

# Tests on the acoustic positioning system of the PPM-DOM

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KM3NeT General Meeting  
Marseille, January 29 – February 1, 2013

# Acoustic positioning system

*The acoustic positioning system (APS) is a mandatory subsystem for the detector*

*KM3NeT APS goals:*

- *relative positioning accuracy : < 10 cm (less than DOM diameter)*
- *absolute positioning accuracy: < 1 m to optimize pointing resolution*

*Key elements :*

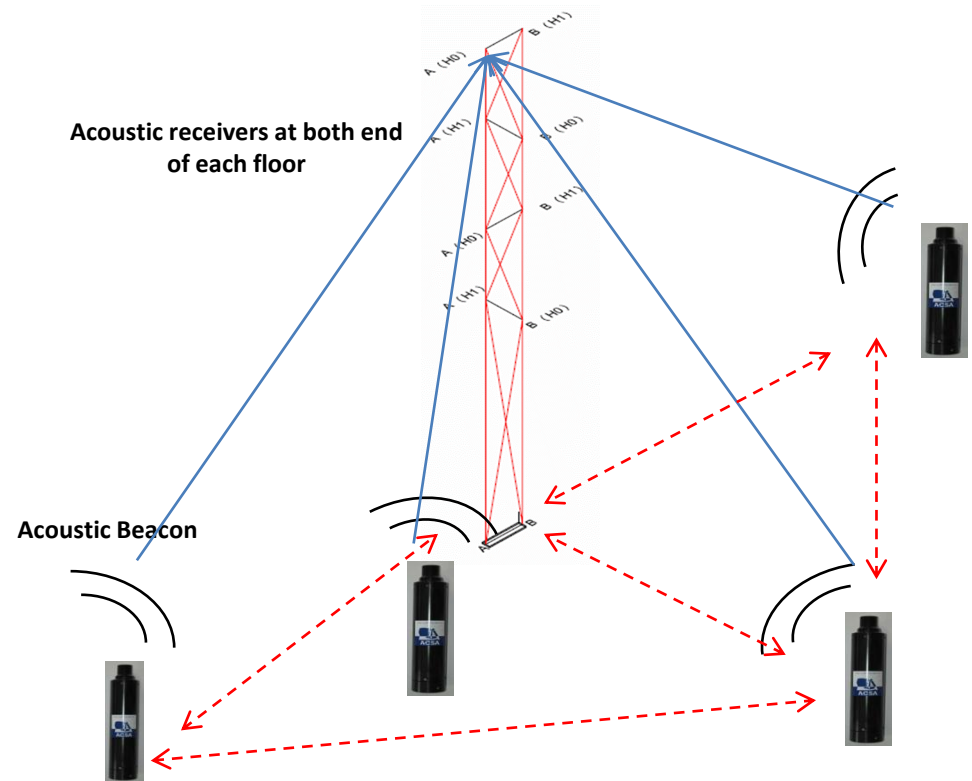
- *Long Baseline of acoustic emitters anchored in known and fixed positions*
- *Array of acoustic sensors (hydrophones) moving with the mechanical structures*

*Measurement Technique:*

1. *ToA (Time of Arrival):*

$$T^{Em}(Beacon) - T^{Rec}(Hydro)$$

2. *Geometrical triangulation*



# All data to shore technology

**The KM3NeT positioning system is based on “all data to shore” technology**

- **Signal acquisition and digitization off-shore (data rate 6.2 Mbps per channel)**
- **Signal processing performed on shore :**
  - **improves measurement accuracy**
  - **Opens to other science**
  - **Reduces power consumption (no need for “intelligence” in deep sea)**
- **Cost reduction with respect to commercial equivalent systems**

**Other applications:**

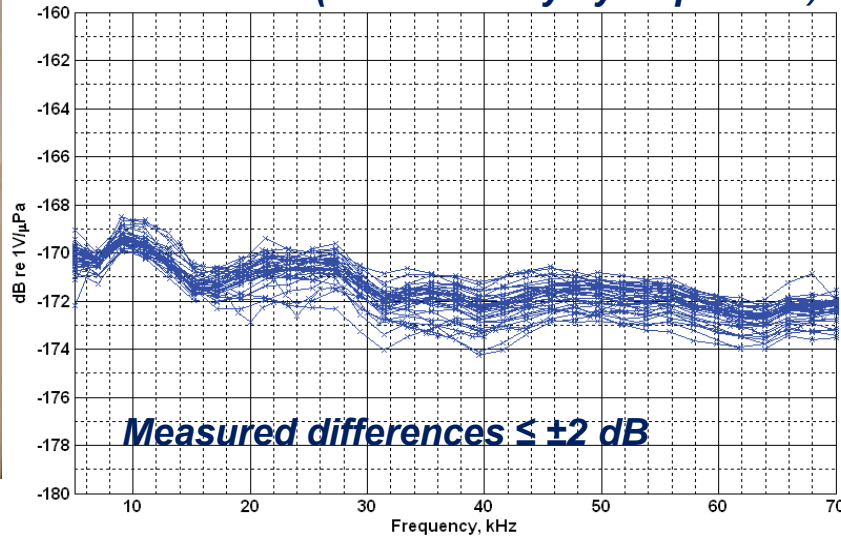
- **Earth and Sea Science (bioacoustics, geo-physics, acoustic oceanography)**
- **Acoustic neutrino detection (preliminary studies)**

# Acoustic sensors in PPM-DOM and PPM-DU

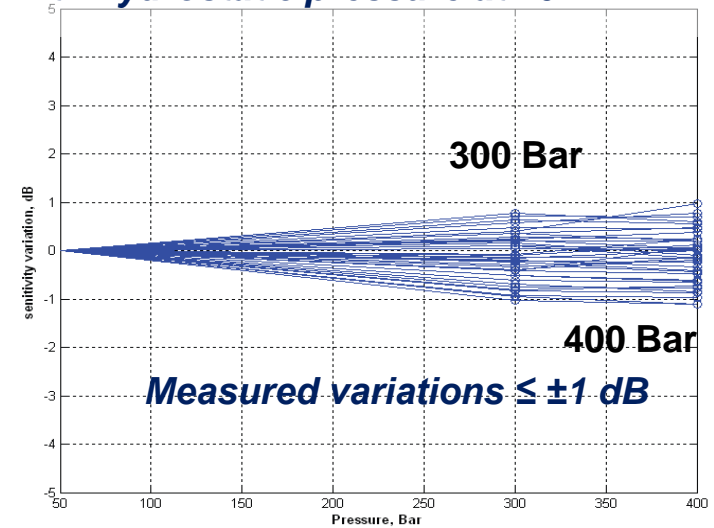
**Large bandwidth hydrophone (100 Hz – 70 kHz) developed by SMID and NEMO**



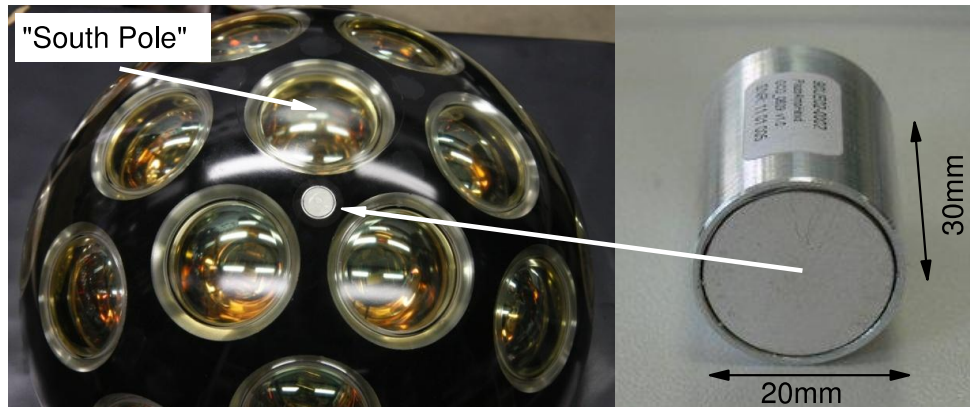
**Hydrophone + preamplifier calibrated at NATO - URC (40 sensitivity hydrophones)**



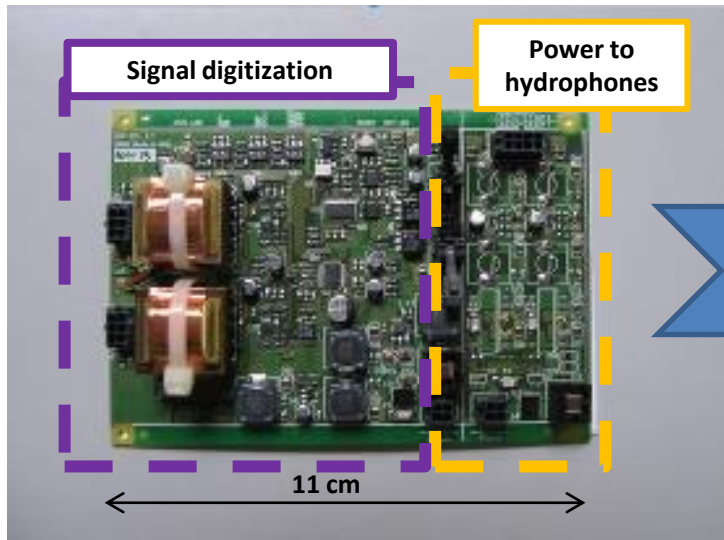
**Relative Hydrophone sensitivity variation with hydrostatic pressure at 20 kHz**



