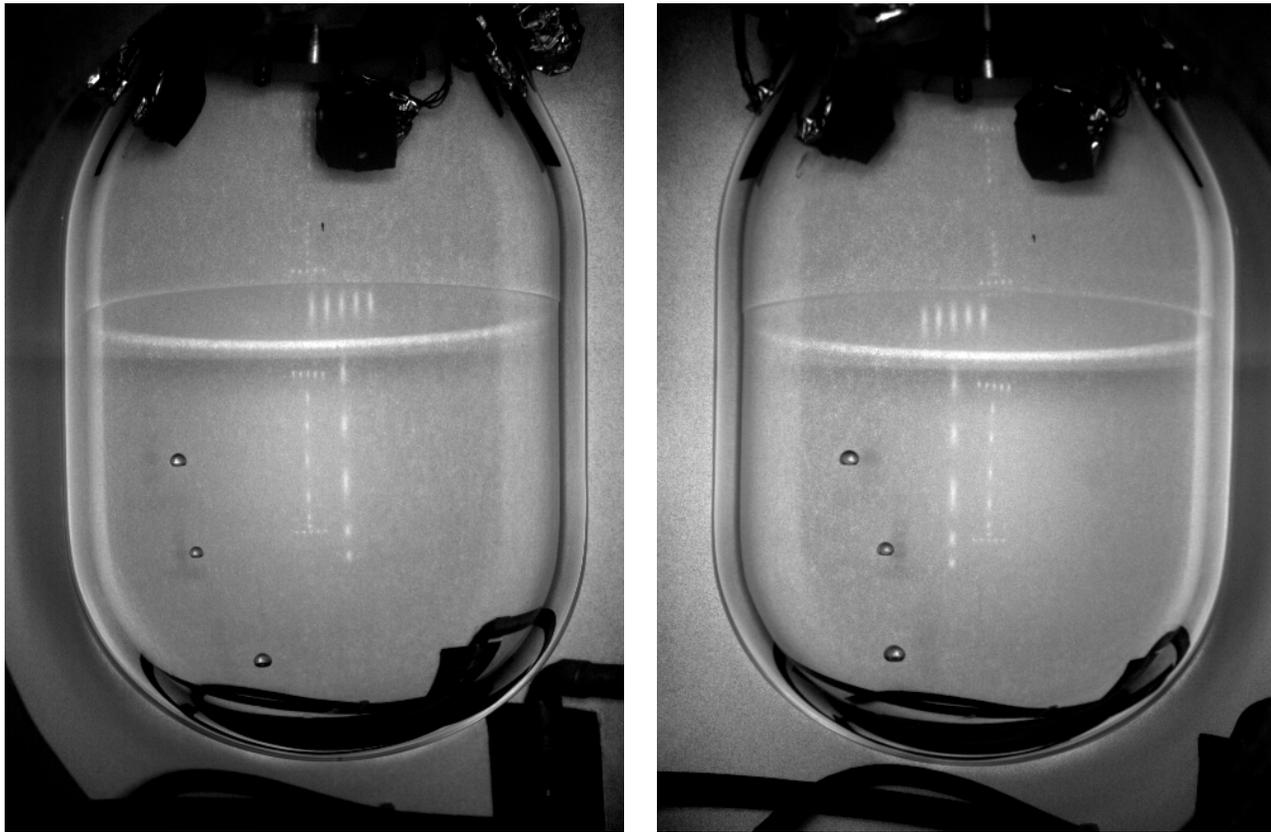


A COUPP Update

Acoustic Discrimination, and Progress on the 60kg chamber



The COUPP Collaboration

University of Chicago

Juan Collar (PI, spokesperson), C. Eric Dahl, Drew Fustin,
Matthew Szydagis

Indiana University South Bend

Ed Behnke, Joshua Behnke, J. Henry Hinnefeld, Ilan Levine (PI),
Andrea Palenchar, Tina Shepherd, Brendan Sweeney

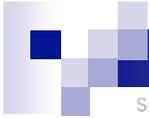
Fermilab

Steve Brice, Dan Broemmelsiek, Peter Cooper, Mike Crisler,
Jeter Hall, Martin Hu, Erik Ramberg, Andrew Sonnenschein,
Fermilab Engineers and Technicians

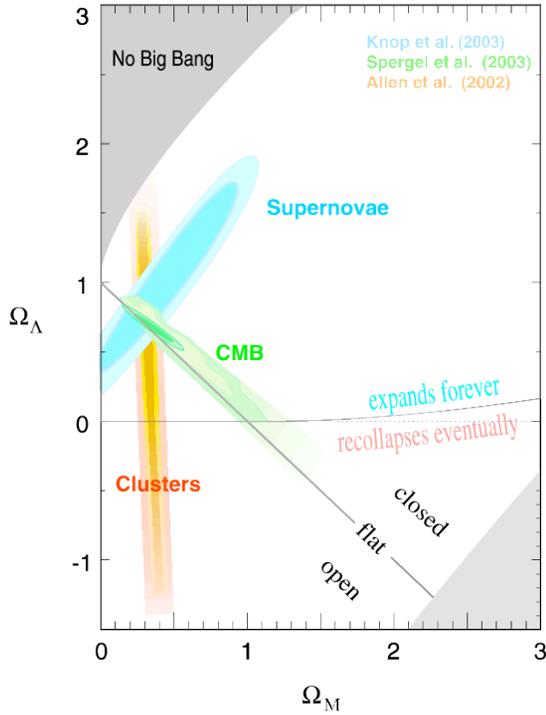


Kavli Institute
for Cosmological Physics
AT THE UNIVERSITY OF CHICAGO

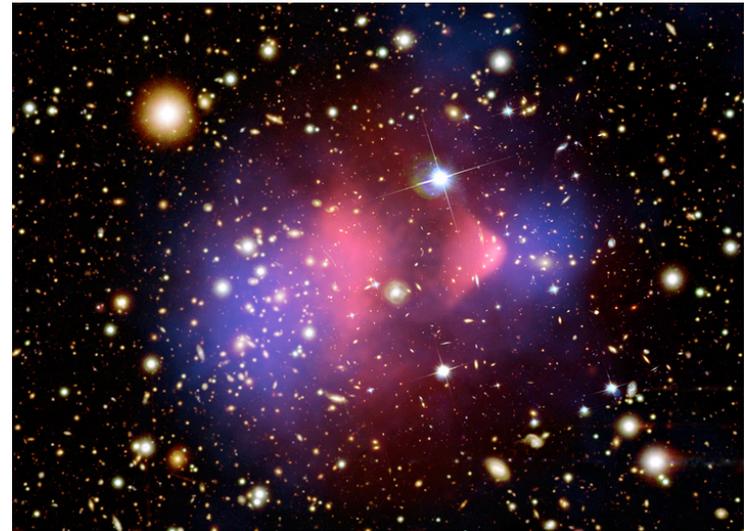
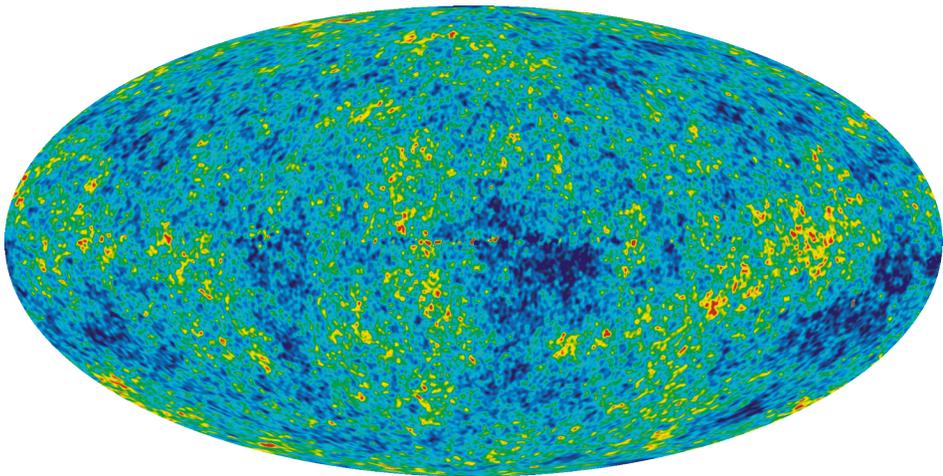
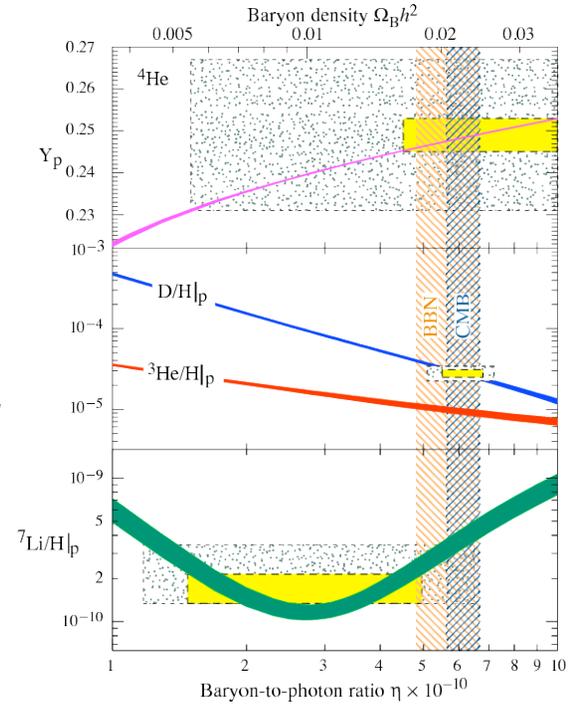
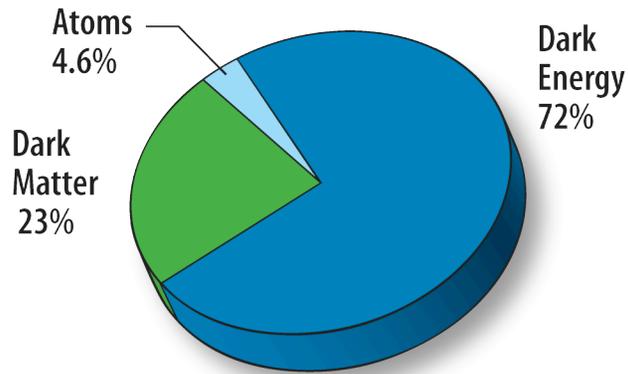




Supernova Cosmology Project



Evidence for Dark Matter

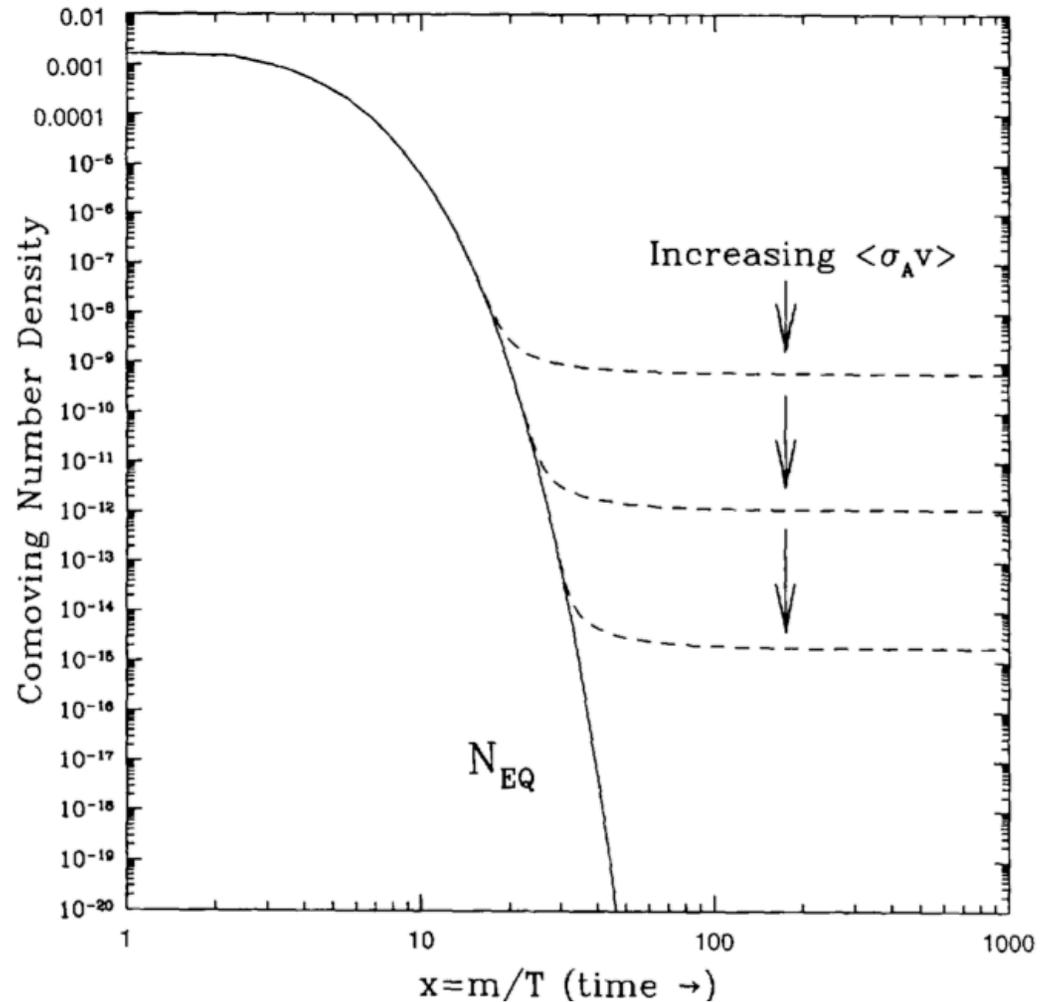


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February 22, 2010

Relics and Miracles

- Suppose Dark Matter is:
 - Stable Particle (LSP...)
 - Thermal Relic of Big Bang
- Weak-scale interaction gives required density for dark matter

$$\frac{dn_\chi}{dt} = - \langle \sigma_a v \rangle \left[(n_\chi)^2 - (n_\chi^{eq})^2 \right] - 3Hn_\chi$$



