Fissile material experiments at the Device Assembly Facility

CVT Workshop – October 20, 2016

Michael Hamel[1], Pete Chapman[2], Michael Streicher[1]

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Campaign objectives

- July 11-21, 2016, CVT and CNEC conducted experiments with Cat-I SNM at DAF for a second time
- Provided CVT and CNEC students, post-docs, and faculty with the opportunity to conduct hands-on experiments with Category I (weapons usable) special nuclear material (SNM)
- Included a neutron generator for active interrogation of HEU

CNEC | Consortium for Nonproliferation Enabling Capabilities

Device Assembly Facility

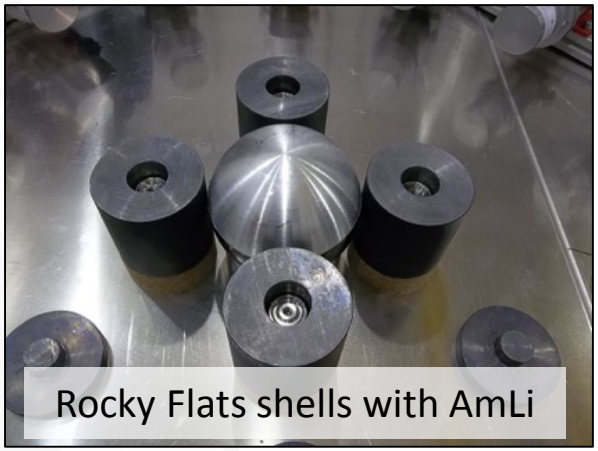
- Located within the Nevada National Security Site, 90 minutes northwest of Las Vegas
- Operated by NSTec for the NNSA
- Houses the National Criticality Experiments Research Center
- Supports critical and subcritical measurements of WGPu, HEU, and Np

CVT campaign participants

- North Carolina State University
  - Prof. John Mattingly, Jonathan Mueller, Pete Chapman
- Princeton University
  - Prof. Alex Glaser, Sebastien Phillipe, Benjamin Reimold
- University of Illinois
  - Prof. Clair Sullivan, Mark Kamuda
- University of Michigan
  - Prof. Igor Jovanovic, Michael Streicher, Bennett Williams, Jason Nattress, Lazar Supic, Michael Hamel
- Oak Ridge National Laboratory
  - Jason Newby
- Los Alamos National Laboratory
  - Jesson Hutchinson, Donnette Lewis, et al.

Sources

- SNM sources
  - BeRP ball: 4.5-kg WGPu metal sphere
  - Thor core: 4.1-kg WGPu metal disk
  - Rocky Flats shells: 13.7-kg HEU metal shells
  - Neptunium: 6.1-kg metal sphere
- Interrogating Sources
  - AmLi
  - DD neutron generator
  - DT neutron generator

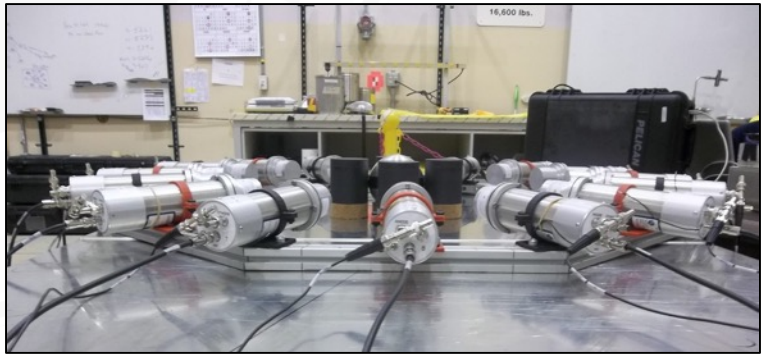


Rocky Flats shells with AmLi

Assembly of Rocky Flats shells

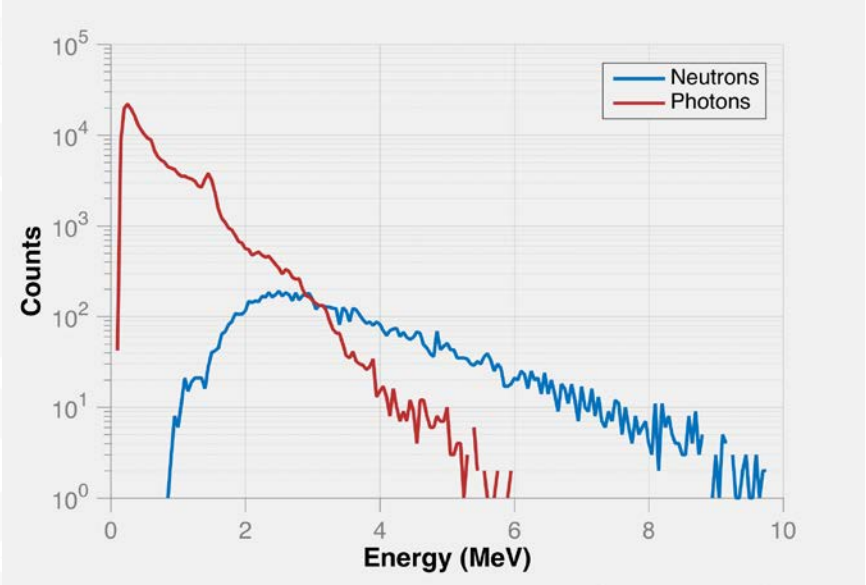
Instruments

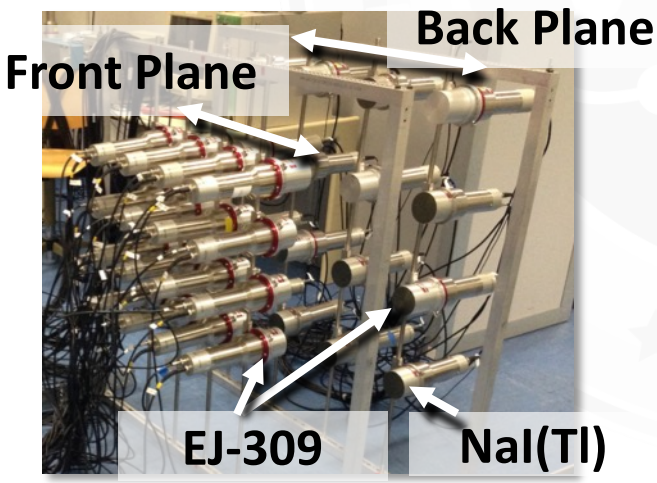
- Neutron coded aperture imager (ORNL/SNL)
- Bubble detectors array (Princeton)
- NaI, CsI scintillators (Illinois)
- Dual particle imager (Michigan)
- One dimension transmission imager (Michigan)
- Polaris and Orion CZT imagers (Michigan)

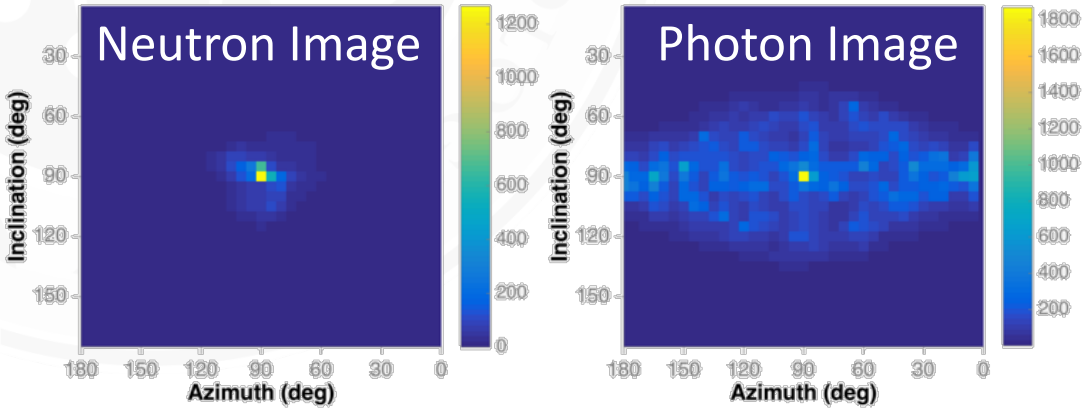


Dual-particle imager

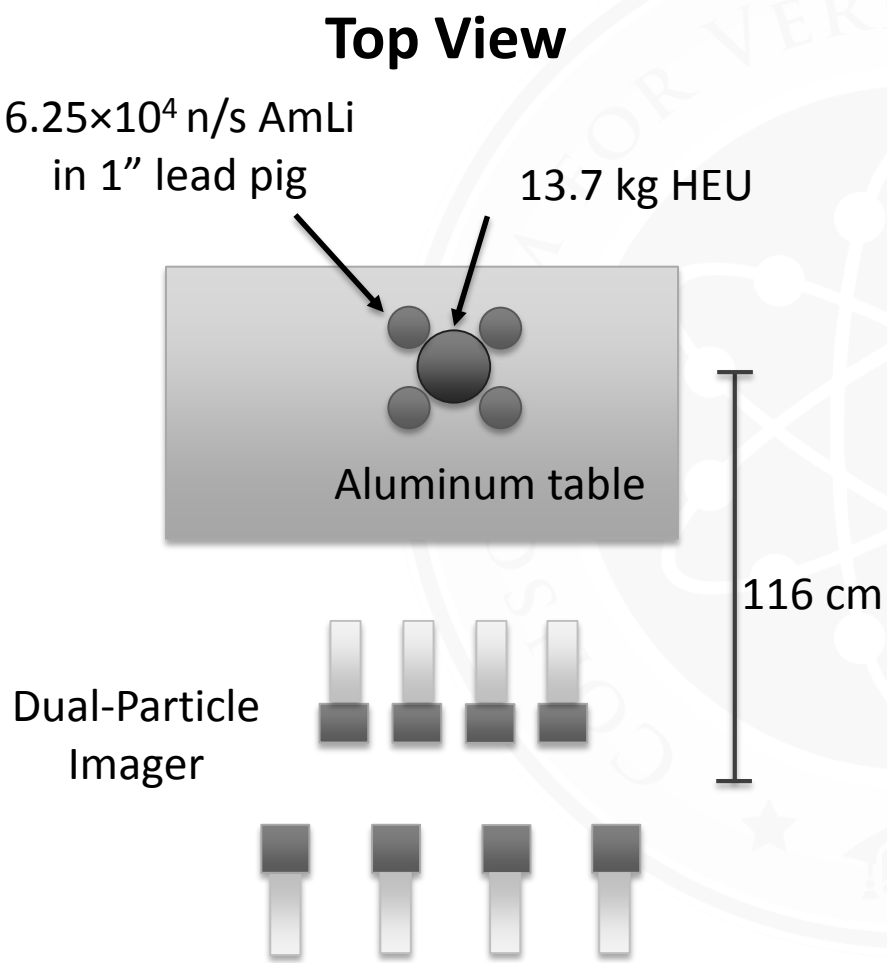
- Combined Compton and neutron scatter camera
- Two-plane design
  - Front Plane: EJ-309 liquid organic scintillators
  - Back Plane: EJ-309 and NaI(Tl)
- Separate neutron and photon signals

