Status of the Angra Experiment

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For the Angra Collaboration

Outline:

- Introduction: Monitoring Angra-II
- The Angra Neutrino Laboratory
- Design
- Mechanics
- Electronics
- Simulation
- First Tests
- Deployment Status
- Conclusions

The collaboration

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Motivation

- In the early 2000s people were looking for a non-zero value of θ_13. The Angra dos Reis reactor could have provided a good site for such experiment.

  J.Anjos. et al. “Angra dos reis Reactor Neutrino Oscillation Experiment”, Braz. Jour. Phys. 36 (2006).
- The internaltional community was more oriented toward Double-Chooz/Daya-Bay/Reno. It was however recognized the oportunity of a local small scale experiment of “applied neutrino physics” for safeguard purposes.
- Small scale experiments are vital for more ambitious experimental programs.

Monitoring Nuclear Reactor with Neutrinos

- The idea of applying neutrinos to monitor nuclear reactors is not new.

  E.Christensen et al. "Antineutrino reactor safeguard – a case study" arxiv:1312.1959 and ref. therein.

- The principle have been demonstrated with detectors shielded from cosmic rays and reactor radiation by several meters of rock (~25mwe).

  A.Bernstein et al. "Monitoring the Thermal Power of Nuclear Reactors with a Prototype Cubic Meter Antineutrino Detector"

- The Angra Neutrino Experiment would provide a similar measurement at surface allowing a more flexible application at any reactor.

The site (i)

- Angra dos reis: charming turistic place

The site

- Laboratory (refurbished container) located at ~30m from reactor core (4Gw thermal power).
- Room for other experiences (like CONNIE - see talk by Carla).

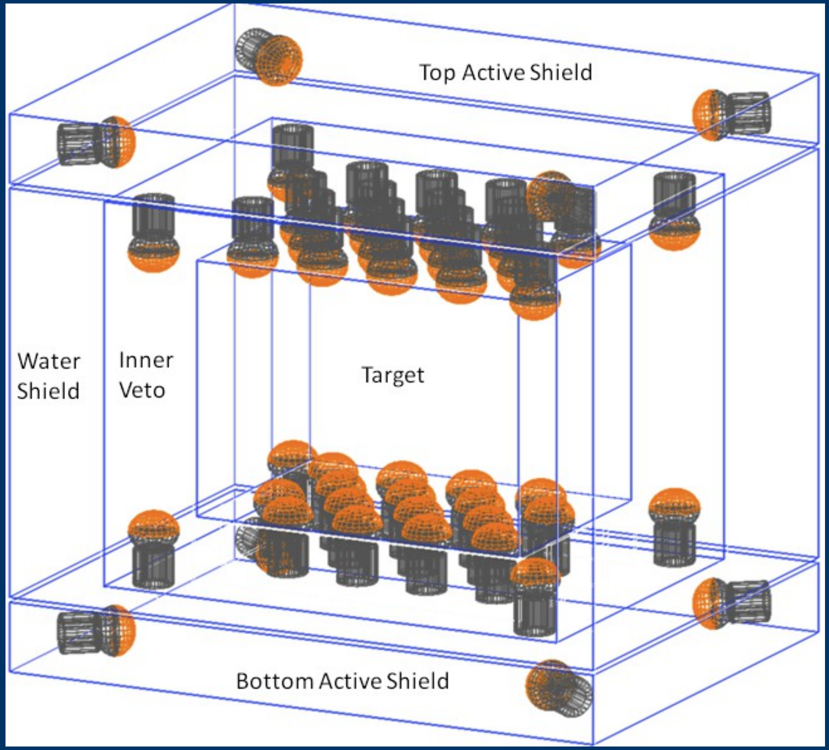
Design (i)

- Detection channel: inverse beta decay. $\bar{\nu}_e \; p \rightarrow e^+ \; n$
- Need proton rich target: water or organic scintillator.
- Liquid organic scintillators are flammable: excluded for safety reasons. Plastic scintillator an option but expensive. New water based scintillators another option.
- Water Cherenkov detector far cheaper.
- Water Cherenkov is not senstive to proton recoil due to fast neutrons.
- A target with about 1 ton fiducial mass is needed.
- Signal over noise is increased by measuring delayed coincidences between (prompt) positron and (delayed) neutron.
- 0.3% Gd is added to target to improve neutron detection (~10μs prompt-delayed).

