Angra Neutrino Project: status and plans

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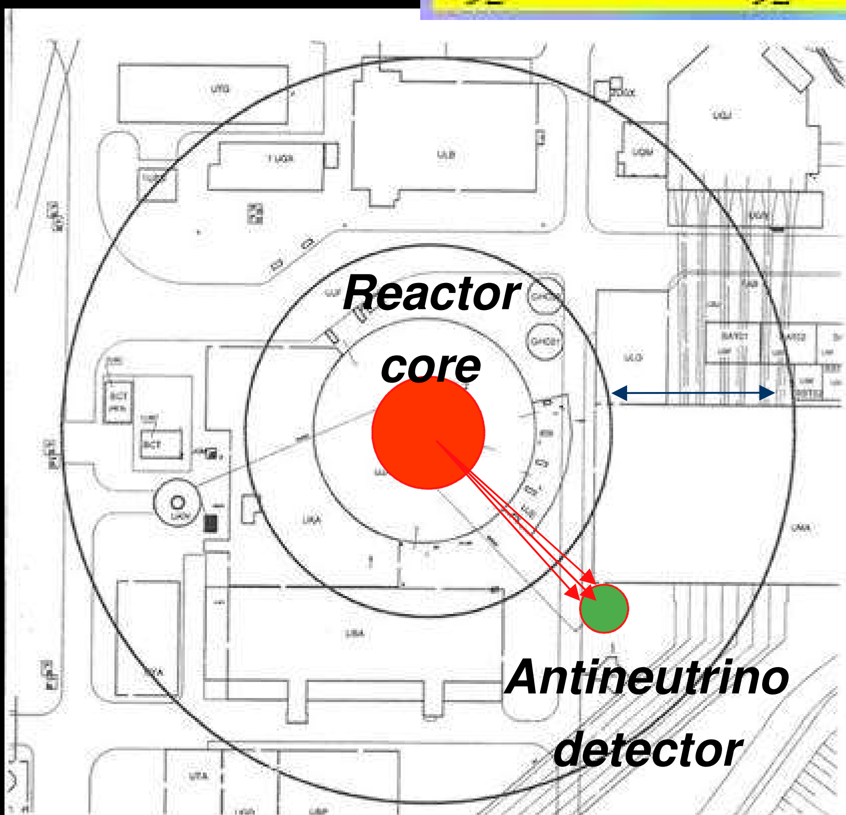
Why the interest in antineutrino detectors?

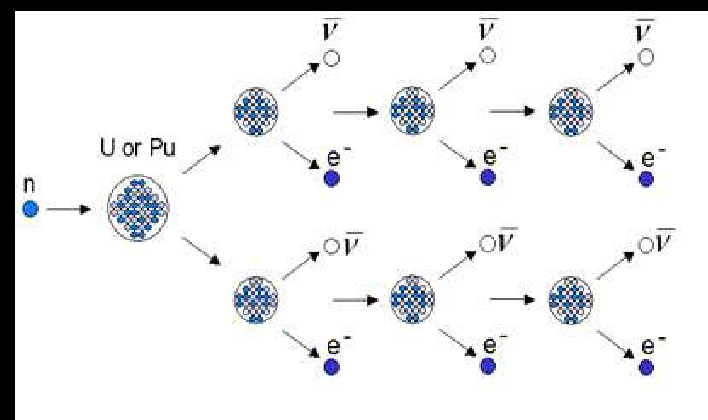
- *Search for new methods on safeguards verification*
- *Antineutrinos can not be shielded and are produced in very large amounts*
- *Antineutrinos produced in reactors can reveal fissile composition of nuclear fuel*
- *Non-intrusive: Remotely monitor real-time reactor state: thermal power and fissioning material*

Non intrusive method to check reactor activity

$$^{238}_{92}U + n \rightarrow ^{239}_{92}U \xrightarrow{23\ min} ^{239}_{93}Np \xrightarrow{2.3\ d} ^{239}_{94}Pu$$



