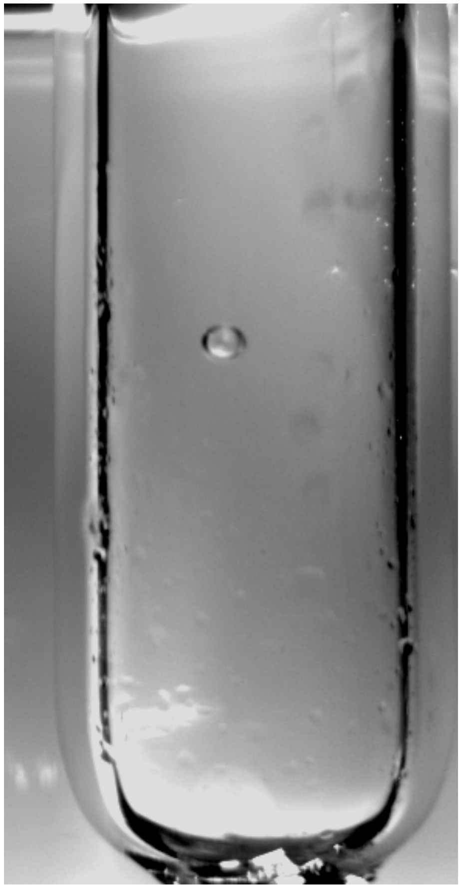
COUPP

Andrew Sonnenschein

Apologies from our spokesman and S4 PI Juan Collar

Lead, SD 8/2/09



THE UNIVERSITY OF CHICAGO

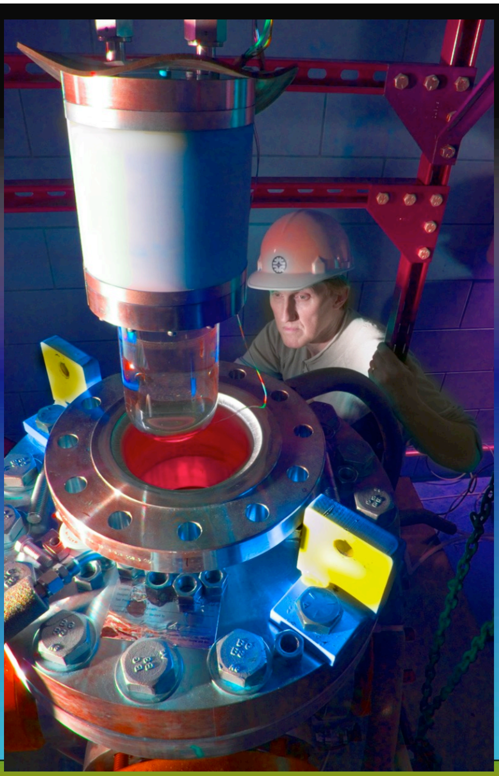
Fermilab

COUPP

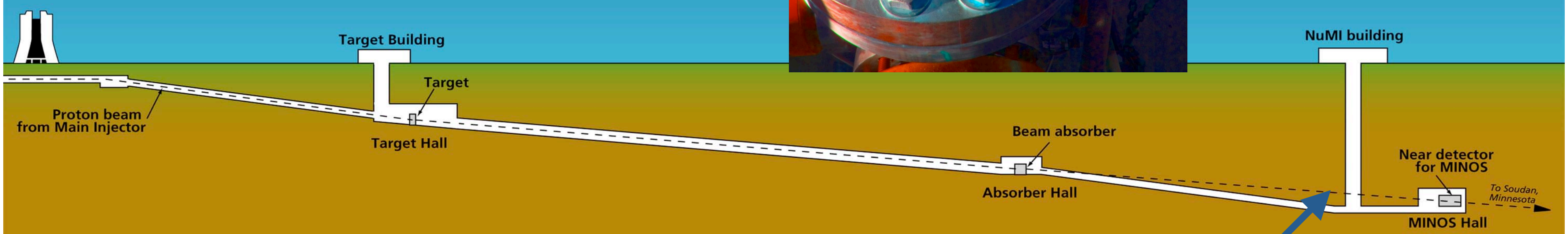
University of Chicago

Indiana University, South Bend

Fermilab



1 liter (2 kg)
Bubble Chamber
In NuMI tunnel



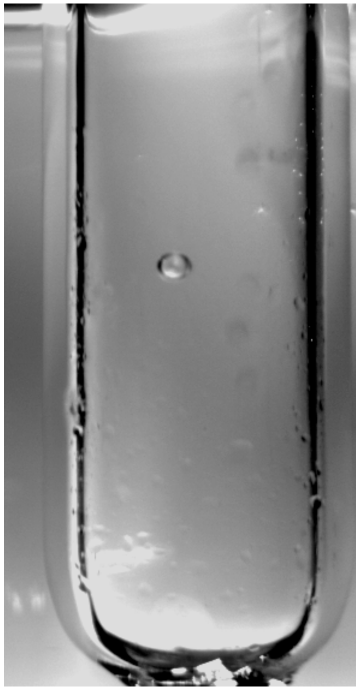
test site
~300 m.w.e.

Why Bubble Chambers?

1. **Large target masses would be possible.**
   - Multi ton chambers were built in the 50's- 80's.
2. **An exciting menu of available target nuclei.**

   ***No liquid that has been tested seriously has failed to work as a bubble chamber liquid* (Glaser, 1960).**

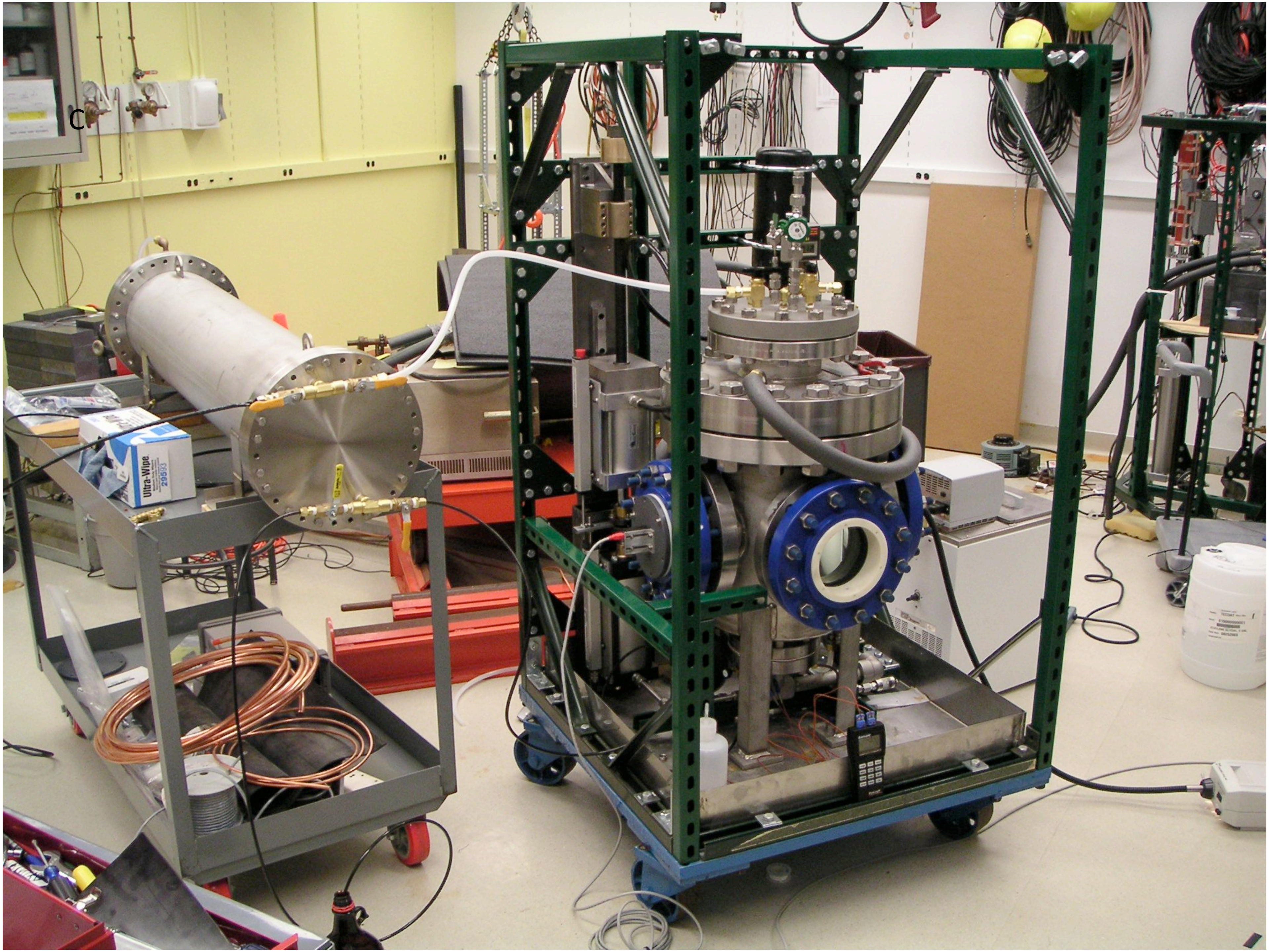
   - Most common: Hydrogen, Propane
   - But also "Heavy Liquids": Xe, Ne, CF_3Br, CH_3I, and CCl_2F_2.
   - Good targets for both spin- dependent and spin-independent scattering.
   - Possible to "swap" liquids to check suspicious signals.



