# Status of the NEMO project

***Piera Sapienza on behalf of the NEMO collaboration***

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

NEUTRINO MEDITERRANEAN OBSERVATORY

# Outline

- The NEMO R&D activities: towards an underwater km$^3$ neutrino telescope
  - Site exploration - Capo Passero site properties
  - Feasibility study and preliminary design of the km$^3$ detector
- NEMO Phase-1 (2003-2007) @ *the LNS Test Site (2000 m)*
  - Aim of the project and system description
  - Achievements and lessons learned
- NEMO Phase-2 (2005-2008) @ *the Capo Passero Site (3500 m)*
  - Description of the infrastructure
  - Detector prototypes
- Conclusions and perspectives

# The NEMO Collaboration

**INFN**
**Bari, Bologna, Catania, Genova, LNF, LNS, Napoli, Pisa, Roma**
**Universities**
**Bari, Bologna, Catania, Genova, Napoli, Pisa, Roma *"La Sapienza", Pavia CIBRA***


**CNR**
**Istituto di Oceanografia Fisica, La Spezia**
**Istituto di Biologia del Mare, Venezia**
**Istituto Sperimentale Talassografico, Messina**

**Istituto Nazionale di Geofisica e Vulcanologia (INGV)**

**Istituto Nazionale di Oceanografia e Geofisica Sperimentale (OGS)**

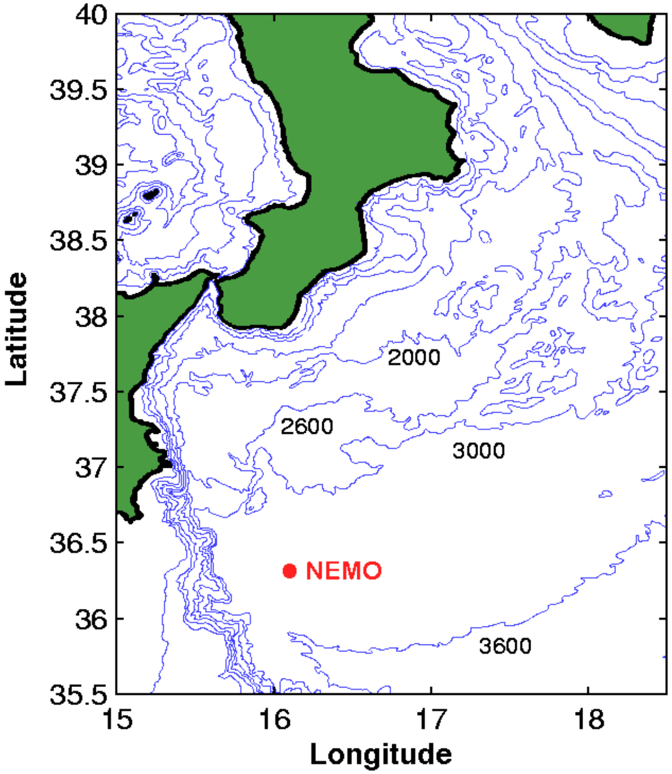
**Istituto Superiore delle Comunicazioni e delle Tecnologie dell'Informazione (ISCTI)**

