Complete simulation of the Angra Neutrino Project

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Abstract

The Angra Neutrino Project aims to measure neutrinos from the Angra Nuclear Power Plant/Rio de Janeiro for safeguard purposes. The detector is under deployment at Centro Brasileiro de Pesquisas Físicas (CBPF) to be soon installed in Angra. After the project overview we present its complete simulation, including the effects of electronic noise. Expected neutrino detection efficiencies, backgrounds and signal over noise ratios are then discussed. Finally we show the status of construction and tests.

Motivation

Interesting project for the Brazilian science:

- Possibility for Brazil, as a IAEA member State, to contribute to the development of future verification techniques to implement safeguards for the non proliferation of nuclear weapons.
- Possibility to innovative experimental neutrino physics profiting from already existing facility (Angra II nuclear reactor).

Why the interest in antineutrino detectors?

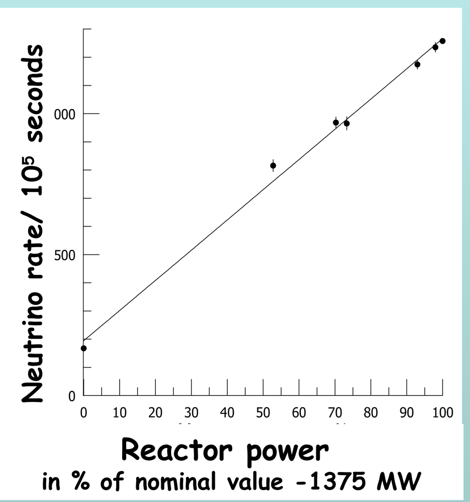
- Antineutrinos can not be shielded and are produced in very large amounts in nuclear reactors **(~ 10^{20} antineutrinos/s)**
- Non-intrusive, quasi-real time, remote monitoring of reactor thermal power.
- Energy spectrum of antineutrinos produced in reactors can reveal the fissile composition of nuclear fuel.
- Search for new methods on verification of safeguards.

Reactor Thermal Power and Antineutrino flux

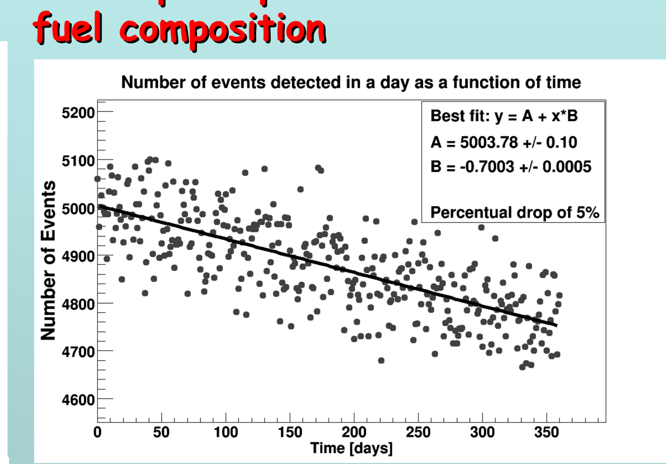
$$N_\nu = \gamma \cdot (1 + k) \cdot P_{th}$$

Dependence on detector features

Burn-up: Dependence on fuel composition



(figure from Valery SINEV)



(simulation results, ANGRA Collaboration)

