Stand-off Nuclear Radiation Detection

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Approaches To Brookhaven National Laboratory

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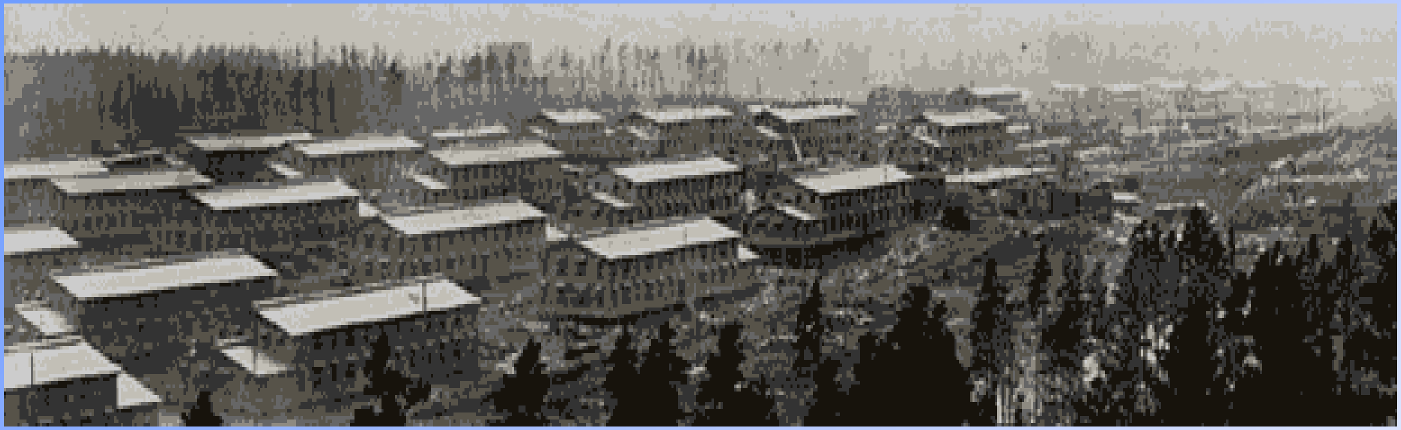
Camp Upton

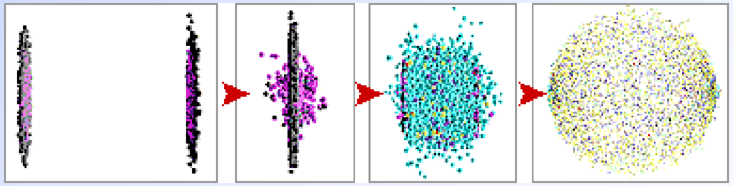


- Established in 1947 on Long Island, Upton, New York, Brookhaven is a multi-program national laboratory operated by Brookhaven Science Associates for the U.S. Department of Energy (DOE).

- Six Nobel Prizes have been awarded for discoveries made at the Lab.

- Brookhaven has a staff of approximately 3,000 scientists, engineers, technicians and support staff and over 4,000 guest researchers annually.

- Brookhaven National Laboratory's role for the DOE is to produce excellent science and advanced technology with the cooperation, support, and appropriate involvement of our scientific and local communities.



Collision of gold nuclei at RHIC

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Lab work with Industry:
Radiation Portal Monitor Testing and Evaluation

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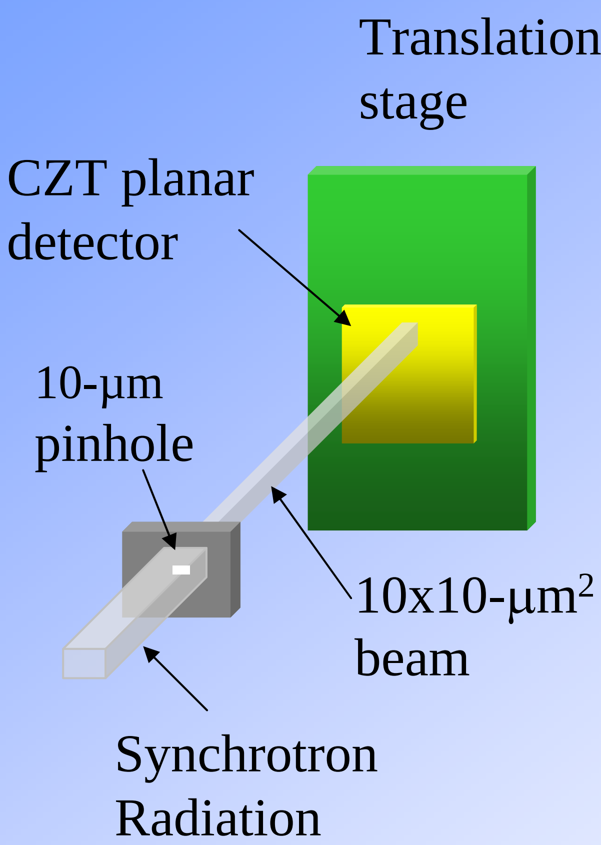
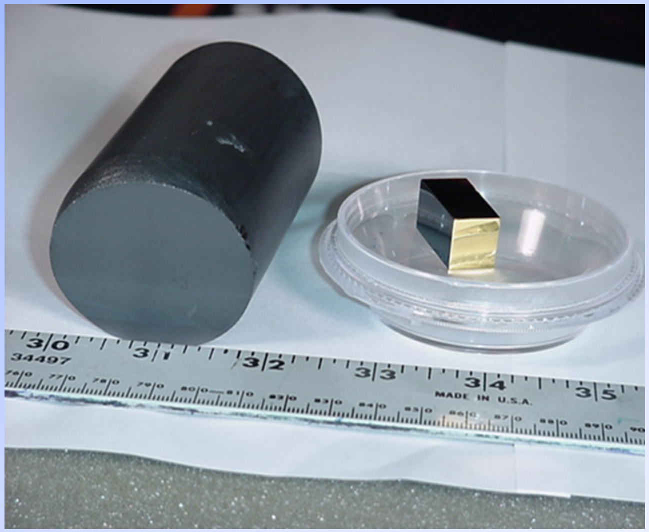
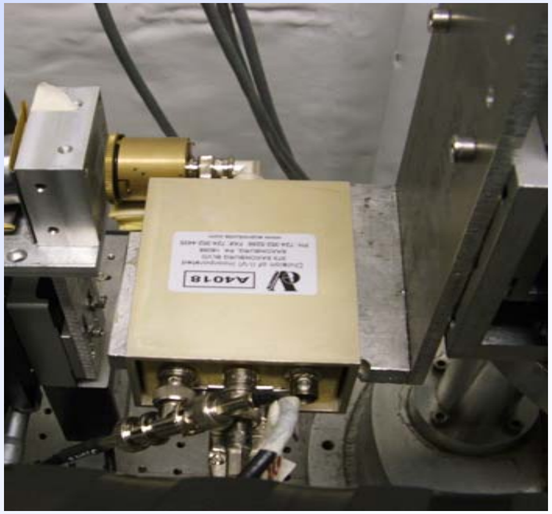
Lab work with Industry: Cadmium Zinc Telluride material evaluation







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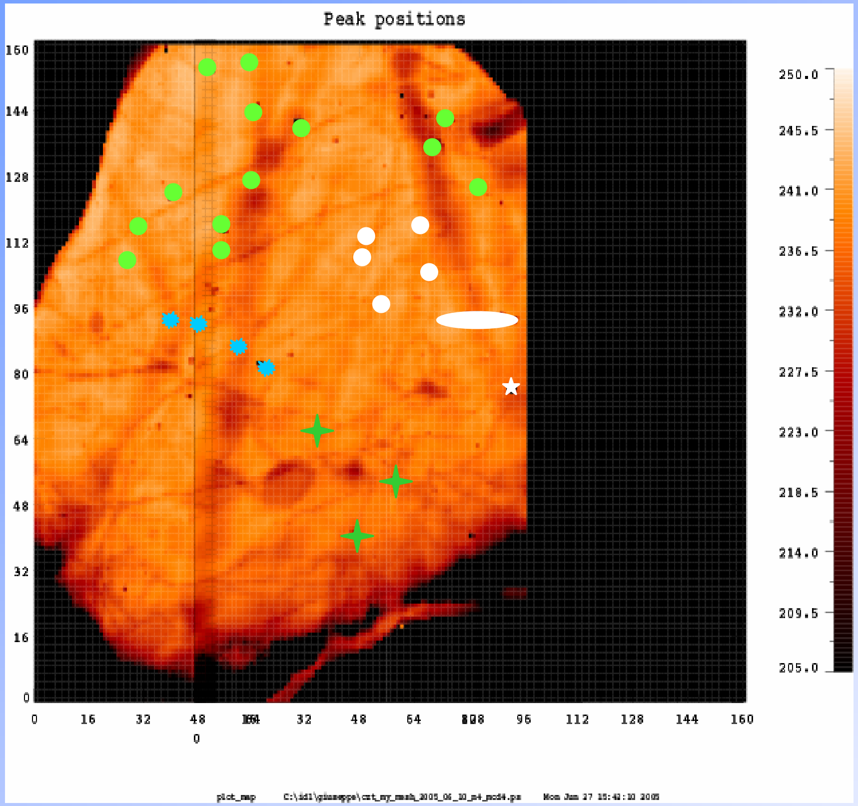
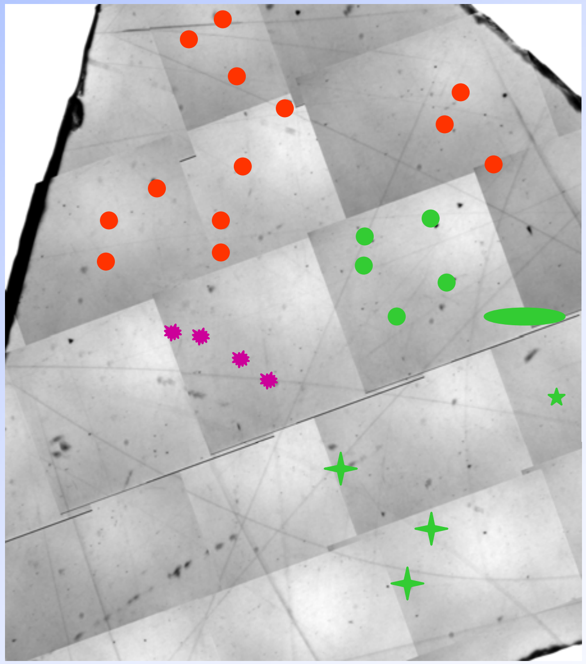
Correlations between x-ray map & IR image

This x-ray map shows the degraded regions precisely correspond to Te precipitates on the right

This IR image shows Te precipitates, which could be identified by shape with IR microscope





100% correlations were found for all CZT samples tested in this work.

