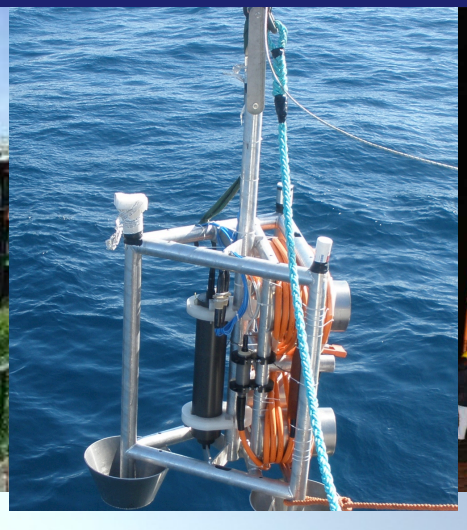
NEMO:
Status and perspectives

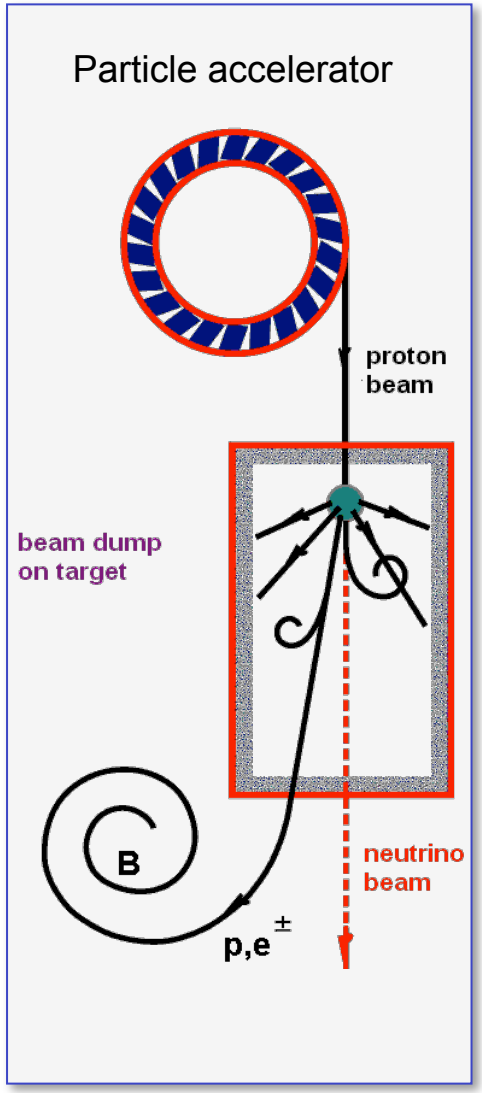


Giorgio Riccobene INFN-LNS

LNS User Committee - 22 June 2011

The astrophysical beam dump: neutrino production

Fermi acceleration of protons and electrons in astrophysical sources



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

Hadronic HE ν and γ production

p + p (SNR,X-Ray Binaries)→ X,π

p + γ (AGN, GRB, μQSO) → N,π

Same interaction as GZK

Decay of pions

neutral pions → **HE *gammas***

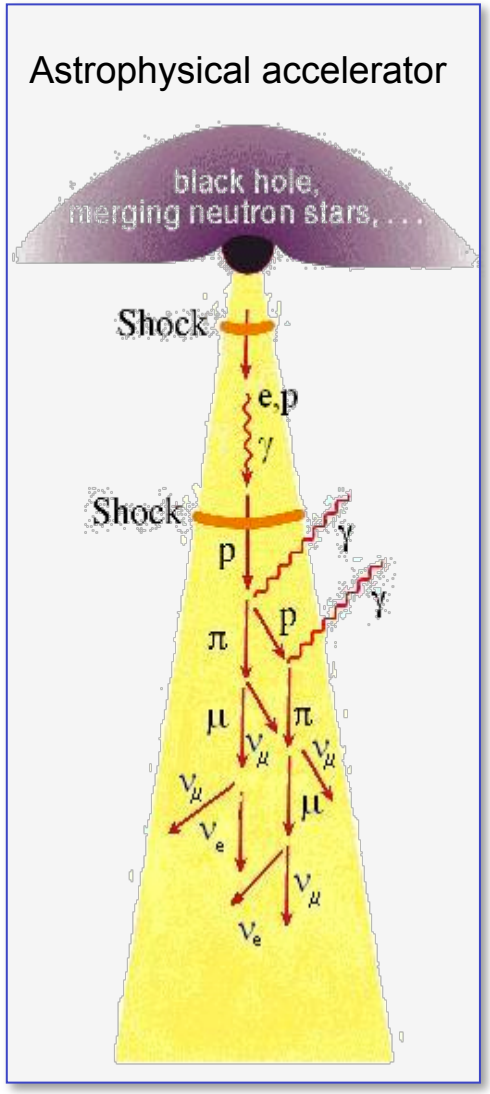
charged pions → **HE *neutrinos***

Leptonic HE γ production

synchrotron radiation followed by IC

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

$L_{attenuation}$ (γ_{HE} + CMBR)~ 10 Mpc



News from gamma rays: SNR, Galactic Centre, Fermi bubbles

Galactic SNR: p acceleration and beam-dump on nearby gas molecular clouds

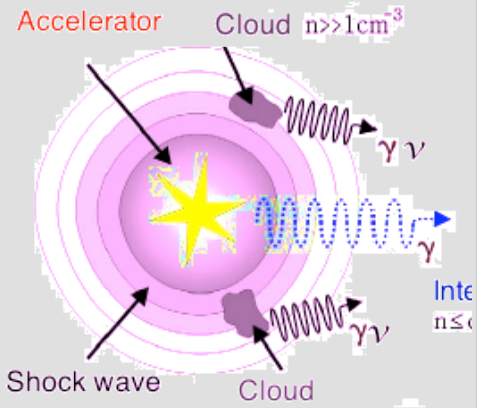
RXJ1713.7-3946

Power law spectrum $E^{-\gamma}$ observed up to several tens TeV

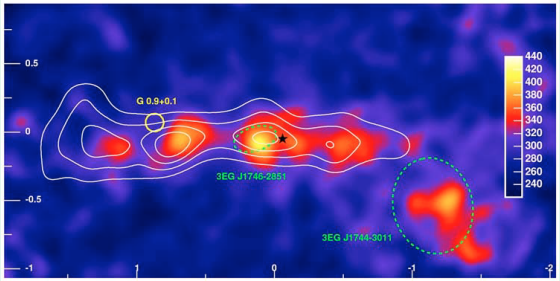
Spectral index $\gamma \approx 2$ implies acceleration of p up to 1000 TeV

Young SNR (e.g. W28)

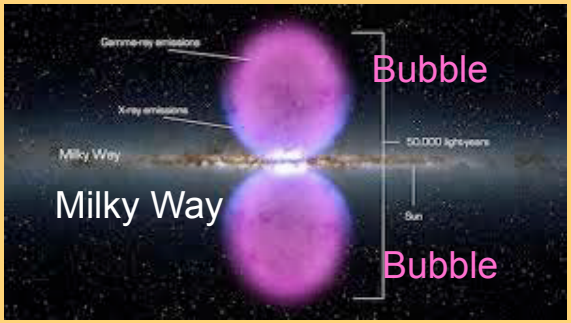
Particles E >100 TeV well confined in the shell during ≈100 years



Gamma-rays from gas molecular clouds in Galactic Centre: a result of an active phase in Sgr A* with acceleration of CRs some 10^4 yr ago?



Fermi Bubbles: result of pp interactions of CRs produced in the Galactic Centre and accumulated in D ~10 kpc regions over 10^7 yr

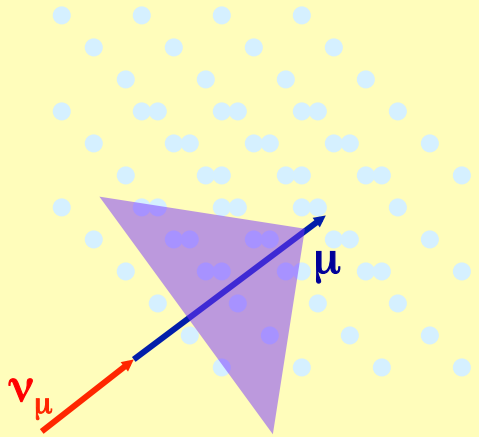


Neutrinos are the ultimate smoking gun to probe hadronic processes

Large Area Detectors for HE neutrinos

1 TeV — 100 PeV — 1000 ZeV

Optical Detection (ICECUBE-KM3NeT)



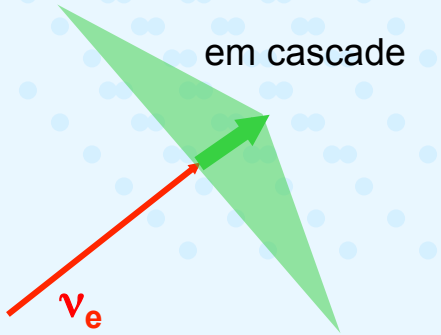
Medium: Seawater, Polar Ice

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 (ANITA, RICE, ICERAY)



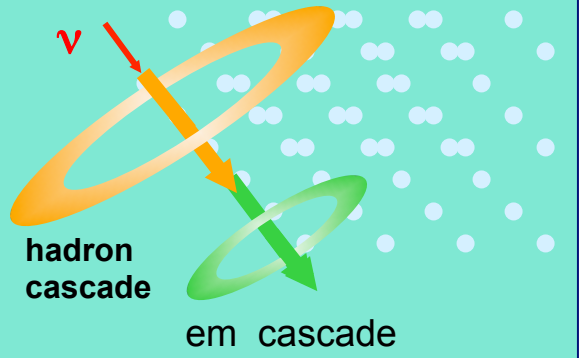
Medium: Salt domes, Polar Ice

ν (cascades)

Carrier: Cherenkov Radio
Attenuation length: 1 km

Sensors: RF-Antennas
Instrumented Volume: >>1 km^3

Acoustic Detection (SAUND, NEMO, AMADEUS)



Medium: Seawater (Salt)

ν (cascades)

