Fast Neutron Imaging Systems

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Fast neutron imaging systems

- Sandia has developed fast neutron imaging systems with a variety of imaging techniques:
  - Double-scatter imaging (MINER)
  - Coded aperture imaging
  - Time-encoded imaging
- These systems have different operational characteristics that can benefit:
  - Search and localization missions
  - Device diagnostic applications

MINER: the Mobile Imager of Neutrons for Emergency Response

16 independent 3”x3” EJ-309 liquid scintillator cells

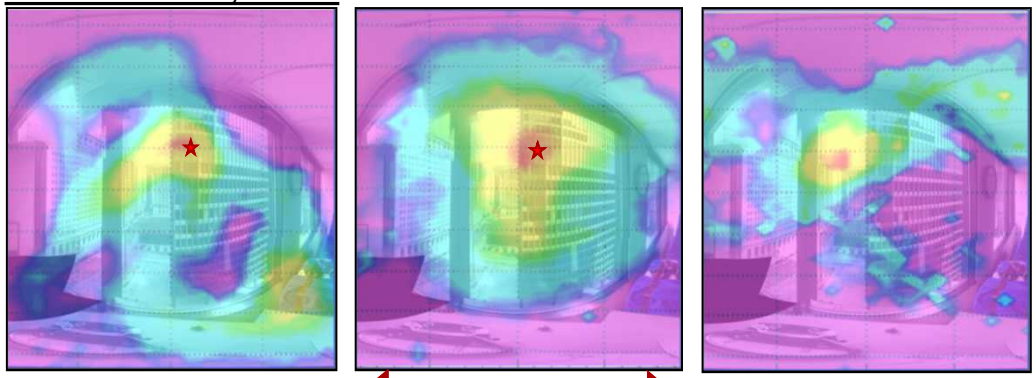
Cylinder is 36” tall, 15” diameter when closed

MINER generates images of neutrons and gammas

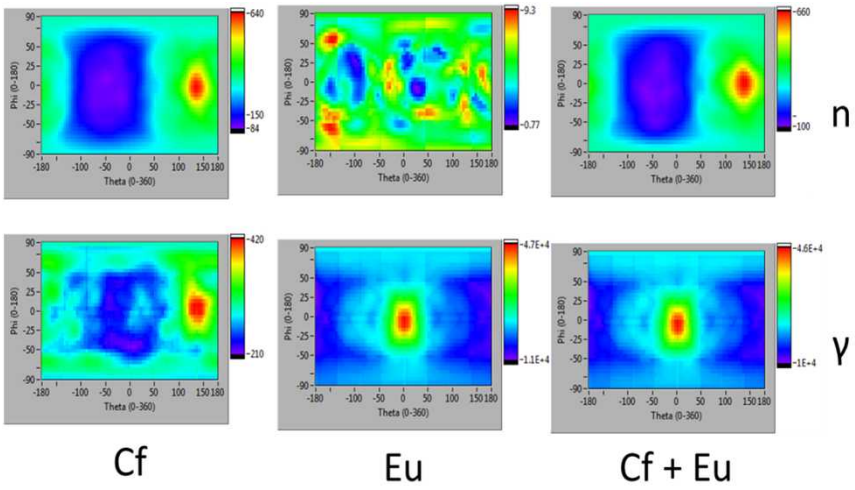
^{252}Cf unshielded, 30 min

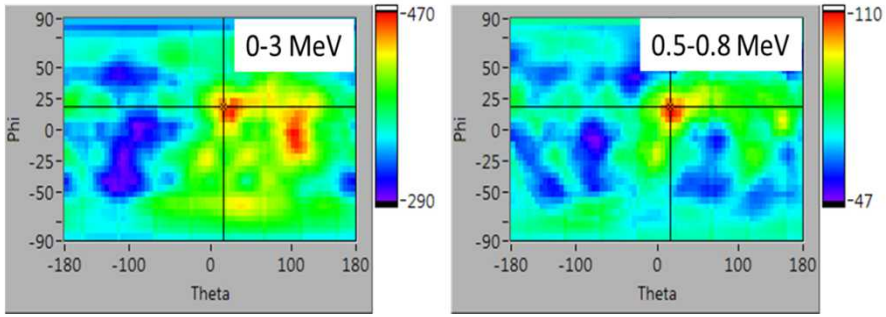
^{252}Cf through 4" poly, 618 min

10-hour background (dominated by open sky to left of building)



