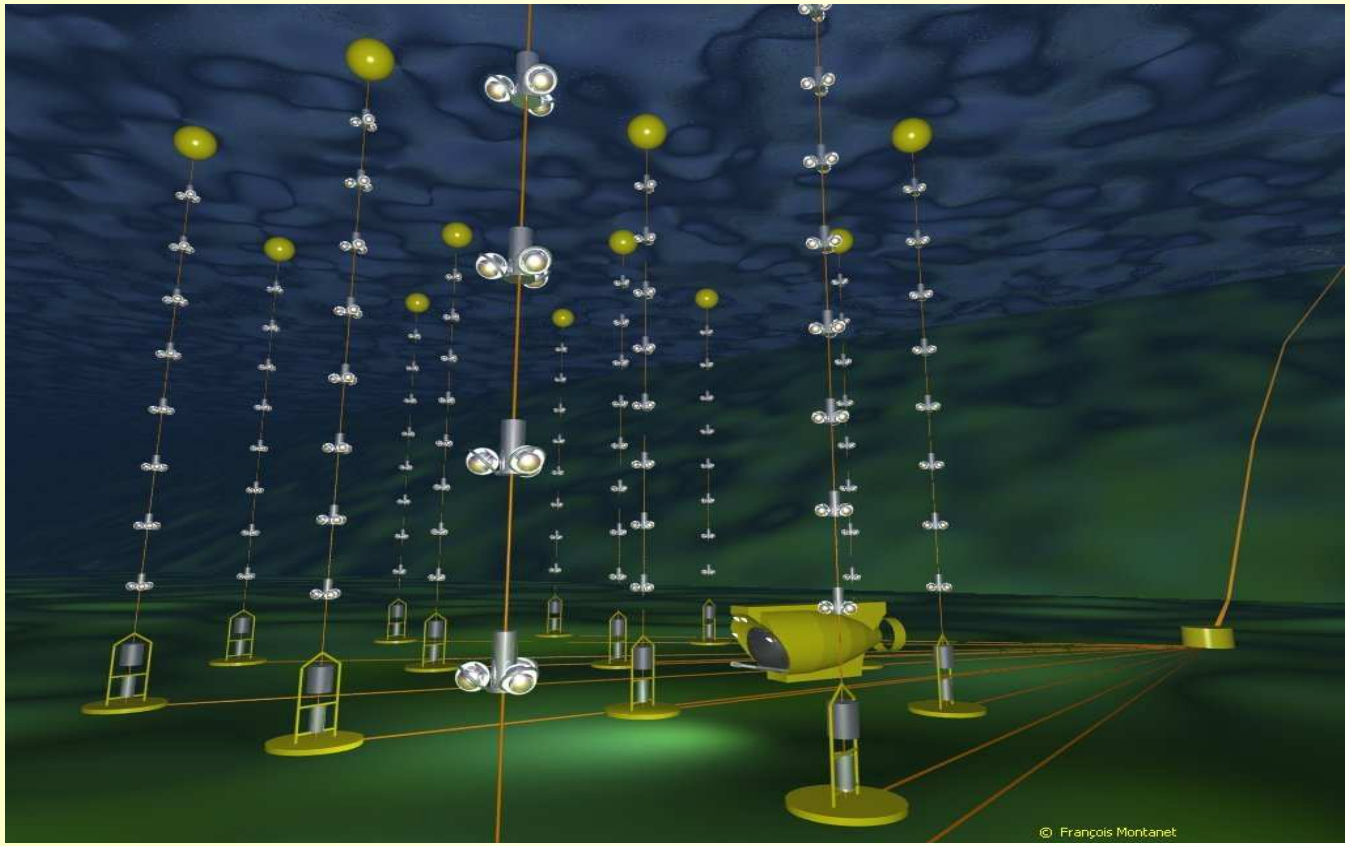
Deep-Sea Neutrino Telescopes ANTARES and KM3NeT

Miguel Ardid and Manuel Bou-Cabo
Universitat Politècnica de València, Spain



UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Outline

- Physics with deep under-water (or ice) Neutrino Telescopes

- The ANTARES Neutrino Telescope in Mediterranean Sea :
  - the detector
  - physics goals
  - data and first results

- The future: KM3NeT

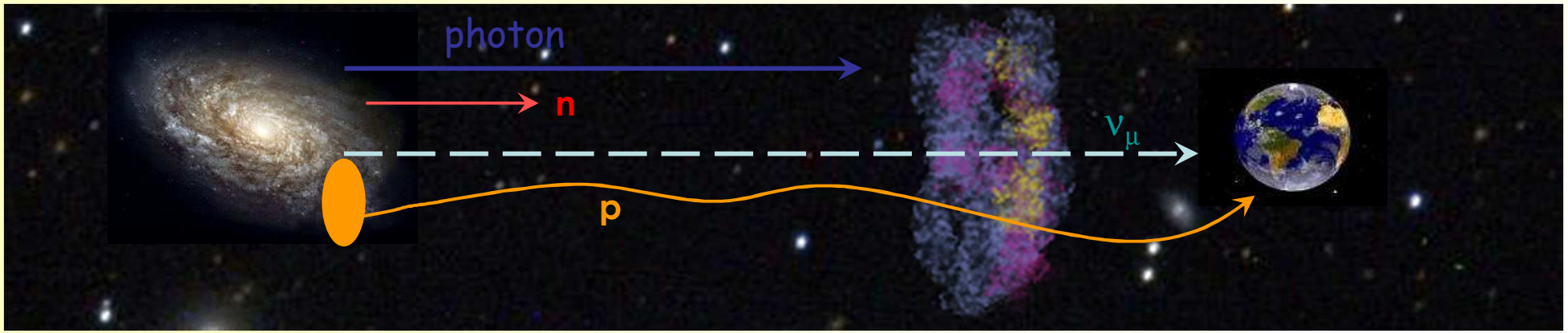
- Acoustic activities in underwater neutrino telescopes

Neutrino astronomy

Advantages w.r.t. other messengers (to study the deepest Universe):

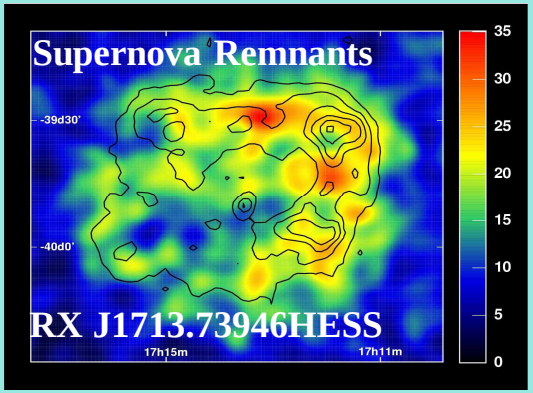
- Photons: interact with CMB and matter
- Protons: interact with CMB and are deflected by magnetic fields
- Neutrons: are not stable
- Neutrinos point back to the source of emission

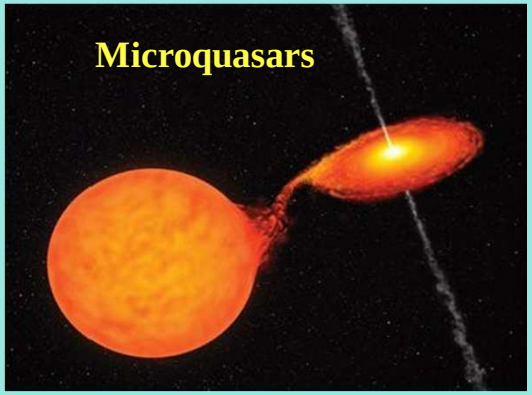
- Drawback: large detectors (~GTon) are needed.



Point-like cosmic Neutrino Sources

Galactic

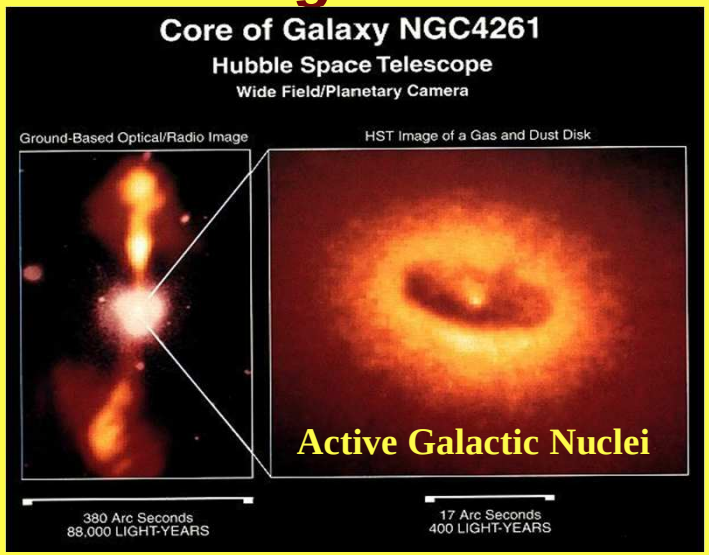


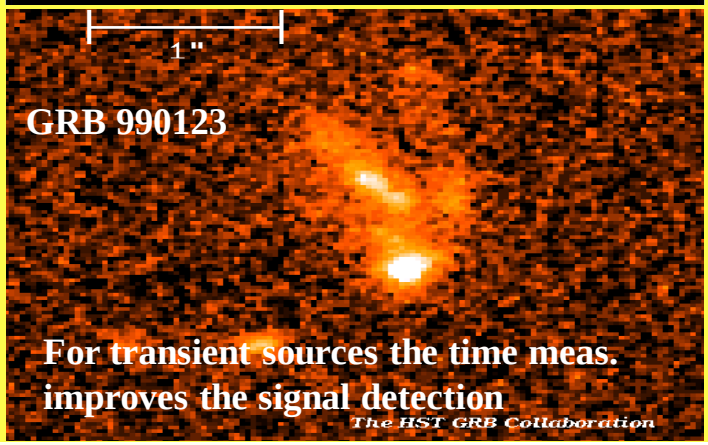


Their identification requires a detector with accurate angular reconstruction

$$\sigma(\vartheta) \leq 0.5^\circ \text{ for } E_\nu \geq 1 TeV$$

Extragalactic





Experimental signal : statistical evidence of an excess of events coming from the same direction

Diffuse Cosmic Neutrino Sources

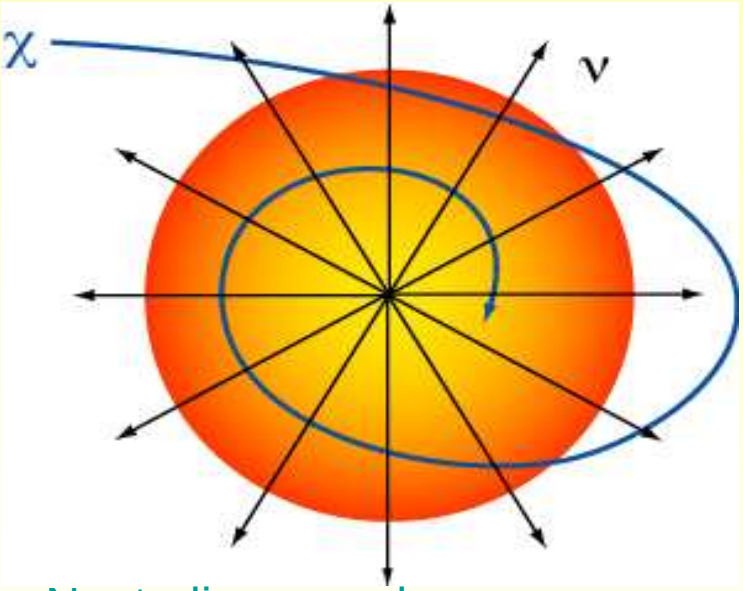
- Unresolved AGN
- Neutrinos from "Z-bursts"
- Neutrinos from "GZK like" proton-CMB interactions
- Neutrinos foreseen by Top-Down models
- ….

Their identification out of the more intense background of atmospheric neutrinos (and muons) is possible at very high energies (E_μ > TeV) and implies energy reconstruction.

… not only neutrino astrophysics…

… also open problems in particle physics …

- Dark Matter searches:
  - Neutralino annihilation in Sun, Earth, Galactic Center
- Monopoles
- Acceleration mechanisms
- Neutrino interaction Cross sections
- …



Neutralino search: $\chi\chi \rightarrow \nu + \ldots$

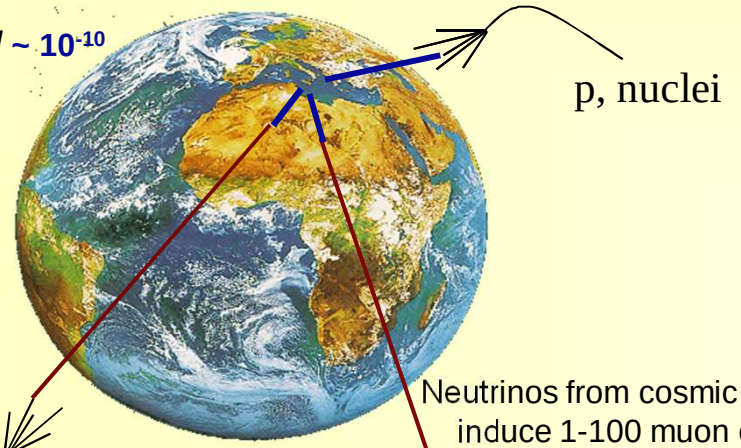
Detection principle

Search for neutrino induced events, mainly $\nu_\mu N \rightarrow \mu X$, deep underwater

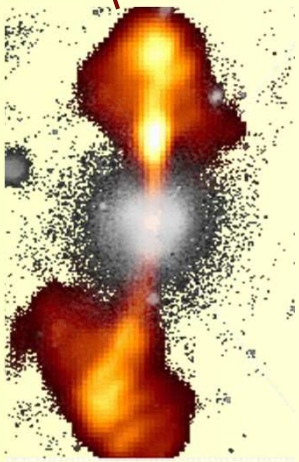
Down-going μ from atm. showers

$\mu_{upgoing} / \mu_{atm}$ **~ 10^{-6} at 3500m w.e. depth**

***S/N* ~ 10^{-10}**



Neutrinos from cosmic sources induce 1-100 muon evts/y in a km³ Neutrino Telescope



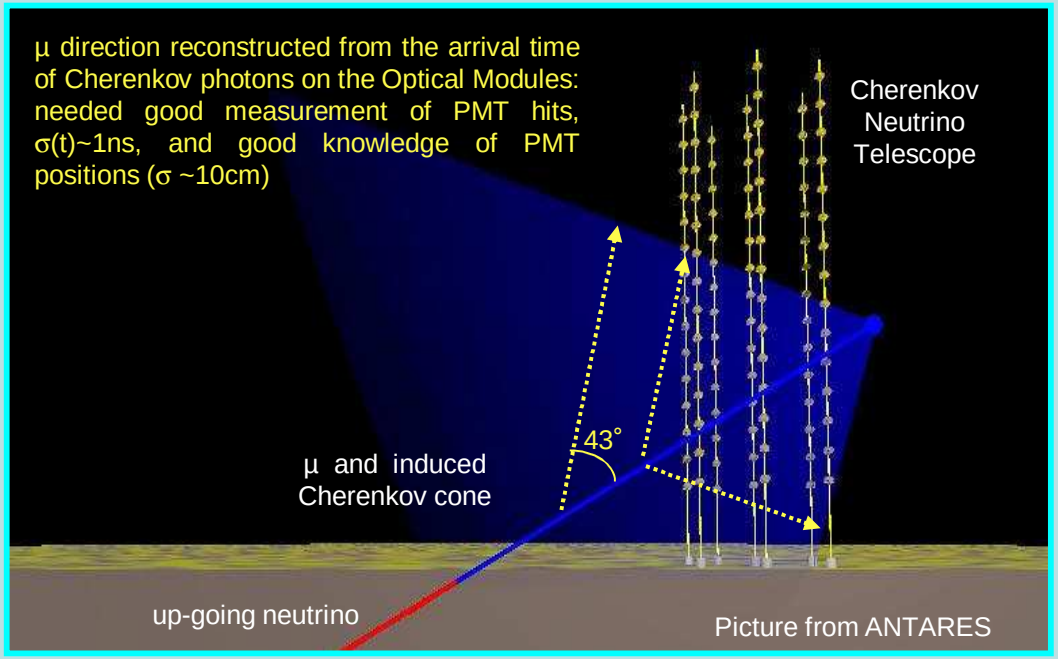
Up-going μ from neutrinos generated in atm. showers

***S/N* ~ ν_{astro} / ν_{atm} ~ 10^{-4}**

- Atmospheric neutrino flux ~ E_ν^{-3}
- Neutrino flux from cosmic sources ~ E_ν^{-2}
  - Search for neutrinos with E_ν>1÷10 TeV

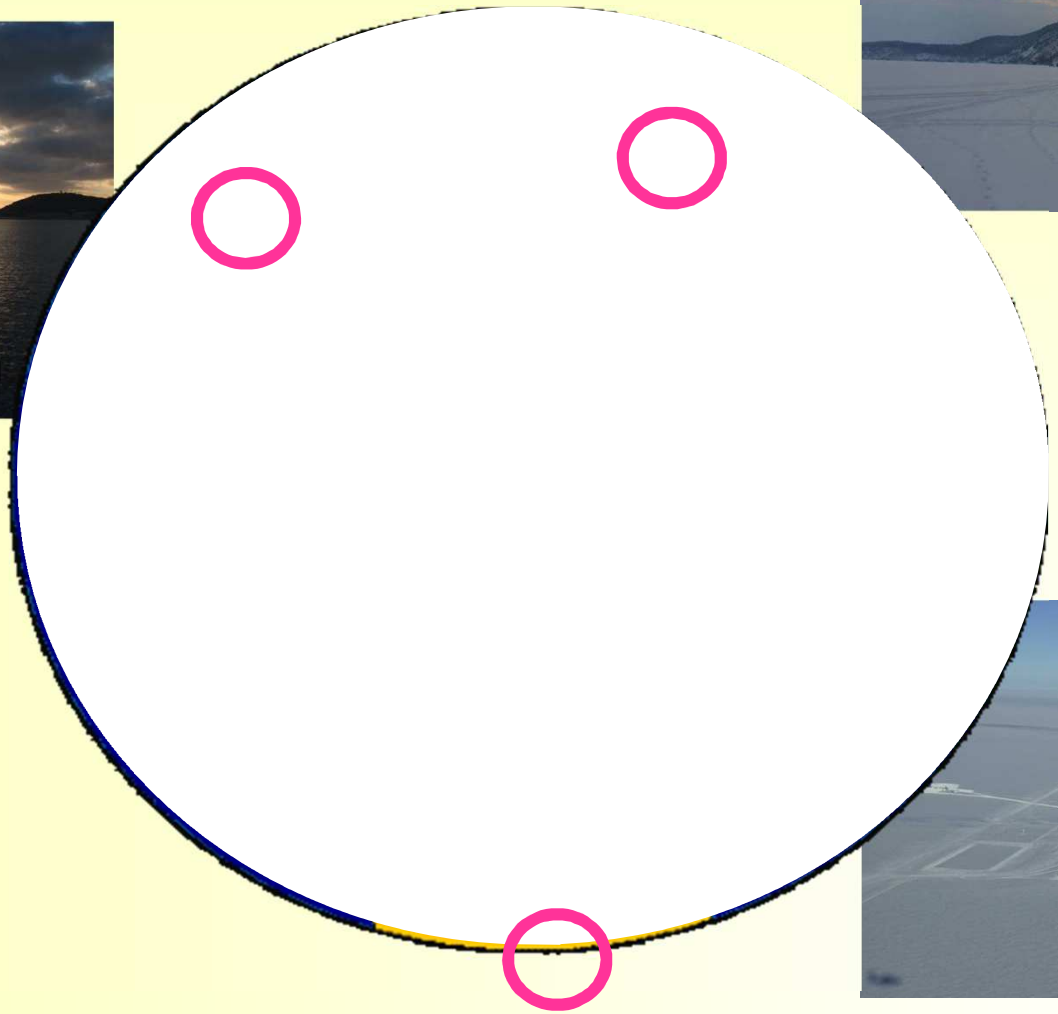
- ~TeV muons propagate in water for several km before being stopped
  - go deep to reduce down-going atmospheric μ backg.
  - long μ tracks allow good angular reconstruction

$$For\ E_\nu \geq 1TeV \quad \theta_{\mu\nu} \sim \frac{0.7°}{\sqrt{E_\nu[TeV]}}$$

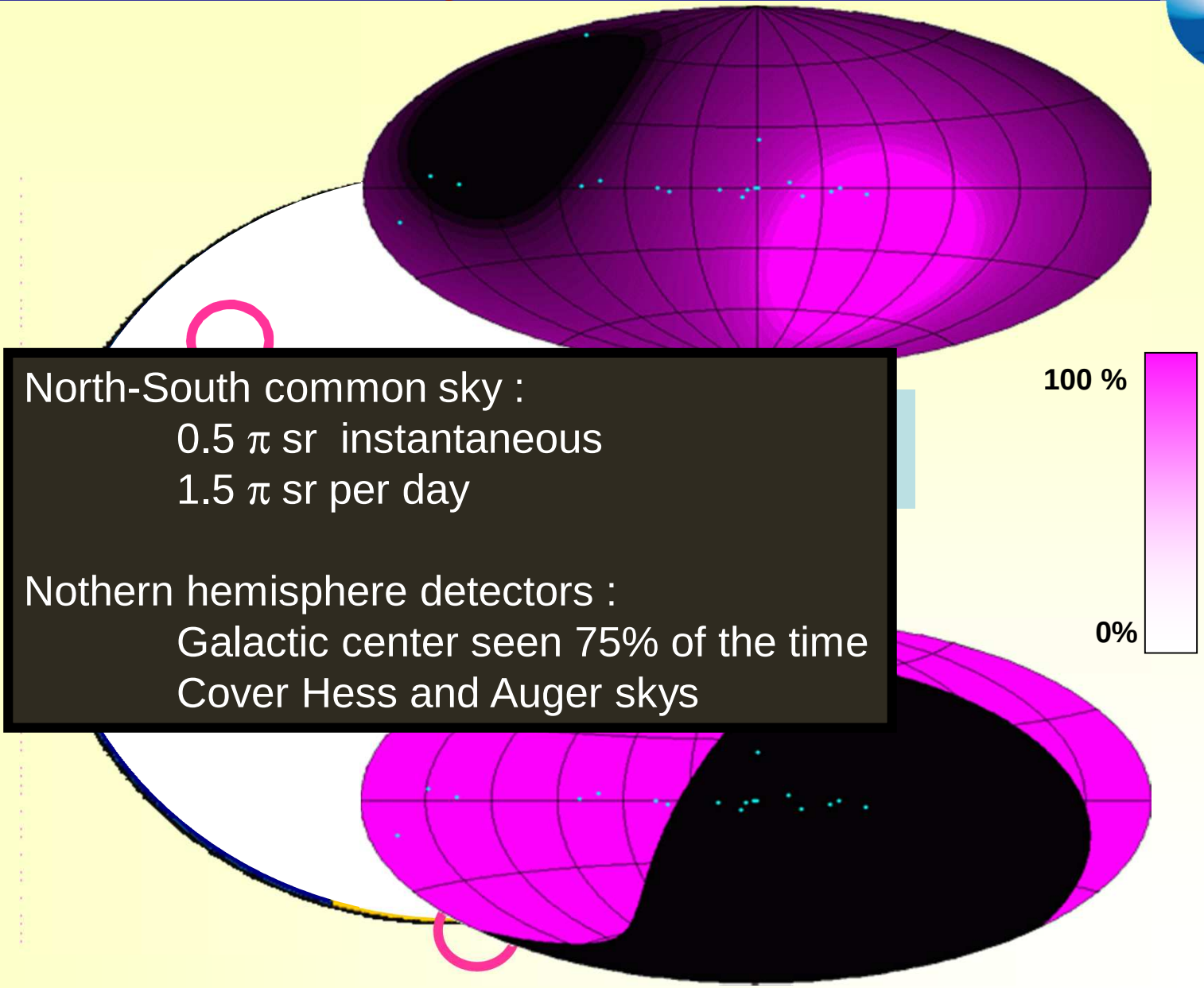


UNIVERSITAT POLITÈCNICA DE VALÈNCIA

High Energy ν telescopes



Sky view



North-South common sky :

0.5 π sr instantaneous

1.5 π sr per day

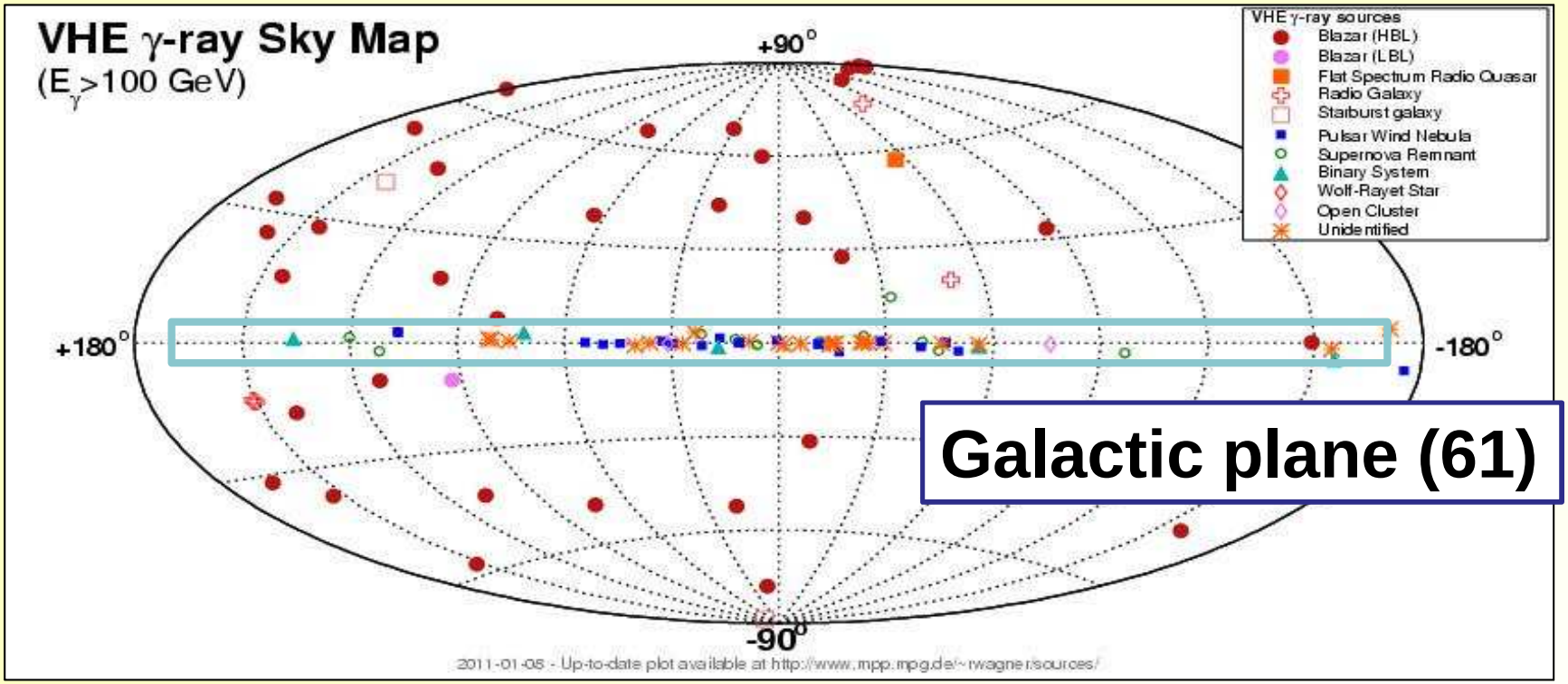
Nothern hemisphere detectors :

