Recent achievements of the NEMO project

E. Migneco

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

Outline of the talk

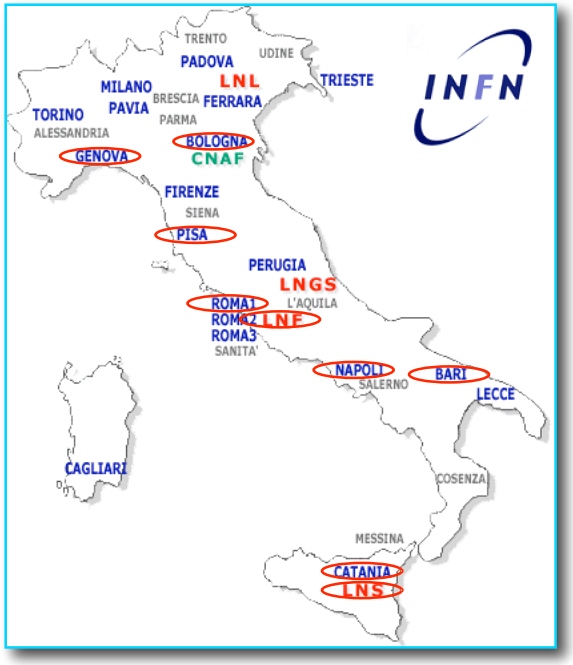
- Introduction: the NEMO R&D activities
  - Site esploration
  - Preliminary design of the km^3 detector
- NEMO Phase-1
  - Aim and objectives of the project
  - System description
  - Preliminary results
- NEMO Phase-2
  - Description of the apparatus
  - Status
- Conclusions and outlook

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)

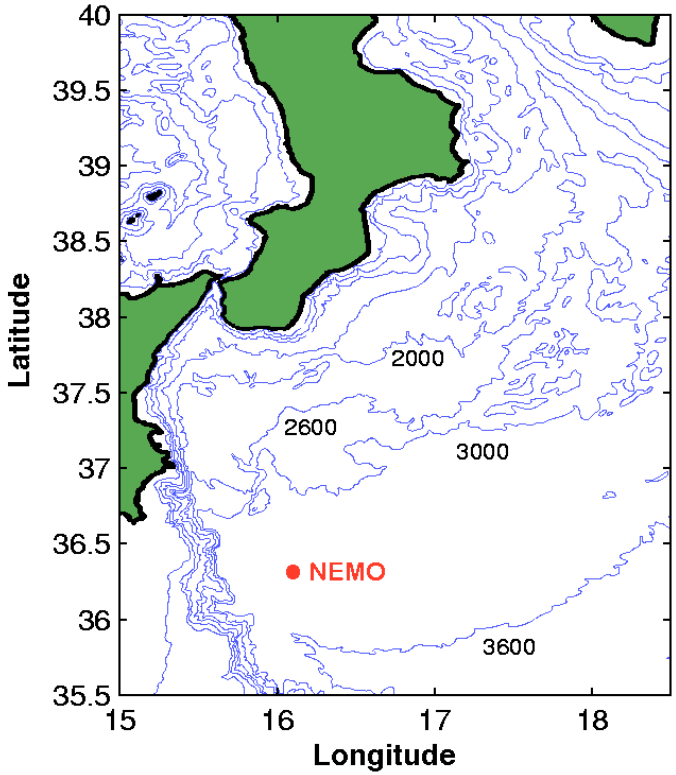
Istituto Superiore delle Comunicazioni e delle Tecnologie dell'Informazione (ISCTI)

More than 80 researchers from INFN and other italian institutes

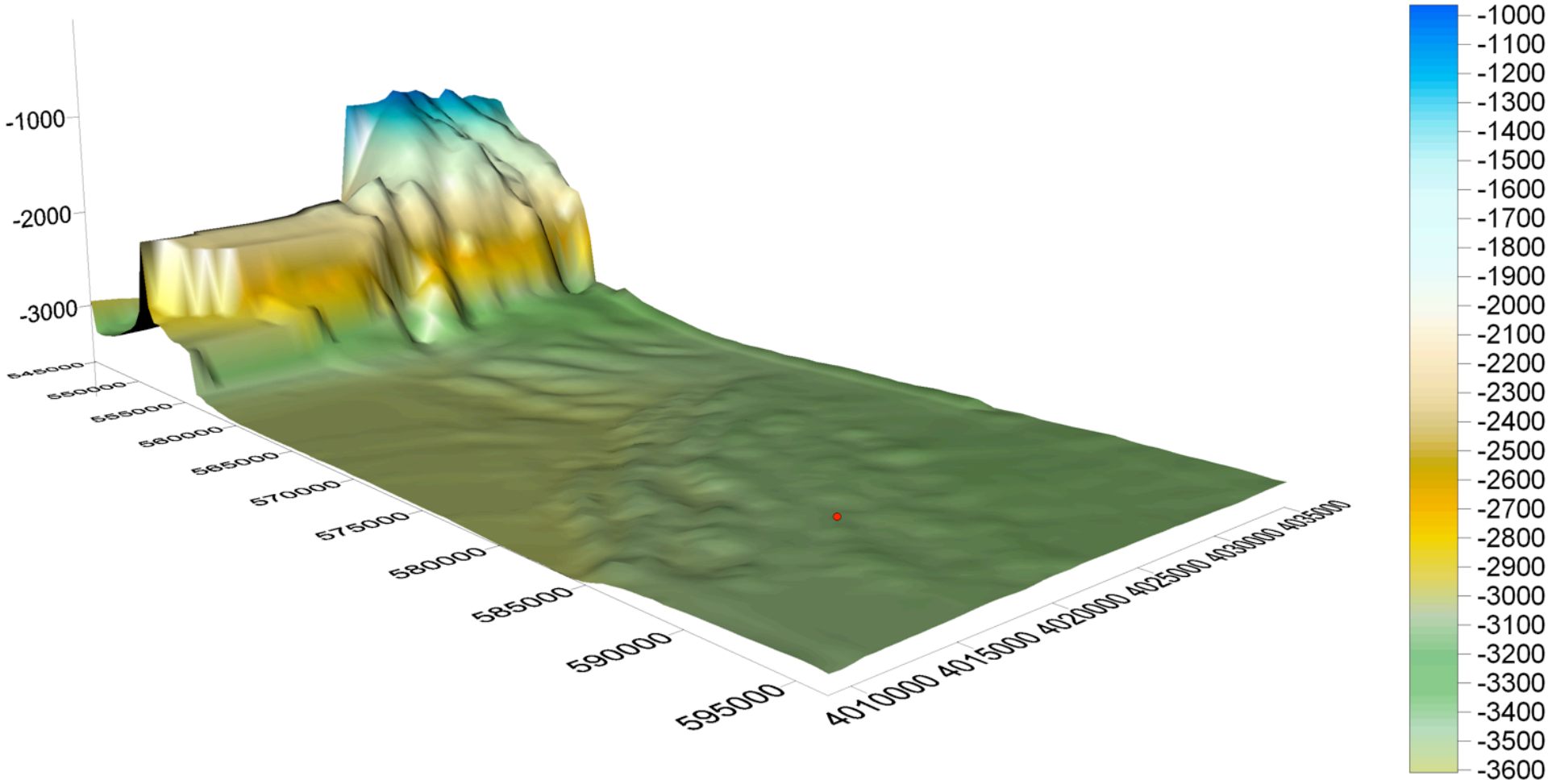
The Capo Passero site

The site has been proposed in january 2003 to ApPEC as a candidate for the km3 intallation

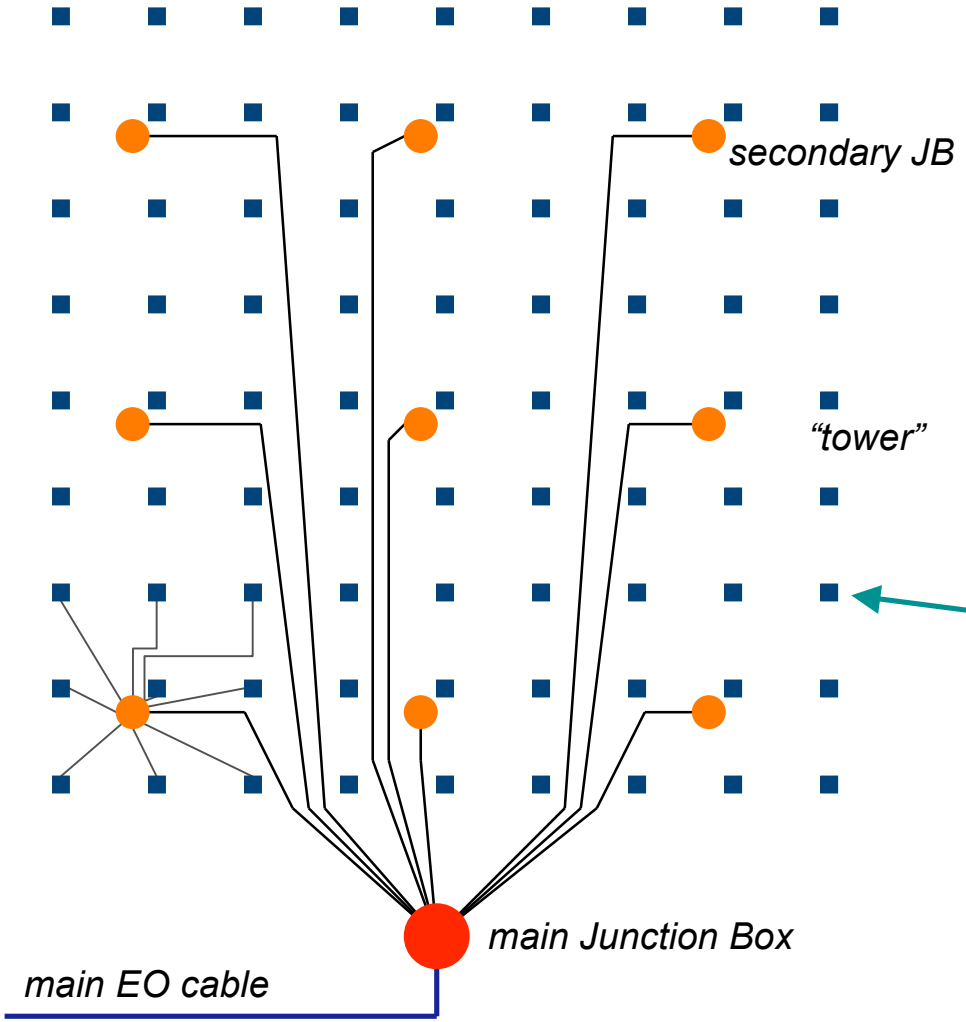
- Depths of more than 3500 m are reached at less than 100 km from the shore
- Water optical properties are the best observed in the studied sites ($L_a \approx 70$ m @ $\lambda = 440$ nm)
- Optical backgroung from bioluminescence is extremely low
- Stable water characteristics
- Deep sea water currents 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



Feasibility study for the km3 detector

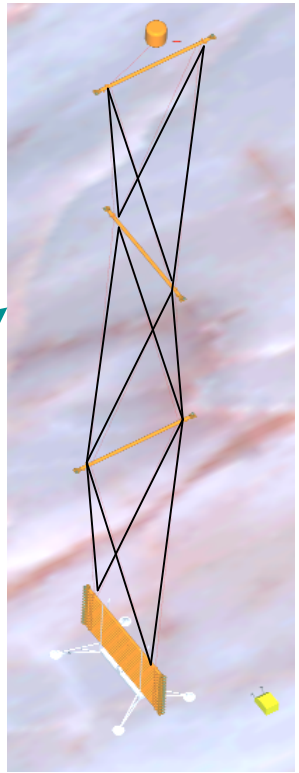


Detector architecture issues

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

Detector modularity

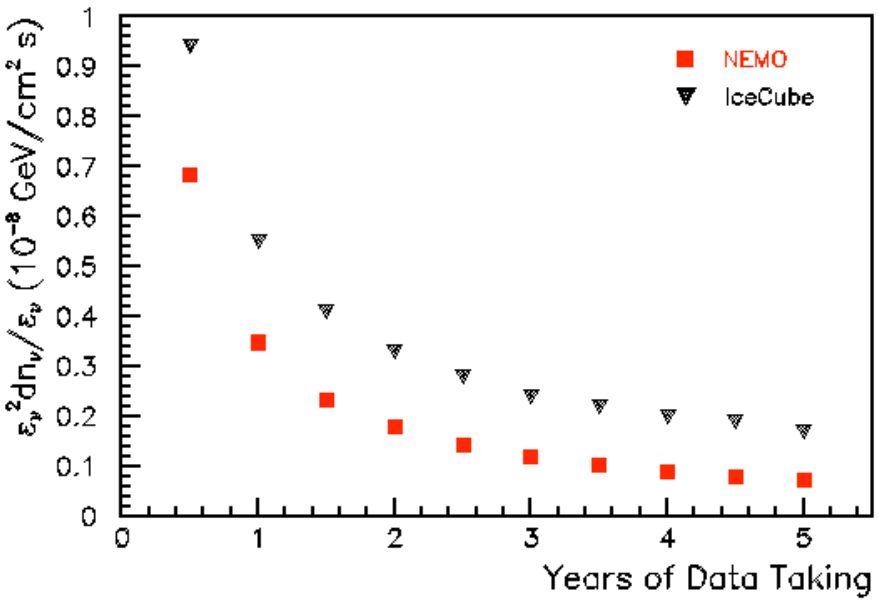
"Towers" with non homogeneous distribution of sensors



