Underwater acoustic positioning system for the KM3NeT-IT project

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Acoustic positioning system

The acoustic positioning system is a mandatory subsystem for an underwater neutrino telescope

Aims:

1. **Provide optical module positions during the telescope operation for muon track reconstruction**

2. **Give a guide during the deployment of the telescope structures and infrastructures**

Key elements:

-**Long Baseline of acoustic transceivers anchored in known and fixed positions.**

-**Array of acoustic sensors (hydrophones) moving with the Detection Unit mechanical structure**

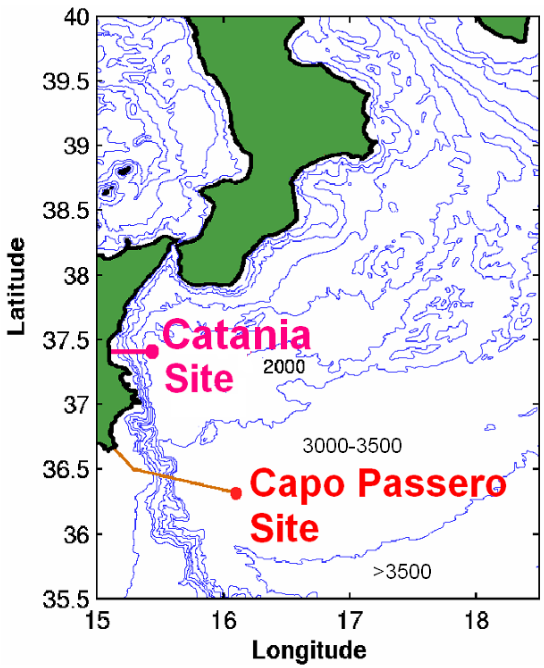
-**Auxiliary devices: compasses, CTD , sound velocimeters , current meters**

KM3NeT- Italia geometrical layout

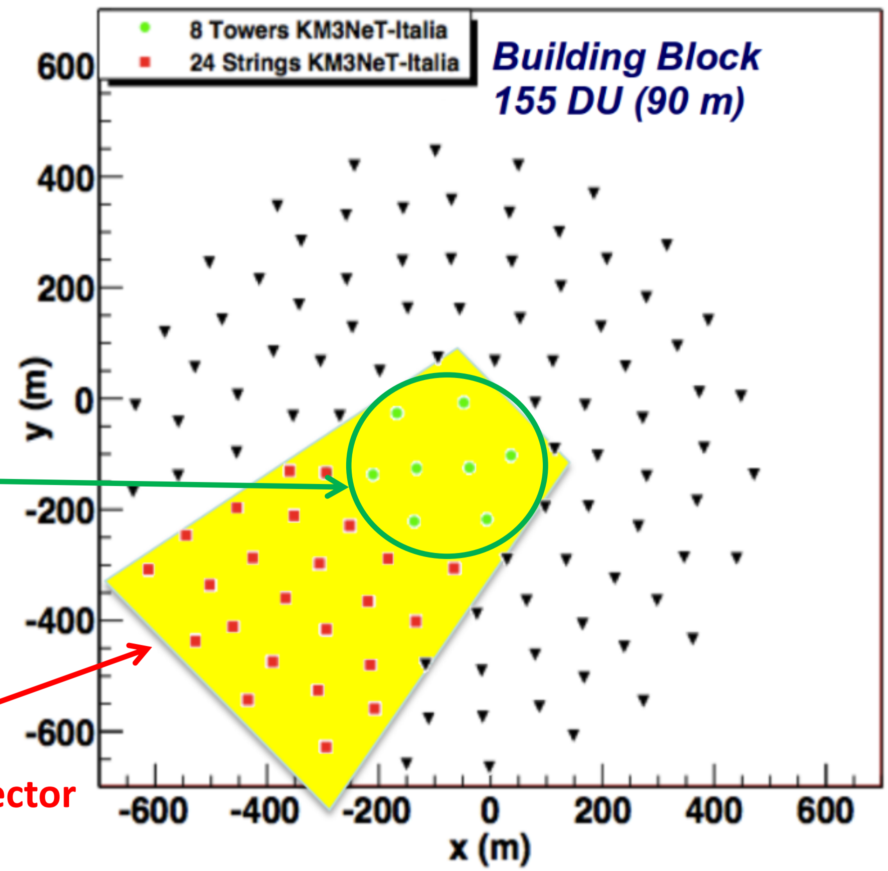
KM3NeT-Italia plan:

- **8 Detection Units in 2014**
- **24 Detection Units in 2016**
- **A full Building Block before 2020**

Capo Passero site (3500 m depth)



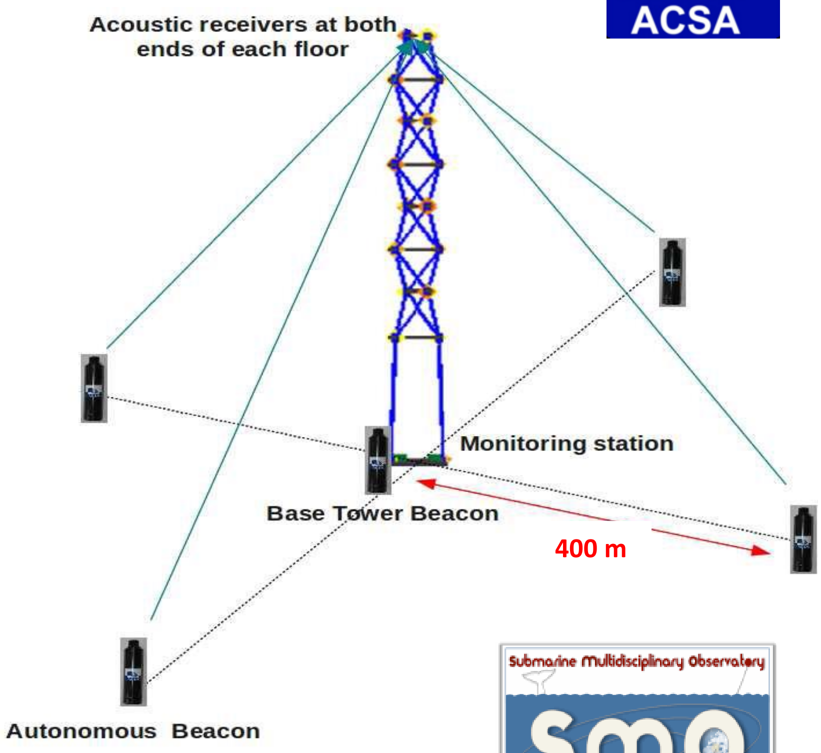
First stage
(8 towers)



KM3NeT-IT Phase-I detector

The NEMO–SMO experience

The acoustic positioning system for the 8 towers of KM3NeT-Italia detector will be based on the positioning system developed by NEMO-SMO teams in collaboration with ACSA for NEMO Phase-2 prototype



NEMO – SMO positioning system design:

- 5 autonomous beacons (32 kHz – TSSC code)
- 2 acoustic sensors per floor
- Monitoring station

Time of Emission (ToE) of each beacon pulse, is obtained measuring the Time of Arrival (ToA) of this pulse at the hydrophones mounted on the base tower (monitoring station) that are anchored on the seafloor in known positions.

