SAND2012-9825P

Comissão Nacional de Energia Nuclear (CNEN) Meeting

Radiation & Nuclear Detection Systems

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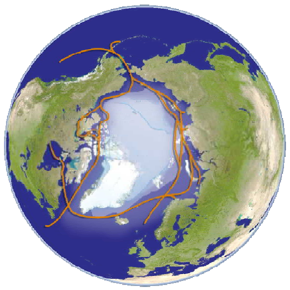
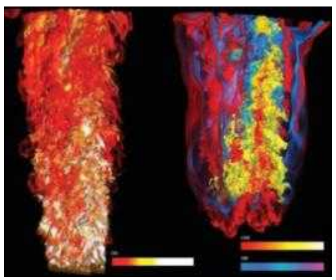
Sandia National Laboratories

Livermore, CA

Sandia is a science-based engineering research and development laboratory

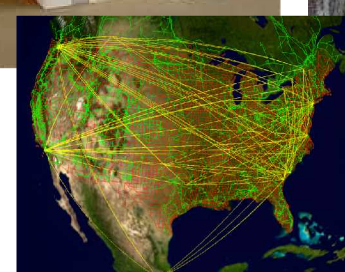


Energy, Climate & Infrastructure Security



Nuclear Weapons

International, Homeland & Nuclear Security



Defense, Systems & Assessments

Sandia National Laboratories

Mission driven – Multi site

Albuquerque

End of FY12

> 10,825 people total
~ 1,184 in California
~ 1,941 w/ Ph.D. (lab-wide)
~ $2.4B total revenue

