WATCHMAN's Sensitivity to Remote Reactor Discovery

O.A. Akindele *on behalf of The Watchman Collaboration*

Abstract

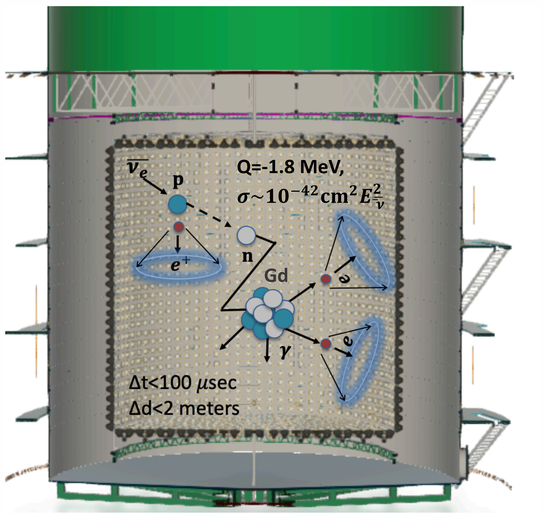
The Water Cherenkov Monitor of Antineutrinos (WATCHMAN) is a planned demonstration of far-field reactor monitoring for nonproliferation. To date, antineutrino experiments dedicated to nonproliferation used compact scintillator-based detectors situated on the order of meters from the reactor core. This proximity to the reactor core requires accommodations by the host facility, while detectors situated on the order of kilometers will allow for unobtrusive monitoring and verification of reactor activities. This poster details the sensitivity of the planned WATCHMAN detector, a Gd loaded water Cherenkov detector, to the exclusion of the existence of undeclared reactors from a specified radial distance, and the presence of a hidden reactor near a declared reactor facility through Monte Carlo simulations.

Objective

- How well can a WATCHMAN like detector discover or exclude the presence of a nuclear reactor from a region.
- How well can a WATCHMAN like detector confirm the range and operating power of a nuclear facility.

Detector Description

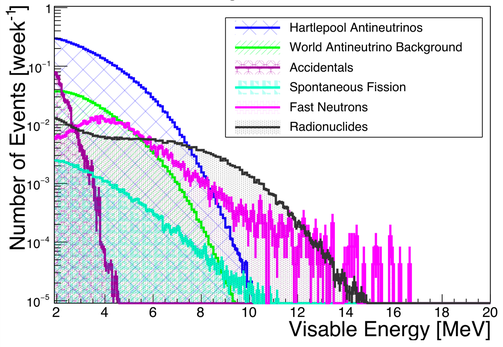
- WATCHMAN is a 20m by 20m cylindrical detector to be built in the Boulby Underground Laboratory ~1100 meters underground.
- The detector will monitor the Hartlepool Power Station which consists of two 1.5 GWt reactors at a 25 km standoff from the detector.



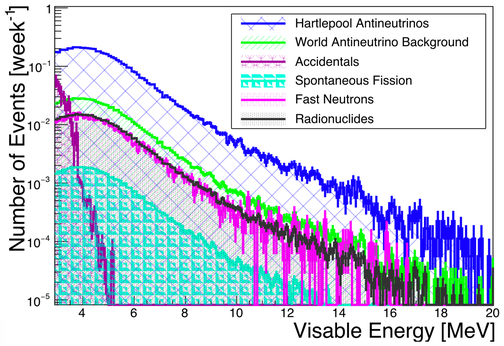
Methodology

- Simulations of the signal and backgrounds were performed using rat-pac and the reconstruction of the events was determined using BONSAI, a tool developed by M. Smy.
- A two-dimensional log-likelihood fit to the prompt and delayed events based on their energy and the position of reconstruction on the detector was used to evaluate the sensitivity with a Feldman-Cousins Approach.

Prompt Events



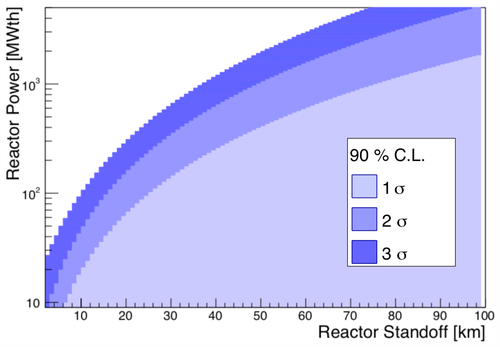
Delayed Events



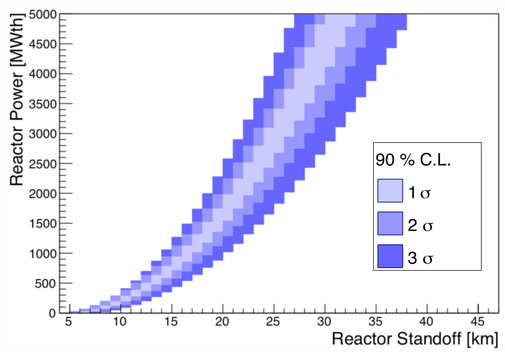
Results

- The sensitivity to any nuclear reactors for a one-year dwell time is shown below. The sensitivity to reactors on order of 10's, 100's, and 1000's MWth covers the broad spectra of reactors of interest.
- Given the energy resolution of a water-Cherenkov detector, the ability to confirm the operating power of a nuclear reactor complex requires previous knowledge of the reactor location (and vise versa).

One Year Dwell Time 0 MWth



One Year Dwell Time 3000 MWth



Event Summary

Contribution	Yearly Events	$< \sigma >$/N
Reactor Signal	354.32 ±31.39	
Statistical		5.3%
Thermal Power		5%
IBD Cross Section		0.5%
Neutrino Flux		5%
Antineutrino Background	47.41 ±9.01	
Statistical		14.5%
Capacity Factor		10%
geoneutrinos.org[18]		5%
Neutrino Flux		5%
Accidentals	32.40 ±9.21	
Statistical		17.6%
Radioassay		10%
Voxilation		20%
Muogenic Radionuclides	13.73 ±7.80	
Statistical		26.9%
Model Validation[24, 25]		50%
Muogenic Dineutrons	13.00 ±6.32	
Statistical		27.7%
Model Validation[12]		40%
Spontaneous Fission	2.60 ±1.62	
Statistical		62%
Model Validation		3%
Total	463.46 ±68.40	

Summary and Outlook

- WATCHMAN is a kiloton scale detector planned for deployment in the Boulby Underground Laboratory to detector antineutrinos using Gd-doped water. Water-based scintillator is also under consideration.
- The world reactor antineutrino background in the UK, makes the results of the sensitivity a conservative understanding of this technology at the 1 kiloton scale.
- Even with moderate sensitivity on the order of 10's of km, WATCHMAN is suitable for cooperative mid-field monitoring of nuclear reactors.
- However, due to the scalability of this design, larger scale detectors can be utilized to extend the range of sensitivity for specific applications.

WATCHMAN will be the First Large-Scale Antineutrino Detector used to Monitor Nuclear Reactors for Nonproliferation

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