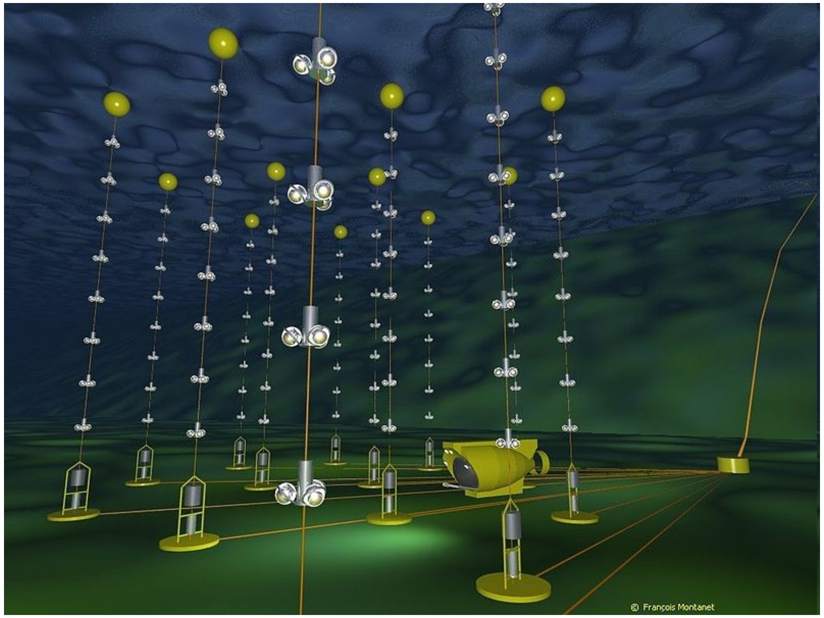
Status and first results of the ANTARES neutrino telescope

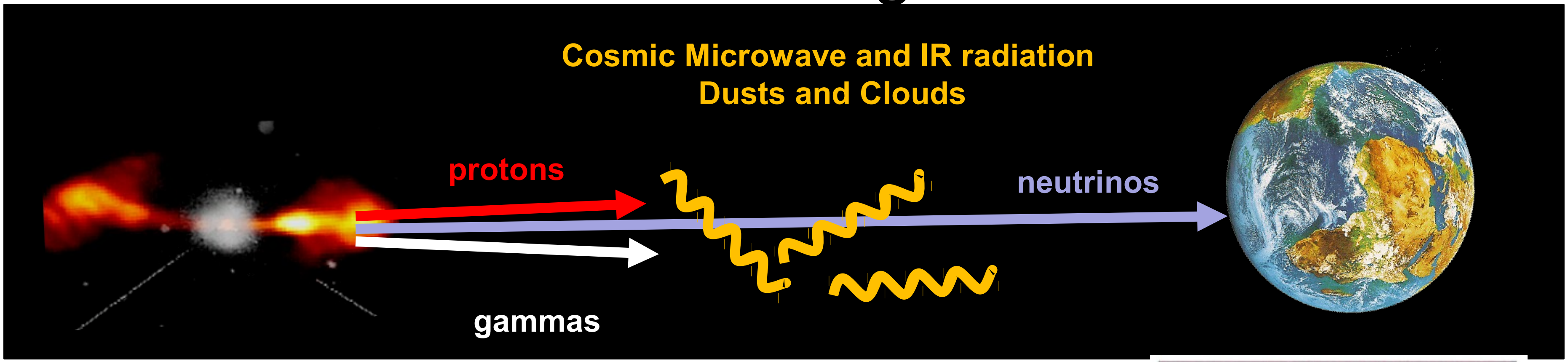
- research goals
- the detector setup
- status and performance
- first results

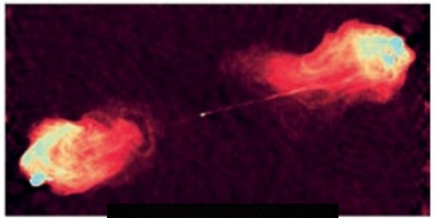
summary

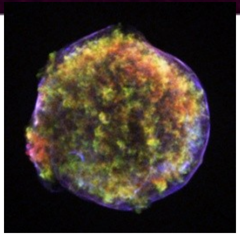


Heide Costantini
INFN, Genova, Italy

Research goals







cosmic sources of neutrinos

- Active Galactic Nuclei: super-massive black hole in center of galaxies
- micro quasars: X-ray binaries (in our galaxy)
- supernova remnants and shock acceleration

$p/A + p/\gamma \rightarrow$

$\pi^{\pm} \quad + \quad \pi^{0} + \ldots$

$\downarrow \qquad \downarrow$

$\nu_{\mu} \; \mu \qquad \gamma \; \gamma$

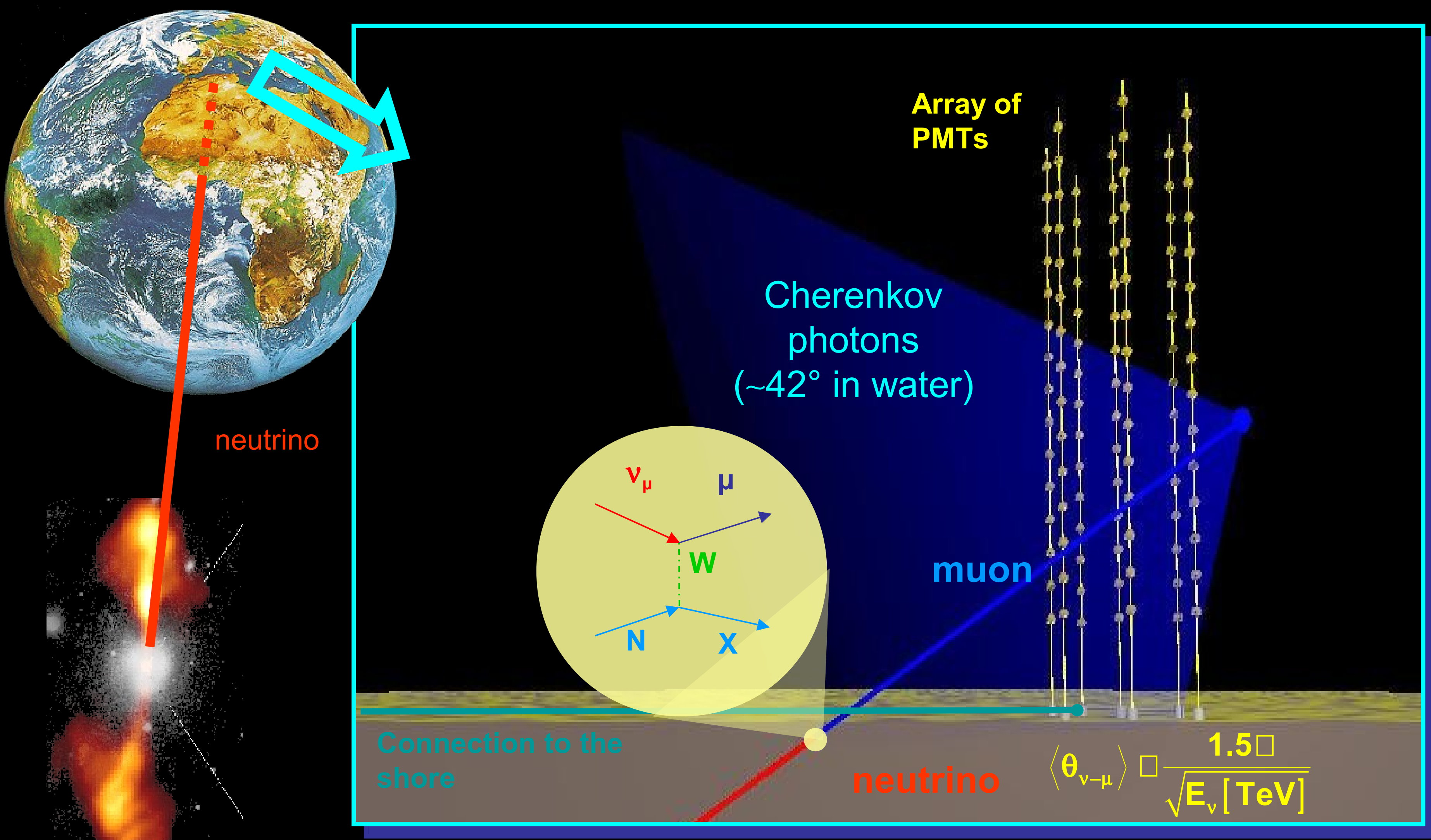
$\downarrow$

$\nu_{\mu} \; \nu_{e} \; e$

intriguing science questions:

- origin of cosmic rays
- astrophysical acceleration mechanism
- origin of relativistic jets

Detection principle



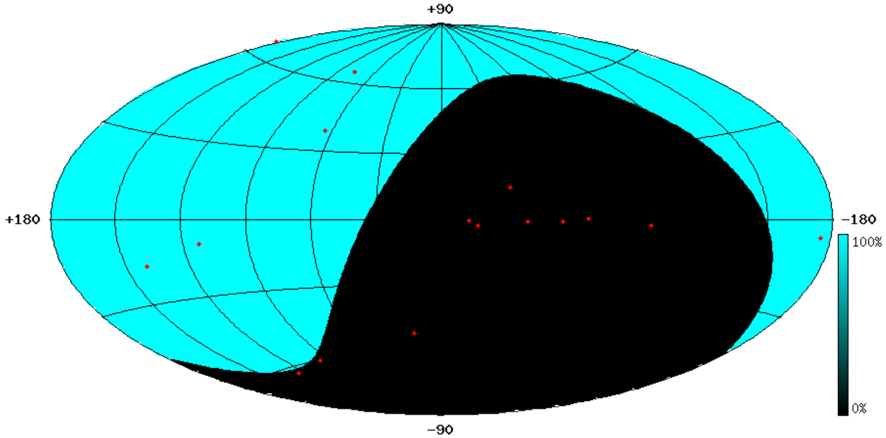
- Main detection channel: ν_μ interaction giving an ultrarelativistic μ
- Energy threshold ~ 10 GeV

