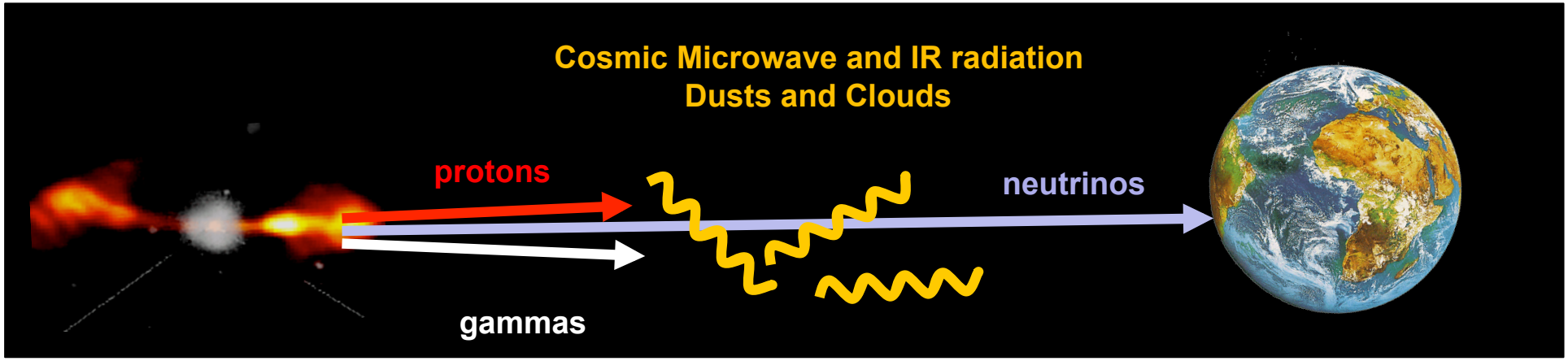
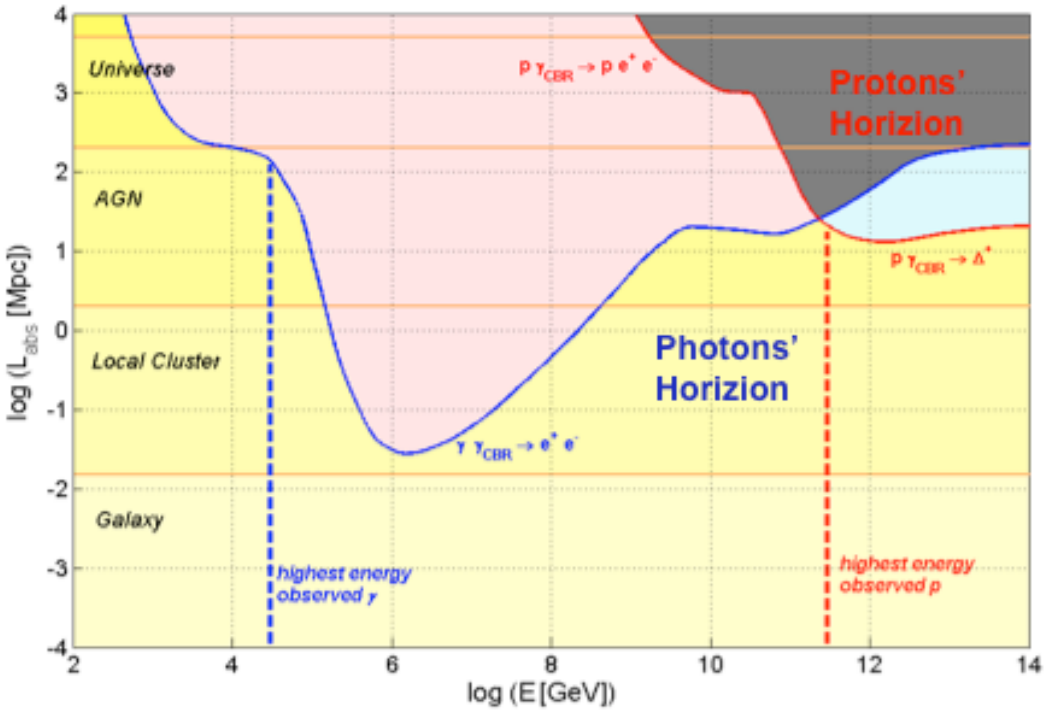
Present results of the ANTARES telescope

Carla Distefano
for the ANTARES Collaboration
INFN-LNS

PLANCK 2011

Absorption lenght of protons and gammas in the Universe





Neutrinos can probe the far and violent Universe

Hadronic HE ν and γ production

p + p (SNR,X-Ray Binaries)→ X,π

p + γ (AGN, GRB, μQSO) →Nπ

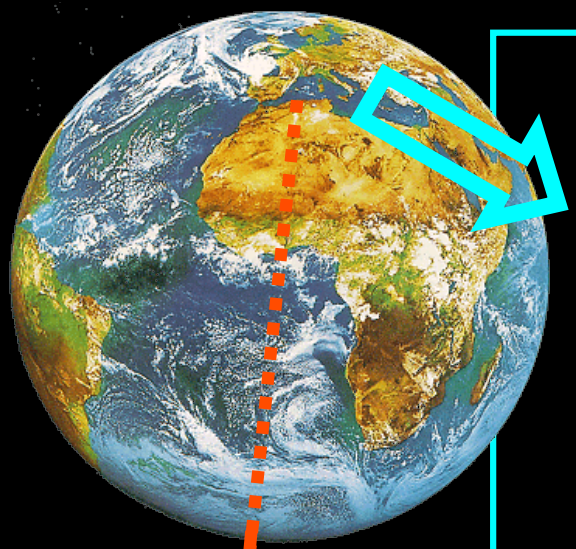
Decay of pions

neutral pions → HE gammas

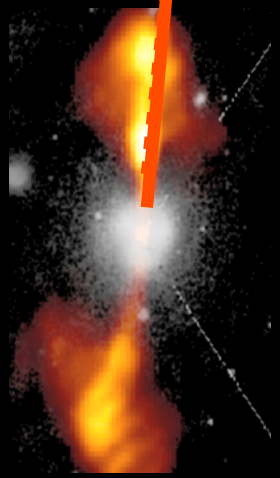
charged pions → HE neutrinos

Spectrum $dN_{p,e}/dE \propto E^{-2}$

Underwater Cherenkov HE neutrino detectors

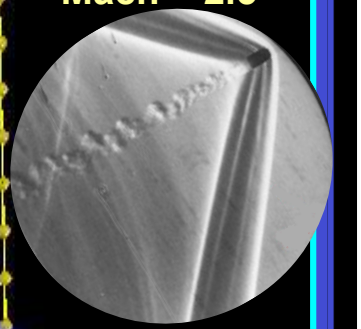


neutrino

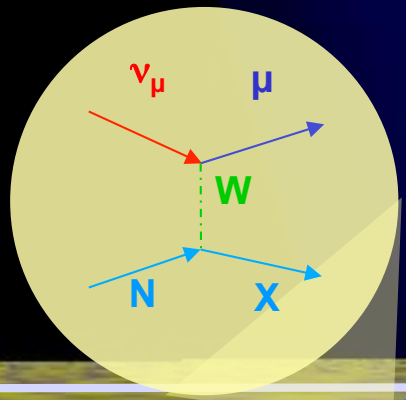


Array of PMTs

A bullet at Mach = 2.5



Cherenkov photons (~42° in water)