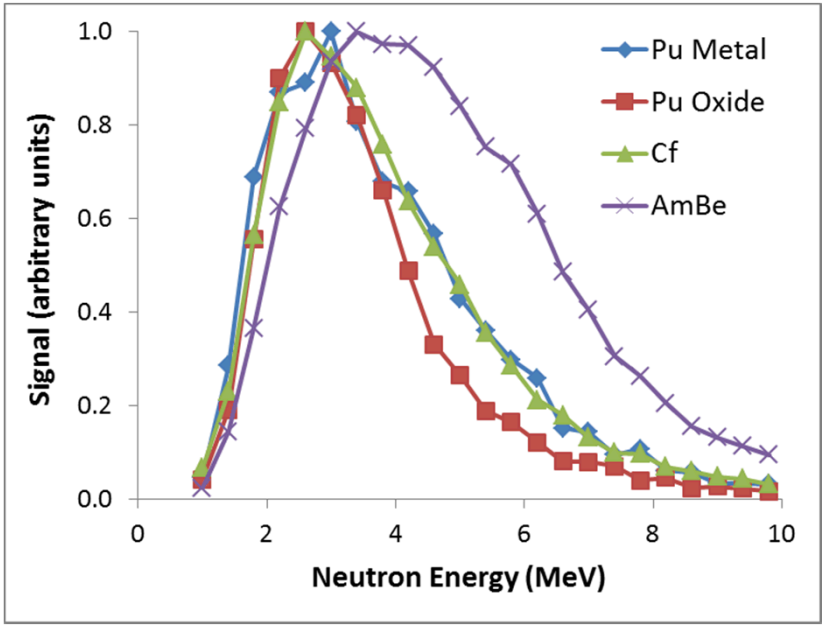
Lab demonstration with ^{252}Cf and ^{152}Eu

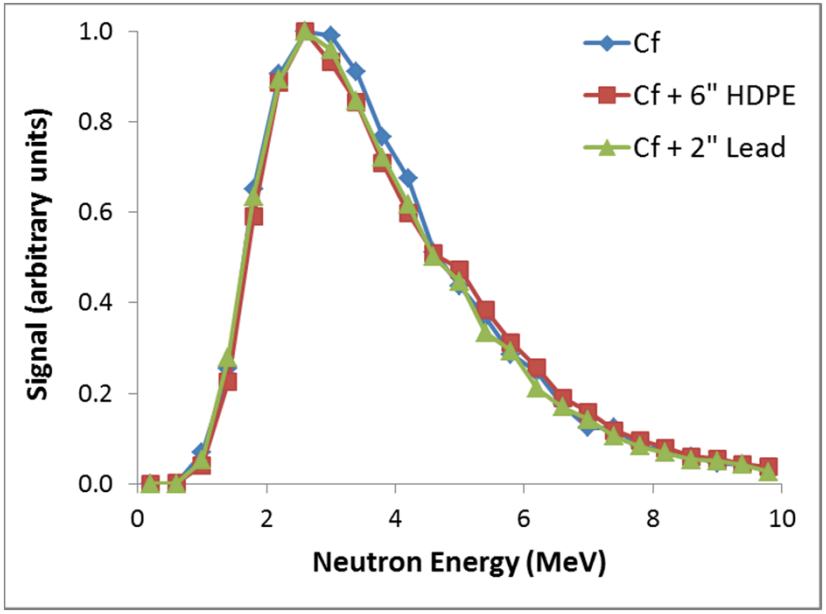




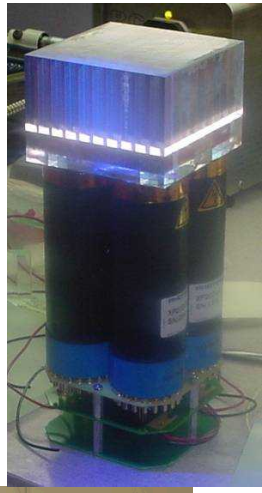
Building-to-building demonstration with ^{252}Cf and ^{137}Cs

