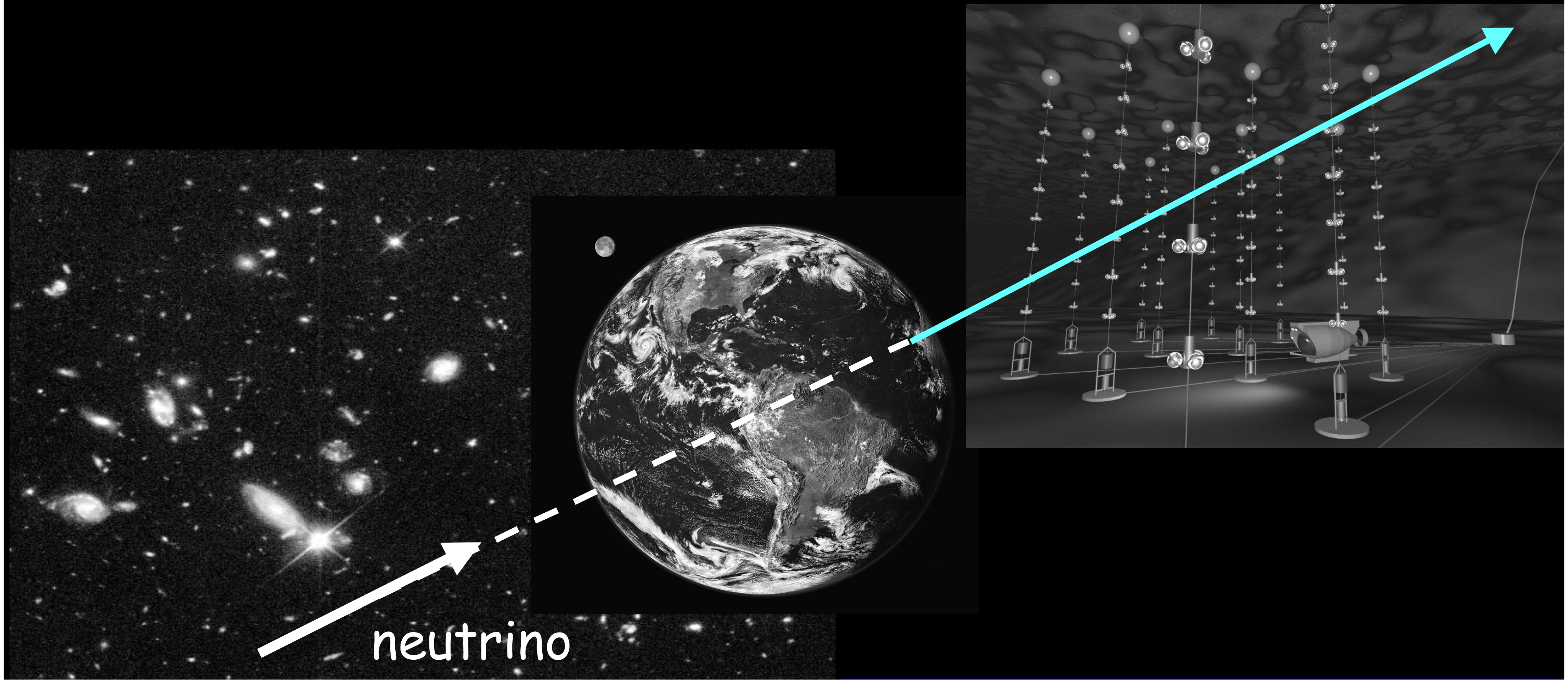
Neutrino Telescopes in the Mediterranean

John Carr (Centre de Physique des Particules de Marseille)

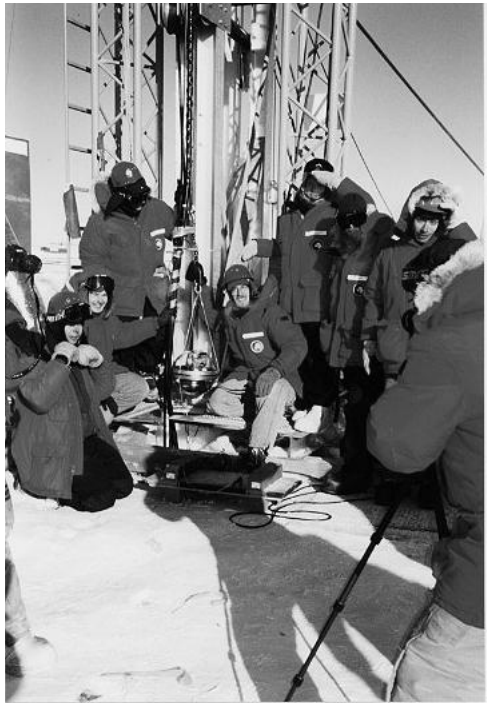
- Motivation for a Northern Hemisphere Water Detector
- Status of Mediterranean Projects: **ANTARES, NEMO, NESTOR**



Water versus Ice

Deployment

Ice gives solid platform to install detector
Sea experiments need boats/ platforms
Ice detectors worked first (Baikal deploys from ice)



Angular Resolution

Light scattering much less in water
AMANDA : ~ 3° (real detector)
ANTARES : ~ 0.4 ° (simulations)

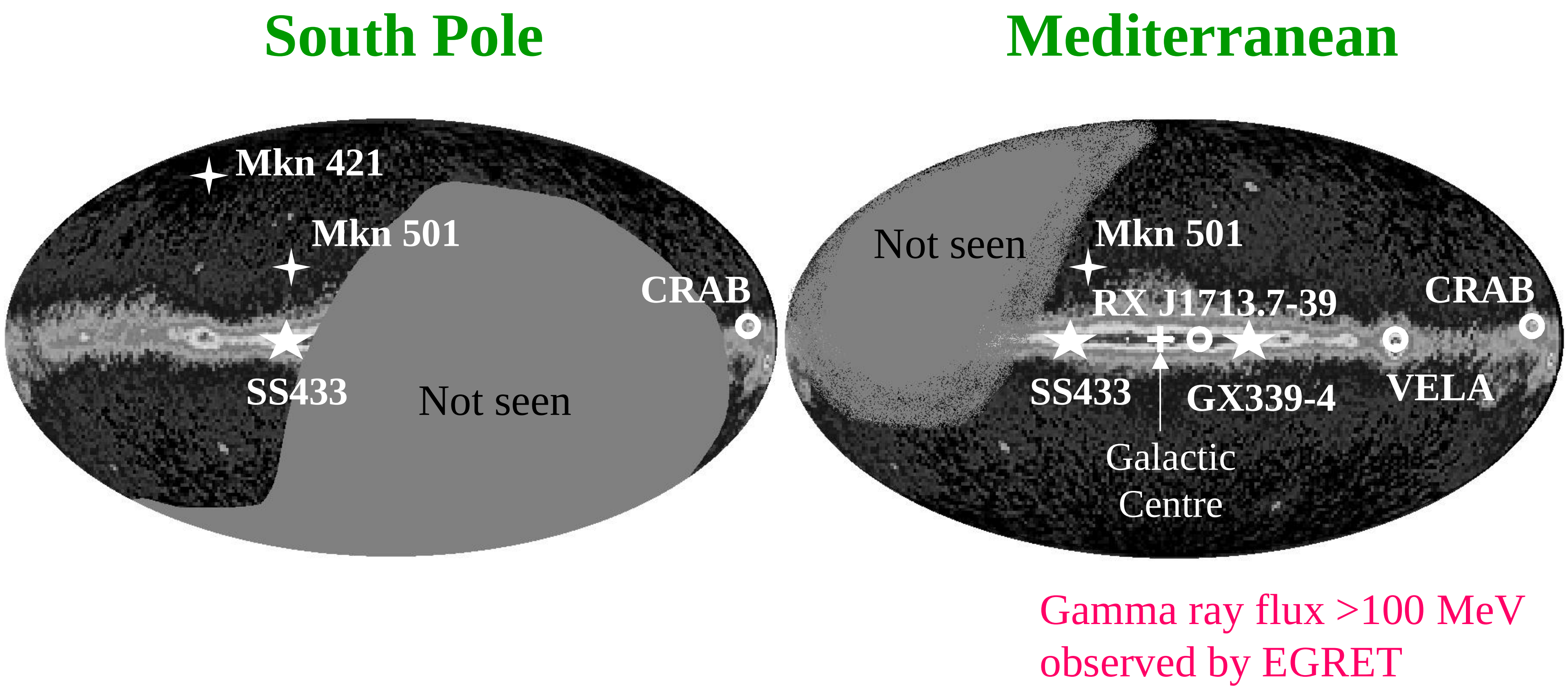
Uniformity of Detector response

Water homogeneous
Ice has dust layers, bubbles
Knowledge of efficiency simpler in water

Noise Backgrounds

Water: ^{40}K /bioluminescence ~ 60kHz / PMT
Ice: only dark tube noise ~ 5kHz / PMT
Detector design must take into account

Sky Observable by Neutrino Telescopes

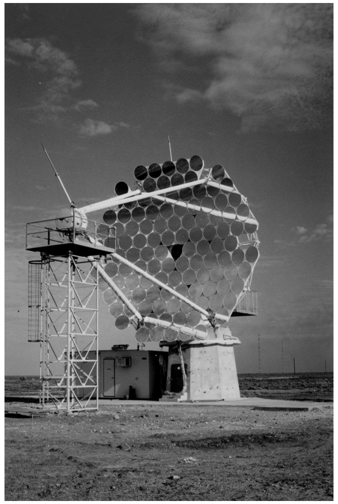


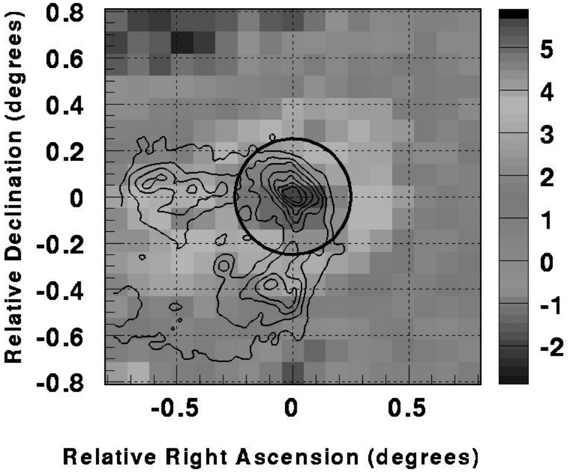
Region of sky seen in galactic co-ordinates
assuming efficiency=100% for 2π downwards

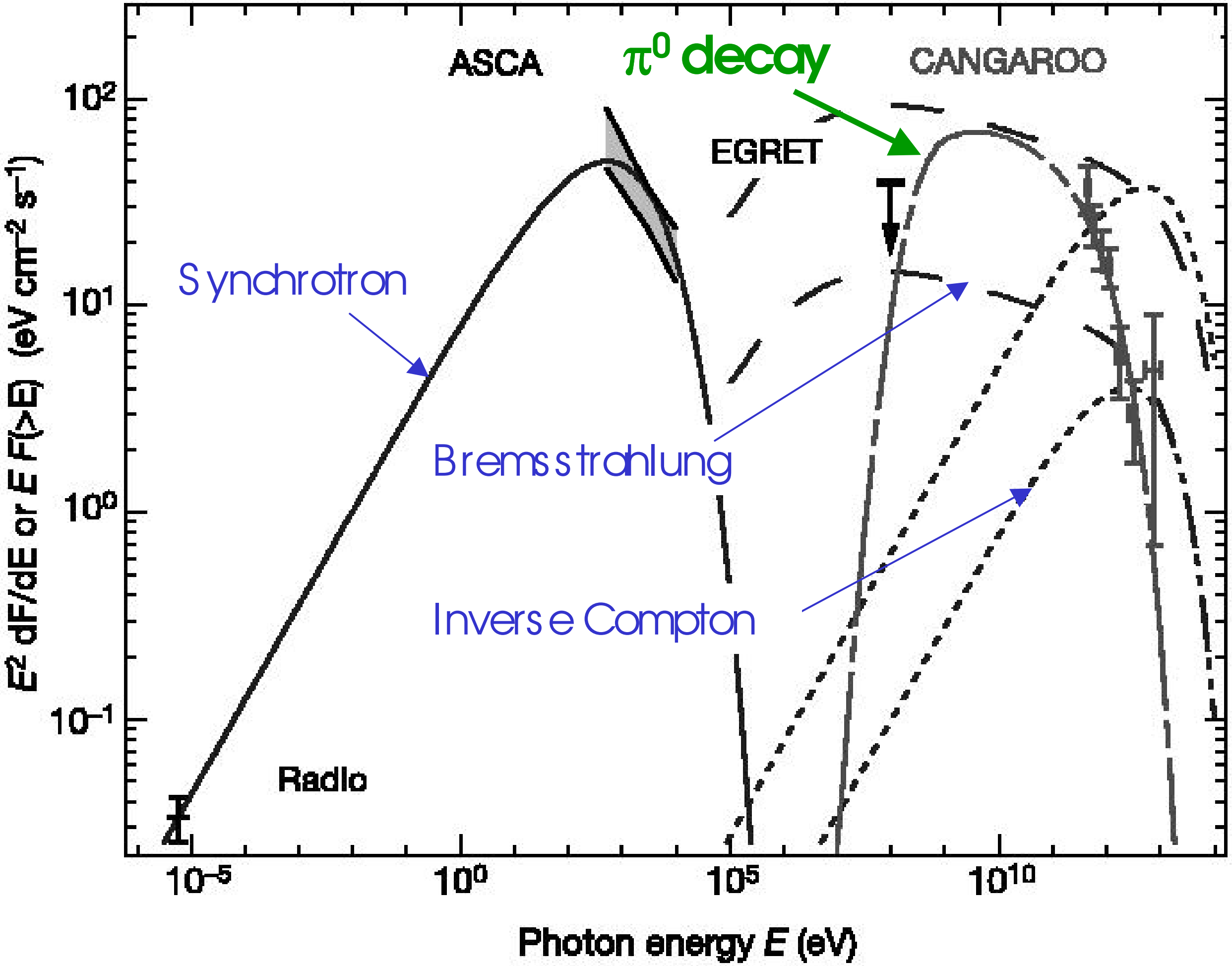
Need Neutrino Telescopes in both hemispheres to see whole sky