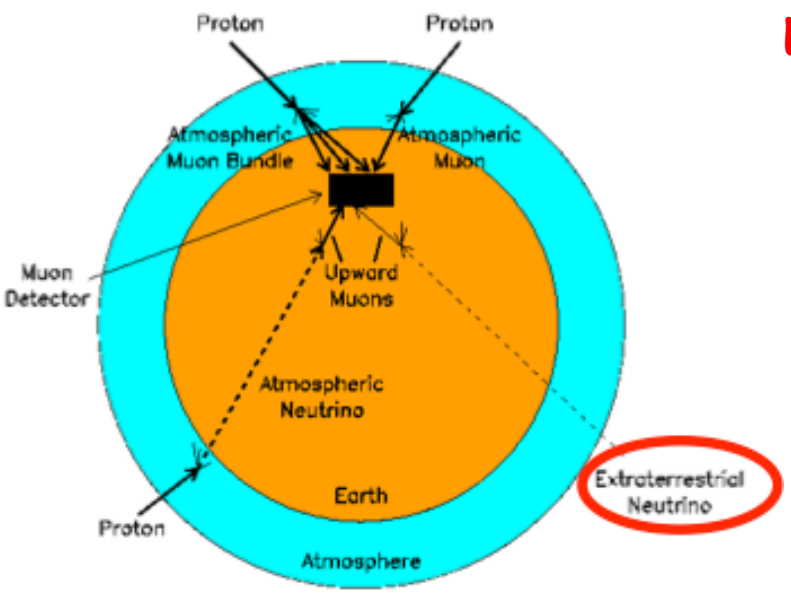
muon

Connection to the shore

neutrino

$$\langle \theta_{\nu-\mu} \rangle \approx \frac{1.5^\circ}{\sqrt{E_\nu\,[\mathrm{TeV}]}}$$

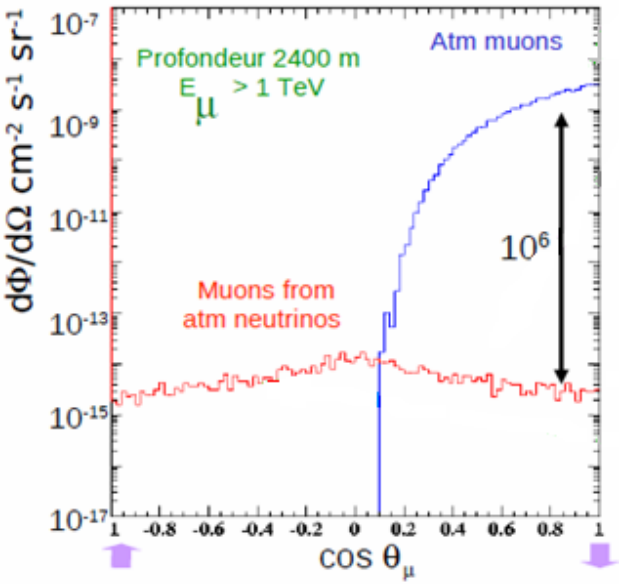
Background sources



Event backgrounds

From the interaction of cosmic rays with the atmosphere at the detector:

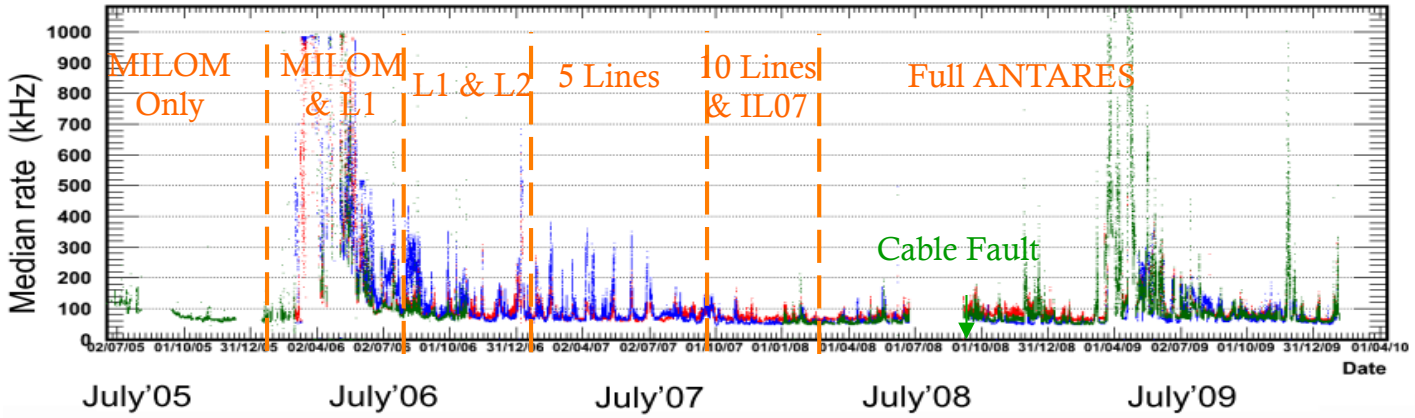
- down going atmospheric muons
- 4π atmospheric neutrinos

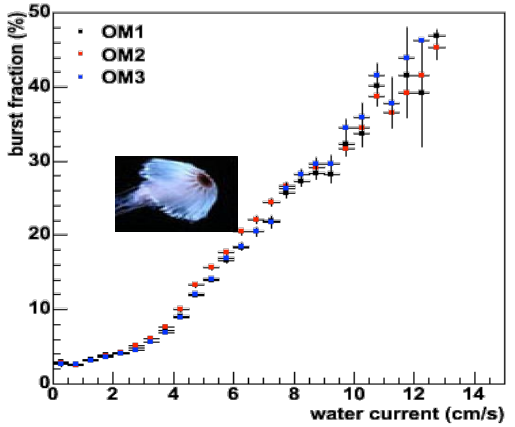


Optical background in sea water

- ^{40}K decay (salt in sea water) baseline of ~ 30 kHz in 10" PMT
- bioluminescence (bacteria) baseline ~ 40 kHz + bursts from macro-organisms few MHz

Bioluminescence is strongly dependent on the local sea current





What is ANTARES

The largest neutrino telescope in the Northern Hemisphere (Toulon, France), with 0.1 km^2 footprint

The first neutrino telescope under the sea

A high-depth real-time platform for multidisciplinary observations

A major step toward the km3 detector in the Mediterranean Sea

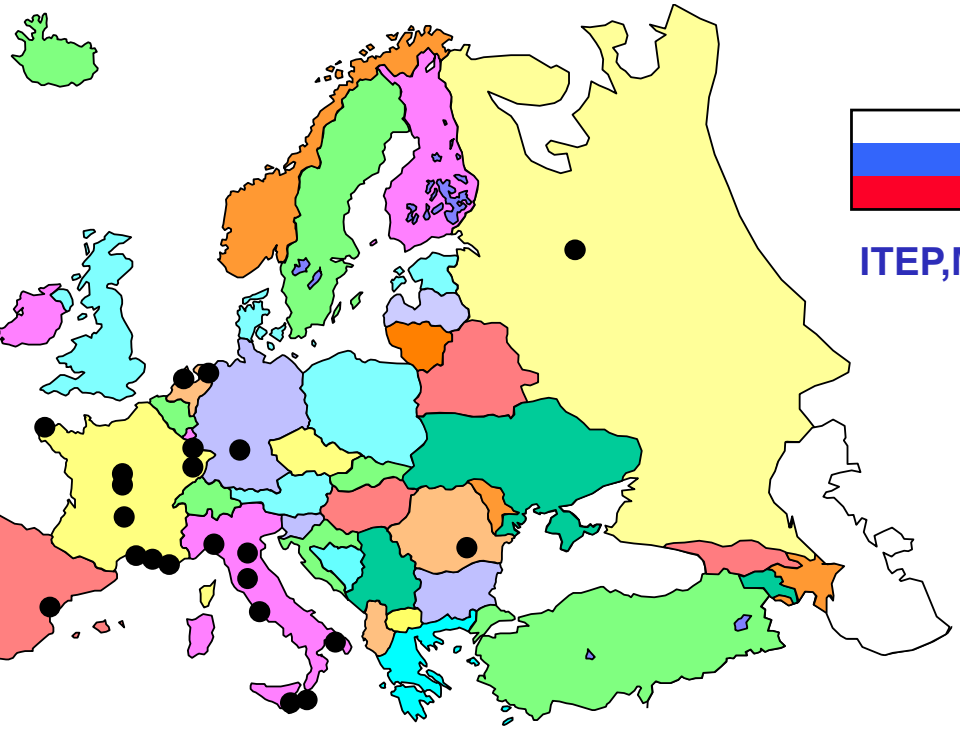
Who is in ANTARES

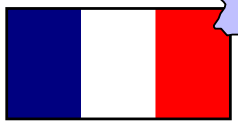
7 countries
27 institutes
150 scientists+engineers

