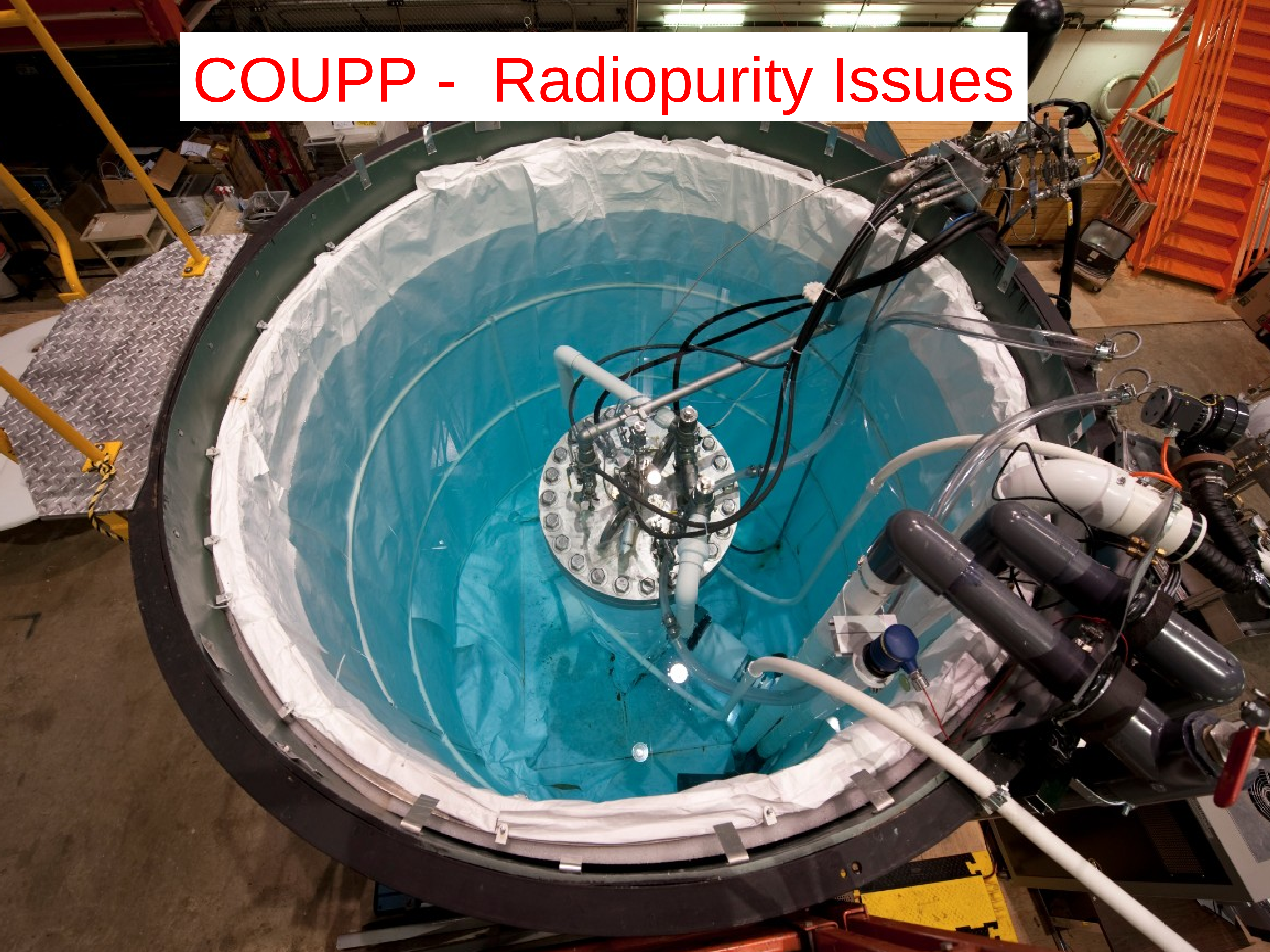
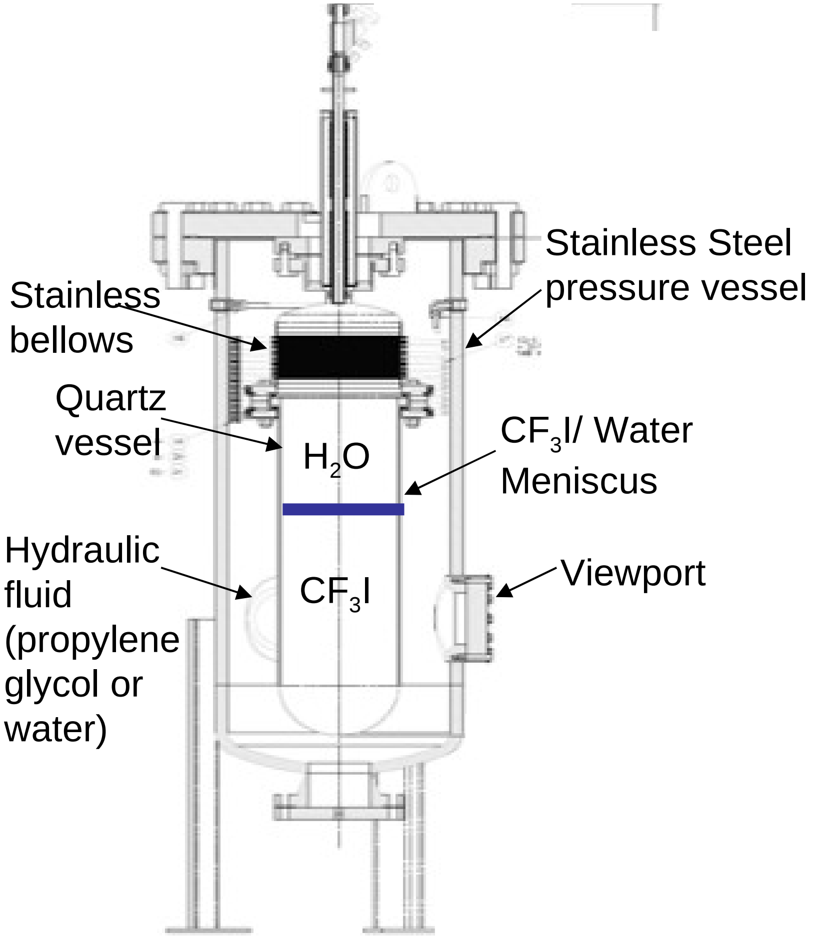
COUPP - Radiopurity Issues



