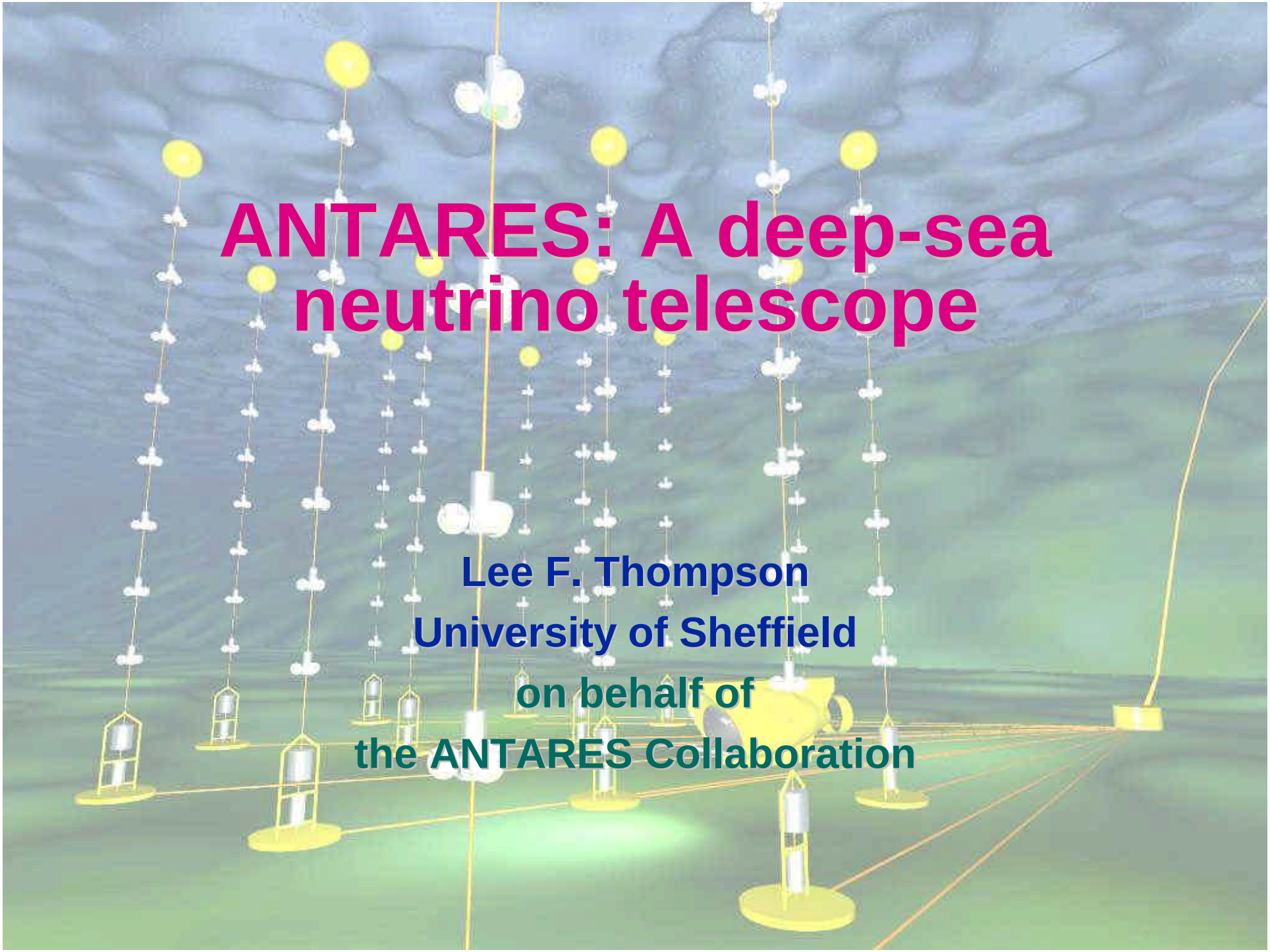


ANTARES: A deep-sea neutrino telescope

Lee F. Thompson

University of Sheffield

on behalf of

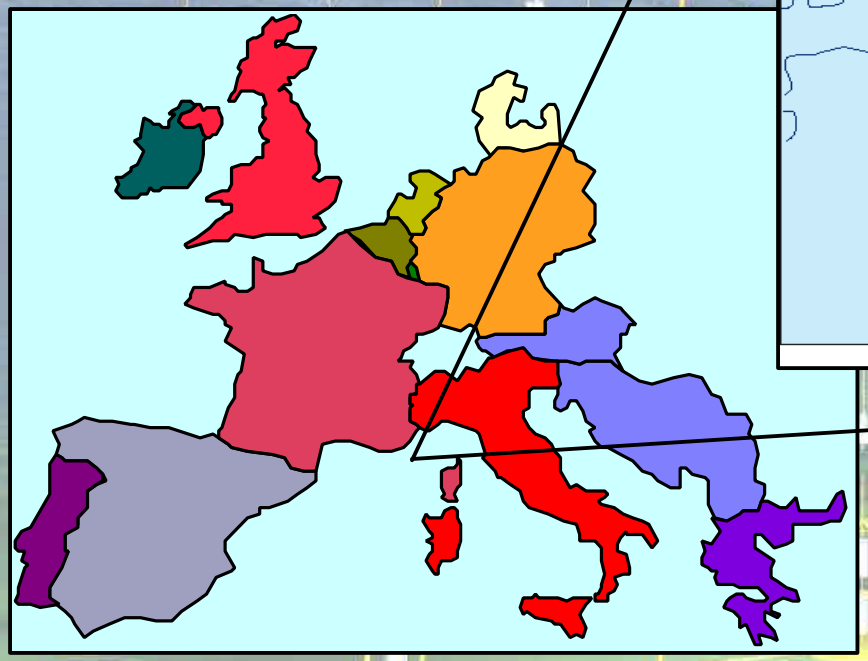
the ANTARES Collaboration

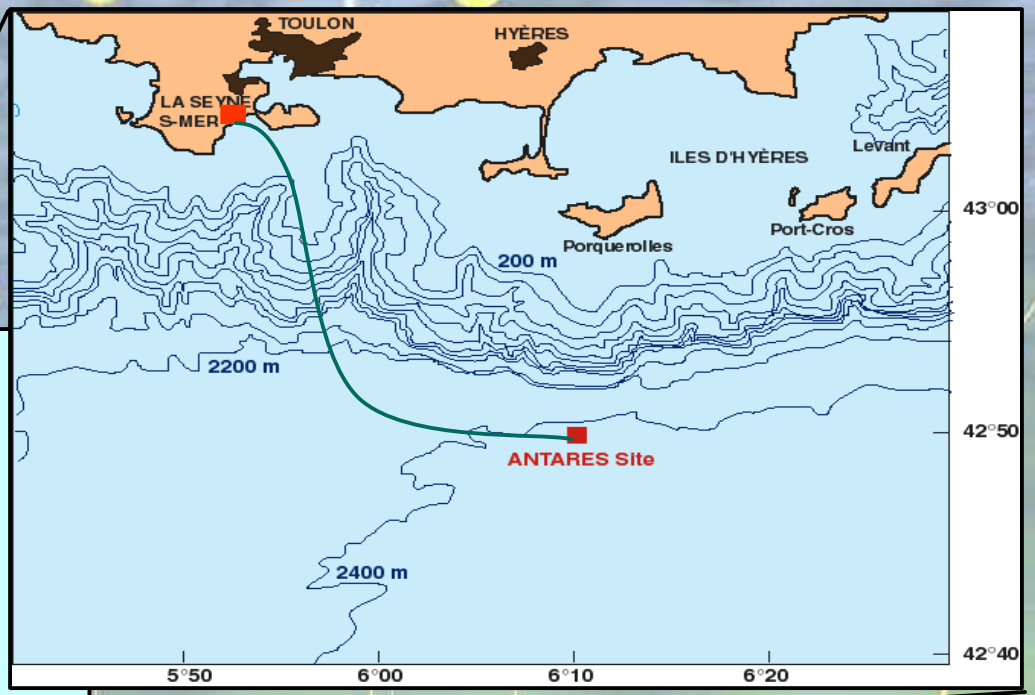
The ANTARES Collaboration

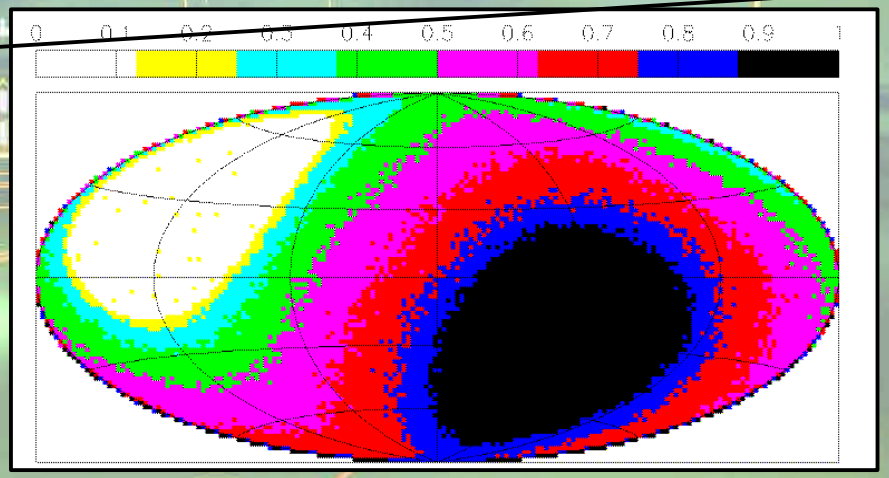
- **France**
  - *CPPM Marseille*
  - *DSM/DAPNIA Saclay (CEA)*
  - *IReS Strasbourg*
  - *Universite d'Haute-Alsace Mulhouse*
  - *Centre d'Oceanologie de Marseille*
  - *Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER)*
  - *INSU-CNRS/IGRAP Provence*
- **Spain**
  - *IFIC Valencia*
- **United Kingdom**
  - *University of Birmingham*
  - *University of Oxford*
  - *University of Sheffield*
- **Russia**
  - *ITEP Moscow*
- **Netherlands**
  - *NIKHEF Amsterdam*
- **Italy**
  - *Universita di Bari*
  - *Universita di Bologna*
  - *Universita di Catania*
  - *LNS-Catania*
  - *Universita di Roma*
  - *Universita di Genova*

ANTARES Site and Sky Coverage

- Mediterranean Sea
- 30km off the coast of Toulon in Southern France
- 2400m below sea level