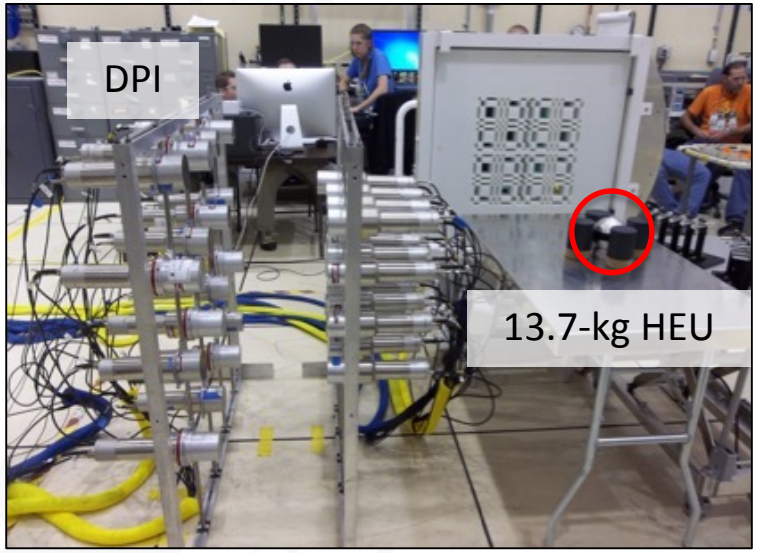






AmLi experiment

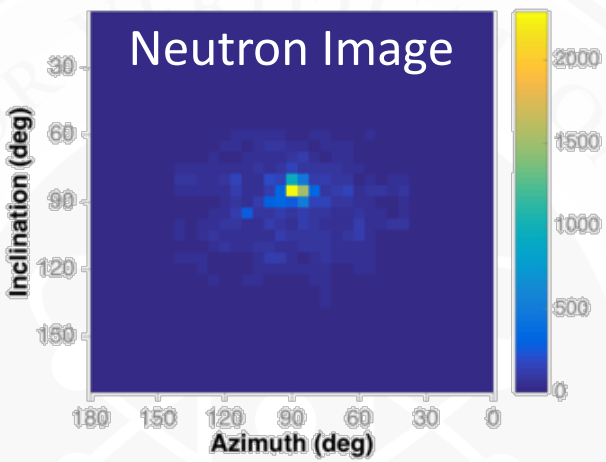


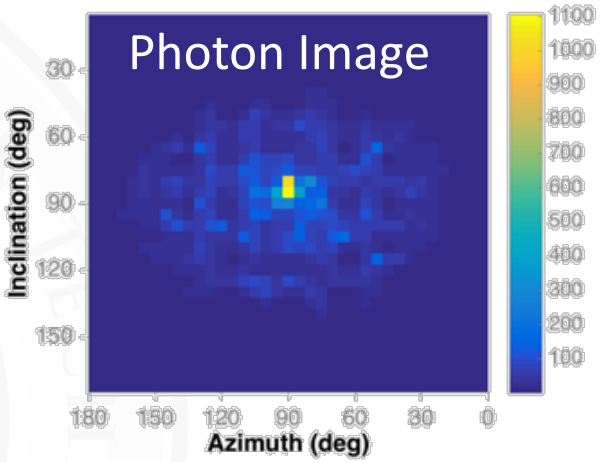


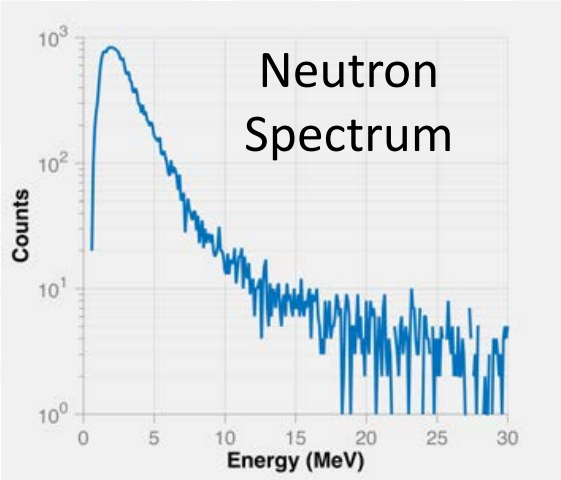
Measurement time: 850 min

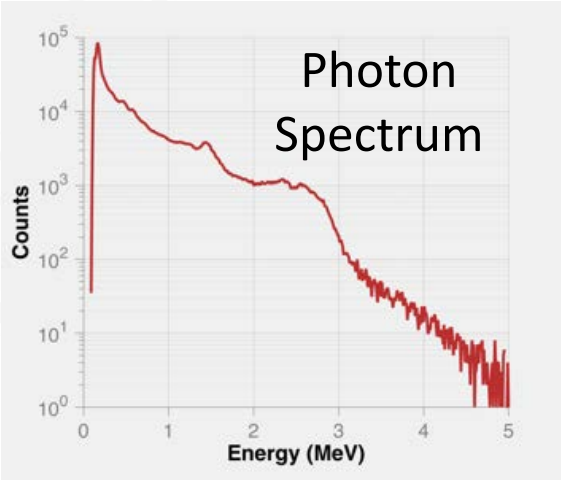
AmLi experiment

- Most neutron emitted by AmLi are less than 1.5 MeV
- Threshold of DPI ensures measured neutrons are from induced fission

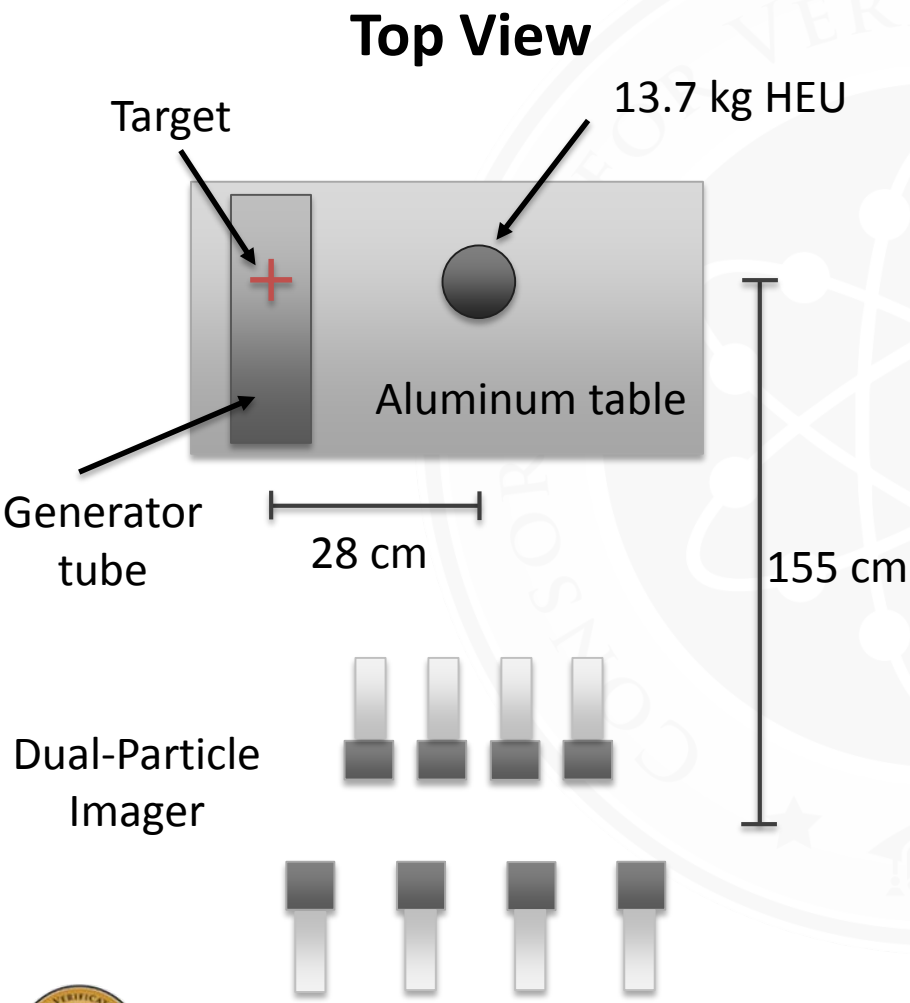


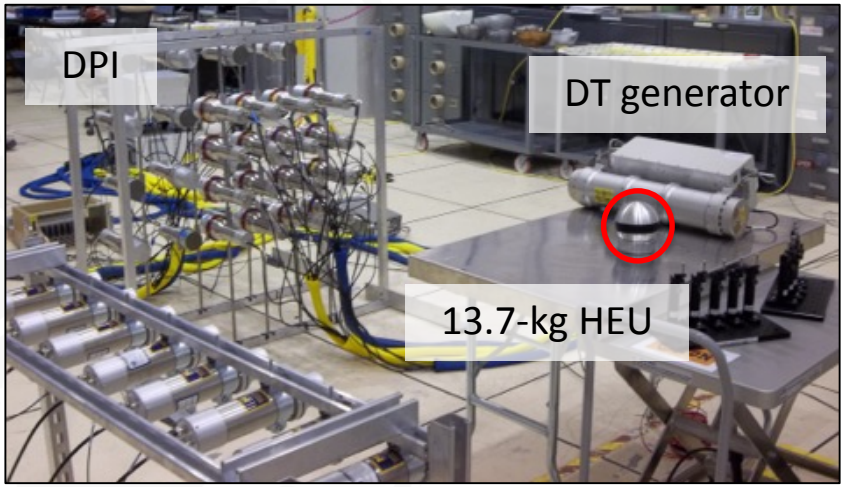






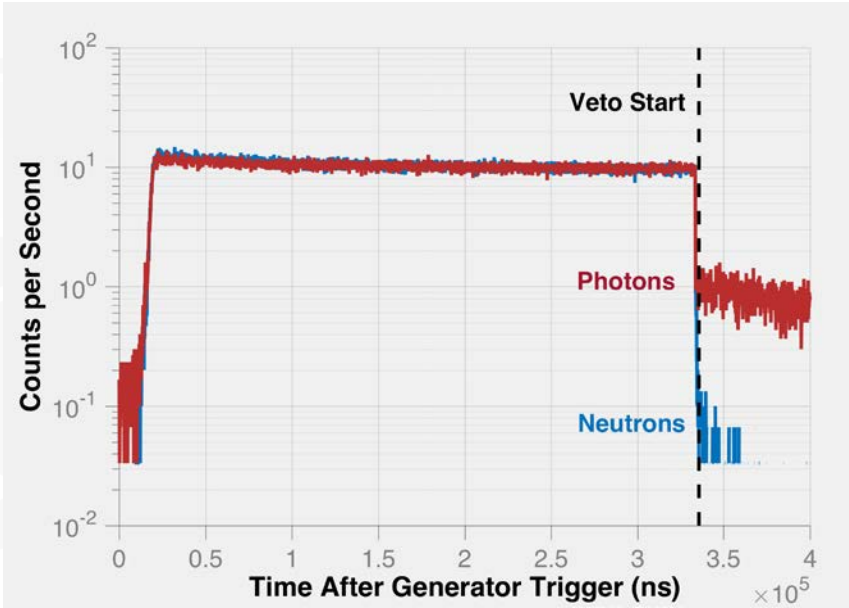
DT experiments

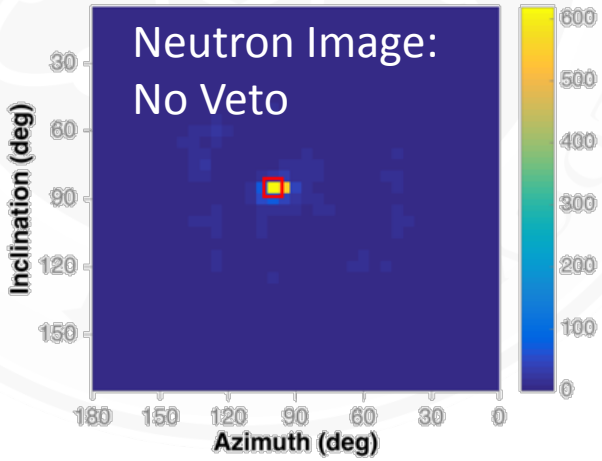




DT experiments

- Generator emitted 14.1 MeV neutrons
- Operated at 300 Hz with a 10% duty cycle
- 333 µs pulse length
- Digitized start of veto signal and vetoed based on pulse arrival times
- 335,700 ns after start of pulse

