Dark Matter Search Results from the COUPP 4kg Bubble Chamber

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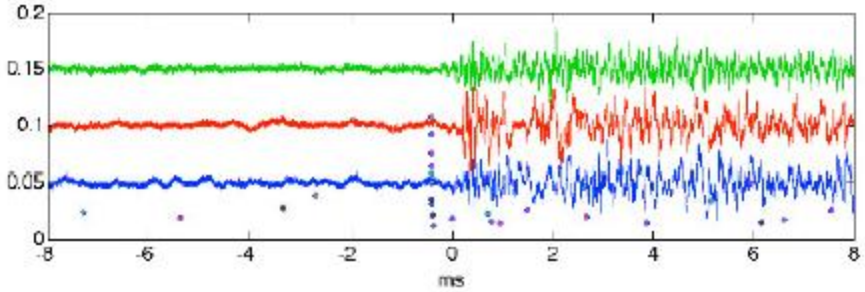
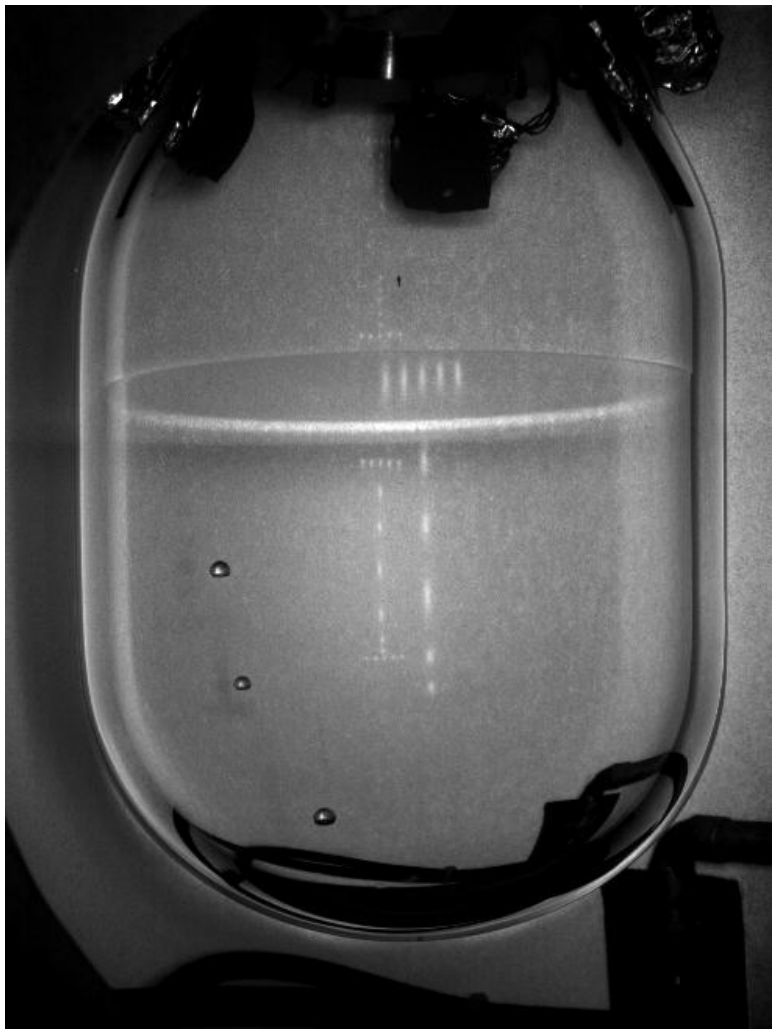
COUPP bubble chambers

- Superheated fluid CF_3I
  - F for spin dependent
  - I for spin independent
  - Other fluids, eg C_3F_8 offer complementary sensitivity.

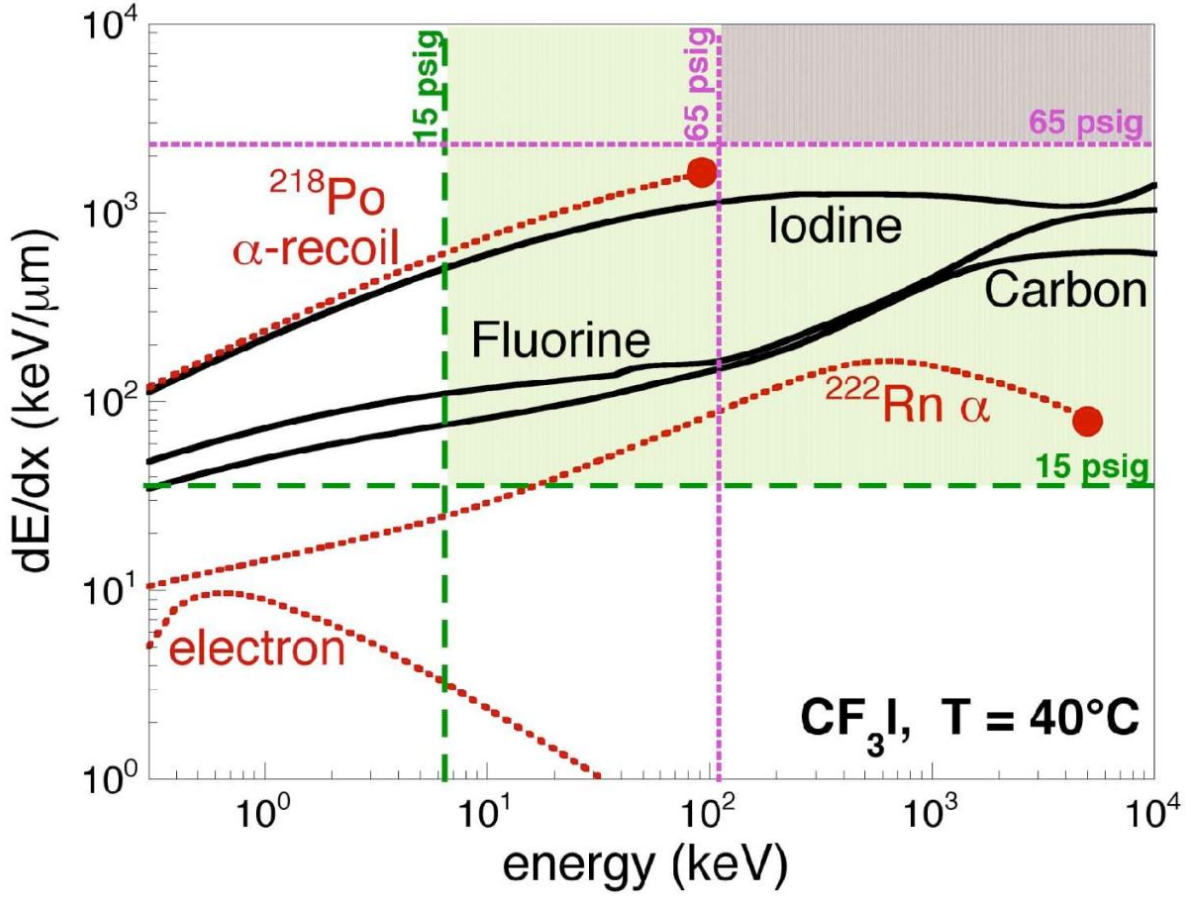
- Observe bubbles with two cameras and piezo-acoustic sensors.





