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Aboveground Antineutrino Detector for Reactor Monitoring

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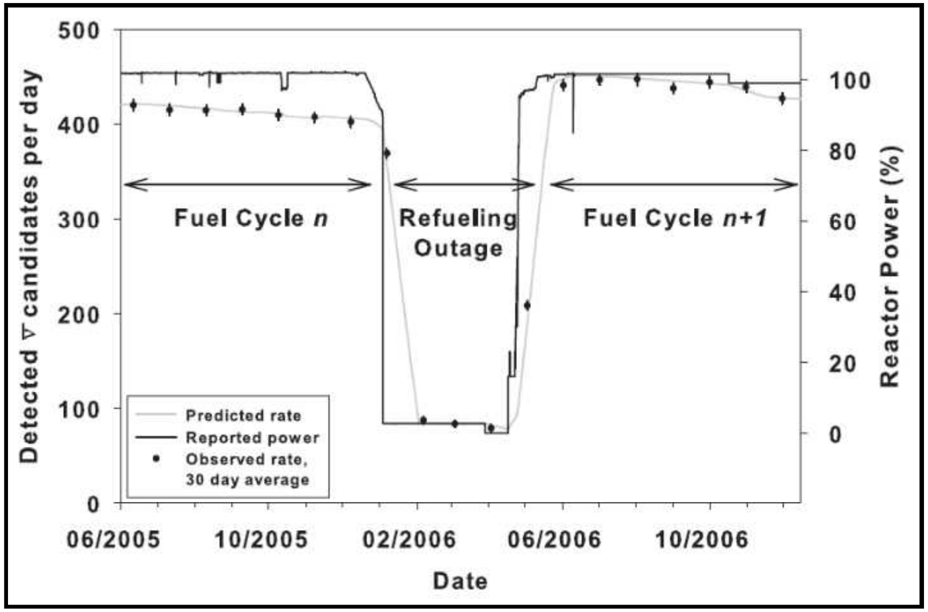
Outline

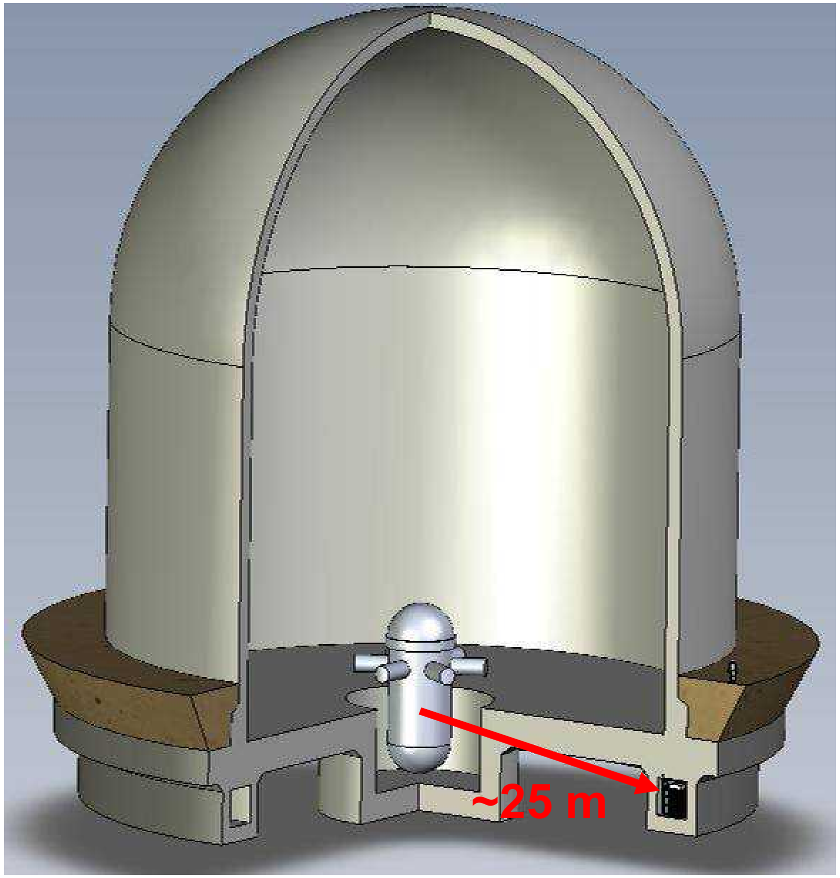
- End-user interest
- The challenges posed by aboveground antineutrino detection
- Deployment considerations
- Conclusions