Inverse beta decay reaction

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

AngraII Nuclear Reactor & Neutrino Laboratory

conteiner: 1st laboratory in Angra

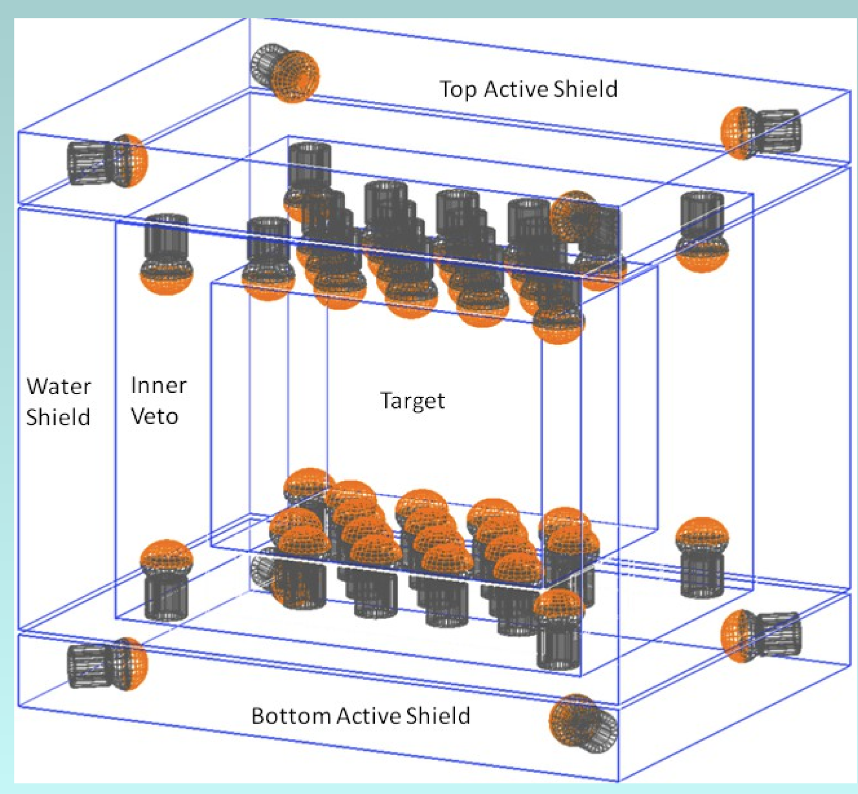
Detector Design: Water Cherenkov

A challenging configuration:

- Water Cherenkov detector (loaded with Gd) running above ground in a commercial container.
- Choices to comply with:
- Safety rules of ELETRONUCLEAR, power plant operator
- Recommendations of the Workshop on Antineutrino Detection for Safeguards Applications sponsored by IAEA in 2008:

"small, safe and easily deployable detectors"

