# ACOUSTIC PARAMETRIC TECHNIQUES FOR NEUTRINO TELESCOPE

**Dídac D.Tortosa**
e-mail: didieit@upv.es
M. Ardid, M. Campo-Valera, C.D. Llorens,
J.A. Martínez-Mora, M. Saldaña


**ARENA 2018**
**Laboratori Nazionali del Sud – INFN**
**Catania, 12th – 15th June 2018**



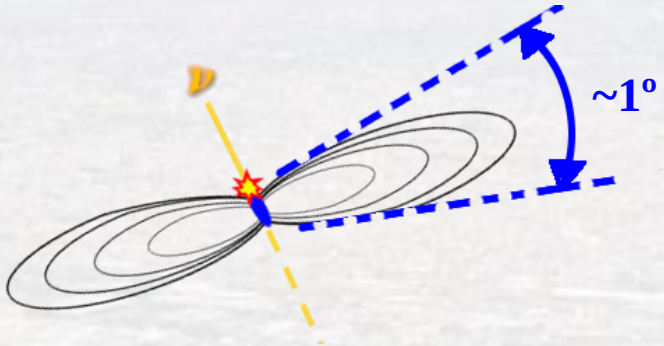
UNIVERSITAT POLITÈCNICA DE VALÈNCIA
CAMPUS DE GANDIA

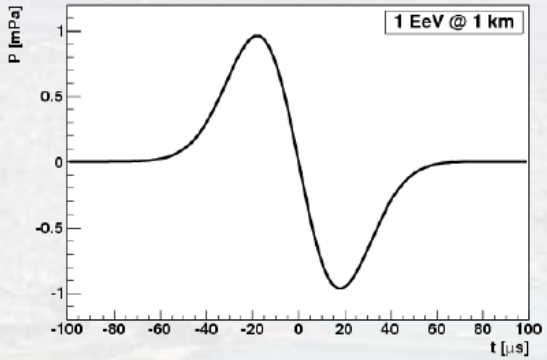
# CONTENTS

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

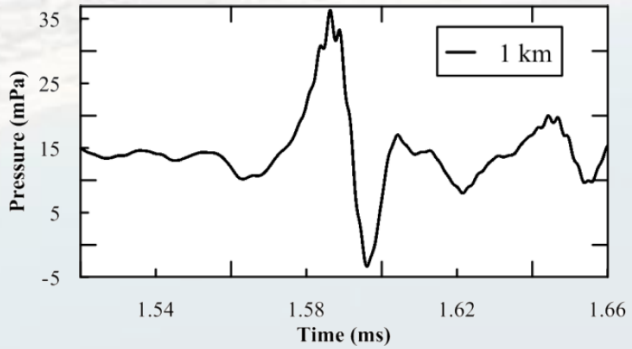
## 1.1 ACOUSTIC SIGNATURE OF NEUTRINO

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



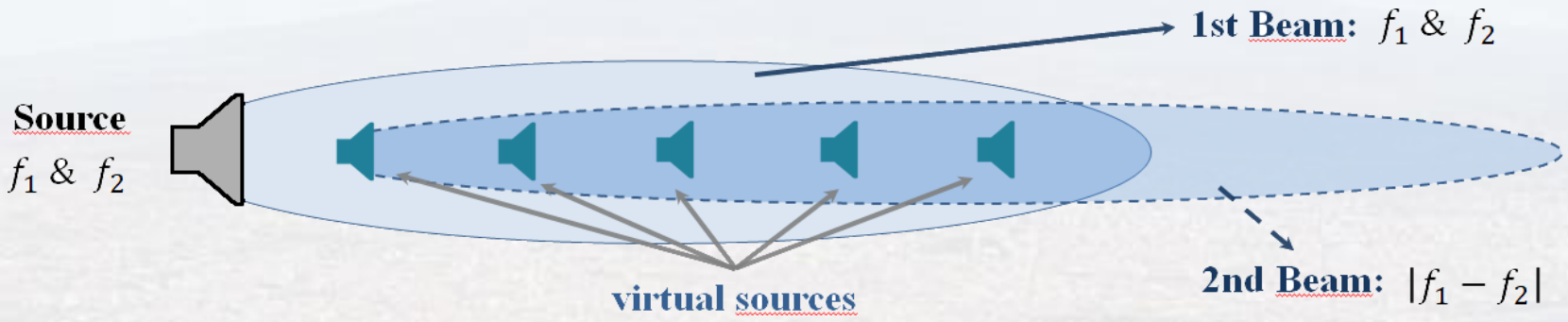

$f \cong [2{,}50]kHz$




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

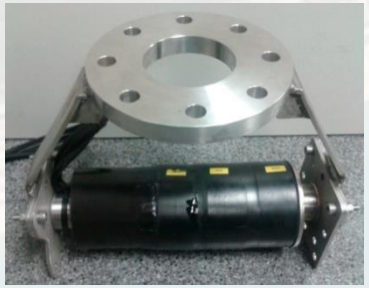
## 1.3 STATE OF THE ART

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*].



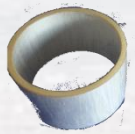
❖ Low effieciency of parametric generation
❖ Emmiters misaligned

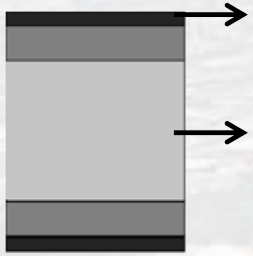
# 1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

