Next Fill of COUPP Bubble Chamber

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Feb. 5, 2007

All Experimenters Meeting

COUPP, the "Chicagoland Observatory for Underground Particle Physics"

University of Chicago

Juan Collar (PI, spokesperson), Keith Crum, Smriti Mishra, Dante Nakazawa, Brian Odom, Julia Rasmussen, Nathan Riley, Matthew Szydagis

Indiana University South Bend

Ed Behnke, Ilan Levine (PI), Nate Vander Werf

Fermilab

Peter Cooper, Mike Crisler, Martin Hu, Erik Ramberg, Andrew Sonnenschein, Bob Tschirhart

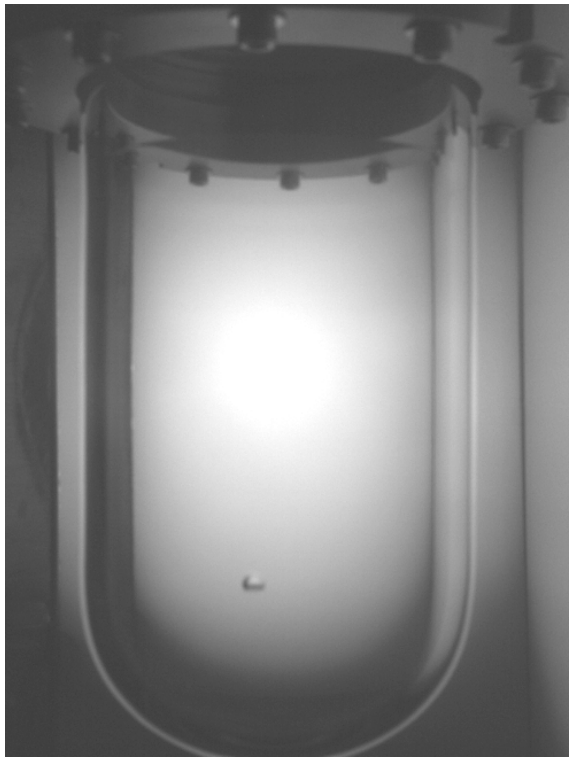
Kavli Institute for Cosmological Physics AT THE UNIVERSITY OF CHICAGO

Fermilab

COUPP (E961)

- An experiment to search for dark matter particles with a new bubble chamber technology.
- Initiated with tests of 1-liter (2 kg) chamber in NuMi gallery as Test Beam Proposal T945
- Development of larger experiment (~60 kg target) approved by director in Nov. '06 after consideration by PAC (see **www-coupp.fnal.gov**).

Our signal:
single bubbles



Principle background:
alpha decay from radioactive impurities in detector liquids

(neutrons also important, but less challenging)

Dec. 2005- Dec. 2006 Run

Progress reported at April 3 and Sept. 11 All Experimenters Meetings and in PAC proposal:

- Nearly continuous operation, with incremental trigger improvements leading to >70% live time fraction by middle of run.
- Sensitivity to low-energy nuclear recoils from neutrons consistent with theoretical expectations.
- Extreme insensitivity to gamma rays.
- Relatively high, temperature dependent backgrounds due to alpha decay in bulk fluid.
- Wall events from alphas ~ 300/day
- Stopped taking data in Dec. due to apparent jamming of inner vessel pressure control bellows. Precise nature of problem likely to become clear when we disassemble (~ 100,000 bellows cycles).

