NESTOR

Neutrino Extended Submarine Telescope with Oceanographic Research

Leonidas K. Resvanis

NYGRENFEST, 2014

NESTOR Data Acquisition System Based on Waveform Capture

David Nygren Jerry Przybylski Jozsef Ludvig

August 13, 1998

1 Scope

This paper provides a technical description of a test data acquisition system (TDAQ) for NESTOR, to be deployed in autumn of 1998. In addition, the definition of deliverables, responsibilities and interface details is intended to serve as a memorandum of understanding between the NESTOR collaboration and LBNL. As such, this note will evolve as details become clearer and issues are resolved.

The NESTOR detector will initially consist of two floors separated by approximately 30 meters. For this deployment each hexagonal floor has a diameter of 11.8 meters, for a luminal crossing time of about 60 ns. OM pairs are placed in an up-down configuration at the vertices of the star. Thus our TDAQ must acquire and process information from 12 x 2 = 24 channels of PMT anode signals.

The primary DAQ will be supplied by a Rome group; our TDAQ will provide backup to theirs, and also provide us with experience and data useful to evaluate our technical approach. The schedule pressures dictated by the NESTOR deployment constraints (within CY 1998) drive the design goals. The underlying perspective is to develop only essential capabilities, and to forego many features that are merely desirable. We need to emphasize that success cannot be guaranteed within some optimum weather window for deployment; however, we believe that the technical challenges are manageable, and have confidence that a credible delivery date can be defined soon.

1

+ Joshua Sopher,

joined soon thereafter

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Nuclear Instruments and Methods in Physics Research A 552 (2005) 420–439
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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Operation and performance of the NESTOR test detector

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Received 2 December 2004; received in revised form 24 June 2005; accepted 30 June 2005
Available online 27 July 2005

Abstract

NESTOR is a deep-sea neutrino telescope that is under construction in the Ionian Sea off the coast of Greece at a depth of about 4000 m. This paper briefly reviews the detector structure and deployment techniques before describing in detail the calibration and engineering run of a test detector carried out in 2003. The detector was operated for more than 1 month and data was continuously transmitted to shore via an electro-optical cable laid on the sea floor. The performance of the detector is discussed and analysis of the data obtained shows that the measured cosmic ray muon flux is in good agreement with previous measurements and with phenomenological cosmic ray models.
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PACS: 95.55.Vj; 29.40.Ka; 13.15.+g

Keywords: Neutrino; NESTOR; Deep-sea; Telescope; Operation; Performance

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Astroparticle Physics 23 (2005) 377–392
Astroparticle Physics
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A measurement of the cosmic-ray muon flux with a module of the NESTOR neutrino telescope

The NESTOR Collaboration

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Received 5 January 2005; accepted 10 February 2005
Available online 11 March 2005

Abstract

A module of the NESTOR underwater neutrino telescope was deployed at a depth of 3800 m in order to test the overall detector performance and particularly that of the data acquisition systems. A prolonged period of running under stable operating conditions made it possible to measure the cosmic ray muon flux, $I_0 \cdot \cos^{\alpha}(\theta)$, as a function of the zenith angle θ. Measured values of index α and the vertical intensity I_0

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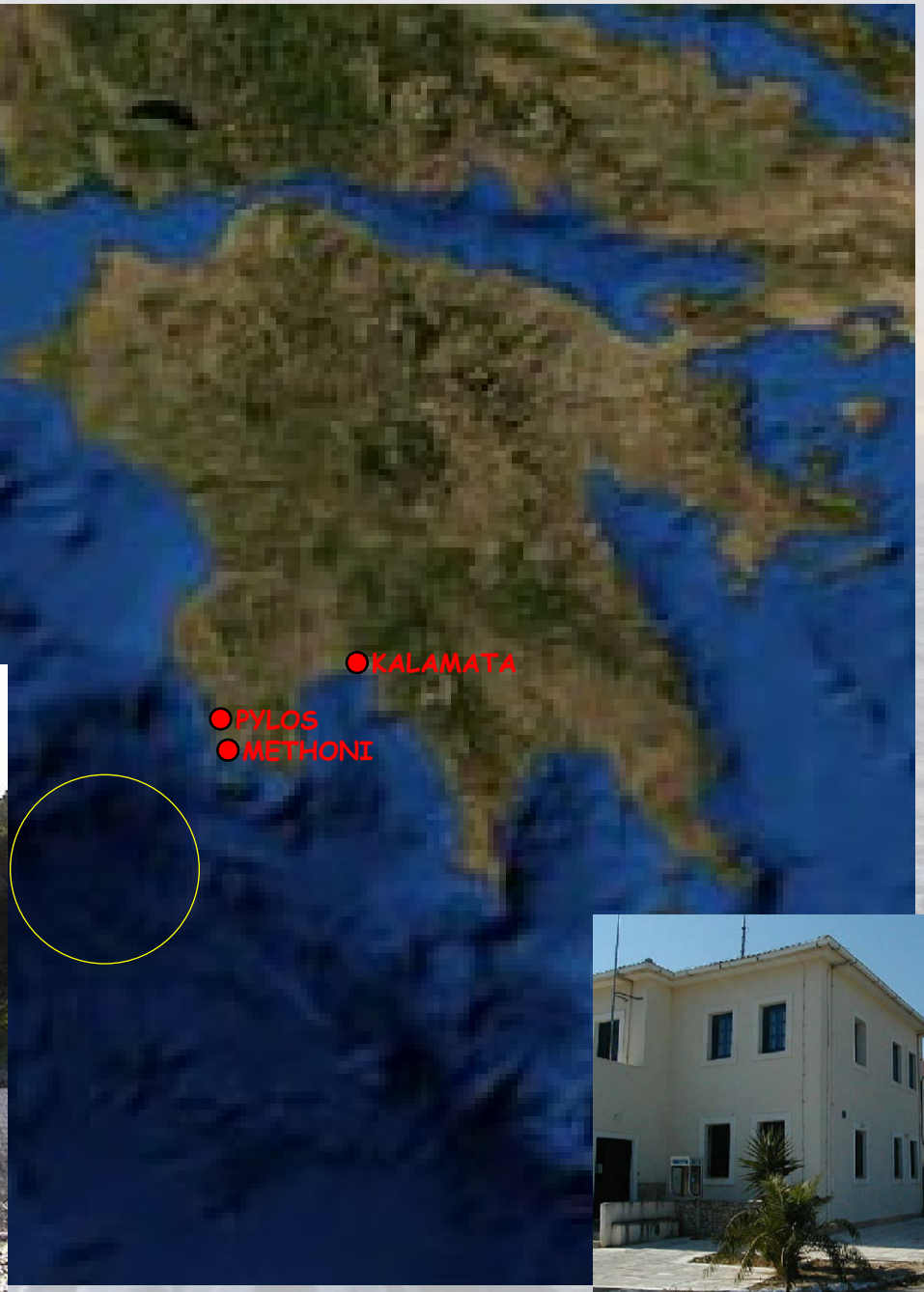
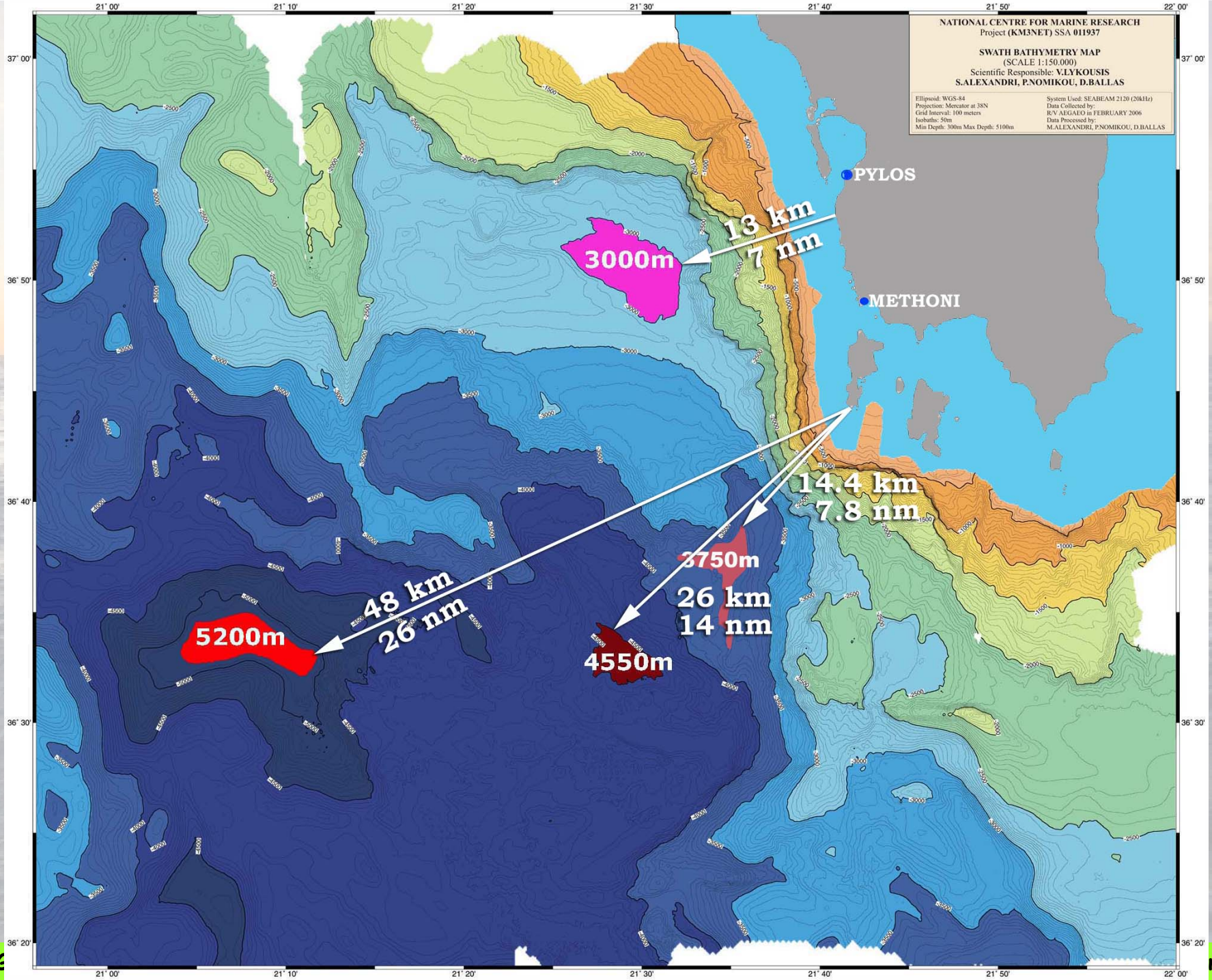
NESTOR

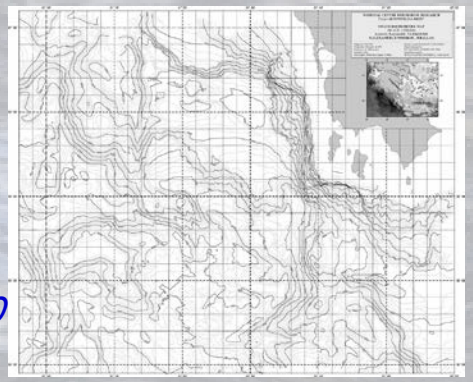



NATIONAL CENTRE FOR MARINE RESEARCH
Project (KM3NET) SSA 011937
SWATH BATHYMETRY MAP
(SCALE 1:150.000)
Scientific Responsible: V.LYKOUSIS
S.ALEXANDRI, P.NOMIKOU, D.BALLAS
Ellipsoid: WGS-84
Projection: Mercator at 38N
Grid Interval: 100 meters
Isobaths: 50m
Min Depth: 300m Max Depth: 5100m
System Used: SEABEAM 2120 (20kHz)
Data Collected by:
R/V AEGAEO in FEBRUARY 2006
Data Processed by:
M.ALEXANDRI, P.NOMIKOU, D.BALLAS
PYLOS
METHONI
13 km
7 nm
3000m
14.4 km
7.8 nm
3750m
26 km
14 nm
4550m
48 km
26 nm
5200m
21° 00'
21° 10'
21° 20'
21° 30'
21° 40'
21° 50'
22° 00'
37° 00'
36° 50'
36° 40'
36° 30'
36° 20'