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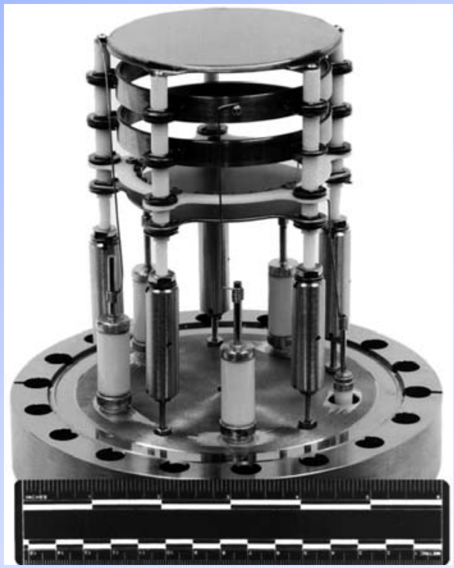
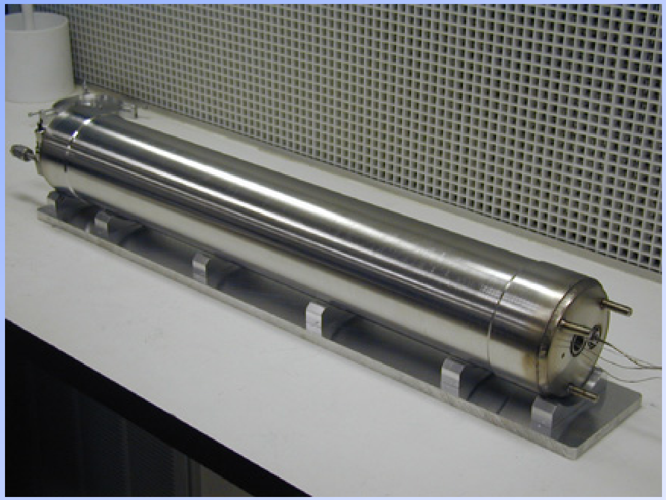
Lab Work with Industry – Compressed Xenon Spectrometers

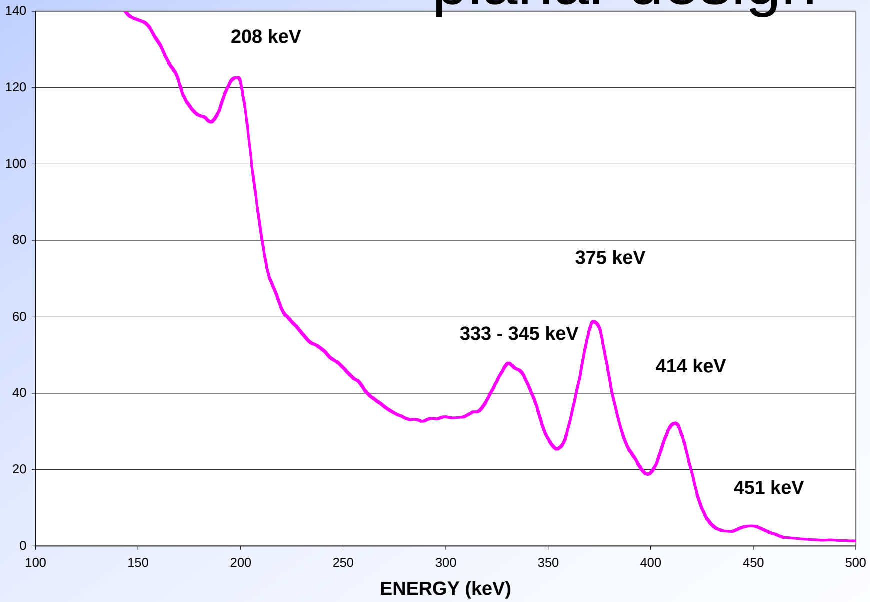
- Operate at room temperature
- Sufficient resolution to identify isotopes
- Scalable to large volumes - increased sensitivity
- Identify special nuclear materials
- Allow passage of medical isotopes
- Allow naturally occurring radioactive materials
- Reduce false positive rate



planar design



CTC coaxial design



Pu-239 spectrum using xenon

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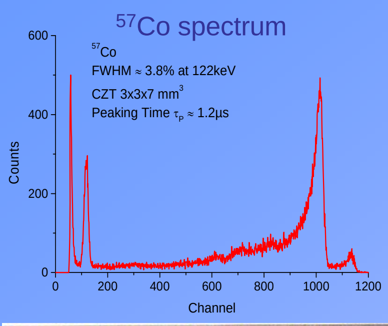
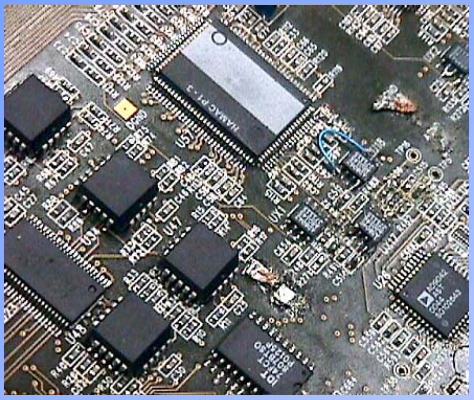
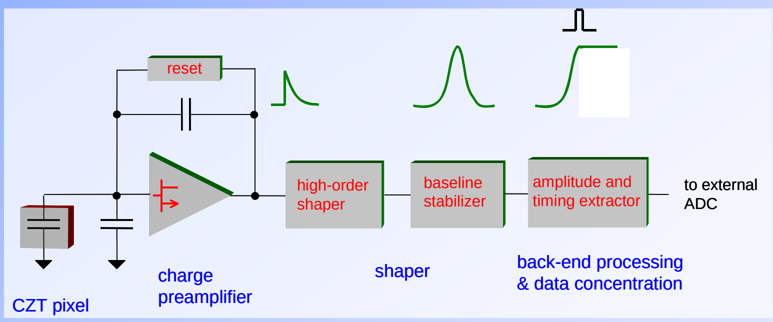
High-speed, radiation-tolerant sampling/digitizing board





240-channel multichip module for Si drift detector readout

Low-power ASICs



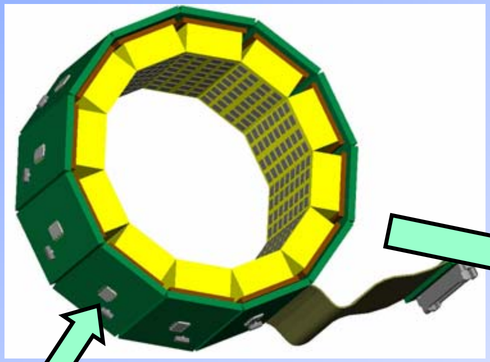
Preamplifier/shaper ASIC block diagram

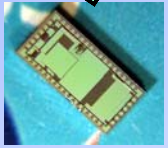
Microelectronics Group

AREAS OF EXPERTISE

- **CMOS monolithic circuits**
- **charge-sensitive sensor interface**
- **analog signal processing**
- **low noise, low power techniques**
- **VLSI custom design + layout**

Gamma Imaging

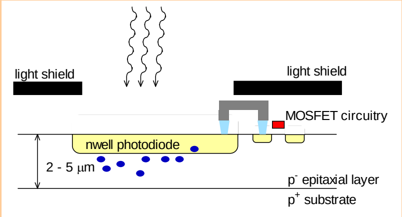




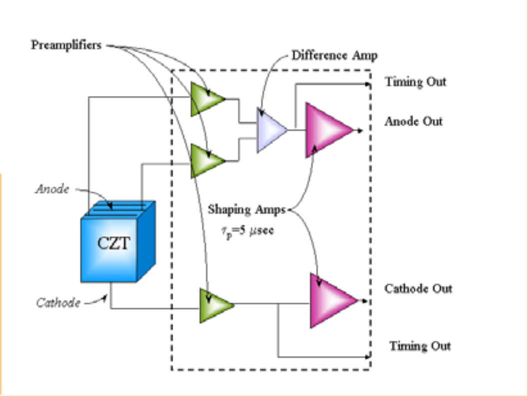
Positron emission tomograph for imaging the awake animal brain

