NEMO: Status and Perspectives

- Introduction & Physics Case
- Nemo Project
- KM3NeT

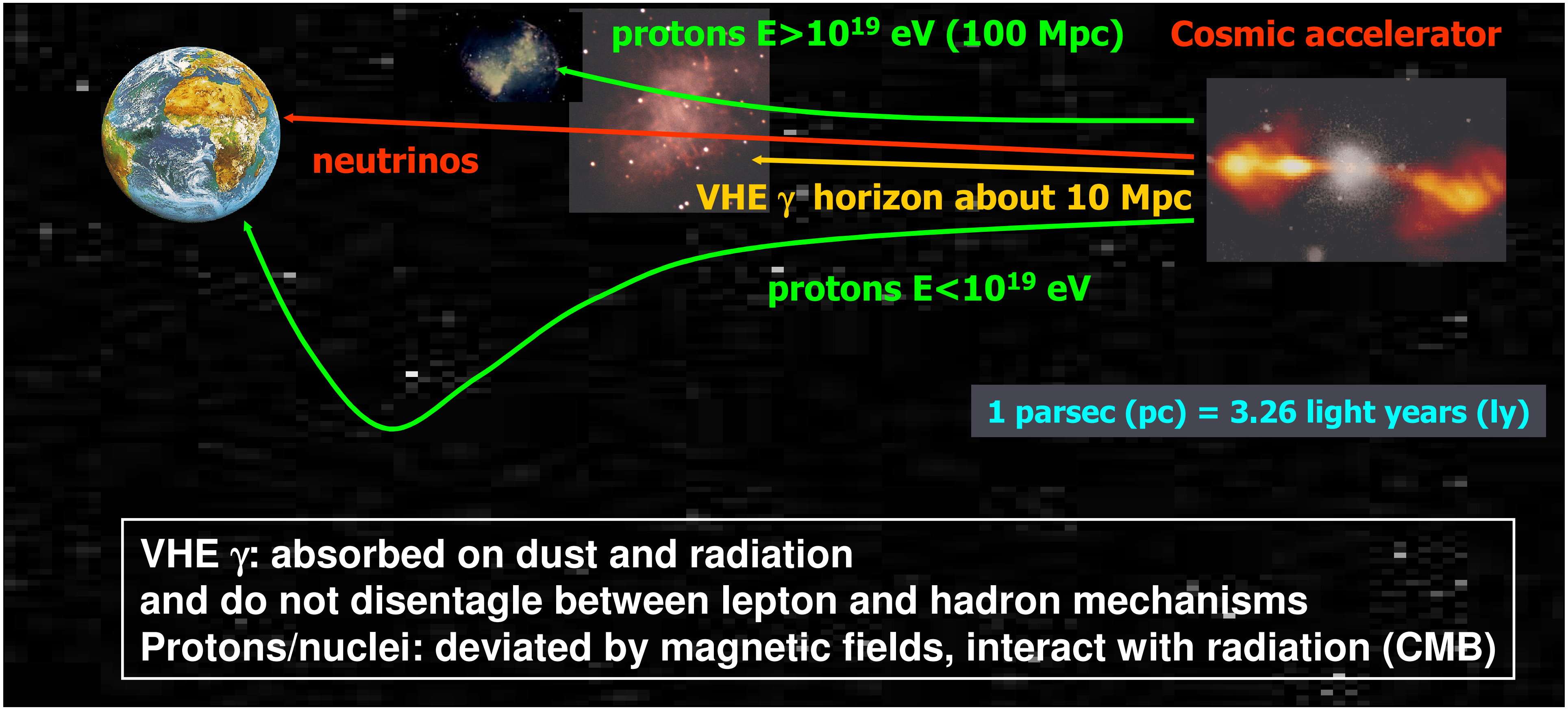
High energy neutrino astronomy: physics case

- Astrophysical high energy neutrino sources (E>1 TeV)
  - Galactic (Supernova Remnants, MicroQuasars, …)
  - Extragalactic (Active Galactic Nuclei, Gamma Ray Bursts)
- Origin of the highest energy cosmic rays
- Indirect search of dark matter
- Unknown sources

- But also Interdisciplinary Research

Why High Energy neutrinos?

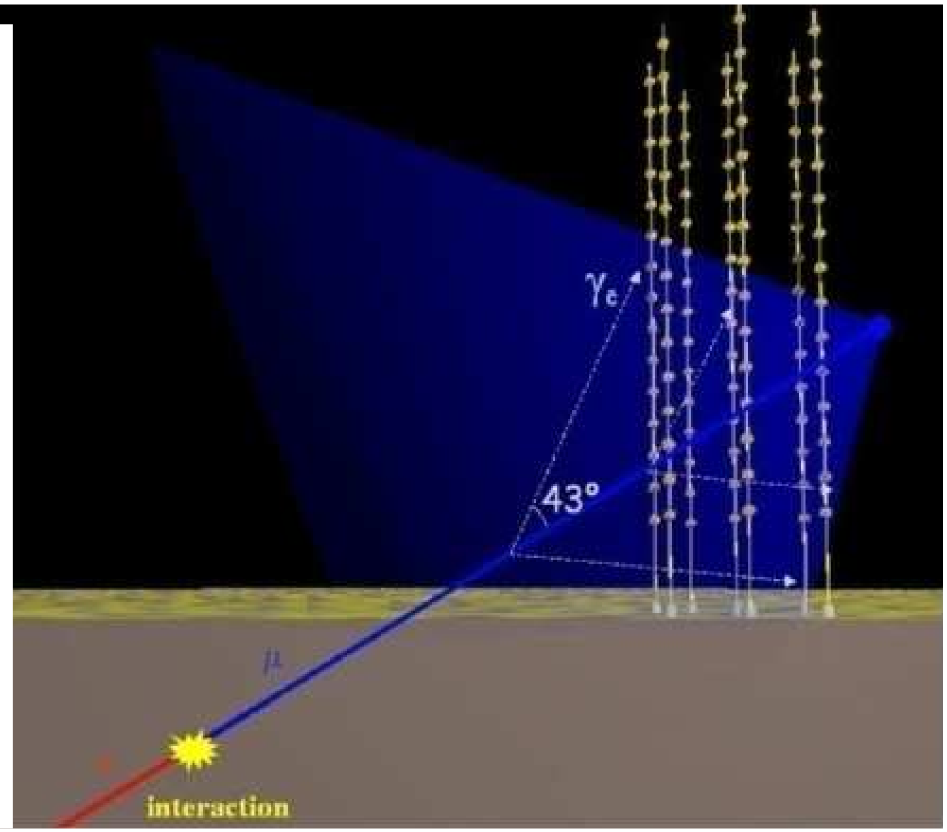
Neutrinos will provide unique info on High Energy Universe



