The ANGRA Cherenkov detector

E. Kemp *on behalf of the Neutrinos-ANGRA Project*

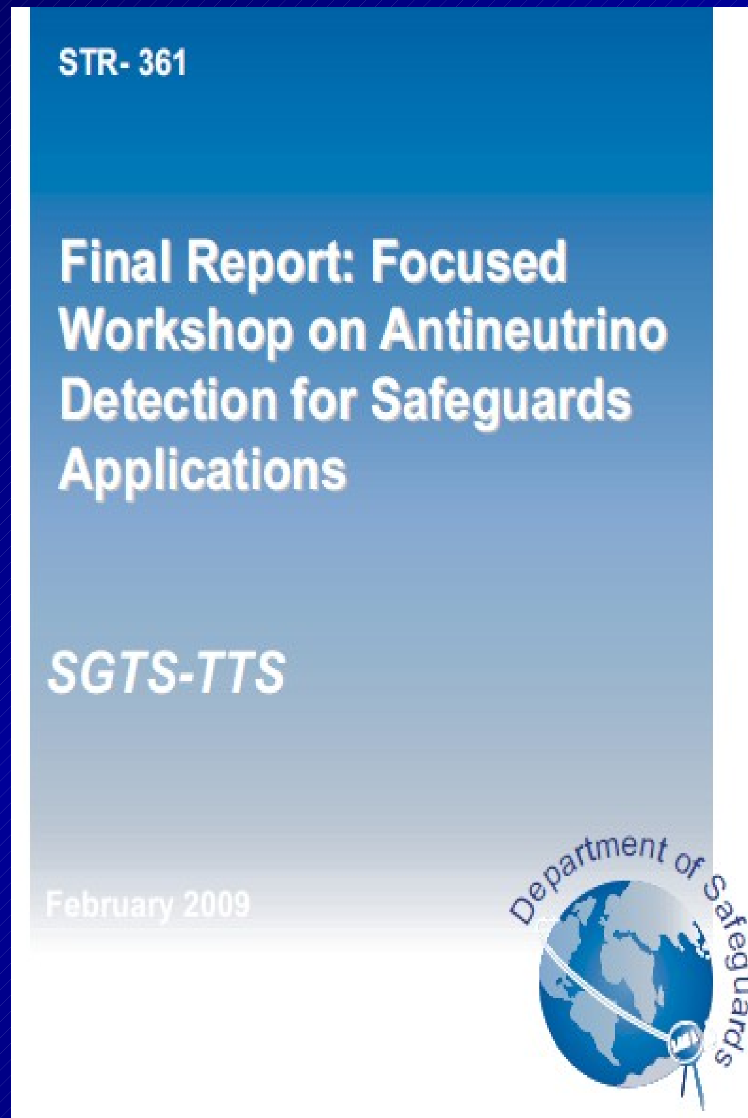
AAP 2010 – Sendai - Japan

Talk Overview

- The Challenge
  - A surface measurement using a non-favorable technique
- The Site
  - Brief description of the ANGRA site
- The Detector
  - Conceptions
- Conlusions and perspectives

Neutrinos-ANGRA: the challenge

IAEA.org
International Atomic Energy Agency


STR- 361

Final Report: Focused Workshop on Antineutrino Detection for Safeguards Applications

SGTS-TTS

February 2009

Neutrinos-ANGRA: the challenge

IAEA.org
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7 Future Developments for Incorporation of Antineutrino Detection Technology into Safeguards

7.1 Short Term Goals:

2. Demonstrate robust long term burnup monitoring of power reactors with an easily deployable detector that is acceptable to the safeguards agency and reactor operators. Among other criteria, the definition of robustness should include the ability to relocate the detector via normal commercial freight channels, without special placarding or otherwise onerous shipping requirements. Further work is needed to confirm *long term* monitoring capability with a robust detector such as the plastic designs (though other designs may also work, including non-toxic and high flashpoint liquid designs), while suffering little or no compromise in performance over a fuel cycle. Such a demonstration can certainly be accomplished in less than five years with suitable support from member states.

Neutrinos-ANGRA: the challenge

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International Atomic Energy Agency

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

The Neutrinos-ANGRA Project

ANGRA:

NEUTRINOS ANGRA Project

23/09/2008

conteiner: 1st laboratory in Angra

Angra dos Reis nuclear plant features

- 3 PWR Reactors: 2 in operation + 1 planned

Reactor (starting date)	Thermal Power (GW)	Average Uptime	Fuel Cycle
Angra-I (1985)	2.0	83 %	~1.5 years
Angra-II (2000)	4.0 ~ 1.2 x 10^{20} f/s	90 %	~1.3 years
Angra-III **Construction starting 2009**	4.0	-	-

Neutrinos & Non-proliferation

- ~ 438 reactors worldwide:

  The International Atomic Energy Agency - IAEA is responsible to inspect nuclear installations and verify safeguards agreements

- ~200kg of Pu are produced in each PWR typical cycle (~ 1.5 year)

  ~90 Pu tons/year in global scale

  IAEA verifies the pacific destination of this material.

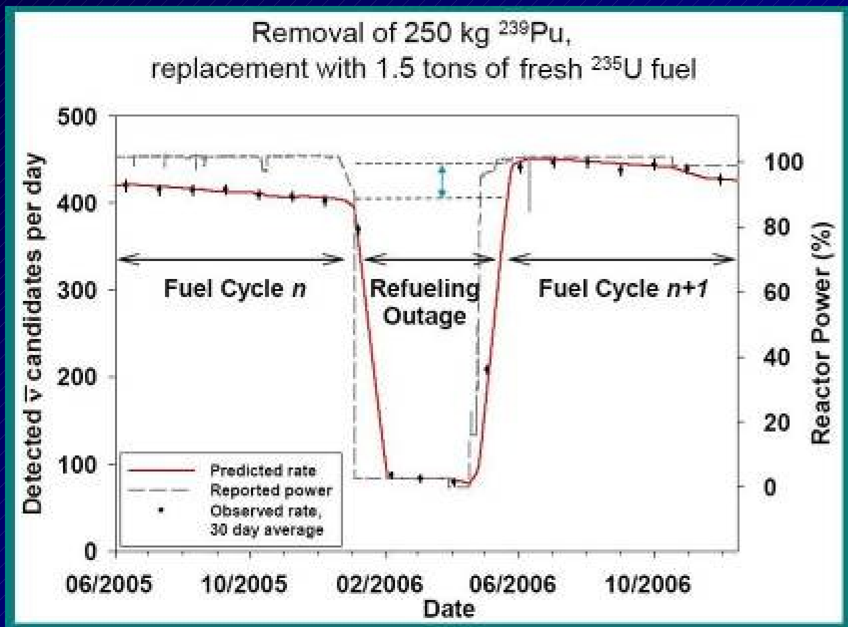
- IAEA is the verification authority:

  Non-Proliferation Treaty of Nuclear Weapons (NPT):

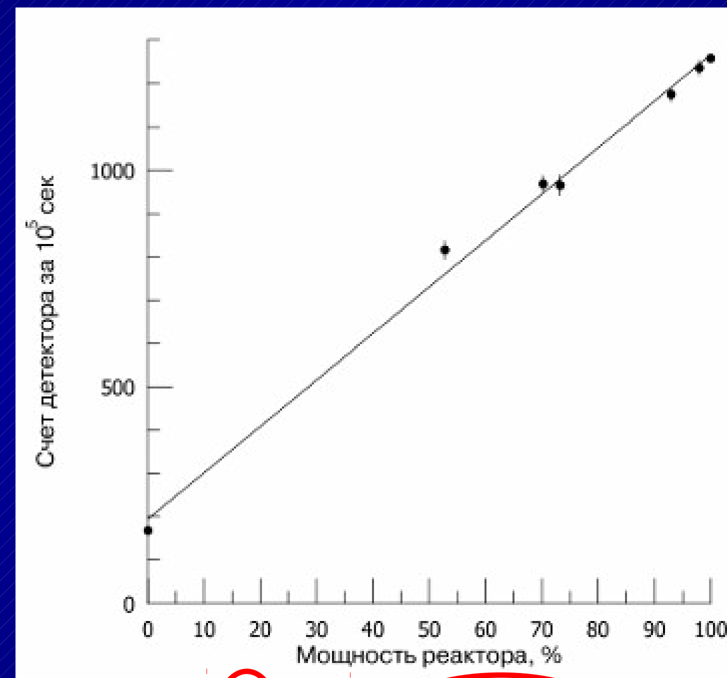
  Keep track of all the Pu produced in nuclear installations !

