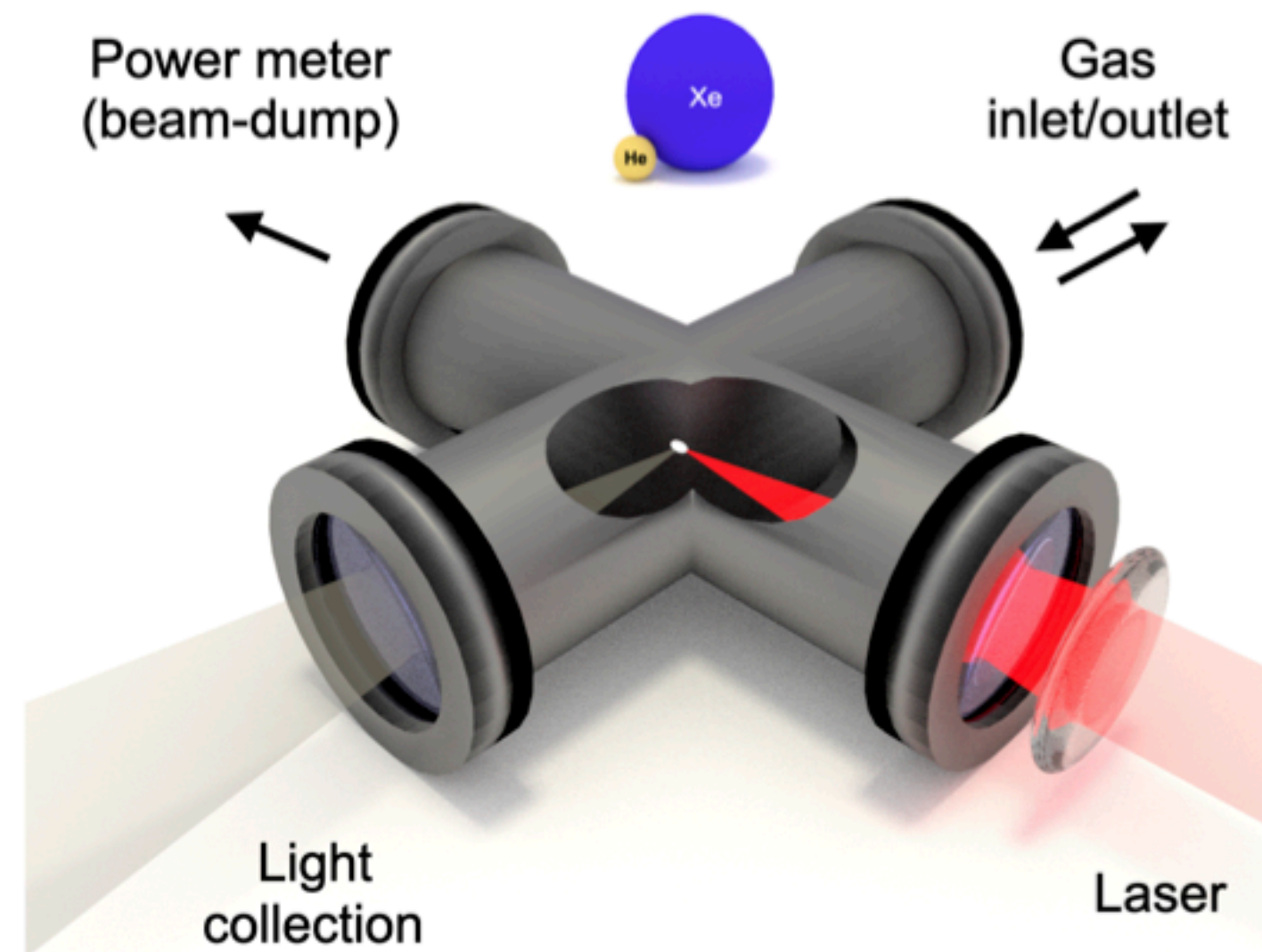
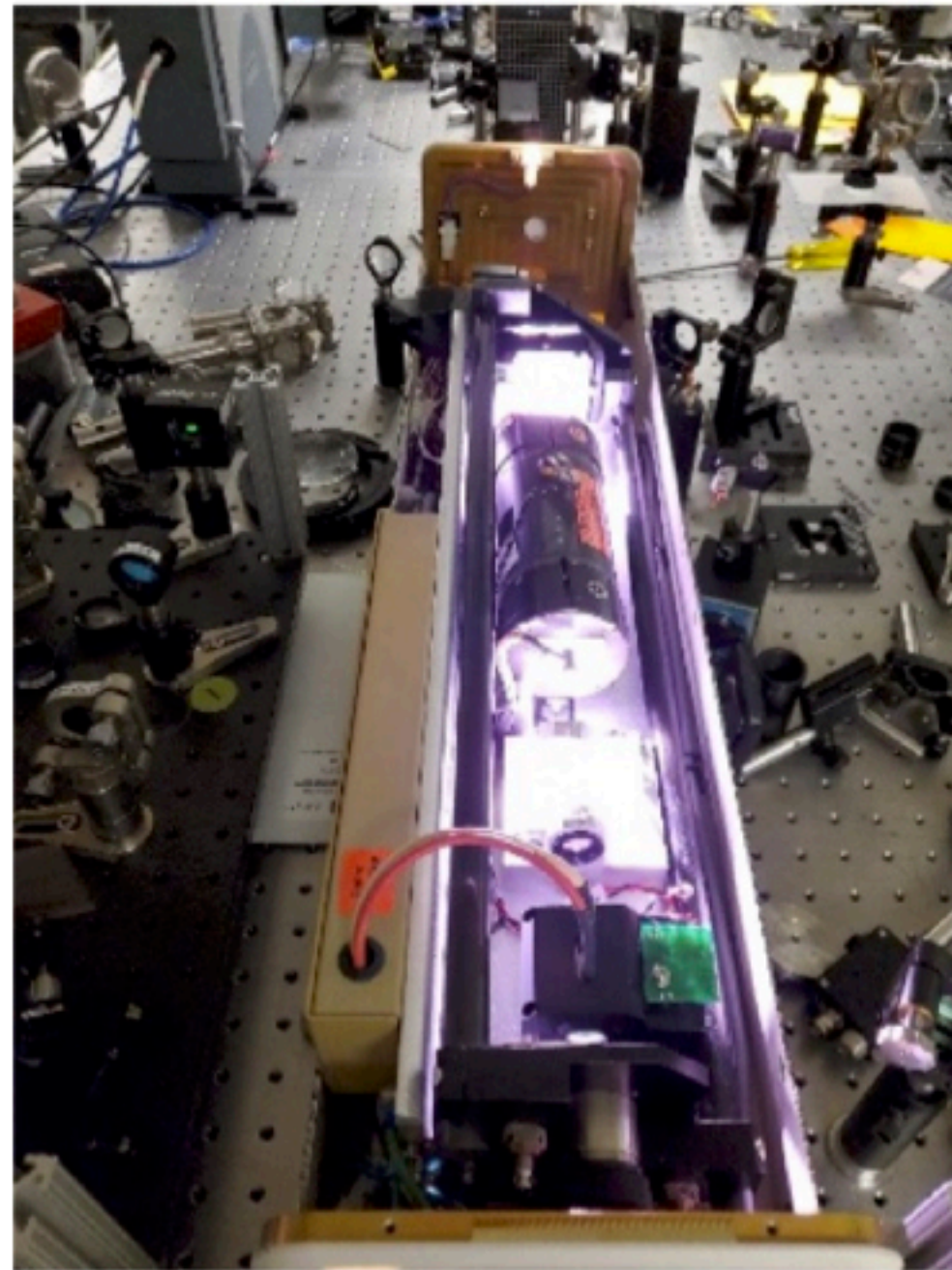
- Absorption, time-resolved fluorescence, and pump-probe techniques → sensitivity and **specificity** to uranium exposure
- Suitable for remote measurements via laser filamentation

Nuclear Photonics



- Laser-based radiation sources: laser Compton scattering, 10 GeV electrons, positrons, ions, neutrons, muons
- Nuclear physics, radiography, and active interrogation
- Strong relationship with STFC's Central Laser Facility

Optical Instrumentation for Advanced Reactors



- Trace detection of xenon in high-temperature gas reactors
- In-situ composition measurements of molten salts
- Optical material performance in high-radiation field
- Robotic inspection of dry casks for chlorine deposition

Impact and Opportunities

- Detect foreign weapons activities
- Increase nuclear security
- Improve safety and security of nuclear power
- Contribute to fundamental science

Our research offers ample opportunities for collaboration with UK-based colleagues and builds on an existing solid foundation.

We welcome adding the international dimension to all of our current initiatives, as well starting new ones!

Many thanks to our sponsors:

