The ANTARES project

L. Moscoso

DSM/DAPNIA,

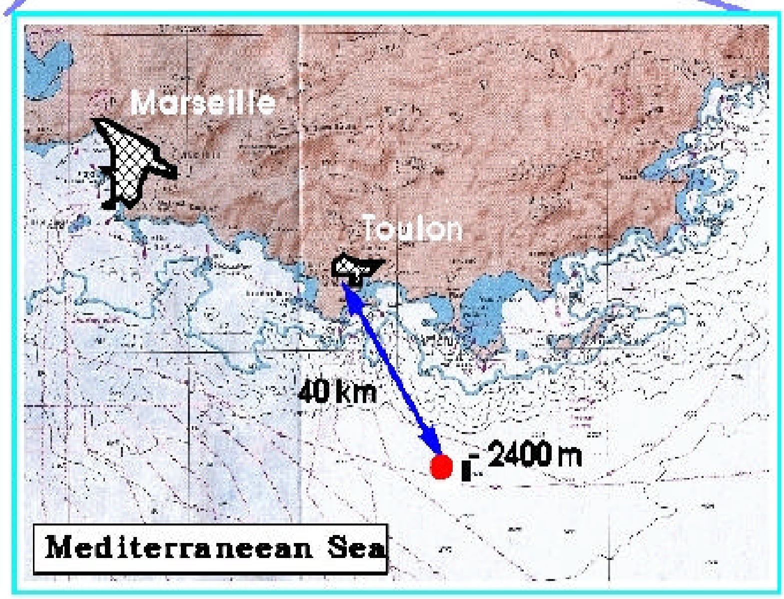
CEA/Saclay

Venice, Italy, Feb. 22-26, 99

The ANTARES project

• Construction of a prototype (few lines connected to the shore) of a neutrino telescope extrapolable to a km^3 detector

• Programme of measurement of environmental parameters



• 40km off-shore from Toulon, France

• 2400m depth

THE ANTARES COLLABORATION

The project involves European laboratories:

•**Particle Physics:**

- **DAPNIA-CEA Saclay, France**
- **IFIC-Valencia, Spain**
- **IN2P3-CNRS: Marseille and Mulhouse, France**
- **ITEP, Moscow, Russia**
- **NIKHEF, Amsterdam, The Netherlands**
- **Oxford and Sheffield Universities, U.K.**

•**Astronomy & Astrophysics:**

- **LAS Marseille, France**
- **Marseille Observatory, France**

•**Sea Science:**

- **Centre d'Océanologie de Marseille, France**
- **IFREMER, France**

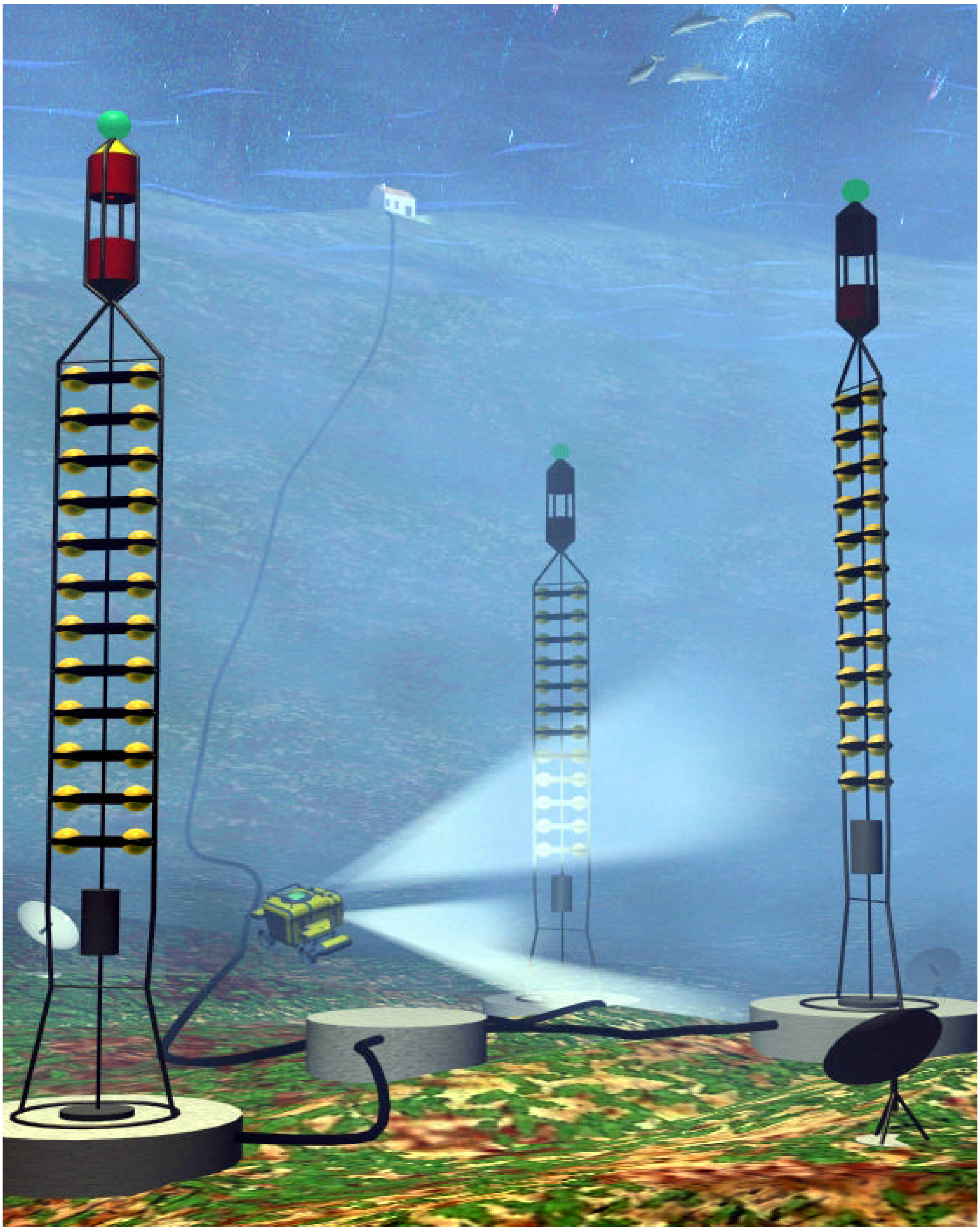
ANTARES demonstrator

- **40 km long electro-optical cable: May 98**
- **Mechanical tests on a full string: June 98**
- **Connection-disconnection tests with a submarine: December 98**
- **First partially equipped string (8 PMTs), electronics, slow control, electro-optical cable: Spring 99**
- **Fully equipped line (≅ 50 PMTs): 2000**

And after:

10-15 strings: 2001-2003

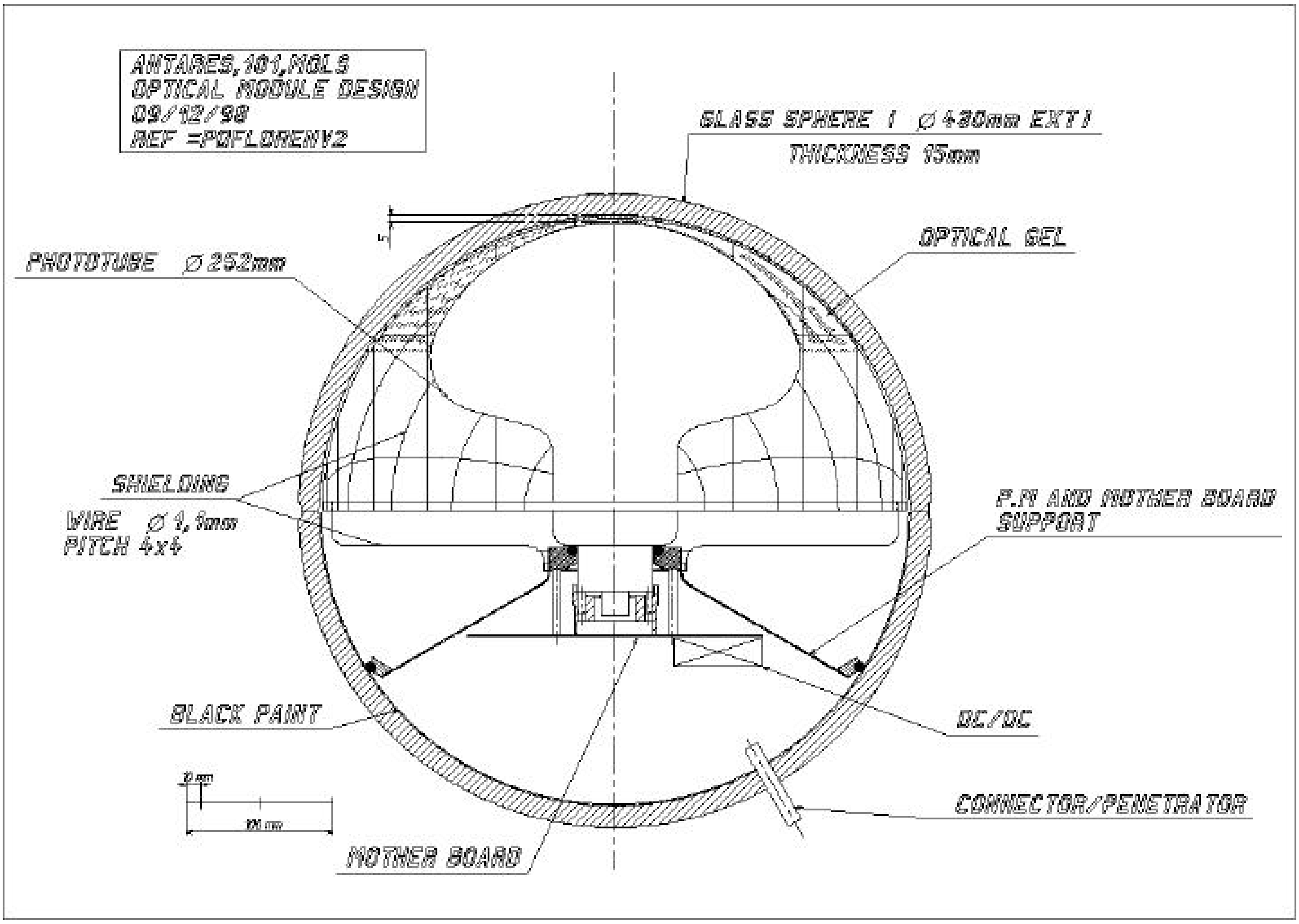
ANTARES demonstrator



THE OPTICAL MODULES

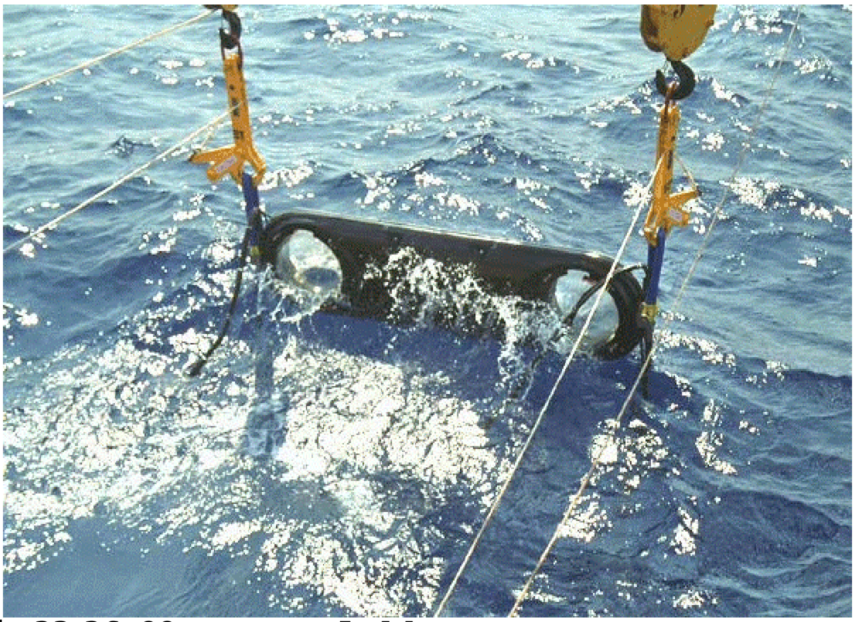
The photomultiplier is housed inside a high pressure resistant glass sphere:

- **Large cathod photomultipliers**
- **Signal locally digitized.**
- **Slow control.**



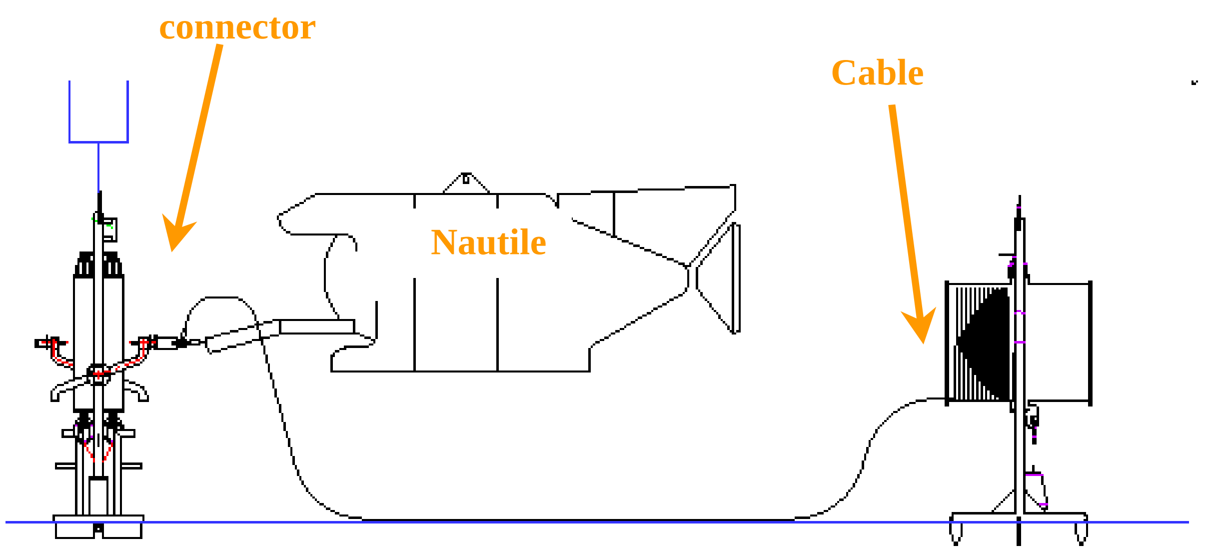
The first prototype in its cage

SOME PICTURES OF THE PROTOTYPE DEPLOYMENT



In Dec. 1998, “Le Nautile” has been used to test the connection between a cable and a high pressure container:

Tests pursued in 1999 and in 2000.



site at -2400 m


NAUTILE
IFREMER
NAUTILE

ANTARES site measurements

Several strings have been developed to measure the environmental parameters:

- **Autonomous acquisition (optical modules, currentmeter, tiltmeter,…)**
- **Long term measurements (a few months)**

ANTARES
site measurements

- **Optical background**

  Done ten times off-shore from Toulon and Corsica

- **Fouling of optical surfaces**

  Long term counting rates

  Sediment trap, sampling box

  Done three times with two orientations

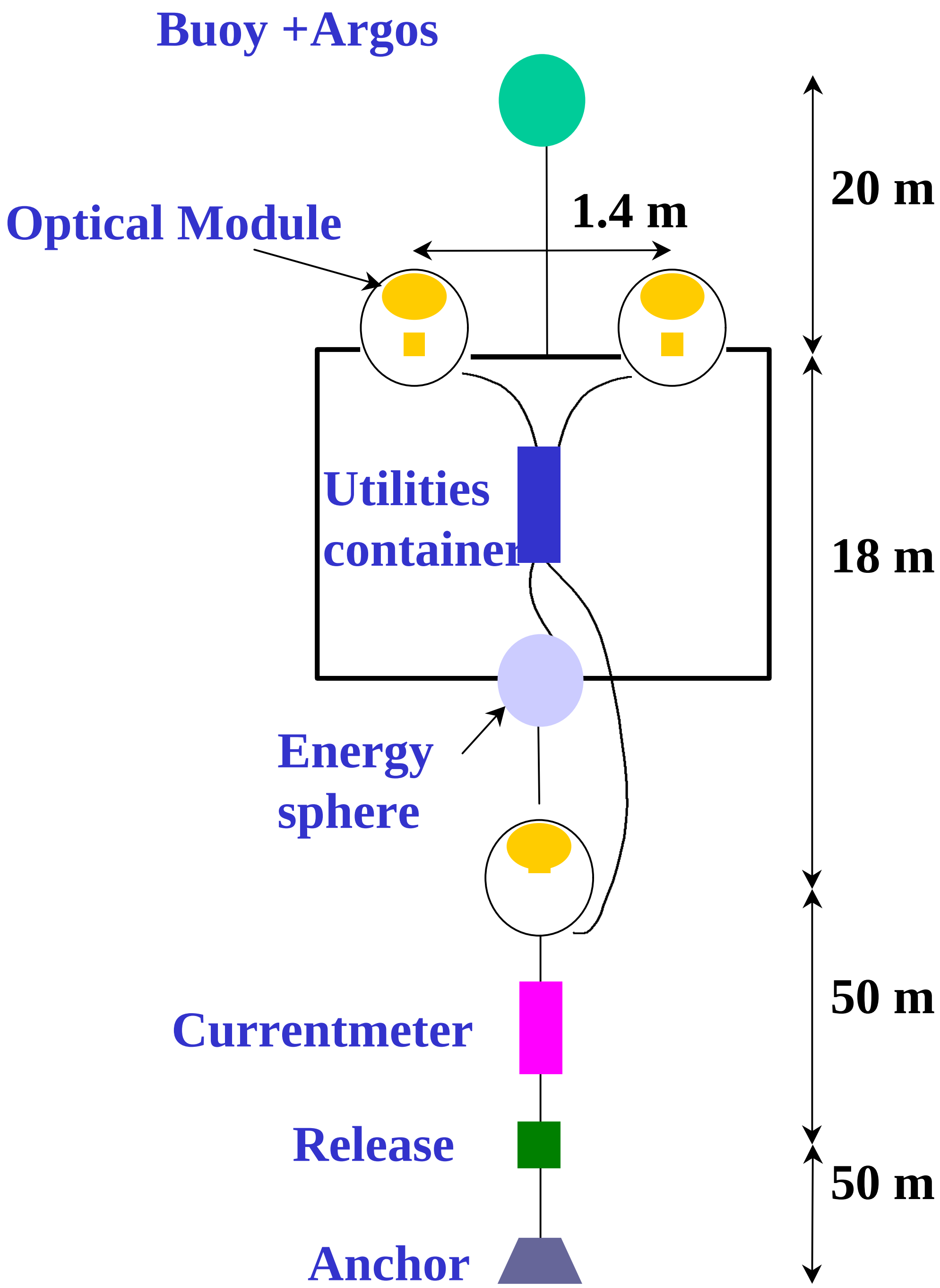
- **Water transparency**

  Long and rigid structure: λ_{att}

  Repeated with pulsed LED: July 98.

