NEMO
NEUTRINO MEDITERRANEAN OBSERVATORY

Status Report

Antonio Capone, Roma

on behalf of the NEMO Collaboration

DIPARTIMENTO DI FISICA
SAPIENZA UNIVERSITÀ DI ROMA

Very Large Volume Neutrino Telescope
VLVνT workshop

INFN Istituto Nazionale di Fisica Nucleare
SEZIONE DI ROMA

Outline of the talk

- NEMO-R&D activities
  - sites exploration
  - preliminary design of a km^3 detector
- NEMO-Phase1
  - aim and objectives of the project
  - the NEMO mini-tower
  - lessons learned and preliminary results
- NEMO-Phase2
  - the Capo Passero infrastructure
  - the NEMO-Phase2 16 floor tower
  - status of the project

The NEMO Collaboration

INFN
Bari, Bologna, Catania, Genova, LNF, LNS, Napoli, Pisa, Roma

Università
Bari, Bologna, Catania, Genova, Napoli, Pisa, Roma *"La Sapienza"*

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)

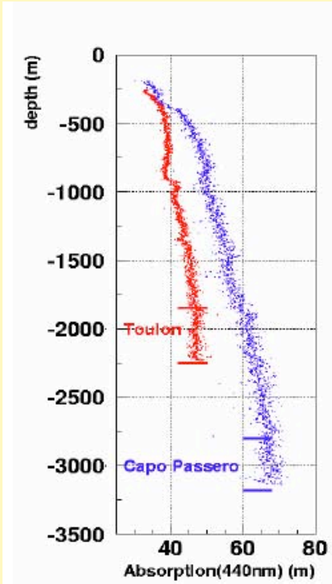
Istituto Superiore delle Comunicazioni e delle Tecnologie dell'Informazione (ISCTI)

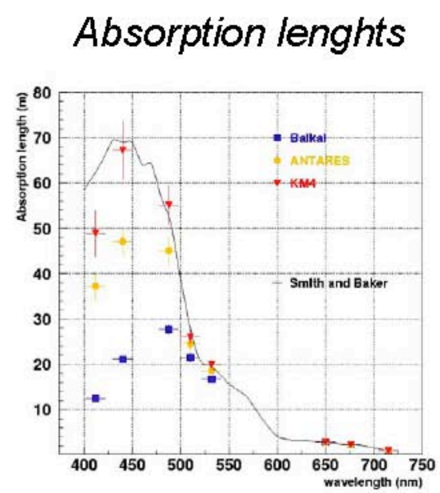
More than 80 researchers from INFN and other italian institutes

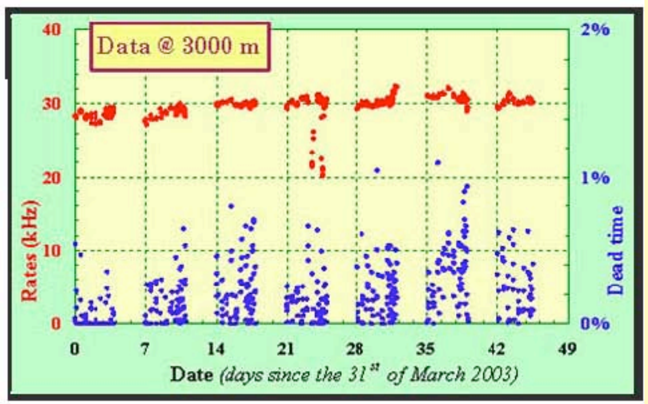
1998-2004 NEMO R&D and site selection

- Extensive site exploration of Mediterranean Sea: selected Capo Passero site near Catania, depth 3500 m
  - best optical properties out of studied sites L_a ~70m @ 440nm
  - no seasonal variations of water optical properties
  - extremely low background from bioluminescence
  - deep Sea water current are low (3cm/s avg.) and stable
  - Wide abyssal plain, far from the shelf break, allows for possible reconfigurations of the detector layout

- R&D towards km³: detector architecture, mechanical structures, electronics, readout, cables …, junction box, all technological issues;
- Simulations





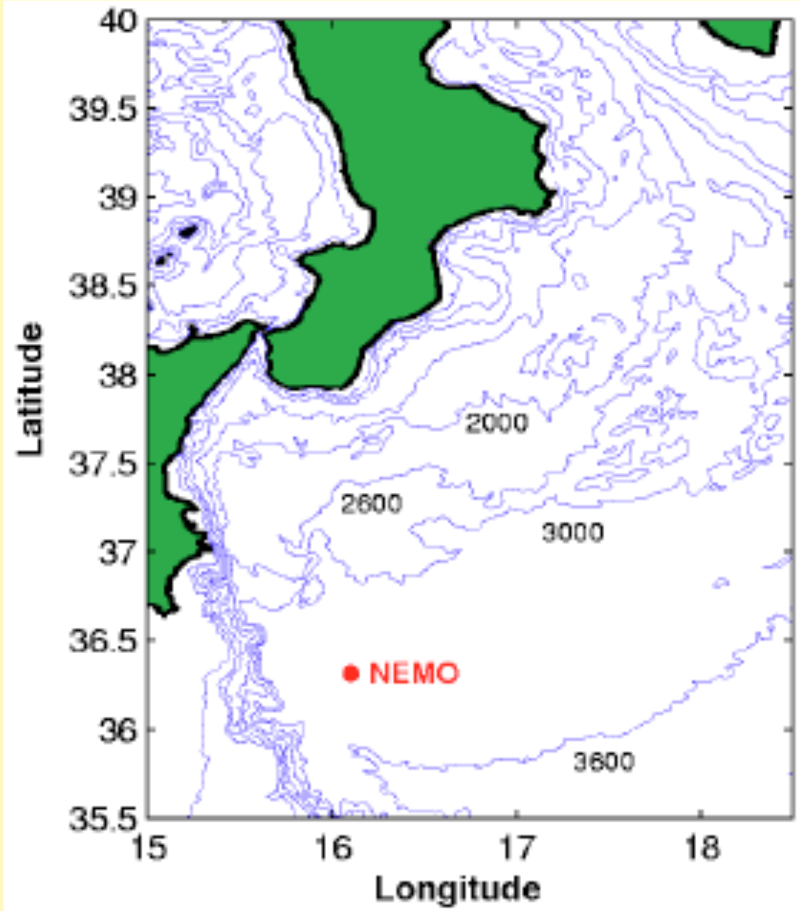


➢ PMT: 10"
➢ Thres: ~.5 SPE

Fraction of time
R > 200 kHz

The Capo Passero site

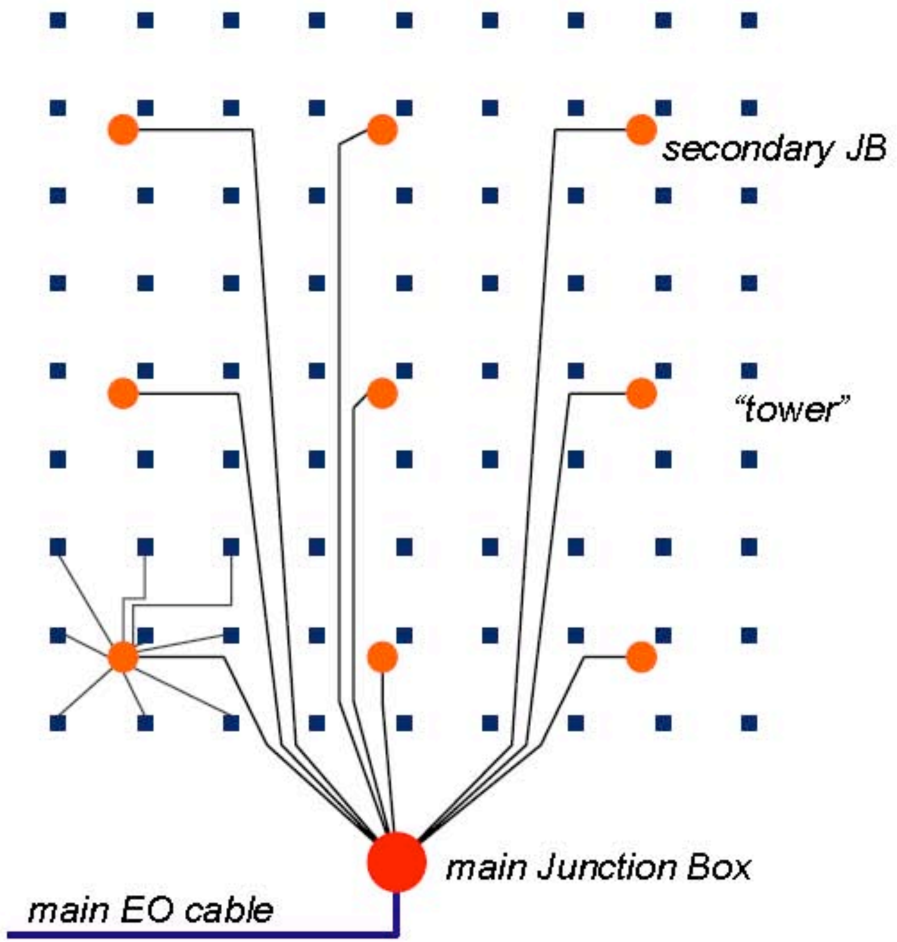
- The site has been proposed to ApPEC, in January 2003, as a candidate the km^3 Neutrino Telescope deployment
  - Depths of more than 3500m are reached at less than 100km from the shore
  - Water optical properties are the best observed in the studied sites: **L_a ~70 m @ λ = 440 nm**
  - Optical background from bioluminescence is extremely low
  - very weak deep sea currents: **<v> ~ 3 cm/s, v_{peak} ~10 cm/s**
  - Stable deep-sea water environmental parameters
  - wide abyssal plain, far from the shelf break, offers the possibility to configure the detector layout according to any scheme.