National Security

Handheld imaging probe for gamma radiation



Radiation sensitive pixel readout

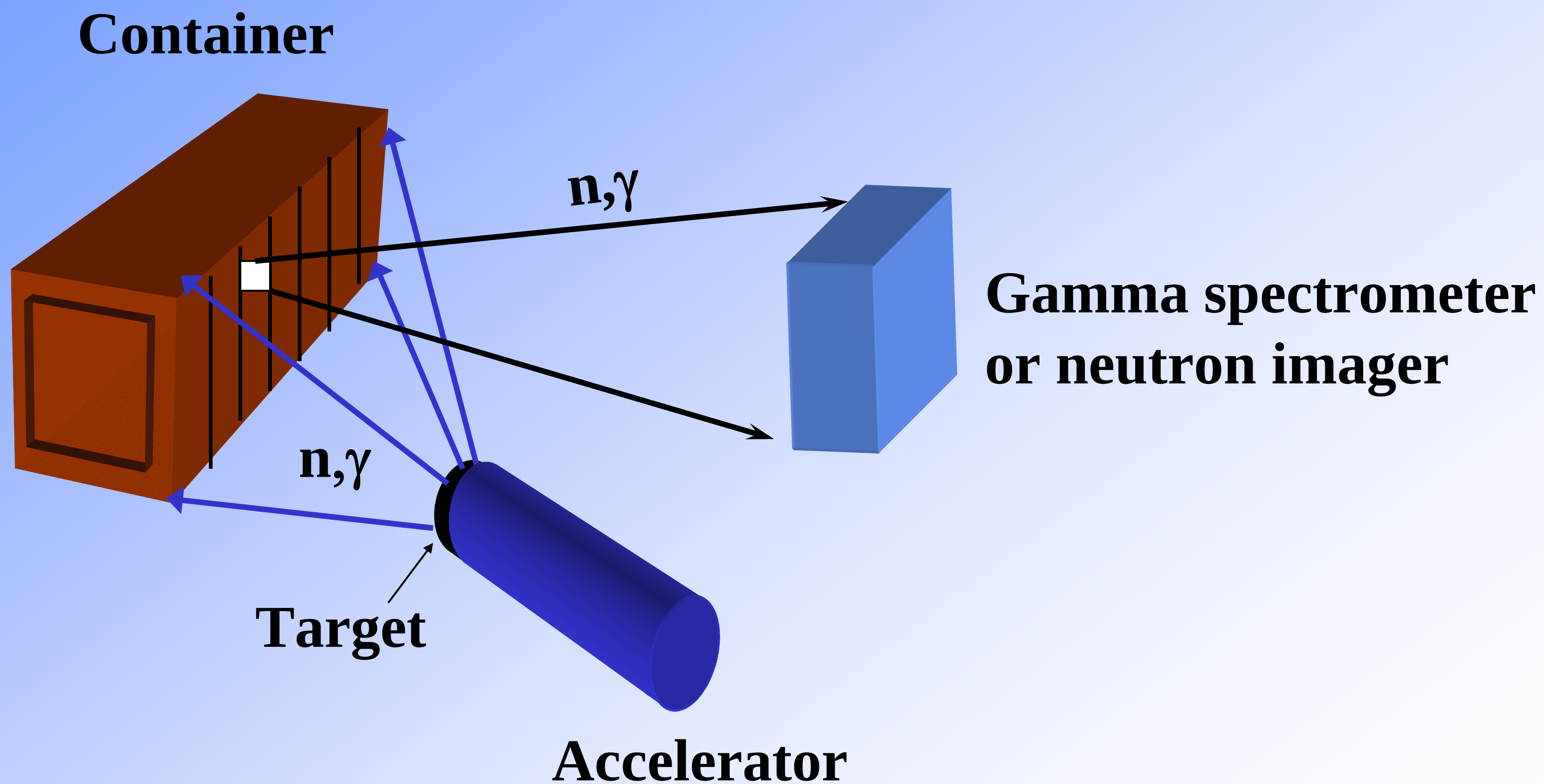


Gamma spectrometer for detection of nuclear materials

Technology investment by BNL that can be helpful in solving SOLIC challenges

- Assume that terrorists will use any means to get attention, including radioactive materials
- Develop of new radiation detectors
  - Gamma spectrometers
  - **Neutron imagers**
- Improve interdiction of radioactive materials traffic
  - Force protection from Radiation Dispersal Devices
  - Force protection from Improvised Nuclear Devices

Interrogation of containers and trucks



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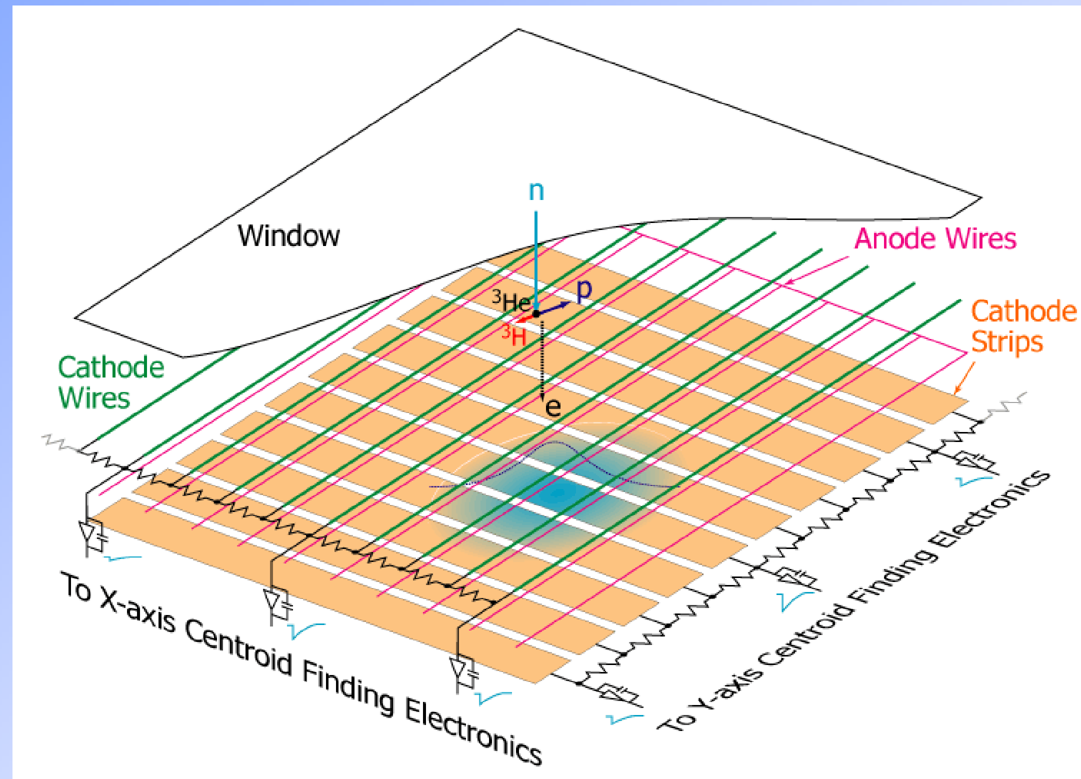
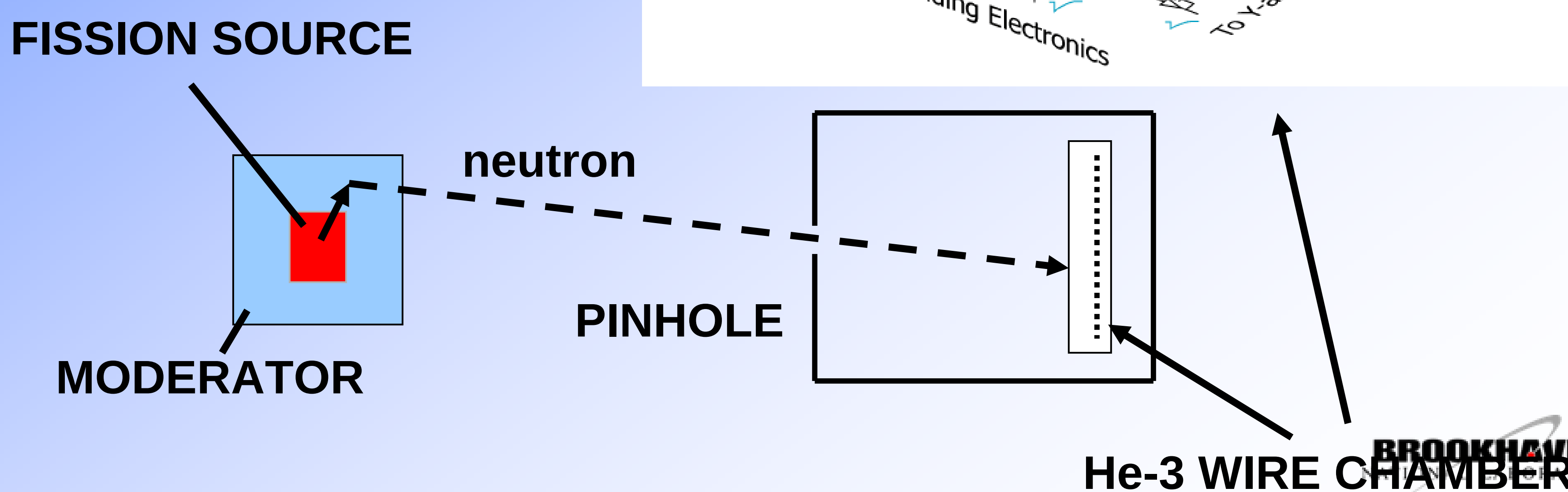
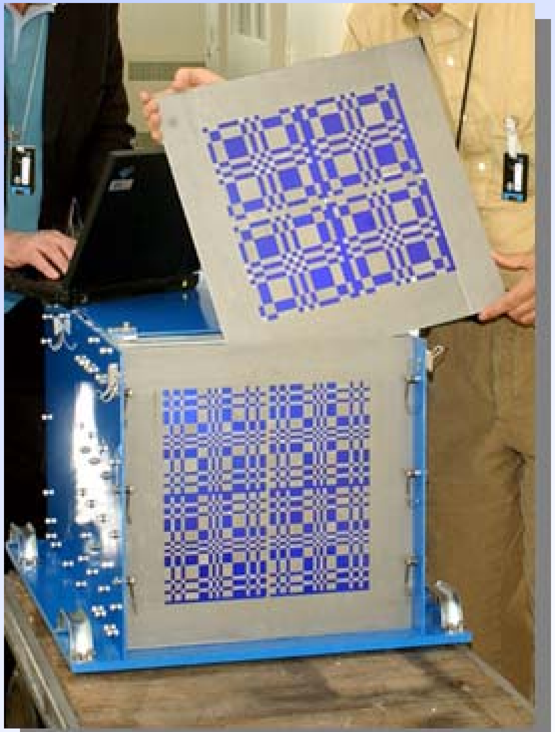
Directional Detection and Imaging