Design(ii)

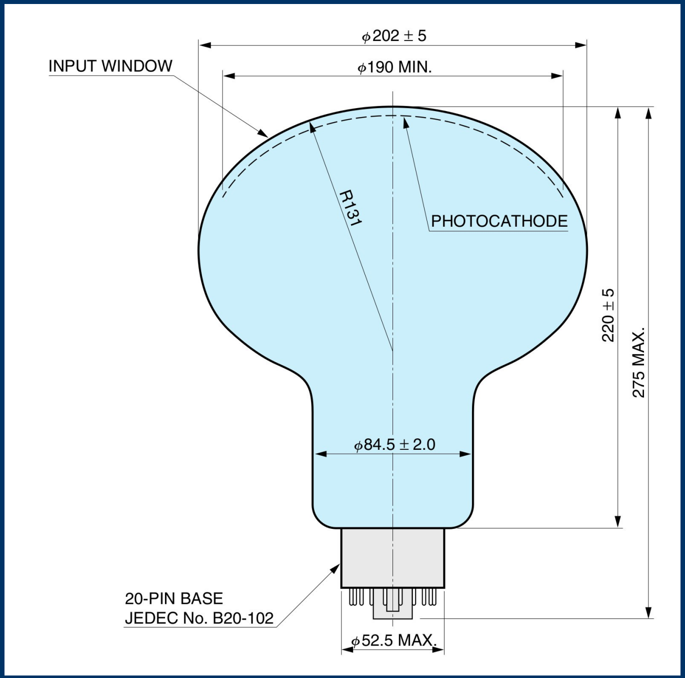
- Inner target (Gd-Cl3 solution) of ~1.4 ton mass instrumented with 32 PMTs (optimized coverage) and folded with Gore.
- Target is surrouded by veto (inner, top and bottom) and shield volumes.
- Veto and shield volumes are filled with “pure” water (very effective in stopping neutrons and cheap).
- ~14 ton total mass

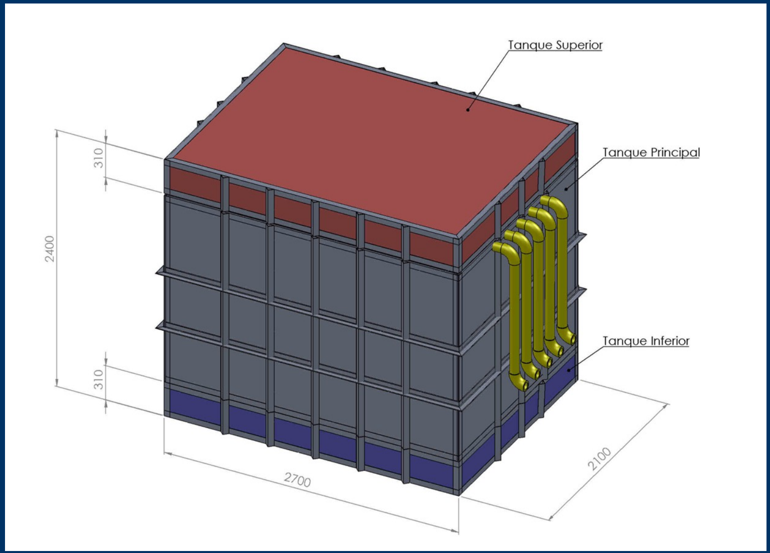
$$R_\nu \sim 5.07 \cdot 10^3 \text{ events/day}$$



Mechanics

- PMTs: Hamamatsu R5912 with waterproofed base
- PMT support and target vessel in polyethylene manufactured by a local firm
- External steel container
- Water recirculation with filters and uv lamp

