



**HAL**  
open science

## Antares: A Deep-Sea 0.1 km<sup>2</sup> Neutrino Telescope

V. Bertin

► **To cite this version:**

V. Bertin. Antares: A Deep-Sea 0.1 km<sup>2</sup> Neutrino Telescope. Moriond Workshop Very High Energy Phenomena in the Universe 21, Jan 2001, Les Arcs, France. pp.1-13. in2p3-00012819

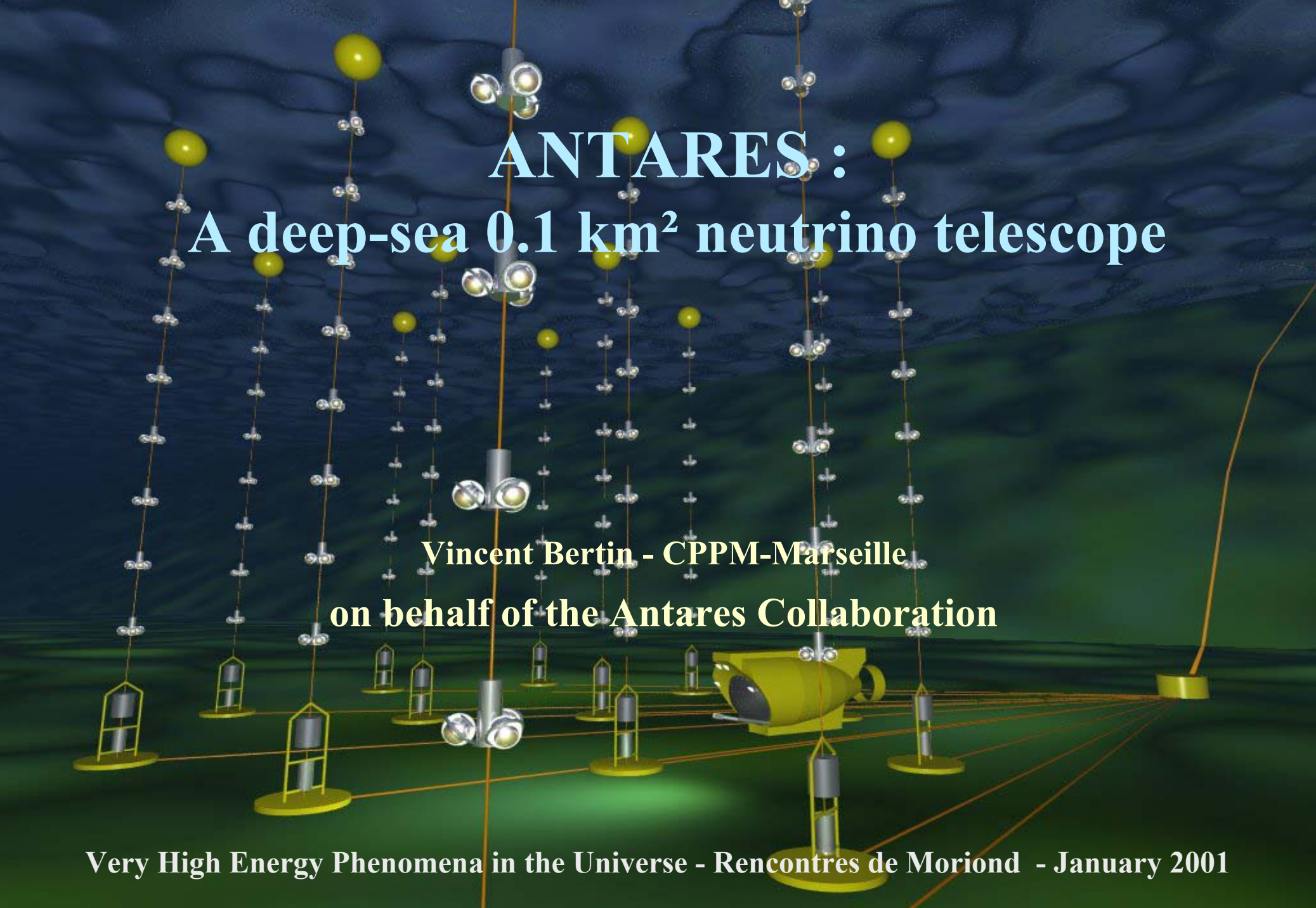
**HAL Id: in2p3-00012819**

**<https://in2p3.hal.science/in2p3-00012819v1>**

Submitted on 27 May 2003

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A 3D computer-generated illustration of the ANTARES neutrino telescope. The structure consists of numerous vertical strings of optical modules (OMs) suspended in a dark blue, rippling deep-sea environment. Each string is anchored to a yellow circular base on the seafloor. The OMs are arranged in a grid pattern, with some strings having yellow spherical floats at the top. The overall scene is dimly lit, with a greenish glow emanating from the seafloor.

# ANTARES :

## A deep-sea 0.1 km<sup>2</sup> neutrino telescope

Vincent Bertin - CPPM-Marseille  
on behalf of the Antares Collaboration

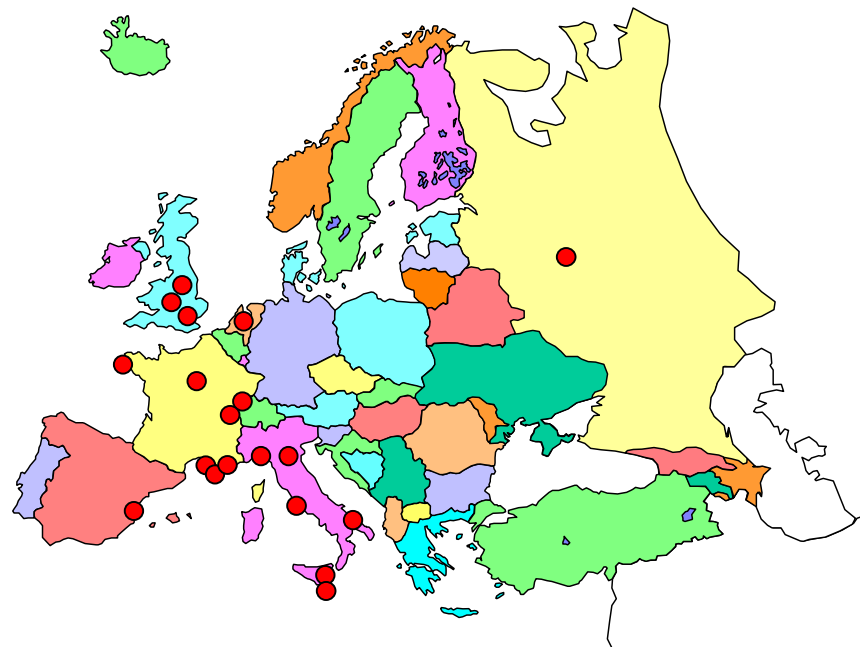
# The ANTARES Collaboration



- ❖ CPPM, Marseille (IN2P3)
- ❖ DSM/DAPNIA, Saclay (CEA)
- ❖ IReS, Strasbourg
- ❖ Univ. of H.-A., Mulhouse
- ❖ C.O.M. Marseille
- ❖ IFREMER, Marseille/Brest
- ❖ IGRAP (INSU), Provence



