BNL-98221-2012-CP

Stereoscopic System of Coded Aperture Neutron Pad Cameras for Warhead Counting

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Presented at the SNM Movement Detection/Radiation Sensors and Advanced Materials Portfolio Review
RadSensing 2012 Conference

Albuquerque, New Mexico
June 5 – 7, 2012

Nonproliferation and National Security Department

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SNM Movement Detection / Radiation Sensors and Advanced Materials Portfolio Review

RadSensing2012

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Brookhaven National Laboratory

June 7, 2012

Stereoscopic System of Coded Aperture Neutron Pad Cameras for Warhead Counting

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Collaborators:	Cynthia Salwen, BNL
	Leon Forman, Ion Focus Technology
	Graham Smith, BNL
	Neil Schaknowski, BNL
Budget:	FY11 $650k (received in June 2011)
	FY12 $500k
	FY13 $500k
	Total: $1650k

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Outline

- Coded aperture thermal neutron imaging
- Warhead counting application
  - Multiple warheads in various configurations: need for multiple view imaging
- Imaging multiple sources with the multi-wire camera
- New design: Neutron pad detector
  - Test experiments with ORNL/BNL prototype pad detector
  - Diagnostic tests
  - New data acquisition card design
  - Modifications of the pressure vessel (lighter design)
- Preparations for multiple view (stereo) imaging
- Summary and future work

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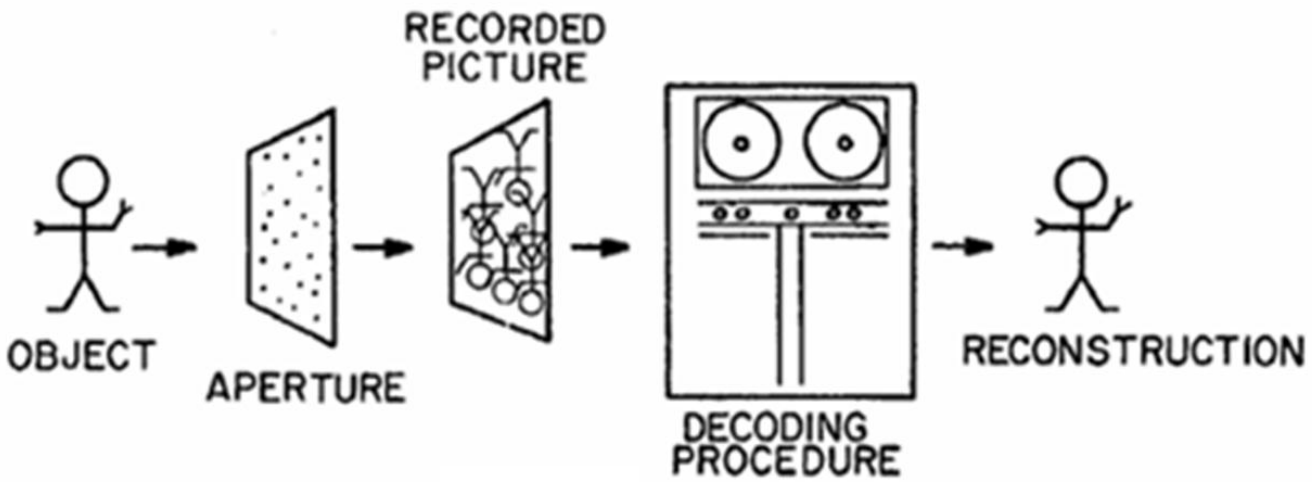
Coded aperture imaging of non-focusable radiation



E. E. Fenimore and T. M. Cannon, Coded aperture imaging with uniformly redundant arrays. United States Patent 4360797 1980

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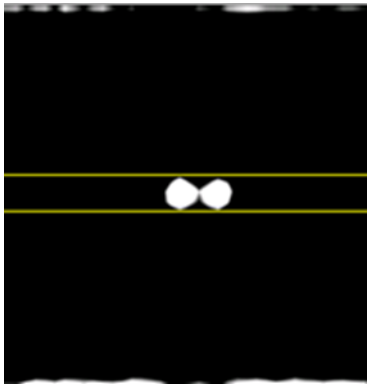
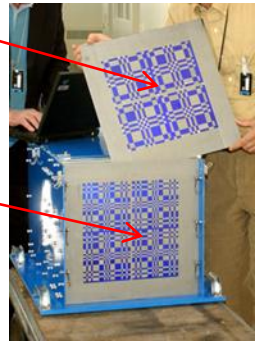
Coded aperture imaging of thermal neutron sources