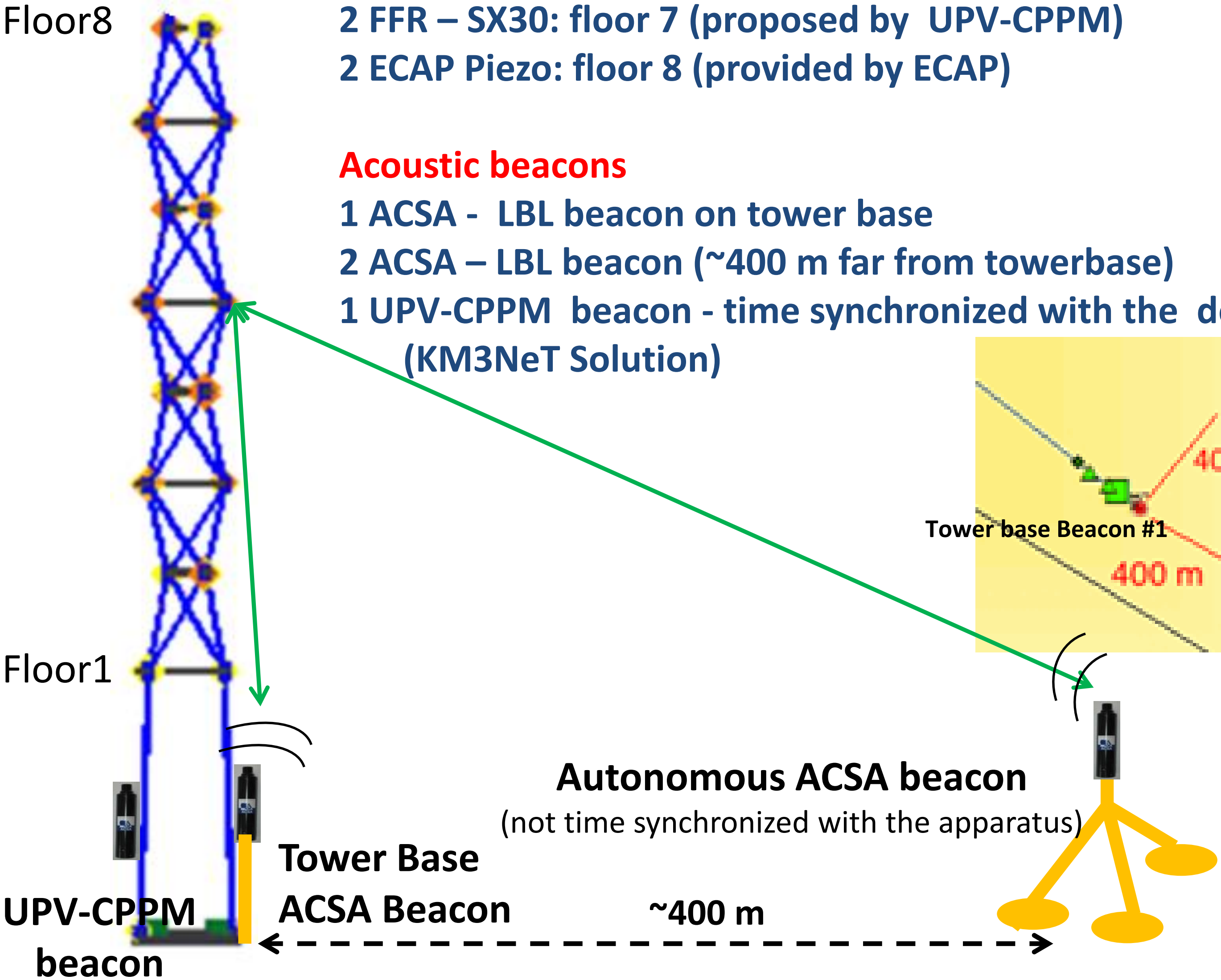
NEMO – SMO acoustic positioning system

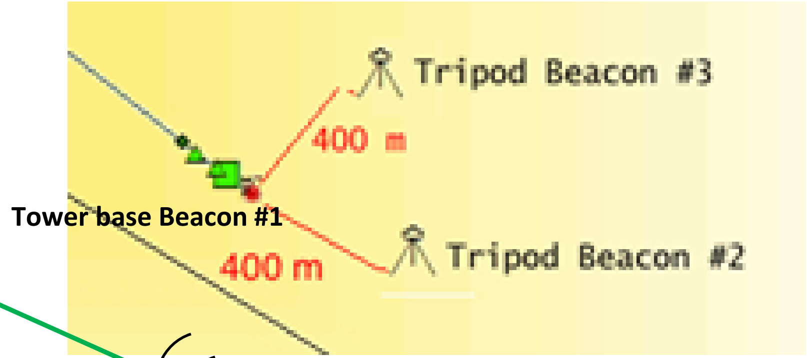
14 acoustic sensors

10 SMID hydrophones: floors 1, 2, 3, 4, 6 (no F0 monitoring station)
2 FFR – SX30: floor 7 (proposed by UPV-CPPM)
2 ECAP Piezo: floor 8 (provided by ECAP)

