Telescopi per neutrini di alta energia

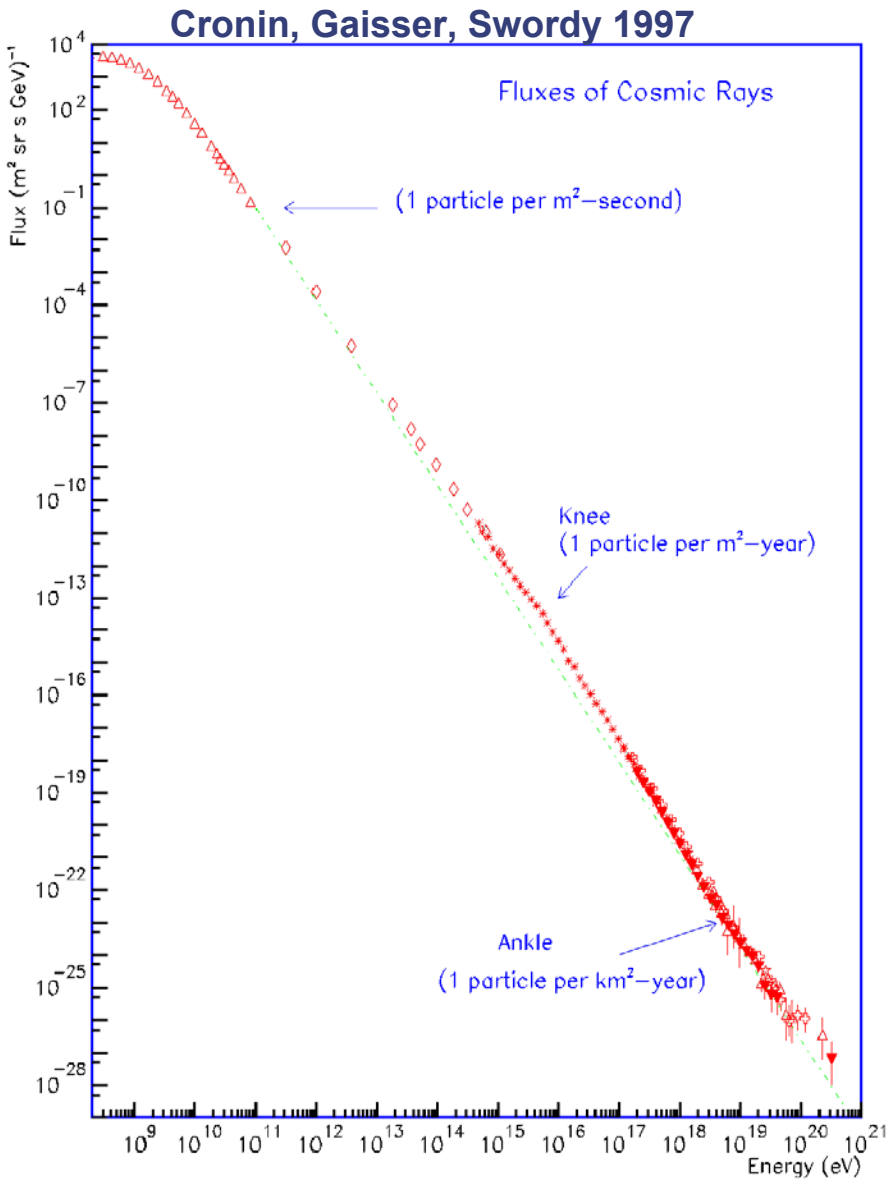
- Astronomia con neutrini di alta energia
- I telescopi km^3 Cherenkov
  - la situazione internazionale
  - la sfida tecnologica
  - il progetto NEMO
- Conclusioni e prospettive

High energy neutrino astronomy: the 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

- Interdisciplinary research

L'Universo ad alta energia



Raggi cosmici osservati con energie fino a 10^{20} eV

Fino a 10^{15} eV probabilmente di origine galattica

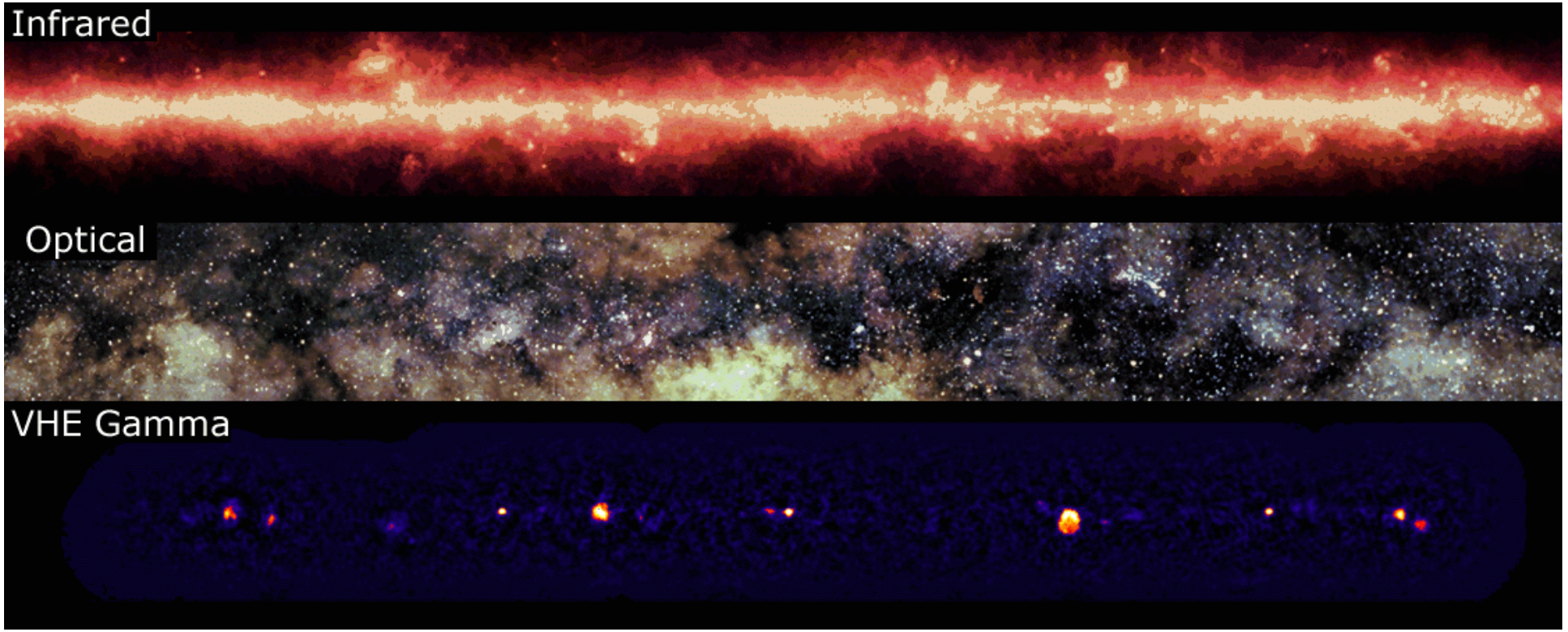
Il cambiamento di pendenza per $E > 10^{19}$ eV potrebbe essere un' indicazione di componenti extragalattiche

Problemi aperti:

- Meccanismo di accelerazione
- Identificazione delle sorgenti
- UHECR puzzle

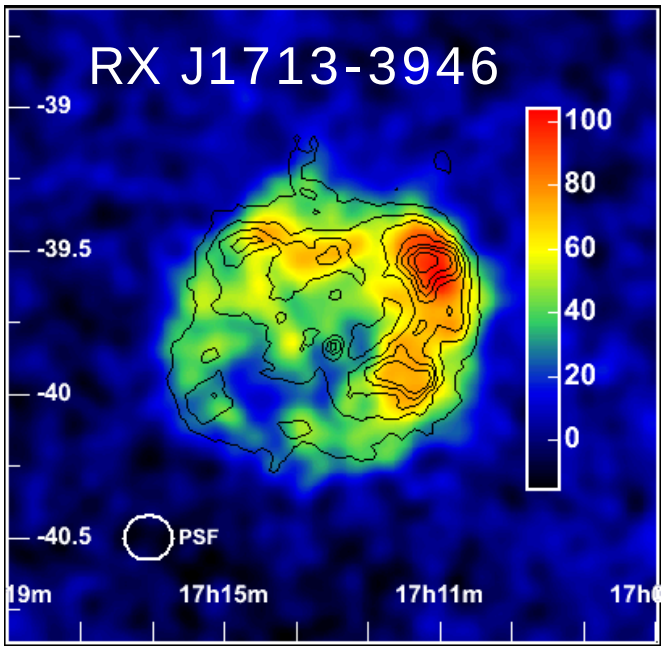
L'Universo in una nuova luce: l'astronomia γ di alta energia

L'ultima generazione di telescopi (HESS and MAGIC) ha aperto una nuova finestra osservativa

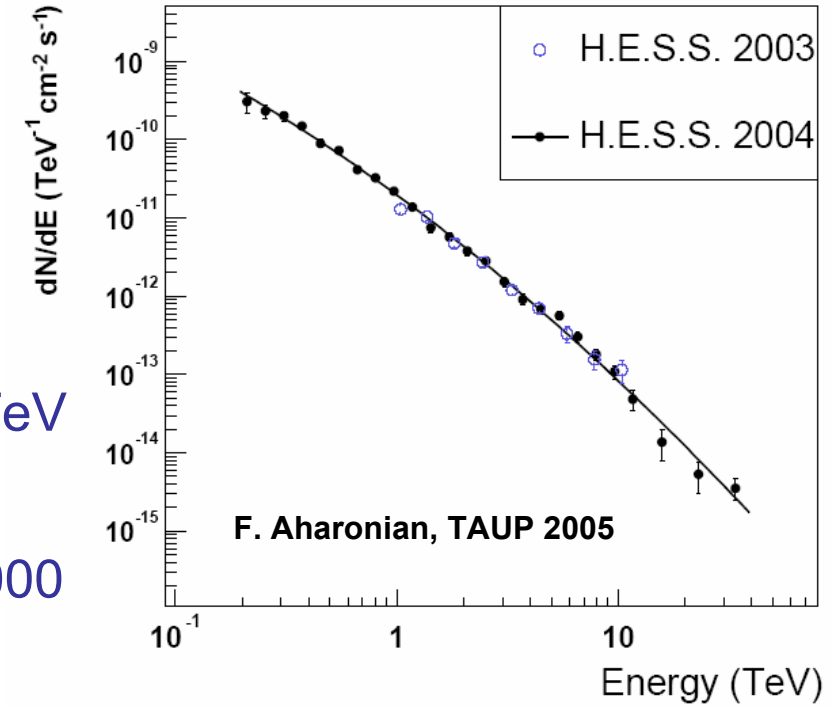


Il piano galattico osservato a diverse lunghezze d'onda

A high energy source example: the SNR RX J1713-3946



Good angular resolution allows for extended source morphology studies



Power low spectrum observed up to 30 TeV

Spectral index ≈ 2.1 - 2.2

Implies acceleration of primaries up to 1000 TeV

Spectrum hardly explainable with IC mechanisms call for proton acceleration

Perché astronomia con neutrini di alta energia (E>1TeV)?

