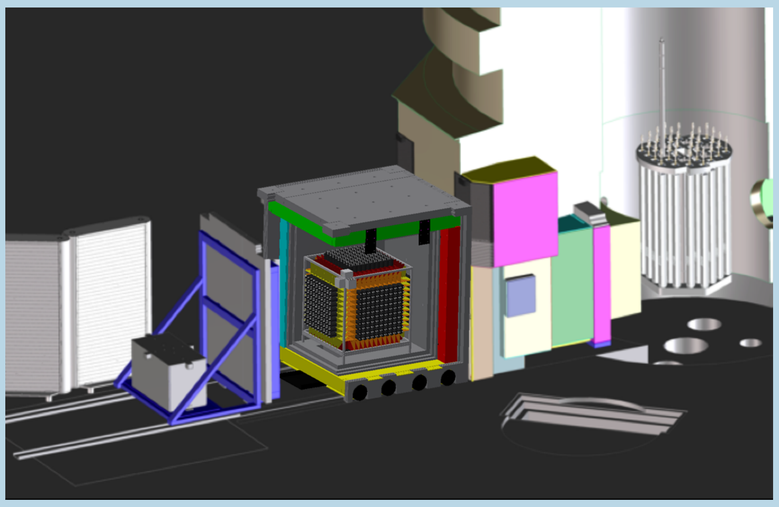
NuLat: A Compact, Segmented, Mobile Anti-neutrino Detector

Ryan Dorrill, Bruce Vogelaar, and John Learned, for the NuLat collaboration

NuLat Motivations

1. Demonstrate reactor monitoring:
   - Security monitoring
   - Commercial burn-up monitoring
2. Investigate fast neutron directionality capabilities for
3. Detection of special nuclear materials
4. Probe reactor anomalies
   - Sterile neutrino search
   - Precision ν_e energy spectrum measurement
5. Exceptional background rejection



Above: simulated deployment at NIST

Detector Features

Feature	Rational
Excellent Energy Resolution	Precision Spectral Analysis – Distortions from prediction
Unique Start Signal	separate positrons from gammas, neutrons, and electrons
Unique Stop Signal	separate n-capture from backgrounds
Short Time Delay	improves real/random
Fine Segmentation	smaller improves real/random
E,x,y,x,t complete event topology	best method to remove residual backgrounds
Minimal Wall Material	improves systematics and signal degradation
Fast Timing (Sub Nanosecond)	time-ordering of energy deposits
Minimal Fiducial Cut Required	minimizes shielding size
Strong neutrino source	L/E easier at shorter distances, better S/B
Movable	Vary L without E, multiple sources and uses
Minimal R&D required	Short time-scale and cost for early science

NuLat Demonstrator Design

5x5x5 lattice The current demonstrator, being tested above middle, features 125 cubes.
PMTs Hamamatsu PMTs for light collection
IRD3d Fast timing electronics previously deployed in miniTimeCube at NIST's NCNR
EJ-200 Eljen ^{6}Li doped scintillator with PSD

References

[1] C. Lane, B. Vogelaar, et. al. Nulat: A new type of Neutrino Detector for Sterile Neutrino Search at Nuclear Reactors and Nuclear Nonproliferation Applications
arXiv, 1501.06935, Jan 2015.

[2] V. Li, J. Learned, et. al. *Invited Article: miniTimeCube.* Review of Scientific Instruments, 87:021301, 2016.

