

COUPP

First data from a deep-site bubble chamber



Dahl, Moriond EW
March 18, 2011

The COUPP Collaboration

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Kavli Institute
for Cosmological Physics

AT THE UNIVERSITY OF CHICAGO

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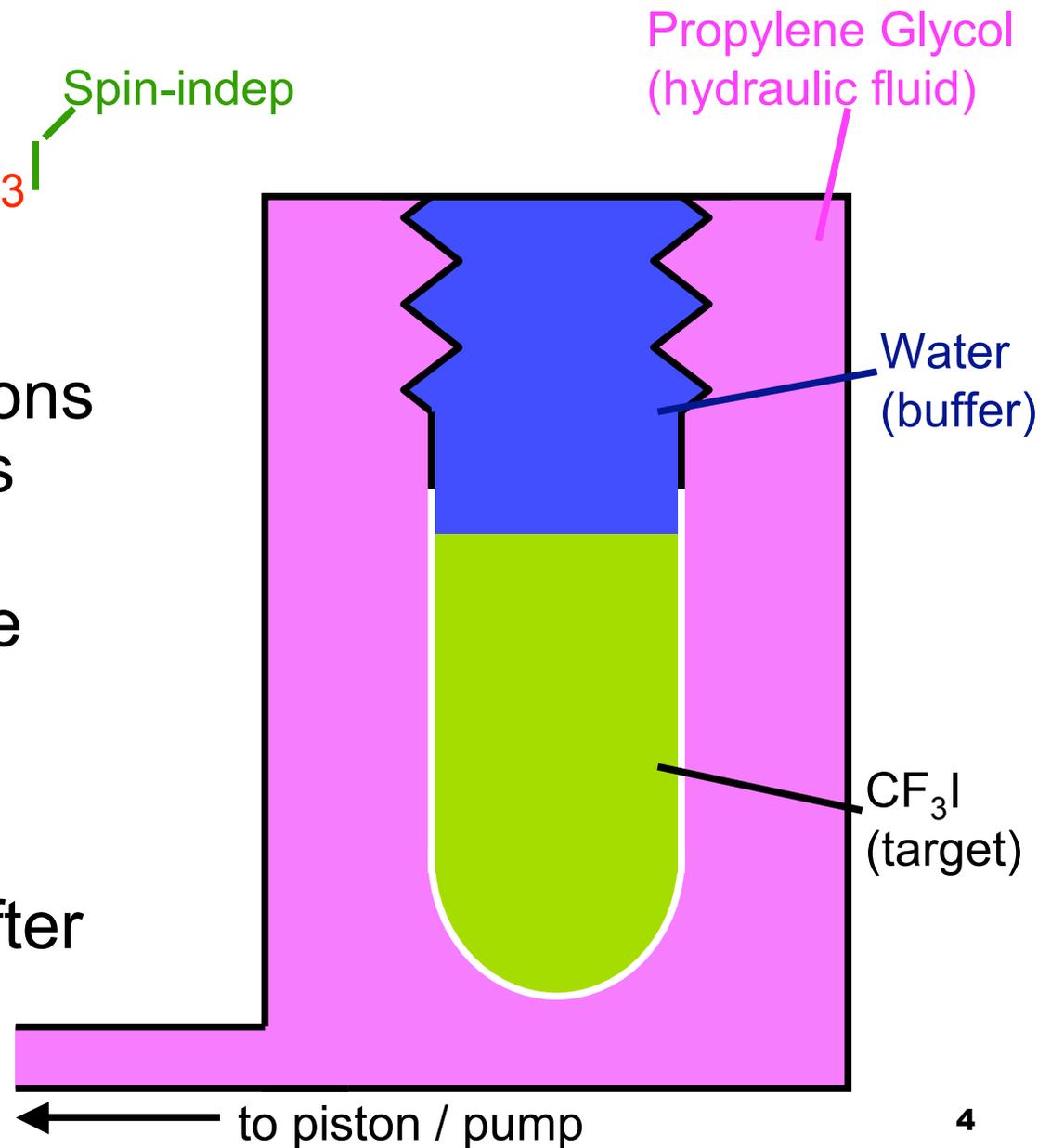


Outline

- Bubble Chamber Review
- COUPP 4kg @ MINOS, results
Phys.Rev.Lett.106:021303,2011
- COUPP 4kg @ SNOLAB, status and results
- COUPP 60 @ MINOS, status

