COUPP-60 Minos Run Results and Chemistry Issues

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COUPP-60 Review

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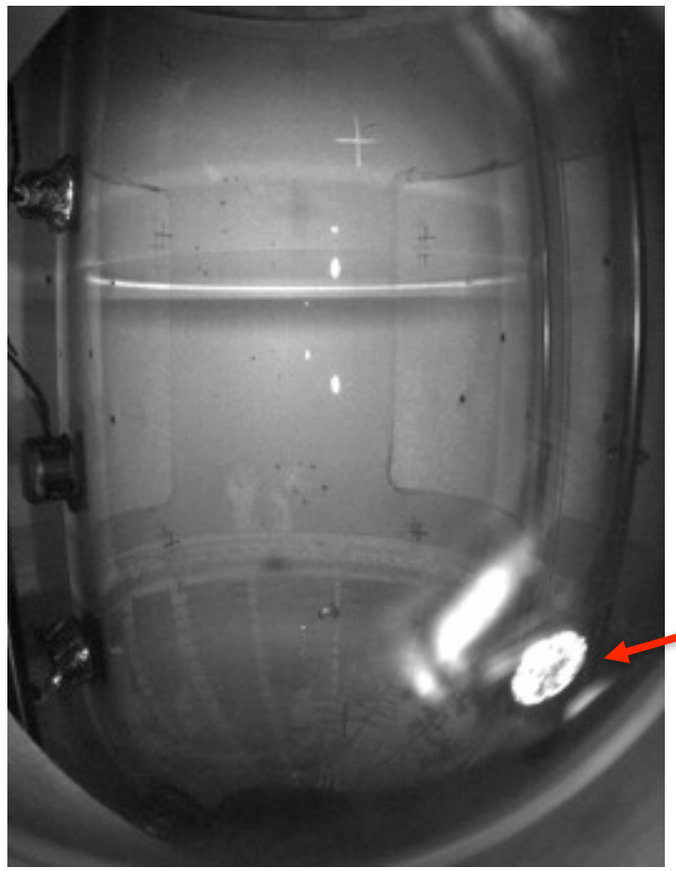
COUPP-60 Commissioning

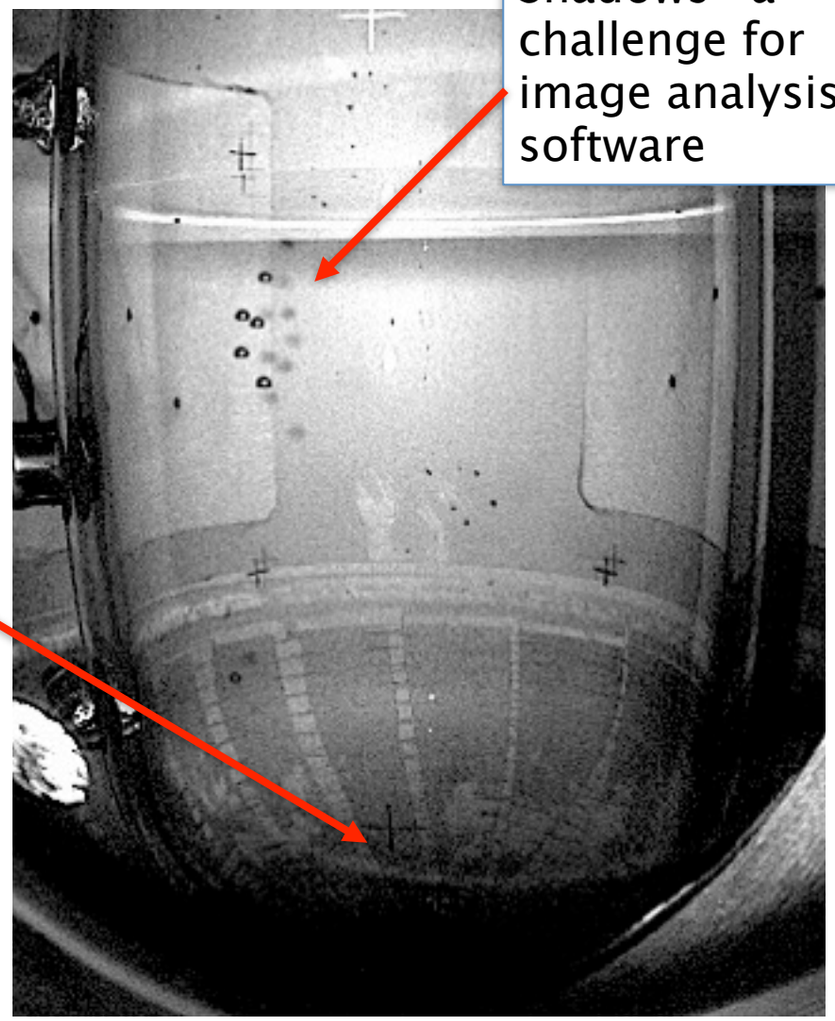
- First run at NuMI took place July-August, 2010
- Demonstrated the existence of discrimination between alphas and nuclear recoils in COUPP-60
- Achieved low background
  - 2.2 alphas/kg/day identified by acoustic signature
  - ~ 1 single bubble/kg/day from piezos and windows (sources identified with help from COUPP-4)
- Exposed serious problems with optics and chemistry