Acoustic beacons

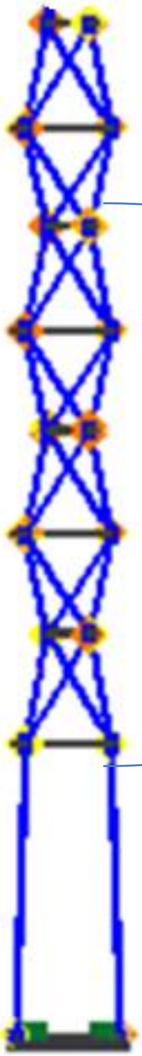
1 ACSA - LBL beacon on tower base
2 ACSA – LBL beacon (~400 m far from towerbase)
1 UPV-CPPM beacon - time synchronized with the detector Master Clock (KM3NeT Solution)

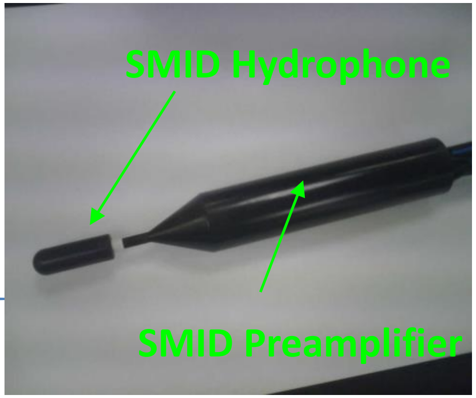


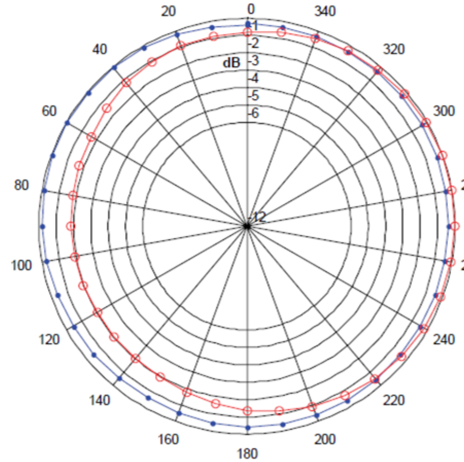


NEMO-SMO acoustic sensors

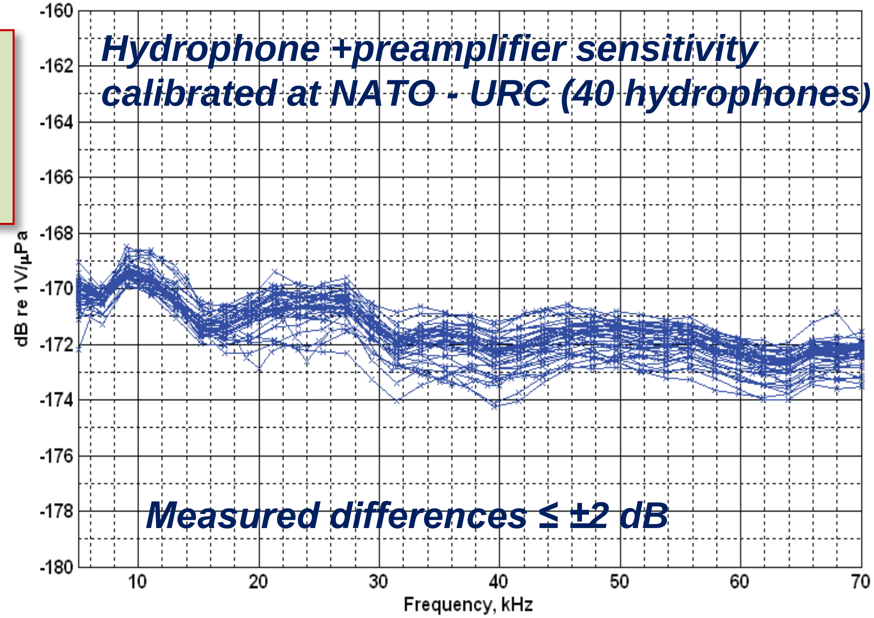
Floor #1 ÷Floor #6 +Tower-base
SMID Hydrophones
+ SMID preamplifiers (gain: +38 dB)

