Status and Perspectives of the Neutrino Angra Project

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Abstract. This is a status report of the Angra Neutrinos Project, in developing an antineutrino detector with the purpose of monitoring the nuclear reactor activity. Angra has a small (1ton) target and is designed to fit a commercial container. The detector will be operational by the end of 2013.

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INTRODUCTION

Neutrinos (actually antineutrinos) were first signed by Cowan and Reines[1] in 1956, detected from a nuclear reactor at the Savanah River Site. In the middles 80's scientists found out that these antineutrinos could be used for monitoring reactor thermal power. This practical usage of Neutrino Physics is very attractive for nuclear safeguards since it allows a non-intrusive, quasi-real time, remote monitoring of reactor's thermal power and fuel composition [3]. Although the very first detectors were small (of the order of $1m^3$), cosmic radiation have prevented neutrino counting without a dense shield. Nowadays, improvements on fast data acquisition seems to have reached a limit were those measures should be possible and this is the challenge that the Angra Neutrino Project is intended to face.

First presented in 2006 as a $theta_{13}$ measurement experiment[2], the **Angra Neutrino Project** (Angra, for short) is a compact safeguard detector and has been developed in Brazil at the Angra nuclear power plant (*Angra dos Reis -RJ* city). Angra's target consists of a 1.4ton water+Gadolinium Cerenkov detector, surrounded by two additional layers: a pure water inner veto and a water shield (which is active on its top and bottom parts). The whole detector is placed inside a commercial container just outside the reactor containment, about 33m from the Angra II reactor core, which has a 4GW thermal power. This power will provide a few thousand antineutrino inverse beta decay interactions per day. The main challenge of the project will be to overcome the very high cosmic ray induced background at sea level, consisting mainly of muons, neutrons, gammas and electrons.

STRUCTURE

To overcome the background the detector will consist of following subsystems (Fig.1): A muon veto (98% simulated efficiency) placed in the outer most detector layer, composed of a top and bottom shield, to look for coincidences (equipped with $4 \times 8''$ PMTs each); A neutron shield 30cm thick filled with water and; A central detector consisting of a inner neutron shield 25cm thick and a one ton central target filled with a mixture of water and 0.2% of gadolinium and equipped with $32 \times 8''$ PMTs.

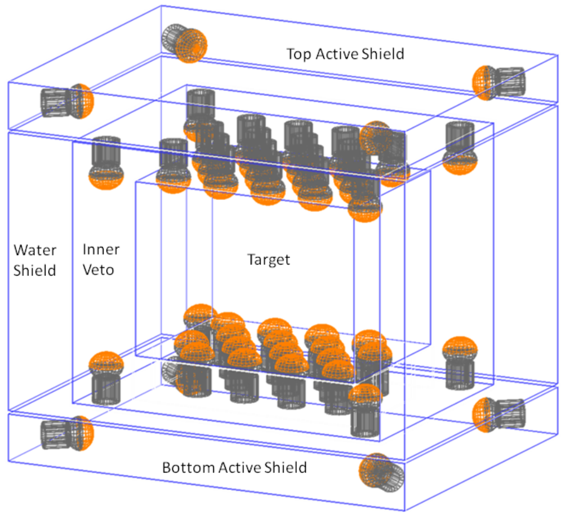

FIGURE 1. Geant4 model of the detector configuration: A central **Target**, with $1m^3$ fiducial volume, filled with water and Gd(0.2% by mass), equipped with 32 PMTs; A surrounding **Inner Veto**, filled with pure water and watched by 8 PMTs; A **Water Shield**, divided into three parts: a lateral tank (not PMTs) and a top and a bottom layer, equipped with 4 PMTs each, acting as an active shield. The total water shielding power is approximately 1m.