MINER spectrum measurements: sensitive to SNM chemical form, but not intermediate material



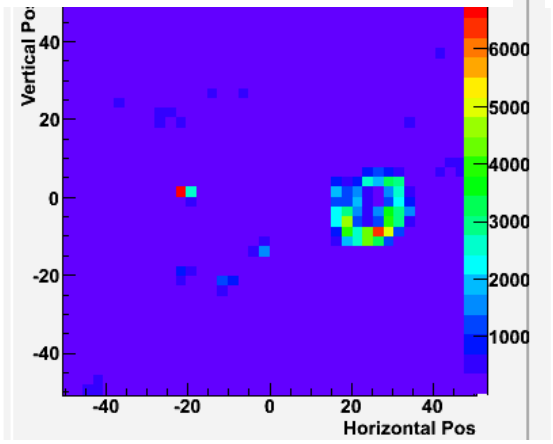


Neutron coded aperture imager

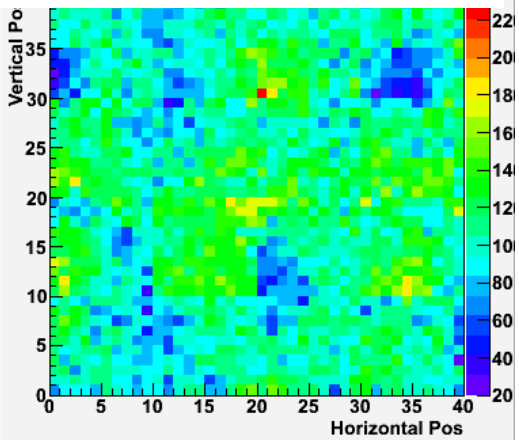


- ORNL/SNL fast neutron coded aperture imager developed for arms control treaty verification.
- Image plane consists of 16 organic scintillator pixelated block detectors
  - Each block consists of a 10x10 array of 1 cm. pixels.
  - PSD and pixel id accomplished by 4 photomultiplier tubes.
- Mask plane consists of 2.5 to 10 cm of HDPE.

Reconstructed image



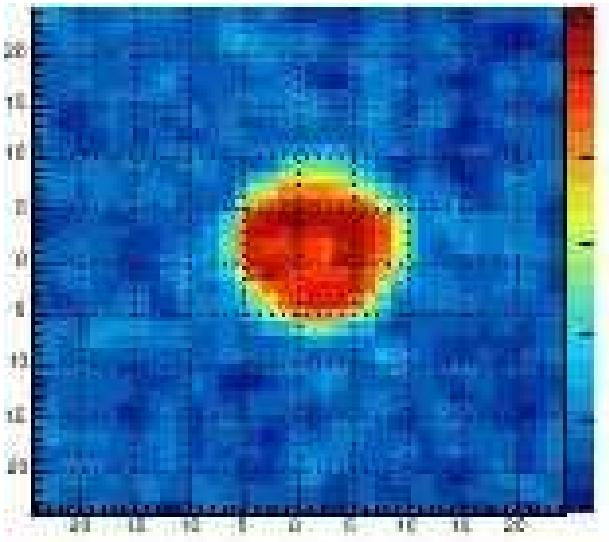
Raw counts



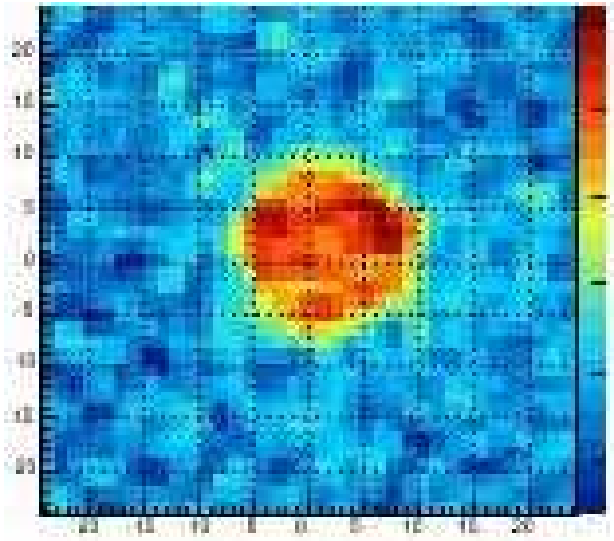
Detector developed in collaboration with ORNL: P. Hausladen, J. Newby, M. Blackston