Livermore

WIPP, Carlsbad, New Mexico

JBEI, Emeryville, California

Pantex, Texas

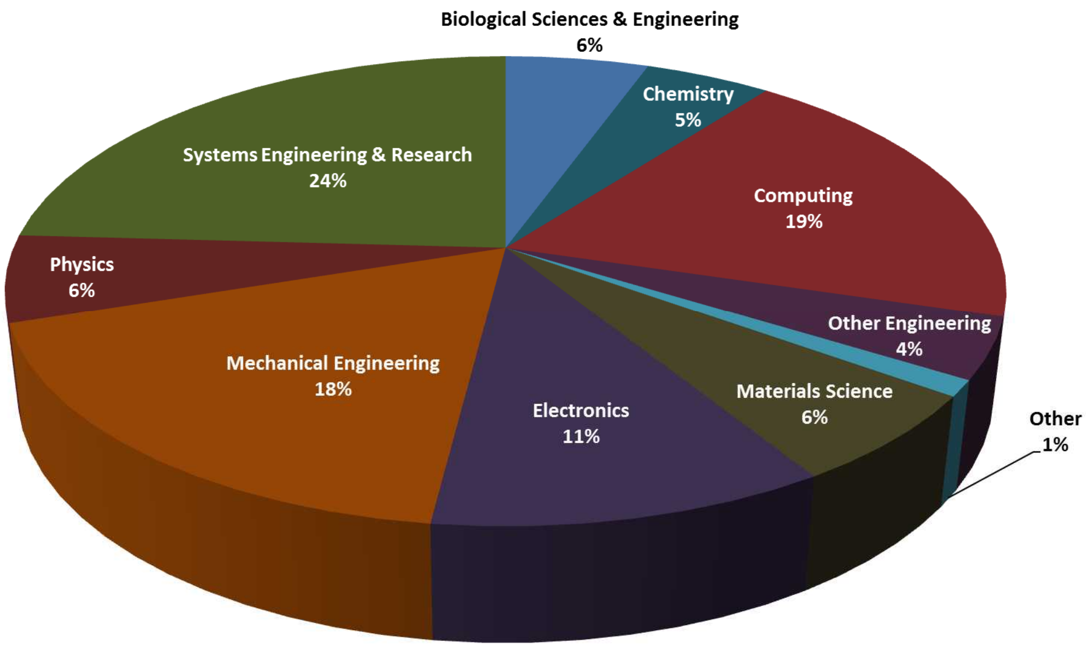
Tonopah Test Range, Nevada

Sandia National Laboratories

California Laboratory people and programs

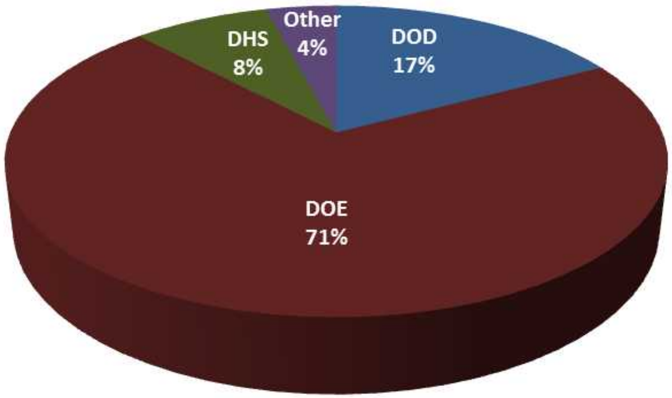
- On-site workforce: 1,015
- R&D staff: 524

R&D staff by discipline



37% of Technical Staff have a PhD

(most of the rest have Masters degrees)



FY12 CA Costing by Sponsor

Total FY12 Direct Costing = $253M

(additional $140M of indirect work)

Includes 64 highly talented international workers

Sandia National Laboratories

Department 08132
Radiation & Nuclear Detection Systems
Mission Statement

We undertake research and development of ionizing radiation and rare signature detection systems to address broad nuclear security needs in DS&A, IHNS, and NW SMUs. Through internal collaborations we target applications in neutron generators (02700), nuclear proliferation detection (01656, 01719, 05717, 08128), nuclear non-proliferation (06810), international safeguards (06832), arms control treaty verification (06831), radiological emergency response (06630, 08131), and other national security objectives such as explosives detection (08131).

Areas of significant experience and expertise include fission-energy neutron detection and imaging, anti-neutrino detection, weak source detection techniques, and high-channel-count systems. Our work includes a range of basic to applied research, and involves equipment at various technology readiness levels:

- Basic Research (TRL 1-2)
  - Experimental study and characterization of radiation signatures encountered in nuclear security scenarios
  - Conception and development of new radiation detection techniques
- Development of radiation detection systems (TRL 3-4)
  - Feasibility studies and rapid detector system prototyping
  - Laboratory tests of prototype systems: controlled experiments emulating relevant aspects of real-world scenarios
- Field Experiments (TRL 5-6)
  - Deployment of mature detection systems to understand their performance in real measurement environments

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Radiation & Nuclear Detection Systems Capabilities

- **Highly skilled technical staff with expertise in**
  - A wide range of radiation detector types: organic/inorganic scintillators, HPGe, He-3, H_2O Cherenkov, etc.
  - Fast analog and digital data acquisition
  - Sophisticated analysis of large datasets
  - Advanced imaging and statistical algorithms
  - Complex radiation transport and detector Monte Carlo simulation (SRN and SCN)
- **Multiple laboratories for developing and testing systems**
  - Investigate applications in nuclear weapons, arms control, and counterterrorism in security environments ranging from public access to SRD
  - High-bay laboratory for testing of large systems
- **Extensive field operating experience in extreme environments (nuclear power plants, uranium enrichment facilities, accelerator facilities, transoceanic shipping vessels, Pantex, DAF)**
- **Large inventory of advanced analog / digital electronics and modular detector components for rapid system prototyping**
- **Local inventory of radiation sources and neutron generators**
- **Partnership with Advanced Systems Engineering & Deployment department (08125) for innovative engineering solutions to evaluate new concepts quickly and efficiently**
- **Partnership with Rad/Nuc Detection Materials department (08131) to apply advanced materials to challenging detection problems**
- **Access to SCIF**

Department 08132
Radiation & Nuclear Detection Systems
Design Experience

We specialize in designing detection systems for the anticipated radiation signature and background for a specific application. Using as much information in the expected radiation signature as possible, we design

- detectors for standoff detection and localization of radiological materials
- detectors for rare event signatures
  - antineutrino and coherent neutrino scattering detection
- high resolution imaging detection systems
  - Discriminate between point and extended radiation sources
  - Identify chemical elements in 3D through high-Z shielding
- detectors in high background / high rate environments
  - active interrogation, above ground nuclear reactor monitoring, neutron generator monitors
  - Particle identification and discrimination

Action Sheet 22

ACTION SHEET 22

between

The United States Department of Energy (DOE)

and

The National Nuclear Energy Commission of Brazil (CNEN)

for

International Safeguards Assessment for the Monitoring of Reactor Antineutrinos

Drafted in 2009

Signed March 2012

a) analysis and review of safeguards requirements as they apply to the projected current program at Angra dos Reis;