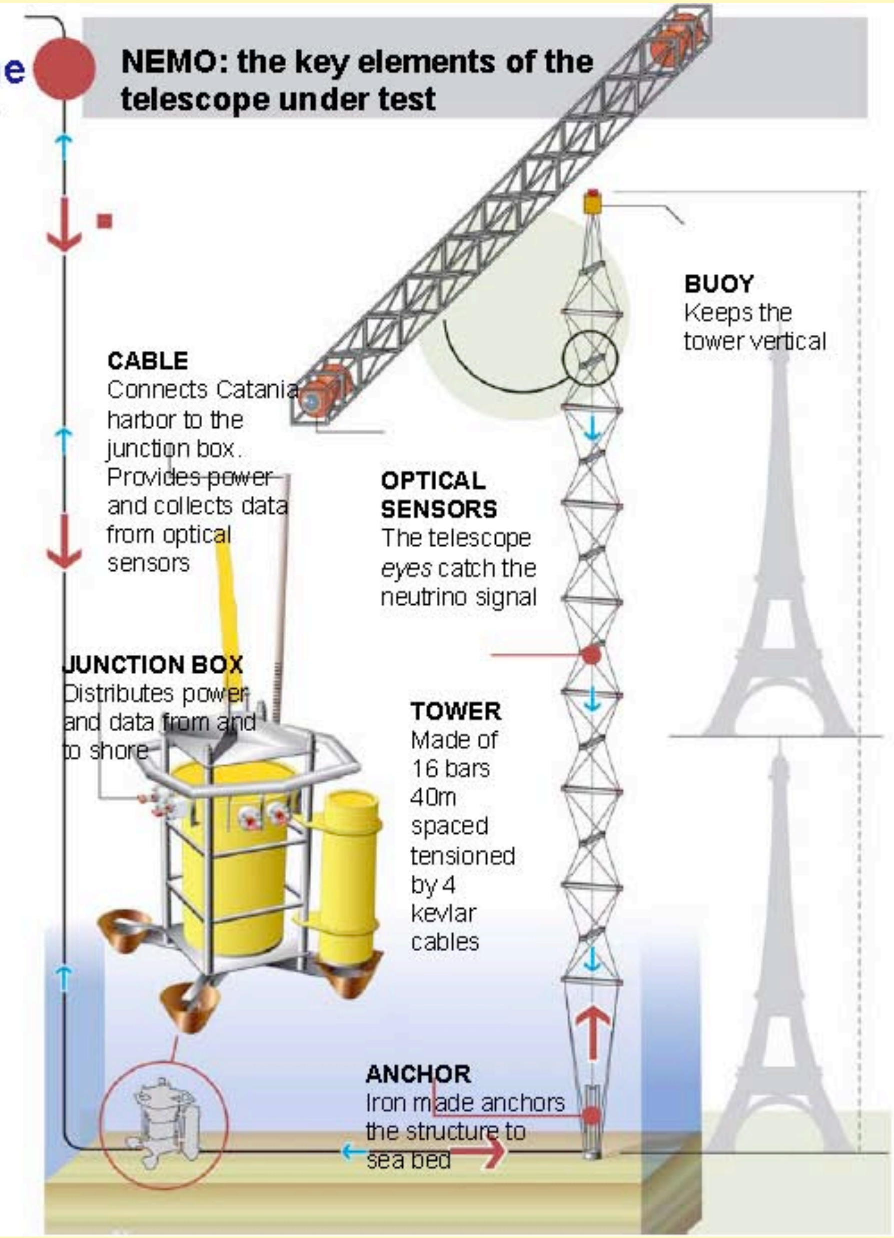


NEMO-R&D technologies for the Neutrino Telescope

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

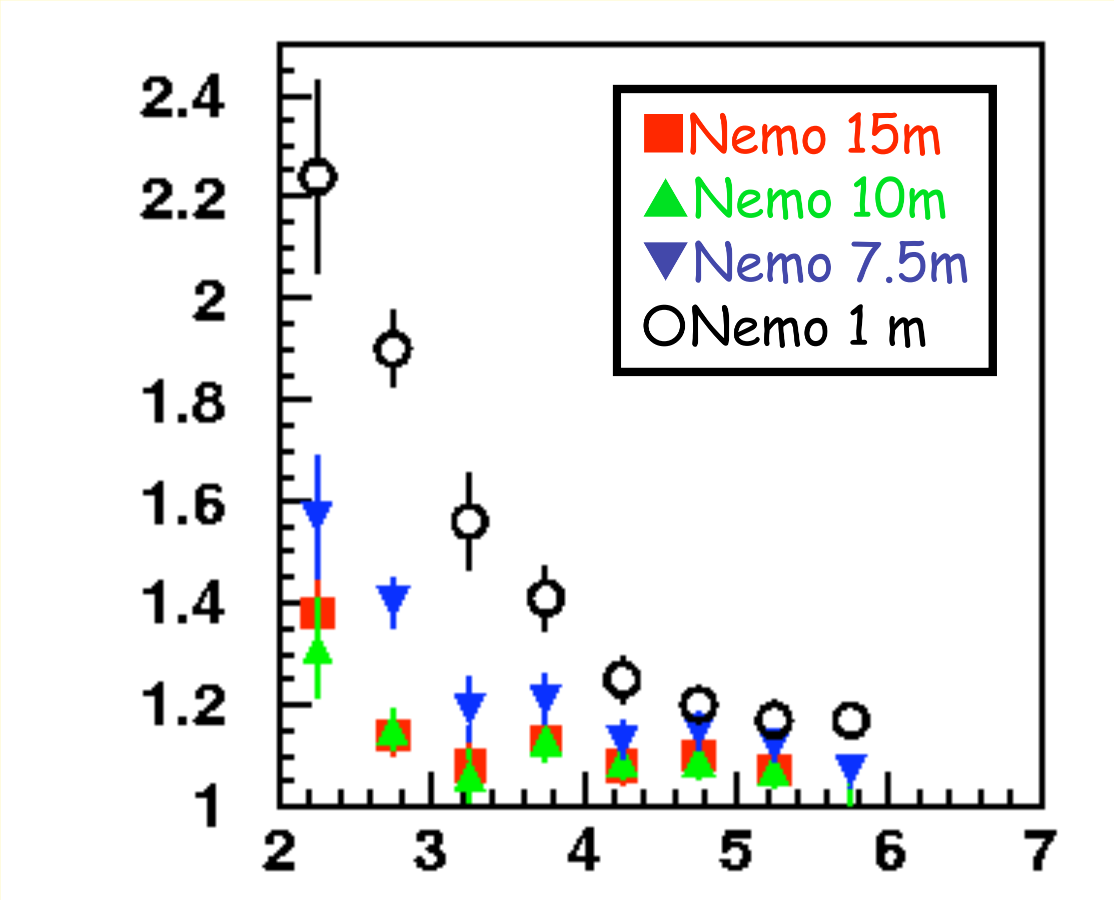
Detector modularity





Why long arms on the Tower ?

Effective area (20m length)/ Effective area (shorter arm lengths) for given angular resolution

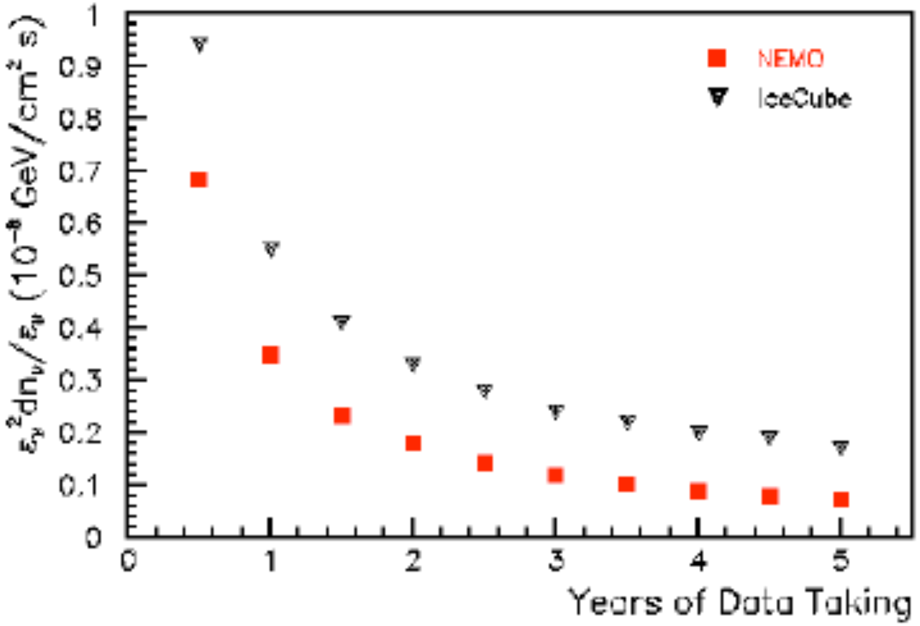


Full simulation (using ANTARES code) show that arms with length < 10m lose angular resolution

see R. Coniglione talk on Physics parallel session

Sensitivity

Sensitivity to point-like sources (E_ν^{-2} spectrum)



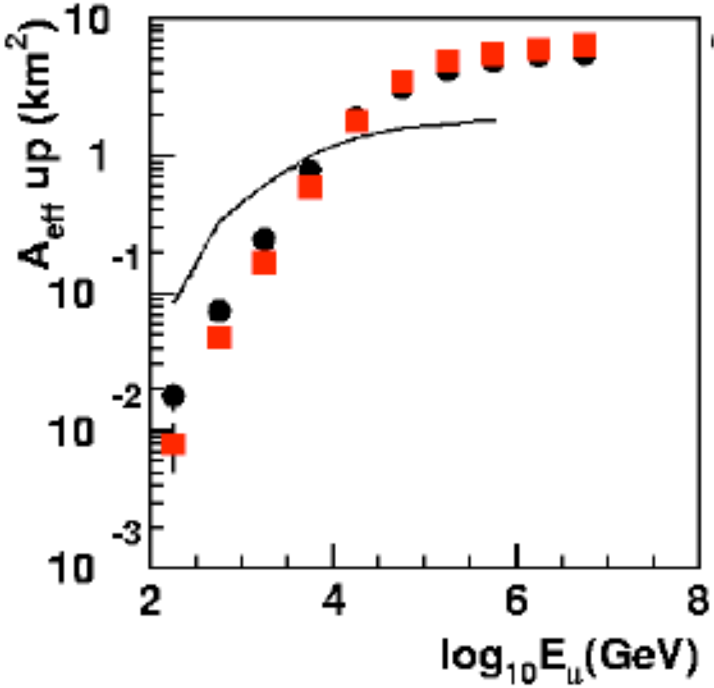
IceCube simulations from Ahrens et al. Astrop. Phys. 20 (2004) 507

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

NEMO search bin 0.3°
IceCube search bin 1°

Reconfigurability

Effective areas with different element spacing

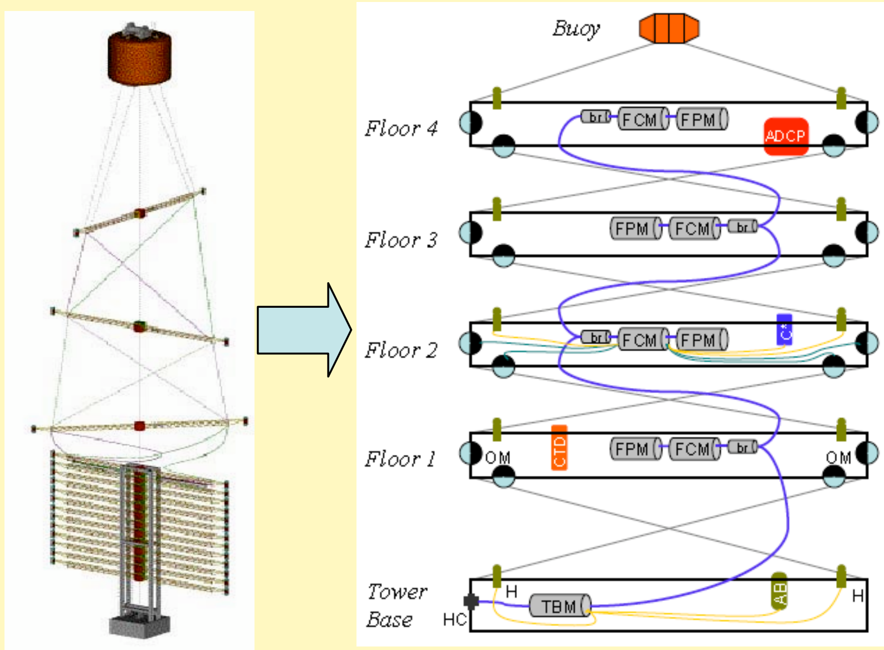


	tower spacing	floor spacing
Black line	140 m	40 m
Red square	300 m	60 m
Black points	300 m	40 m

