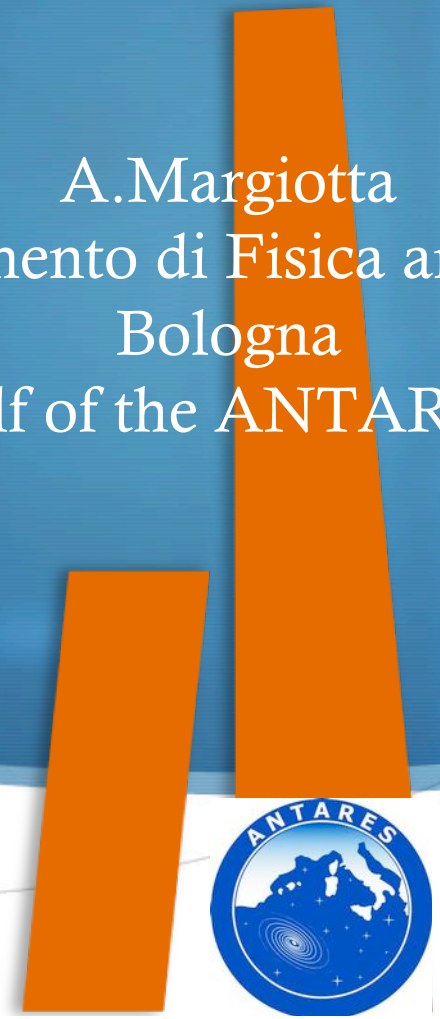
The ANTARES detector status and results

A.Margiotta
Dipartimento di Fisica and INFN
Bologna
on behalf of the ANTARES Coll.



INFN
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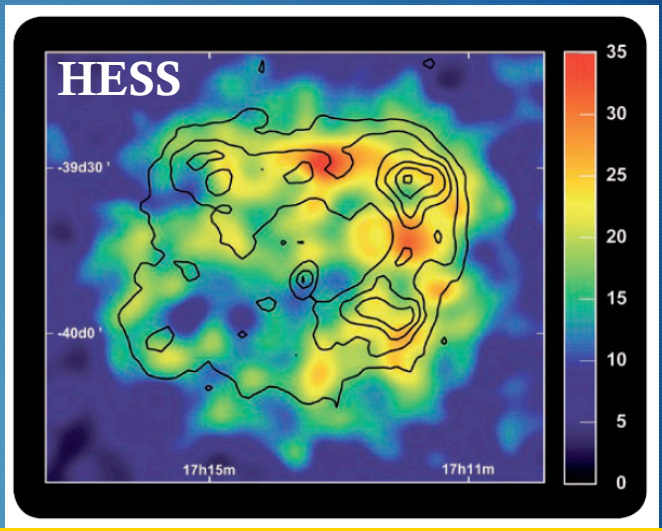
Sezione di Bologna

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
A.D. 1088

ANTARES
the largest Northern neutrino telescope

- Neutrino astronomy:
  - origin and acceleration of cosmic rays
  - dark matter
  - exotics
- Cosmic sources of neutrinos
  - **extragalactic:** Active Galactic Nuclei, GRBs
  - **galactic**: micro quasars, supernova remnants …
  - **diffuse flux** of neutrinos
- A. Kouchner's talk this afternoon

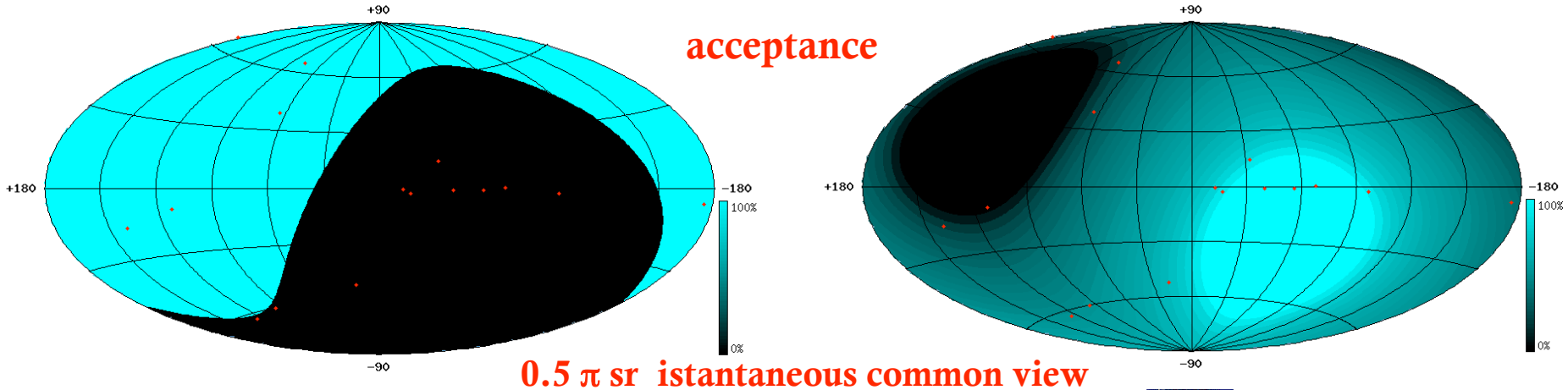


TeV γ rays ($p+X \rightarrow \pi^0 \rightarrow \gamma\gamma$) at the centre of **our galaxy** from supernova remnant *RX J1713.7-39.*

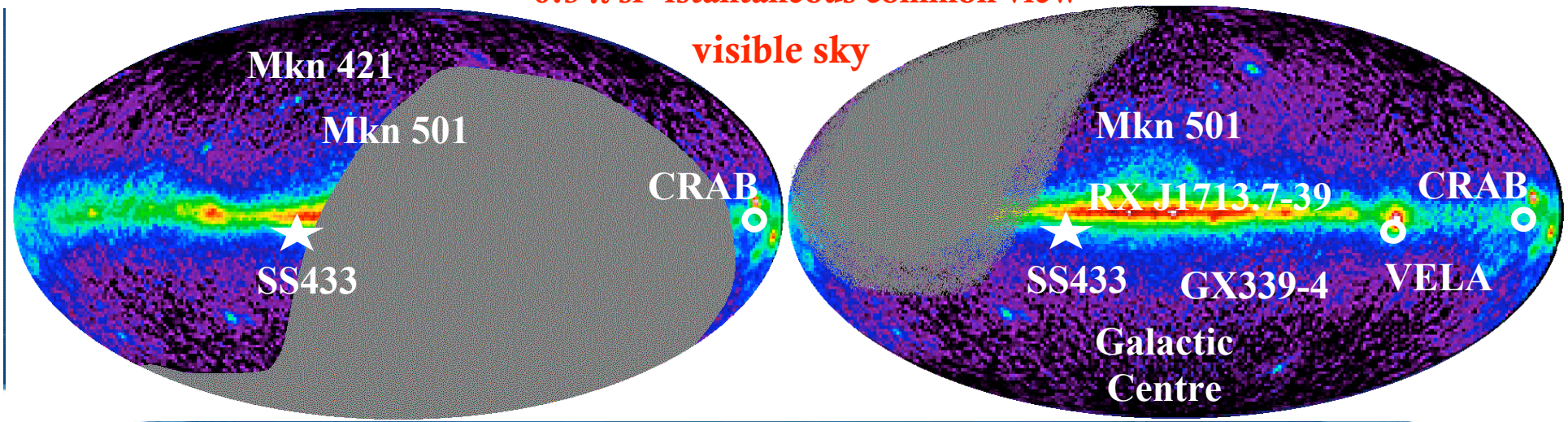
expected: $p+X \rightarrow \pi^{\pm} \rightarrow \nu(\bar{\nu})$

sky view (galactic coordinates)

