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Manager, Radiation Effects and Detection
Lab POC: Consortium for Verification Technology
Nuclear Science and Security Consortium

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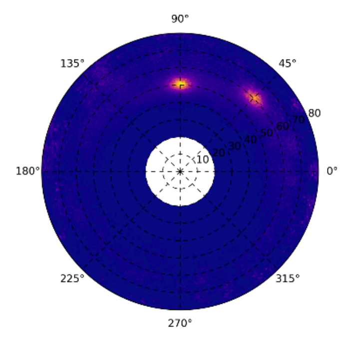
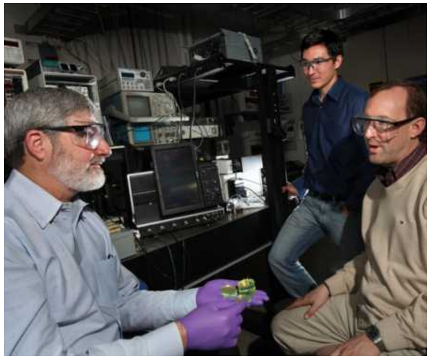
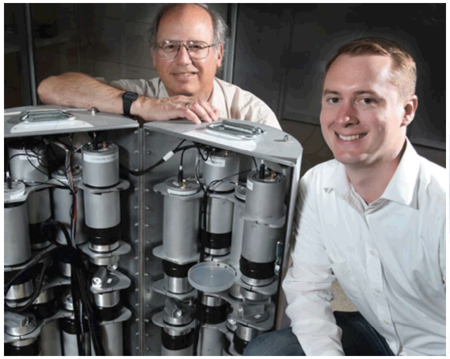
Staff Physicist, Radiation and Nuclear Detection Systems

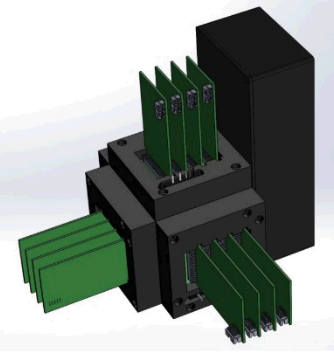
- Albuquerque, New Mexico
- Livermore, California
- Pantex Plant - Amarillo, Texas
- Tonopah, Nevada
- Kauai, Hawaii
- Waste Isolation Pilot Plant - Carlsbad, New Mexico

