Background Reduction in COUPP using Acoustic Sensors

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Fermilab PPD COUPP R&D Project Review
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IUSB Astroparticle Experimenters

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Chemistry + Physics

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BS Physics

Josh Behnke
BS Physics (Purdue)

S. Rey Brandt
Education

William Feighery
(already discovered dark matter)

Eric Greiner
Physics

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Physics (Cornell)

Ilan Levine
Assoc. Professor of Physics

Cynthia Muthusi
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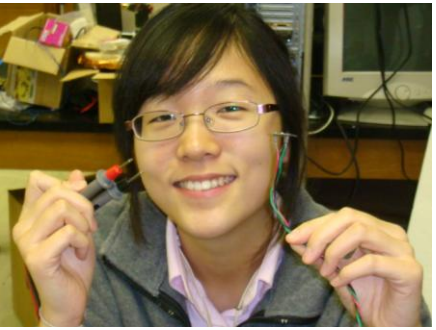
Earl Neeley Biochemistry



In Young Park
Marian HS

Tina Shepherd
BS Chemistry

Naomi Tankersley
BA Political Science

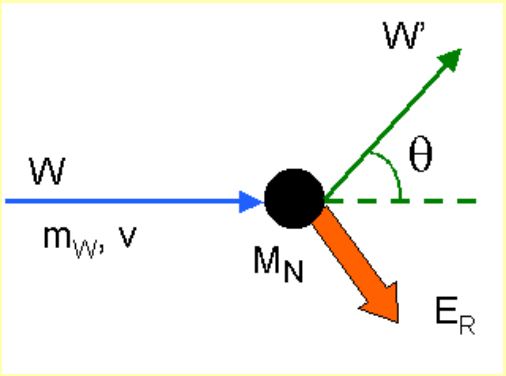
Nate Vander Werf (L)Physics.
Eric Abarbannel (R) History.

COUPP Detector Principle

Direct Detection

Elastic scatter of WIMP and target nucleus.

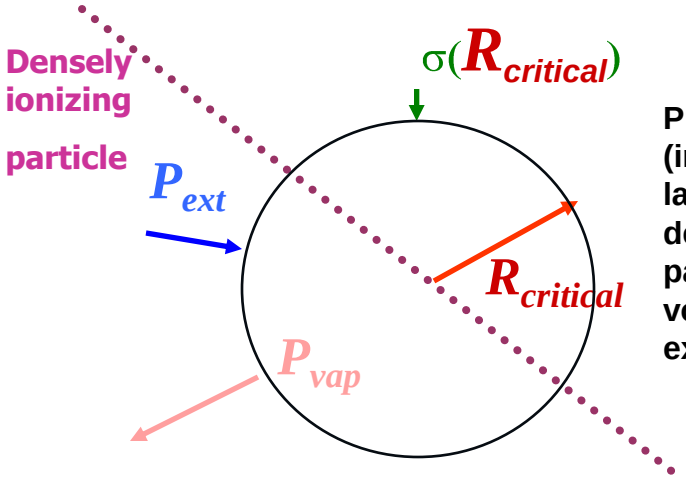
CDMS, XENON, DAMA, PICASSO, COUPP etc…



Recoiling nucleus has energy in range ~1 to 100keV.

Use some amplification trick…

Fluids can be maintained in liquid phase even above normal boiling temperature! No nucleation *sites* →no phase transition until higher temperature. Liquid in "Superheated" state.



Provide a large enough void (impurity, rough surfaces, or large enough energy deposition by a charged particle in a small enough volume) → P_{vapour} wins → explosive boiling!

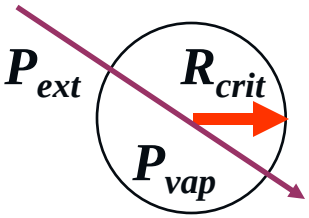
http://www.youtube.com/watch?v=SC_NtH8vWSc&NR=1

Impressive, but a bubble is just a bubble. What caused the bubble?

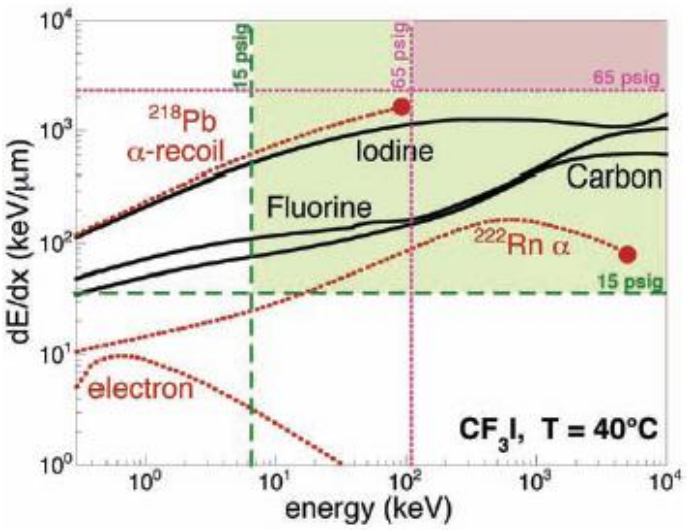
Bubble Chambers can be operated 'blind' to MIPS

