Brazilian Report on Safeguards Application of Reactor Neutrinos

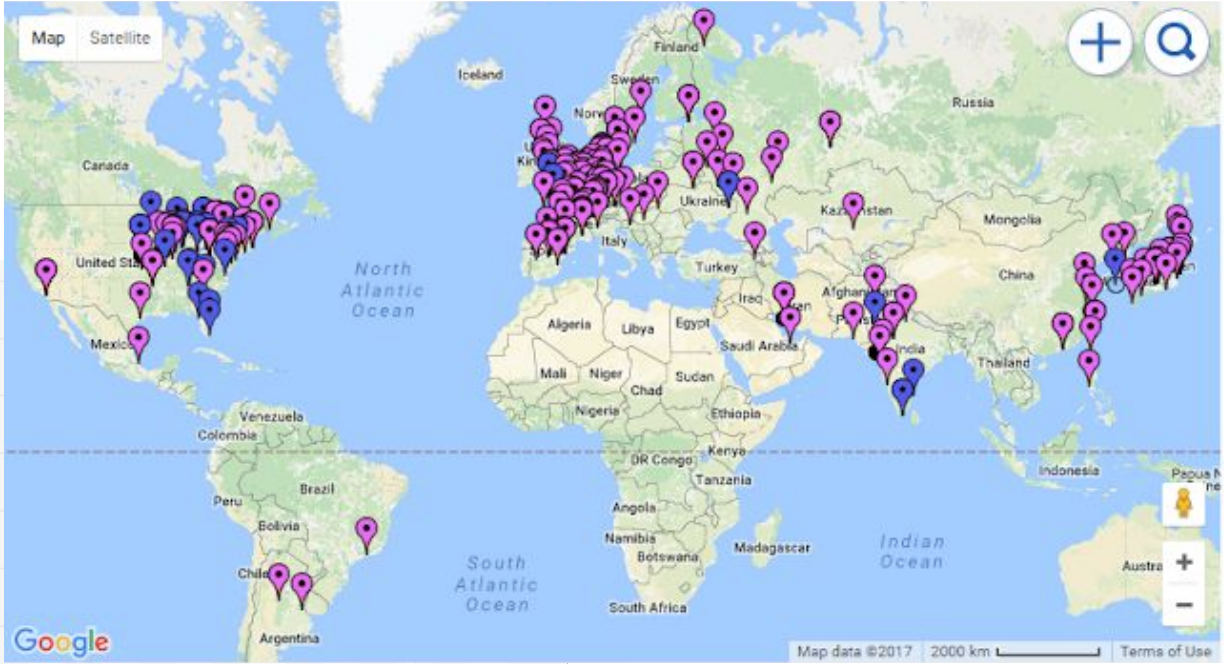
II Latin American Strategy Forum for Research Infrastructure

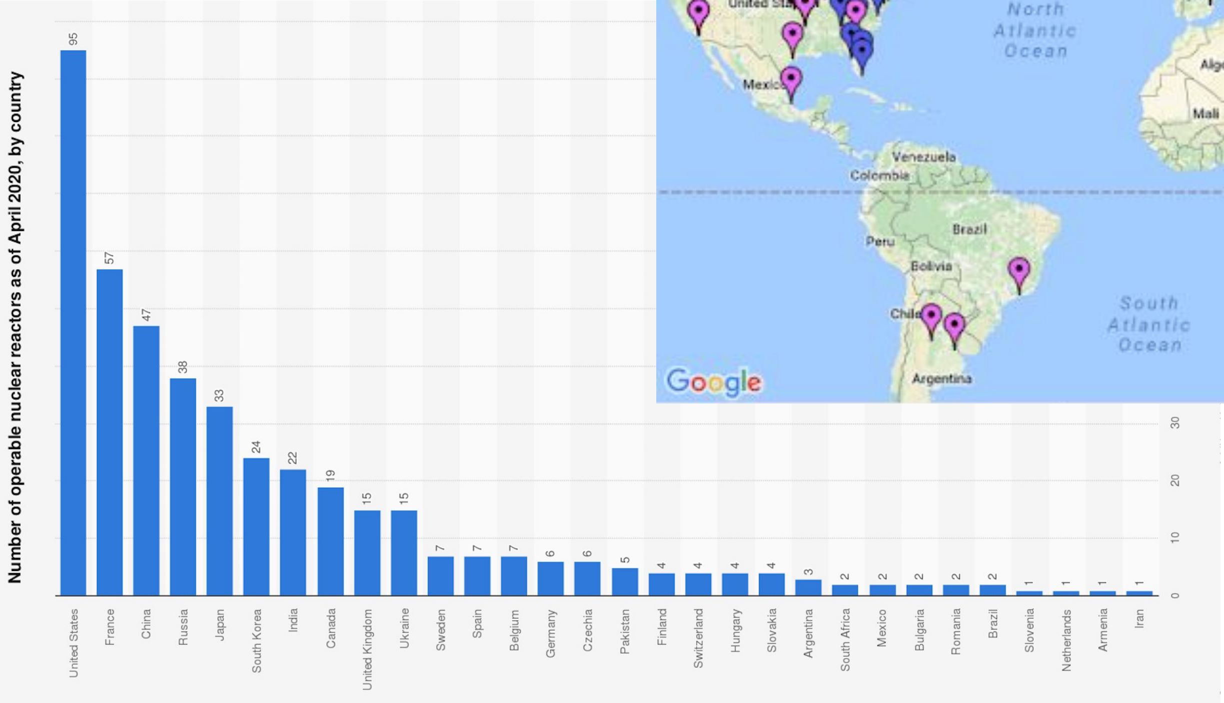
July 6-10, 2020
ICTP-SAIFR, São Paulo, BR

Ernesto Kemp (kemp@ifi.unicamp.br),
on behalf of the Neutrinos Angra Collaboration.

Reactor Neutrinos as Safeguards Tool

440 nuclear reactors in operation in ~ 30 countries around the world.





A 1000 MWe light water reactor gives rise to about 25 tonnes of used fuel a year, containing up to 290 kilograms of plutonium.

It takes about 10 kilograms of nearly pure Pu-239 to make a bomb

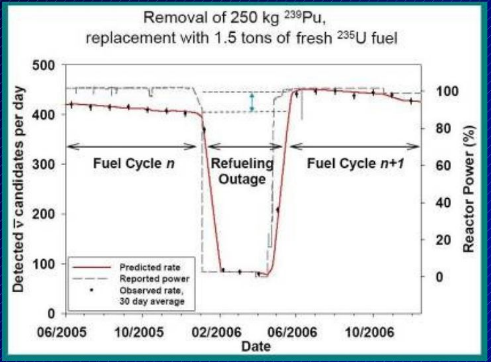
Reactor Neutrinos as Safeguards Tool

Why the interest in antineutrino detectors?