The ANTARES site

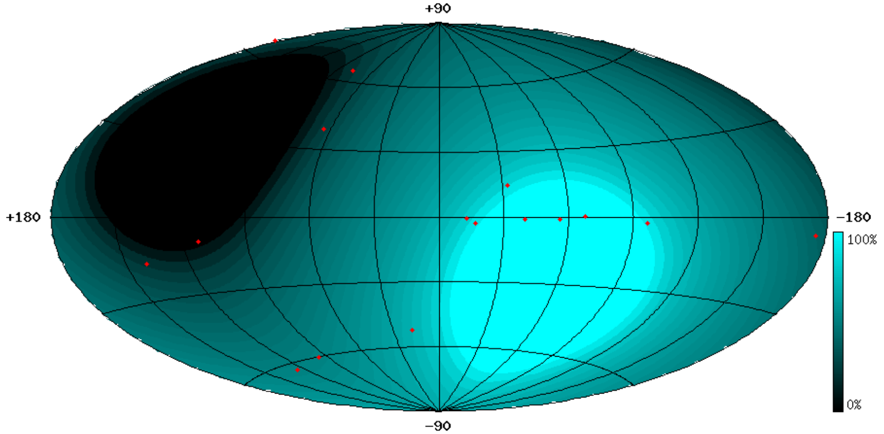
- 42°50’ latitude Nord
- 6°10’ longitude Est

The Galactic center is visible 75% of the day

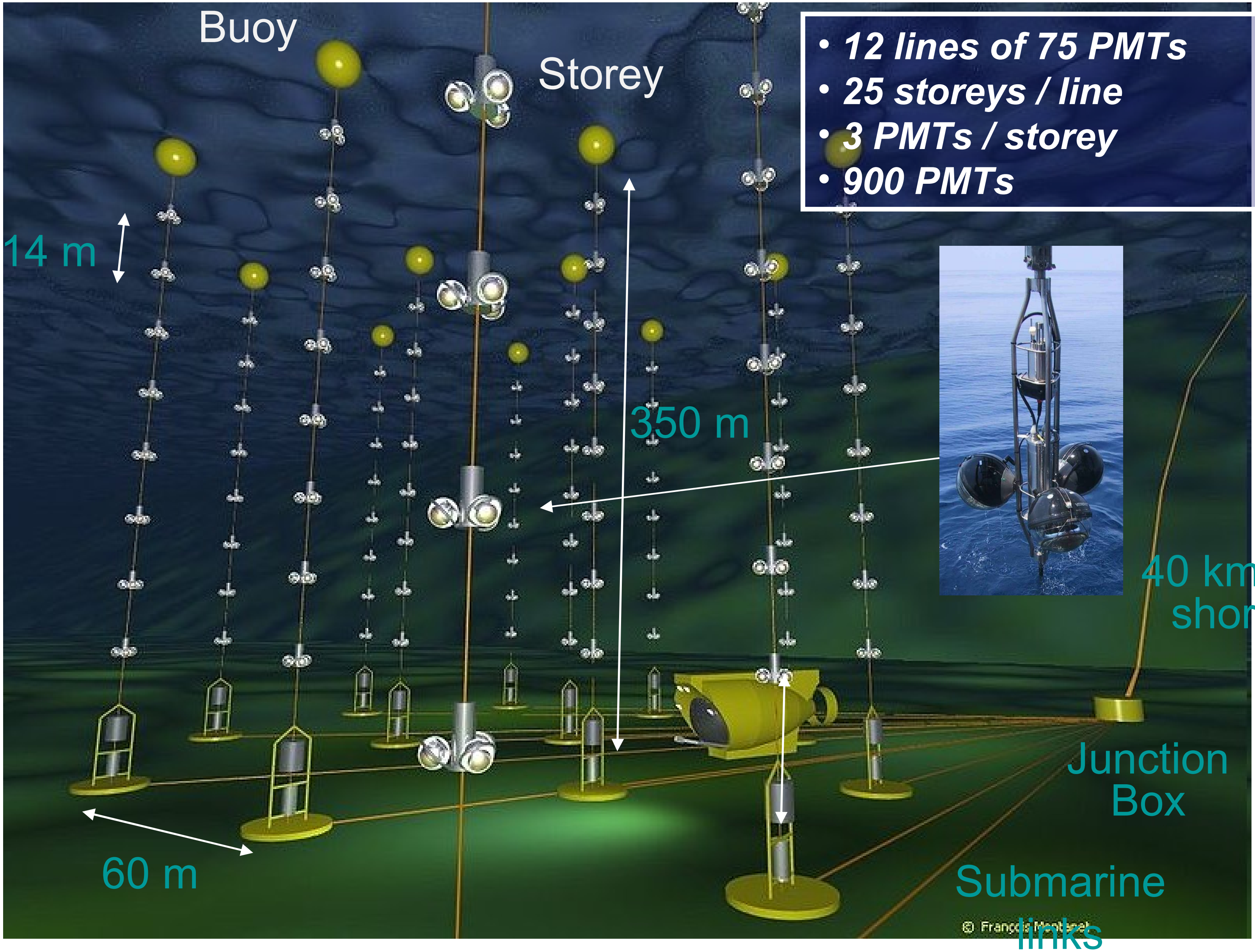
AMANDA/IceCube (South Pole)



ANTARES

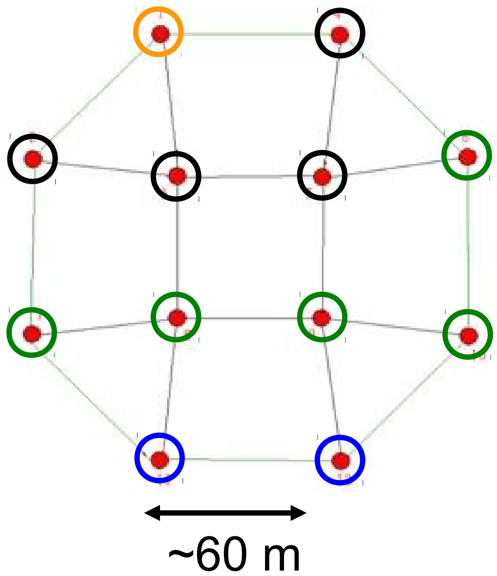


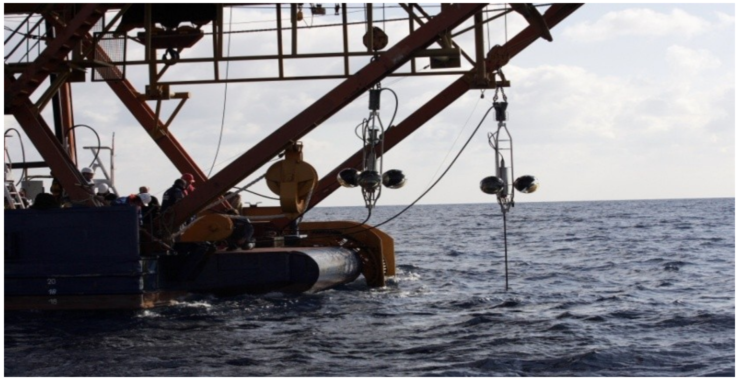
The ANTARES detector



- *12 lines of 75 PMTs*
- *25 storeys / line*
- *3 PMTs / storey*
- *900 PMTs*

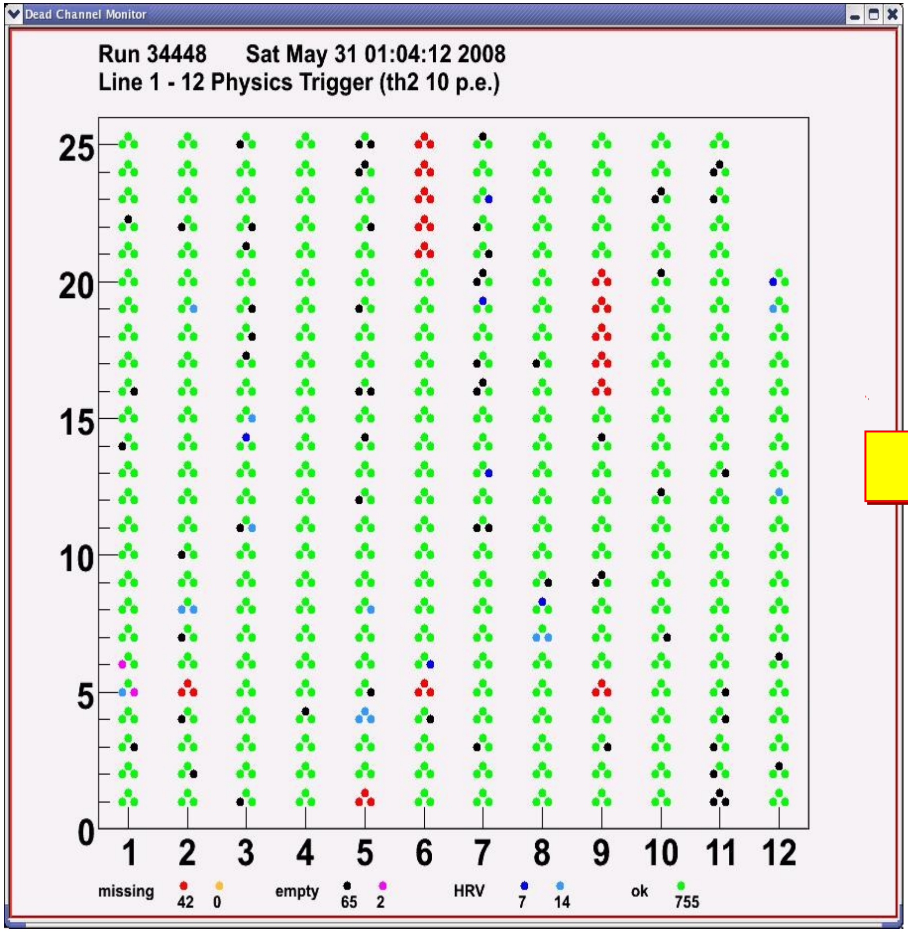
2006 – 2008: deployments of the detector lines