2010 run issues – Optics

- Two intense light sources produced shadows
- De-lamination of lenses giving glare
- Dark spots at bottom



Lens delamination from pressure cycling

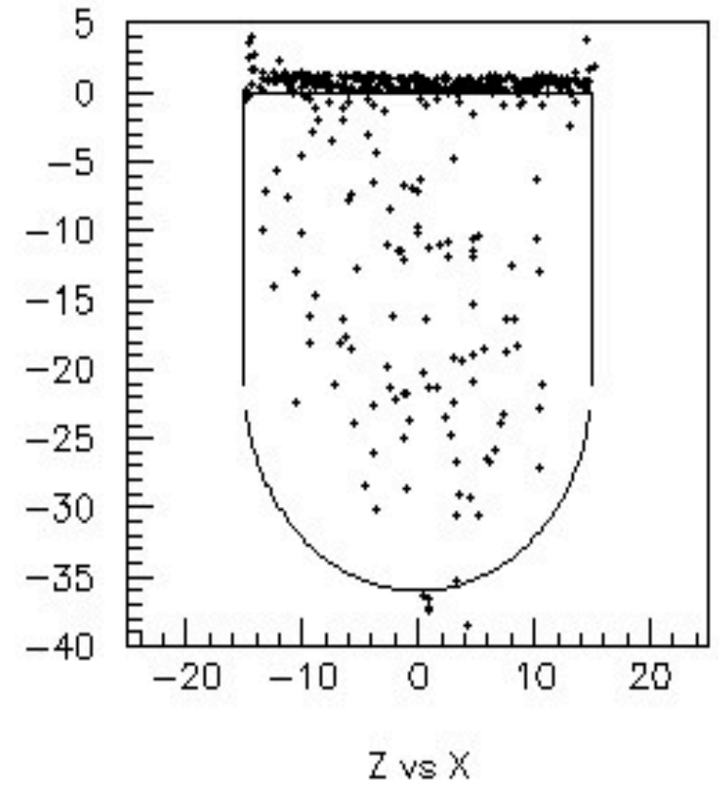


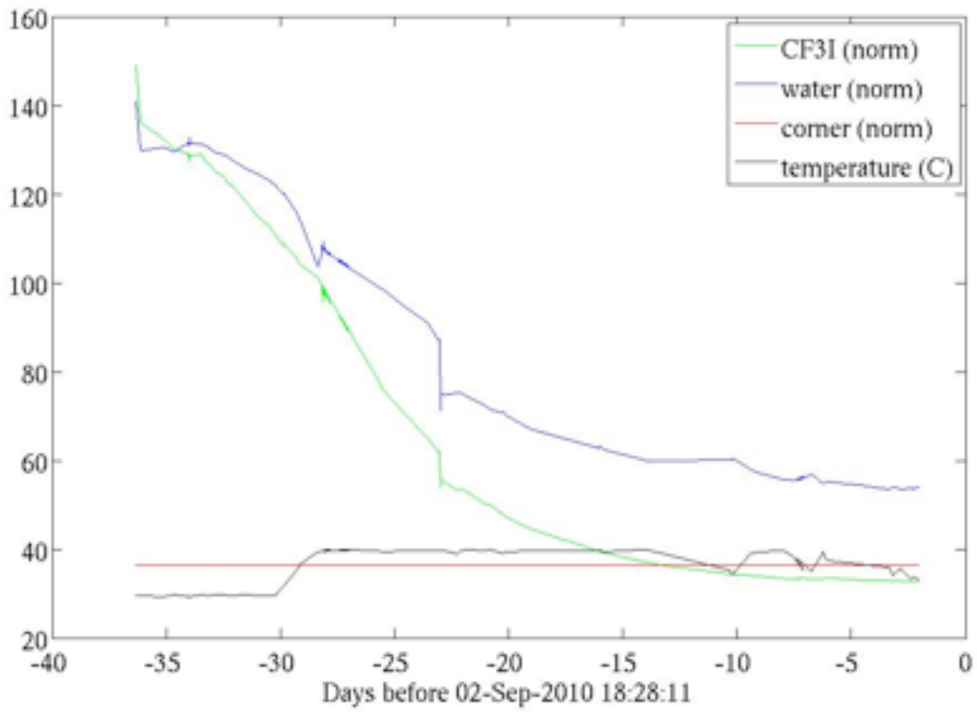
Shadows- a challenge for image analysis software

