Update on COUPP status and activities

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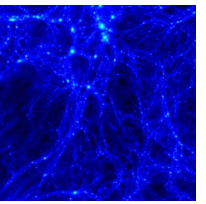
MultiDark
Multimessenger Approach
for Dark Matter Detection



Summary

- Coupp update.

- Acoustic activities at Gandia's lab.
  - Piezoelectric studies.
  - Multilayer model.

- Conclussions

Coupp update.

- Coupp 4kg (review).

  Installation in summer 2010

  First Physics run begins Nov.3, 2010 & second Physics run in 2012.

  Energy thresholds were;

  First physics run.

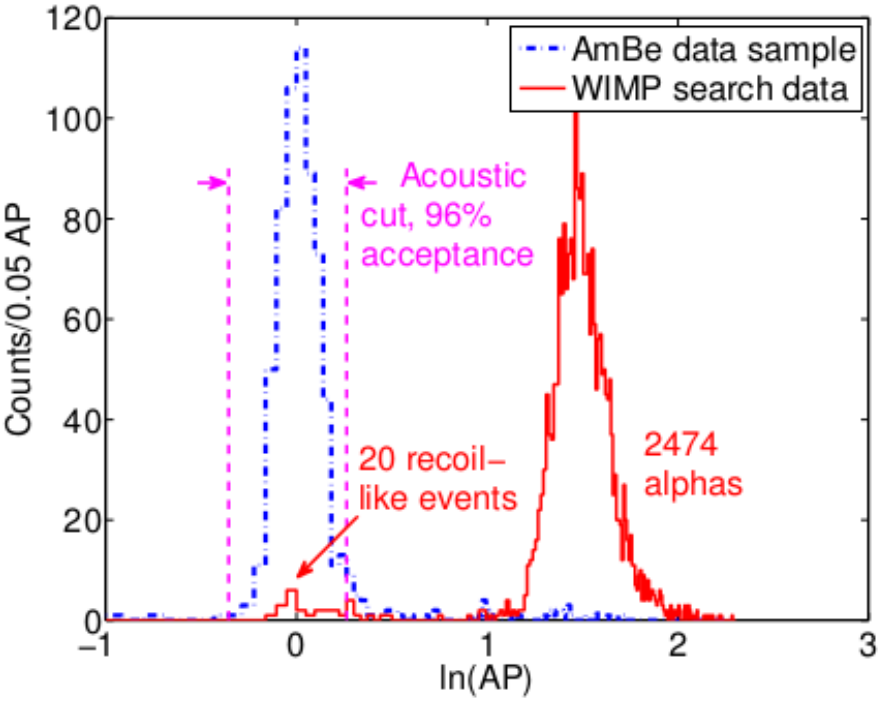
  8 KeV, 11 KeV & 15KeV

  → 20 events like Wimp.

  Second physics run.

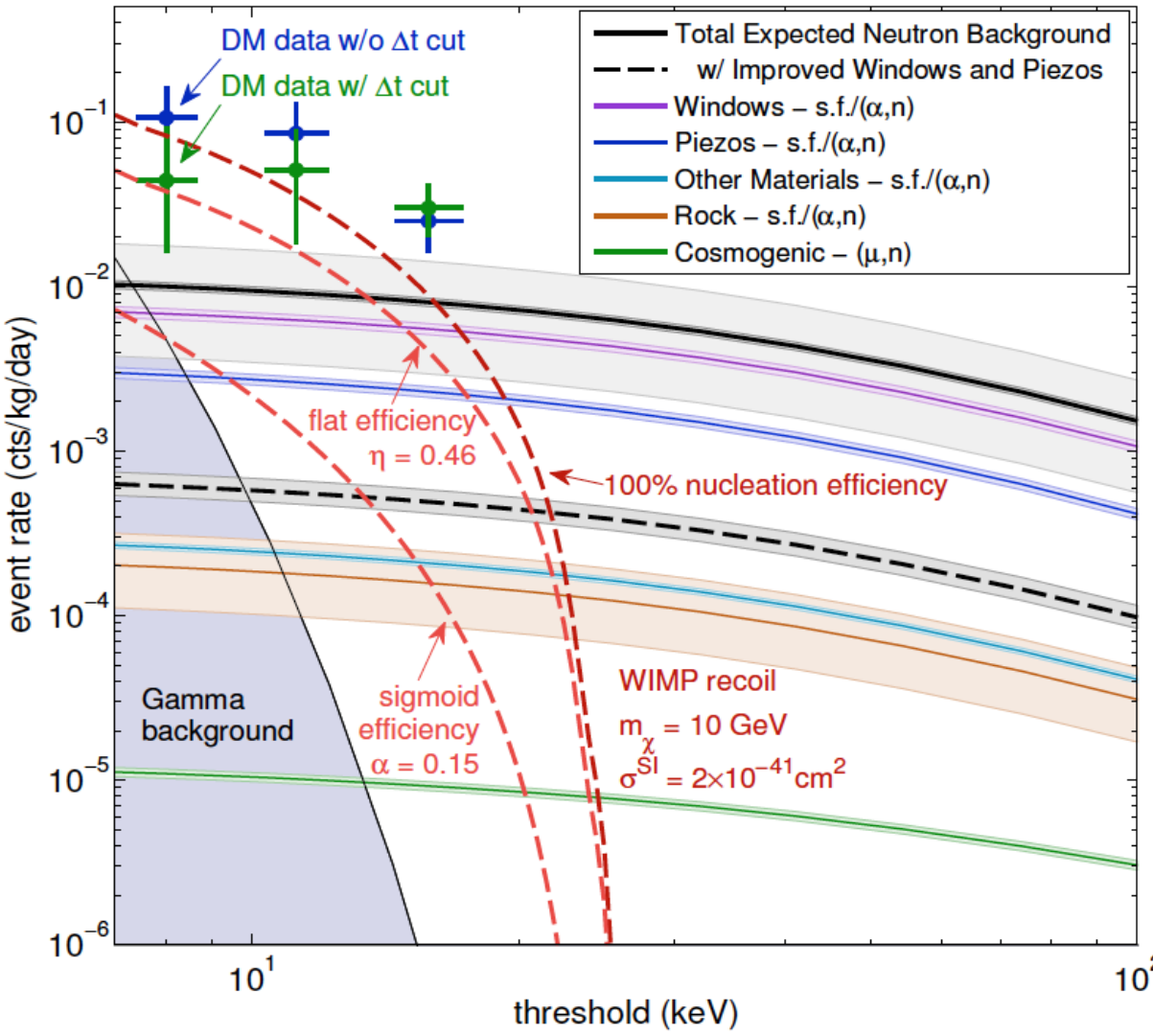
  8 singles events , 1 double,

  1 triple.



Was obtained an alpha rejection > 98.9% using the acoustic parameter.

Coupp update.



Results obtained during 553 days of exposur Coupp 4

Coupp update.

- PICO-2L:

  Pico 2L detector presents the same dimensions that Coupp 4 but in this case super heated liquid is C3F8.

  Improved SD and low-mass sensitivity ,
  (achievable: 3 keV)

Pressure vessel has been simplified reducing in ¼ the mass of steel used in comparison with COUPP-4.

Same Fused silica Quartz Jar that used in Coupp 4Kg.

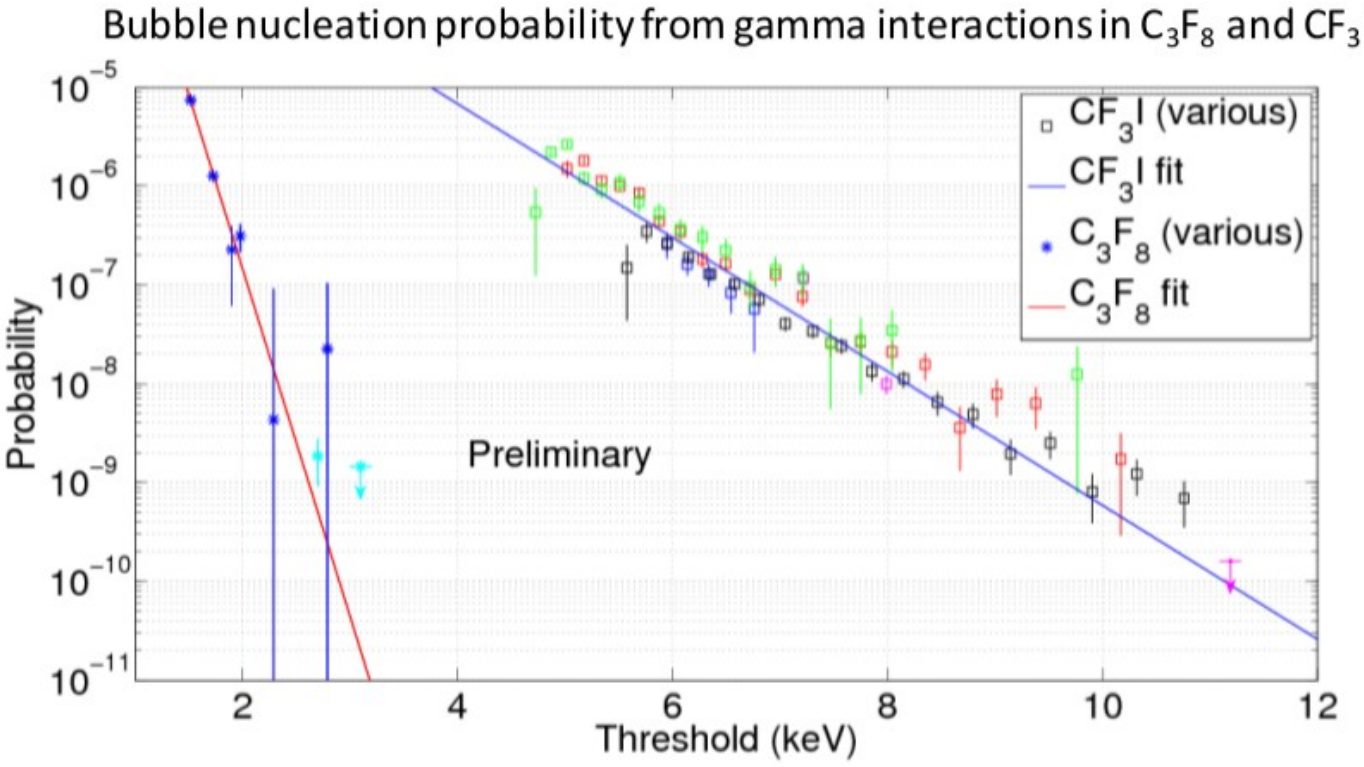
Coupp update.