  Disentangle $\lambda_{scatt}/\lambda_{abs}$

OPTICAL BACKGROUND



OPTICAL BACKGROUND

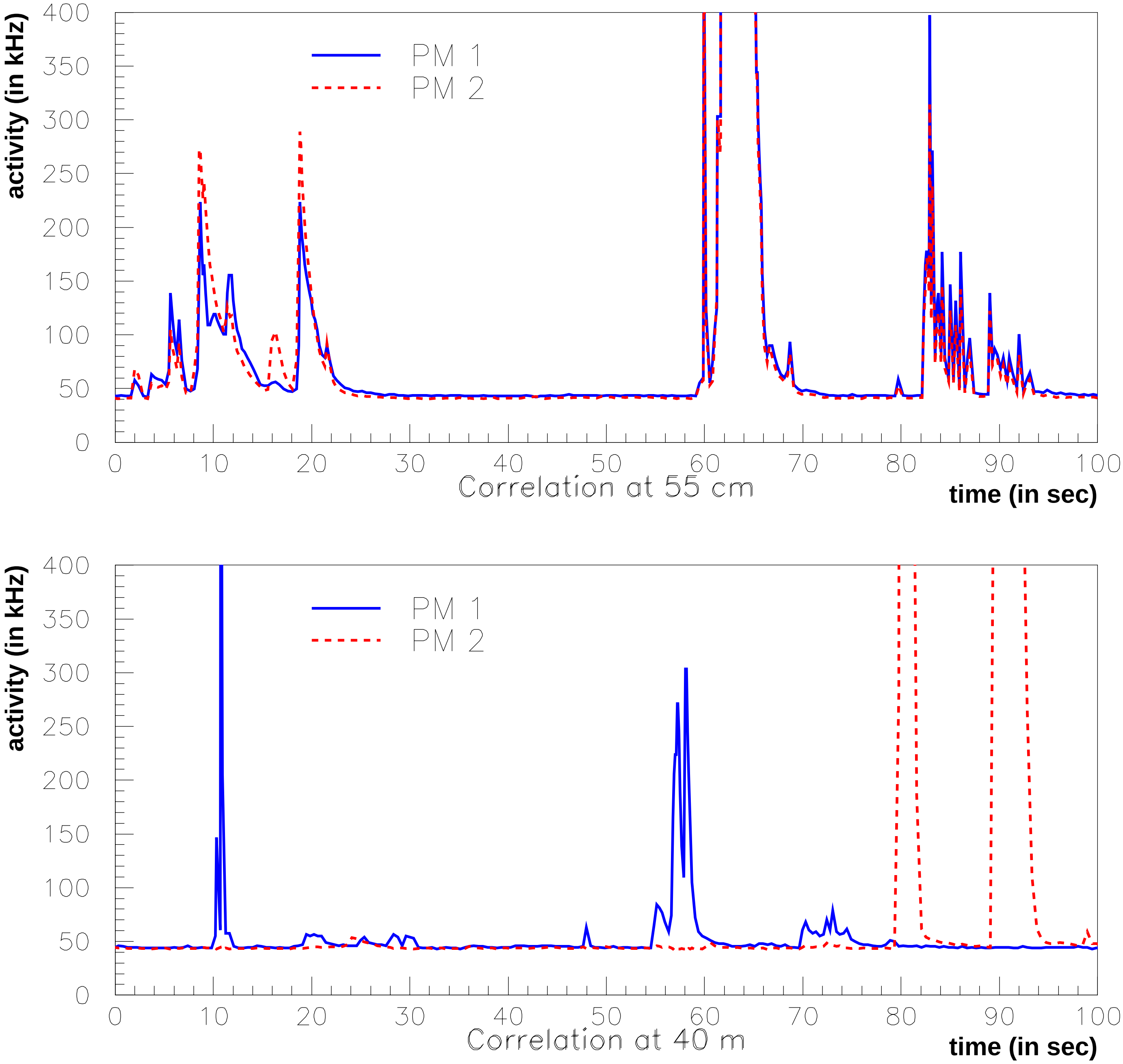
OPTICAL BACKGROUND

- Baseline: ^{40}K decay = 40 kHz

- 3-4% of dead-time for PMTs

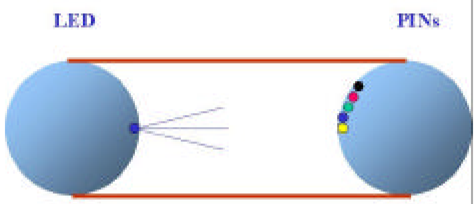
- No correlation for two OMs >20m apart

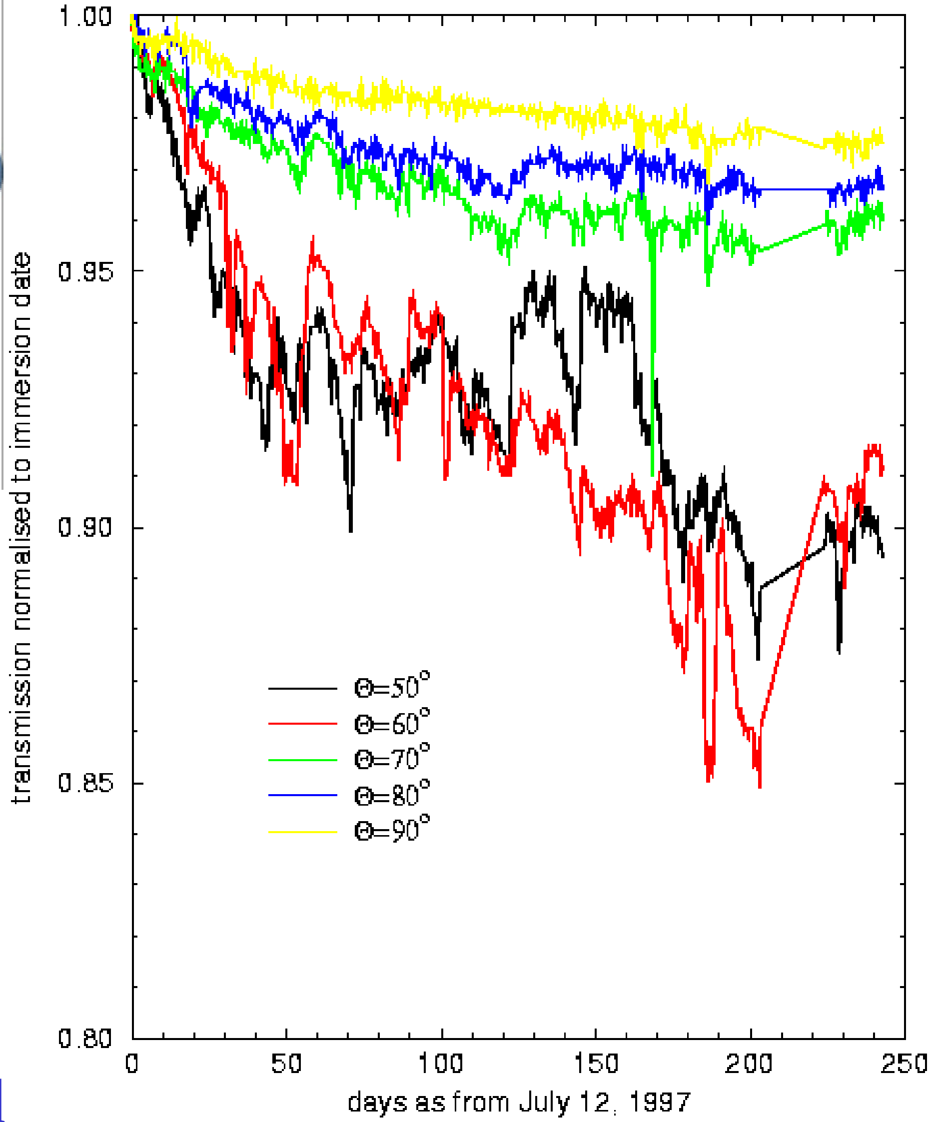
INFLUENCE OF DISTANCE ON CORRELATION BETWEEN PM



Fouling

Fouling and sedimentation decrease the glass transparency.





