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Fast Neutron Detectors (and other CVT contributions by UF)

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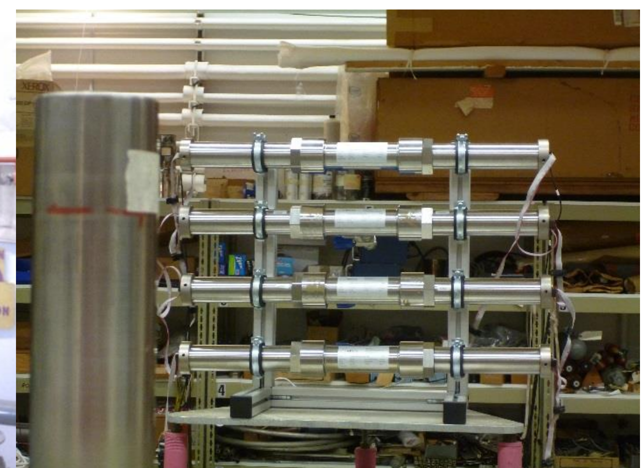
Collaboration with Ohio University

Time-of-Flight Experiments

- Our detection system and PSD methods were used in time of flight experiments at Ohio University – Van de Graaff generator
- With a long flight path good temporal discrimination between neutrons and photons is achieved
- Al(d,n)-reaction using 7.44 MeV deuterons on Al-27. Producing neutrons of ~0.5-12 MeV energy.



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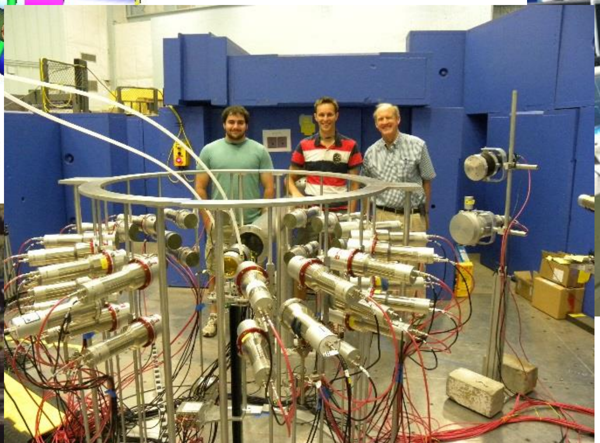
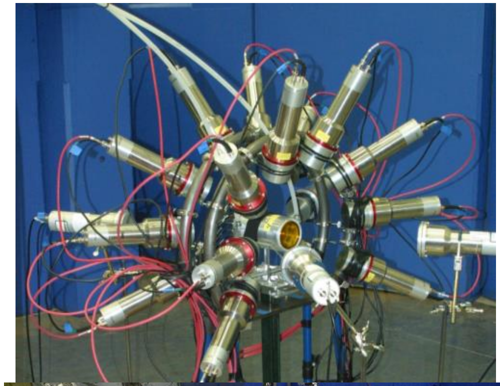
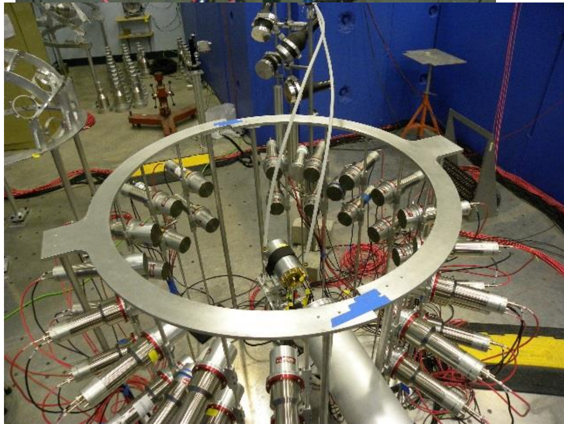
Analysis Support for Fast Neutron Measurements for Relevant Fission Data

- ^{235}U fission chamber; double TOF experiment
- Fission spectra, neutron correlations, neutron multiplicity distrubutions.
- Fast neutron counter assembly design

