Status of the NEMO Project

Hamburg

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Outline of the talk

A (short) introduction on HE neutrino astronomy:

The cosmic rays, gamma and neutrino connection

Underwater Cherenkov neutrino detectors

The NEMO (Neutrino Mediterranean Observatory) Project

Deep Sae site seek and characterisation

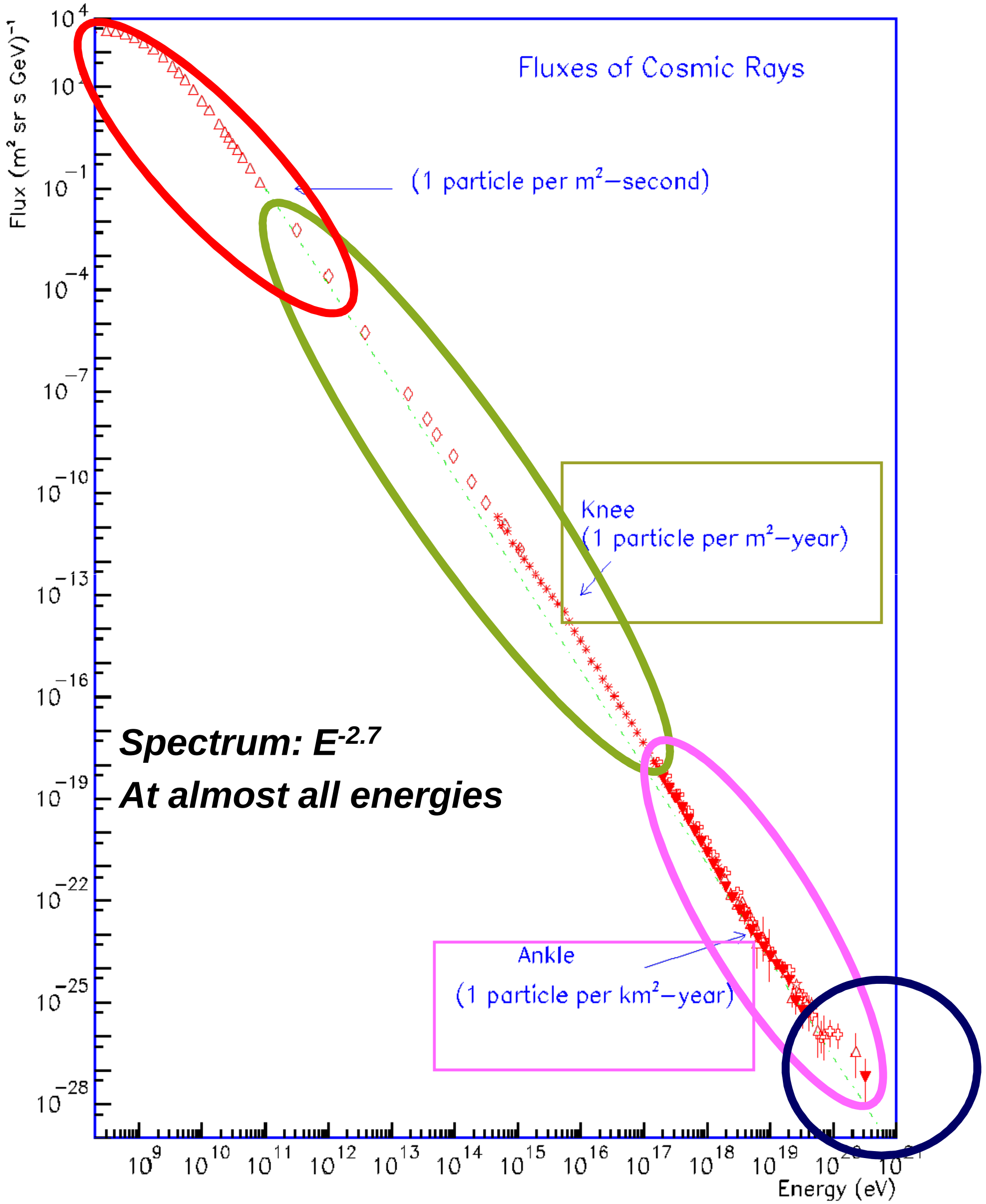
Architecture

Phase 1

Phase 2

NEMO and KM3NeT

The CR Spectrum



- $E<10^3$ GeV

direct detection

AMS, CAPRICE, JACEE

NINA, PAMELA

- $E>10^3$ GeV

indirect detection

KASKADE, EAS-TOP,...

KASCADE-GRANDE

- $E>10^8$ GeV

EAS, N_2,Cherenkov

AGASA, Fly's Eye, HiRes

- $E>10^{10}$ GeV

Combined techniques: Auger

The Fermi Acceleration Mechanism

Observed $E^{-2.7}$ spectrum

Non-thermal spectrum. Statistical acceleration

Fermi's idea:

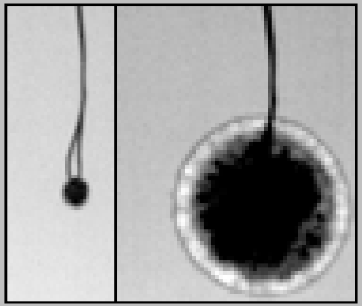
Particles gain energy hitting on clouds moving at V«c (inefficient)

Bell's shock acceleration (E^{-2}) :

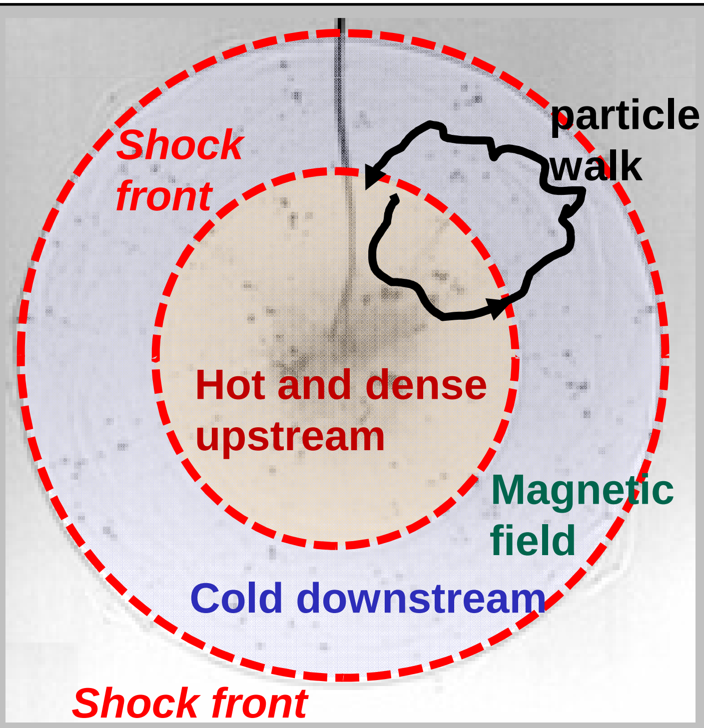
Each time a particle hit on the shock front it gains energy

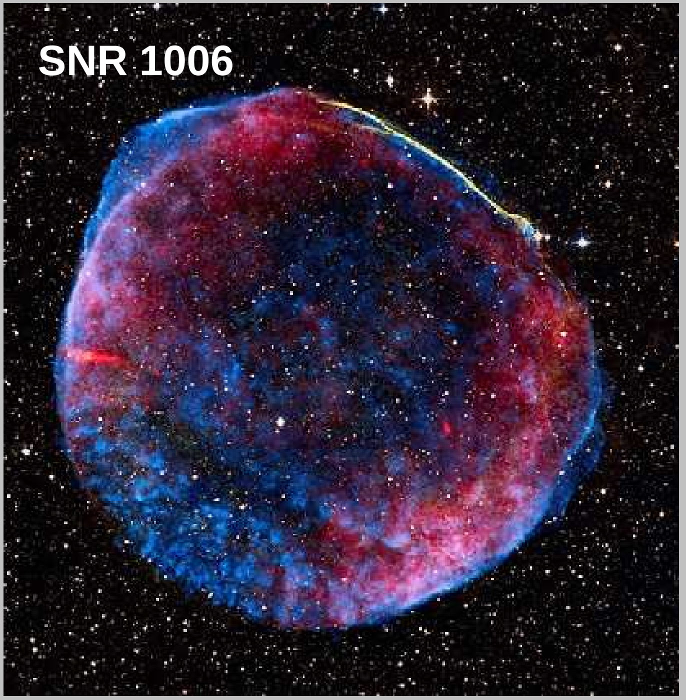
charged particles are confined by the object magnetic field

maximum energy $\propto$ number of hits $\propto$ (confinement) B x R



Shock wave produced by the detonation of a TNT charge

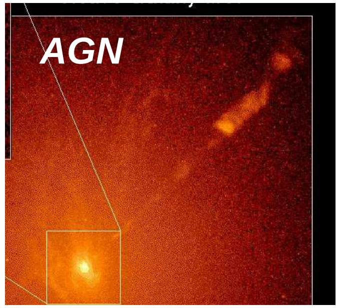


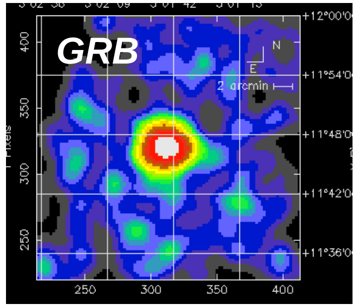


The Hillas' Plot

$$E_{max} \approx \beta_{shock} Z \cdot B[\mu G] \cdot R[kpc] \cdot 10^{18} eV$$

$$\frac{dN}{dE} \propto E^{-2}$$





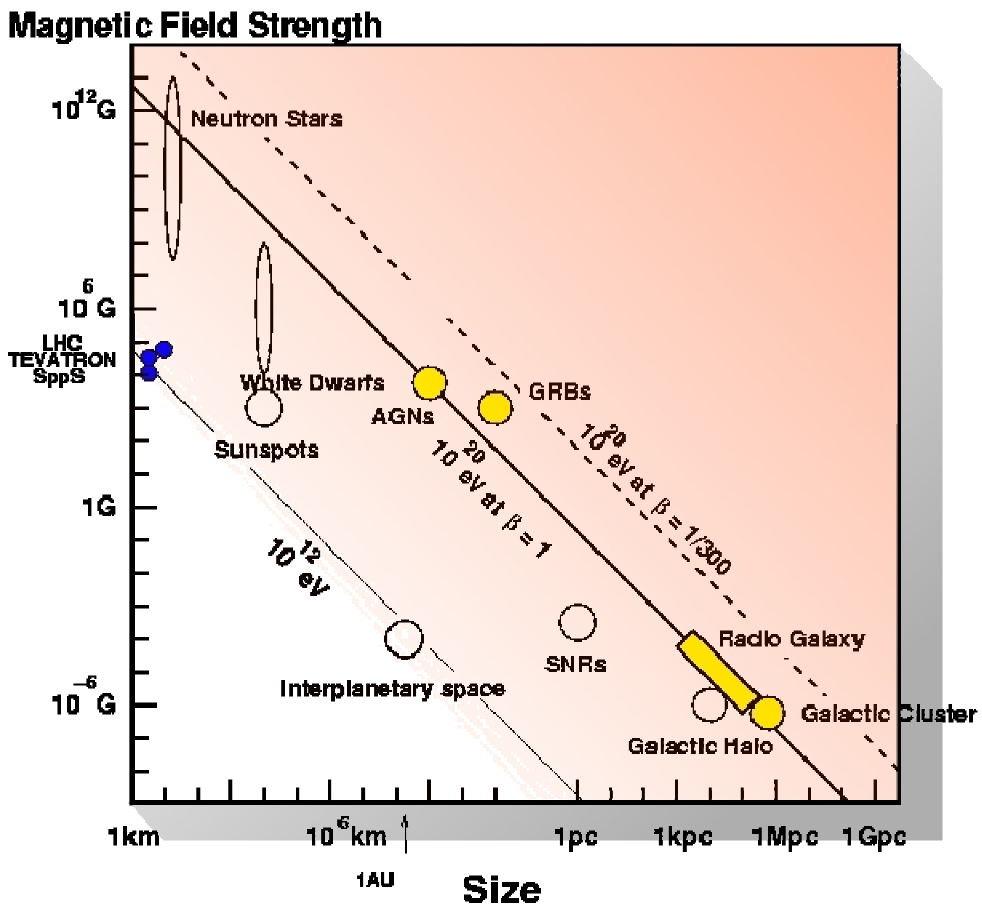
Galactic SNR:

$E_{max} \approx$ 100 TeV x Z

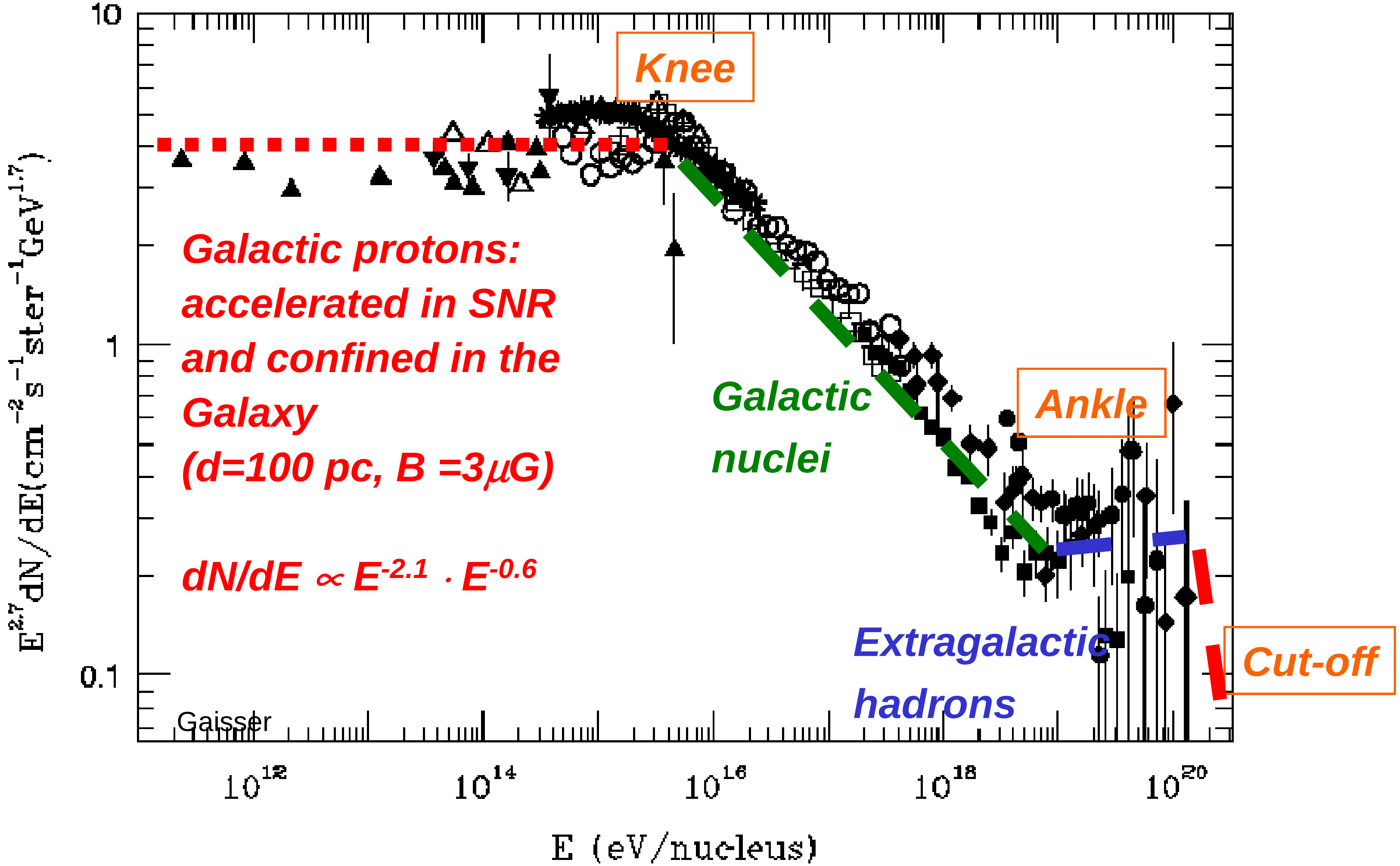
Fermi acceleration to Ultra and Extra high energies requires:

- ***Large cosmic objects***
- ***Intense magnetic field***
- ***High shockwave velocity***

Candidate extragalactic sources: AGN and GRB



CR Origin: the Standard Scenario



Sources of high energy hadrons exists and they dominate the CR spectrum

GZK effect and BZ neutrinos

$N\gamma_{CMBR} \rightarrow \Delta^{+} \rightarrow N\pi$ (GZK: Greisen Zatsepin Kuzmin)

$$E_p E_{CMBR} \geq \frac{m_\Delta^2 - m_N^2}{2}$$

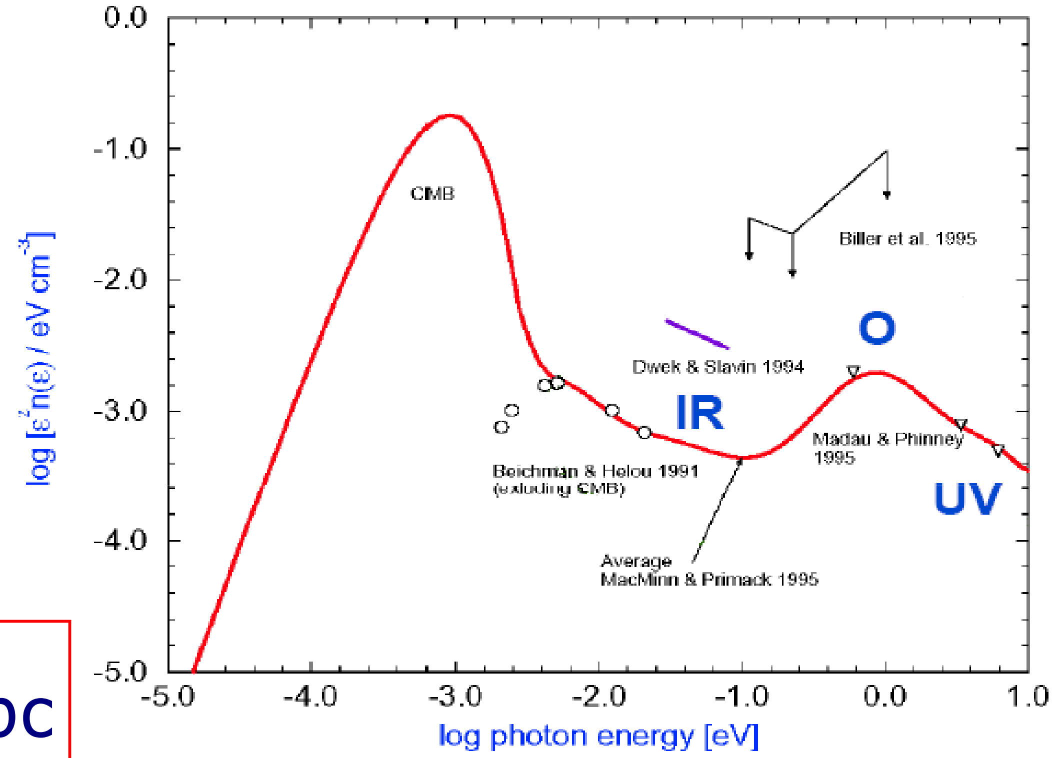
$E_{CMBR} \sim 6.6 \cdot 10^{-4}$ ***eV***

$E_p \sim 10^{19.5}$ ***eV***

$n_{CMBR} \sim 400\ cm^{-3}$

$\sigma_{p\gamma} \sim 100\ \mu barn$

$$\lambda_{att}^{pCMBR} = \frac{1}{\sigma_{p\gamma} n_{CMBR}} < 50\ \text{Mpc}$$

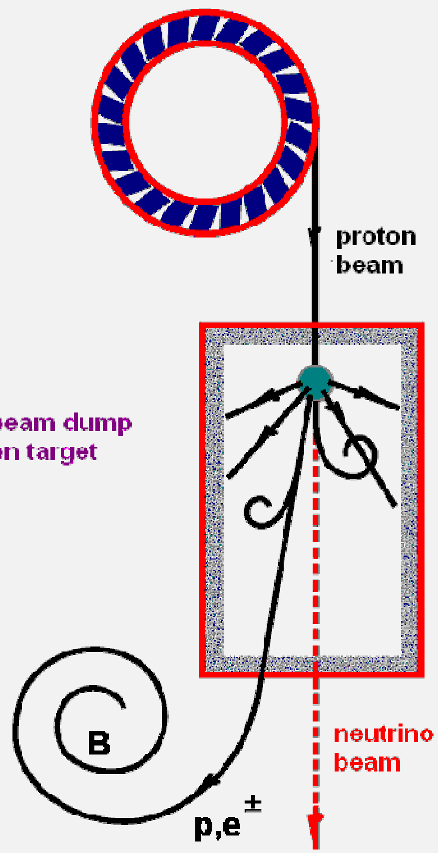


- ***Only the closest sources (AGN) are visible***
- ***"Guaranteed" BZ neutrinos (Berezinsky Zatsepin) from UHECR***

The Astrophysical Beam Dump

Fermi acceleration of protons and electrons in astrophysical sources

Particle accelerator



Spectrum $dN_{p,e}/dE \propto E^{-2}$

Leptonic HE γ production

synchrotron radiation followed by IC

$e + \gamma_{Synchrotron} \rightarrow e' + \gamma'_{HE}$

Hadronic HE ν and γ production

p + p (SNR,X-Ray Binaries) $\rightarrow$ X,π

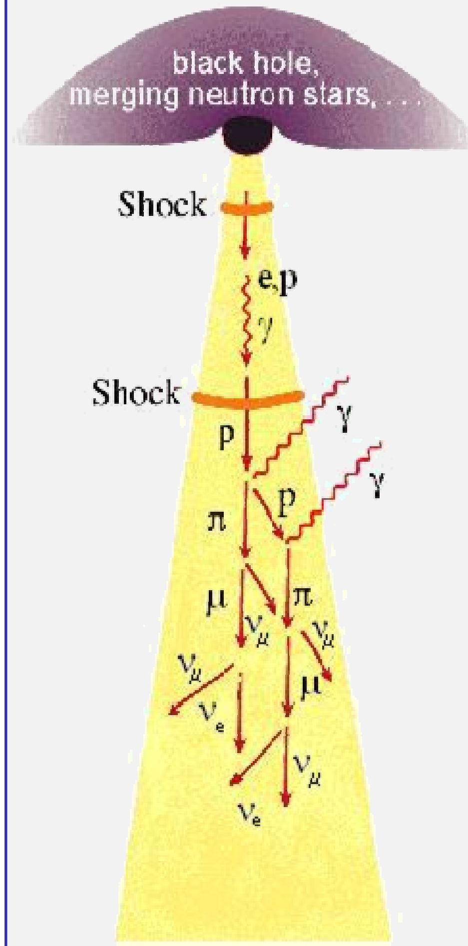
p + γ (AGN, GRB, μQSO) $\rightarrow$ Nπ

Decay of pions and muons

neutral pions → HE gammas

charged pions → HE neutrinos

Astrophysical jet



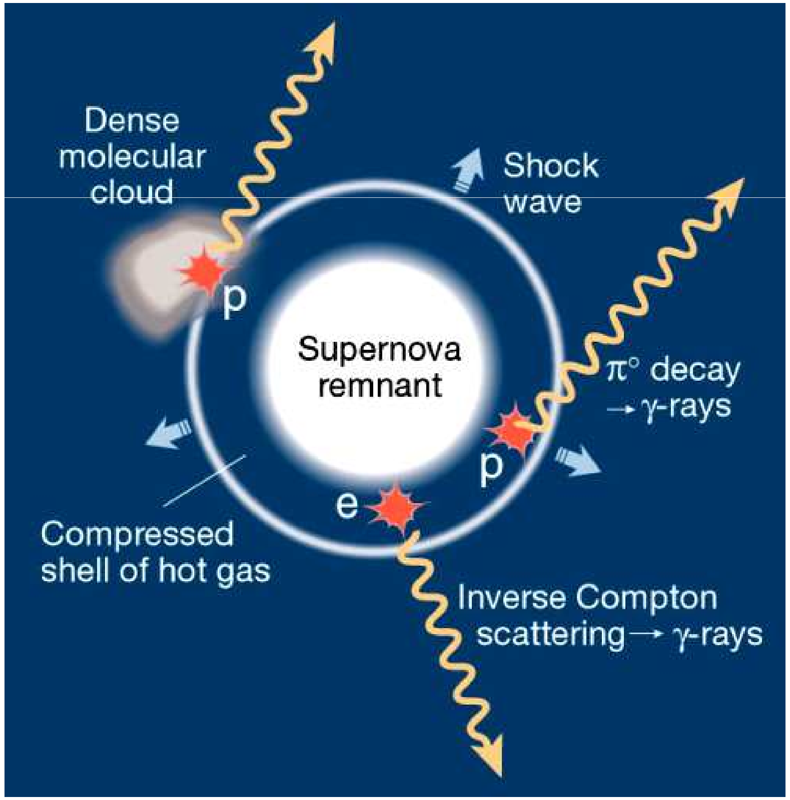
First Hadronic Gamma Ray Source detection ? (HESS)

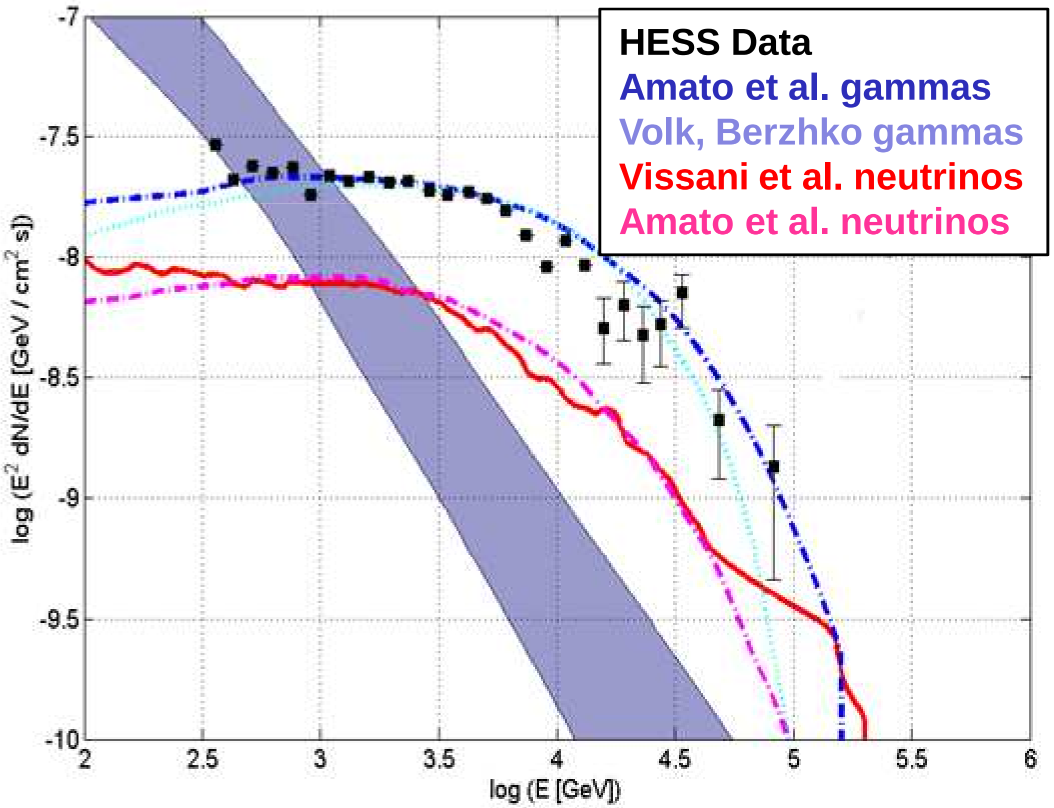
The Case of Galactic SNR RXJ1713.7-3946

proton acceleration + beam dump on nearby molecular clouds (dense target for VHE p)