SAND2017-12868PE









CVT collaborative research at Sandia National Laboratories

www.sandia.gov

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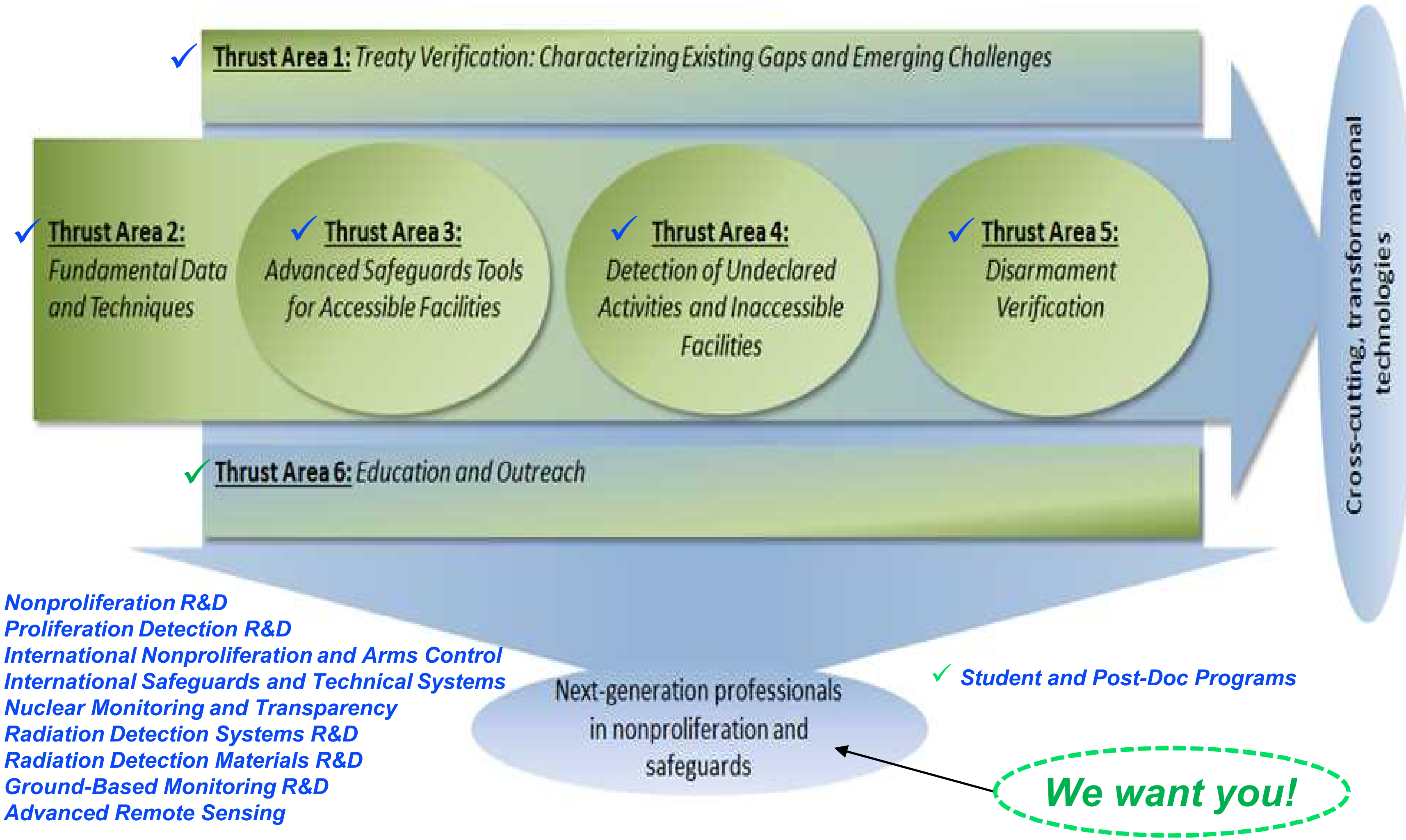
"The CVT's overarching theme is the advancement of the state-of-the-art in technologies and policies related to the verification of these [nonproliferation and arms control] treaties."

Sandia National Laboratories



- ✓ ***Nonproliferation R&D***
- ✓ ***Proliferation Detection R&D***
- ✓ ***International Nonproliferation and Arms Control***
- ✓ ***International Safeguards and Technical Systems***
- ✓ ***Nuclear Monitoring and Transparency***
- ✓ ***Radiation Detection Systems R&D***
- ✓ ***Radiation Detection Materials R&D***
- ✓ ***Ground-Based Monitoring R&D***
- ✓ ***Advanced Remote Sensing***

✓ ***Student and Post-Doc Programs***

* Consortium for Verification Technology Proposal - University of Michigan

CVT students at SNL

Student	Institution	Mentor	Duration	Project
David Goodman	UM	Brubaker	2016 - present	Neutron Imaging with Polaris
Kyle Weinfurther	NCSU	Brubaker	Summer 2016 - present	Compact Scatter Camera (SVSC PiPS)
Aditi Rajadhyaksha	UM	Kiff	Summer 2017	Well counter efficiency
Mateusz Monterial	UM	Marleau	2014 - Received PhD Now LLNL post doc	Correlated g-n timing
Marc Ruch	UM	Marleau	2015 - Received PhD Now LANL post doc	Si-PM – PSD and timing in Compact Scatter Cameras
Niral Shah	UM	Marleau	Summer 2017	Adaptive high resolution time encoded imaging
Kyle Polack	UM	Marleau	Received PhD Now SNL staff	Dual Particle Imaging Algorithms
Michael Hamel	UM	Weber	2015 - Received PhD Now SNL staff	Fissile Material Imaging with the Dual Particle Imager

CONFIDANTE - CONfirmation using a Fast-neutron Imaging Detector with Anti-image NULL-positive Time Encoding

