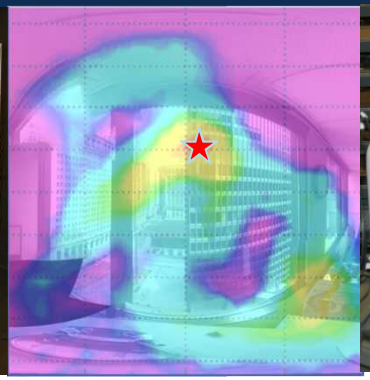
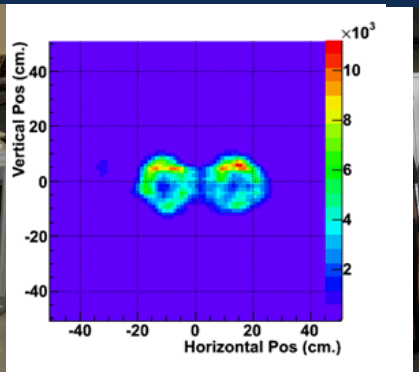
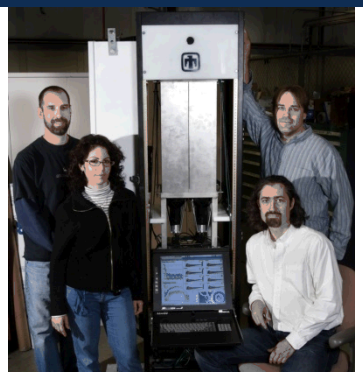
SAND2015-0109PE

Exceptional service in the national interest

Sandia National Laboratories





Sandia National Laboratories

Craig R. Tewell, PhD

Manager, Rad/Nuc Detection Systems

U.S. DEPARTMENT OF ENERGY | NNSA

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Sandia's Sites

Albuquerque, New Mexico

Livermore, California

Kauai, Hawaii

Waste Isolation Pilot Plant, Carlsbad, New Mexico

Pantex Plant, Amarillo, Texas

Tonopah, Nevada

International, Homeland, and Nuclear Security

Program Areas

- Global Security
- WMD Counterterrorism and Response
- Homeland Security
- Cyber and Infrastructure Security
- Homeland Defense and Force Protection

Capabilities

- *Nuclear, radiological, biological, explosives, and chemical science and engineering*
- *System analysis, engineering, and integration*
- *Physical and cyber security methods, technologies, and systems*
- *Predictive modeling and simulation of interdependent systems*
- *Decontamination and restoration approaches and technologies*
- *International security technologies and policy*

Gary Laughlin
IHNS Deputy

Jill Hruby
IHNS PMU VP

Sandia National Laboratories

Global Security
Rodney Wilson

- Engineered Security Systems — *Holly Dockery*
- Arms Control, Nonproliferation and Nuclear Security — *Pablo Garcia*
- Cooperative Threat Reduction — *Ren Salerno*

Key Customers: DOE (NNSA NA-21, NA-23, NA-24), DOS, DOD (DTRA)

WMD Counterterrorism and Response
Billy Marshall

- Airworthiness and Infrastructure Assurance — *Bob Mata*
- Nuclear Incidence Response — *Brad Parks*
- Nuclear Counter Terrorism — *Billy Marshall*
- CBRNE Technology Development — *Brad Parks*

Key Customers: DOE (NNSA), DOD, FAA, FBI

Homeland Security Programs
Duane Lindner

- Chem-Bio National Security — *Paula Imbro*
- Nuclear & Radiological Security — *Sheryl Hingorani*
- Weapons Remediation — *Jim Lund*
- Aviation & Explosives Security — *Wen Hsu*
- Disaster Management & Resilience — *Richard Griffith*
- Borders & Maritime Security — *Holly Dockery*
- Homeland Security Policy & Initiatives — *Nate Gleason*

Key Customers: DHS (S&T, CBP, FEMA, DNDO, TSA, USCG, USSS, OHA, Policy), DHHS (NIH), DOD (Army, DTRA, DARPA)

Cyber and Infrastructure Security
Len Napolitano

- Cyber — *Bob Hutchinson*
- Resilient Infrastructure Systems — *Bill Rhodes*

Key Customers: DHS (NPPD, S&T)

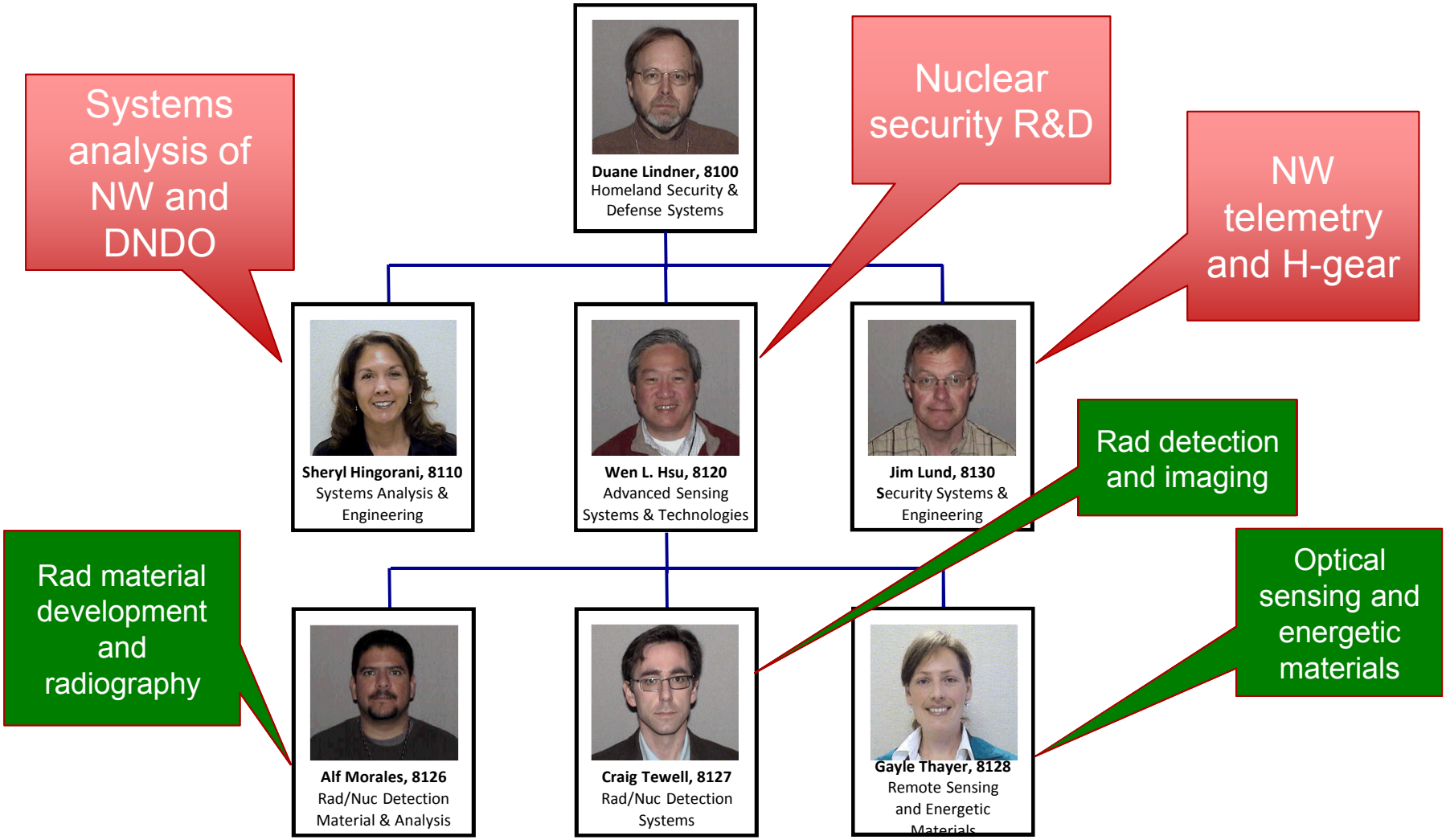
Homeland Defense & Force Protection
David Corbett

- Air Force Nuclear Security Engineering — *Randy Peterson*
- DOE/NNSA Nuclear Security Engineering — *Randy Peterson*
- Navy Nuclear Security Engineering — *Jennifer Nelson*
- Technologies and Systems For Emerging Threats — *Phil Heermann*

Key Customers: DOD (Air Force, Navy, Army, DTRA, DARPA, COCOMs), DOE (NNSA), Industry

8100 Organization Structure

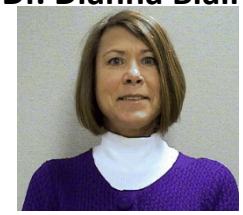
Sandia National Laboratories



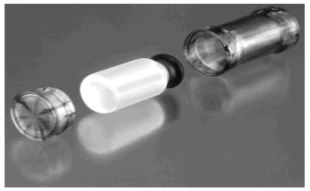
SNL has rich history with IAEA

Pablo Garcia

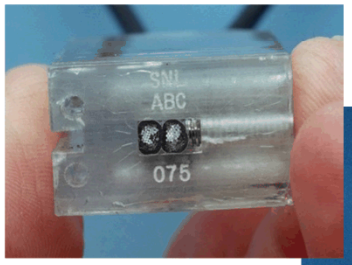
Dr. Dianna Blair

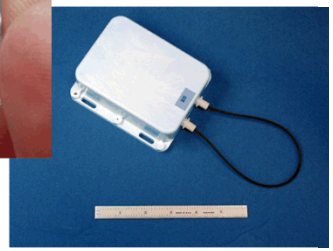


Email: dsblair@sandia.gov
Tel: 505-845-8800



- Containment and surveillance
  - Effort grew out of our background in physical protection
  - Tamper indicating enclosures
    - Sample Vial Secure Container (1990s)
      - Vial for transporting liquid samples that provides confidence in sample integrity after loss of custody
    - Cobra Seal
      - Passive fiber optic loop seal
    - Remotely Monitored Sealing Array (RMSA)
      - Recently approved for Routine use by the IAEA
      - SNL supporting commercialization efforts





- Vulnerability Reviews and Assessments
  - We work have worked directly for IAEA on projects
- Data assurance
  - Authentication/encryption
    - IAEA Policy Paper establishing data authentication requirements was written by a Sandian on loan to IAEA
- Unattended and remote monitoring
  - Deployed VPN field test
  - Developing and field testing technology to split operator signal at UK facility (EDAS)