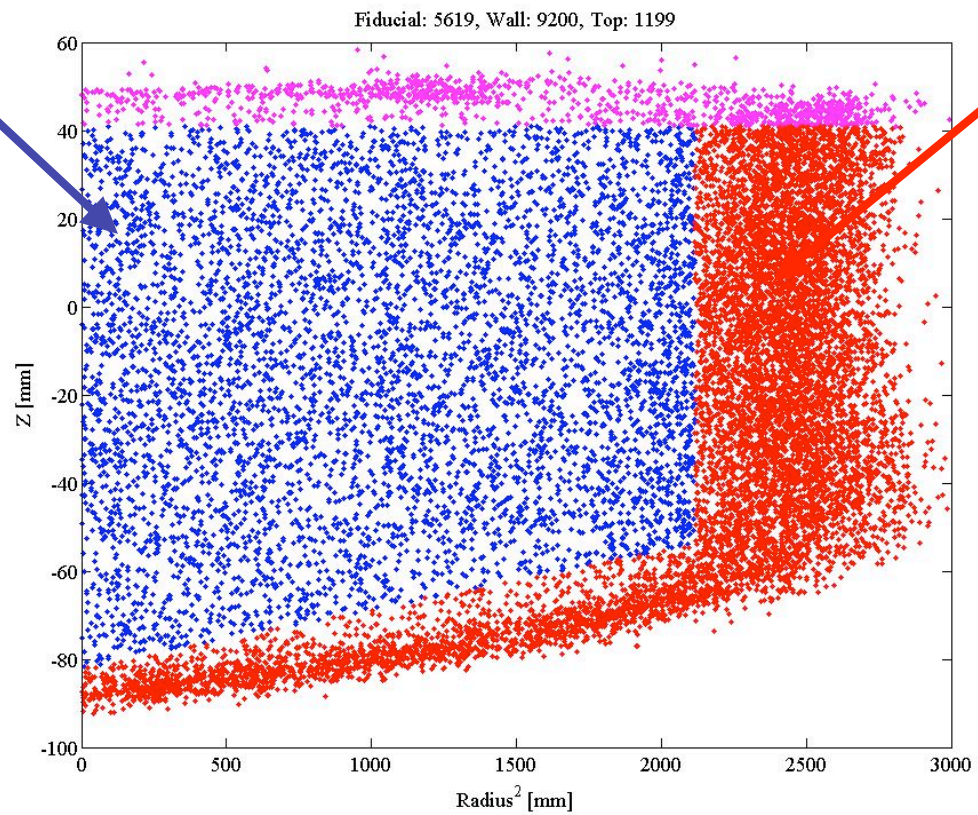
Spatial Distribution of Single Bubbles

Bulk events: indistinguishable from WIMP interactions on an event-by-event basis.

~ 20- 100 events/day

Wall Events: not a background, but they reduce our live time due to the need to decompress afterwards, prohibitive for larger chambers.