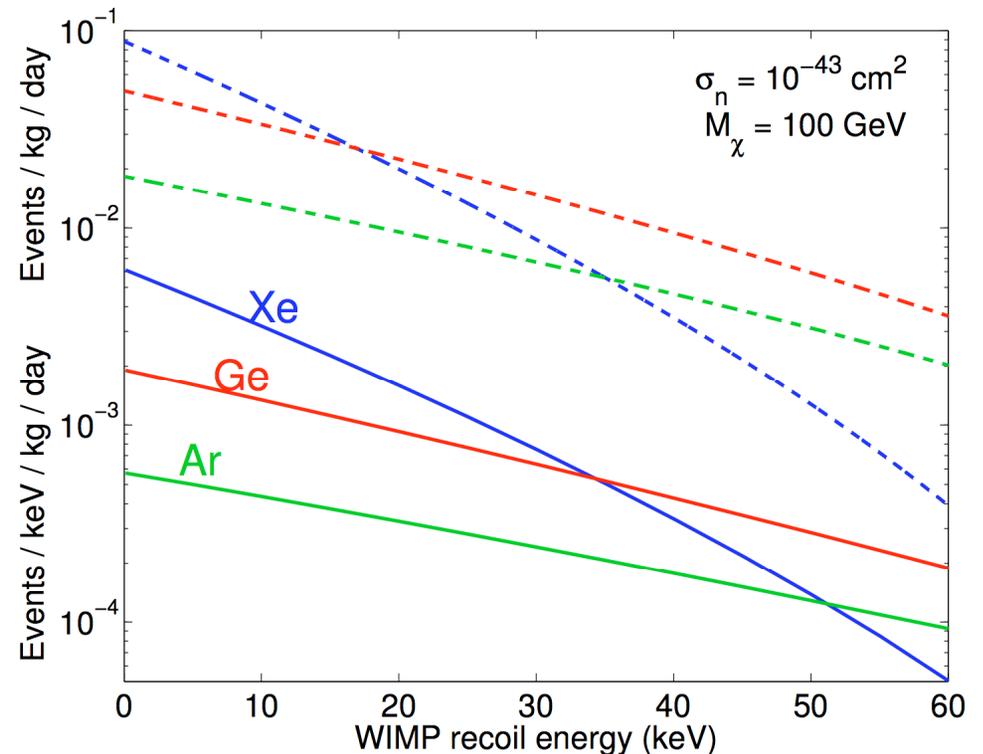
How to Catch a WIMP

- WIMPs should exist locally!

- Expected density 0.4 GeV/cm^3
- rms velocity 230 km/s

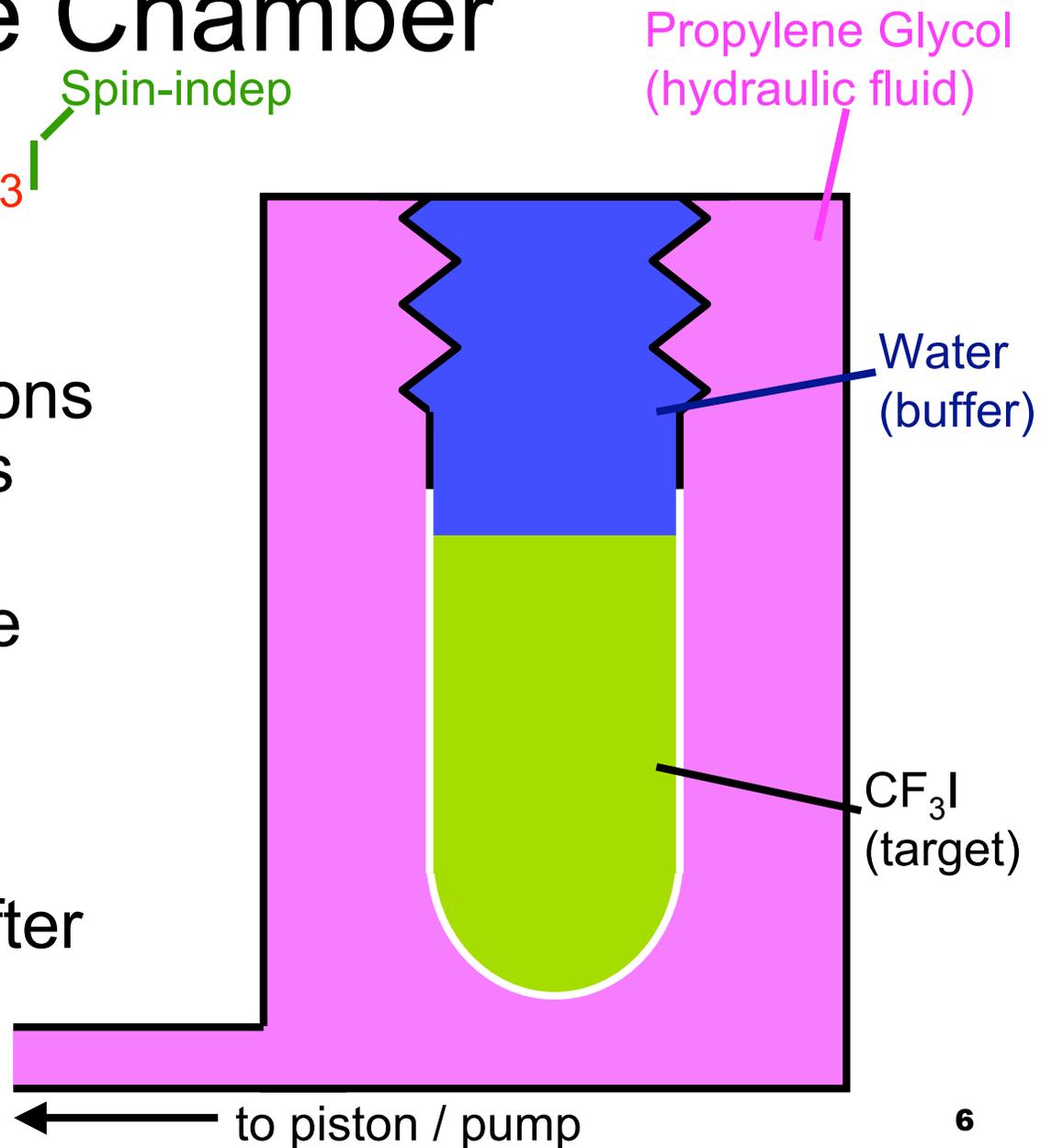
- Look for coherent elastic scattering off of nuclei

- Recoil energies $O(10) \text{ keV}$
- Big, low background, low threshold detectors



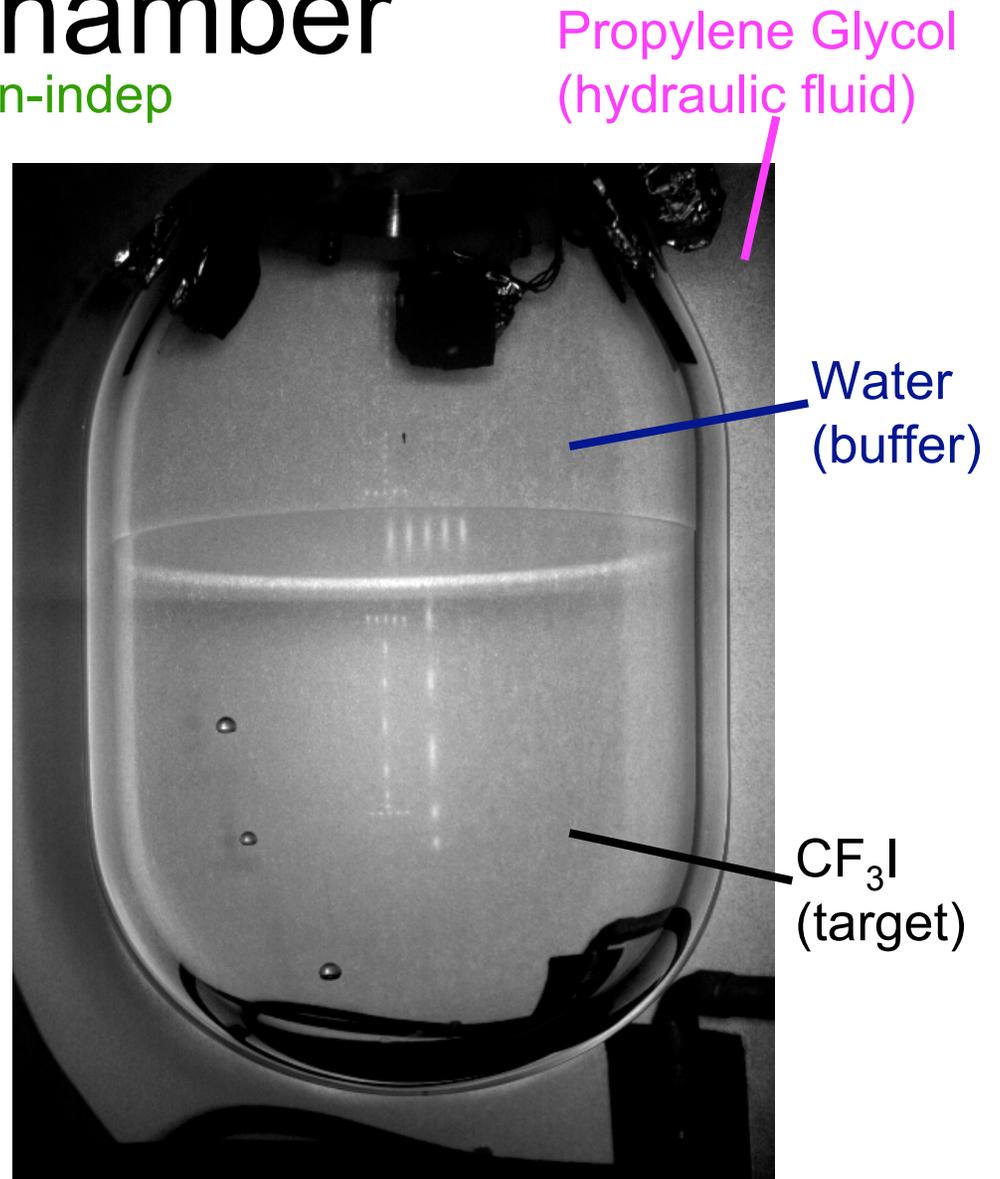
The Bubble Chamber

- Superheated CF_3I target Spin-dep Spin-indep
- Particle interactions nucleate bubbles
- Cameras capture bubbles
- Chamber recompresses after each event



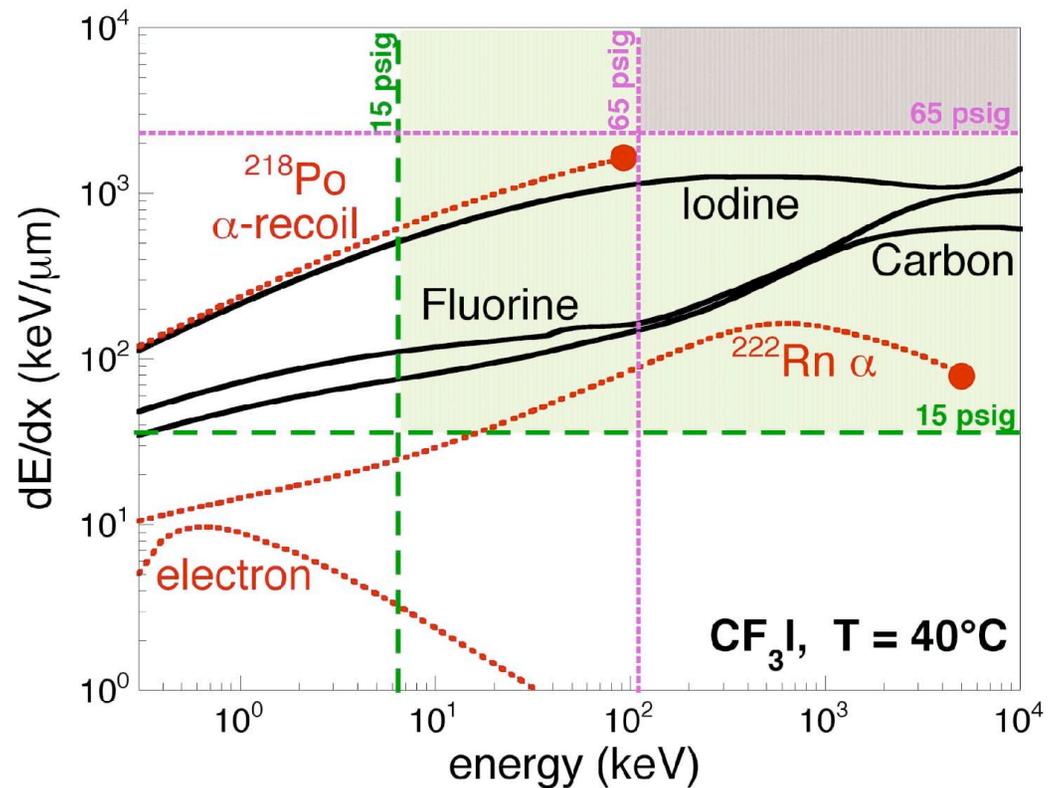
The Bubble Chamber

- Superheated CF_3I target
Spin-dep
- Particle interactions nucleate bubbles
- Cameras capture bubbles
- Chamber recompresses after each event



Why bubble chambers?