See Rosa Coniglione talk on 23/4 morning parallel session on Physics

NEMO-Phase1 - 2004-2007

- Created a "**Deep-Sea Test Site**", 20 Km East of Catania at 2000m depth, connected with 25 km long EOC to the shore station of INFN-LNS
- **Validation of the technological solutions** proposed for the realization and installation of the km^3 detector
- Realization of a technological demonstrator including all the key elements of the NEMO km^3 concept
  - *Mechanical structures*
  - *Optical and environmental sensors*
  - *Readout electronics*
  - *Data transmission system*
  - *Power distribution system*
  - *Acoustic positioning system*
  - *Time calibration system*

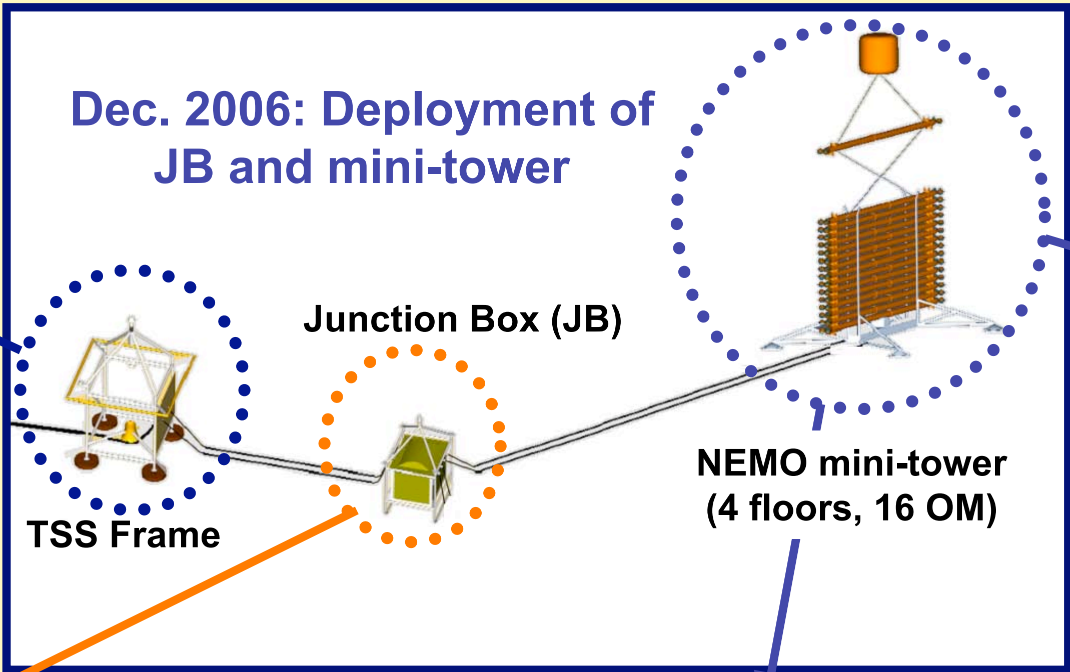


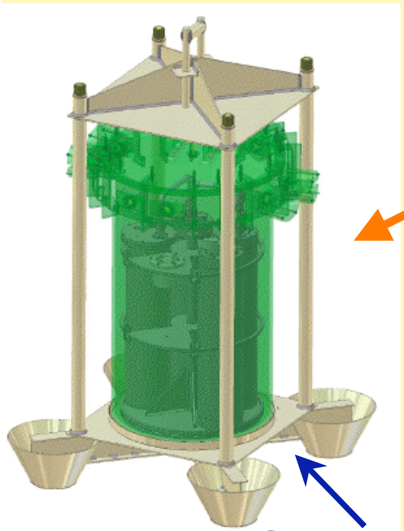
- **Multidisciplinary active laboratory**:
  - ***SN-1 by INGV: the first operative node of ESONET***
  - ***Oνde (measurements of the acoustic background at 2100 m depth, dauphins and sperm whales)***

NEMO Phase-1: a 4 floors tower @ 2000m depth

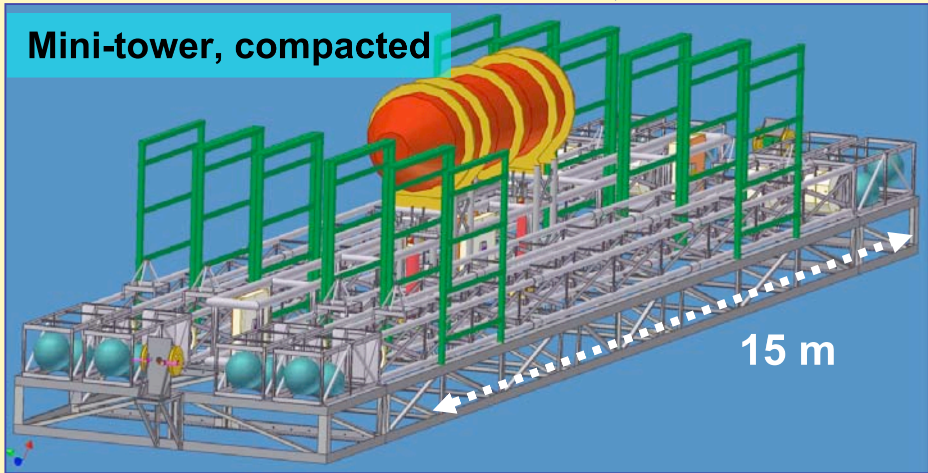
In the INFN NEMO Test Site, 20 km East of Catania

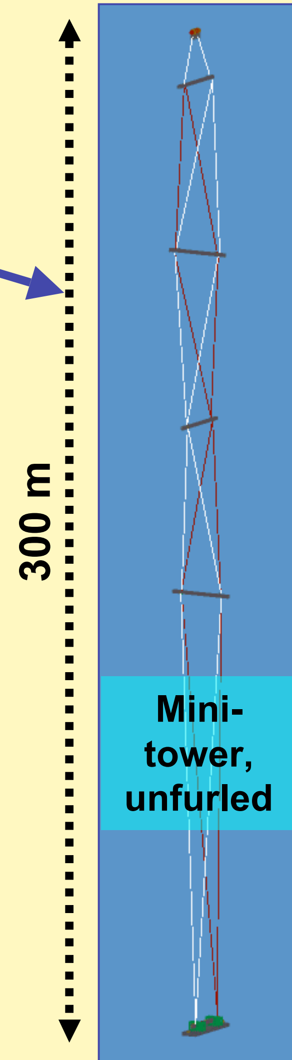
Deployed January 2005





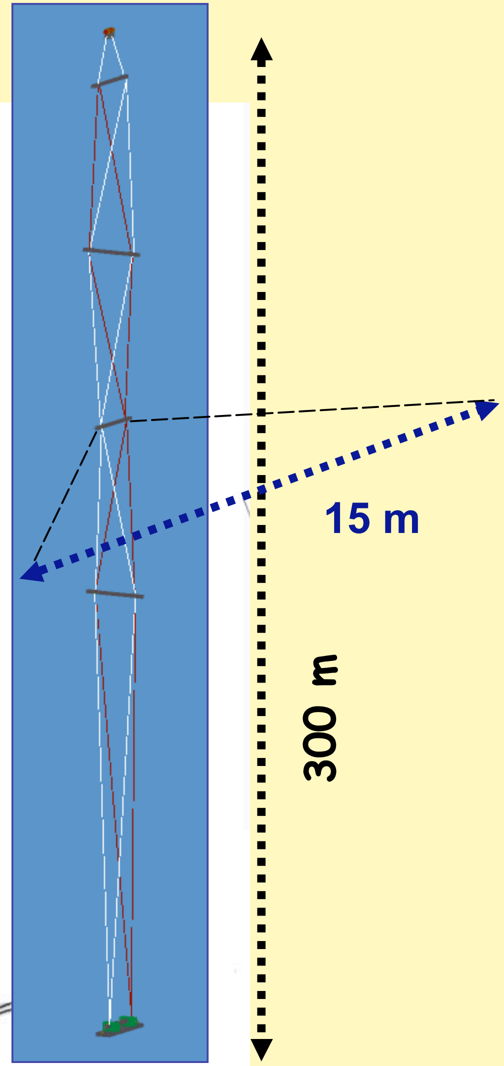
NEMO Junction Box new low cost technology