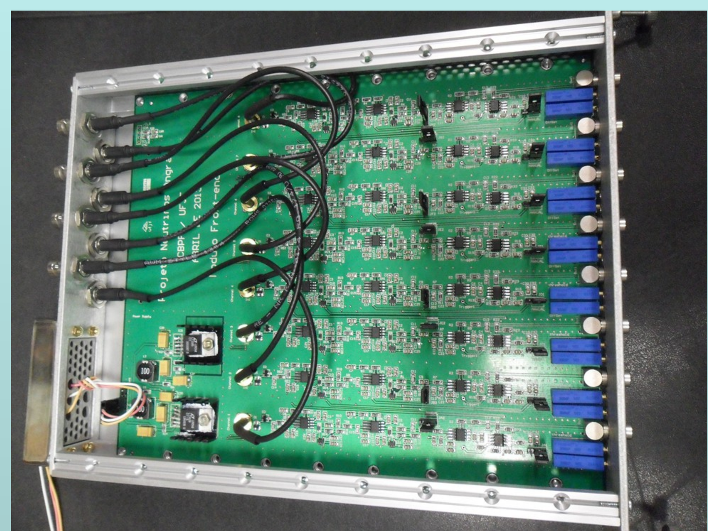
Schematic of the Detector System



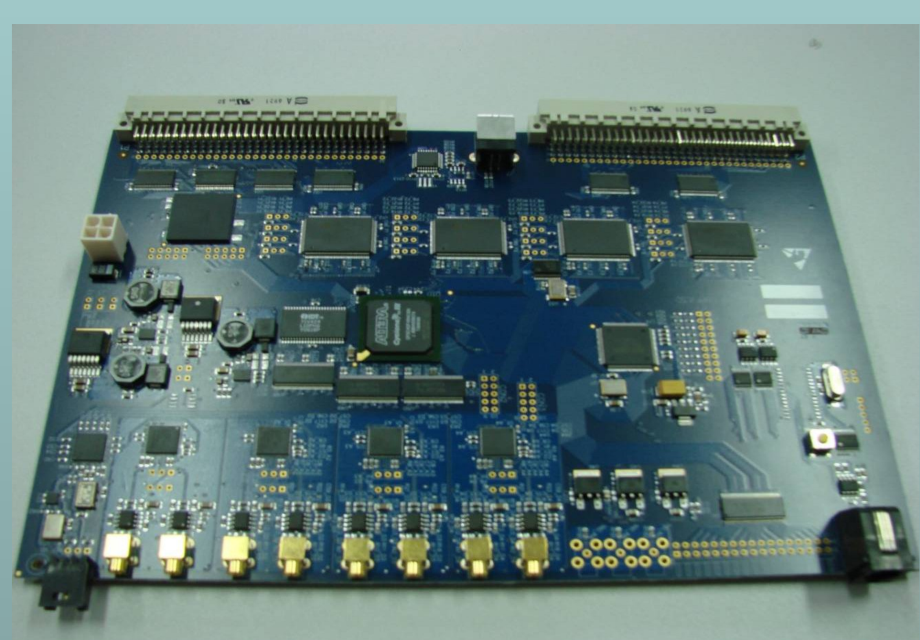
- Central detector target: water + 0.3% Gd viewed by 32 PMT's (8")
- Target Fiducial volume: ~ 1.4 ton
- External active shield (16PMTs): pure water;

Front-end Electronics and Data Acquisition

- Custom low-noise N.I.M. Pre-amplifiers



- Custom VME waveform digitizer (FADC) and TDC



All Electronic modules built and tested!

Construction is ongoing@CBPF

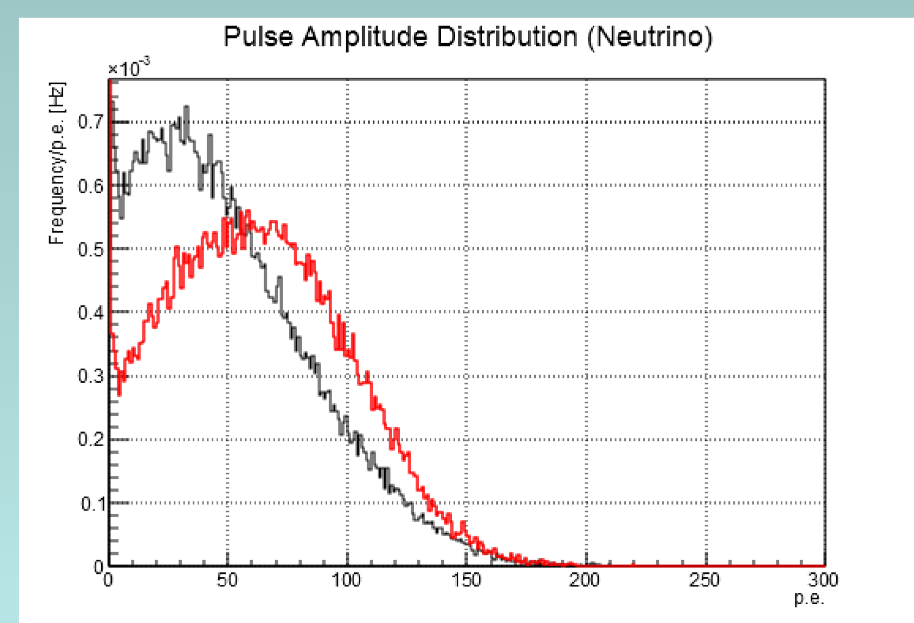
Simulation

Principal stages:

- Primary generators: models for neutrino signals, cosmic rays particles (muons, electrons, positrons, gammas, protons, neutons and pions), and environment (gammas)
- Geant4: including optical processes
- Mixer: generating proper time distributions for simualted events (Poisson processes)
- Electronics: including pmt amplification, pre-amp. Noise and FADC digitization.