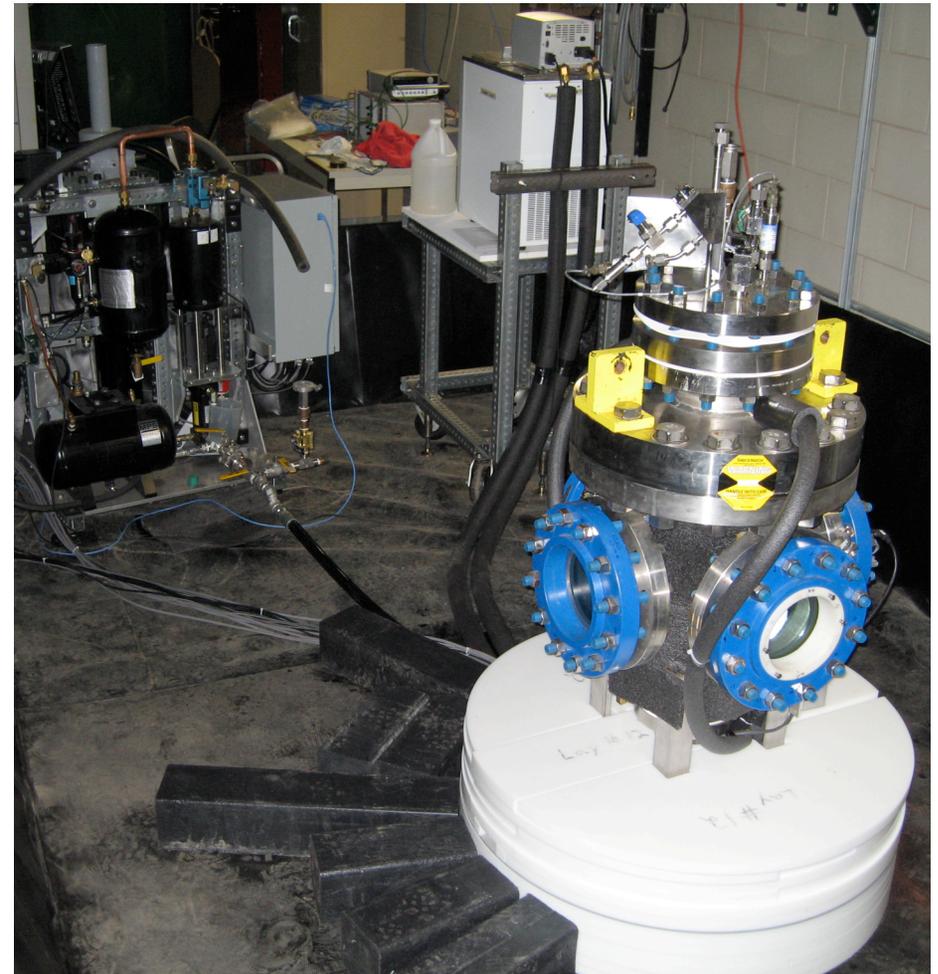
- Only proto-bubbles with $r > r_{\text{crit}}$ grow to be macroscopic
- Critical proto-bubble requires minimum dE within minimum volume
- Recoil must be over thresholds in both E and dE/dx



No sensitivity to γ 's or β 's,
but α 's do make bubbles

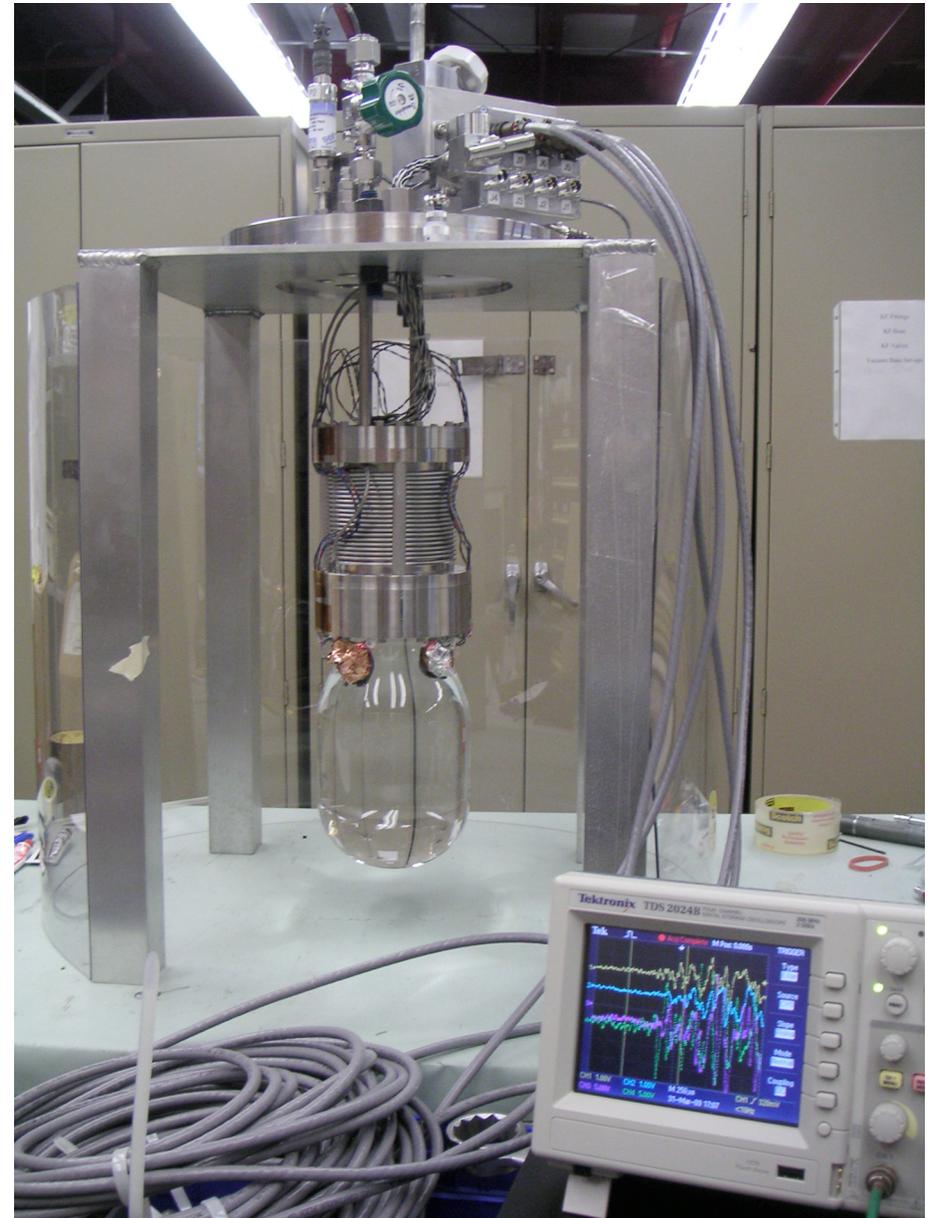
COUPP 4kg

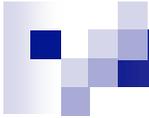
- Ran Aug 19 – Dec 18 in NuMI tunnel at Fermilab
 - 300 mwe underground
 - Over 300 kg-days unattended operation



COUPP 4kg

- 3 stated goals
 - Reduce wall rate
 - Reduce bulk alpha rate
 - Commission new veto
- Added goal:
 - Look for acoustic alpha discrimination reported by PICASSO





The Fill

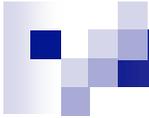


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Full of slush

- Apparently, CF_3I and H_2O form a clathrate below 10°C
- Previous fills must not have been as cold as we thought





Melting



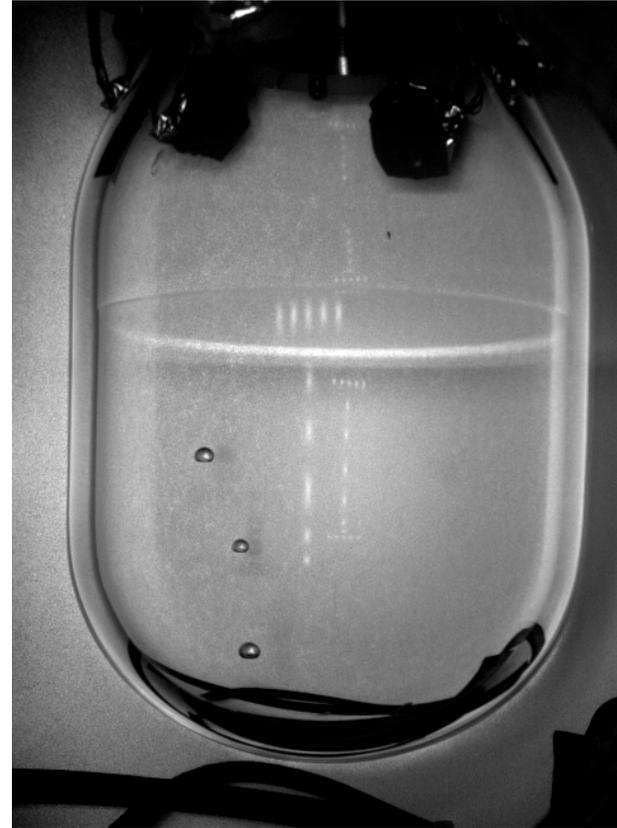
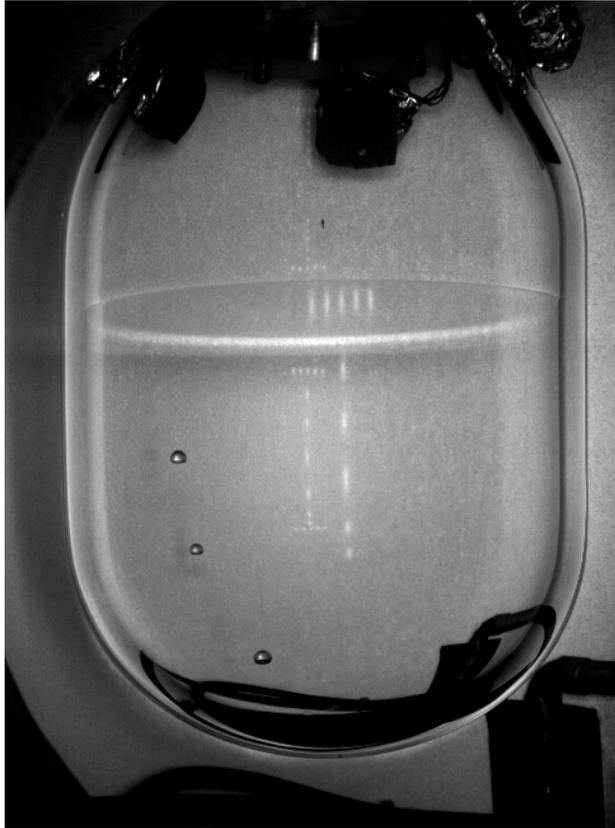
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Drama...

- First expansion at 30°C, 27psia (20 keV threshold)
 - No bubbles for several minutes
 - This is either very good or very bad
- Turn on sAmBe neutron source
 - After 320 seconds...

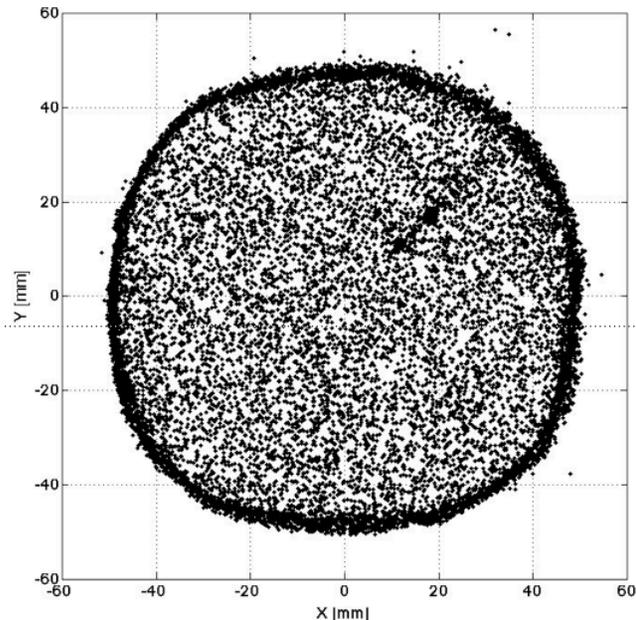
First Bubbles



- An auspicious start!
 - Only 11 of 605 sAmBe events are 3-bubble events

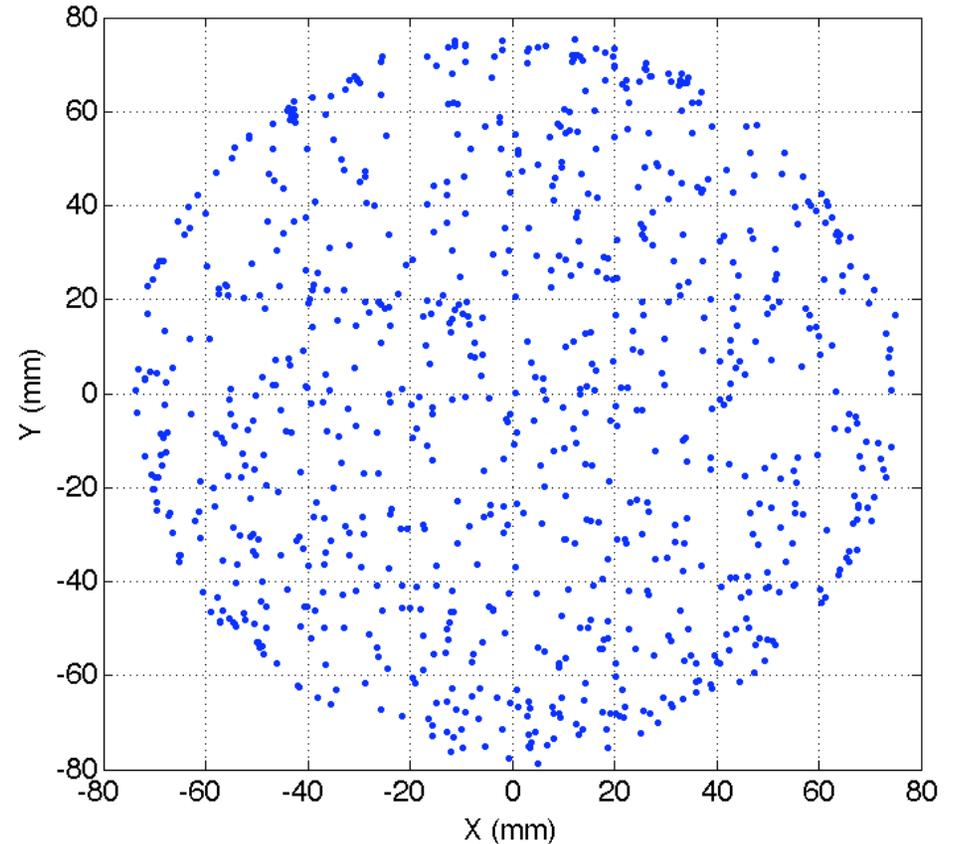
Goal #1: Wall rate reduction

Natural Quartz: $0.8/\text{day}/\text{cm}^2$



~40 live-days
(2007-08)