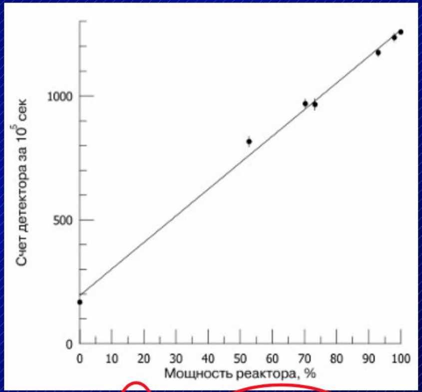
- Antineutrinos can not be shielded and are produced in very large amounts in nuclear reactors
  (~ 10^{20} antineutrinos/s)
- Antineutrinos produced in reactors can reveal fissile composition of nuclear fuel
- Non-intrusive monitoring in real-time the reactor state:
  - thermal power & fissile material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

Monitoring nuclear reactors with antineutrinos: It is feasible

San Onofre (USA)



Rovno/Ukraine



Thermal power control:
Interesting topic for Eletronuclear

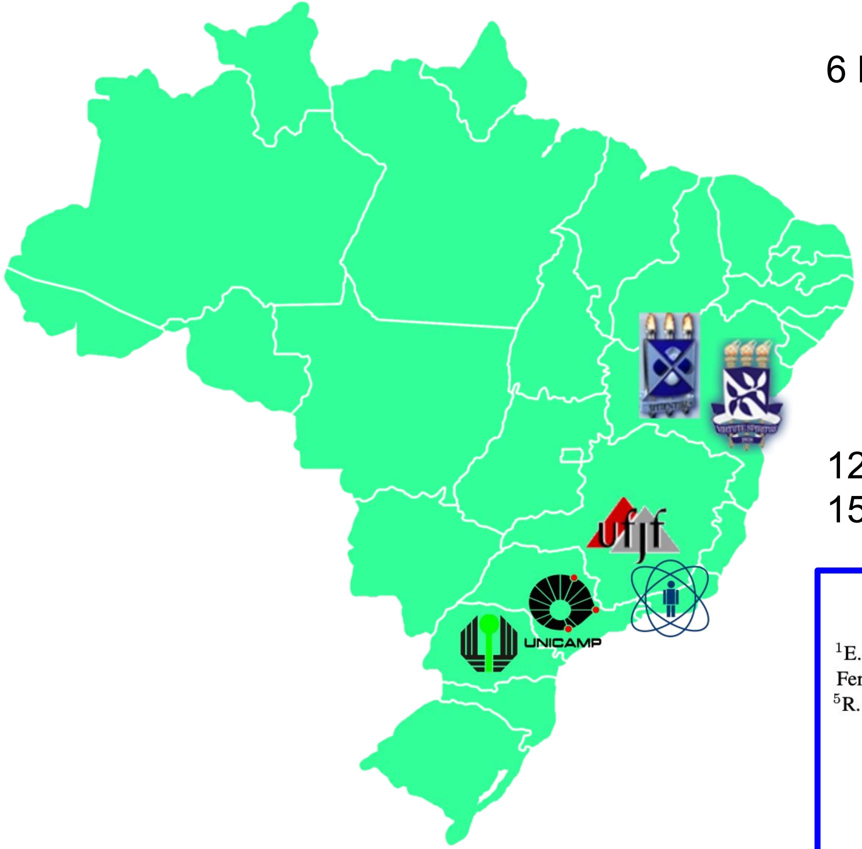
$$N_\nu = \gamma \cdot (1 + k) \cdot P_{th}$$

Factor carrying detector features

Factor carrying fuel composition features

The Neutrinos Angra Experiment

The Angra Collaboration



6 Brazilian Institutes:

- CBPF (Rio de Janeiro - RJ)
- UEFS (Feira de Santana - BA)
- UEL (Londrina - PR)
- UFBA (Salvador - BA)
- UFJF (Juiz de Fora - MG)
- Unicamp (Campinas - SP)

12 Researchers
15 Students

Brazilian Report on Safeguards Application of Reactor Neutrinos

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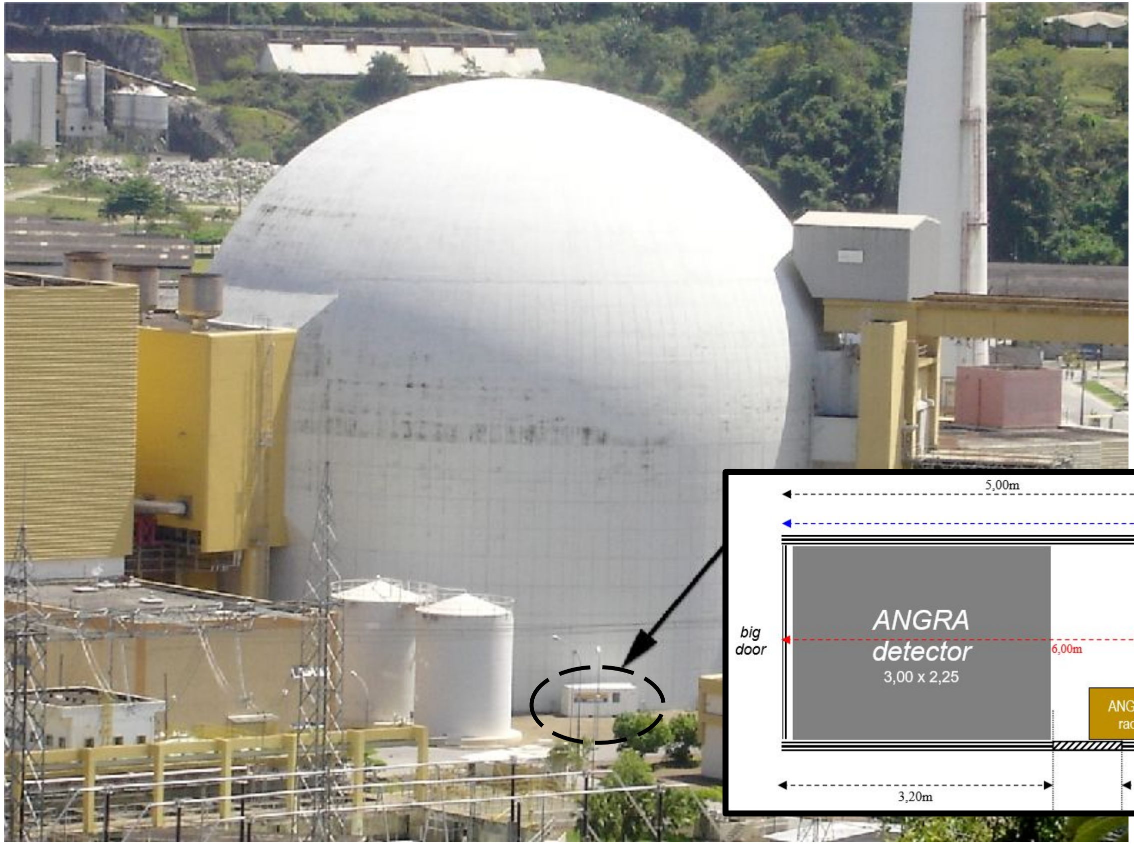
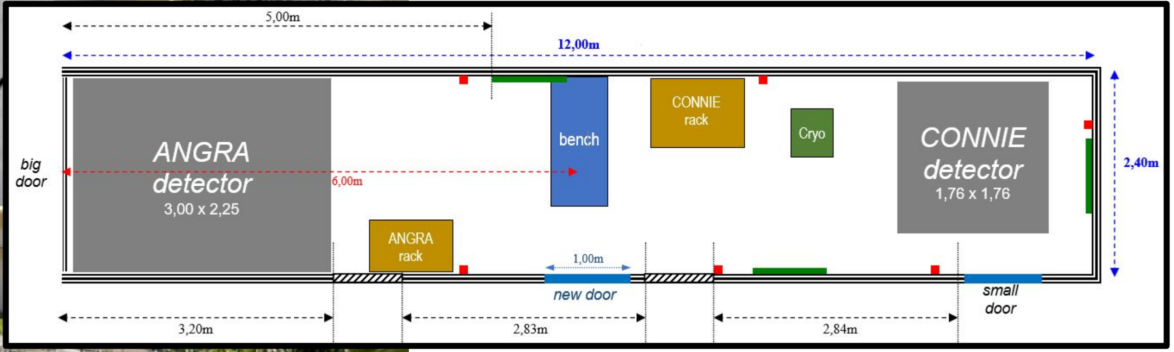
arXiv:1912.11039v1 [physics.ins-det] 21 Dec 2019