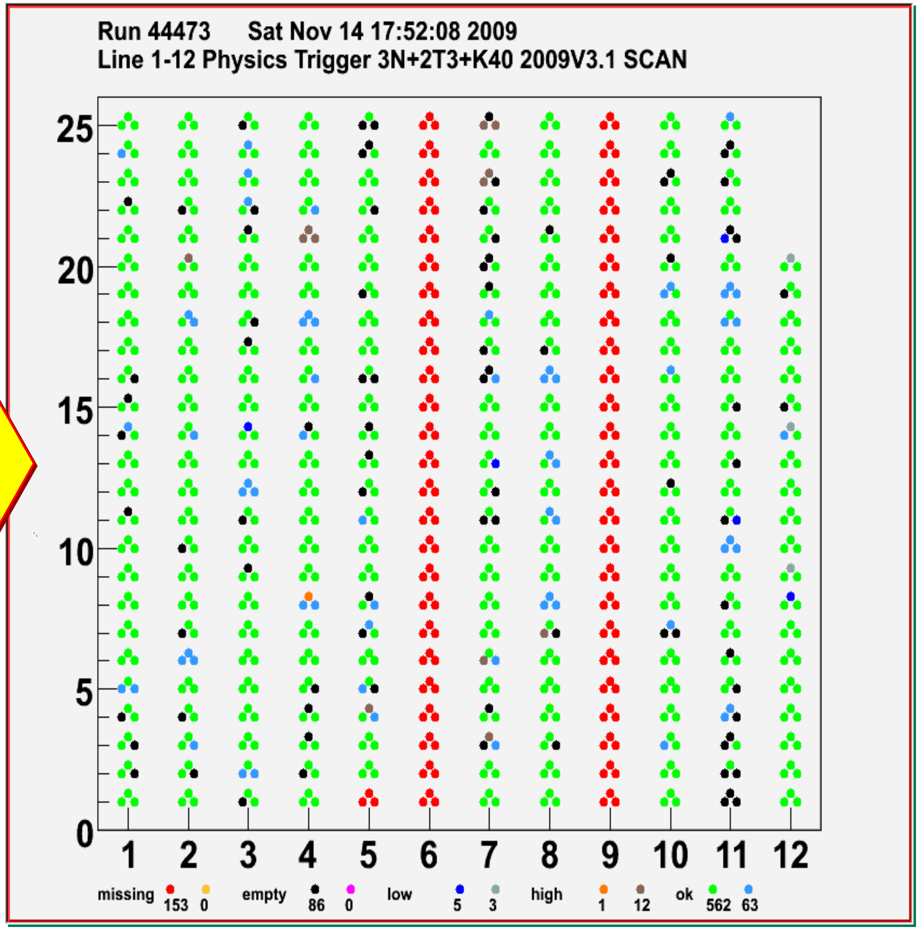




- **Line 1**: 03 / 2006
- **Line 2, 3, 4, 5**: 01 / 2007
- **Line 6, 7, 8, 9, 10**: 12 / 2007
- **Line 11, 12**: 05 / 2008

Status of the apparatus





At end of construction

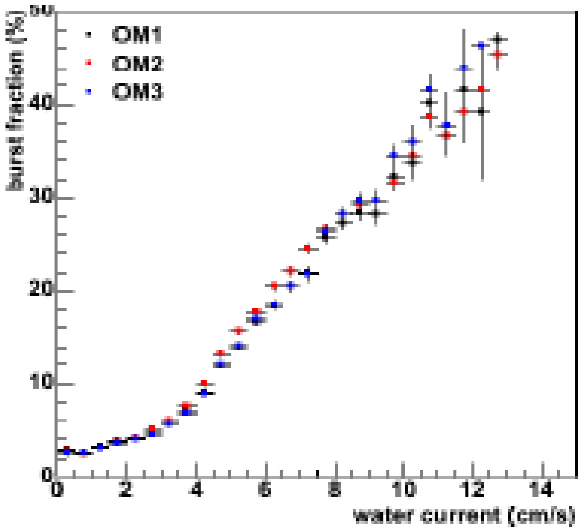
- **~90% of optical modules operational**

Regular maintenance of in-situ infrastructure

Today

- **Line 6 recovered, Line 9 planned to be recovered**
- **Line 12 repaired and reconnected**

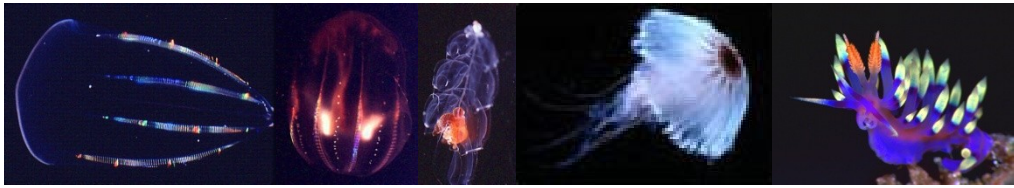
The sea: optical background

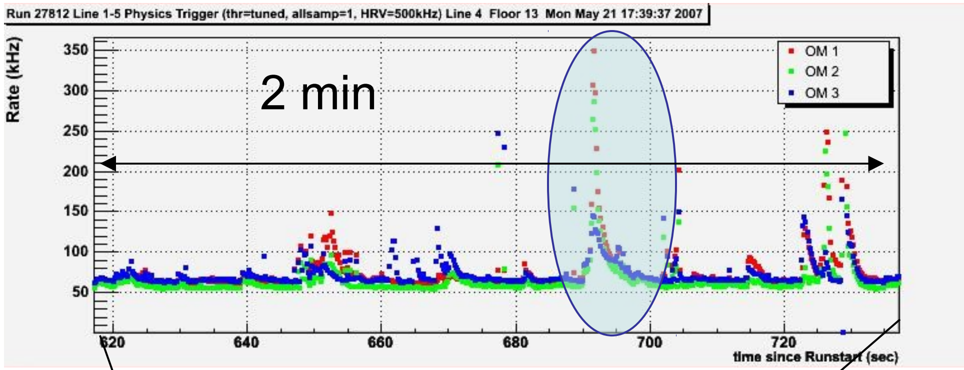


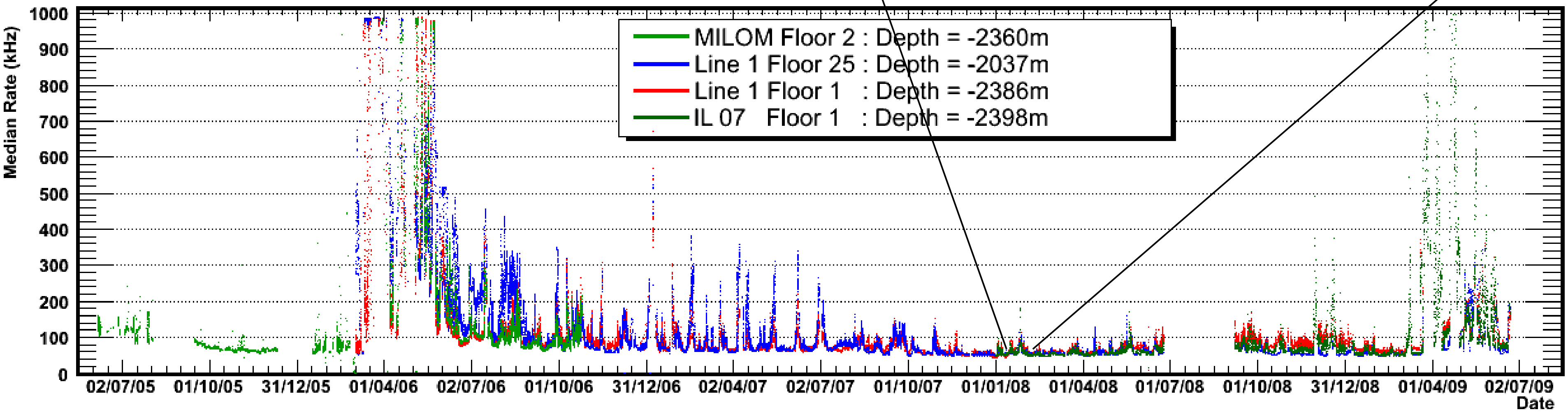
Mean rate~ 70 kHz

↓

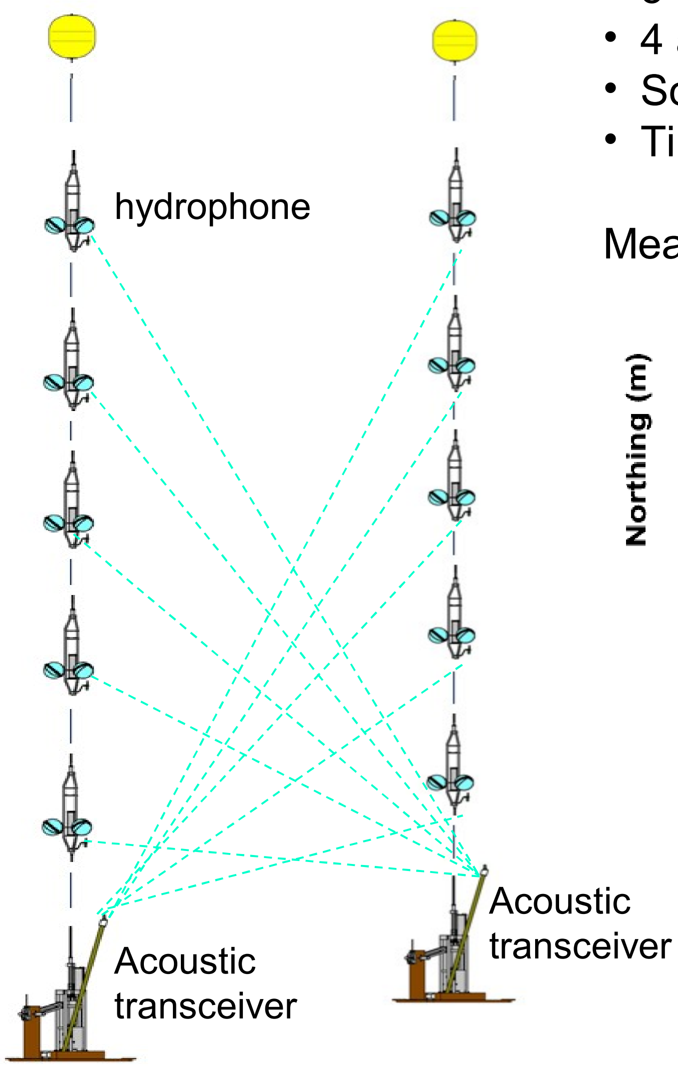
40 kHz (^{40}K)+30 KHz (bioluminescence)