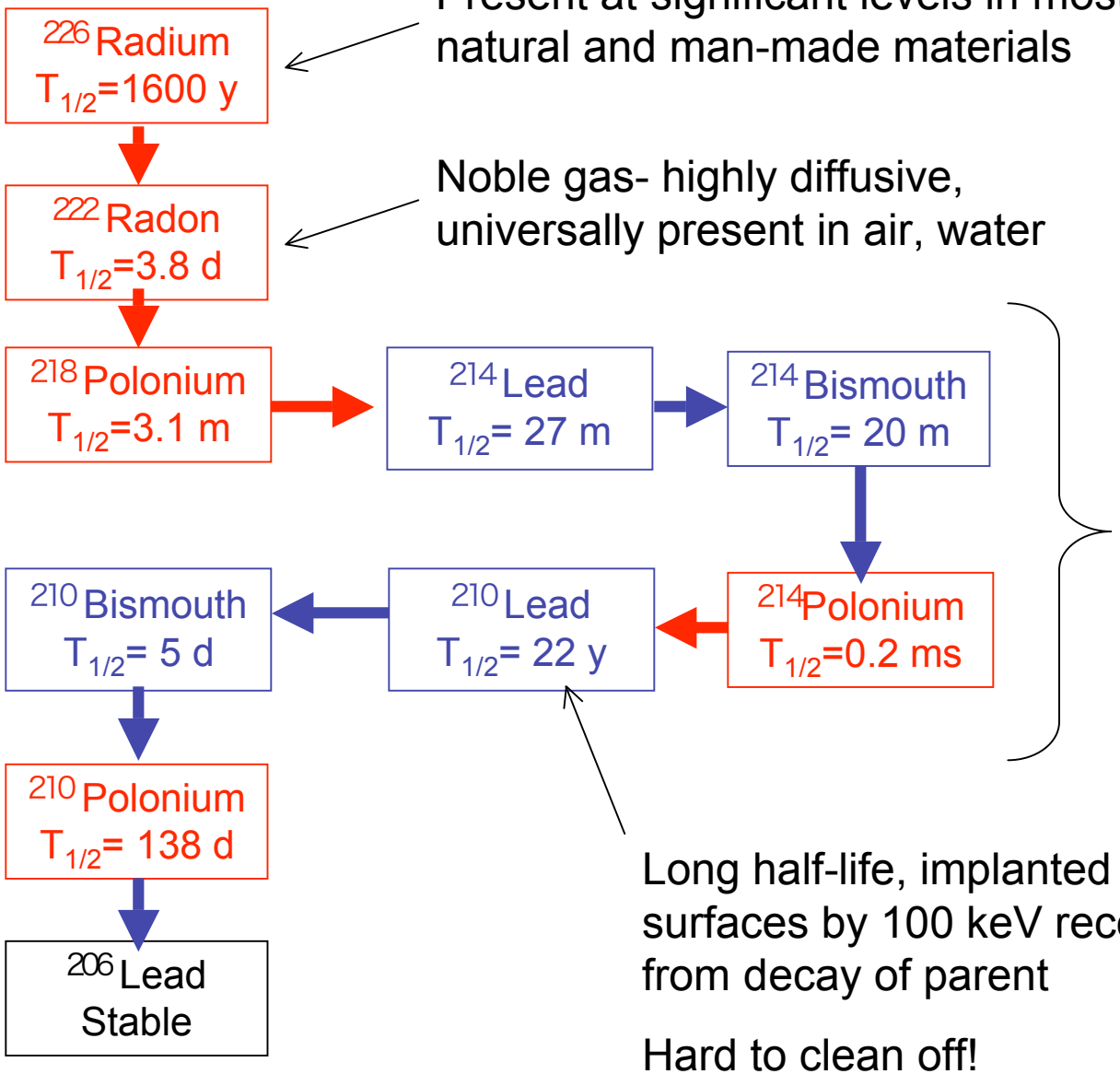
~ 300/day



Radium Decay Chain: Dominant Source of Environmental α's

Red= alpha decay

Blue= beta decay



Present at significant levels in most natural and man-made materials

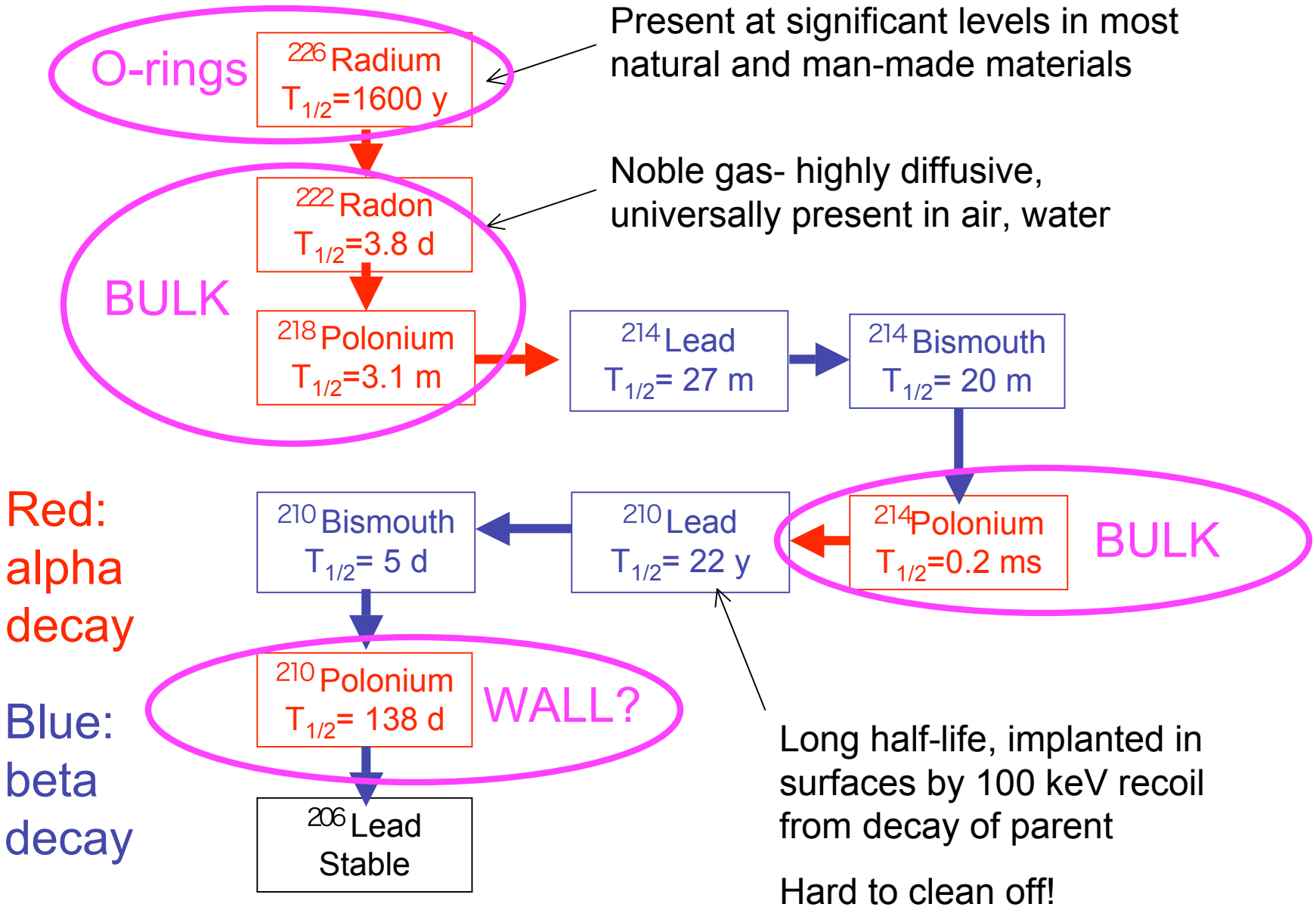
Noble gas- highly diffusive, universally present in air, water