Galactic center seen 75% of the time

Cover Hess and Auger skys

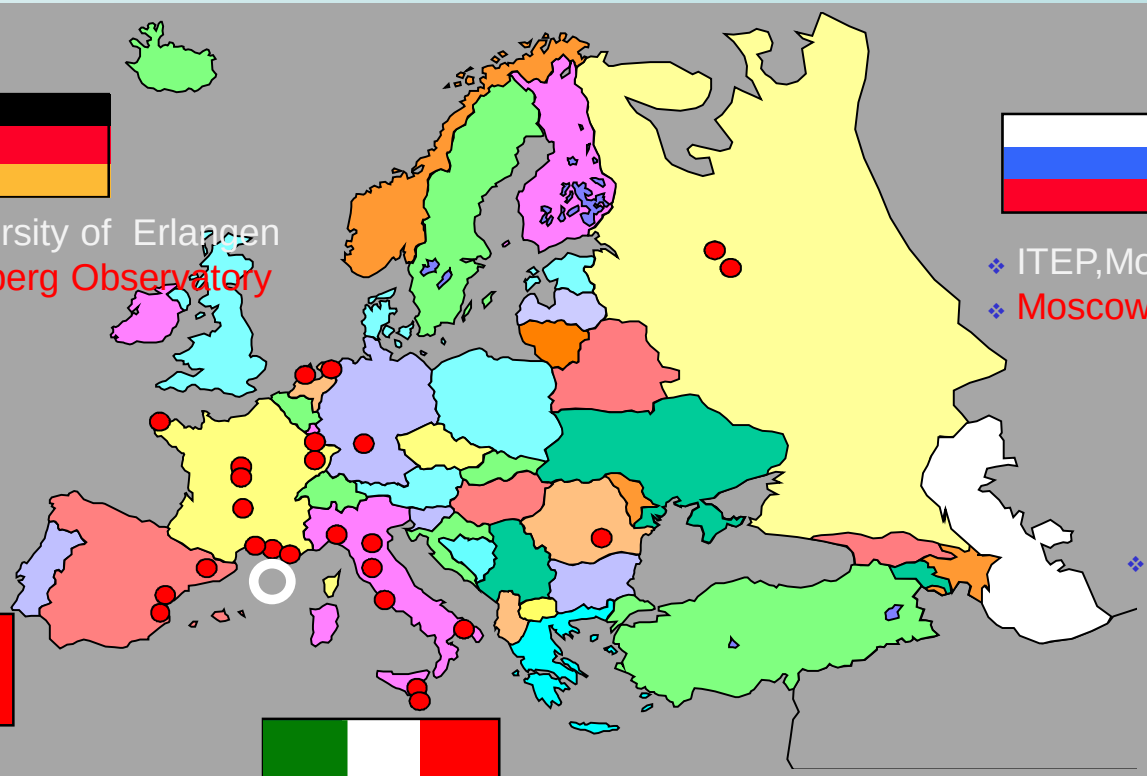
Searches for sources…

VHE γ-ray sources (107) detected by Cerenkov telescope



→ Many sources without counterpart (unidentified)

ANTARES Collaboration



- NIKHEF,
- Amsterdam
- Utrecht
- KVI Groningen
- NIOZ Texel

- University of Erlangen
  Bamberg Observatory

- ITEP,Moscow
- Moscow State Univ

- ISS, Bucarest

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

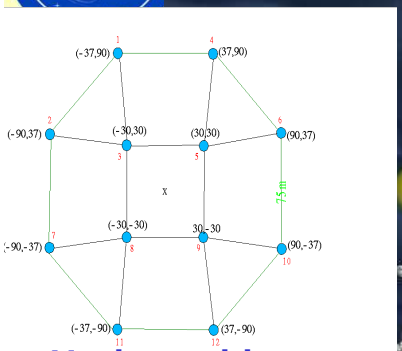
- CPPM, Marseille
- DSM/IRFU/CEA, Saclay
- APC, Paris
- LPC, Clermont-Ferrand
- IPHC (IReS), Strasbourg
- Univ. de H.-A., Mulhouse
- IFREMER, Toulon/Brest
- C.O.M. Marseille
- LAM, Marseille
- GeoAzur Villefranche

- 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

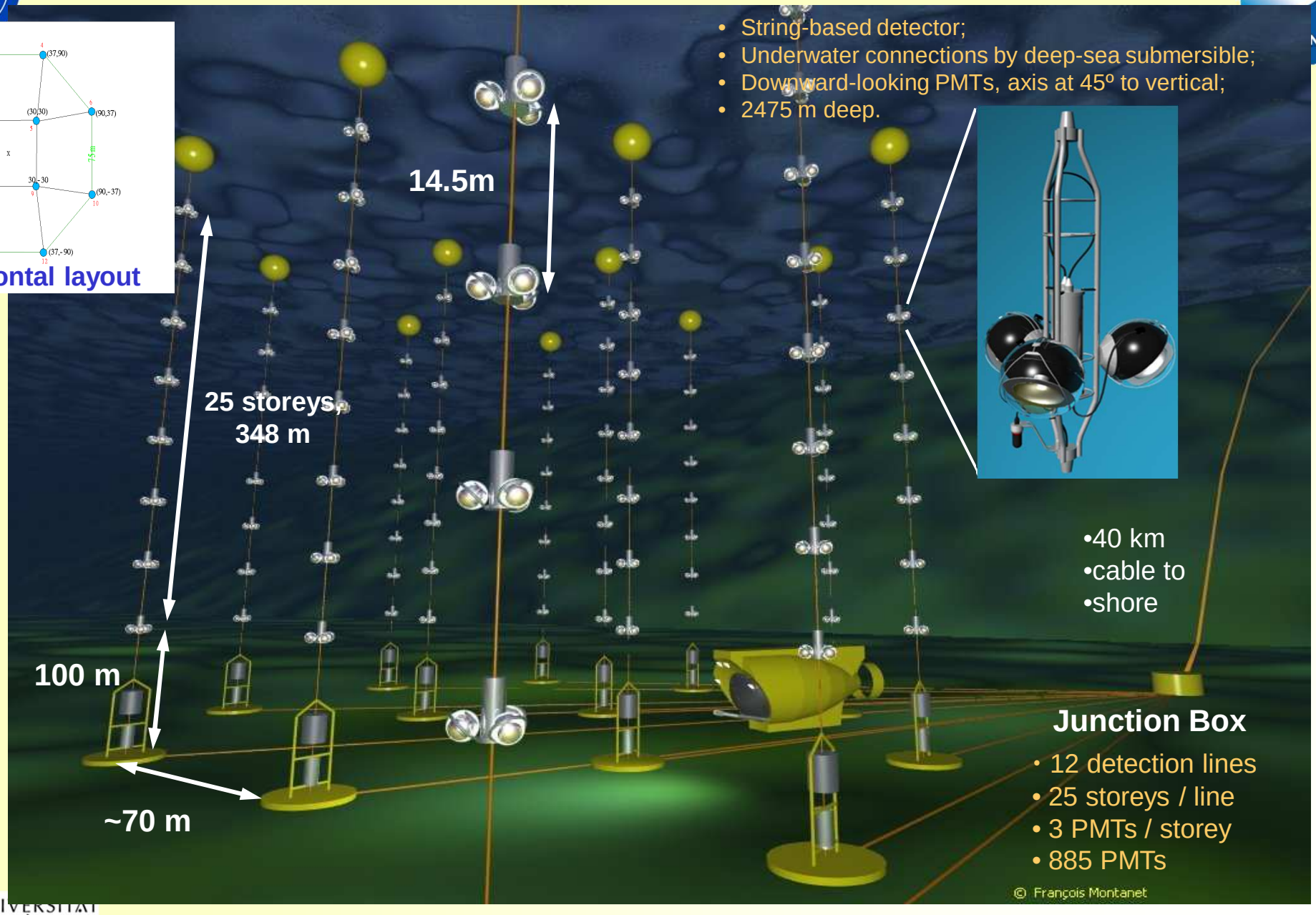
7 countries
29 institutes
~150 scientists+engineers

ANTARES site is about 2475 m deep and 40 km from Toulon (France)

The ANTARES experiment



Horizontal layout



- String-based detector;
- Underwater connections by deep-sea submersible;
- Downward-looking PMTs, axis at 45º to vertical;
- 2475 m deep.

•40 km
•cable to
•shore

Junction Box

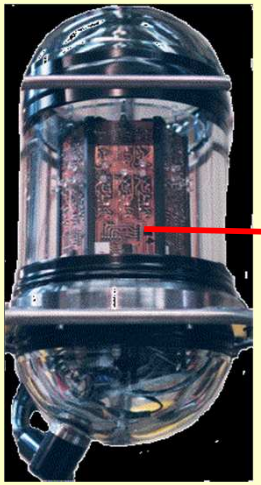
- 12 detection lines
- 25 storeys / line
- 3 PMTs / storey
- 885 PMTs

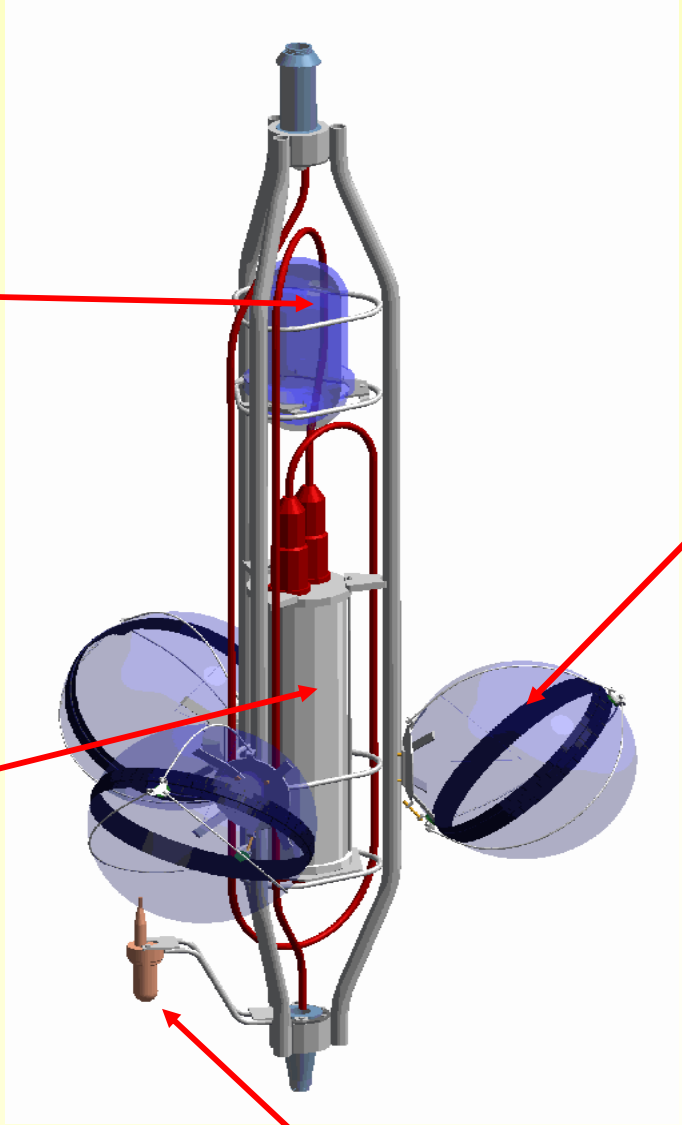
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

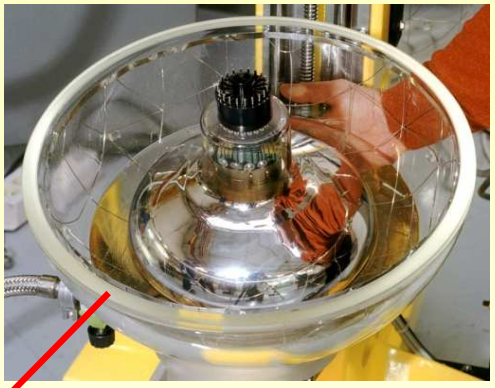
"ANTARES: The first undersea neutrino telescope", NIM A **656** (2011) 11-38.

Storey: Basic detector element

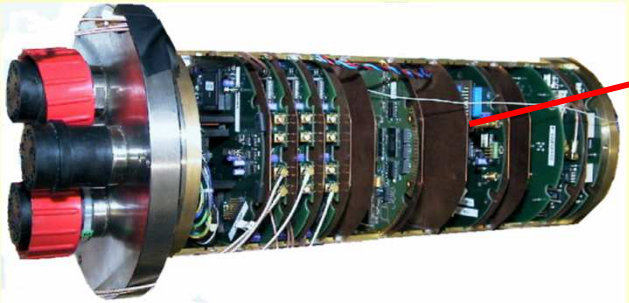
Optical Beacon for timing calibration (blue LEDs) 1/4 floors







Optical Module in 17" glass sphere

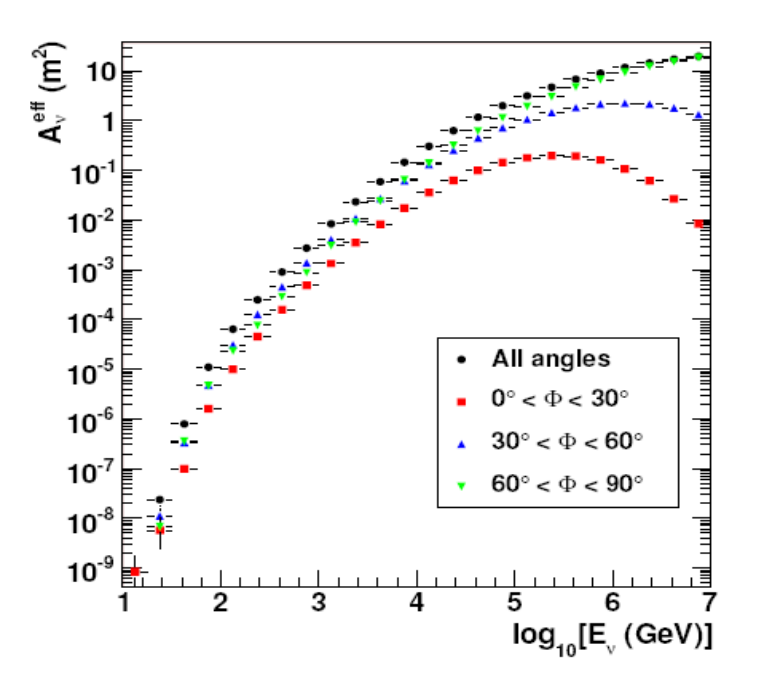


Local Control Module (in the Ti-cylinder)

Hydrophone RX

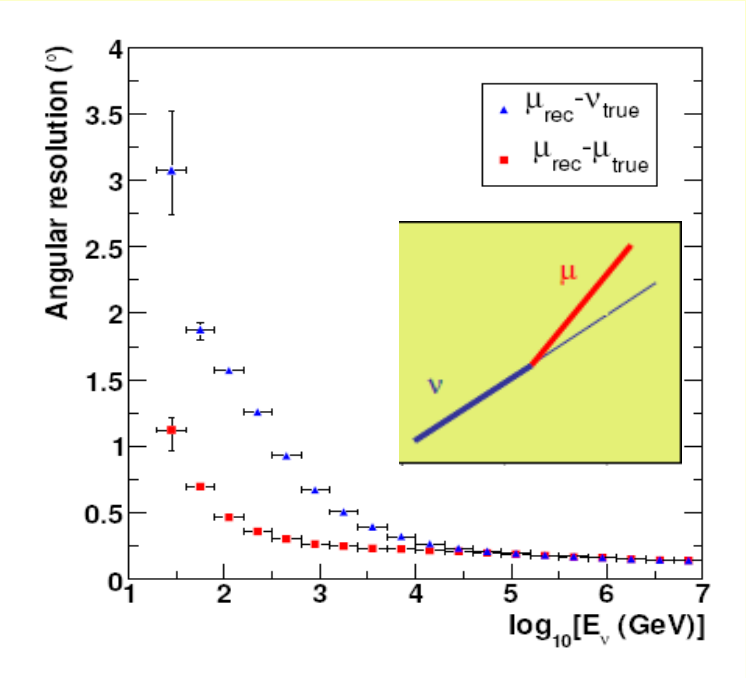
Expected Performances (full detector)

Neutrino effective area



- For E_ν<10 PeV, A_{eff} grows with energy due to the increase of the interaction cross section and the muon range.
- For E_ν>10 PeV the Earth becomes opaque to neutrinos.

Angular resolution

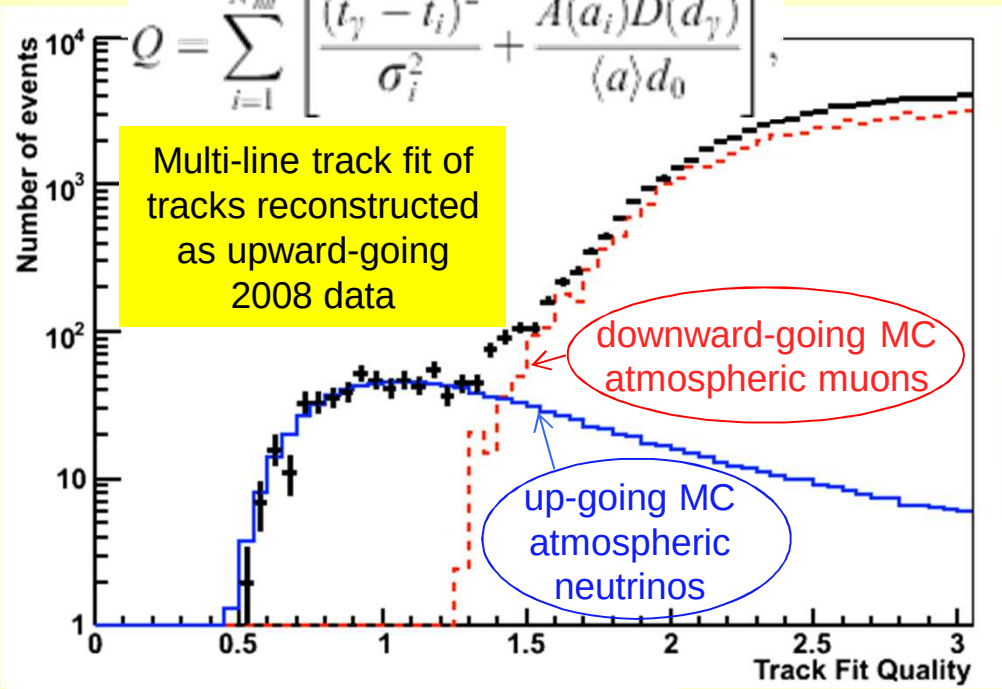


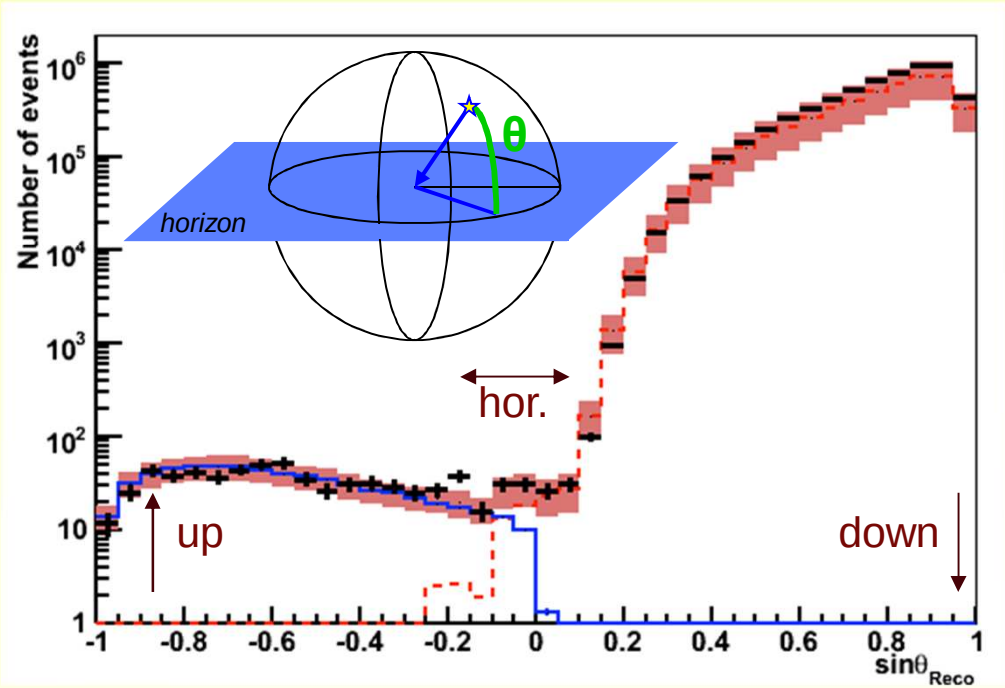
- For E_ν<10 TeV, the angular resolution is dominated by the ν-μ angle.
- For E_ν>10 TeV, the resolution is limited by track reconstruction uncertainties.

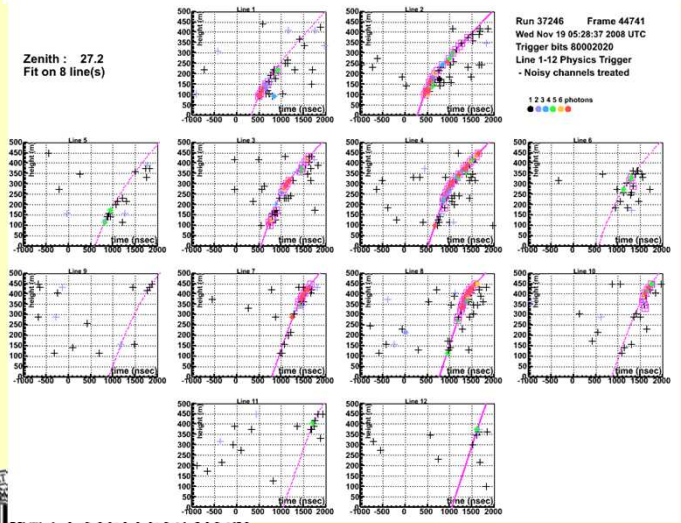
Reconstructing the muon track direction: a χ^2 strategy

Track reconstruction based on χ^2 fit of the photon arrival times on fired PMTs

$$Q = \sum_{i=1}^{N_{hit}} \left[\frac{(t_\gamma - t_i)^2}{\sigma_i^2} + \frac{A(a_i)D(d_\gamma)}{\langle a \rangle d_0} \right],$$



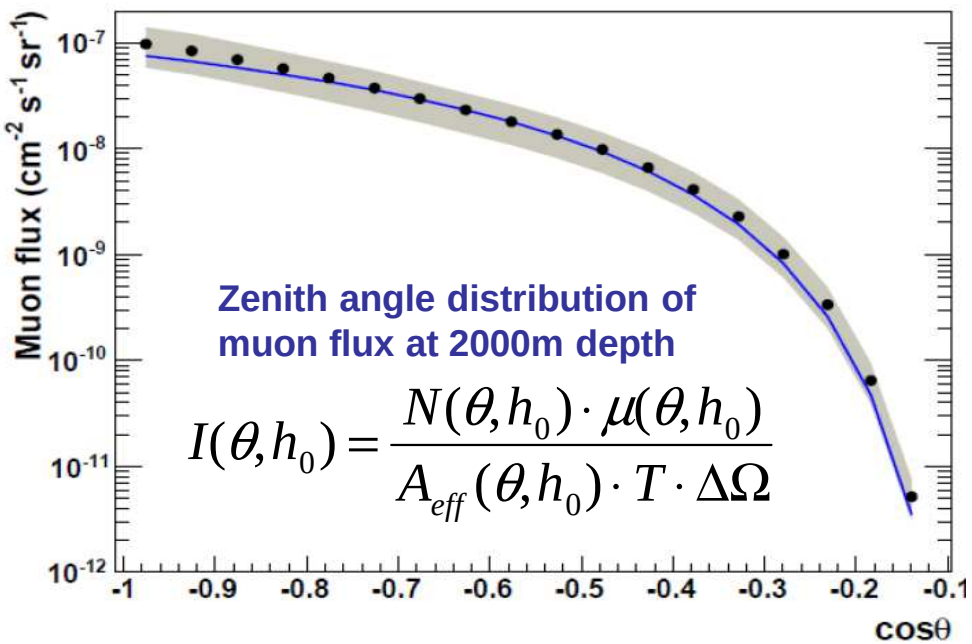




Elevation angle distribution for events with Q<1.4
Data points are compared with the MonteCarlo predictions for atmospheric down-going muons and up-going neutrinos

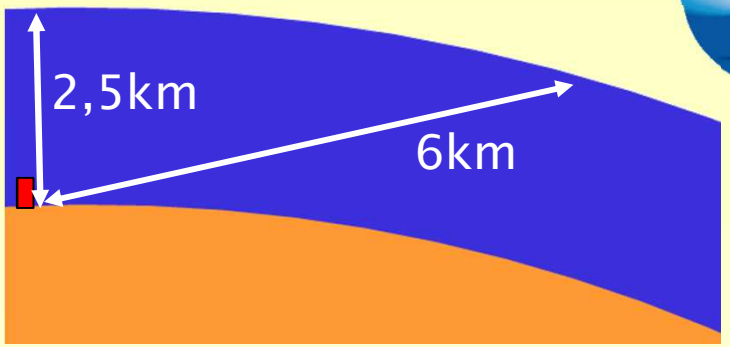
A Fast Algorithm for Muon Track Reconstruction and its Application to the ANTARES Neutrino Telescope, Astroparticle Physics **34, Issue 9,** (2011) 652-662

5 lines (2007): Depth Intensity Relation



Zenith angle distribution of muon flux at 2000m depth

$$I(\theta,h_0)=\frac{N(\theta,h_0)\cdot\mu(\theta,h_0)}{A_{eff}(\theta,h_0)\cdot T\cdot\Delta\Omega}$$



$$I(\theta=0,h)=I(\theta,h_0)\cdot|\cos\theta|\cdot c_{corr}(\theta)$$

$h=h_0/\cos\theta$ **slant depth**

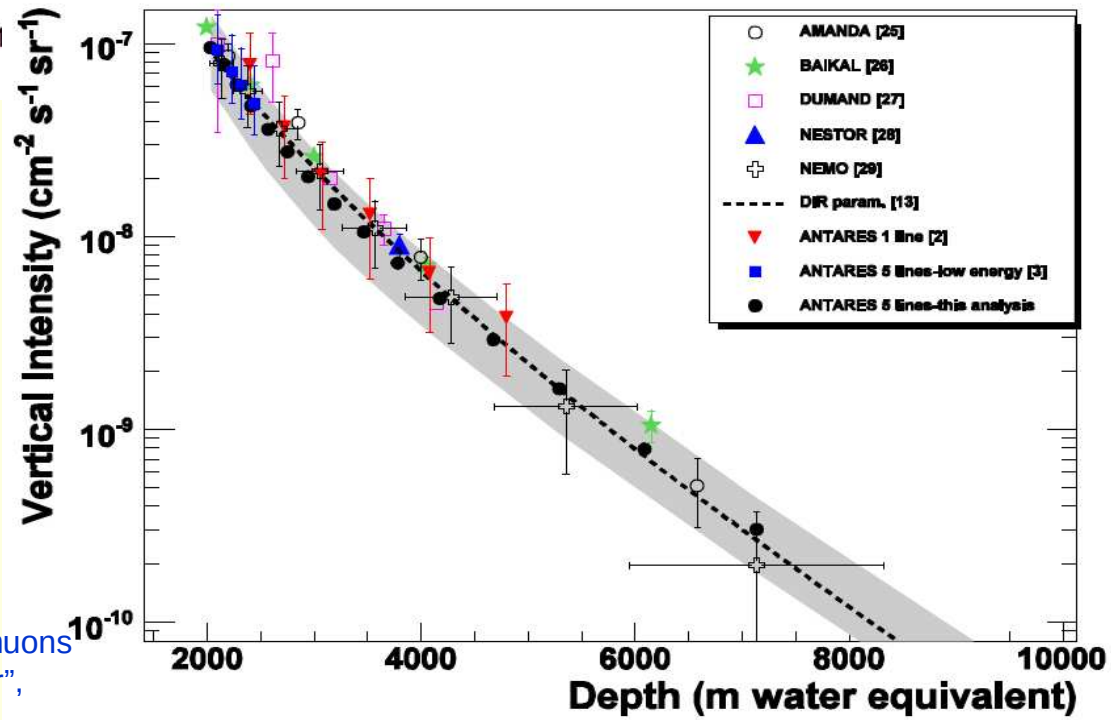
$N(\theta,h_0)$ **# of muons in angular bin**

$\mu(\theta,h_0)$ **mean bundle multiplicity**

$c_{corr}(\theta)$ **Earth curvature correction**

D.I.R. parametrization from:
E.V. Bugaev et al., Phys. Rev. D 58 (1998) 05401.

