COUPP Review

Dec. 8 2009

Introduction: What Are Our Goals for Work at D0 and NuMI?

From our September DOE Field Work Proposal:

1. Demonstrate that the detector is fully functional. This includes tests of the achievable live time fraction, the quality of the video images, the stability of the pressure and temperature control systems, the efficiency of the video trigger, the speed of hydraulic compression and the functionality of the data acquisition hardware and software.

   CAN BE DONE MOST EASILY AT D0, BUT ALSO POSSIBLE IN NUMI TUNNEL

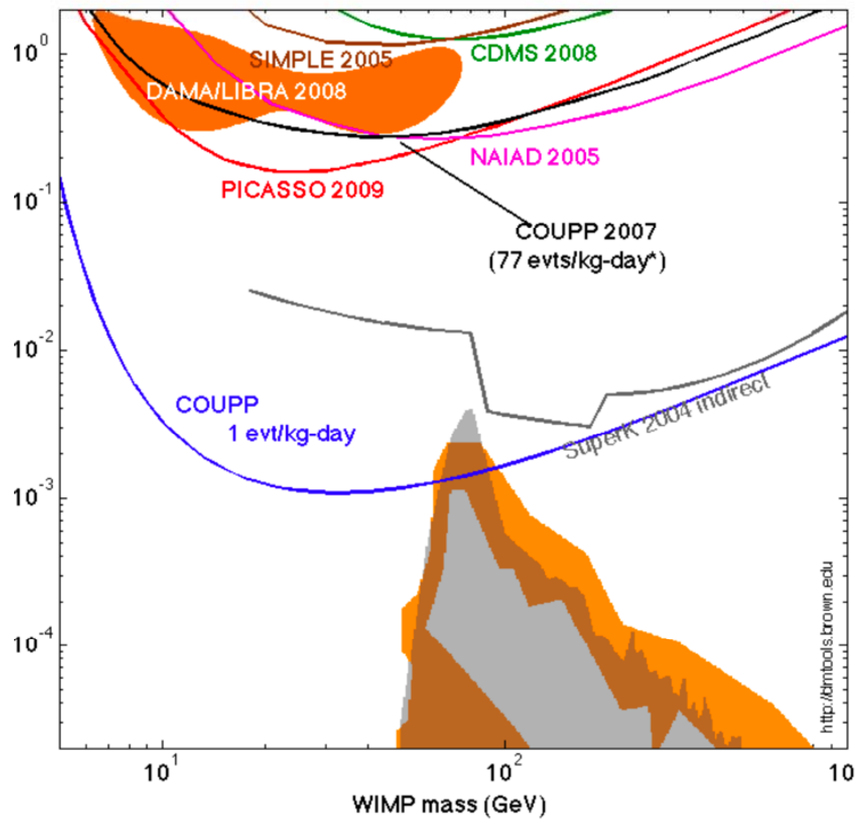
2. Demonstrate that the detector can operate reliably for long periods of time without operator intervention. This is essential for efficient operation at a remote underground site.

3. Demonstrate that the backgrounds due to α-emitters dissolved in the bubble chamber liquids are low enough to achieve leading sensitivity to spin-dependent WIMP interactions. Our goal in the commissioning phase is to reach a level below 60 alpha decays per day in 60-kg of target liquid, or 1 event/kg-day.

   ONLY POSSIBLE IN NUMI

Secondary Goal: Physics

- Neutron background at NuMI can be suppressed to a level which will allow us to begin to probed SUSY dark matter by spin-dependent interactions.
- It appears that we can do this very soon with the currently-operating 4 –kg chamber, which has already reached the required background level.
- Therefore, focus of 60-kg should clearly be on the fastest possible deployment at Snolab.



POSSIBLE AT NUMI

Snolab Proposal

- Propose to bring 60-kg chamber to Snolab.
- Was presented to Snolab external advisory panel in August and Fermilab PAC in November.
- Has been approved by both labs.
- Engineering for Snolab infrastructure is already in progress at Snolab and construction will start soon using Snolab resources.
- Timeline from proposal:

FY09	Complete fabrication and testing at D0
FY10	Commissioning and operation at NuMI, Installation of underground infrastructure at SNOLAB
FY11	Recommission experiment deep underground, begin running
FY12-13	Operations deep underground

Progress Relative to Previous Schedule(s)

- Schedules were reported in Dec. 2008 (PPD R&D Review), May 2009 (FCPA), August 2009 (DOE Site Visit), September 2009 (DOE Field Work Proposal)
- Table below shows slide in milestones since May 11 FCPA Review

Milestone	Schedule (May 11)	Actual / Expected
Ready to Operate D0	May 22	August 8
Achieve long superheat times	June 3	October 15
Inner vessel assy complete	June 23	February 2010
Full DAQ system at D0	July 7	Mid-November
Good data at D0	July 22	March 2010
Ready to operate at NuMI	Aug 24	May 2010

Some Sources of Schedule Slip

• Illumination problems (poor contrast and corrosion of LED array) were a serious source of delays for both the 4-kg and 60-kg over the summer. The need for testing and rework impacted the D0 installation schedule.

• The failure of the illumination system now requires work to be done on a replacement.

• Three activities which were envisioned to occur in parallel (D0 installation, fluid handling cart, final vessel assembly) actually are in serial because they all need close attention from one person, Russ Rucinski, whose time has dropped as low as 40% during some months (Note: retaining largest possible fraction of Russ's time on this project is our highest priority request to PPD).

• Delays on welding during summer accelerator shutdown.

• DAQ software has taken longer than expected. Problems with driver incompatibility, camera processor performance, serial communications…

• Development of electronics and firmware for muon veto PMTs was delayed and has slowed the veto commissioning.

Successes

- Mechanical and control systems performed as expected with only minor exceptions (e.g. rusting valves).

- While some tests remain and significant delays have occurred, DAQ development appears to be on a successful path.