3. Backgrounds due to environmental gamma and beta activity can be suppressed by running at low pressure.

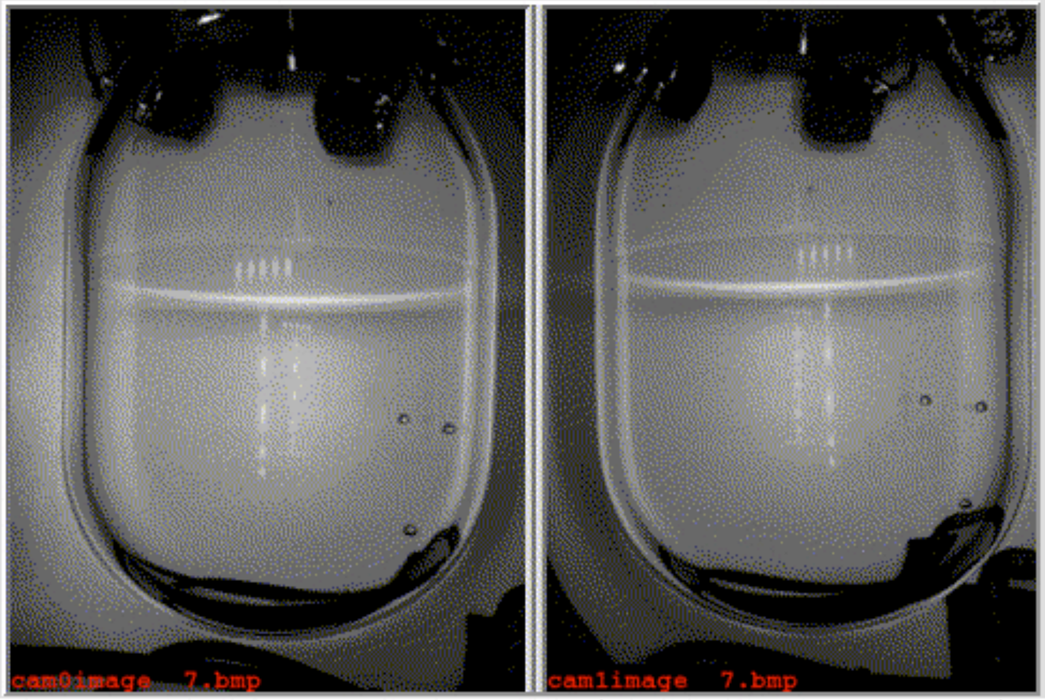
- Bubble nucleation depends on dE/dx, which is low for electrons, high for nuclear recoils

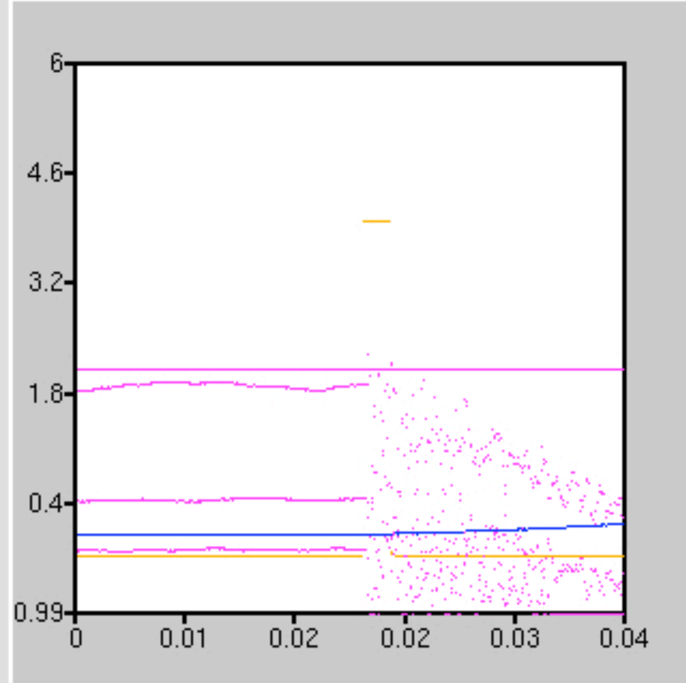
C



Windows

Run: 20091001_0 Event: 131 Current Time: Thu Oct 1 22:45:02 2009





Time

run start: Thu Oct 1 01:40:36 2009
this event: Thu Oct 1 22:35:52 2009
msec time: 224969353

Pressure [PSIG]

inner: 183.26
outer: 28.04
dp inner: 0.191
dp outer: 0.073
setpoint: 25.00
cart readback: 25.10

Pressure Ramp

phase: 0.000
count: 0
min [PSI]: 20.0
max [PSI]: 40.0
period [s]: 21600.0
state: 0

Temperature [degC]

top: 30.18
bot: 29.84
setpoint: 30.00
neslab bath: 29.04
neslab setpoint: 30.14

Event Timing [s]

compressed time: 30.1
expanded time: 539.4
live time: 534.4

Frame Timing [ms]

Time betwen frames [ms]

	1-0	2-1	3-2	4-3	5-4	6-5	7-6	8-7	9-8
cam0:	12	12	11	10	11	11	11	12	10
cam1:	10	12	11	11	12	11	10	11	12

cam1 frame0 - cam0 frame0: 1
skipped frames cam0: 0 cam1: 0

Pixels

hit pixels

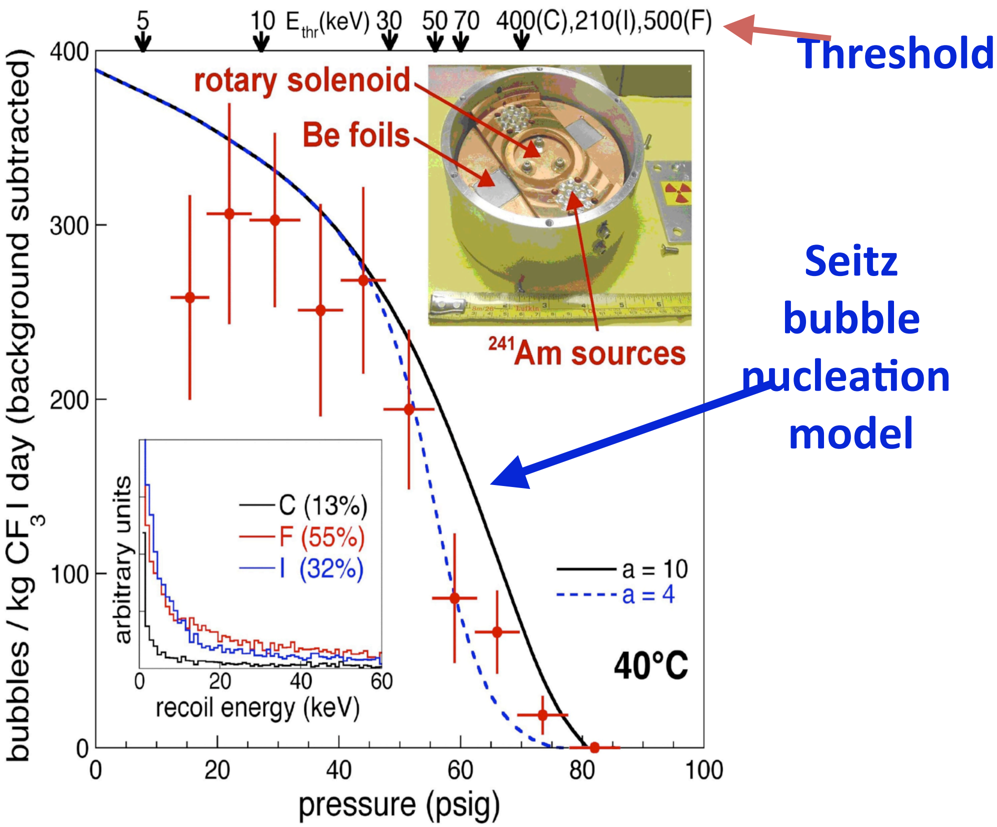
	0	1	2	3	4	5	6	7	8	9
cam0:	3	1	3	0	2	47	239	454	710	982
cam1:	1	2	1	1	1	36	215	394	624	854

