The ANTARES Status Report

The ANTARES Project

Preparatory Phase

Lessons from Prototypes

The Future

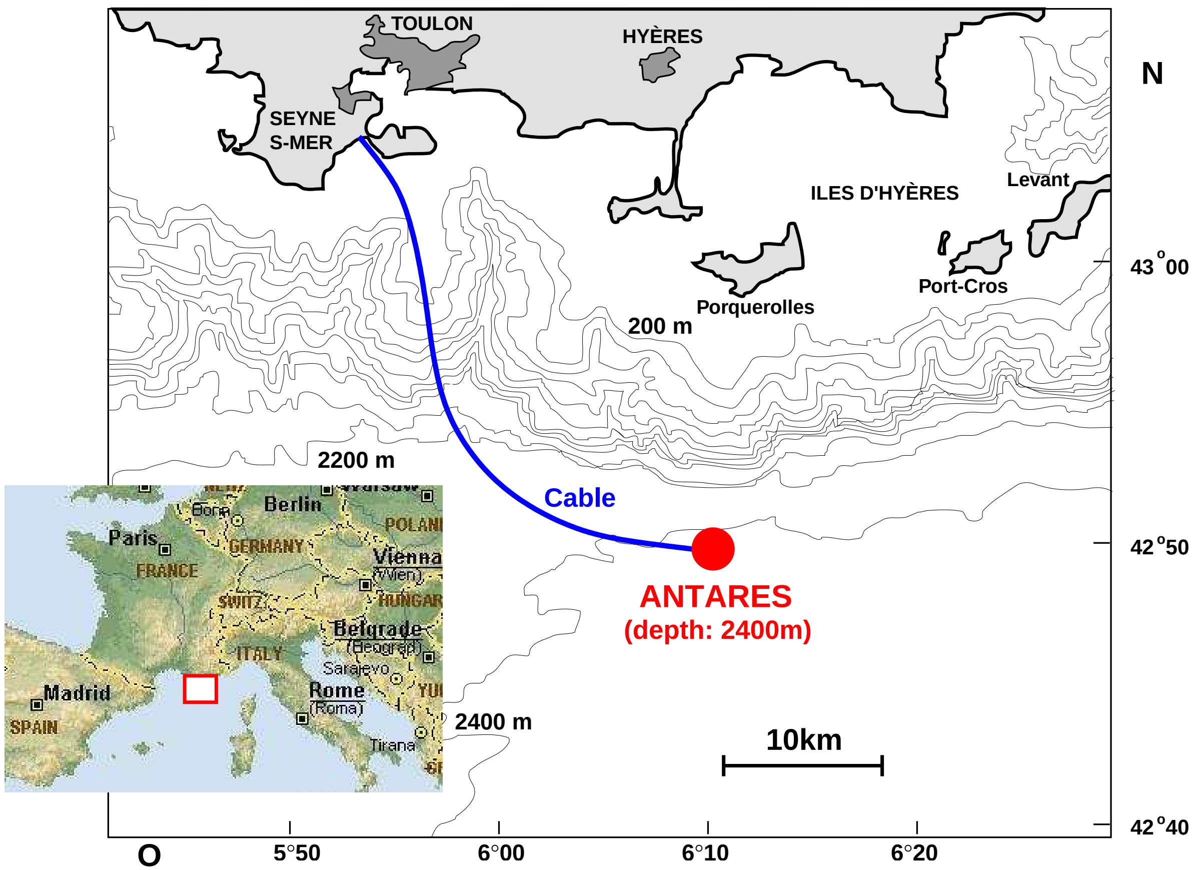
Summary

Uli Katz
University of Erlangen

The ANTARES Project

The ANTARES Collaboration

- European Collaboration:
  France, Germany, Italy, NL, Spain, Russia, UK.
- Particle physics, astronomy and sea science institutes.



The mission

Design, construct and operate a neutrino telescope in the Mediterranean Sea.