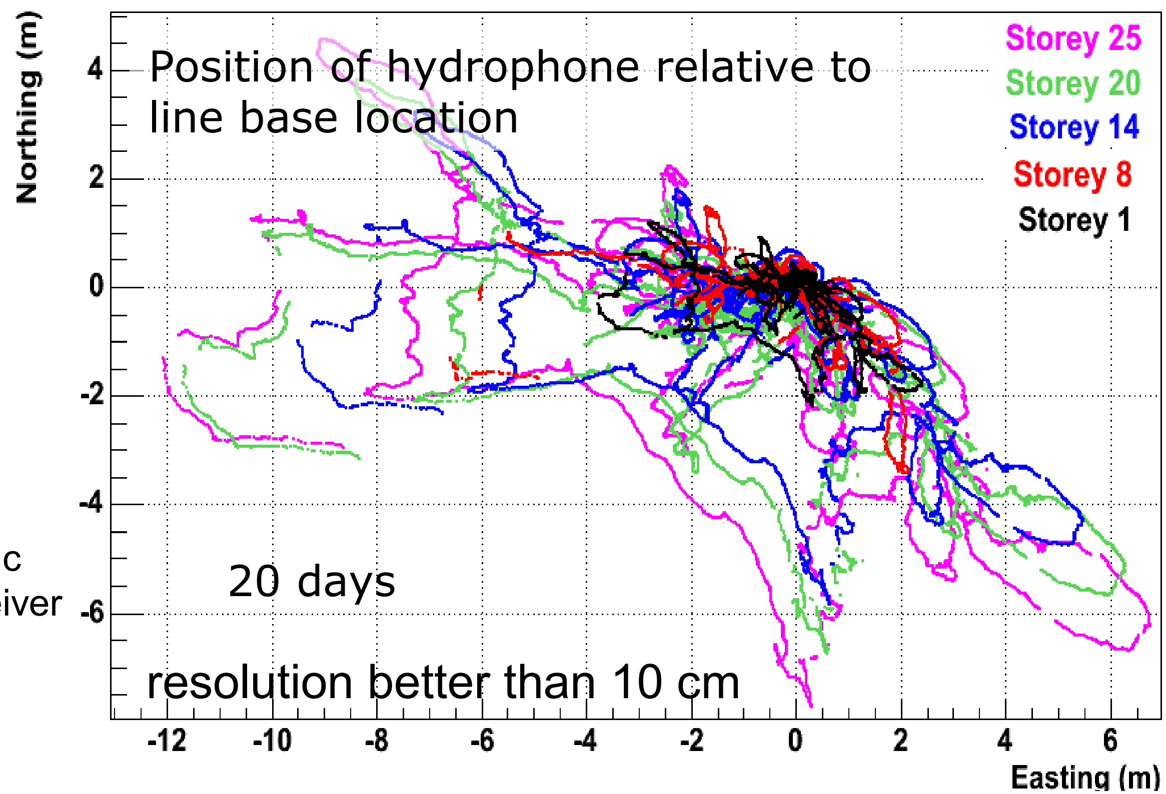


Calibration: detector acoustic positioning

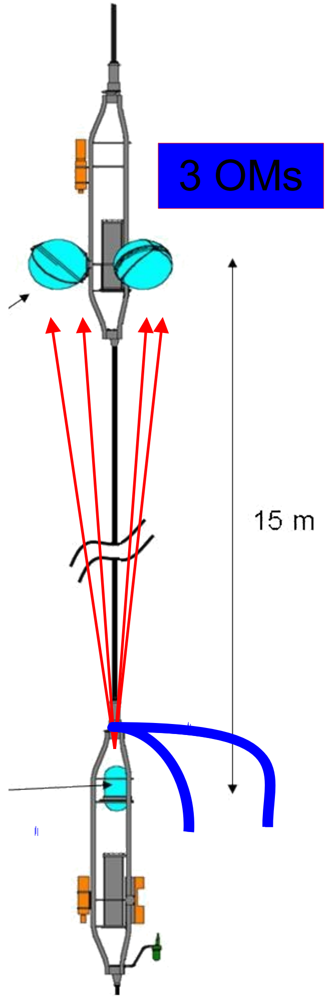


- Transceivers on the bottom of each line
- 5 hydrophones at specific heights on each line
- 4 autonomous transponders around the apparatus
- Sound velocimeters installed at various depths
- Tiltmeter and compass at each storey

Measurements performed every 2 minutes

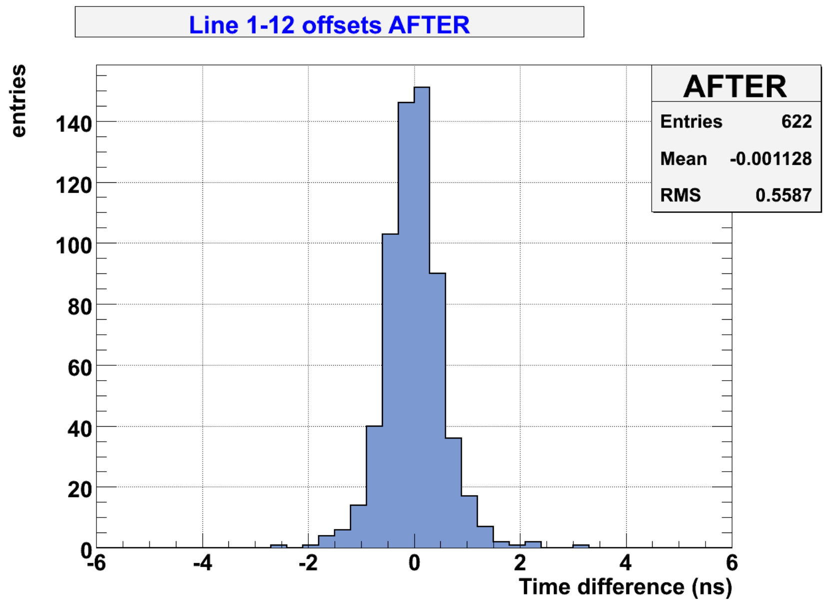


Calibration: timing and PMT resolution



Optical LED beacon

Time of signal in OMs relative to reference PMT for optical beacon flashes



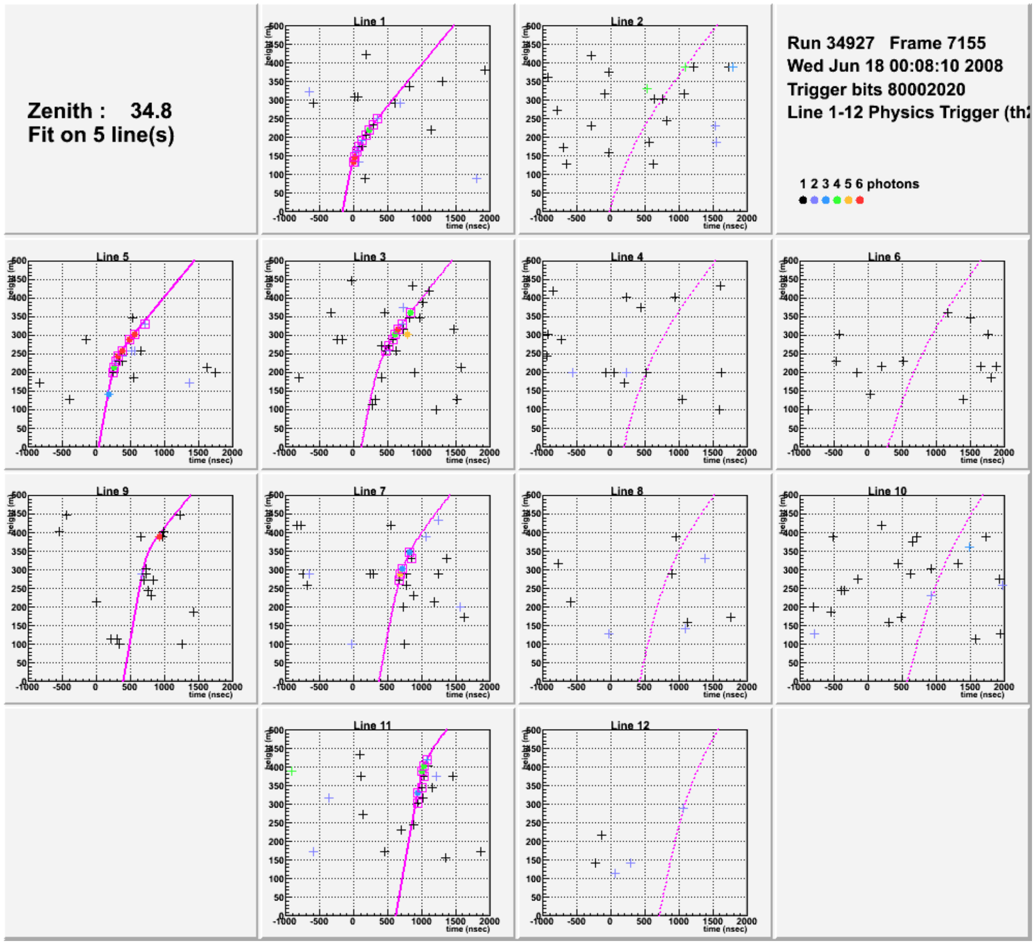
- **Electronics + calibration → σ ~ 0.5 ns**
- **TTS in photomultipliers → σ ~ 1.3 ns**
- **Light scattering + dispersion in sea water → σ ~ 2 ns**