Tower detector performance

Sensitivity

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



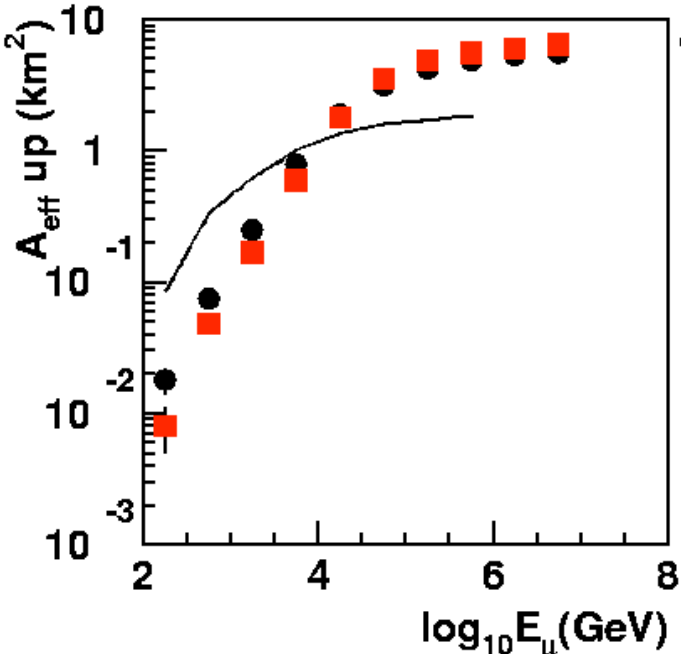
IceCube simulations from Ahrens et al. Astrop. Phys. 20 (2004) 507

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

- NEMO Phase-1 (2003-2007)
  @ the LNS Underwater Test Site (2000 m)
  - Test prototypes of the main km3 components
  - Validate installation and connection procedures
- NEMO Phase-2 (2005-2008)
  @ the Capo Passero Site (3500 m)
  - Establish a deep sea infrastructure on the Capo Passero site suitable for a km3 scale detector
  - Test and validate advanced detector prototypes
  - Allow for long term monitoring of site properties

NEMO Phase-1

Installation
First data

The NEMO Phase-1 project

Underwater infrastructure realized by the Laboratori Nazionali del Sud to test detector prototypes
A seismic and environmental observatory of INGV has been istalled and connected to the EO cable

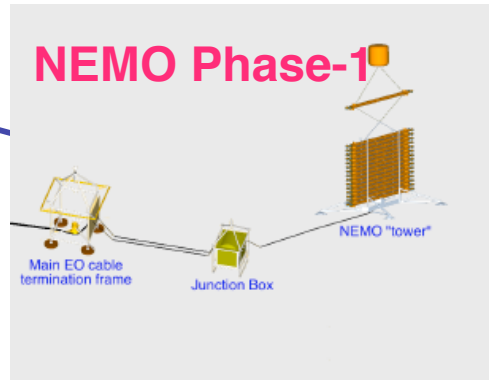
Double armed cable
2.330 m

Single armed cable
20.595 m

BU

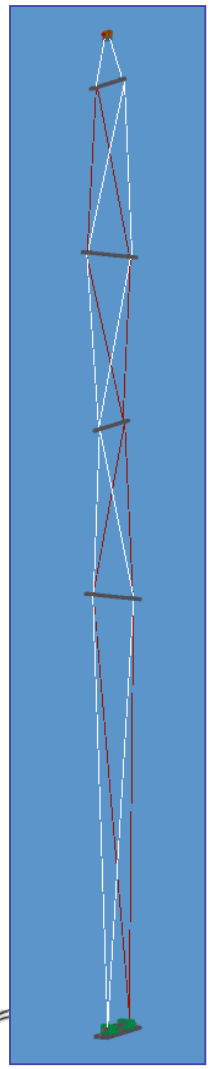
North branch
5.220 m

South branch
5.000 m



- ***Electro-optical cable reaching 2000 m depth***
- ***Phase-1 apparatus installed in december 2006***
- ***Project jointly funded by INFN and MIUR***

Layout of the NEMO Phase-1 apparatus



300 m

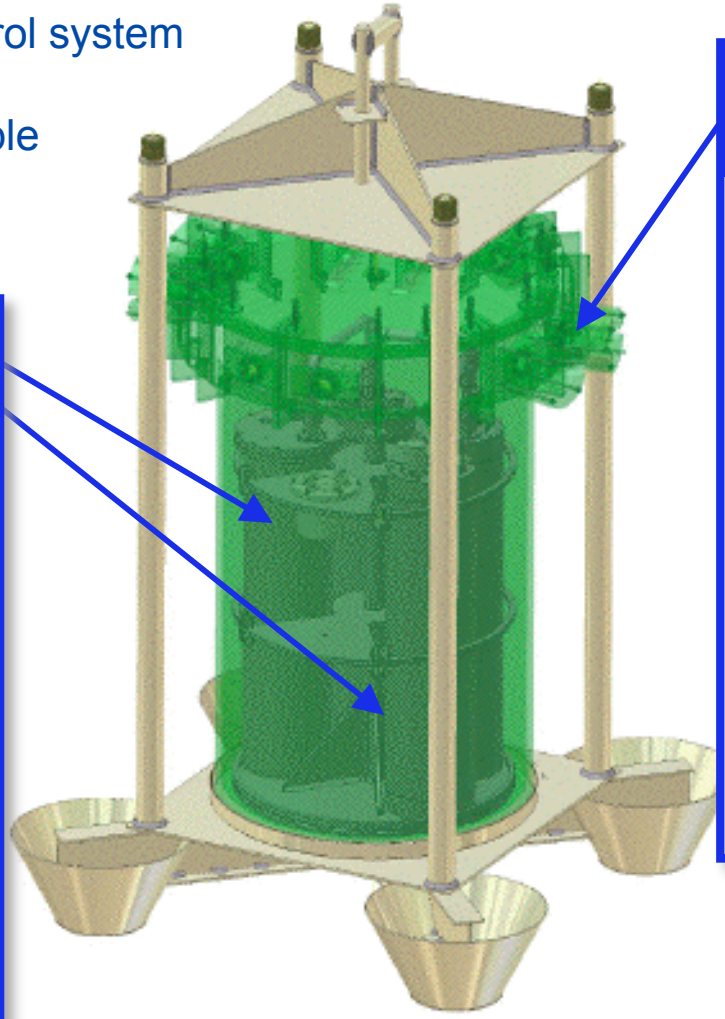
Junction Box

TSS Frame

The Junction Box

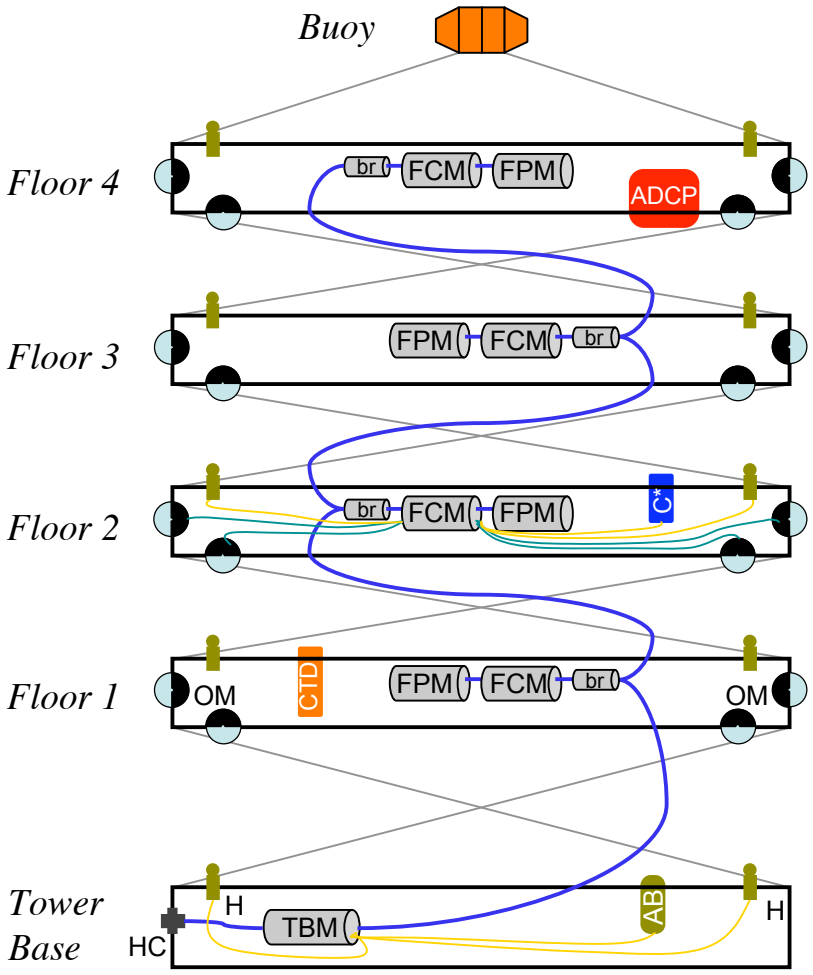
Data transmission electronics
Power distribution and control system
Optical fibre splitters
Innovative design to decouple the corrosion and pressure resistance problems