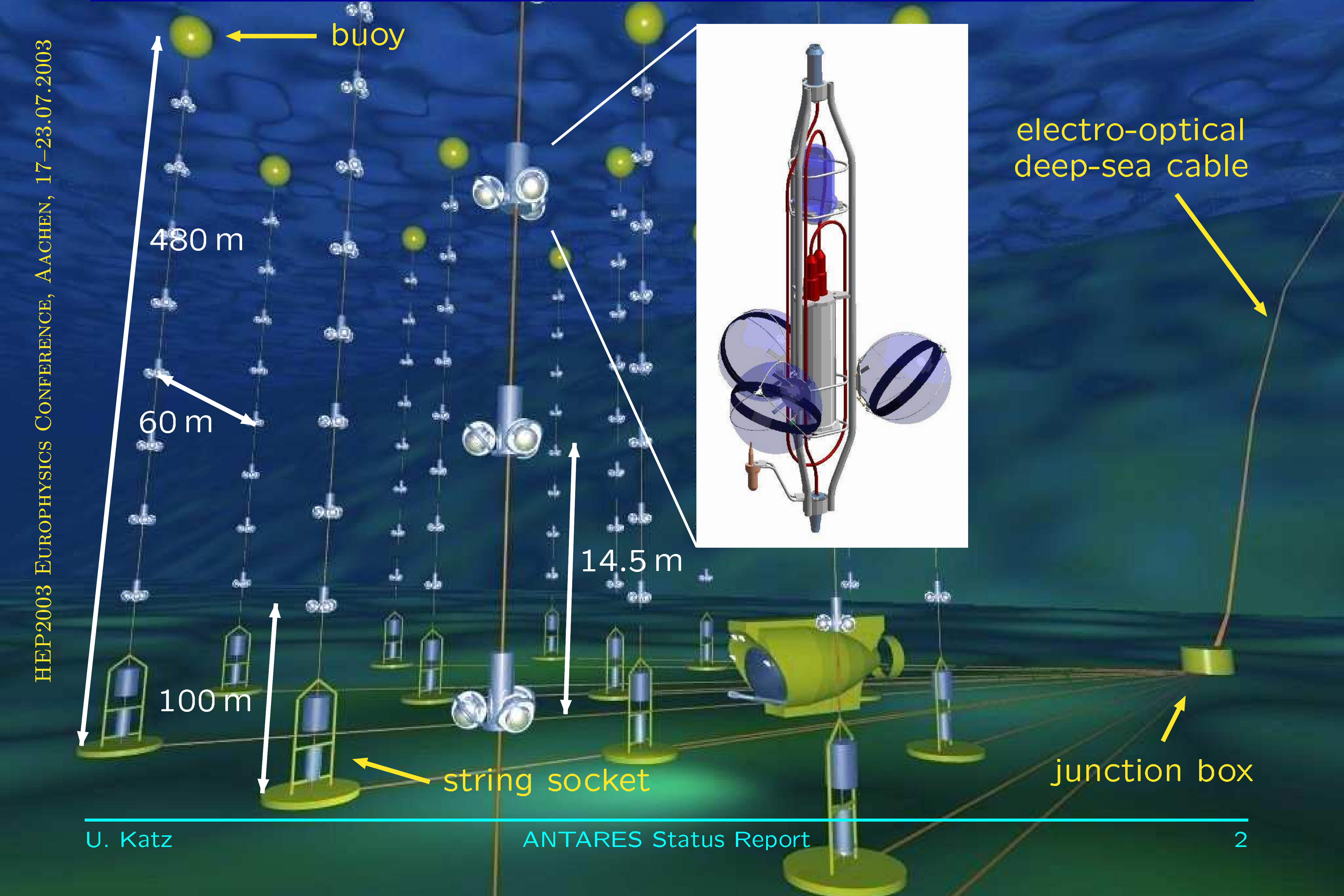
The objectives

- Physics:
  Detect neutrinos,
  astrophysical sources,
  WIMP annihilation,
  neutrino oscillations,
  ...
- Technology:
  Prove feasibility and long-term stability of a deep-sea neutrino telescope.

The challenge

Build a high-tech particle detector in a hostile, poorly known and uncontrollable deep-sea environment.

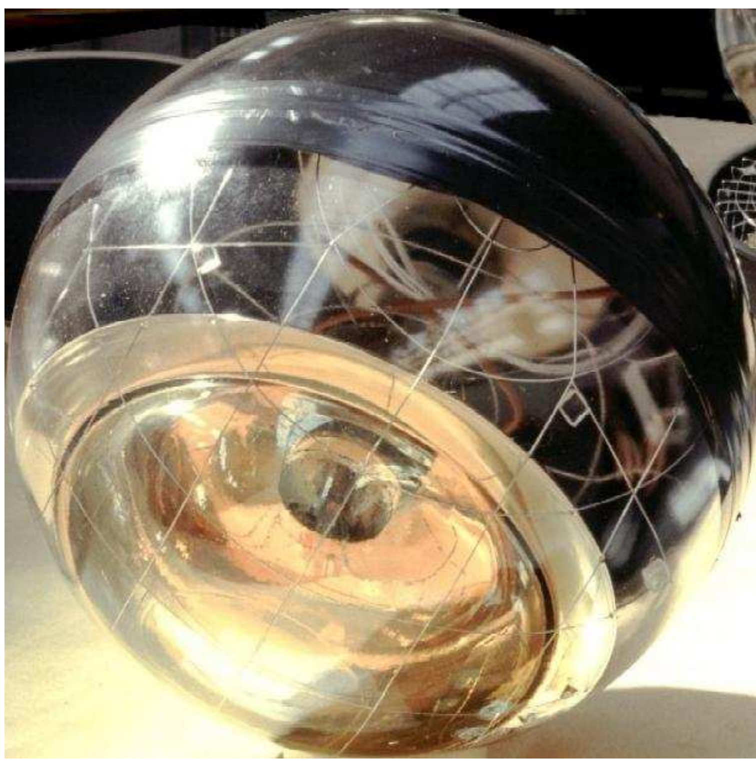
The ANTARES Neutrino Telescope



Optical Modules

- **Photo multiplier tubes:**
  Hamamatsu 10″ (550 cm^2 cathode area);
  transfer time spread (TTS) ~ 2.7 ns;
  quantum efficiency $> 20\%$ @ 1760 V
  for $330\,\mathrm{nm} \lesssim \lambda \lesssim 460\,\mathrm{nm}$.
- **Glass spheres:**
  outer diameter 43 cm;
  qualified for 600 bar;
  light transmission $\gtrsim 95\%$.

43 cm



Physics Perspectives: WIMPs . . .