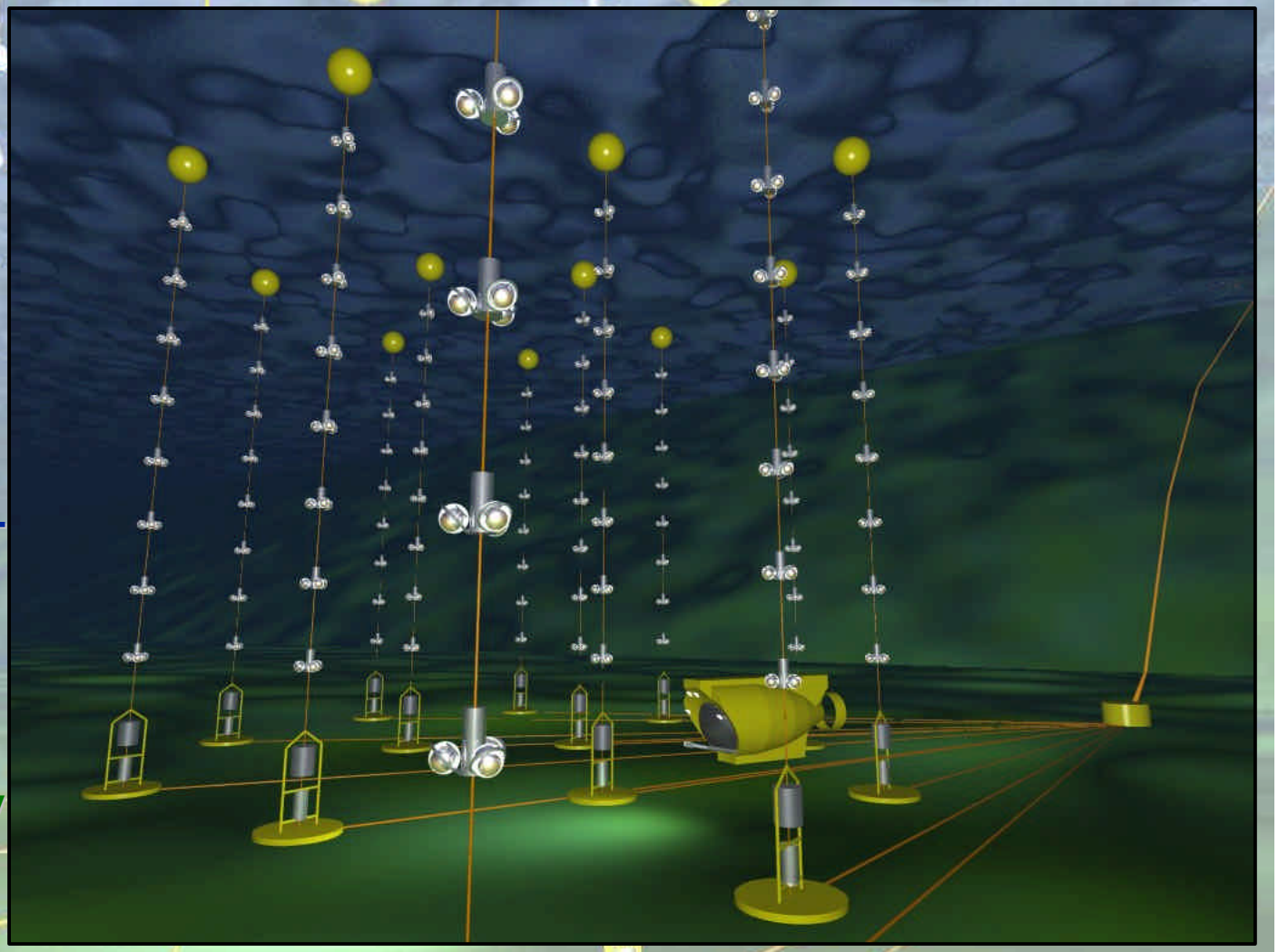




- Sky coverage: 3.6 p sr
- Overlap with AMANDA: 0.6 p sr

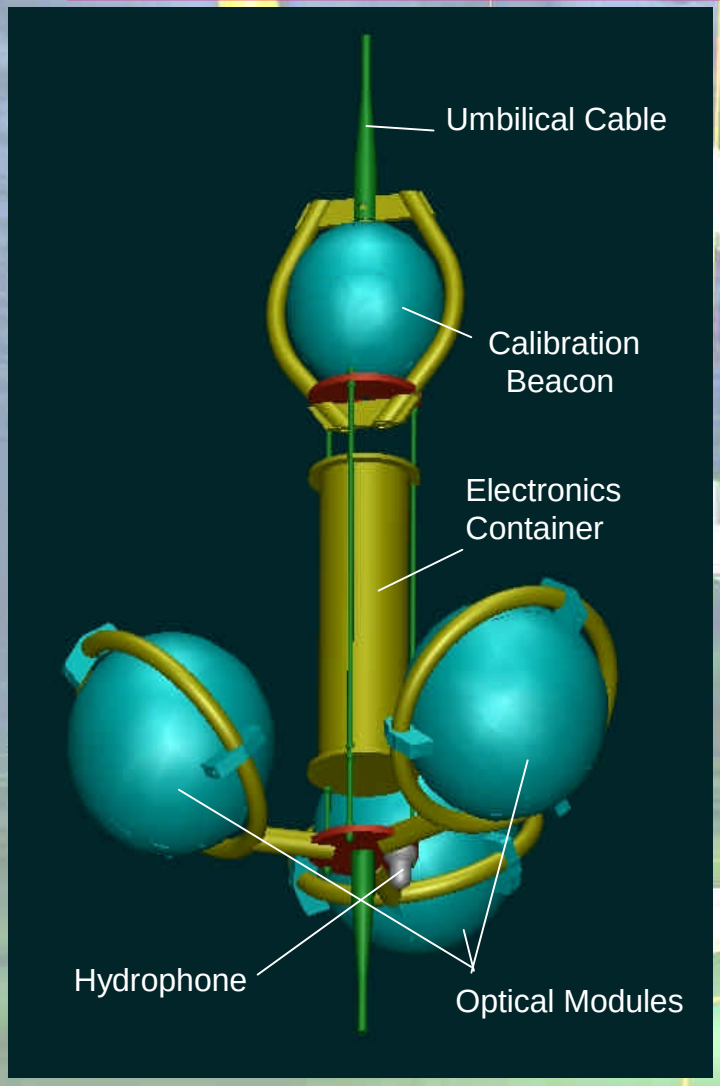
ANTARES Detector Design

- 13 flexible strings of photosensors Strings are anchored at the sea-bed and held taut by their own buoyancy
- Each string is 450m high with the first 100m un-instrumented
- 30 storeys per string, 12m between storeys
- 3 PMTs per storey
- 60m between strings



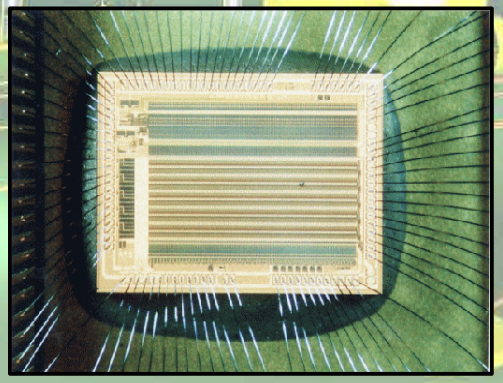
- Power into the array and data readout is via a 40km electro-optical cable
- Each string is connected to the electro-optical cable via a Junction Box

ANTARES Detector Design



- Electronics containers sit above each PMT triplet

- PMTs are 10” diameter hemispherical PMTs sitting in a 17” pressure-resistant sphere



- Fast digital electronics will be used for DAQ and readout

Status and Timeline

1996 to 1999

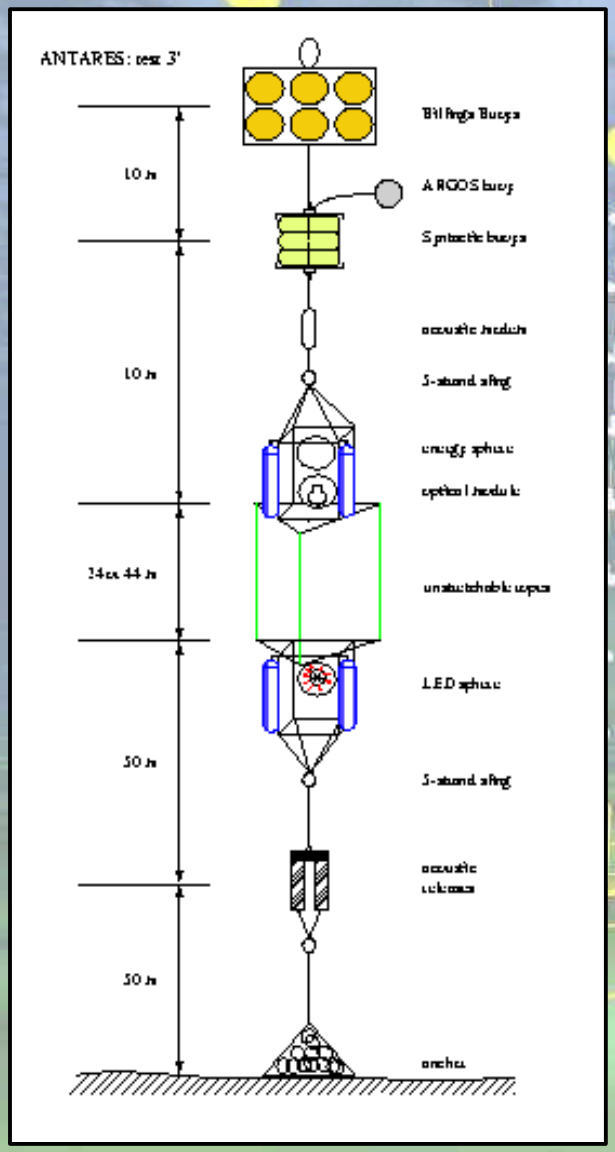
- Assessment of potential sites via the deployment of ~30 autonomous strings to measure
  - *optical water properties*
  - *biofouling and sedimentation*
  - *optical backgrounds due to bioluminescence and ^{40}K*
- Test of electro-optical cable connection
- Verification of mechanical structures and deployment techniques

- Deployment of demonstrator string to address
  - *mechanical issues*
  - *acoustic positioning*
  - *track reconstruction*