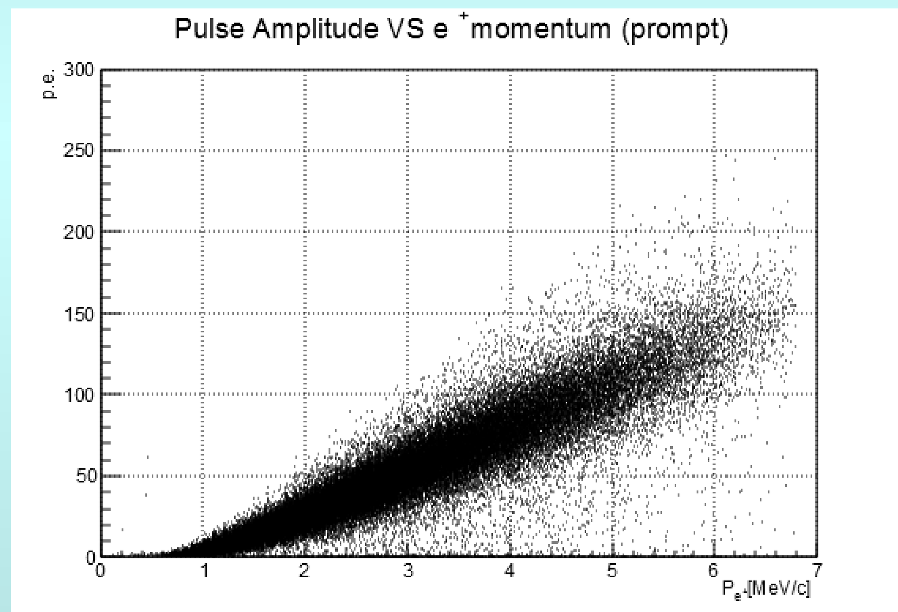
Preliminary versions available for each stage!

Prompt and delayed signals

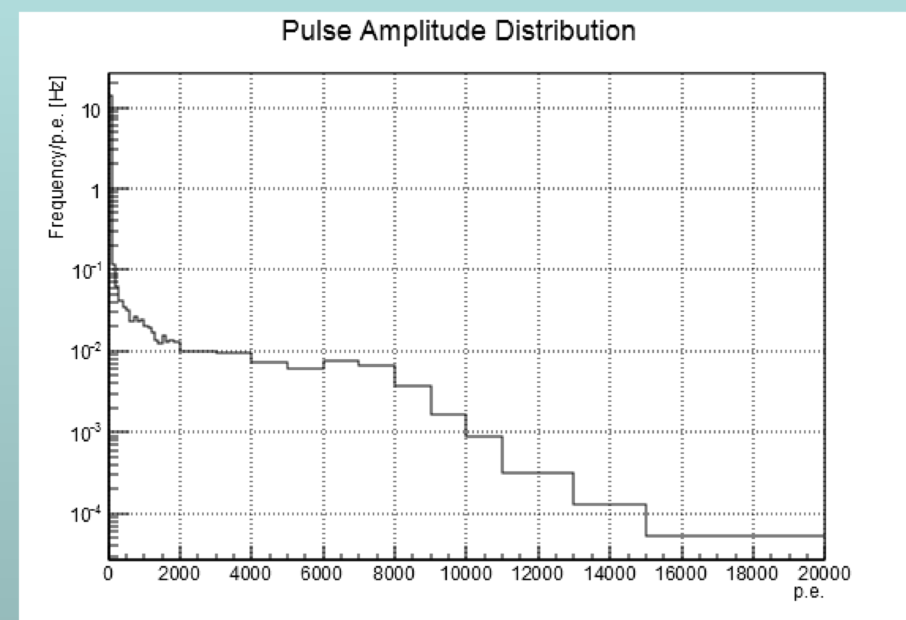


In Red: prompt signal
In Black: delayed signal
Neutrino Interactions total rate: 0.06Hz

Neutrino momentum from P.E.



Total background spectrum



<200 p.e.: mostly of electromagnetic origin (gammas)
200-400 p.e.: mixture of e-m, neutrons and muons
>400 p.e.: mostly muons
Backgrounds total rates (excluding dark current):1.5KHz

Signal over Noise

Selection criteria:

- Pulses > ~15 p.e.
- Pulses < ~200 p.e.
- No signal in veto
- ~5μs<ΔT<~50μs

Neutrino efficiency: 50%-80%

Expected signal over noise after one day:S/√B>~30

Conclusions:

- Neutrino Laboratory @ ANGRA is OPERATIONAL.
- Simulation suggest good signal in a day of data
- Construction and first tests in progress
- Neutrino detection expected in Angra this year!

Bibliography:

A. Bernstein et al, arXiv:0908.4338
J. C. Anjos et al, AIP Conference Proceedings 1222, 427-430 (2010)