The Acceleration of cosmic-ray protons in the supernova remnant RX J1713.7-3946

R. Enomoto et al., Nature, v416, p823,25 April 2002

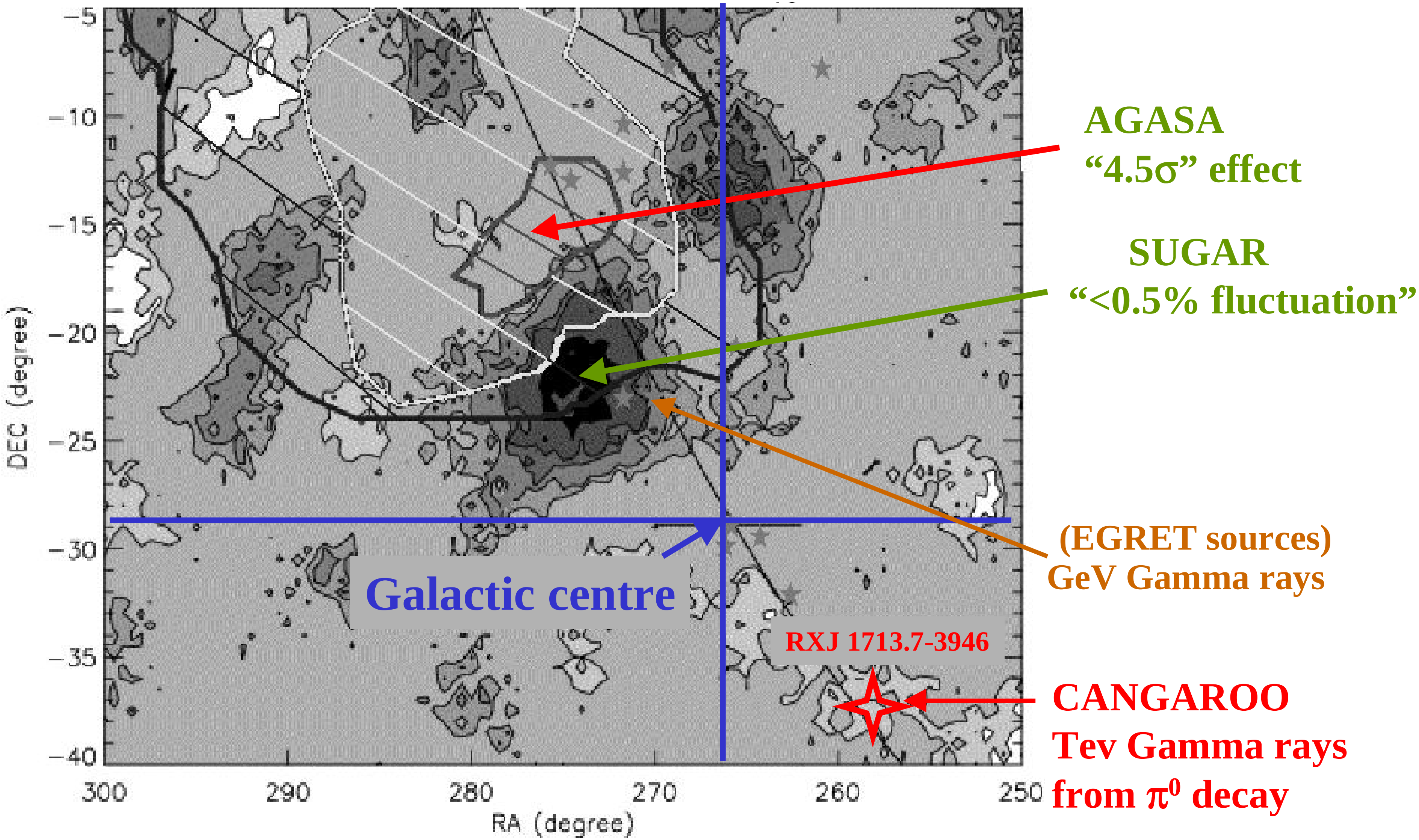






Cosmic Rays near Galactic Centre

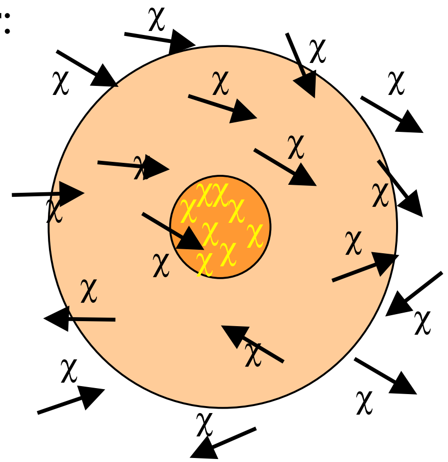
Density plot of Charged Cosmic Rays E ~ 10^{18} eV



Search for Dark Matter as Neutralino

Halo of Dark Matter:
$\rho_\chi \sim 0.3$ Gev/ cm^3,
$v_\chi \sim 300$ km/sec

Collisions $\rightarrow v_\chi < v_{esc}$
captured in centre
of earth, sun, galaxy



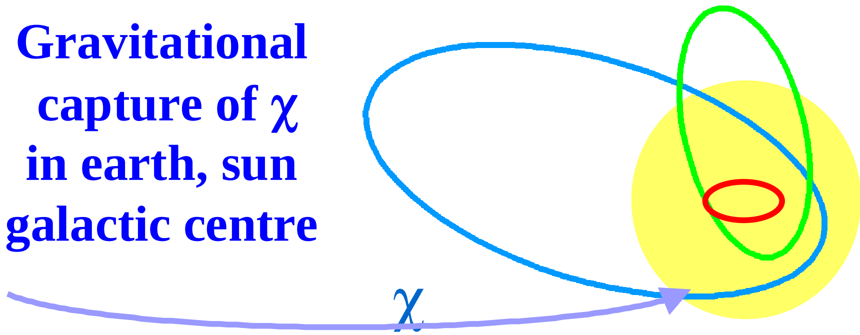
$\chi + \chi \rightarrow$ **WW, bb, ….**