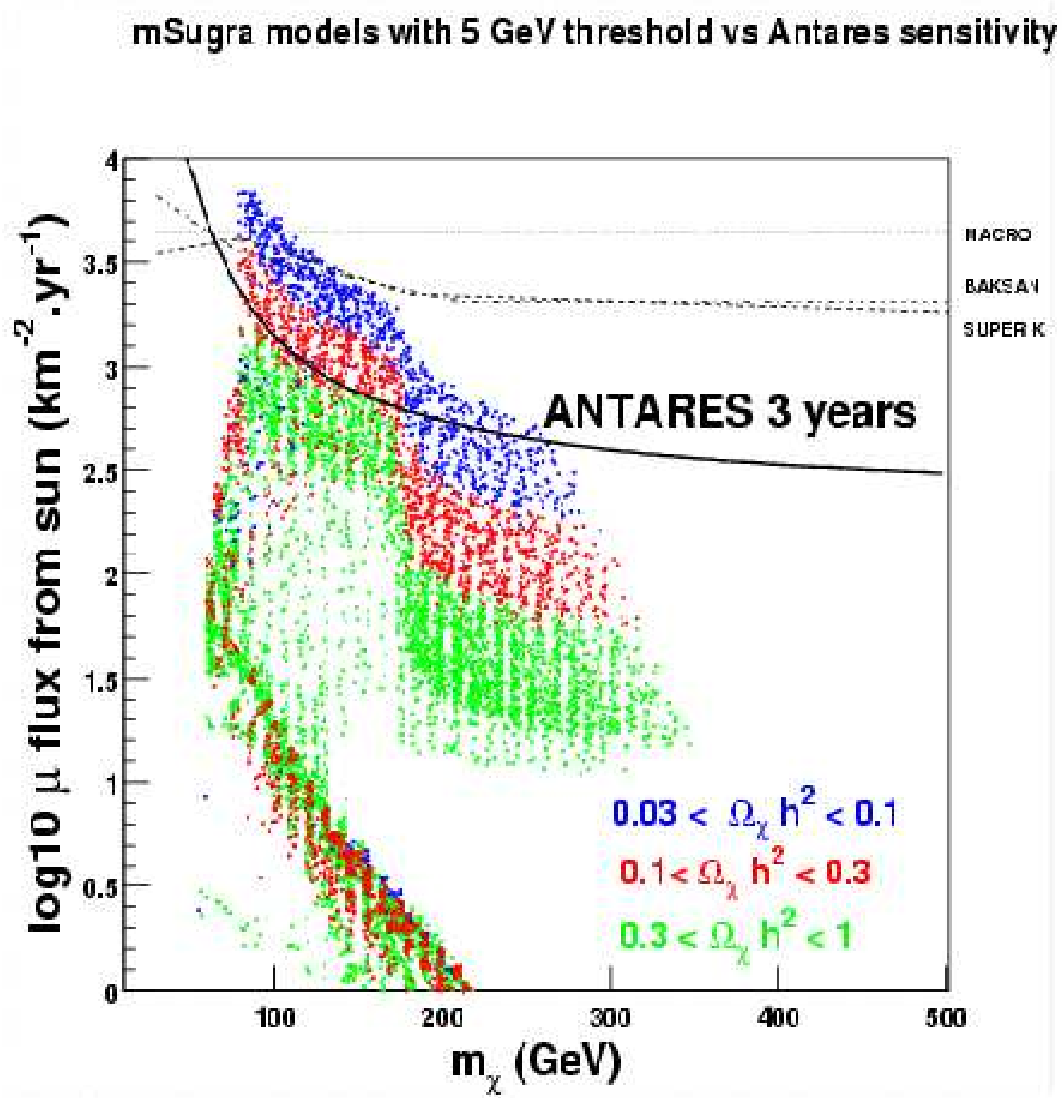
Indirect WIMP detection

- **Gravitational trapping:**
  WIMPs may be trapped in the gravitational field of Earth, Sun or Galactic Center.
- **Candidate particle:**
  SUSY Neutralino (χ).
- **WIMP annihilation**

$$\chi + \chi \rightarrow \text{hadrons} \rightarrow \nu + X$$
$$\chi + \chi \rightarrow Z^0 Z^0 \rightarrow \nu\bar{\nu} + X$$

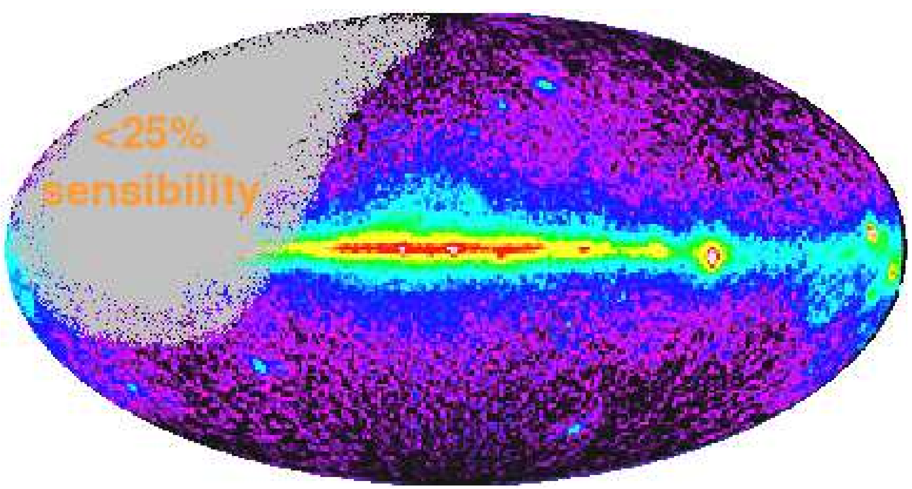
  ν energy spectrum depends on neutralino mass and on annihilation products
  $\rightarrow$ estimated sensitivity extremely model-dependent.
- **The ANTARES sensitivity**
  covers part of the SUSY parameter phase space.
  High sensitivity for low Ω_χ (high annihilation cross section).

