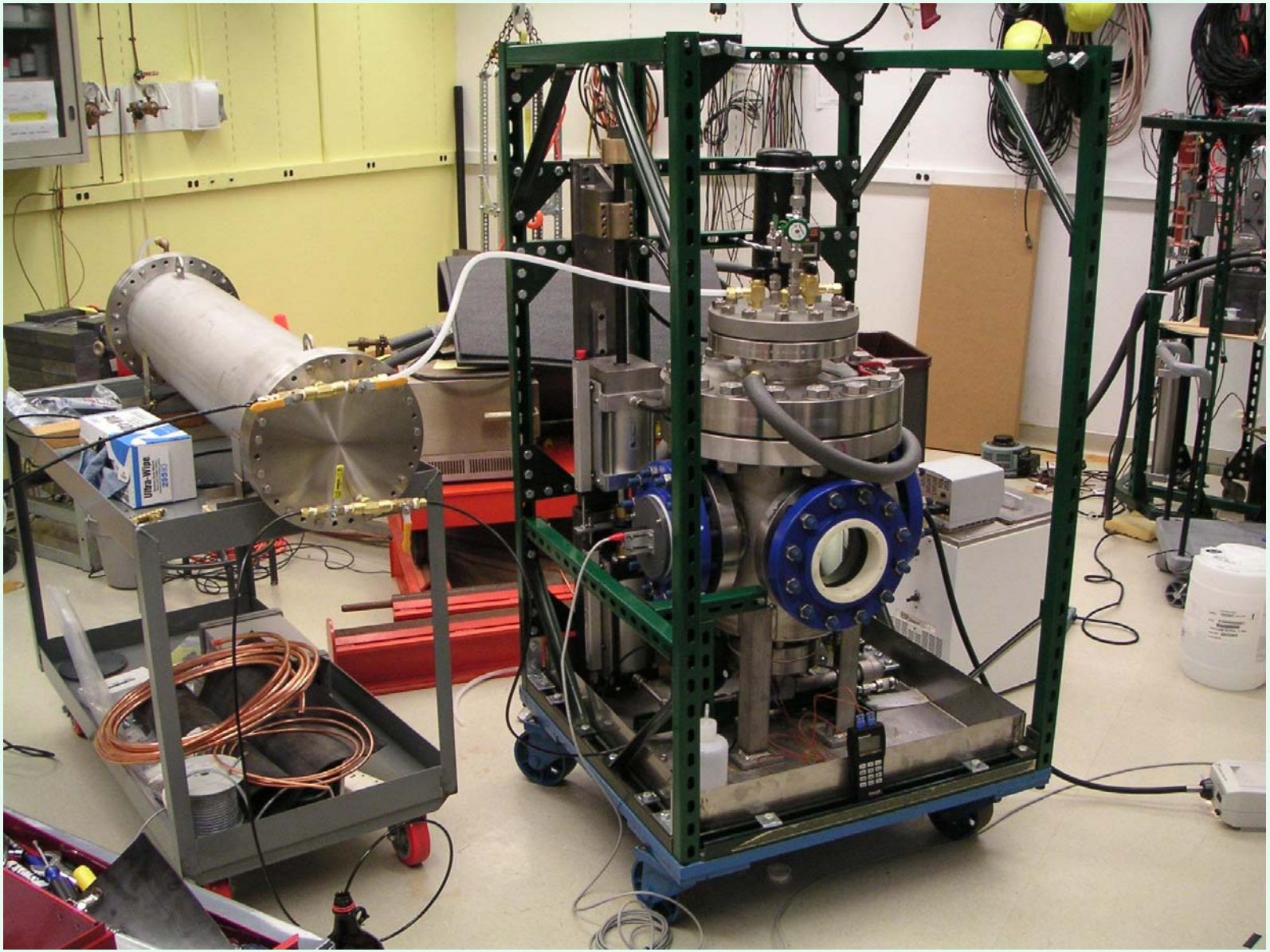
Fermilab Engineering Note

T-945: COUPP ~~1-liter~~ 2-liter ! Bubble Chamber

M. Crisler, PPD COUPP R&D Review, 10 December 2008

COUPP original 1-liter chamber designed, built, and commissioned at U.C By Andrew Sonnenschein 2004



Tested at UC in summer 2004
Moved to Fermilab February 2005

Installed in MINOS near-detector Hall

Run 1 aborted, Run 2 successful

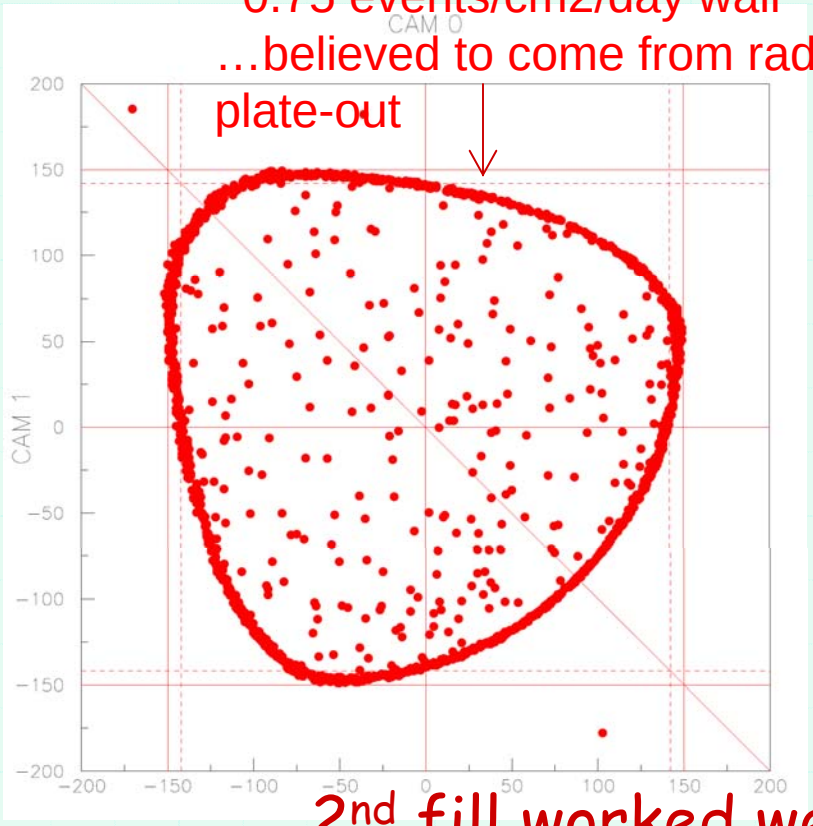
- 1st fill July 2005 - this one failed
  - distillation didn't behave well
    - Different behavior from what we saw at UC
  - chamber was "effervescent"
    - We had seen this before but not so dramatic…
  - lots of work to improve trigger…
    - Clearly it wasn't going to work.
  - …finally we punted

