Angra Neutrino Project: Present Status

V Antineutrino Applied Physics Workshop
AAP-2009, Angra dos Reis
March 19, 2009

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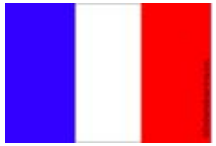
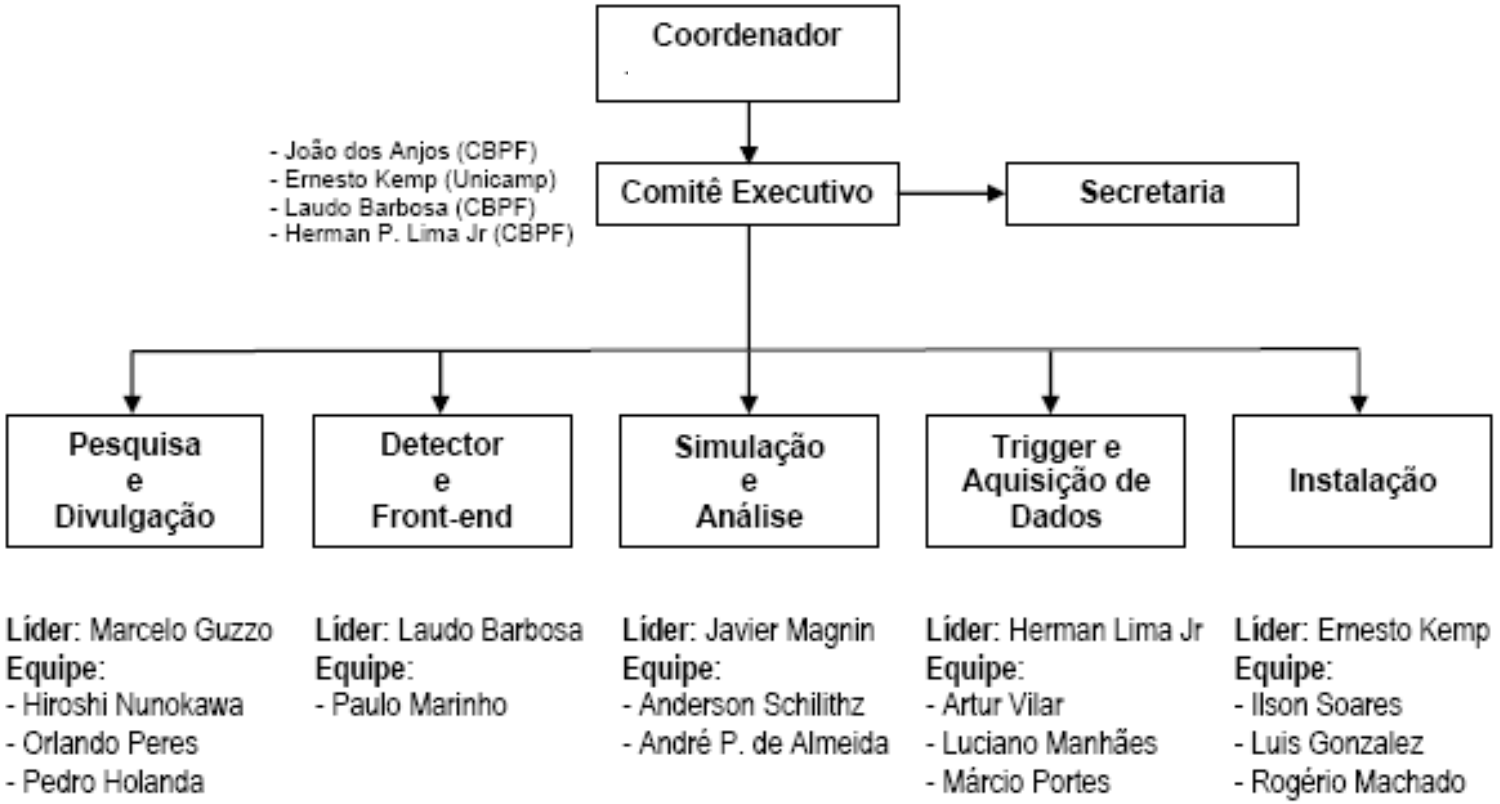


Thierry Lasserre (informal support)

Projeto Neutrinos Angra

Estrutura Funcional

20/03/2007



Angra Collaboration meetings

1st Angra Collaboration Meeting
(CBPF, May 24-25, 2007)

2nd Angra Collaboration Meeting
(CBPF, December 10-11, 2007)

3rd Angra Collaboration Meeting
(CBPF, June 04-05, 2008)

4th Angra Collaboration Meeting
(UNICAMP, December 2008)

Motivations for ANGRA

- **Very interesting for the Brazilian science:**
  - Possibility to do frontier experimental neutrino physics profiting from already existing facilities:
    Angra-I and II nuclear reactors.
  - Low cost investment compared with Angra II reactor cost
  - Possibility to do neutrino applied physics:
    nuclear safeguards applications.

Non-proliferation in Latin-America: ABACC

- Project is supported by ABACC:
- **Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC)**
- Binational agency created by Brazil and Argentina (1991), for verifying the pacific use of nuclear materials

Why the interest in antineutrino detectors?

- Search for new methods on safeguards verification
- Antineutrinos coming from different isotopes have different energy spectrum: Antineutrinos measurement may reveal in principle fissile composition of nuclear fuel
- Non-intrusive, Real Time, Remote reactor monitoring: thermal power & fissile material

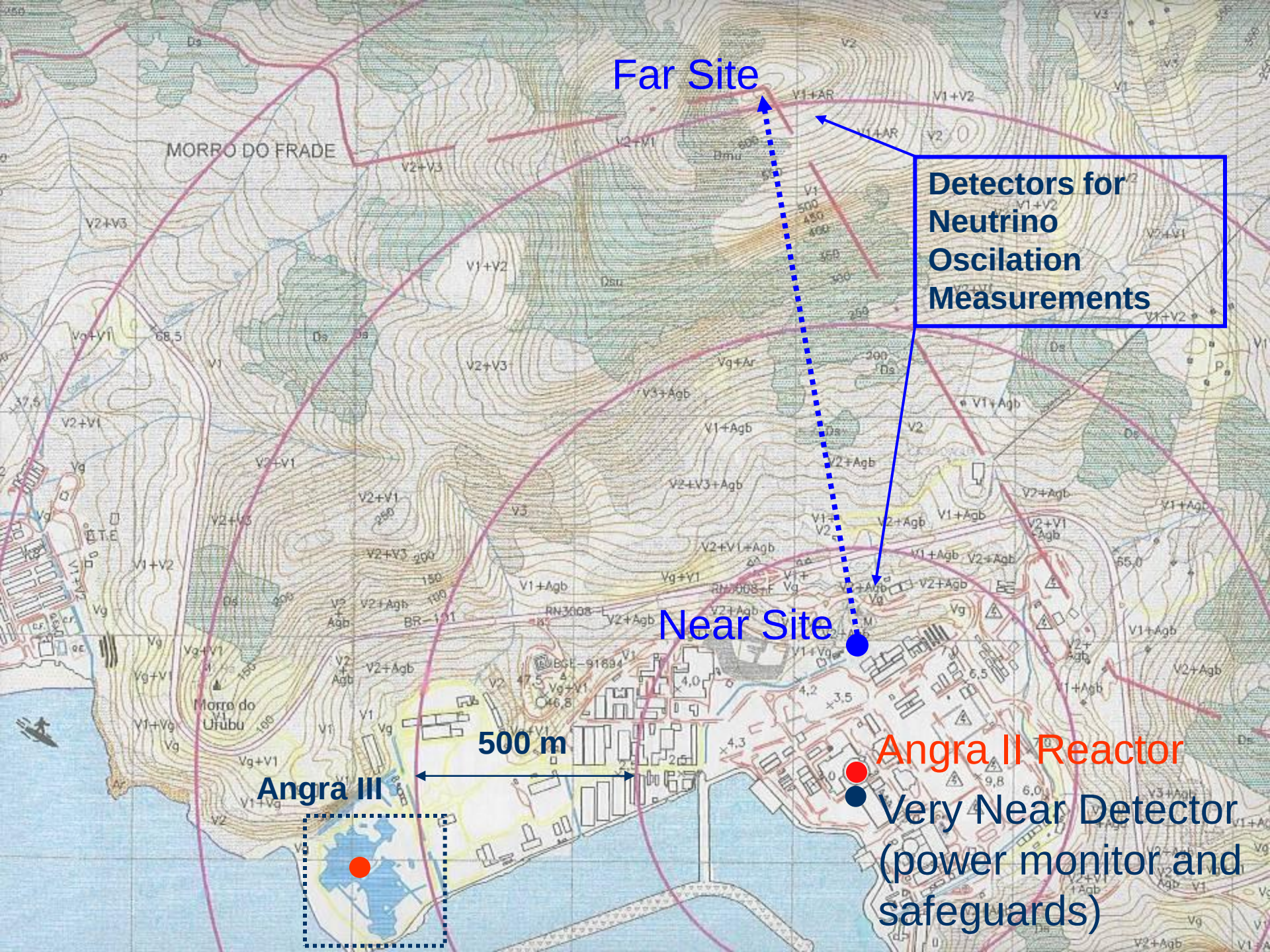
The ANGRA Neutrino Project

- **Safeguards tools development**

Angra dos Reis nuclear plant features

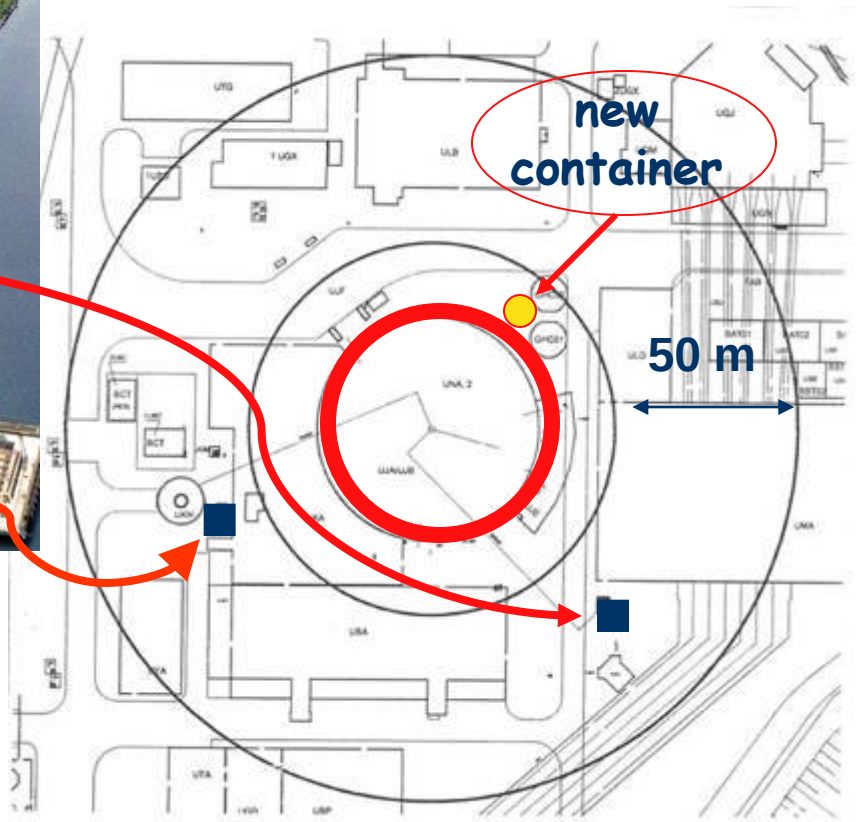
- 3 PWR Reactors: 2 in operation + 1 planned