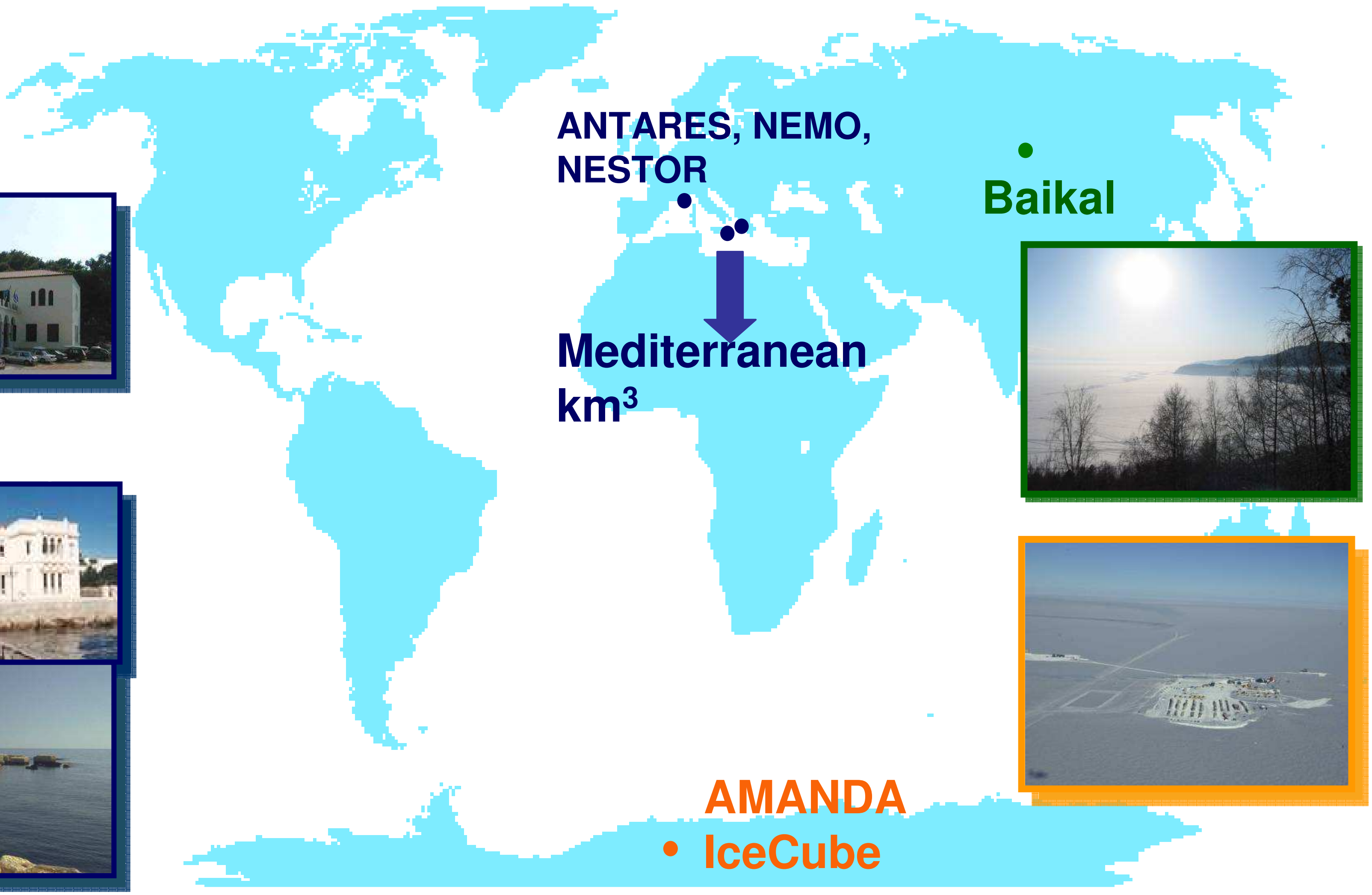
Detection principle TeV- PeV => Optical Cherenkov

Detector volumes of the order of km^3 needed for ν astronomy

- Upward-going neutrinos interact in rock or ice or sea/lake water.
- Emerging charged particles (in particular muons) produce Cherenkov light in water/ice
- Detection by array of photomultipliers.
- ν_μ is the golden channel for astronomy



High energy neutrino telescope world map



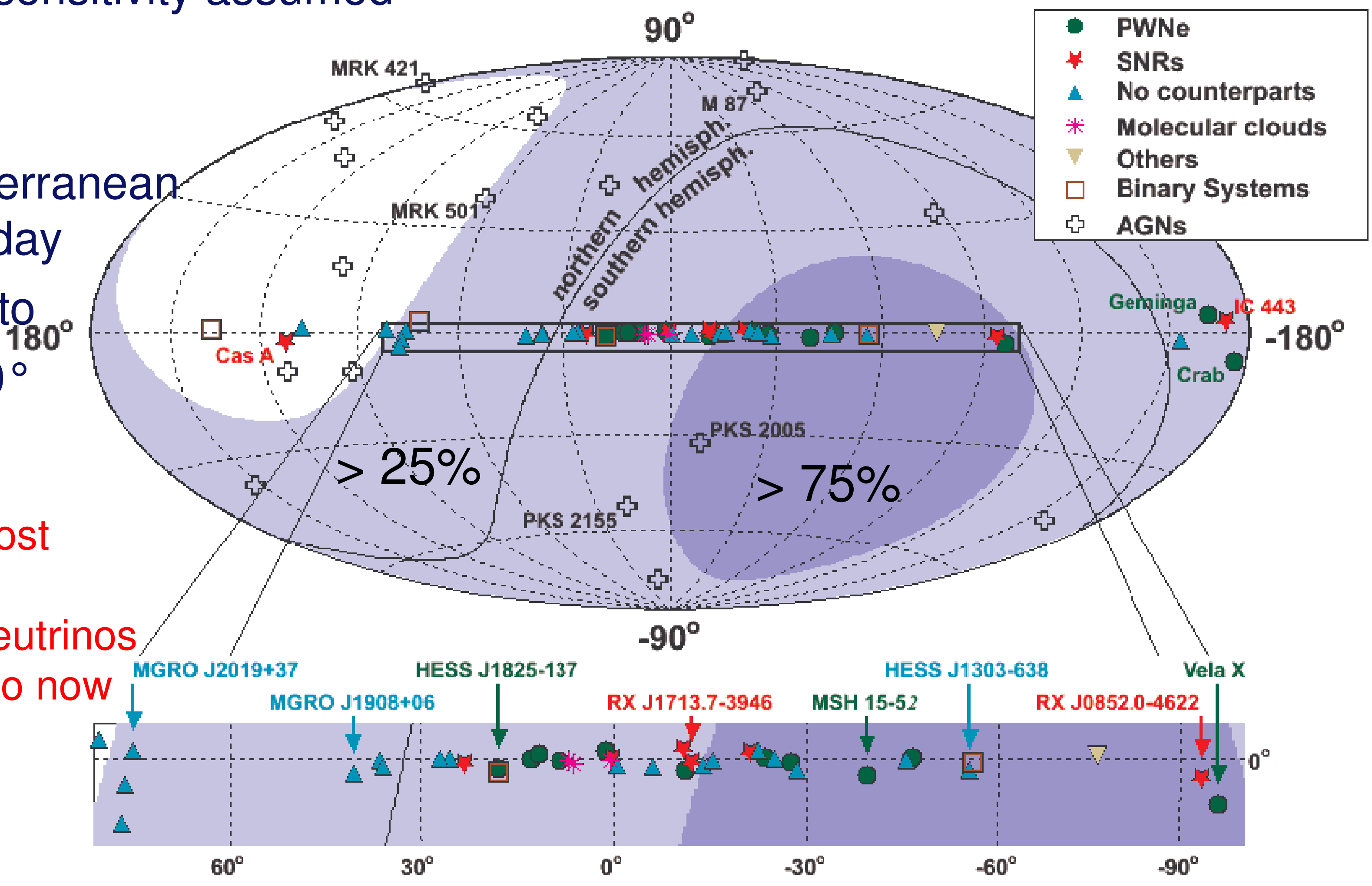
Sky view of a Mediterranean Sea telescope

Downward sensitivity assumed

From Mediterranean
24h per day

visibility up to about δ=-50°

IceCube almost completed
No cosmic neutrinos detected up to now



The NEMO project

- Design and validation of techonologies for the realization of a neutrino telescope in the deep Mediteranean Sea
- Search and characterization of a site for the installation of the km3 telescope close to the italian coasts
- Telescope architecture optimization
- Multidisciplinary Activities

LNS infrastructures

- LNS operates two stations, one in Catania and one in Portopalo, dedicated to the NEMO activities
- Shore stations of deep-sea infrastructures
  - Landing of the electro-optical cables
  - Power system for the under-water installations
  - Data acquisition
- Facilities for users
  - Laboratories (electronics and mechanics)
  - Assembly hall (in Catania)
  - Guest house (in Capo Passero)

