# Active Coded-Aperture Neutron Imaging

LABORATORY DIRECTED RESEARCH & DEVELOPMENT


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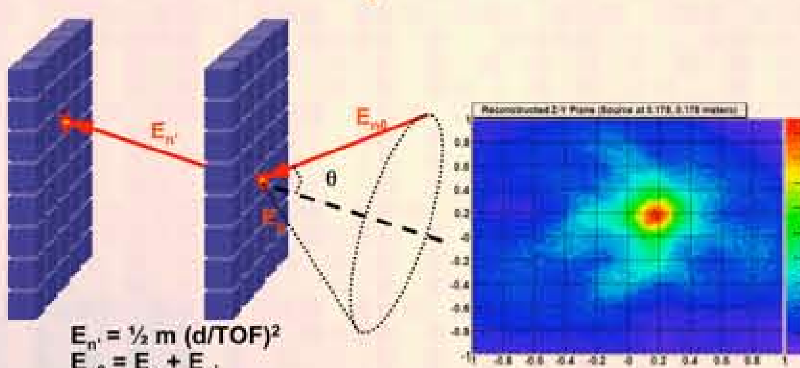
## Summary


Imaging energetic neutrons may be the most-effective method for detecting and locating Special Nuclear Material (SNM) at great distances. Although neutrons are more penetrating than gamma rays, no efficient imagers of energetic neutron sources exist. Thus, most current approaches continue to use gamma-ray imaging. We proposed a new technique for energetic neutron imaging that uses an active coded-aperture, which simultaneously images using double-scatter and coded-aperture methods. This more efficient, combined approach should improve detection speed, range, and sensitivity. Preliminary experiments and simulations support this hypothesis. Design and testing work for a proof-of-concept system is underway. Once this system is built, we will compare its combined- and single-mode imaging performance. If successful, we would fill a void in available technology to efficiently image SNM neutrons. Improved long-range detection and location of SNM and other neutron-emitting radioactive materials would be a transformational capability for national security. DNDO, DTRA, and DOE now fund R&D for long-range SNM detection. This LDRD project will enable Sandia to lead by proposing a new solution.

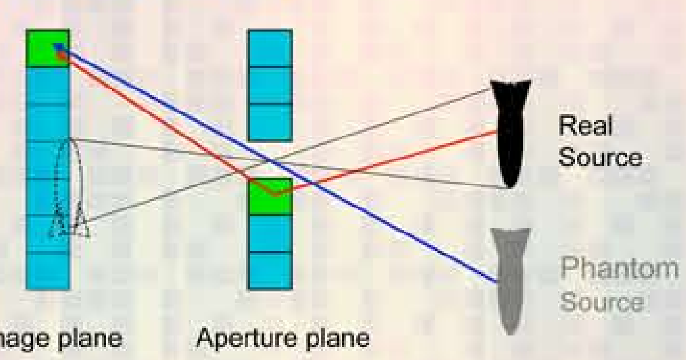

### *We previously built several neutron double-scatter imagers, which have limited detection efficiency*




$E_{n'} = \frac{1}{2} m\,(d/TOF)^2$
$E_{n0} = E_p + E_{n'}$
$\theta = \tan^{-1}(E_p/E_{n'})$

Imaging improves standoff source detection by reducing the impact of cluttered background radiation, but higher detection efficiency is needed.

### *We combine double-scatter and coded-aperture imaging methods to improve detection efficiency*

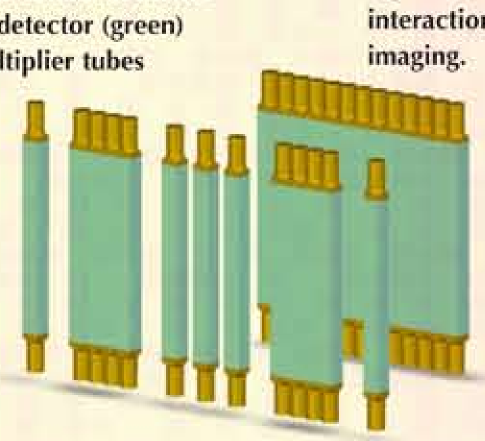



- Coded-aperture imaging inherently has higher efficiency, but opaque apertures for energetic neutrons are difficult to make.
- An active aperture "vetoes" neutrons that scatter in the aperture, effectively increasing its opacity.
- Higher aperture opacity improves image quality. (e.g., red vectors are not mistakenly imaged as blue vector.)
- Total efficiency increases further by imaging the "vetoed" neutrons using double-scatter methods.

### *Conceptual detector design is a 1D coded-aperture system made using arrays of reconfigurable detectors*

Light pulses from radiation detection events in each liquid scintillator detector (green) are collected by photomultiplier tubes (gold) at both ends.