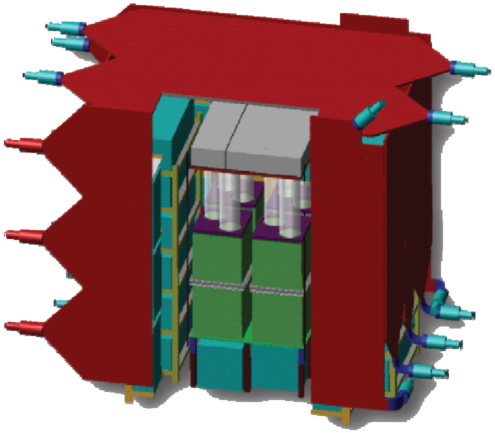
Antineutrinos provide an opportunity for the safeguards community to independently verify reactor operations

- **Sandia/LLNL have ~10 years experience of building and deploying antineutrino detectors for reactor safeguards**
  - Recognized as a world leader in this application
- **What information do antineutrinos provide?**
  - Cannot be shielded
  - Burnup measurements
  - Reactor power
  - Can calculate total Pu production over an operating cycle (IAEA interest)
- **Why do we need a reactor for testing?**
  - The only way to get an intense antineutrino flux sufficient for statistically-significant measurements
  - San Onofre Nuclear Generating Station

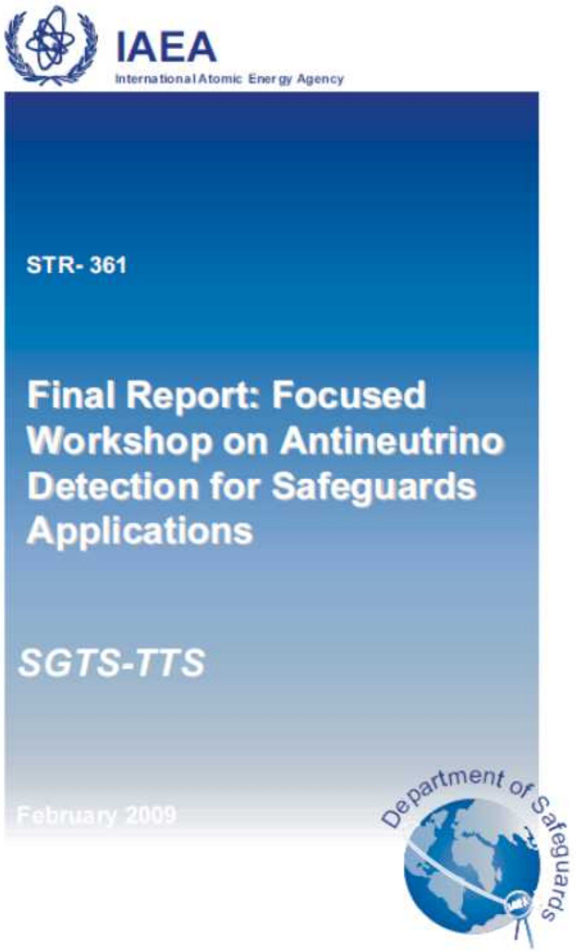


Previous deployments at SONGS





Project motivation: IAEA recommendations



7 Future Developments for Incorporation of Antineutrino Detection Technology into Safeguards

This report illustrates the rapid development in the last five years of antineutrino detectors for the monitoring of reactors for safeguards purposes. The technology has reached a level of maturity where integration in the safeguards regime can be realistically envisaged.