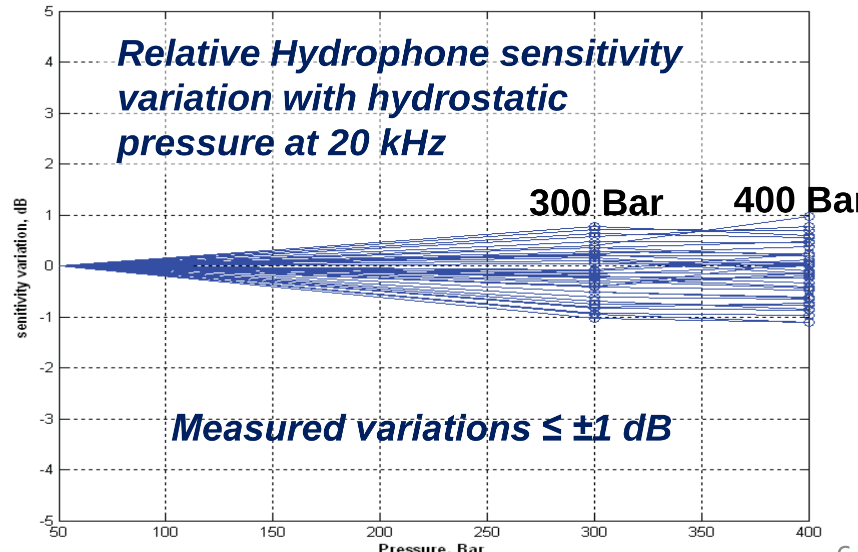




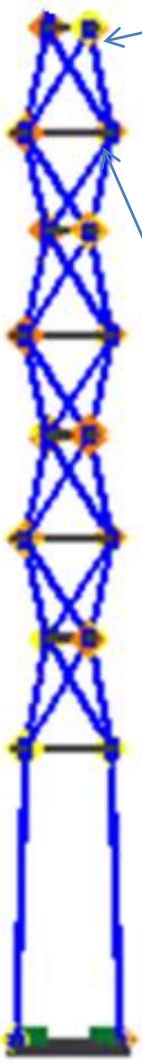


Radiation lobe
30 kHz
50 kHz

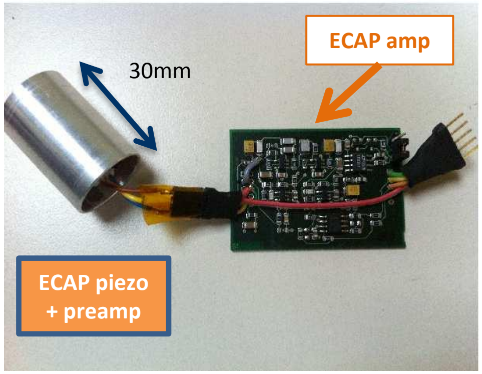


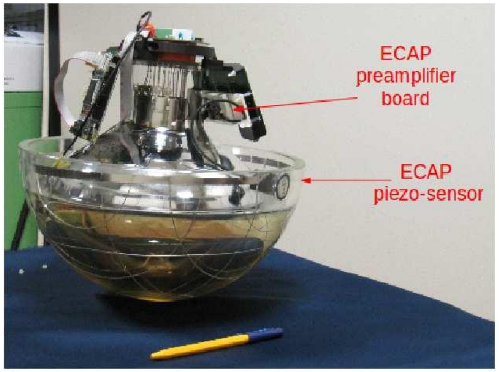


Additional acoustic sensors



Floor #8
ECAP Piezo sensors + ECAP preamplifiers





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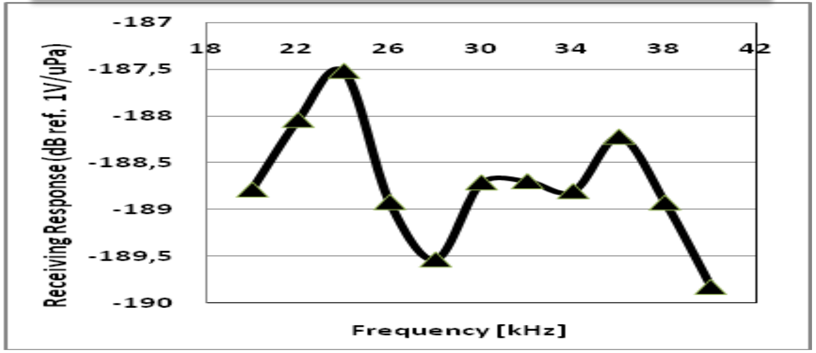
Floor #7
FFR (Free Flooded Rings) Hydrophones + SMID preamplifiers (gain :+38 dB)

Sensor Technology STD FFR - SX30

Receiving Response of the System



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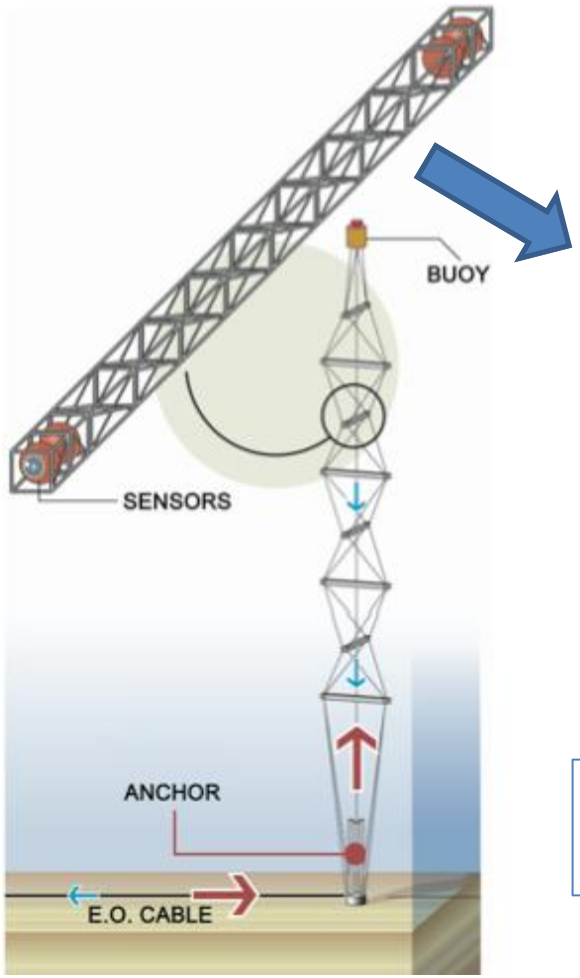
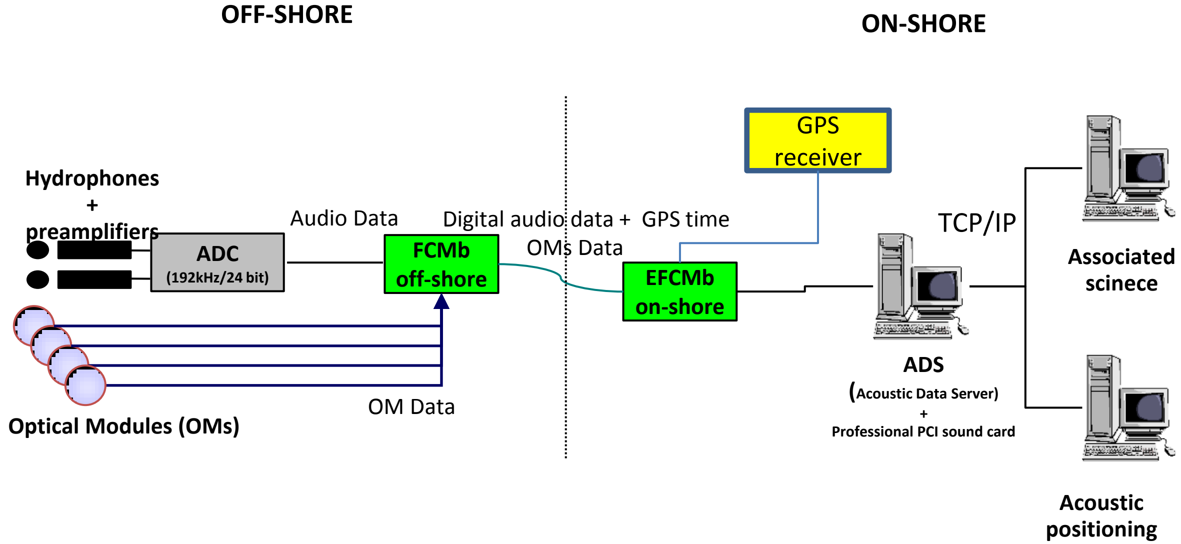
IGIC Instituto de investigación para la gestión integrada de zonas costeras