- ❖ University of Bari
- ❖ University of Bologna
- ❖ University of Catania
- ❖ LNS – Catania
- ❖ University of Rome
- ❖ University of Genova



- ❖ University of Oxford
- ❖ University of Sheffield



- ❖ ITEP, Moscow



- ❖ IFIC, Valencia



- ❖ NIKHEF, Amsterdam

# Detection Principle

Lattice of Photomultipliers : “Optical Modules”

Muon track direction from arrival time of light

Neutrino direction:  $\bar{\Delta} (\theta_{\nu} - \theta_{\mu}) \approx 0.7^{\circ} / E^{0.6}(\text{TeV})$

Muon energy from energy loss and range

Cherenkov  
light cone

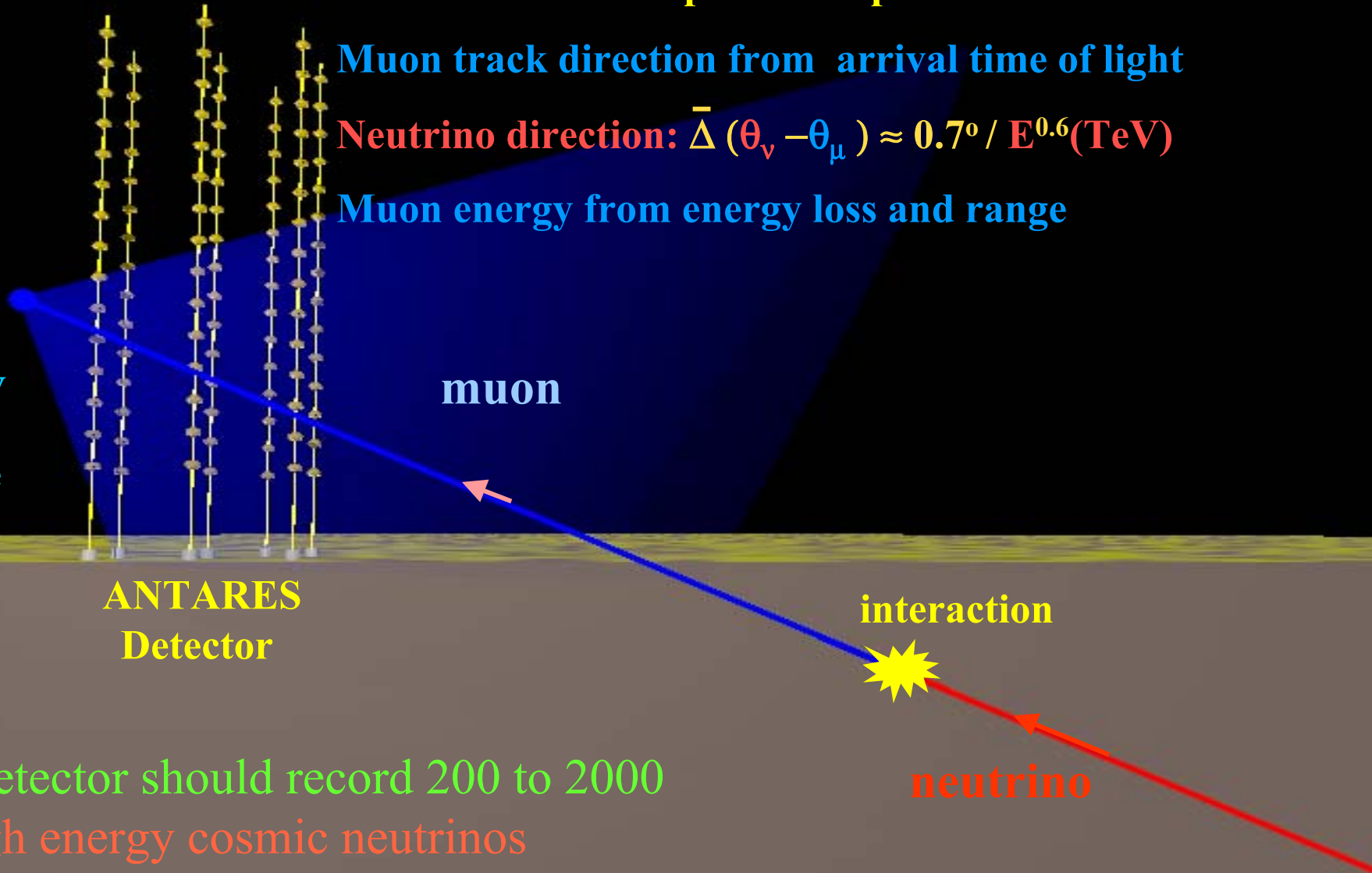
muon

ANTARES  
Detector

interaction

neutrino

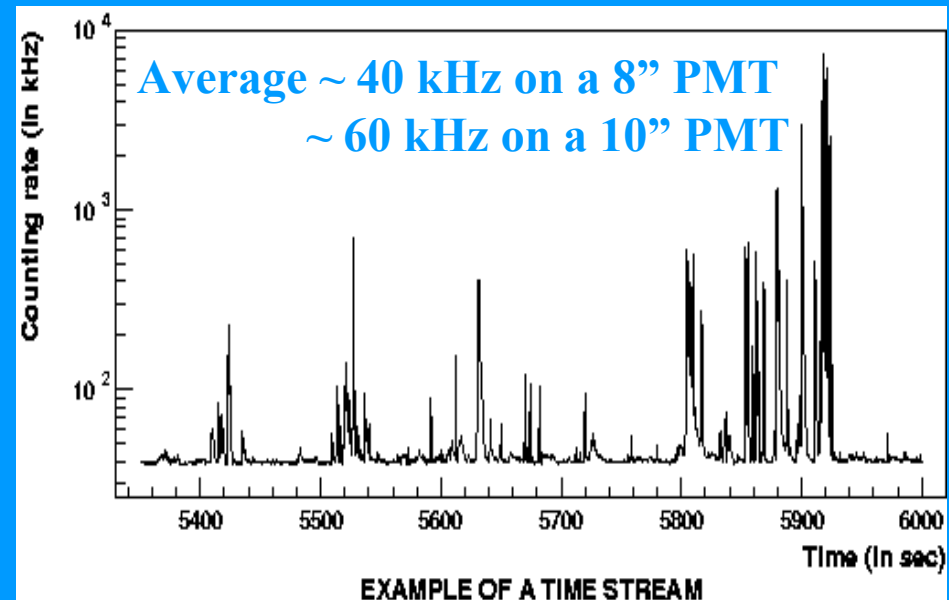
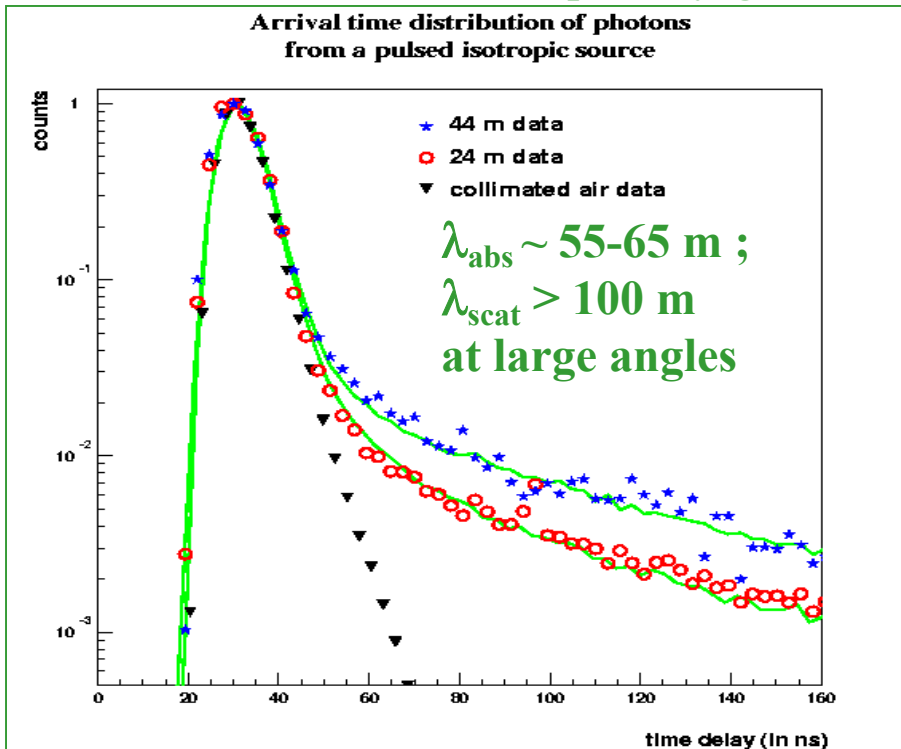