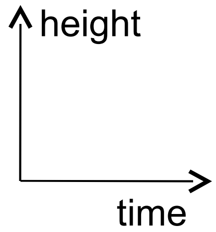
Angular resolution → 0.3° (above few TeV)

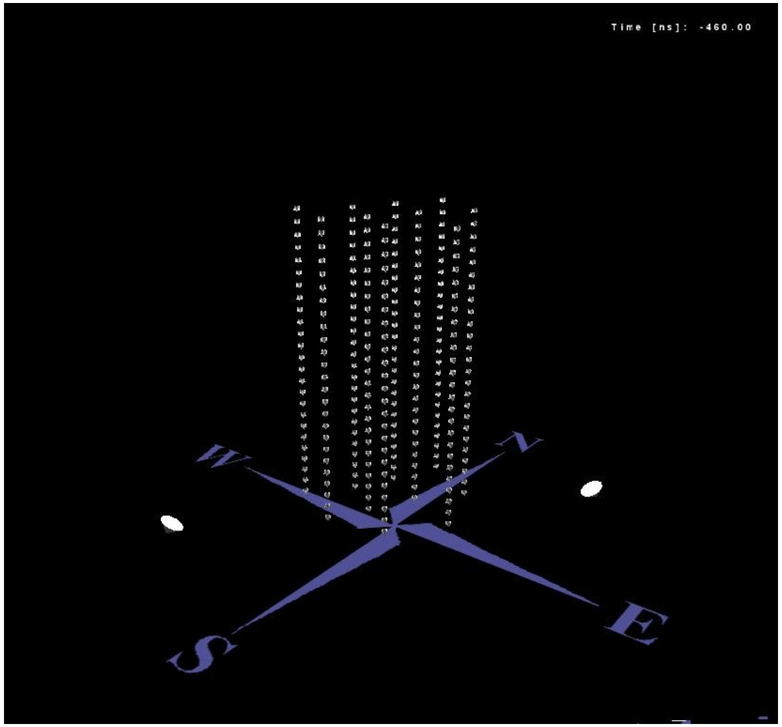
Including the acoustic position resolution and the ν-μ angle

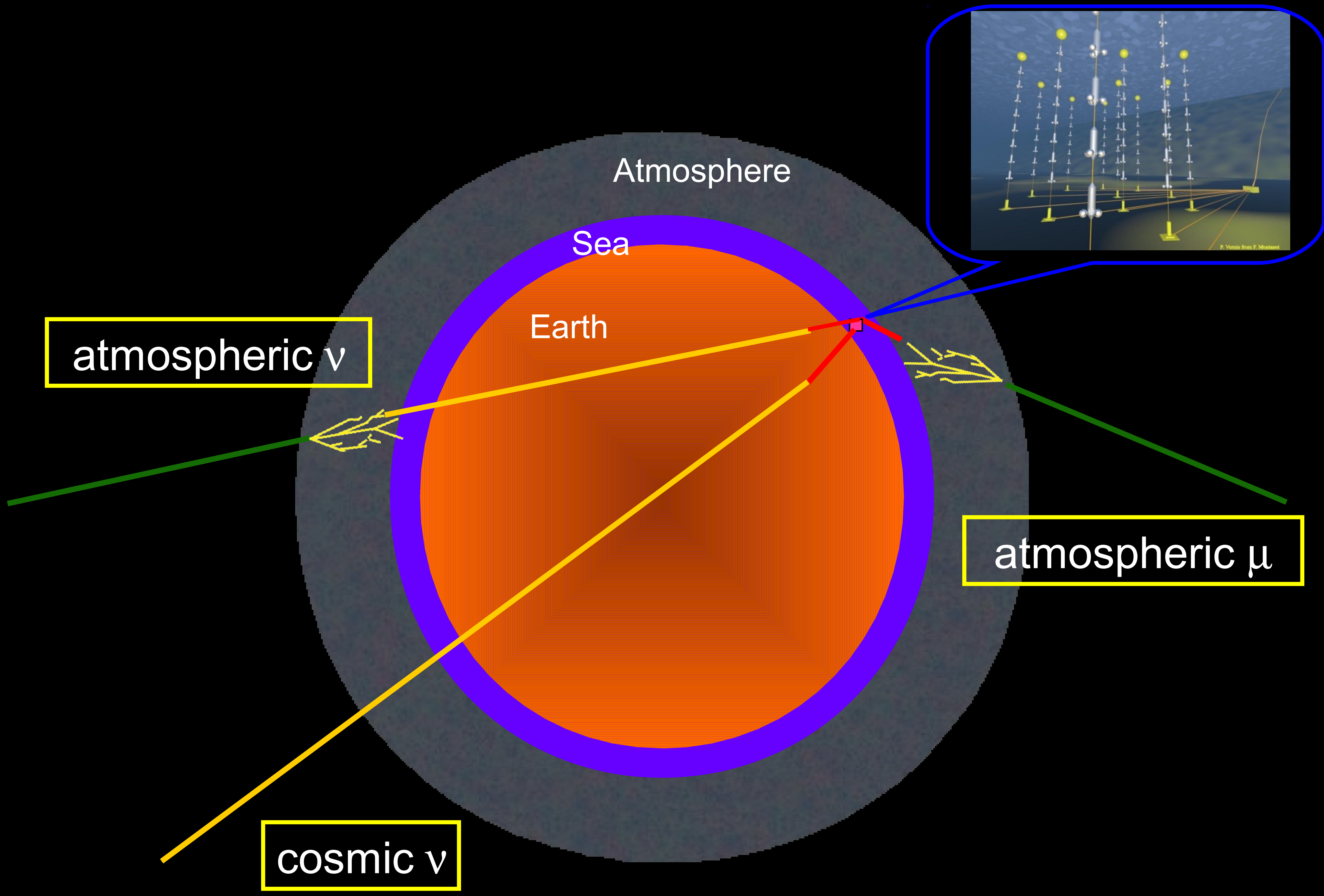
up-going muon: neutrino candidate

reconstruction of muon trajectory from **time, charge and position** of PMT hits assuming relativistic muons emitting **Cherenkov light**