## 1.4 DESIGN & DEVELOPMENT AN ARRAY

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

Emitter: **UCE-534541** piezo-ceramic



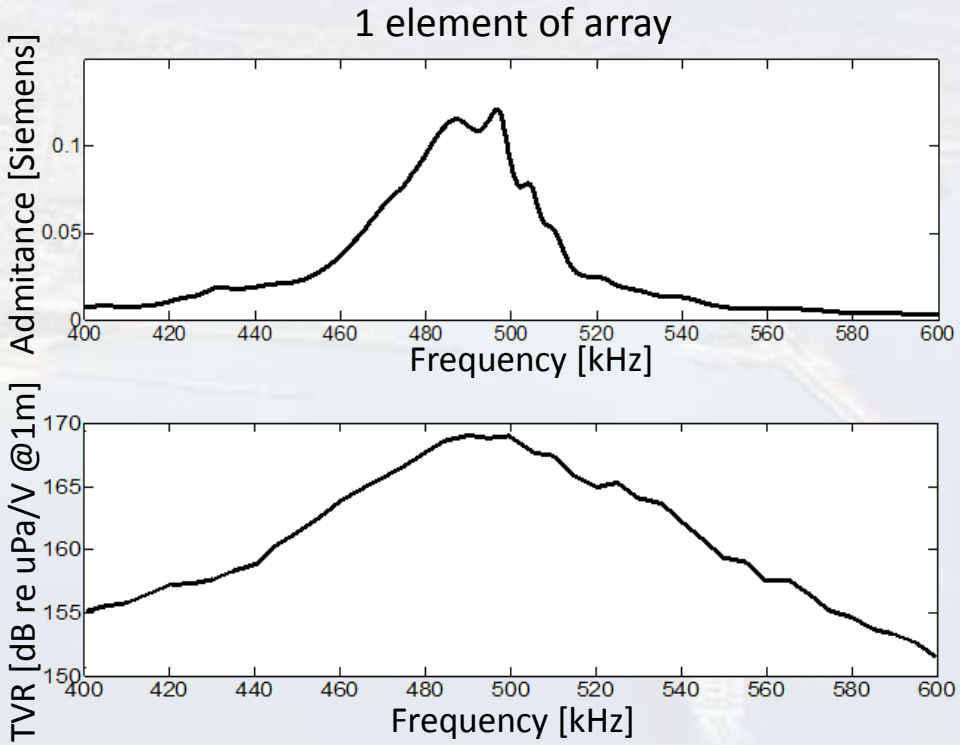


Matching: ***Polyurethane EL241F***

Backing: ***Aluminum***

$f_r$ = 496 kHz

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

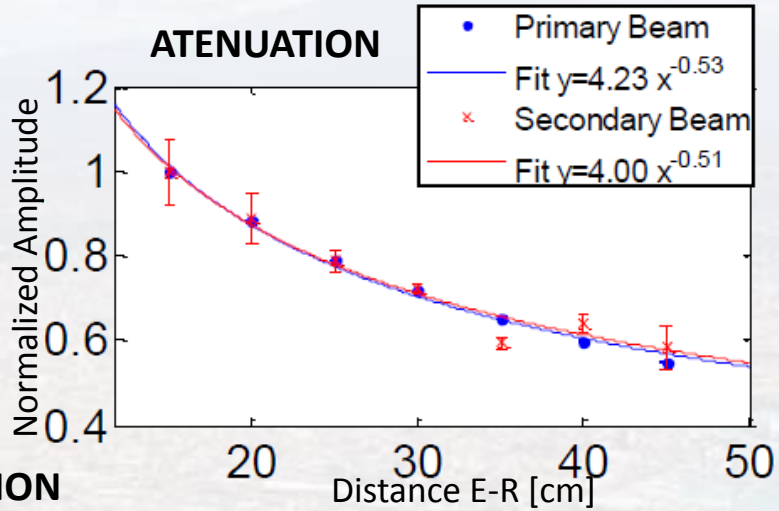


# 1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

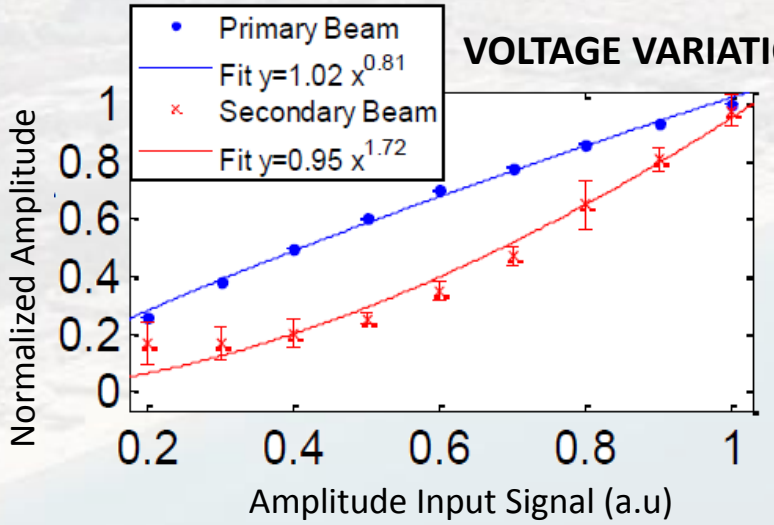
## 1.4 DESIGN & DEVELOPMENT AN ARRAY

**1 element of array:**
***Characterization to parametric emission***

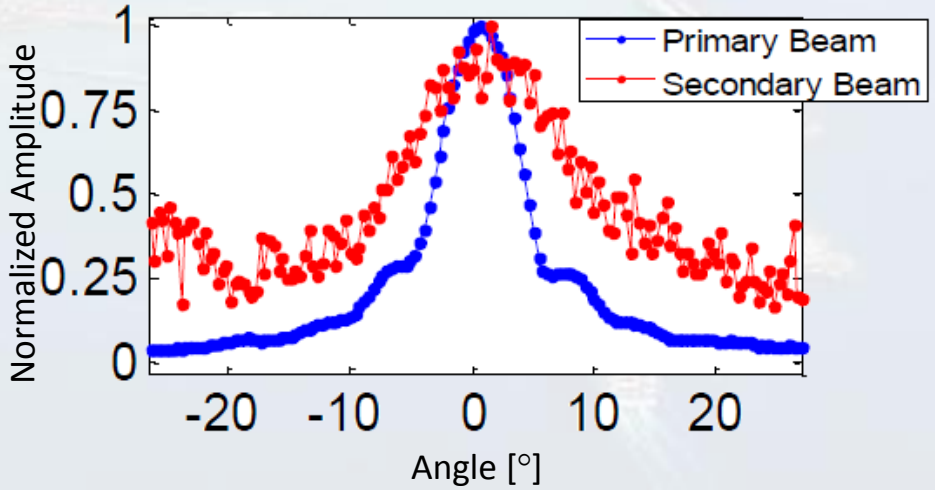