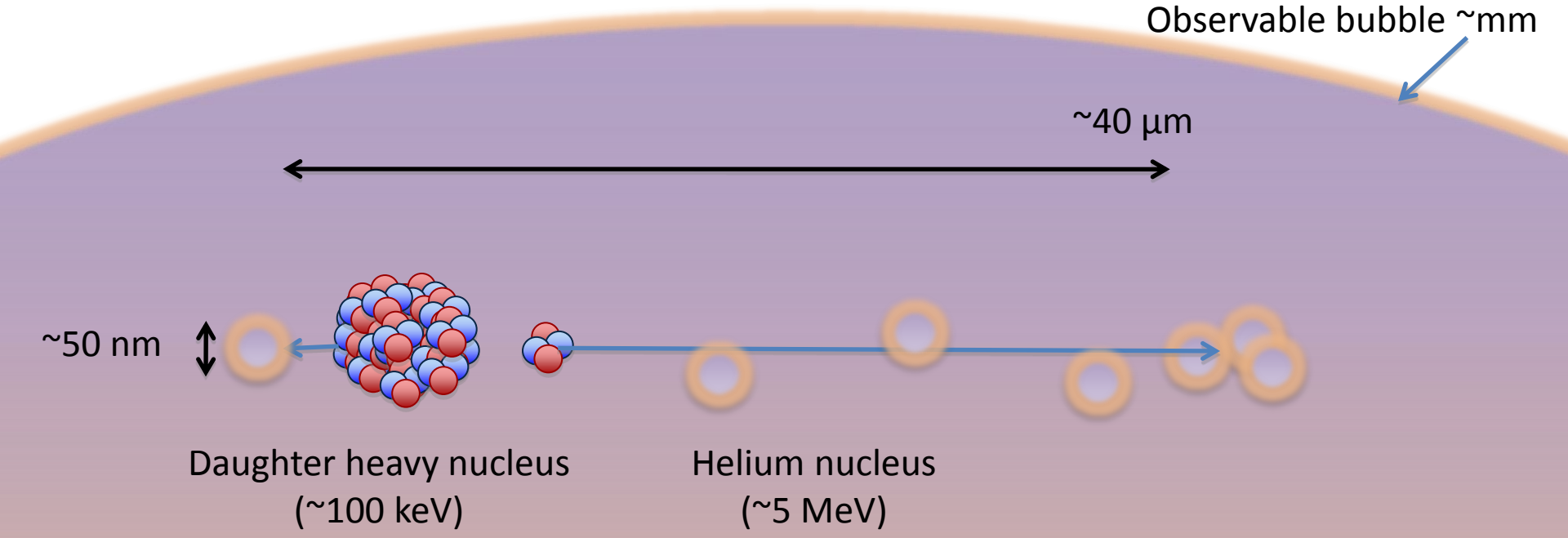
Why bubble chambers?

- Only proto-bubbles with $r > r_{crit}$ grow to be macroscopic
- Better than 10^{-10} rejection of electron recoils (betas, gammas).
- Alphas are (were) a concern because bubble chambers are threshold detectors.



Acoustic discrimination

- Discovery of acoustic discrimination against alphas (Aubin et al., New J. Phys.10:103017, 2008)
  - Alphas deposit their energy over tens of microns.
  - Nuclear recoils deposit theirs over tens of nanometers.
- In COUPP bubble chambers alphas are several times louder.