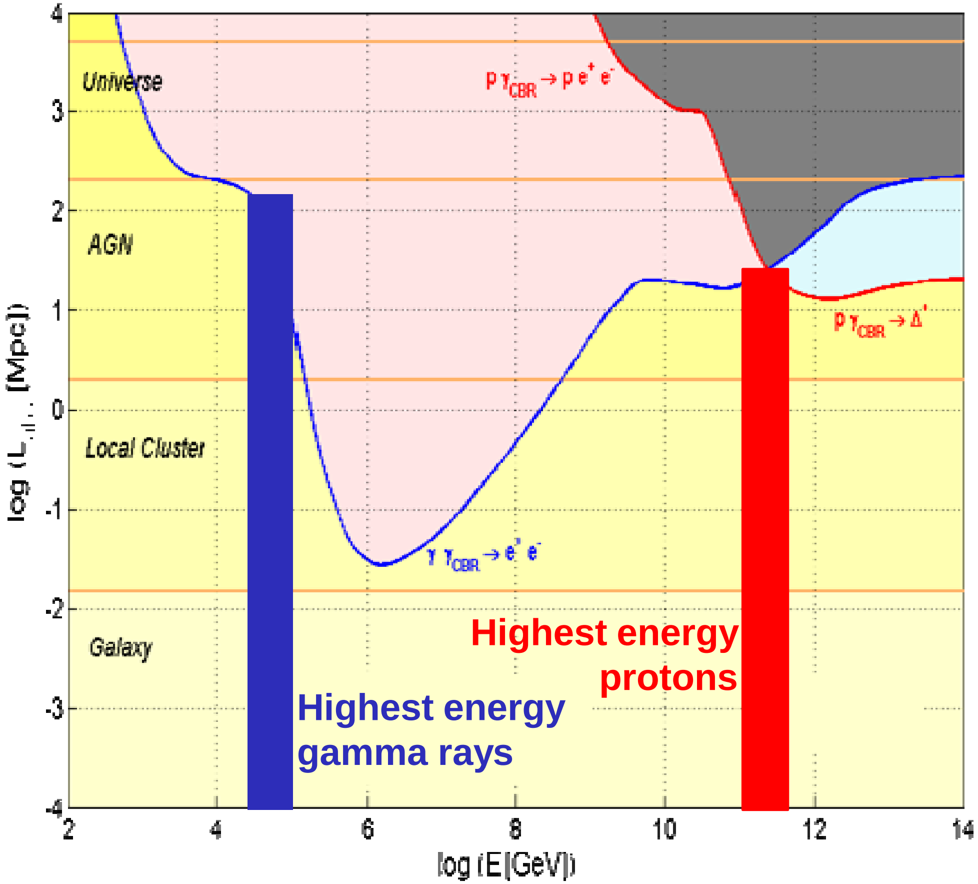
- ***Gammas observed up to several tens TeV***
- ***Spectrum features hardly explainable with IC mechanisms***

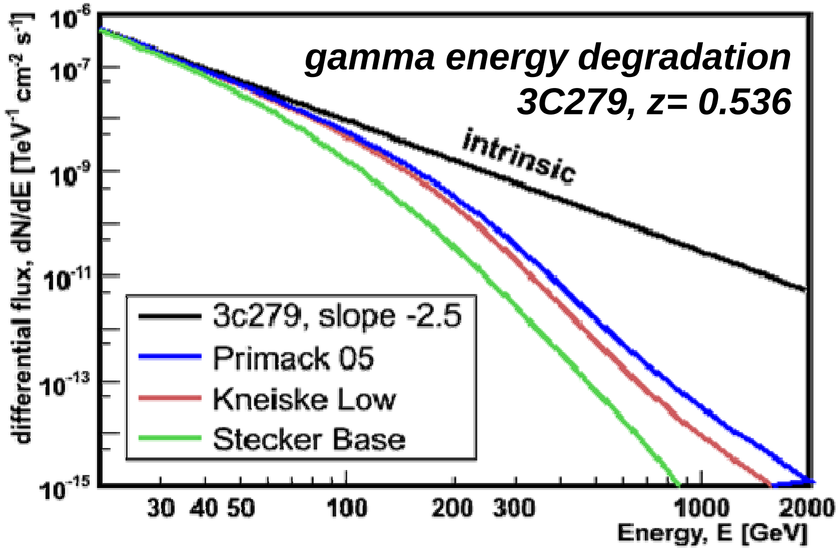
Neutrinos are the smoking gun for hadronic processes

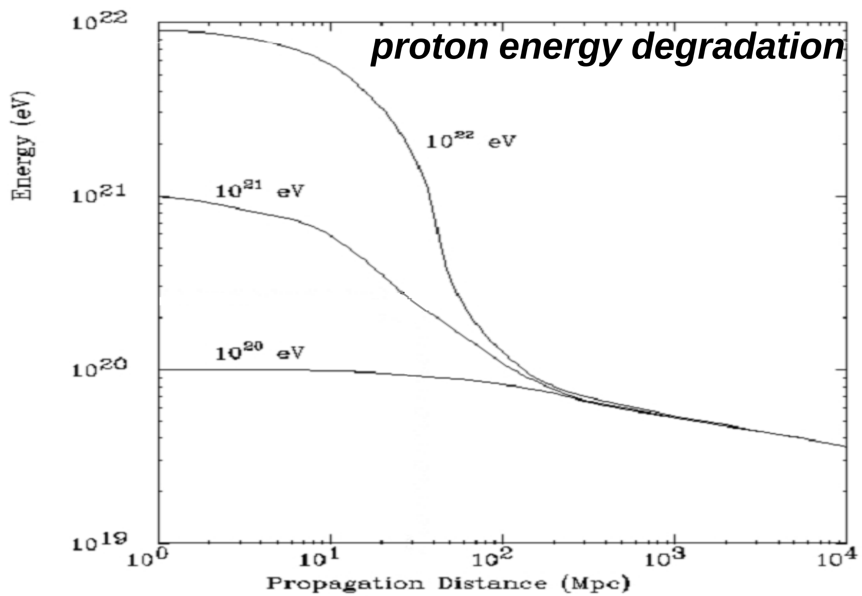




The far universe is opaque to UHE gammas and protons

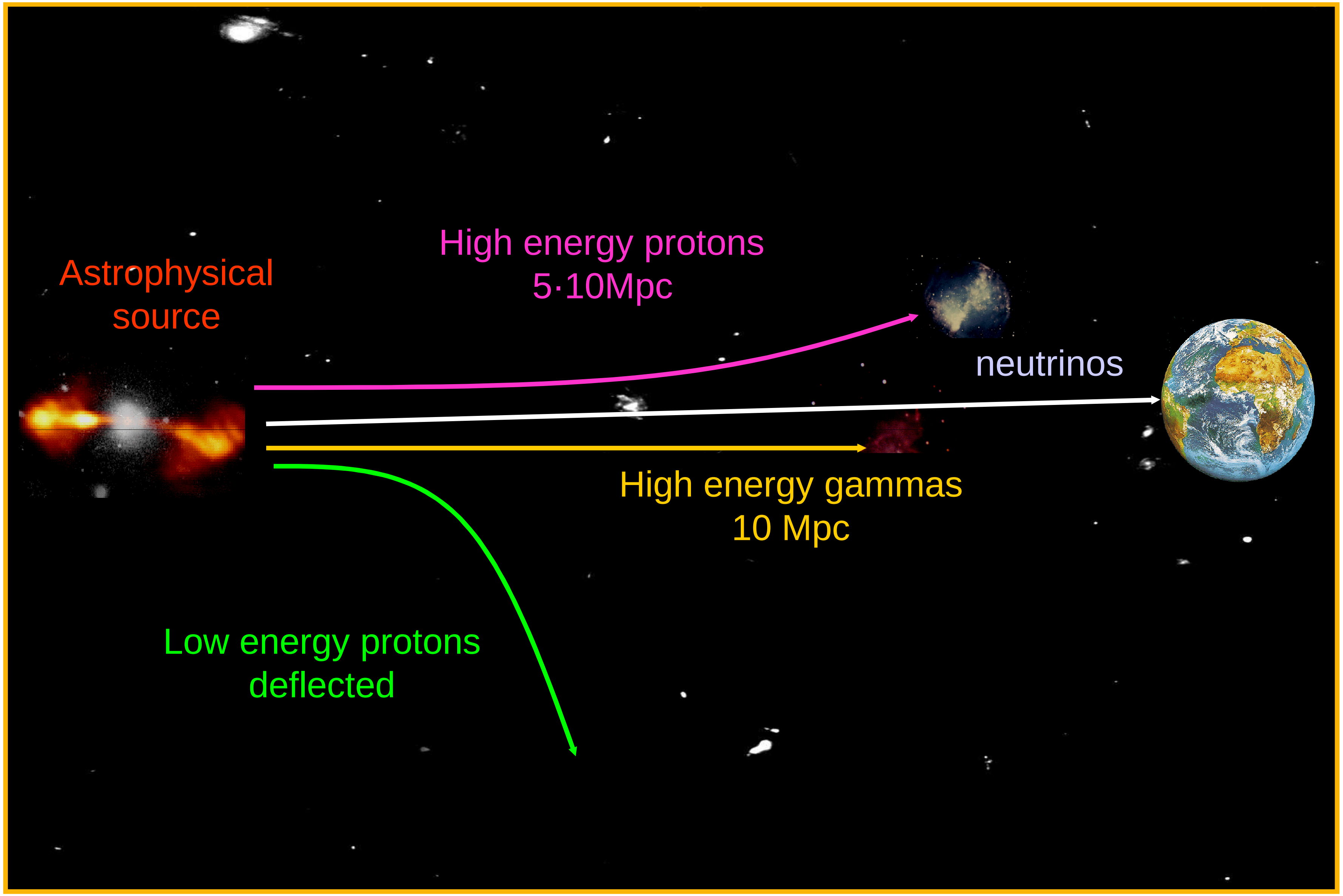






Only neutrinos can reach the Earth from cosmological sources

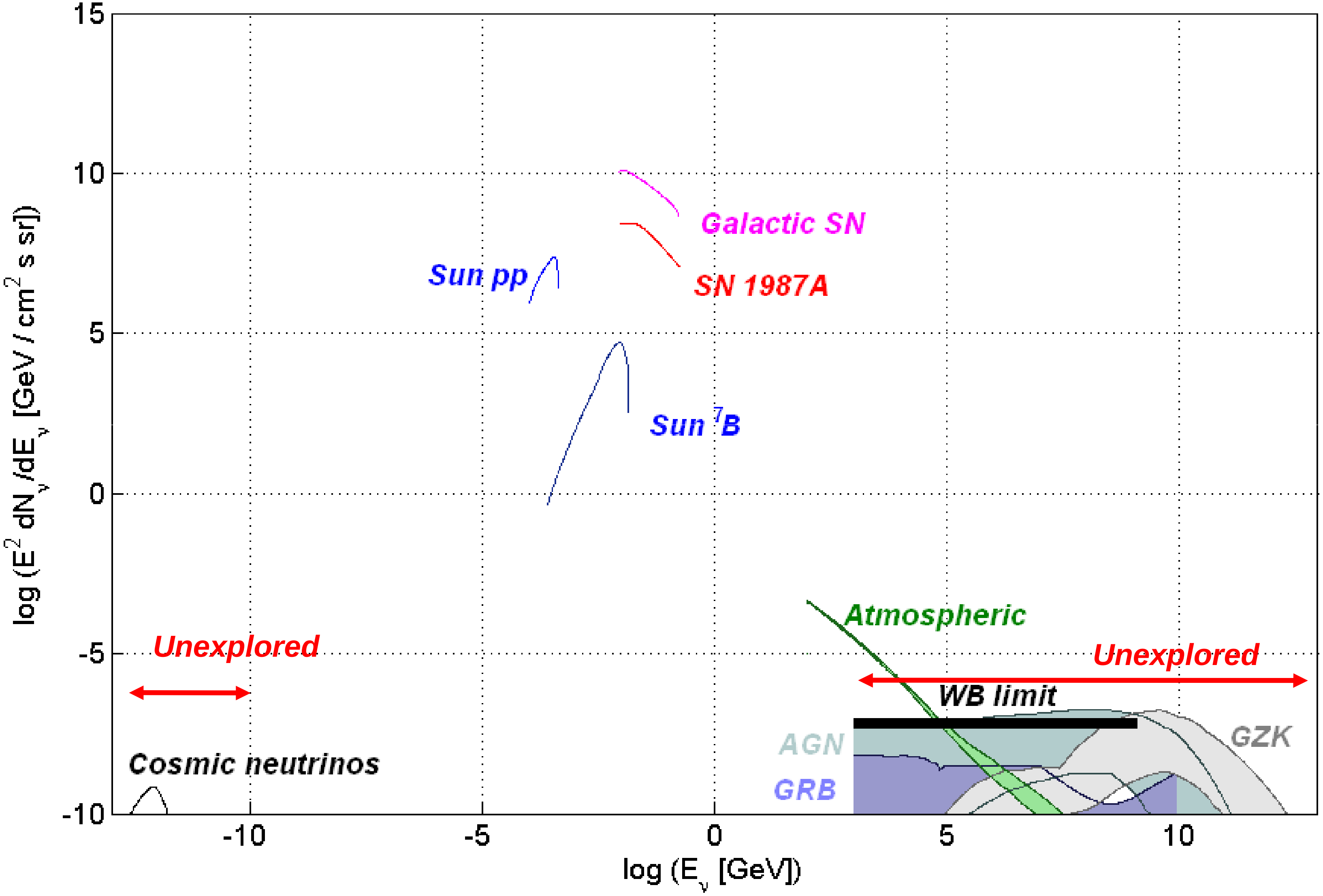
Limits for UHE protons and Gamma Ray Astronomy



Motivations for high energy neutrino astronomy

- Extend the high energy CR and γ Horizon (>GZK limit)
- Identify the sources of CR
- Explore deep inside the source (where τ »1 for CR and γ)
- Probe hadronic models in astrophysical sources

Neutrino fluxes: known and unknown



The requirement of large neutrino interaction target induced Markov and Zheleznykh to propose the use of natural targets.

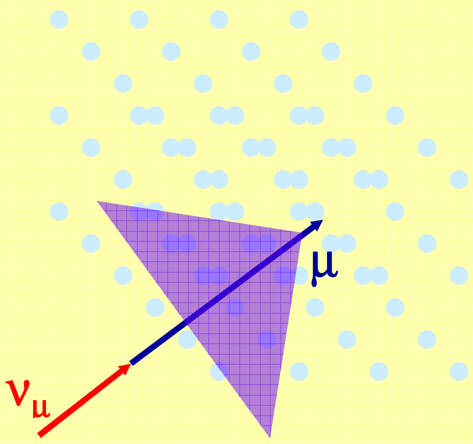
Deep seawater and polar ice offers:

- *huge (and inexpensive) target for neutrino interaction;*
- *shielding from cosmic background;*
- *good characteristics as optical and radio Cherenkov radiators;*
- *good characteristics as acoustic wave propagators*

High Energy neutrinos detection techniques

1 TeV — 100 PeV — 1000 ZeV

Optical Detection (ICECUBE-KM3NeT)



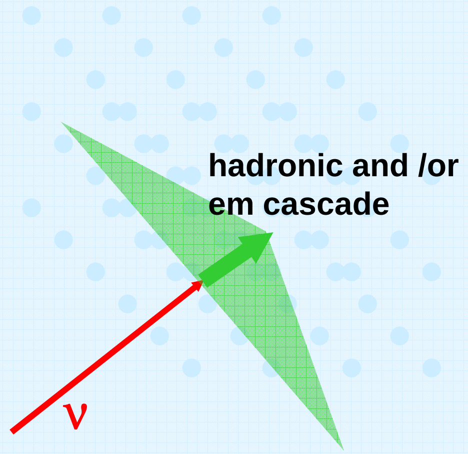
Medium: Seawater, Polar Ice

ν_μ (throughgoing and contained)
$\nu_{e,\tau}$ (contained cascades)

Carrier: Cherenkov Light (UV-visible)
Attenuation length: 100 m

Sensor: PMTs
Instrumented Volume: 1 km^3

Radio Detection (RICE, SALSA, ICERAY)



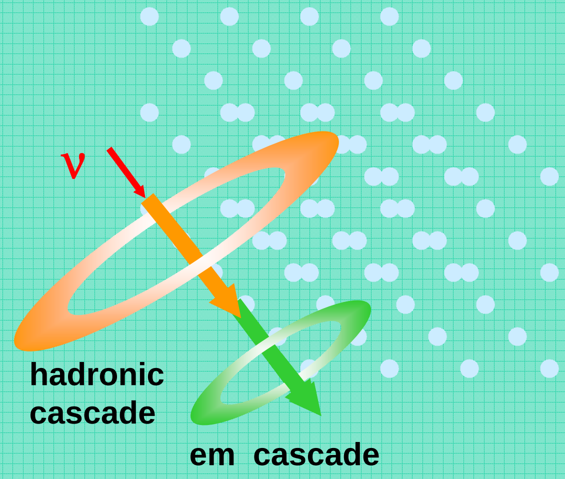
Medium: Salt domes, Polar Ice

ν (cascades)

Carrier: Cherenkov Radio
Attenuation length: 1 km

Sensors: Antennas
Instrumented Volume: >10 km^3

Acoustic Detection (Prototypes)



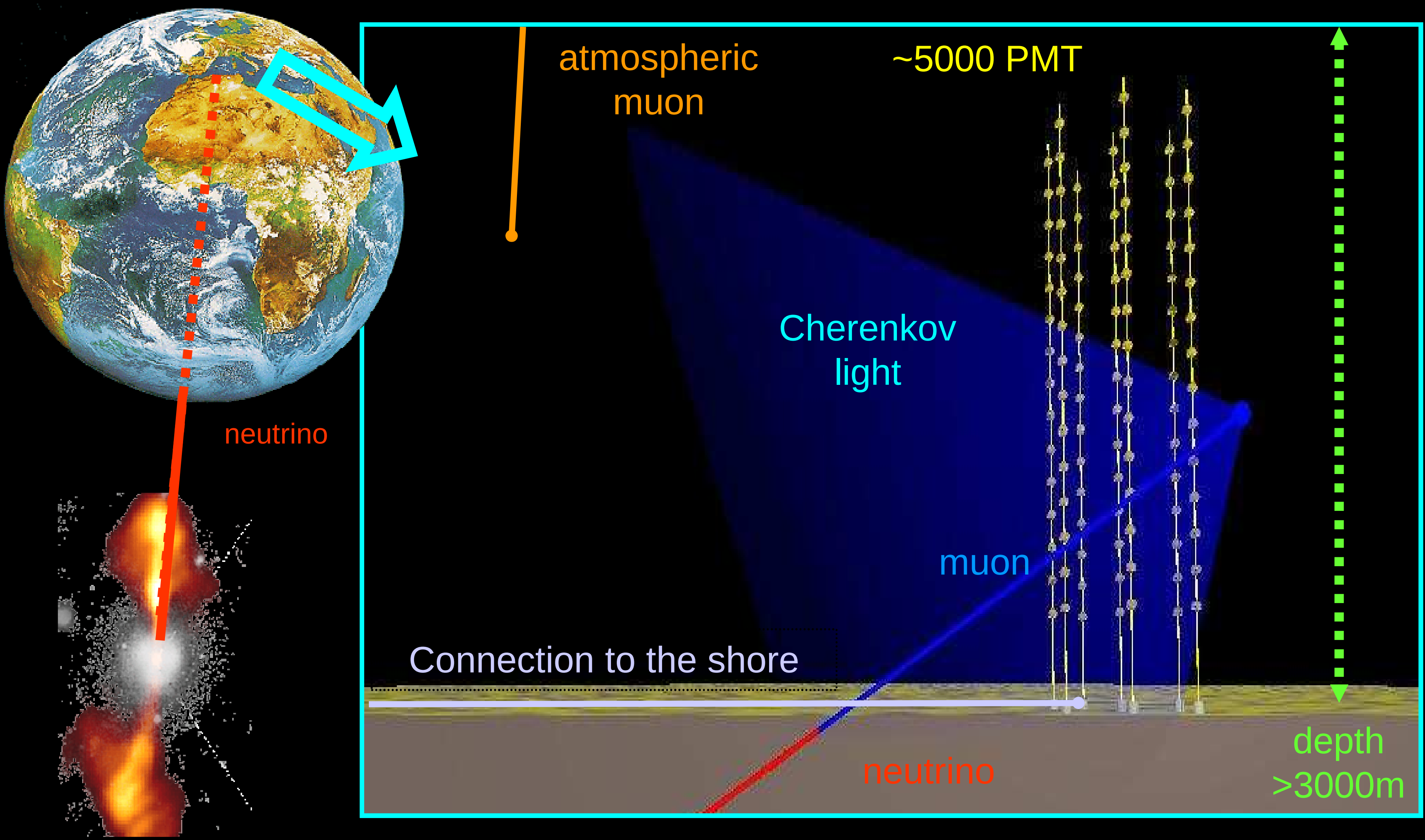
Medium: Seawater, Polar Ice, Salt Domes

ν (cascades)

Carrier: Sound waves (tens kHz)
Attenuation length: ~ 10 km

Hydro(glacio)-phones
Instrumented Volume: >100 km^3

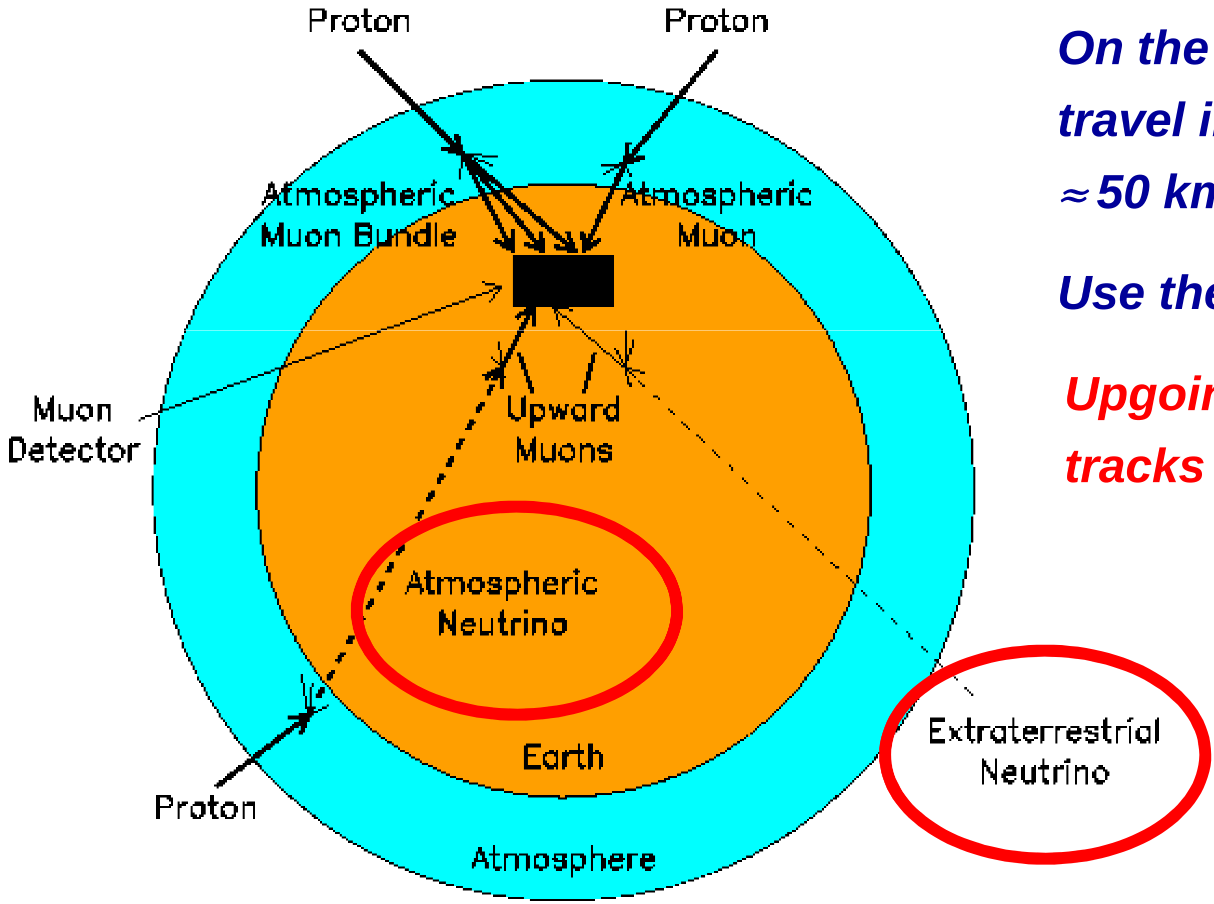
Underwater Cherenkov detectors



The km3 telescope: a downward looking detector

Neutrino telescopes search for muon tracks induced by neutrino interactions

The downgoing atmospheric μ flux overcomes by several orders of magnitude the expected μ fluxes induced by ν interactions.