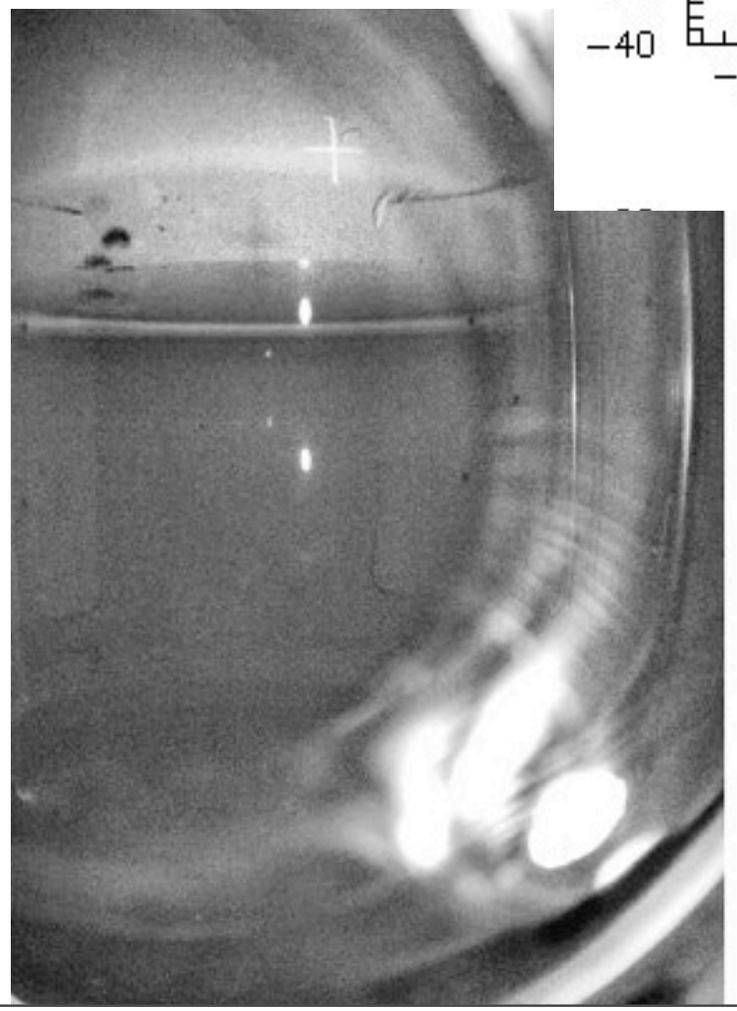
Dark region at bottom, poor photography, poor triggering

2010 run issues – Chemistry

- Chemistry
  - Excessive surface boiling led to unacceptable loss of live-time given recompression required for each bubble
  - Progressive darkening of the images rendered data taking impossible after a month