- I neutrini viaggiano attraverso l'Universo senza essere deflessi ne' assorbiti
  - puntano indietro alla sorgente che li ha emessi
  - permettono di esplorare le regioni più interne degli acceleratori cosmici
  - potrebbero consentire di allargare i confini dell'Universo conosciuto
- I neutrini sono prodotti in interazioni adroniche
  - la rivelazione di neutrini sarebbe uno *smoking gun* per meccanismi di accelerazione adronici piuttosto che elettromagnetici

Sorgenti candidate e flussi previsti

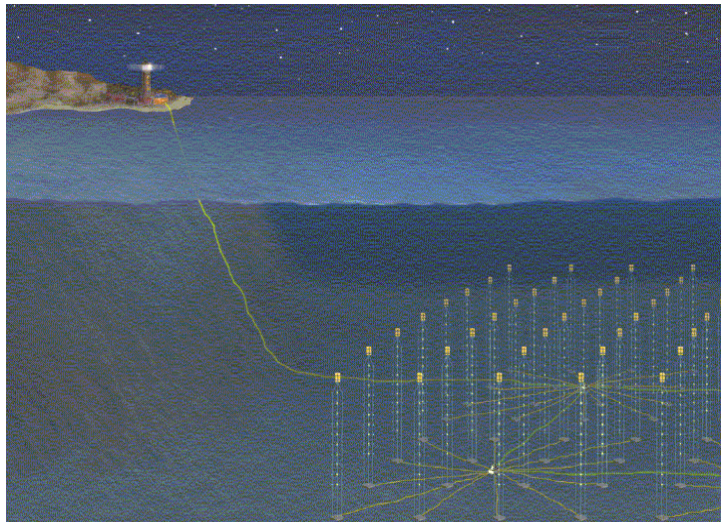
Eventi attesi per km^2

Flussi diffusi

GZK neutrinos	0.5 / year
GRB *(Waxman)*	50 / year
AGN (thin) *(Mannheim)*	few / year
(thick)	>100 / year

Sorgenti puntiformi

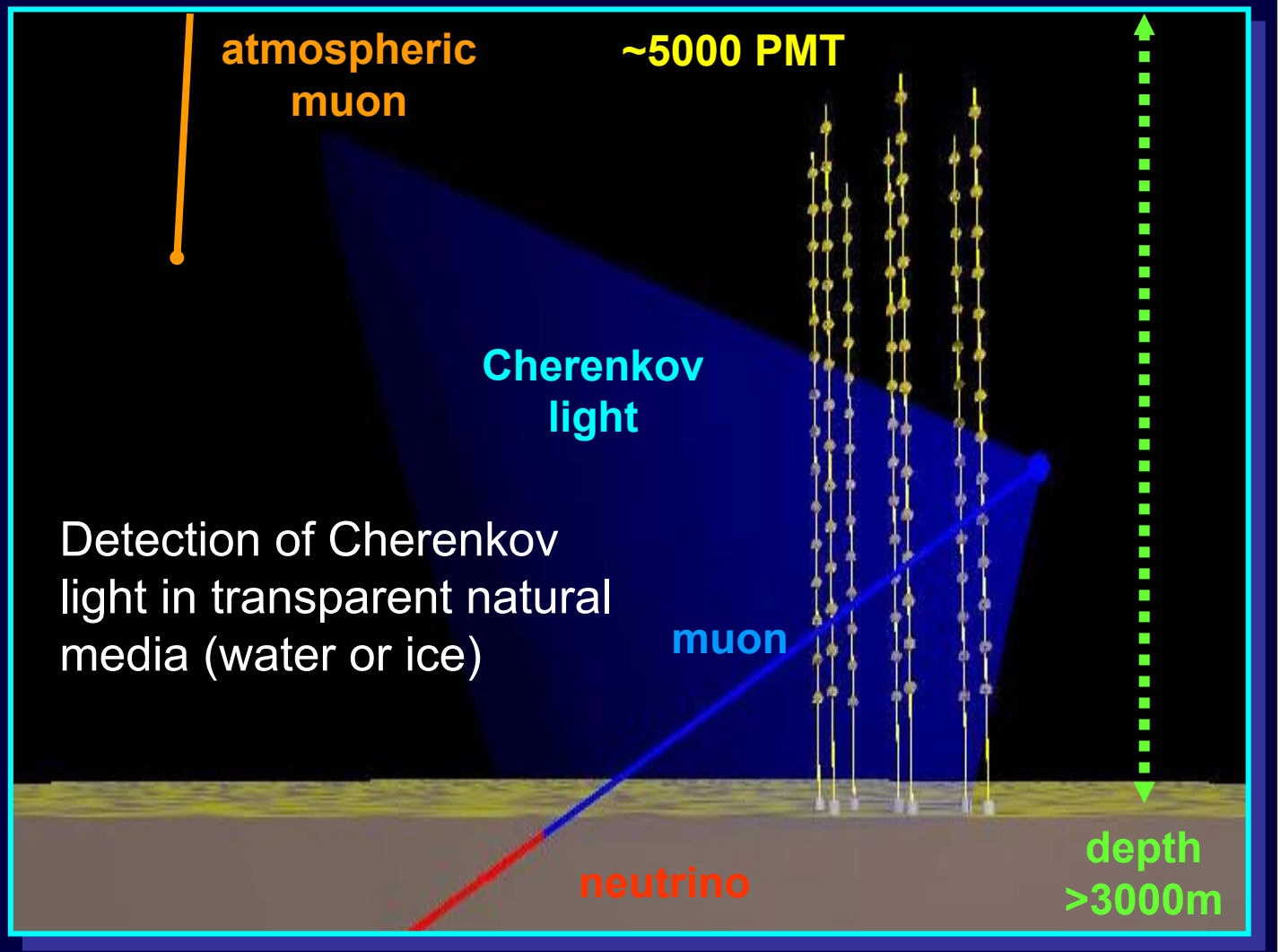
GRB (030329) *(Waxman)*	1-10 / burst
AGN (3C279) *(Dermer)*	few / year
Galactic SNR (Crab) *(Protheroe)*	few / year
Galactic MicroQuasar *(Distefano)*	1-100 / year



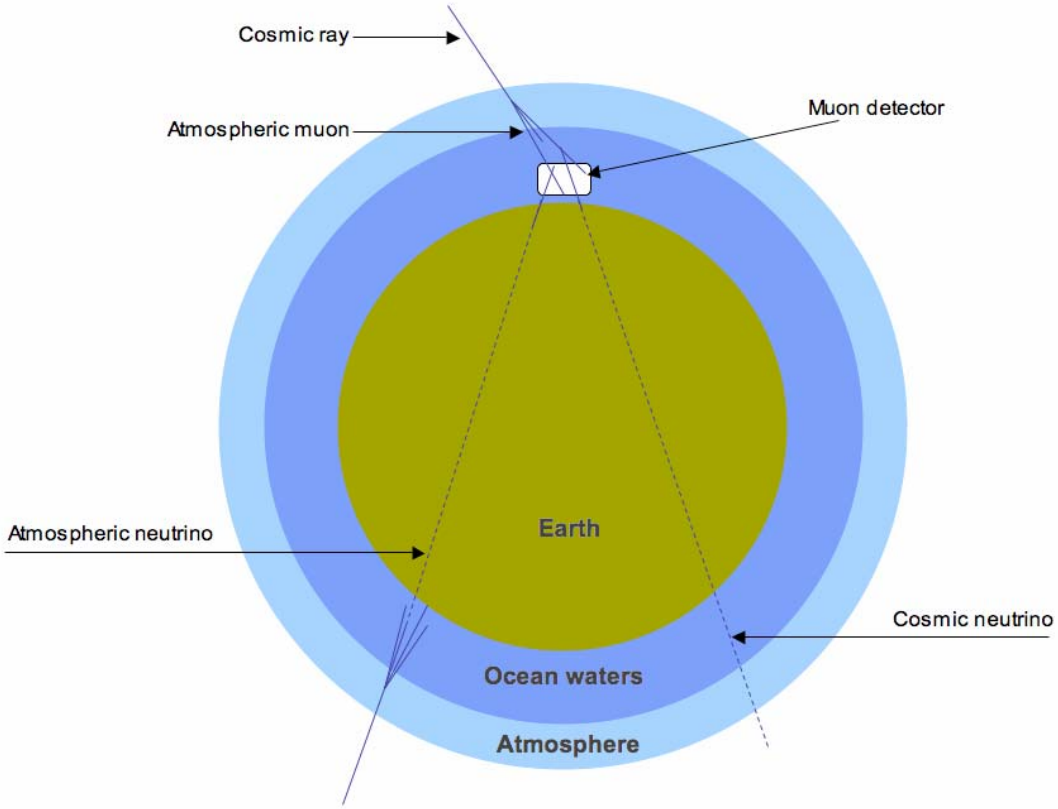
COME? Una possibile soluzione è "instrumentare" un mezzo trasparente naturale e buio come gli abissi marini o le profondità dei ghiacci polari per rivelare la luce Cherenkov emessa dai secondari prodotti nelle interazioni di neutrino.

Neutrino astronomia: principi di rivelazione

L'acqua (ghiaccio) ha una triplice funzione:
- schermo
- bersaglio
- radiatore



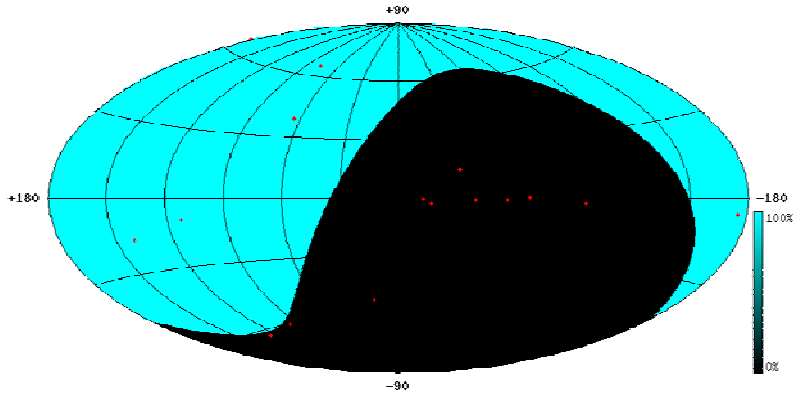
Neutrino-astronomia: guardare il cielo a testa in giù

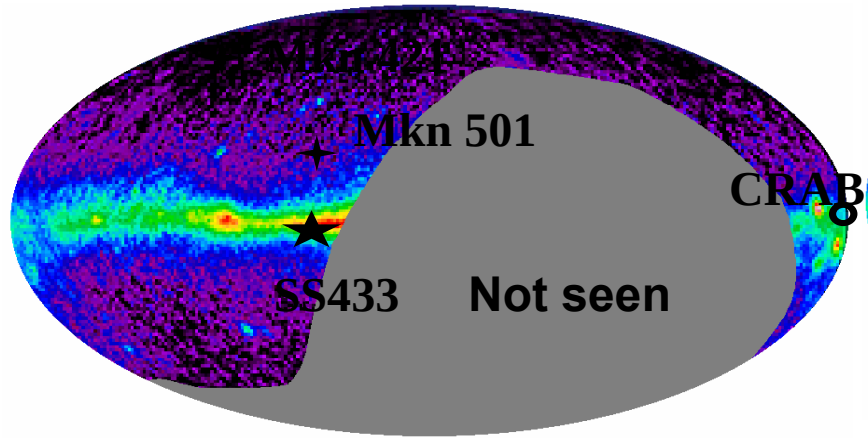


- Search for muon tracks from neutrino interactions
- Earth is used as shield to cut off the downgoing atmospheric μ background
- Upgoing tracks can unambigously be attributed to neutrinos
- The flux atmospheric neutrinos produced on the other side of the Earth cannot be suppressed (but it's also a natural calibration source)