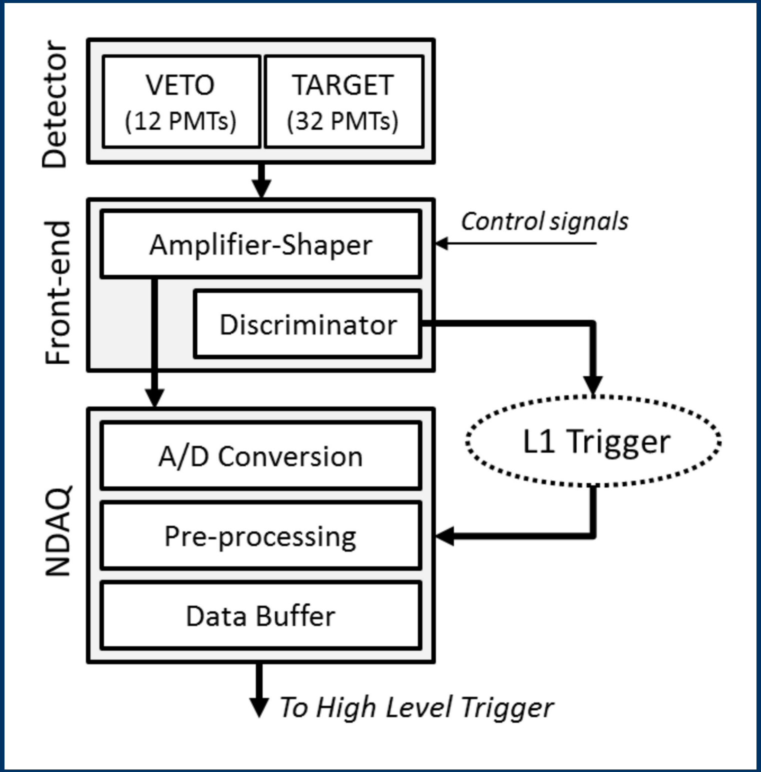




Few Pictures

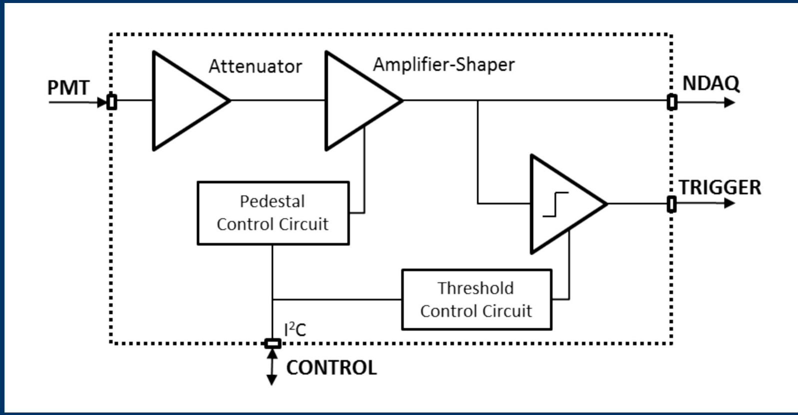
Electronics (i)

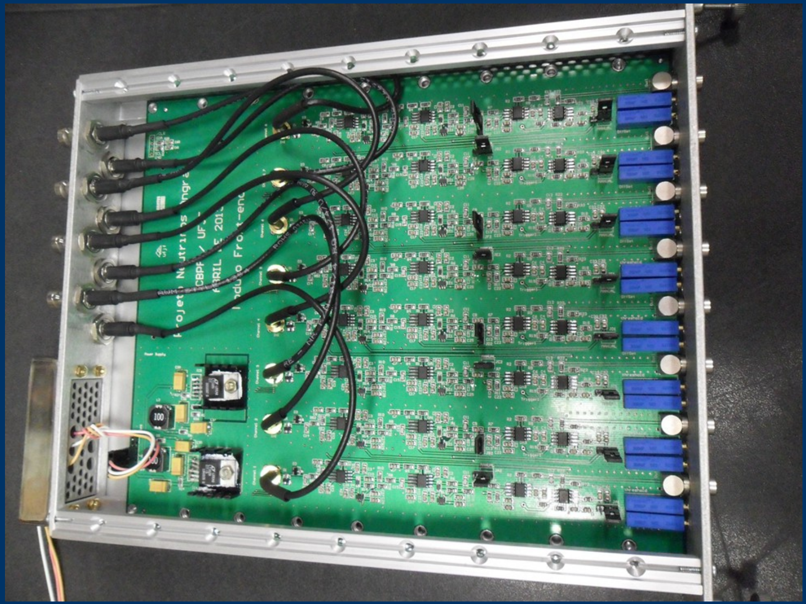
- Water Cherenkov Signal is fast (~10ns for a muon crossing the detector)
- Front-end electronics with fast, low noise pre-amplifier, shaper and discriminator
- Discriminated signal goes to trigger board (commercial Altera FPGA)
- Analog signal is sampled by a DAQ board
- Events are read-out by a VME crate computer (MVME3100)
- Both FEE and DAQ board have been developed by the collaboration
- HV: CAEN SY4527