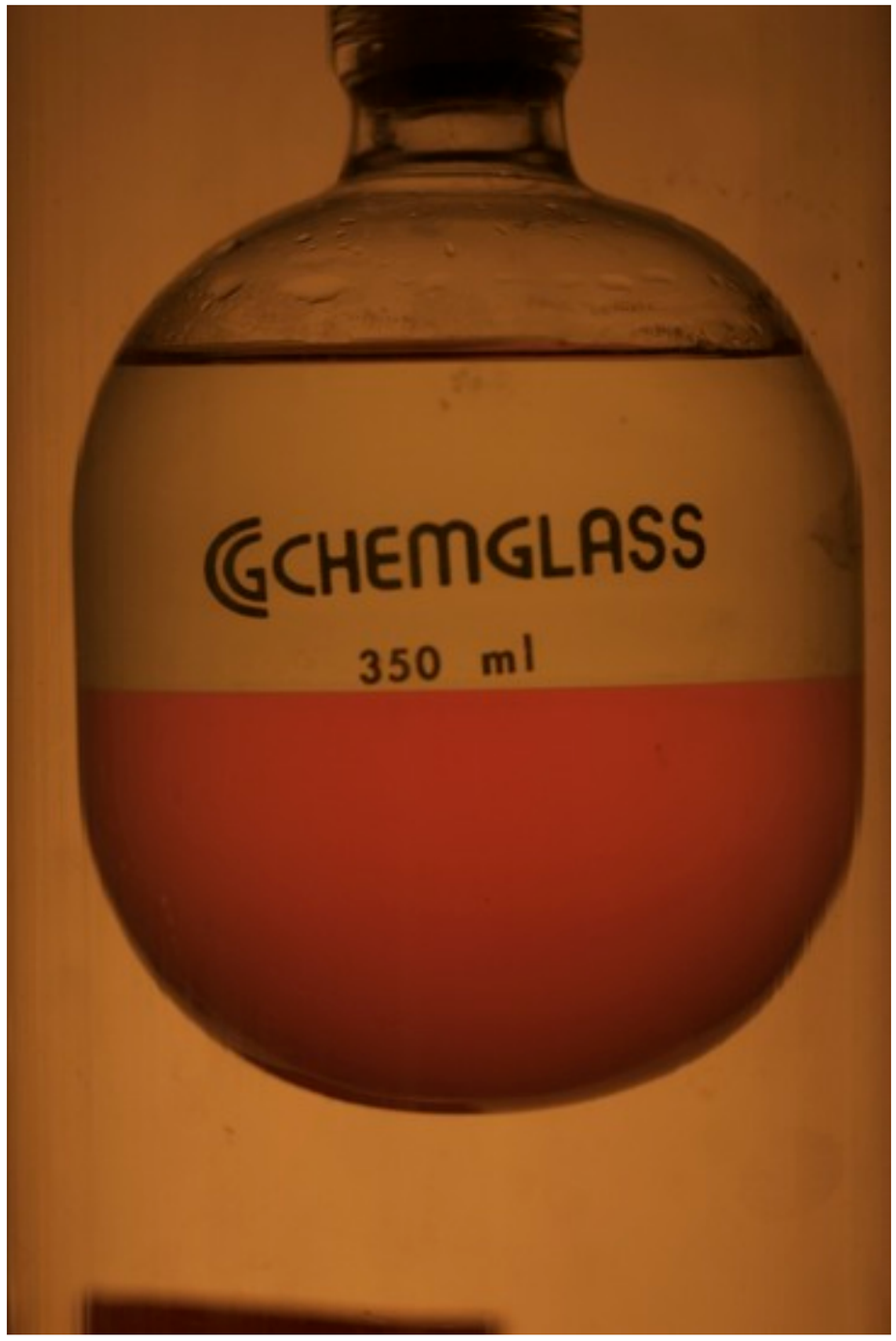






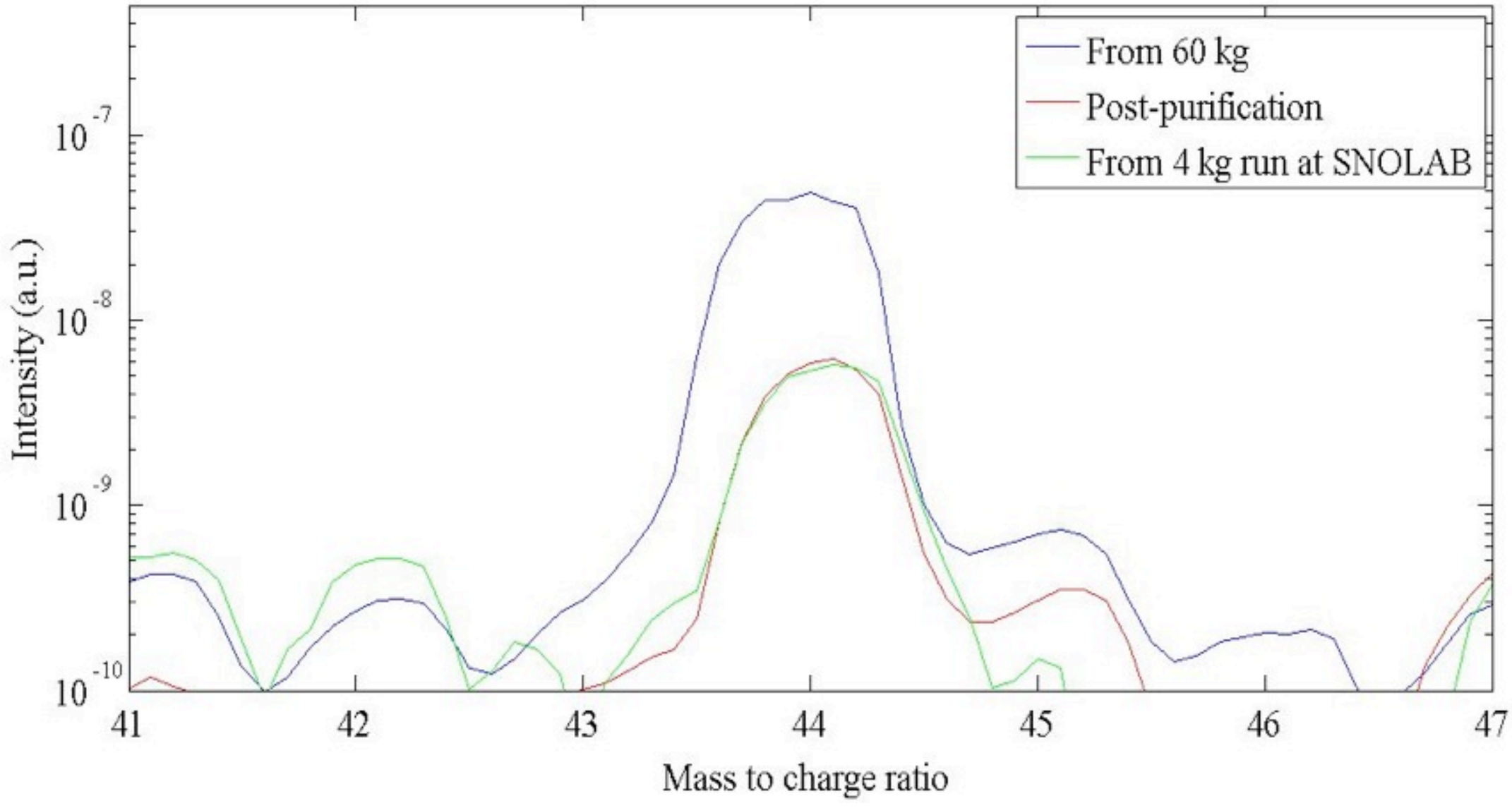
Chemistry test stand

- Darkening traced to photodissociation of the CF_3 – I bond, with iodine producing the color
  - $2\ CF_3I + 2\ hv \rightarrow 2CF_3 + I_2$
- Still not clear why previous chambers have not seen significant darkening
  - Less intense light source
  - Steel bolt in fluid inhibits the reaction
  - Potentially related to impurity as a seed
- Ilya Shkrob of Argonne recommended sodium sulfite (Na_2SO_3) in the water
  - The sulfite transfers equilibrium to move iodine into the water and ionize it (colorless)
    - $I_2(aq) + I^- \rightarrow I_3^-$
    - $I_3^- + SO_3 + H_2O \rightarrow I^- + SO_4 + 2H$
  - In test stand, no evidence of darkening with 5 mMol of sulfite added to water



Surface boiling

- Gas analysis of the fluid recovered from the run found more than 1% contamination by CO_2
- Additional purification step using a molecular sieve and a getter eliminates CO_2 by at least an order of magnitude (limited by sensitivity of RGA)