Imaging of an unclassified Pu oxide item provides useful information

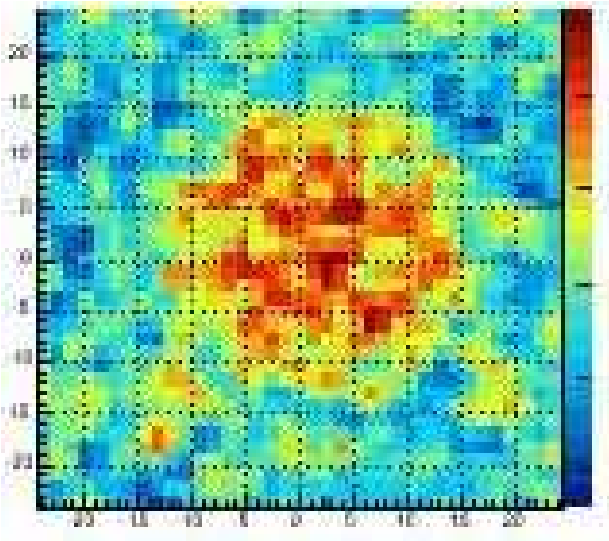
Gamma image: maps SNM surface



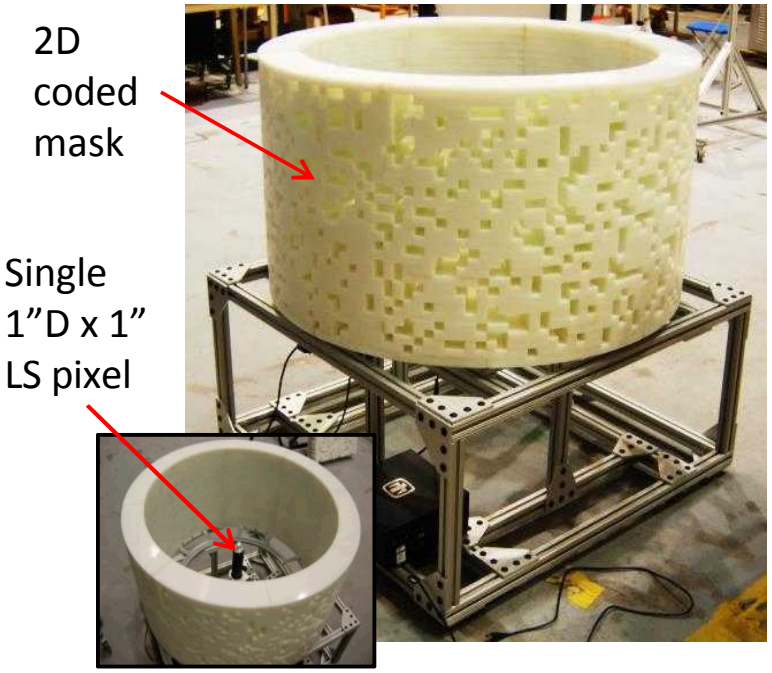
Fast neutron image: structure of extended SNM source