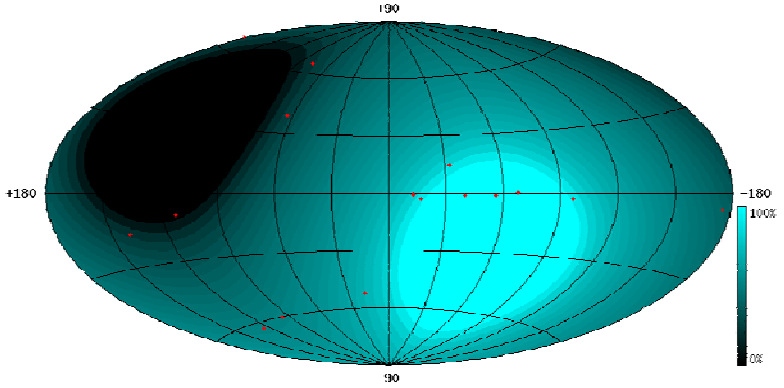
Visibilità dei telescopi a neutrini

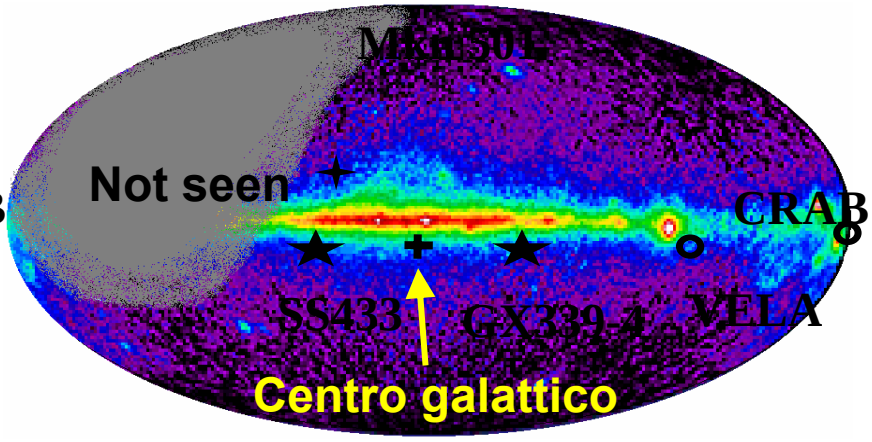
Polo Sud





Mediterraneo





Necessari due telescopi per guardare tutto il cielo

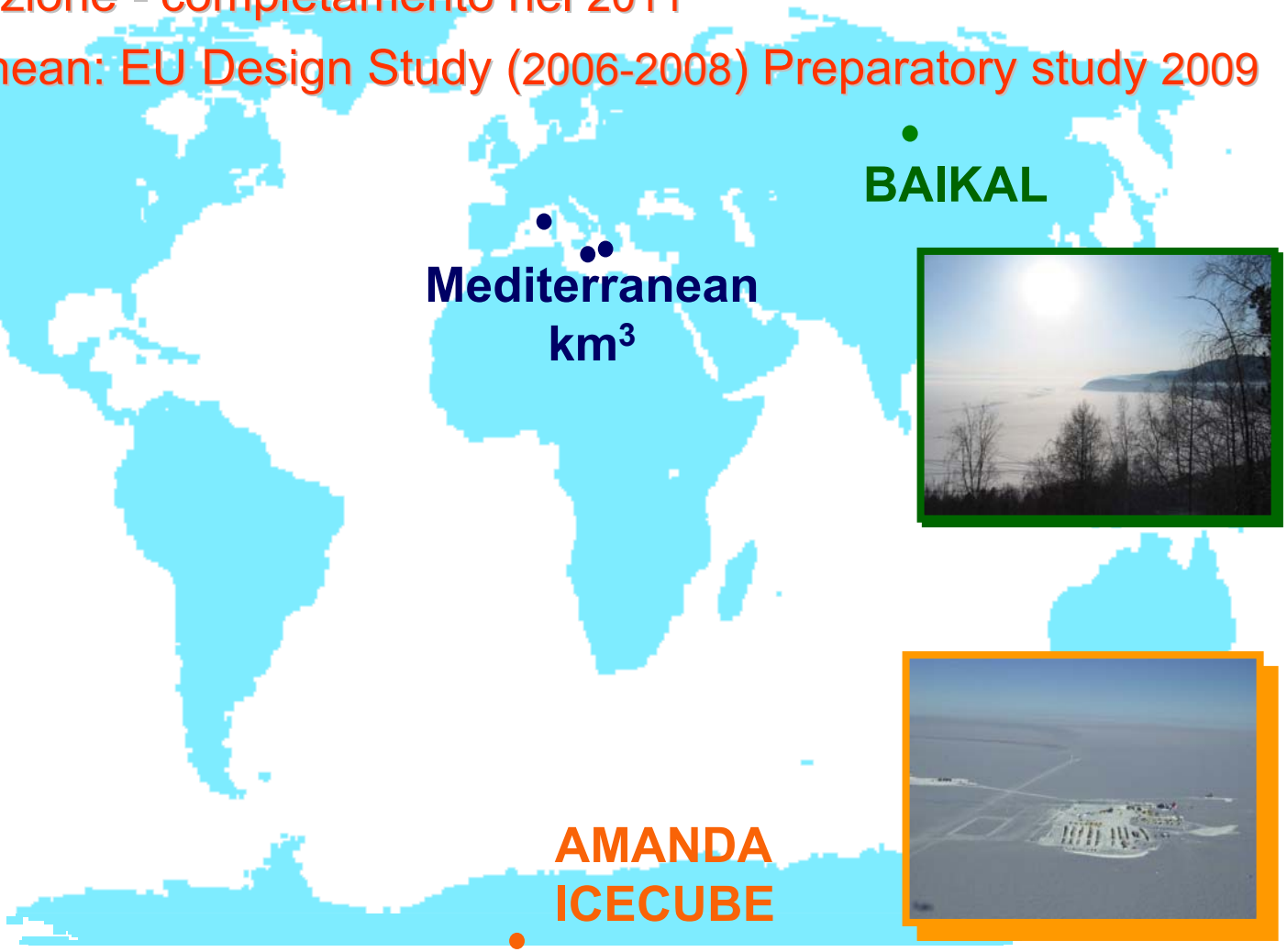
Il centro galattico può essere osservato solo da un telescopio nel Mediterraneo

Il contesto internazionale

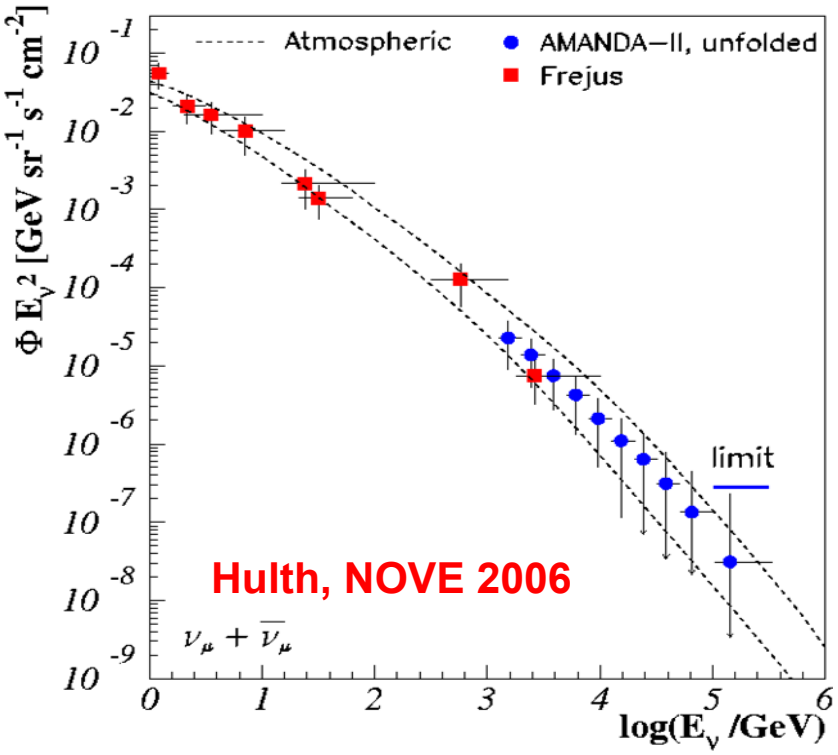
Telescopi prototipi & R&D: BAIKAL, AMANDA, ANTARES, NESTOR, NEMO

ICECUBE: in costruzione - completamento nel 2011

KM3NeT Mediterranean: EU Design Study (2006-2008) Preparatory study 2009



The AMANDA neutrino sky

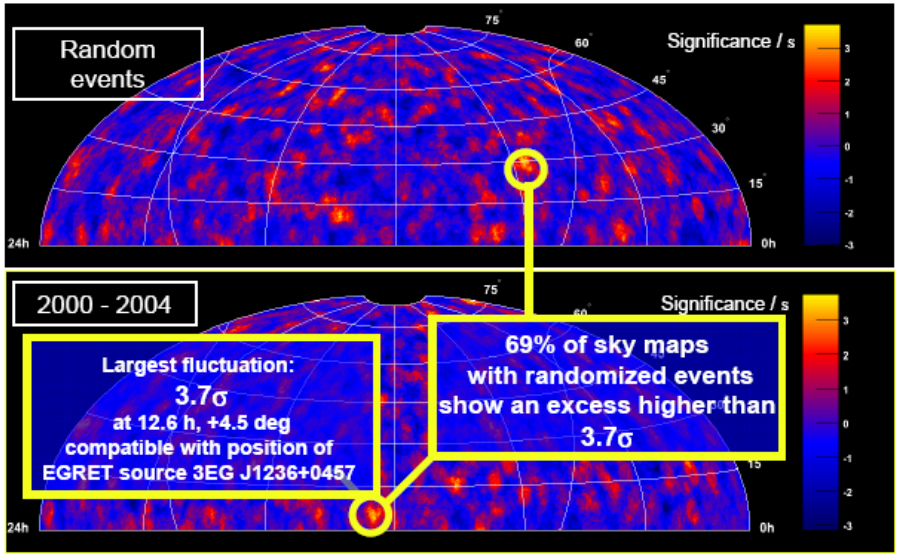


First four years of data (3369 events) are compatible with the expected atmospheric neutrino flux

No evidence of point-like sources with E_ν^{-2} spectrum

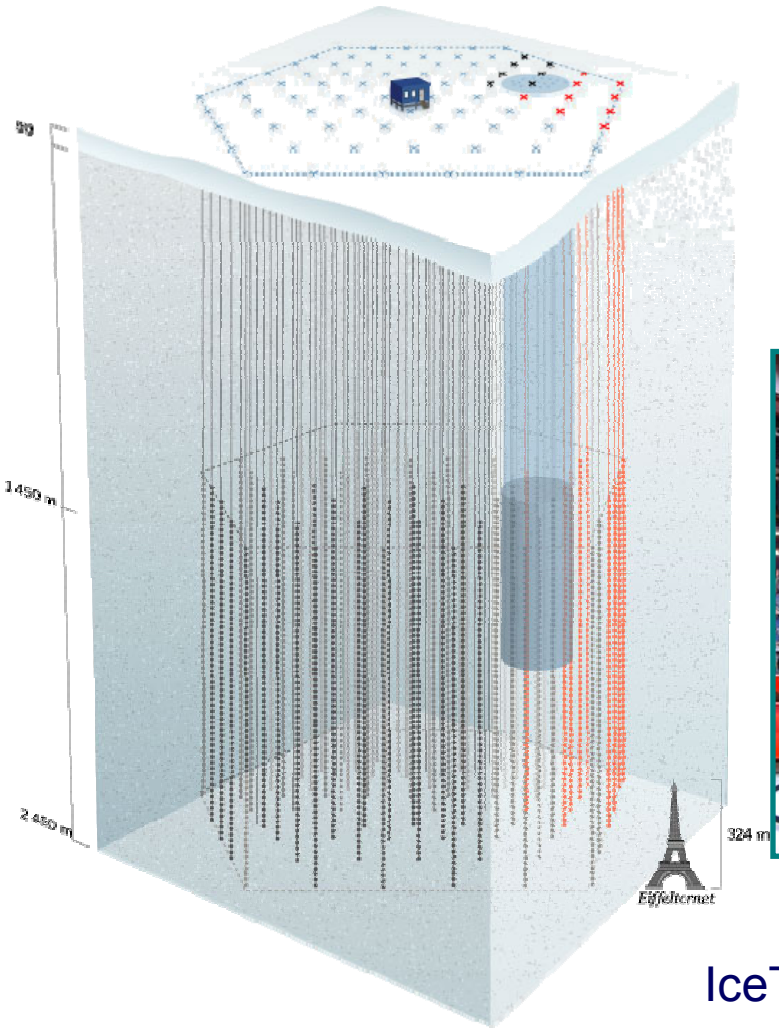
AMANDA : 2000-4 Skymap

AMANDA II (19 strings) since 2000



IceCube: il km^3 nel ghiaccio

La costruzione del km^3 nel ghiaccio è iniziata, completamento nel 2011



70-80 stringhe (60 PMT ognuno) 22 già installate

4200-4800 10” PMT (downward)