NIKHEF, Amsterdam
KVI Groningen
NIOZ Texel

University of
Erlangen

IFIC, Valencia
UPV, Valencia





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

University/INFN of Bari
University/INFN of Bologna
University/INFN of Catania
LNS – Catania
University/INFN of Pisa
University/INFN of Rome
University/INFN of Genova

ITEP,Moscow

ISS, Bucarest

ANTARES and the international context

Antares The largest operating neutrino telescope in the Northern hemisphere

ANTARES, NEMO, NESTOR
joined efforts to prepare
a km**3**-size neutrino telescope in the Mediterranean Sea: KM3NeT

IceCube IC79 taking data since 2010, IC59 data analysis started

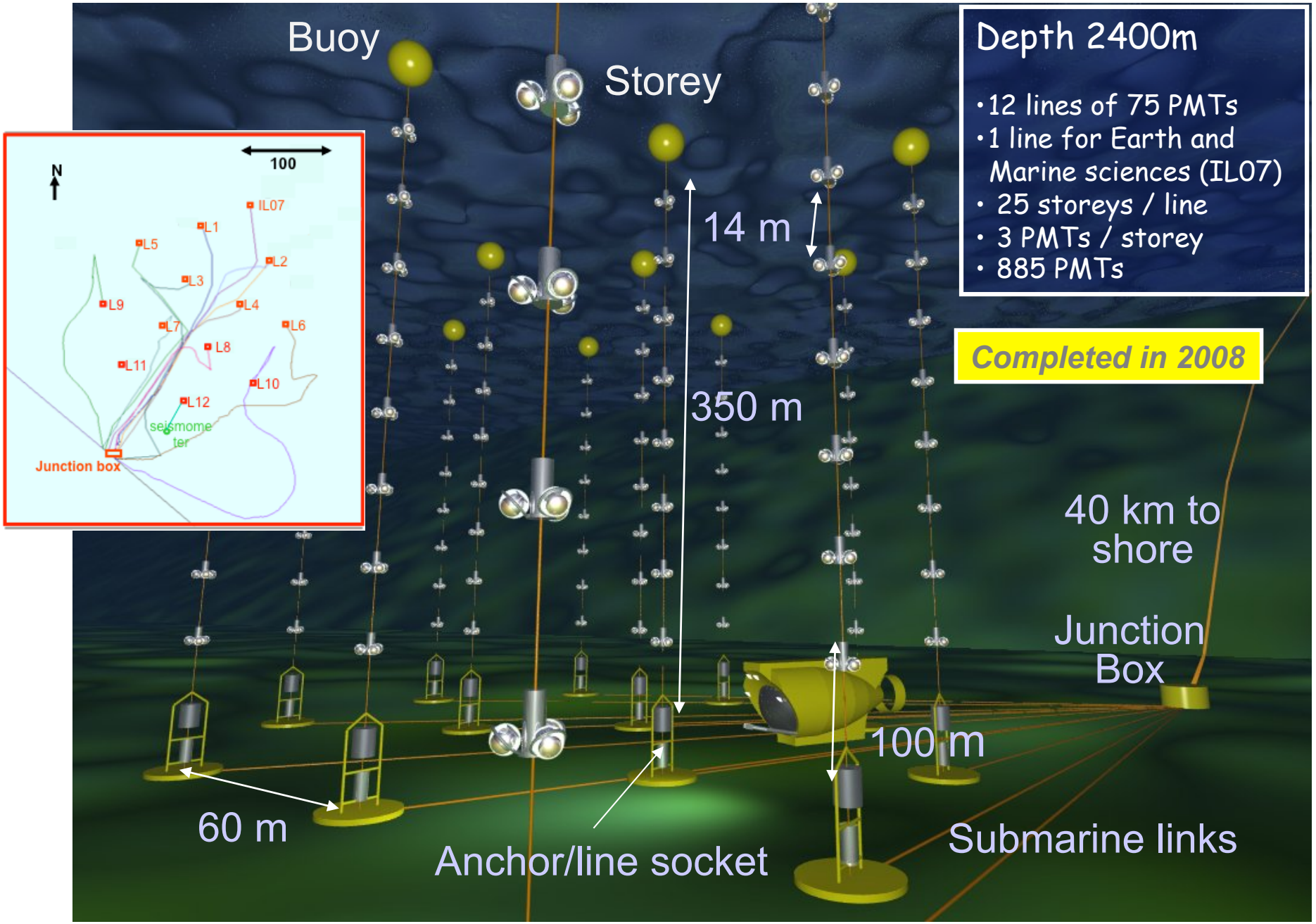
BAIKAL

Mediterranean
km³

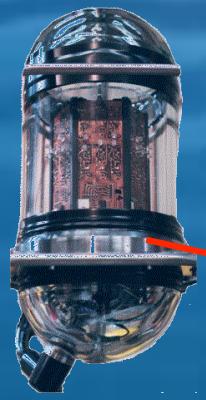
DUMAND

AMANDA
ICECUBE

ANTARES: the detector



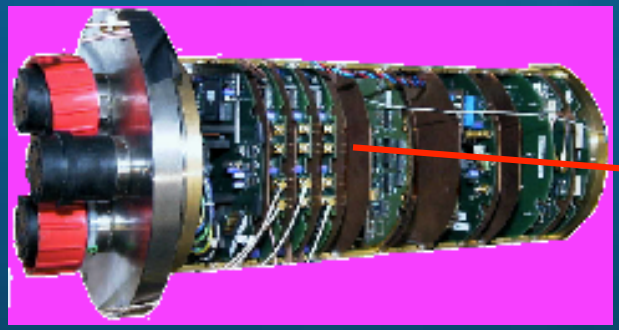
The ANTARES Storey



Optical Beacon with blue LEDs: timing calibration

titanium frame: support structure (2m)

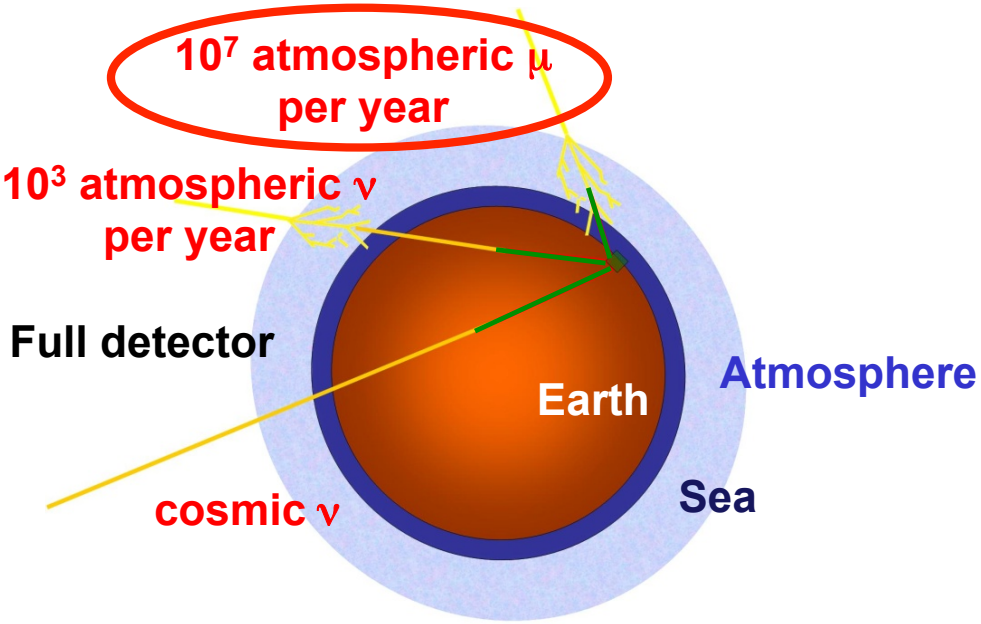
Optical Module: 10" Hamamatsu PMT in 17" glass sphere ($\sigma_{TTS} \approx 1.3$ ns) photon detection