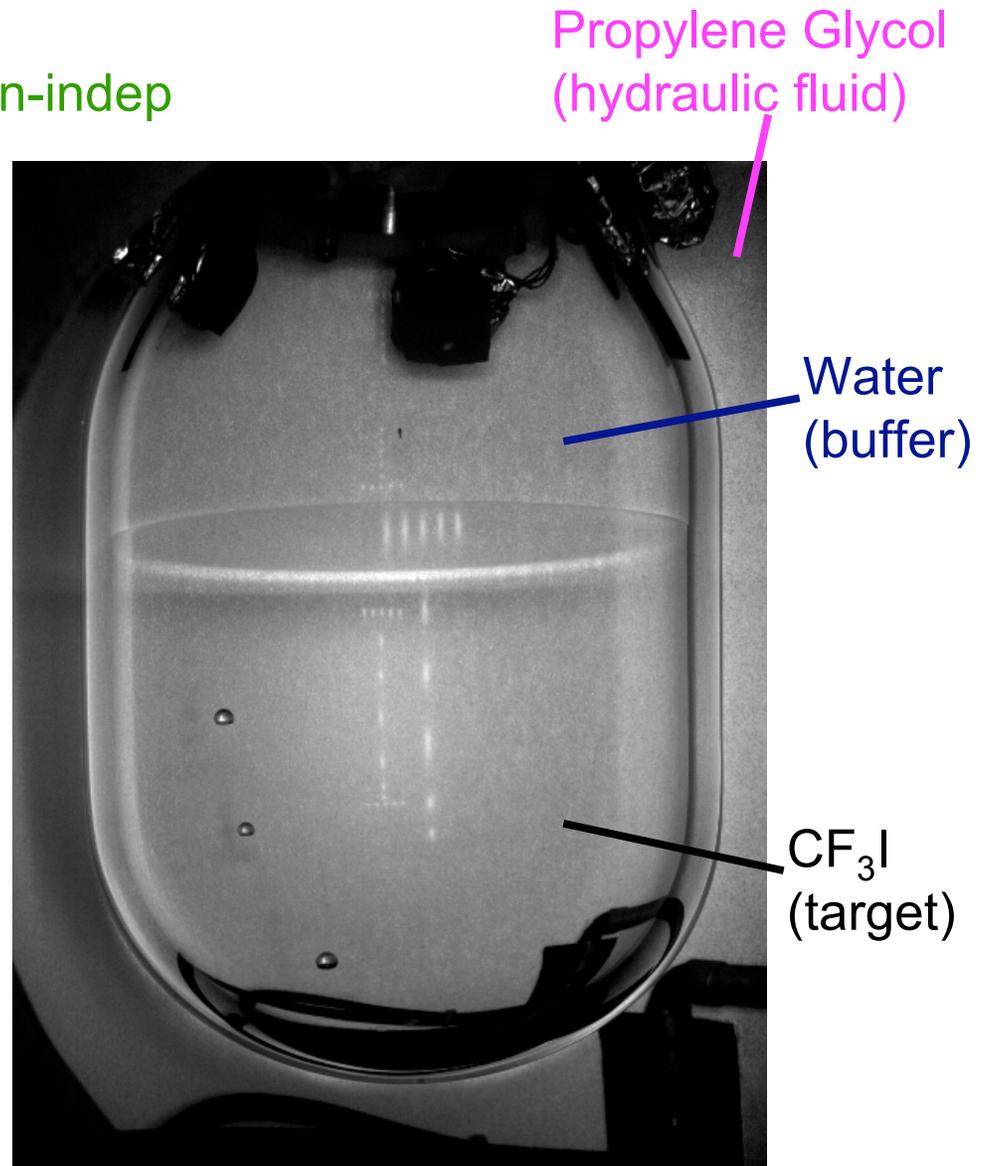
Review

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



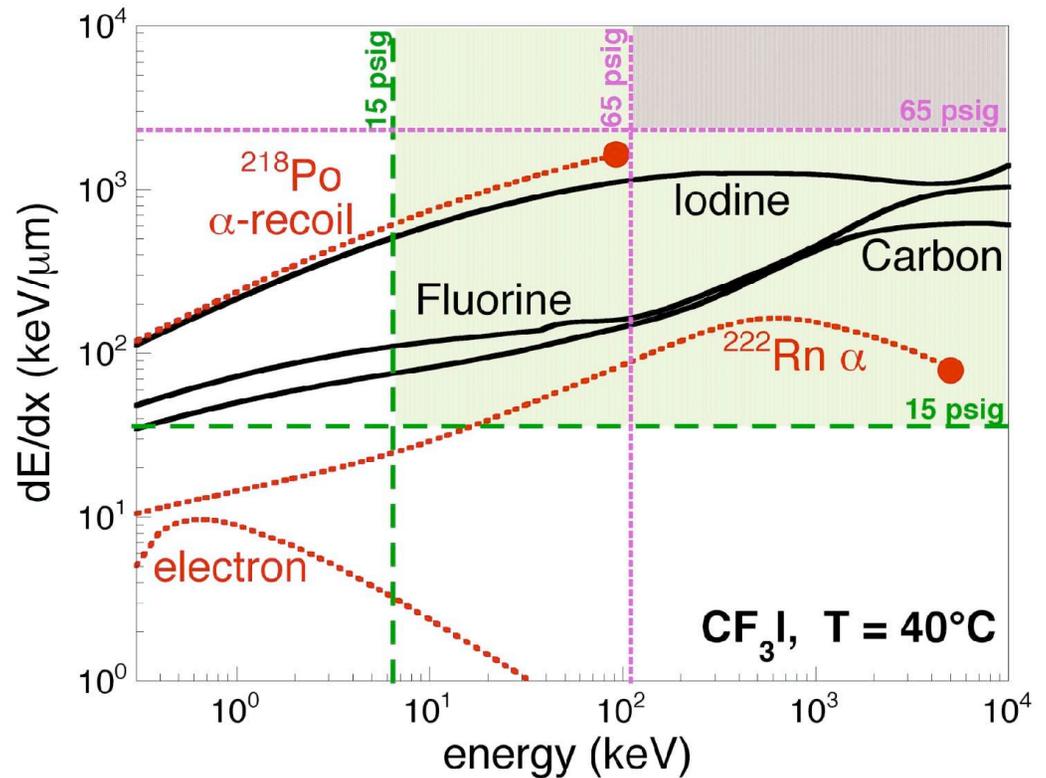
Review

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



Review

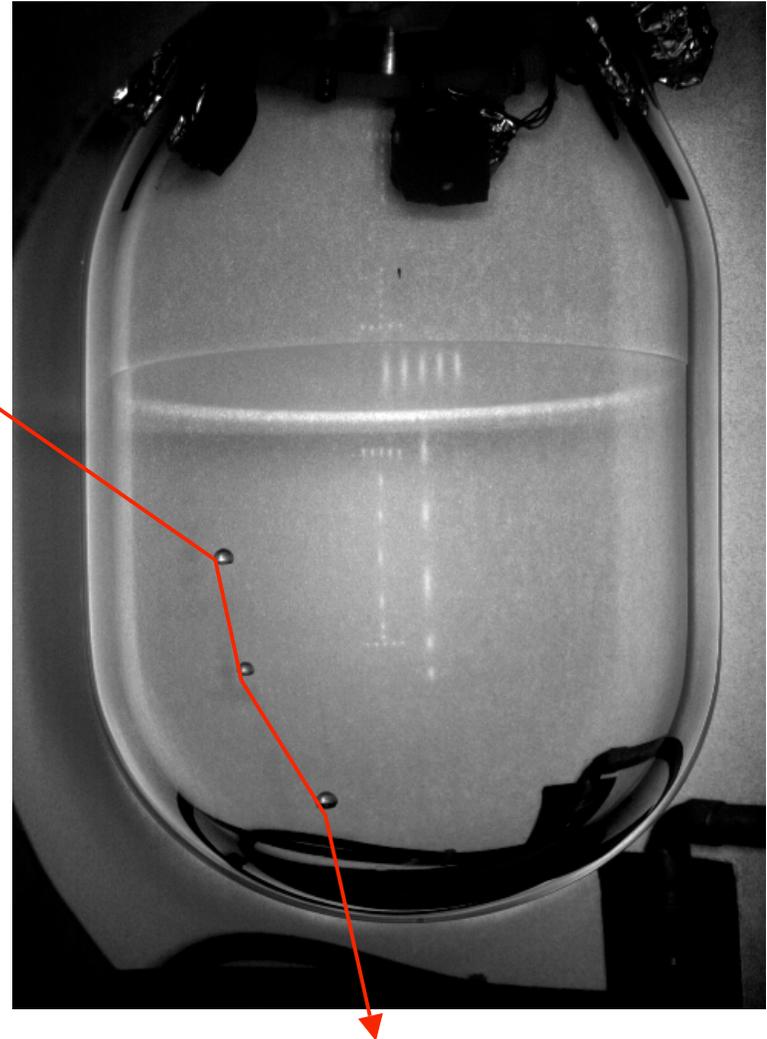
- Only proto-bubbles with $r > r_{\text{crit}}$ grow to be macroscopic
- Critical proto-bubble requires minimum dE within minimum volume
- Recoil must be over thresholds in both E and dE/dx



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

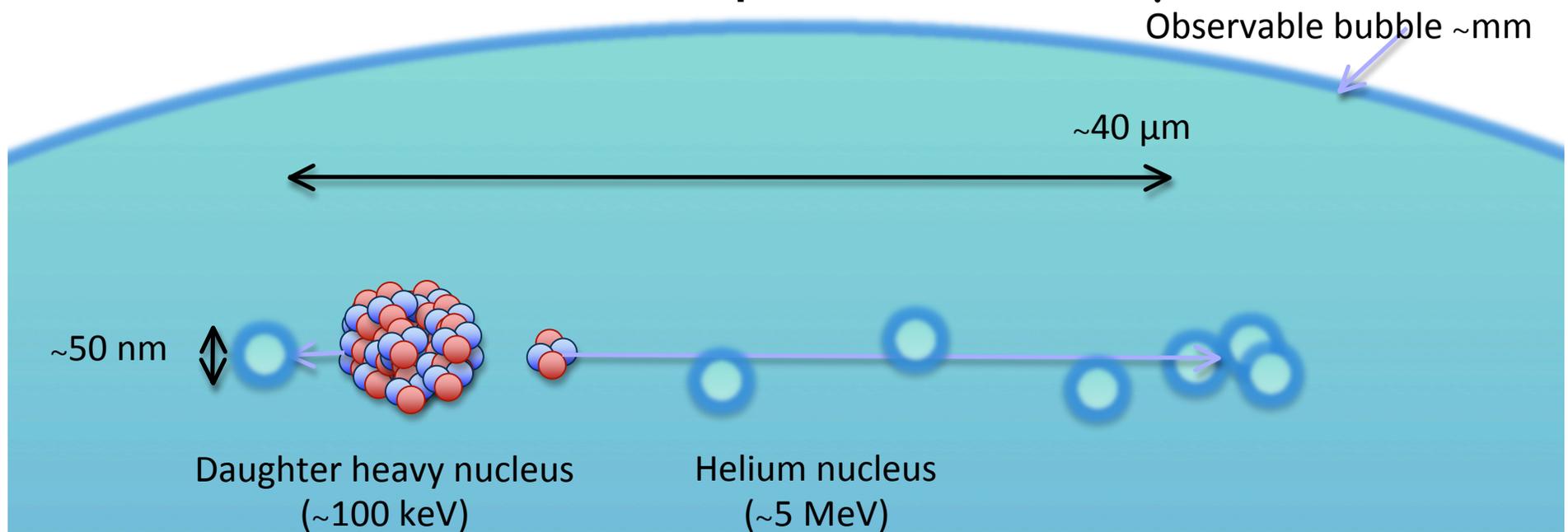
3 basic event types

- alpha-decays
 - Nuclear recoil + 40 μm alpha track
 - U,Th chain impurities in fluid, especially radon and its daughters
- neutrons
 - Nuclear recoils, mean free path ~ 20 cm
 - Produced by cosmic muons, fission, and (α,n) reactions
- WIMPs
 - Single nuclear recoil (mean free path $> 10^{12}$ cm)