More than 80 researchers from INFN and other italian institutes

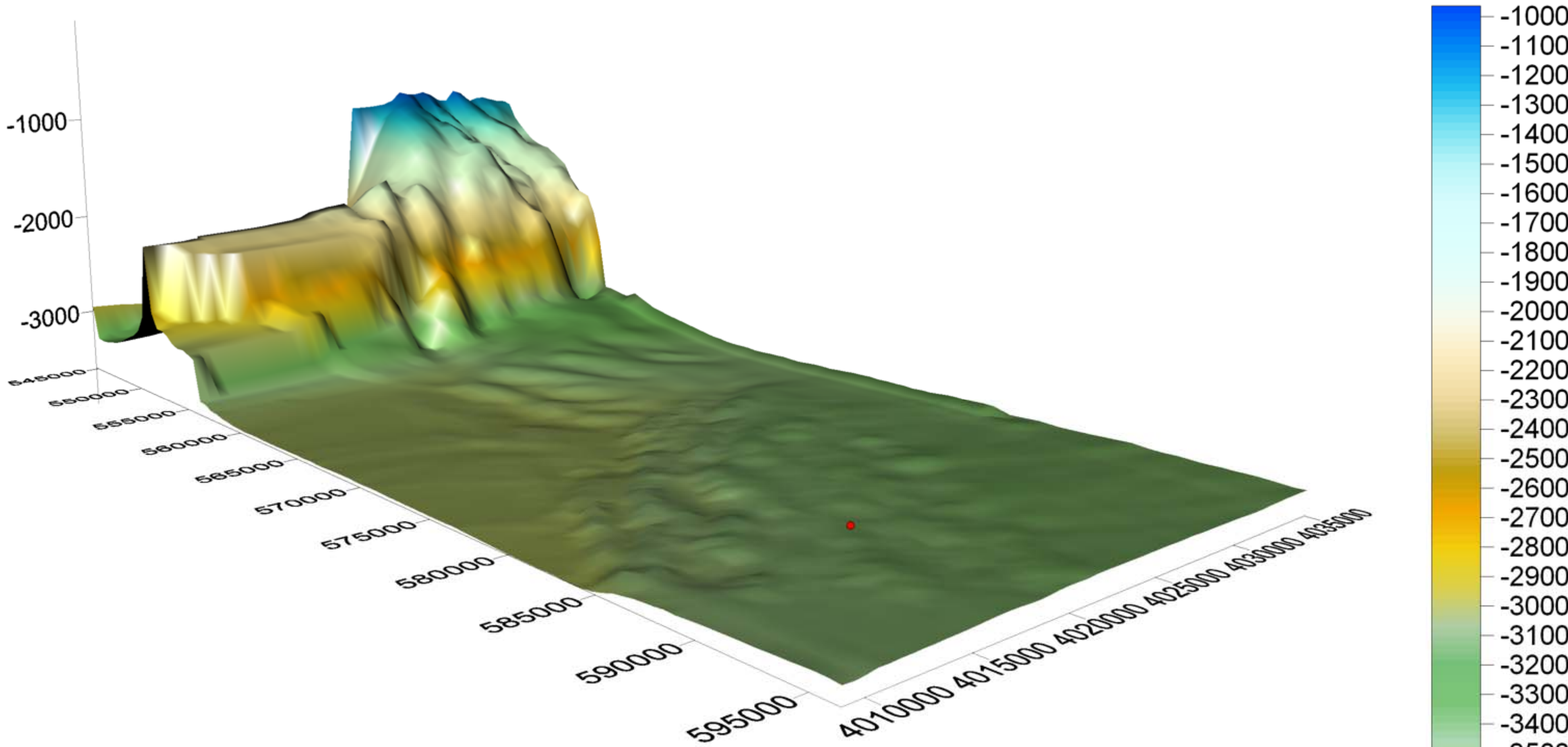
# The Capo Passero site

## The site was proposed in january 2003 to ApPEC as a candidate for the km$^3$ installation

- Depths of more than 3500 m are reached at about 100 km distance from the shore
- Water optical properties are the best observed in the studied sites ($L_a \approx 70$ m @ $\lambda = 440$ nm)
- Optical background from bioluminescence is extremely low
- Stable water characteristics no seasonal variation observed
- Deep sea water currents are low and stable (3 cm/s avg., 10 cm/s peak)
- Wide abyssal plain, far from the shelf break, allows for possible reconfigurations of the detector layout

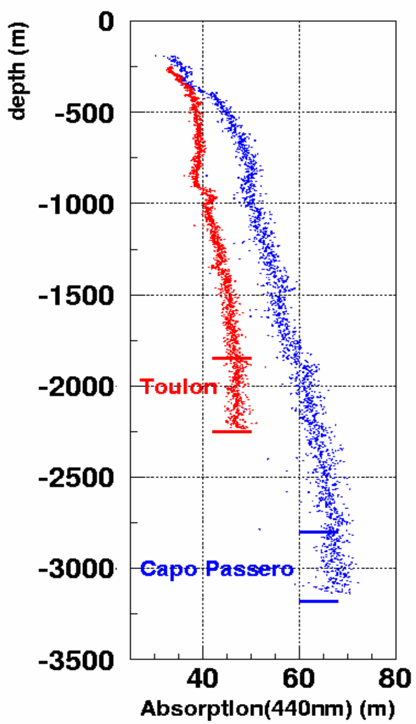


# 3D view of the area

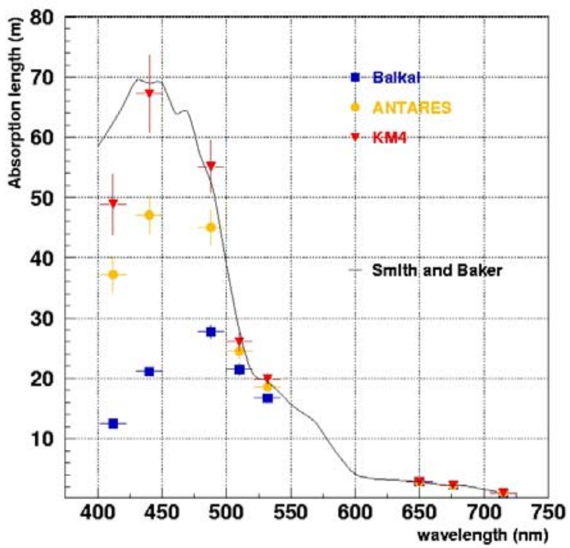


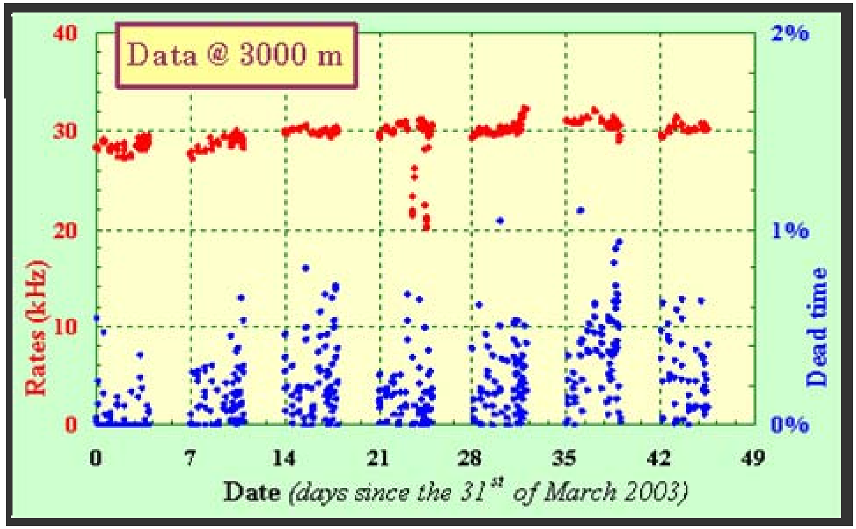
# Optical Water Properties @ Capo Passero

More than 25 campaigns performed. Several joint NEMO-ANTARES campaigns to measure water properties in Capo Passero and Toulon




*Absorption lenghts*




- PMT: 10”
- Thres: ~.5 SPE

Fraction of time
R > 200 kHz

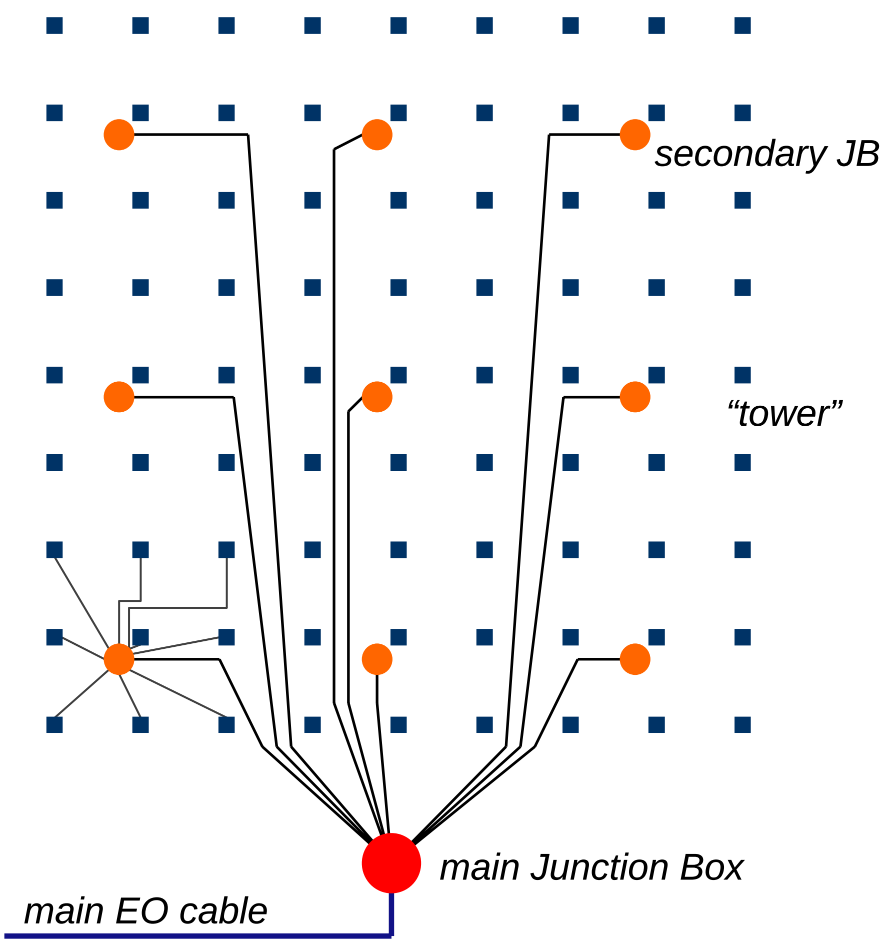
Absorption lengths measured in Capo Passero are compatible with optically pure sea water data