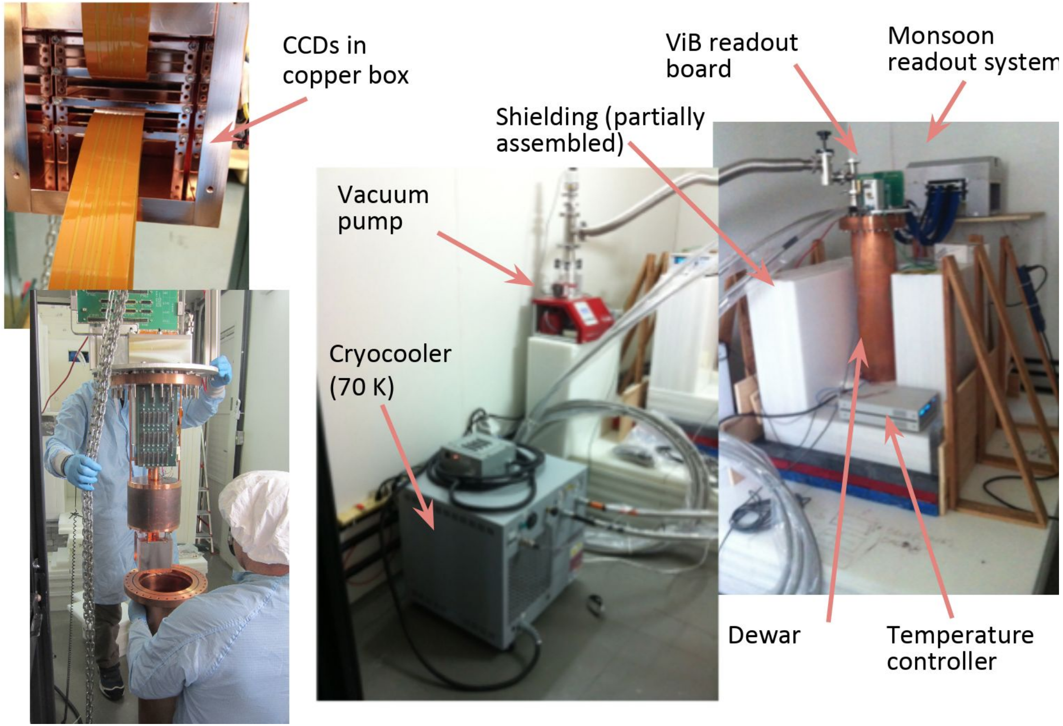
The Laboratory





The experimental Lab

CONNIE detector installed in 2014



More on I. Nasteva talk:

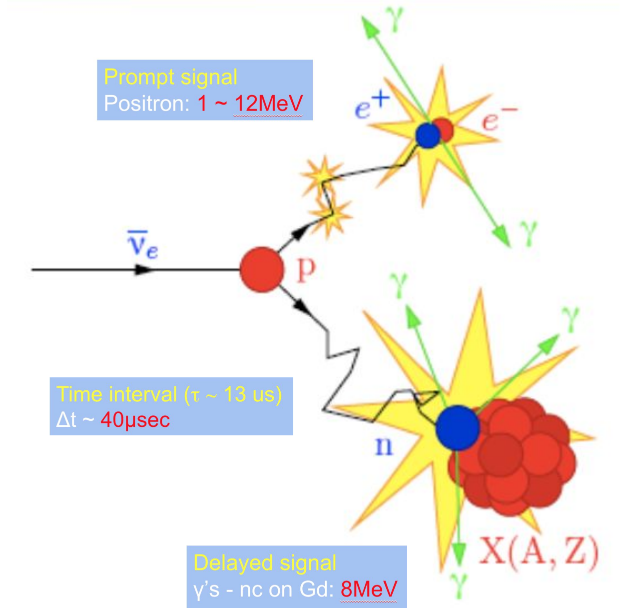
Tuesday July 7 Chair: R. Rosenfeld

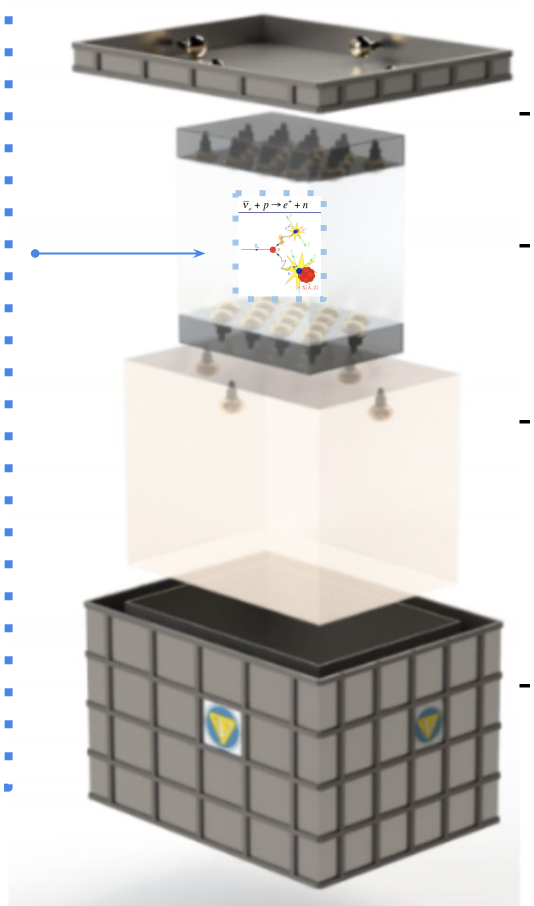
10:30-11:00	**Plenary II: Neutrinos (Yepes)**
11:00-11:10	Hyper-Kamiokande: Possible Contributions from Latin America, H. Nunokawa
11:10-11:20	An Andean Deep-Valley Detector for High-Energy Tau Neutrinos, A. Romero-Wolf.
11:20-11:30	Coherent Neutrino-Nucleus Scattering Experiment (CONNIE), I.Nasteva.
11:30-11:40	DUNE in the Report on LASF4RI: the Colombian case, D. Moreno.
11:40-11:50	Latin America Contribution to JUNO, P. Chimenti.
11:50-12:00	Short baseline neutrino experiment in nuclear reactors in Argentina, G. Moroni.
12:00-12:10	The ANDES Deep Underground Laboratory, X. Bertou
12:10-12:20	Neutrino White Paper, E. Segreto.
12:20-13:05	Discussion

