Status of the Angra Neutrino Project*

Chimenti,P.†

Universidade Federal do ABC - UFABC

Anjos, J.C., Azzi, G., Castromonte,C., Lima Jr,
H.P., Machado,R., Rocha, O., and Souza,M.J.N.

Centro Brasileiro de Pesquisas Fsicas - CBPF

Cerqueira, A.S. and Nóbrega, R.A.

Universidade Federal de Juiz de Fora - UFJF

Farias, P.C.M.A., Pepe, I.M., Ribeiro, D.B.S., and Simas Filho, E.F.

Universidade Federal de Bahia - UFBA

Guedes, G.P.

Universidade Estadual de Feira de Santana - UEFS

Gonzales, L.F.G., Kemp,E., and Rodrigues, O.B.

Universidade Estadual de Campinas - UNICAMP

Nunokawa, H. and Wagner, S.

Pontifícia Universidade Católica de Rio de Janeiro - PUC-Rio

Valdiviesso, G.A.

Universidade Federal de Alfenas - UNIFAL-MG

(Dated: March 24, 2016)

Abstract

The Angra Neutrino Project aims at measuring neutrinos from the Angra-II power plant for monitoring purposes. The water Cherenkov detector, with a fiducial volume of about 1.4 ton filled with a solution of $GdCl_3$, is under construction in Rio de Janeiro. All parts are already constructed and are being assembled and tested first at CBPF to be installed in Angra later this year. The current status of simulations, construction and tests is presented. This will be the first neutrino detector entirely designed, constructed and operated in Brazil.

INTRODUCTION

The possibility to use anti-neutrinos emitted by a nuclear power plant for monitoring and non-proliferation purposes was noted long ago (see [1] for a recent overview of the subject). Only recently however advances in detector technology permitted the actual realization of this original idea. Along this line of research the Angra Neutrino Project [2] (ANP for short) aims at developing a low budget detector to monitor the Angra-II power plant as a proof of concept.

Most recent efforts in this field were focused on the application of scintillators, either plastic of liquid, as detection technology. Due to budget consideration and safety requirements we focused our effort on the development of a Water Cherenkov detector employing a $H_2O - GdCl_3$ solution (0.3% in mass of Gd) to increase the signal-over-noise ratio. Indeed good quality plastic scintillators are relatively expensive and liquid scintillators are flammable with a flash point considered too low for a safe operation in a nuclear power plant environment. Moreover past experiments were placed in a site with an overburden of some meters of rock water equivalent. Neutrinos Angra would provide the first measurement at surface (no overburden).

It must be emphasized that the development of local small scale experiment is extremely important to train students and young researchers to experimental particle physics and to boost local technologies. Indeed this will be the first neutrino experiment completely designed, built and operated in Brazil. In this sense the Angra Neutrino Experiment has a usefulness extending much longer its scientific goal.

DESIGN

The Angra-II power plant is a Pressurized-Water reactor with a nominal thermal power of 4 GW. The detection channel is the inverse beta decay: an electron anti-neutrino interact on a proton yeilding a neutron and a positron. The neutron is subsequently captured by a gadolinium nucleus dissolved in water resulting in a cascade of deexcitation gammas. The interaction signature is therefore a prompt event given by the positron and a delayed event generated by the neutron.

The position of closest approach where a detector could be installed is at about 30 m from the reactor core. In order to have a sizable event rate (more than about $10^3\,\mathrm{day}^{-1}$ a detector with a fiducial mass of about 1 ton must be built. The detector also has to be installed inside the neutrino laboratory: a standard high cube 12 m container installed near the reactor dome. This sets important geometrical requirements.

In order to reduce the background rate, the detector has to be shielded. Again the technology of choice for this pourpose was based on water tanks: water, being an excellent neutron moderator, is very efficient in reducing the amount of enviromental neutrons entering the detector. Moreover the water shield tanks can be instrumented to act as an active veto against cosmic rays.

The detector design as implemented in the Geant4 simulation is illustrated in Fig. 1.

MECHANICS AND ELECTRONICS

The mechanical design is implemented with stainless steel containers for both the veto volumes and as support to the polyethylene vessel containing the Water-Gadolinium solution. Indeed this solution is corrosive and if in contact with metallic surfaces would degrade the water transparency. Internal surfaces of the tanks are folded with tyvek or gore-tex in order to increase the light collection efficiency. Photons are detected by the classic 8 inches Hamamasu R5912 Photomultiplier tube with waterproof base. Water is recirculated through microfilters and UV lights to mantain tranparency.

