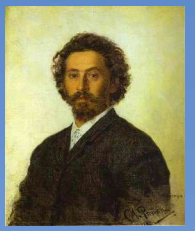
Current Status of the ANTARES Neutrino Telescope



QUARKS-06, St. Petersburg, Russia

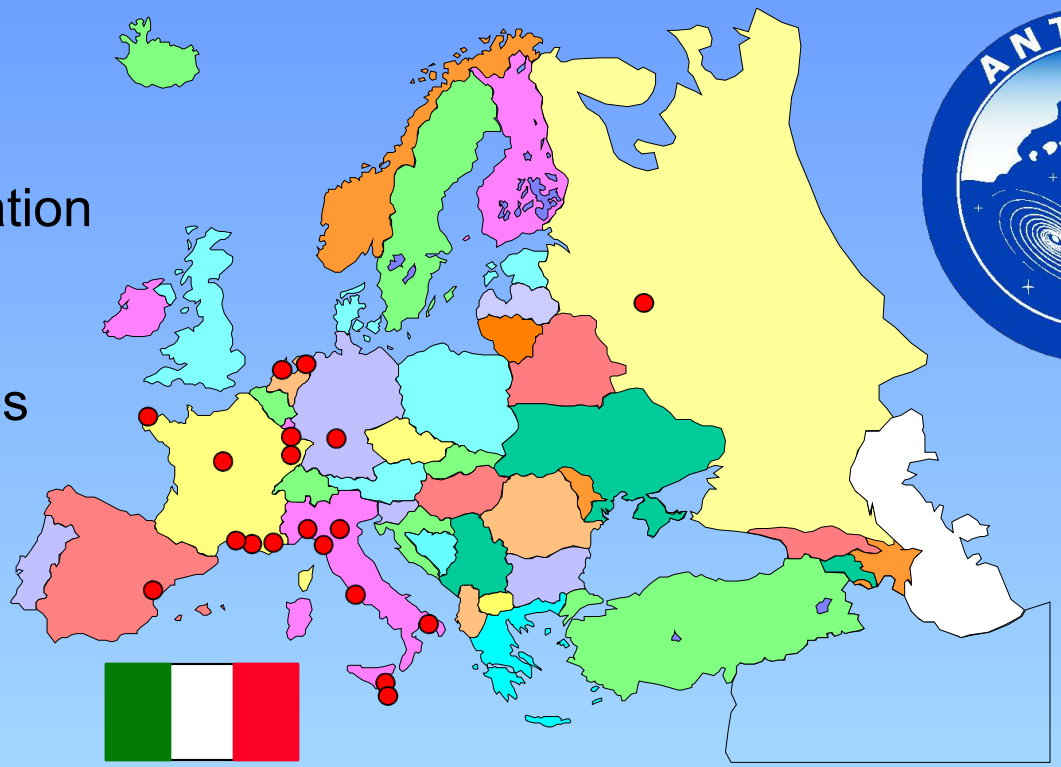
Christopher Naumann, University of Erlangen, Germany
for the ANTARES collaboration

ANTARES Collaboration

International Collaboration

- 21 Institutes
- 6 European Countries

Aim: *ν telescope in Mediterranean Sea*



- CPPM, Marseille
- DSM/DAPNIA/CEA, Saclay
- APC Paris
- IPHC (IReS), Strasbourg
- Univ. de H.-A., Mulhouse
- IFREMER, Toulon/Brest
- C.O.M. Marseille
- LAM, Marseille
- GeoAzur Villefranche

- University of Bari
- University of Bologna
- University of Catania
- LNS – Catania
- University of Pisa
- University of Rome
- University of Genova

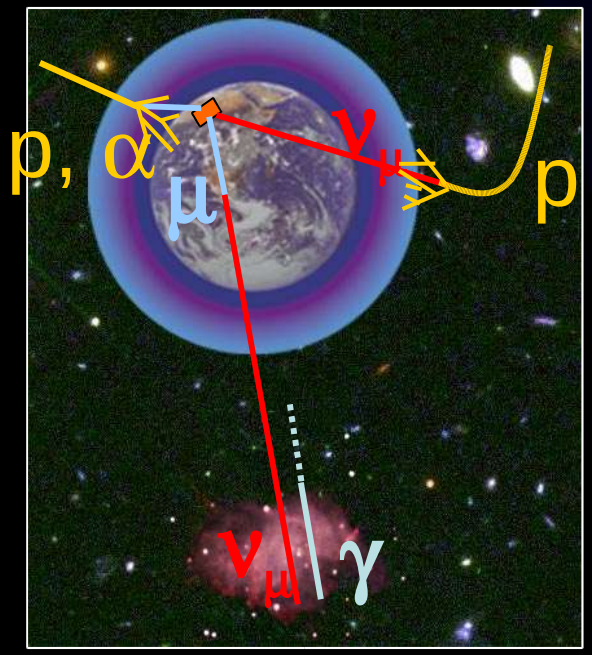
- IFIC, Valencia

- ITEP, Moscow

- NIKHEF, Amsterdam
- KVI Groningen

- University of Erlangen

Neutrino Telescope: Detection Principle



3D PMT array

Cherenkov light from μ

sea floor

42°

interaction

μ

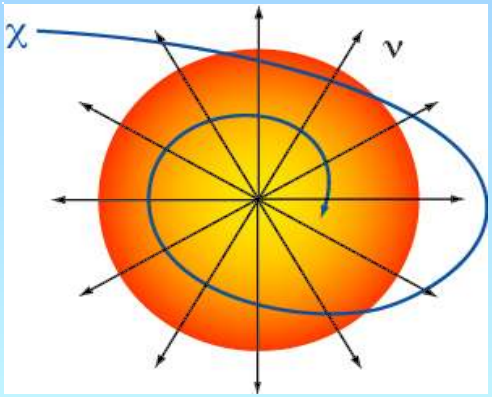
ν

reconstruct muon (neutrino) trajectory from position and timing of hits

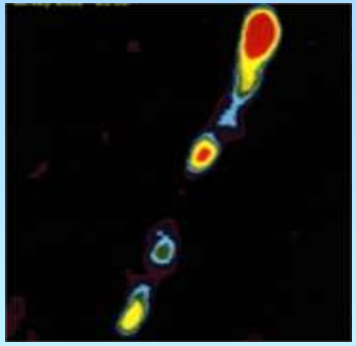
ANTARES Physics Goals

- **High energy neutrino astrophysics**:
  - *Point Sources* (Active Galactic Nuclei, Gamma Ray Bursts etc.)
  - *Diffuse Fluxes*
- **New Physics**:
  WIMPs, Monopoles, Nuclearites
- **Interdisciplinary Deep Sea Studies**
  (bioluminescence, sea current etc.)