ν-ANGRA: a Water Cherenkov Detector

MADE IN BRAZIL

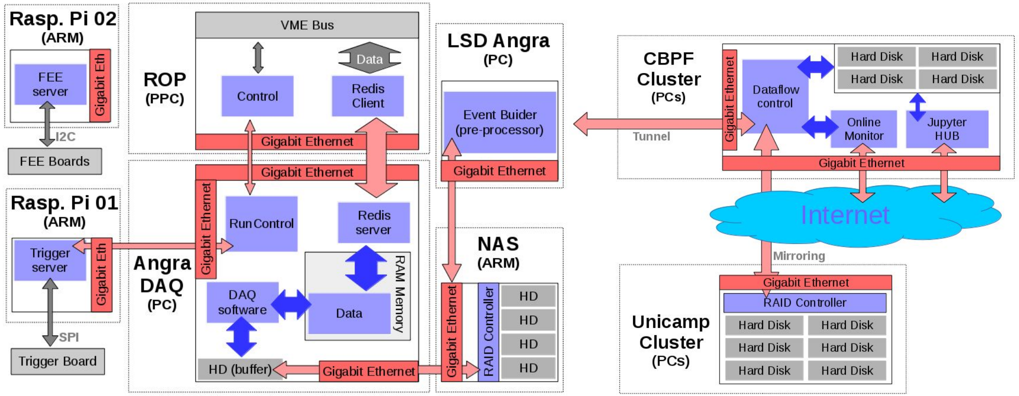
$$\bar{\nu}_e + p \rightarrow e^+ + n$$

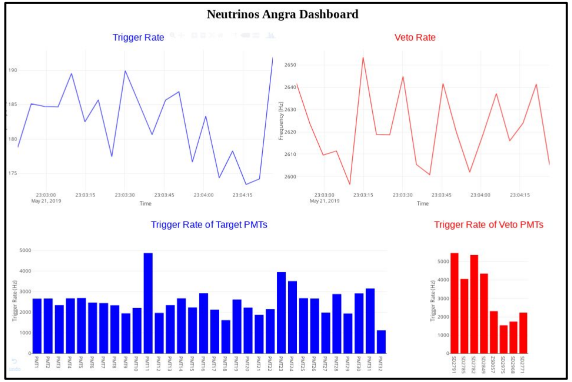


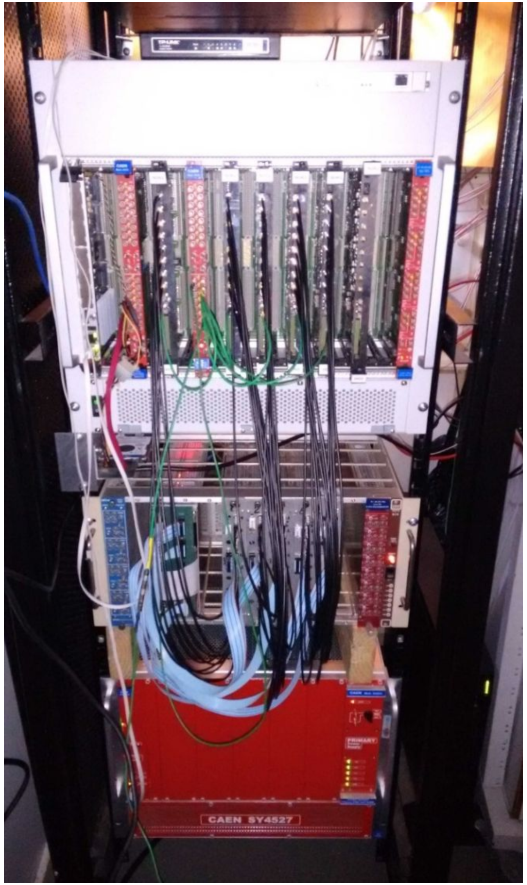


- Top veto (active): 4 PMTs
  25 cm height - pure water
- Neutrino Target (active): 32 PMTS
  ~ 1 ton GdCl3 doped water (0,2%)
- Inner Veto (active): 4 PMTs
  25 cm thick - pure water
- Shield (passive):
  25 cm thick- pure water

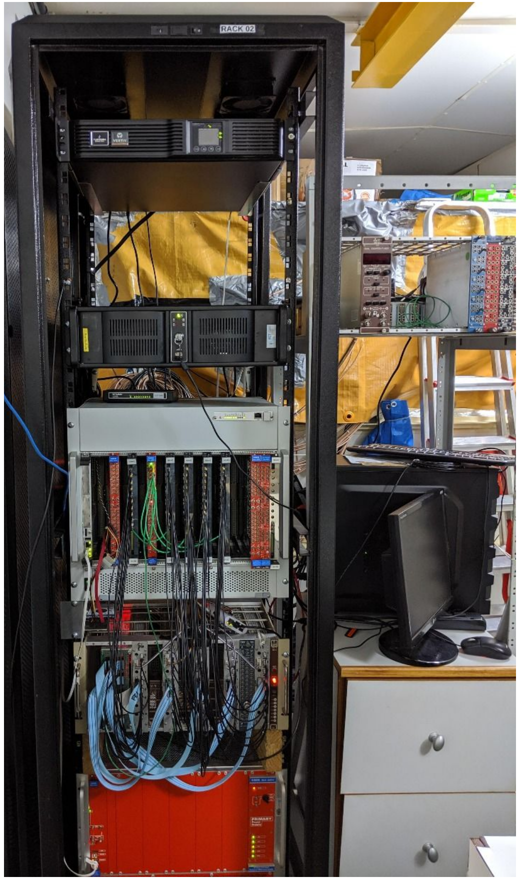
The Data Acquisition System (DAQ)