Reconstructed track rate=1.52Hz

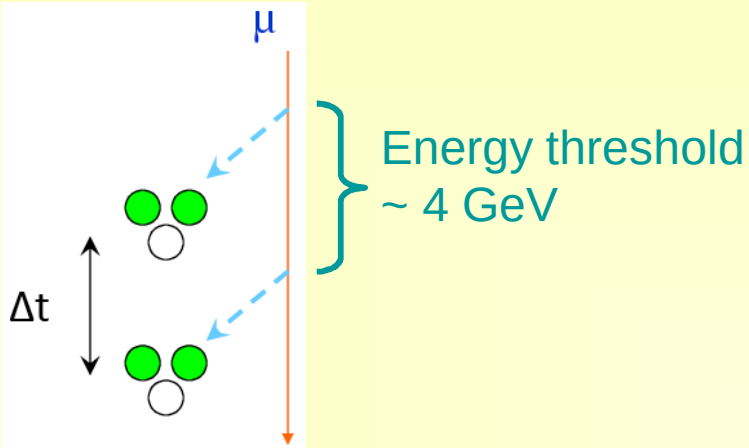


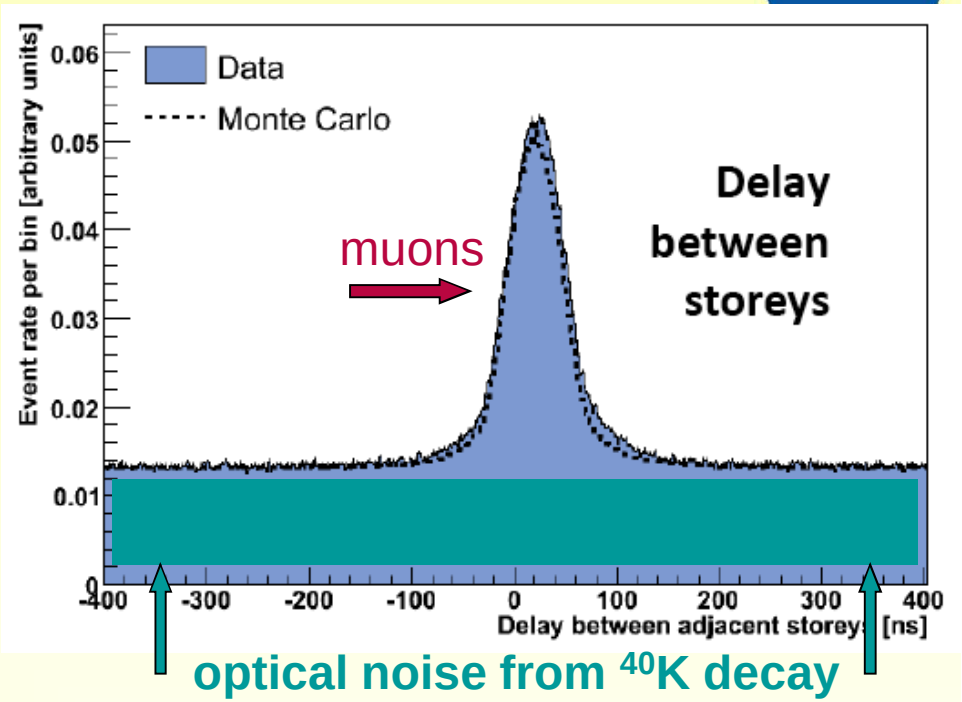
"Zenith distribution and flux of atmospheric muons measured with the 5-line ANTARES detector", Astroparticle Physics **34** (2010) 179-184

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Coincidences between adjacent storeys (low E atm. muons)

Analysis performed on 5-line detector data



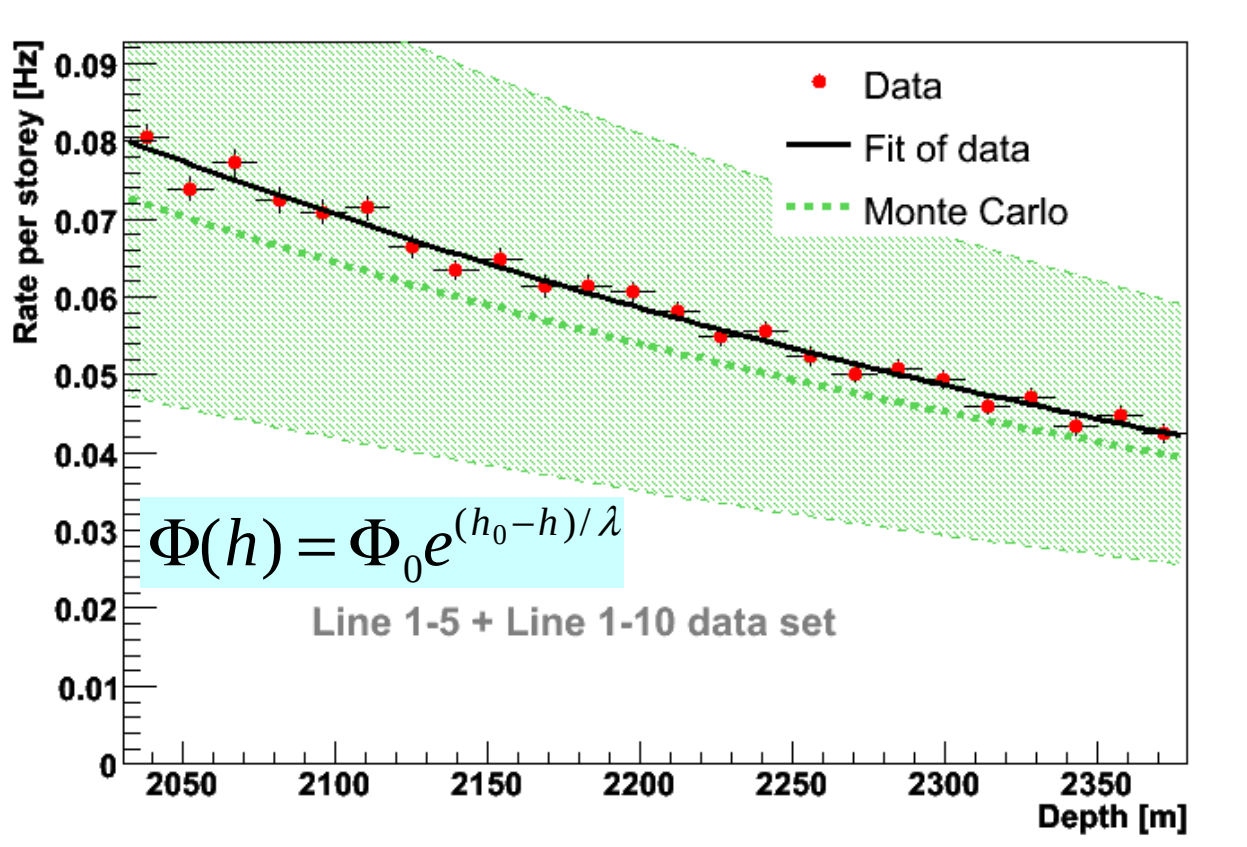


Data/MC ratio ≈ 1.1

- Data: low-background (<100 kHz) ^{40}K runs with 5-line and 10-line detector. Effective live time = 4.1 hours with 5 lines + 3.2 hours with 10 lines (52.5 line-hours)
- Monte Carlo: MUPAGE, Geant4 angular acceptance. Resulting curve is rescaled to account for low-efficiency & dead OMs in real data

Event rate as a function of floor depth

By repeating the analysis for every detector storey the effect of muon flux reduction with depth is directly measured



After corrections for the presence of dead channels and uneven efficiencies of the OMs, as measured with ^{40}K, the fluctuations of data points are compatible with statistical errors

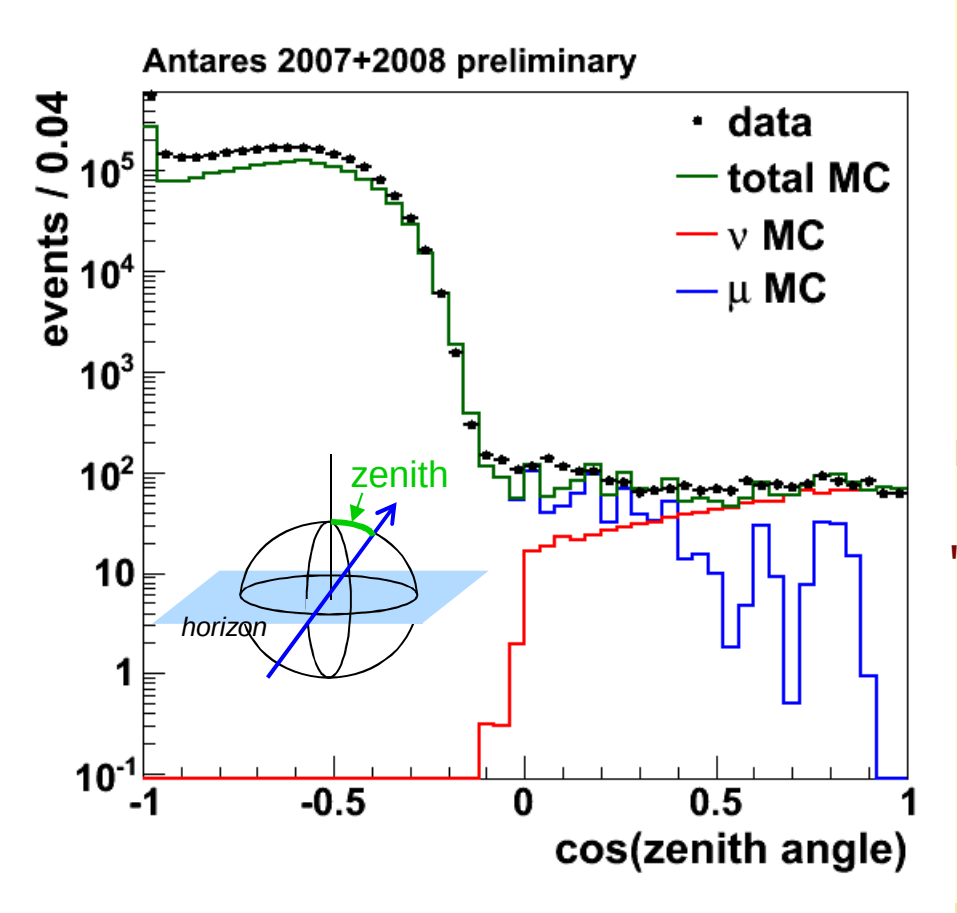
Systematic errors mainly in normalization (+50/-35%), otherwise ~3%

"Measurement of the atmospheric muon flux with a 4 GeV Threshold in the ANTARES neutrino telescope"
Astroparticle Physics **33** (2010) 86-90

$$\Phi_0 = 1.18 \pm 0.01(stat)^{+0.63}_{-0.39}(syst) \cdot 10^{-3} m^{-2} s^{-1}$$
$$at \quad h_0 = 2200m \quad \text{with} \quad \lambda = 540 \pm 25m$$

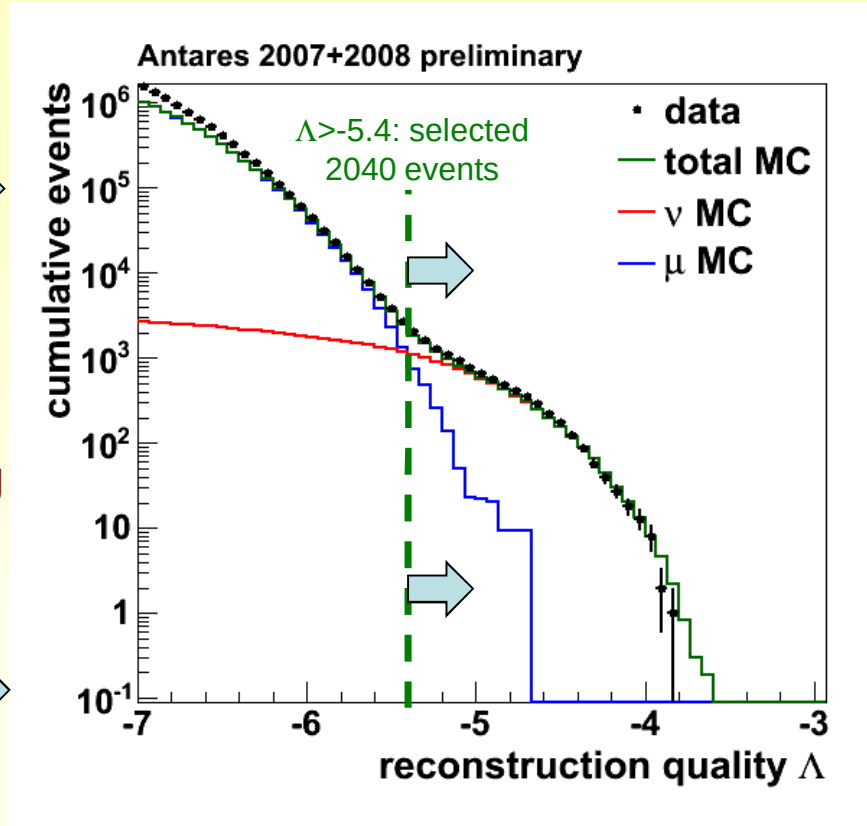
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

2007 and 2008 data analysis: ν_μ from point sources



Selected up-going reconstructed tracks
From MC: angular error estimate < 1°

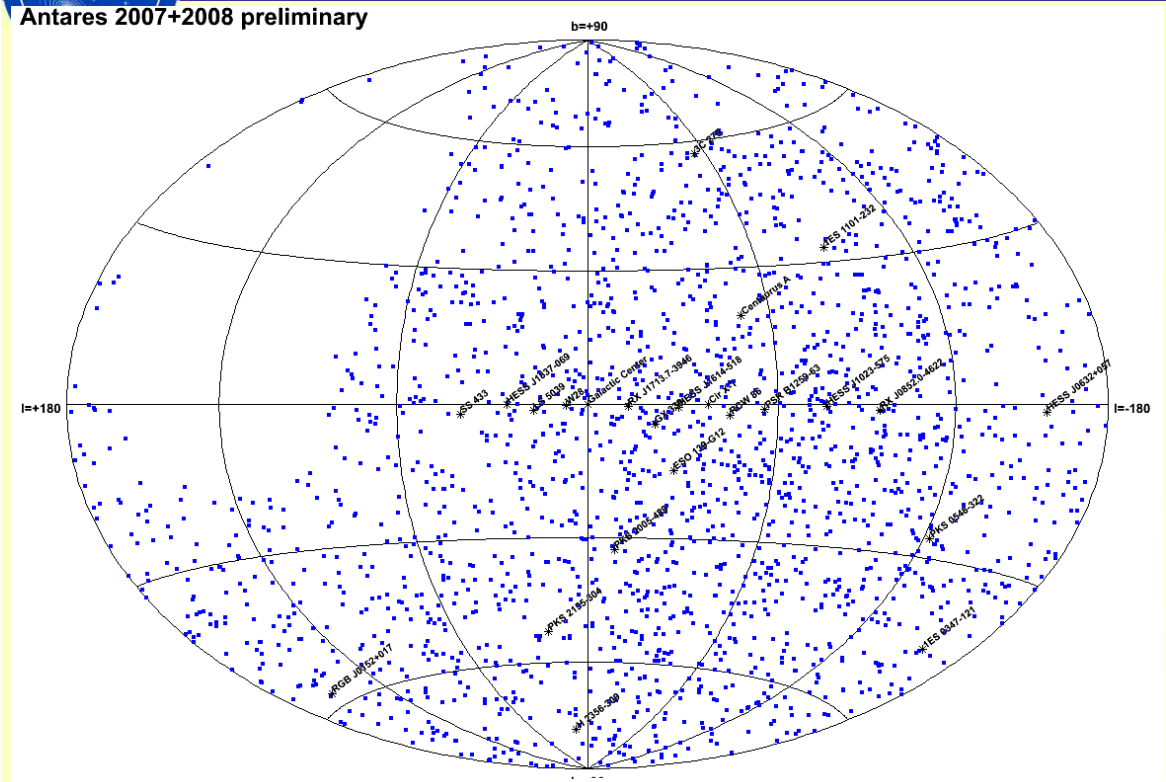
Look for neutrinos into the "up-going tracks".



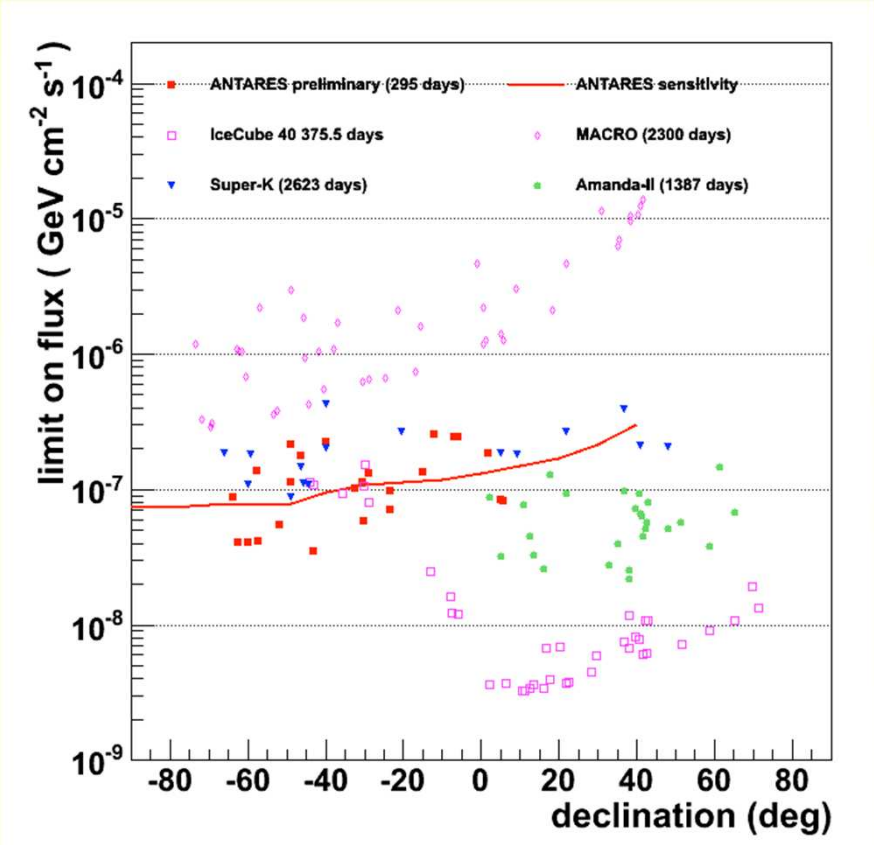
- Reconstruction algorithm (max. **Likelihood strategy**) optimized to reach angular resolution ≤0.2° for E_μ> TeV and to reduce the atmospheric muon background
- Blinding policy followed

The selected sample of tracks dominated by up-going atmospheric ν_μ and mis-reconstructed down-going muons.
The Λ quality cut enhances the ν_μ component in the up-going reconstructed tracks sample.

ANTARES: search for point like sources

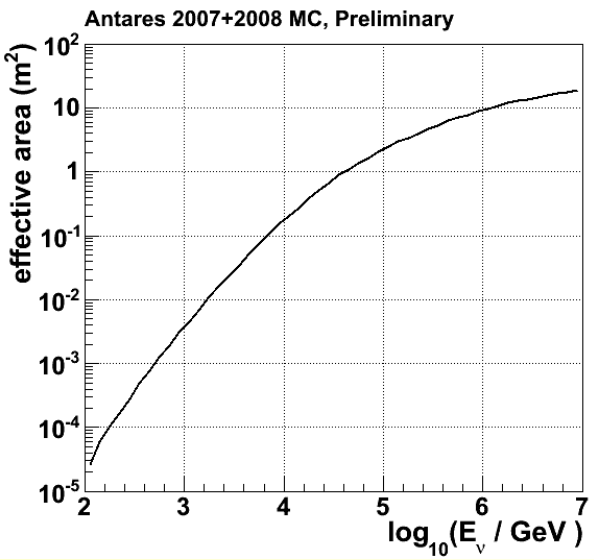


Search for point-like sources at their known location



ANTARES 2007+2008 preliminary Skymap Galactic Coordinates

2040 up-going ν_μ



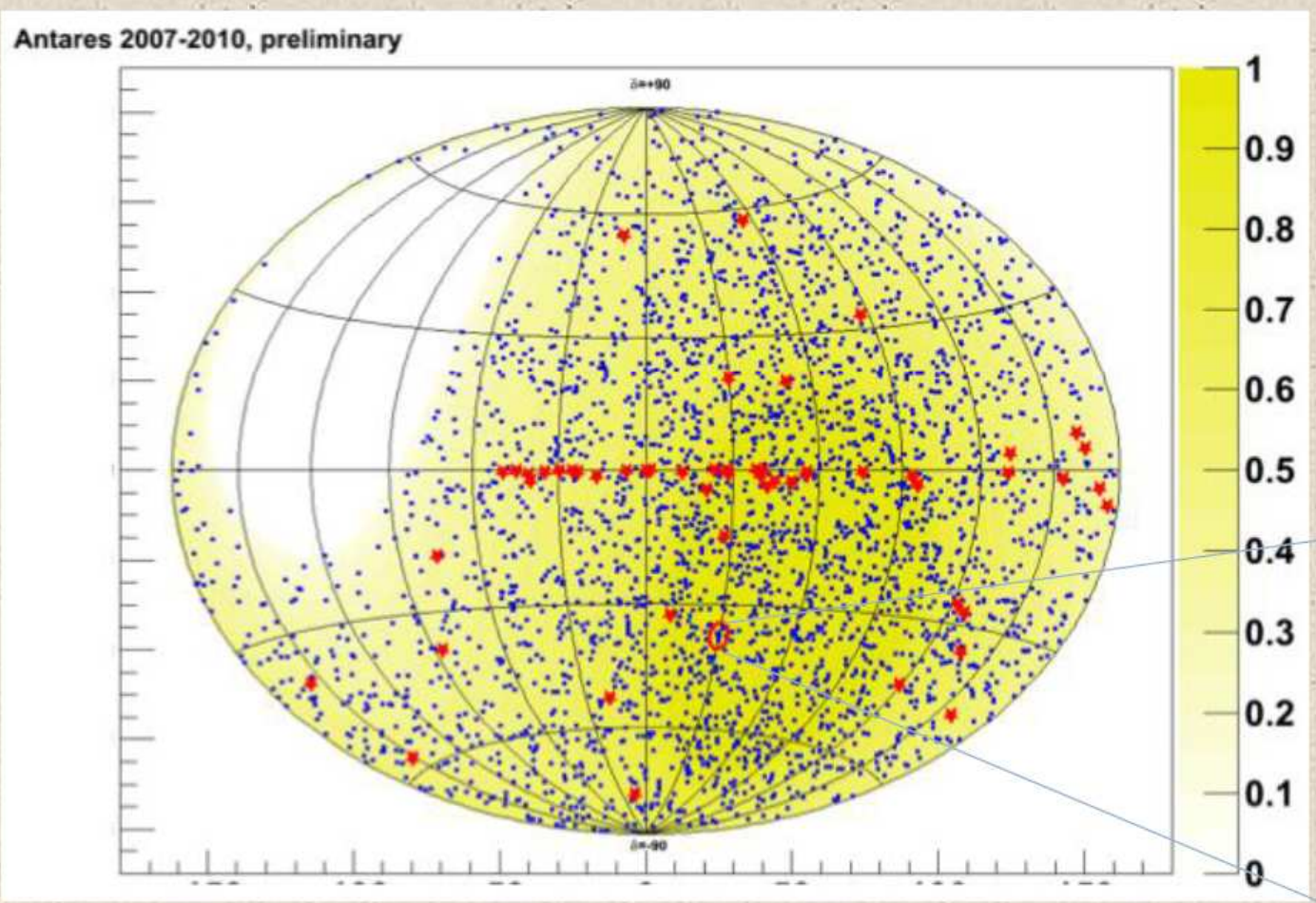
ANTARES: flux limits on 24 candidate point sources and sensitivity (median expected limit)