AMANDA / IceCube (South Pole) **ANTARES (43° N)**

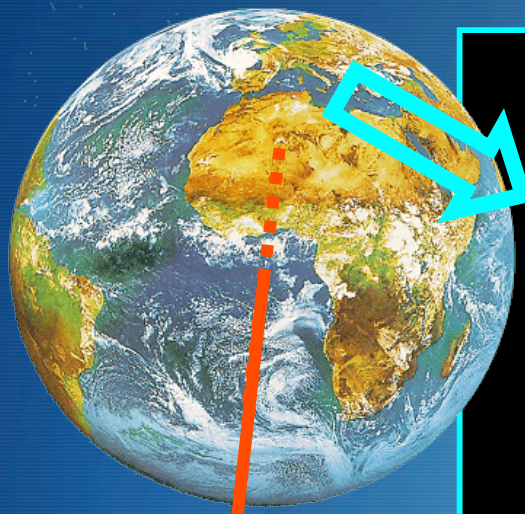


0.5 π sr istantaneous common view



1.5 π sr common view over a day

Detection principle



neutrino

HE μ from ν_μ CC-interaction

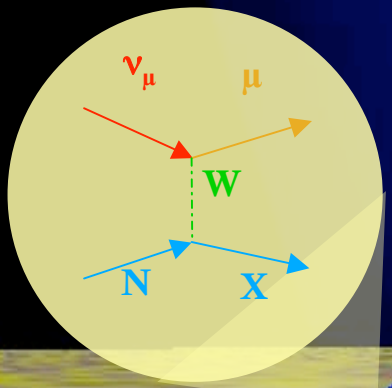
Energy threshold ~ 10 GeV

$$\frac{dN}{dx} = 3.5 \times 10^4 \, m^{-1}$$

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

Array of PMTs

Cherenkov photons (~42° in water)



muon

neutrino

Reconstruction of μ trajectory (~ ν) from timing and position of PMT hits

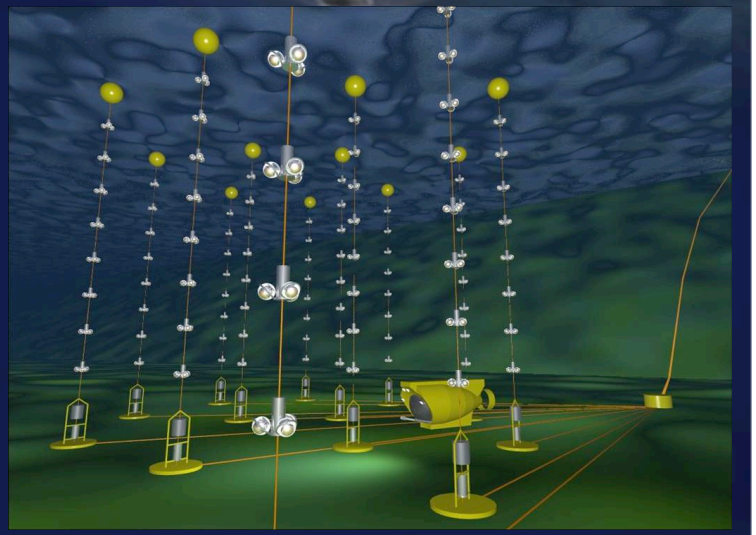
The ANTARES site

Toulon

Institut M. Pacha
control room

La Seyne-sur-Mer

Electro-optical
Cable of
40 km

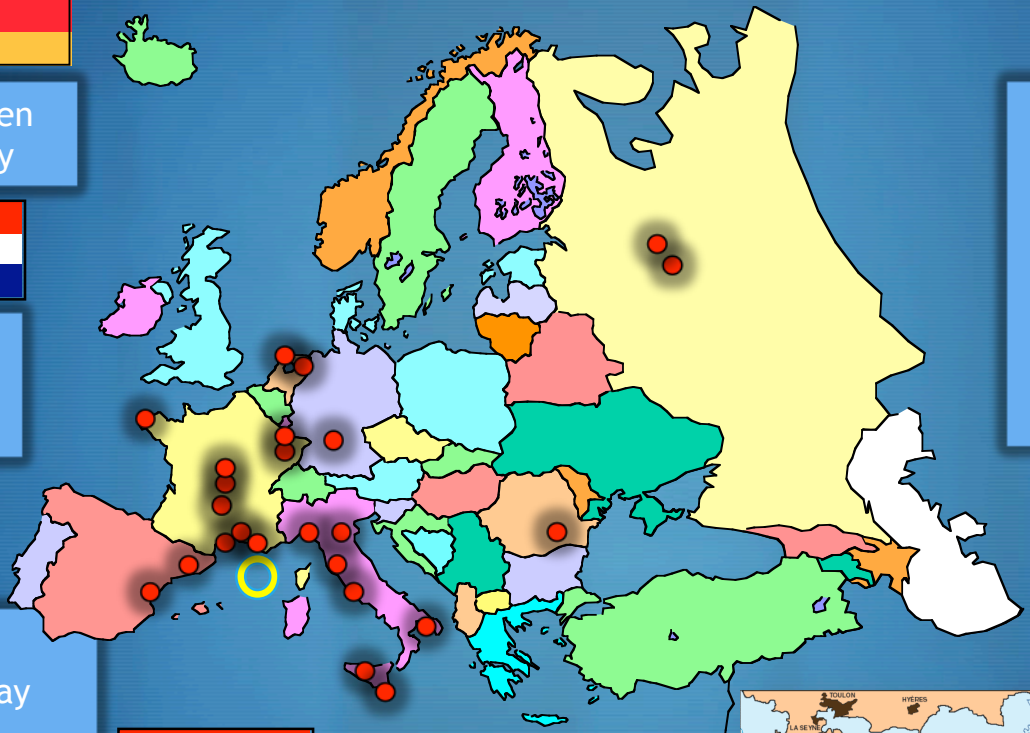


Site ANTARES
42° 50' N, 6° 10' E

~ 2500 m under s.l.

Google
© 2008 Cnes/Spot Image
Image © 2008 DigitalGlobe
Image NASA

The ANTARES Collaboration



- University of Erlangen
- Bamberg Observatory

- NIKHEF (Amsterdam)
- KVI (Groningen)
- NIOZ Texel

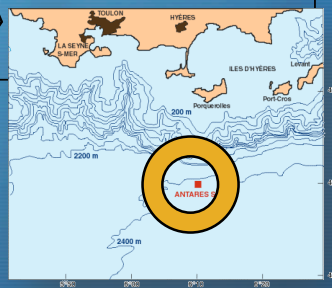
- CPPM, Marseille
- DSM/IRFU/CEA, Saclay
- APC, Paris
- LPC, Clermont-Ferrand
- IPHC (IReS), Strasbourg
- Univ. de H.-A., Mulhouse
- IFREMER, Toulon/Brest
- C.O.M. Marseille
- LAM, Marseille
- GeoAzur Villefranche