NEMO-SMO data acquisition chain

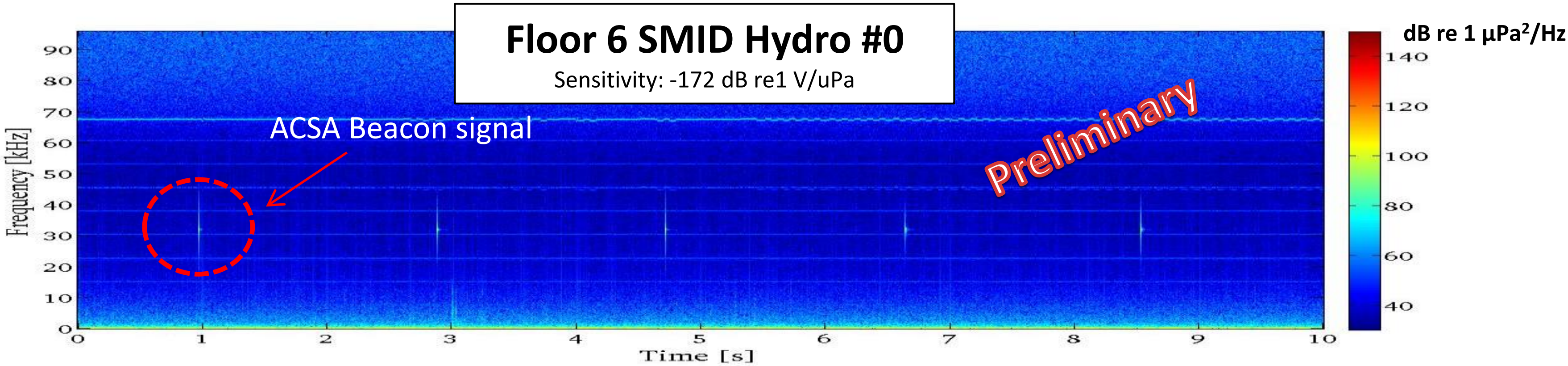
Raw data are continuously acquired underwater at 24 bit/192kHz by the acoustic sensors and transmitted to shore in AES/EBU protocol on a local internet network at the shore station

