Status report on the ANTARES high energy neutrino detector

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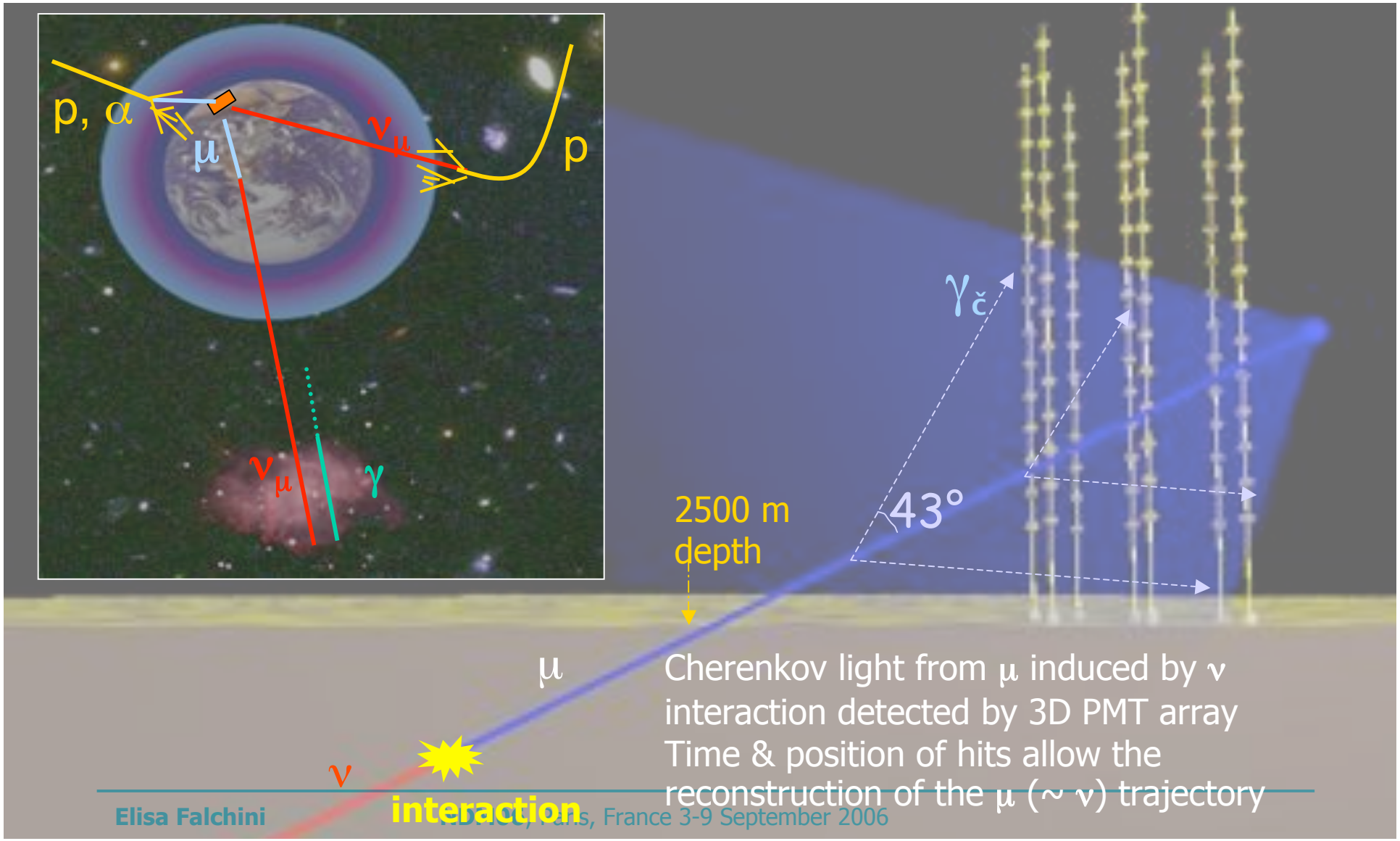
on behalf of the ANTARES Collaboration

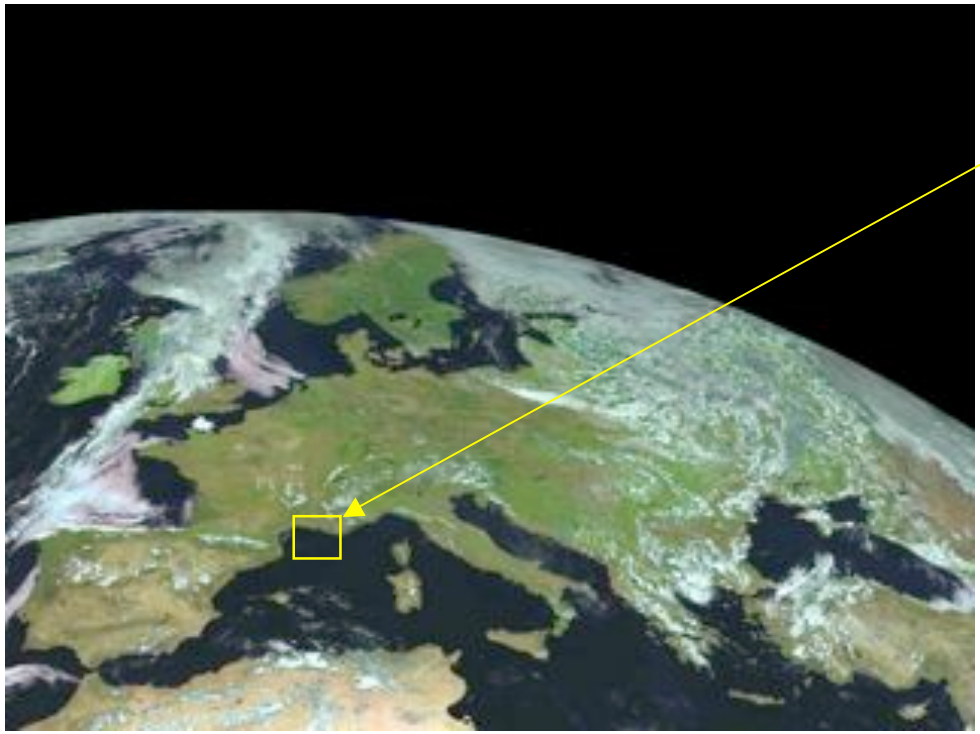
Neutrino detection principle

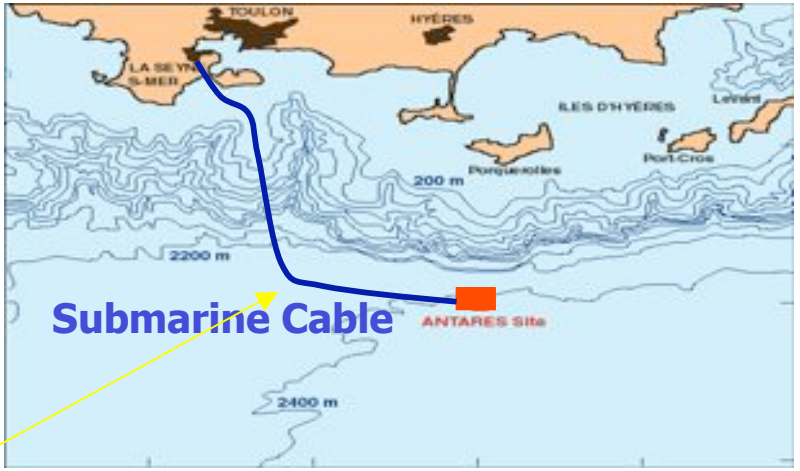


Cherenkov light from μ induced by ν interaction detected by 3D PMT array
Time & position of hits allow the reconstruction of the μ (~ ν) trajectory

ANTARES Site

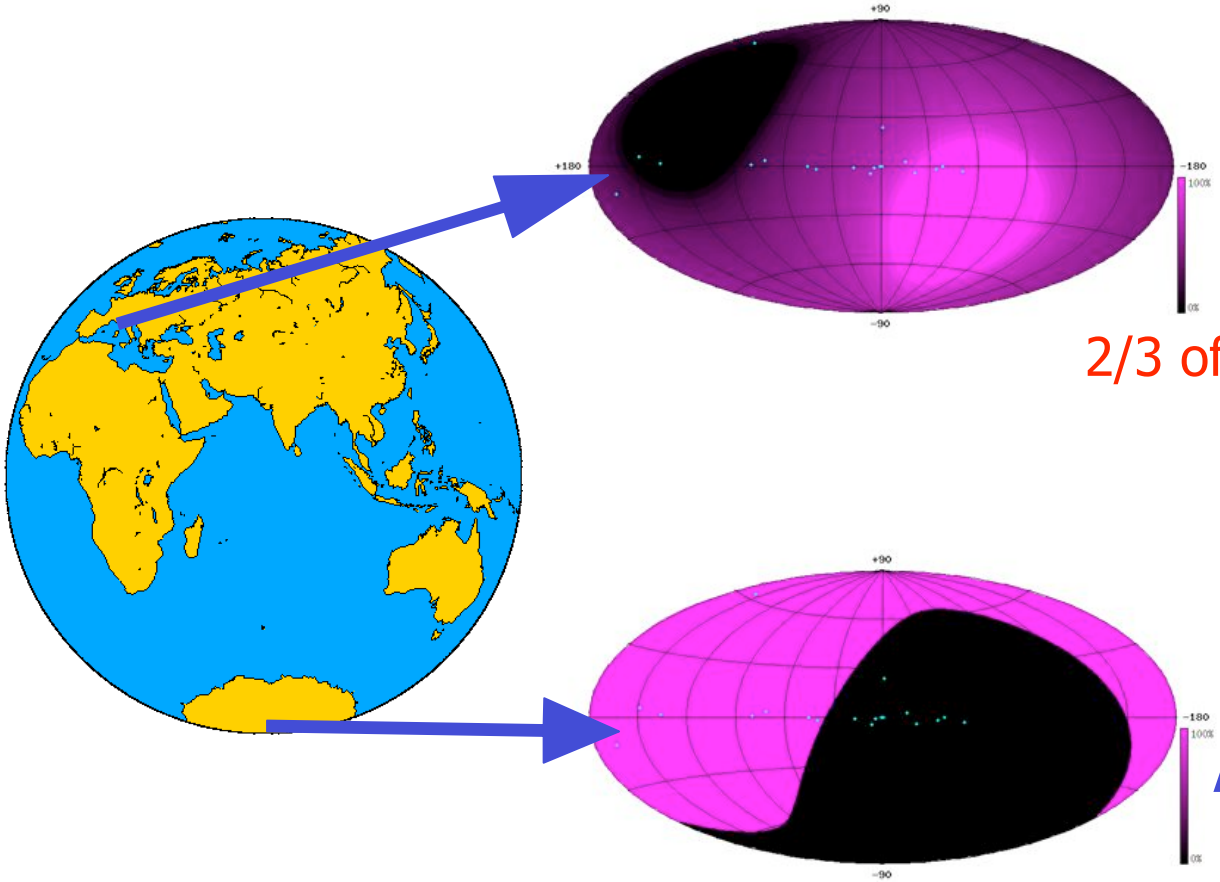
The detector will be located in the Mediterranean Sea (42º50'N, 6º10'E), 40 km off the coast of Toulon (France) at a depth of about 2500 m.