- *IFIC, Valencia*
- UPV, Valencia
- UPC, Barcelona

- 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

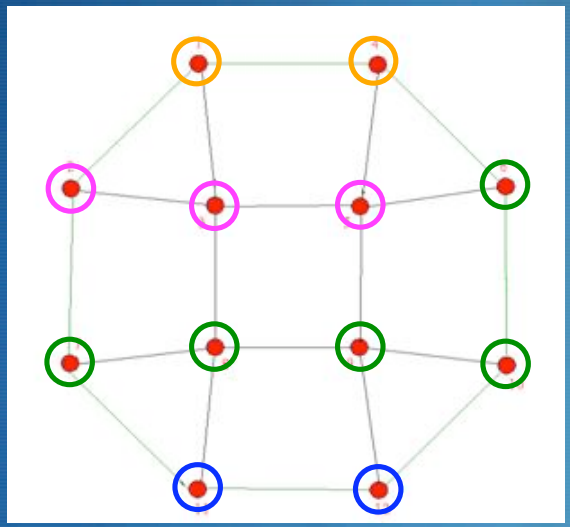
- ITEP, Moscow
- **Moscow State Univ**

ISS, Bucarest

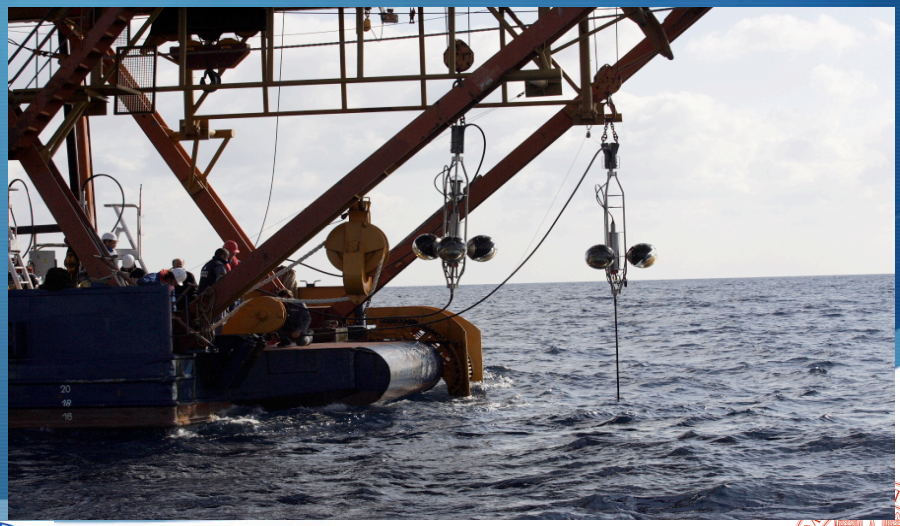


7 COUNTRIES
28 INSTITUTES
~ 150 SCIENTISTS AND ENGINEERS

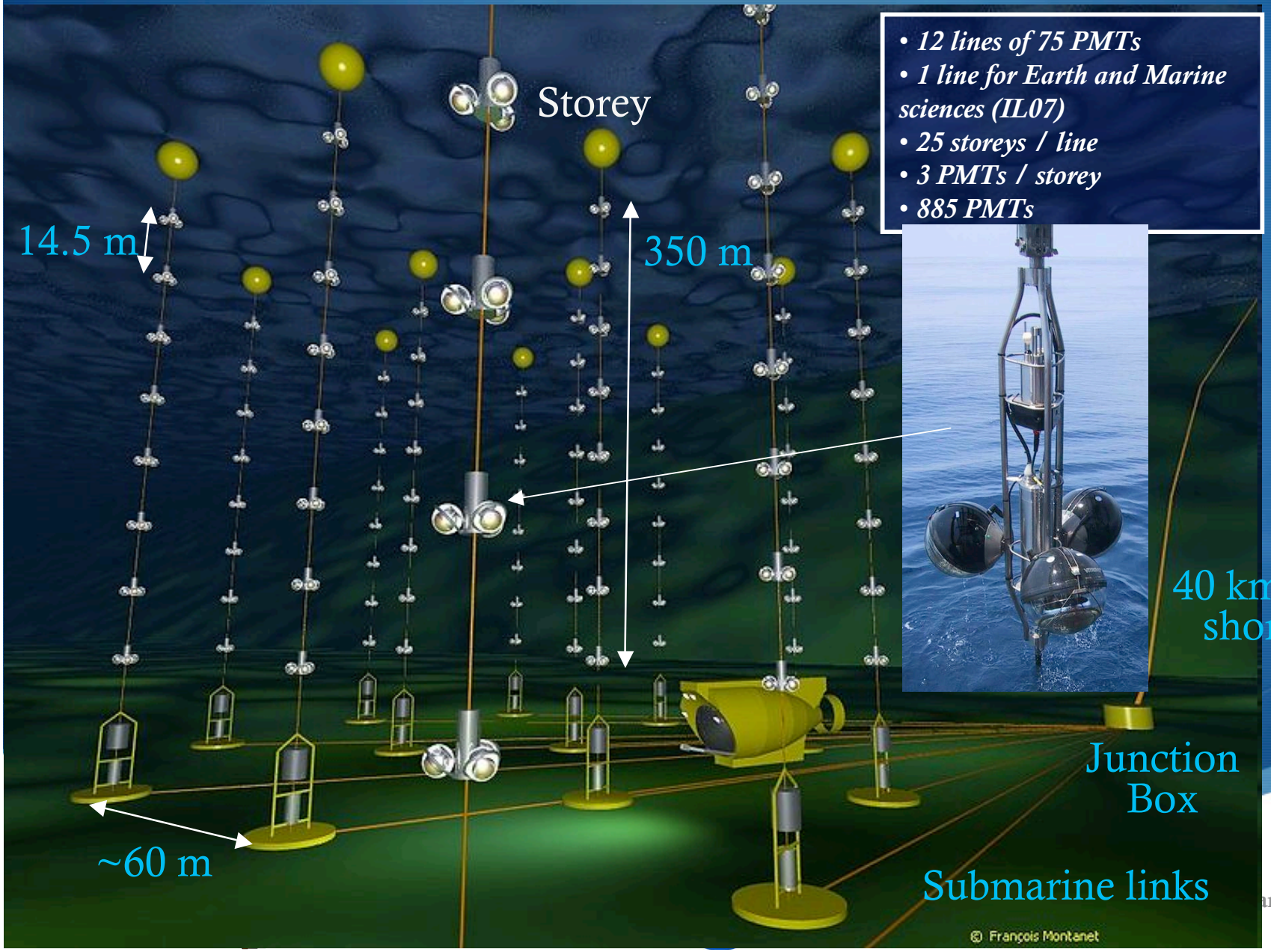
2006–2008: deployments of the detector lines



- **Line 1, 2**: 2006
- **Line 3, 4, 5**: January 2007
- **Line 6, 7, 8, 9, 10**: December 2007
- **Line 11, 12**: May 2008



The telescope setup



- *12 lines of 75 PMTs*
- *1 line for Earth and Marine sciences (IL07)*
- *25 storeys / line*
- *3 PMTs / storey*
- *885 PMTs*

The storey

titanium frame: support structure (2m)

Optical Beacon with blue LEDs: timing calibra

l Module: amatsu PMT ass sphere ≈ 1.3 ns) detection

rophone: positioning

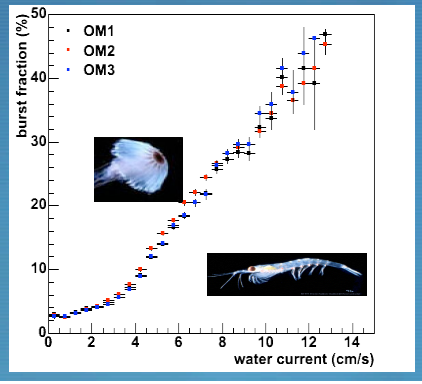
Local Co (in Ti Front- DAQ/S Clock, ti power di

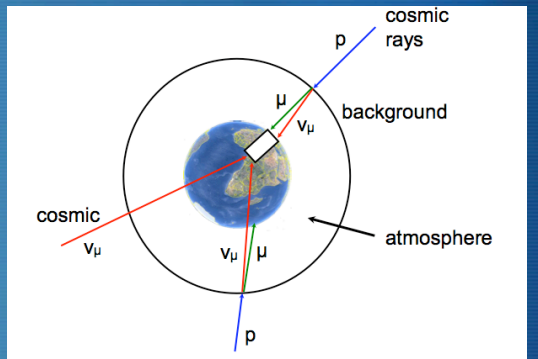
Background

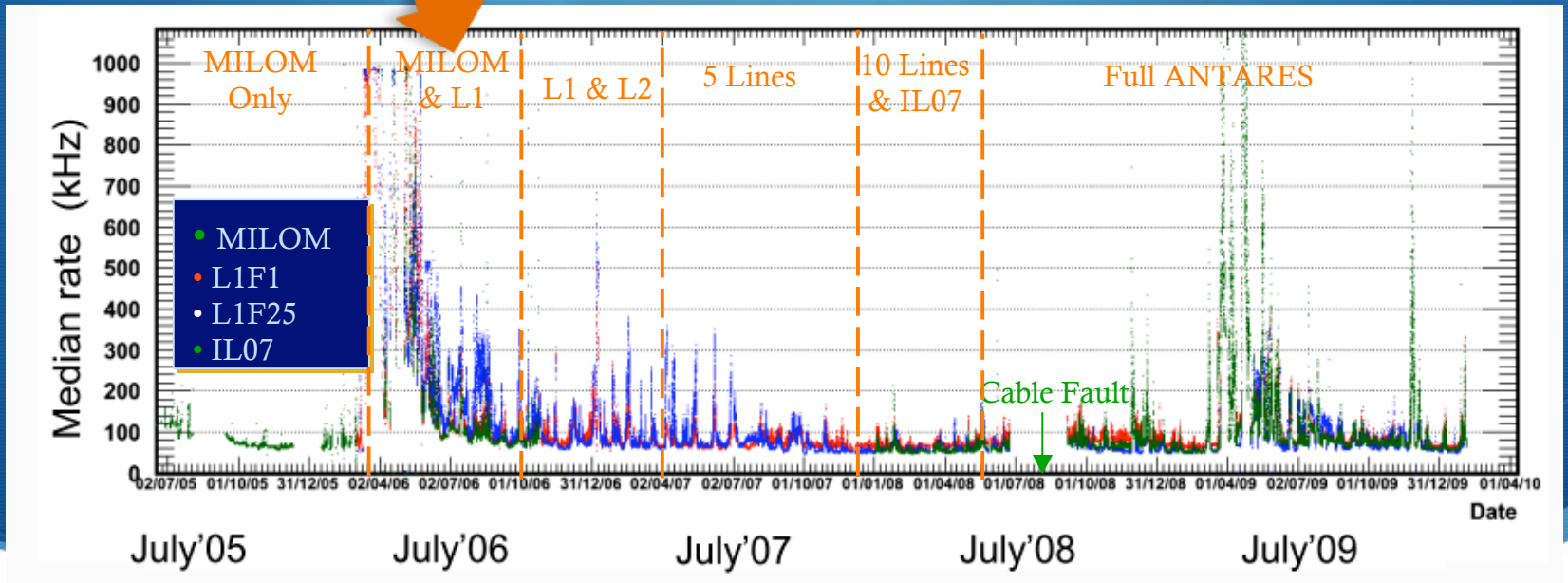
Optical Background: bioluminescence (bacteria) and ^{40}K decay (sea environment) ~70 kHz + bursts from macro-organisms few MHz, strongly affected by sea currents