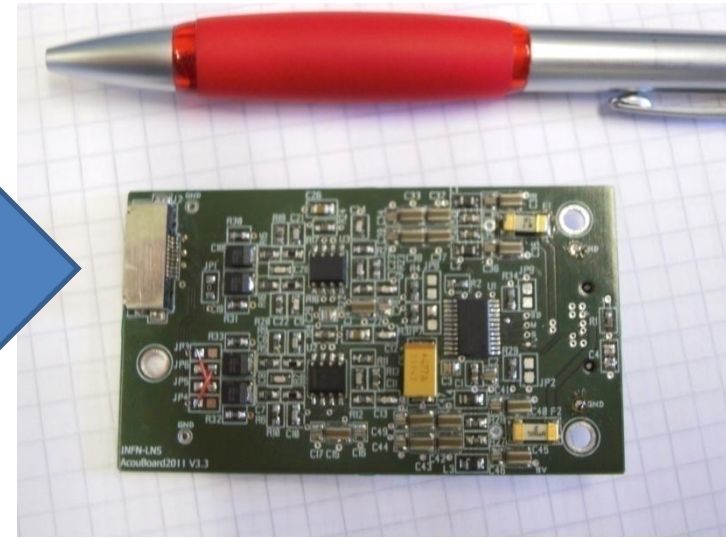
**Custom piezoelectric acoustic sensor developed by ECAP**



# From NEMO-SMO AcouBoard to KM3NeT AcouPlug



**NEMO-SMO ACOUBOARD**



**ACOUPLUG**

- **Stereo ADC Crystal CS-5381**  
**24 bit/192kHz, Max input  $2 V_{RMS}$**



- **EBU/AES-3 stereo compliant DIT**  
**(Digital Interface Transmitter)**



- **Power lines to 2 hydrophones**  
**80 mA@5V per channel**



- **AcouBoard – hydrophones coupling**  
**via transformers**



- **Stereo ADC Crystal CS-5381**  
**24 bit/195.3125 kHz, Max input  $2 V_{RMS}$**
- **I<sup>2</sup>S to CLB**
- **AcouPlug controlled by CLB (clock, reset,...)**

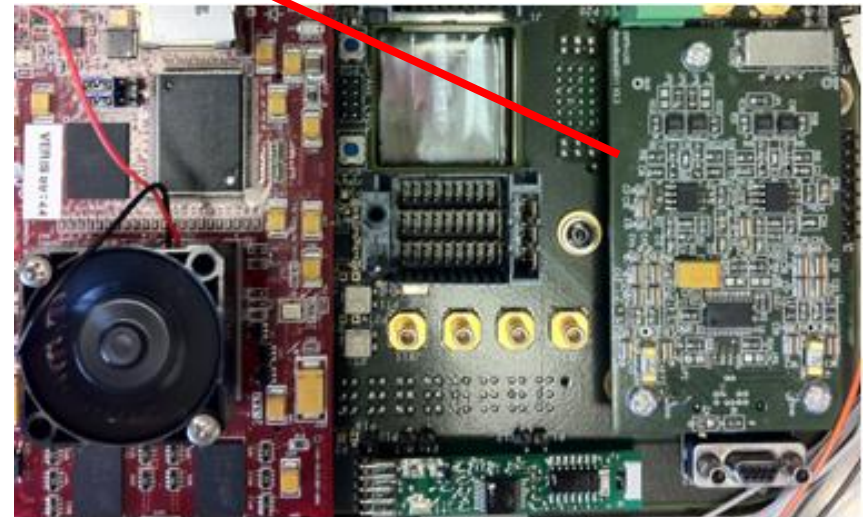
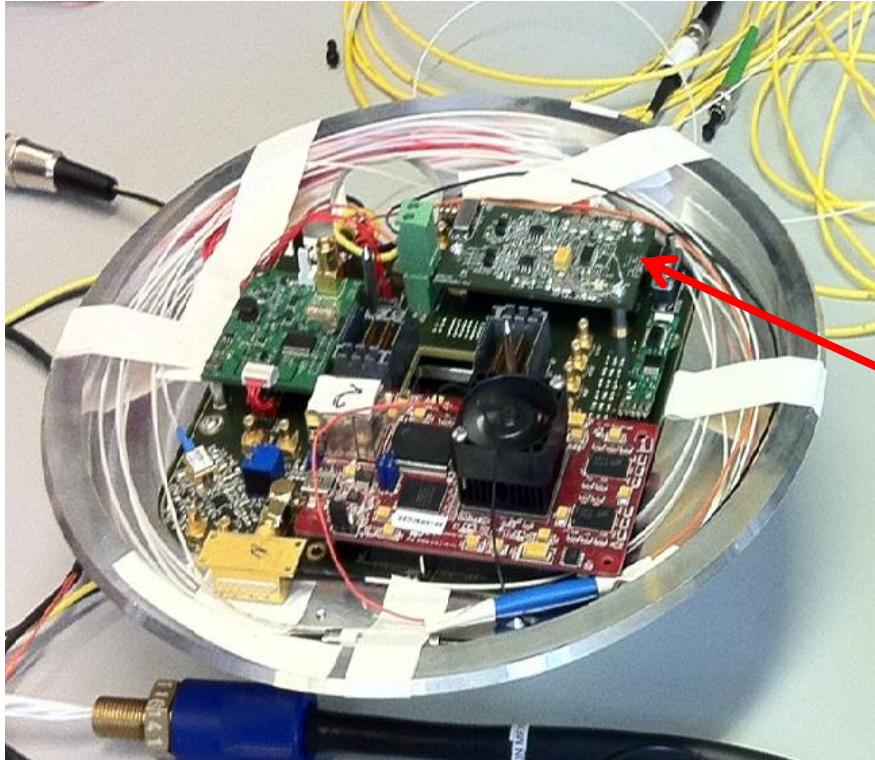
- **2 Power lines at 5 VDC available**
  - 1 line used for external hydrophone
  - 1 line unused (piezo sensor powered by Octopus Board)

- **AcouPlug– hydrophones AC coupling**



# Implementation on PPM-DOM

AcouPlug is plugged on the CLB.

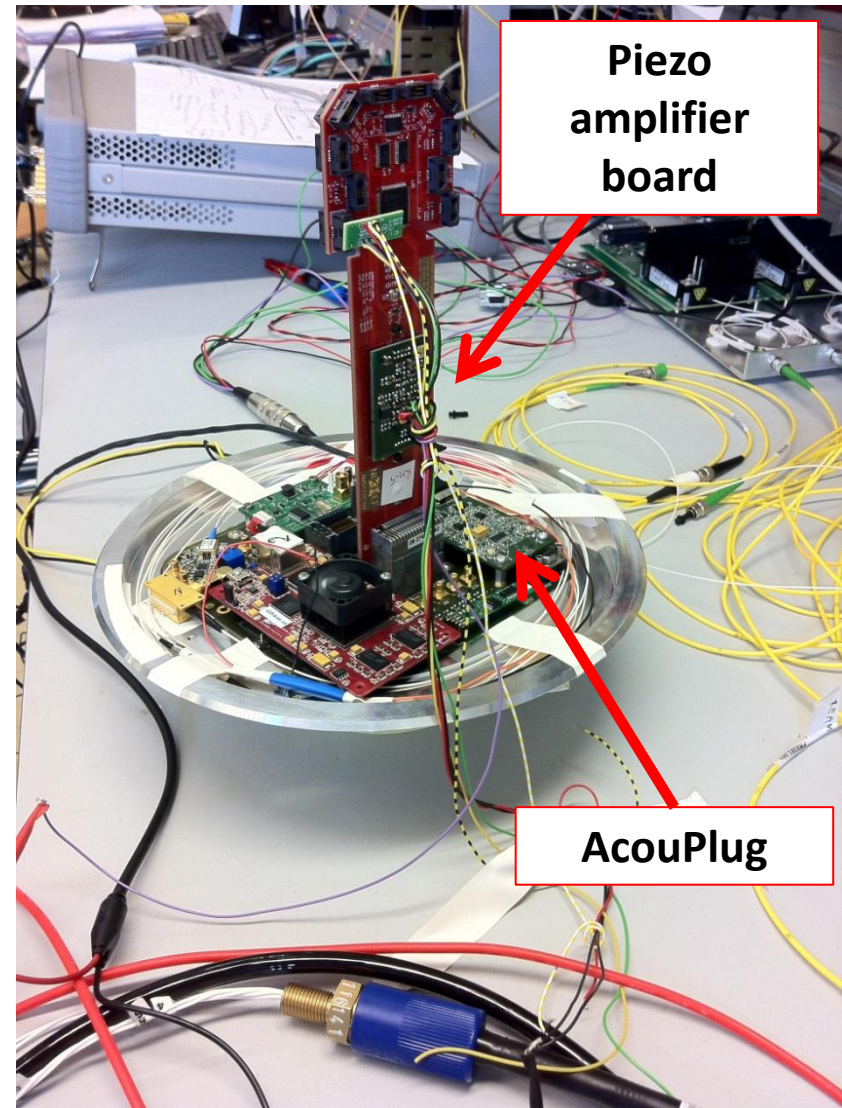


# PPM-DOM acoustic sensors read-out

*The system consists of an external hydrophone and an integrated piezo and their readout.*

*The hydrophone differential signal is routed directly to the AcouPlug. The ADC is read out by the CLB and data is formatted for transmission to shore.*