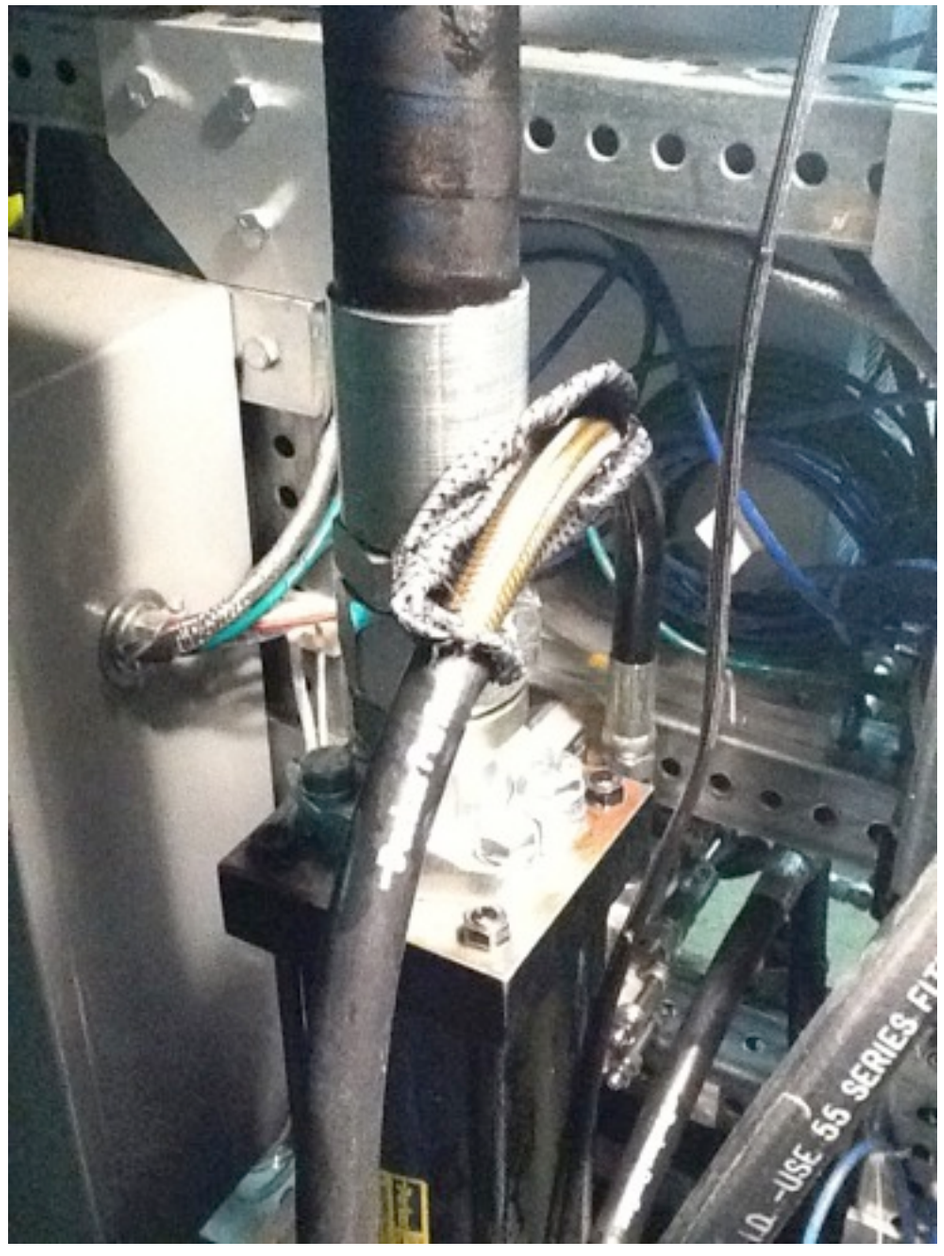


New commissioning run

- Temporary optics solutions (permanent solutions discussed by C. Dahl)
  - New LED array to improve shadowing and decrease overall light exposure
  - Silicone rubber to couple lenses to viewport
- Addition of sodium sulfite to the water to prevent darkening
- New purification step
  - Filled detector with the same batch of CF_3I after purification (historically we have not reused fluids)

Technical delays

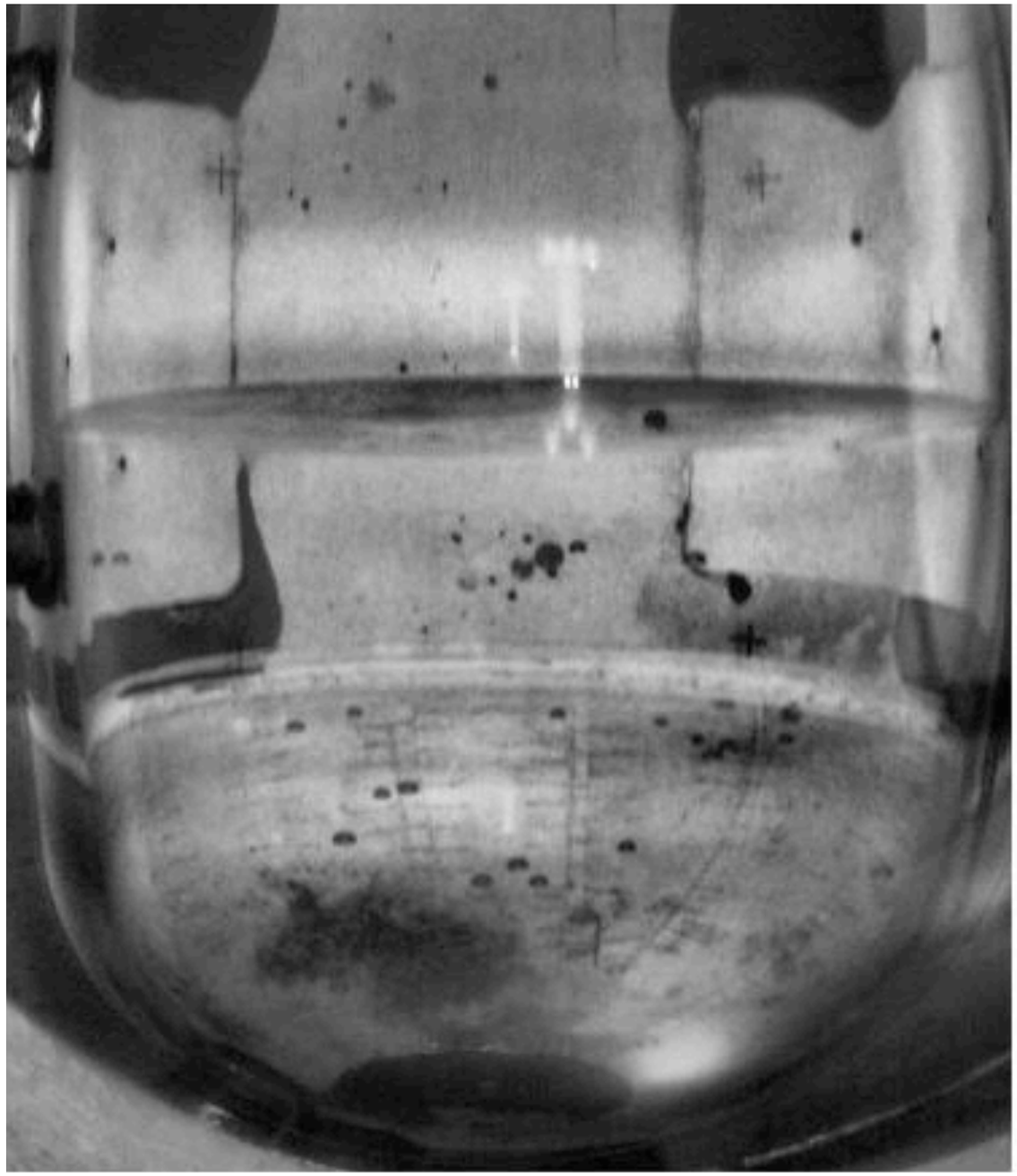
- In July, just before doing the first cycles, a hydraulic line burst
  - –Problem traced to incorrect installation of lines
  - –Re-installed the entire hydraulic piping system
- Issues regarding as-built drawings of pressure vessel also required a delay