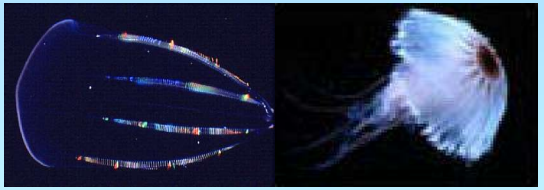
Crab Nebula



Neutralino Annihilation

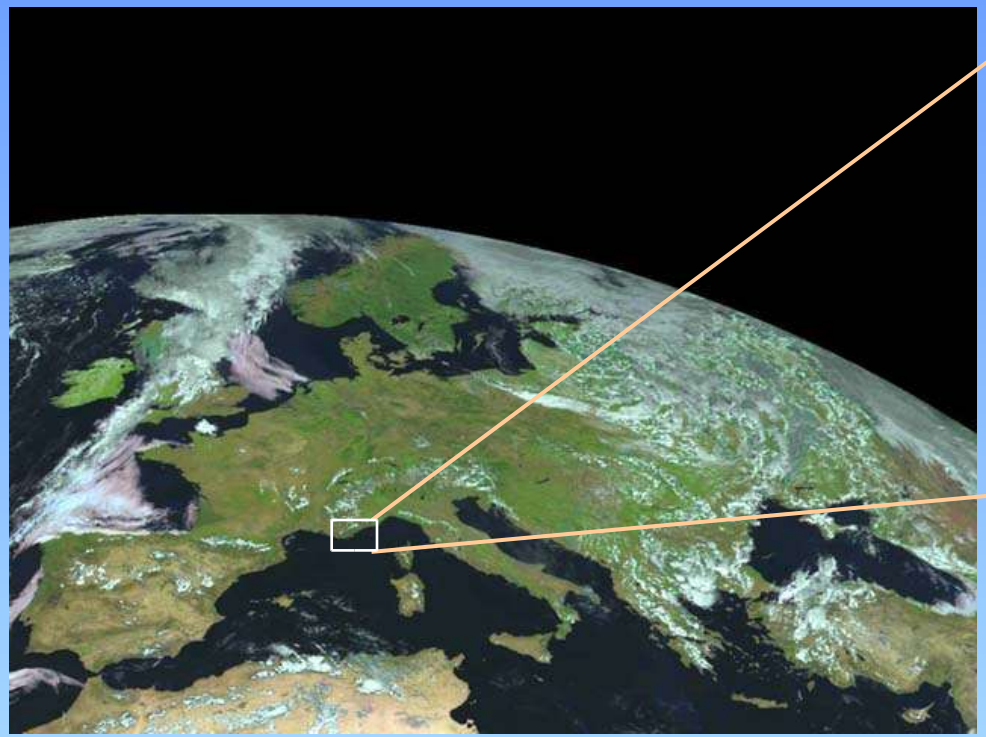


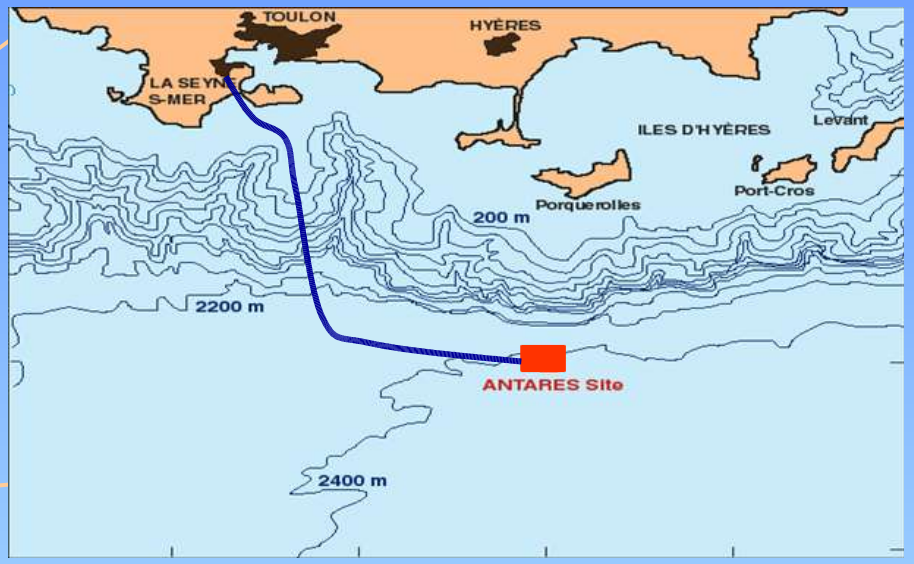
Microquasars



Bioluminescent Organisms

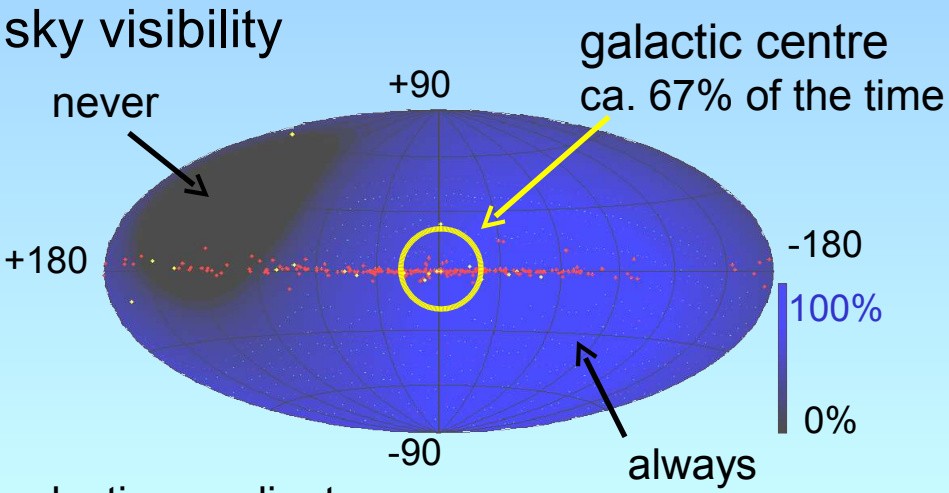
ANTARES Site





Location: Toulon, 42°50'N, 6°10'E

Depth: 2400 m



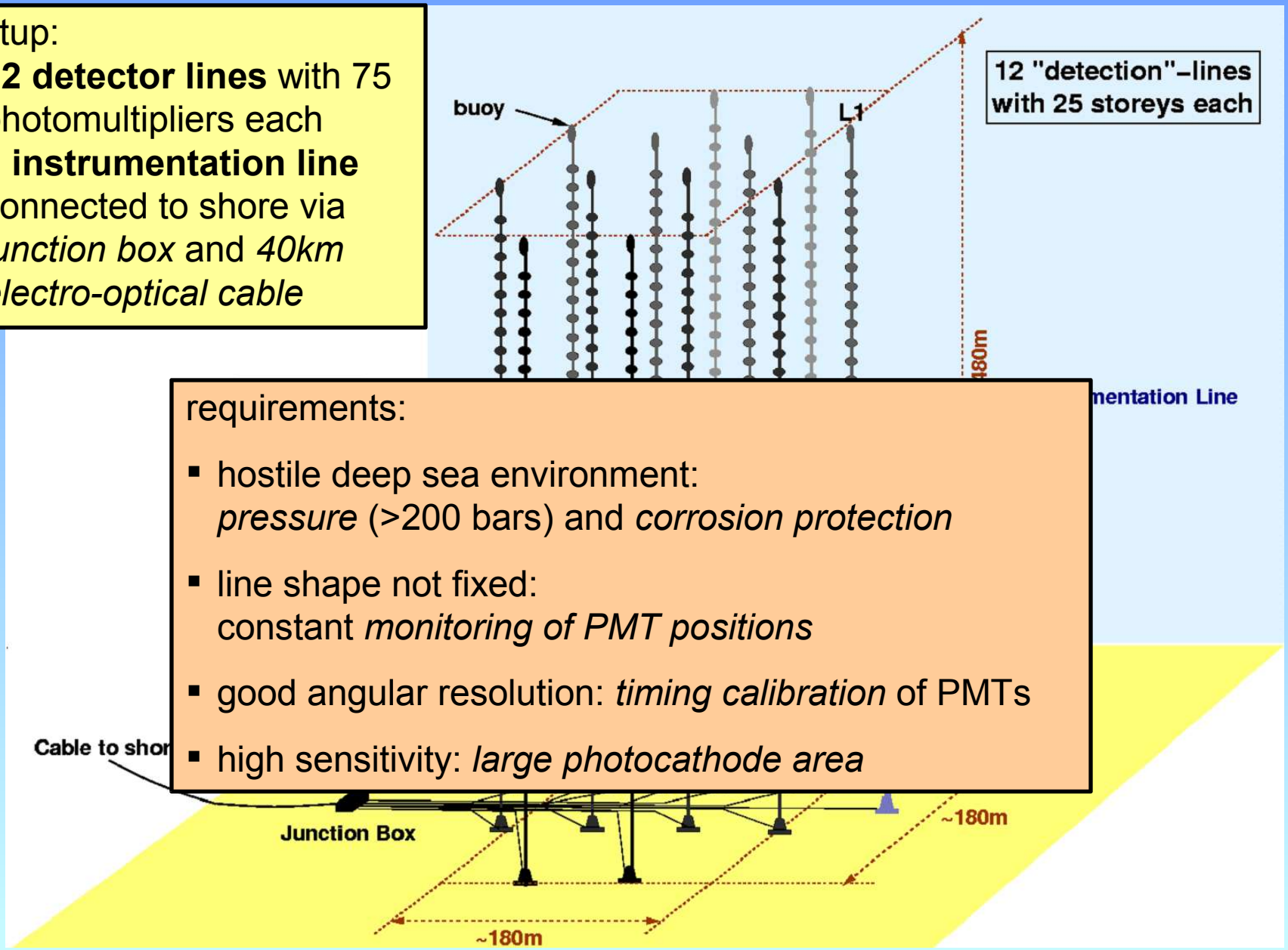
Located on Northern Hemisphere:

- Southern Sky visible (including *Galactic Centre* !)
- complementary to south pole detectors (AMANDA / IceCube)

The ANTARES Neutrino Telescope

Setup:

- **12 detector lines** with 75 photomultipliers each
- **1 instrumentation line**
- connected to shore via *junction box* and *40km electro-optical cable*



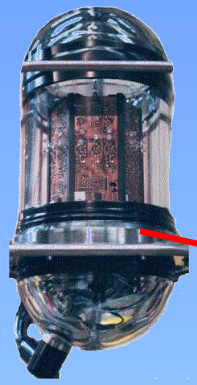
requirements:

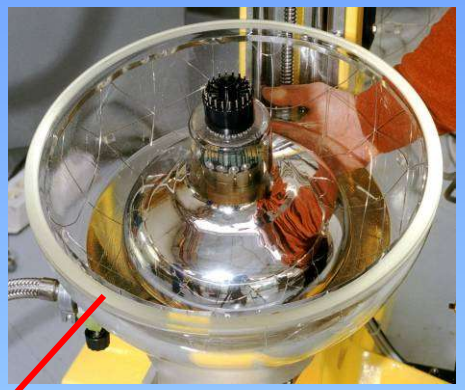
- hostile deep sea environment: *pressure* (>200 bars) and *corrosion protection*
- line shape not fixed: constant *monitoring of PMT positions*
- good angular resolution: *timing calibration* of PMTs
- high sensitivity: *large photocathode area*

Basic detector element: storey

titanium frame: *support structure*

Optical Beacon:
timing calibration



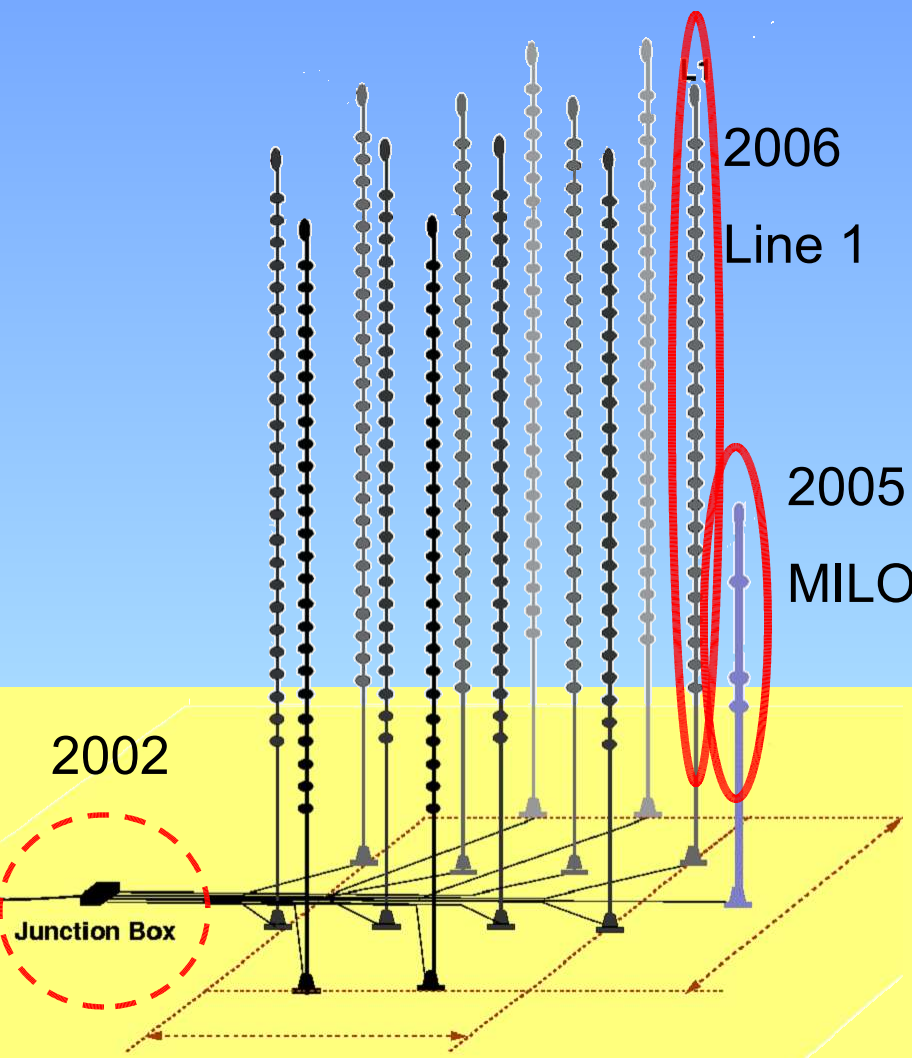


10” Hamamatsu PMT
in 17” glass sphere
(active element)

Local Control Module
(in Ti Cylinder):
DAQ and Slow Control
+ Compass Cards

Hydrophone:
acoustic positioning

ANTARES Construction Milestones



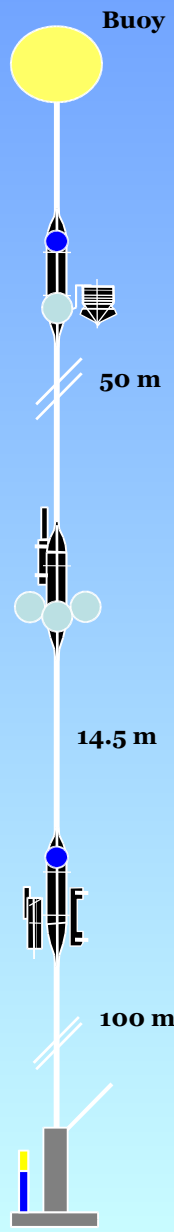
- before 2005
  - various *Demonstrator Lines*
  - *Junction Box* (since 2002)
- 2005 - now
  - *Mini Instrumentation Line* (MILOM)

    running since 12 April 2005
  - *Line 1*

    running since 2 March 2006,

    first complete detector line
- 2006 - 2007
  - Installation of *remaining 11 lines*
  - *full Instrumentation Line* (2007)
  - *acoustic detectors* (Erlangen !)
- **2007+: Physics with full detector** !