Sandia National Laboratories

8128 Remote Sensing and Energetic Materials

Personnel

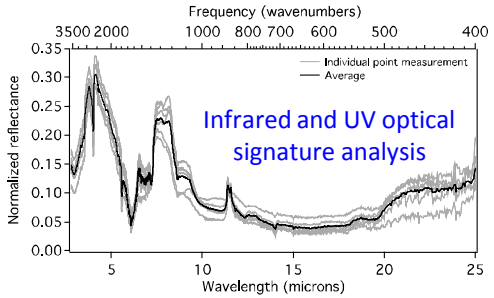
Manager: Gayle Thayer

Direct Reports: 9 PhD, 1 Bachelors,1 Associate

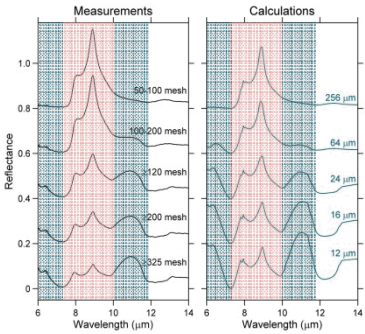
Field of Degree:

- Applied Physics
- Chemistry
- Mechanical Engineering
- Electrical Engineering

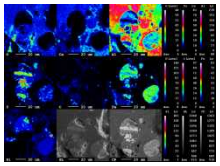
Solids Signatures

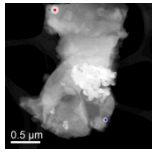


Modeling and simulation



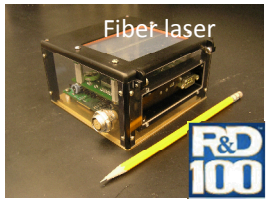
Chemical and morphological studies

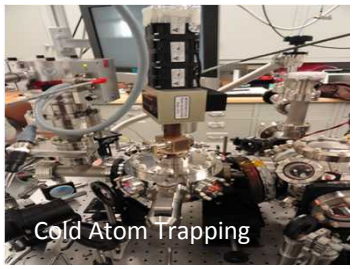




Optical Sensing and Source Development

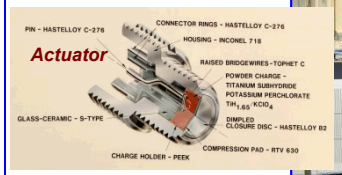
- Novel laser sources that are efficient and robust
- New approaches to single atom detection
- Quantum sensing for the ultimate detection sensitivity and selectivity





Energetic Materials

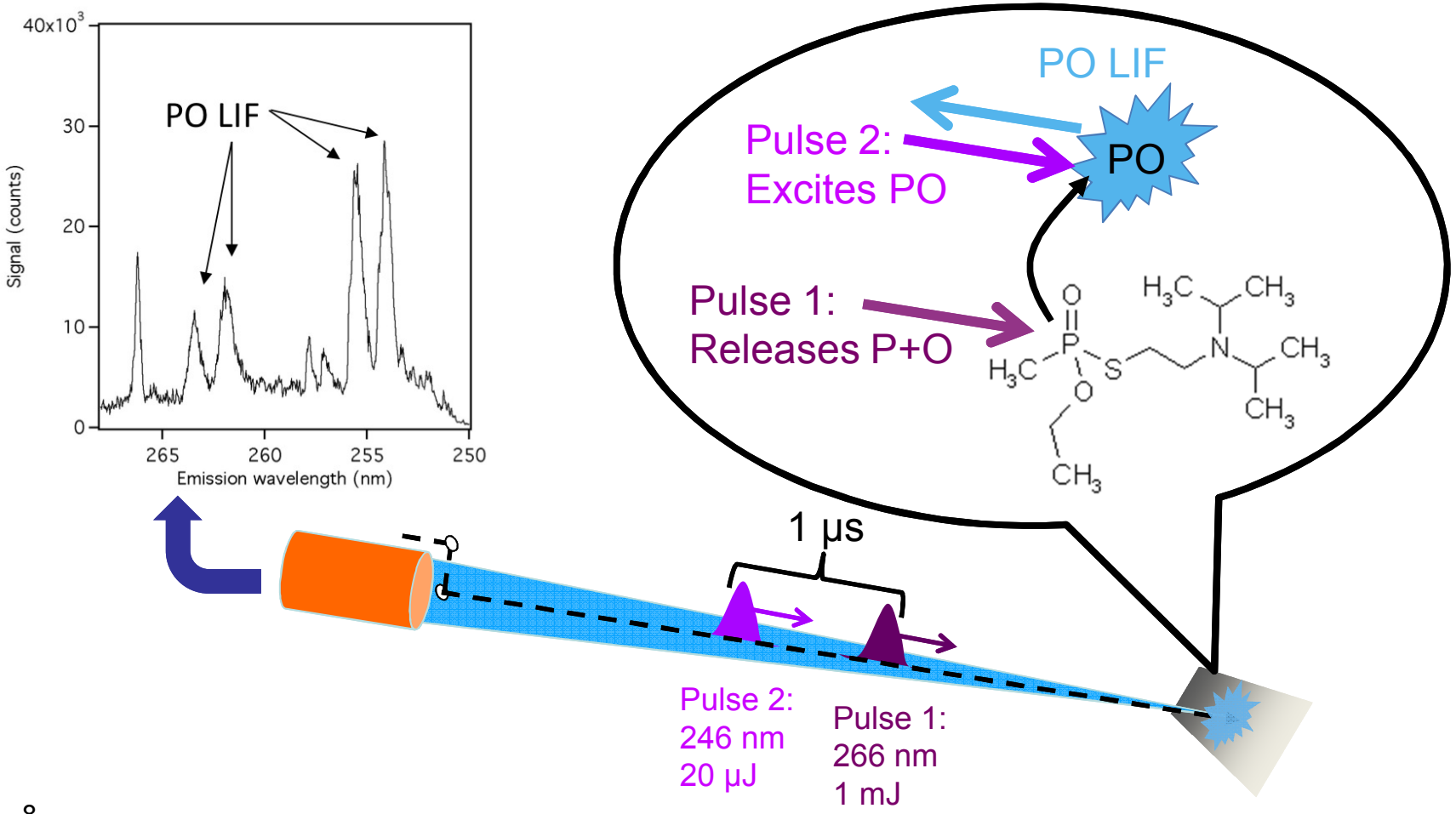
- Tools provide detailed analyses of EM reaction chemistry
- Rapidly assess the behavior of new ingredients and formulations
- Measure critical chemistry and physics that control EM sensitivity and aging



Short-Range Standoff Detection of Low Volatility Agents on Surfaces

Scott E. Bisson, Tom Kulp and Thomas A. Reichardt

The LA-LIF surface-bound LVA detection method

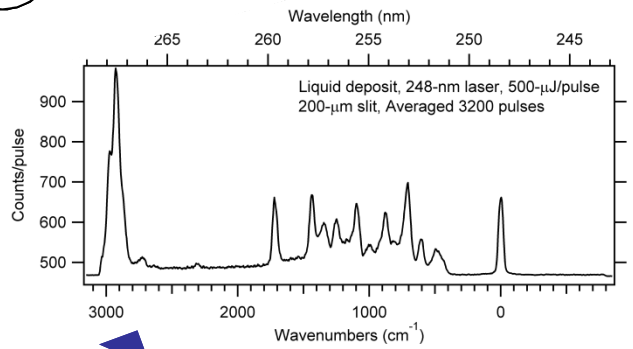


Potential implementation

1 Map location of organophosponate materials

- 30 µg/cm^2 detection at ≥1000 pts/s
- Example: ≥1 meters/s at full linear coverage (every mm)

2 Confirm LVAs using Raman

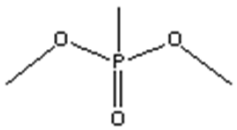


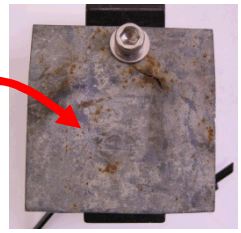
Longer dwell time allocated only for PF-LIF "hits"

LA-LIF successfully detected 4 surrogates on 6 realistic substrate materials (all combinations tested)

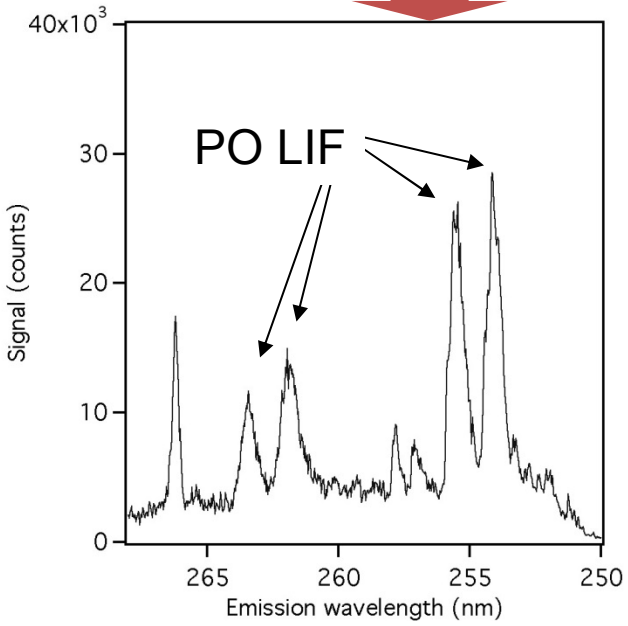
DMMP on oxidized steel, one day after deposit

DMMP

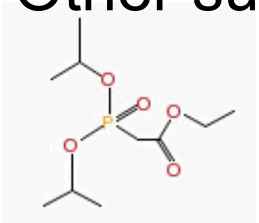




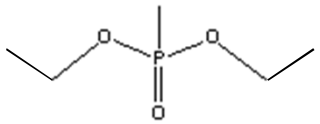
Oxidized steel



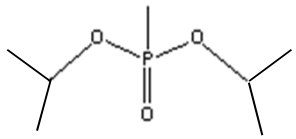
Other surrogates detected:



DIPP



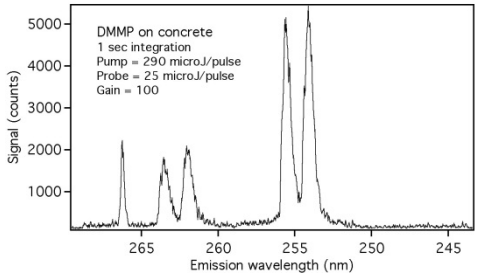
DEMP



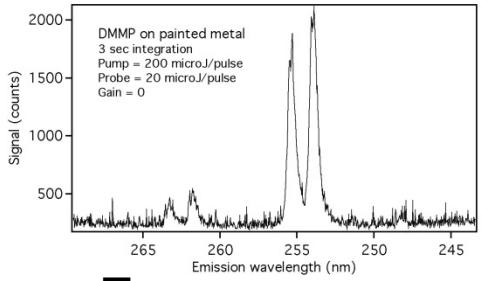
DIMP

Other substrates tested:

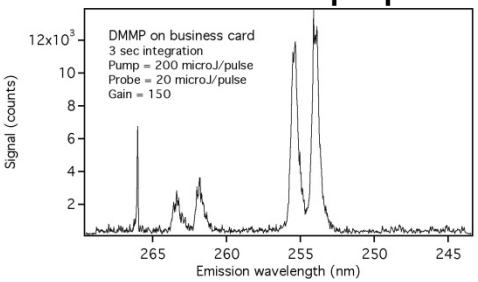
Concrete



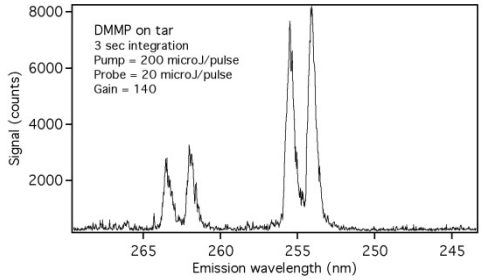
Painted metal



Whitened paper



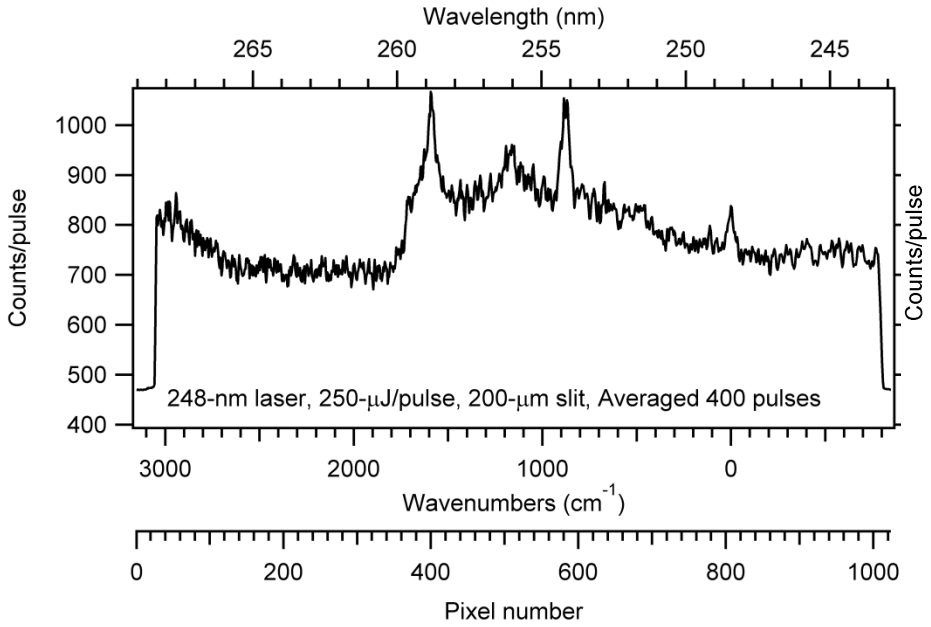
Tar



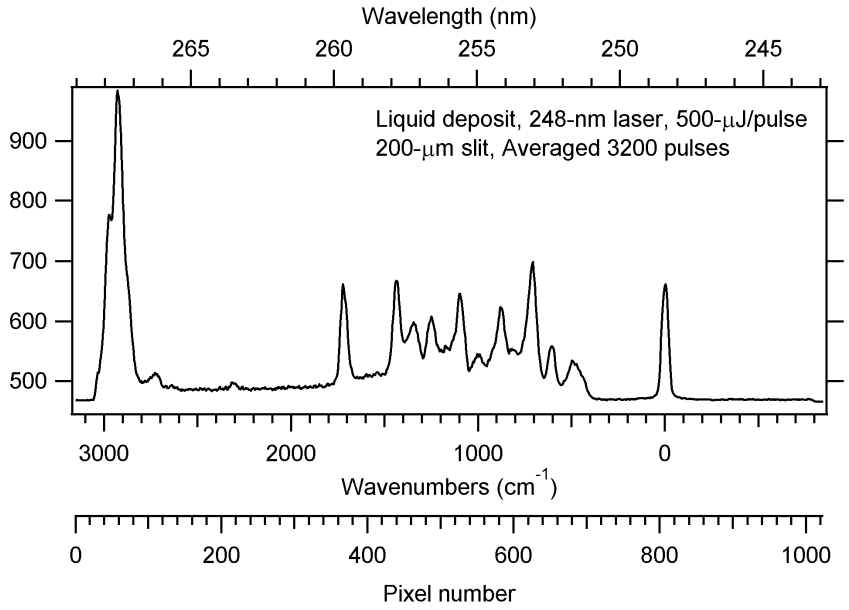
Aluminum (not shown here)

Raman is a potential orthogonal channel

Raman of thick Betco soap on aluminum



Raman of thick DIPP on aluminum



- Measurements made with same laboratory hardware as for LA-LIF
- One instrument could perform both measurements (Raman, LA-LIF)
- Rapid LA-LIF would cue slower Raman

8126 Rad/Nuc Detection Material and Analysis

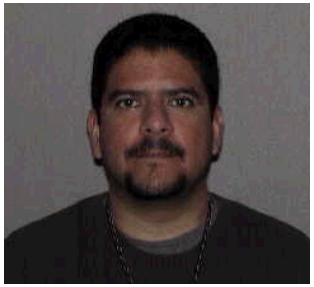
Personnel

Manager: Alf Morales

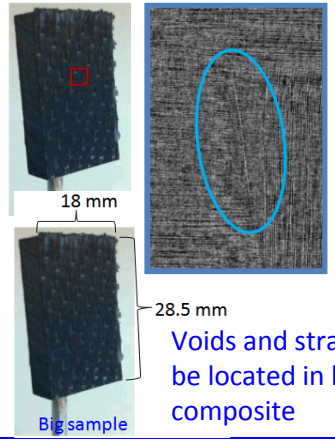
Direct Reports: 11 PhD, 1 Associate

Field of Degree:

- Nuclear Engineering
- Materials Science
- Physics
- Applied Physics
- Physical Chemistry
- Materials Modeling
- Computer Science

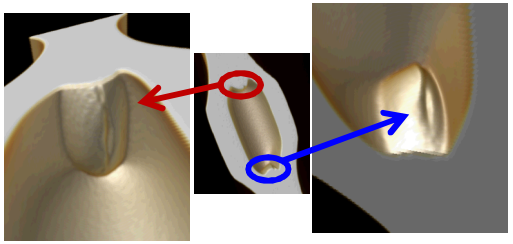


State-of-the-art Radiography and Non-destructive Analysis



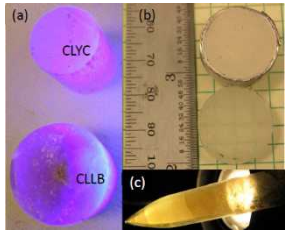
Voids and stray fibers can be located in large carbon composite

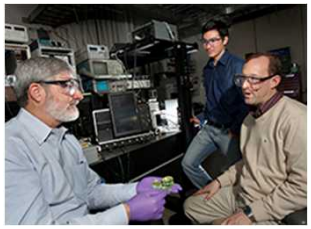
Pinch weld computed tomography



Rad Detector Material Development

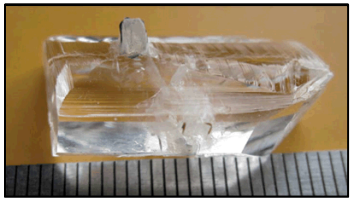
- Develop novel materials that provide superior performance (faster, brighter, more robust)
- Distinguish between neutrons and gammas





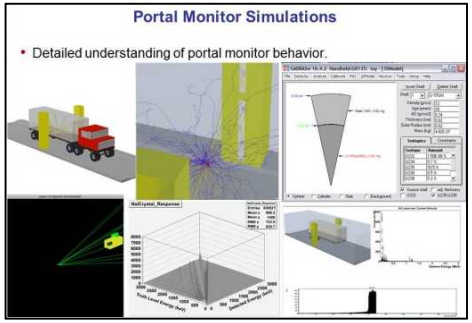
R&D

Triplet Harvesting Plastic Scintillator



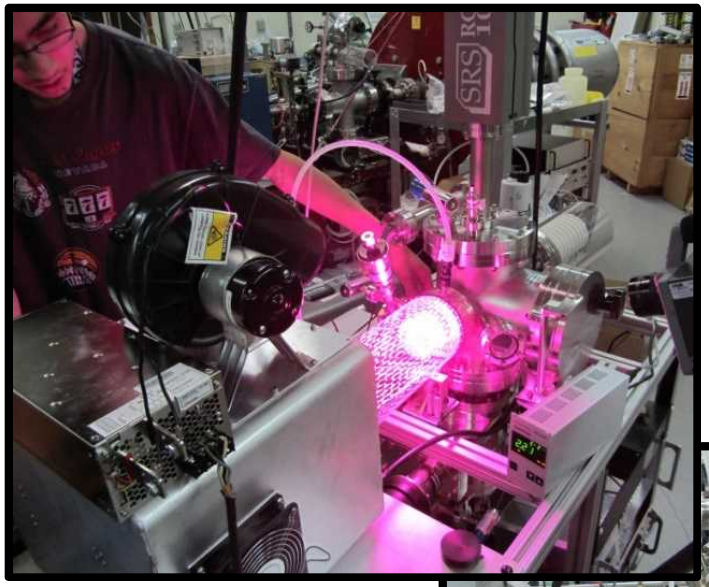
Rad/Nuc Reachback

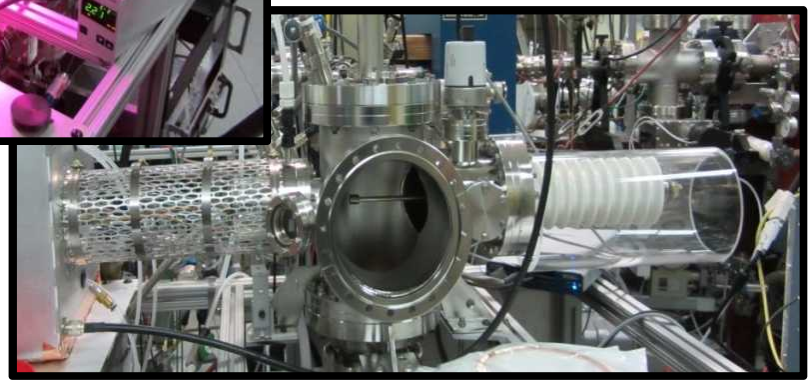
- Triage: real time, 24/7 reach back capability. On call spectroscopists adjudicate alarm
- Technical Reach Back: data analysis to provide situational awareness, analysis tools, and reports to help Triage-like programs.