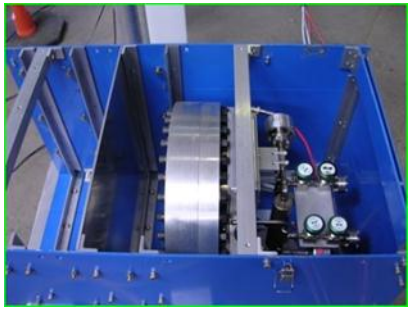
(Developed by P. E. Vanier & L. Forman, BNL)



Low resolution mask

High resolution mask





Multi-wire position sensitive ^{3}He detector in cadmium enclosure, cadmium mask (three resolutions at present). Achieved resolution < 3^{o}.

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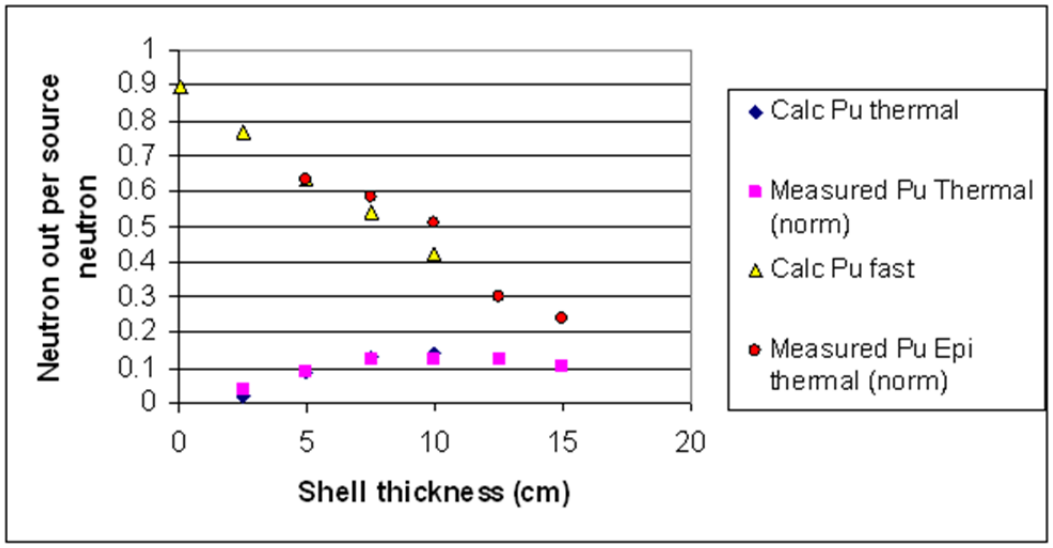
Application of the thermal neutron imager for warhead counting based on thermalization of neutrons in the high explosive shell.

Fast and Thermal neutron output for Plutonium source through shells of high explosive
Measured values are for melamine simulant and calculated ones are for HMX



Measurements and MCNPX calculations indicate that the thermal neutron output saturates at around 5-7 cm shell thickness.

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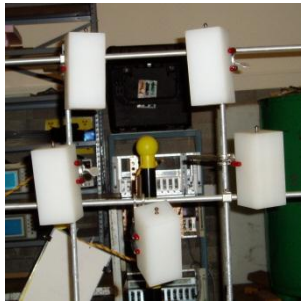
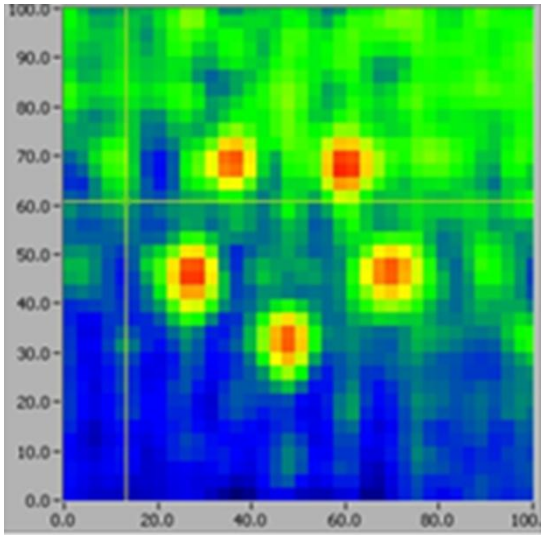
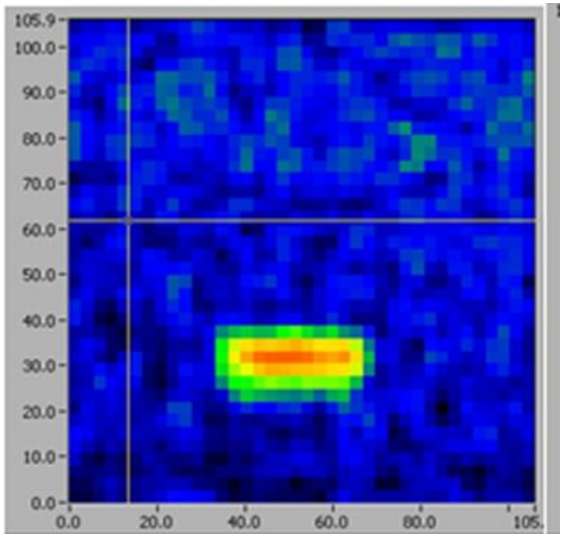
Imaging multiple thermalized sources