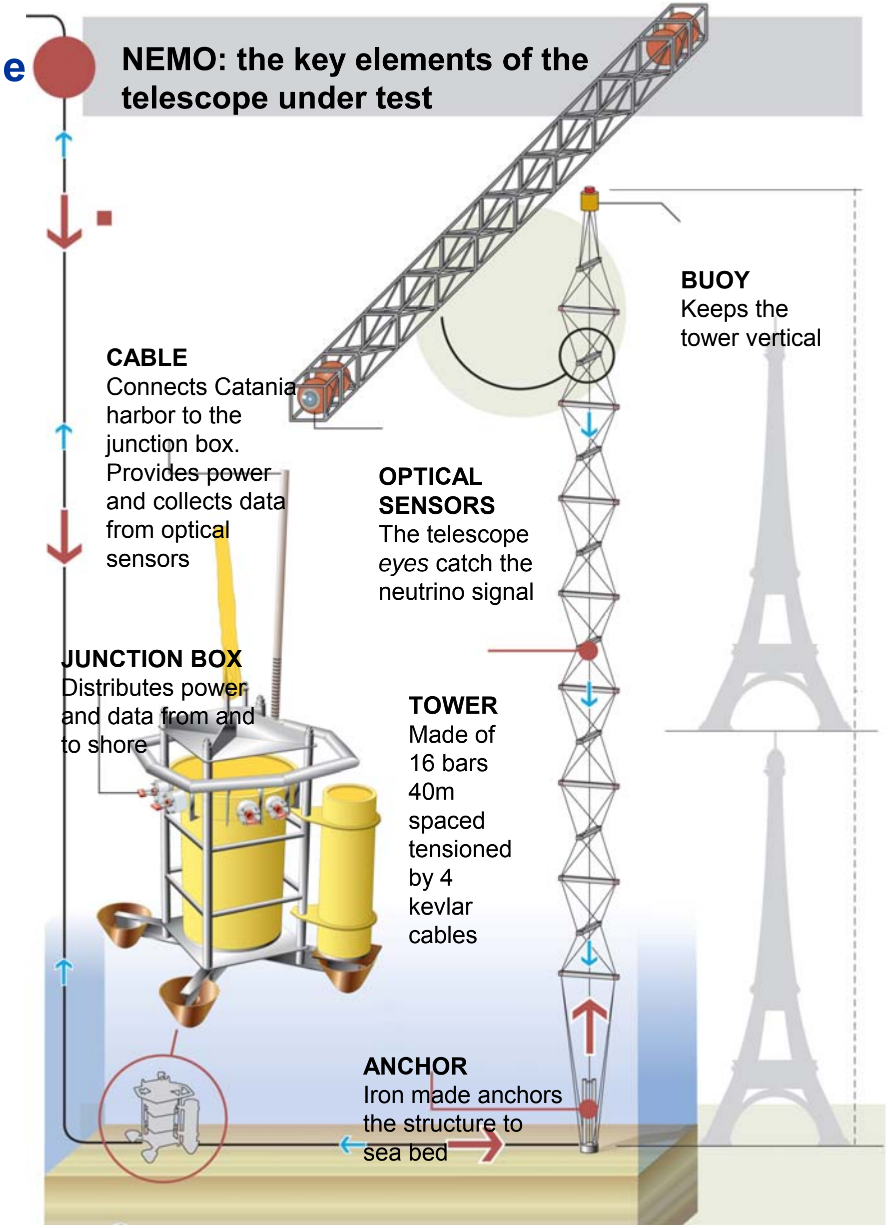
The measured value of about 30 kHz is compatible with pure $^{40}K$ background