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	-	-


Far Site
Detectors for Neutrino Oscilation Measurements
Near Site
500 m
Angra III
Angra II Reactor
Very Near Detector (power monitor and safeguards)
MORRO DO FRADE
Morro do Urubu

3-D Site View (Fluka input)

Safeguards Detector site:

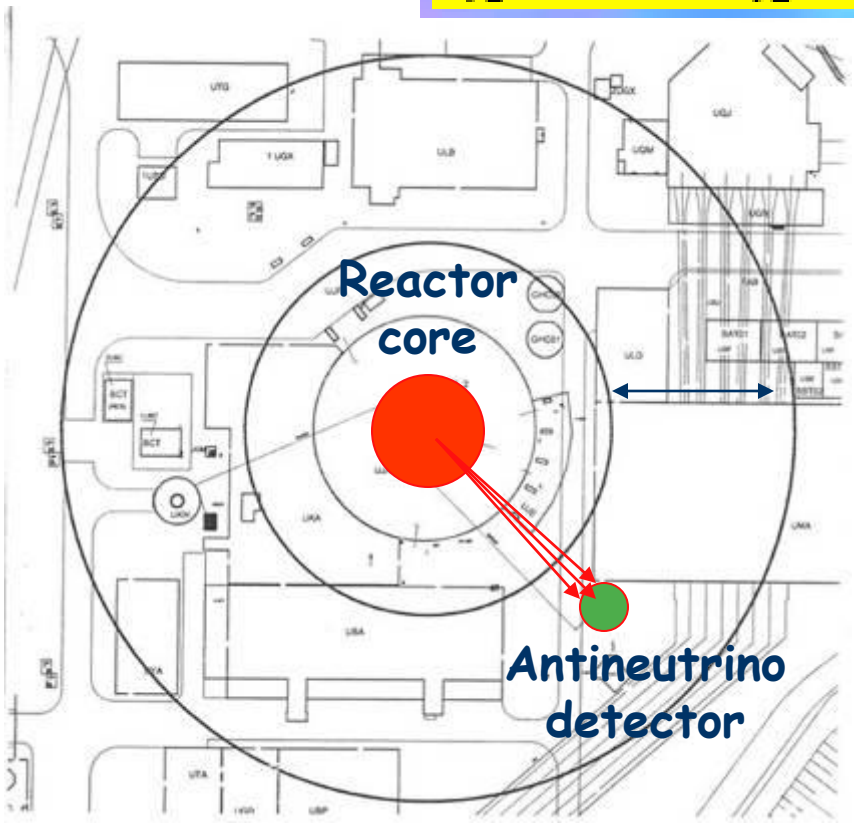


Selected Places for the

SAFEGUARDS
DETECTOR

Non intrusive method to check reactor activity

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



Plutonium production chain

Angra Project

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

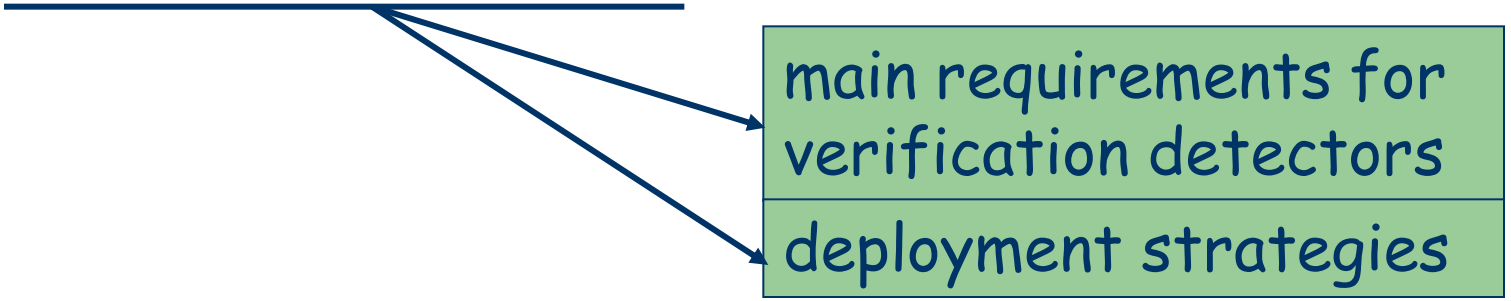
Main Requirements for Safeguards Antineutrino Detectors:

Workshop on the ANGRA detector design

(CBPF - May 16-19, 2006, Rio de Janeiro – BR)

- Prescriptions

discussions ↔ agreements



Workshop Prescriptions: SANDS & ANGRA approaches:

- SANDS (+)
  - Simple
  - Robust
  - Well known technologies
  - Easy to be adapted in a compact design

- ANGRA (+)
  - High performance
  - State-of-Art of antineutrino detection (Chooz, KamLAND)
  - Foot-print: at least the same as current experiments

- SANDS (-)
  - Restricted performance

- ANGRA (-)
  - Complex
  - Development Stage

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)

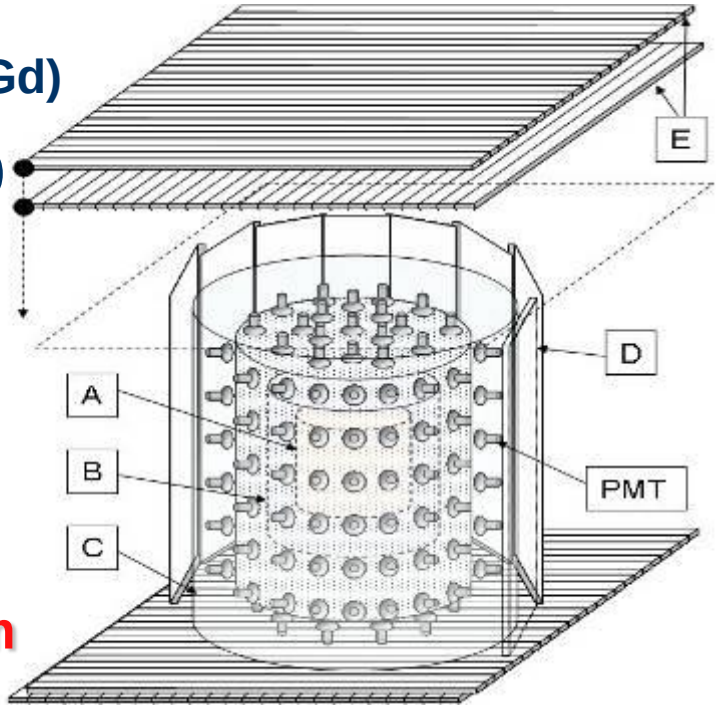
- **Steel vessel + mineral oil**

D) Vertical Tiles of Veto System

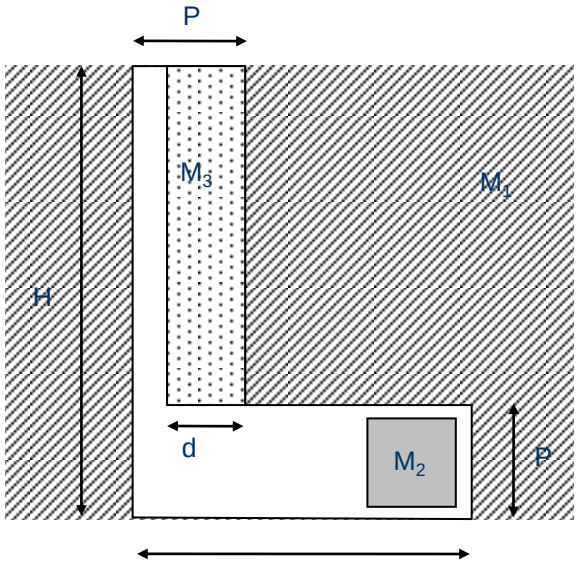
E) X-Y Horizontal Tiles of Veto System

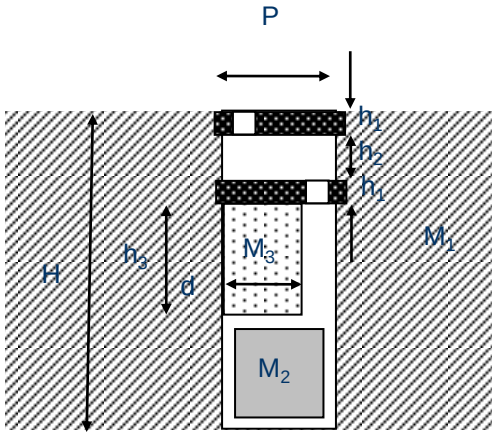
- **Plastic scintillator paddles**

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



Underground laboratory: 2 designs to ELETRONUCLEAR





	Arquitetura (a)		Arquitetura (b)		comentário
	Configuração I	Configuração II	Configuração I	Configuração II	
H	20m	12.5m	20m	12.5m	Supondo densidade 2 para o solo
P	5.5m	5.5m	3.5m	3.5m	0.5m livre em torno do detector
d	4m	4m	2m	2m	
L	12m	-	10m	-	
h_1	-	1m	-	1m	densidade do material ≈ 7
h_2	-	2m	-	2m	
h_3	15m	7.5m	15m	7.5m	

Expected Signal & Background

Cylindrical Detector dimensions
R_3= 1.40m; H=3.10m target=1ton

Distance (m)	Signal(day^{-1})
60	1270
70	933
80	714
90	564
100	457

Depth (mwe)	Muons (Hz)
20	755
30	450
40	350
50	245
80	110

FINEP - Funding Agency Present Status

- Project presented to the Minister of Science and Technology in September 2006, who then gave the "GO AHEAD"
- Detailed project presented to funding agency FINEP in December 2006
- Project Neutrinos Angra approved by FINEP Board of Directors in March 05, 2007 ~ 0.5 million dollars
- Contract FINEP-CBPF finally signed in November 06, 2007
- Funds already available: 1st installment in December 2007

Diário Oficial da União - Seção 3

Nº 218, terça-feira, 13 de novembro de 2007

Espécie: ENCOMENDA VERTICAL PROJETO DE PESQUISA (01.07.0454.00) ref. n.º 5197/06; Data da Assinatura: 06/11/2007; Partes: Financiadora de Estudos e Projetos - FINEP; CNPJ n.º 33.749.086/0001-09 e Fundação de apoio ao Desenvolvimento da Computação Científica - FACC; CNPJ n.º 06.220.430/0001-03; Objeto: NEUTRINOS ANGRA; Valor: R$ 942.843.60; Empenho: 2007NC002266 e 2007NC002267; Programa de Trabalho: 4884; Natureza da Despesa: 33.90 e 44.90; Fonte: Recursos Ordinários (0100); Executor/Co-Financiador: R$ 1.800.000,00 sob a forma de recursos financeiros e R$ 240.000,00 sob a forma de recursos NÃO financeiros; Prazo de Vigência e Execução Física e Financeira do Projeto: até 24 (vinte e quatro) meses, a partir da data da assinatura do Convênio; Prestação de Contas Final: até 60 (sessenta) dias, contados da data do término da vigência, conforme previsto na Instrução Normativa n.º 01/97 - STN.