Shore station

Sky View

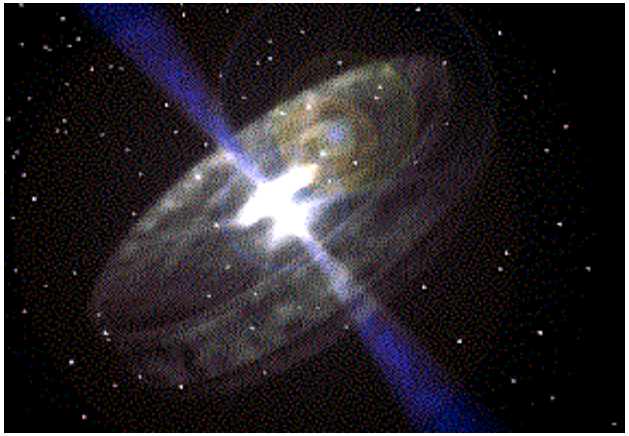


ANTARES
43º North
2/3 of time: Galactic Centre

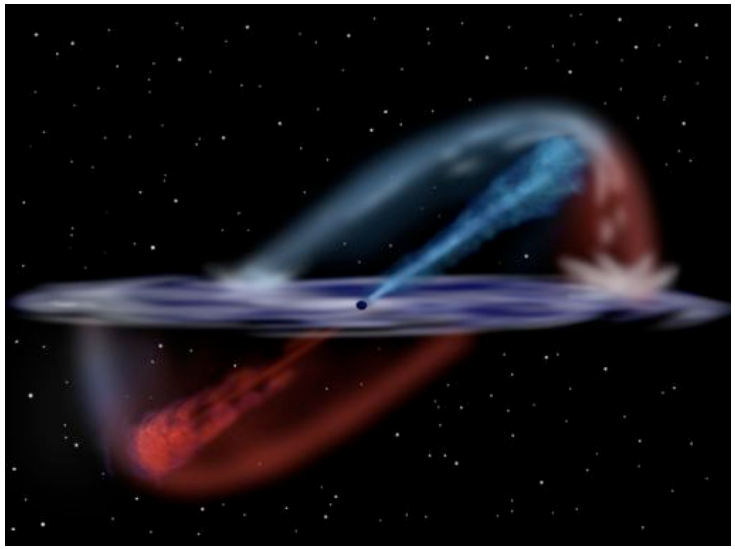
AMANDA/IceCube
South Pole

Sources to be studied in neutrinos exp.

- Neutrinos from galactic sources:
  - Pulsars, Supernova Remnants
  - Microquasars
  - Intense activity in Galactic centre reported by TeV γ-ray telescopes



- Neutrinos from extragalactic sources:
  - Active Galactic Nuclei
  - Gamma Ray Bursts



WIMPs indirect detection

- **Dark Matter**

Indirect detection of Dark Matter from the observation of the products of the WIMPs (gravitationally trapped) annihilation.

In many MSSM models the favorite candidate is the lightest ***neutralino*** χ; other interesting candidate is the lightest Kaluza-Klein (***LKK***) particle predicted in models with Universal Extra Dimensions (*hep-ph/0206071*).

From neutralino: neutrinos are produced in the decay of the primary annihilation products, ν get ~1/10-1/2 of the χ energy (~GeV-TeV).

The LKK particles would annihilate ~4% of the time directly to neutrinos so the latter will have the higher energy.

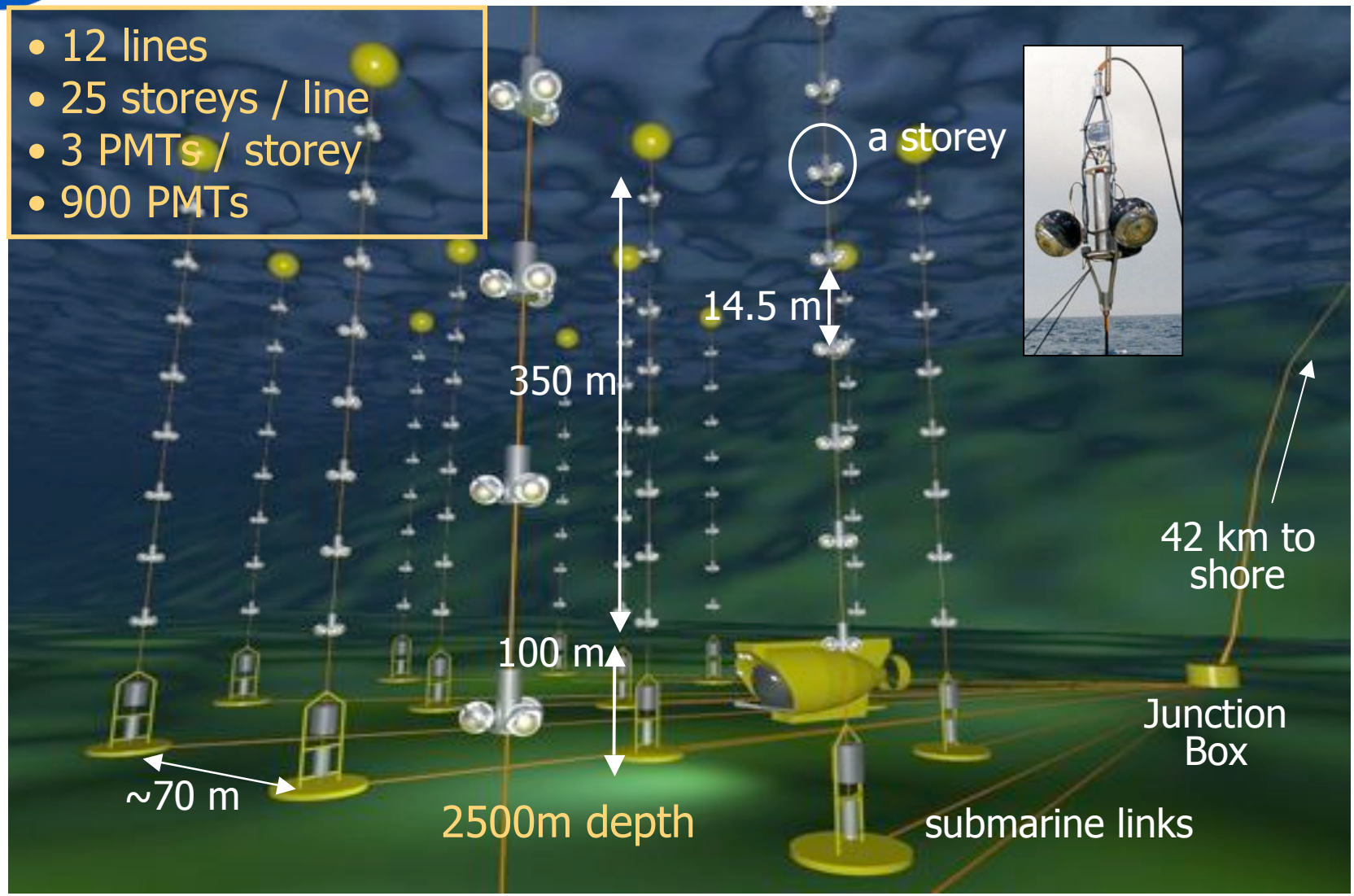
- annihilation of WIMPs in the Sun

The location of the ANTARES detector, at intermediate latitudes, is an important advantage for the detection of the neutralinos in the Sun. Compared with direct searches, ANTARES will be more competitive in the high χ masses region (>100 GeV)

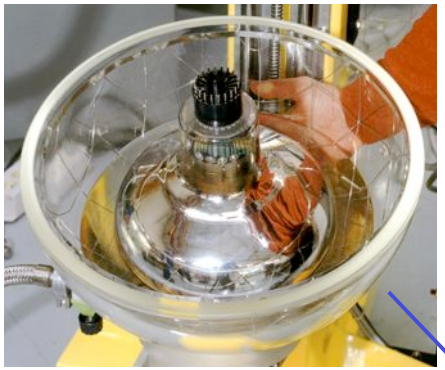
- annihilation of WIMPs in the Galactic Centre

Some models of the density profile of DM in the Galaxy seem to agree with very "cuspy" profiles, for which the ν production is most favoured. The location of the telescope in the Northern Hemisphere is advantageous: the Galactic Centre is visible for 2/3 of the time.

