ANTARES and NEMO – toward a km^3 Neutrino Telescope in the Mediterranean Sea

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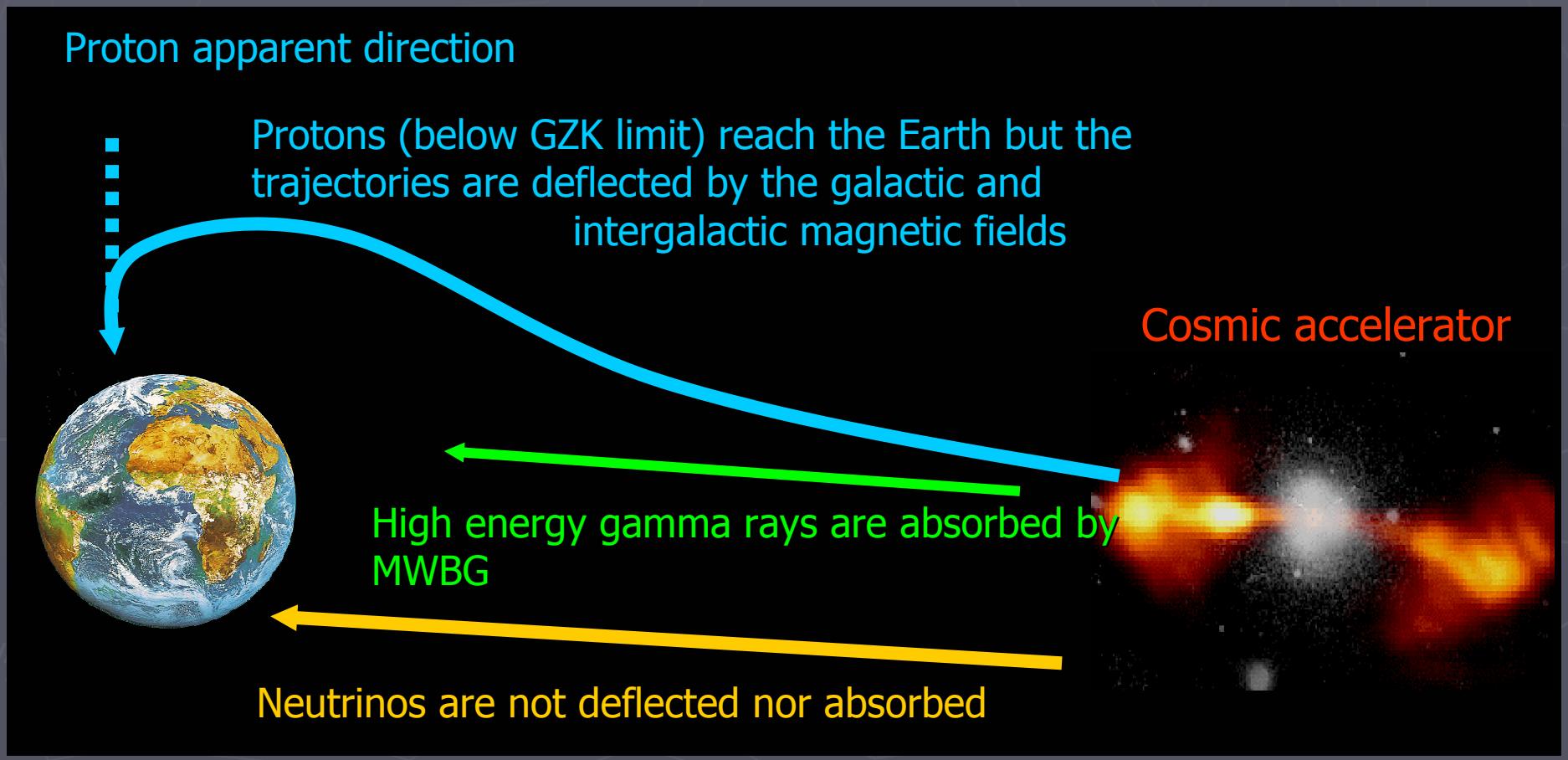
OUTLINE

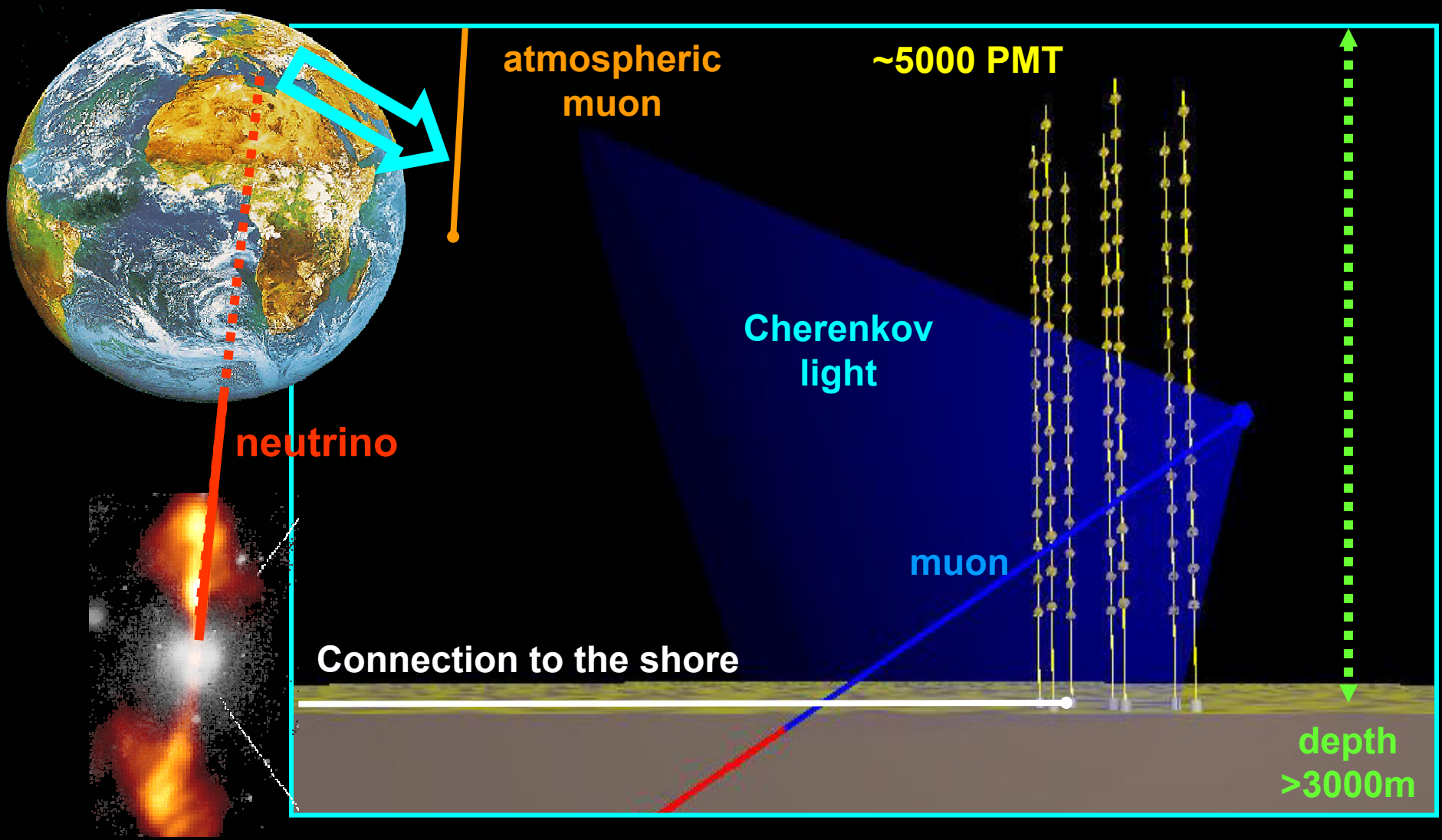
- Introduction
- The ANTARES and NEMO project
  - Description
  - Results
  - Perspectives
- Conclusions

Physics Motivations

- High Energy Neutrinos are a powerful tool to investigate the hadronic mechanisms of Cosmic Ray production