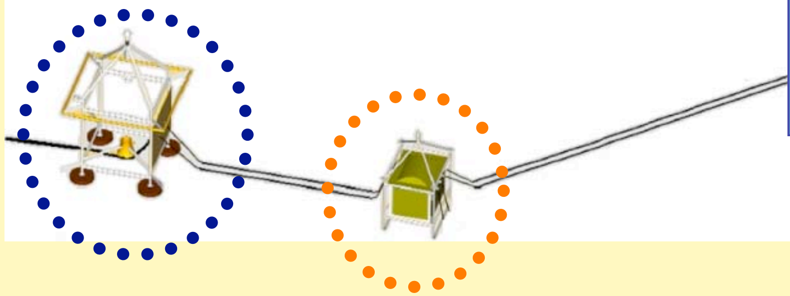


Layout of the NEMO Phase-1 apparatus

The OνDE acoustic station was installed on the TSS

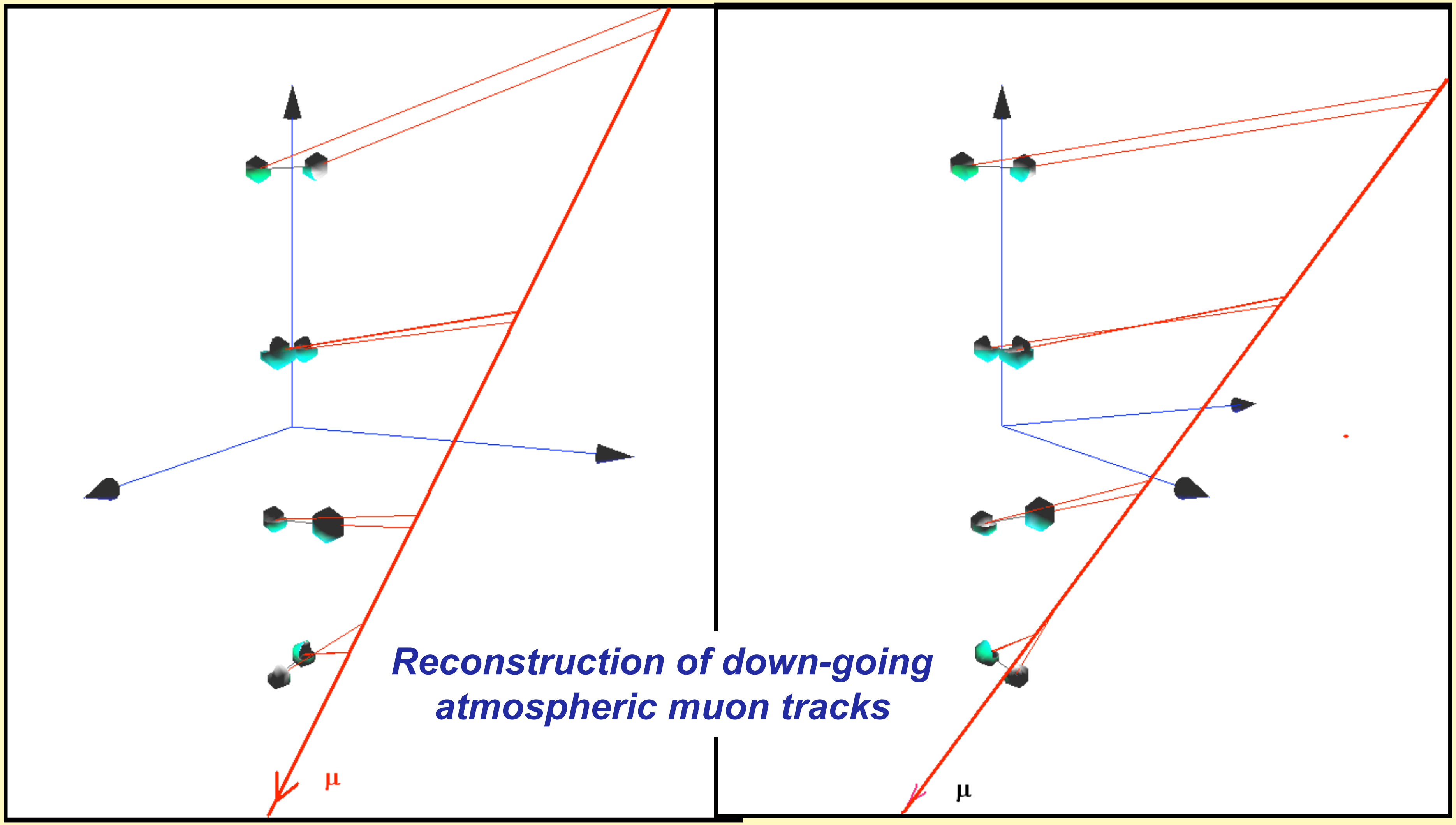


TSS Frame



Preliminary data

see Isabella Amore talk on Physics parallel session



Reconstruction of down-going atmospheric muon tracks

January 24 2007 - Run R17 file 1 Event # 366059 13 PMT hit

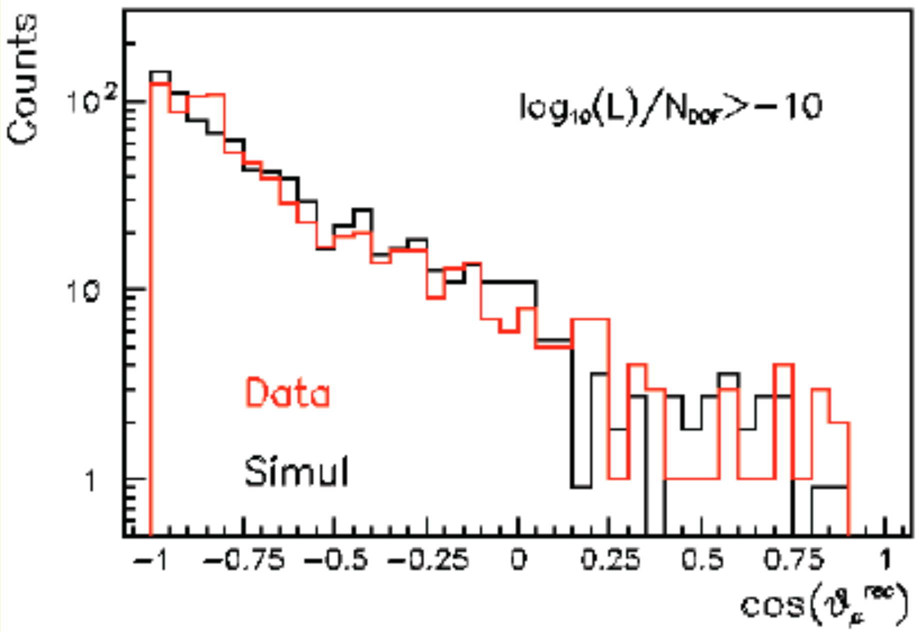
Angular distribution of reconstructed tracks

Rate Data tracks reconstructed = 0.047 ± 0.001 Hz

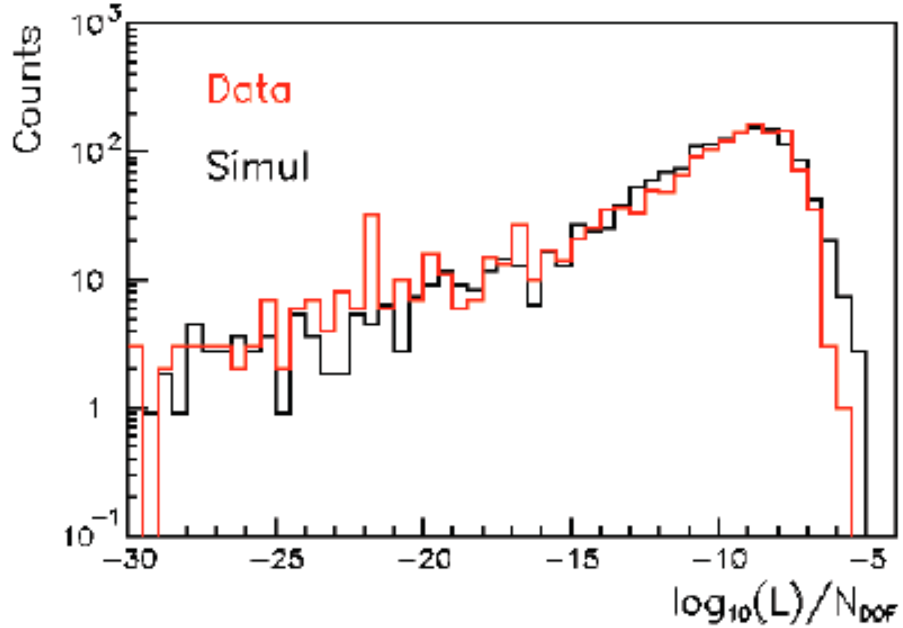
Rate Simulated tracks reconstructed = 0.044 ± 0.001 Hz

see Isabella Amore talk on Physics parallel session

Atmospheric muon angular distribution



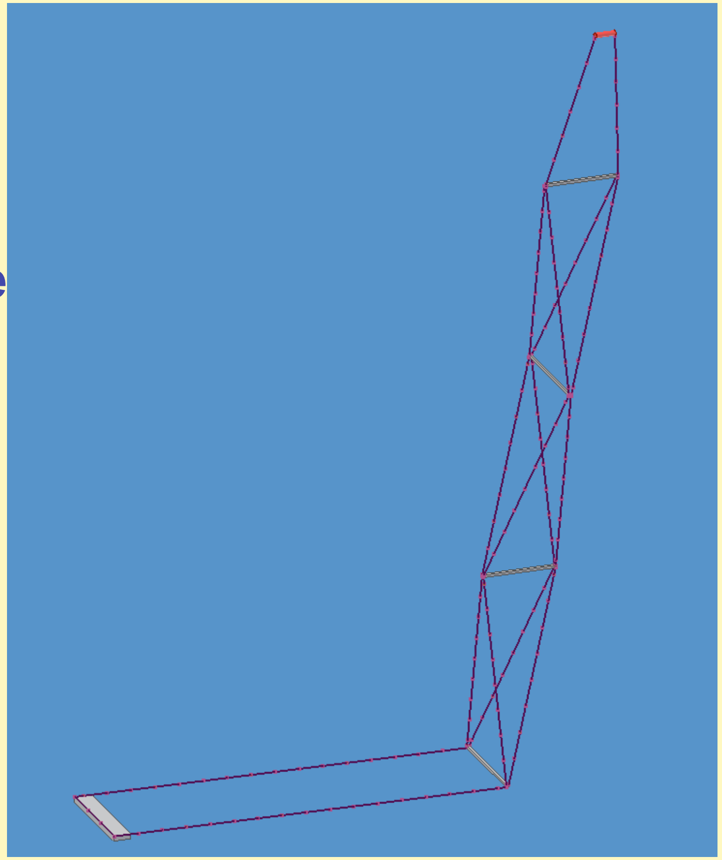
Likelihood Distribution



Preliminary results: tracks angular distribution for short period, 10 hours, of data acquisition

NEMO mini-tower, big success … but also some problem …

The **mini-tower deployment**, **connection** to the main EOC and **unfolding** operations went quite **smoothly**. **All active elements** (PMT, electronics, acoustic positioning, data transmission and acquisition, **did work perfectly**.



Two weeks after the deployment the buoy started to sink and the mini-tower, while data were produced, very slowly went towards the Sea-floor: the two lower floors finally did lay on the Sea bottom. An ROV visual inspection did confirm the new “geometry” of the mini-tower as indicated by the acoustic positioning system.

The explanation for the failure of the buoy was indicated by tests performed by the producer that admitted a production error.

We have studied, and possibly we will perform, **an action to add new buoys** and then **to recover the mini-tower correct position in water**.

Junction Box story and related problems

- During the deployment operation, the JB, already raised by the winch, did fall on the ship deck from 2m height. The deployment operation was stopped, the JB status was tested extensively. 24 hours later, after all the needed tests, and a repair to the external mechanics, the JB was declared “working” (only an electronics card belonging to a redundancy system, was not replying to the tests). We decided to resume the deployment (December 2006).

- Problems on optical data transmission system
  - Few weeks after the deployment we noticed an increase of the optical attenuation: the problem was localised inside the Junction Box
  - The optical attenuation increased slowly but continuously and in March we lost the communication with the higher floor.

- Problems on the power system
  - May 2007 we experienced an anomaly on the power transmission system that did originate a short on one of the 3 phases of the AC power transmission system

Junction Box story, … analysis and repairs

In order to get experience for the operation of the JB with the NEMO-Phase2 tower in KM4 we decided to recover the JB and to investigate the problems occurred. **On May 16, with the ship "Teliri", we recovered the JB.**

In general the JB did not show any failure due to the accidental fall. **The steel structure did show no corrosion.**

The **short in the power distribution** system was **attributed to the** shock due to the **JB fall**. We **improved** the **fixation** and the **reliability** of all components even for events like the one happened to the JB.