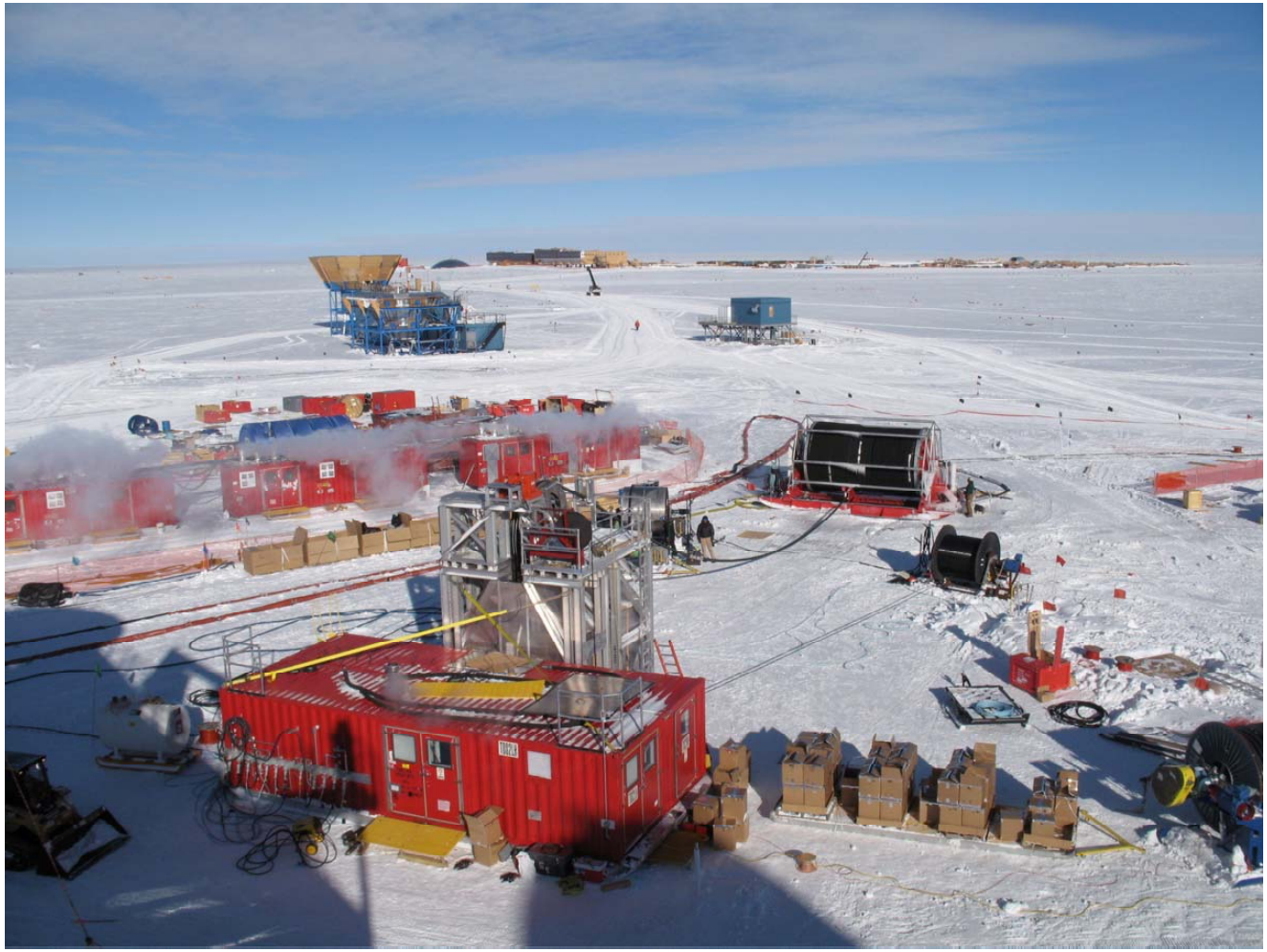
125 m distanza tra stringhe

17 m distanza tra i PMT

Volume instrumentato: 1 km^3 (1 Gton)

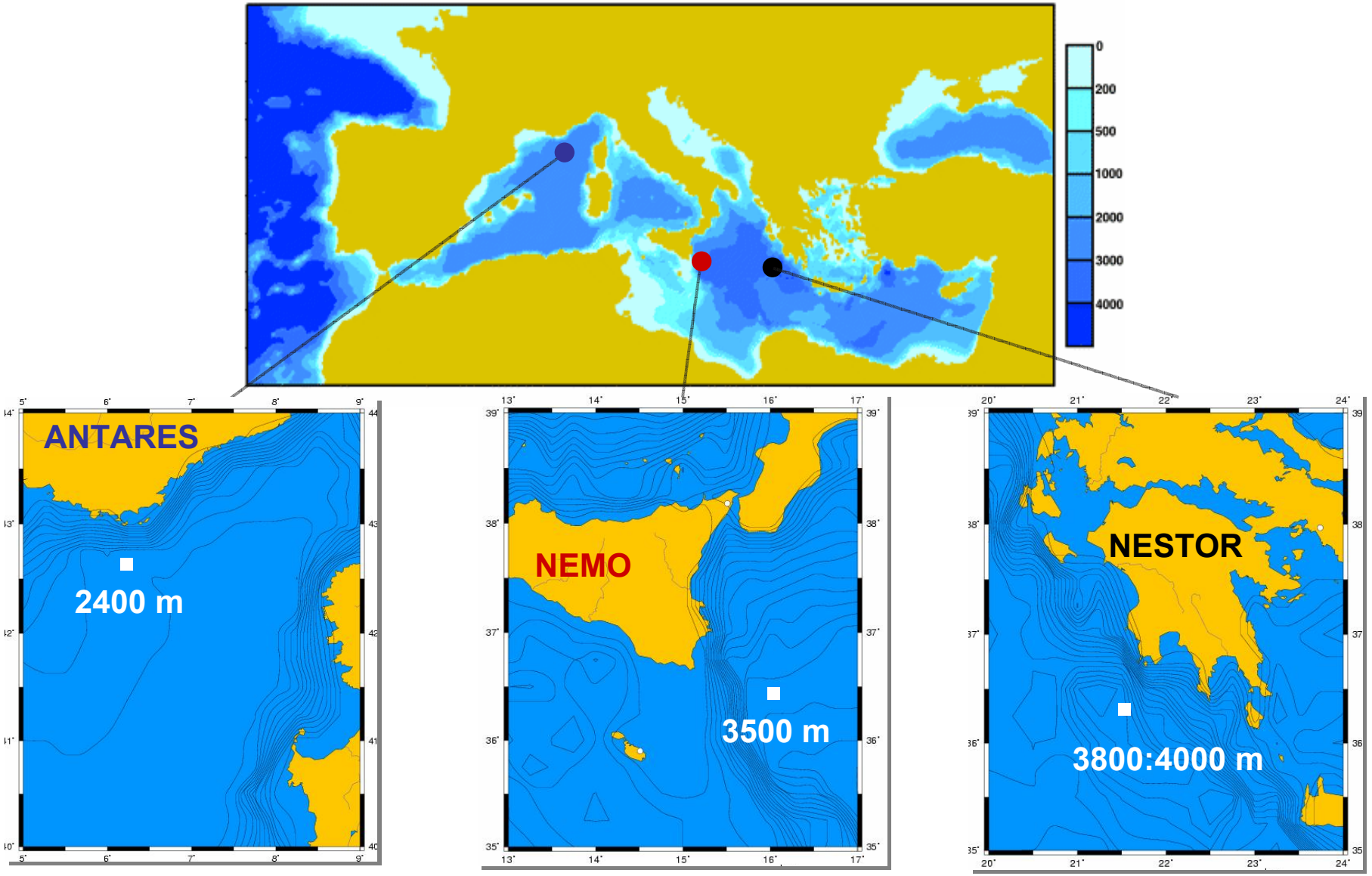
IceTop air shower array 80 pairs of ice Cherenkov tanks

IceCube al Polo Sud

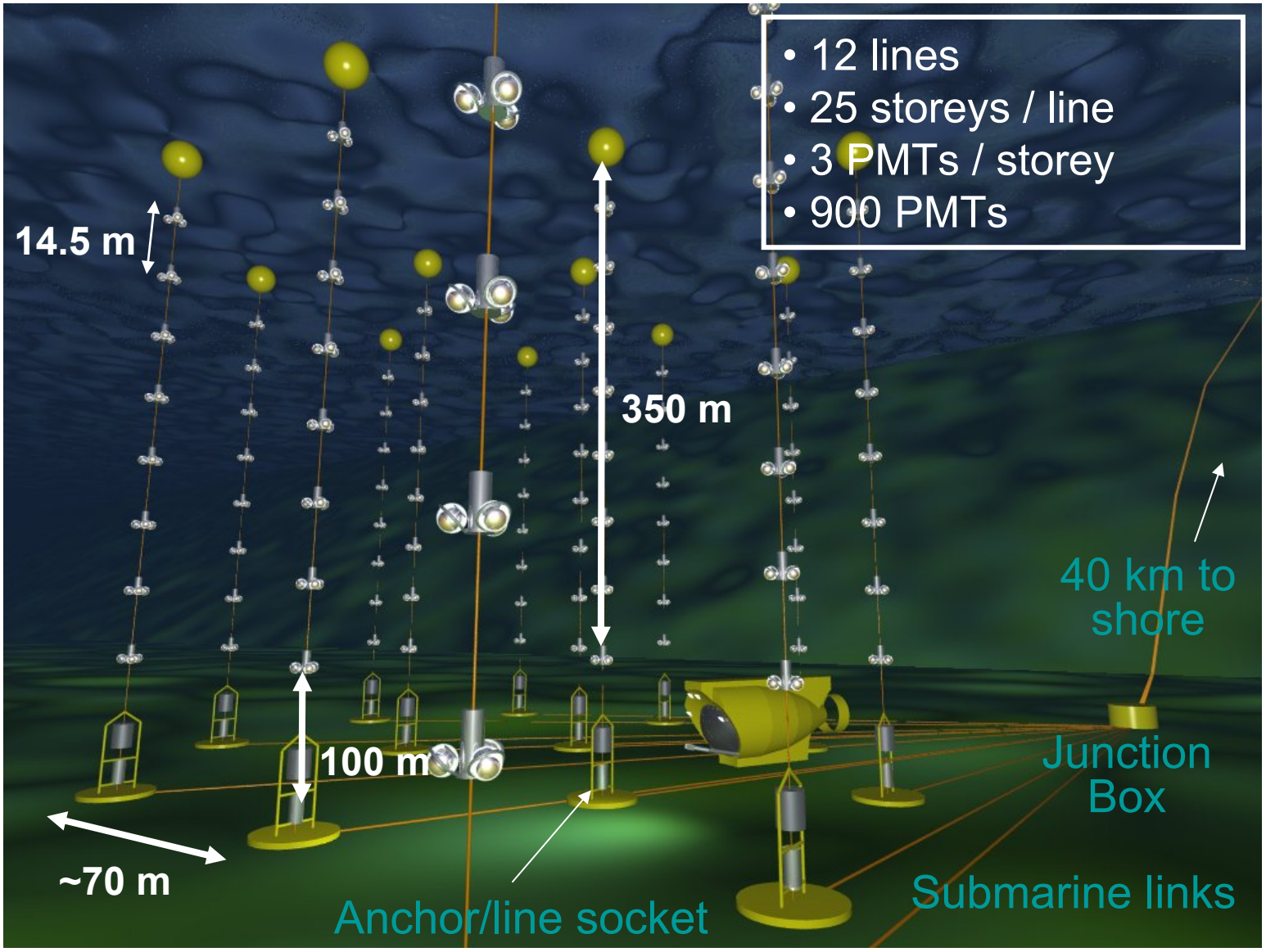


La stazione di Amundsen-Scott durante la stagione estiva 2006-7. E' visibile in primo piano la torre nella quale viene effettuato il drilling e il cavo di supporto per i moduli ottici. In fondo si intravede la nuova stazione dove ci sono gli alloggi.