2005: the MILOM



top storey:
1 optical module
current profiler

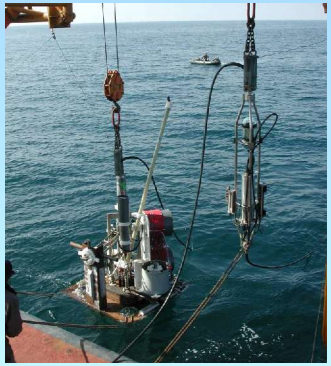
middle storey:
3 optical modules

bottom storey:
LED beacon

base:
acoustic transducer

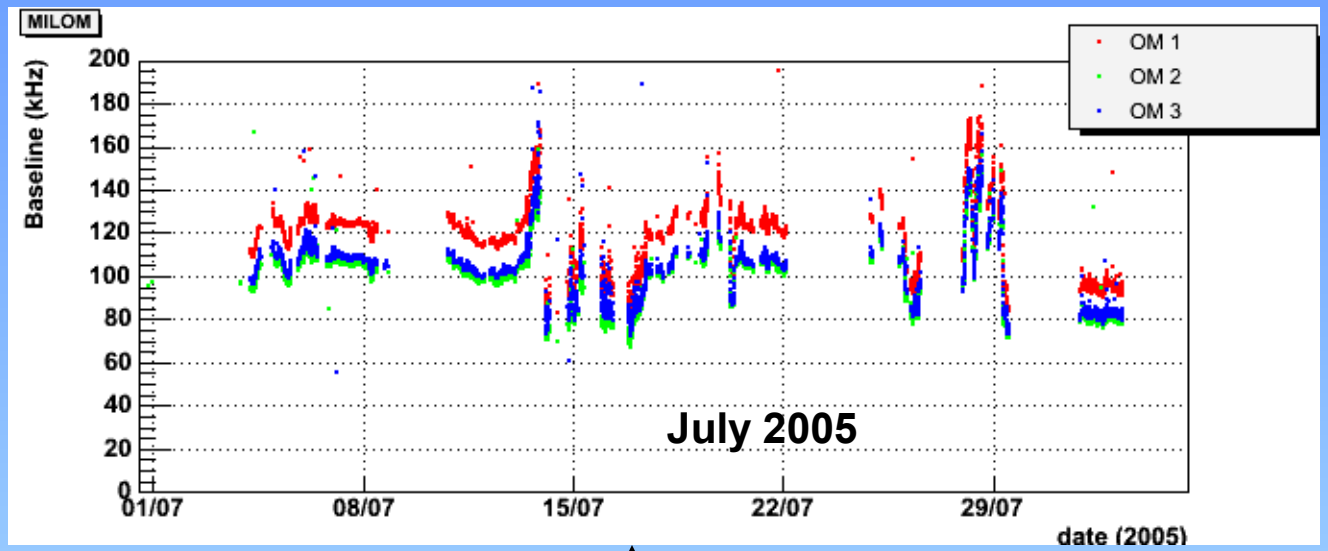
Prototype line for **data taking** and **instrumentation**

- Deployed 18/03/2005, still taking data
- equipped with optical modules and
- various instruments for
  - -acoustic positioning
  - -time calibration
  - -sea current profile measurement
  - -light and sound transmission...



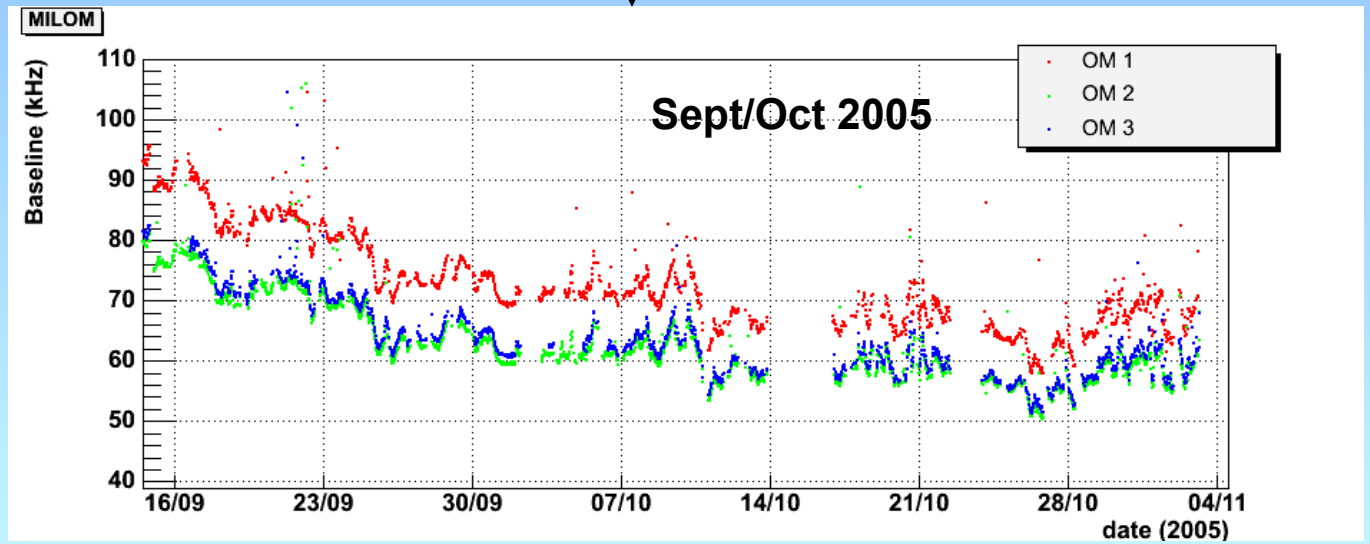
The MILOM at 2500m

MILOM Singles Counting Rates



single photoelectron rates in optical modules

seasonal variations !

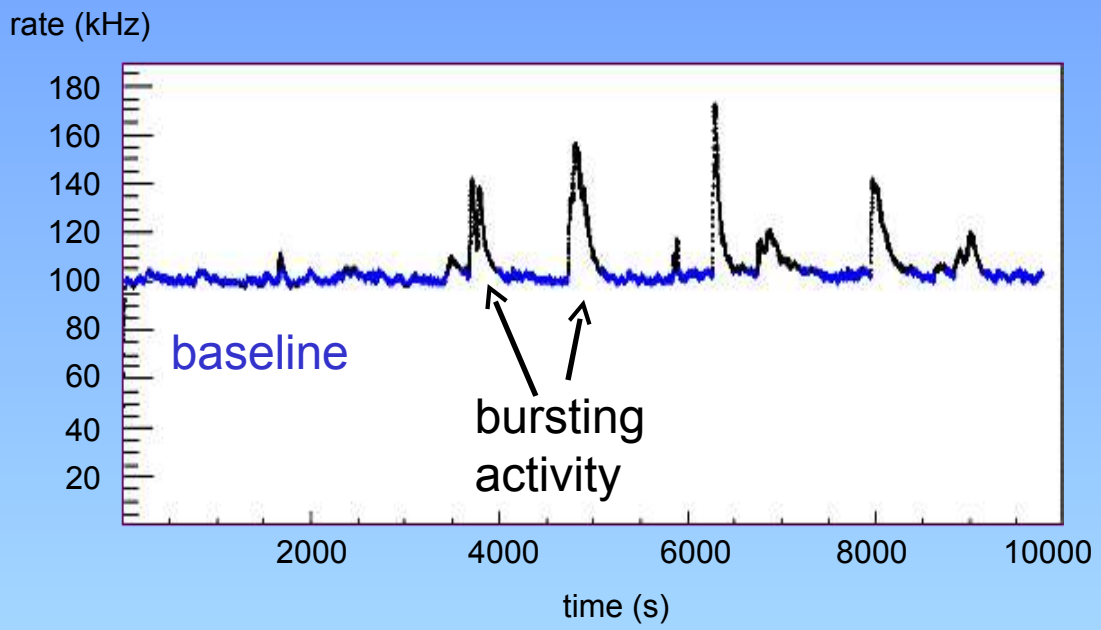


difference between modules due to different gain / efficiency

main contributions: ^{40}K decays, bioluminescence, atmospheric muons

Baseline and Bursts - Definition

Short term behaviour (single PMT, 10000 s)



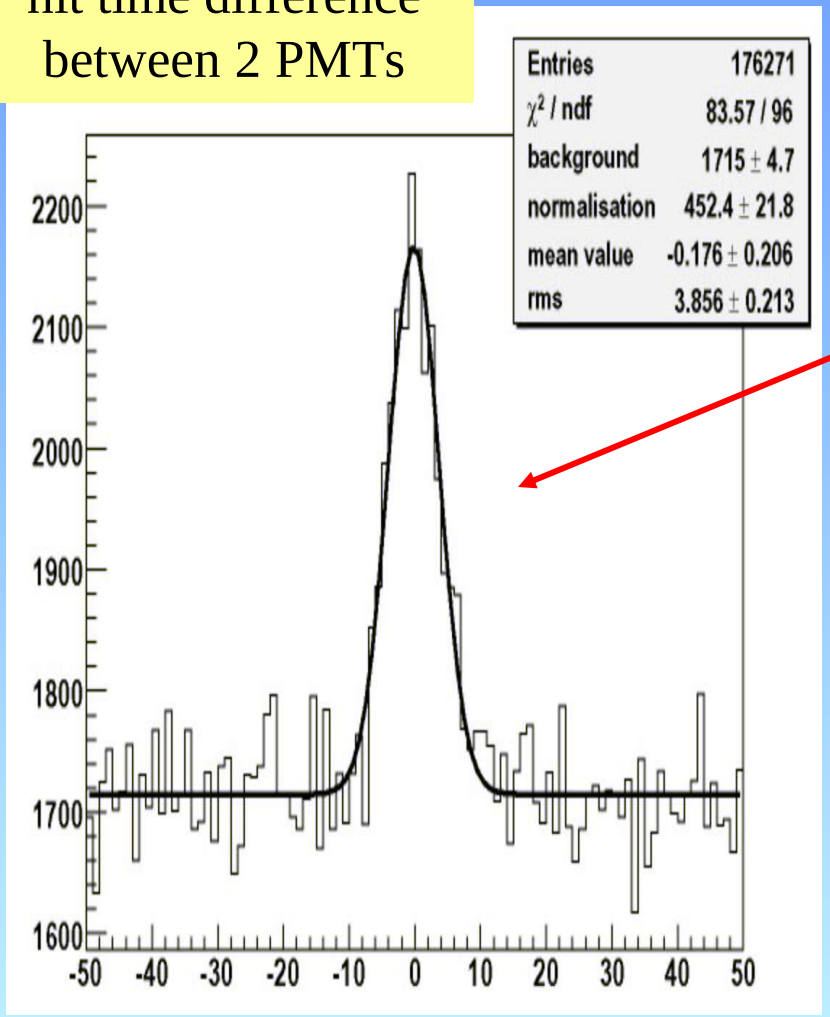
two components of counting rates:

- baseline = mainly ^{40}K and bioluminescence of microorganisms
- bursts = temporary local increase of counting rates due to
  - single organisms (fish)
  - correlated bioluminescence (swarms)

define "burst fraction" := amount of time when (local) rate more than 20% above (global) baseline

Coincident Photoelectrons – Time Spread

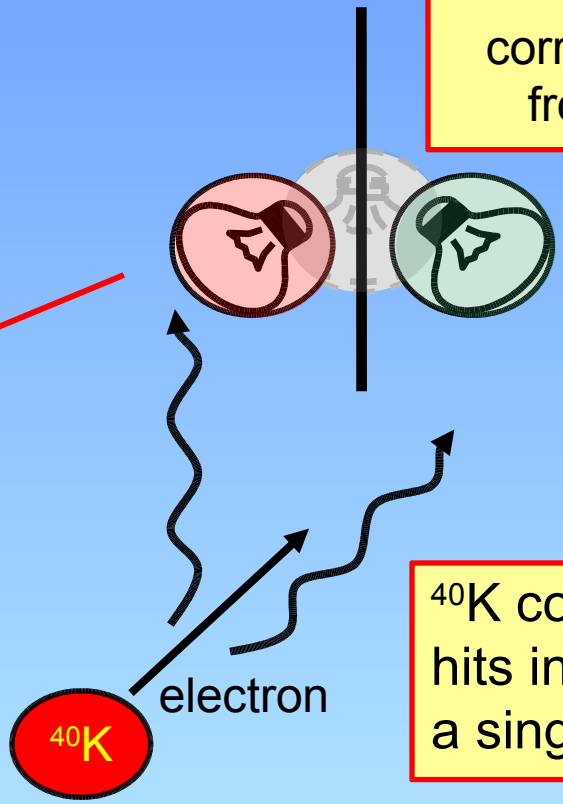
hit time difference between 2 PMTs



Δt (ns)

main contribution:

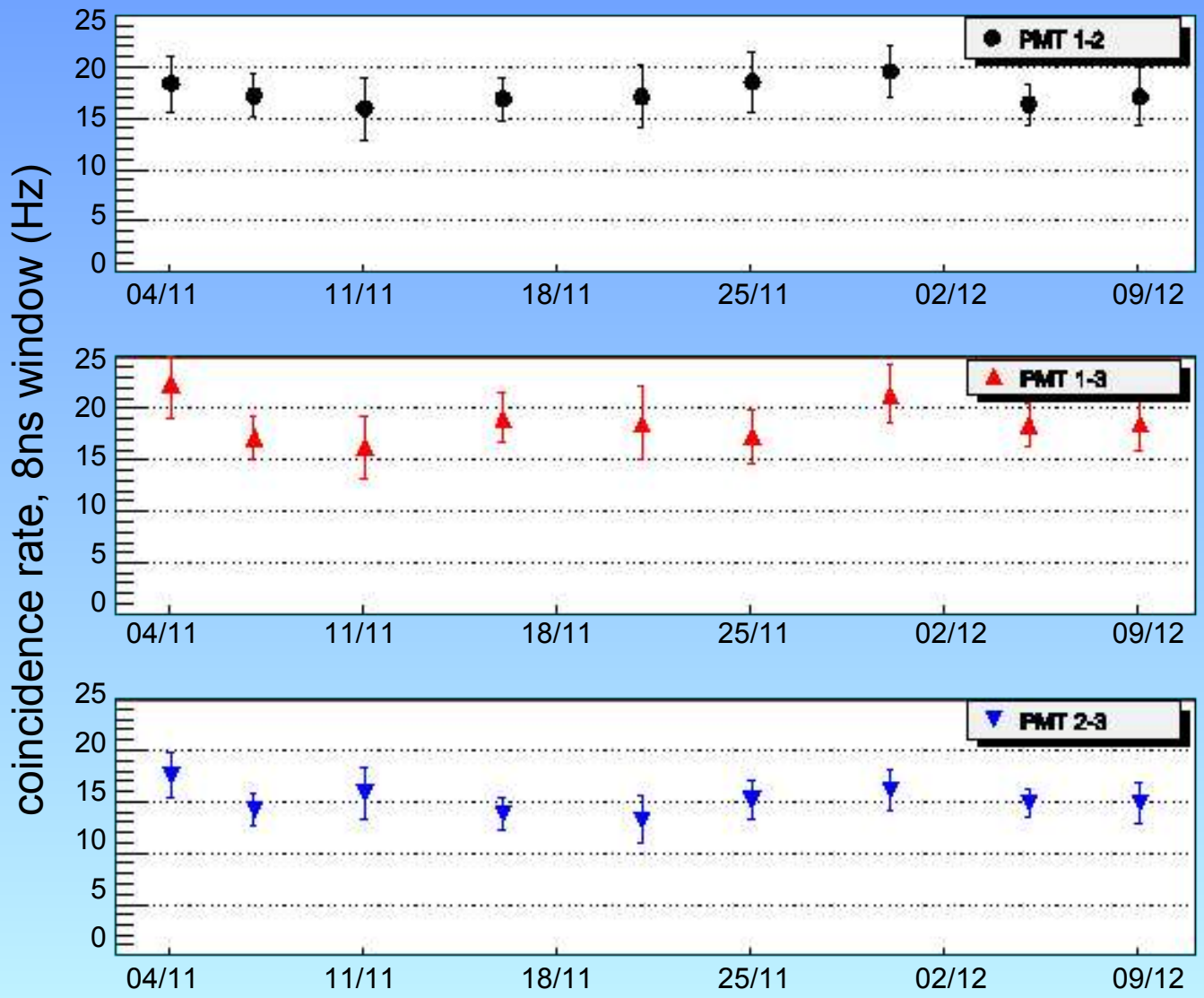
correlated photons from ^{40}K decay



^{40}K coincidence: hits in 2 PMTs from a single ^{40}K decay

good agreement with expectations !

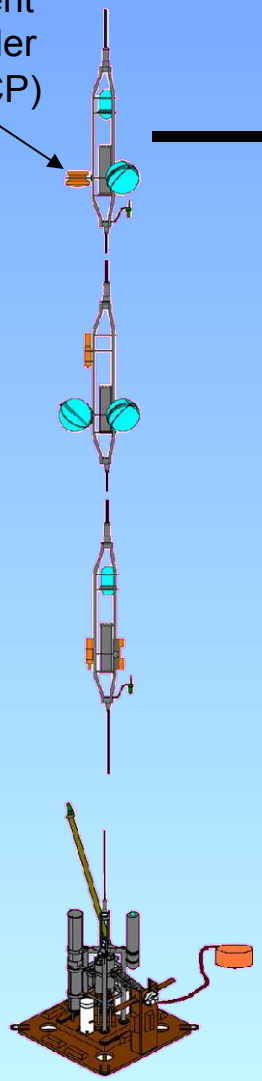
Coincidence Rates

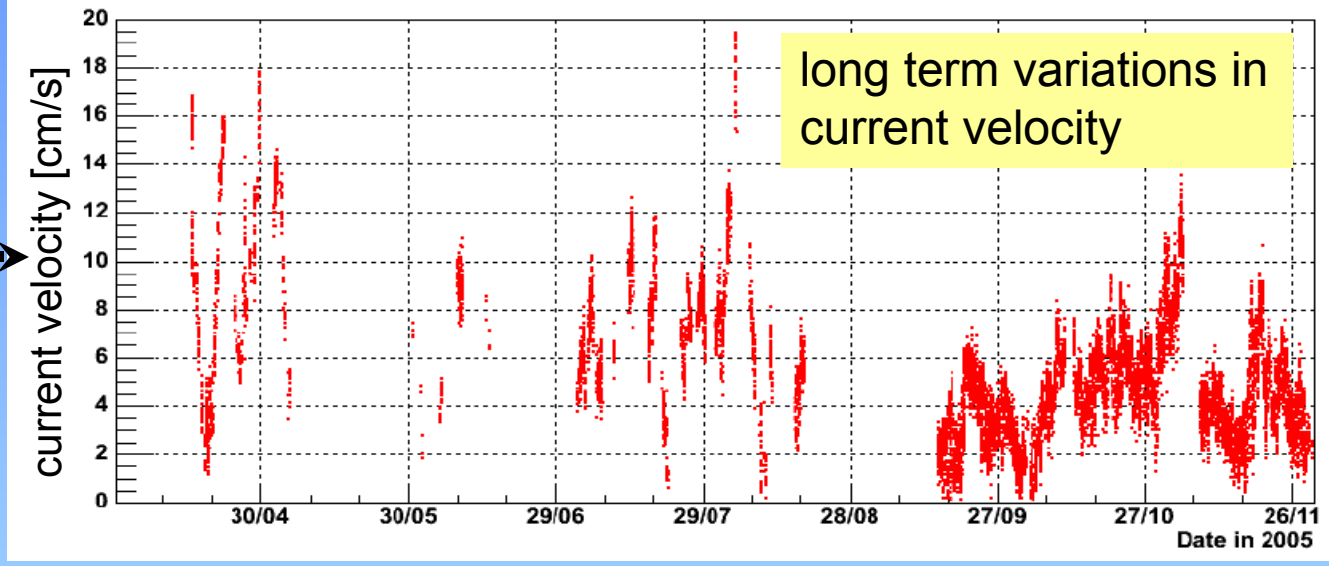


Coincidence rates in the MILOM vs time: ca. 15-20Hz and stable

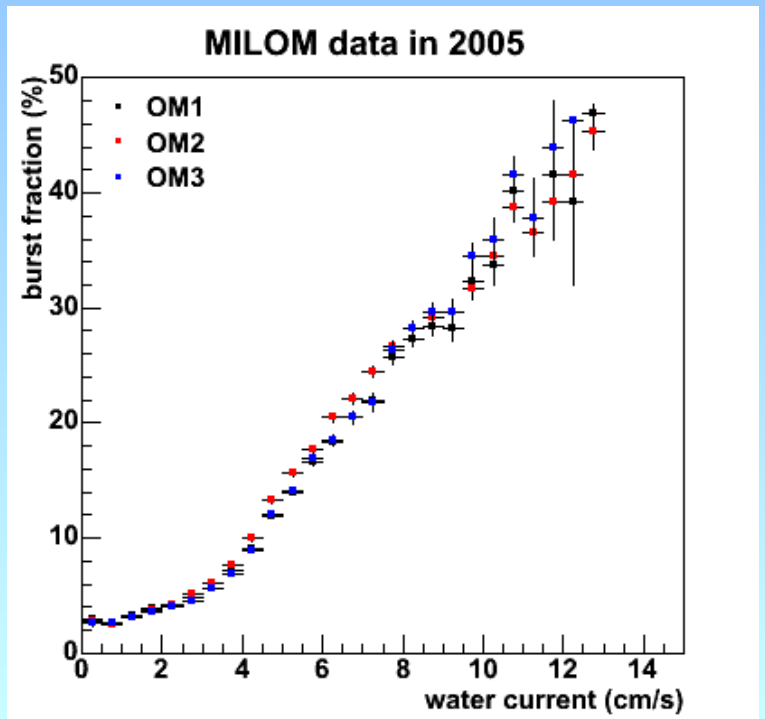
Correlation between Water Current and Bioluminescence