Monitoring nuclear reactors with antineutrinos: It is feasible

San Onofre (USA)



Rovno/Ucraine



Thermal power control:
Interesting topic for Eletronuclear

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

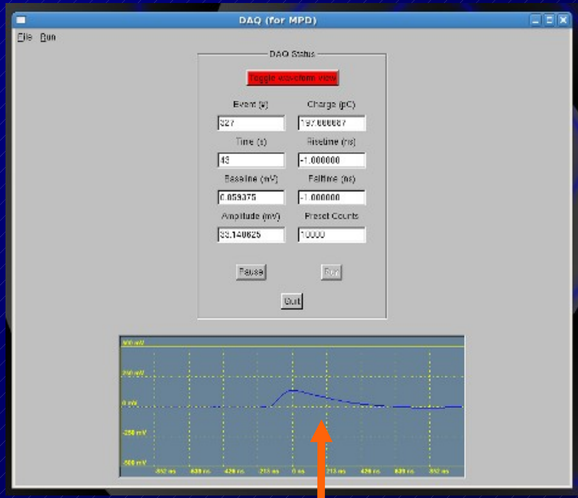
Factor carrying detector features

Factor carrying fuel composition features

Angra Site Infrastructure
Remote control of DAQ

- On-line Muon flux measuments with a Cerenkov detector
- Remote DAQ trough IP's released by Eletronuclear

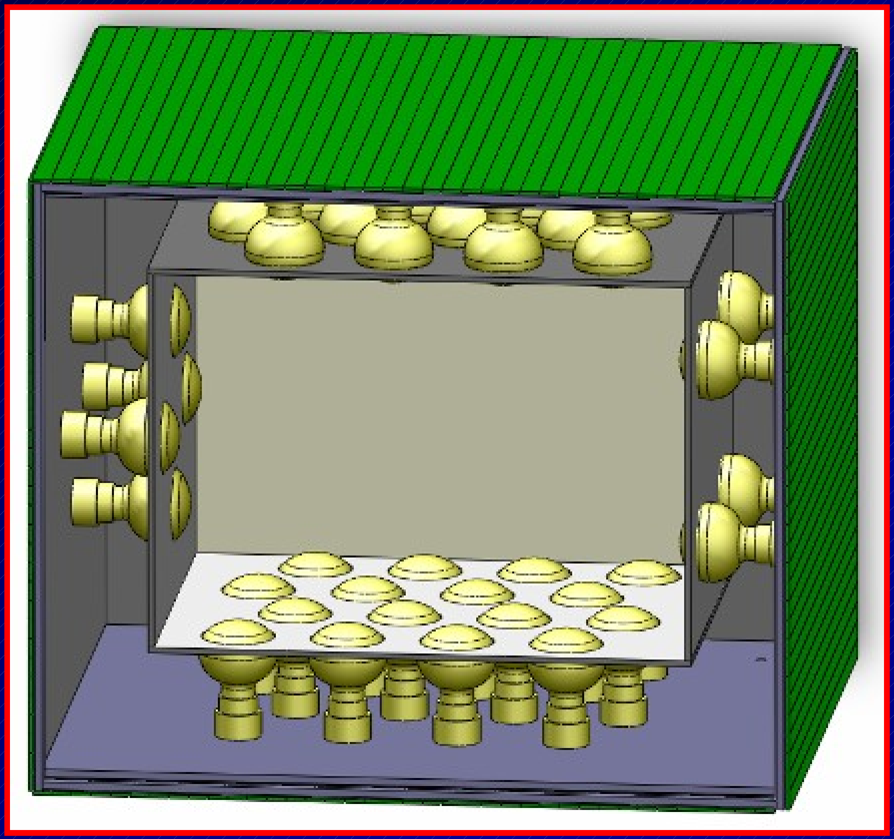
20' container
next of the reactor dome

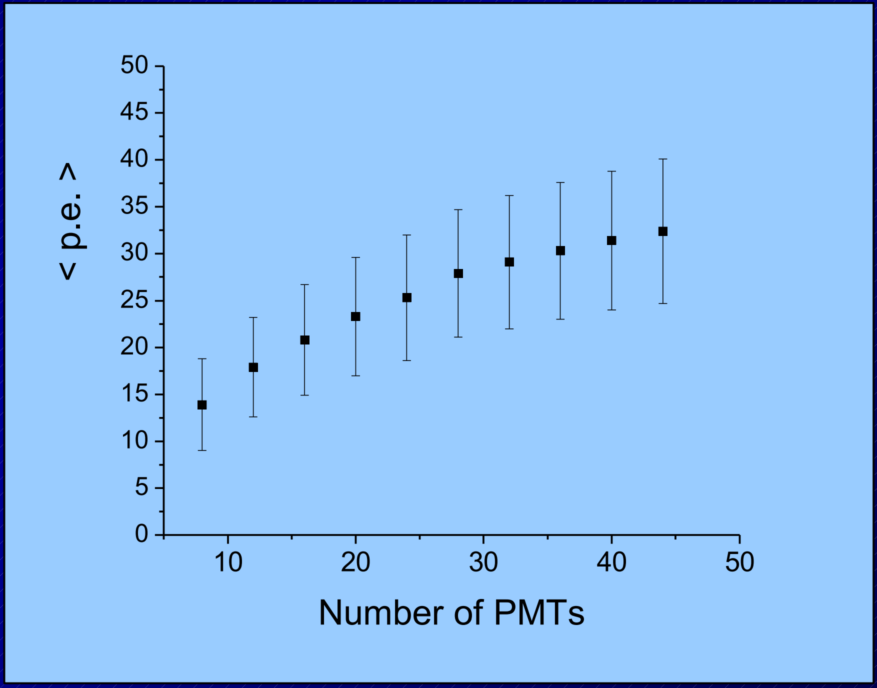


PC monitor @ CBPF
in Rio de Janeiro

Target design: external box + internal reflector

Desenho completo do detector em andamento



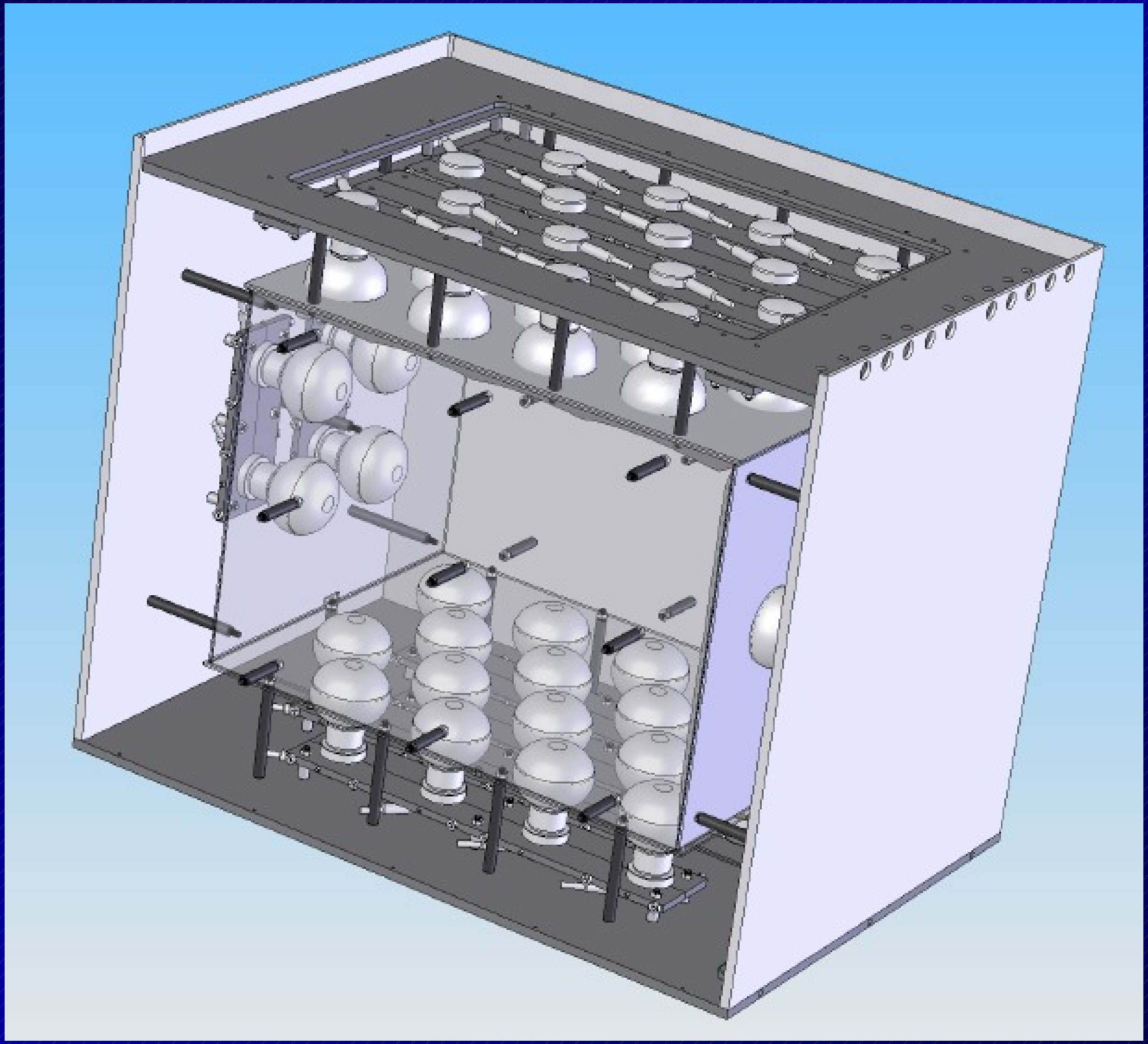


Studies on optimal number of PMTs:

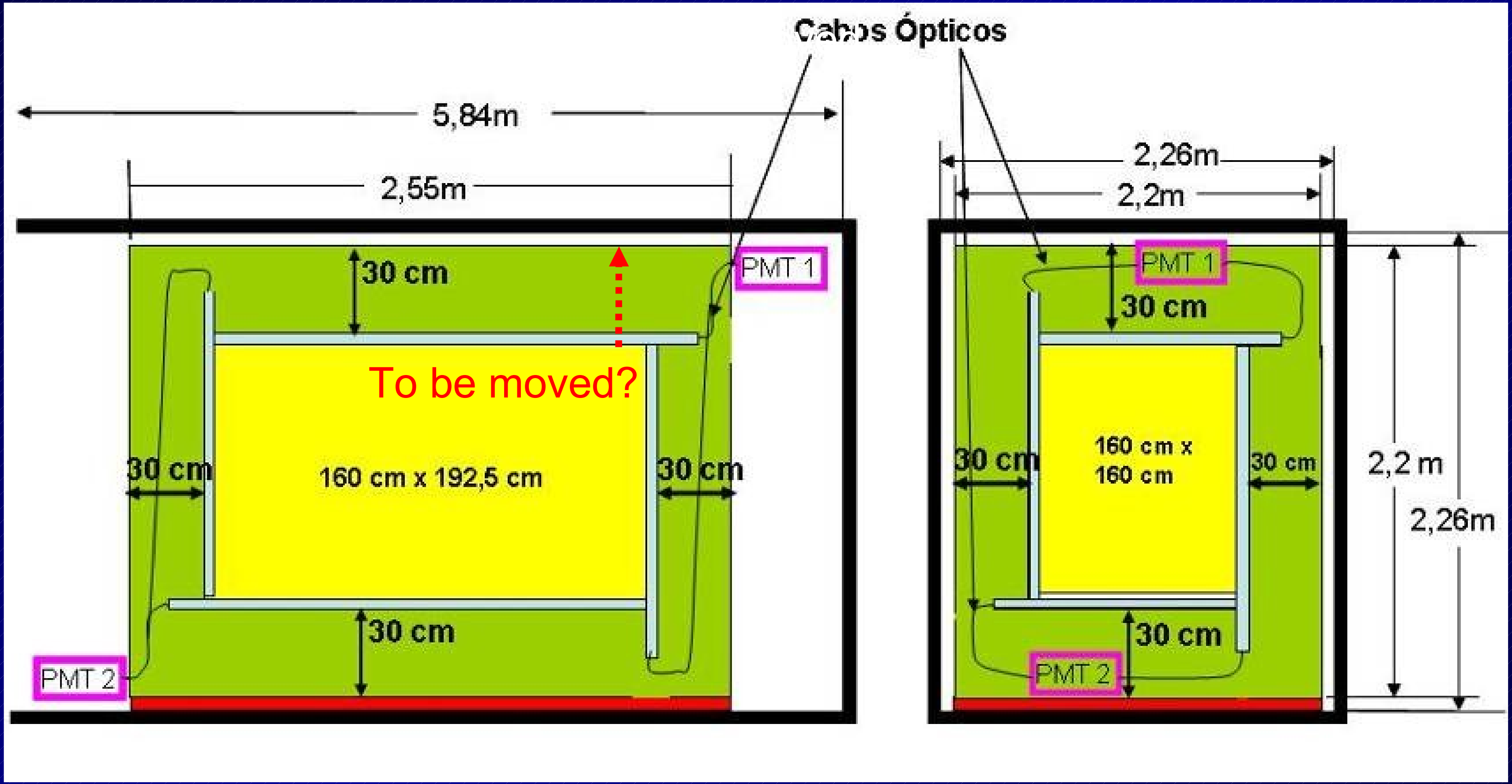
GEANT4 simulation of 2 MeV positrons on the detector centre

Target: ~ 1 ton H_2O (inside reflector box) + 0.1% Gd
viewed by 40 Hamamatsu 8" R5912 PMTs

target assembly parts drawings (to be sent to the workshop)