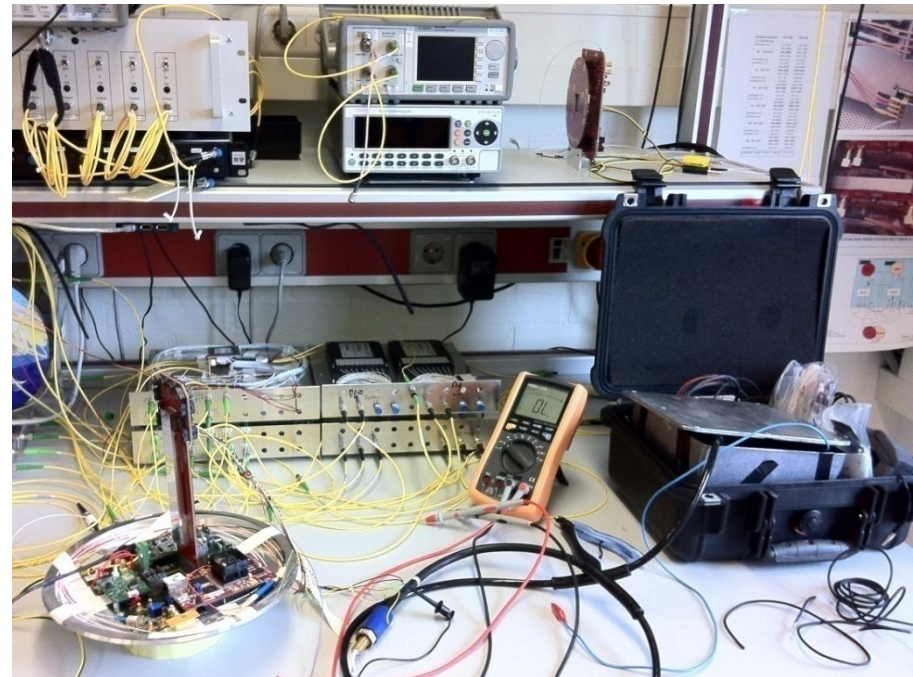
*The piezo signal (preamplified, single-ended) is read-out through the piezo amplifier board (piggy-backed on octopus board), from there a differential signal is routed to the AcouPlug through the Octopus and the CLB.*





# Nikhef Tests 6-9 August

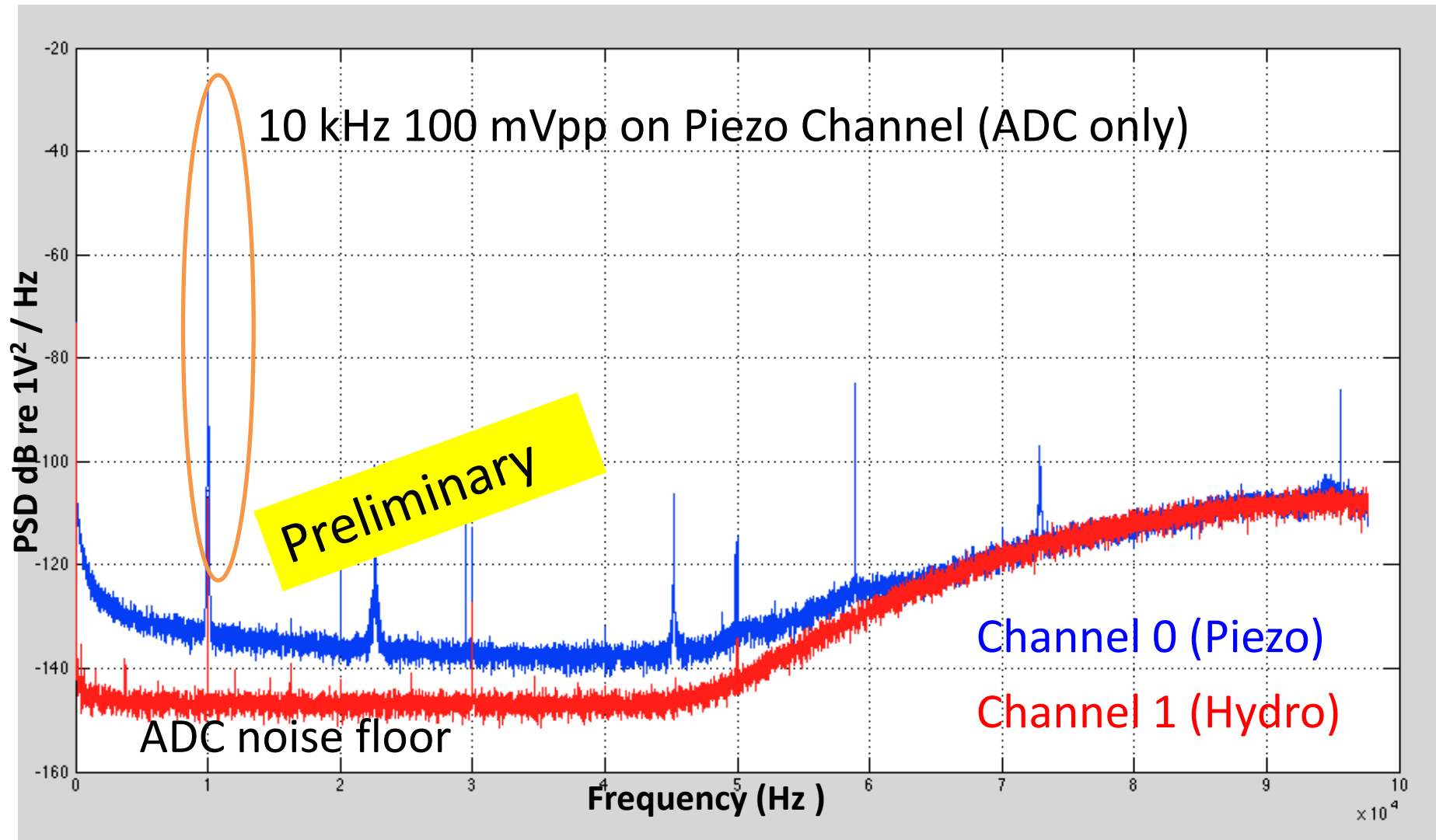
- AcouPlug
- Piezo Erlangen inside the DOM
- INFN hydrophone (external)