Five sources in circle



Five sources in line

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Mask-antimask technique and statistical analysis

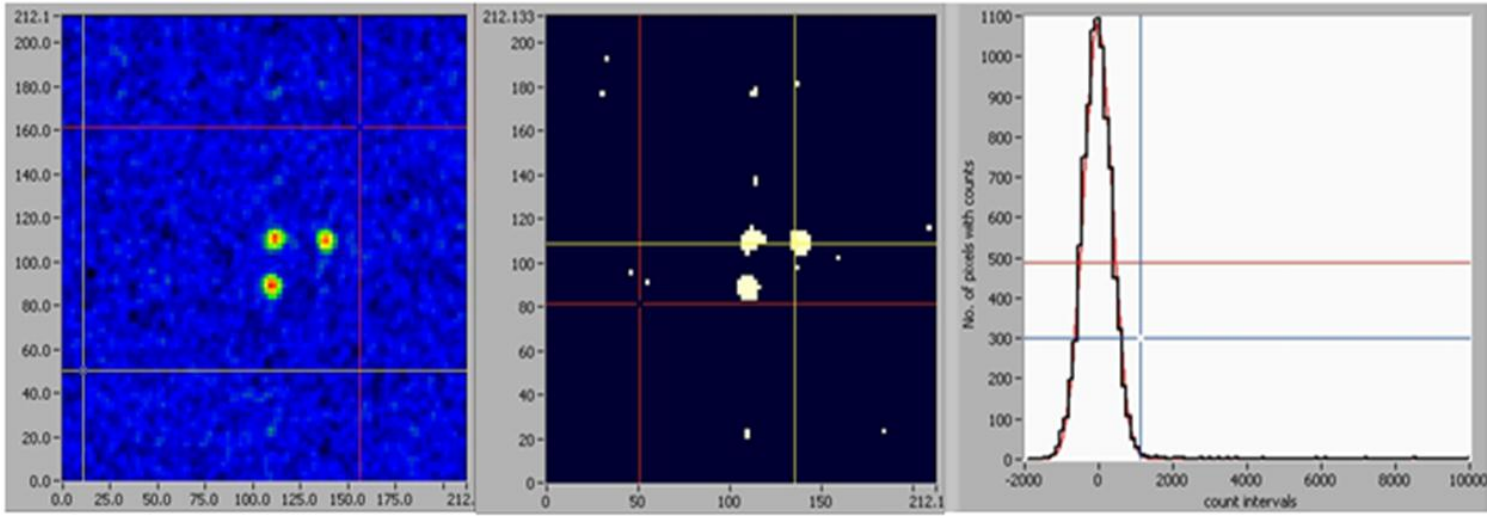

Image of three sources was created using two exposures with a coded aperture mask and an “antimask”. The right panel shows the frequency distribution of counts in pixels and a fitted normal distribution curve (red).
This distribution establishes the statistically meaningful limit for the background (3 σ), which was used to determine the threshold for the middle image.