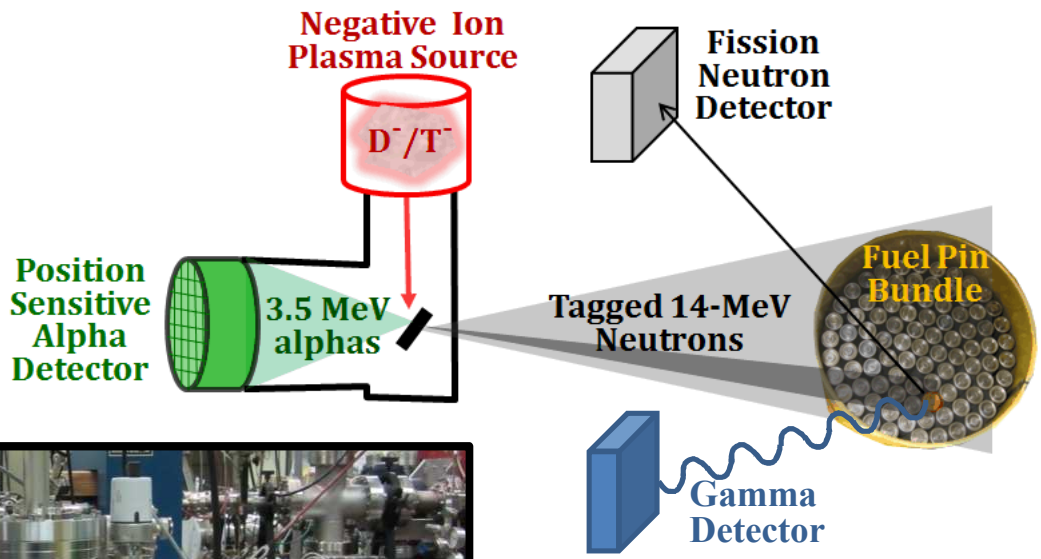


SNL/CA Active Neutron Imaging

World's first demonstration of a compact associated particle neutron generator based on a negative ion source

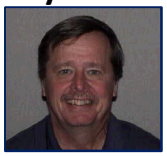






Contact

Dr. Arlyn Antolak



Email: antolak@sandia.gov

Tel: 925-294-3363

Negative Ion Source Enables

- HV operation without arcing
- High resolution (1-mm spot size)
- High neutron production efficiency (100% monatomic ions)

Reliable high fidelity neutron imaging for Arms Control, Treaty Verification, Safeguards, and other Nonproliferation applications.

Sandia National Laboratories

8127 Rad/Nuc Detection Systems

Personnel

Manager: Craig Tewell

Direct Reports: 9 PhD, 3 Bachelors,1 Associate

Field of Degree:

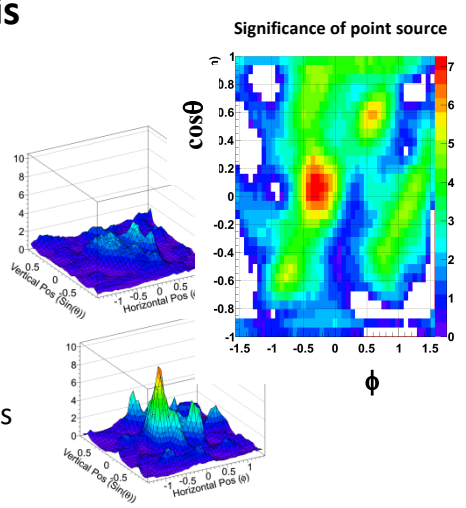
- Nuclear Engineering
- Engineering Physics
- Applied Physics
- Chemistry
- Liberal Arts

Fast Neutron Detection

- Standoff detection
- Localization of radiological material
- High resolution imaging
- High-background operation
- Neutron/gamma discrimination

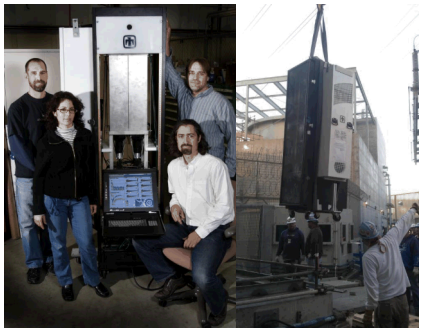
Source Imaging and Analysis

- Source design
- Imaging analysis
- Complex radiation transport and detector Monte Carlo simulation
- Characterizing complex radiation backgrounds
- Extensive field operating experience in extreme environments
- Local inventory of radiation sources and neutron generators

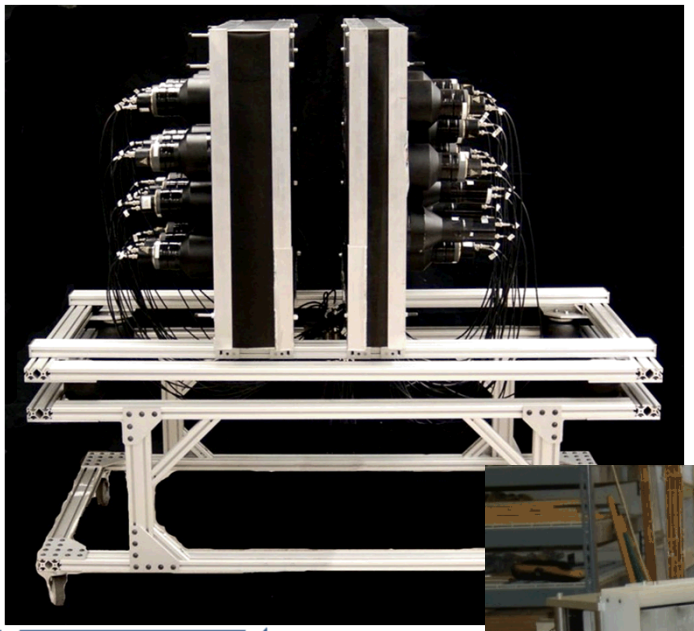


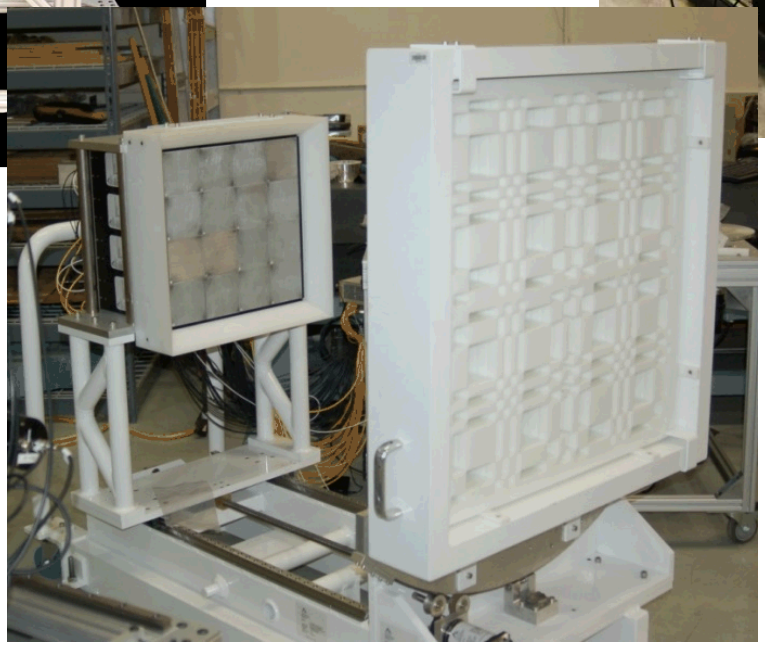
Antineutrino Detection Applications

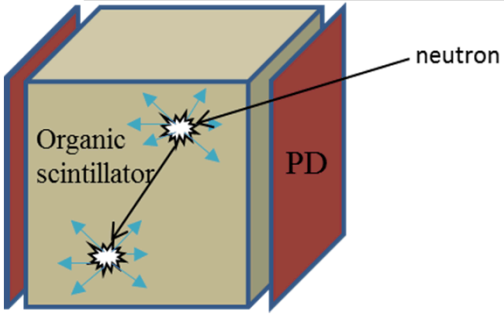
- Antineutrinos provide a capability to detect and monitor nuclear reactor operation and explosives tests
- Focus on “near field” capabilities (less than 1km from source)
  - Cooperative reactor monitoring
  - Verification of sub-critical explosive tests (i.e. CTBT)