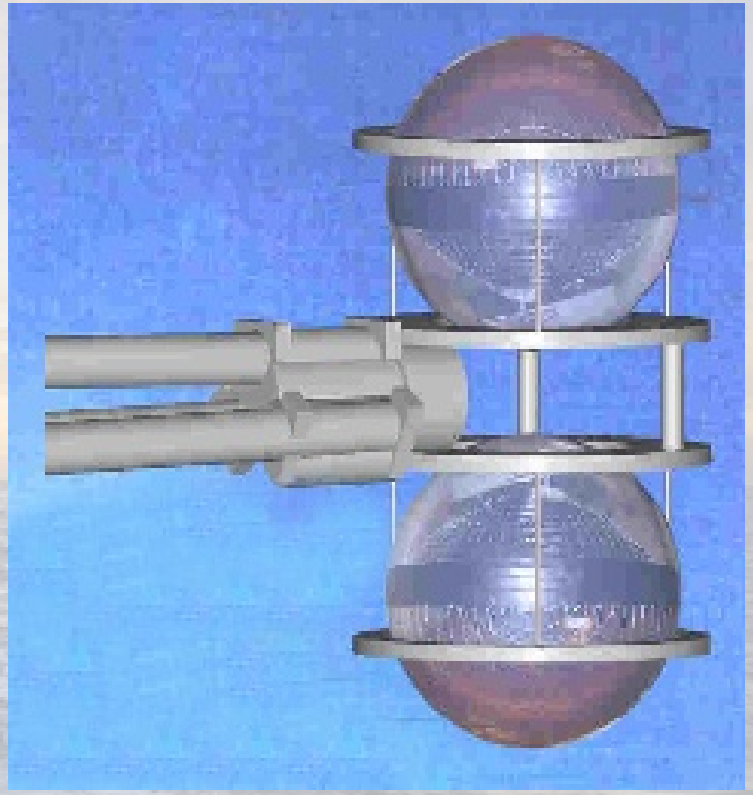
Key characteristics of the NESTOR site

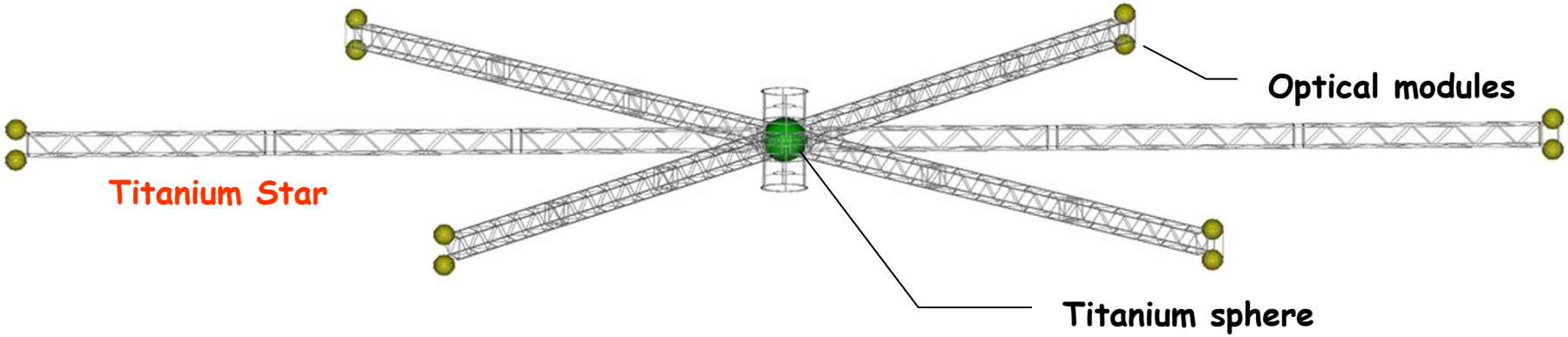
- **Area:** Extended underwater plateau; at least *8x9 km²*
- **Distance:** *7.5 NM from the shore,* 20 NM from a harbor
- **Depth:** Choose from 3000 m to 5200 m
- **Clear water:** Transmission length *55±10m* at *λ=460nm*
- **Underwater currents:** Speed less than *7 cm/sec*
- **Sedimentation:** Flat clay seabed, minimum of sedimentation (ancient clay), river outlets far away
- **Optical noise:**
  - Optical Module rate less than 50 kHz (from K^{40} *decay*)
  - **Bioluminescence:** Low rate (1% of live time), atrophic waters

Site requirements for a neutrino detector
- Wide area with gentle slope
- Short distance from the shore
- Deep water
- Clear water
- Low underwater current speed
- Low sedimentation



- HAMAMATSU PMT R2018-03 (15”)
- BENTHOS spheres
- μ-metal cage
- EMI power supply




Optical modules
Titanium Star
Titanium sphere

DAQ electronics

"Floor Board"

- PMT pulse sensing
- Majority logic event triggering
- Single & coincidence rate scaling
- Waveform capture & digitization
- Data formatting & transmission
- FPGA & PLD reprogramming

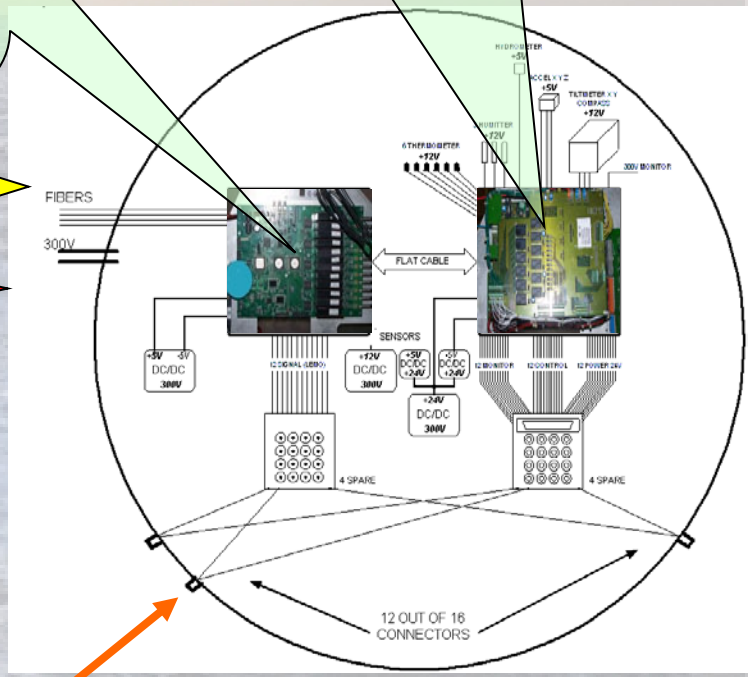
"HouseKeeping Board"

- PMT control
- Calibration Beacon control
- PMT HV monitor
- Power Supply monitors
- Environmental monitors (temperatures, humidity)

Shore Station

Control transfer

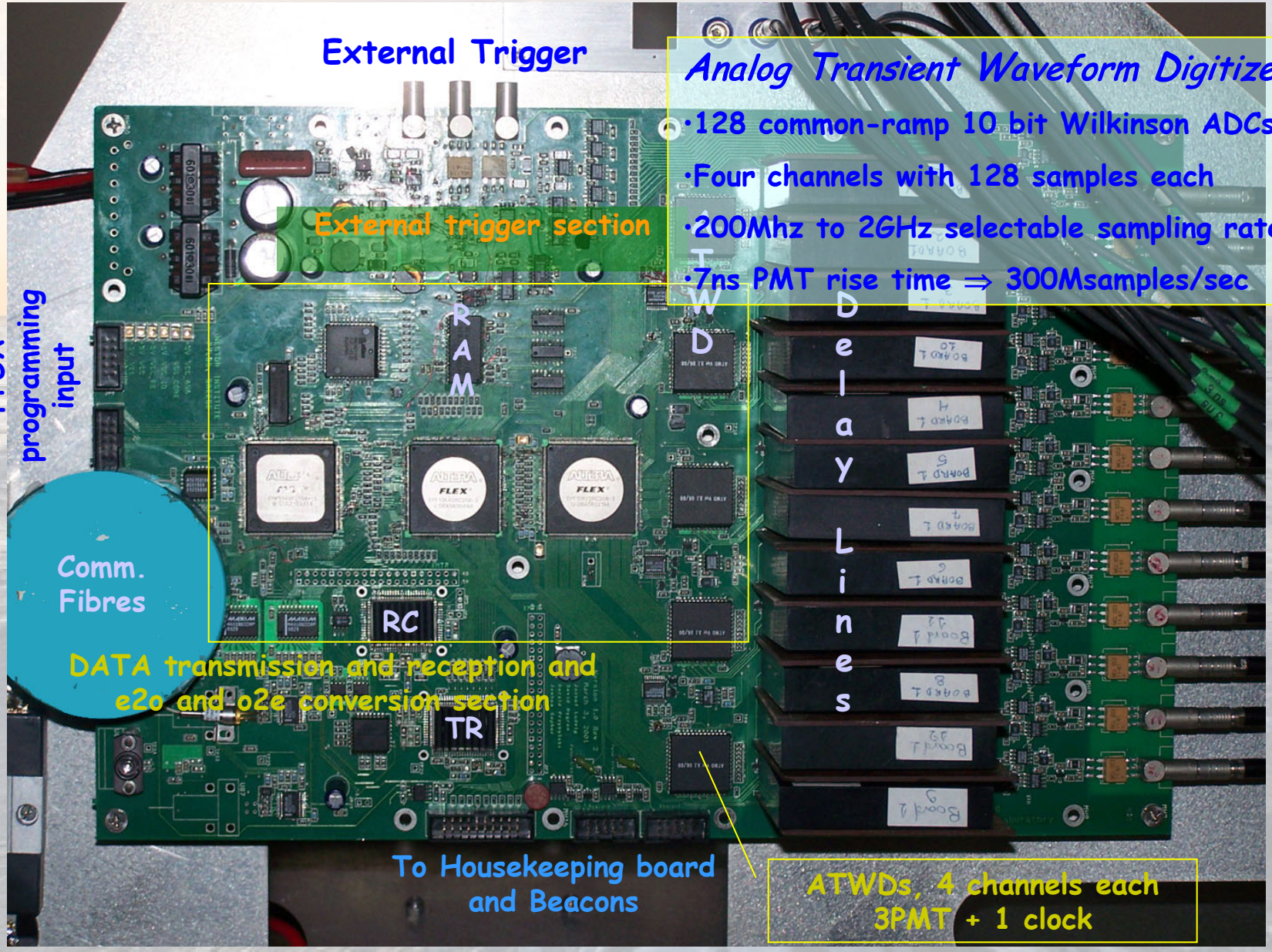
Power



OM

- PMT signal transmission
- low voltage supply (24V)
- control and monitoring HV
- signal transmission

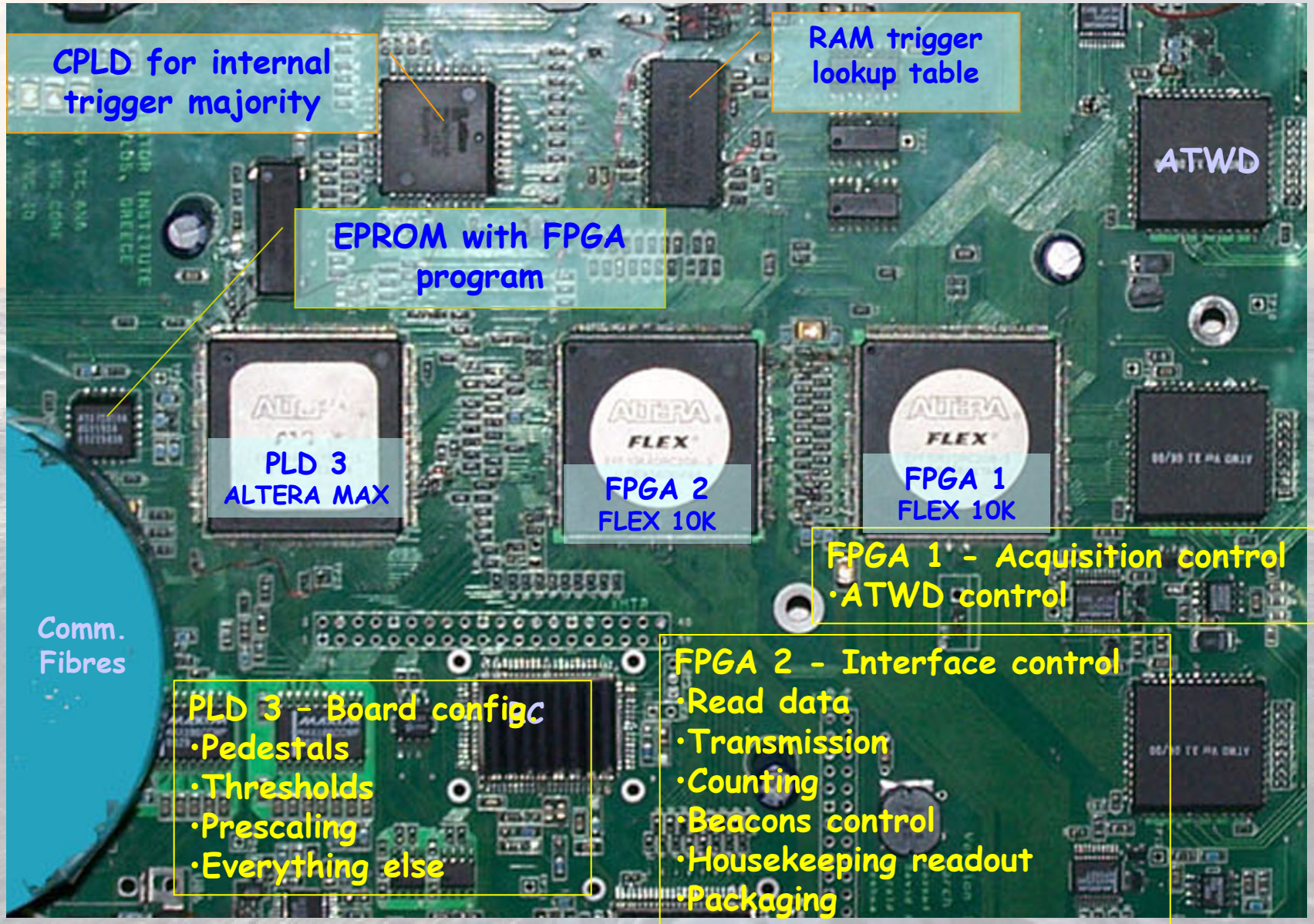
The "Floorboard"