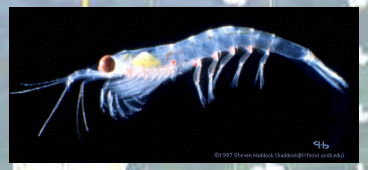
1999 to 2003

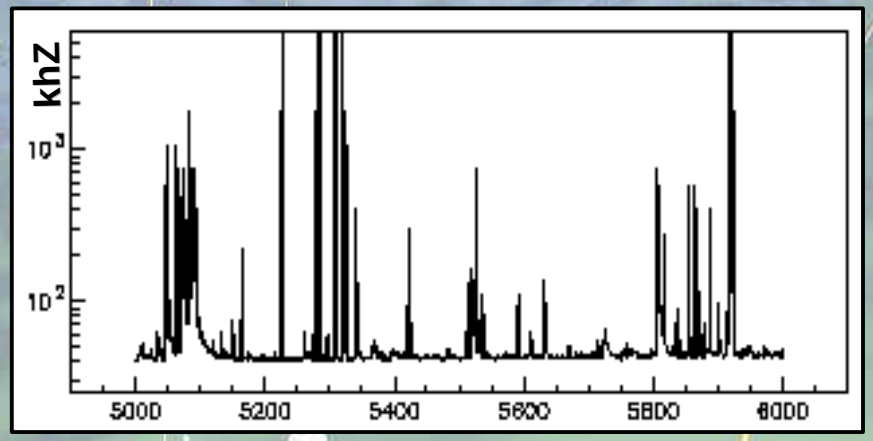
- Move into final design and construction phase
- Deployment of first string in summer 2001
- Subsequent deployment of 0.1 km^2 array in 2002 and 2003

Optical Water Properties

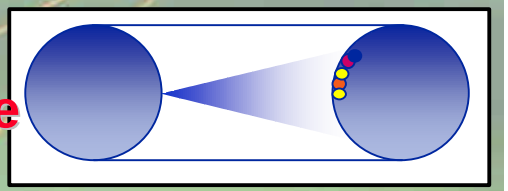


- **Absorption length has been measured with blue light (466nm) as 60m, scattering length is seen to be > 100m for large angle scattering**



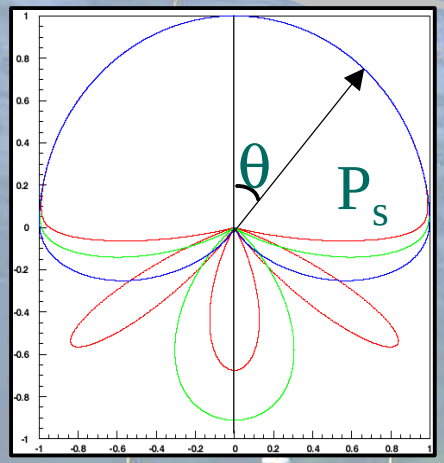


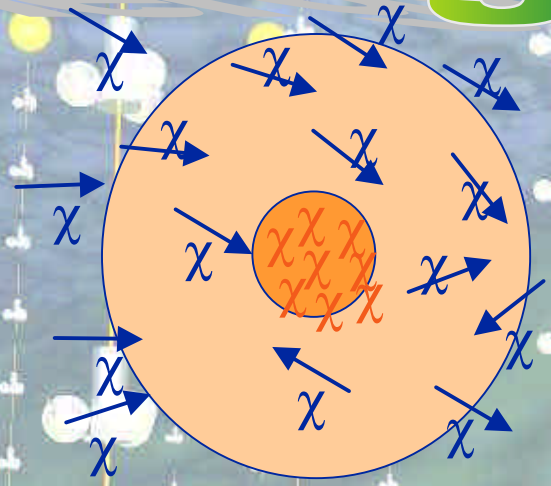
- **Optical background rate due to ^{40}K is typically 40kHz (for an 8" PMT) with short bursts due to bioluminescent activity**
- **Biofouling of the optical surfaces is less than 2% in one year for angles below the horizontal**
- **Sedimentation is negligible**