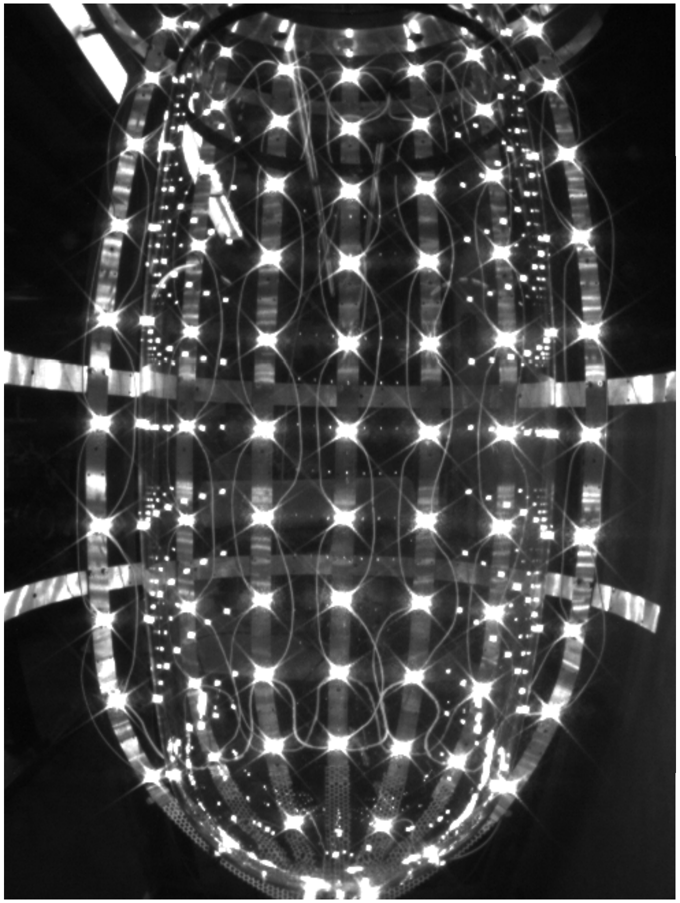
- Veto is in good shape, given large signals seen in PMTs and nearly acceptable performance of "Rev. 0" electronics.

- A viable replacement illumination system has been tested and is ready to be installed.

- Impressive R&D accomplishments from 4-kg have been recorded over the last year, including elimination of surface backgrounds, significant reduction in bulk alpha backgrounds and dramatic measurements of acoustic background discrimination. These developments are largely beyond the scope of the present technical review, but have a profound impact on the physics potential of COUPP-60.

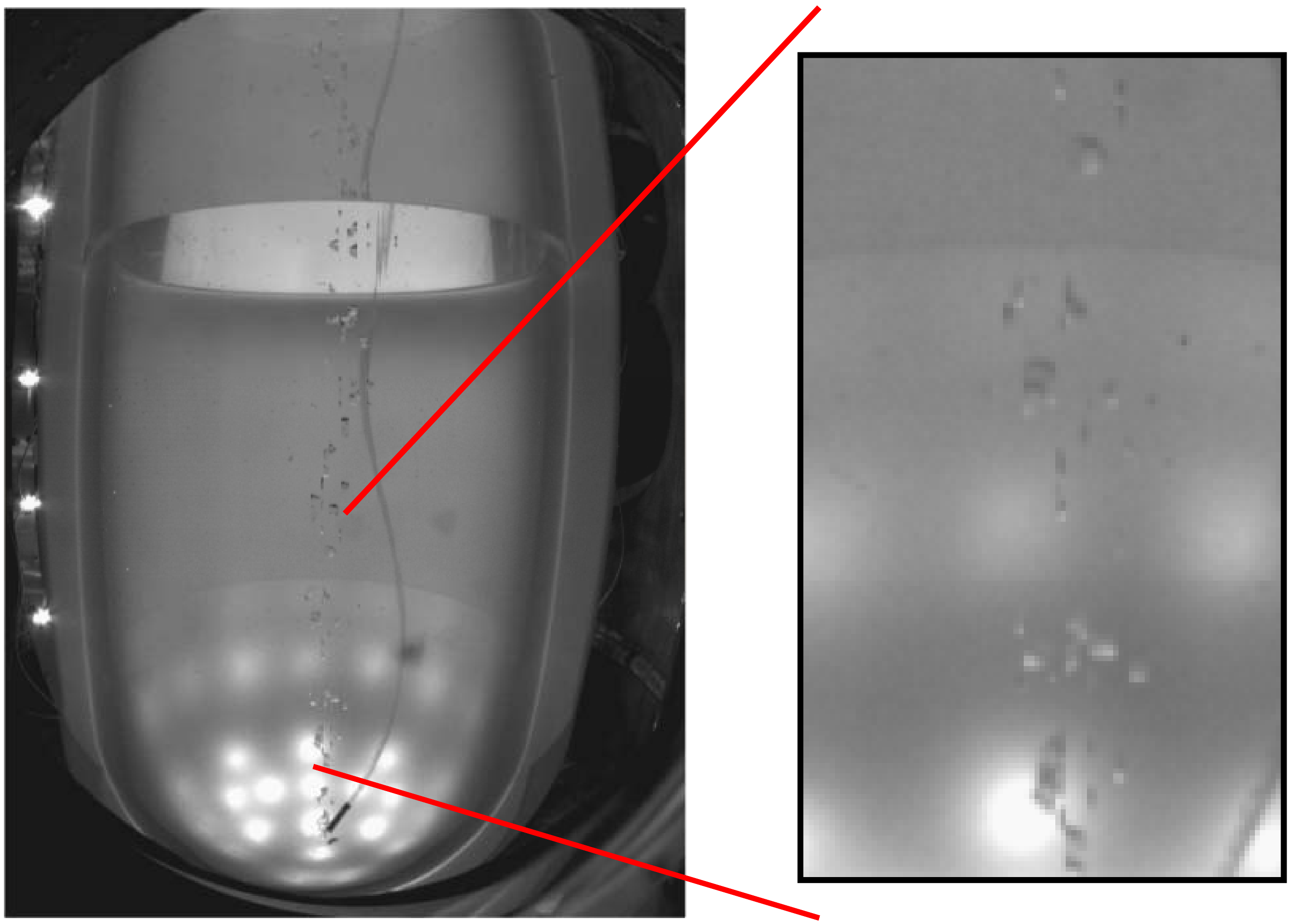
Original Illumination Concept

- Large array of high-powered LEDs immersed inside propylene glycol buffer fluid.
- Acrylic diffuser panel.
- Prototype tested in March 2008 and final version in Spring 2009.