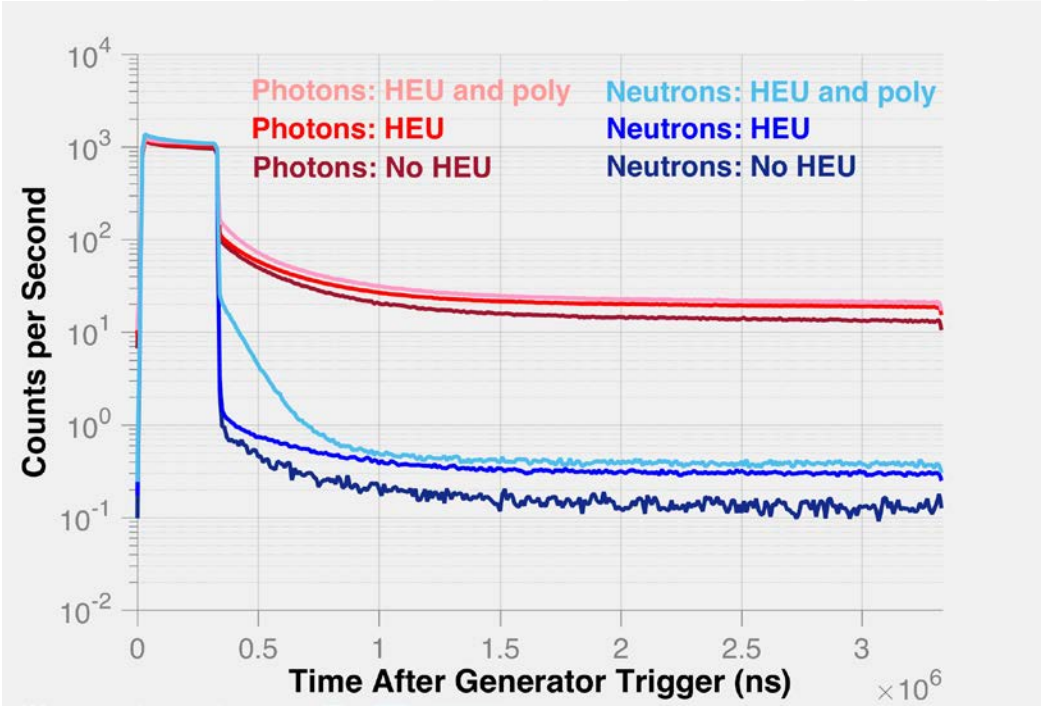


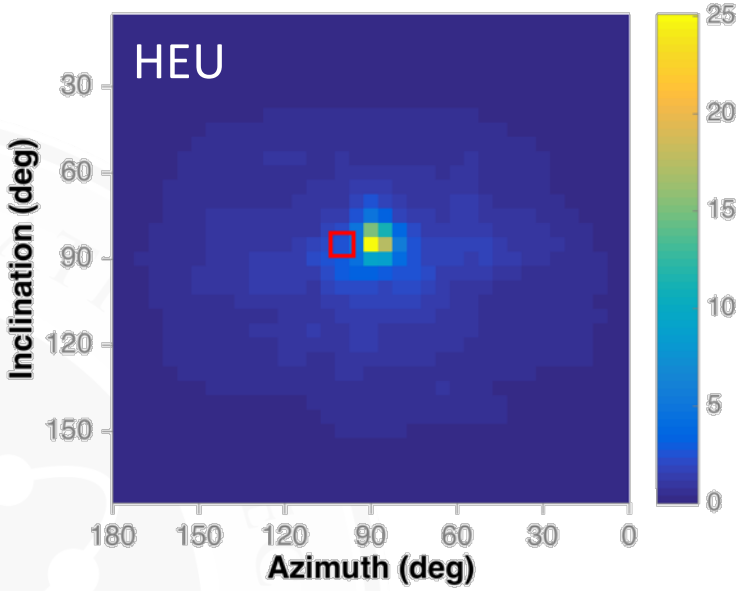


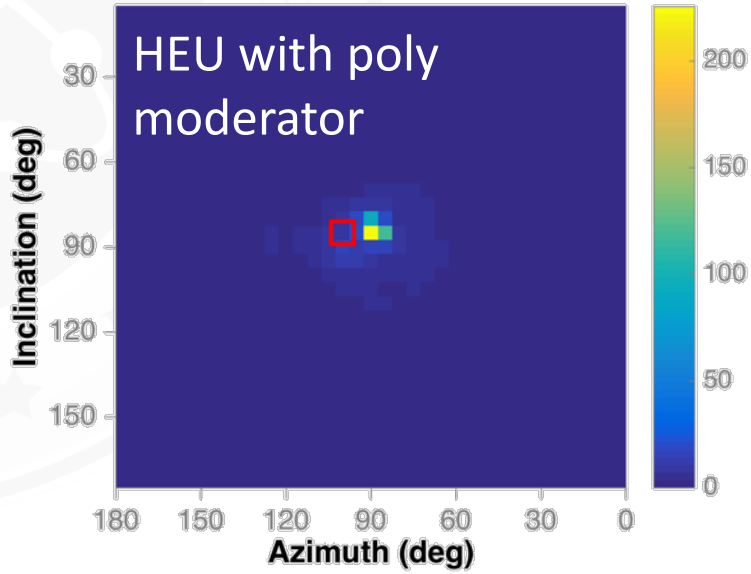
Neutrons per Second	
No Veto	With Veto
698	0.0048

DT experiments

DT Generator position

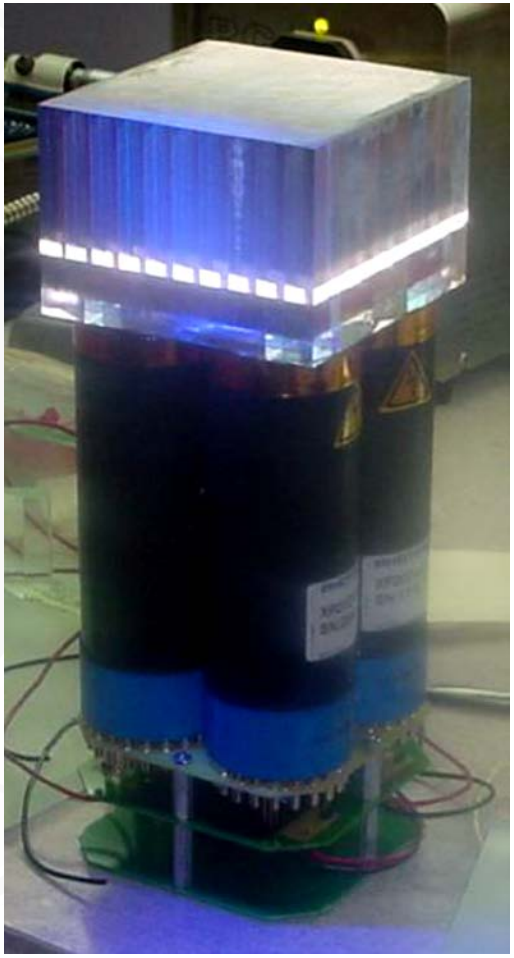






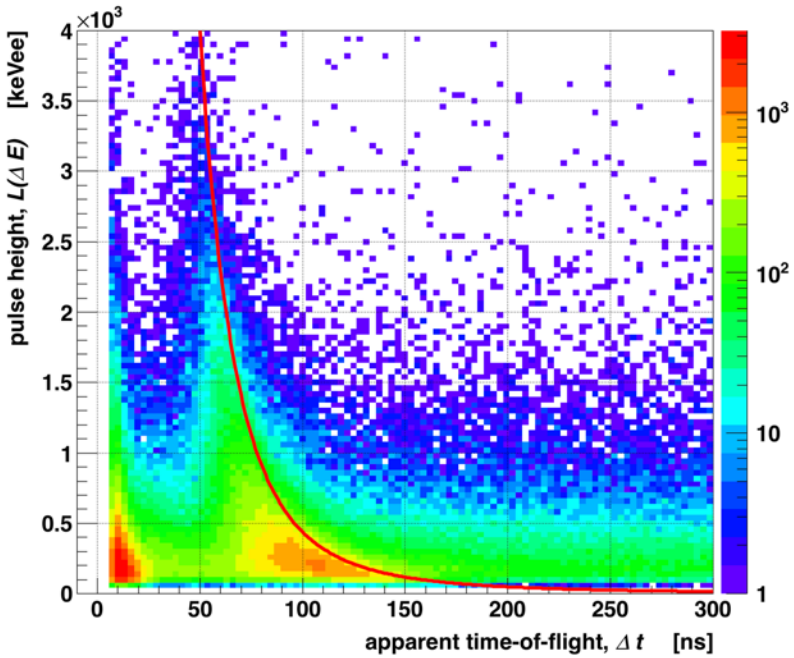
Identifying Fissile Assemblies in Fast Neutron Images

Neutron Coded Aperture Imager (NCAI)