# Feasibility study for the km$^3$ detector

**Reduce the number of structures to reduce the number of underwater connections and allow operation with a ROV**

**Detector modularity**

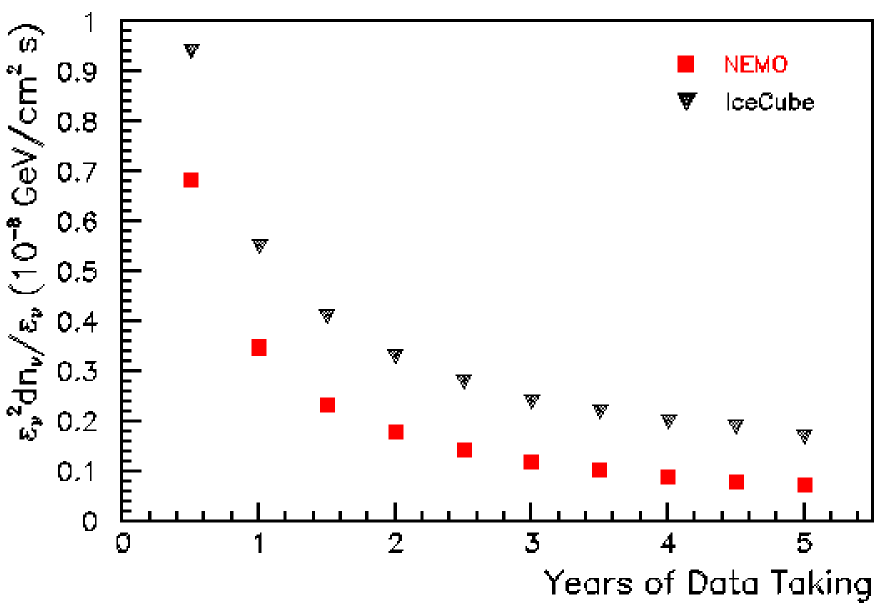


# Tower detector performance

## Sensitivity

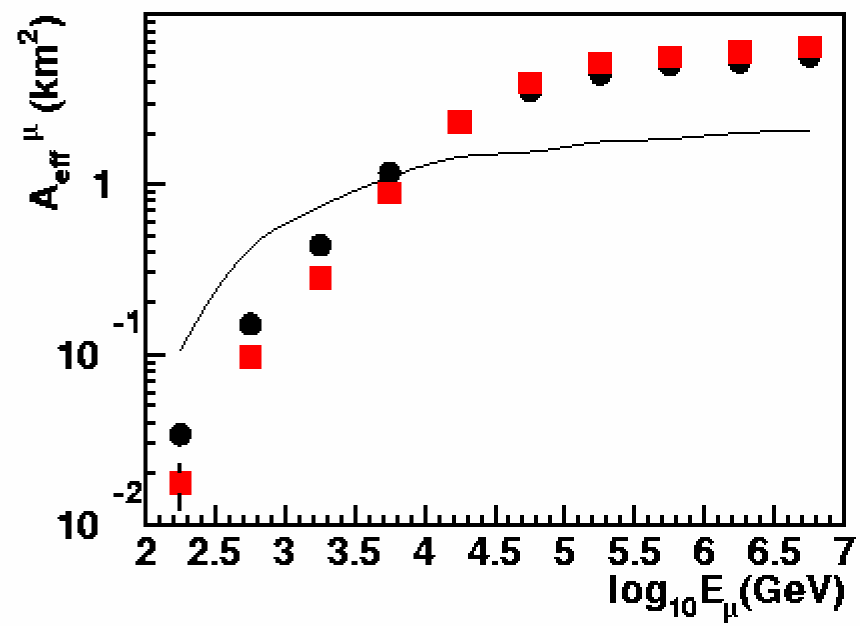
Sensitivity to point-like sources ($E_\nu^{-2}$ spectrum)




*IceCube simulations from Ahrens et al. Astrop. Phys. 20 (2004*

## Reconfigurability

Effective areas with different element




NEMO 81 towers 140m spaced - 5832 PMTs
IceCube 80 strings 125m spaced - 4800 PMTs

**NEMO search bin 0.3°**
**IceCube search bin 1°**

| | tower spacing | floor spacing |
|---|---|---|
| Black line | 140 m | 40 m |
| Red square | 300 m | 60 m |
| Black points | 300 m | 40 m |

# The NEMO Phase-1 project

- Validation of the technological solution proposed for the realization and installation of the km$^3$ detector
- Realization of a techonological demostrator including all the key elements of the km$^3$
  - *Mechanical structures*
  - *Optical end environmental sensors*
  - *Read out electronics*
  - *Data transmission system*
  - *Power distribution system*
  - *Acoustic positioning system*
  - *Time calibration system*
- Multidisciplinary activities
  - *O$\nu$de (measurements of the acoustic background at 2100 m depth, daulphins and sperm whales)*
  - *SN-1 (first operative node of ESONET)*

# NEMO Phase-1- LNS test site

Double armored cable
2.330 m

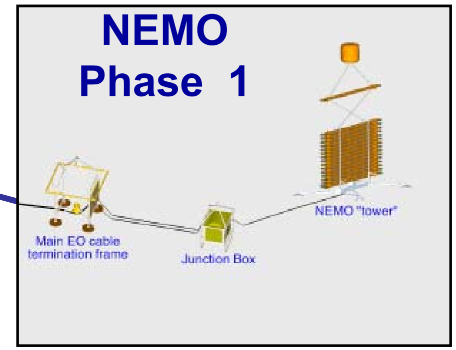
Single armored cable
20.595 m

BU

North branch
5.220 m

SN-1 recorded a large number of seismic events.

South branch
5.000 m




**Cable features**

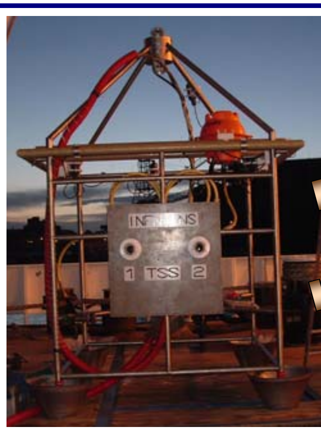
10 optical fibers ITU-T G-652

6 electrical conductors $\Phi = 4\ mm^2$

Junction Box

Mini-tower - 4 floors

Frame



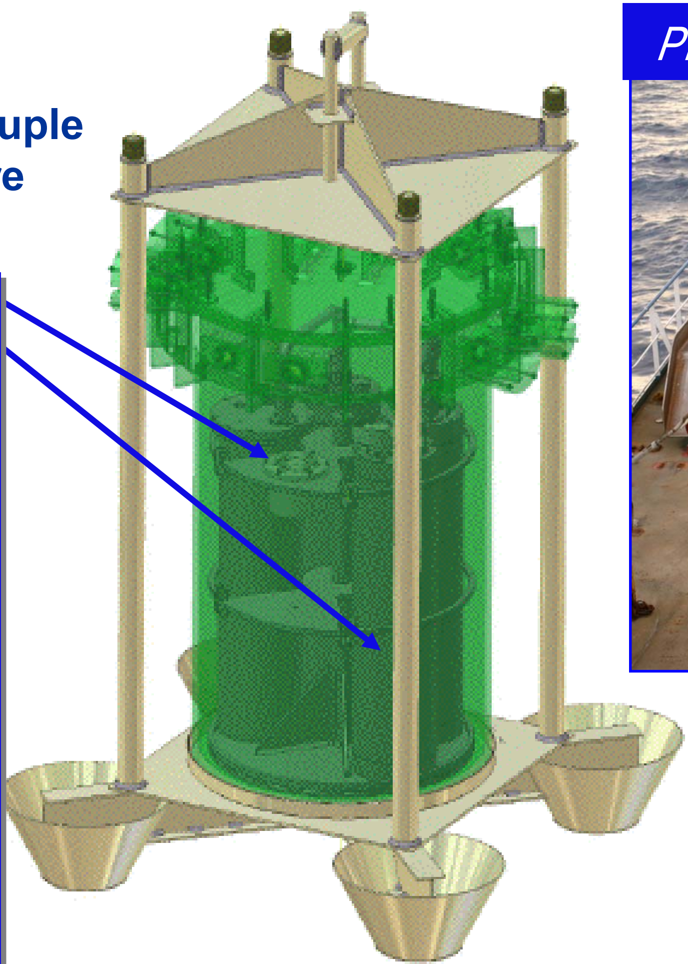
Jumper 300m

Jumper 300m

# The Junction Box

**Data transmission electronics**
**Power distribution and control system**
**Optical fibre splitters**
**Innovative design to decouple the corrosion and pressure resistance problems**