- Dr. Patricia Schuster

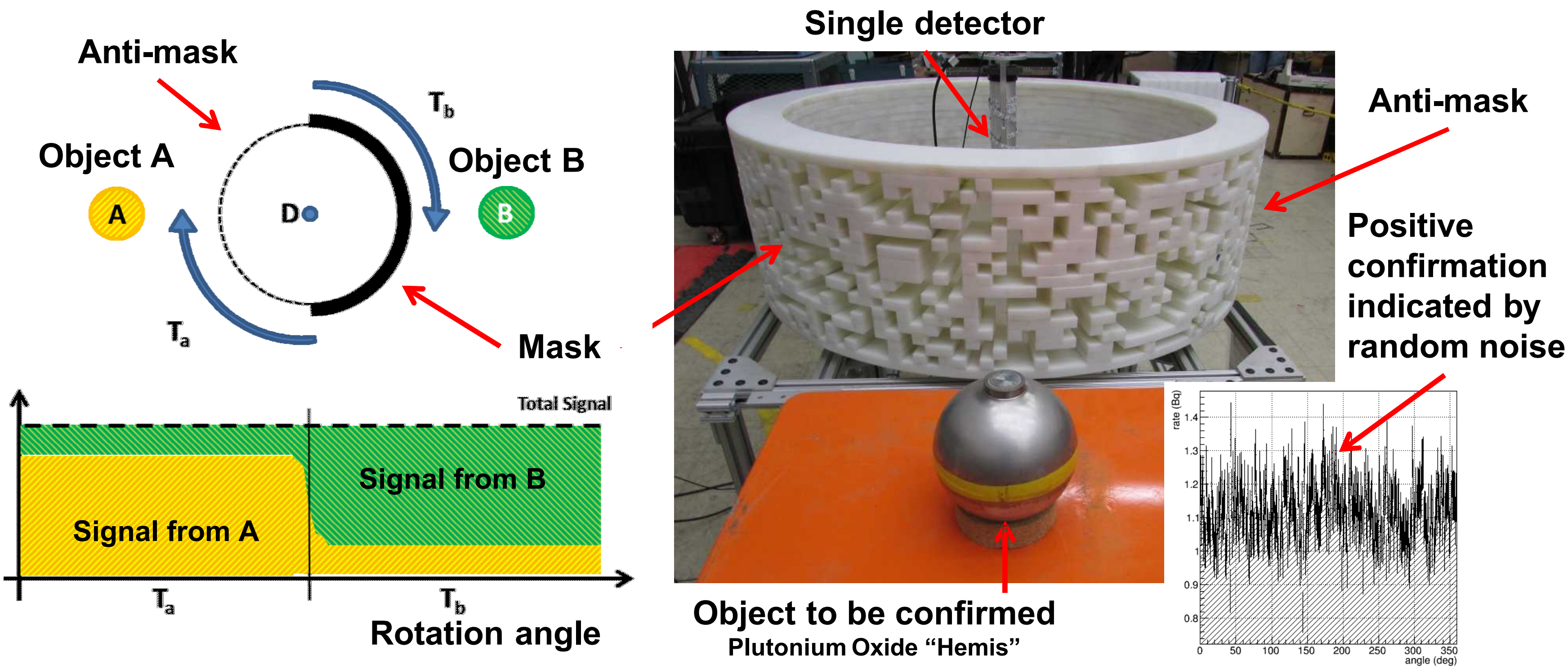


Figure - (Left-top) Top view of the simplest illustration of the CONFIDANTE concept. One half of the mask is the anti-mask of the other. (left-bottom) If A and B are identical, then the sum of signals (y-axis) will be consistent with random noise as a function of rotation angle (x-axis) even though the contributions from A and B vary. (Right) Photograph of the CONFIDANTE prototype confirming two objects are identical as indicated by a completely random signal (right inset).