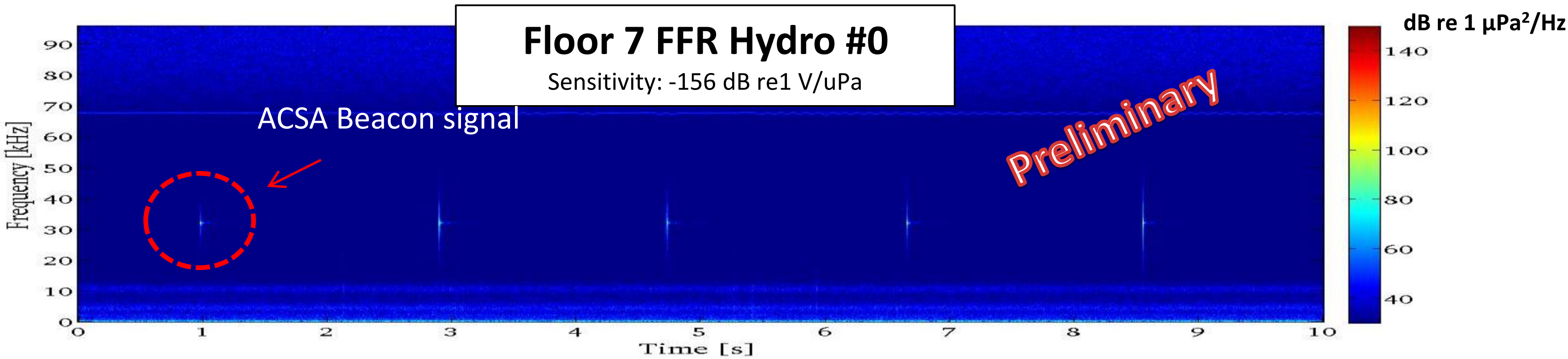


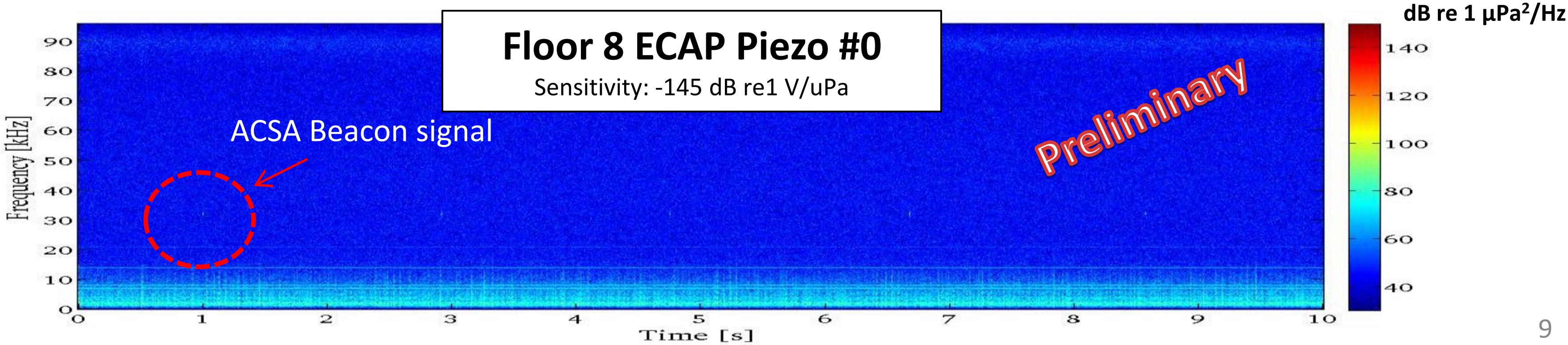


The acoustic signals are sampled by ADC and "labeled" with absolute GPS time

NEMO-SMO: sensors performances 1/2



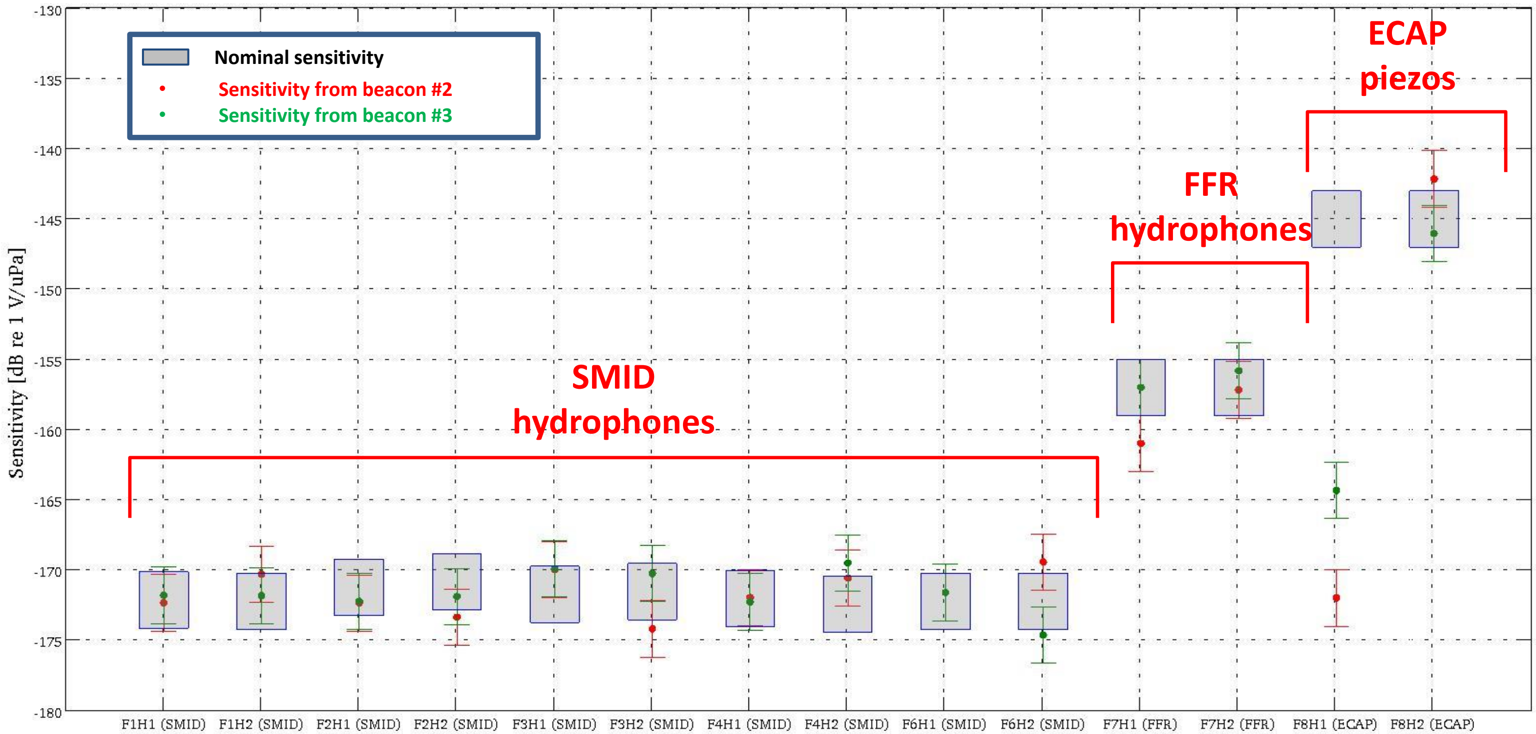




NEMO-SMO: sensors performances 2/2

Acoustic signals from external beacons (about 400 m far from tower base) confirm the nominal sensitivity of SMID and FFR hydrophones. Some inconsistences have been found for ECAP piezos installed inside the Optical Acoustic Modules.

Sensitivity has been calculated taking into account the geometrical attenuation and absorption related to the ionic relaxation of $MgSO_4$ and $B(OH)_3$.



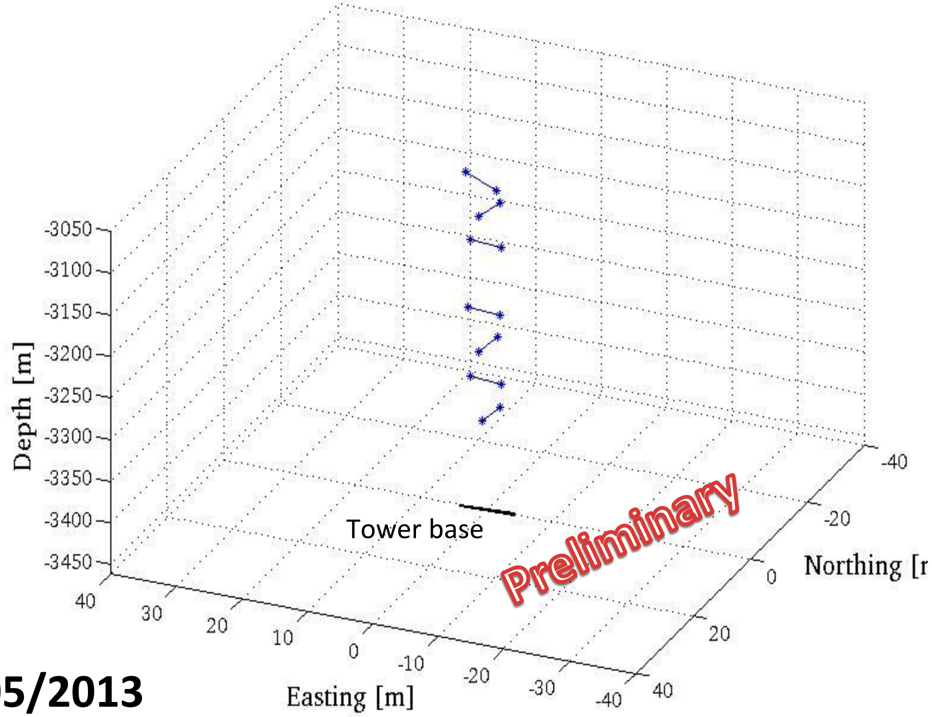
Acoustic positioning: first results

Hydrophones positioning script

Input:

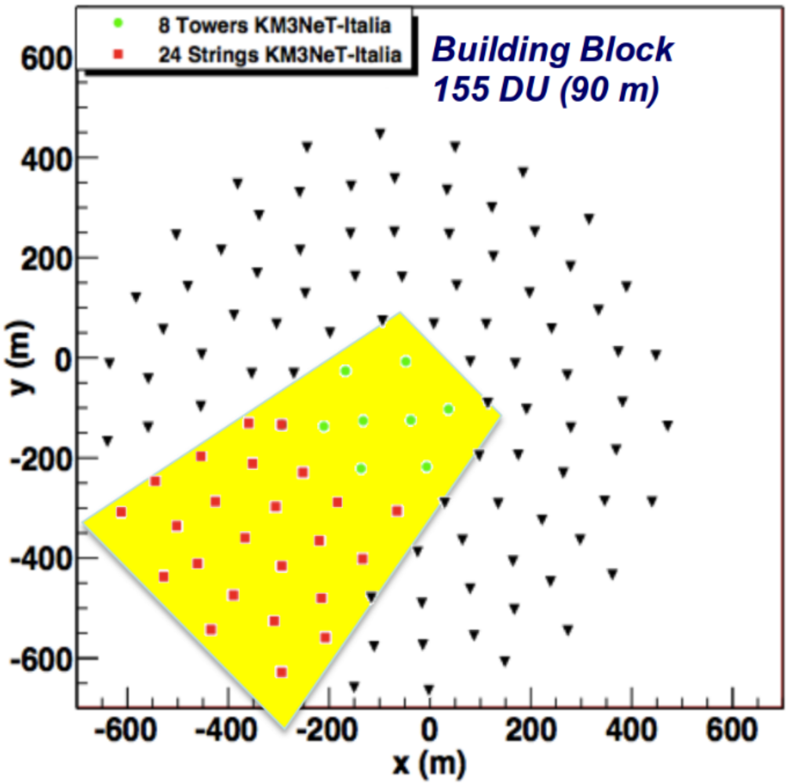
- **Beacons positions**
- **TOAs**
- **Distances between hydrophones in the same floor**
- **Sound velocity (CTDs data)**

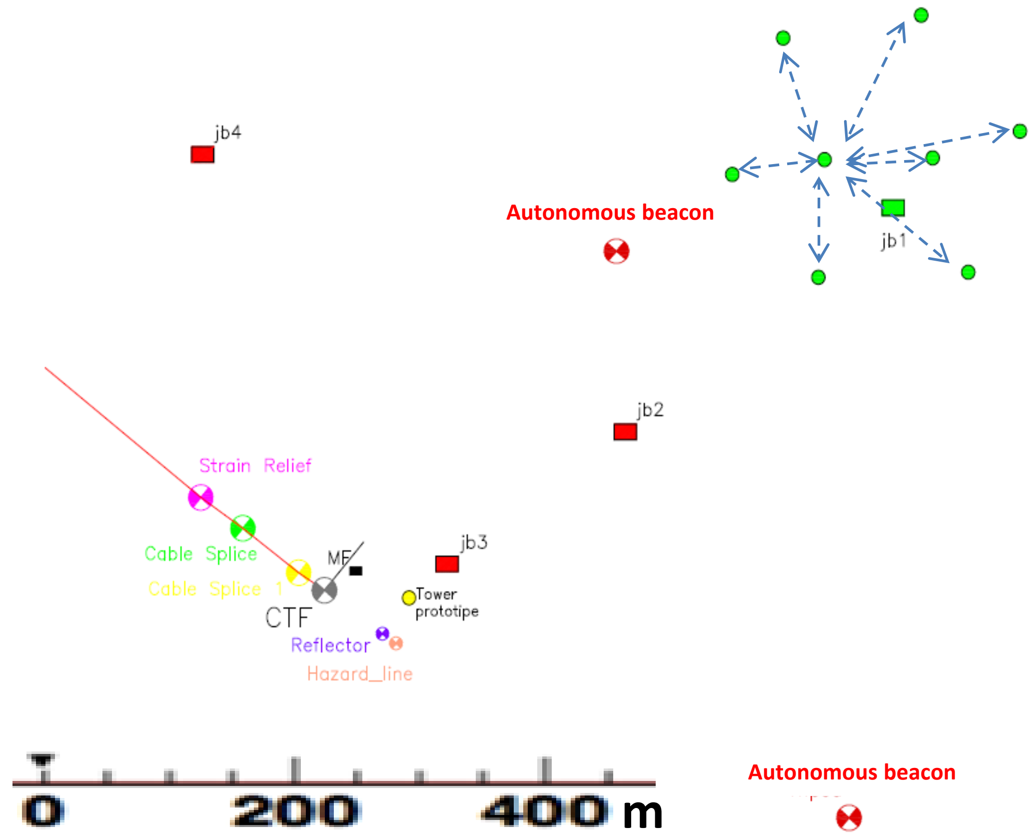
The code finds iteratively a root (zero) of a system of nonlinear equations.



07/05/2013
00:00 UTC

KM3NeT-Italia LBL layout





- **Beacons installed on each tower base close to hydrophones (autocalibrating LBL)**

- **Autonomous beacons : help to triangulate in the first stages of the installation**

- **Beacons on Junction boxes**

KM3NeT-Italia new approach

- **Auto-calibrating LBL (beacon + receiver)**
- **Timing:**
  - **Master Clock beacon**
  - **Time stamped receiver**
- **Programmable acoustic emission signal (frequency, amplitude and waveform) through RS-232 link**
- **FCM emission trigger signal reception (LVDS link)**
- **Max emission level 190 dB re 1 µPa @ 1 m**
- **Acoustic beacons equipped with pressure gauge**

KM3NeT-Italia: acoustic sensors

In KM3NeT-Italia "Digital Hydrophones (DH)" solution will be employed
Preamplifier, ADC and DIT on board, molded in the cable connecting the hydrophone to the FCM

- **Bandwidth:** 100 Hz- 70 kHz
- **Frequency sampling:** 192 kHz
- **Resolution:** 24 bit
- **Communication with FCM:** AES/EBU standard

2 types of hydrophones

High Sensitivity Digital Hydrophones (HS-DH)
Sensitivity: -190 dB re 1 V/µPa w/o preamplifier
Floors: 13,14 (2 x HS-DH) /floor

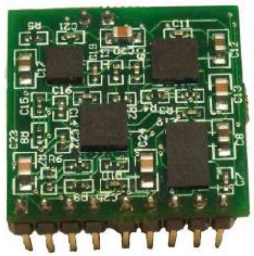
Low Sensitivity Digital Hydrophones (LS-DH)
Sensitivity: -200 dB re 1 V/µPa w/o preamplifier
Foors: 1÷12 (2 x LS-DH) /floor & tower base (1 x LS-DH)