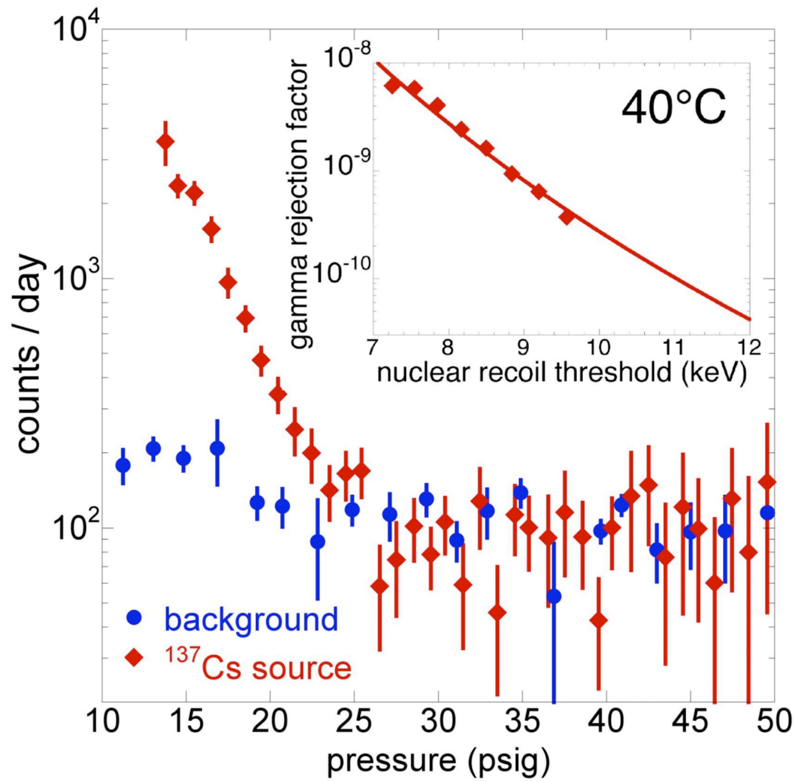
Misc.

trigger type: 2(video)
run type: 0
hydraulic ram pos [%]: 63.0
pneumatic ram pos [%]: 80.7

Neutron and Gamma Calibrations

• Neutron scattering data (^{241}Am-Be) is well-described by standard Seitz bubble nucleation theory with the assumption of a sharp energy threshold.
• Exposure to high-intensity gamma sources demonstrates insensitivity to beta and gamma backgrounds.

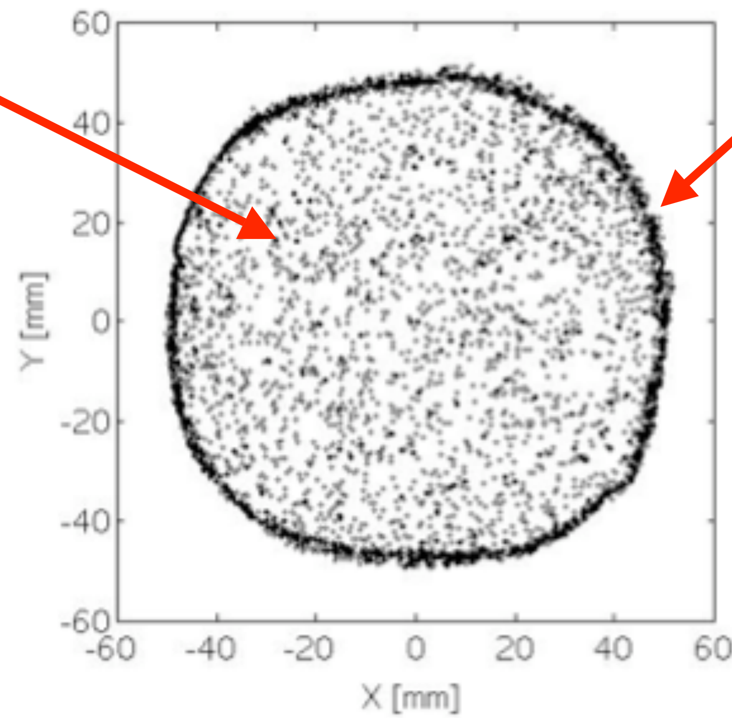




Spatial Distribution of Single Bubbles

Bulk events: indistinguishable from WIMP interactions on an event-by-event basis, but with different integral energy spectra.

~ 20- 100 events/day

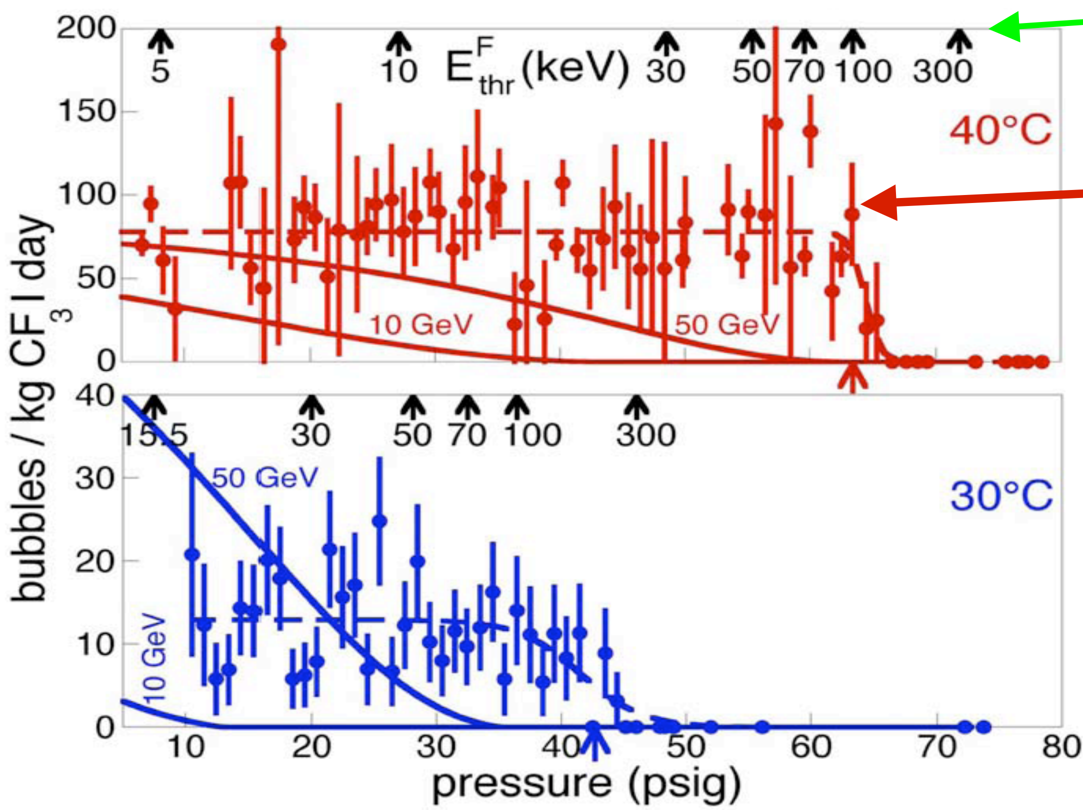


Wall Events: not a background, but they reduce our live time due to the need to decompress afterwards, prohibitive for larger chambers.

