

Overview of COUPP Program

Andrew Sonnenschein, April 16, 2010

Charge to Committee

Red items to be addressed in this talk

Scientific and Technical Merit:

1. Will operation at a deep underground site significantly advance the state of the art of bubble chambers for DM searches?
2. Are the proposed science goals significant enough to warrant operation of the 4kg chamber in a deep site, in light of the expected deployment of the 60kg chamber within the next year?
3. What are the conflicts or synergies between operation of the 4kg and 60kg devices?

Technical preparedness:

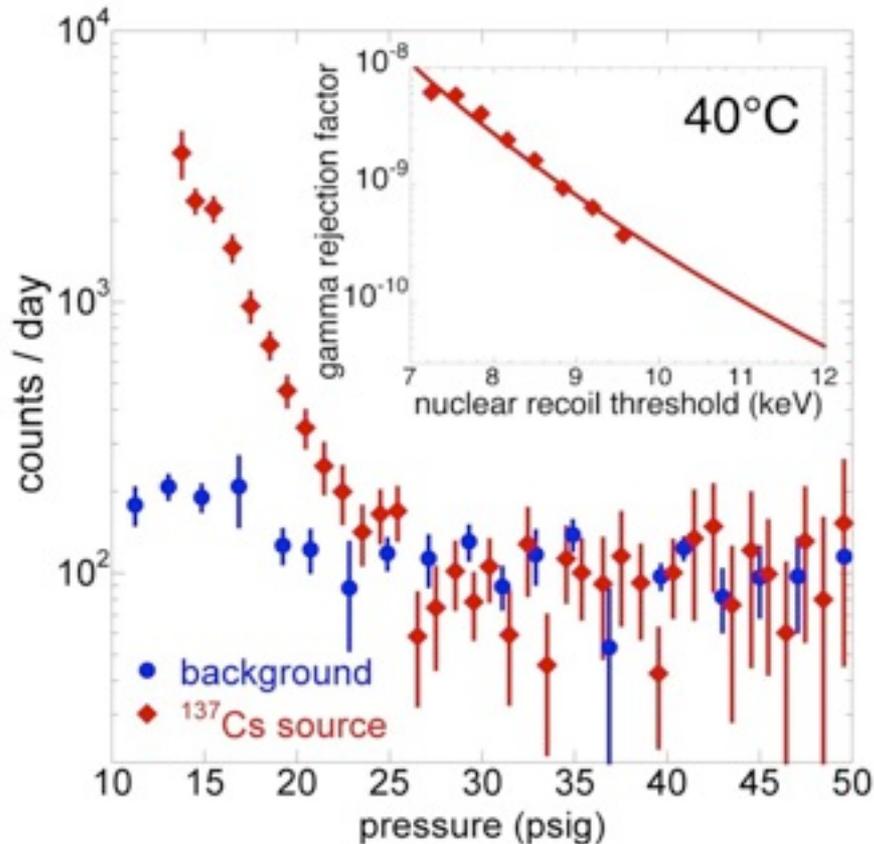
1. Have the controls and DAQ problems encountered in December 2009 been satisfactorily resolved?
2. Is the system robust enough for extended operation in a remote location?

Resource requirements:

1. Does the proposed plan cover all of the steps likely to be required for this deployment?
2. What labor (scientific, engineering and technician) and M&S resources will be needed? Are the estimates reasonable and well justified?
3. Are the resource estimates consistent with past experience with the 4kg chamber?
4. Are there areas that are likely to require contingency beyond the estimates?
5. What is the plan for operating the 4kg chamber at SNOLAB, in light of the need to simultaneously operate the 60 kg chamber in the NUMI tunnel? Evaluate the manpower and travel required to accomplish this.
6. Will work on the 4kg deployment by technicians, engineers or scientists incur any significant delays in commissioning the 60kg chamber in the MINOS underground area?
7. How does COUPP propose to fund this effort?