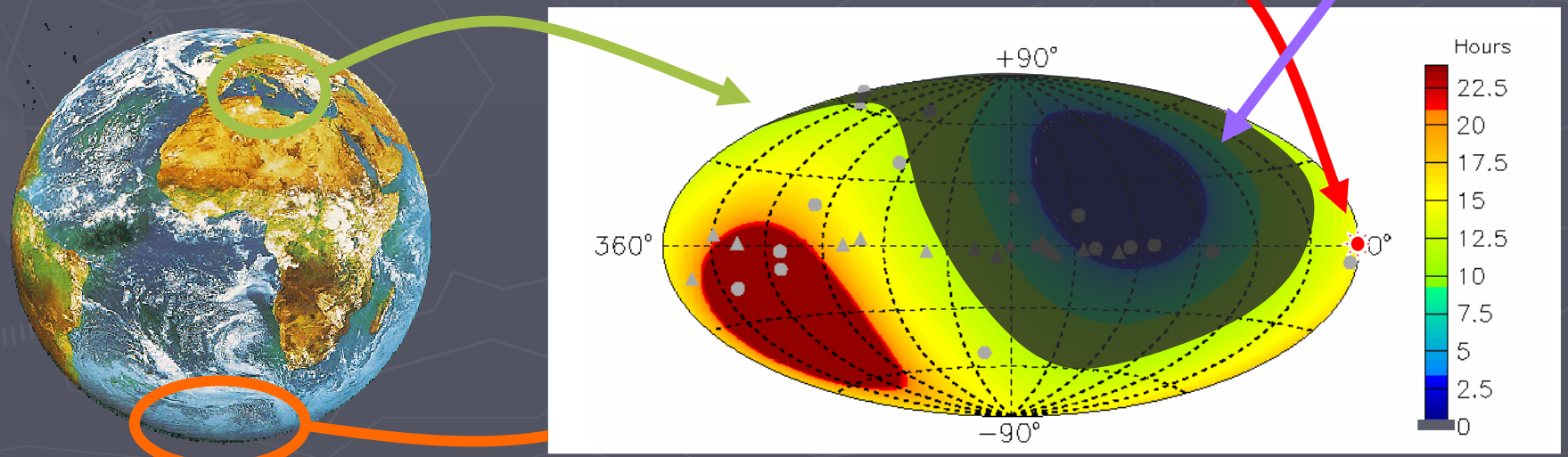


Physics Motivations



Physics Motivations

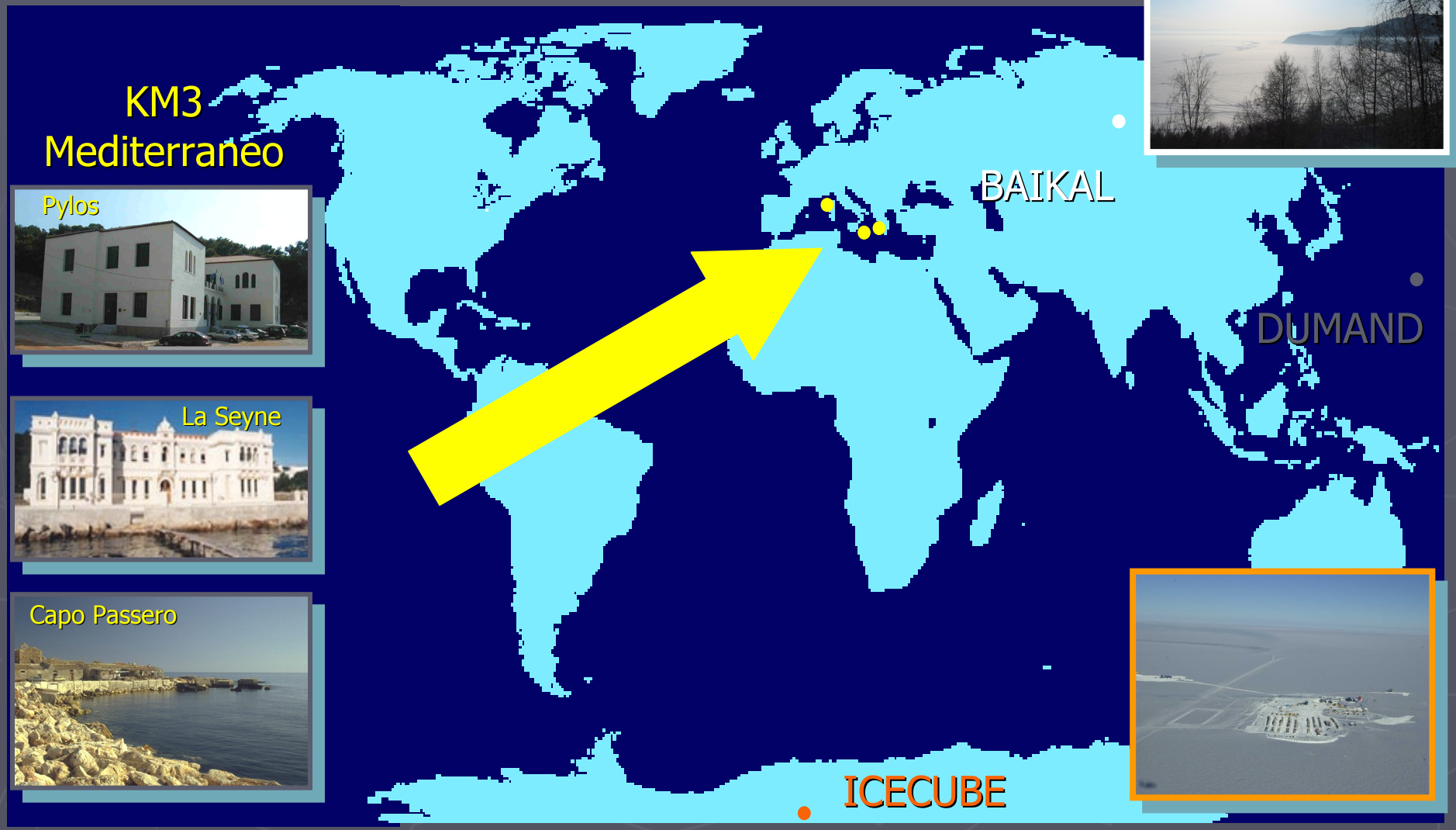
- A neutrino telescope in the Northern Hemisphere will provide:
  - Complementary sky survey to ICECUBE
  - Overlap observation region with ICECUBE
  - Study of the Galactic Center



Physics Motivation

- The small cross section and the expected low neutrino flux require
  - large volume telescope ~ 1 km^3
  - long observation time ~ yrs
- The atmospheric muon background requires
  - a shielding > 2000 m water equivalent
- The Mediterranean Sea provides convenient sites

The Sites


KM3
Mediterraneo
Pylos
La Seyne
Capo Passero
BAIKAL
DUMAND
ICECUBE

The ANTARES Collaboration

- Physics Institutes from:
  - France
  - Germany
  - Italy
  - NL
  - Spain
  - Russia
  - UK
- Sea biologists, geophysicists

The NEMO Collaboration

- INFN
  - Bari, Bologna, Catania, Genova, LNF, LNS, Napoli, Pisa, Roma
- Universities
  - 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)