Carrier: Sound waves (tens kHz)
Attenuation length: ~ 1÷10 km

Hydro-phones
Instrumented Volume: >>1 km^3

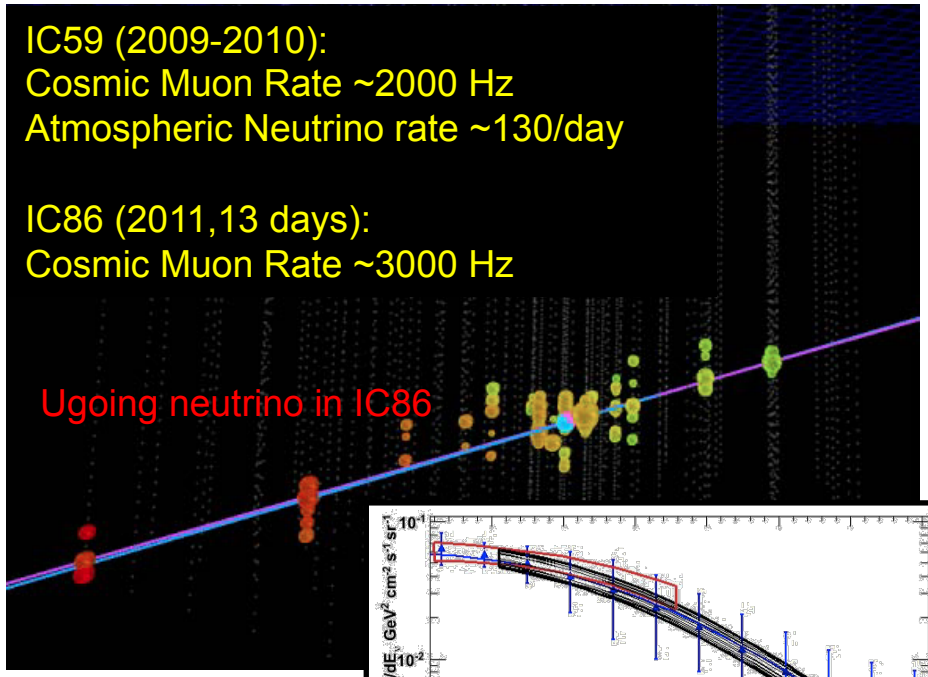
IceCube:The first km3-scale neutrino telescope

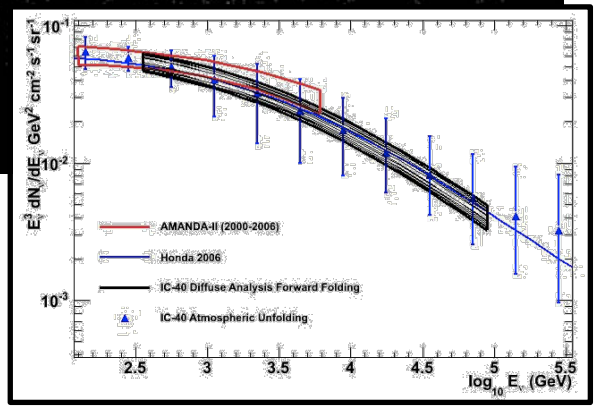
Location: Geographic South Pole
86 strings (60 PMT each)
125 m inter string distance
16 m spacing along a string
ICETOP 18 stations, Deep Core 8 lines

IC59 (2009-2010):
Cosmic Muon Rate ~2000 Hz
Atmospheric Neutrino rate ~130/day

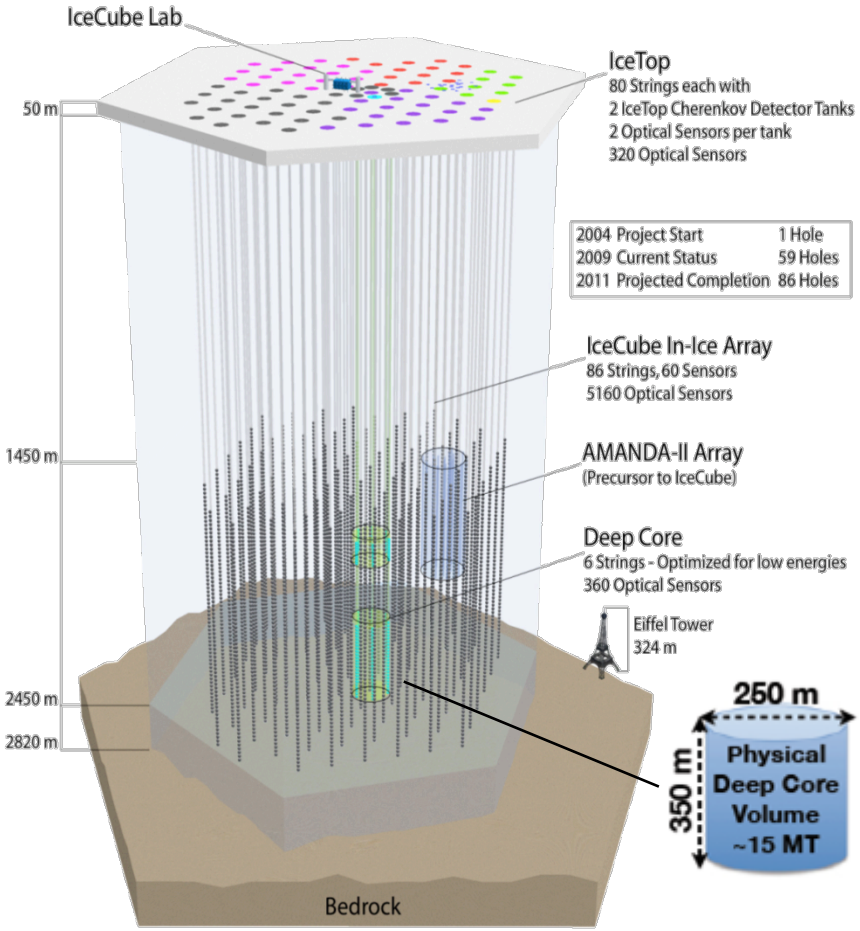
IC86 (2011,13 days):
Cosmic Muon Rate ~3000 Hz

Ugoing neutrino in IC86



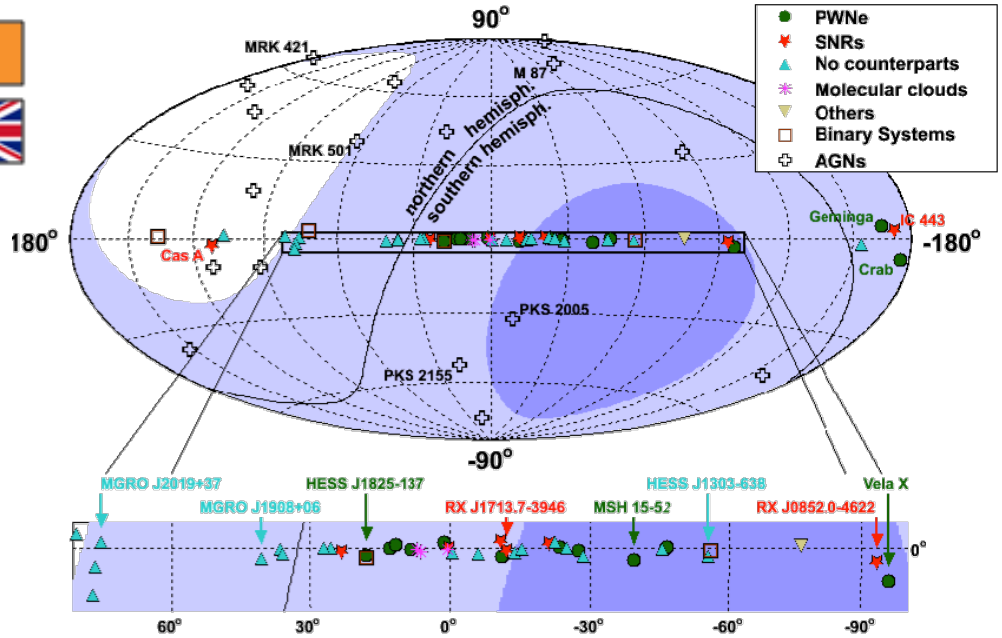


Atmospheric neutrino flux measured by Icecube



Towards the Mediterranean km^3: KM3NeT

→ **Need two telescopes (North and South Hemisphere) to cover the whole sky.**
→ **The Galactic Centre can be seen only from the Mediterranean telescope**



Born from the experience of the Mediterranean pilot projects:

ANTARES
NEMO
NESTOR

KM3NeT

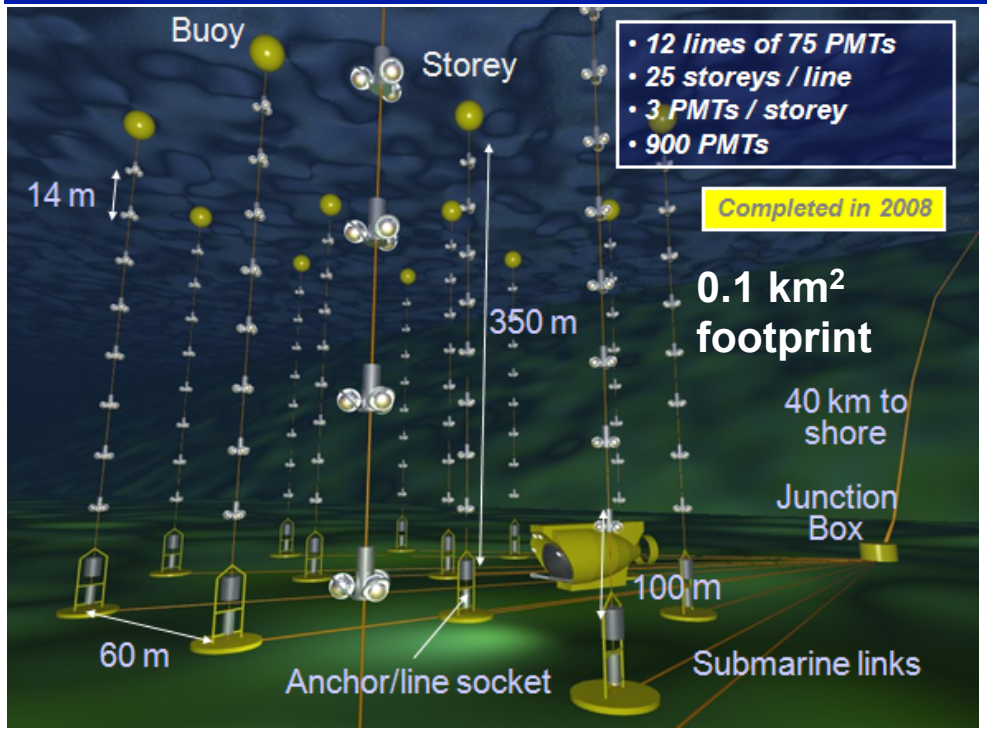
Intense technological R&D and coordination of Institutes

2006-2009 KM3NeT Design Study, Coordinated by Uni. Erlangen
2009-2012 Preparatory Phase, Coordinated by INFN