$$E_{dep} = \frac{dE}{dx} \cdot R_{crit} \geq E_{\min}$$

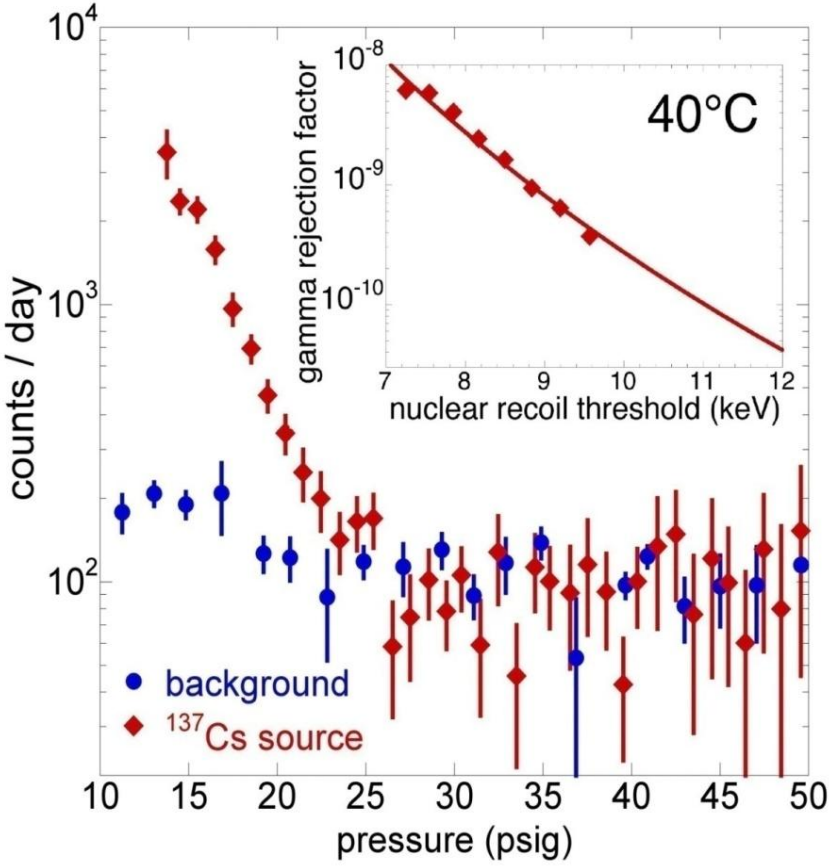
Densely ionizing particle



Double threshold:
Total energy and energy density



Adjust superheat to 'dial' sensitivity to different particles.

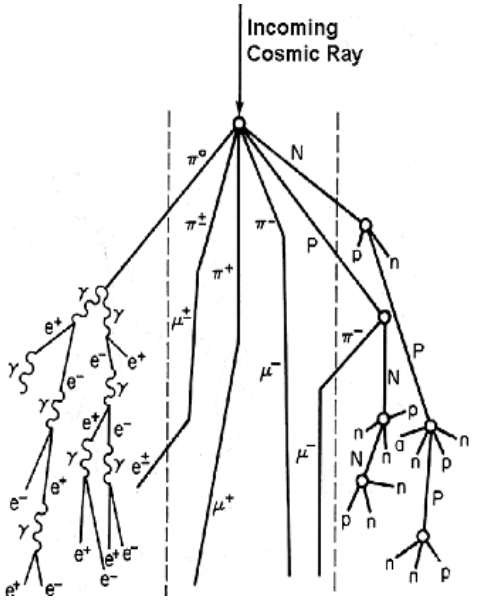


→Measured *intrinsic* rejection of MIPs (~10^{10} at 10 keV threshold!)
No arguing about effects of 'cuts': β, γ, and μ don't cause phase transition!

Competing experiments background cut rejection efficiencies of ~10^{-2} (XENON), ~10^{-4}-10^{-5}(CDMS) to 10^{-7} -10^{-8} (WARP)

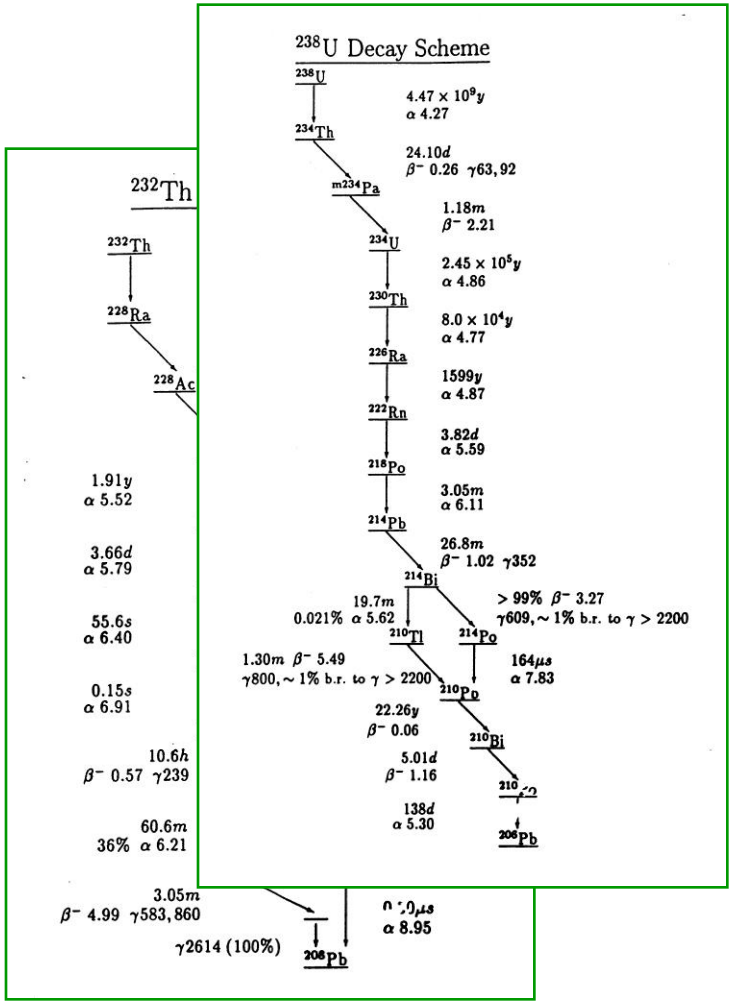
Backgrounds To Which COUPP Is Not Blind:

- Spallation Neutrons,
- (α,n)
- Alphas from radioactive decay (and recoiling daughters)



At Earth's surface ~140 muon/m^{2}s.

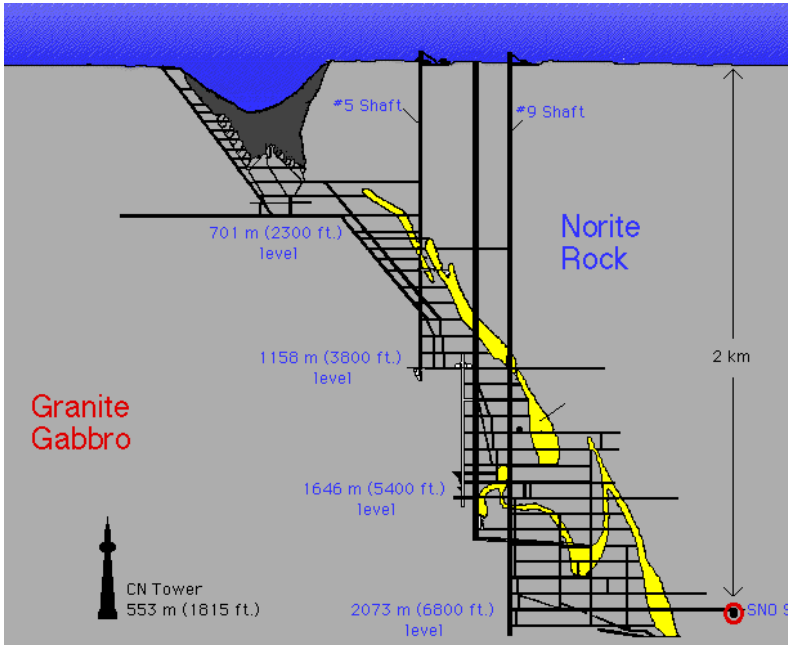
+ from any nearby neutrino beam...