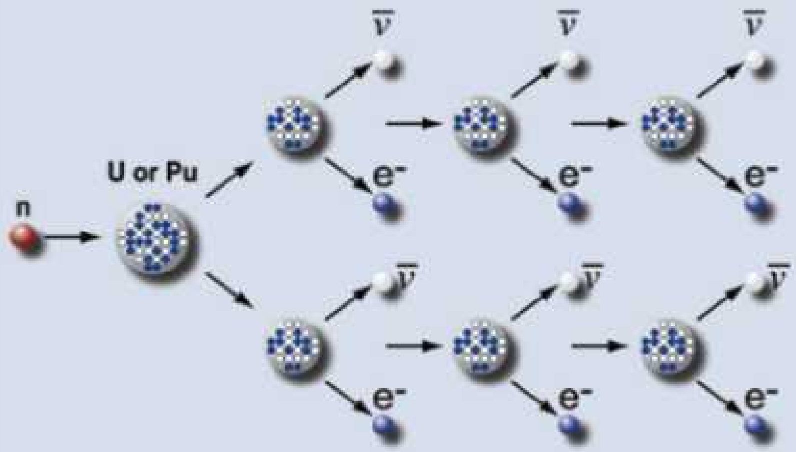
b) identification of potential contributing information from antineutrino monitoring and an assessment of the quality and precision of such data in regards to the safeguards requirements; and

c) design of a monitoring scenario that could be evaluated by international and regional safeguards agencies, the IAEA and the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), respectively.

Reactors Produce Antineutrinos

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)

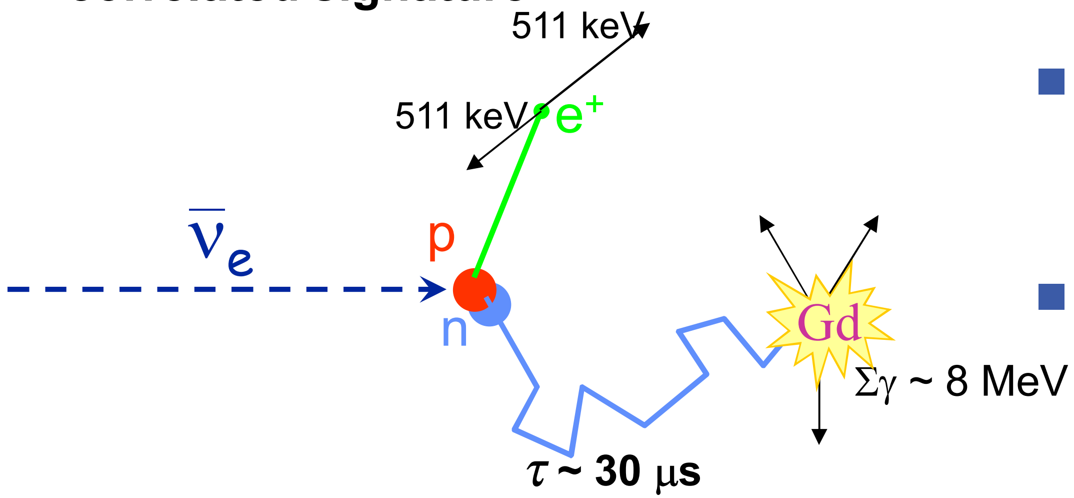
Example: detector total footprint with shielding is 2.5 meter on a side at 25-m standoff from a 3-GWt reactor

Standard Detection of Inverse Beta-decay

- **We use the same antineutrino detection technique used to first detect (anti)neutrinos:**

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

- **Standard detectors of gammas and neutrons are sufficient to find this correlated signature**