Nemo under-water infrastructure off-shore Catania harbour

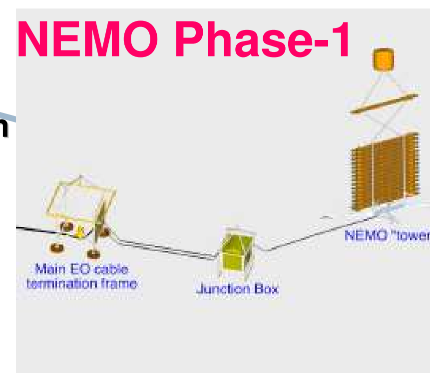
Double armed cable
2.330 m

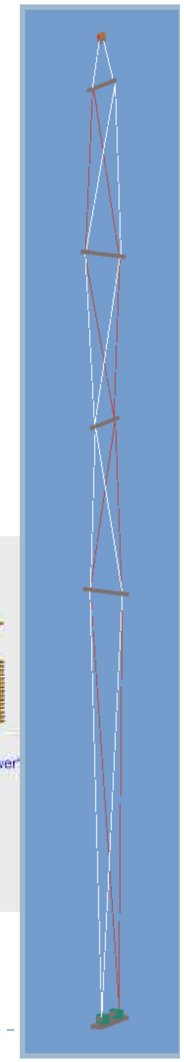
Single armedcabler
20.595 m

BU

North branch
5.220 m

South branch
5.000 m

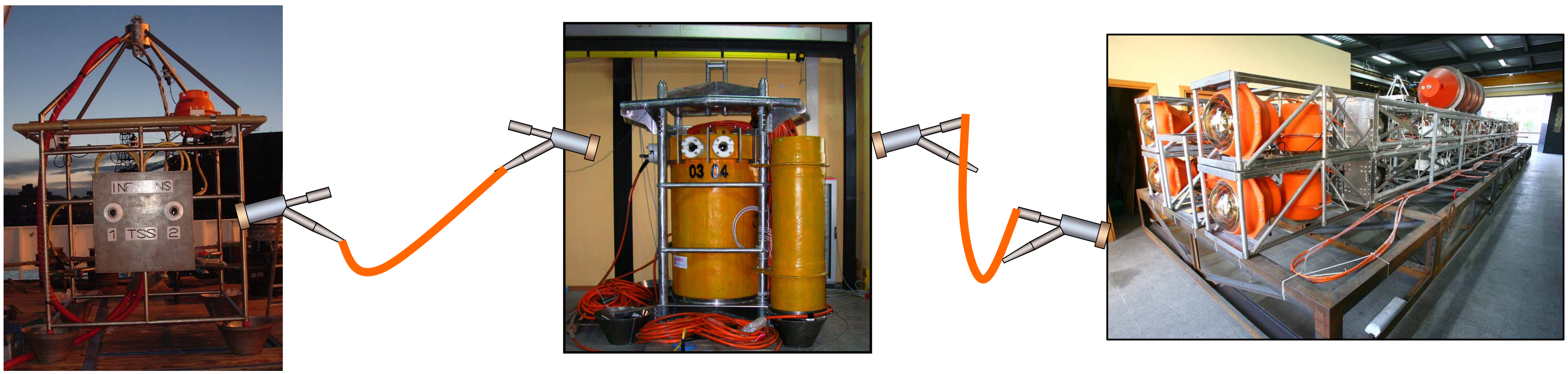




LNS underwater infrastructure to test detector prototypes of the main elements for the km3 underwater neutrino telescope

Infrastructure open to interdisciplinary use for deep sea research

NEMO experimental activities @ LNS test site

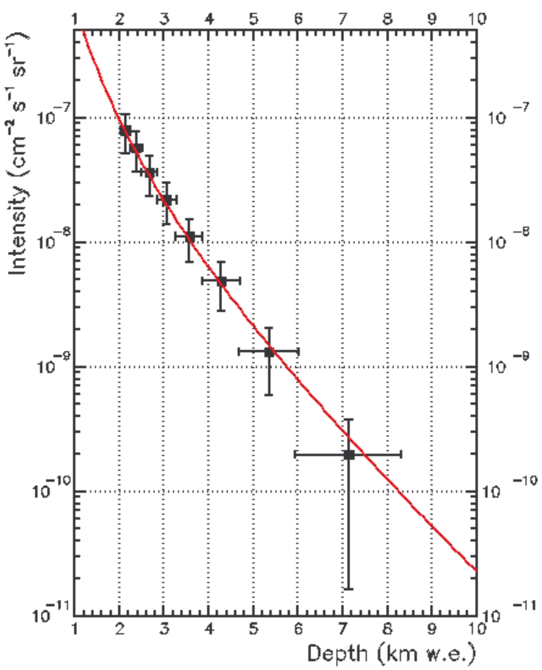


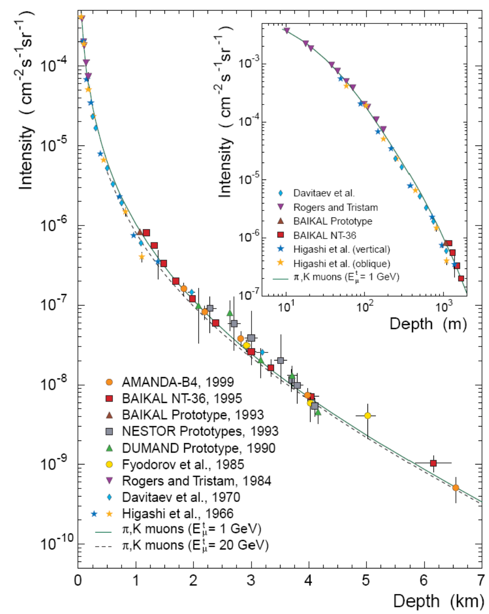
Frame **Junction Box** **Mini-tower - 4 floors**

- *Acoustic monitoring station OnDE operated from jan 2005 to dec 2006*
  - Monitoring of deep sea acoustic background
  - - Sperm wale and dolfin detection LNS-Cibra (Pavia)
  -> "Very large mammal population" many articles on press and results on Nature
- *JB and mini-tower installed in december 2006*
- *SN-1, a seismic and environmental observatory of INGV, connected to the cable (2005-2008) recorded a large number of seismic events. Lido will be redeployed in 2010*

Nemo: Physics @ Test Site

- Vertical Muon intensity as a function of depth from data recorded on 23-24 Jan 2007 parametrization from *Bugaevet al, Phys. Rev. D58, 05401 (1998)*





S. Aiello et al, Astroparticle Physics vol. 33 issue 4 (2010) 263

LNS infrastructure in Porto Palo

Shore Laboratory in Capo Passero Harbour

The Alcatel 10 kW MVC wassuccesfully deployed in November 2009

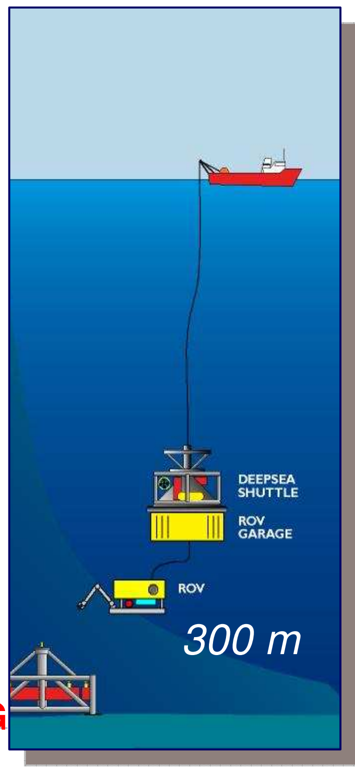
Shore laboratory
Power supplier 10 kV - 50 kW
Data Acquisition Room
Optical fiber to LNS (requested)