**ATENUATION**




**VOLTAGE VARIATION**



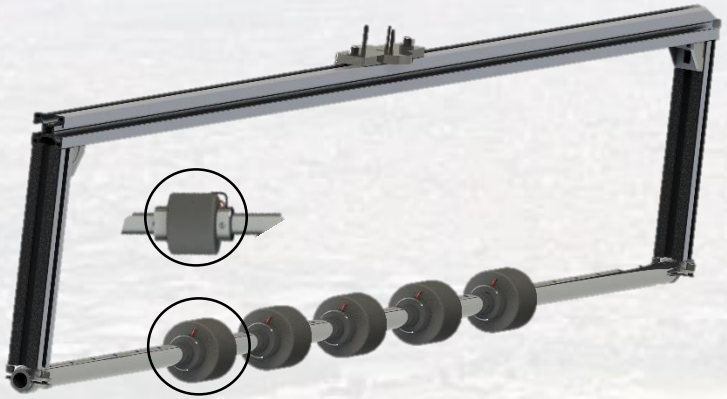

**DIRECTIVITY**

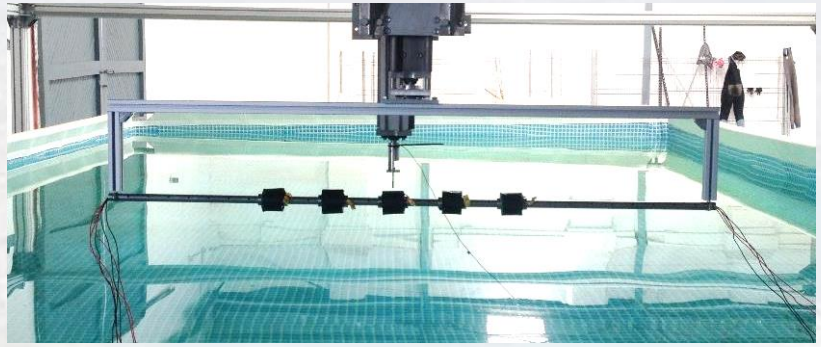


# 1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

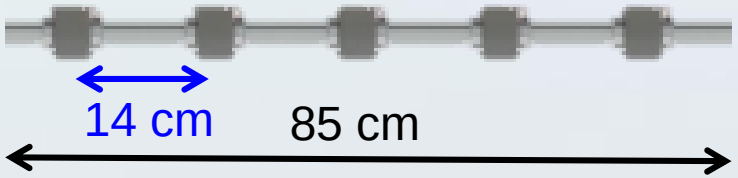
## 1.4 DESIGN & DEVELOPMENT AN ARRAY

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



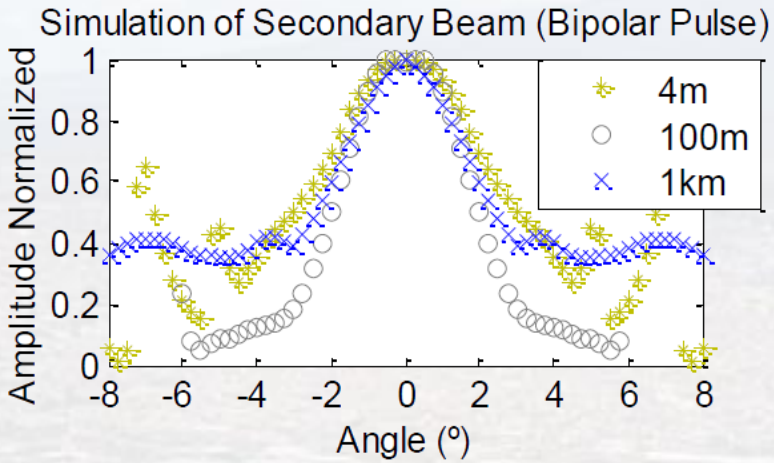


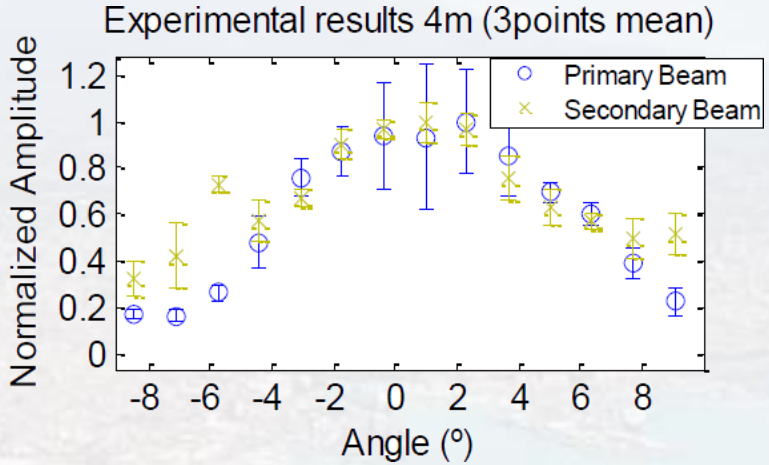
The studies reveal that the optimum separation between elements is among 10 and 15 cm to obtain the best acoustic neutrino signature (~1° opening).



