ACOUSTIC PARAMETRIC TECHNIQUES FOR NEUTRINO TELESCOPE

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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

CAMPUS DE GANDIA

CONTENTS

1) **REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY**
   1.1 ACOUSTIC SIGNATURE OF NEUTRINO
   1.2 PARAMETRIC EFFECT
   1.3 STATE OF THE ART
   1.4 DESIGN & DEVELOPMENT AN ARRAY
   1.5 FUTURE STEPS

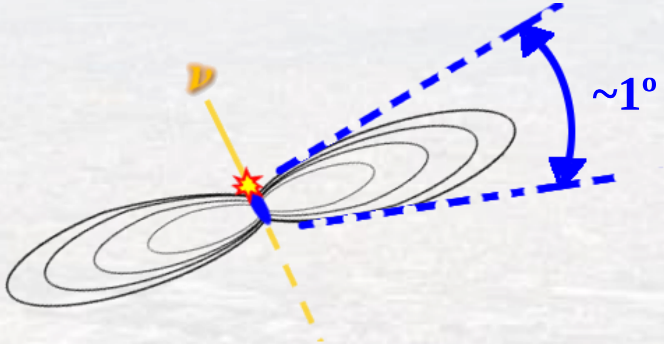
2) **CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NeT WITH PARAMETRIC TECHNIQUE**
   2.1 CALIBRATION OF KM3NeT-DOM ACOUSTIC SENSOR
   2.2 EXPERIMENTAL SETUP
   2.3 RESULTS IN A TANK
   2.4 EXPECTATIVES IN A SMALL POOL
   2.5 FUTURE STEPS
   2.6 COMUNICATION APPLICATION

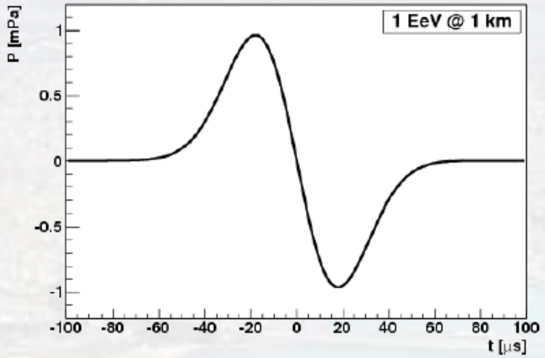
3) **CONCLUSIONS**

1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

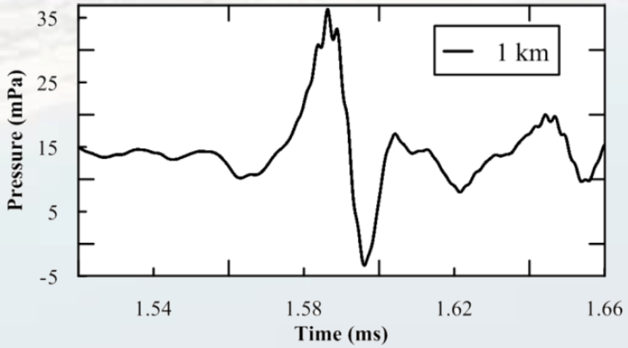
1.1 ACOUSTIC SIGNATURE OF NEUTRINO

Askaryan, G. 1957. *"Hydrodynamical emission of tacks of ionising particles in stable liquids". Atomic Energy 3, p152.*





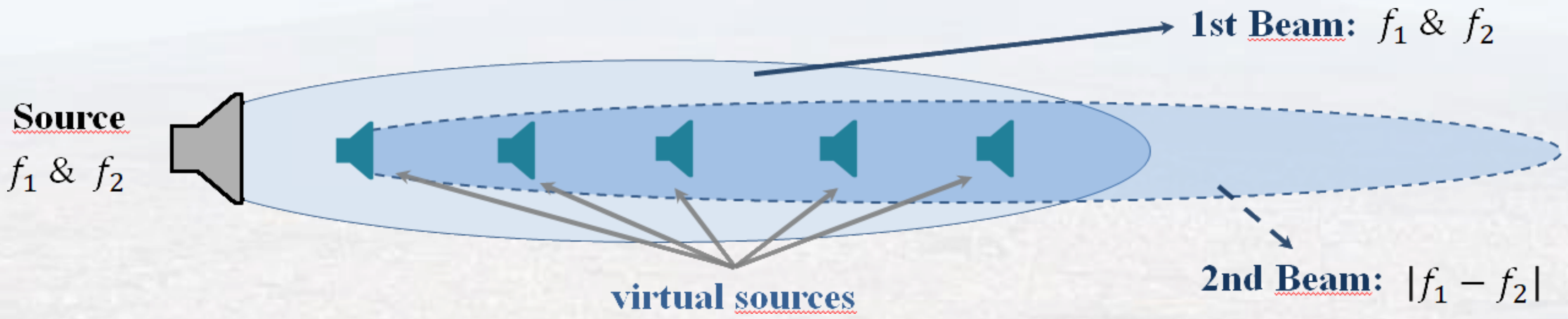
$f \cong [2{,}50]kHz$



Signal obtained by the propagation of the signal of the parametric array to 1 km distance.

1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

1.2 PARAMETRIC EFFECT



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

Therefore, the resulting wave $p(x,t)$ will be proportional to the second derivative of the square envelope of the emitted signal.

Moffet, M.B. and Mellen, R.H. . 1977. *“Model for parametric acoustic sources”. J. Acoust. Soc. Am., 61.*

1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

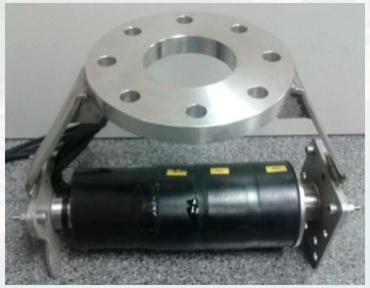
1.3 STATE OF THE ART

Previous works in acoustic calibration to detection of neutrino:

- **Linear array with 8 acoustic emissors (length: ∼8 m)** to generate bipolar pulse at 23 kHz [*Ooppakaev, W. Northumbria University*].