PICO 2L is under neutron calibration period:

Monoenergetic neutron beams at Universite de Montreal.

Low energy Y/Be neutron source at University of Chicago.

In-situ Am/Be neutron source at SNOLAB.



Considering the C3F8 as a target material, seems that is possible achieve the factor 10^-10 for gamma rejection. Possibility of use lower threhold implies extend the sensitivity to lower mass of WIMP's.

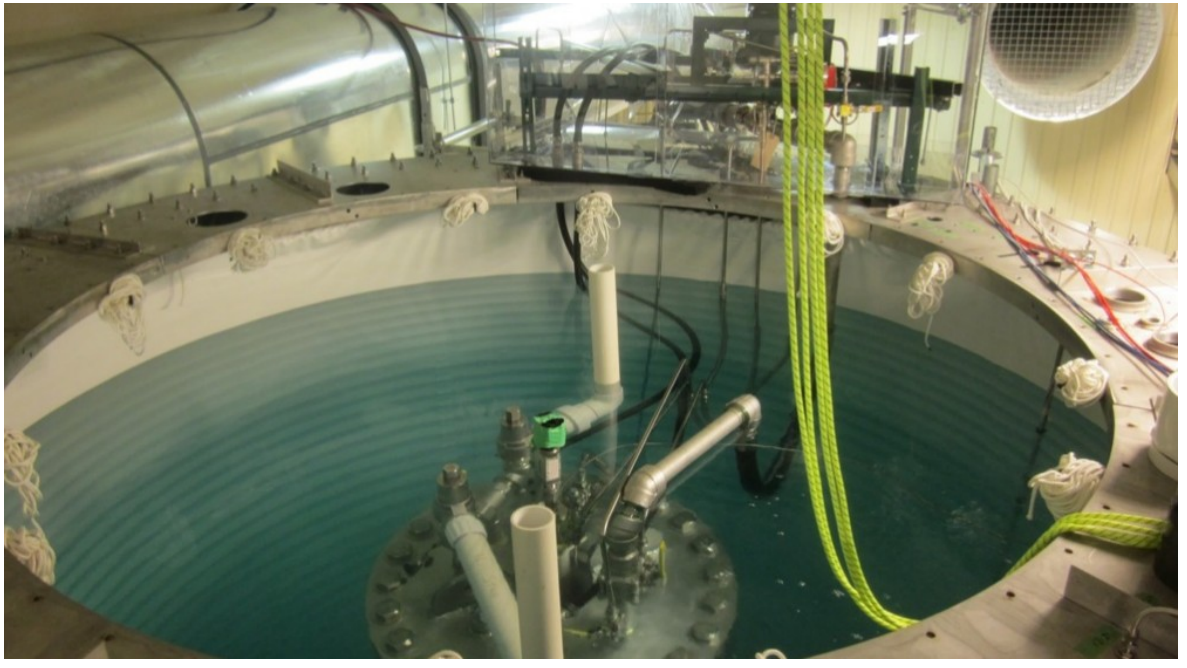
Coupp update.

- Coupp 60:

  Detector has CF3I as a target material (36.8 kg) and was filled completely in April 2013.

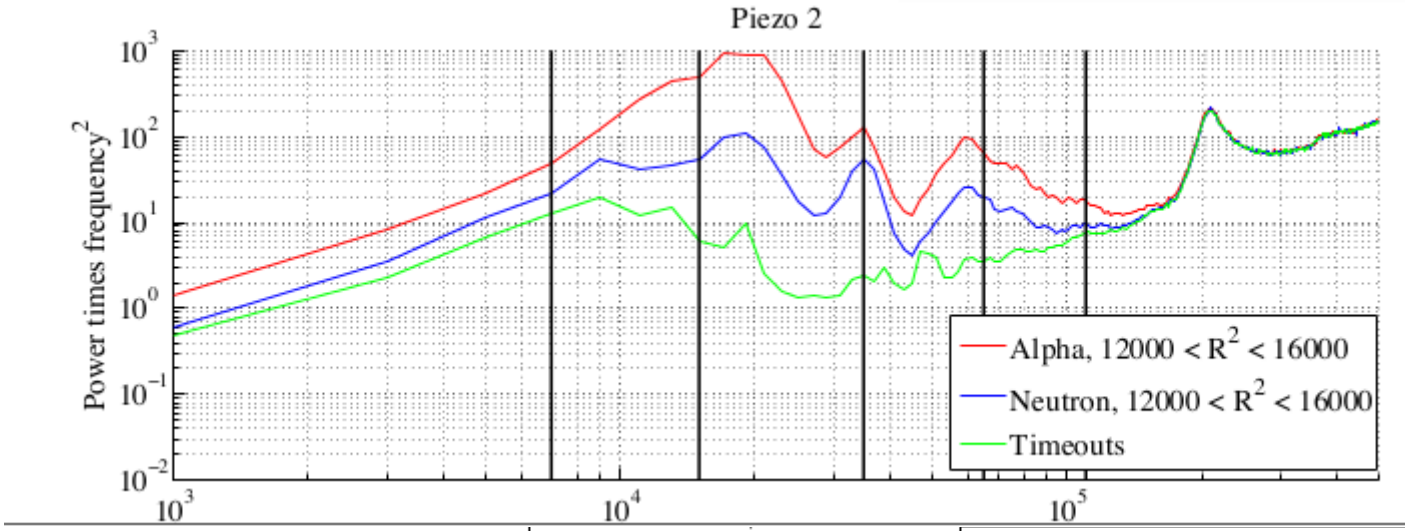
  Physics run started in June.

  Has been collected more than 1378 kg-day n dark matter search mode within the range from 10 KeV to 20 KeV.



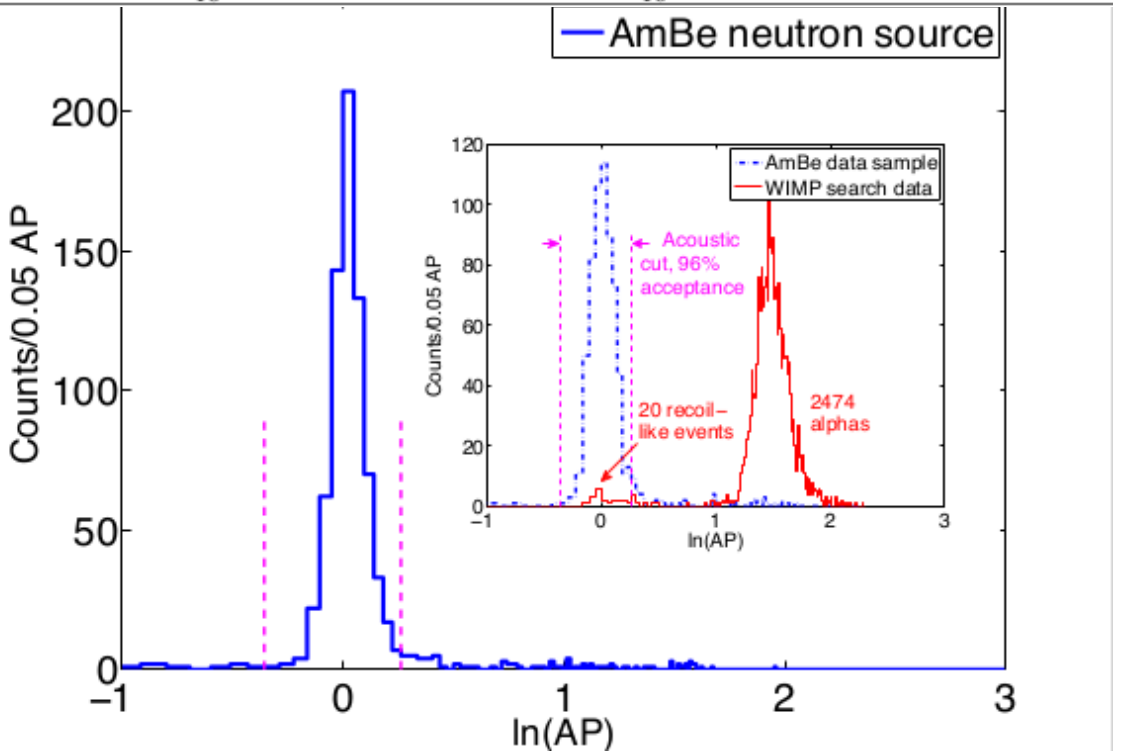
Coupp update.

Alpha interactions are louder than neutron interactions.