Poor Contrast From LED Backlighting with Curved Diffuser

60-kg Chamber



2-kg Chamber

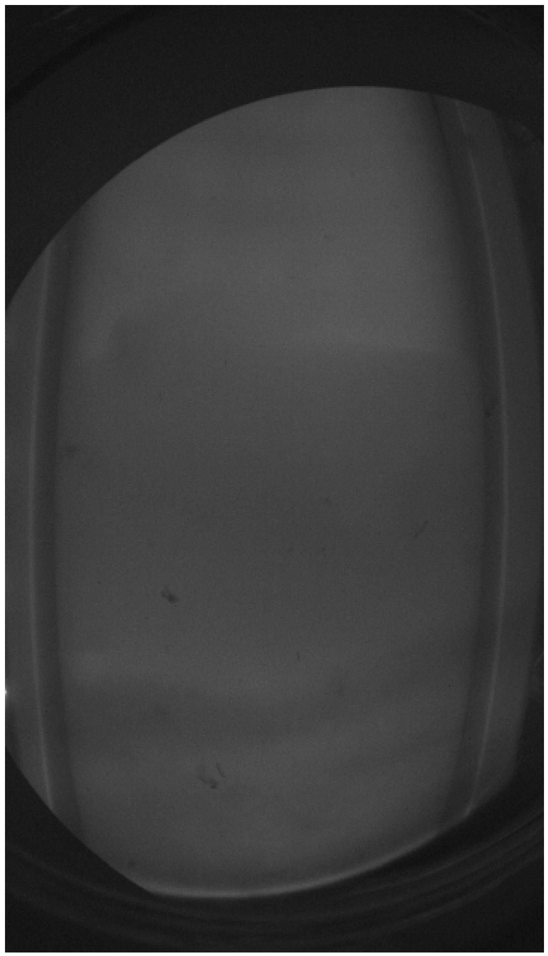
LED electrode corrosion problem

- Observed during the 2L vessel test and on benchtop using corrosion inhibited propylene glycol (Dynalene)
- Not observed with pure PG (duration of test? Temperature?)

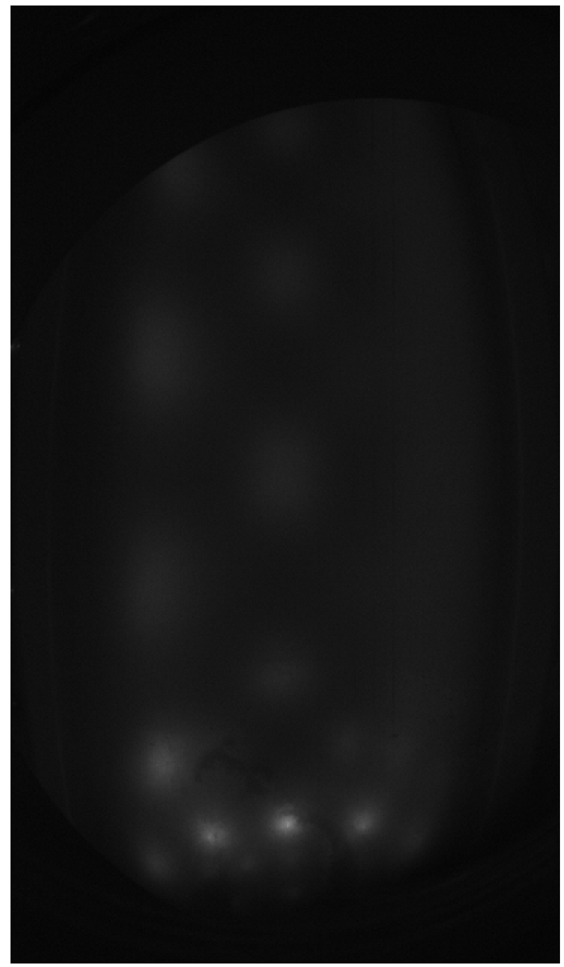
Failure of 60-kg LED Array

- Progressive loss of bias current and illumination power beginning soon after filling.
- Now down to about 5% of original illumination power.
- Attempts to revive array with larger voltage bias were not successful.

Sept 24



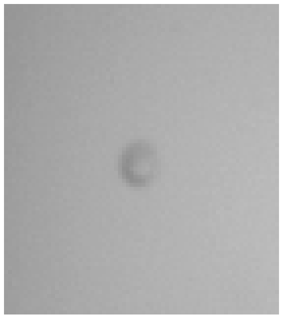
Oct 27



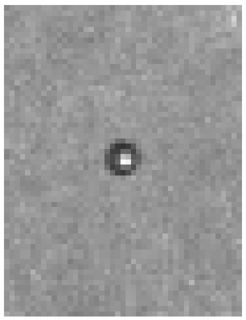
Retroreflective Lighting

• Retroreflective materials reflect light rays back in the direction incidence.
• Absence of “sideways- going” light improves contrast- an ideal backlighting source.
• Much more efficient use of light, since with illumination source near to camera lens, a large fraction of light returns to the camera.