SNL/CA Passive Fast Neutron Imagers







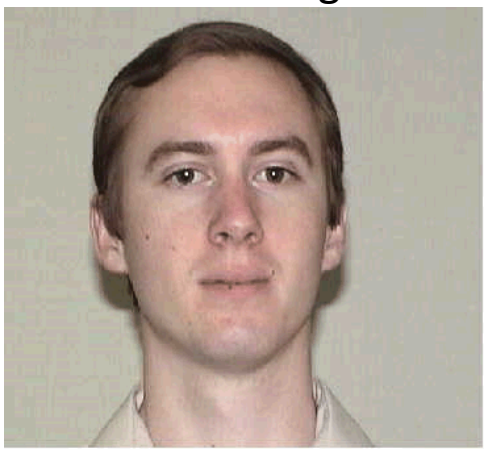
Sandia National Laboratories

SNL/CA Passive Fast Neutron Imaging Group

Erik Brubaker

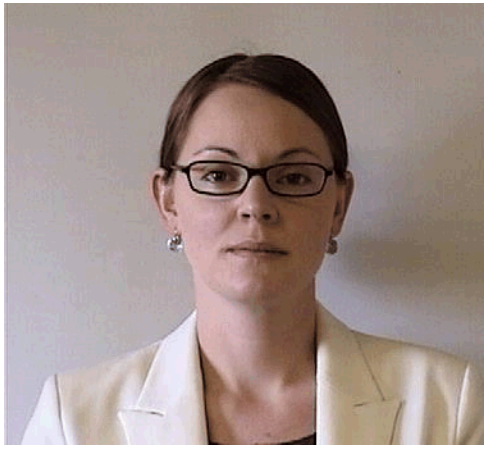
John Goldsmith

Mark Gerling



Scott Kiff

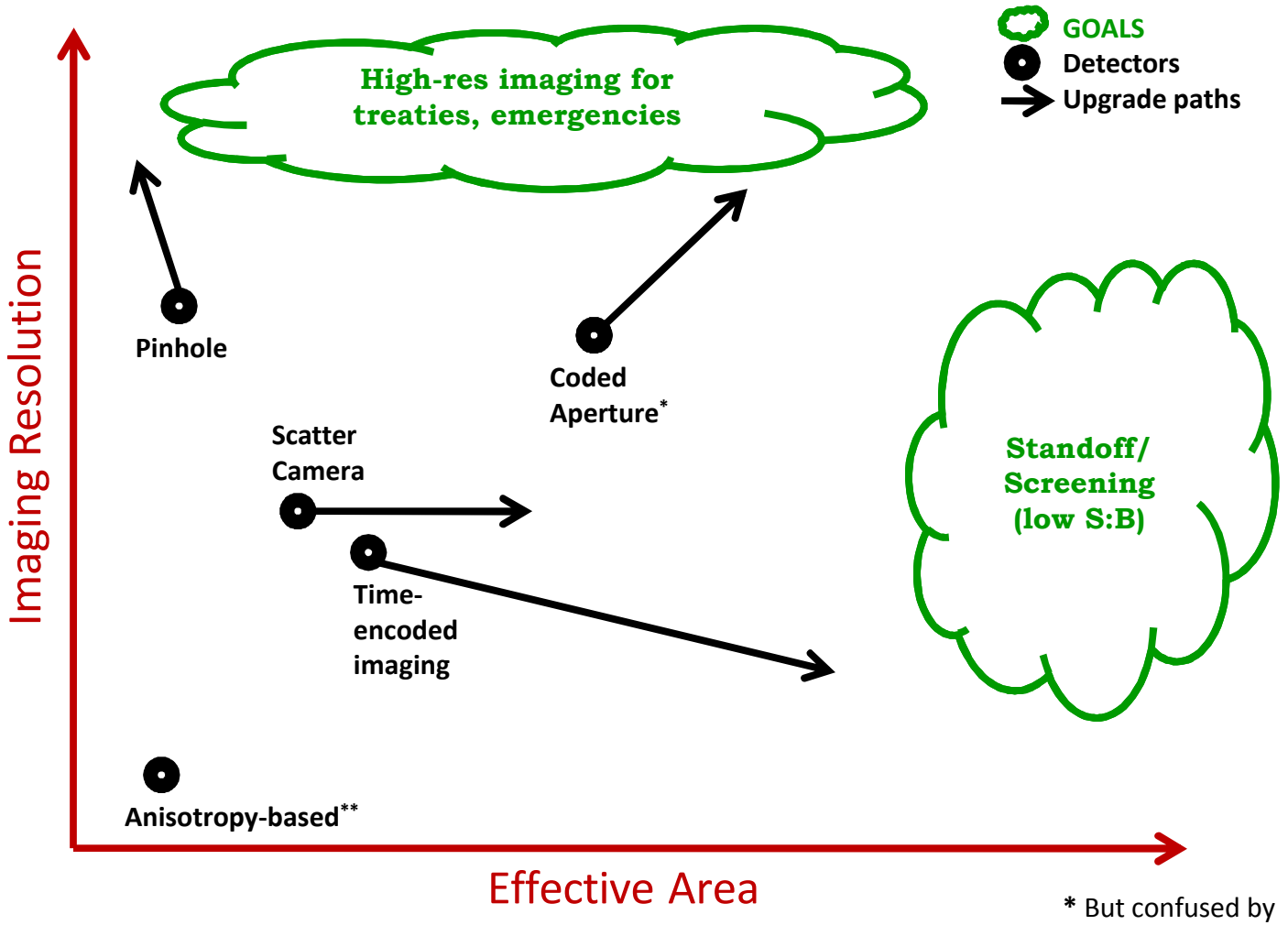
Peter Marleau



Melinda Sweany

Sandia National Laboratories

SNL/CA Passive Fast Neutron Imaging Application Space



* But confused by multiple/extended sources

** But compact

Sandia National Laboratories

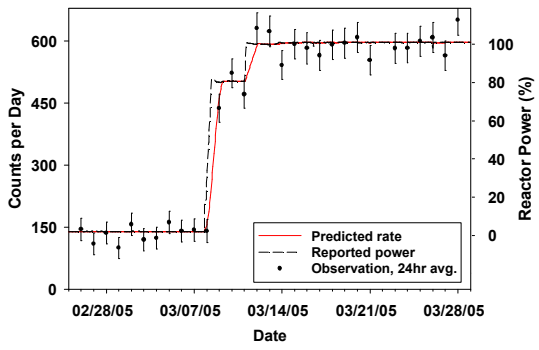
Antineutrino Monitoring Past and Present

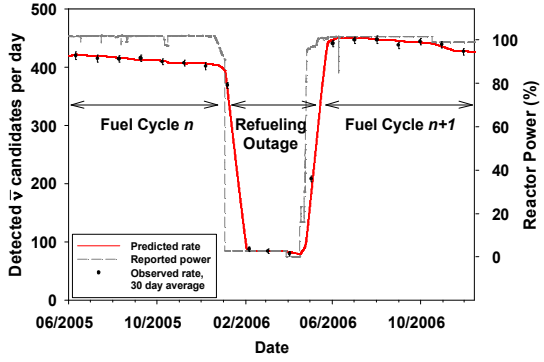
Joint SNL/LLNL Work under NA-22

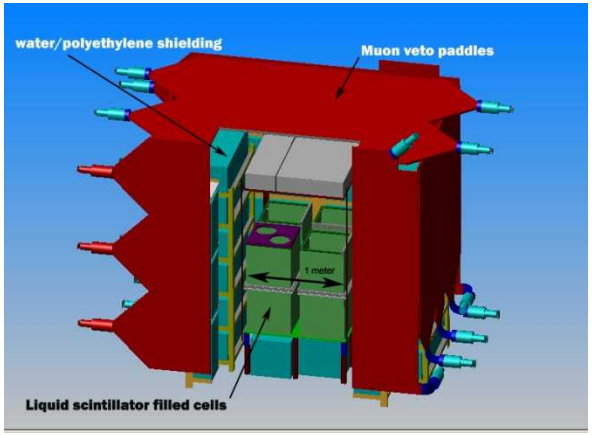
- Phase I (2002) Concept Inception
- Phase II (2003-2006) Proof of Principle
  - Initial deployment at SONGS
  - Refinement of basic Liquid Scintillator detector
  - Successful demonstration (SONGS1)
- Phase III (2007-2012) Aboveground
  - Detector technology innovation

Phase IV (2012-) SG Applications

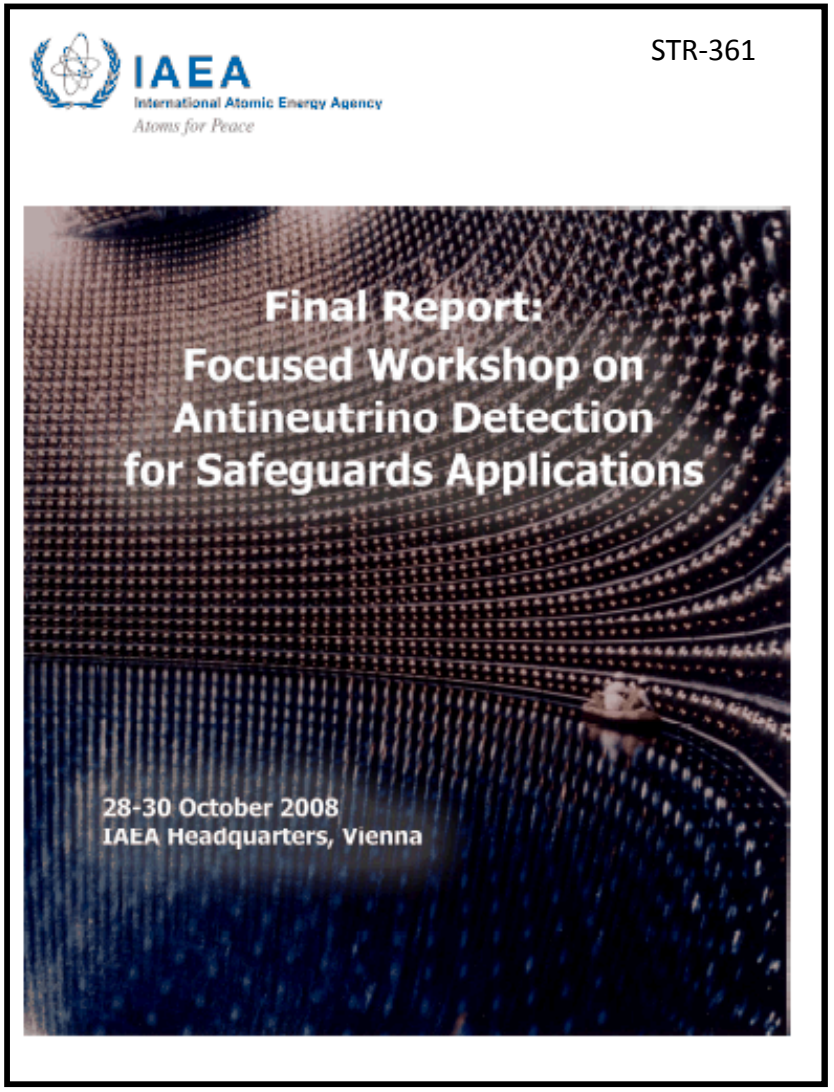
- Large Standoff (Watchman)
  - Large liquid detectors
  - Effort led by LLNL
    - Primarily focused on Water Cerenkov Technology development
- Near Field Monitoring
  - Requires compact, robust detectors
  - Effort led by SNL
    - Engaged outside sponsors (DoS) to continue development of aboveground technology