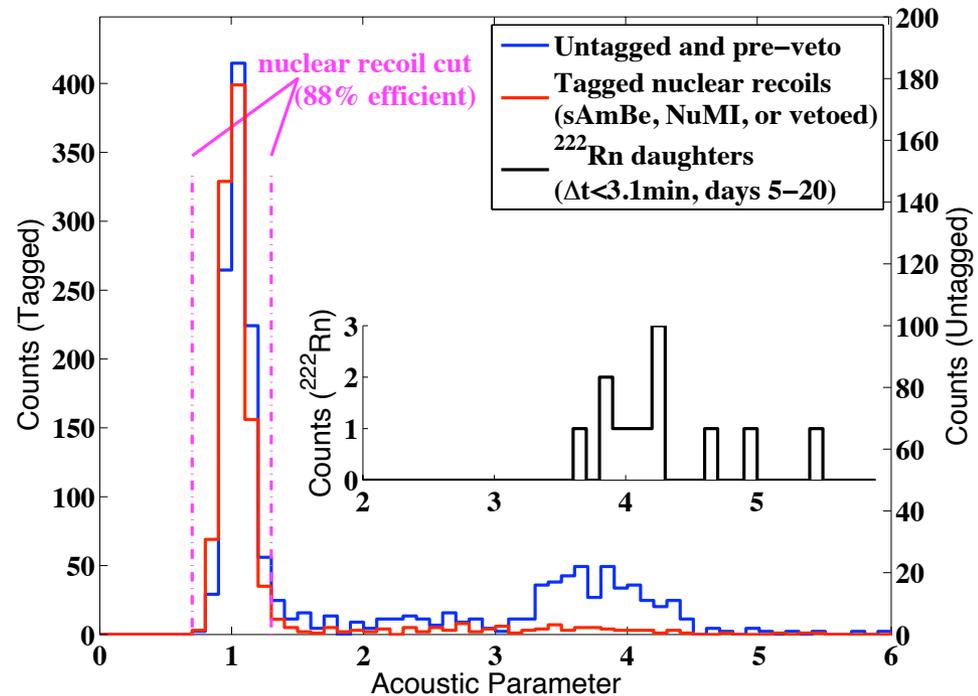
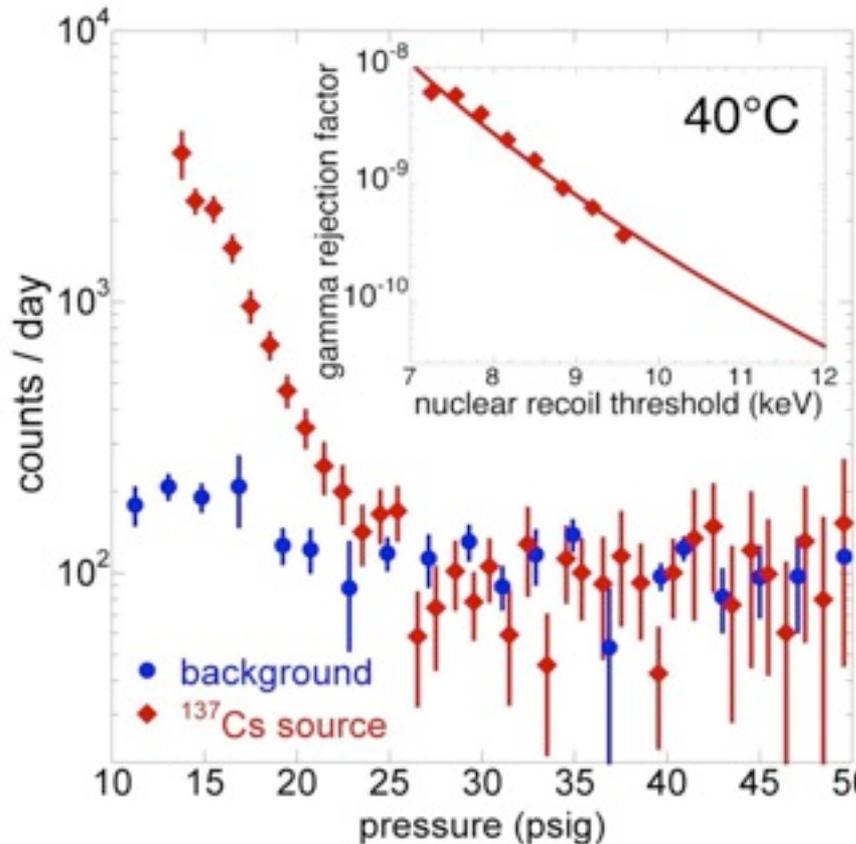
Mission of COUPP

- Exploit remarkable features of bubble nucleation physics to discover dark matter:
 1. Insensitivity to γ and β backgrounds when pressure and temperature are tuned to require high dE/dx .
 2. More acoustic emission from α events than nuclear recoils. ← New



Mission of COUPP

- Exploit remarkable features of bubble nucleation physics to discover dark matter:
 1. Insensitivity to γ and β backgrounds when pressure and temperature are tuned to require high dE/dx .
 2. More acoustic emission from α events than nuclear recoils. ← New