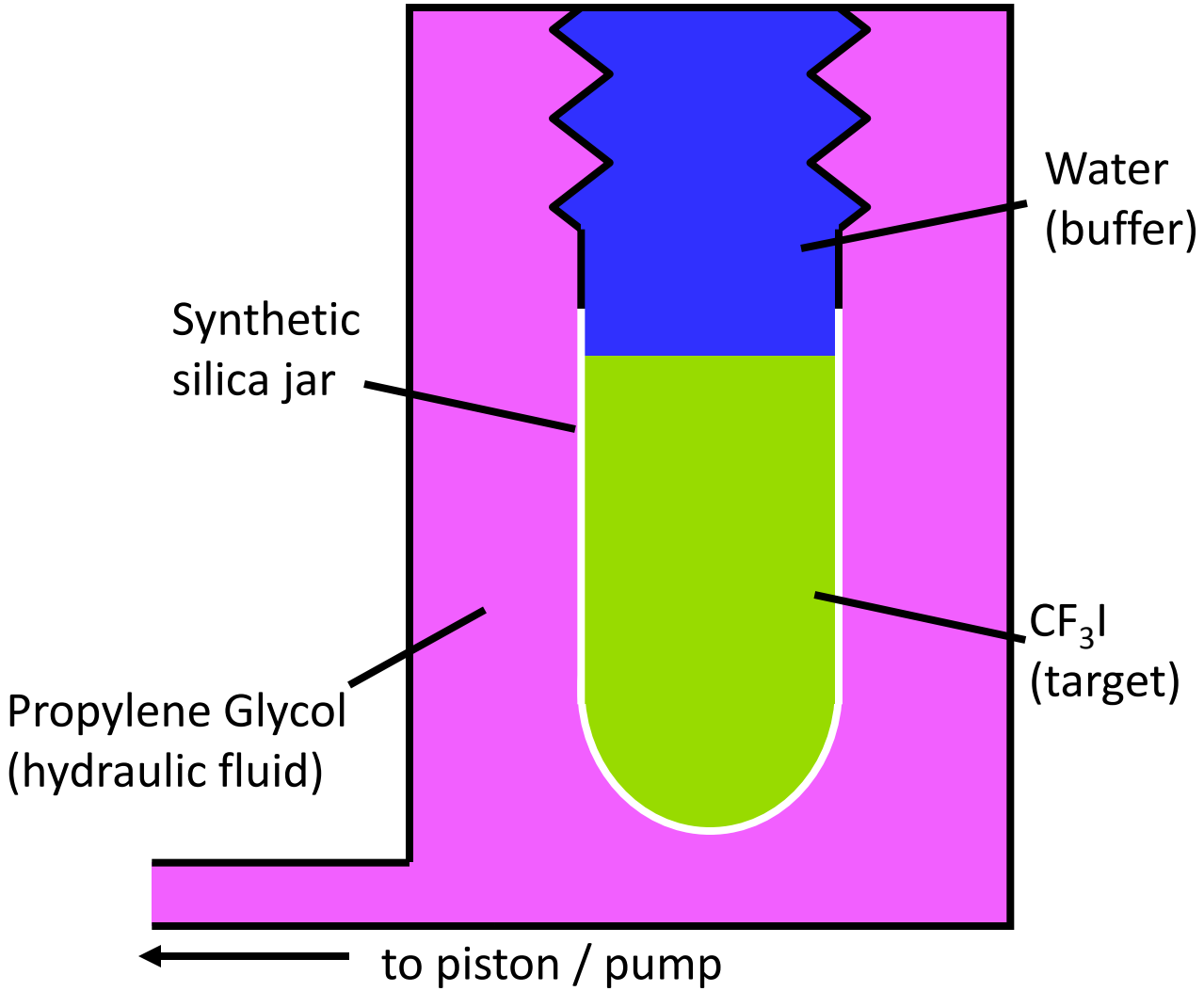


Bubble chamber operation

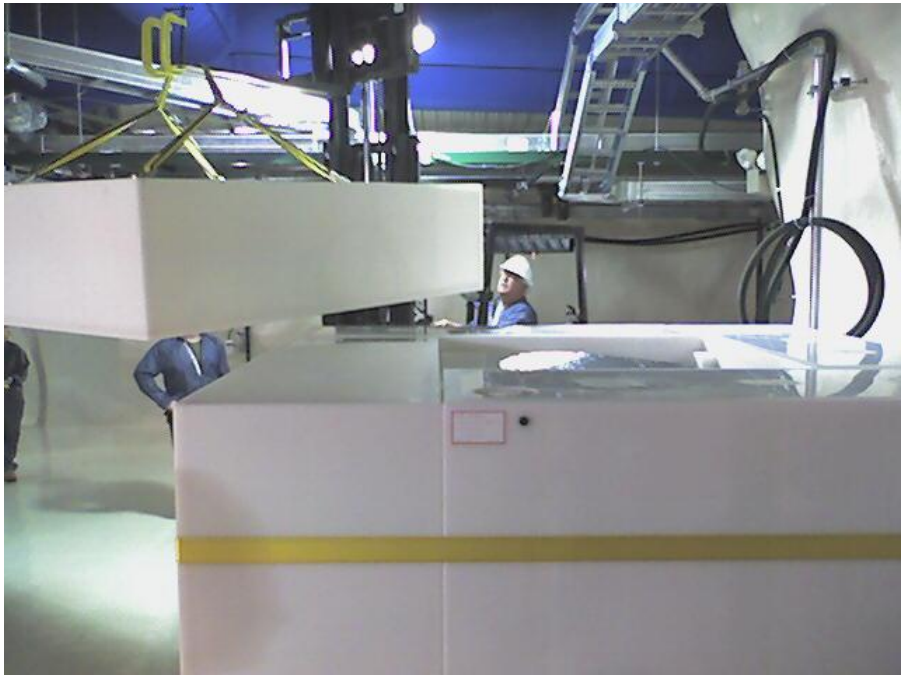
• Expand the chamber to the superheated state (10sec).

•Cameras see the bubble
  - •Trigger
  - •Stereoscopic position information

•Recompress the chamber (100msec) and wait 30sec after every bubble.