Auxiliary devices: Altitude Heading Reference System

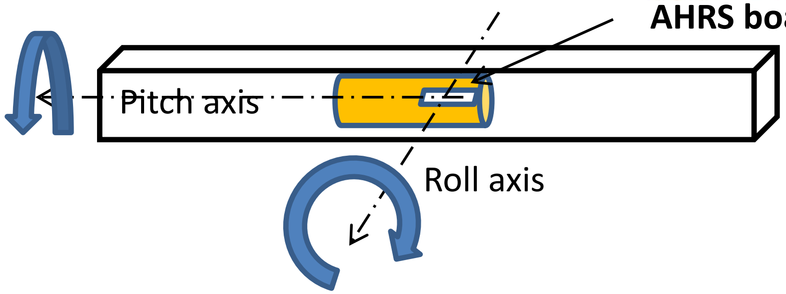
The real time monitoring of yaw, pitch and roll of each floor is provided by an Attitude Heading Reference System (AHRS) board, developed by INFN, placed inside each FCM vessel.

- **Perform measurements of absolute orientation of the FCM vessel**
- **Provide information on the acceleration (during opening and during operation) of the floor**

It consists of MEMS gyroscopes, accelerometers and magnetometers on all three axes. The yaw, pitch and roll are calculated by means of a 9th order extended Kalman filter with a dynamic angular resolution of 0.01°.



AHRS board



Conclusions

- NEMO-SMO acoustic array fully functional since deployment

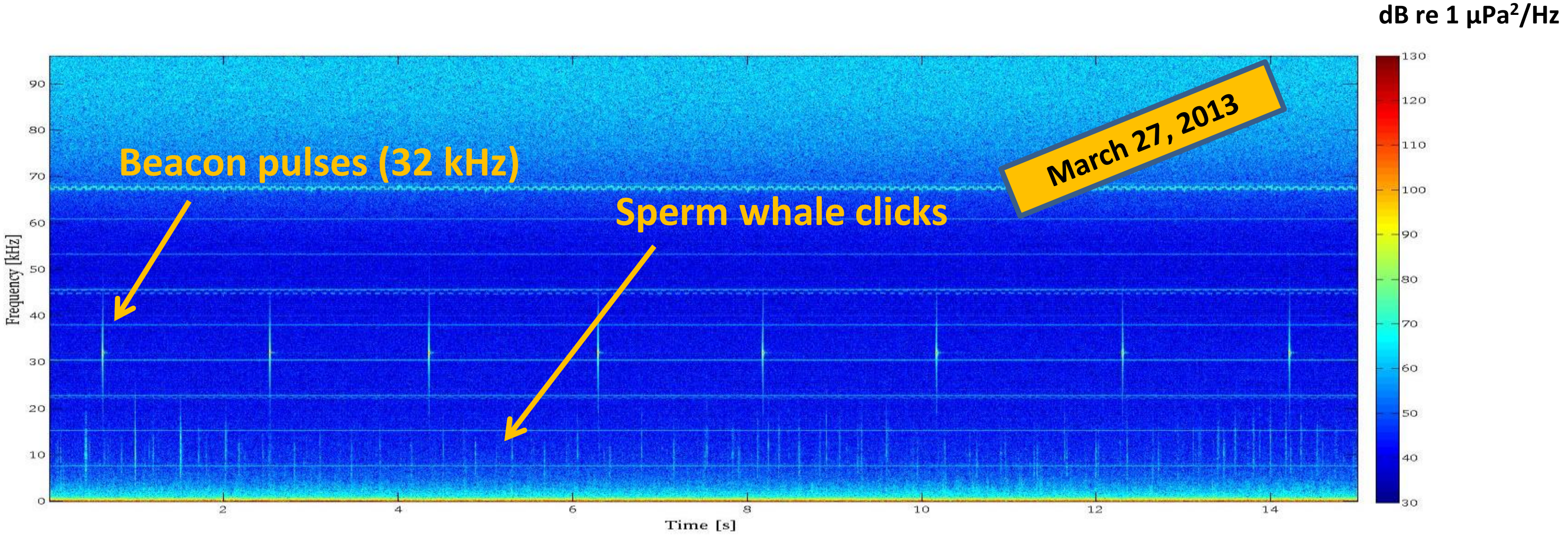
- All hydrophones working with the expected performances

- Acoustic beacon's signals can be easily disentangled from the underwater background acoustic noise.

- Positioning code ready

Multidisciplinary approach successful

- Automatic codes for acoustic sperm whale detection and evaluation of their size
- First sperm whale detection after 3 days of data acquisition



Perspectives

- Digital hydrophones to improve S/N ratio and detector integration

- Autocalibrating LBL

- The largest acoustic array in the Mediterranean Sea

- Acoustic correlations with data from EMSO cabled acoustic arrays in Catania site (2000 m depth)

HIGH ENERGY PHYSICS PERSPECTIVES

Long term and real-time monitoring of high frequency acoustic background at different depths.

Input for simulations of large scale acoustic detector in Capo Passero Site

- ***Test of sensors and electronics for a future deep sea acoustic neutrino detector***
- ***Test of DSP techniques to improve acoustic signal detection***
- ***Detection of neutrino-like signals produced by calibrated sources***

Thank you for your attention

BACKUP

Auxiliary devices : sound velocity measurement

Standard oceanographic sensors will be displaced the towers 2001- 2002- 2003 on-board tower base and dedicated instrumented floors.

TOWER 2001	TOWER 2002	TOWER 2003
Floor 14 → CTD (CTDs Microcat SBE 37)	**Floor 14 → DCS** (Aanderaa Zpulse 4520-DW)	**Floor 14 → Sound Velocimeter** (miniSVS Valeport)
Floor 7 → DCS (Aanderaa Zpulse 4520-DW)	**Floor 7 → CTD** (CTDs Microcat SBE 37)	**Floor 7 → Oxigen Sensor** (AanderaOptode 4831-DW)
Floor 1 → CTD (CTDs Microcat SBE 37)	**Floor 1 → DCS** (Aanderaa Zpulse 4520-DW)	**Floor 1 → Sound Velocimeter** (miniSVS Valeport)
TB →Pressure gauge (Paroscientific 8BT4000-I)	**TB →Pressure gauge** (Paroscientific 8BT4000-I)	**TB →Pressure gauge** (Paroscientific 8BT4000-I)

This allows sufficient vertical sampling of the water column for calibration and oceanographic purposes