Plutonium production chain

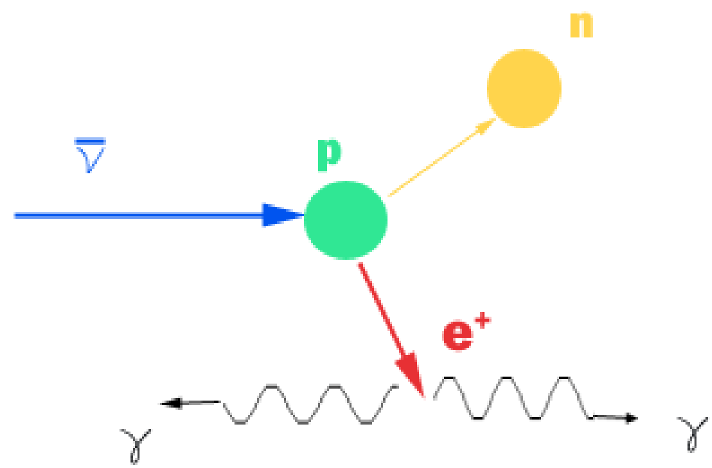


$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Detection of Antineutrinos

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

The antineutrino interacts with a proton producing…



– A 1-7 MeV positron

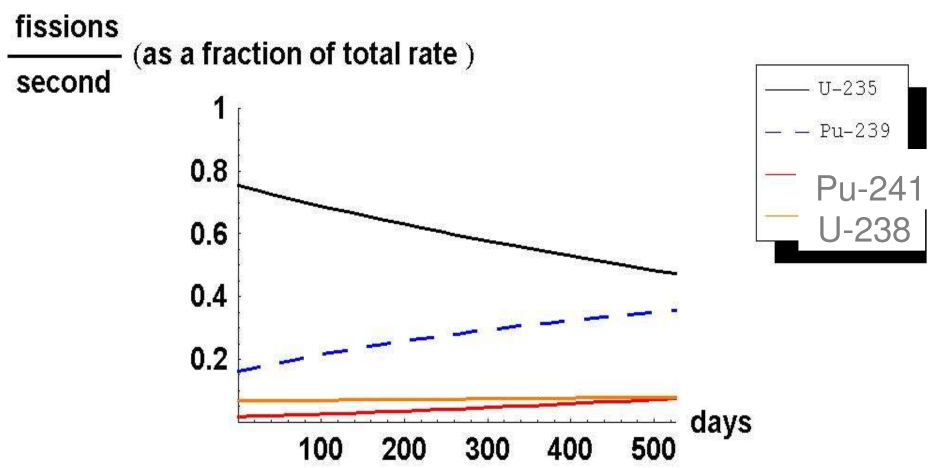
– A few keV neutron

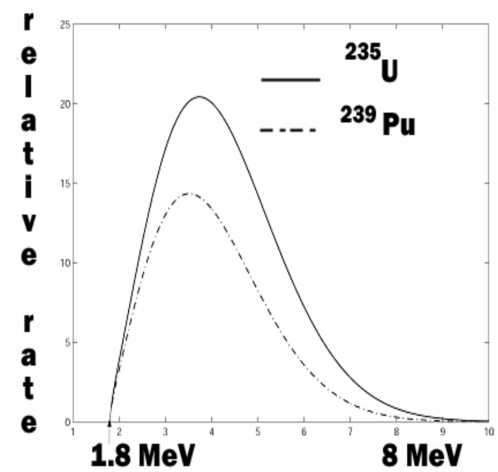
– mean time interval 28 μsec

Both final state particles deposit energy in a scintillating detector over 10s or 100s of microsecond time intervals (depending on the medium)