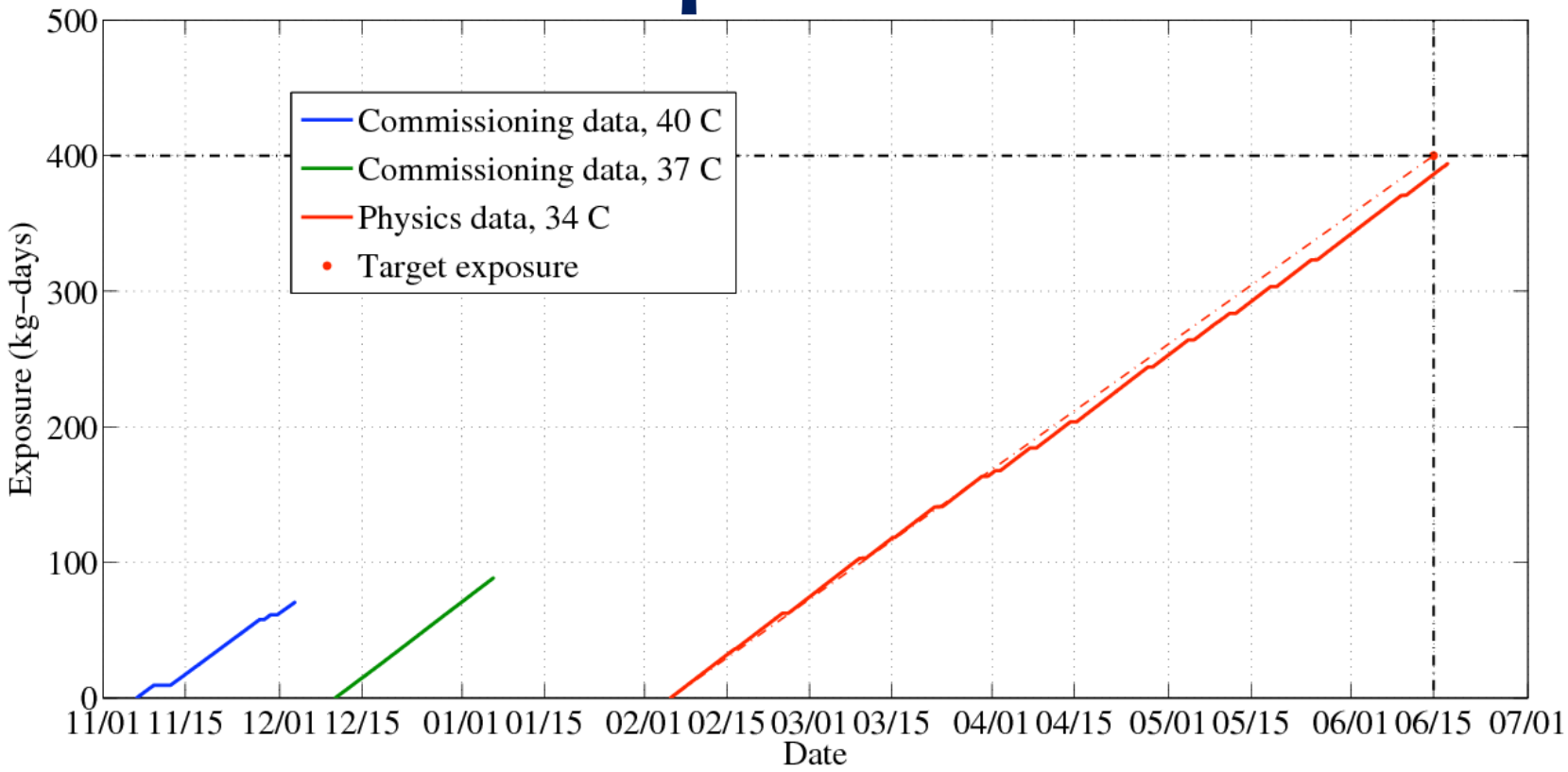
COUPP-4 at SNOLAB



SNOLAB: 2.1km underground

COUPP-4 ran 2010-2011

Exposure

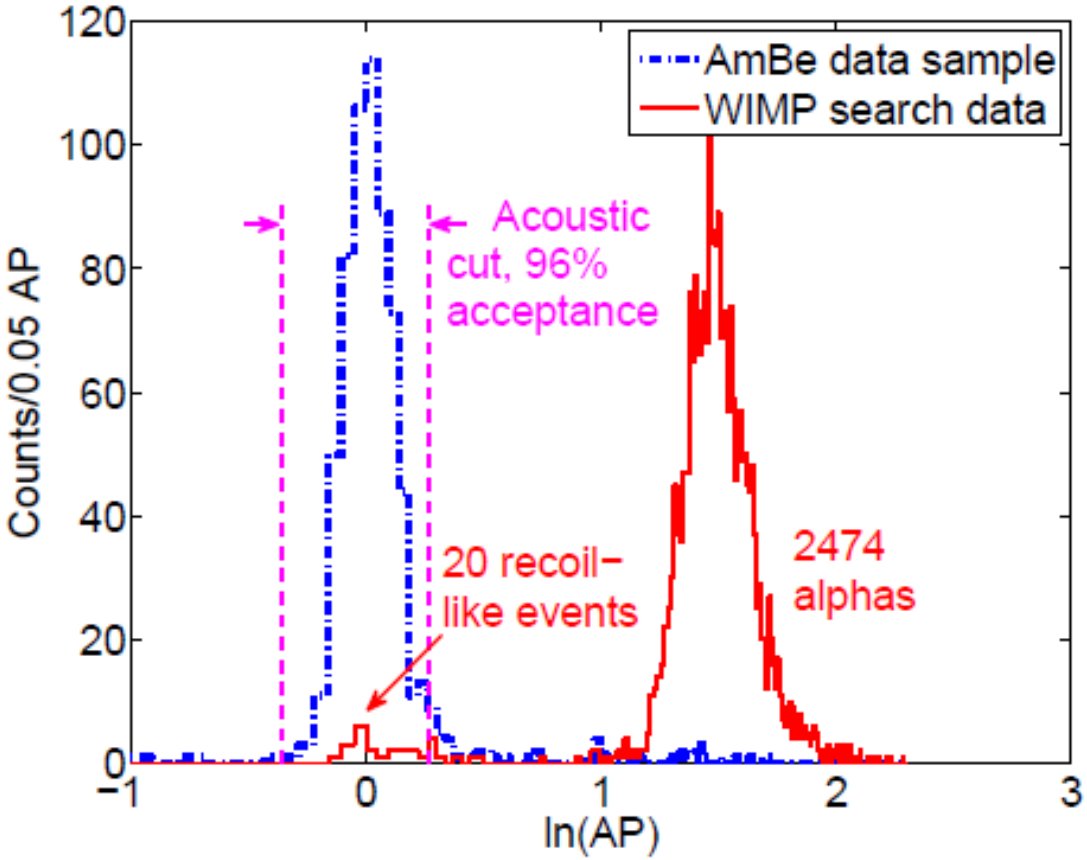


- 17.4, 21.9, 97.3 live-days at 8, 11, 16 keV thresholds
- 4.048 kg target, 79% cut-efficiency for nuclear recoils