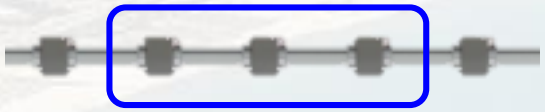
# 1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

## 1.4 DESIGN & DEVELOPMENT AN ARRAY

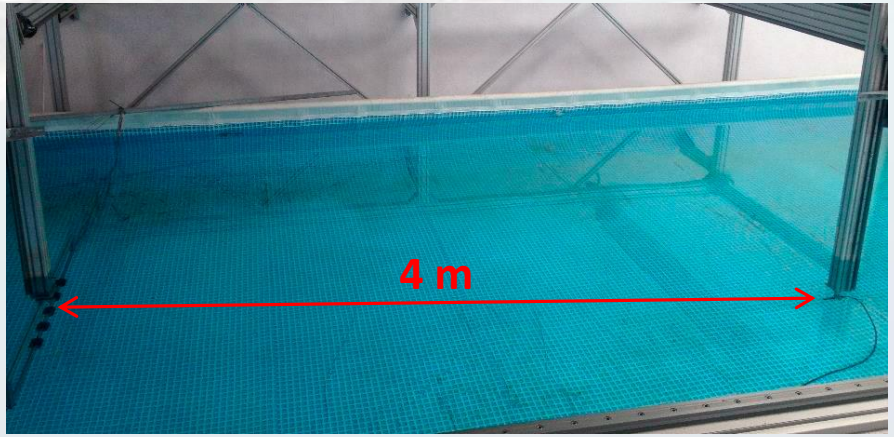



***Directivity to parametric emission***

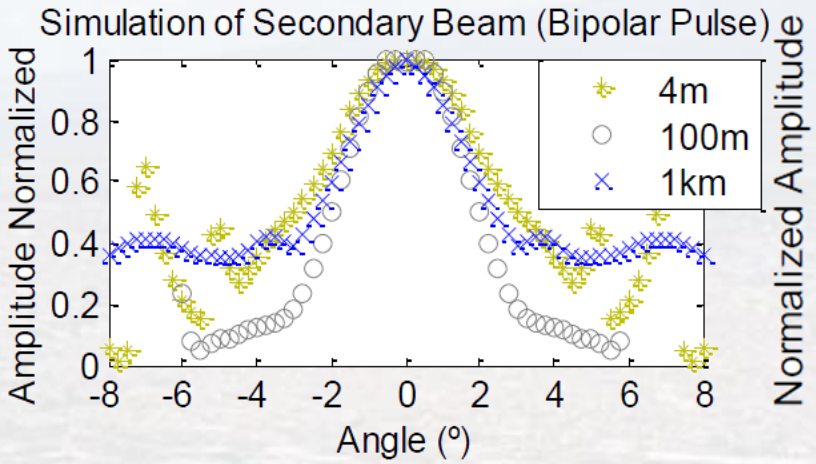


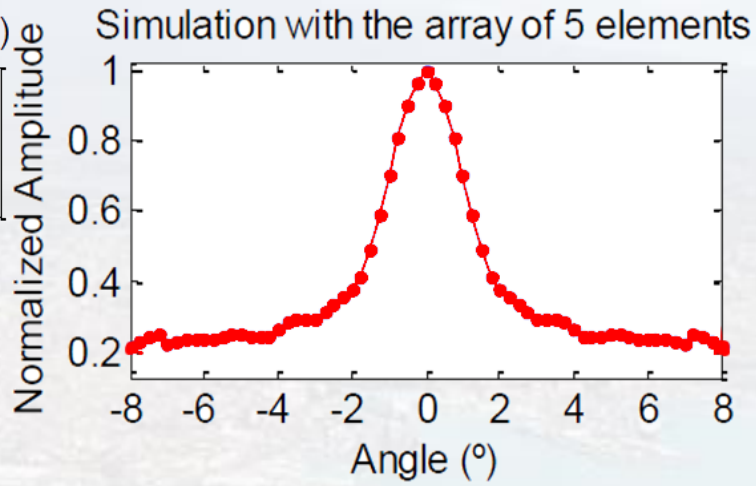
**Array with 3 elements**



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

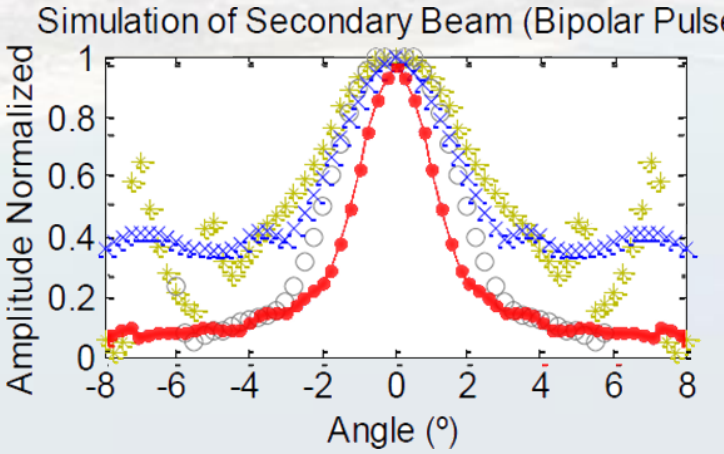
## 1.4 DESIGN & DEVELOPMENT AN ARRAY

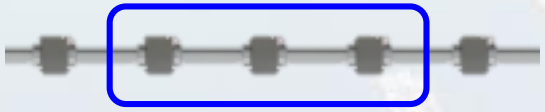



***Directivity to parametric emission***

**Array with 5 elements**



**Array with 3 elements**

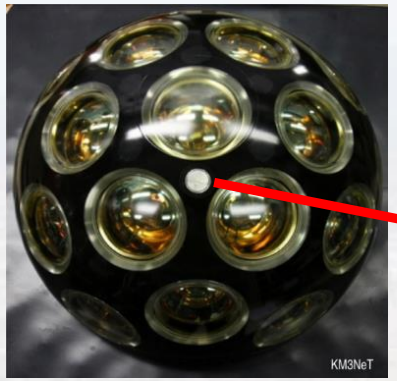
# 1) REPRODUCE THE ACOUSTIC SIGNATURE OF NEUTRINO WITH A PARAMETRIC ARRAY

## 1.5 FUTURE STEPS

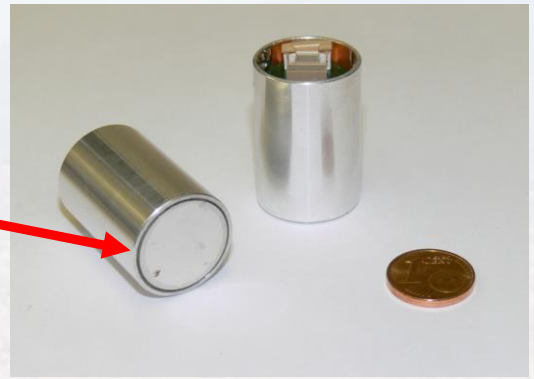
- Study the optimum configuration to improve the array: number of elements, distance between elements, …
- Design and development of the electronics to give the needed power to each element of the array.
- Tests the array for long distances and *in situ*.