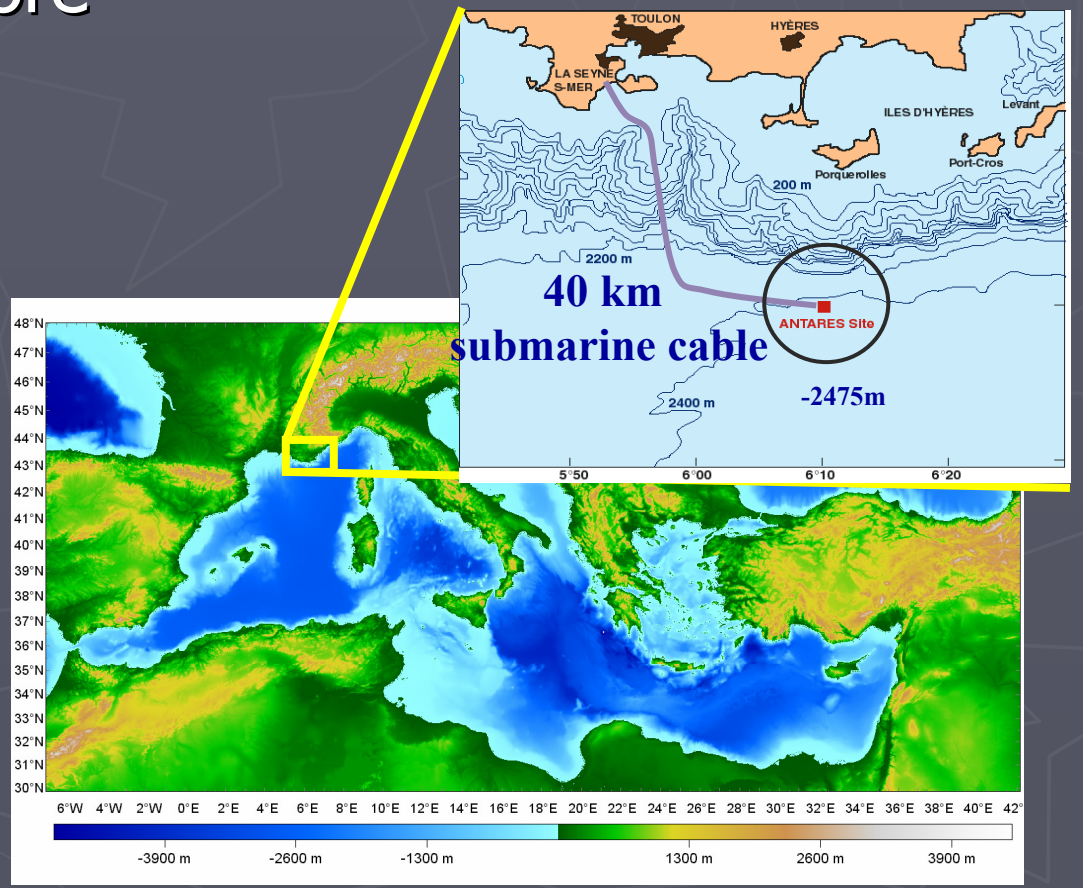
more than 70 researchers involved

Technical Requirements

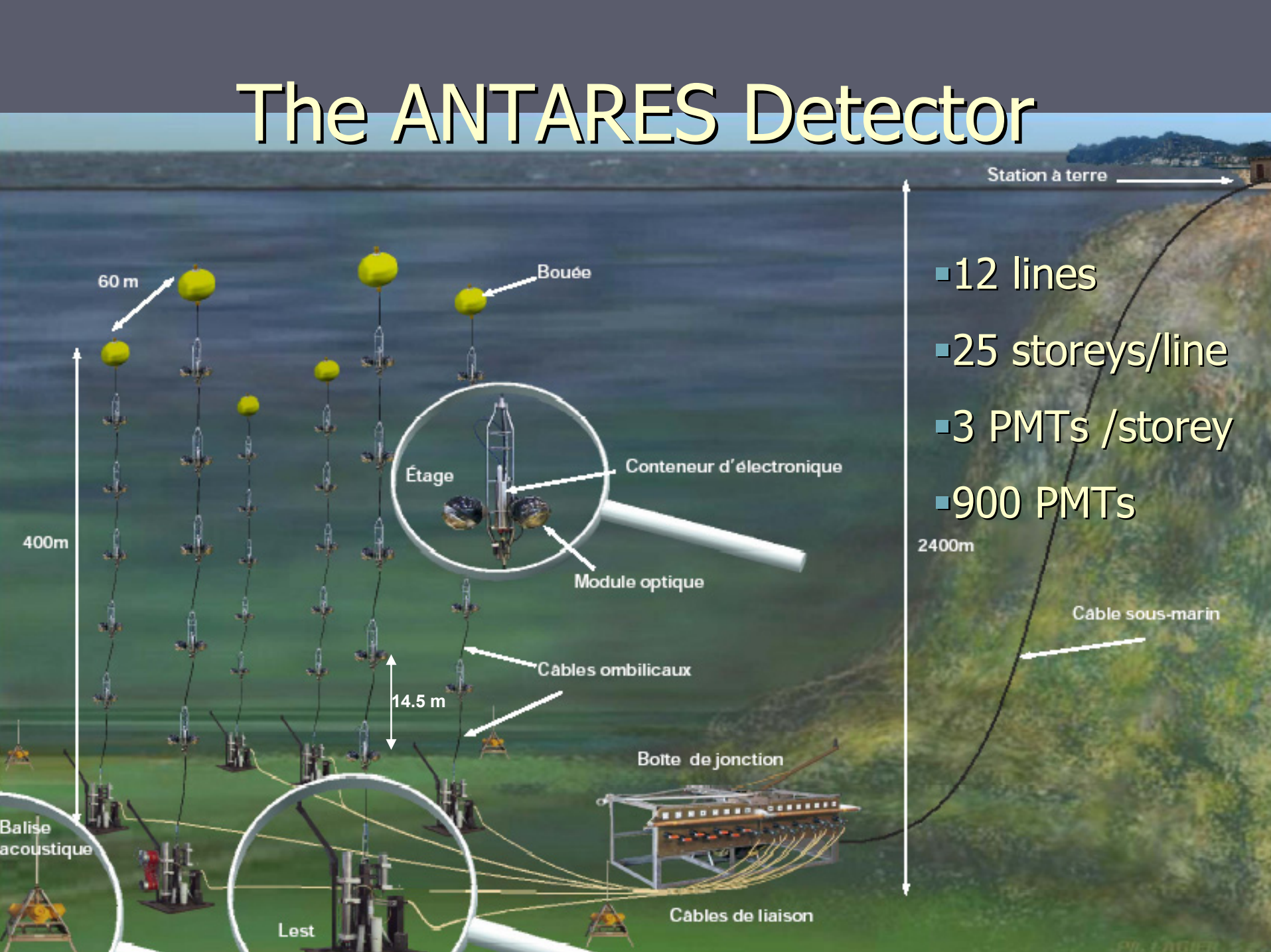
- Issues to be solved to realize a km^3 neutrino telescope in the Mediterranean Sea
  - Best site location (i.e. depth, water quality …)
  - Optical background from ^{40}K-decay and bioluminescence
  - Detector deployment
  - Detector rigidity against sea currents
  - Resistance to corrosion from salt water

The ANTARES Site

- 2400 m sea depth
- short path to the shore (40 Km)
- infrastructures (IFREMER,..)
- latitude : 42° 50’ N

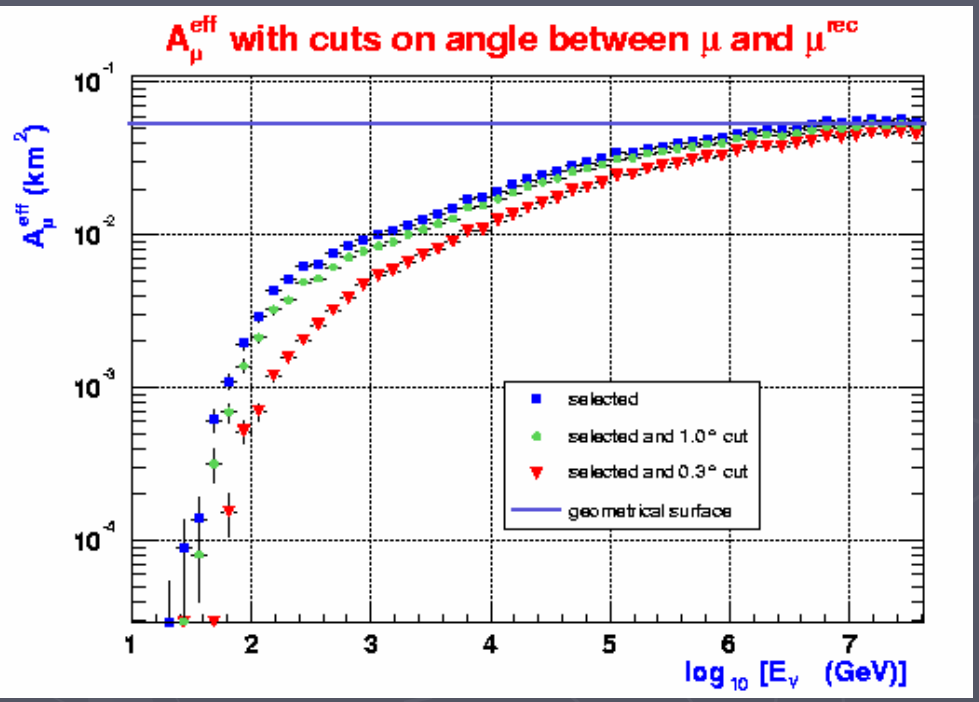


The ANTARES Detector



- 12 lines
- 25 storeys/line
- 3 PMTs /storey
- 900 PMTs

ANTARES Expected Performance



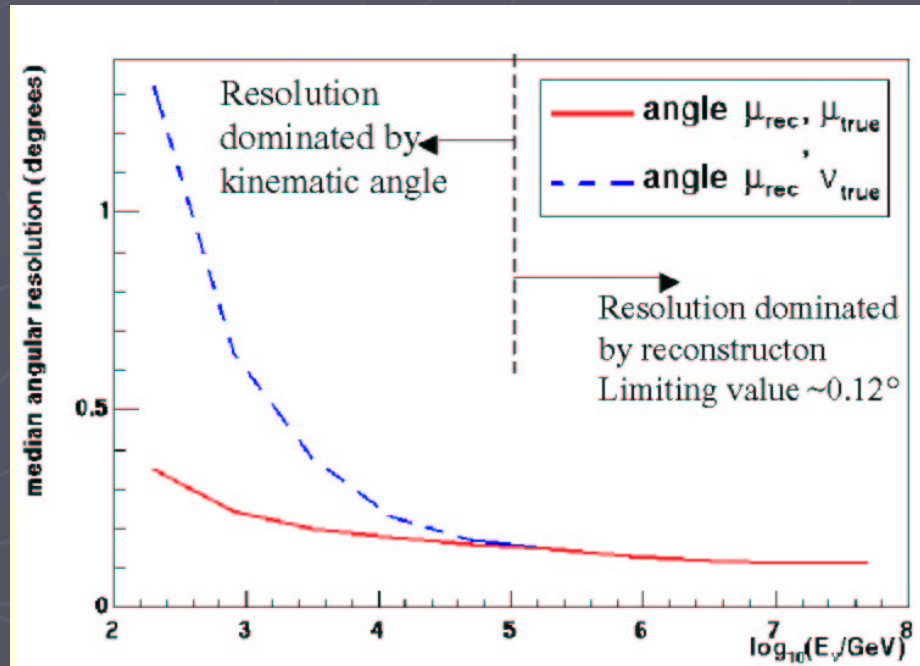
Effective area

depends on :

- reconstruction efficiency
- selection cuts
- absorption length

Angular resolution

- below 10 TeV: dominated by ν_μ-μ angle
- above 10 TeV: ≤ 0.2° after reconstruction