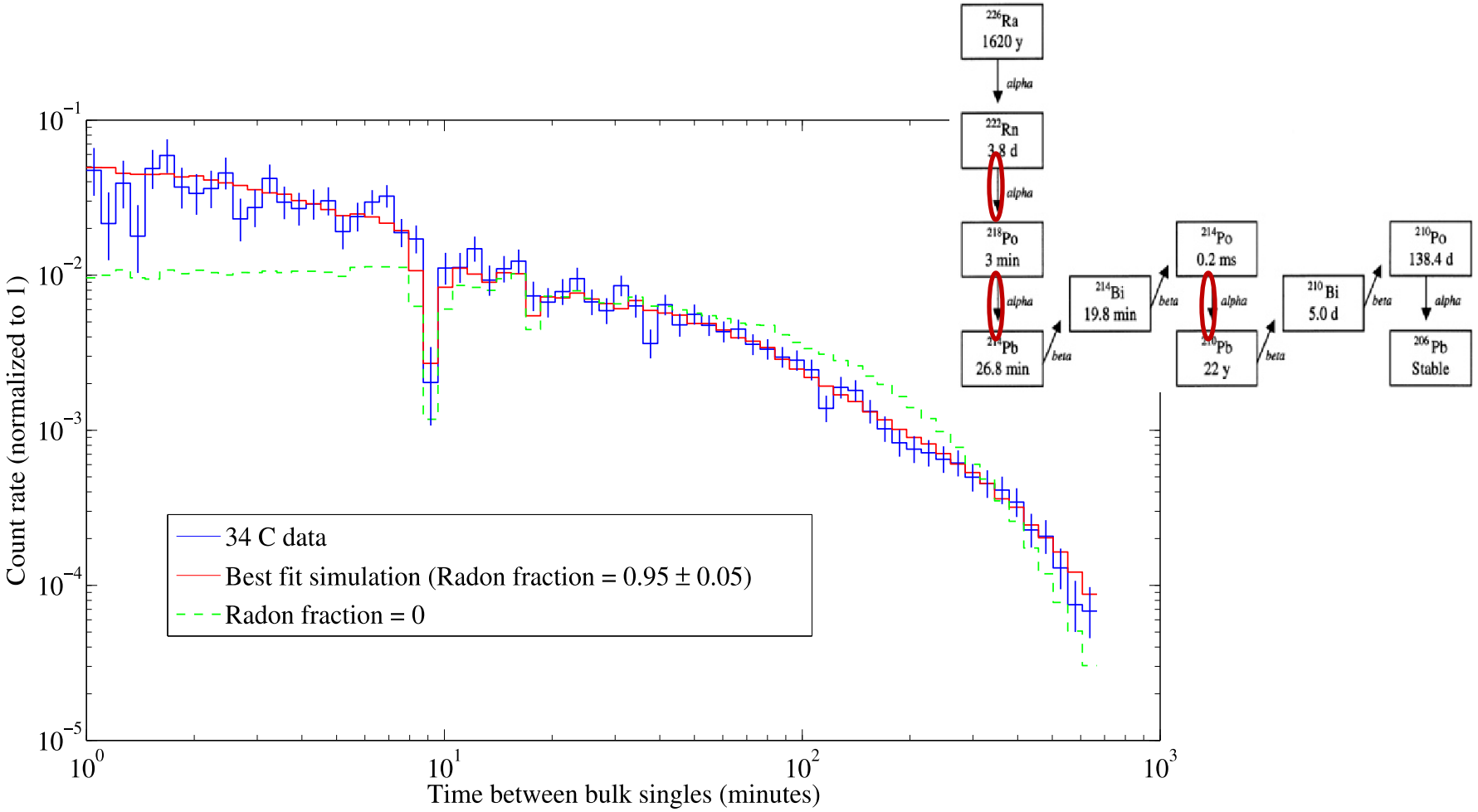
Alpha rejection

- Better than 98.9% rejection against alphas with all data sets.

- Better than 99.3% rejection at 16keV threshold.



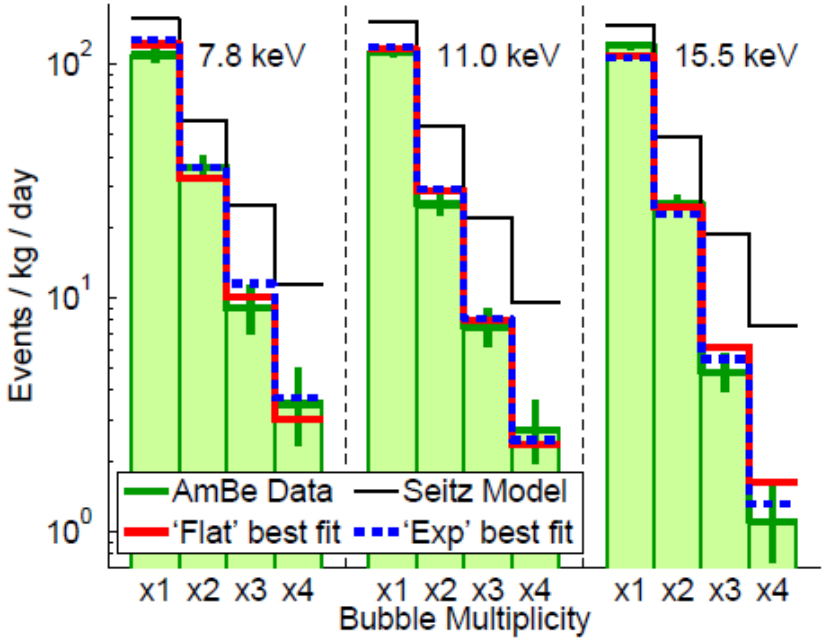
Alpha timing (radon)