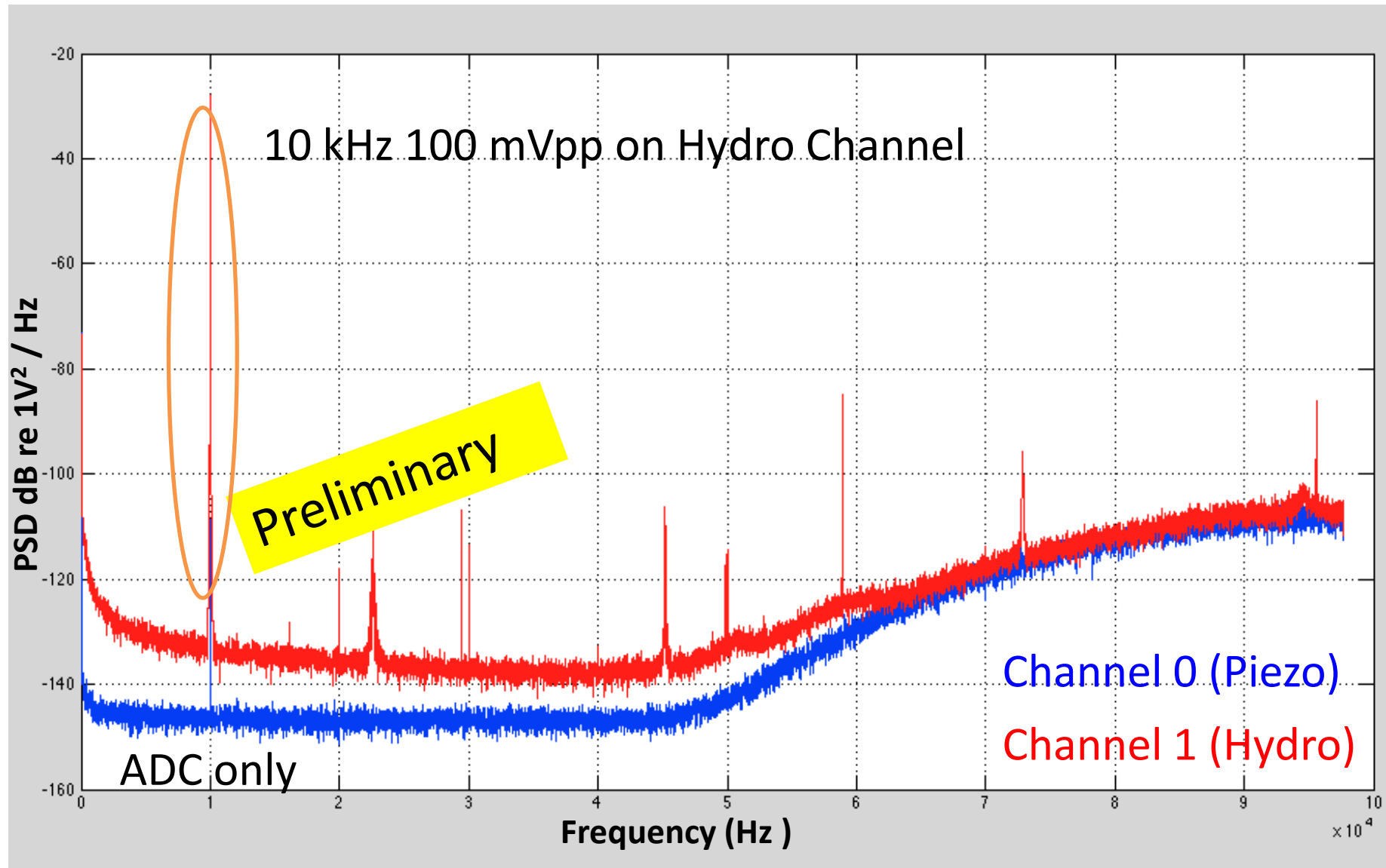
# Nikhef Tests 6-9 August

## ADC Tests

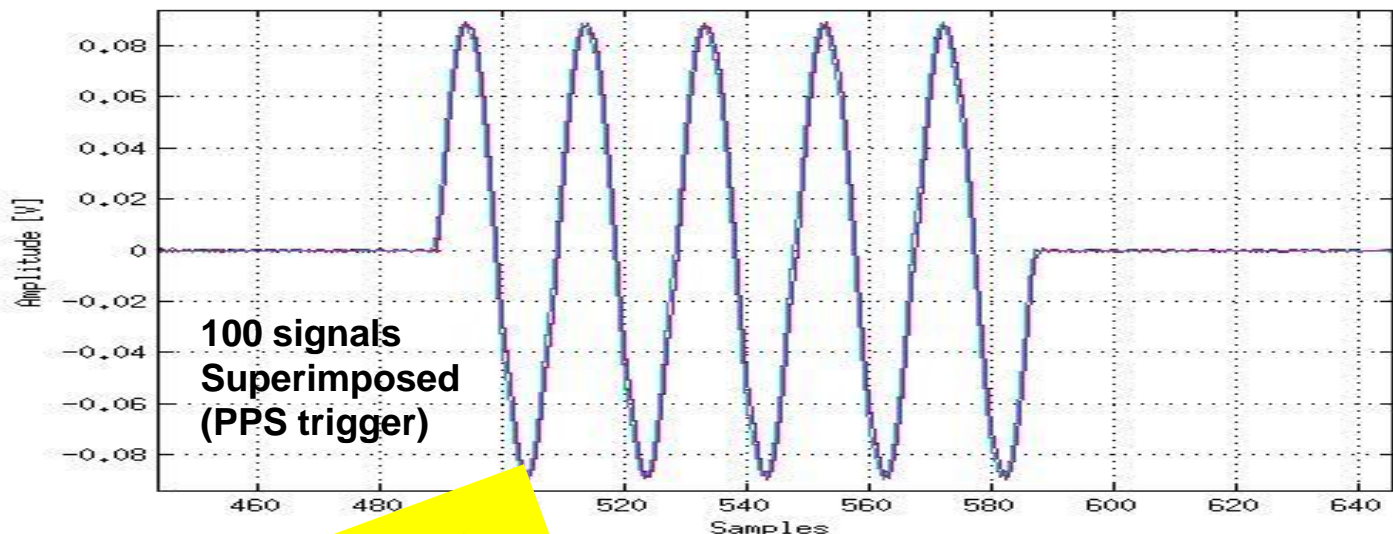


# Nikhef Tests 6-9 August

## ADC Tests



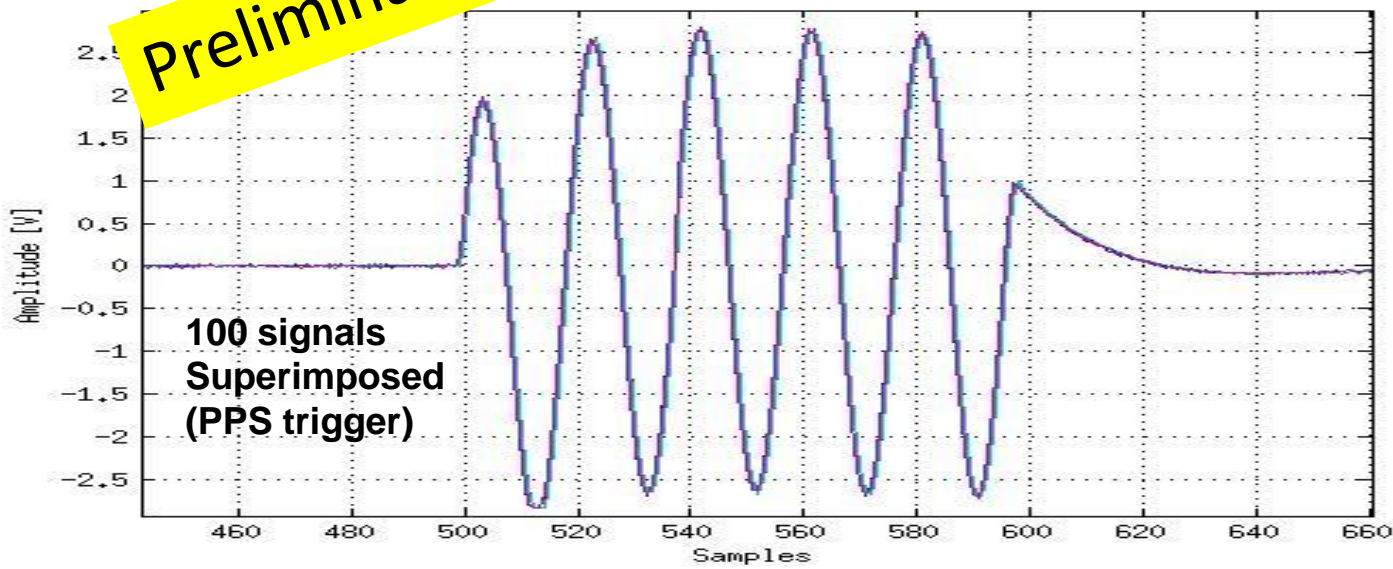
# Nikhef Tests 6-9 August: time and amplitude response