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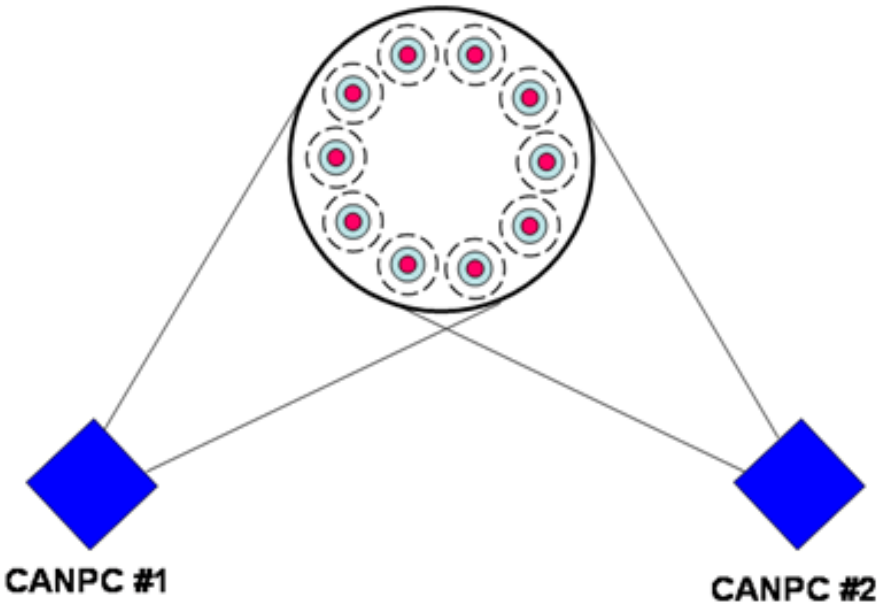
Multiple view imaging in warhead counting



Multiple view (stereo or higher order) has higher accuracy and less uncertainty in resolving complicated structures. → We need two cameras.

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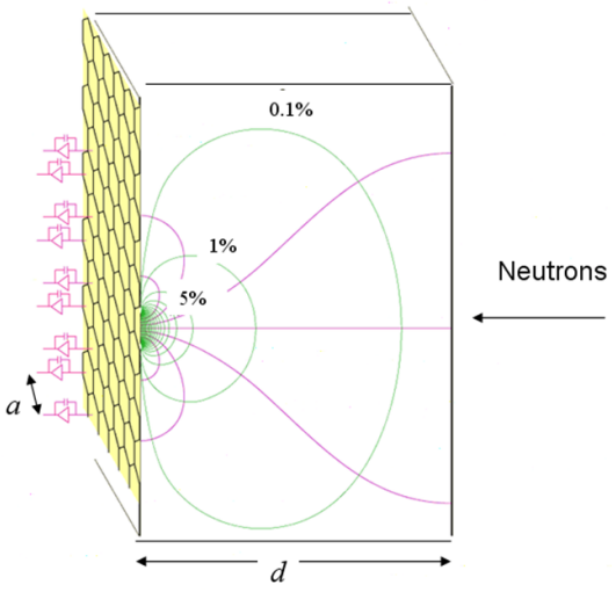
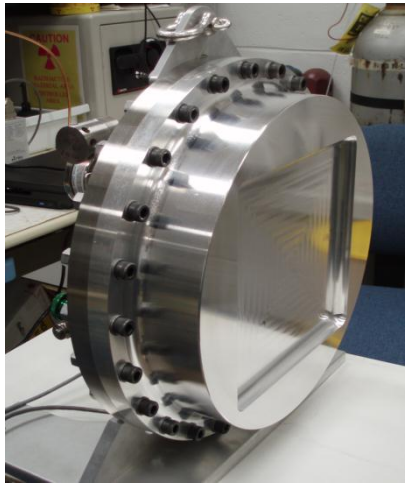
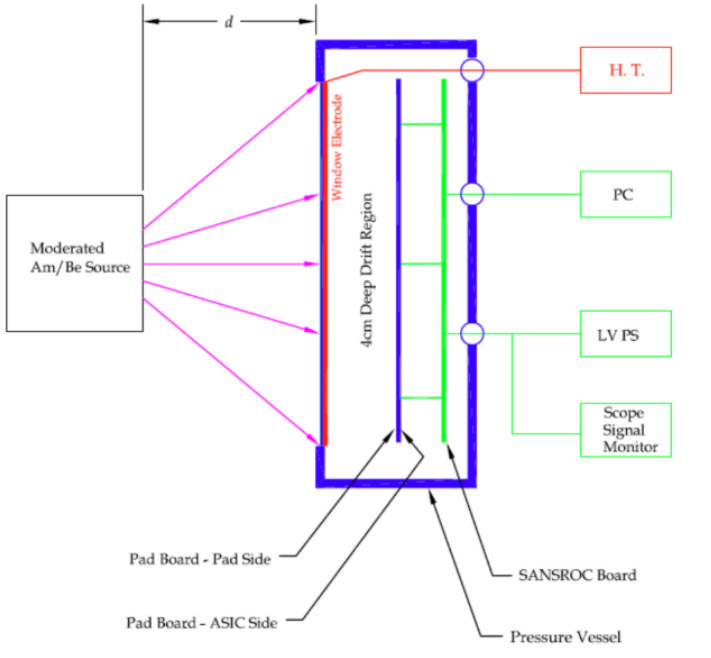
Advanced Neutron Detectors with Pad Readout