COUPP Chamber Construction

- Dimensions will change, but we expect future chambers be built much like COUPP-60:

Inner/Outer Vessel Assembly



Inner Vessel

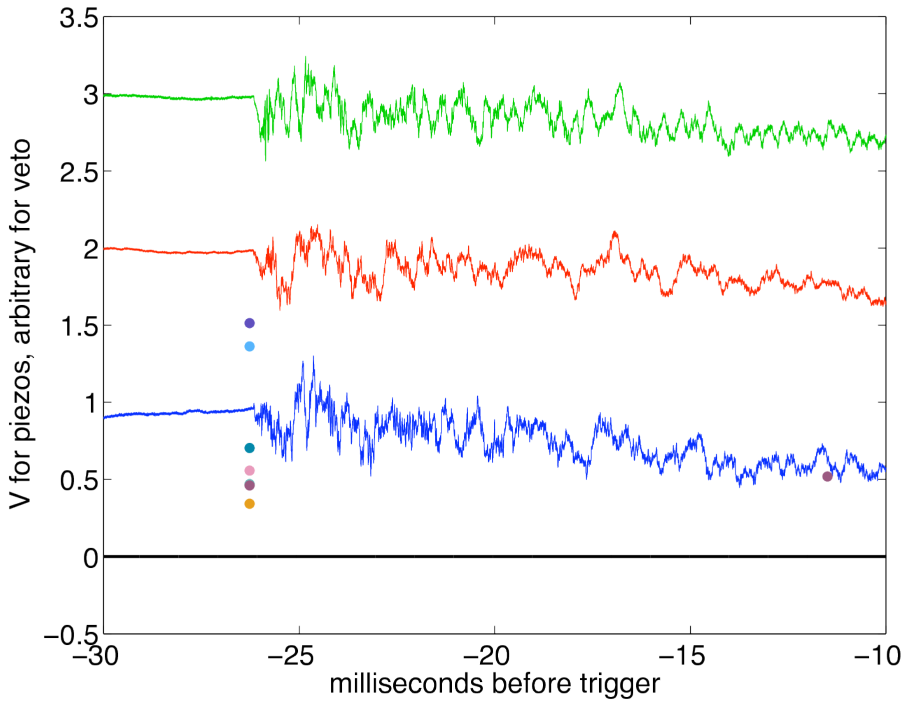
E-961 progress: 60kg chamber construction