Channel 1 (Hydro)  
ADC

10 kHz pulses on  
AcouPlug

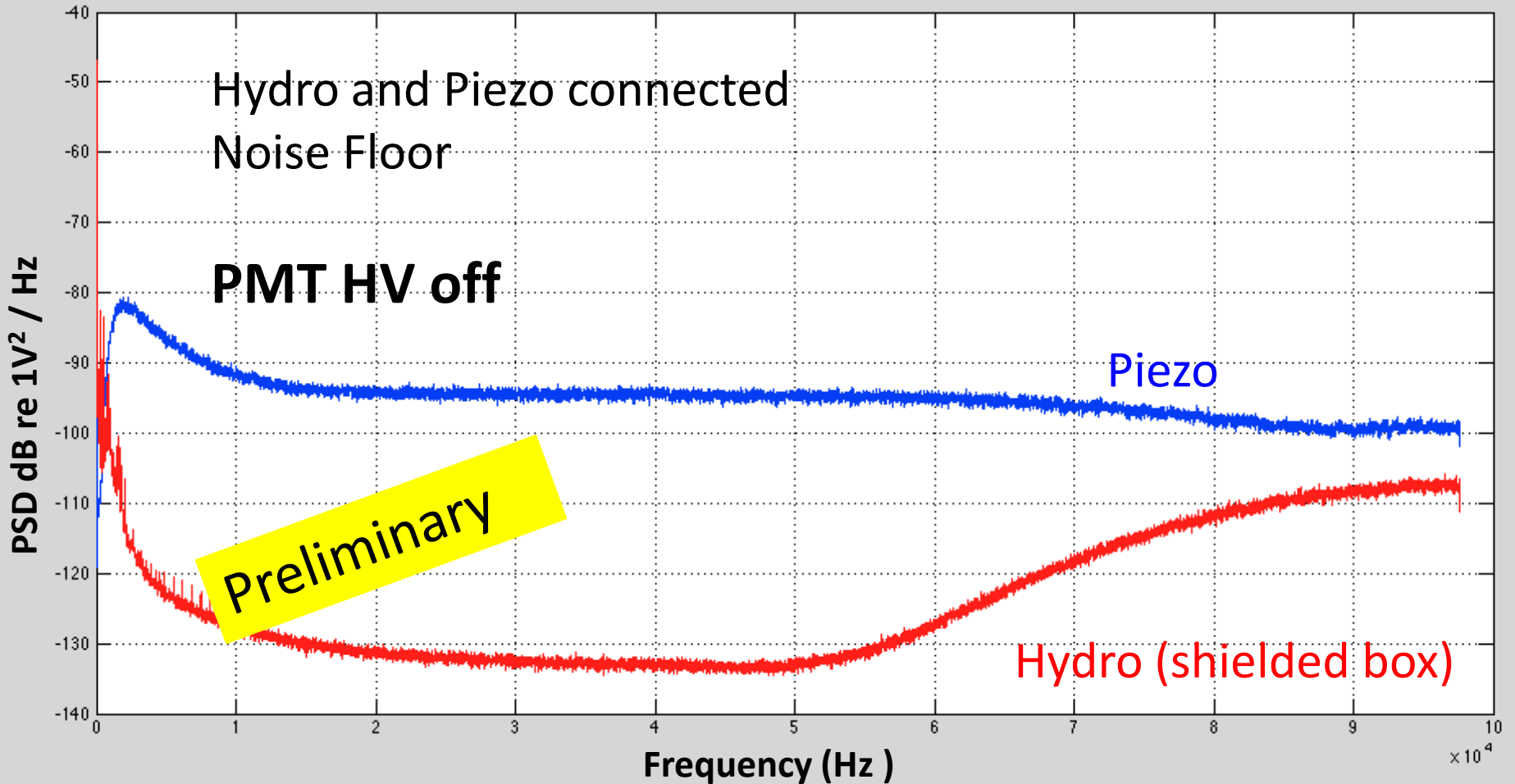
Preliminary



Channel 0 (Piezo)  
ADC + PiezoAmp

10 kHz pulses on  
piezo amplifier  
board

# Nikhef Tests 6-9 August

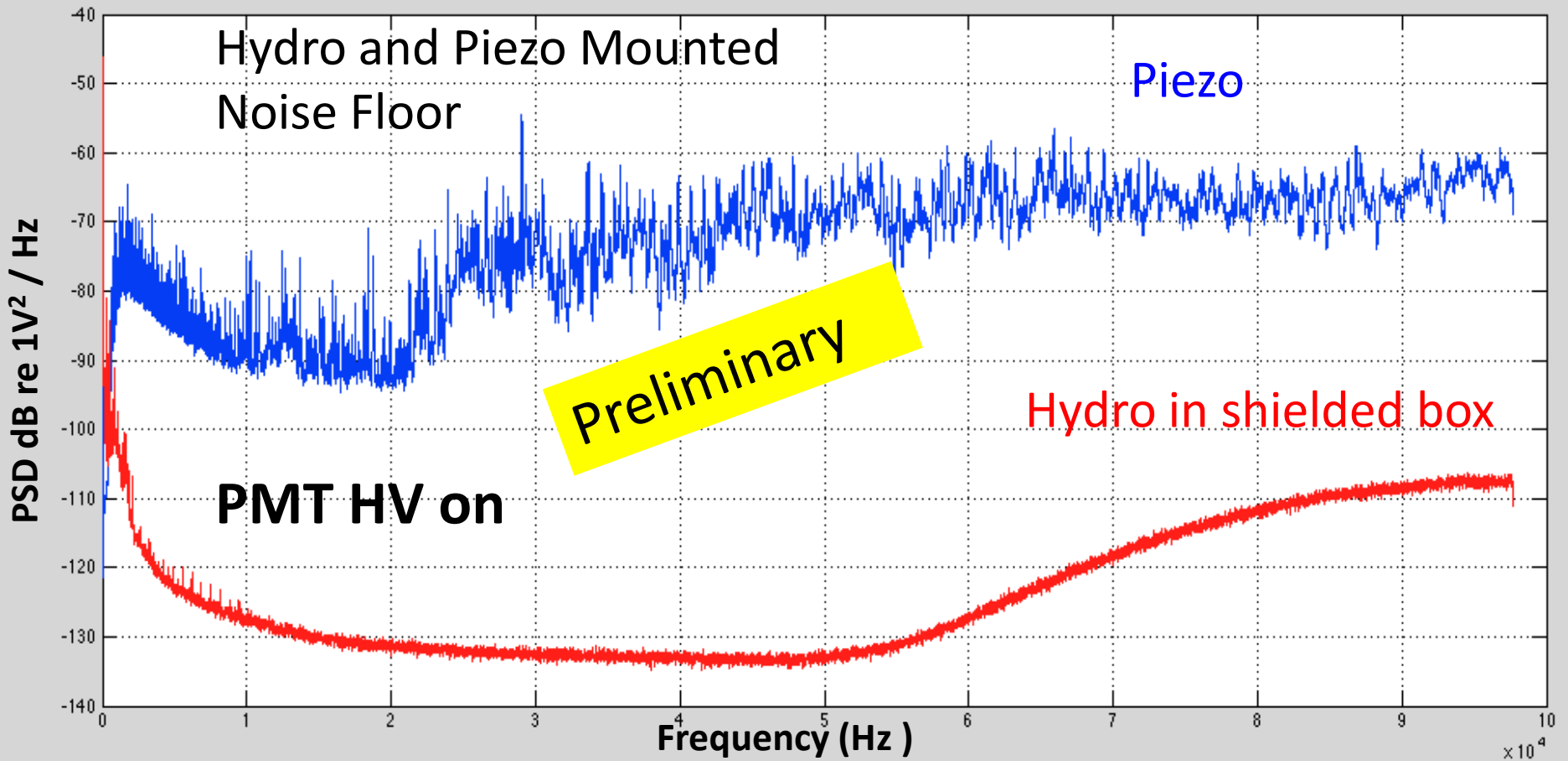


SMID +preamp sensitivity: -172 dB re 1 V/uPa

Piezo + preamp sensitivity: - 145 dB re 1 V/uPa



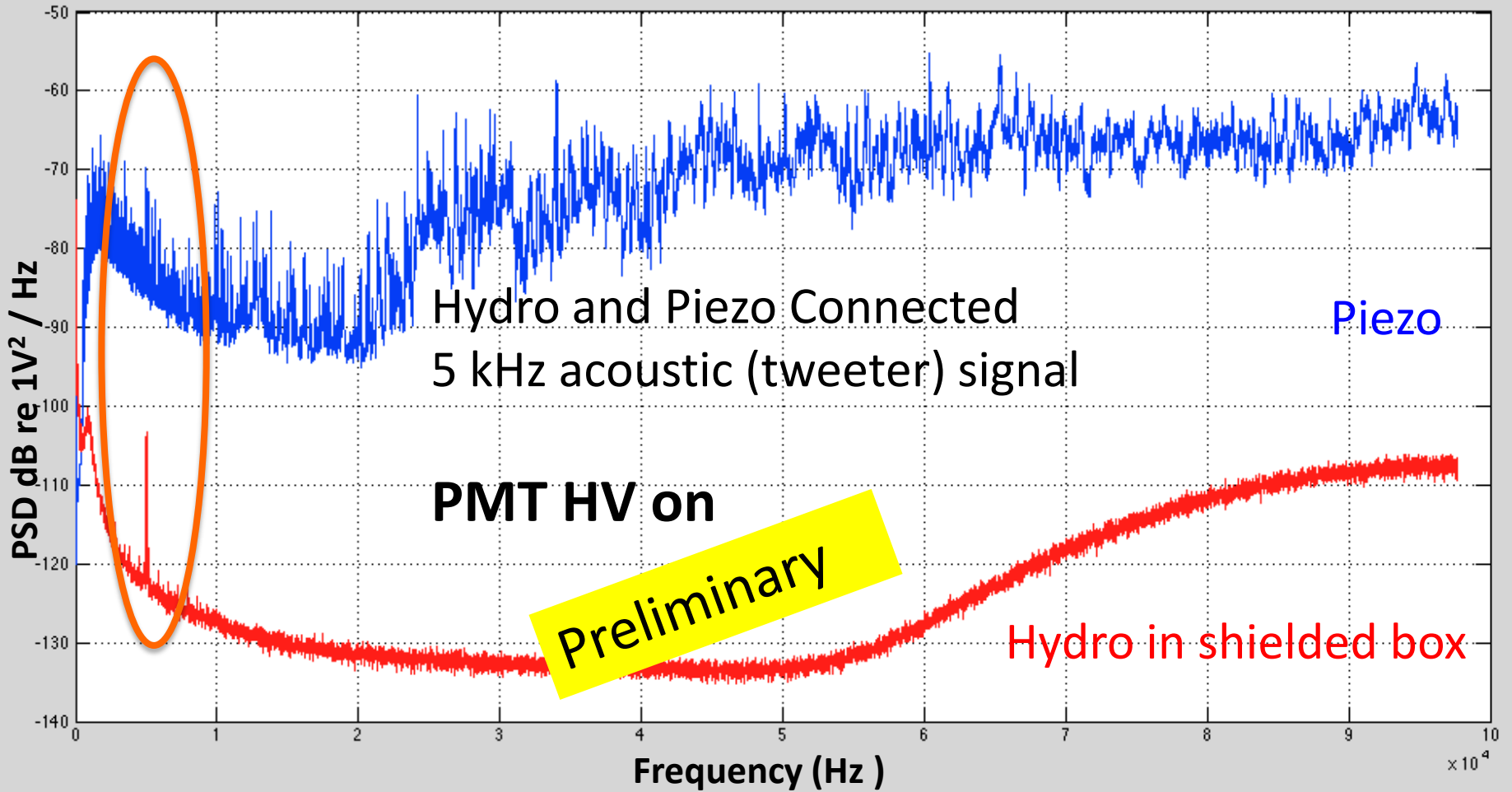
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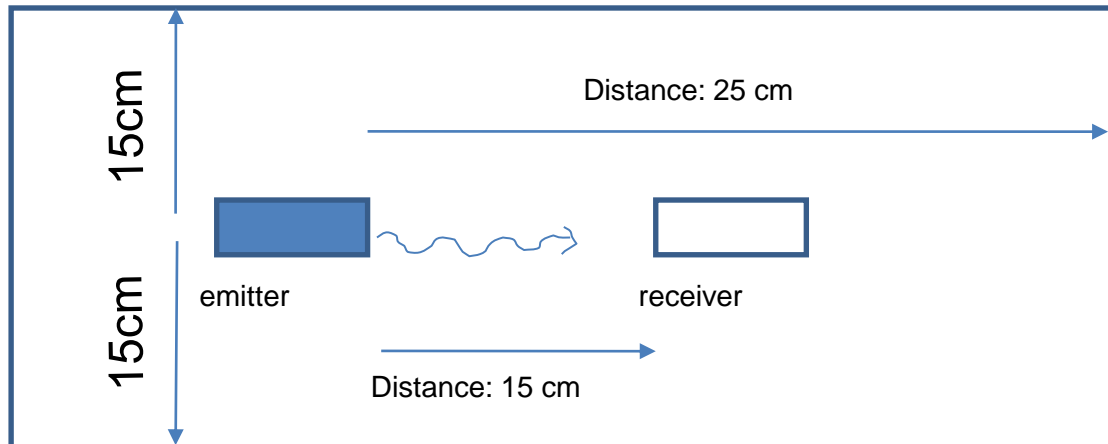


# Acoustics: DOM test @ CPPM and Foselev

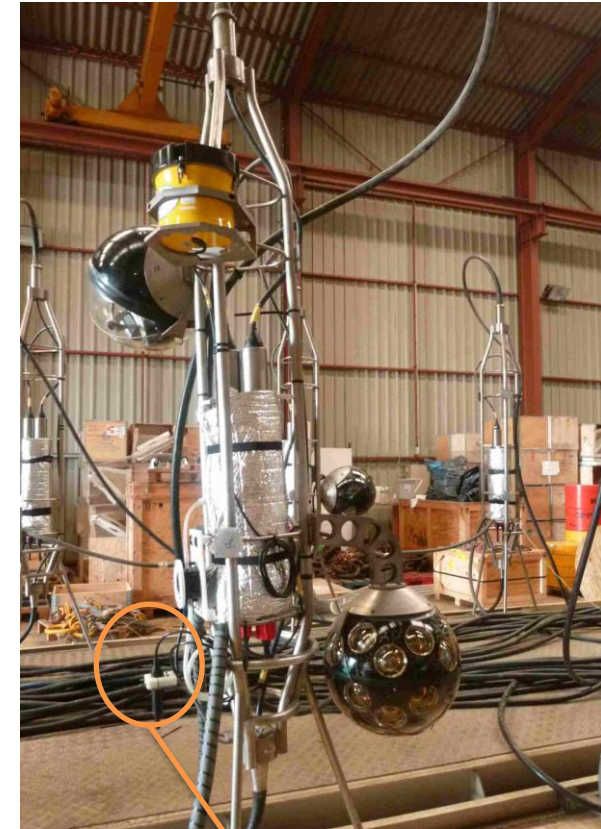
Dimensions of the water tank:

42 cm length, 32 cm with 19 cm height

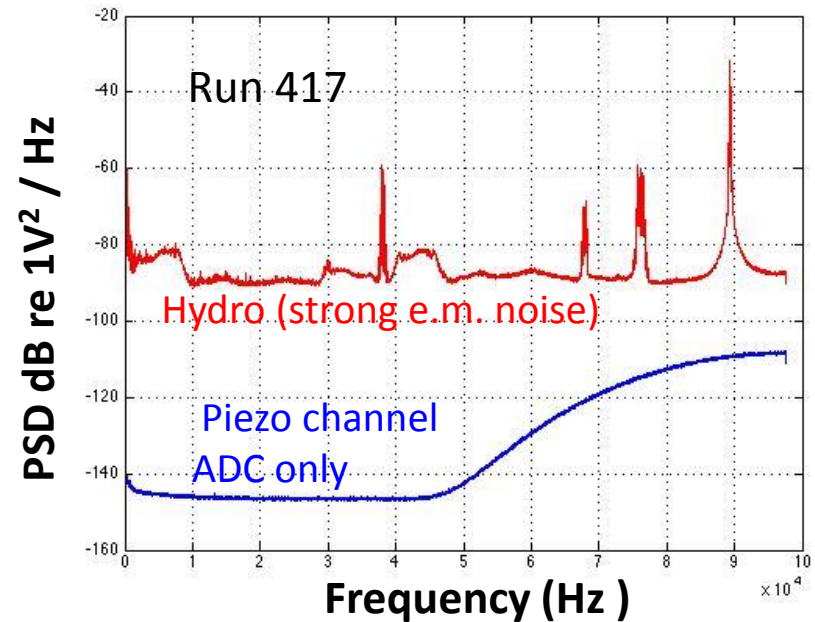
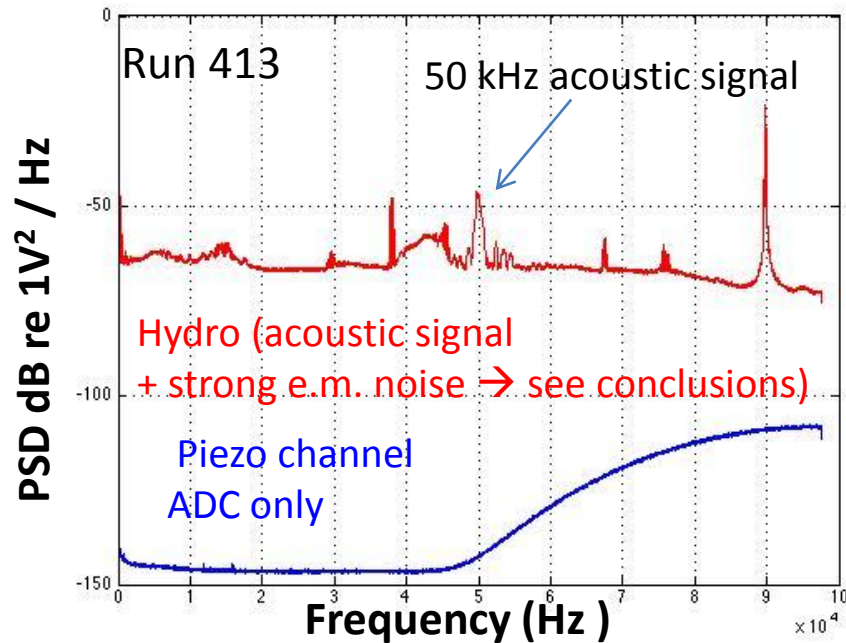
The hydrophone was placed at 5 cm (h) from the box



- Frequency range : 44.522 to 60.235 kHz
  - Sv (+/- 3dB) : 144dB re  $\mu\text{Pa} / \text{V} / \text{m}$
  - Axial directivity (+/- 3dB) : +/-  $60^\circ$
  - Radial directivity (+/- 3dB) : +/-  $180^\circ$
- Sequence :
- 50 kHz, 1 ms every 1 s, A = 10 Vpp



# CPPM Test 23 October 2012

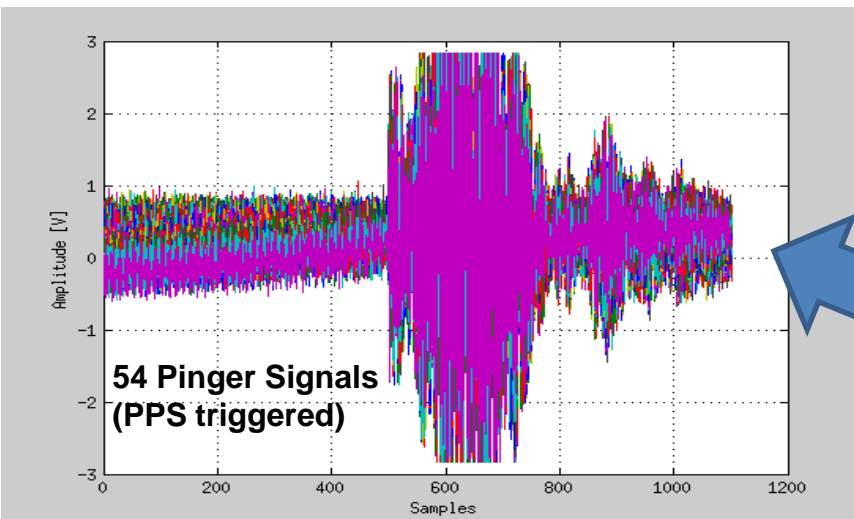
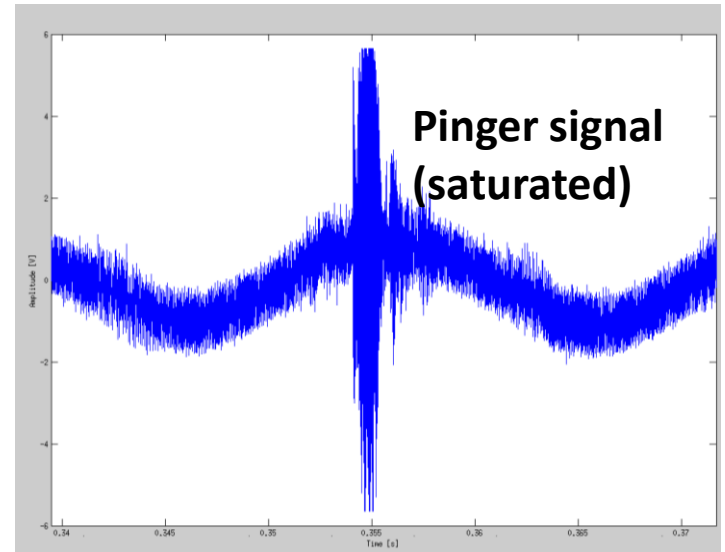
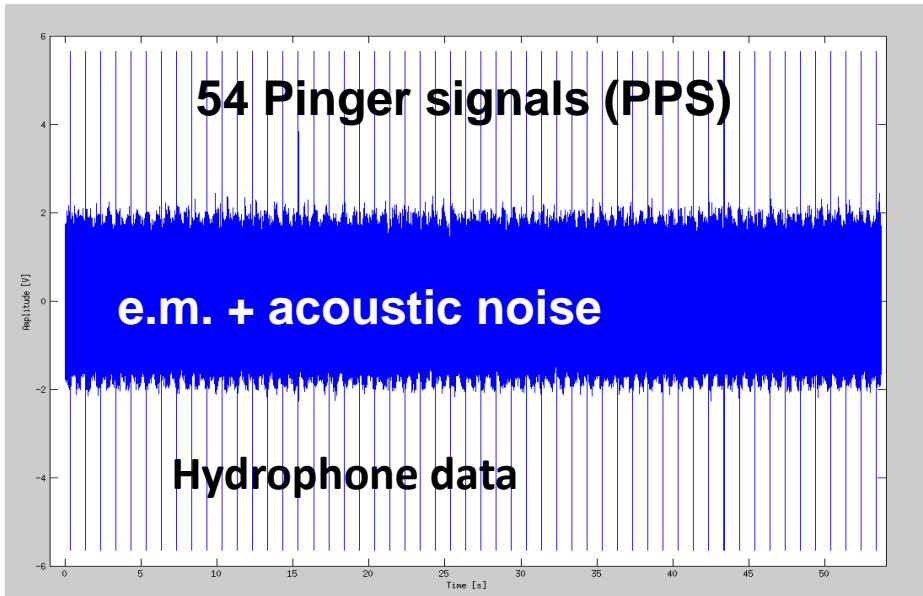


- run 413 Hydro in a water tank with an ANTARES pinger, piezo ON, PMTs ON  
Pulser: period 1s - pulse width 10ms - frequency 50kHz)
- run 417 Hydro in a water tank with an ANTARES pinger, piezo ON, PMTs ON

