Acoustic studies for alpha background rejection in dark matter bubble chamber detectors

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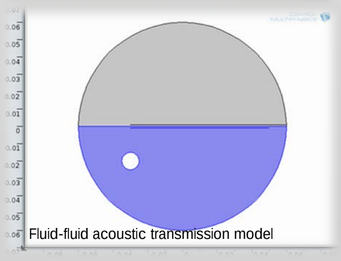
COUPP

Chicagoland Observatory for Underground Particle Physics employs bubble chambers to detect WIMP–nucleus interactions. Acoustic techniques have been successfully used in order to reduce alpha background. This panel presents our studies to better understand acoustic signal generation, propagation and detection in bubble chambers. The simulation tools developed and the acoustic test bench under development to validate the tools are also described. The aim of the studies is optimizing acoustic systems and analysis techniques for the next generation 500 kg bubble chamber.

Acoustic Test Bench

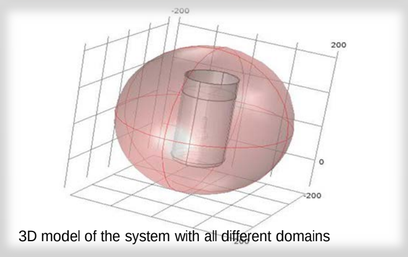
Image of the automation system


Fluid-fluid acoustic transmission model

Finite element and analytical methods are used to understand the acoustic propagation and transmission in the mediums that compose the COUPP bubble chamber (water, cf3i, quartz). Several signals like tones, sweeps, mls, squares and pulses have been used to understand its behavior over the whole frequency range of interest (from 0 Hz to 200 kHz).

The results are compared with a experimental setup made of a vessel full of fluid that is excited by a spherical ITC transducer. Where the acoustic signal emitted is recorded by an RESON TC4038 hydrophone.


Image of the vessel, emitter and hidrophone

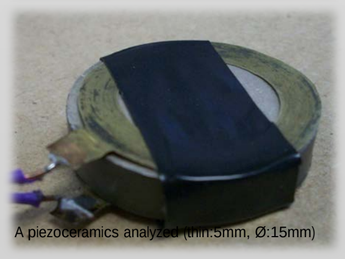

3D model of the system with all different domains

Moreover, these techniques are used to define the impedance of different PZ piezoceramic types and sizes both free and glued in some positions on the external quartz vessel surface.

The results are compared to more complex numerical simulations to study both acoustical processes and electro-mechanical features of the ceramics.

This is a first approximation analyzing the different piezoceramics feasibility as detectors and a way of validate our simulation tools.


Image of the vessel and glued piezoceramic

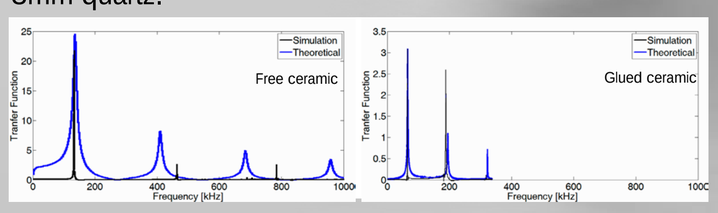

A piezoceramics analyzed (thin.5mm, Ø:15mm)

The next step is comparing simulation results from a numerical model of the COUPP bubble chamber with experimental data of its runs received. Firstly the behavior of the simulated chamber when is excited by different bubble sizes an with different types of signals is studied. The aim of this is knowing the possible eigenmodes of the vessel. Secondly the pressure rise within the chamber and the signal received by the ceramics in different position along the vessel surface is studied in order to search the best position and optimize the type of piezoelectrics.

Results

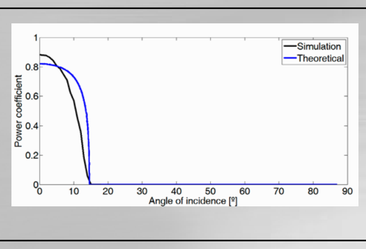
Piezoelectric sensors

Comparison between the impedance of PZ 27 ceramic (thickness: 8,7mm, radius: 8mm) as free as glued to a 3mm quartz.