  ❖ Tested *in situ* in ANTARES: Signal no detected (poor signal or bad pointing to the detector)

- **Compact parametric array with 3 acoustic emissors (length: ∼40 cm**) [*Adrián, S. Universitat Politècnica de València*].



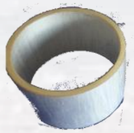
❖ Low effieciency of parametric generation
❖ Emmiters misaligned

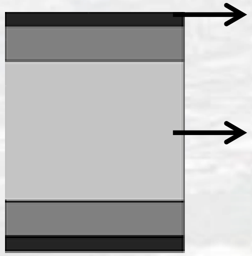
1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

1.4 DESIGN & DEVELOPMENT AN ARRAY

- Aim: Development a new compact calibrator to study the viability of neutrino acoustic detection in underwater detectors.

Emitter: <u>**UCE-534541**</u> piezo-ceramic



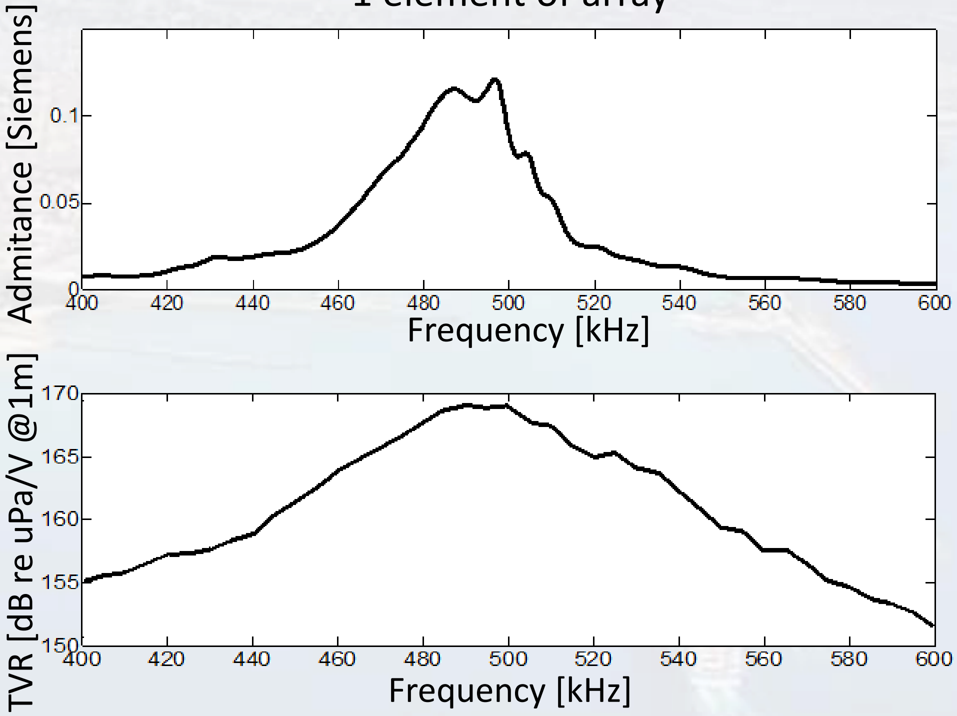


Matching: ***Polyurethane EL241F***

Backing: ***Aluminum***

f_r = 496 kHz

1 element of array



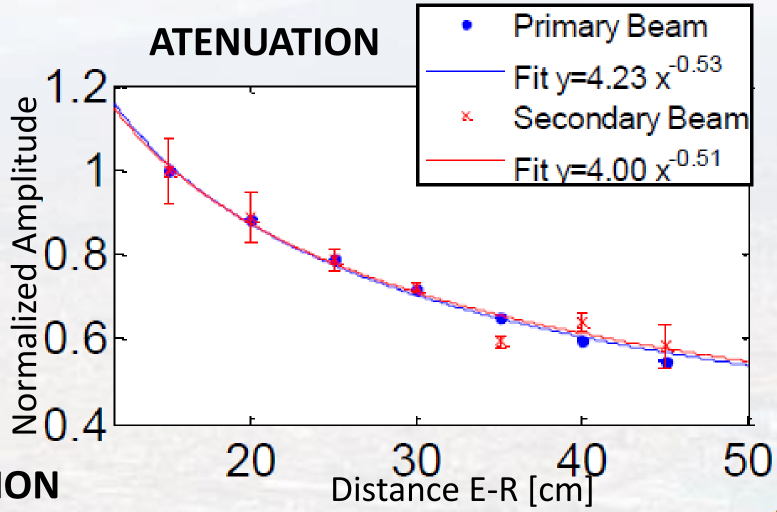
Saldaña, M. et al., *2016. "Transducer Development and Characterization for Underwater Acoustic Neutrino Detection Calibration". Sensors, 16 (8).*