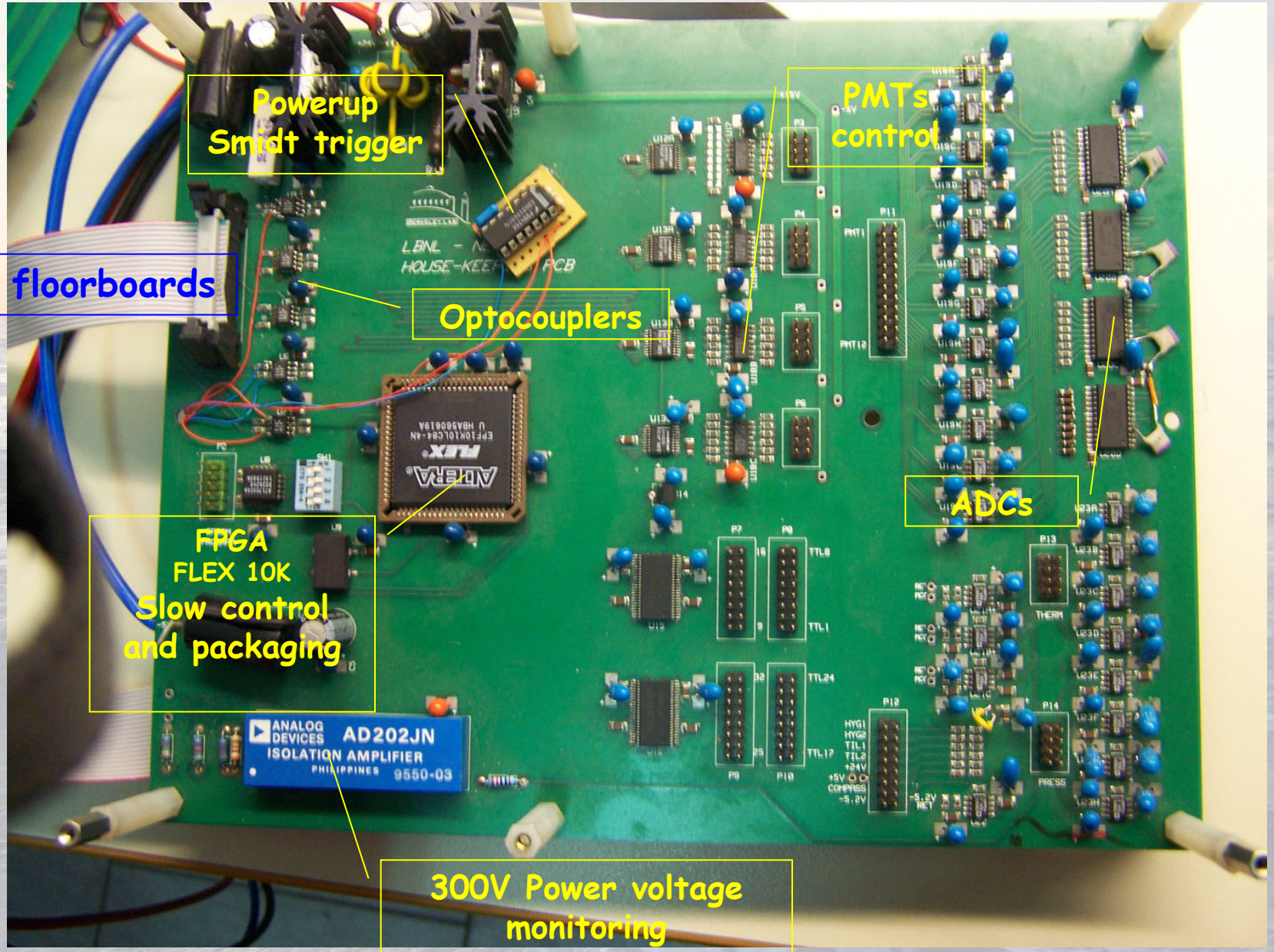
Analog Transient Waveform Digitizer

- 128 common-ramp 10 bit Wilkinson ADCs
- Four channels with 128 samples each
- 200Mhz to 2GHz selectable sampling rate
- 7ns PMT rise time ⇒ 300Msamples/sec

The "Floorboard"



The "Housekeeping" boards



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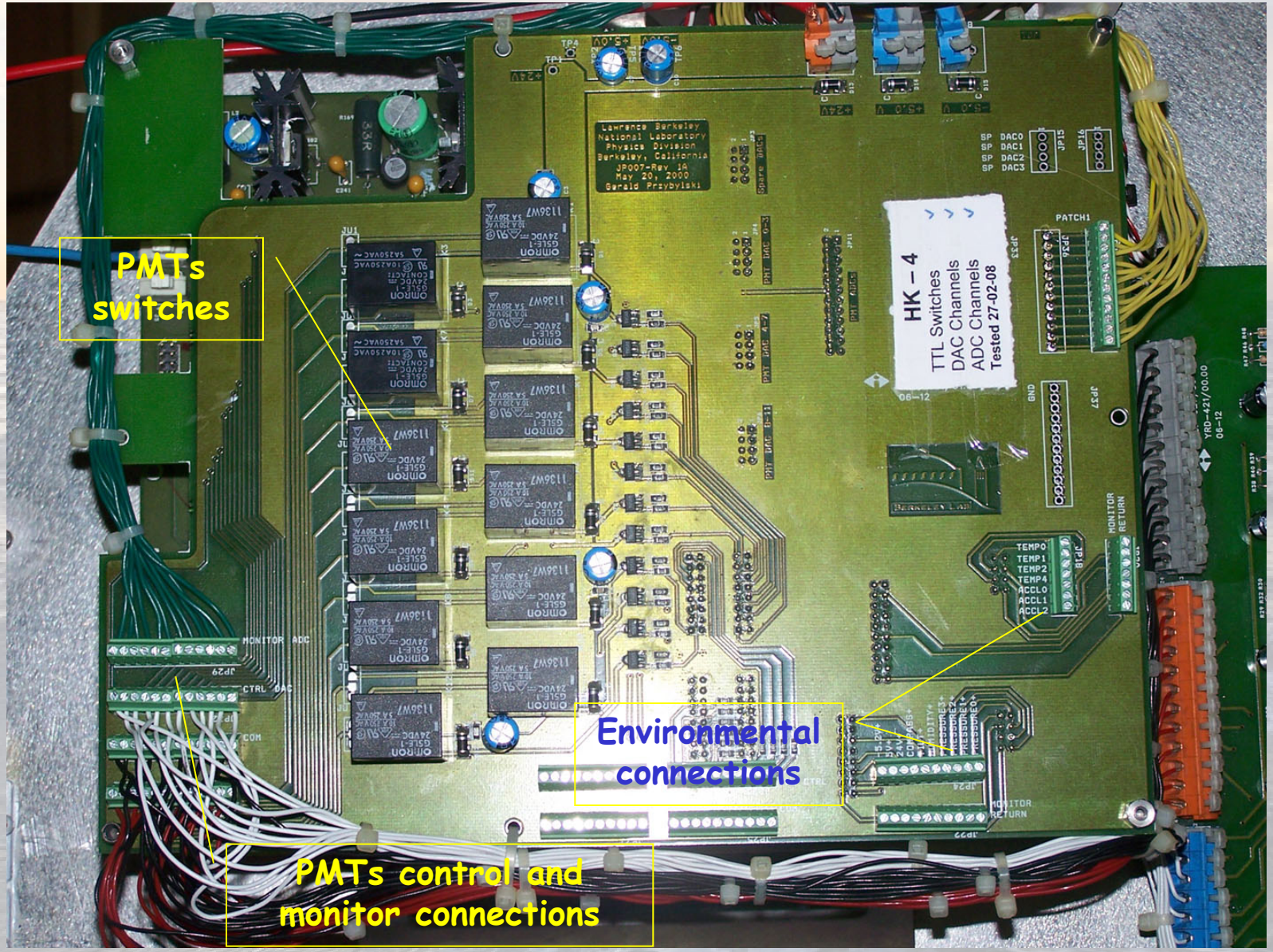
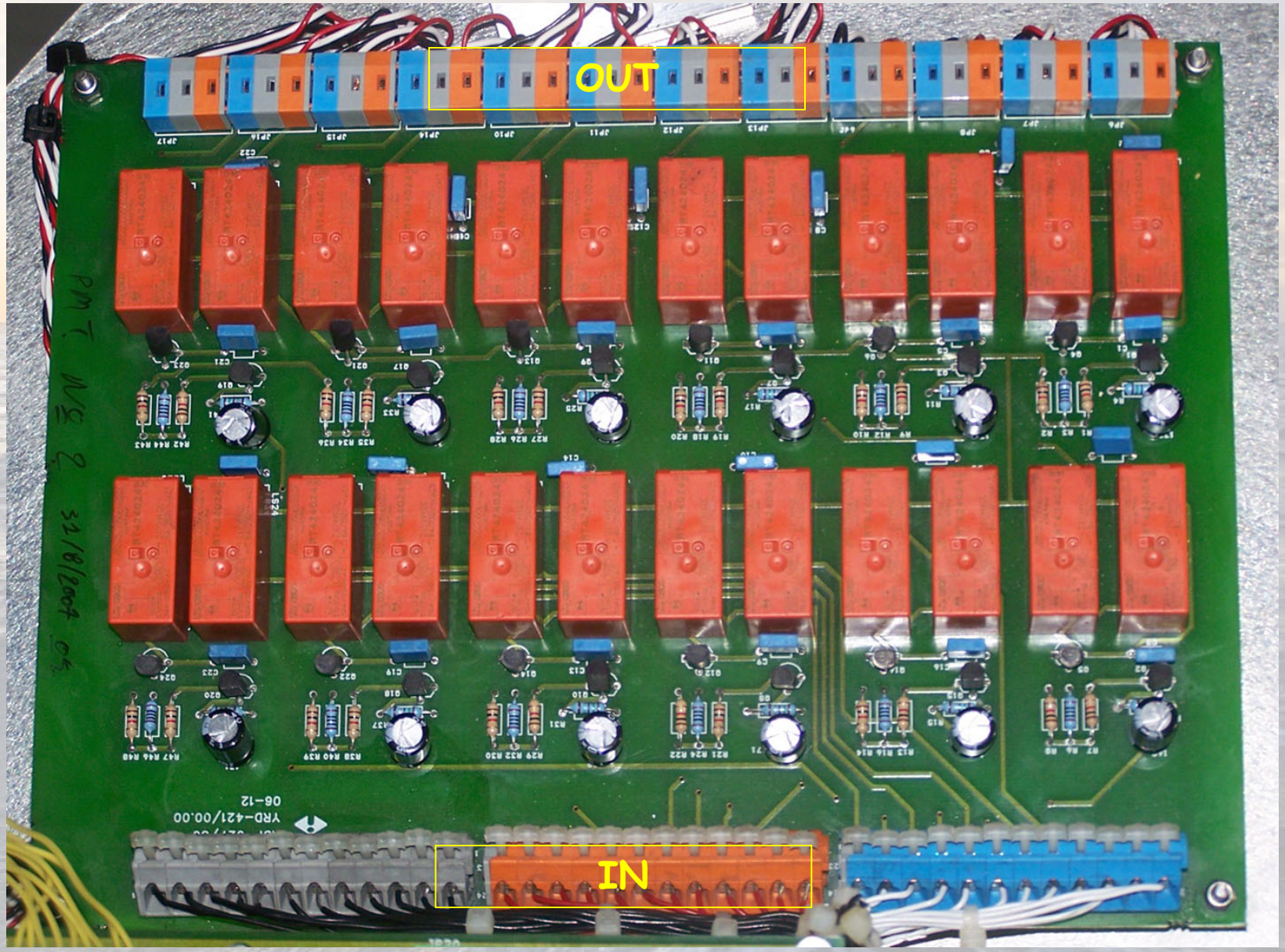
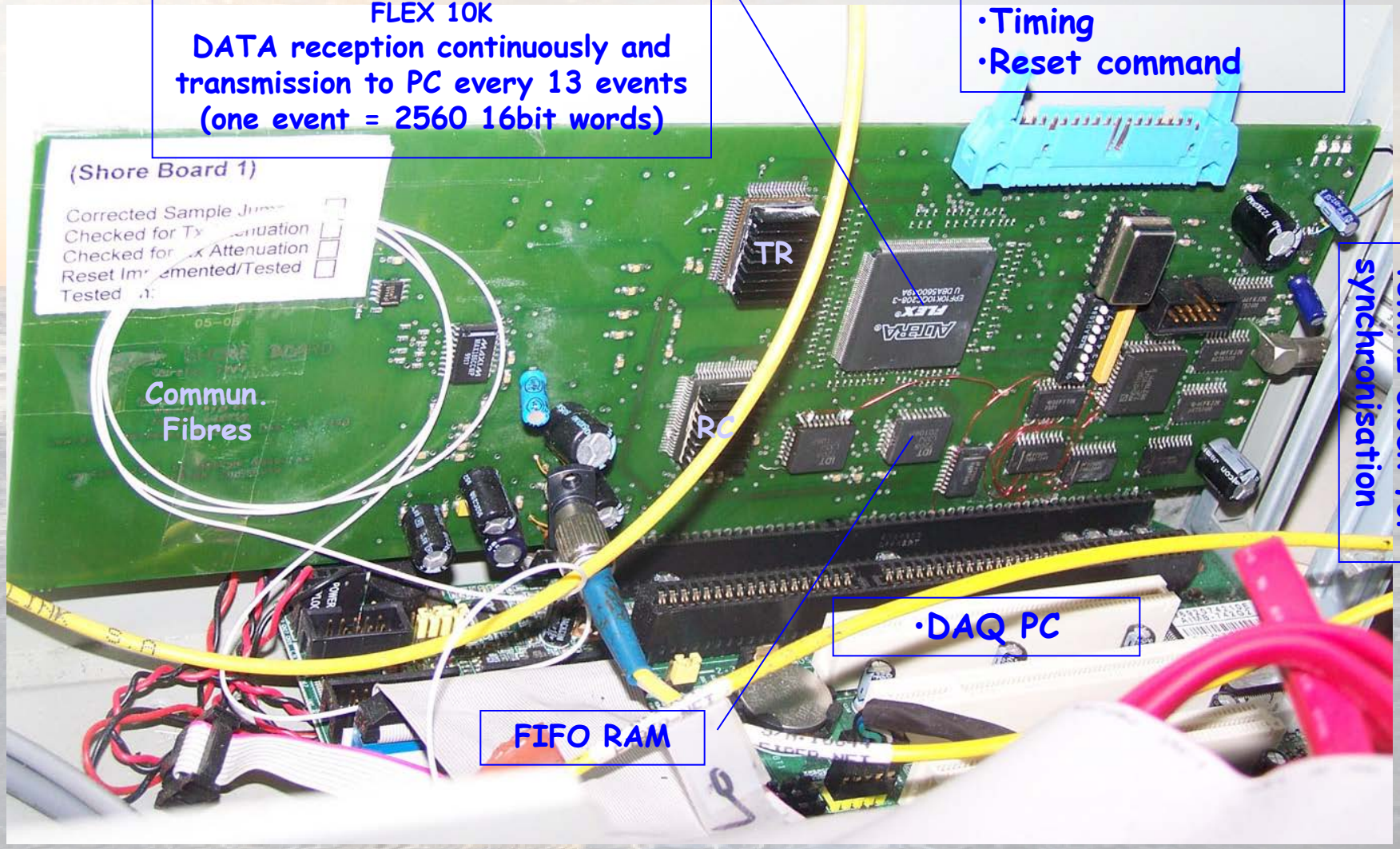