Electronics pressure vessels



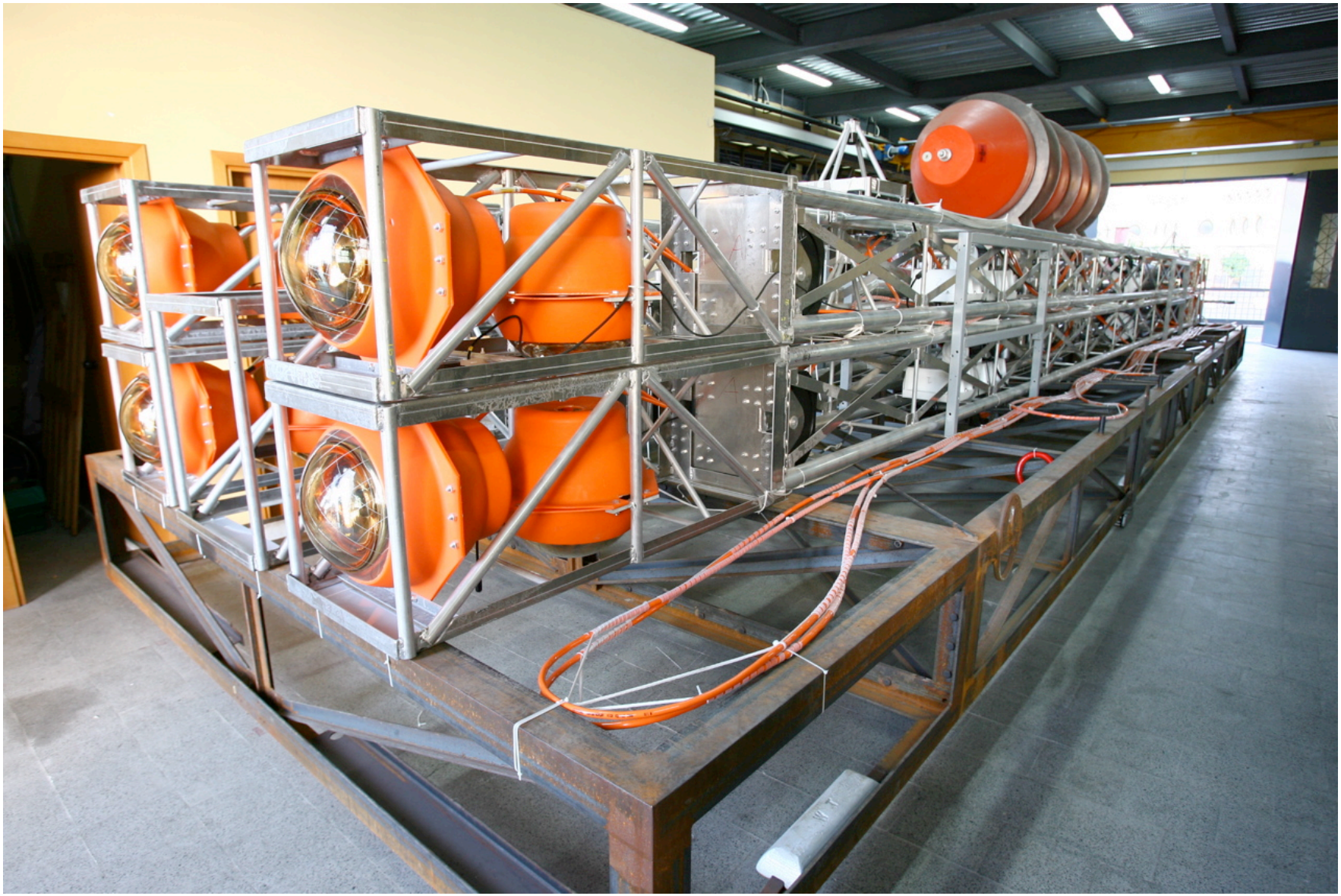
External fibreglass container

Scheme of the prototype Tower



- Fours 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*

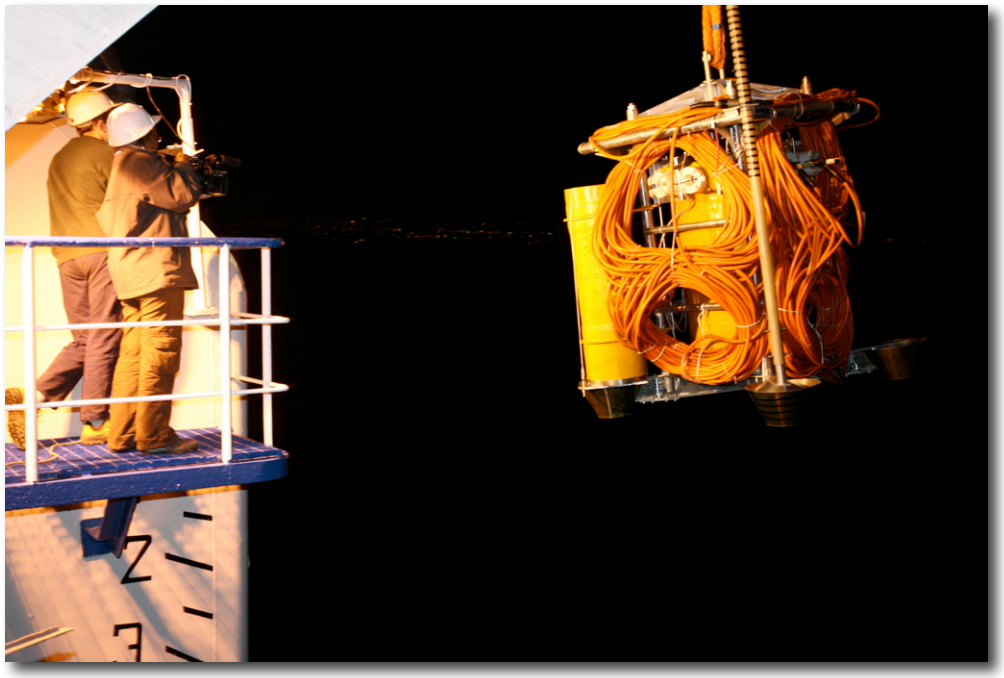
The prototype tower



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

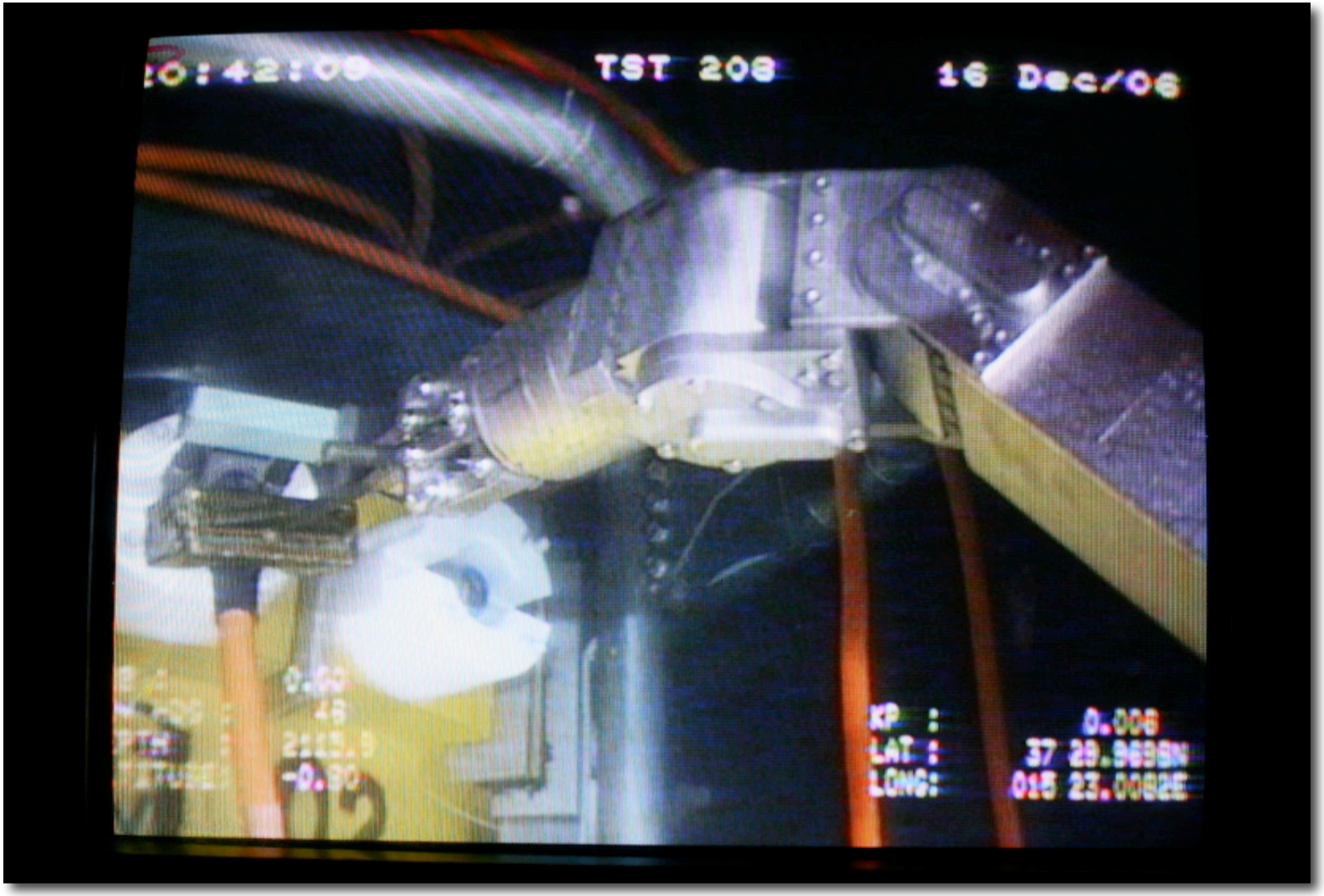
December 13 2006 *Loading of the tower on board the Teliri*

NEMO Phase-1 installation

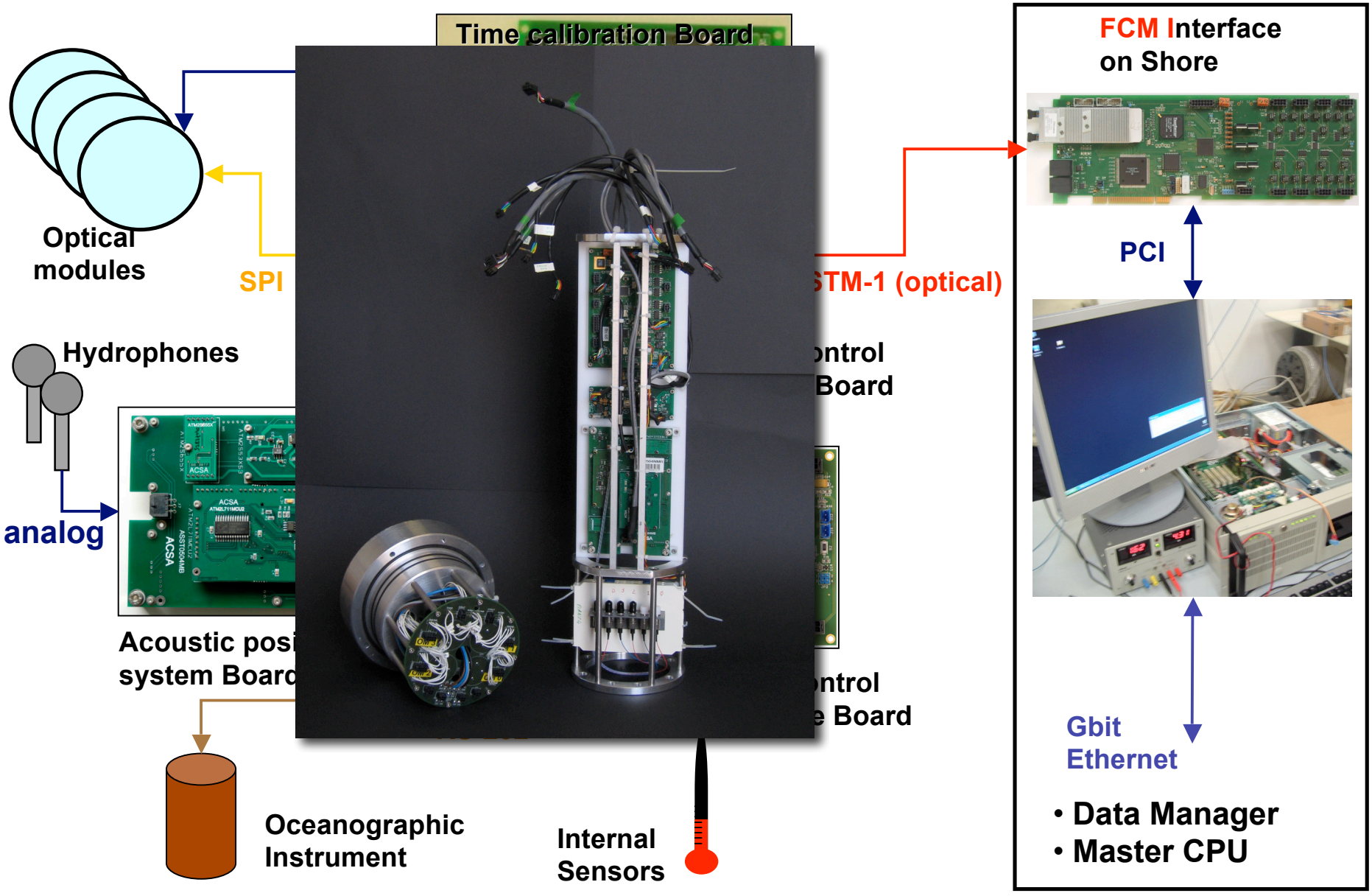
December 15 2003 *Deployment of the tower*

NEMO Phase-1 installation

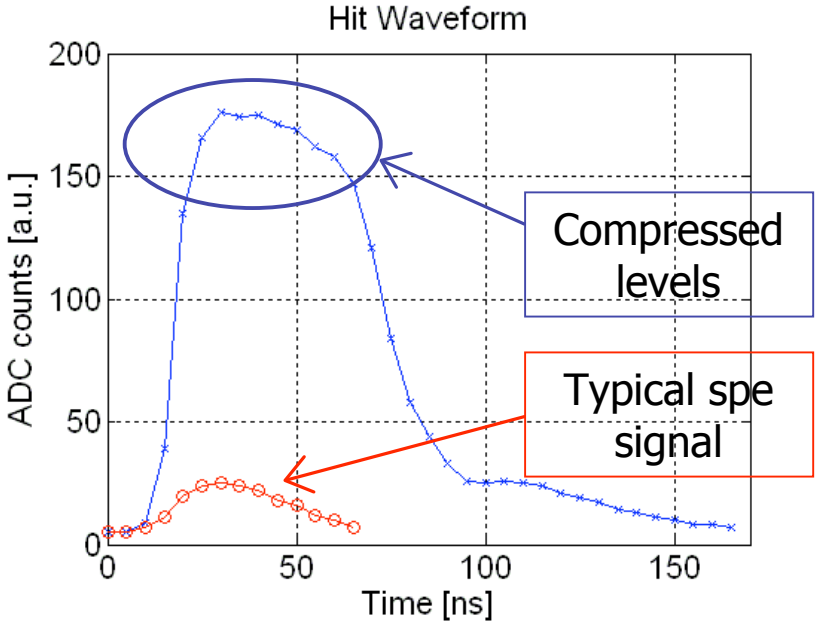
December 16 2006 *Connection of the tower to the JB*