Physics Background : cosmic rays (atmospheric μ and ν).

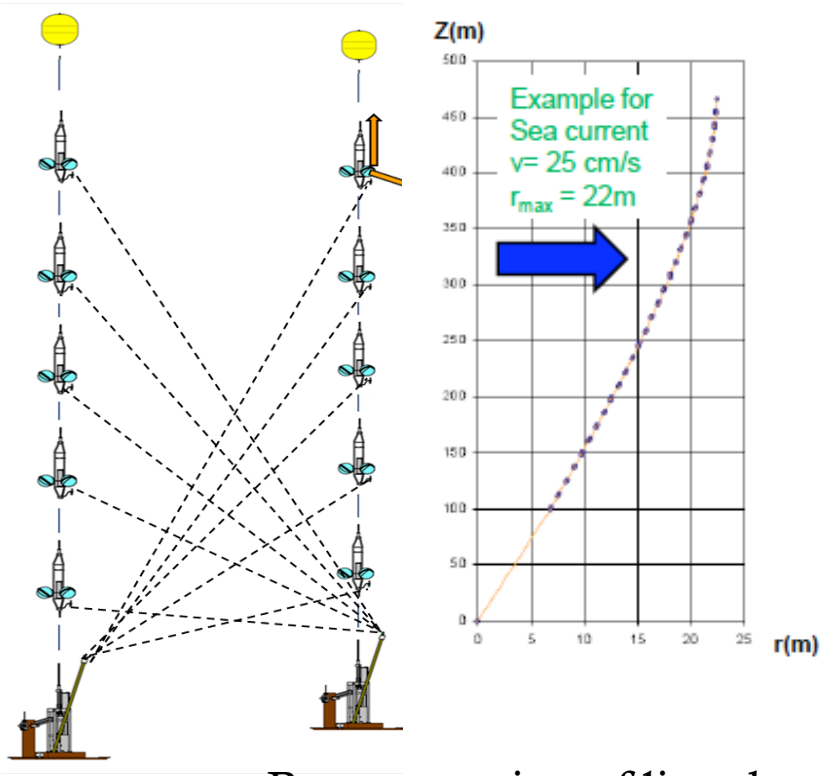
dense-water formation (cold winter) and local sea current instabilities caused sinking of large amounts of bioluminescent material (crustacea, zooplankton….)
In press in Ocean Science







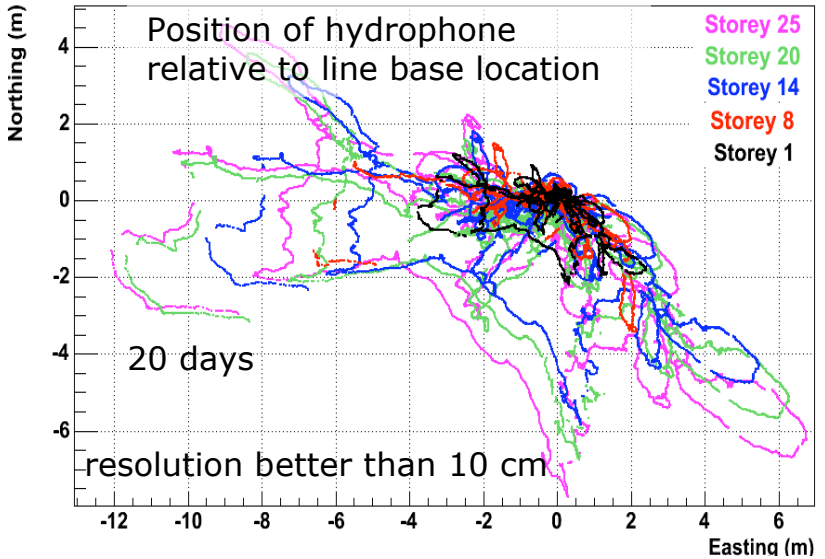
Position calibration



Reconstruction of line shape

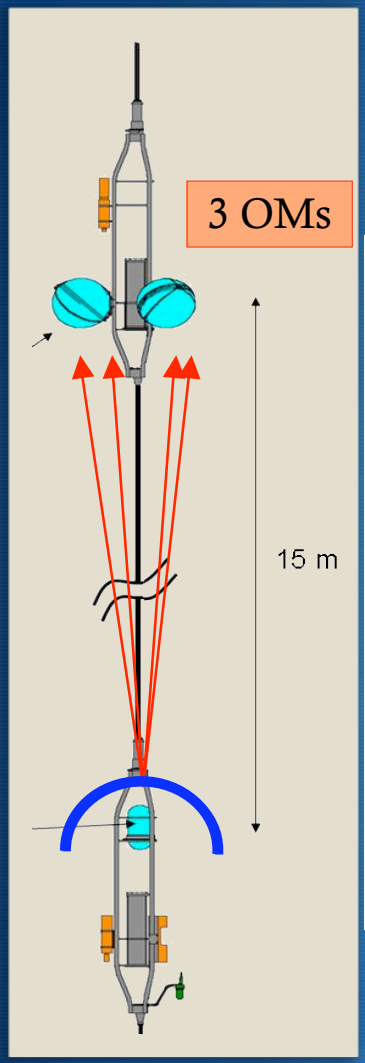
- 1 emitter/receiver at the bottom of each line
- 5 receivers along each line
- 4 autonomous transponders around the apparatus
- Sound velocimeters installed at various depths
- Tiltmeter and compass at each storey

Measurements performed every 2 minutes

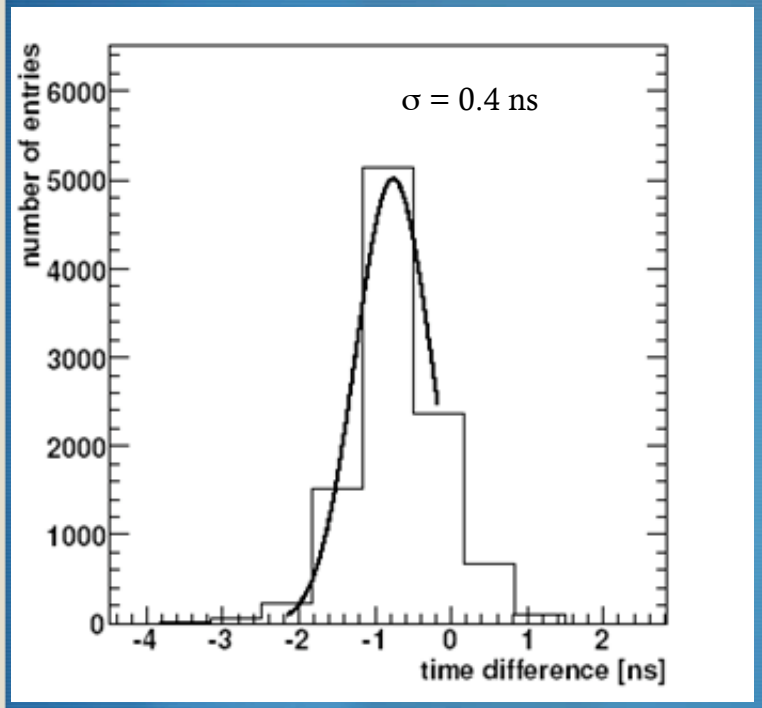


Time calibrations

Time difference between the LED OB and an OM



Optical LED beacon



- Electronics + calibration → σ ~ 0.5 ns
- TTS in photomultipliers → σ ~ 1.3 ns
- Light scattering + dispersion in sea water → σ ~ 1.5 ns at 40 m