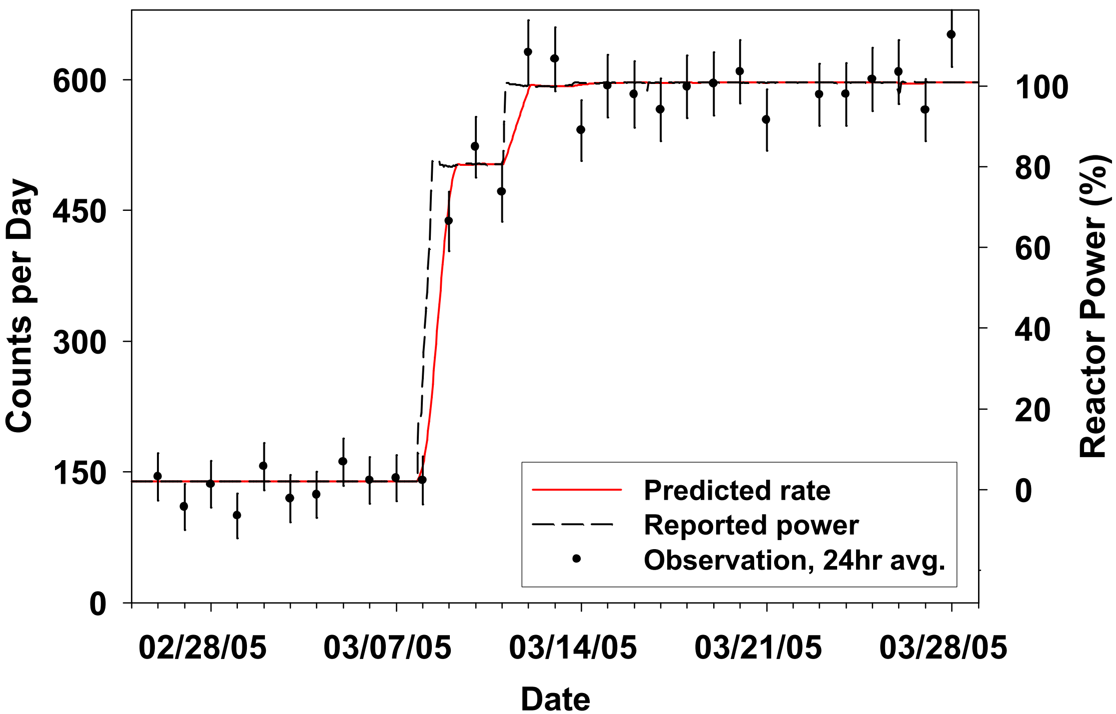


- Positron
  - Immediate
  - 1- 8 MeV (incl 511 keV γs)
- Neutron
  - Delayed (τ = 28 μs)
  - ~ 8 MeV gamma shower

(200 μs and 2.2 MeV for KamLAND)

prompt signal + n capture on Gd

Reactor Power Monitoring using only $\bar{\nu}$



Timescale

1 – 3 Hours:

Sudden changes in operational status (on/off)