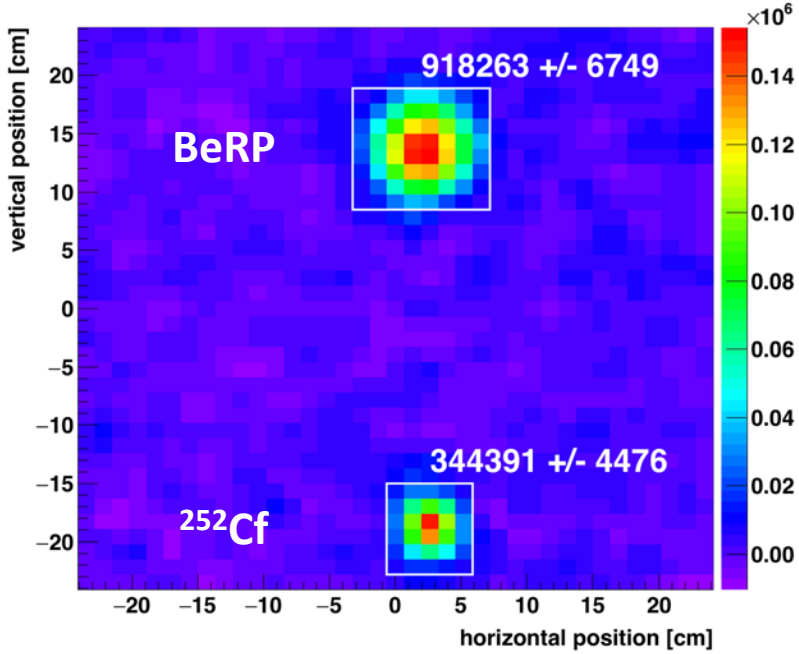


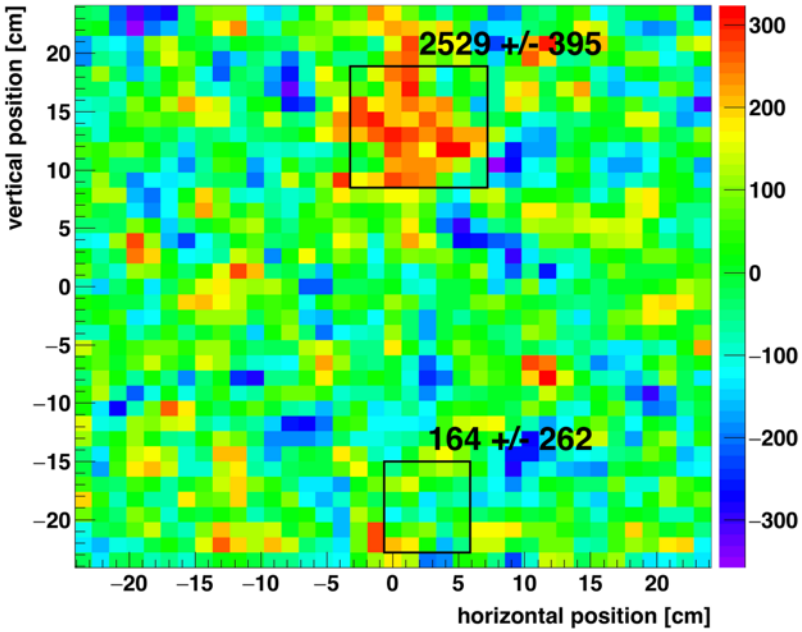
2015 DAF Campaign Update

- Passive measurements of bare BeRP ball (WGPu)
- Used Time-Correlated Pulse-Height (TCPH) analysis to identify fissile assemblies
- Neutrons depositing more energy than predicted by their time-of-flight indicate fission chain reactions



2015 DAF Campaign Update





2016 DAF Campaign

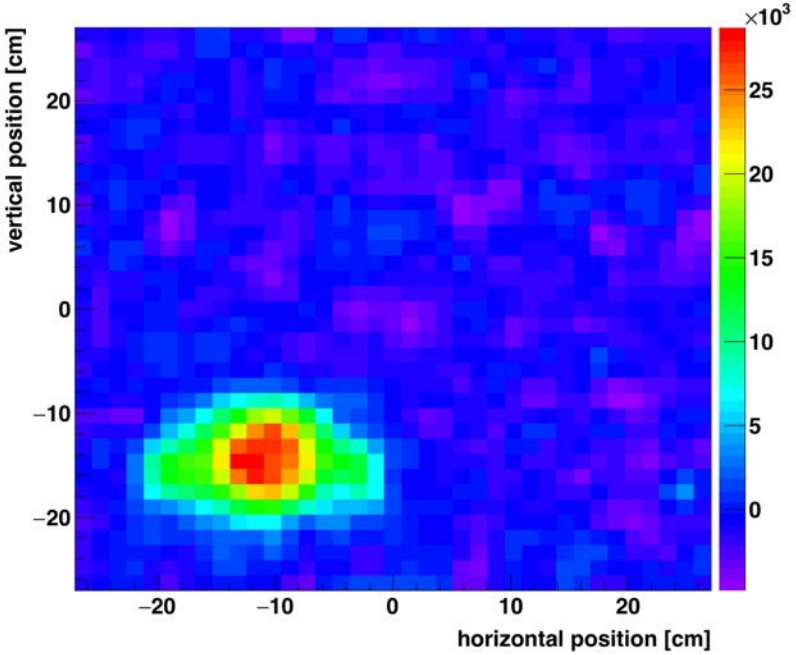
- Active measurements of Rocky Flats HEU shells
- AmLi, DD and DT generator drivers
- Used energy or time cuts to identify fissile assemblies

AmLi Sources

- 4x AmLi sources
- ~ 10^5 n/s
- Rocky Flats shells 1-24
- 15 hour run time

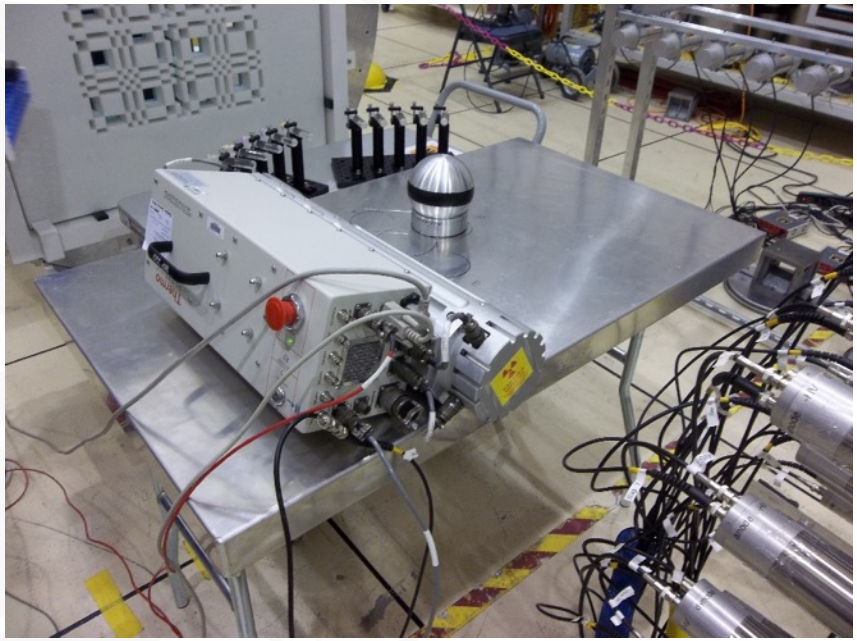
AmLi Sources

- No cuts needed

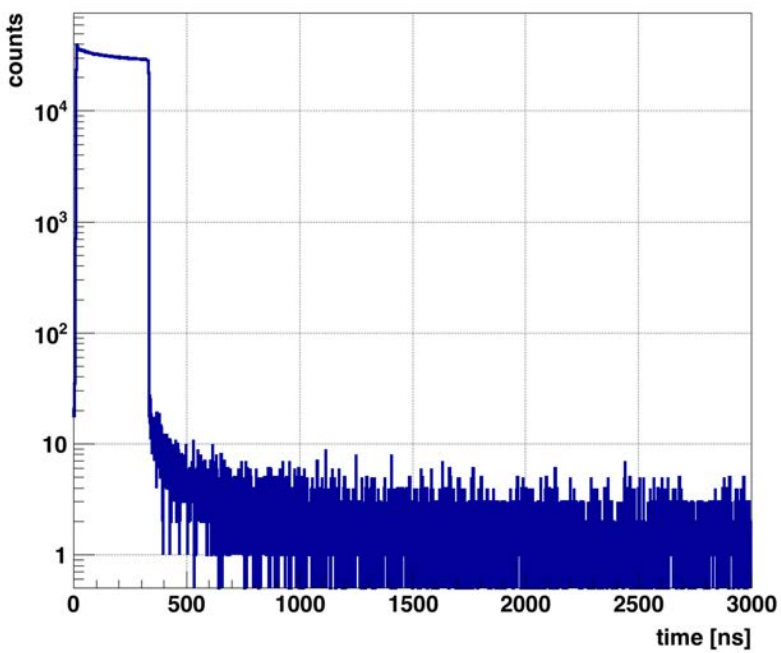


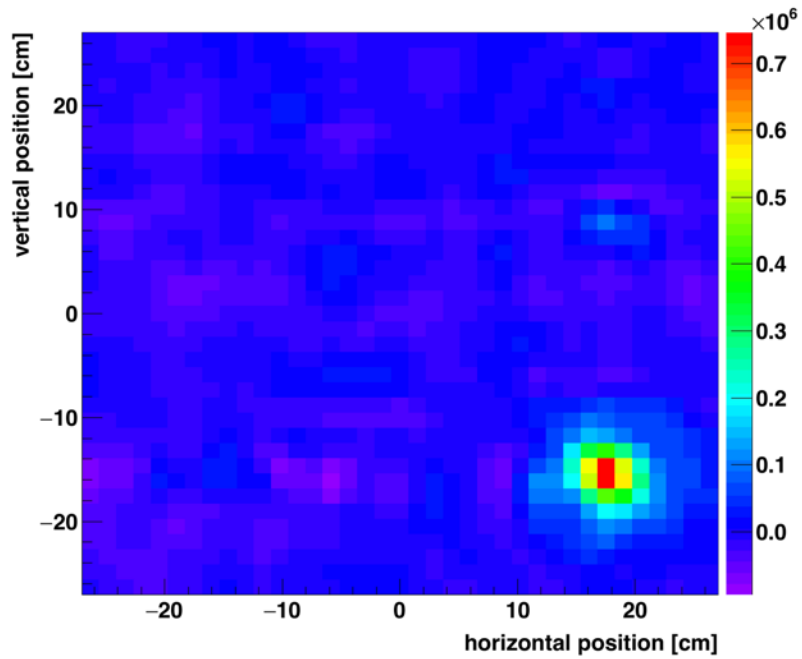
D-D Generator

- 300 Hz
- 10% duty cycle
- ~ 10^6 n/s
- Rocky Flats shells 1-24
- 100 minute run time