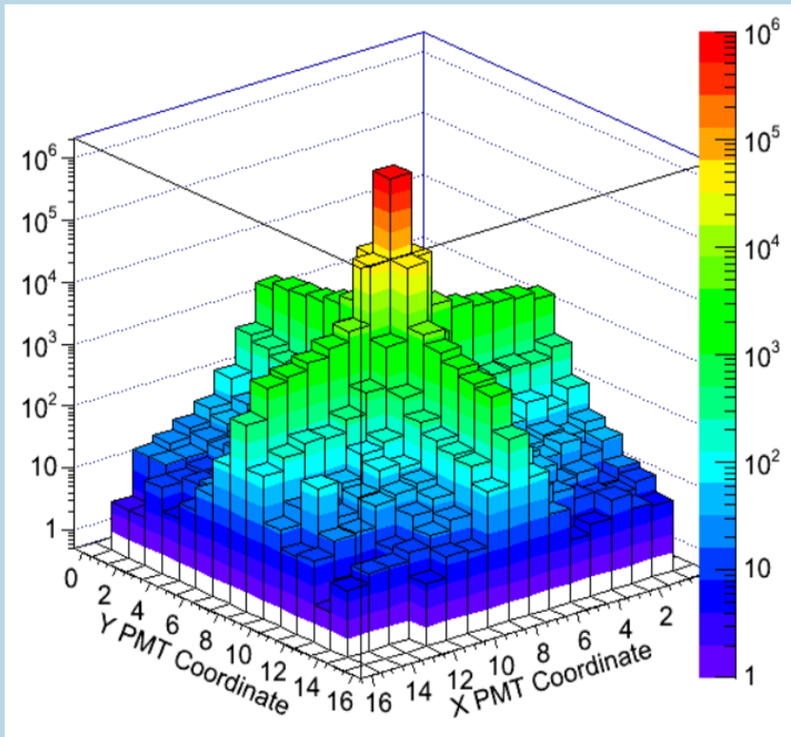
Contact Info

Ryan Dorrill is his research assistant at UH Manoa:
Web www.phys.hawaii.edu/∼ nulat/
Email dorrill@hawaii.edu
Phone (808) 956 2958

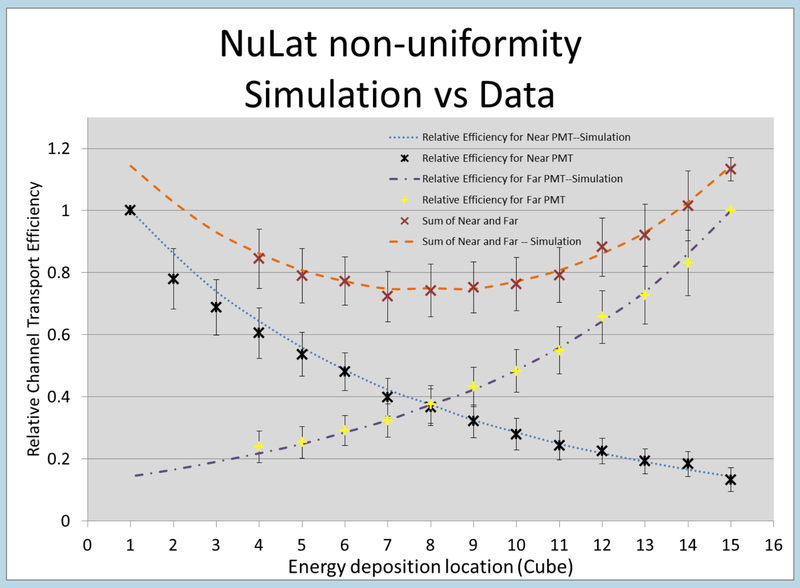
John Learned is a professor of physics at at UH Manoa:
Web http://www.phys.hawaii.edu/∼ jgl/
Email jgl@phys.hawaii.edu

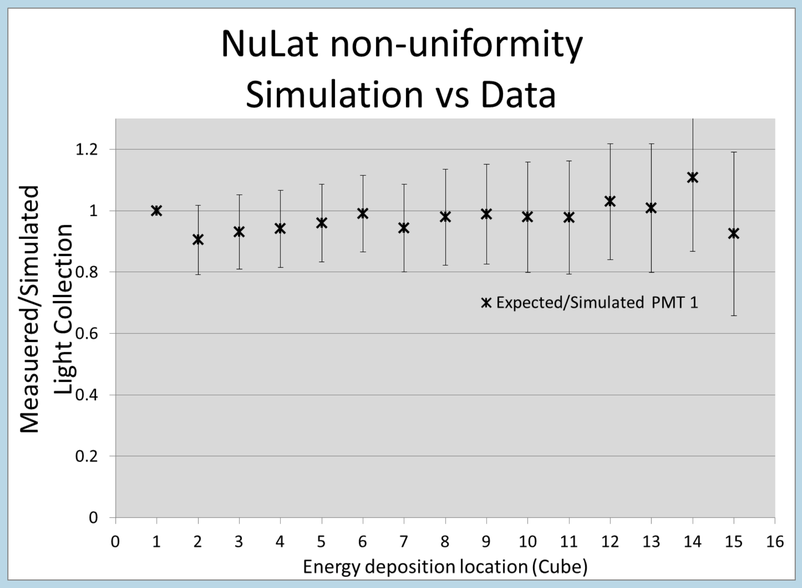
Raghavan Optical Lattice (ROL)

The ROL detector design uses complete 3-D optical segmentation, instead of typical 2-D segmentation and time-of-flight methods, for precision localization of events in a large volume detector. The cells in a ROL detector are independent and short ranged events can be localized in a cell, thus the position resolution of a ROL detector is equal to the cell's size. Furthermore, ROLs allow for the topology of multiple deposits to be analyzed.



