Status of the NEMO project

Piera Sapienza on behalf of the NEMO collaboration

Istituto Nazionale di Fisica Nucleare
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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

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

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 40K background.
Feasibility study for the km³ detector

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

Detector modularity

- **main EO cable**
- **secondary JB**
- **“tower”**
- **main Junction Box**

**JUNCTION BOX**
Distributes power and data from and to shore

**BUOY**
Keeps the tower vertical

**OPTICAL SENSORS**
The telescope eyes catch the neutrino signal

**TOWER**
Made of 16 bars 40m spaced tensioned by 4 kevlar cables

**ANCHOR**
Iron made anchors the structure to sea bed

**CABLE**
Connects Catania harbor to the junction box. Provides power and collects data from optical sensors
Sensitivity
Sensitivity to point-like sources ($E\gamma^{-2}$ spectrum)


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

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

NEMO search bin 0.3°
IceCube search bin 1°

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 technological demonstrator including all the key elements of the km$^3$
  - Mechanical structures
  - Optical and 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, dolphins and sperm whales)
  - SN-1 (first operative node of ESONET)
NEMO Phase-1 - LNS test site

Cable features
- 10 optical fibers ITU-T G-652
- 6 electrical conductors $\Phi = 4 \text{ mm}^2$

Frame
- Double armored cable 2.330 m
- Single armored cable 20.595 m

Junction Box
- Mini-tower - 4 floors
- North branch 5.220 m
- South branch 5.000 m

SN-1 recorded a large number of seismic events.

Frame
- Jumper 300m

NEMO Phase 1
- Mini-tower cable connection branches
- Junction Box

Frame
- Jumper 300m

SN-1 recorded a large number of seismic events.
The Junction Box

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

Preparation to the deployment December 2006

Piera Sapienza
Taup 2007-Sendai, 11-15 september 2007
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
- Length 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
December 13 2003

Loading of the tower
December 15 2003

Deployment of the tower
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 ($\Delta t=20\text{ns}$)
- 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 ($\Delta t=20\text{ns}$)
- Aart Reconstruction
- Background rejection $\rightarrow$ 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
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