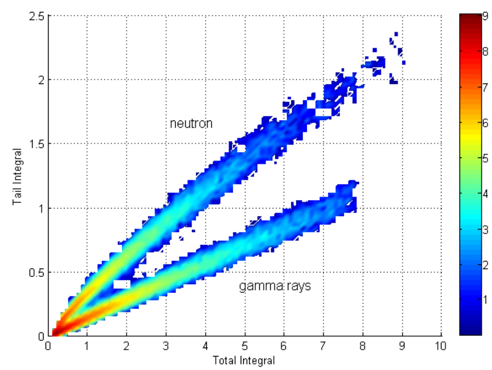
<u>Wide angle coverage</u>

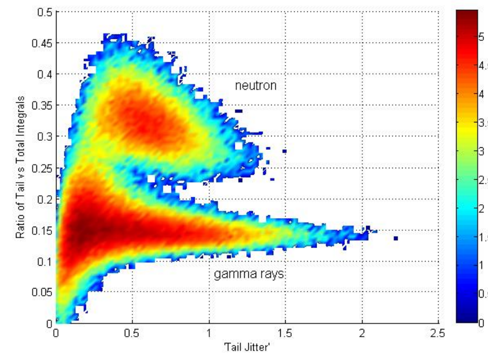


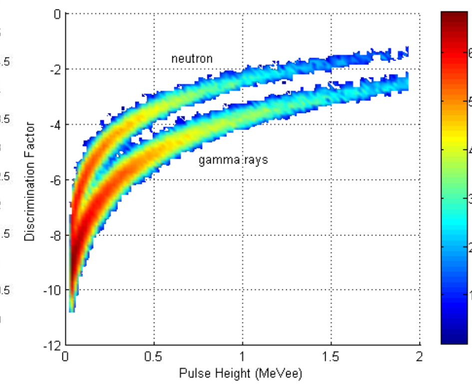




Multiple PSD Methods







Digital Charge Integration

Compares the total integral of the pulse with the integral of the pulse's tail.

$$\sim \int_{pulse} f(t)dt$$

Pulse Tail Analysis

Analyzes the tail behavior of the pulse and plots it against the ratio of the tail and total pulse integrals. (Enqvist: manuscript in progress)

$$\sim \sum_{tail} f(t) * |t_i - t_{i-1}|$$

Simplified Digital Charge Collection

Examines the pulse shape by taking the log of the sum of squares of each data point and plots it against the pulse height. [Gamage, Joyce, Hawkes, 2011]

$$\sim \log\left(\sum_i [f(t_i)]^2\right)$$

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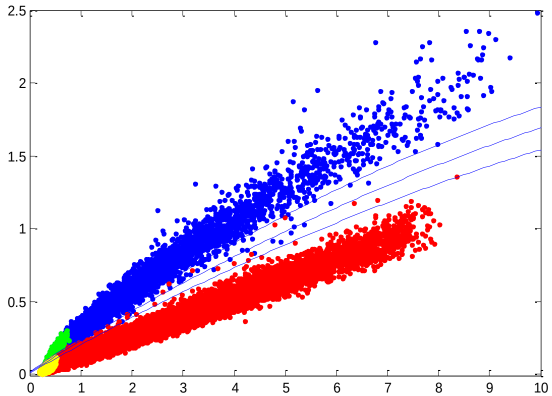
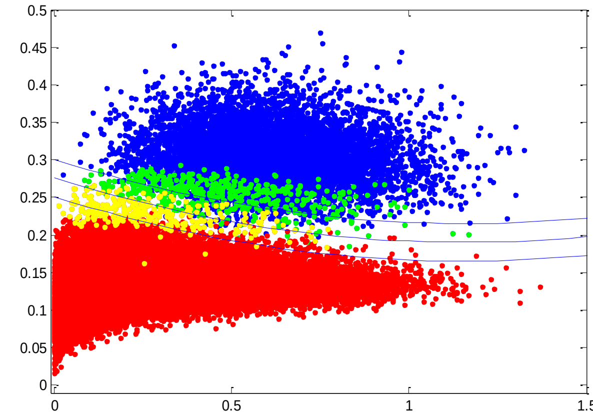
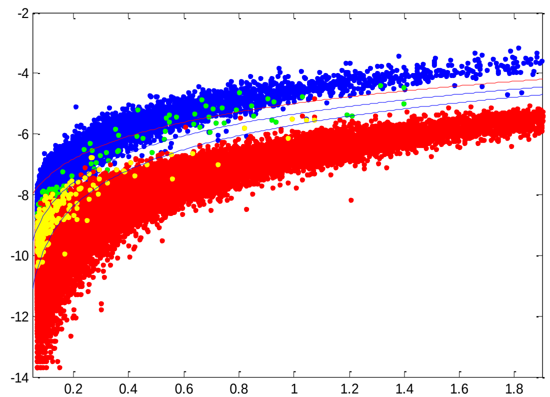
Combined PSD Method-use