~ 300/day in small chamber

Data from 2006 Run

- Data from pressure scan at two temperatures.
- Fit to alphas + WIMPs



Energy Threshold
In KeV

Radon
background

<u>Solid lines:</u>
Expected WIMP

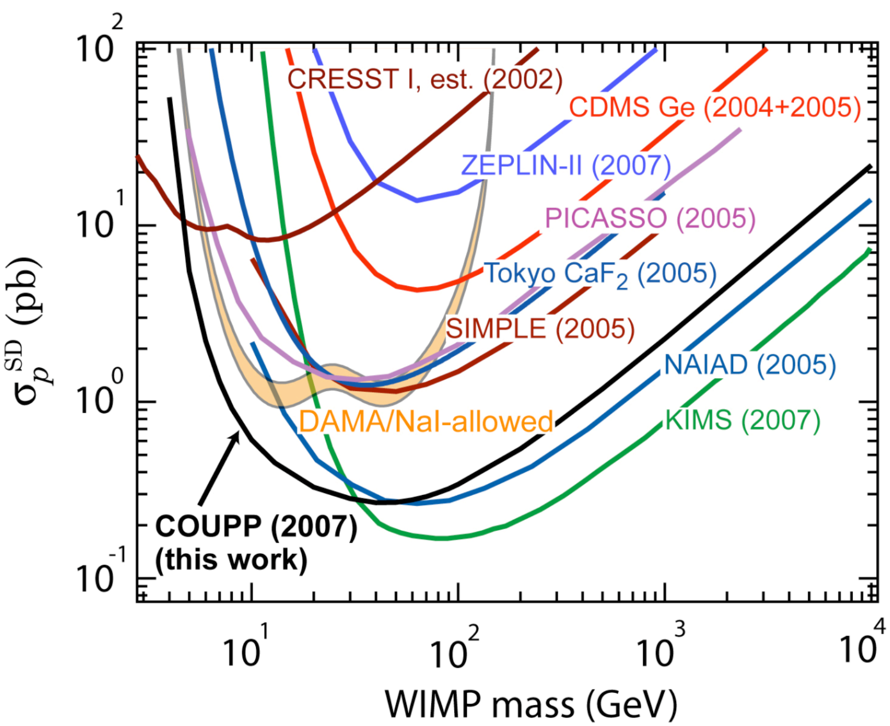
response for

$\sigma^{SD(p)}$=3 pb

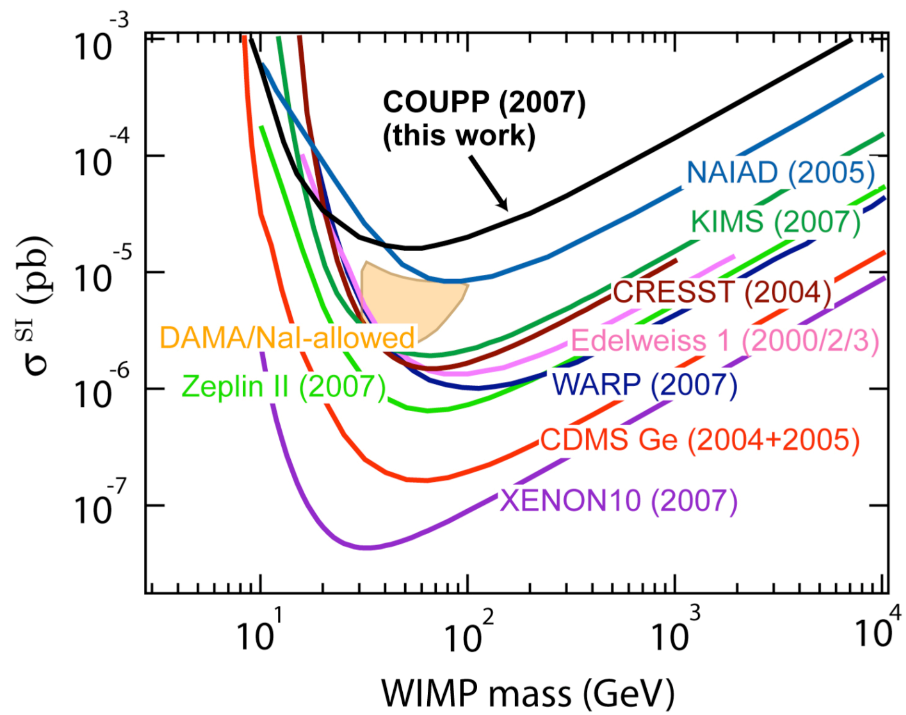
COUPP: First Results

- We have competitive sensitivity for spin-dependent WIMP-proton scattering, despite high radon background in 2005-2007 runs of 2-kg chamber.

Spin-dependent

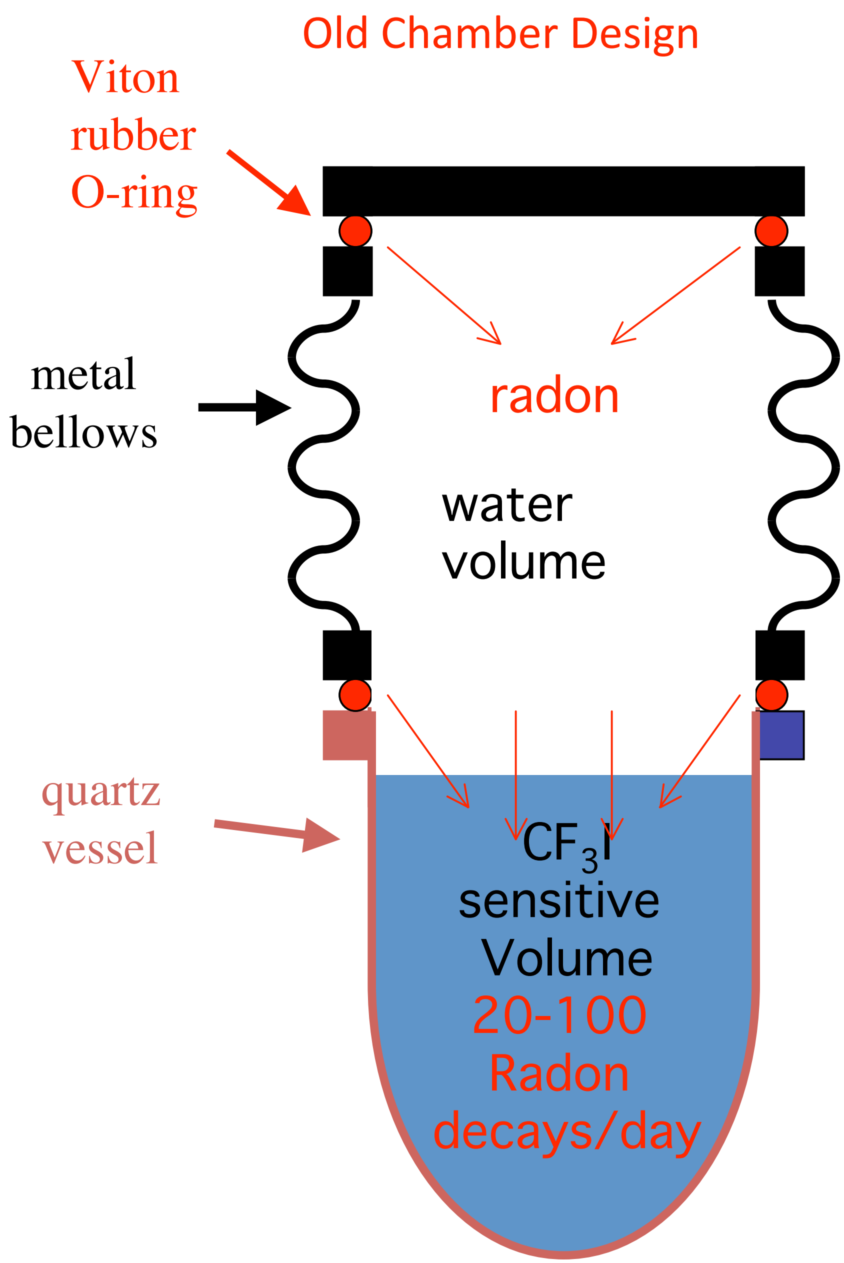


Spin-independent

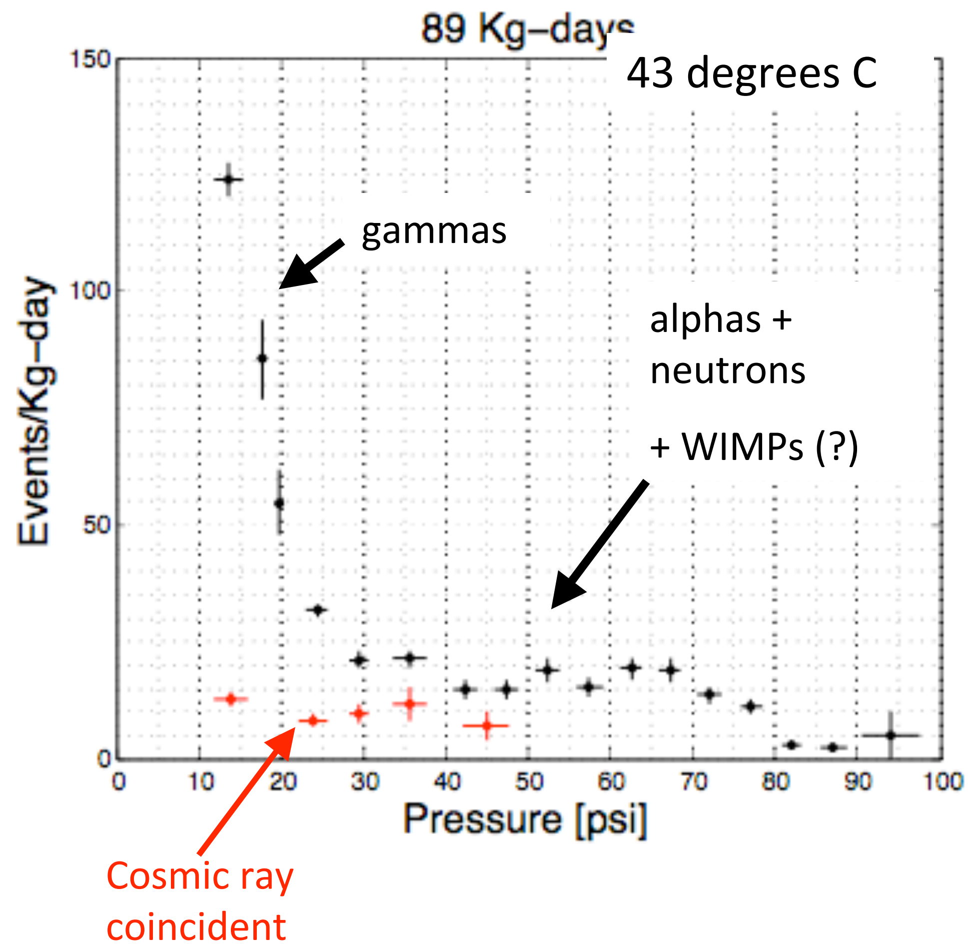


Science, 319: 933-936 (2008).

2-kg Chamber 2008 Data



- Radon greatly reduced by replacement of Viton O-rings with metal seals.
- We begin to see backgrounds from cosmic-ray coincident neutrons



Quartz Purity

- Current rate of wall events (0.8/cm^2-day) can be explained by 42 ppm contamination of quartz by Uranium + daughters (natural GE-214 quartz).
- This causes a ~30% dead time due to compression periods between events in 2-kg chamber; would be prohibitive for larger detectors.
- Our newer small detectors and the 60-kg chamber use lower-activity synthetic quartz.