General Considerations

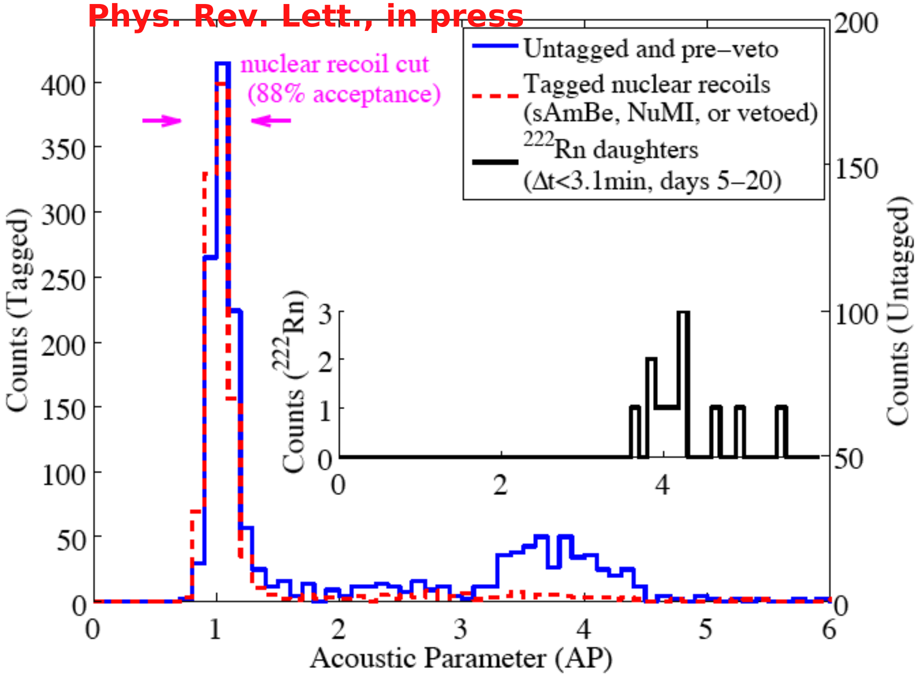
- Gamma/Beta: Since chamber is insensitive to electron recoils with a discrimination factor $<10^{-10}$, we are very tolerant of most common activities in construction materials. Requirements for future chambers will be modest.
- Alpha: Very sensitive to alpha activity of the liquids in the inner vessel and the surface alpha activity of the quartz vessel.
  - An individual WIMP bubble looks like an alpha bubble to video cameras.
  - Threshold scanning allows separation of this background at the cost of additional running time by accumulating an integral energy spectrum.
  - New acoustic discrimination technique can separate alphas from nuclear recoils on event-by-event basis. So far demonstrated only at the 10% level. However, shape of neutron and alpha acoustic distributions hint that acoustic rejection can be very powerful.
- Neutrons: Same issues as other dark matter experiments for the most part.
  - In large chambers, most neutrons multiple scatter and can be rejected by requiring no hits outside a fiducial volume.
  - We will need to pay attention to fission and (alpha,n) in construction materials to avoid necessity of deep fiducial volume cuts.