- Yellow and Green pulses are low voltage pulses
- 1.77% of pulses inside of confidence lines

- Yellow and Green pulses are inside of method 1's confidence lines.
- 1% of pulses in method 1 and method 2's confidence lines

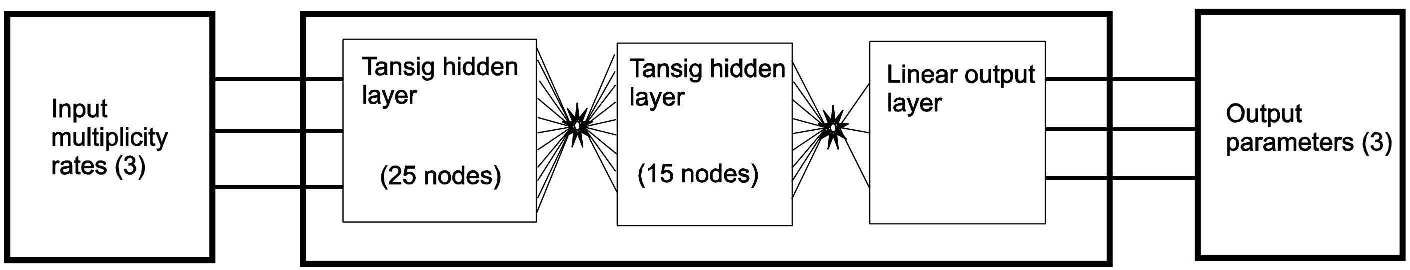


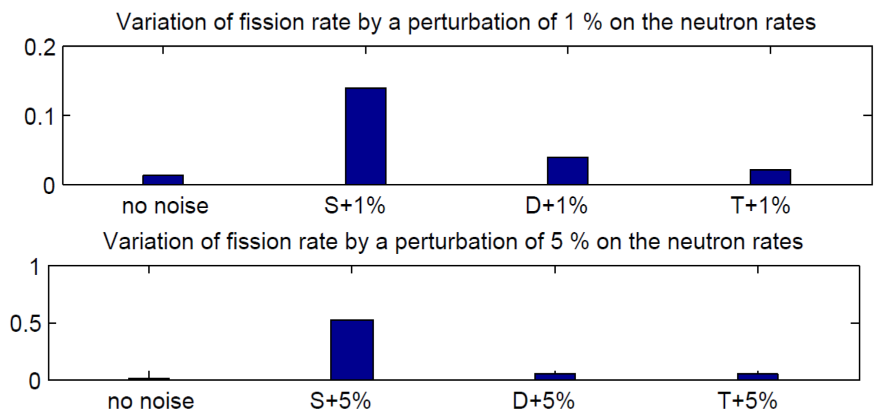
- Yellow and Green pulses are inside of method 1 and method 2's confidence lines.
- .87% of pulses in all three methods confidence lines

- PSD implementation option: real-time computer, post-processing currently. Board option in future?

Analysis methods applied to fast neutron multiplicity data

- Neural network approach for neutron multiplicity. Additionally, The formalism was extended to take into account not only gamma rays, but also mixed particle multiples such as nnp, np.
- The analysis grows more complicated which motivated the usage of artificial neural networks for inverting the solutions.
- Parameter unfolding using the information in an overdetermined system. (Collaboration with Senada Avdic).