*Electronics pressure vessels*



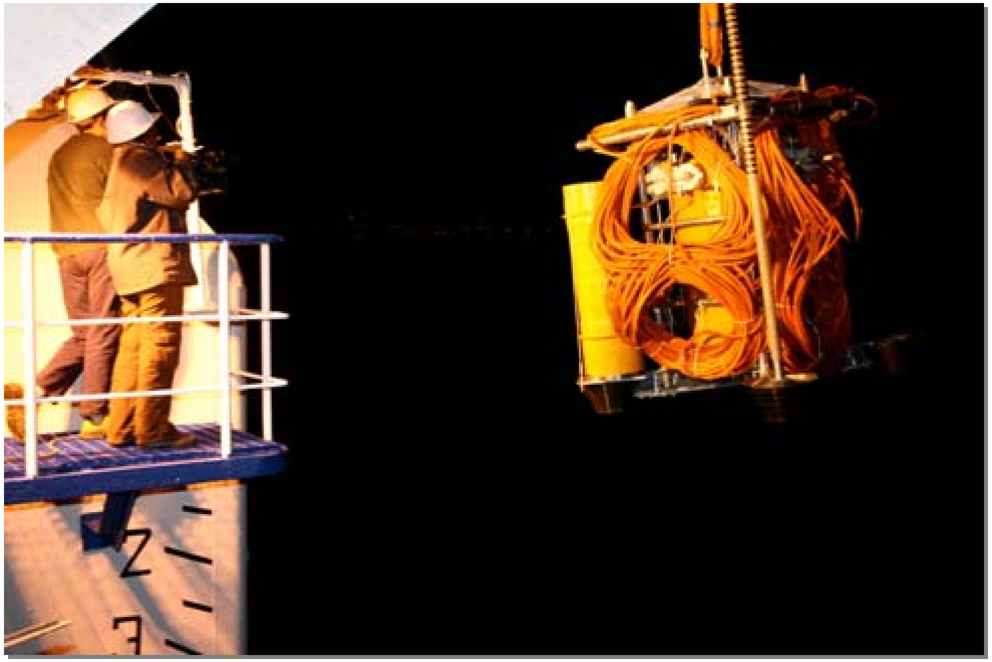
**December 2006**

*Preparation to the deployment*

# NEMO Phase-1 installation

**December 10 2006**

*Deployment of the Junction Box*

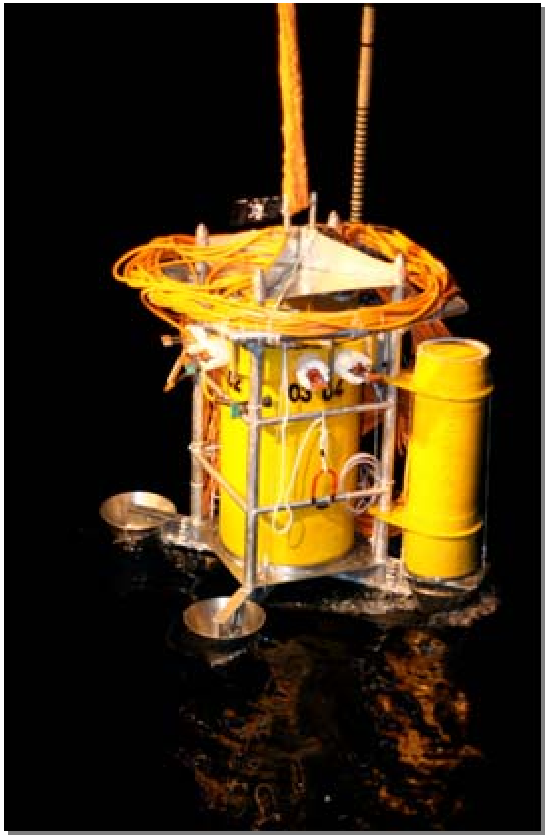


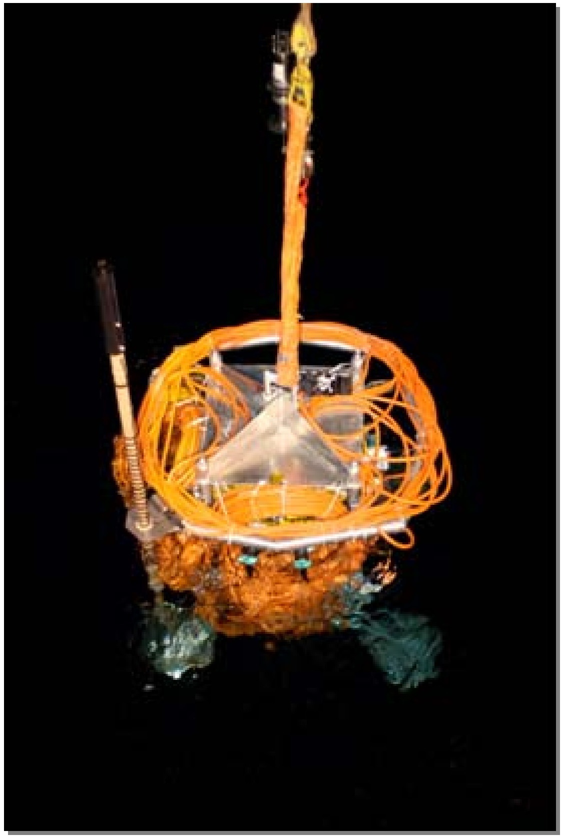
*Accidental fall on the ship deck during deployment*
*JB tested for functionality and deployed*

