Active Coded-Aperture Neutron Imaging

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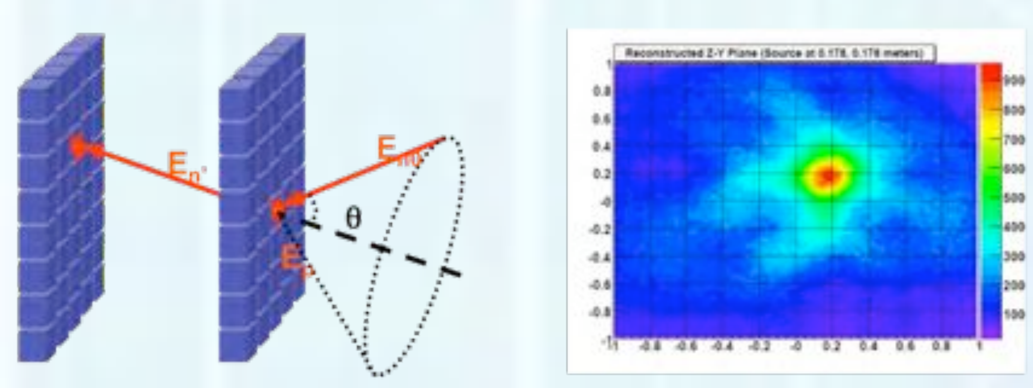
Problem

There is an urgent national security need for systems that can detect special nuclear material (SNM) at great stand-off distance and/or obscured by shielding. Because of their penetrating power and very low occurrence in natural background, energetic "fast" neutrons offer the possibility of detecting shielded or distant SNM. We are investigating a wholly new approach to fast-neutron imaging — an active coded-aperture system that uses a coding mask made of neutron detectors. By simultaneously imaging using both coincident (double scatter) and anti-coincident (active mask) detection, this new dual design allows for high-efficiency imaging of neutron sources and should lead to an instrument capable of locating SNM at greater distances at shorter dwells than any existing instrument or technique.

Approach

We have had great success with neutron double-scatter imagers ... But requiring two scatters lowers detection efficiency

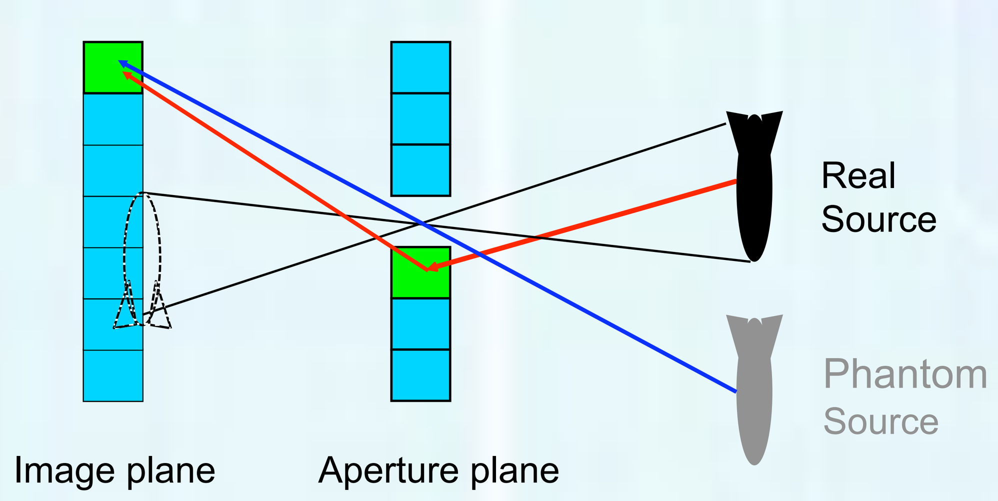


Imaging leads to better Signal/Noise for improved standoff by reducing background:

S/N ~ √(Efficiency * Area * Dwell Time)/ Angular Res

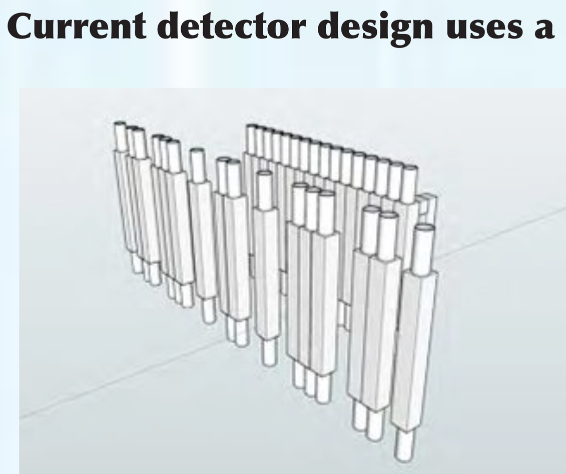
Our Coded Aperture Neutron Imaging System aims for good angular resolution while maintaining high efficiency (single scatter).

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.
- Total efficiency increases further by imaging the "vetoed" neutrons using double-scatter methods.

Current detector design uses a 1D coded aperture



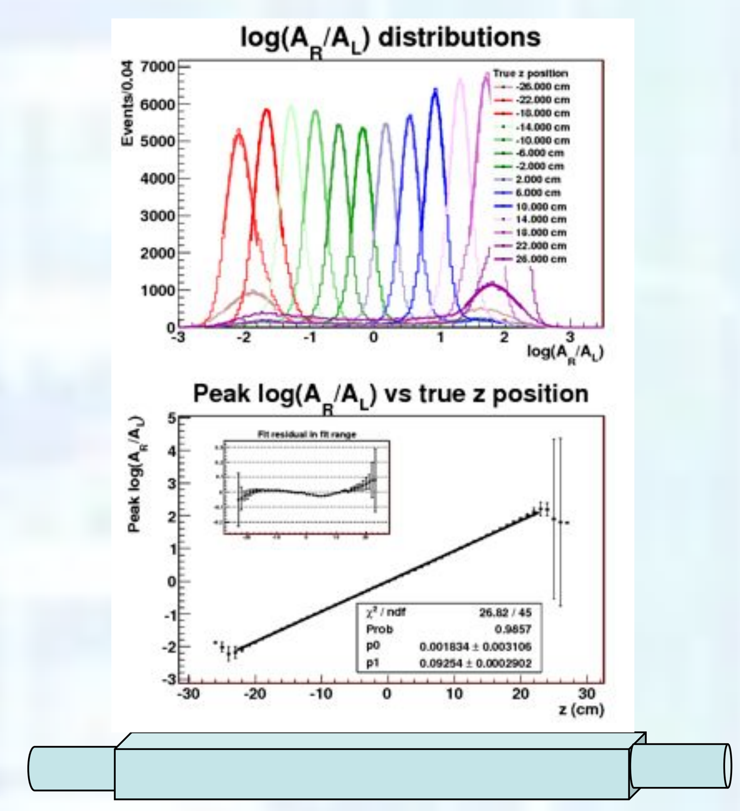
Modular detector design: measure position, time, and g/n probability for every interaction.

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

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

Results

Calibration & Reconstruction: Position Sensitivity

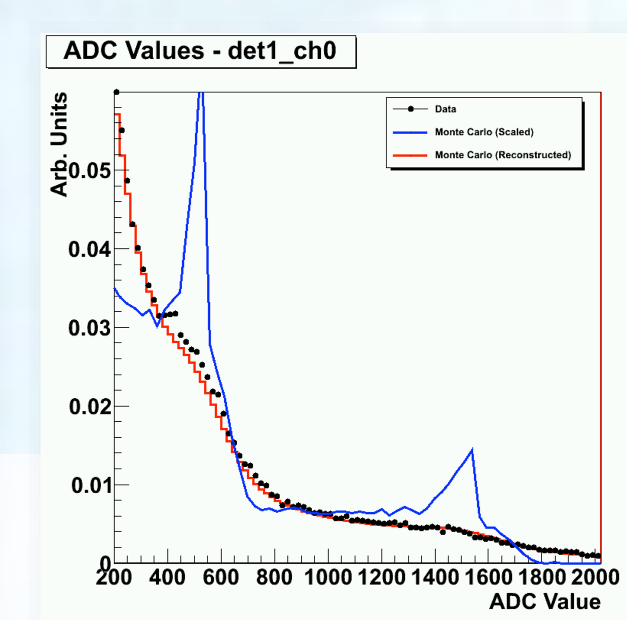


- Position of interaction within a detector cell is determined from the relative amplitude of light pulses at each end.
- Excellent resolution (~1.5 cm) obtained.