Diffuse backlight
(2 kg chamber)

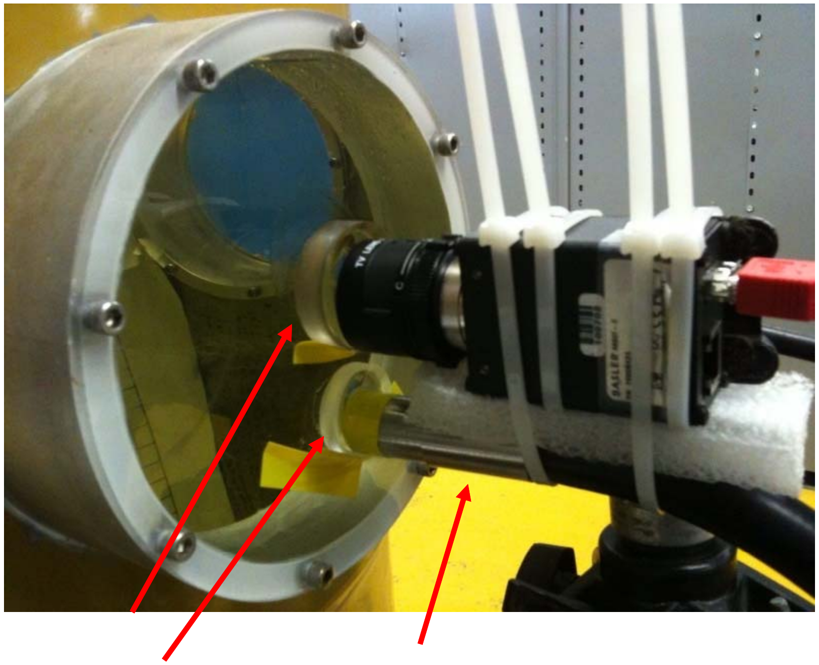


Scotchlite
Retroreflector
(4 kg chamber)



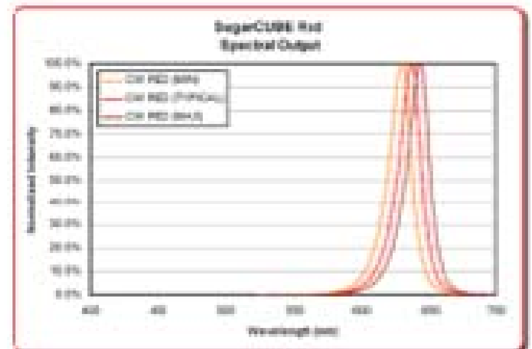
Commercial Lighting Solution for COUPP-60

• Light would be provided by a commercial fiber optic illuminator which can bring light to the camera viewport through a long fiber bundle.
• Diffusers and lenses are used to spread the light into a wide beam at the camera viewport.



Planoconcave lenses

Fiber optic bundle



Radiometric Output (1) Continuous Operation								
Color	Minimum Lumen Output	Radiometric Flux (W)	Minimum		Typical		Maximum	
			Peak λ	Dom λ	Peak λ	Dom λ	Peak λ	Dom λ
Red	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(1) Preliminary data