DAQ and time calibration electronics

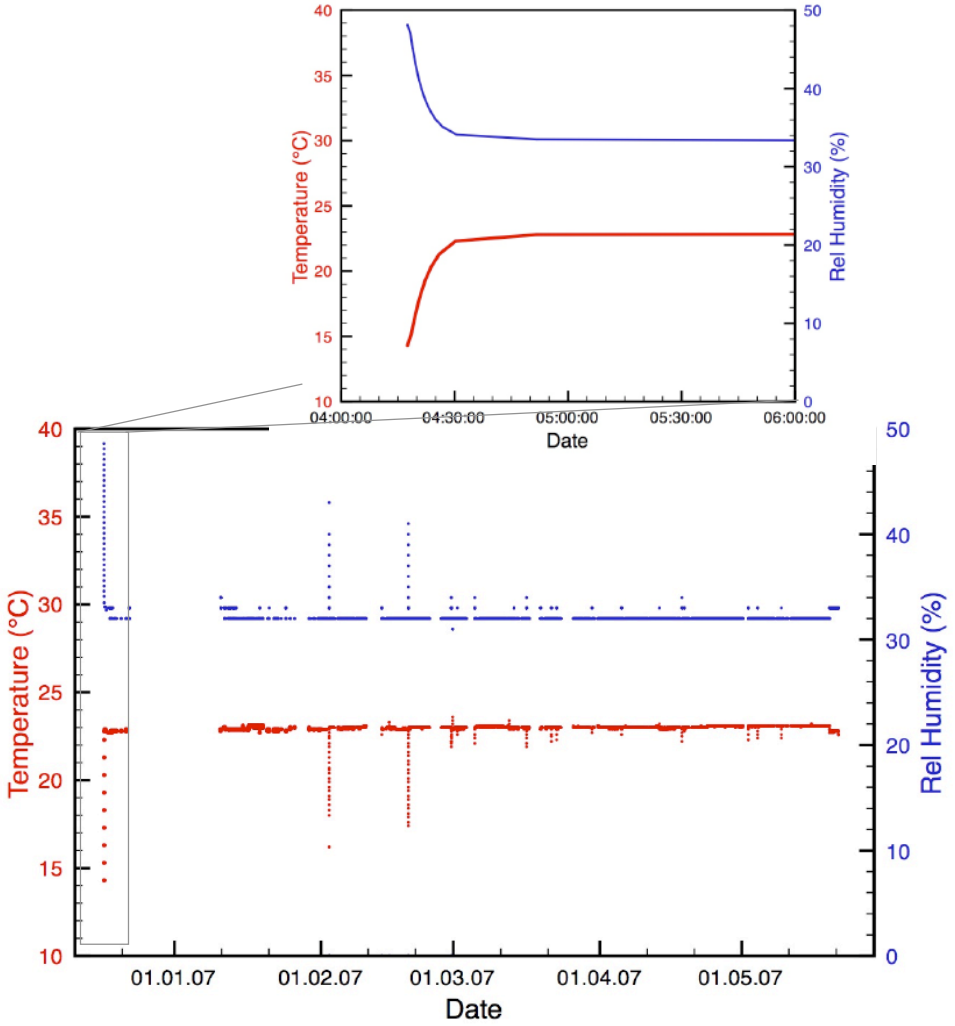


OM data

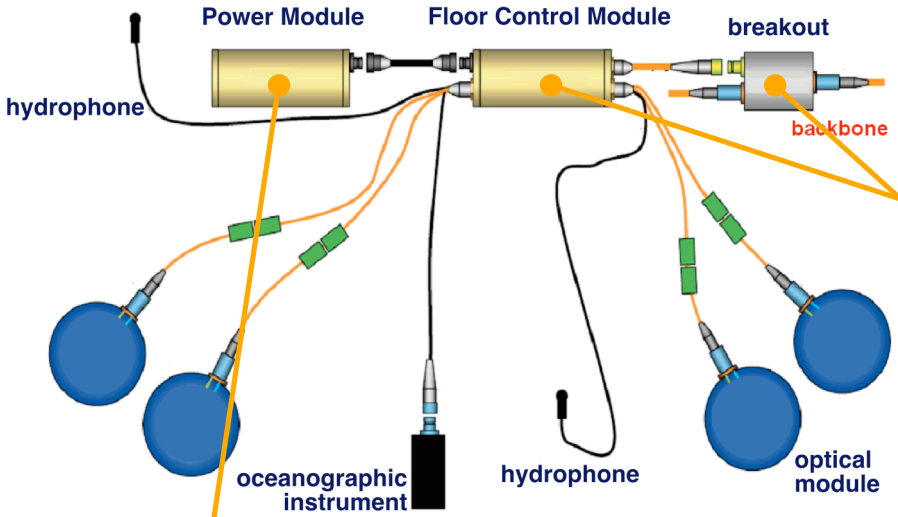


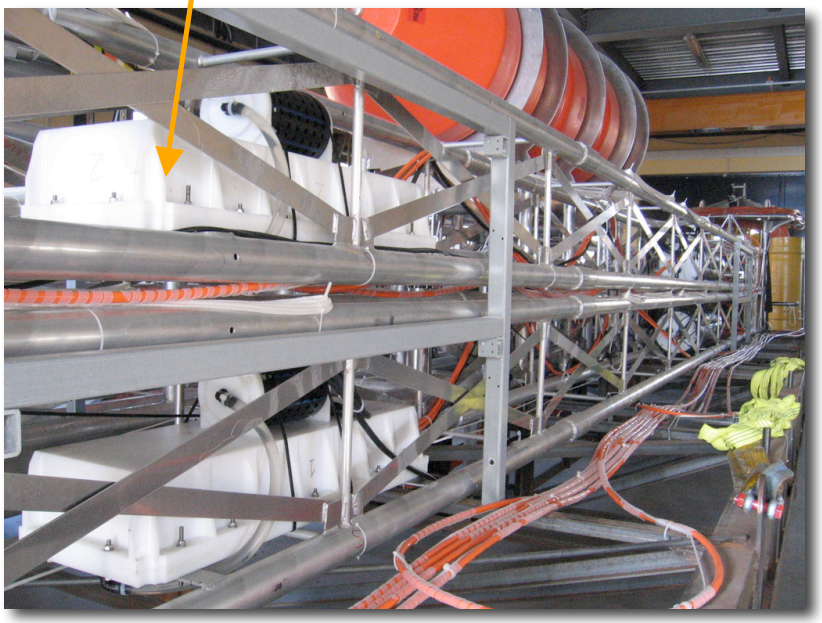
Typical PMT signals

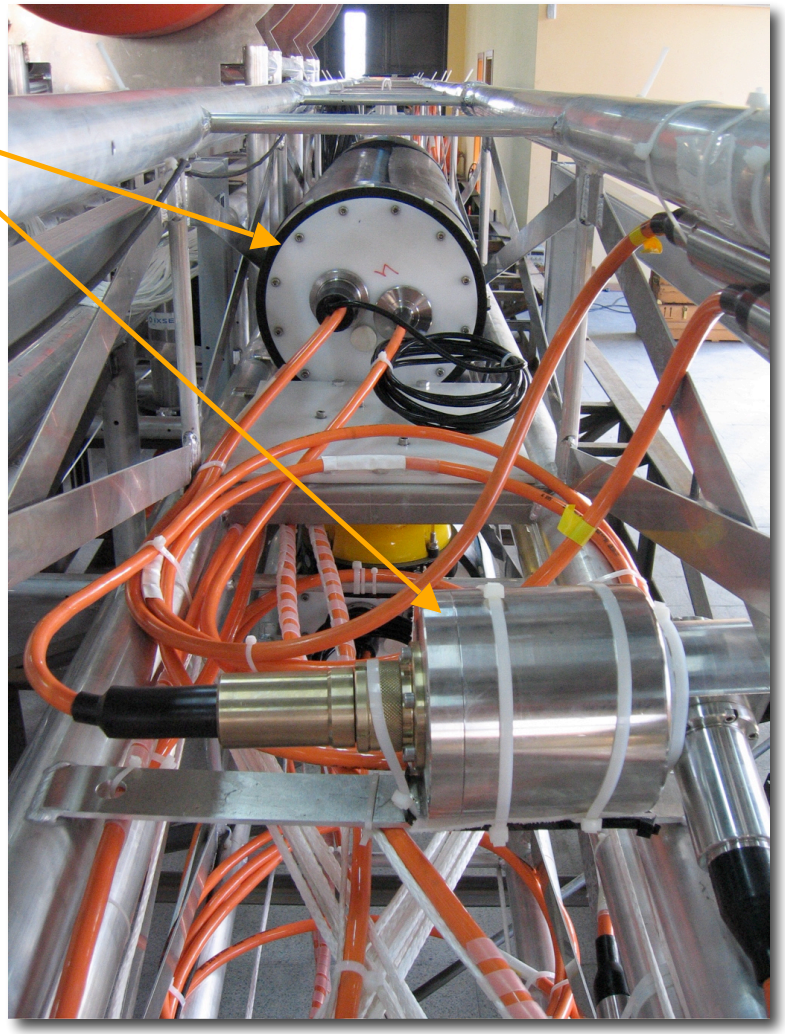
Environmental OM data



Floor cabling







Acoustic positioning system

B4

Long Baseline acoustic positioning system based on five Acoustic Beacons

350m

250m

tower

350m

B5

B1

B3

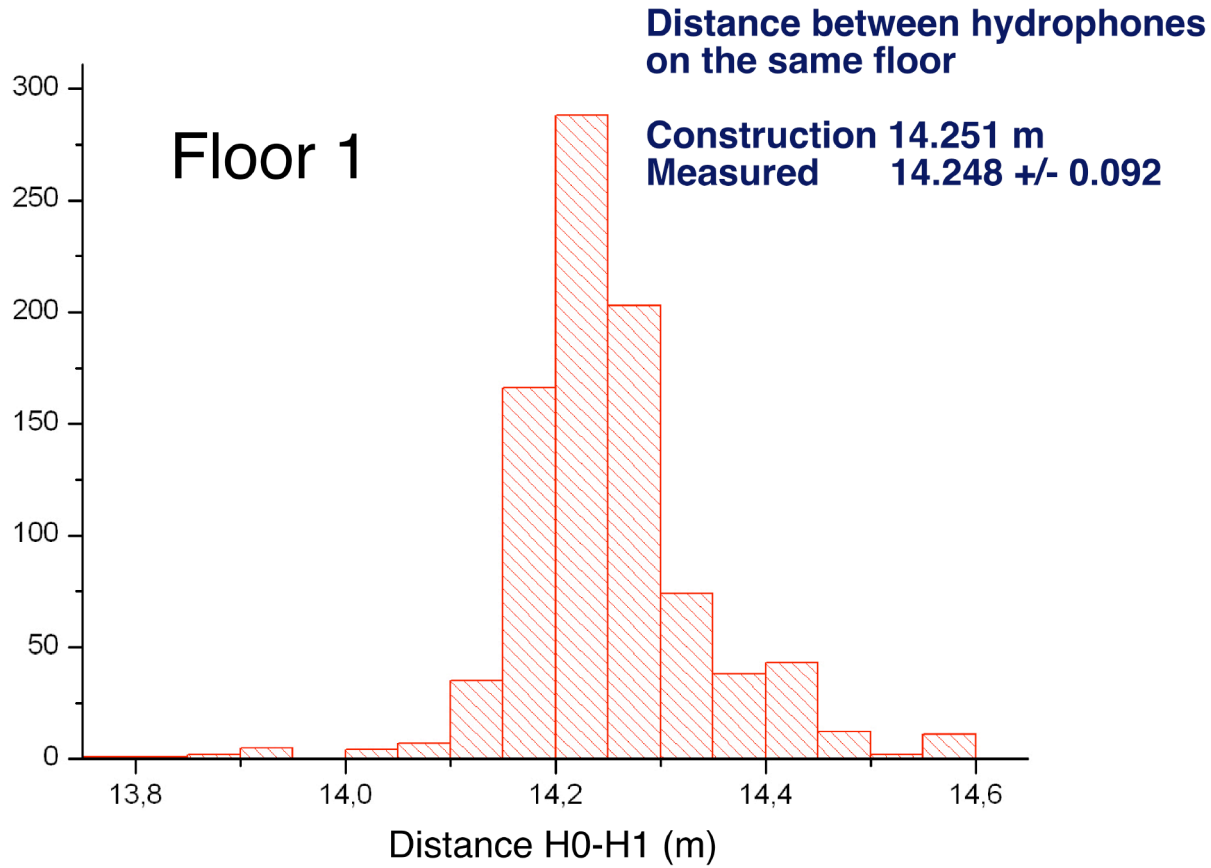
350m

B2

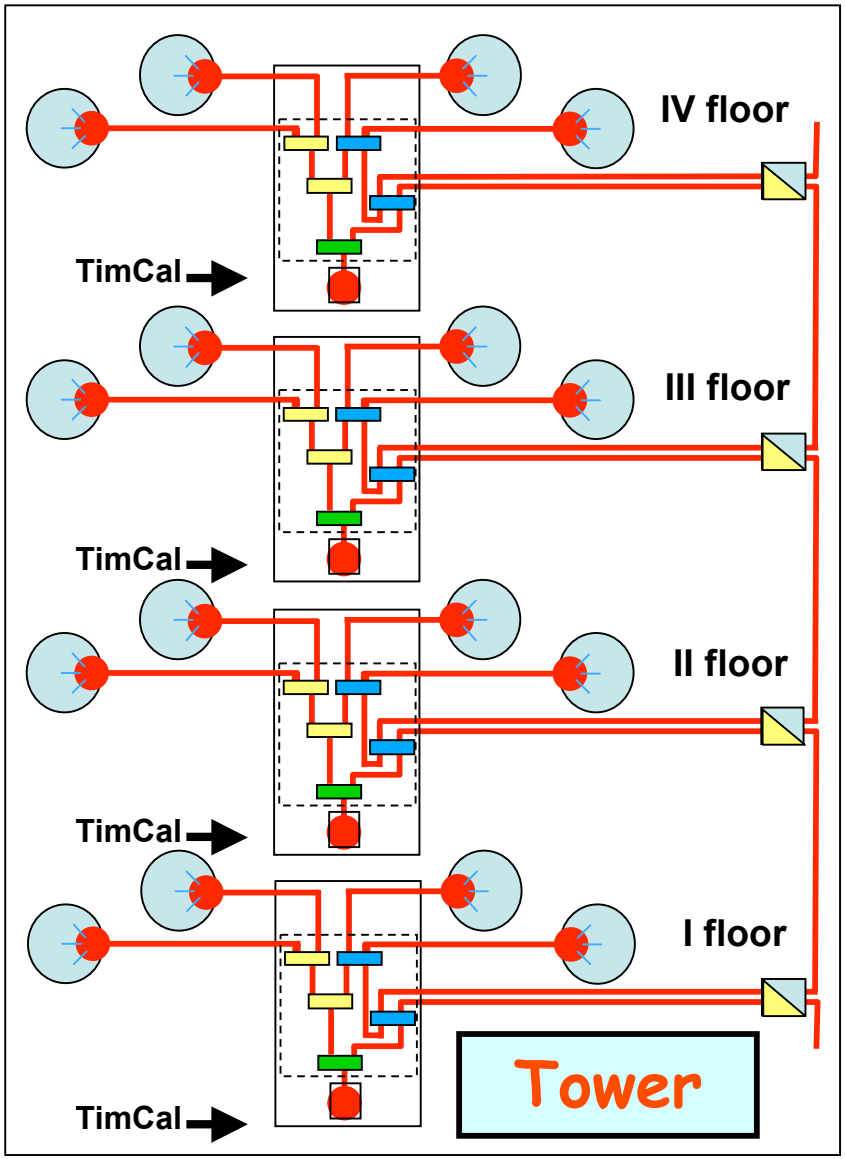
3 autonomous (battery powered) beacons
1 beacon on the JB (not working)
1 beacon on the tower base

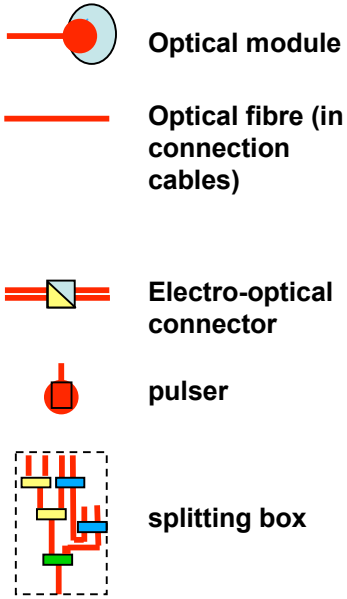
Acoustic Positioning system

Accuracy of he system estimated by measuring the distance between the two hydrophones on the same floor