Acoustic Discrimination

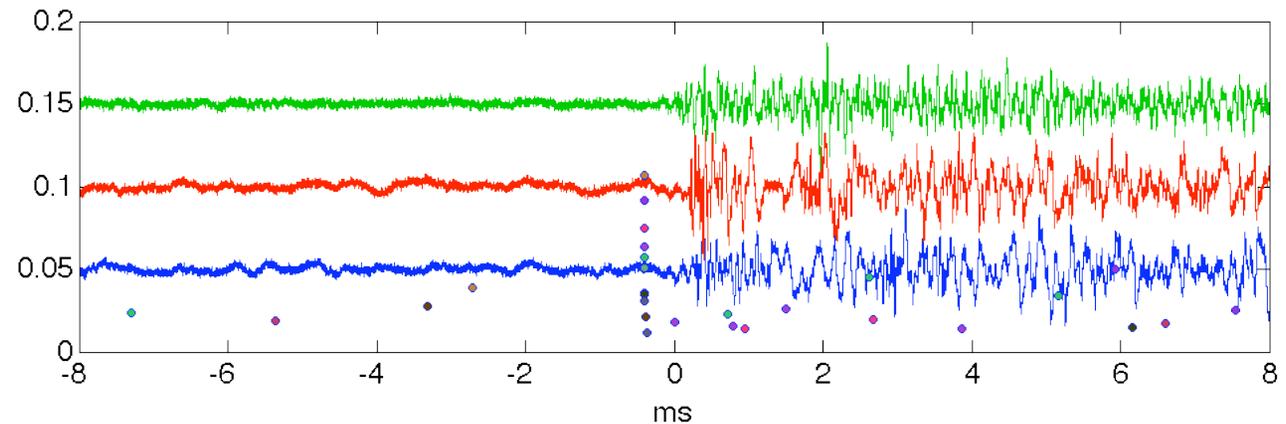
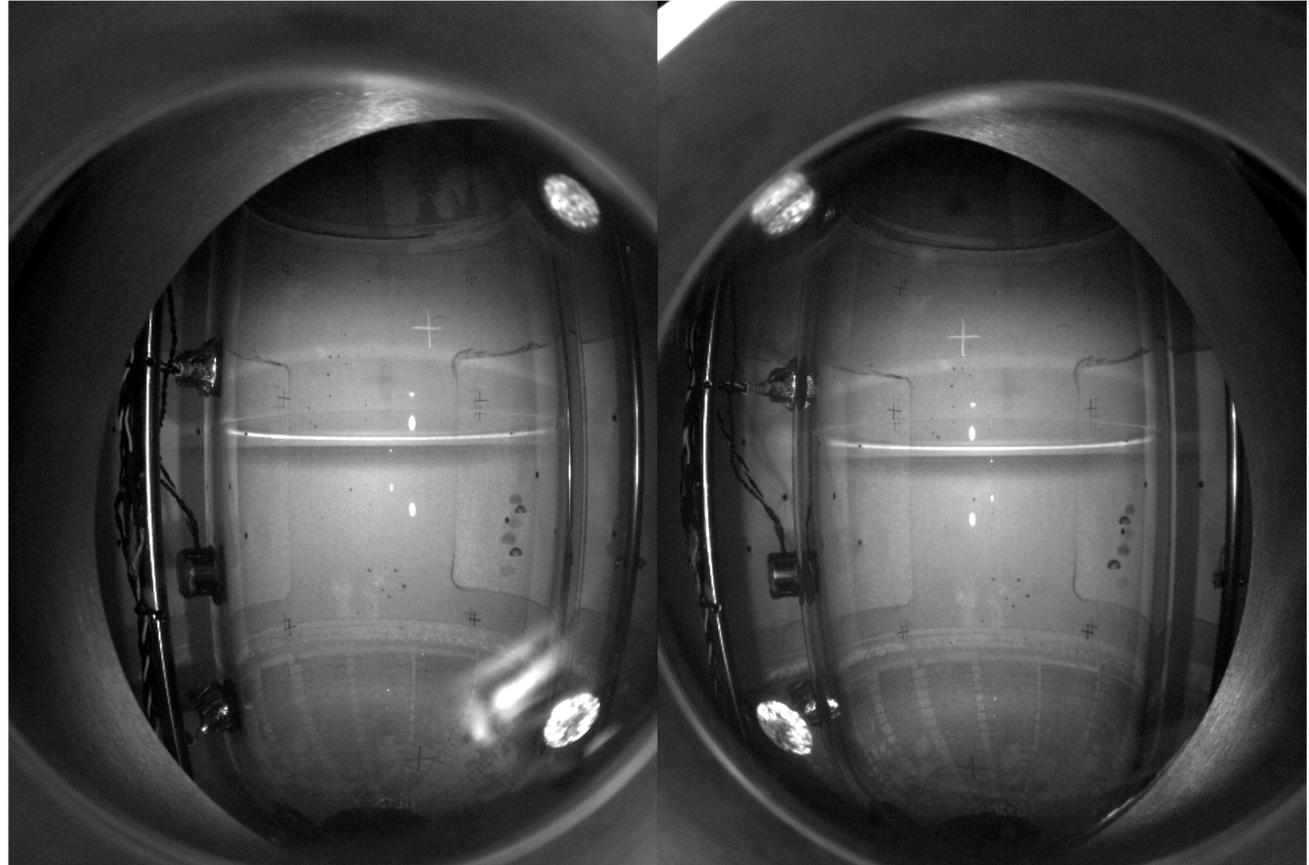
- Alpha louder when probing length scales $< 40 \mu\text{m}$
- Acoustic emission peaks at $\sim 10 \mu\text{m}$



COUPP 60 @ MINOS

First data,
July 28, 2010

- Cosmic-induced neutron (2 bubbles)

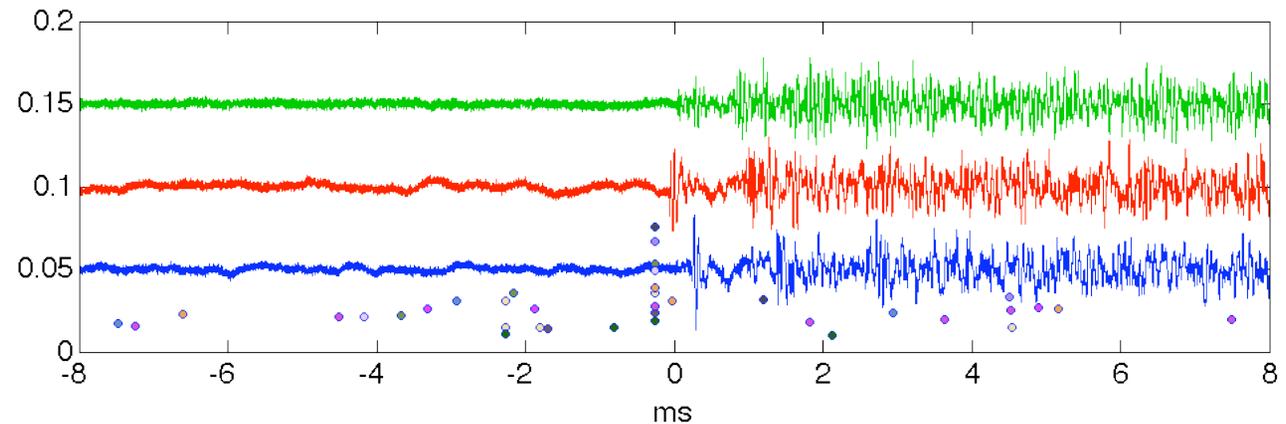
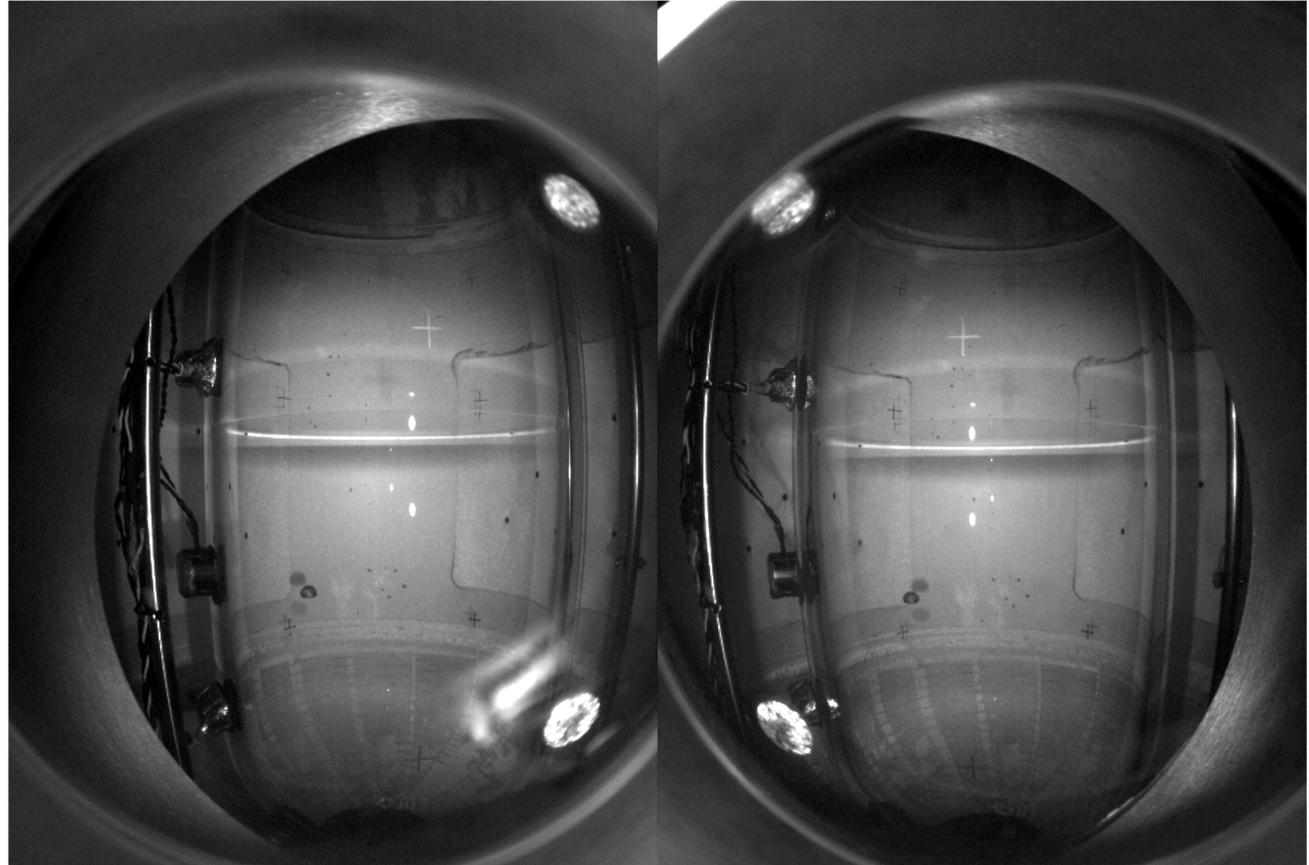


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COUPP 60 @ MINOS

First data,
July 28, 2010

- Cosmic-induced neutron (1 bubble)