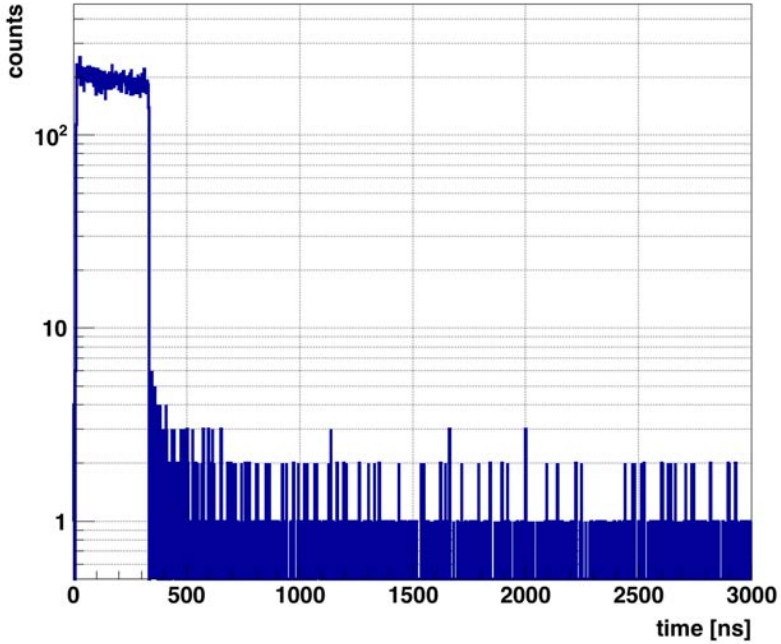


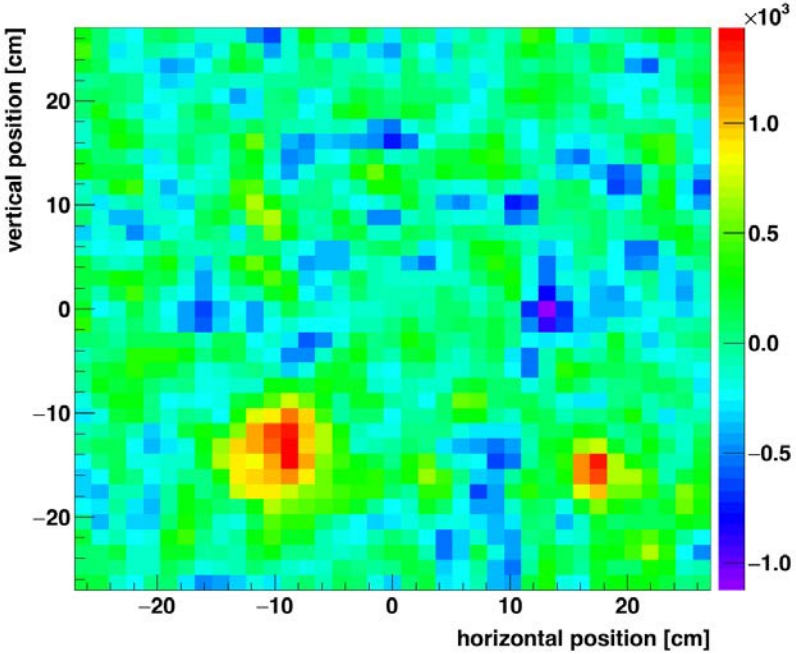
D-D Generator





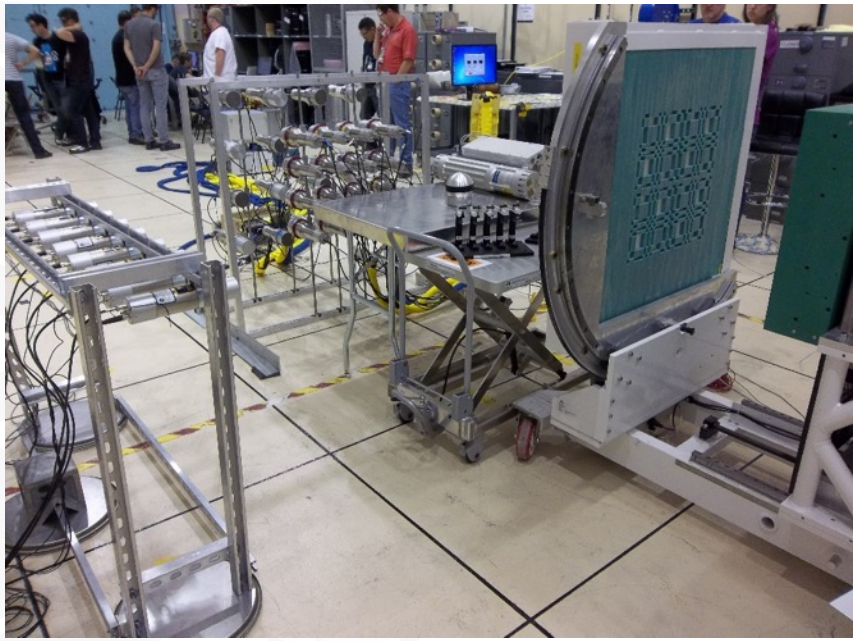
D-D Generator Energy Cut (E_{dep} > 2.75 MeV)



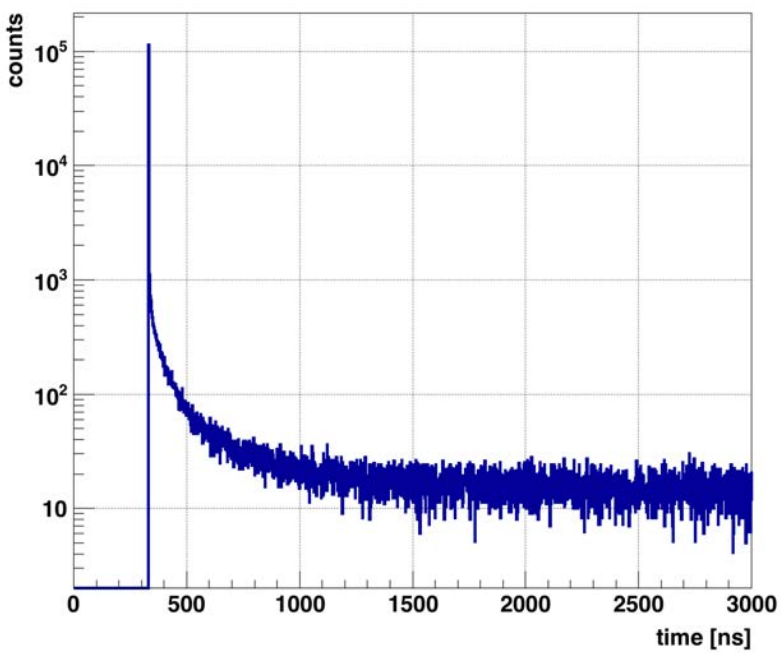


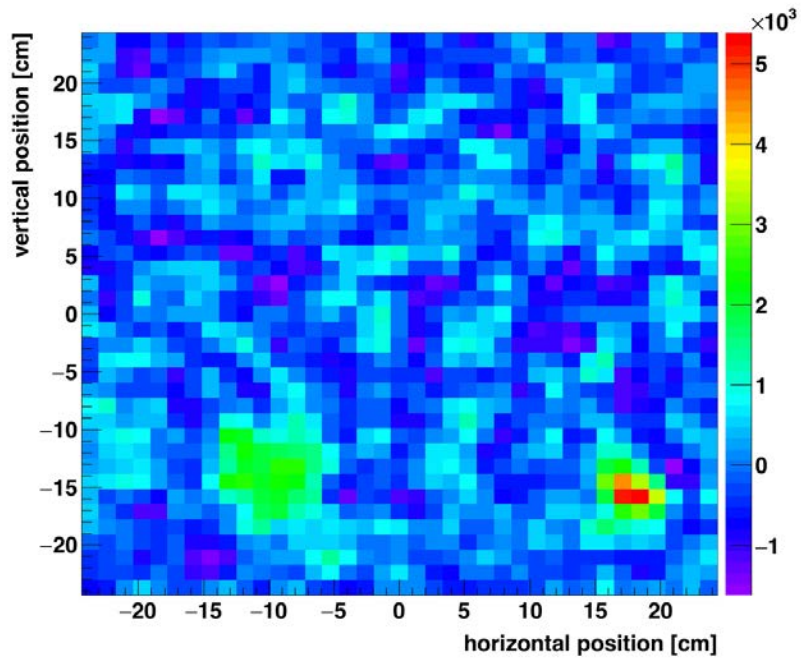
D-T Generator

- 300 Hz
- 10% duty cycle
- ~ 10^7 n/s
- Rocky Flats shells 1-24
- 1 hour run time

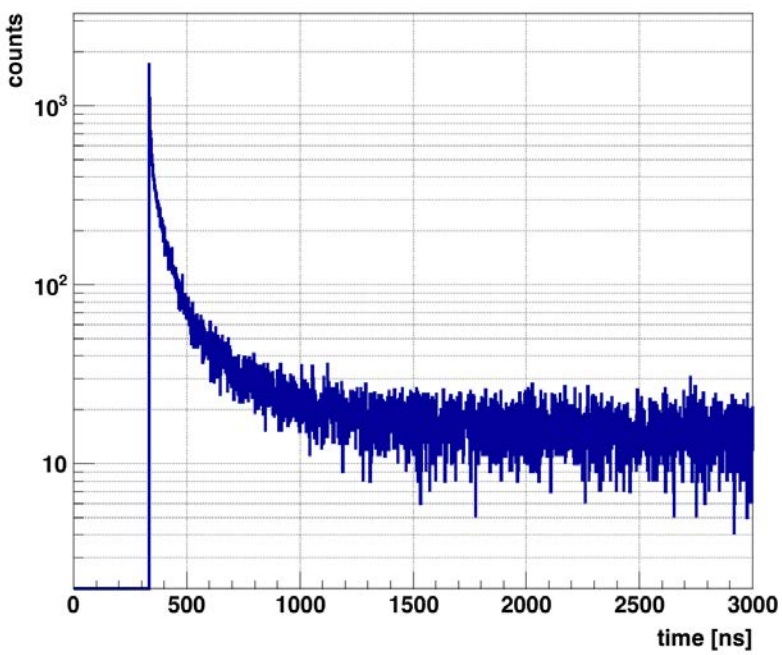


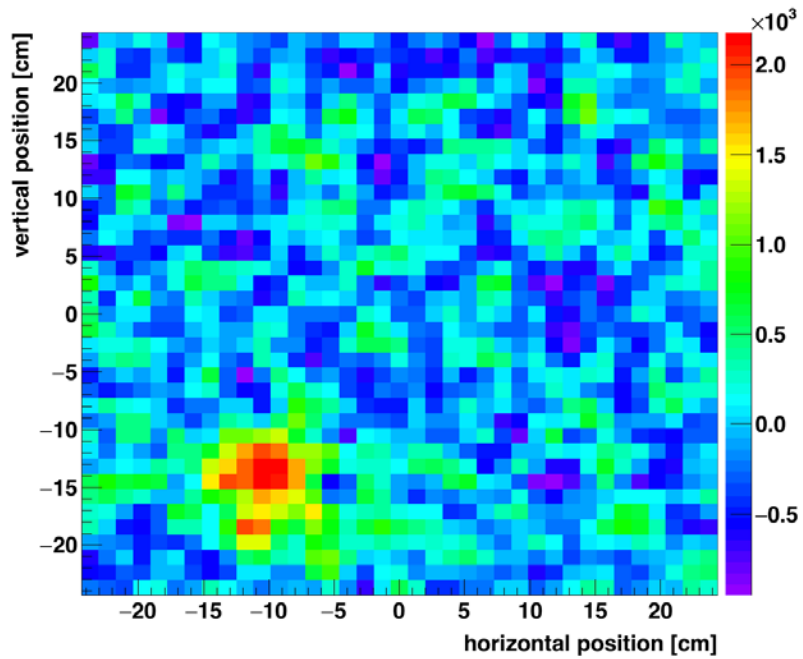
D-T Generator





D-T Generator Time Cut (t > 333 ns)