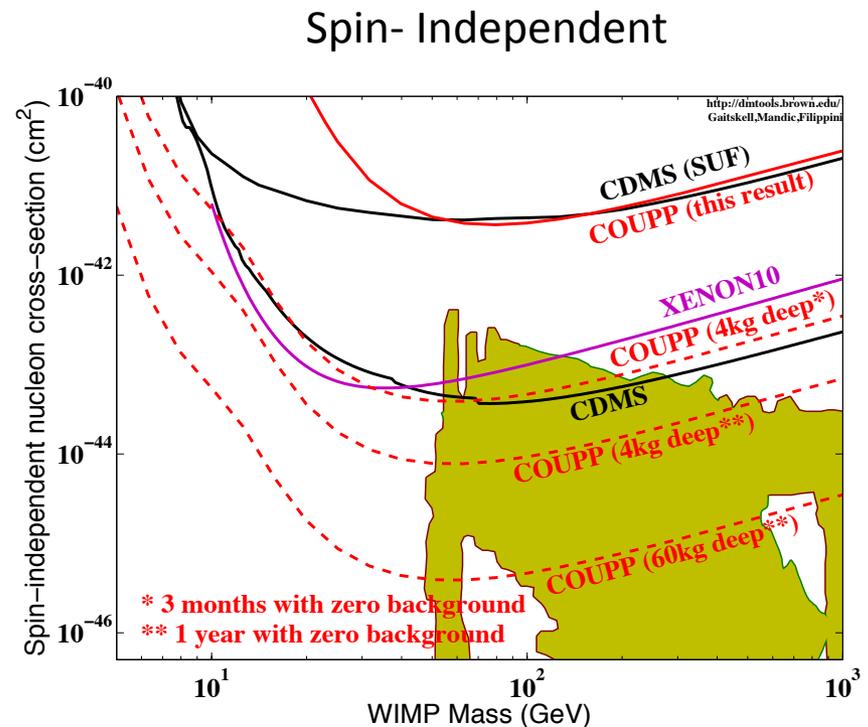
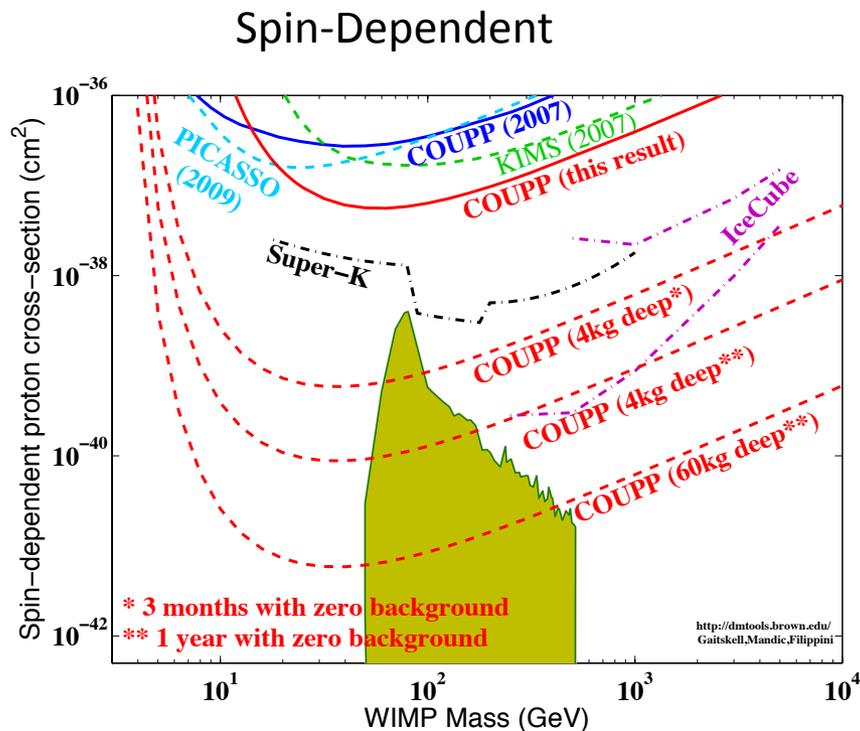
COUPP Timeline

| | 2003 | 2005 | 2007 | 2009 | 2011 |
|--------------------|--|--|---------------------------------------|---|---------------------|
| Mass | 18 grams | 2-Kg | | 4-Kg | 60-Kg |
| Site | UChicago | NuMI Tunnel | | | SNOLAB |
| Depth | 10 m.w.e. | 300 m.w.e. | | | 6000 m.w.e. |
| Backgrounds | 7000 events/kg-day | 77 events/kg-day | 7 events/kg-day | 0.7 events/kg-day 0.1 events/kg-day after acoustic cut | 0.01 events/kg-day? |
| Physics | | World's best spin-dependent sensitivity (W-p) | | Best spin-independent? | |
| Technical | | 10 ⁻¹⁰ gamma rejection | Metal seals Radon eliminated | Acoustic background discrimination Fused silica inner vessel Wall events eliminated High purity fluid handling system | |
| | Nearly continuously sensitive bubble chamber | Pressure balancing of inner/outer vessel | | Retroreflective illumination, small angle stereo | |
| | | Hydraulic pressure control | w/ automatic temperature compensation | | |

- Active mass increased by factor of ~3,000 since first bubble chamber in 2003.
- Backgrounds decreased by factor of ~10,000

We've Become Much More Ambitious

- If alpha rejection power is as high as we think, the COUPP technique is likely to yield the best sensitivity to both spin-dependent and spin-independent channels, possibly even within the next year.
- To compete with CDMS/ Xenon-100, we need alpha rejection in the range 10^{-2} - 10^{-4} , depending on how much improvement we get in radiopurity (10^{-4} for no improvement beyond current level of 1/kg-day)