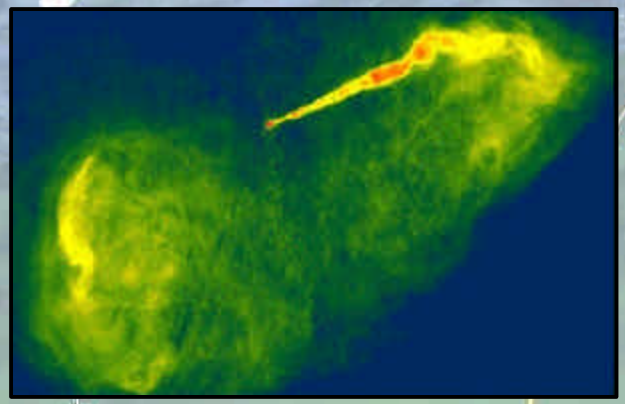


Scientific Programme

--- Energy --->

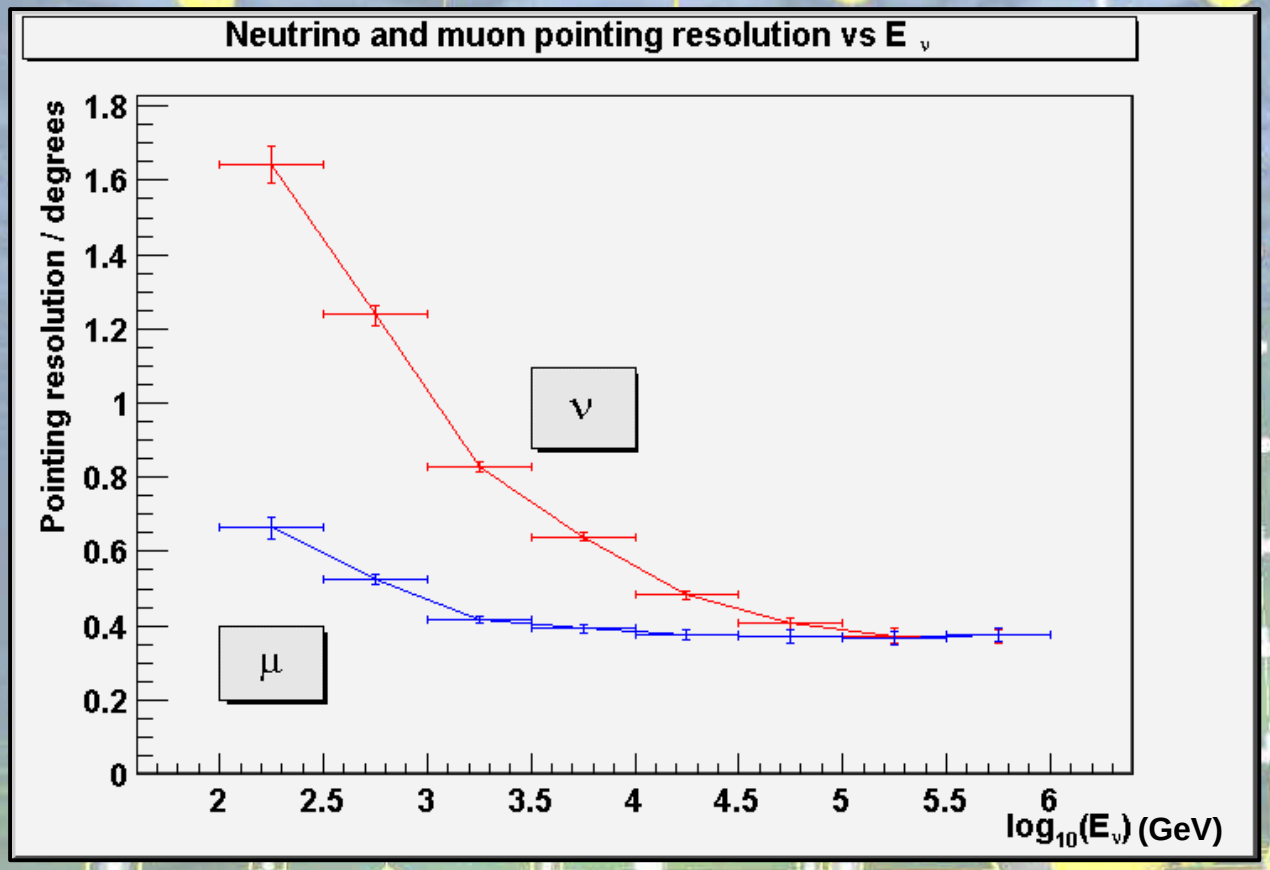






Low energy	Medium Energy	High energy
• Neutrino oscillations via the modification in the energy spectrum due to observation of the first oscillation minimum	• Search for neutralinos via their self-annihilation to products containing neutrinos at the centre of the Earth, Sun and Galaxy	• Observation of neutrinos from (extra-)galactic sources such as GRB, AGN, Supernovae remnants, molecular clouds, etc.

Angular Resolution



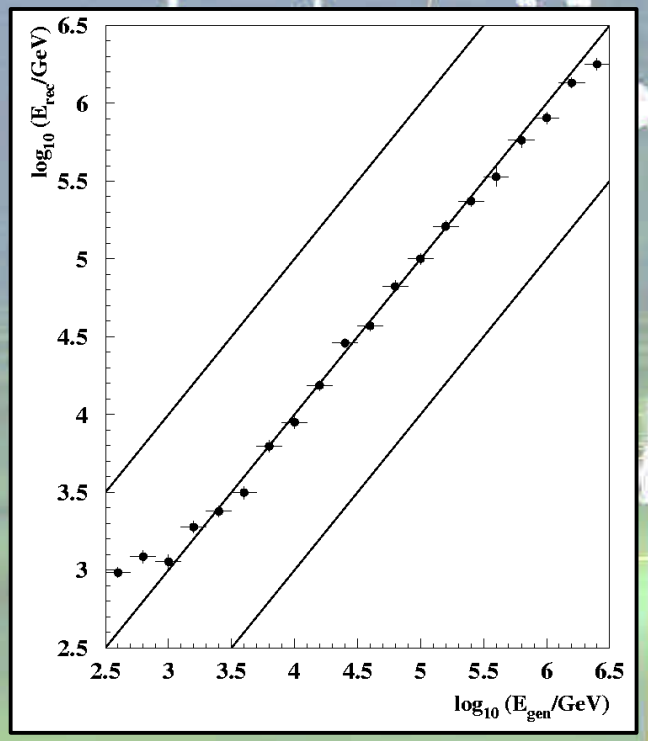
The angular resolution of the detector depends on

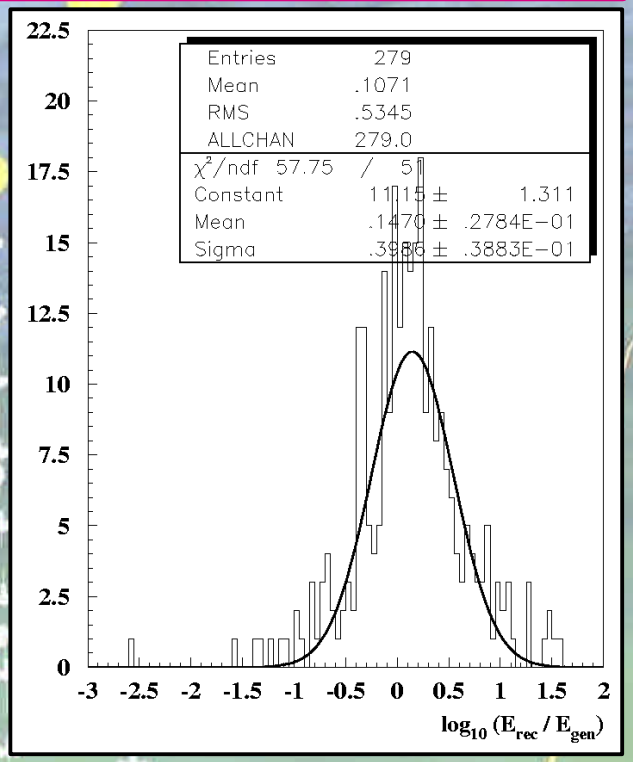
- *reconstruction algorithms*
- *selection programs*
- *timing accuracy (PMT timing error, positional error on OMs, timing calibration error)*

- At high energies the neutrino pointing accuracy is 0.4 degrees or better including scattering effects
- Note: at high energy error is dominated by reconstruction errors, at low energy error by the angle between the muon and neutrino

Energy Resolution

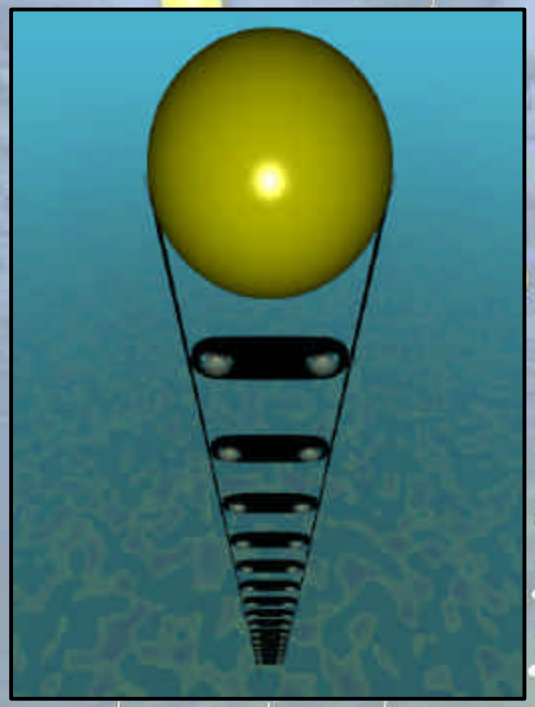
- Different techniques are used in different energy regimes
- At energies above 1 TeV the muon energy loss is dominated by catastrophic energy loss (bremsstrahlung, pair production) which increases with energy. A truncated mean parametrization is used