FEE

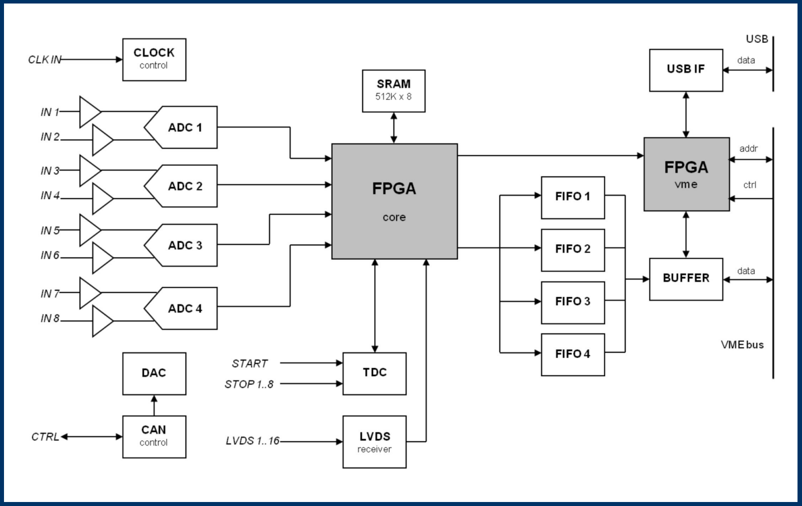
- NIM modules, 8channel/module
- ~20ns rise time
- ~80ns fall time
- Pulse height proportional to charge
- 37mV/ p.e. For nominal PMT gain (10^7)
- 52p.e. dynamic range
- Pedestal and threshld tuned by I2C controller

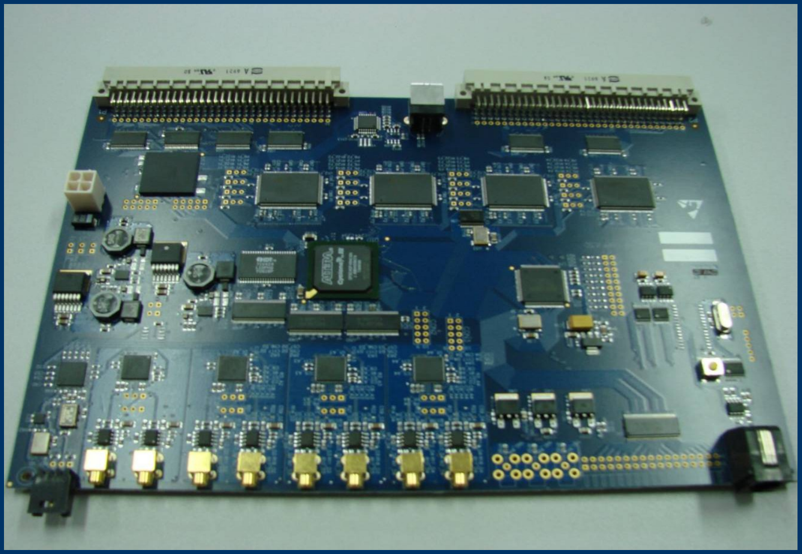




DAQ

- VME modules, 8channels/module
- ADC: 10 bits (effective), 125MHz, 2Vpp
- TDC: 81ps resolution, 9.8μs range
- ADC and TDC controlled by Altera FPGA
- Optimal Filter for Pulse Amplitude Estimation running on FPGA
- VME and USB interfaces for data acquisition
- CAN controller for configuration