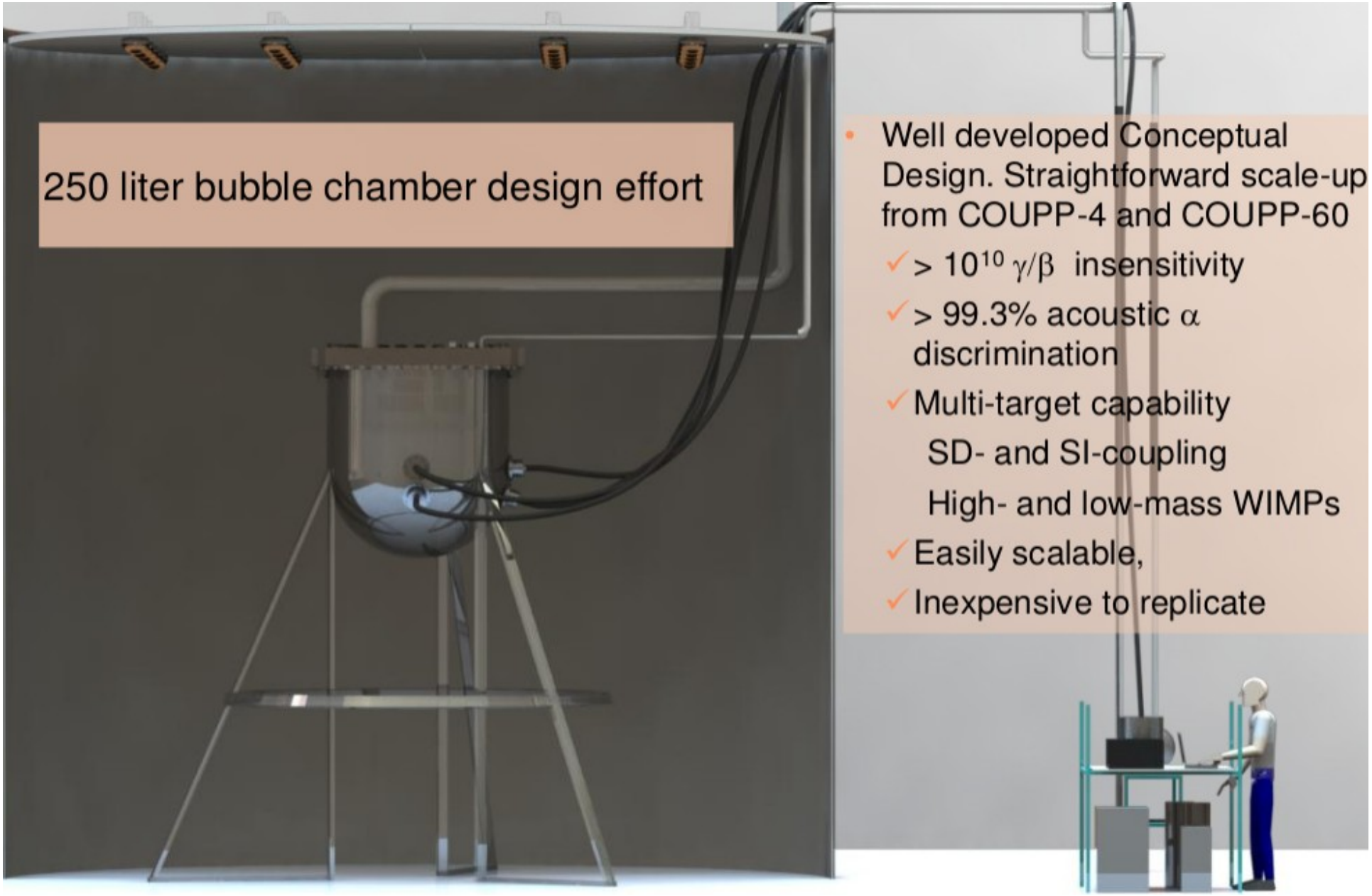


Acoustics still working well, achieving a very good discrimination.

Based on data obtained using calibration source seems that is achieved a narrower distribution in comparison with COUPP4.

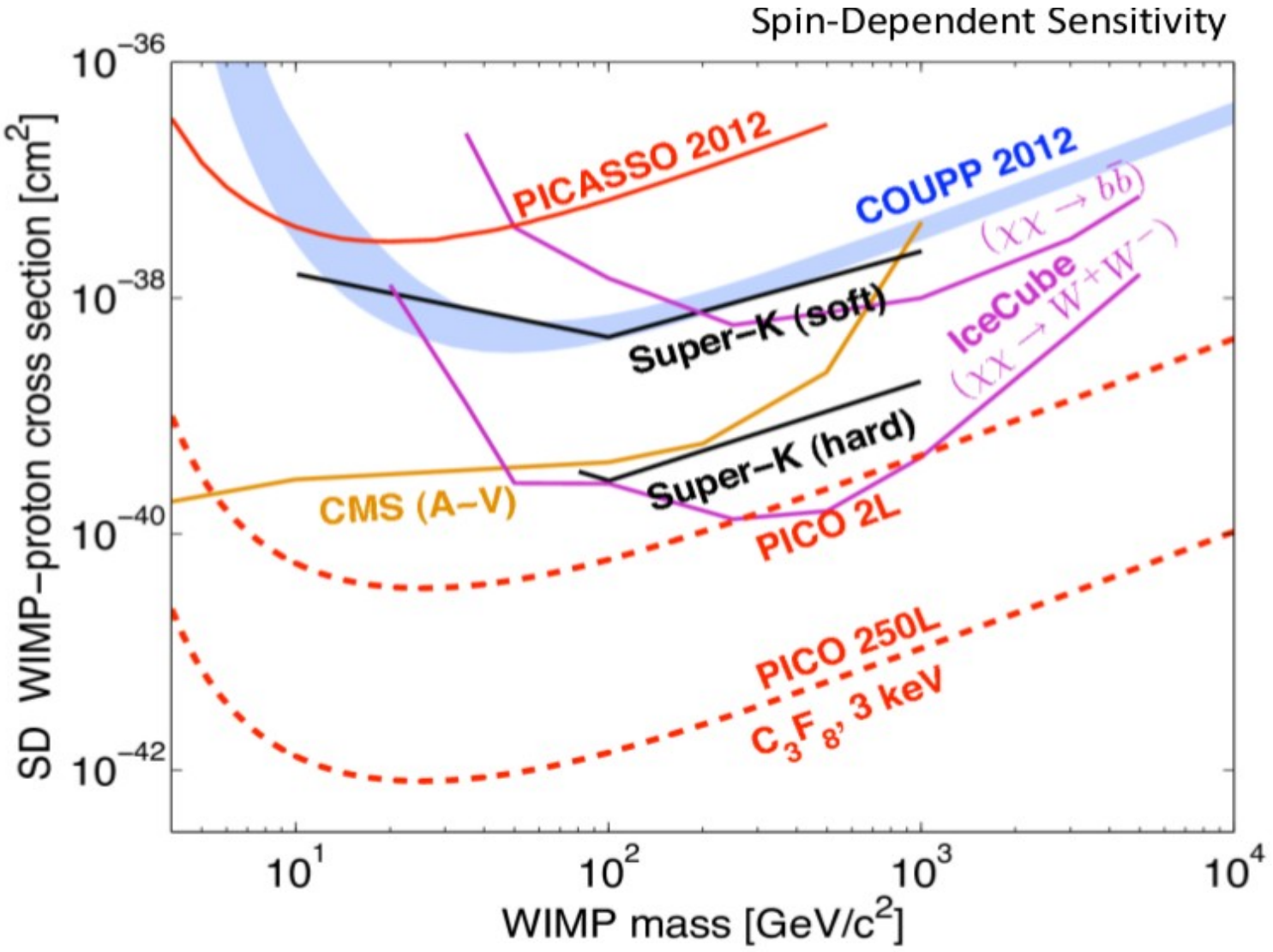


Coupp update.