Detector Layout

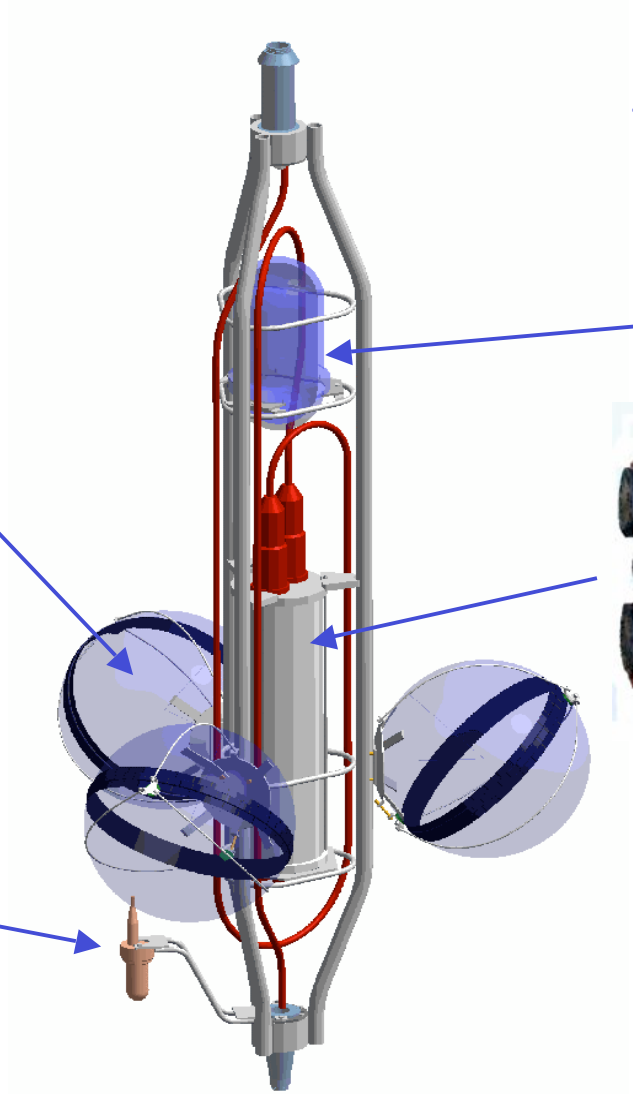


Basic detector element: storey

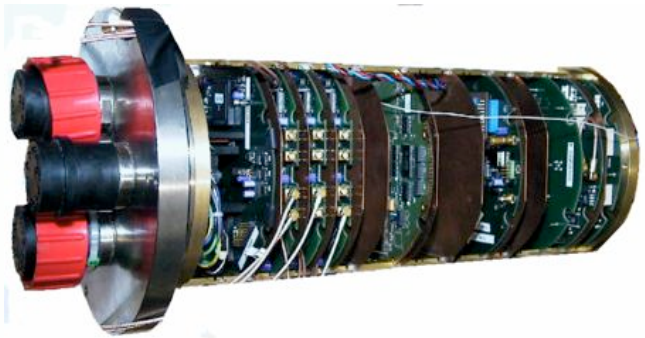


Optical Module
17″ glass sphere
10″ PMT Ham. R7081-20

Hydrophone RX
for acoustic positioning

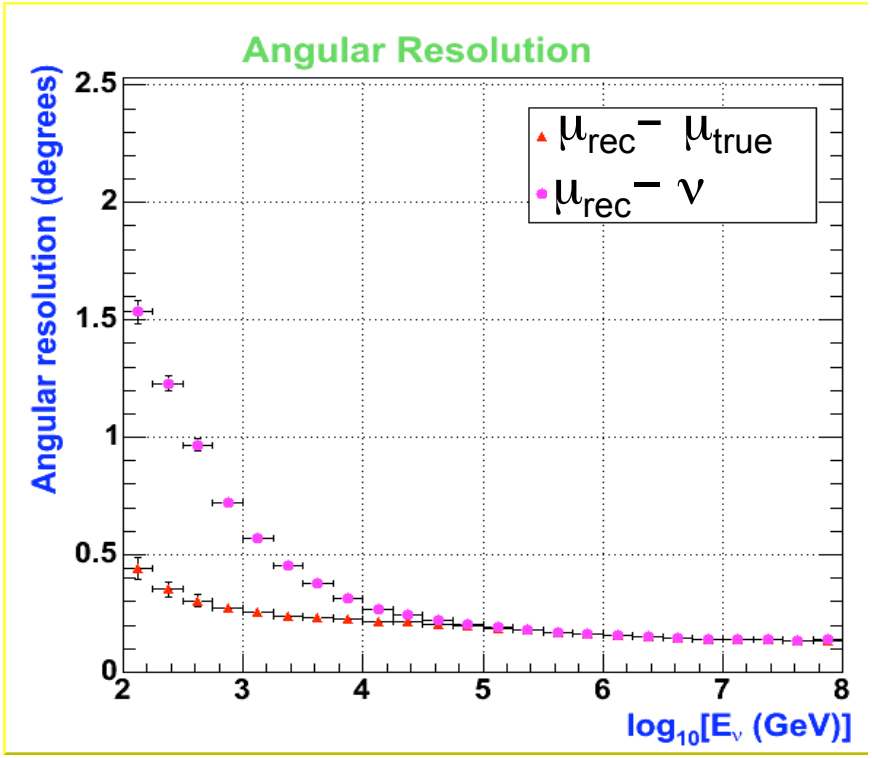


Optical Beacon
for timing calibration
36 LEDs + 1 PMT



Local Control Module
electronics boards for readout of PMT signal and data acquisition (plus calibration equipment)

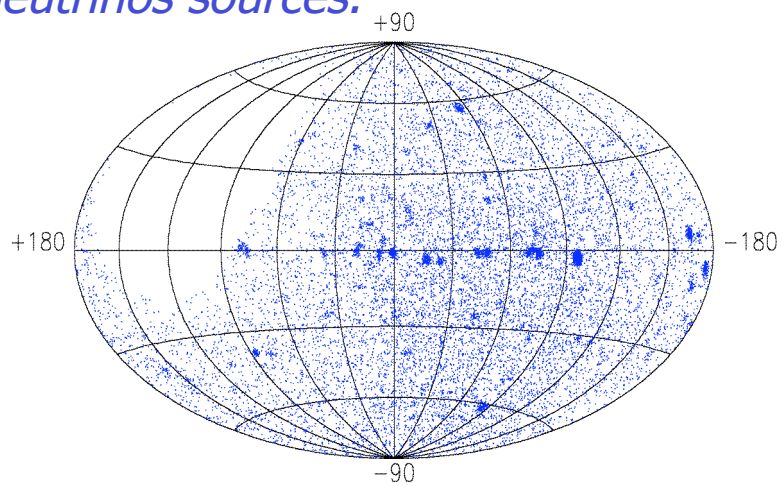
Expected angular resolution



Angular resolution:

- below 10 TeV: angular error is dominated by kinematic angle
- above 10 TeV: angular resolution is better than 0.2^0

Such a good angular resolution will allow an excellent mapping of the neutrinos sources.



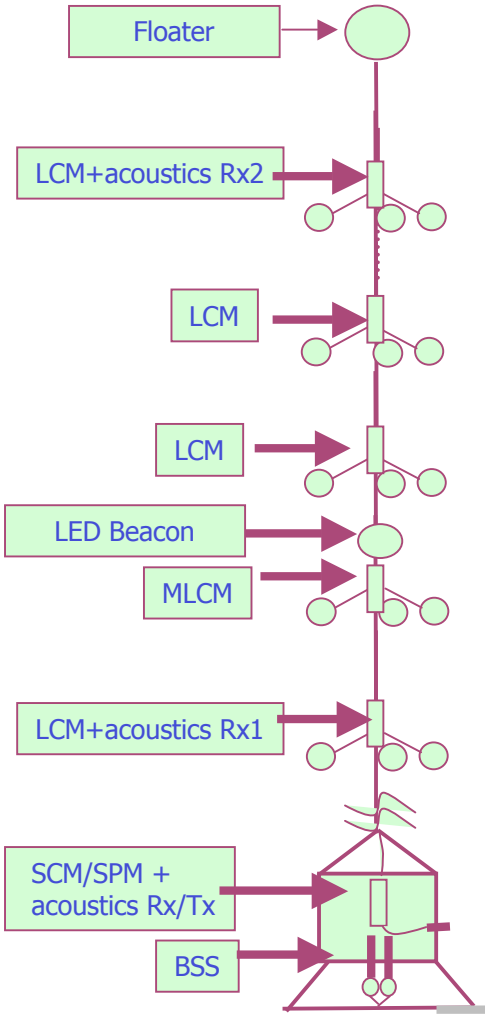
Construction status

- Nov 1999 – Jun 2000: "Demonstrator Line"
- Oct 2001: deployment of the final **Electro-Optical Cable**
- Dec 2002: deployment of the **Junction Box**
- Spring 2003: Prototype Sector Line (PSL) and Mini Instrumentation Line (MIL)

Construction status

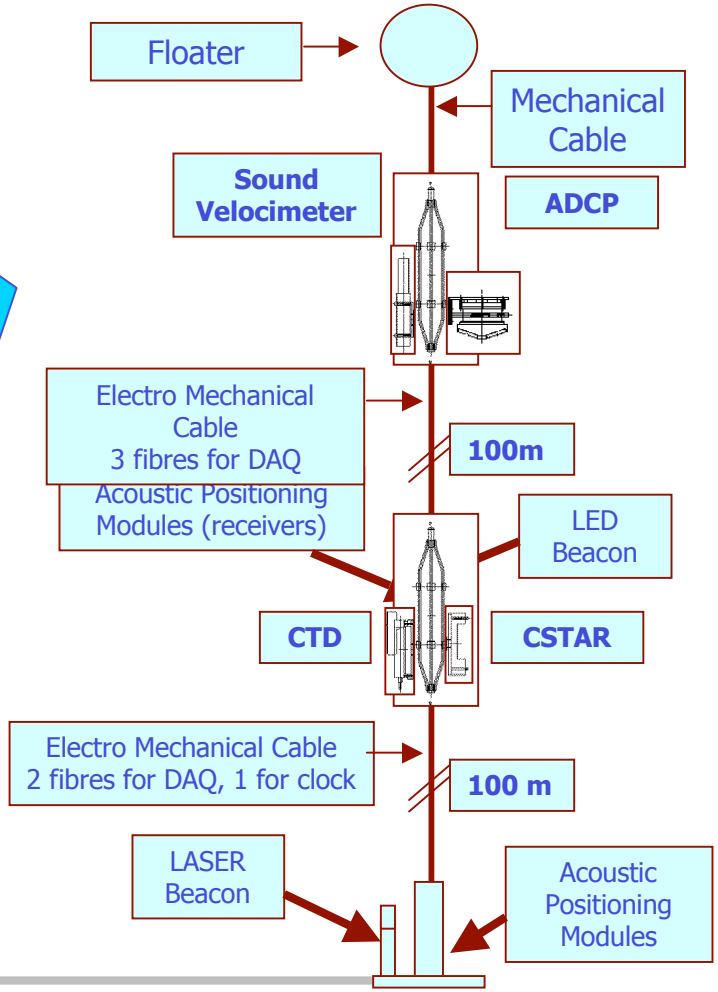
- Nov 1999 – Jun 2000: "Demonstrator Line"
  - ✓ prototype line instrumented with 7 PMT
  - ✓ the atmospheric muon zenith angular distribution was reproduced
  - ✓ first test of the acoustic positioning system: relative accuracy ~5 cm
- Oct 2001: deployment of the final Electro-Optical Cable
- Dec 2002: deployment of the Junction Box
- Spring 2003: PSL and MIL lines
  - ✓ successful sea operations (connections with submarine)
  - ✓ long term measurements of optical background in the deep sea
  - ✓ water leak in 1 LCM => new connector
  - ✓ broken fiber in EMC => new EMC

2003: PSL & MIL



- The ***Prototype Sector Line*** (PSL) is a 1/5 of a complete line.

- The ***Mini Instrumentation Line*** (MIL) contains devices for calibration and environmental parameter monitoring.