The Need for Alpha/ Neutron Calibrations With COUPP-4 at Snolab

- We now suspect that COUPP has the best experimental technique for **both spin-independent and spin-dependent** WIMP dark matter searches.
- BUT..... We can't prove it yet. We have measured the alpha rejection factor only at the 10% level.
 - It needs to be in the range $10^{-2} - 10^{-4}$ for us to compete with next generation spin-independent experiments.
 - A measurement of alpha rejection at the level of 10^{-4} in COUPP-4, combined with good radiopurity results from COUPP-60 (0.01 alphas / kg-day) would motivate construction of ~10 Ton chamber arrays at DUSEL, as we have proposed to the NSF
- To prove our case, we need a **high statistics alpha sample** in an environment with **minimal neutron background** to demonstrate high alpha rejection efficiency.
- *The measurements can not be done with the 60-kg while simultaneously using that detector to search for dark matter*
 - *Need high statistics runs at different pressures and temperatures*
 - *Avoid contamination of the COUPP-60 detector with alpha sources.*

Deep Site Deployment Plan 4kg

- Mike's talk has details on this.
- *Deploy* the COUPP-4 chamber to SNO Lab
 - Repairs & Improvements complete April 2010
 - Re-commissioning tests in Lab F May 2010
 - Ship out June 2010
 - Data taking for “background studies” July-Sept 2010
 - ~300 kg days nominal
 - Competitive with CDMS/ Xenon-100 if alpha discrimination is high.
 - Data taking with alpha source will commence when COUPP-60 arrives

Deep Site Deployment Plan 60 kg

- COUPP-60 goals for commissioning in NuMI Area. As discussed in our Field Work Proposal:
 - *Demonstrate* stable robust operations
 - *Confirm* α -contamination less than 1 α -recoil/kg/day
- Move to Snolab scheduled for fall 2010.
 - Proposals to do this were considered and approved by Snolab and Fermilab directorates in November.
 - Snolab is responsible for shielding and other infrastructure. Long lead-time items have been designed and ordered.
 - New DOE Field Work Proposal will be required for Fermilab part of funding (\sim 300 k\$).

COUPP-60 Progress

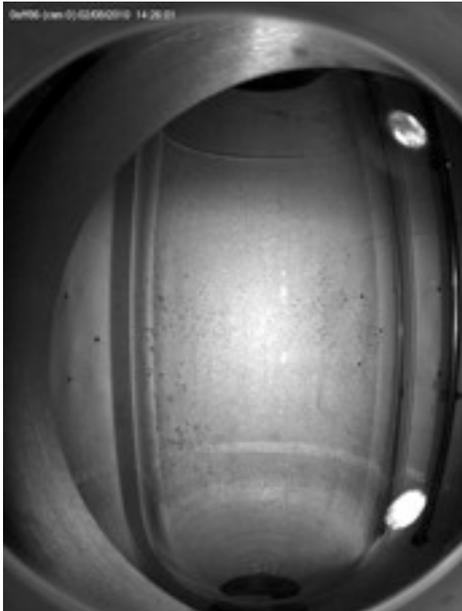
High Purity Inner Vessel Assembly (1/29/10)



Insertion into Outer Vessel 3/23/10



New
Illumination
System Test,
(2/8/10)



Move to NuMI Tunnel (3/29)



Fluid Handling Cart Leaving Cleanroom (4/2)



COUPP-60 Status

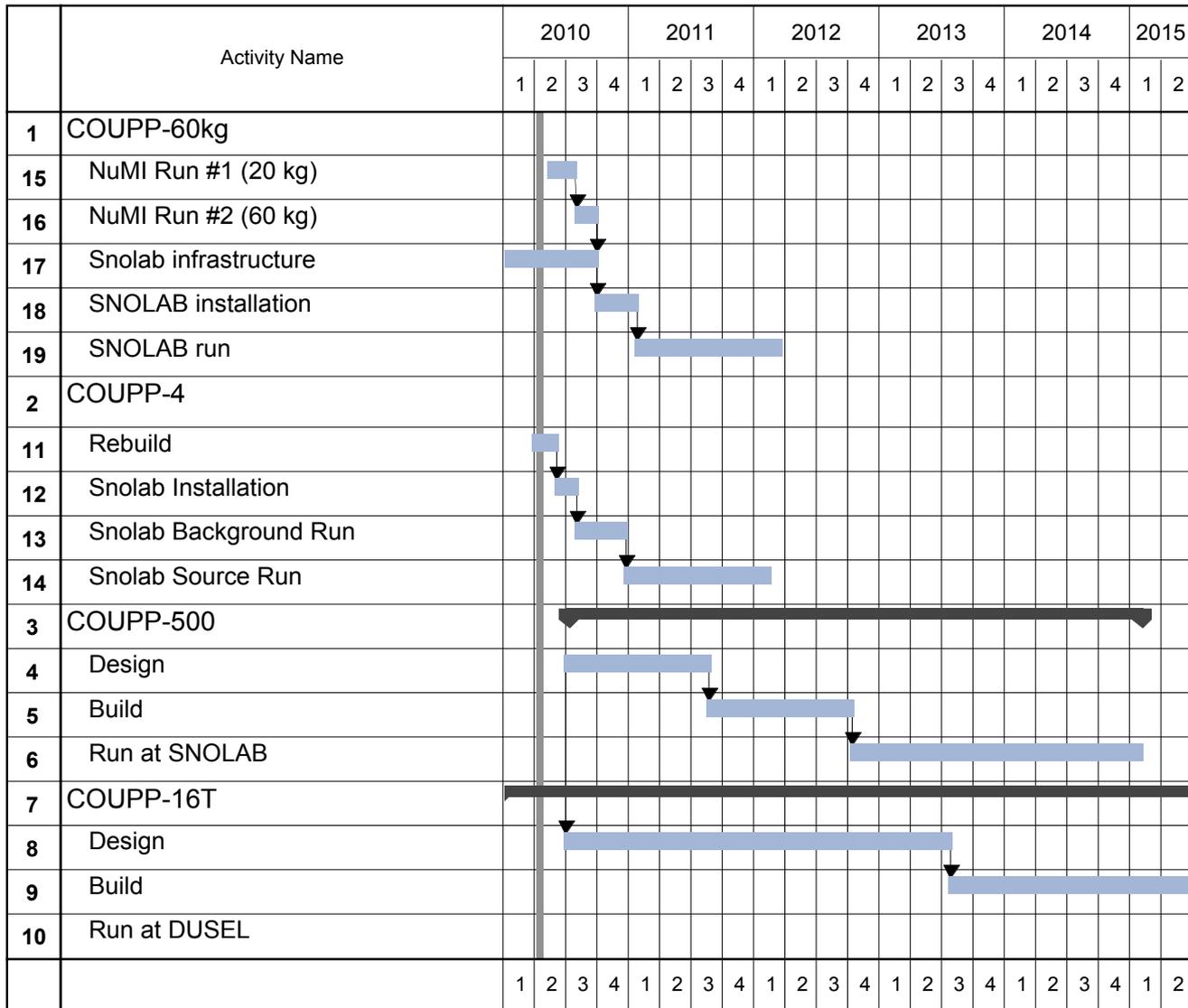
- Replacement of illumination system -- Finished
- Construction of High Purity Inner Vessel– Finished
- Acoustic sensor array – Finished
- Assembly of Inner Vessel into Outer Vessel – Finished
- Fluid Handling Cart– Finished