CONFIDANTE news release

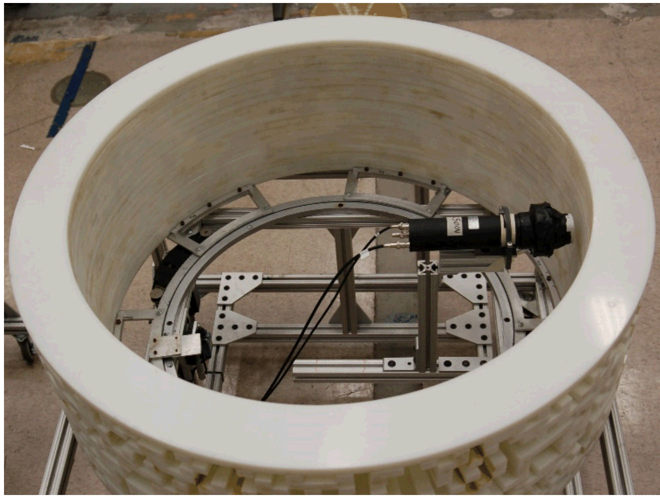
Sandia National Laboratories

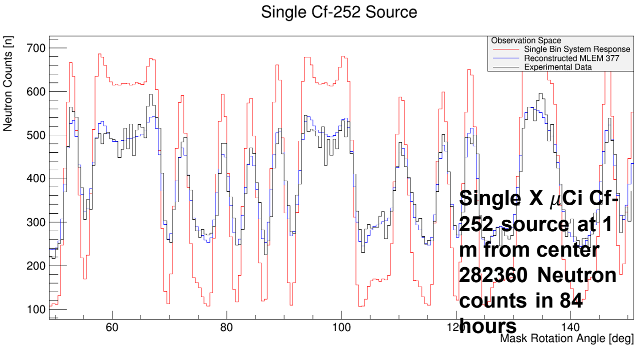
Overcoming the trust barrier in nuclear weapons verification measurements

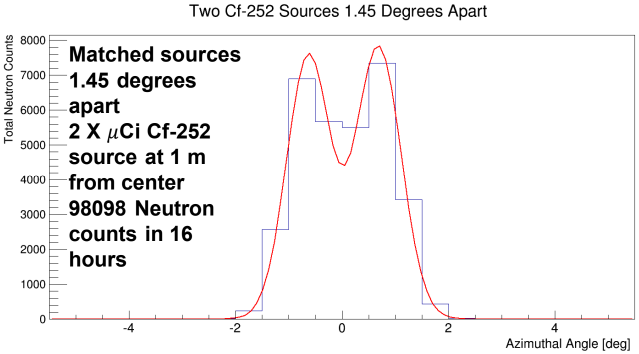
https://share-ng.sandia.gov/news/resources/news_releases/warhead_verificiation/

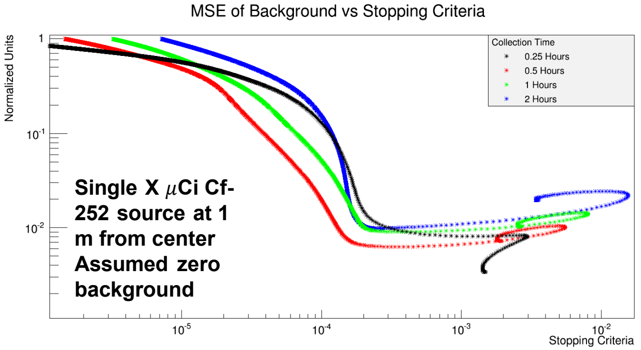
High resolution adaptive 2D TEI

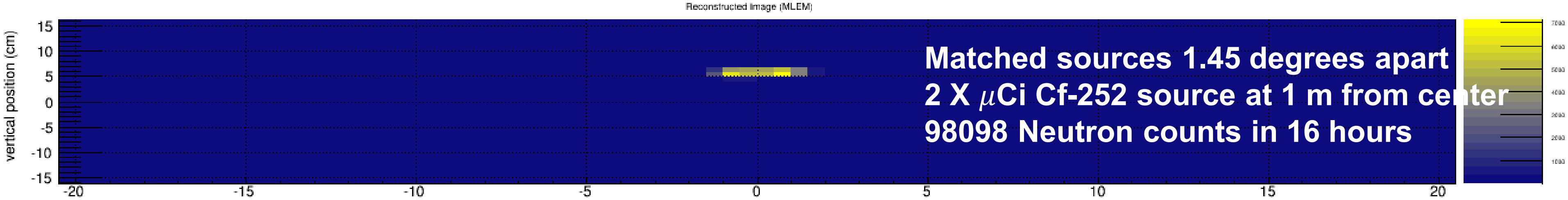
- Niral Shah (Advised by Professor Wehe) – see poster
- Detector shifted off-axis
  - Improves resolution while making directional
  - Increase magnif. -> larger detector-> greater efficiency
  - Limited field of view
- Adjoint-MCNP simulations for response map
  - Half degree bins in azimuthal, z, and rotation angle
  - No symmetry and large amount of scattering