7.2 Medium Term:

If the above near-term goals are met, it is the opinion of the workshop conferees that antineutrino detectors will have demonstrated utility in response to the stated inspector needs in some specific areas of reactor safeguards. To further expand the utility of antineutrino detectors, several useful medium term (5-8 year timeframe) R&D and safeguards analysis goals are proposed.

1. Above ground deployment. Above ground deployment will enable a wider set of operational concepts for IAEA and reactor operators, and will likely expand the base of reactors to which this technology can be applied;
2. Provide fully independent measurements of fissile content, through the use of spectral information. This will allow the IAEA to fully confirm declarations with little or no input from reactor operators, purely by analysis of the antineutrino signal;
3. Develop improved shielding and reduced detector footprint designs, to allow for more convenient deployment. Current footprints are of order 2-3 meters on each side; modest reductions in footprint would expand the general utility of antineutrino detectors. In this regard, a possible deployment scenario is envisaged where the component parts of the detector, shielding and all associated electronics are contained within a standard 12 metre ISO container, facilitating ease of movement and providing physical protection to the instrument. It should be noted that due to size and weight restrictions of ISO containers (approximately 25,000 kg net load) the

Aboveground deployment motivation

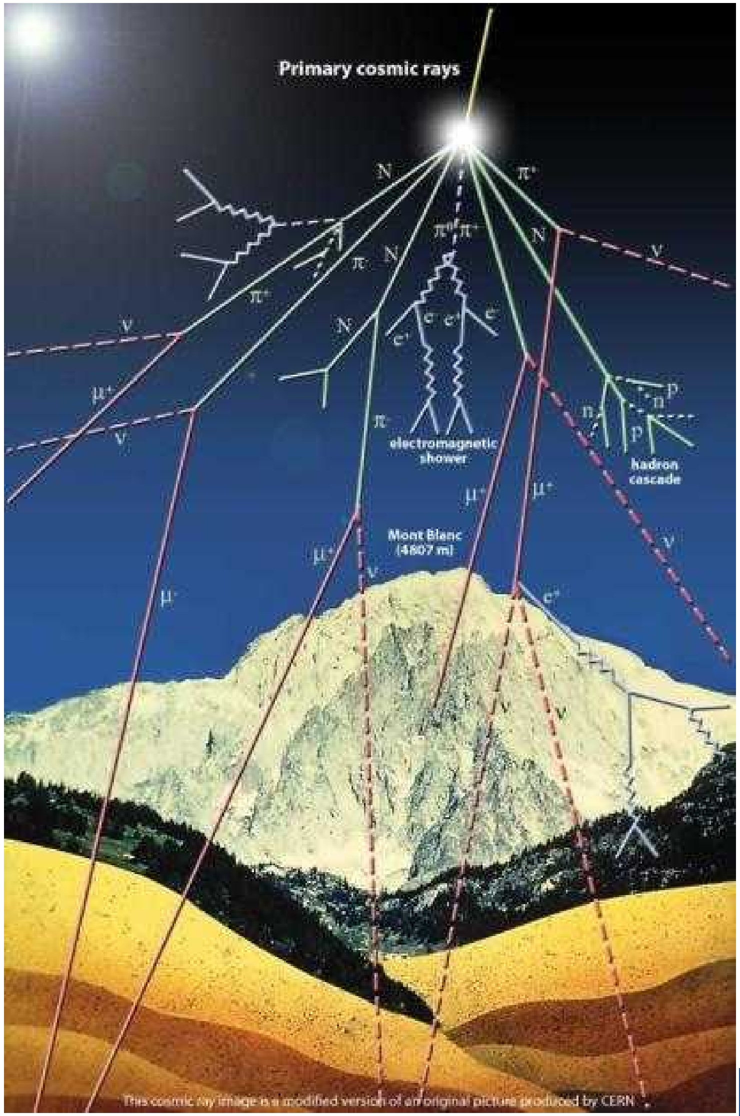
- To increase deployability of this technology
  - Having no overburden requirement would vastly increase the range of possible deployment locations

- The problem: Background!

- Our initial goal is to see a reactor transition on/off
  - (This means making measurements during reactor operation and well through the transition into an outage.)