On the other hand, muons cannot travel in rock or water more than $\approx$ 50 km at any energy

Use the Earth as a filter

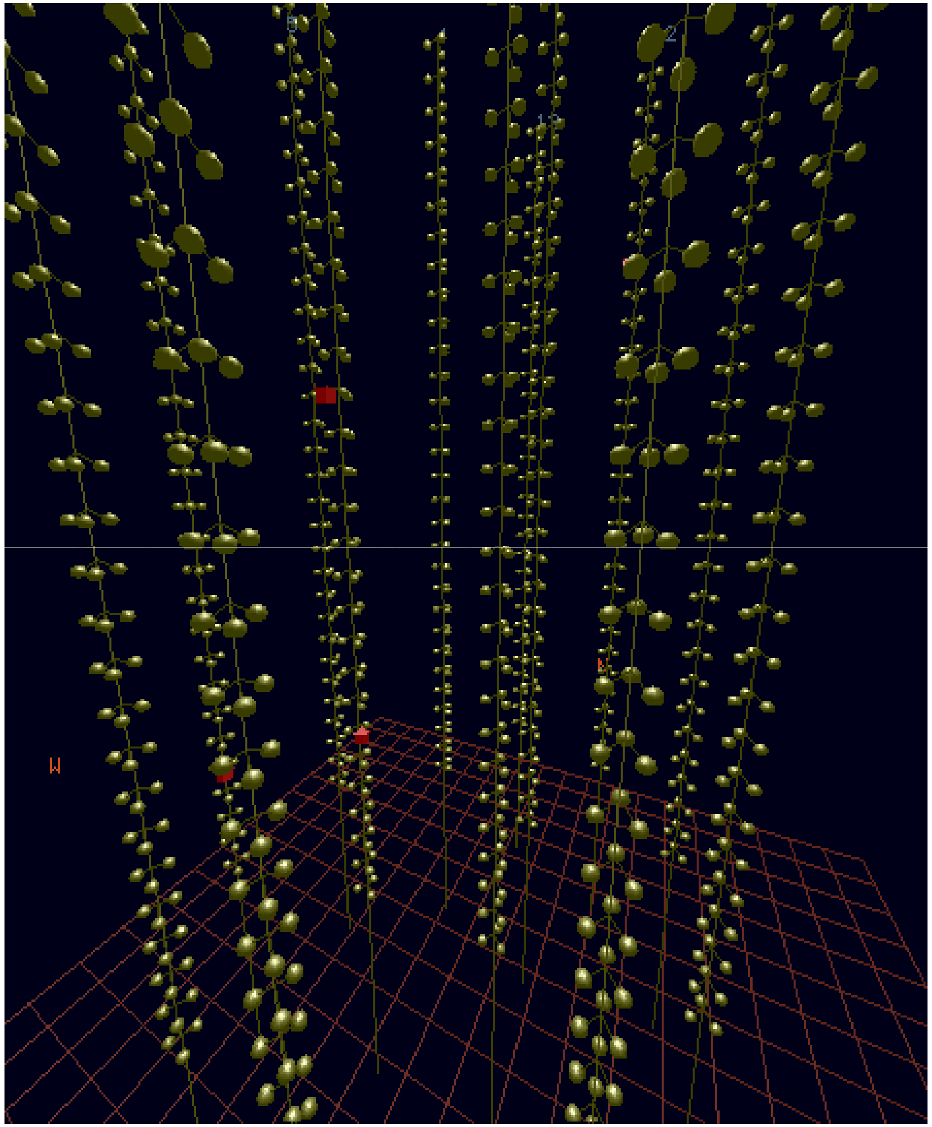
Upgoing and horizontal muon tracks are neutrino signatures

Cherenkov photons emitted by the muon track are correlated by the causality relation:

$$c(t_j - t_0) = l_j + d_j \, tg(\vartheta_c)$$

The track can be reconstructed during offline analysis of space-time correlated PMT signals (hits).

Required resolution:
1 ns in time
10 cm in position



AMANDA and IceCube at the South Pole

The first km3-scale neutrino telescope: IceCube

Adapted from A.Karle, 2009

Completion January 2011:

86 strings (60 PMT each)

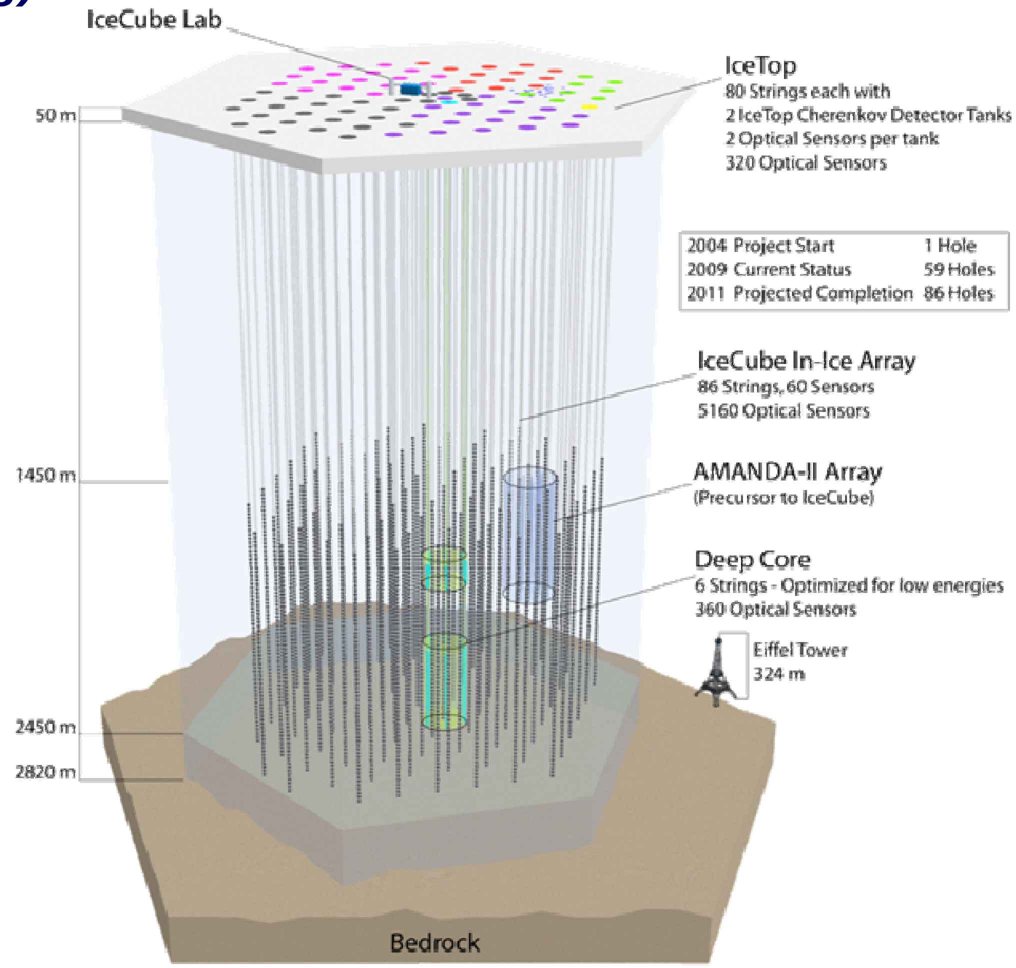
4800 10" PMT (only downward looking)

125 m inter string distance

16 m spacing along a string

Instrumented volume: 1 km^3 (1 Gton)

180 surface tanks for IceTop

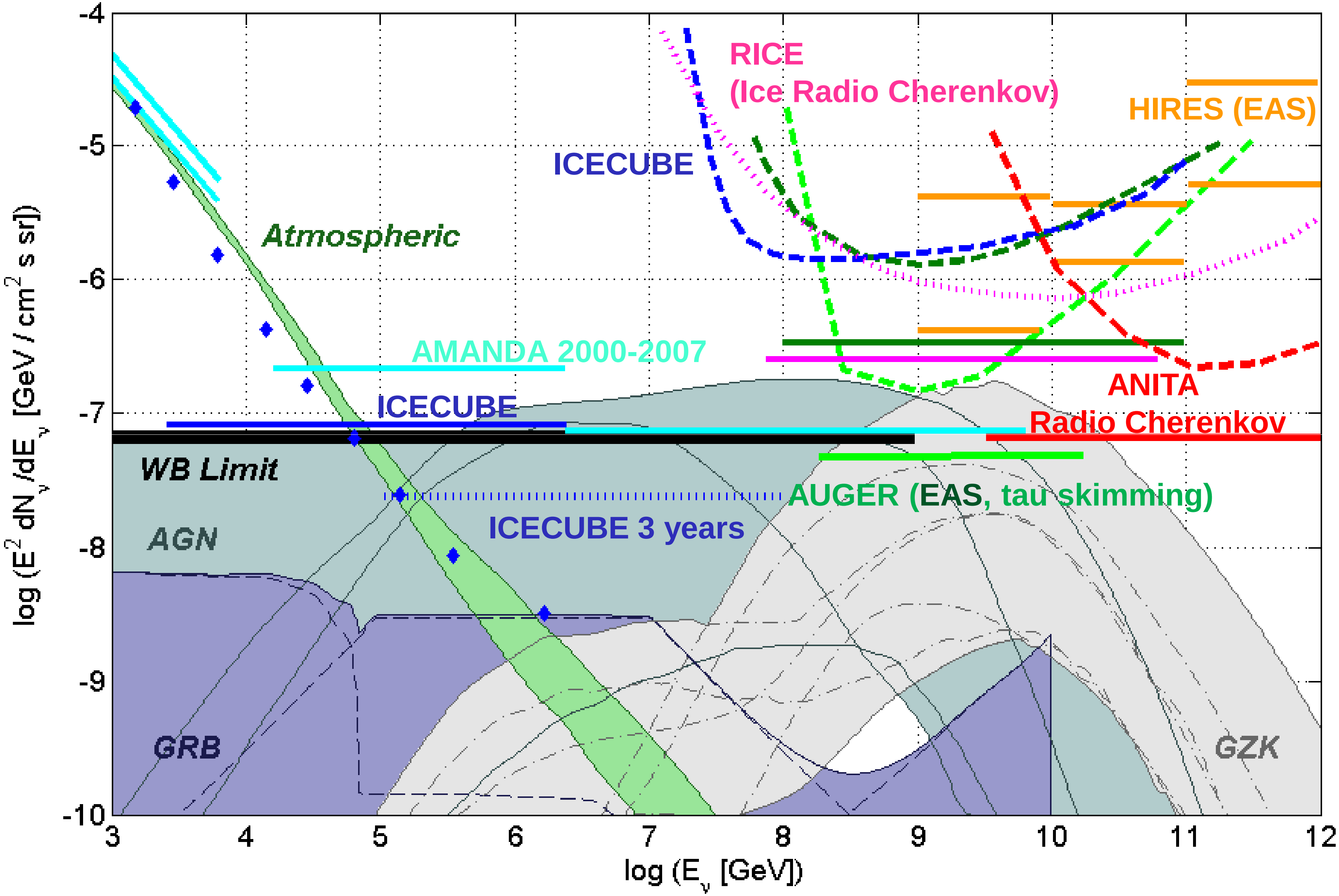


Present Status

- ***59 strings***
- ***118 IceTop tanks***

The Detector is taking data during the construction phase.

Present Limits on Neutrino Fluxes



The Mediterranean km3 detector KM3NeT

There are strong scientific motivations that suggest to install two neutrino telescopes in opposite hemispheres :

- ***Full sky coverage***
- ***Galactic Center only observable from Northern Hemisphere***

PANAGIC 2002

HENAP recommendations

The most convenient location for the Northern km3 detector is the Mediterranean Sea:

vicinity to infrastructures

good water quality

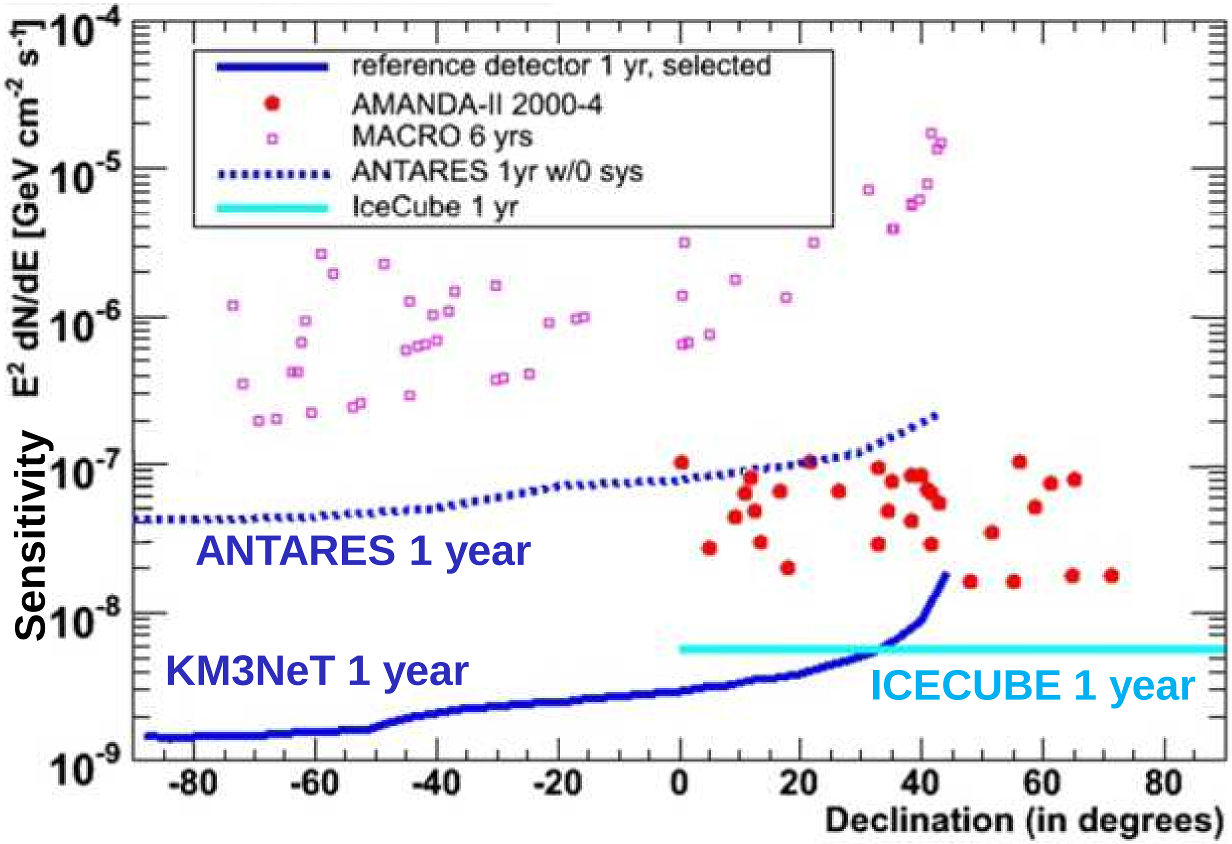
good weather conditions for sea operations

The KM3NeT Detector Target Performances

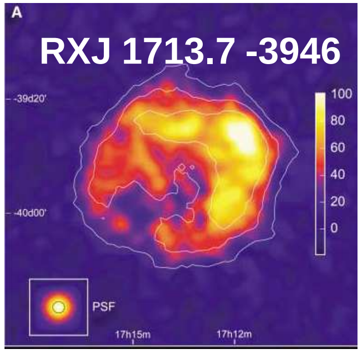
KM3NeT is deep-sea research infrastructure hosting a high energy neutrino telescope to be constructed in the Mediterranean Sea.

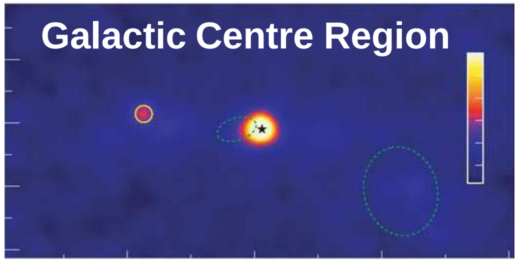
41 Universities and Research Institutes from 10 European Countries: nuclear and particle physics, astrophysics, geophysics and deep sea science.

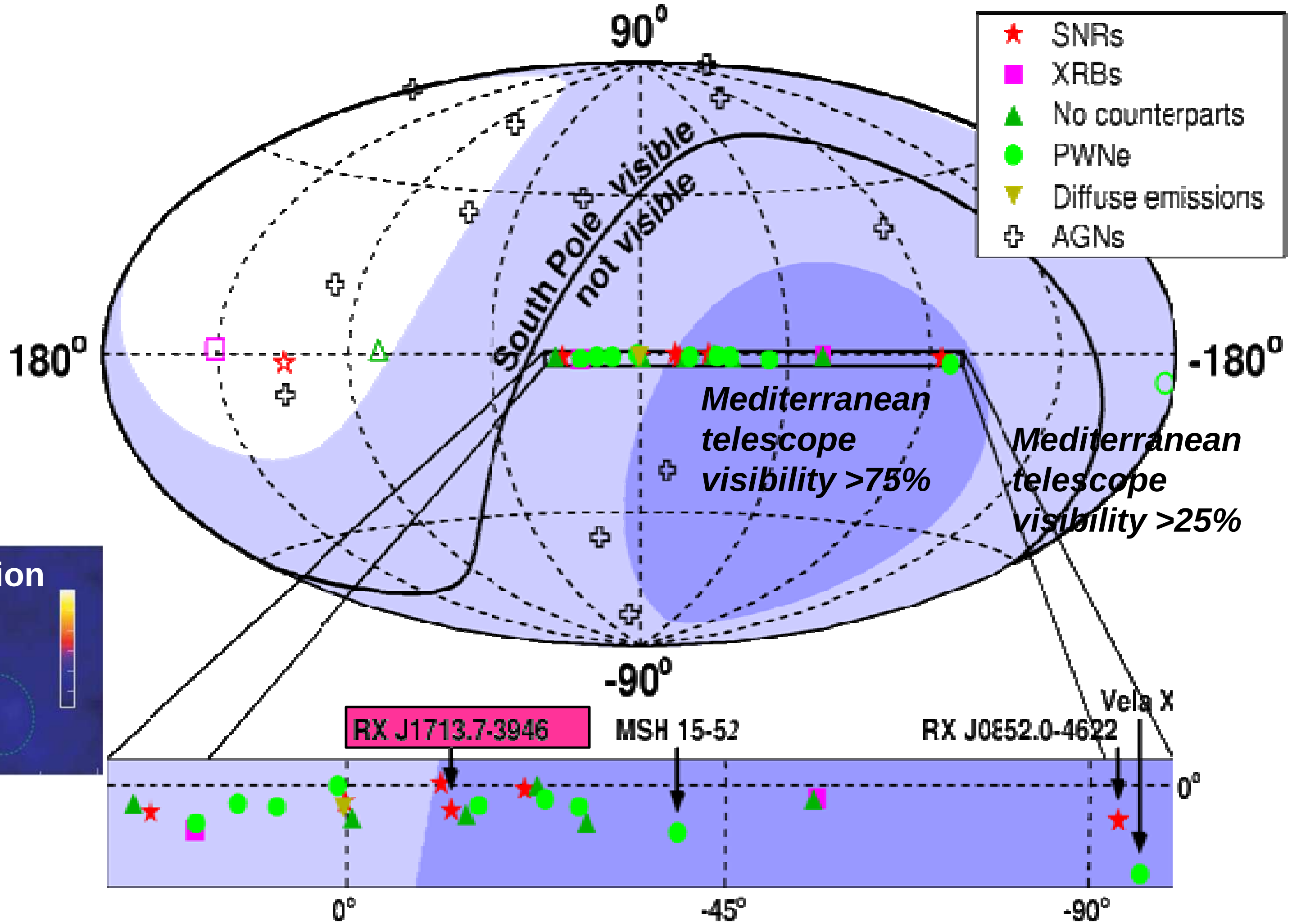
Thanks to water optical properties and larger depth KM3NeT is expected to be more sensitive than IceCube



Mediterranenan-km3 and Icecube visibility







Need two telescopes to cover the whole sky.
The Galactic centre can be seen only from the Mediterranean telescope.
Combined studies with HESS sources.

The Mediterranean km³ detector potentials and payoffs

Structures can be recovered:

- The detector can be maintained
- The detector geometry can be reconfigured

The underwater telescope can be installed at depth ≥ 3000 m

Muon background reduction

Light effective scattering length (>100 m) is much longer than in ice (20 m)

Cherenkov photons directionality preserved

Payoffs must be minimized selecting a deep sea site with:

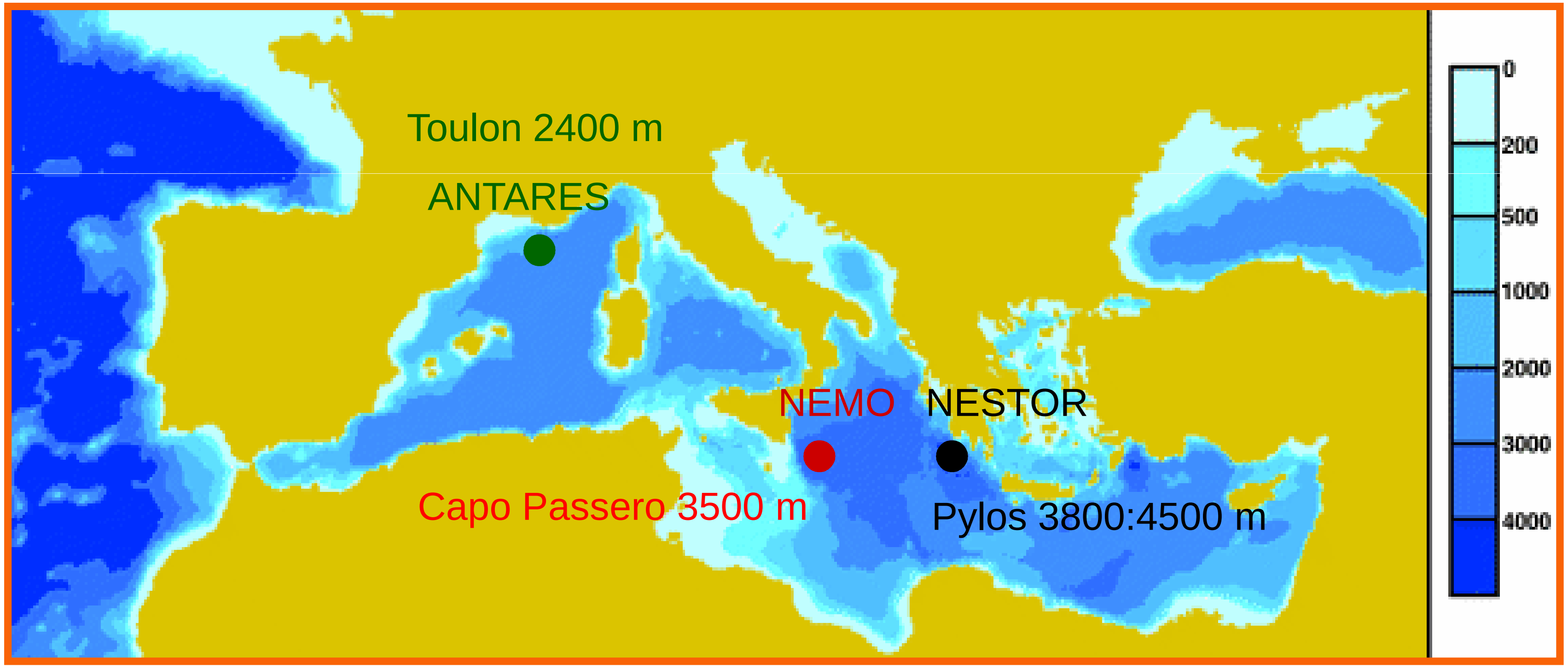
long light absorption length

low bioluminescence (^{40}K density is almost constant in the Sea)

low biofouling and sedimentation rates

The Mediterranean km^3

There are three collaborations active in the Mediterranean Sea:
ANTARES, NEMO and NESTOR



NEMO – Towards the km^3

INFN funded NEMO with the goal of constructing a km^3 scale underwater detector for astrophysical neutrinos in the Mediterranean Sea at >3500 m

Activities:

- Search and characterization of deep sea sites
- Detector architecture design
- Technological demonstrator: NEMO Phase-1
- Realization of an infrastructure for the km3

More than 80 researchers from INFN and other Italian institutes

NEMO is part of the KM3NeT consortium

Site Selection and characterization activity

Since 1998 more than 30 naval campaigns exploring deep sea sites in the Mediterranean Sea (and in Baikal Lake for comparison).

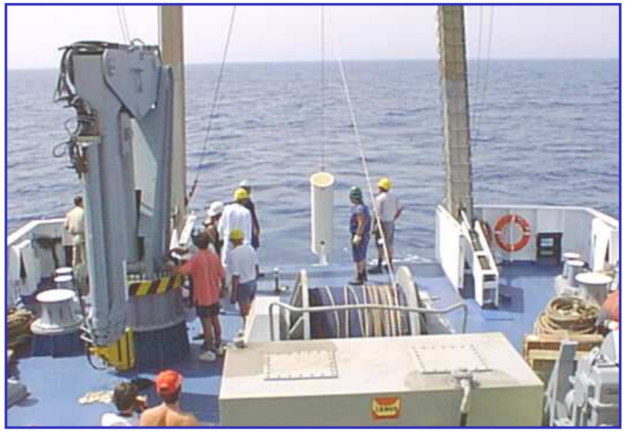
Optimal site found about 80 km SE of Capo Passero (Sicily)

Deep sea water properties in Capo Passero site have been monitored since year 2000

Light optical background monitoring station

Light transmissometer

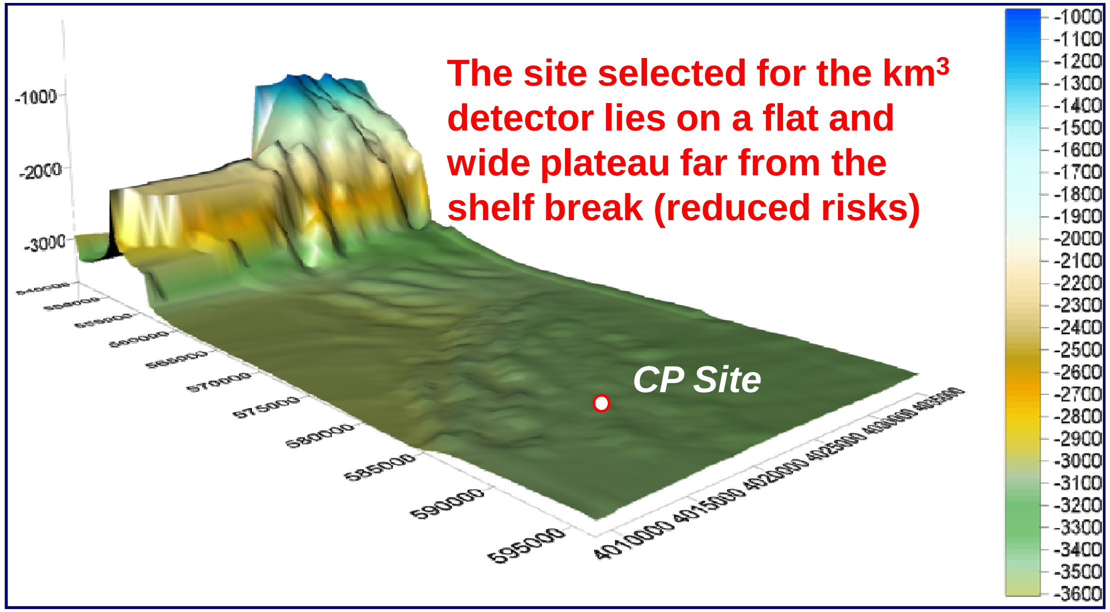
Biofouling monitoring station

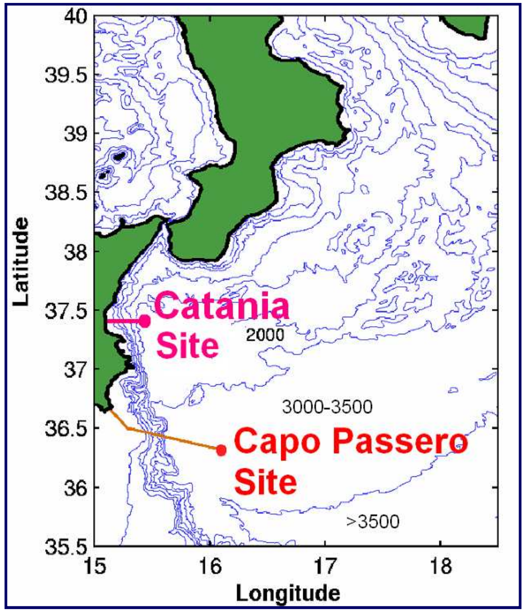


Sediment Trap

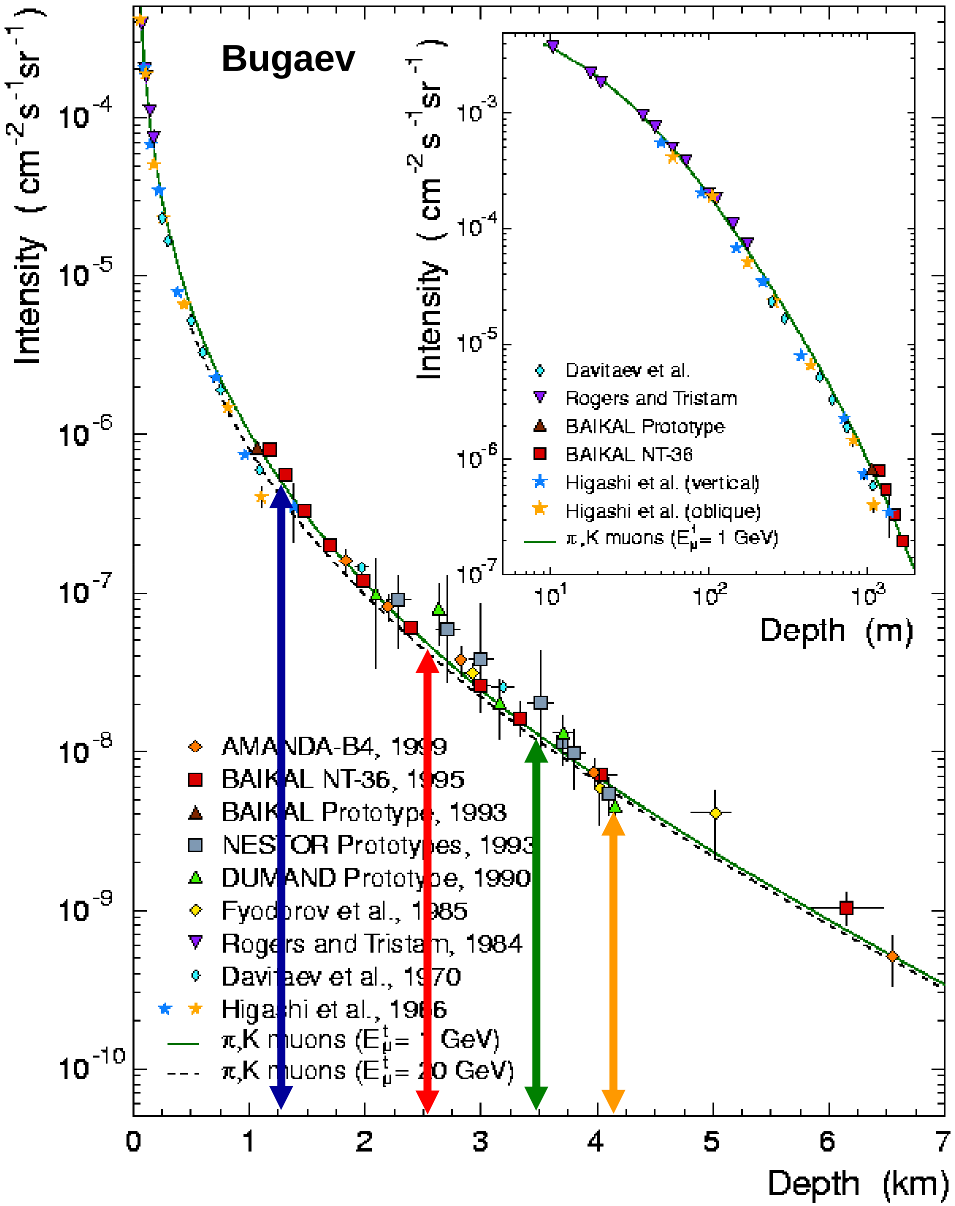
The Capo Passero Site

- *Depths of more than 3500 m are reached at about 80 km distance from the shore*
- *Water optical properties are the best observed in the studied sites ($L_a \approx 70$ m @λ = 440 nm)*
- *Optical background from bioluminescence is extremely low (40 kHz on 10" PMT, 0.3 s.p.e.)*
- *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 reconfiguration and large extension of the detector*





The depth issue: atmospheric muon background rejection



Downgoing muon background is strongly reduced as a function of detector installation depth.