Time calibration system



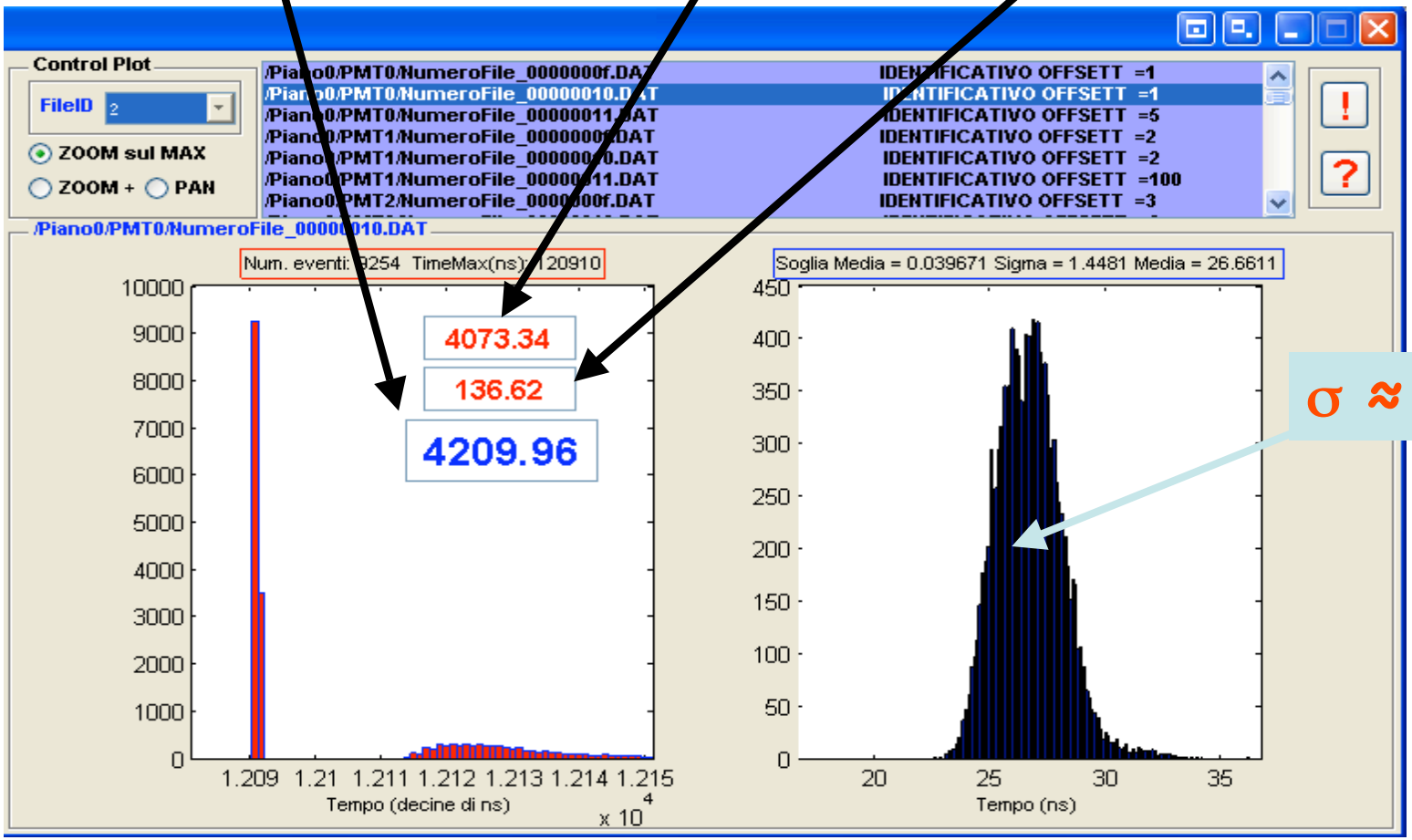


- Same LED pulse generated by the TimCal board sent to OMs on each floor and on the adjacent ones
- Same configuration on each floor
- Solution expandable and adaptable to different detector geometries

Solution: network of optical fibres to flash several OMs at one time with fast LED light pulses

Evaluation of the time offsets

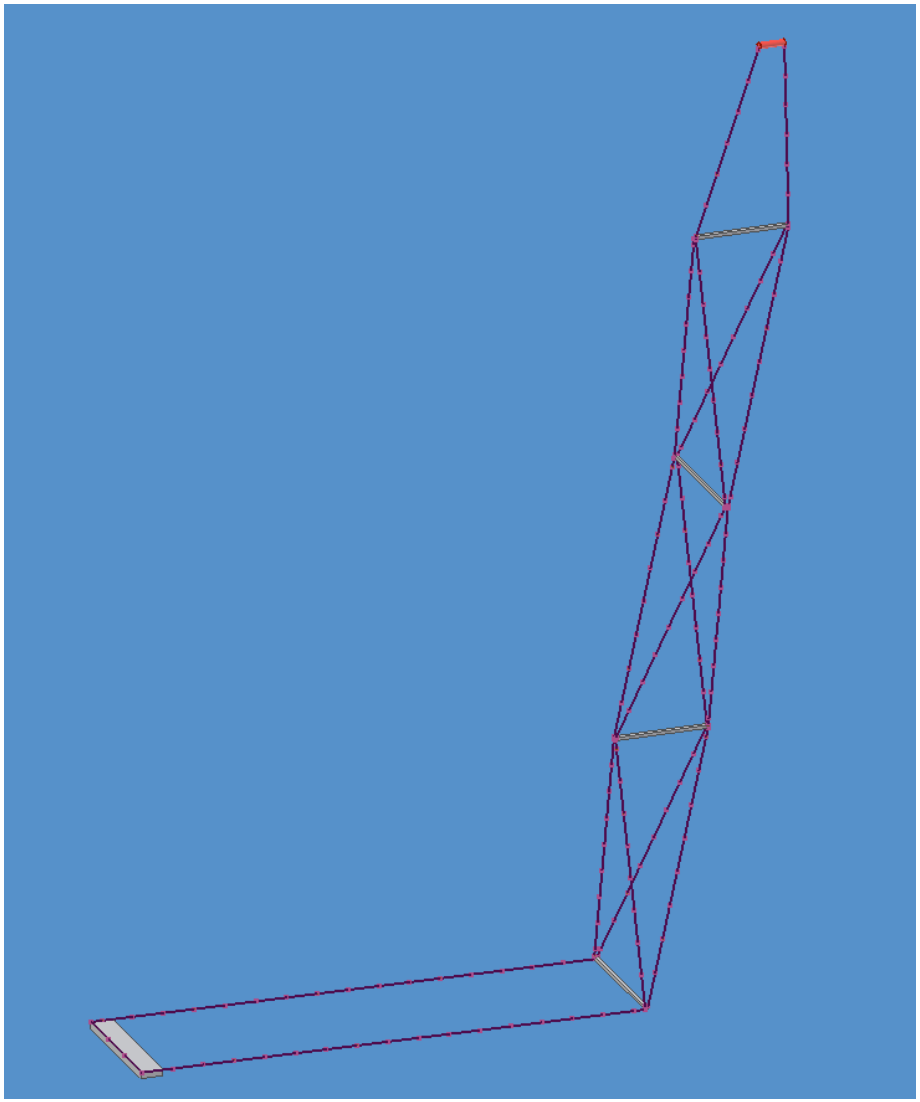
$$Offset_i = 125\ \mu s - t_{peak,\,i} + corr_i$$



$\sigma \approx 1.5$ ns

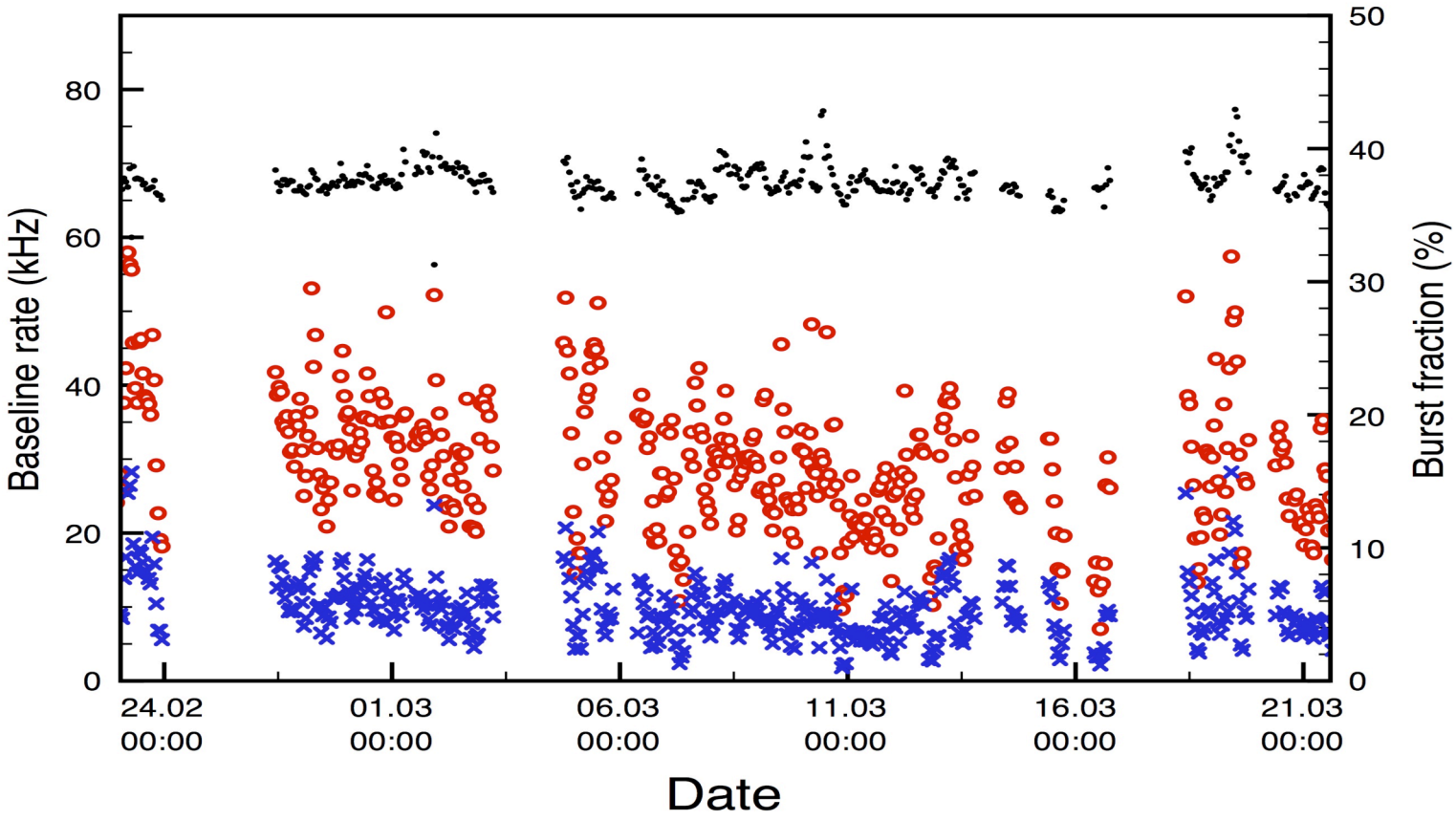
Shape of the tower

- Since january the position of the tower has lowered
- First and second floor are now close to the seafloor
- This process has started after some days of normal operation and has progressed with a slow rate
- A ROV inspection has confirmed the configuration
- Tests on samples of the buoy material from the same batch has confirmed a deterioration of the buoy with a loss of buoyancy
- Intervention with the addition of an extra buoyancy on top is planned

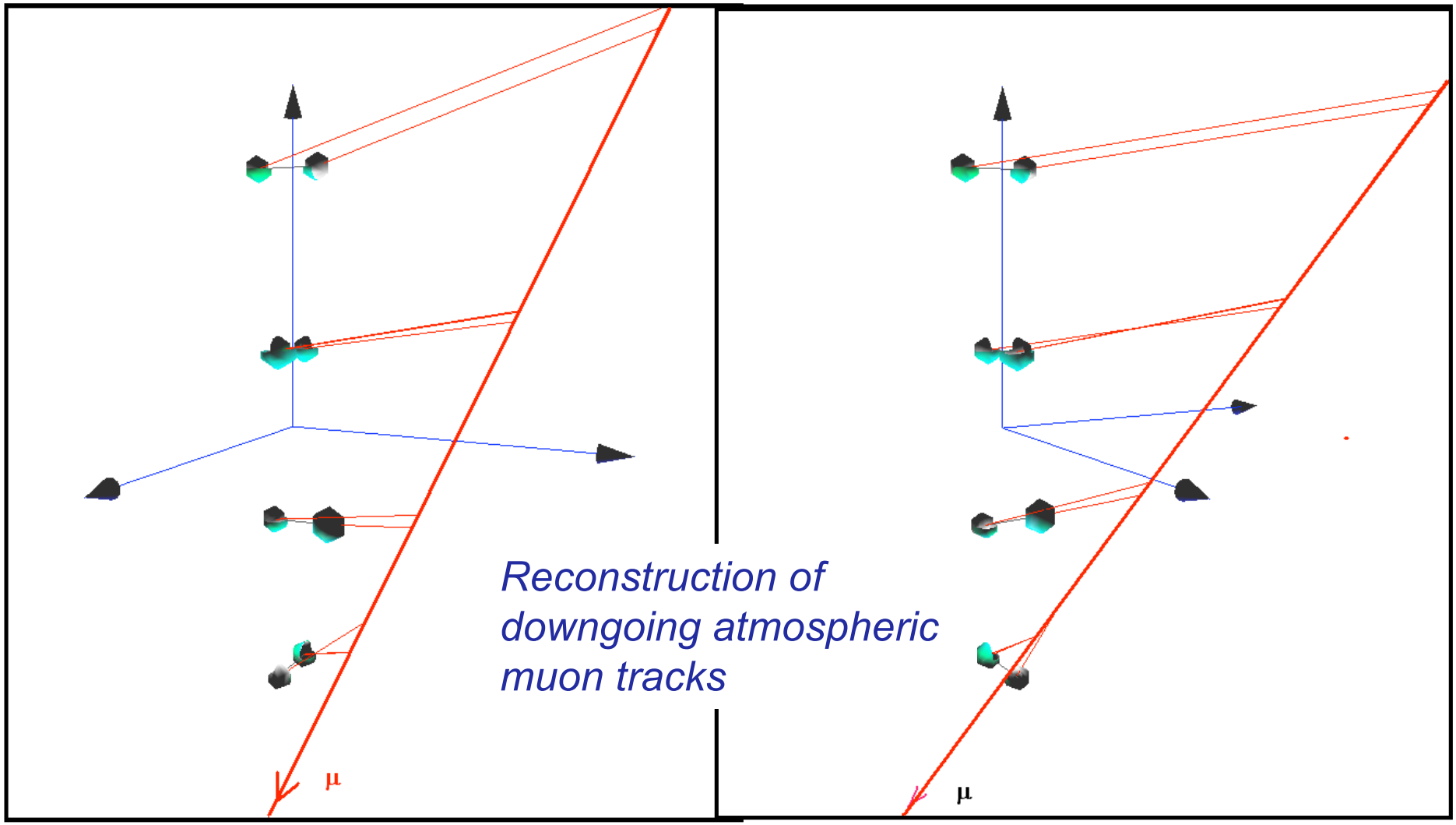


Optical background

Systematics over one month of:
the baseline rate (•)
burst fraction evaluated as time above 1.2xbaseline (o)
burst fraction evaluated as time above 200 kHz (×)