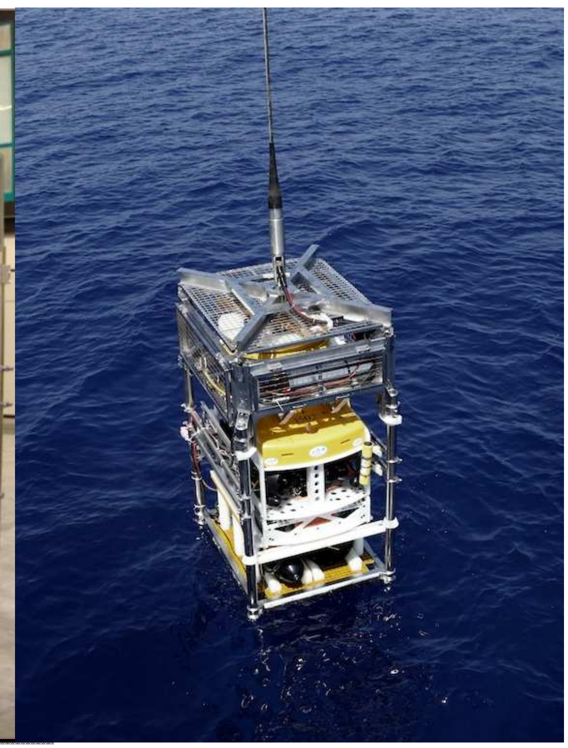
Submarine cable
100 km - 20 fibres,
DC-sea return

Submarine Infrastructure
DC/DC Converter 10 kV-375 V
Neptune's-like design
3 ROV connectors for users

PEGASO: ROV and Deep Sea Shuttle for deployment, connection and maintenance

A INFN-INGV infrastructure co-funded by “Regione Sicilia”
Cougar Seaeye ROV upgraded to 4000 m
The DSS holds ROV garage or heavy structures
The ROV moves horizontally (300 m theter cable)





NEMO test of mechanical prototype

Full mechanical prototype

- 12 storeys @ 40m
- 12 m long bars
- 4 x17" spheres per storey

•Deployed : 2 h
•Unfurled : 15’
• INFN/INGV ROV

Feb. 13th, 2010 - Catania site (1652 m depth)

Next Nemo steps

Deployment of the mini-string “a l’Antares”

- Online site monitoring

Full equipped tower @ Capo Passero

-Tower with PMTs, enviromental sensors and hydrophones
For positioning and deep sea acoustic mesurements

-Electronics already designed

- Online long term site monitoring

- Long term test of telescope components @ 3500 m

Ongoing Interdisciplinary Activities

ESONeT-EMSO is a European Network of Excellence aiming at the constructon of a network or seafloor multidisciplinary observatories around Europe.

The Mediterranean Sea sites are of common interest between ESONeT and KM3Net.

INFN joined ESONeT-EMSO in 2007.

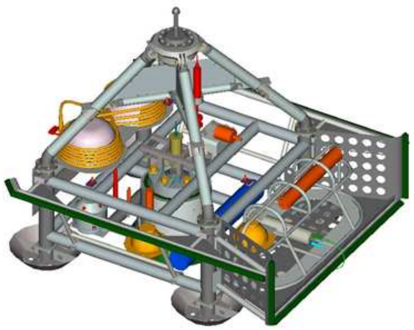
The East Sicily Infrastructure (Catania and Capo Passero), built by LNS-INFN is also the first cabled node of ESONeT EMSO.

The SN1 (INGV- Geophysics) and NEMO-OnDE (INFN and CIBRA – Particle Physics and bio-acoustic) experiments were the first deep sea experiments capable to provide data in real time to the ESONeT community.

LIDO @ Catania Test Site Infrastructure

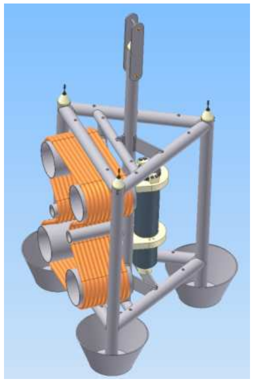
LIDO (Listening to Deep Ocean) is a Demonstration Mission of ESONeT aims at the installation of two observatories off-shore Catania.

The Test Site North Observatory will host:
- geophysics sensors (seismometers, magnetometers, pressure meters, etc)
- bio-acoustic sensors (4 hydrophones)



The Test Site South Observatory will host:
- bio-acoustic sensors (4 hydrophones)

INFN-LNS is in charge to :
- build the whole TSS station
- build the acoustic sensor DAQ and optical data transmission chain for the TSN Station
- operate the deep sea infrastructure (cable, terminations)
- operate shore laboratory infrastructure
- set up the data reporitory and distribution
- coordinate the marine operations



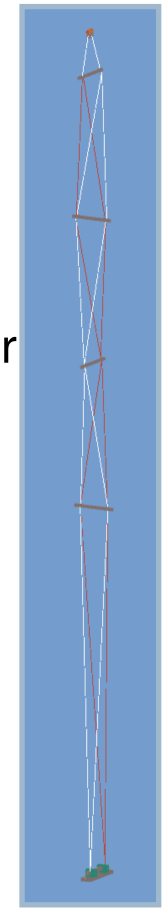
The Submarine Multidisciplinary Observatory Project @ Capo Passero (Firb funds)

The SMO project aims at the design and construction of an innovative submarine antenna equipped with:acoustic, electromagnetic and environmental sensors.

SMO Science Goals :
•Bio-acoustics
Cetaceans research and environmental monitoring
•Geophysics
Tests of novel geophysics techniques
•HE Physics
Tests of novel HE neutrino detection techniques

SMO feasibility/uniqueness:
•Available infrastructures
-Two deep sea cabled sites and shore labs
- Deep sea ROV and heavy-duty shuttle
- INFN computing / networking facilities
•Established deep sea technology
•Innovative data acquisition/transmission electronics

Sensors will be "hosted" in the Instrumented tower



KM3NeT

- Consortium including the collaborations working on the pilot projects in the Mediterranean
  - 40 Institutes from 10 European Countries (Cyprus, France, Germany, Greece, Ireland, Italy, The Netherlands, Rumania, Spain, U.K.)
- KM3NeT Design Study define the telescope design and outline the main technological options
  - Approved under the 6th FP
  - 2006-2009 funded by the EC for 9M€
  - Coordinated by ErlangenUniversity
  - Conceptual Design Report published in 2008

KM3NeT

- KM3NeT Design Study (continue)
  - KM3NeT-DS activity culminate in the Technical Design Report (TDR) that outline the main technological options for the construction, deployment and maintenance of a deep sea km3 neutrino telescope
  - TDR draft already distributed to the whole collaboration and will be published in a few weeks
- KM3NeT Preparatory Phase define legal, governance and funding aspects. Production planes for the detector elements, infrastructure features and prototype validation will be also defined.
  - Approved under the 7th FP
  - 2008-2012 funded by the EC for 5M€
  - Coordinated by INFN-LNS (E. Migneco)

KM3NeT main objectives

- <u>Main physics goals:</u>
  - Investigate neutrino “point sources” optimisation in the energy regime 1-100 TeV
  - Complement IceCube field of view
  - Exceed IceCube sensitivity target at about 5 km^3
- <u>Implementation requirements</u>:
  - Construction time ≤5 years
  - Operation over at least 10 years without “major maintenance”

Technical Design Considerations

- **Technical design**
  Objective: Support 3D-array of photodetectors and connect them to shore (data, power, slow control)
  - Optical Modules
  - Front-end electronics & readout
  - Readout, data acquisition, data transport
  - Mechanical structures, backbone cable
  - General deployment strategy
  - Sea-bed network: cables, junction boxes
  - Calibration devices
  - Shore infrastructure
  - Assembly, transport, logistics
  - Risk analysis and quality control

Design rationale:

Cost-effective
Reliable
Producible
Easy to deploy

Builds on the experience gained with ANTARES, NEMO and NESTOR

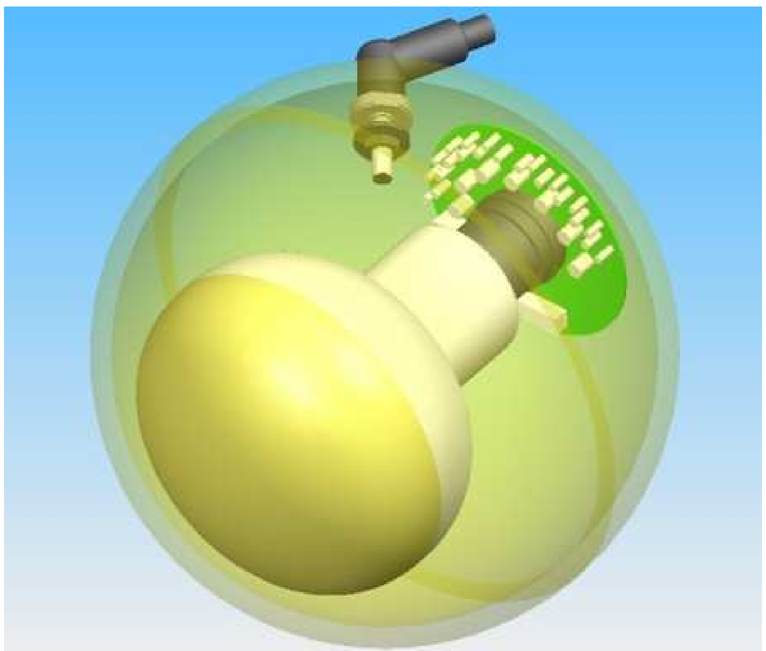
Otherissuesaddressed in the Design Study

- **Site characteristics**
  Objective: Measure site characteristics (optical background, currents, sedimentation, …)
- **Simulation**
  Objective: Determine detector sensitivity, optimise detector parameters
- **Earth and Sea science requirements**
  Objective: Define the infrastructure needed to implemement multidisciplinary science nodes

TDR (contents "frozen" in november 2009) Major alternative options (1)

- Optical Modules

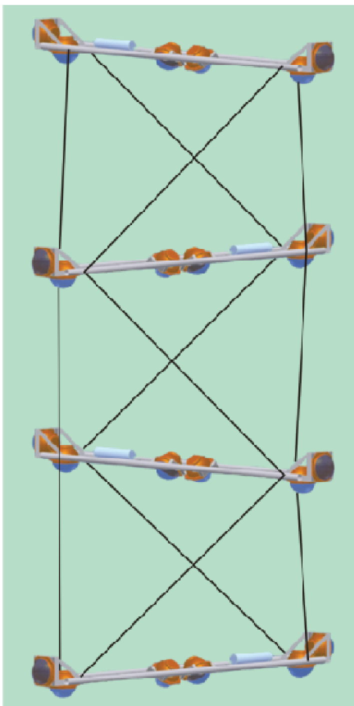
Single-PMT OM
One large PMT (8") in a 13" glass sphere

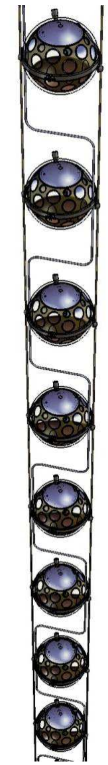


Multi-PMT OM
31 small PMTs (3") in a 17" glass sphere

TDR (contents "frozen" in november 2009) Major alternative options (2)

- Detection Units





Bar
6 m long bars with 6 OM

Triangle
2.5 m diameter storeys with 6 OM

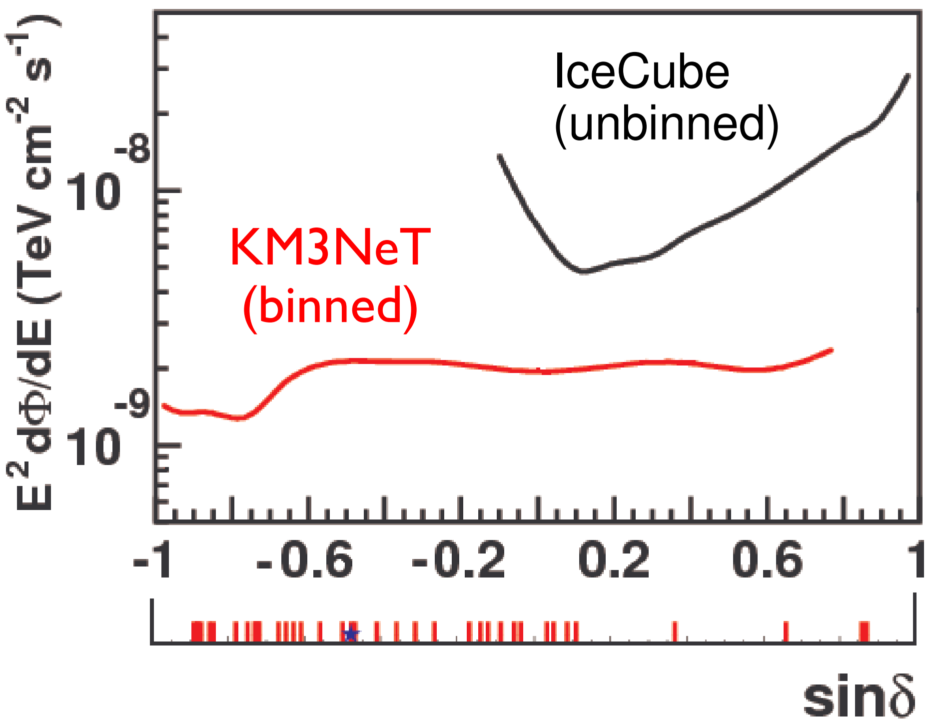
String
Vertical sequence of multi-PMT OMs

TDR (contents “frozen” in november 2009) Deploymentstrategy

- All three mechanical solutions:
  Compact package – deployment – self-unfurling (<= Nemo)
  - Eases logistics
    (in particular in case of several assembly lines)
  - Speeds up and eases deployment;
    several DUs can be deployed in one operation
  - Self-unfurling concepts need to be thoroughly tested and verified
- Connection to seabed network by ROV

TDR - Point source discovery potential(1year)

Expected discovery potential (5σ 50%)



Evaluated for a 310 DU telescope with bar structure DUs (<=Nemo-like)

E^{-2} spectrum no cut-off

○ Observed Galactic TeV-γ sources (SNR, unidentified, microquasars)
F. Aharonian et al. Rep. Prog. Phys. (2008) Abdo et al., MILAGRO, Astrophys. J. 658 L33-L36 (2007)

Discovery potential for the RXJ17.13.7-3946 SNR source

- With a full KM3NeT detector a 3 sigma indication and a 5 sigma discovery can be reached in about 1 and 3.5 years of observation time respectively

Significance level	Obs Years	N_{sig}	N_{back}
5 σ 50%	3.5	9.4	1.4
3 σ 50%	1.3	3.2	0.4

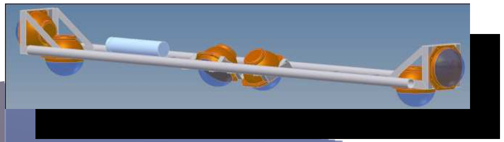
Expected numbers of signal and background neutrino events estimated minimizing the MDF (search cone ~ 0.3°) for the expected neutrino spectrum from G. Morlino et al., (Astrop. Phys. 31 (2009) 376) for the RXJ17.13.7-3946 SNR ***point-like*** *source*