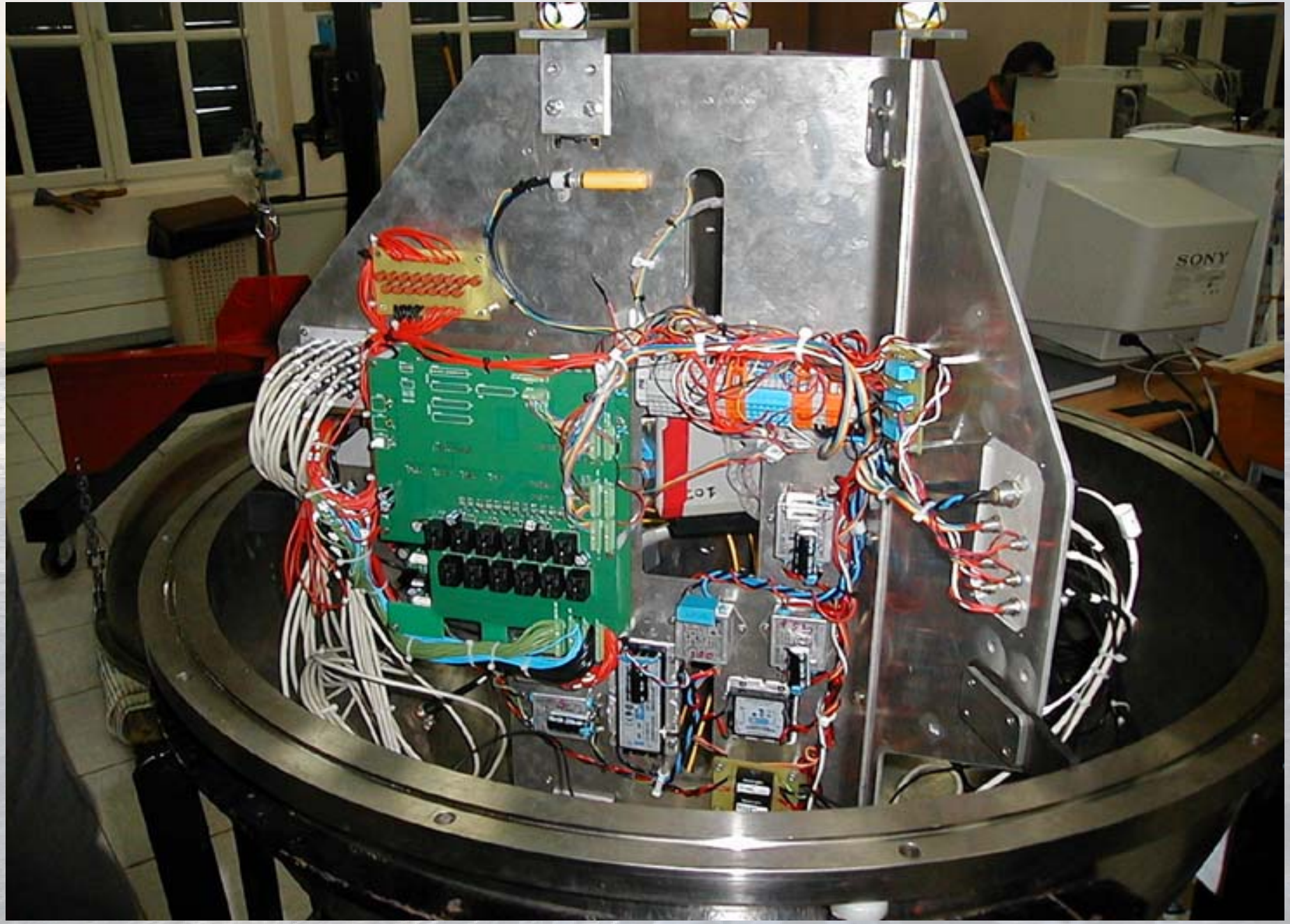
The "PMT smart fuses" board

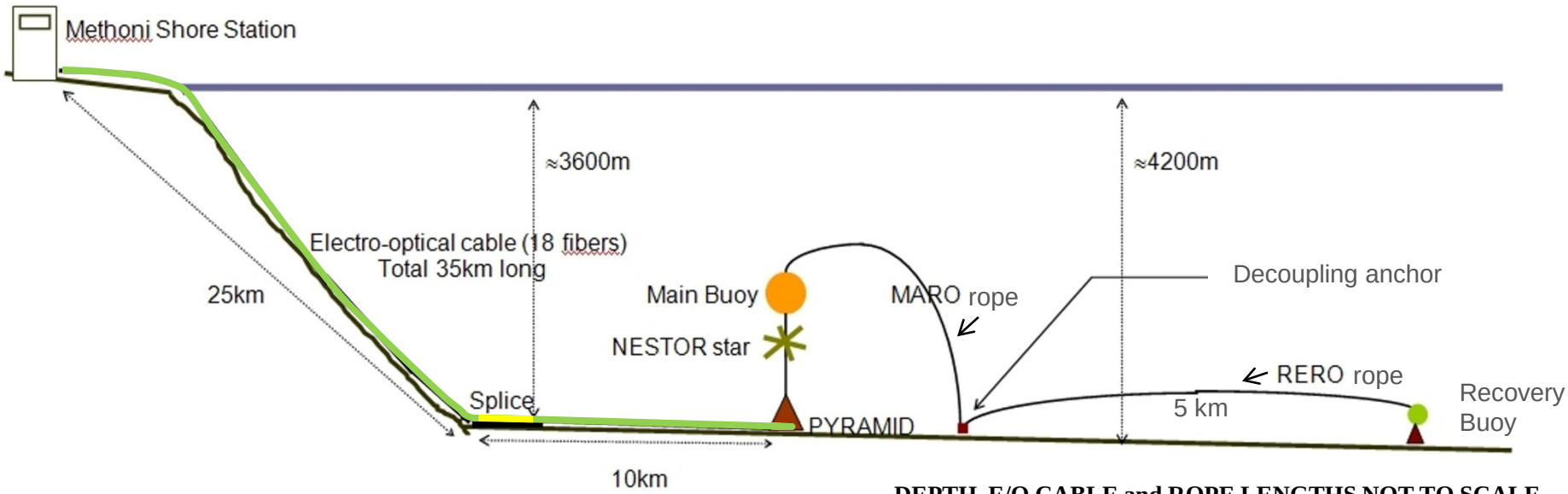


The "Shoreboard"



SONY


SONY



DEPTH, E/O CABLE and ROPE LENGTHS NOT TO SCALE

PYRAMID: Anchor Unit with Environmental Instrumentation

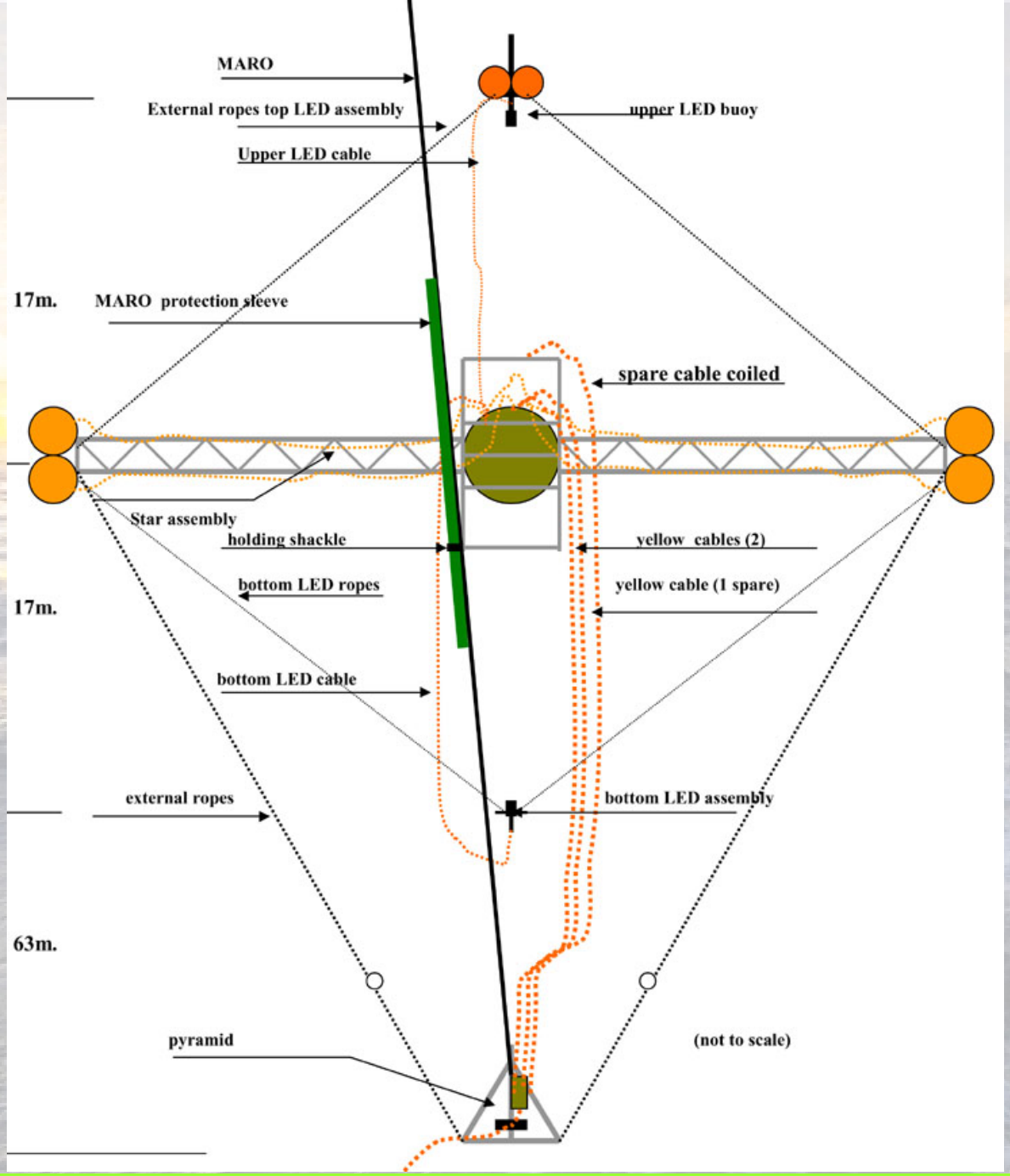
NESTOR floor (one star fully equiped)

ELECTRO-OPTICAL CABLE

"ZERO BUOYANCY" ROPES (MARO and RERO are neutral buoyancy ropes))

MARO MAin buoy recovery Rope (about250m)

RERO REcovery Rope (about 5500m)


MARO
External ropes top LED assembly
upper LED buoy
Upper LED cable
17m.
MARO protection sleeve
spare cable coiled
Star assembly
holding shackle
yellow cables (2)
bottom LED ropes
yellow cable (1 spare)
17m.
bottom LED cable
external ropes
bottom LED assembly
63m.
pyramid
(not to scale)

June 2000

Deployment of 31 km long Electro-Optical cable (25 km standard + 6 km torque free deep sea cables, with 18 fibers +1 conductor)

Deployed in June 2000 by the cableship MAERSK-FIGHTER (ALCATEL- TELEDANMARK)

Cable was damaged during laying because of ship's problems (3 fibers lost at the 17th km from shore + torque free cable damaged)

Cable landing completed at Methoni Bay

09:48:57
07/06/00
N
W
E
S
262

Junction box

Current meter

Ocean Bottom Seismometer

Main Recovery Rope

Anchor weight

E-O cable bend restrictor

E-O cable

January 2002

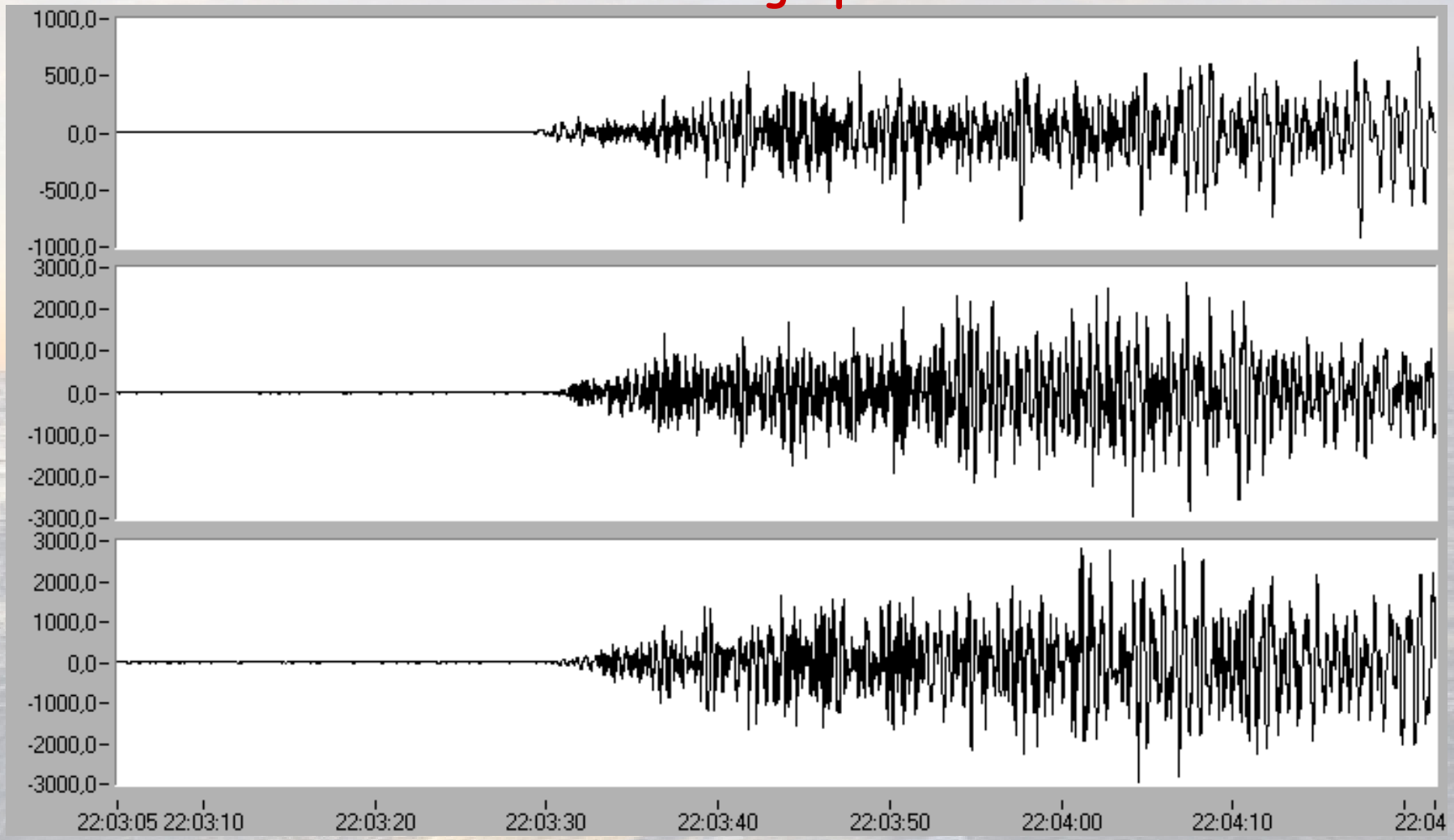
35 km of Electro-optical cable (25 km from the deployed cable + 10 km of new cable; with18 fibers +1 conductor)