Our primary challenge: increased backgrounds

- **Without overburden, an aboveground detector is exposed to:**
  - **An increased muon rate**
  - **Hadronic component**
  - **Electromagnetic component**
  - **Secondaries produced by all of the above, in the detector and its surroundings**



Project trajectory

- We are currently in year 3 of a 4 year project cycle
  - Years 1-2: devoted to studying & understanding backgrounds, detector technologies
  - Now: deployed one aboveground design at SONGS; testing an advanced scintillator prototype in our labs
  - It is time to think about a full-scale system deployment of the advanced scintillator design (only way to get antineutrinos)

- Desire a large antineutrino flux for system deployment (high reactor power, proximity)
  - will improve the signal relative to background
  - helps us achieve an on/off measurement

Deployment at a reactor

- We have a long and successful history with San Onofre
  - They are willing to help meet our deployment needs for this project
- BUT…
  - Laydown areas are very limited at their site, making a suitable deployment location challenging
  - Steam generator replacements at both San Onofre units make current and future scheduling difficult
- A new reactor site is desired to meet our project requirements and deadlines

Desirable properties of Browns Ferry

- **Multiple units**
  - **Probability of overlapping reactor outage & antineutrino deployment schedules is high**
- **High reactor powers**
  - **All >1000 MWe implies favorable antineutrino rates**

What is needed for a successful deployment (1)

- Location
  - Outside containment, as close to reactor as practical (10s of meters)
  - Space for shipping container
  - Power (actual installed configuration of ongoing SONGS experiment)
    - 20A, 240V for air conditioning
    - 20A, 240V for data acquisition system
    - 2 x (20A, 120V) for miscellaneous
    - 20A, 120V for spare circuit
    - Total power draw (with spare loaded): 12.6 kVA
  - Communication
    - Broadband wireless or modem and phone line
  - Minimal access by LLNL/Sandia; no TVA maintenance
    - Installation (~2 weeks)
    - Retrieve data (~1 day/month)
    - Repairs (guess 2-4 days/quarter)
    - Removal (~1-2 weeks after completion of data collection)
    - Total time required for successful deployment: many months, up to a year

What is needed for a successful deployment (2)

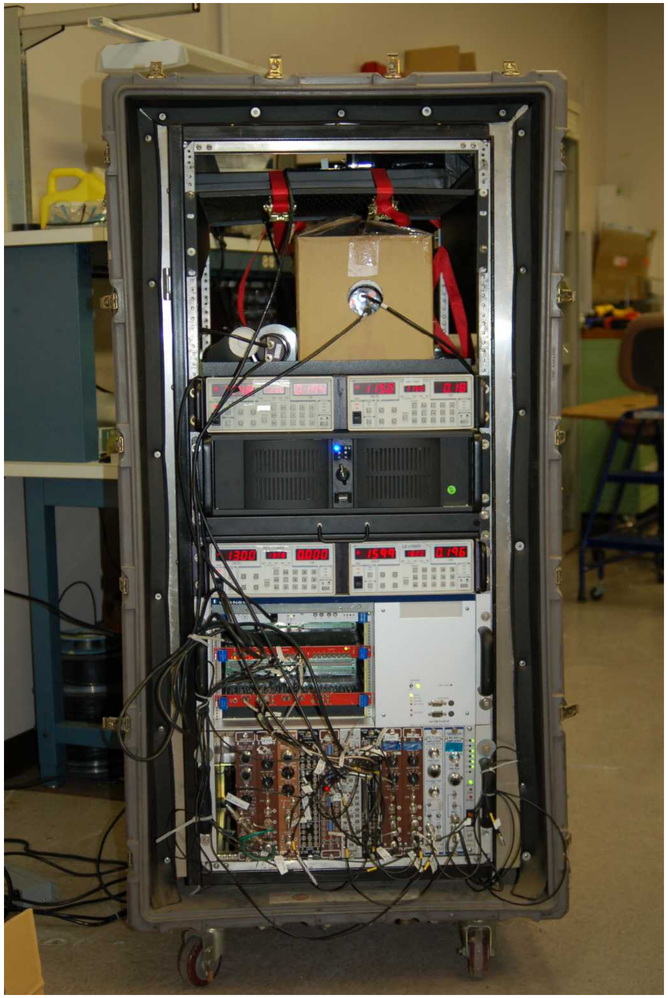
- **Detector**
  - Hydrogenous detector material
  - 1 m^3 $\rightarrow$100s of antineutrinos detected per day
  - Organic scintillator is an obvious choice
  - Materials considerations (flammable liquids vs. solid plastic)