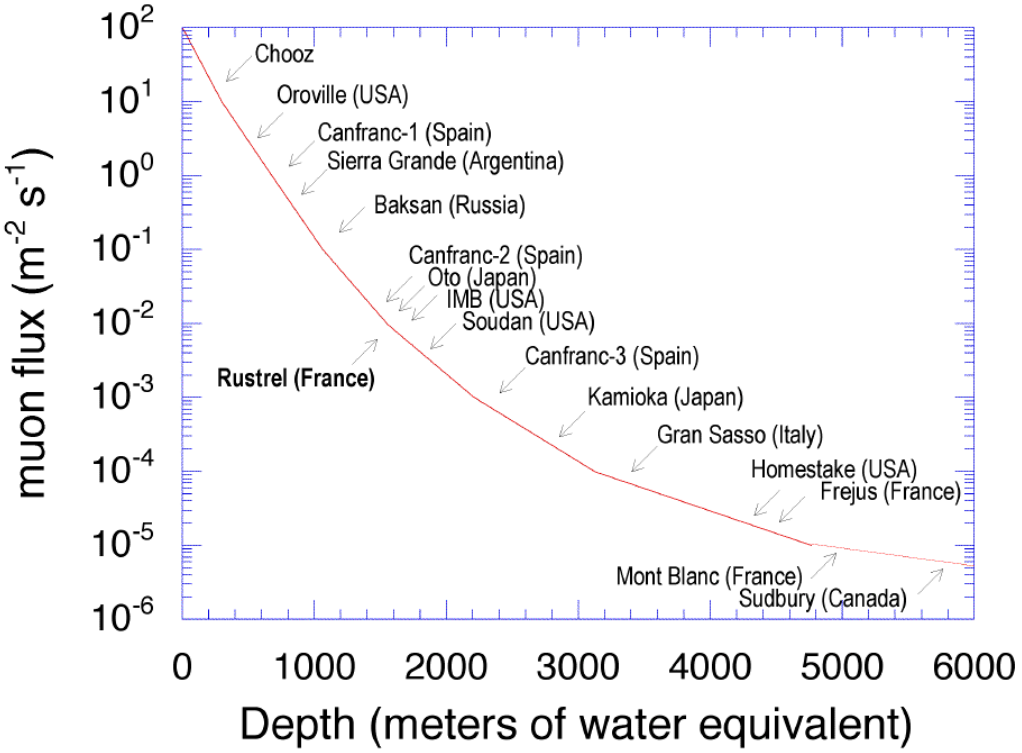


The Enemies!

Neutrons

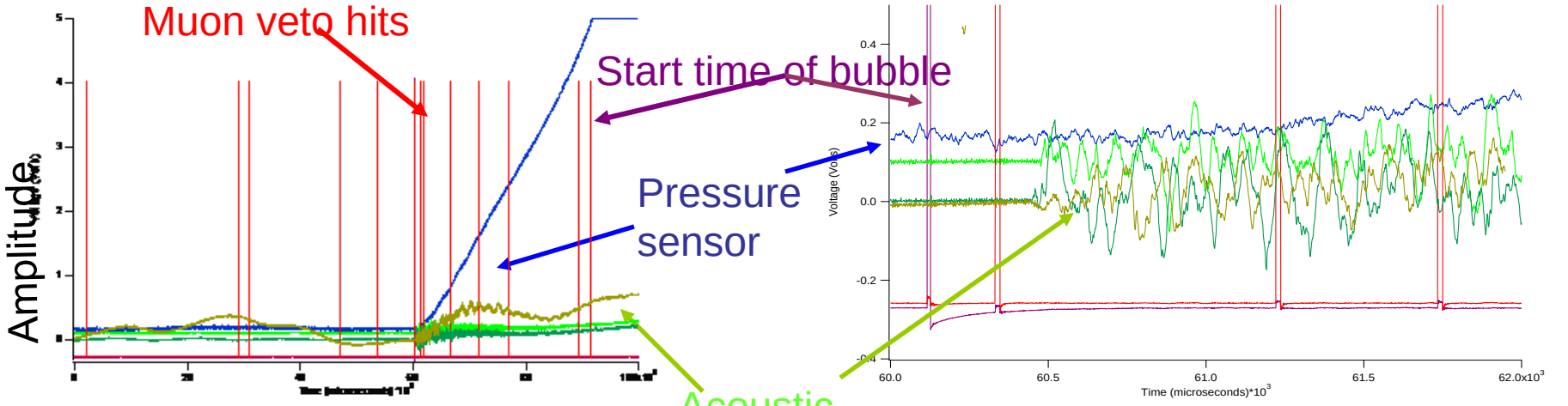
Spallation Go deep (soon!)