Material	Uranium [ppt]
Natural (GE-214)	42,000 (0.8 /cm^2-day)
Heraeus Suprasil synthetic (20 kg chamber)	21*
Covalent T-6040 synthetic (60 kg chamber)	< 100
Corning synthetic	260*
Dynasil synthetic	226*
Kvartzsteklo synthetic	17*
St. Gobain Spectrosil	< 4.6*

2-kg chamber, Published results

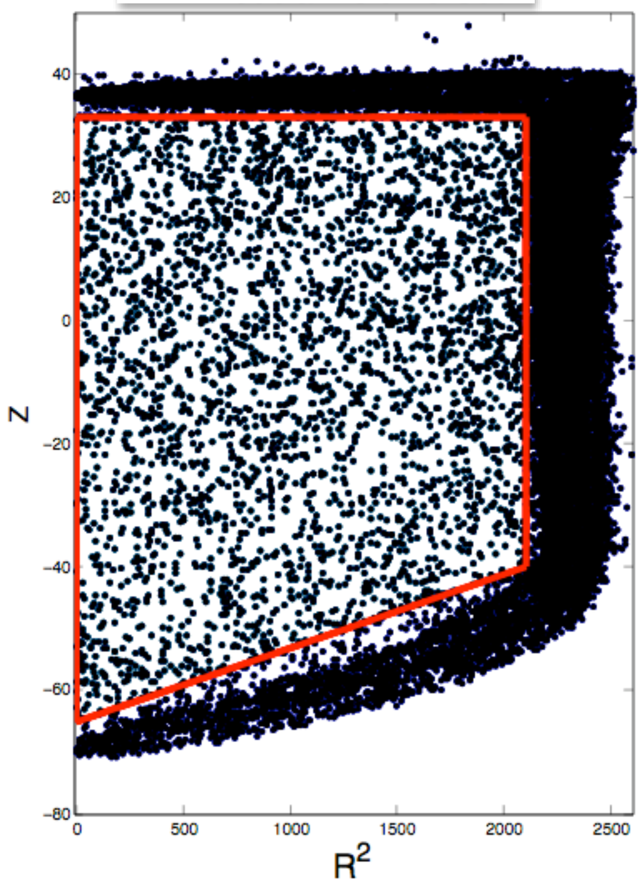
20-kg chamber Tests underway

60-kg chamber inner vessel procured. Available in sizes up to 500 kg

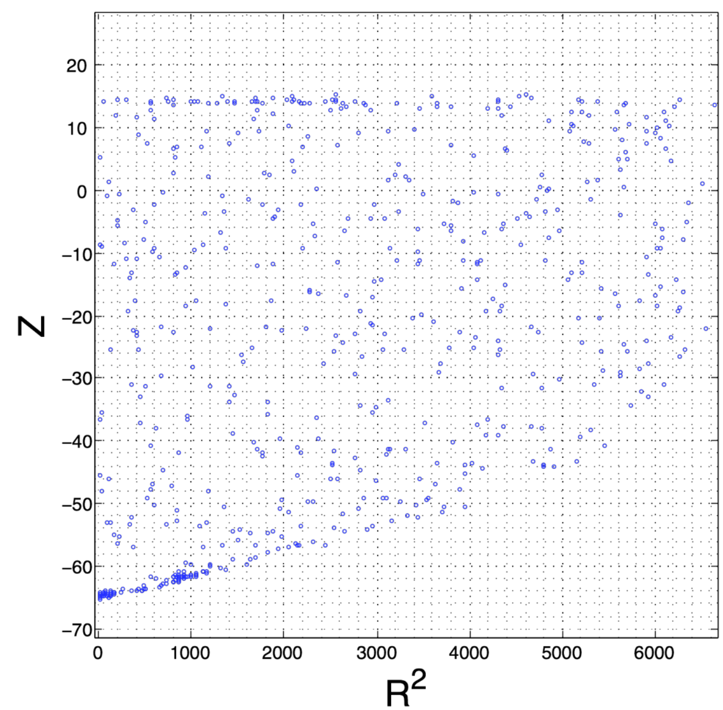
* EXO compilation of quartz activity measurements [Arxiv 0709.4524.v1]

High Purity Quartz (Fused Slica) Eliminates Wall Events

GE-214 Quartz



Suprasil Synthetic Fused Silica

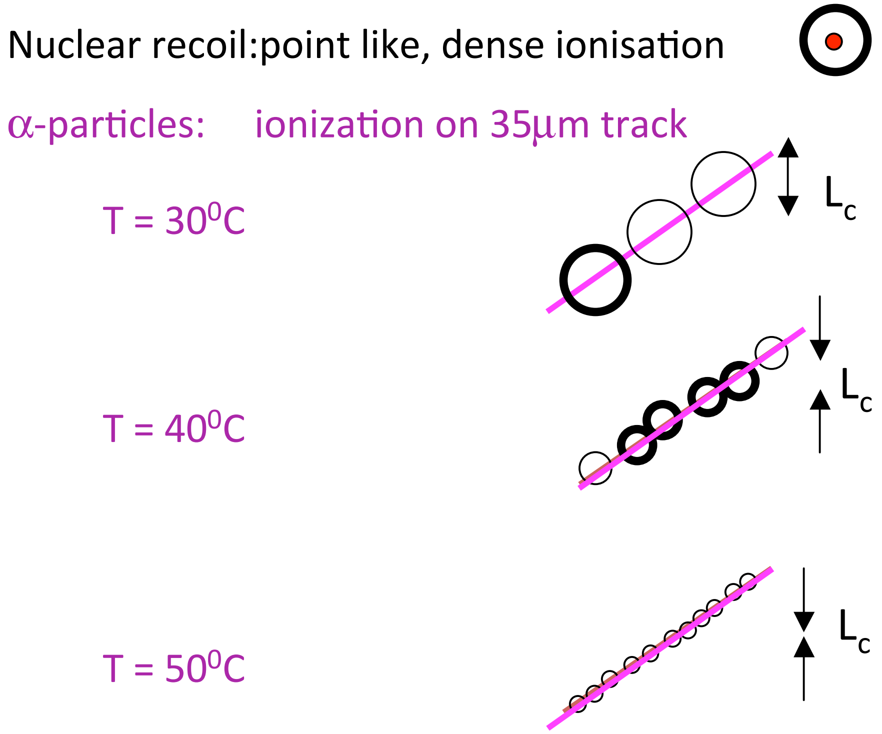


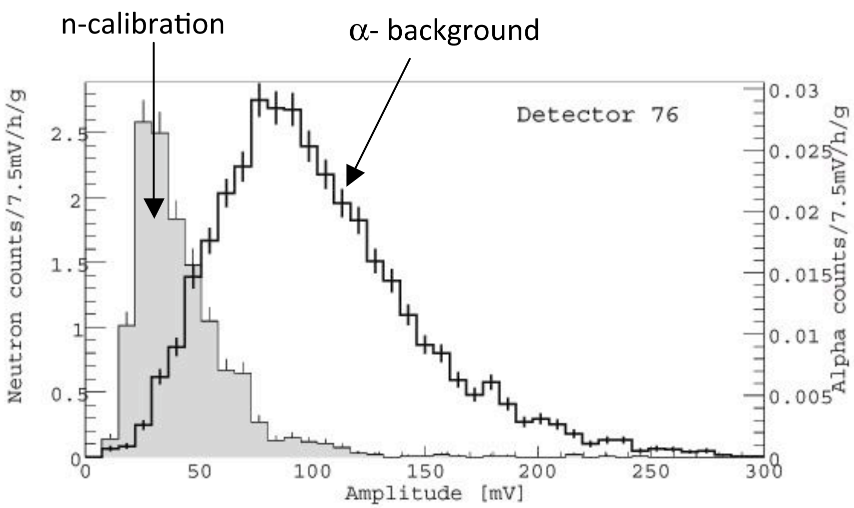
R&D: Acoustic Discrimination of Nuclear Recoils from a Particles

- PICASSO discovered a significant difference between amplitudes of neutron and α-particle induced events! New J. Phys. 10 No 10 (October 2008) 103017 (11pp) arXive: 0807.1536

- Now taking data with COUPP 4-kg chamber to look for this effect.