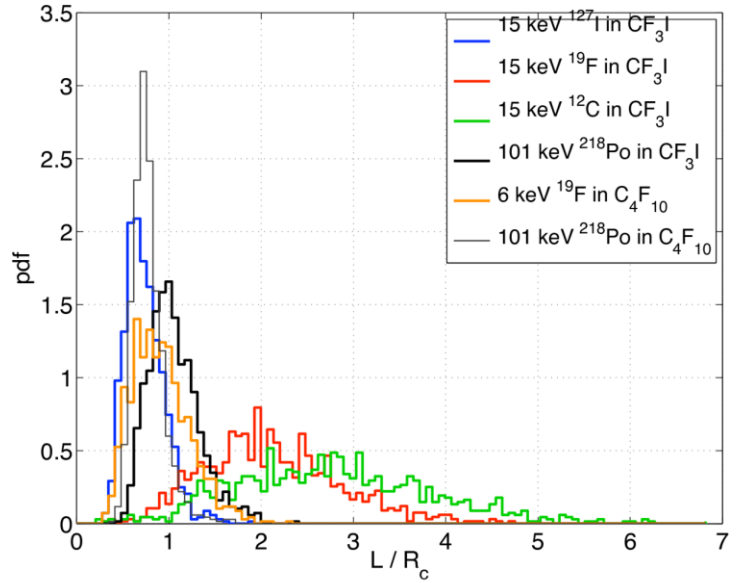


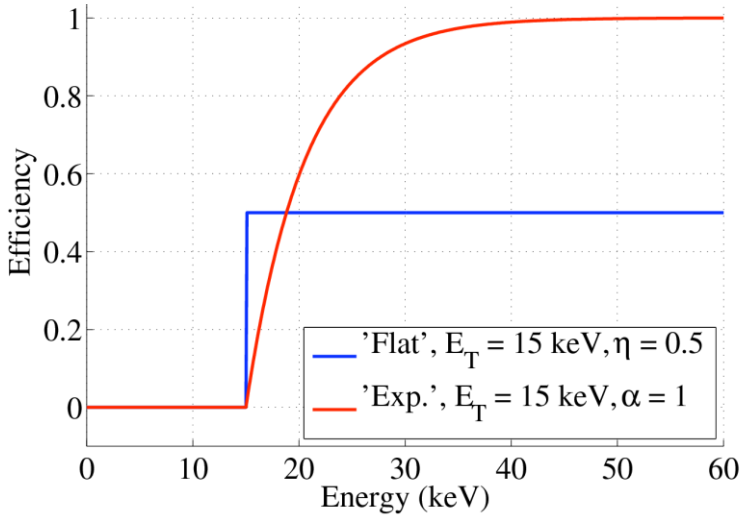
Neutron calibrations

•Threshold is determined using Seitz 'Hot Spike'Model, Phys. Fluids 1, 2 (1958).

•Checked with neutron sources (AmBe, ^{252}Cf) employed regularly during the run.







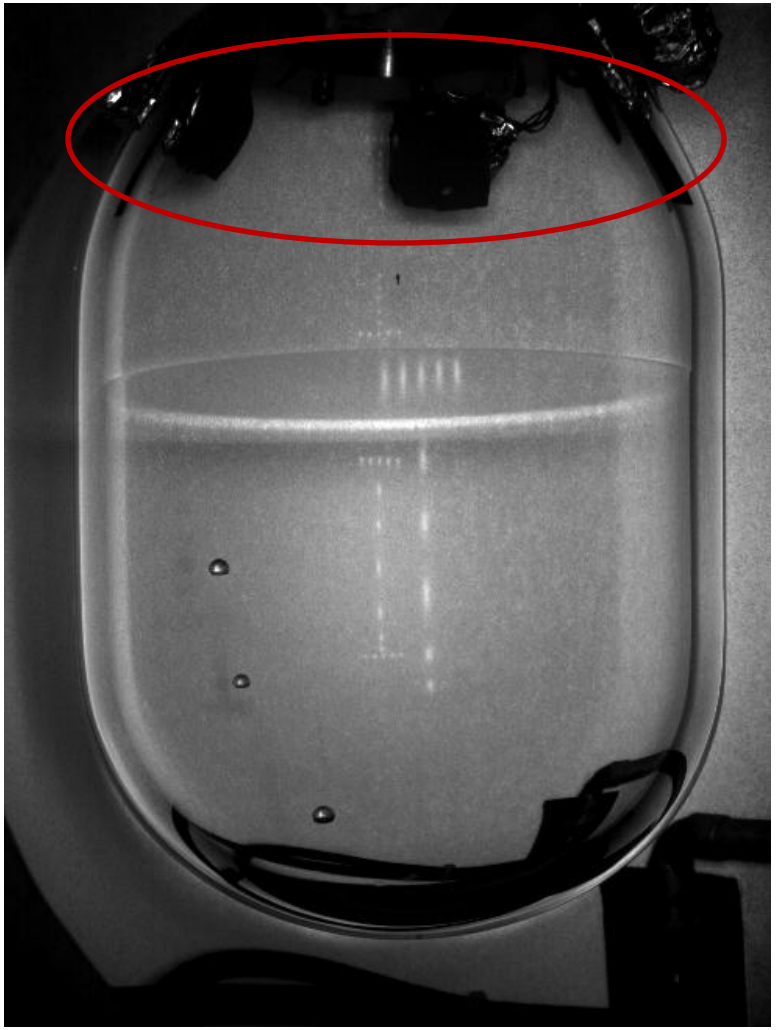
COUPP-4 results

- 20 WIMP candidates
  - 8 at 8keV
  - 6 at 11keV
  - 8 at 16keV

- 3 multiple bubble events → **neutrons**

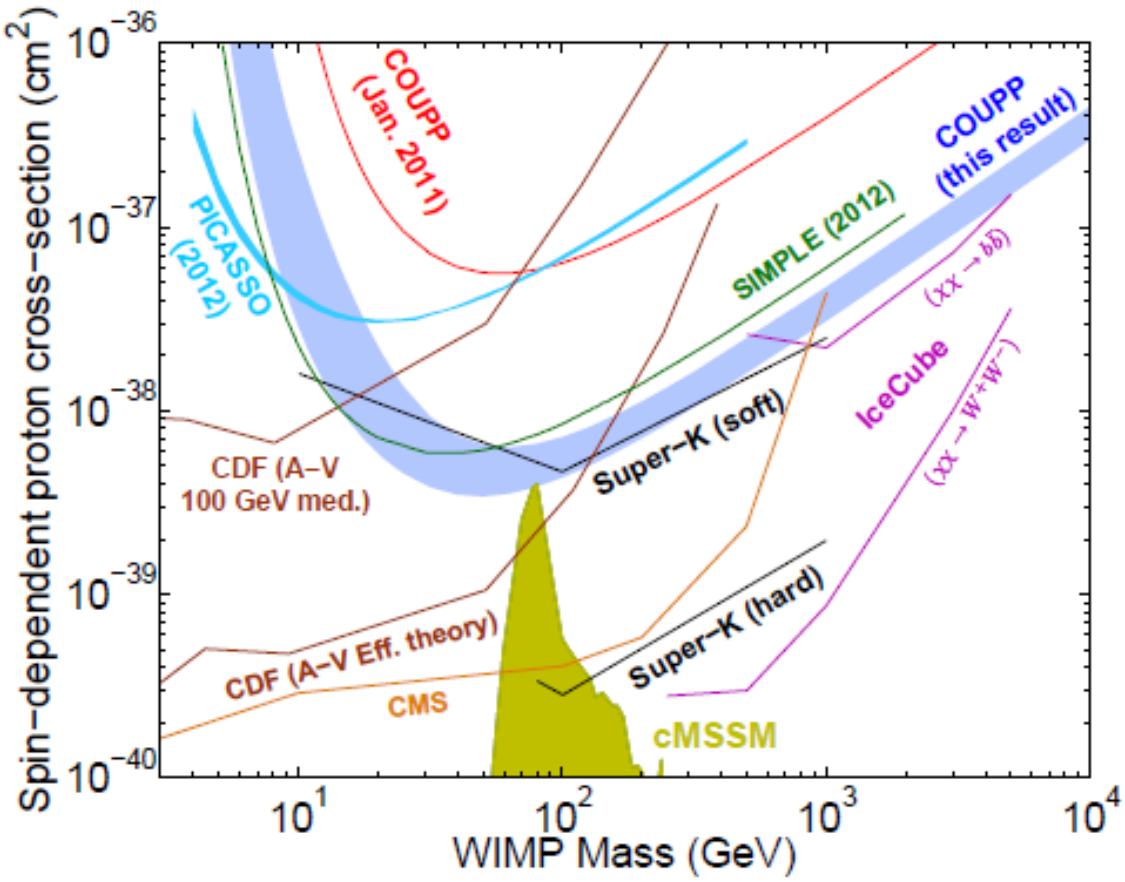
- 5 expected neutron events from U, Th (α,n) in piezo-acoustic sensors and viewport windows.