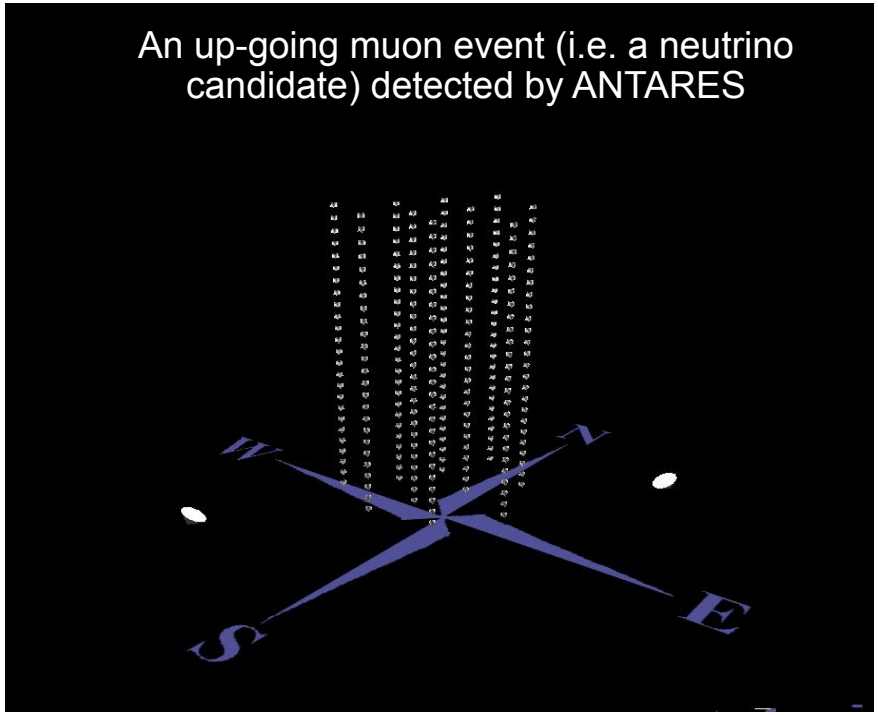
Goal: KM3NeT ~5 times more sensitive than IceCube
- larger total photo-cathode area (larger detector)
- better direction resolution (sea water)

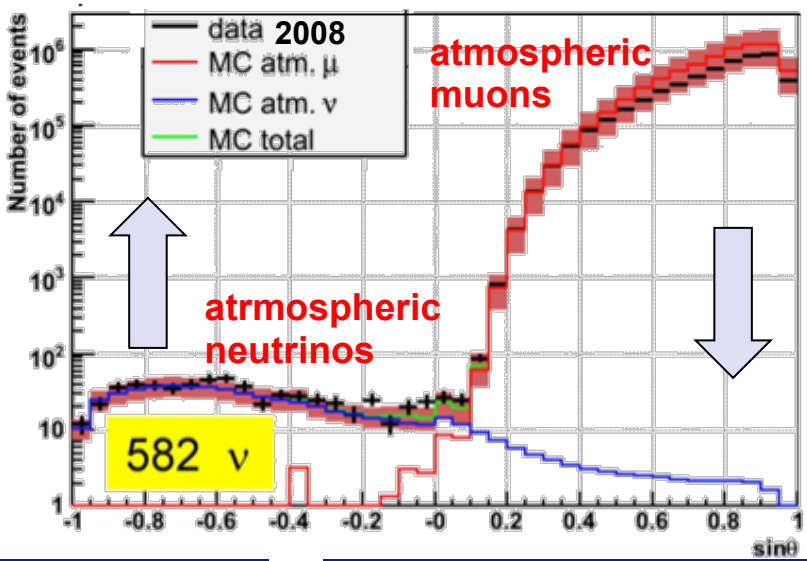
KM3NeT

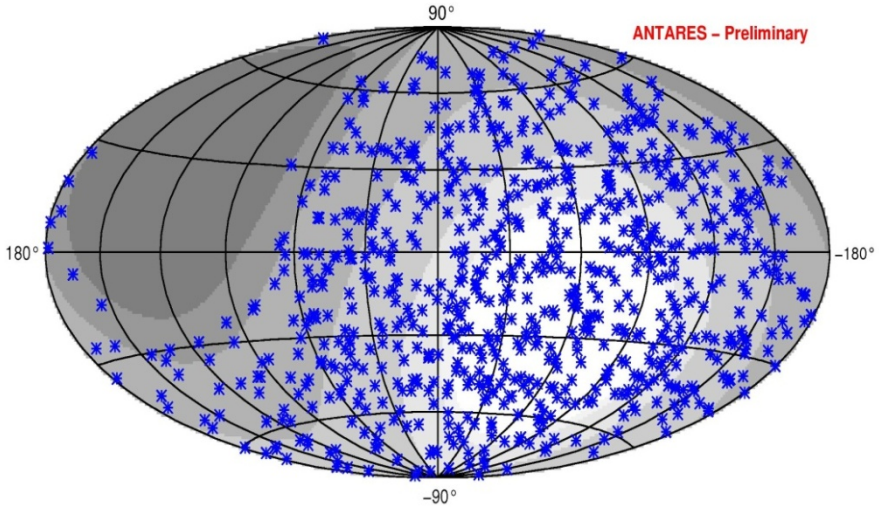
ANTARES: the largest neutrino telescope in the North



An up-going muon event (i.e. a neutrino candidate) detected by ANTARES



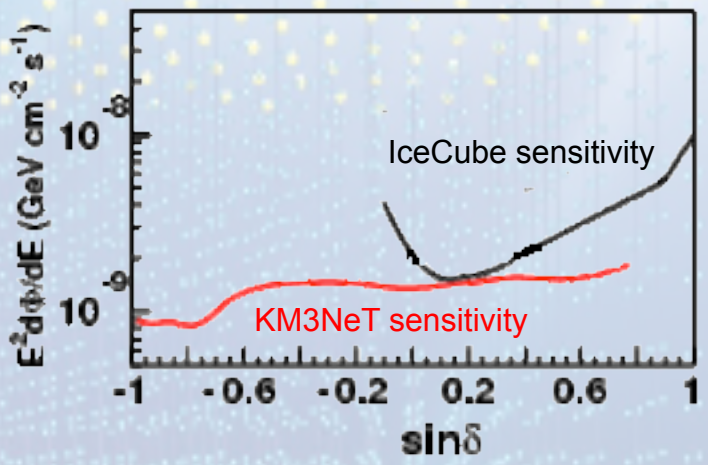




750 up-going neutrinos 2007+2008 data

Towards the Mediterranean km^3: KM3NeT

300 DU
20 storey/DU
6m long storey
40m storey spacing
1 km DU height
180m DU distance
2 DOMs/storey
31 PMT (3") per DOM
5 km^3 volume
Budget 220 M€



"building block" architecture: 1 "bb" → 100 DU

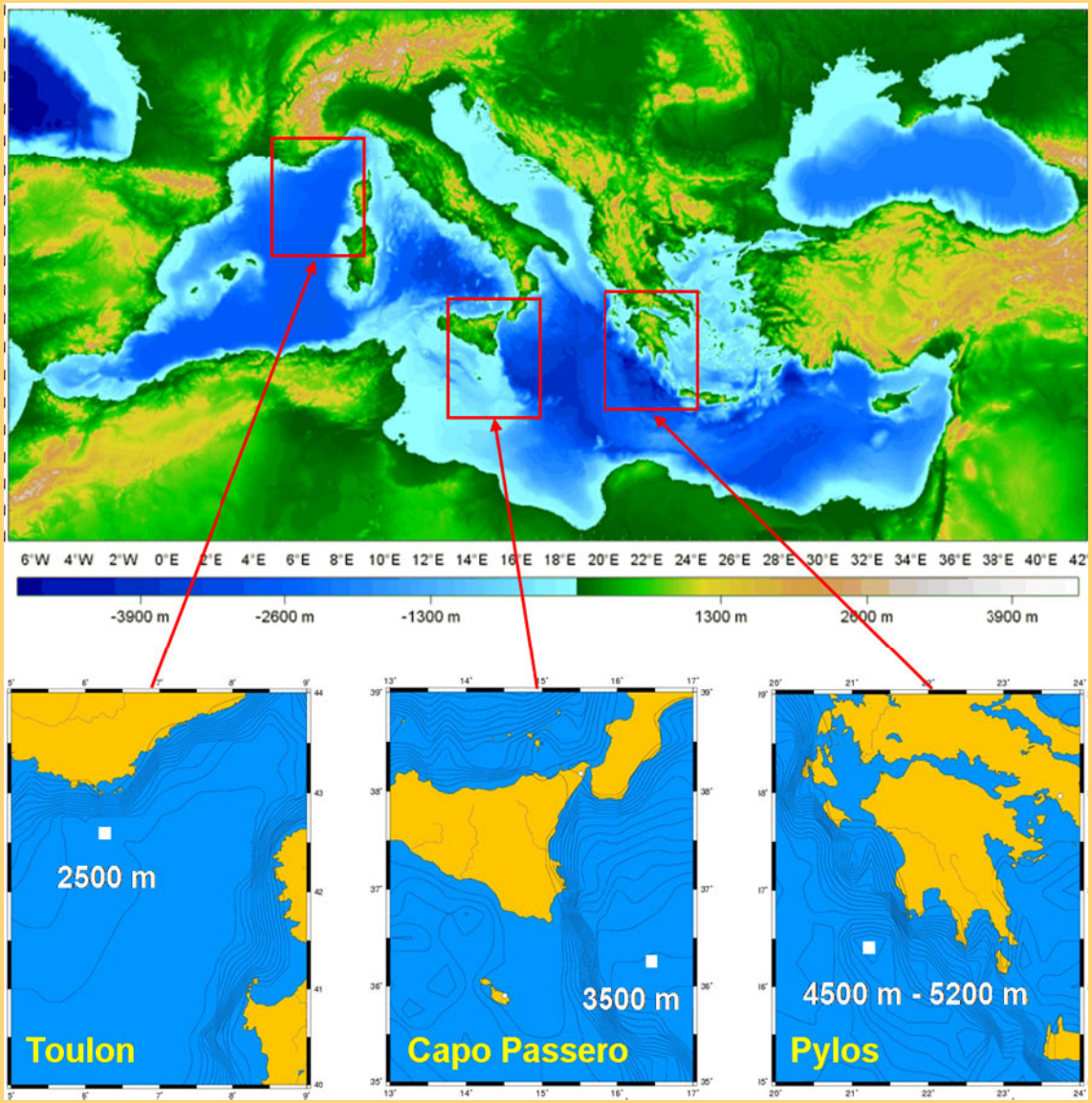
KM3NeT DS: FP6 contract no. 011937
KM3NeT PP: FP7 grant agreement no. 212252

Techincal Design Report
DOM-Bar concept

Multi-PMT Optical Module
Digital PMT readout
Point-to-point connection
Optical DWDM
DC power supply
Bar mechanical design
Acoustic detectors
Submarine network arc'ture