ANTARES – Sea Operations

The ANTARES Project

- Mar 01: Sea bed survey
- Oct 01: Electro Optical cable deployment
- Dec 02: Junction Box (JB) deployed
- Dec 02 – Feb 03: Prototype Sector Line (PSL) & Mini Instrumentation Line deployed
- Mar 03: PSL and MIL connected to JB by submarine
- Jun 03: MIL & PSL recovered (diagnose: attenuation of the optical signal inside the mechanical electro optical cable of the lines)
- Mar 05: Line 0 & MIL deployed
- May 05 : Line 0 recovered (still attenuation of the optical signal inside the mechanical electro-optical cable of the lines due to a different reason)
- Oct 05: MIL still operating
- Oct 05: integration of Line 1 started with attenuation problem fixed
- Jan 06-Dec 07 : installation of the 12 lines

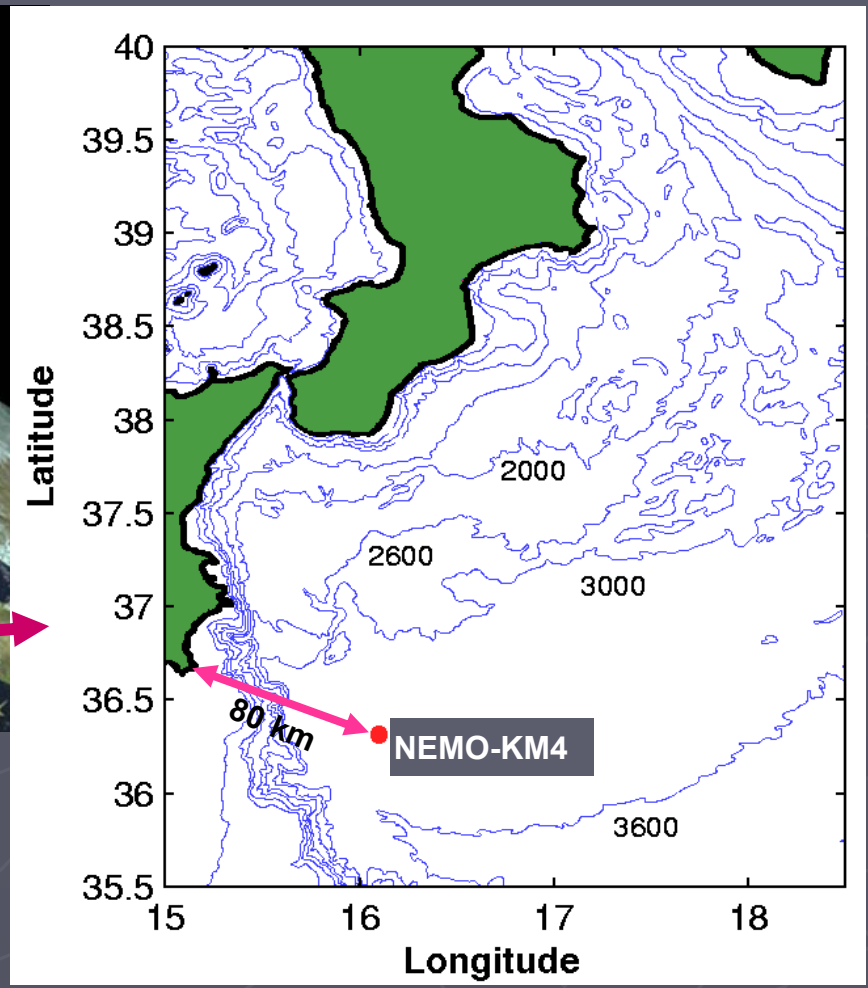
The NEMO Project

- R&D phase (1999-2002)
  - Site selection and characterization
    - Several sites close to the italian coasts have been studied.
  - R&D Activities
    - Development of dedicated ASICS for the underwater front-end electronics
    - Development of large area direction-sensitive optical modules
  - Feasibility Studies
    - All detector critical components and the deployment procedures have been examined
    - A preliminary project for the km^3 detector has been developed
- Phase-1 and prototyping (2002-2006)
  - Realization and deployment of a prototype including all critical components
- Phase-2 (2006-...)
  - Realization of an underwater infrastructure at -3500 m

NEMO R&D Activity

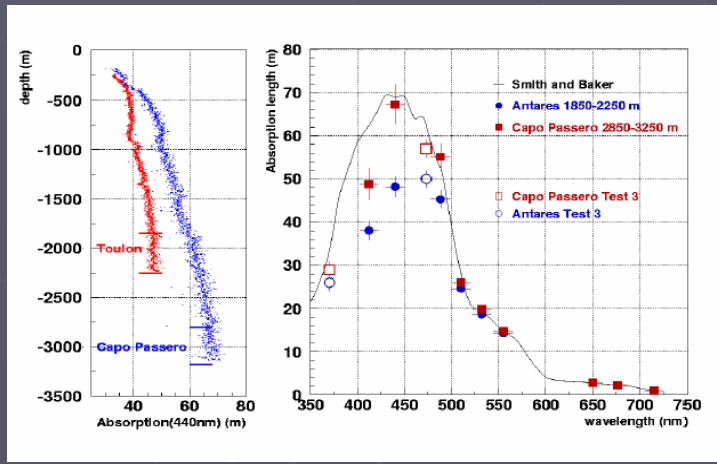
- Site location
  - More than 25 sea campaigns since 1998

- NEMO-KM4
  - 80 km off-shore
  - 3500 m depth

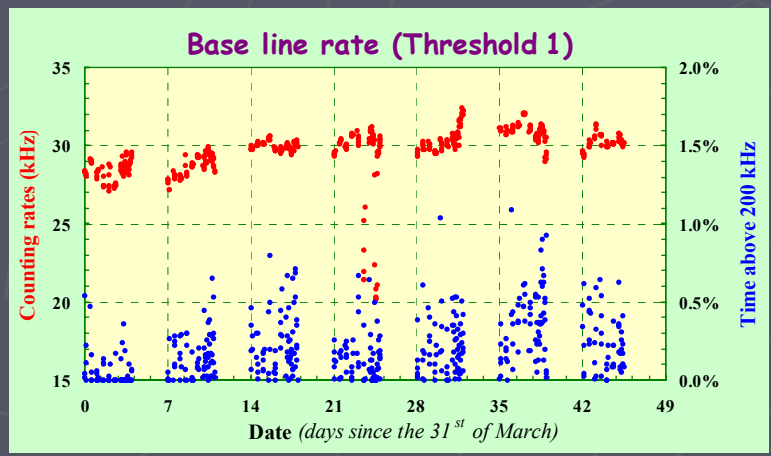


NEMO-KM4 Properties

- High water transparency
  - Data compatible with pure salt water properties
  - No seasonal variations



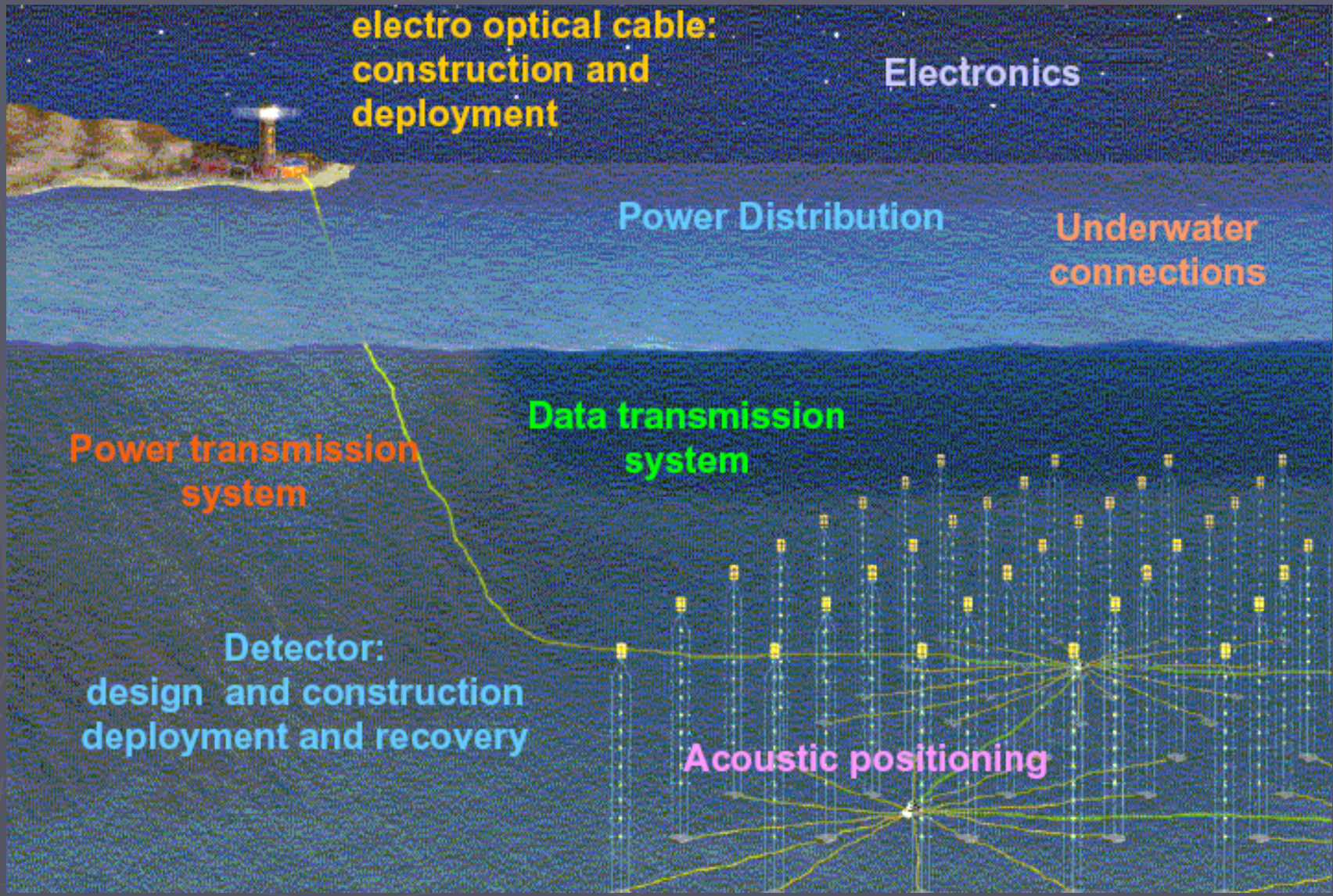
- Reduced background, mostly from ^{40}K decay
  - 10” PMT thres. 0.5 p.e. noise rate ~ 30 kHz
  - Bioluminescence almost absent