I siti candidati nel Mediterraneo



The ANTARES 0.1 km^2 telescope

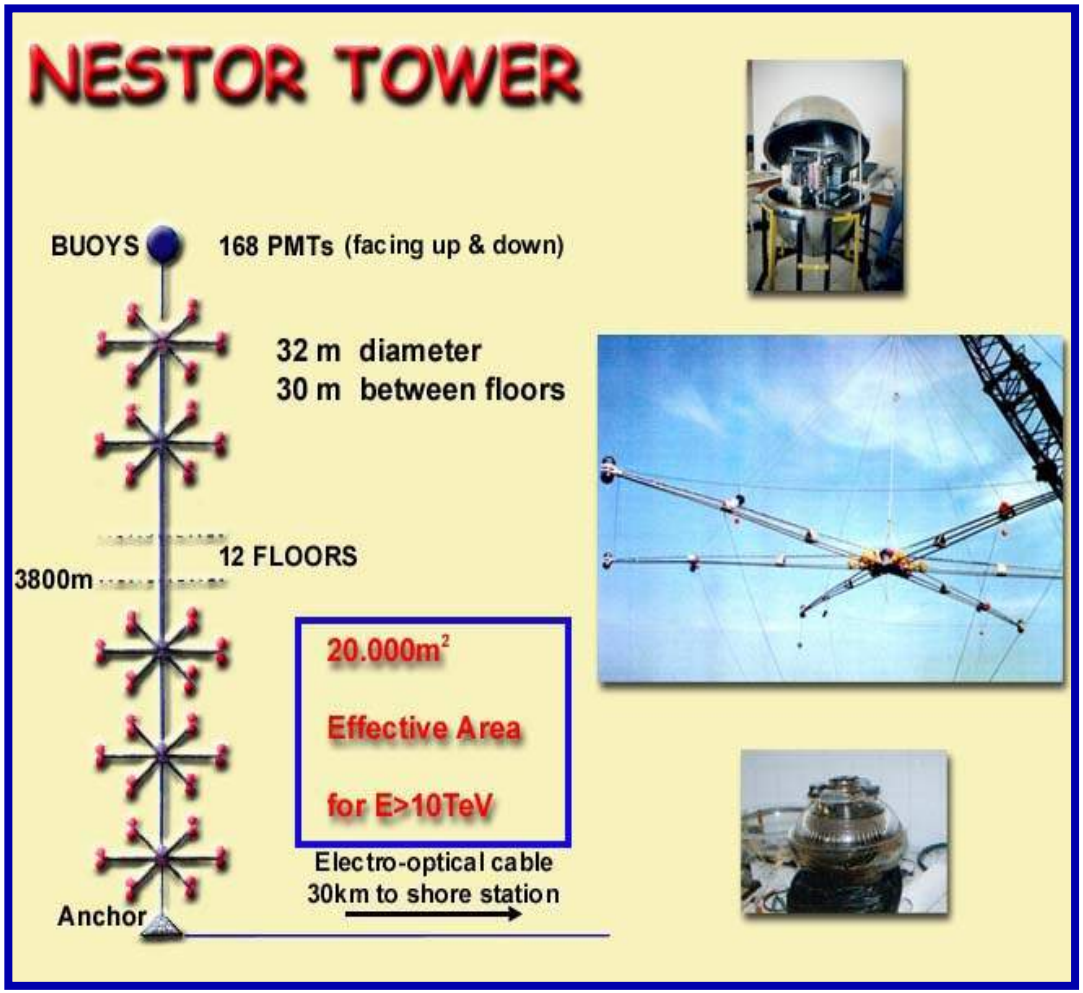


Seven lines presently deployed and five in data taking First neutrino candidates

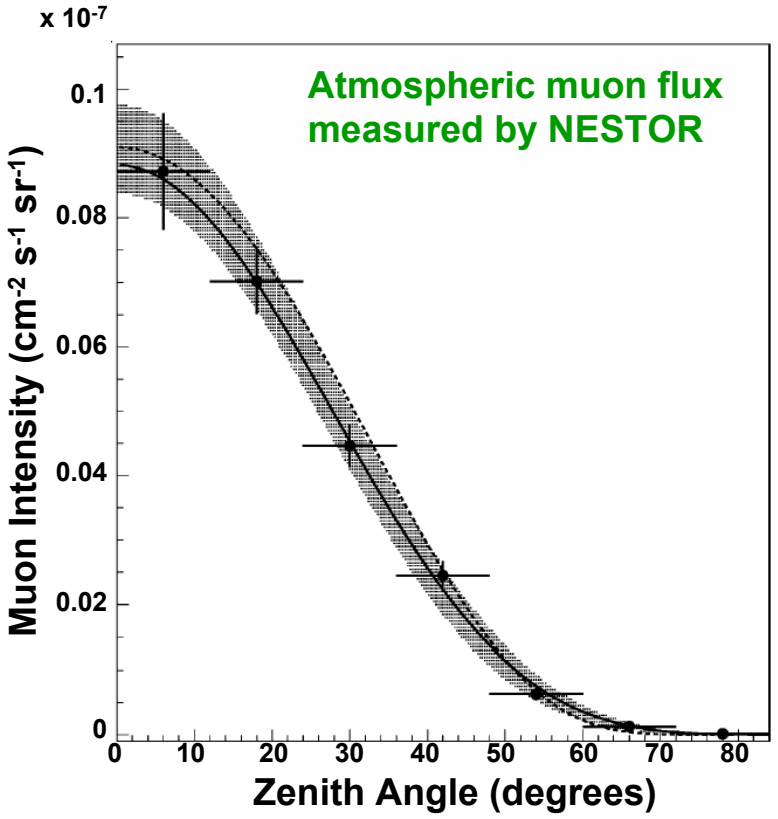
La stringa ANTARES

The ANTARES line before deployment

NESTOR



1 piano di 12 m di diametero con 12 PMT installato a 3800 m depth nel marzo 2003. Dopo circa un mese perdita della connessione.



745 eventi di muoni atmosferici ricostruiti

Il progetto NEMO

- Ricerca e caratterizzazione di un sito ottimale per l'installazione del telescopio km^3 nel Mediterraneo
- Realizzazione e installazione di un dimostratore tecnologico per il km^3 nel Mediterraneo
- Studio delle prestazioni del telescopio per neutrini di alta energia: architettura, influenza dei parametri ambientali (profondità, rumore ottico,…), sensibilità…

INFN Bari, Bologna, Catania, Genova, LNF, LNS, Napoli, Pisa, Roma

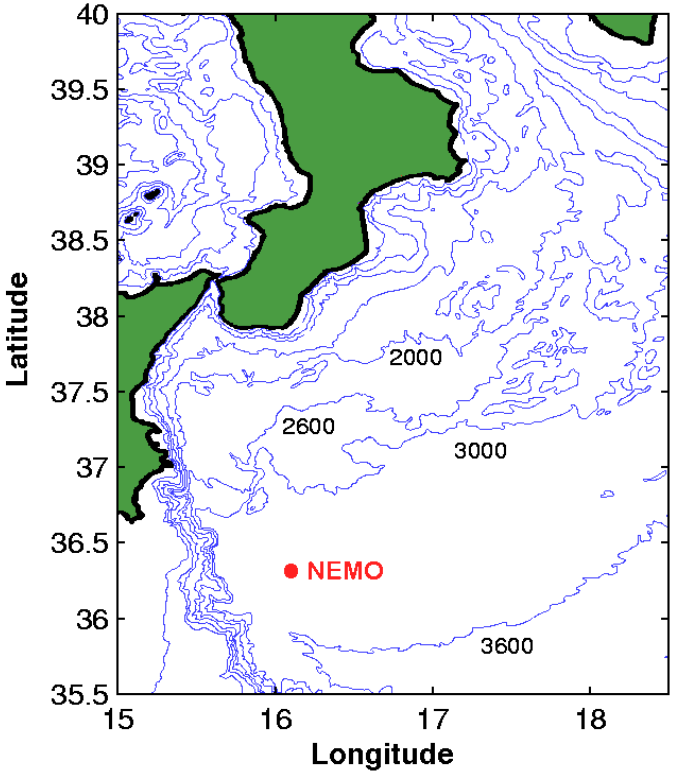
Università Bari, Bologna, Catania, Genova, Napoli, Pisa, Roma *"La Sapienza", CIBRA Università di Pavia*

Istituto Nazionale di Geofisica e Vulcanologia (INGV)

The Capo Passero site

The site has been proposed in january 2003 to ApPEC as a candidate for the km^3 installation

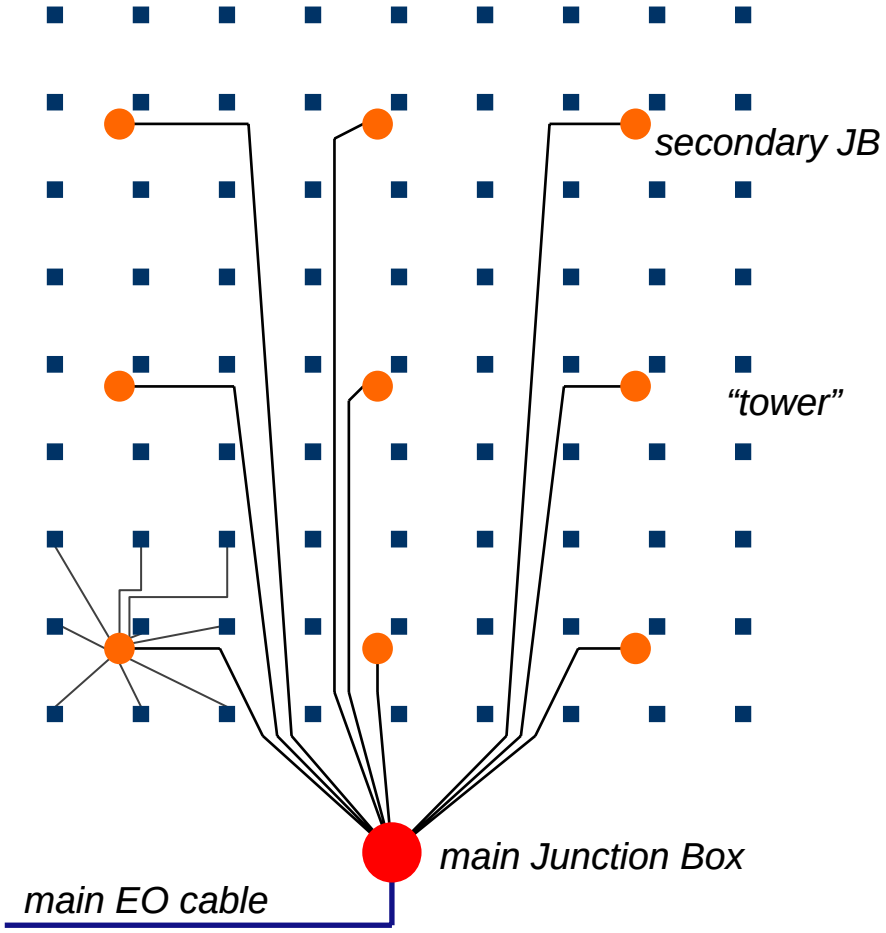
- Depths of more than 3500 m are reached at about 100 km distance from the shore
- Water optical properties are the best observed in the studied sites ($L_a \approx 70$ m @ $\lambda = 440$ nm)
- Optical background from bioluminescence is extremely low
- Stable water characteristics
- Deep sea water currents are low and stable (3 cm/s avg., 10 cm/s peak)
- Wide abyssal plain, far from the shelf break, allows for possible reconfigurations of the detector layout