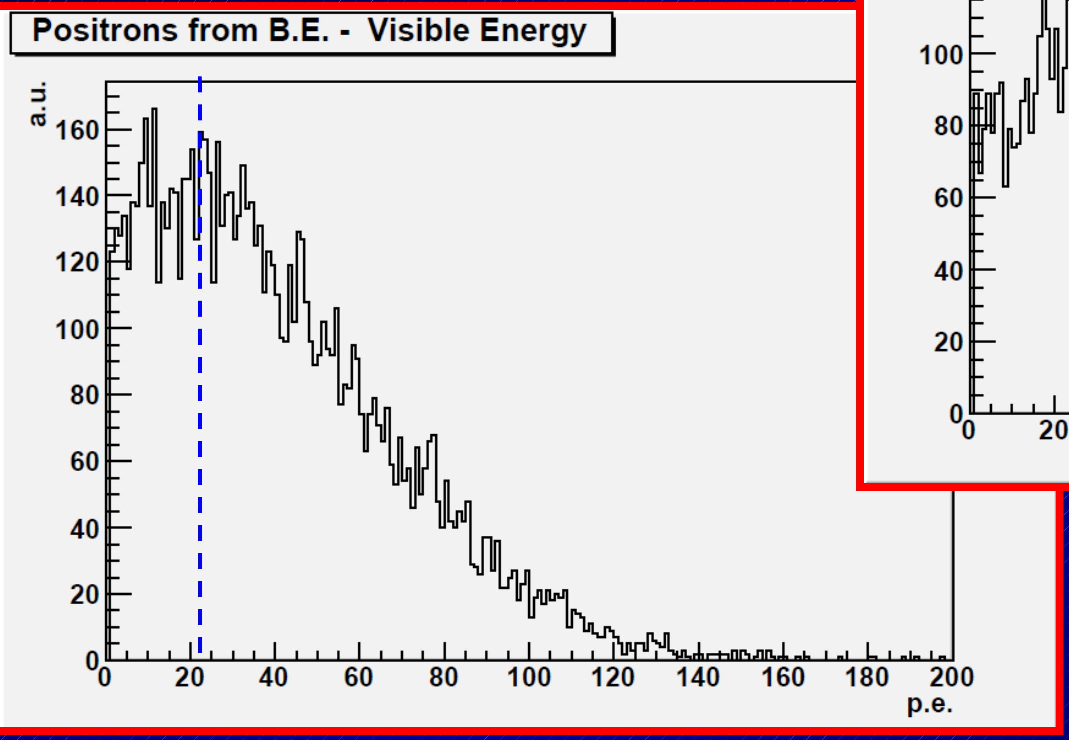


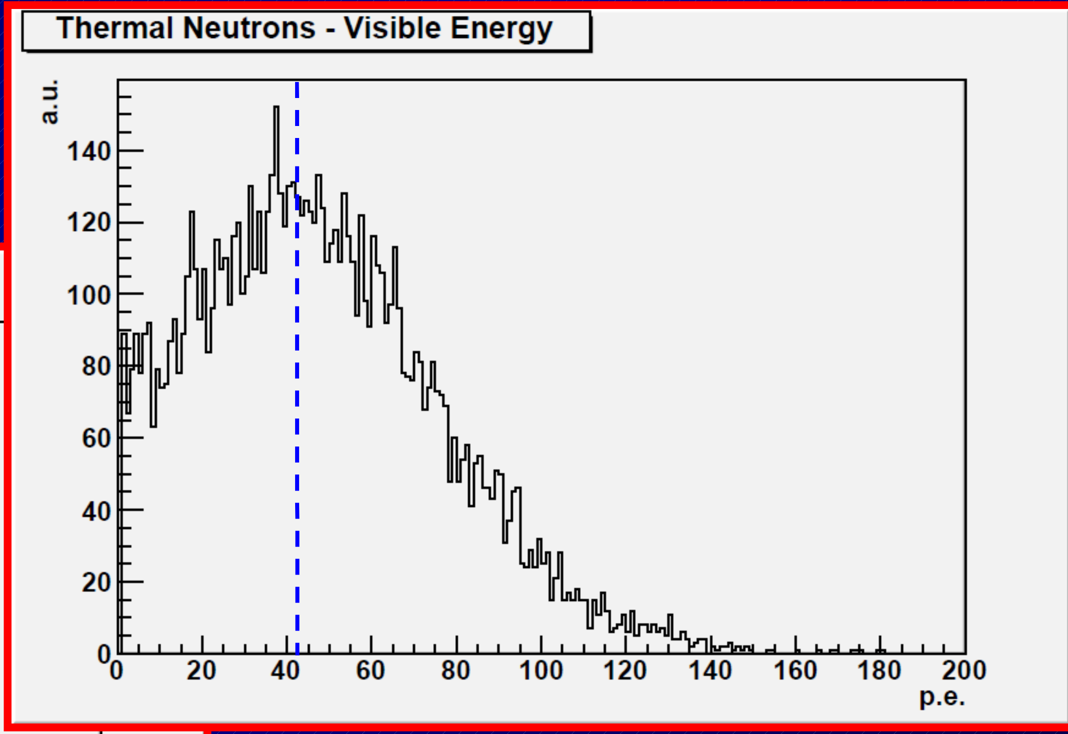
VETO assembly studies



GEANT4: antineutrinos expected signals

e^+ Prompt signal

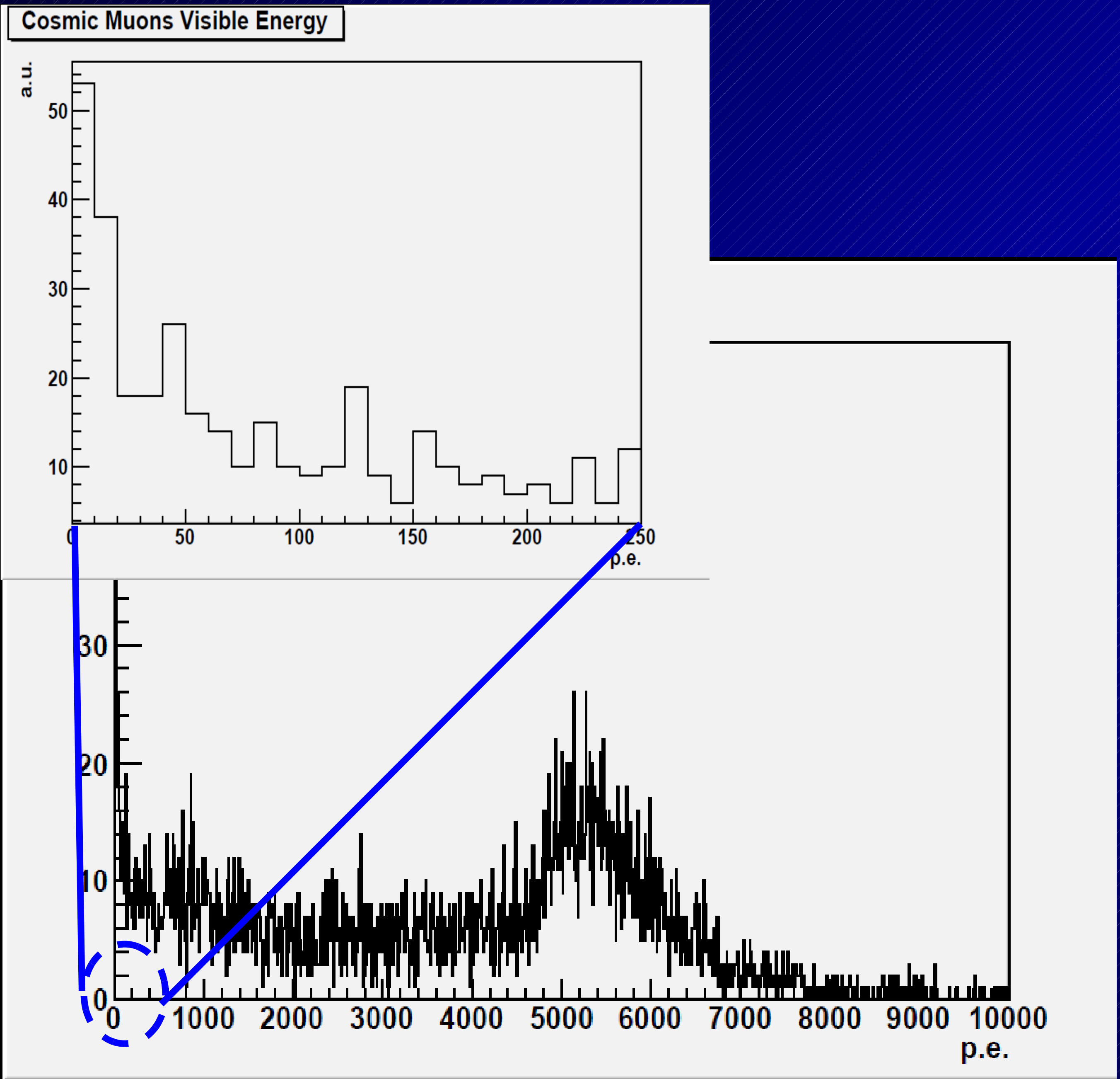




Neutron capture signal

Distribution of total number of p.e. Collected in the PMTs

GEANT4: muon background



Muon background rejection

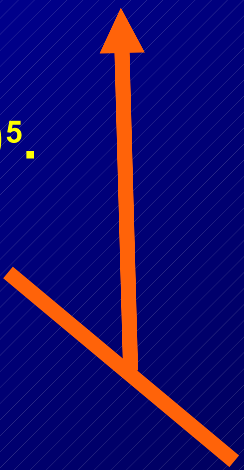
- Cosmic muons crossing the detector = 1KHz
  ➔ 10^8 muons / day

- Expected neutrino interactions rate ~ 10^3 / day

$$\varepsilon_\mu = \varepsilon_\mu^{veto} \times \varepsilon_\mu^{window} \times \varepsilon_\mu^{threshold} \times \varepsilon_\mu^{direction}$$

$$\begin{cases} \varepsilon_\mu^{veto} \approx 0.1 \\ \varepsilon_\mu^{window} \approx 0.095 \\ \varepsilon_\mu^{threshold} \approx 0.05 \\ \varepsilon_\mu^{direction} \approx 0.01 \end{cases}$$

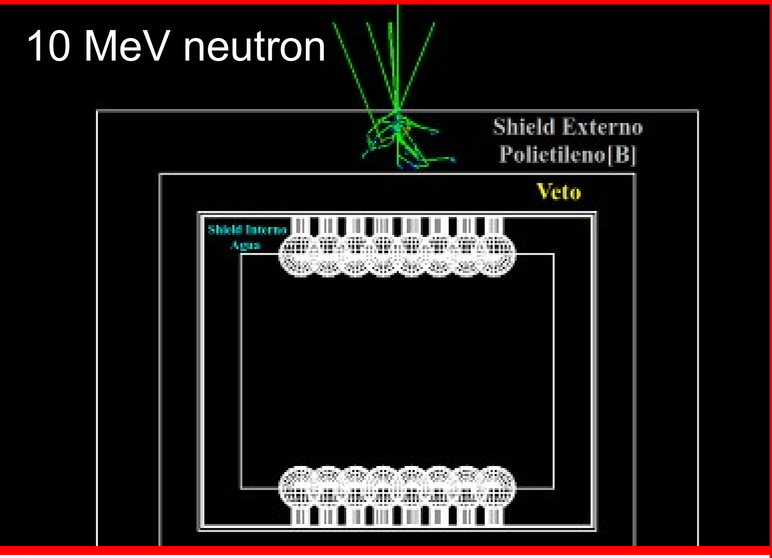
$$\Rightarrow \quad \varepsilon_\mu \approx 10^{-6}$$ → Final bkg rejection factor