Reactor Management Company Eletronuclear: present status

- Meeting in September 2006 with Eletronuclear President to define cooperation agreement and next steps.
- 1st draft Eletronuclear-CBPF-UNICAMP Agreement submitted in March 2007
- New 5-years Cooperation Agreement with modifications suggested by Eletronuclear layers submited in August 2008
- March 2008: informal authorization to place container next to the reactor building to start background measurements.

NEUTRINOS ANGRA Project

23/09/2008

conteiner: 1st laboratory in Angra

Phase I:
Setup infrastructure at the Angra site:

- 20' container

near reactor building

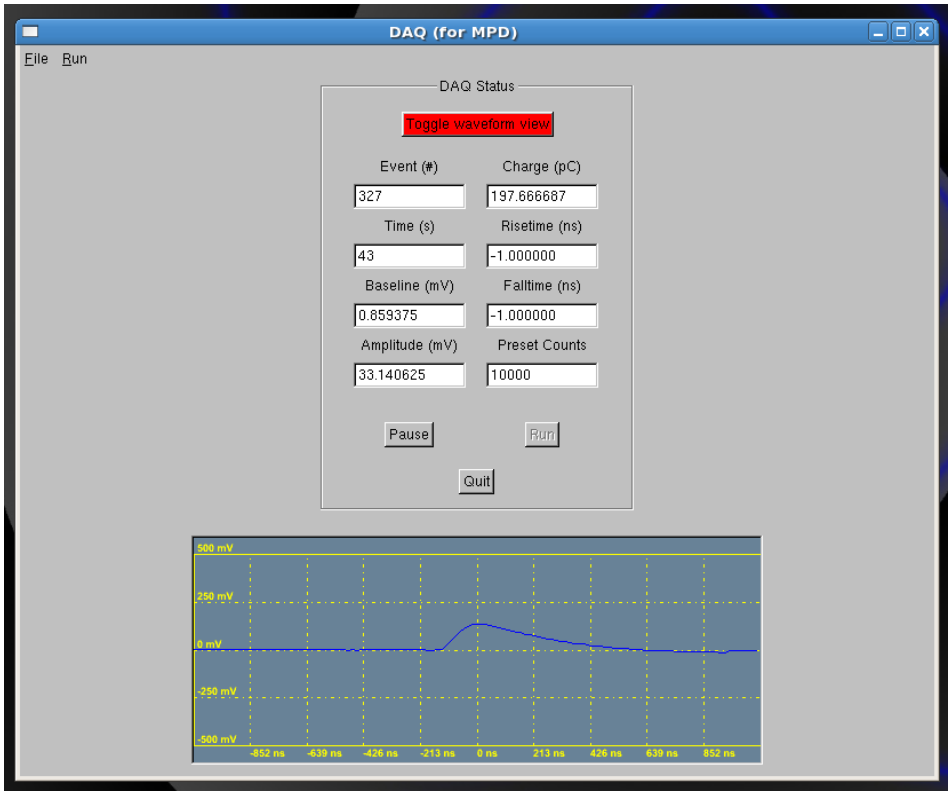
- Measurement of local muon flux: Cerenkov detector

(Auger test tank)

- Remote data acquisitio

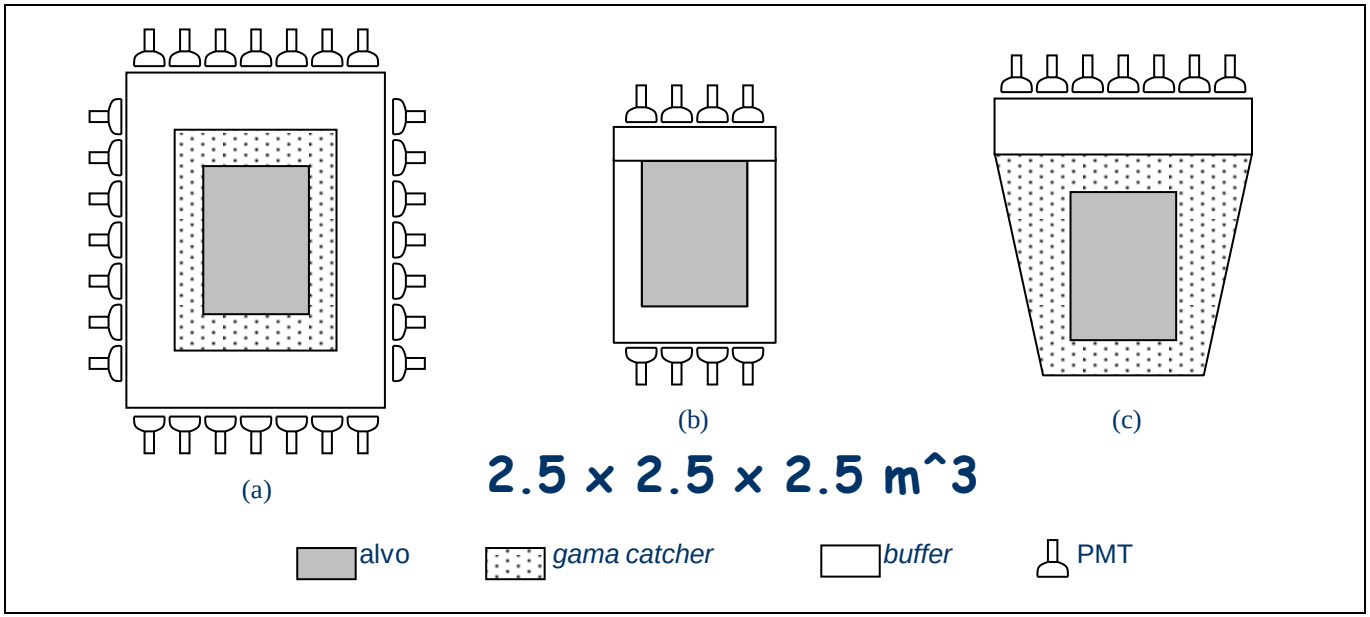
5 IP's in Eletronuclear network

Cerenkov muon detector: Remote DAQ system working



Detector geometries:
High performance x simple & small

4.5 x 4.5 x 4.5 m^3



Simulations are underway to decide the best configuration:
minimum size + good energy resolution

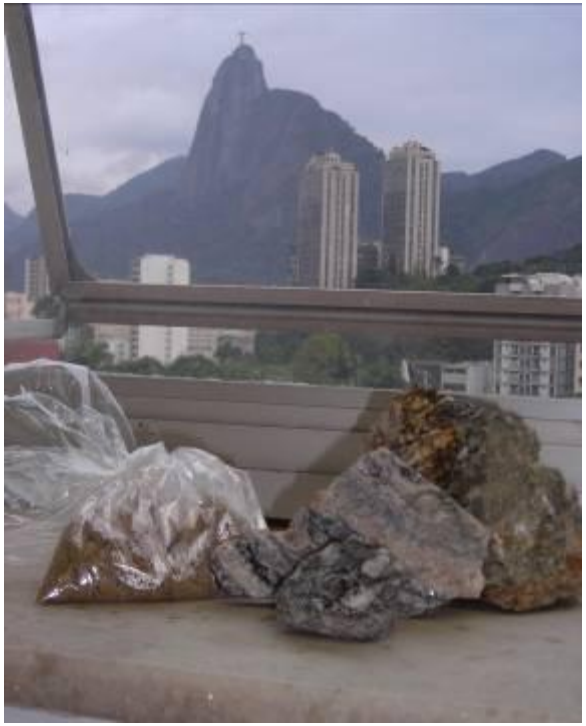
R&D Phase I:

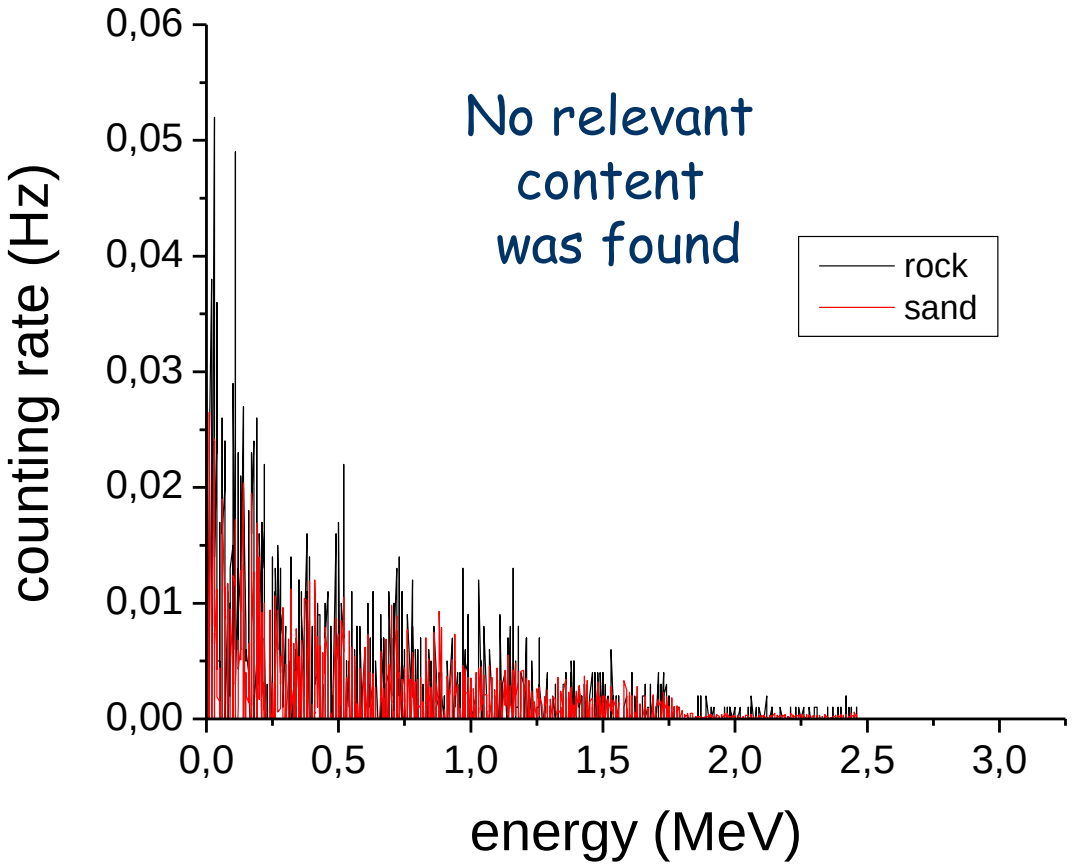
Setup infrastructure at CBPF & UNICAMP:

Started testing of components at CBPF and UNICAMP:

- **Central detector:** test 8" phototubes
- **Muon veto:** test 64-channel PMT's
- **DAQ:** design VME electronics
- **High Voltage:** design power supply
- **Radioactivity background:** test local material
- **Network communications:** build infrastructure

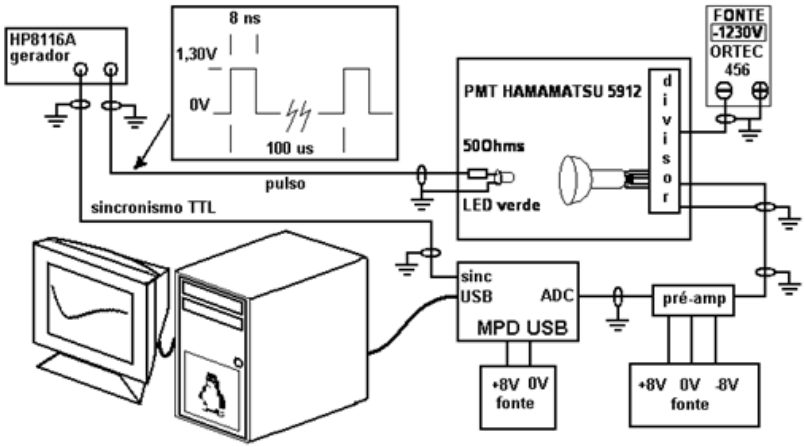
R&D Phase I:
Radioactivity Background (rock & sand)

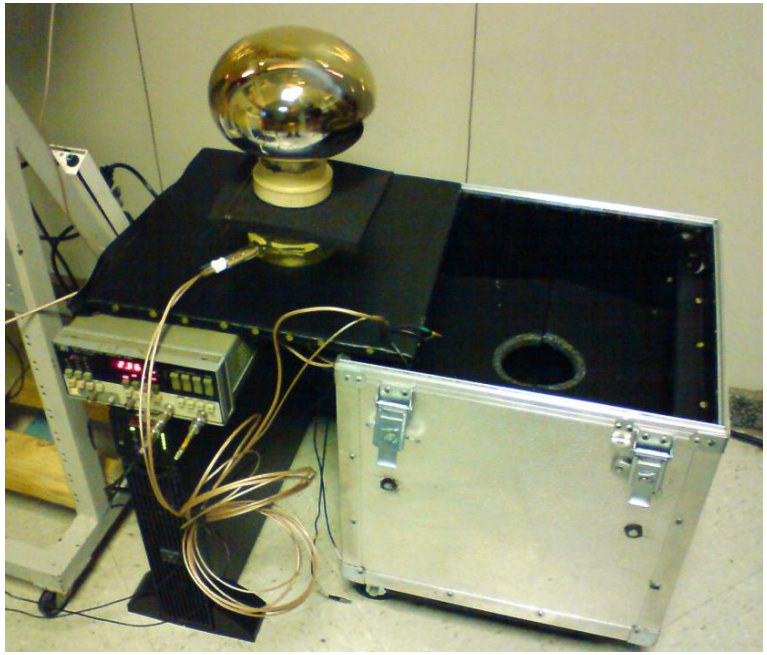




R&D Phase I at CBPF:

Photomultiplier characterization

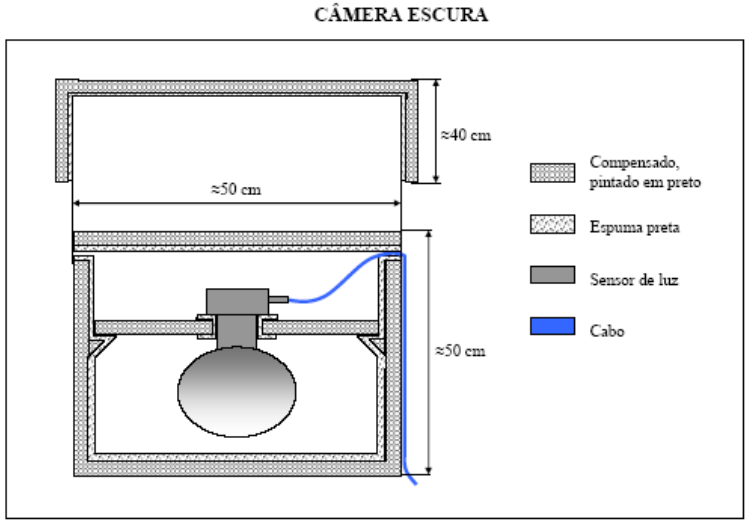


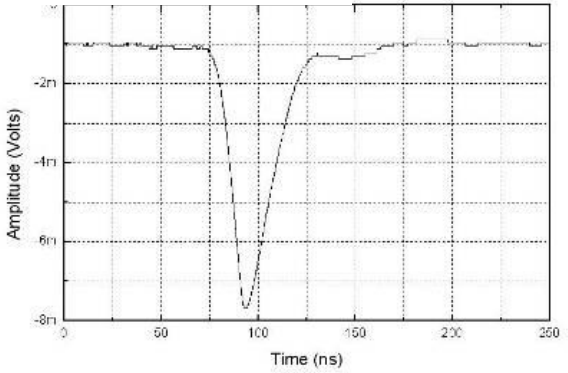


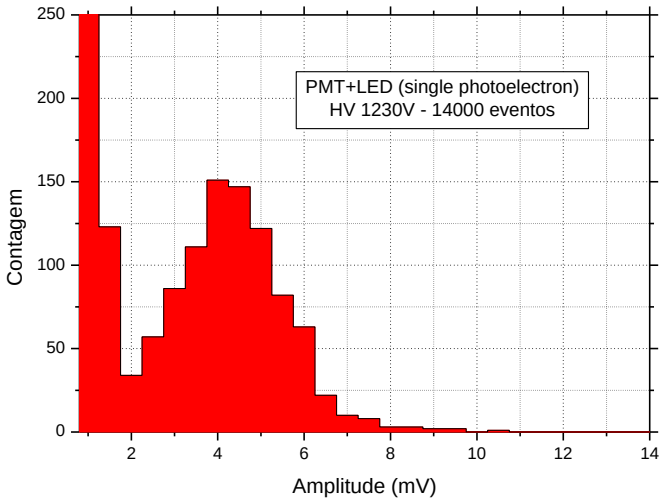
R&D Phase I at CBPF:

Photomultiplier characterization

- Hamamatsu R5912 (8")







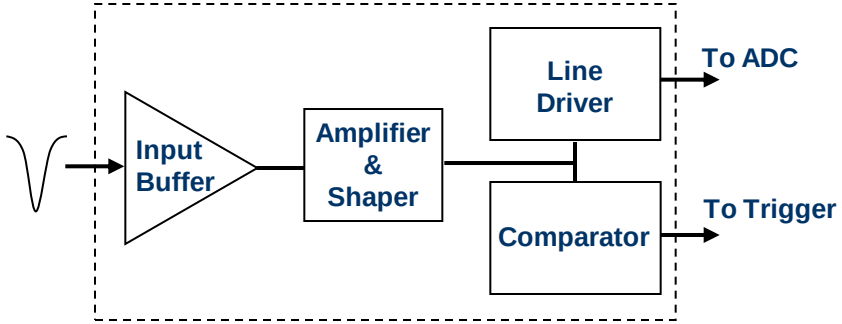
Tipical Signal, *100MHz* digital osciloscope rise time ≈*15ns*, duration ≈*30ns* (FWHM)