JB

Spring 2005: the LINE 0

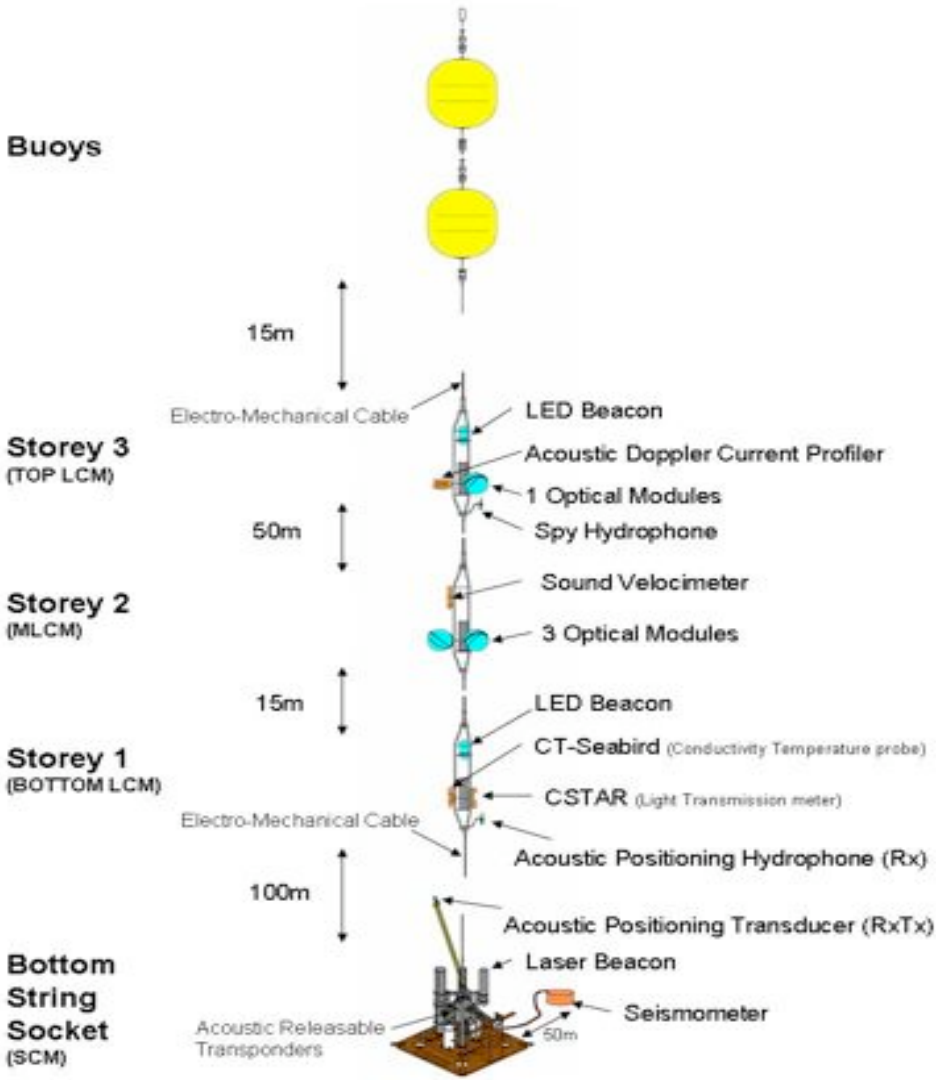
- test of mechanical structure of a full line (23 storeys)
- equipped with water leak sensors and sensors for attenuation measurements

Recovered in May 2005:

✓ no water leaks in electronic containers

✓ optical transmission losses due to an interface problem between EMC penetrators and the LCM cylinder ⇒ solution under study

Spring 2005: the MILOM



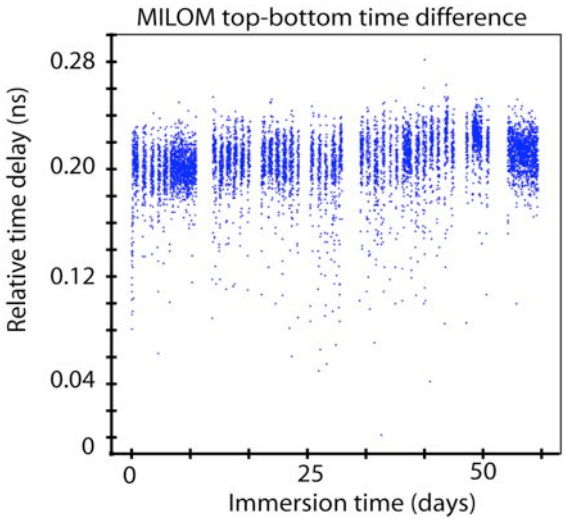
Validation of final electronics cards and OMs, of optical calibration and acoustic positioning systems
+ environmental parameter measurement and long term monitoring

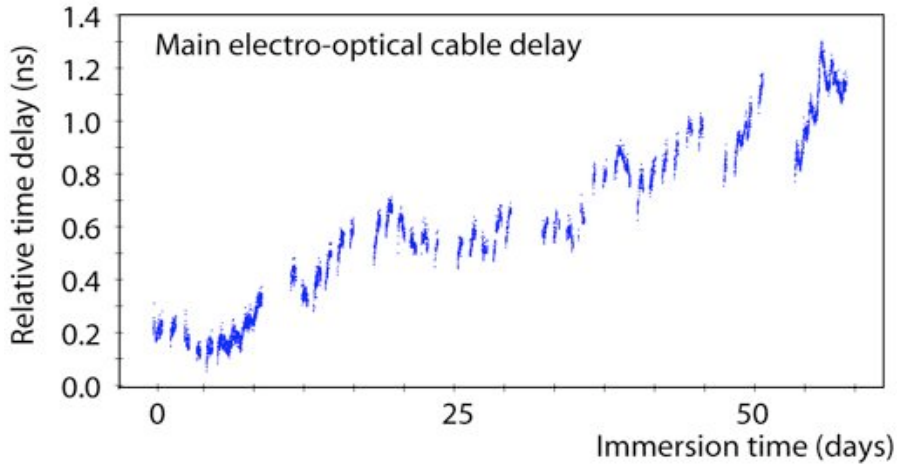
Continuous evolution of instruments ⇒ will be frequently recovered and deployed

Results from the MILOM

The excellent angular resolution of ANTARES relies on good timing resolution of the light signals recorded in the OMs. The timing resolution is limited by the TTS of the PMTs which have σ ~1.3 ns. To achieve this all electronics and calibration systems are each required to contribute < 0.5 ns to the overall timing resolution.

Reference Clock calibration

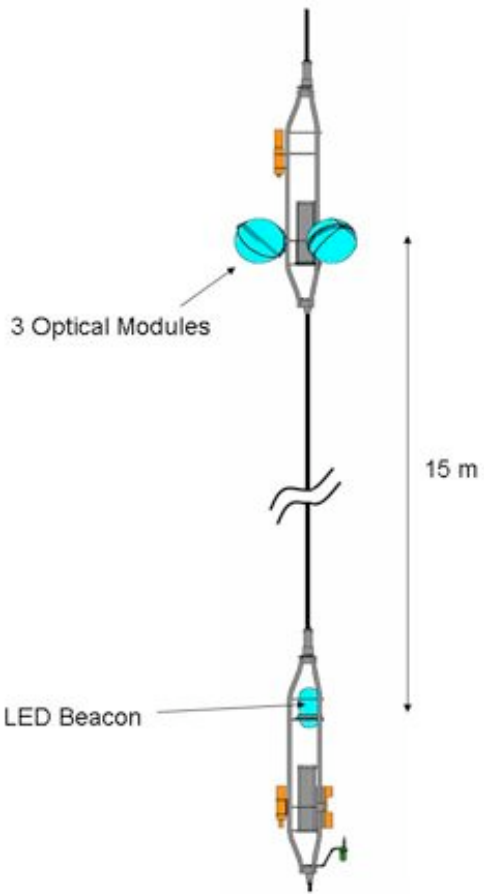




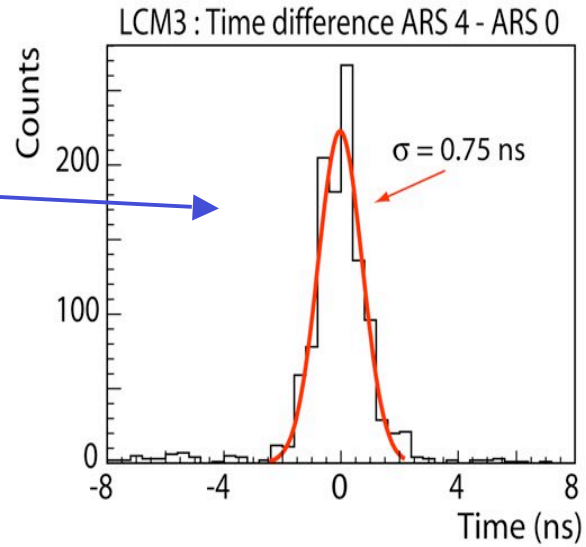
→ time resolution ~ 0.01 ns !!!

Results from the MILOM

Optical Module Timing Resolution



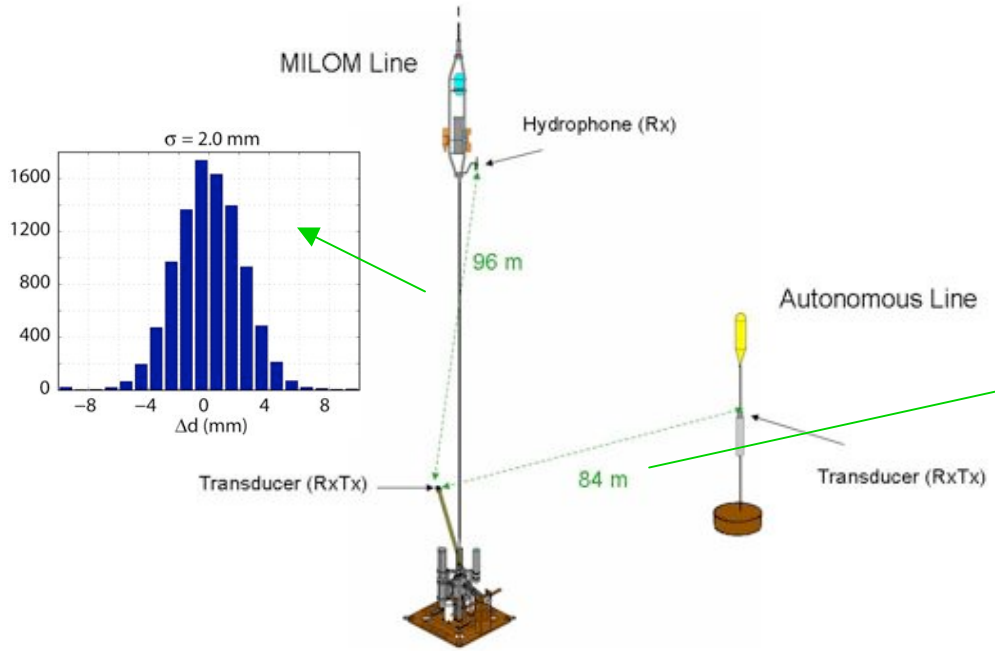
Time difference between signals between 2 OMs in a storey
(2 OMs 0.5 x √2 = 0.75 ns)
for large pulses (not determined by TTS but by electronics)



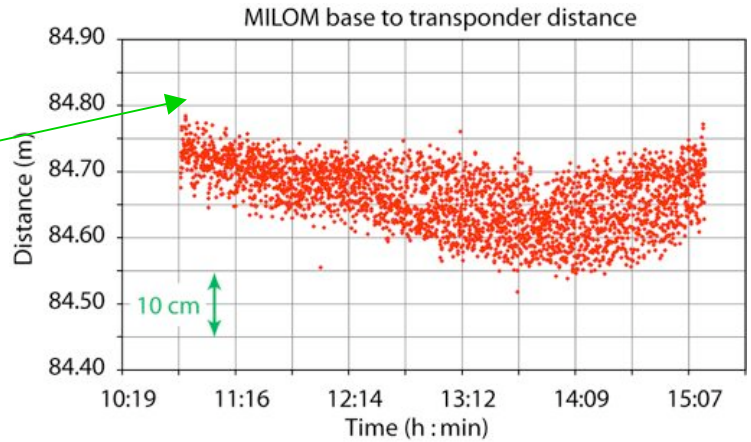
Results from the MILOM

The second essential element to realise the necessary angular resolution of the neutrino telescope, is the knowledge of the position in 3D space of the optical modules with a precision of ~10 cm in real time. These position measurements are provided by the acoustic positioning system.