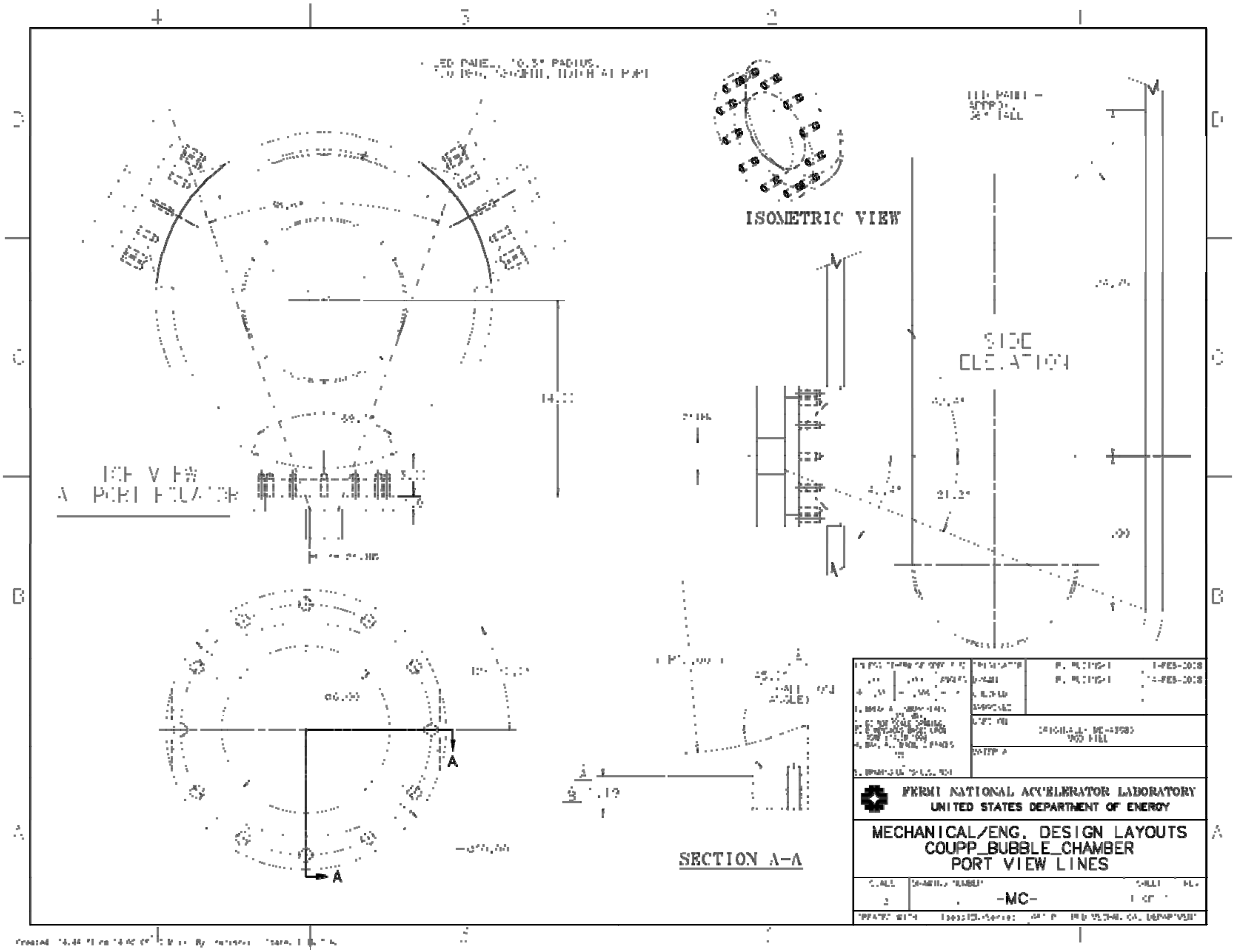
View Cart

$1625.00

Add to Cart

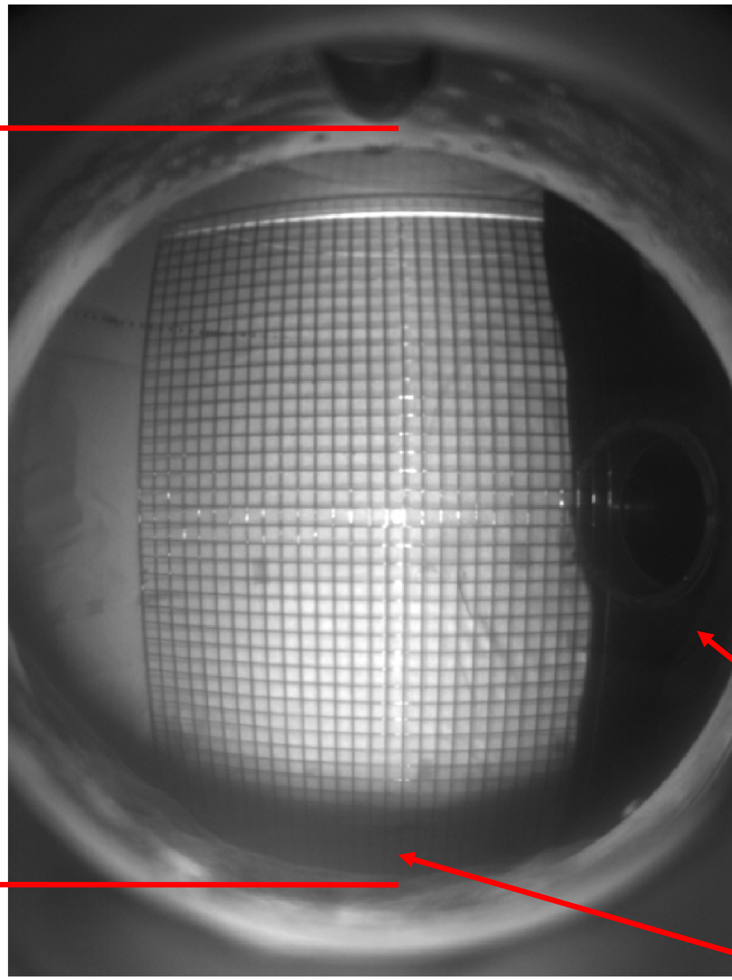
- Over 5.5 watts of optical output power
- Capable of driving up to a 1 inch fiber optic bundle
- Over 60,000 hours without a lamp change (> 70% lumen maintenance)
- Consumes only 65 watts at full power vs over 200 watts for a conventional 150 watt halogen illuminator.
- Quiet operation (<45db)

Product Brochure



ISOMETRIC VIEW
SIDE ELEVATION
SECTION A-A
A
A
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
MECHANICAL/ENG. DESIGN LAYOUTS
COUPP_BUBBLE_CHAMBER
PORT VIEW LINES
-MC-

Test Photo Inside 50-gal Drum

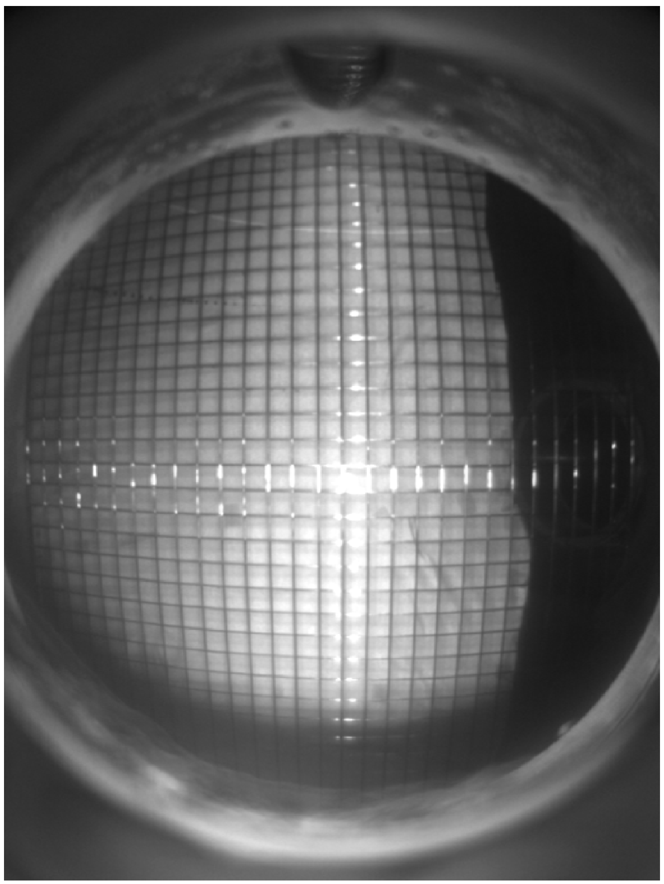


- Photo of wire grid located at same distance from camera as center of 60-kg inner vessel.
- Wires are on a 0.5 inch pitch.
- Camera shutter speed is 1.2 ms– acceptable for 60-kg bubble photos