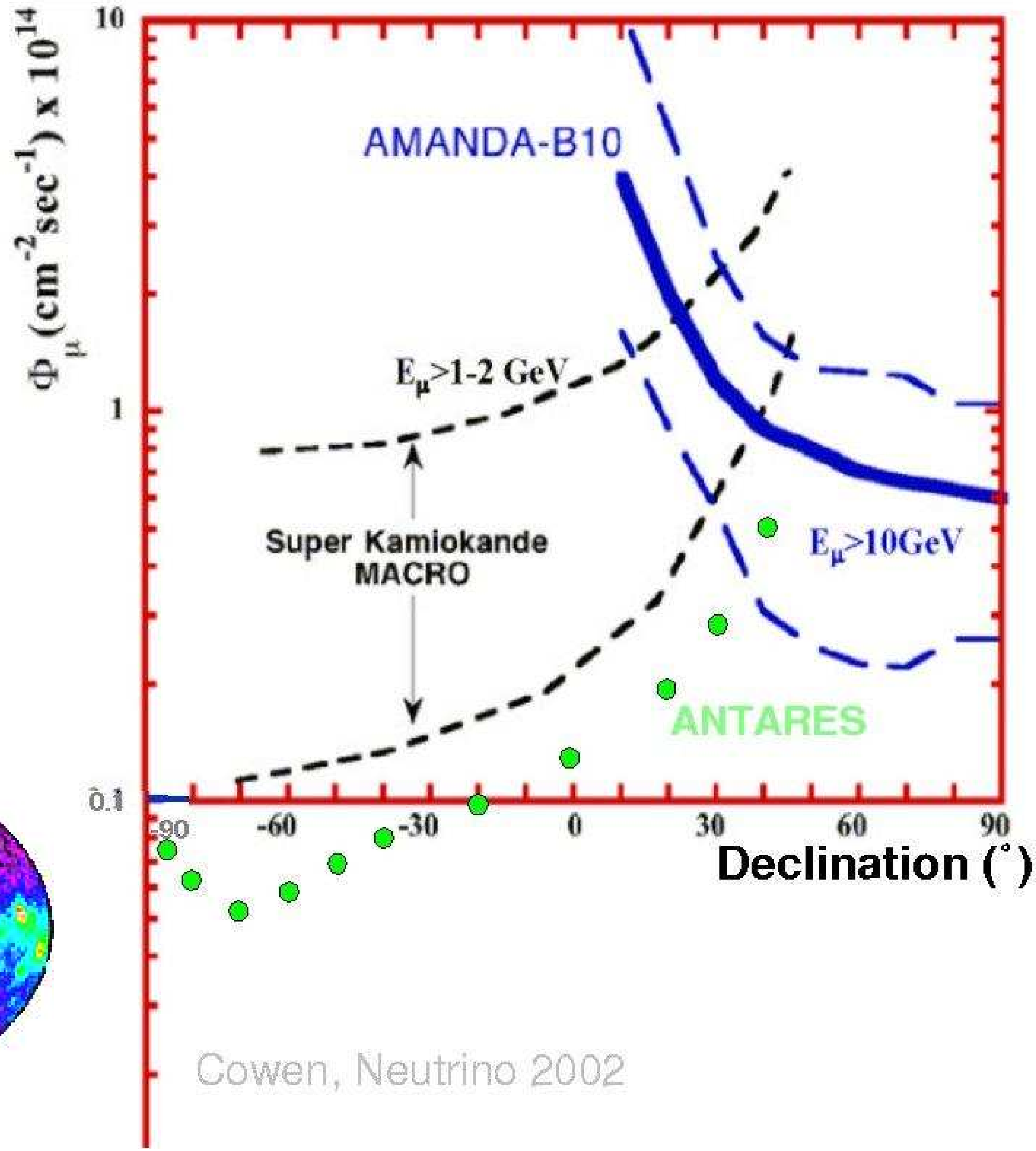
Neutralinos from the sun



. . . and Neutrinos from Astrophysical Point Sources

- **Sky coverage:**
  Complementary to AMANDA/ IceCube,
  Galactic Center seen $\sim 70\%$ of the time.
- **High sensitivity**
  due to good angular resolution ($0.2-0.3^\circ$ at high ν energy).
- **Expectation after 1 year:**
  Improve existing limits for Southern hemisphere or discover something!





Preparatory Phase

Environment assessment

- **Development of tools**
  for measuring environmental parameters.
- **Numerous measurement campaigns:**
  - optical parameters of water;
  - salinity, temperature,. . . ;
  - current velocity and direction;
  - sedimentation and biofouling;
  - bioluminescence;
  - bathymetric profile.
- **Sea floor survey**
  with deep-sea submarine.