Synthetic Silica: $\leq 1e-4/\text{day}/\text{cm}^2$

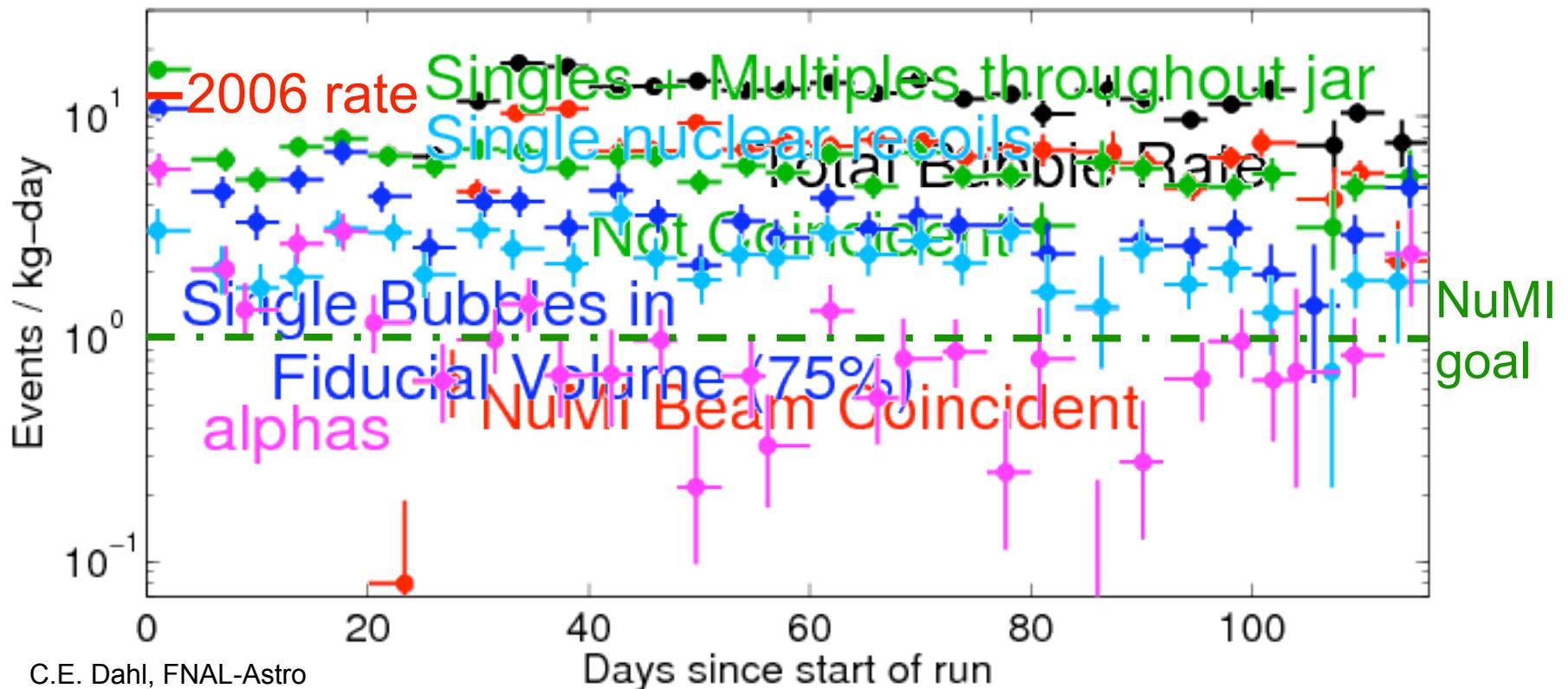


88 live-days (2009)

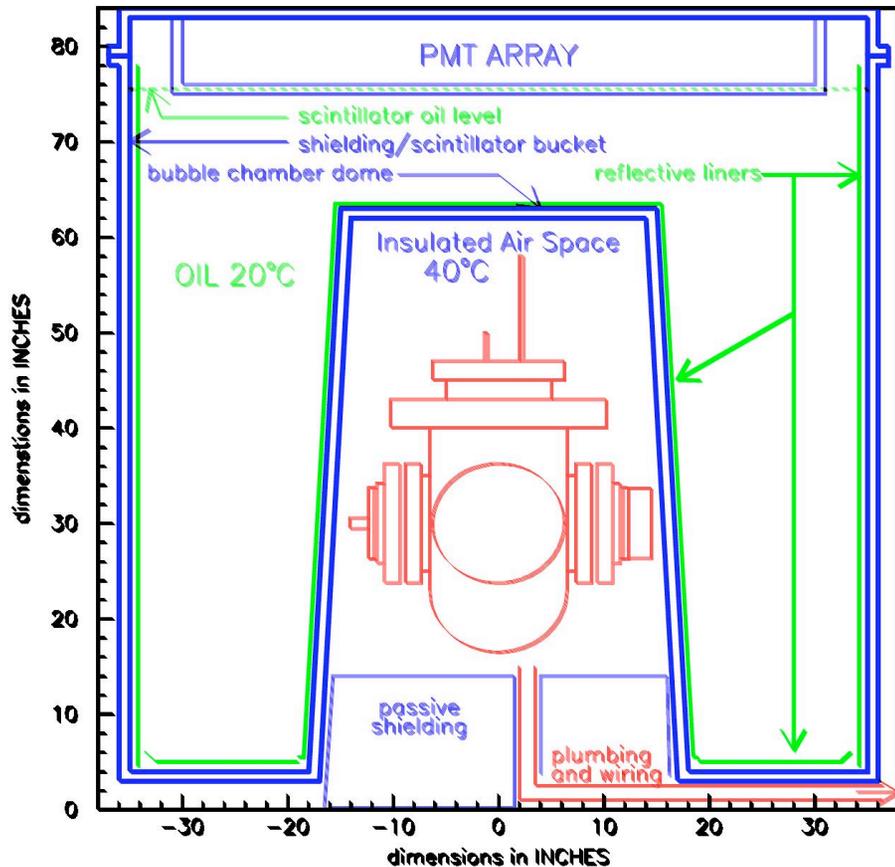
Goal #2: Bulk alpha reduction

■ Targeting radon

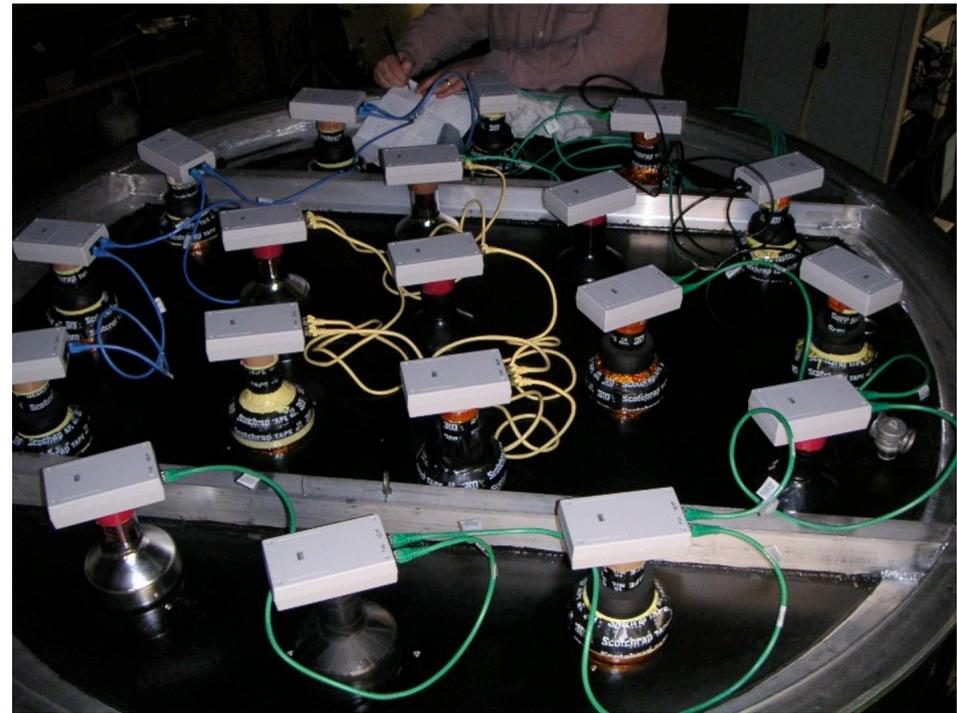
- Materials known to emanate radon removed
- No steps taken to purify CF_3I , remove ^{210}Pb , etc



Goal #3: New muon veto



Liquid Scintillator “Bundt Cake”

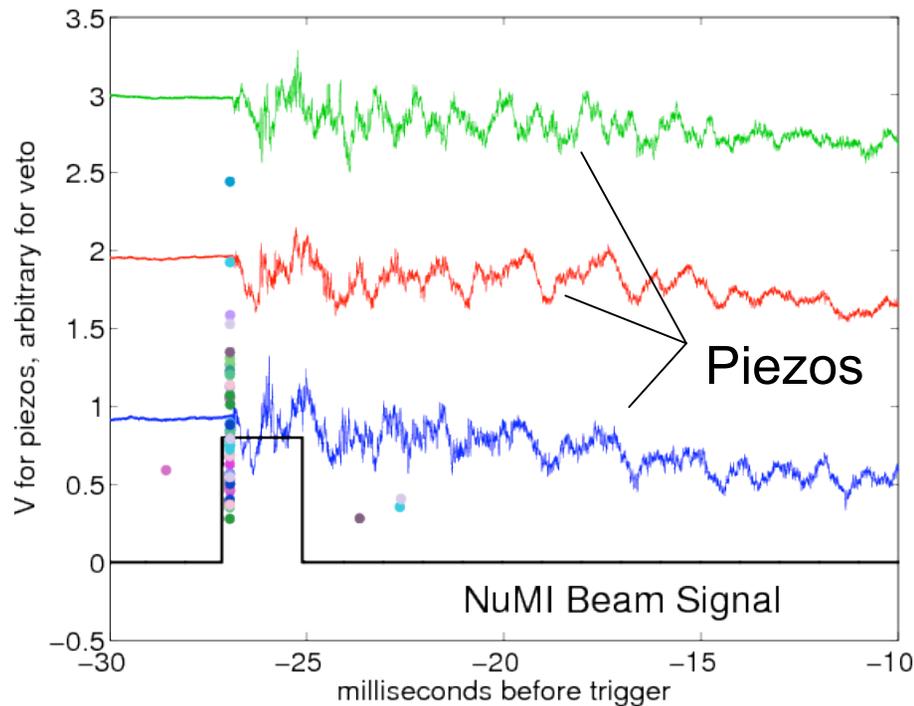


PMT Bases feature:

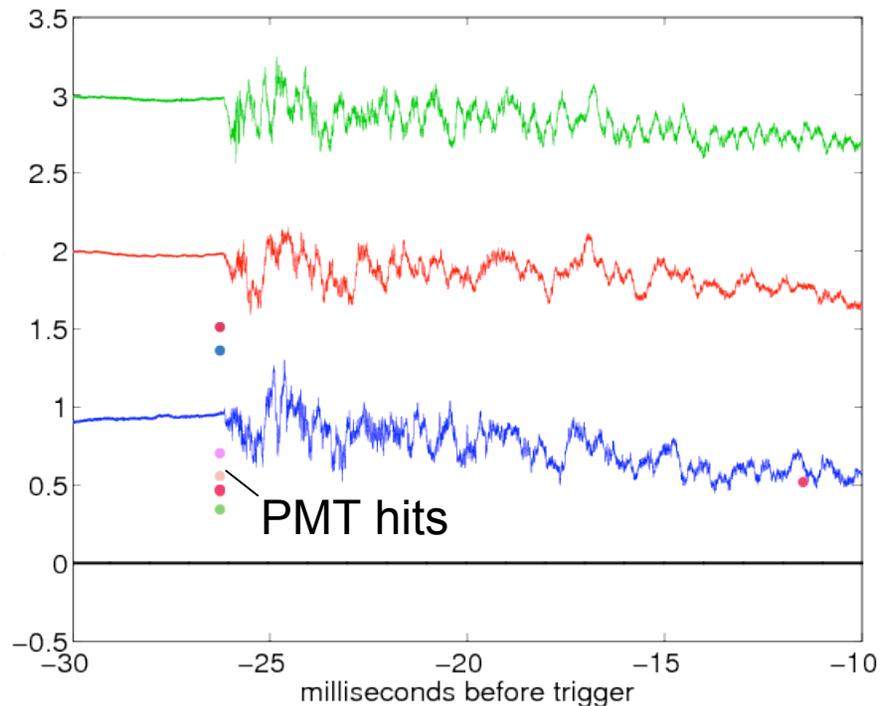
- On board digitizers
- Cockcroft-Walton HV
- Power and data over ethernet