Signals carry information about first moment of bubble formation





60-Kg Chamber Construction

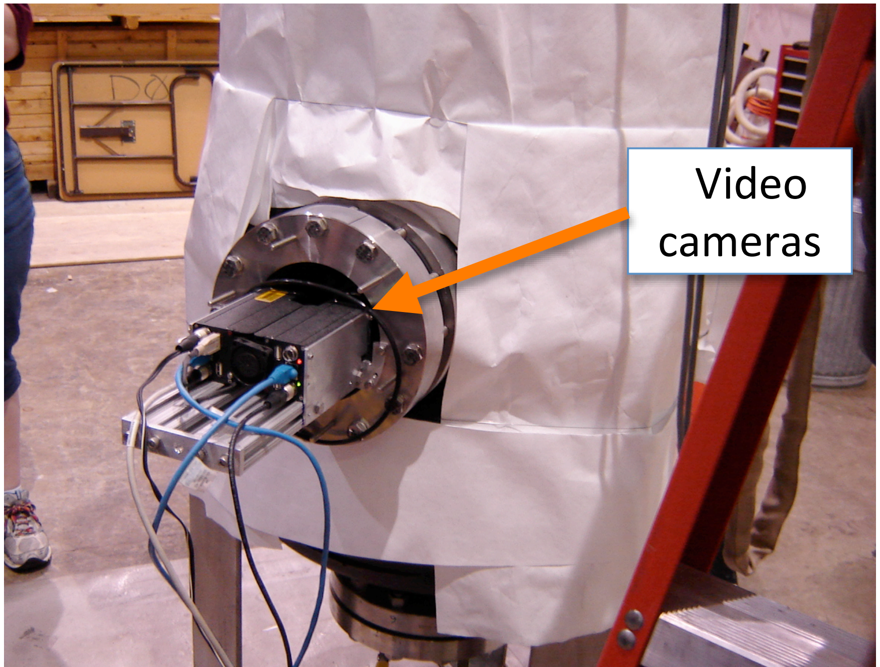
Outer Pressure Vessel

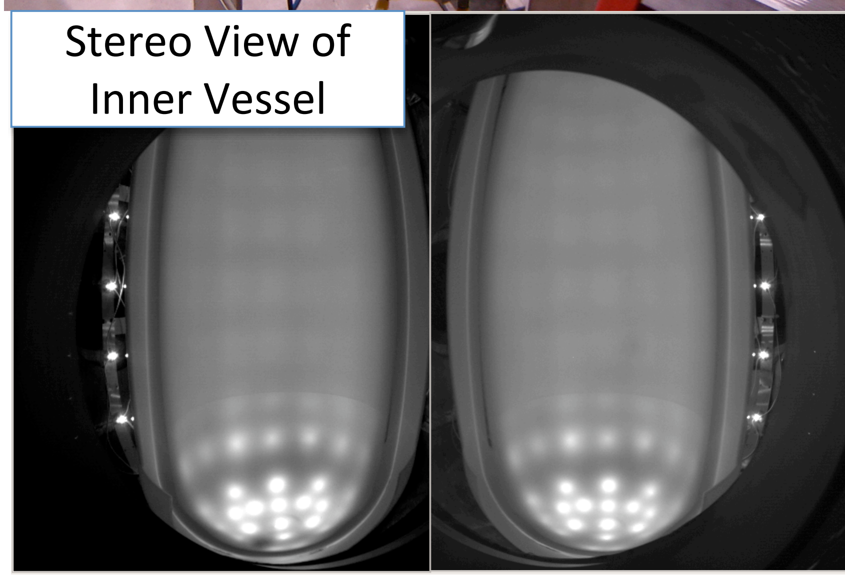
Prototype Inner Vessel

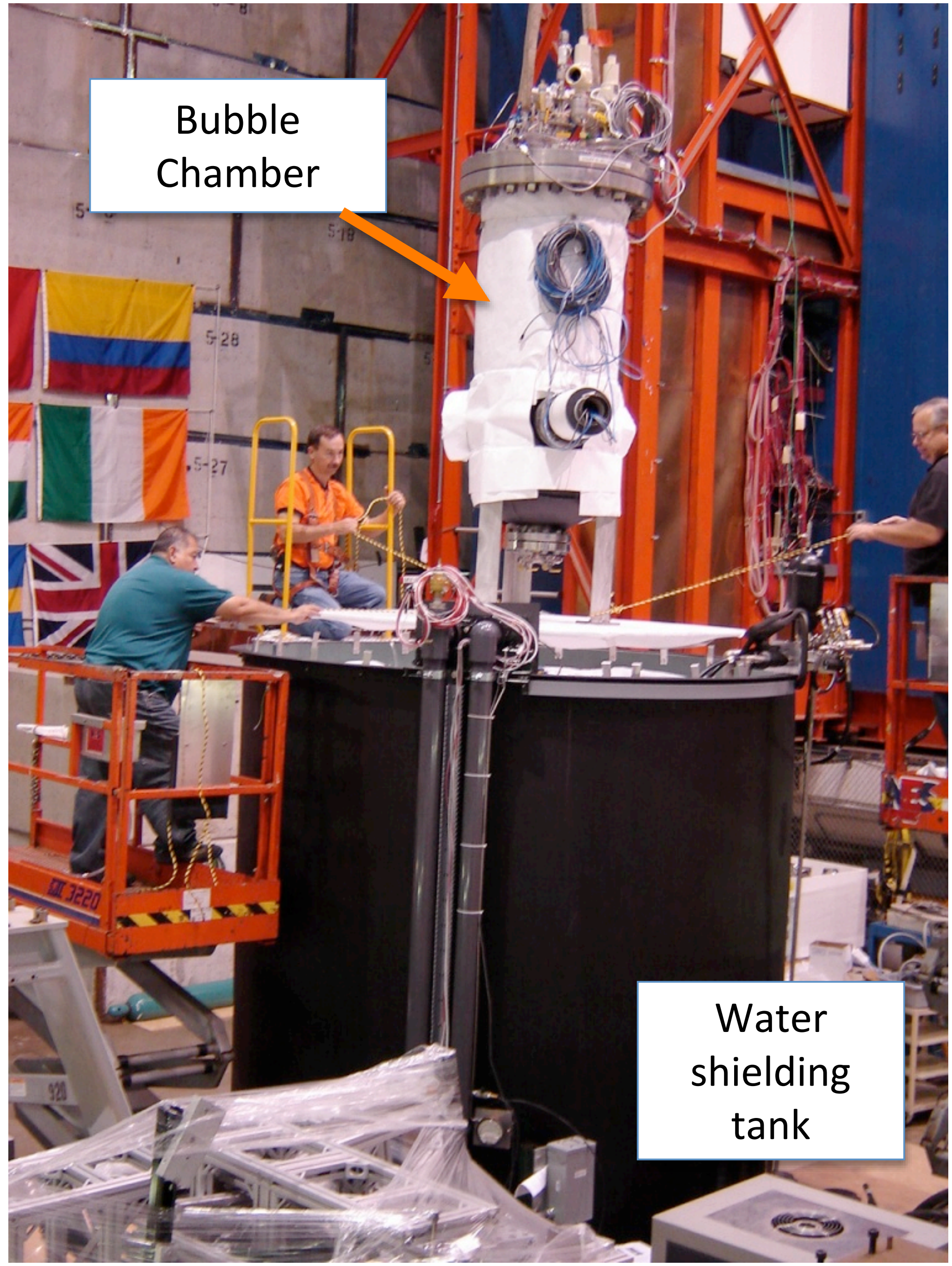
Final electropolished inner vessel top

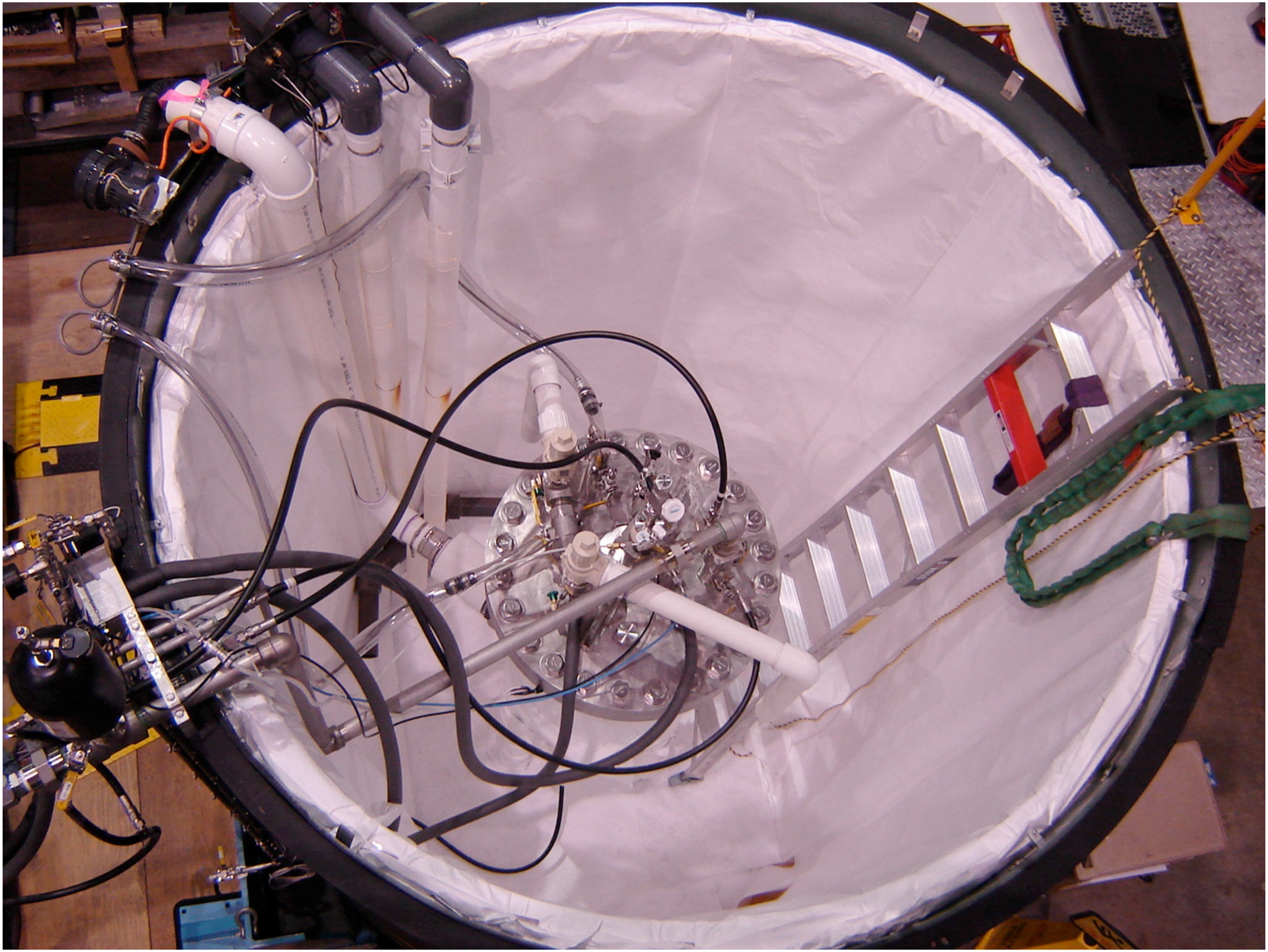
Final fused silica vessel

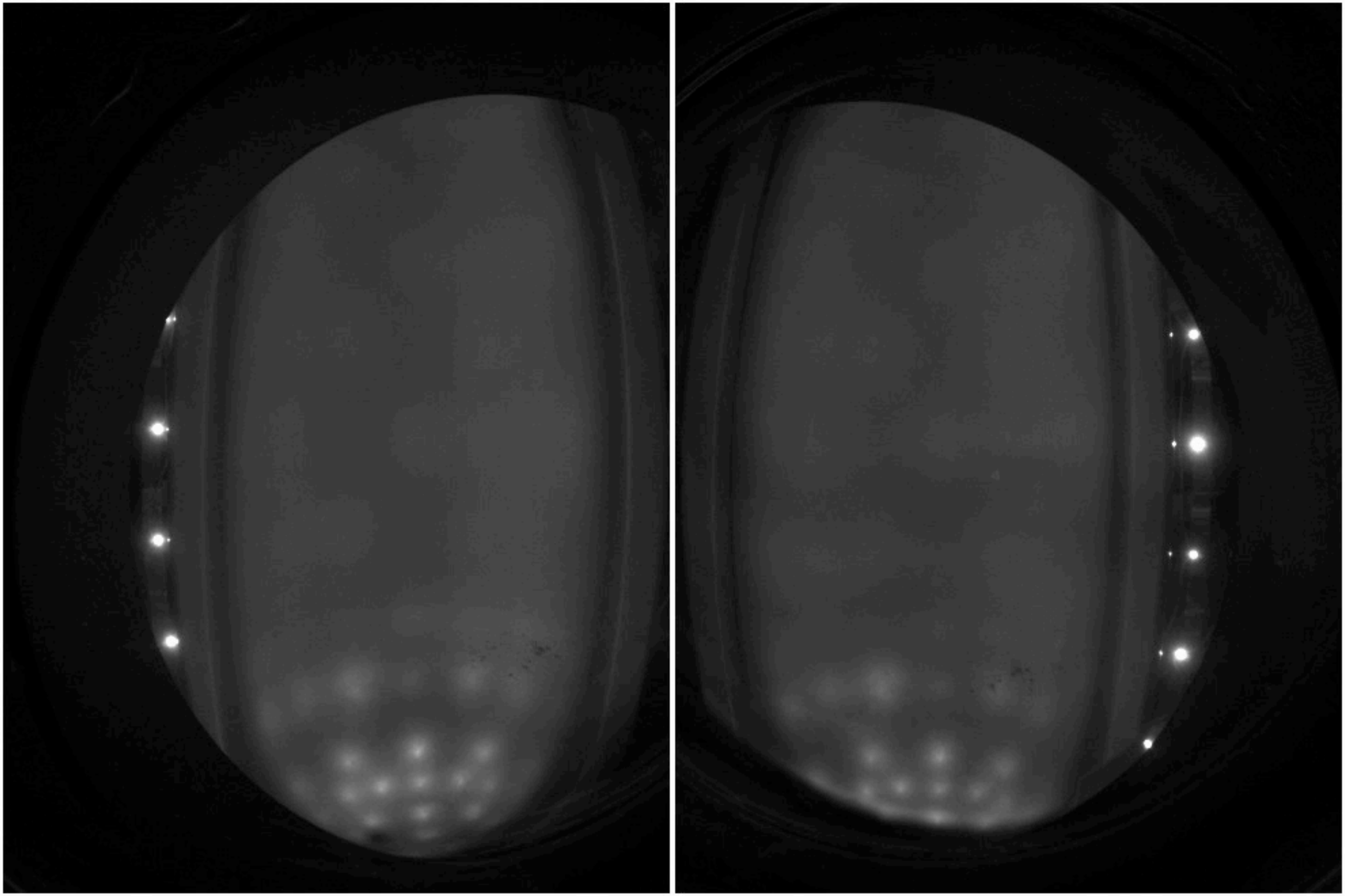
60-kg Chamber Above- Ground Installation, June, 2009











Next Steps for COUPP

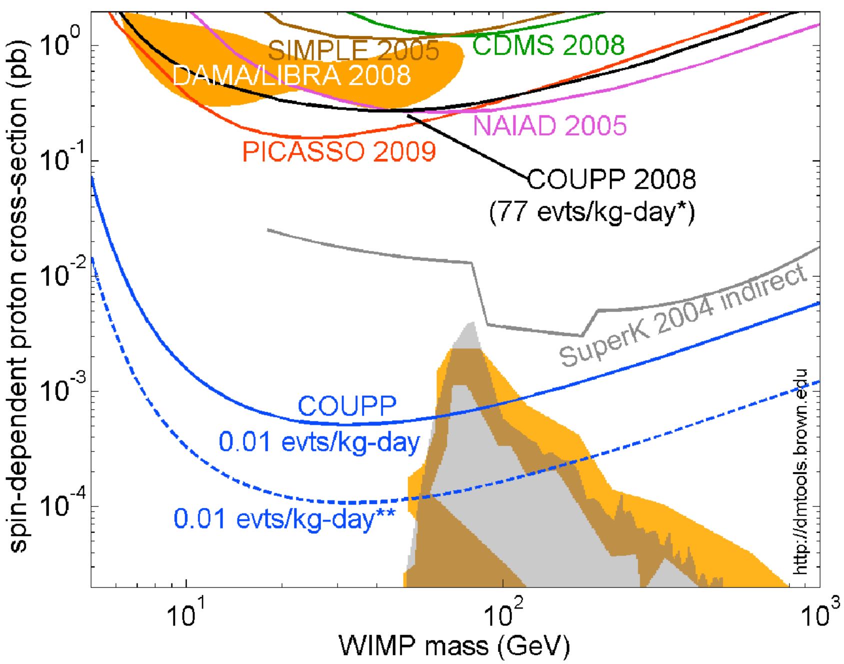
- R&D continuing with small chambers
  - quartz purity, control schemes, photography, acoustic background discrimination?