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Full-sky search

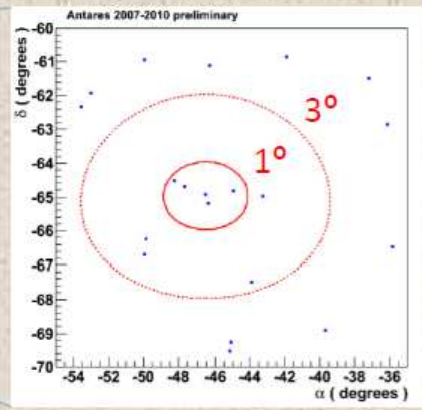
Sky map in Galactic Coordinates
Background colour indicates visibility

- Blue points: selected events (3058)
- ★ Red stars: candidate source list



Most significant cluster at:
$\mathcal{RA}$= −46.5°,
δ= −65.0°

N_{sig} = 5
Q = 13.02
p-value = 0.026
Significance = 2.2 σ



Result compatible with the background hypothesis

ANTARES: search for a flux of "diffuse ν_μ"

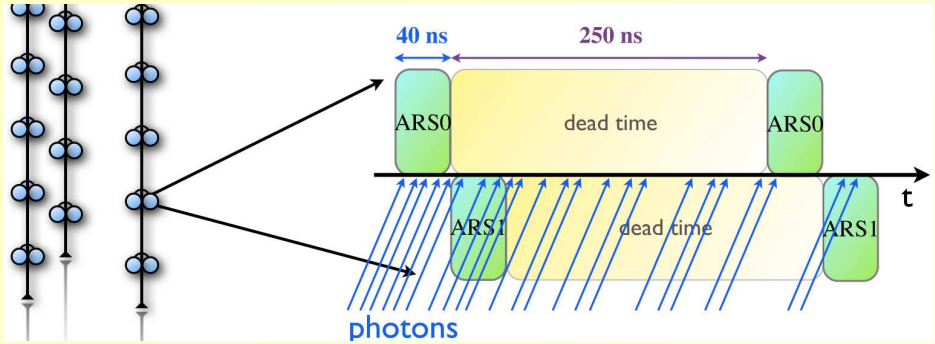
Selection criteria

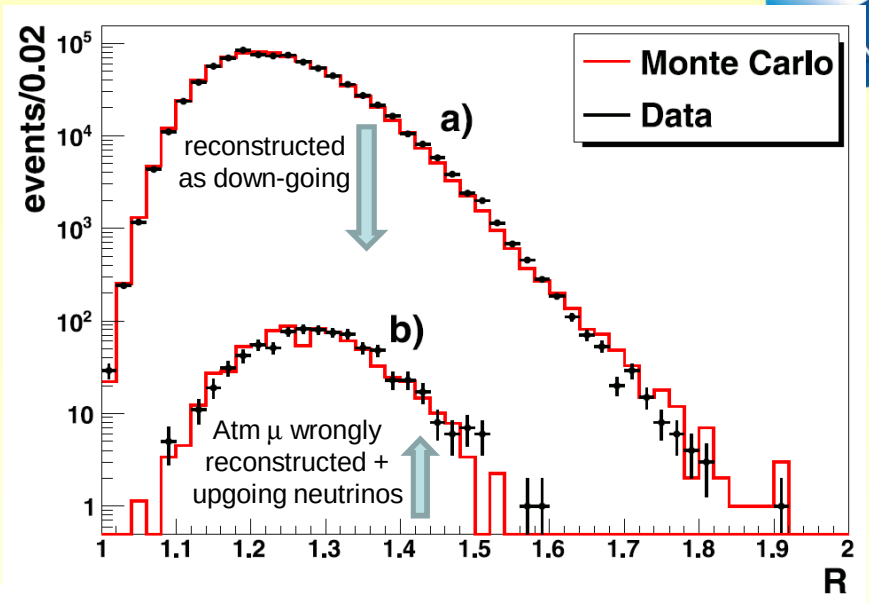
First level: good quality upgoing tracks.

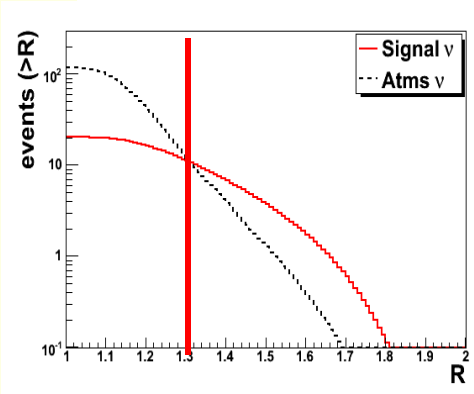
Second level: Λ vs N_{hit}

Energy estimator:

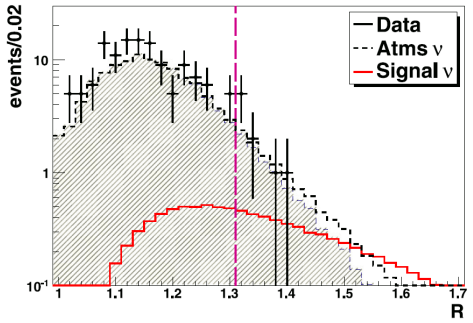
Repetition (R) of integration gate on the same Optical Module





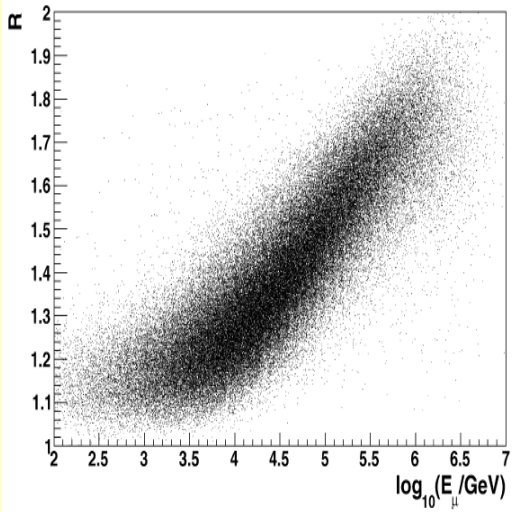


Optimization by
Model Rejection factor



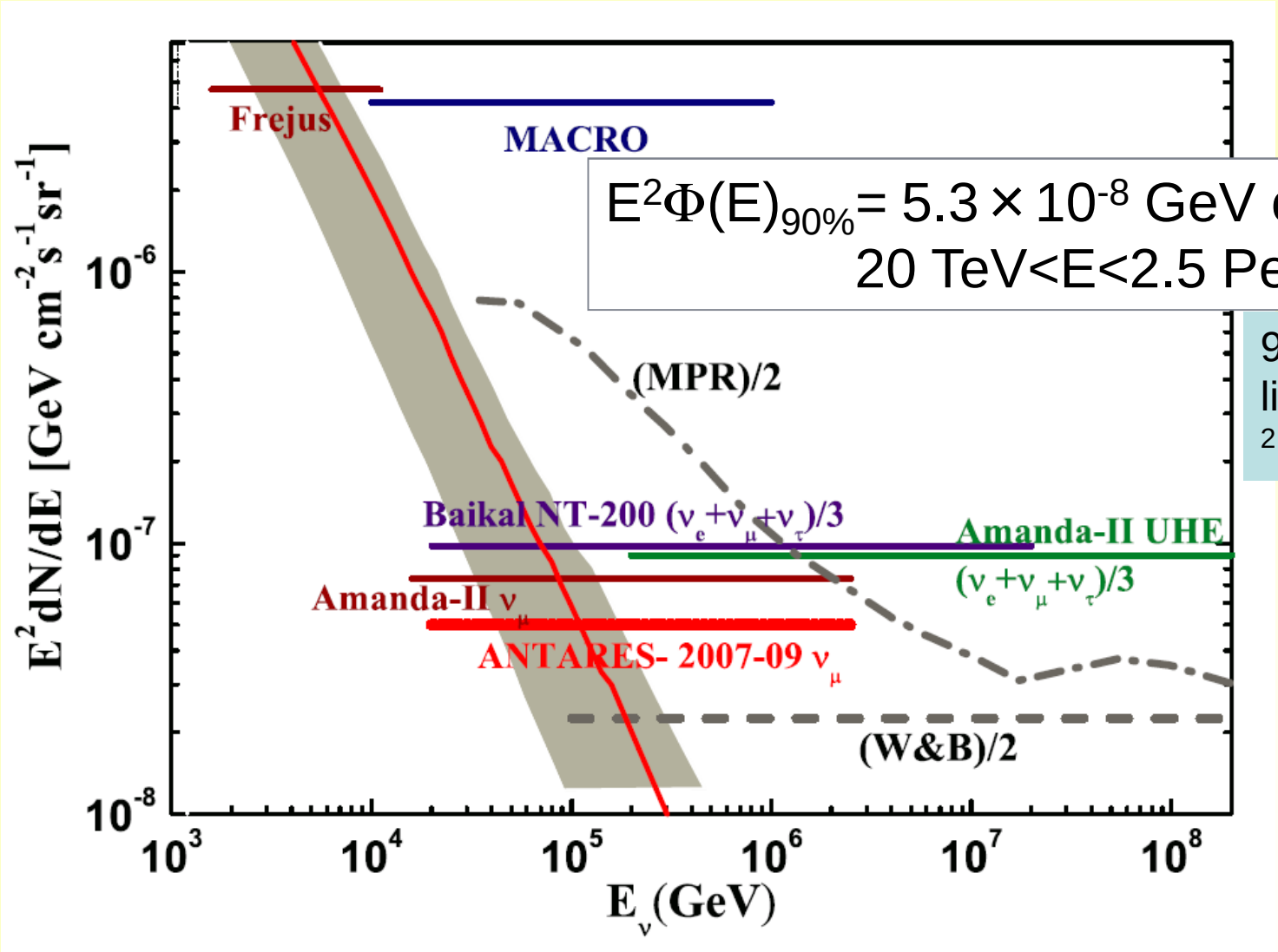
Distribution of the *R* parameter for the 134 neutrino candidates in the 334 days of equivalent live time

R vs Energy



UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ANTARES: search for a flux of "diffuse ν_μ": results



$E^2\Phi(E)_{90\%} = 5.3 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}
20 TeV<E<2.5 PeV

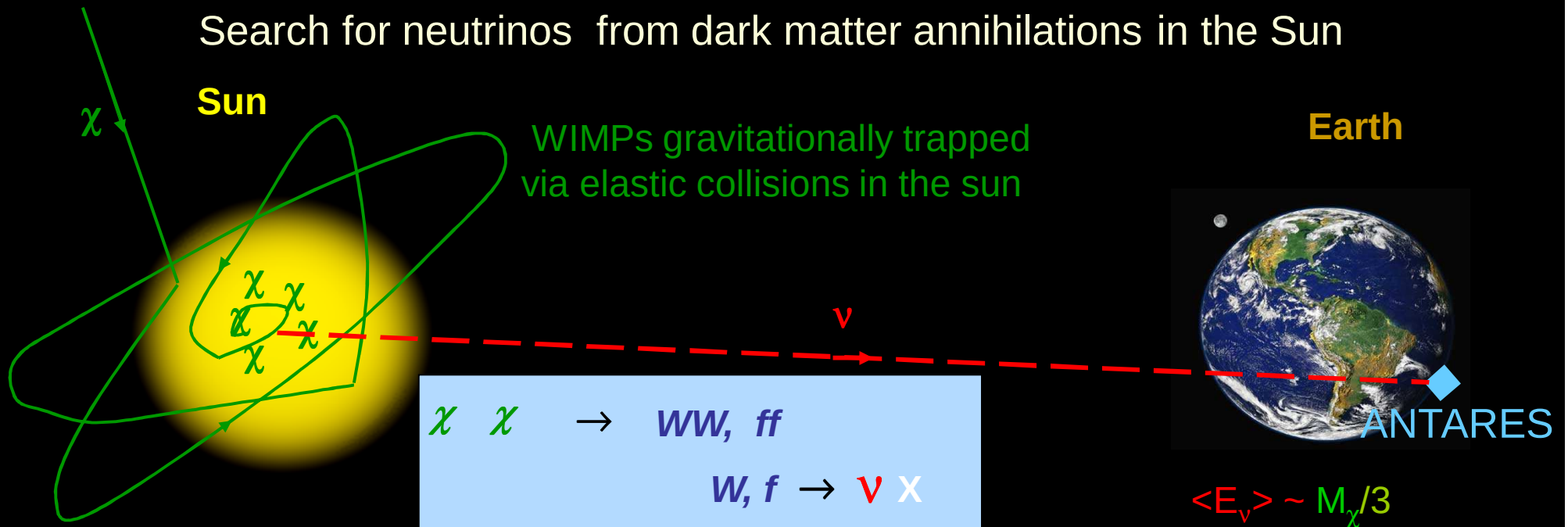
90% C.L. upper limit assuming E^{-2} flux spectrum

"Search for a diffuse flux of high-energy ν_μ with the ANTARES neutrino telescope"
Physics Letters **B696** (2011) 16-22.

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ANTARES: indirect search for Dark Matter

Search for neutrinos from dark matter annihilations in the Sun

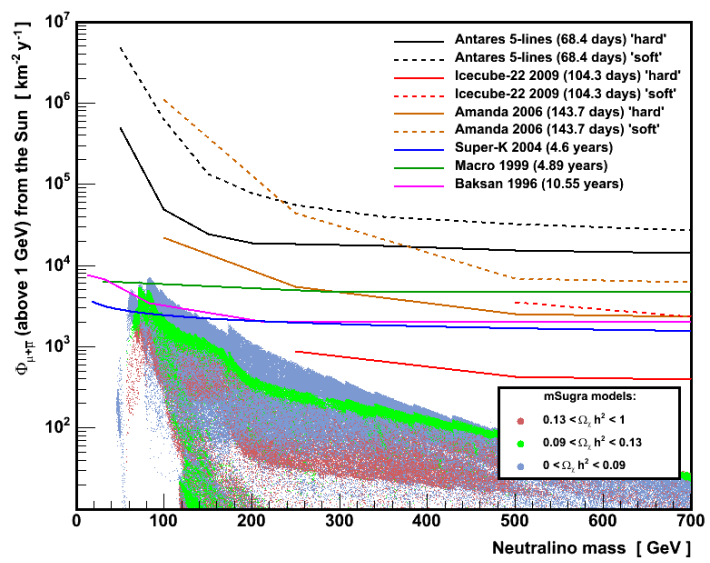


Upper limit on the neutrino flux from the Sun

arXiv:0905.2316v3

mSugra model predictions

- **green : WMAP favoured relic density**
- **red : > WMAP favoured relic density**
- **blue : < WMAP favoured relic density**



Upper limit on the total $\Phi(\nu_\mu+\nu_\mu)$ from neutralino annihilations in the Sun as function of m_χ

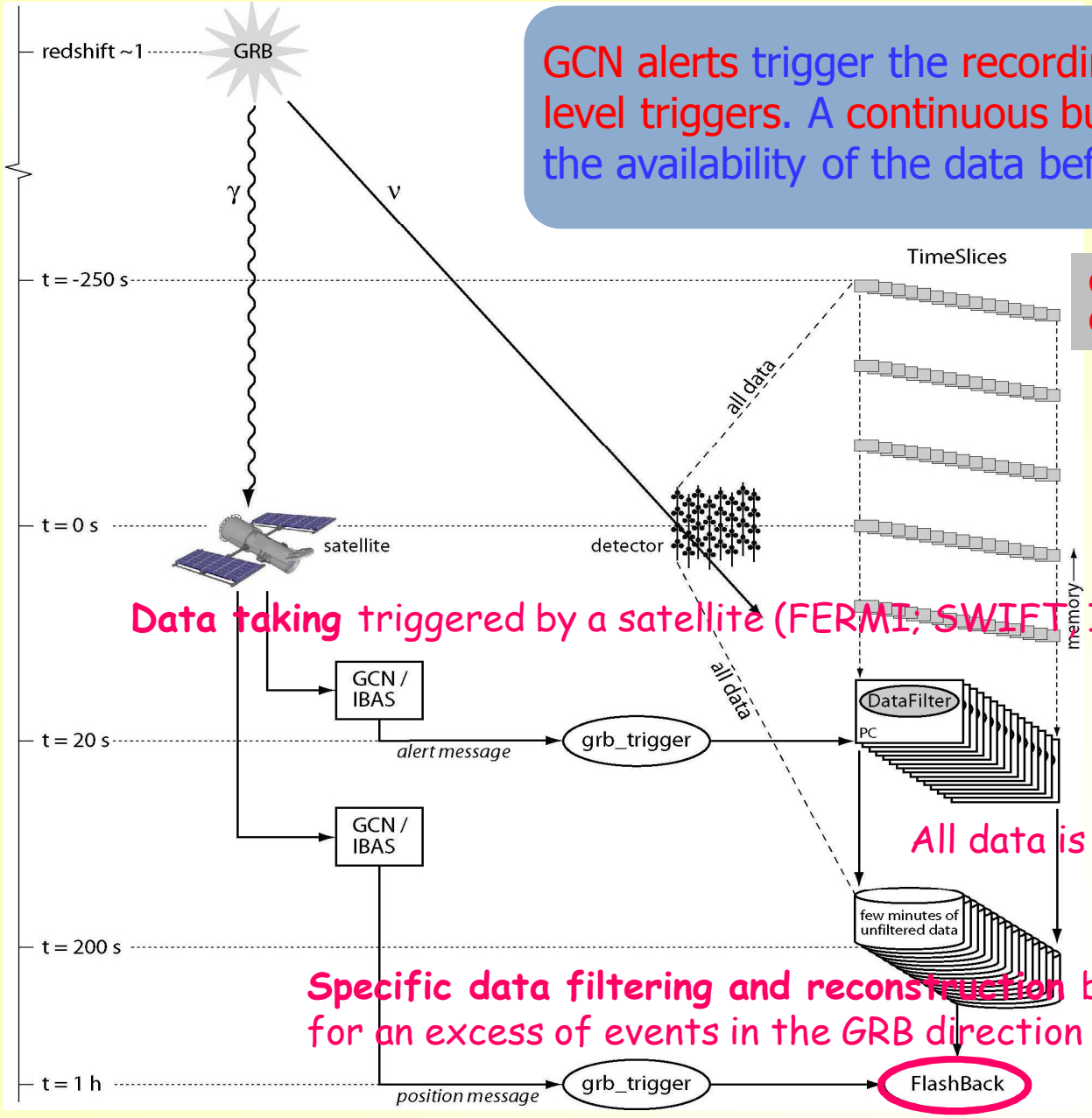
5 Line Detector
Feb - Dec 2007
168 active days

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

A multi-messenger approach: “GRB trigger”

GCN alerts trigger the recording of all the low level triggers. A continuous buffer ensures the availability of the data before the alert

GCN=Gamma Ray Burst Coordination Network



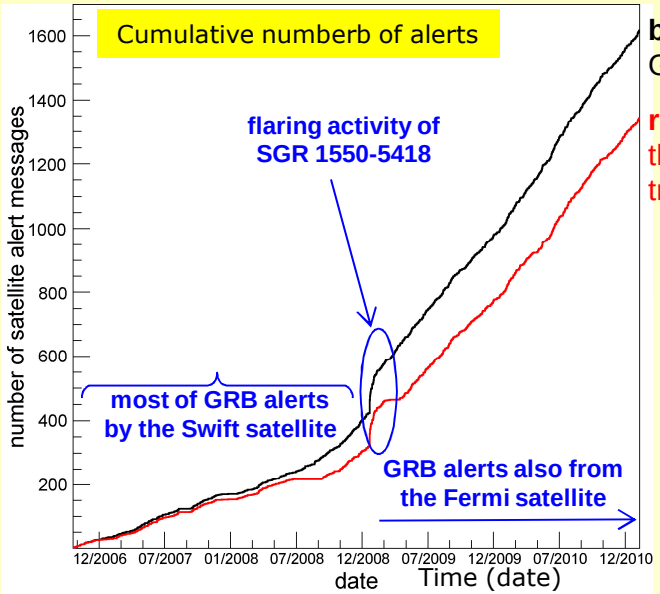
Data taking triggered by a satellite (FERMI, SWIFT, INTEGRAL)

All data is written to disk

Specific data filtering and reconstruction by searching for an excess of events in the GRB direction (offline)

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

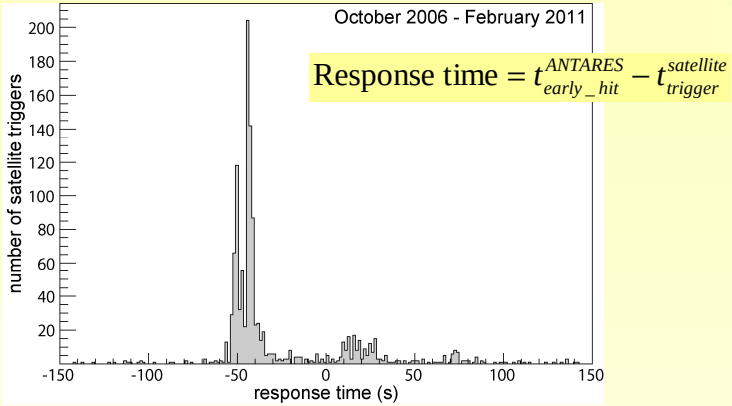
“GRB triggered” data analysis



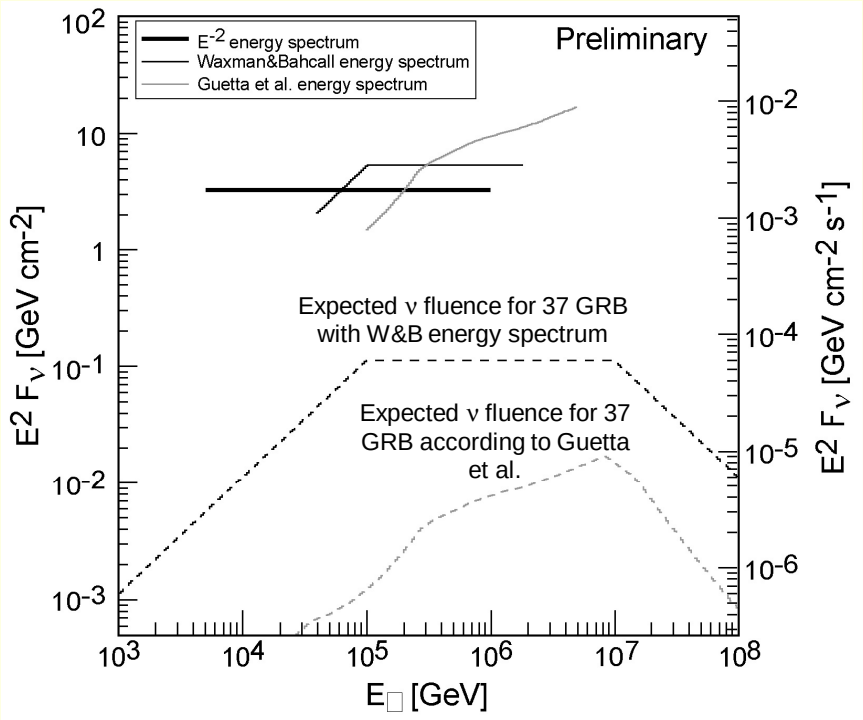
black:
GRB alerts received

red:
the ones Antares triggered on

ANTARES time response to a satellite alert message



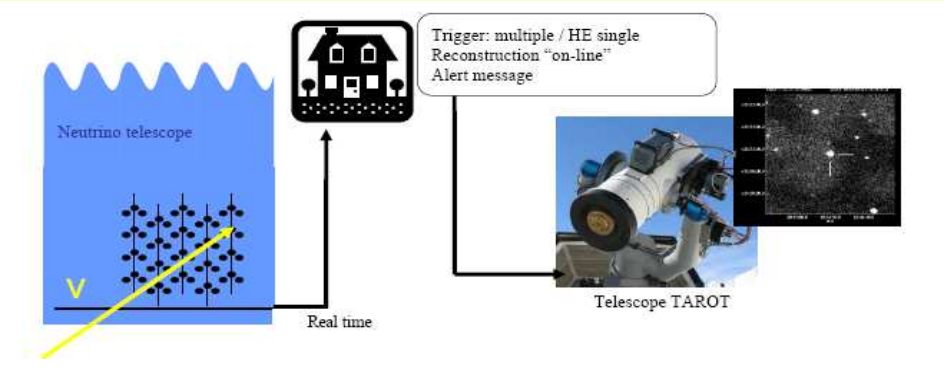
90% Upper limits on ν fluxes form 37 GRBs

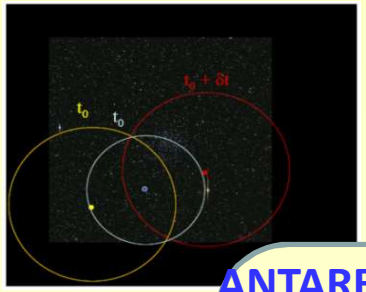


- > 1300 alerts from GCN have been recorded (Jan 2011)
- The analysis of Lines 1-5 data is going on: the time period contains 37 GRB alerts.
- The total prompt emission duration of the 37 GRBs is 1882 s

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Multi-messenger approach





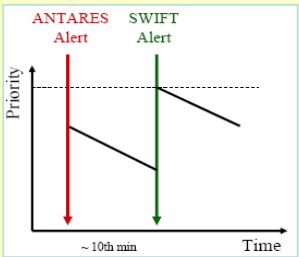
Agreement with TAROT

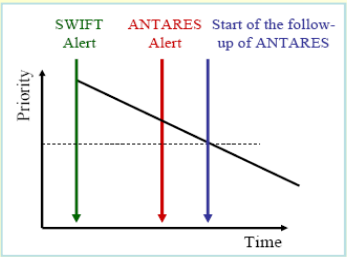
Telescopes à Action Rapide pour l'Observation de Transients)

- TAROT: two 25 cm telescopes at Calern (France) and La Silla (Chile)
- FOV 1.86° x 1.86°
- ~10 s repositioning after alert reception

ANTARES alert

- Two events with
  - $\Delta\Omega < 3^o \times 3^o$
  - $\Delta t < 15$ min
  - Rate(atm) = 0.05 yr^{-1}
- High Energy ν event
  - Rate ~ 2 per month



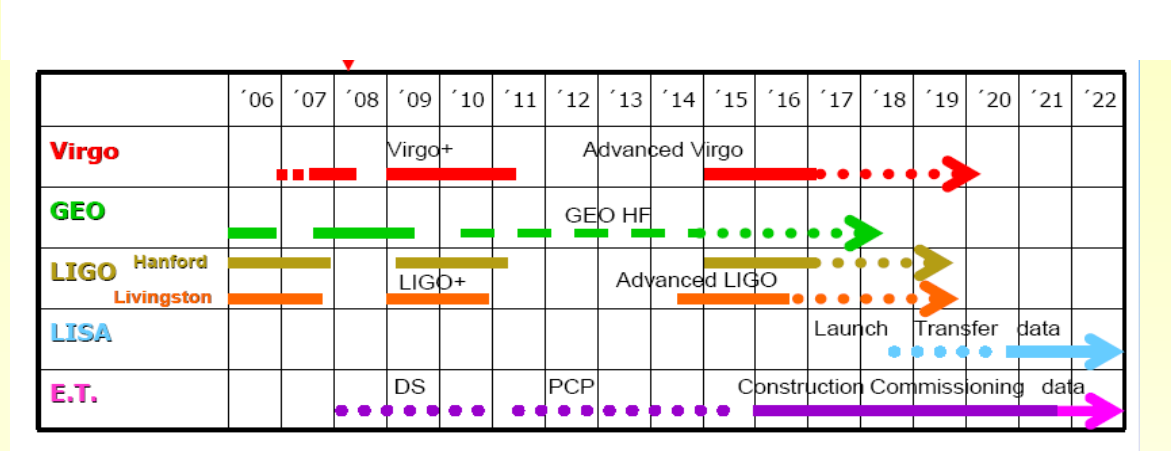


Priorities (decreasing with time) are set to alerts.
SWIFT has the highest priority

- Operational since beginning of 2009: > 20 alerts have been sent to the robotic telescopes.
- MoU has been signed with Tarot, a second MoU is in discussion with ROTSE, whose 4 telescopes receive the Antares alerts since 1 year.
- A paper on the performances of the alert system submitted to Astroparticle Phys.