# NEMO Phase-1 installation

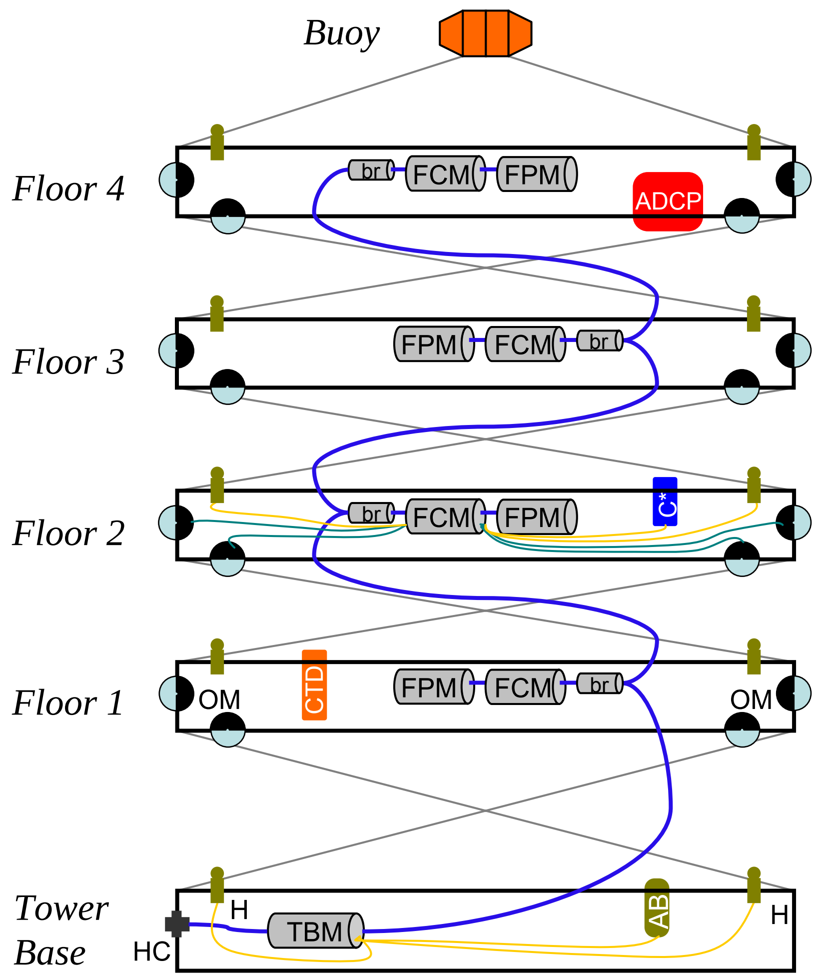
**December 10 2006**

*Deployment of the Junction Box*



# Scheme of the prototype tower




4 floors

*Lenght 15 m*

*Vertical spacing 40 m*

16 Optical Modules with 10" PMT

Acoustic Positioning

*2 hydrophones per floor*

*1 beacon on the tower base*

Environmental instrumentation

*1 compass + tiltmeter in each Floor Control Module*

*CTD (Conductivity-Temperature-Depth) probe on floor 1*

*C* (attenuation length meter) on floor 2*

*ADCP (Acoustic Doppler Profiler (including compass) on floor 4*

# NEMO Phase-1 installation

**December 13 2006**

*Exit from the shore station*

# NEMO Phase-1 installation

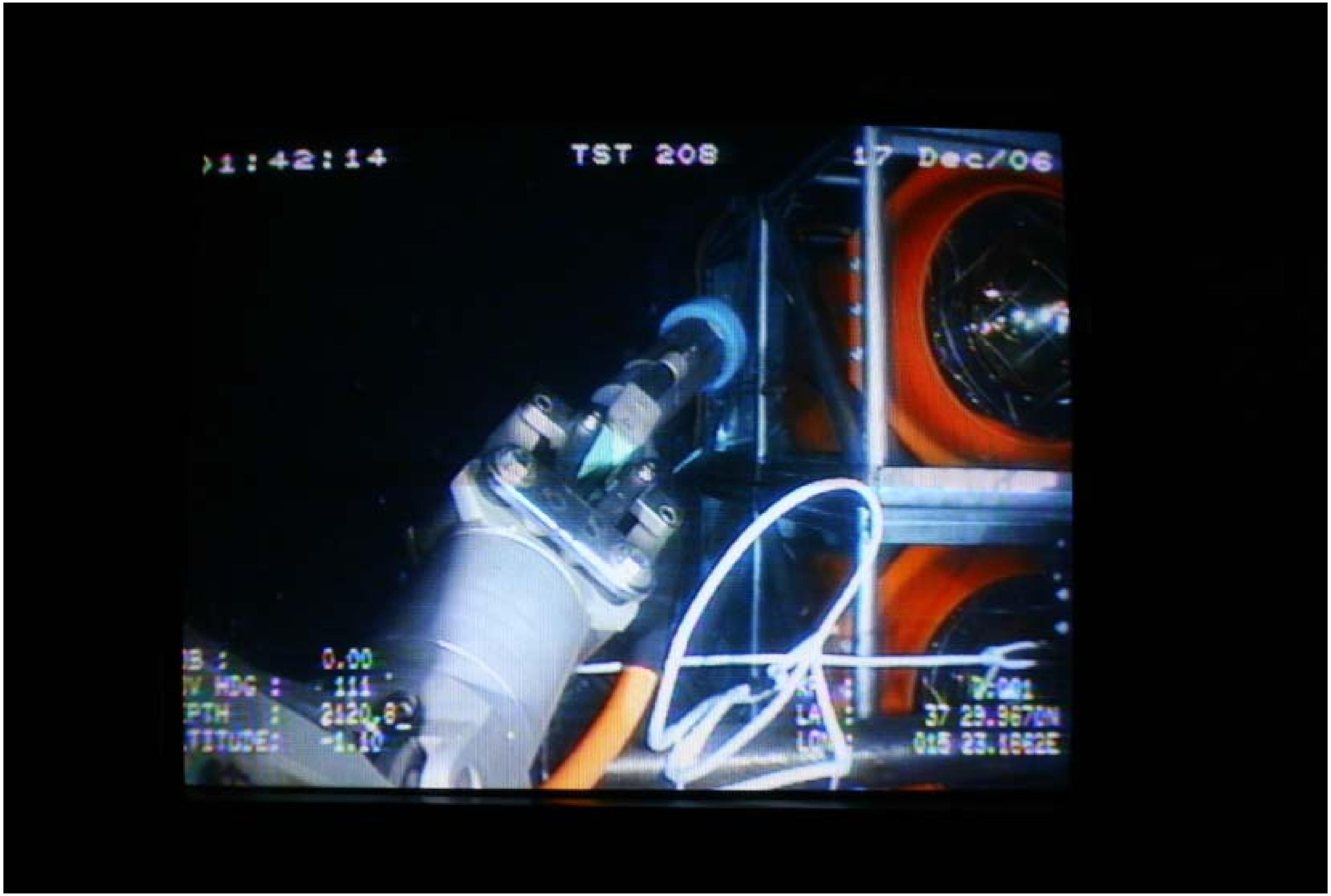
**December 13 2003** *Loading of the tower*