- Installation at NuMI – In progress

- First data at NuMI– Scheduled for mid- May

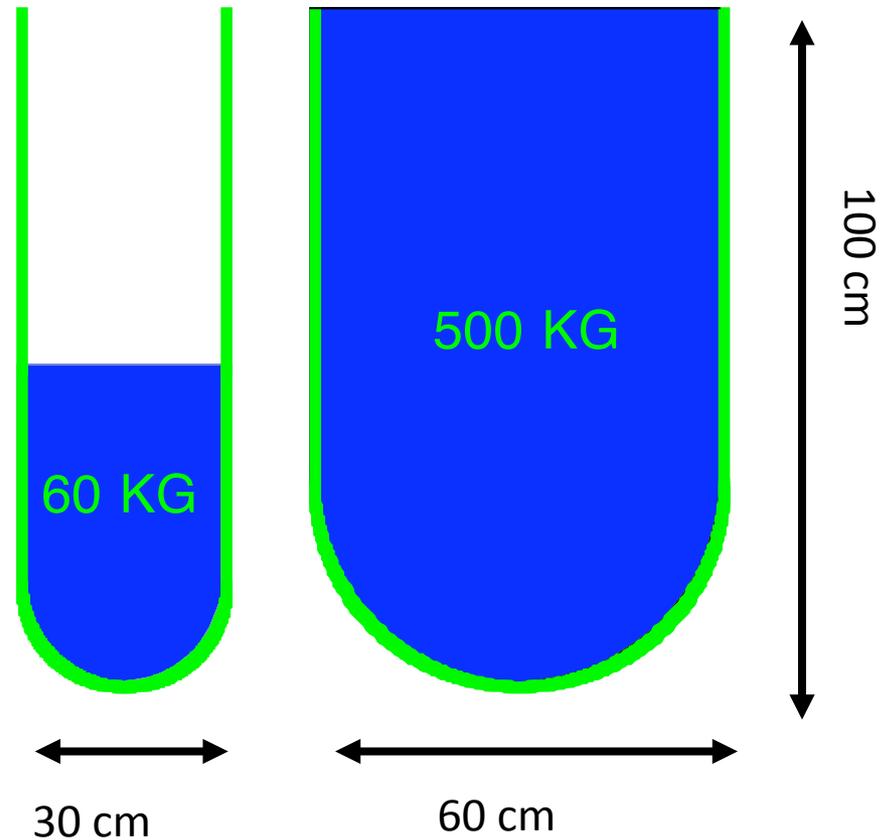
Detailed schedule information is included in extra slides at the end of this talk.