Multi-messenger approach

Gravitational Waves and Neutrinos



- Possible common sources

(GRB-core collapse into BH; SGR – powerful magnetars; hidden sources)

- Sky regions in common
- Expected low signals, coincidences increase chances of detection
- GW & HEN is a must

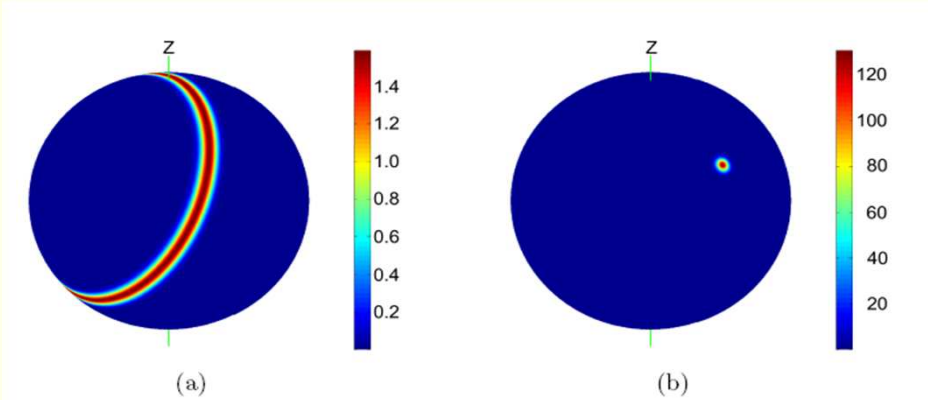
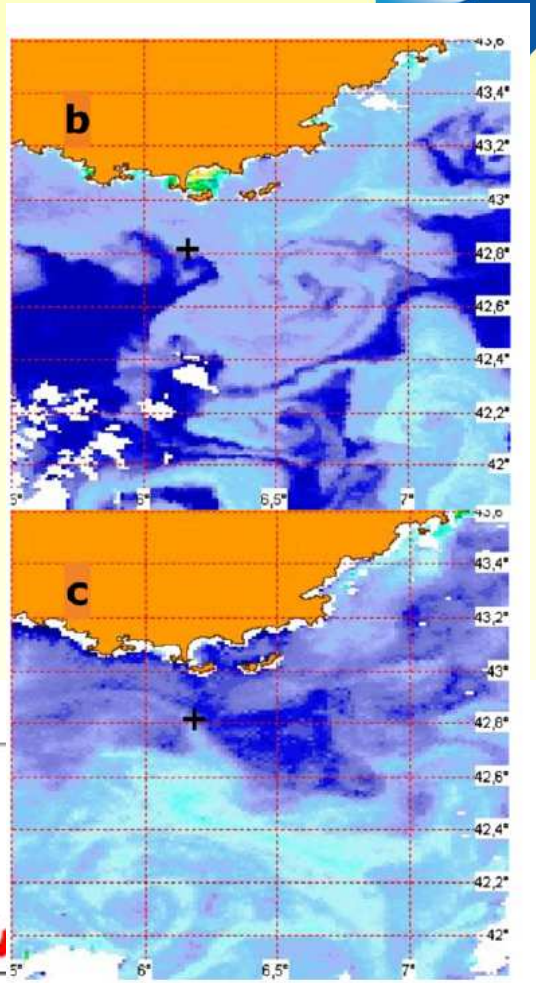


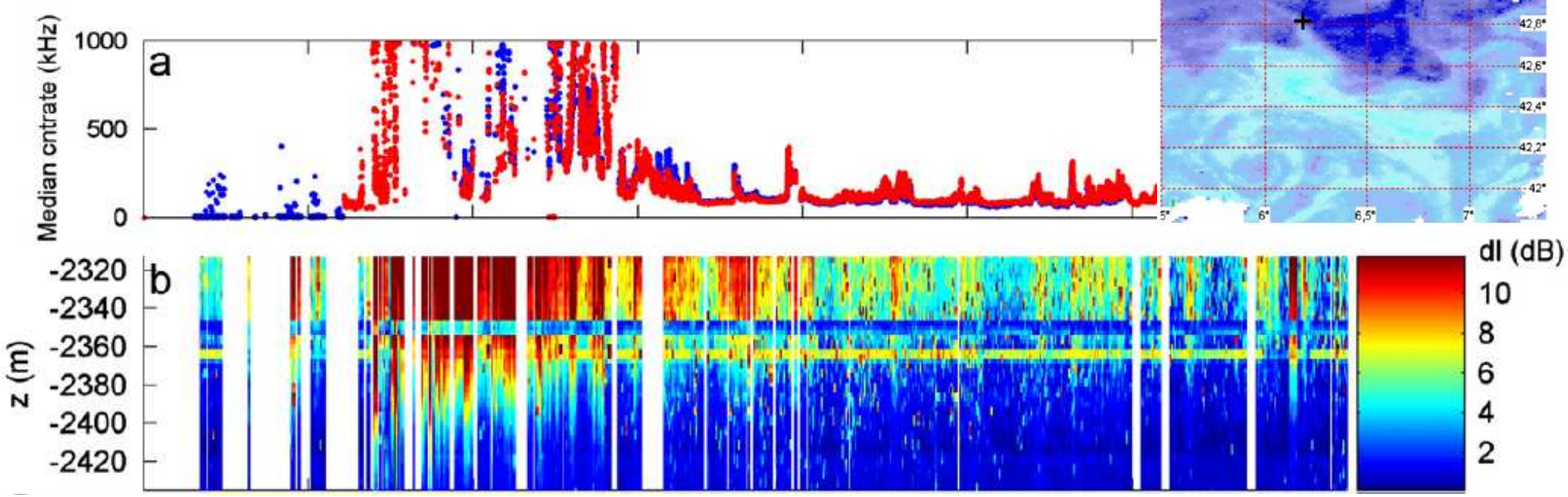
Figure 2. Examples of spatial probability distribution functions (SPDFs). (a) SPDF of a LIGO event with $\tau = 4\,\mathrm{msec}$ and $\delta\tau = 440\,\mu\mathrm{sec}$. (b) SPDF of an IceCube event with $\sigma_\nu = 2°$. The plots are shown in Earth based coordinates with the z-axis pointing along the north pole. Both SPDFs are normalized to 1 for integration over the sphere.

Earth-Sea Science

- Continuous monitoring of oceanographic instrumentation:
  - Correlation between different parameters: sea currents, salinity, temperature, bioluminiscence, count rates, etc...
  - Bring some light in complex multidisciplinary problems

"Acoustic and optical variations during rapid downward motion episodes in the deep north-western Mediterranean Sea"
Deep Sea Research I **58** (2011) 875-884.

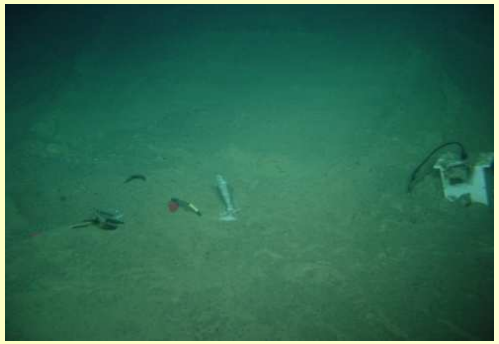




Earth-Sea Science

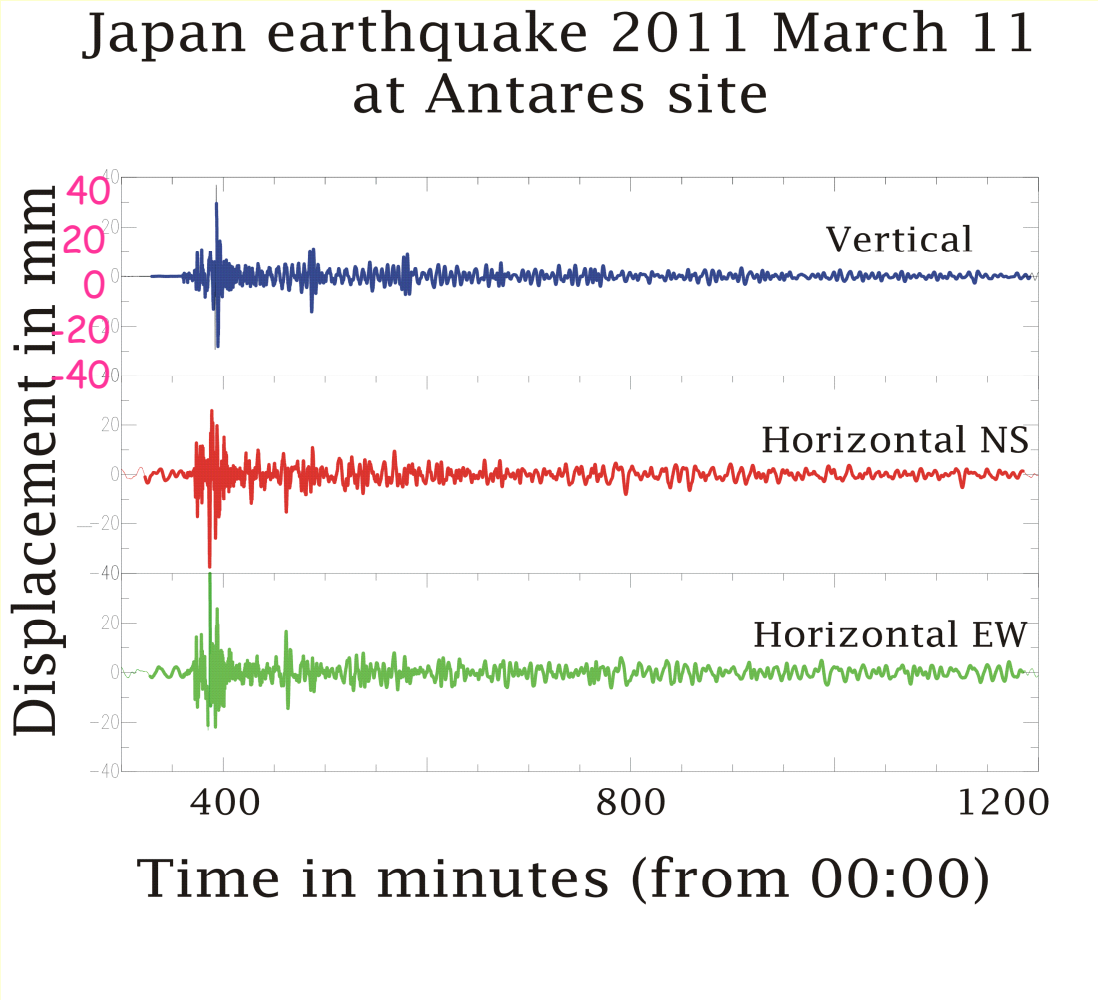
In laboratory

Deployment



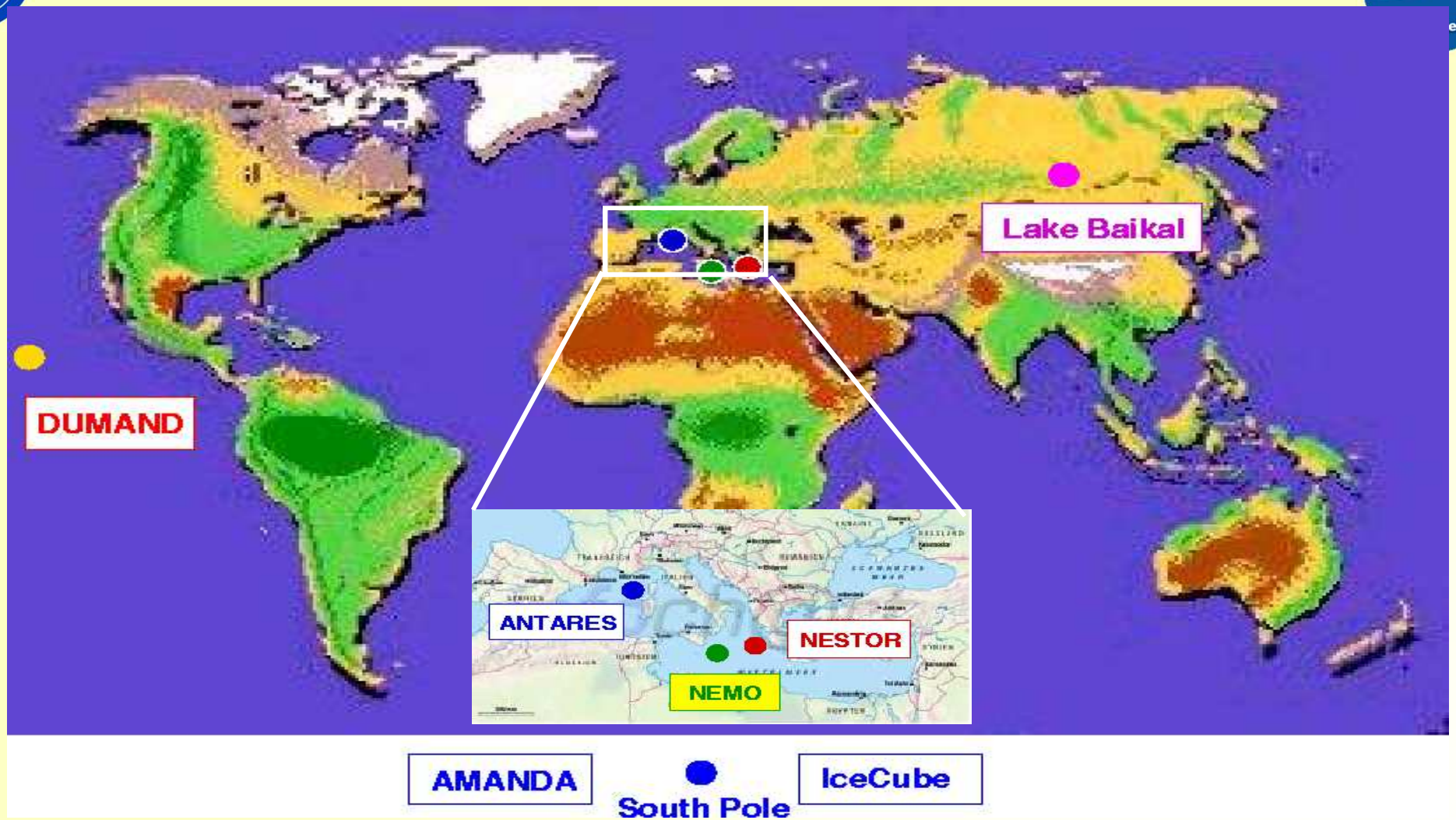
Buried at site

Seismograph



UNIVERSITAT POLITÈCNICA DE VALÈNCIA

The Neutrino Telescope World Map



ANTARES + NEMO + NESTOR joined their efforts to prepare a km^3-scale Cherenkov neutrino telescope in the Mediterranean →KM3NeT Consortium

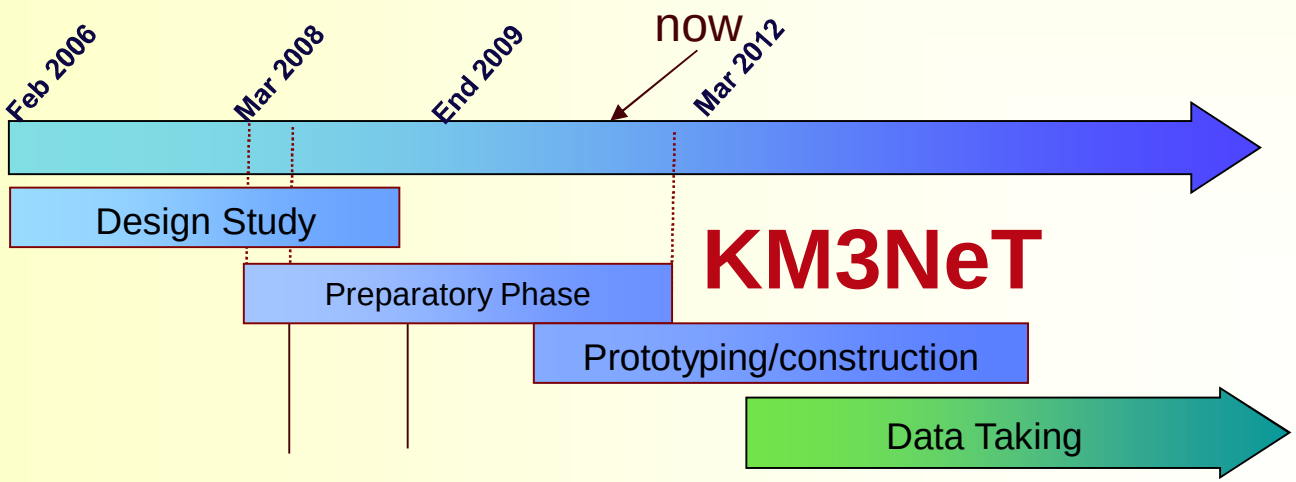
KM3NeT

- **KM3NeT consortium** is formed by **(40) European institutes or university groups** from the following **ten countries**: Cyprus(1), France(6), Germany(2), Greece(5), Ireland(1), Italy(12), Netherlands(5), Romania(1), Spain(3), UK(4)

- **KM3NeT**, an **European deep-sea research infrastructure** (included in the **ESFRI** list), will host a **neutrino telescope with a volume of several cubic kilometres** at the bottom of the Mediterranean Sea.

- The facility will also house **instrumentation from Earth and marine sciences** for long term and on-line monitoring of the deep sea environment.

- Design Study and Preparatory Phase funded by the **EU Framework Programs**.



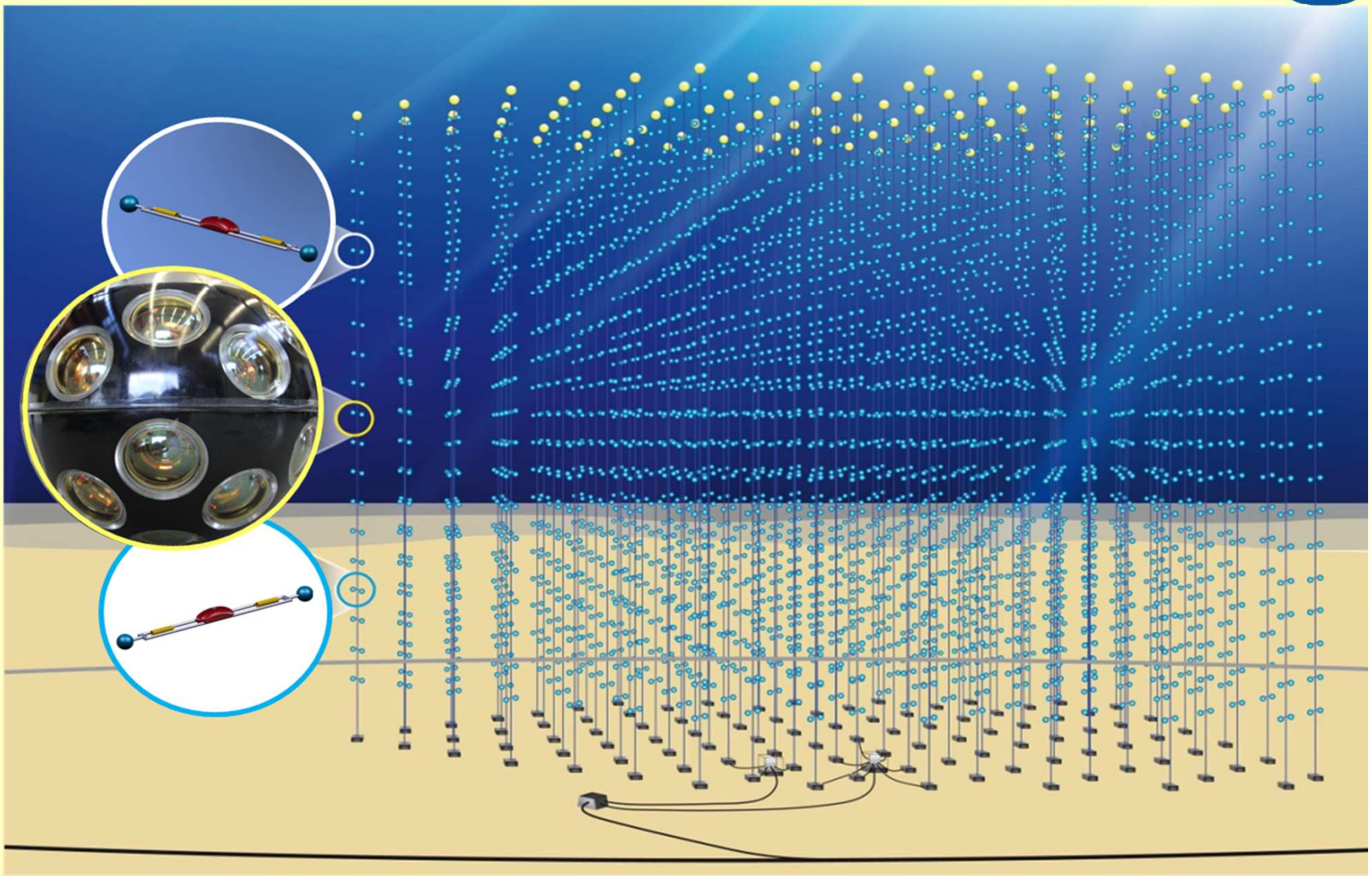
The KM3Net Detector

Digital Optical Module (DOM)

floors

Detection Units (DU)

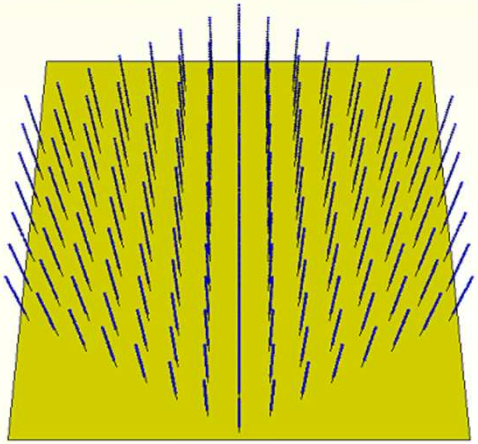
Compact Deployment



Detector configuration

- 320 DUs @ 180 m
- 20 floors @ 40 m / DU
  - Active height = 760 m
- 2 DOMs / floor
- 31 PMTs/DOMs
- Hexagonal sea floor layout

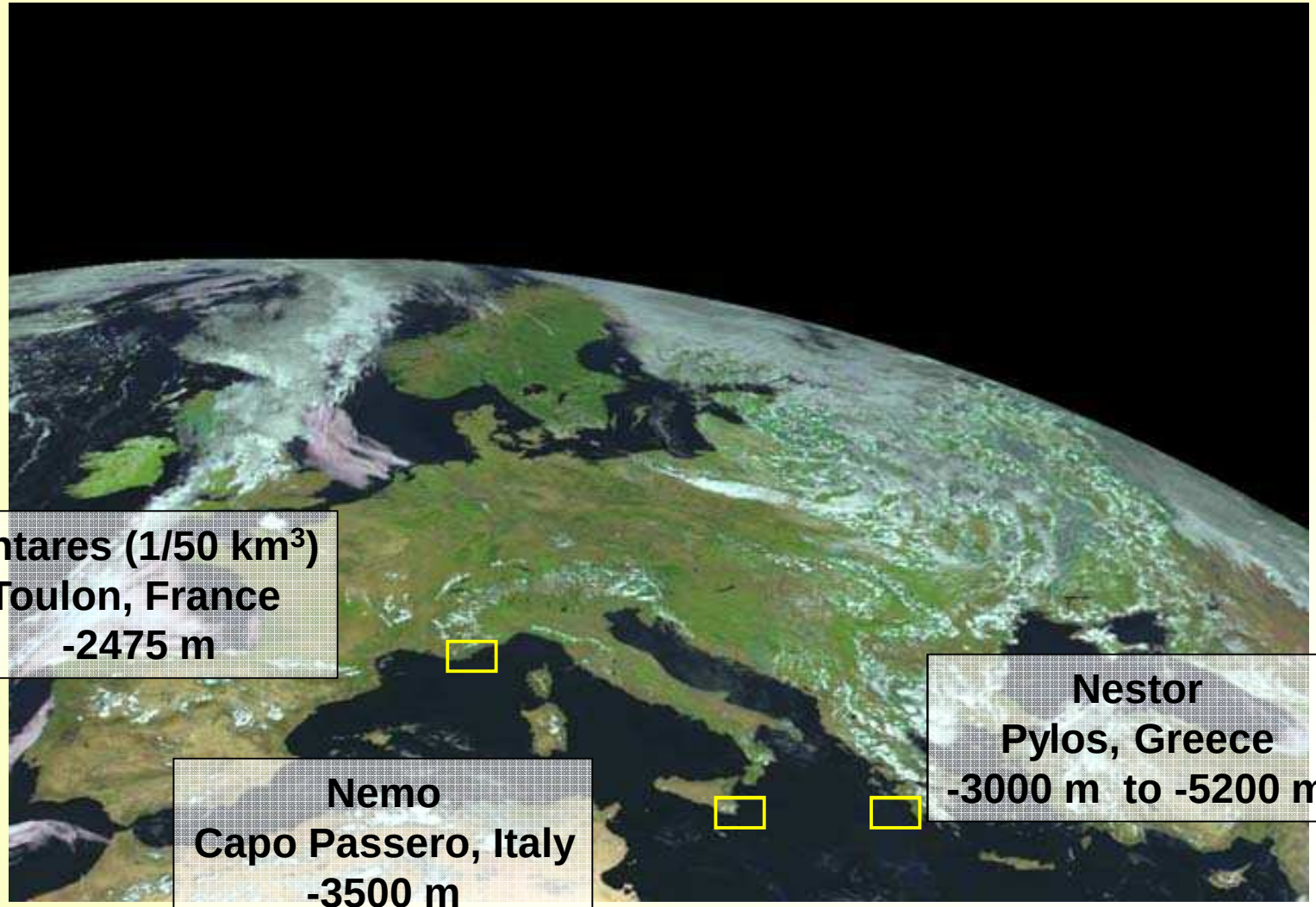
- ~ 50 DUs → 1 km^3 instrumented volume



- Total Estimated Cost: 200 M€

- Pre-Production Model of the DU being built. To be deployed and tested in 2012

Single Site or Distributed Sites



Summary

- **ANTARES** is the **largest** neutrino telescope in the **Northern hemisphere**, the **first** one **at deep-sea**
- **Full volume** (12-detection lines) **reached in May 2008**
- Detector is well **working**, **within design specifications**
  - **Technical challenge** successfully realized
  - **Maintenance** in deep sea is **possible**
  - **Data** collection **ongoing**
  - **Long-term investment** in software framework and procedures
  - Data **analysis ongoing**, **first results published**
- **Multidisciplinary platform** for associated sea sciences
- **Milestone towards the km^3** underwater neutrino telescope
- **KM3NeT** is progressing, and now in a critical phase:
  - Pre-Production Model to **validate the technology**
  - **Set** the legal **entity and** clarify the **funding**