E-961 progress: acoustic alpha - nuclear recoil

Neutron discrimination



Phys. Rev. Lett., in press



We observe two distinct families of single bubble bulk events in a 4 kg chamber:

- Discrimination increases with frequency, as expected.
- We have a handle on which is which (Rn time-correlated pairs following injection, S-AmBe calibrations, NUMI-beam events).
- Polishing off the method, but potential for high discrimination against α's is clear.
- Challenge in obtaining same discrimination in the 60kg device: increasing sensors to 24, also their bandwidth (IUSB group)

A zero-background experiment soon?

Quartz Purity

• We had problems in 2005-2008 with a high rate of events near the quartz vessel walls in our small chamber.

• Low background alpha counting demonstrated that ~ 0.8 alpha/cm^2-day is emitted by natural quartz samples (a.k.a. fused quartz, which comes from melting high purity sands). Gamma counting found 42 ppb ^{238}U equivalent in samples, consistent with alpha rate.

• Synthetic quartz materials (see below) have much lower Uranium activity and we have now (2009-2010) shown that they do not produce measurable surface bubbling.

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*

Vessels possible up to > 2 meters diameter

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

Inner Vessel Fluids

• Radiopurity requirement for fluids in inner vessel (CF_3I and H_2O) is highly dependent on the obtainable level of acoustic alpha rejection.

10^{-14} g/g (10^{-4} discrimination) -> 10^{-17} g/g (10^{-1} discrimination)

• These levels of purity are in the range demonstrated by SNO, Borexino and Kamland for liquid scintillator and water.

• Unfortunately, they are mainly beyond the sensitivity limit of conventional screening devices.

ICPMS useful for water down to 10^{-15} g/g Uranium

NAA or AMS might make some headway on CF_3I with a very serious, dedicated effort but more challenging than liquid scintillator due to presence of iodine.

• Suggestions welcome…

Construction Materials

- Limited number of materials, due to simplicity of detector:

  Water or glycol hydraulic buffer fluid
  Stainless steel
  Fused silica
  Teflon-coated nickel or gold O-rings
  PZT-27 ceramic acoustic sensors

  } Inner vessel

  Glass or quartz pressure vessel windows
  Video cameras
  Other small sensors (temperature, pressure…)

  } Outer vessel– shielded by buffer fluid

- We anticipate need to screen all these materials by Ge spectroscopy at the ~ 1 ppb level for U and Th. Probably a maximum of a few dozen samples over a 2-3 year period.

- A few of the inner vessel materials and the buffer fluid may require higher sensitivity, but still within the established range for Ge counting or ICPMS.

- Sensitivity requirement is relatively modest because, (1) neutron yields are low compared to gamma yields and we are only sensitive to the neutrons, (2) most of the problematic materials are located outside the buffer region, which provides neutron shielding.

Summary

- We do not yet have detailed radiopurity requirements for COUPP at DUSEL or the ~1-ton pre-DUSEL experiment which we have proposed at SNOLAB. More simulation and design work are needed.

- Main radiopurity problem is alpha decay inside inner volume. How hard this will be depends on ultimate reach of acoustic discrimination technique. Unfortunately, conventional screening techniques not much use since we would need to reach beyond 10^{-14} g/g Uranium.

- Radon emanation measurement at the level of ~1 count per day per m^3 of gas would be very useful for screening inner vessel (some work on this by our collaborator Ilan Levine at IUSB).

- Will need to screen a few dozen samples with Ge detectors to make sure that neutron emission from construction materials is within required range. It seems that we are not pushing beyond state-of-the art radiopurities or detection limits with any of these materials and the number of samples will be modest.