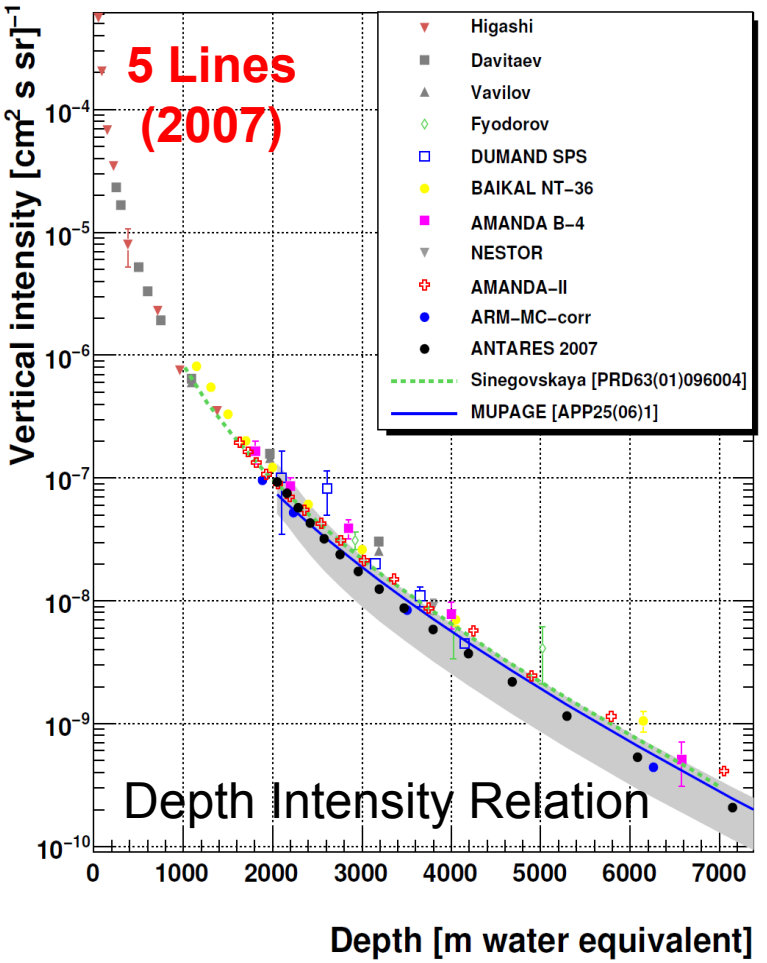


Local Control Module (in Ti cylinder): Front-end ASIC, DAQ/ SC, DWDM, Clock, tilt/compass, power distribution…

Hydrophone: acoustic positioning

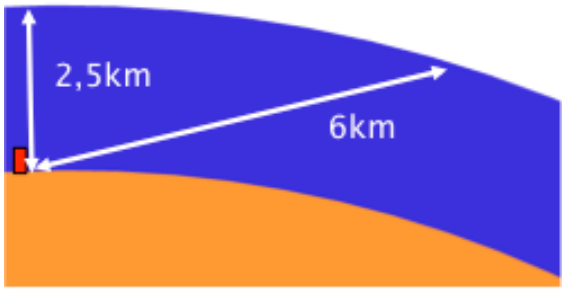
Atmospheric muons





- 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



Astr. Phys. 34 (2010) 179-184, Astr. Phys. 33 (2010) 86-89

Diffuse ν_μ flux

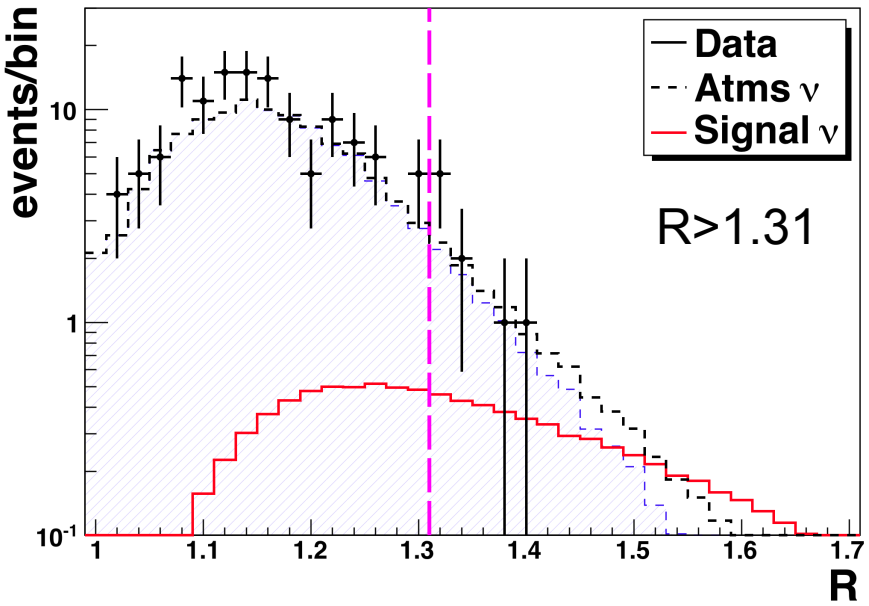
Background rejection:

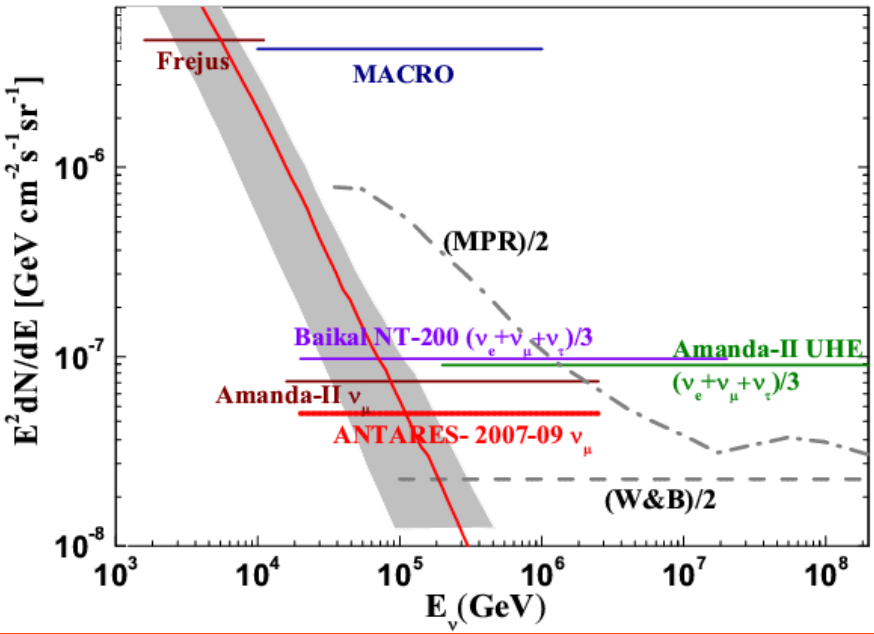
- Atmospheric muons: cuts on the measured zenith angle, track reconstruction quality parameter and number of hits. Selection based on Monte Carlo.
- Atmospheric neutrinos: cuts on the R parameter related to the neutrino energy. Cut optimization based on Monte Carlo where the Model Rejection Factor method was applied (APP 19 (2003)393)