Both energy depositions and the time interval are measured

The Basic Technical Idea





- *Relation between delivered thermal power and antineutrino flux*

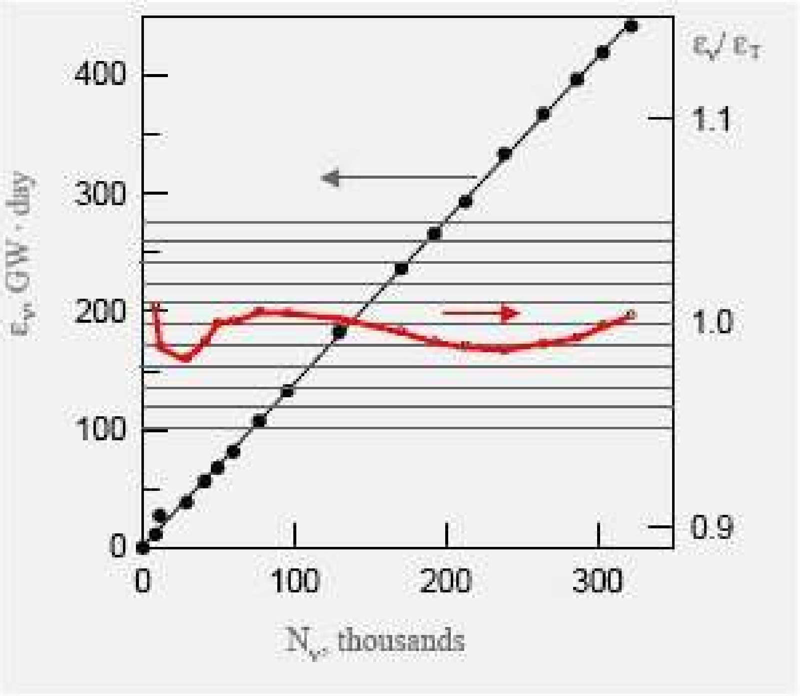
$$N_\nu = \gamma \cdot (1 + k) \cdot P_{th}$$