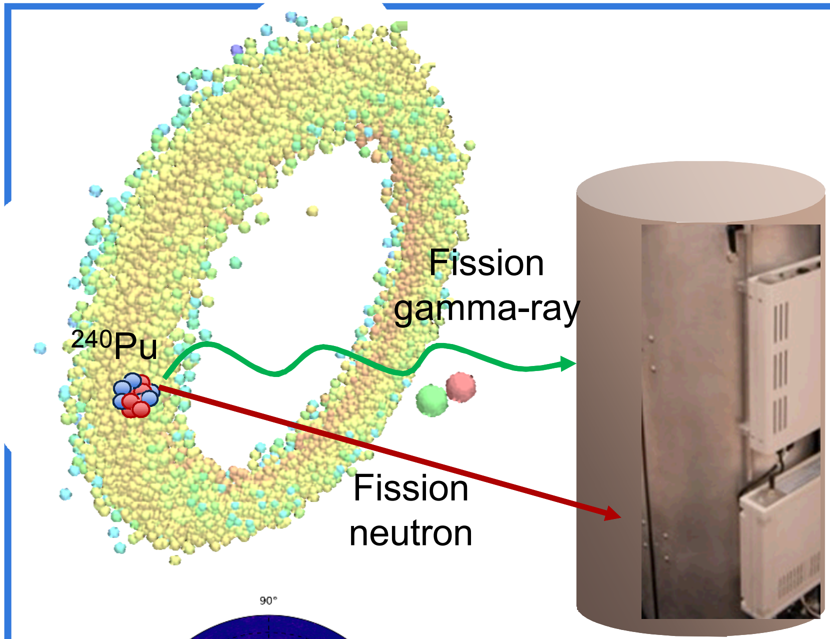


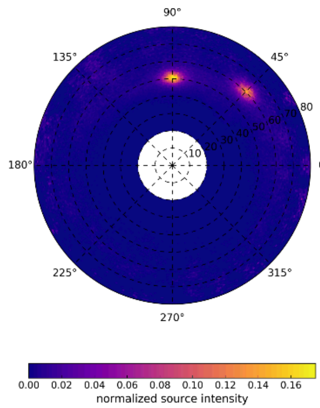






Correlated γ-n 3-D Imaging





MINER

$$\Delta t_{n-\gamma} = \frac{R_n}{v_n} - \frac{R_\gamma}{c}$$

and/or

$$cos^2\theta_{n1} = \frac{E_{n1}}{E_{n0}}$$

Imaging modality:

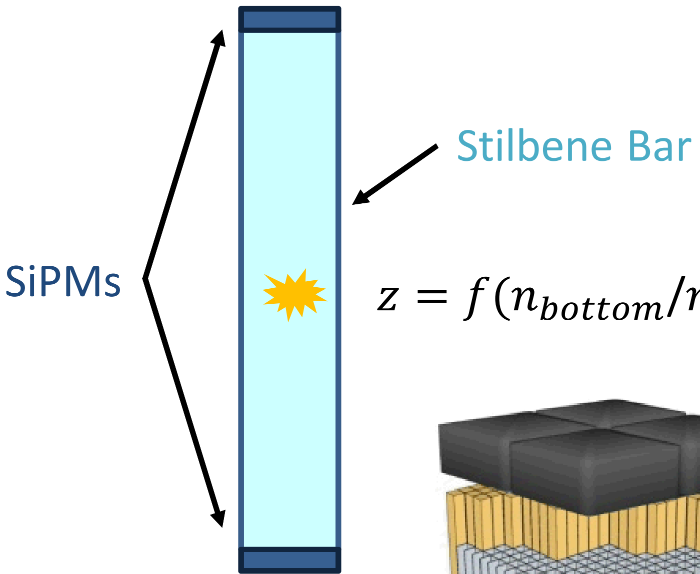
Double scatter kinematics + time to correlated gamma.

- Double neutron scatter provides cone of possible solutions; time to correlated gamma-ray further constrains the distance of emission.