The reason for the increase of the optical attenuation was found in a "Splitting Box" made by Ocean Design, inside the used penetrators. The element has been sent to ODI, repaired and extensively tested.

Since Friday 18th, the JB is on the ship "Certamen", to be re-deployed.

Short term program of work for NEMO-Phase1

- Junction Box re-deployment ad connection: **today ??**
- Resuming all data taking while the mini-tower is still partially laying on the Sea-floor.
- Envisaging an action with ROV to add buoyancy to the mini-tower and recover its position in deep water (operation still to be defined)
- Finally resuming data taking

NEMO Phase-2

Lessons learned from NEMO-Phase-1

- The compact integration and deployment system allowed easy operations: viable procedure !
- Proper behaviour of the used aluminium alloy (floor mechanics)
- Electronics cards under pressure are reliable
  - Used for all components of the power system
  - No problem from any of the components selected and used
- Double containers steel(pressure) - fibre glass(corrosion) optimal choice:
  - Reduced costs
  - Perfect behaviour (no water leaks)
  - Easy integration, handling and maintenance

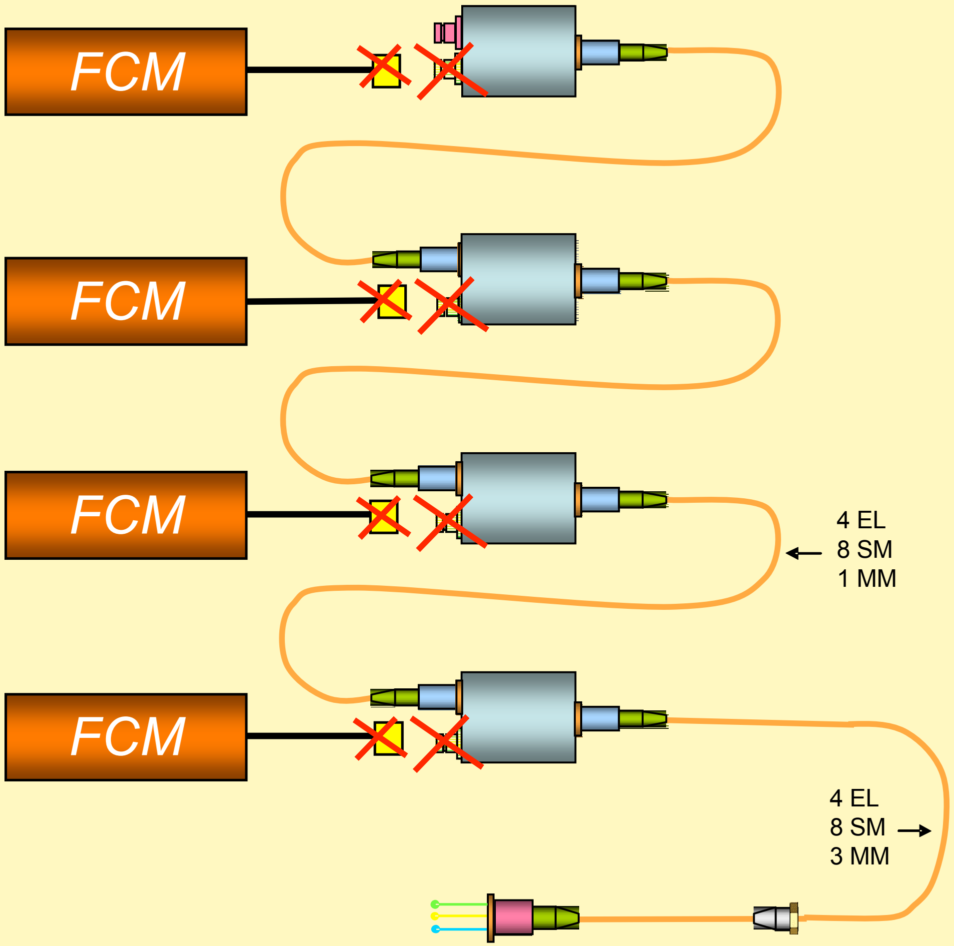
Lessons learned from NEMO-Phase-1

- Importance of redundancies
  - All control channels in the JB duplicated
- Need of thorough tests of each component (the buoy case but also … electronics components, mechanics, …)

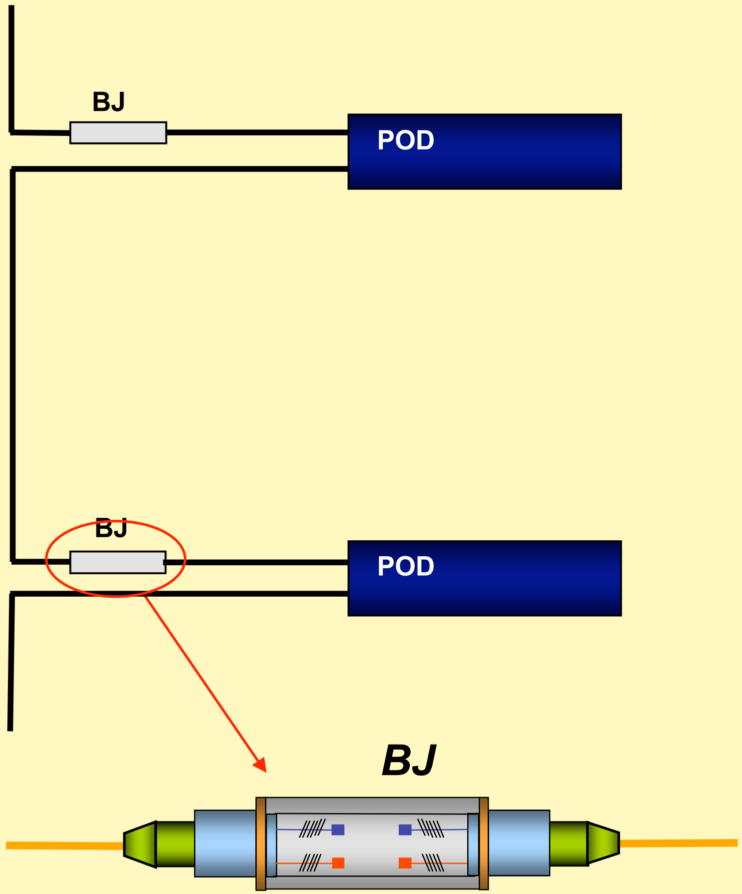
  see S. Russo talk on 23/4 morning parallel session on Engineering
- Characteristics of the front-end electronics and data transmission system to be kept in Phase-2 design
  - Acquisition of the signal waveform
  - Remote firmware dynamic loading
  - Very low power dissipation (12 W / floor)
  - Synchronous link
  - "Symmetric" On/Off-shore electronics
- Positive first experience in integrating a complex structure, but some choices need to be revised
  - Simplification of the backbone cable
  - Optimization of the floor modules

Tower backbone

Phase-1



Phase-2



Connectors mounted for tests will be replaced by fibre splicing at final integration

Segmented backbone cable will allow for an easier integration and cost reduction

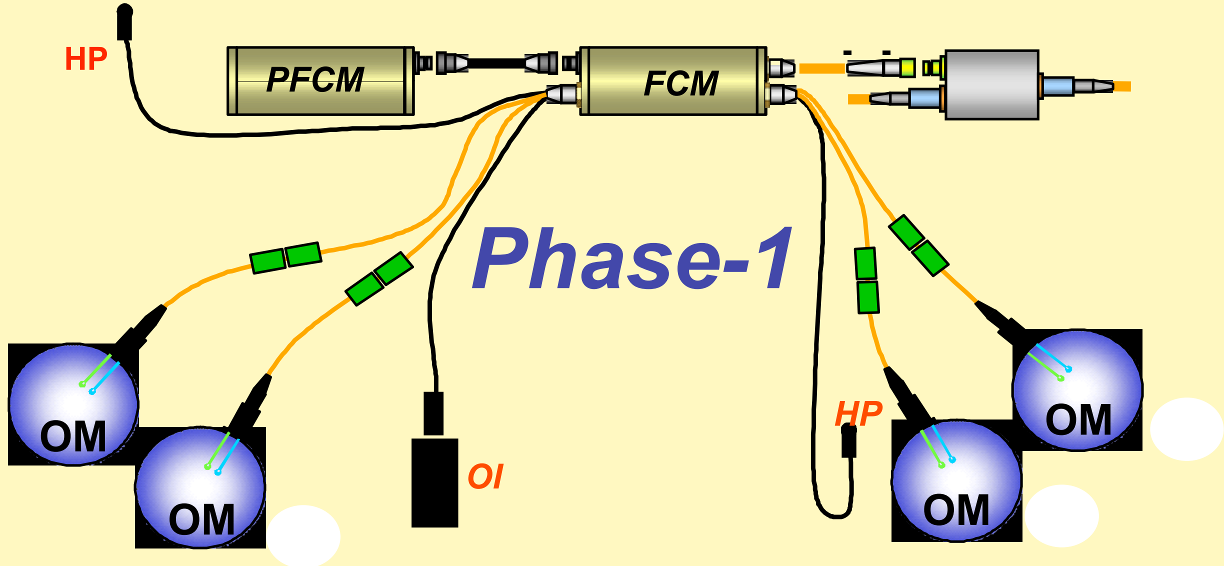
Floor cabling

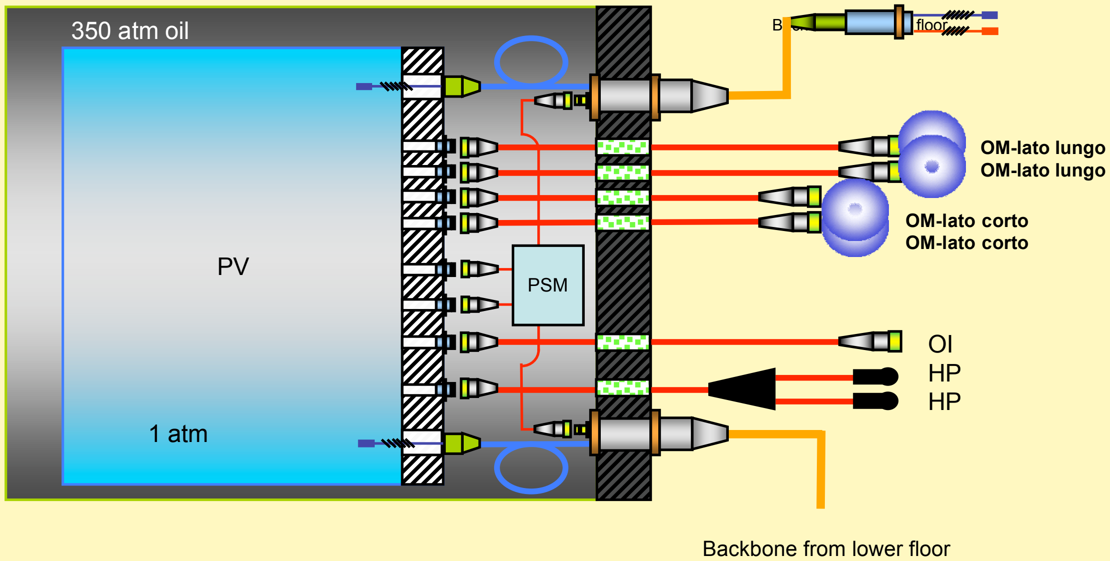
See A. D'Amico talk on 23/4 morning parallel session on Engineering