$\downarrow \quad \downarrow$

$\mu\nu \quad c\mu\nu$

$E_\nu \sim 0.3\text{-}0.5\ m_\chi$

Gravitational capture of χ in earth, sun galactic centre



WIMP looses energy by elastic interaction

=> if $v < v_{escape}$, capture

capture + annihilation balance

=> constant density in core

Search for Annihilation at centre of Earth, Sun or Galactic

Galactic Centre and Sun more visible from North

Comparison between ANTARES and Direct Detection

Using example of

mSUGRA model

$A_0=0$, $\mu>0$, $\tan\beta=10$,

$M_{1/2}=0\text{-}800$ GeV,

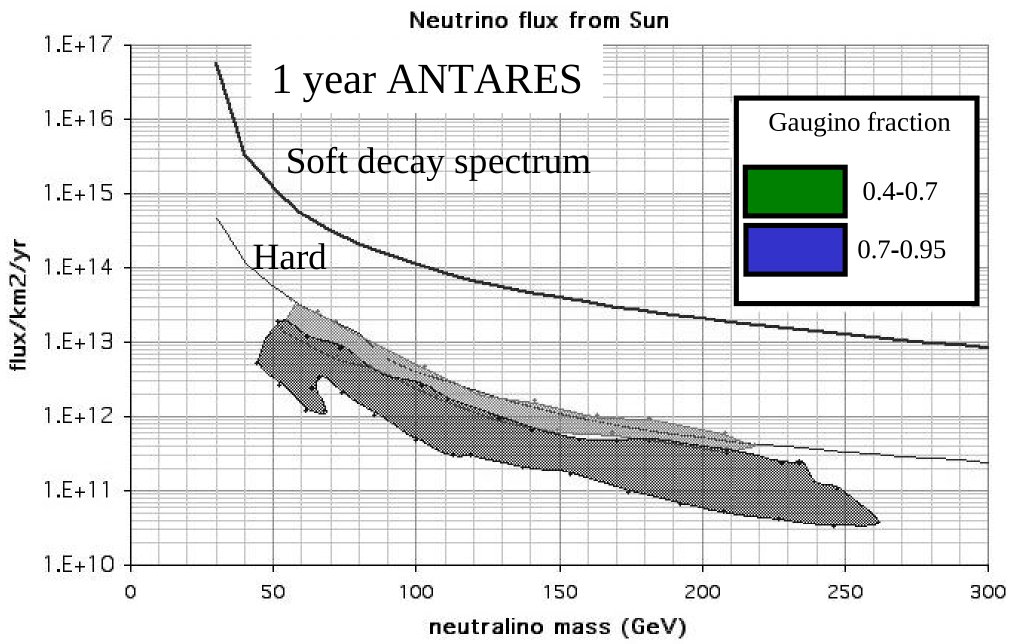
$M_0=0\text{-}1000$ GeV

+ $\Omega_{wimp}h^2 < 1$

+ LEP constraint

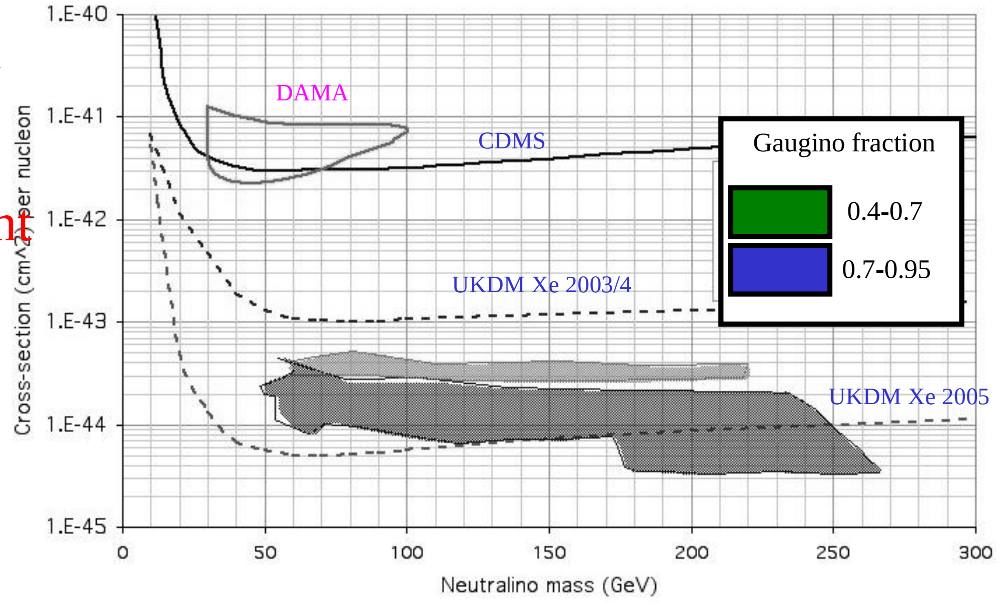
Neutrino telescope

ν flux from sun



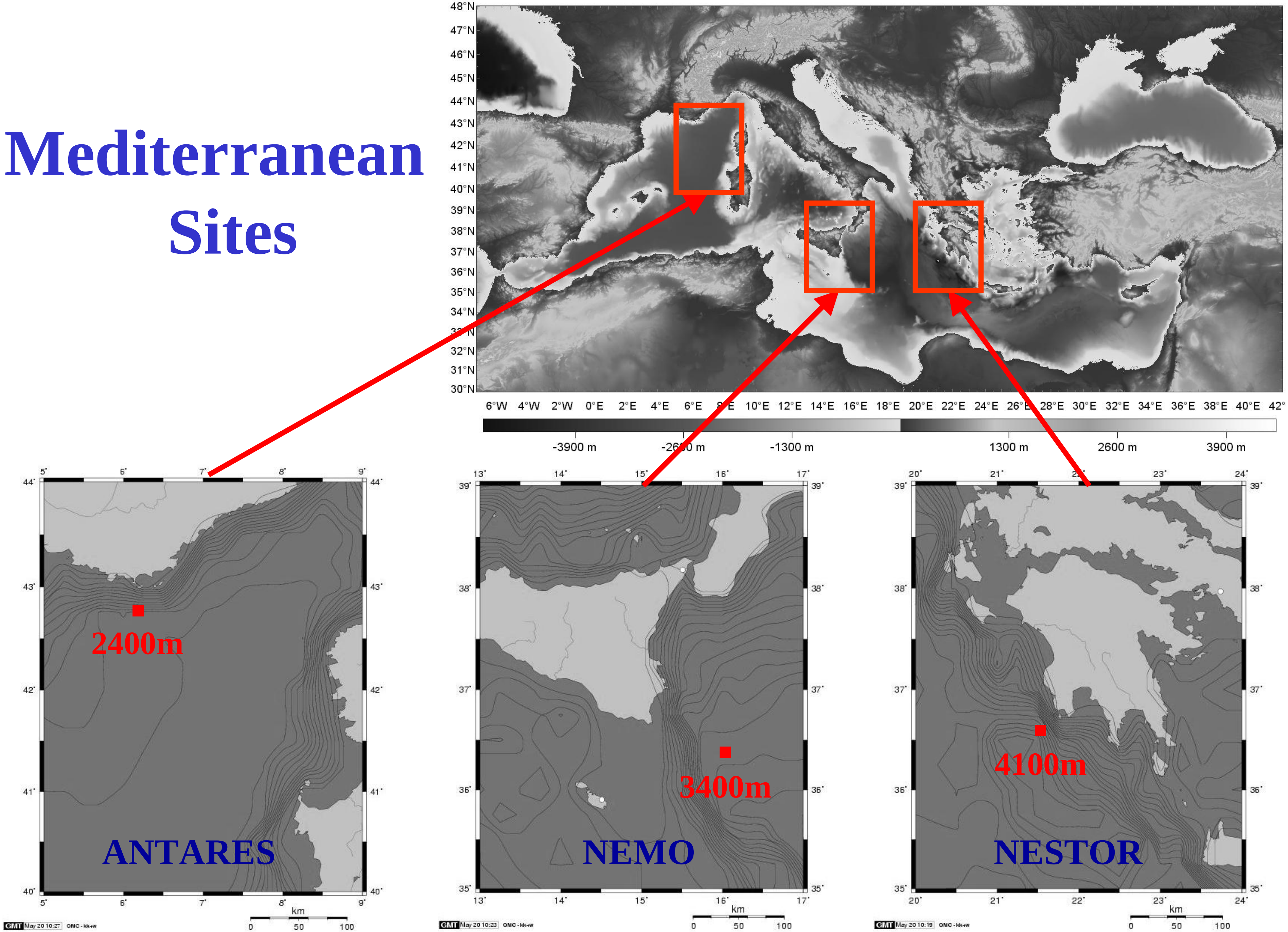
Direct Detection

spin-independent cross-section



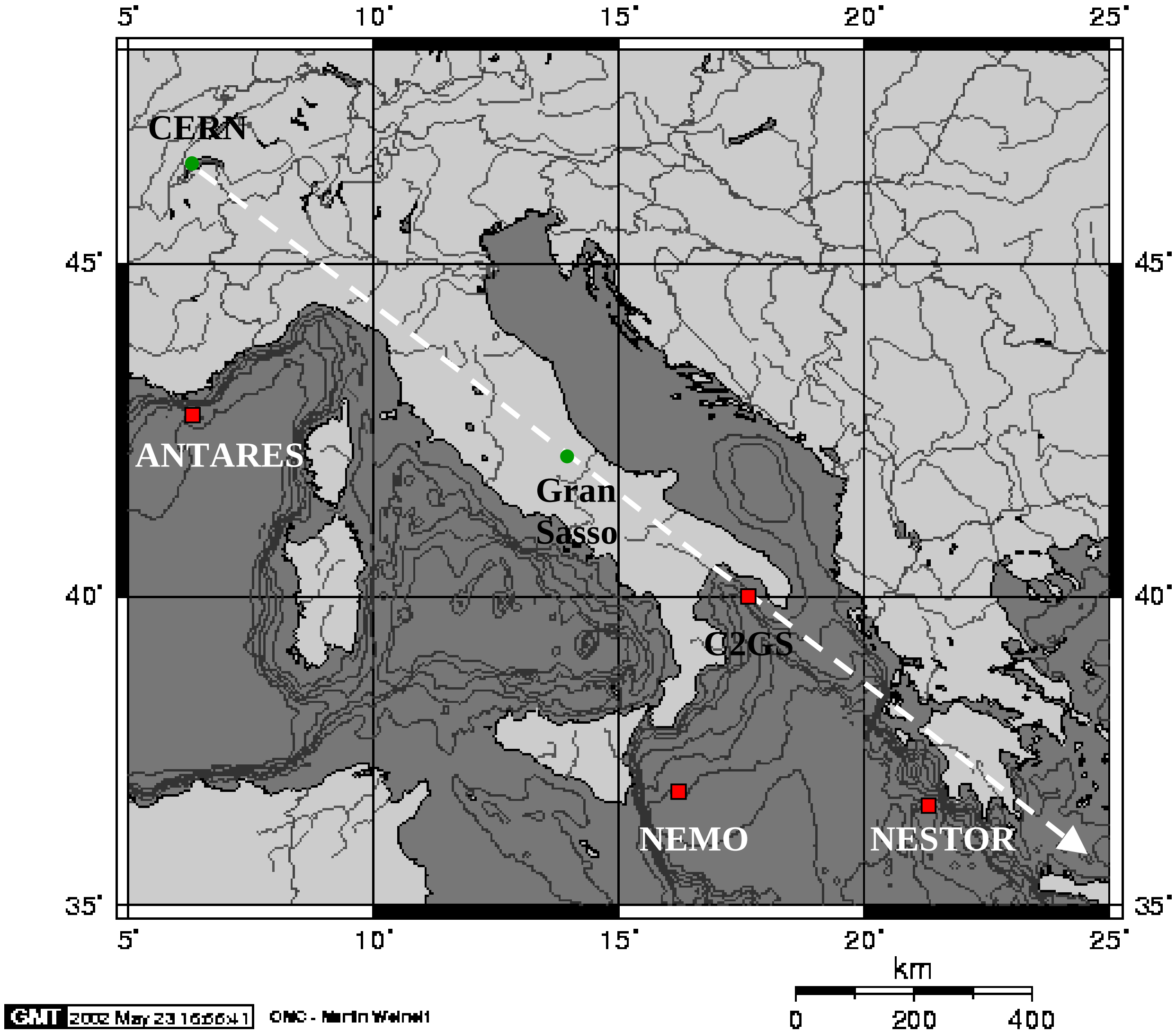
⇒ Neutrino Telescopes very competitive

Mediterranean Sites

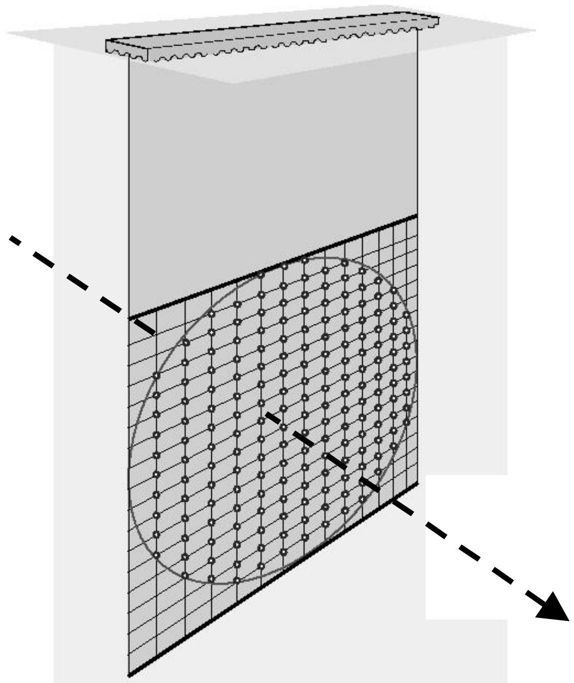


C2GS

See talk of F. Dydak



Detector
4000 PMT
2D array



Evolution of Mediterranean Projects

NESTOR

	1991 -	R & D, Site Evaluation
Summer	2002	Deep-sea deployment (4100m) & run 2-floors
Winter	2003	Recovery & re-deployment with 4-floors
Autumn	2003	Full Tower deployment in the deep sea
	2004	Add the three DUMAND strings around tower
	2005 - ?	Deployment of more NESTOR towers e.g. 7

ANTARES

	1996 - 2000	R&D, Site Evaluation
January	2000	Data from Demonstrator line
	2001	Start Construction of ~ $0.1km^2$ at Toulon site
September	2002	Deploy pre-production prototype line
December	2004	10 line detector complete
	2005 - ?	Construction of $1km^3$ Detector

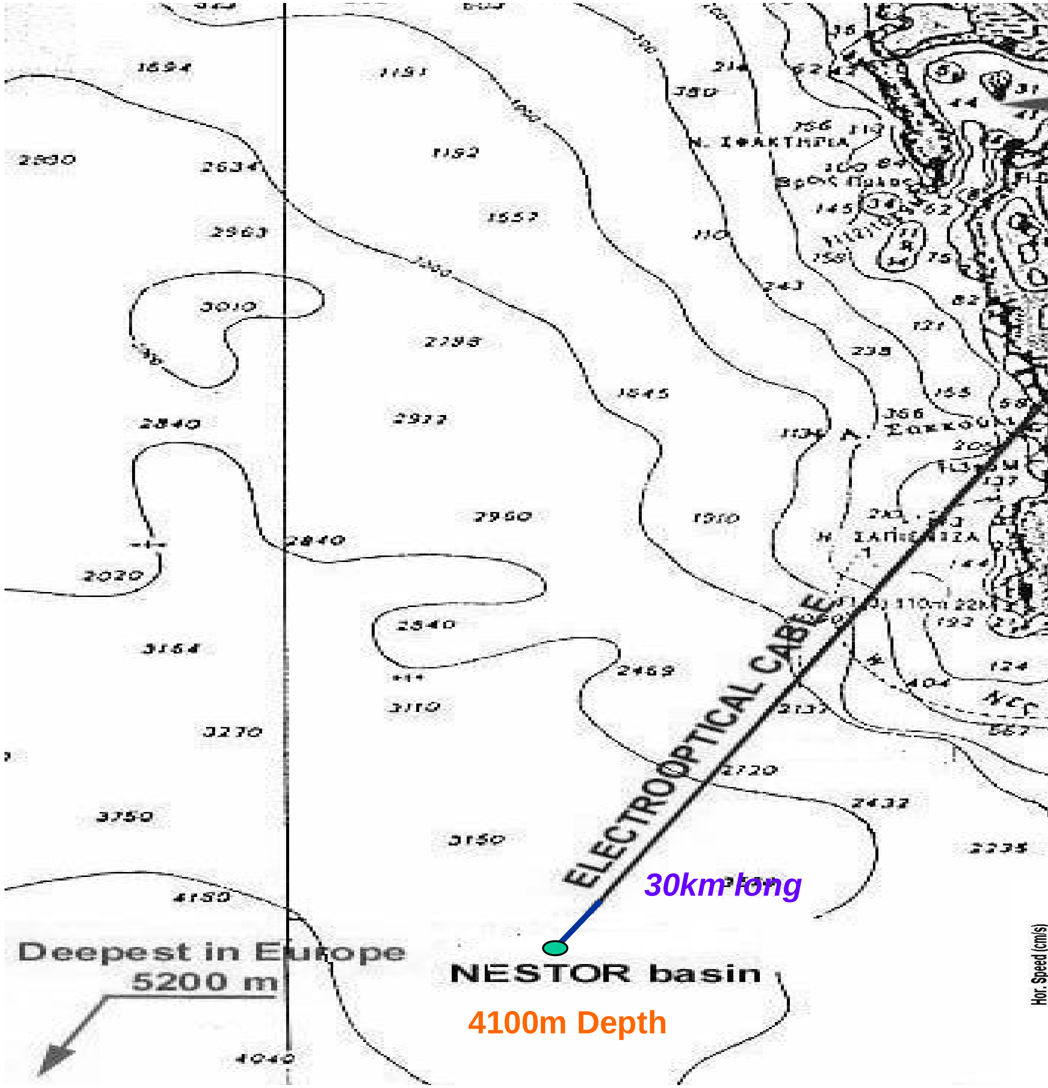
NEMO (Neutrino Mediterranean Observatory)