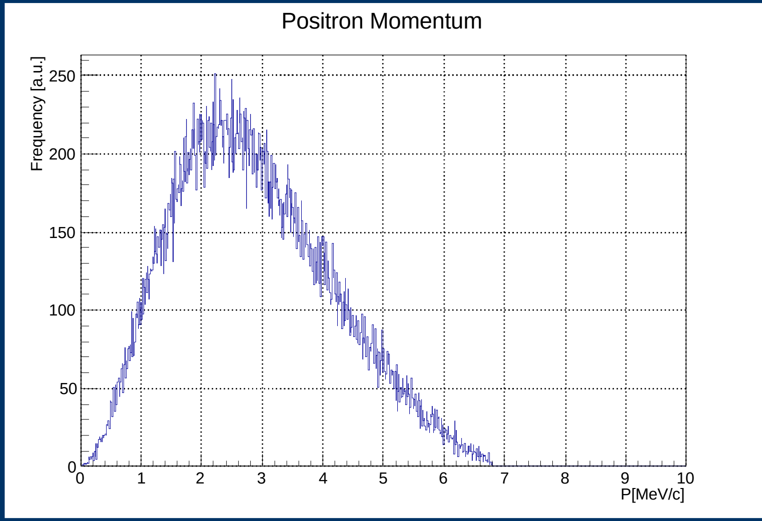
Simulation (i)

Multistage aproach with well defined interfaces:

- Primary generators
- G4 Simulation
- Mixer
- Electronics

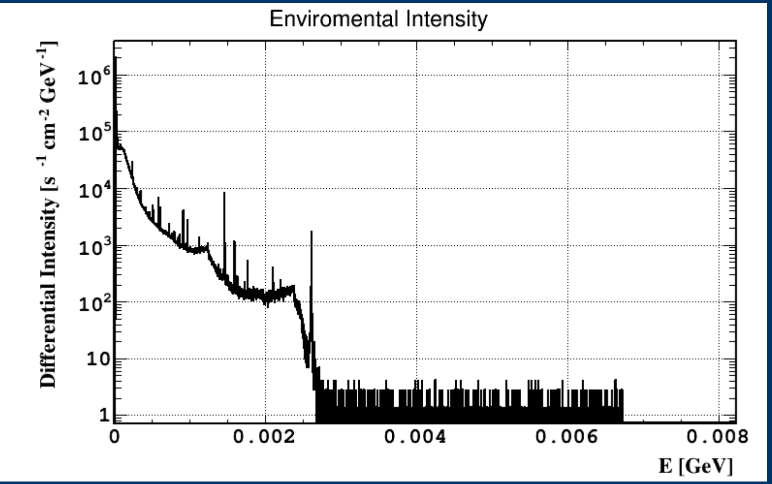
Reactor anti-neutrino generator:

- Huber-Schwetz model for reactor spectra
- Bemporad-Gratta-Vogel ibd cross section



Background Generators

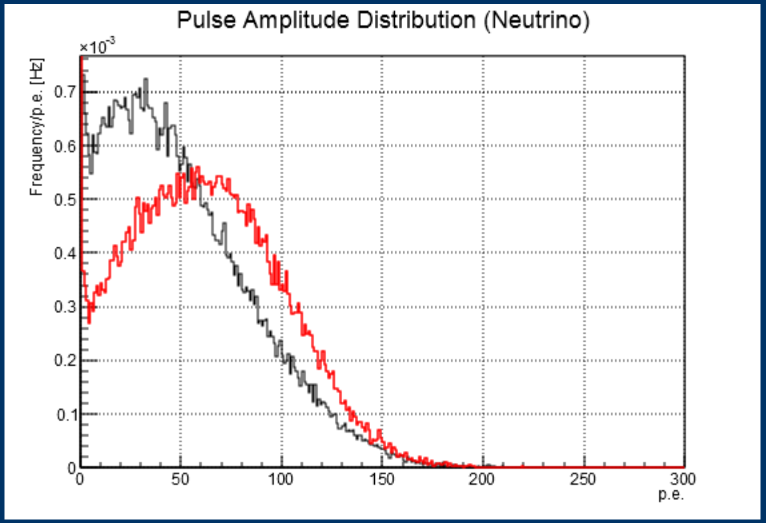
- Compilation of Cosmic Rays spectra from Grieder (excluding neutrons)
- Enviromental gammas from dedicated mesurements