Interaction with Safeguards Agencies



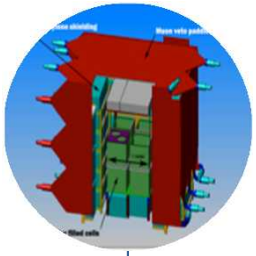
Expert's Meetings at IAEA – NTU

- Introduction of technology – 2003
  - Called for further development
- Focused Workshop – 2008
  - Suggested Application against
    - Research Reactors
    - Bulk Process Reactors
  - Requested Improvements in
    - Robust Deployability
    - Fully Independent measurement of fissile content
- Ad-Hoc Working group – 2011
  - Reiterated interest in application to future reactors and alternative fuel cycles
  - Requested application to PMDA

Also of Interest

- Recent work with Brazil – 2014
  - Bilateral (US-DOE / CNEN) Action Sheet "*International Safeguards Assessment for the Monitoring of Reactor Antineutrinos*"
  - Focused on the Angra dos Reis Nuclear Power Plant

Antineutrino Detector Technology Tree



2005-6

SONGS1 (Liquid Scintillator)

Result: Success

Liquid Scintillator

Optimized

Never deployed

?

Water Cerenkov

2007

250 liter prototype

Inconclusive Result

2010

Improved 1-ton

Inconclusive Result

2012-?

Watchman

NA-22

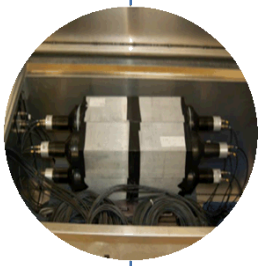
LLNL/SNL

Plastic Scintillator

2007

+ Gd sheets

Success



2011-12

+ Li:ZnS

Successful Background Rejection

2013-14

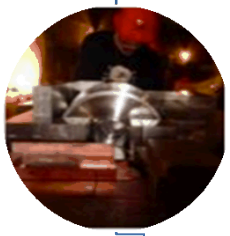
DoS-VFUND

SNL

+ WLS

Successfully demonstrated 2m segments

Germanium



2008

1kg first test

Failed

(needs further development)

2009-12

LDRD for technology development

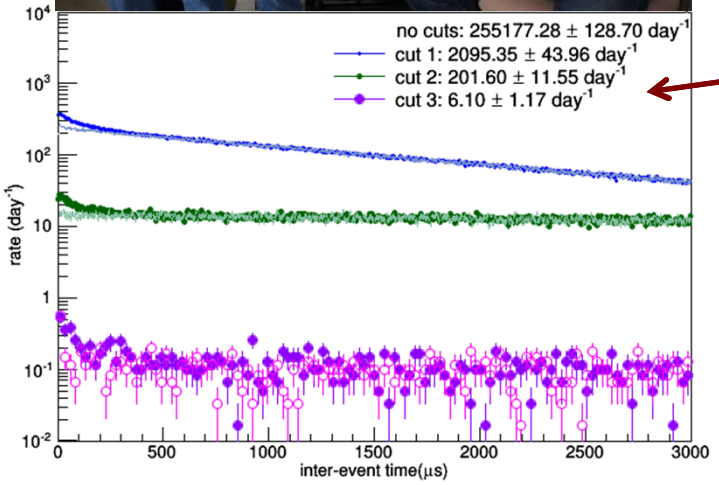
SNL

2012-15

ULGeN Collaboration NA-22 WMS

SNL/LBNL

Near-Field Monitoring

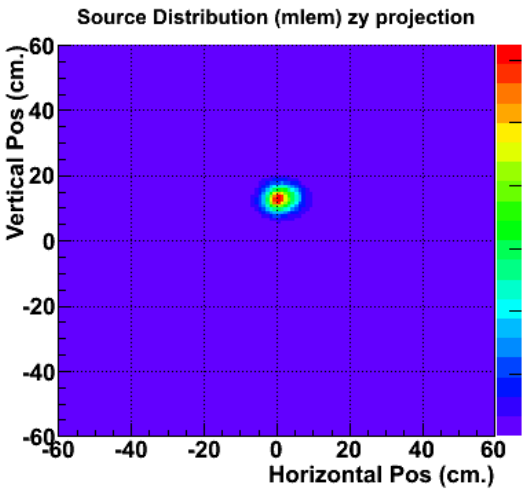


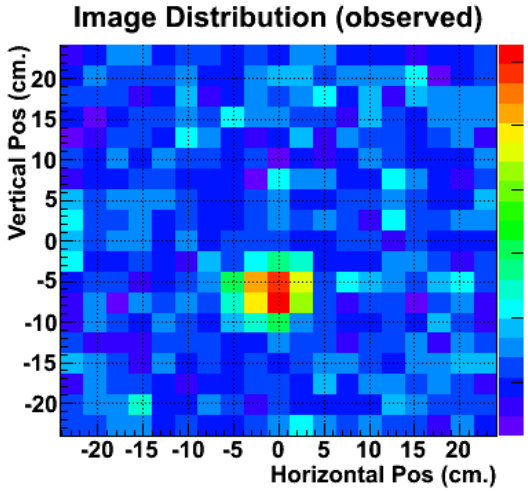
- Demonstrated capability for short and long term relative monitoring of power, operational status, and fissile content in reactors
- Potentially broader applications space
  - Antineutrinos provide a capability to detect and monitor any man-made nuclear fission process
  - Does not have immediate (plug and play) compatibility with current IAEA safeguards but they have expressed interest for future reactor designs (Gen IV and bulk process)
  - Post disaster (reactor meltdown) characterization
  - Treaty verification (CTBT, FMCT, PMDA)
- Very encouraged by performance of Segmented Scintillator prototype
  - This technology is focused on reducing the overall footprint and enabling a transportable detector that can be deployed in high-background or unshielded locations
  - Demonstrated rejection of backgrounds of 5 orders of magnitude even without an external shield
    - Data from unshielded deployment at SONGS showing rejection of backgrounds as successive selections are applied
  - Recent VFUND supported improvements have solved remaining technical challenge
    - Patent application filed based on recent results
- Road to fieldable capability
  - Need Testing of multi-segment prototype detector system to characterize background rejection as number of segments is scaled up.
  - Deployment at reactor to provide final antineutrino efficiencies
  - Would provide a fieldable technology option for SG negotiators in the near term

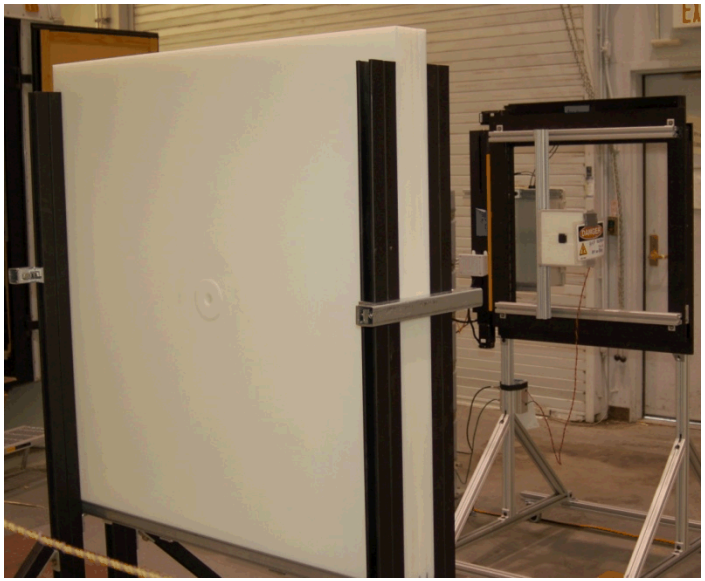
Extra slides

Pinhole imager

- Just like a pinhole camera—detect neutrons streaming through a single hole in a thick mask.
- Simplest possible directional detector.
- But low effective area.

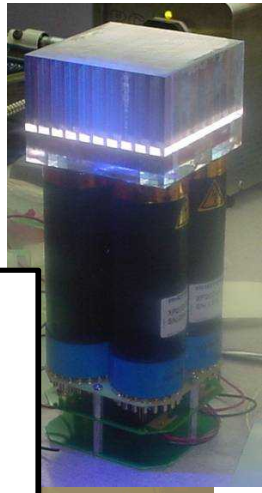




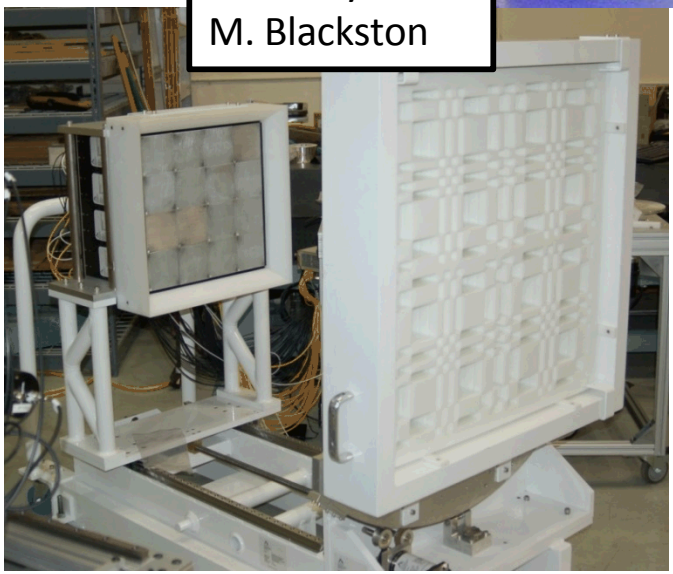


Neutron coded aperture imager

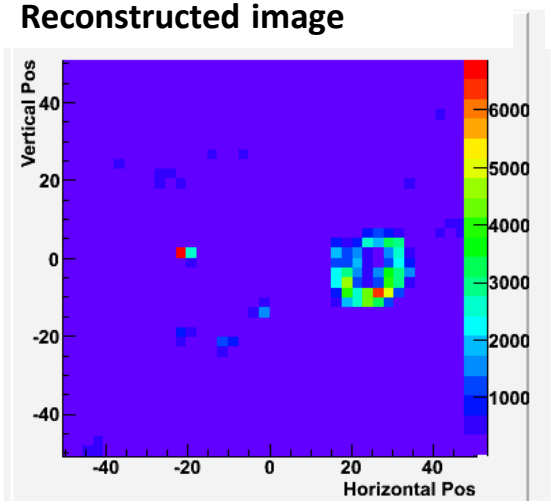
- Extension of pinhole with much higher effective area: signal modulated in unique 2-d patterns.
- ORNL/SNL fast neutron coded aperture imager being developed for arms control treaty verification.
- Image plane consists of 16 liquid organic scintillator pixilated block detectors
  - Each block consists 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 centimeters of HDPE.