Low amplitude, wide band ⇒ needs preamplifier

Sampling with ADC *100MHz* ⇒ needs *shaping circuit*

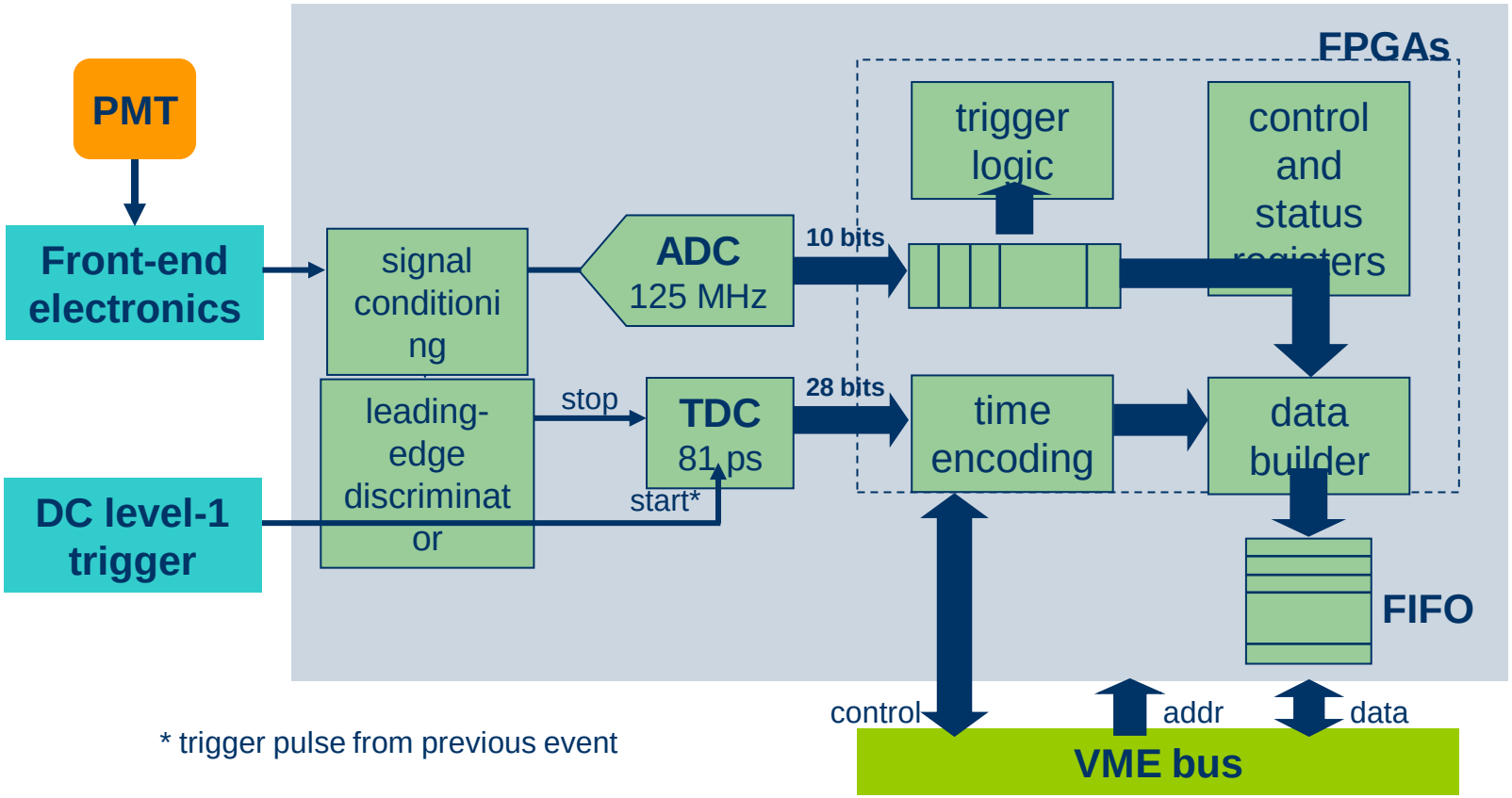
Phase I: Electronics & DAQ

- Front-end electronics
  - ✓ input buffer + amplifier/shaper
  - ✓ To ADC: + line driver
  - ✓ To Trigger system: + comparator



- Data Acquisition (DAQ)
  - ✓ VME-based
  - ✓ off-the-shelf high-performance devices (ADCs, FPGAs, FIFOs)
  - ✓ two sub-systems: neutrino signal / VETO
  - ✓ Neutrino: ~ 120 input channels sampled at 250Msps / 10-bit resolution
  - ✓ VETO: ~ 110 LVDS signals to a large/fast FPGA (Stratix II)

Muon electronics conceptual diagram:



* trigger pulse from previous event

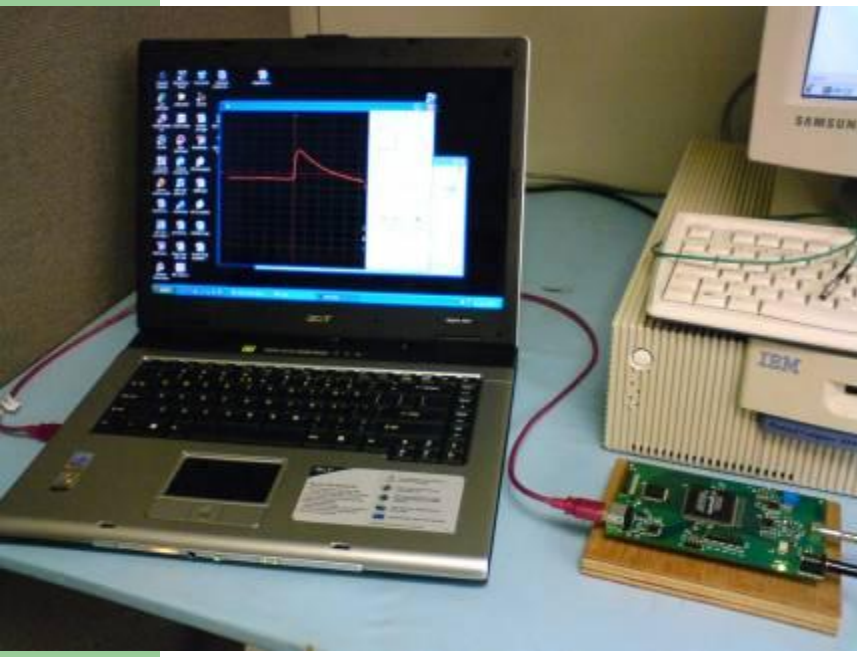
Phase I: R&D at CBPF: waveform digitizer prototype

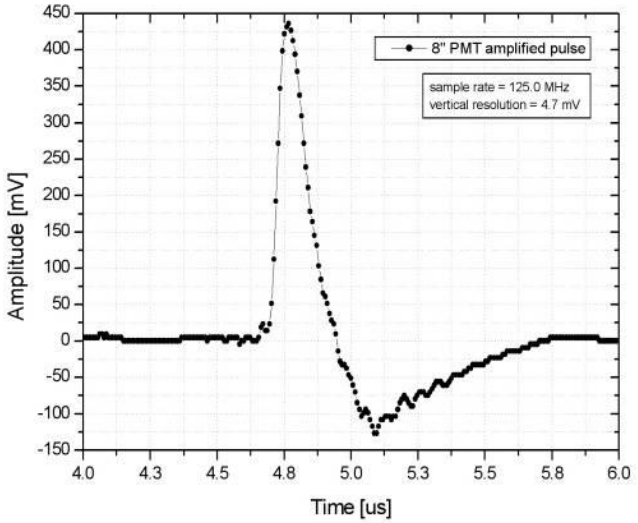
- 1 analog input channel (ADC)
  - sample rate = 125 MHz
  - dynamic range = 1.2 Vpp
- 8 time-measurement channels (TDC)
  - time resolution = 81 ps
  - dynamic range = 9.8 μs
- 10 input/output digital channels
- USB 1.1 compliant (~1 MB/s)
- programmable hardware (FPGA)

3 prototypes fully assembled

Prototype tests

ADC tests





TDC tests

computed resolution = 82.3 ps

START-STOP applied (ns)

START-STOP measured (ns)

Palavra lida do TDC para StartOffset = 0000H

Delay Gerador (nS)	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Valor Hexa	Valor Lido x 82,3045pS (nS)
100	0	0	0	0	0	0	1	0	0	1	0	1	1	1	0	0	X	4B8h	99,42
200	0	0	0	0	0	1	0	0	1	0	1	1	1	X	X	X	X	0970h	198,85
300	0	0	0	0	0	1	1	1	0	0	0	1	1	X	X	X	X	0E30h	298,93
400	0	0	0	0	1	0	0	1	0	1	1	1	1	0	1	X	X	12F4h	399,41

TDC results

Linearity in the lowest **1ns range** (steps of 100ps)

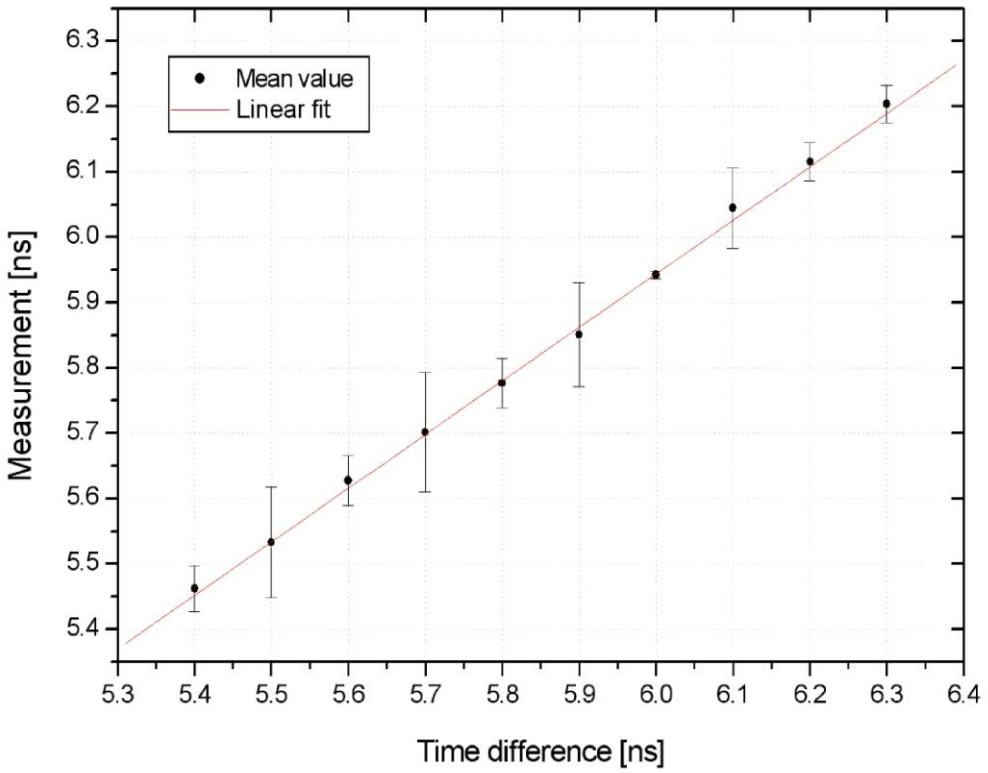
- setup:
  - testing only channel 1 of the TDC
  - START&STOP pulses generated by a dual-channel generator (AFG-3252 - Tektronix)

- errors due to skew between channels not taken into account

- statistics: 76200 measurements per time difference

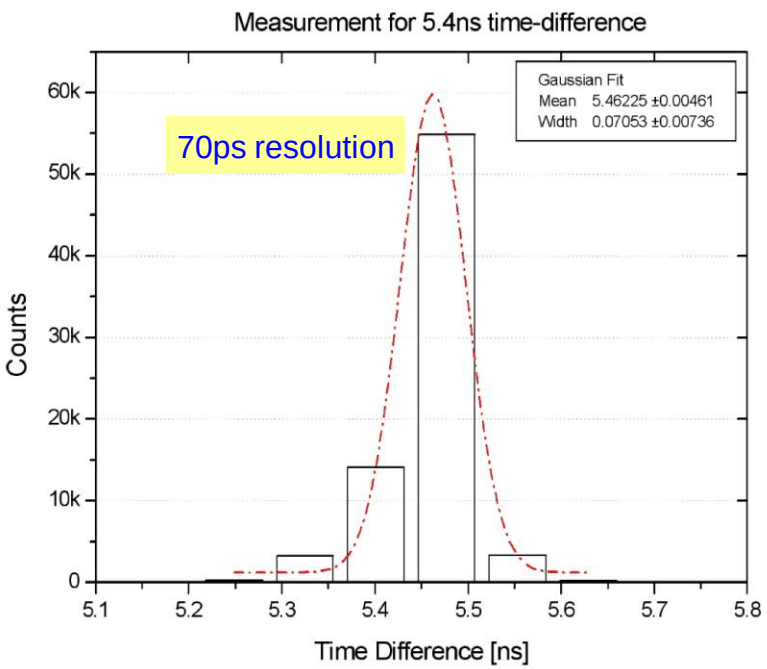
- first input configuration is 5.4ns due to TDC lower-limit specification