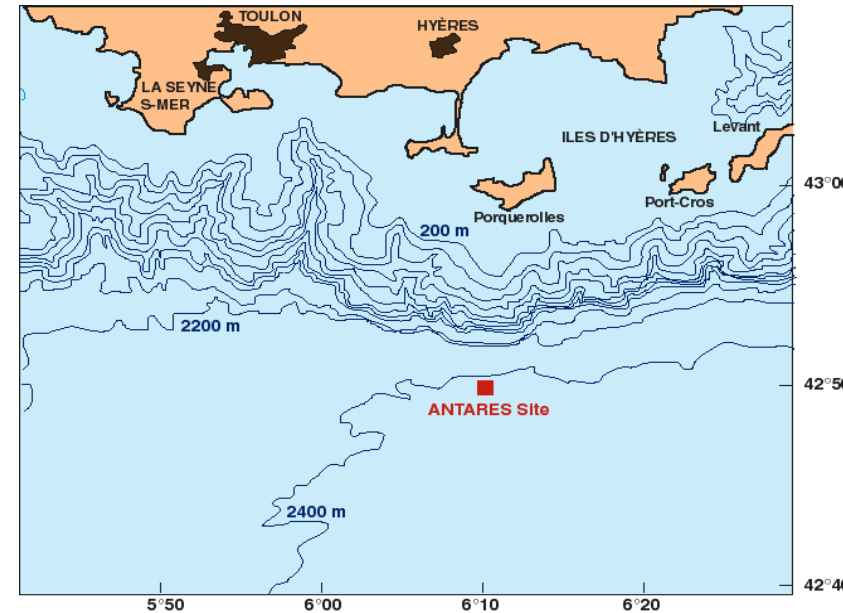
A 1km<sup>3</sup> detector should record 200 to 2000  
high energy cosmic neutrinos  
per year ( $E_{\nu} > 10\text{-}100 \text{ TeV}$ ).



# Phase I : Water properties measurements

■ Perform precise measurements of crucial environmental parameters :

- ◆ In situ measurements on Antares site (2400 m depth off French Mediterranean coast)
- ◆ Long term measurements of optical background ( $^{40}\text{K}$  decays, bioluminescence) and biofouling of Optical Modules
- ◆ Measurement of water transparency @ 466 nm :

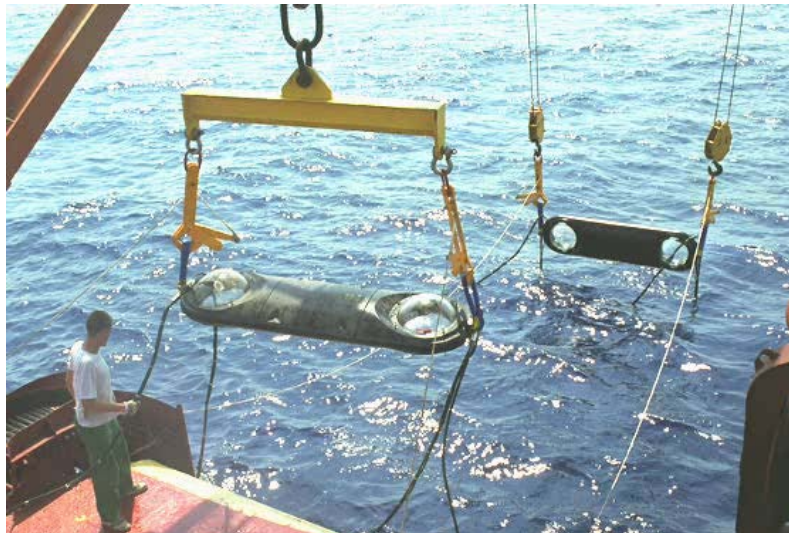


# ANTARES Phase I : Demonstrator

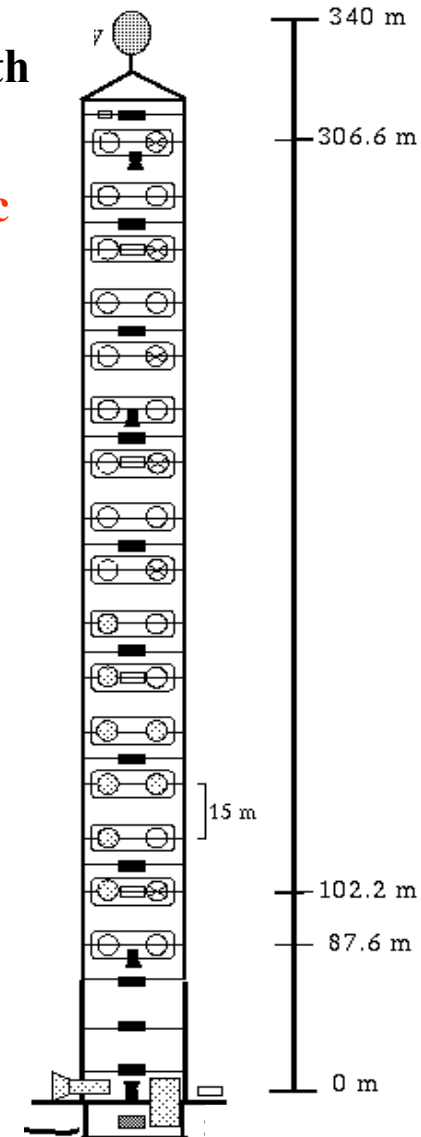
## ■ First line of 350m high equipped with 16 pairs of Optical Modules