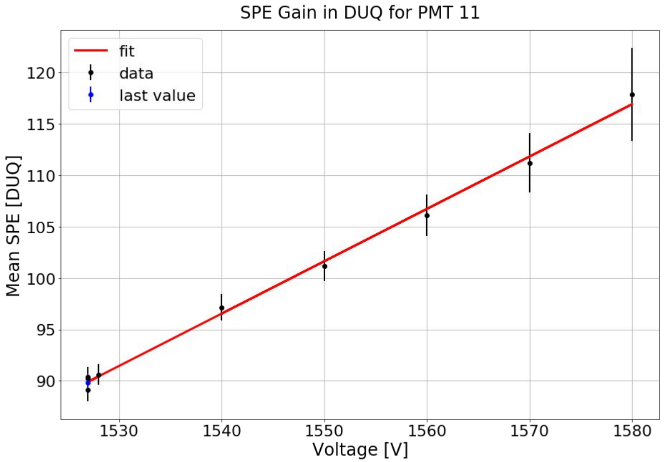


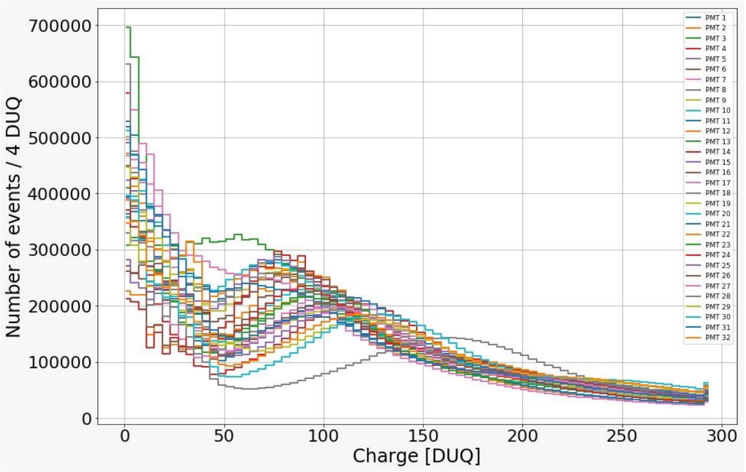


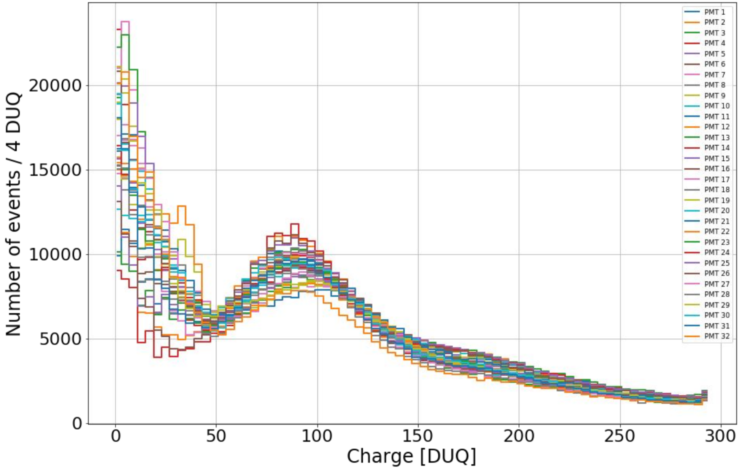
Commissioning



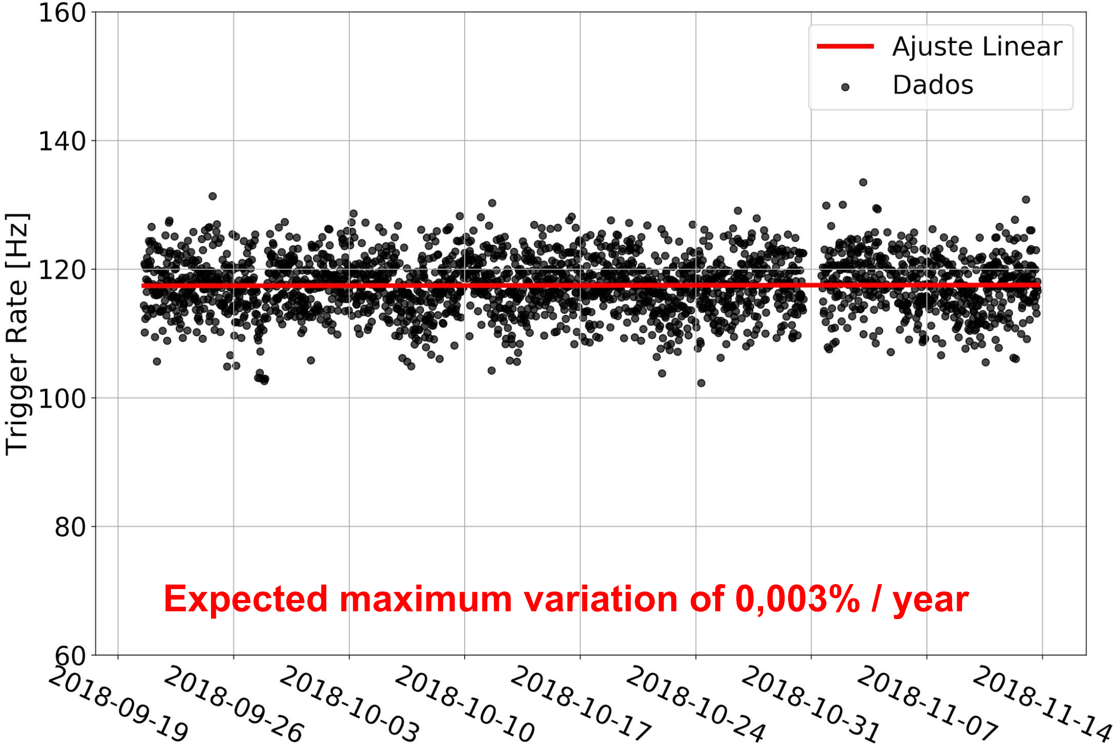
Full DAQ Control: Down to photoelectron level