- Pinhole camera
- Poor sensitivity



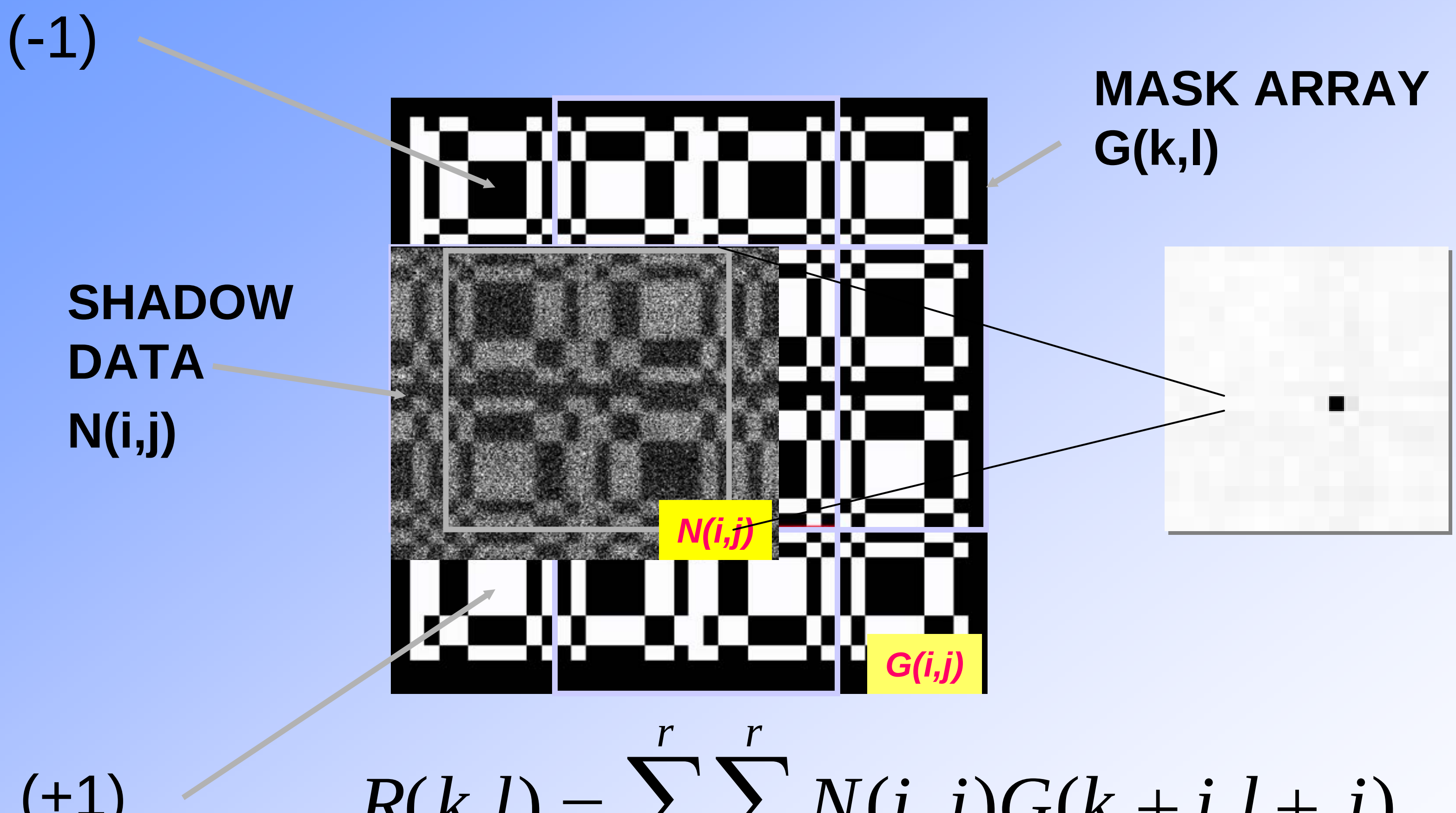


Thermal Neutron Imager



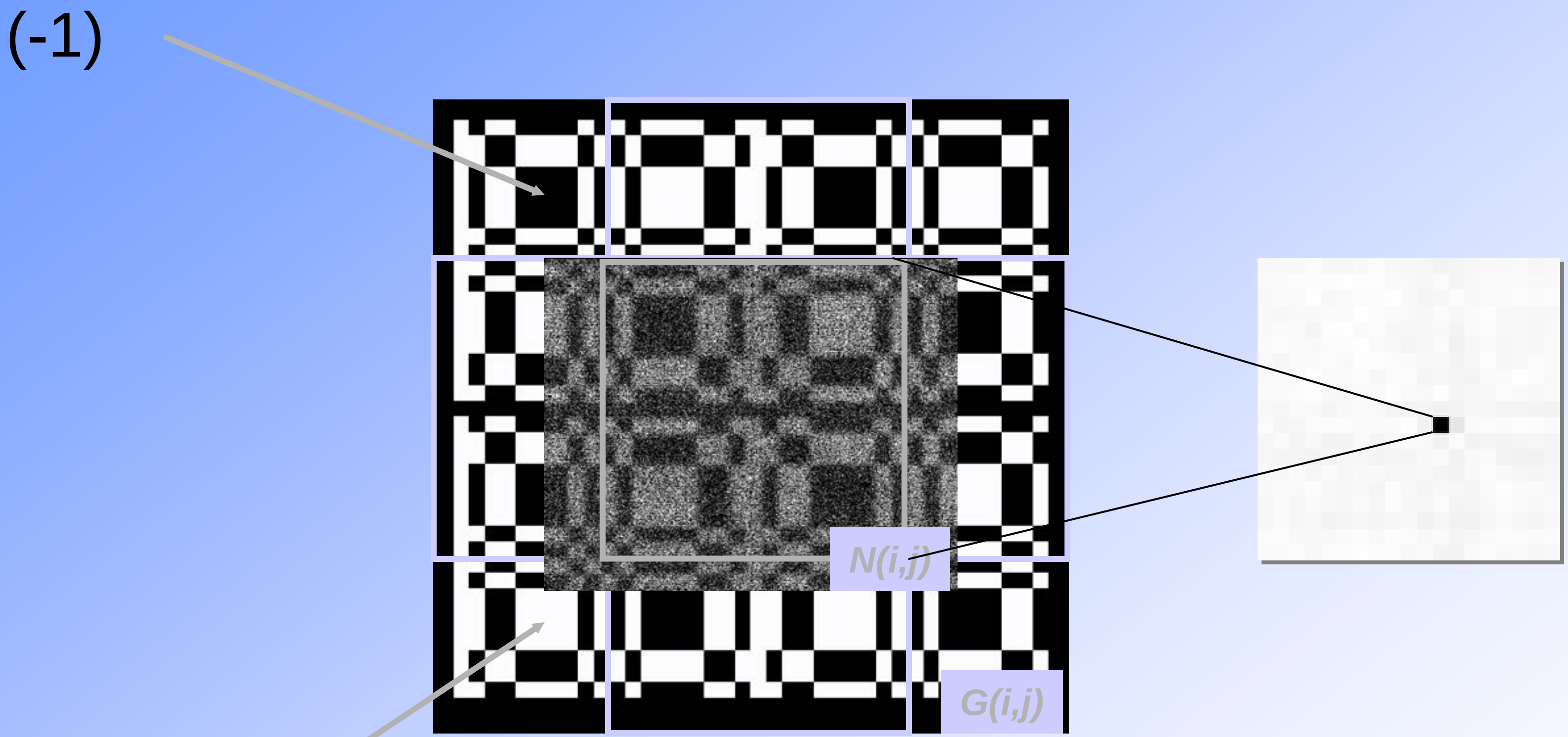
4. Cadmium-lined coded aperture camera

Reconstructing the image from the shadowgram



$$R(k,l)=\sum_{i=1}^{r}\sum_{j=1}^{r}N(i,j)G(k+i,l+j)$$

Reconstructing the image from the shadowgram



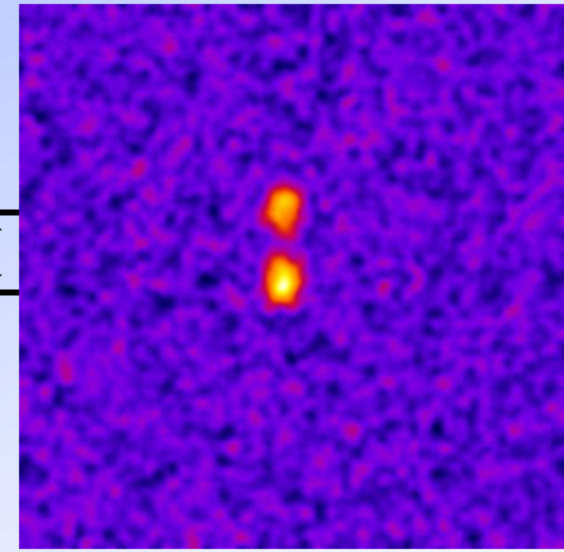
$$R(k,l) = \sum_{i=1}^{r} \sum_{j=1}^{r} N(i,j) G(k+i, l+j)$$