Liquid Scintillator Multiplicity Work

- **The Number Distribution of Neutrons and Gamma Photons Generated in a Multiplying Sample.** A. Enqvist, et al. (NIMA)
- **A Note on the Multiplicity Expressions in Nuclear Safeguards.** I. Pazsit, A. Enqvist et al. (NIMA)
- **Unfolding Sample Parameters from Neutron and Gamma Multiplicities Using Artificial Neural Networks."** S. Avdic, A. Enqvist et al. (ESARDA bulletin)
- **Initial Evaluation for a Combined Neutron and Gamma-ray Multiplicity Counter.** A. Enqvist, et al. (NIMA)
- **Characterization of a Mixed Multiplicity Counter Based on Liquid Organic Scintillators.** A. Enqvist et al (TNS)

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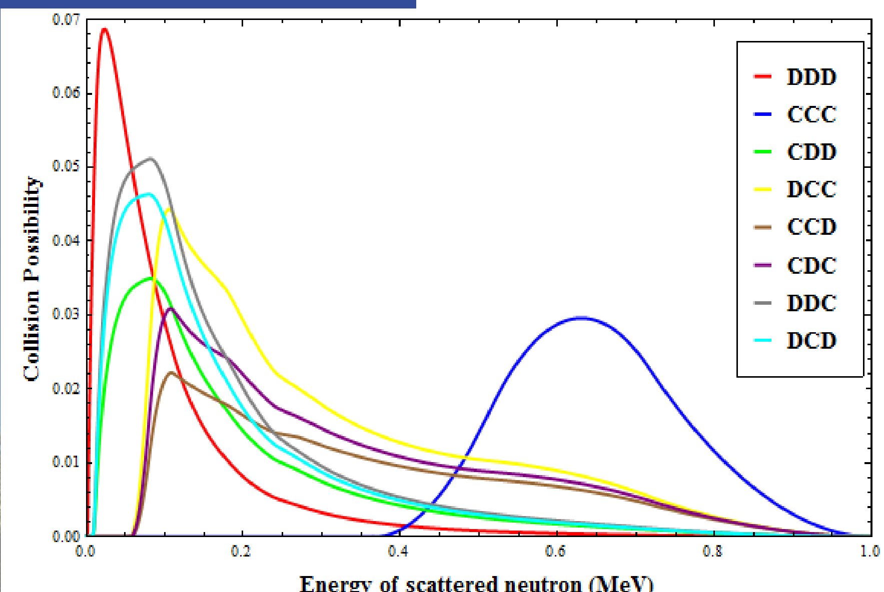
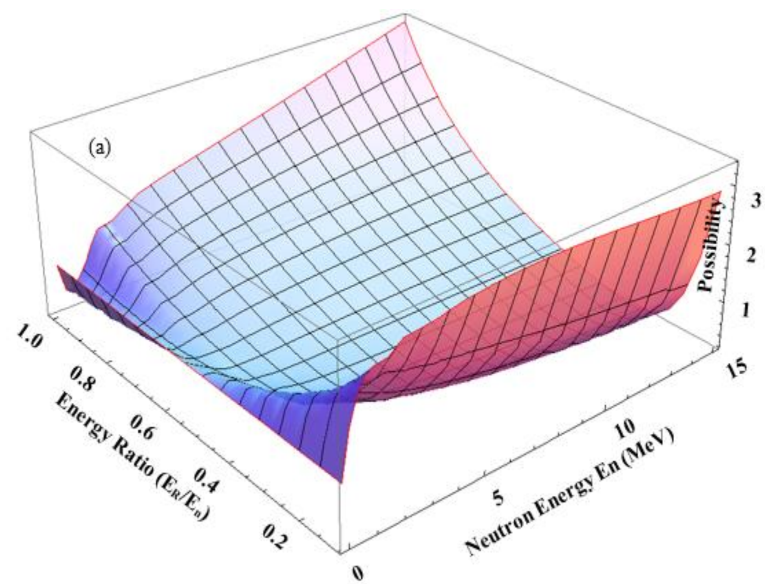
Scillation Modelling

- Unique work extended into double differential cross section, and applicable to practically any element/isotope.





Recoil nucleus kinetic energy distribution of scattered neutrons due to Deuterium