R_i= number of hits on i-th PMT

$R = \Sigma R_i$ / number of all PMTs contributing to the event

Signal flux 4.8 $\times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}



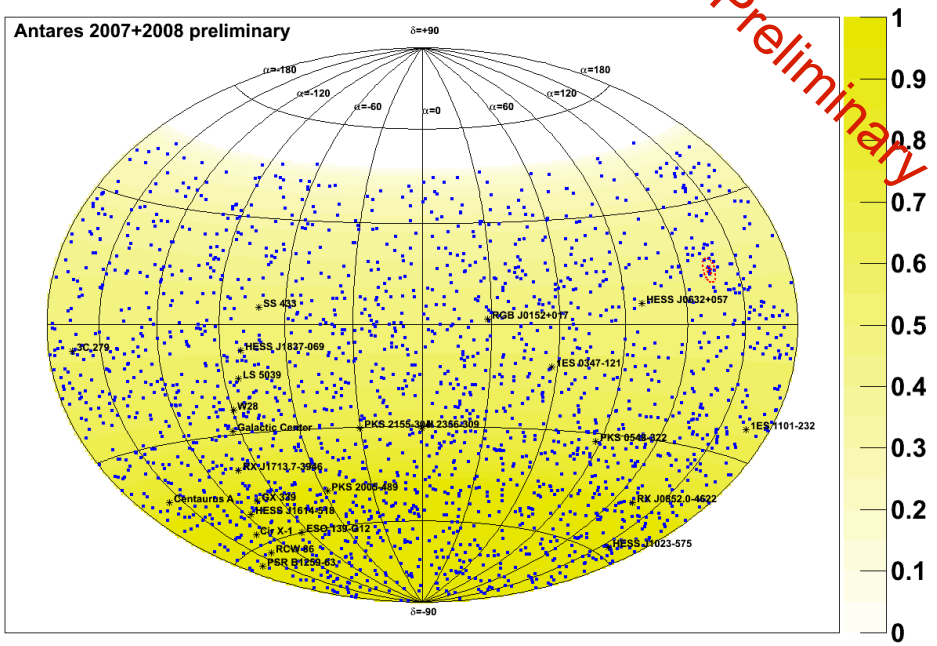


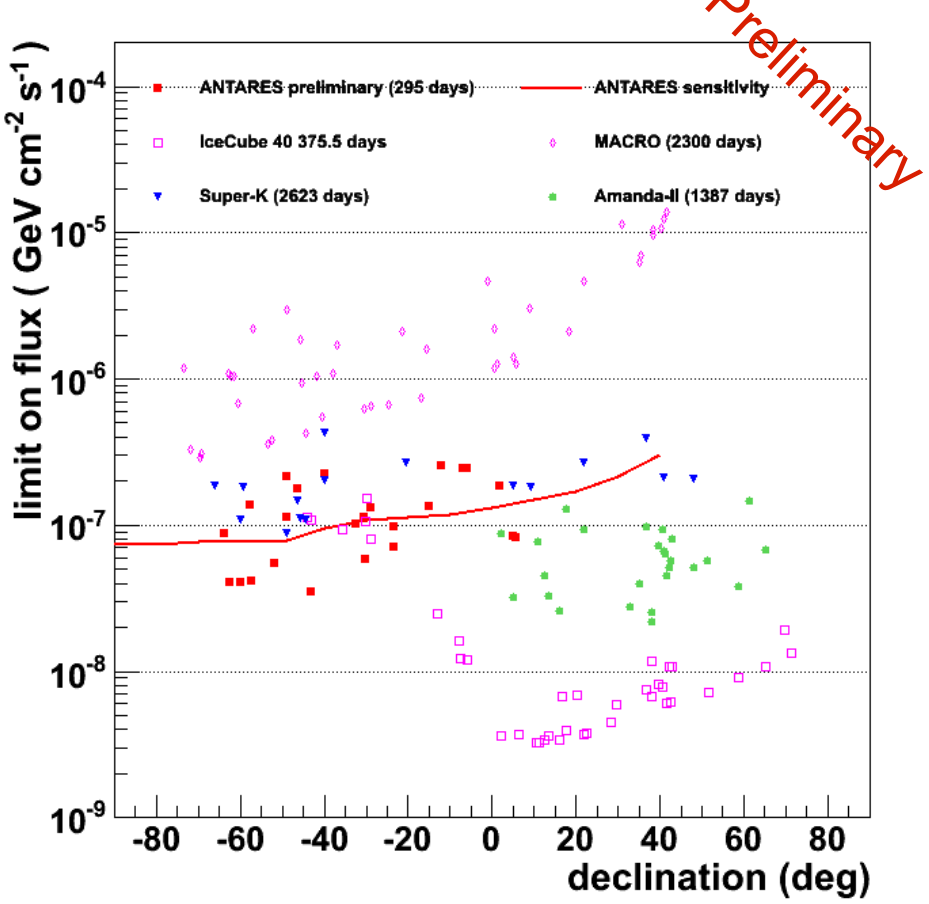
No excess found:
9 events from data
10.5 ± 2 events expected from MC

Average upper limit at 90% of c.l.
$E^2 \Phi = 4.8 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}
(20 TeV < E < 2.5 PeV)

Search for point sources

Definition of a list of 24 potential sources
(stringent cuts to reduce background)
Analysis optimization based on simulations

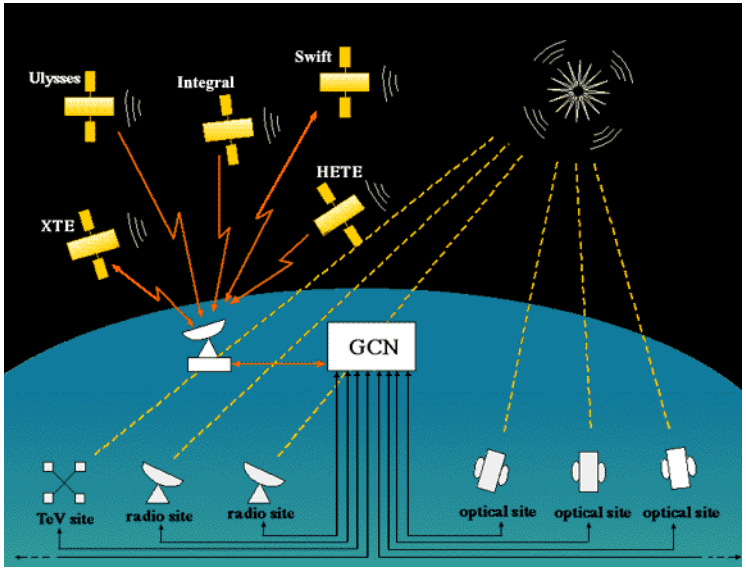




Effective livetime of 295 days competitive with multi-year exposures of previous experiments

Multi-messengers astronomy with ANTARES

GCN (Gamma-ray bursts Coordinates Network)