Run began Oct. 7, 2011

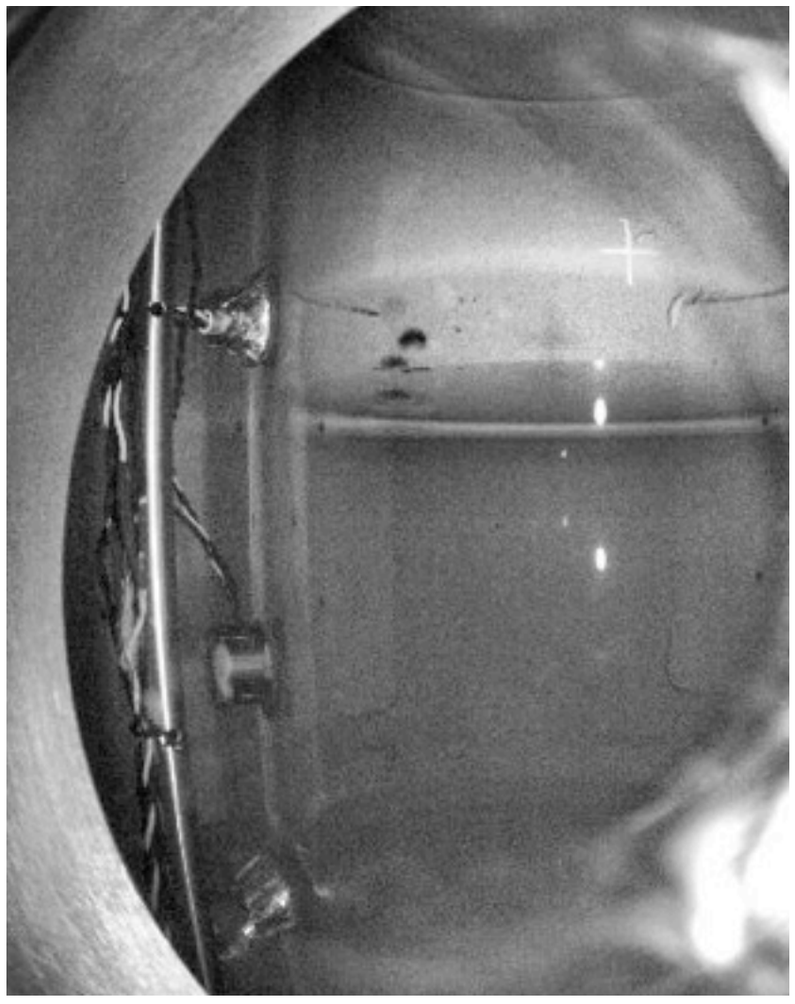
Optics problems

- Shadowing no longer present
- No evidence for de-lamination of lens
- We did observe a failure of the retro-reflector (the large armpits, the many black spots)
  - Too much cycling of the hydraulic fluids
  - No effort made to clean or replace since the last run