**Piezo is OFF! Only ADC noise recorded !!!**  
**Log says piezo on ... Should be tested!**



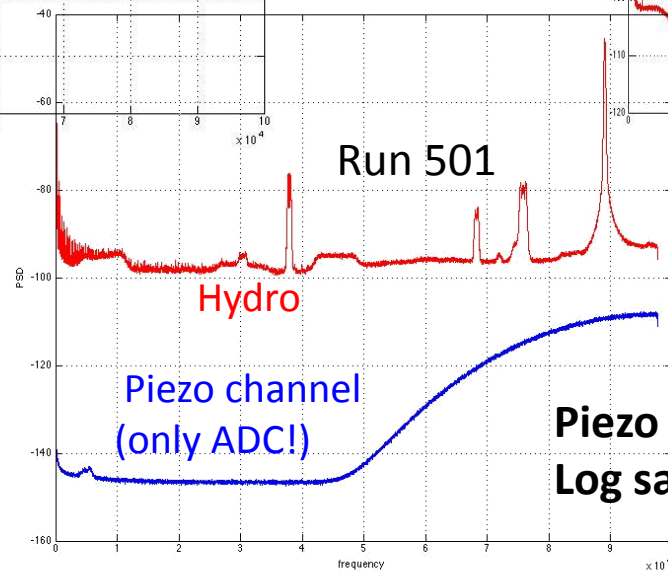
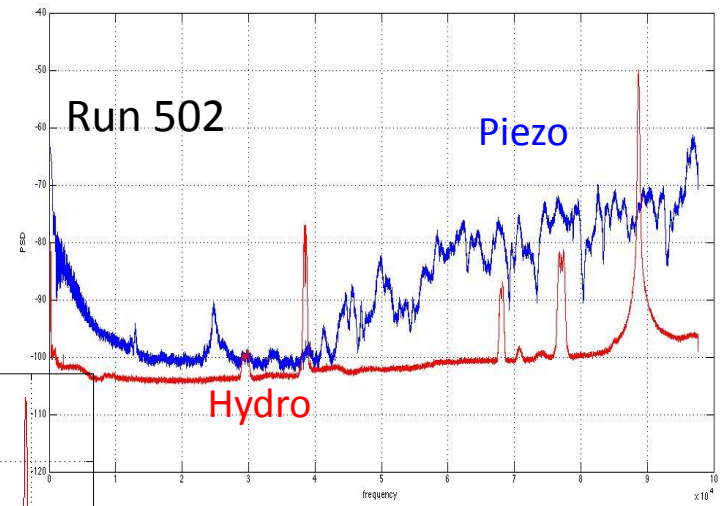
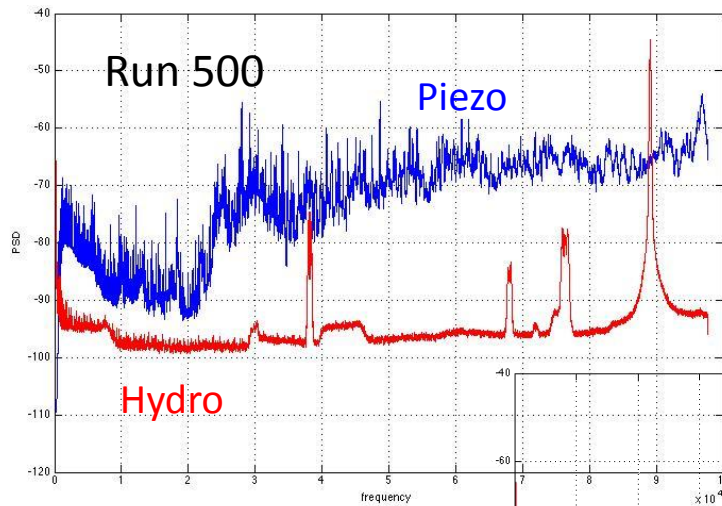
# CPPM Test 23 October 2012



Hydrophone – emitter distance = about 15 cm

Timing OK !

# Foselev Tests 20 November 2012



**Piezo is OFF! Only ADC noise recorded**  
**Log says piezo on**

- run 500 with PMTs ON
- run 502 PMTs not configured, piezo/hydro activated
- run 501 with PMTs + piezo/hydro + nanobeacon (at some intensity/frequency)

# Hydro and piezo on-board the NEMO-SMO Project

The acoustic positioning system technology for KM3NeT will be also tested in NEMO-SMO at 3600 m water depth (Capo Passero Site)

SMID - INFN acoustic sensors (6 floors + base): SMO detector

On floor 7: 2 FFR hydrophones (UPV-CPPM)

On floor 8: 2 ECAP piezos

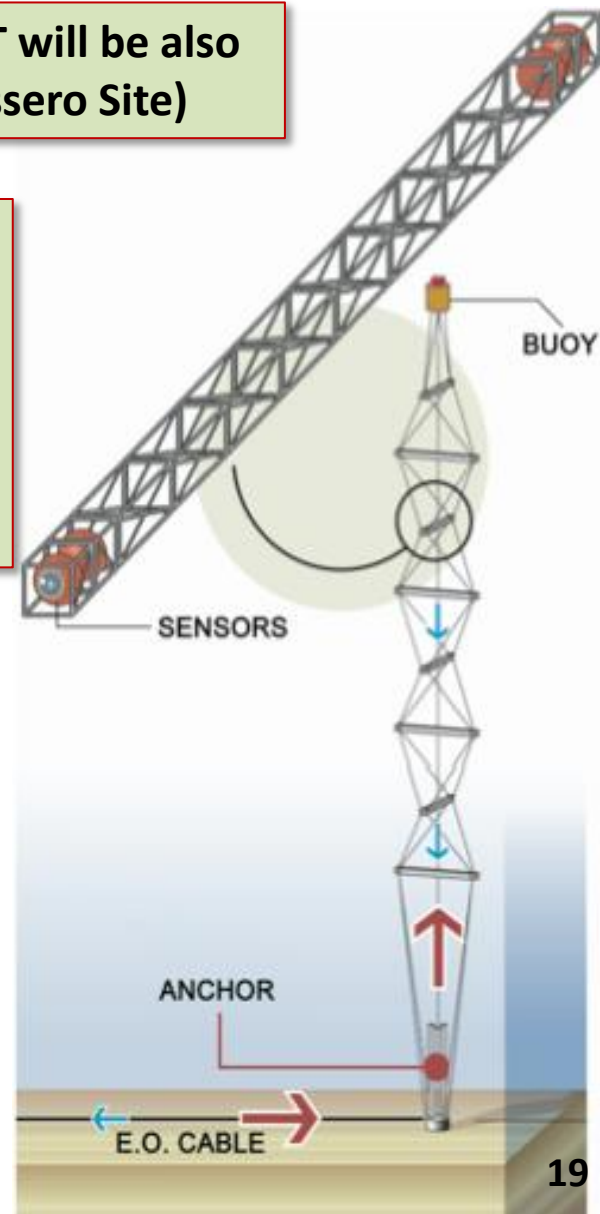
All sensors installed onboard the NEMO – Phase II tower