3 Floor vessels
(FCM - PFCM - breakout)

↓

Single vessel
(Protective Oceanic Device)





Phase-2

Simplified cabling layout

Thanks to the volume reduction due to the new DC power system, only one vessel per floor

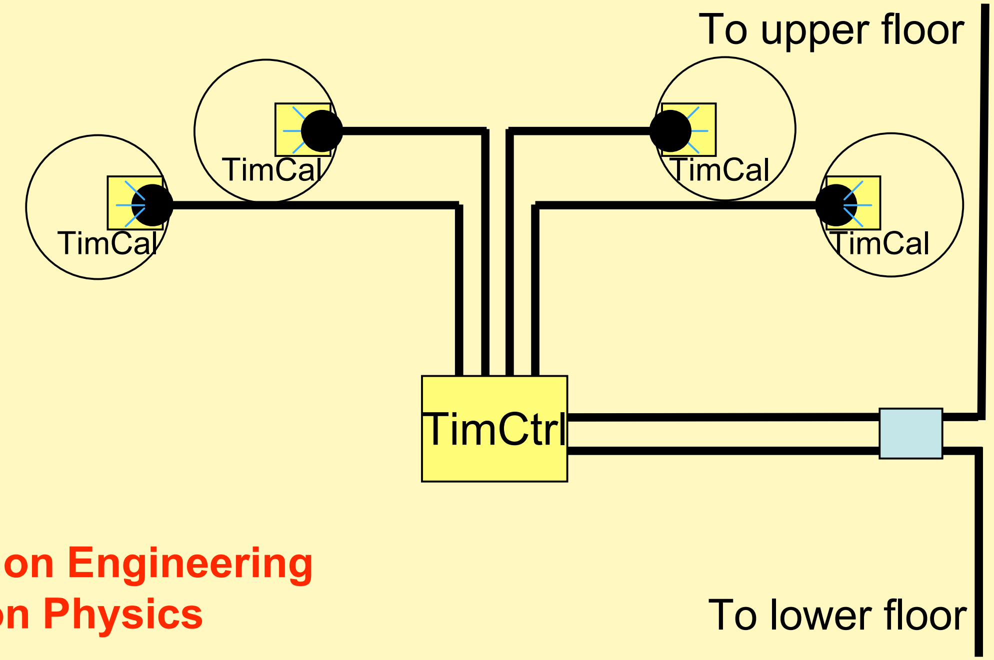
Only point to point connections from a central POD to instruments (except hydrophones)

Revised calibration system

Same principle: measure of time delays of LED flashes

LEDs moved inside the OM to avoid transmission of light signals on optical fibres inside the floor

One board in the FCM controls light flashes



See:
M. Circella talk at parallel session on Engineering
R. Megna talk at parallel session on Physics

Other modifications / upgrades of the full tower

- Full tower with 16 floors
  - Equipped with the same electronics of Phase-1, but two floors reserved for testing of new electronics (LIRA), directional OMs, …

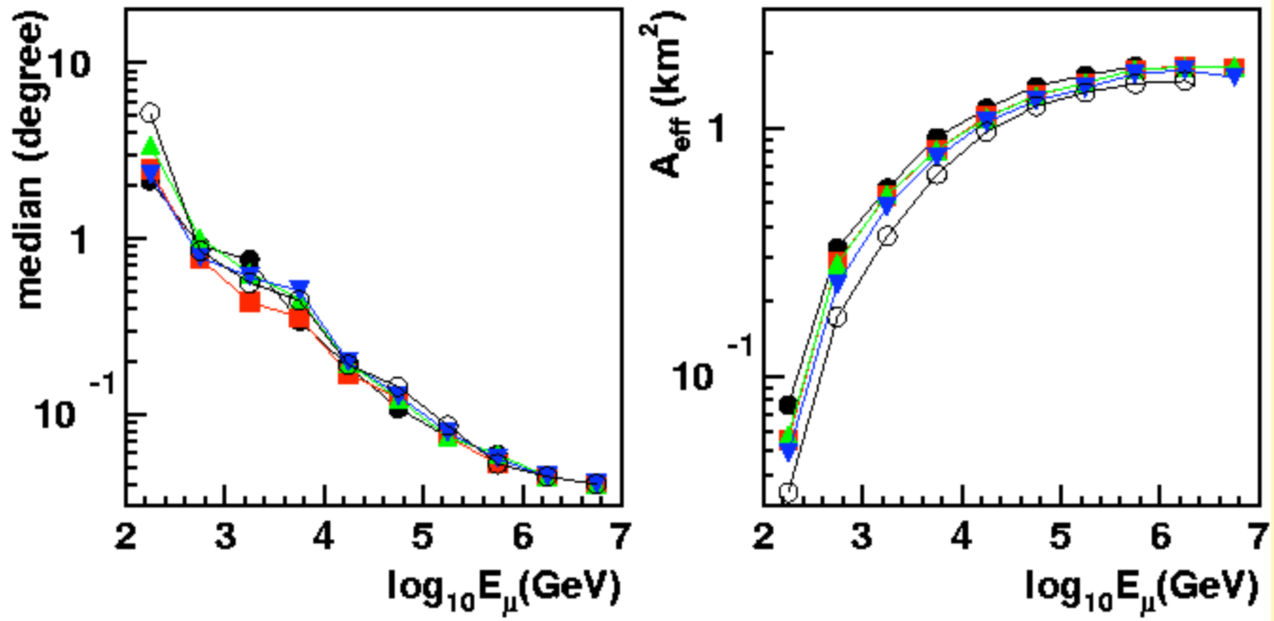
  see D. Lo Presti talk on 23/4 morning parallel session on Engineering
- New DC power system to comply with the feeding system provided by Alcatel
- Optimization of the electronics and data transmission
  - Increase of the A/D conversion accuracy
  - Increase of the data bandwidth
  - Decrease of the power consumption

  see G. Giovanetti talk on 23/4 morning parallel session on Engineering
- New DC power system to comply with the feeding system provided

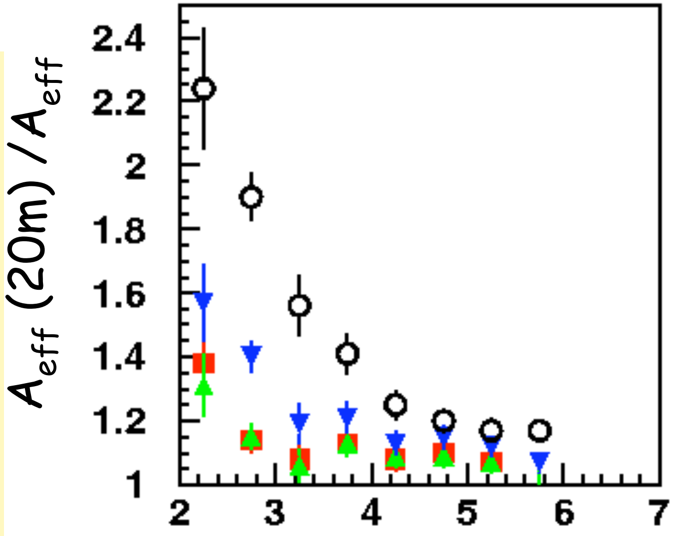
  see R. Cocimano talk on 23/4 morning parallel session on Engineering
- Integrate a new acoustic station in the acoustic positioning system

  see F.Simeone-N.Randazzo talk on 23/4 morning parallel session on Engineering
- Reduction of the floor length to 12 m to fit the compacted tower to a standard 40 ft container

●Nemo 20m
■Nemo 15m
▲Nemo 10m
▼Nemo 7.5m
○Nemo 1 m



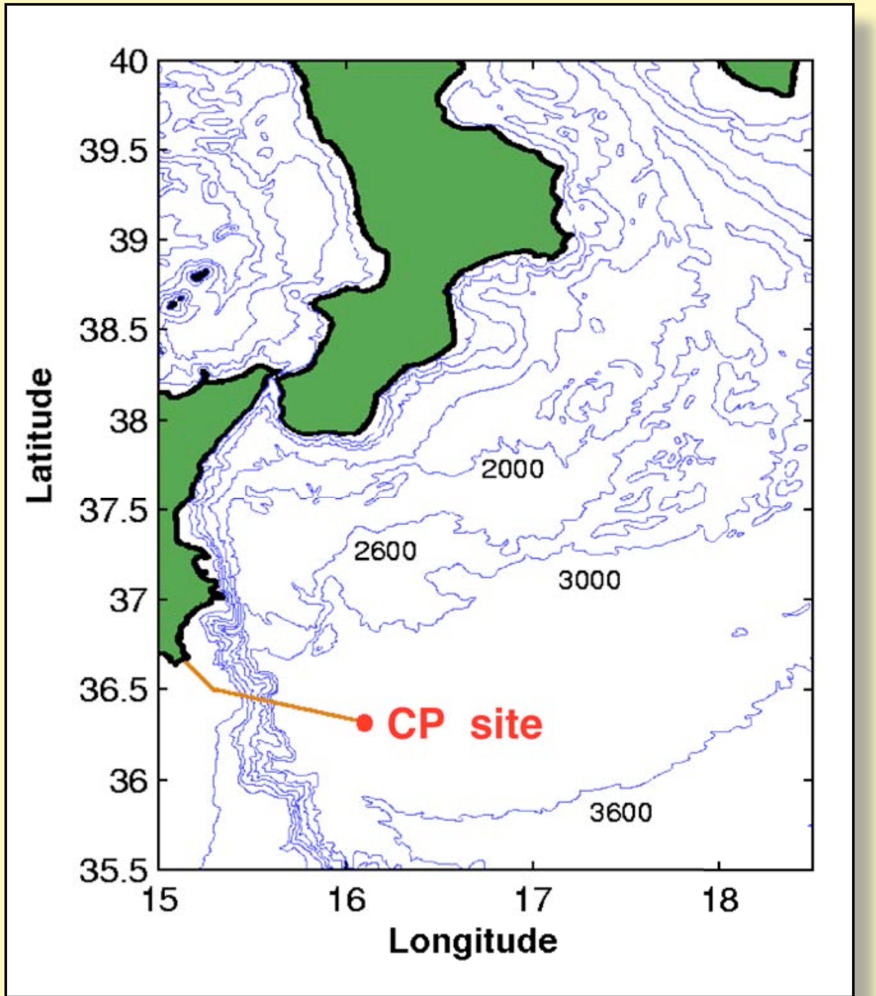
A reduction of the floor length from 15 to 12 m does not have significant effects of the km^3 Telescope performances