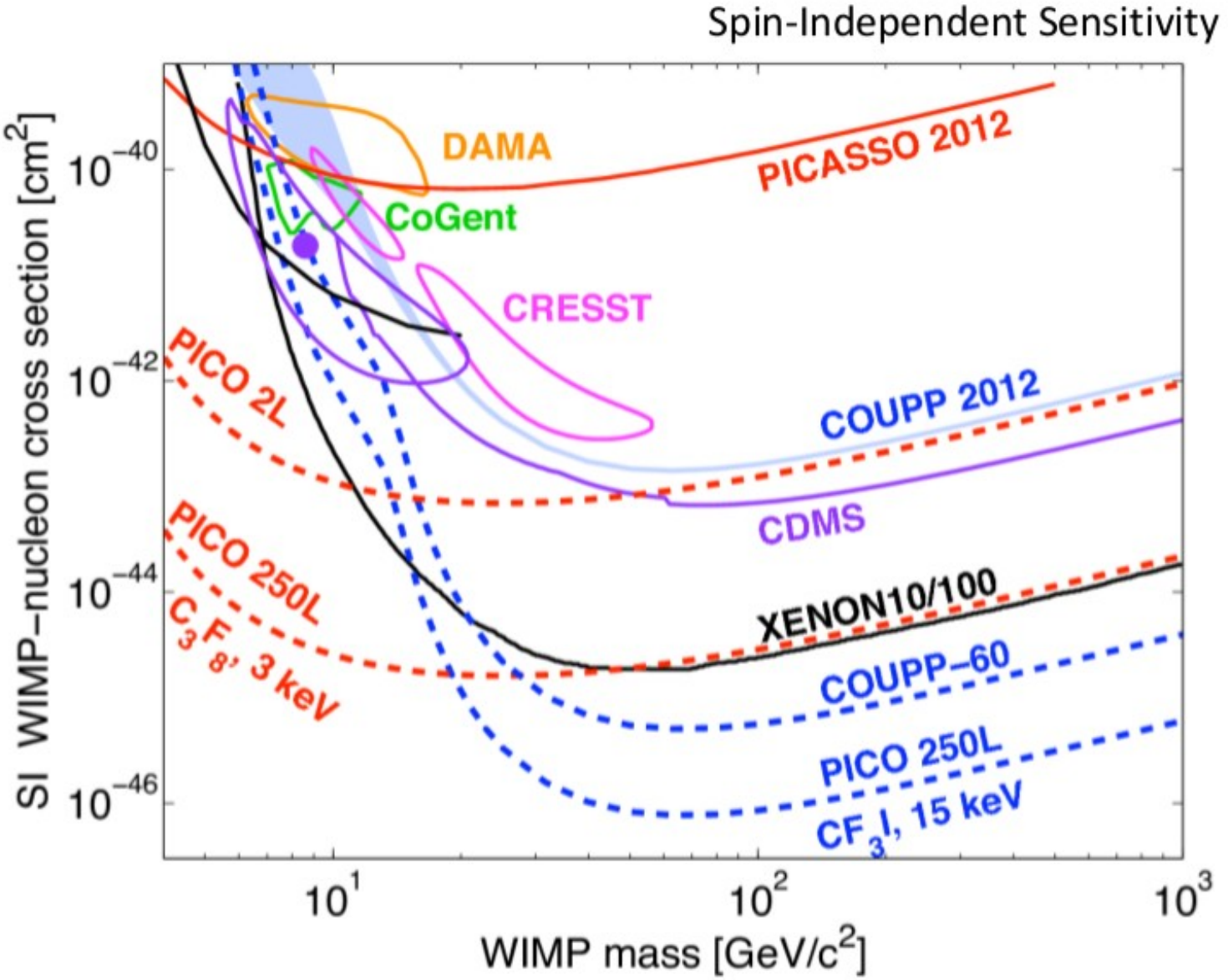
Coupp update.

Sensitivity.



Coupp update.

Sensitivity.



Coupp update.

- Physics run at SNOLAB completed for COUPP-4

  Results published in 2012

  Spin-dependent competitive limit achieved

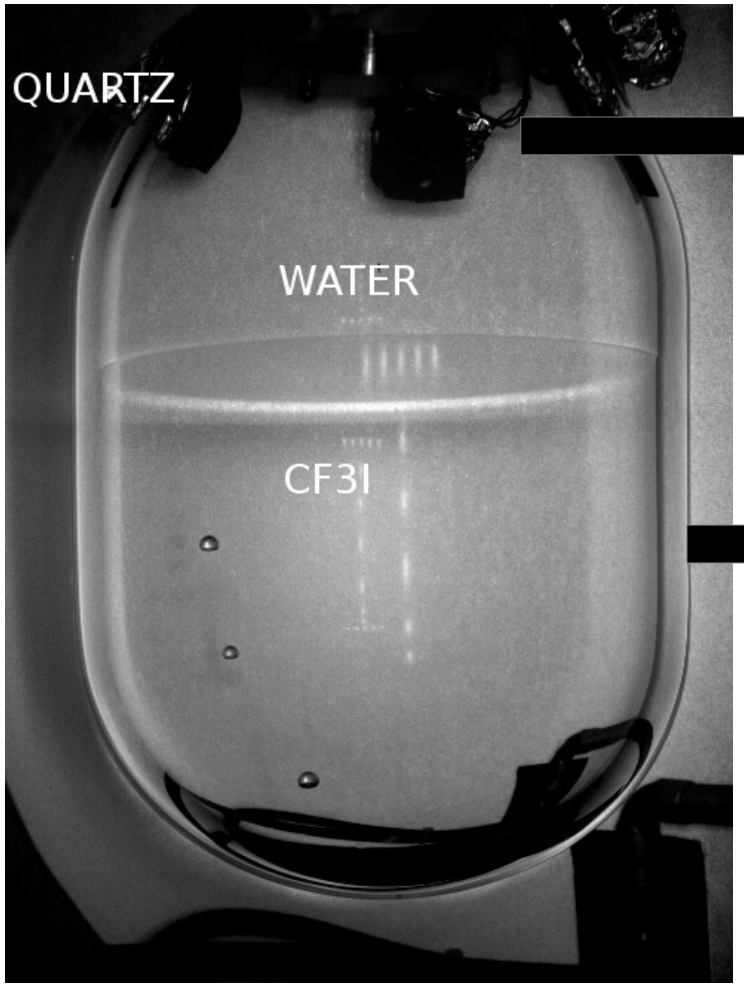
  Excellent acoustic alpha rejection: > 99%
- Growing Collaboration (PiCo): merged with PICASSO.
- COUPP family of detectors making huge improvements
- PICO-2L is the first experiment for the new PICO collaboration group,
- After few calibration processes, at this moment is taking data after being tested at ~ 4keV threhold.
- Future plans contain perform more calibration and try to decrease the threshold energy level.

Coupp update.

- COUPP-60 at SNOLAB: physics run going on (with 37kg)
- PiCO-250L is coming fast. At this moment the draft for the PICO 250L is under preparing / writting process.

Acoustic studies (Gandia's lab)

- Studies shown in this talk are related with:



- Characterization and improvement of piezo-electric transducers, using FEM simulation techniques (tested with experimental data obtained with a self made experimental setup).

- Transmission of sound phenomena through different layers, trying to study the influence of vessel wall dimensions on the spectral component of the received signal.

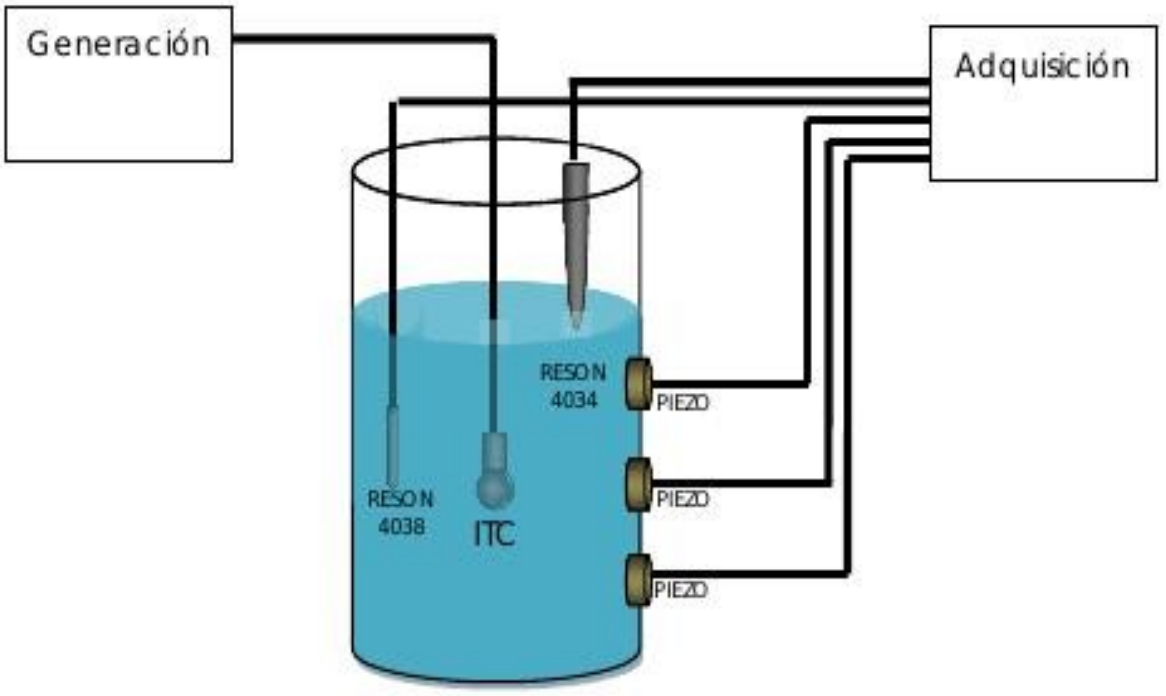
Piezoelectric studies.

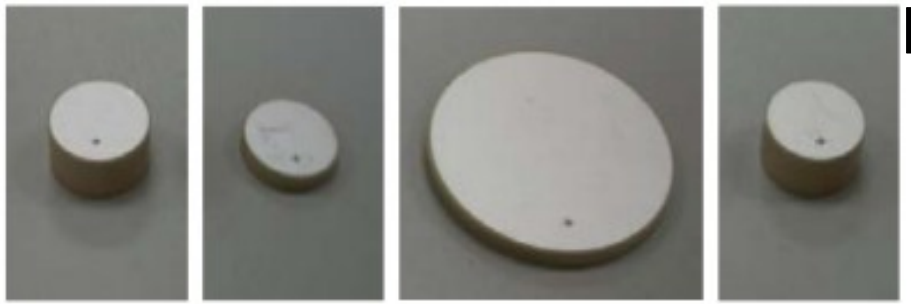
- As was presented in previous meetings, acoustic test bench has been buit at Gandia's lab.
- Principle aim;

  -Characterization of piezo-transducer.

  -Try to improve the sensitivity.

  -Propose a method to calibrate the transducer at Coupp experimental set-up.