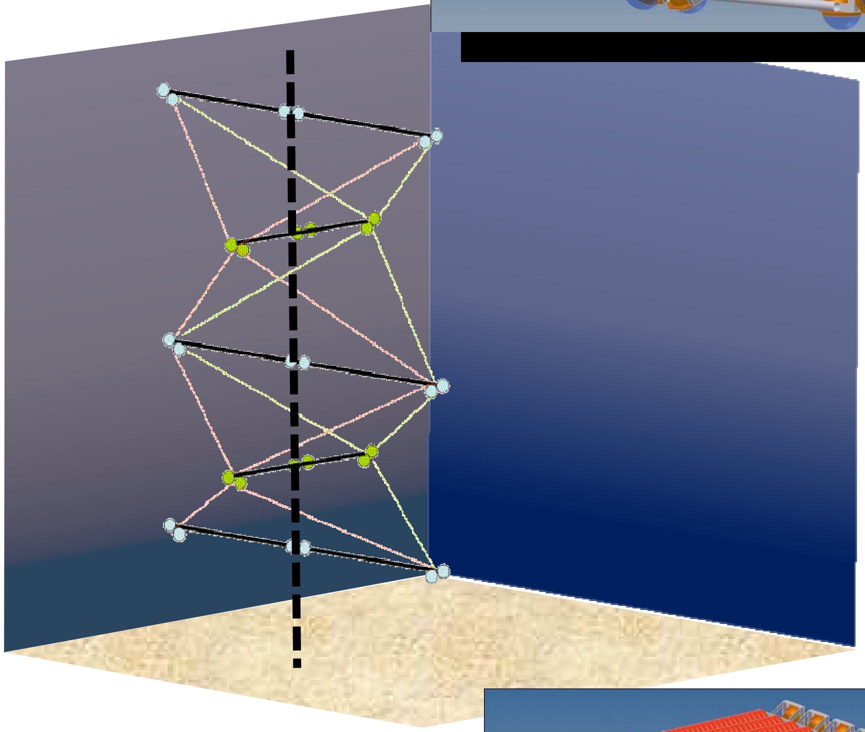
From TDR to Convergence

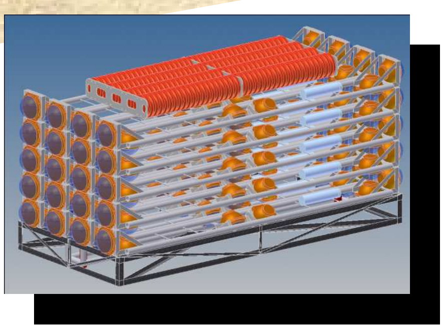
- Convergence towards an unique design
- Agreement on advantages offered by a “bar” option with horizontal extent
  - Revised design and plan for extensive deployment tests defined
- Advantages offered by the multi-PMT option
  - Needs validation of technology and integration procedures
  - Common study on the multi-PMT Optical Module and its implementation on the tower
  - Simulation of the detector performance on going

Convergence–Flexible towers (Nemo concept)

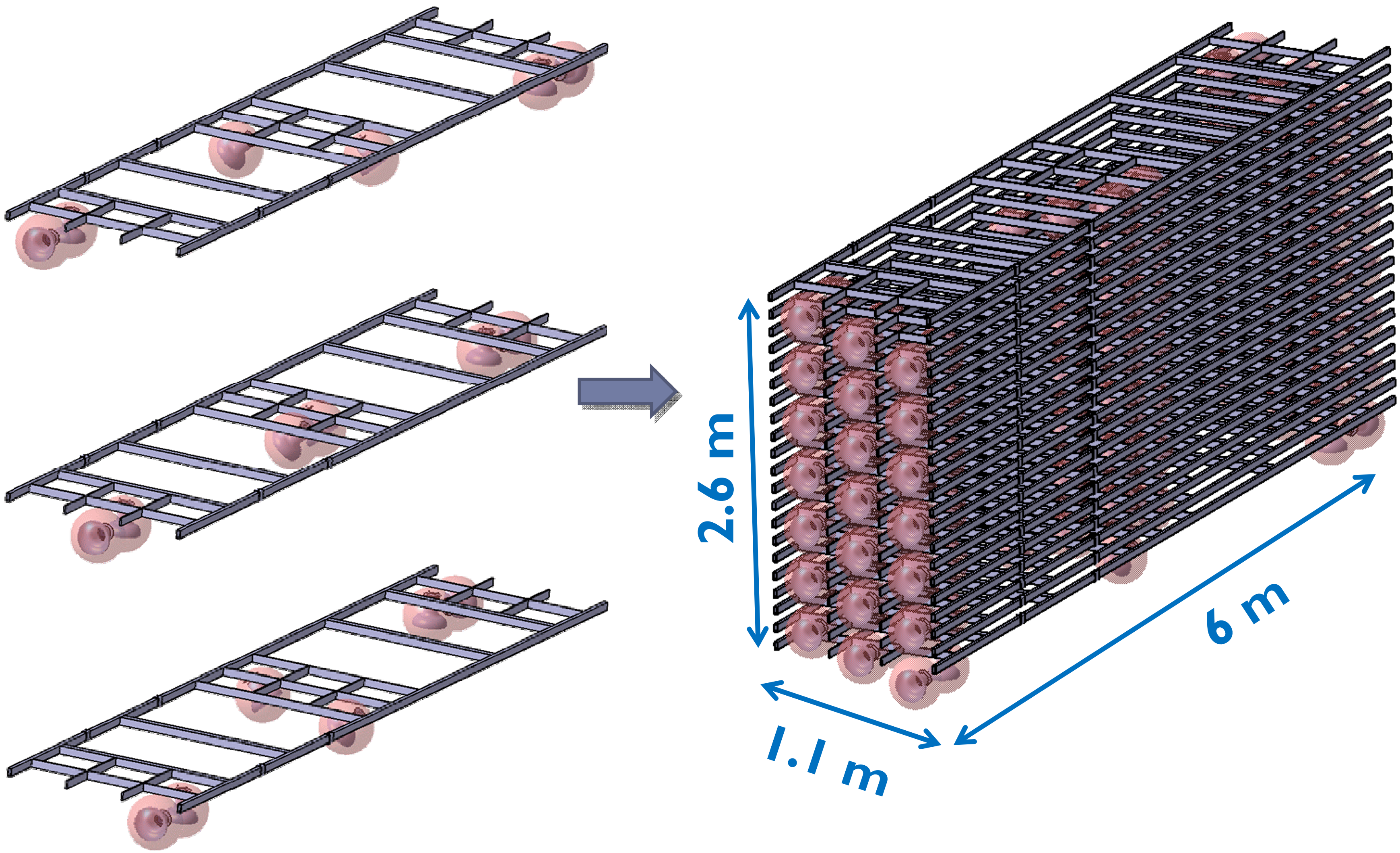
- Mechanics
  - 6 m long bars
  - Design presently developed for 6 PM/storey
  - 20 storeys @ 40 meters
  - Compactness for transportation and deployment
  - Unfurling from sea bed
  - Evolution from existing bar design (no breakthrough)







New design of the storey frames



DU mechanics development plan (off-shore Toulon)

- **Phase 1 : Concept validation - (August-September 2010)**
  - 4 Deployments of a **4 storey-DU** + instrumentation @ 200 m
  - preliminary version of bar structure

  →final design

- **Phase 2: Design validation - December 2010**
  - 2 Deployments of **10 storey-DU** @ 500 m
  - Final version of bar structure (6 PMTs)
  - Qualification test of the cabling
    - Optimization of the cable path