1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

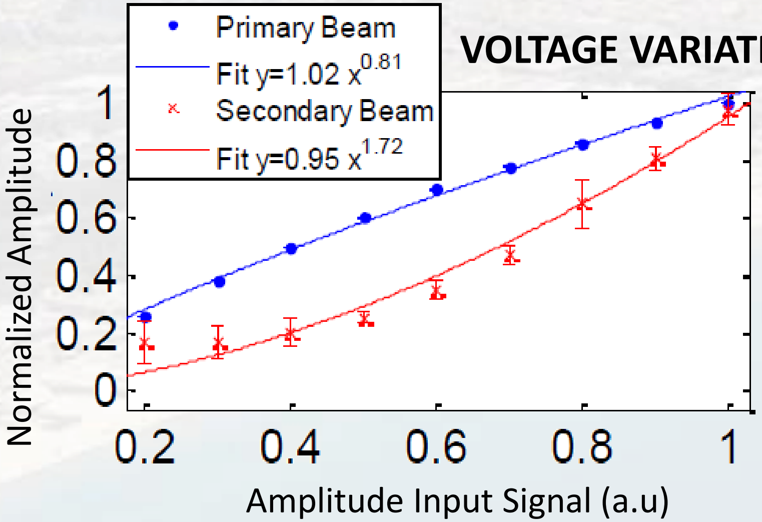
1.4 DESIGN & DEVELOPMENT AN ARRAY

1 element of array:
Characterization to parametric emission

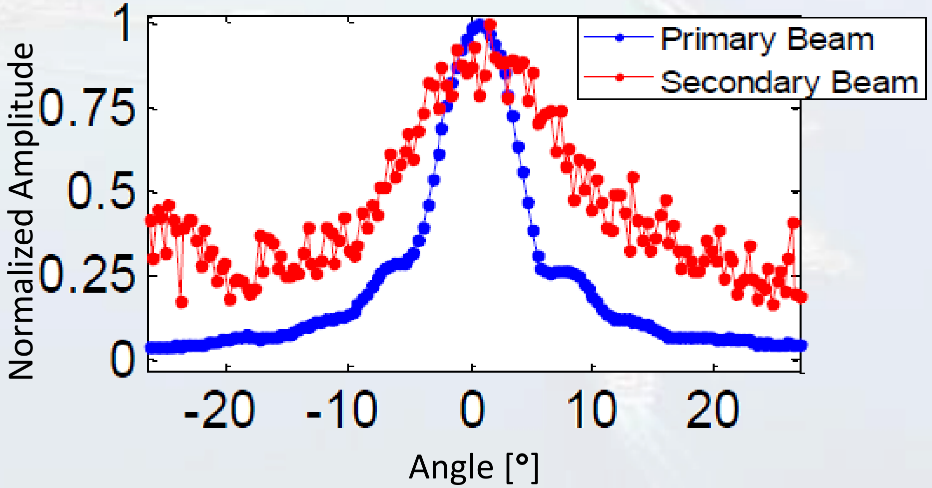
ATENUATION



VOLTAGE VARIATION



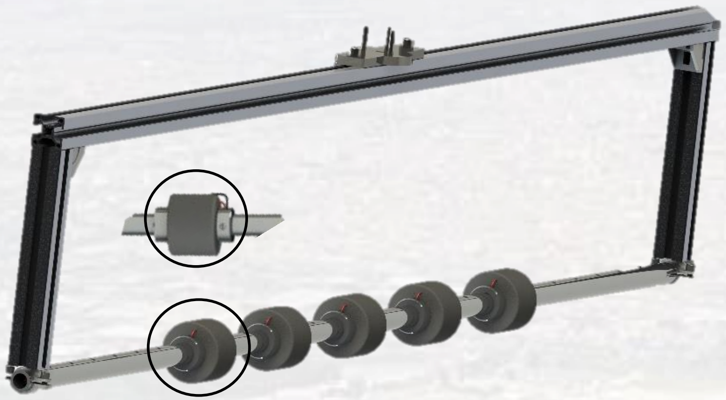
DIRECTIVITY

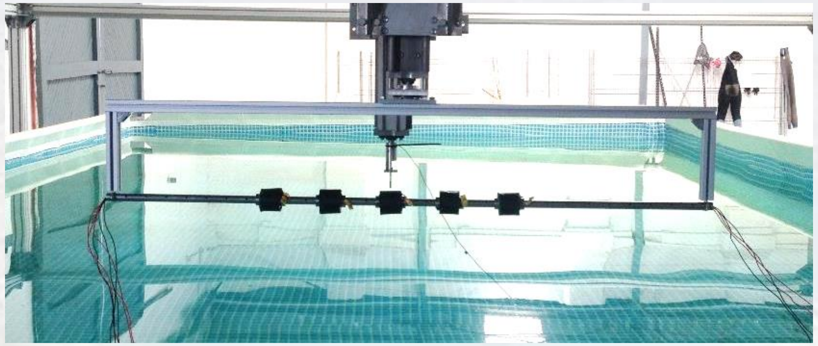


1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

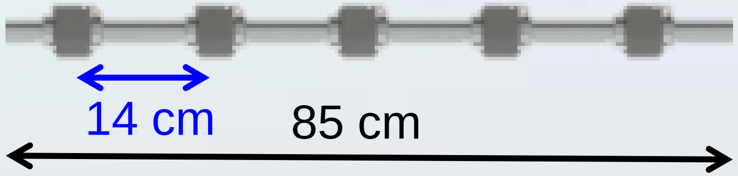
1.4 DESIGN & DEVELOPMENT AN ARRAY

Saldaña, M. et al. *2018. "Acoustic System Development for Neutrino Underwater Detectors". PhD thesis, Escola Politècnica Superior de Gandia (UPV).*



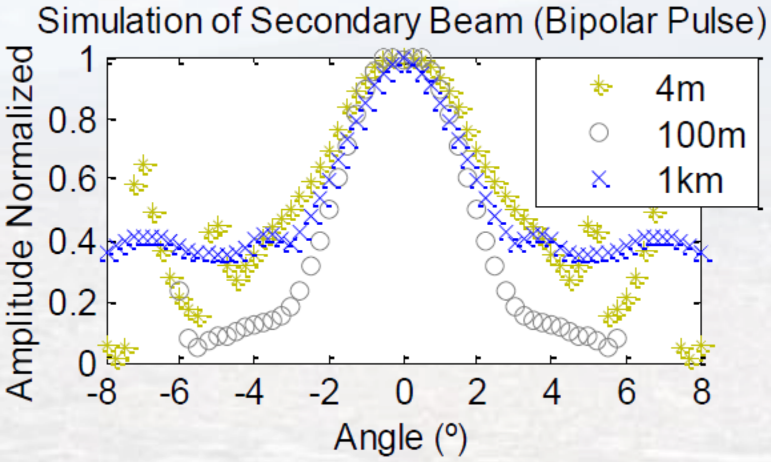


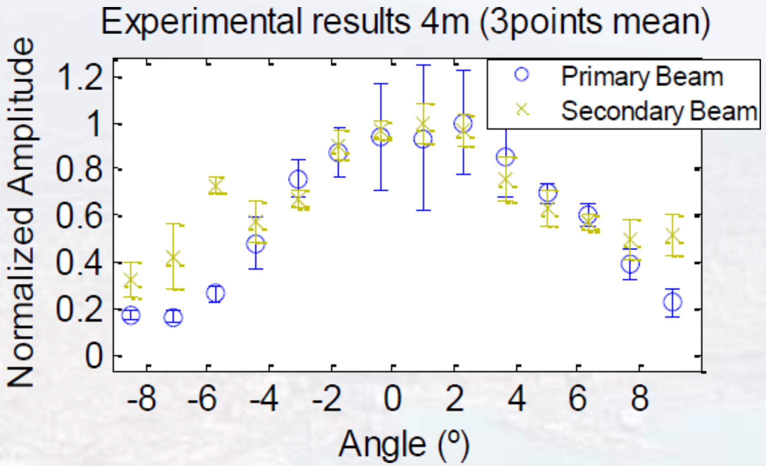
The studies reveal that the optimum separation between elements is among 10 and 15 cm to obtain the best acoustic neutrino signature (~1° opening).