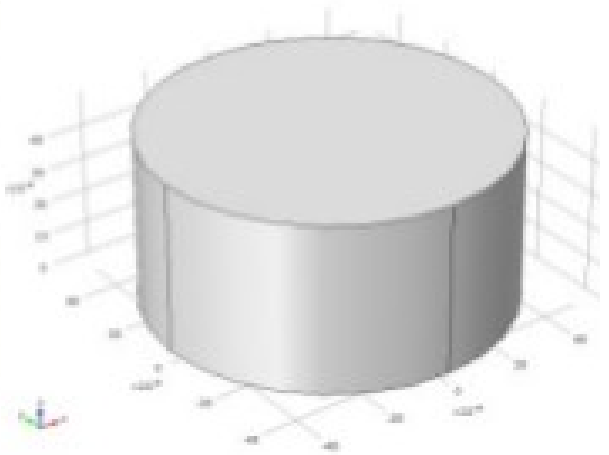




Different configurations of piezo-ceramics were purchased with the aim to validate the simulation model developed.

Piezoelectric studies.

- FEM model has been developed using Comsol multiphysics.



Simulation model implements the characteristics of piezo-ceramic disc (3D model) and solve the differential equations that relates the mechanical and electrical behaviour of transducer.

$$\vec{E} = -\nabla V$$

$$\varepsilon_S = \varepsilon_{0,vac} \cdot \varepsilon_{rS}$$

$$\varepsilon = \frac{1}{2}\left[\left(\vec{\nabla}\vec{u}\right)^T + \vec{\nabla}\vec{u}\right]$$

$$\vec{\sigma} = c_E / \varepsilon - e^T \cdot \vec{E}$$

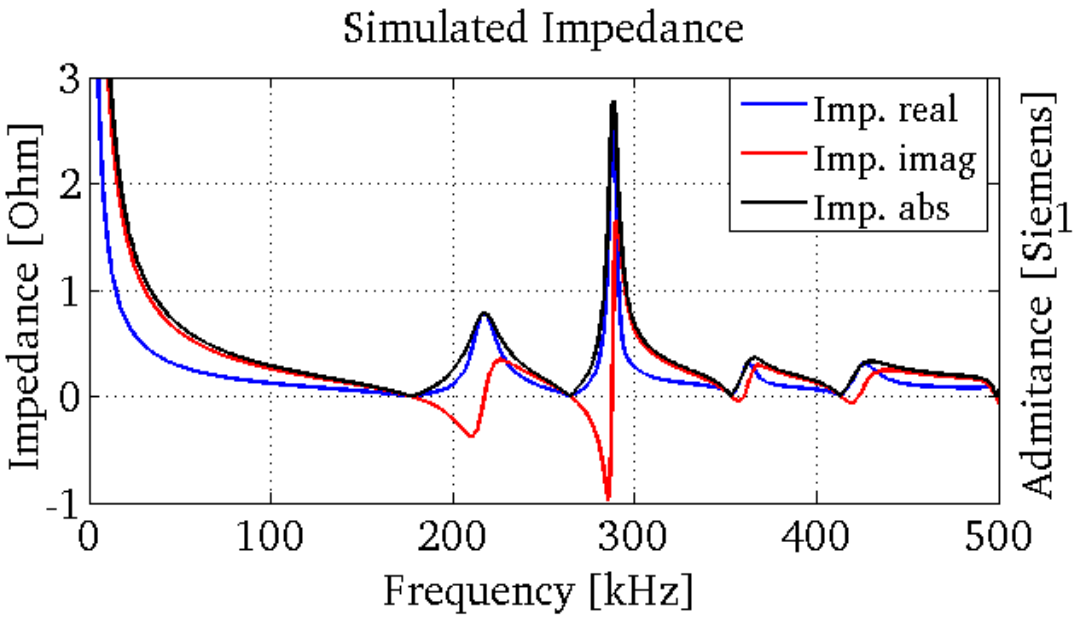
$$\vec{D} = e / \varepsilon + \varepsilon_S \cdot \vec{E}$$

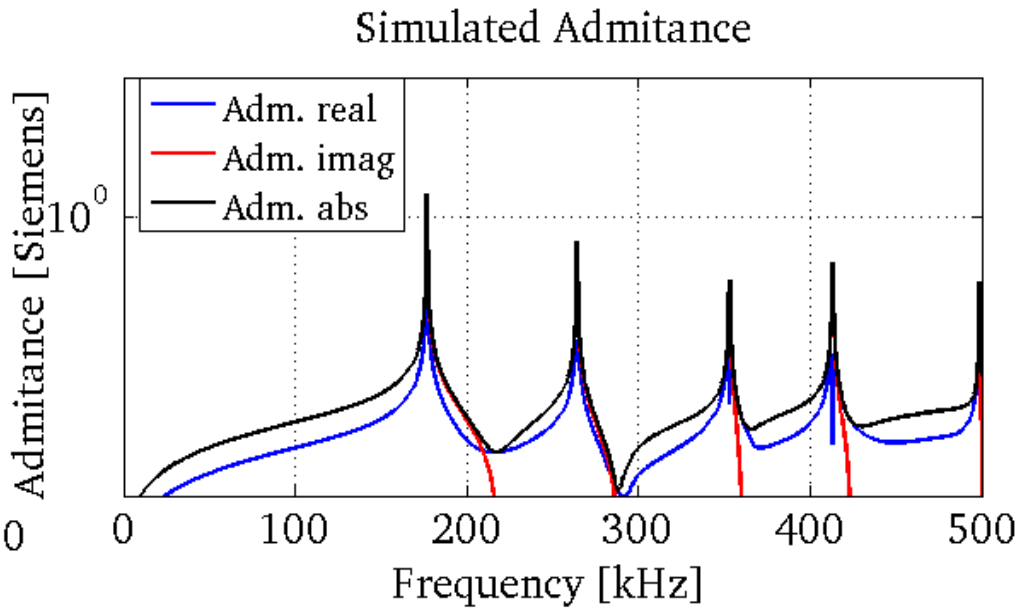
$$-\rho(2\pi f)^2 \vec{u} - \vec{\nabla}\cdot\vec{\sigma} = \vec{F}_v e^{i\phi}$$

$$\vec{\nabla}\cdot\left(\vec{D} + \vec{J}_i (i\omega)^{-1}\right) = 0$$

Piezoelectric studies.

- Simulation of piezocermic using FEM technique.





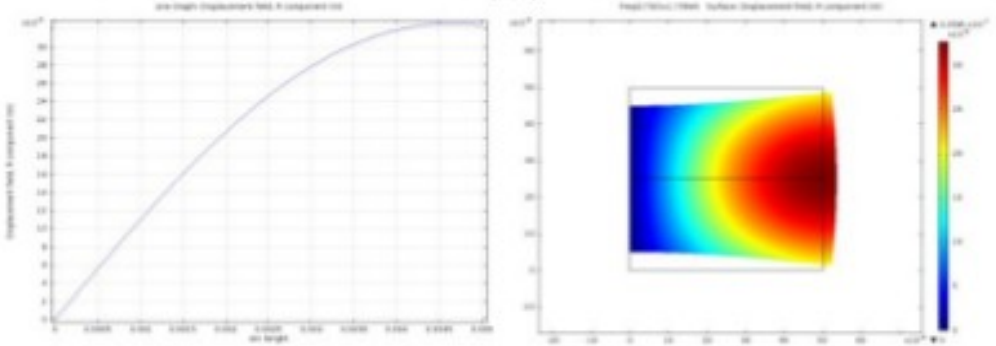
-Simulated Impedance and Admittance of piezo-ceramic disc (Pic ceramic 255, 5mm of diameter and 10 mm of thickness).

-Results obtained, must be validated by experimental measurements, of piezo characteristics.

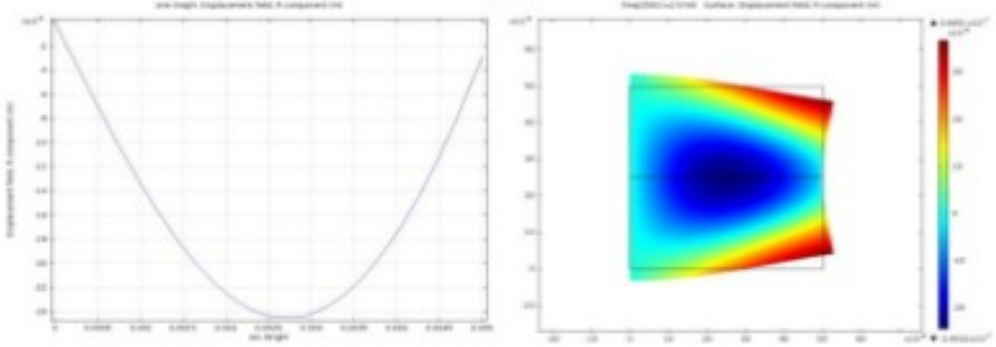
Piezoelectric studies.

Simulation can give us the displacement of the piezo for each harmonic, this is useful to discriminate between radial, longitudinal or combinated modes.