Thermal neutron image: extent of hydrogenous material

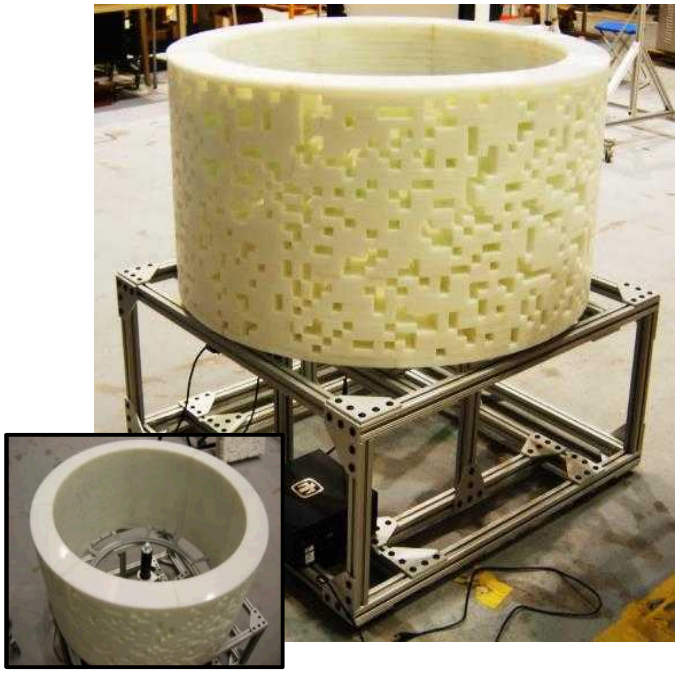


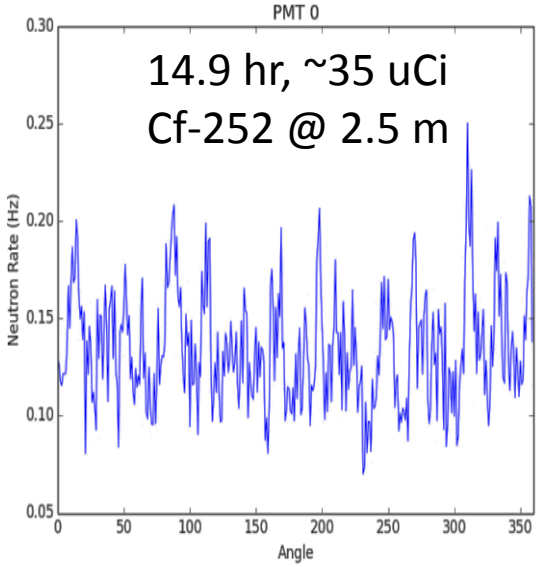
2D Time-Encoded Imaging: high resolution with design tradeoffs



- TEI uses a rotating mask that generates time-modulation on a single detector
- Compared to coded aperture imaging, which produces spatial modulation on a detector plane:
  - Added complexity: moving mask, mask mass
  - Simple electronics: detection plane and readout use one/a few channels
    - Cheaper
    - Calibration remains self-consistent
  - Longer dwell times

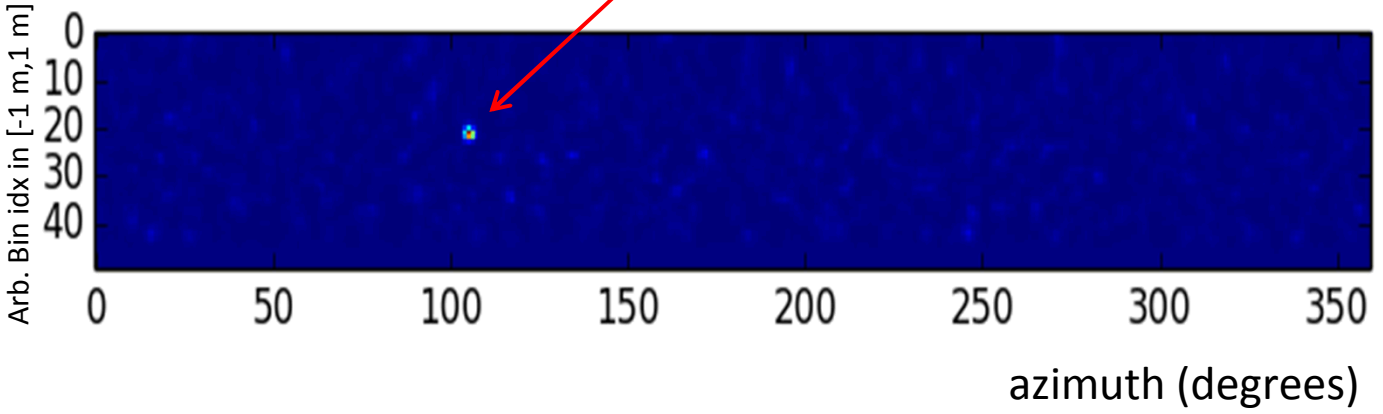
A simple TEI-2D example





Single pixel rate is modulated by the mask as it rotates.