Actually, use Fast Fourier Transforms

Lab test of imaging capability

R = 300 cm, f = 30 cm

20 cm



Neutron image

Three 10-cm cubes of polyethylene, with two Cf-252 sources embedded (courtesy of A. Caffrey, INL)

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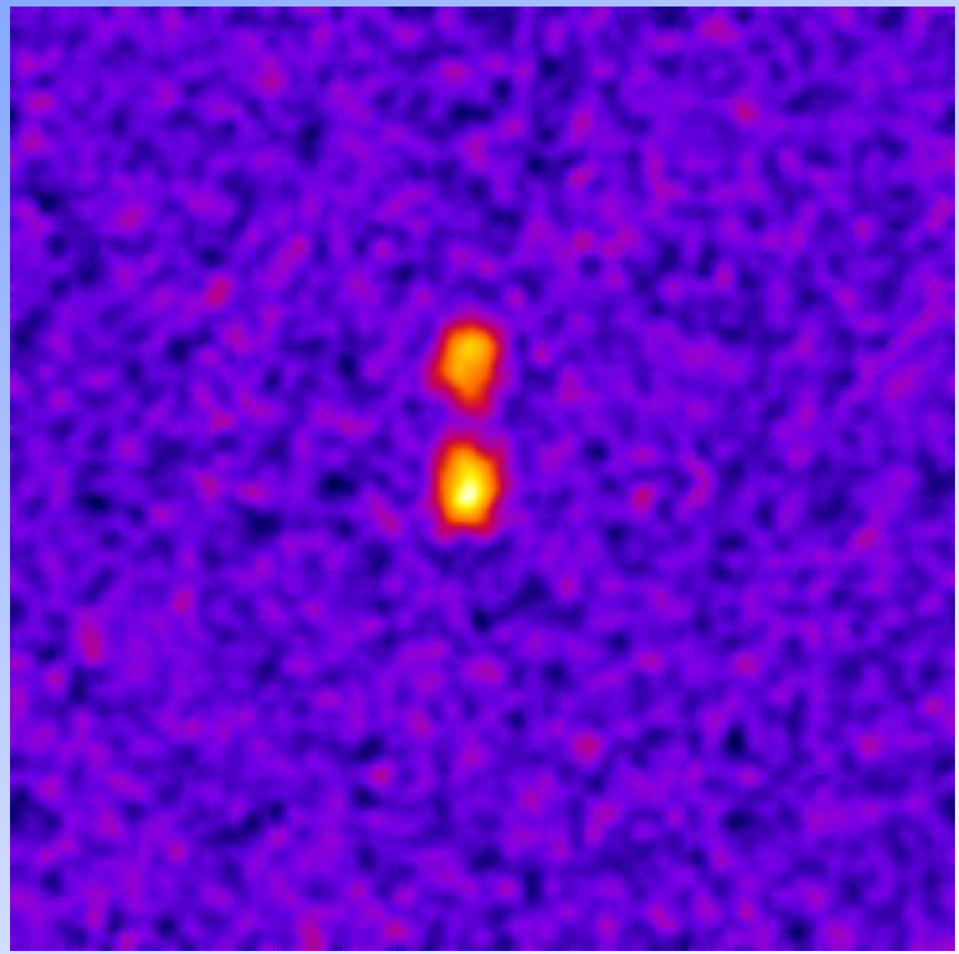
Neutron image

20 cm



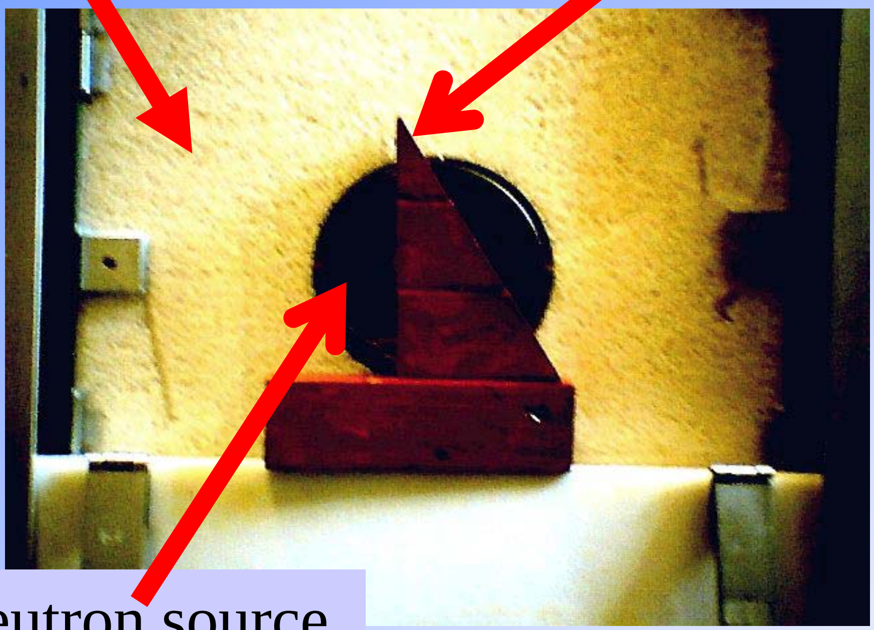
R = 300 cm, f = 30 cm

Tests in the lab

Photograph

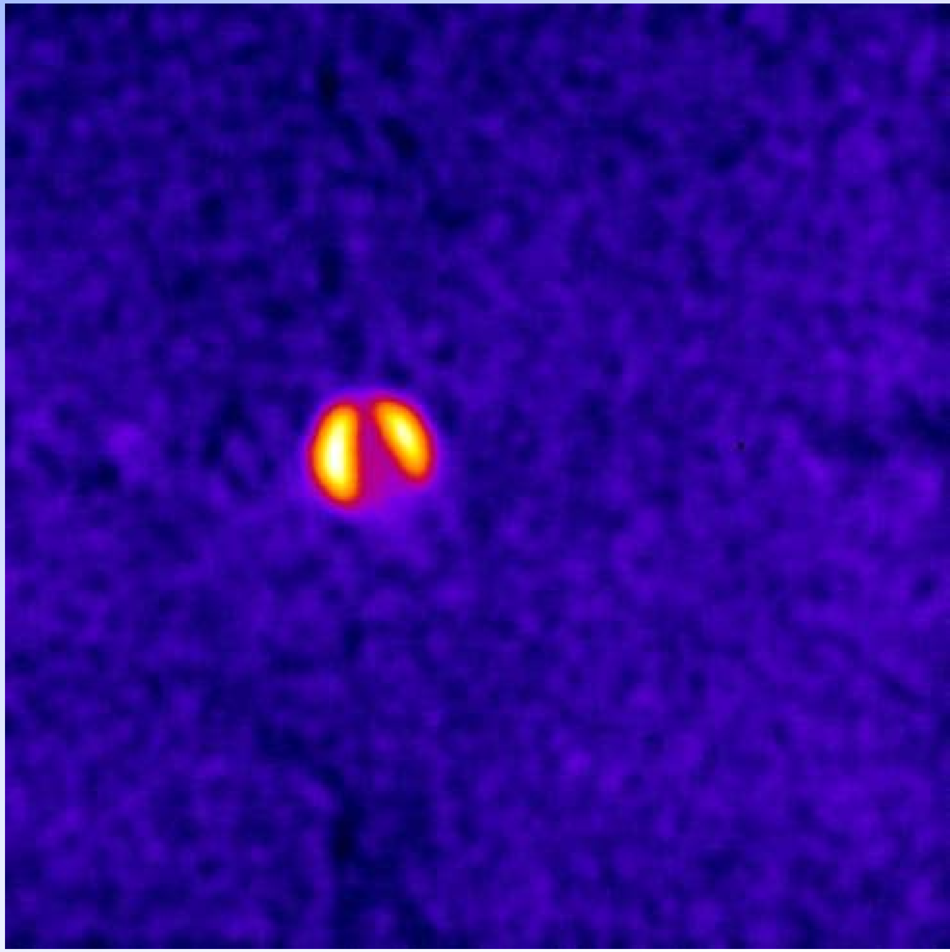
BPE Shielding

Wooden wedge



Neutron source behind paraffin cylinder

Neutron Image



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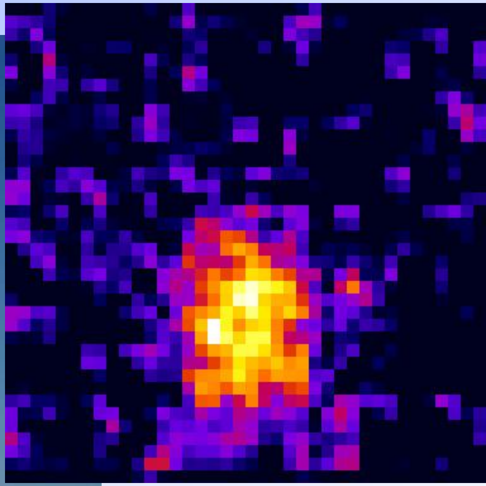
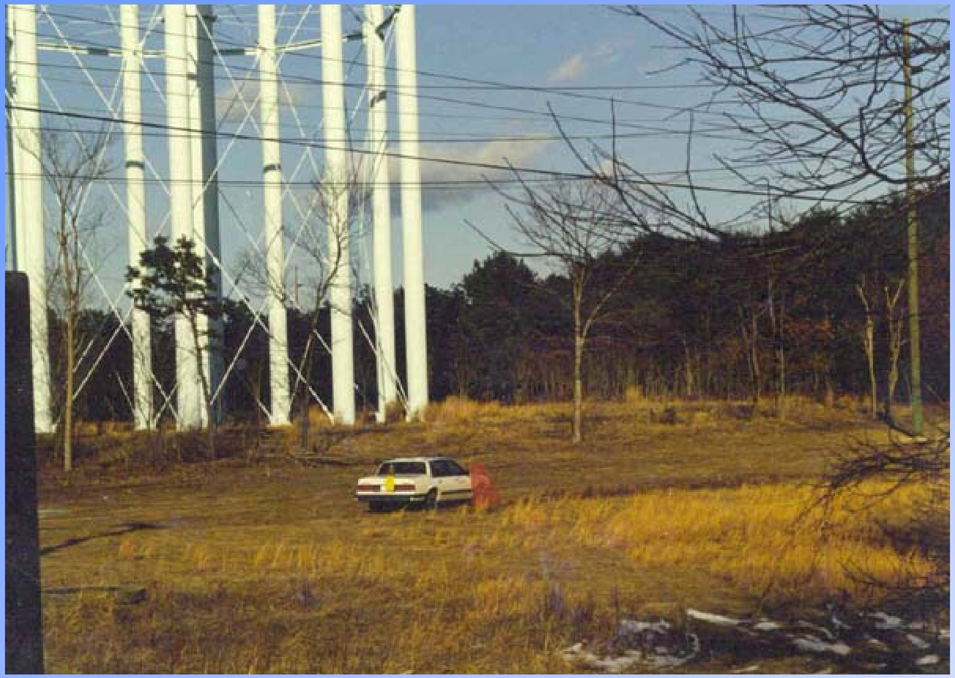
Tests in the field