Next step:
operation of the PPM

Candidate sites for KM3NeT



Three candidate sites

- *Toulon (France)*
- *Capo Passero (Italy)*
- *Pylos (Greece)*

Long-term site characterization measurements performed

Site decision requires scientific, technological and political input

Connection with funding opportunities

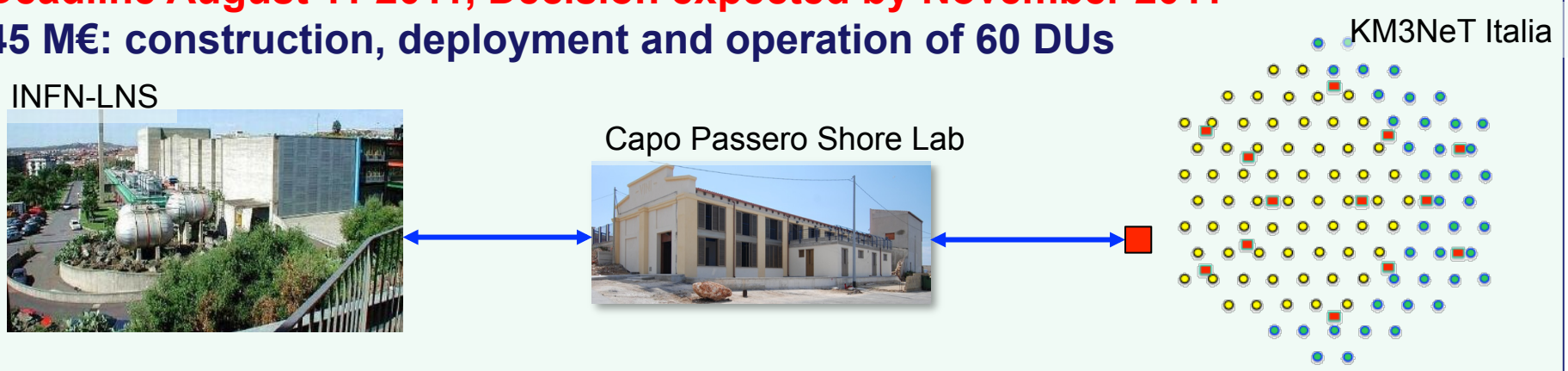
Multi-site option under study

KM3NeT Italia

KM3NeT Italia objective : 100 KM3NeT DUs to be installed in Capo Passero

First funding: 1M€ from MIUR (budget 2010)

A new funding request will be soon addressed by INFN under PON 2011
Deadline August 11 2011, Decision expected by November 2011
45 M€: construction, deployment and operation of 60 DUs

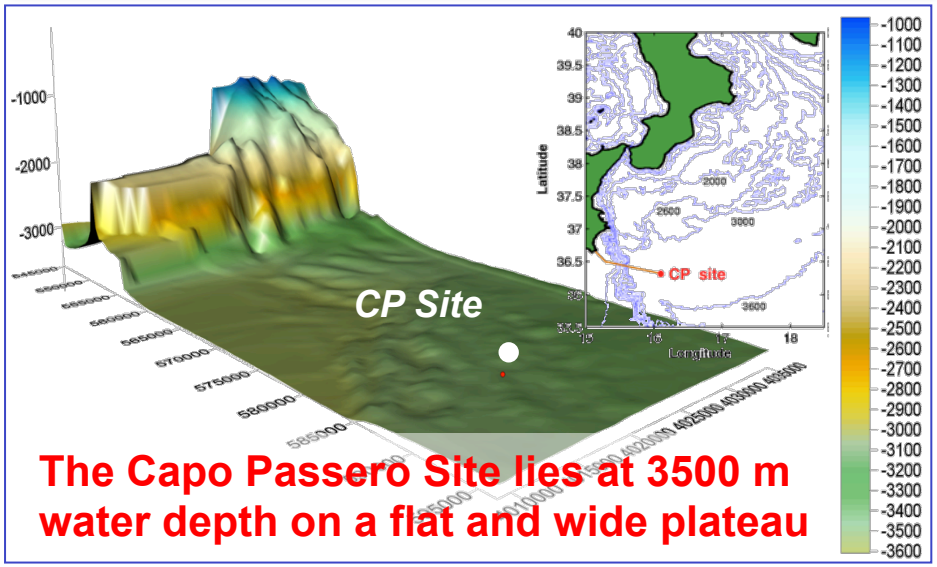


- The largest nu-telescope in the Northern Hemisphere (about 10xANTARES)
- More sensitive than Icecube
- Will observe the “Southern Sky”

Similar actions ongoing in France and Greece

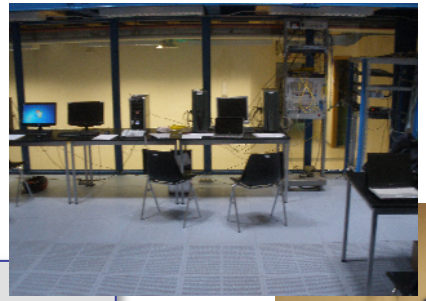
- Distributed Infrastructure
- Common technology
- Common Management (ERIC, European Reasearch Infrastructure Consortium)

The Capo Passero Site infrastructure



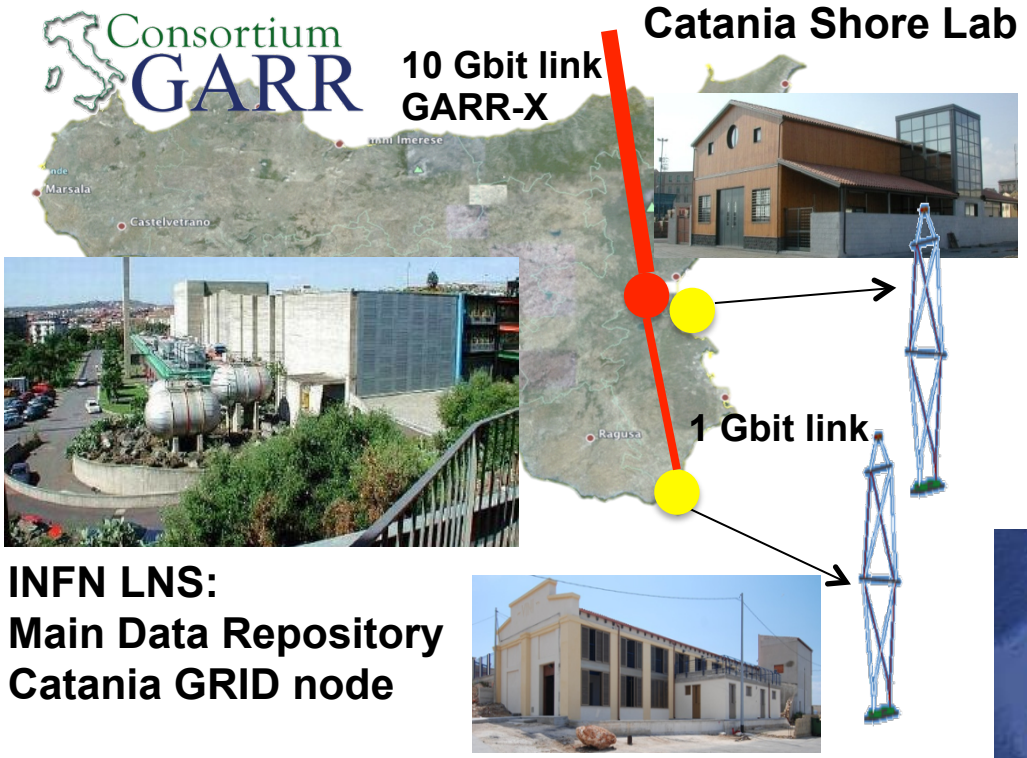
Capo Passero is an infrastructure suitable for the km^3-scale neutrino telescope installation (KM3NeT)

Shore laboratory operational:
On shore power supply 10 kV - 50 kW
Construction Hall
Data Acquisition Room
Guest House
Optical-fibre link to LNS GARR-X (2011)
Submarine cable and infrastructure:
100 km - 20 fibres, DC-sea return
DC/DC Converter 10 kV/375 V - 10 kW
3 ROV e.o. output connectors



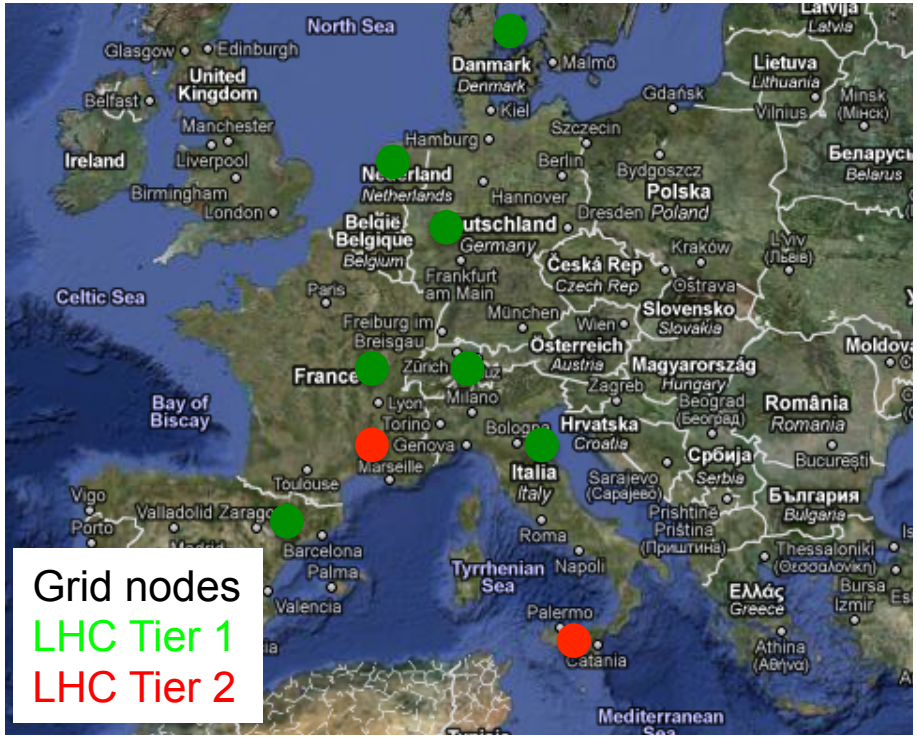
Next operations:
Deployment of an ANTARES mini-line (soon)
Deployment of NEMO Phase II (end 2011)
Deployment of KM3NeT Preproduction Model (2012)

Capo Passero: optical fibre link from deep-sea to LNS



Capo Passero will be the first KM3NeT site with direct optical fiber connection from deep-sea to EGI (IGI in Italy) nodes.