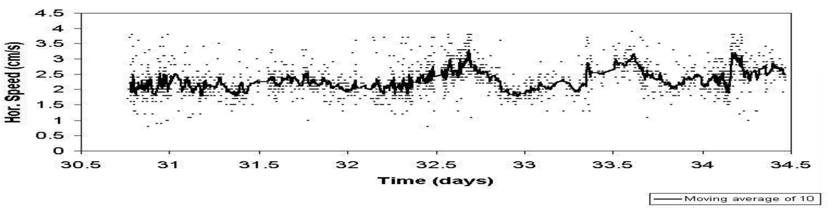
1999 - 2001	Site selection and R&D
2002 - 2004	Advanced R&D and prototyping at Catania Test Site
2005 - ?	Detector realization

NEMO and ANTARES collaborating since 2000

work together to build $0.1km^2$ at Toulon site with agreement to choose best site for future detector

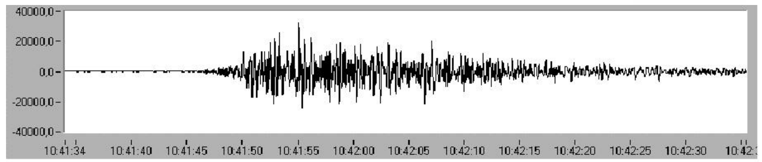
NESTOR Project





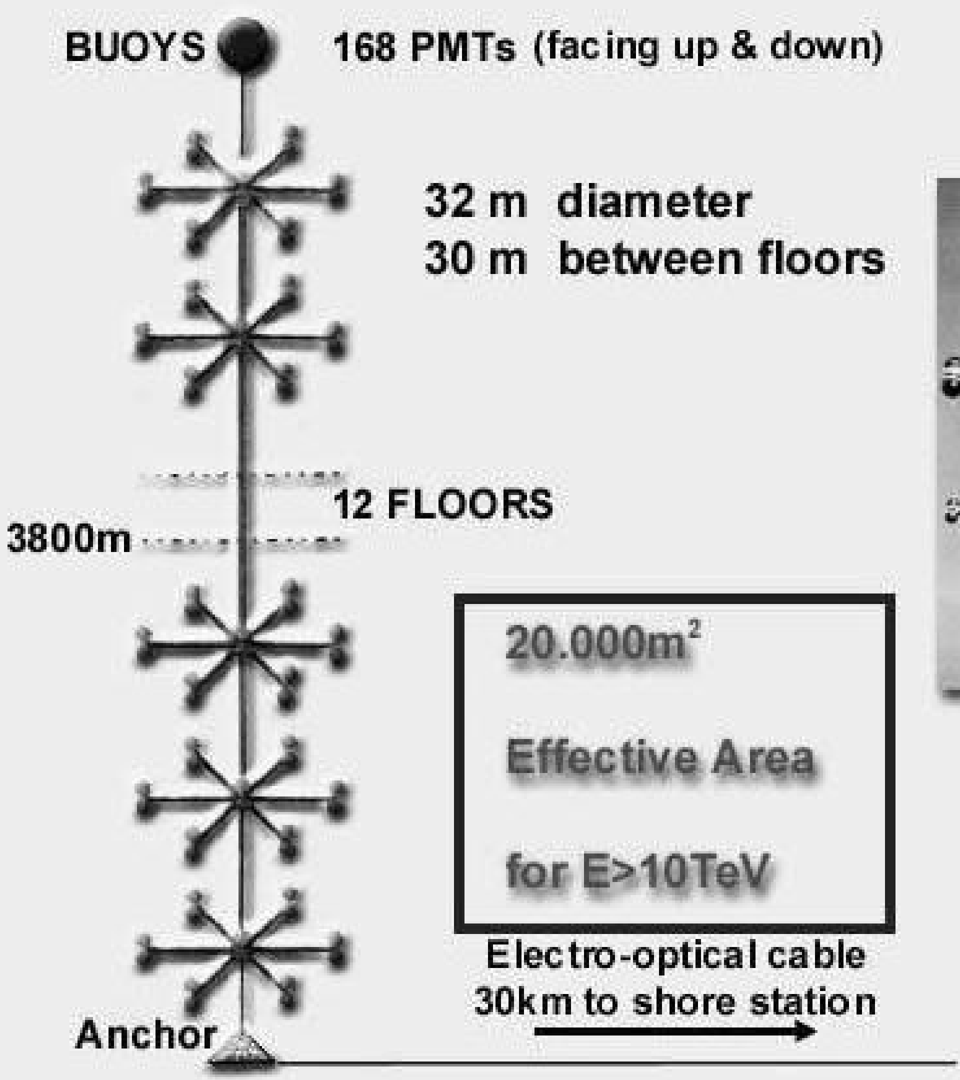
Cable laid and damaged June 2000

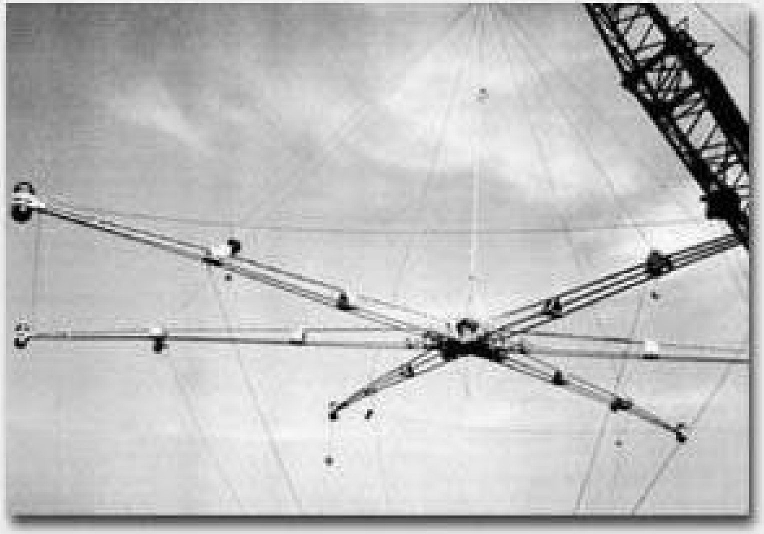
Retrieved and repaired January 2002



21.1.2002

NESTOR TOWER





Nestor Electronics

(Lawrence Berkeley National Laboratory)

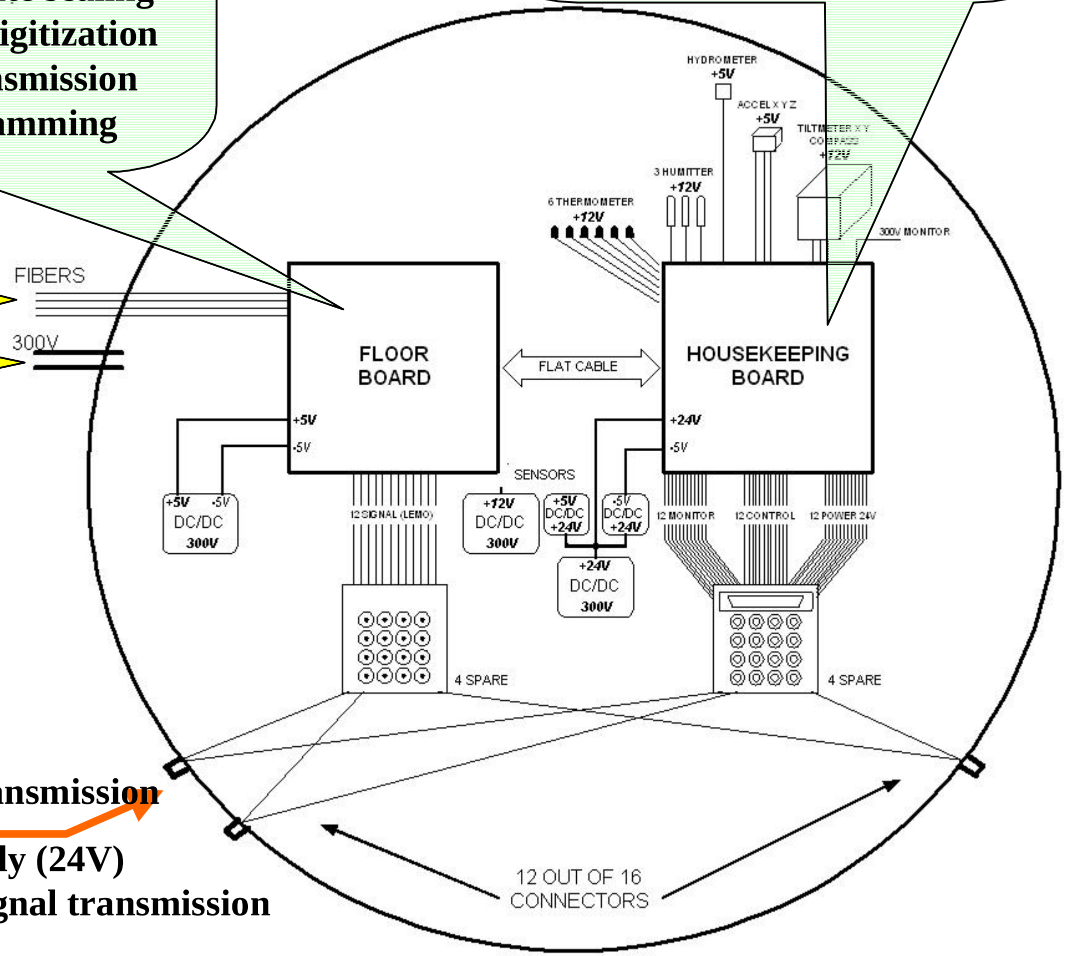
Floor Board
- PMT pulse sensing
- Majority logic event triggering
- Single & coincidence rate scaling
- Waveform capture & digitization
- Data formatting & transmission
- FPGA & PLD reprogramming

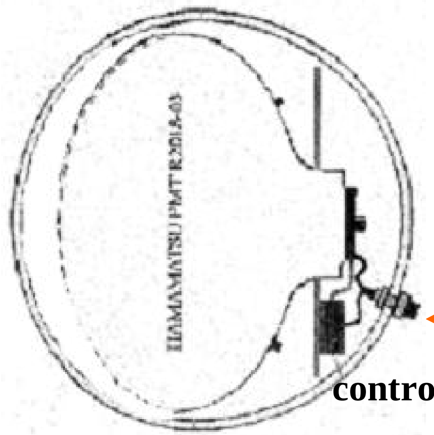
House Keeping Board
- PMT control
- Calibration Beacon control
- PMT HV monitor
- Power Supply monitors
- Environmental monitors