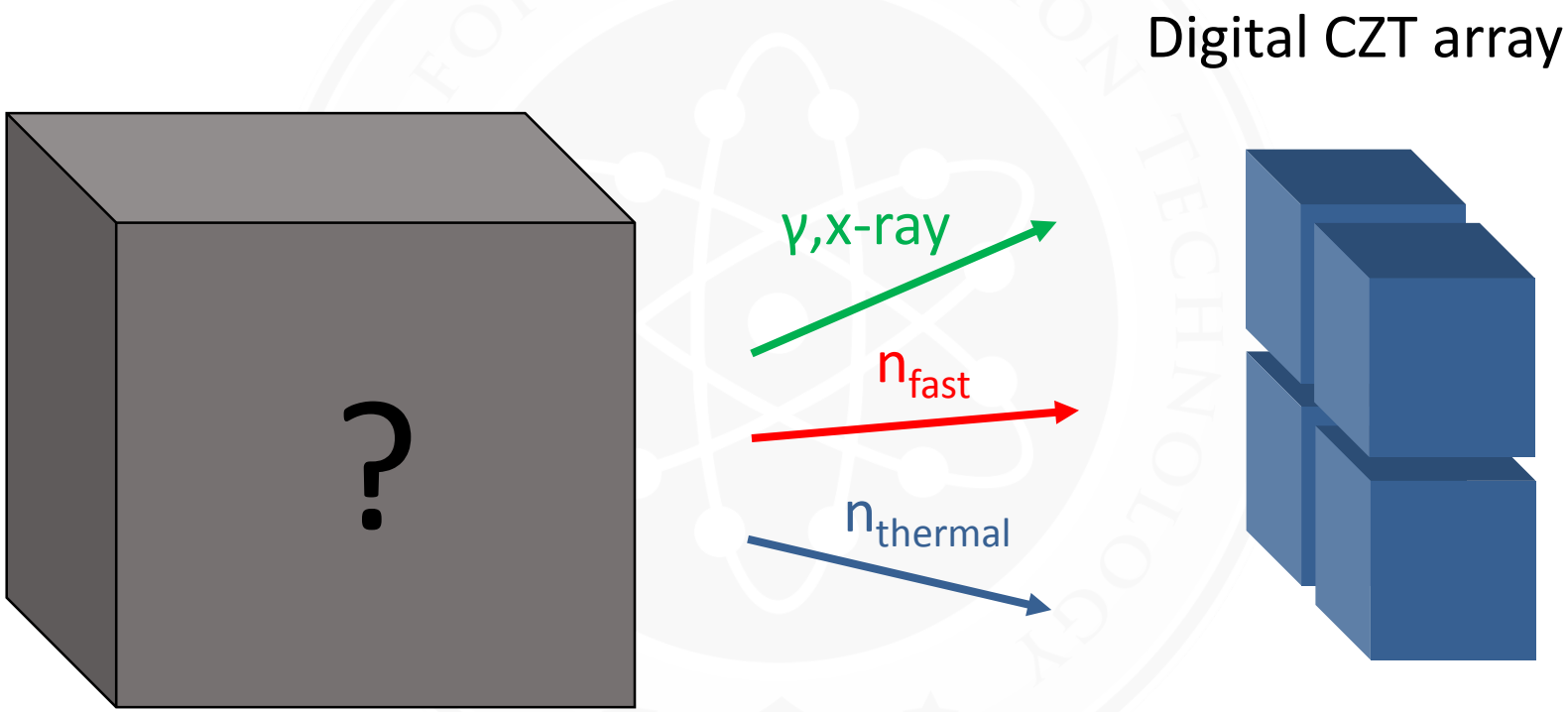




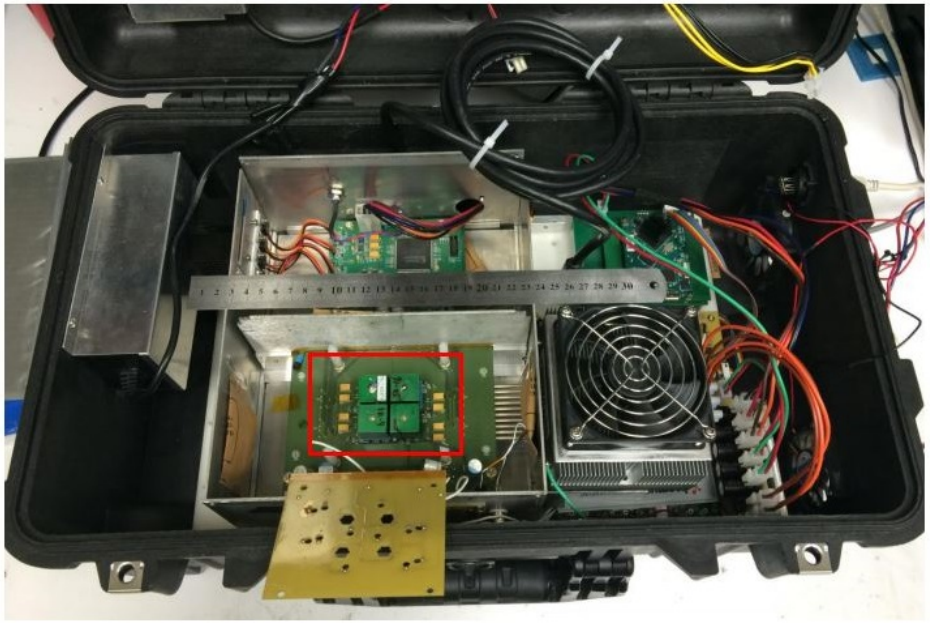
Fast Neutron Images of Fissile Assemblies

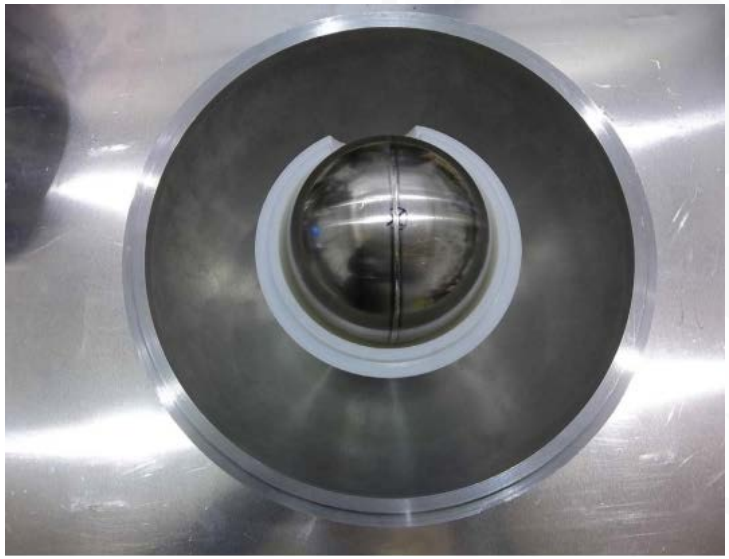
- 2016 DAF Campaign Conclusions
  - AmLi drivers may be used without cuts
  - D-D generators may be used with energy cuts
    - Best to operate in continuous mode
    - Some tritium still present
  - D-T generators may be used with time cuts
    - Must be used in pulse mode with veto
- Future Work
  - Perform simulations of 2015 DAF Campaign scenario to investigate lower bound of multiplication for which a TCPH-filtered image successfully identifies a multiplying assembly

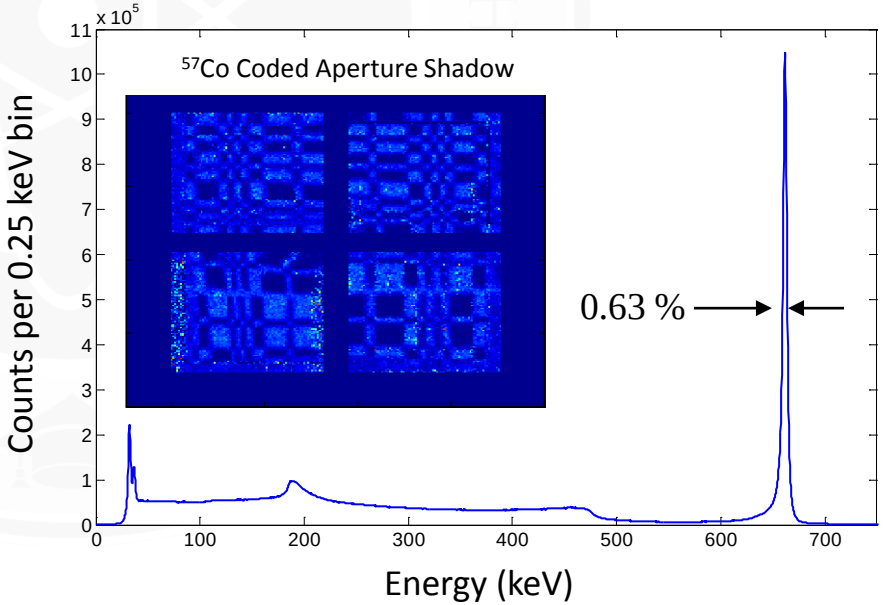
"Black Box" Complete Source Characterization



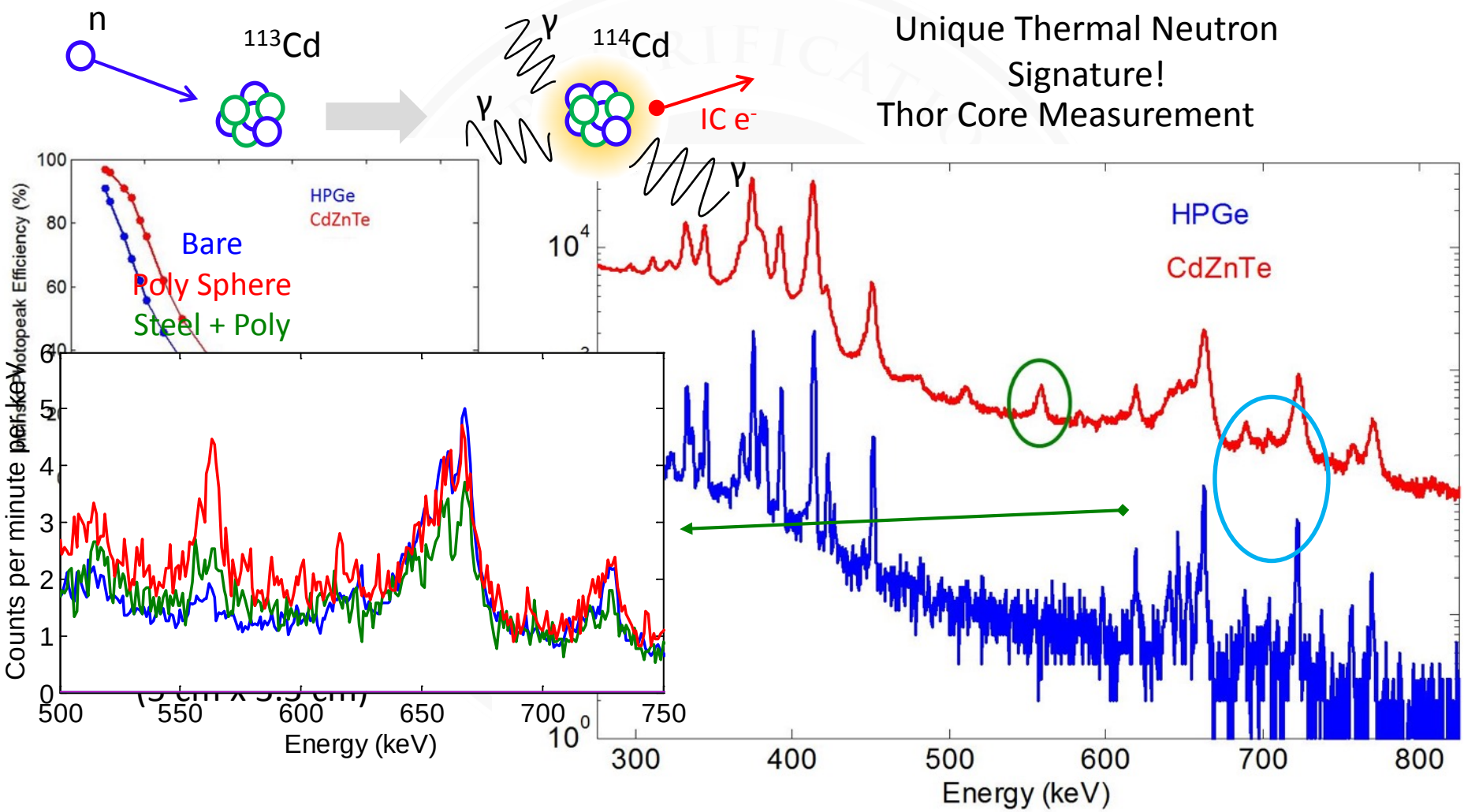
- Orion Prototype Digital CZT Array System
- Objects:
  - Rocky Flats Shells
  - BeRP Ball
  - Thor Core (2015)
  - Np Sphere (2016)