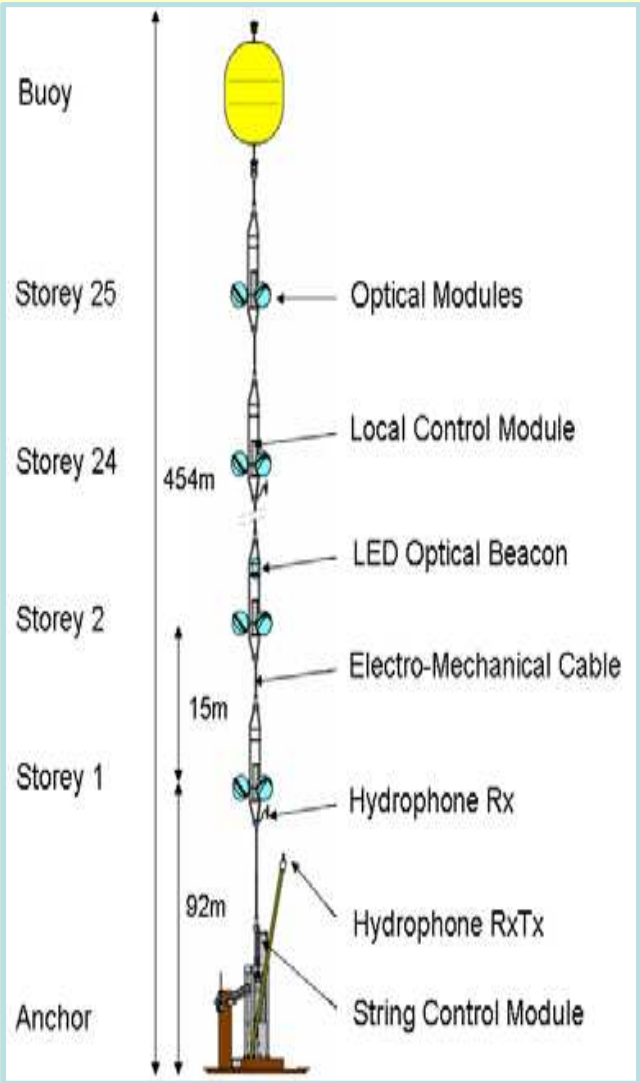
Acoustics for underwater neutrino telescopes

Miquel Ardid and Manuel Bou

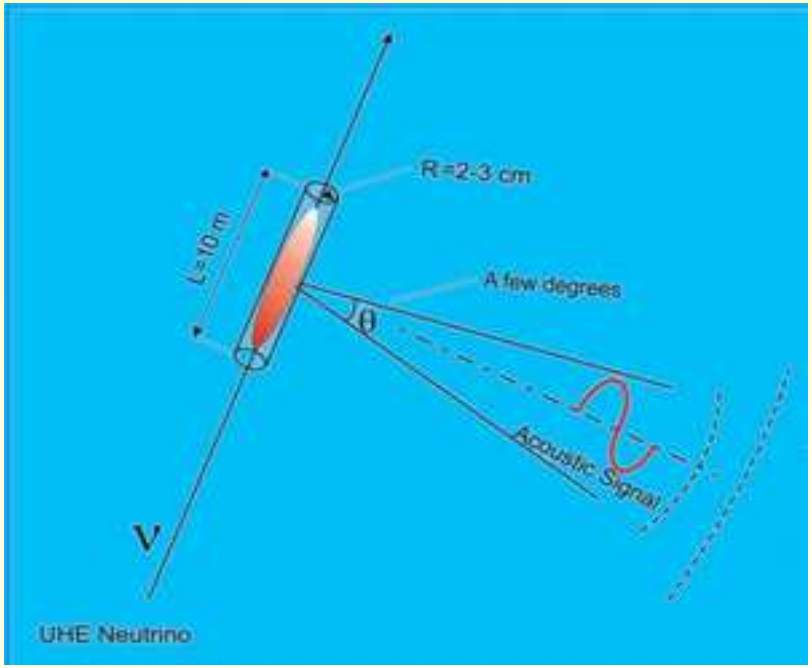
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Acoustic Activities

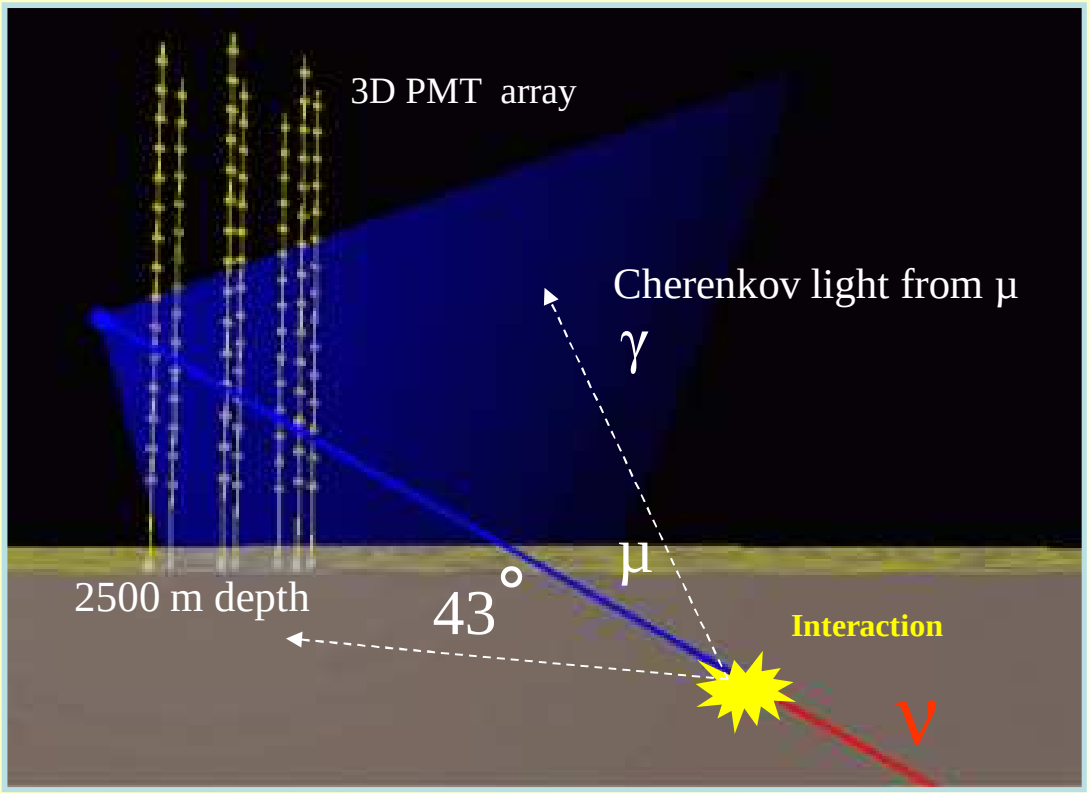
Acoustic positioning system



Acoustic detection of neutrinos



Acoustic positioning system (Intro).



$$cos\vartheta_c = \frac{c/n}{\beta/c} = \frac{1}{\beta \cdot n}$$

$$\frac{d^2N}{d\lambda dx} = \frac{2\pi\alpha sin^2\vartheta}{\lambda^2}$$

Measurement :
Time, position &
amplitude of hits

μ (~ ν) trajectory
&
energy

Acoustic positioning system (Intro).

APS must provide the position of :

- Mechanical structures, in a geo-referenced coordinate system, with an accuracy of about 1 m.

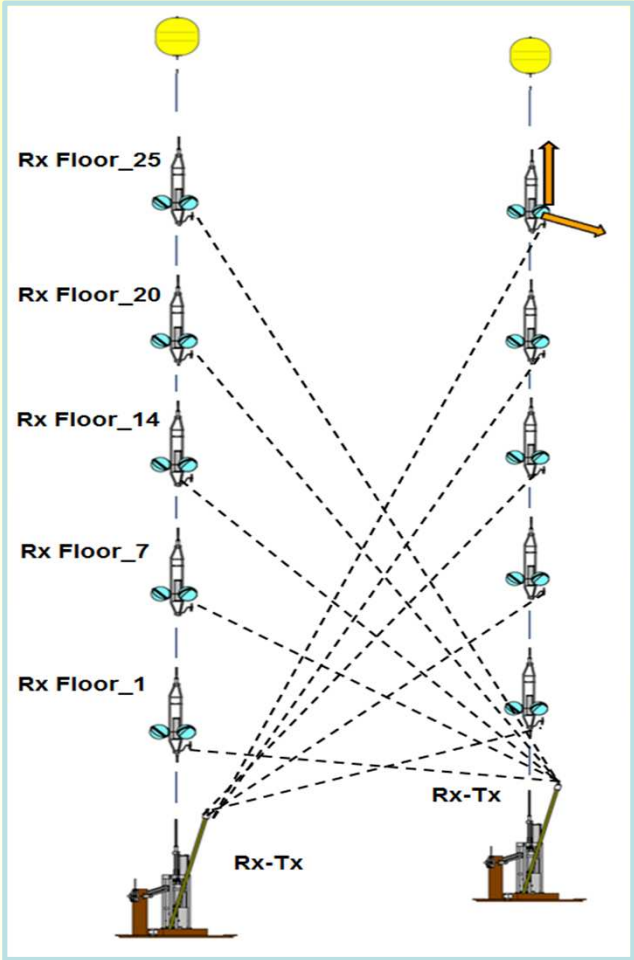
- The positions of OMs in deep sea, with an accuracy of about 10 cm.

APS is composed by three main items:

- (LBL) set of acoustic transceivers.

- An array of acoustic receivers (hydrophones) rigidly attached to the telescope mechanical structures.

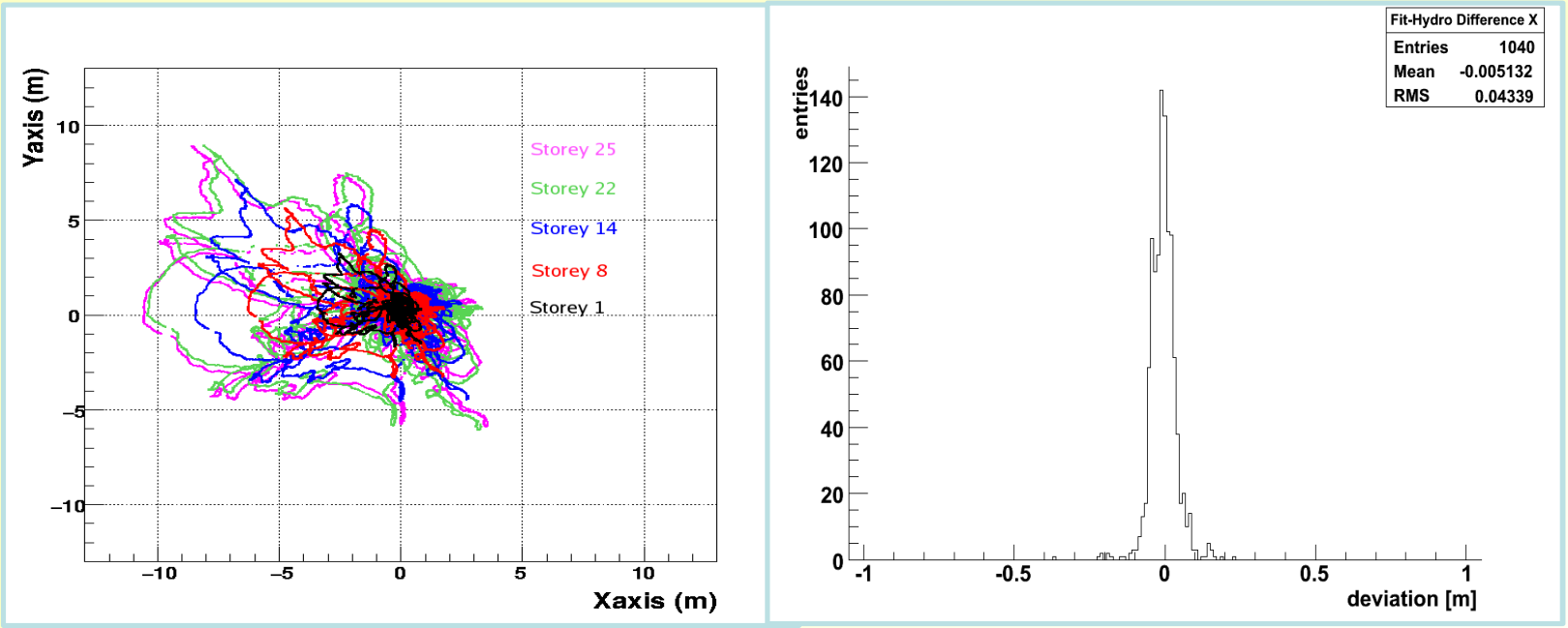
- An onshore PC farm to analize the APS data analysis, on-shore.



Detail of acoustic positioning system operation in ANTARES

Acoustic positioning system (Antares).

- Thorough its construction Antares telescope has passed through different number of lines and configuration. APS was extensevely studied



Left The horizontal movements from BSS, of all hydrophones on Line 11 for a 6 month period

Right-The difference between the X-position of storey 14 on Line 1 calculated by the hydrophone data and the X-position obtained by the line fit.

The accuracy nedeed has been achieved

Acoustic positioning system (KM3NeT).

- During last years Gandia`s group is involved in R & D for the acoustic positioning system for KM3NeT in collaboration with the INFN (Istituto Nazionale di Fisica Nucleare) and CPPM (Centre de Physique des Particules de Marseille).

- Long Base Line Acoustic Positioning system for KM3NeT consists of a series of acoustic transceivers distributed on the sea bottom. Each of these acoustic transceivers is composed of a transducer and the associated electronics.

LBL designed is composed by

- Emitter transducers.
- Sound emission board.

Transducers specifications:

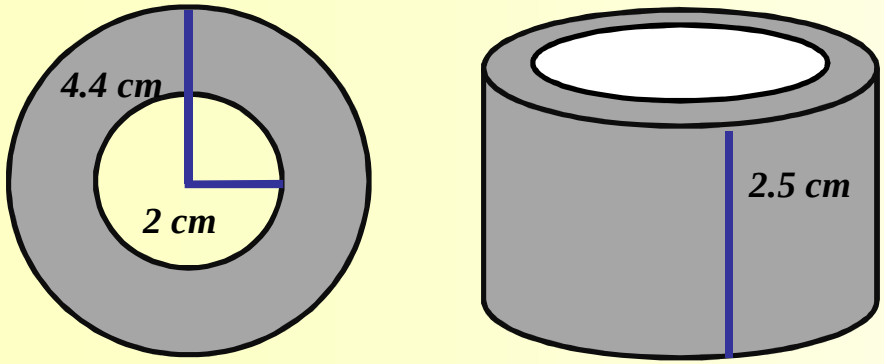
- Reasonable power level.
- Convenient resonance frequency.
- Capacity of work at high depth.
- Good directivity (omnidirectional desired)

Electronic board specifications

- Power consumption < 1W at 5V & 12V.
- RS232 Communication Port .
- Times sinchronization with an accuracy around 1µs.
- It might work in emission and reception mode.

Acoustic positioning system (Hydrophones).

Free Flooded Ring (FFR) sensors, model SX30 manufactured by Sensor Technology Ltd



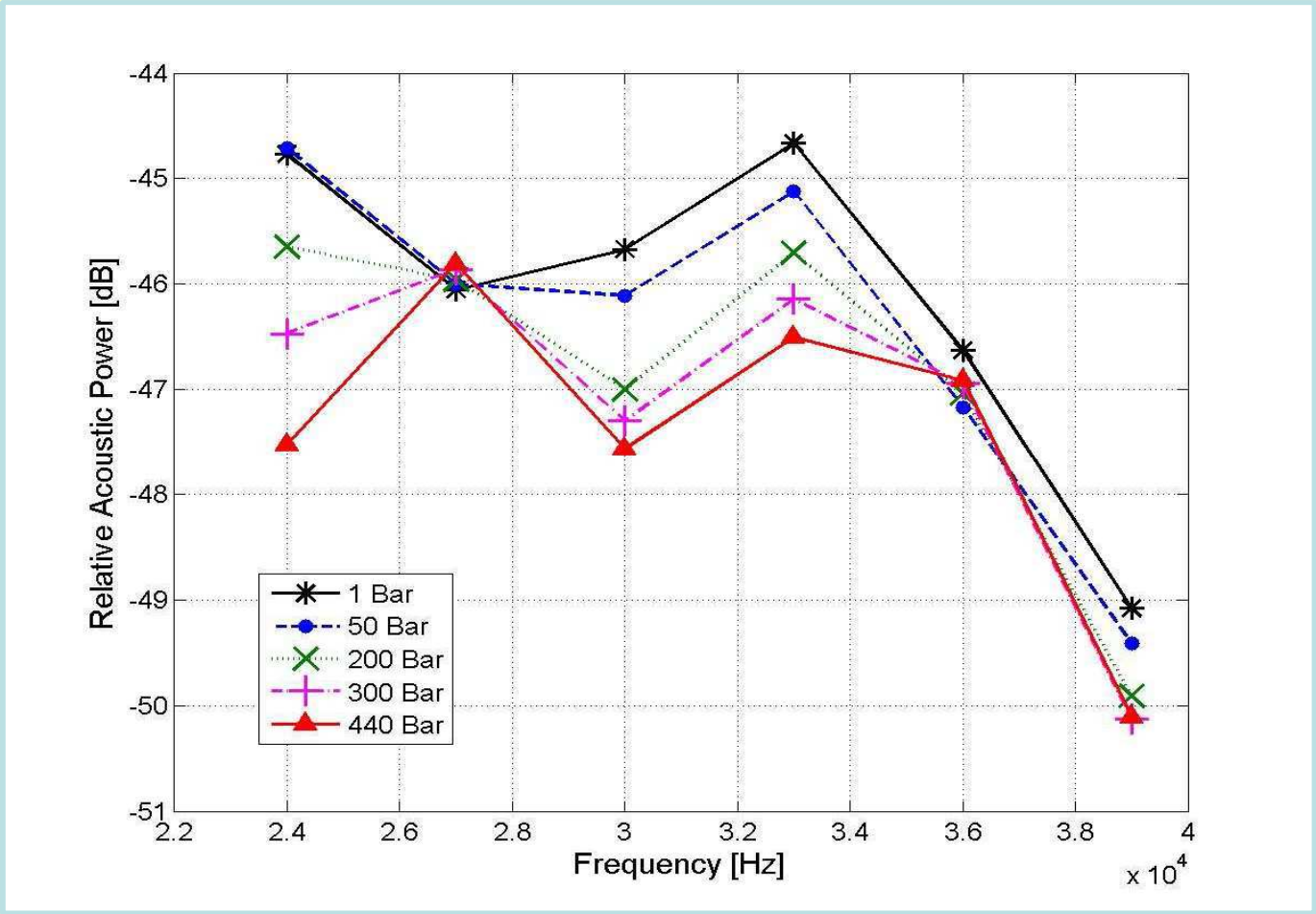
- Efficient transducer, that provides reasonable power of level.
- Have “unlimited” depth for operation (has been tested up to 440bars).
- Omnidirectional directivity pattern.
- Transmitting voltage response :
  133 dB Ref. 1µPa/V at 1m
- Receiving Voltage response
  -193 dB Ref. 1V/µPa,
- The maximum input power is 300 W with 2% duty cycle.
- 20–40 kHz frequency range.

Acoustic positioning system (Hydrophones).

Hydrohones have been tested in lab and under high pressure conditions.

Hyperbaric tank at IFREMER research facilities, PLOUZANE (near Brest - France)

Acoustic positioning system (Hydrophones).



Example of results obtained in relation with pressure test

Some little variations in the relative acoustic power with the pressure in the [24-40] kHz frequency range. In addition, no significant drifts on time were observed

Acoustic positioning system (SEB).

- *Sound Emission Board* has been developed at IGIC-UPV Gandia. It is specially adapted to the FFR transducers and is able to feed the transducer with high amplitude short signals (a few ms) with arbitrary waveform.

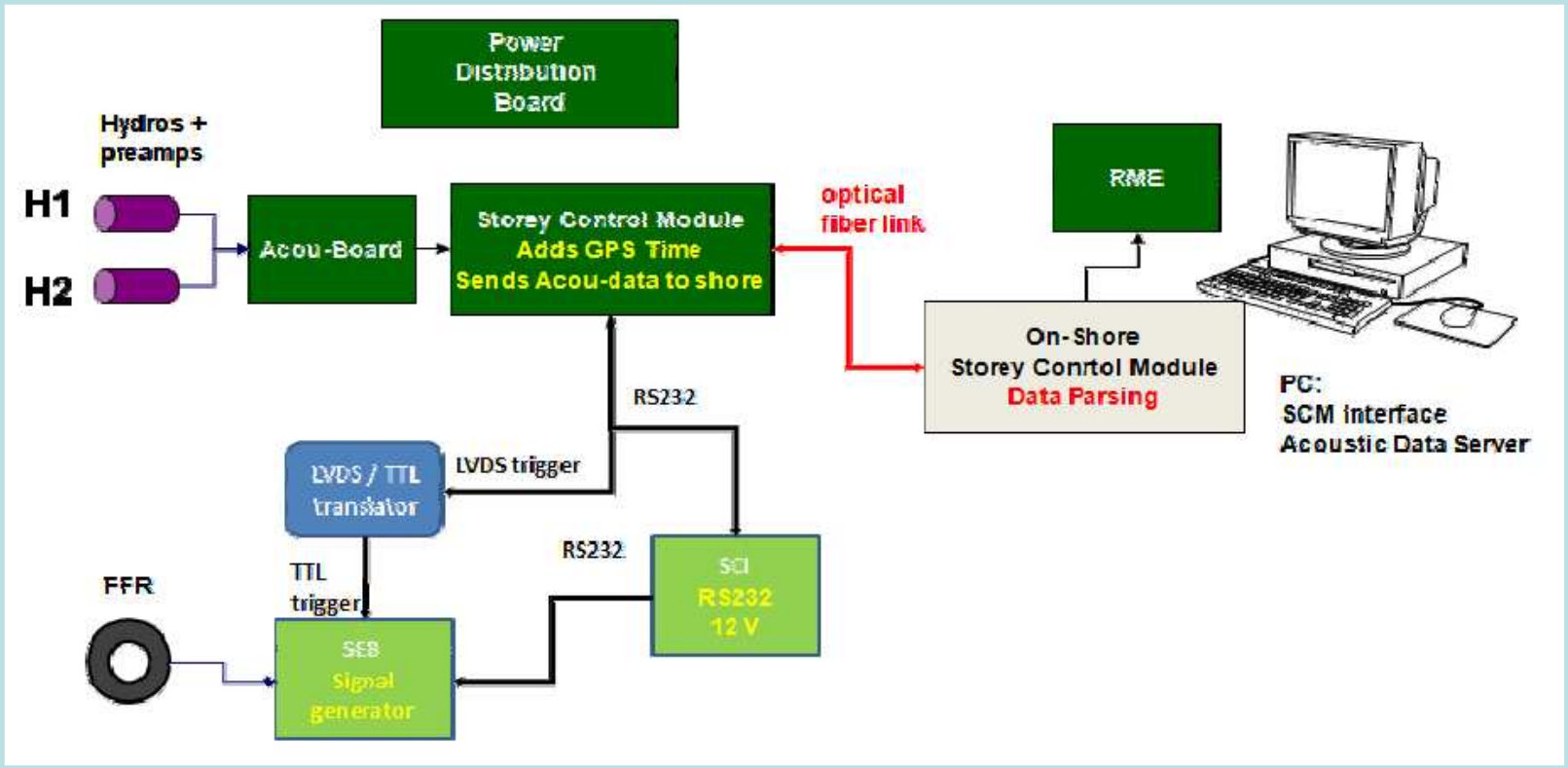
Board specifications

- Use the power supply granted by the telescope. 1 W approx
- It must have a low speed port for configuration (RS232,RS485…)
- The board have to emit the signal when it detect a LVDS trigger signal. The accuracy in the emitting delay must be less than 1µS.

- The system life expectancy must be more than twenty years.

Acoustic positioning system (SEB + HYD).