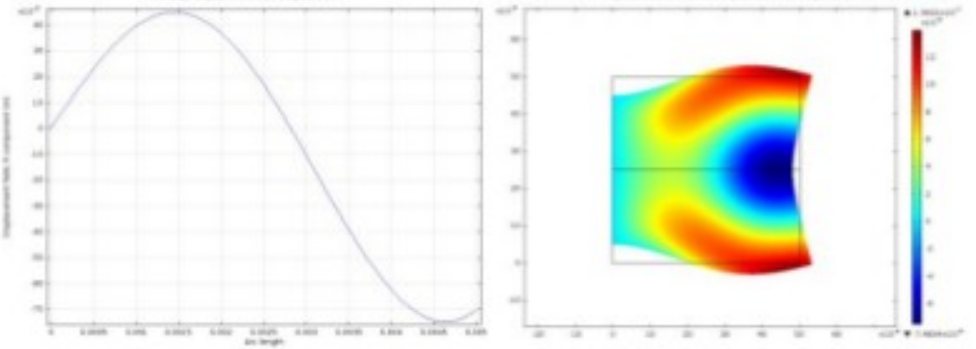
$f_{sim} = 176\ kHz\ (f_{exp} = 176\ kHz)$



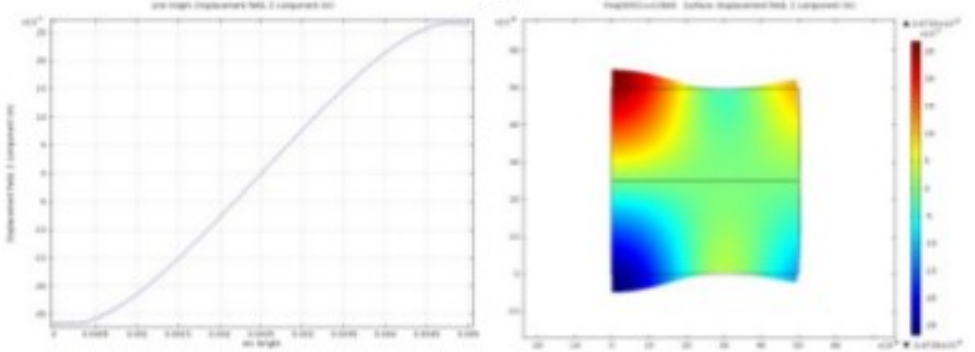
$f_{sim} = 265\ kHz\ (f_{exp} = 268\ kHz)$



$f_{sim} = 353\ kHz\ (f_{exp} = 352\ kHz)$



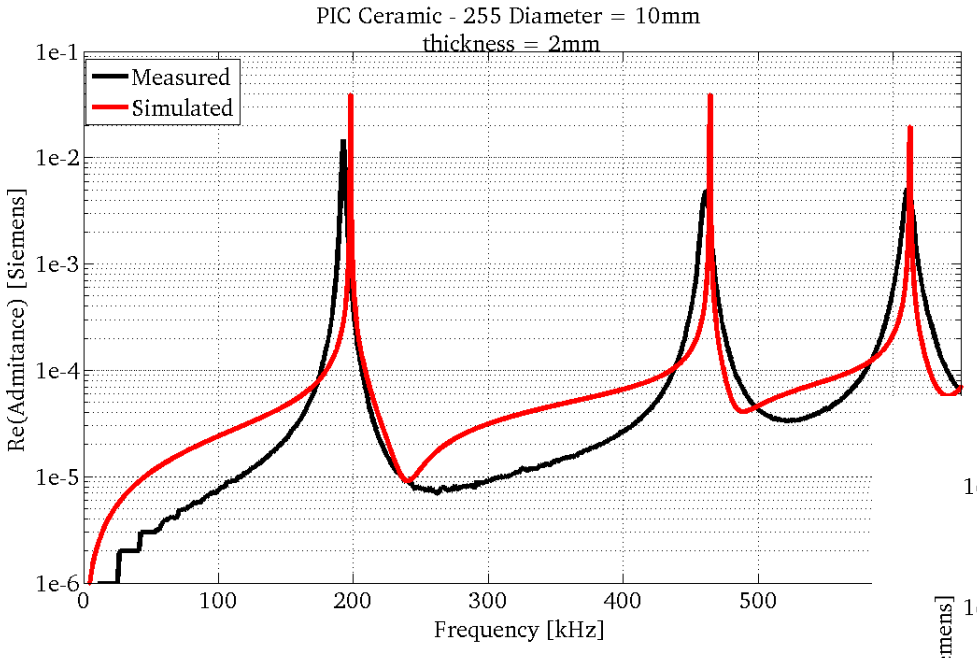
$f_{sim} = 413\ kHz\ (f_{exp} = 423\ kHz)$



Is possible to observe that first harmonic correspond to a radial mode, while the fourth harmonic obtained is related with longitudinal mode.

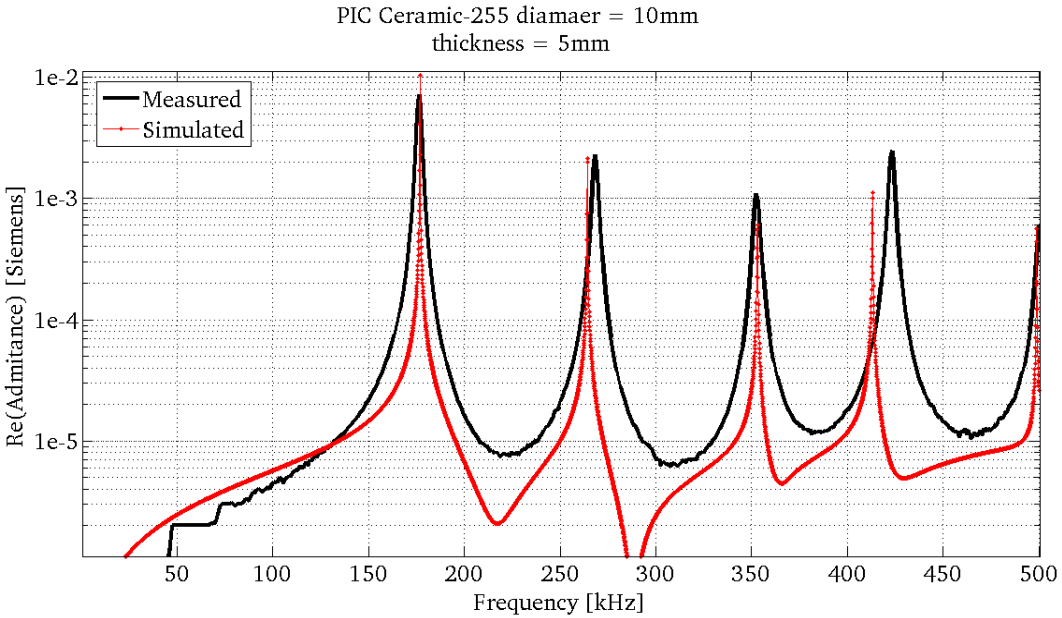
Piezoelectric studies.

- With the aim to validate the theoretical simulation, the behaviour of the piezo disc has been measured.



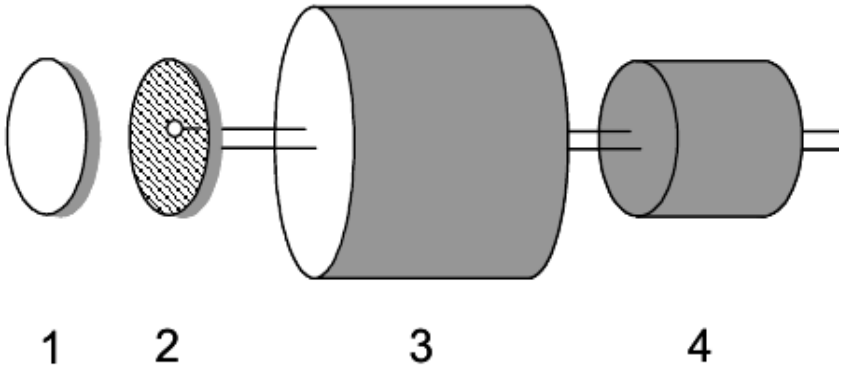
Were measured different configuration of piezo-disc.

Results obtained are in good agreement with simulations.



Piezoelectric studies.

- Second step is optimize the transmission between media and piezo transducer, with the aim to increse the sensitivity.