Depth >3000 m (≈1 km rock) is optimal for detector installation

BAIKAL

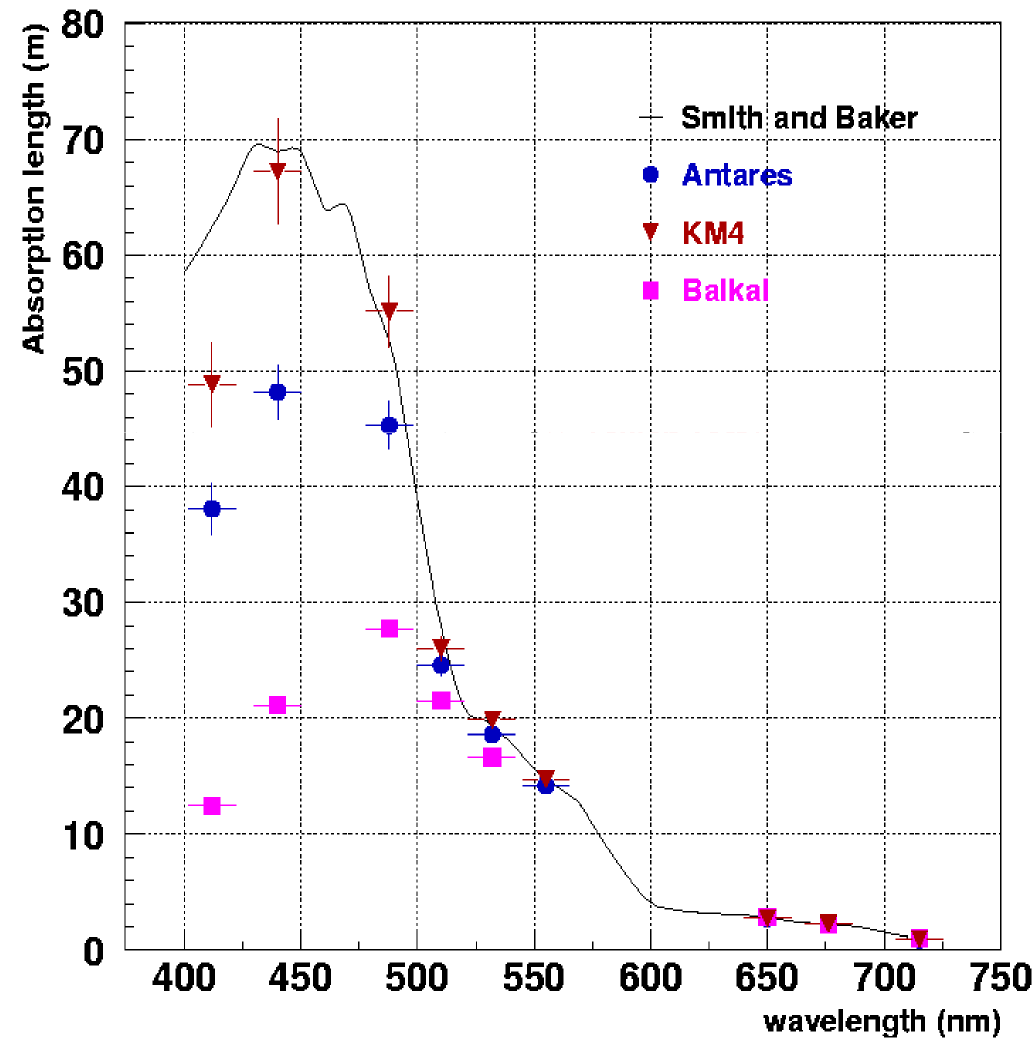
ANTARES (Toulon,France)
ICECUBE (South Pole)

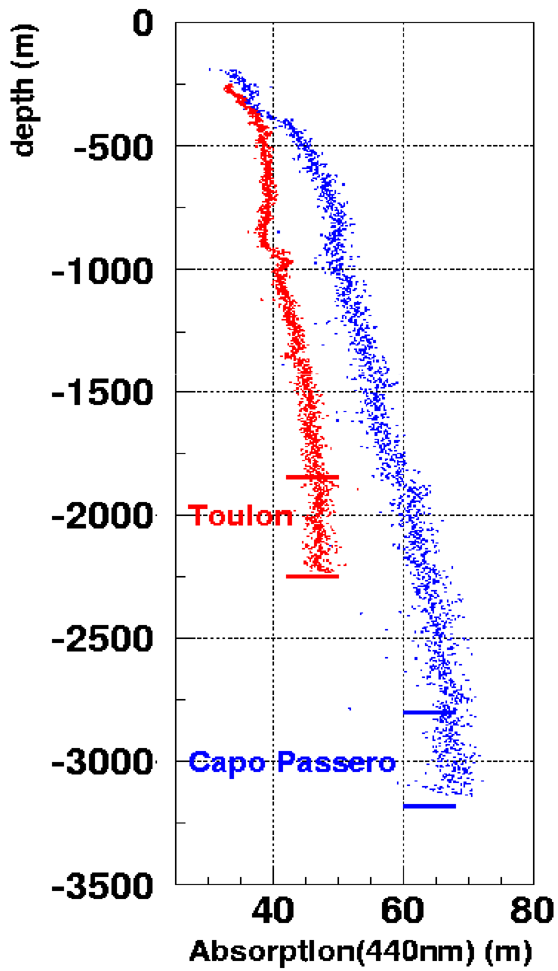
NEMO (Capo Passero, Italy)

NESTOR (Pylos, Greece)

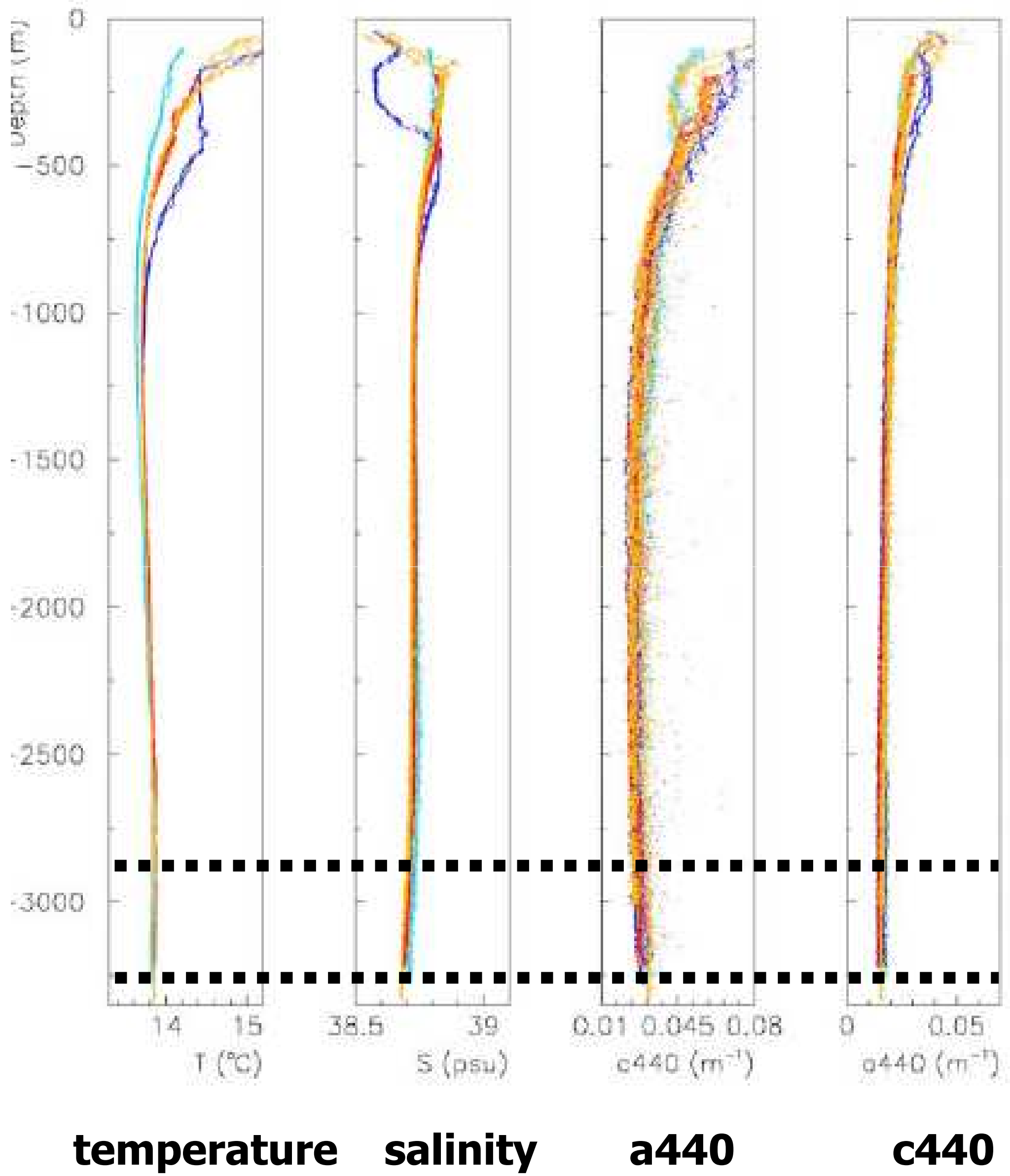
Comparison with ANTARES and Baikal waters

Optical properties have been measured in joint ANTARES-NEMO campaigns in Toulon and in Capo Passero (July-August 2002)





Water transparency in Capo Passero Site



Seasonal dependence of oceanographical (Temperature and Salinity) and optical (absorption and attenuation) properties has been studied in Capo Passero

Variations are only observed in shallow water layers

Data taken in:

Aug 03 (2 profiles superimposed)

Aug 02 (3 profiles superimposed)

Mar 02 (4 profiles superimposed)

May 02 (2 profiles superimposed)

Dec 99 (2 profiles superimposed)

Optical Background in Capo Passero

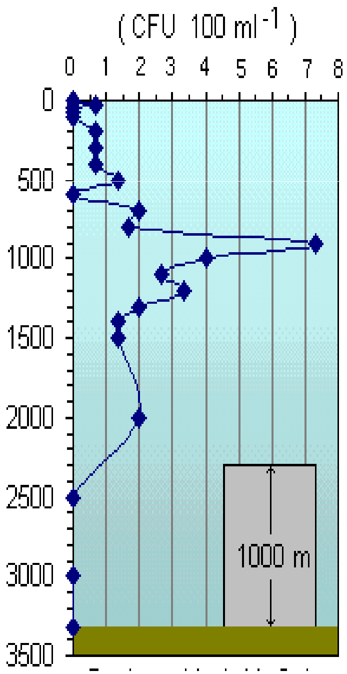
Potassium 40 decay

$^{40}K \rightarrow {}^{40}Ca + e^{-} + \nu_e$ (B.R. = 89.28%)

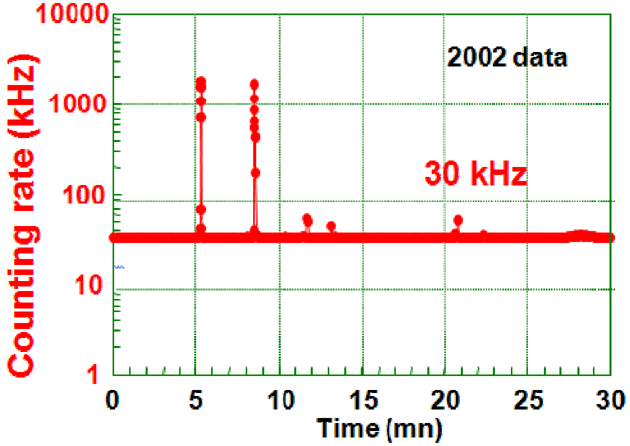
$^{40}K + e^{-} \rightarrow {}^{40}Ar + \nu_e + \gamma$ (B.R. =10.72%)

Induces a Constant rate 30 kHz (10" PMT @ 0.5 spe)

Bioluminescence



Capo Passero data (subset of 2 months)



Increase average rate and produce bursts

Capo Passero Seascapes

NEMO Towards the Mediterranean km^3 : architecture

The design of the Mediterranean km^3 detector is addressed to fit physics requirements:

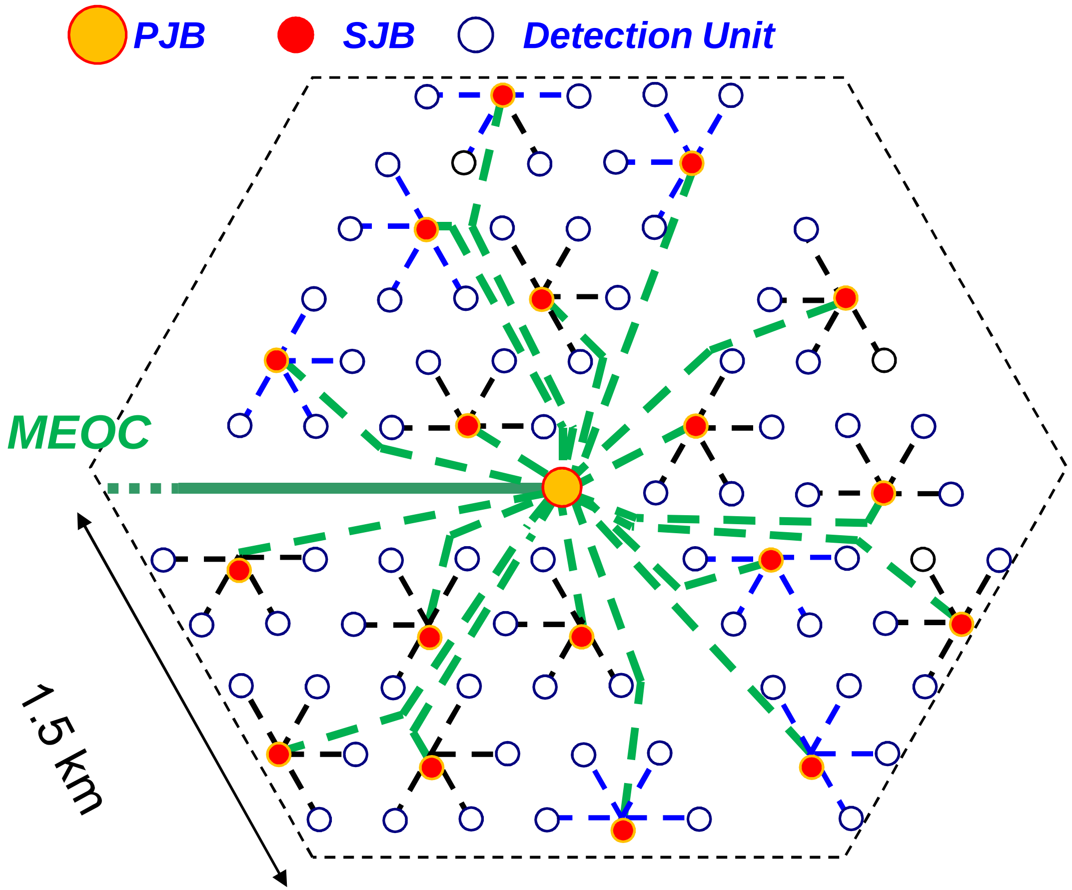
- **Effective area $\geq$ 1 km^2**
- **Angular resolution close to intrinsic resolution ($\leq$ 0.1° for muons produced by $E_\nu \geq$ 10 TeV)**
- **Energy threshold of a few 100 GeV**

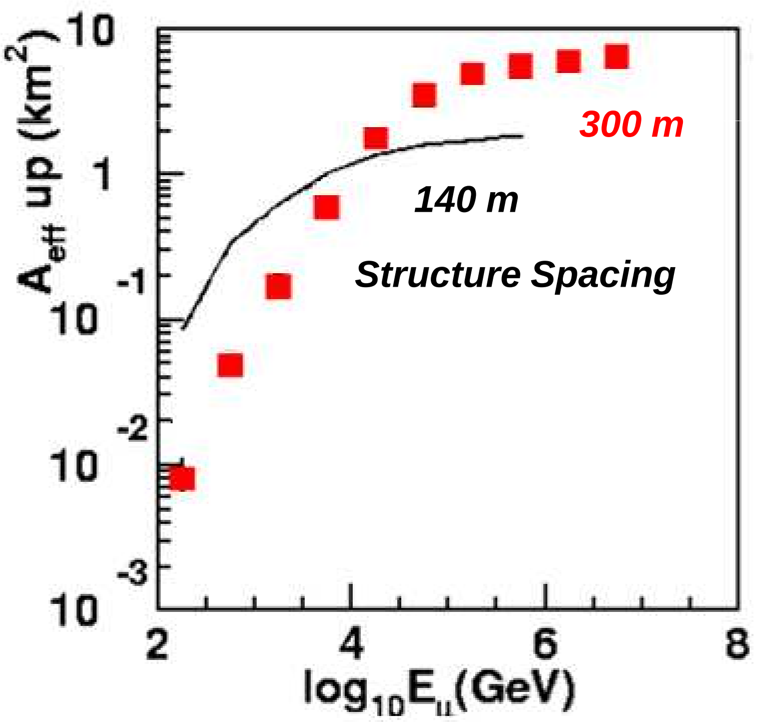
Design detector layout and study detector performances as a function of site parameters (depth, water properties,...)

NEMO Architecture studies

Design based on detector modularity

- *reduce the number of structures*
- *reduce the underwater connections*
- *allow operation with ROV and reconfigurability*

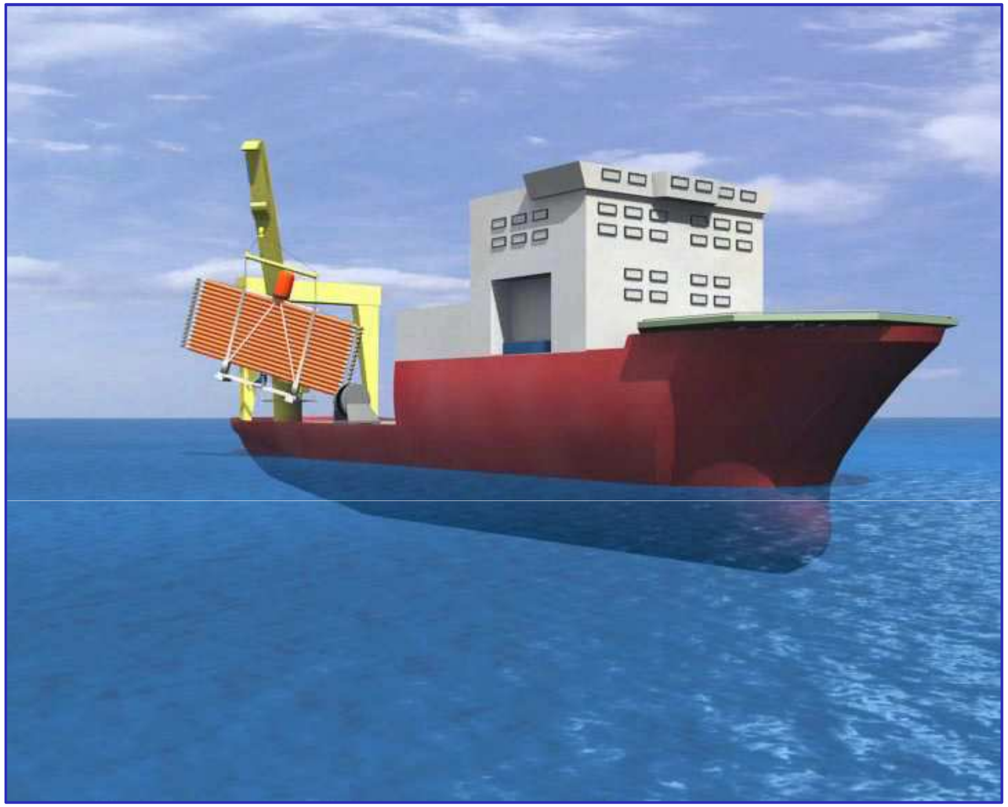




The NEMO Detection Unit: the Tower

The NEMO tower is a semi-rigid 3D structure with high PMT density

- ***easy deployment and recovery***
- ***local trigger***
- ***improve muon reconstruction***



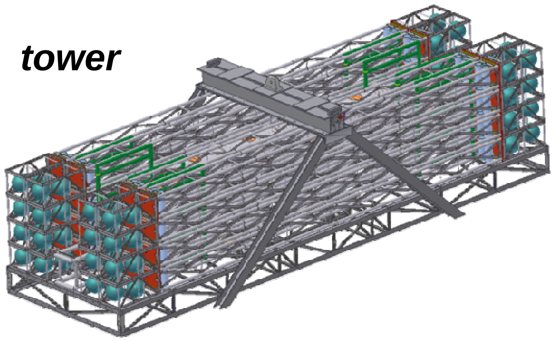
Tower Height:

compacted	*4:5 m*
total	*750 m*
instrumented	*600 m*
# storeys	*16 to 20*
# PMT	*64 to 80*