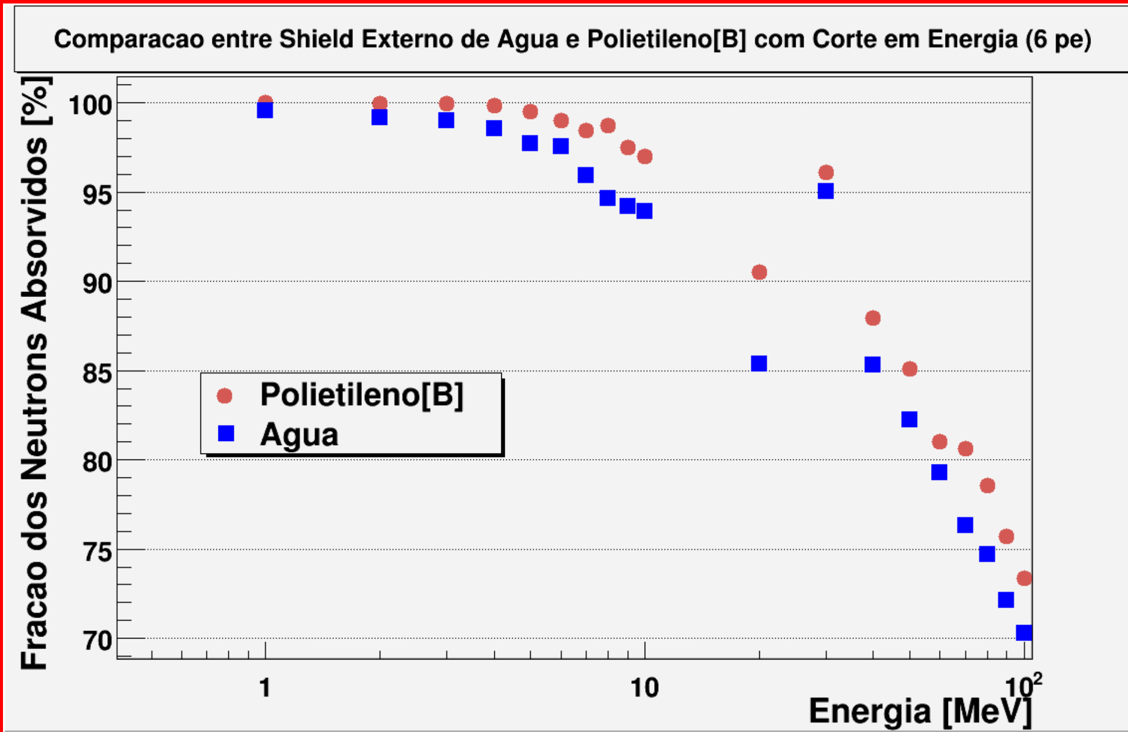


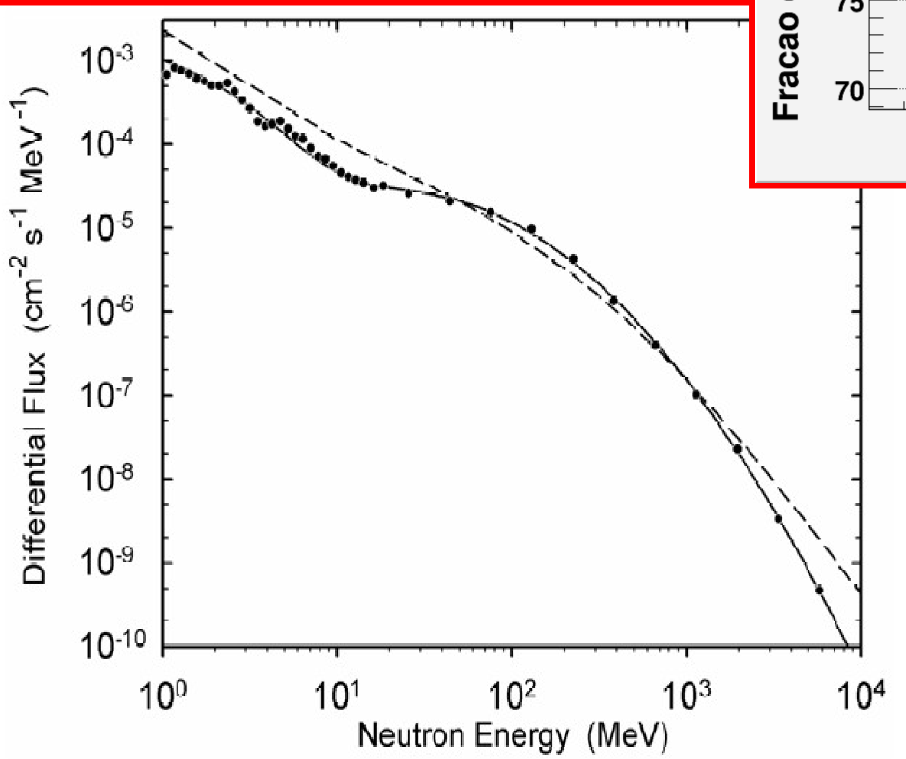
- **Signal/Noise ratio must be reduced by a factor 10^5.**

- Muon rejection techniques:
  - **External VETO**: scintillators - 4 π veto system for the target
    - Assuming 90% of efficiency ➔ 1 order of magnitude of rejection
  - **Time window coincidence:**
    - 100μs of coincident pulses ➔ muon rates fall down to 10%;
  - **Thresholds**
    - Muons signals are very high (rejection power of ~ 95%);
  - **Directionality**:
    - Muons are "downwarding" particles. PMTS shold be more illuminated at the bottom by muon events. Charge balance in PMTs can help to distinguish *isotropic events:* additional ~ 1 % rejection factor

GEANT4: neutron shielding studies







Flux measured @ LNGS – external room (1000 m): En > 10 MeV

N_flux = 75 n/m^2.s

Angra (at the sea level): 3x reduction factor

N_flux = 25 n/m^2.s

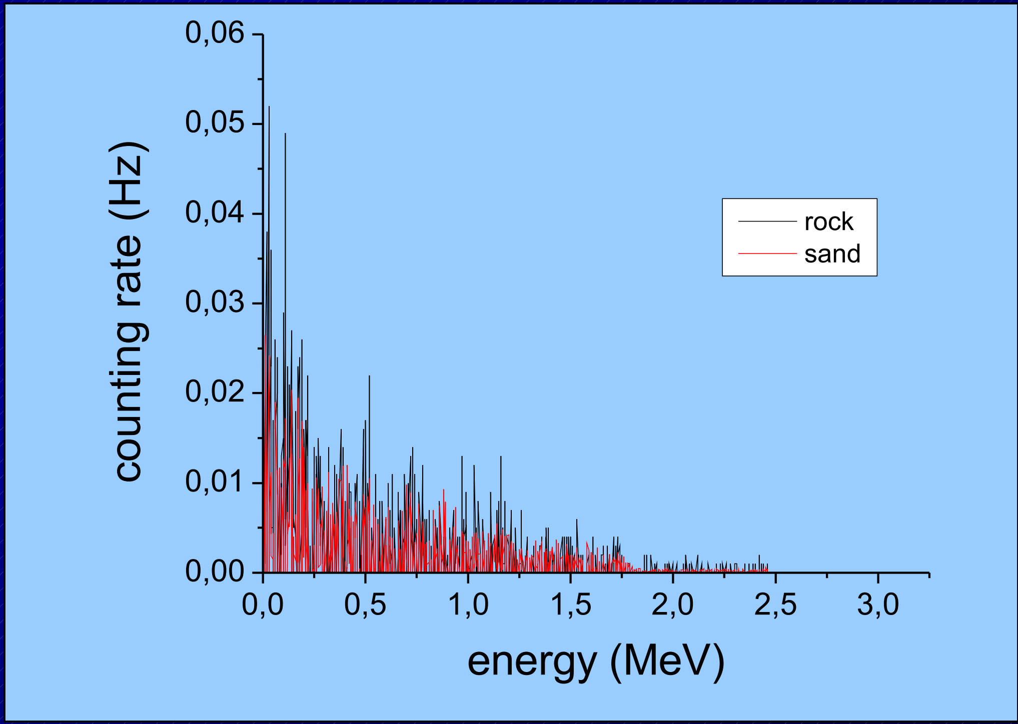
Shielding attenuation
(~ 85% acima de 10 MeV)

N_flux = 4 n/m^2.s ➔ ~ 5% of contamination

10 Sendai

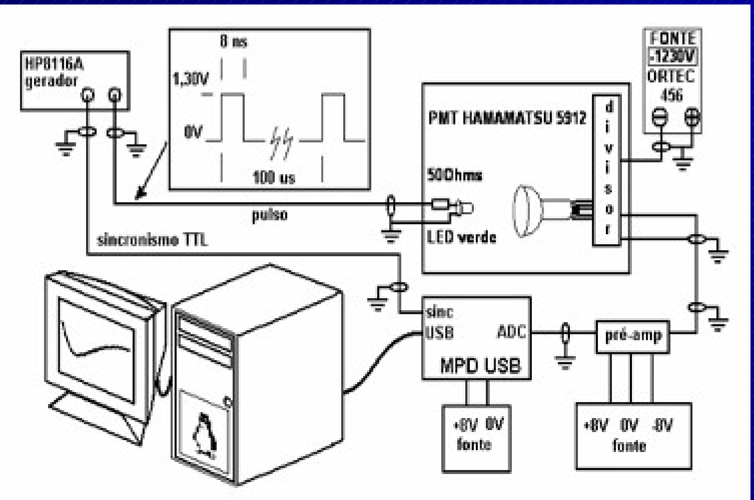
Natural radioactivity 1st check: ok...