# 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*

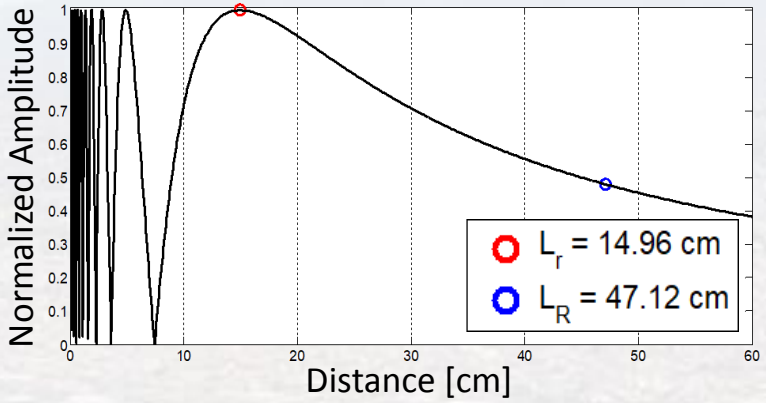
Using parametric effect

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

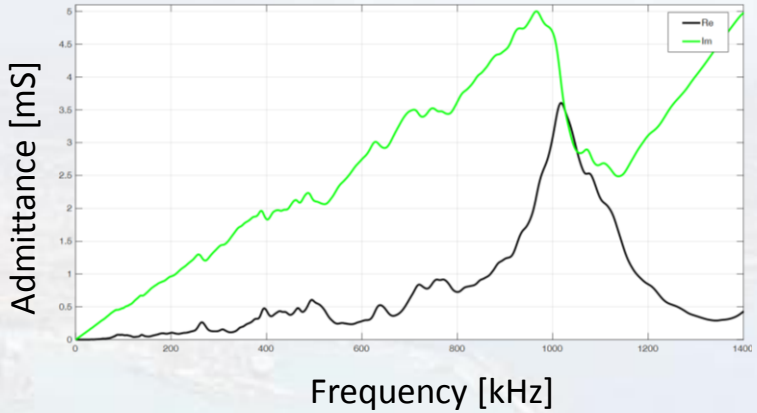
## 2.2 EXPERIMENTAL SETUP

RESON TC3027

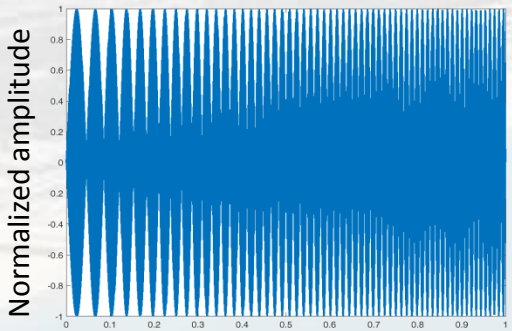
$f_r$ = 1 MHz