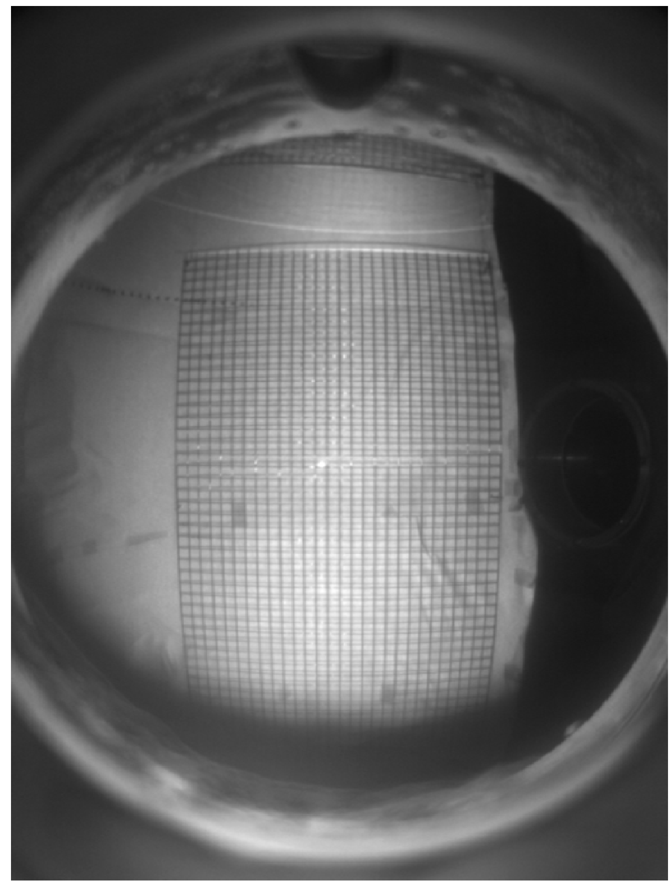
Depth of Field

- Demonstration that optical system allows full volume of inner vessel to be in focus.
- Wires are 1.2 mm in diameter– similar to bubbles we hope to detect.

Grid at position of Inner vessel front surface

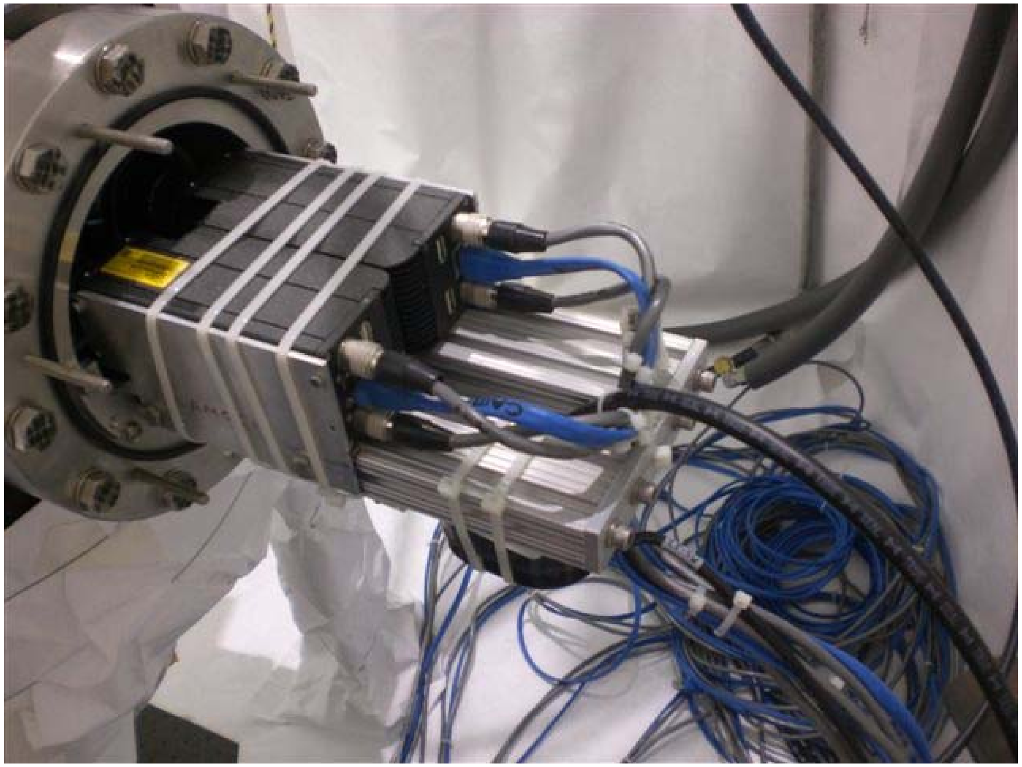


Grid at position of Inner vessel rear surface



Work Needed to Install New System in 60-kg Chamber

- Two optical fibers will be added to existing camera mount.
- New lenses will be glued to observation window.
- Fiber optic illuminators will be installed on a shelf near top of water tank.



Summary

- Lighting system deployed in 60-kg chamber has failed, probably due to electrochemical corrosion.
- Even at its best, this system yielded low contrast bubble photos.
- Tests in 4-kg chamber show that retroreflective backlighting would produce higher contrast.
- A new system based on retroreflective lighting and an off-the-shelf fiber illuminator has been demonstrated. It meets all requirements and is simple to retrofit into the chamber.