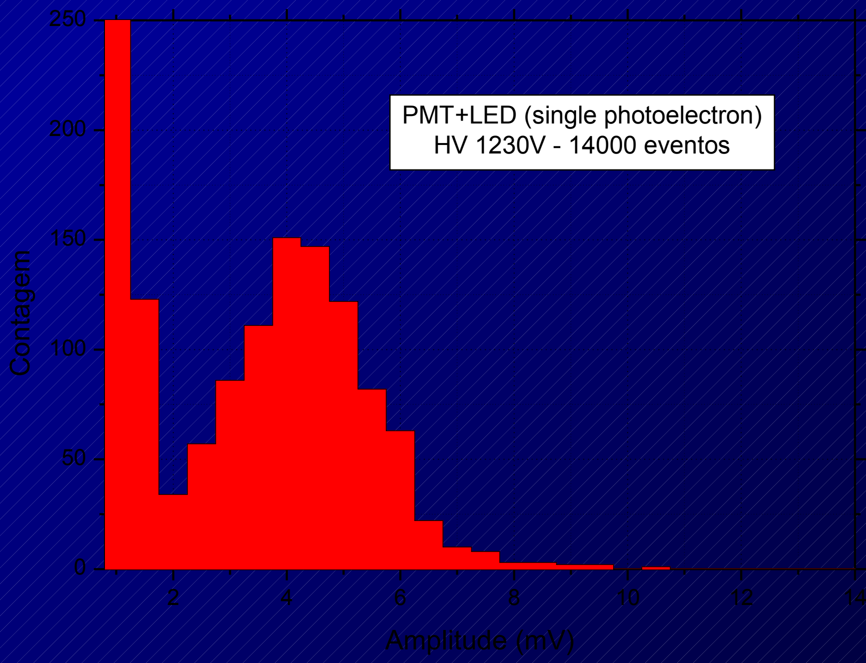
No relevant component found



PMTs Characterization

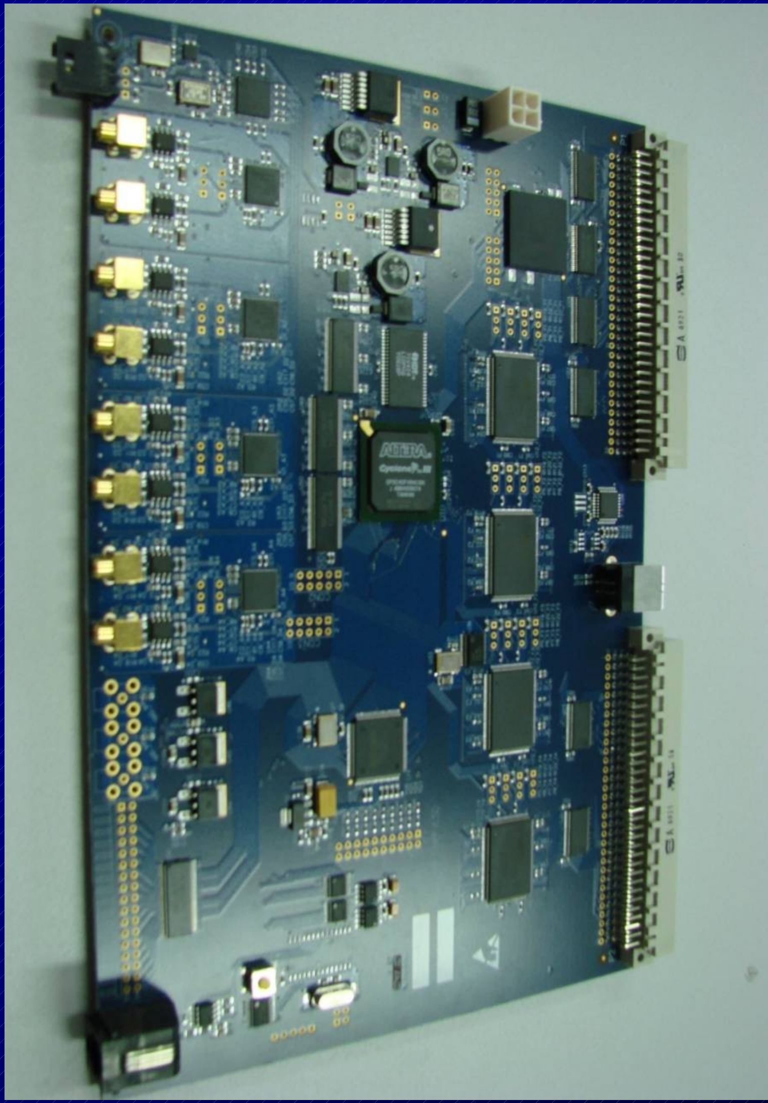
Hamamatsu 8” R5912
Single Photo-Electron
Distribution





DAQ VME

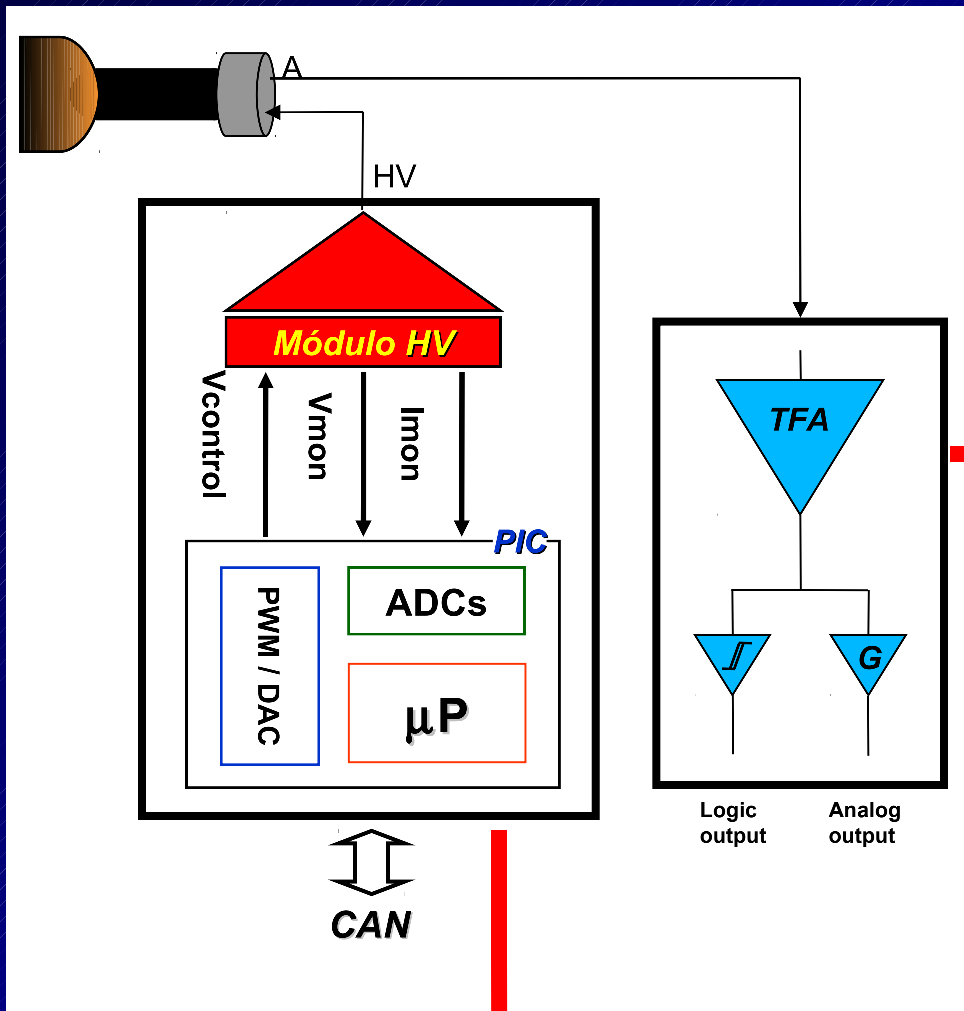
Waveform digitizer: VME 6U standard
ADC: 8 analog channels @ 125 MHz
or
4 analog channels @ 250 MHz
Dynamic range = 2 Vpp
Buffer per channel = 64k samples
TDC: 8 channels for time measurements
time resolution 81ps
dinamic range = 9.8 μs
2 firmware versions (8 ou 4 channels)
control and status registers
slow control:CAN communication



Project by CBPF, Board lay-out and assembly made at Campinas local company (CADSERVICE)

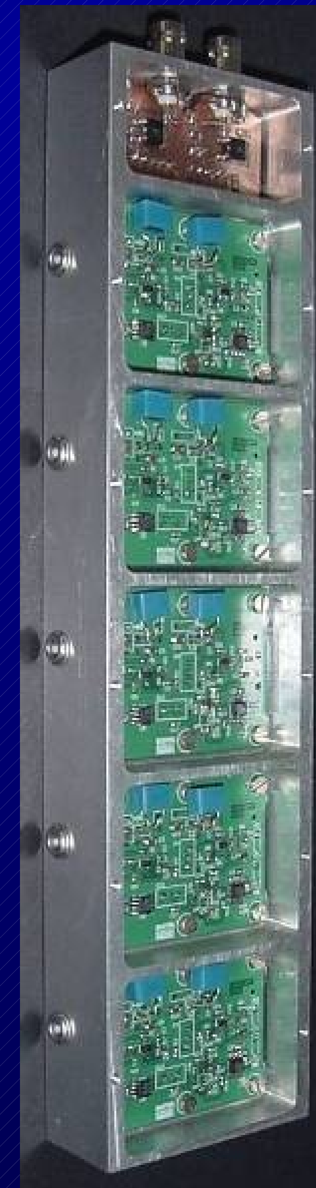
- 10 unities ready – already assembled - in debbugging phase
- First real measurement tests soon...