1 Day:

Large power changes

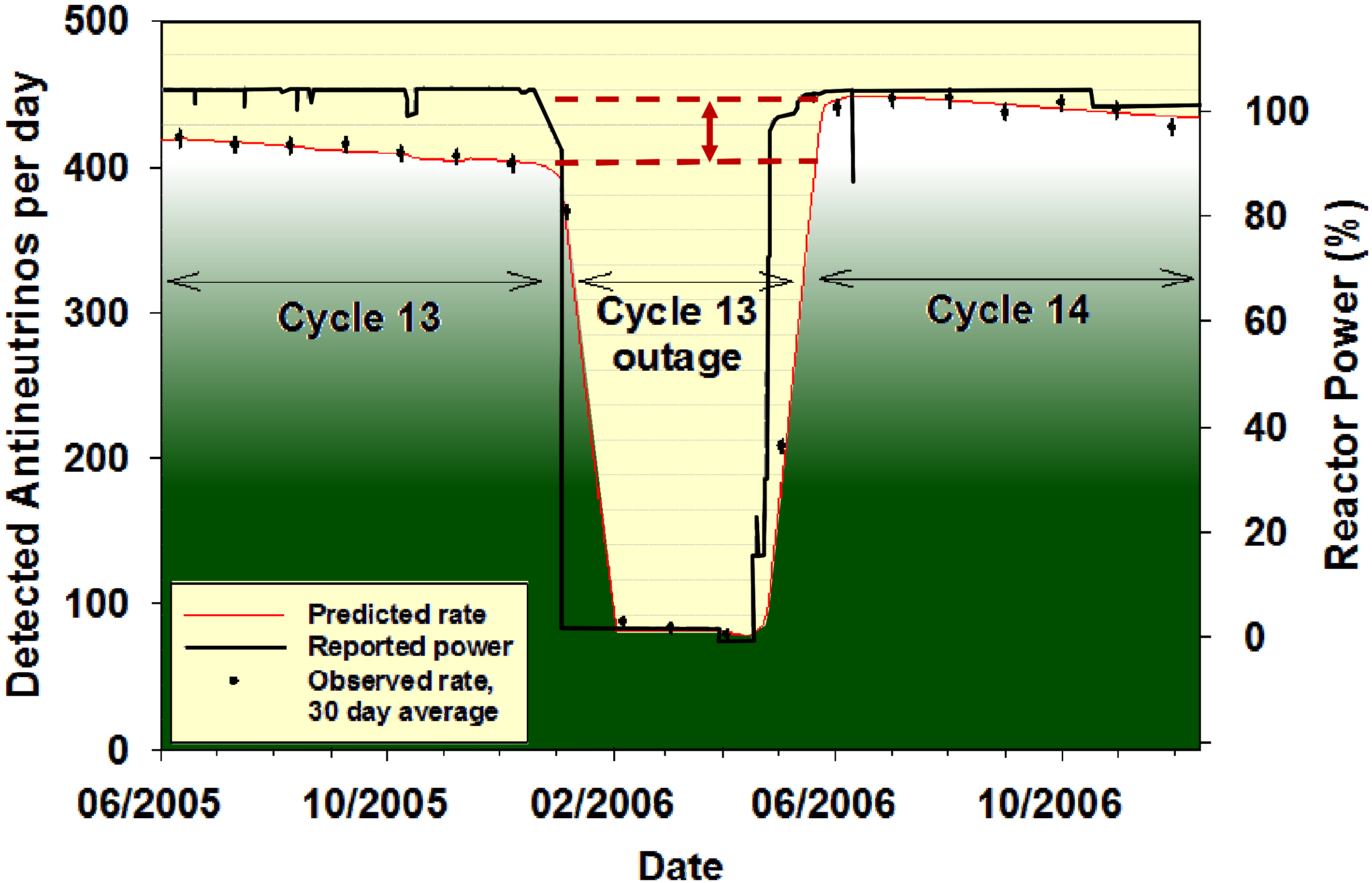
7 Days:

Relative thermal power measurement (2 – 3%)

Large power changes are readily observed with no physical connection to the plant

$\overline{\nu}$ Provides Information on Fuel Composition

Standard Refueling is Clearly Visible



Sensitive to undeclared removal of 70 kg ^{239}Pu

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Example Technologies: Deployable

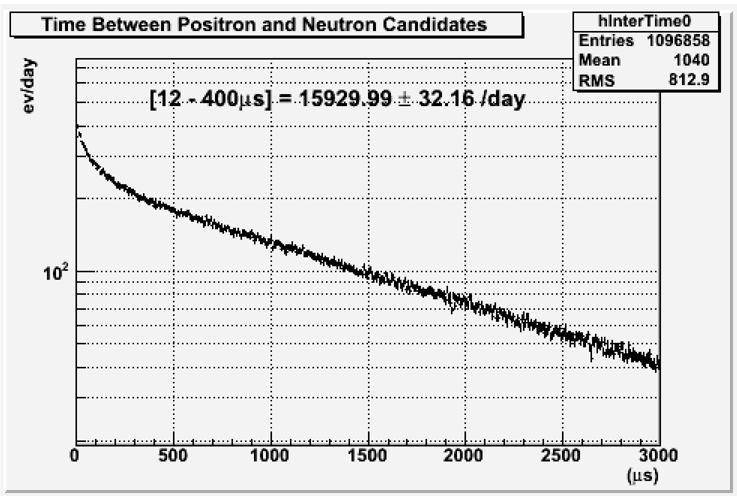
- **Packaged 4-cell prototype for optimal deployment**
  - Total system (detector, electronics, HV, computer) fits within a single rack
  - Shipped fully assembled (no assembly required)
- **Deployed below ground, without shield or muon veto**
  - Uses novel detector technology to provide particle identification
  - Fully operational within 2 hours of being placed at location
- **Stable operation since January 2012 at SONGS**
  - Began data taking during a reactor refueling outage
  - Reactor turn-on delayed until December 2012 (or later)