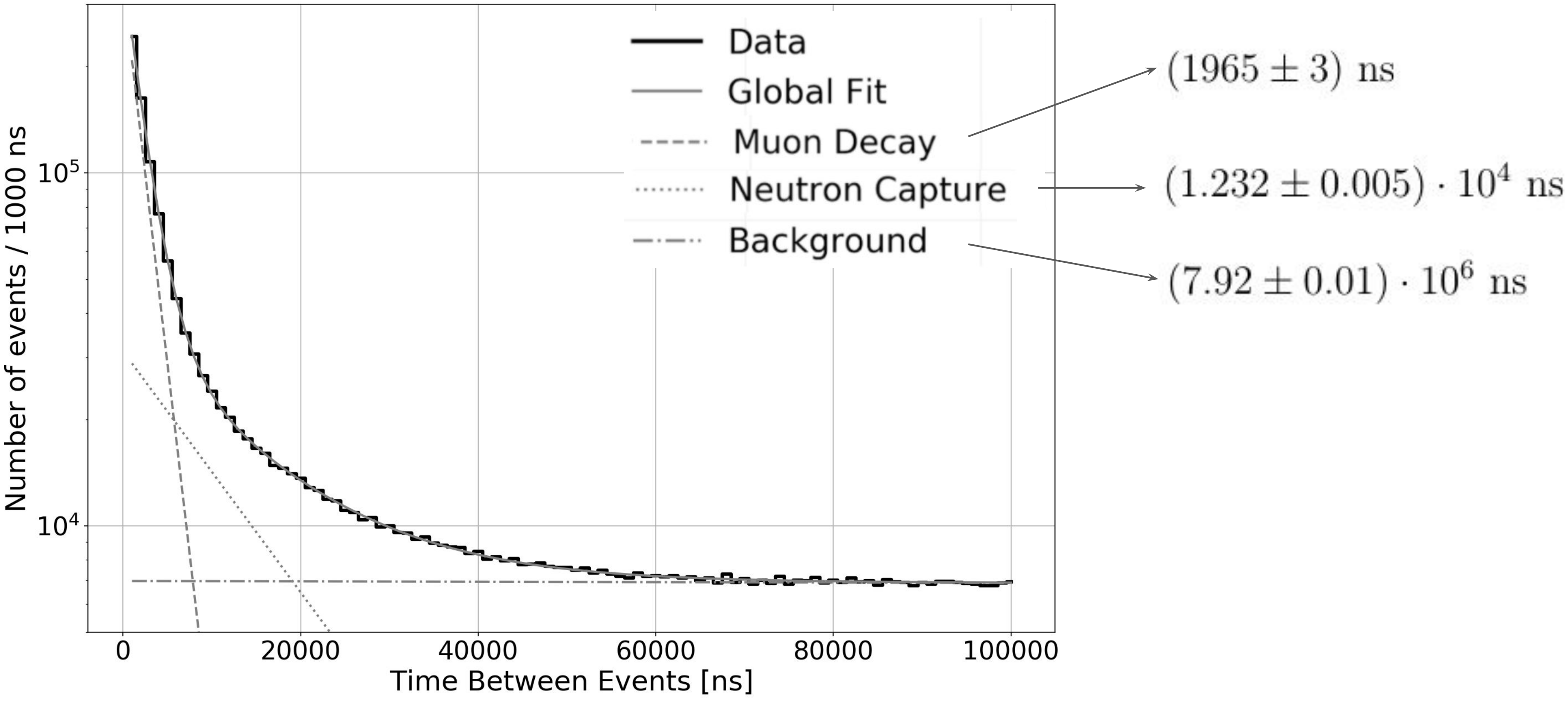


Stability

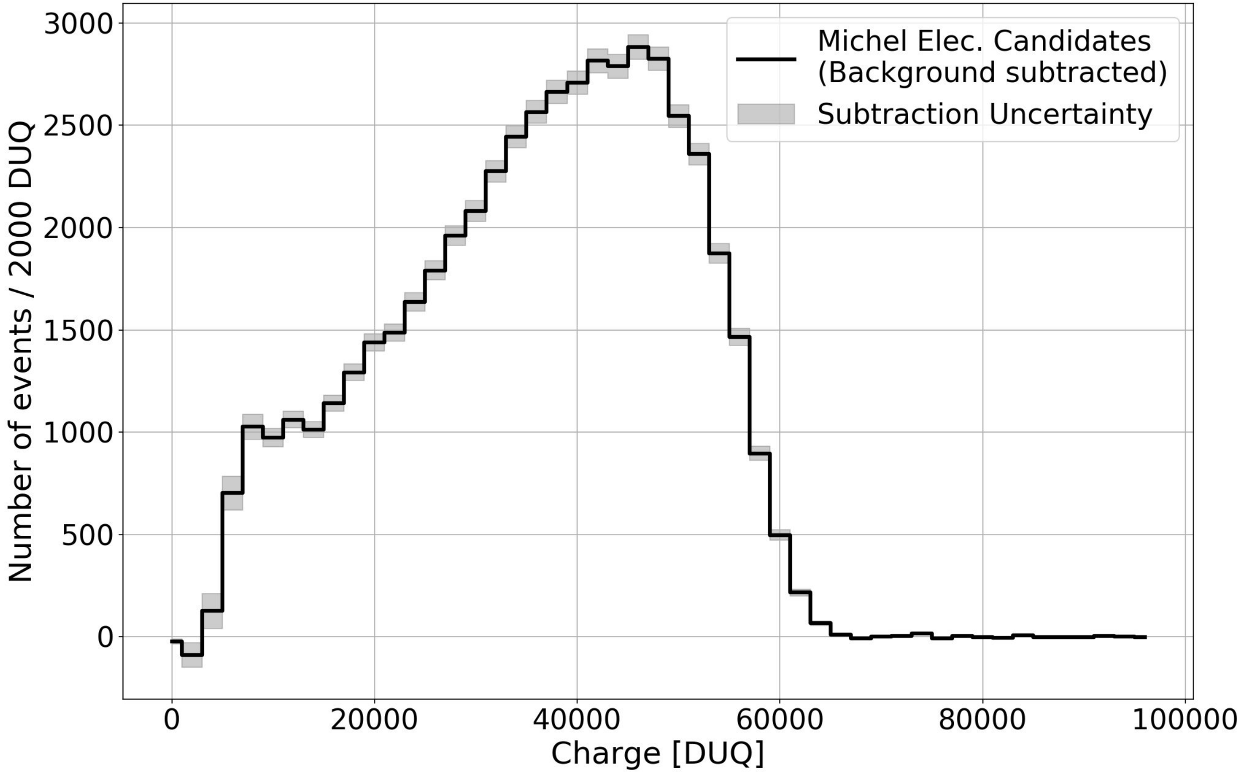

Ajuste Linear
Dados
Trigger Rate [Hz]
160
140
120
100
80
60
2018-09-19
2018-09-26
2018-10-03
2018-10-10
2018-10-17
2018-10-24
2018-10-31
2018-11-07
2018-11-14
Expected maximum variation of 0,003% / year