- ◆ Summer 98 : successful deployment test at 2300m depth performed with Dynamical Positioning ship
- ◆ December 99-June 00 : demonstrator equipped with 7 PMTs + acoustic positioning system linked to shore station by electro-optical cable

*NAUTILE*



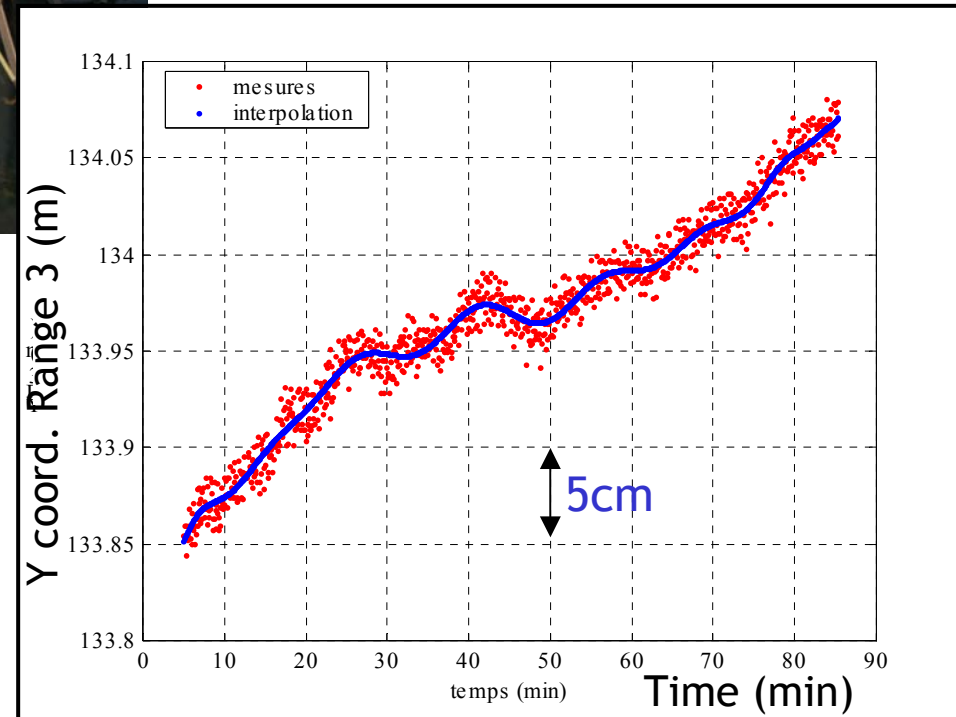
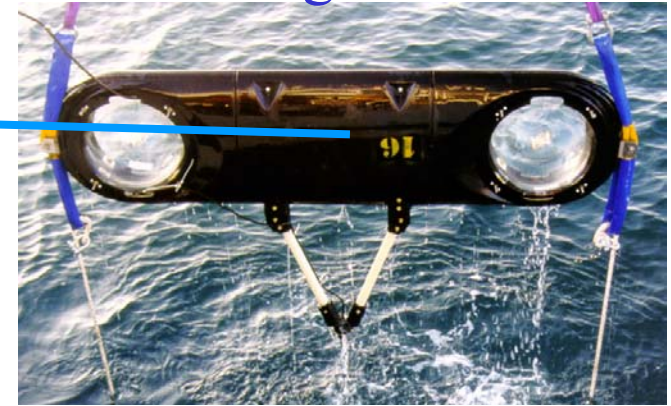
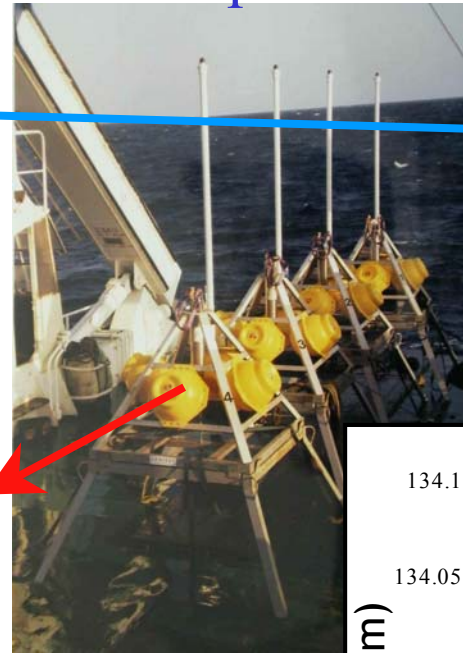
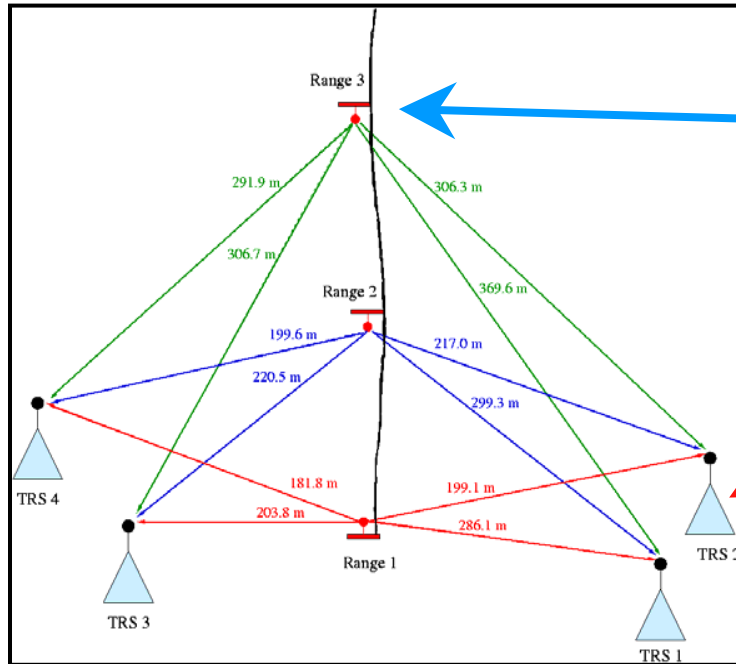
- December 98 : successful undersea electrical connection test of detector anchor performed at 2400m depth by IFREMER submarine vehicle *Nautilie*