Cable repaired by the O.T.E. specialist on the cableship TENEO (TyCom)

Successful deployment of the PYRAMID unit with environmental instrumentation to 4000m

15th of January: The first environmental data transmitted through the 35km electro-optical cable to the Methoni counting room

Underwater seismograph at 4000m



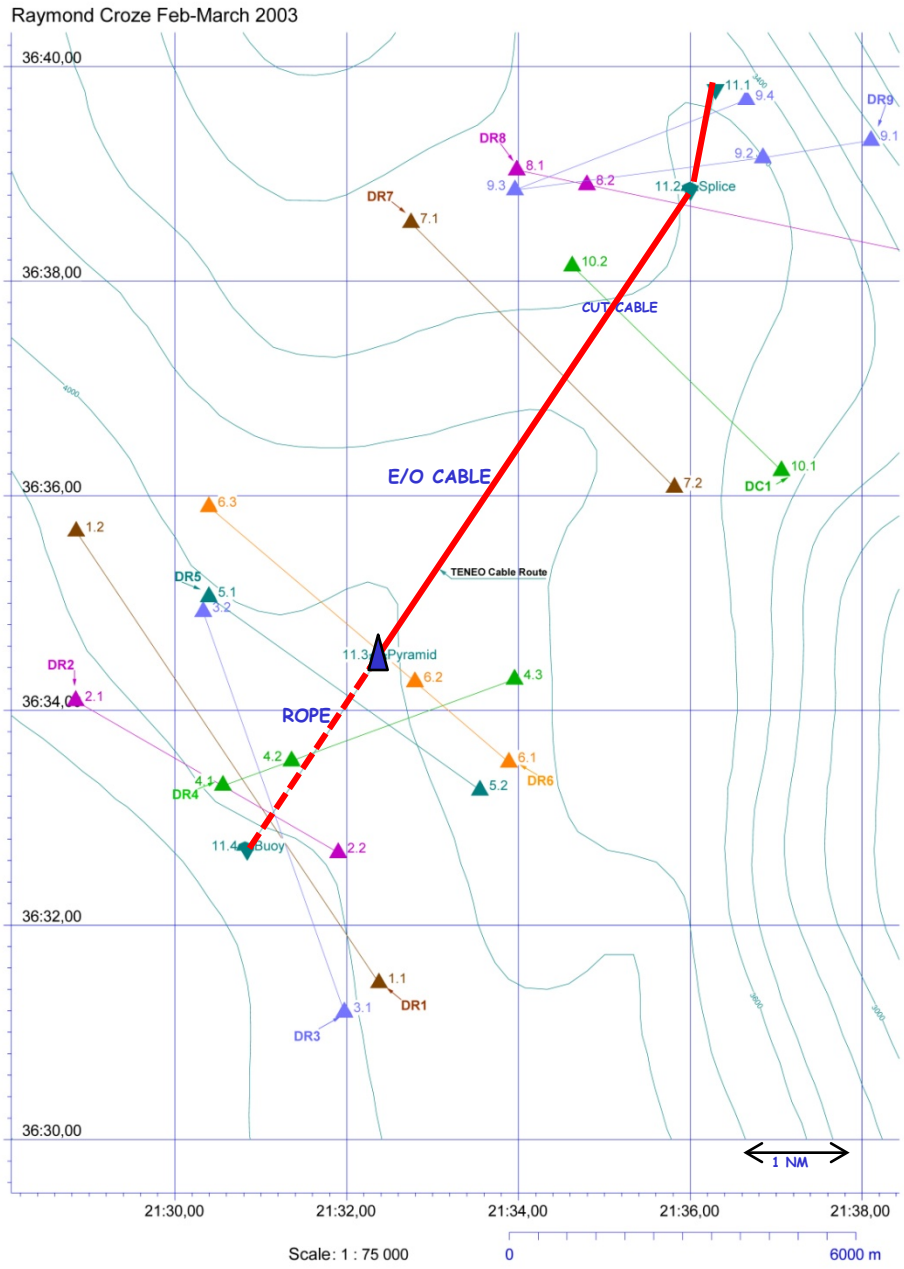
Typical Ocean Bottom Seismometre (OBS) graph

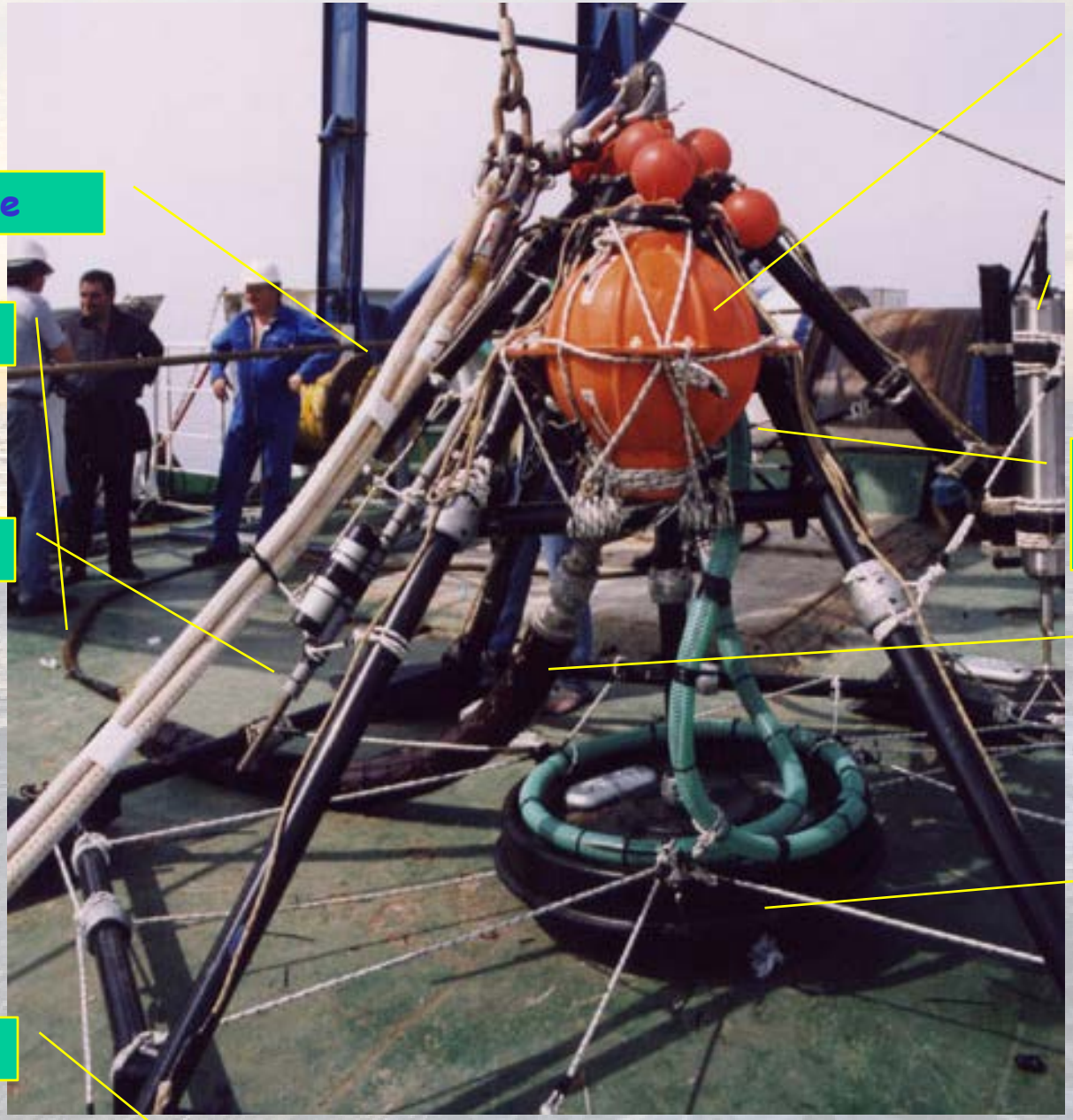
Correspond to earthquake recorded by the National Observatory of Athens, at 30 January 2002, 20:03:33.8 GMT, magnitude 3.9, depth 5km και epicentre at 37.66°N, 21.66°E, about 120km north of telescope.

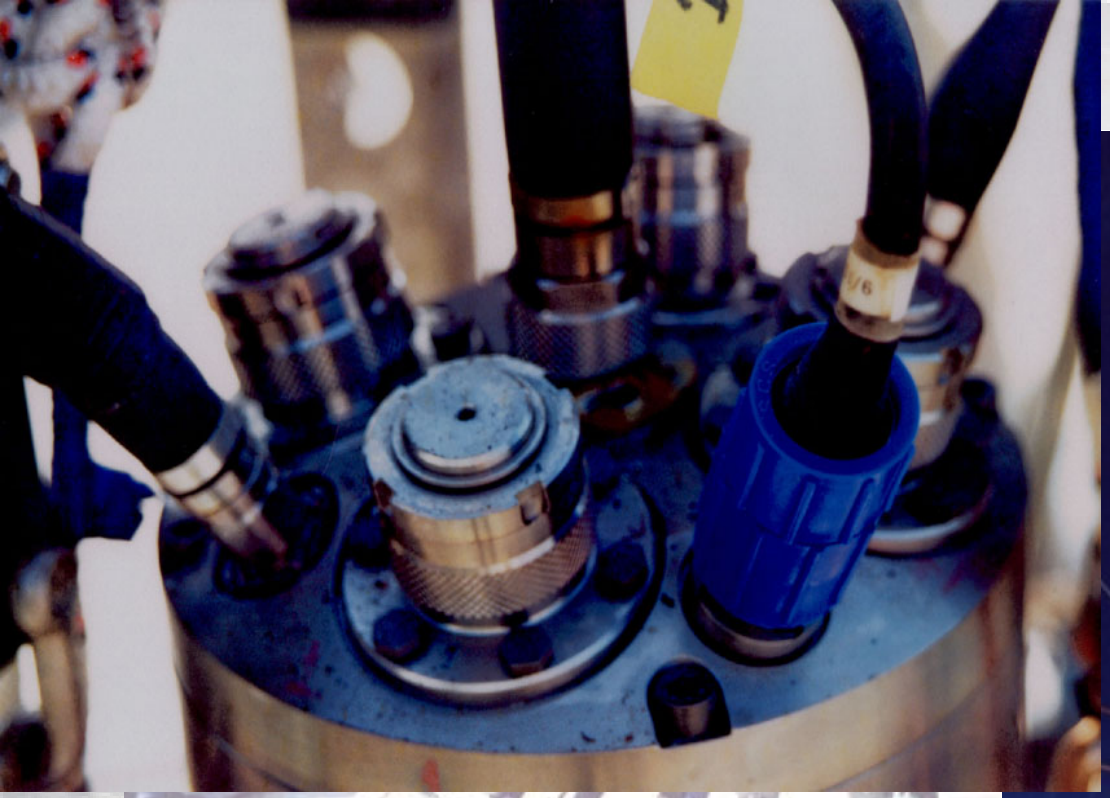
Successful deployment of NESTOR prototype, one star with 12 Optical Modules to 4000m