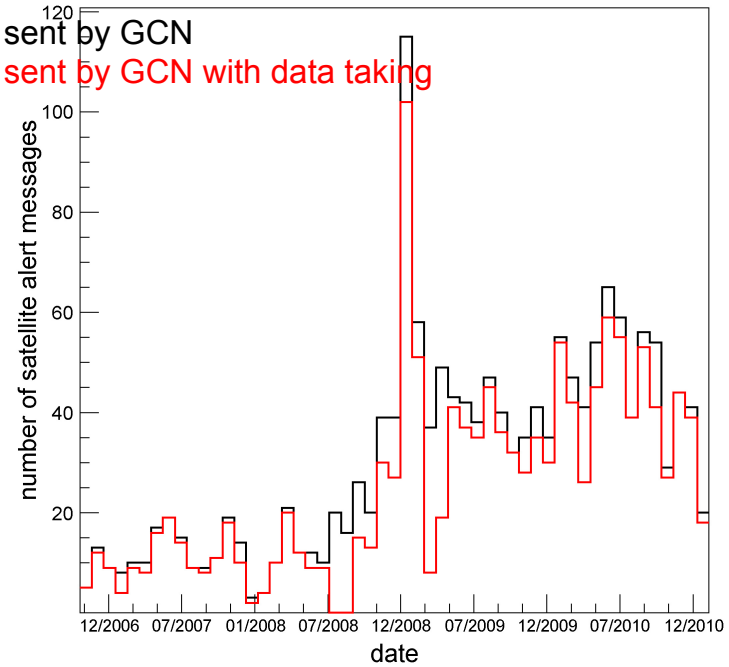


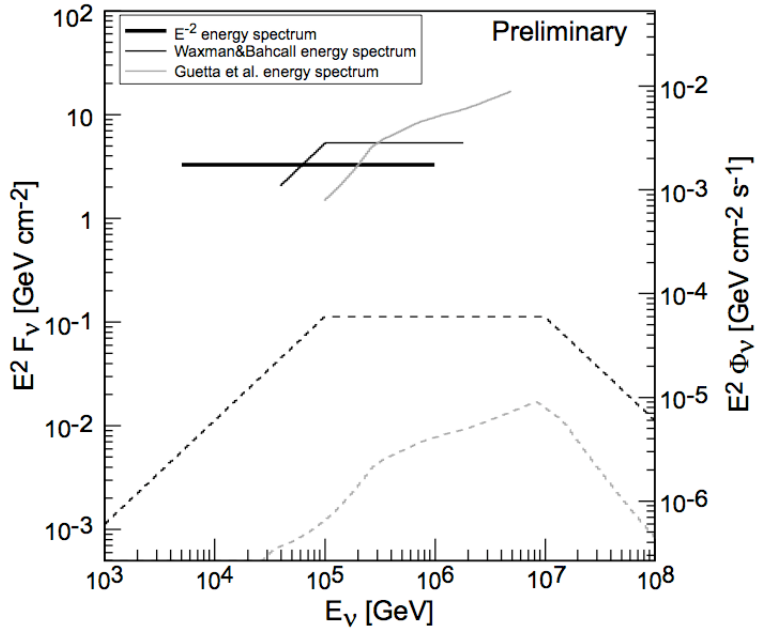
GRB alerts from satellites (Fermi, Swift…). Connection with GCN

- **Search for coincident neutrinos within time window (~100 s) from defined directions ➔ background strongly reduced.**
- **On-line special trigger implemented.**

Alerts sent by GCN

Alerts sent by GCN with data taking

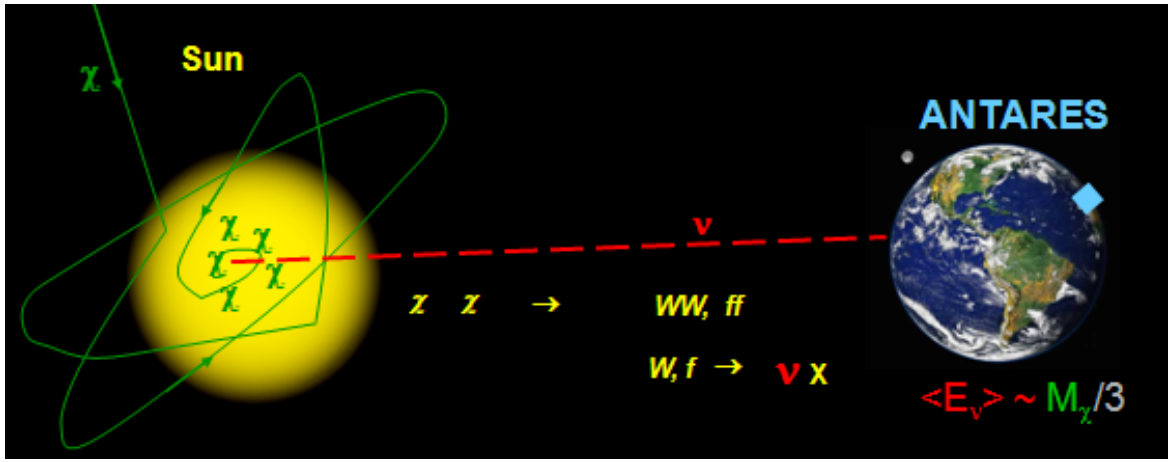




Dark Matter Search

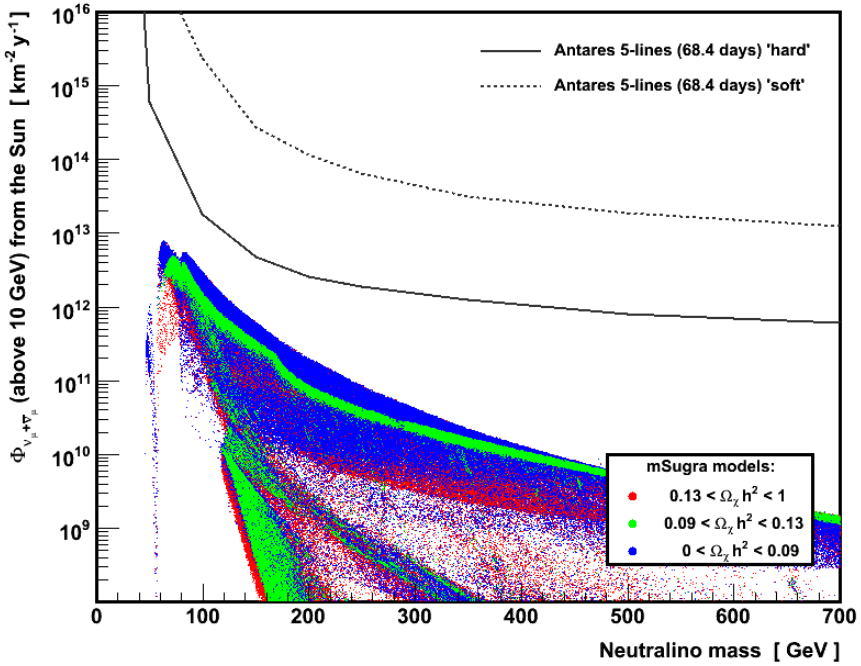
WIMPs gravitational trapped via elastic collisions in the Sun

$\Phi_{\nu_\mu + \bar{\nu}_\mu}$ **from the Sun**

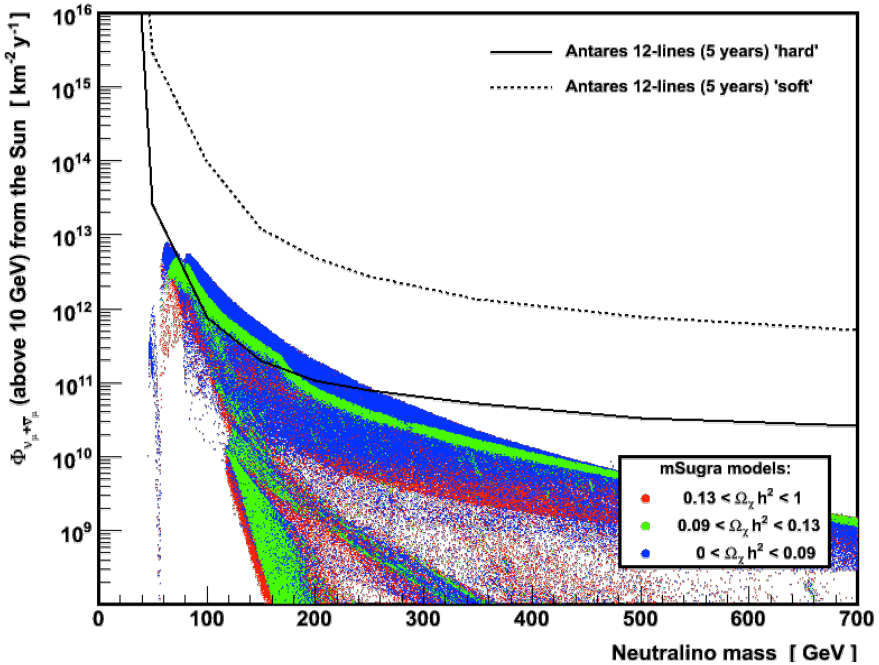


No excess observed (90% C.L. limits) à la Feldman-Cousins

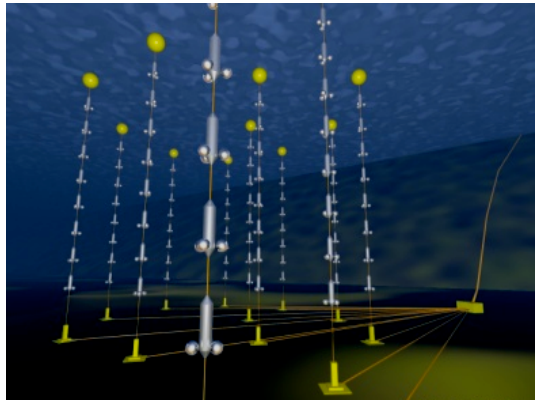
5 lines, 68 days



12 lines, 5 years extrapolated



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
- Unexplored regions of sensitivity
- astronomical sources, dark matter, oscilllations, ……
- Multi-messenger approach strongly encouraged