# Acoustic positioning system

4 transponders

3 rangemeters

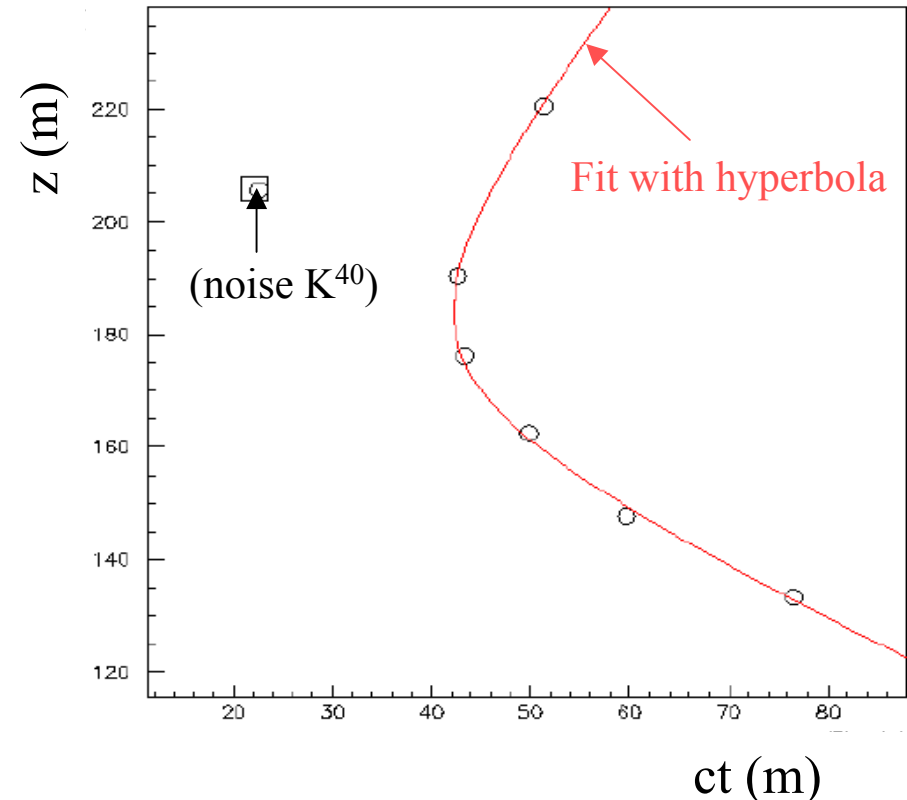
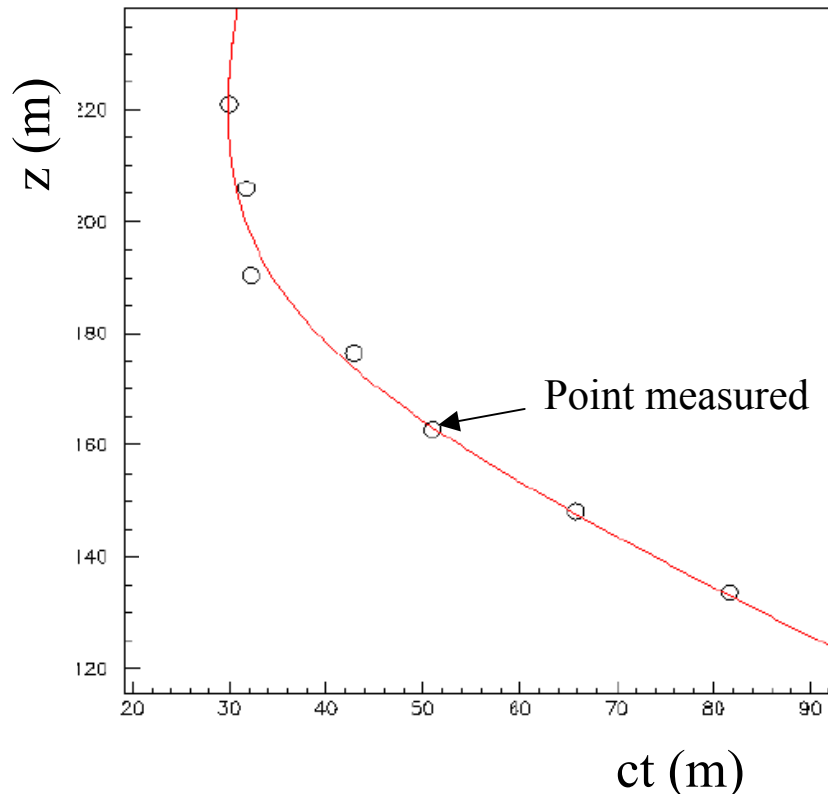


| Devices           | Accuracy ( $\sigma$ ) |
|-------------------|-----------------------|
| Inter-rangemeter  | $\sim 1$ cm           |
| Inter-transponder | $\sim 1$ cm           |
| Rang.-Transpond.  | $\leq 3$ cm           |

Triangulation allows  $\leq 5$  cm accuracy

# Reconstruction of Atmospheric Muons

- More than  $5 \times 10^4$  coincidences in all 7 PMTs have been recorded.
- Polar angle of down-going muons deduced from depth vs. time pattern.
- Hyperbolic fit (including multimuons).
- $^{40}\text{K}$  filtered out by the reconstruction software (see boxed hit in example).