Preliminary data



Reconstruction of downgoing atmospheric muon tracks

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

Lessons learned

Junction Box

- Effectiveness of the oil bath solution
  - Solution applied for 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 august)

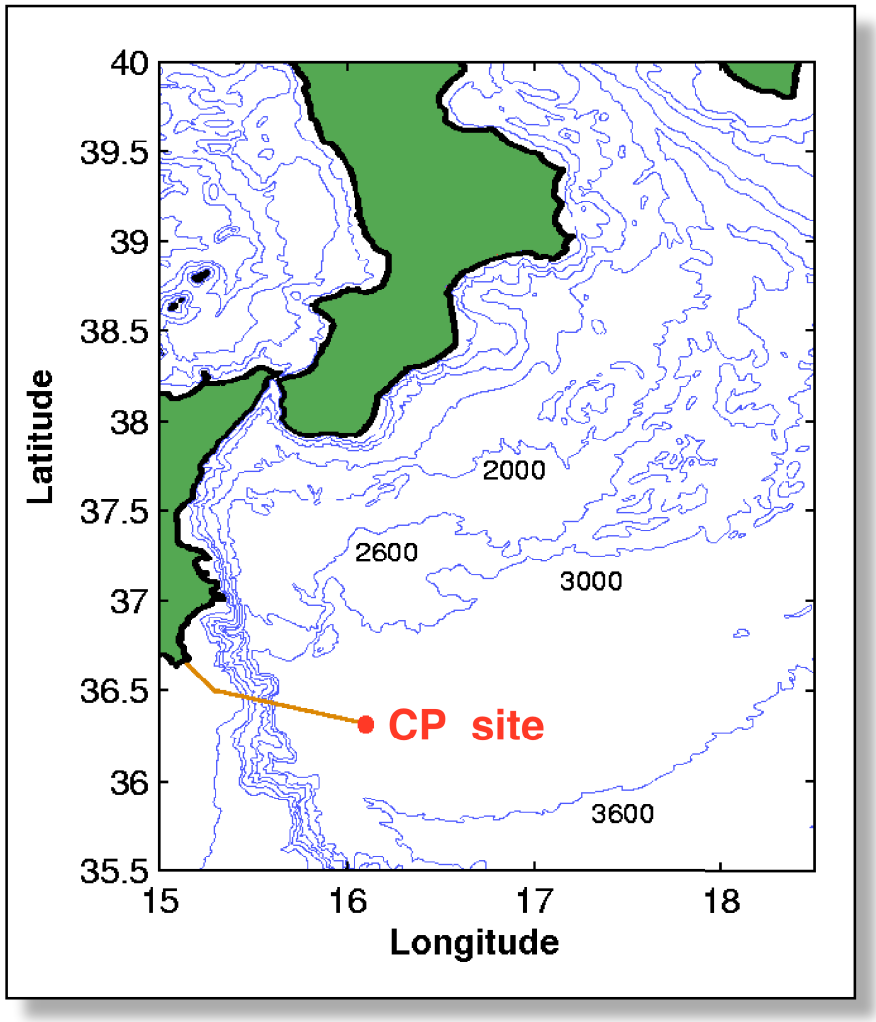
Tower

- Absence of any water leakage
- 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
  - 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

Phase-2 project

Phase-2 project

A deep sea station on the Capo Passero site



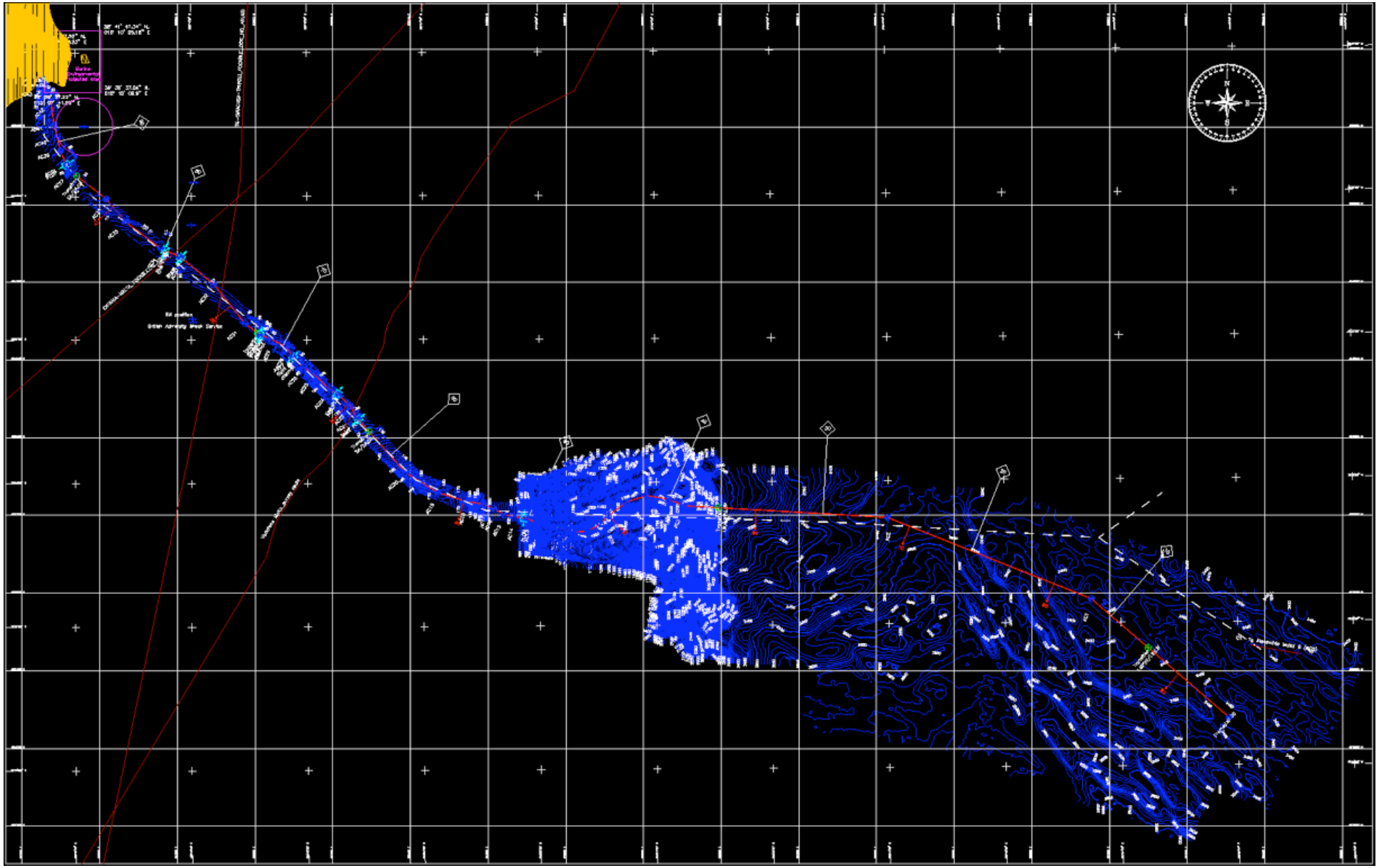
INFRASTRUCTURE UNDER CONSTRUCTION

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

STATUS AND PLANS

- Electro-optical cable (>50 kW, 20 fibres) delivered and loaded onboard the cable layer vessel
- Cable deployment 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

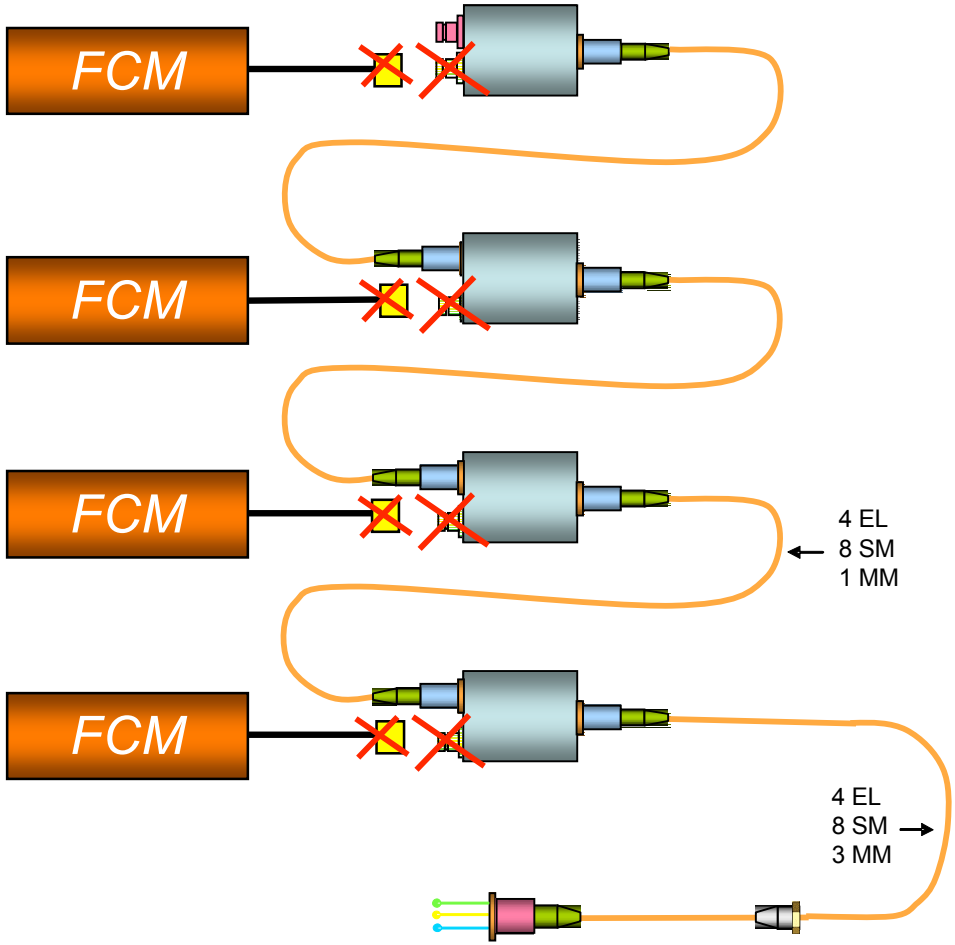
Bathymetry of the cable path and termination area