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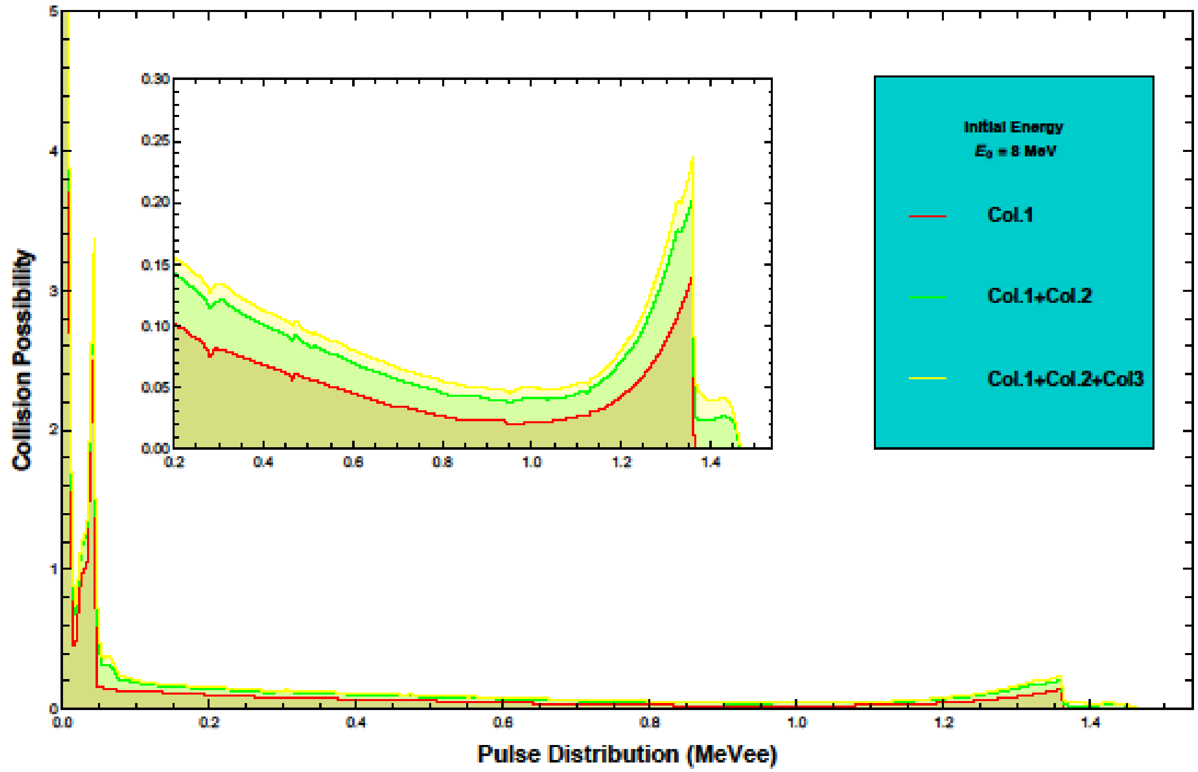
Scintillation Modelling (cont'd)



Collision History	Detector Dimensions (h=d)				
		1 cm	5 cm	10 cm	15 cm
1 MeV	$P_0 = W(E_0)$	0.7833	0.6257	0.4605	0.3362
	P_D	0.0883	0.1256	0.1160	0.1043
	P_C	0.0804	0.0982	0.1153	0.1058
	P_{CC}	0.0085	0.0163	0.0303	0.0330
Probability of first four collisions		0.9988	0.9742	0.9292	0.8259

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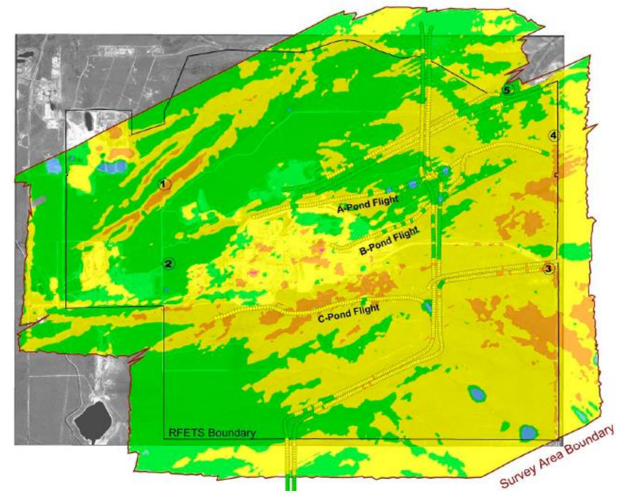
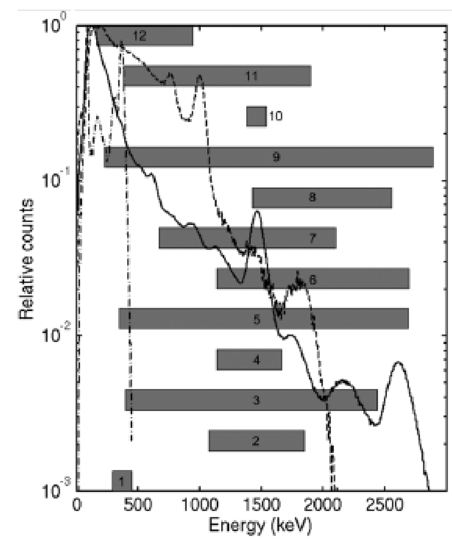
Monitoring of Nuclear Facilities Via Aerial and Wide-Area Mapping