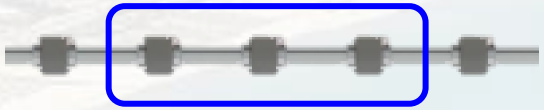
1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

1.4 DESIGN & DEVELOPMENT AN ARRAY

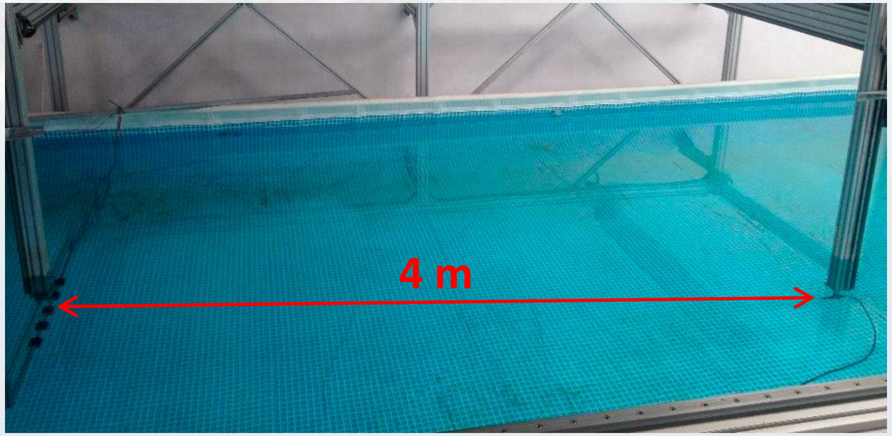




Directivity
to parametric emission

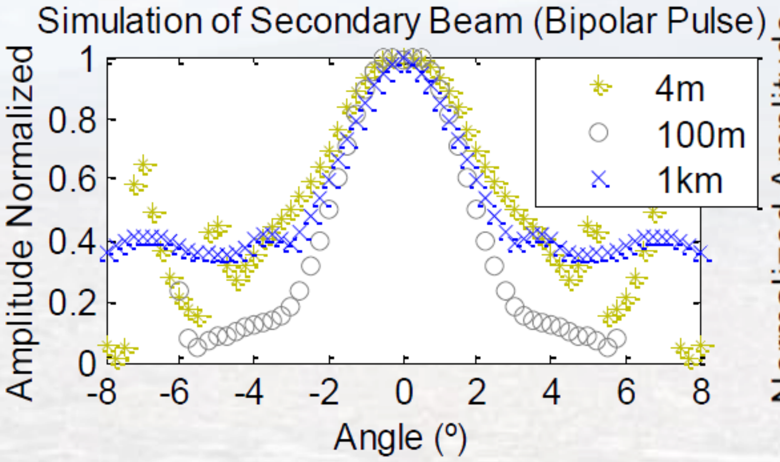


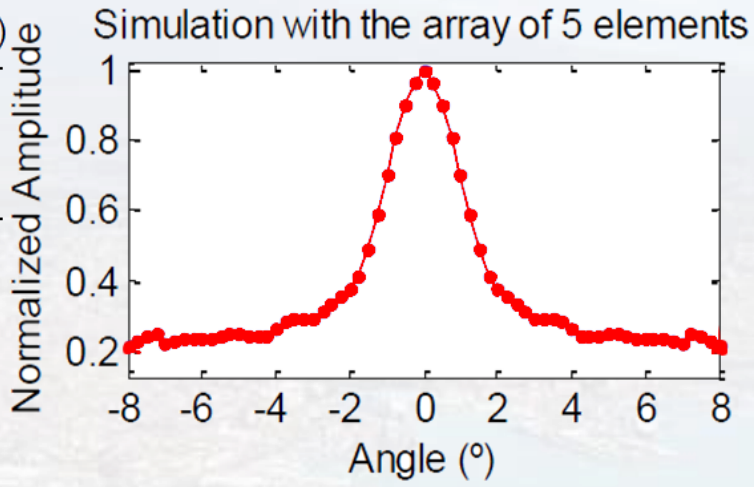
Array with 3 elements



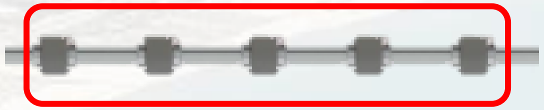
1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