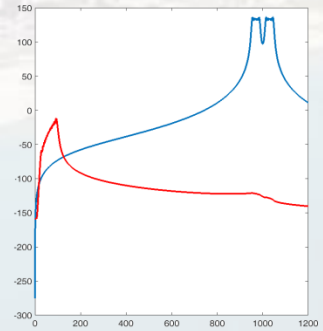



***Real* & *Imaginary* Adm.**

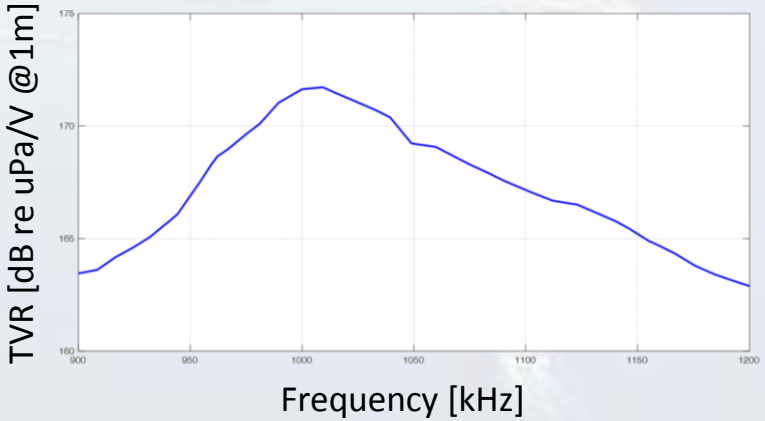



**Signal emitted:**



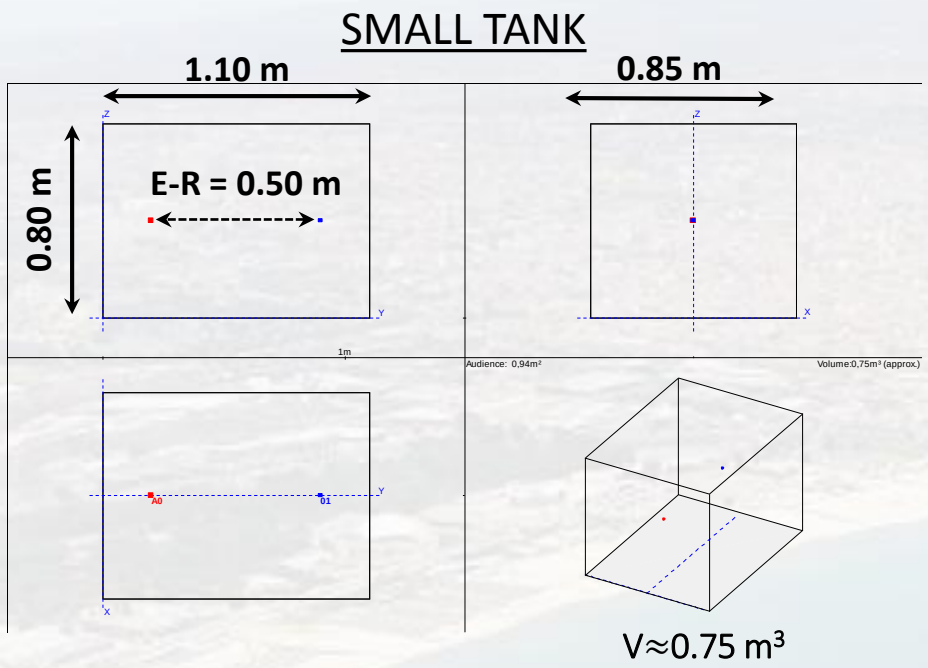



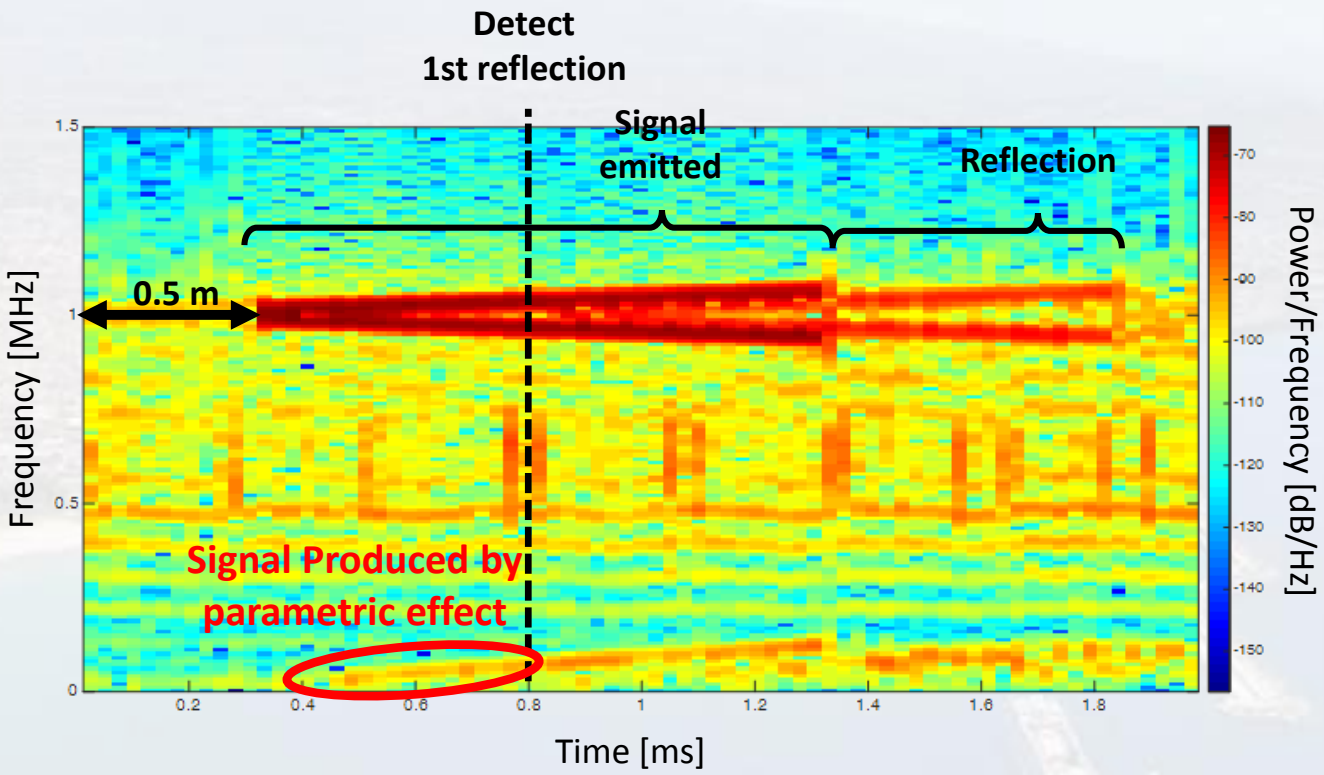

- $f_c$ = 1 MHz
- *Sweep:* $f \in [10,50]kHz$
- *2nd beam:* $f_d \in [20,100]kHz$