Acoustic Doppler Current Profiler (ADCP)

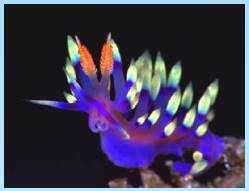




long term variations in current velocity

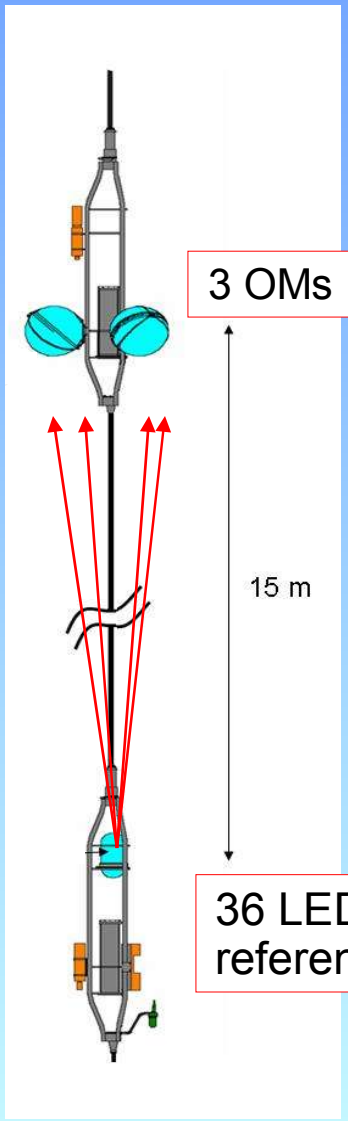


burst fraction vs. current velocity



strongly increased bioluminescence at high sea currents !

LED Beacon Measurements of OM Timing Resolution

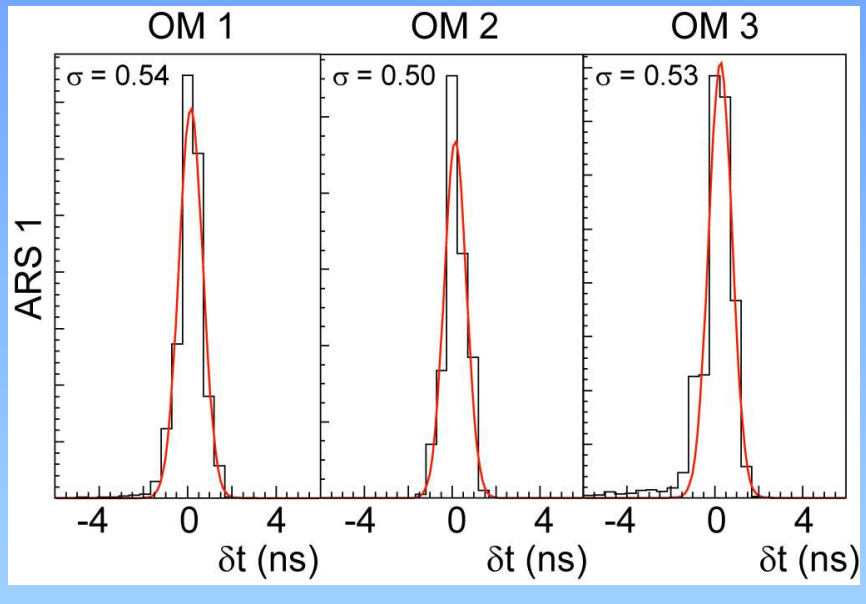


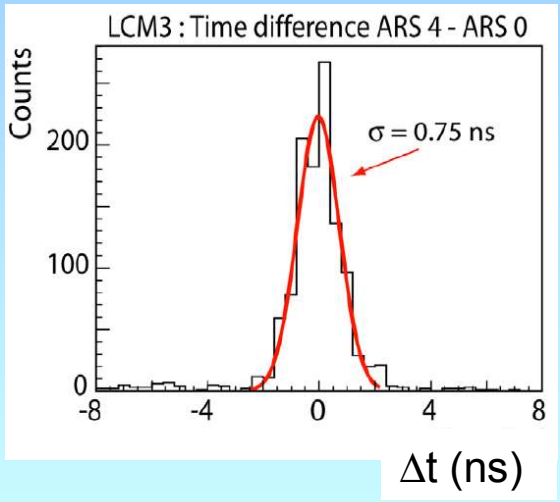
measure light from optical beacon within line (*known distance*)

⇒spread of photon arrival time

⇒absolute timing from reference PMT in beacon

arrival time spread wrt. to reference PMT



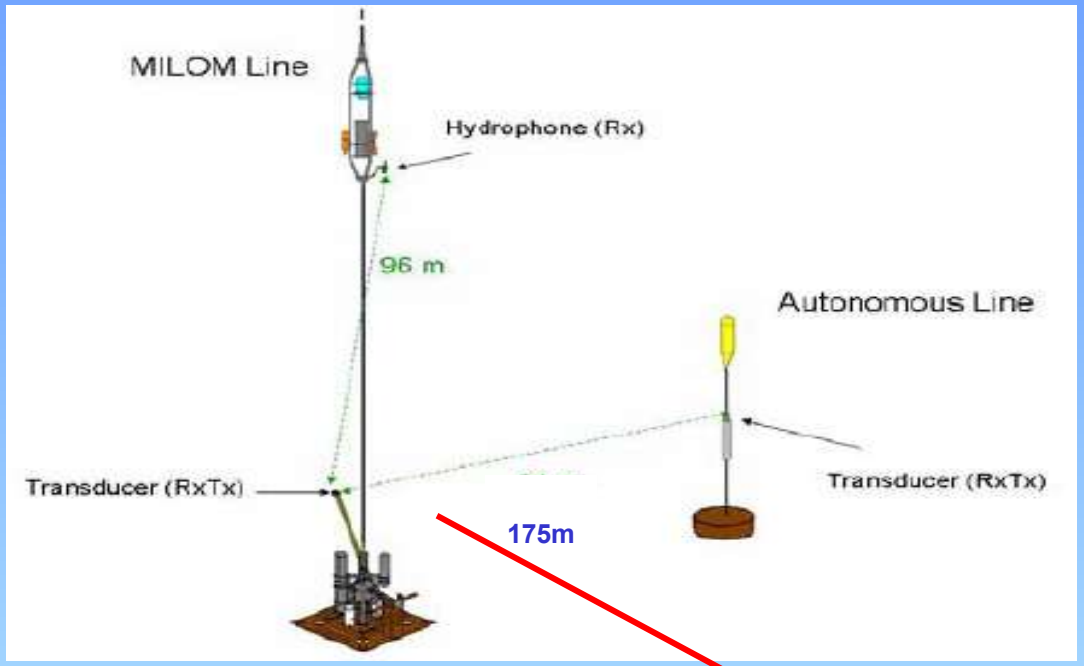


2 OMs in a storey:

σ ≈0.75 ns

⇒ timing resolution of PMT+electronics < 0.5ns

Test of Acoustic Positioning

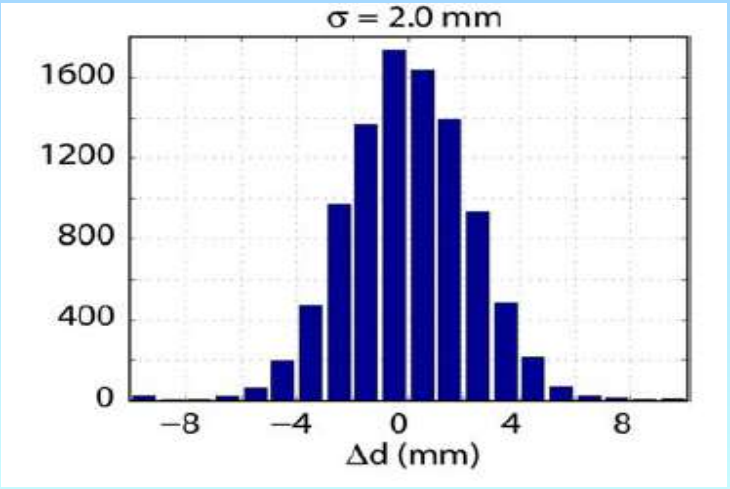


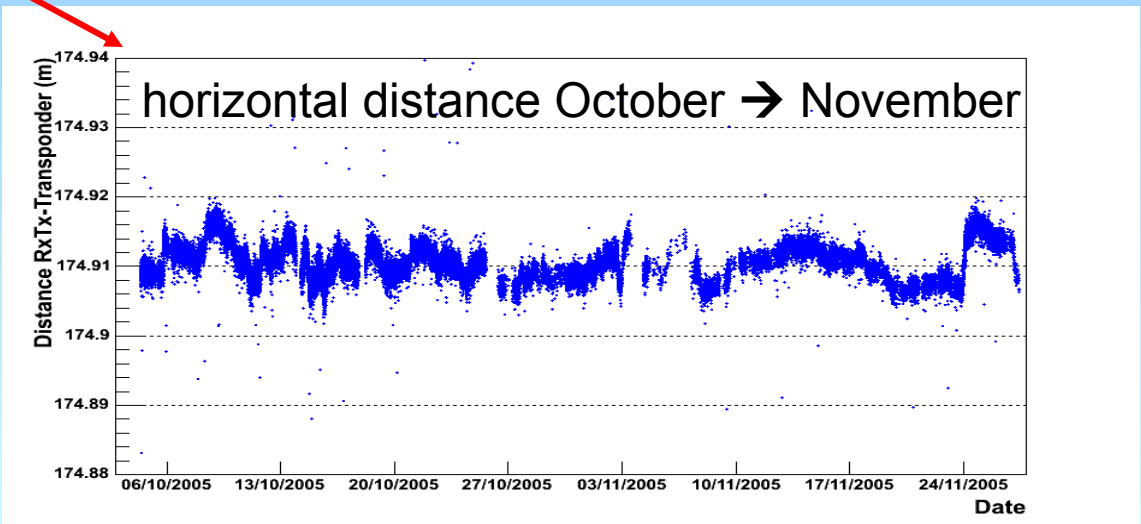
- Use autonomous acoustic transponders and RxTx transducer on base of MILOM to "reconstruct" position of MILOM anchor
- Monitor variation of this *fixed distance* → positioning resolution