Goal #3: New muon veto

Beam Event



Cosmic Event



- Require:
- 300 ns coincidence between PMTs
 - 500 μ s coincidence with piezos

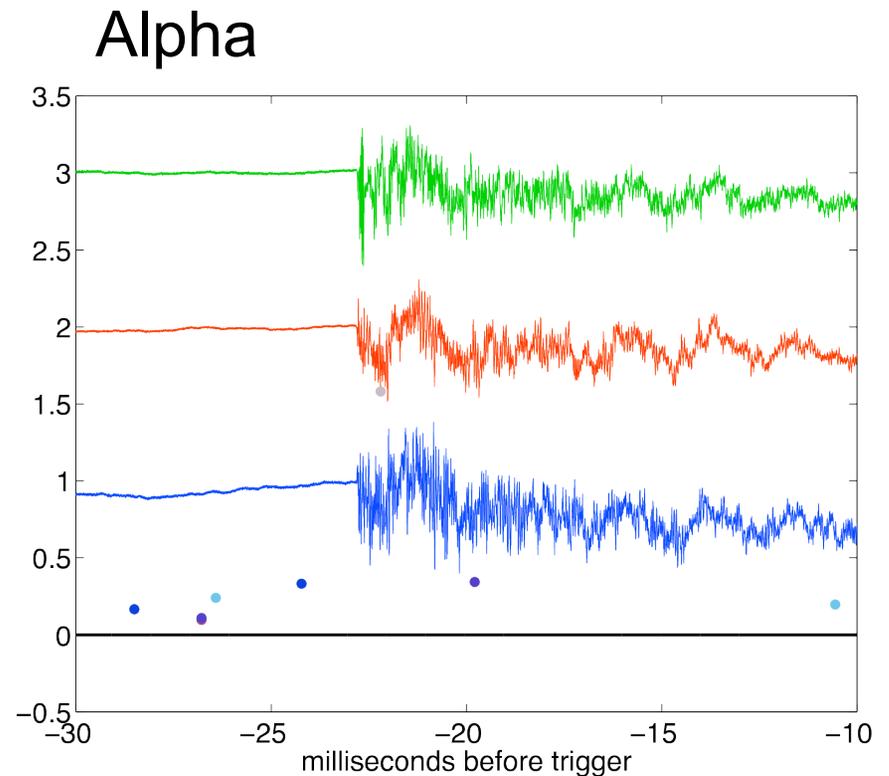
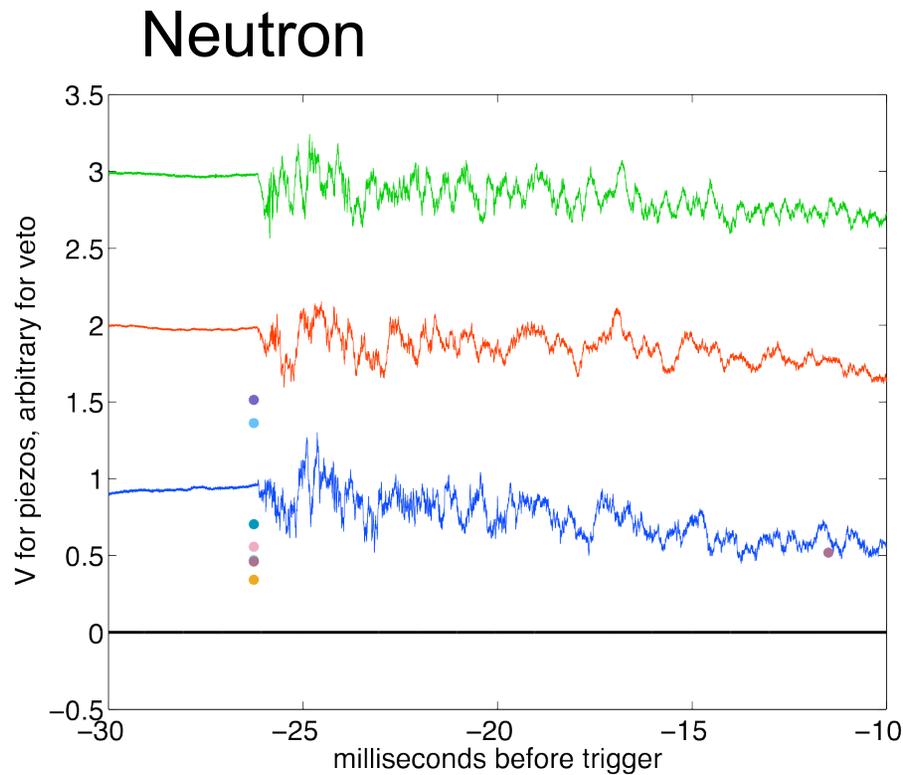


Bonus: Acoustic Discrimination

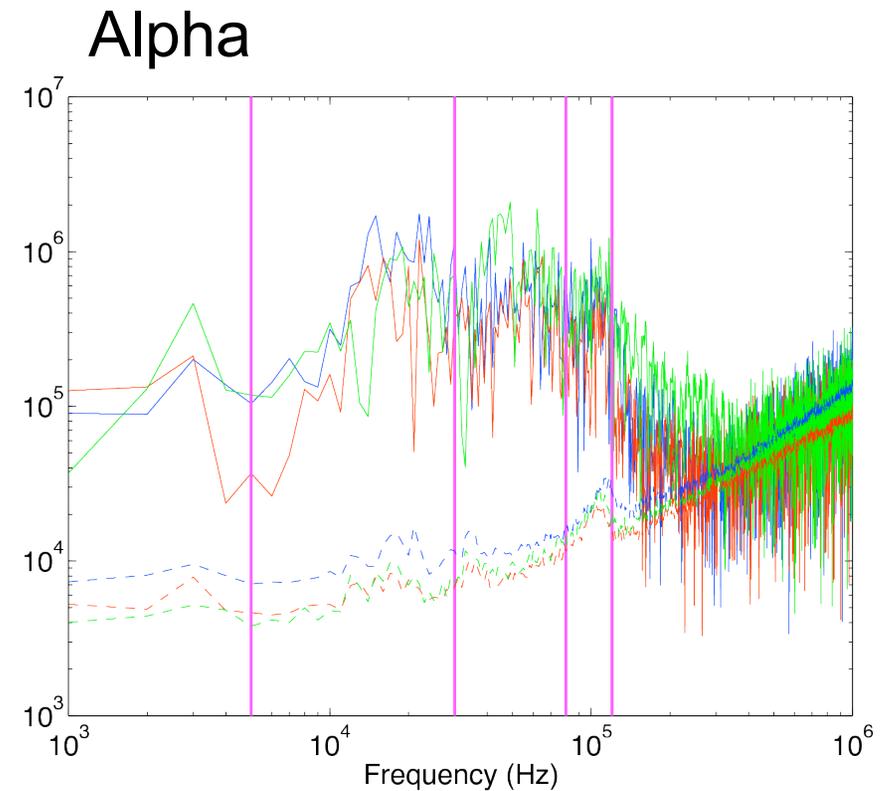
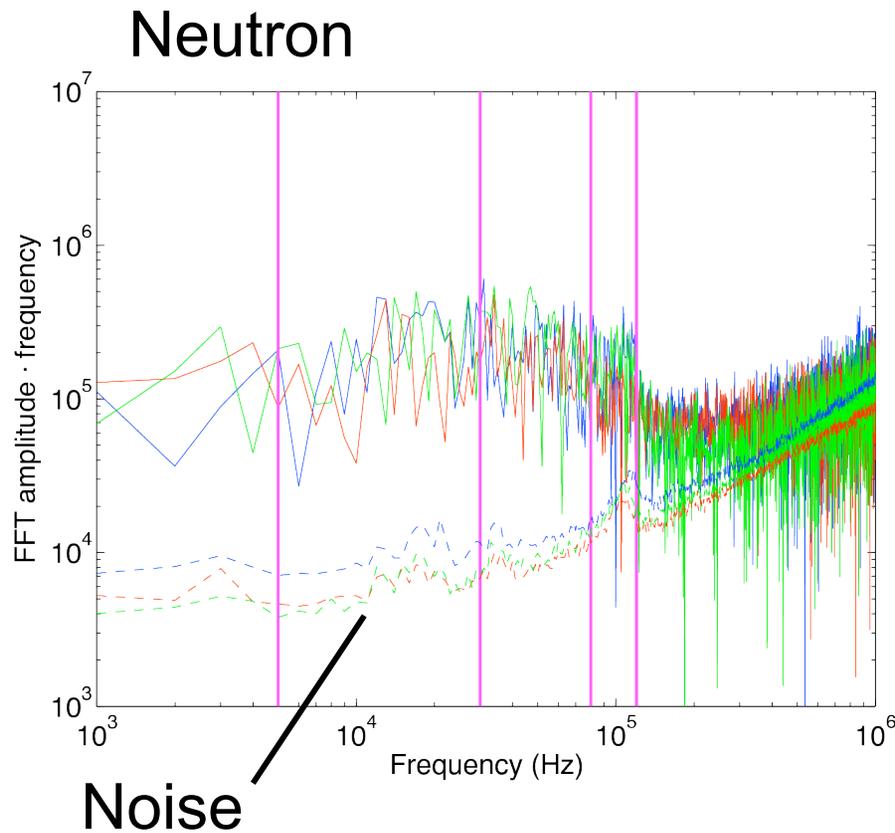
PICASSO (Aubin et al., arXiv:0807.1536)

- Nuclear recoil: 1 proto-bubble
- Bulk α -decay: 2+ proto-bubbles
 - 1 proto-bubble from α -recoil
 - 1+ proto-bubbles from alpha
- Alpha's should be louder...