Shore Laboratory

Signal transmission & Control

Power supply



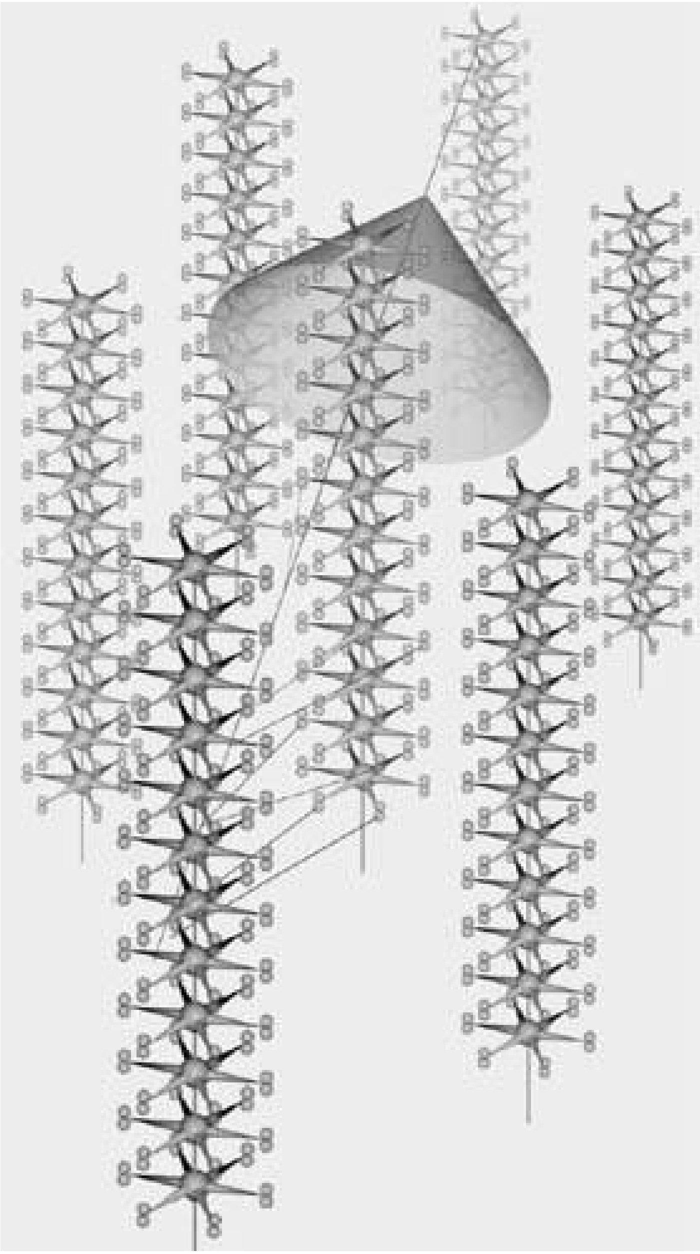


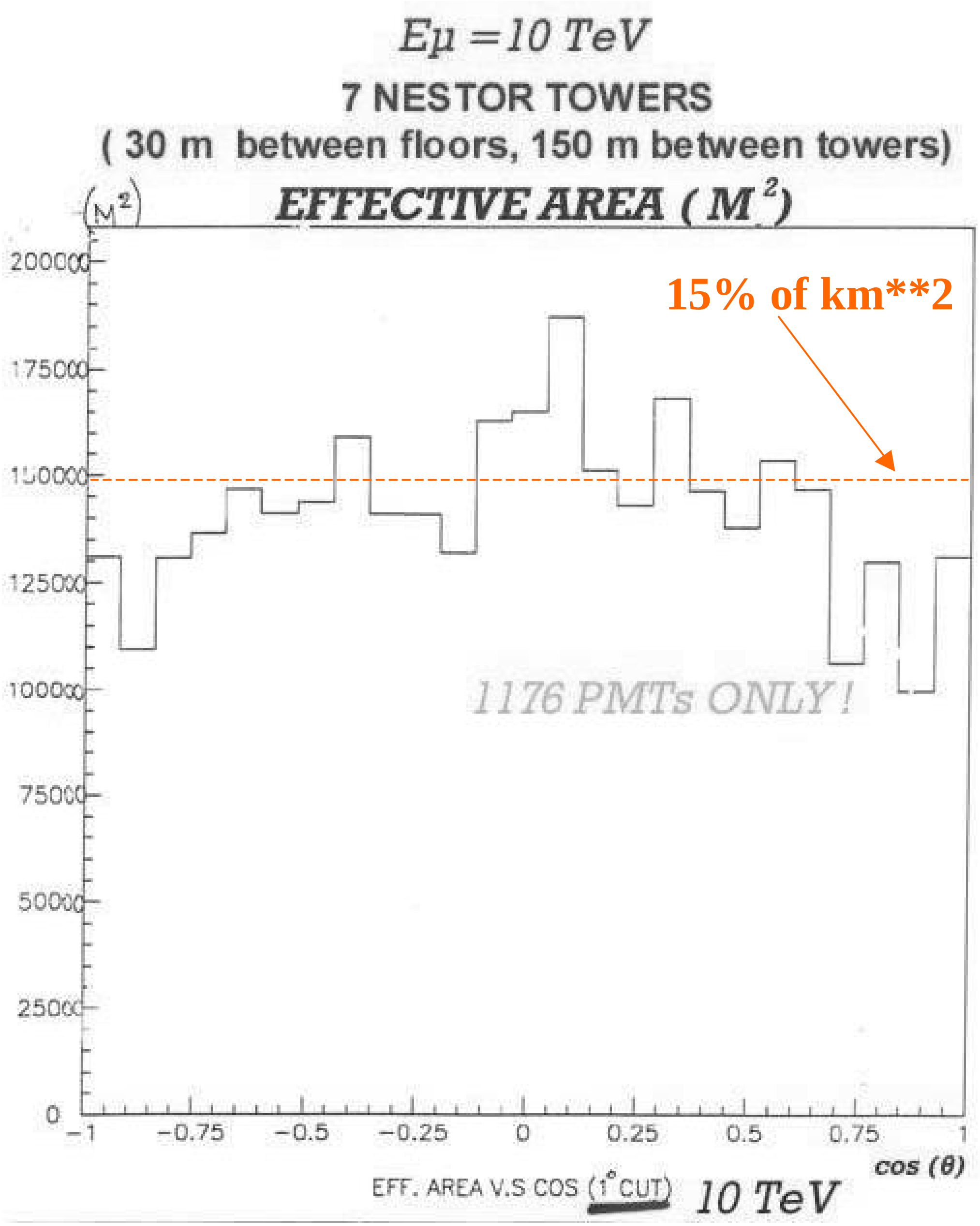
15” PMT signal transmission

low voltage supply (24V)

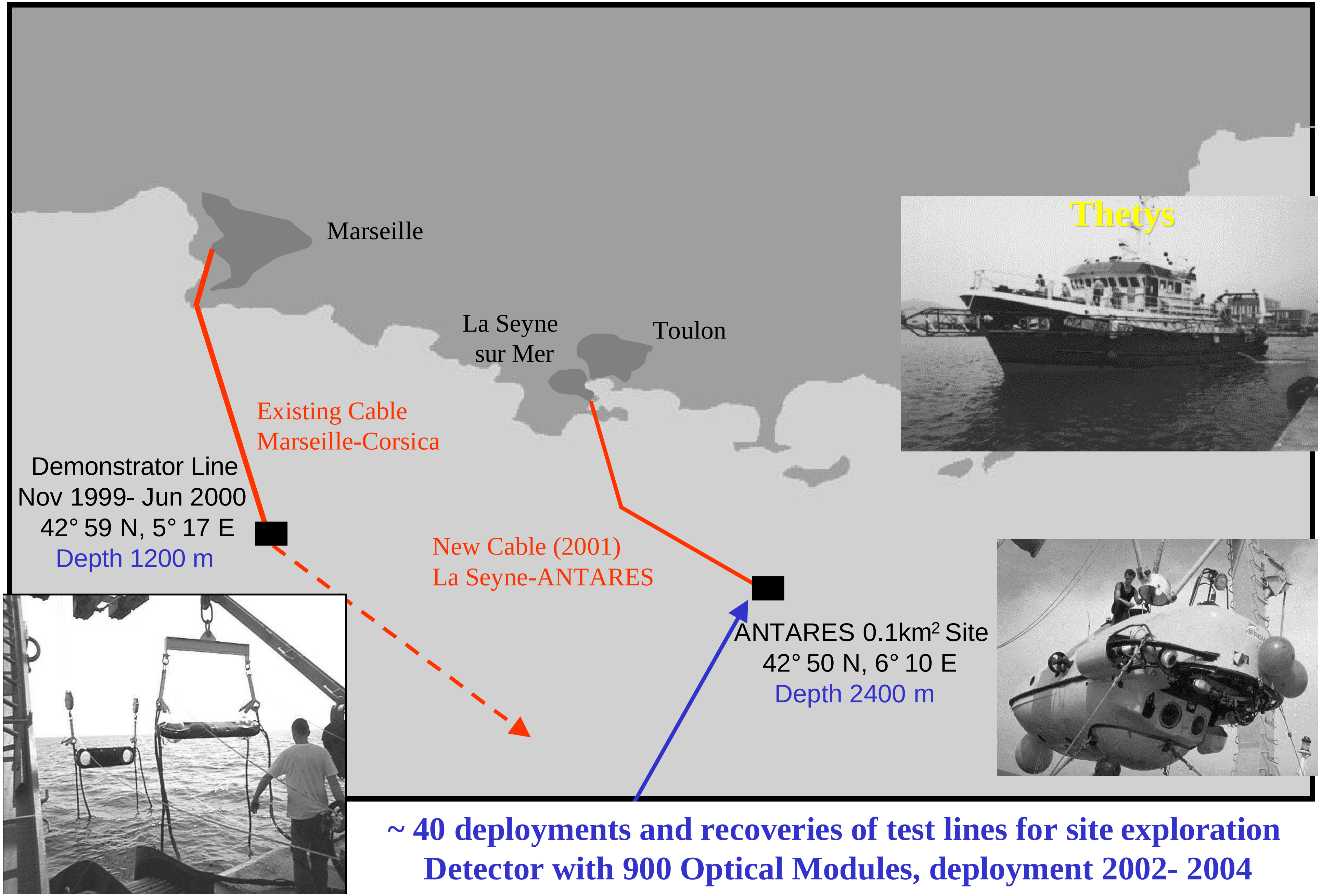
control and monitoring signal transmission

NESTOR Future Plans



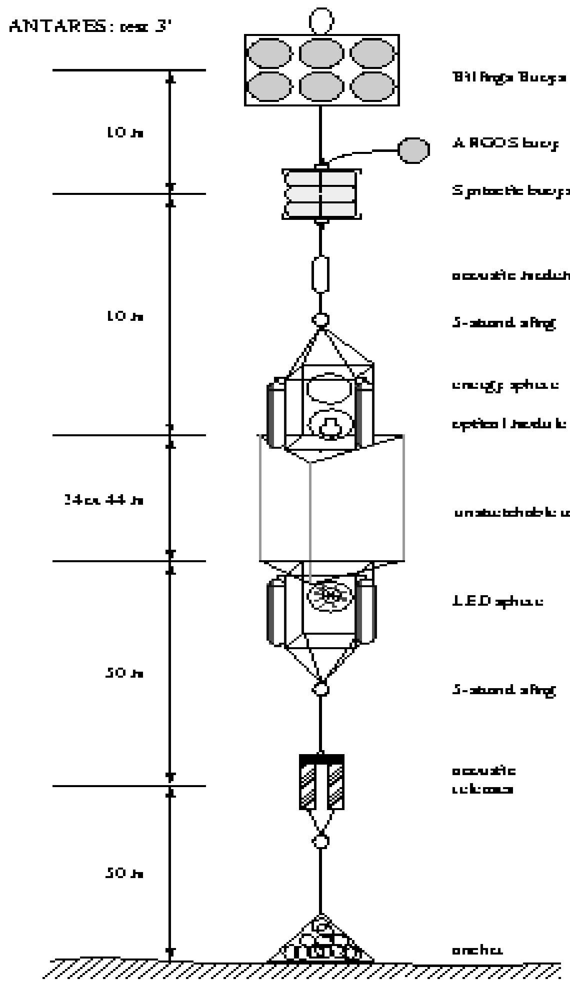


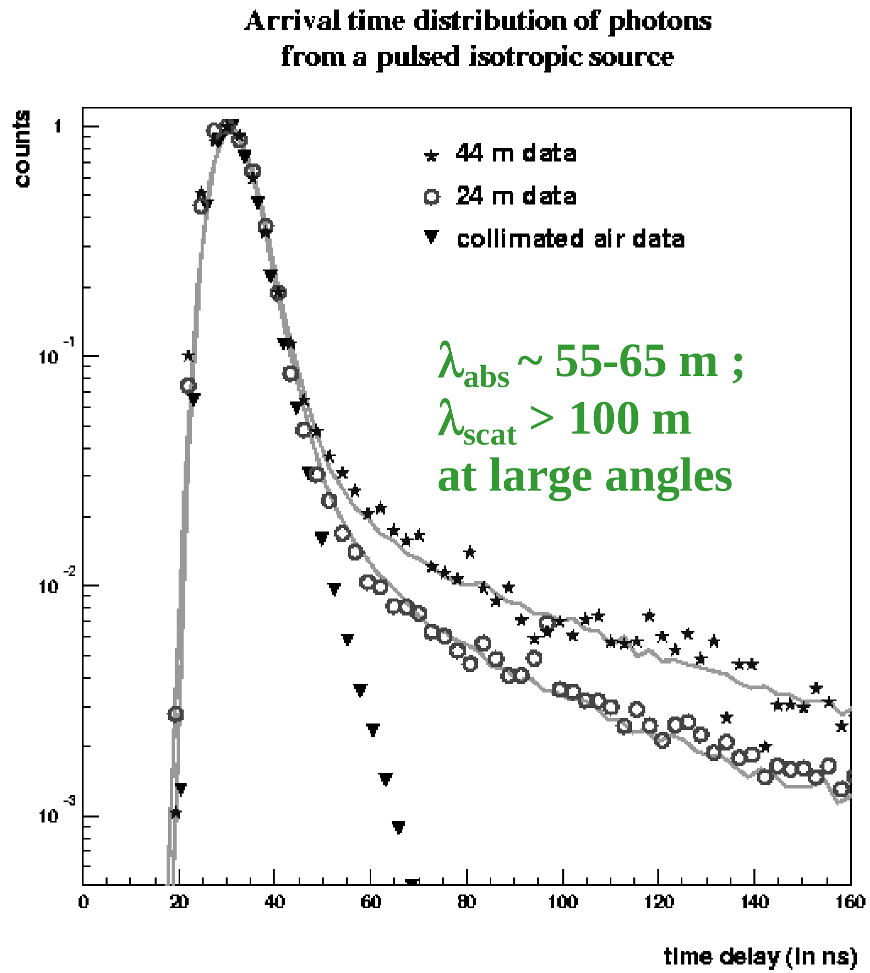
ANTARES Deployment Sites



~ 40 deployments and recoveries of test lines for site exploration
Detector with 900 Optical Modules, deployment 2002- 2004