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

## 2.3 RESULTS IN A TANK



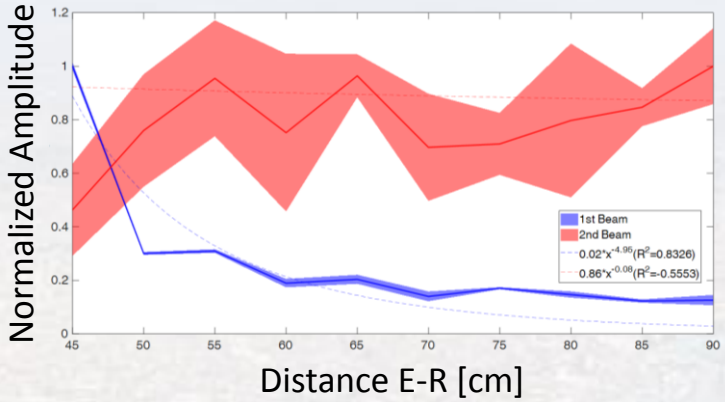



# 2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

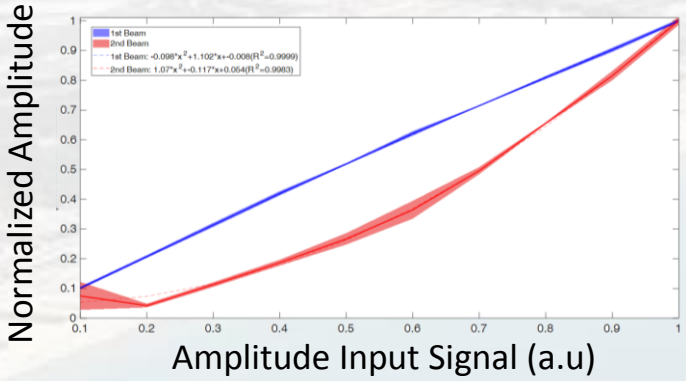
## 2.3 RESULTS IN A TANK

***Characterization to parametric emission***

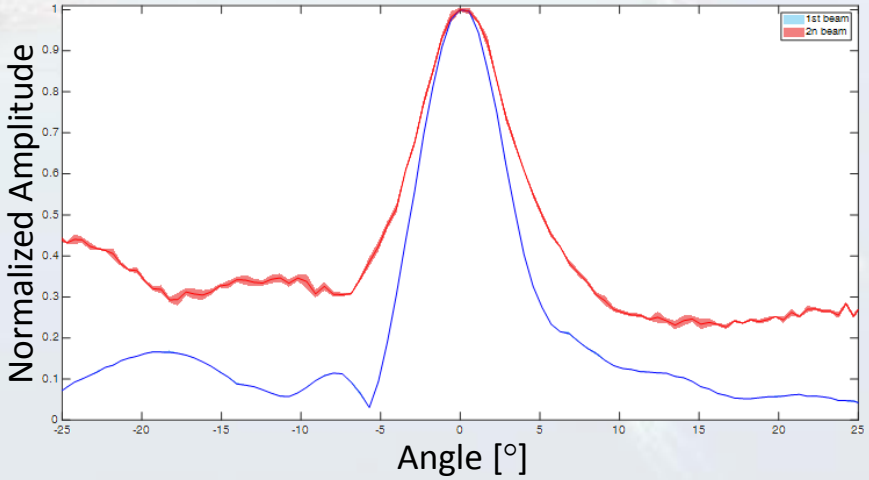
**ATENUATION**




**VOLTAGE VARIATION**



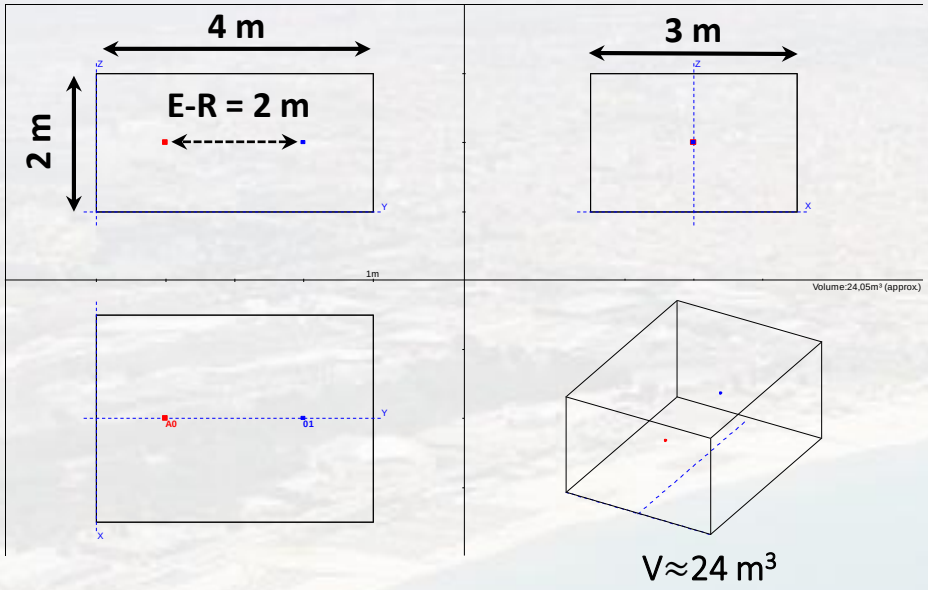

**DIRECTIVITY**



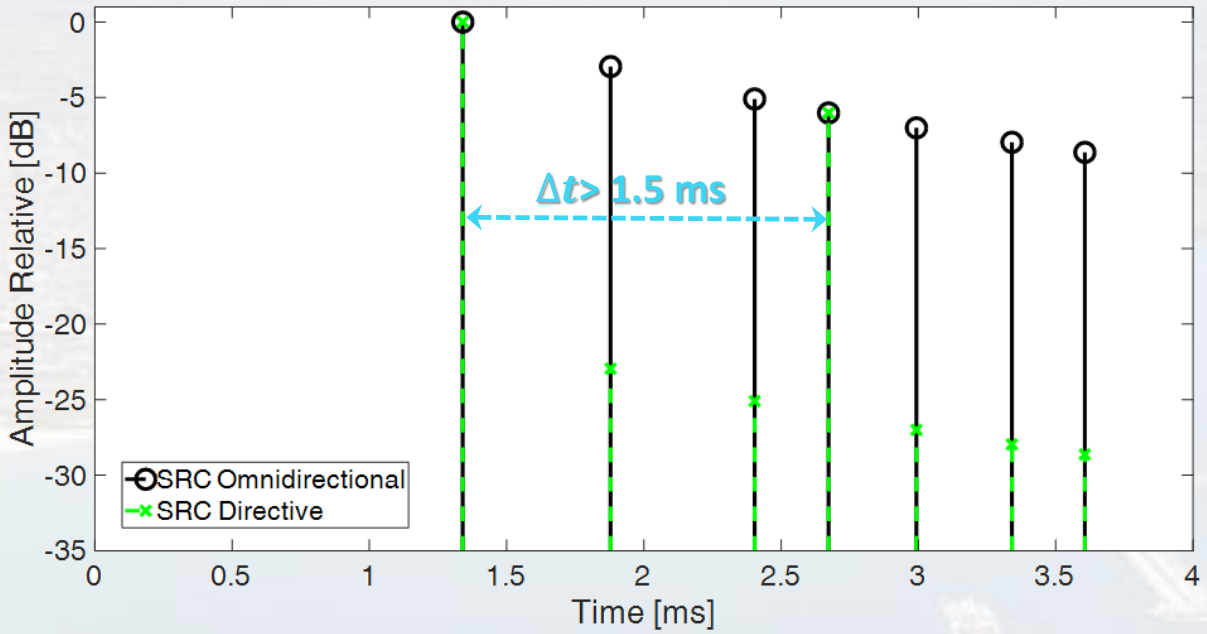
# 2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

## 2.4 EXPECTATIVES IN A SMALL POOL

SMALL POOL



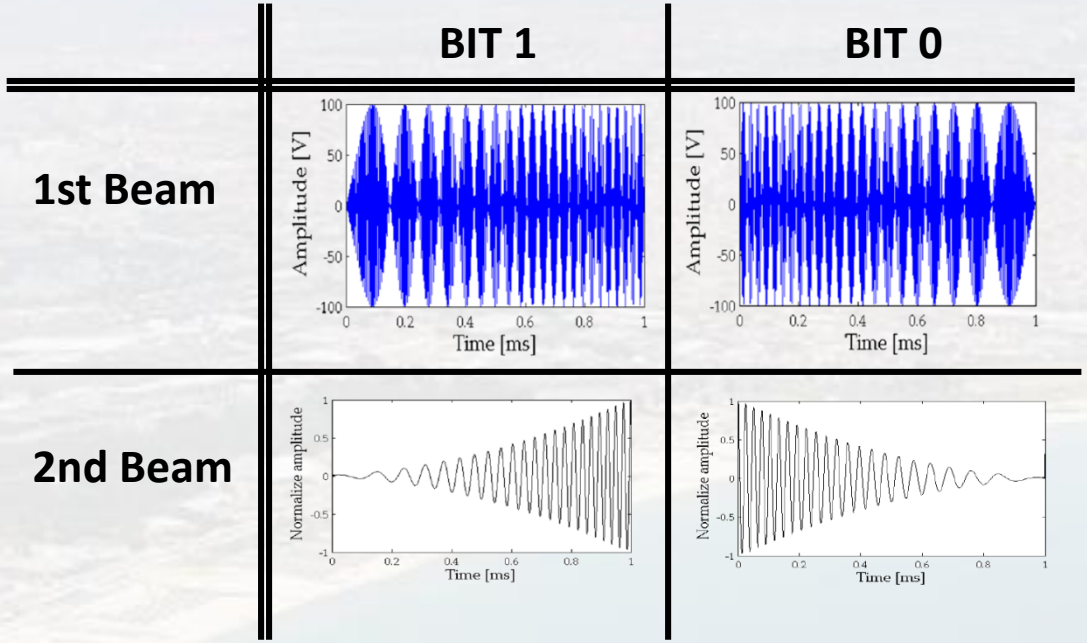