Acoustic Signatures, time domain



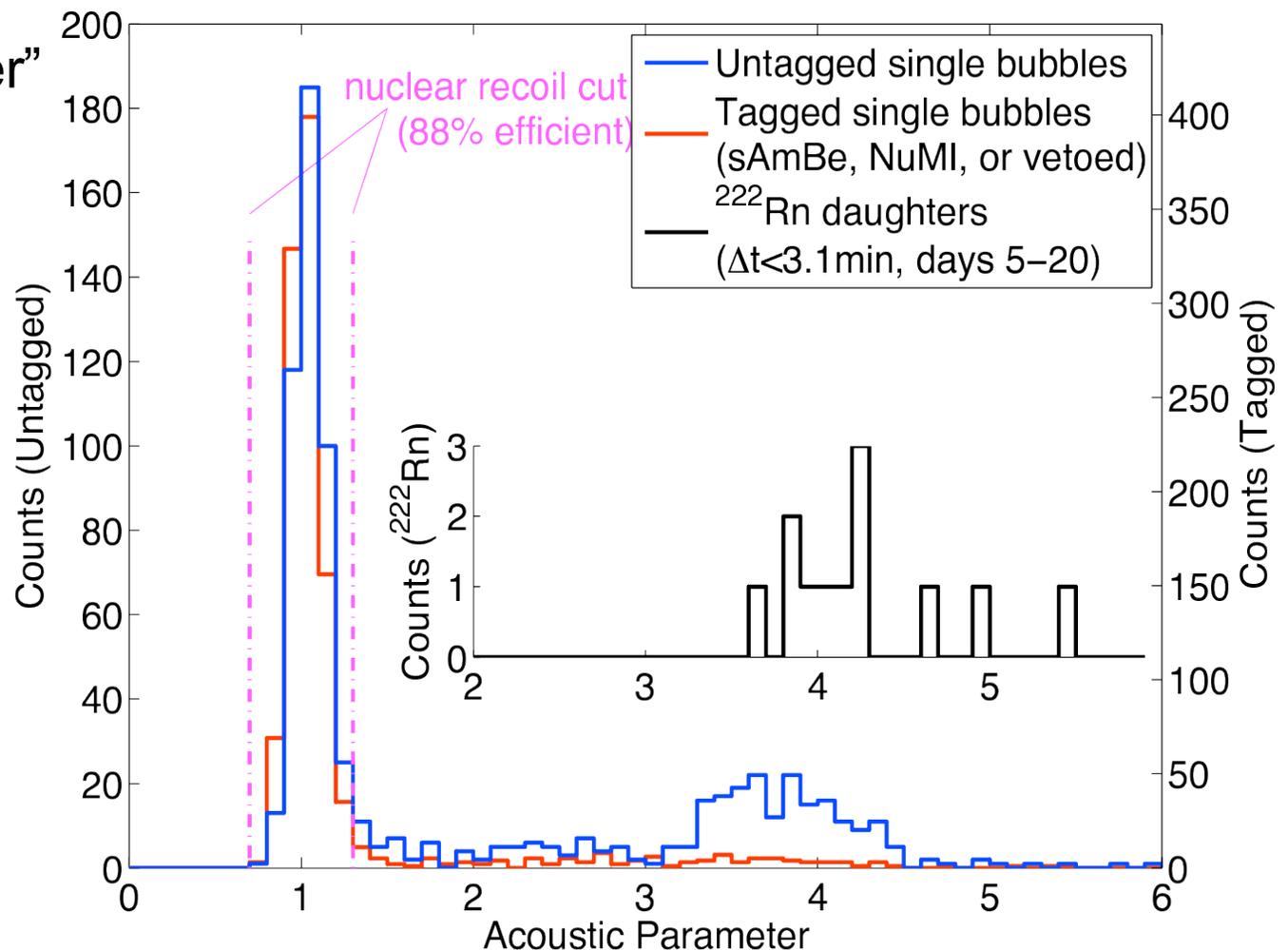
Acoustic Signatures, freq domain



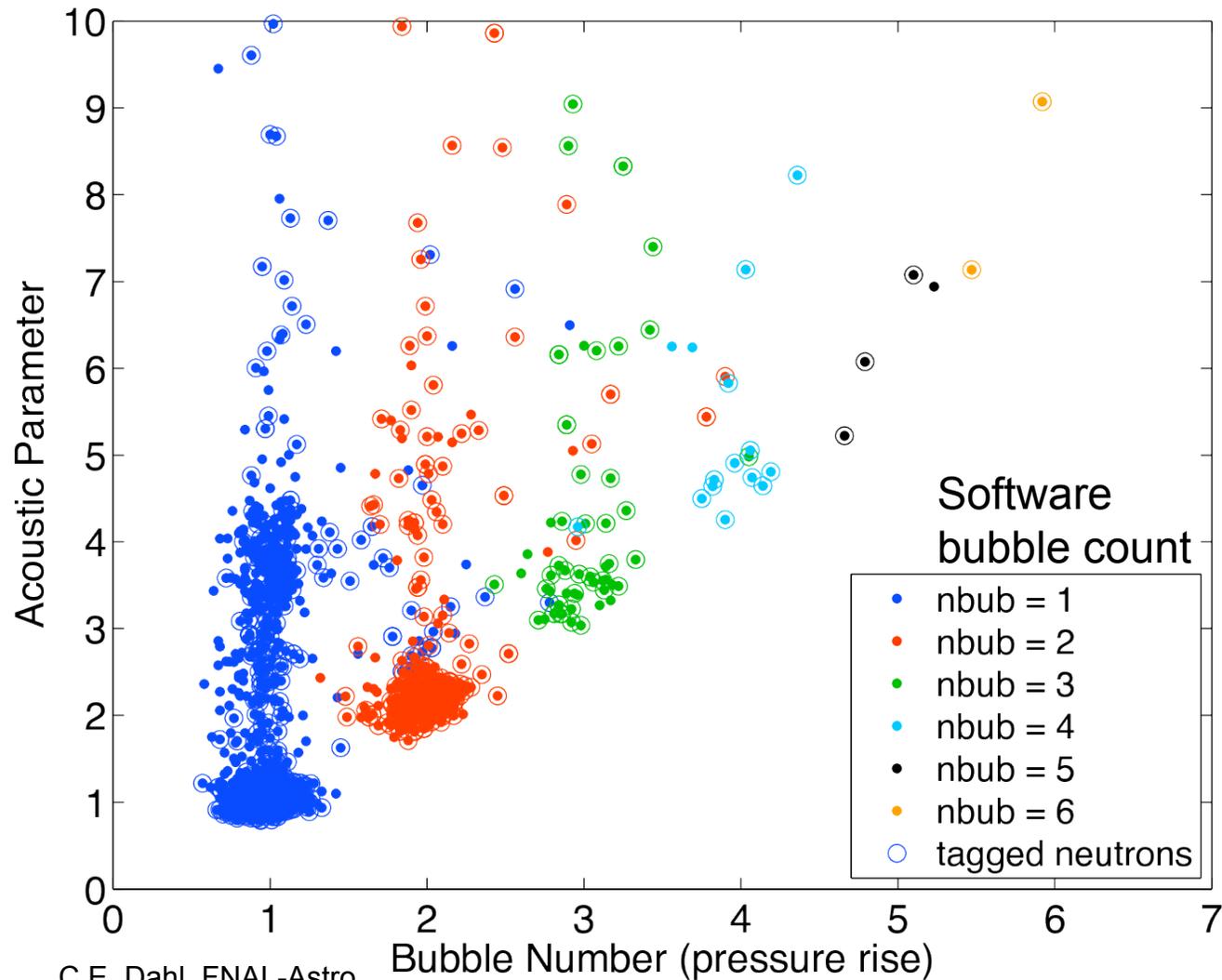
Acoustic Discrimination

“Acoustic Parameter”

- $(\text{Amp} * \omega)^2$
(Normalized and position-corrected for each freq-bin)
- Measure of acoustic energy deposited in chamber

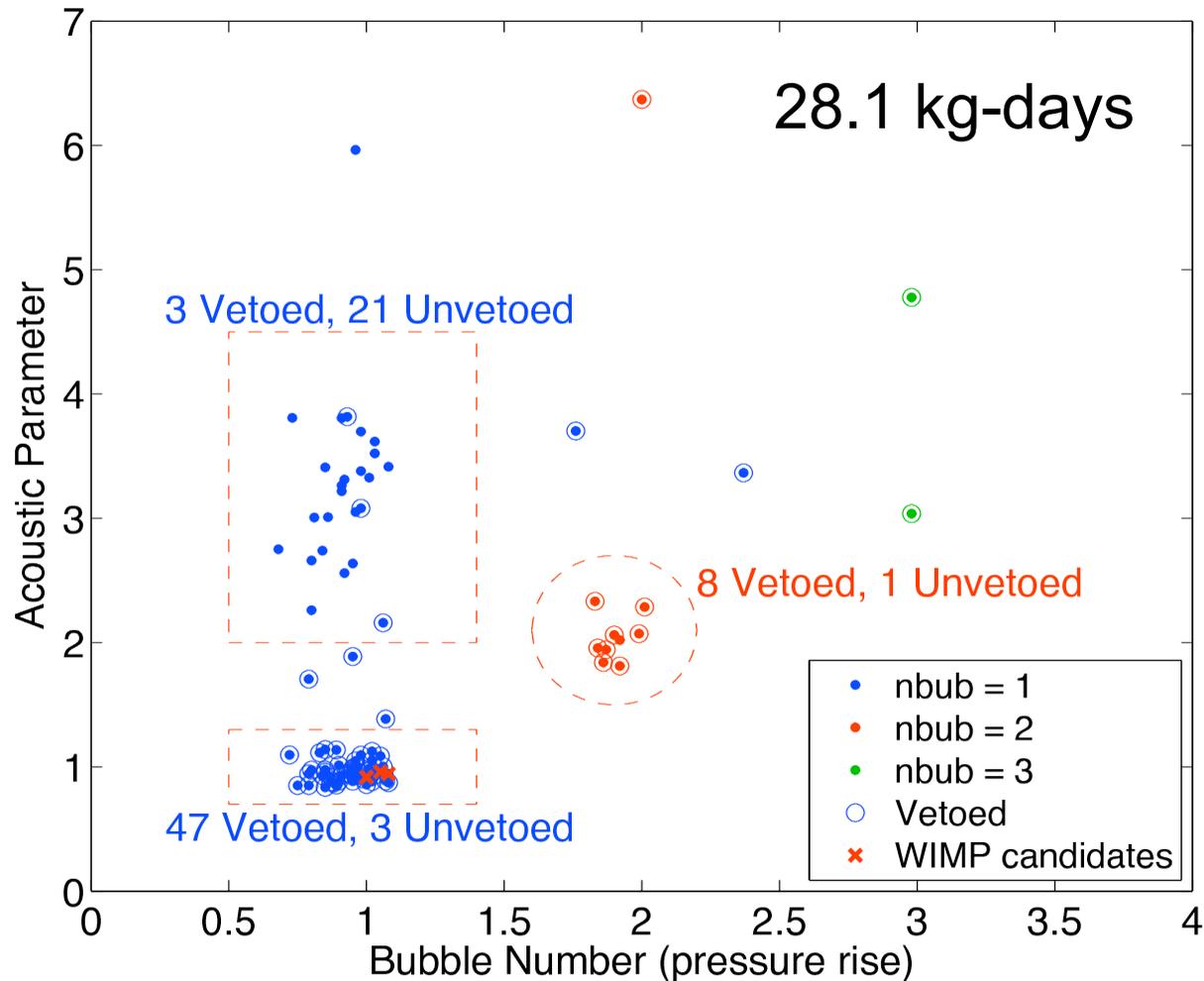


Acoustic Discrimination



- 291 kg-days, mostly before veto installation
- Acoustic Parameter (AP) scales with # of bubbles
- No tails at low AP
- All bubble numbers have tail at high AP

Acoustic Discrimination

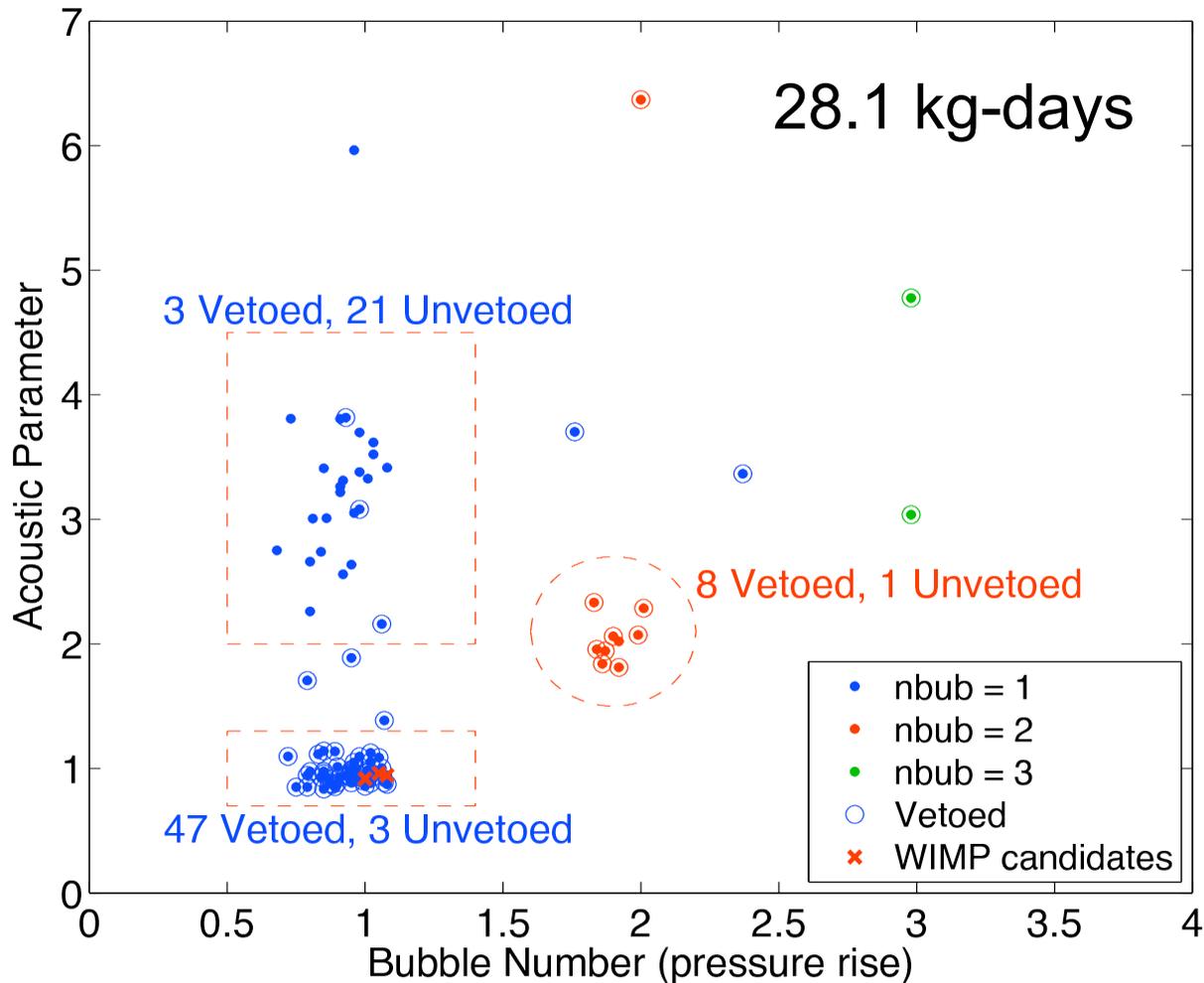


- 3 “WIMP candidates” could be

- alphas
- neutrons
- WIMPs

- Note un-vetoed 2-bubble event...

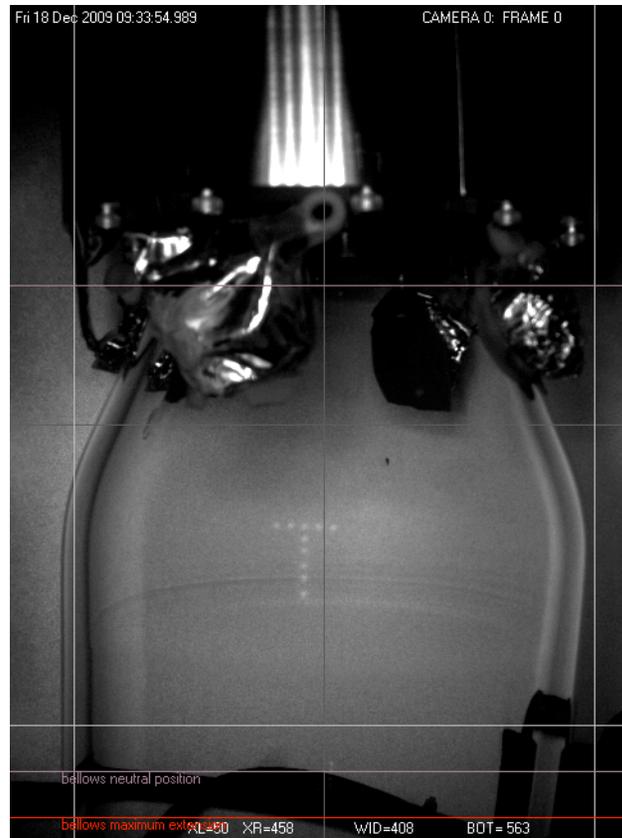
Acoustic Discrimination



- Counting WIMP candidates as possible alphas...
- ^{222}Rn and un-vetoed singles give >80% alpha rejection at 90% CL