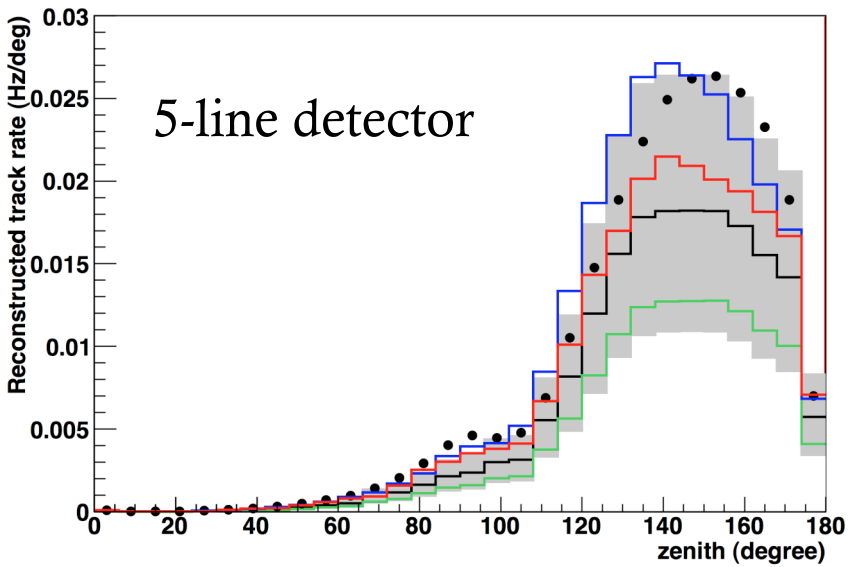
Angular resolution → 0.3° (for E_ν > 10 TeV)

SELECTED RESULTS

- Atmospheric muon flux
- Atmospheric neutrinos
- Point sources
- Diffuse ν_μ flux

Atmospheric muons

Zenith distribution and flux of atmospheric μ measured with the 5-line ANTARES detector, arXiv:1007.1777v1, in press in APP (DoI: 10.1016/j.astropartphys.2010.07.001)



- **black points : data 5-line detector (2007)**
- : MUPAGE Monte Carlo **[Com. Phys. Comm. 179(2009)915]**
- : CORSIKA + QGSJET + NSU param for primary CRs
- : CORSIKA + QGSJET + "poly-gonato" param for primary CRs
- : CORSIKA + SIBYLL + NSU param for primary CRs.

For details on:

- NSU model : E. V. Bugaev et al., Phys. Rev. D58 (1998) 05401.
- Polygonato model: J. Horandel, Astropart. Phys. 19 (2003) 193.
- MUPAGE : G. Carminati et al., Comput. Phys. Commun. 179 (2008) 915.

Main sources of systematic uncertainties:

- environmental parameters (absorption and scattering length)
- detector parameters (OM efficiency)
- **Shadowed band:** systematic uncertainty w.r.t. the black line (± 40 %) .

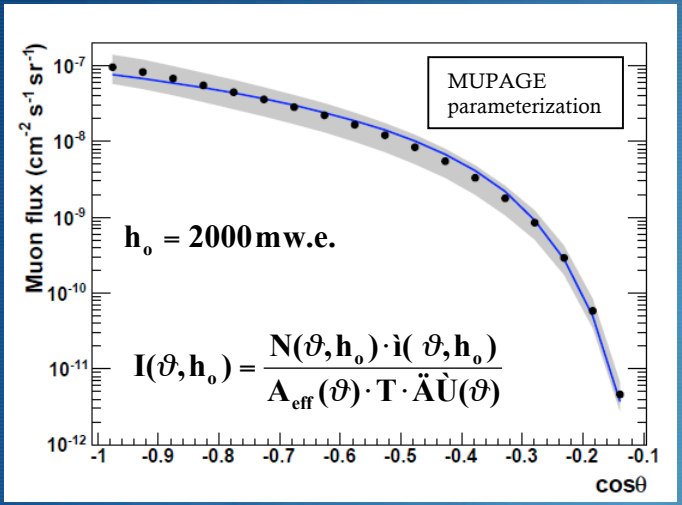
- physics:
  - hadronic interaction models
  - models of cosmic ray composition

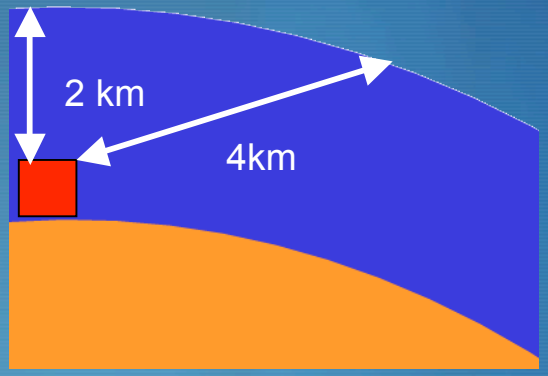
- within systematic uncertainties data are reproduced by MC

➔ good understanding of the detector and its environment

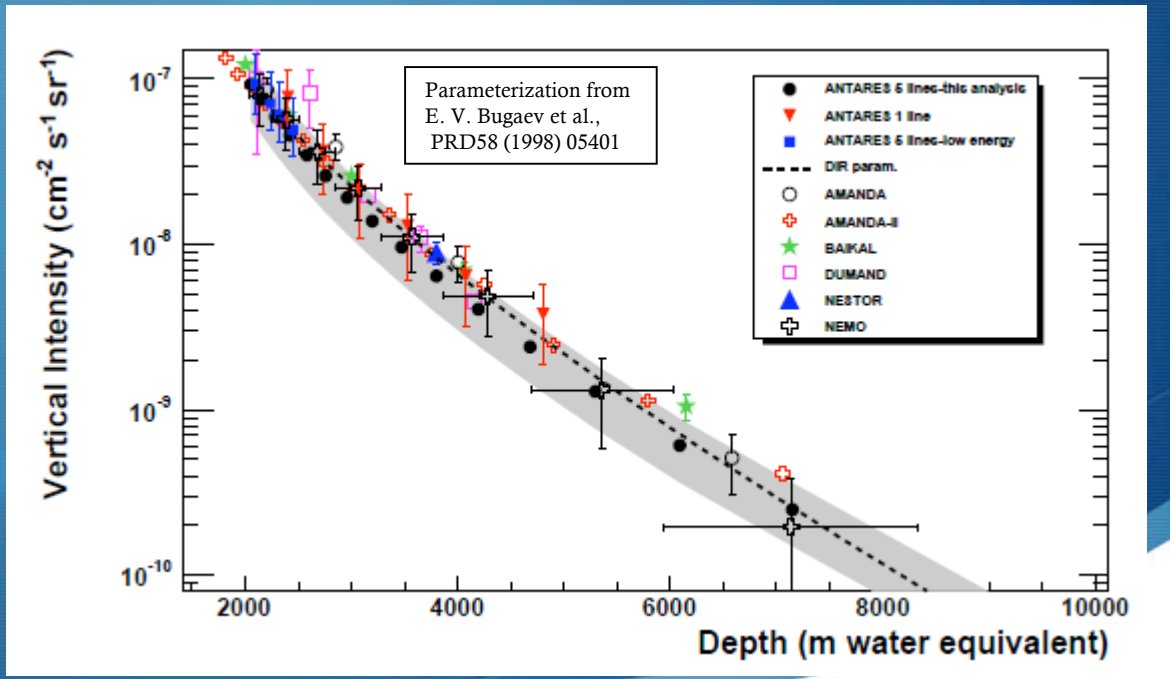
- work in progress to reduce uncertainties