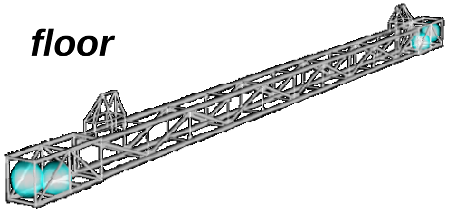
Beams:

length	*6 :10 m*
spacing	*30:40 m*

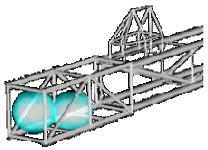
tower



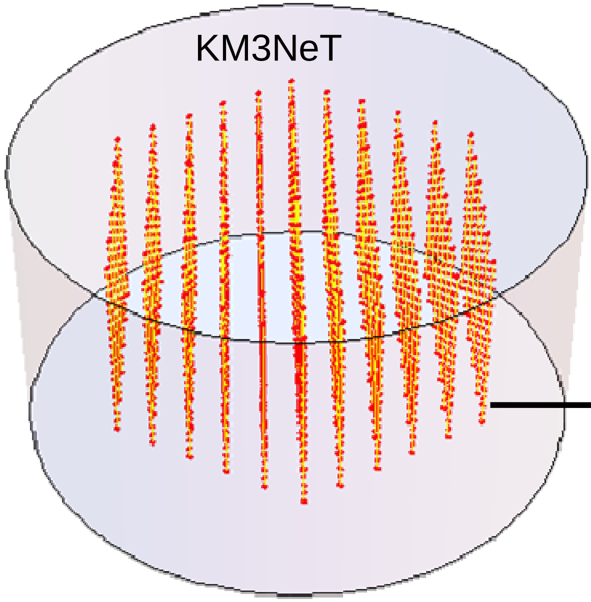
floor

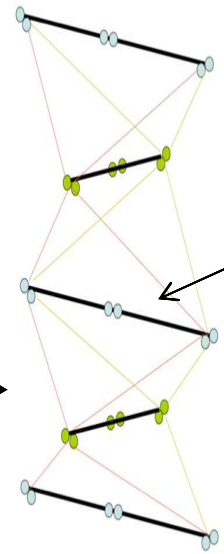


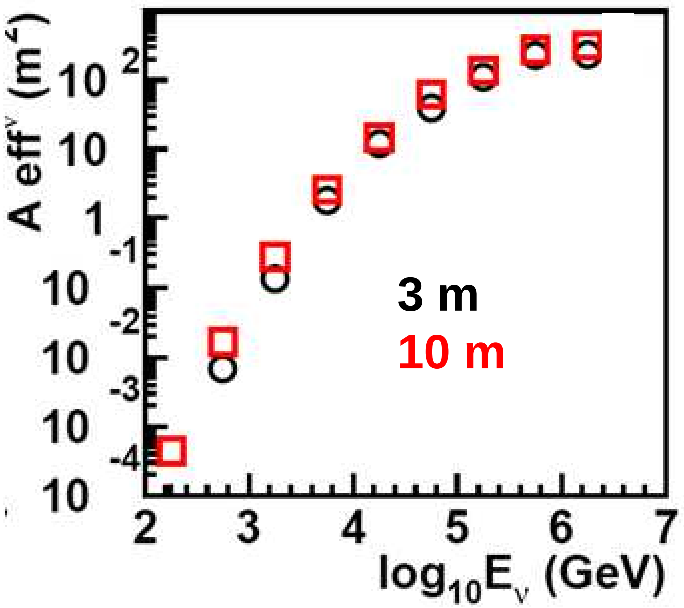
PMT Couple

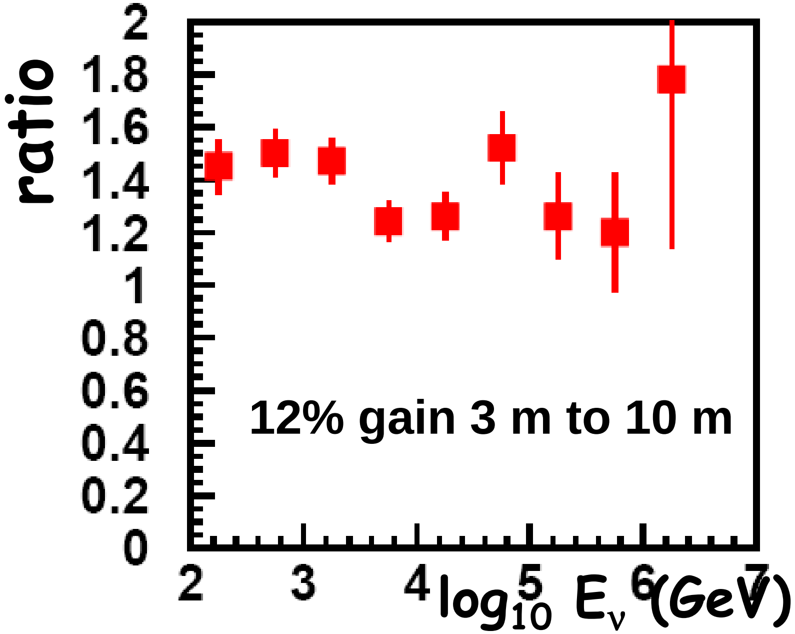


The tower improves detector sensitivity: the “bar effect”

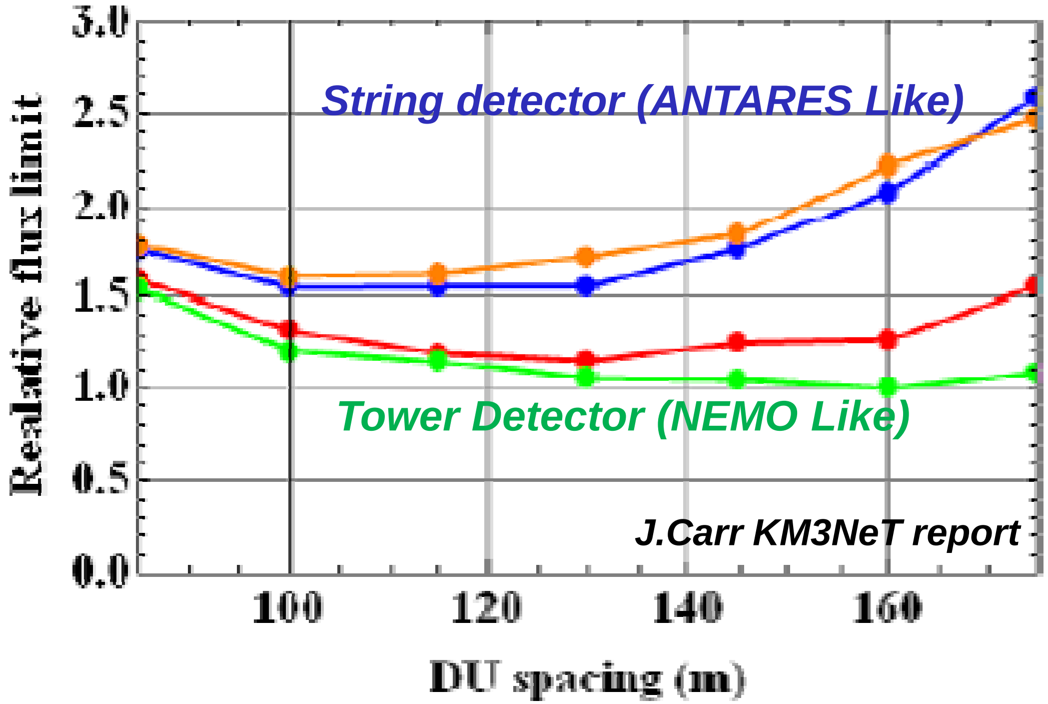








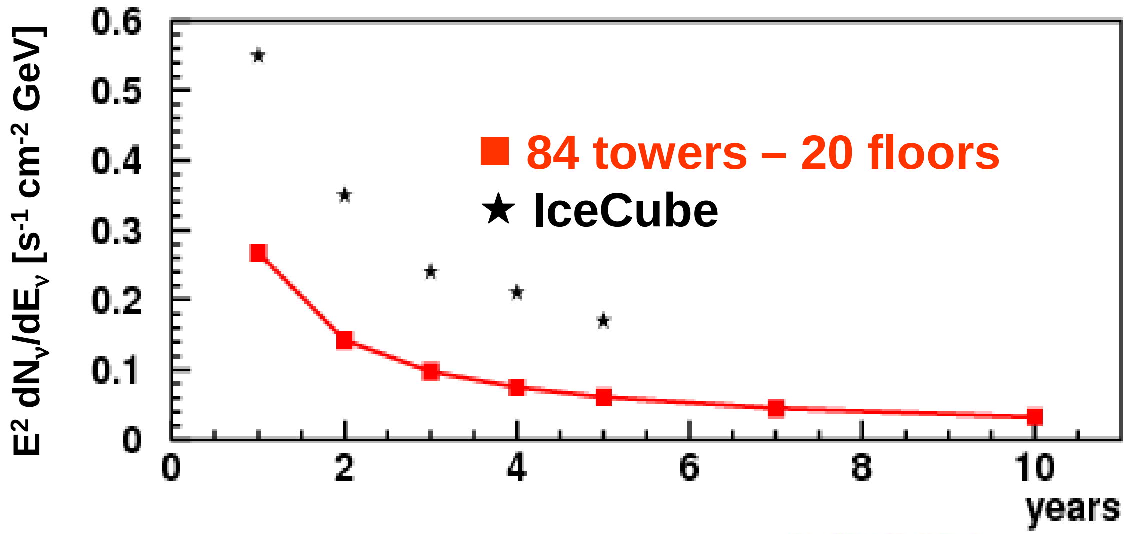
Bar effect and distance between Detection Units



Detector compared for a fixed number of PMTs

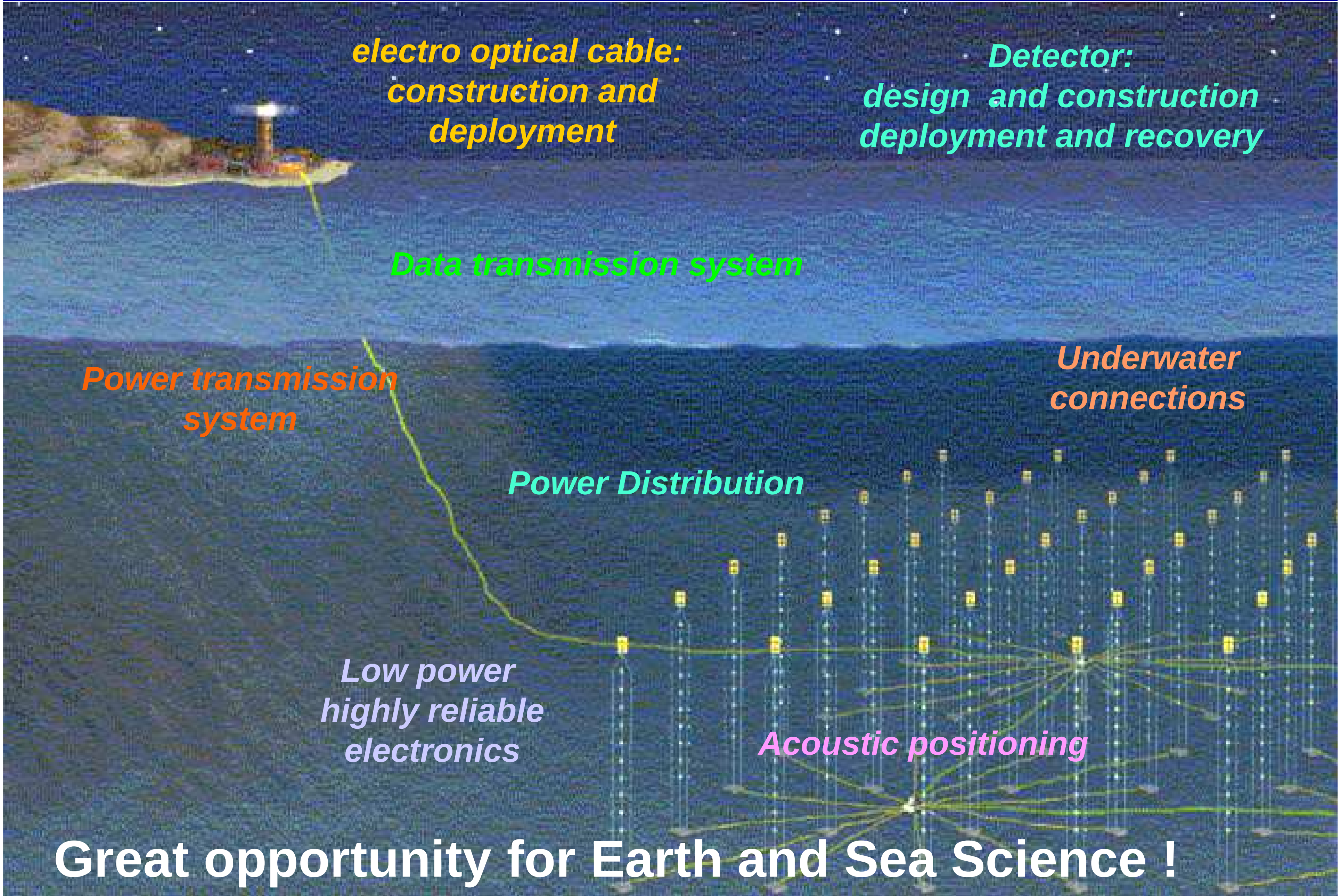
Designs similar at small DU spacing, due to saturation, larger differences at large spacing

Results from different software tools confirm the bar effect .



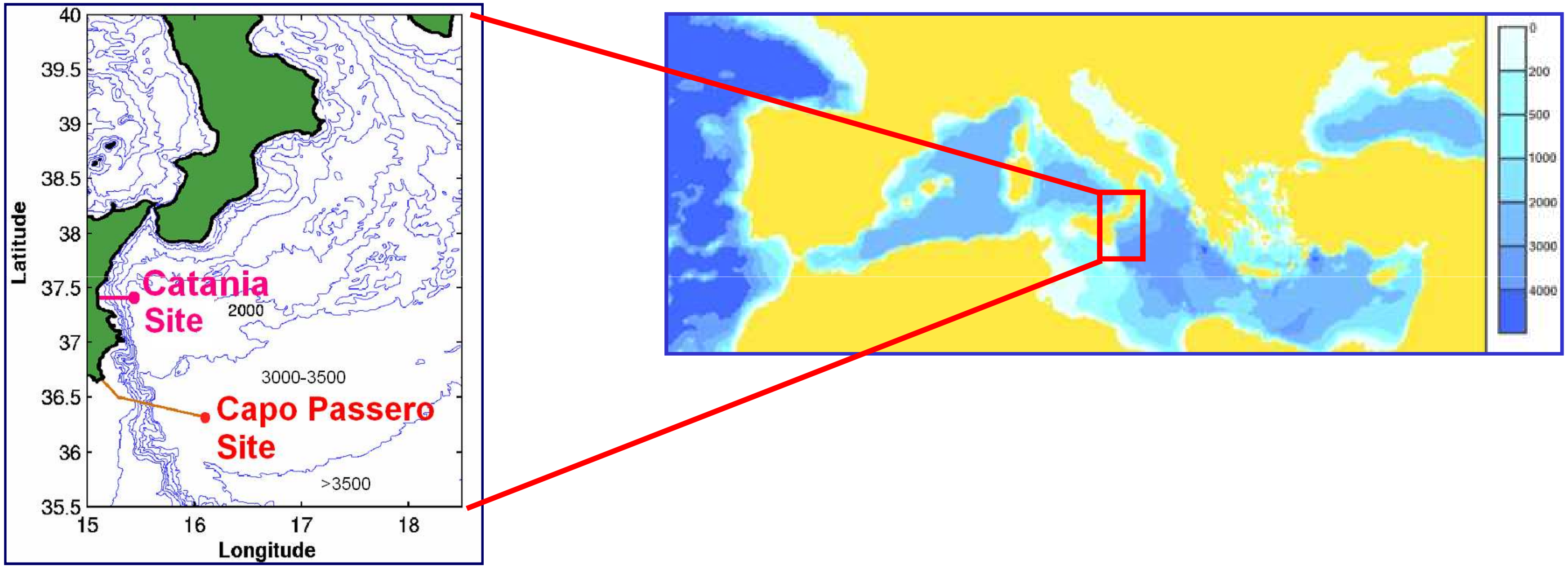
Sensitivity ratio between 127 towers vs 84 towers = 1.3

NEMO Towards the Mediterranean km^3: technological R&D



Nemo Phase 1: The Catania Test Site

NEMO Phase 1 is installed in the Ionian Sea, 25 km East offshore the port of Catania (East Sicily) at 2050 m depth.



INFN has also deployed a new 100 km cable in Capo Passero (3500 m depth) for the project's next step

The INFN-LNS Shore Lab infrastructure in Catania

The Shore laboratory is equipped with workshops, a large structures construction hall, a data acquisition hall a computing room.

A 32 Mbps radio link is available to transmit data from the Shore Lab to the Laboratori Nazionali del Sud (LNS-INFN) of Catania, i.e. one of the 4 major laboratores of INFN in Italy.

INFN-LNS is directly connected (1 Gbps) to the high speed ethernet link EumedConnect and to the main Italian Internet infrastructure for research (GARR)

The NEMO Test Site Submarine Infrastructure

Cable (INFN property) features

10 optical fibers ITU-T G-652

6 electrical conductors Φ = 4 mm²

(3-phase AC Power cable)

North branch 5.220 m
2 direct fibers
2 fibers North-South

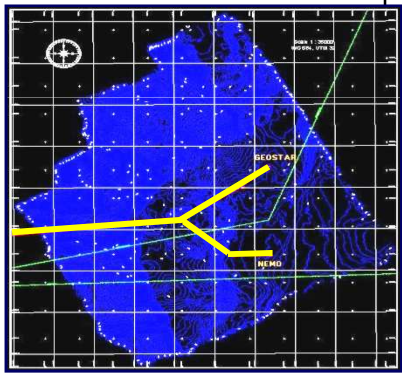
SN1:
Earth and
Sea Science

Joint — Frame

Double armour cable
2.330 m

Single armour cable
20.595 m

BU



Joint — Frame

South branch 5.000 m
4 direct fibers
2 fibers North-South

NEMO
OnDE,Phase-1

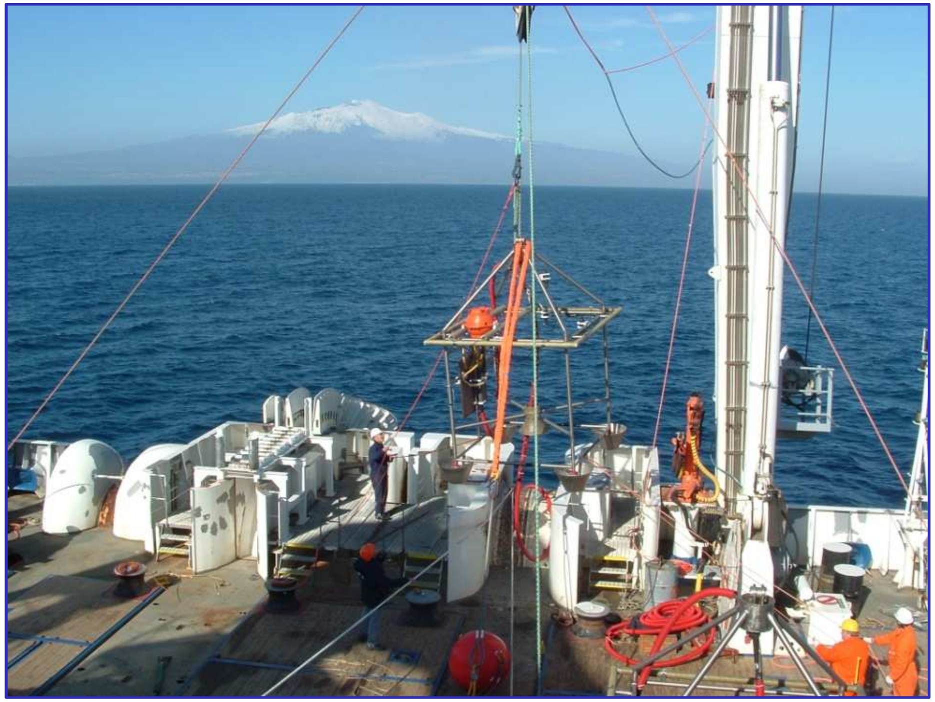
Installation Schedule

2005 ***Cable termination recovery. Frames, SN1 and OnDE installation***

2006 ***Deployment and operation of NEMO phase 1***

January 2005: Cable Joint and Frame Installation

The operation was performed on January 2005, using the Elettra Tlc-Pertinacia C/L. The mission consisted in: recovery of cable termination, frame installation, frame deployment and station activation both at North and South branch. About 7 days were required for the whole opeartion.



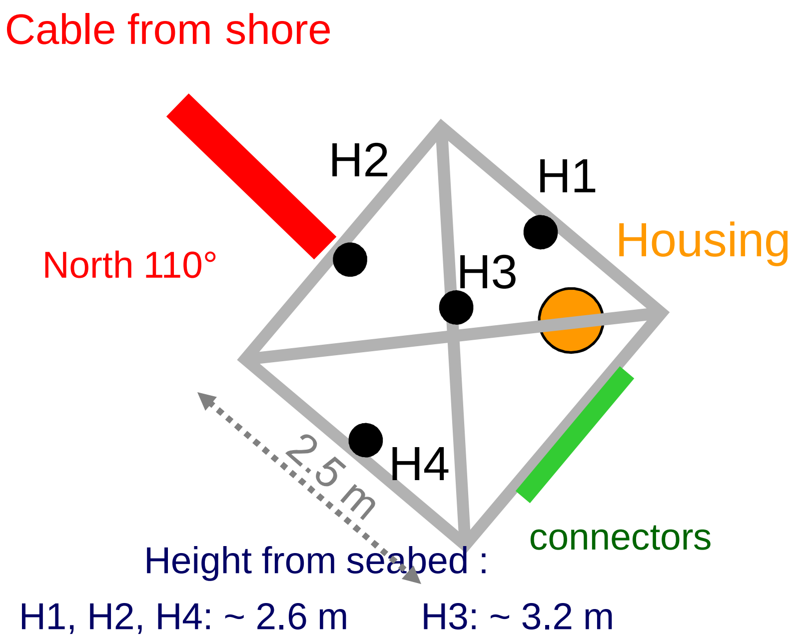
The frame is a titanium structure, about 3 m high, equipped with two ROV mateable electro optical connectors that provide connection to shore.

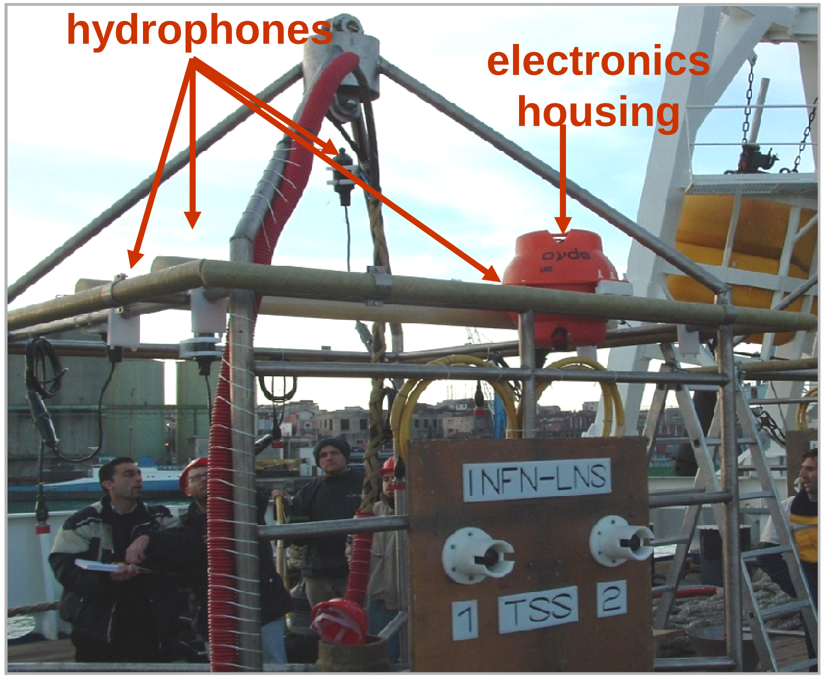
OνDE: Ocean Noise Detection Experiment

The first deep sea cabled scientific acoustic station in the Mediterranean

Goals: Deep sea acoustic noise monitoring
Bioacustics

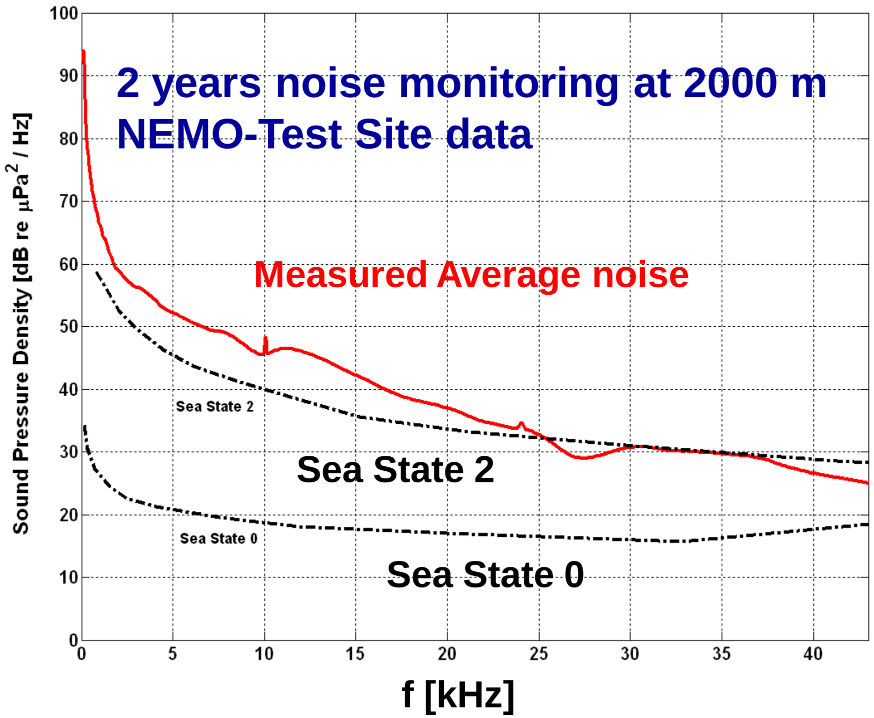
Equipped with 4 hydrophones (10 Hz-40 kHz bandwidth) synchronized.
Acoustic signal digitization (24bit@96 kHz) at 2000m depth.
Data transmission on optical fibers.
On-line monitoring and data recording on shore.
Data taking from January 2005 to November 2006 (NEMO Phase 1 deployed).



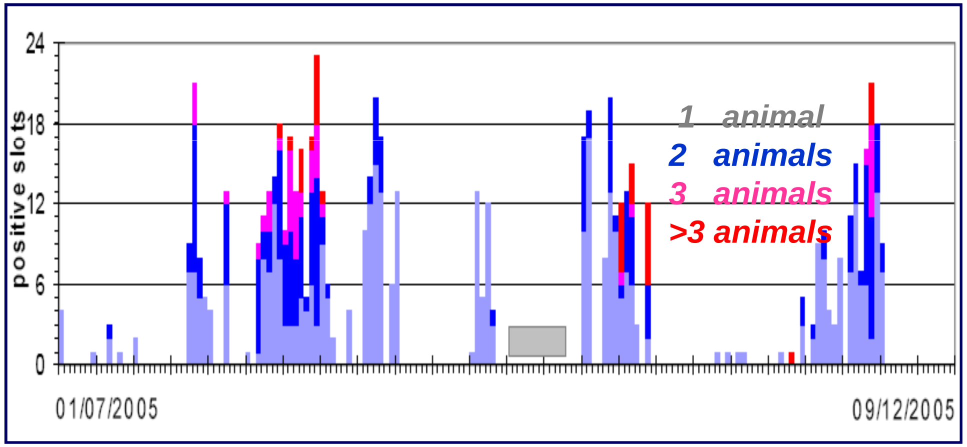


OνDE First Results

Study of acoustic background level and its variation as a function of time (due to weather, seismic, biological and anthopogenic sources).
Fundamental parameter to simulate acoustic neutrino detector response.
Signal pattern recognition and source tracking is on going.