1.4 DESIGN & DEVELOPMENT AN ARRAY

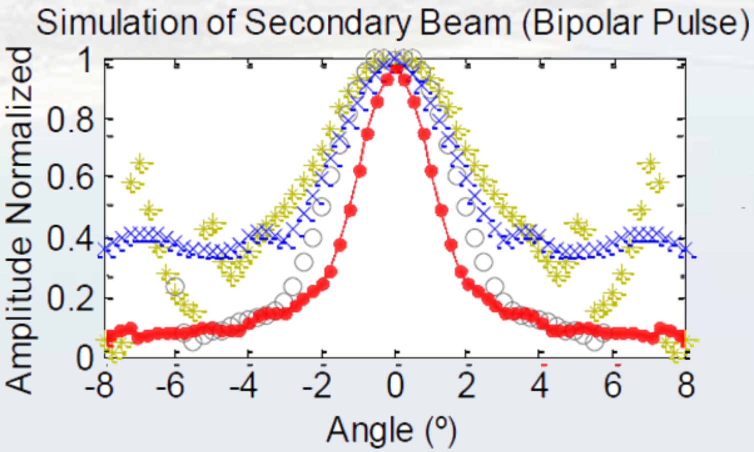


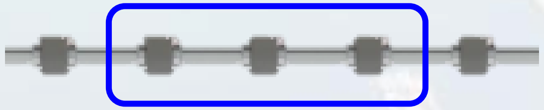


<u>Directivity to parametric emission</u>



Array with 5 elements





Array with 3 elements

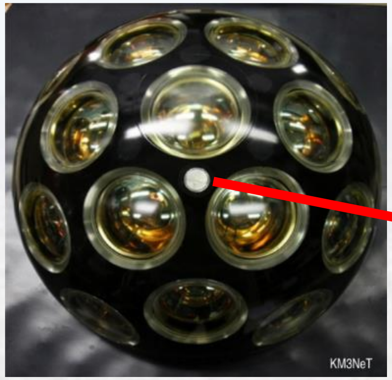
1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

1.5 FUTURE STEPS

- Study the optimum configuration to improve the array: number of elements, distance between elements, …
- Design and development of the electronics to give the needed power to each element of the array.
- Tests the array for long distances and *in situ*.

2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

2.1 CALIBRATION OF KM3NeT-DOM ACOUSTIC SENSOR



The South Pole of DOM

Piezo-ceramic sensor

To calibrate the piezo-ceramic sensors in DOMs of KM3NeT

- An anechoic tank
- A directive emitter in low frequencies

See presentation:

E.J.Buis et al. 2018. *"Characterization of the KM3NeT hydrophone". In ARENA2018*

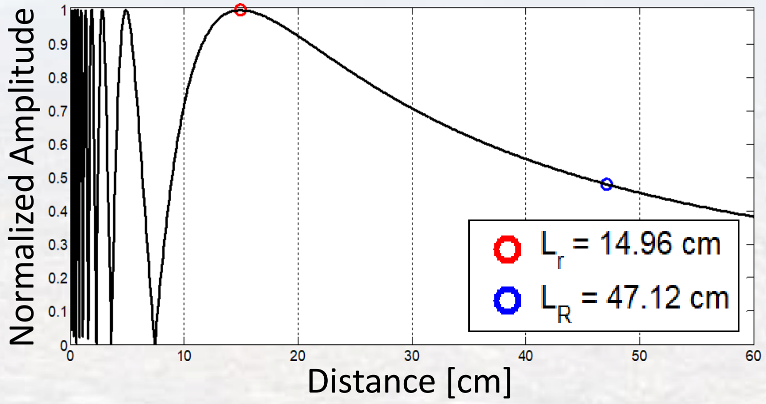
Using parametric effect

2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

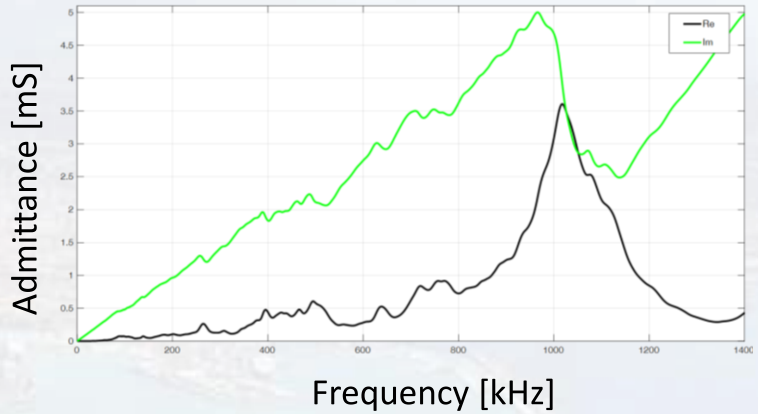
2.2 EXPERIMENTAL SETUP

RESON TC3027

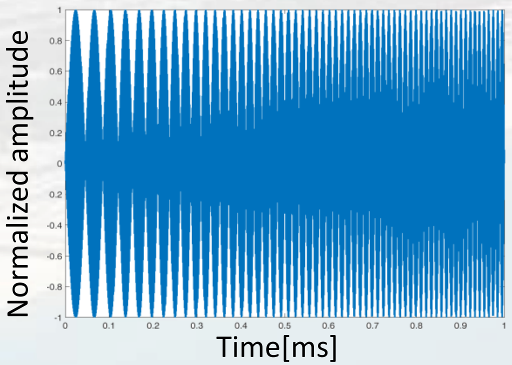
f_r = 1 MHz

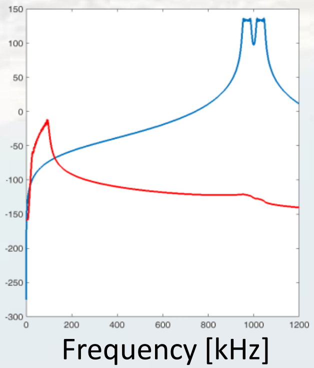


***Real* & *Imaginary* Adm.**

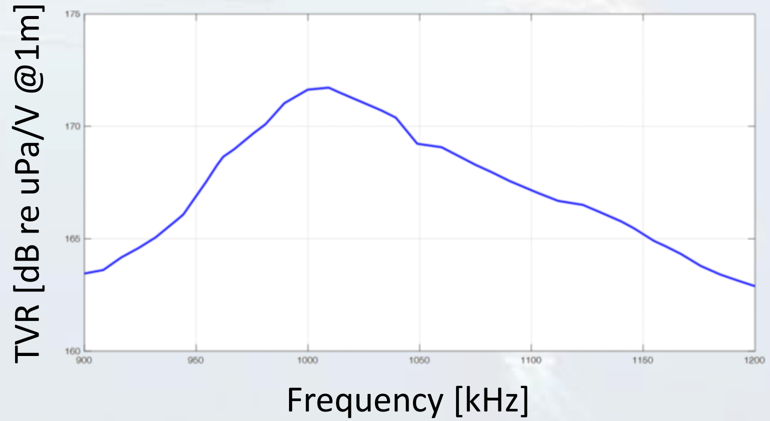


Signal emitted:



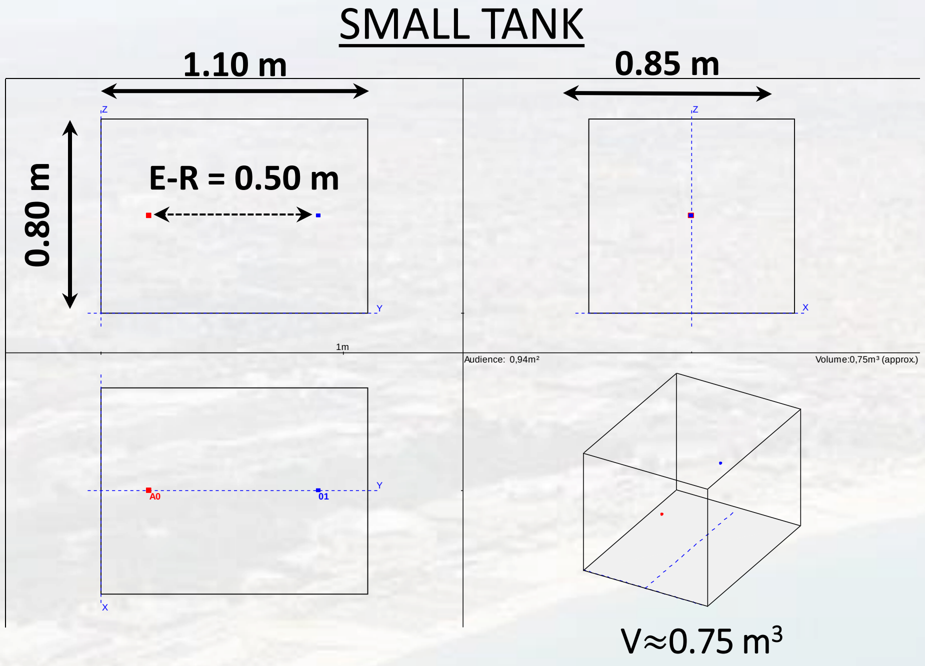


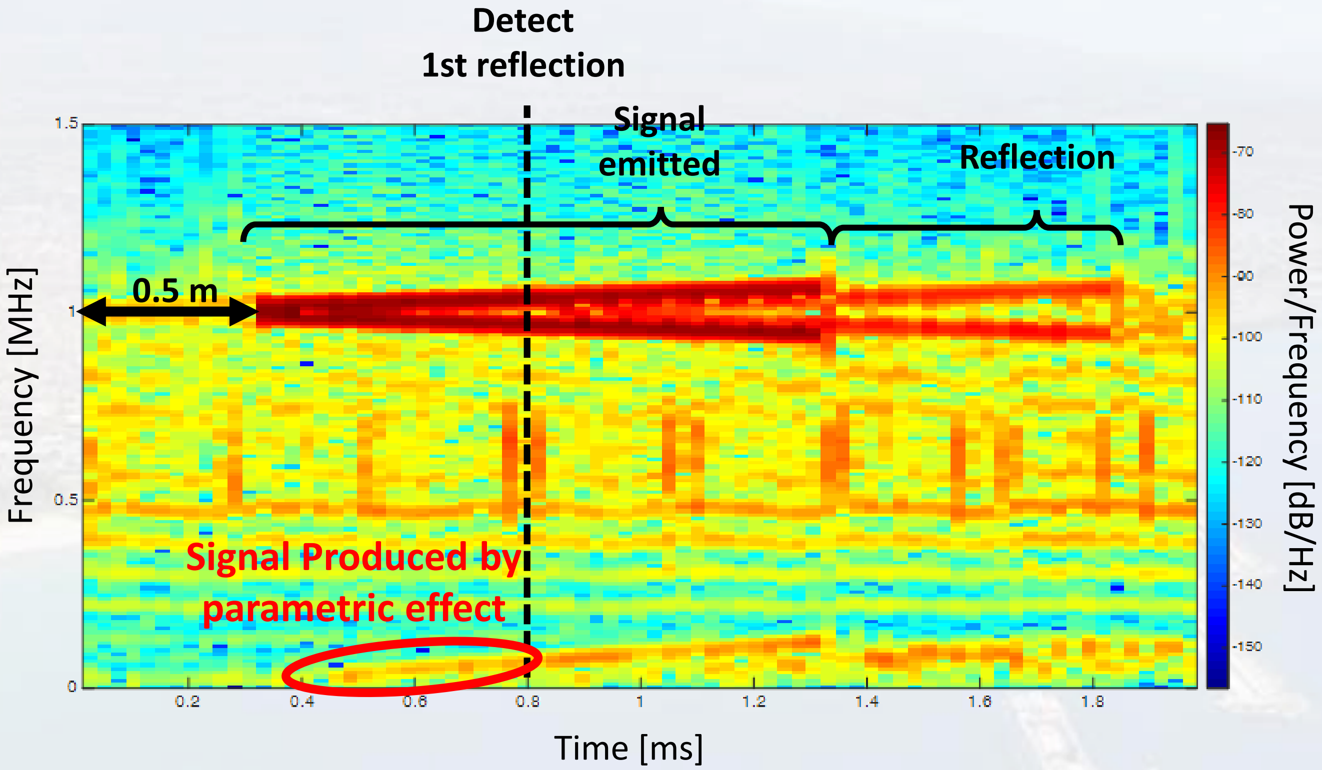
- f_c = 1 MHz
- *Sweep:*
  $f \in [10,50] kHz$
- *2nd beam:*
  $f_d \in [20,100] kHz$