Muon Depth-Intensity relation



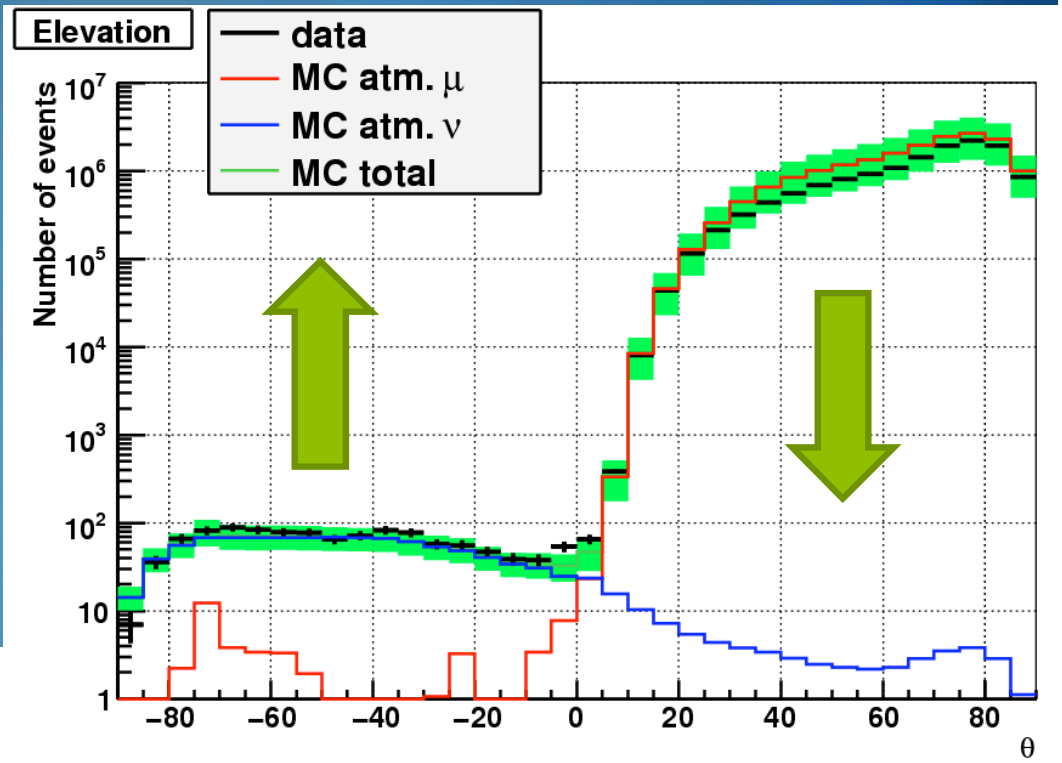


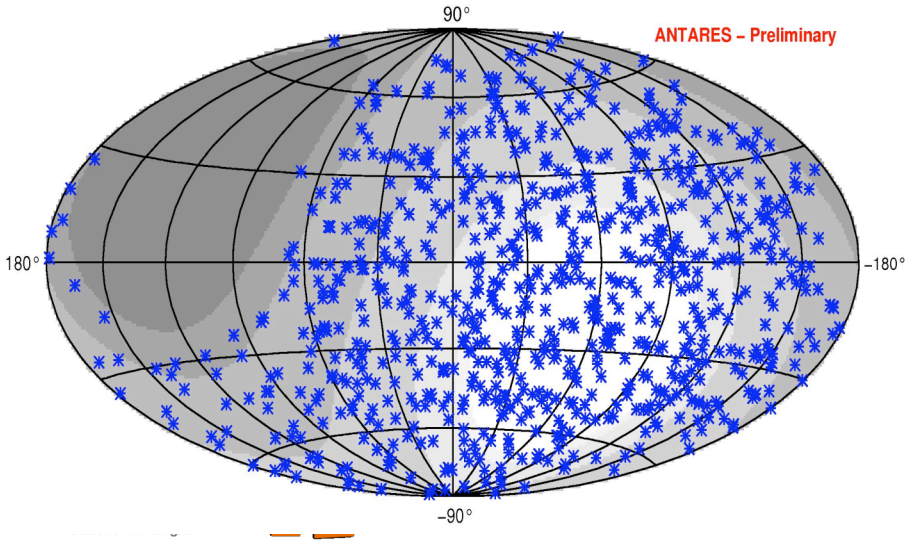
$$I(\vartheta = 0, h) = I(\vartheta, h_o) \cdot |\cos(\vartheta)| \cdot c_{corr}(\vartheta)$$



Atmospheric neutrinos

- May 2007 - December 2008
  341 days detector live time
- **Upgoing:**
  1062 neutrino candidates: **3.1 ν**/day
- **Monte Carlo:**
  atmospheric neutrinos: 916
  (30% syst. error)
  bad reco atmospheric μ : 40
  (50% syst. error)



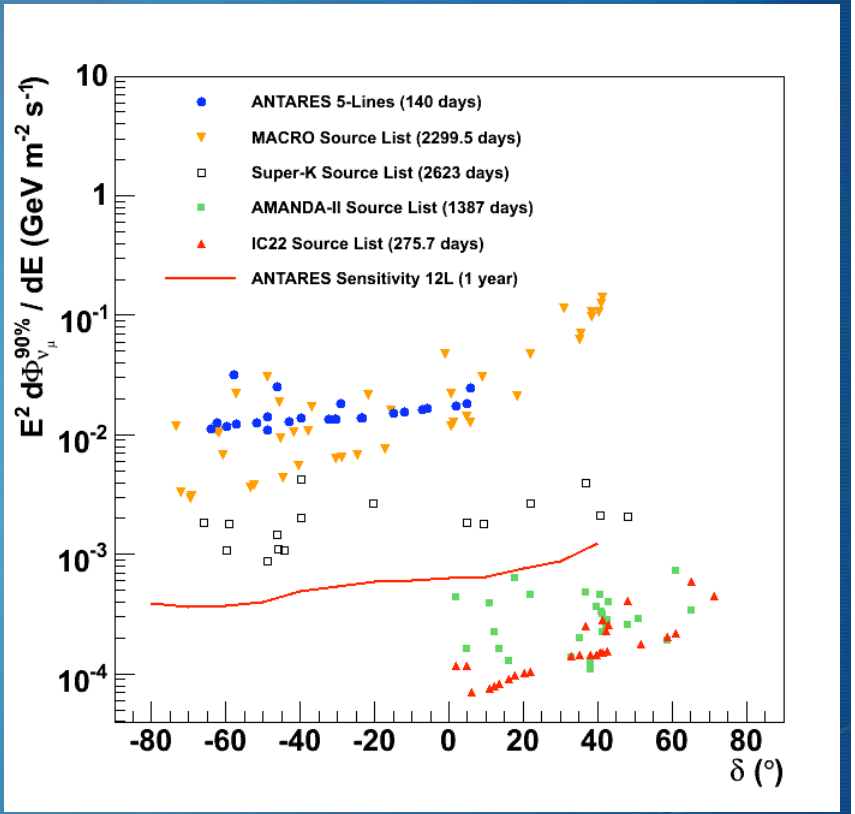


Scrambled ANTARES sky map

Point sources – 5 lines

search for clusters of neutrinos

25 potential sources (stringent cuts to reduce background)
analysis optimization based on simulations
5-line data unblinding ➔ 140 days of detector livetime
no excess found



12 lines analysis in progress

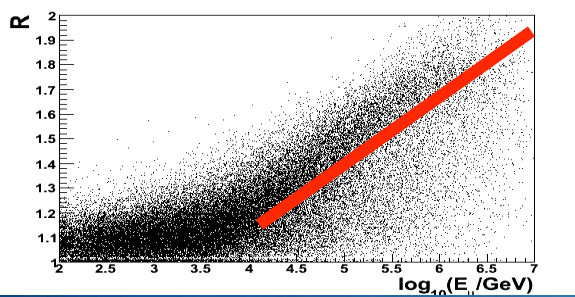
Diffuse flux analysis

Selection of high energy neutrino events ➔ Background rejection

- Atmospheric muons : quality cuts on track reconstruction
- Atmospheric neutrinos : low energy events removed using an energy estimator

High energy events➔ high probability to have more than 1 hit on each PMT.