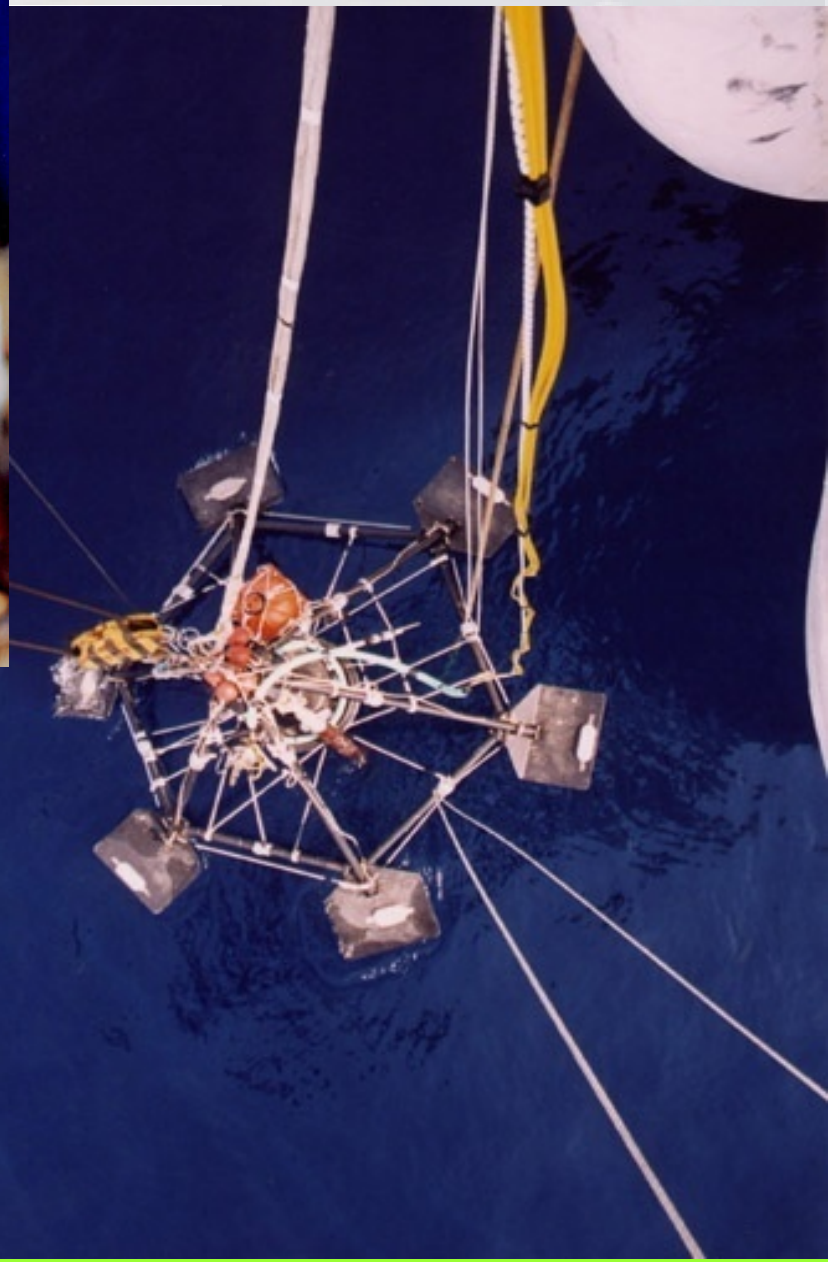
using the cableship RAYMOND CROZE (FranceTelecom)

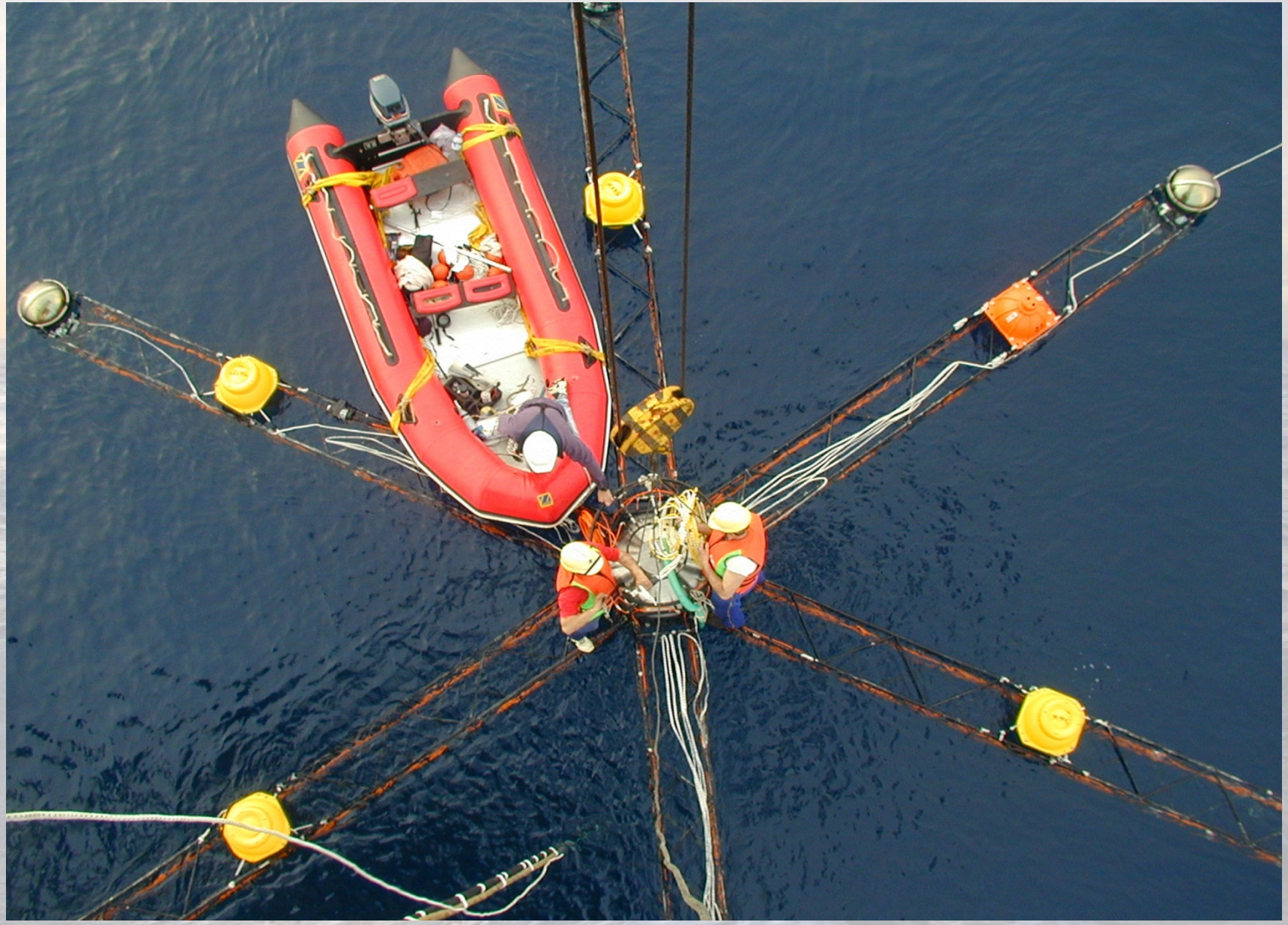
29th of March: The first deep sea muon data transmitted to shore; through a 30km long electro-optical cable to the Methoni counting room

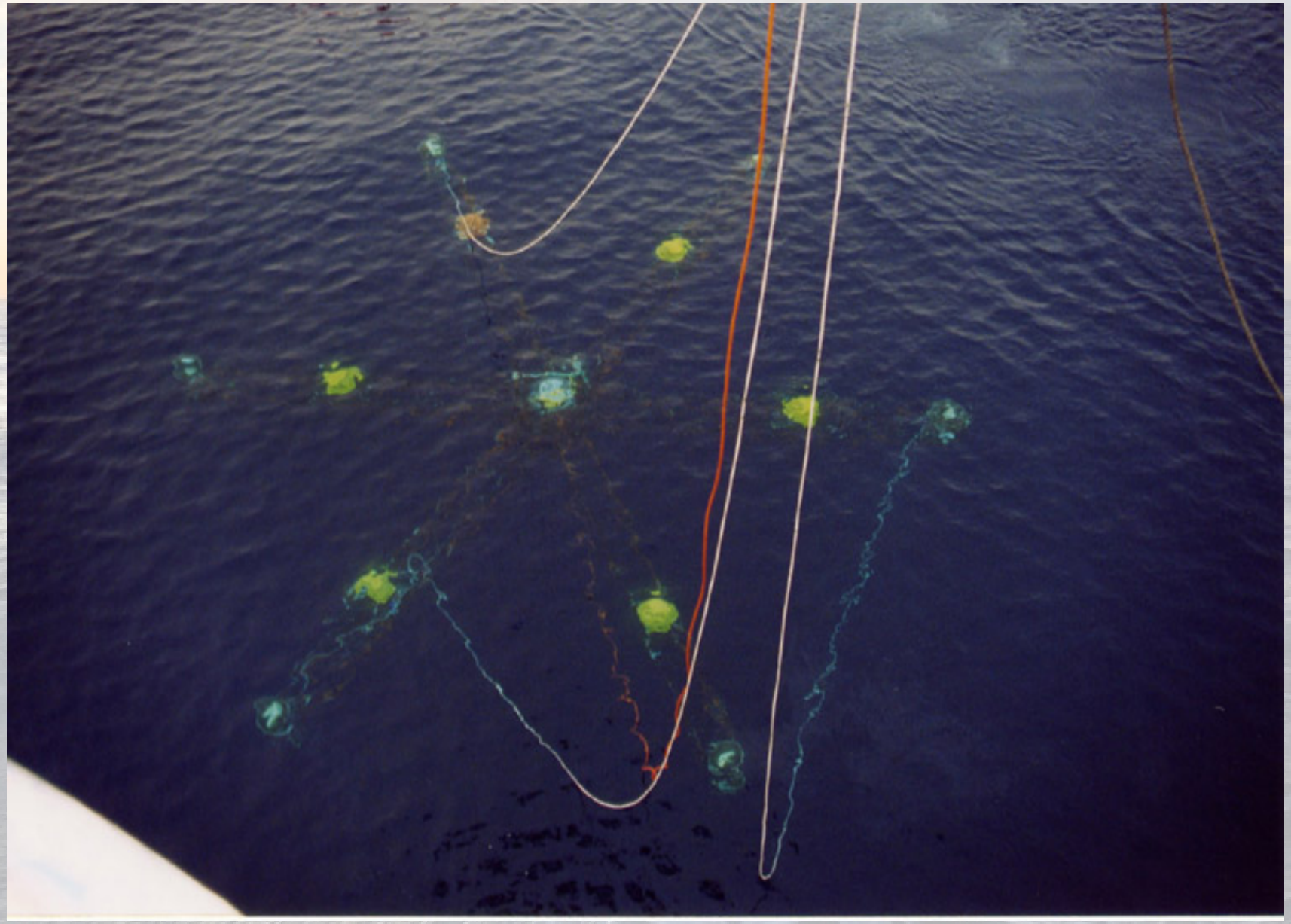

Raymond Croze Feb-March 2003
36:40,00
36:38,00
36:36,00
36:34,00
36:32,00
36:30,00
21:30,00
21:32,00
21:34,00
21:36,00
21:38,00
11.1
9.4
DR9
9.1
DR8
8.1
9.2
9.3
8.2
11.2 Splice
DR7
7.1
10.2
CUT CABLE
E/O CABLE
7.2
DC1
10.1
6.3
1.2
TENEO Cable Route
DR5
5.1
3.2
11.3 Pyramid
6.2
4.3
DR2
2.1
ROPE
4.2
6.1
DR6
4.1
DR4
5.2
11.4 Buoy
2.2
1.1
DR1
3.1
DR3
1 NM
Scale: 1 : 75 000
0
6000 m


Transporder
MainRope
Current meter
E-O cable
Junction box
Sea return
E-o cable bend restrictor
Anchor
OBS