- Geologically stable

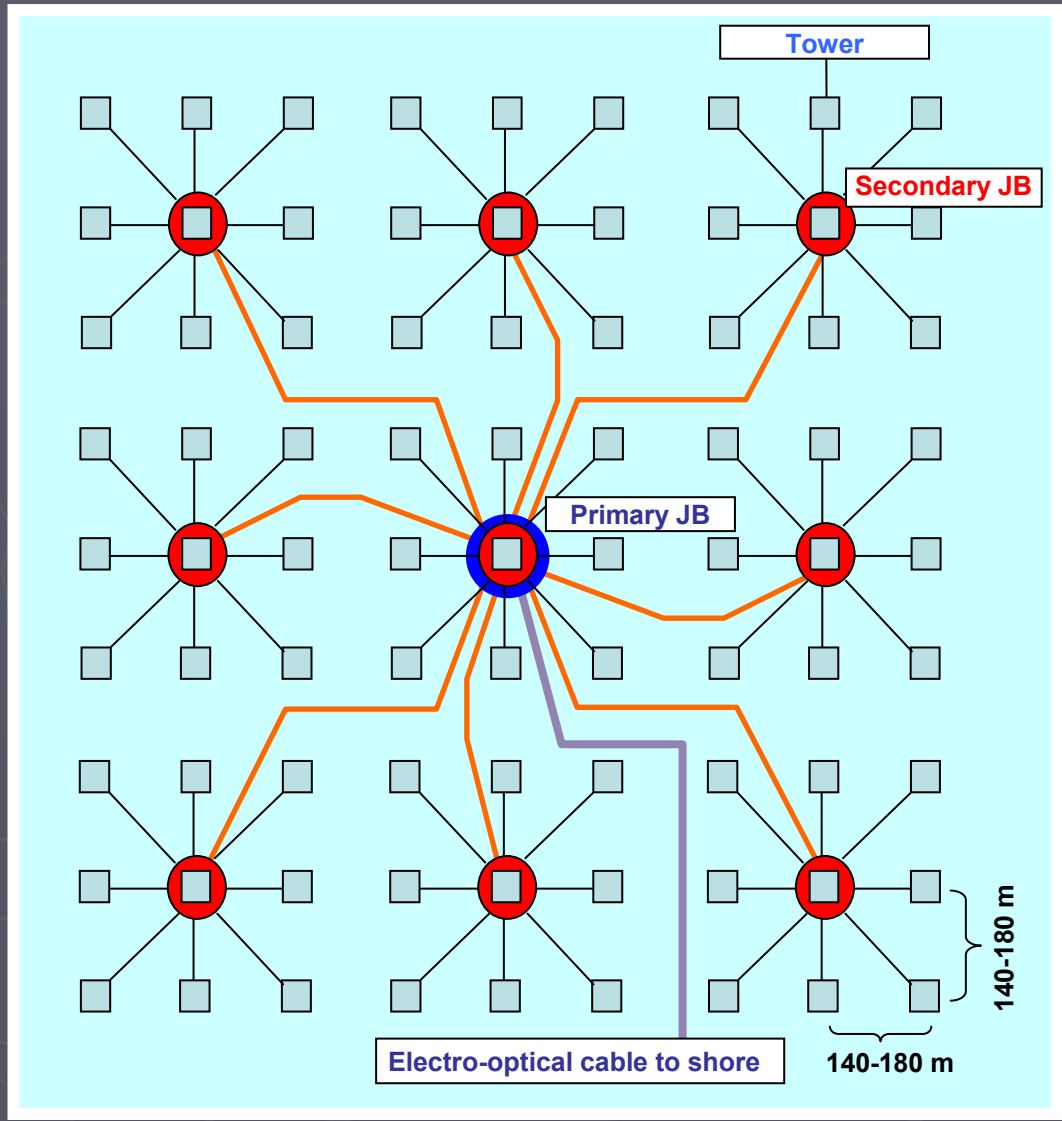
-3000 m

NEMO km^3 Conceptual Design



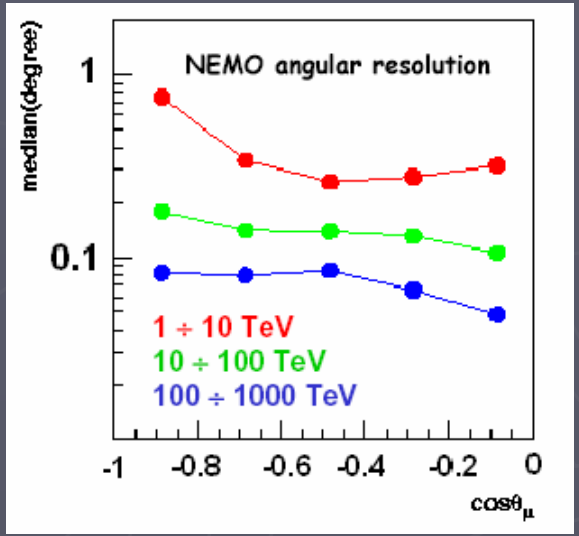
NEMO km^3 Conceptual Design

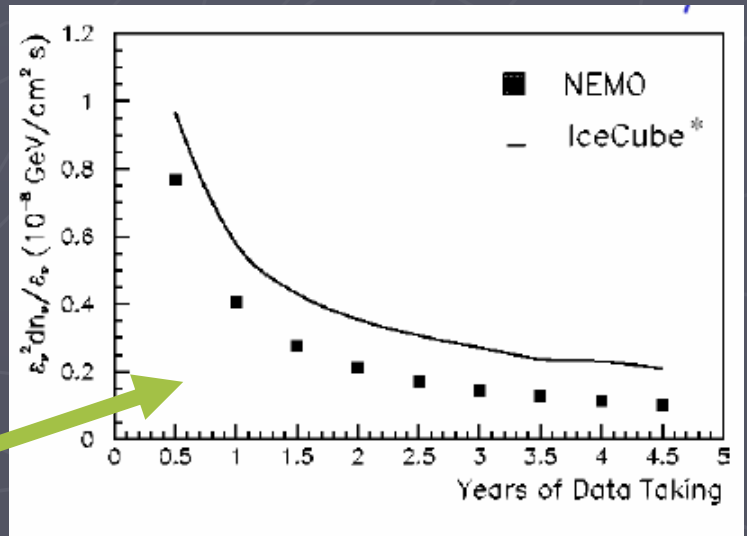
- Proposed lay-out
  - 10 junction boxes
  - 81 towers
  - 5832 PMTs



Expected Performance

- Simulations show excellent angular resolution and sensitivity
  - NEMO
    - 81 towers 140 m spaced
    - 5832 PMTs
  - ICECUBE
    - 80 strings 125 m spaced
    - 4800 PMTs