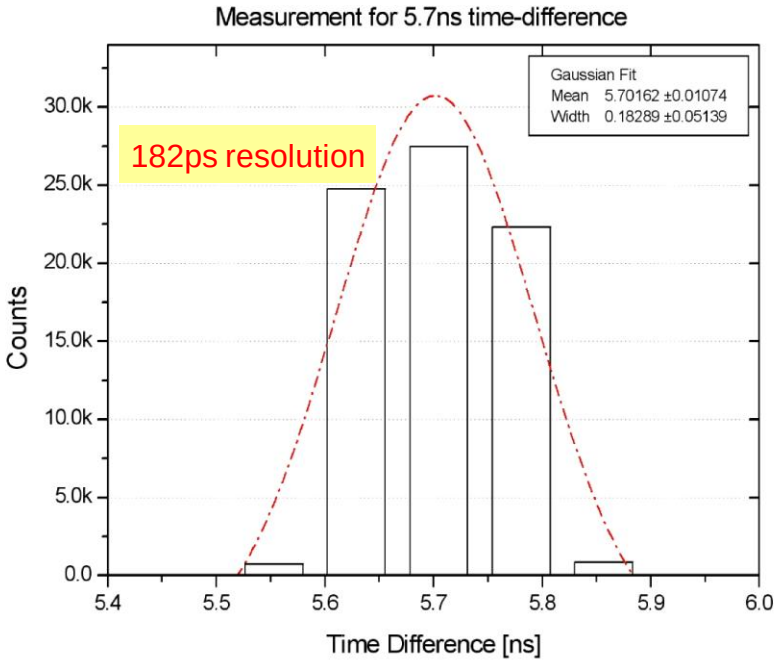
- **maximum error = 1.52%** (deviation from mean)



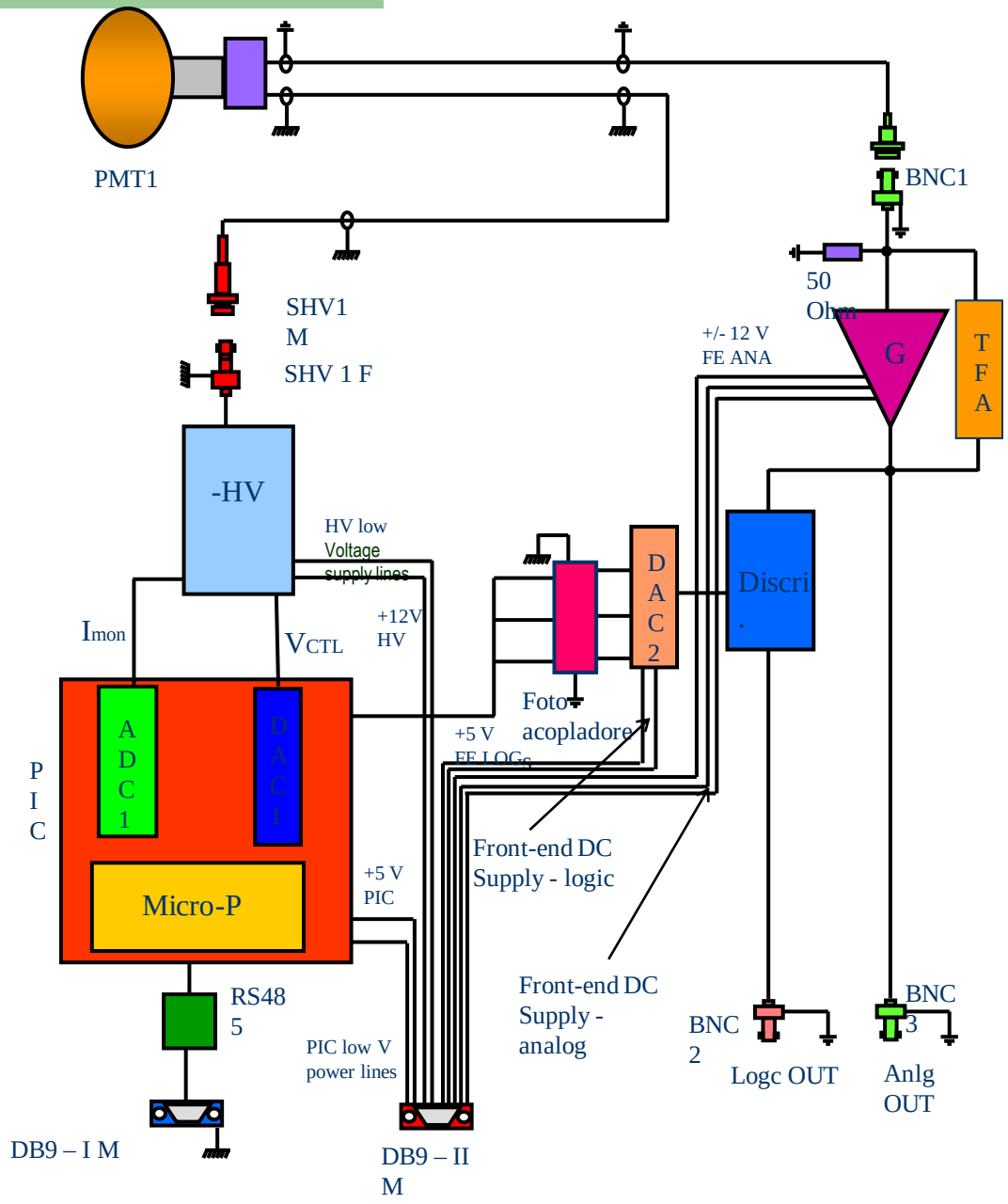
TDC results

Resolution in the lowest **1ns range**





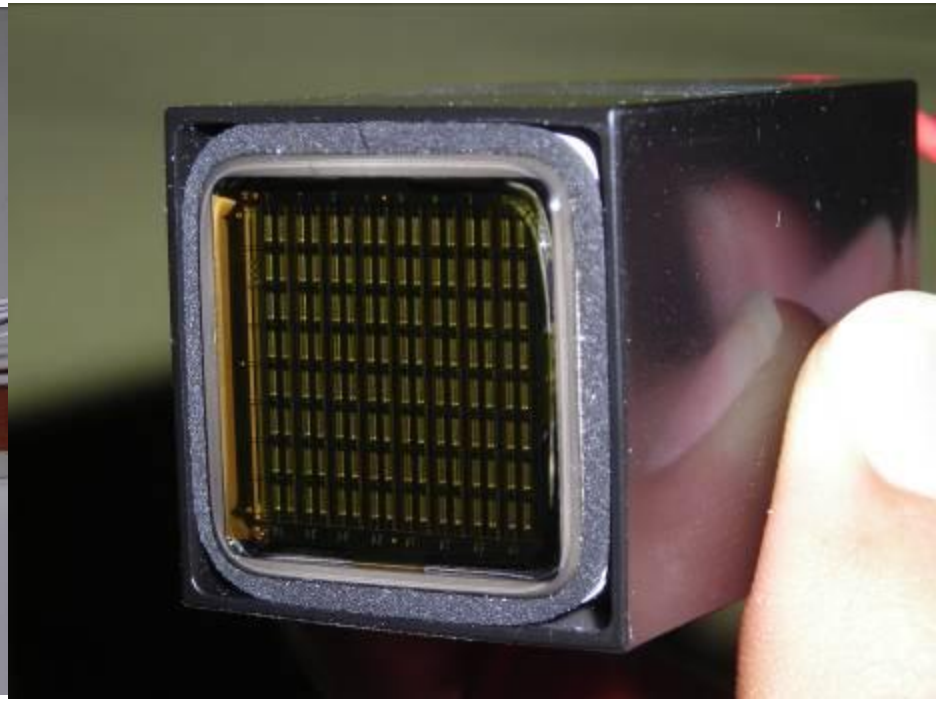
Front-end Integration



- Based on PIC microcontroller to set HV and Pre-Amp parameters
- HV and pre-amp decoupled by optoelectrical device: noise supression

Phase I: R&D at CBPF:
Outer muon veto tests

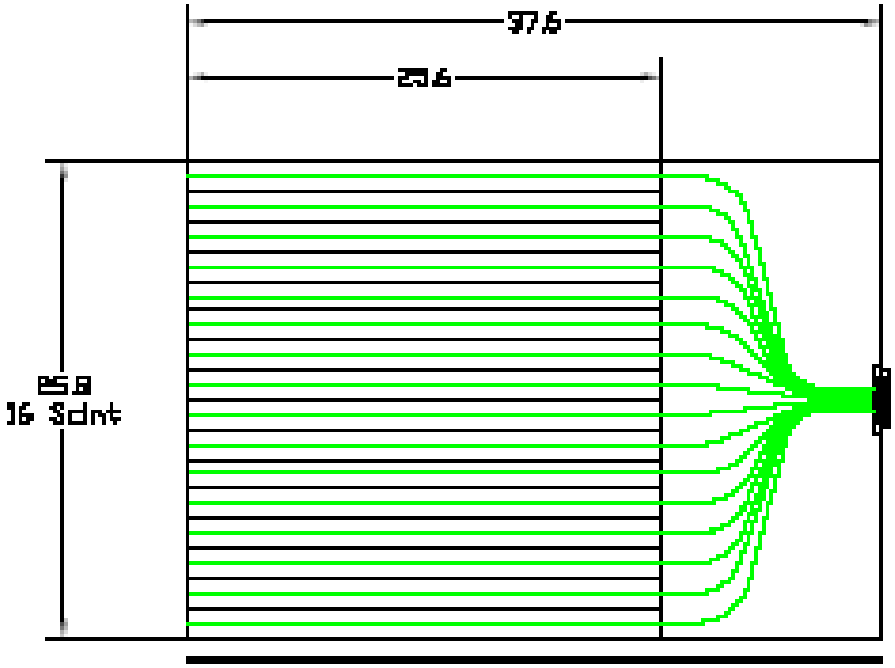
- 64-channel photomultipliers **Hamamatsu R8520**

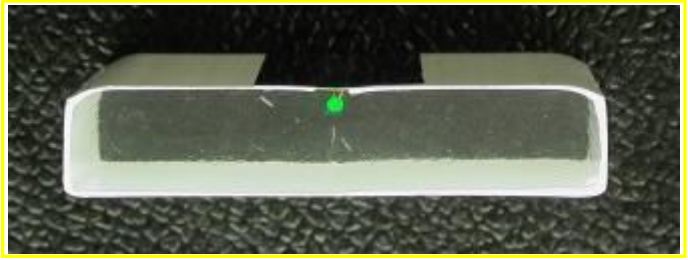


Phase I: R&D at CBPF:

Outer Muon Veto tests

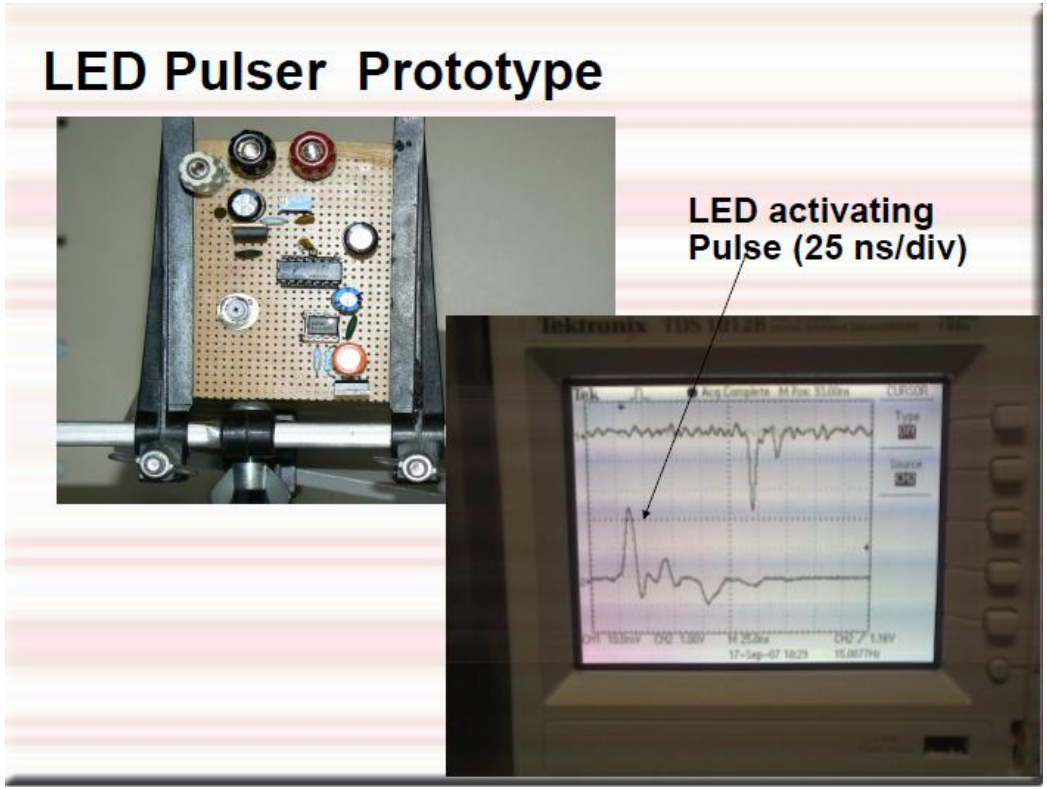
- Muon telescope: 4 planes (Minos type scintillator)
- September2008: 270 scintillator strips: 1.6m x 5cm x 1cm



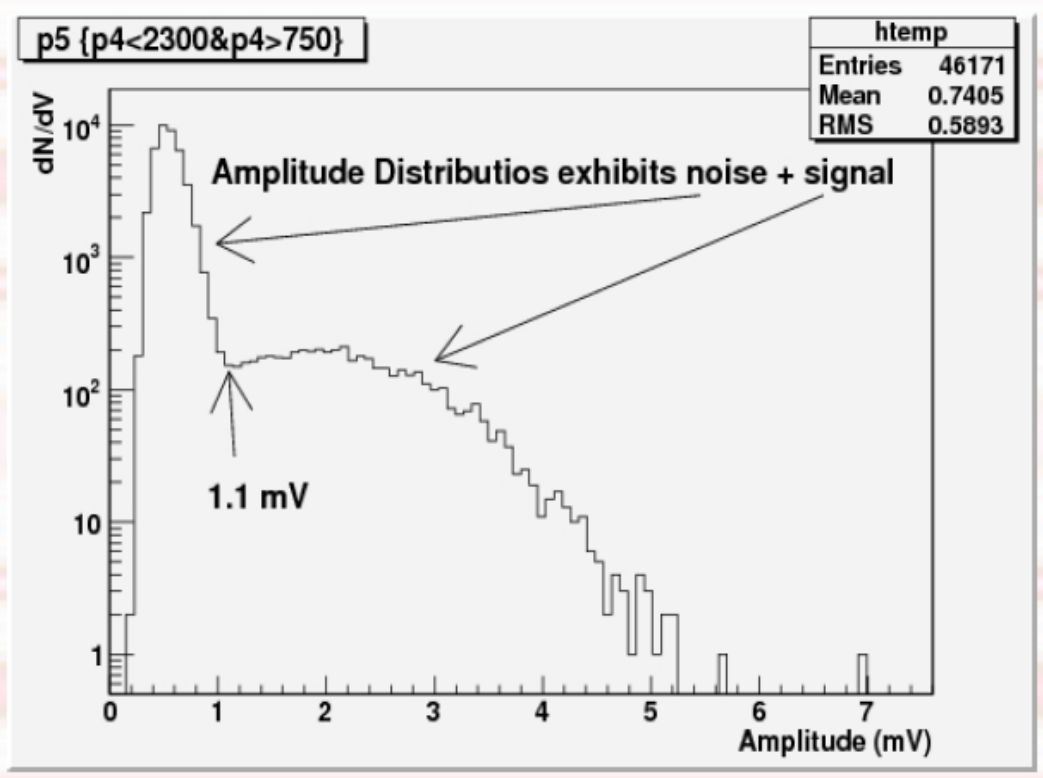


Scintillating strips with WLS fibers to test PMTs

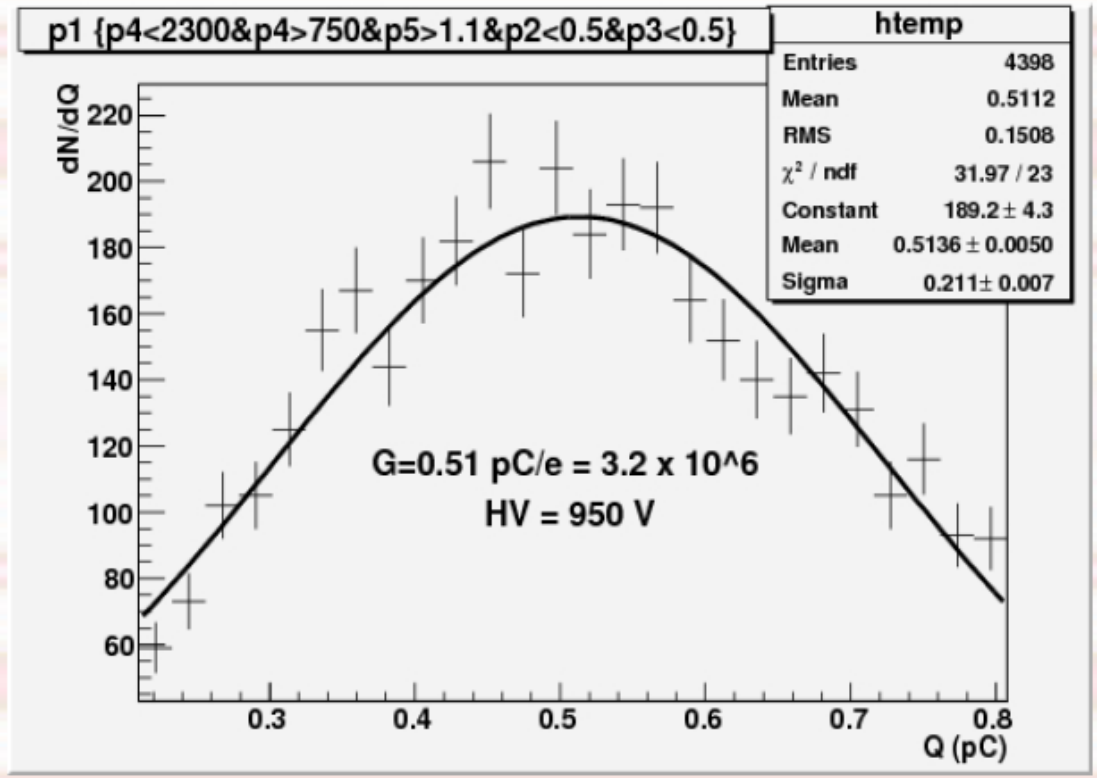
Photomultiplier Tubes Testing and Characterization



Preliminary Results 1



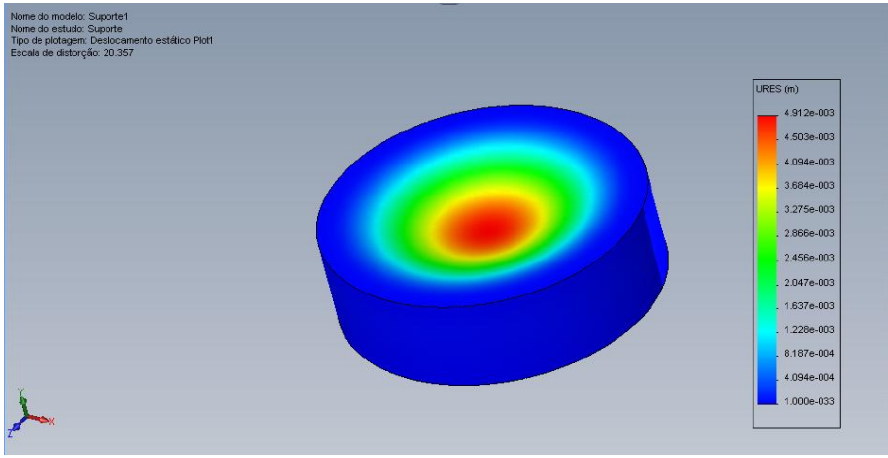
Single Photoelectron Charge Amplification