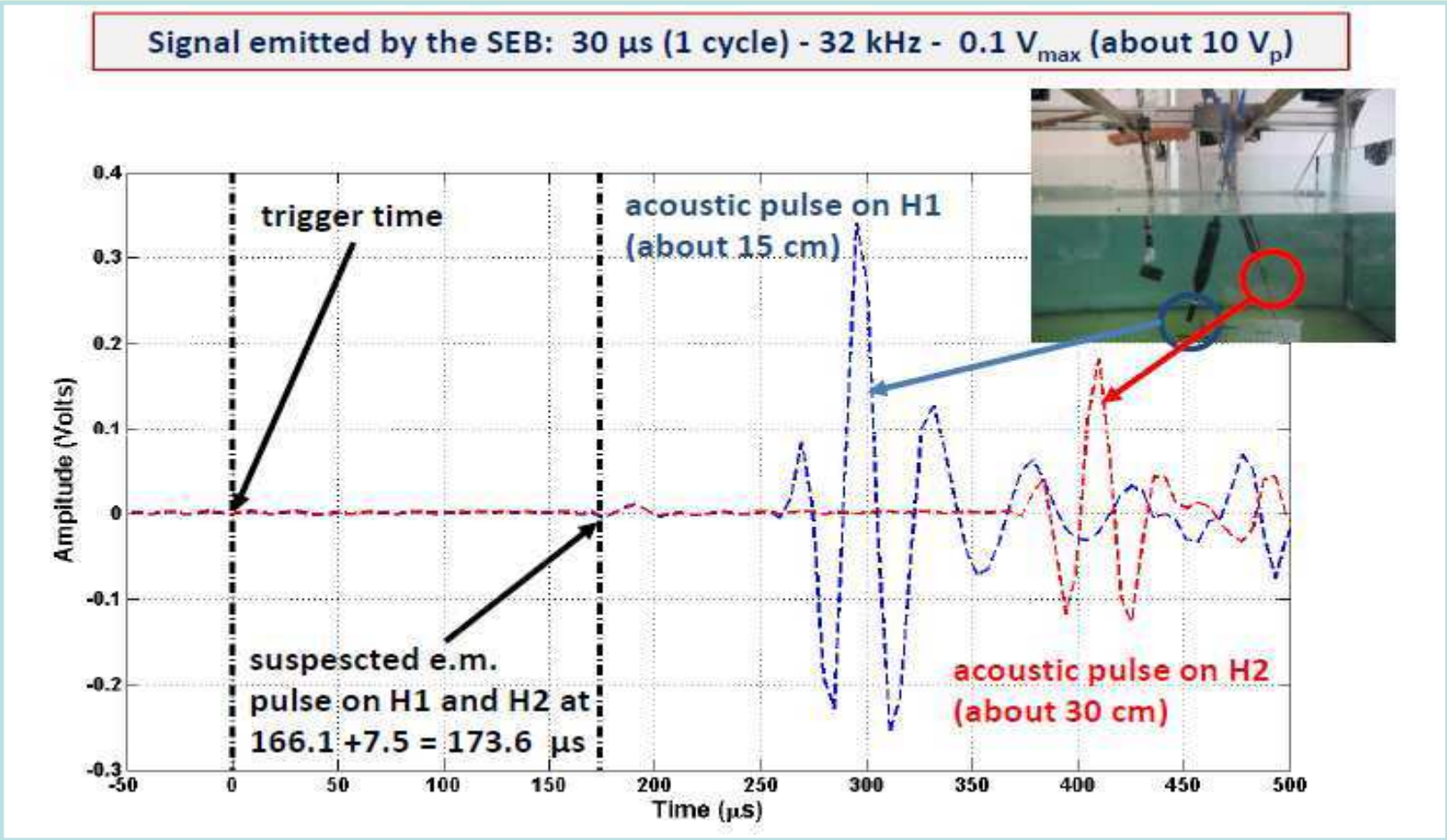
- Tests have been done in the laboratory of the IGIC-UPV in Gandia in the week the 5-12 May 2010 together with INFN INFN-Italy, CPPM-France and ECAP -Germany.



- Goal of the test was to prove compatibility and functionality of different hardware and software developed within KM3Net for an innovative acoustic positioning system

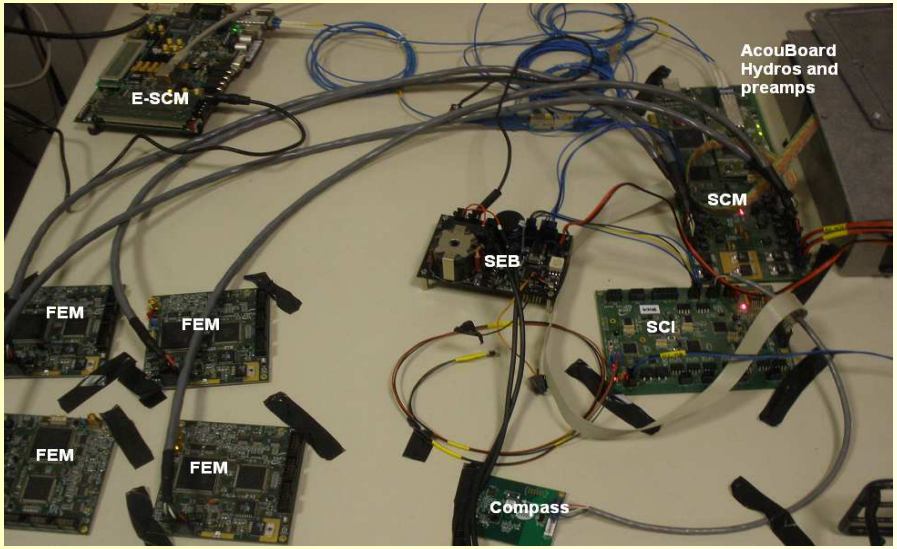
Acoustic positioning system (SEB + HYD).

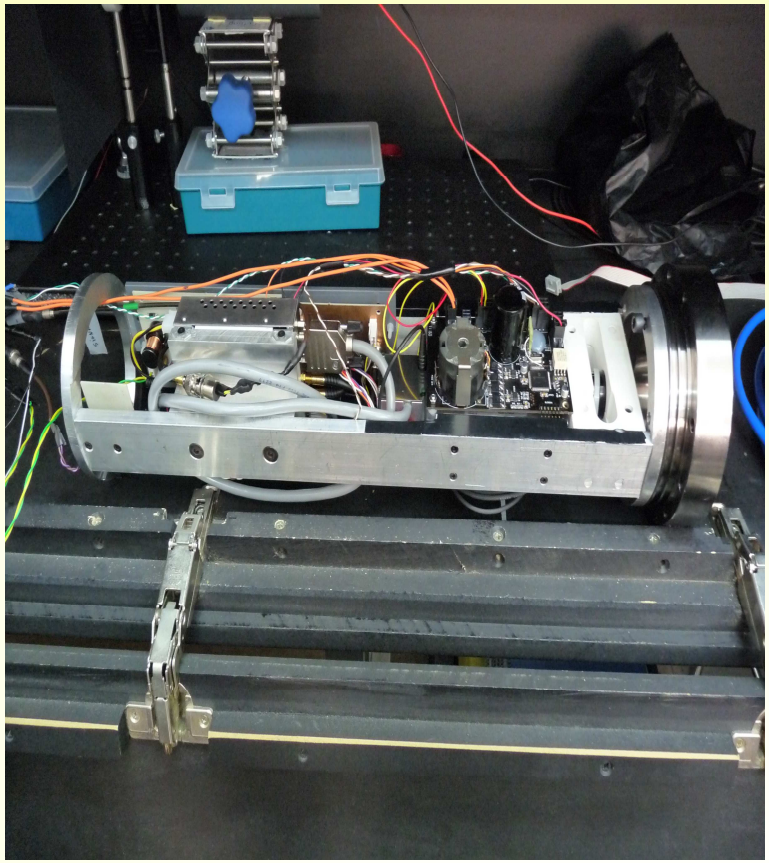
- Latency time of the full system.



Acoustic positioning system (SEB + HYD).

Developed system is currently integrated in IL11 of Antares (will be connected in a few weeks).
In addition a SEB + FFR is under integration process in the framework Nemo Phase 2.

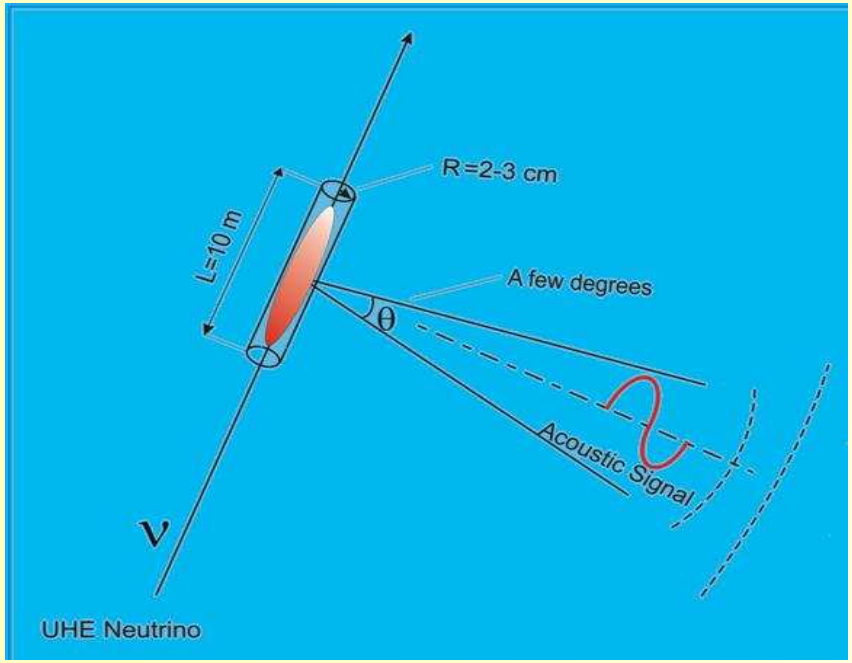


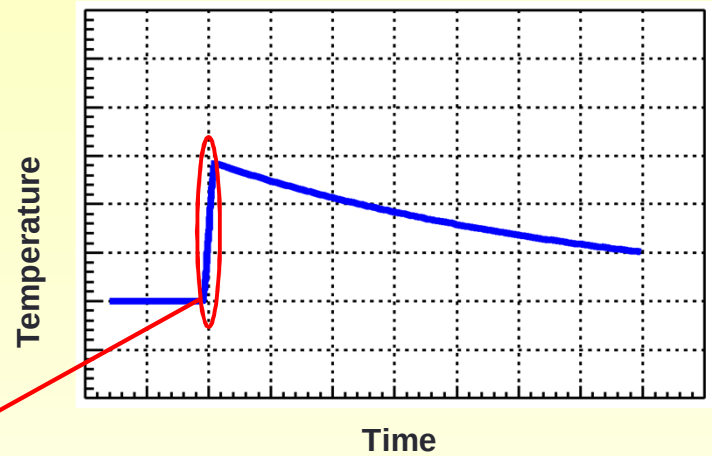


Detail of SEB integrated inside of titanium vessel (Laser calibrator developed by IFIC team).

Acoustic detection neutrinos (Intro)

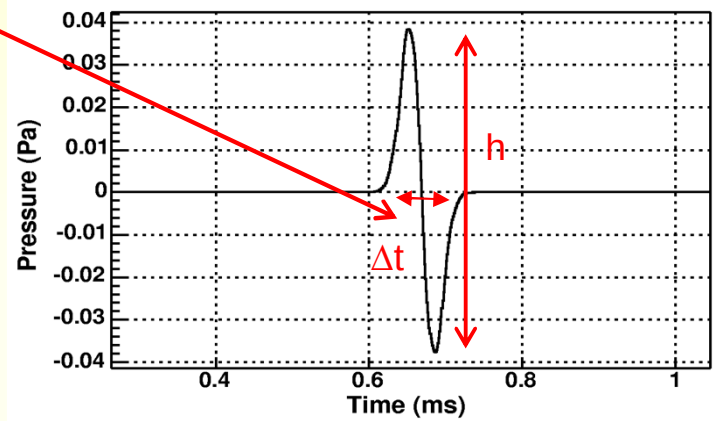
G.A.Askaryan. *Hydrodynamical emission of tracks of ionising particles in stable liquids*. J. At. Energy 3 (1957) 921.





$$\frac{d^2}{dt^2}$$

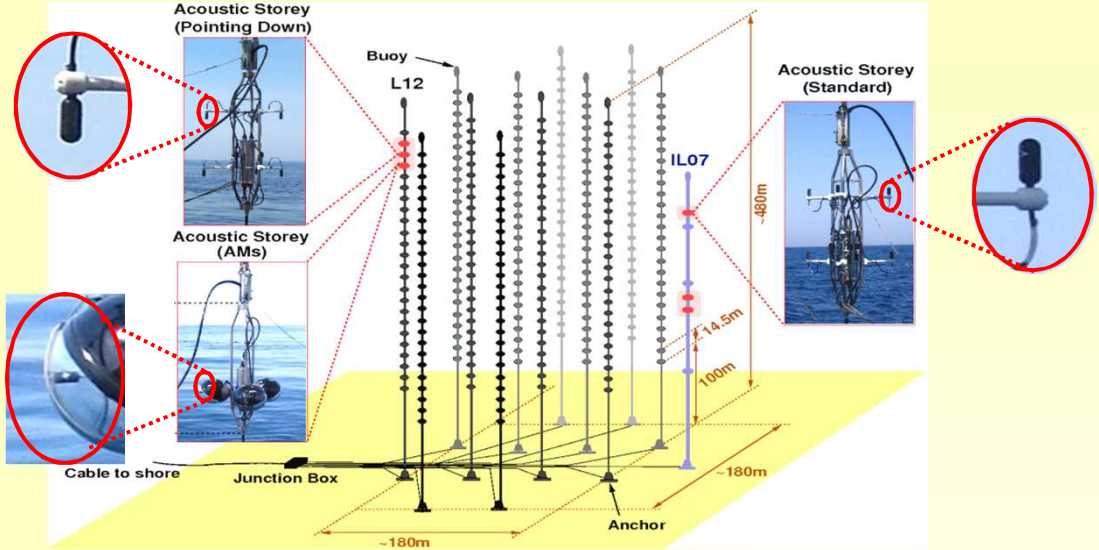
$$h \propto \frac{\alpha\,\beta}{C_p}$$

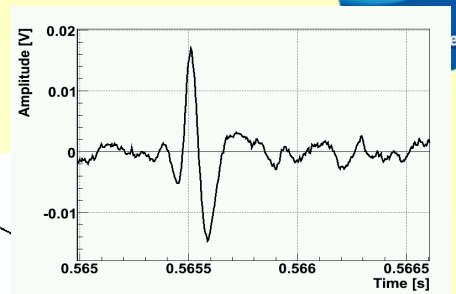


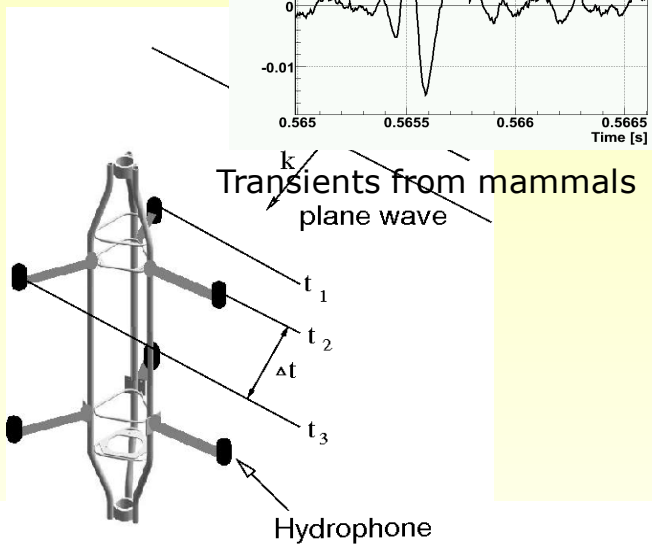
When a UHE neutrino interacts with the matter, the energy is deposited fast and locally. A thermo-acoustic pulse is generated and propagates perpendicularly to the direction of the hadronic shower produced.

The acoustic signal has a bipolar shape in time and a 'pancake' directivity

Acoustic neutrino detection (AMADEUS)



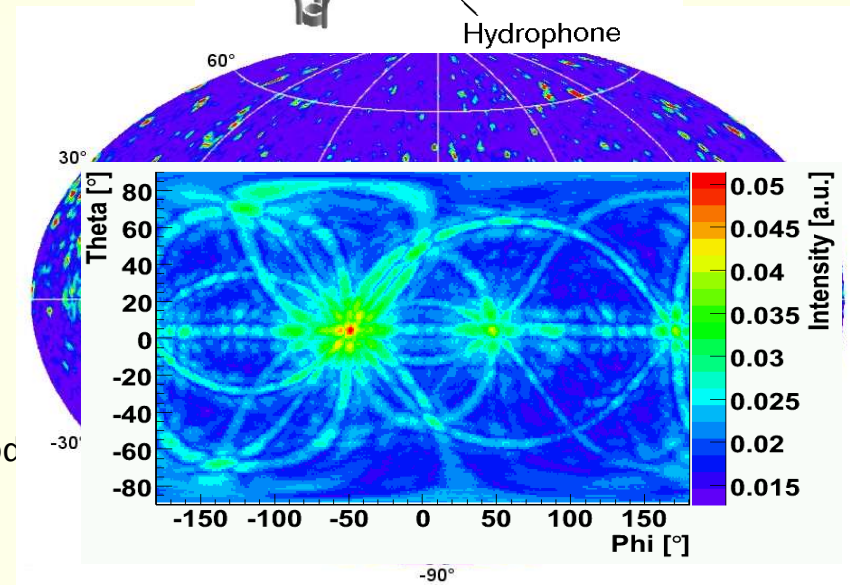




- Total of six acoustic storeys.
- Three on the Instrumentation Line (IL07).
- Three on the 12th detection line (L12).
- 34 sensors fully operationally. .

Studies performed.

- Long term background investigations.
- Investigation of spatial correlations for transient signals and for persistent background on different length scales
- Development and tests of data filter and reconstruction algorithms
- Investigation of different types of acoustic sensors and sensing methoc
- Studies of hybrid (acoustic and optical) detection methods.

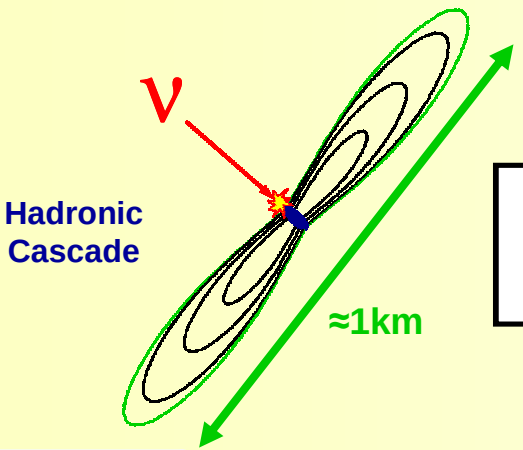


UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Acoustic neutrino detection (Calibrator)

- For the acoustic detection of neutrino it is very important to have a good calibrator in order to:
  - Check and monitor the sensitivity.
  - Test the system and the reliability.

- Due to the properties of the acoustic neutrino signal (short bipolar pulse with ‘pancake’ directivity) it is not easy to reproduce it.

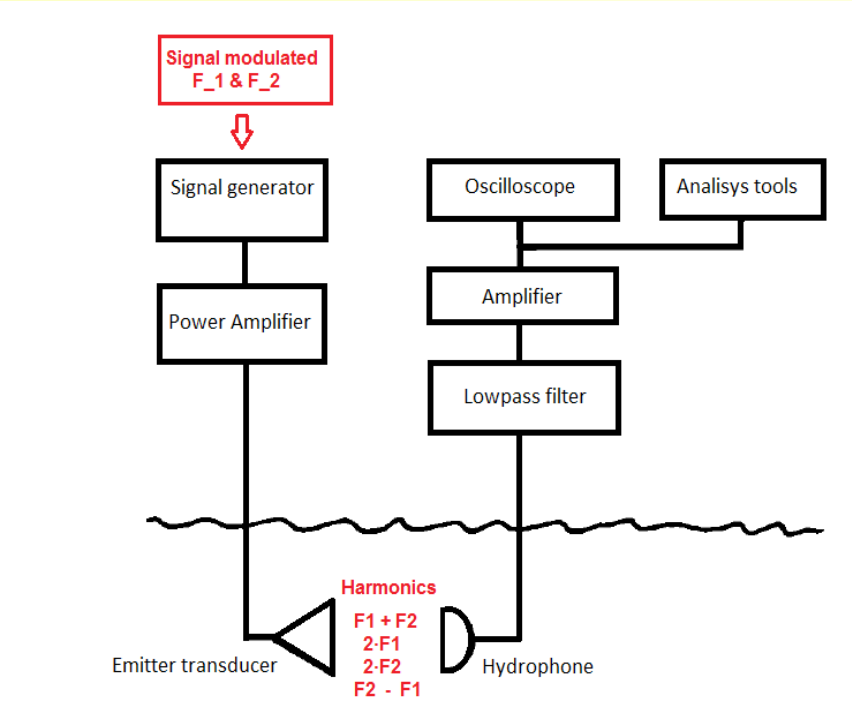


CALIBRATOR:Parametric Acoustic Sources

Bipolar Pulse
Cylindrical Propagation
Pancake Directivity ≈ 3º

Acoustic detection neutrinos(Param Ac. Src)

- Parametric acoustic generation is a well known **non linear effect** first time studied at 60's.
- Parametric acoustic generation consist in a non linear effect that occurs **along the sound wave path** when a transducer is fed with a modulated signal with two close frequencies.

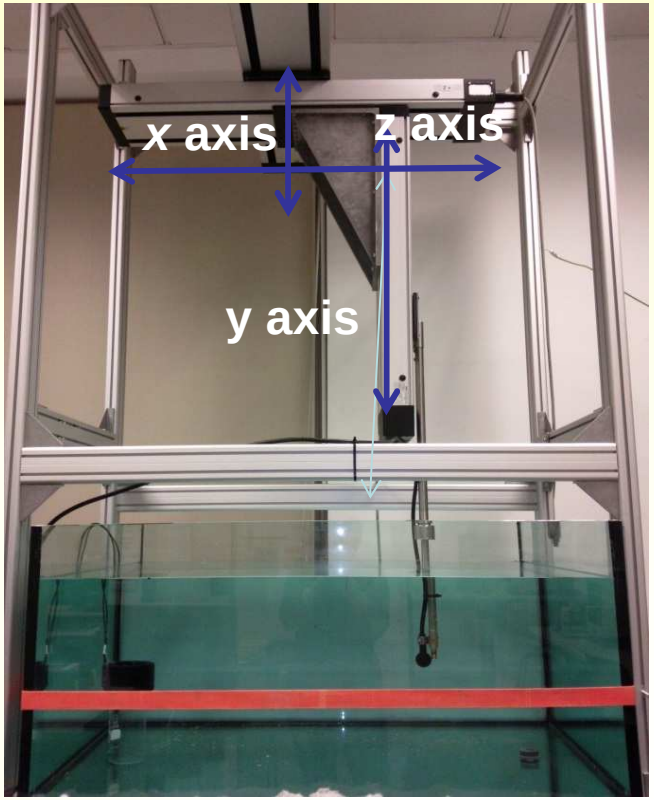


- Small fraction of energy is converted into new spectral components.
- Larger frequencies are rapidly absorbed in the medium → most interesting harmonic is the frequency difference.
- It can be used to obtain a low frequency secondary signal with directivity similar to the high frequency primary beam.

Acoustic detection neutrinos (Exp set up)

Emitter hydrophone:10 kHz Free Flooded Ring
- 380 kHz frequency resonance used for our studies
- It is usually used at lower frequencies, so it can be used as well as a classical transmitter at high frequency

Receiver hydrophone:
More sensitive below 100 kHz than for 380 kHz. More sensitive to the bipolar pulse (hardware filtering)



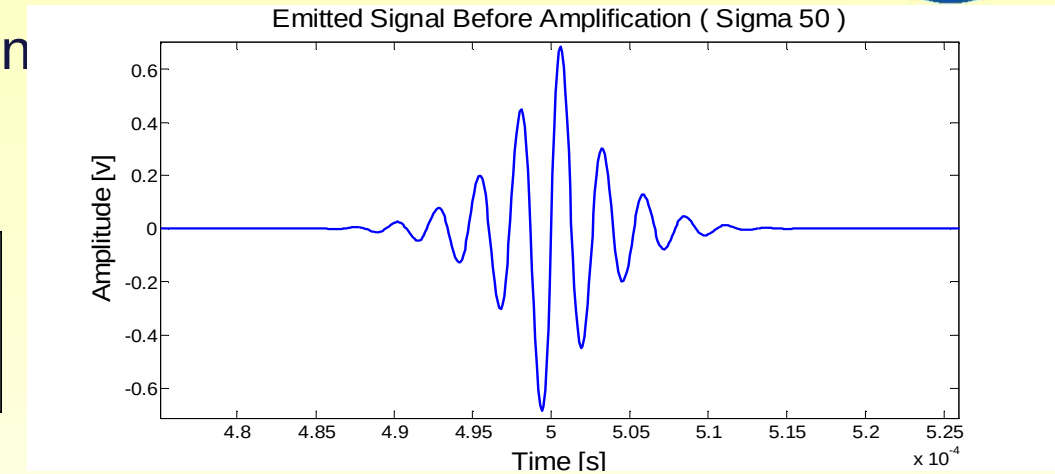
Emitter is fixed, whereas the receiver hydrophone scans along x, y and z axis using a micropositioning system.

- Generador PCI-5412 (National Instruments).
- Amplificador RF ENI 1040L (400W, +55dB, Rochester, NY).
- Digitalizador PCI-5102 (National Instruments)
- Dimension of tank is ~ 1 m3

Acoustic detection neutrinos (Results)

- **Modulation** of signal for emission calculated from parametric theory:

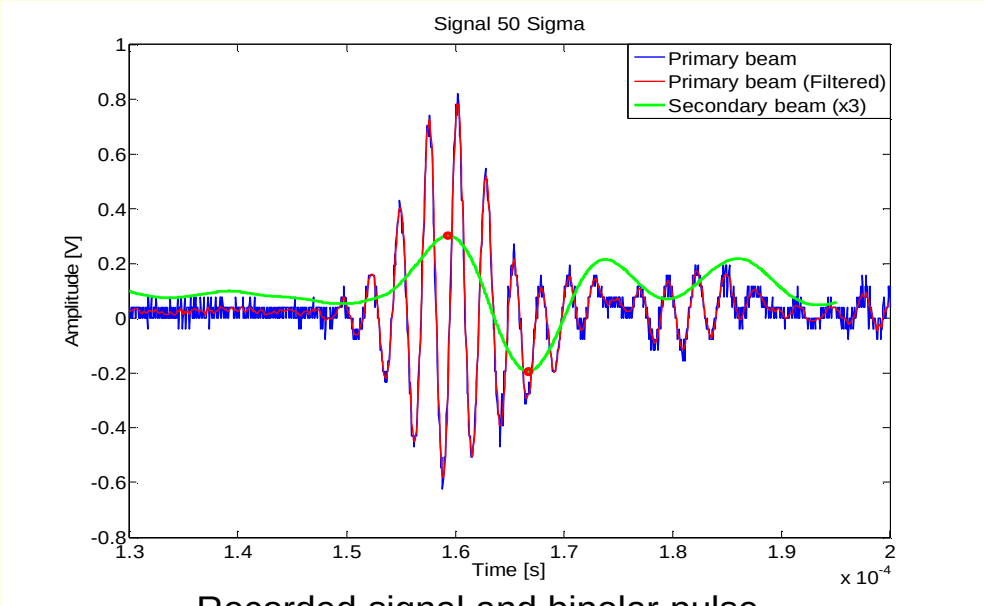
$$p(x,t)=\left(1+\frac{B}{2\cdot A}\right)\cdot\frac{P^2\cdot S}{16\cdot\pi\cdot\rho\cdot c^4\cdot\alpha\cdot x}\cdot\frac{\delta^2}{\delta t^2}\cdot\left[f\left(t-\frac{x}{c}\right)\right]^2$$



- First studies were done using planar transduces in order to understand and control the parametric acoustic generation.