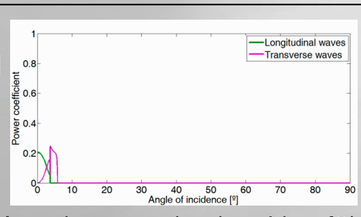
Water

Power transmission coeff. for cf3i-water (fluid – fluid interaction).

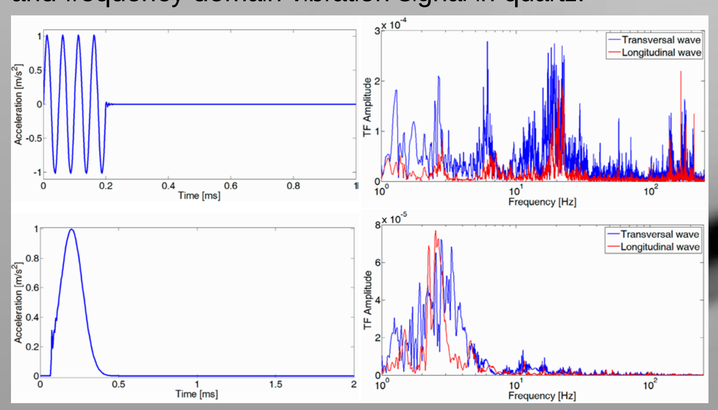


Fused silica quartz

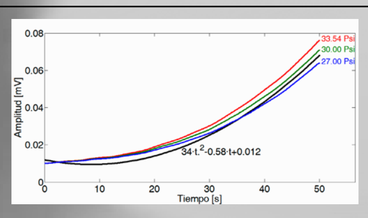
Power transmission coeff. cf3i-quartz (fluid – solid interface).



Relationship between time domain acoustic signal in cf3i and frequency domain vibration signal in quartz:

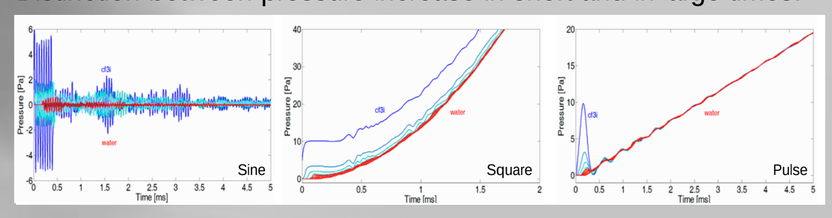


Pressure detectors

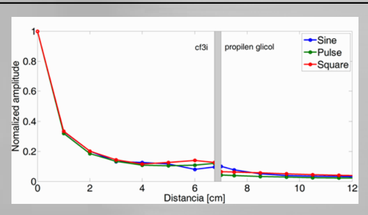


Pressure increase within the chamber for a pulse excitation in contrast with average pressure increase due an experimental event. Dependency of temperature.

Distinction between pressure increase in short and in large times:



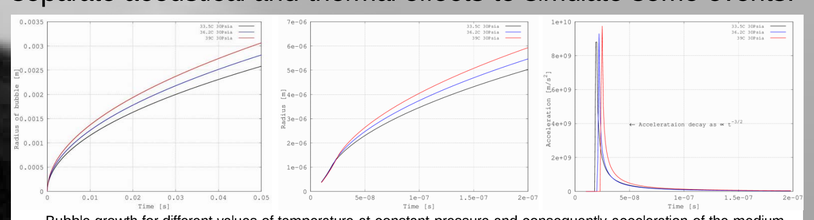
CF_3I



Propagation of different type of signals within the vessel and through the wall of quartz.

Acoustic emission of bubble

Some acoustic signals (sine, sweep, mls, square, pulse) are used to test the behavior of the system in a large range of situations. However, the acoustic signal due to the bubble growth is well known (Mikic's model). By this relationship we can simulate separate acoustical and thermal effects to simulate some events:



Bubble growth for different values of temperature at constant pressure and consequently acceleration of the medium.

Future work

- Study the coupling of acoustic and piezoelectric models in the same numerical model.
- Expand these estudies to complet 3D numercial