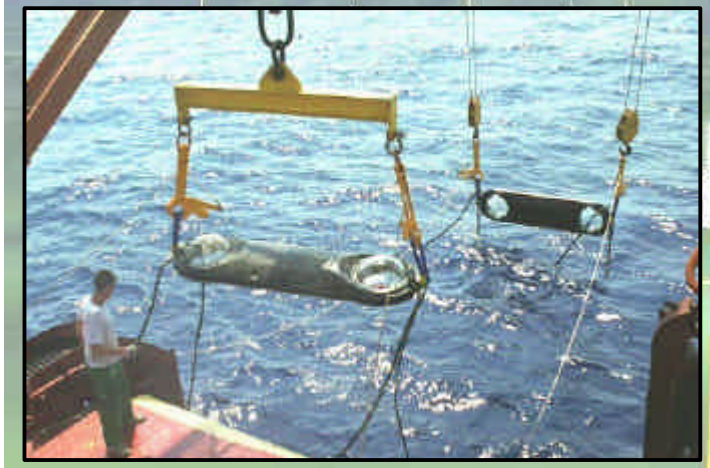




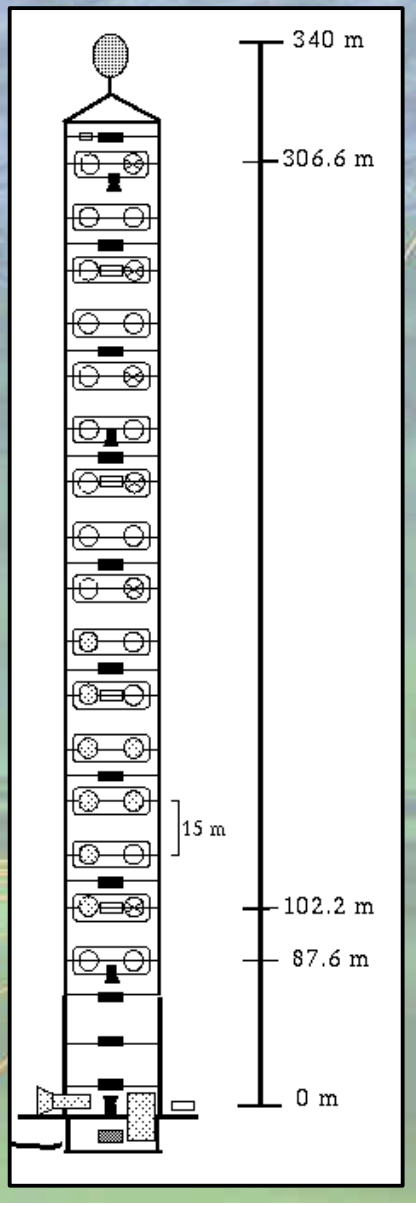
- The corresponding energy resolution is typically a factor of 3 for E > 1 TeV
- Below 100 GeV the energy can be estimated from the range of the muon - this requires contained events
- Use of the hadronic shower energy may improve energy resolution at medium and low

A Demonstrator String



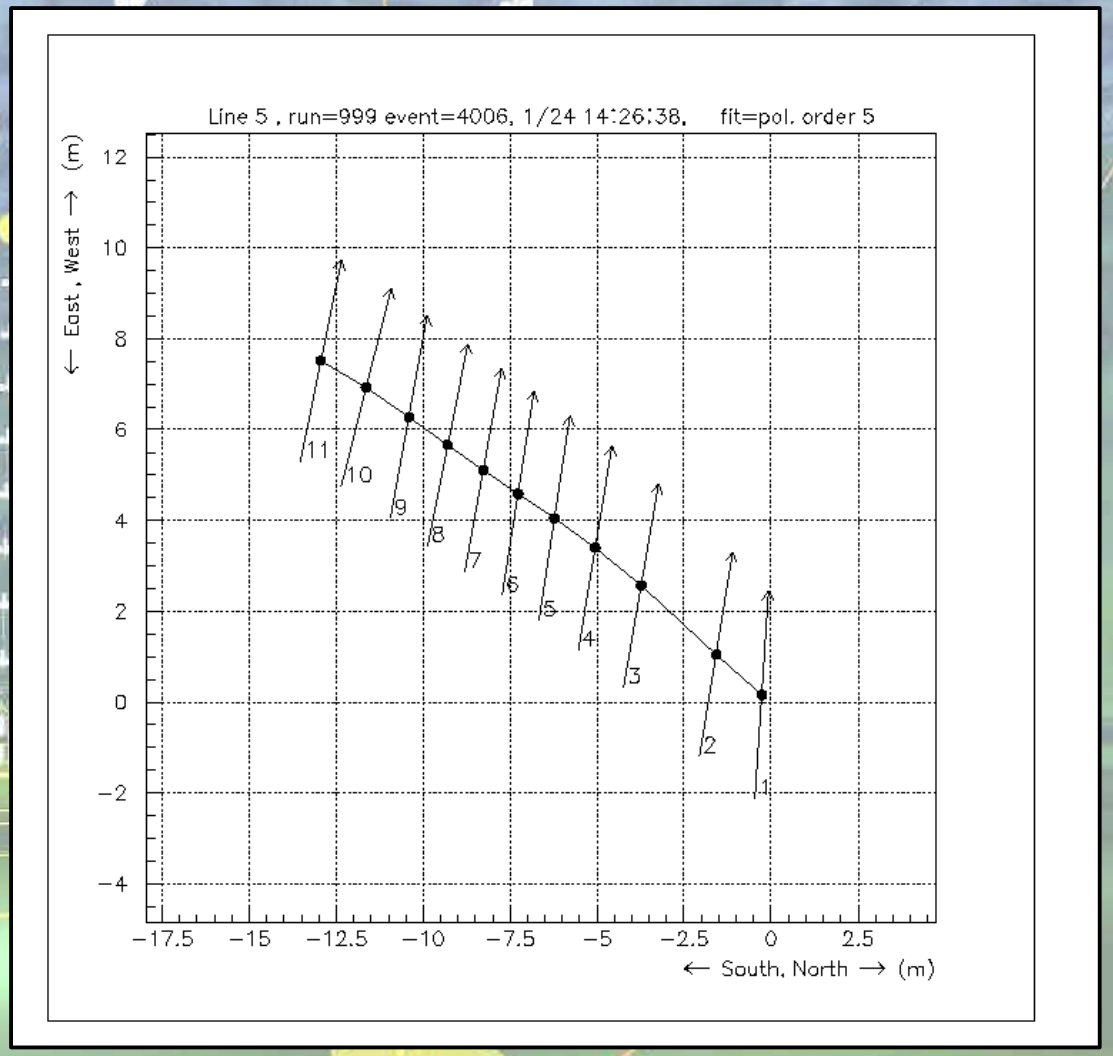


- A part-instrumented line 340m in length
- Deployed in November 1999 at a site 40km from Marseille at 1100m depth
- Equipped with six 8” and one 10” hemispherical phototubes
- Also instrumented with assorted measuring devices including CTD, tiltmeters, acoustic positioning system, etc.
- Control and readout via 37km electro-optical cable
- Operational from December 1999
- More than 50000 seven-fold co-incidences have been recorded
- To be retrieved in June 2000