M.Ardid et al. "Use of parametric acoustic sources to generate neutrino-like signals," Nucl. Instr. and Meth. A, vol. 604, Jun. 2009, pp. S208-S211.

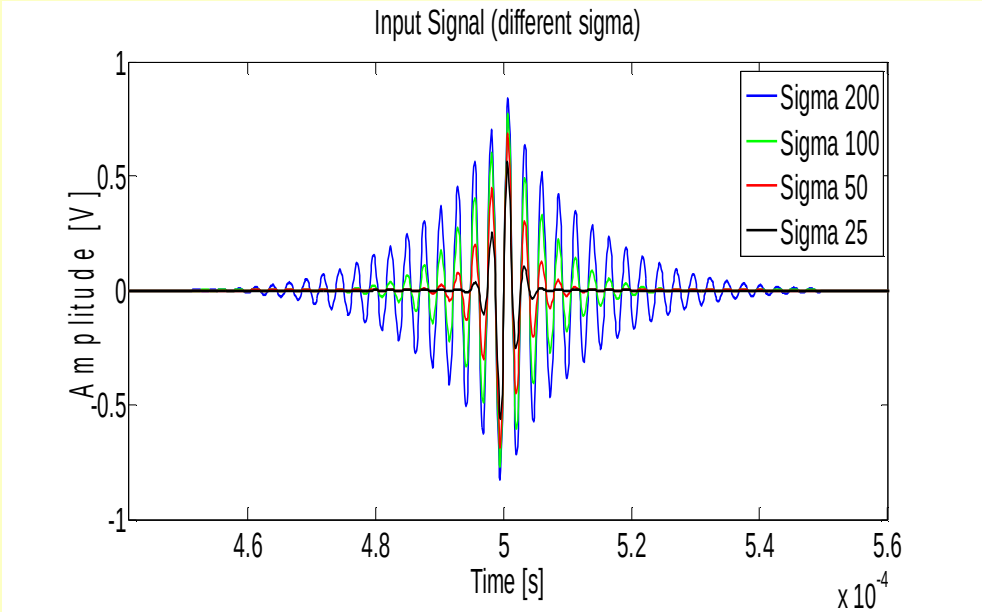
- To disentangle the primary and secondary beams we applied different filters.



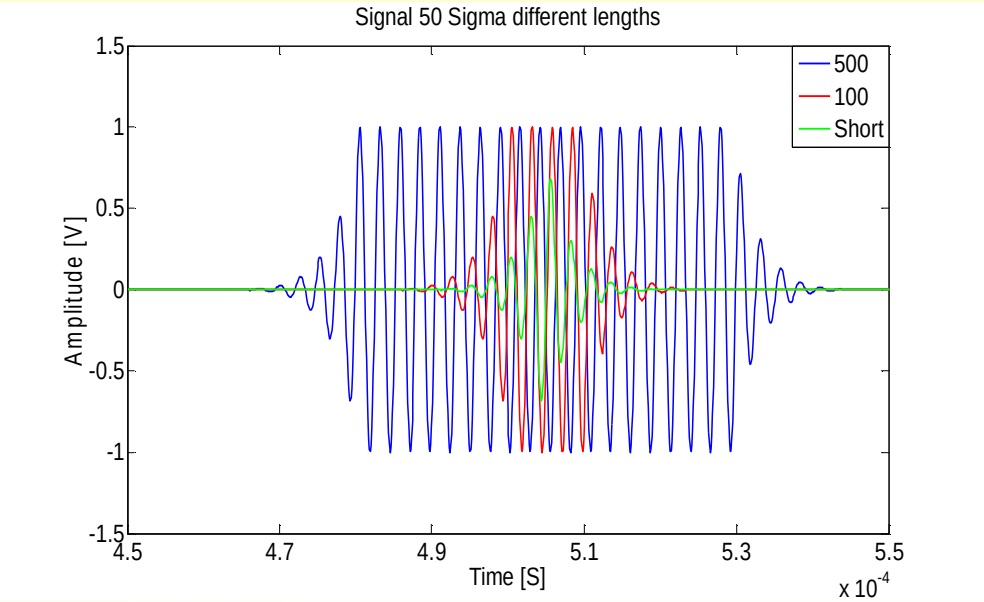
Recorded signal and bipolar pulse

Acoustic detection neutrinos (Results)

Emitted signals with **different width** (different sigma used)



Emitted signals with **different adding time** between the increasing and decreasing amplitude regions

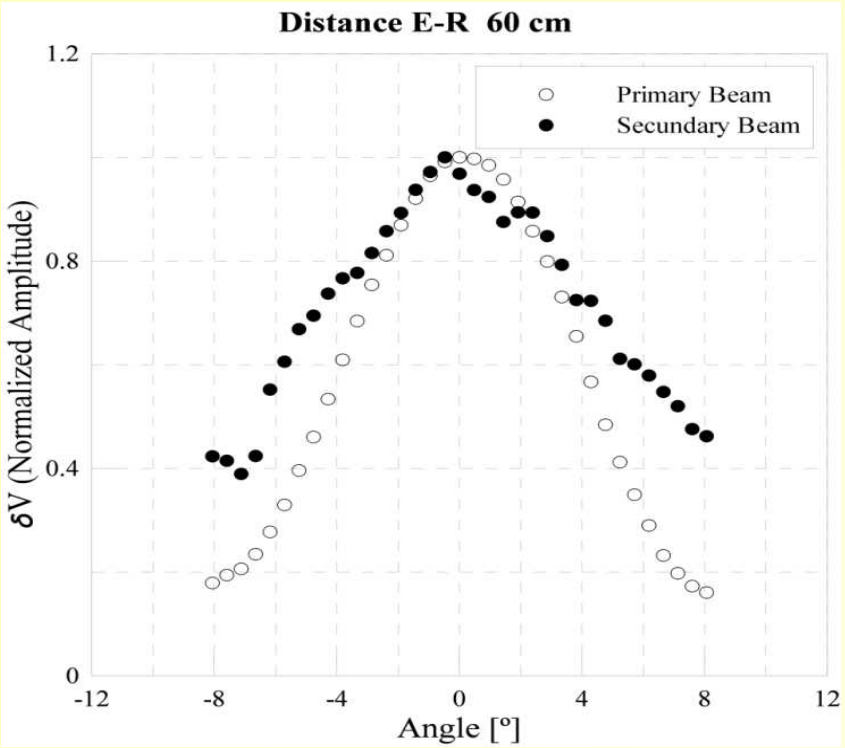


- Different emitted signals were studied in order to evaluate the **generation control** of bipolar pulse in the medium

M.Ardid et al. "R&D studies for the development of a compact transmitter able to mimic the acoustic signature of a UHE neutrino interaction," Nucl. Instr. and Meth. A, doi:10.1016/j.nima.2010.11.139.

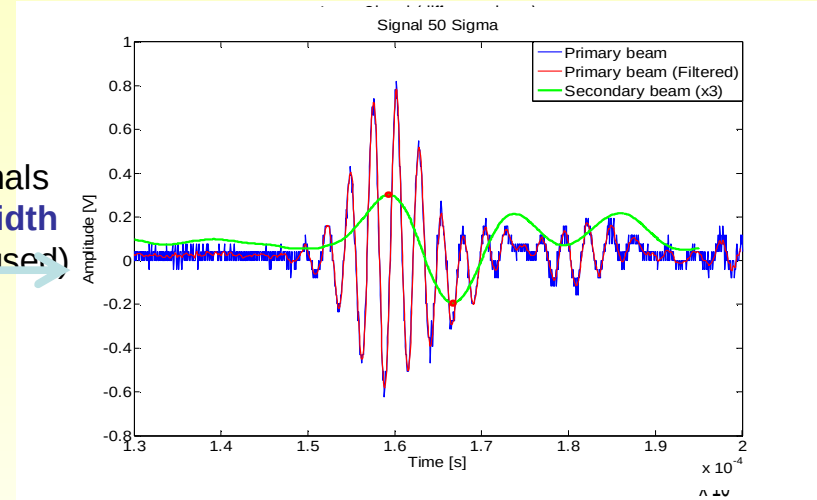
Acoustic detection neutrinos (Results)

- ***Directivity studies***

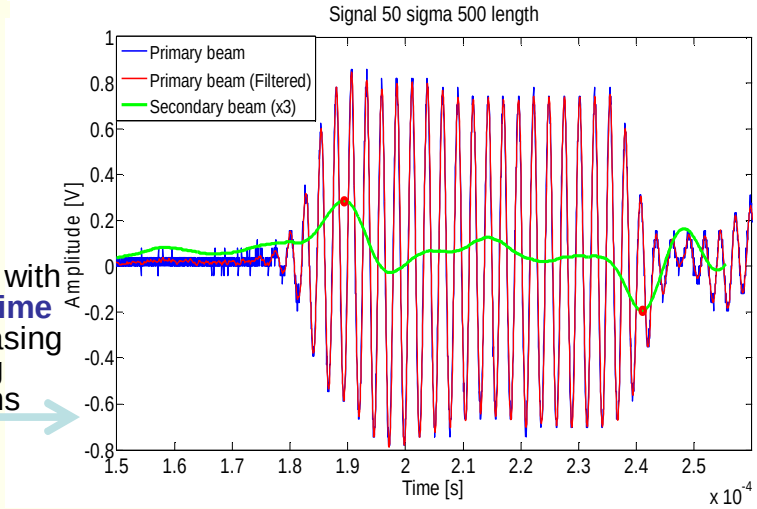


- ***Shape studies***: Control generation of bipolar pulse

Emitted signals with **different width** (different sigma used)



Emitted signals with **different adding time** between the increasing and decreasing amplitude regions

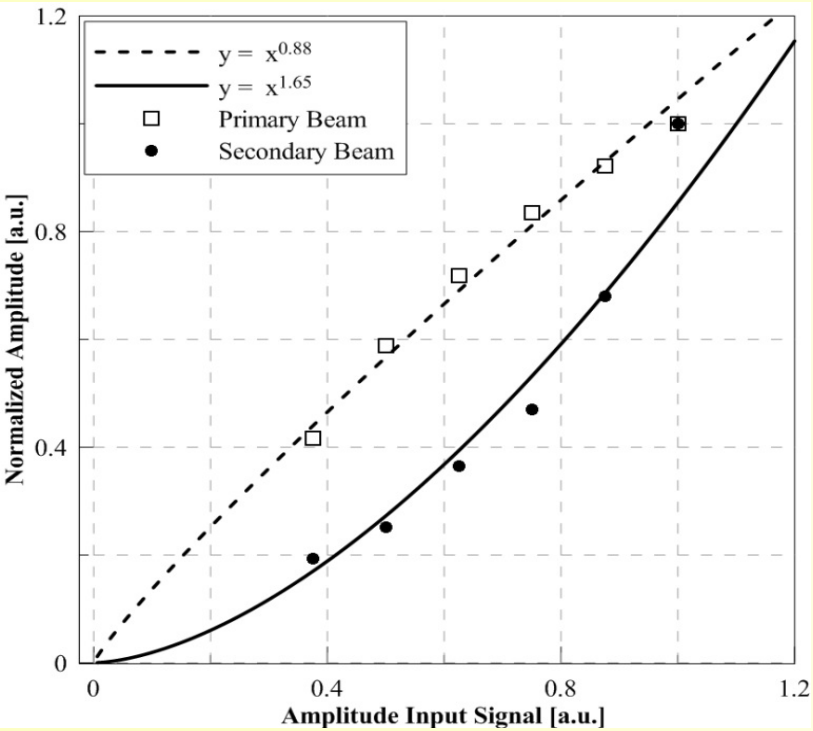


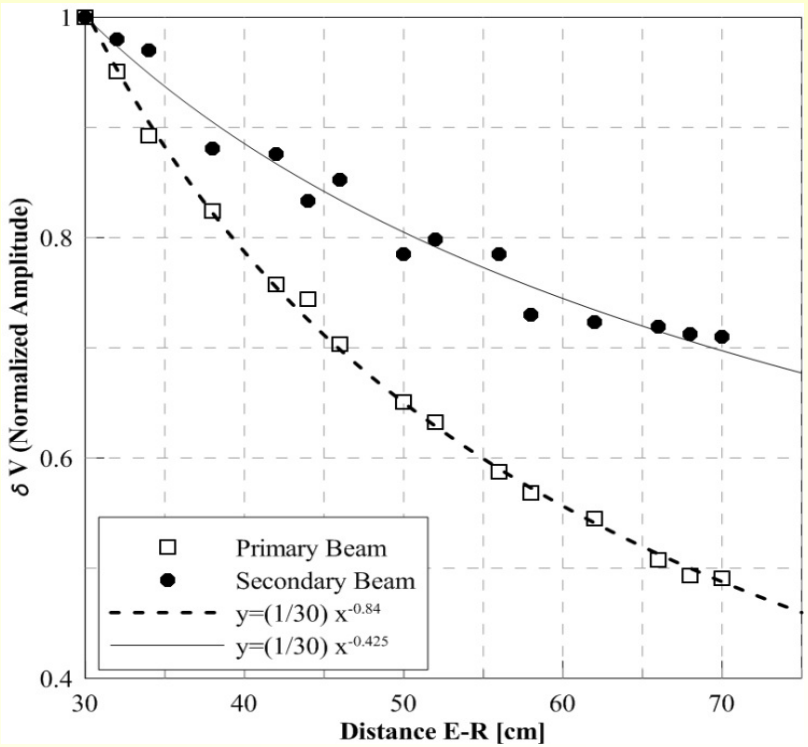
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Acoustic detection neutrinos (Results)

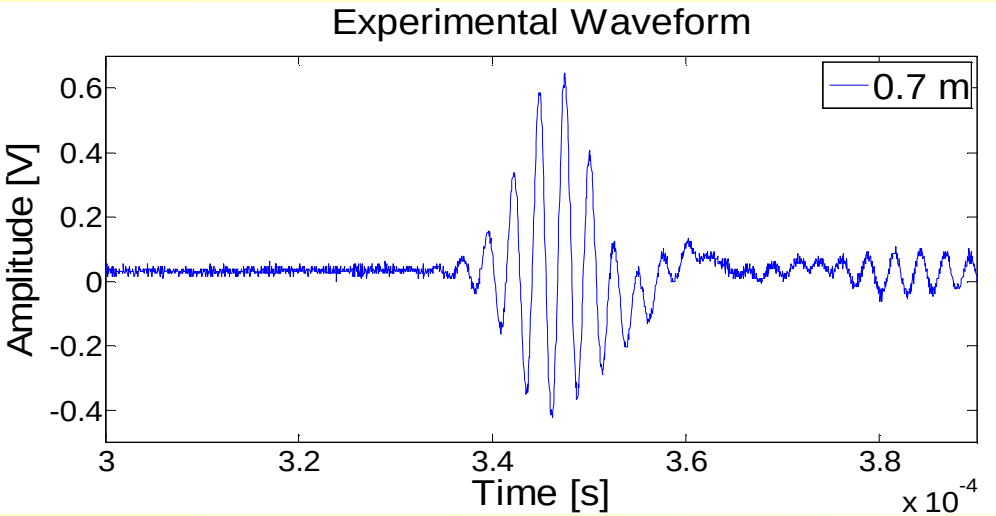
M.Ardid et al. "R&D studies for the development of a compact transmitter able to mimic the acoustic signature of a UHE neutrino interaction," Nucl. Instr. and Meth. A, doi:10.1016/j.nima.2010.11.139.

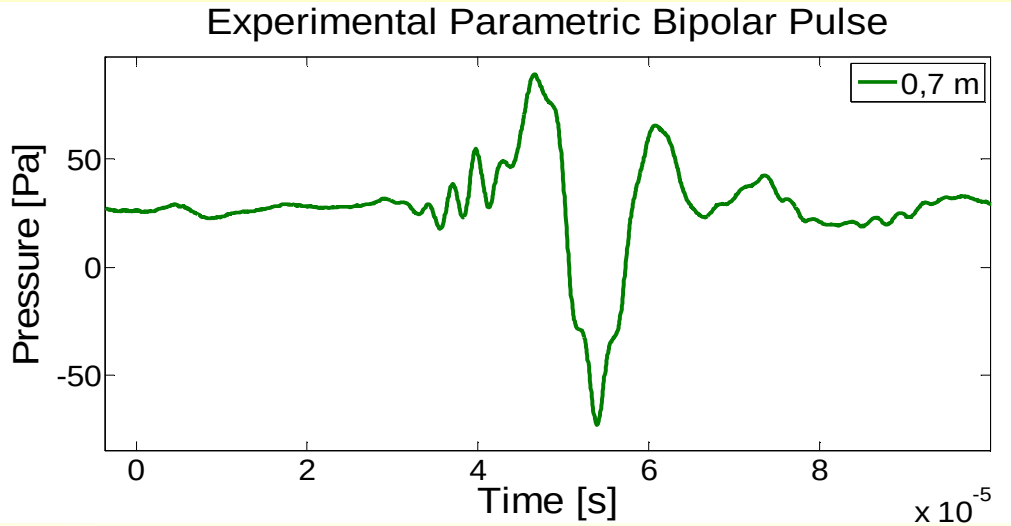
*Relationship between the **amplitude** of the **primary** and the **secondary** beam:*



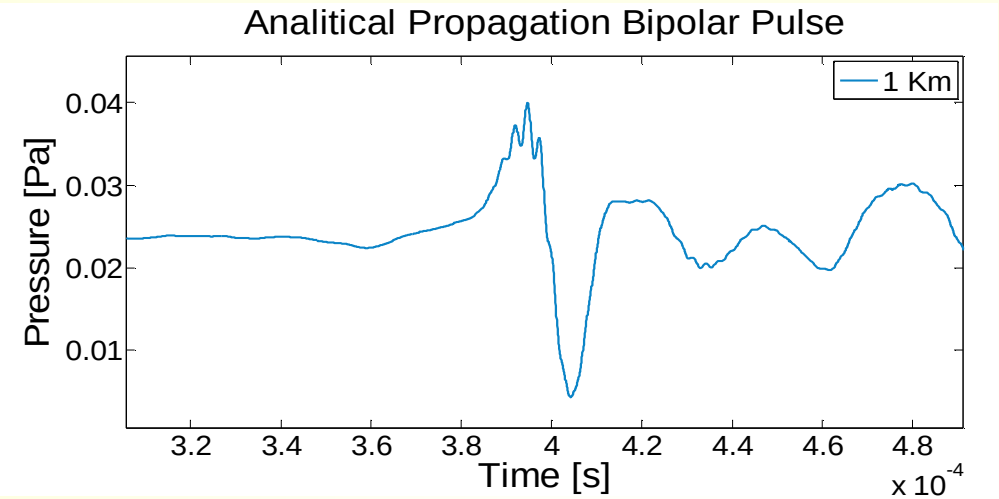


Acoustic detection neutrinos (Results)



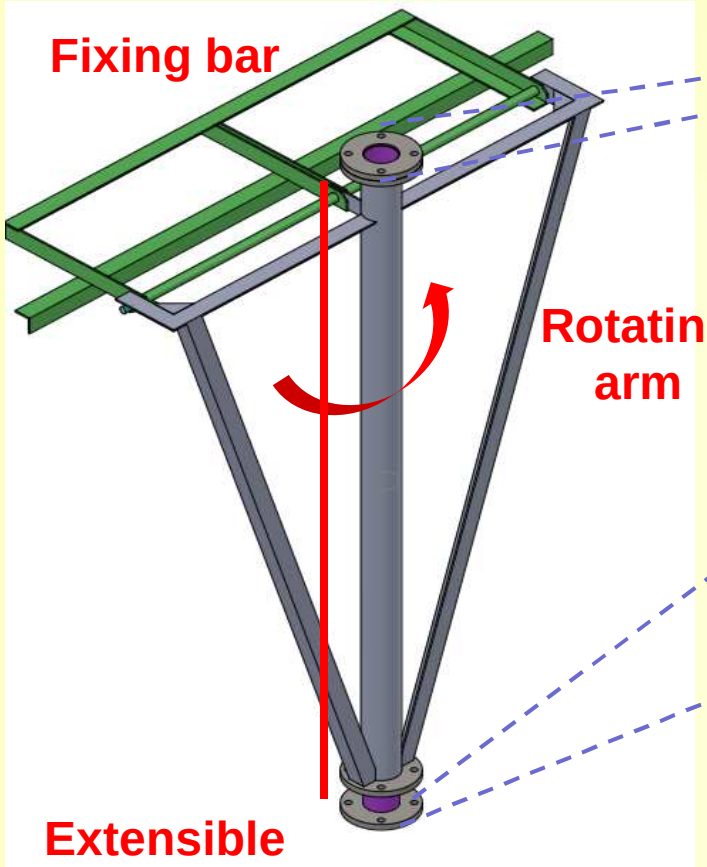


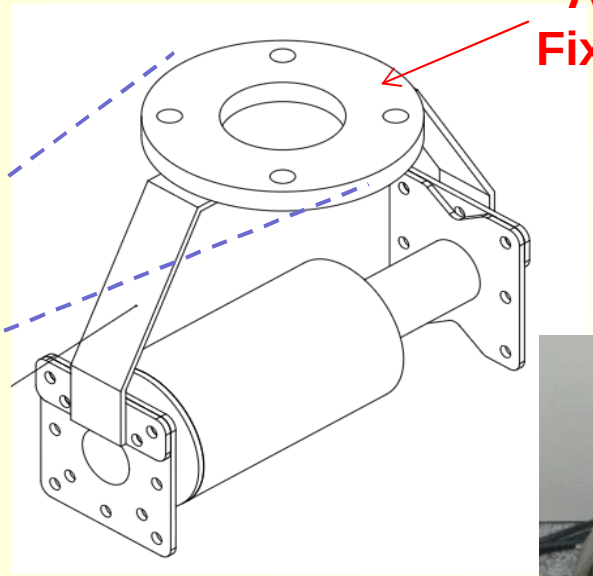
Reference of pressure
0.1 Pa at 1Km
by neutrino of
$10^{20}\ eV$ interaction

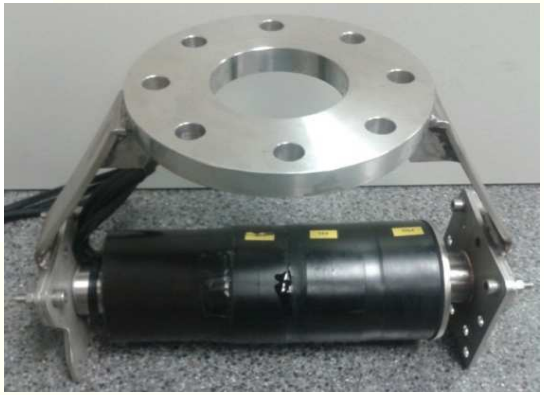


Acoustic detection neutrinos (Array)

- Array set up







Acoustic detection neutrinos (Conclussions)

It seems clear that the solution proposed based in parametric acoustic sources could be considered as good candidate to generate the acoustic neutrino-like signals, achieving the reproduction of both specific characteristics the signal predicted by theory:

- bipolar shape in time
- ‘pancake directivity’.

Complete the characterization of the prototype:

Laboratory

Gandia´s port

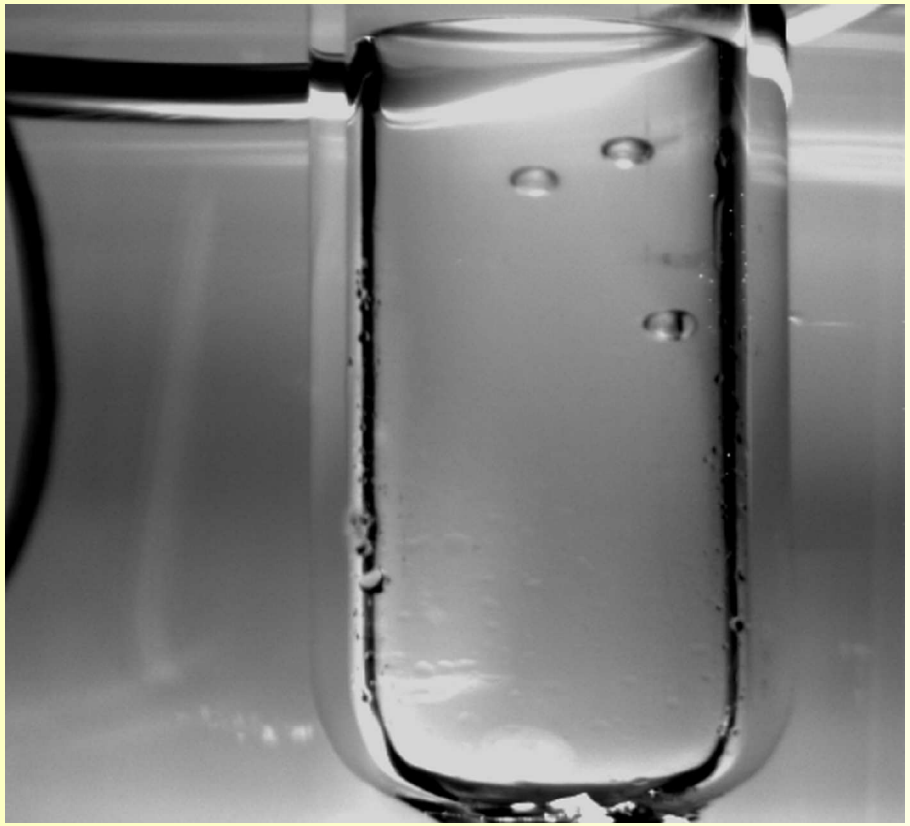
Test the behavior of the transmitter using the Amadeus system.

Future sea campaign (vessel)

In situ integration at neutrino telescope

Acoustic detection of WIMP'S

Acoustics is not only present in underwater neutrino telescope, can be a useful tool to detect WIMP'S.



That´s all

Thanks for your attention