Dependence on detector features

Dependence on fuel composition

Reactor power x neutrino flux

Power generation

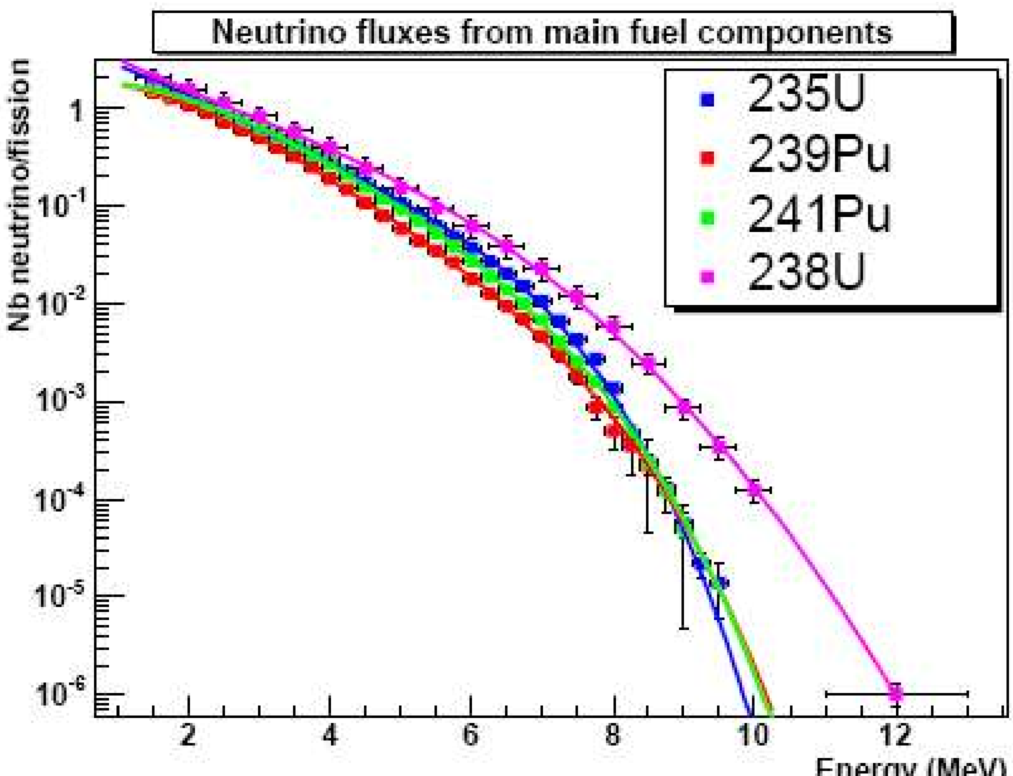


Number of antineutrinos

Power **ν** */ Power Th*

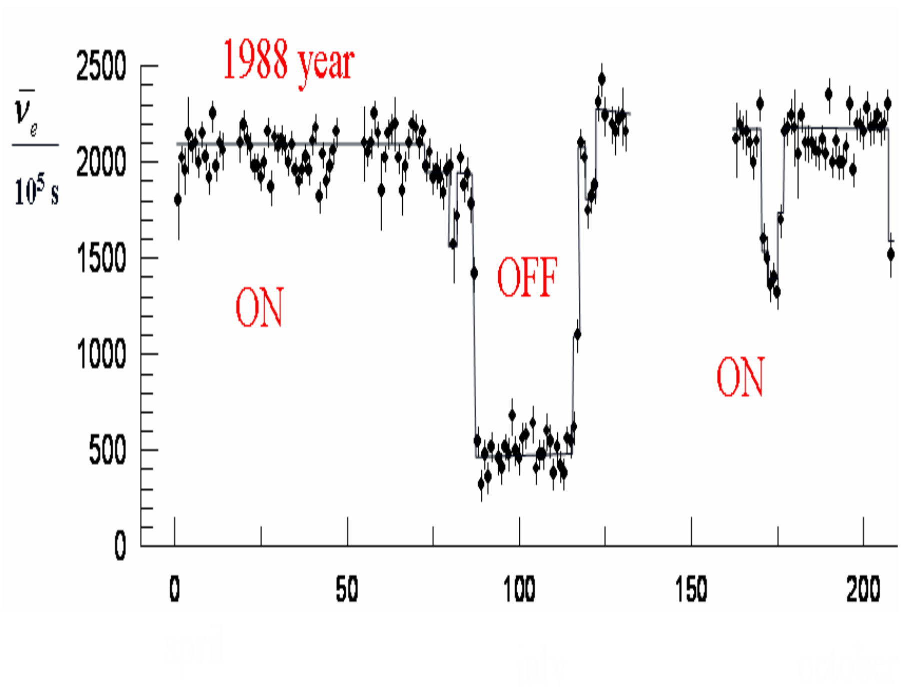
Antineutrino Emission Spectrum from Reactor Fuel

	Mean energy per fission (MeV)	Start of Cycle	End of Cycle
^{235}U	201.7 ± 0.6	60.5%	45.0%
^{238}U	205.0 ± 0.9	7.7%	8.3%
^{239}Pu	210.0 ± 0.9	27.2%	38.8%
^{241}Pu	212.4 ± 1.0	4.6%	7.9%