- Measurement of emissions from nuclear facilities for verification of activities
- Wide-area mapping and signal correlation of aerial and ground-based instrumentation
- Development of improved algorithms for source/anamoly detection through EWR optimization.
- Understanding signatures and impact to IMS



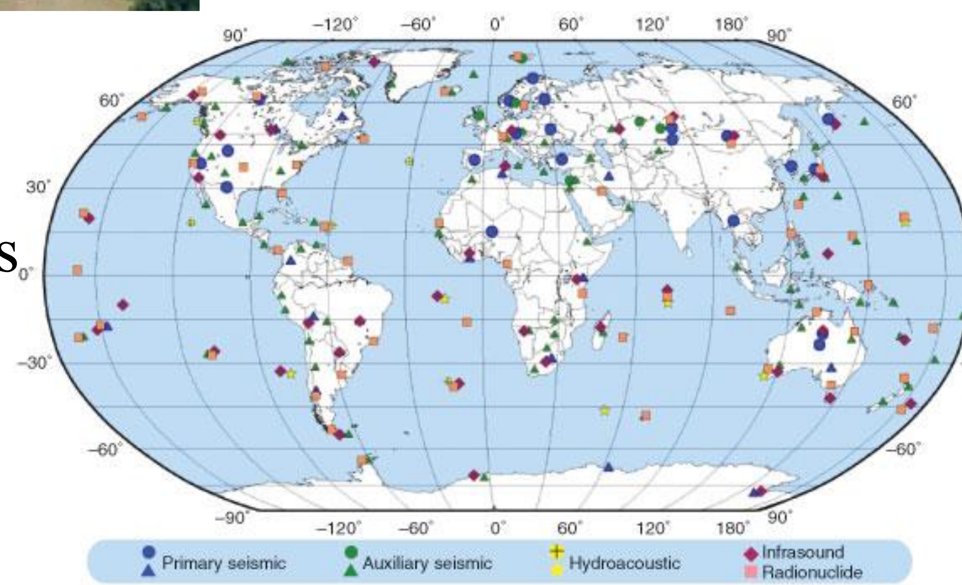


D. Pfund, IEEE, 2007

Why at UF? – Medical Isotope Production Reactors

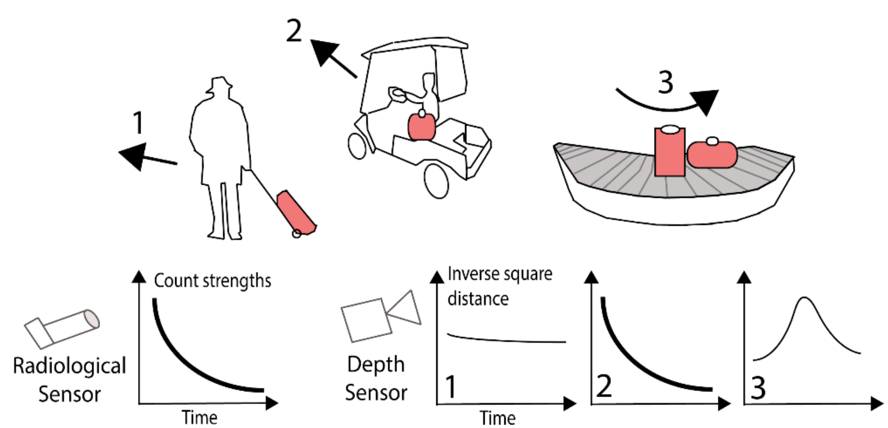
"$250M facility to bring 164 high-paying jobs to Alachua"

(Gainesville Sun, August 19, 2014)