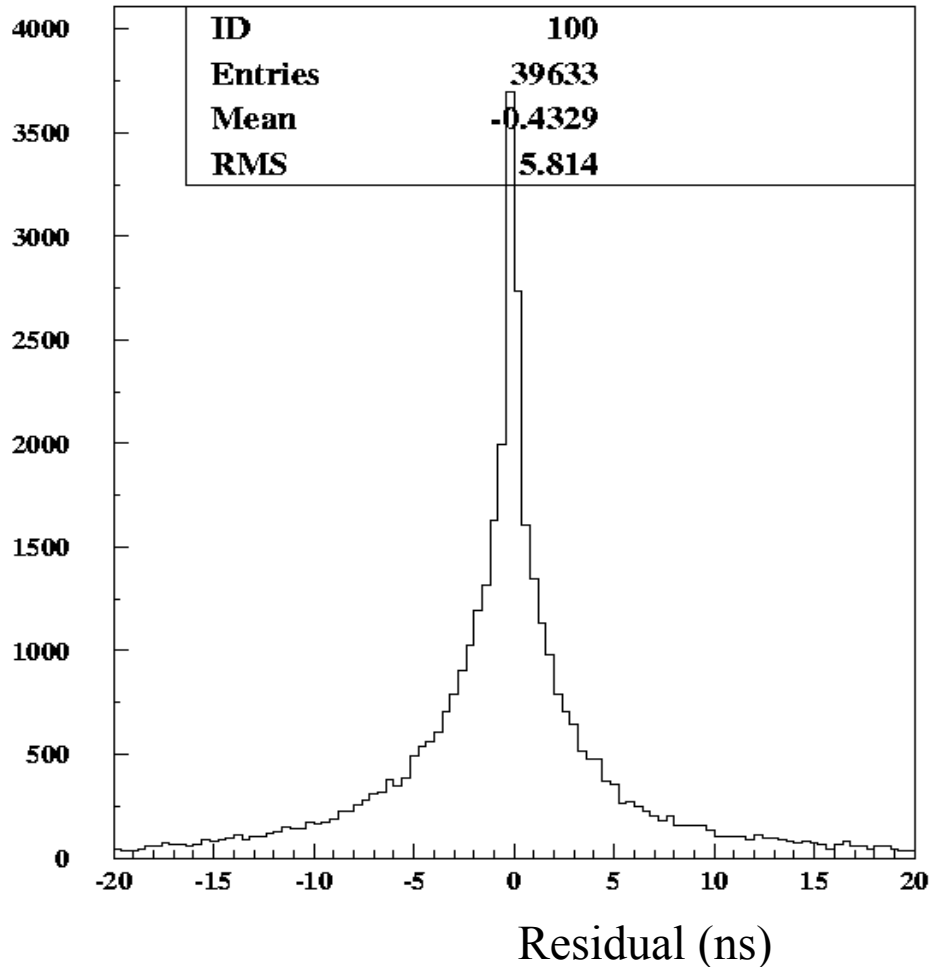


# Reconstruction of Atmospheric Muons

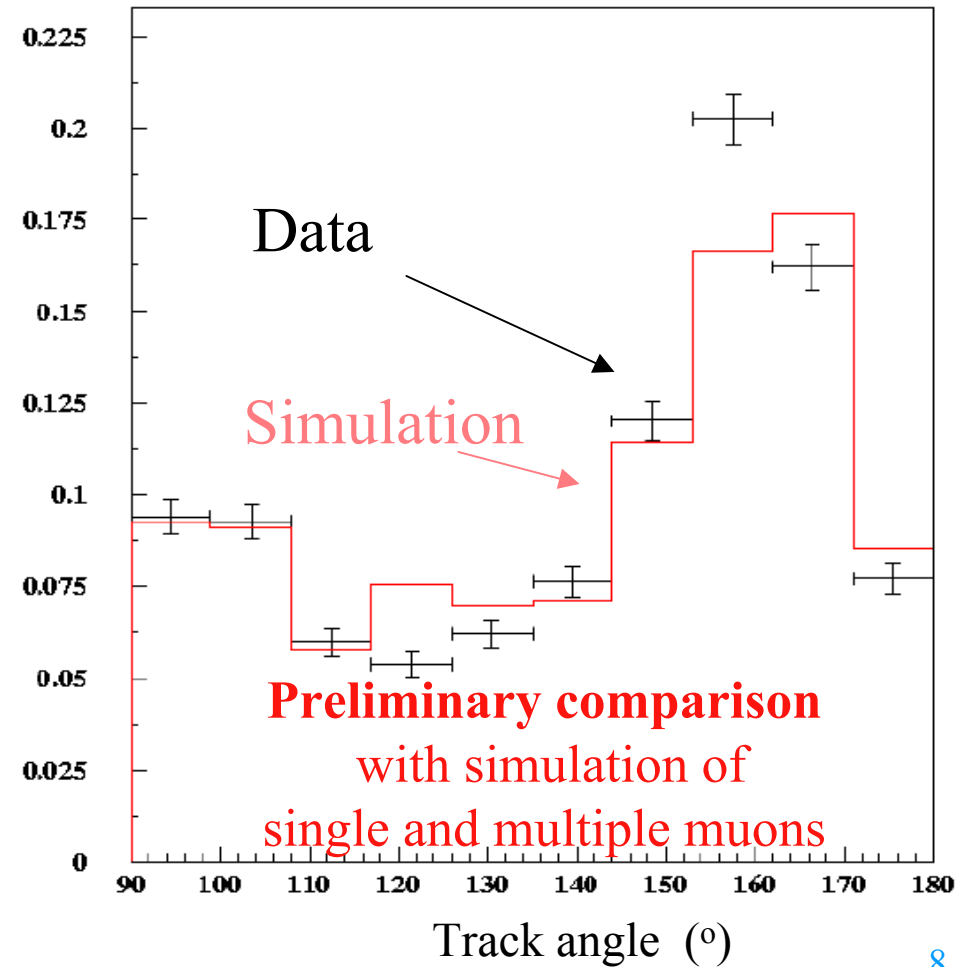
Over 50k 7-fold coincidences recorded

➡ more than **1350 reconstructed events per day**

$\Delta(\text{fit-point})$  in ns



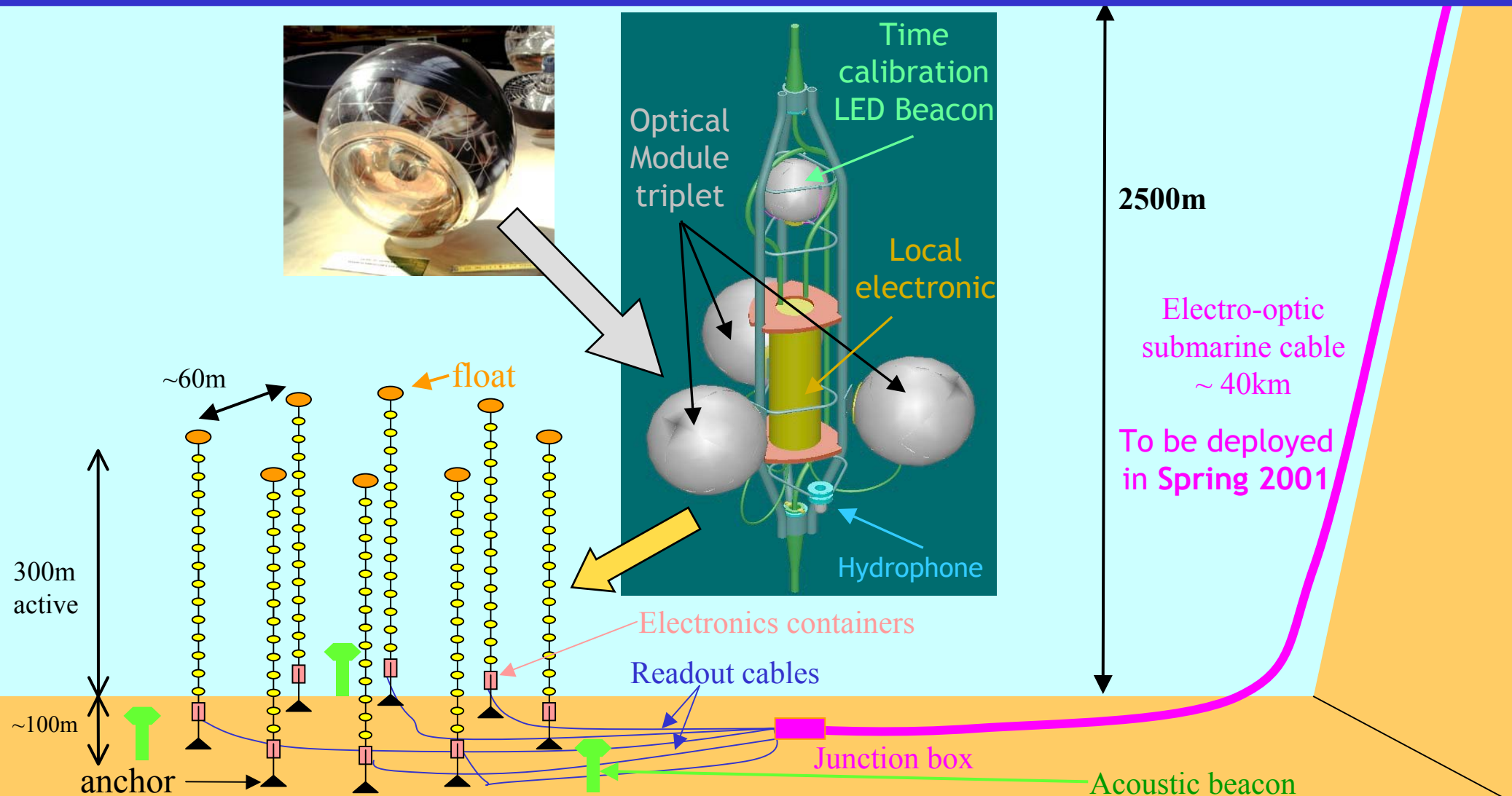
Angular Distribution



# ANTARES Phase II : 0.1 km<sup>2</sup> Detector

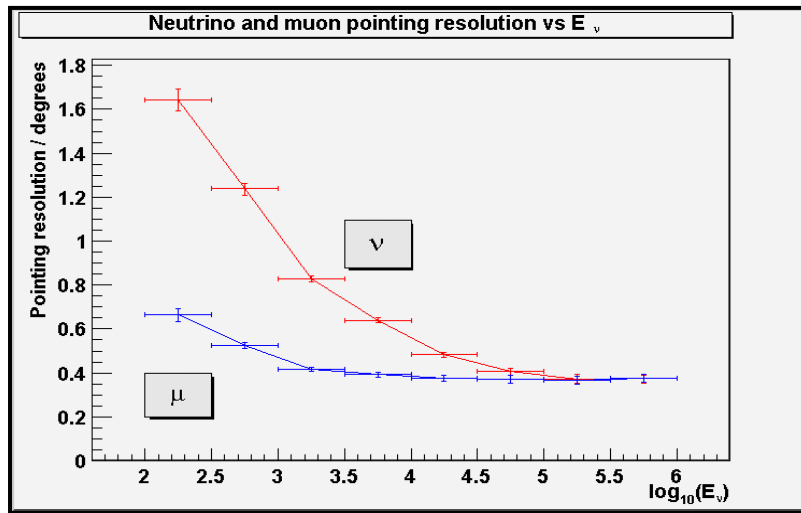
10 strings : 900 PMTs in total  
Detector to be deployed at ANTARES site by 2002 - 2004