see P. Sapienza talk on 23/4 morning parallel session on Physics

Phase-2 project

A deep sea station on the Capo Passero site



INFRASTRUCTURE UNDER CONSTRUCTION

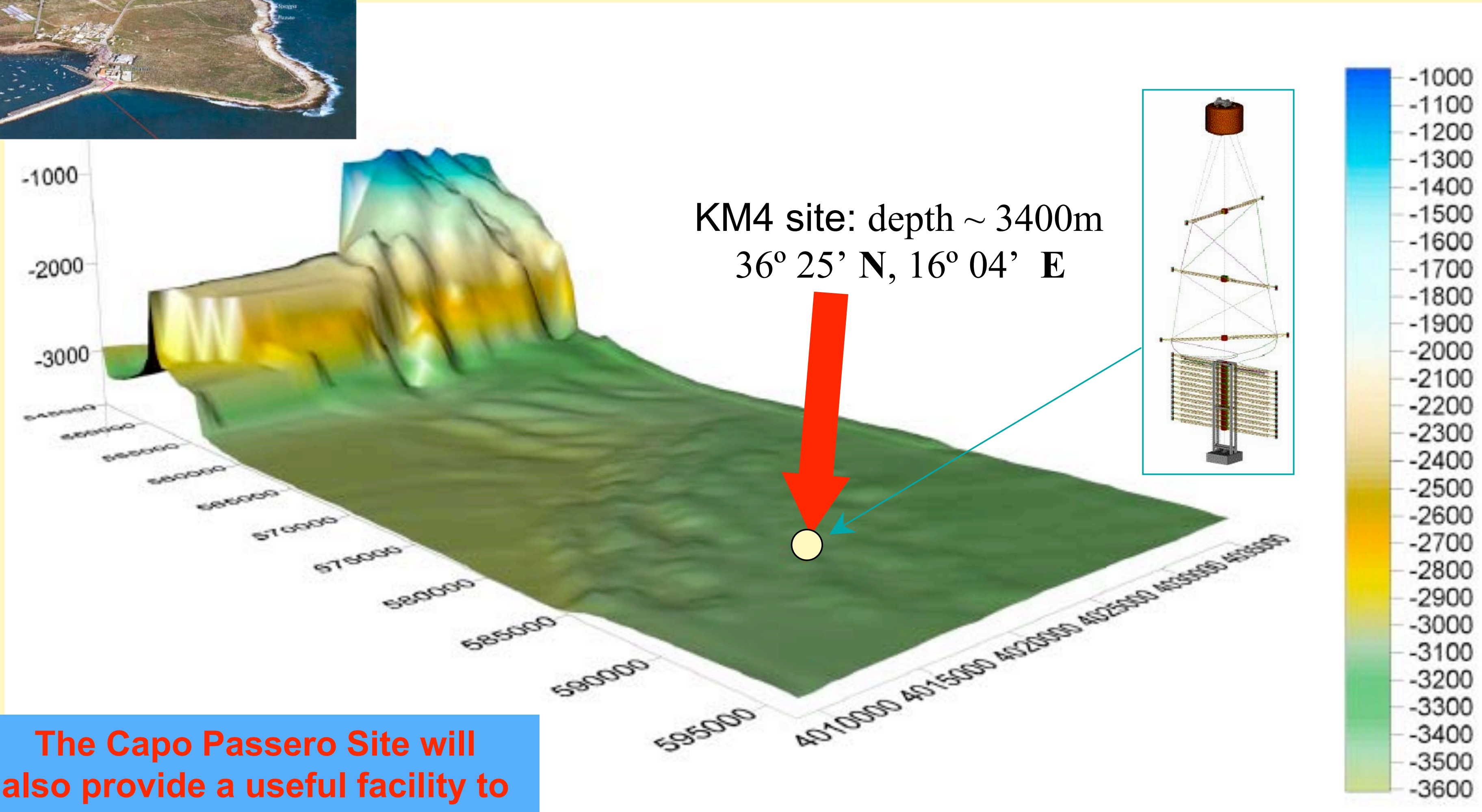
- Shore station in Portopalo di Capo Passero
- 100 km electro optical cable
- Underwater infrastructures

STATUS AND PLANS

- Electro-optical cable (>50 kW, 20 fibres) laid
- Power feeding system under construction, acceptance tests December 2007
- Installation of cable termination frame with DC/DC converter (Alcatel) originally planned for beginning 2008, but some problems may delay it to October 2008
- Renovation of the shore station building under way. Completion beginning 2008
- Tower deployment foreseen for end 2008

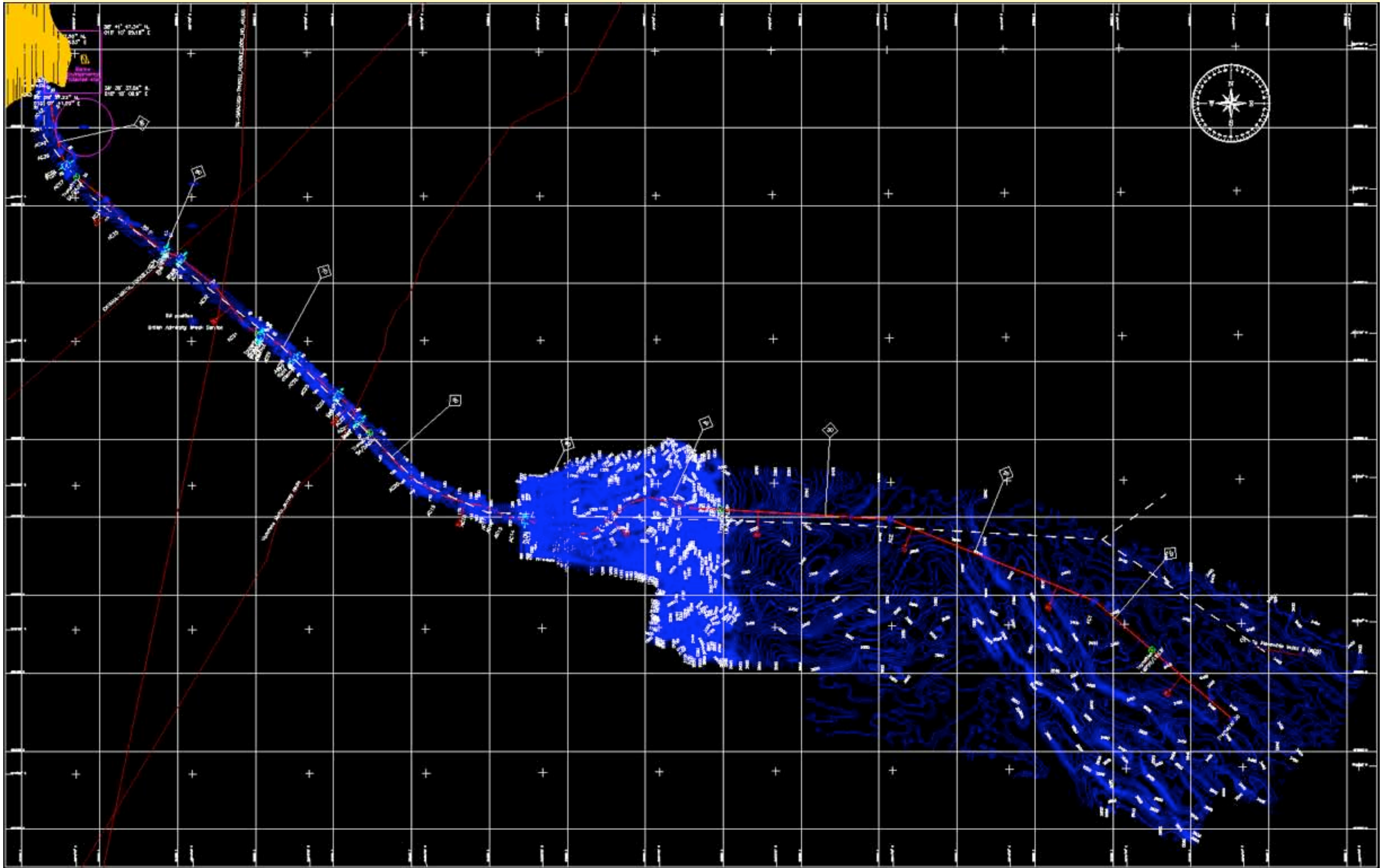
The Capo Passero site

Bathymetry, a 3D view



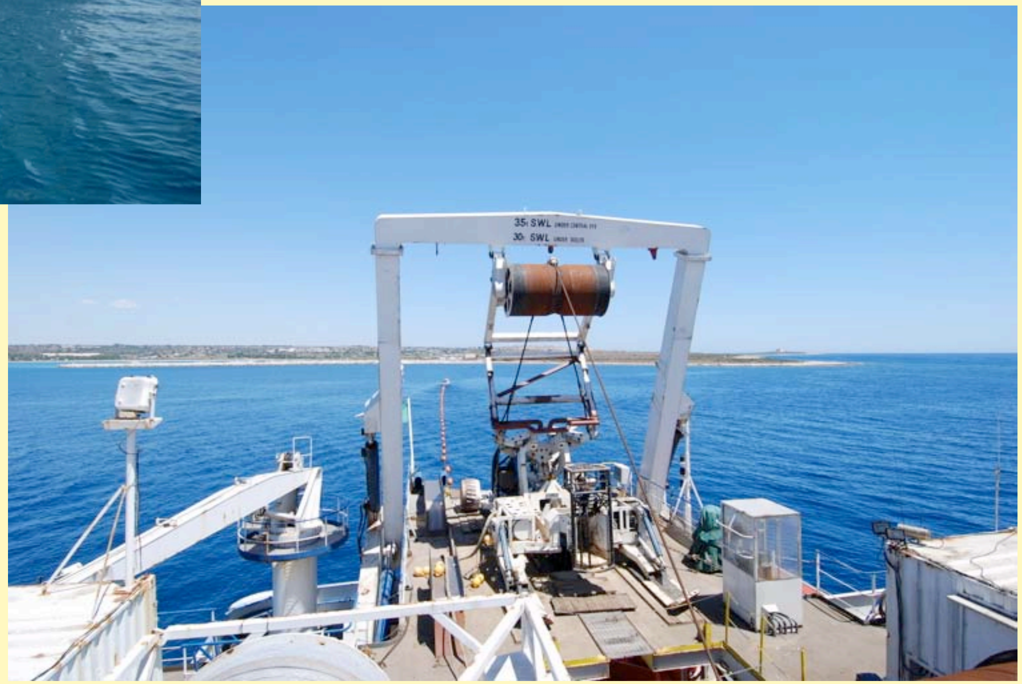
The Capo Passero Site will also provide a useful facility to test KM3NeT technologies