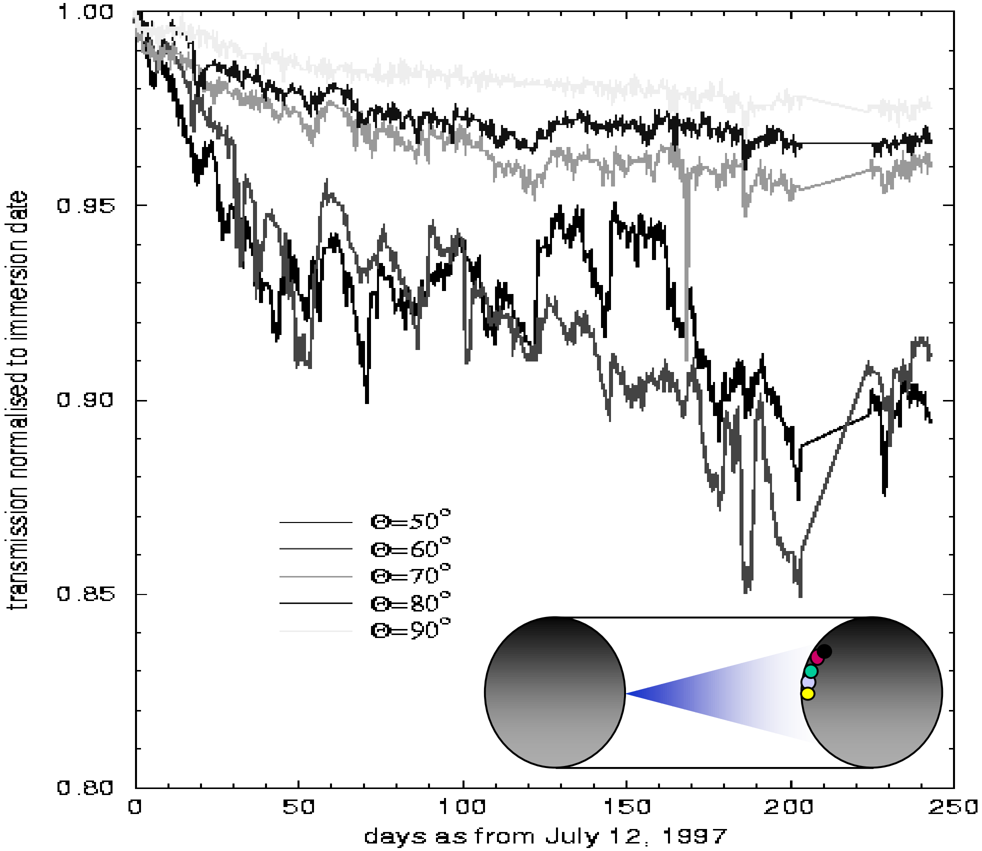
Water Transparency





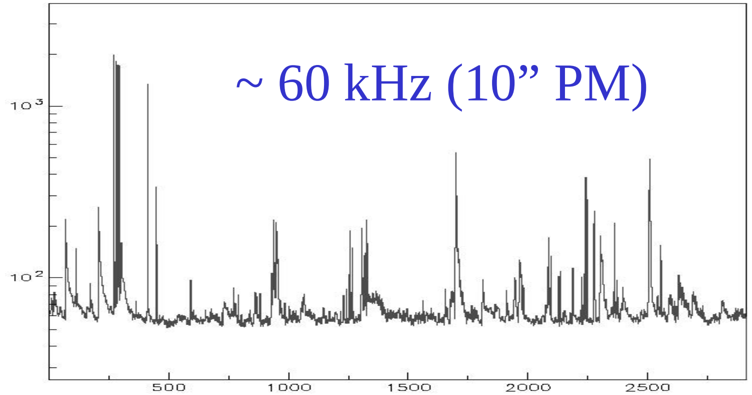
$\lambda_{abs} \sim$ 55-65 m ;
$\lambda_{scat} >$ 100 m
at large angles

Biofouling

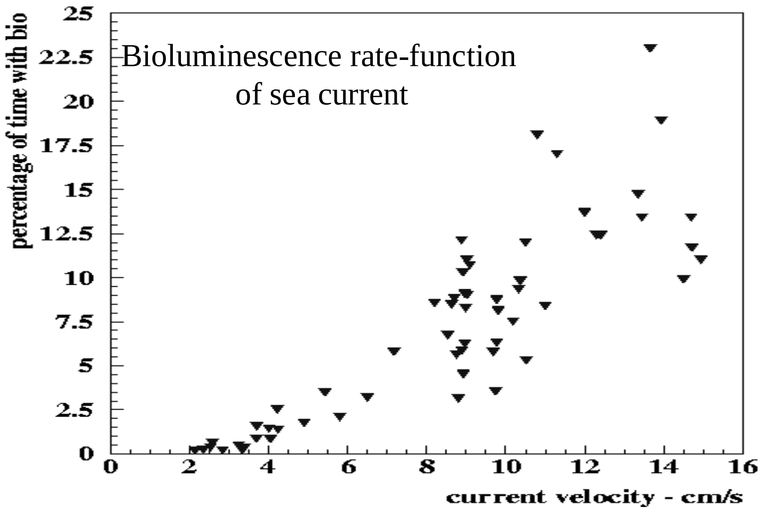


For θ > 90° transmission loss < 1.5% in 1 yr (and saturates)

Optical Backgrounds



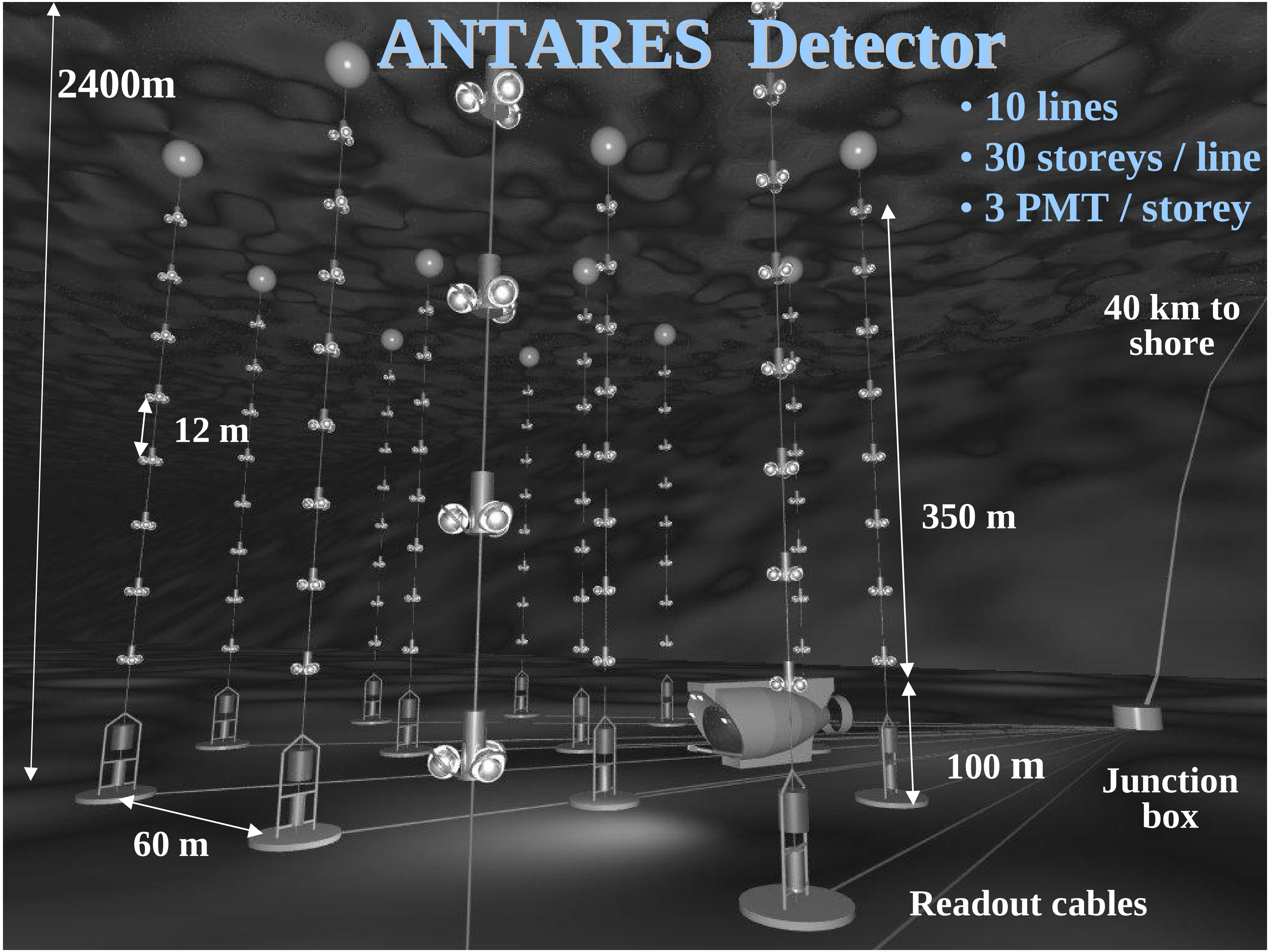
Short bursts (bioluminescence) over a continuous background (^{40}K).



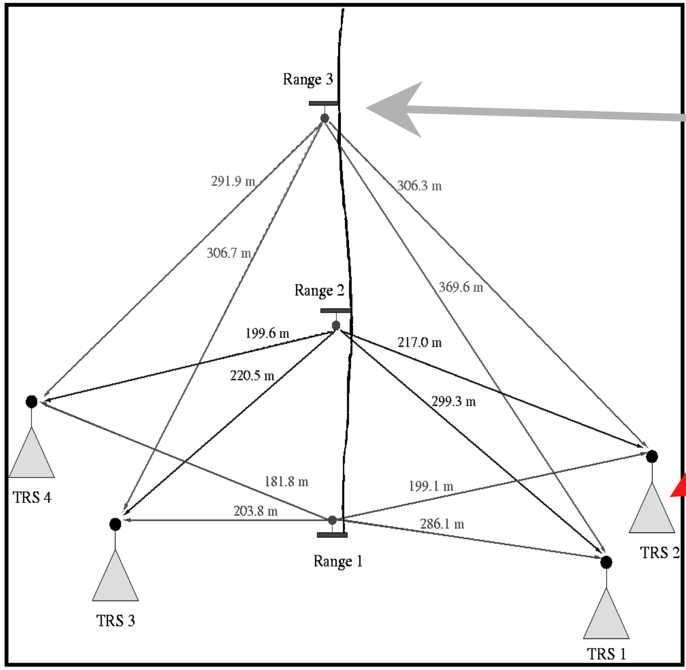
~5% of time a PMT is unusable

ANTARES Detector

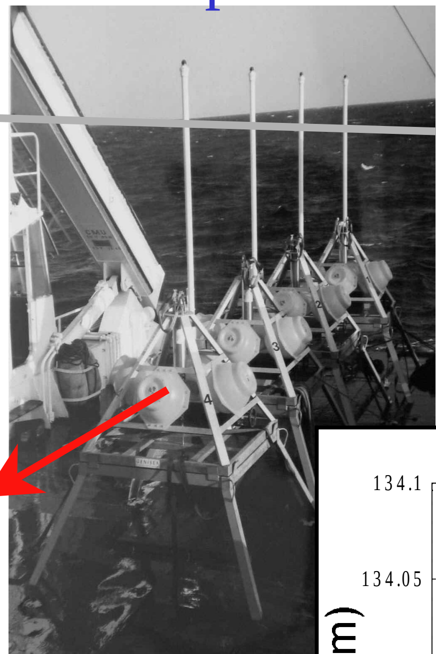
- 10 lines
- 30 storeys / line
- 3 PMT / storey