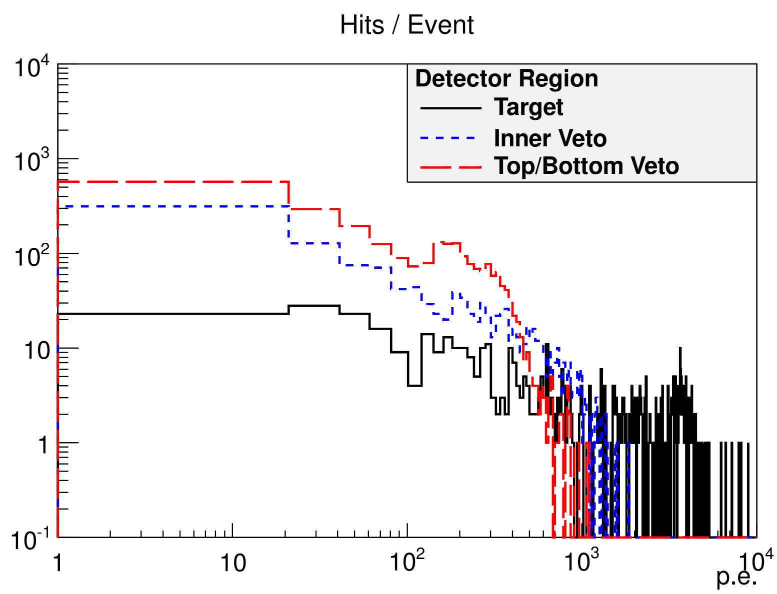

FIGURE 2. Number of photoelectrons (p.e.) produced in the PMTs of each of the three sensitive part of the detector.

EVENT RATE

The relation between antineutrino flux detected and thermal power is linear. Using the geant model and GPS coordinate system, the relative position between the detector and the reactor core is determined, with a center to center distance of 33m. A Monte Carlo (MC) simulation showed that the expected number of event is 4.5×10^3 per day (0.05Hz), inside the fiducial volume. The average number of p.e. generated inside the target, per neutrino event (positron Cerenkov and neutron capture) is around 5Hz.

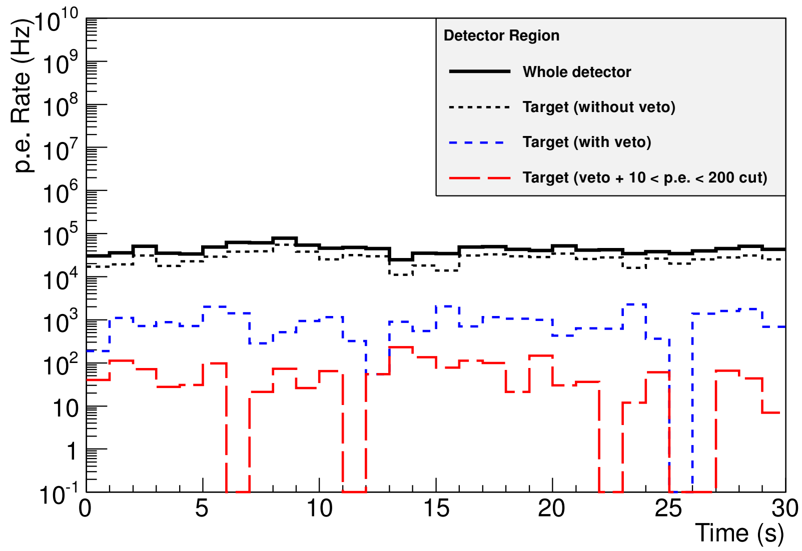

FIGURE 3. Reduction of expected trigger rate before and after veto and cuts.

BACKGROUND

The background is dominated by the muon flux, which have been measured on site. When extrapolated for the whole detector volume, the muon rate is expected to be the order of 350Hz. Using this as a constrain, MC event generation gives the other rates for all atmospheric components (namely muon, neutron, gamma, electron and pion). The total number of photoelectrons generated on the detector, by atmospheric background, is showed on Fig.2.

The event analysis strategy to overcome the large background is to cut on the number of p.e. generated per event. Our simulations shows that 88% of the neutrino events will generate between 10 and 200 p.e.. As one can see from Fig. 2, background can generate up to 10^4 p.e.. Besides the cuts, the detection strategy if based on the observation of a time correlated sequence of a Cerenkov flash and a gamma cascade emitted by the Gadolinium (which captures the emitted neutron after a moderation time). The expected time window between the two events is 100μs (3τ). The total p.e. rate at the target (32 PMTs) is of the order of 35kHz. When applying the veto from the external PMTs, the rate drops to around 1kHz. The further application of the p.e. cut ($10 <$ p.e. < 200) reduces the rate to 75Hz (see Fig3). Simulations shows that the time correlation criteria is enough to select the neutrino events from this signal, even though the initial signal/background ratio is of 1/15.

CONCLUSIONS

The perspectives for the Angra Project are promising and instigating. Simulations shows that the minimum shielding required in order to count reactor antineutrinos has been achieved. The fast electronics has been tested and is currently under production. The physical structure of the detector has been build and is going to be installed at the Angra site in the second half of 2013. The detector is scheduled to be operational before November 2013.

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