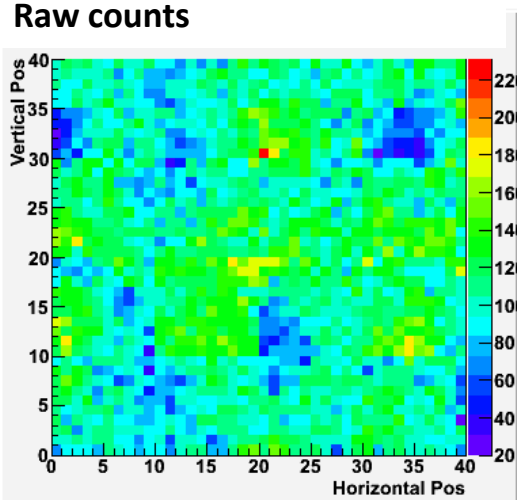
Collaboration with ORNL:
P. Hausladen
J. Newby
M. Blackston



Reconstructed image

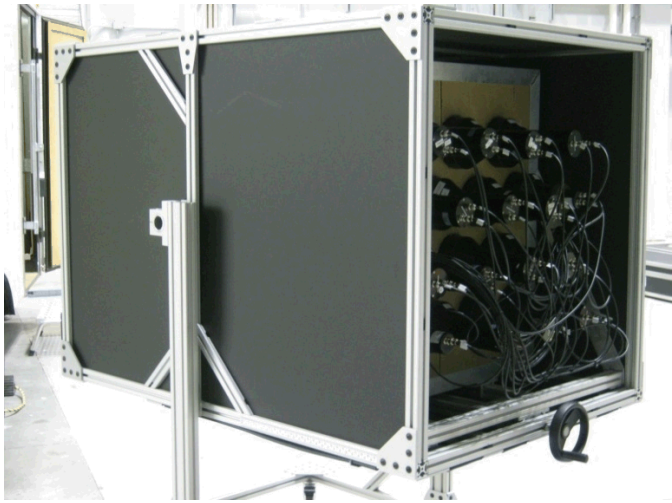


Raw counts

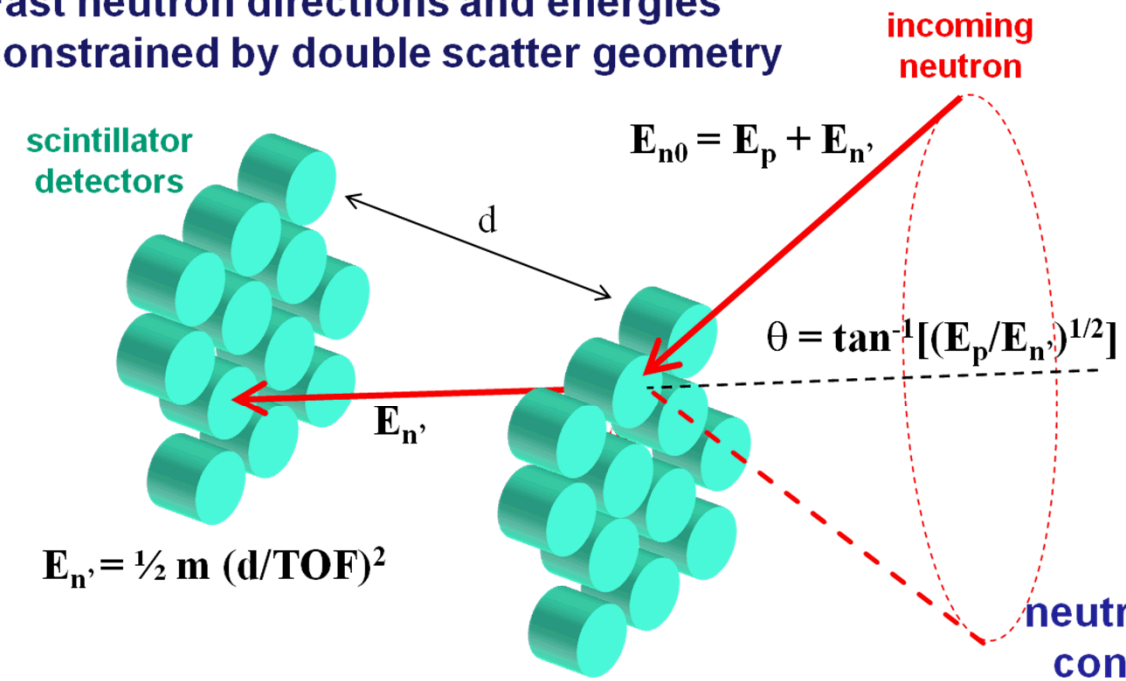


Neutron scatter camera

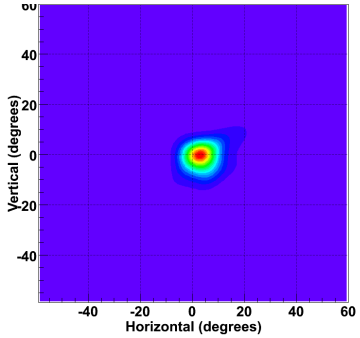
- Fast neutron imaging spectrometer
- Variable plane separation allows tradeoff of effective area, image resolution



Fast neutron directions and energies constrained by double scatter geometry



neutron direction constrained to cone surface



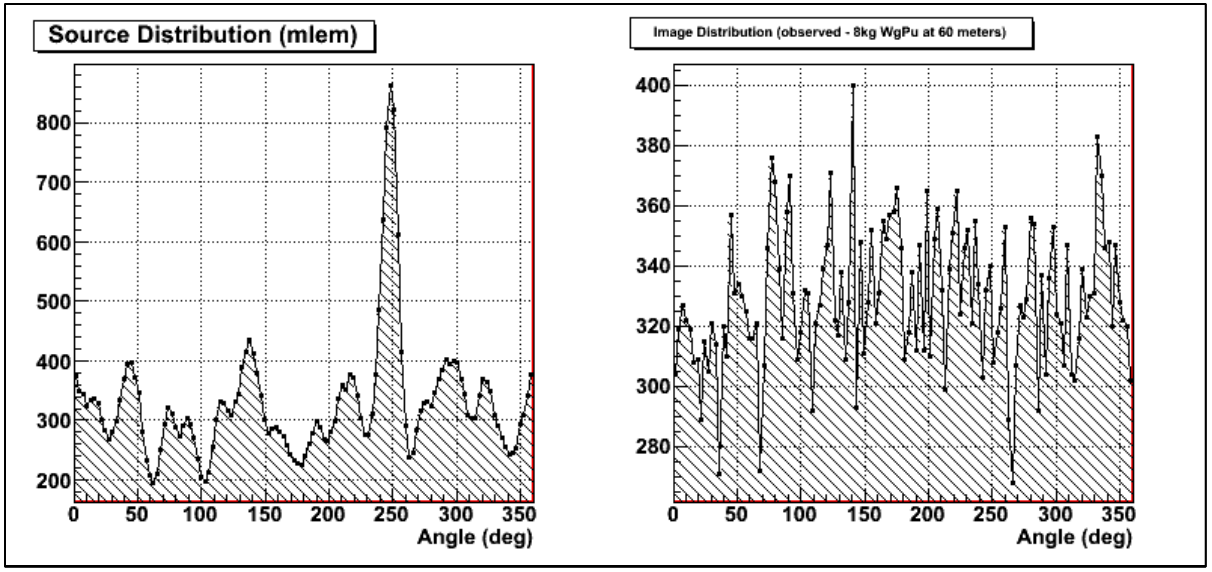
An MLEM-reconstructed neutron point source image.

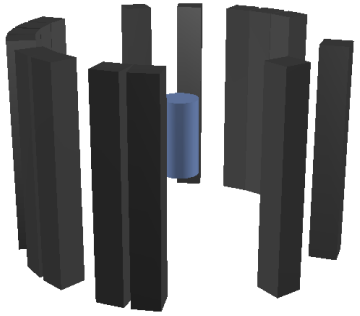
Multimode capability includes

- ***Neutron energy spectrum.***
- ***Compton imaging.***

Time-encoded imaging

- Like coded aperture imagers, but switch spatial modulation for time modulation.
- Simple and robust, low-channel-count detectors.
- Can scale to large effective area. (In 1D.)