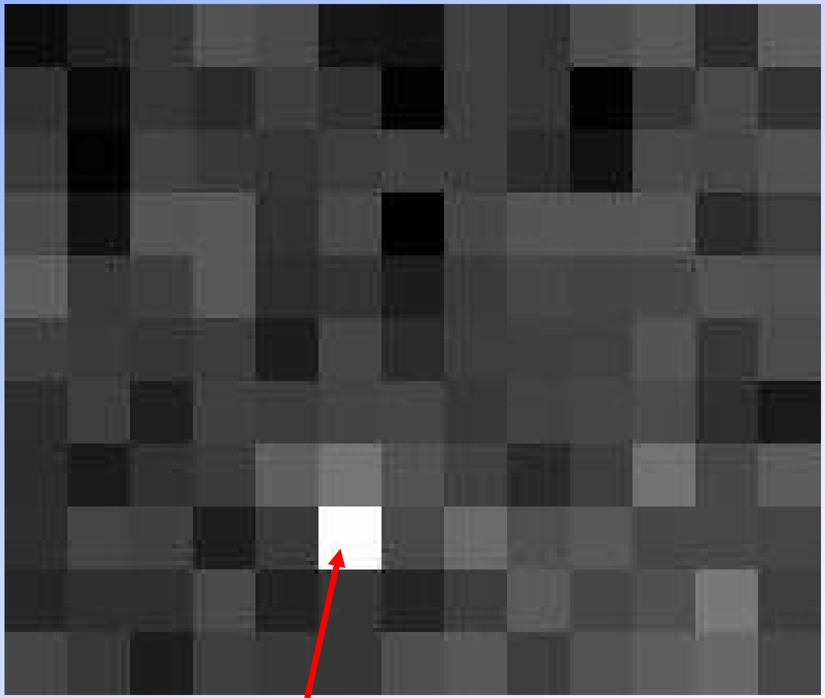
Thermal neutron image

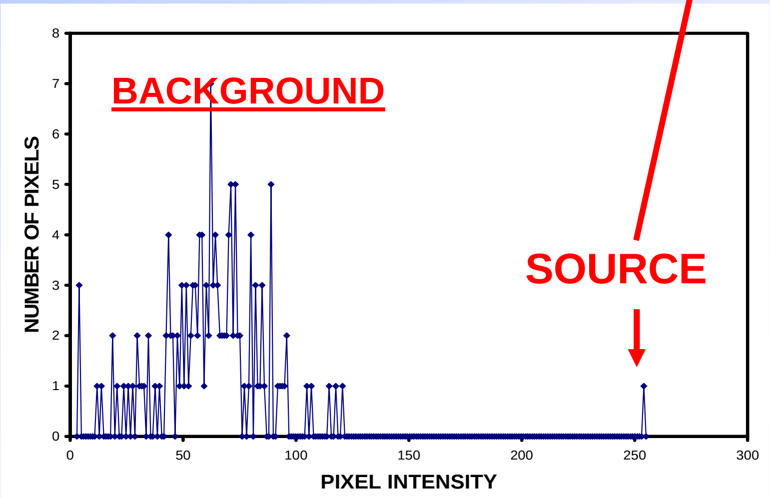
Spent nuclear fuel storage casks at Idaho National Lab