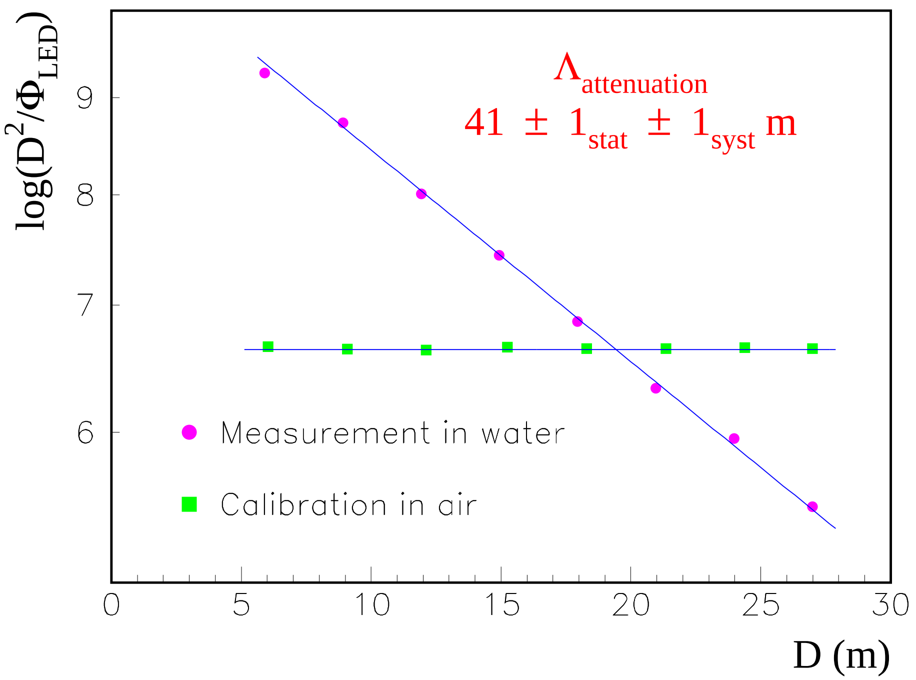
Prototype string

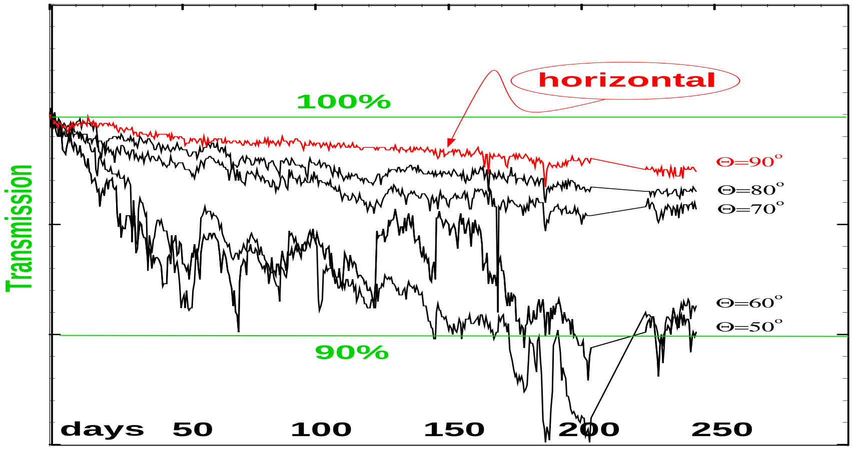
- **Design:**
  16 storeys à 2 PMs, 350 m long, equipped with full readout electronics and slow control devices.
- **Operation:**
  Several battery-operated immersions (1998/99), connected to shore (1999). Successful data taking.