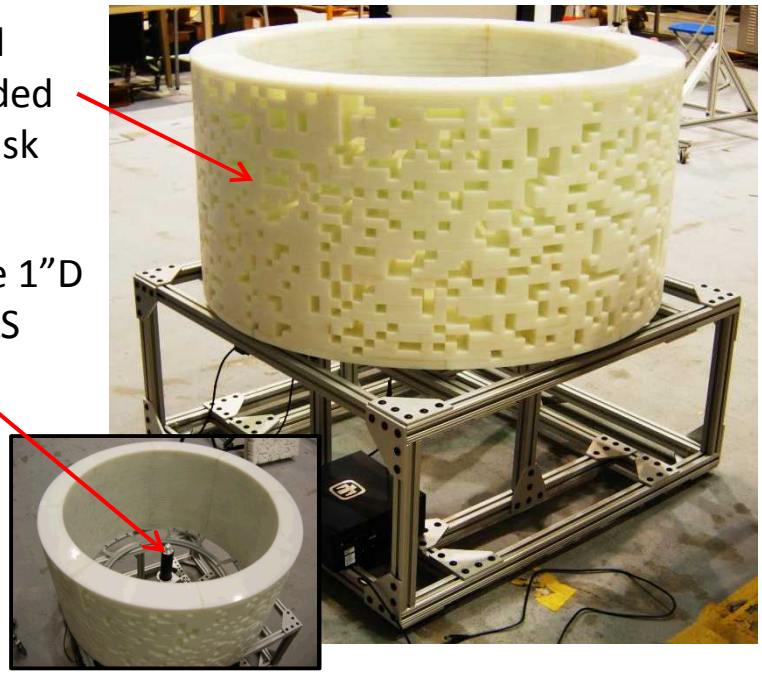




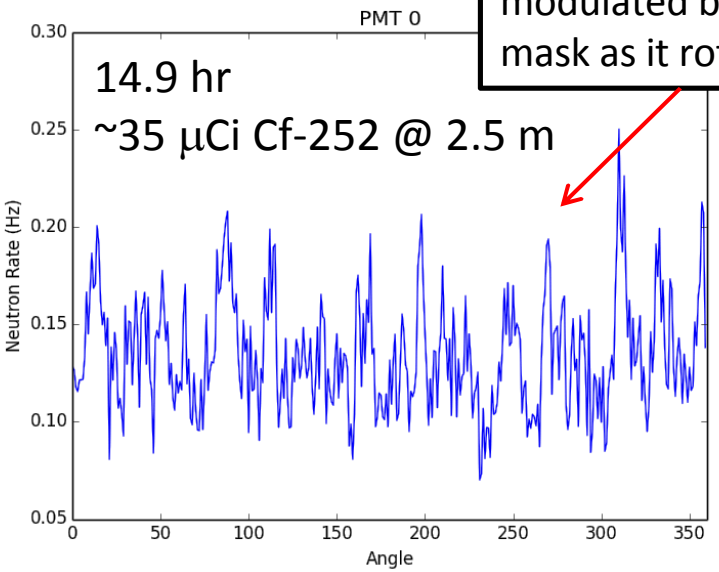
Time Encoded Imaging in 2D

2-d coded mask

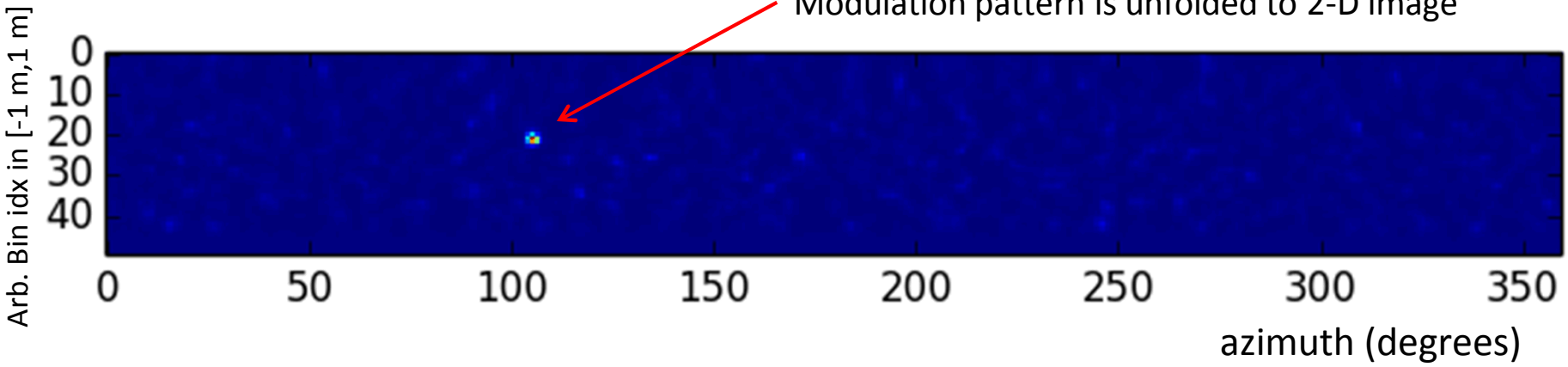
Single 1”D x 1” LS pixel



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

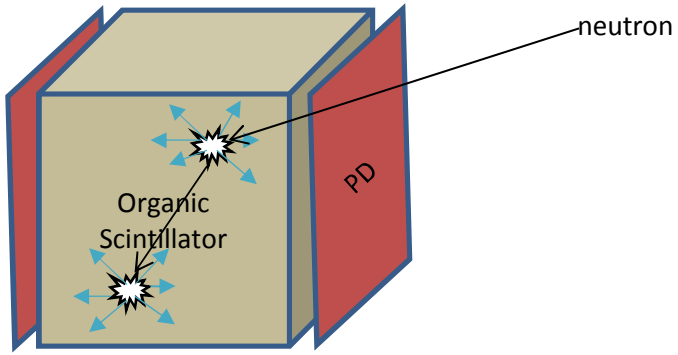


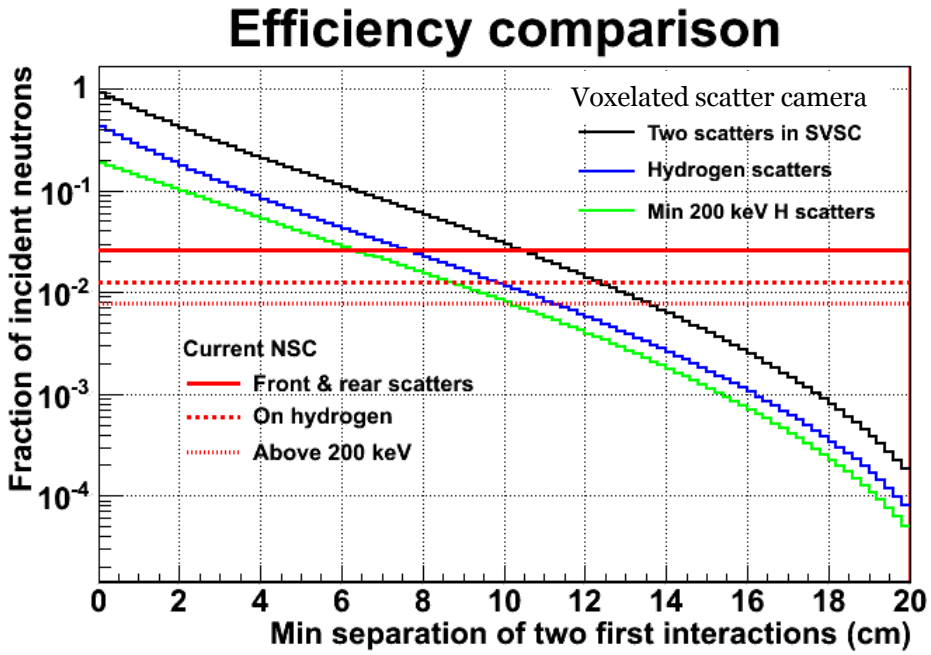
Modulation pattern is unfolded to 2-D image



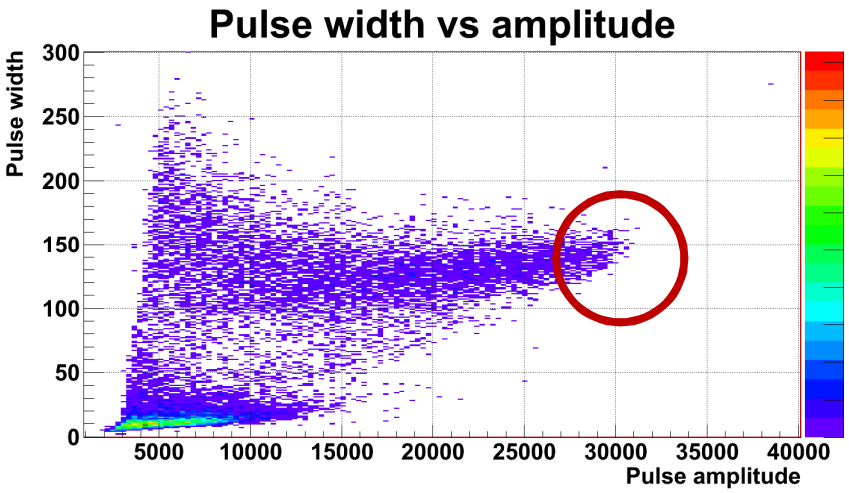
Single-Volume Scatter Camera

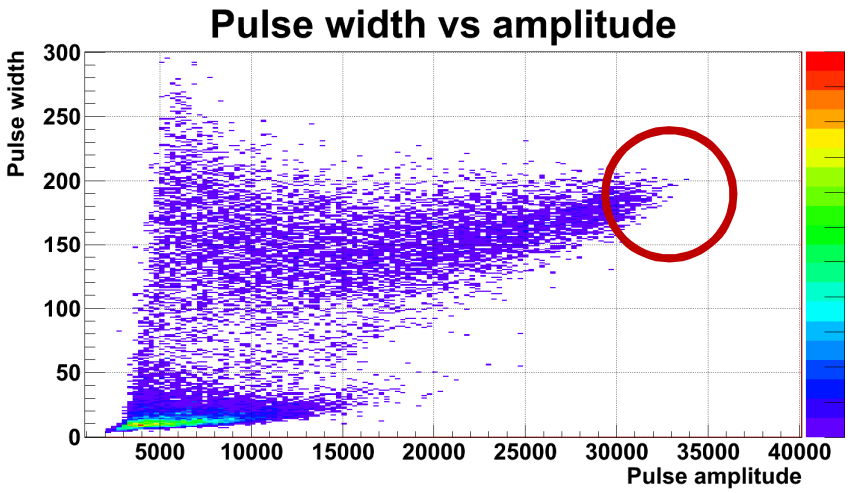
- Current development of a single-volume neutron scatter camera aims to address efficiency limitations of SNL NSC.
- A scatter camera built from a single active scintillator volume recovers more than an order of magnitude of efficiency if nearby interactions can be resolved.
- Resolving multiple interactions of a neutron separated by O(cm) and O(ns) in a bulk scintillator is difficult!
- Excellent spatial and temporal resolution of photodetectors based on microchannel plates is the key enabling technology.





Imaging via anisotropies





- DPA crystal
- 14 MeV neutron generator
- Crystal was rotated by 90^{o}
- Neutron pulse height and width increased!

Can we invert the effect to *measure* neutron direction?