Other CVT-relevant efforts

- Creating a modular digital thermal neutron counter (He-3 based) for comparison with fast neutron models.
- Compact Cf-source/detector for active interrogation and Rossi/Feynmann-alpha analysis (NRC funded)
- "Radiological Source Detection and Tracking Based on Multi-Sensor Data Fusion", radiological, IR, laser sensors fused to a single system. (DHS-DNDO funded)



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Other CVT-Related Efforts

- Organic Photodetectors for Scintillator Radiation Detection Applications (DTRA Funded)
- He-4 Scintillation Neutron Detectors
- BiI_3 Gamma-Ray Detector for Nuclear Safeguards Applications (DOE-NEUP Funded)
- Backscatter Radiography for Security Applications (UF Funded)
- Algorithm Development and Data Analysis for the ARES Program (PNNL Funded)
- Radiation Mapping for Environmental/Emission Monitoring of Reactor Facilities (NRC Funded)

Classes at UF related to CVT

- ENU 4930 – Introduction to Nuclear Safeguards
  - Tied with visit to ORNL, taught annually
- ENU 6937 – Perspectives on Nuclear Security and Non-Proliferation
  - Topics vary by professor, but has been taught by former and retired national laboratory staff
  - This year’s focus has been to detector development and radiation measurements within select security and non-proliferation topics
- ENU 4930 – Introduction to Nuclear Criticality Safety

Other UF Items of Interest to CVT

- Florida Institute for National Security
  - Provides graduate students multi-year scholarships (stipend plus-ups) and signing bonuses for students working on national security related/funded projects
  - Consolidates all faculty/research in rad/bio/chem/nuke security research under one flag

Students at UF with CVT Affiliation

- Hannah Gardiner (NRC Fellow)
- Christopher Greulich
- Paul Johns (NEUP Fellow)
- Jessica Salazar (NRC Fellow)
- Enrique Wong (US GSFA)
- Gabriel Sandler (UG)
- Robert Weinmann-Smith (UG)

Course Outline & Activities




Week 1 – Foundations

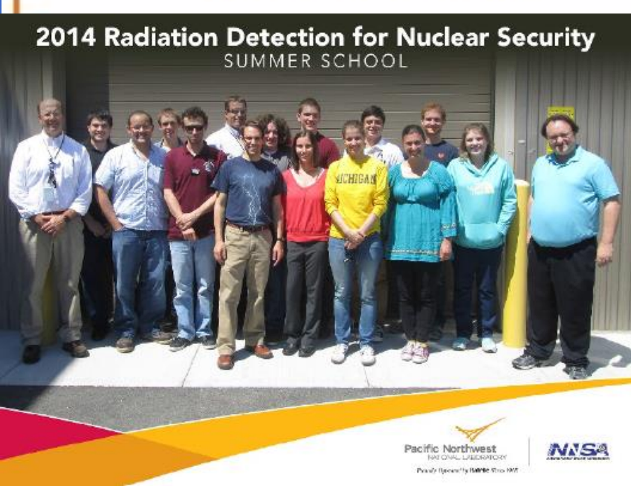
Lectures include
- Fundamentals of Radiation Detection
- Gamma-ray Spectroscopy
- Neutron Multiplicity Counting
- Nuclear Fuel & Enrichment

Activities include
- Modeling Source Terms
- Detector Sensitivity vs. Selectivity
- Neutron Moderation

Week 2 – Applications

Lectures include
- Nuclear Safeguards
- Arms Control & Treaty Verification
- Interdiction
- Emergency Response

Activities include
- Border Guard Training
- Tours of AREVA Fuel Fabrication Plant & Hanford B Reactor



We will be offering the Nuclear Security Summer School again in June 2016. Specific dates will be announced in the fall of 2015.

PNNL's Nuclear Security Summer School (NSSS)

- Universities that have sent students include
  - UF, Georgia Tech, TAMU, UT-Austin, UT-Knoxville, Wisconsin, WSU, Washington, NC State, UC-Berkeley, Ohio State, UMass-Lowell, CSM, MSU, Penn State
- Lecturers and lab instructors include: Bob Runkle, Mitch Woodring, and Jim Baciak
- Guest Lecturers vary year-to-year, but have included:
  - Arden Dougan, David Beach, David Bowman
  - Eric Smith, Jon Schwantes, Dave Kostorowski, Jason Shergur
- We limit number of students to 12-16