The first step towards the KM3NeT computing system



Possible use of GRID computing for KM3NeT

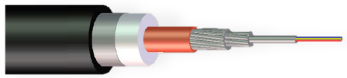
5-10% of LHC data traffic
Catania is a LHC Tier2
Marseille is a LHC Tier 2

Infrastructure for the km^3 in Capo Passero

UPS

On-shore power supply (50 kW, 10 kV) installed in Capo Passero shore Lab

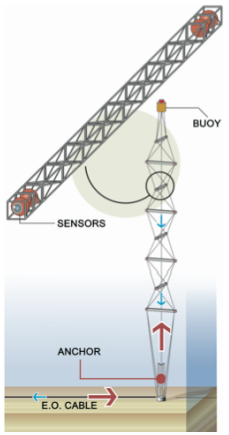
96 km underwater cable
20 optical fibres
10 kV DC monopolar with sea return



ANTARES
Mini-line
2 o.f.
375 VDC

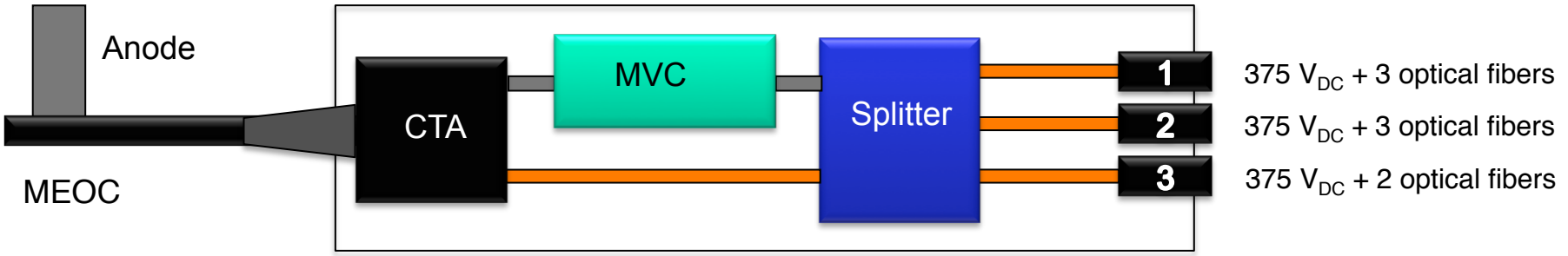
NEMO
Phase II
3 o.f.
375 VDC

KM3NeT
PPM
3 o.f.
375 VDC

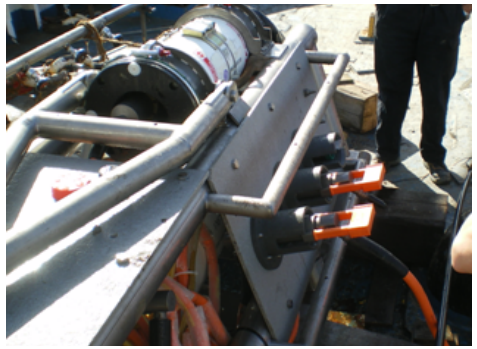


Input voltage: 400VAC 3-phases
Power factor: > 0,9
Output 1: 0-10 kV DC, 5 A
Output 2: 0-1.5 kV; 1,4 A (Branching unit control)
Regulation < 0,1%
Output voltage noise < 1 V rms
Output current noise < 10 mA rms
SCU (Switch control Unit):
- Setting of different operation modes
- Displays for voltage and current values
- Cable Head and Earth switches
- Dummy load
- RS232 PFE remote control

Capo Passero: electro-optical submarine node



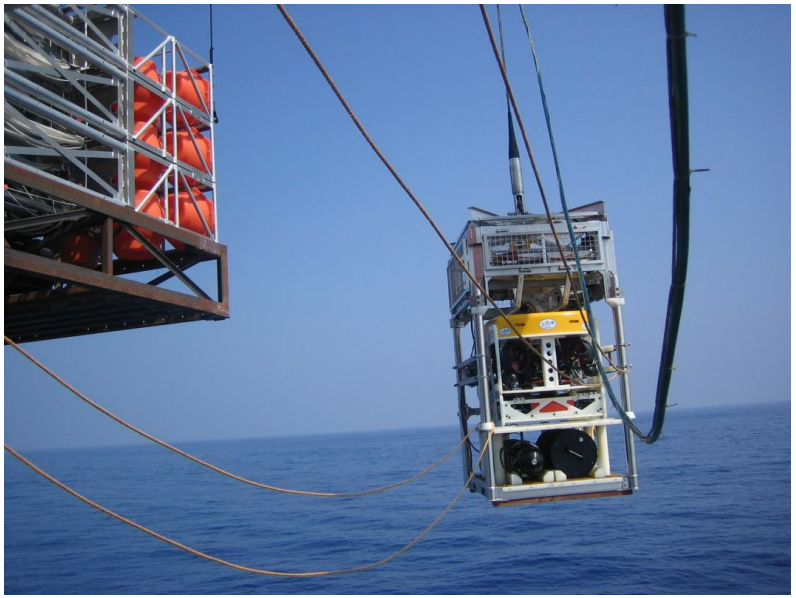
MVC: DC/DC converter 10 kVDC - 375 VDC
Cable Termination Assembly: 20 fibers, 1 electrical conductor
Splitter box: Routing of 8 fibres and 3 x 375VDC outputs
3 ROV mateable connectors

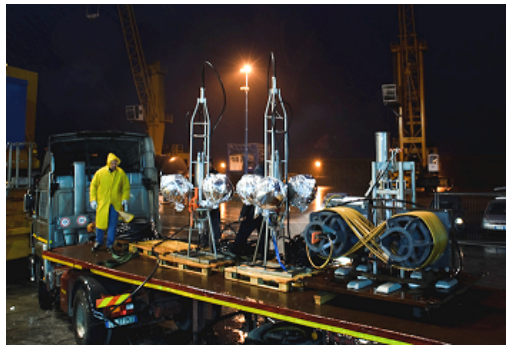


The Alcatel MVC main features:
DC Input Voltage : 5,7kV - 10 kV
DC Output Voltage: 375 V
Power: 10 kW
Input shut down voltage: 5,2 kV
Efficiency @ 10 kV, full load : 87%
Voltage undershoot (10% to 90% step up) @ 10kV: 40 V
Voltage overshoot (90% to 10% step down) @ 10kV: 43 V
Output Ripple Voltage (rms @ 100 kHz) < 1,5 V

PEGASO: a Remotely Operated Vehicle and Deep Sea Shuttle

ROV Cougar Seaeye upgraded to 4000 m operative water depth





ROV Missions:

Video Monitoring of NEMO mechanical prototype (1700 m)

Feb. 2010, Sucessfull

Connection of ANTARES mini-line in Capo Passero (3500 m)

Dec. 2010, Postponed due to bad weather

Deployment of LIDO-ESONET Stations in Catania (2100 m)

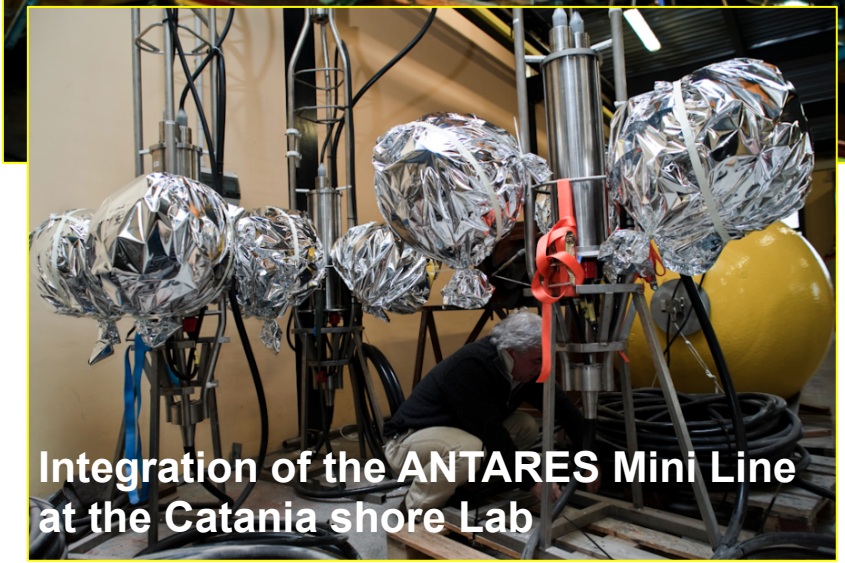
March 2011, Sucessfull site inspection

Failed connection due to ROV failure

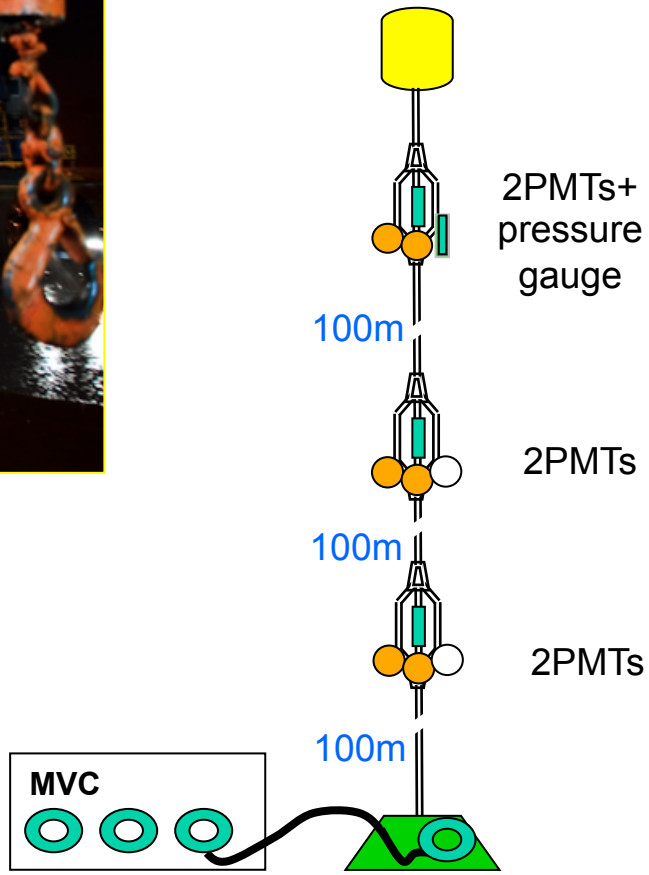
ROV now under reconditioning at Seaeye

The ANTARES Mini-Line in Capo Passero

Long term monitoring of Capo Passero site with an ANTARES line (site comparison)
Study of ANTARES line mechanical response in Capo Passero
Test of sea operations and ROV connections at 3500 m w.d.