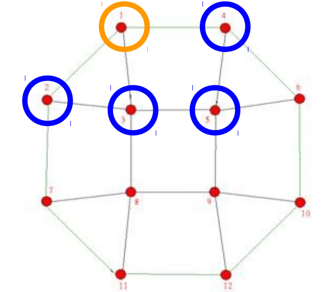


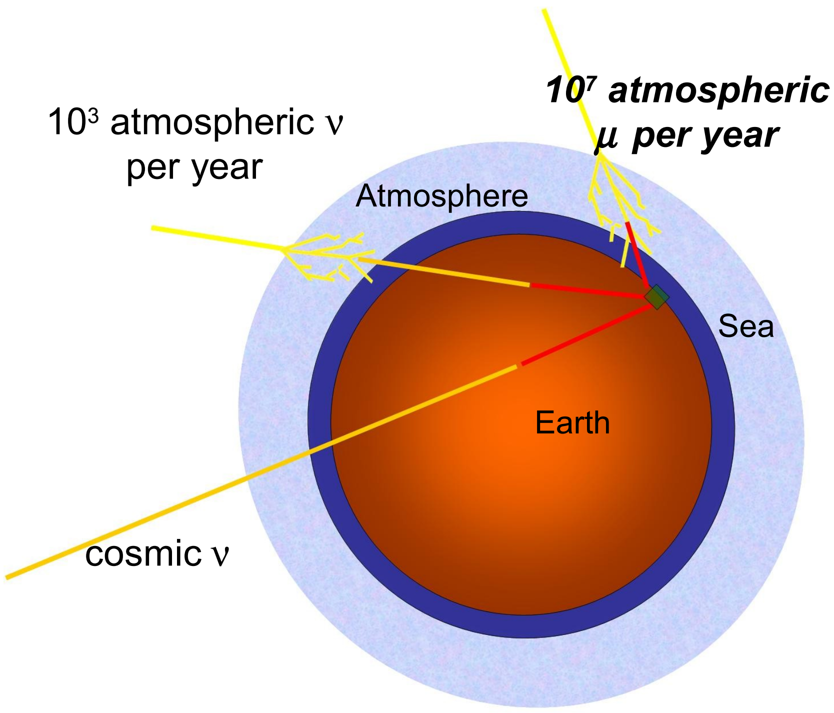


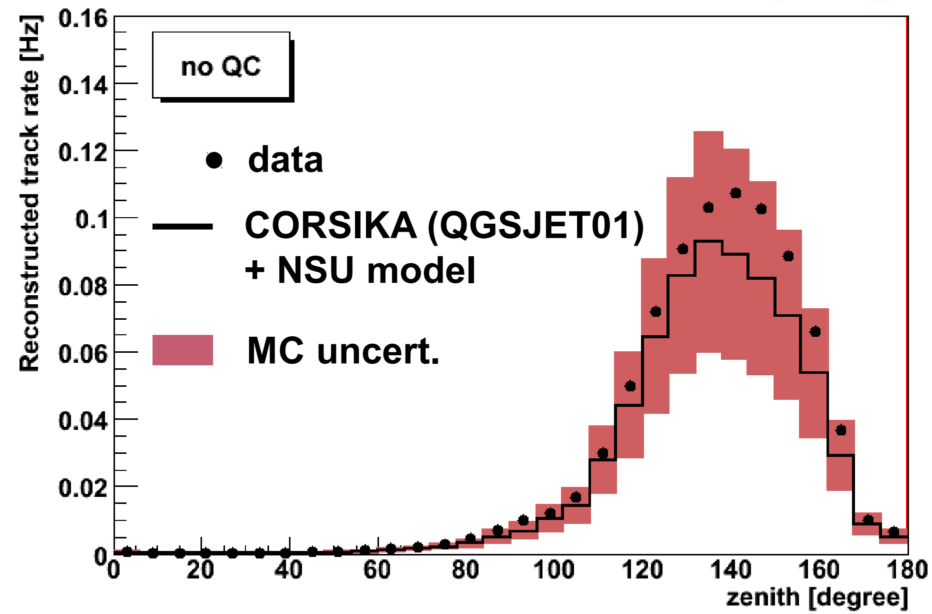



Atmosphere
Sea
Earth
atmospheric ν
atmospheric μ
cosmic ν

Analysis: Atmospheric muons

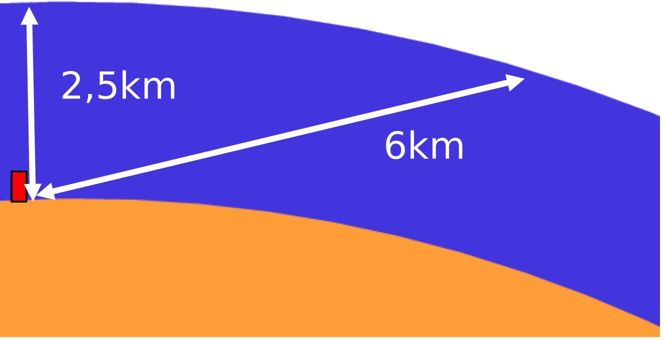


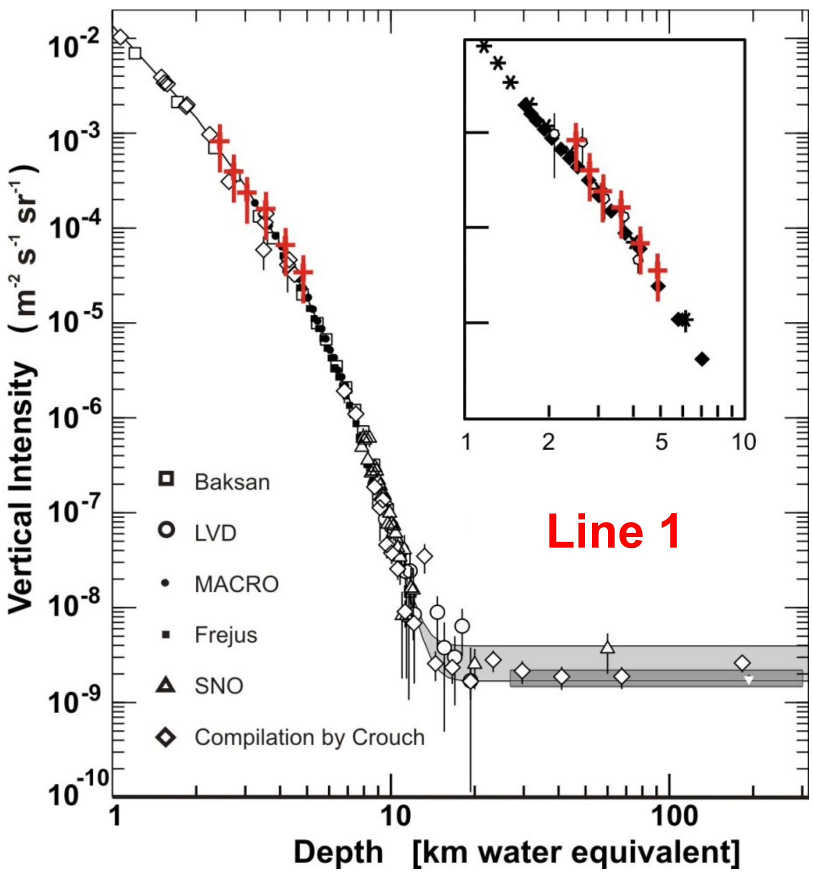


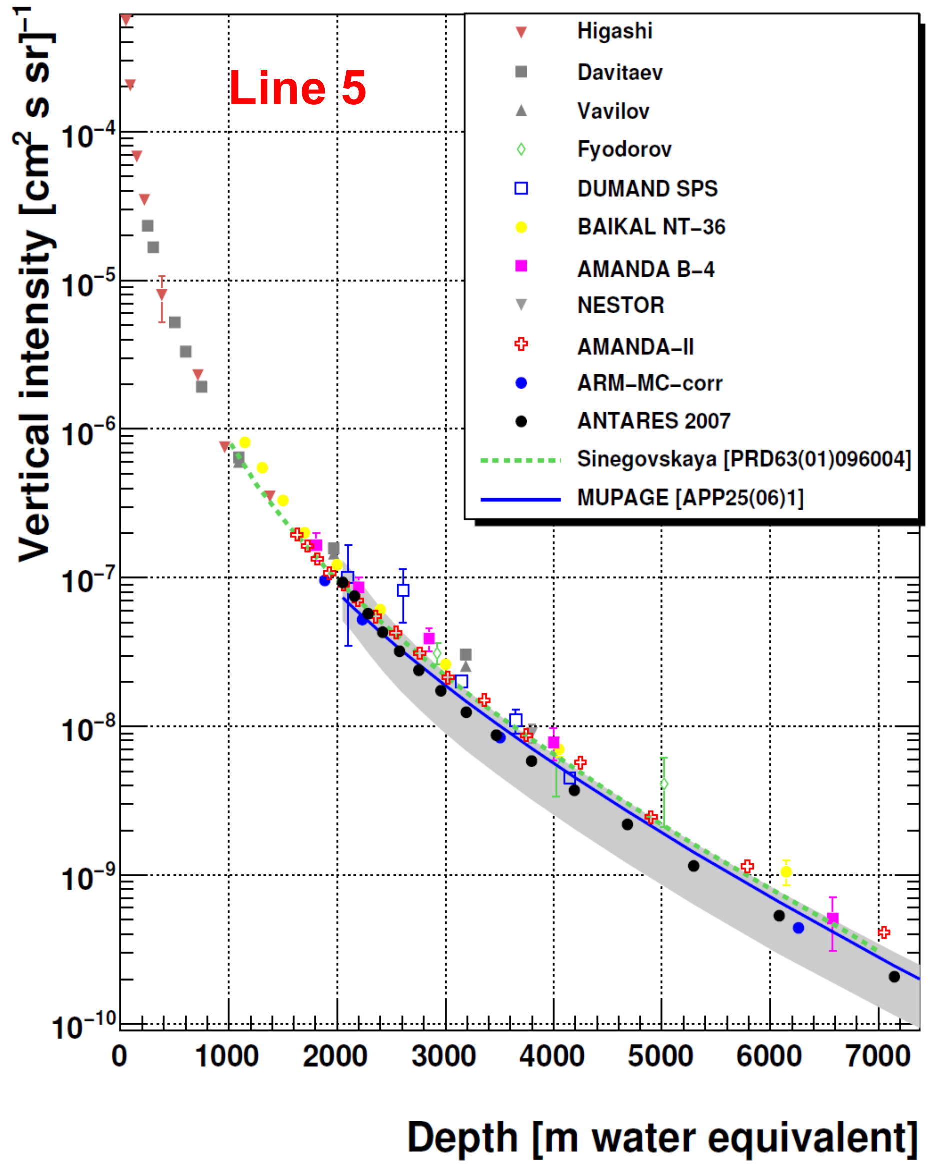


- Agreement between simulations and data is satisfactory
- Details of apparatus geometry and performance well understood
- Main sources of simulation uncertainty are:
  - optical module response
  - absorption length of light in water

Depth intensity Relation

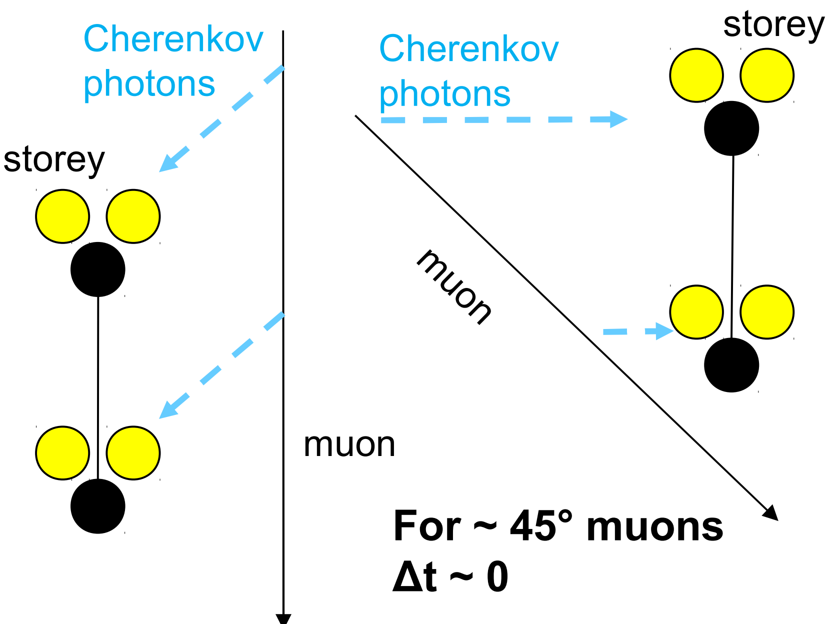






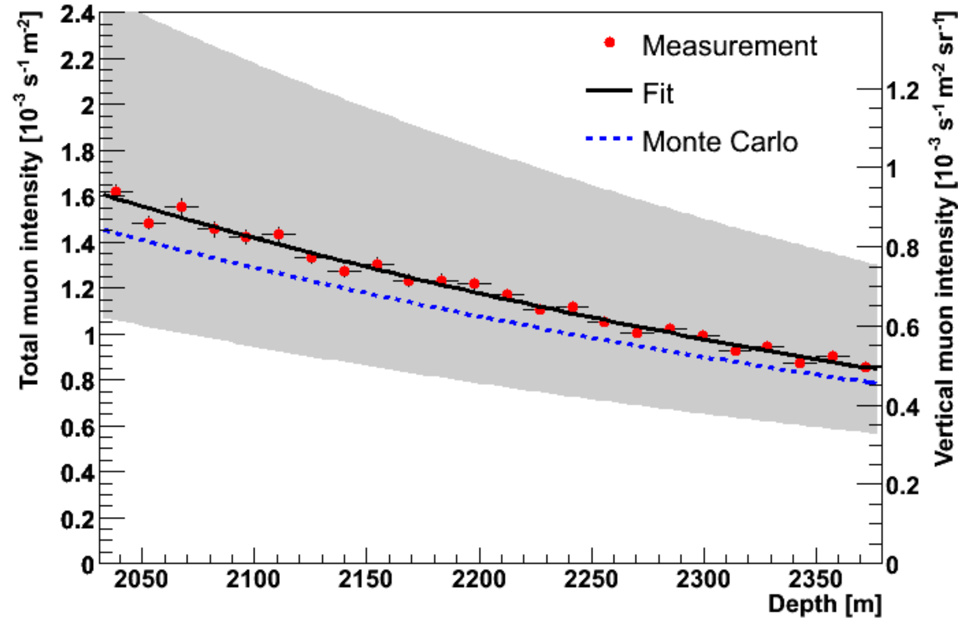
Depth intensity Relation without muon reconstruction