- Events at low threshold in particular are inconsistent with WIMPs
  - events show clustering in time (e.g. 3 in 3 hours, 4 in 9 hours)
  - events are not consistent with neutron AP distribution
  - events are correlated with activity at the water/CF_3I boundary

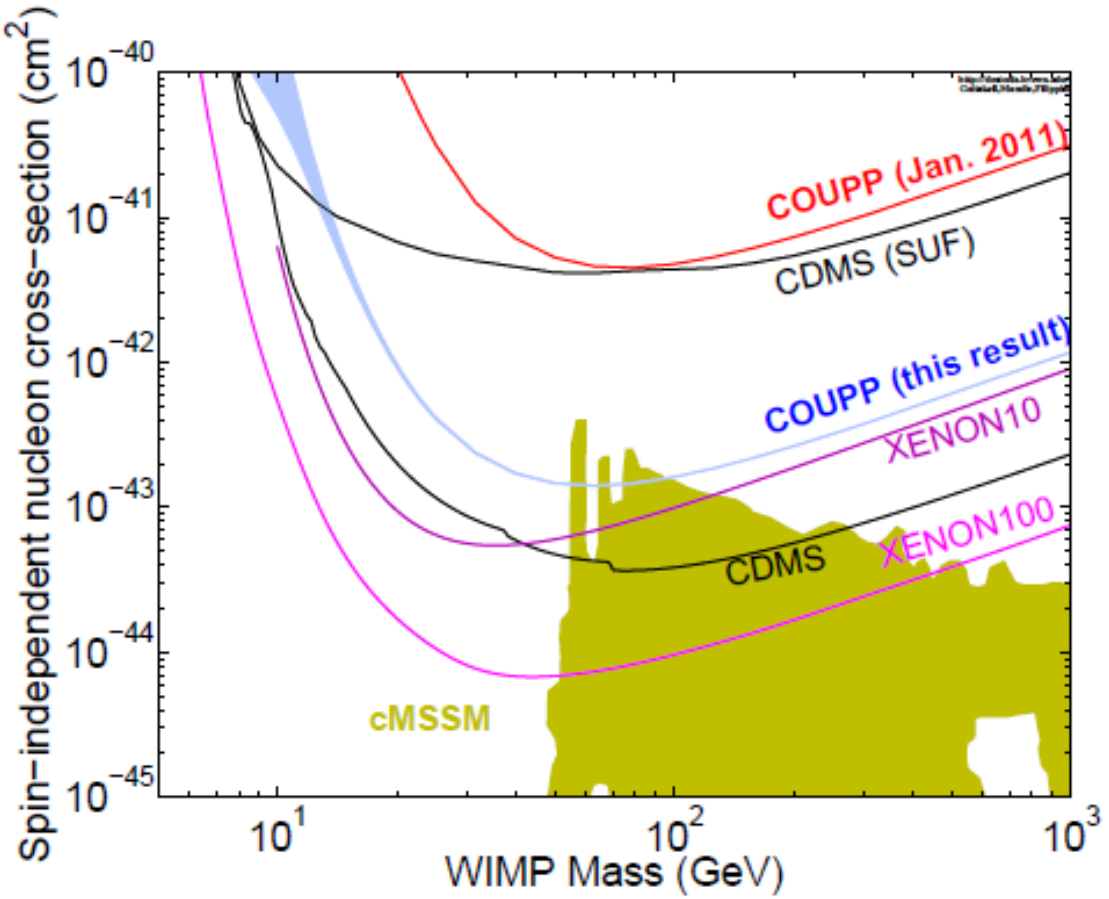


Spin-dependent limits

•Given uncertainties on background predictions, we do no background subtraction, arxiv:1204.3094