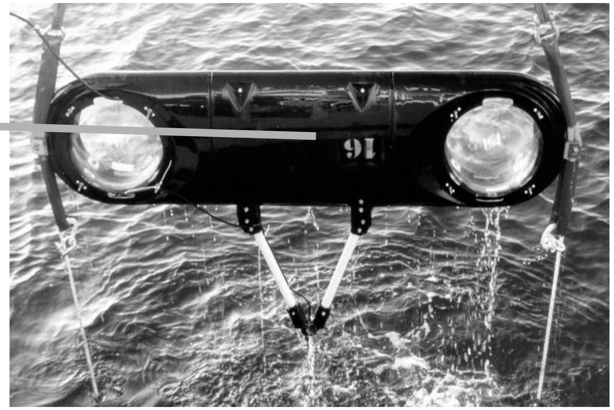
Acoustic Positioning Prototype

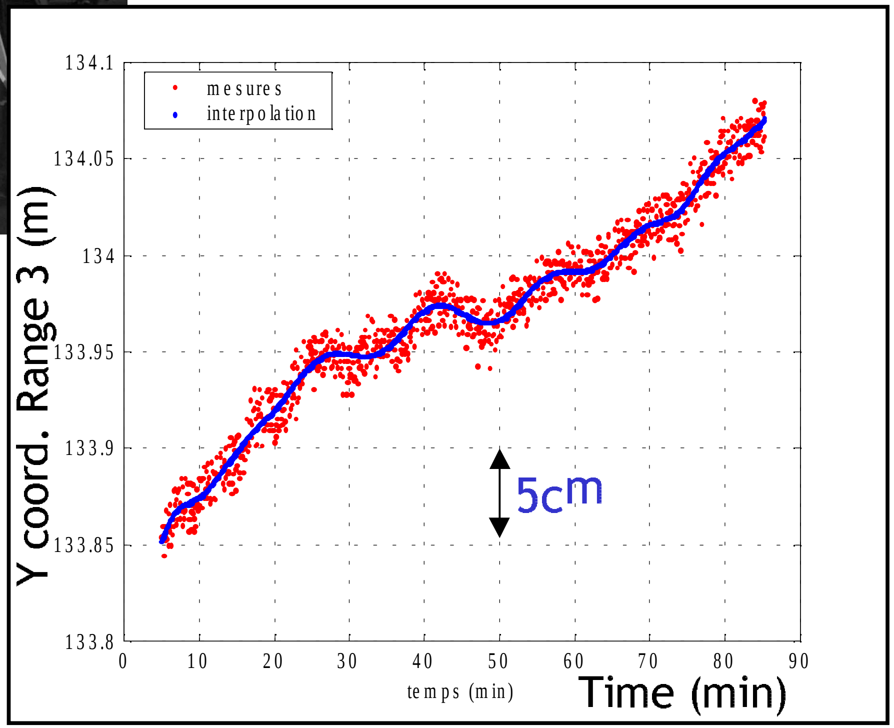


4 transponders



3 distancemeters

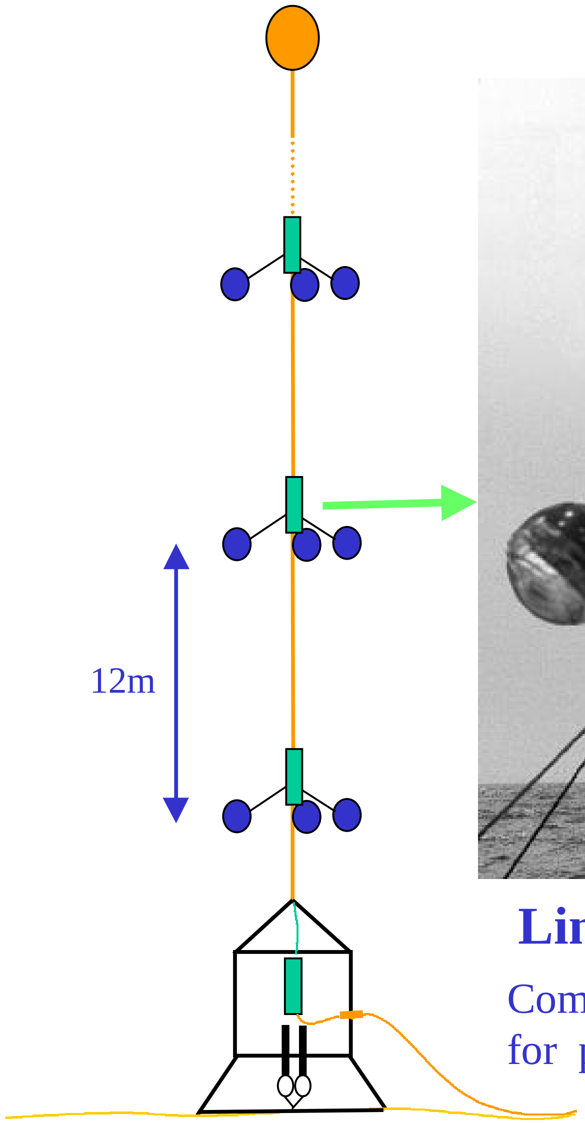


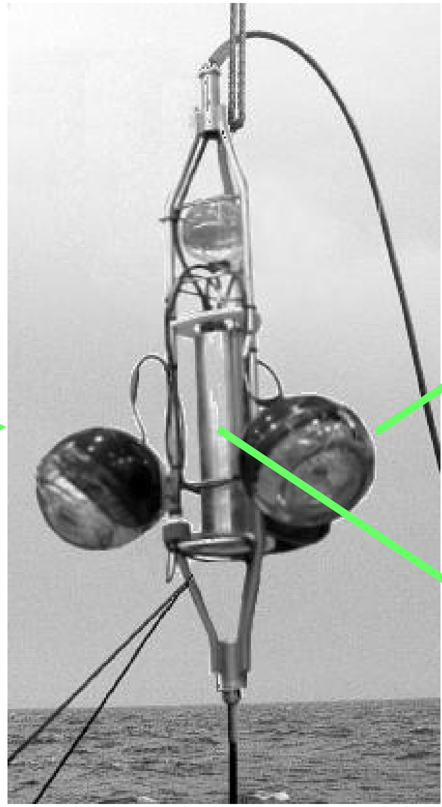


distance	Precision (σ)
Inter-distancemeter	~ 1 cm
Inter-transponder	~ 1 cm
Range-Transponder	≤ 3 cm

Triangulation → ~5 cm final precision

ANTARES Detector Line





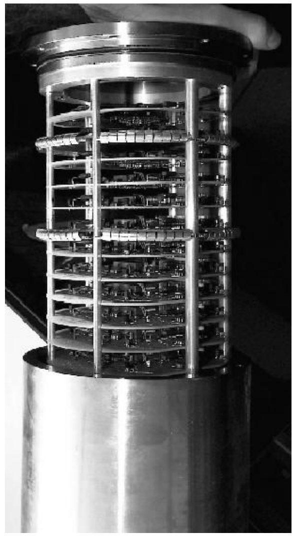
Line mechanics

Components available
for pre-production line

Optical Module

All components delivered
industrial production
underway for 900 OM

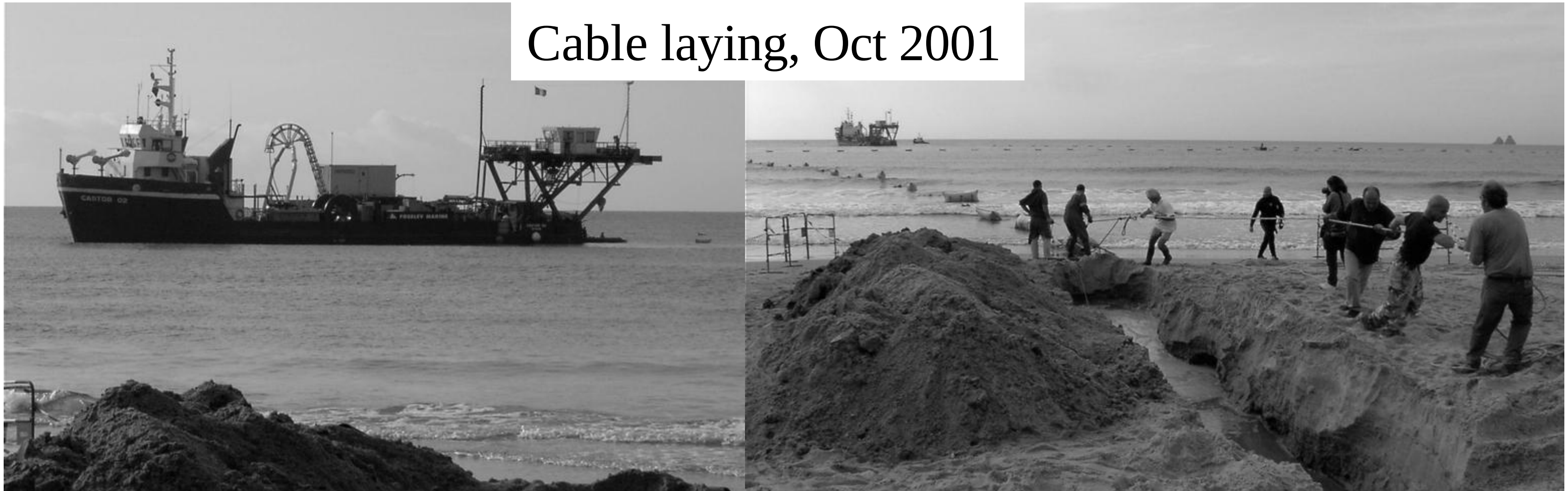
Sea Electronics



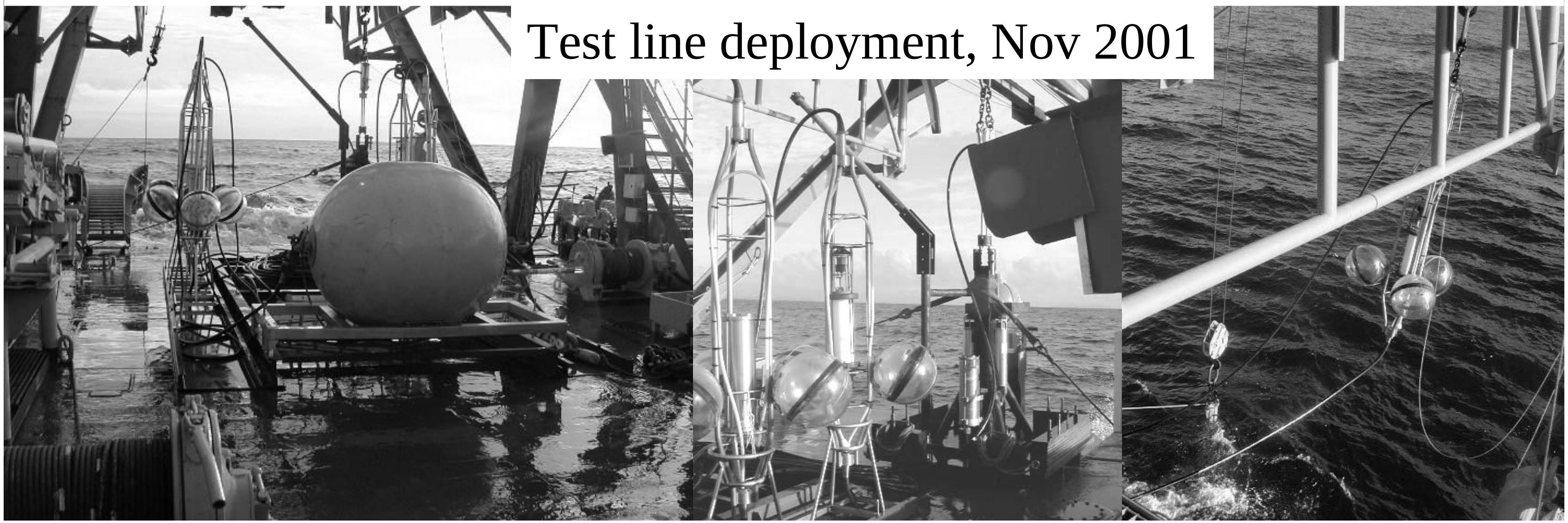
One complete set of electronics
working in lab.
Set of electronics for
pre-production line
ready mid June