# NEMO Phase-1 installation

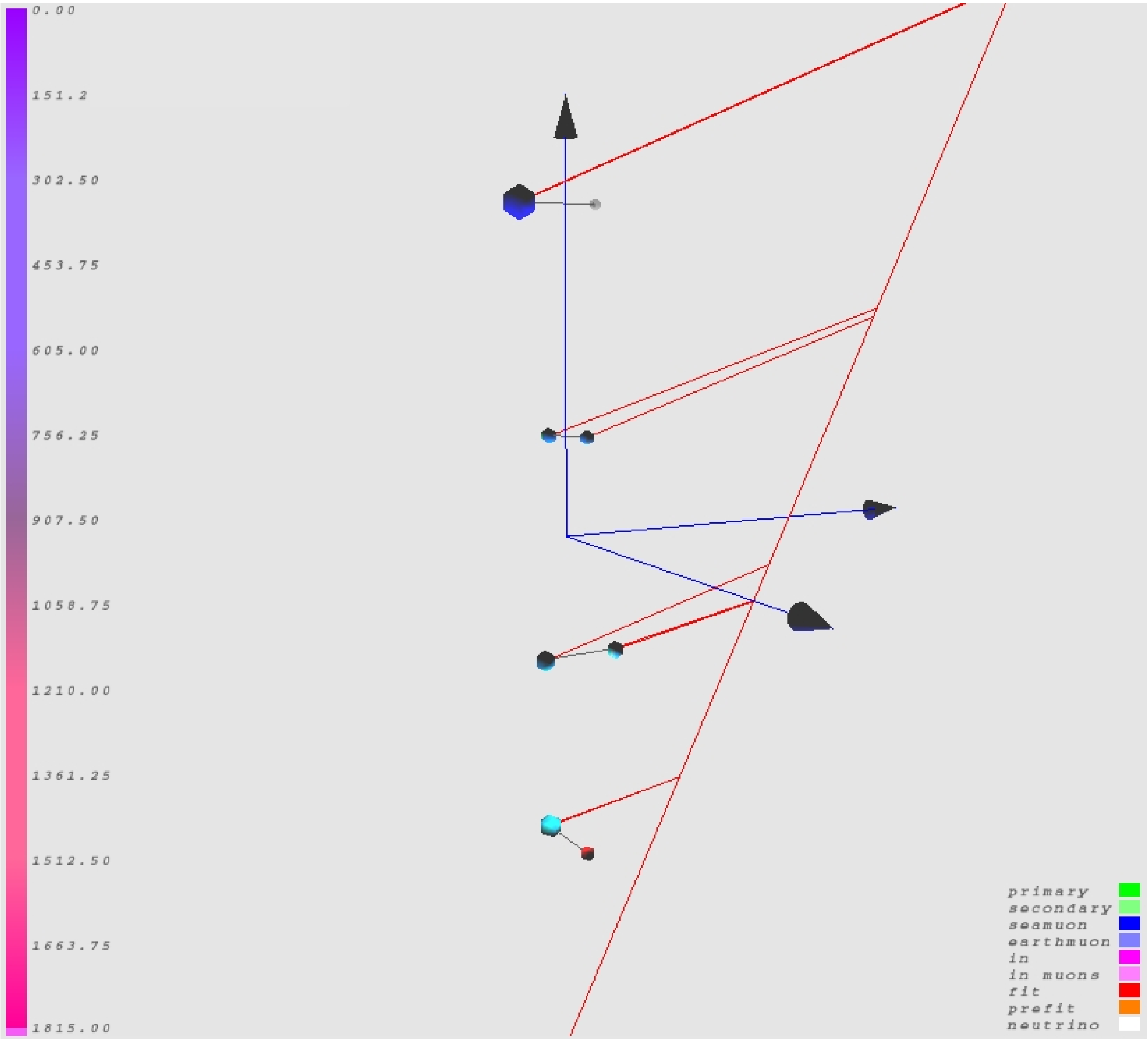
**December 15 2003** *Deployment of the tower*