Shore Laboratory in Capo Passero harbour

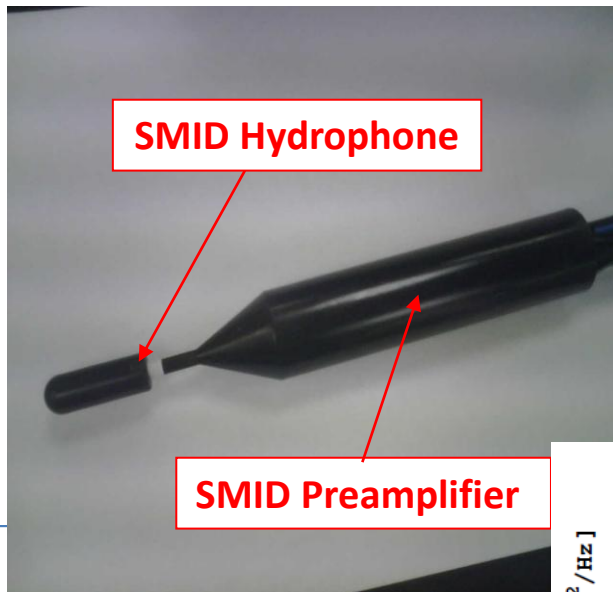


96 km  
20 optical fibres  
10 kV DC monopolar with sea return

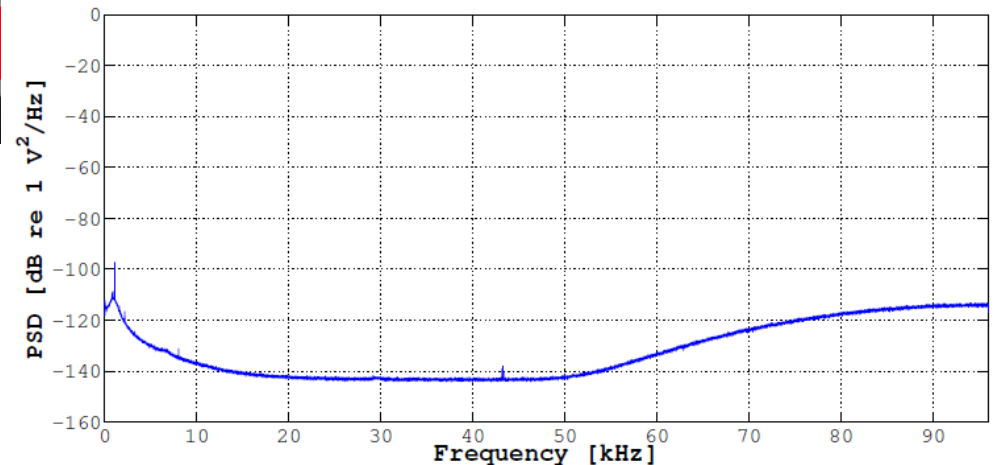


# NEMO-SMO sensors: SMID hydrophone

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



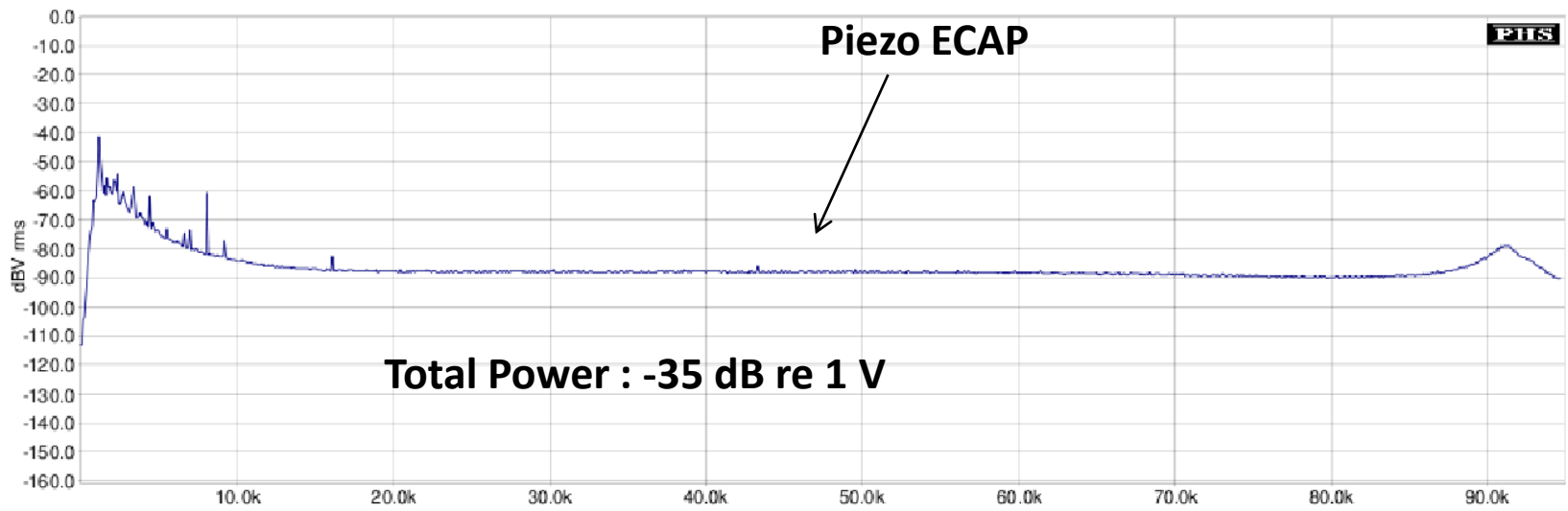
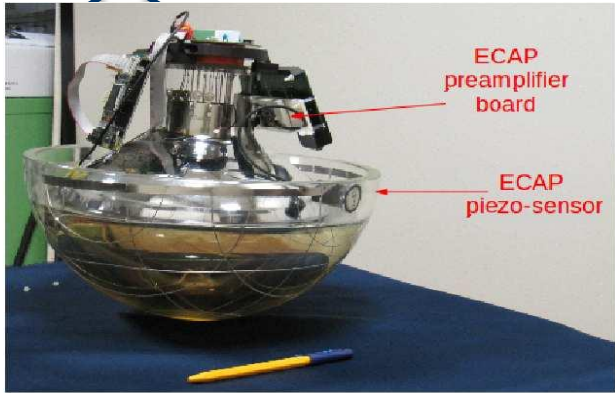
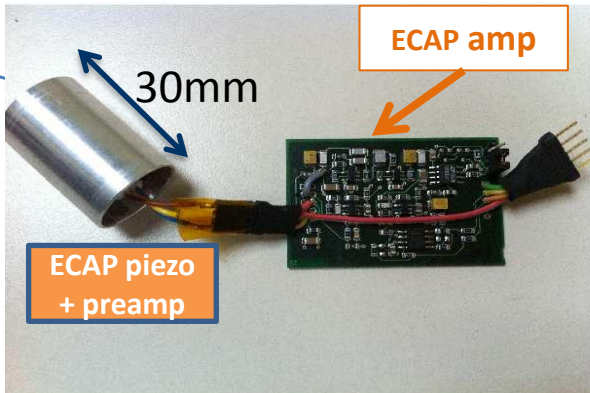
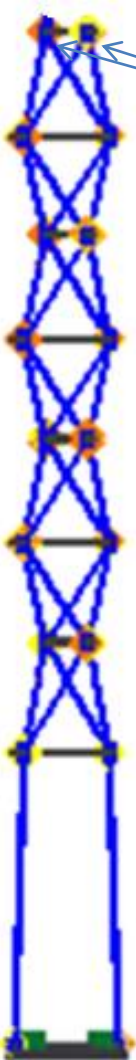
Total power: -72 dB re 1 V



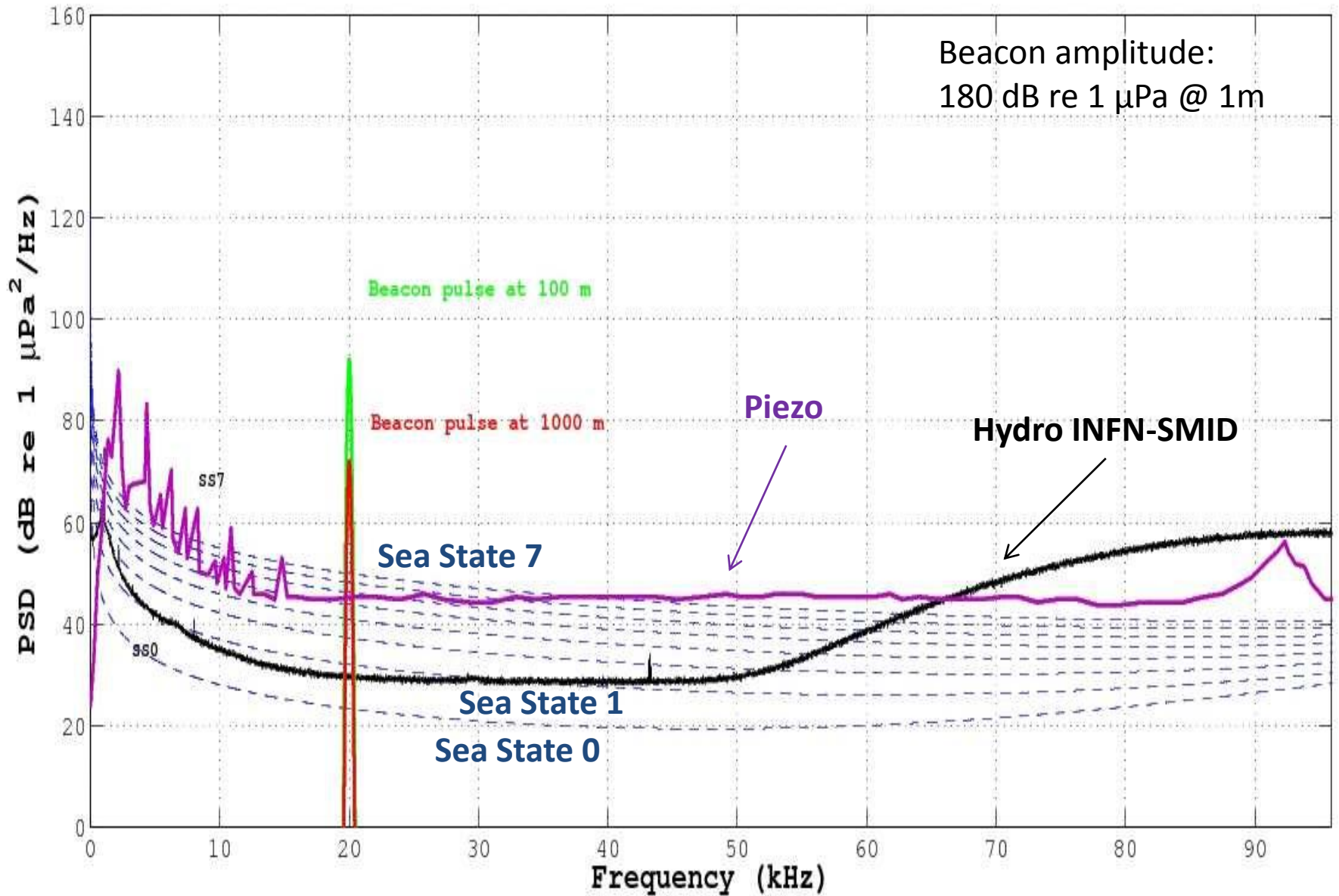


# NEMO-SMO sensors: SMID hydrophone

**Floor #8**  
**ECAP Piezo sensors + ECAP preamplifiers**



# NEMO-SMO sensors: SMID hydrophone



# Conclusions

**AcouPlug on-board PPM-DOM fully functional and compliant with DAQ**

**Three (+2 spare) AcouPlugs ready for PPM-DU (2 tested @ Saclay)**

**Results and improvements:**

**→ Read-out (after PPM-DU) new ADC under-test (low noise > 50 kHz)**

**→ Hydrophones: reliable technology**

**e.m. noise reduction: Guard ring implemented for PPM-DU hydros (...if any...!)**

**Low cost hydrophones under test for positioning + cetaceans (after PPM-DU)**

**→ Piezo: promising technology**

**Noise is too high: improve signal and power lines coupling (e.g. results in NEMO-Phase II)**

**Transfer function in deep sea not well known: DOM and Phase II will be test benches**

**→ Long Base Line: Missing**

**Must be installed. UPV and CPPM efforts in Km3NeT DS (but test only in NEMO- Phase II)**