Run 1 aborted, Run 2 successful

- Working theory "CO_2" in the CF_3I bottle
  - "CO_2" dissolves in the water, defeats the degassing process.
  - "CO_2" effervesces while we're waiting for a bubble
- 2nd fill December 2005, improved CF_3I handling:
  - Tap bottom of CF_3I vessel, transfer liquid to a secondary container
  - Vent the secondary container before initiating the distillation
- Ran thru December 2006

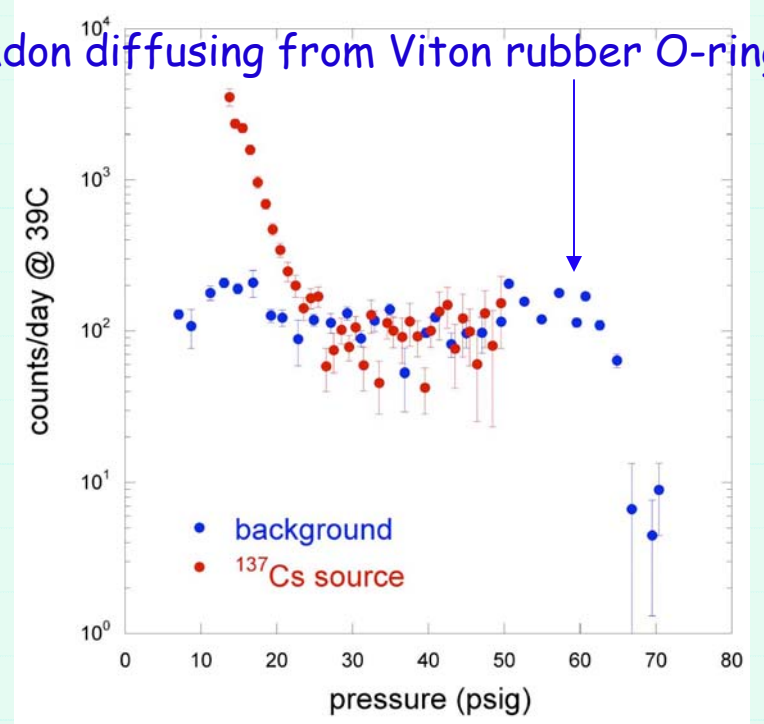
Wall events and bulk bubbles

~0.75 events/cm2/day wall
…believed to come from radon plate-out



~70 events/kg/day bulk

Radon diffusing from Viton rubber O-ring



2nd fill worked well, produced physics

Fermilab Engineering Note

THIS IS NOT R&D

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Reports

Spin-Dependent WIMP Limits from a Bubble Chamber

E. Behnke,1 J. I. Collar,2* P. S. Cooper,3 K. Crum,2 M. Crisler,3 M. Hu,3 Levine,1 D. Nakazawa,2 H. Nguyen,3 B. Odom,2 E. Ramberg,3 J. Rasmussen,2 N. Riley,2 A. Sonnenschein,3 M. Szydagis,2 R. Tschirhart3

Bubble chambers were the dominant technology used for particle detection in accelerator experiments for several decades, eventually falling into disuse with the advent of other techniques. We report here on a new application for these devices. We operated an ultraclean, room-temperature bubble chamber containing 1.5 kilograms of superheated CF3I, a target maximally sensitive to spin-dependent and -independent weakly interacting massive particle (WIMP) couplings. An extreme intrinsic insensitivity to the backgrounds that commonly limit direct searches for dark matter was measured in this device under operating conditions leading to the….

Issues with the first 2 fills:

- CF_3I isn't sufficiently pure out of the bottle for the basic thermodynamics to work…
  - What about radio-purity?
- Sound engineering on vessels, pressure balancing, sketchier on subordinate systems
  - Hydraulic controls
  - Instrumentation & wiring
  - DAQ…

Preparations for 2007 run:

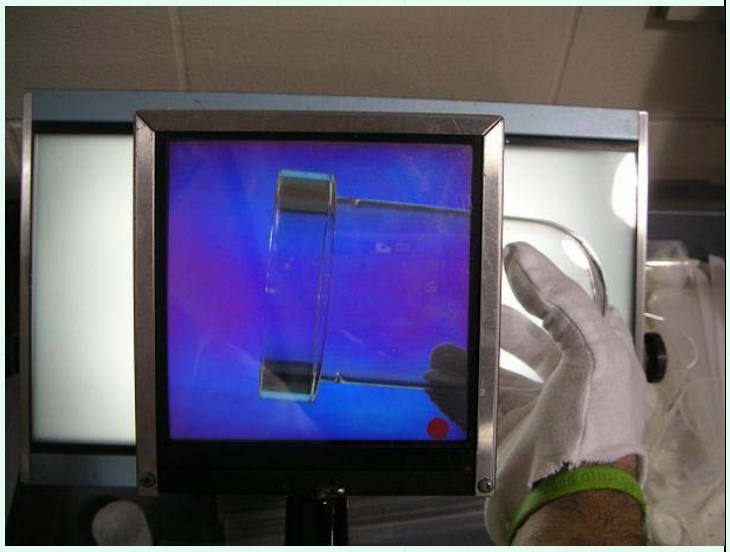
- Written procedures for everything:
  - Quartz vessel shipping and handling
  - Quartz vessel cleaning and assembly
  - Water distillation
  - CF3I distillaton
  - Chamber cooldown, Chamber warm up
  - Hydraulic fluid addition, removal…
  - …..

Preparations for 2007 run:

- Quartz-to-metal seal: Replace viton o-ring with non-radioactive seal
  - A few false starts:
    - Aluminum helicoflex seals work nicely, but al is a suspect material in terms of CF3I compatibility
    - Silver plated seals worked well, but ditto…
    - Inconel seals are OK material but don't seal to quartz sucessfully
  - The solution:
    - Teflon coated inconel sealed well, teflon screened successfully for radioactivity.