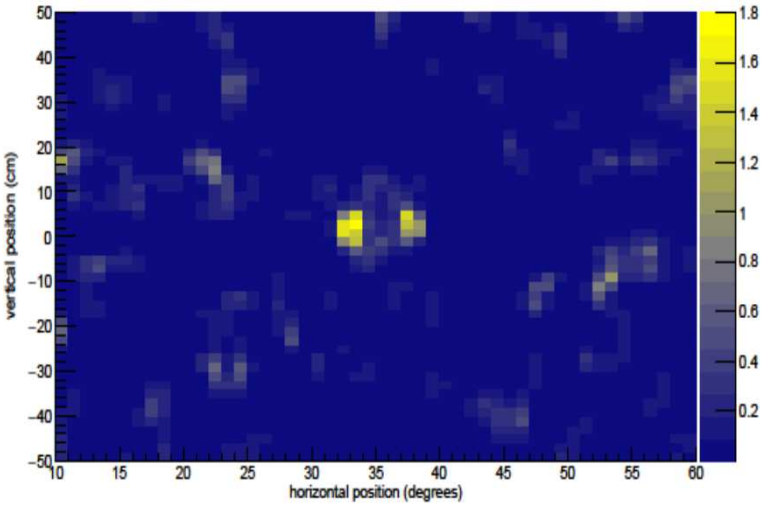
Modulation pattern is unfolded to 2-D image



TEI-2D: spatial information

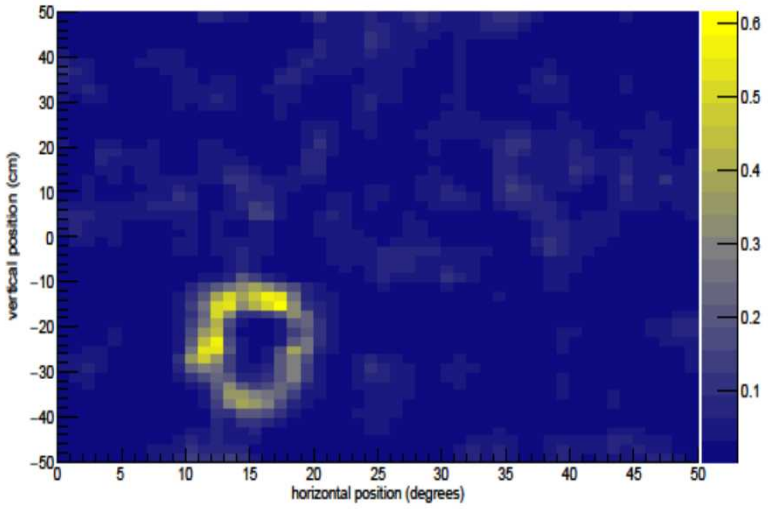
Two 1.4e5 n/s ^{252}Cf point sources at 2 meters standoff.

5 degree separation in 1 hour (50 mlem iterations)



A single 1.4e5 n/s ^{252}Cf point source moved through an extended pattern at 2 meters.

72 hours (100 mlem iterations)



Some topics for collaborative efforts

- Imaging systems have shown promise, but more work is needed to make them fieldable and optimized to the mission space.
  - Hardware development:
    - Need to take advantage of SiPM technology for minimizing volume of readout system/eliminate need for HV.
    - What is the lower size limit for a useful coded aperture system?
  - Algorithm development:
    - Direct queries of raw pixel maps vs. reconstructing images; sometimes we call this task-based imaging
    - Uncertainty quantification
  - Joint technology demonstrations of imaging systems with interesting objects/measurement scenarios.