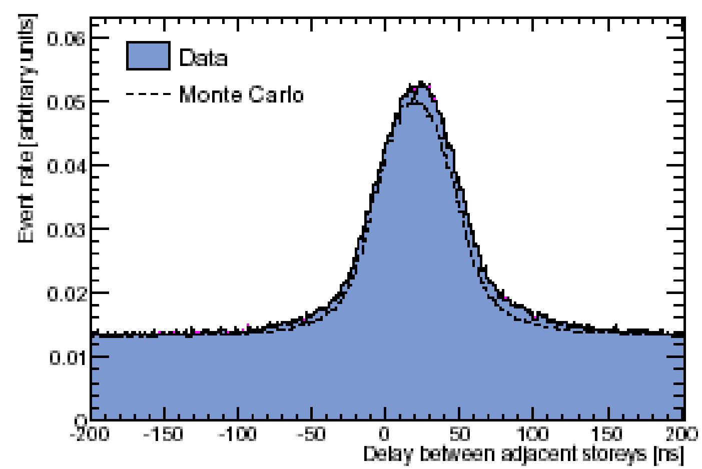
Simple method based on coincidences on adjacent storeys. No reconstruction needed.



For ~ 45° muons
Δt ~ 0

For vertical muons
Δt = L / c ≈ 50 ns

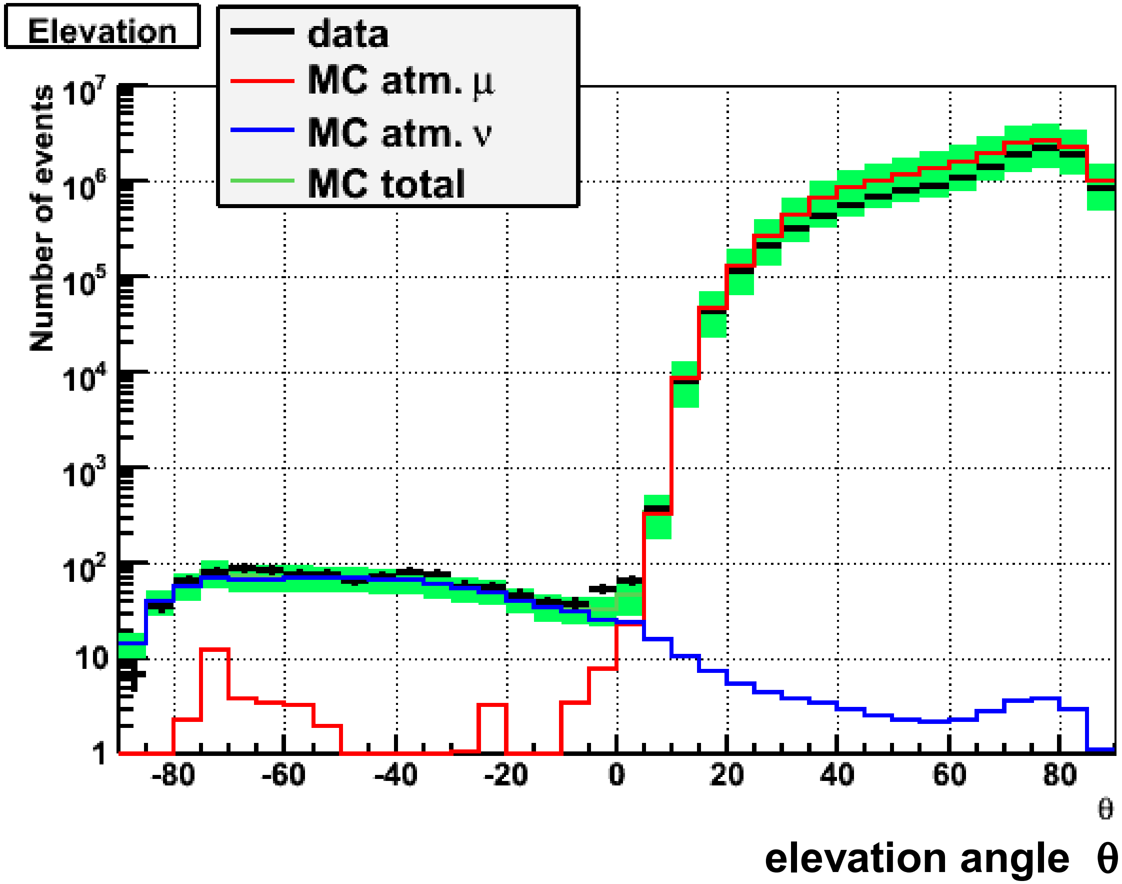


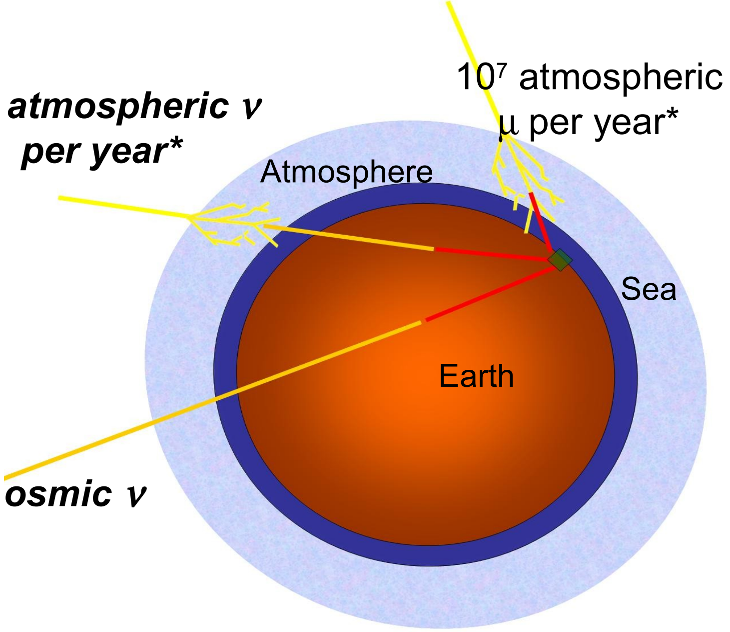


Rate vs. depth distribution can test optical module efficiency and acceptance

Method allows to measure the depth-intensity relation of muons with no systematic errors from trigger or reconstruction algorithms (main uncertainty: optical module acceptance)

Analysis: Atmospheric neutrinos





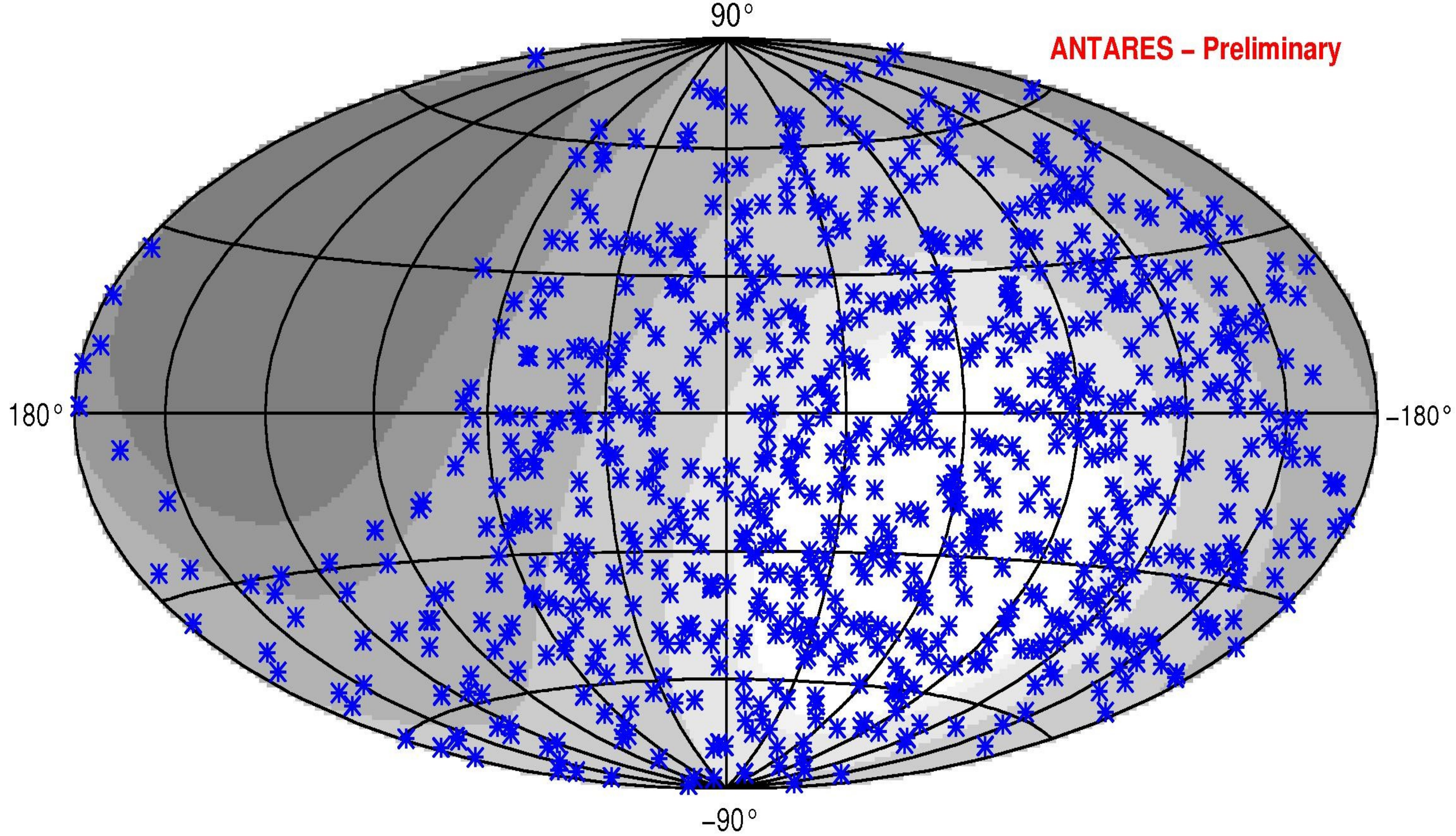
5-line data (May-Dec. 2007)+
9-12 line data (2008)