Determination of $\Lambda_{attenuation}$

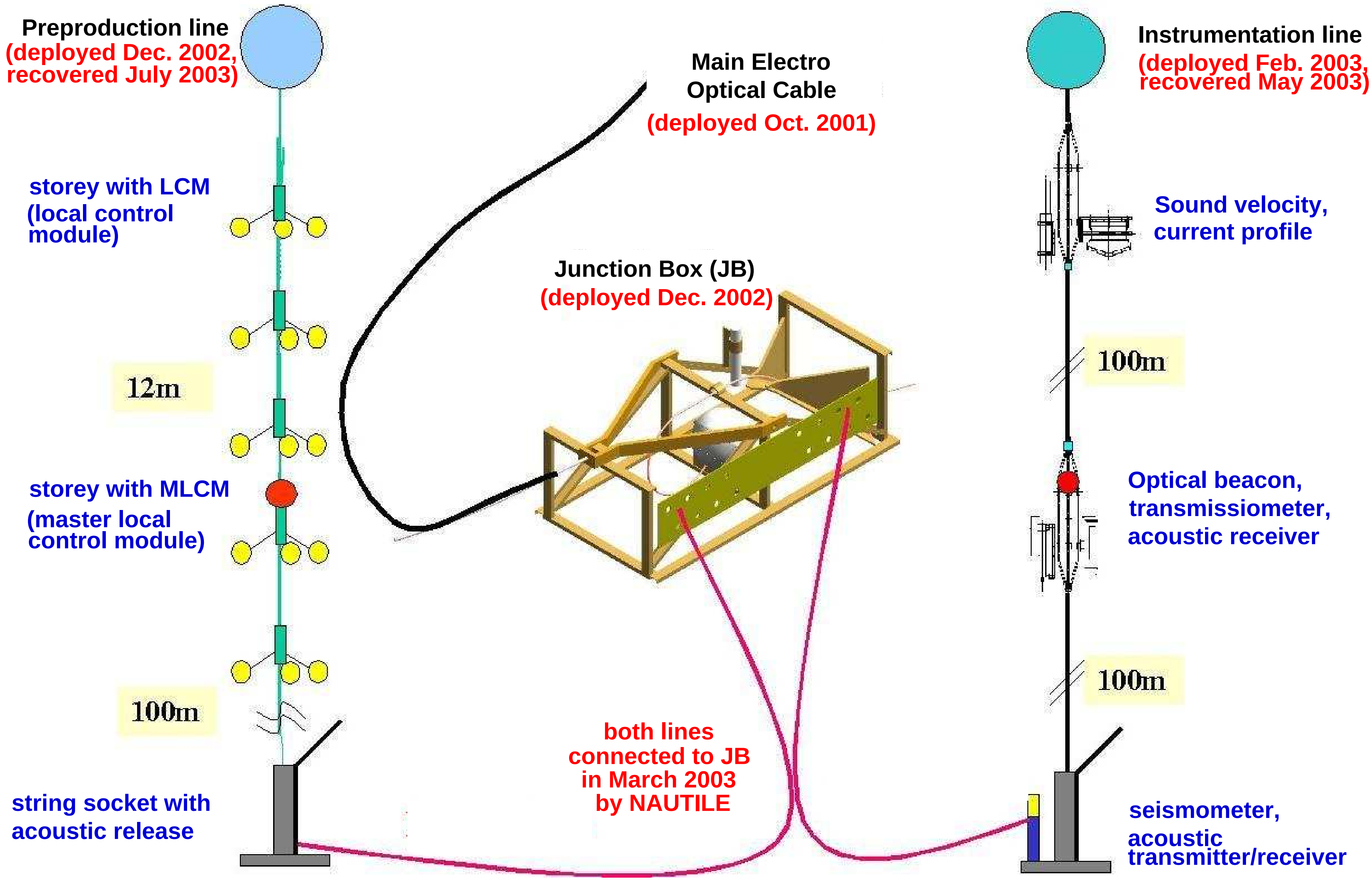
D: Distance between LED and PMT

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





Detector Status



Sea Operations

Positioning accuracy

- **Surface position**
  monitored and stabilized
  by differential GPS.
- **Underwater position**
  monitored by acoustic triangulation.
- **Accuracy on sea bed:**
  a few meters!

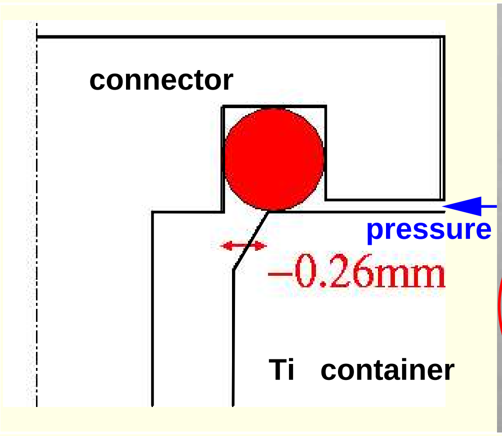
2 Problems and Their Diagnose

The clock fiber failure

- **The symptom:**
  The clock signal did not arrive at the readout modules (both lines!)
- **The consequences:**
  → no data with ns time resolution;
  → no measurement of signal charges;
  → no acoustic positioning.
  However, we still were able to
  → measure PM rates;
  → control HV settings, thresholds;
  → take slow control data (compasses, tiltmeters etc.).
- **The diagnose:**
  One plastic tube around the optical fiber for the clock signal collapsed.
  ⇒ Plastic material changed by manufacturer without notification.
  ⇒ Even worse: material not qualified for high-pressure applications!
- **The remedy:**
  Final cable design modified (use steel tubes now).

