Background Radiation Studies for Future, Above-Ground Antineutrino Detectors

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Abstract

This poster will describe an assembly of detectors that quantifies the background radiation present at potential above ground antineutrino detector sites. Antineutrino detectors show great promise for safeguard applications in directly detecting the total fission rate as well as the change in fissile content of nuclear power reactors. One of the major technical challenges that this safeguard application must overcome is the ability to distinguish signals from antineutrinos originating in the reactor core from noise due to background radiation created by terrestrial and cosmogenic sources. To date, antineutrino experiments have increased the signal to noise in their detectors by surrounding the experiments with significant shielding and placing them underground. For the safeguard's agency, this background radiation shielding is less than optimal, increasing the overall size and limiting the placement of this system. For antineutrino monitoring to be a widely deployable solution, we must understand the backgrounds found above ground at nuclear power plants that can mimic the antineutrino signal so that these backgrounds can be easily identified, separated, and subtracted rather than shielded. The design, construction, calibration, and results from the deployment of these detectors at a variety of sites will be presented.

Antineutrino Safeguards and Monitoring

Cooperative Monitoring

- Agencies such as the I.A.E.A. track the flow of fissile material through the civilian nuclear fuel cycle
- Current reactor safeguards involve
  - ✓Checking declarations
  - ✓Containment and surveillance
  - ✓Item accountancy
- Flawed
  - ✓Require expensive detailed inspections
  - ✓Do not directly measure the Pu created in the reactor

Antineutrino Monitoring

- Determine operational status (On vs. Off)
  - 99% confidence within 5 hours
  - directly measure the thermal power of the reactor
    - 8.3% error for daily measurements
    - 3% error for weekly measurements
- Directly track fissile content of the reactor core
- Detector is low maintenance, remotely deployable, and gives real-time estimates of the fissile content

see also:

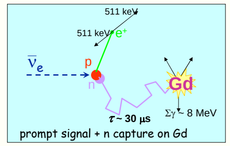
Bowden, N.S. Neutrinos 2008 talk Monday 3:30-4 pm

Bowden, N.S., *et. al.* NIM A 572 985 (2007)

Bernstein, A., *et. al.* J. App. Phys. 103, 074905 (2008).

Antineutrino Detection

Signal



- Use inverse beta decay process:

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

- Positron decays quickly
  - -contains ν energy spectrum
- Neutron is captured after characteristic time
  - -30 μs for Gd doped liquid scintillator

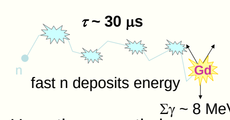
➢ **Produces a time correlated signal-effective background suppression**

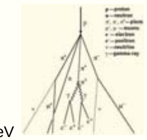
Uncorrelated Backgrounds

- Two particles from **unrelated** events deposit energy in the detector
  - gammas, muons, etc.
- Random time intervals between events
- Reduce the background
  - Require correlated timing
    - –Done in analysis
  - using radiopure materials
  - Adding gamma and neutron shielding
    - –Adds excessive size to the footprint

Correlated Backgrounds

- Two particles from the **same** event deposit energy in the detector





- Have the same timing as antineutrino events
- Reduce the background
  - Going underground
    - –Reduces the deployable locations
  - Tagging muons near the detector
  - Adding neutron shielding
    - –Adds size to the footprint

Background Monitor-Deployment and Results

Background Detector Assembly

- NaI
  - –Gamma spectrum with 10% energy resolution at 662 keV
  - –Energy range- 600 keV to 4 MeV
- Liquid Scintillator
  - –2" cell with Eljen 301 scintillator
  - –Gamma/Neutron pulse shape discrimination
  - –Energy range 600 keV to 4 MeV
- Muon Paddle
  - –Allows for correlations between muons and gamma/neutrons
- ^{3}He
  - –Thermal neutron rate

Deployment-

01/2008 Above-ground Sandia, California

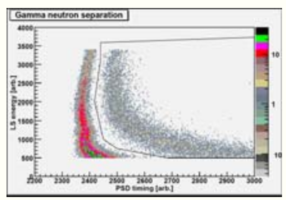
02/2008 6 meters water equivalent (m.w.e.), University of Chicago

03/2008 2nd floor above-ground, University of Chicago

Summer 2008 Above-ground at a nuclear power plant (planned)

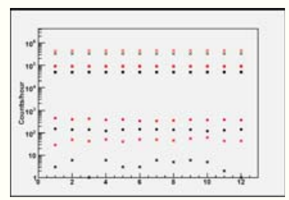
Detector Calibration

Pulse Shape discrimination



- ^{241}Am/Be source 1 meter from liquid scintillator cell
- Two dimensional cut on energy and pulse timing

Detector Results



Comparison of detector rates at:

6 mwe at UC

2nd story office in LASR at UC

x	Gamma rates
▪	Muons
•	Fast neutrons
•	Thermal neutrons

Conclusion and Ongoing work

- Portable background radiation monitor with multiple detector sites is important when moving antineutrino detectors above ground.
- Both correlated and uncorrelated antineutrino backgrounds will increase one to two orders of magnitude above ground

Next:

- Measure absolute radiation rates at a variety of above-ground sites
- Measure timing correlations between muons and other radiation particles
- Compare rates to the underground tendon gallery
- Incorporate results into new models to design above-ground antinuetrino detectors

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, or the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory in part under Contract W-7405-Eng-48 and in part under Contract DE-AC52-07NA27344.

SAND Number: 2008-3210C

National Nuclear Security Administration

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