Preliminary Results

Time analysis

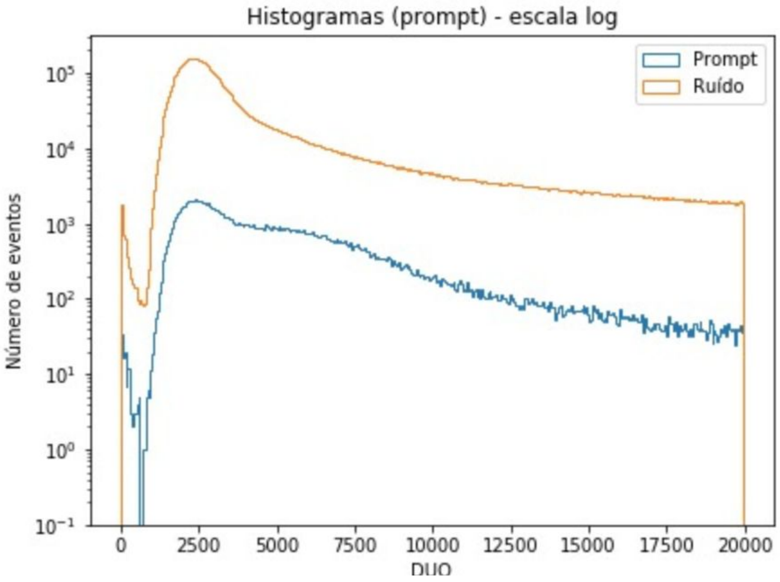


1st Physics analysis: Michel Electron Candidates



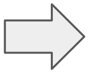
Searching for IBD candidates

Before Selection

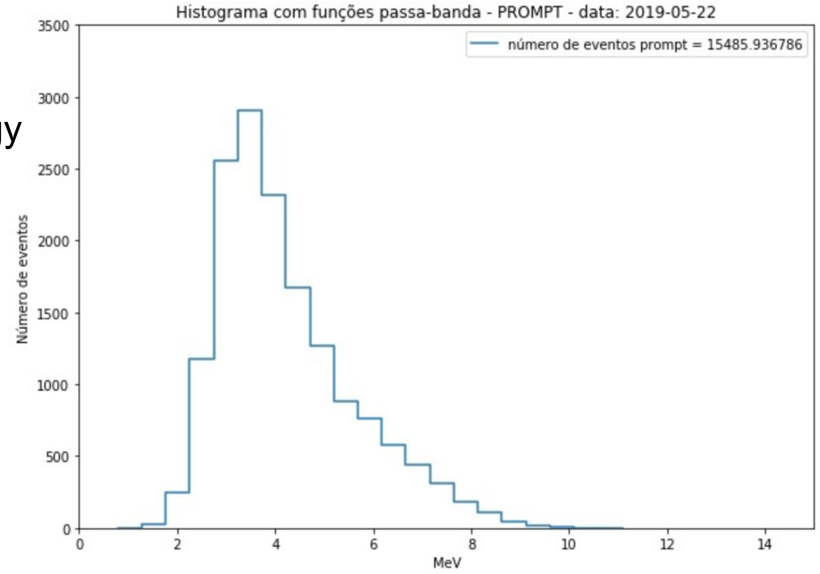


~ 1.7 x 10^7 ev/day

time & energy cuts

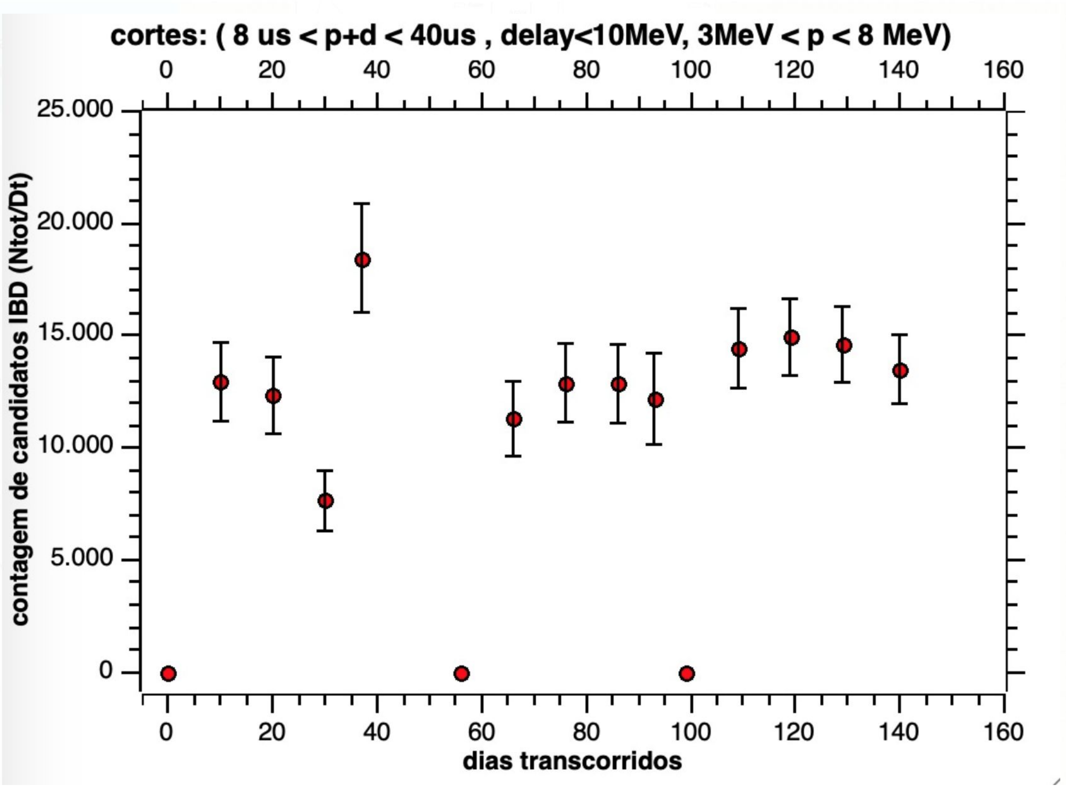


After Selection



~ 1.5 x 10^3 ev/day

Preliminary Results



Final Remarks

- The Neutrinos Angra Experiment was totally made by Brazilian scientists and engineers.
  - We have designed, prototyped, built, tested, and commissioned the detector, the FE electronics, and the DAQ boards and required software.
  - The whole R&D was made in Brazilian labs also in cooperation with local commercial partners, demonstrating the maturity of Brazilian experimental groups to conduct autonomous high-level research.

- We have preliminary results showing that the data has been taken with high quality, and the physics program is close to be completed.
  - Major and current goal: to demonstrate the ability of the detector to count antineutrino events in correlation with the delivered thermal power of the reactor.
  - The future physics program might include measurements of the fractions of nuclear isotopes in the nuclear fuel.

Final Remarks

- Different technologies can be explored in a second run.
  - Stringent safety rules imposed by the reactor operations put severe restrictions to the materials and equipment allowed inside the power plant.
    ⇒ Preliminary stages to check the possibility to use water based liquid scintillator (WBLS).
      → total compliance with the safety rules + larger energy resolution
      → additional physics topics ?
  - Towards a more compact experiment: using silicon photomultipliers (SiPMs)
    ⇒ SiPMs can operate easily in the photon counting regime with LV (less dangerous)
- New technologies require knowledge and expertise growth of local research groups.

Final Remarks

- The Angra nuclear reactors have shown to be an excellent tool for the development of particle detectors technology and also to perform particle physics research.

- The experiments ν-Angra and CONNIE are sharing space and running in the neutrino lab.
  - We have successfully created a Latin American research facility with the cooperation of the power plant operator.
    - Any scientific group, in principle, can carry experimental programs using the reactor as a particle source.

- The facility has a large potential to boost Latin American science using nuclear reactors
  - Easier, when compared to overseas labs.

- The facility can be very attractive for international researchers
  - healthy exchanging of knowledge and technology.