Acoustic Sensor Testing

• Testing of acoustic sensors in 4-kg has resulted in the discovery of very large background discrimination power, likely enough to make COUPP-60 competitive with SuperCDMS-100, Xenon-100, WARP-140 for spin-independent WIMP searches and to extend its spin-dependent sensitivity by more than an order of magnitude beyond the prediction that appears in our proposals.

• *The collaboration wants to make sure that we get at least the same quality of information from the 60-kg detector as we currently have from the 4-kg.*

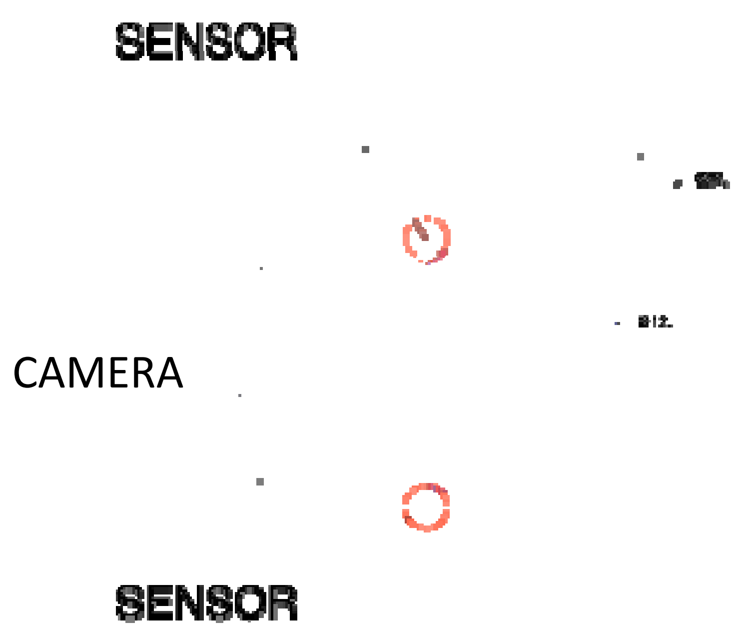
• The main issues are:
  - The number of acoustic sensors required
  - Their locations on the inner vessel
  - The electronic gain of the preamps in the sensors.

• We want to test sensors on the prototype inner vessel before attaching them to the final high purity quartz vessel. Once attached, sensors can not be removed.

•Acoustic sensor tests could be done either in D0 or underground at NuMI, but would require more manpower if underground, due to lack of crane coverage

Acoustic Sensor Placement

• We expect to attach 4 sensors to the prototype inner vessel, at points where they will interfere minimally with the camera view.



Acoustic Measurement is "Game Changing"

- *The acoustic background discrimination technique appears to be powerful enough that the 4-kg chamber will be capable of reaching sensitivity comparable to that originally intended for the 60-kg chamber (e.g. by running background free at a deep underground site for a year).*

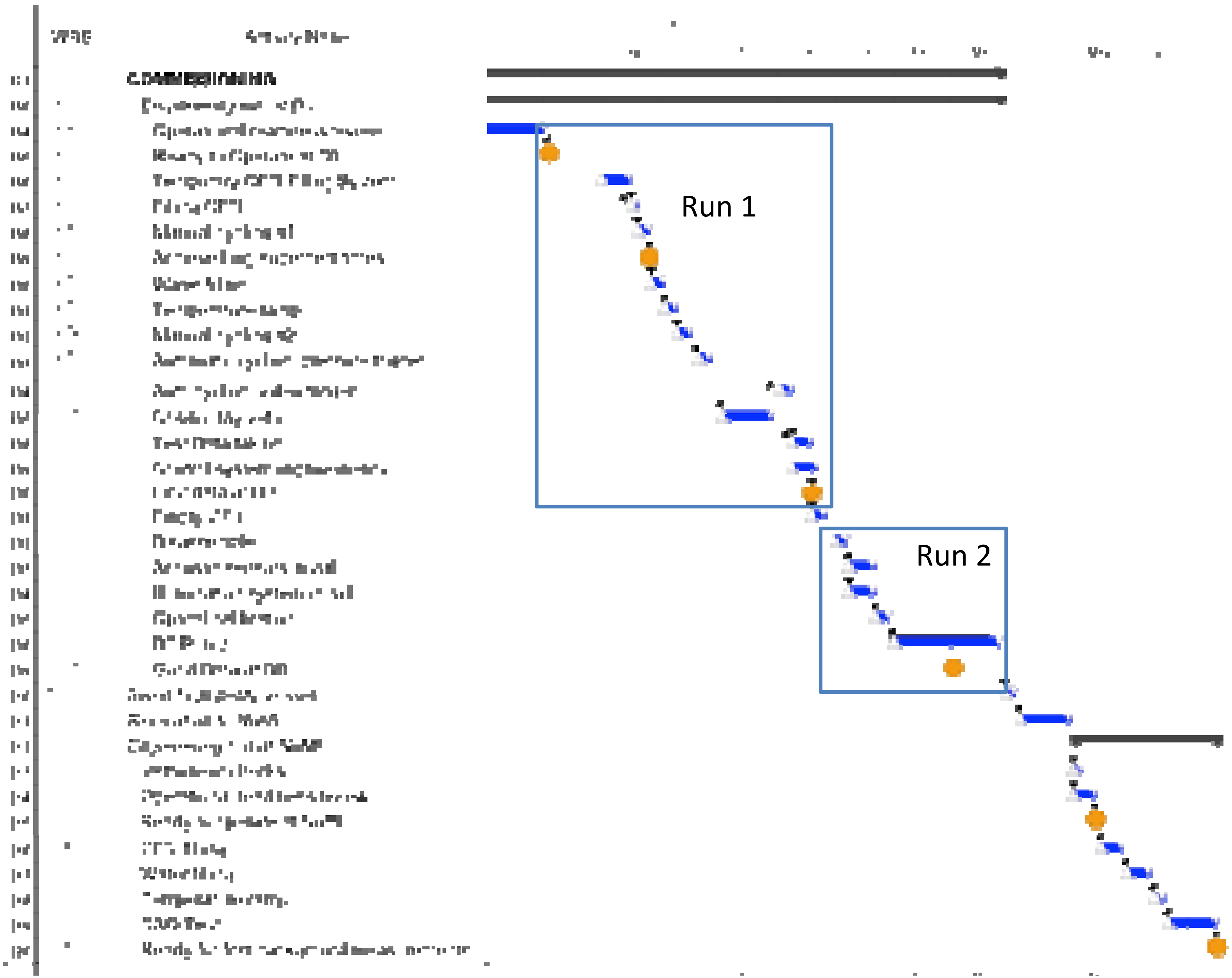
Therefore:

- *The urgency of moving the 60-kg chamber into NuMI is somewhat reduced, because the 4-kg chamber will do all the physics that can be done at NuMI before being background limited by residual cosmic-induced neutrons.*

- *Taking the 60-kg chamber to Snolab without a high quality acoustic sensor array is no longer considered by the collaboration to be a sensible plan. It would be better to take the already-existing 4-kg chamber.*

Motivation for Second Run at D0

- Due to illumination system failure, the goal of taking analyzable data at D0 can not be achieved in current run.
- The replacement of the illumination system requires removal of all fluids, disassembly of the chamber, installation of reflector sheets inside the detector, then reassembly and filling with propylene glycol and water, followed by test photos. While CF3I filling is not required, this represents a significant fraction of the work required to start a second run.
- We think it makes sense to go ahead and fill with CF3I, allowing testing of the trigger and DAQ with proper lighting.
- Acoustic sensor testing could also be accomplished in a second run. The presence of acoustic sensors would likely motivate a longer second run than would optical and DAQ testing alone, but this depends on what problems are seen in the data.


Run 1
Run 2

Long Range Schedule

- Stated goal in proposals (DOE, Fermilab, Snolab) is to be operational at Snolab in early FY11

- From our DOE Proposal “The duration of tests at NuMI depends considerably on the level of background we observe. Once we achieve a bulk background level of 1 event/kg-day, we will want to move as soon as possible to a deep site. If no improvements are required, the tests at NuMI could take as little as three months, while major improvements, such as the fabrication of a complete new inner vessel, might require as long as a full year to complete and test.”

- Since writing the proposal, we have achieved the background goal (1 event/kg-day) in the 4-kg chamber. This suggest that major radiopurity-related upgrades, considered the largest schedule risk, will not be needed.

- Our technical successes may lead to unexpected schedule shortcuts: depending on outcome of acoustic testing at D0, it may turn out that a NuMI run is superfluous: alpha/neutron discrimination could allow a measurement of the alpha rate at D0 in the presence of a high cosmic neutron background or high measured discrimination power could mean that large alpha rates are tolerable at Snolab.

Questions for Committee

1. Has the implementation plan presented at the prior reviews been completed? Have the requested resources been applied to the project?

The implementation is behind schedule. The operations which were anticipated at D0 are now nearly complete, but a full DAQ test is prevented by the failure of the illumination system. The high purity inner vessel and fluid handling module are not ready for integration with the hardware at D0.

To some extent, the delays in the inner vessel assembly and high purity fluid cart are due to a shortage of engineering resources (especially Rucinski's time– an issue which we have raised at each review but continues to be a problem)

2. Are each of the baseline components on track for full operation and installation in the MINOS near detector hall by January 2010?

No, given the illumination system failure.

3. What are the remaining technical issues for each system? Can these be resolved in a timely fashion or is a change in design or scope needed? See talks

4. What system(s) set(s) the critical path for installation?

Replacement of illumination system followed by testing. High purity fluid cart. Acoustic sensor testing.

5. What resources are needed to complete the complete commissioning in D0?

6. What resources will be required for the move and installation in the MINOS near detector hall (people and durations)?

See Rucinski talk.

Charge to Committee- Second Set of Questions

1. What additional information will be gained by a test on the 60kg chamber over what can be learned with existing tests on the smaller (4kg) chamber?

   The principle issue is what effect the differently shaped, larger inner vessel will have on the acoustic signals. This will determine the number and location of final sensors on the high purity vessel and the gain of the preamps.

2. What additional resources will be required to carry out these studies?

   This will probably require 1 month more running time at D0 than would be required simply to test the new illumination system. About a man week of technician labor will be involved in the mounting and wiring of the test sensors.

3. How much will this proposal delay installation in the MINOS near detector hall?

   By 1-3 months depending on how the run goes and whether the “baseline” which is being compared to includes a test at D0 of the trigger and DAQ with the new illumination system. The largest savings would come from eliminating more above ground tests of any of these systems at the risk of having to do more work underground, less efficiently.

4. Is it feasible to install the acoustic sensors after the chamber has been moved underground? What would be the impact on the overall schedule?

   All the tests which can be done at D0 could also be done underground, but more manpower would be needed because of the lack of crane coverage. We estimate the extra work to be about 6 man weeks to move the detector and water tank from the operating position at NuMI to the area of the shaft where the inner vessel can be removed and then back into place again. This is about 2 weeks for 3 people.

Resources

- Our top priority for resources in PPD is the participation of Russ Rucinski at a 60% level or greater (approximately his current level). His participation will be important at least through the Snolab installation phase. Russ's level of effort drives the schedule to a great extent.
- We think that the average level of technical support required through shipping to Snolab is approximately 1 FTE engineer plus 1 FTE technician. This is compatible with the budget in our DOE Field Work Proposal.
- In the next two months we are in dire need of a welder (2 weeks full time equivalent work) to complete the fluid handling module. This appears to be a lab-wide problem.
- We have one very compelling postdoc candidate this year– he could have a big impact on our ability to efficiently operate the 60-kg chamber and fully analyze the data.