2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

2.3 RESULTS IN A TANK



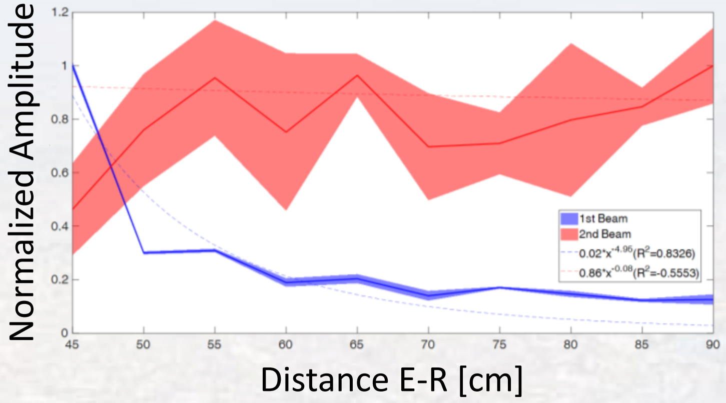


2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

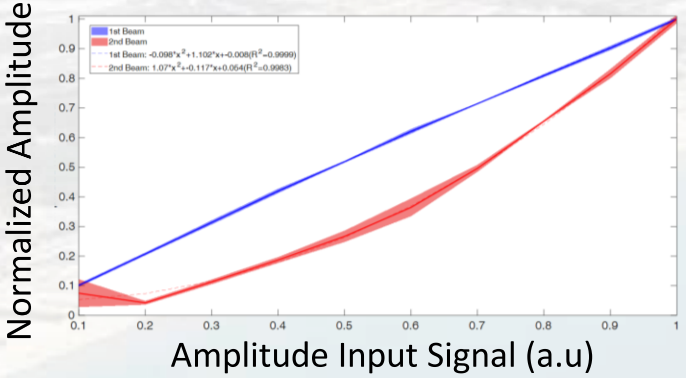
2.3 RESULTS IN A TANK

Characterization to parametric emission

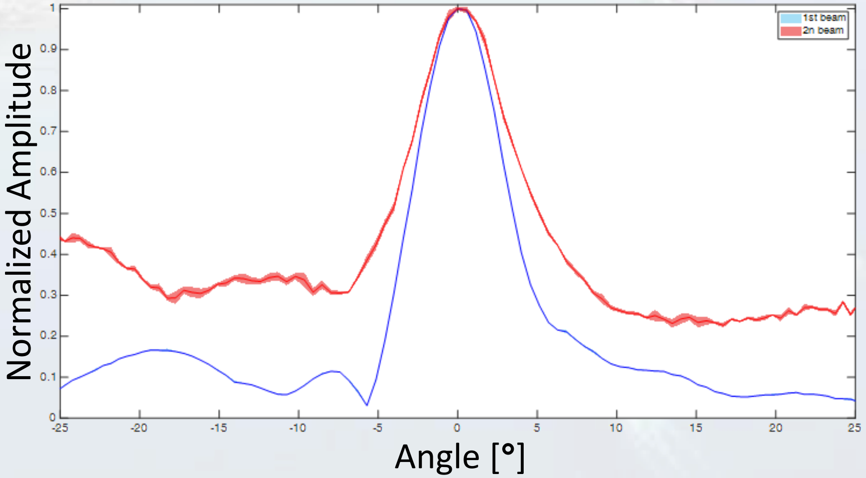
ATENUATION



VOLTAGE VARIATION



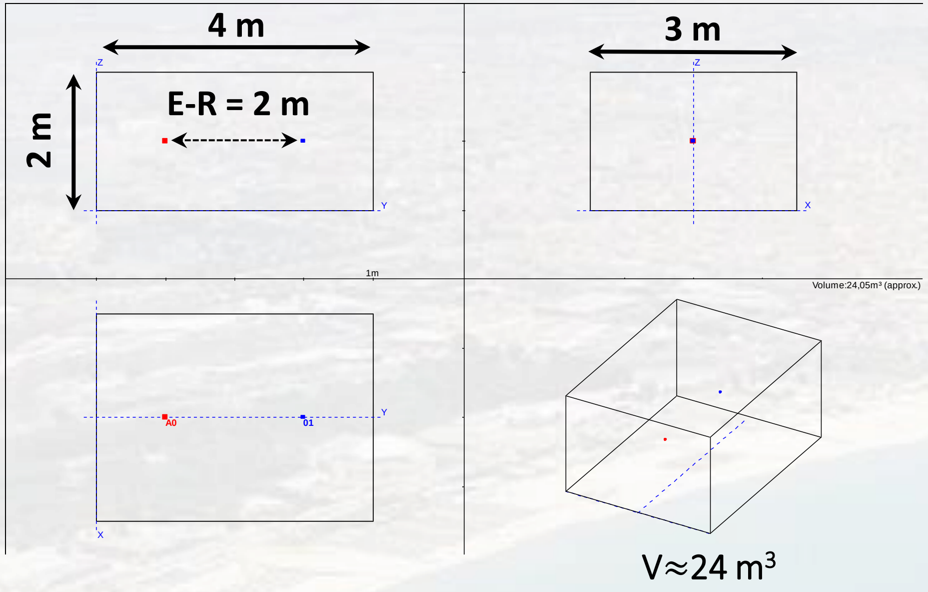
DIRECTIVITY



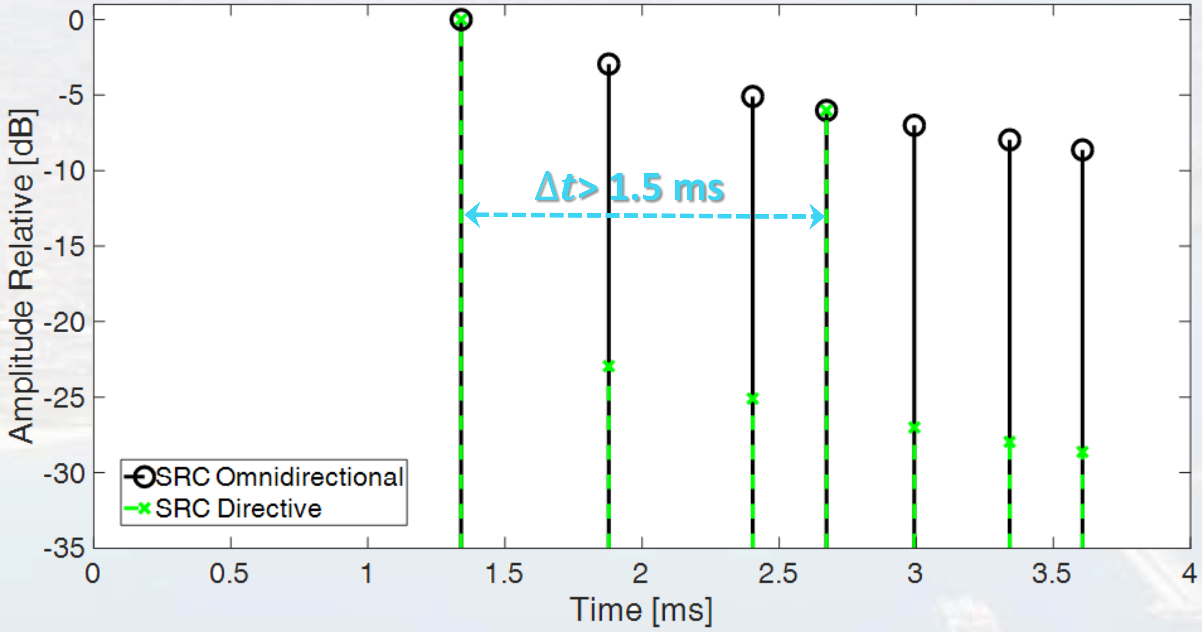
2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