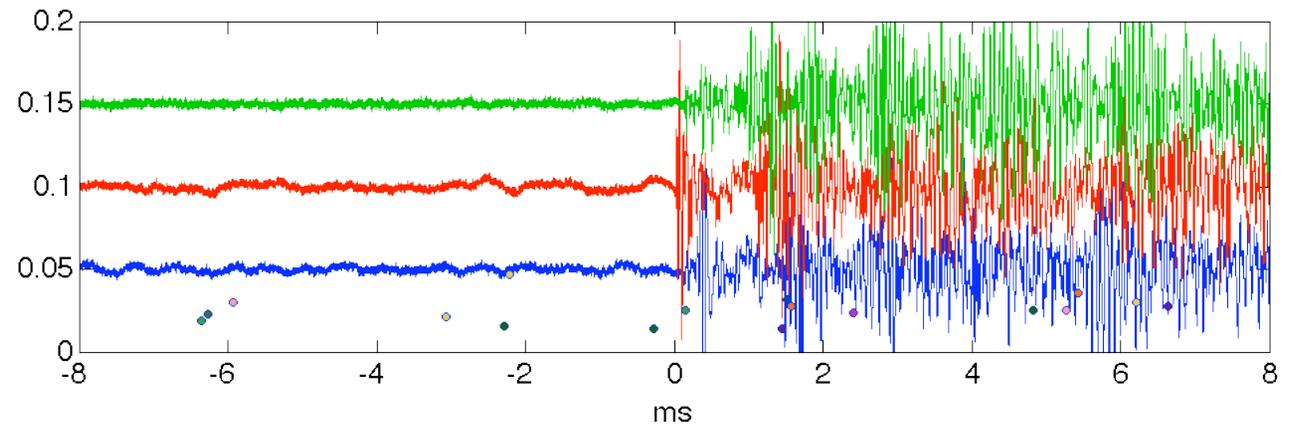
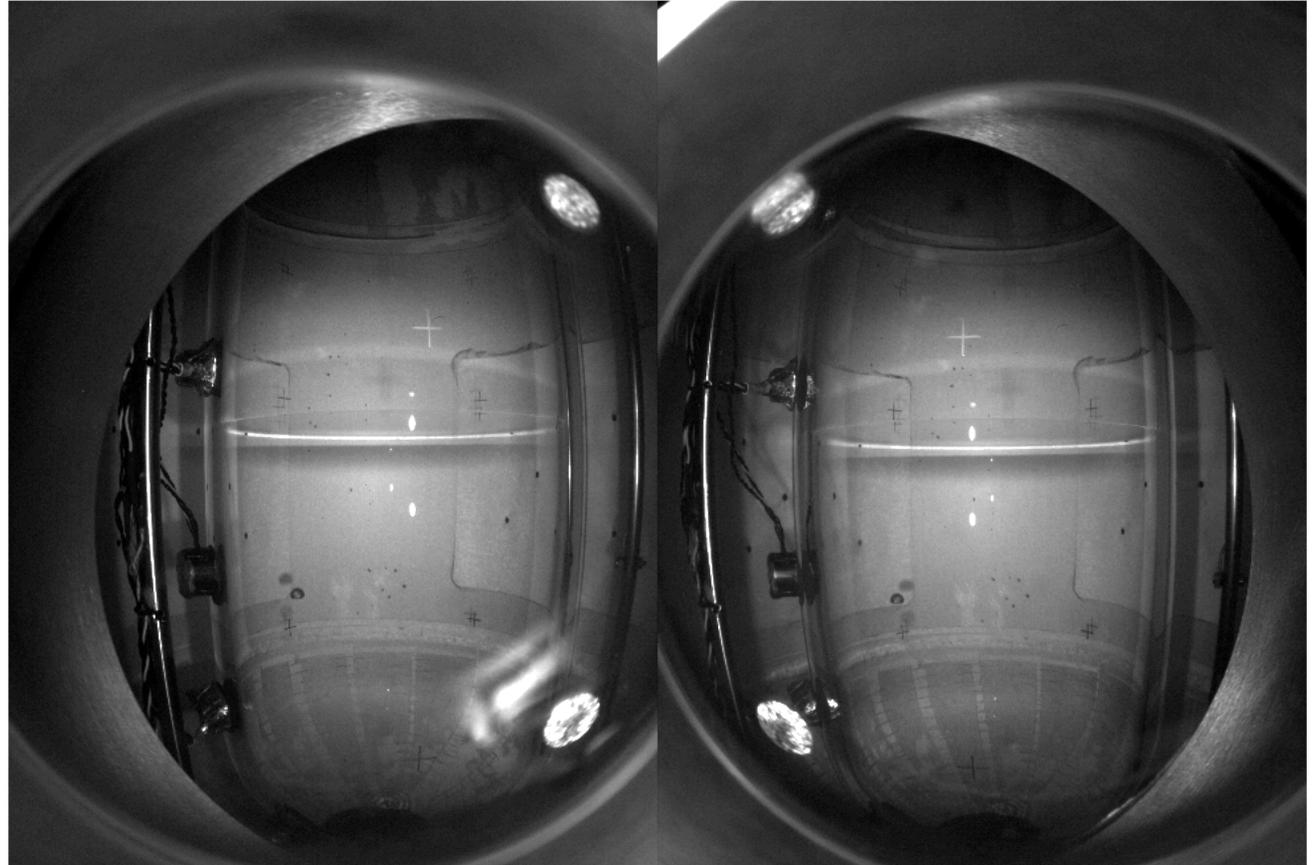


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COUPP 60 @ MINOS

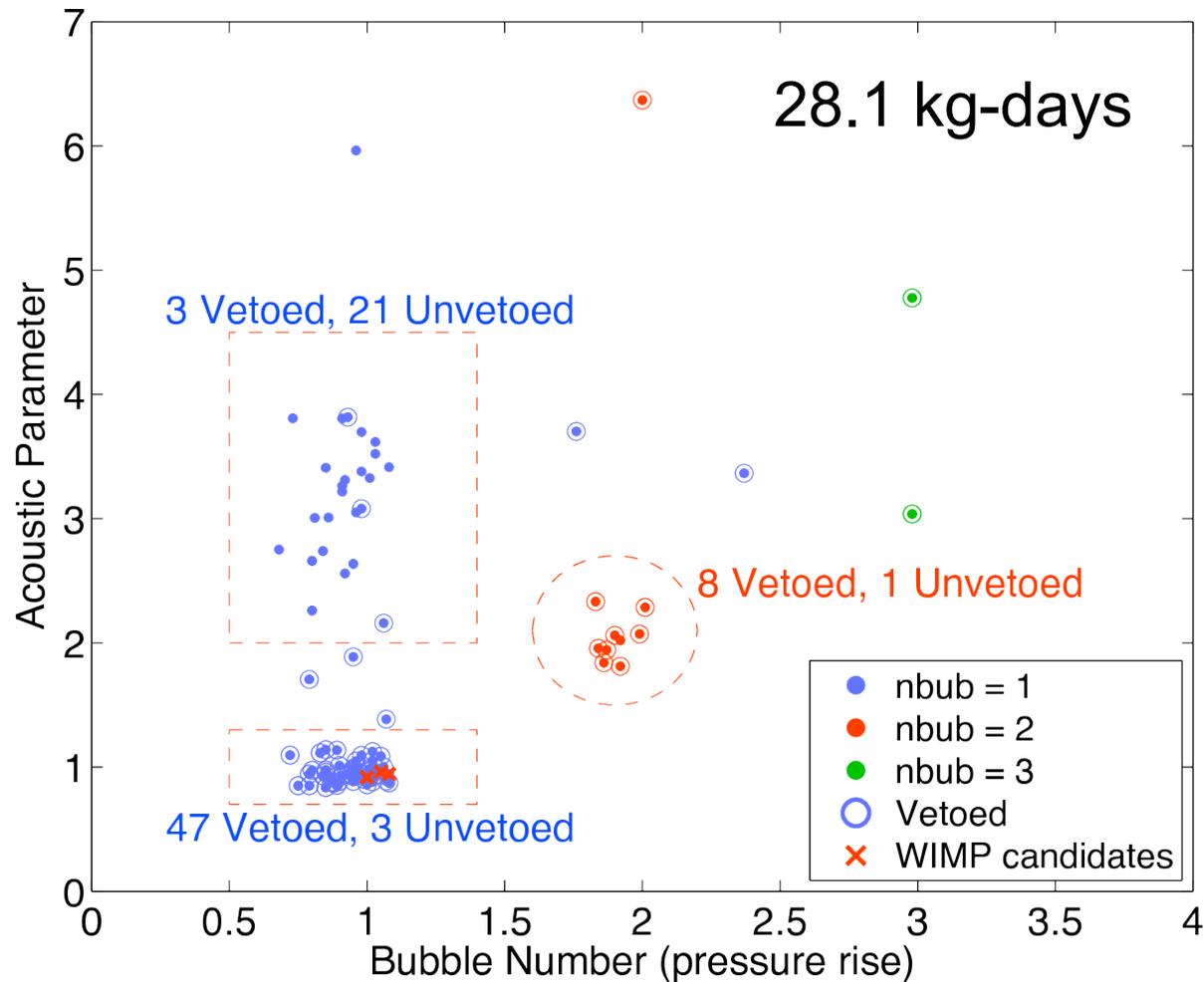
First data,
July 28, 2010

- Alpha-decay
(1 bubble)