Acoustic Positioning Resolution

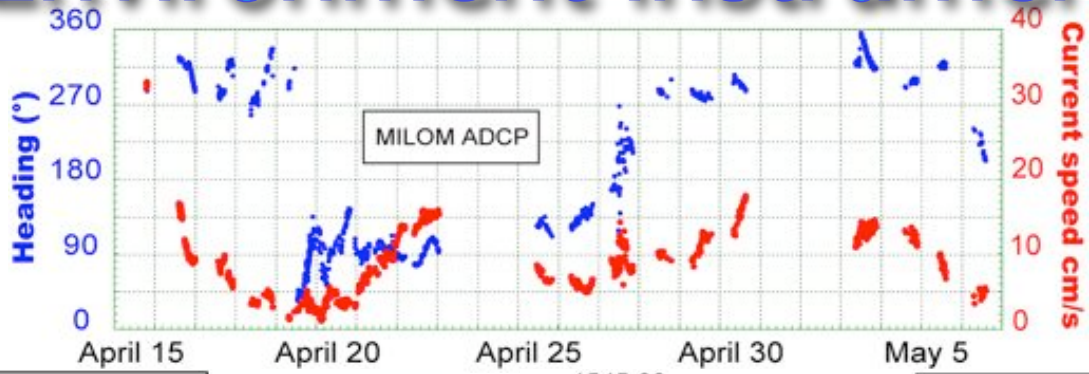


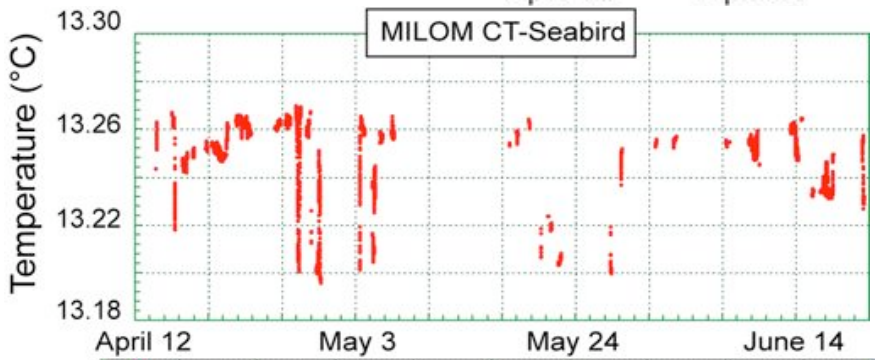
Resolution of ~3cm on a distance measurement of ~84m