Front-End Electronics



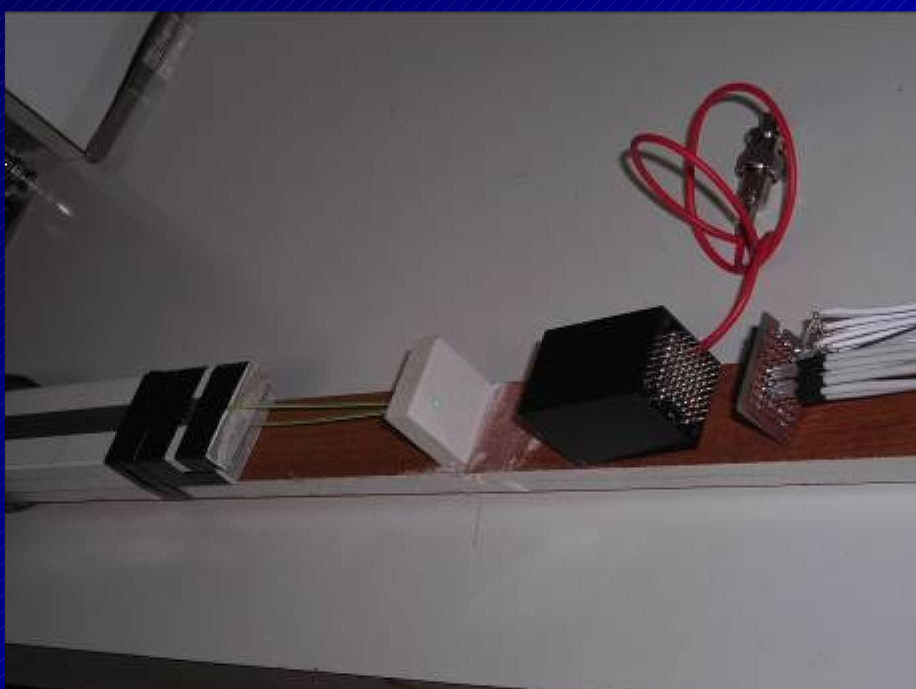
CBPF

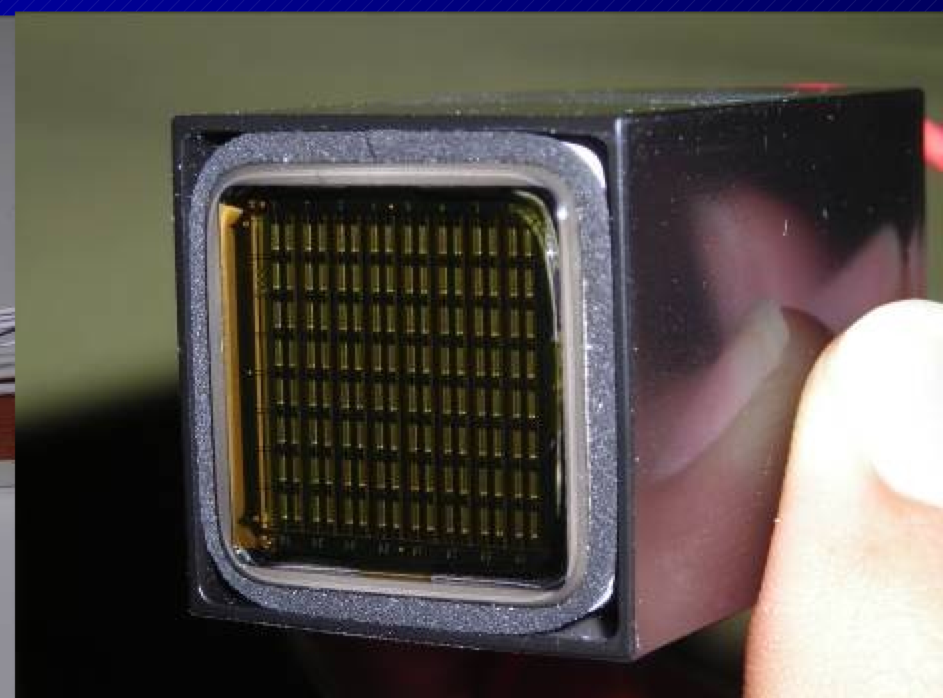
UEFS



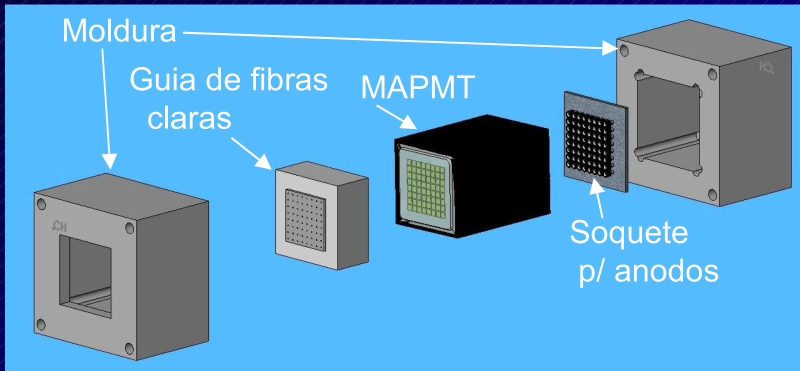
Development of muon VETO

64 channel **Hamamatsu** PMT **R7546A**

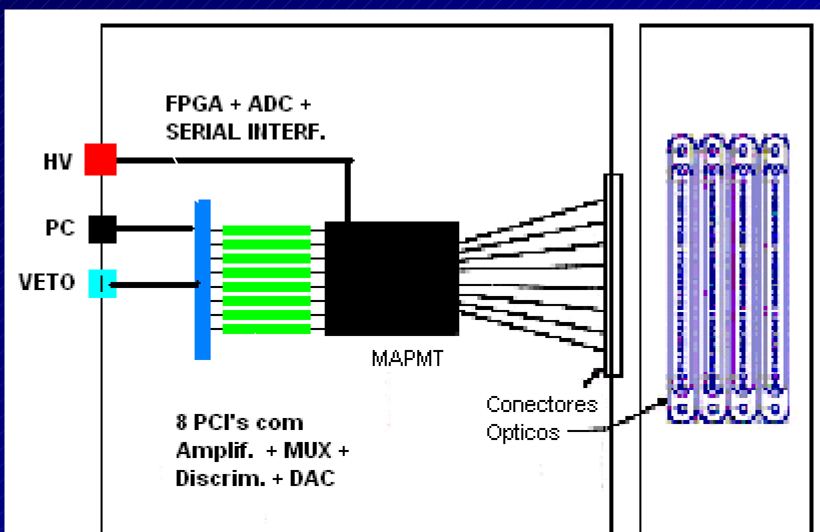




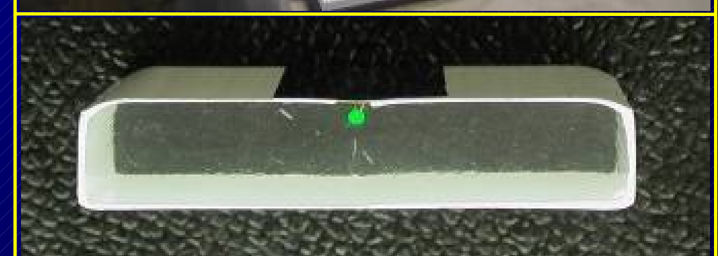
MAPMT Box



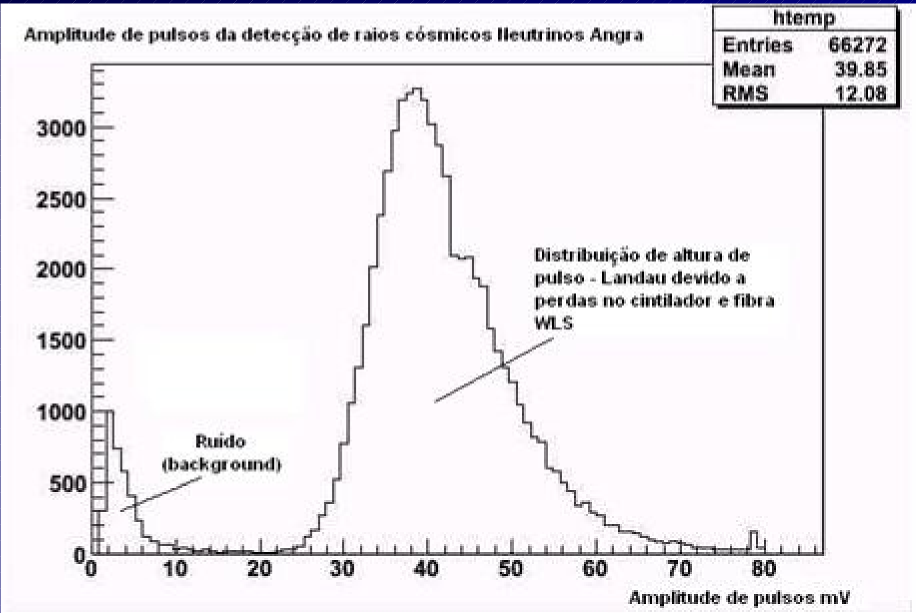
Moldura para integrar MAPMT, guia de fibras ópticas claras e conector elétrico

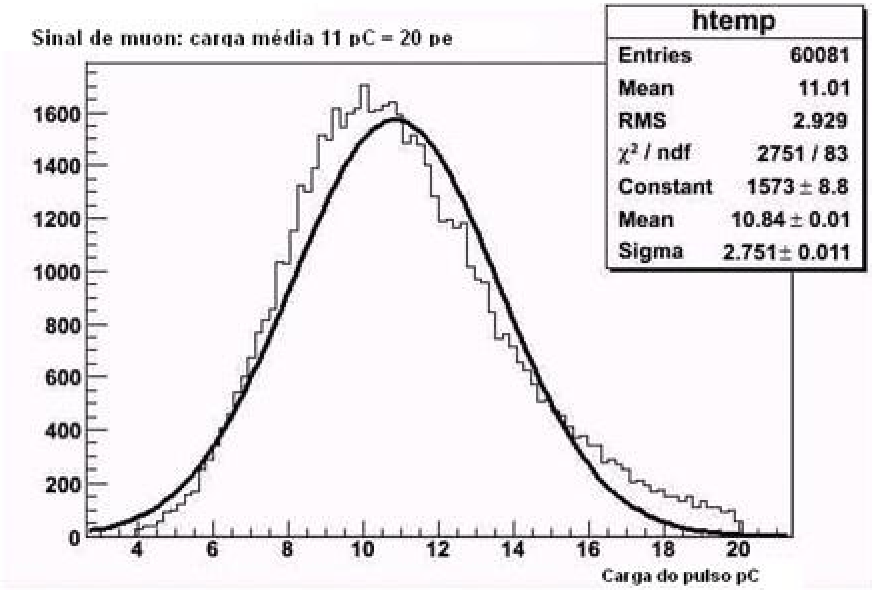


Caixa da MAPMT: blindagem óptica e eletromagnética p/ PMT e circuitos



Test results from MAPMT H7546A (voltage divider + pre-amplifier @ 900V) : amplitude and charge from cosmic muons crossing the VETO plastic scintillator)





Amplitude de pulsos de muons bem acima do ruído de fundo no protótipo do veto de múons

Sensibilidade do protótipo do sistema de veto de múons de 20 p.e. (p.e.= 0.5 pC)