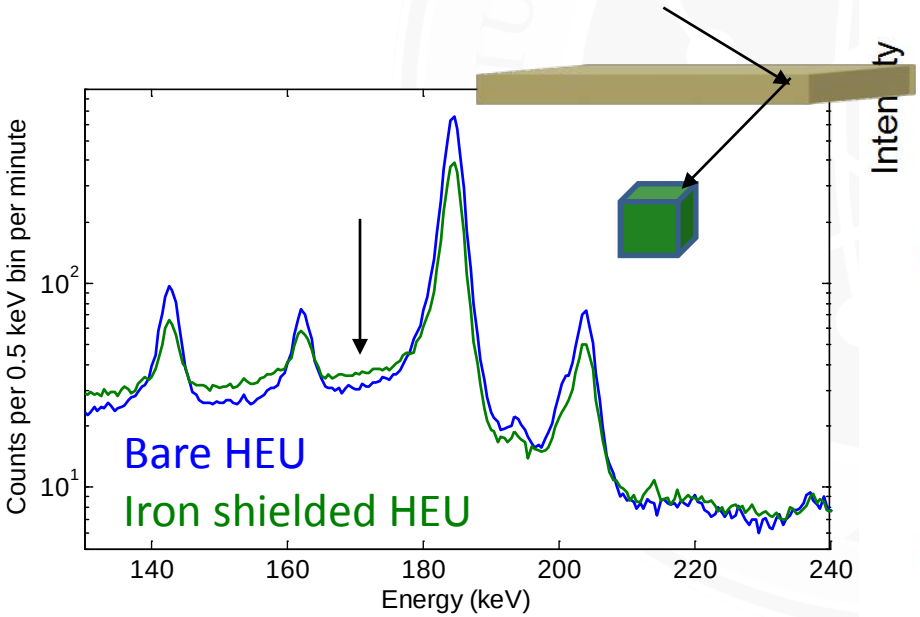


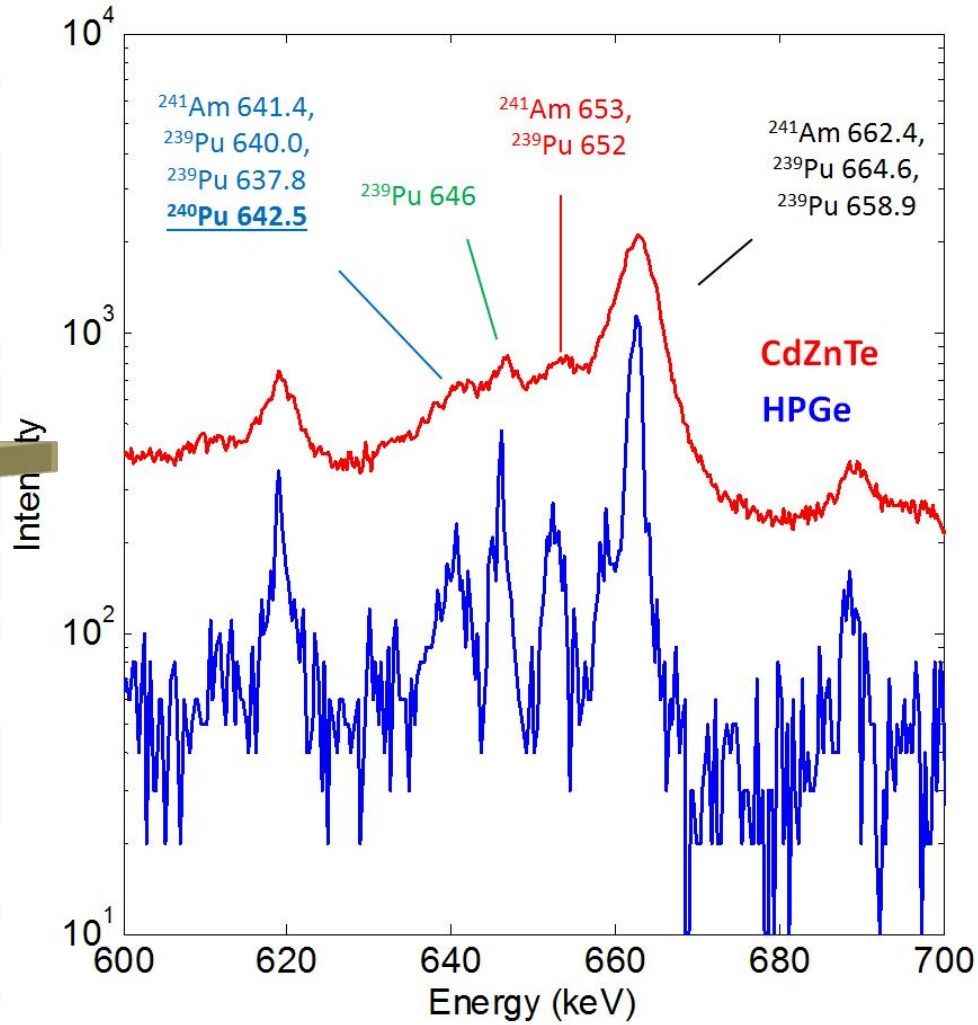
Rich Spectral Information Comparable with HPGe



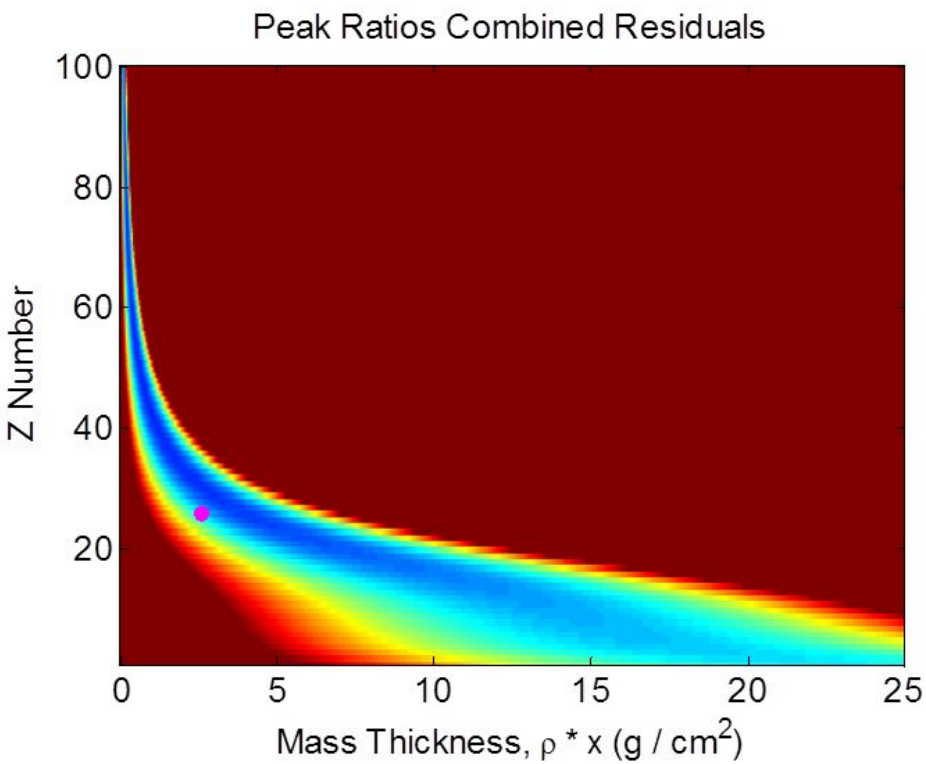
Rich Spectral Information Comparable with HPGe

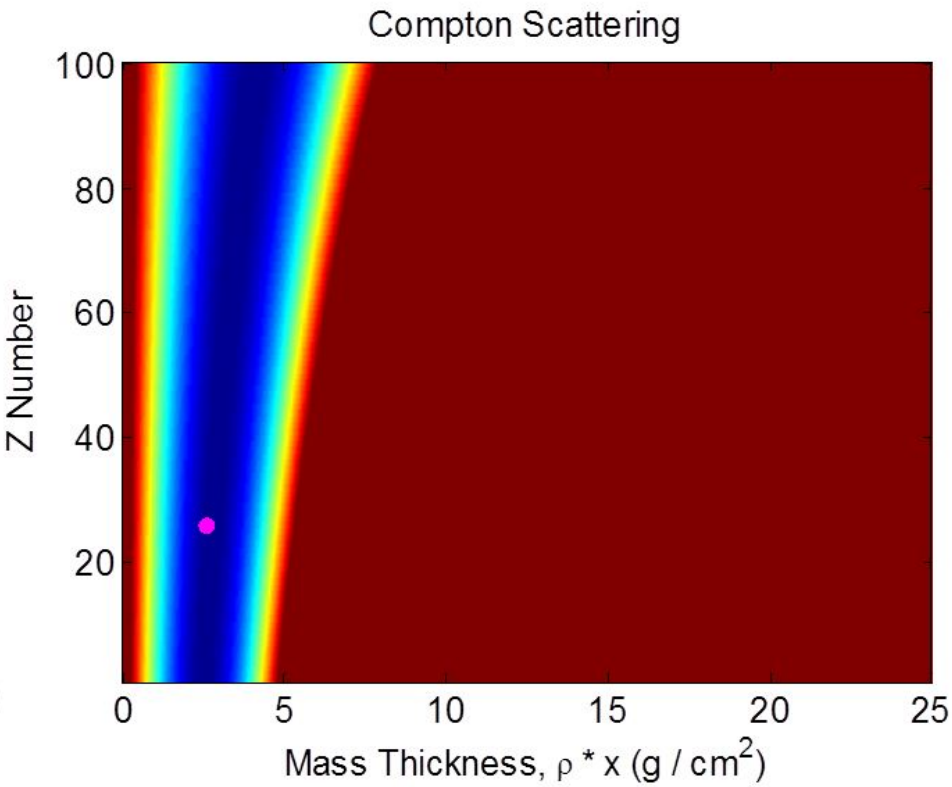
- Energy resolution sufficient to estimate ^{240}Pu
- Use spectral data to identify shielding