Attracted to surfaces by electrostatic charge

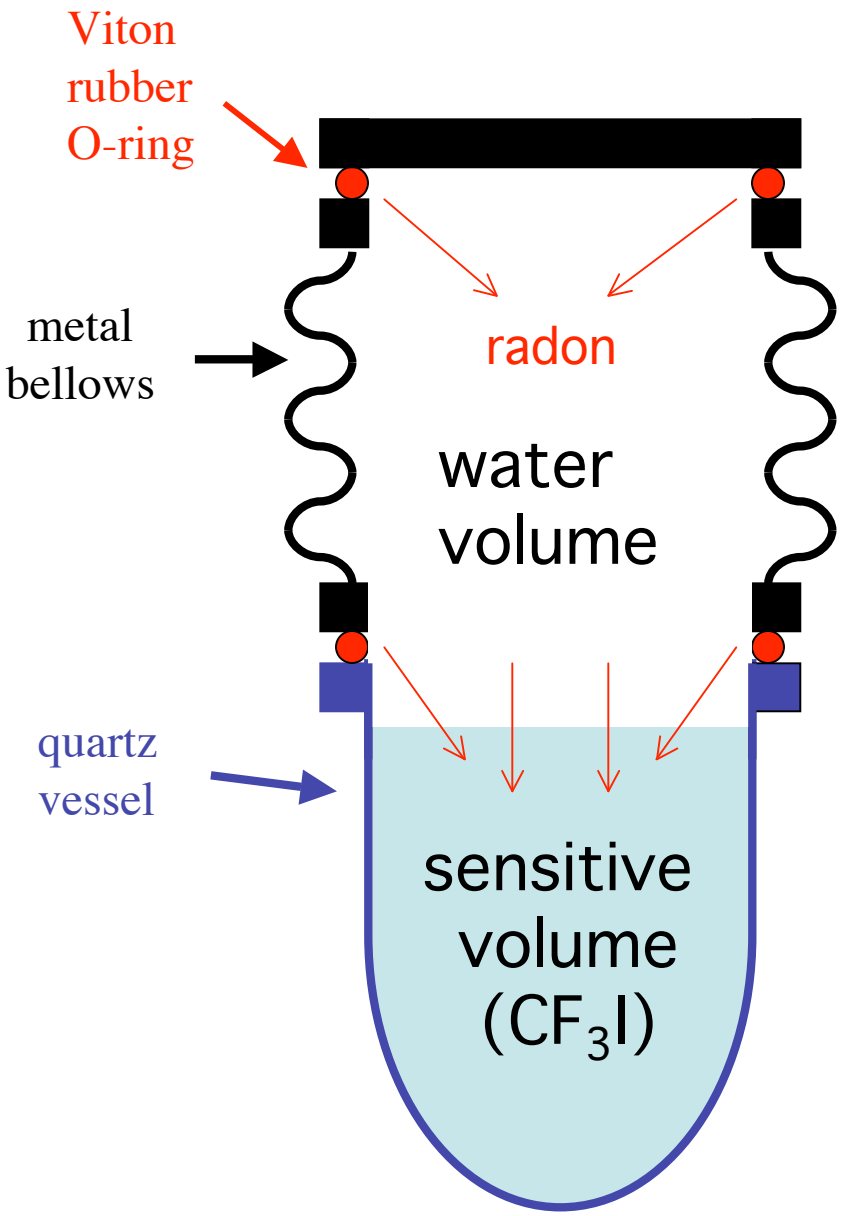
Long half-life, implanted in surfaces by 100 keV recoil from decay of parent