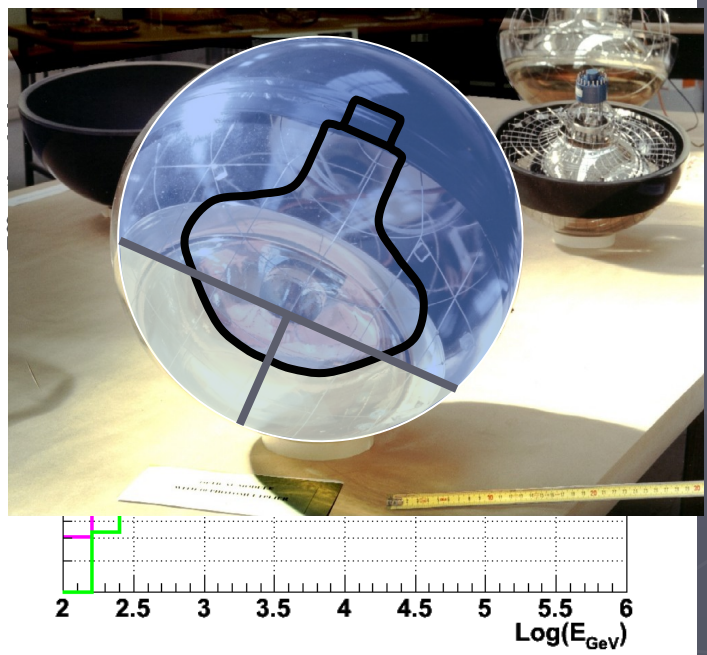


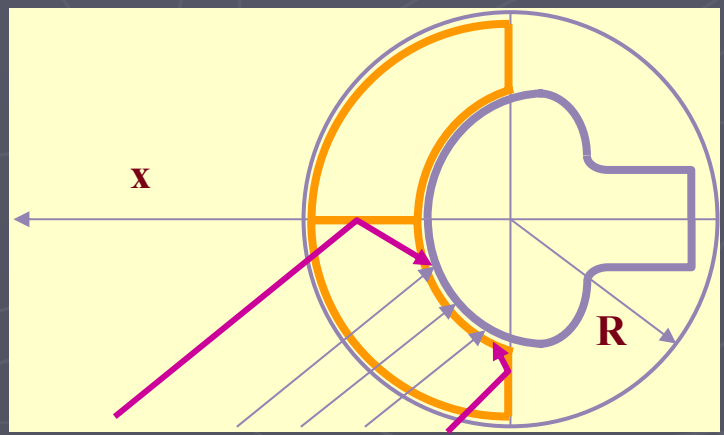


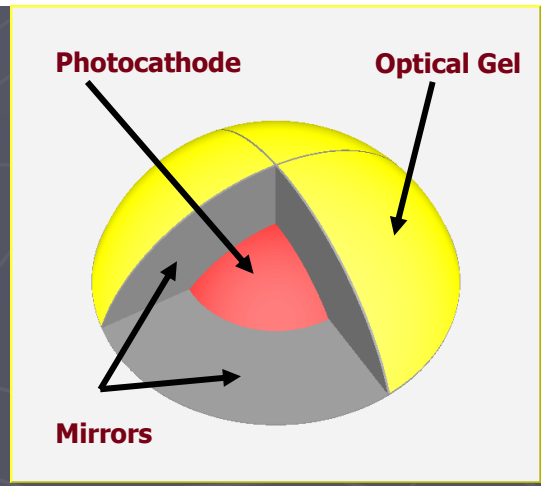
Sensitivity to a E^{-2} neutrino spectrum from a pointlike source

Position-sensitive OMs

- Cherenkov light is emitted at fixed angle
  - Knowledge of direction of incoming light reduces background and uncertainties
- INFN Genova and MSU are collaborating to realize a prototype
  - 4 anode PMT
  - Mirror system







The NEMO Phase-1 Activity

Shore station in the port of Catania

The Catania test site:
- 25 km off the coast of Catania
- 2000 m depth
- already equipped with a double-termination cable

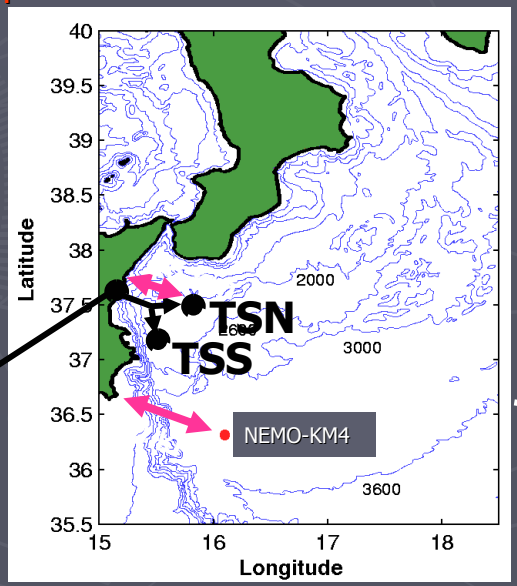
Geoseismic station SN-1 (INGV)

5 km e.o. cable

21 km e.o. cable with single steel shield

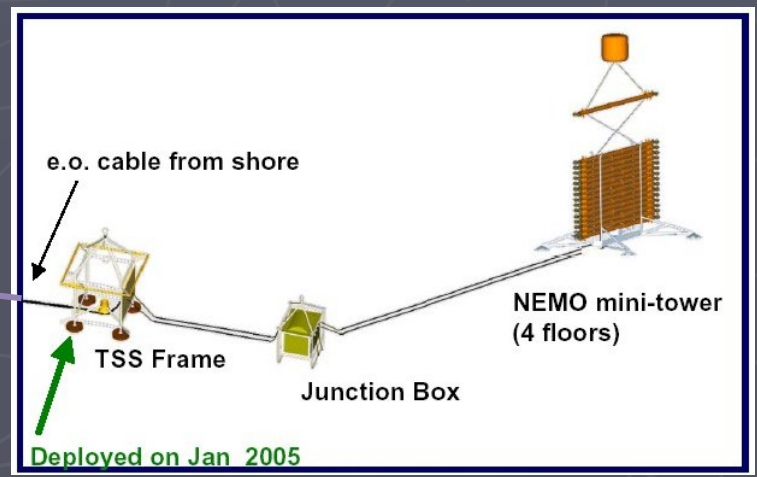
Branching Unit

2.5 km e.o. cable with double steel shield



Catania

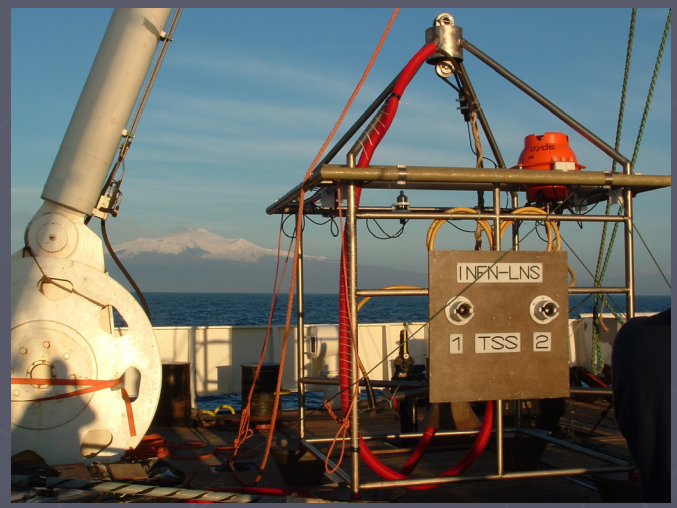
5 km e.o. cable

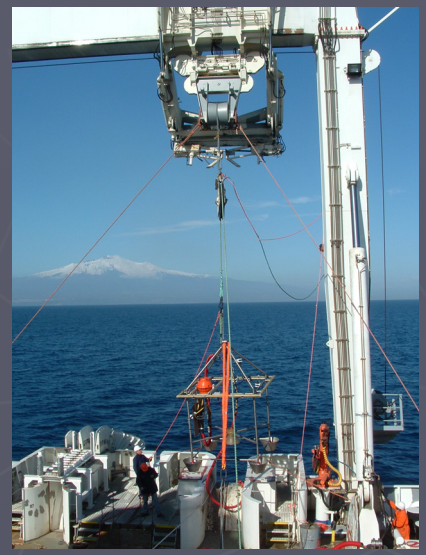


NEMO Phase 1

The NEMO Phase-1 Activity

- Installation of the cable termination frames with electro-optical connectors

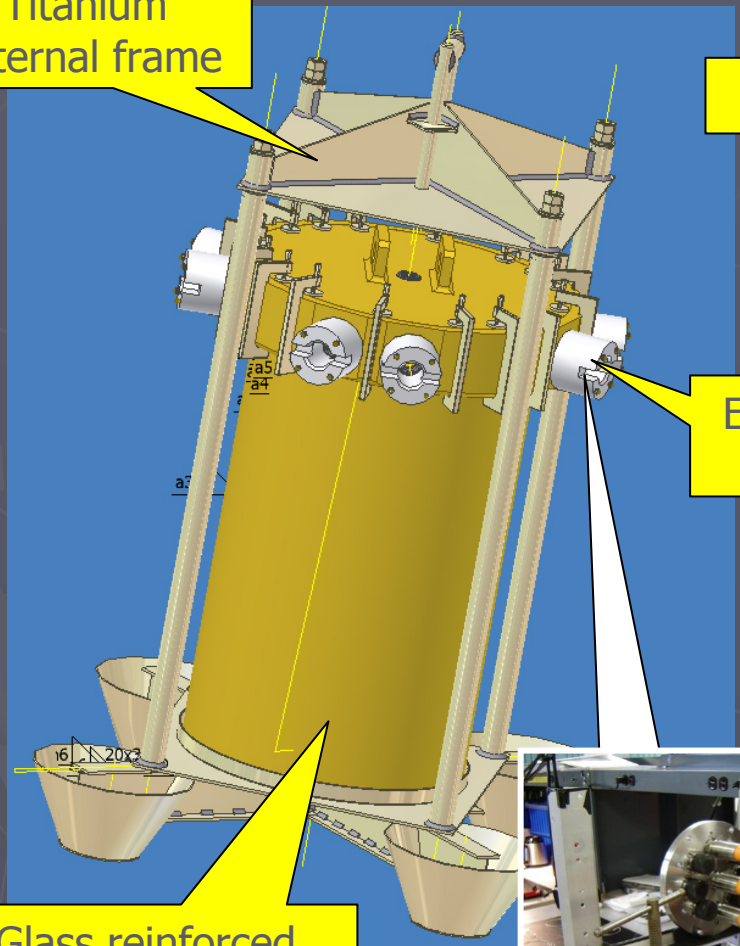




- Deployment and connection of
  - Acoustic detection station
  - INGV environmental observatory