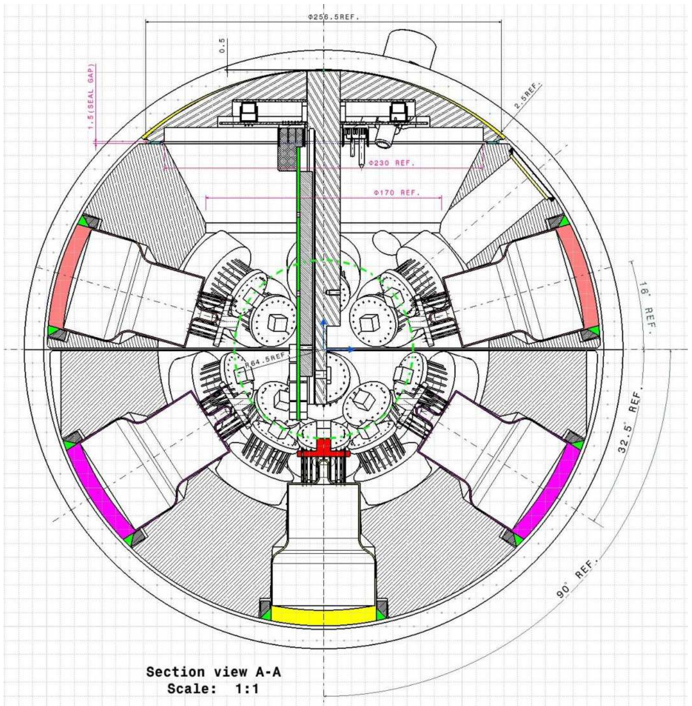
- **Phase 3: Full mechanical prototype - April 2011**
  - Deployment @ 1000 m

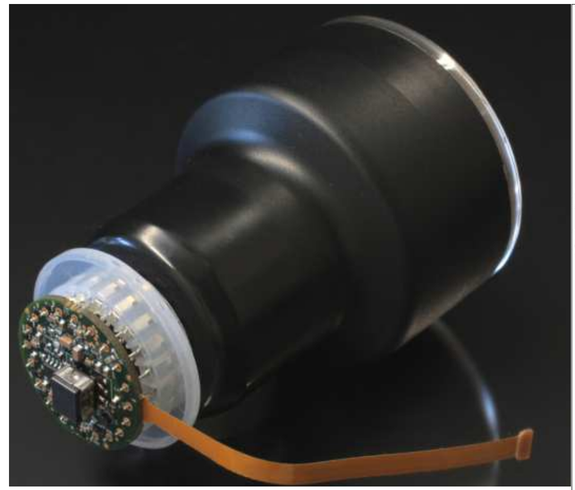
Multi-PMT Optical Module

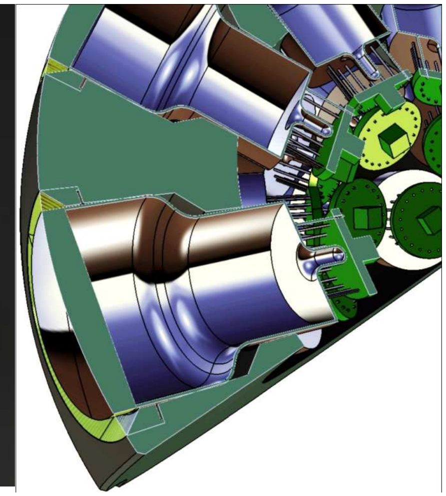
Three mechanical prototypes:
- optical contact
- temperature
- form factors
- assembly (mechanical)

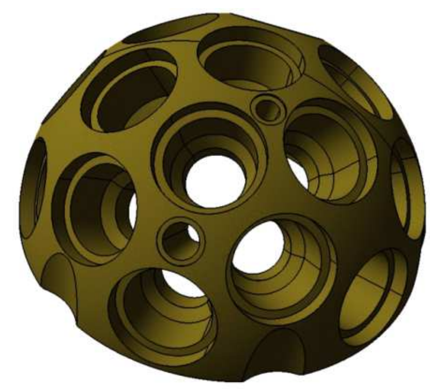
Custom board (25 mW)
- HV (4.5 mW)
- Amplifier
- Discriminator

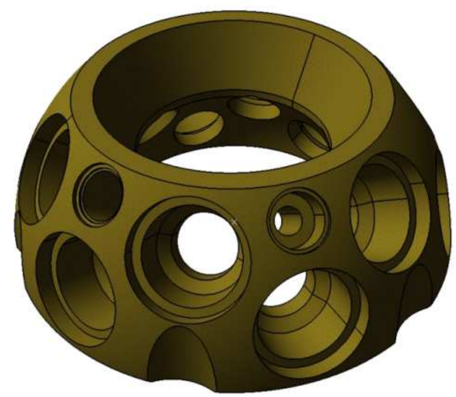
Convergence - Multi-PMT Optical Module











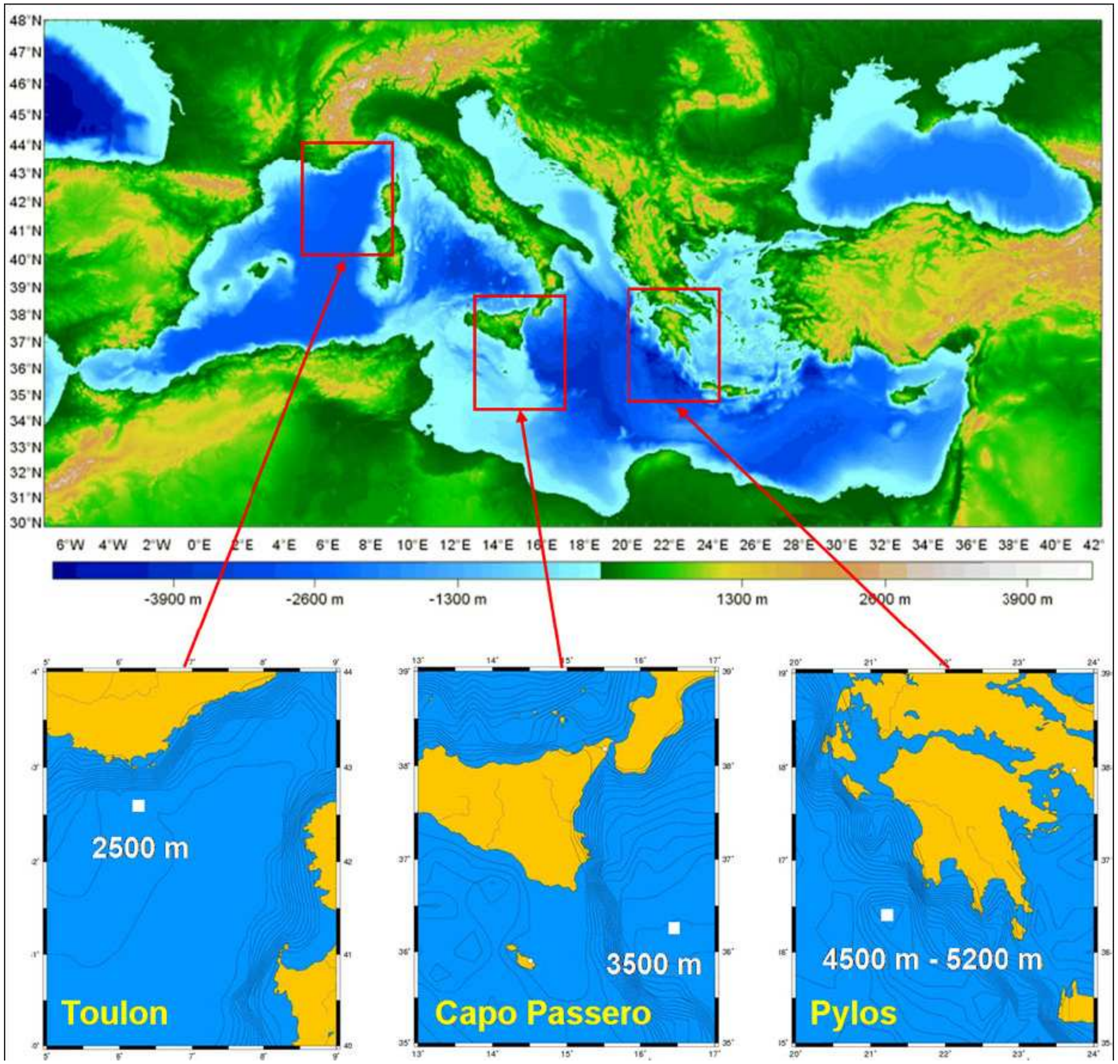
Multi-PMT Optical Module development plan