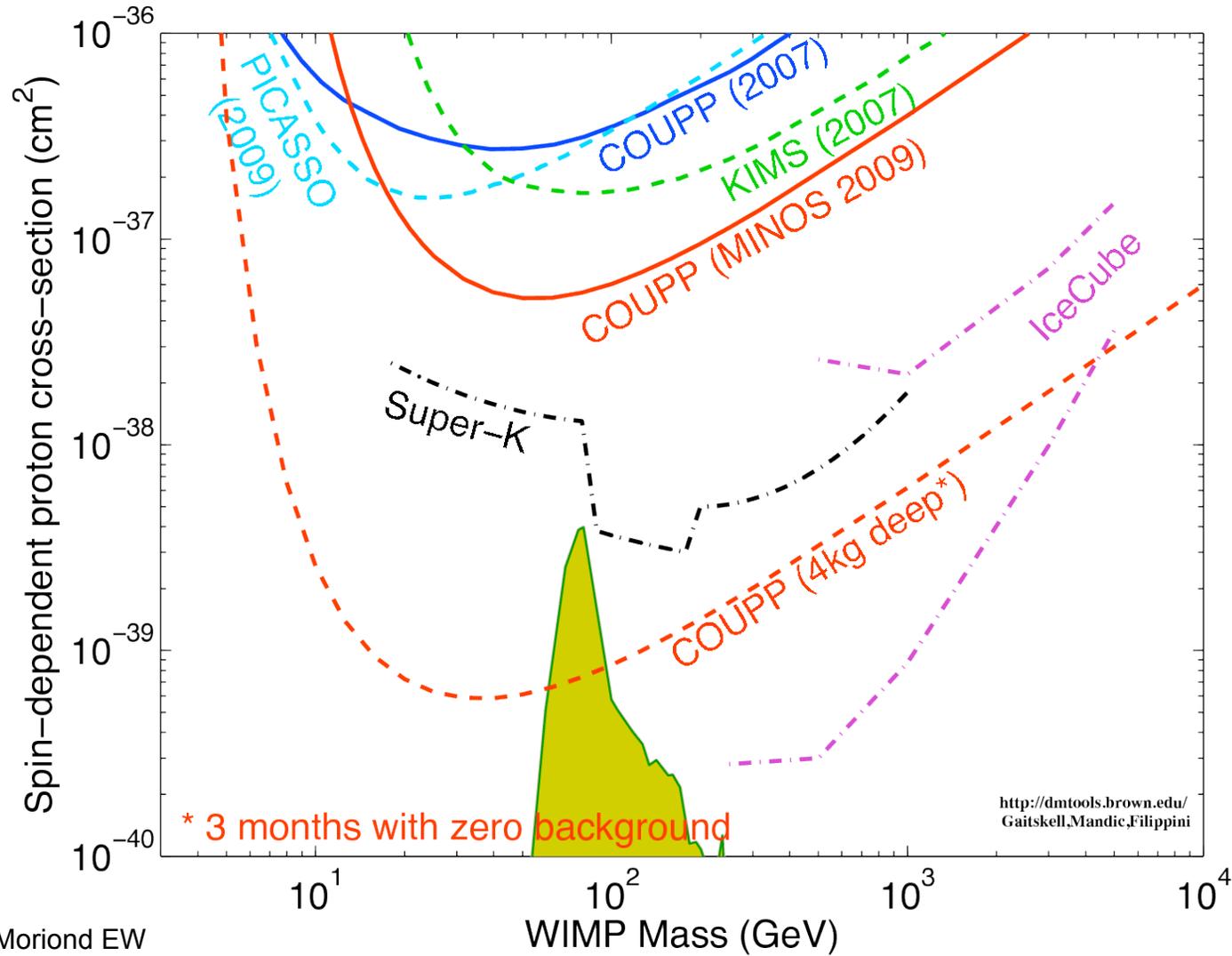
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COUPP 4kg @ MINOS, 2009



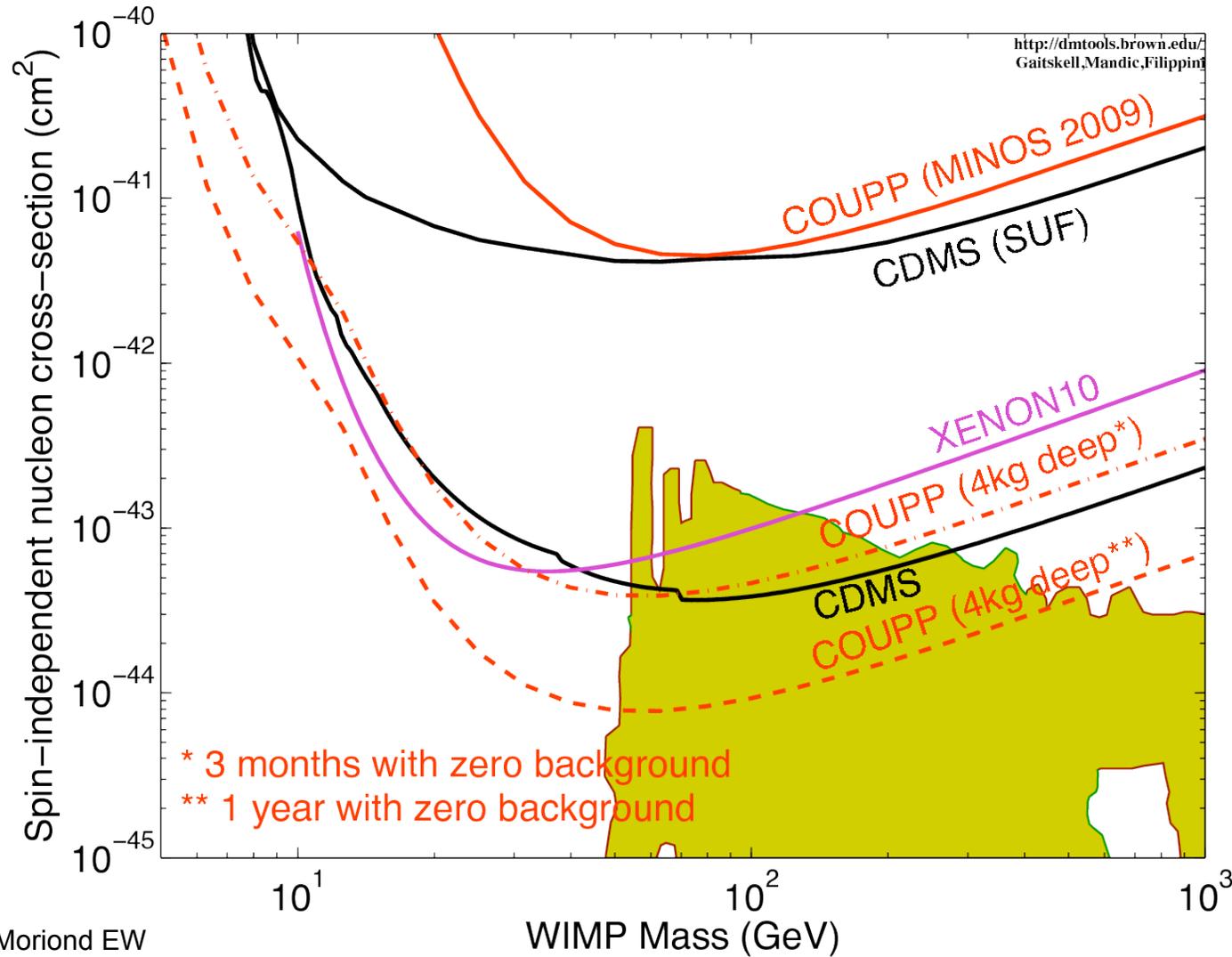
- 3 “WIMP candidates” could be
 - alphas
 - neutrons
 - WIMPs
- Note un-vetoed 2-bubble event...
- *At least 74% alpha discrimination*