Principle of operation



Fully assembled prototype



Cross cut diagram

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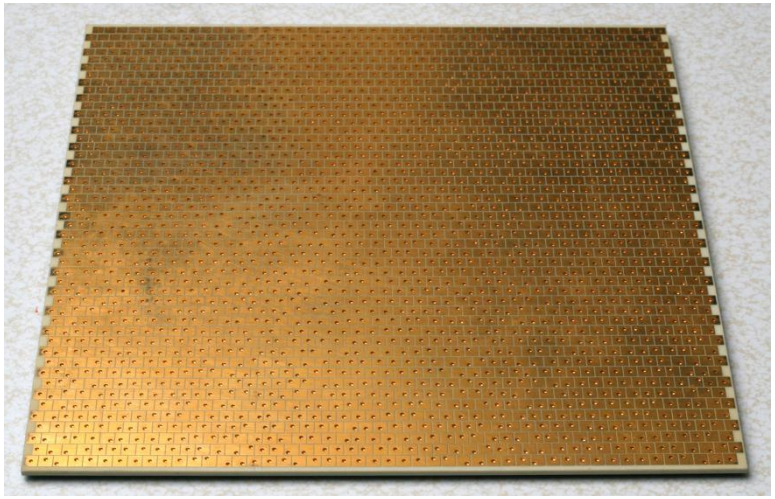

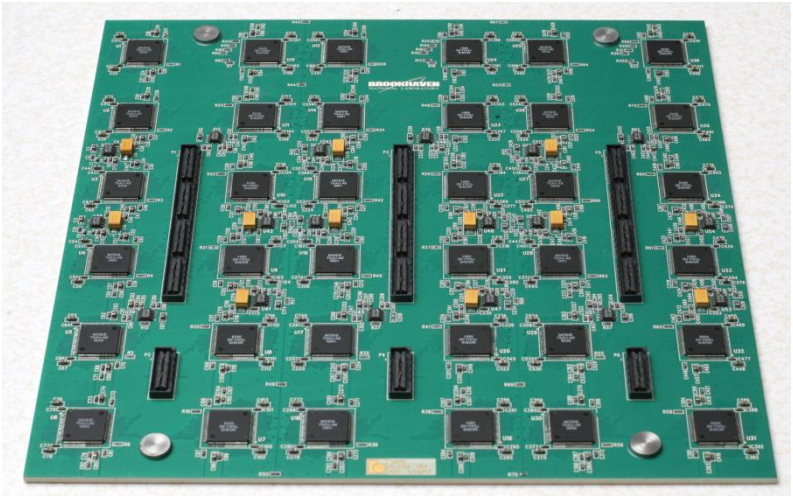

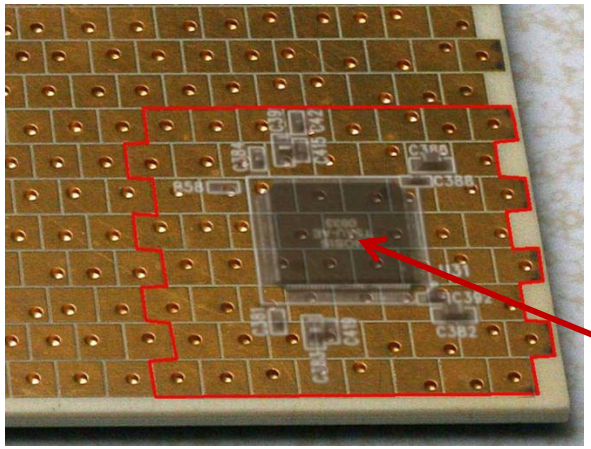

48x48 pixel pad array (upper left), 36 ASICs mounted on the back of the pad array (above) and detail of a pad array showing 64 channels connected to an ASIC (lower left).