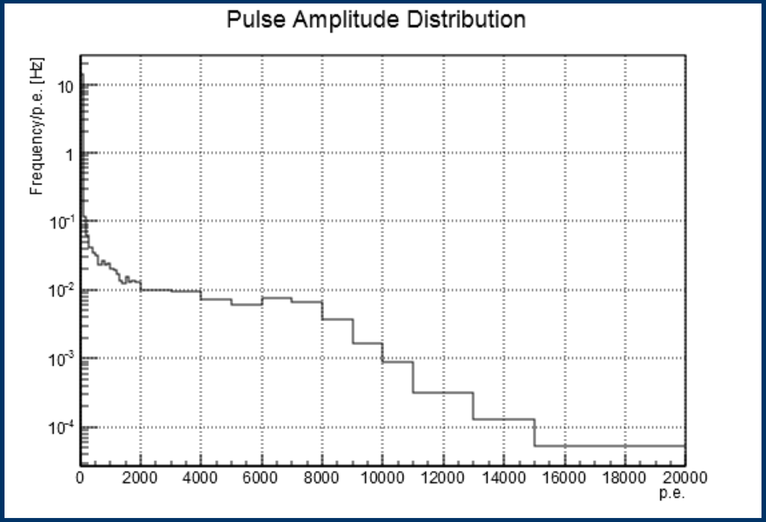


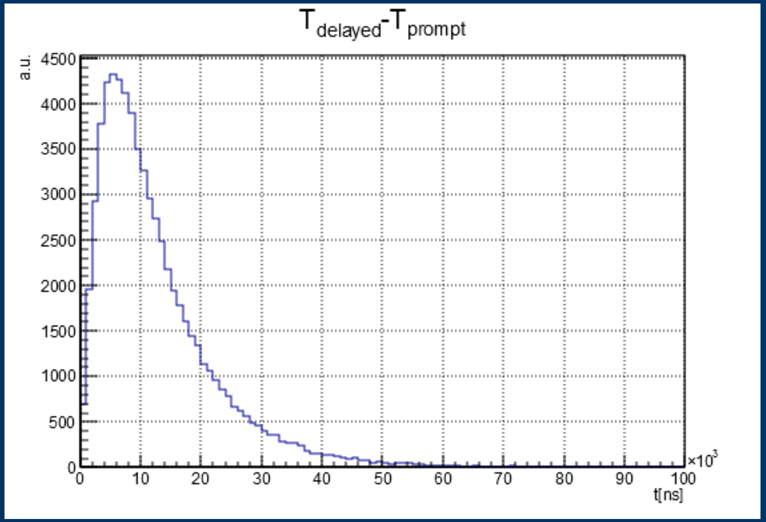
Particle	Total Intensity [s-1 sr-1 cm-2]	Particle	Total Intensity [s-1 sr-1 cm-2]
Electrons	$4.4 \cdot 10^{-3}$	Pions	$6.32 \cdot 10^{-6}$
Muons	$8 \cdot 10^{-3}$	Positrons	$1.7 \cdot 10^{-3}$
Neutrons	$3.6 \cdot 10^{-3}$	Protons	$1.87 \cdot 10^{-4}$
Photons	$1.27 \cdot 10^{-2}$		

Signal and Background Spectra

- Prompt and delayed signals yield up to 200 p.e.
- Crossing muons yield about 6000 p.e.
- Background at low p.e. is mostly e.m. and neutrons





