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

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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 $\nu_e$ energy spectrum measurement
5. Exceptional background rejection

Above: simulated deployment at NIST

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

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 7$\mu$s time correlation (0.5% by wt. $^6$LiPVT) that is mono-energetic at approximately 400 keV$_{ee}$ 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.

References


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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.