SAND2012-3792C

A Compact and Portable Antineutrino Detector for Reactor Monitoring

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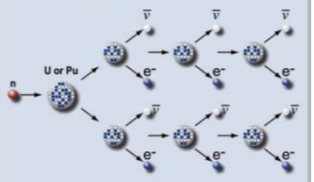
This work supported by NA-22

A joint collaboration between Sandia National Laboratories and Lawrence Livermore National Laboratory

Reactor Monitoring 101:

Reactors emit huge numbers of antineutrinos

- 6 antineutrinos per fission from beta decay of daughters
- 10^{21} fissions per second in a 3,000-MWt reactor



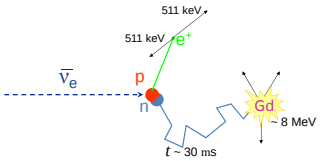
About 10^{22} antineutrinos are emitted per second from a typical PWR unattenuated and in all directions

Detected rates are quite reasonable

- 10^{17} antineutrinos per square meter per second at 25-m standoff
- 6,000 events per ton per day with a perfect detector
- 600 events per ton per day with a simple detector (e.g., SONGS1)

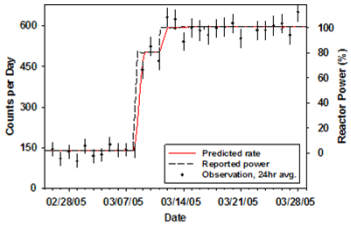
Example: detector total footprint with shielding is 2.5 meter on a side at 25-m standoff from a 3-GWt reactor

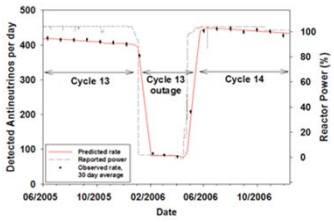
Anti-neutrino Detection through Inverse-beta Decay:



Standard detection of gammas and neutrons in coincidence

Previous Demonstrations of Monitoring Reactor Power and Fuel Burnup



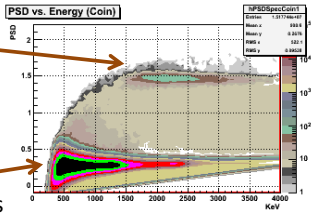


Segmented Scintillator Detector

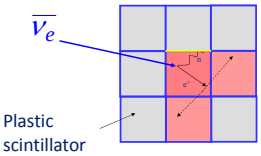
2 Scintillators Distinguish 2 Particles Through PSD

ZnS:Ag/^{6}LiF screens allows identification of neutron capture

Plastic Scintillator gives fast response to standard EM interaction



Potential Positron Identification through Topology



- Segment size chosen to match penetration depth of 511keV gammas
- Only constructed 4-cell prototype so topological testing is only rudimentary

2 Deployments at San Onofre Nuclear Generating Station (SONGS)

Aboveground in a shielded enclosure ~50m from Reactor Core

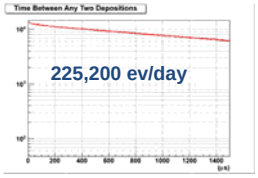
- Limited proof-of-principle runs between Dec 2010 and June 2011

Belowground unshielded in a compact design ~25m from Reactor Core

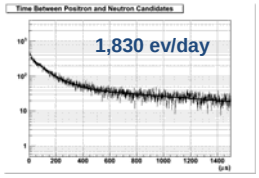
- This deployment is ongoing and we await a reactor on/off transition for validation of antineutrino detection efficiency

Particle Identification Yields 4 Order of Magnitude Background Rejection

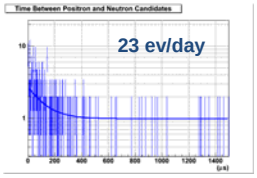
No PID Used



Only Neutron PID



Positron + Neutron PID



Results from Shielded Aboveground Operation

Event Definition	Reactor Off (8 days)			Reactor On (30 days)		
	Correlated	Un-correlated	Subtracted Signal	Correlated	Un-correlated	Subtracted Signal
1) Using only neutron PID	1421 ± 14	482 ± 8	939 ± 16	1118 ± 8	368 ± 5	750 ± 9
2) Neutron + positron PID	167.4 ± 4.7	40.6 ± 2.3	126.8 ± 5.2	119.1 ± 2.6	28.7 ± 1.3	90.4 ± 2.9

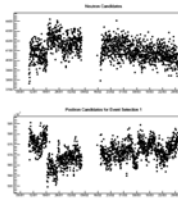
Unshielded Operation Showed Promise

- Uncorrelated rates increase by x 40
- Correlated only goes up by x 2—3

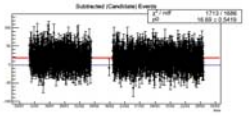
Event Def.	Unshielded Operation (20 days)		
	Correlated	Un-correlated	Subtracted Signal
1)	15930 ± 32	13835 ± 30	2095 ± 44
2)	1371 ± 9	1168 ± 9	203 ± 13

Belowground Performance Shows Promise

Robust/Continuous unattended operation for several months



Automated calibration/analysis shows stable performance



Expected Signal (~40 ev/day) is larger than error on background (~12ev/day)

Increased Array Size Should Improve Signal/Background

	16-Cell Array		64-Cell Array	
	Increase for Event Def. 1	Increase for Event Def. 2	Increase for Event Def. 1	Increase for Event Def. 2
Increase in Mass	x 4	x 4	x 16	x 16
Neutron Capture Efficiency	x 2	x 2	x 2.5	x 2.5
Positron Detection Efficiency	no change	x 1.8	no change	x 2
Total Signal Increase	x 8	x 14	x 40	x 80
Total Background Increase	x 4	x 4	x 16	x 16
Improvement in S/√B	x 4	x 7	x 10	x 20