- Mateusz Monterial's doctoral thesis: "Measuring Fission Chain Dynamics Through Inter-event Timing of Correlated Particles".
- Single-sided 3-D imaging enabled by combining the time to correlated gamma ray with double scatter neutron.
- SNL/University of Michigan jointly filed patent (15/377,624).

(1) M. Monterial, P. Marleau, S.A. Pozzi, "3D Image Reconstruction Technique of Gamma-Neutron Sources", IEEE Transactions on Nuclear Science, Vol 64, Issue 7, 2017
(2) M. Monterial, P. Marleau, M. Paff, S. Clarke, S. Pozzi, "Multiplication and Presence of Shielding Material from Time-Correlated Pulse-Height Measurements of Subcritical Plutonium Assemblies", Nuclear Instruments and Methods in Physics Research Section A, vol. 851, pp. 50-56, 2017. (http://dx.doi.org/10.1016/j.nima.2017.01.040)

Optically-Segmented Compact Neutron Imager (two photodetectors per volume)



$$z = f(n_{bottom}/n_{top})$$

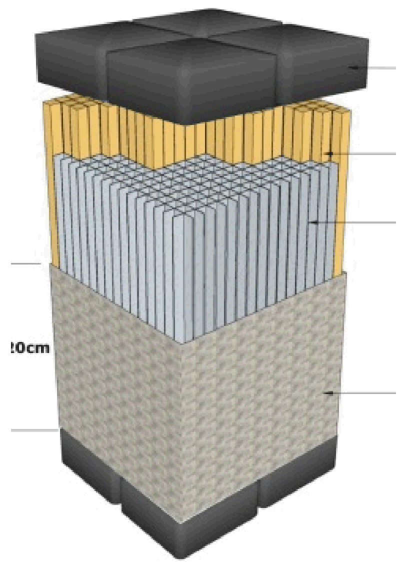


Figure – This scatter camera is comprises a close packed array of scintillating "bars" with photodetectors coupled to each end for "z" position resolution.

Imaging modality:

Double Scatter Kinematics

- Same as double scatter imager, but position resolution along the length of each "bar" provides continuous range of interaction locations rather than assuming cell center.

- Marc Ruch's doctoral thesis: "Silicon Photomultipliers for Compact Neutron Scatter Cameras"
  - SiPM PSD and timing characterization as photodetectors for double sided readout of "bar" detectors.
  - Applicable to UM's hand held dual particle imager.
- Kyle Weinfurther
  - MCP-PM vs. SiPMs for optically segmented pillars.
  - Applicable to NCSU's SVSC PiPS.

(1) M.L. Ruch, J. Nguyen, M. Flaska, S.A. Pozzi, "Time Resolution of Stilbene Coupled to Silicon Photomultipliers for us in a Handheld Dual Particle Scatter Camera", in 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference, San Diego, CA, 2015.
(2) K. Wienfurther, et al – "Model-based Design Evaluation of a Compact, High-Efficiency Neutron Scatter Camera" https://arxiv.org/pdf/1710.06480.pdf

Laboratory Fellowships

Dr. Lorraine Sadler – NERS 490 Nuclear Arms Control Policy and Technology shortcourse

Dr. Peter Marleau – TBD.

Dr. Lorraine Sadler
Location: U. Michigan
CVT Faculty: Prof. Sara Pozzi

Dr. Peter Marleau
Location: U. Michigan
CVT Faculty: Prof. Sara Pozzi

NERS 490: Nuclear Arms Control Policy and Technology

Dr. Paul Rockett, Consultant in Arms Control and Nonproliferation at Lawrence Livermore National Lab, and Dr. Lorraine Sadler, Systems Analyst at Sandia National Labs, combine efforts to produce a 10 day shortcourse. Students take part in a lecture series which discuss the art and history of

Dr. Paul Rockett serves as guest lecturer for NERS 490 shortcourse

Dr. Lorraine Sadler (photo left) enjoys lunch with a group of PhD students at the University of Michigan.

treaty verification under INF, START I, New START, and more.

Students also determine ways in which the technologies can be circumvented and discuss the consequences of circumvention. This approach relies on the Risk Informed Management of Enterprise Security (RIMES), a risk analysis framework developed at Sandia National Labs.

*Images borrowed from CVT UPR presentation.