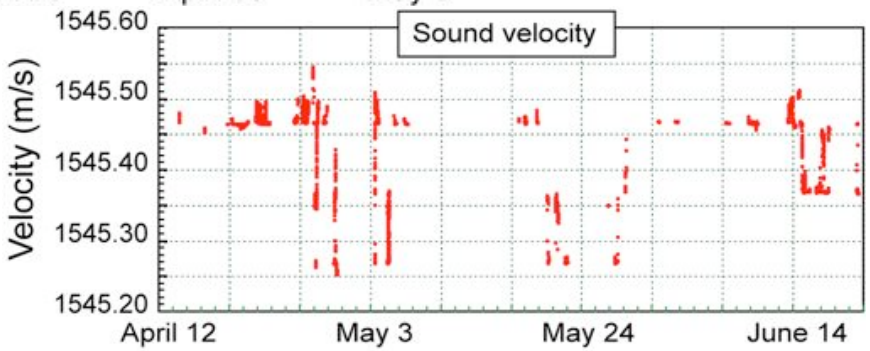


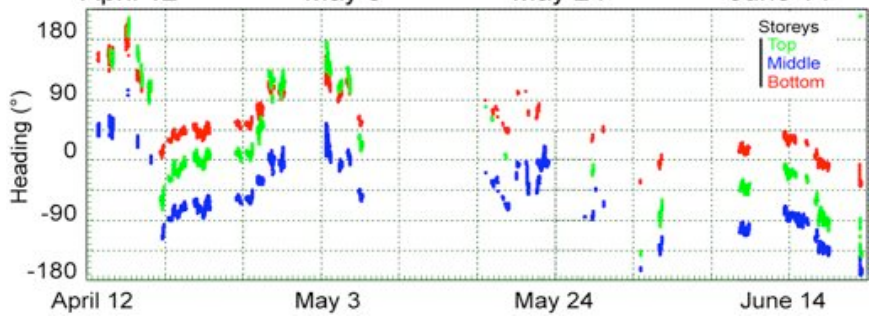
Results from the MILOM

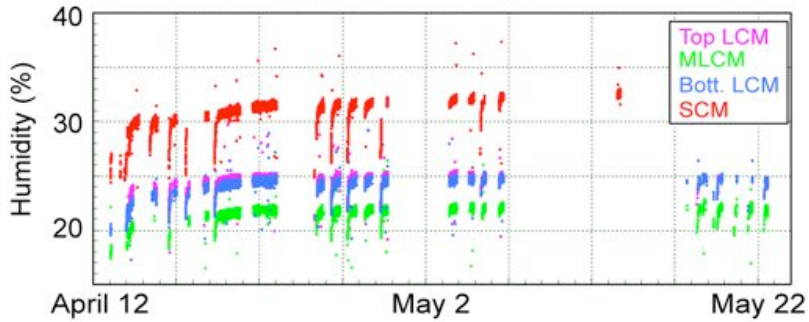
Environment instruments



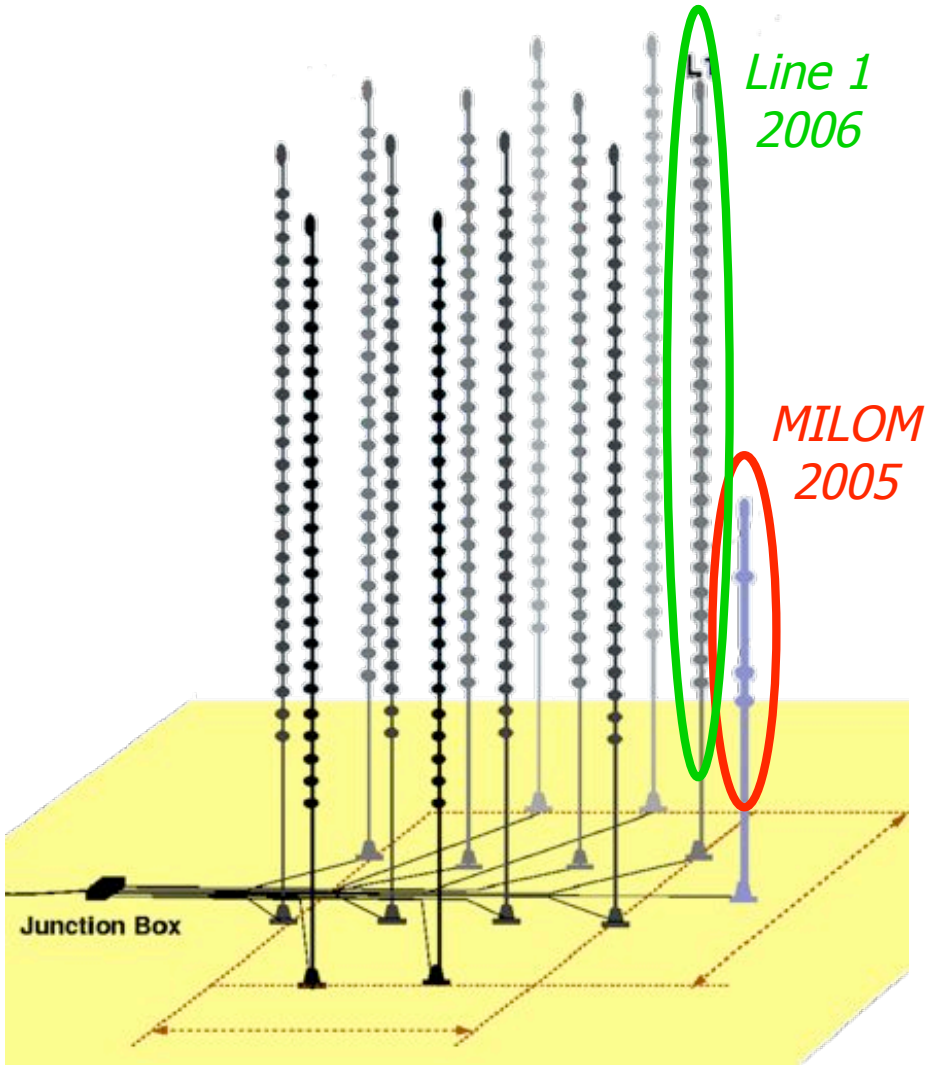




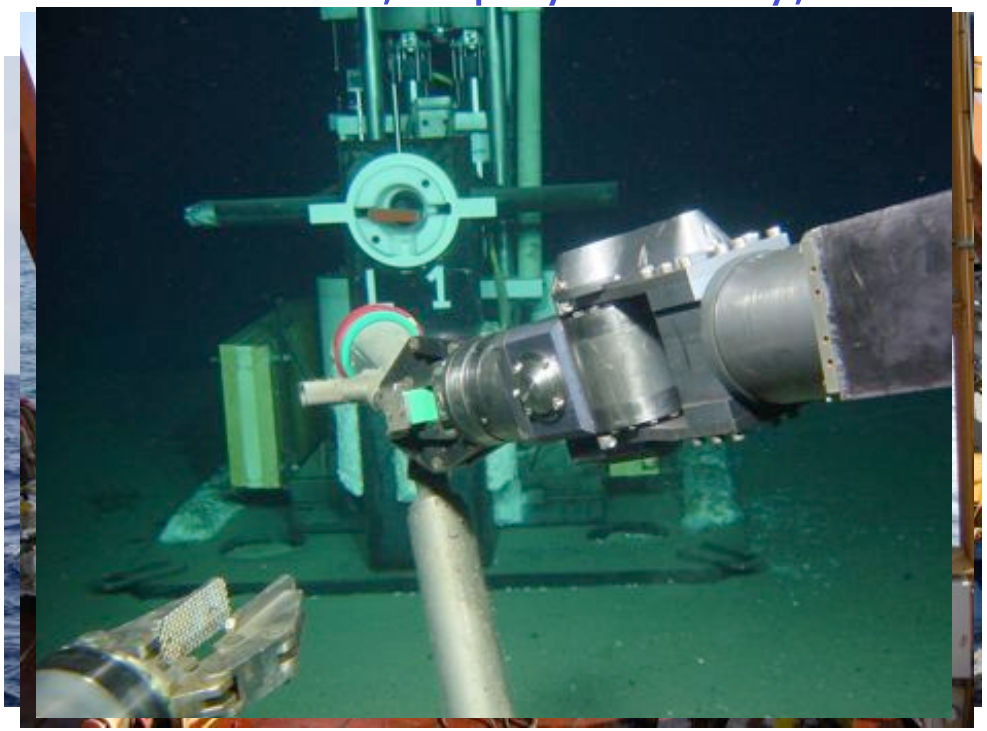




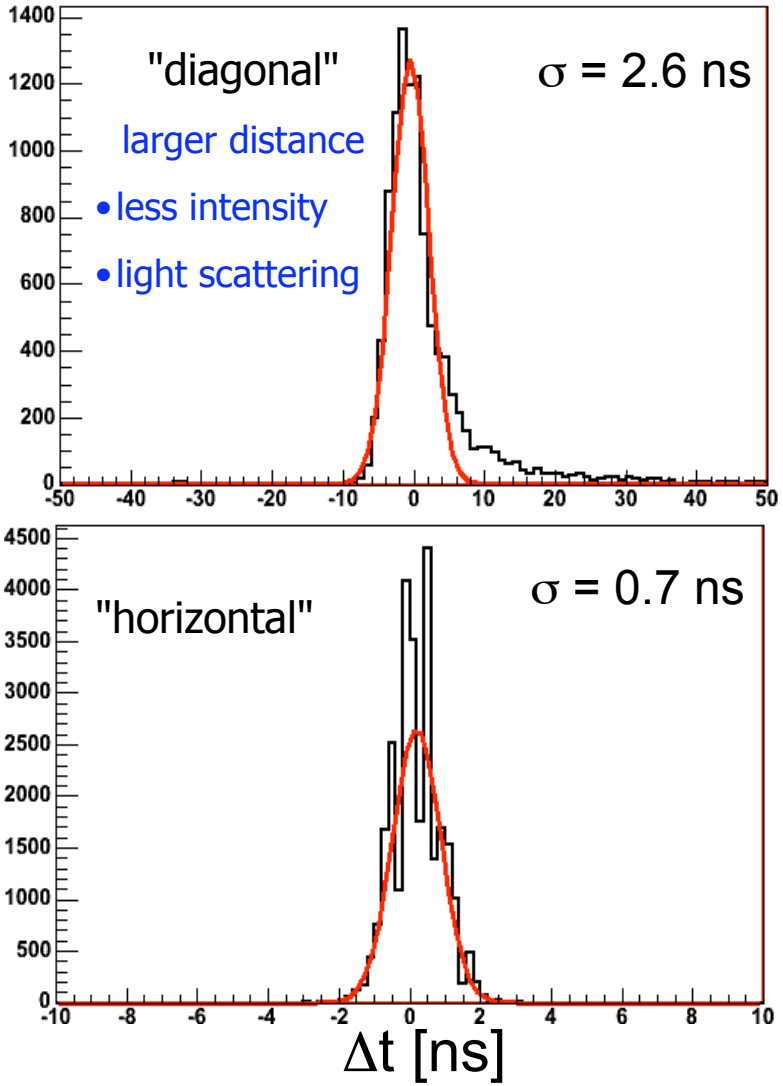
Construction status

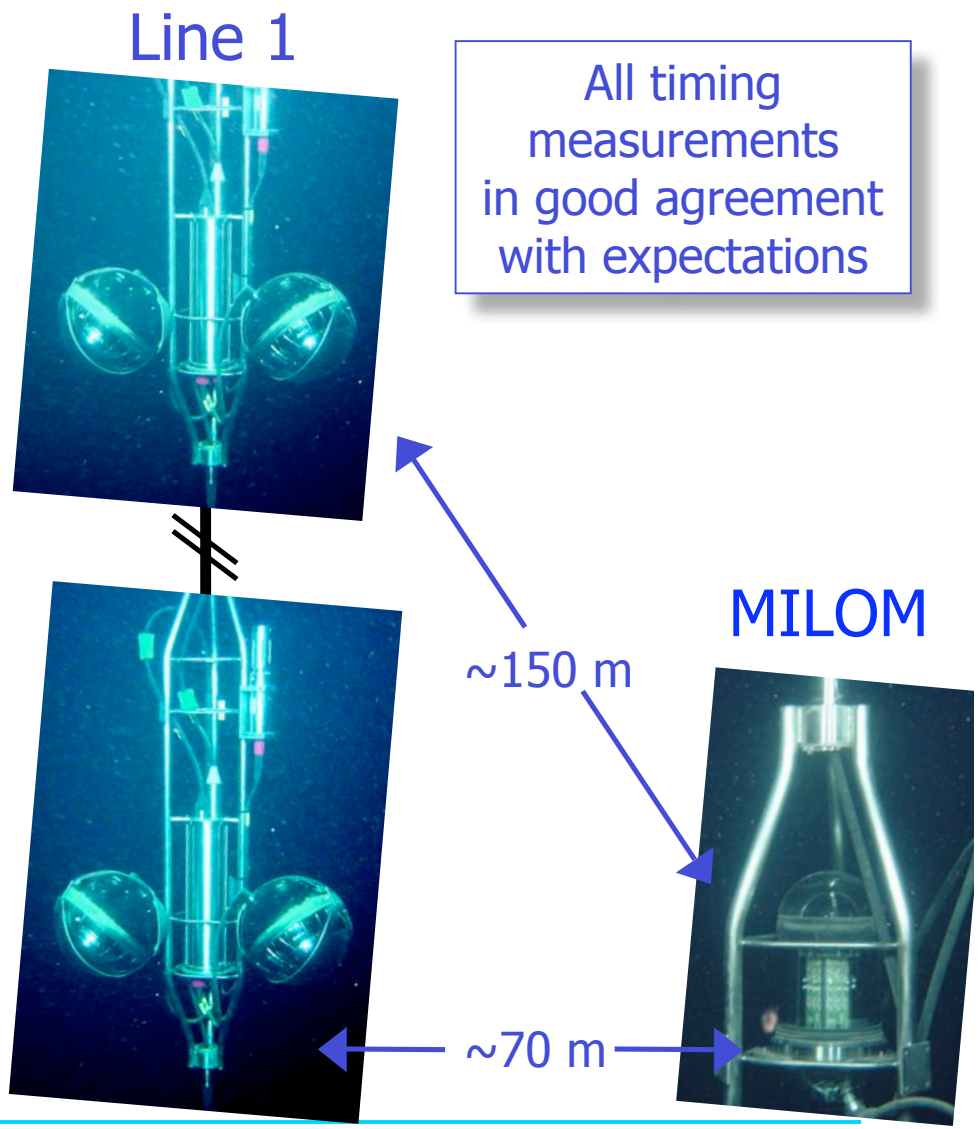


- Apr 2005: Mini Instrumentation Line with OMs (**MILOM**)
- Mar 2006: **Line 1**, first complete detector line
- 2006: **Line 2**, deployed in July, to be



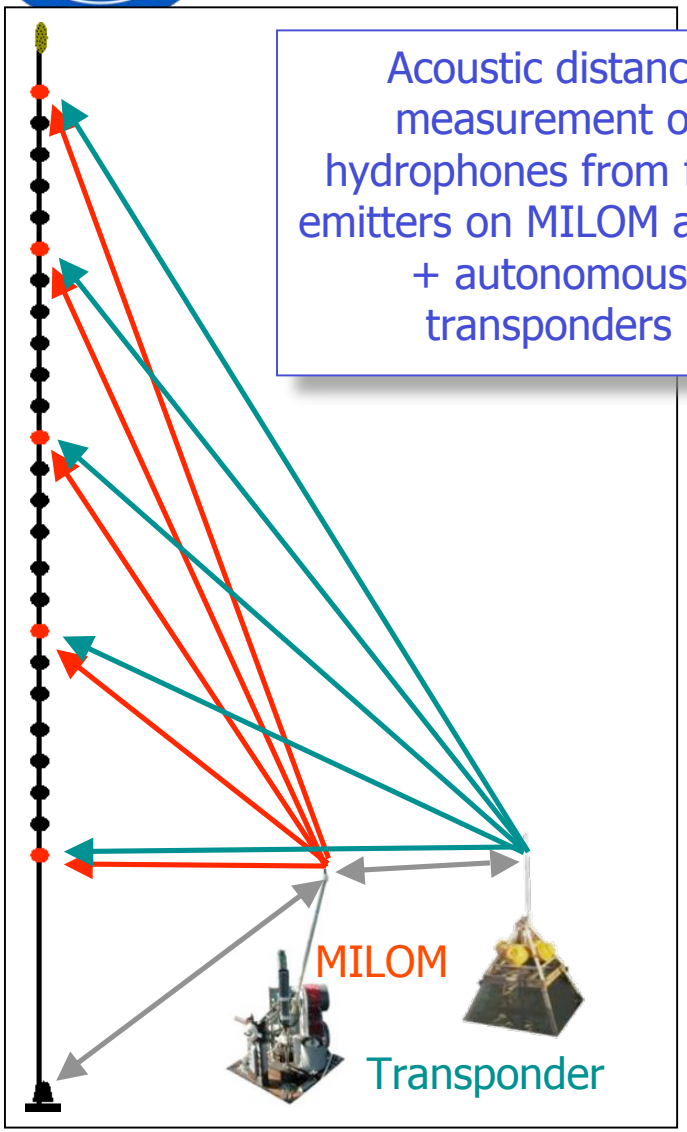
Line 1 time calibration with MILOM LED beacon