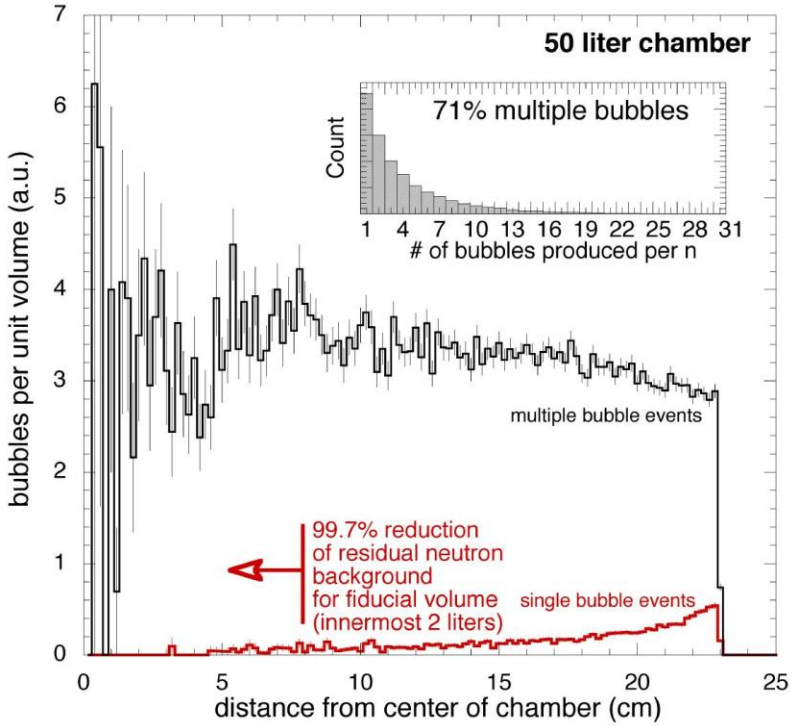
Neutrons

For now, at NuMi, use muon chambers + acoustic sensors

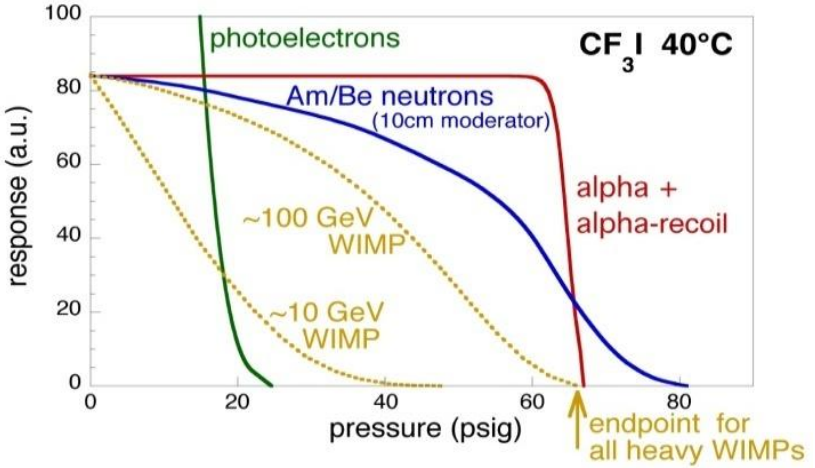


- Fast rise time (~5μs) of acoustic sensors leads to small veto-induced dead time.
- High efficiency when pulses are relatively large (low operating pressure, low energy threshold)
- Becomes challenging as energy threshold is increased (noise level, low gain, inadequate acoustic coupling.)

Other Handles On Neutrons



Neutron contribution:
Muon veto, go deep, volumetric analysis, multiplicity ratios

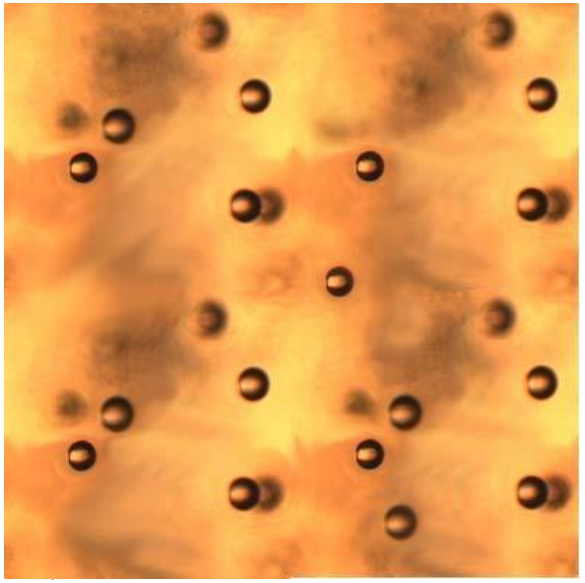


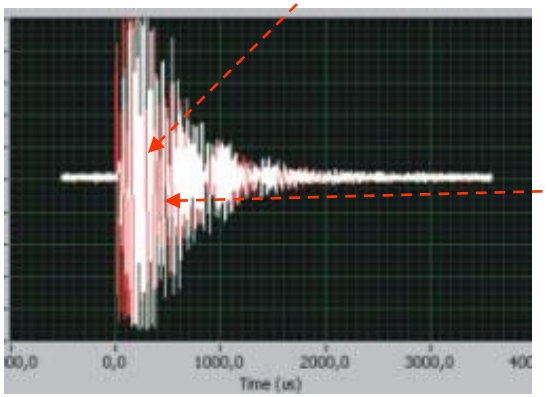
An irreducible α contamination from U/Th in detector and Radon diffusion/emanation is the sole background of concern. The PICASSO collaboration has made a discovery – alpha induced bubbles are louder than neutron (or WIMP) induced bubbles!