- **Shielding to reduce natural background**
  - Usually a combination of water or HDPE for neutron moderation

- **Ideal deployment**
  - Several months with reactor at power
  - Overlap with an outage to measure reactor-off backgrounds

Background Detection Assembly: deployment

- Self-contained background measurement device
- Multiple detectors:
  - NaI (gammas)
  - He-3 (thermal neutrons)
  - Liquid scintillator (fast neutrons)
  - Plastic scintillator panel (muons)
- Tells us if backgrounds are stable and sufficiently low



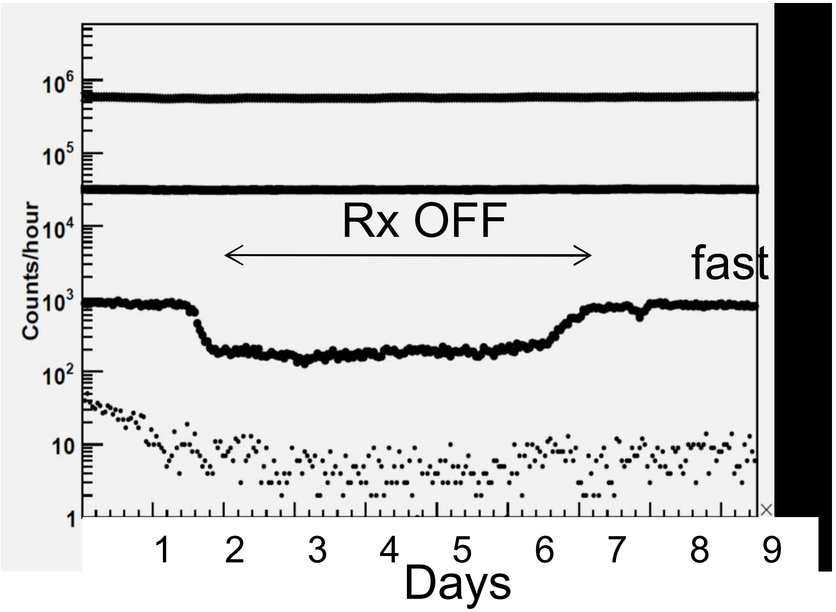
Comparison of scalar rates at various locations

Deployment Location	Overburden (m water eq)	Gamma Rate (Hz)	Muon Rate (Hz)	Fast Neutron Rate (Hz)	Thermal Neutron Rate (Hz)
Livermore, CA	0	93.4	26.7	0.67	0.035
CGS (471')	0	50.5	16.9	0.67	0.043
U. Chicago (2nd floor lab)	0	129.7	25.0	0.1	0.014
U. Chicago (basement lab)	6	92.4	13.7	0.006	0.001
SONGS (U3TG)	25	76.7	4.5	0.036	0.055