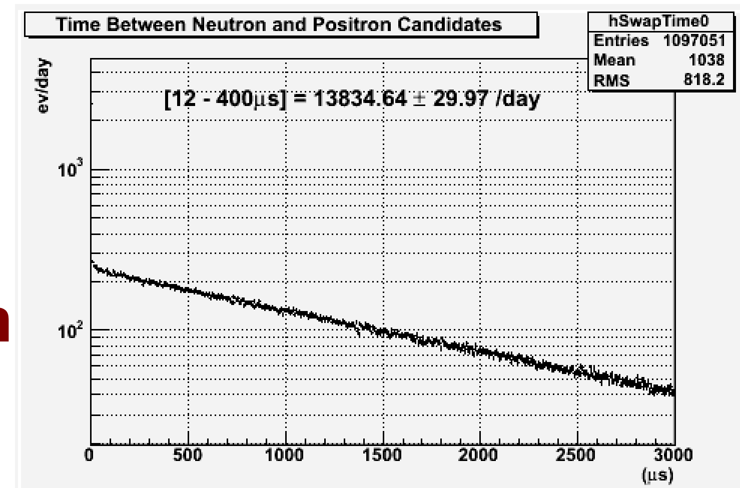
Operation Outside of Shield

Signal

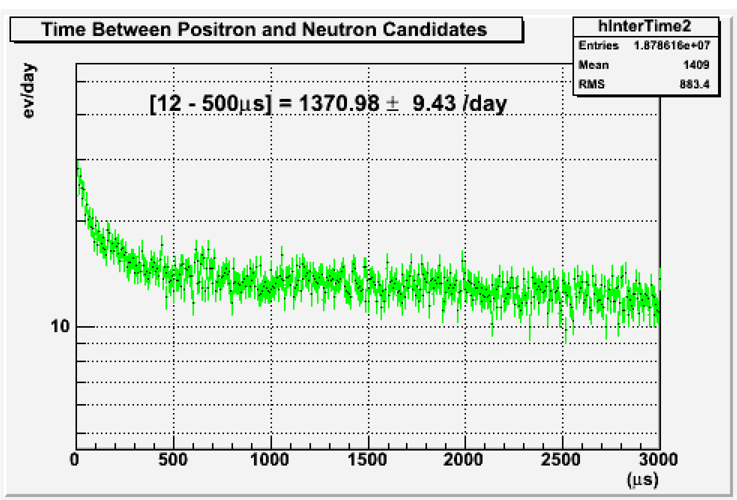
Background

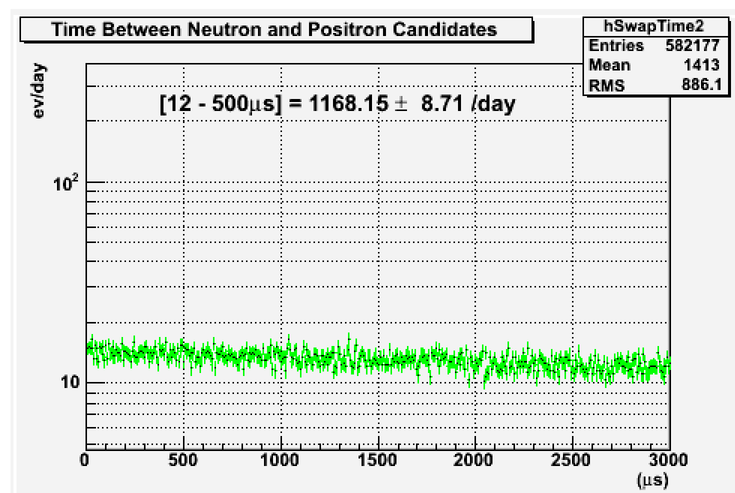
Only Neutron PID





Neutron and Positron PID





Segmented Scintillator

	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

- We believe that a larger version of this detector would demonstrate reactor antineutrino sensitivity
  - Especially below ground
  - Possibly even without a shield
- This compact detector system can fit inside of a single sealed rack
  - 4-cell prototype mounted vertically
  - Single VME crate of electronics
- Scheduled to deploy this small setup underground in the SONGS Unit-2 Tendon Gallery later this year

Conclusion

- **Antineutrino detectors can be used to monitor nuclear reactors remotely, non-intrusively, *and transparently***
- **The antineutrino community is actively working to broaden the suite of demonstrations**
- **Interactions with the Safeguards community are essential to identify the most useful applications for this technology**
- ***Can continuity of knowledge be maintained by antineutrino power monitoring during failures of technical surveillance equipment?***

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