Preparations for 2007 run:

- New Quartz Inner Vessel
  - Improved Handling
  - Reduced Radon Exposure



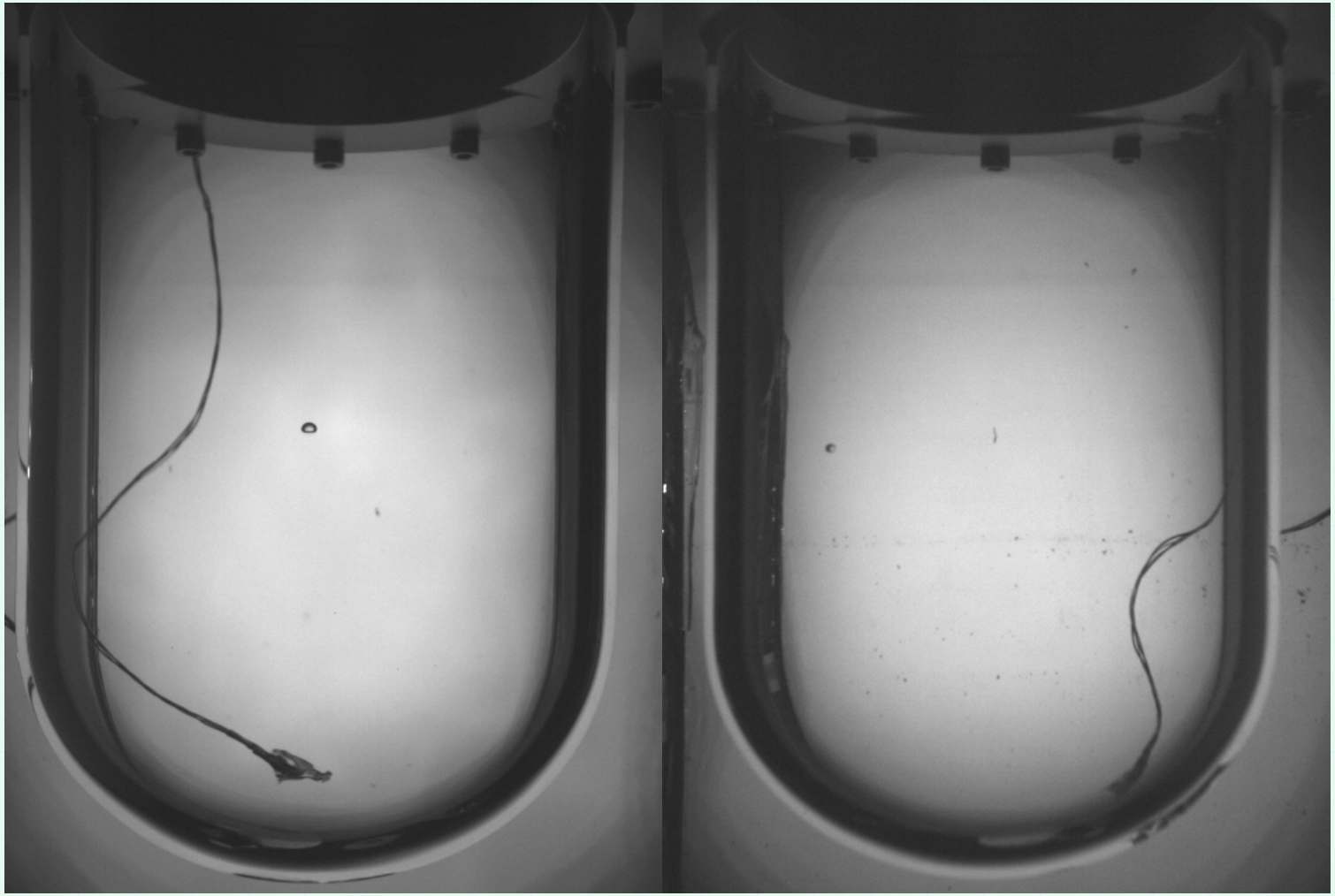
- Radon tight bag at vendor
- Radon tight cap for storage
- Short cycle from fabrication to fill

Preparations for 2007 run:

- New Bellows Assy (non-Thoriated weld)
- Ultra High Purity Water (SNOLAB)
- Improved Cleaning Procedures (U of C & A-0)

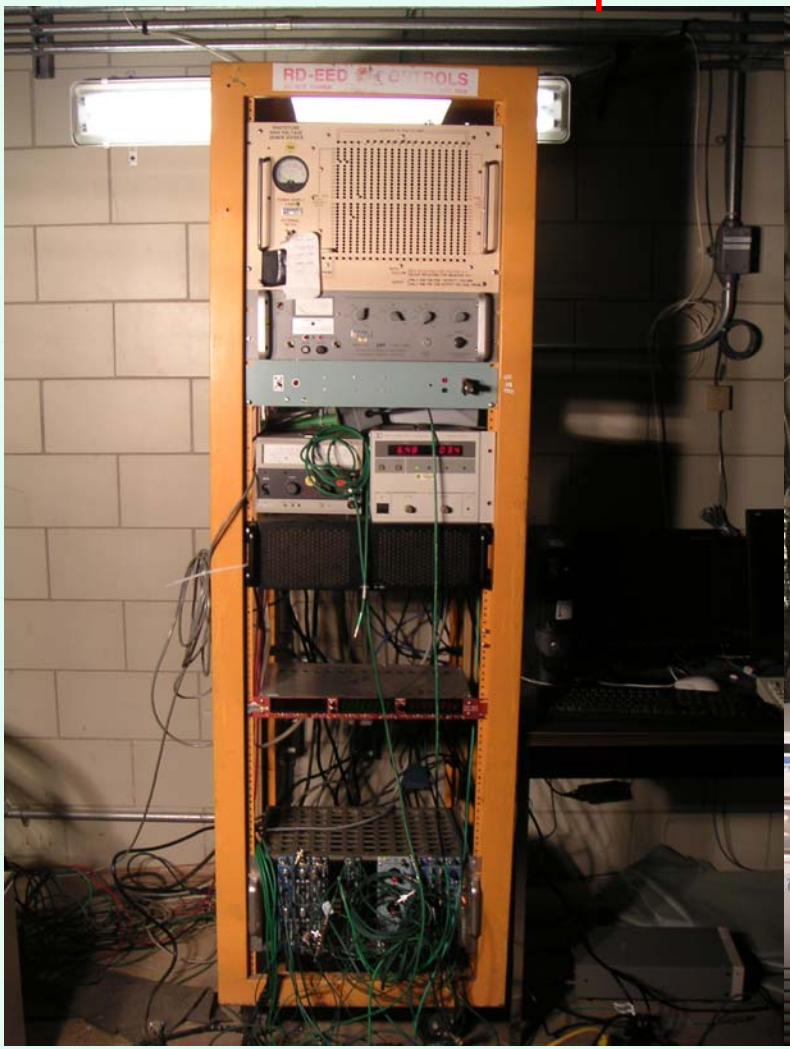
Preparations for 2007 run:

Improved Photography



Preparations for 2007 run:

Clean-up the electronics…



before…

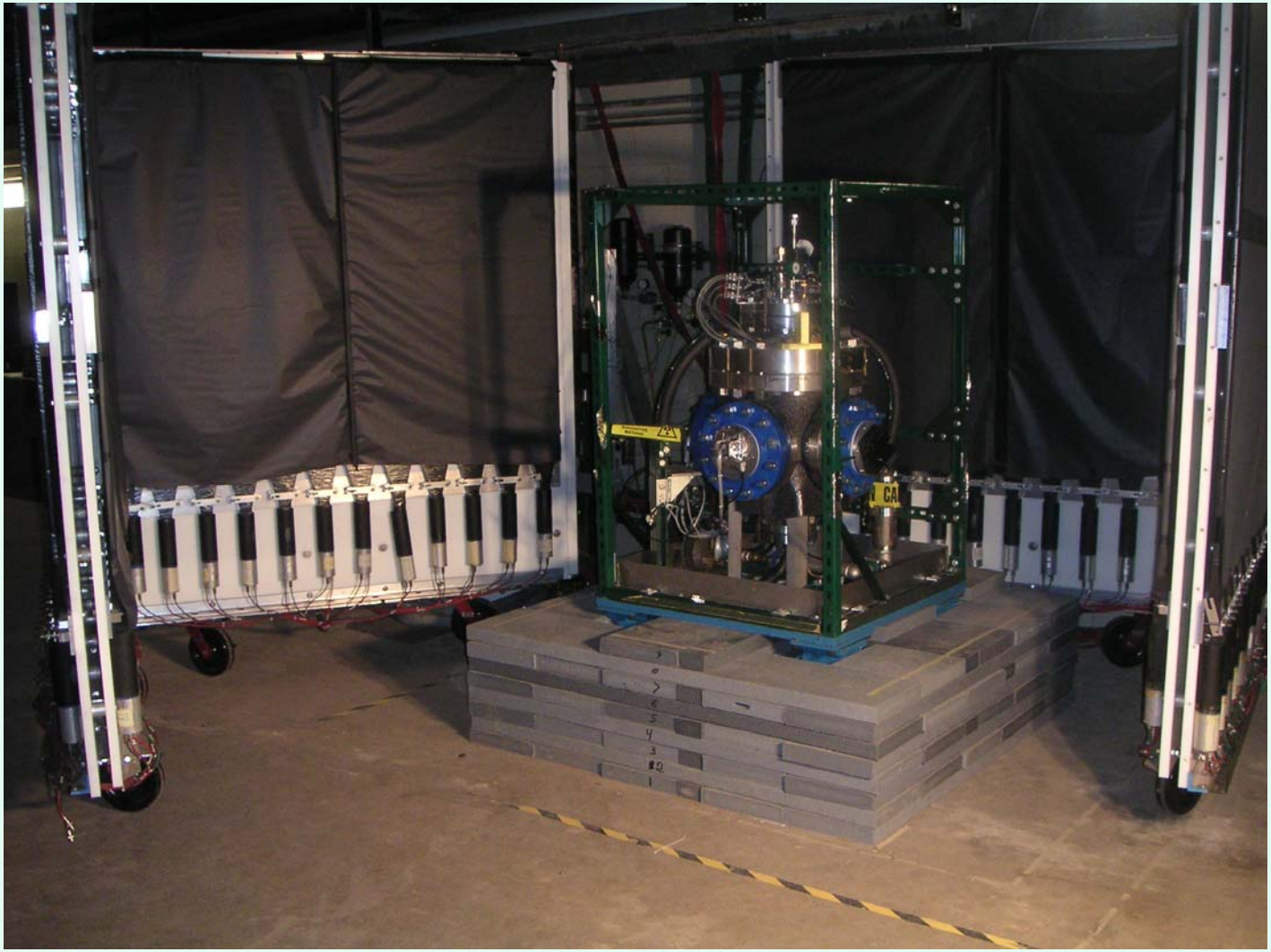
after…

Improved Data Acquisition

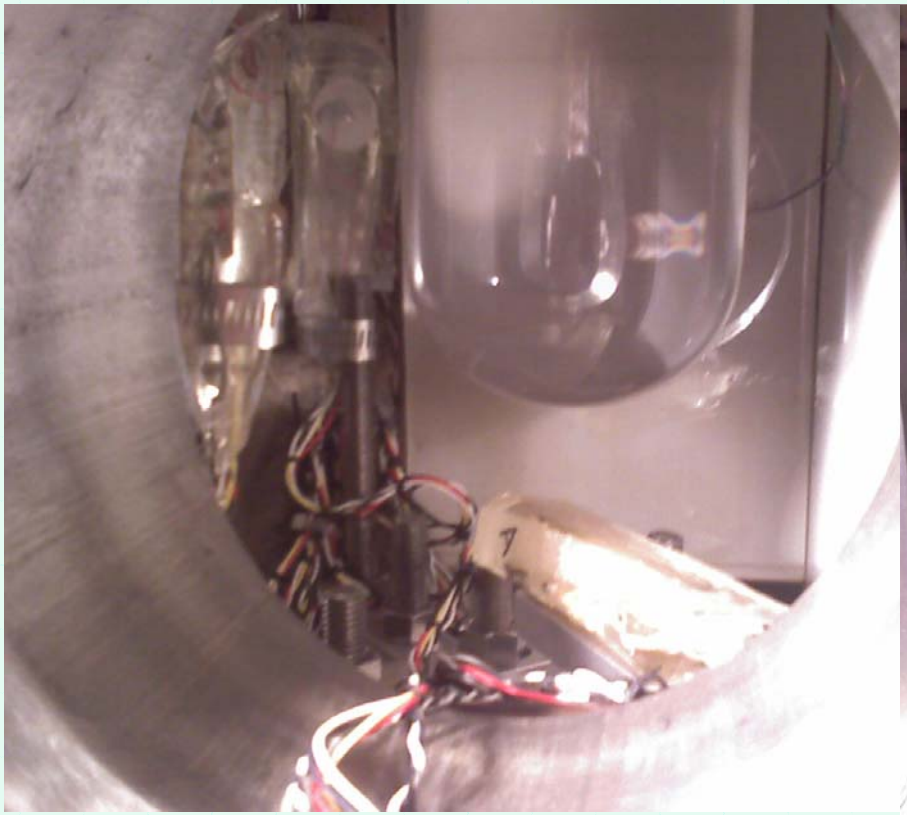
- Removed DAQ computer from the network
- Used a linux machine as a data server and a firewall (DAQ machine on local network, linux machine on fnal network.)
- Stripped DAQ machine of virus protection, security scanning, etc…

