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

buoy
480 m
60 m
100 m
14.5 m
string socket
electro-optical deep-sea cable
junction box
Optical Modules

- **Photo multiplier tubes:**
  Hamamatsu 10″ (550 cm² cathode area); transfer time spread (TTS) \( \sim 2.7 \text{ ns} \);
  quantum efficiency > 20% @ 1760 V
  for \( 330 \text{ nm} \lesssim \lambda \lesssim 460 \text{ nm} \).

- **Glass spheres:**
  outer diameter 43 cm;
  qualified for 600 bar;
  light transmission \( \gtrsim 95 \% \).
Indirect WIMP detection

- **Gravitational trapping:**
  WIMPs may be trapped in the gravitational field of Earth, Sun or Galactic Center.

- **Candidate particle:**
  SUSY Neutralino ($\chi$).

- **WIMP annihilation**
  \[ \chi + \chi \rightarrow \text{hadrons} \rightarrow \nu + X \]
  \[ \chi + \chi \rightarrow Z^0 Z^0 \rightarrow \nu \bar{\nu} + X \]

  $\nu$ 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 $\Omega_\chi$ (high annihilation cross section).
... 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 \(\nu\) energy).

- **Expectation after 1 year:**
  Improve existing limits
  for Southern hemisphere
  or discover something!

\[ \phi (cm^{-2}sec^{-1}) \times 10^{14} \]

- **AMANDA-B10**
- **Super Kamiokande**
- **MACRO**
- **ANTARES**

Cowen, Neutrino 2002
**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:**

**Determination of \( \Lambda_{\text{attenuation}} \)**

\( D: \) Distance between LED and PMT

\( \Phi_{\text{LED}}: \) LED luminosity to obtain a constant current on PMT

![Graph showing the determination of \( \Lambda_{\text{attenuation}} \).](image)

\( \Lambda_{\text{attenuation}} = 41 \pm 1_{\text{stat}} \pm 1_{\text{syst}} \text{ m} \)

**Graph:**
- Measurement in water
- Calibration in air

**Transmission normalised to immersion date**

- **Graph showing transmission over time.**
- Horizontal and inclined lines indicating transmission levels (90%, 90%, 100%, 90%) for different angles (\( \Theta = 90^\circ, 80^\circ, 70^\circ, 60^\circ, 50^\circ \)).

**Graph:**
- Days range from 50 to 250
- Transmission percentages (90%, 100%) indicated by horizontal lines.
Instrumentation line

Preproduction line

Main Electro Optical Cable
(deployed Oct. 2001)

Junction Box (JB)
(deployed Dec. 2002)

Sound velocity, current profile

Optical beacon, transmissiometer, acoustic receiver

seismometer, acoustic transmitter/receiver

string socket with acoustic release

storey with LCM (local control module)

storey with MLCM (master local control module)

both lines connected to JB in March 2003 by NAUTILE
Sea Operations

- Junction Box deployment
- Underwater connection by NAUTILE
- Preproduction line deployment

**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 ($^{40}\text{K}$: ~50 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.
  – **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.
  – **VLV$\nu$T workshop** in Amsterdam, 5-8. Oct. 2003: dedicated to technical aspects of the future deep-sea $\nu$T.
• 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.