<u>Hard to clean off!</u>

Radium Decay Chain: Dominant Source of Environmental α's



Radon Emanation from Viton Rubber Seals



- Borexino collaboration has measured Viton to release radon at a rate of 15 atoms/cm^2-day

  => Our O-rings should each emit 50 decays/day of radon

- Expect a total of 300 alpha decays per day in inner vessel, accounting for 2 O-rings and 3 alpha emitters in the decay chain.

- We observe only a fraction of this decay rate in the sensitive volume (20- 100 per day). Decays in water are undetectable.

- Variation in counting rate believed due to changes in efficiency of radon transport with temperature and operating conditions.

New O-rings

• Clean metal surfaces can have extraordinarily low radon emanation rates, due to the very short diffusion length of radon in metals.

• Material choice for metal seal between quartz and stainless steel parts was a bit challenging:

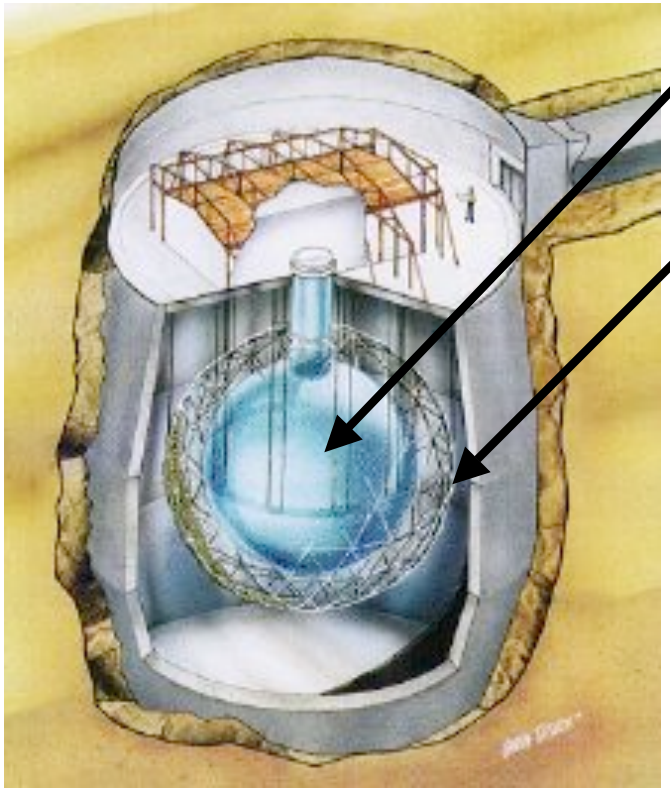
Copper	Reacts with CF_3I
Stainless steel	Too hard for sealing to quartz
Aluminum	Corrosion in presence of water and steel.
Silver	Discoloration in CF3I
✓ Gold	Looks good so far!

Water from Sudbury Neutrino Observatory

- The SNO collaboration developed special techniques for water purification and low-level measurements of radium and radon in water.
- Purity corresponding to **total α activity ~ 0.01 decays/L-day**.

Probably least radioactive water ever produced, certainly best studied.

- They kindly agreed to supply us with water for the next COUPP run.