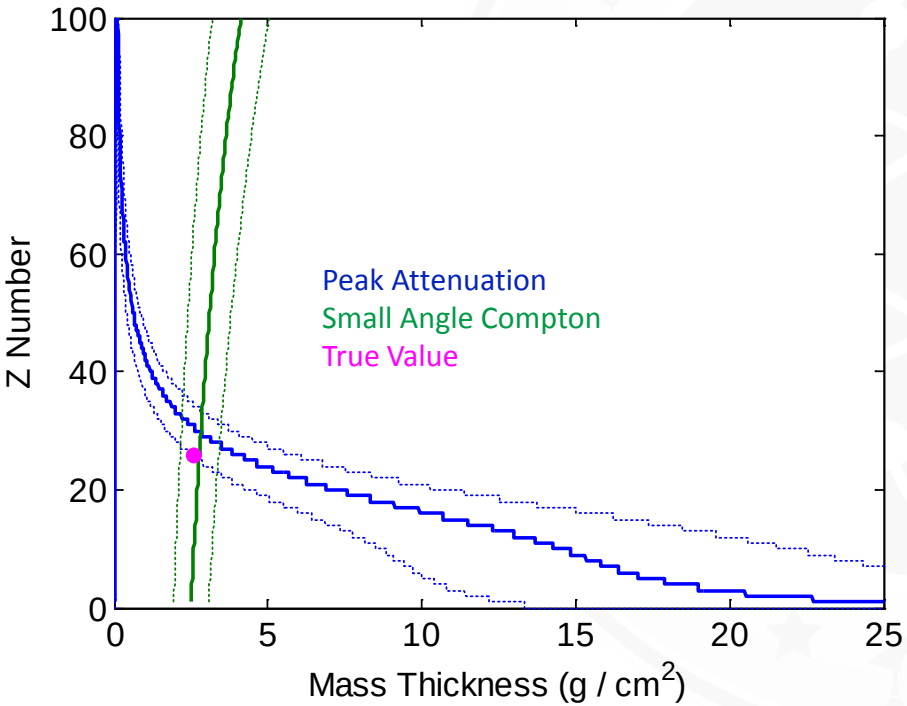
Spectral-Based Shielding Identification

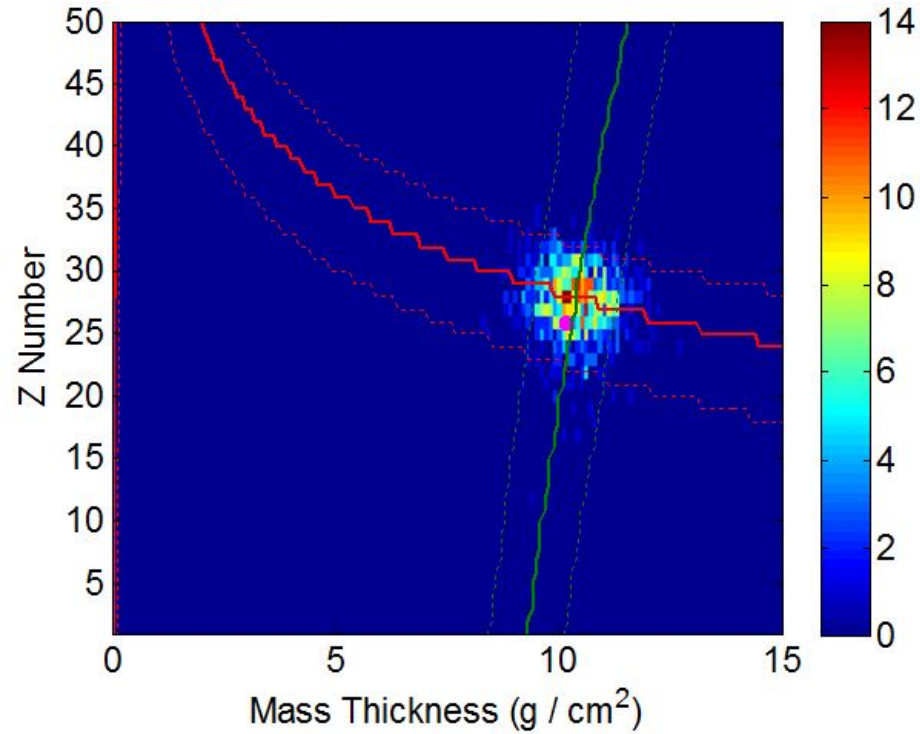




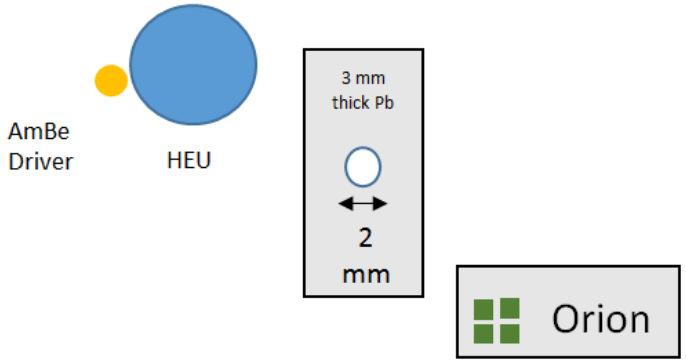
Final Shielding Identification Results

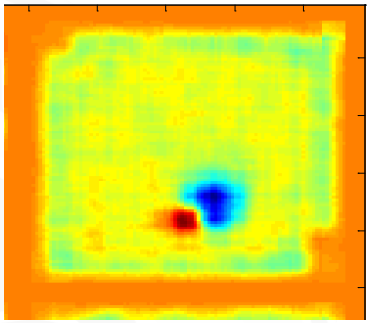
- Demonstrated on Pu, U, and Np sources

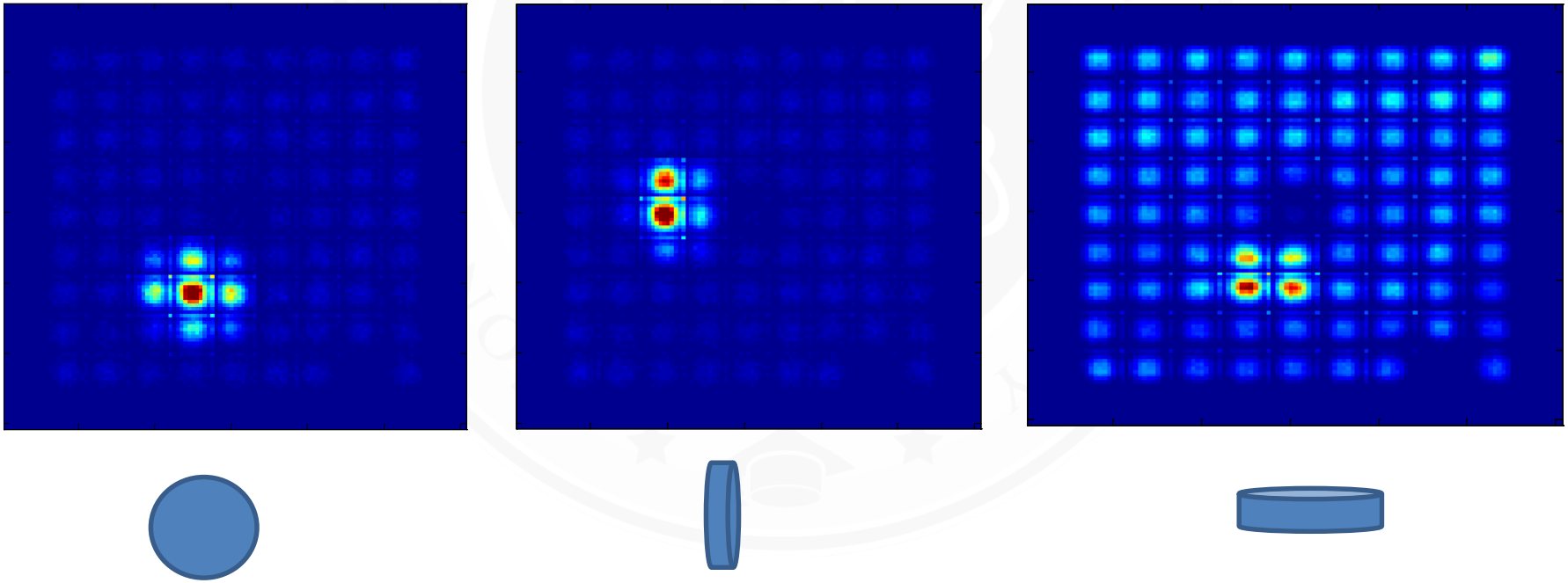




SNM Orientation through Gamma-ray Imaging

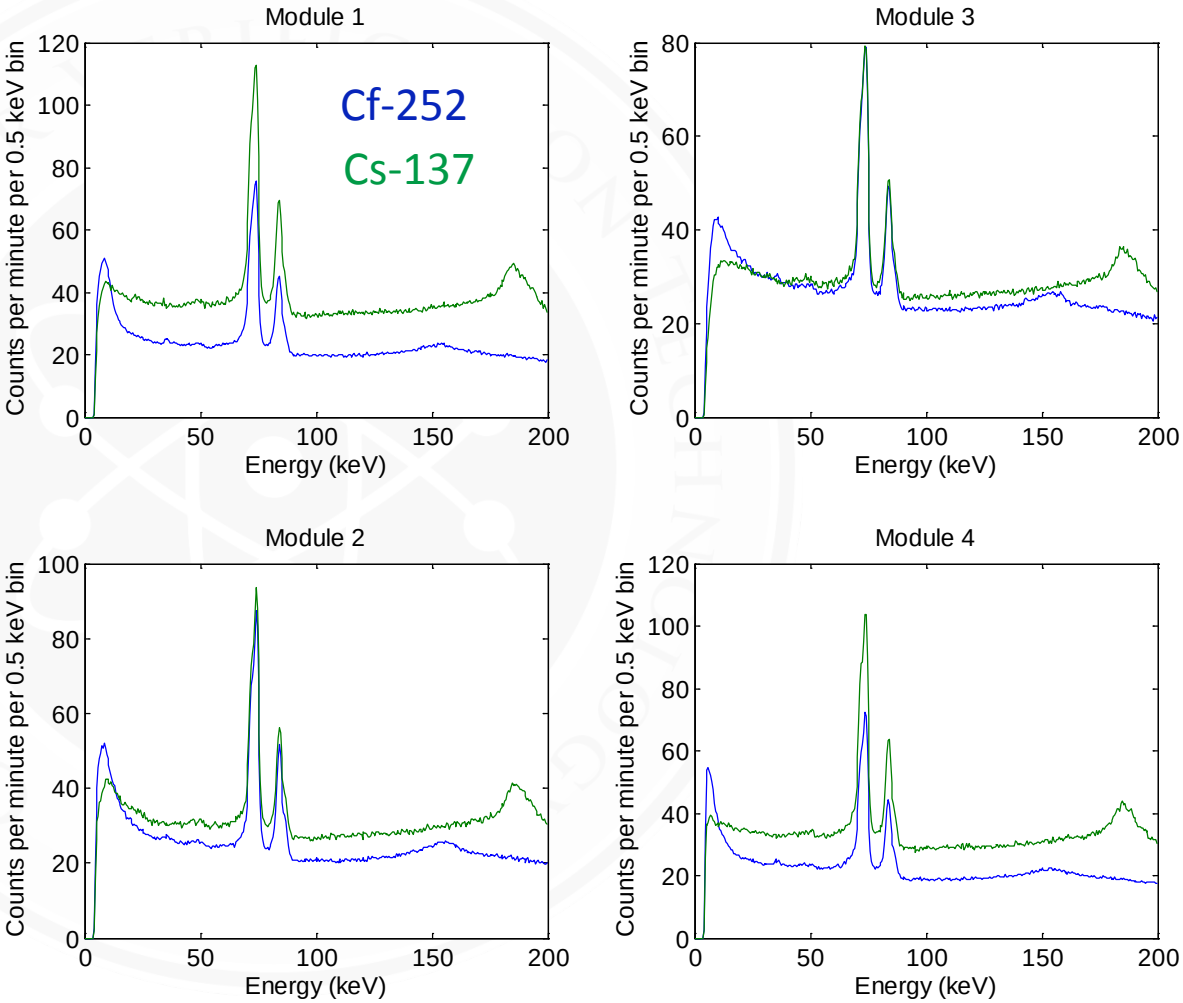






Fast Neutron Detection

- Nuclear recoil in high-Z materials generate very few electron-hole pairs
- Energy depositions less than 20 keVee are candidates
- Many experiments have confirmed fast neutron detection
  - See upcoming IEEE NSS conference



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