Bathymetry of the cable path and termination area



Deployment of the Main Electro-Optical cable

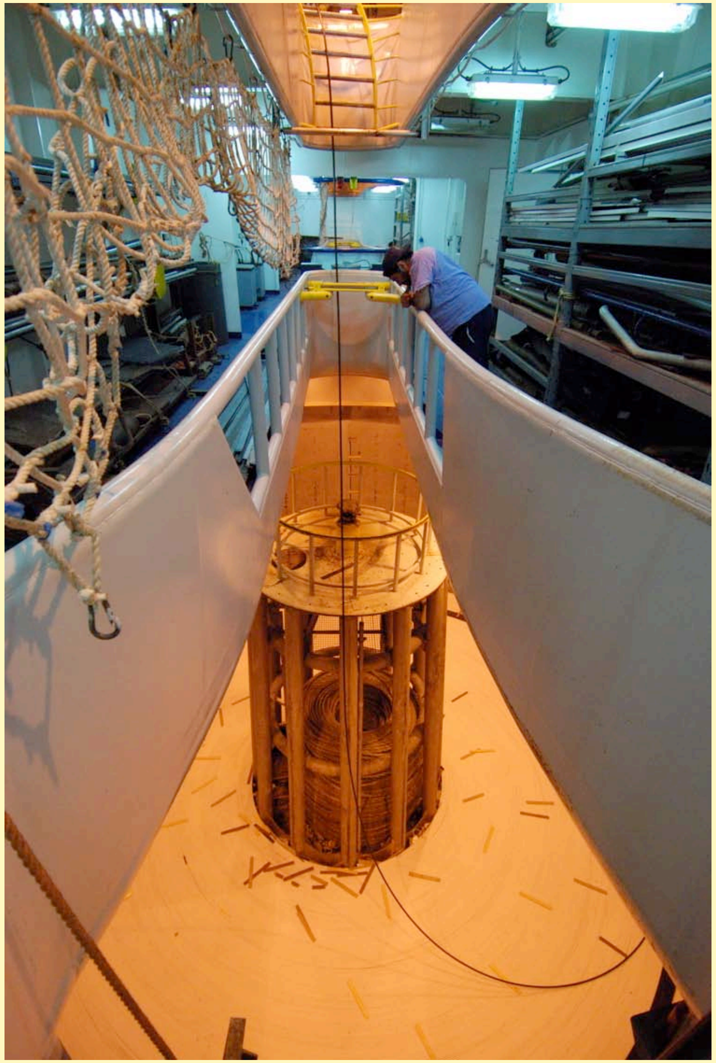
Laying of the Main Electro-optical cable's shore-end at Portopalo



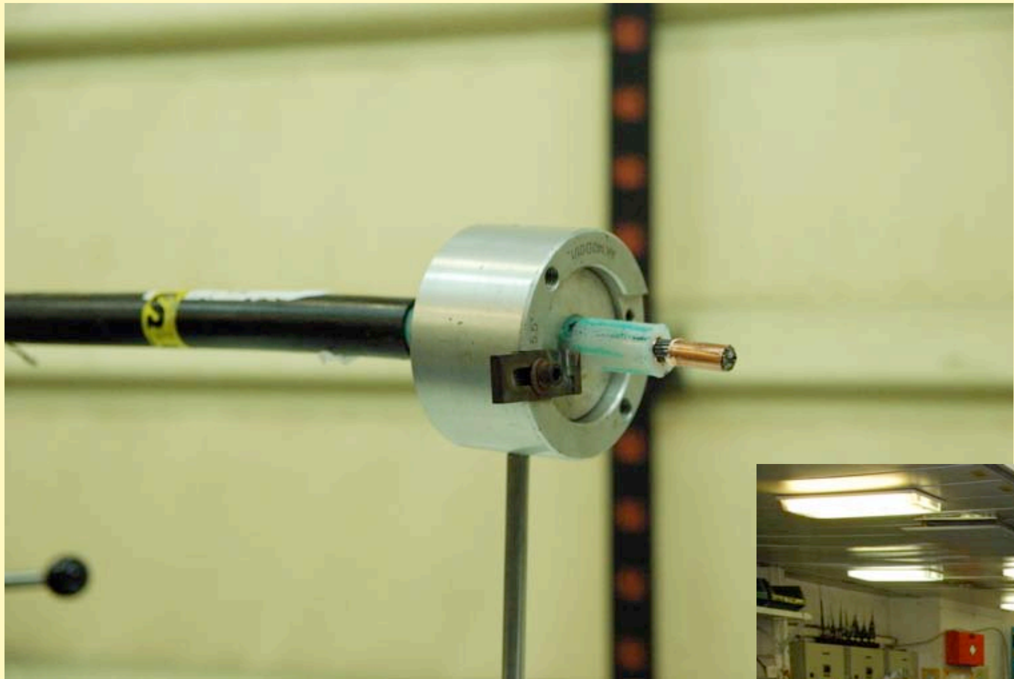
Deployment of the Main Electro-Optical cable

Fibres splicing

Deployment of the Main Electro-Optical cable



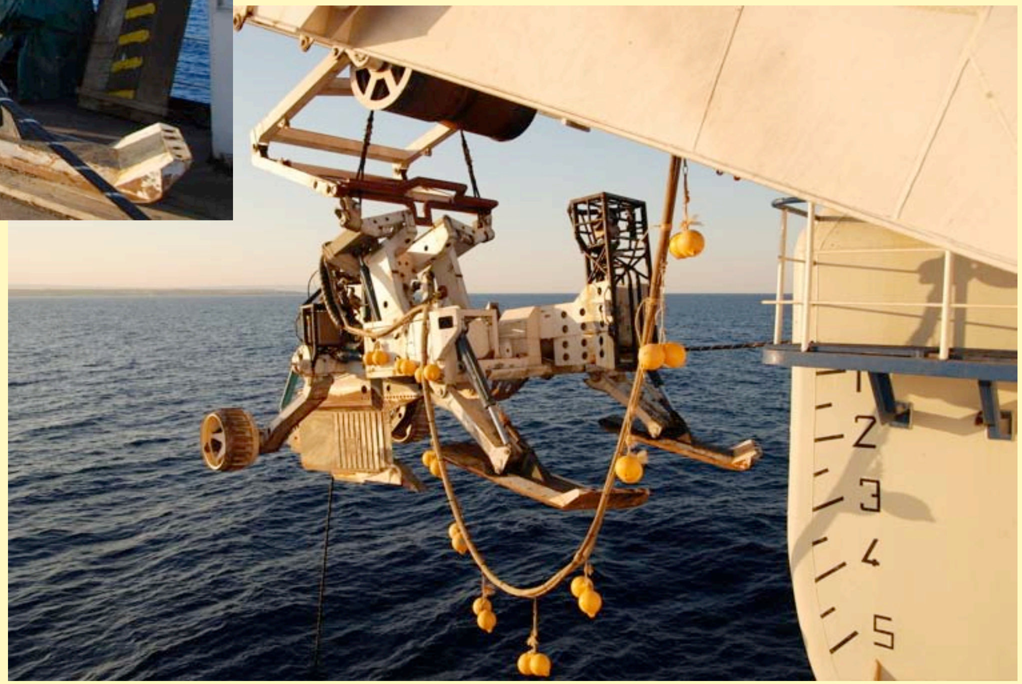
Deployment of the Main Electro-Optical cable



Temporary termination of the main electro-optical cable

Deployment of the Main Electro-Optical cable

The special tool used to dig the path for the main EOC



Portopalo Shore Station

An old building (a winery) has been acquired, to be used as shore laboratory and counting room. It is located at Portopalo (SR). At present is under restoration

Shore Power System installed!

Rooms designated to host the NEMO-Phase2 power system have been already renovated and are, already, at the disposal of the NEMO Collaboration

DC/DC converter

	Requirements	Current achievements
Input Voltage	-10 kV VDC	OK
Max Steady State	-10kVdc max steady state; -5.7kV, -5.2kV hysteresis	OK
Input ripple Current	Maximum 1.5mA at 50kHz	T b C
Input Surge Current	3A at turn on	OK
Output Voltage	400 VDC	OK
Output Ripple Voltage	500 mV Max	1 V rms is the target
Output Current	0 - 12.5 A	0.6A - 25 A

The DC/DC converter is under test (ALCATEL): at the end of May it will be tested with real NEMO loads

DC/DC shore power system

	Requirements	Current achievements
Output Voltage Overshoot	Maximum of 6V and 1 msec settling time for a step change from full load to half-load	+40V (with clamping device) from full load to 10 % of load- Settling time : few ms
Output Voltage Undershoot	Maximum of 6V and 1 msec settling time for a step change from half load to full-load	- 30V from 10% to full load Settling time : few ms
Output Regulation	± 1 % over load, line variations and temperature variations	OK
Output short circuit protection	Pulsed mode, TBD sec intervals	T B C ???
Switching frequency	50 kHz ± 5 %	Shall be changed to 100 kHZ to improve noise level
Efficiency	> 90 %	almost OK

The system has been installed in Portopalo shore station, connected to a load equivalent to NEMO Tower and successfully tested (16/04/2008)

The future

NEMO data acquisition in Catania site (an interdisciplinary laboratory exploited with INGV) and in KM4 (the full NEMO Tower) will continue.

R&D projects still going on for future choices (like the mixed cupper-fibre data transmission solution (**see F.Ameli - S.Russo talk on Engineering parallel session**), the multi-anode directional Optical Module solution (**see A. Bersani and E. Leonora talks on Photodetection parallel session**), a new deep sea mateable connector (**see D. Torazza talk on Engineering parallel session**), …

NEMO collaboration is fully participating to KM3NeT Design Study and Preparatory Phase projects.

Our aim: the construction of the Mediterranean Neutrino Telescope in an common infrastructure where sea-science groups will perform their activities.

NEMO contributions to VLVnT08

Parallel session on Physics

- **I. Amore**, Results from the NEMO Phase1 experiment
- **R. Coniglione**, **KM3NeT**: optimization studies for a km^3 neutrino detector
- **P. Sapienza**, Study of the angular acceptance of a km^3 telescope in the Mediterranean Sea

Parallel session on Engineering

- **D. Lo Presti**, Low Power Multi-Dynamics Front End Architecture for the Optical Module of a Neutrino Underwater
- **G. Giovanetti**, The NEMO-Phase2 data acquisition and transmission system
- **S. Russo**, Qualification tests and readout electronics reliability analysis for the deep sea underwater telescope NEMO
- **F. Ameli**, A proposal design for data transmission system on copper backbone
- **A. D'Amico**, The electro-optical cabling system for the NEMO Phase-2 tower
- **D. Torazza**, **KM3NET** deep sea wet mateable connector: report of performed tasks and results
- **R. Cocimano**, A comparison of AC and DC power feeding systems based on the NEMO experiences
- **F. Simeone**, The acoustic positioning system for NEMO Phase 2
- **A. Orlando**, On line monitoring of the power control and engineering parameters systems of the NEMO Phase-2 tower.
- **M. Circella**, Time Calibration of the NEMO apparatus

Parallel session on Photodetection

- **A. Bersani**, Instrumentation of A New Direction Sensitive Segmented Optical Module.
- **E. Leonora**, Characterization of a prototype of a new multianodic large area photomultiplier