SMALL POOL REFLECTIONS



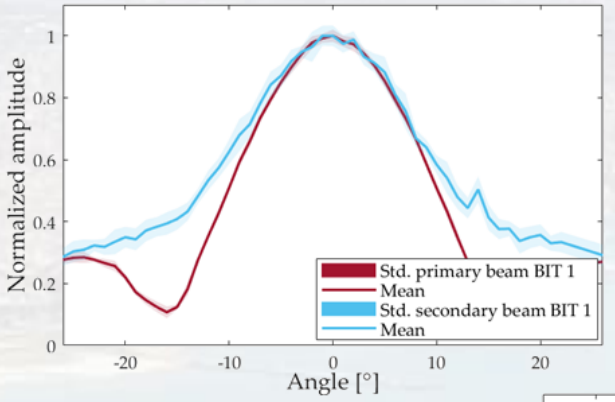
# 2) CALIBRATION OF THE ACOUSTIC SENSOR OF KM3NET WITH PARAMETRIC TECHNIQUE

## 2.6 COMUNICATION APPLICATION

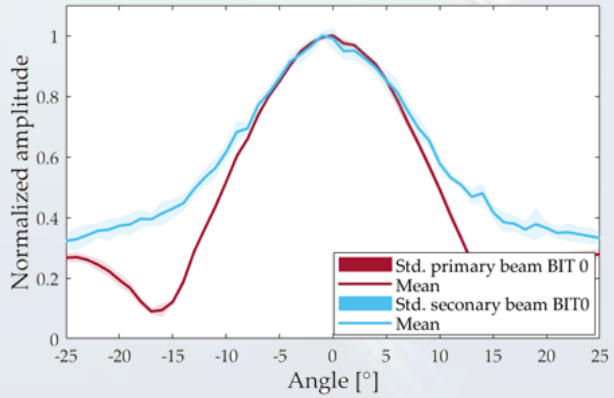
**Campo-Valera, M. et al.,** *2017. "Underwater communication using acoustic parametric arrays" in 4th International Electronic Conference on Sensors and Applications. (1 - 6). Online: Sciforum.*




**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

**ARENA 2018**

**Laboratori Nazionali del Sud – INFN**

**Catania, 12th – 15th June 2018**

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

CAMPUS DE GANDIA