Assembly of pre-production line July, deployment Sept

ANTARES Sea Operations

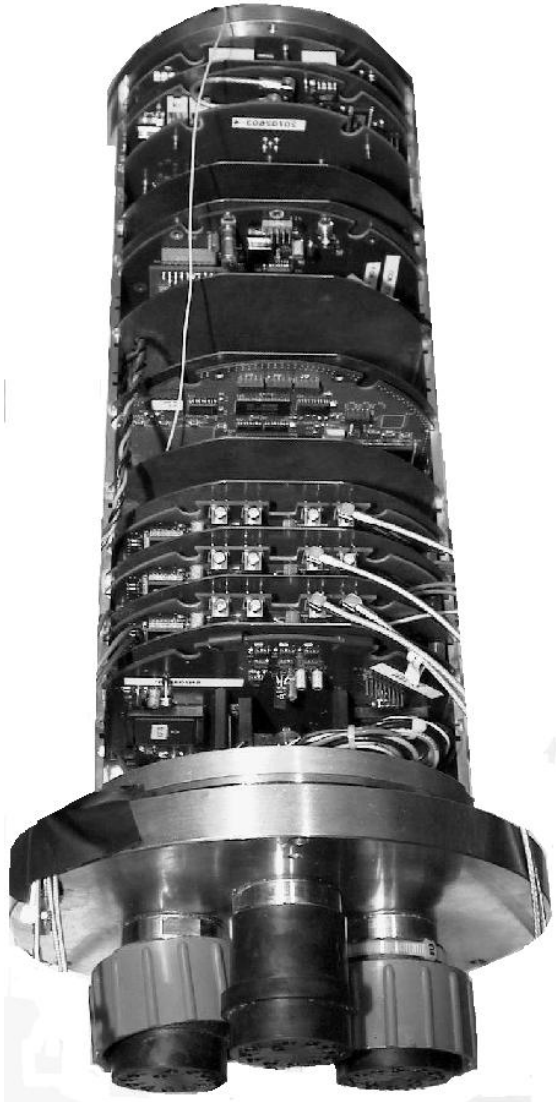


Cable laying, Oct 2001

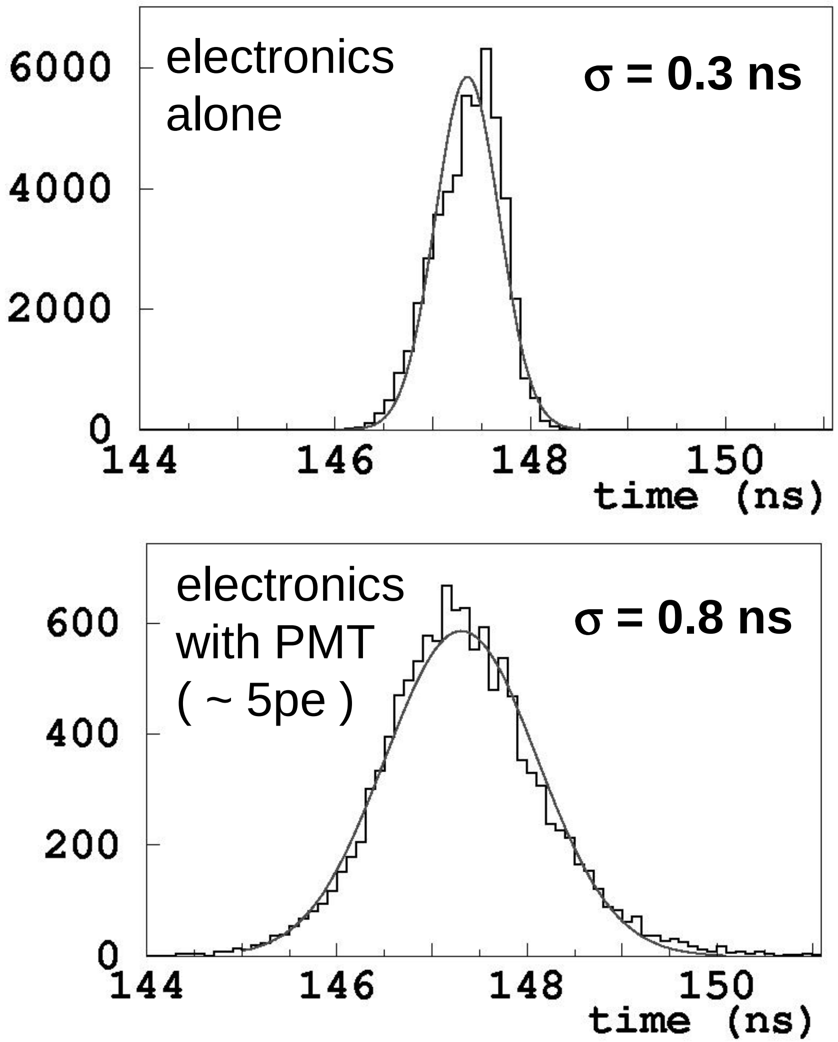


Test line deployment, Nov 2001

ANTARES Readout Electronics



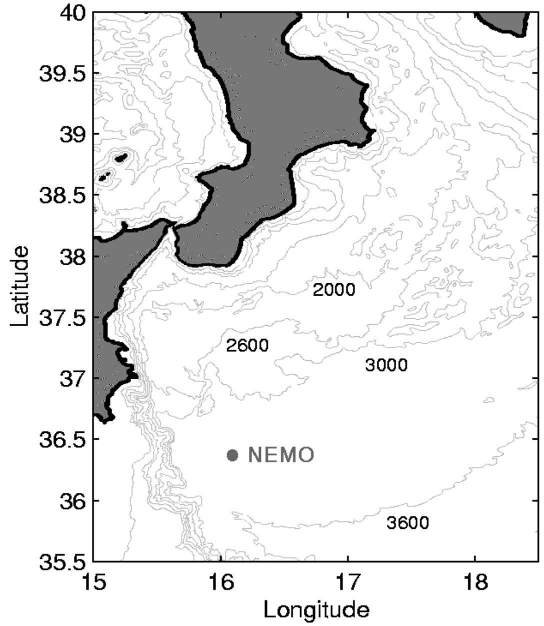
Timing resolution



Electronics in production for pre-production line

NEMO *Neutrino Mediterranean Observatory*

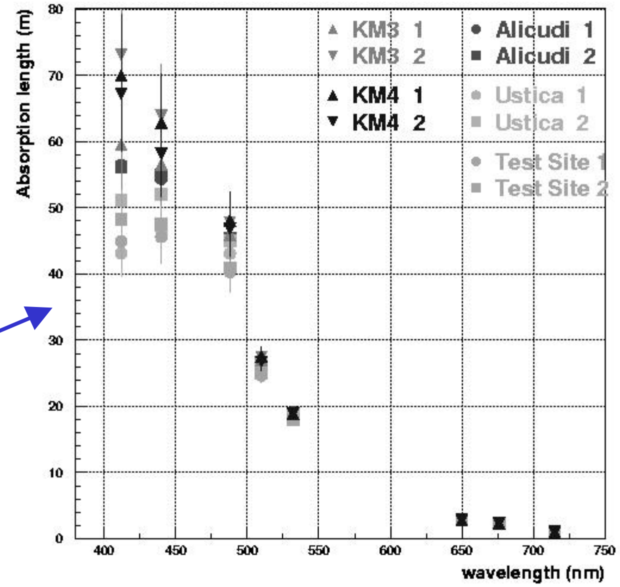
The Capo Passero Site



The site exploration results show that the **Capo Passero** site has optimal characteristic

- Close to the coast (~ 80 km) and to existing infrastructures
- About 3500 m deep
- Measured currents are low and regular (2-3 cm/s average; 12 cm/s peak)
- Very good optical properties (light absorption length 70÷90 m)
- Very low sedimentation and biological activity

Water absorption length in Capo Passero



NEMO R&D at Catania Test Site

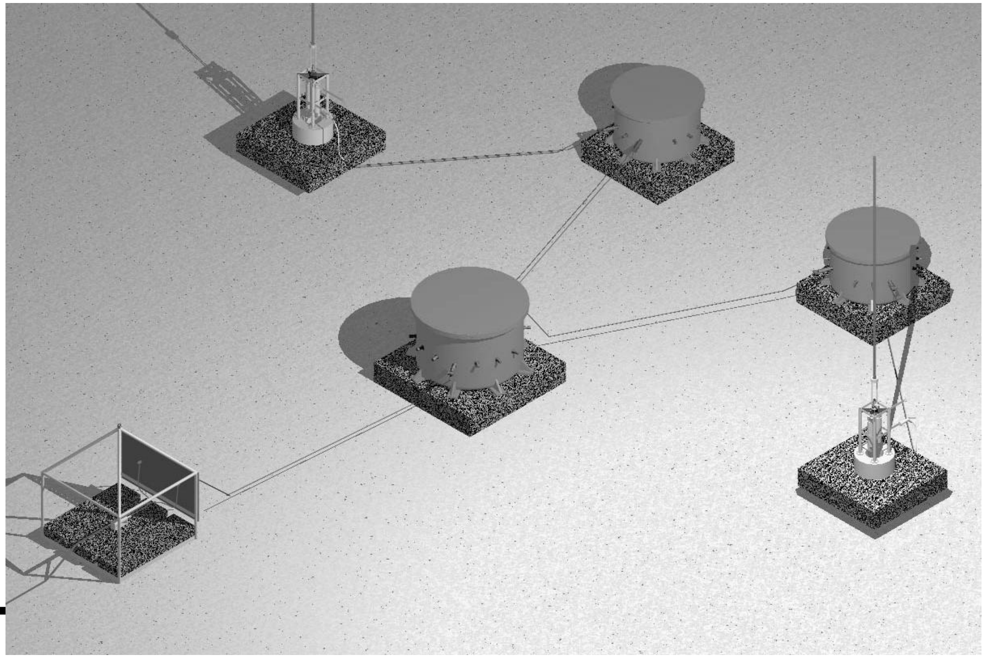
The "Phase 1" project

At the LNS Test Site

Realization of a complete detector subsystem including all critical components

SHORE LABORATORY

EO Cable



EO CABLE

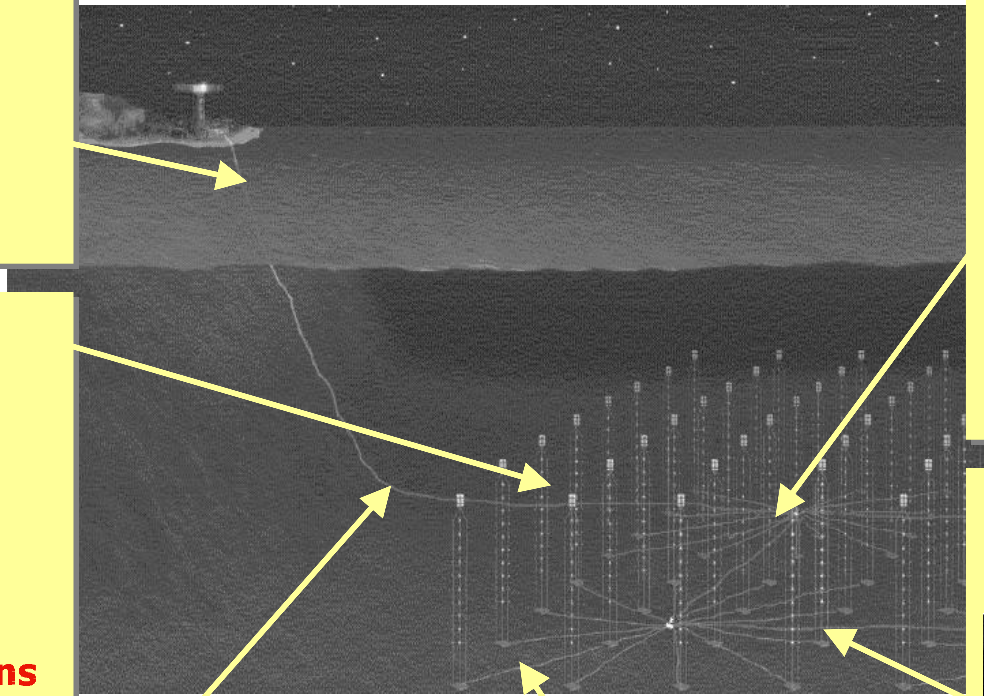
- **Length – 25 km**
- **10 Optics Fiber ITU- T G-652**
- **6 Electrical Conductors Φ 4 mm^2**

UNDERWATER LABORATORY

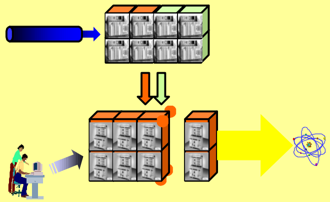
- **N.1 Main Junction Box**
- **N.2 Secondary Junction Boxes**
- **N.2 NEMO Towers**

R&D for 1km^3

The technological challenges

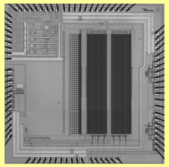


Data transmission



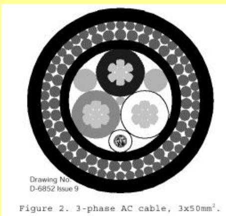
High bandtwidth data transmission

Electronics



Low power microelectronics for underwater applications

Underwater cable network

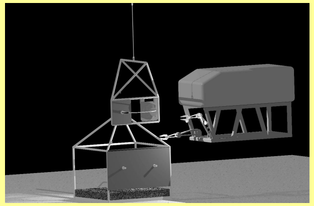


High power load electro-optical cables for deep sea applications

Connections

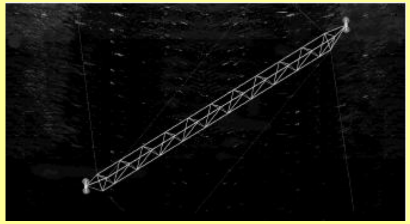
Underwater electro-optical connections

Deployment



Deployment and connection of the structures with underwater vehicles

Mechanical structures



Innovative materials for deep sea applications

Conclusions

Science case for one $1km^3$ Neutrino Telescope in each hemisphere

Water detector in northern hemisphere complementary to ice detector in south

(See coming report by HENAP committee)

Ice deployment more successful in past

but water detectors now using technology developed for oil industry

Current Status of Mediterranean Projects

3 sites explored and found to have good water properties

3 sites linked to shore by submarine cables (*Catania Bay not Capo Passero in Sicily*)

NESTOR promises one tower 2003, expansion later

ANTARES 10 line detector (AMANDA scale) operational 2004, room to expand

NEMO and ANTARES involved in R&D for large scale detector

Expanding collaboration forming for the $1km^3$ detector in Mediterranean

ANTARES Sphere Implosion Test

Stored potential energy in sphere at 2600m: VΔP~ 1 mega Joule !!

⇒ Risk of accidental implosion provoking a catastrophic chain reaction (a la SuperKamiokande)

Tests (June 2000) – Two storeys 12m apart, 1 sphere weakened, implosion occurred at a depth of 2600m

RESULT:
- Neighbouring spheres on same storey also imploded
- Electronics in LCM destroyed

- Upper storey intact
- Mechanical cable unbroken