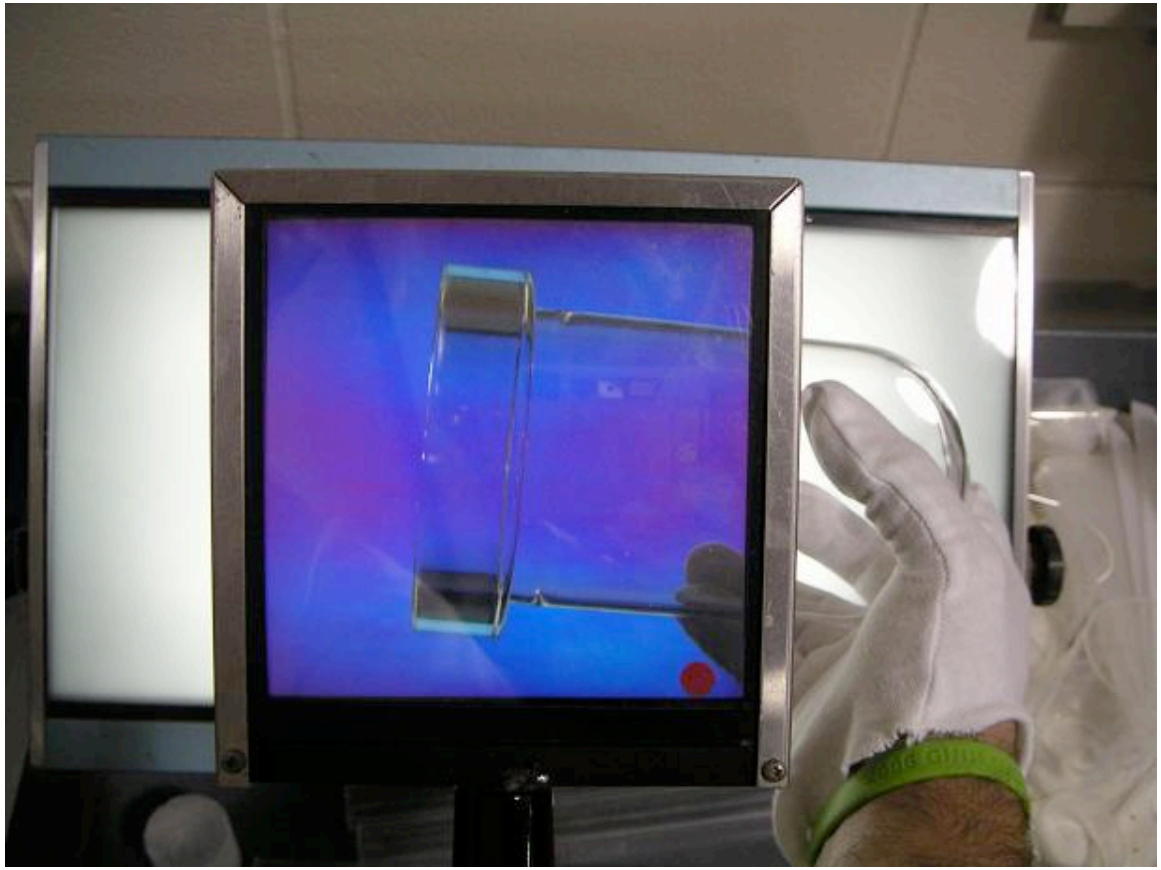


Heavy water D_2O (neutrino target)
normal water (shielding)

Container from Fermilab being filled at SNO

New Quartz Inner Vessel

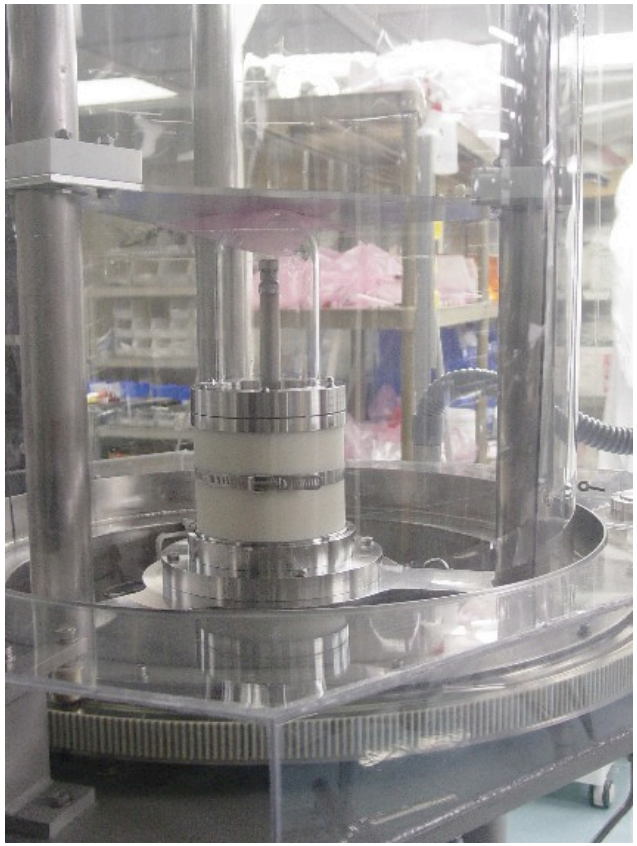
- Rate of wall events consistent with ^{210}Pb buildup during a ~1 year air exposure
- The maximum implantation depth from 100 keV nuclear recoil is <0.1 micron.
- New vessel was lightly etched by vendor in HF acid to remove quartz surface.
- Post- etch exposure to radon was limited with a radon-tight cap.