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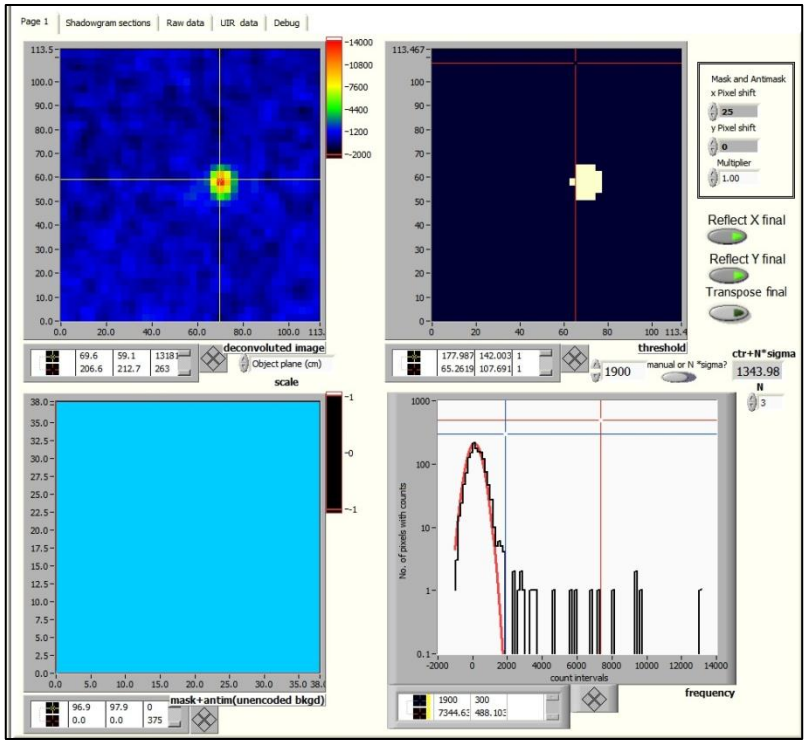
First coded aperture image taken with the prototype camera.



Top left: reconstructed image. Top right: threshold cut image.
Bottom left: unused. Bottom right: pixel intensity distribution with fit.

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Ongoing development work for the NA-22 supported new detector:

- Replace propane stopping gas with non-flammable CF_4
- Design lighter, more compact pressure enclosure
- Design new data acquisition board to replace ORNL design
- ASIC development (BNL Instrumentation Division)
- Software diagnostics tools to monitor performance individual pads and ASIC channels

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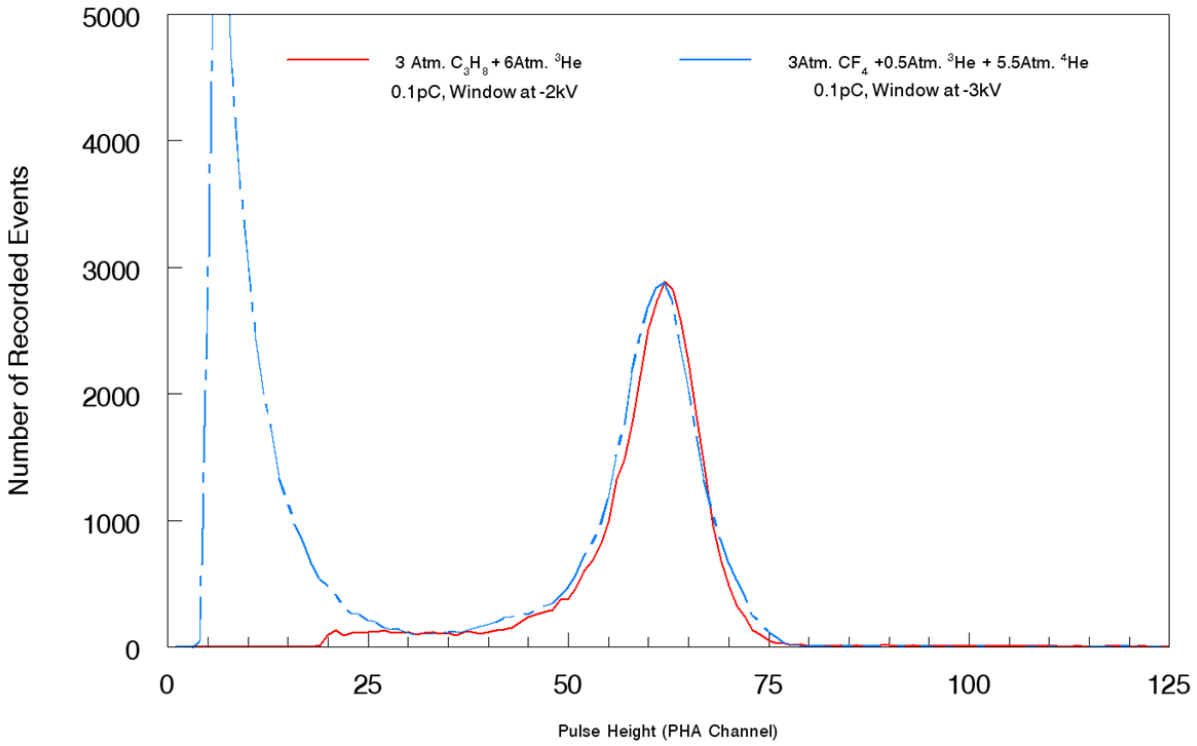
Comparison of Neutron Stopping Gases