COUPP 4kg @ MINOS, 2009



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COUPP 4kg @ MINOS, 2009



Phys.Rev.Lett. 106:021303,2011



Sudbury, Ontario

6800 Feet Down



COUPP 4kg @ SNOLAB

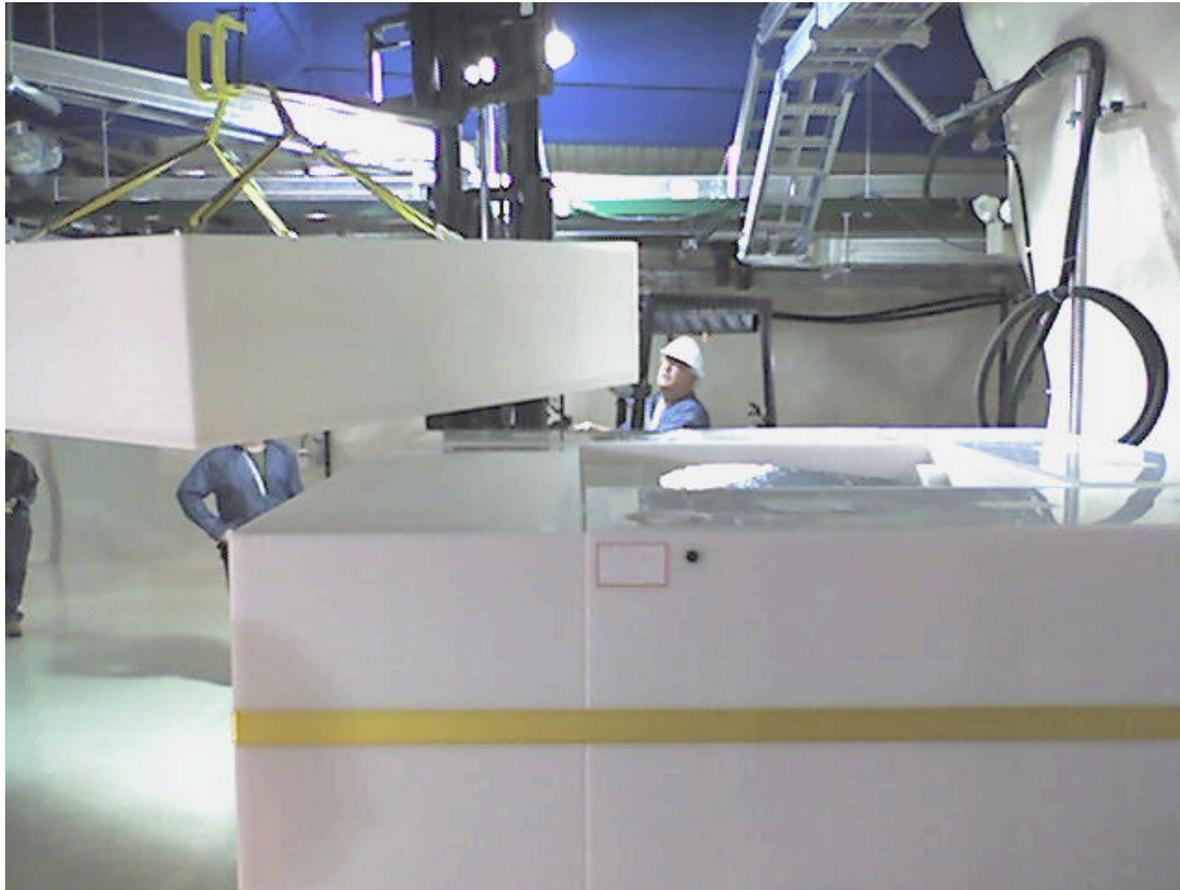


Installation Begins:
July 27, 2010

July 27, 2010, DAQ and Pressure Control
Move Underground

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COUPP 4kg @ SNOLAB



Nov 3, 2010, Shield is completed
Physics data begins!

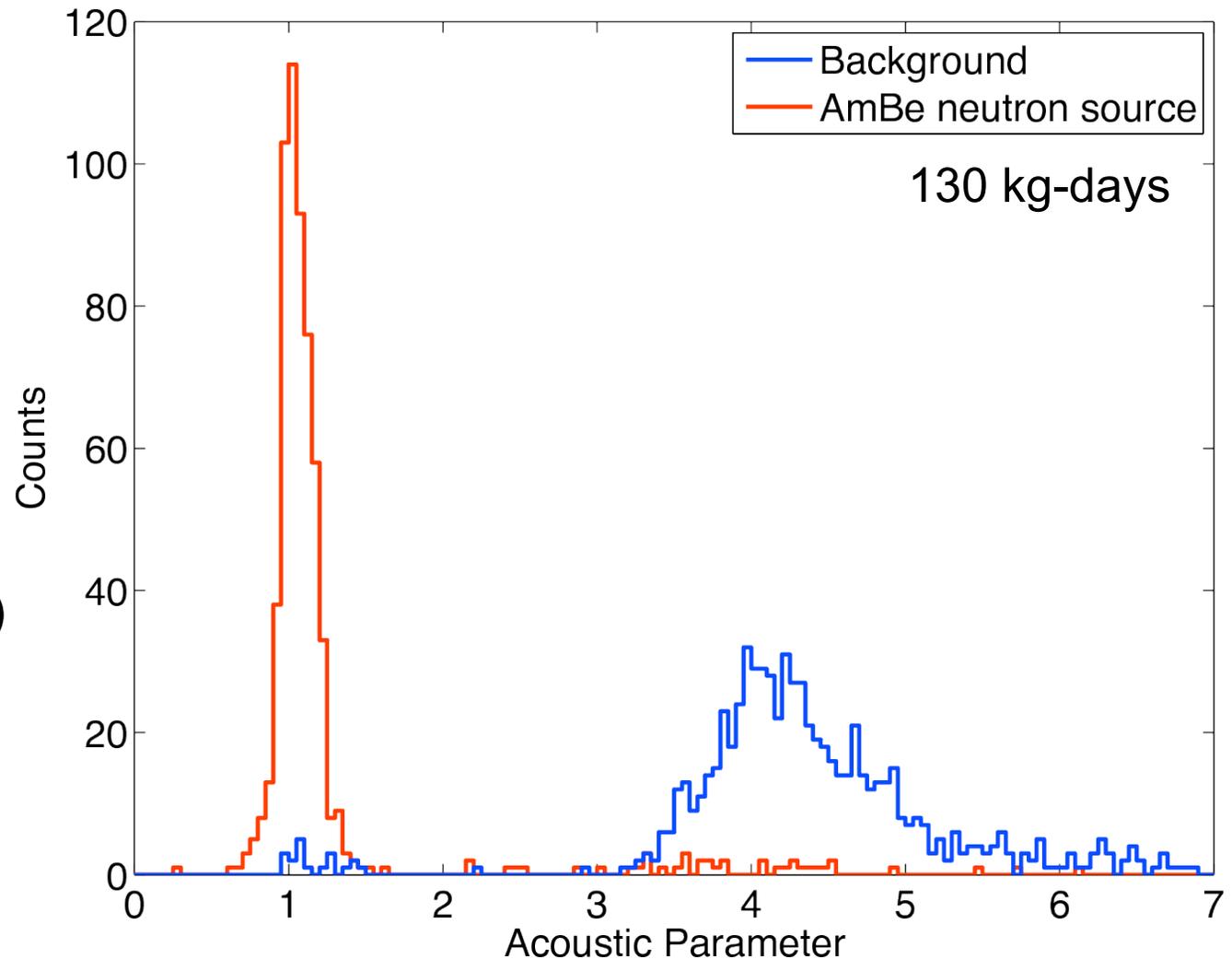
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One leaky accumulator,
a few leaky plumbing lines,
a slightly overstretched bellows, and
one unusual occurrence report
later...

Installation Ends:
Nov 3, 2010

COUPP 4kg @ SNOLAB

- 18.1 live-days at 7 keV threshold
- 21.5 live-days at 10 keV threshold
- 3.3 kg fiducial cut (out of 4.0 kg)