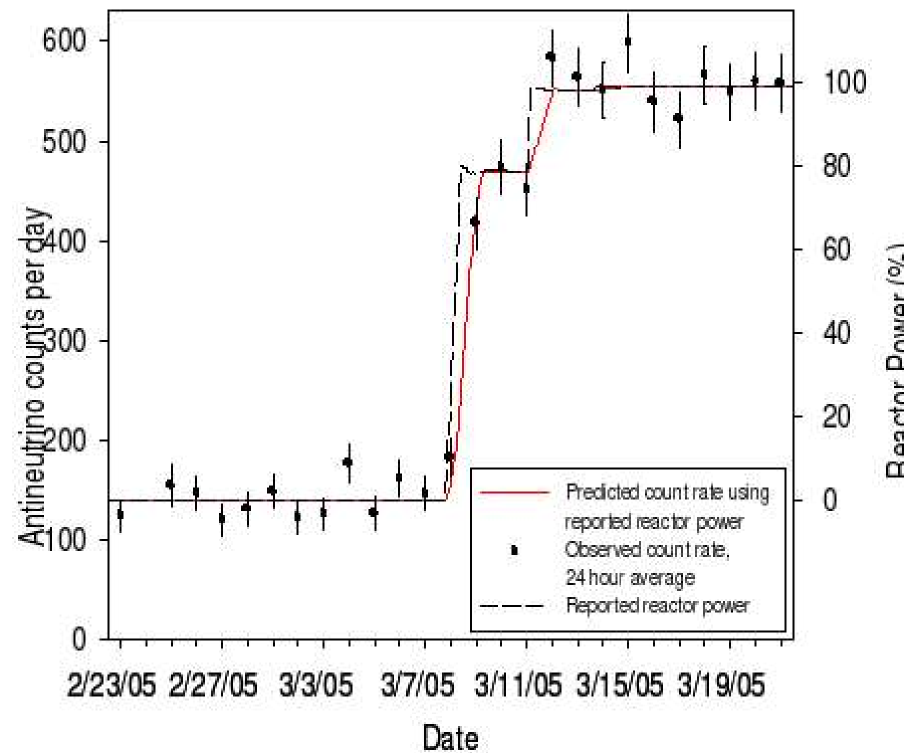


Antineutrino spectra measured by ILL group 1983-1989

Checking reactor activity:

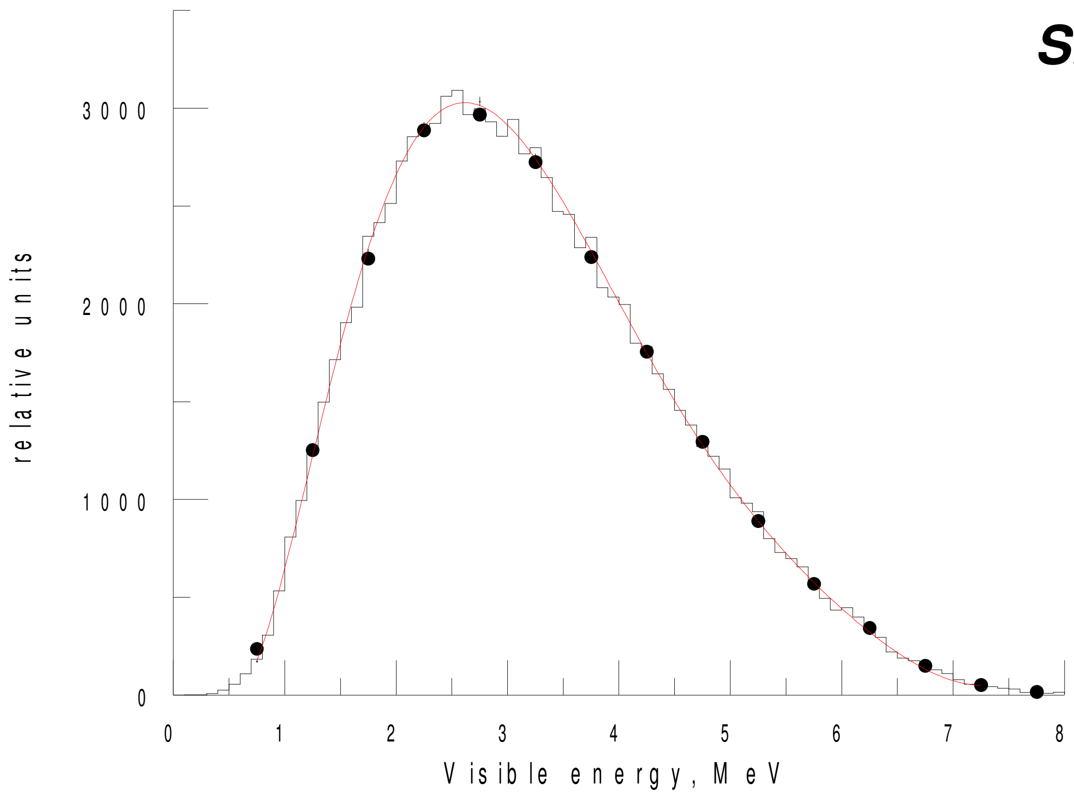


Rovno (Ukraine)



San Onofre (USA)

Fuel composition Virtual experiment:



Simulated spectrum:

235U = 0.614,

239Pu = 0.274,

238U = 0.074,

241Pu = 0.038,

fitting spectrum:

235U = 0.631±10%,

239Pu = 0.260,

238U = 0.074,

241Pu = 0.035,

Very Near Detector: Standard 3 volumes Design

A) Target (R_1=0.5m; h_1=1.3m)

- **Acrylic vessel + lqd scintillator(+Gd)**

B) Gamma-Catcher (R_2=0.8m h_2=1.9m)

- **Acrylic vessel + lqd scintillator**

C) Buffer (R_3=1.4m; h_3=3.10m)

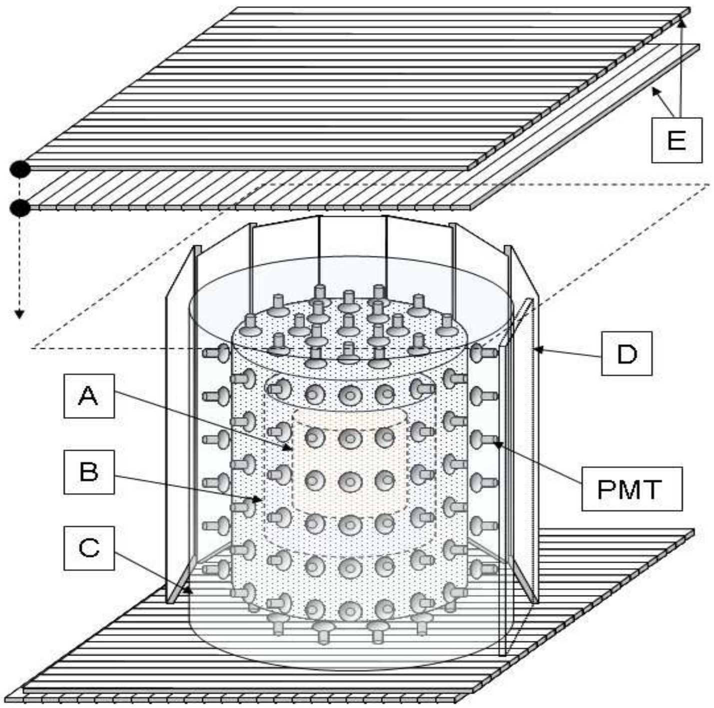
- **Steel vessel + mineral oil**

D) Vertical Tiles of Veto System

E) X-Y Horizontal Tiles of Veto System

- **Plastic scintillator padles**

above and under the external steel cylinder: muon tracking through the detector



Phase I:
Setup infrastructure at the Angra site:

- **20' container near the reactor building**
- **Measurement of local muon flux:**
- **Cerenkov detector (Auger test tank)**
- **Muon telescope (4 Minos type scintillator planes)**
- **Measurement of radioactive background: (rocks and sand)**