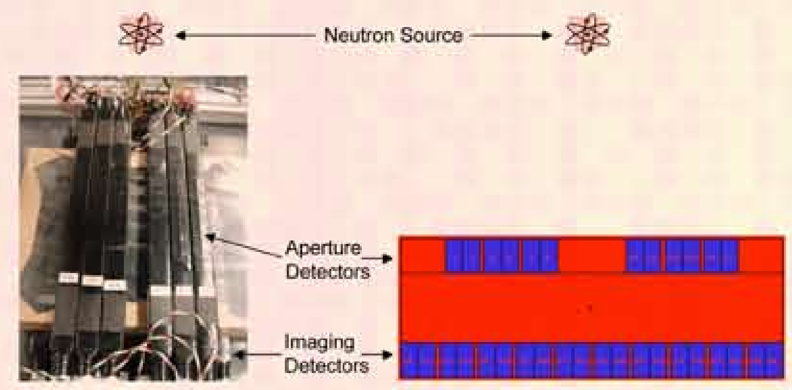
Signal timing and amplitudes determine interaction location, which is needed for imaging.



Signal pulse shape and amplitude distinguishes between neutron and gamma ray interactions for improved threat detection.

Higher threat sensitivity is obtained by simultaneously performing 1D coded-aperture and 2D double-scatter imaging.

### *Configuration of experiment and simulation of active coded-aperture neutron imaging concept tests with small, plastic-scintillator detectors*




Pairs of 0.5 x 1 x 10 inch detectors were bundled and wrapped together in black tape. The neutron shadow pattern of the slit aperture is recorded by the imaging detectors.

### *These experiments and simulations show the anticipated increase in shadow contrast for active coded apertures*

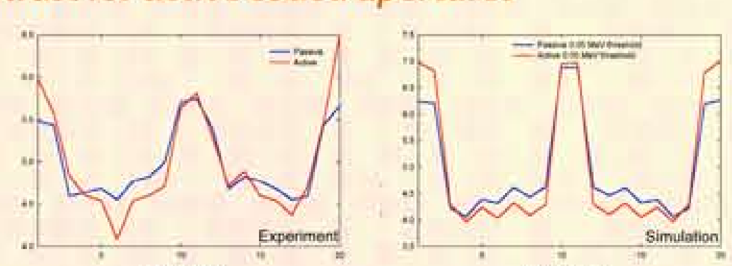
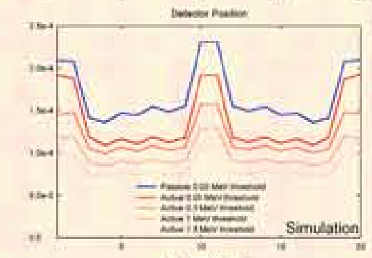
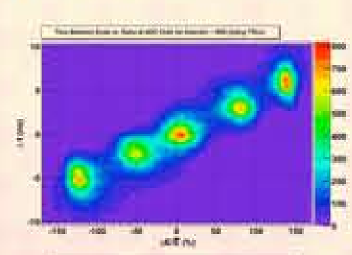


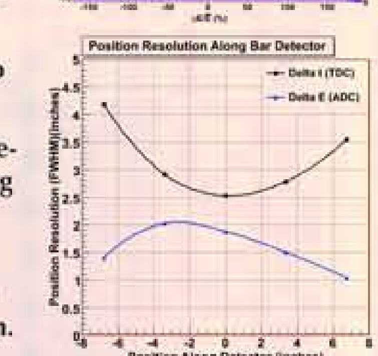

Image contrast, or the difference in counts in the central peak and the surrounding "shadow," increases as the detection threshold is reduced.



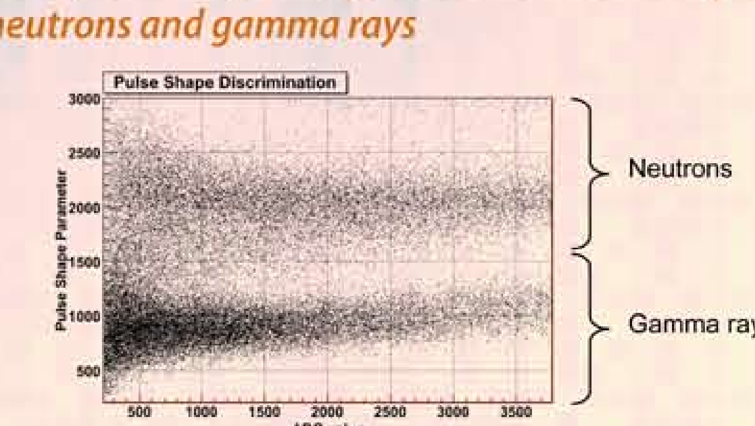

### *We measured position and detection sensitivities of larger, liquid-scintillator prototype detectors*



- A collimated gamma-ray source was moved to five positions on a 2x2x20 inch detector.
- Position of interaction within the prototype detector was determined from the relative timing and amplitude (i.e., energy) of light pulses at each end of the detector.
- A better method will be to jointly utilize both timing and energy data for position estimation.




### *Experiments with combined neutron and gamma-ray sources show the ability of these prototype detectors to distinguish between neutrons and gamma rays*




Unlike plastic scintillators, our liquid scintillator prototypes exhibit pulse-shape discrimination between neutrons and gamma rays, which will be crucial for reducing the problems caused by a high natural gamma-ray background that would hide most neutron sources.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