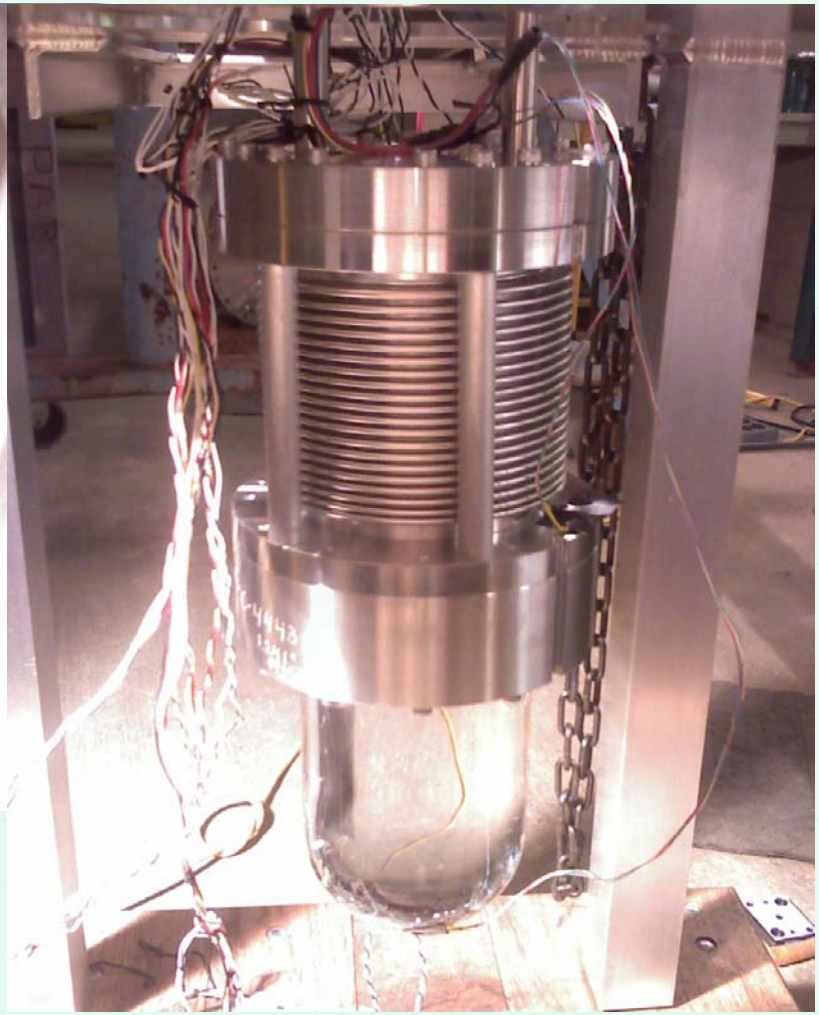
- Vastly improved performance and stability.