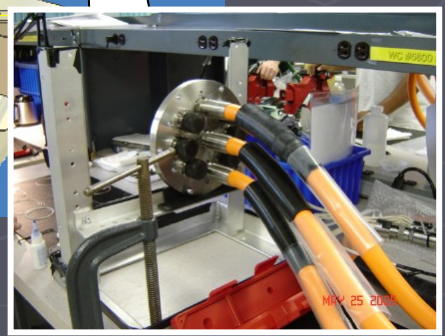
- Fully operational since January 2005

The NEMO Junction Box



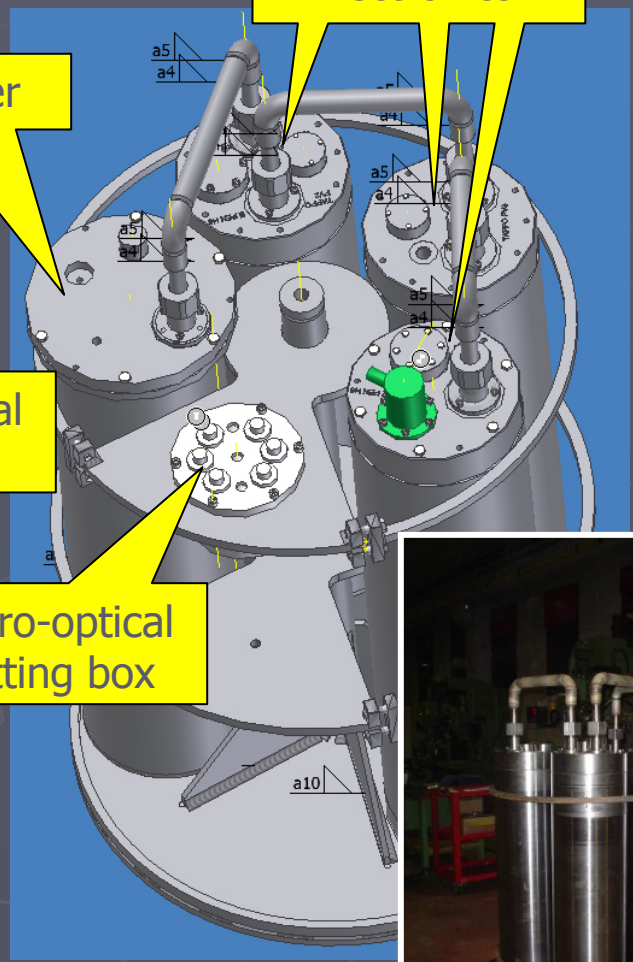
Titanium external frame

Glass reinforced plastic container



Electro-optical connectors

Transformer

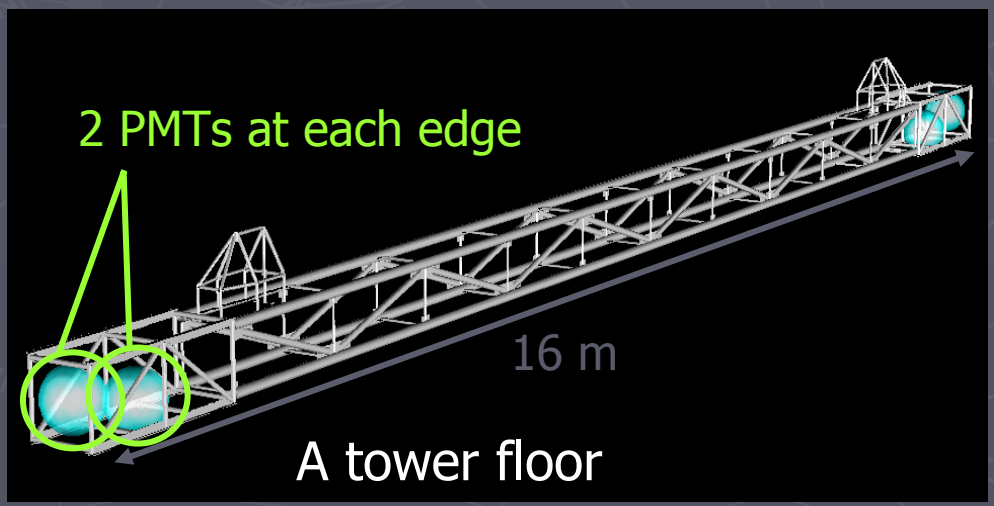


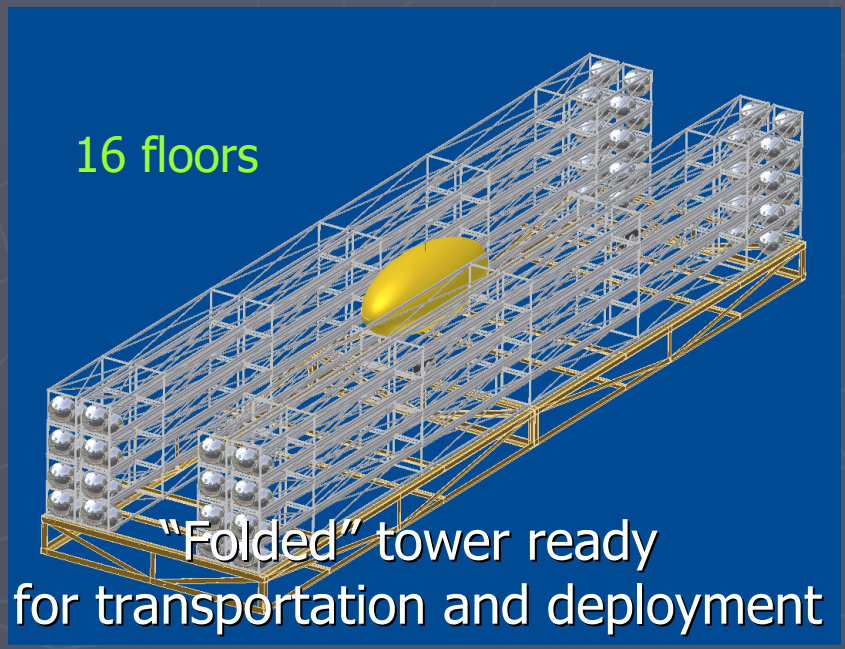
Electronics

Electro-optical splitting box

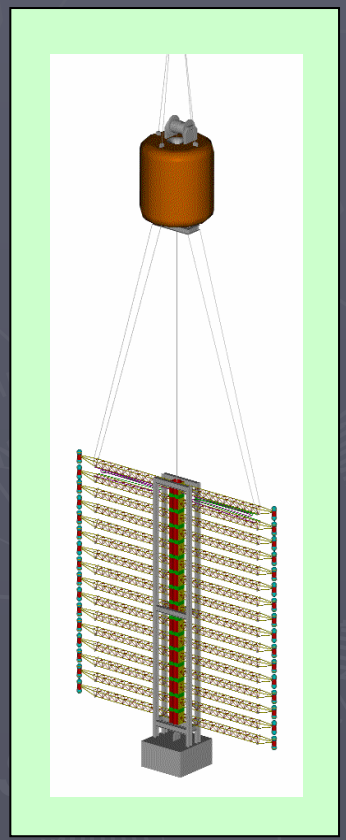
The NEMO Tower

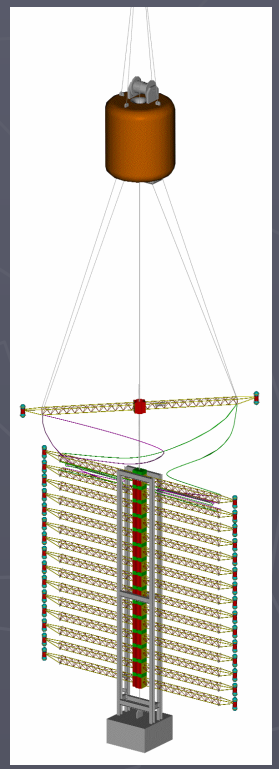
- Semi-rigid structure provides "easy" assembly, transportation and deployment
  - A 1:5 4-floor prototype has been successfully deployed and recovered in Spring 2004