Picasso

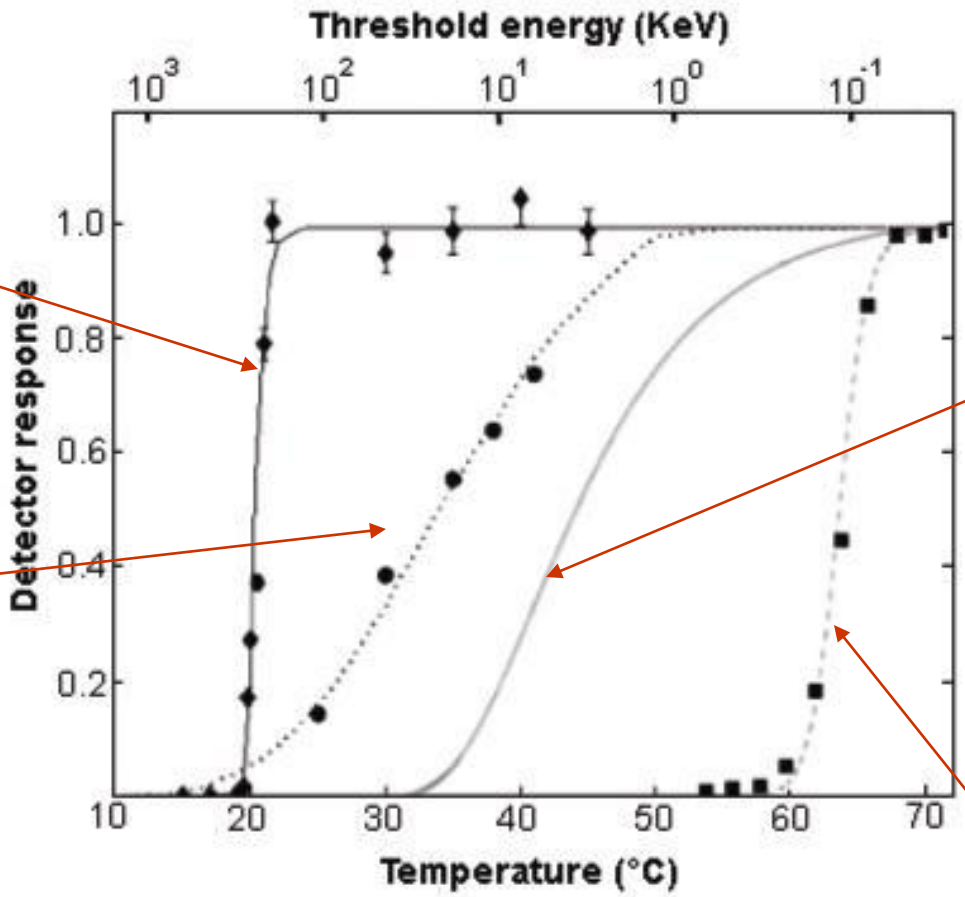
- Superheated droplets at ambient T & P
- 150μm droplets of carbofluorides dispersed in polymerised gel
- Active liquid: C_4F_{10} T_b= - 1.7 °C)
- Radiation triggers phase transition
- Events recorded by piezo-electric transducers
- In midst of 2.6kg run phase

(goal 700kg days by end of 2009, sensitivity ~0.06pb SD)





Detector Response



^{226}Ra spike (200 μm Ø)

AcBe neutrons (data +MC)

Recoil nuclei from 50 GeV WIMP

γ & MIP response

Gamma & MIP rejection better 10^{10} above E_{rec}= 10keV!

Hot off the Press!

Discrimination of Nuclear Recoils from Alpha Particles

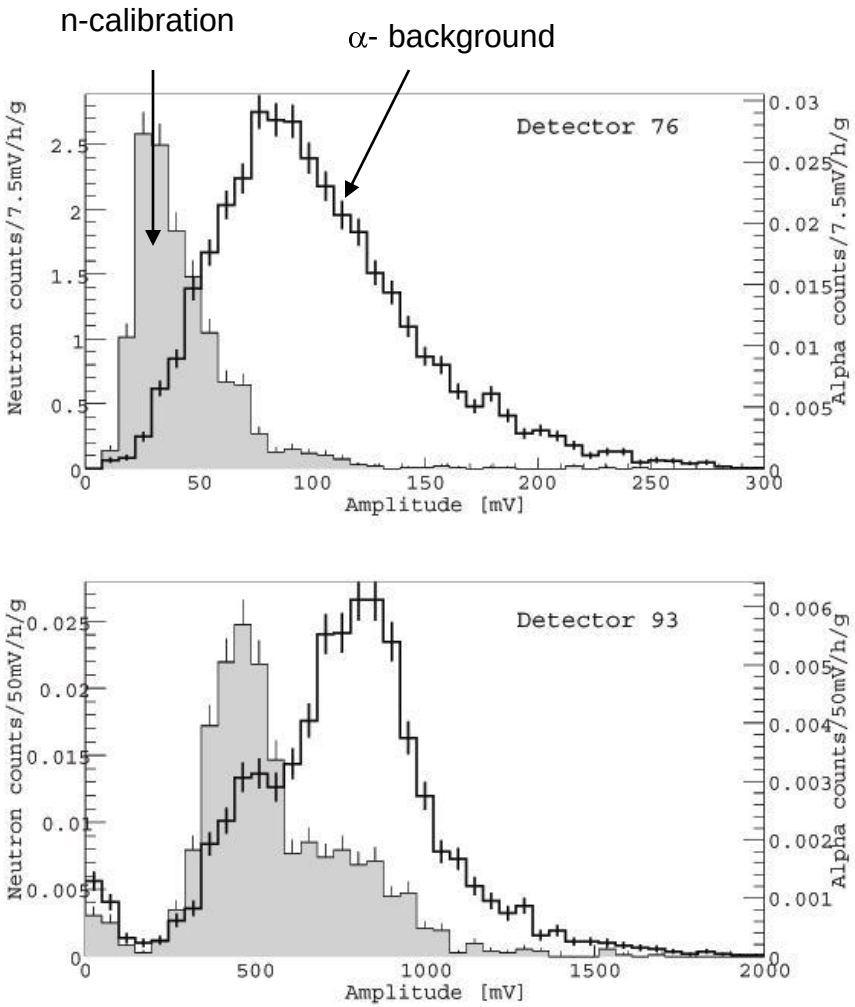
PICASSO discovered a significant difference between amplitudes of neutron and α- particle induced events !