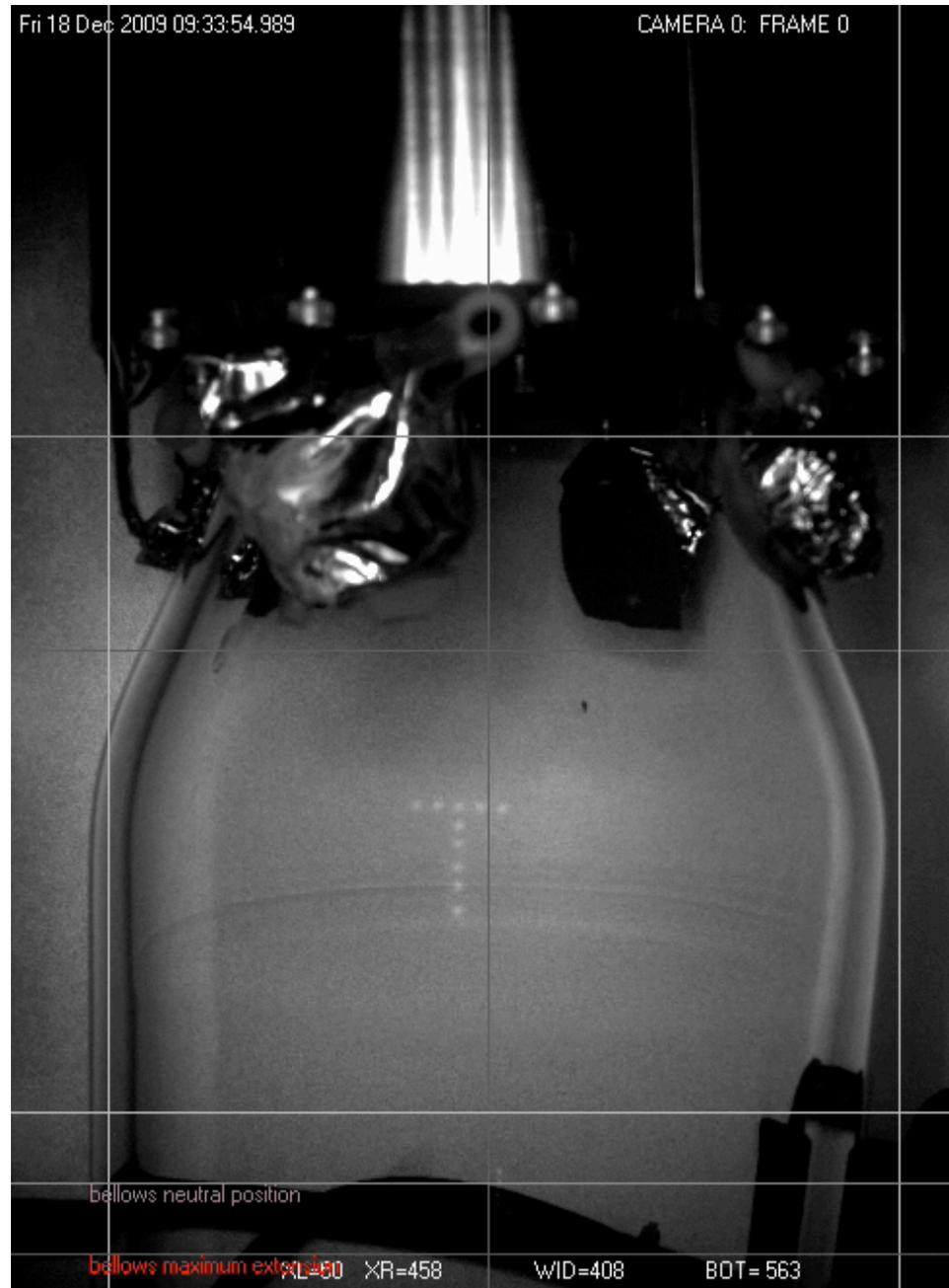
COUPP 4kg: End of the Run

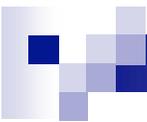
- Clear opportunity for dark matter physics with 4kg chamber, but...



DAQ Fail

- Camera drivers stopped taking new images
- Missed a bubble
 - P_{inner} to 80 psia (CF₃I vapor pressure)
 - P_{outer} maintained at 27 psia
 - Differential pressure equivalent to 700 lb linear force





COUPP 4kg: End of the Run

- Clear opportunity for dark matter physics with 4kg chamber, but...
- Run ended prematurely due to technical failure
 - Failure understood
 - Chamber operational but compromised
 - Decision to end run and make repairs
- What can we do with data in hand?

...come to Jeter Hall's wine and cheese to find out!

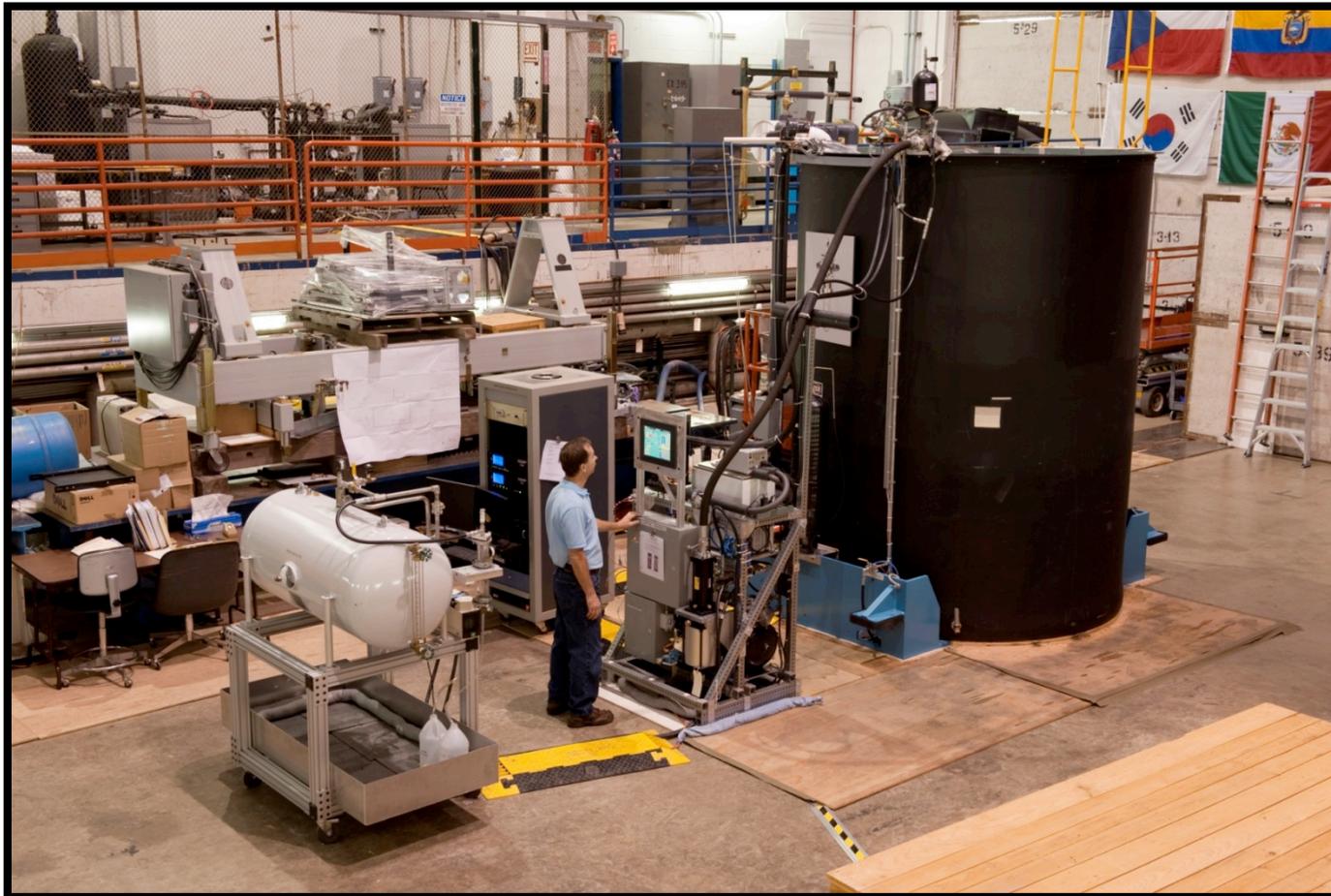


Meanwhile...

- COUPP 4kg moving to the surface for repairs
- COUPP 60kg moving underground for its first run with
 - Complete DAQ
 - Retro-reflector lighting
 - Acoustic sensors
 - High purity vessel
 - High purity fluid handling cart

Engineering Run at D0, Sept-Dec 2009

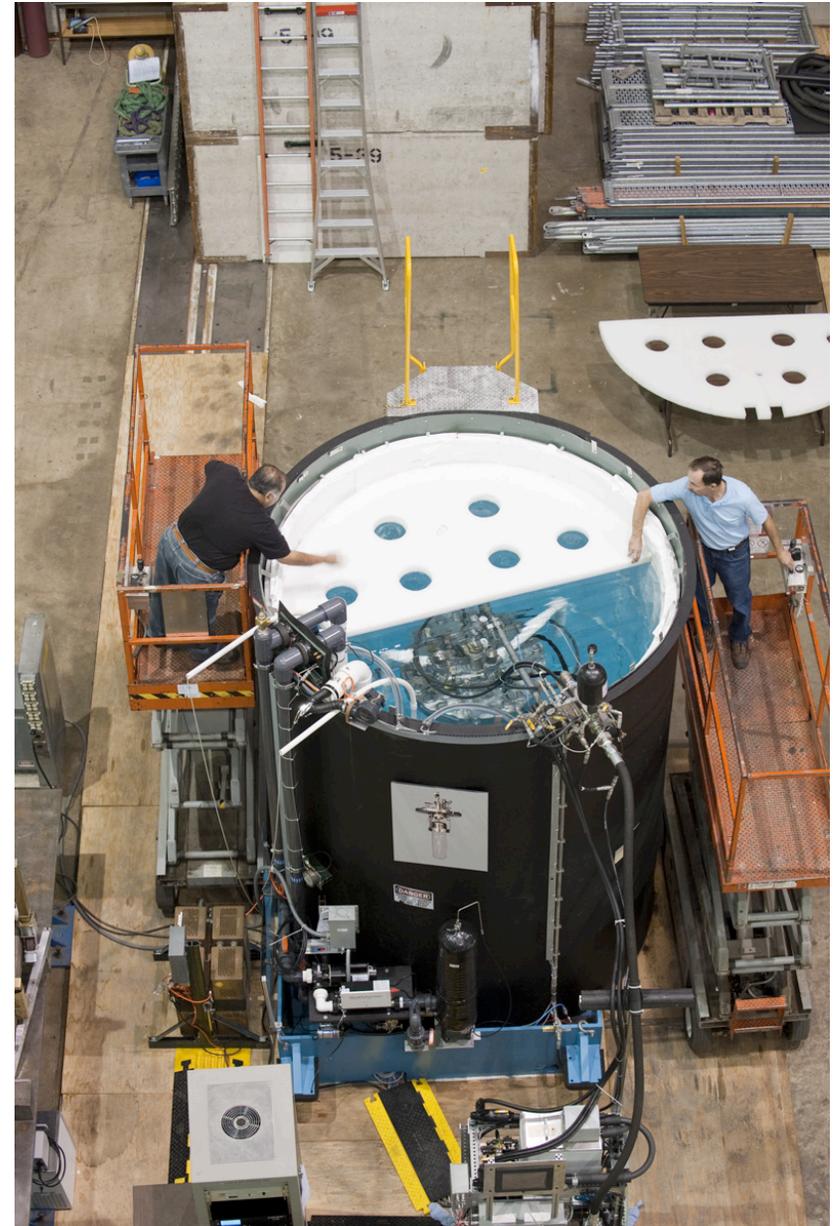
- Filled mechanical prototype with 23 kg CF_3I



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Successes at D0

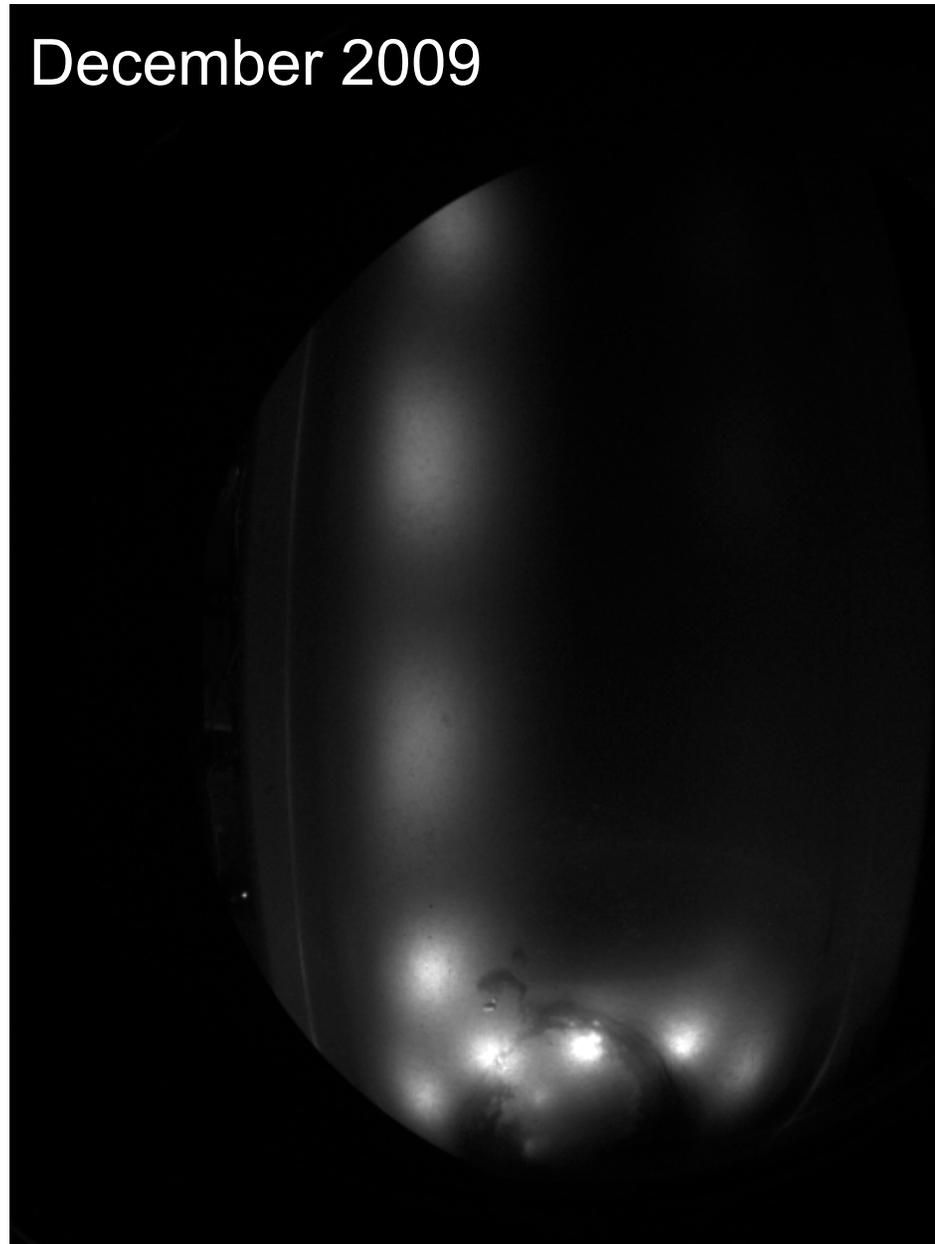
- Water Cherenkov muon veto
 - Same bases as 4kg veto
- Pressure cart
 - Industrial PLC
 - Triggers on pressure rises, etc
 - Integrated with DAQ, camera triggers