μ direct photons + μ scattered photons + light from EM showers

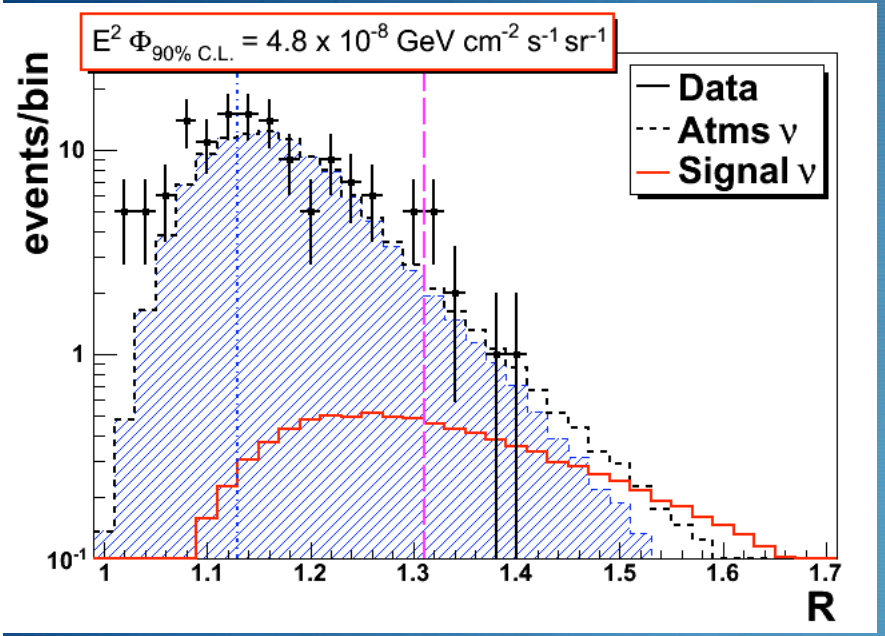


- R_i = number of hits on i-th PMT
- $R = \Sigma R_i$ / number of all PMTs contributing to the event

$R > 1.31$

analysis optimized using MC to define the best R cut :
Model Rejection Factor technique **[APP 19 (2003)393]**

Diffuse flux analysis



R< 1.31

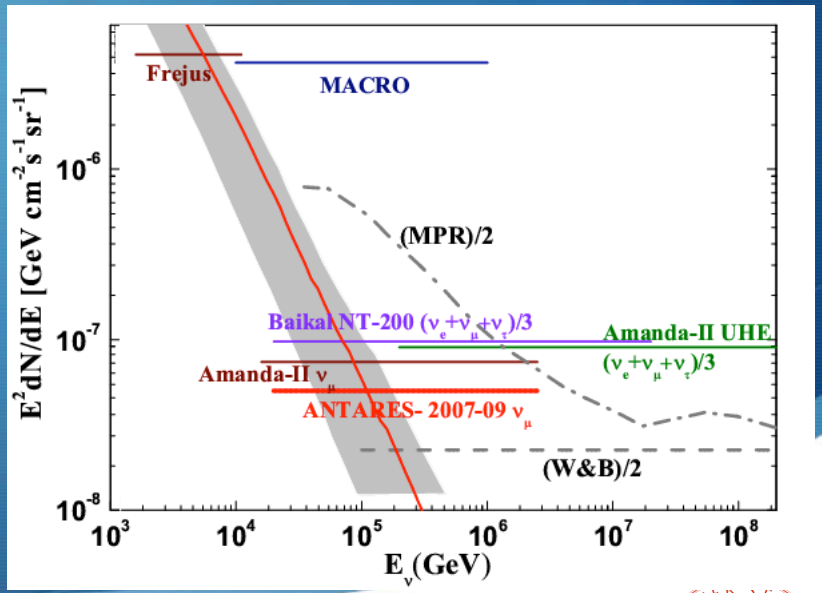
Bartol (conventional ν)	104.9
Max "prompt" model	2.1
Data	120

R≥ 1.31

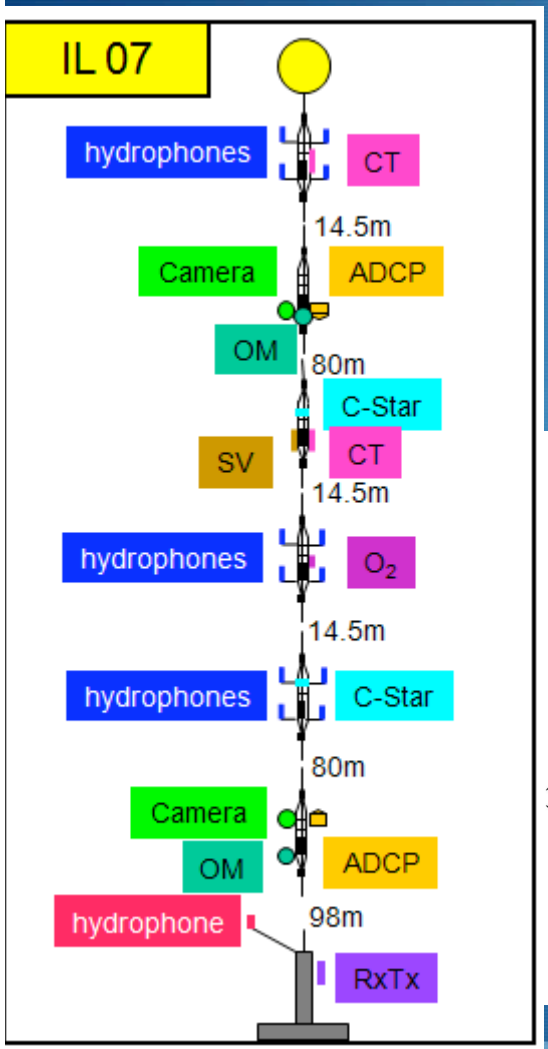
Atmospheric ν	10.5 ±2
Data	9

$E^2\Phi(E)_{90\%} = 4.8\times10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}

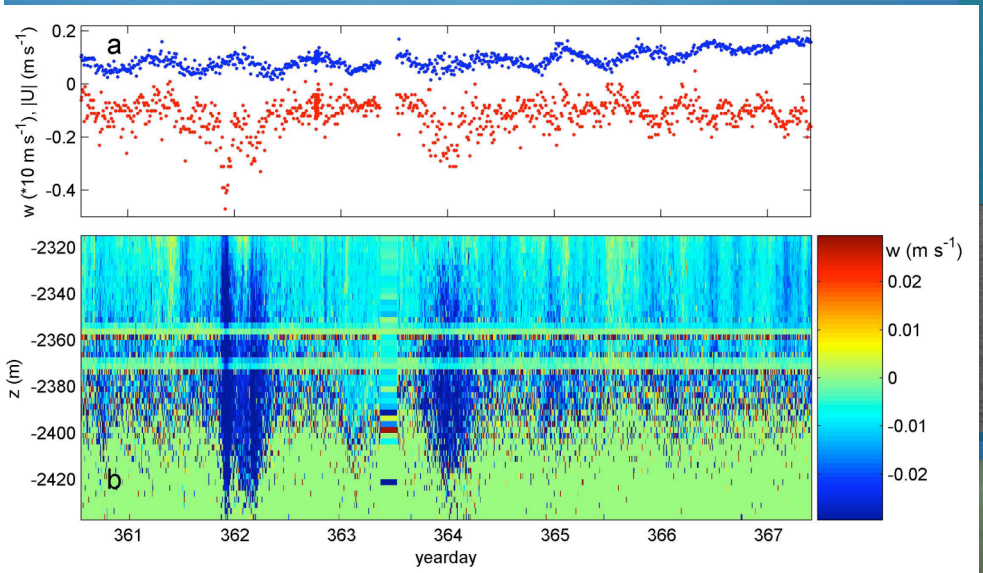
20 TeV<E<2.5 PeV

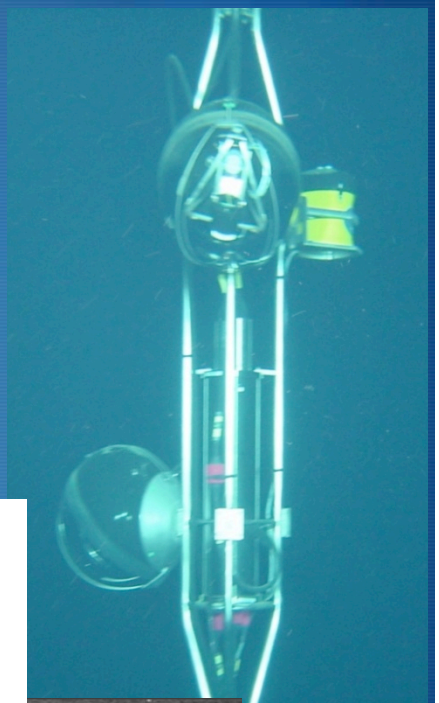


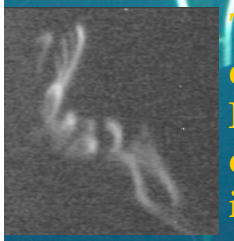
Earth and Sea Science with the Instrumentation Line