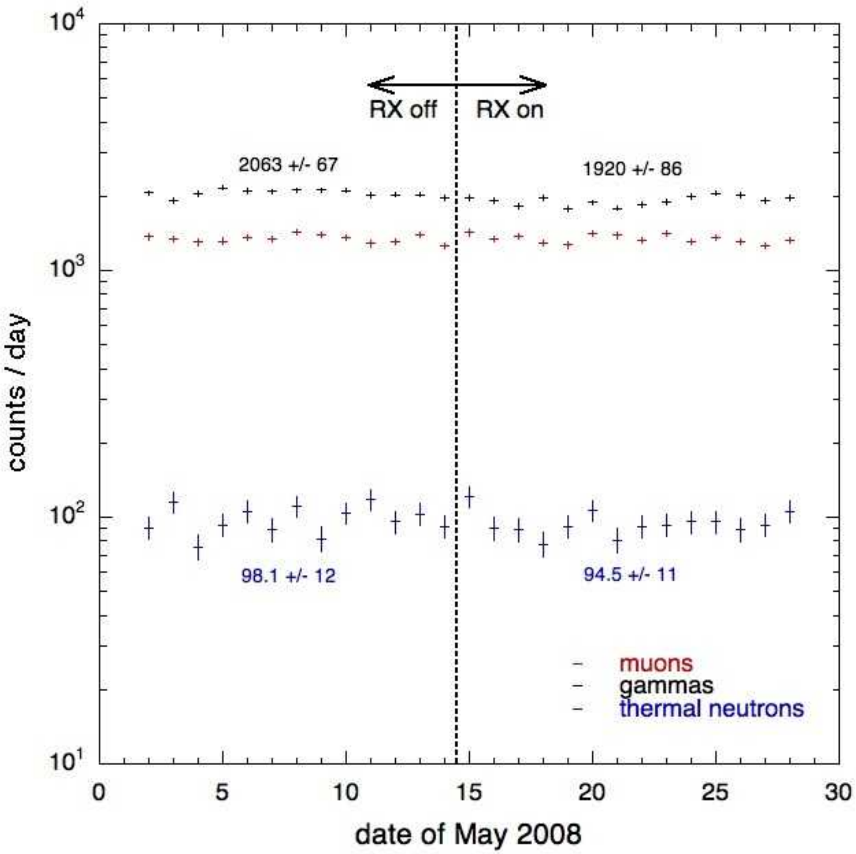
It is possible for detector backgrounds to be coupled to reactor operation

- **At some locations, reactor correlations are seen!**

Columbia Generating Station



SONGS Tendon Gallery



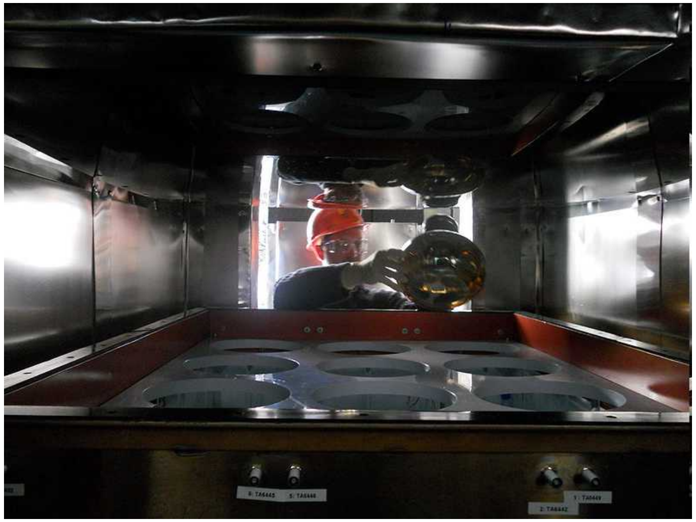
The aboveground detector (current configuration)

Interior Volume: 1.5m x 1m x 1.5m

45 cm HDPE on all sides of detector

Muon detectors lining 5 sides of HDPE

Currently fits within a
20' L x 8' W x 9'6" H container



Conclusion

- **Considerable end-user interest (IAEA) in antineutrino detectors for reactor monitoring**
  - **Aboveground detection capability is a clear request**
  - **Increased backgrounds are the main challenge for aboveground antineutrino detection**

- **Our aboveground detection project has identified background & detection technologies**
  - **Now is the time to consider deployment**
  - **Need a power reactor to test on/off measurement**

- **Current design concept: pre-assemble detector, ship to site**

Discussion topics

- Background Detection Assembly deployment?
- Upcoming reactor outages
- Deployment locations at Browns Ferry
  - Proximity to reactor(s)
  - Power, communications, temperature controls
- Time/events for a deployment to happen
- Badging/escorting
- Underground locations
- Fuels (BLEU)
- Long-term major site events?