PMTs are powered by a CAEN SY4527 H.V. system. Their signals are pre-amplified and discriminated by a custom front-end electronic NIM module and finally read-out by a FADC board entirely designed at CBPF. Pre-amplified signals exhibits rise time of order 20 ns, fall

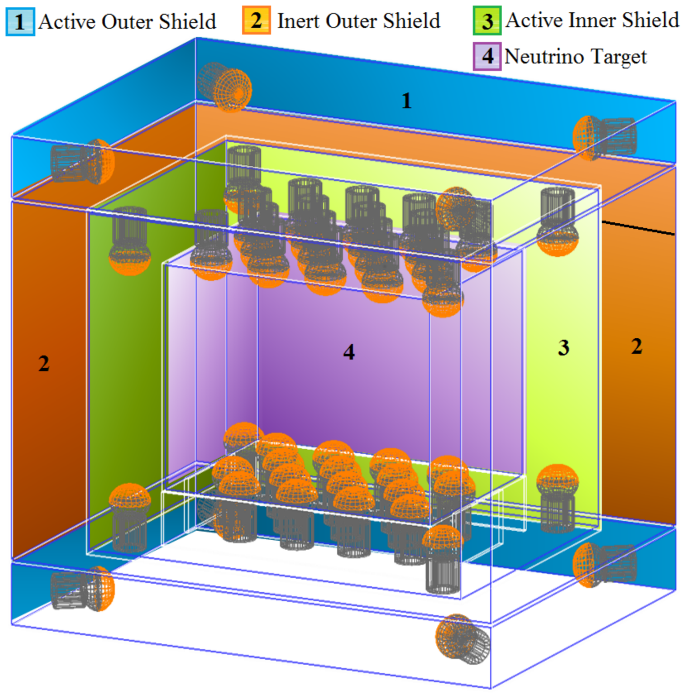

FIG. 1: Design of the Angra Neutrino Detector.

time of order 80 ns and pulse height of about 37 mV/*p.e.* at nominal PMT gain of 10^7. Front-end electronics saturates at about 52 p.e.. Pedestals and discrimination thresholds can be tuned remotely by an on board I2C controller.

Pre-amplified signals are sampled by custom boards (DAQs) assembling both FADCs and TDCs combning good signal charge and time reconstruction. FADCs have $2\,\mathrm{V_{pp}}$ dynamic range, 10 bits of effective resolution and work at 125 MHz. TDCs have 81 ns resolution and $9.8\,\mu$s range. Onboard FPGAs implement optimal filters and control comunication with read-out boards both through USB or VME interfaces. DAQ boards inlcude a CAN controller for remote configuration.

Signals are finally acquired on PC by a VME bus single board computer (MVME3100 by Emerson Network Power).

All mechanical and electronic elements have been built or purchased and are being assembled and tested at CBPF [3].

SIMULATION

The simulation code is divided in to four domains with well defined interfaces:

- Primary Generators: this code provides samples of neutrino and background primary interations in the detector. It collects all the available information on primary particle distribution. Primary interaction samples are stored in text files with HepEVT formatting.

- Geant4 [4] Simulation: the responsability of this domain is to simulate the propagation and interaction of primary particle with the detector. Results are stored (after post-processing) in root files containing information about photoelectrons generated in each PMT by each event. Time at this stage is relative to the primary interaction.

- Mixer: this domain distributes simulated events of both neutrino interactions and background according to poisson distribution in the right time order.

- Front-end simulation: this domain simulate the response of both electronics and trigger logic producing output files equivalent to the one produced in a real data acquisition.

The first three domains are in an advanced phase of development. A first prototype of the last domain has been also implemented.

First simulation, not yet tuned against detector calibrations, indicate antineutrino detection efficiency between 50% and 80%, depending on selection criteria. Also we foresee the possibility of detecting reactor on/off with high significance in a day of data acquisition. The results however heavily depend on precise estimation of backgrounds [5].

FIRST TESTS AND CONCLUSIONS

First tests are being performed with the inner detector filled with water and half equipped with PMTs. In this configuration we verified the capability of detecting single p.e. generated by Cherenkov. Also the light yield is about as expected by simulation. Light yield however strongly depend on water transparency, which has to be carefully monitored during the experiment lifetime.

In conclusion the experimental results expected by the Angra Neutrino Experiment are still interesting and well placed within the international effort to provide a nuclear safeguard technology employing neutrinos. The project is ongoing and results of preliminary tests of the equipment are according to expectations.

The Angra Collaboration acknowledges the support of Ministério de Ciência, Tecnologia e Inovação (MCTI), the Conselho Nacional para o Desenvolvimento Cinetífico e Tecnológico (CNPq), Finandiadora de Estudos e Projetos (FINEP) and the following state research agencies: FAPESP, FAPMIG and FAPERJ. P.Chimenti thanks the support of FAPESP funding grant 2015/12505-5.

---

* *Presented at NuFact15, 10-15 Aug 2015, Rio de Janeiro, Brazil [C15-08-10.2]*

† `pietro.chimenti@ufabc.edu.br`; Speaker

[1] M. Cribier, J. Phys. Conf. Ser. **593**, 012004 (2015).

[2] J. C. Anjos et al., Nucl. Part. Phys. Proc. **267-269**, 108 (2015).

[3] T. A. Alvarenga et al. (2016), manscript submitted for publication.

[4] S. Agostinelli et al. (GEANT4), Nucl. Instrum. Meth. **A506**, 250 (2003).

[5] P. Chimenti et al. (2014), angra Internal Note.