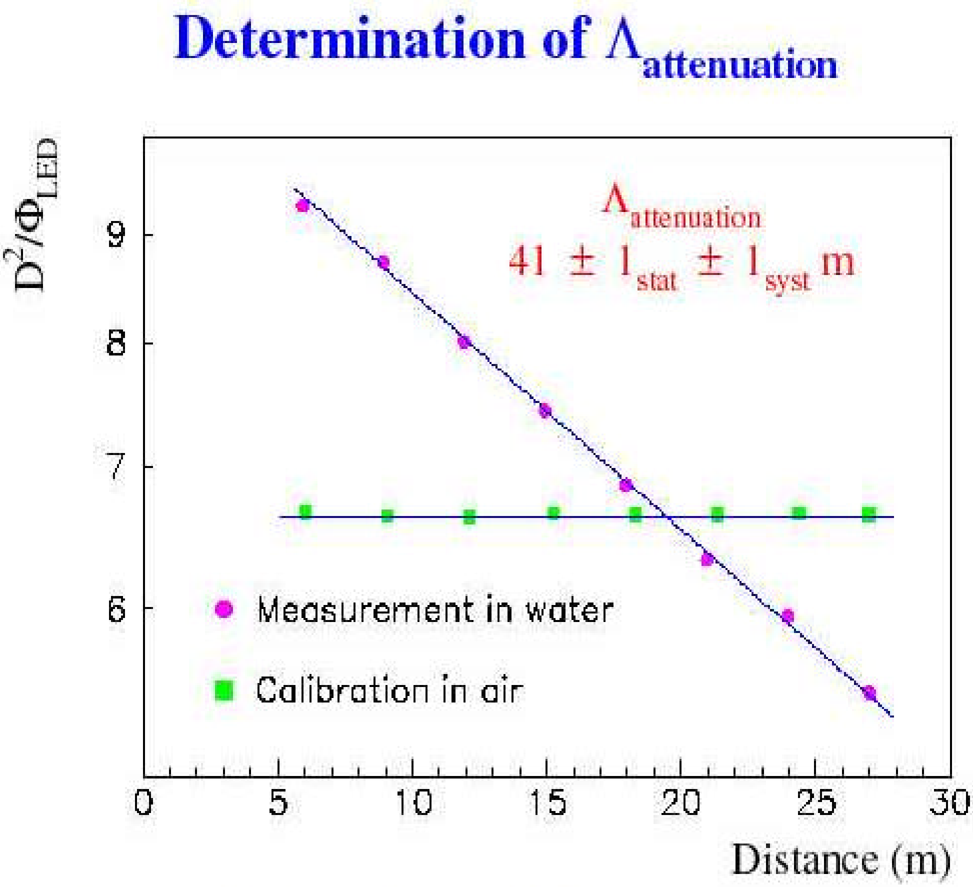
Small effect in the horizontal position:

1.5% effect after one year

Sea water attenuation length

Sea water attenuation length

DC measurement



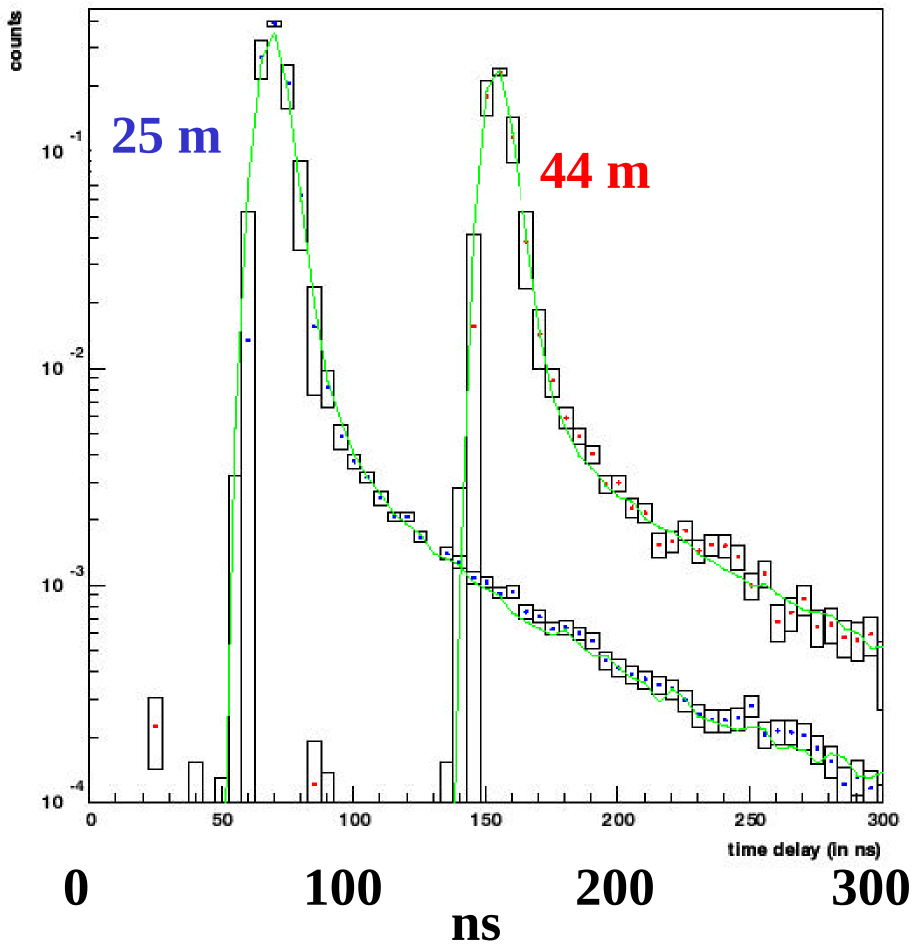
D: Distance between LED and PMT

Φ_{LED}: LED luminosity to obtain a constant current on PMT

Pulsed LEDs

Measured with a blue pulsed LED (467 nm):

- **Attenuation length ≅ 40 m**
- **Scattering length > 100 m**



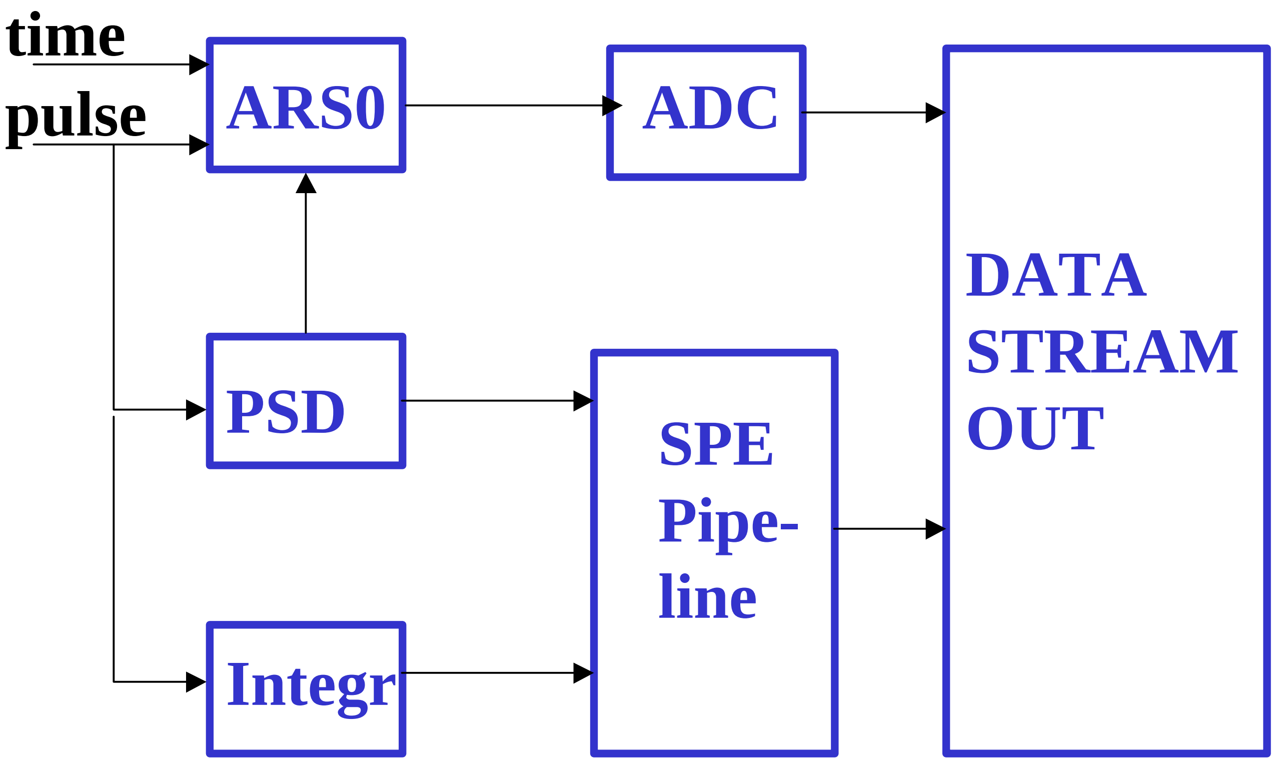
Present activities

- **Digitized signals transmission**
- **Study and choice of PMTs**
- **Positioning and slow control**
- **Mechanics and deployment**
- **Software**