Added Muon Veto

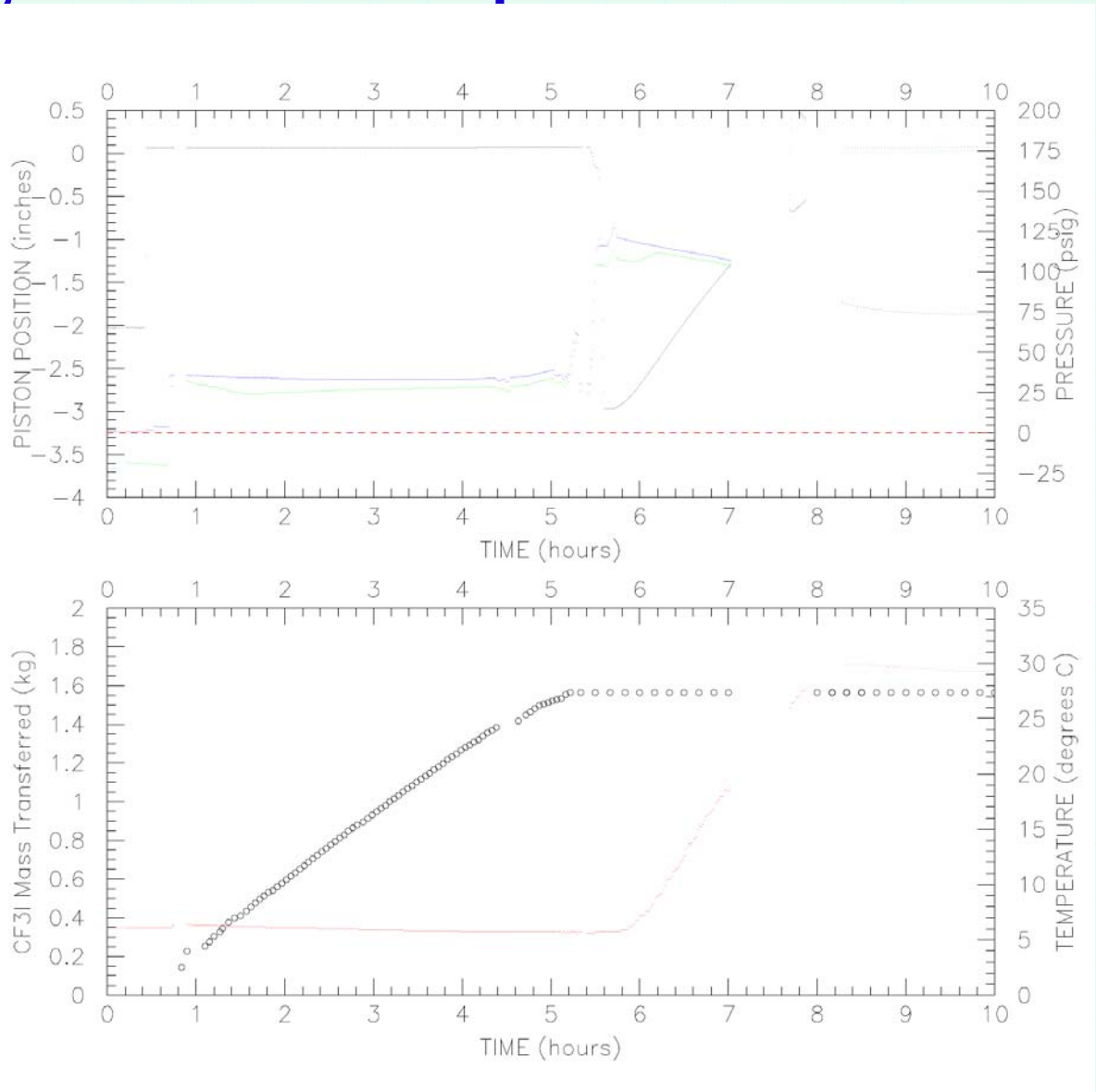


Added Acoustic Sensors

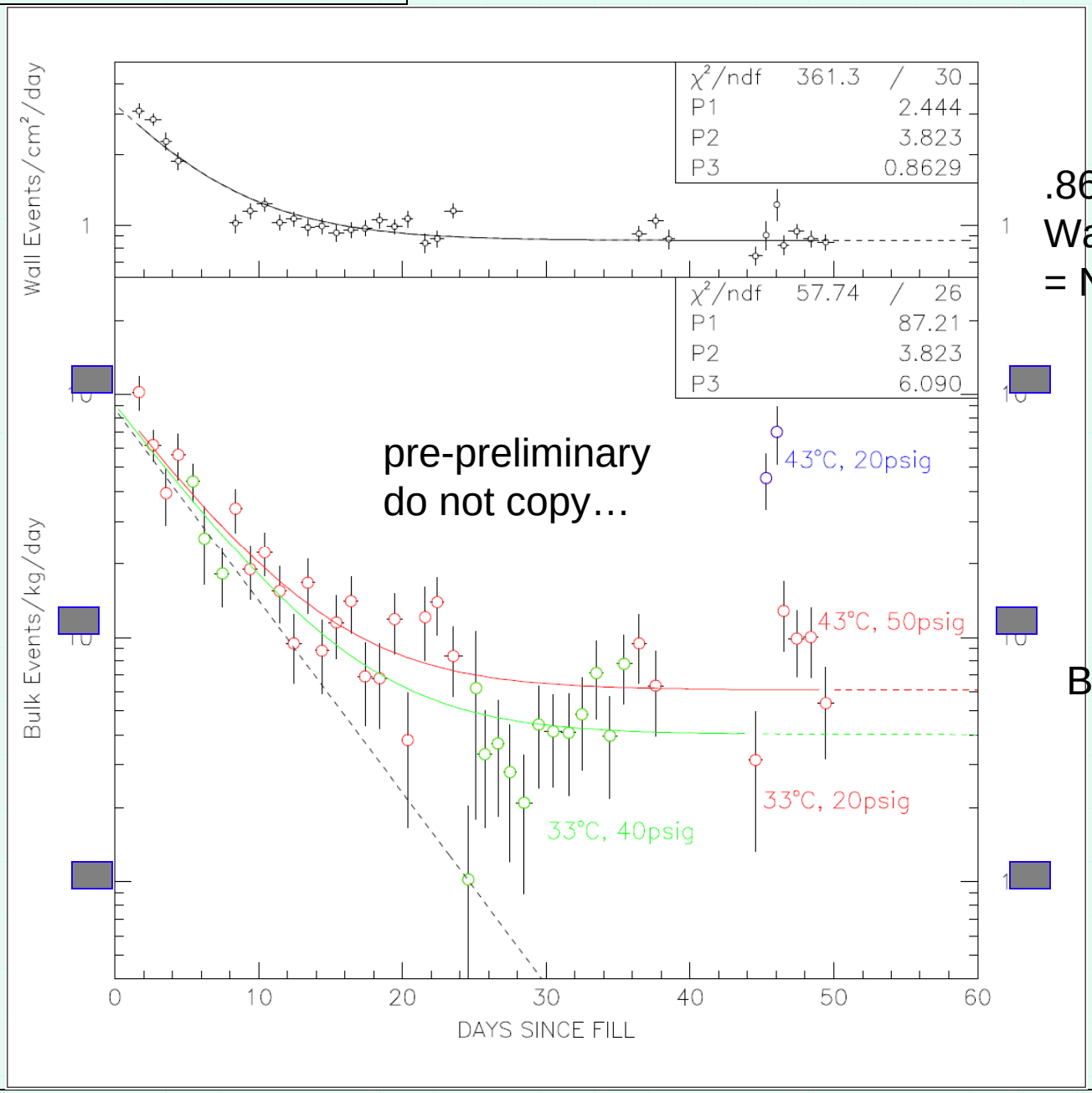




CF_3I fill accomplished in one shift



7/30/07



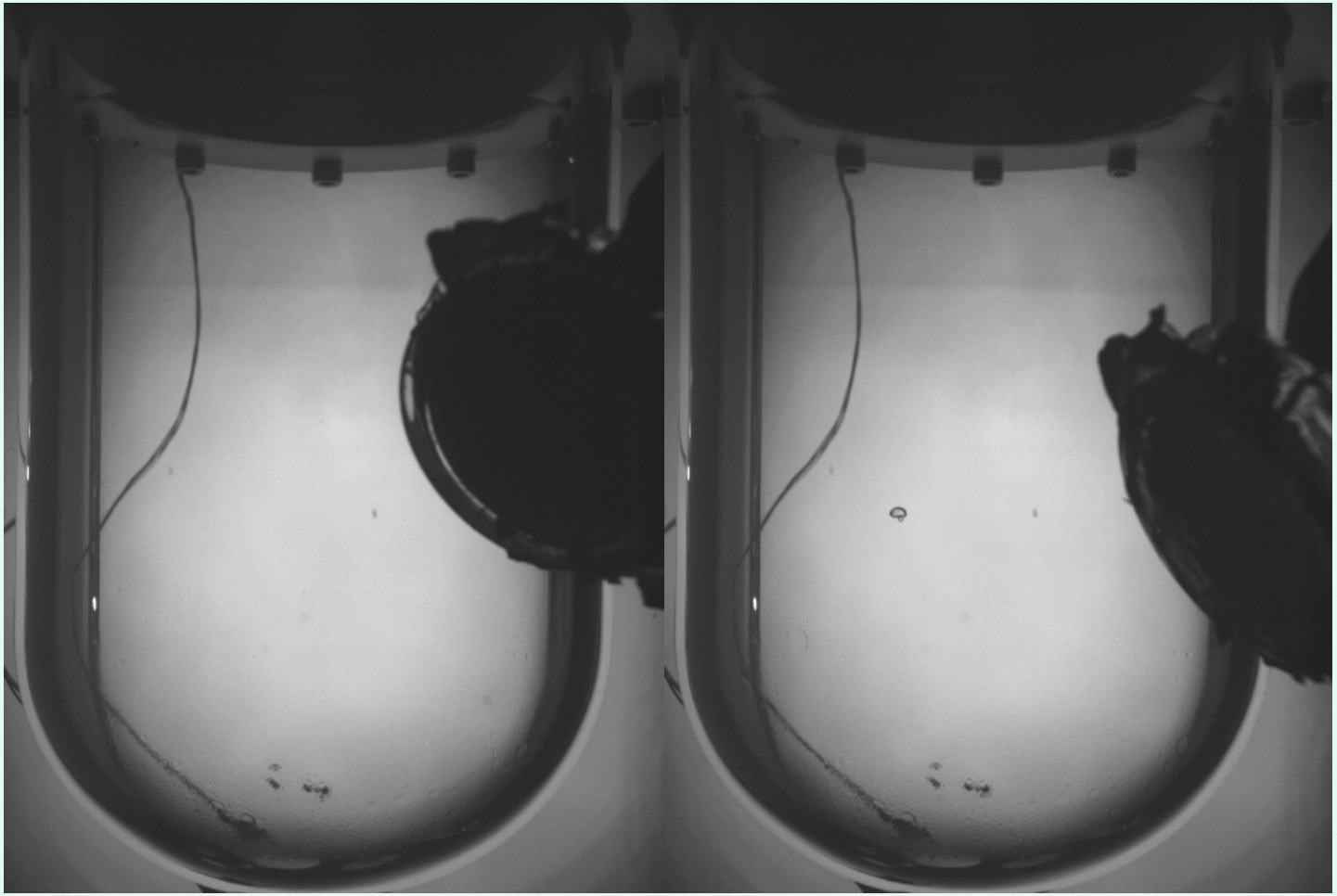
.86 events/cm2/day
Wall events
= NO IMPROVEMENT

Bulk rate low…

but…

- NO IMPROVEMENT in wall event rate
  Wall rate due to intrinsic U and Th contamination in natural quartz!
- C.R. veto did not work sufficiently well
- Acoustic sensor performance was marginal
- Bugs in DAQ
  - issues with Pressure and Time measurements
- …and

Camera occlusion led to premature EOR



- Likely no physics result from 2007 run.

  Can't sort out cosmic ray contribution from α-emitter contribution

Plans for 2009 run:

- Synthetic silica 2-liter vessel

- Improved instrumentation and wiring
  - Improved acoustic sensors, RTD's
- Improved DAQ
  - National Instruments Embedded Processor
- Improved hydraulic control system

- Improved muon veto

New inner vessel assembly

New Rack Setup

before…

after…

New LabVIEW system…

New Hydraulic Controller

← Newly minted
(at Chez Korienek)