1. Matching layer (Head)

2. Piezo ceramic (active element)

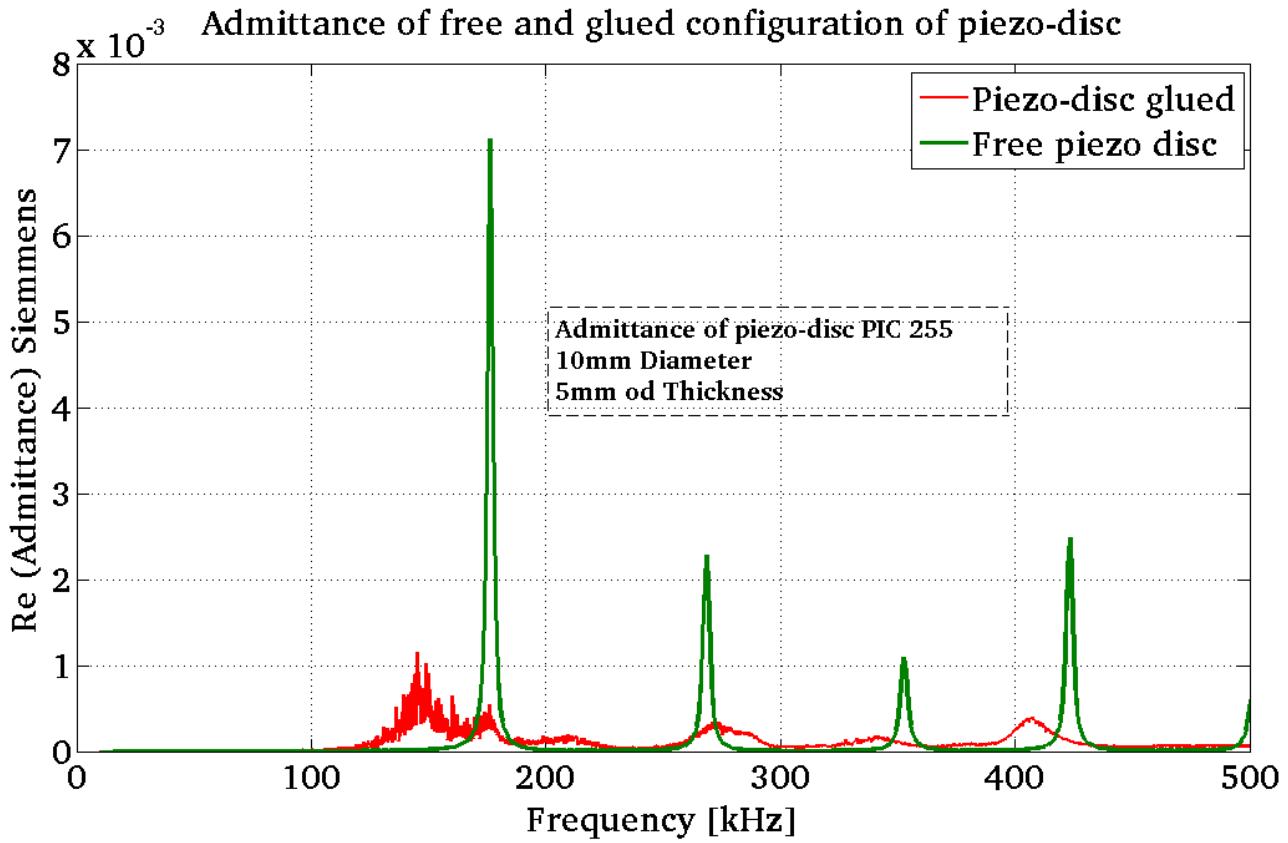
3. Casing

4. Backing

Couple the acoustic impedance between piezo ceramics and medium could increase the sensitivity of the transducer.

Piezoelectric studies.

- In previuos meetings were pointed the possibility of change the behavior of the piezo transducer when its attached at the wall vessel.



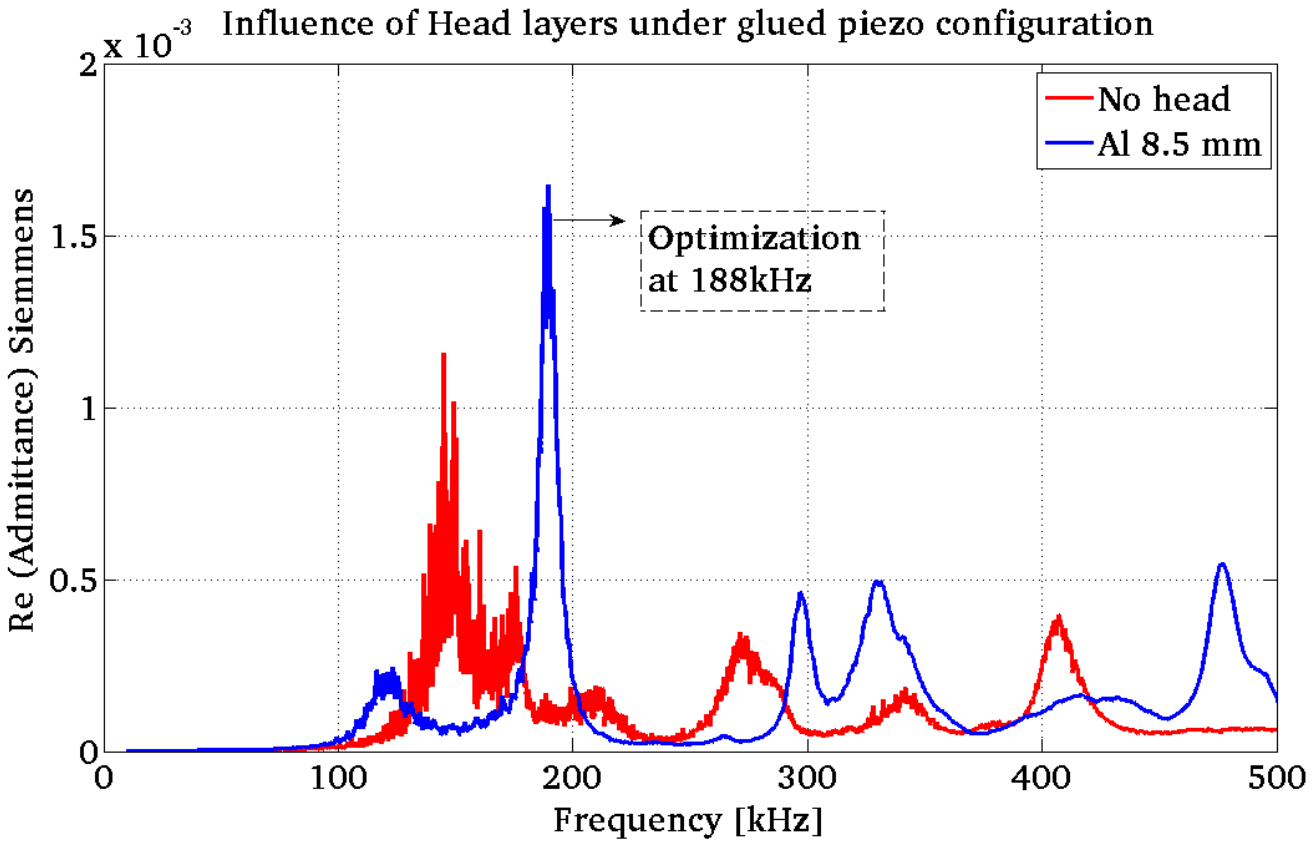
- Has been compared the admittance of the transducer in free and glued configuration.

- The spectral behavior of the transducer presents variation among this two configurations.

- Would be useful calibrate the transducer when its attached to the wall of the jar.

Piezoelectric studies.

- After characterize the piezo-transducer when is attached, next step would be try to improve the sound transmission between medium and piezo transducer, adding a matching layer.



- Has been added a matching layer of aluminum of 8.5 mm of thickness.

- Assuming that vibrates in $\lambda/4$ is expected that the admittance could increse at ~ 188 kHz.

- Experimental data is in good agreement with design proposed in this test.

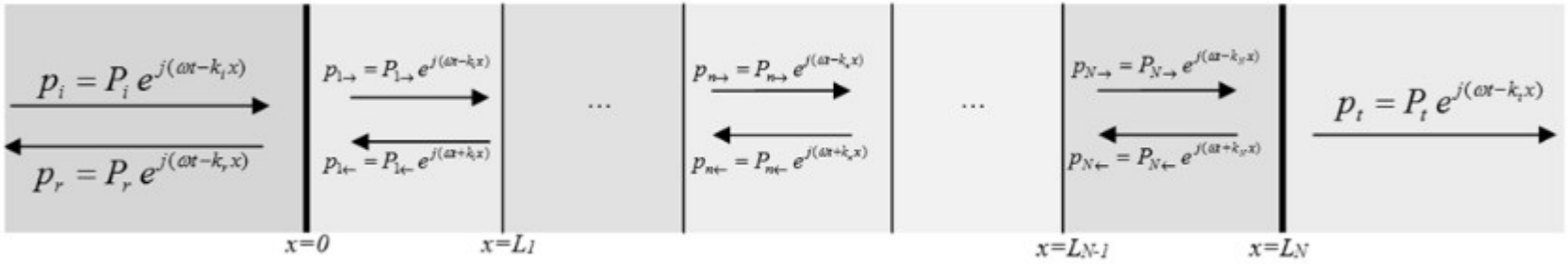
Multilayer model.

- In order to understand the properties of the acoustic signal received by the piezo-transducers, ts important study the travel of sound through different layer and its possible influence on the spectral component of the received signal .

- Has been developed a multilayer model that bring us the transmission and reflection coefficients, in function of frequency.

- One important aspect that can be studied is the influence of the jar wall, on the acoustic signal.

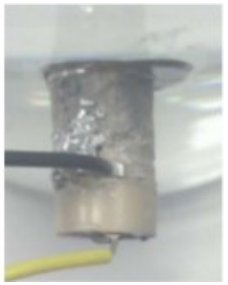
$$\frac{P_{n\rightarrow}}{P_{n\leftarrow}} = \frac{e^{2jk_nL_n}\left(e^{2jk_{n+1}L_n}\left(Z_{n+1}-Z_n\right)+\frac{P_{n+1\rightarrow}}{P_{n+1\leftarrow}}\left(Z_{n+1}+Z_n\right)\right)}{e^{2jk_{n+1}L_n}\left(Z_{n+1}+Z_n\right)+\frac{P_{n+1\rightarrow}}{P_{n+1\leftarrow}}\left(Z_{n+1}-Z_n\right)}$$