3 e.o. cables 100m
1 pressure gauge
2 OMs /storey



NEMO Phase II

Installation of a NEMO tower in Capo Passero

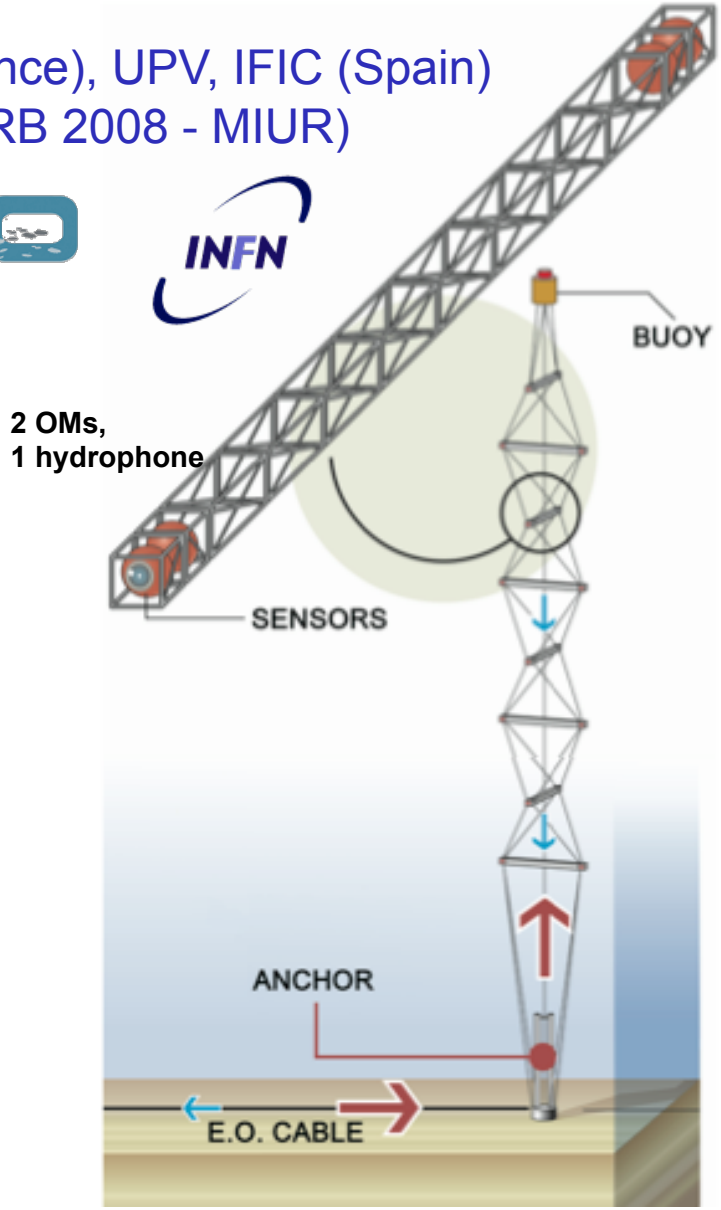
Direct collaboration of: ECAP (Germany), CPPM (France), UPV, IFIC (Spain)

Submarine Multidisciplinary Observatory onboard (FIRB 2008 - MIUR)

8 floors + tower base

floor length 8m, inter-distance 40 m, total height 450 m

64 optical modules, 14 hydrophones, oceanographic instruments



Major improvements wrt NEMO Phase I:

- Upgraded mechanics to 3500 m w.d. (INFN, IFIC)
- New 13" optical modules (INFN)
- Upgraded time calibration system (INFN, IFIC)
- New power feeding system (INFN)
- New optical transmission system (INFN)
- New acoustic poisitioning system (INFN, CPPM, UPV, ECAP)
- SMO: Bioacoustics, Geophysics, HE Particles acoustic detection

The SMO project onboard NEMO Phase II

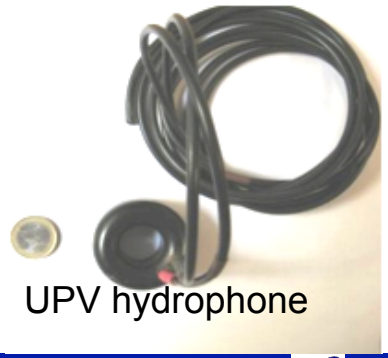
SMO (Submarine Multidisciplinary Observatory) onboard the NEMO Phase II detector

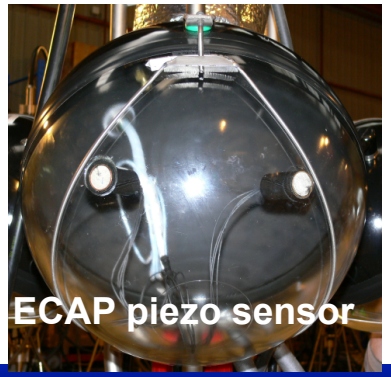
2 novel hydrophones on each floor
10 Hz-70 kHz band, High sensitivity, full depth calibrated (NATO)

Innovative (and low-cost !) electronics:
Underwater sampling 24 bits/192 kHz
All data to shore
GPS synchronization
GPS time stamping offshore <1 μs precision (1.5 mm in water)

Multidisciplinary use of data:
Acoustic positioning system (NEMO, KM3NeT)
Bioacoustics, Geophysics, Acoustic Particle Detection (SMO)

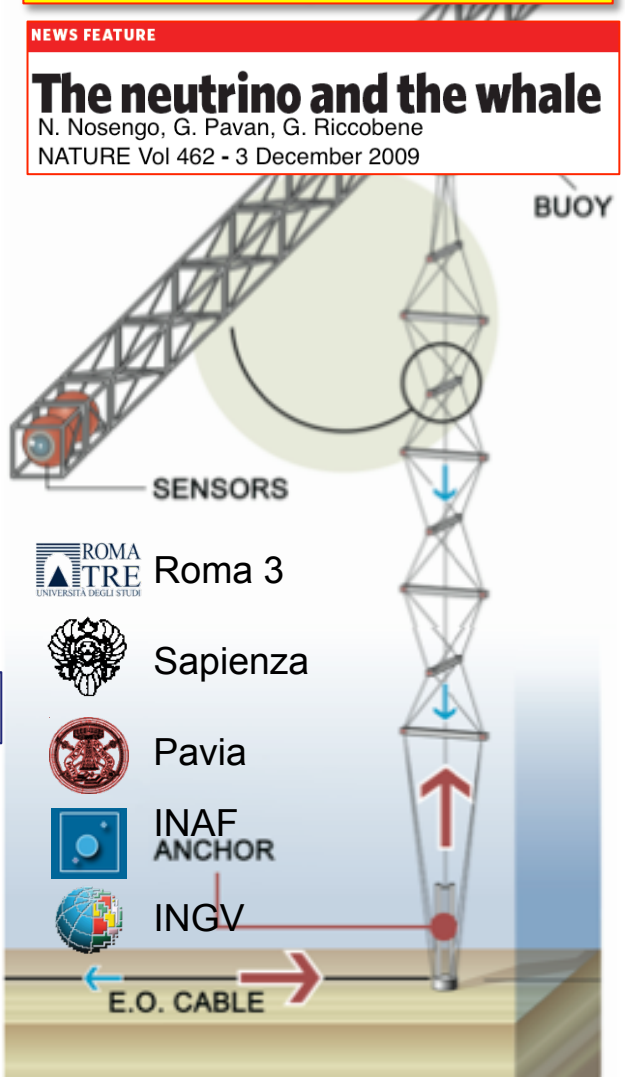
Test of hydrophones from UPV/CPPM & ECAP (INFN read-out)


UPV hydrophone


ECAP piezo sensor

INFN acoustics electronics and hydrophones selected for the KM3NeT-PPM

Acoustic waves are an optimal information carrier to probe the deep-sea



The KM3NeT Preproduction Model (PPM) in Capo Passero

Bar Structure

6 m-long storey 2 DOM/storey

20 storeys, 2 acive storeys (4 DOMs)

DOM in 17'' glass housing

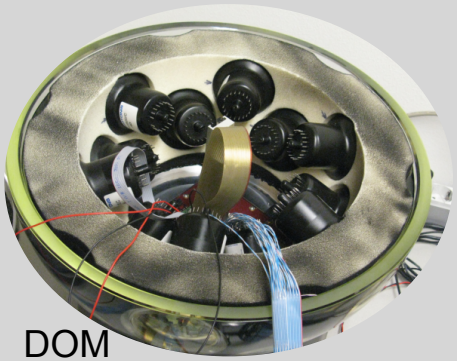
Digital Optical Module

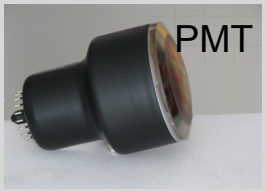
31 PMTs (3'')/DOM, single-photon mode

Time over threshold digital read-out

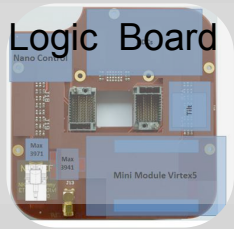
400 VDC main power supply.

FPGA for data serialization and transmission (CLB)





CLB: Central Logic Board
Acou-plug
Tcal-plug
Compass



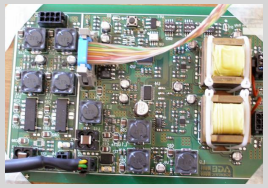
Acoustic System in the DOM

Stereo 192 kHz/24bit, GPS synch&time stamp

1 external hydrophone + 1internal piezo

Interfaced with CLB. All data to shore.

Positioning and multidisciplinary science

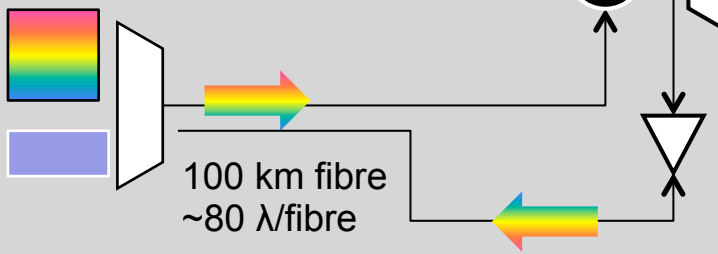


Fibre Point to point connection

Optical DWDM, 10 Gbps

Raman amplification on shore

Continuous wave Laser
and demodulator



Passive
REAM
substitutes
active laser

The Catania Test Site Infrastructure

Shore station

Shore lab,
Port of Catania

Test Site North Branch
5220 m
2 e.c., 4 fibers

TSN

2 ROV electro–optical connectors to shore

Branching Unit

Main e.o. cable
22995 m
6 e.c., 10 fibres

2 ROV electro–optical connectors to shore

TSS

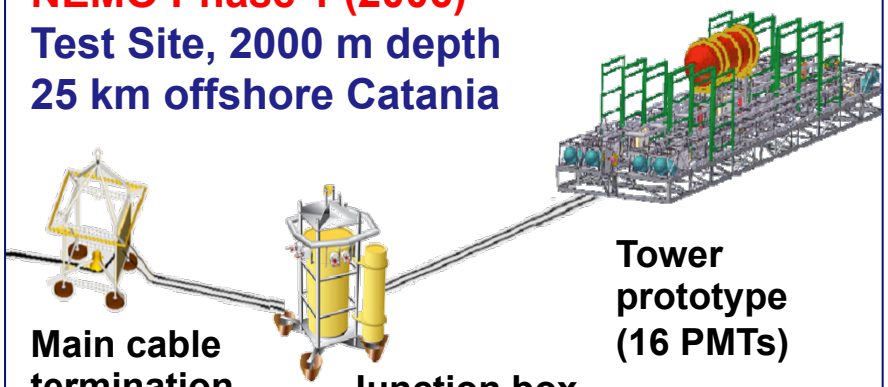
Test Site South branch
5000 m
4 e.c., 6 fibres

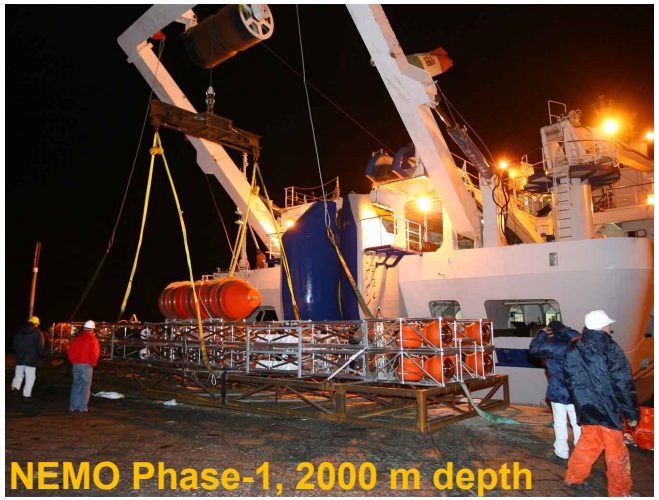
Multi ROV Output
380 VDC 3-phase
DWDM / CWDM