COUPP 5- Year Plan



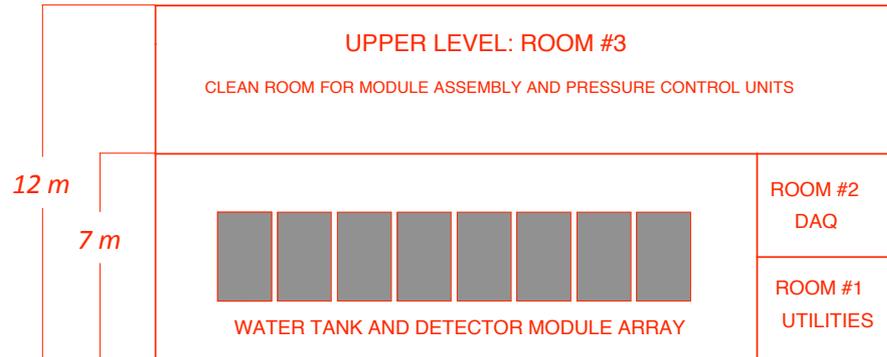
COUPP-500 Concept

- Synthetic quartz bell jar is the component that limits the possible size. Largest synthetic quartz jar that we know can be manufactured would allow 500 kg of CF_3I .
- NSF DUSEL S4 grant to U. Chicago for R&D on COUPP-500 was funded last year (1.7 M \$). This includes work on acoustic background discrimination.
- We expect to request engineering resources towards design of COUPP-500 soon.



Concept for 16 Ton Array of COUPP-500

ELEVATION VIEW

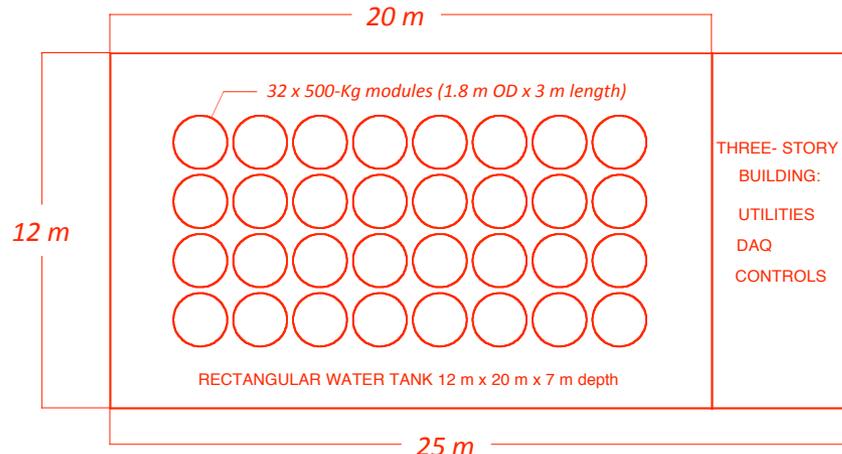


Requires 10^{-4} acoustic alpha Discrimination and State-of-the-art radiopurity 0.01 events/kg-day

Has been proposed for DUSEL initial suite of experiments.

Begin module construction at start of DUSEL funding in 2013?

PLAN VIEW



No Interference Between COUPP-4, COUPP-60

- Engineers and technicians— COUPP-60 effort falling to zero, absent major unexpected problems (currently 1/2 engineer + 1/2 technician). In any case, the work needed for COUPP-4 will be done by different people.
- Physicists— we have enough scientists and postdocs to cover both activities. Physicist manpower on COUPP has approximately doubled in the last year (adding Brice, Hall, Dahl) and continues to increase sharply with new postdoc hires at Fermilab and Chicago.
- Funding, budget— To be addressed in Mike's talk
- Logistics— COUPP-60 installation at Snolab will benefit from early experience of what it takes to install COUPP-4.

- Every small chamber run so far has taught us valuable lessons about the physics and technical characteristics of our detectors, which have been essential for the planning of COUPP-60. Surely this will be the case for the initial run at Snolab.

Strategy

At any given time, we should have:

- A detector operating and producing competitive physics results
- A next-generation detector under construction

COUPP60 -> COUPP500.

- The development of a plan for the next-next detector.

COUPP16T

- Small devices running to answer important R&D questions. At the moment, high priority questions are:

- Understand the tails of acoustic amplitude distributions for alpha and neutrons

— COUPP4 at SNOLAB

- Understand the properties (amplitude, spectral content) the “bare” acoustic signatures. *Acoustic test stand*
- *Understand* the propagation and detection of acoustic signals (scale to larger chambers...). *Acoustic test stand*
- *Confirm* our understanding of our recoil energy threshold. *Beam test device.*

Conclusion

- 4-kg deployment makes sense
- No interference with 60
 - In fact, expect it to identify/solve problems for COUPP-60 deployment
- Likely that we will get a great physics result.
- Long term purpose is R&D on acoustic discrimination
- Will enable future program COUPP-500/16T