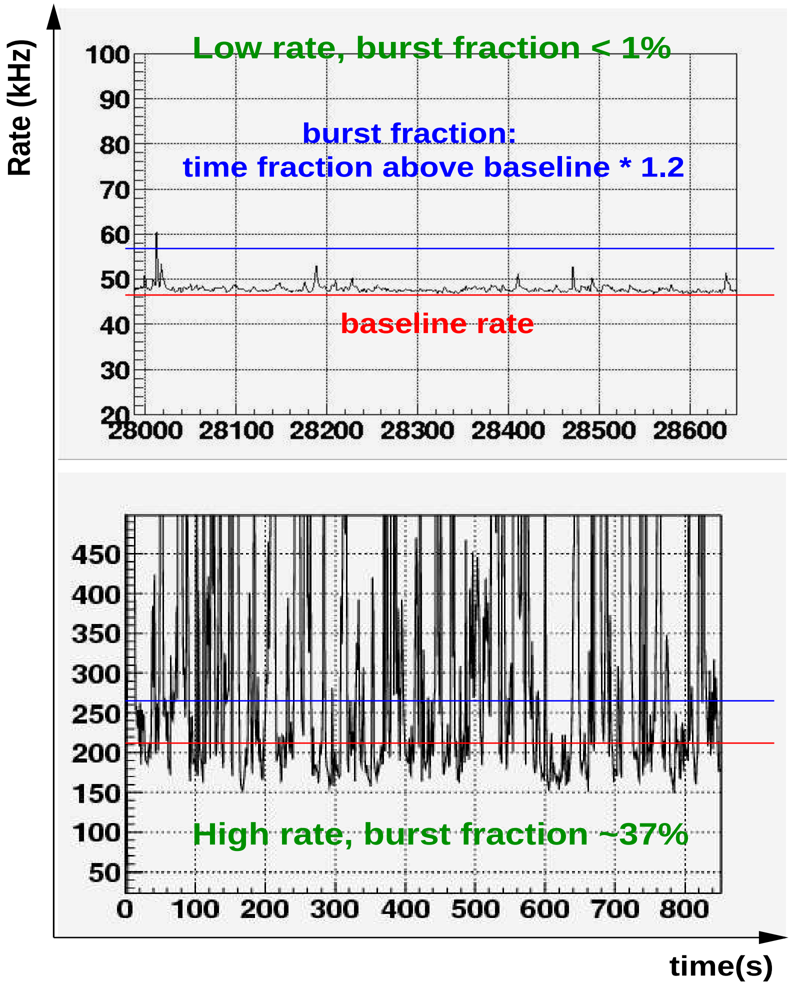
A water leak

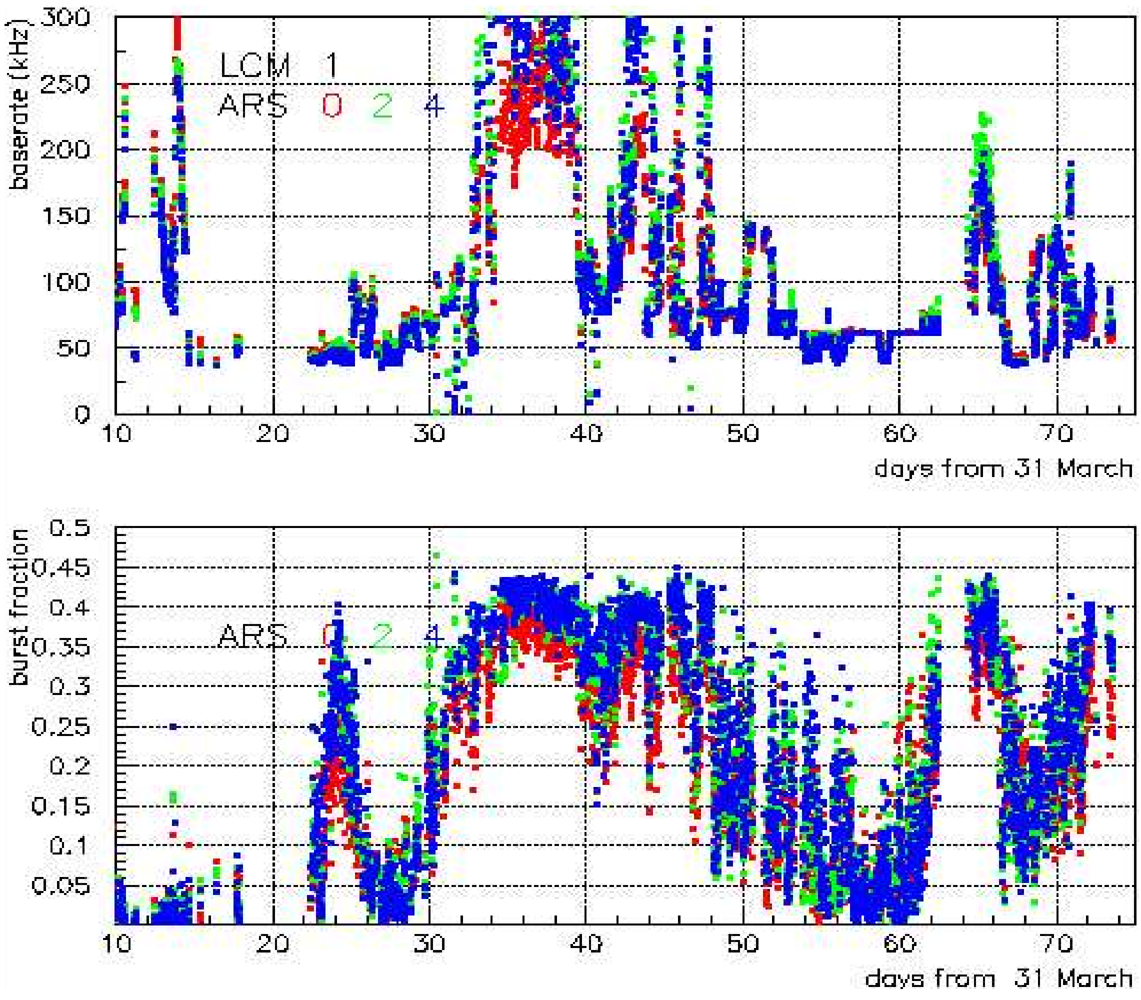
- **The symptom:**
  The mini instrumentation line stopped to work on April 11.
- **The consequence:**
  Immediate recovery of the line.
- **The diagnose:**
  An o-ring secured connector had developed a leak.
  Specifications of hole diameter and tolerances by manufacturer were wrong.
  No problems seen in pressure tests!



- **The remedy:** different connectors.