- 60-kg chamber is ready to turn on.
  - First events seen a few days ago.
  - Commissioning run in shallow Fermilab tunnel in 2010
    - Goal is to bring level of radiopurity up to solar neutrino standards.
      - Borexino ~ 0.01 alpha events/kg-day
    - Sensitivity will be limited by neutron background at level of 0.1/kg-day with water Cerenkov muon veto; 2-3 order of magnitude increase over published sensitivity.
  - Propose to move to Snolab in late 2010

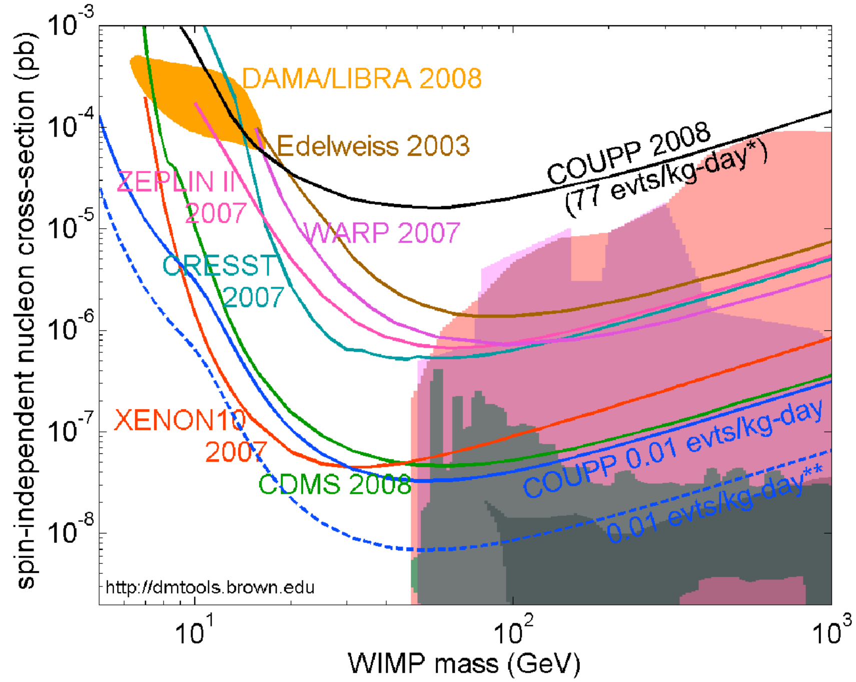
Physics Reach of COUPP-60 at a Deep Underground Site

- Assume alpha background rate reduced to 0.01/kg-day
- Sensitivity shown with and without statistical background subtraction.