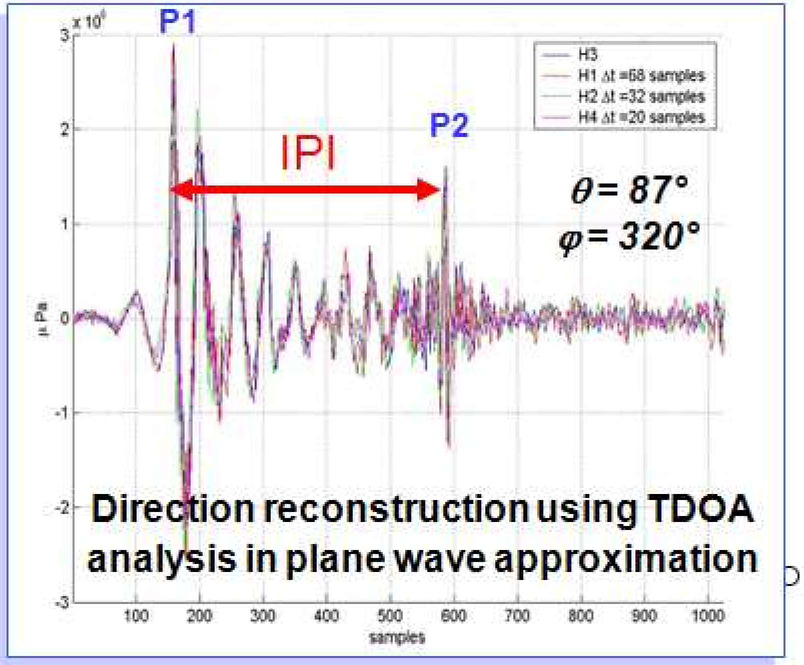


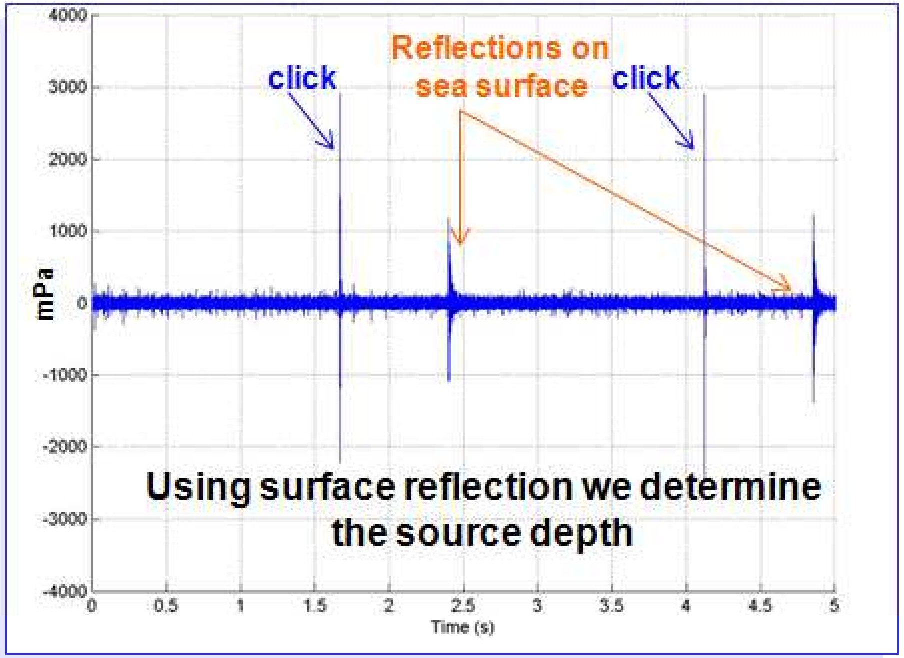
Cetaceans detection in >10 km range

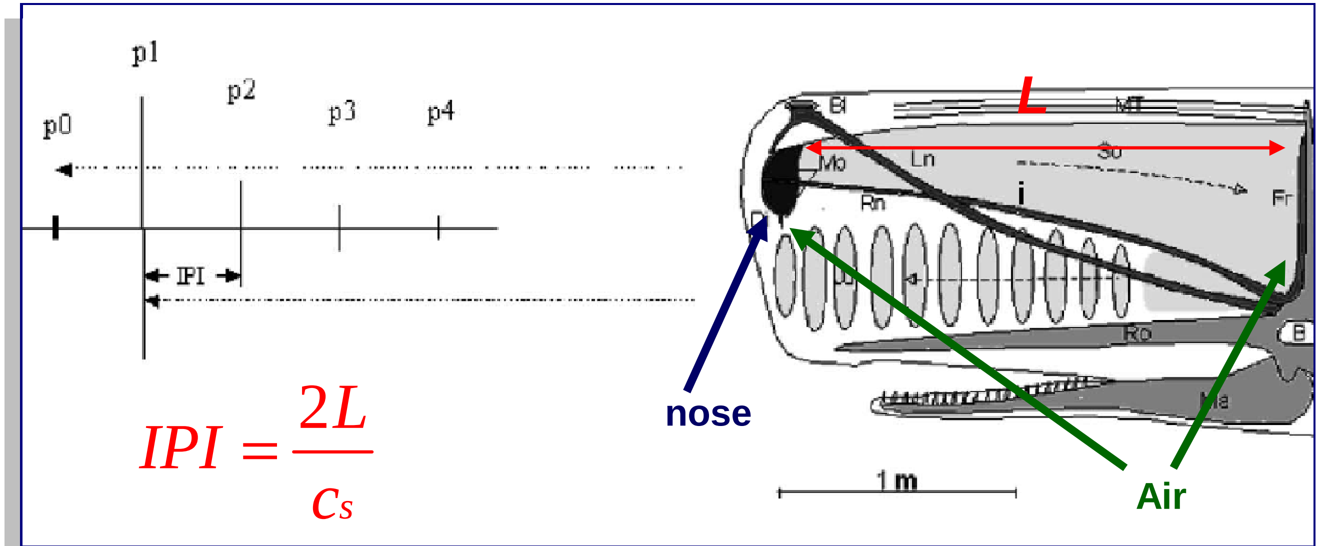


The results indicated also a presence of sperm whales more frequent than previously observed. Long term observation and signal tracking is used to determine marine mammals presence and seasonal routes. (Science, Feb 2007)

Bioacustic: Sperm-whale click analysis







$$IPI = \frac{2L}{c_s}$$

Depth = 560 ± 5 m

L = 3.41 ± 0.05 m
Size = 9.72 - 10.50 m

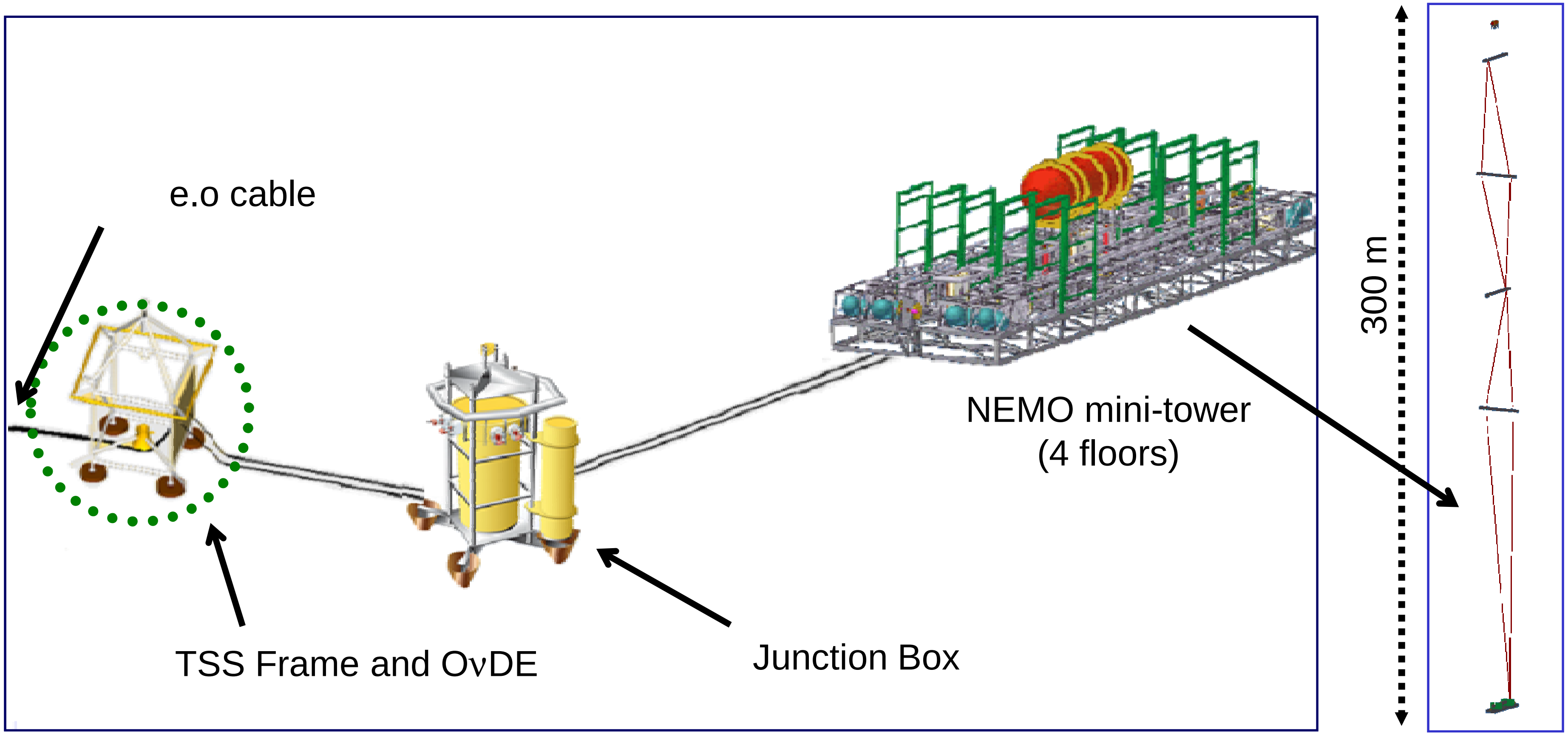
Young male or female

NEMO and ESONET

The NEMO Test Site is now the only cabled site of ESONET- EMSO the European Earth and Sea Science Network of Excellence

NEMO Phase-1

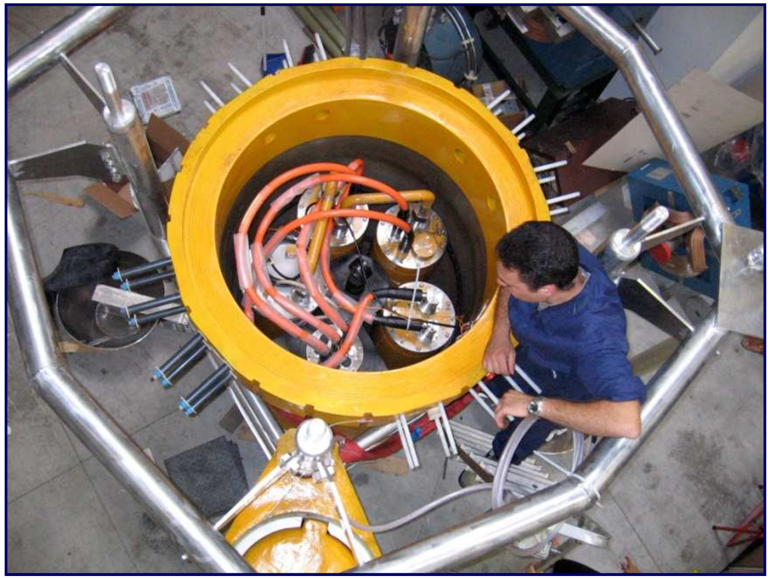
Phase 1, installed in December 2006, is a fully equipped deep-sea facility to test prototypes and develop new technologies for a neutrino telescope.



The Junction Box

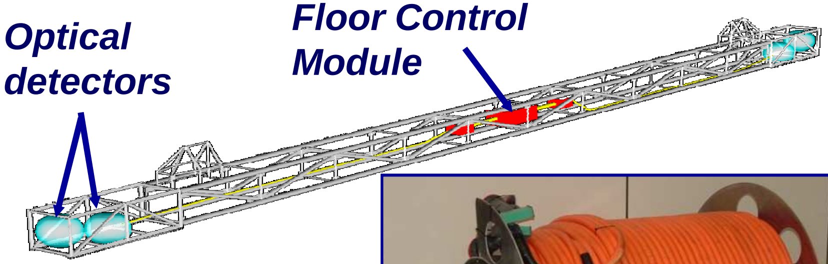
The JB is a fiberglass container (1 m^3) filled with silicone oil, equipped with a pressure compensator (100 litres).
The JB contains four cylindrical steel vessels hosting:

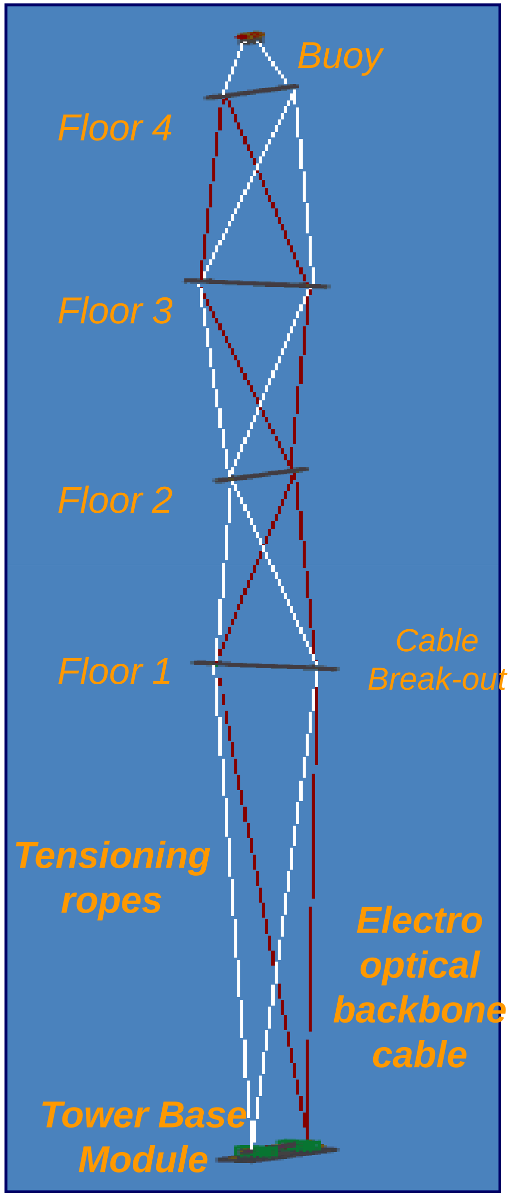
- *the optical multiplexing and data transmission control system*
- *the underwater power control and distribution system*
- *5 electro-optical ROV mateable connectors (2 used for NEMO Phase 1)*



The Mini Tower

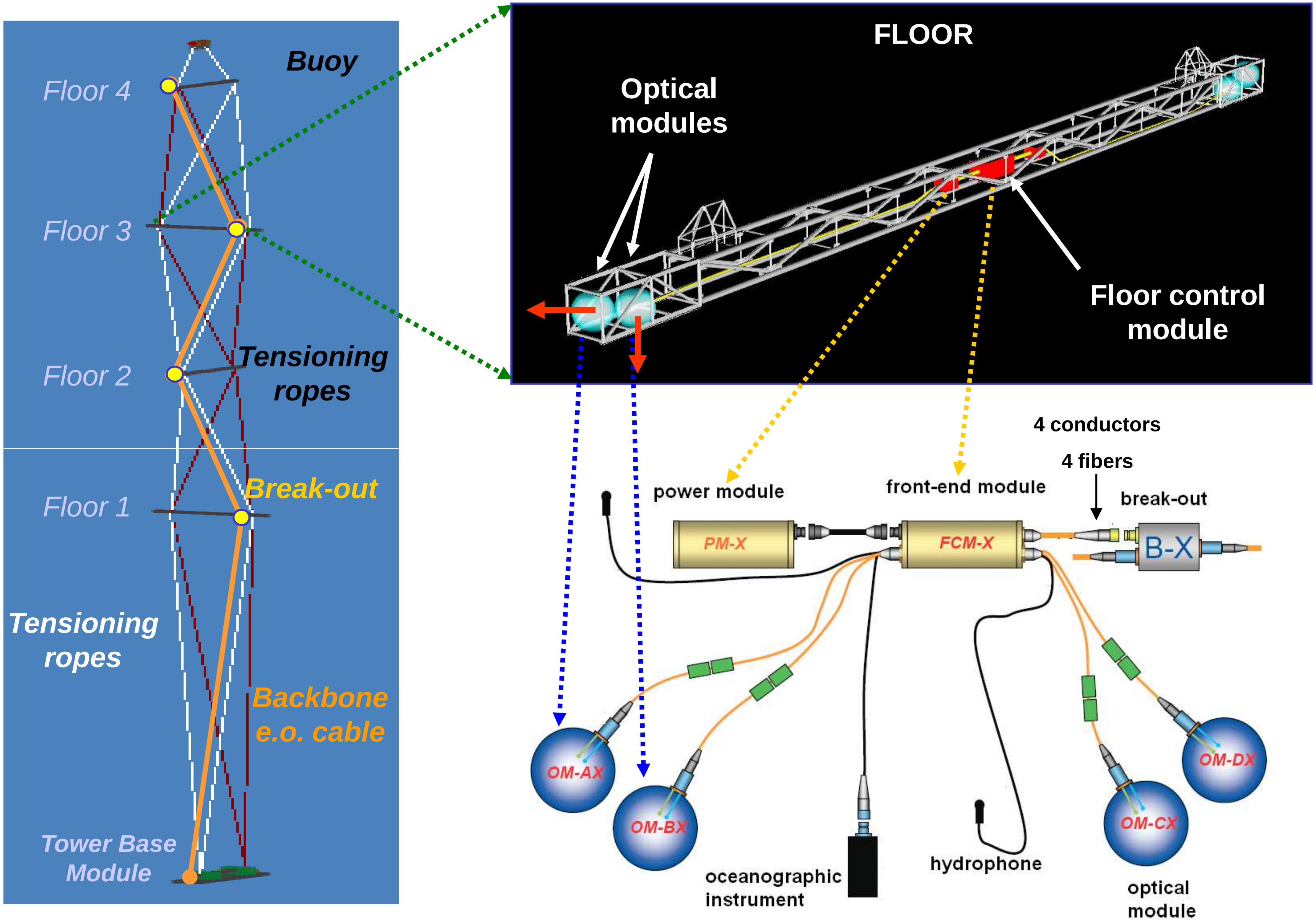
The mini-tower is a 3D flexible structure designed to hold 16 optical sensors, environmental probes (CTD, ADCP, Light Transmissometer), acoustic positioning system, compasses, data transmission and power electronics. It is composed by a sequence of floors hosting instrumentation interlinked by cables and anchored on the seabed.
The whole structure is kept vertical by a buoyancy on the top.





Floors are mechanically interconnected and tensioned by dyneema ropes

The NEMO Mini-Tower connections



Optical Modules DAQ chain: “all data to shore”

Optical Module (OM)

Hamamatsu 10" R7081 SEL

PMT tube + ISEG base

Samples and transmits signal waveform @200 Msample/s

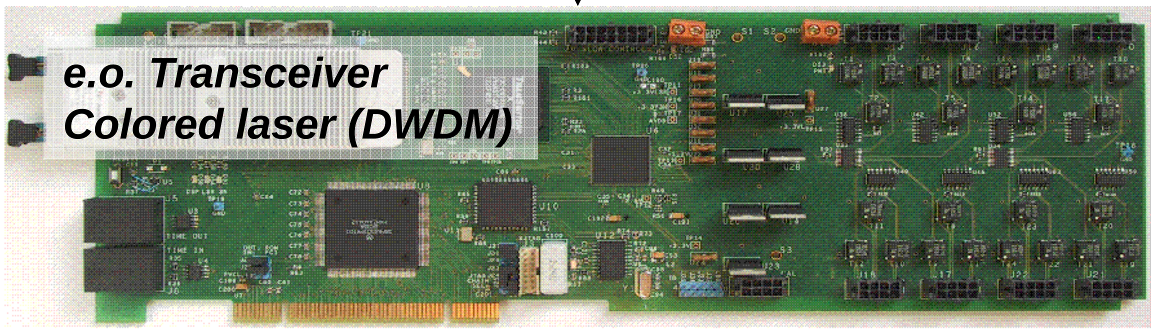
FEM board

Floor Control Module Board (FCMB)

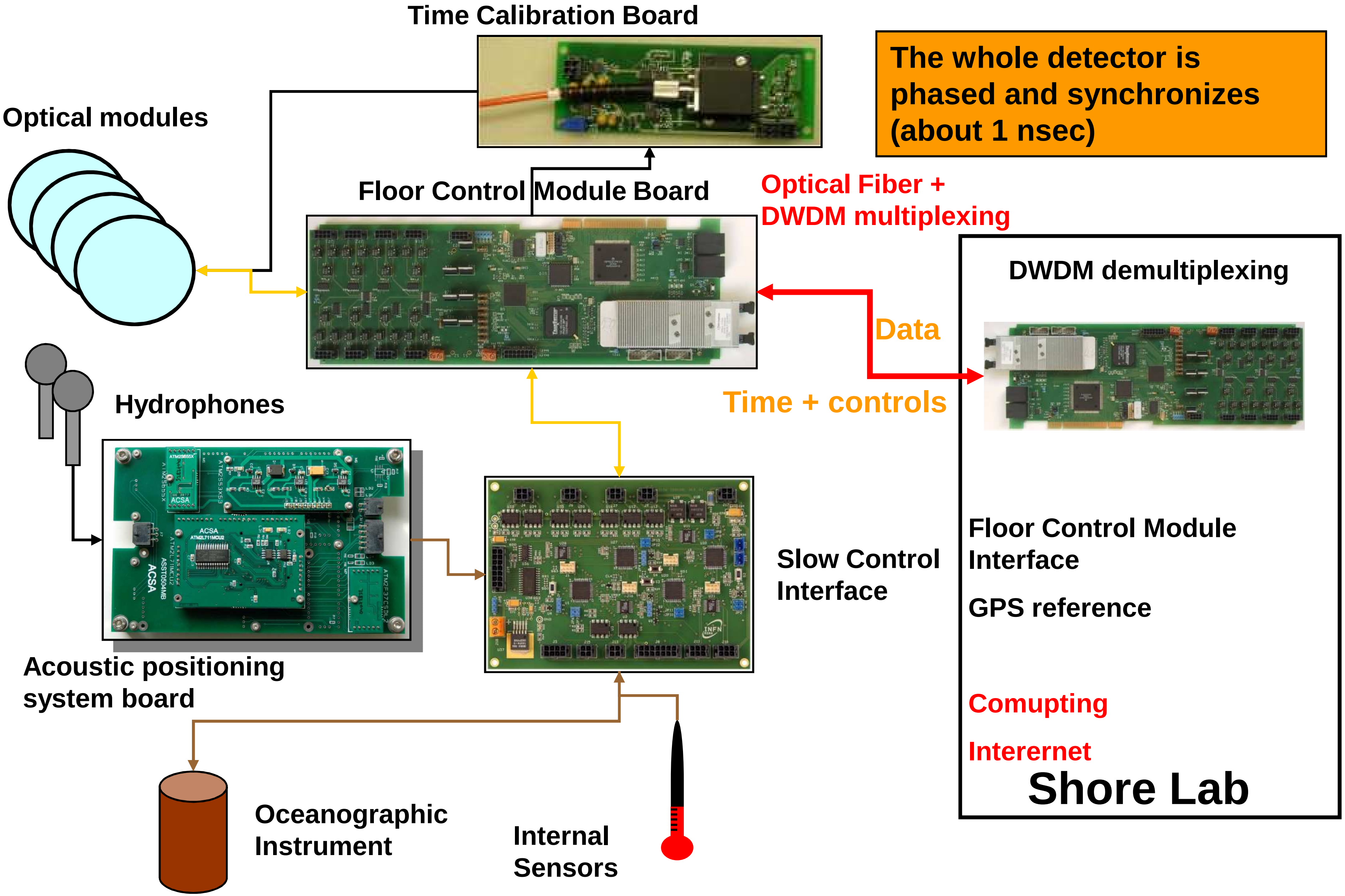
underwater electrical vable

Floor Control Module Board:

Transmits OM and Slow Control data (water parametres, OM position, internal sensors) to shore through Optical Fibre (DWDM technology)



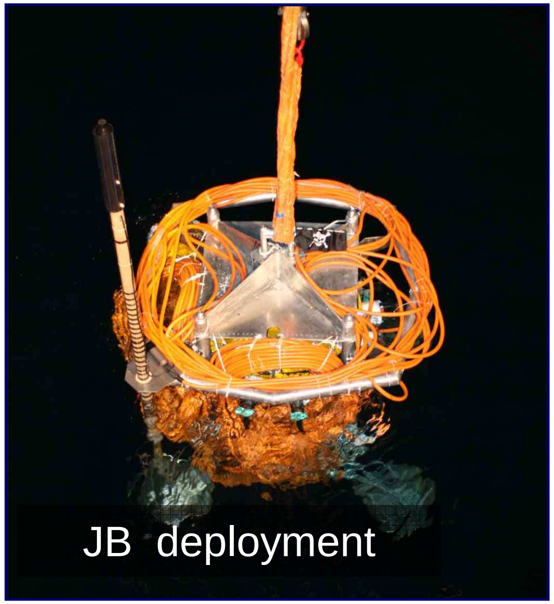
NEMO Phase 1 Data Transmission Chain: Point to Point



NEMO Phase 1 Installation

Phase 1 Installation was carried out on December 2006 using the Elettra Tlc- Teliri C/L. Starting from the port of Catania (logistic base of the Elettra Tlc.)

NEMO Phase 1 Installation


JB deployment


Mini-tower deployment

Mini-tower on the seabed

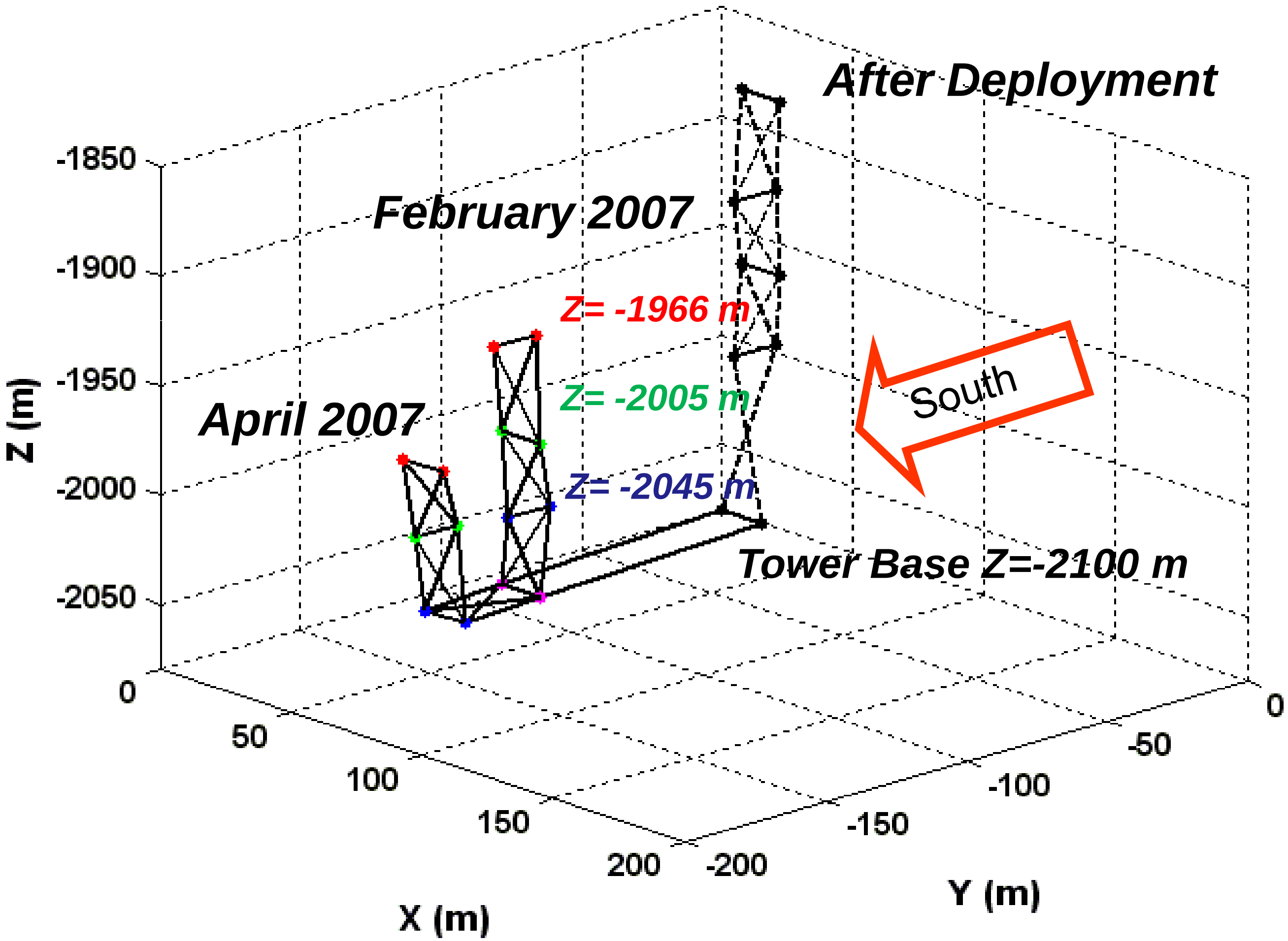

JB connection to the tower

Mini-tower buoy release
Mini-tower unfoding

Acoustic Positioning Data

An annoying accident: they buoy slowly loss buoyancy
The tower started to descend and laid on the seabed from late april 2007

Tower Position reconstruction through the acoustic positioning system



Optical Modules data

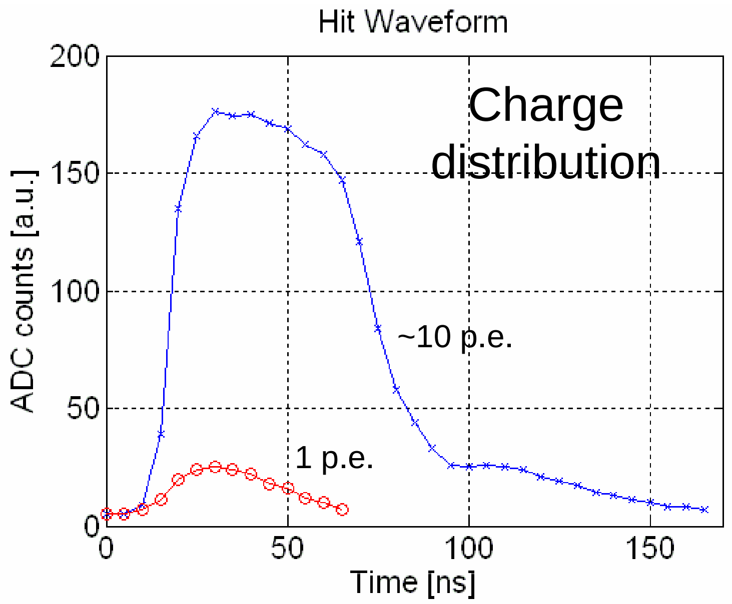
Optical Module Data:

Signal Digitization Sampling ~ 200 MHz

Time resolution ~ 5 ns

Charge Threshold ~ 0.4 p.e.