SOURCE IN TRUNK OF CAR



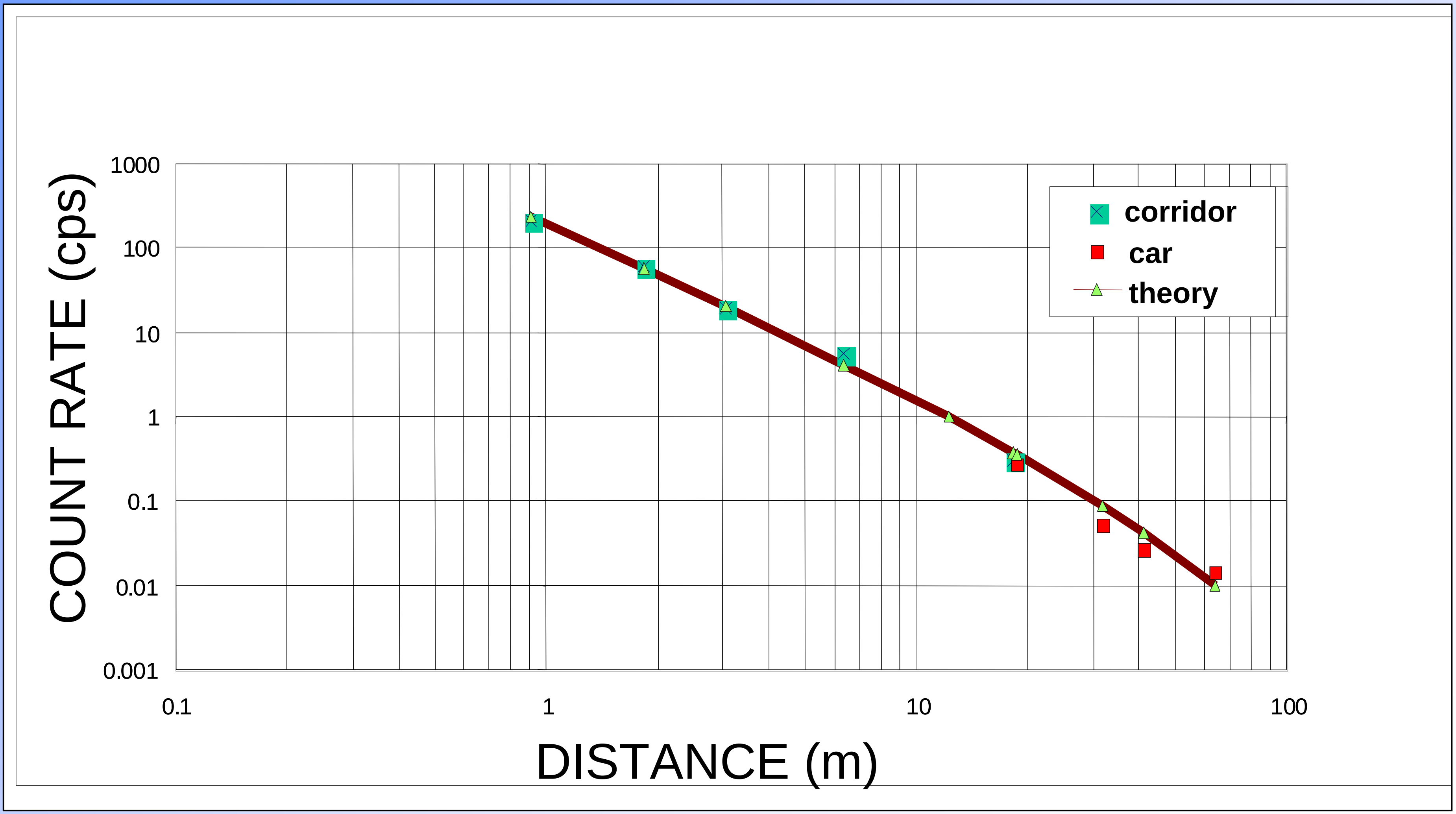
THERMAL NEUTRON IMAGE





PIXEL INTENSITY HISTOGRAM

Count rate as a function of distance



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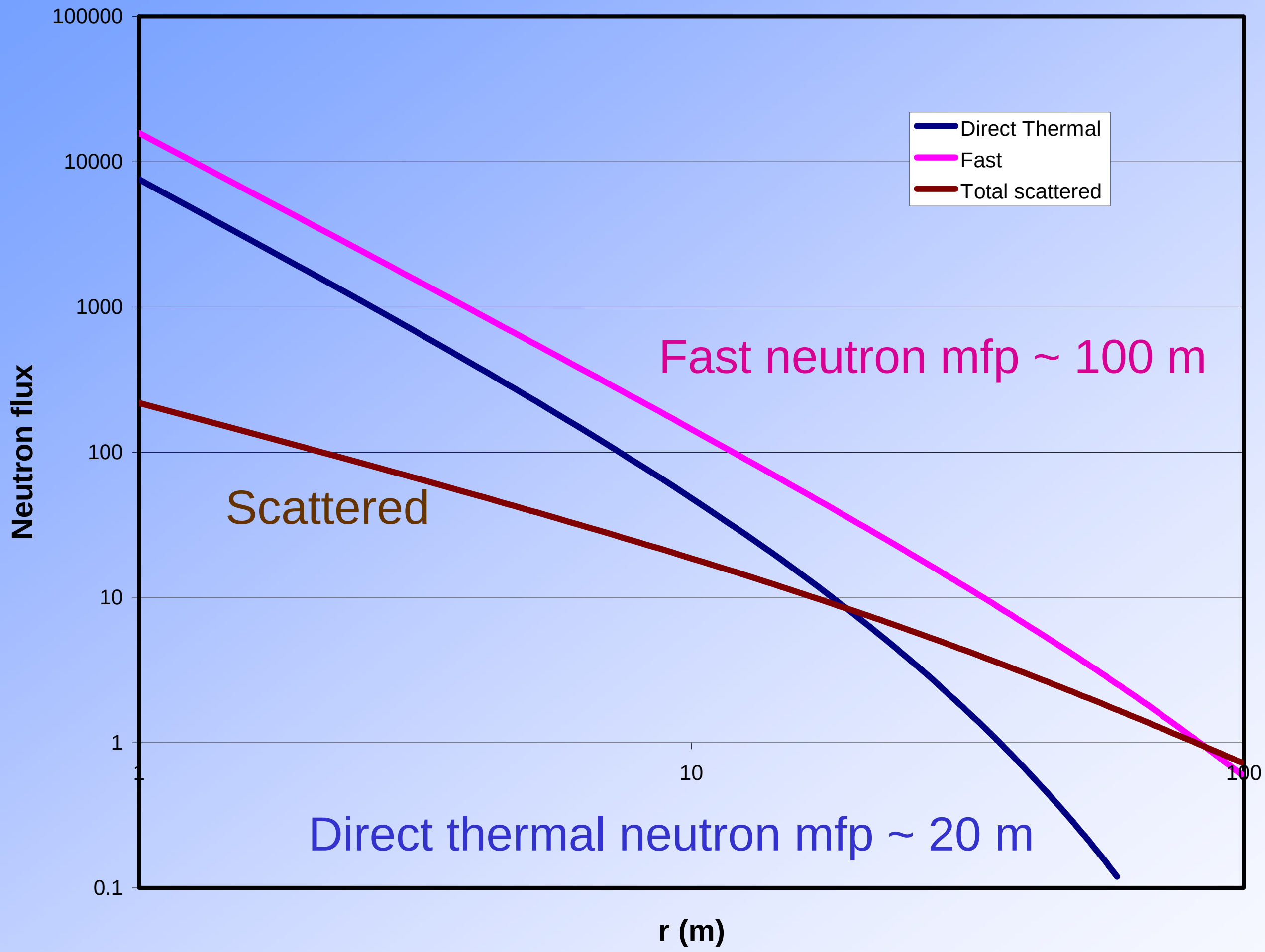
Simple attenuation model for neutron point source in air



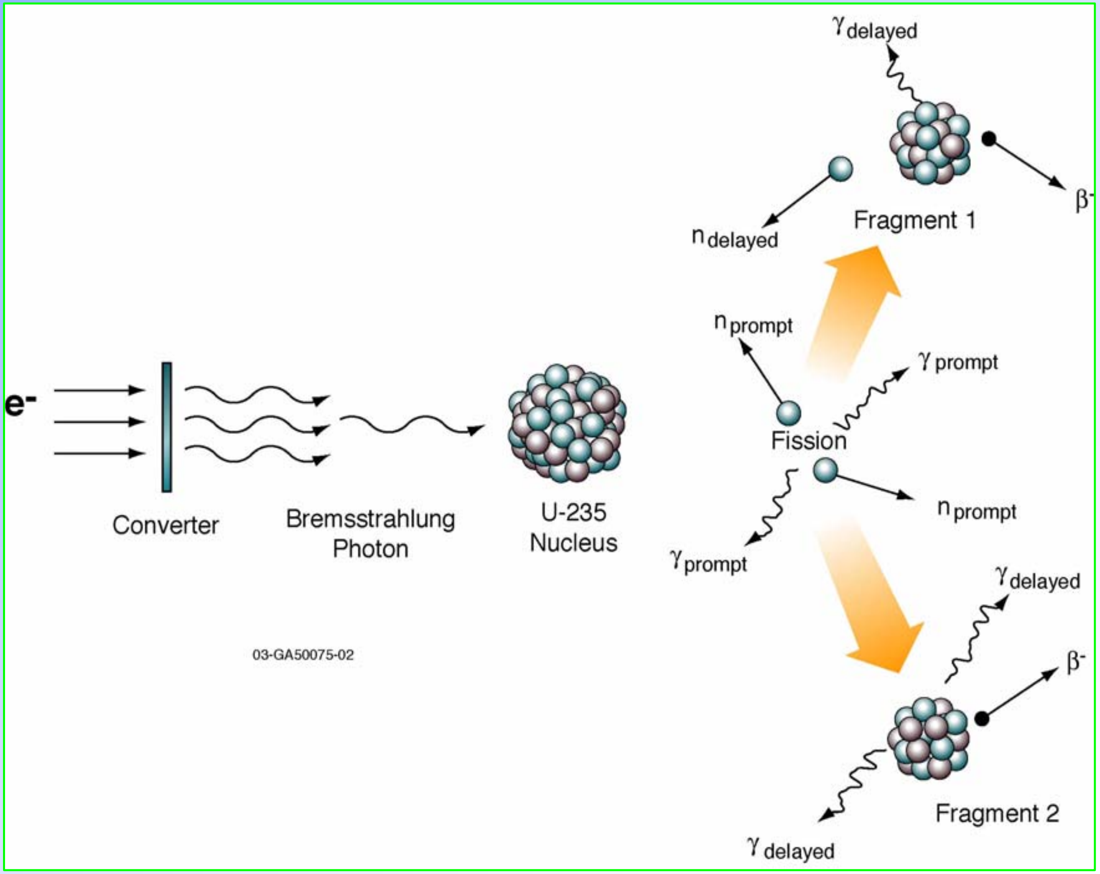
Detectors can be scaled up to increase count rates

20 cm x 140 cm

100 cm x 100 cm

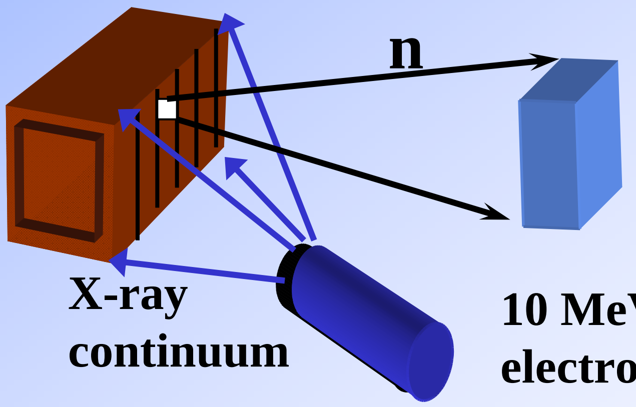
Active interrogation

- A pulsed electron accelerator produces high-energy x-rays (10-MeV) to generate photonuclear reactions
- Nuclear materials will undergo photofission and generate prompt and delayed neutrons
- The delayed neutrons continue to be emitted after each prompt neutron emission



D.R. Norman, J.L. Jones, K.J. Haskell, P. Vanier and L. Forman,
IEEE NSS-MIC Conference Record, October 23-29, 2005

Active Interrogation with Imaging



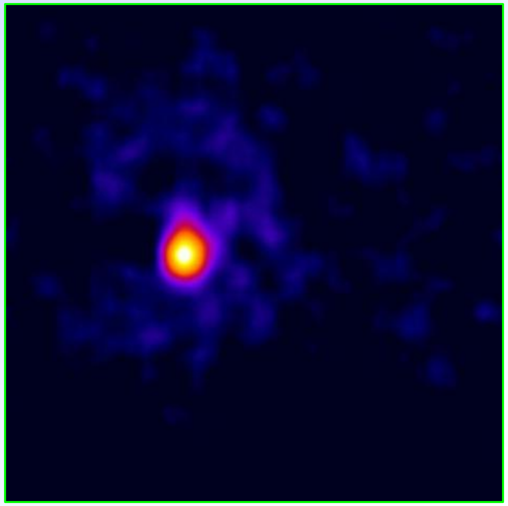


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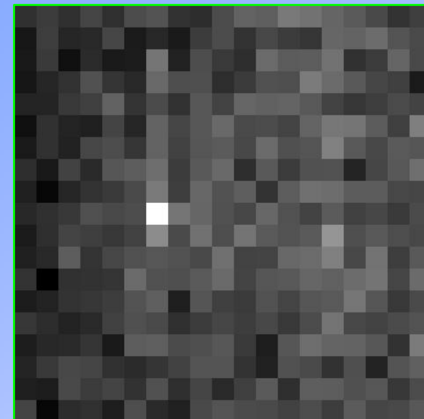
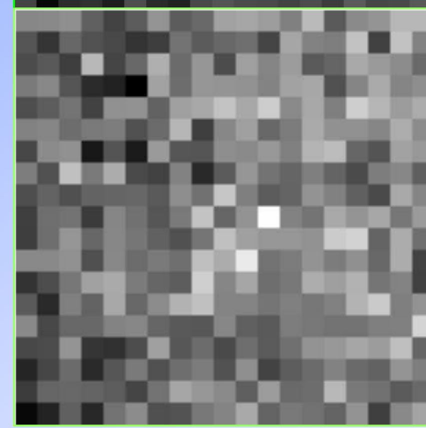
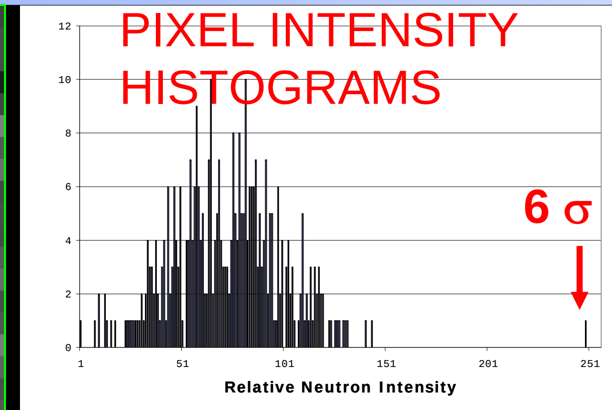
Image analysis