2.4 EXPECTATIVES IN A SMALL POOL

SMALL POOL



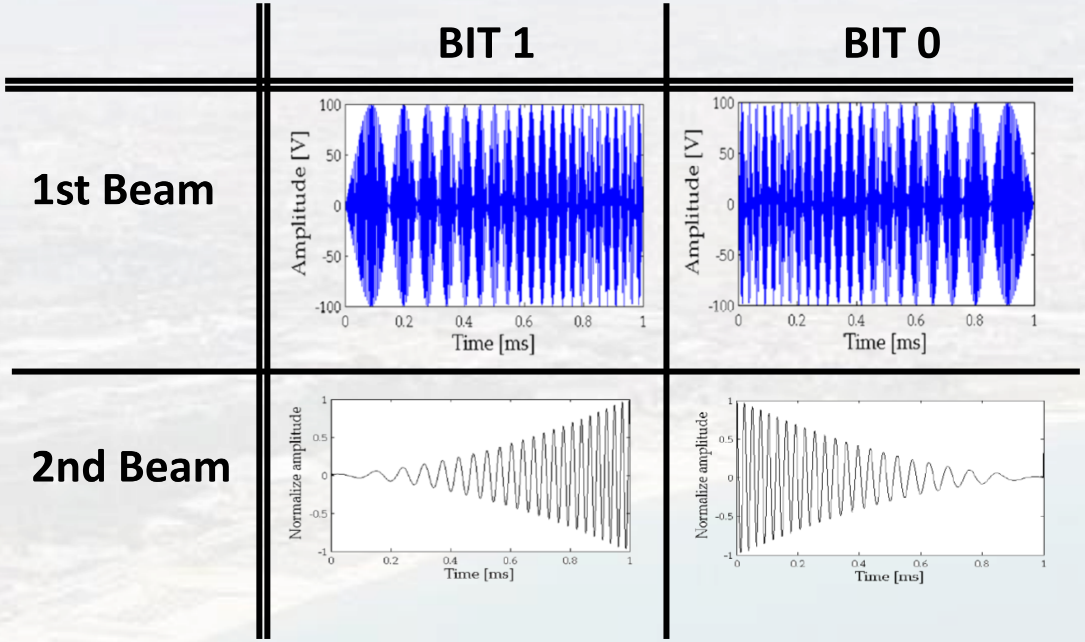
SMALL POOL REFLECTIONS



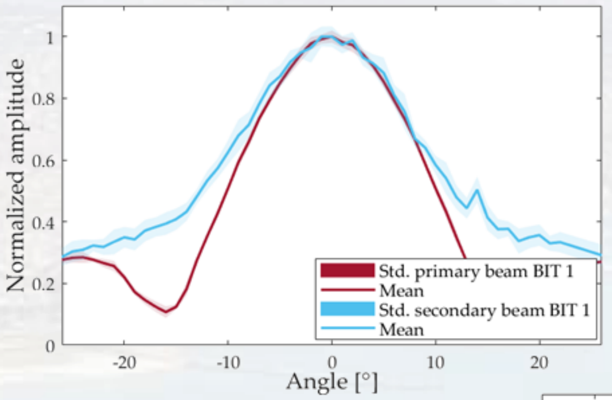
2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

2.6 COMUNICATION APPLICATION

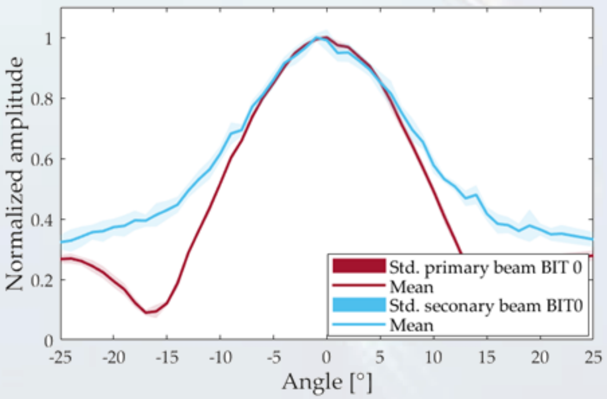
Campo-Valera, M. et al., *2017. “Underwater communication using acoustic parametric arrays” in 4th International Electronic Conference on Sensors and Applications. (1 - 6). Online: Sciforum.*



Directivity BIT 1



Directivity BIT 0



Message:	A	R	E	N	A
Binary (RFC 4648):	01000001	01010010	01000101	01001110	01000001

3) CONCLUSIONS

- The parametric emitted (signal bipolar) is validated using three elements in the array, and very similar signature to the one expected for the neutrino is obtained.
- The simulation of the array with 5 elements present a directivity in 3° Full Width Half Maximum (σ=1.3o).
- Alternative technique to calibrate the acoustic sensor of KM3NeT-DOM without anechoic environment is validated. The next step is to prove it.
- It is possible to apply the directive technique in underwater communication to specific receivers.

THANKS YOU FOR YOUR ATTENTION

e-mail: didieit@upv.es

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