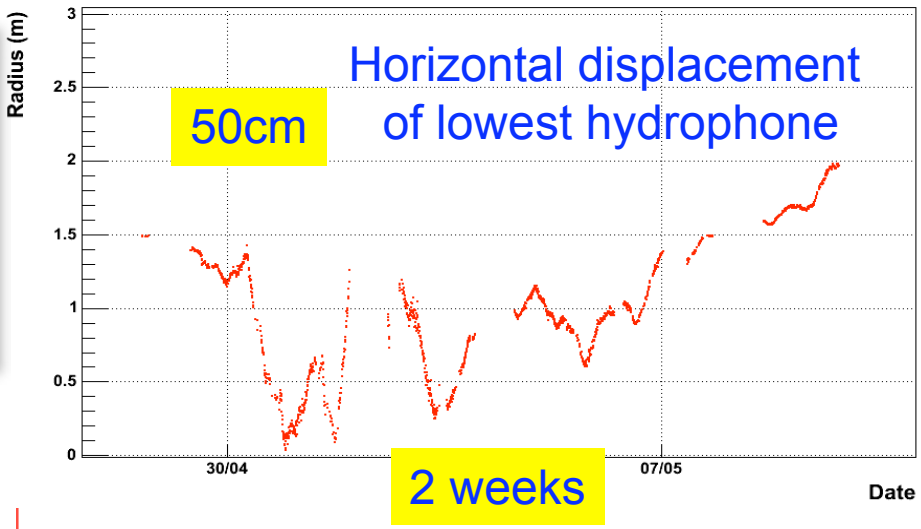


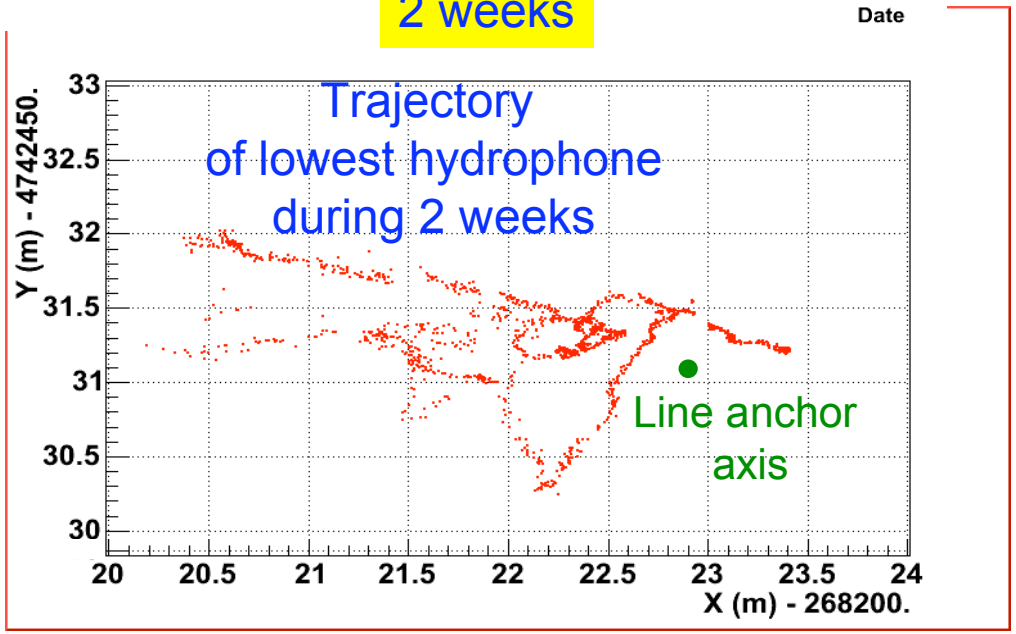


All timing measurements in good agreement with expectations

Acoustic positioning





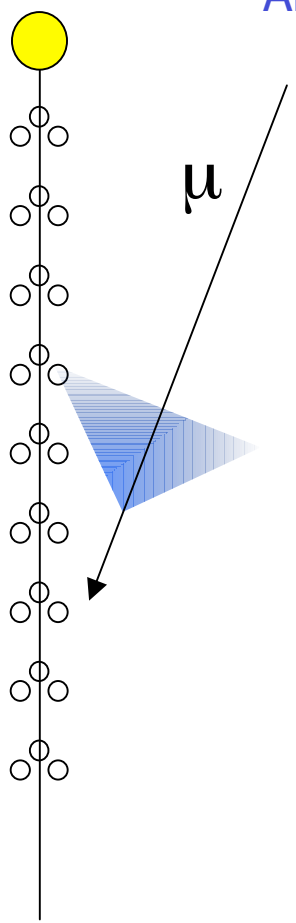


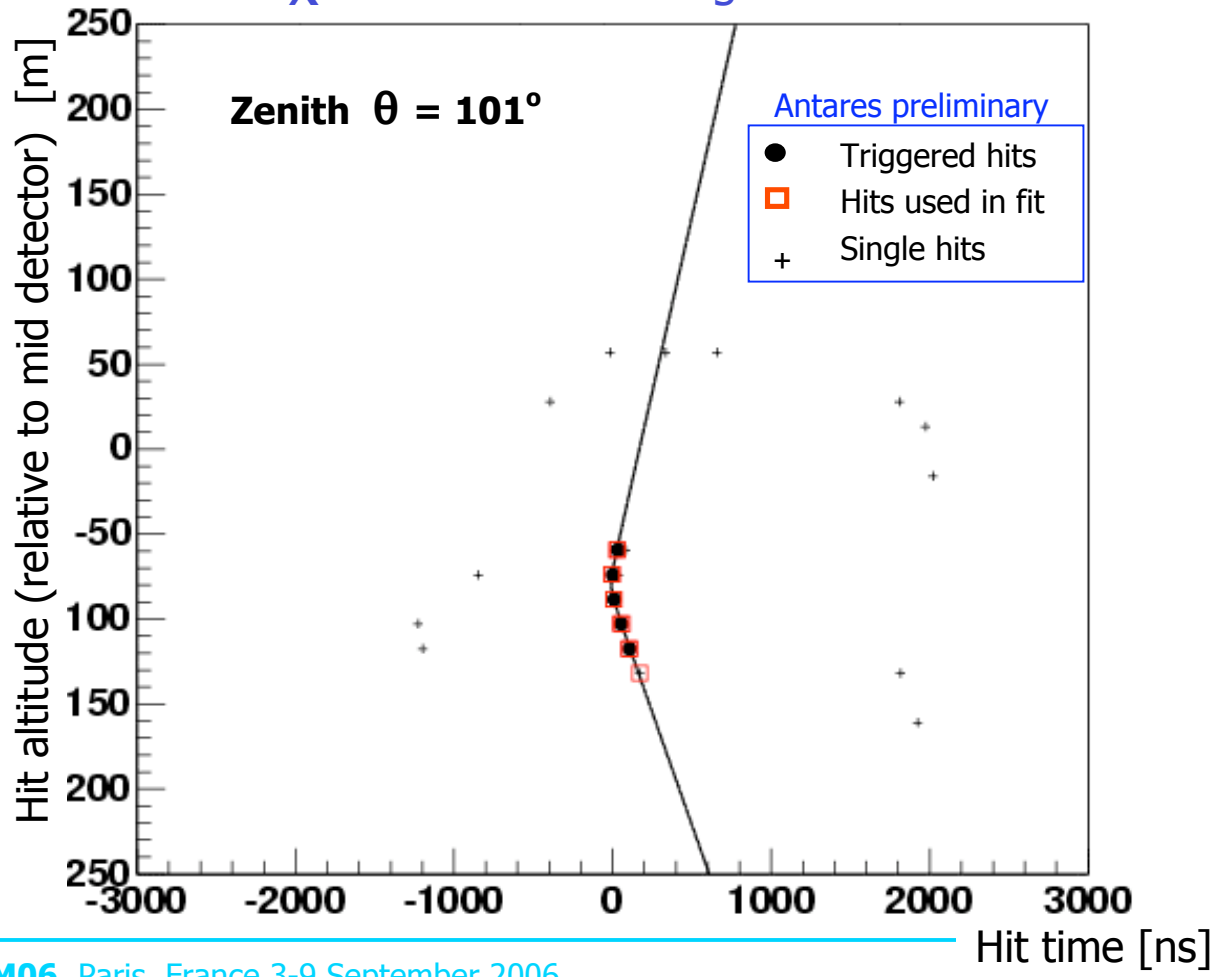
Reconstruction of atmospheric muon tracks

Reconstruction with 1 line (poor sensitivity to azimut):

Altitude vs Time Hyperbola

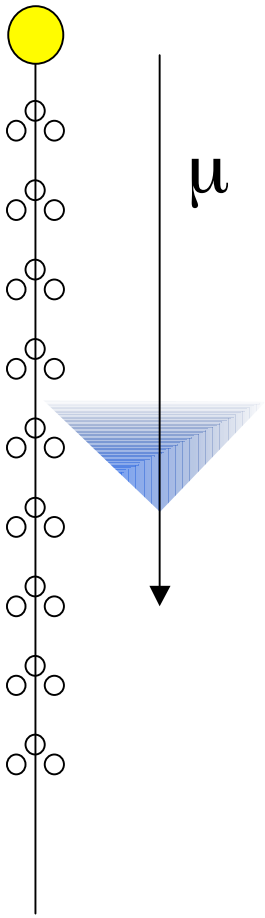
Algorithm minimizes χ^2 to find zenith angle of track