Quartz being inspected for stress with polariscope

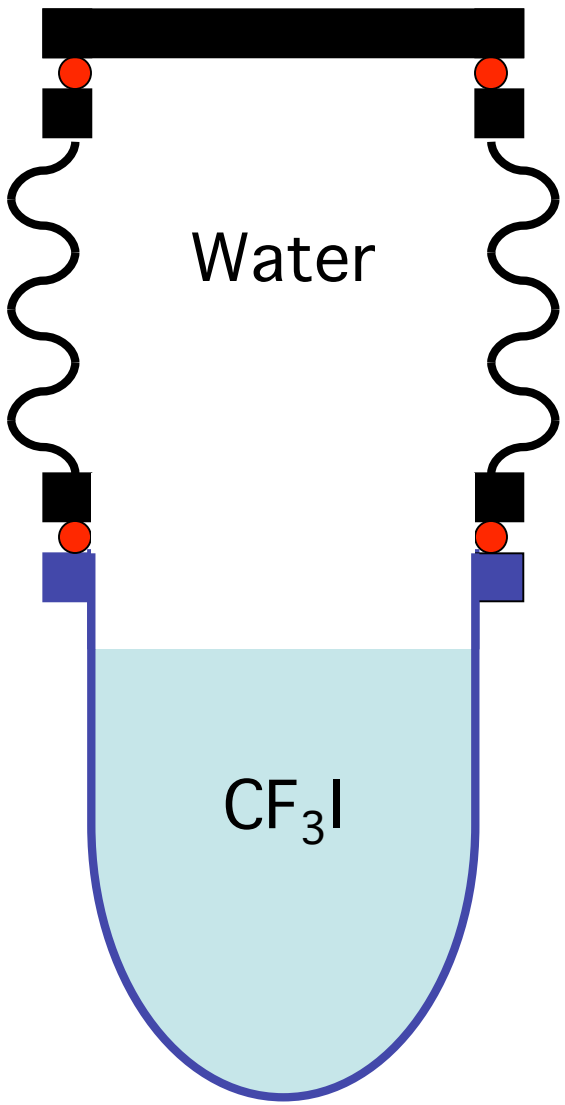
Cleaning at A0

- Accelerator Division has superb cleaning facilities developed for RF cavities: Class 10 assembly area, large ultrasound machines, high pressure rinse machine.
- Using SNO- recommended special detergent formulation to remove non-implanted fraction of ^{210}Pb and ^{210}Po surface contamination.
- High pressure rinse to remove dust -- Goal is 1 microgram per liter for 0.01 bubbles/day.
- Particle counting of filter papers will be done at SciDet as final check on purity.



Inner vessel high pressure rinse test

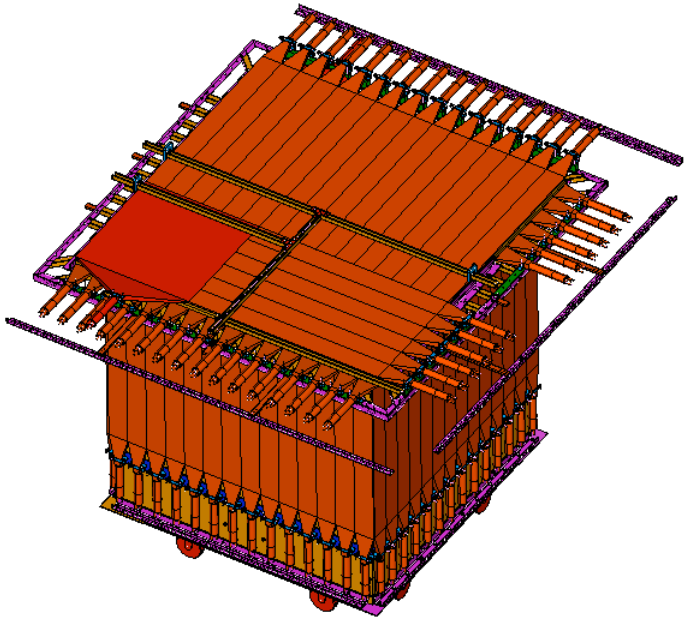
Inner vessel Changes To Reduce Alpha Activity



- Gold-plated inconel seals replace Viton.
- Quartz etched with HF acid by vendor to remove implanted radon daughters.
- All parts cleaned and assembled in Accelerator Division RF cavity cleaning facility at A0.
- Very high purity, well-studied water from Sudbury Neutrino Observatory.
- Bellows made using non-thoriated welding electrodes.