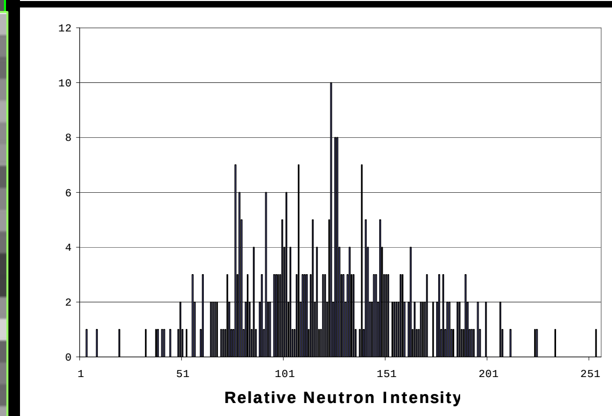
- <u>Depleted uranium</u> in polyethylene
  - 6.5-17.5 ms image window
  - 69k neutrons, mean = 72, σ = 28

- <u>Tungsten</u> in polyethylene
  - 6.5-17.5 ms Image window
  - 17k neutrons, mean = 122, σ = 41









- Use time gate to distinguish prompt neutrons from delayed fission

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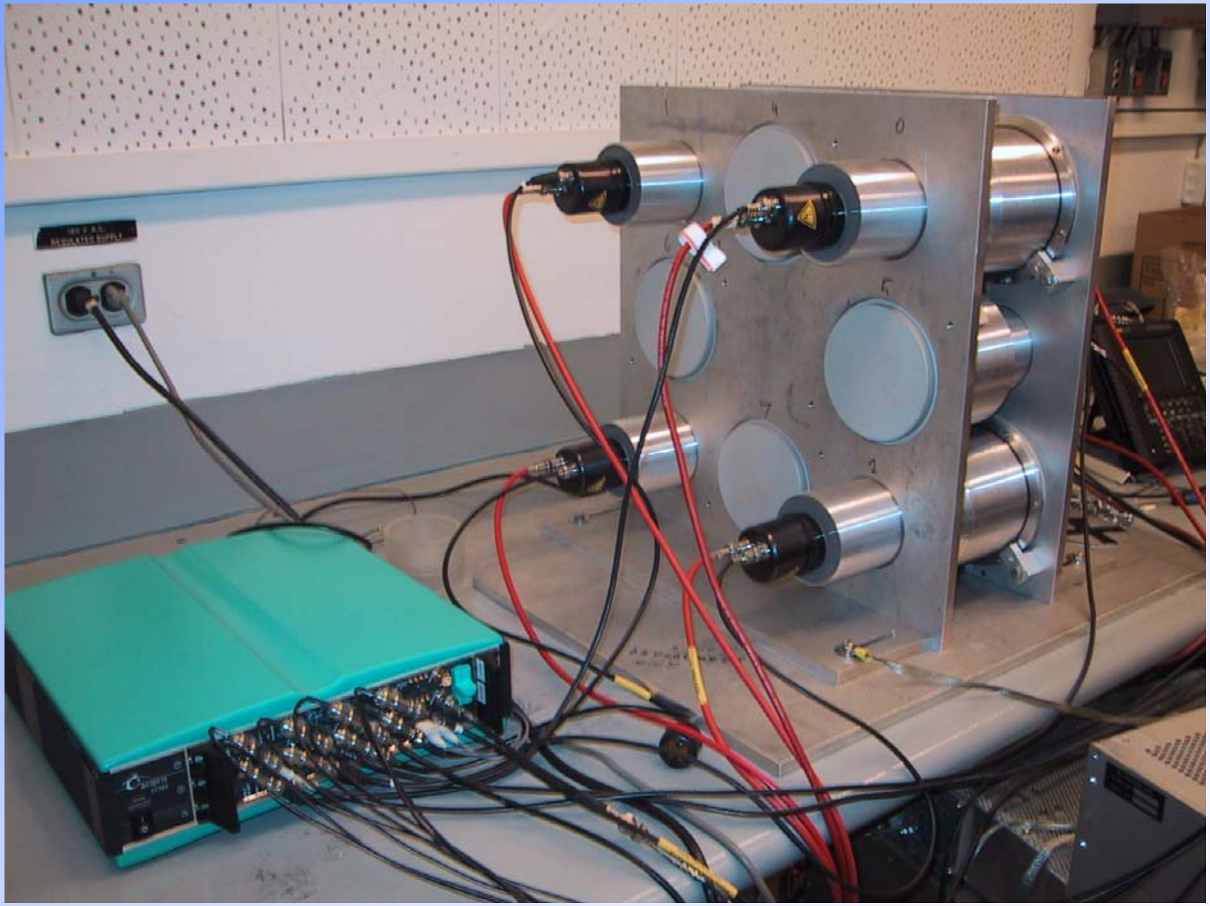
8-element fast neutron double-scatter spectrometer



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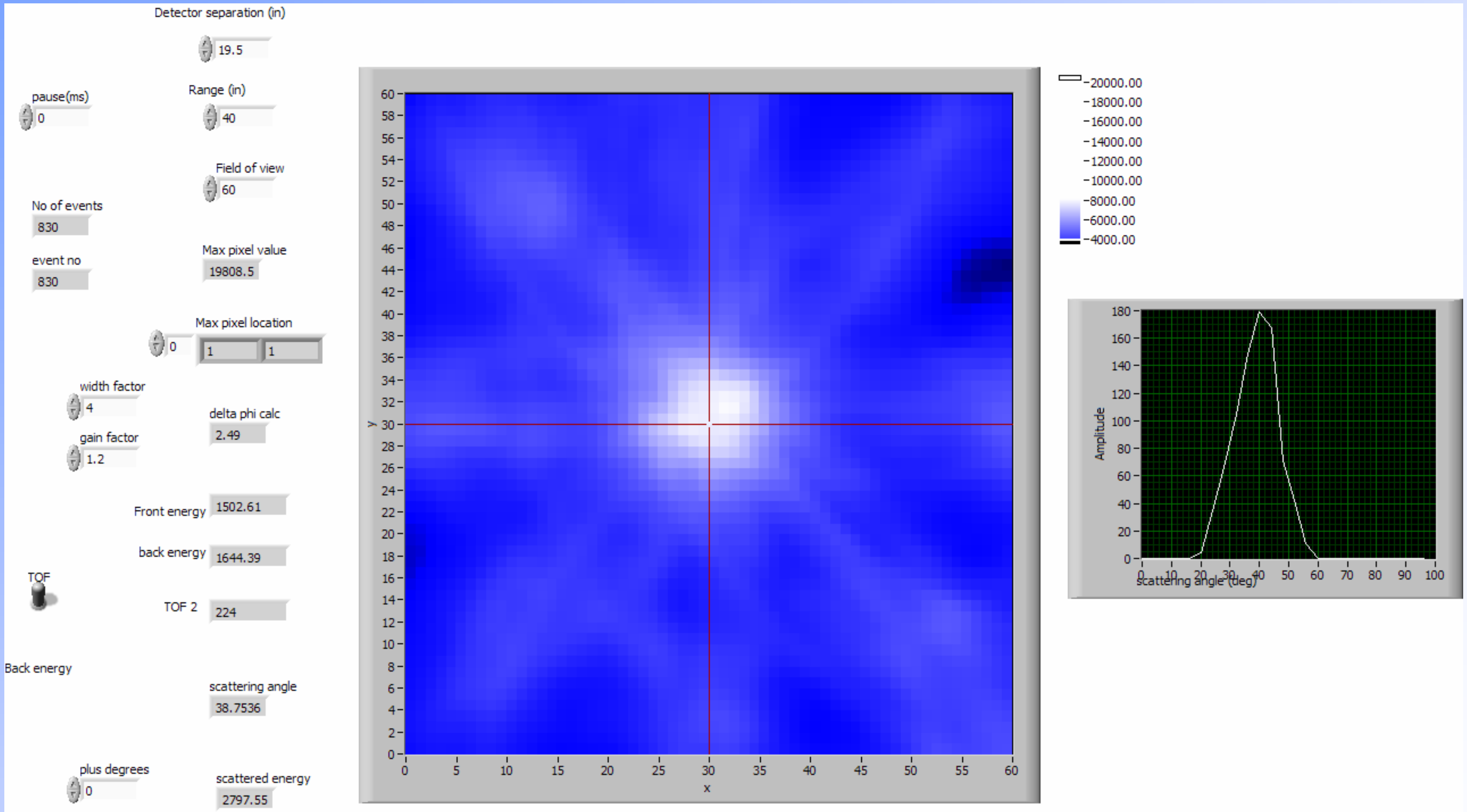
Experimental data,
Fast neutron source centered



Plane spacing = 50 cm, Range = 100 cm

Large area fast-neutron double-scatter directional detector

Area 40 cm x 100 cm
Modular design is expandable

CONCLUSIONS

- Directional detection helps find a neutron source in a uniform background
- There are few naturally occurring neutrons
- Ongoing issues
  - Detector size
  - Efficiency
  - Angular resolution
  - Uniformity
  - Gamma rejection
  - Spectroscopy

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Acknowledgement

The BNL Detector Development and Testing Division is grateful for continuing support from

DOE NA-22, DHS and DTRA

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