New Development:
WLS in water / amino-G

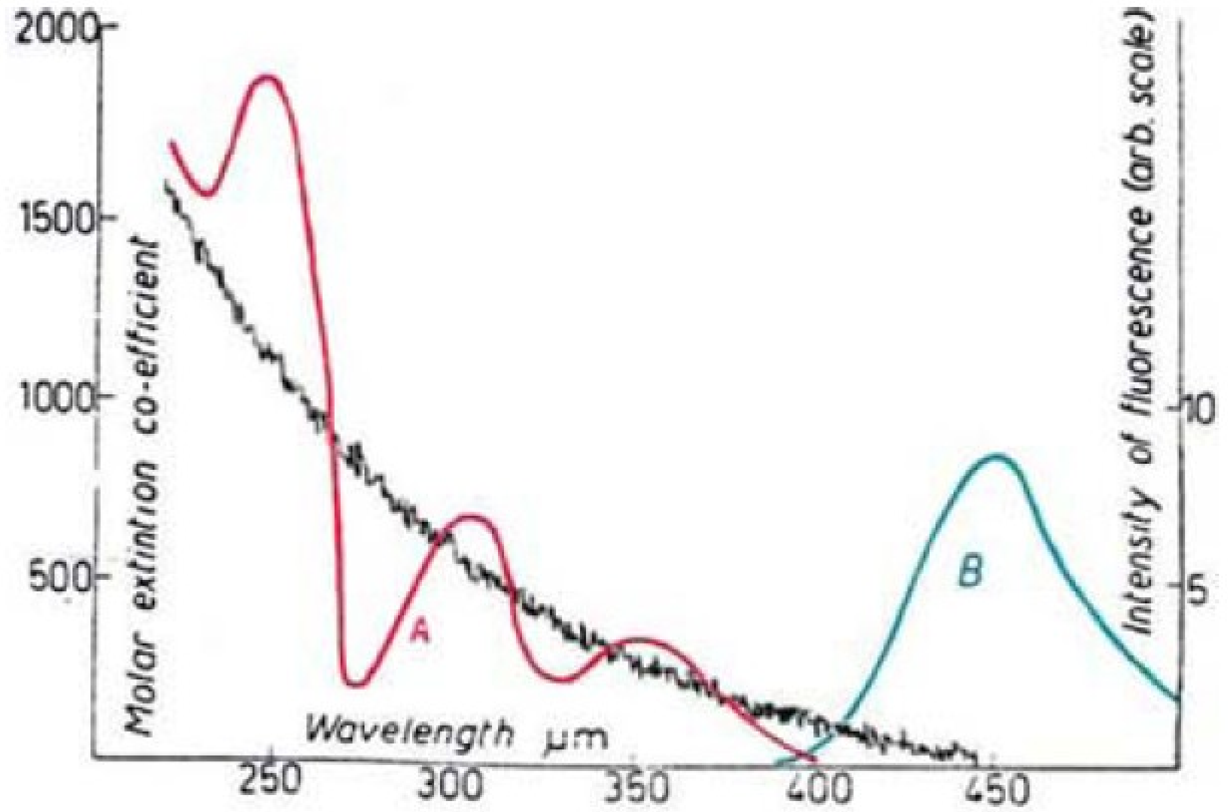
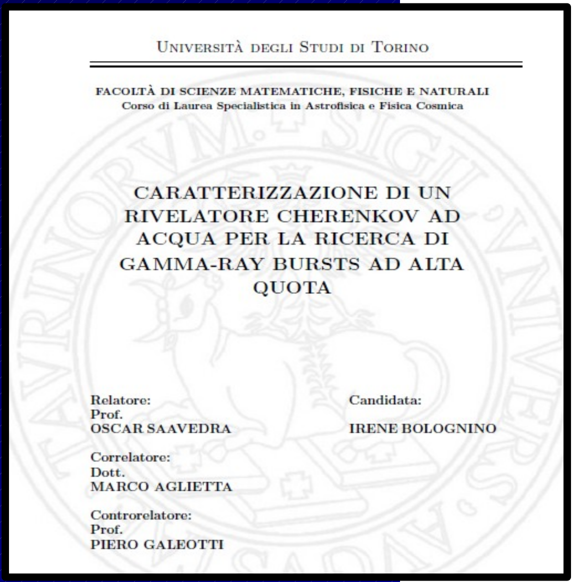


Figura 3.40: Curva di assorbimento (A) e di emissione (B) dell'amino-G in acqua: queste curve sono sovrapposte a quella dei fotoni generati per effetto Cherenkov.

Amino-G enhancement in the photon yield


UNIVERSITÀ DEGLI STUDI DI TORINO

FACOLTÀ DI SCIENZE MATEMATICHE, FISICHE E NATURALI
Corso di Laurea Specialistica in Astrofisica e Fisica Cosmica

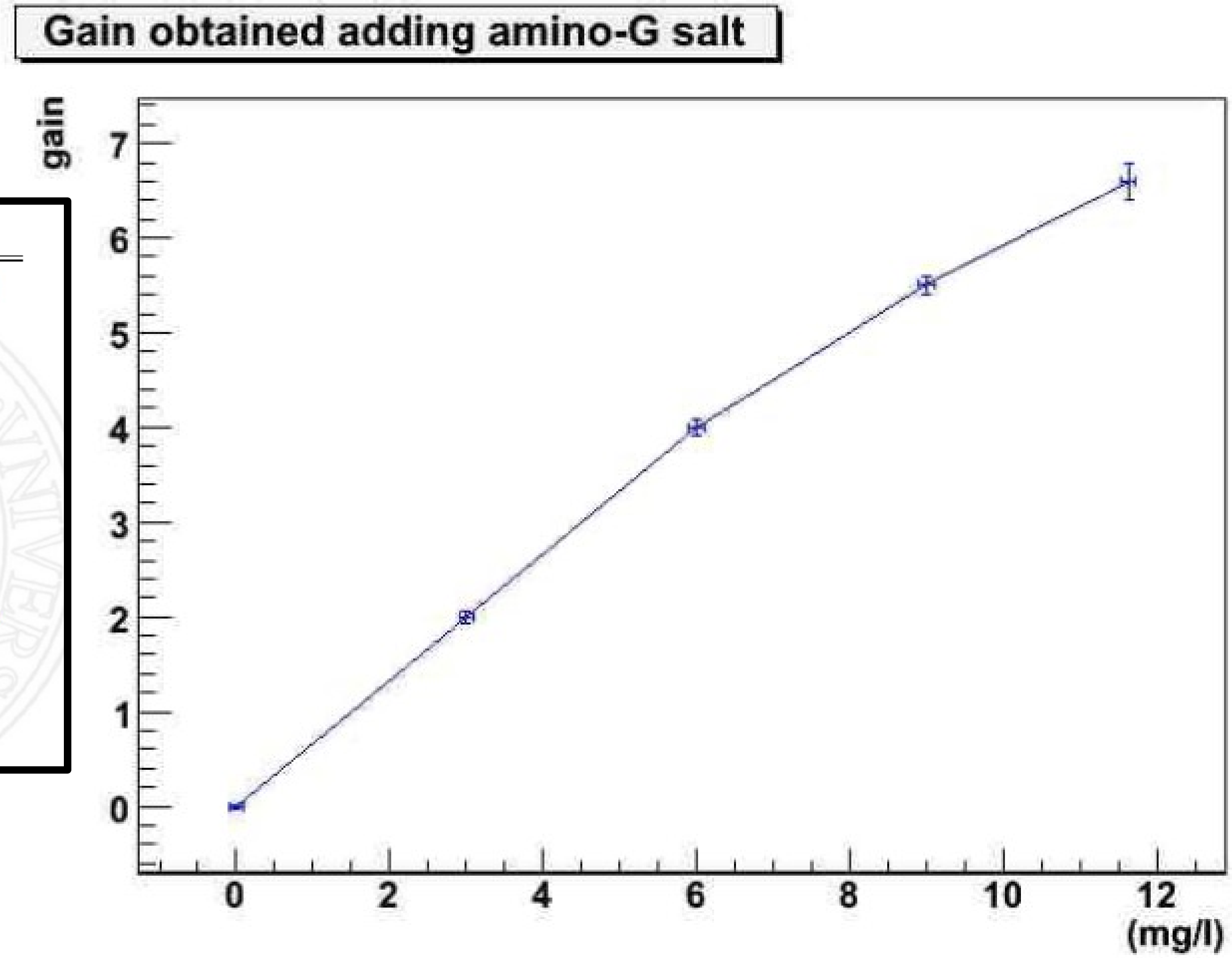
CARATTERIZZAZIONE DI UN RIVELATORE CHERENKOV AD ACQUA PER LA RICERCA DI GAMMA-RAY BURSTS AD ALTA QUOTA

Relatore:
Prof.
OSCAR SAAVEDRA

Correlatore:
Dott.
MARCO AGLIETTA

Controrelatore:
Prof.
PIERO GALEOTTI

Candidata:
IRENE BOLOGNINO



Conclusions

ANGRA project status:

- **Neutrino Laboratory @ ANGRA is OPERATIONAL.**
- **GEANT4 simulation is running and guiding final detector design.**
- **Electronics is almost ready to production phase.**
- **PMTs are being purchased.**

(and workshops are almost to be


DOMO
ARIGATO