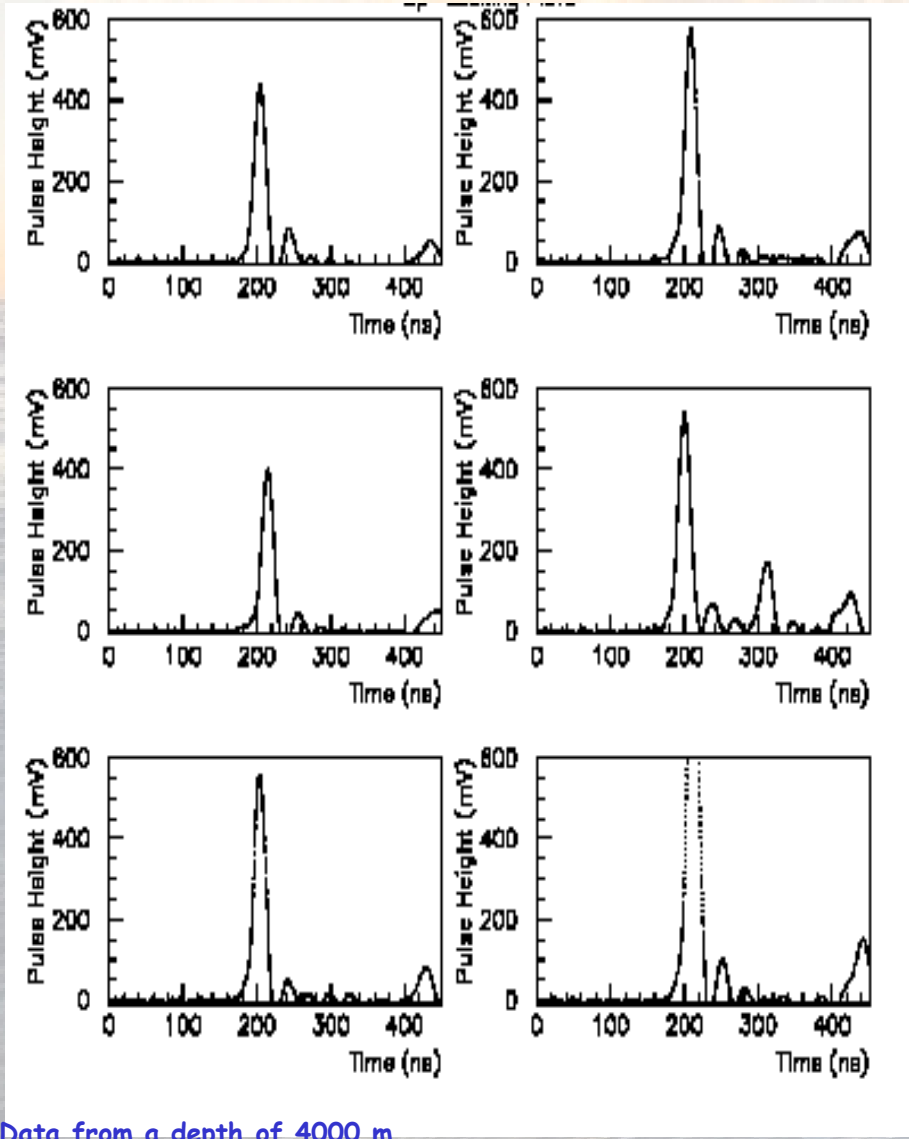




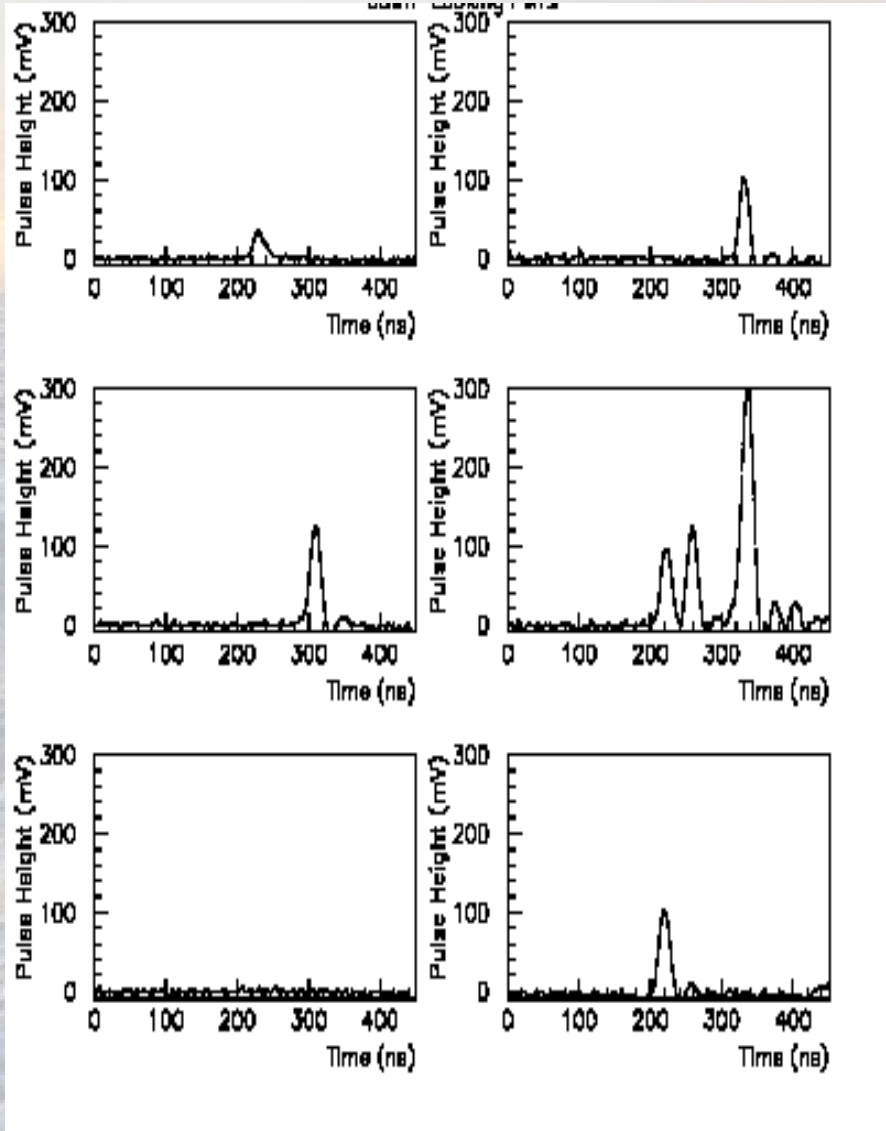


PMTs' Waveforms Captured

Up-Looking PMTs

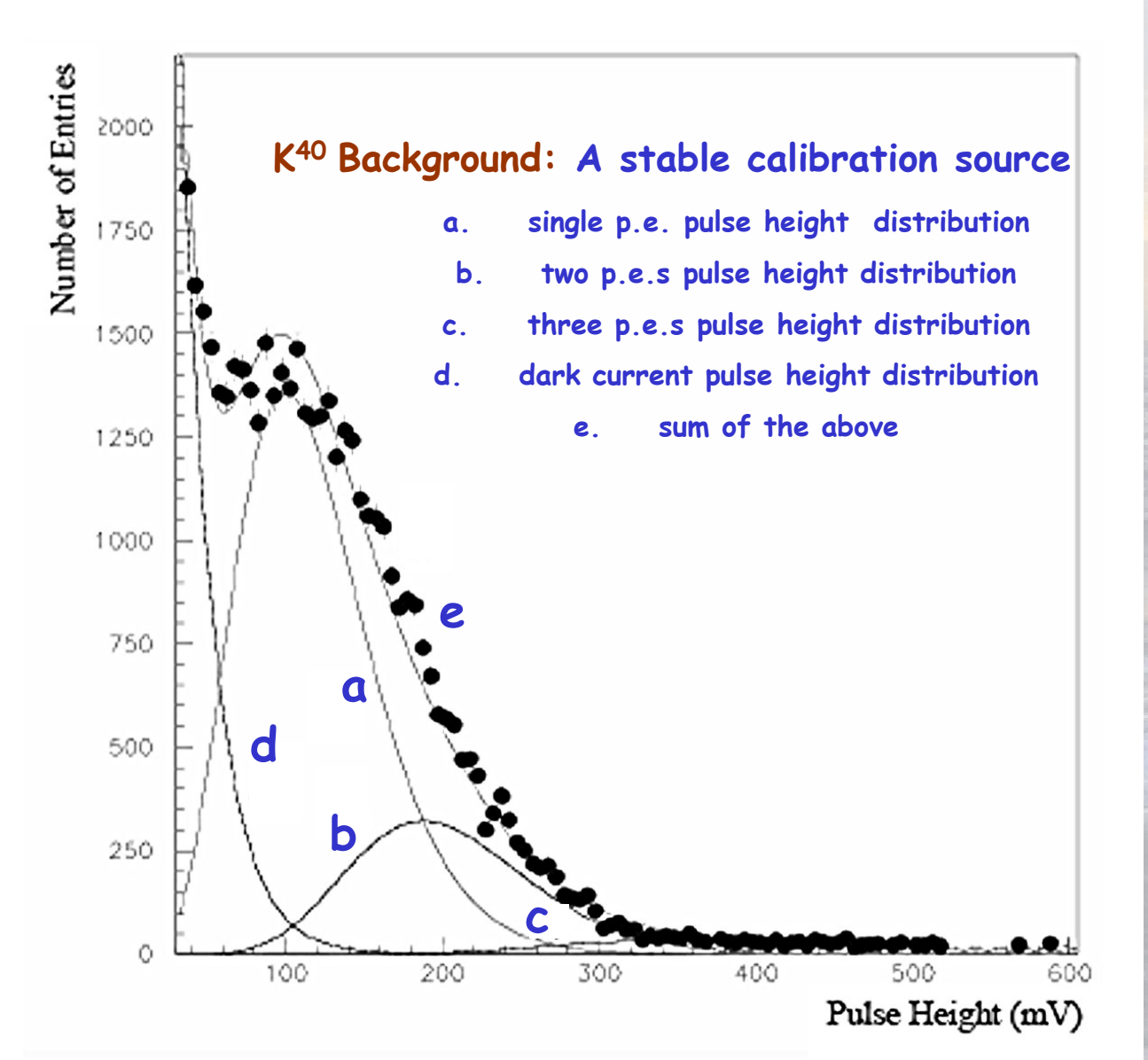


Down-Looking PMTs



Data from a depth of 4000 m

PMTs' Waveforms Captured



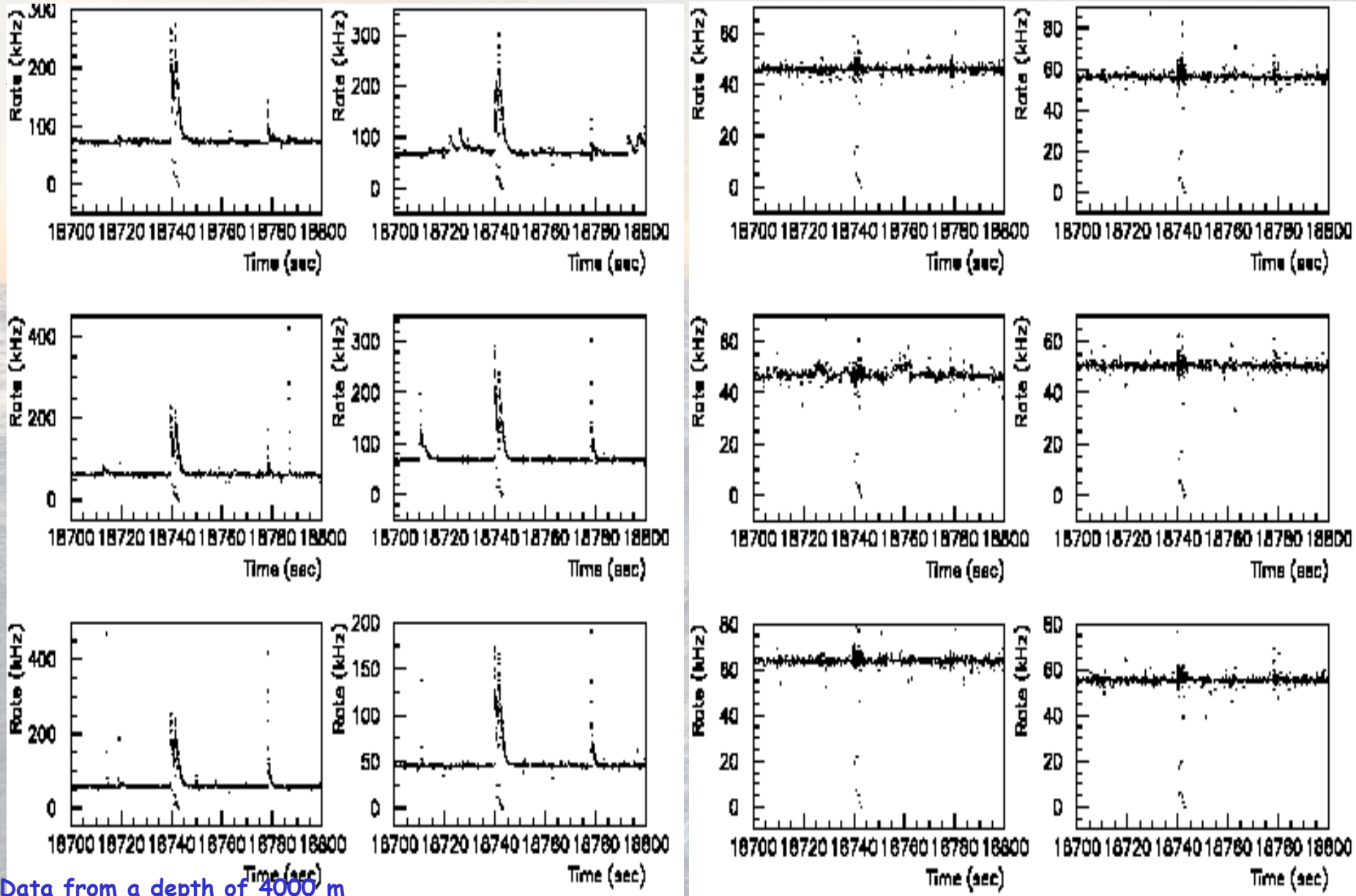
Data from a depth of 4000 m

BIOLUMINESCENCE (BURSTS 1% of the time)