Spin- Dependent

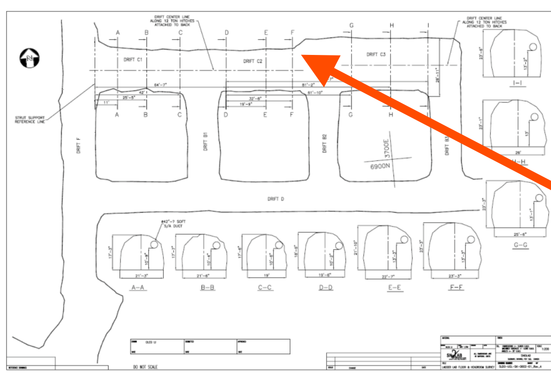


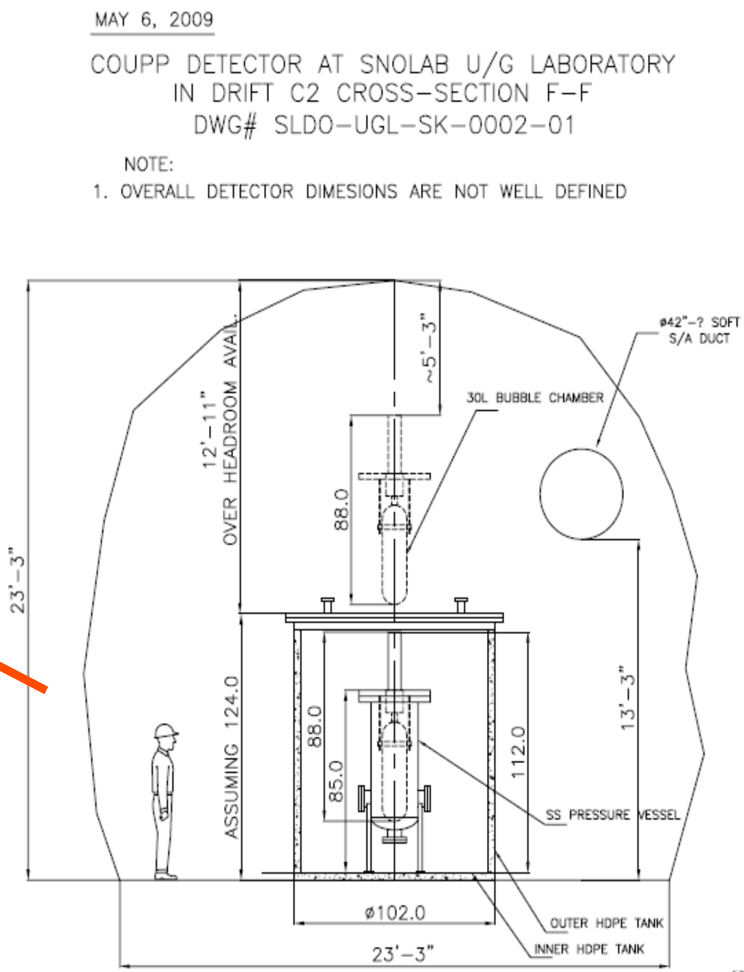
Spin- Independent



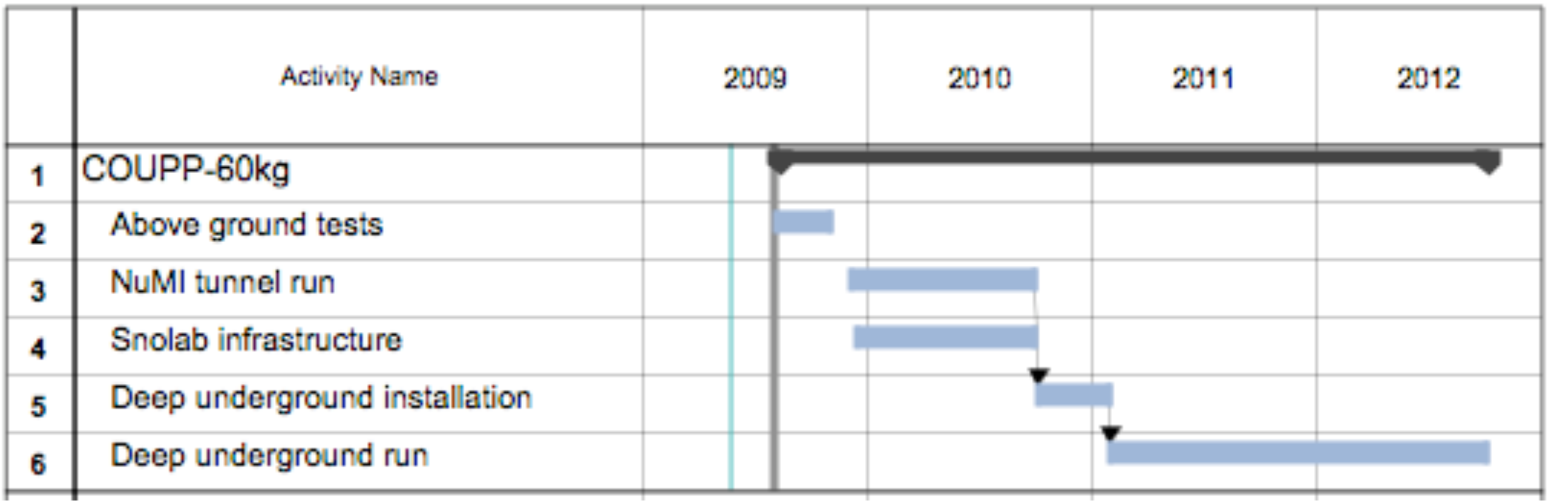
SNOLAB Ladder Lab location

- Consultations with SNOLAB engineering staff have resulted in a possible layout in one of the 'ladder lab' locations.
- Already meets cleanliness specs.
- Pure water is available for filling tank.
- Utilities have not been installed yet.
- No existing crane.
- Fire alarms needed.





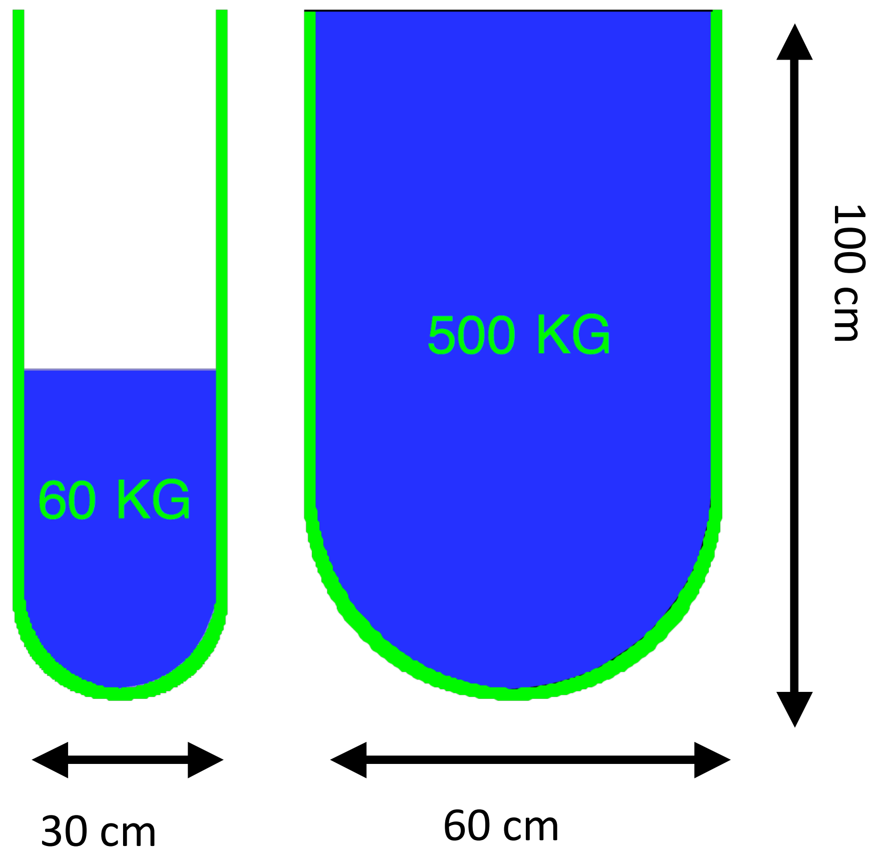
SNOLAB Deployment Schedule



- Was proposed to Snolab in August 2009.
- Proposal will go to Fermilab PAC in November.
- SNOLAB infrastructure will be built up in parallel with NuMI run of 60-Kg chamber.
- Installation schedule will be driven by what we discover in NuMI run. Could be done in late FY10/ early FY11

COUPP-500: One Module of DUSEL Experiment

- Synthetic quartz bell jar is the component that limits the possible size.
- Due to ultra low radioactivity requirement, no known alternative materials (though one could imagine alternative long-term solutions that would require R&D)
- Largest synthetic quartz jar that we know can be manufactured would allow ~500 kg of CF_3I



S4 Objectives

- Develop low-noise, high-sensitivity submersible piezoelectric transducers capable of providing acoustic discrimination between nucleations induced by nuclear recoils and alpha backgrounds, as well as the necessary analysis techniques

- Study the feasibility of building synthetic silica vessels large enough for the envisioned chamber volume by fusing two elements, as described in the proposal.

- Perform engineering studies of the support structures and structural design necessary to ensure the stability during transportation (empty) and operation of a large synthetic quartz vessel.

- Design of a water shield for a 500 kg chamber.

- Design of the safety, fluid recovery and fluid purification (distillation) systems necessary for the successful operation of a 500 kg device.