Real-time readout and in-situ power capabilities facilitates

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

A multidisciplinary deep-sea research infrastructure

A Major step towards the KM3NeT

Neutrino Events

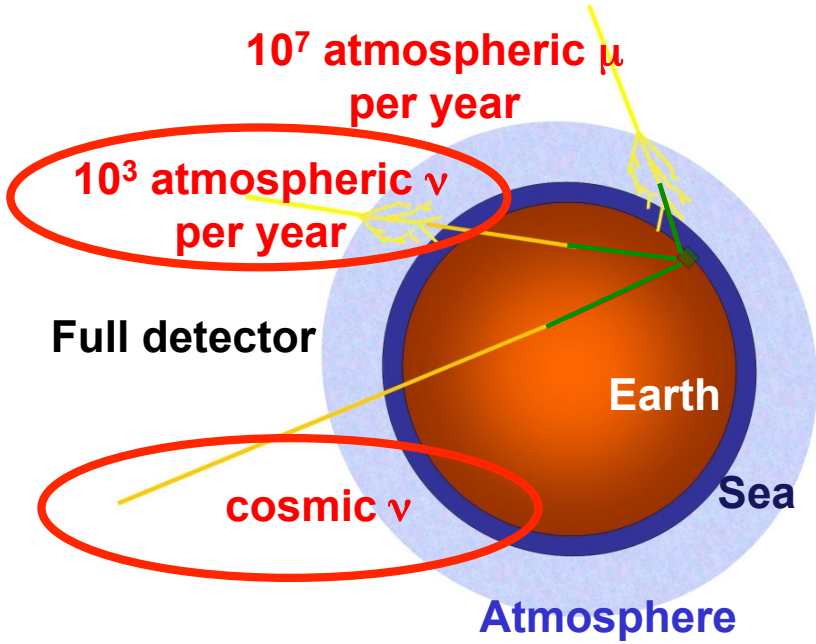
2007

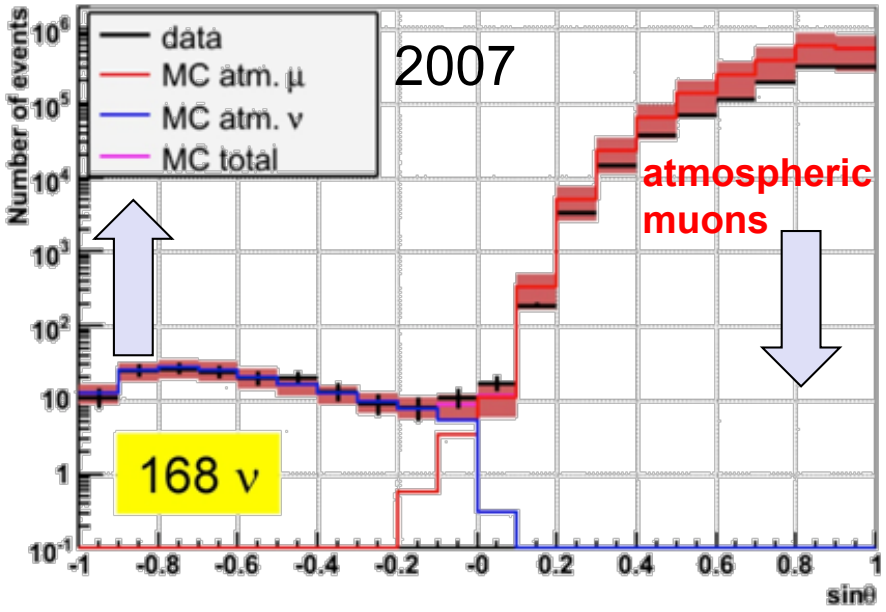
5-line apparatus, 168 days **168 events**

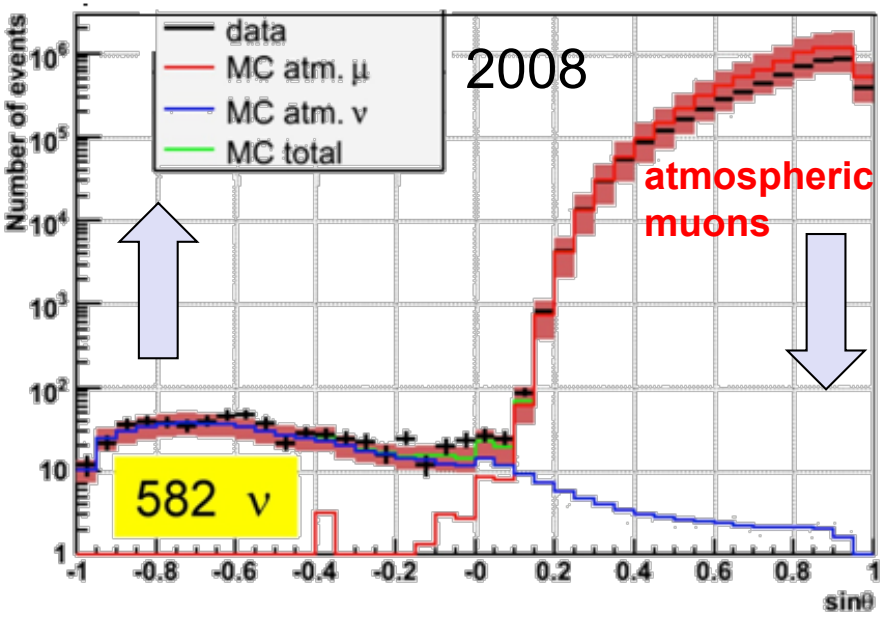
2008

9/10/12-line apparatus,174 days 582 events

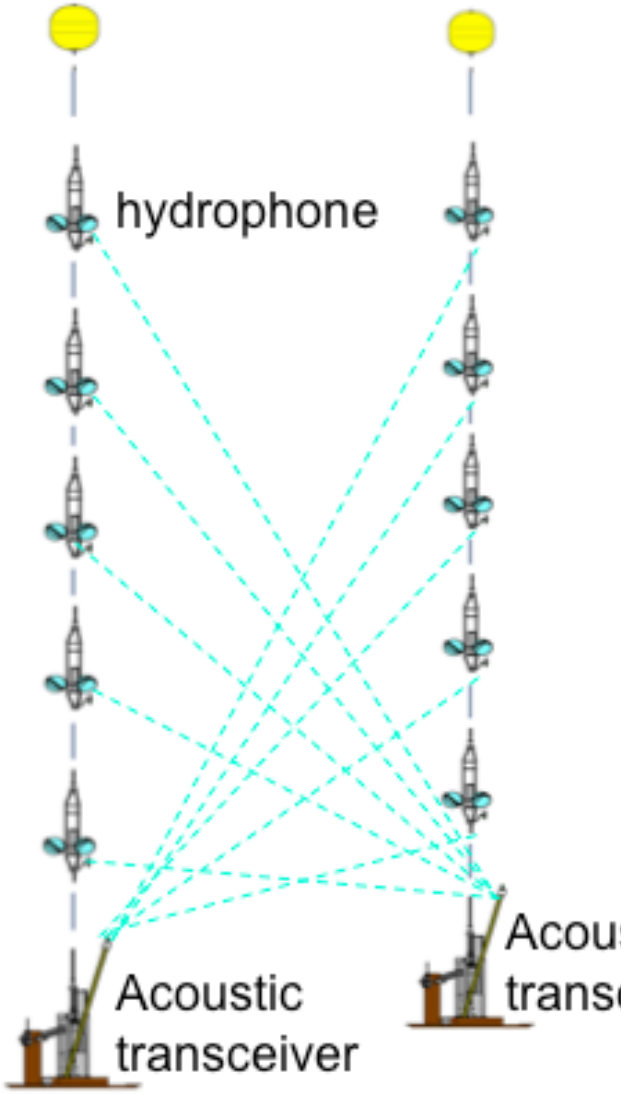
Up to today: more than 1500 neutrino events