$s_{vertical}$ ~ 2 mm

$s_{horiz.}$ ~ 3 mm

(requirement: < 10 cm)





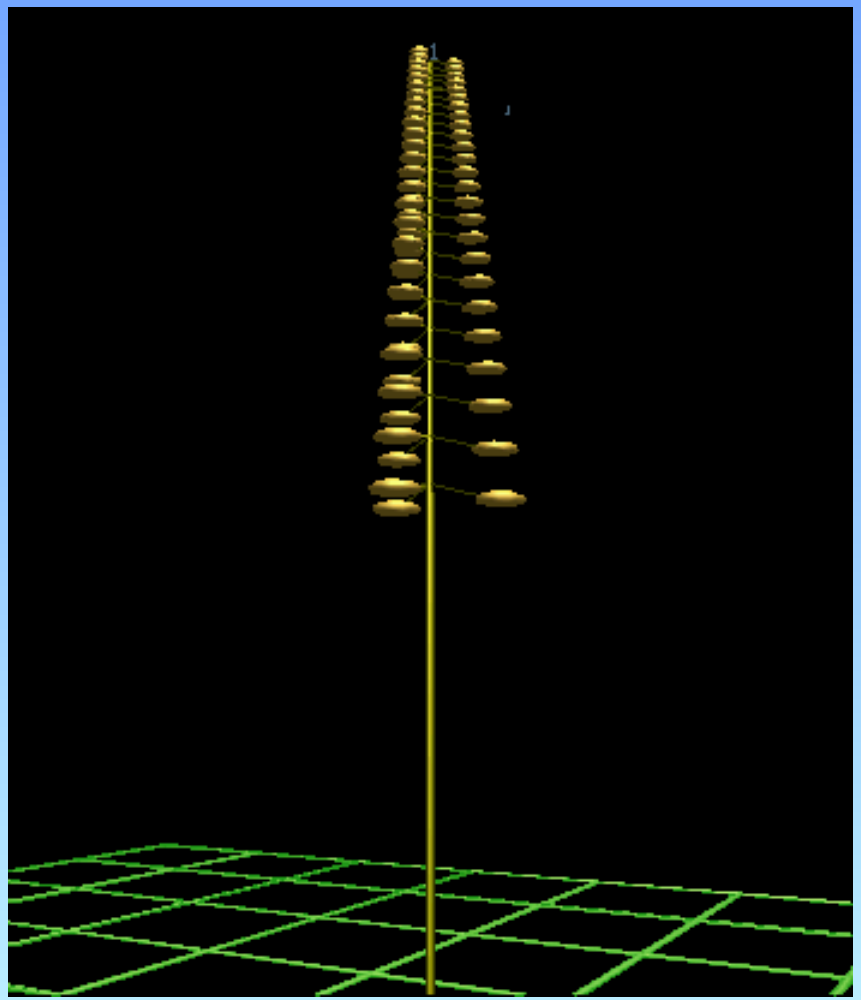
2006: Line 1

first complete detector line

- deployed on 14/02/2006
- connected on 2/03/2006
- full line = 25 storeys with photomultipliers

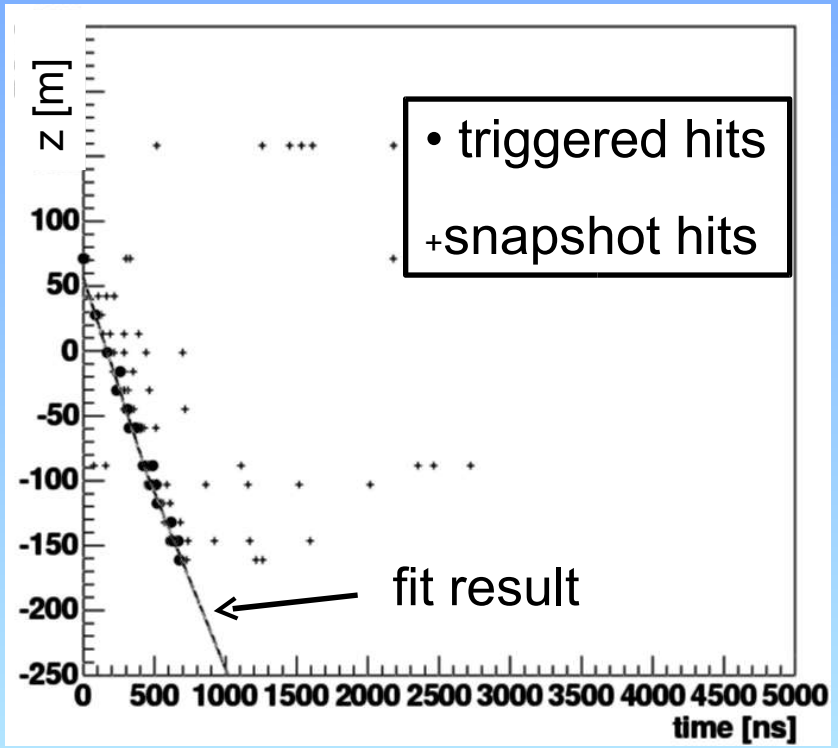
fully operational
=> first data !

First Muons from ANTARES ! (Line 1)



Event Display Aart Heijboer

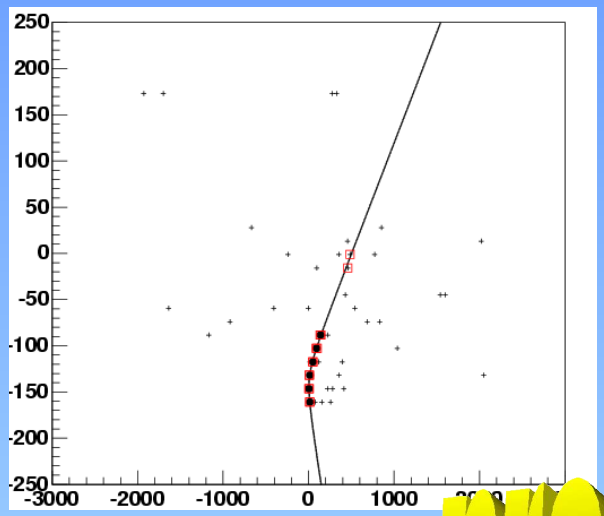
single string muon reconstruction



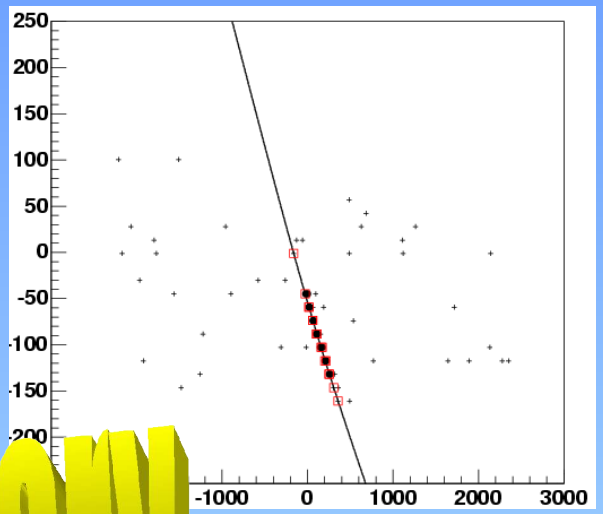
✓muon reconstruction working well

✓can start to look for neutrinos !

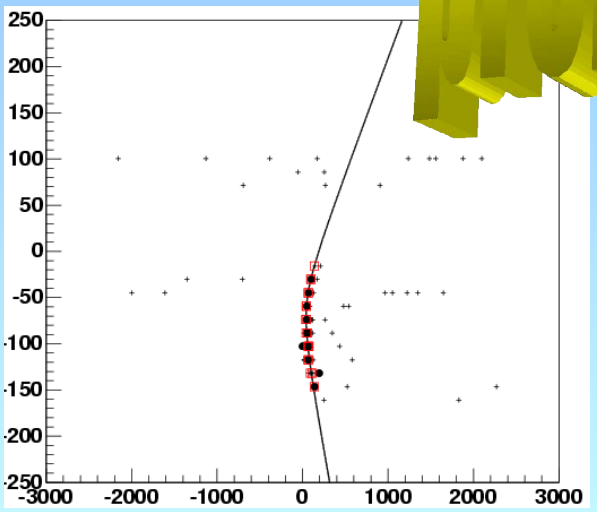
Many More Muons...