Following successful dummy load test →

New Veto System

Welded steel “buntcake” Shaped bucket

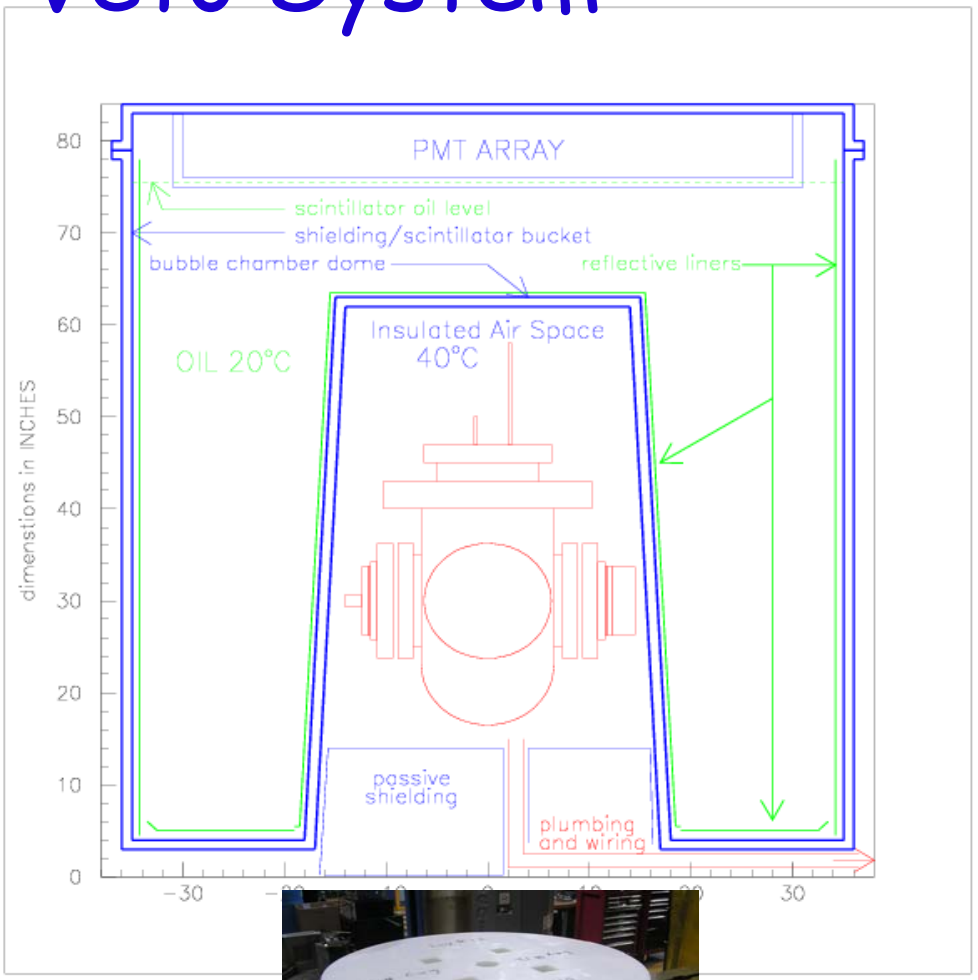
Lined with Alzac

Filled with NuTEV scintillator

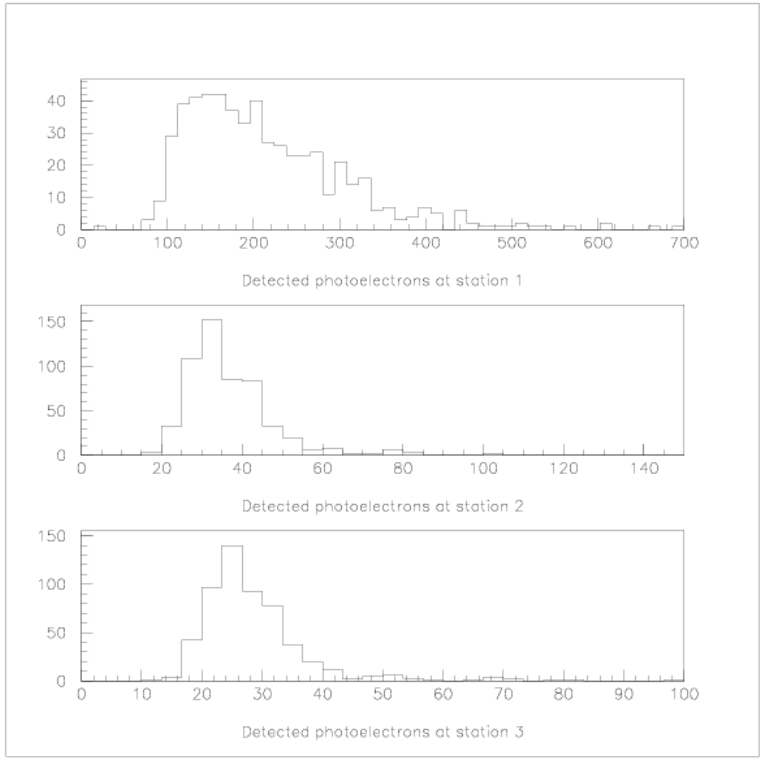
Instrumented with 19 5”diam 1970’s vintage RCA PMT’s

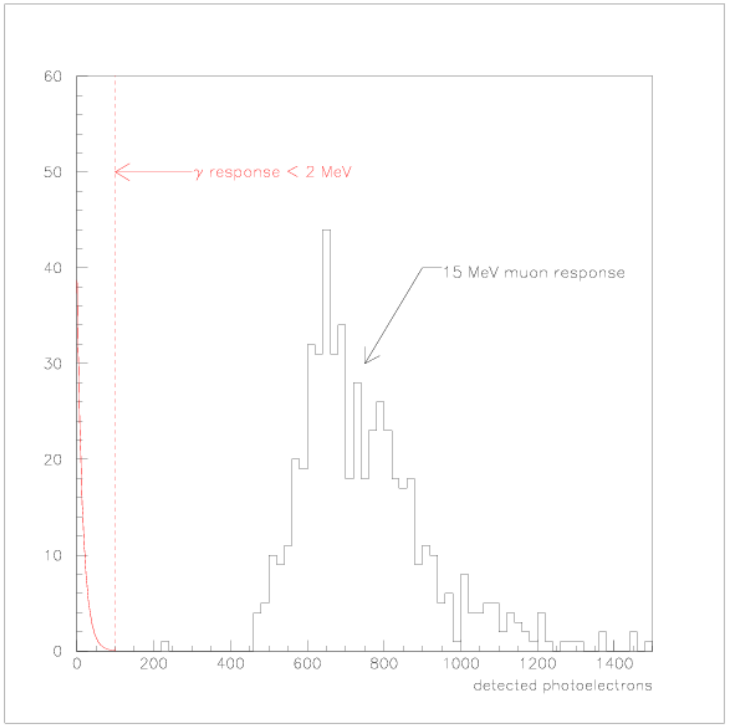
New Base design
- o C-W high-voltage
- o local pulse shaping
- o local digitization
- o ONE network cable

(Sten Hansen)



New Veto System





Status of Preparations:

- Complete inner vessel instrumentation and wiring (Dec 2008)
- Complete NEW DAQ (Dec 2008)

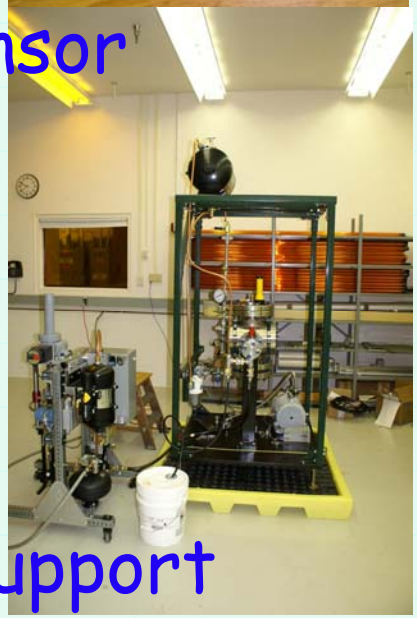
- DAQ full system integration test (Jan 2009)
- Muon Veto integration test (Jan 2009) maybe not with new bases…

- Installation in MINOS (Feb 2009)

THIS IS NOT R&D

- Expect 1-10 events per kg per day
- successful acoustic α-discrimination could reduce this by a factor of 100 or more…
- This is a real physics experiment. We could give CDMS a run for their money…

R&D we need to do:



- Dedicated test bed for acoustic sensor development
- We have most of the hardware →
- We need engineering & technician support
  - (very little, but not zero)
  - one or two FTE-months each would be huge