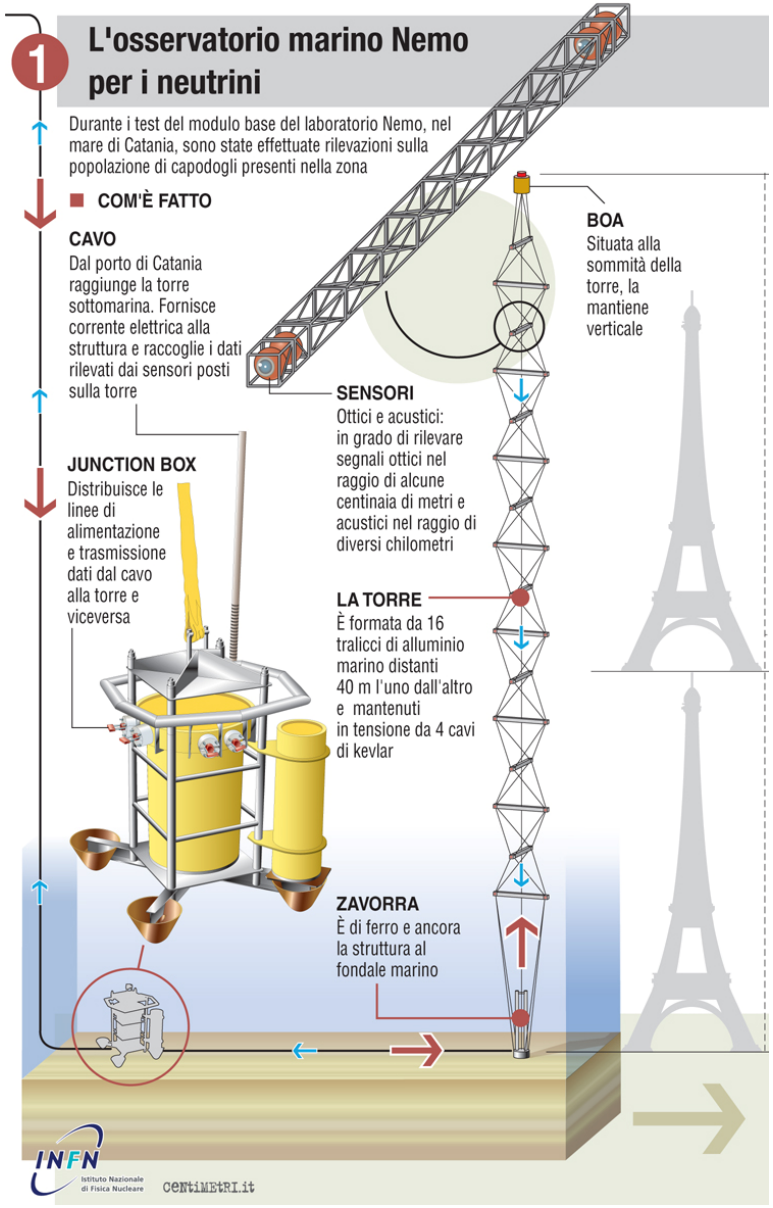


Feasibility study for the km^3 detector

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

Detector modularity

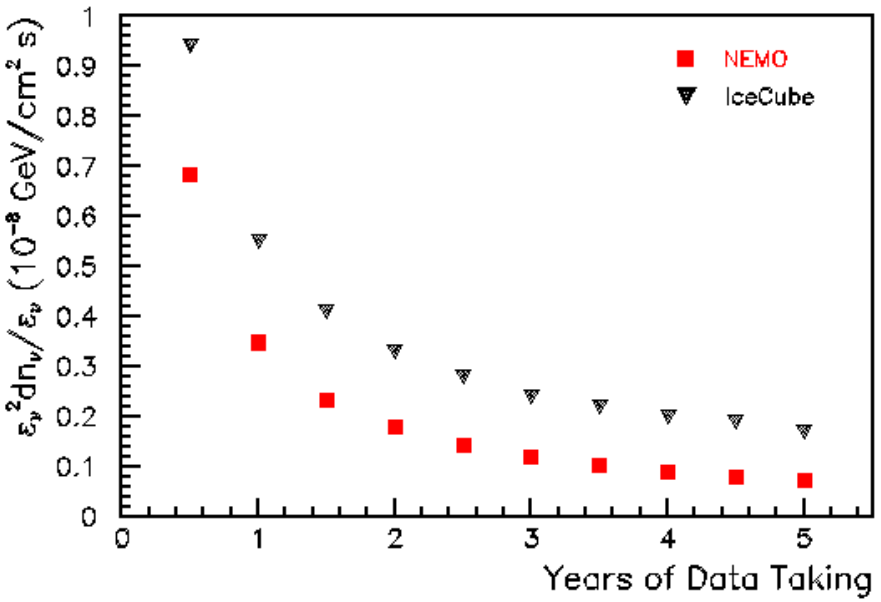




km^3 Cherenkov performance – NEMO vs IceCube

Sensitivity

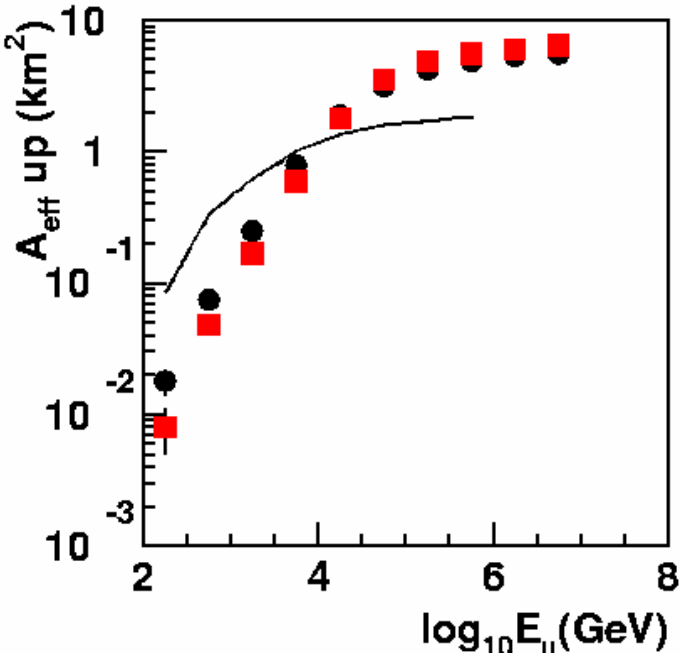
Sensitivity to point-like sources (E_ν^{-2} spectrum)



IceCube simulations from Ahrens et al. Astrop. Phys. 20 (2004) 507

Reconfigurability

Effective areas with different element spacing



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

NEMO search bin 0.3°
IceCube search bin 1°

	tower spacing	floor spacing
Black line	140 m	40 m
Red square	300 m	60 m
Black points	300 m	40 m

The NEMO Phase-1 project

- Validation of the technological solution proposed for the realization and installation of the km^3 detector
- Realization of a system including all the key elements of the km^3
  - *Mechanical structures*
  - *Optical end environmental sensors*
  - *Read out electronics*
  - *Data transmission system*
  - *Power distribution system*
  - *Acustic positioning system*
  - *Time calibration system*
- Multidisciplinary activities
  - *Ovde (measurements of the acoustic background at 2100 m depth, daulphins and sperm whales)*
  - *SN-1 (first operative node of ESONET)*

NEMO Phase-1- LNS test site

Double armed cable
2.330 m

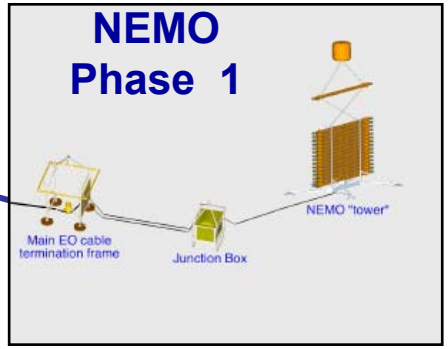
Single armed cable
20.595 m

BU

North branch
5.220 m

SN-1 recorded a large number of seismic events.

South branch
5.000 m



Cable features

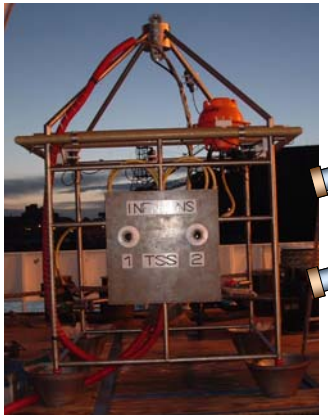
10 optical fibers ITU-T G-652

6 electrical conductors $\Phi = 4\ mm^2$

Junction Box

Mini-tower - 4 floors

Frame



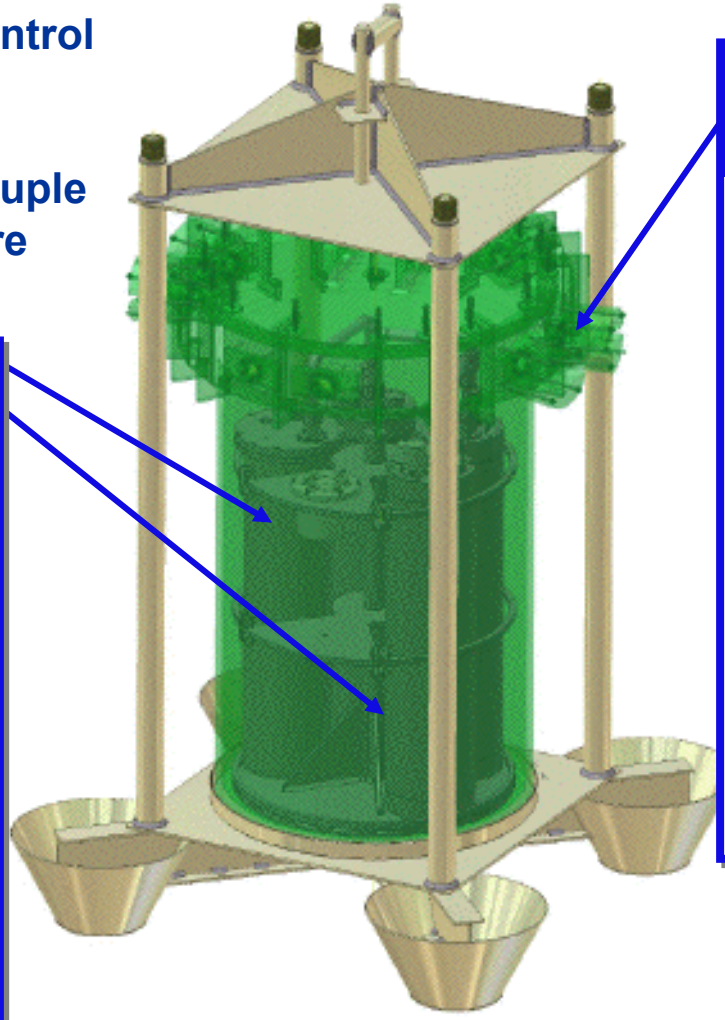
Jumper 300m

Jumper 300m

The Junction Box

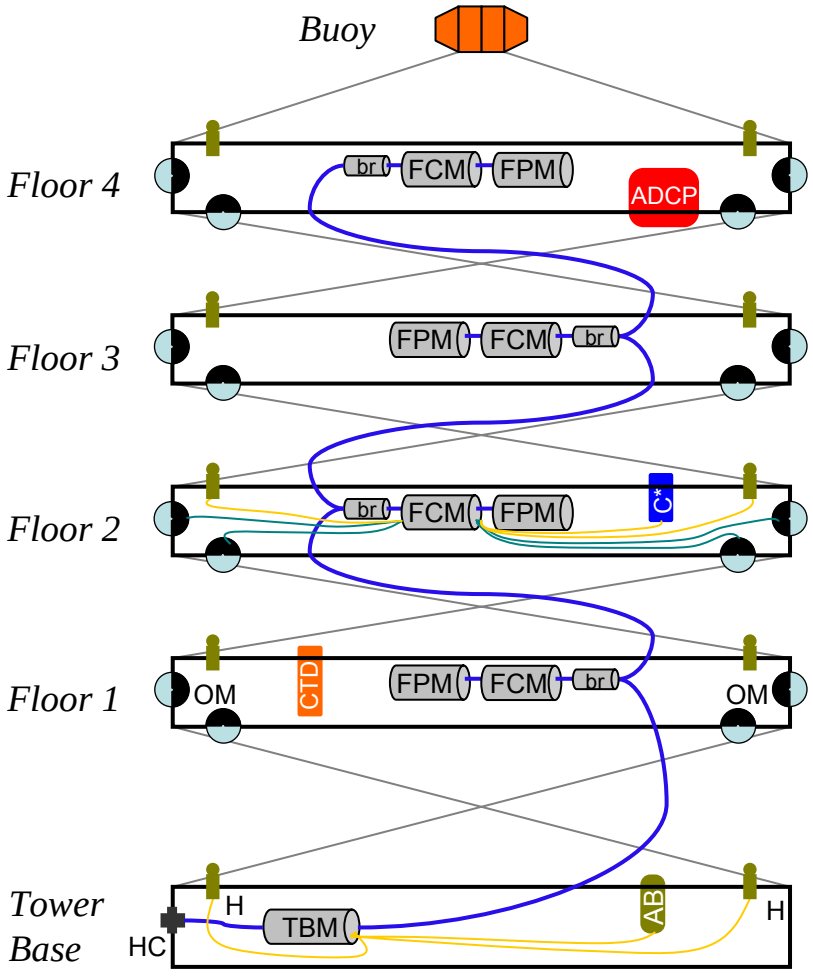
Data transmission electronics
Power distribution and control system
Optical fibre splitters
Innovative design to decouple the corrosion and pressure resistance problems

Electronics pressure vessels



External fibreglass container

Schema e strumentazione della minitorre



Quattro piani

- *Lunghezza 15 m*
- *Spaziatura verticale 40 m*

16 Moduli Ottici con PMT da 10”

Posizionamento Acustico

- *2 idrofoni per piano*
- *1 beacon a base torre*

Strumentazione

- *In ogni FCM 1 bussola + inclinometro (pitch e roll)*
- *Piano 1 CTD (misure di Temperatura, Conducibilità e Pressione)*
- *Piano 2 sonda C* (misura della lunghezza di attenuazione)*
- *Piano 4 ADCP (Acoustic Doppler Profiler (misura del profilo della corrente + bussola)*