Accepted for pub. In New Journal of Physics arXive: 0807.1536

Average of peak amplitudes of nine transducers / detector

High pass filter with cut-off at 18 KHz

Signals carry information about first moment of bubble formation



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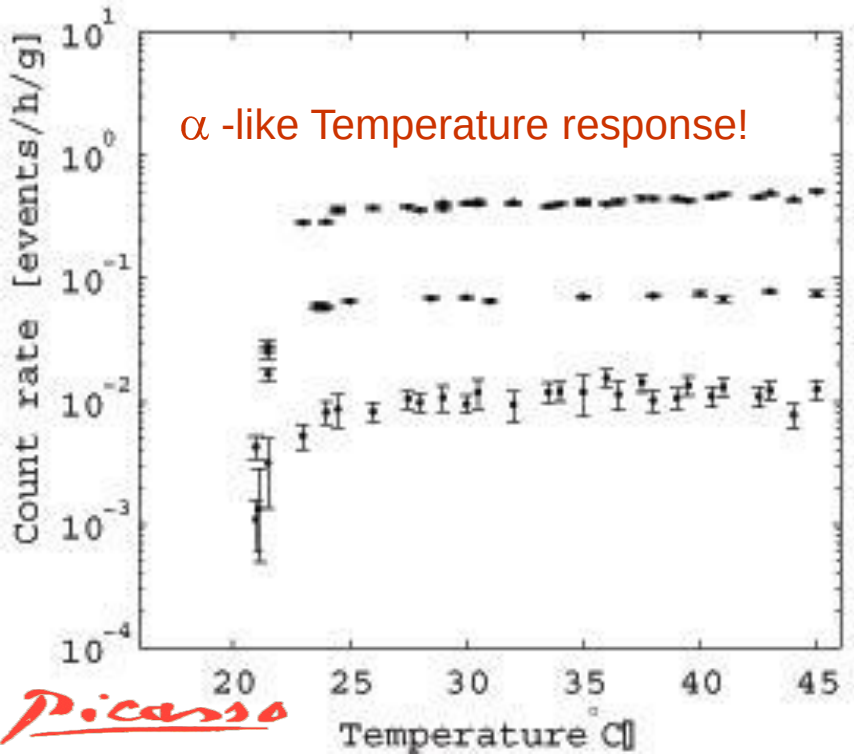
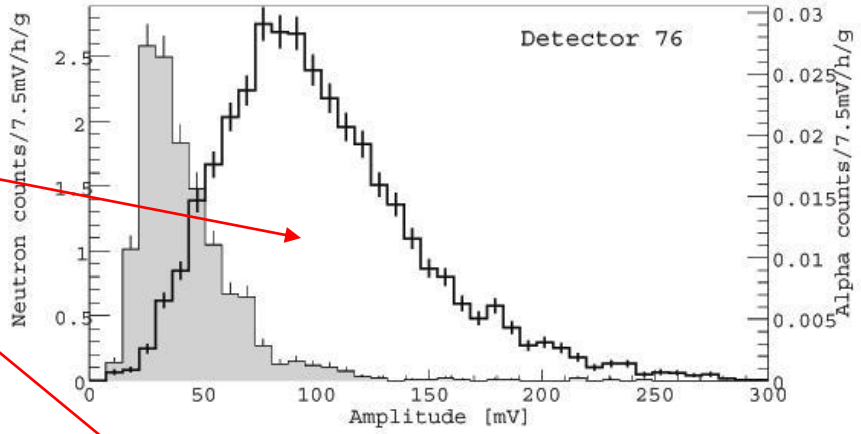
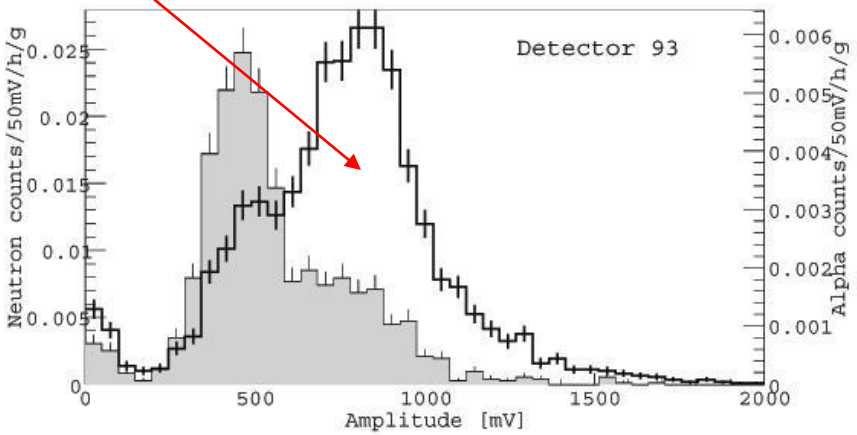
Are these really α events?







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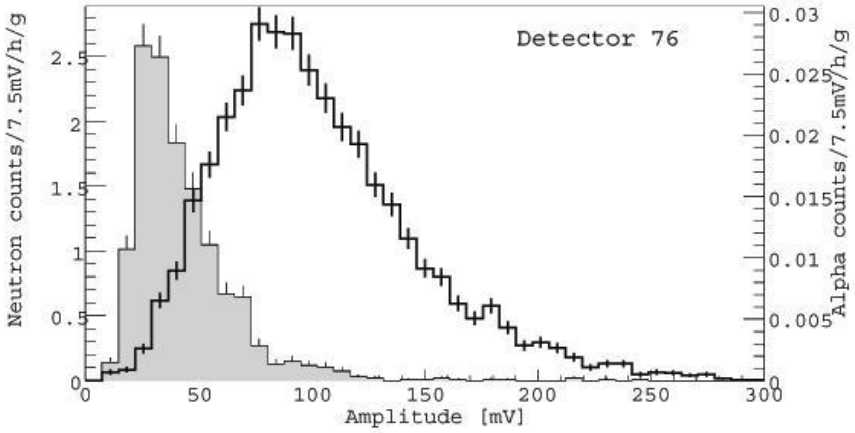
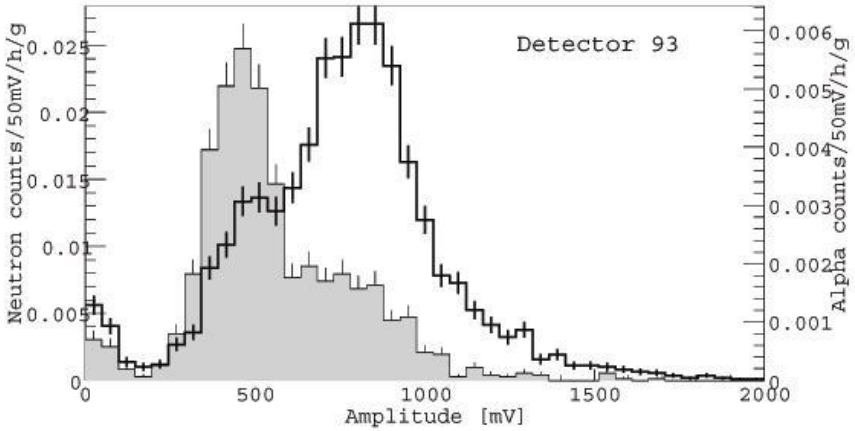
Why not observed earlier?

Previous detector had smaller droplets!