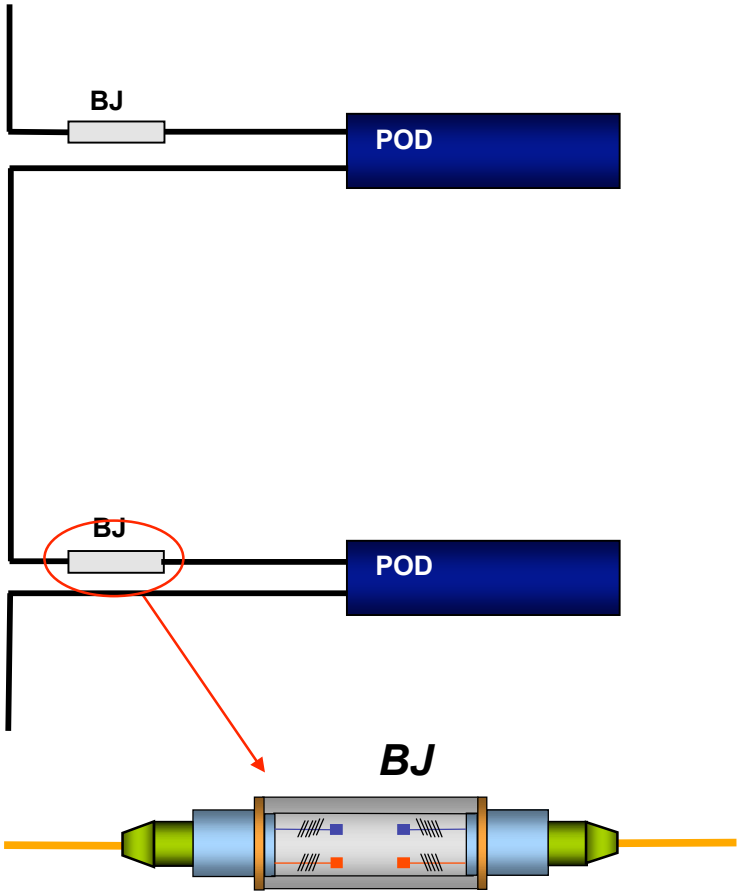
The cable landing area

Tower backbone

Phase-1



Phase-2



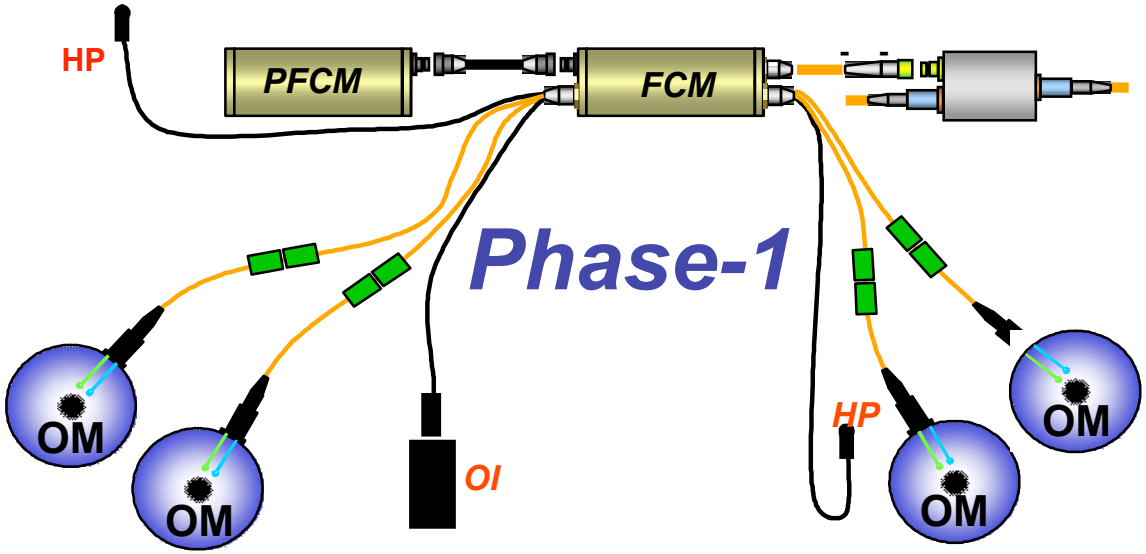
Connectors mounted for tests will be replaced by fibre splicing at final integration

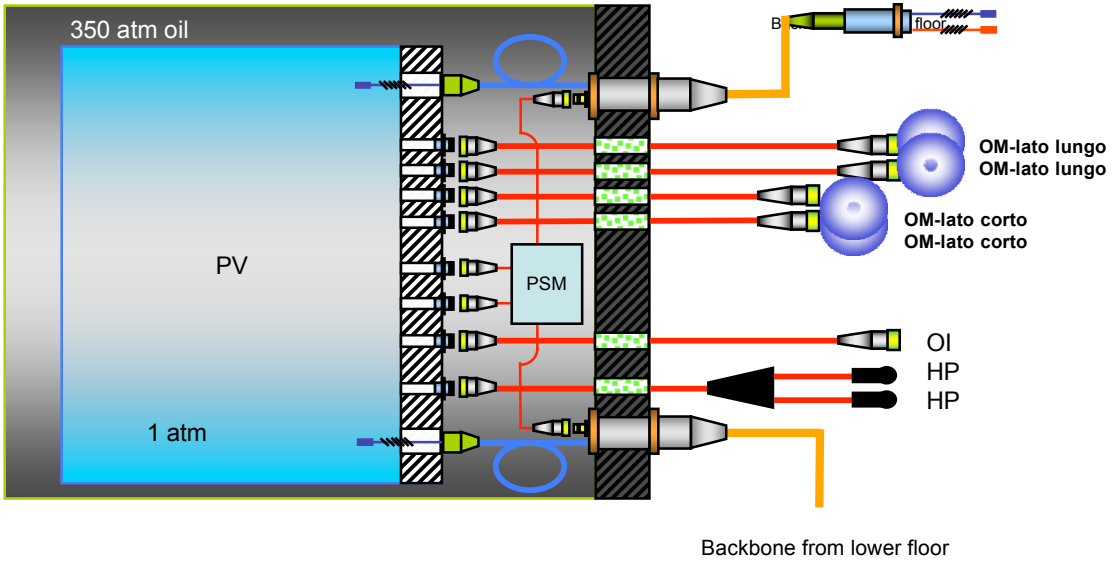
Segmented backbone cable will allow for an easier integration and cost reduction

Floor cabling

3 Floor vessels
(FCM - PFCM - breakout)

Single vessel
(Protective Oceanic Device)





Phase-2

Simplified cabling layout

Only one vessel per floor

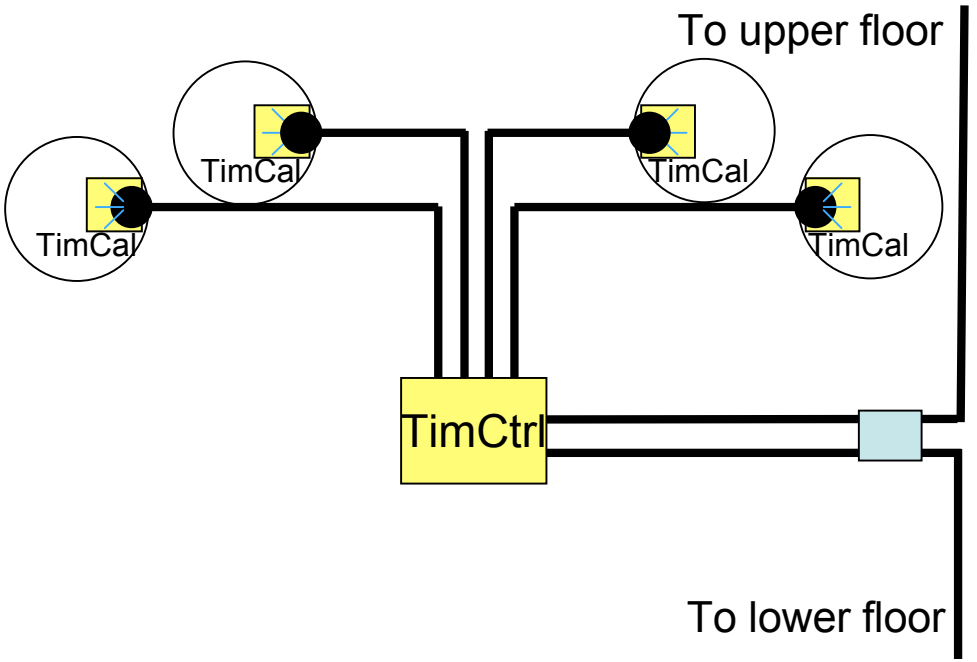
Only point to point connections from a central POD to instruments (except hydrophones)

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



Other modifications / upgrades of the Phase-2 tower

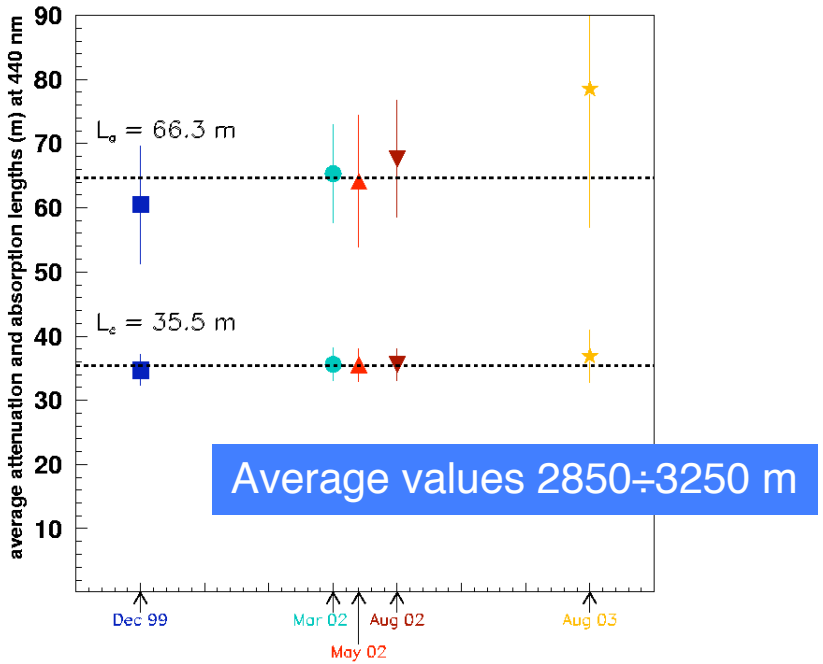
- Full tower with 16 floors
  - Equipped with the same electronics of Phase-1, but two floors reserved for testing of new electronics (LIRA), directional OMs, …
- New DC power system to comply with the feeding system provided by Alcatel
- Optimization of the electronics and data transmission
  - Increase of the A/D conversion accuracy
  - Increase of the data bandtwidth
  - Decrease of the power consumption
- Integrate a new acoustic station

Summary

- Overall successfull experience of Phase-1
- Changes and upgrades in Phase-2 aimed at a simplification of the integration procedures and cost reduction
- The experience gained will contribute to the advancement of the KM3NeT activities

Seasonal dependence of optical properties in Capo Passero

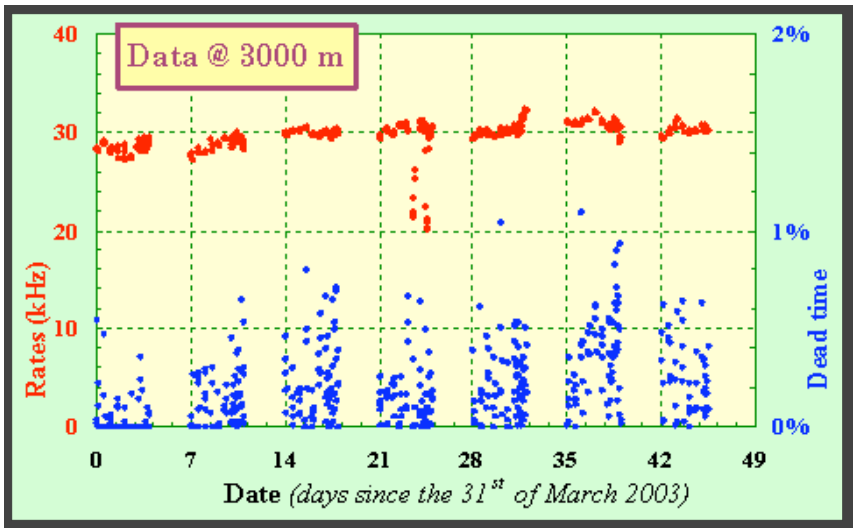
Absorption and attenuation lengths (for λ=440 nm)