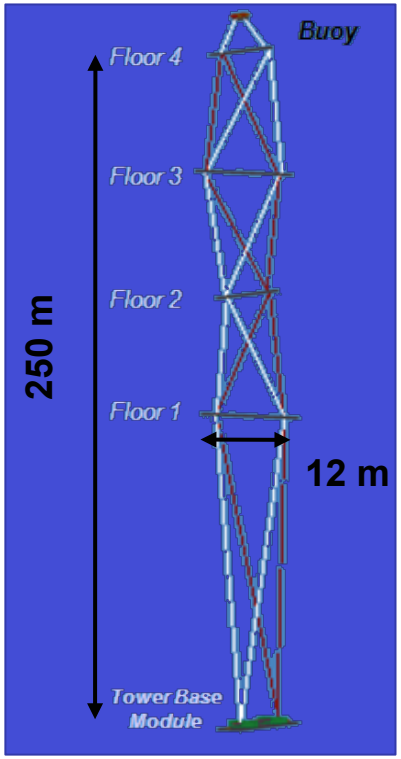
Test Site Frame
(same in TSS and TSN)

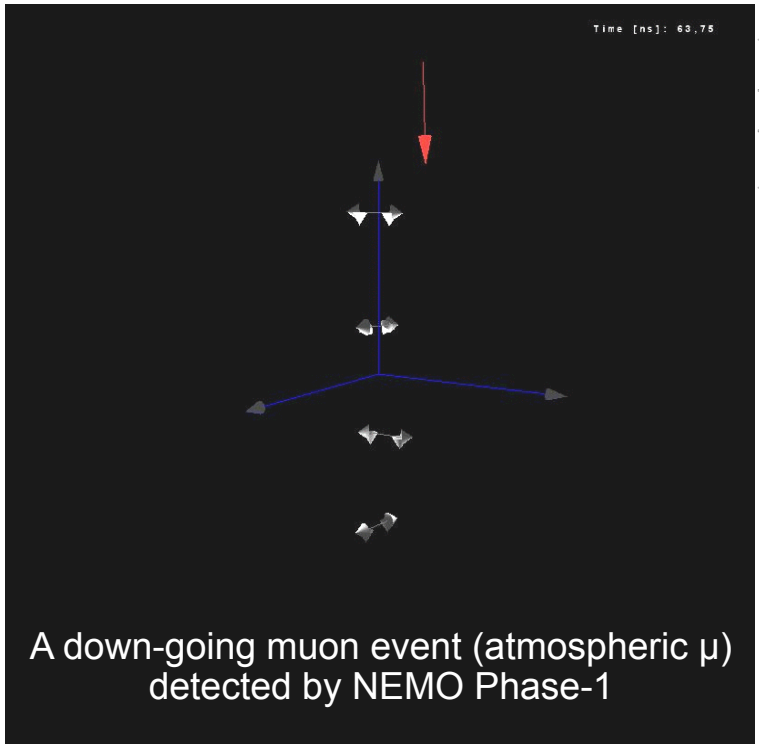
NEMO Phase 1 at the Catania Test Site

NEMO Phase 1 (2006)
Test Site, 2000 m depth
25 km offshore Catania

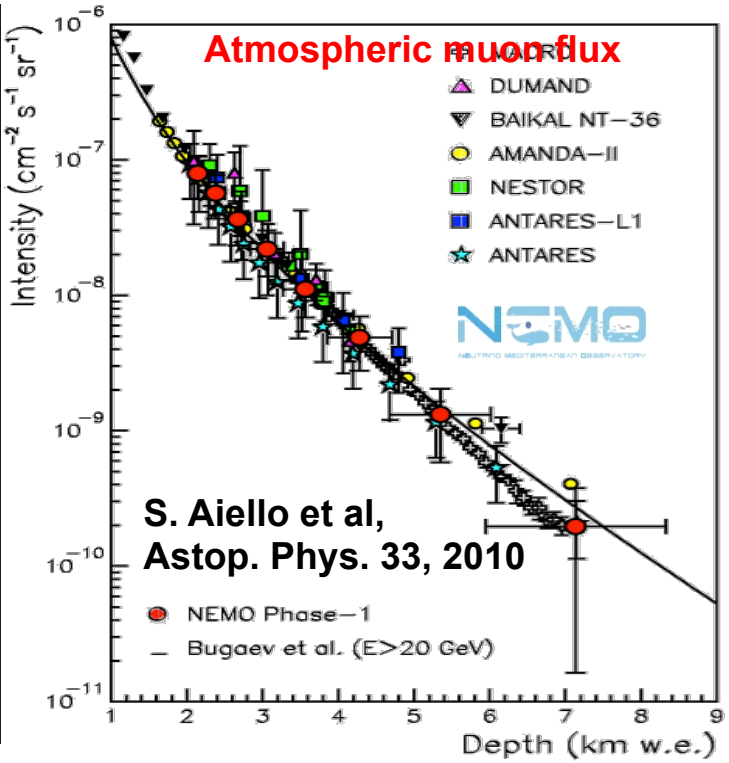








A down-going muon event (atmospheric μ) detected by NEMO Phase-1



The Catania infrastructure: ESONET-EMSO and SMO

LNS-INFN Catania
FC SAN :Main data storage
Data analysis
Conencted to GARR-X

- *LIDO demo mission of ESONET:*
  two observatories with sensors for bioacoustics, ocean monitoring, geohazards. Ready for deployment
- *ESONET Test sites activity: Sea operations, ROV tests*
- *SMO: Common acoustic data-base Catania & Capo Passero*

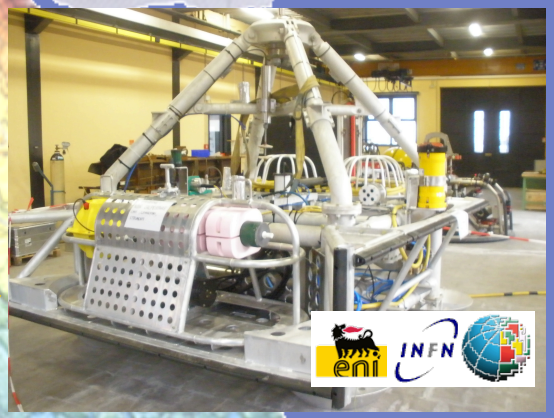
Upgraded Internet Radio Link: 100 Mbps

LNS Test Site Laboratory refurbished during 2010-2011: GPS and o.f. distribution in test labs and construction hall

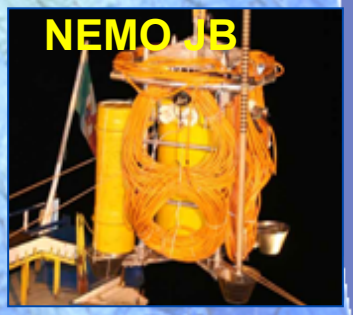
20 km

5 km

5 km



North:
4 LBW hydrophones
2 LF hydrophones
CTD, ADCP,
Seismometers
magnetometers
pressure gauges
GPS time stamping



South:
4 LBW hydrophones
Underwater GPS
time stamping

Infrastructure requested by UCL and CSIC for installation of deep-sea stations in 2013

Summary

Status of the infrastructures

Capo Passero infrastructure is operational and under completion:

Submarine cable OK
Power supply OK
Submarine termination OK (to be upgraded for KM3NeT)
Unique feature: direct o.f. link to GRID (LNS-INFN, Catania)

ANTARES Mini-line (soon)
NEMO Phase II (winter 2011)
KM3NeT-PPM (2012)

Catania infrastructure fully operational:

Underwater infrastructure operational and continuously monitored
Internet radio link to LNS upgraded to 100 Mbps
Construction hall, labs and DAQ systems have been refurbished

LIDO observatories (soon)
Integration and tests of NEMO Phase II (summer 2011)
Request for use from UCL (UK) and CSIC (Spain)

Summary

Status of the NEMO activities at INFN-LNS:

NEMO Phase II / SMO

Test of the tower mechanical demonstrator (2010)
Design completed
Integration from summer 2011. Deployment end of 2011

KM3NeT

TDR (completed)
Pre-Production Model under design
LNS key role in: mechanics, optical fibre link, power supply systems, acoustic positioning system, data acquisition-storage-transmission system

ESONET-EMSO

LIDO stations ready for deployment. Data storage/distribution system OK.
LNS key role in: design, construction and integration of the deep-sea observatories, data acquisition-storage-transmission system

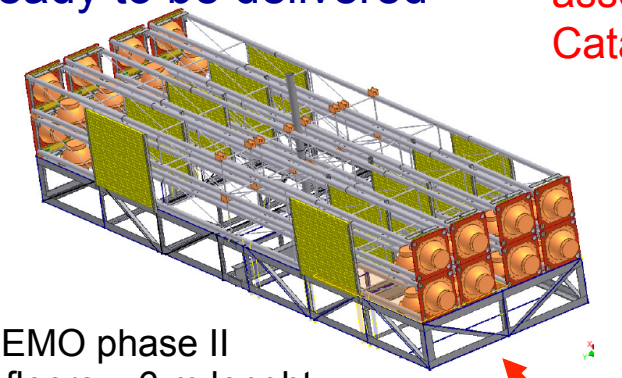
Funding

ESONET (EU) 300 k€, MIUR-FIRB 2008 (IT) 680 k€, MIUR-KM3NeT (IT) 1 M€,
Application to PON-ricerca 2011 (IT) 45 M€