- now 200 μm compared to < 10 μm
- range of nuclear recoils < L_c
- but range of alphas >> L_c
- many bubbles can form on α track (depend on temperature)





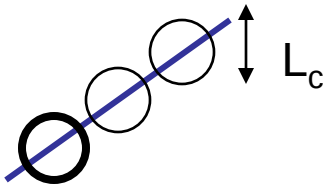
α - n Discrimination: a tentative explanation

Nuclear recoil: point like, strong ionisation

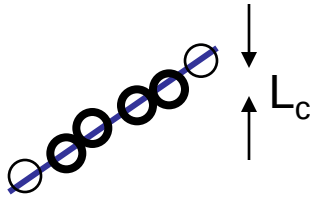
α-particles: ionization on 35μm track

prim. bubbles *Poisson* distributed !

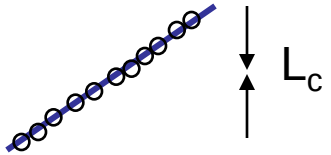
T = 30^{0}C



T = 40^{0}C

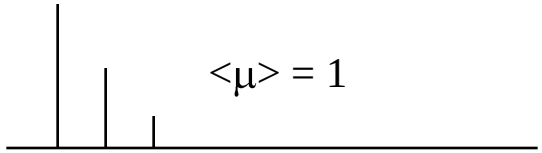


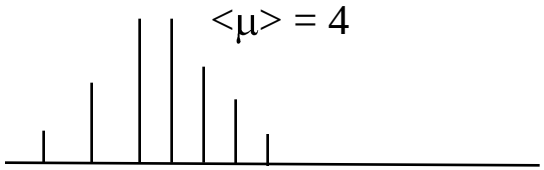
T = 50^{0}C

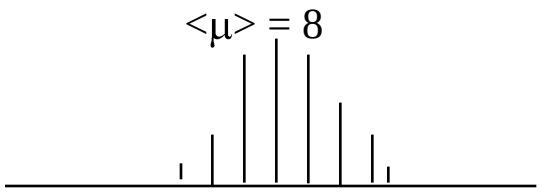


(in MIP sensitive region: T = 60^0 C → > 20 bubbles)

# of primary bubbles



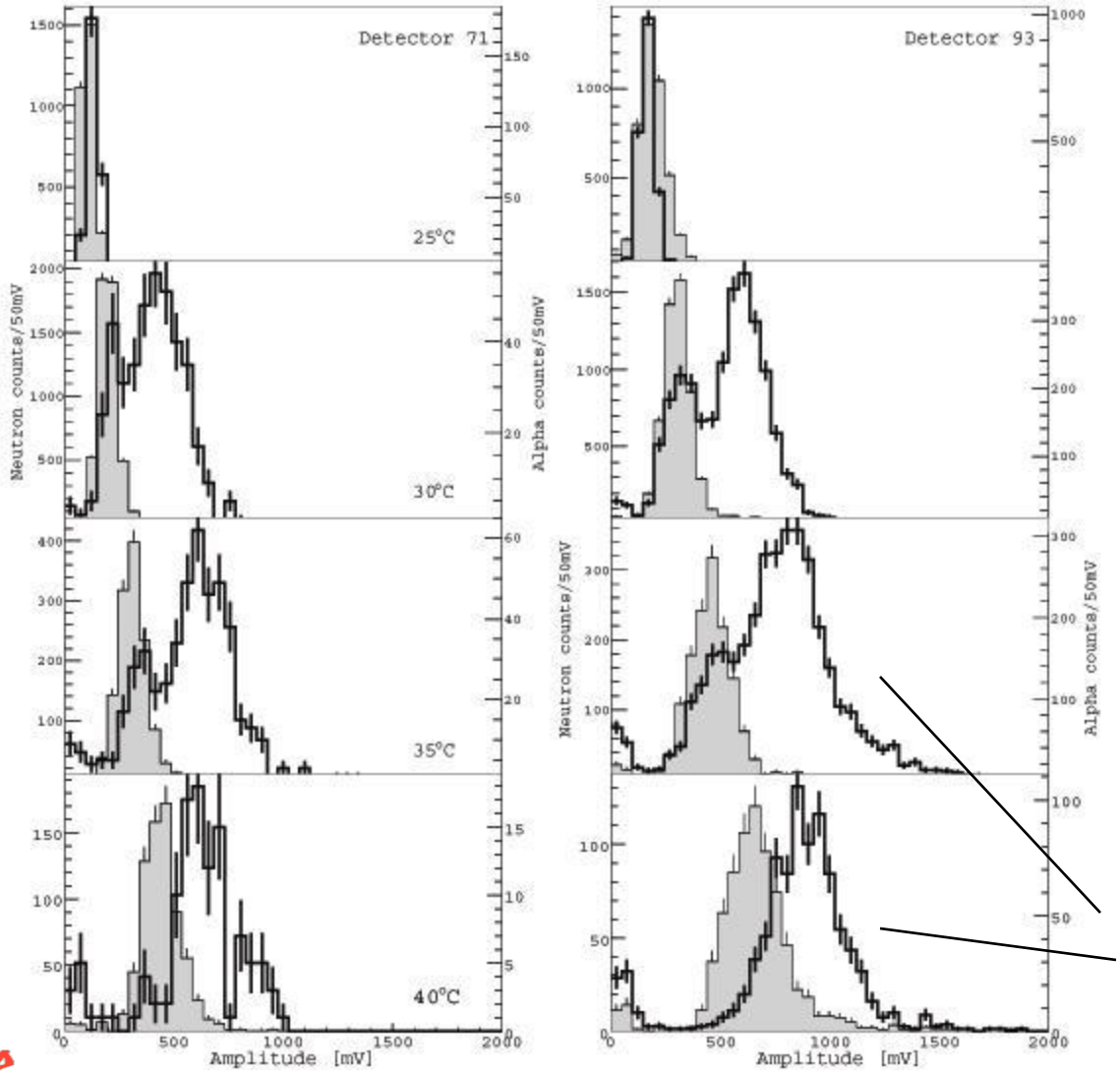




# of bubbles created

Picasso

α - n Discrimination: Temperature Dependence

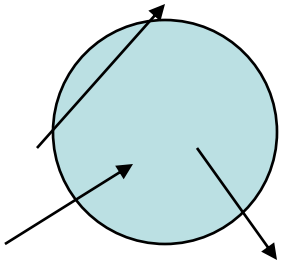


Strong saturation of raw signals above 30⁰C!