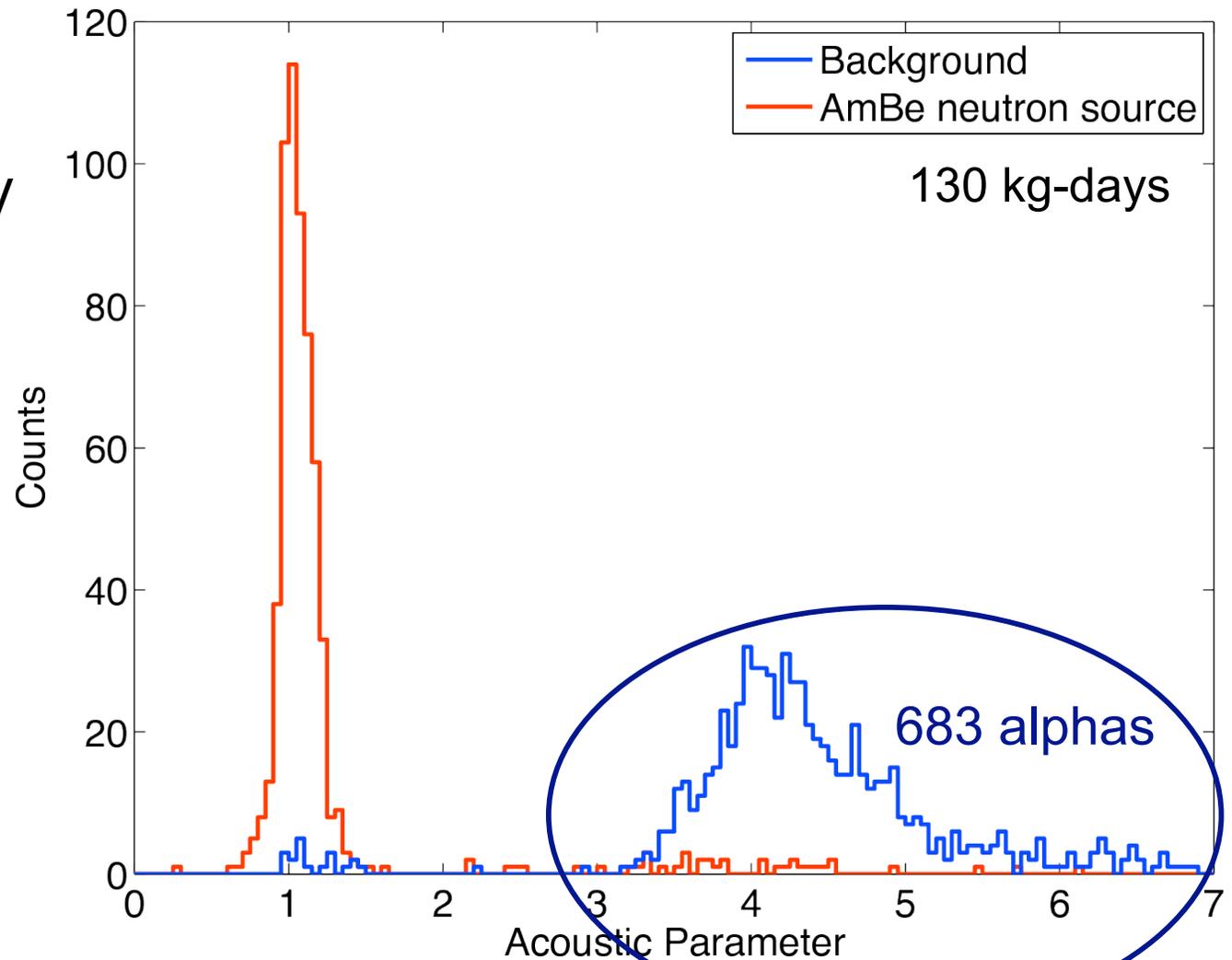


COUPP 4kg @ SNOLAB

- 5.3 alpha-decays / kg-day

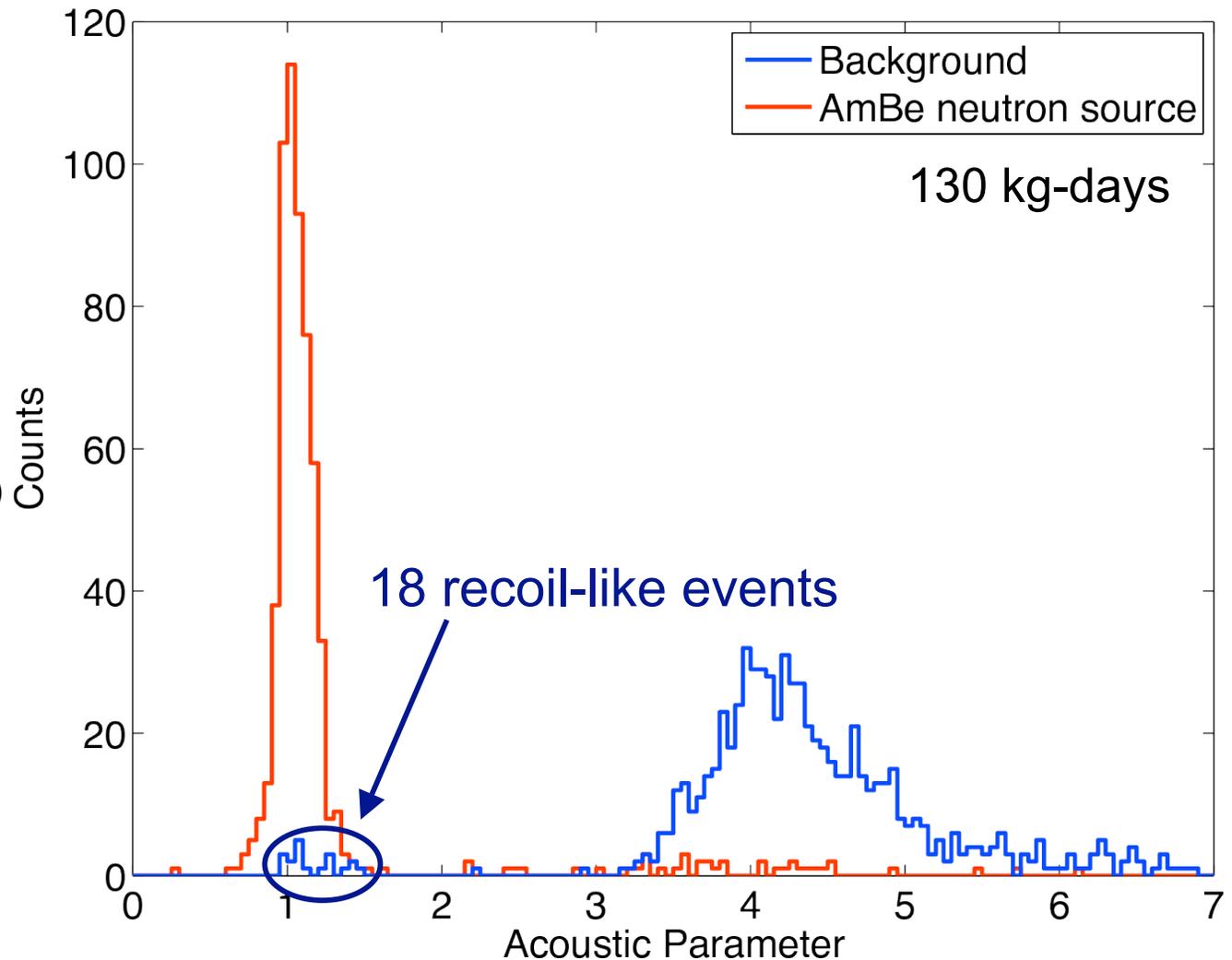
□ 80% ^{222}Rn ,
 ^{218}Po , ^{214}Po
triplets

- >98% alpha rejection



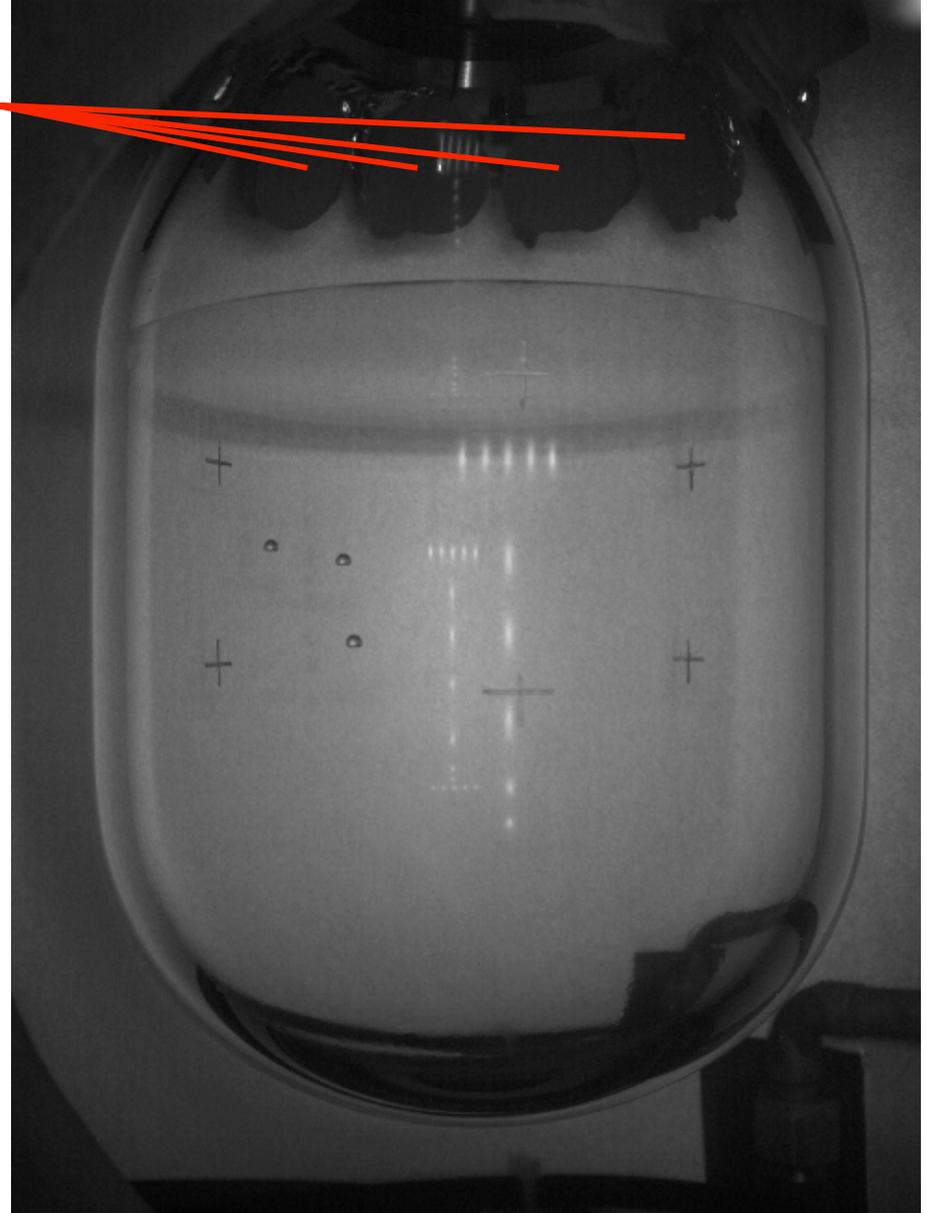
COUPP 4kg @ SNOLAB

- 2 three-bubble events in this dataset!
- Single-bubble background of ~ 0.05 events/kg-day from neutrons (*big* statistical error bar)
- $O(1)$ event/year expected from cosmogenic and environmental neutrons