PSD, TOF measurements are also more complicated in the bar geometry; but extra information could mean more sensitivity than single-channel cell.

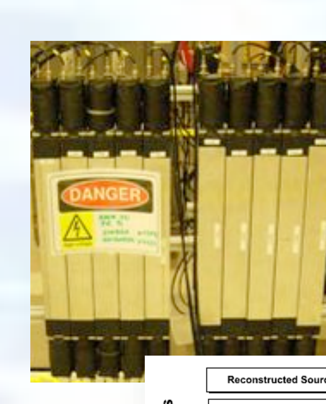
Simulation & Calibration: Energy scale & resolution

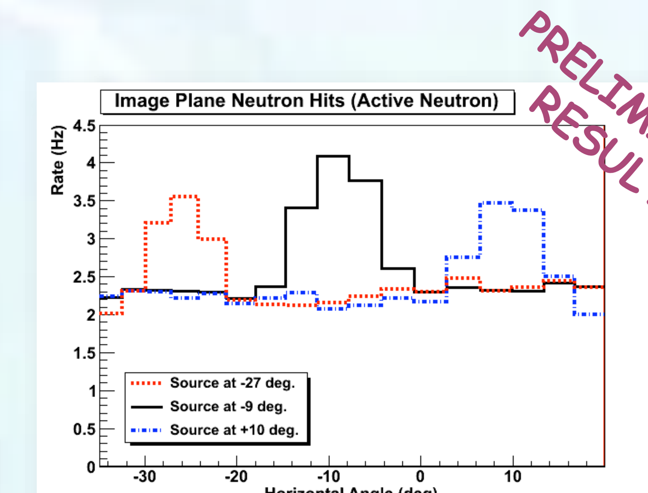
- A set of Monte Carlo simulation tools has been developed.
- Energy calibration uses collimated 22Na datasets from both simulation and a real detector cell.
- Fit channel by channel the energy scale and resolution.
- Results are used in two ways:
  - scale determines most likely energy of any given data event
  - resolution determines smearing needed in simulated events to model detector response for arbitrary configurations

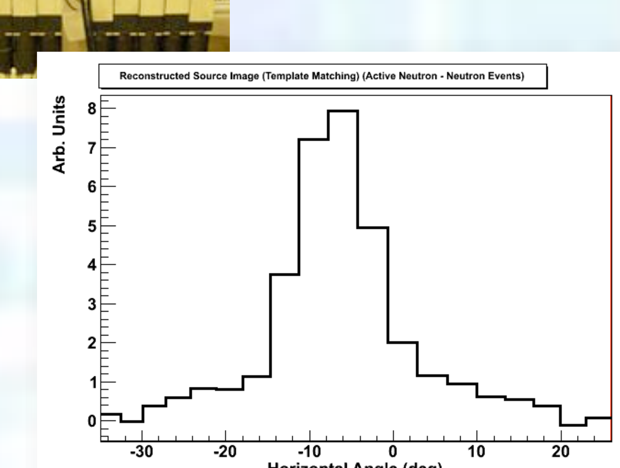


Single Slit Experiment

PRELIMINARY RESULTS







Template matching algorithm applied.

- Source moved to 3 positions.
- ~10 deg. resolution obtained ... can easily be changed by altering the plane separation.
- Opacity increased 10-15% by vetoing on the mask plane. ~50% mask opacity achieved overall.
- Imaging algorithms (template) applied with excellent results.

Significance

We have designed and built a proof-of-concept system and preliminary results are very promising. For the first time, fast neutron imaging using an active mask has been demonstrated. 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.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2009-4945P