Take-away message

- The future of the scientific facility (the neutrino lab) at the Angra dos Reis power plant is very promising;

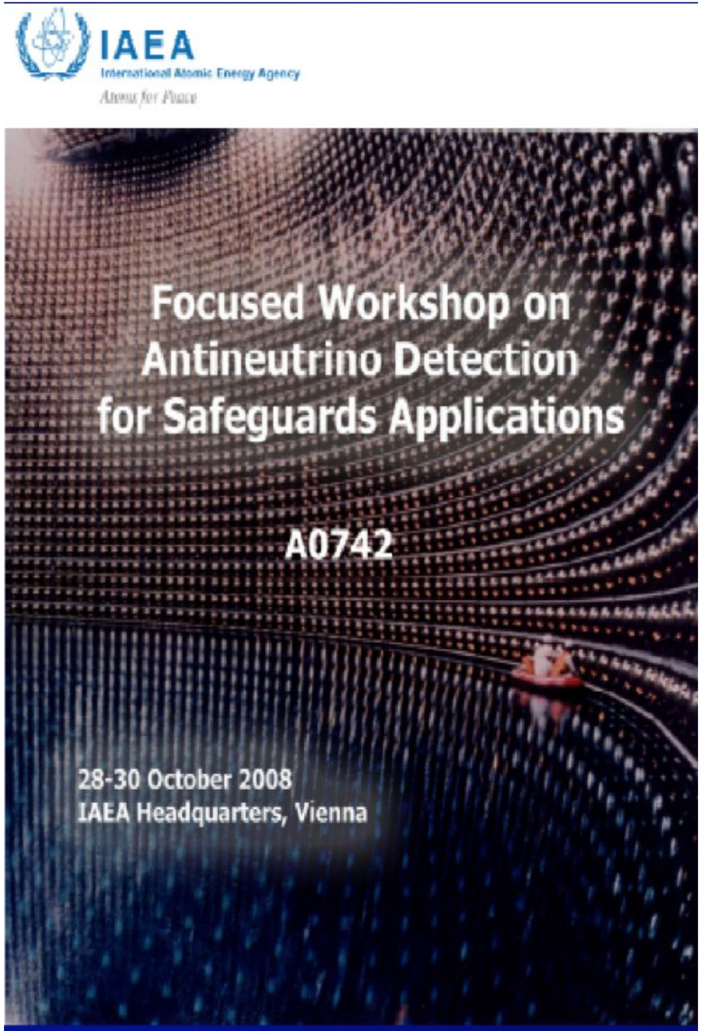
- The two collaborations running neutrinos experiments, ν-Angra (19 papers) and CONNIE (6 papers), have successfully demonstrated the feasibility to conduct high-level and rather complex experiments in cooperation with the power plant operator;

> We DO hope that
> the neutrino lab in Angra dos Reis can insert
> Latin America in the world map of research facilities
> in particle physics.

Thank you!

We acknowledge the cooperation and continuous assistance of Eletronuclear staff,
essential to run the lab

Backup Slides



DESIGN GUIDELINES:

Focused Workshop on Antinu-e

Detection for SG Applications (2008)

7.2 Medium Term:

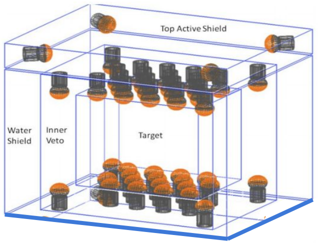
If the above near-term goals are met, it is the opinion of the workshop conferees that antineutrino detectors will have demonstrated utility in response to the stated inspector needs in some specific areas of reactor safeguards. To further expand the utility of antineutrino detectors, several useful medium term (5-8 year timeframe) R&D and safeguards analysis goals are proposed.

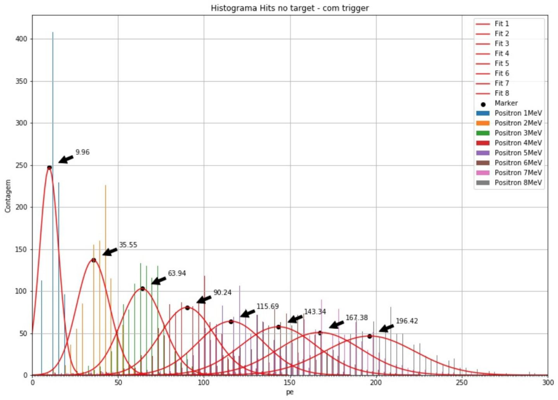
1. Above ground deployment. Above ground deployment will enable a wider set of operational concepts for IAEA and reactor operators, and will likely expand the base of reactors to which this technology can be applied;

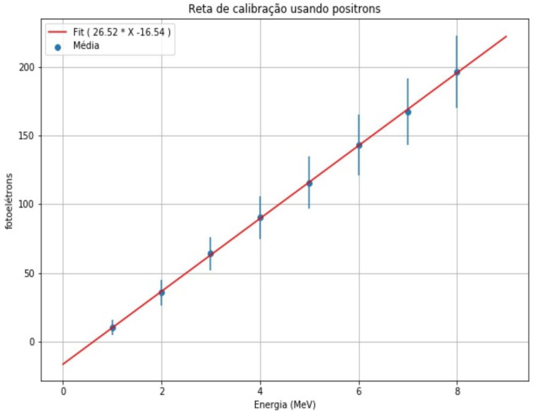
2. Provide fully independent measurements of fissile content, through the use of spectral information. This will allow the IAEA to fully confirm declarations with little or no input from reactor operators, purely by analysis of the antineutrino signal;

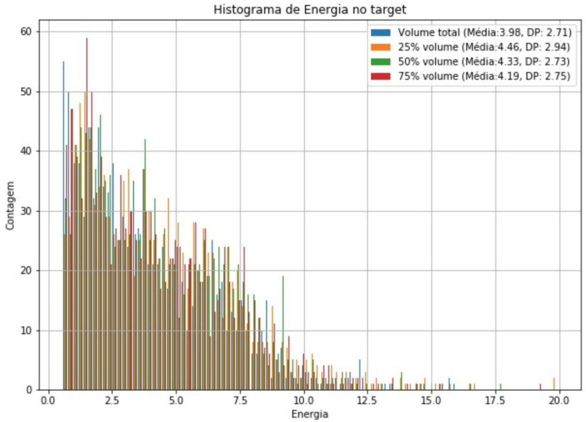
3. Develop improved shielding and reduced detector footprint designs, to allow for more convenient deployment. Current footprints are of order 2-3 meters on each side; modest reductions in footprint would expand the general utility of antineutrino detectors. .In this regard, a possible deployment scenario is envisaged where the component parts of the detector, shielding and all associated electronics are contained within a standard 12 metre ISO container, facilitating ease of movement and providing physical protection to the instrument. It should be noted that due to size and weight restrictions of ISO containers (approximately 25,000 kg net load) the

Full Geant4 Simulation: energy scale









Calibration with Radioactive Sources: under discussion with Eletronuclear