Phase II: Deploy LVD tank

- 1 ton gadolinium doped liquid scintillator tank

- test signal+background

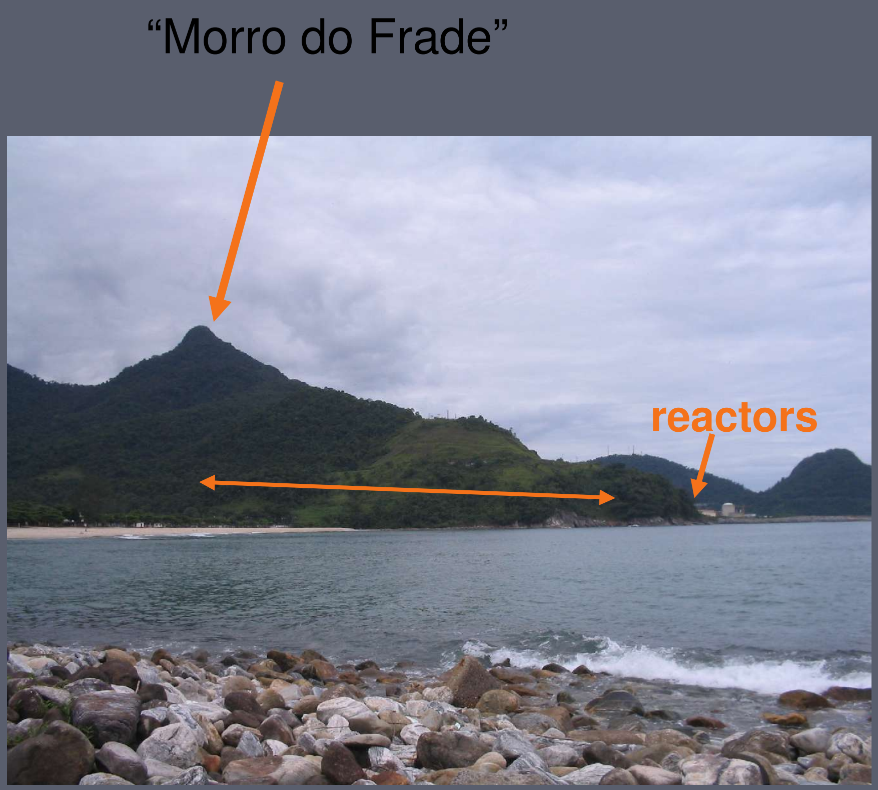
- Tests with Californium source

- Final site selection for underground laboratory

Phase III:

- *Construction of the underground laboratory.*
- *Construction of three volume detector and muon veto.*
- *Deployment of detector parts, integration and commissioning.*

Phase IV (2013?):
high precision measurement of θ_{13} ?



- Near (reference) detector:
  - 50 ton detector (7.2 m dia)
  - 300 m from core
  - 250 m.w.e.
- Far (oscillation) detector:
  - 500 tons (12.5 m dia)
  - 1500 m from core
  - 2000 m.w.e.
    (under "Frade" peak)
- Very Near detector:
  - 1 ton prototype project
  - < 50m of reactor core
- Detector Construction
  - Standard 3 volume design

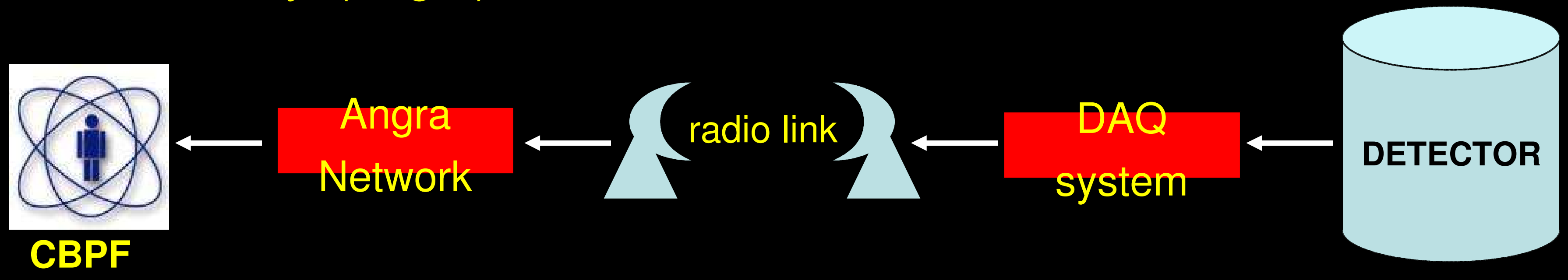
Detector Operation

Remote data acquisition

The detector continuously acquire data, recording events that may be classified as:

- Neutrino events
- VEM
- Other (ex: muons)

Data is locally (Angra) stored and sent to a central station at CBPF



Angra Project: Present Status

- Meeting September 05, 2006 with Eletronuclear representatives to define next steps.
- Detailed project under way to be presented to the Minister of Science and Technology and to FAPESP.
- Start to test components at CBPF and UNICAMP: (phototubes + VME electronics)

Conclusions

- *Previous experiments demonstrate a good capability of using Antineutrinos for Nuclear reactor distant monitoring.*
- *High precision thermal power and fuel composition measurement can be acchieved.*
- *Better accuracy for antineutrino spectra of U & Pu is needed.*
- *Good opportunity develop experimental neutrino physics in Brazil and to contribute to new safeguards techniques.*
- *Short baseline Neutrino Oscillations : collaboration with Double Chooz? High precision experiment around 2013?*