Shore station



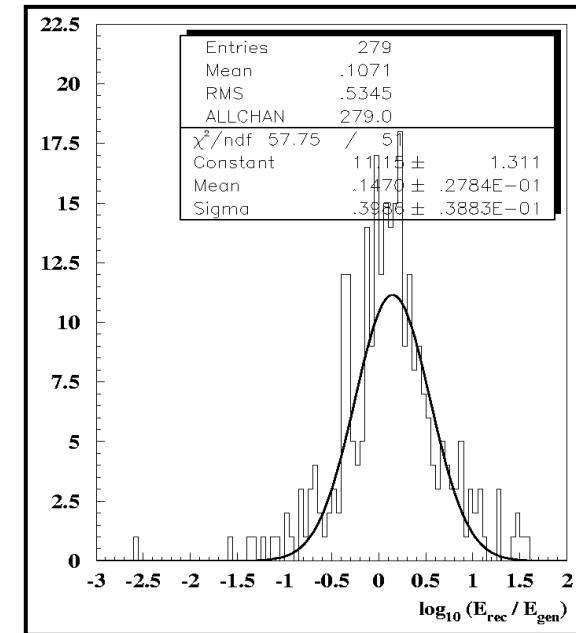
# 0.1 km<sup>2</sup> Detector : Expected performance

## Angular resolution



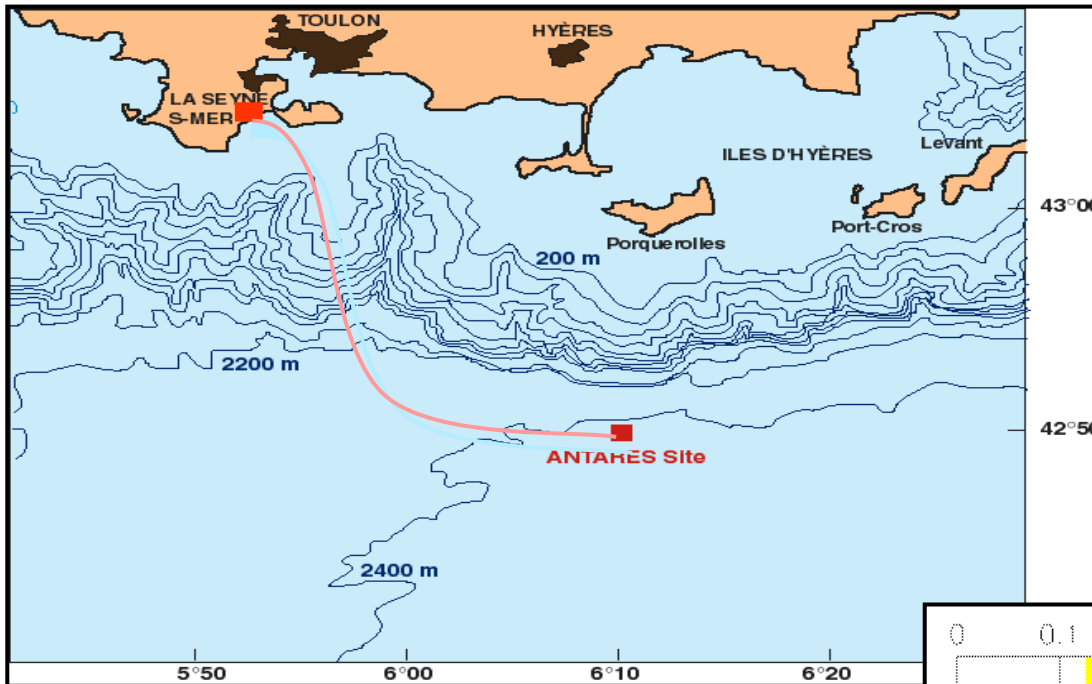
- ❖ Including effects of reconstruction and selection, PMT TTS, positioning, timing calibration accuracy and scattering.
- ❖ Below  $\sim 10$  TeV angular error is dominated by  $\nu$ - $\mu$  physical angle.
- ❖ Above  $\sim 10$  TeV angular accuracy is better than  $0.4^\circ$  (reconstruction error).