Digital optical modules

Application Specific Integrated Circuit (ASIC) in the digital optical modules. Similar to the ATWR (D. Nygren)

Analogue Ring Sampler (ARS)



Performance studies

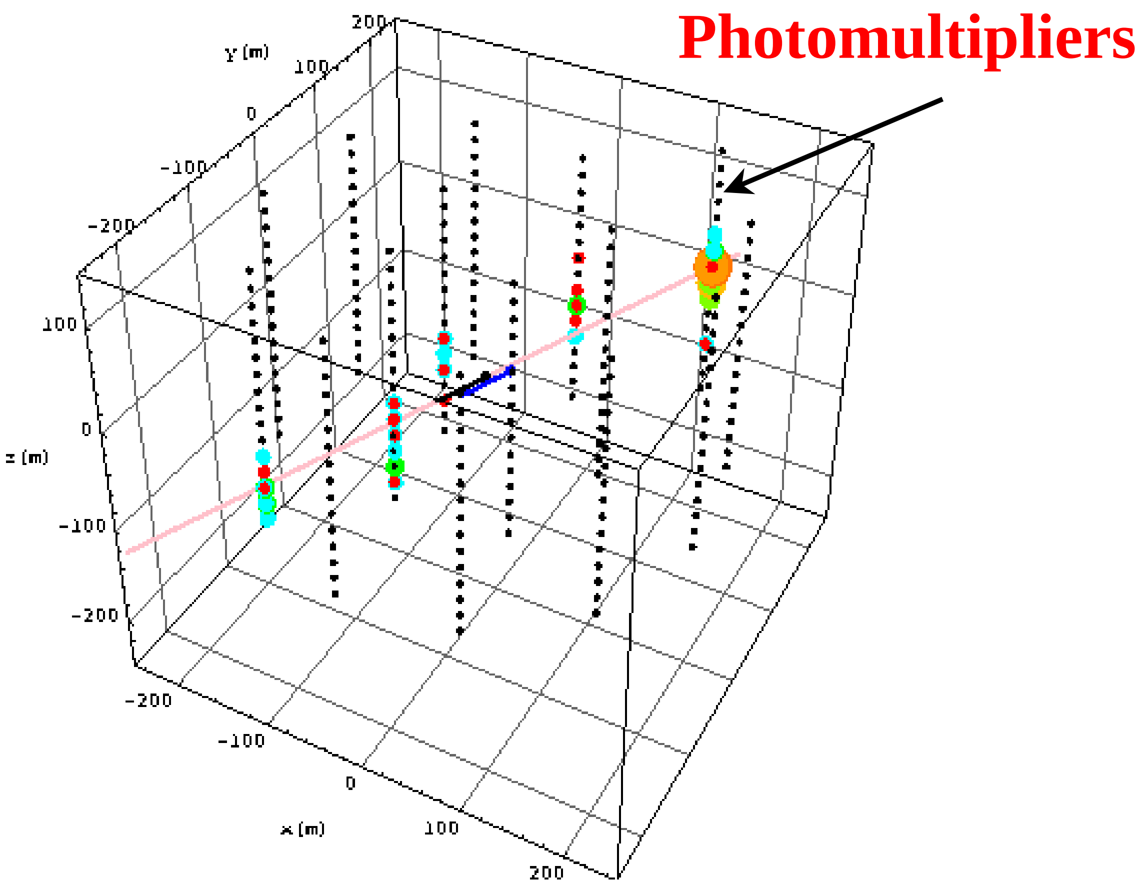
- **Events simulation: including the response of the optical modules**
- **Reconstruction of simulated events**
- **Optimization of the layout for a big detector**
- **Simulation of a 0.1km^2 detector (15 strings, ≅1000 PMTs)**
  - **Detection & reconstruction efficiency**
  - **Angular resolution**
  - **Calorimetry**

DETECTOR LAYOUT

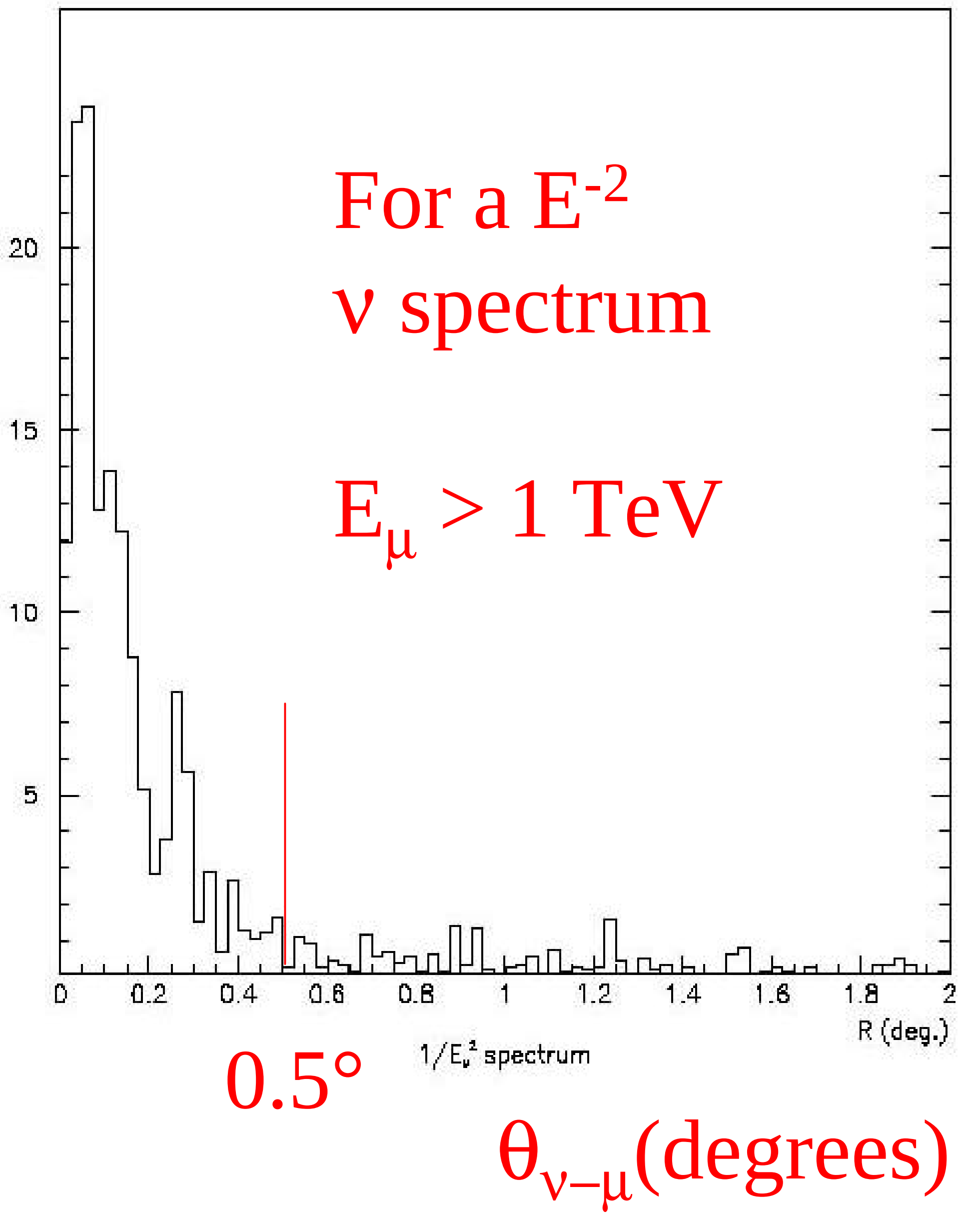
The detector is a network of vertical strings, ~100 m apart from each other.