Potential SNL/CVT rad/det projects

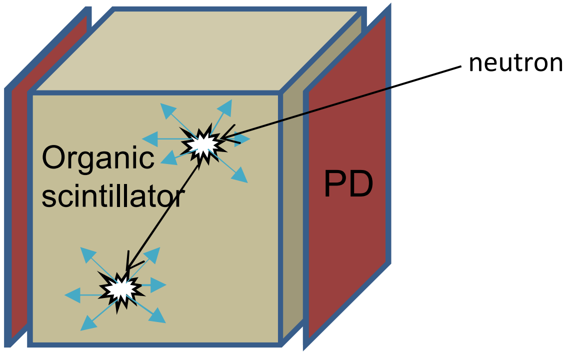
Sandia National Laboratories

Mentor	Potential Projects
Erik Brubaker	RadMAP background data analysis
	Single Volume Scatter Camera event reconstruction analysis
	Advanced image reconstruction techniques
	Anisotropic response of crystalline organic scintillators to neutrons
	Uncertainty quantification for radiation imaging data
	Organic scintillator characterization (temperature, pulse shape)
Scott Kiff	Neutron spectroscopy (fission vs. alpha interaction applications)
	Correlated neutron production by cosmic muons in heavy elements
Peter Marleau	Three dimensional reconstruction using correlated gamma-neutron timing
	Electronic collimation for search/detection applications
	Novel calibration methods for large volume detectors using phoswich style PSD
	Monte Carlo optimization of a Gamma-ray time-encoded imager
Melinda Sweany	Material identification using resonant neutron attenuation
	Material identification using detection of correlated g-n from inelastic scattering
Belkis Cabrera-Palmer	Neutron Scatter Camera application to high-energy spectral unfolding
	Time-encoded imaging using a High-purity G2 detector

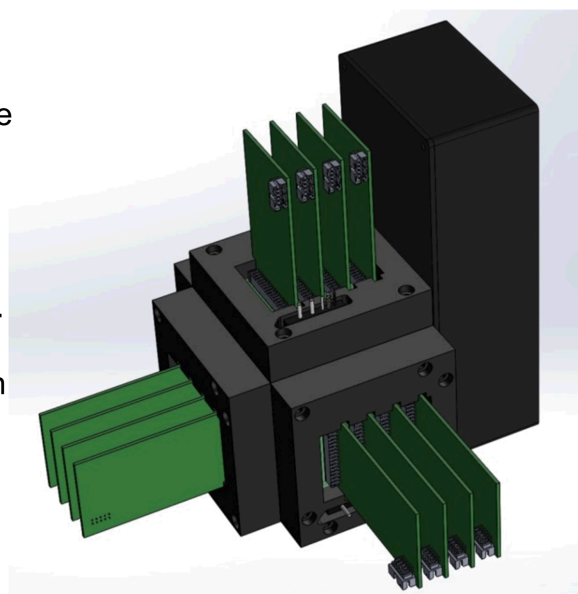
Collaboration Options

- Summer Internships
- Year-round internships (full or supplemental)
  - Student Intern - Radiation Detection R&D Year Round
  - Student Intern/Fellow – National Nuclear Security Administration (NNSA) R&D Grad YR
- Visiting Researcher
  - Pros
    - Freedom to work on non-funded R&D
    - Lab CVT funding for mentors.
  - Cons
    - No funding for hardware at the Lab.
    - **Cost of living**.

Single Volume Scatter Camera (multiple photodetectors on single volume)



Two or more sides of a single volume of scintillator are covered by fast pixelated photodetectors. The time and position of each photon is used to reconstruct multiple scatters..



Imaging modality:

Double Scatter Kinematics

- Multiple scatter locations, times, and energies, within a single monolithic volume of scintillator are deconvolved from the time and location of every detected photon on its surface.

Energy requirements:

- Ideally, single photoelectron (PE) resolution for each photodetector. Used for energy estimation and position of scatters within the volume.

PSD requirements:

- Maybe not. If fast enough timing and single PE resolution can be achieved, then particle discrimination can be accomplished by TOF.

Timing requirements:

- Need 100 picosecond or better on single PEs for position of scatters within the volume and TOF of scattered neutron.

http://www.creteconf.org/presentations/20170613_CRETE2017_SVSC_Cabrera-Palmer_v1_forpdf.pdf