Read-out and data transmission

Off-shore

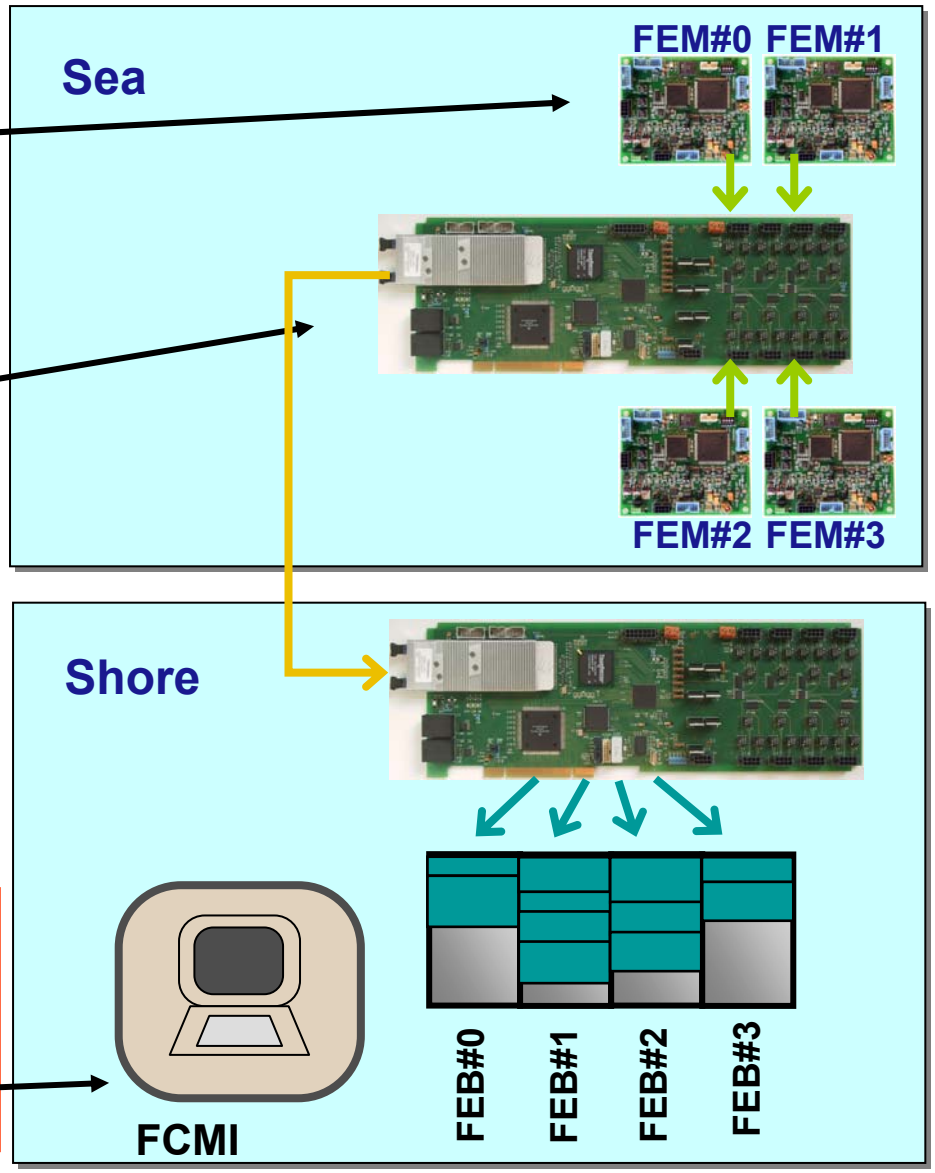
Optical Module data come from 4 **Front End Modules** (**FEM**) on the OM

Off-shore floor data concentration is carried out by a **Floor Control Module (FCM)** board which transmit OM and Slow Control data (water parameters, OM position, internal sensors) to shore through Optical Fibre (DWDM technology)

Data tramsmission is based on Optical Fiber (DWDM technology)

On-shore

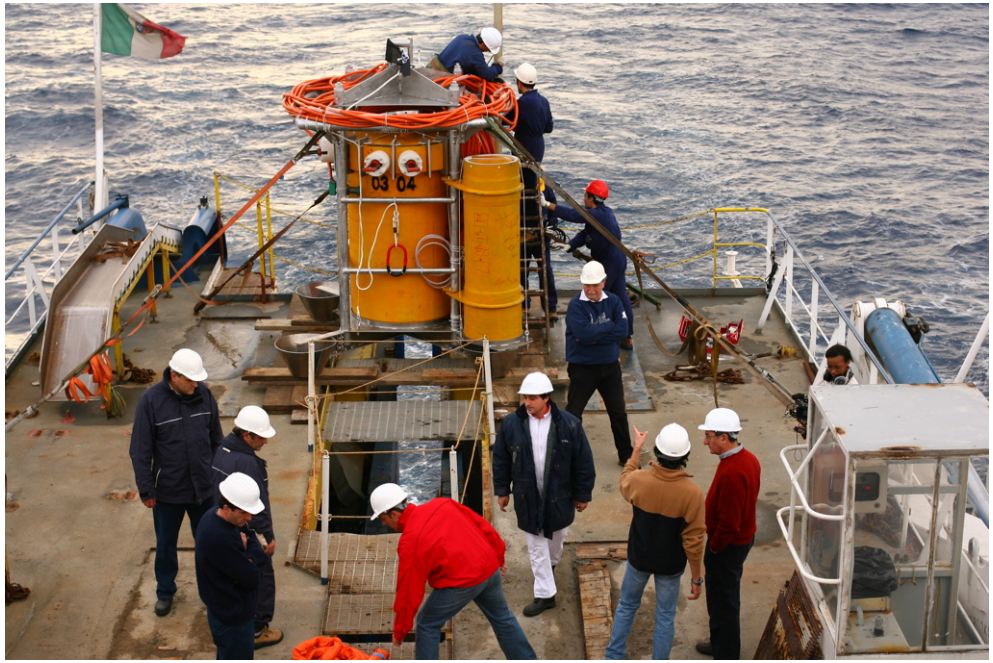
One floor data is received **on-shore** by a **twin FCM** board, plugged on a host machine **(FCM Interface)**



Installazione di NEMO Fase-1

9 dicembre 2006

Preparativi al deployment della Junction Box



Installazione di NEMO Fase-1

10 dicembre 2006

Deployment della Junction Box

Installazione di NEMO Fase-1

13 dicembre 2006 *Imbarco della torre*

Installazione di NEMO Fase-1

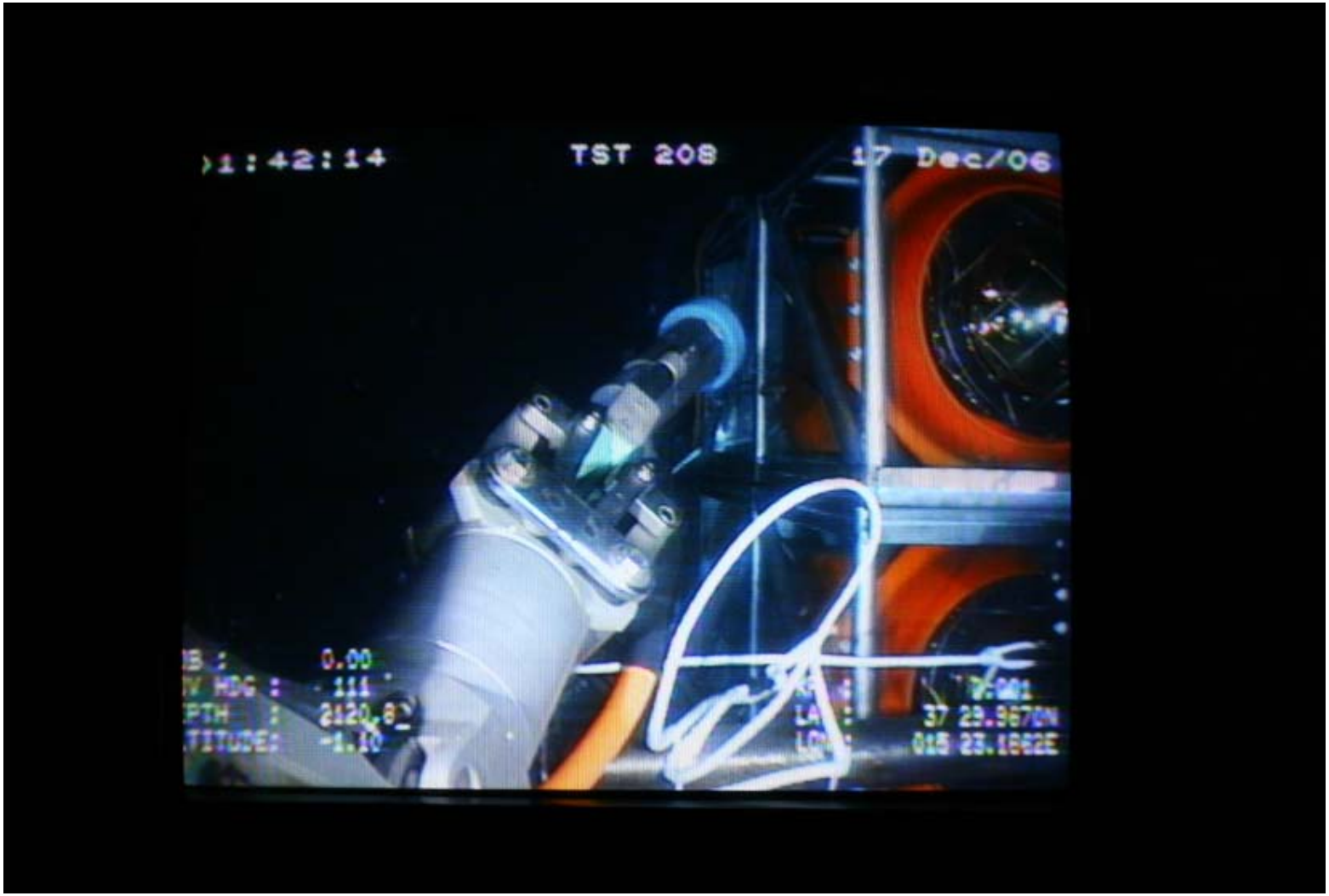
13 dicembre 2006 *Imbarco della torre*

Installazione di NEMO Fase-1

15 dicembre 2006 *Deployment della torre*

Installazione di NEMO Fase-1

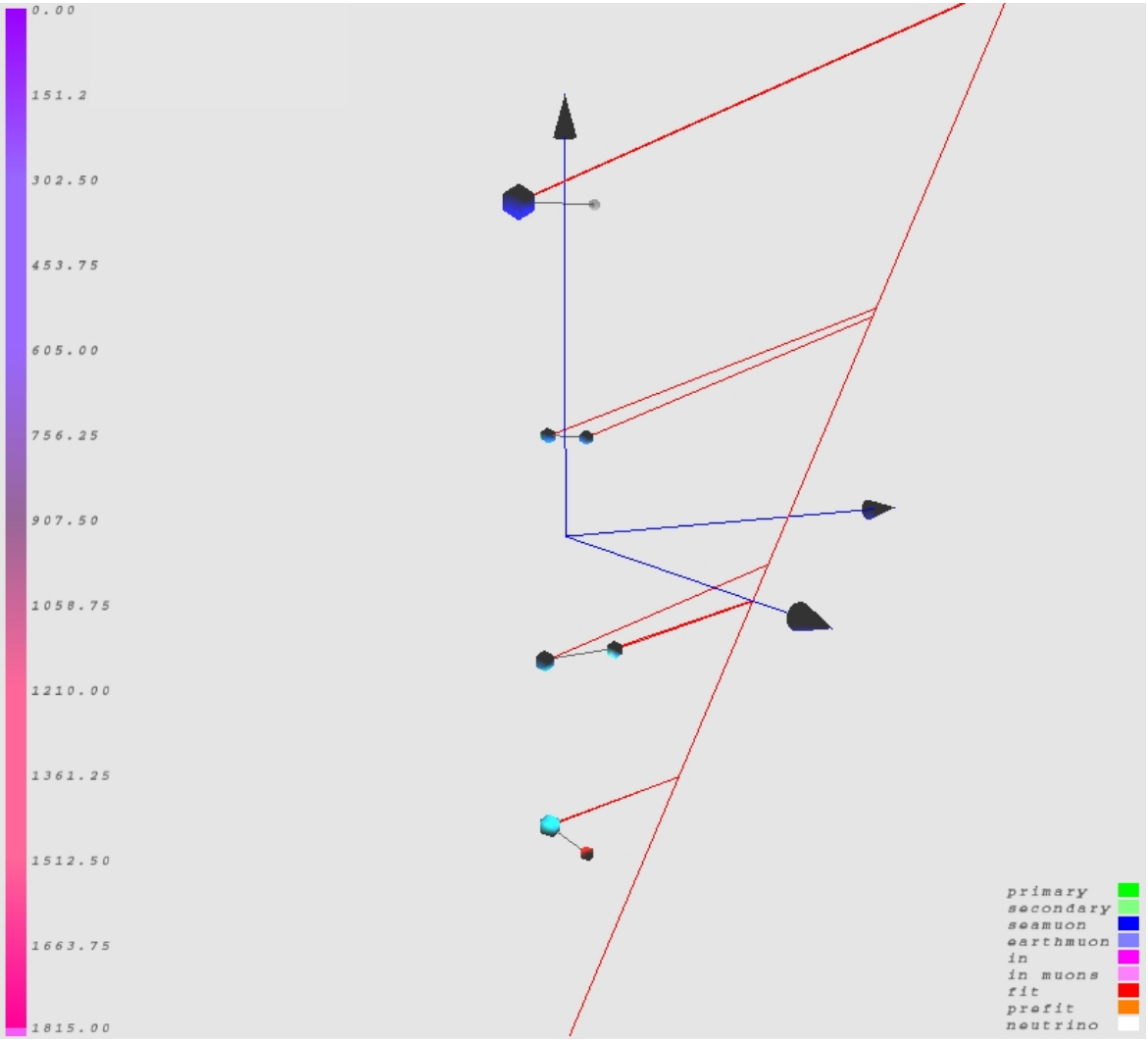
16 dicembre 2006 *Connessione della torre alla JB*