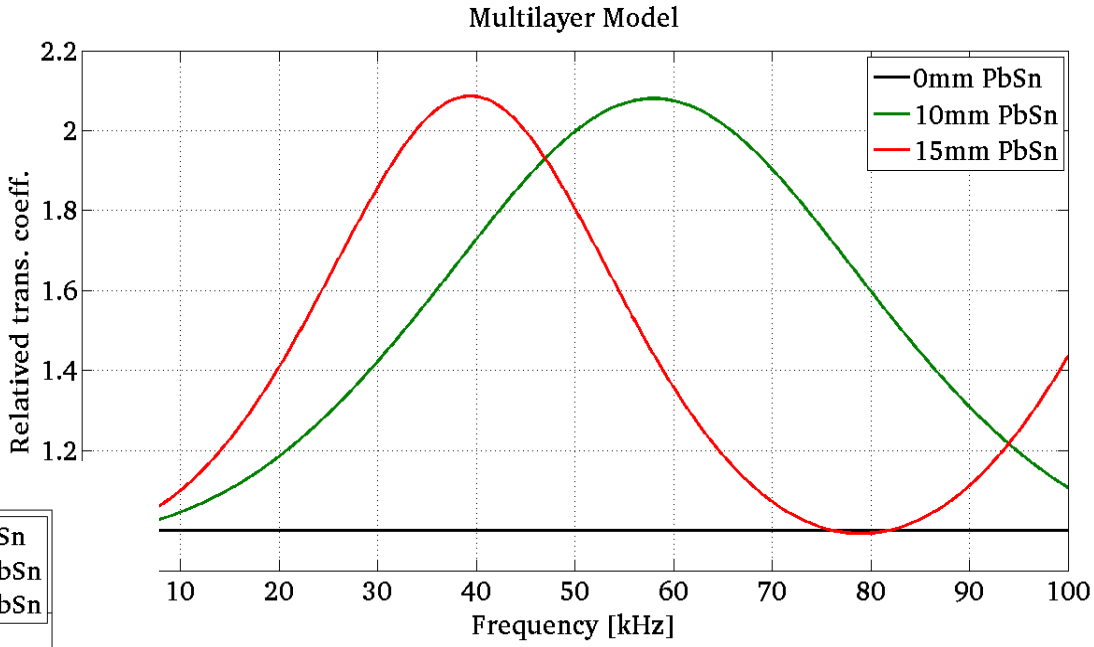


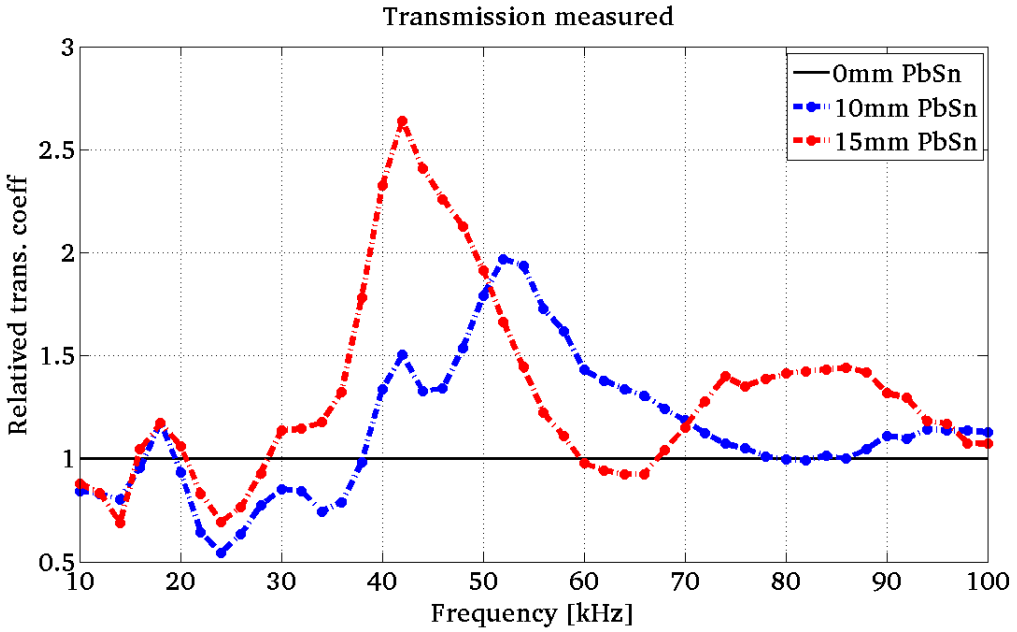
Multilayer model.

- To test the multilayer model, were built some experimental set up considering different kind of layers of different thickness.

Example of pyrex + pbSn layer 15mm + piezo-electric material.



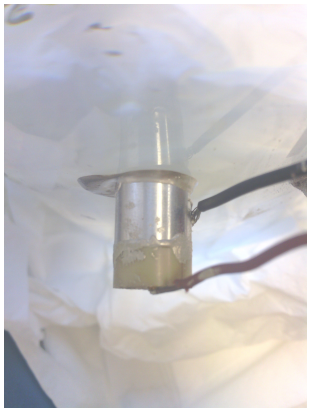


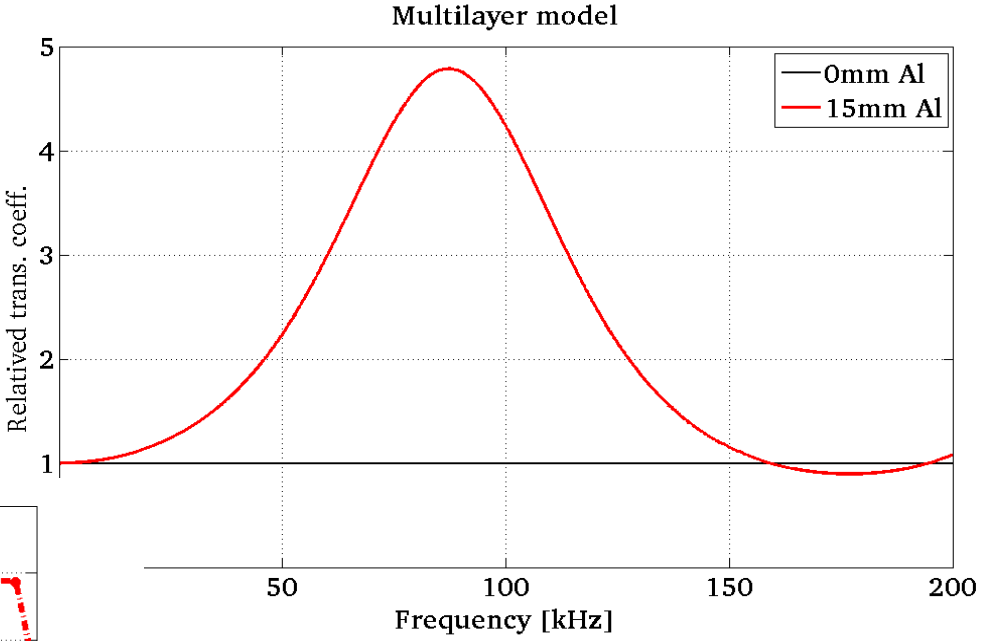


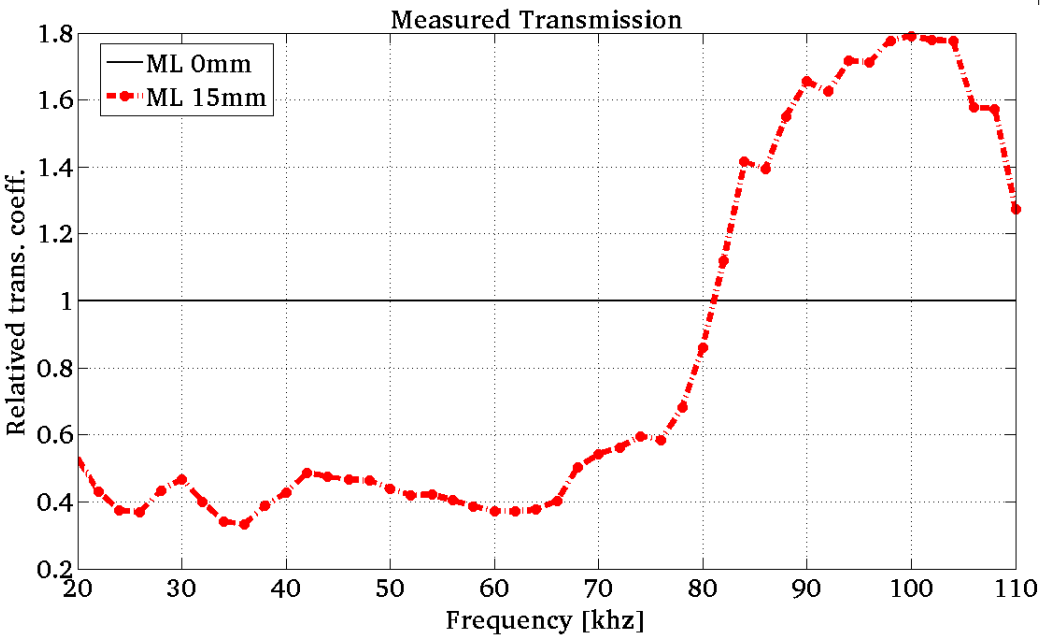
PbSn (mm)	Theoretical (kHz)	Measured (kHz)
15.0	56.0	52.0
10.0	40.0	42.0

Multilayer model.

Example of pyrex + Al layer 15mm + piezo-electric material.







Al (mm)	Theoretical (kHz)	Measured (kHz)
15.0	90	97

Conclusions

- Theoretical model for piezoelectric give a good agreement with measurements, is possible understand better the behavior and characterize the mode of vibration.
- Couple the impedance adding a matching layer could improve the sensitivity of piezo transducer, this can be important in a huge bubble chamber (Pico 250L).
- Multilayer model gives an idea of which spectral components are transmitted through the wall, the idea is take this and adapt the piezo transducer to work with the same frequency in order to improve the sensitivity of reception system.
- Couple the impedances conveniently at a frequency range of transmission through wall is maximum could improve the sensitivity of acoustic reception system (important for huge detector).

Conclusions

- All Coupp detector family is taking data at snolab (PICO 2L, COUPP 60) or under draft proposal writting process. Results, analysis and future built process for PICO 250L are coming stay tuned!!.