## Energy resolution



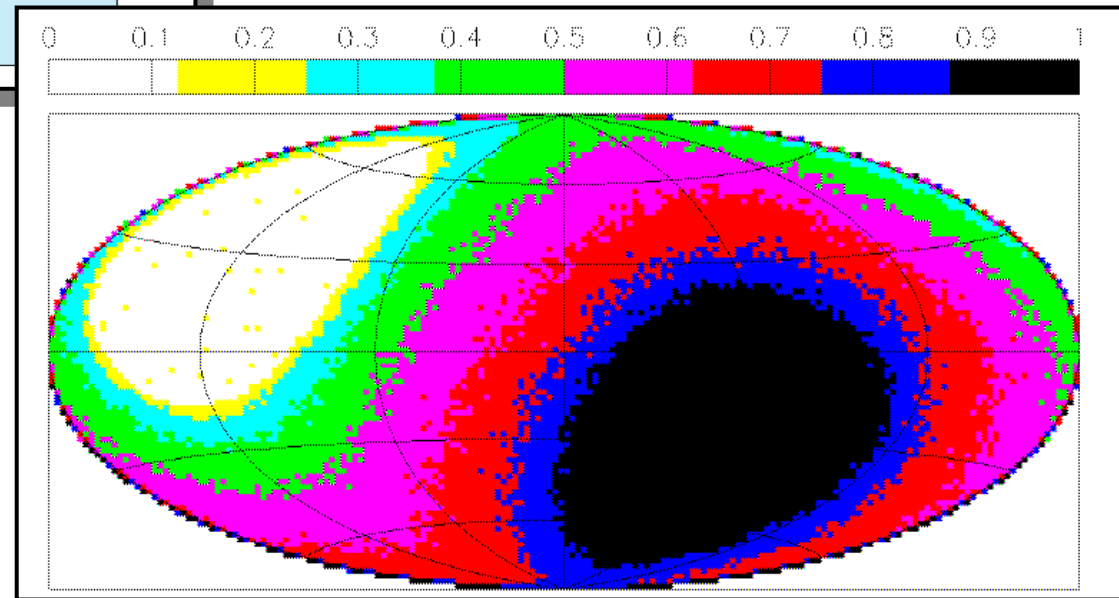
- ❖  $\sigma_E/E \approx 3$  ( $E > 1$  TeV)
- ❖ Below  $E \sim 100$  GeV energy estimation via muon range measurement.

# ANTARES 0.1 km<sup>2</sup> Detector Site



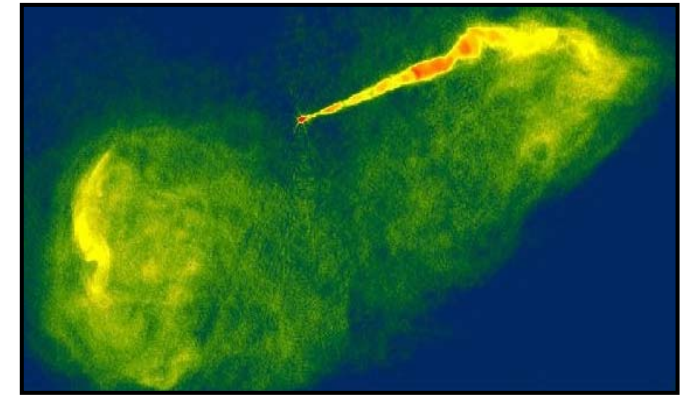
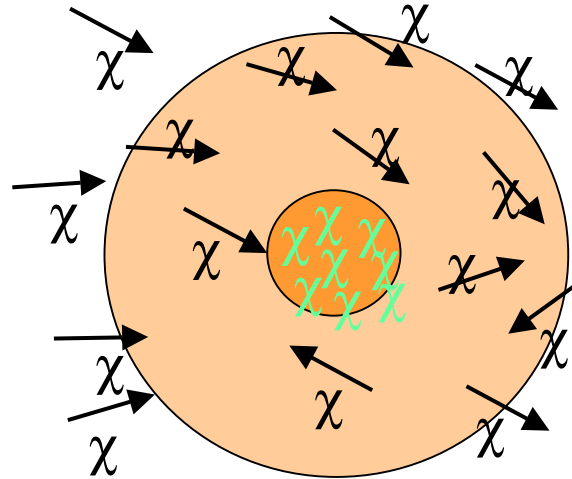
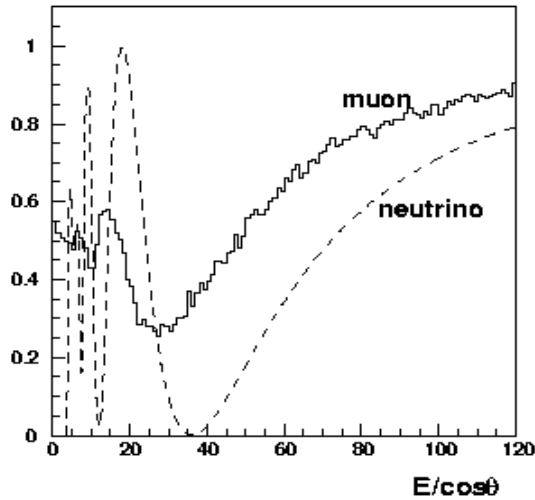
- ❖ 40 km SE of Toulon, Southern France (42° 50' N, 6° 10' E)
- ❖ Shore base at La Seyne-sur-Mer (excellent infrastructure)
- ❖ 2400 m below sea level

- ❖  $3.5\pi$  sr of the sky is covered
- ❖  $0.5\pi$  sr overlap with Amanda
- ❖ Galactic Centre surveyed



# Scientific Programme

# Energy



## Low energy

- **Neutrino oscillations via the modification in the energy spectrum due to observation of the first oscillation minimum**

## Medium Energy


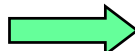
- **Search for neutralinos via their self-annihilation to products containing neutrinos at the centre of the Earth, Sun and Galaxy**

## High energy

- **Observation of neutrinos from (extra-)galactic sources such as GRB, AGN, Supernovae remnants, molecular clouds, etc.**

# Conclusions

ANTARES has made excellent progress over the past 4 years :

- ◆ Site environmental characterisation  **OK**
- ◆ Tests of marine technologies  **under control**
- ◆ Deployment and operation of Demonstrator String
- ◆ First down-going muons reconstructed
- ◆ Expanding Collaboration

ANTARES is well engaged in Phase II of its programme  
by the design, the installation and the running  
of a 10-strings 0.1 km<sup>2</sup> detector in 2002-2004

**Major step forward towards a km-scale  
neutrino telescope in the Mediterranean Sea**