- First full prototype ready in october 2010
  - Equipped with Photonis3" PMTs
  - Test of assembly and performance
- Second series prototypes
  - Equipped with Hamamatsu and ELT 3" PMTs
  - Should be ready in april 2011 to allow timely development towards a final KM3NeT DU prototype
- Concept Design "Bar + mPMT"
  - Under study
  - Preliminary design ready for july 2010
  - Final design ready for end 2010

Other issues

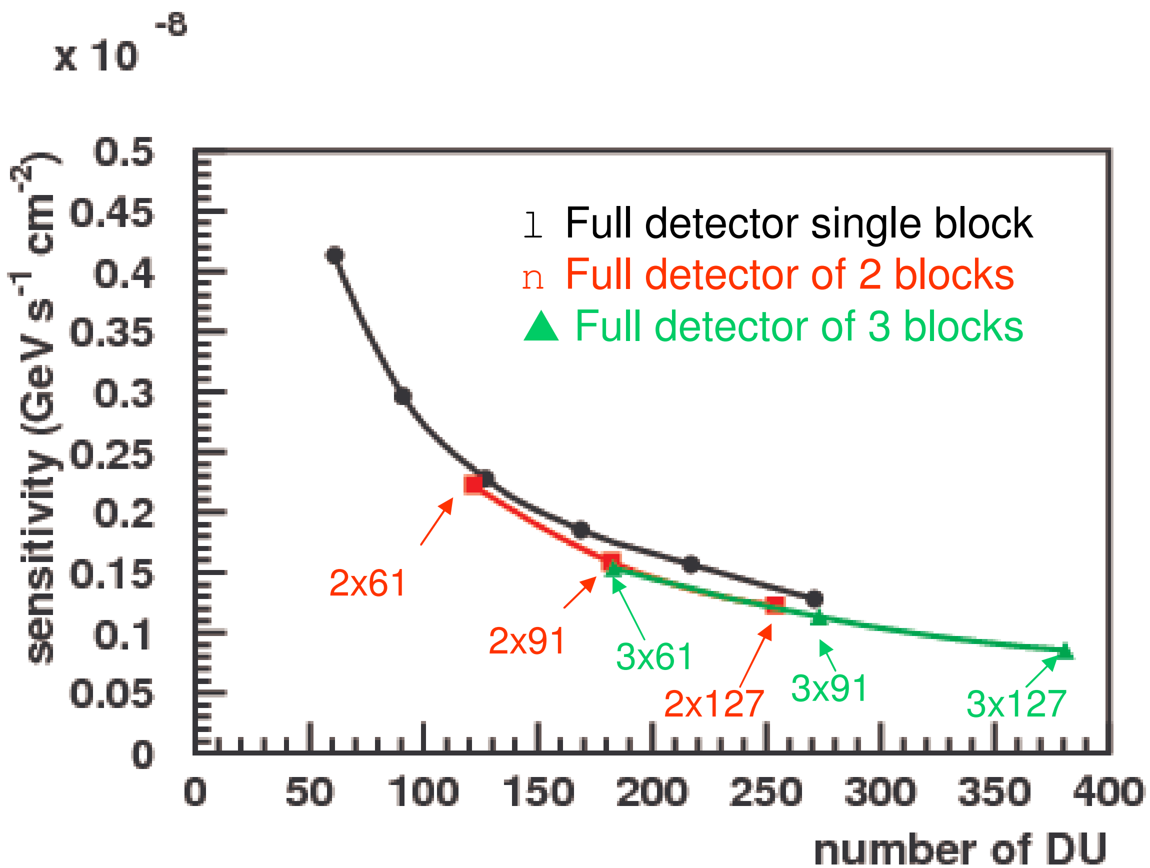
- **Site selection**
  - Critical for a definition of the construction design of the telescope
  - A decision has to be taken at latest at the samet imeas the technical decision
  - Single vs. multi-site option will be assessed by the PP
- **Legal**
  - Significant effort by the EC to provide a common framework (ERIC) for all the research infrastructures
  - The ERIC framework seems suitable for KM3NeT
  - In case of multi-siteoption there will be a single legal entity to manage the distributed infrastructure
- **Funding**
  - Most critical issue
  - Several expressions of interest in different countries ut up to now no firm committments
  - Regional fundings may provide a large fractionof the total budget needed

Candidate sites

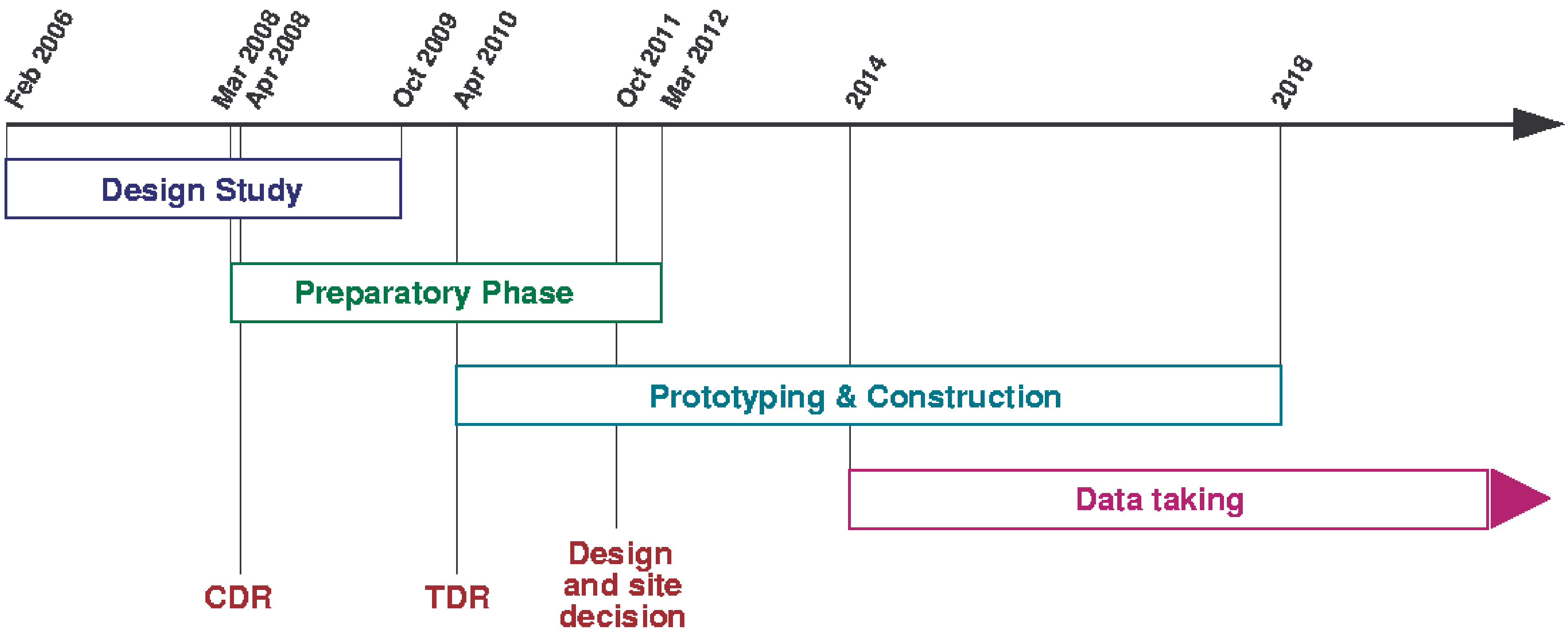


Very preliminary evaluation of single vs multi site performances
(Capo Passero optical water properties @ 3500 m depth)

- Sensitivity to point-like sources as a function of the number of DUs in a single and multiple-block detector



Timeline



Feb 2006
Mar 2008
Apr 2008
Oct 2009
Apr 2010
Oct 2011
Mar 2012
2014
2018
Design Study
Preparatory Phase
Prototyping & Construction
Data taking
CDR
TDR
Design and site decision