Trigger Window 4-10 μs



TRIGGER On-Line → 4 Seeds Implemented

1- Simple Coincidence (SC)

Coincidence between 2 close hits in the same storey

$\Delta T_{CS} \leq 20$ ns

2- Floor Coincidence (FC)

A SC in coincidence with a hit recorded by a PMT located in the opposite site of the storey

$\Delta T_{FC} \leq 200$ ns

3- Charge Shooting (CS)

A hit exceeding a charge threshold

4- Random Trigger (RT)

Open randomly a window of 1 ms with periodicy 1-10 s

Optical Data Trigger

1- Simple Coincidence (SC)

Coincidence between 2 close hits in the same storey

$\Delta T_{CS} \leq 20$ ns

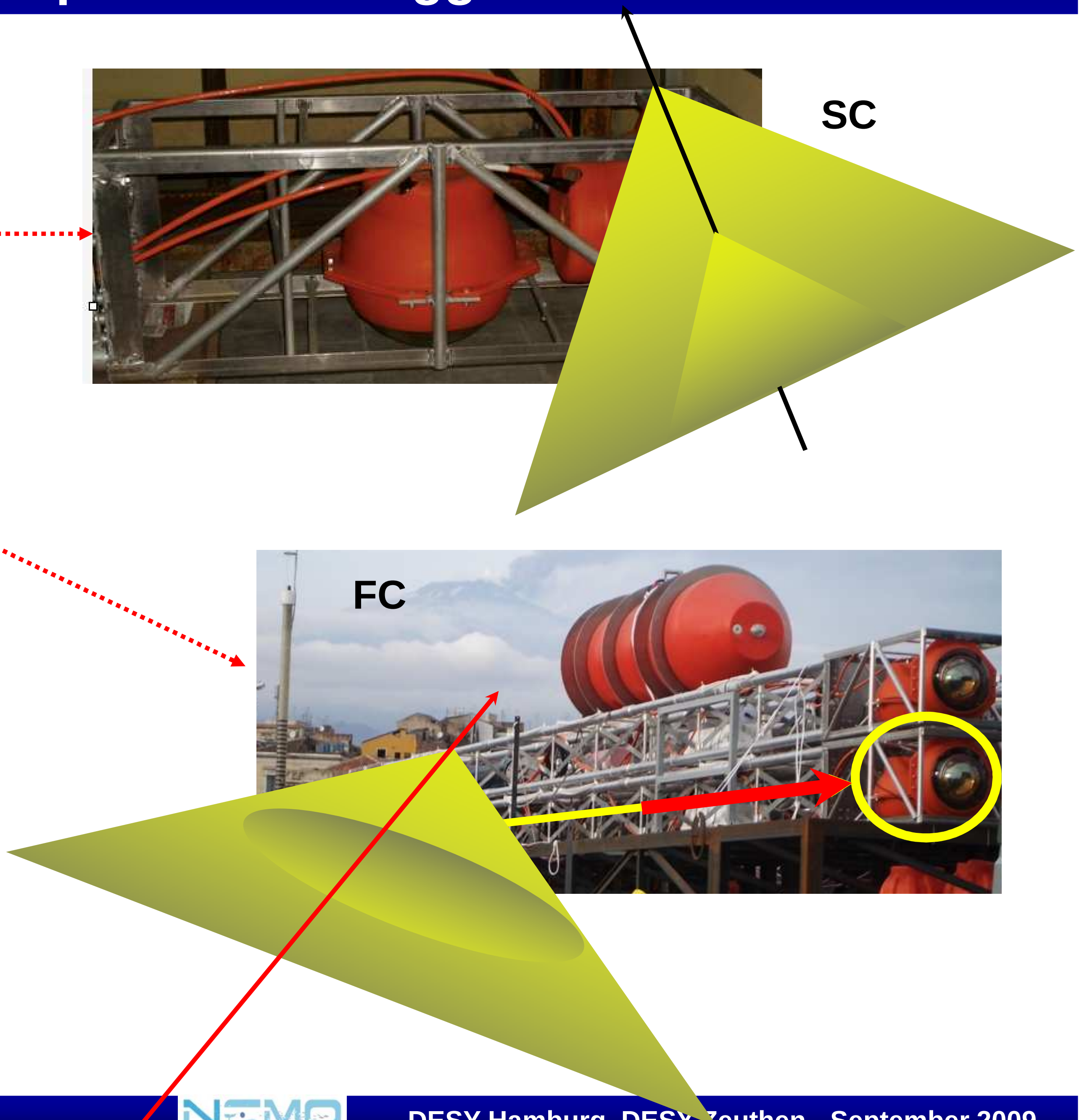
2- Floor Coincidence (FC)

Coincidence between 2 hits recordered at the opposite ends of each storey

$\Delta T_{CS} \leq 200$ ns

3- Charge Shooting (CS)

A hit exceeding a charge threshold of 2.5 p.e.



Reconstructed Atmospheric Muon Tracks

Run 15 Event 11

Date 23 Jan 2007

H. 20:21

Hit = 17

Hit Selected = 14

Hit Reconstructed = 12

θ= 168°

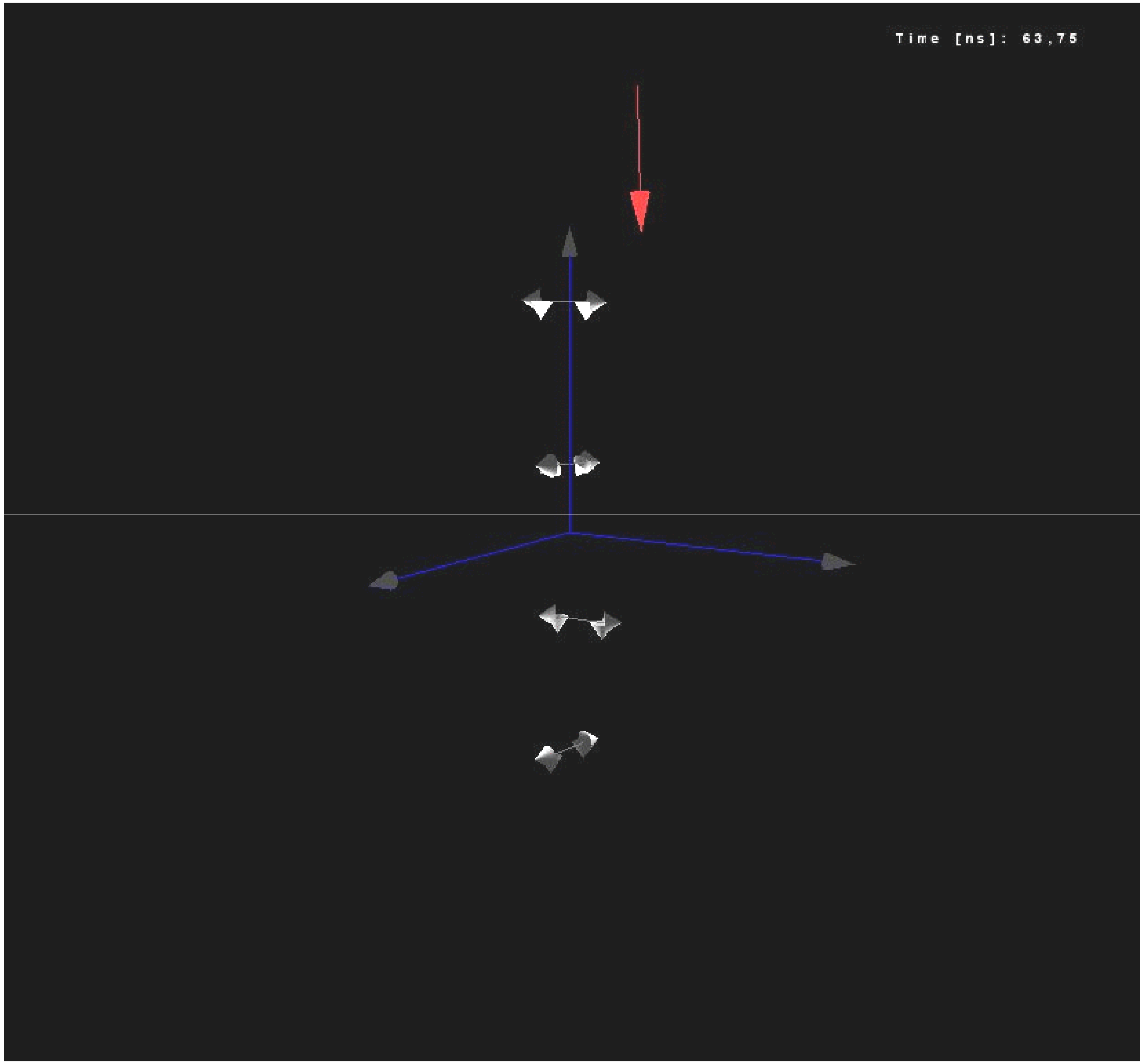
Trigger Seed = 17

SC = 4

FC = 5

CS = 8

$Likelihood_{RED}$= - 8,3



Reconstructed Atmospheric Muon Tracks

Run 17 Event 38

Date 24 Jan 2007

H. 02:20

Hit = 24

Hit Selected = 17

Hit Reconstructed = 16

θ= 132°

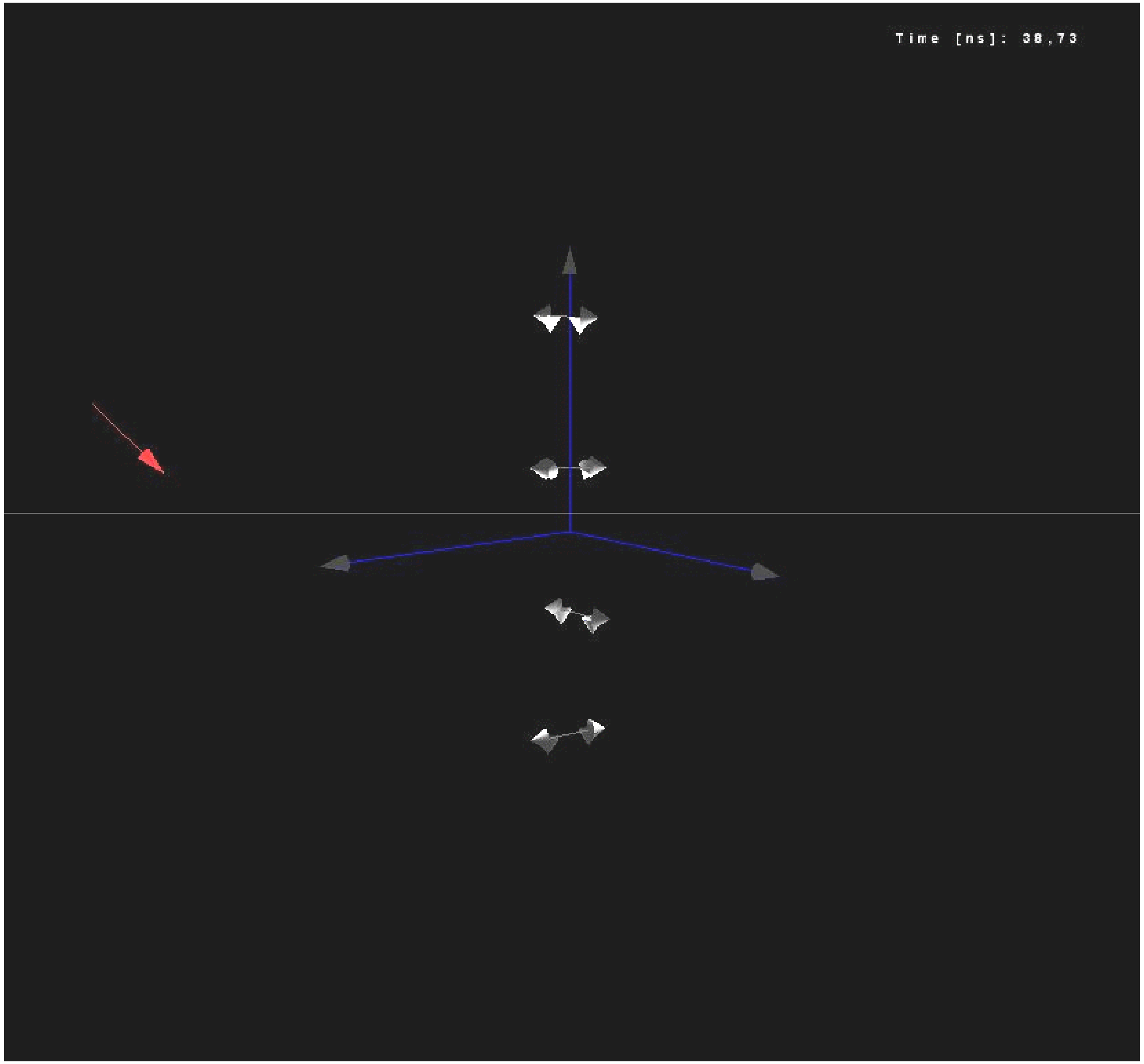
Trigger Seed = 23

SC = 3

FC = 14

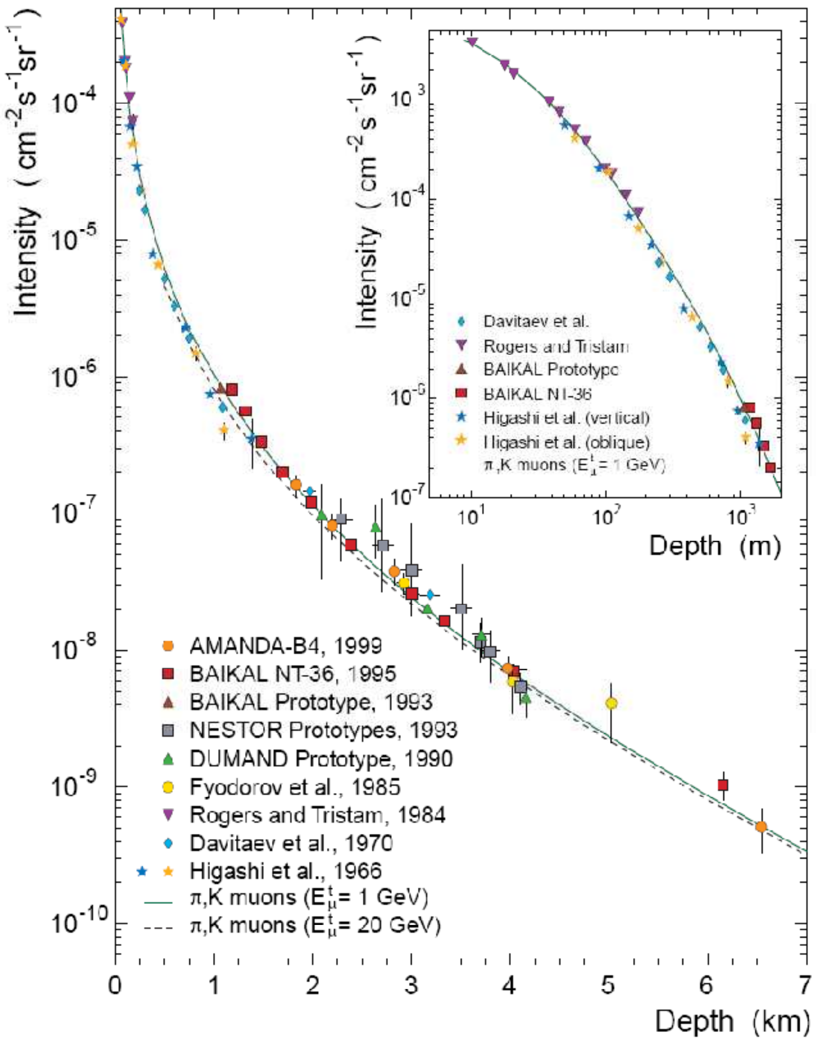
CS = 6

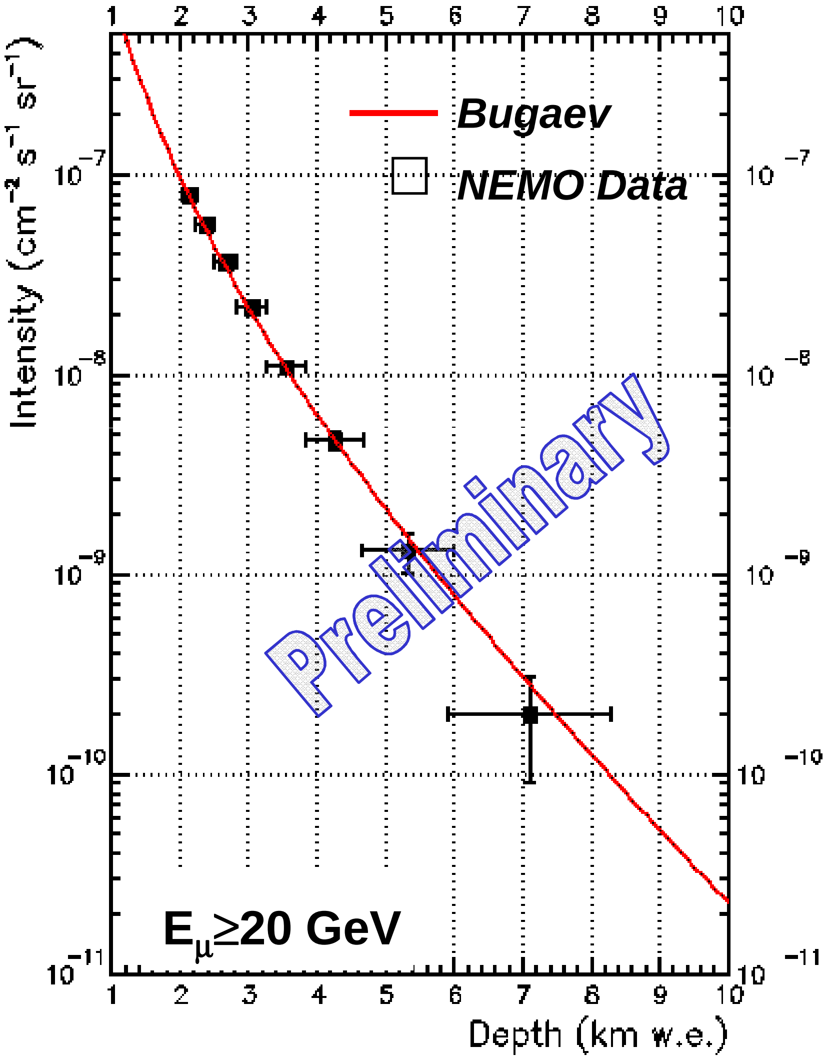
Likelihood$_{RED}$= - 6,9



NEMO Phase 1 First Results

Vertical Muon intensity as a function of depth measured.
Data are compared with Bugaev et al (1998)





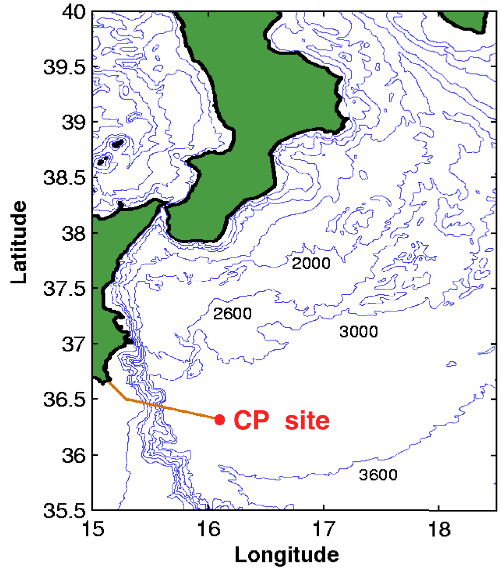
The NEMO Phase-2 and the KM3NeT Prototype

Objectives

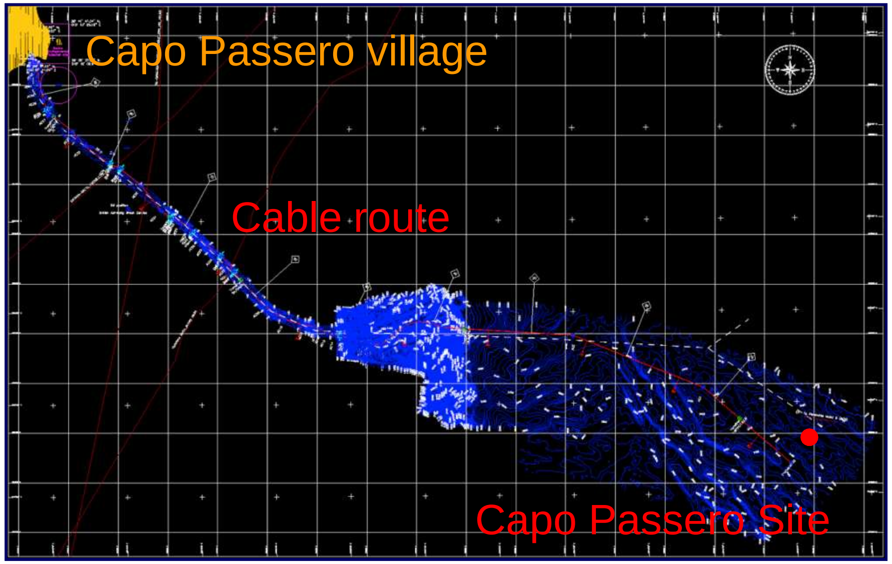
- Realization of an underwater infrastructure at 3500 m on the CP site
- Test of the detector structure installation procedures at 3500 m
- Installation of a 20 storey KM3NeT tower (16 stories“fully equipped”): NEMO / CNRS / CSIS
- Installation of an ANTARES Mini Line (4 floors)
- Long term monitoring of the site

Infrastructure

- Shore station in Portopalo di Capo Passero equipped with:
  Power Supply (60 kW @10 kV), DAQ room, Construction hall, o.f. connection to LNS
- 100 km underwater electro-optical cable
- ROV and Deep Sea Shuttle for deployment, connection and mainenance
- Underwater infrastructure: Medium Voltage Converter (MVC)



NEMO Phase 2 - Cable Installation

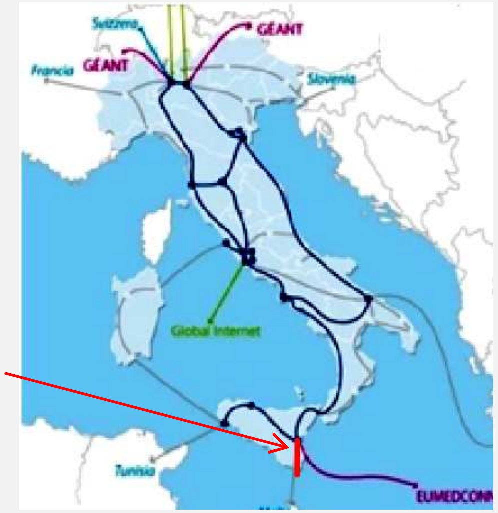


The cable (24 fibres, 1 conductor 100 kW, sea return) was deployed on July 2007 using the Elettra Tlc – Certamen C/L.

The cable fibres were continuoisly monitored from shore during the installation. Monitoring continues.

The cable is suitable for the whole km³

INFN has also applied to GARR within the new GARR-X network for an optical fibre connection (land) from the Capo Passero shore lab to the LNS.