PMTs' Rates

Up-Looking PMTs

Down-Looking PMTs



Data from a depth of 4000 m

NESTOR prototype; Photoelectron number

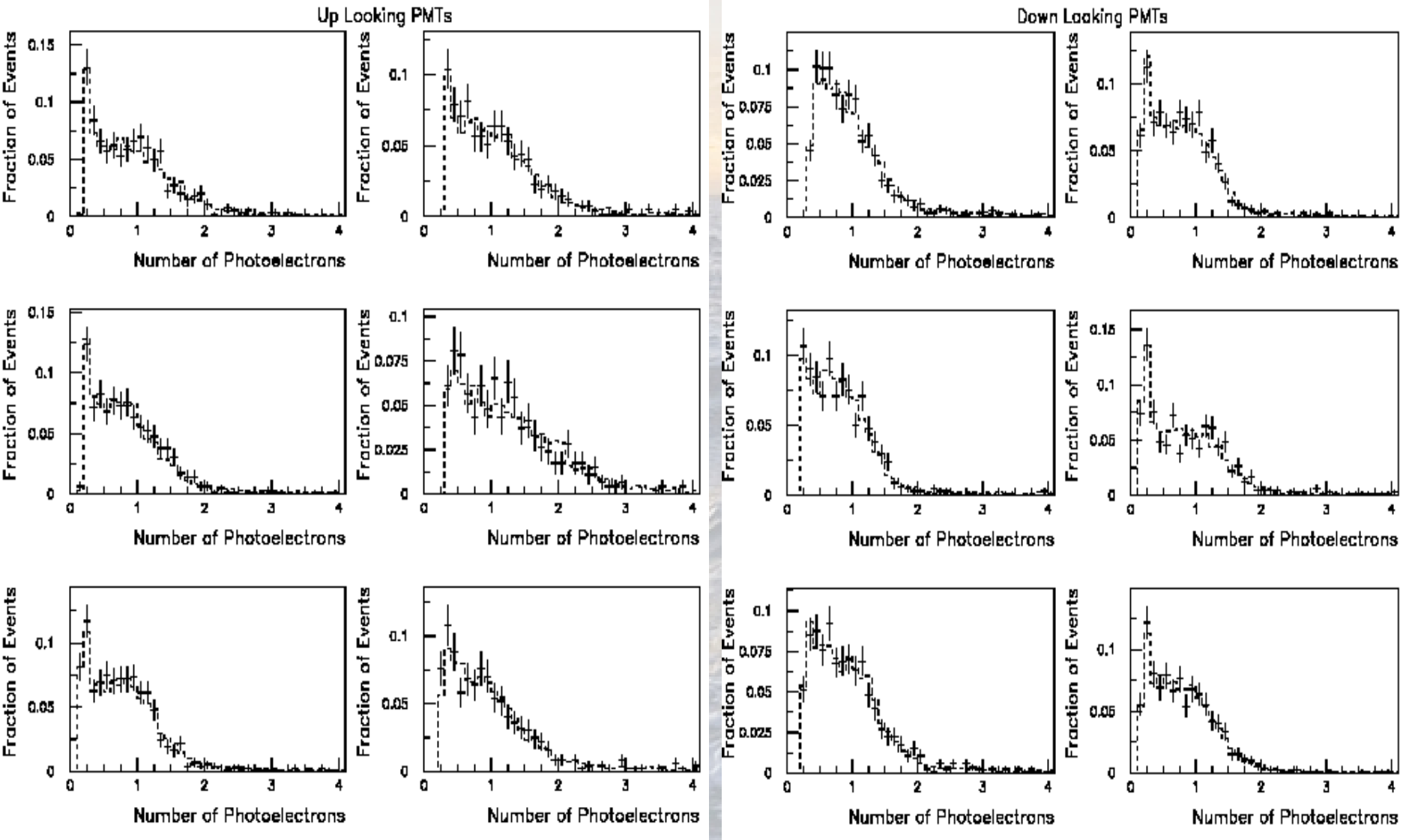
Data from 4000 m depth

With bioluminescence

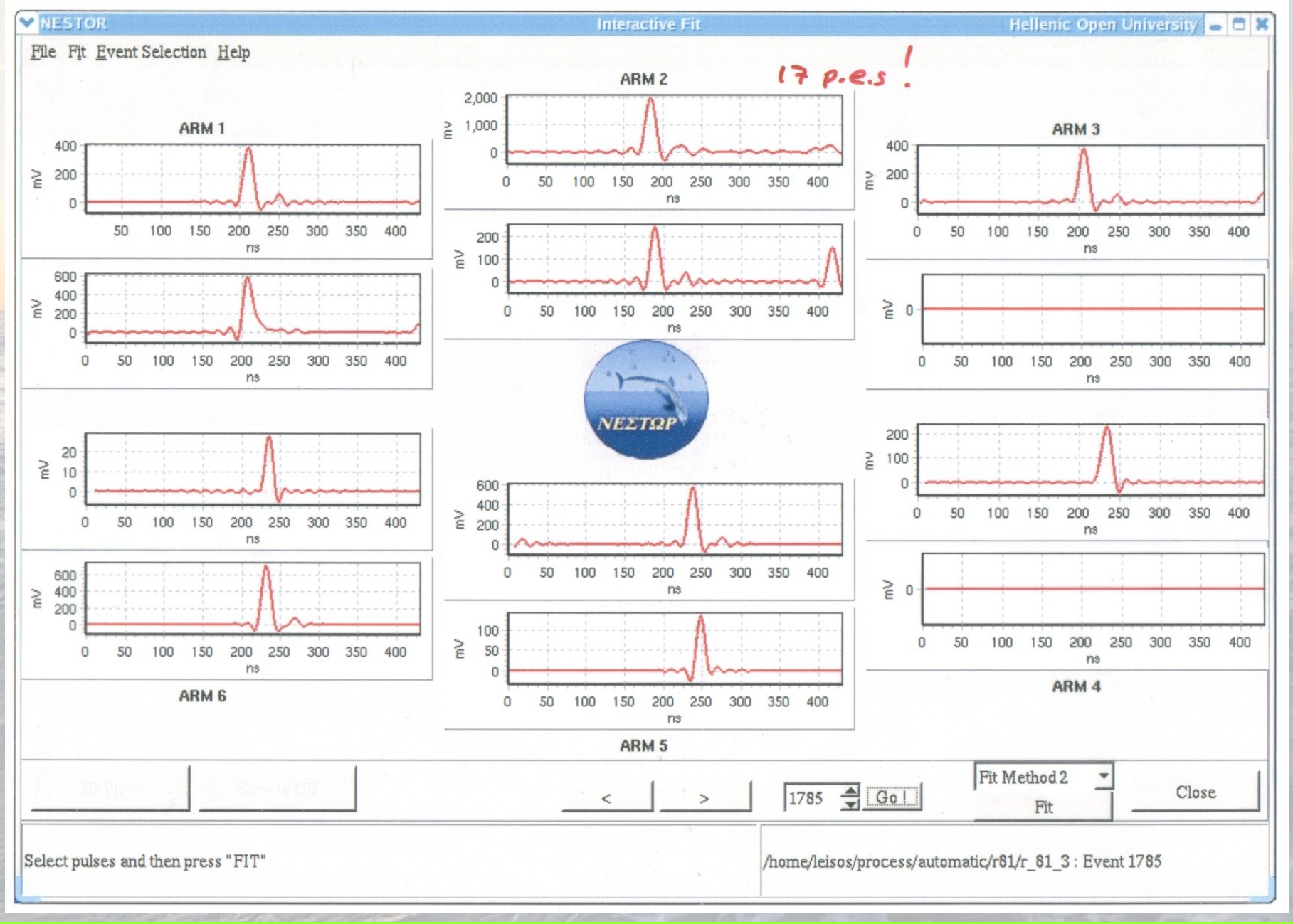
Without bioluminescence

Trigger: 4fold coincidence

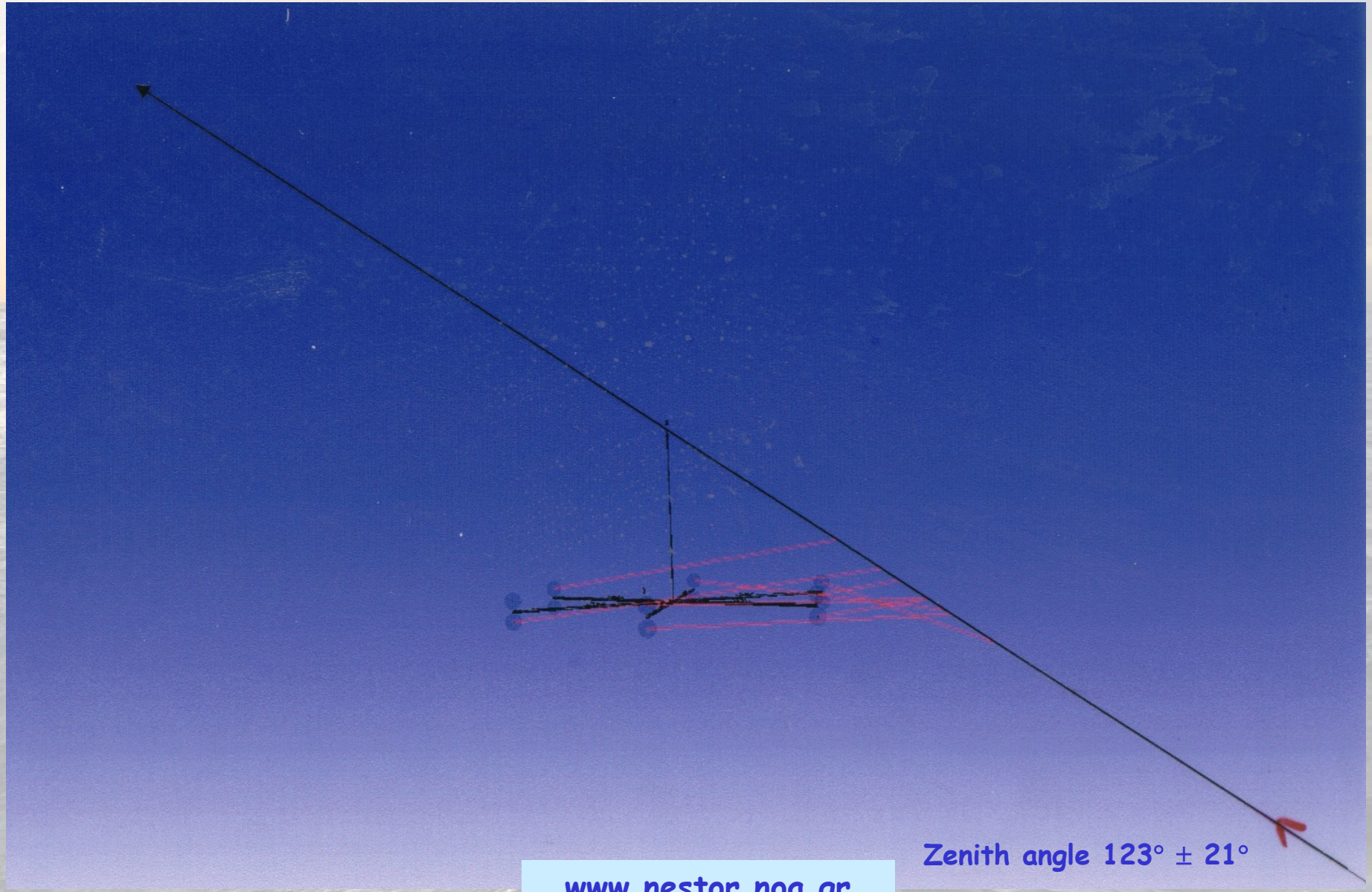
1pe corresponds to ≈120mV



NESTOR prototype; Event 1785, PMT signal display



NESTOR prototype; Event 1785 display



www.nestor.noa.gr

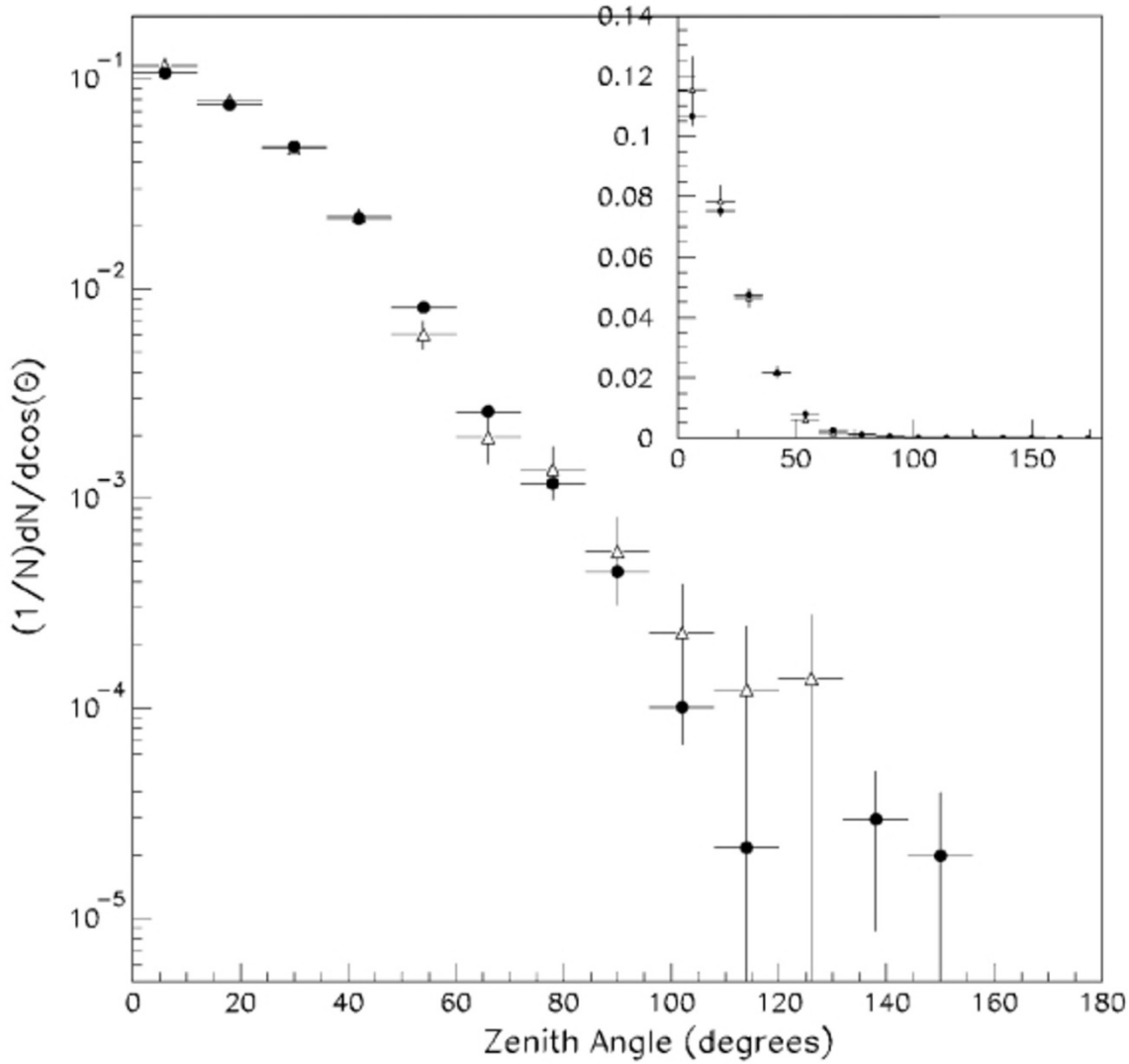
Data from a depth of 4000 m

NESTOR prototype; Zenith Angular Distribution

- PMT pulse selection
- track fit
- χ^2 probability > 0.1
- track selection based on the charge-likelihood
- [track impact - 6m] > σ_{imp}
- more than [4.5 · (number of hits)] p.e.s per track

Distribution of the Zenith angle (y) of reconstructed tracks for the data (triangles) and Monte Carlo (solid points) event samples.

The insert plot shows the same distributions on a linear scale.



·ASTROPARTICLE PHYSICS 23(2005), 377-392
·NIM A 552(2005) 420-439

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Operation and performance of the NESTOR test detector

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Received 2 December 2004; received in revised form 24 June 2005; accepted 30 June 2005
Available online 27 July 2005

Abstract

NESTOR is a deep-sea neutrin
depth of about 4000 m. This paper
detail the calibration and enginee
than 1 month and data was conti
performance of the detector is dis
flux is in good agreement with pr
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PACS: 95.55.Vj; 29.40.Ka; 13.15.+g

Keywords: Neutrino; NESTOR; Deep-sea; Telescope; Operation; Performance

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Astroparticle Physics 23 (2005) 377–392
Astroparticle Physics
www.elsevier.com/locate/astropart

A measurement of the cosmic-ray muon flux with a module of the NESTOR neutrino telescope

The NESTOR Collaboration

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Received 5 January 2005; accepted 10 February 2005
Available online 11 March 2005

ployed at a depth of 3800 m in order to test the
isition systems. A prolonged period of running
under stable operating conditions made it possible to measure the cosmic ray muon flux, $I_0 \cdot \cos^{\alpha}(\theta)$, as a function of the zenith angle θ. Measured values of index α and the vertical intensity I_0

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THANK YOU DAVID