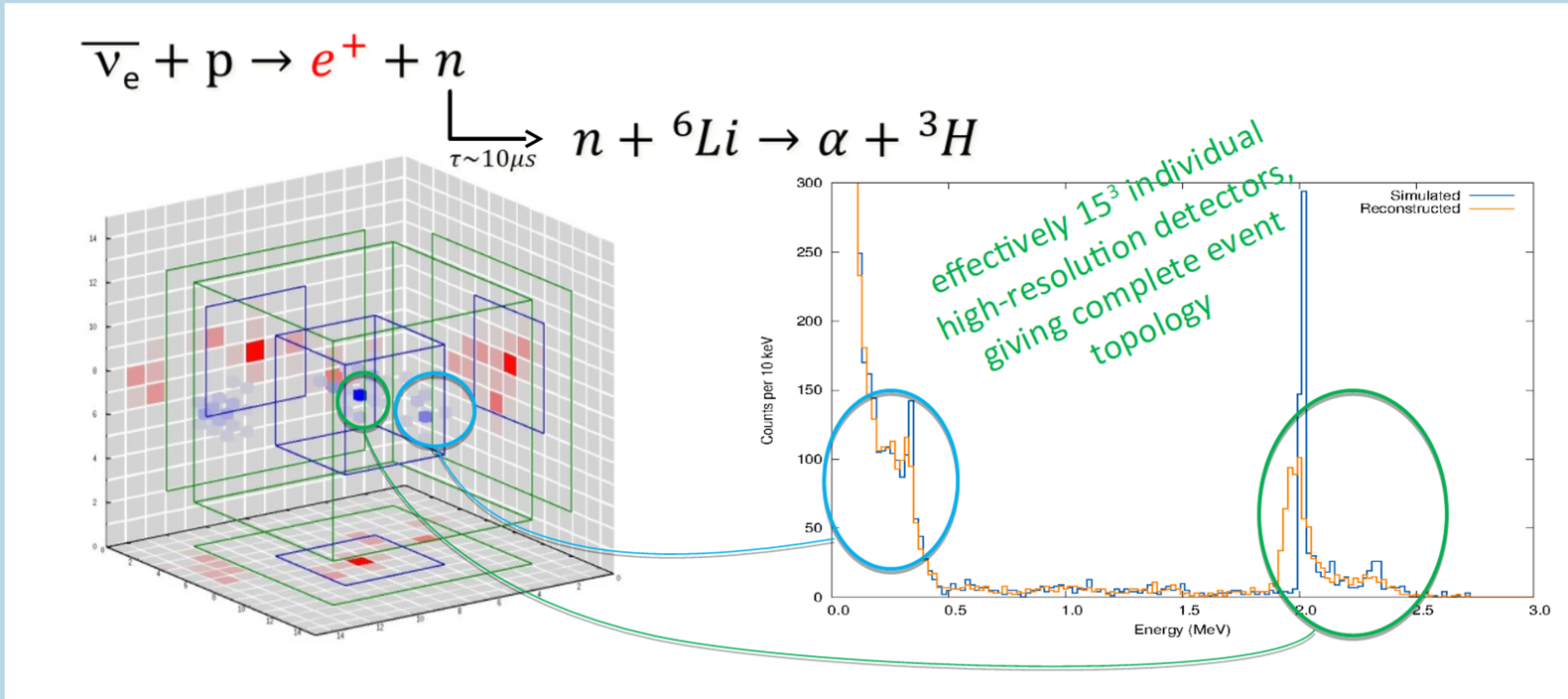
Above left: demonstration of the scintillator cubes with lasers
Above right: log plot of light output on the (X-Y) face of a mirrored NuLat design via deposition of 2 MeV in the central cell, right.
Below: Comparisons of simulated and tested light collection with 15 cubes





Event Topology

Unique start signal: The positron plus annihilation gammas create a large single (sometimes double) cell signal with a small halo (0.1-1.0 MeV total). This helps reject most gammas, with primary reduction via passive shielding when close to reactors
Unique stop signal: The ^{6}Li capture signal features a 7μs time correlation (0.5% by wt. ^6LiPVT) that is mono-energetic at approximately $400keV_{ee}$ with a single cell stop tag and neutron gamma PSD separation. 23% of neutrons capture in same cell as positron 60% of neutrons capture in same cell as positron plus the six facing cells.



Above left: Reconstruction of a typical 2 MeV positron event.
Above right: Average single-cell prompt response to a uniform 3.8 MeV anti-neutrino flux.