+



preliminary



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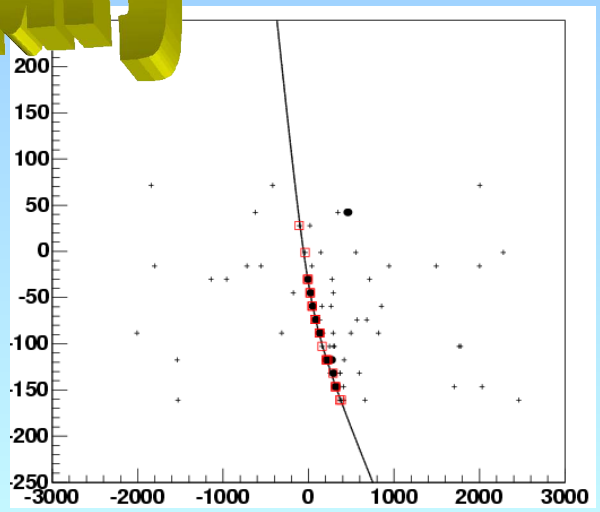
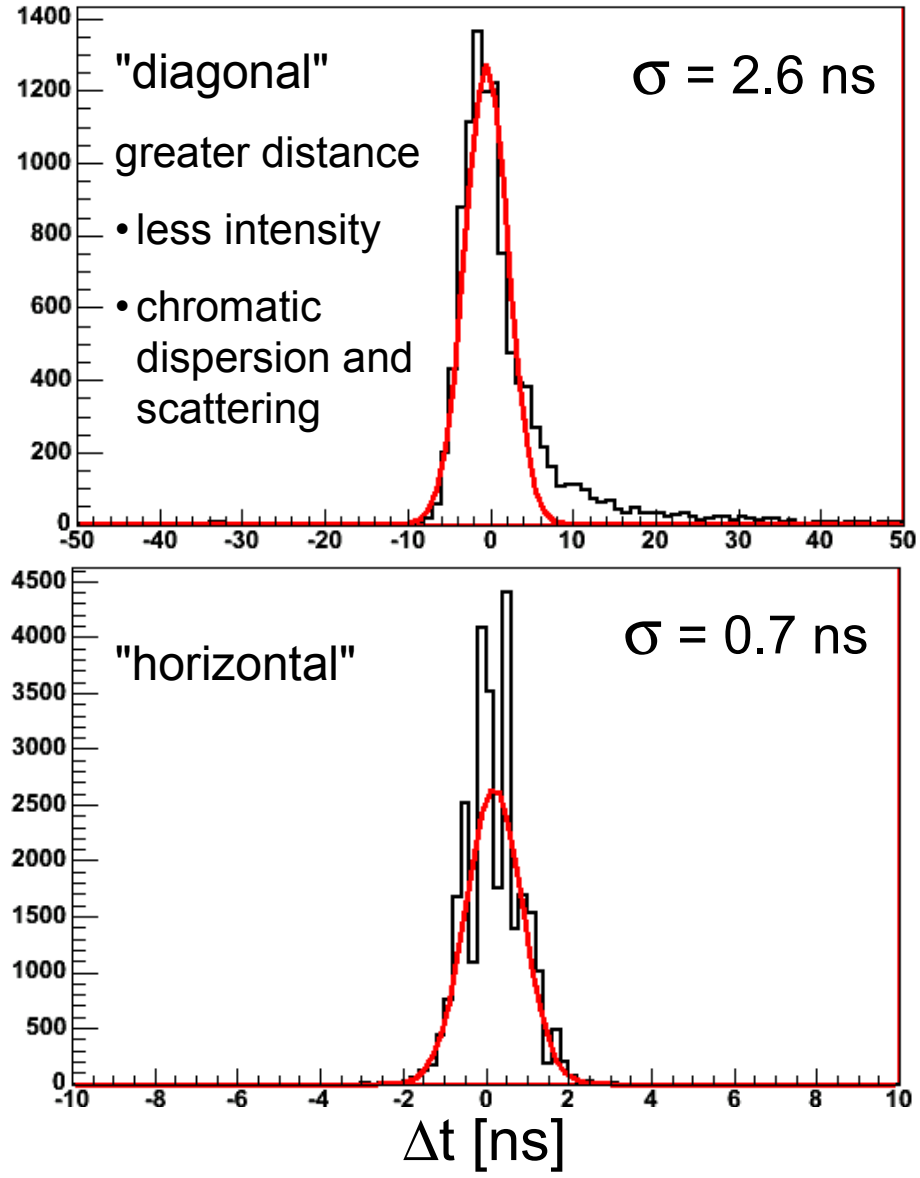
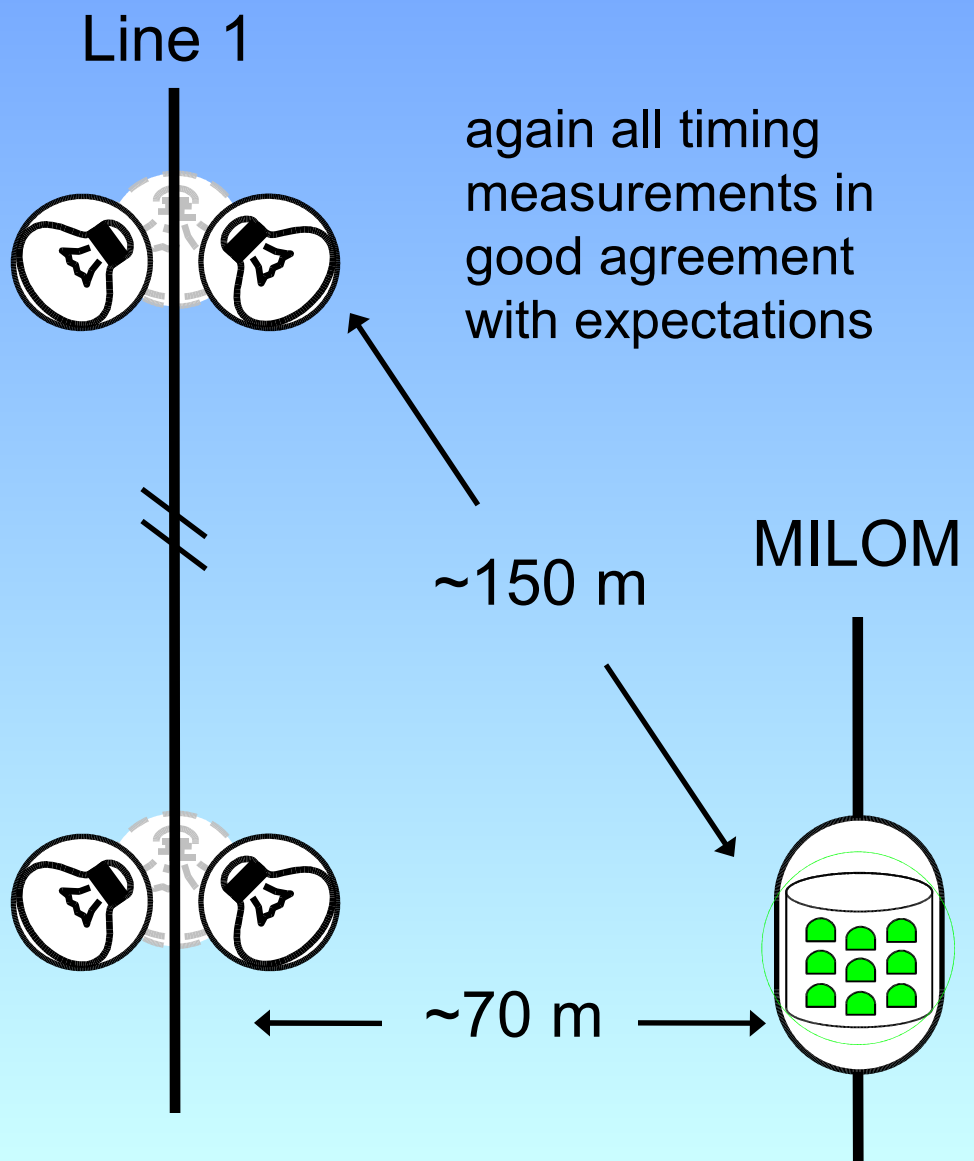


. . .

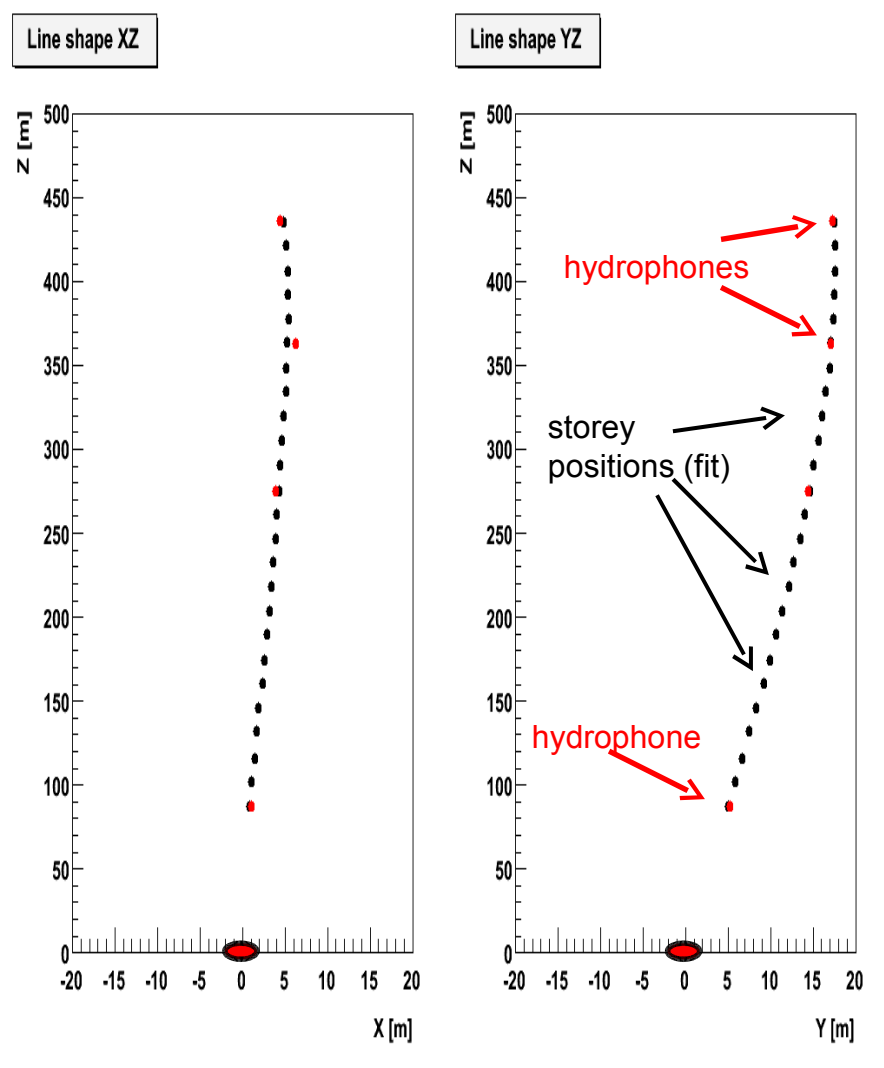
LED Beacon Time Calibration (L1+MILOM)

measure light from LED beacon on ***MILOM*** with PMTs on Line 1





Line Alignment



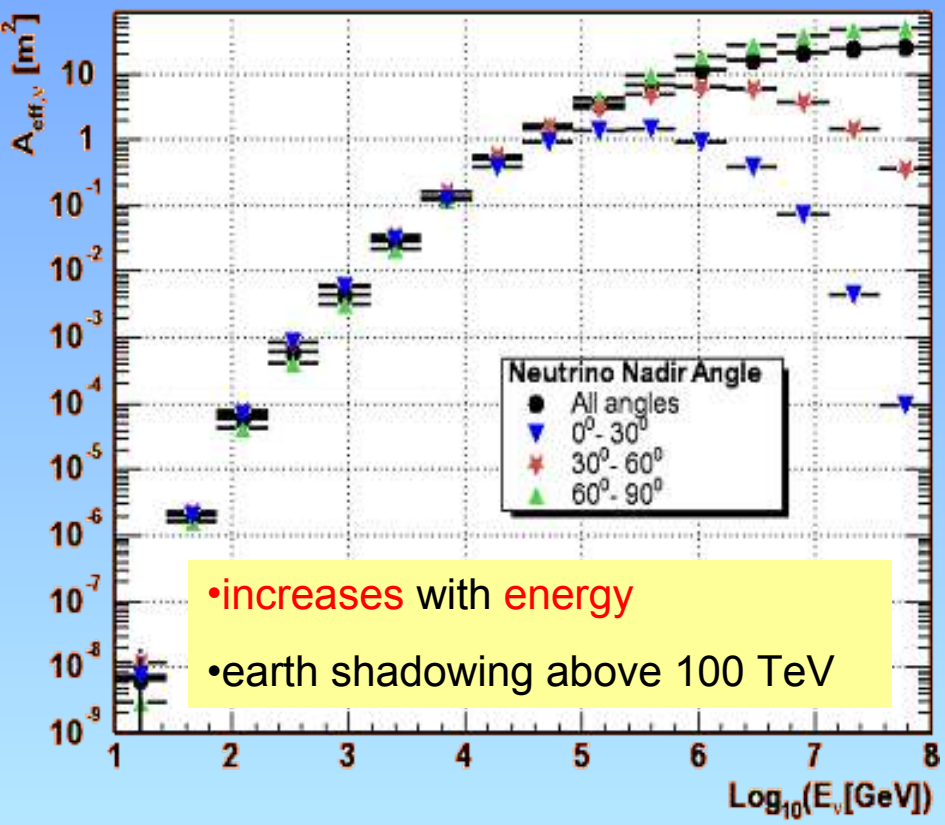
- from storey orientation and tilt (compass cards !) can fit line shape
- compare with results from acoustic positioning system

results:

- at high currents total displacement of top storeys ~20 m
- good agreement between line shape fit and acoustic positioning

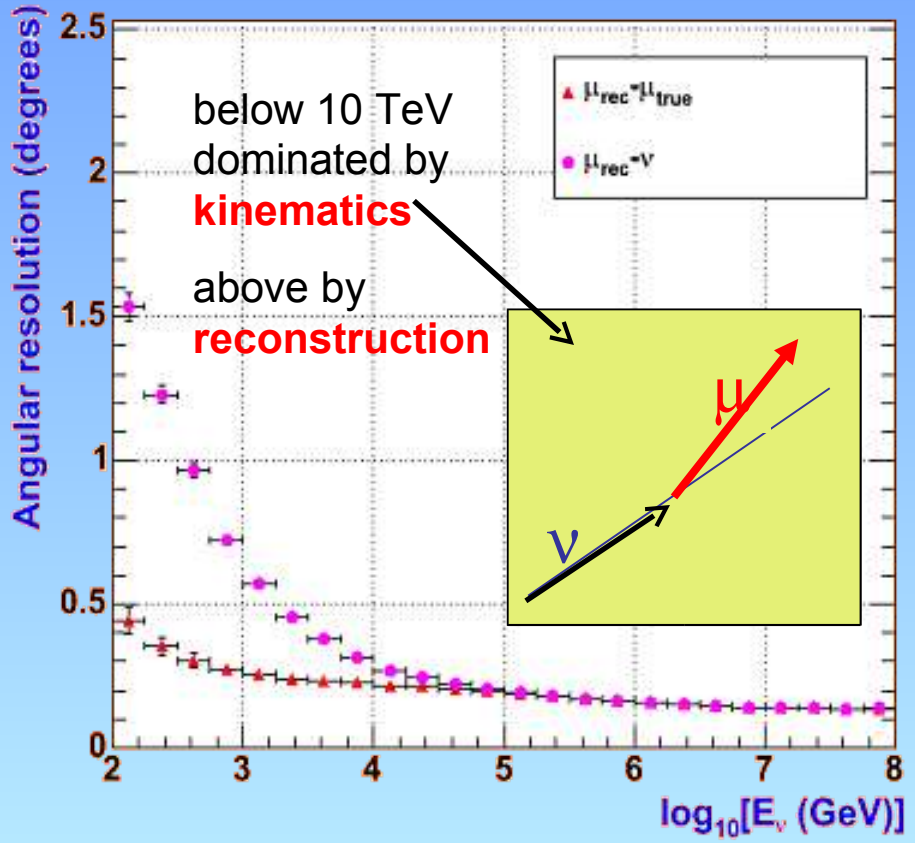
Expected Performance (MC Studies)

Effective Area (Neutrinos)



- increases with energy
- earth shadowing above 100 TeV

Angular Resolution

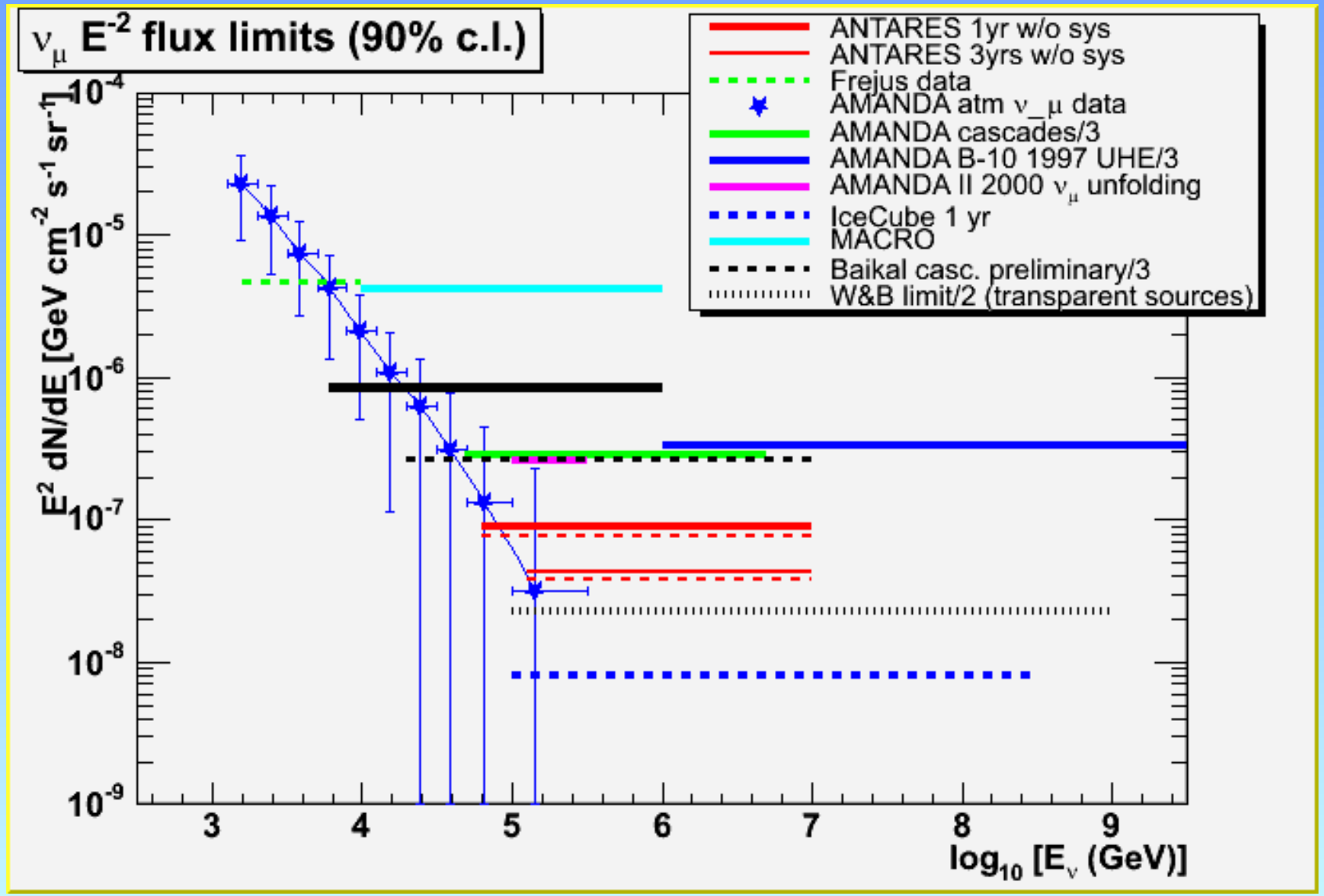


- angular resolution better than 0.3° above a few TeV
- expected energy resolution ≈factor 3
- also investigated: electromagnetic and hadronic shower reconstruction

Conclusions

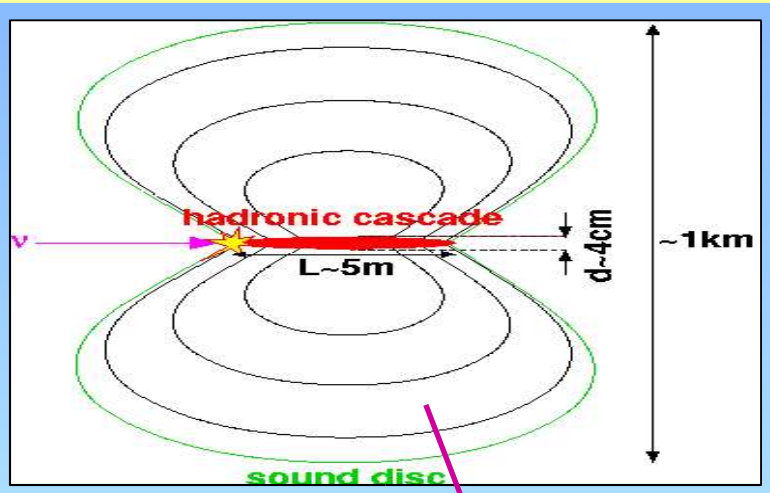
- Detector working within design specifications:
  - Junction box working since Dec. 2002
  - Two lines in operation on the site
  - Technical problems under control
- 12 lines complete end 2007
- Operation for science ≥ 5 years

Expected sensitivity for diffuse fluxes



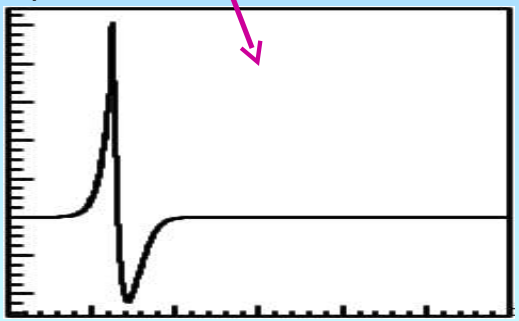
Acoustic Sensors for ANTARES (Erlangen)

- thermoacoustic effect (Askariyan): hadronic cascade heats water => expansion => sound pulse
- range: up to several km
- threshold ≥ 10^{17} eV ?



p (a.u.)

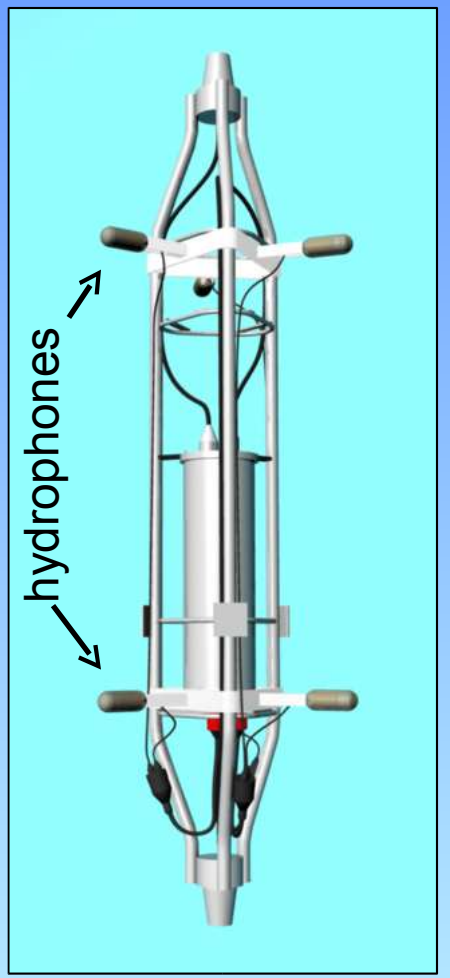
bipolar pressure signal (simulation):



Aim at Erlangen:

equip several ANTARES storeys with hydrophones to measure acoustic background and do studies for much larger, dedicated acoustic detector

principle already tested in an autonomous system "AMADEUS" (spring/summer '05)



sketch of modified ANTARES storey with 6 hydrophones