Rate Measurements and Bioluminescence



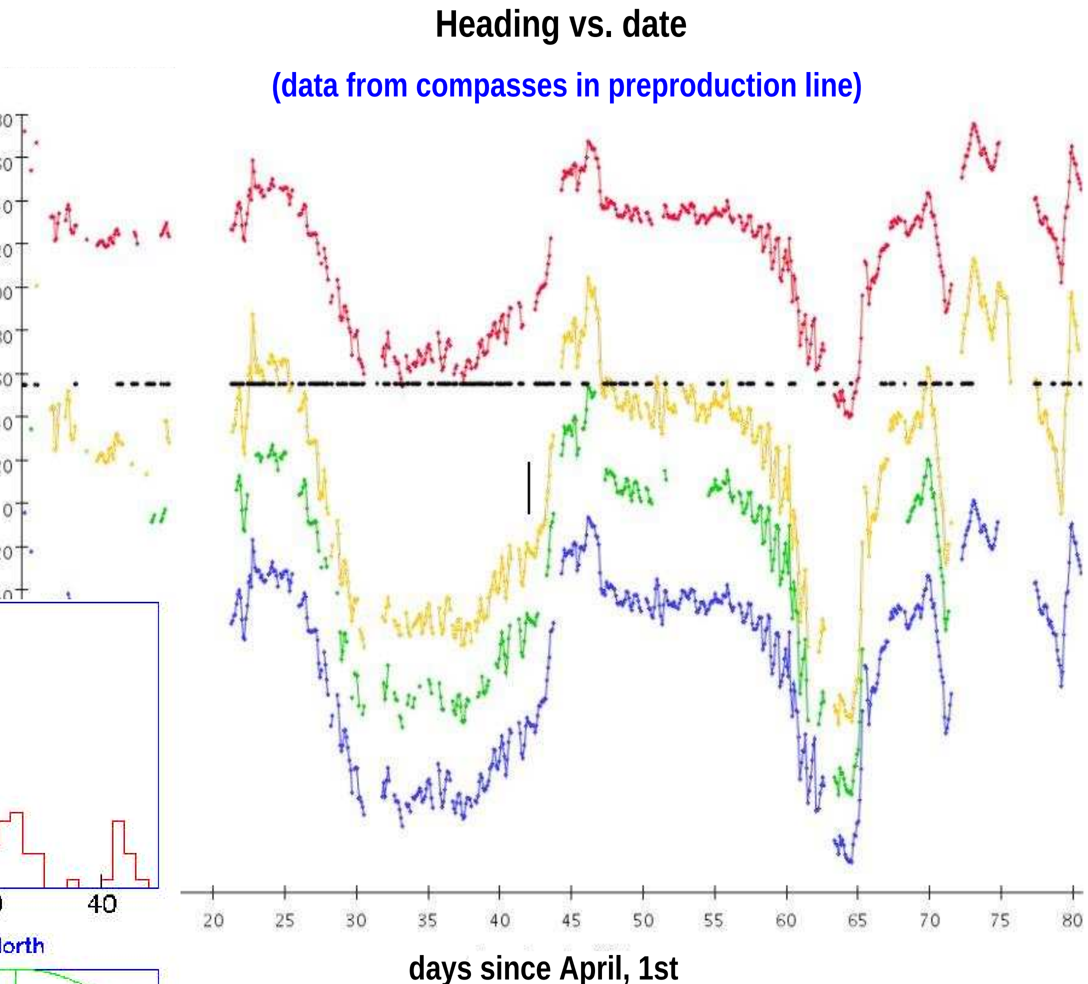


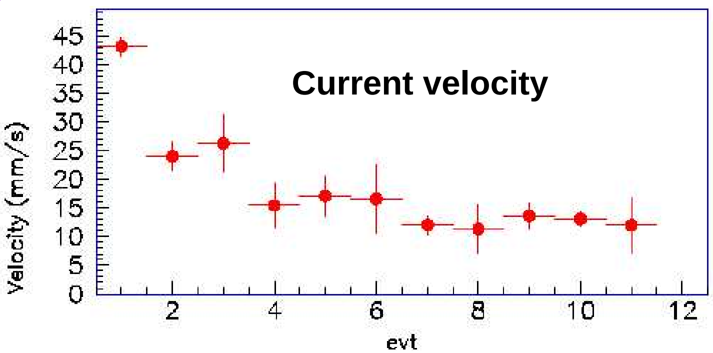
Observations:

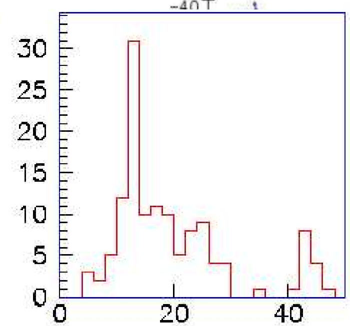
- Strong variability of rates: bursts and slow changes.
- "Base line rate" (BR) and "burst fraction" (BF).
- Some correlation between BR and BF, but low-low, high-low, low-high, high-high all appear.
- Mostly bioluminescence (^{40}K: $\sim 50\,\mathrm{kHz/PM}$).

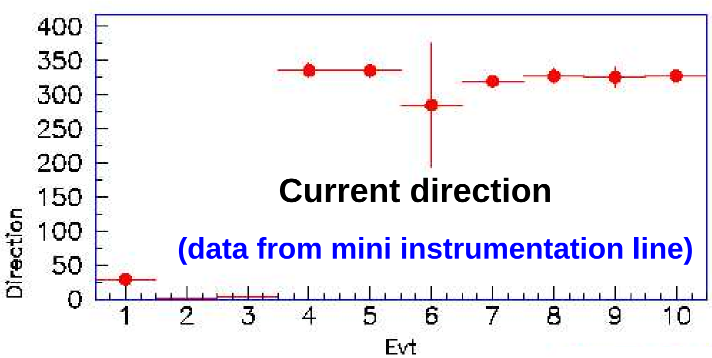
Currents and Line Movement

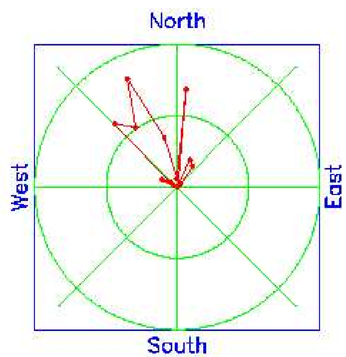
- The storeys move "as a rigid body". Correlation with current!?
- Current measurement operational.
- Short-term movements correlated with PM rates (bioluminescence?).











The detailed understanding of environmental conditions is vital and achievable.

The Future

- **The ANTARES schedule:**
  - **End of 2004:** Deployment and connection of the first string.
  - **2006:** 12-string detector completed.
  - **And then:** Data taking, data analysis, discoveries?!

- **Beyond ANTARES:**
  - A km^3-scale neutrino telescope in the Northern hemisphere to assess the full physics potential of cosmic neutrinos.
  - Natural choice: A deep-sea detector in the Mediterranean Sea.
  - Significant R&D efforts are necessary to develop cost-effective solutions with sufficient long-term stability.
  - A common effort of the European groups to solve the major technical questions has begun in the framework of an EU FP6 Design Study proposal.
  - VLVνT workshop in Amsterdam, 5-8. Oct. 2003: dedicated to technical aspects of the future deep-sea νT.

Summary

- The ANTARES project has completed the design and test phase and entered the construction phase.
- Successful deployment of major components completed (Main Electro-Optical Cable, Junction Box).
- Pre-production test string and mini instrumentation line successfully deployed and connected by submarine.
- Technical problems have been understood and will be avoided in future.
- The long-term system test in deep-sea environment is a major step towards the realization of the detector.
- ANTARES is on a good track to fulfill its mission and to accomplish the objectives.