Backup slides

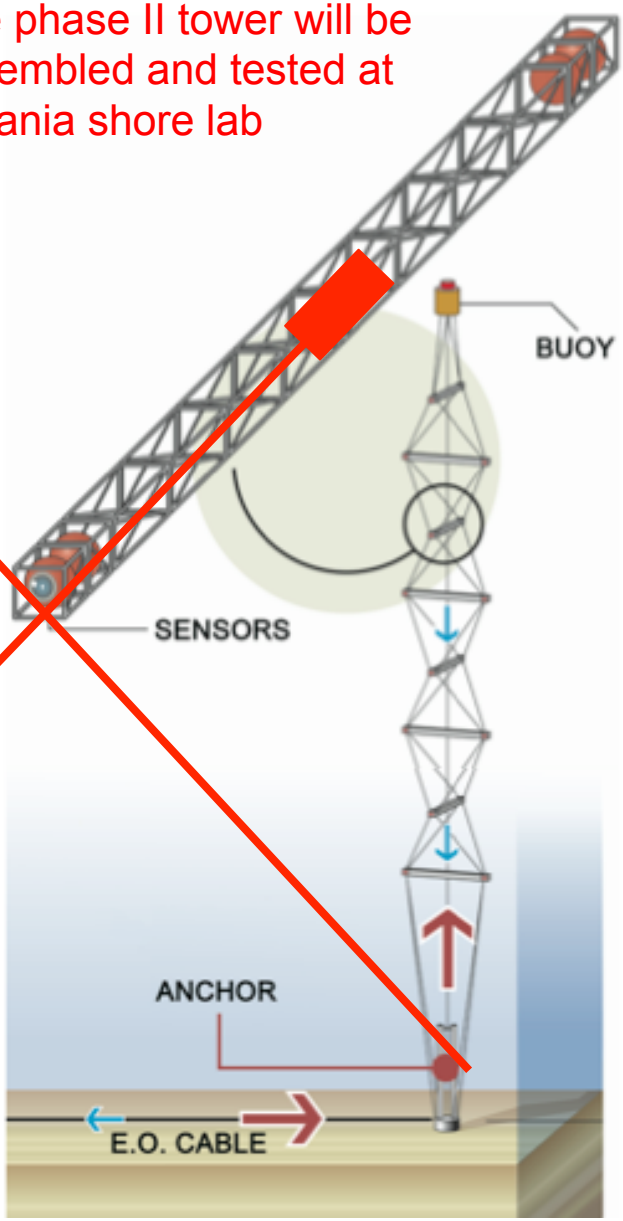
NEMO Phase II: Mechanics

Tower mechanical test carried out succesfully in 2010
Phase II floors (new design) ready to be delivered

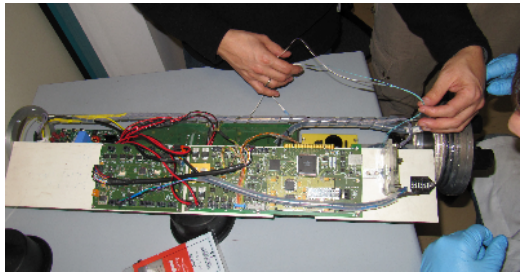


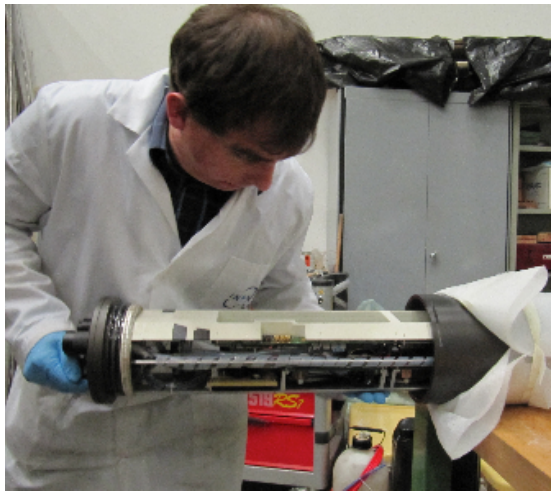
NEMO phase II
8 floors – 6 m lenght

The phase II tower will be assembled and tested at Catania shore lab



Upgraded pressure vessels and floor control module racks
Designed and built, prototype module assembled





NEMO Phase II: Electro-optical vertical backbone

Upgraded optical fiber link:

On-Shore: Raman Amplifier

Off-Shore: vertical backbone with add/drop filters

Upgraded power distribution system:

On-Shore: Power supply (10 kVDC)

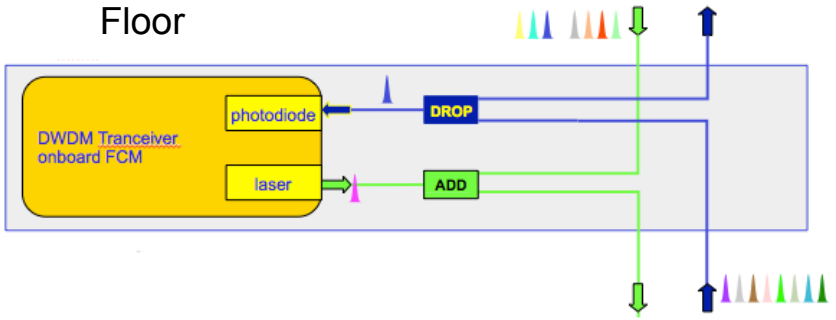
Off-Shore: MVC 10kVDC→375VDC

Floor Power Boards: 375VDC→4.2,5, 12 VDC

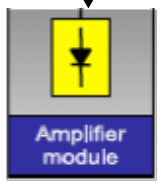
Switch on-off, monitor and control via RS485

Floor

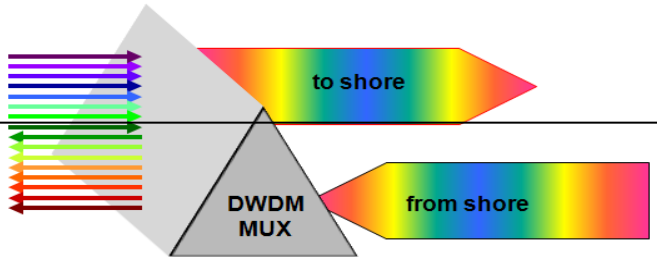
To upper floors

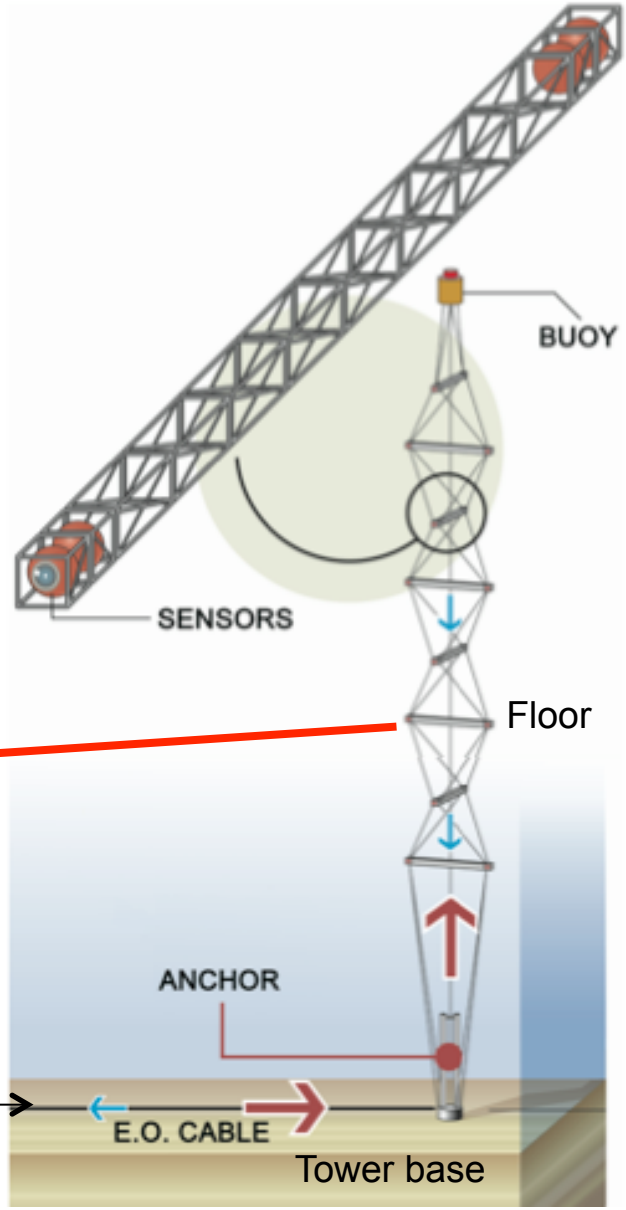


To lower floors



On-Shore
Raman Amplifier
(> 100 km link tested)





NEMO Phase II: Electronics

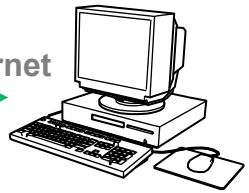
Upgraded electronics

Test bench fully functional at LNS

GPS

Optical data

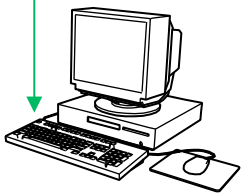
Ethernet

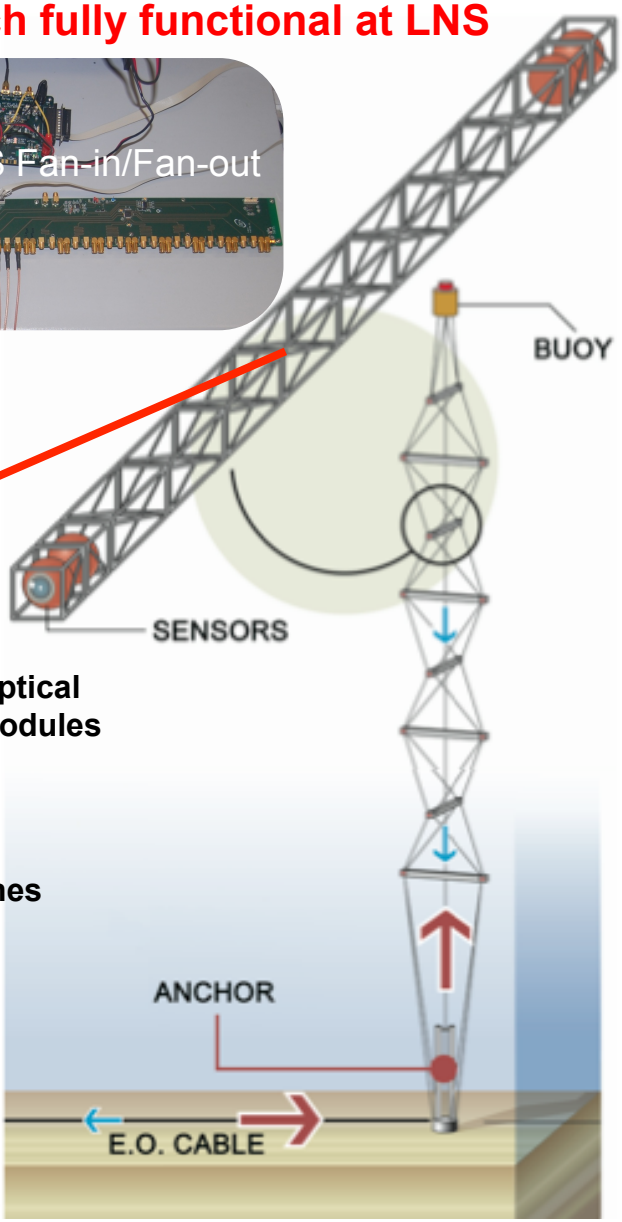


On-Shore
Storey Control Module
(EFCM)
Data Parsing

optical
fiber link

Acoustic data





Power Board
375 VDC
LV DC

Storey Control Module
(FCM)

Time Calibration

Acou-ADC
192 kHz
24 bits

Slow
Control
Interface

Oceanographic
Instrument

Optical
Modules

Hydrophones

Front-end

PMT