NEMO Phase-1

- Deployment and connections (electrical and optical) very successful
- Mini-tower in data taking since 18 December 2006
- After 20 days the first floor of the mini-tower was close to the sea bed. At the end of January also the second floor collapsed. The inspection with the Rov confirmed a loss of buoyancy.
- Installation of a new buoy is under study
- Data analysis in progress. First tracks reconstructed

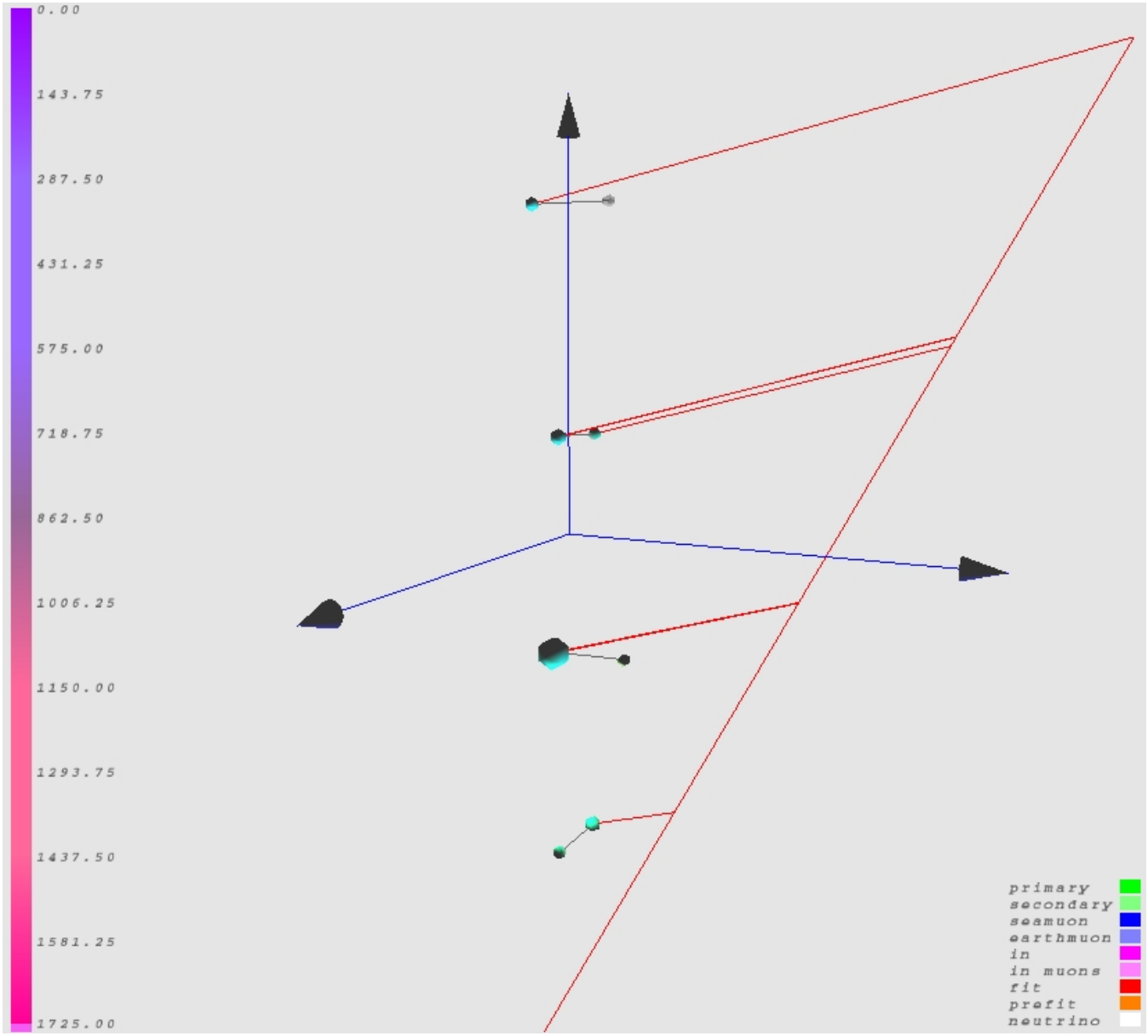
Preliminary data



24 January 2007
Run 23 file 1
Event 189722
11 PMT involved

- Trigger local coincidence up-horizontal (Δt=20ns)
- Aart Reconstruction
- Background rejection -> causality with the highest in charge and in coincidence

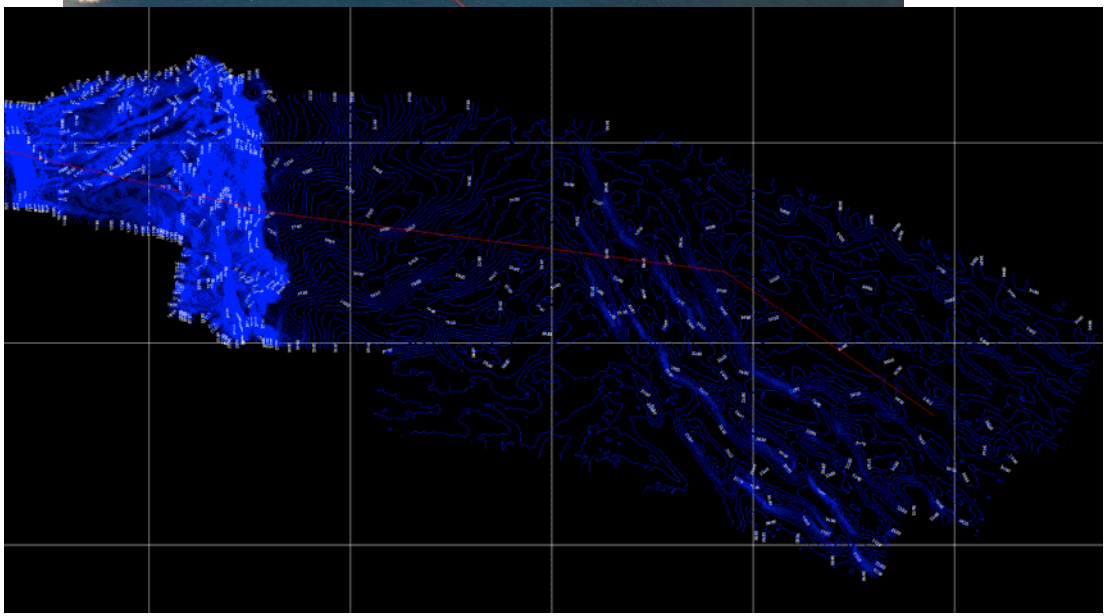
Preliminary data



24 January 2007
Run 23 file 1
Event 356615
11 PMT involved

- Trigger local coincidence up-horizontal (Δt=20ns)
- Aart Reconstruction
- Background rejection -> causality with the highest in charge and in coincidence

The NEMO Phase-2 project



A deep sea station on the Capo Passero site

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 16 storey tower**
- **Long term monitoring of the site**

INFRASTRUCTURE UNDER CONSTRUCTION

- **Shore station in Portopalo di Capo Passero**
- **100 km electro optical cable**
- **Underwater infrastructures**

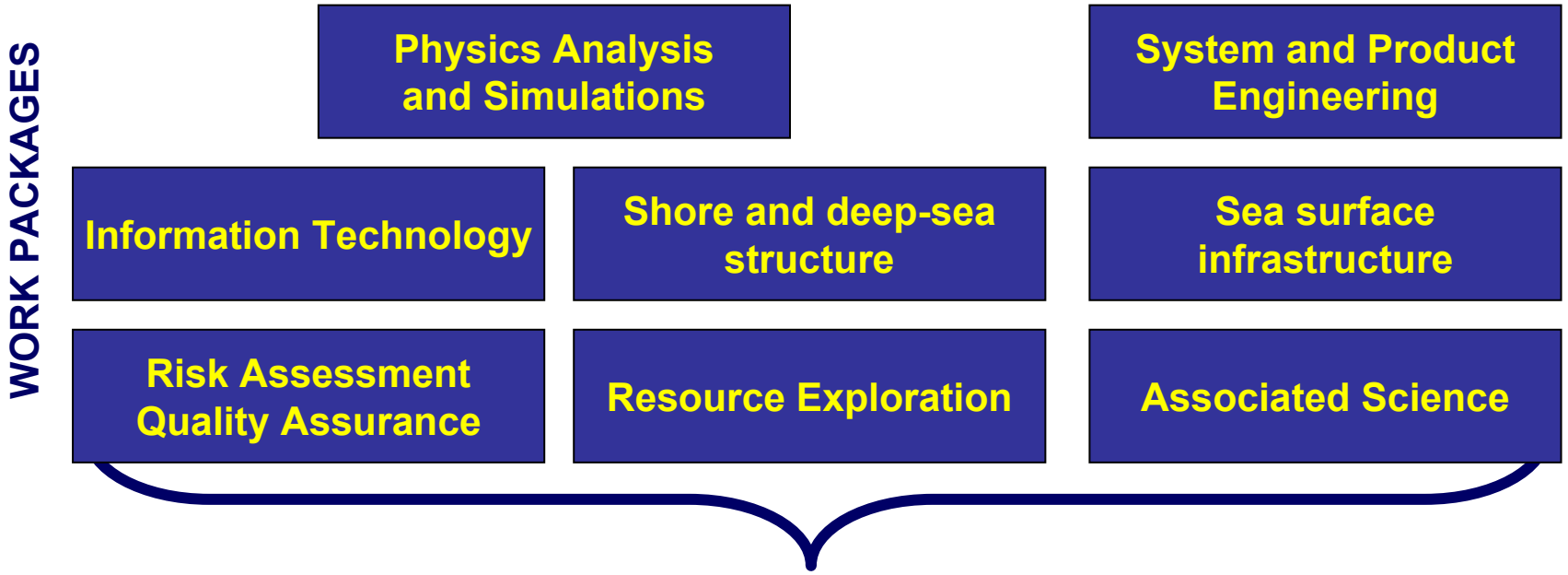
STATUS

- **Electro-optical cable (DC, >50 kW, 20 fibres) ordered**
- **A building (1000 m^2) located inside the harbour area of Portopalo has been acquired. Procedures for its renovation started**
- **Project completion planned in 2008**

The KM3NeT European Design Study

The experience and know-how of the three european collaborations is merging in the KM3-NET activity

- **Collaboration of 8 Countries, 34 Institutions**
- **Aim to design a deep-sea km^3-scale observatory for high energy neutrino astronomy and an associated platform for deep-sea science**
- **Funded for 3 years (2006-2009)**



A Technical Design Report
for a Cubic kilometre Detector in the Mediterranean

Conclusioni e prospettive

- La costruzione del km^3 nel ghiaccio è iniziata
- Le tecnologie per il km^3 nel Mediterraneo sono state sviluppate e “validate”
- La comunità europea converge in km3net e nel “preparatory study” per la costruzione del km^3 nel Mediterraneo
- Il km^3 nel Mediterraneo osserverà il cielo di neutrini non visibile da IceCube e in particolare il centro galattico con maggiore sensibilità alle sorgenti puntiformi