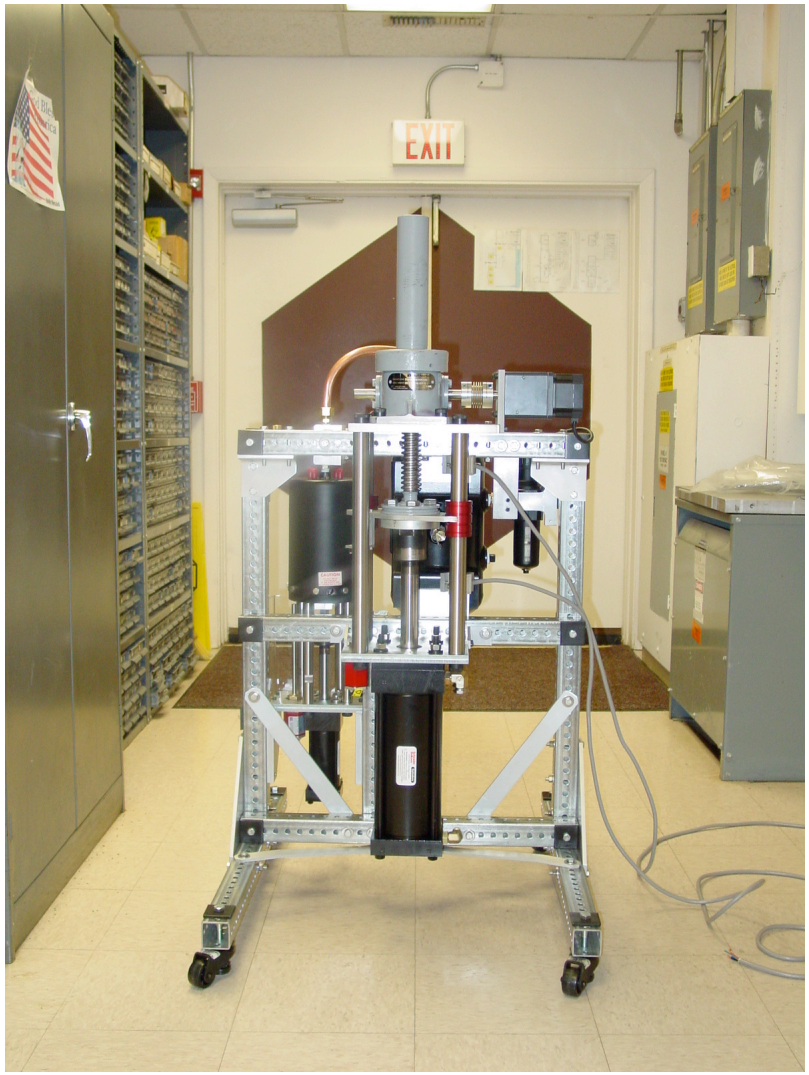
Muon Veto

- We expect to see ~ 5 neutron events per day when radon is gone, due to muon interactions in the steel parts of the chamber.
- An array of counters will be used to tag events with an associated muon.
- Approximately 150 KTeV scintillation counters with new mechanical support structure, DAQ from PREP.
- Construction finished, tests underway.



Second Generation Pressure Control System

- More automatic, more precise pressure regulation, higher speed.
- Explores pressure control ideas useful for larger bubble chambers.
- Four units built:
  - Replace old NuMi pressure control.
  - U. Chicago calibration chamber
  - Fermilab calibration chamber
  - 1 spare



Schedule

Completed:

- Water procurement from SNO
- Quartz vessel procurement.
- Inconel seals procurement.
- Pressure controller
- Muon veto counters

To be completed:

- Leak test of inconel seals (this week).
- Final inner vessel cleaning and assembly (Feb. 12-16)
- Acoustic sensor installation (Feb. 16)
- Draining/ removal of existing inner vessel (Feb. 12-16)
- Installation and filling of new inner vessel (Feb. 19-23)
- Start physics run, (end of Feb.)
- Integration with Muon Veto and new pressure control (mid- April)