20cm Neutron Detector #108 Am/Be Source Response



The experiments show that flammable C_3H_8 can be replaced with non-flammable CF_4. In addition, avoiding hydrogen will reduce the detector high energy neutron response created by proton recoils.

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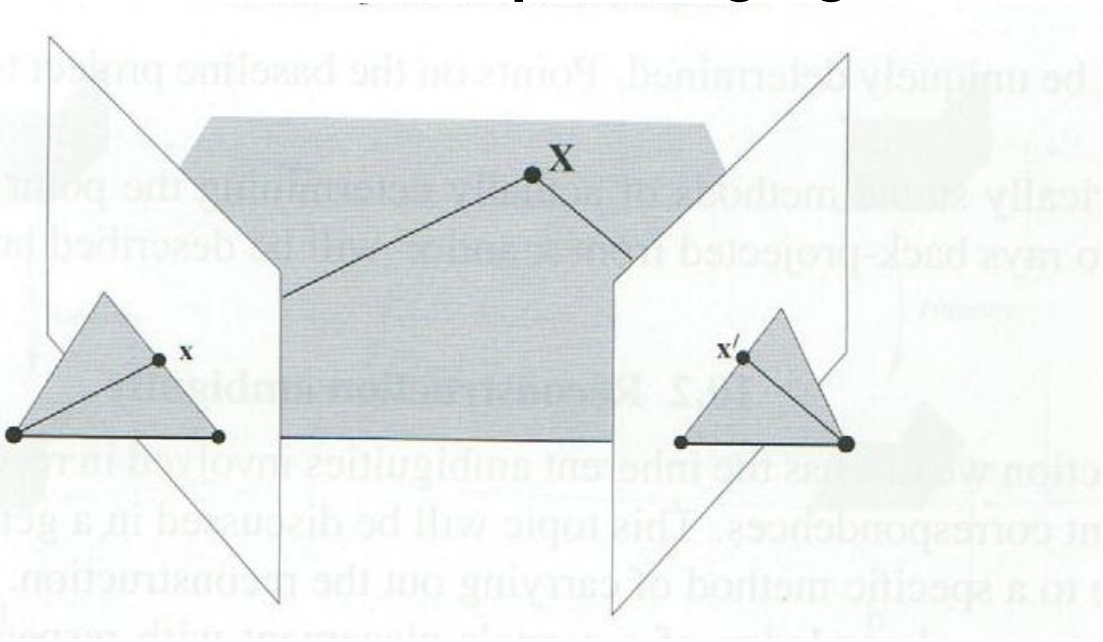
Preparations for stereoscopic imaging



The image points x and x' define the object point X by back projection*.

*R. Hartley and A. Zisseman: Multiple View Geometry in Computer Vision, Cambridge University Press, 2010.

Summary and future work

- Improved analysis technique allowing identifying multiple sources (3 σ criterion).
- Designed a new, light weight, portable pad-based camera.
- Made several improvements in operation and diagnostics.
- Performed initial stereo imaging experiments and designed analysis software.
- We expect to complete the construction of the new camera in the next 6-8 month.
- Testing with multiple sources and stereo imaging to follow.

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We would like to thank U. S. Department of Energy, Office of Nonproliferation and Verification Research & Development, NA-22 for supporting our work!