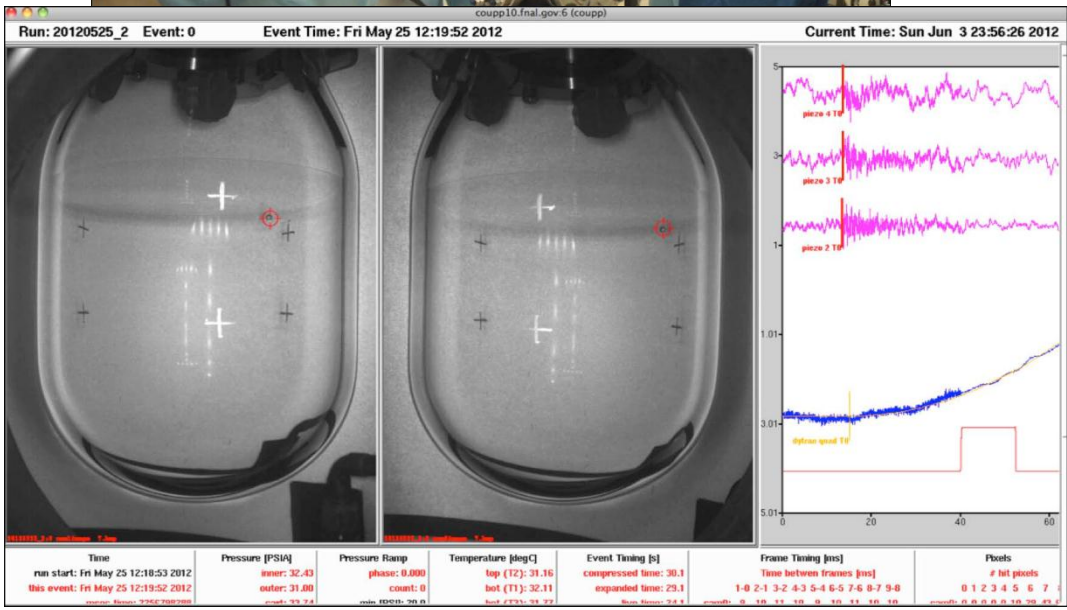


Spin-independent limits



COUPP-4 new run

- COUPP-4 re-installed at SNOLAB in May 2012.
- Piezo-acoustic sensors and viewport windows replaced with certified low-background parts.
- Higher purity CF_3I.
- Results in a few months.

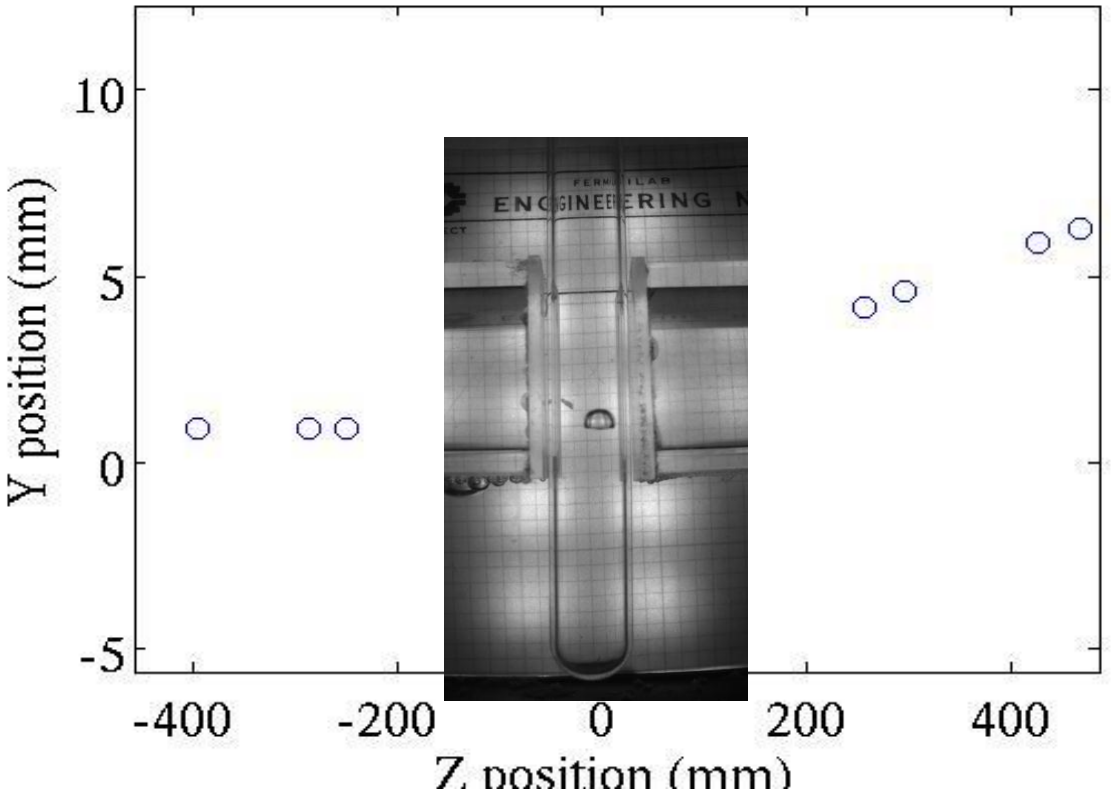


Threshold/efficiency calibrations

• Pion-scattering experiment at Fermilab test beam to measure threshold and efficiency on iodine directly.

• Low, mono-energetic YBe neutron source to attack carbon and fluorine.

• Neutron beam measurements at Notre Dame.

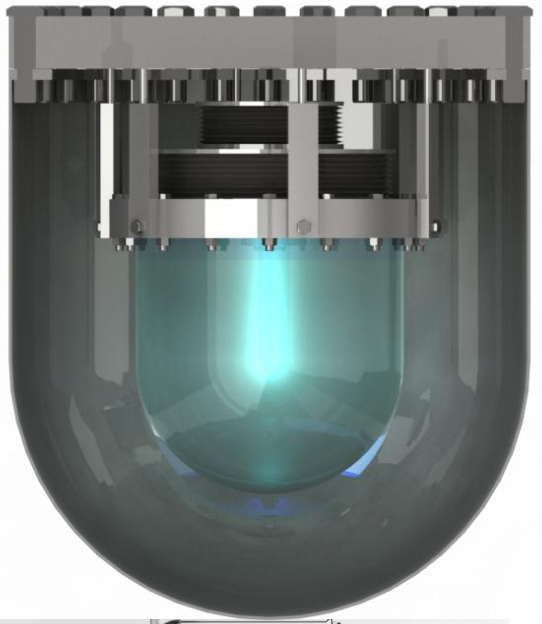


• 12GeV pion beam with silicon pixel telescope to measure scattering angle.
• Example event: 10mrad scatter, 56keV Iodine recoil.

COUPP future

- COUPP-60 ran at shallow site in 2010-2011.
- Being installed at SNOLAB.
- Data taking begins in a few months.

- COUPP-500 engineering and background studies under way.
- Data taking in ~2016.



Sensitivity projections