Average values 2850÷3250 m

Absorption lenght values are compatible with optically pure sea water

Optical background



Data taken in collaboration with ANTARES

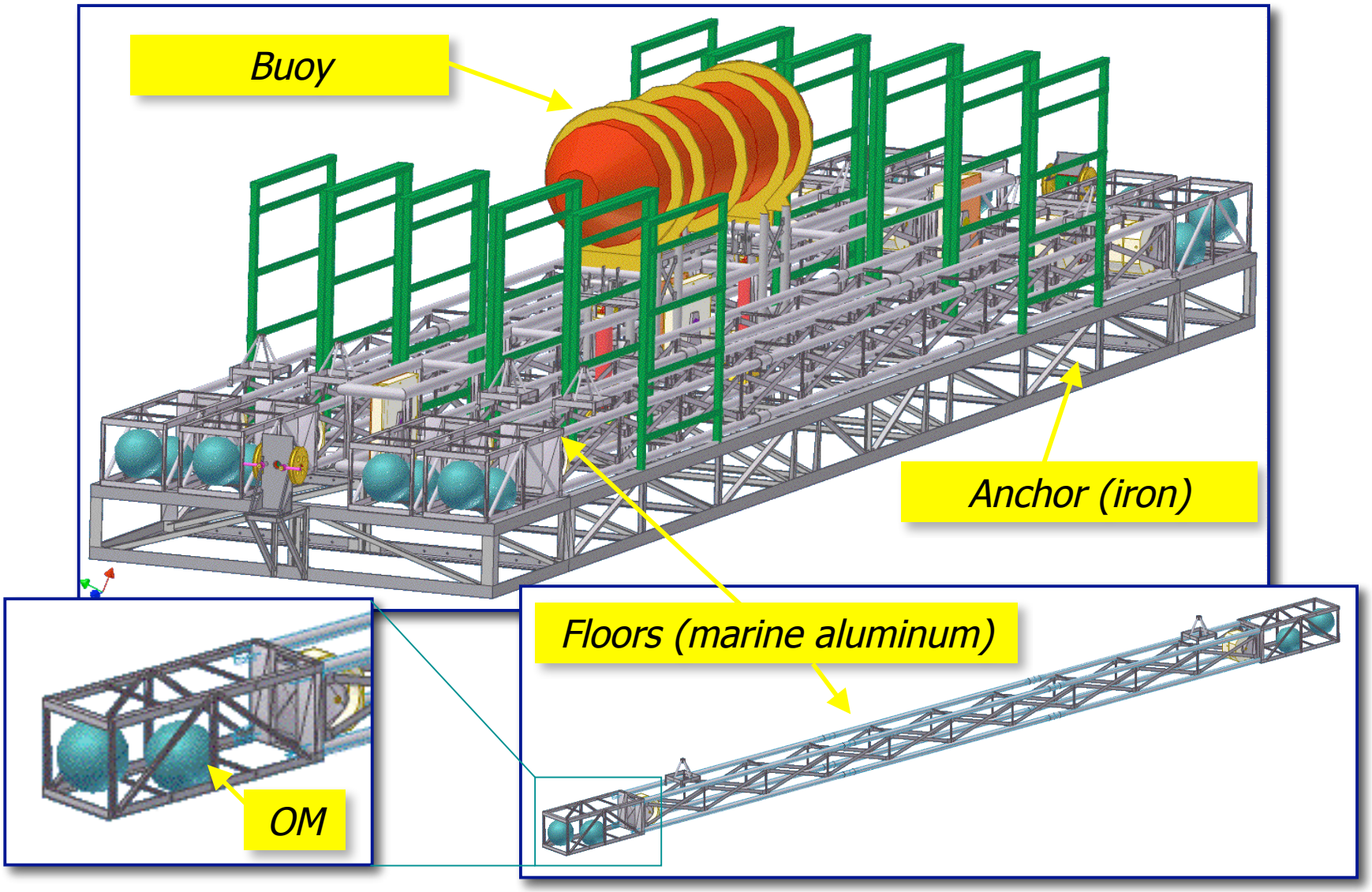
- PMT: 10"
- Thres: ~.5 SPE

Dead time:
Fraction of time with rate > 200 kHz

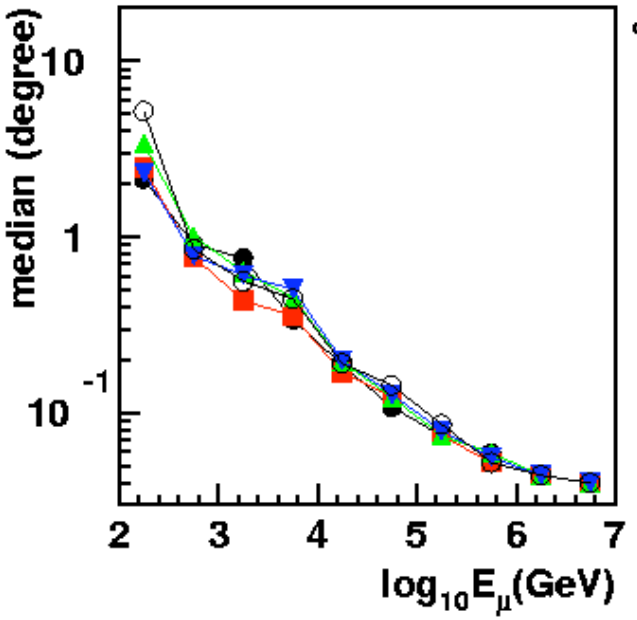
The measured value of 30 kHz is compatible with pure ^{40}K background

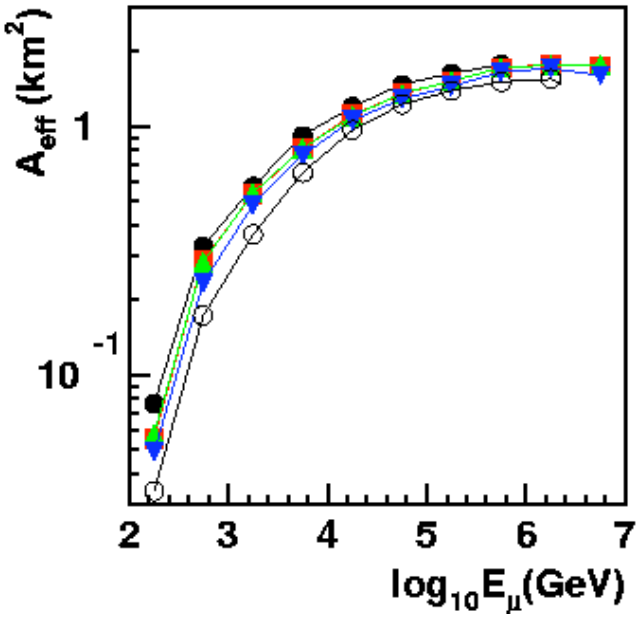
No seasonal dependence observed

The NEMO prototype tower



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

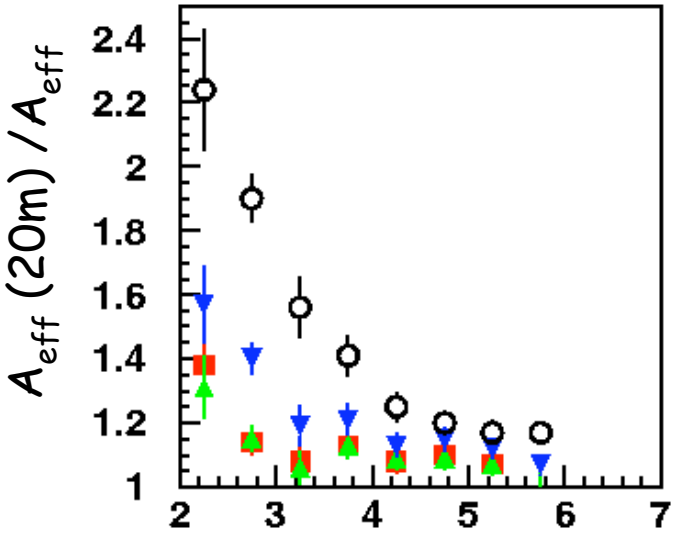




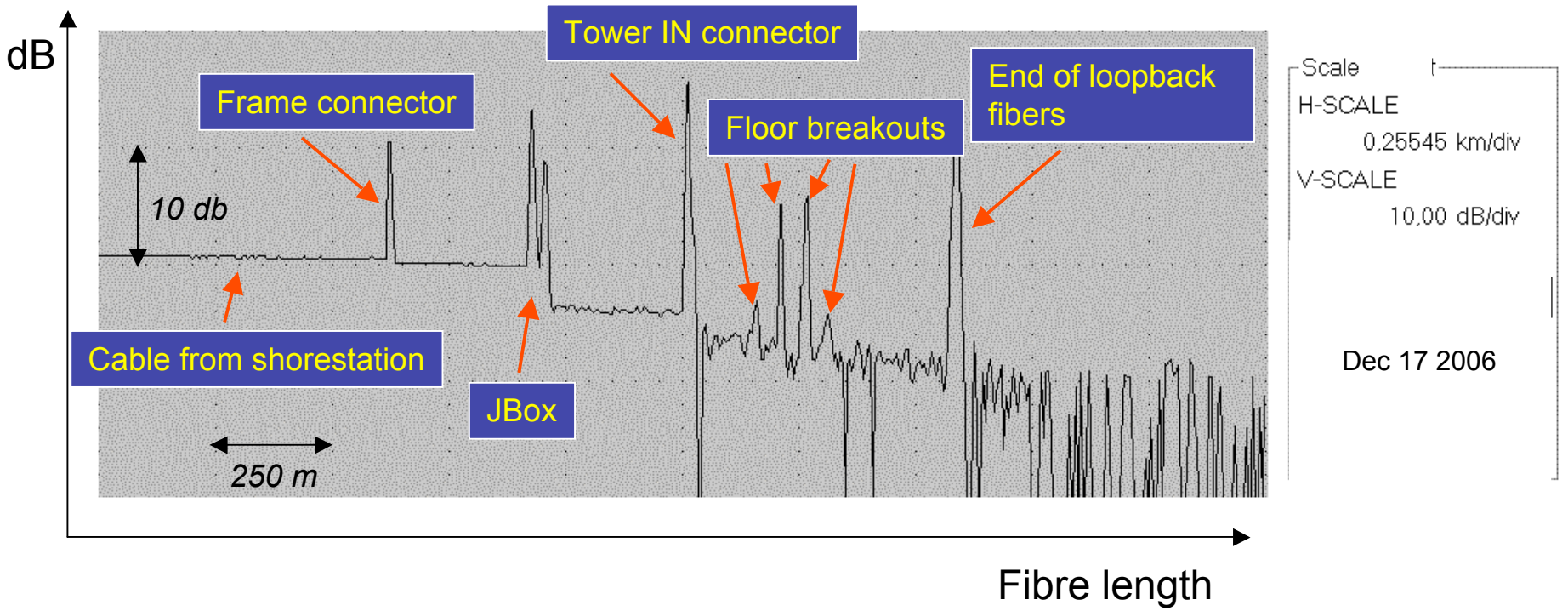
Floor lenght will be shortened from 15 to 12 m

No significant effect on km3 performance

The whole tower could be compacted as a standard 40 ft container

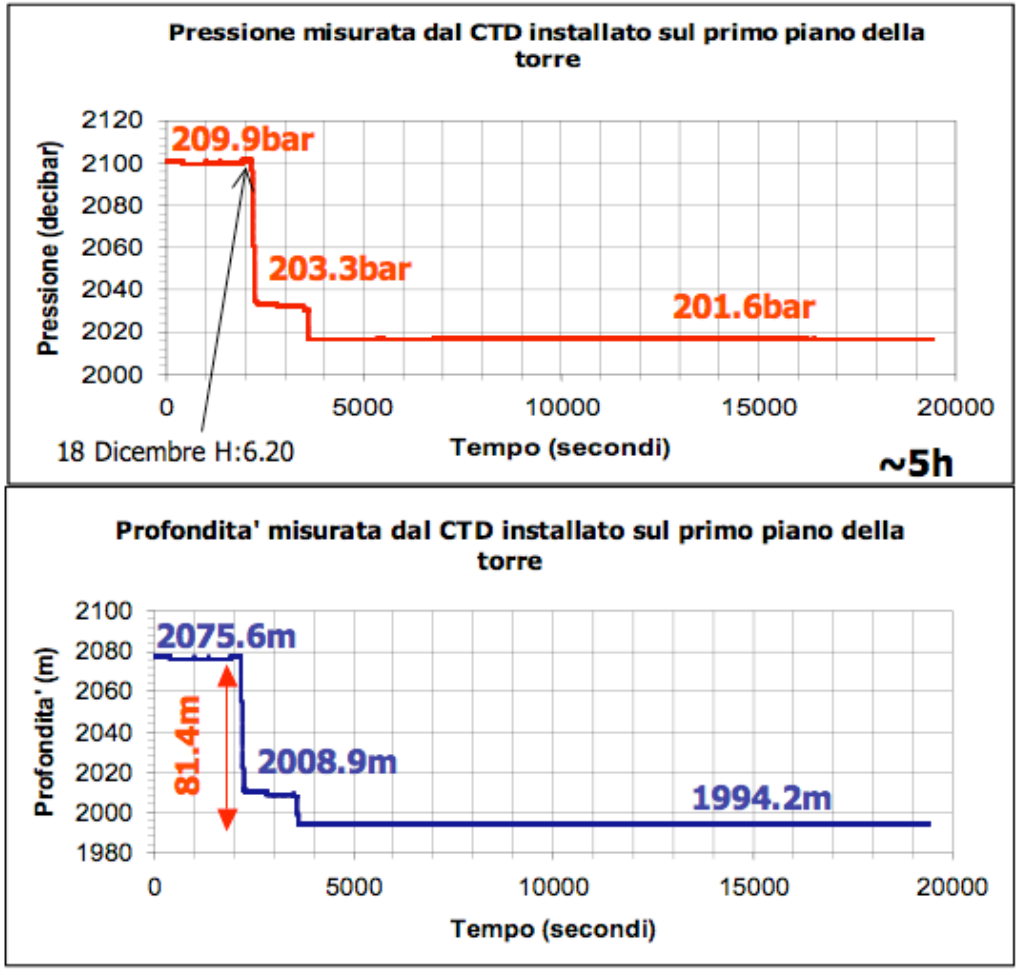


OTDR monitoring of the fibre channel



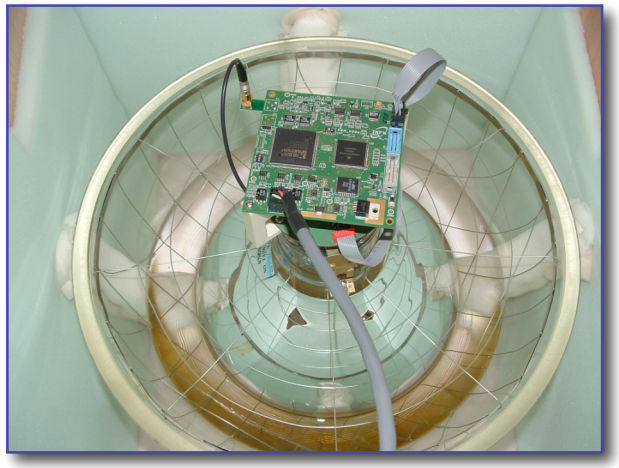
Tower unfurling

Pressure (and depth) given by the CTD installed on the tower lowermost floor



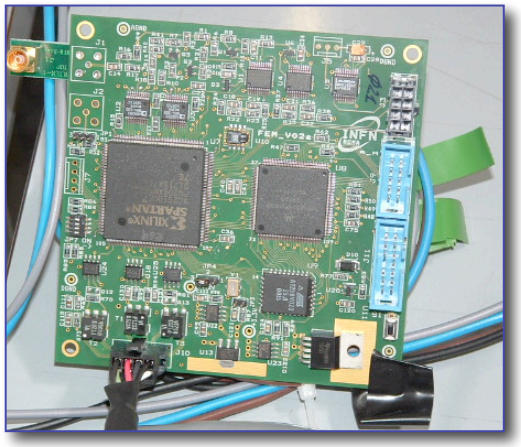
Optical Modules

Hamamatsu 10" R7081 SEL



PMT dimension	10 inch
Spectral response	300-650 nm
λ of max response	420 nm
QE at maximum	25%
Photocathode material	bialkali
Window material	borosilicate glass
Dark counts	<5000 kHz (1/3 p.e.)
Gain	$5*10^7$ for V_{supply} < 1800 Volts
Peak/valley ratio	>2
Pulse TTS	~ 3 ns FWHM
Afterpulse 1	< 1.0%
Afterpulse 2	<8 %
Delayed pulse	<5 %
Pre pulse	<1%

FEM Board



200 Msample/s 8bit (log compression)