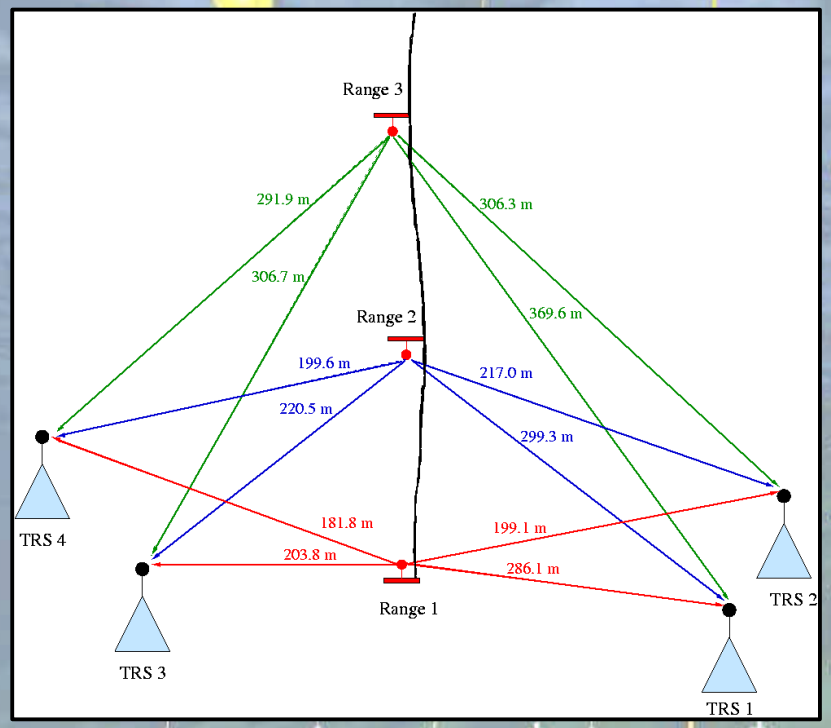


Demonstrator String Positioning

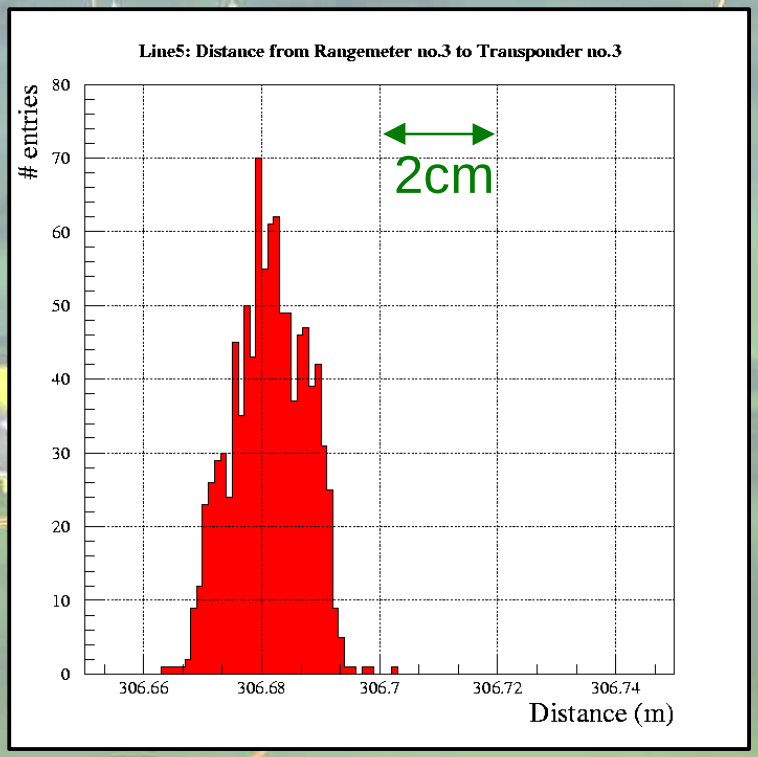
- Position stability from compass data indicates no twist along the string - headings stable to within 2^0 over one week of operation
- Tilt stability monitored via top and bottom tiltmeters - stable to 0.2^0 over a one week period
- Reconstructed line shape from combined tiltmeter and compass data show a straight string inclined at 2.5^0 to the vertical