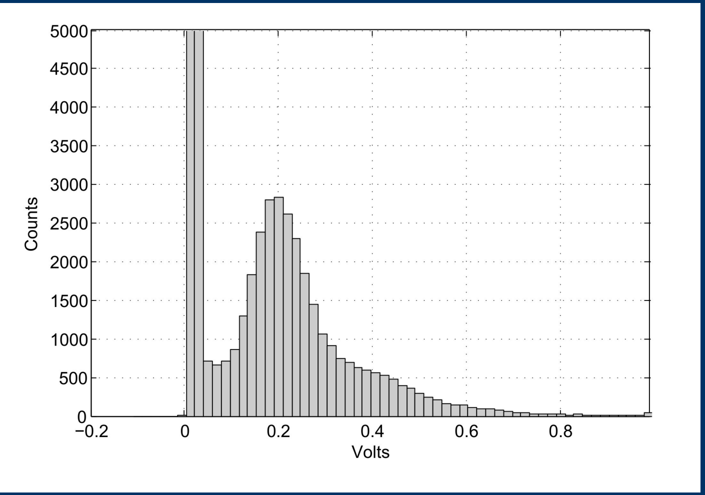


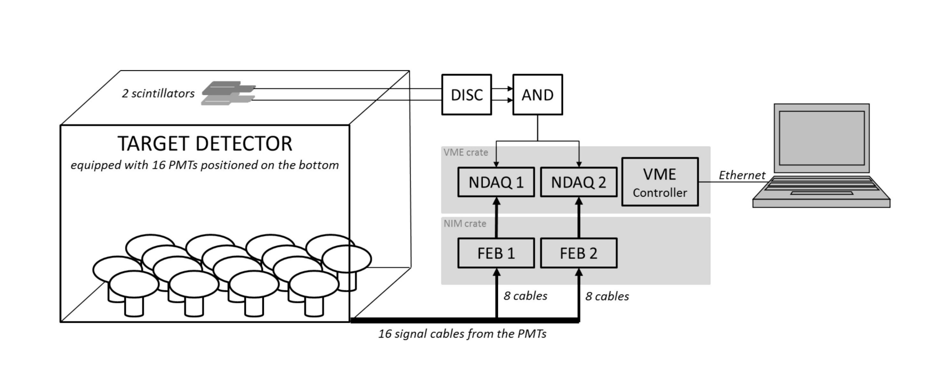
Simulation: expected final rates

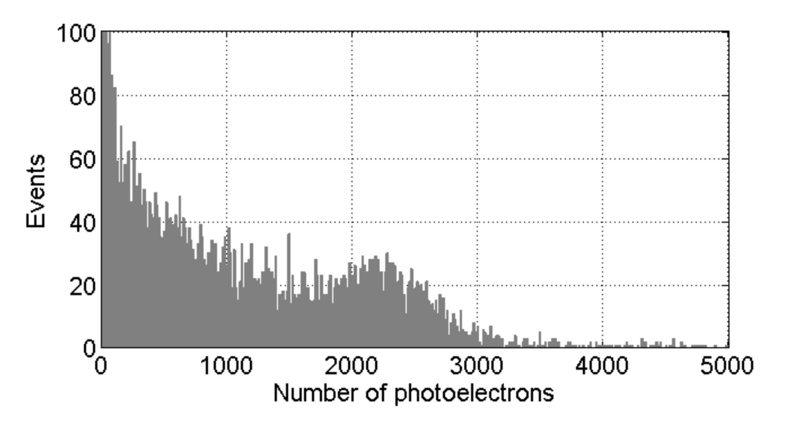
- Dark noise is about 5-10kHz per PMT: 160-320kHz in target. This is controlled by requiring few PMTs in coincidence.
- The uncorrelated background of about 1.5kHz, mostly C.R., is controlled by the time correlation technique.
- A residual correlated backgrounds, due to passage of muons in the detector or nearby, is expected with about 0.1Hz: still higher than neutrino rate (~0.06Hz).
- Signal efficiency is expected to be 50%-80% depending on cuts.
- With integration time of one day we should be able to detect reactor on/off with high significance.
- The simulation still have to be tuned on real data.

First tests

- Single photoelectrons clearly visible.
- Half detector equipped (no Gd yet).
- Cosmic muon spectrum and rate roughly as expected.







Prospects and Conclusions

- Progress now is slow due to limited resources (money, time, people).
- We plan however to complete first tests and move to Angra by the end the year.

- For the first time an experiment is being planned, designed, constructed, run and analyzed in Brasil.
- We are learning a lot about all the critical aspects of the process
- Although late, results are still interesting and within reach.

Last slide

- The Neutrino community in Brazil is growing...
- My sons as well.