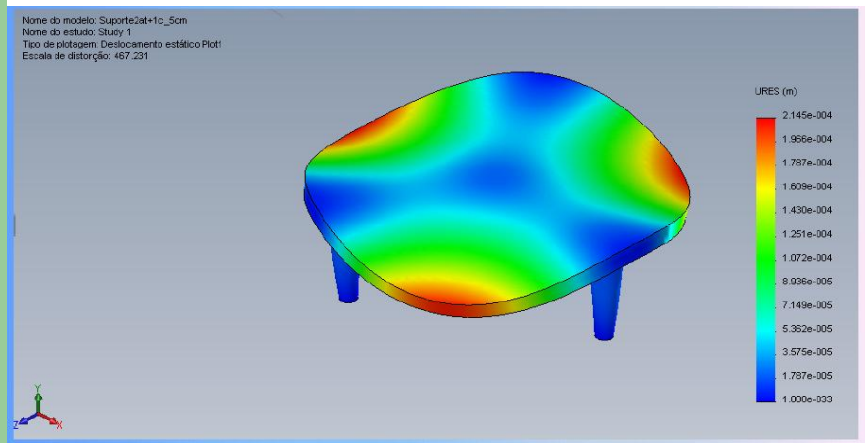


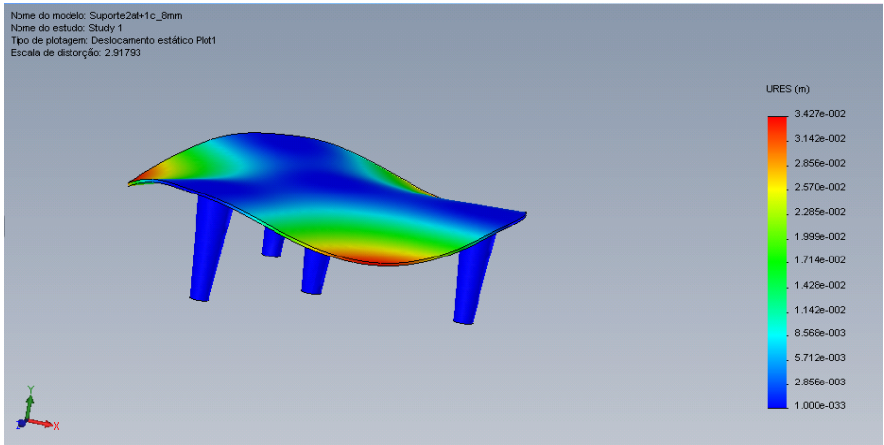
Project of the detector structure

Calculations of mechanical

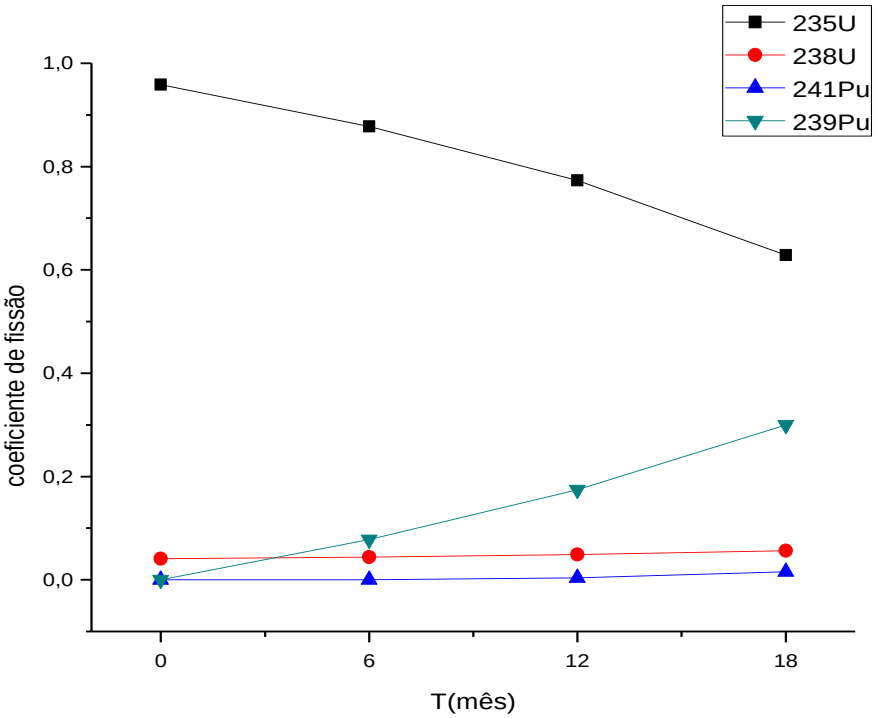
stress on the vessel botton lid







Reactor fuel evolution



R&D:
creation of ANGRA NOTES

Angra Neutrino Project

AngraNote 004-2007

Measurements of Signals from Muons Crossing the Hamamatsu R5912 PMT Enclosure Vertically and Horizontally

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Conclusions

- Previous experiments demonstrate a good capability of using antineutrinos for nuclear reactor distant monitoring.
- First Angra neutrino lab has been deployed.
- New neutrino detector design under development.
- Strategy: First step: on-off measurement
  Second step:thermal power measurement
  Third step: energy spectrum analysis
- Good opportunity to develop experimental neutrino physics in Brazil and to contribute to new safeguards techniques.
- Short baseline Neutrino Oscillations :
  Collaboration with Double Chooz
  High precision experiment for theta13 around 2013?

Good opportunity for Collaboration with IAEA!

janjos@cbpf.br

ANGRA III “preview” by T. Lassere - 2005

Workshop Prescriptions: SANDS & ANGRA synthesis

- SANDS (+)
- ANGRA (+)

Coordinate Effort:
following 2 different approaches

The "*Ideal Detector*":

- **High Performance**
- **Robust**
- **Compact**
- **...**

Faster and Cheaper Development !!!

Preparação de amostras do líquido cintilador

Primeiras amostras com LAB

(produzidas no estágio de Patrick Pfahler)

Testes:

CBPF,

UFABC,

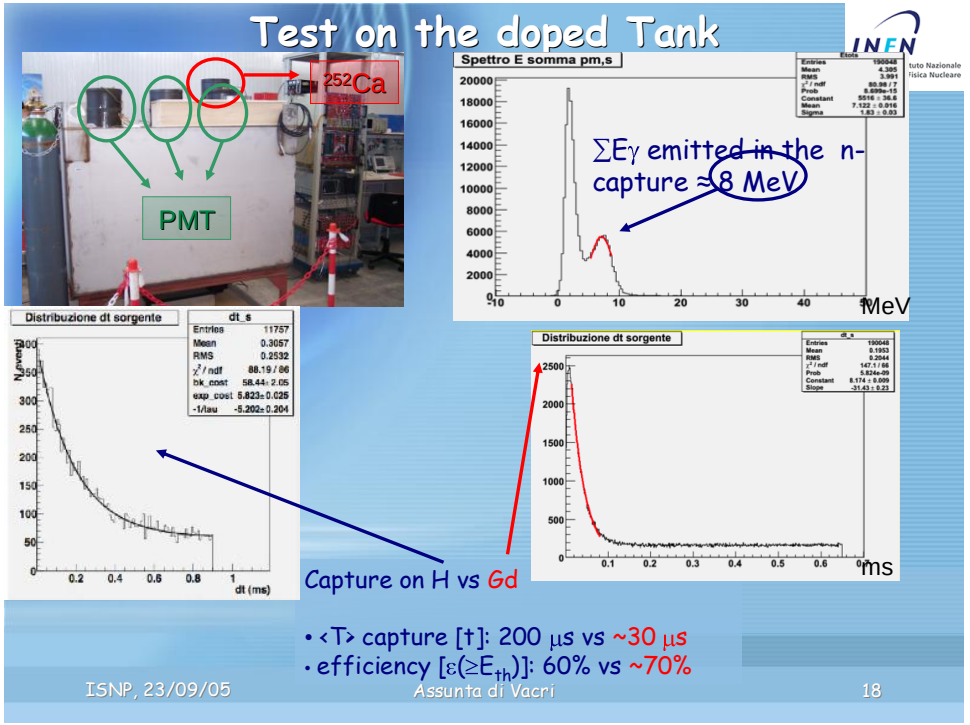
Unicamp

Surface tank

- 1-ton Gd-dopped liquid scintillator tank

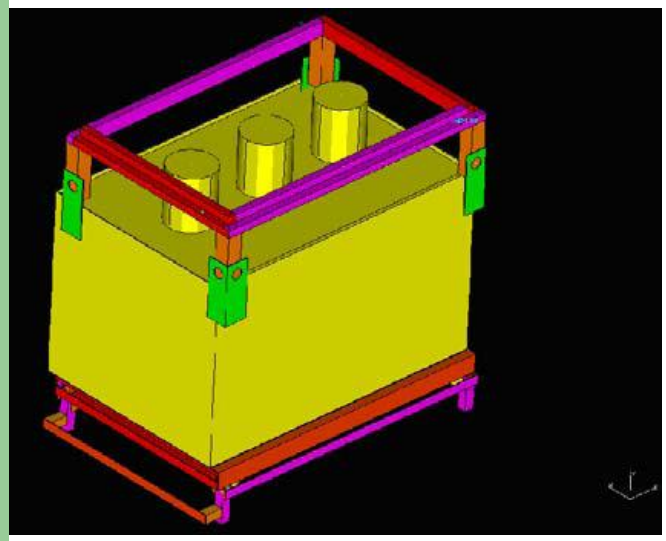
- test signal+background with Californium source

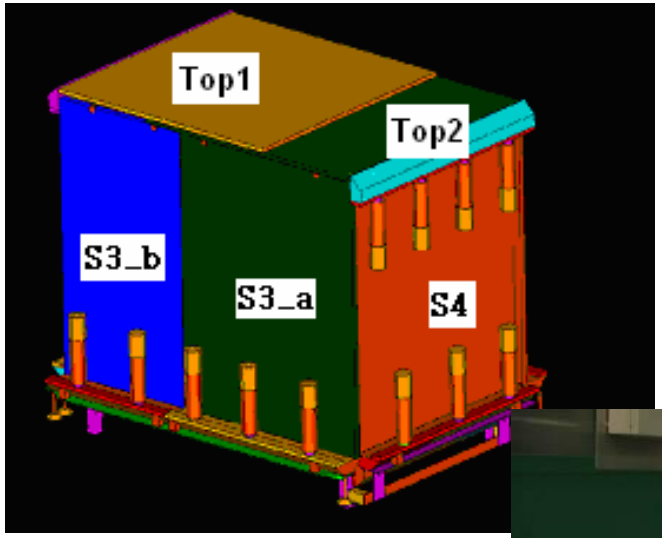
- Good performance, but high flashpoint



surface tank

Muon veto construction at LNGS





Muon Rates at ground level

Realizzazione di un veto su 4π a scintillatori plastici per misure in superficie con un modulo LVD drogato con Gd

M. Aglietta[1,2], A. Bonardi[2,3], G. Bruno[2], A.Giuliano[1,2]

termine delle prestazioni del nostro rivelatore. A tale scopo, presso la centrale da 4 GW_{th} della Elettronuclear ad Angra dos Reis (Brasile), la collaborazione LVD ha in allestimento un laboratorio distante 30 metri dal "core del reattore". La collocazione "in

Modulo	Spess. (cm)	Superf. (m^2)	Soglia D_{98} (mV)	Efficienza p.p.	Rate (Hz)
S1_a	3	1.4	40	99.3%	540
S1_b	3	0.98	40	99.8%	440
S2	3	1.54	40	99.7%	650
S3_a	3	1.4	40	99.1%	540
S3_b	3	0.98	40	99.8%	590
S4	3	1.54	40	99.5%	510
Bottom	3	1.62	30	97.4%*	1200
<Top1+Top2>	2	2.04	10	99.5%	1500

Conclusion: background too high, no clear signal