Demonstrator String Positioning

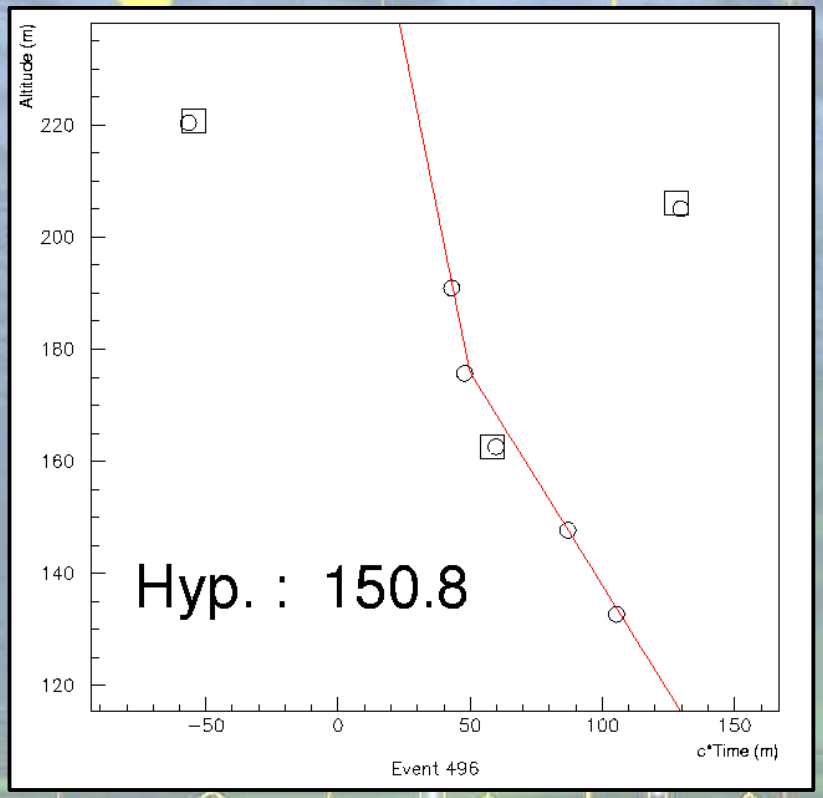


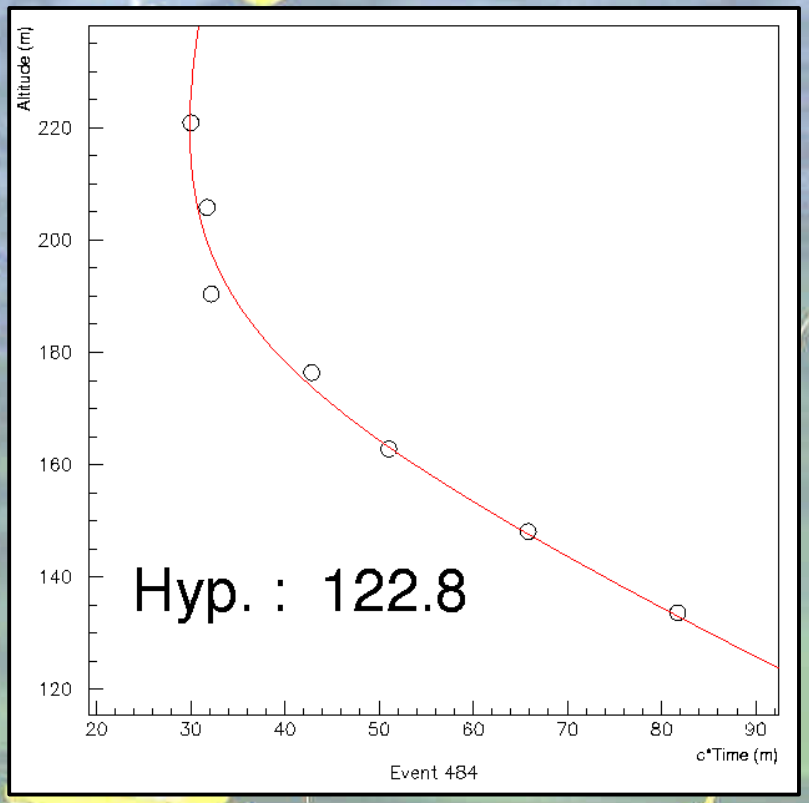
- Distances between rangemeters are determined with a s ~ 1cm
- Distances between transponders have a s ~ 1cm
- rangemeter-transponder mean distances have a s of typically 5cm or less



- 3 rangemeters on the string and 4 transponders around the demonstrator string at 200m distance from base
- Allow a test of the acoustic positioning system
- 12 distances, global fit performed and compared to tiltmeter data

Demonstrator String Events

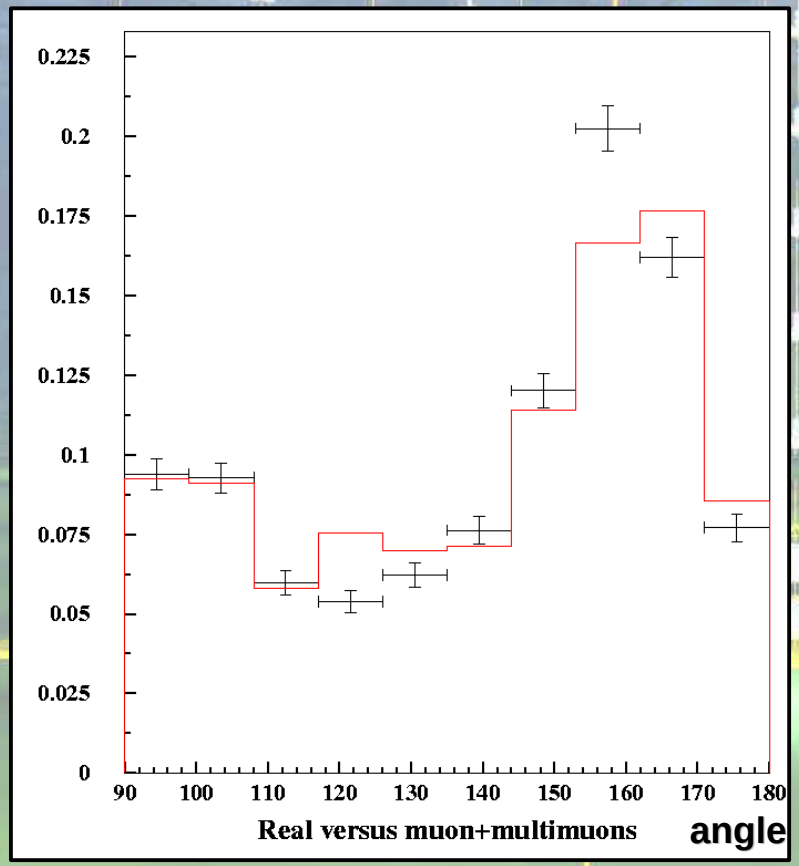


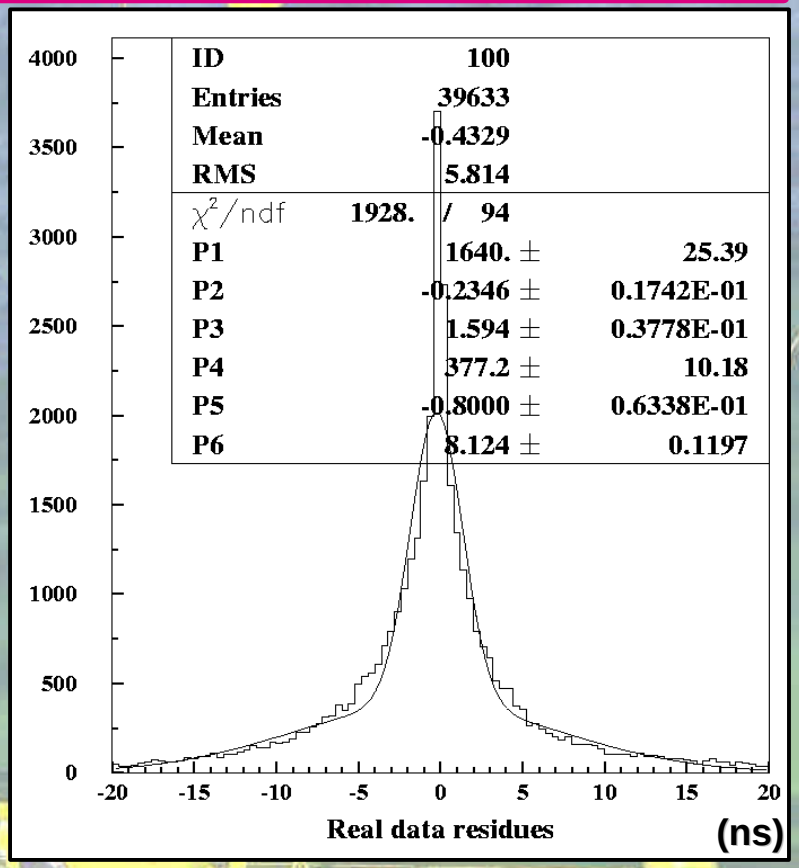


- Example of reconstructed down-going muon events with 7-fold coincidences in the demonstrator string
- curve shows result of a hyperbolic fit
- boxed hits are background hits due to ^{40}K and have been identified by the reconstruction software

Demonstrator String Results

- Over 50k 7-fold coincidences have been recorded
- Angular distribution comparing data with single + multi-muon MCs is in good agreement





- Real data timing residuals - fit with 2 Gaussians for single and multi-muons - agrees well with values from MC
- more than 1350 reconstructed events per day are observed

Conclusion

- **ANTARES has made excellent progress over the past 2 years:**
  - *deployment and operation of first demonstrator string*
  - *first down-going muons reconstructed*
  - *move into construction phase for 0.1 km^2 detector*
  - *test of undersea connection*
  - *expanding collaboration*
- **First string will be deployed in summer 2001**
- **A 13 string, 0.1 km^2 detector will be fully deployed by the end of 2003**
- **This is the first step towards a 1 km^3 detector in the Mediterranean Sea**