# NEMO Phase-1 installation

**December 16 2006** *Connection of the tower to the JB*



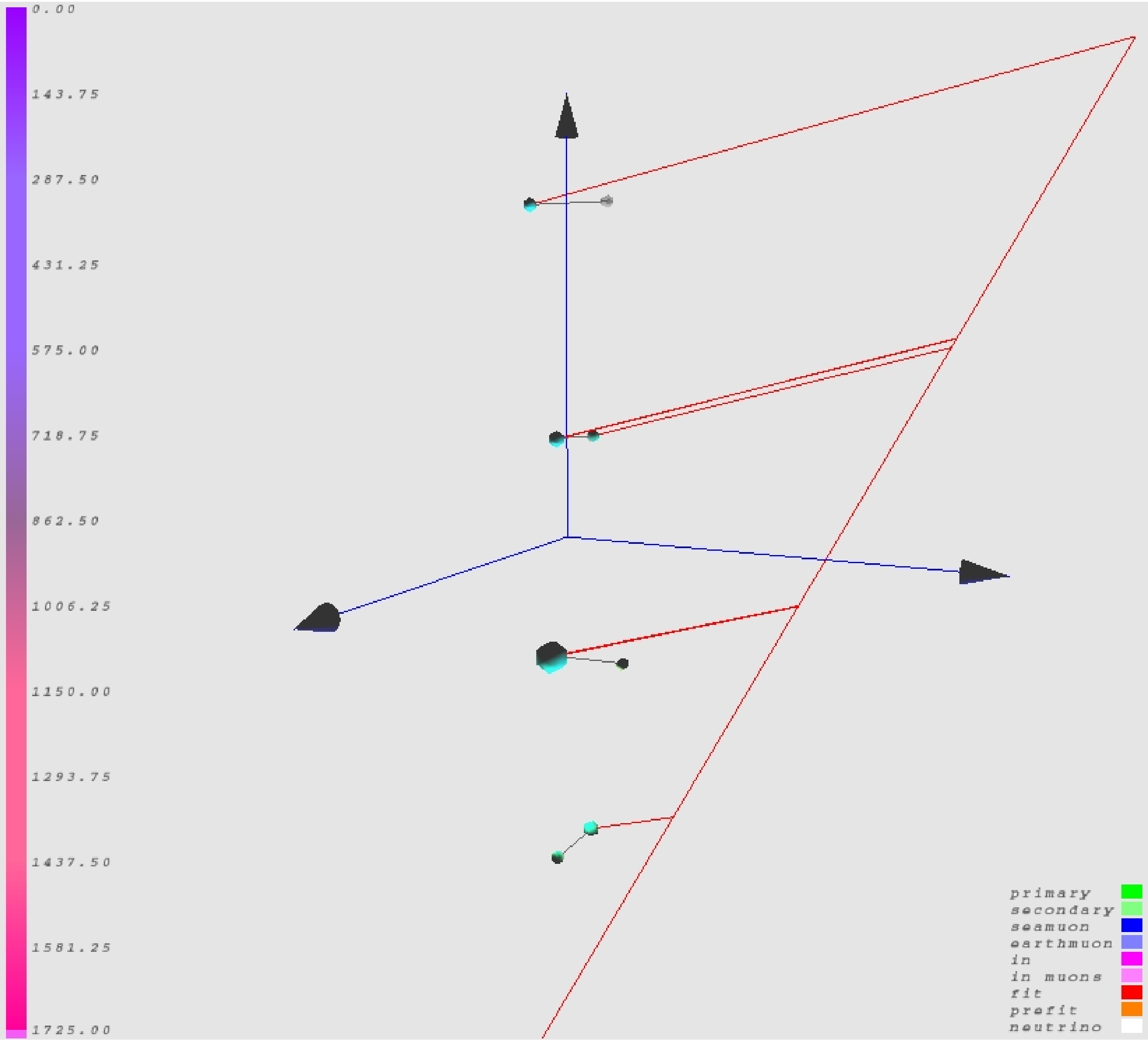
# Atmospheric muon reconstruction




January 2007
Run 23 file 1
Event 189722
11 PMT involved

- Trigger local coincidence up-horizontal ($\Delta t$=20ns)
- Aart Reconstruction
- Background rejection -> causality with the highest in charge and in coincidence

# Atmospheric muon reconstruction




January 2007
Run 23 file 1
Event 356615
11 PMT involved

- Trigger local coincidence up-horizontal ($\Delta t$=20ns)
- Aart Reconstruction
- Background rejection -> causality with the highest in charge and in coincidence

# Lessons learned: the junction box

- Oil bath solution successful
  - Applied to the JB and the electronics containers of the tower
  - All power electronics under pressure in oil bath
- Importance of redundancies
  - All control channels in the JB duplicated
  - Minor failures on some control boards overcome via redundant path

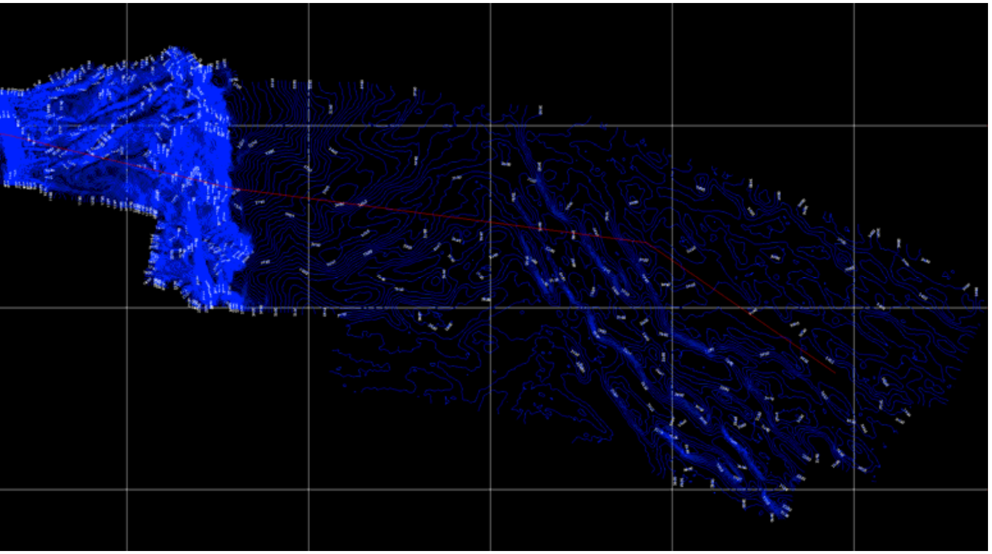
but …

- Malfunctions due to accidental crash
  - Recovery of the JB (June 16 2007)
  - Repair and redeployment (planned in autumn)

# Lessons learned: the tower

- No water leakage
- Loss of buoyancy
  - Due to deterioration of the buoy material under pressure
  - Addition of an extra buoyancy planned
- Need of thorough tests of each component
- Characteristics of the front-end electronics and data transmission system to be kept in Phase-2 design
  - Acquisition of the signal waveform
  - Remote firmware dynamic loading
  - Low power dissipation (12 W / floor)
  - “Symmetric” on-shore off-shore electronics
- Successful integration of a complex structure, but some choices need to be revised
  - Simplification of the backbone cable
  - Optimization of the floor modules

# NEMO Phase-2: a deep sea station (3500 m)

**INFRASTRUCTURE UNDER CONSTRUCTION**

- Shore station in Portopalo di Capo Passero
- 100 km electro optical cable
- Underwater infrastructures

**STATUS AND PLANS**

- Electro-optical cable (>50 kW, 20 fibres) delivered and loaded onboard the cable layer vessel
- Cable deployed (summer 2007)
- Power feeding system under construction, acceptance tests december 2007
- Installation of cable termination frame with DC/DC converter beginning 2008
- Renovation of the shore station building under way. Completion beginning 2008
- Tower deployment foreseen for mid 2008

# Modifications and upgrades in NEMO Phase-2

- Full tower with 16 floors (12 meter size)
  - Same electronics of Phase-1, but two floors devoted to R&D (new electronics, directional OMs, …)

- New DC power system to comply with the feeding system provided by Alcatel

- Optimization of the electronics and data transmission

- Integration of a new acoustic station and new time calibration system

# Conclusions and perspectives

- Overall successful experience of NEMO Phase-1
  - Re-deployment of the Junction Box - autumn 2007
  - Buoyancy
  - Data analysis - in progress
- Changes and upgrades in NEMO Phase-2
  - Simplification of integration procedures
  - cost reduction
- The experience gained will contribute to the advancement of the KM3NeT activities
- NEMO program and time schedule are well fitted to the Design Study and Preparatory Phase (negotiation phase started in these days) of KM3NeT