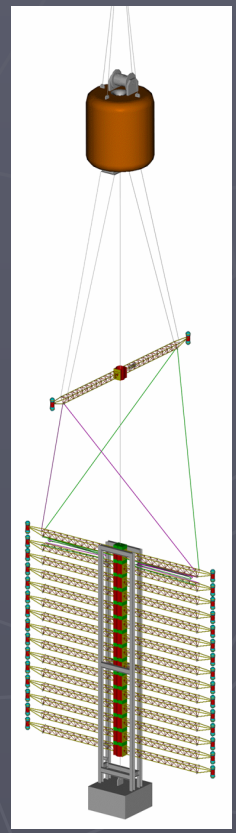


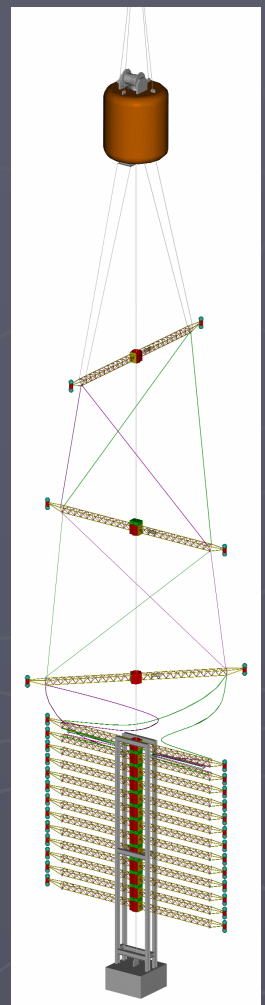


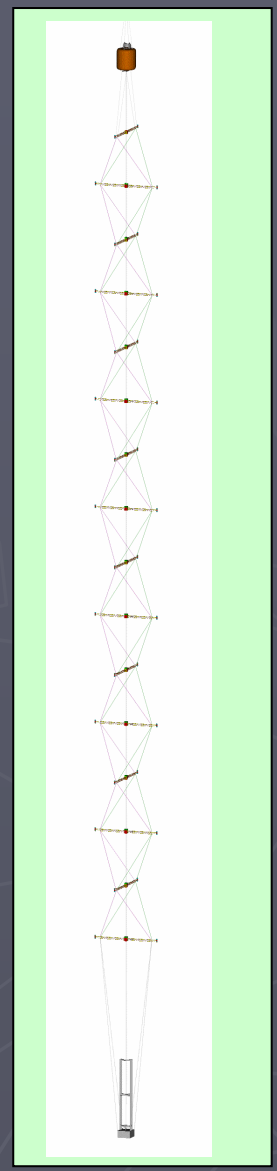
The Tower Deployment





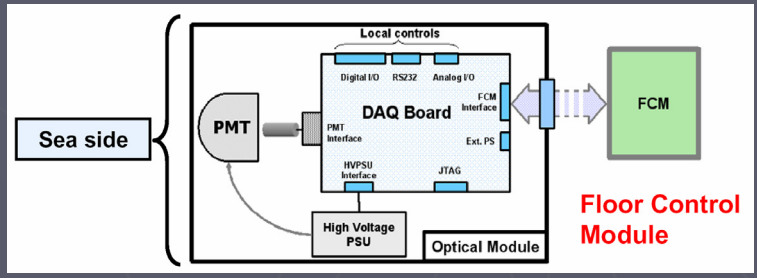




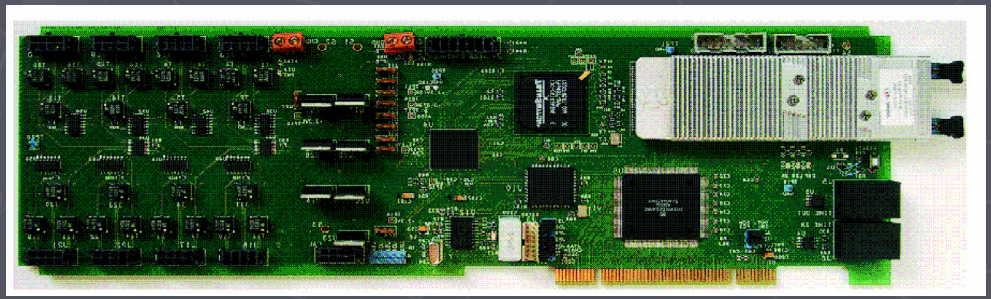


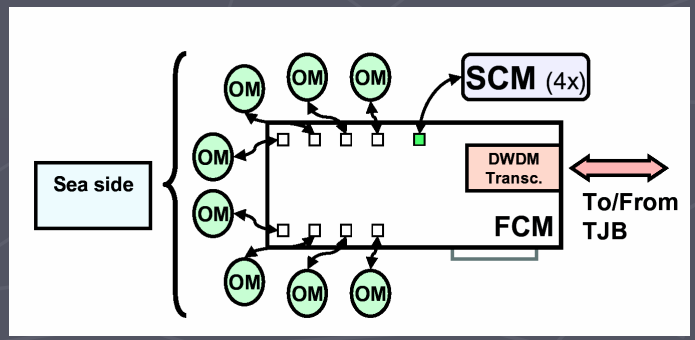
The Read-out Electronics

- Optical Module Electronics
  - 200 Msample/s
  - 8 bit range (log. compression)



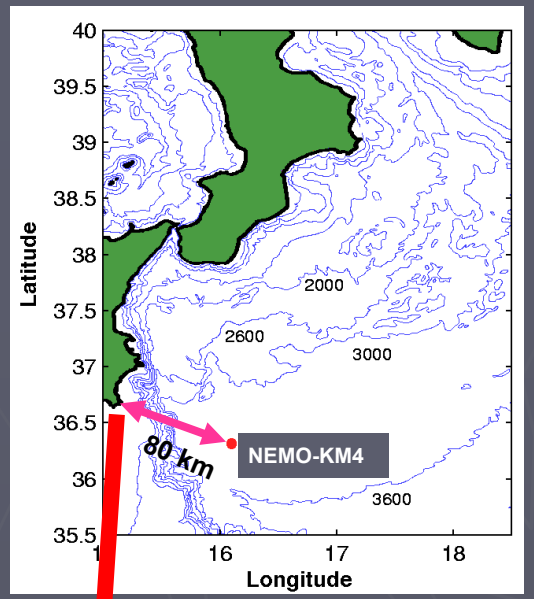
- Floor Control Module Electronics
  - Collects digitized signals from up to 8 OM
  - Sends to the onshore station through the Junction Box

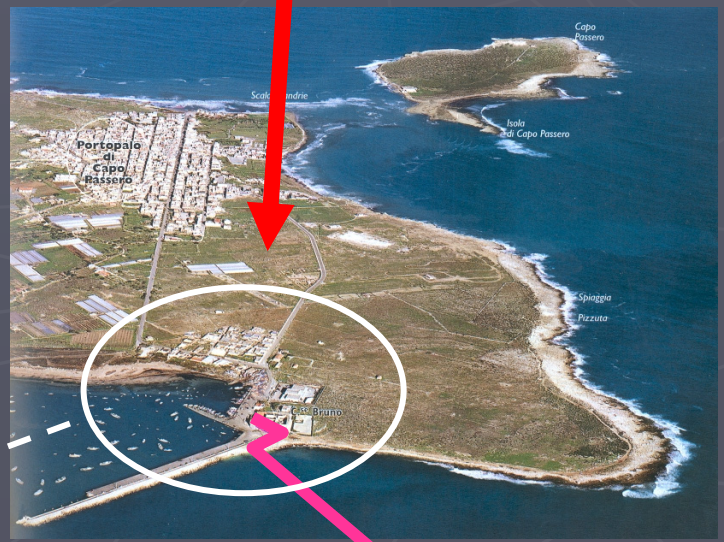




The NEMO Phase-2

- Infrastructures for an -3500 m underwater site
  - Electro-optical cable (40 kW)
    - Purchase under way
  - Shore station in PortoPalo di Capo Passero
    - Building under renovation





to NEMO-KM4

Conclusions and Perspectives

- The ANTARES Collaboration is realizing a small scale (0.1 km^3) neutrino detector in the Mediterranean Sea
  - Line 0 proved useful to solve problems related to data-transmission in high pressure environment
  - Line 1 is being integrated
  - It is expect to deploy the detector by the end of 2007

Conclusions and Perspectives

- The NEMO Collaboration is working on a long-term R&D program toward a km^3 ν-telescope in the Mediterranean Sea
  - An optimal candidate site has been found: NEMO-KM4
  - The NEMO Phase-1, aiming to validate the proposed technologies, is under way at the Catania Test Site
    - Since Jan. 2005 the geoseismic and acoustic stations are fully operative
    - The completion is planned in the first half of 2006
  - The NEMO Phase-2, aiming to realize the deep sea station at NEMO-KM4, is in progress
    - The purchase of the electro-optical cable is in progress
    - The set-up of the onshore station is in progress
    - The deployment of a full-size tower is foreseen in 2007

Toward the ν-Telescope

- EU is funding the joint activity for an European-scale Design Study for a km^3 ν-telescope in the Mediterranean Sea
  - KM3NeT: ANTARES-NEMO-NESTOR consortium
- 2° VLVnT (Very Large Volume ν-Telescope) Workshop to be held in Catania (Italy) 8-11 Nov., 2005