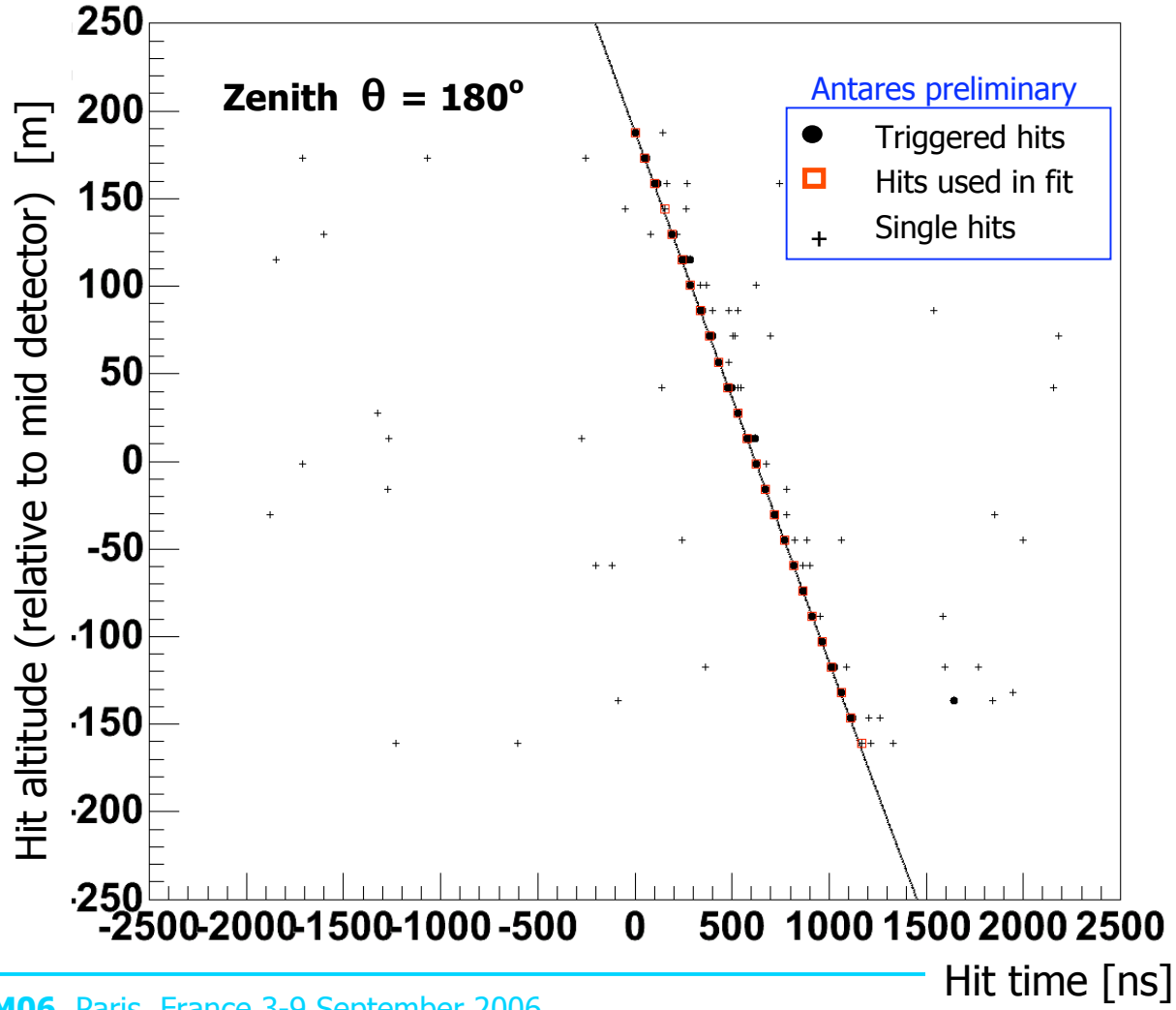




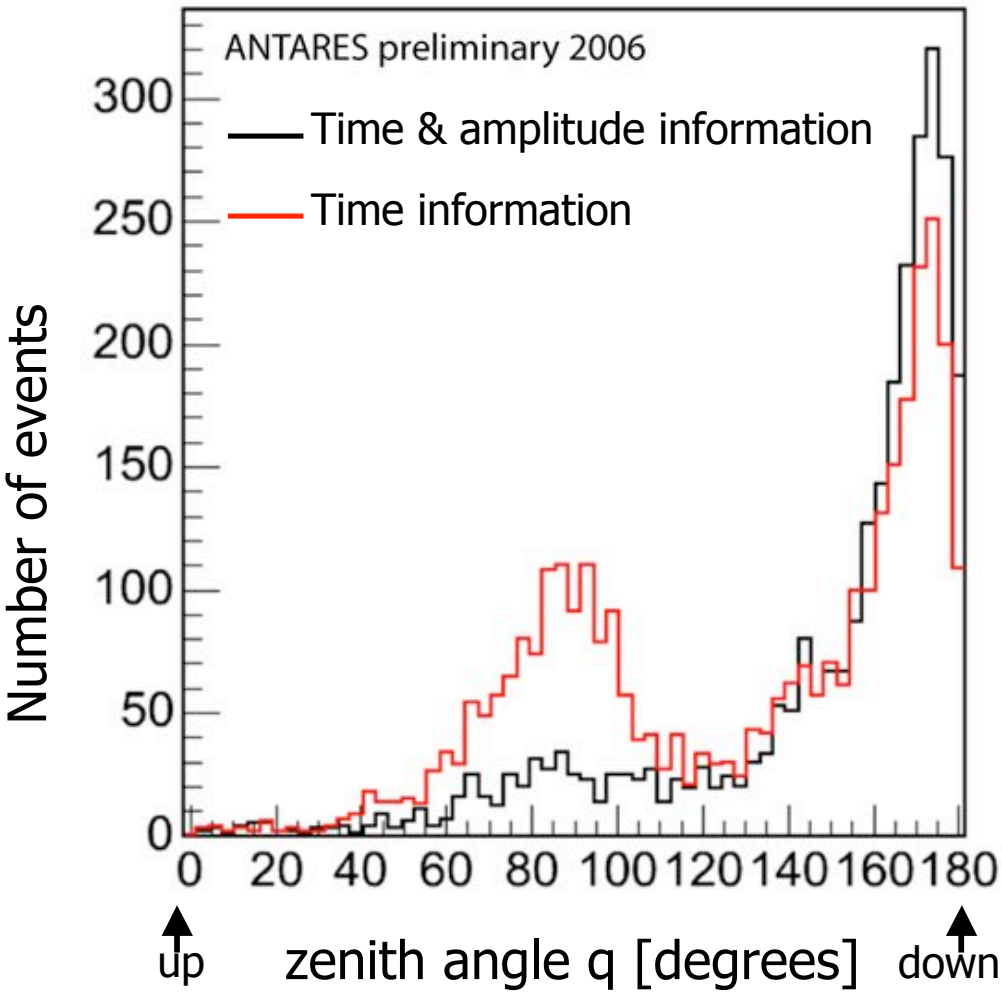
Reconstruction of atmospheric muon tracks

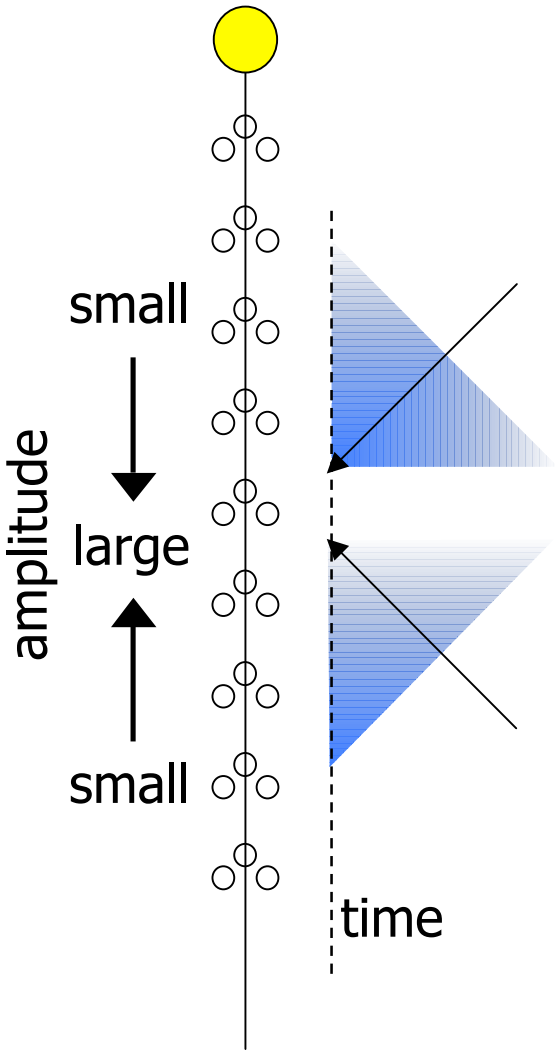
A nice, vertical track which gives hits at each storey of the line



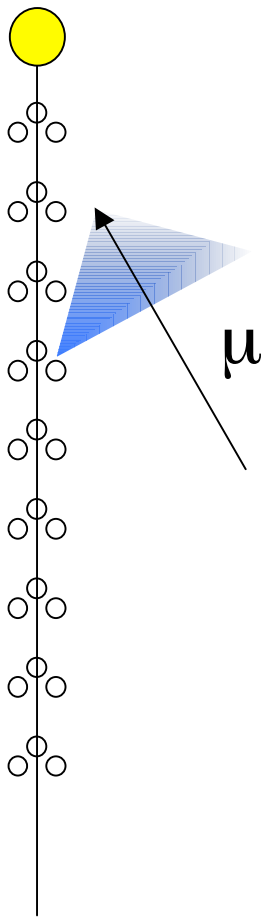


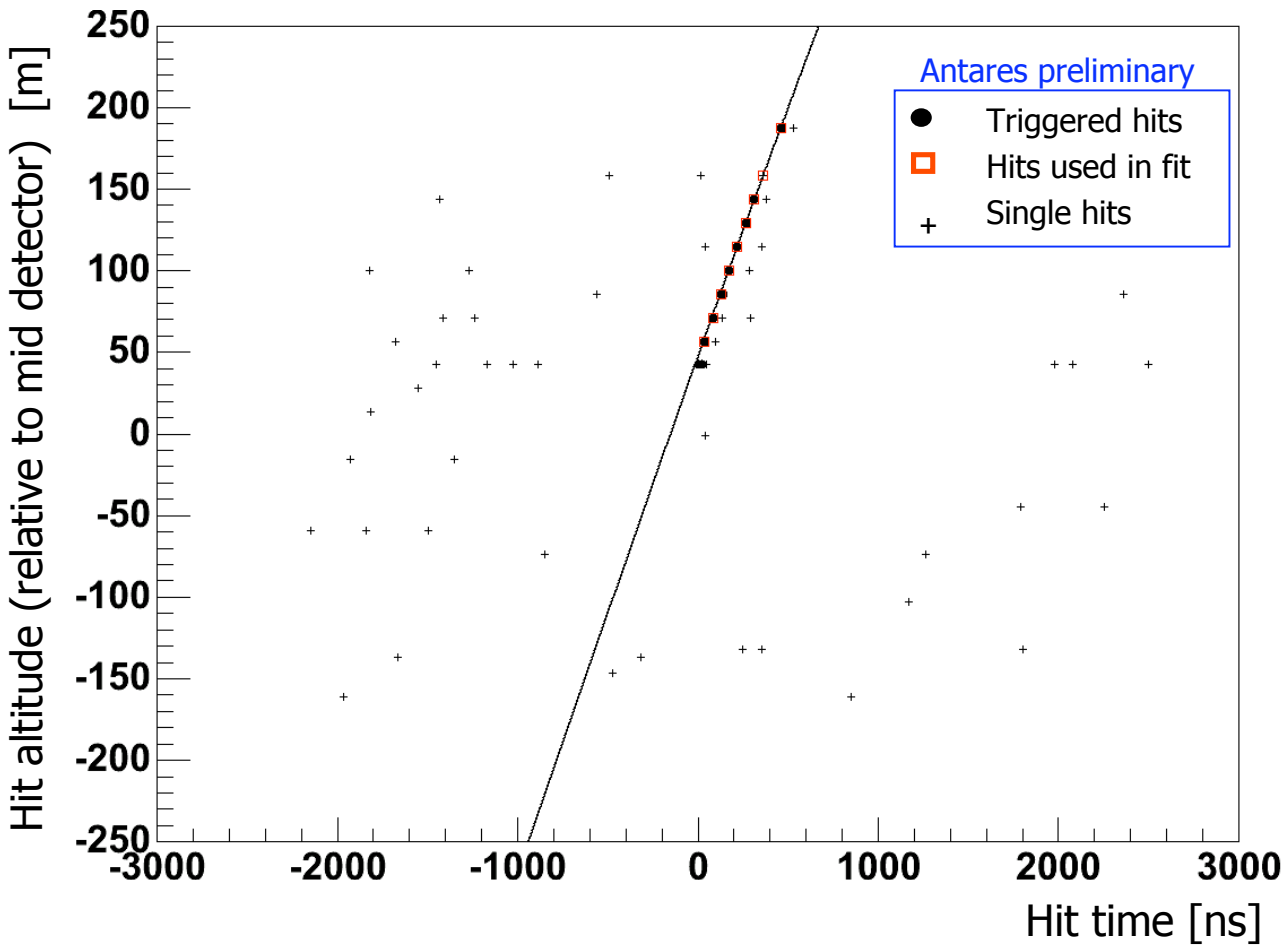
Atmospheric muon zenithal angular distribution





Reconstruction of (neutrino-induced) upgoing muon tracks





Conclusions

- **ANTARES started data acquisition this year!!**

- Detector working well within design specifications:
  - Junction Box in operation since Dec. 2002
  - First detection line + instrumented line delivering data on the site
  - All technical problems solved

- Status of construction:
  - Optical module production complete
  - Electronics and mechanics productions well advanced
  - 3 electronics integration sites active in Italy
  - 2 line integration sites active in France
  - line 2 being deployed this week and connected in September
  - integration of lines 3 and 4 starting (to be installed by end 2006)

- **12 lines apparatus completed by end 2007**
  Operation for science ≥ 5 years

- Milestone towards a KM^3 underwater detector (ANTARES participates in the KM3NeT design study for a KM^3 neutrino telescope in the Mediterranean Sea)