Application to COUPP

This should work better

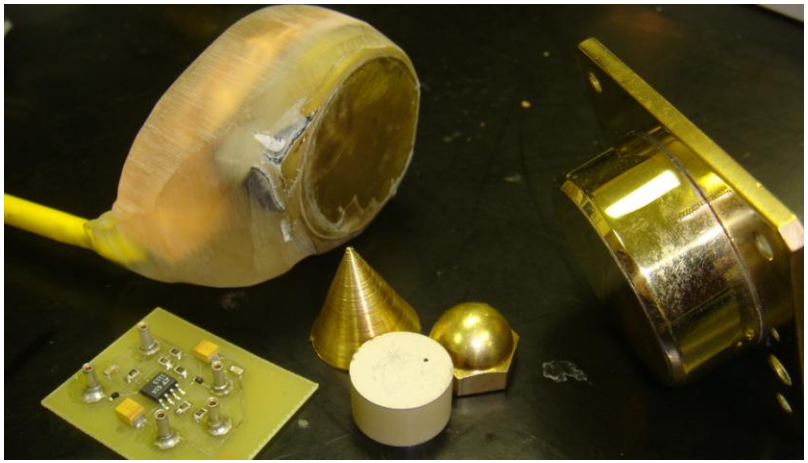
- No droplet edge effects
- No gel effects



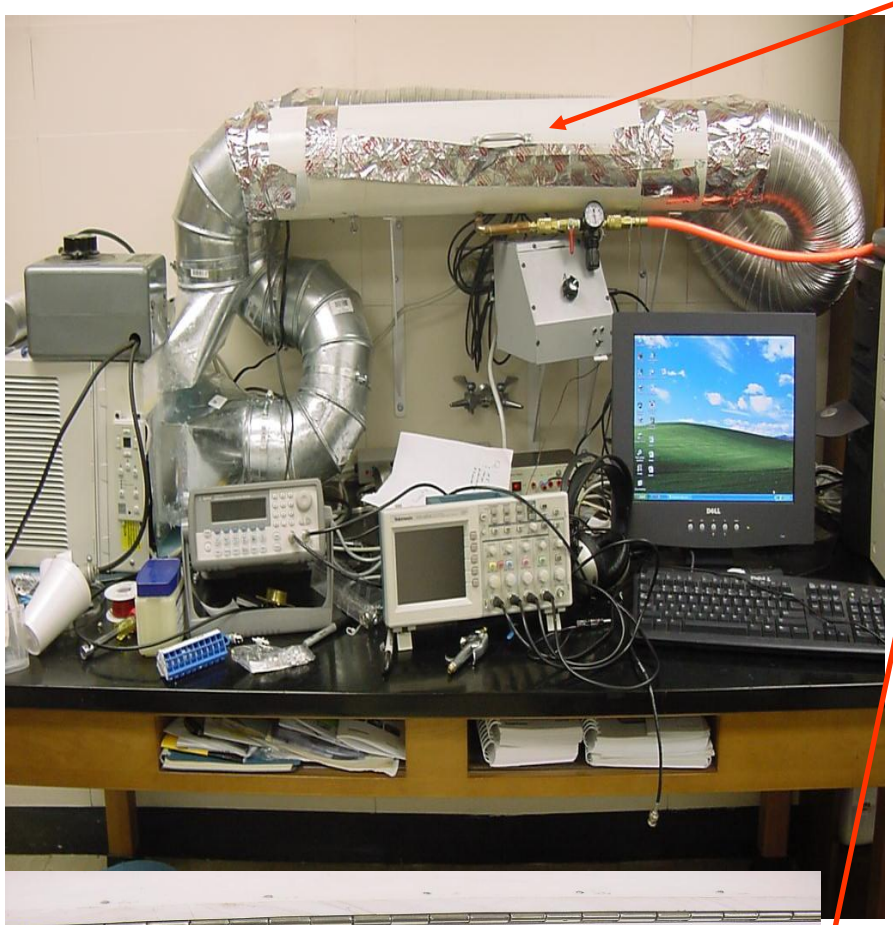
Transducer construction R&D

Location

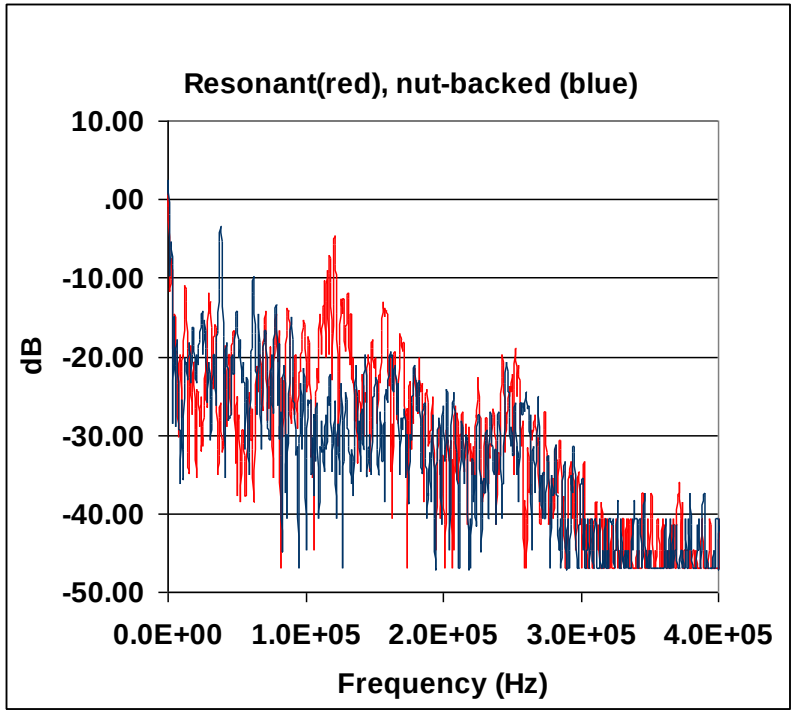
Dedicated 1l R&D chamber



Environment Chamber



- Tube: Location of Sounding Block
- Switch Box: 12 inputs, 4 outputs, and 3 channel switch designed to minimize electric noise
- Air Blast: used as a white noise source coming out under the sounding block.
- Capture FFT and Waveforms 2014 TDS
- Air Conditioner (temperature cycling)
- Heater (temperature cycling)
- Aluminum Bar (sounding block)
- Temperature cycle range 0°C- 60°C
- Holds up to 12 acoustic transducers in test model,12 full cycles per day



First step in resonance reduction.
Radial next? Backing type?