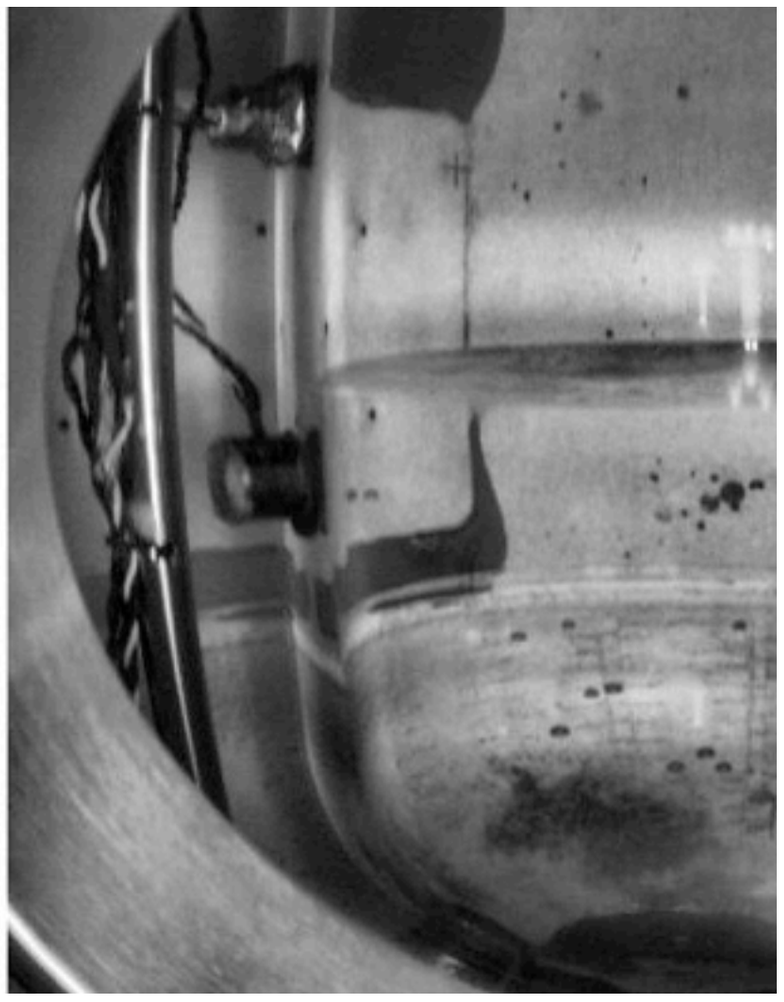


Darkening

2010 run after 25 days



2011 run after 50 days



- Less than 10% darkening after 50 days of light exposure
  - No significant difference between the water and CF_3I
  - The observed change is likely related to the LEDs/cameras

What is tolerable surface rate?

- There are two problems with high rates – the need to compress after each event and the requirement of a minimum expansion time to allow the chamber to equilibrate
  - The first limits the live fraction of the detector
  - The second requires a long "mean superheat time", t, measuring the average time from expansion to bubble
- Set 75% live fraction as a target
- We have a mean compression time, t_c, of 57 s (9 cycles of 30 s with 1 long compression of 300 s every 10th compression)
  - For 75% live fraction, $t/(t + t_c) = 0.75 \Rightarrow t = 172$ s
  - We allow 30 s for chamber to reach equilibrium, so $t >> 30$ s is satisfied
- For $t = 172$ s, we have $N_b = 86400/172 = 500$ bubbles/live-day or 20 bubbles/hr
- 20 bubbles/hr is therefore the maximum rate we can tolerate and still achieve a live fraction of 75%

Surface boiling

	Threshold	Total rate	Surface rate
2010 run	7 keV	200 cts/hr	150 cts/hr
	10-15 keV	115 cts/hr	92 cts/hr
2011 run	7 keV	60 cts/hr	15 cts/hr
	8 keV	56 cts/hr	9 cts/hr
	17 keV	30 cts/hr	7 cts/hr

Surface boiling

- Improvement by an order of magnitude in surface rate
- About a factor of 4 improvement in total rate (over 50% live at 17 keV despite longer than usual compression times)
- Rate dominated by the NuMI beam (20/hr)
  - About 10/hr coming from cosmics and internal backgrounds
- Evidence from past chambers that high rates can lead to an unstable running condition
  - It is likely that the 30 events/hr we get from NuMI and cosmics prevent assessing the true stability of the chamber
- Achieved target of < 20 surface events/hr, even at the lowest threshold

Continuing chemistry work

- We have found a reliable supplier of 99.9% pure CF_3I
- We have also added the new purification stage
- These new elements will be used in the upcoming COUPP-4 run
- Analysis of fluids ongoing
- Working with Anna Pla-Dalmau on GCMS capabilities at Fermilab for more testing

Operational reliability

- Over 15000 pressure cycles at relatively high rates in the two runs – equivalent to 1 month at 20 events/hr, 3 months at rate observed in COUPP-4 at SNOLAB
  - Main fault condition was lost communication between hardware logic controller and DAQ (see talk by C. Dahl)
  - Other faults also related to DAQ computer
- New controls system and DAQ will be tested for a month at SNOLAB with new pressure vessel before installation of inner vessel
- System hardware performed well, except...

Operational reliability

- On Nov. 3, 2011, a leak formed at the flat gasket seal between the pressure vessel and the viewport window
  - Bolts were not re-torqued after initial installation
  - Fixable, but we chose to end the run

Conclusion

- Problems observed during 2010 commissioning run are under control
  - –New pressure vessel and optics/camera design
  - –Reddening eliminated by sodium sulfite
  - –Surface boiling reduced to tolerable level by new purification, with expectation for further reduction
- Ready for low background operation at SNOLAB