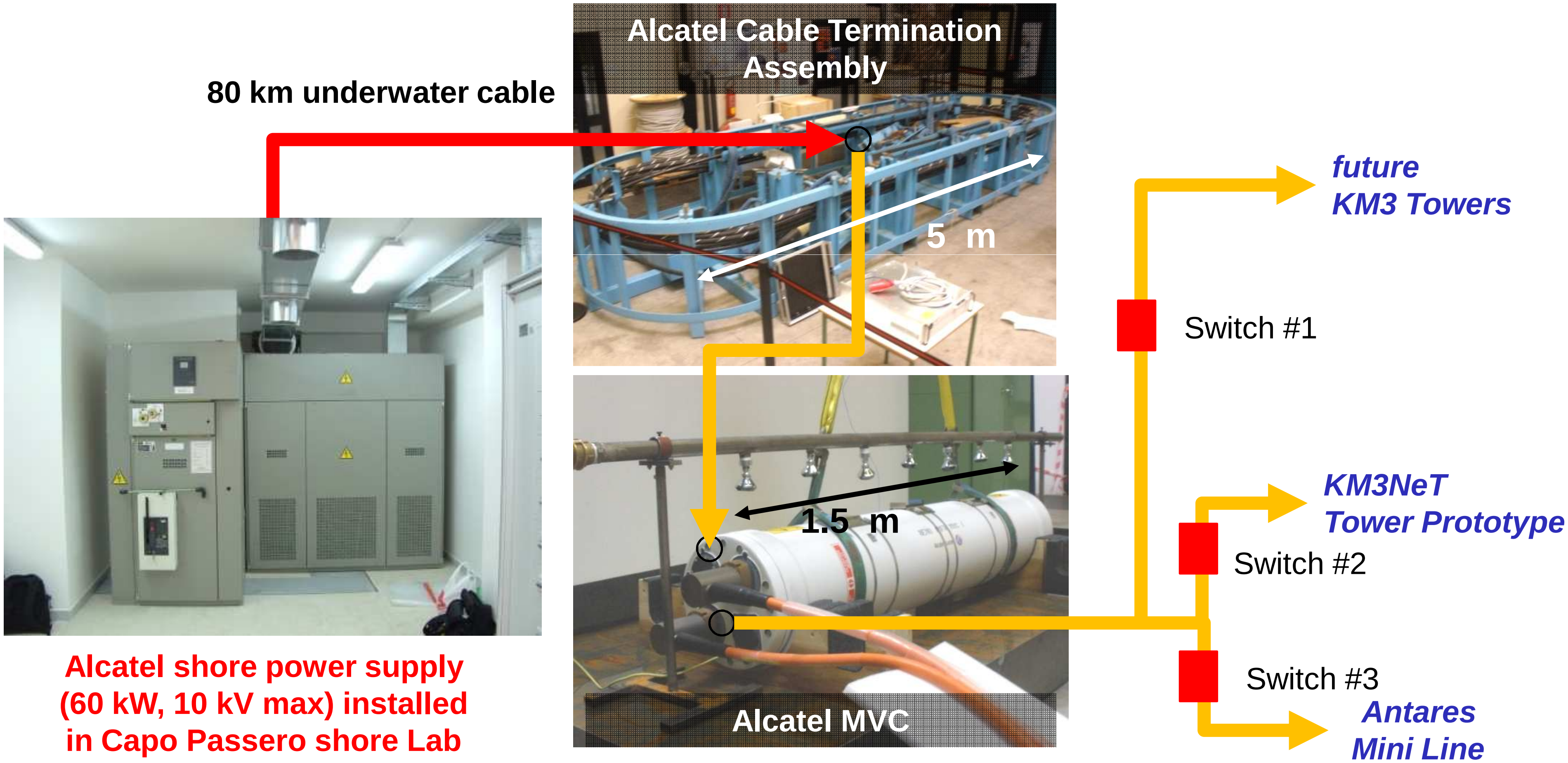
Underwater infrastructure for the km³ in Capo Passero

The underwater cable will be terminated with:

→The Cable Termination Assembly (cable optical fiber and conductor splitter)

→The Medium Voltage Converter

System Positively Tested – Deployment: October 2009



Underwater infrastructure for the km³ in Capo Passero

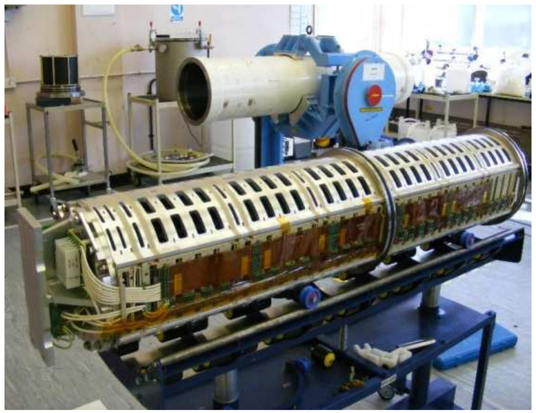
The Medium Voltage Converter:

10 kV-DC from shore (60 kW at full work load) to 375 VDC

Max output current 25 A, Operational with no load, Output Voltage ripple 1.5 V

Voltage Overshoot and Undershoot on boot/stop: 8%

Safety switch off at 100 A output for t > 30 µs



48 sub converters: 200Vin - 50Vout
divided in to 6 stacks each with a control unit.

The 48 sub converters have:
- Inputs in series
- Outputs in series/parallel matrix

Large number of Sub Converters can fail without loss of output current, (50%).

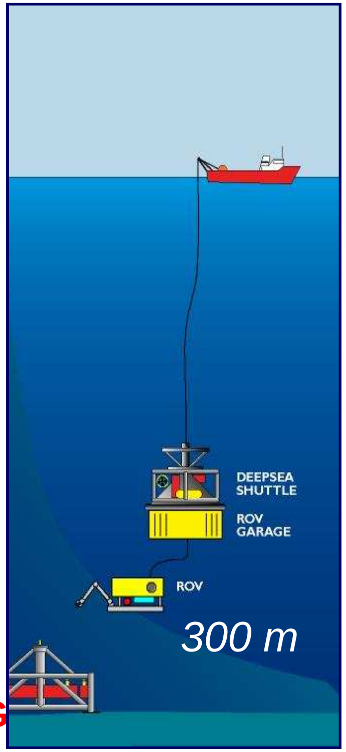
Cooling system in Fluorinert.

Topology used in space crafts by JPL NASA and designed for the Deep-Sea Observatory Neptune (USA).

The PEGASO ROV and Deep Sea Shuttle

Cougar Seaeye ROV upgraded to 4000 m
The DSS holds ROV garage or heavy structures
The ROV moves horizontally (300 m theter cable)

Very first dive test (Sept. 2009)power failure at 1500 m.
Seaeye is repairing the damage.
Next test Oct. 2009



The ANTARES Mini Line

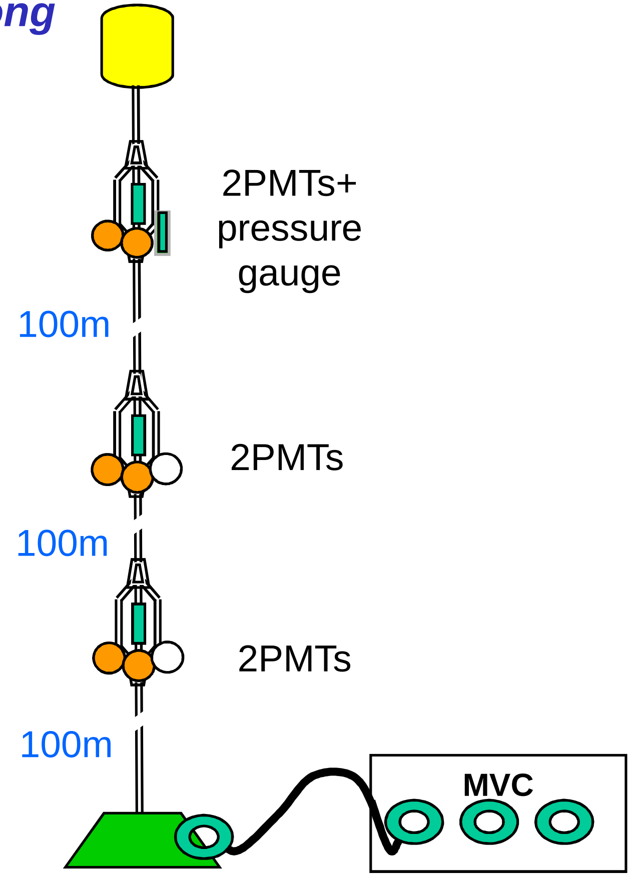
Comparison in the same environmental conditions of the two presently available detector designs with respect to:

- *Response to the external solicitations (sea current)*
- *Sea operations and ROV connections*
- *Bioluminescence stimulated by the structure*

Monitoring of the NEMO site with a similar apparatus used in ANTARES

Deployment October 2009

3 electro optical cables 100m long
1 pressure gauge on top storey
2 OMs /storey for coincidence



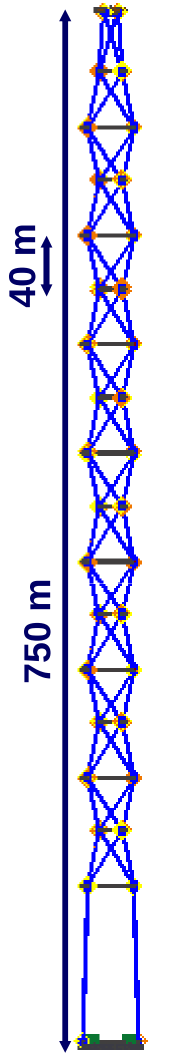
KM3NeT prototype tower

A tower mechanical demonstrator (12 floors) is ready: deployment October 2009

A full Tower of 20 floors (16 instrumented) will be deployed in late 2010-2011

Construction and integration at the
Catania LNS Test Site Laboratory

The KM3NeT Prototype in Capo Passero



NEMO Tower

Installation and operation of a "full scale" tower in Capo Passero
20 floors, 16 floors instrumented, 64 Optical Modules, 750 m total height

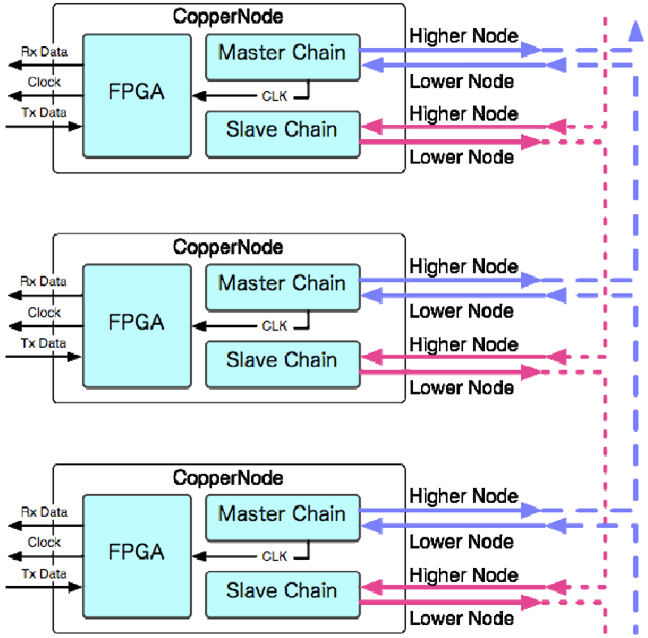
Mechanics and electronics and DAQ and DAT improved for faster integration
Studies on bar length (6 to 10 m)

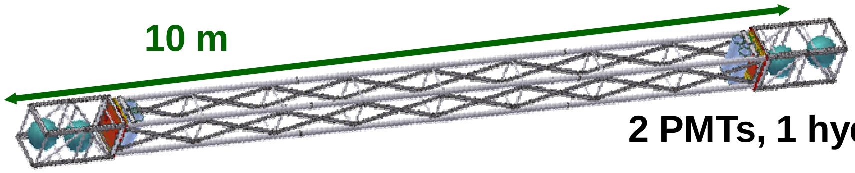
Phase-1 "like" point to point solution fully proven for the km^3.

Test of a different data transmission system based on electro-optical Daisy Chain.

Optical to electrical conversion at each node.
Optical transmission from tower base to shore.

Each detection unit has two daisy chain readout links 2.5 Gb/s by using only 2 colours (reduce the number of colors per DU)



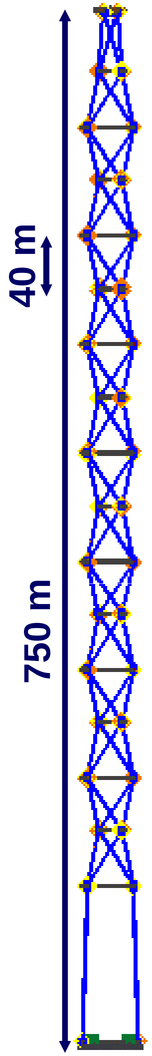


2 PMTs, 1 hydrophone

2 PMTs, 1 hydrophone

NEMO Floor

The KM3NeT Prototype in Capo Passero



NEMO Tower

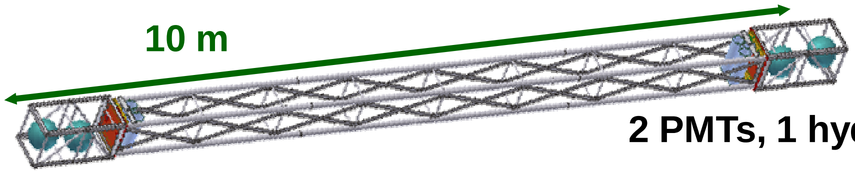
Installation and operation of a "full scale" tower in Capo Passero
20 floors, 16 floors instrumented, 64 Optical Modules, 750 m total height

Mechanics and electronics and DAQ and DAT improved for faster integration
Studies on bar length (6 to 10 m)

34 hydrophones for Acoustic Positioning …And for Acoustic Physics / Biology

→ Reduce costs and improve reliability of the tower acoustic positioning system
→ 750 m long antenna for feasibility studies on acoustic detection
→ Optical and acoustic data in the same data stream with the same time
   All signals are phased !
   A viable solution for KM3NeT

Hydrophones (SMID-NATO)	sensitivity -207 dBre 1uPa Tested for 3500 m
Preamp (SMID-NATO)	32 dB gain, 0.8 nV/ √Hz input noise
ADC-board	24 bits, 192 kHz sampling, 3 dB gain
FCM	all data to shore + GPS time stamp

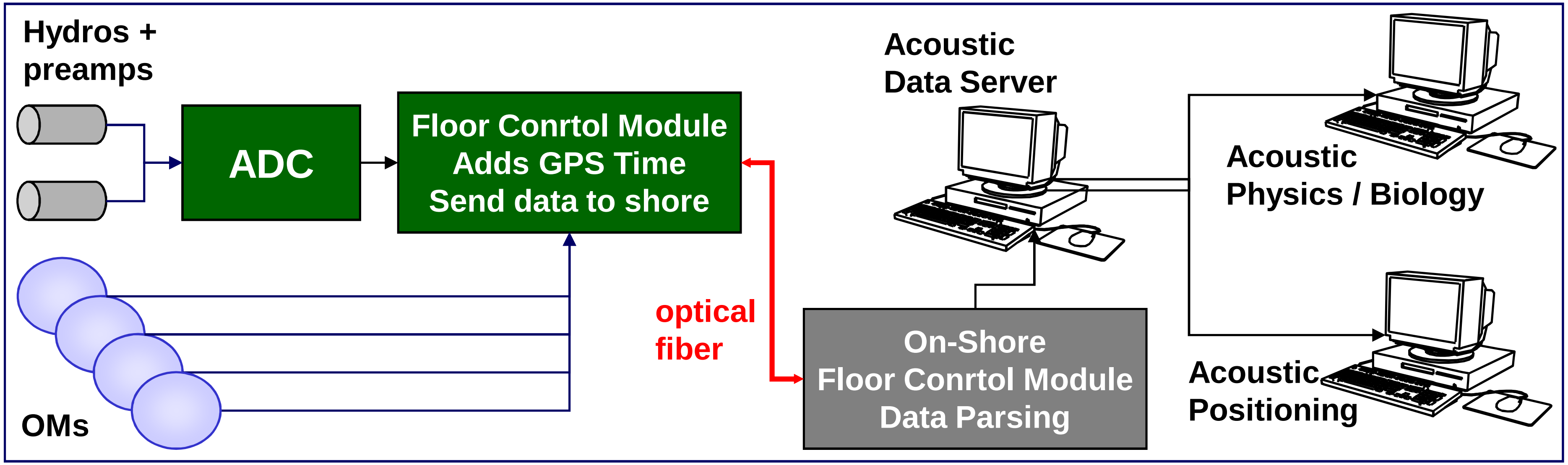


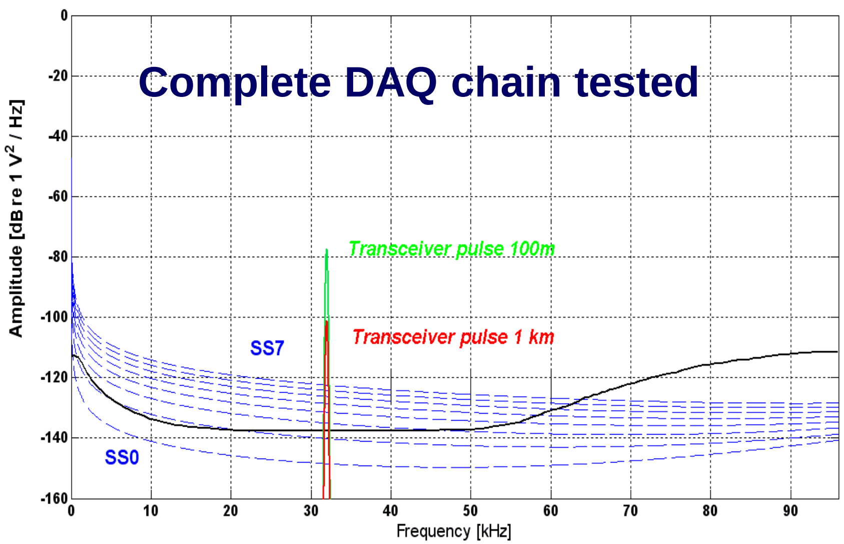
NEMO Floor

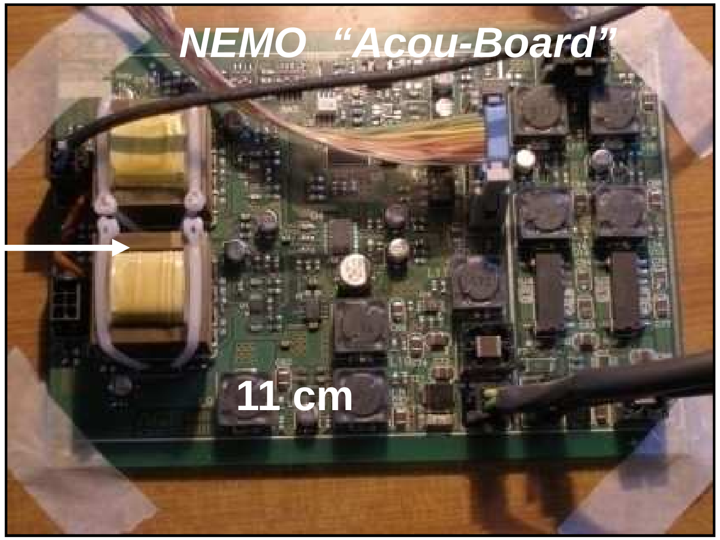
KM3NeT Prototype “Acoustic” Electronics Chain

“All data to shore” philosophy

data payload: 2 Hydros = 1 OM, fully sustainable







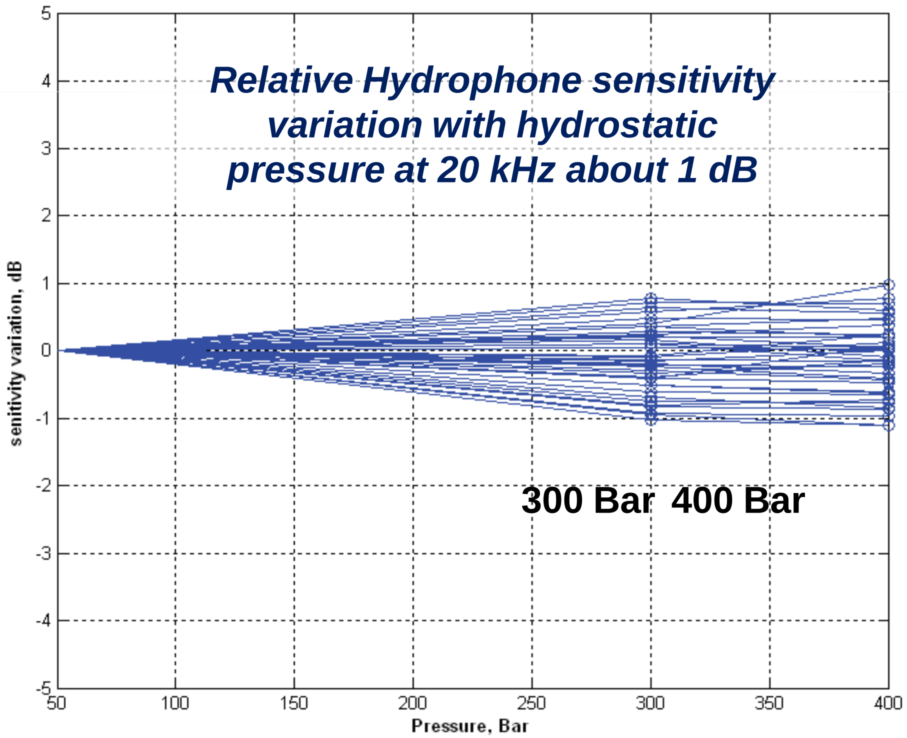
KM3NeT Prototype Acoustic Positioning: Hydrophones

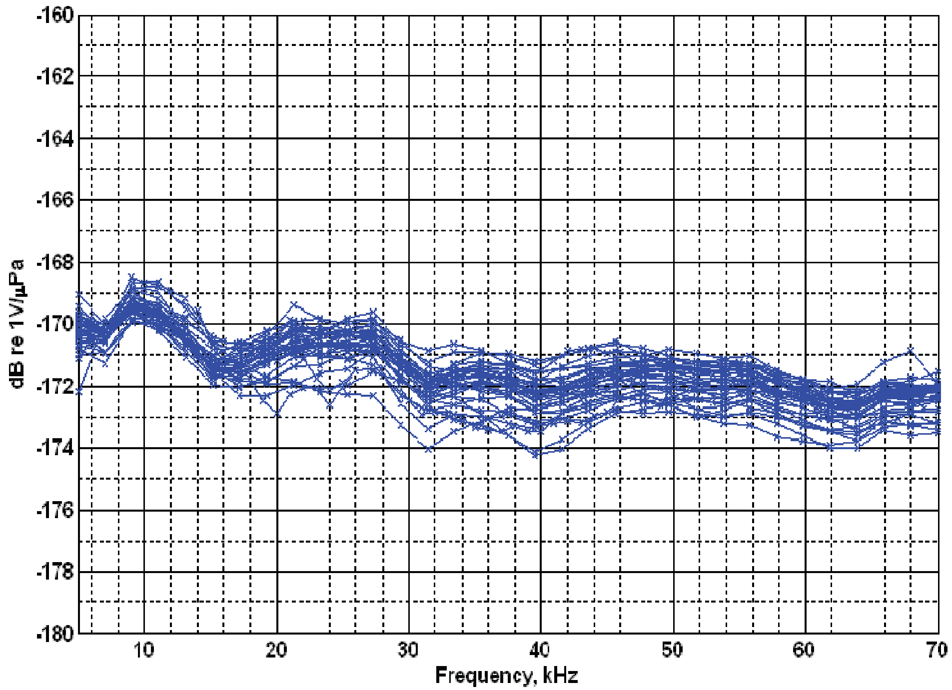
Commercial hydrophones are typically factory calibrated:
→ piston test at 250 Hz, water pool test above 5 kHz (due to reflections)
→ directionality pattern

But for many hydrophones sensitivity changes as a function of pressure (~3 dB/1000 m)

NEMO and an italian company (SMID) have ***developed low cost hydrophones for 4000 m*** *depth,* ***with no change of sensitivity as a function of depth****.*

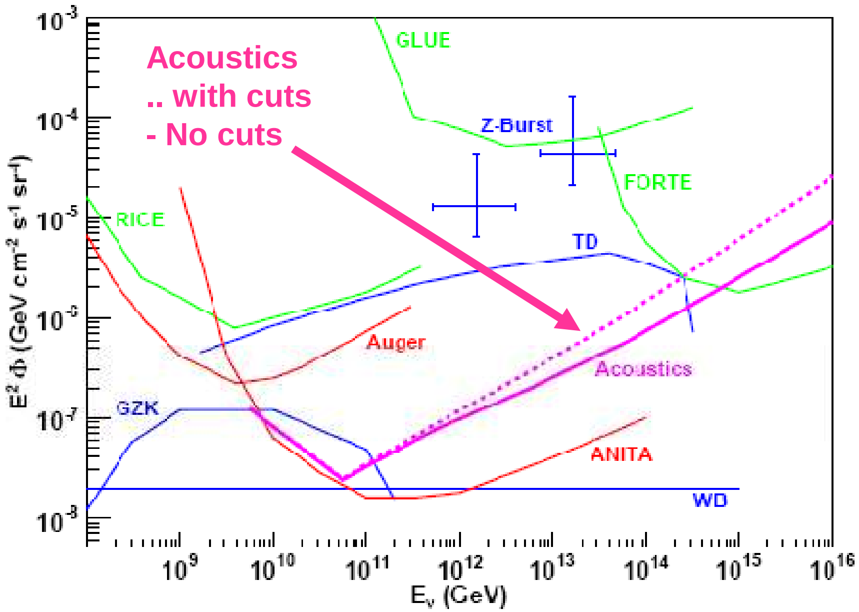
NATO has developed for/with NEMO a standard procedure for calibration under pressure





Acoustic Detector Sensitivity

ANTARES (Marseilles, Erlangen)

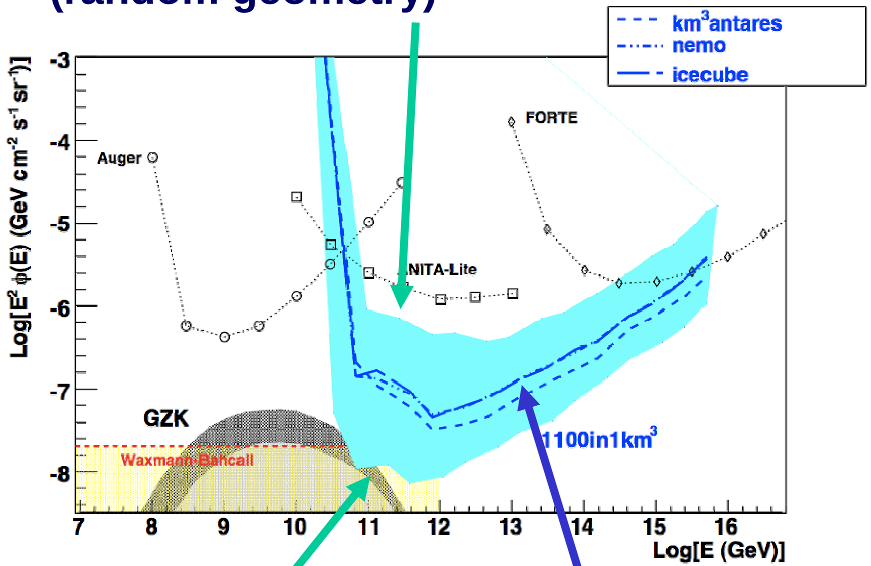


1500 km³ , 200 hydros per km³
5 years
threshold 5 mPa

ACORNE

1100 hydros in 1 km³

1 year, threshold 35 mPa, 95% CL (random geometry)



km³ regular geometries
5 years, 15 mPa, 95% CL

10 years, threshold 5 mPa, 90% CL (random geometry)

A "complementary" km³-scale detector ?

Conclusions

Neutrino astromomy is a powerful tool to investigate hadronic accelration mechanism in astrophisical sources

IceCube is providing first results on neutrino fluxes limits

The Mediterranean-km3 is expected to be more sensitive than IceCube and it will be able to look at several Galactic Sources

The NEMO collaboration:

- has selected and charaterised and optimal deep sea site for the construction of the Mediterranean km3 detetcor
- has conducted a R&D activity on detector architecture, mechanics, electronics finalised with the operation of NEMO Phase 1 in Catania
- is relising shore and deep sea infrastructures for the km3 in Capo Passero
- is developing and is going to test prototyes of the KM3NeT Detection Units in Capo Passero

Danke !