Failure at D0

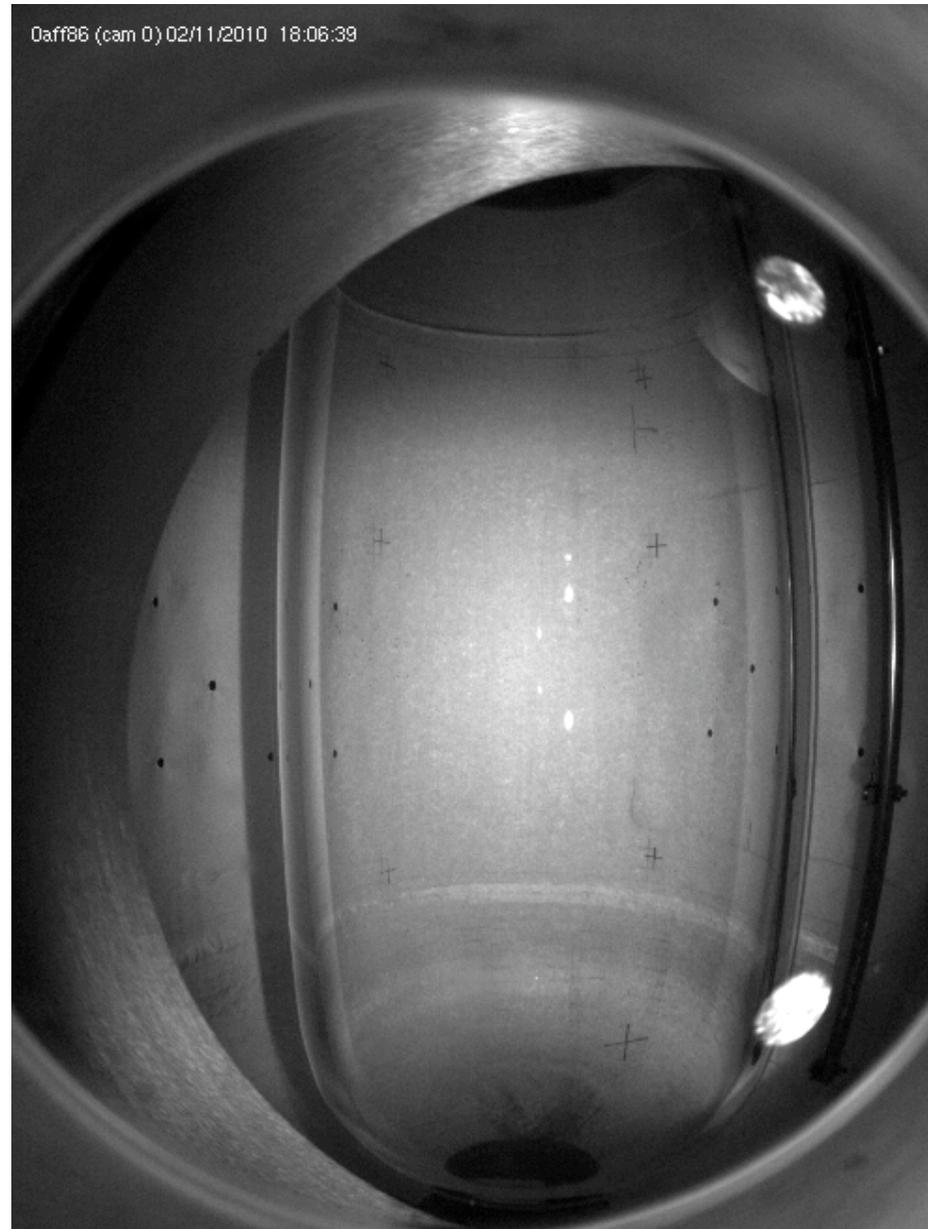
- Lighting system
 - Back-lighting through diffuser (inferior to front-lighting with retro-reflector)
 - LED's gradually failed over several months in glycol

December 2009

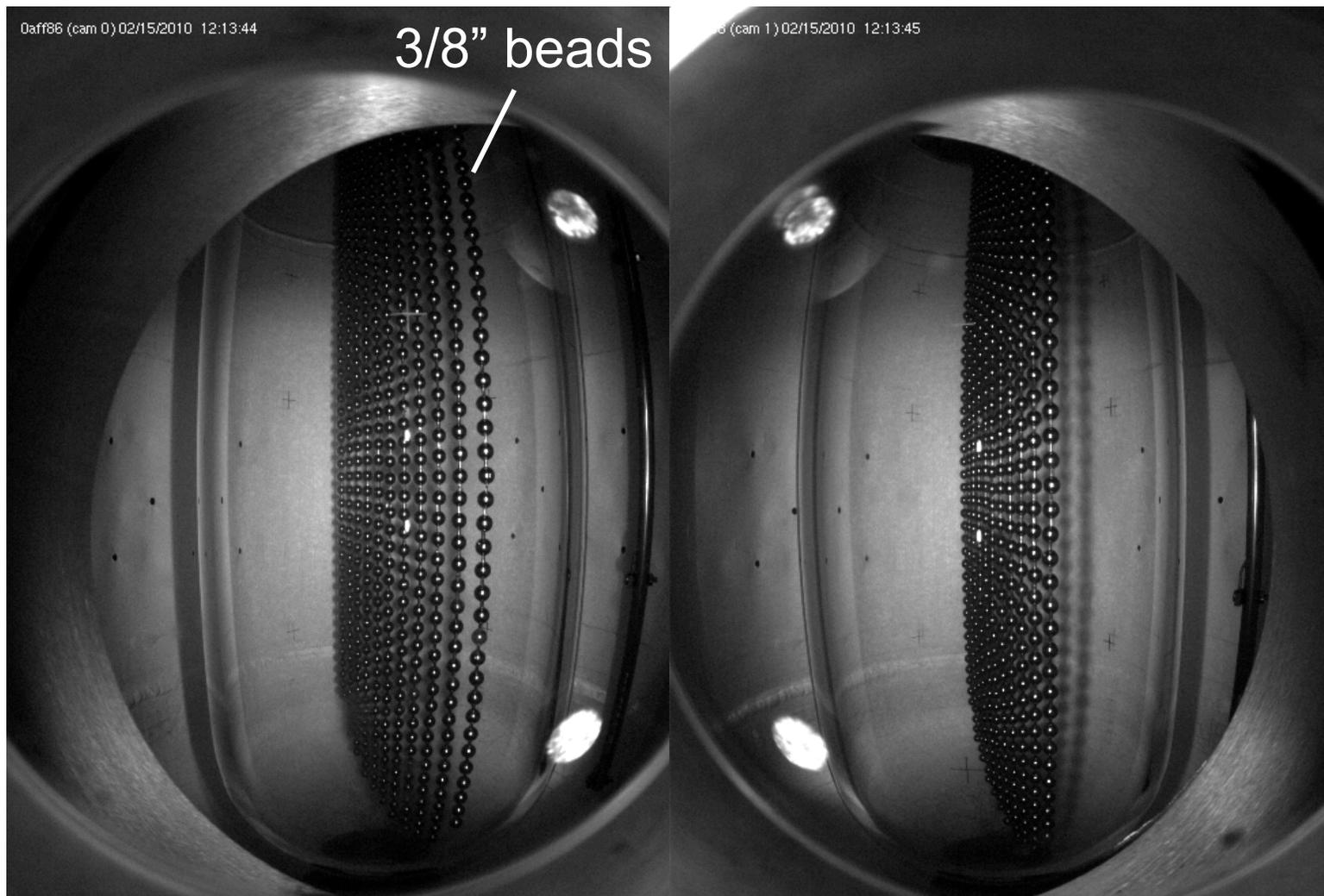


Retro-reflective lighting

- Light source next to cameras
- Retro-reflector on pressure vessel walls

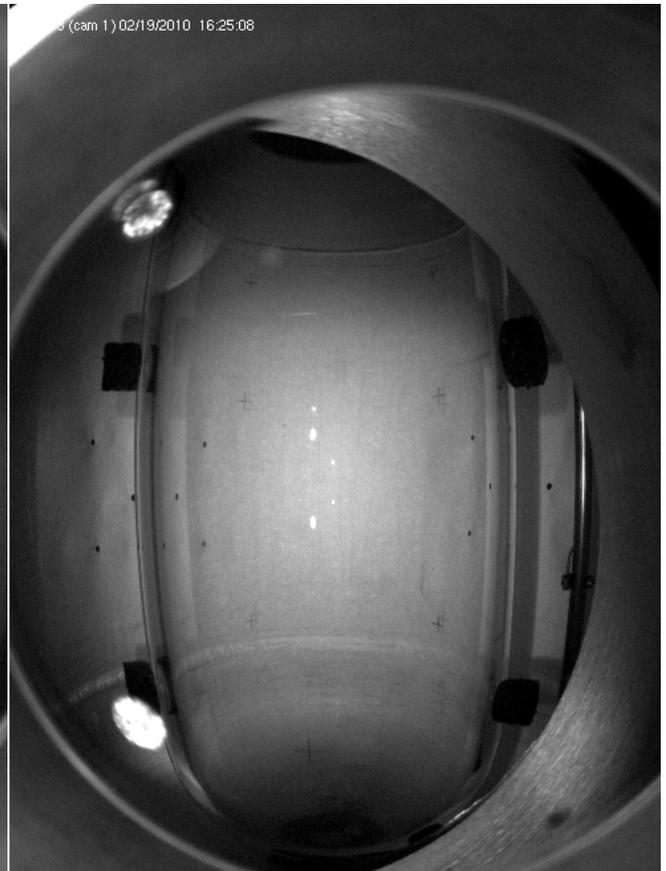
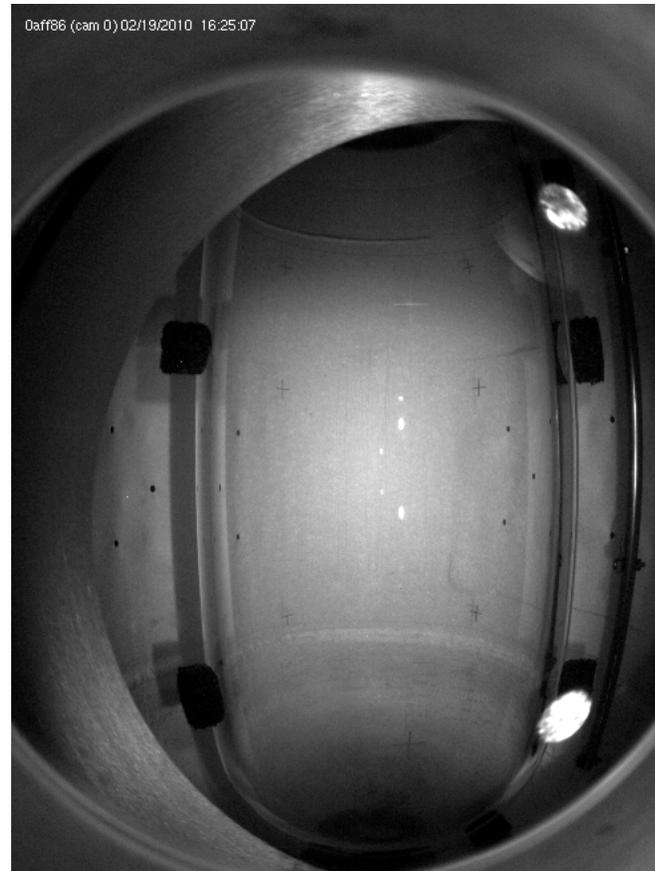


Position Calibration



Piezo Positioning

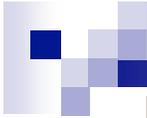
- Piezo's placed in columns such that neither camera is obstructed
- View out the back of the chamber is also clear



High Purity Assembly

- Sealed and leak-checked
- Rinsed, evacuated, and back-filled





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High Purity Fluid Handling Cart

- Millipore purifier and radon stripper for H₂O
- Two distillation tanks for dual use (H₂O and CF₃I)





COUPP60 Schedule

- Assembled detector and veto scheduled to move underground week of March 15
- Start running in April (requires high purity fluid handling cart)
- SNOLAB in the near future...

Summary

- Wall rate reduced
 $<10^{-4}$ evts/cm²/day
- Bulk rate reduced
 <1 evt/kg/day
- New muon veto
Installed on 4kg
and 60kg detectors
- Acoustic
discrimination
 $>80\%$ rejection at
 88% acceptance
- COUPP60 on its
way
Data in April