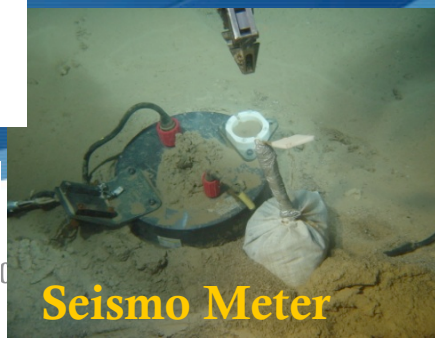
- Bioluminescence
- Environmental Monitoring
- Seismology
- Oceanography (Med Sea Circulation)







The deepest Infra-red camera in the sea



Seismo Meter

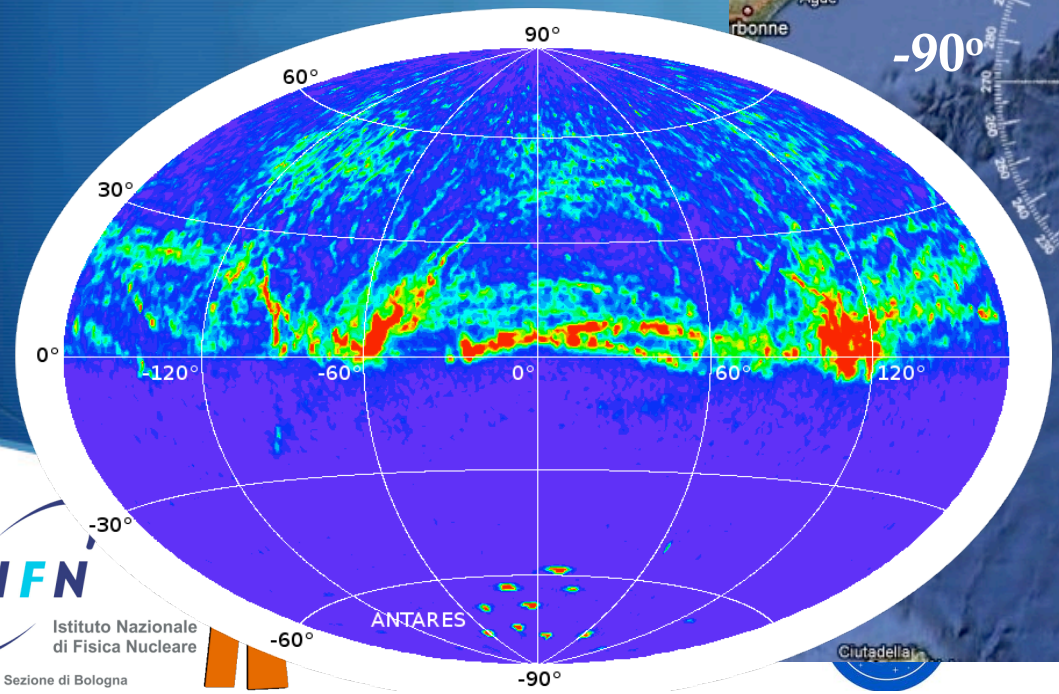
Centre d'océanologie de Marseille
Sezione di Bologna

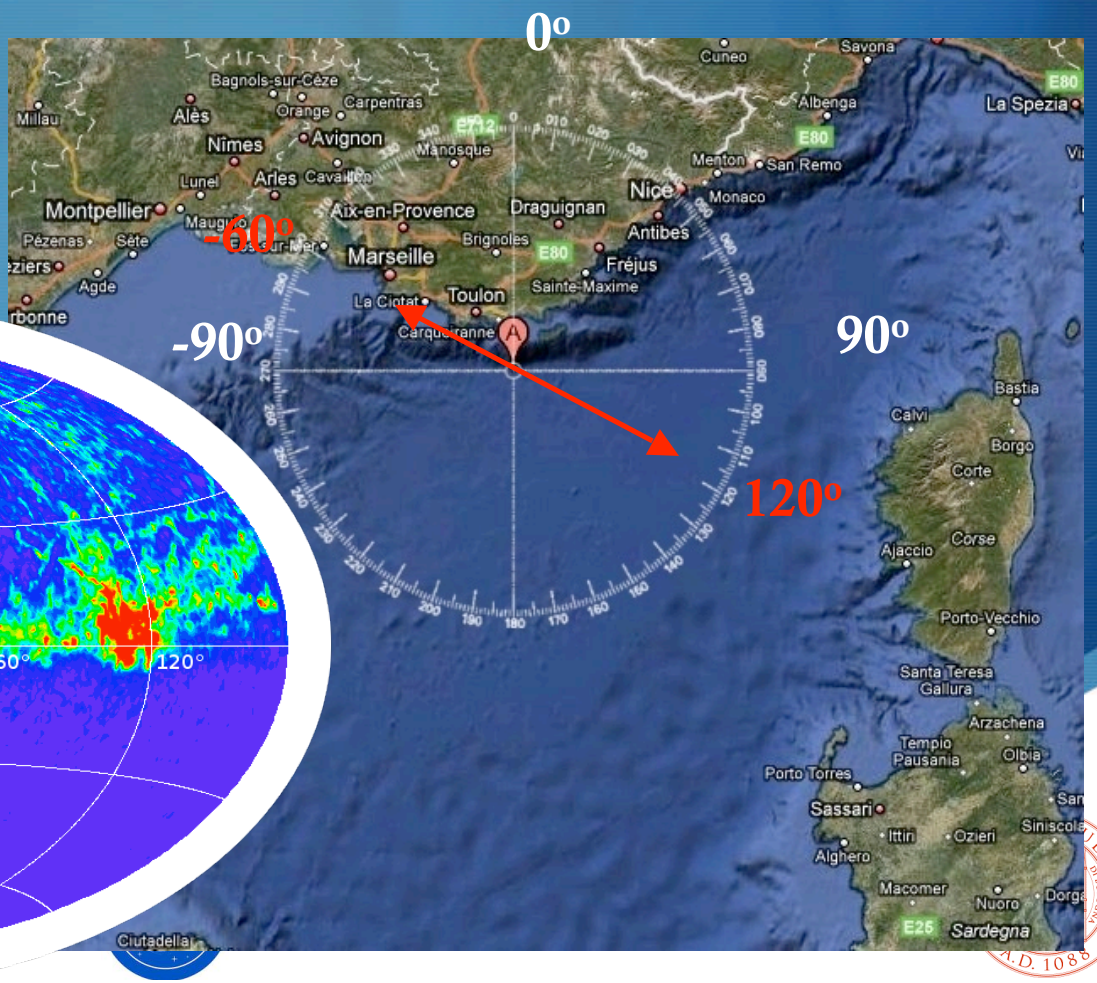
GEOSCIENCES Azur -2010

Next future: deployment of a secondary JB for Scientific and technological applications IFREMER/CNRS

AMADEUS

- R&D activity for acoustic neutrino detection
- System of hydrophones on the IL07 and line 12
- Study of environmental background
- Direction recostruction





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Ongoing combined searches

- Receive GRB alerts from satellites (Fermi, Swift...)
  - search for coincident neutrinos within time window (~100 seconds)
- Send neutrino cluster alert for optical follow-up
  - Trigger: multiple / HE single neutrino event; Reconstruction "on-line" (<10ms)
  - Alert message to Tarot Telescope in La Silla (Chile)
  - Tarot takes 6 images of 3 minutes immediately and after 1, 3, 9 and 27 days sending alerts to the ROTSE system (4 telescopes) since 3 months
- Correlation with AUGER source distribution investigate directional correlation of neutrinos and UHE particles
- Correlation with VIRGO-LIGO signals investigate correlation of neutrinos and gravitational waves

Conclusions

- ANTARES detector completed in May 2008
  - detector operation and calibration under control
  - maintenance capability demonstrated
- Exciting physics program ahead
  - over two thousand neutrinos already reconstructed
  - astronomical sources, multi-messenger approach, other analyses 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

  (E. de Wolf's talk – tomorrow afternoon - 3P_PA2)