Each string is ~400 m long with ~100 photomultipliers.

Detector connected to the shore by an EO cable (DAQ, slow control and power).



ANTARES-0.1km^2 Angular resolution



Extrapolation of the 2nd EGRET catalogue

- **2nd EGRET catalogue:**
  Differential spectral index $\cong 2$

- **High energy γ-rays are absorbed over large distances (GZK effect)**

- **If all HE γ are produced by π° :**

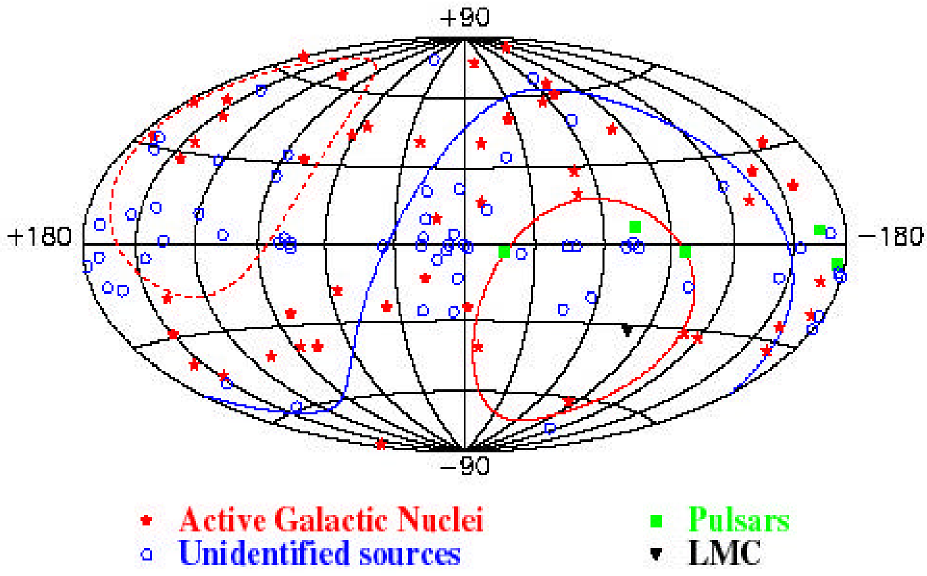
$$N_{\pi} \approx N_{\pi^\circ} \Rightarrow \Phi_{\nu} \cong 0.4\Phi_{\gamma}$$

- **Neutrinos are not absorbed**

- **116 measured sources on a long period (April 91 to September 93)**

$$0.1 < E_{\gamma} < 10 \text{ GeV}$$

2nd EGRET catalogue



How many sources are detectable?

(CL < 10^{-4} with at least 5 events)

0.1km^{2}year at 45°N

- **Only few pulsars. No AGN**
- **Summing over 42 possible AGNs:**

  Background = 2.7

  B+S = 8-67 (spectral index = 2.2-2.0)

NEUTRINO OSCILLATIONS

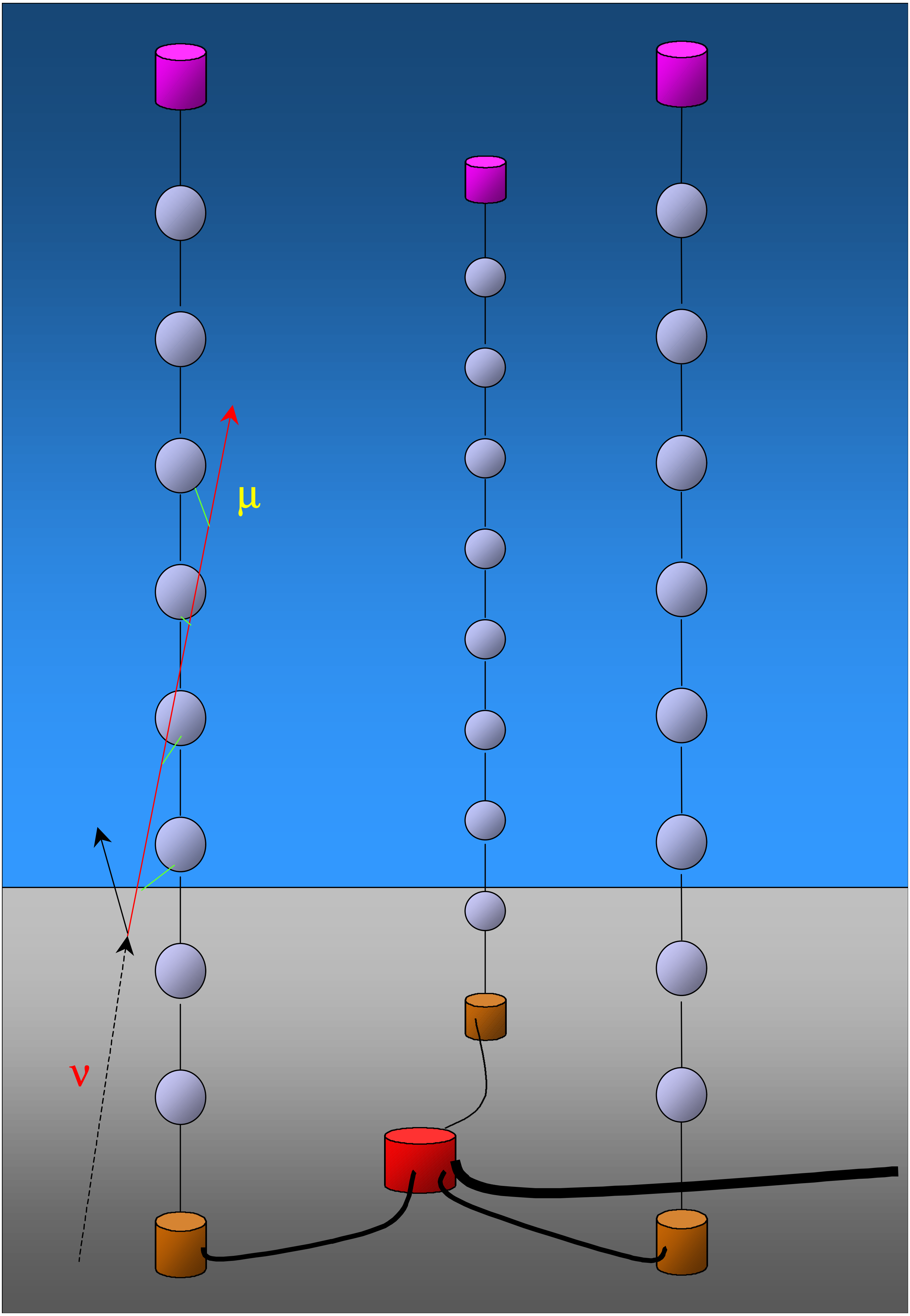
Atmospheric neutrinos to study the Super-Kamiokande evidence:

Measure ν_μ disappearance in the domain L/E ~ 600 km/GeV

Idea: measure the vertical upward-going ν_μ flux

- **The base line length is always the same: L ≈ 12 740 km (Earth diameter)**
- **The only variable is the neutrino energy: 5 < E < 50 GeV**

⇒ 255 < L/E < 2550 km/GeV


μ
ν

Survival Probability

Battistoni & Lipari

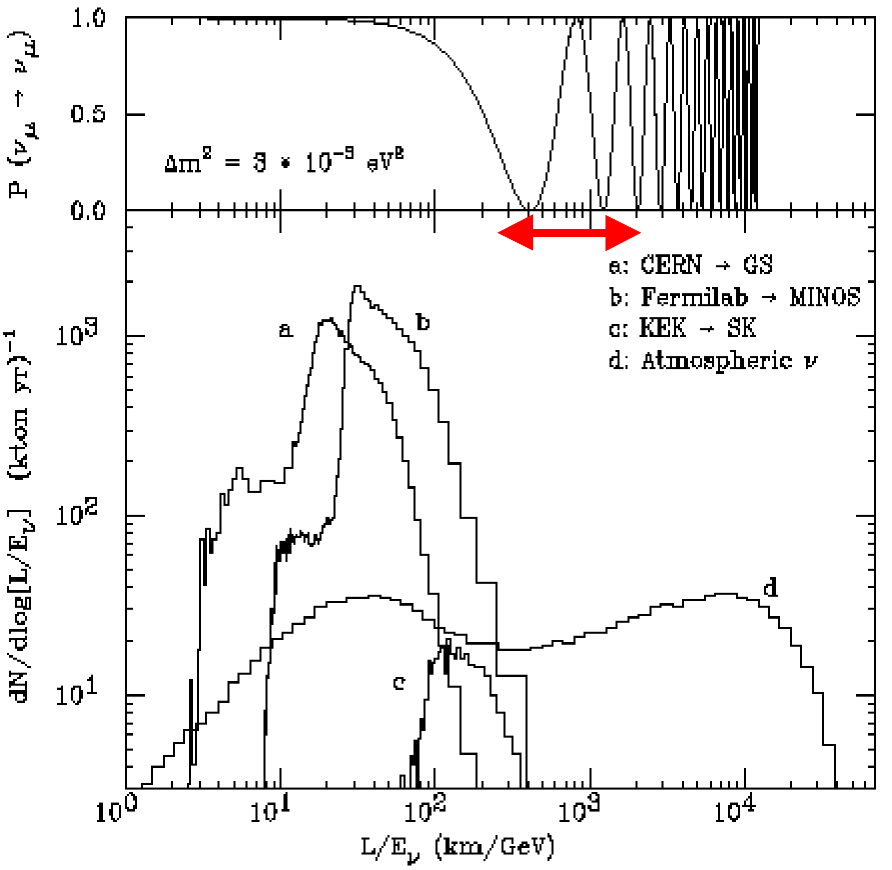


Figure 2: Distribution in L/E_ν of the charged current events expected (in the absence of oscillations) in three LBL experiments, and for atmospheric neutrinos with a cut $p_\mu \geq 0.2$ GeV. In the upper panel we show the oscillation probability for maximal mixing and $\Delta m^2 = 3 \times 10^{-3}$ eV^2.

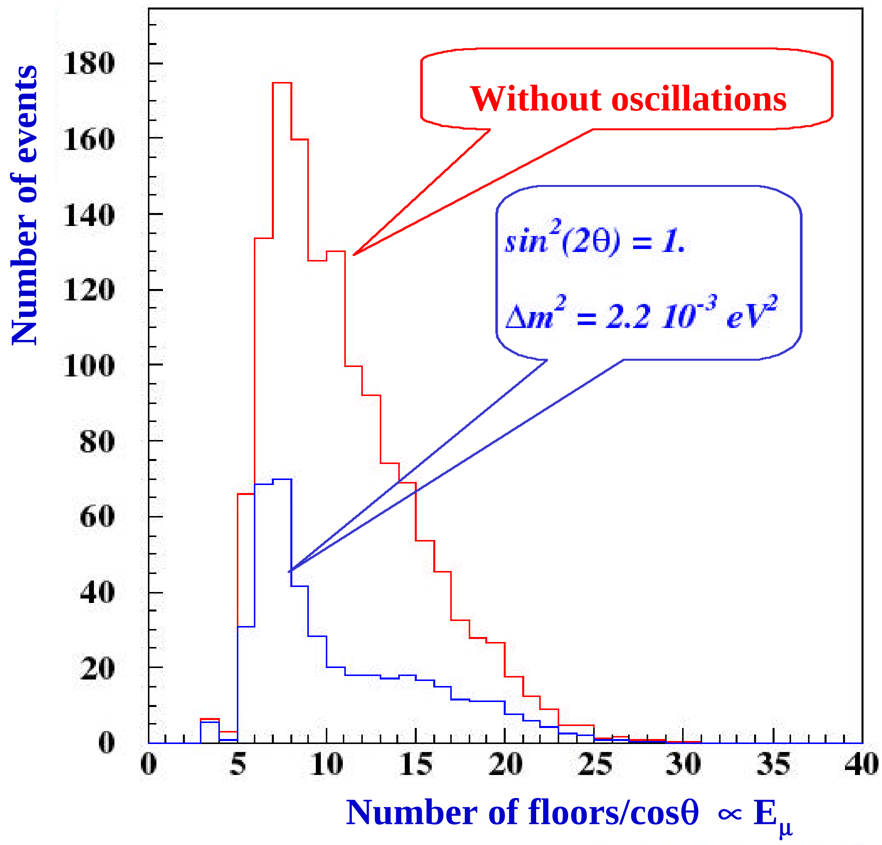
26

Method:

- Use vertical events: $\cos\theta > 0.97$
- The muon energy is estimated by its range

Use the events interacting inside the detector volume

Simulated E_μ spectrum with/without oscillation



⇒ **Require a densely equiped detector**

Physical background

- Downward-going muons
- Showers
- Low energy misreconstructed neutrino interactions

Conclusions

• The ANTARES project has accumulated a lot of measurements of water parameters.

• Ready for the deployment of the first string connected to the shore.

• Physical studies on neutrino mixing and on HE cosmic neutrinos starting in 2001.