341 days detector live time,
single- and multi-line fit:

1062 neutrino candidates:
3.1 ν candidates/day

good agreement with **Monte Carlo**: **atmospheric neutrinos: 916 (30% syst. error)**
atmospheric muons: 40 (50% syst. error)

Neutrino Events: sky map



750 upgoing neutrinos: 2007+2008 data

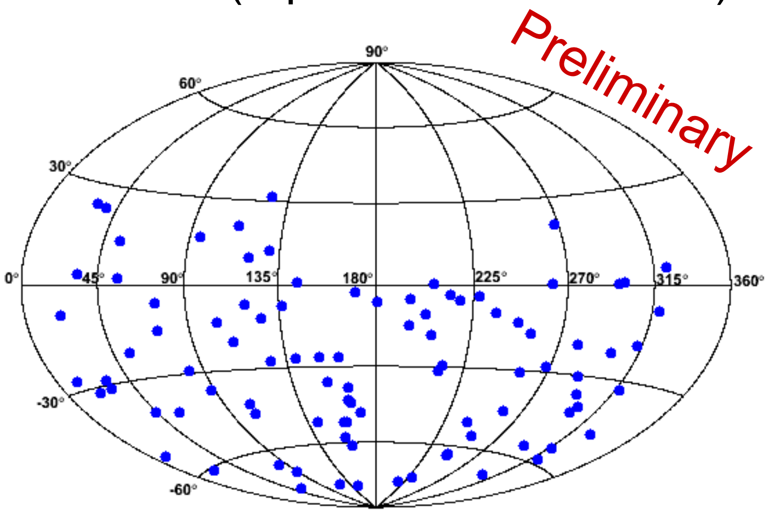
Search for point-like neutrino sources

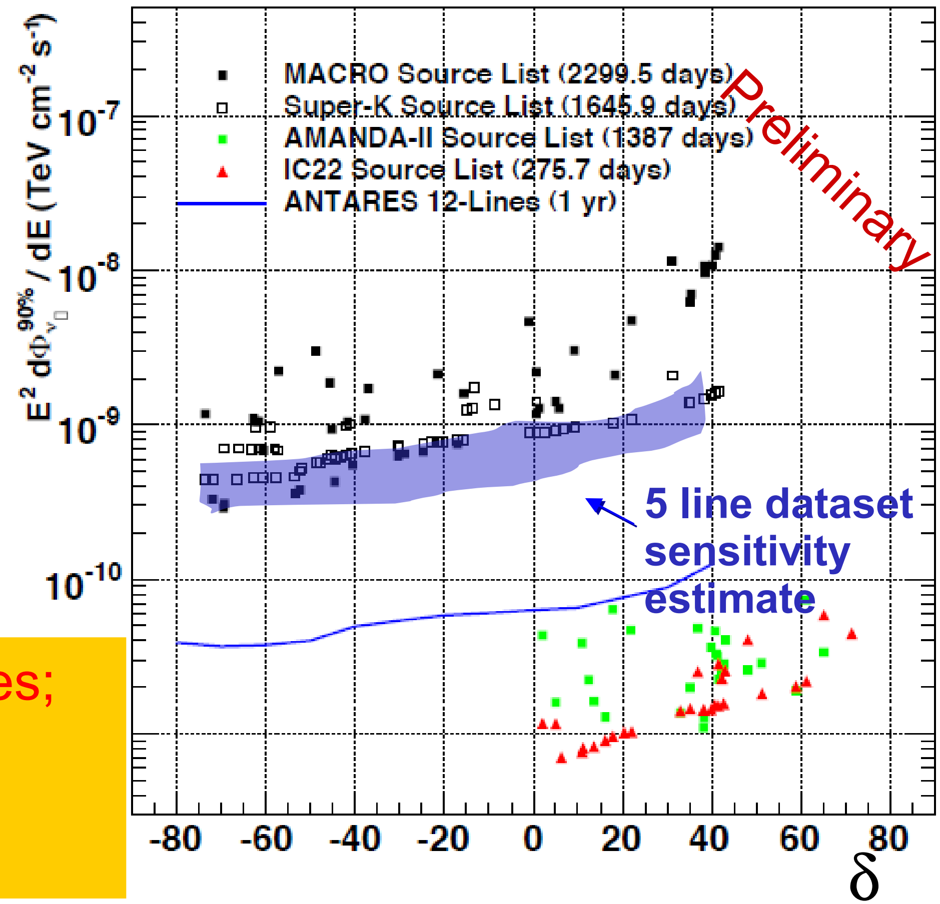
with the 2007 (5-line) data: effective live time 140 days

stringent selections: low background

high reconstruction quality (ang. resolution < 0.5^{o})

binned, unbinned searches
on data with scrambled coordinates
of 94 events (equatorial coordinates):





no correlation with 25 potential ν sources;
no excess (± 1σ) in all-sky search;
sensitivity competitive with multi-year exposures of previous experiments

Multi-Messenger astronomy

Strategy: higher **discovery potential** by observing different probes
higher **significance** by coincidence detection
higher **efficiency** by relaxed cuts

MoUs for joint research

?

SNEWS
SuperNova Early Warning System

Ligo/Virgo
Gravitational waves: trigger + dedicated analysis chain

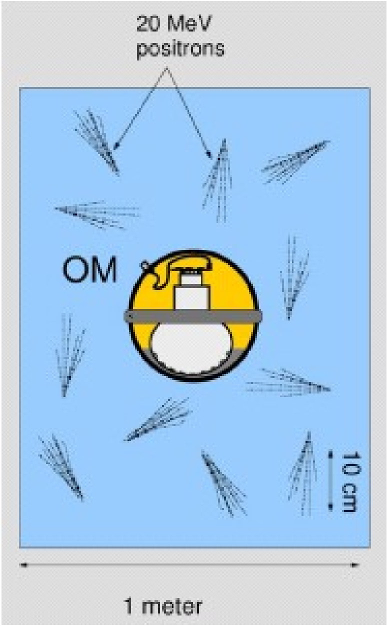
TAROT
optical follow up: 10 s repositioning

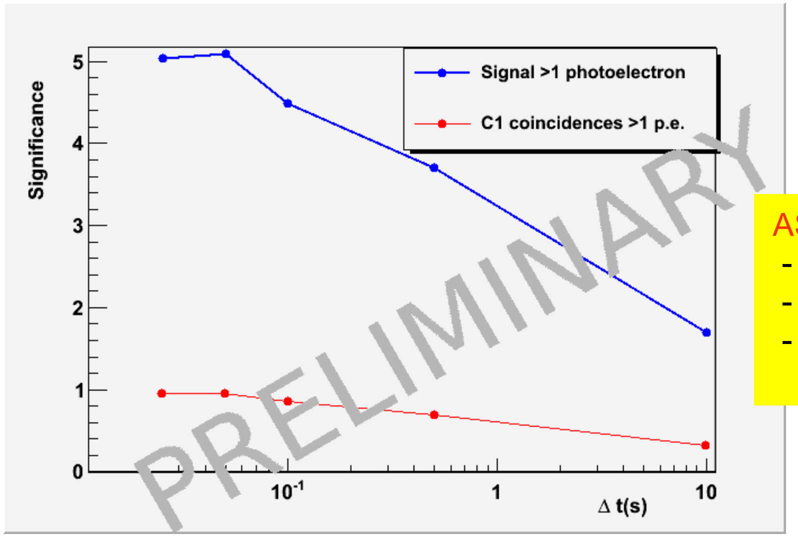
GCN
GRB Coord. Network: γ satellites

Supernova neutrinos in ANTARES?

- MeV neutrinos are produced in first seconds of a SN explosion
- Detect the global rate increase in the whole detector

First suggested for AMANDA: F. Halzen, et al Phys. Rev. D49(1994), 1758



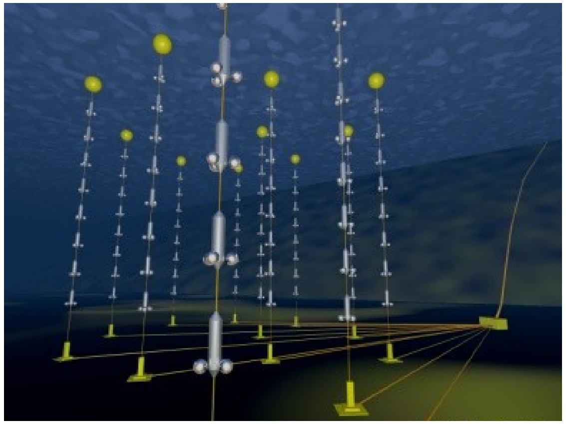


$$S = \frac{\Delta R}{\sigma}$$

ASSUMPTIONS:
- NO bioluminesce bursts
- 900 OMs
- Bck has Poissonian fluctuations

- Amanda-Ice Cube is participating to SNEWS network
- ANTARES could detect global rate increase above background fluctuations due to galactic SN if bioluminescence bursts are cut efficiently

Conclusions and Outlook



ANTARES detector completed in May 2008

Detector operation and calibration under control

Maintenance capability demonstrated

Exciting physics program ahead

Over a thousand neutrino already reconstructed

astronomical sources, multi-messenger approach, other analysis in progress

Real-time readout and in-situ power capabilities facilitates

a large program of synergetic multi-disciplinary activities: biology, oceanography……

A multidisciplinary deep-sea research infrastructure

A Major step towards the KM3NeT