Extra Slides

| Activity Name | Duration (Work Days) | Start Date | Finish Date | Resources Assigned | 2010 | | | | |
|---|----------------------|----------------|----------------|----------------------------|------|-----|-----|-----|----|
| | | | | | Jan | Feb | Mar | Apr | Ma |
| Camera and Illumination System | 35.00 | 1/11/10 | 2/26/10 | | | | | | |
| Scotchlite Coating of Vessel | 17.00 | 1/11/10 | 2/2/10 | Simon | | | | | |
| Modification of Camera Mount | 5.00 | 1/22/10 | 1/28/10 | Simon | | | | | |
| Set up vessel for calibrations | 4.00 | 1/29/10 | 2/3/10 | Simon | | | | | |
| Calibration Fixtures | 5.00 | 1/11/10 | 1/15/10 | Flores | | | | | |
| Calibration lid | 10.00 | 1/22/10 | 2/4/10 | Hardin, Machinist, M&S | | | | | |
| Install New Lenses for Cameras and Fibers | 4.00 | 2/4/10 | 2/9/10 | Simon, Sonnenschein | | | | | |
| Test Photos of calibration vessel | 5.00 | 2/10/10 | 2/16/10 | Simon, Brice, Sonnenschein | | | | | |
| Calibration photos | 5.00 | 2/17/10 | 2/23/10 | Simon, Brice, Sonnenschein | | | | | |
| Acoustic sensors test photos | 3.00 | 2/24/10 | 2/26/10 | Simon, Sonnenschein | | | | | |
| Light box mounting | 10.00 | 2/5/10 | 2/18/10 | Simon | | | | | |
| Inner Vessel | 57.00 | 1/4/10 | 3/23/10 | | | | | | |
| Assembly Procedure | 10.00 | 1/11/10 | 1/22/10 | Rucinski | | | | | |
| Prepare seal parts and tools | 5.00 | 1/22/10 | 1/28/10 | Ruschman | | | | | |
| Prepare 1/4 inch manifold parts | 20.00 | 1/4/10 | 1/29/10 | Ruschman | | | | | |
| Weld 1/4 manifold | 5.00 | 2/1/10 | 2/5/10 | Welder | | | | | |
| Prepare cleanroom | 4.00 | 1/22/10 | 1/27/10 | Ruschman | | | | | |
| Assemble seal | 1.00 | 1/29/10 | 1/29/10 | Rucinski, Ruschman | | | | | |
| Leak test | 5.00 | 2/1/10 | 2/5/10 | Ruschman | | | | | |
| Prepare rinsing hardware | 5.00 | 1/22/10 | 1/28/10 | Ruschman | | | | | |
| | | | | | Jan | Feb | Mar | Apr | Ma |

| Activity Name | Duration (Work Days) | Start Date | Finish Date | Resources Assigned | 2010 | | | | |
|---|----------------------|-----------------|----------------|-------------------------|------|-----|-----|-----|----|
| | | | | | Jan | Feb | Mar | Apr | Ma |
| Rinse | 5.00 | 2/8/10 | 2/12/10 | Ruschman | | | | | |
| Assemble 1/4 manifold | 3.00 | 2/15/10 | 2/17/10 | Ruschman | | | | | |
| Prep for Shipping to D0 | 2.00 | 2/18/10 | 2/19/10 | Ruschman, Kubinski | | | | | |
| Unpacking at D0 | 2.00 | 2/22/10 | 2/23/10 | Ruschman, Simon | | | | | |
| Remove old IV from OV flange | 3.00 | 1/22/10 | 1/26/10 | Flores, Ruschman, Simon | | | | | |
| Attach new IV to OV flange | 3.00 | 2/24/10 | 2/26/10 | Flores, Ruschman | | | | | |
| Install acoustic sensor feedthrough | 3.00 | 2/1/10 | 2/3/10 | Simon | | | | | |
| Install acoustic sensors | 11.00 | 3/8/10 | 3/22/10 | Sonnenschein | | | | | |
| Insert inner vessel into pressure vessel | 1.00 | 3/23/10 | 3/23/10 | Simon | | | | | |
| NuMI installation | 39.00 | 2/10/10 | 4/5/10 | | | | | | |
| Electrical Utilities Install | 10.00 | 3/23/10 | 4/5/10 | Technician, Voirin, M&S | | | | | |
| Compressed air line | 10.00 | 3/23/10 | 4/5/10 | Technician, Voirin | | | | | |
| Nest pressure vessel in water tank | 1.00 | 3/24/10 | 3/24/10 | Simon | | | | | |
| Prep equipment at D0 for shipping to NuMI | 20.00 | 2/10/10 | 3/9/10 | Simon | | | | | |
| Rig down shaft and position equipment | 1.00 | 3/29/10 | 3/29/10 | Voirin, Simon | | | | | |
| Hook up hoses, cables | 5.00 | 3/30/10 | 4/5/10 | Simon | | | | | |
| Fluid Handling Cart | 352.00 | 12/22/08 | 4/27/10 | | | | | | |
| Design | 280.00 | 12/22/08 | 1/15/10 | Rucinski | | | | | |
| Prep lines and instruments for welding | 15.00 | 1/11/10 | 1/29/10 | Kubinski | | | | | |
| | | | | | Jan | Feb | Mar | Apr | Ma |