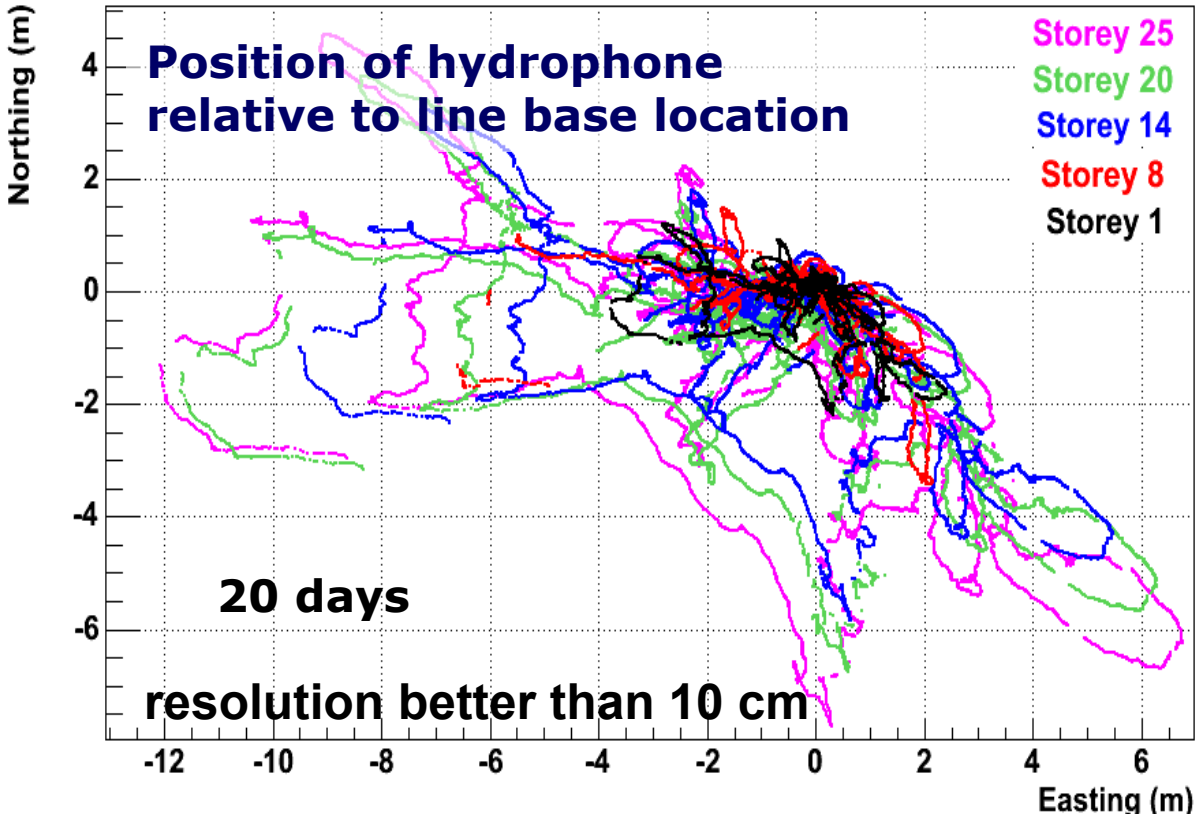


Calibration: detector acoustic positioning

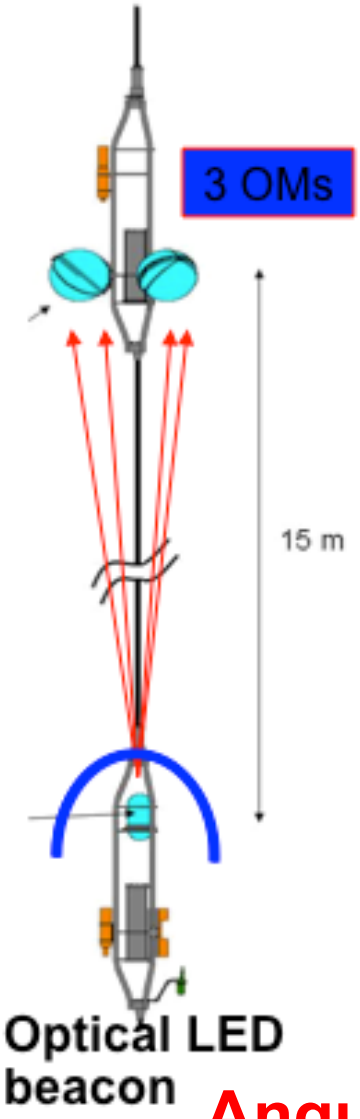


- Transceivers on the bottom of each line
- 5 hydrophones at specific heights on each line
- 4 autonomous transponders around the apparatus
- Sound velocimeters installed at various depths
- Tiltmeter and compass at each storey

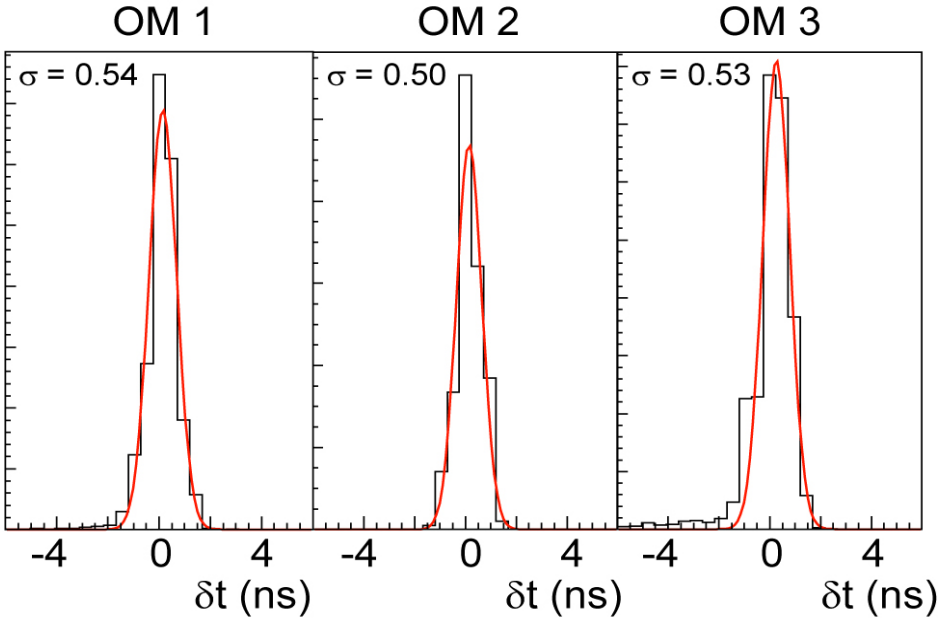
Measurements performed every 2 minutes



Calibration: timing and PMT resolution



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 → 0.2° – 0.3° (above few TeV)

Including the acoustic position resolution and the ν-μ angle