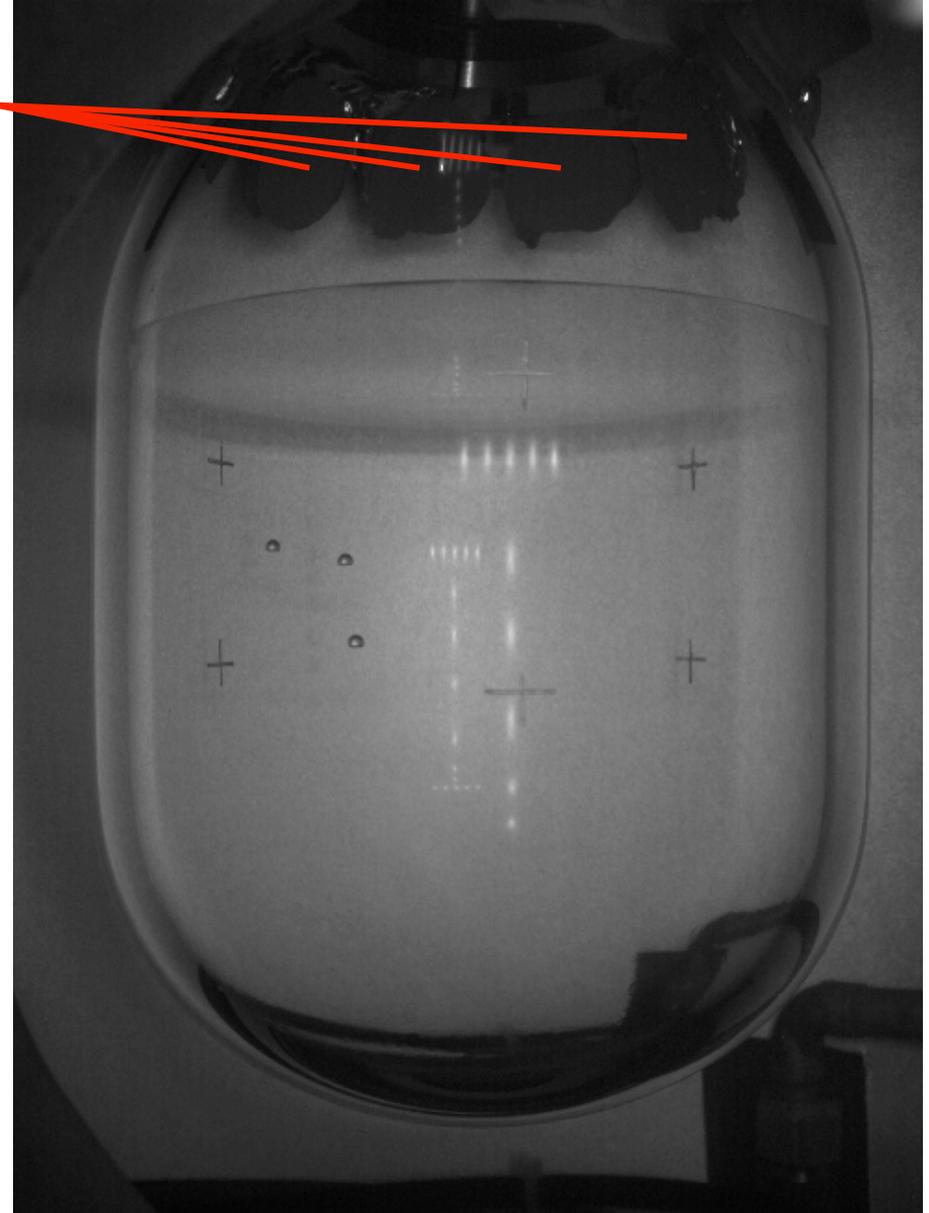
Neutron sources!

- Piezoelectric is the ceramic PZT (Lead zirconate titanate)
- 4.2 ppm ^{238}U
1.4 ppm ^{232}Th
plus lots of modern lead with ^{210}Pb
- Both fission and (α, n) on light elements
- *Preliminary* calculation gives ~ 1 neutron/day from 8 acoustic sensors



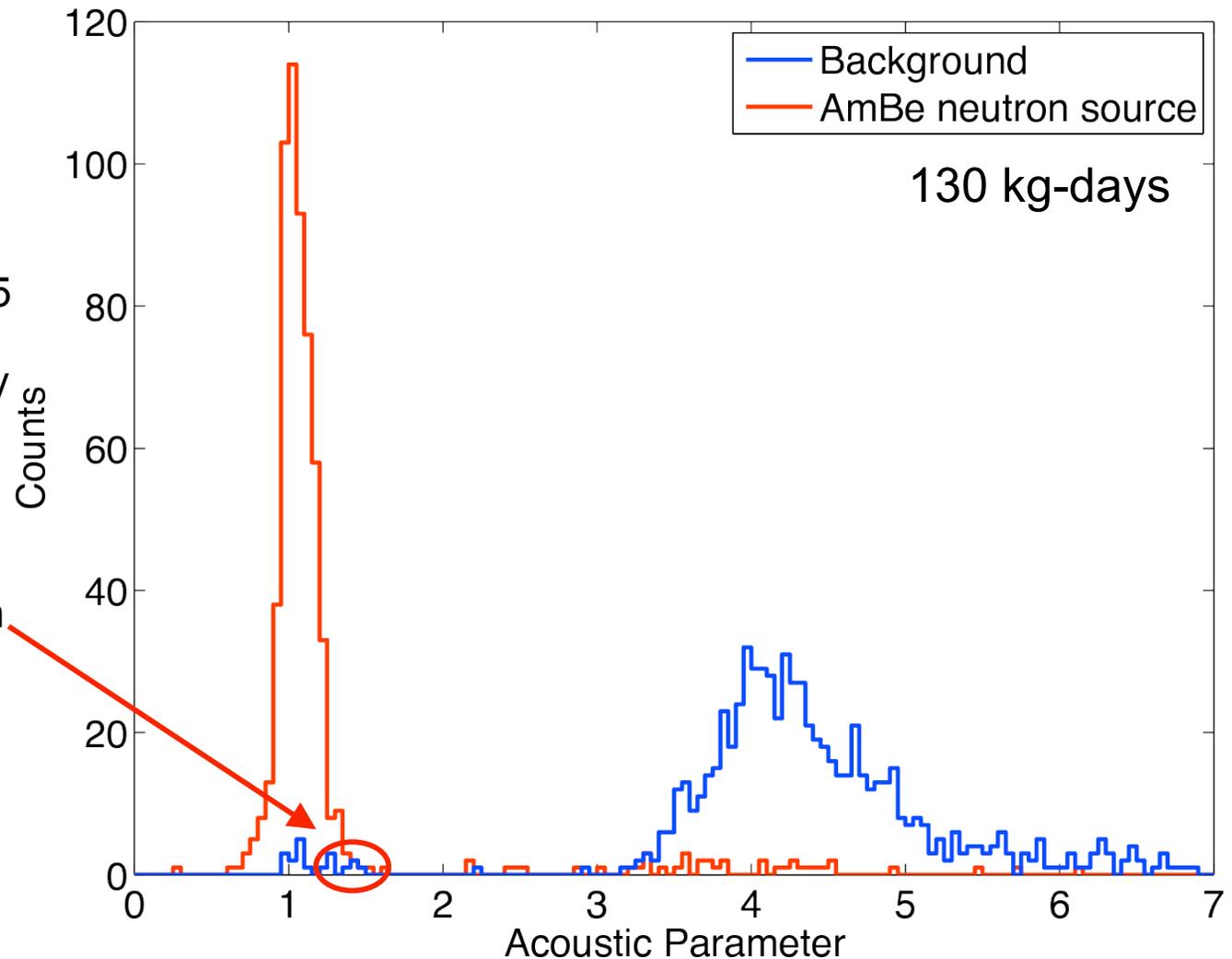
Neutron sources!

- Currently screening alternate piezoelectric materials
- Lower background ceramics are a solution for the 4kg chamber, for 3 months background free
- Plan to refit chamber with low background components this spring



COUPP 4kg @ SNOLAB

- Evidence for 2nd, time-varying background
 - Clusters of 3 and 5 events in 3 and 9 hours, respectively at 7 keV threshold
 - Less clustering at 10 keV threshold, but several events are outliers at high AP
- Several plausible sources, still investigating...





COUPP 60, milestones

- ~3 weeks successful data taking at MINOS
- Successful commissioning of new pressure control hardware, PLC, DAQ system
- Demonstration of acoustic discrimination in large chamber



COUPP 60, final hurdles

■ Chemistry

- CF_3I reacting with impurities or illumination
- High bubble nucleation rate at CF_3I - H_2O interface

■ Optics, Imaging

- Higher resolution and frame-rate desired
- More uniform illumination, lower intensity light source

■ Neutron Backgrounds

- Acoustic sensor replacement needed
- Screening of other elements ongoing...



Conclusions

- 130 kg-days from a bubble chamber deep underground
- >98% acoustic alpha discrimination, will get better as we eliminate backgrounds
- First direct detection experiment limited by internal neutron background
- Will refit 4kg chamber with low background components this spring
- Progress continues on COUPP 60, with much input from 4kg chamber