| Activity Name | Duration (Work Days) | Start Date | Finish Date | Resources Assigned | 2010 | | | | |
|--|----------------------|----------------|----------------|------------------------|------|-----|-----|-----|-----|
| | | | | | Jan | Feb | Mar | Apr | May |
| Welding | 15.00 | 2/4/10 | 2/24/10 | Welder | | | | | |
| Post weld assembly | 15.00 | 3/5/10 | 3/25/10 | Kubinski | | | | | |
| Water flushing | 5.00 | 3/22/10 | 3/26/10 | Kubinski, Rucinski | | | | | |
| Leak check | 5.00 | 3/29/10 | 4/2/10 | Kubinski | | | | | |
| Add insulation | 5.00 | 4/6/10 | 4/12/10 | Kubinski | | | | | |
| Build clean enclosure | 5.00 | 4/6/10 | 4/12/10 | Kubinski | | | | | |
| Make tags for valves and instruments | 5.00 | 4/6/10 | 4/12/10 | Kubinski | | | | | |
| Procedures for water test | 4.00 | 4/5/10 | 4/8/10 | Sonnenschein | | | | | |
| Test water operations | 5.00 | 4/14/10 | 4/20/10 | Rucinski, Sonnenschein | | | | | |
| Move fluid cart underground | 0.00 | 4/20/10 | 4/20/10 | Voirin | | | | | |
| Purchase parts for gas transfer line | 5.00 | 3/22/10 | 3/26/10 | Sonnenschein | | | | | |
| Welding for gas transfer line | 3.00 | 4/5/10 | 4/7/10 | Welder | | | | | |
| Clean parts for gas transfer line | 5.00 | 4/8/10 | 4/14/10 | Wilson | | | | | |
| Assemble gas transfer line underground | 5.00 | 4/20/10 | 4/27/10 | Ruschman, Sonnenschein | | | | | |
| Operations | 142.00 | 3/23/10 | 10/6/10 | | | | | | |
| CF3I Safety Note | 15.00 | 3/23/10 | 4/12/10 | Rucinski | | | | | |
| Update FMEA | 1.00 | 4/6/10 | 4/6/10 | Rucinski | | | | | |
| Operational Readiness Clearance | 5.00 | 4/20/10 | 4/27/10 | Ramberg | | | | | |
| Glycol filling procedure revision | 3.00 | 4/9/10 | 4/13/10 | Sonnenschein | | | | | |
| Water filling procedure | 5.00 | 4/14/10 | 4/20/10 | Sonnenschein | | | | | |
| CF3I filling procedure revision | 4.00 | 4/21/10 | 4/26/10 | Sonnenschein | | | | | |
| | | | | | Jan | Feb | Mar | Apr | May |

| Activity Name | Duration (Work Days) | Start Date | Finish Date | Resources Assigned | 2010 | | | | |
|---|----------------------------|-------------------|--------------------|------------------------------|------|-----|-----|-----|-----|
| | | | | | Jan | Feb | Mar | Apr | May |
| DAQ system | 25.00 | 4/7/10 | 5/11/10 | | | | | | |
| <i>Breakout boxes</i> | 5.00 10.00 | 4/13/10 4/7/10 | 4/19/10 4/20/10 | Dahl Hansen, Dahl | | | | | |
| <i>Cables</i> | 10.00 | 4/7/10 | 4/20/10 | Fustin, Dahl | | | | | |
| <i>Fast digitizer code</i> | 10.00 | 4/7/10 | 4/20/10 | Dahl | | | | | |
| <i>Slow digitizer code</i> | 10.00 | 4/7/10 | 4/20/10 | Dahl | | | | | |
| <i>Test- Manual Triggers No Pressure Cart</i> | 5.00 | 4/21/10 | 4/27/10 | Dahl | | | | | |
| <i>Reconstruction Code</i> | 15.00 | 4/7/10 | 4/27/10 | Brice | | | | | |
| <i>Offline Structure</i> | 10.00 | 4/28/10 | 5/11/10 | Brice | | | | | |
| <i>Networking</i> | 10.00 | 4/7/10 | 4/20/10 | Cooper | | | | | |
| Monitoring tools... | 32.00 10.00 | 4/7/10 4/7/10 | 5/20/10 4/20/10 | | | | | | |
| Offline Processing... | 20.00 | 4/9/10 | 5/6/10 | | | | | | |
| Ready for operations at NuMI | 0.00 | 4/27/10 | 4/27/10 | | | | | | |
| Water Filling of Inner Vessel | 5.00 | 4/27/10 | 5/4/10 | Rucinski, Sonnenschein, Dahl | | | | | |
| CF3I distillation | 5.00 | 5/5/10 | 5/11/10 | Rucinski, Sonnenschein, Dahl | | | | | |
| CF3I Filling Inner Vessel -20 KG | 5.00 | 5/12/10 | 5/18/10 | Dahl, Rucinski, Sonnenschein | | | | | |
| Start taking Data | 0.00 | 5/18/10 | 5/18/10 | | | | | | |
| Water filling of tank | 2.00 | 5/19/10 | 5/20/10 | Ramberg | | | | | |
| Temperature ramp to 40 degrees | 3.00 | 5/21/10 | 5/25/10 | Sonnenschein, Dahl | | | | | |
| Install Veto | 5.00 | 5/21/10 | 5/27/10 | Ramberg, Hall | | | | | |
| Run with 20-kg for 1 Month | 20.00 | 5/28/10 | 6/24/10 | Dahl, Sonnenschein | | | | | |
| Measurement of alpha rate < 1/kgd | 0.00 | 6/24/10 | 6/24/10 | | | | | | |
| | | | | | Jan | Feb | Mar | Apr | May |