Fermilab

PPD Project Review of the COUPP 60 kg Detector

December 8, 2009

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1. Committee Charge

The COUPP 60kg bubble chamber (E-961) has been assembled and is undergoing initial commissioning in the D0 Assembly Building. Initial commissioning is being carried out in D0 where there is full crane coverage and reconfiguration is much simpler than in the MINOS hall. It is anticipated that the experiment will be ready for installation in the MINOS near detector hall for a first run early in 2010. The goal of this run is to demonstrate the backgrounds are under control, and this is expected to take most of 2010. If this run is successful, the collaboration proposes to move the 60 kg chamber to SNOLAB and do a deep underground dark matter search.

The COUPP project was reviewed on Dec 10, 2008 by PPD (http://wwwppd.fnal.gov/DivOffice/internal_rd/Reviews.htm) and on May 11, 2009 by FCPA (http://astro.fnal.gov/projects/Reviews.html). At these reviews the plans for completion of the chamber, hydraulics, cameras, DAQ system, and veto systems were presented.
The COUPP proponents have made significant progress on this project since these reviews. However, while it was anticipated that the experiment would be ready to move underground by the summer of 2009, the commissioning in D0 is still in progress.

The purpose of this review is to evaluate the preparedness of the experiment for the move to the MINOS near detector hall, and to advise the project, the FCPA and PPD on any actions that are needed to ensure that the installation can take place as early as reasonably possible. This will be a technical review of the status of the project not a review of the science of the experiment.

The reviewers should evaluate the technical progress of the baseline project and each of its systems. The systems include bubble chamber and mechanical systems, camera and illumination, DAQ hardware and software, and the veto. The evaluation should cover:

1. Has the implementation plan presented at the prior reviews been completed?
2. Have the requested resources been applied to the project?
3. Are each of the baseline components on track for full operation and installation in the MINOS near detector hall by January 2010?
4. 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?
5. What system(s) set(s) the critical path for installation?
6. What resources are needed to complete the complete commissioning in D0?
7. What resources will be required for the move and installation in the MINOS near detector hall (people and durations)?

The proponents have expressed interest increasing the scope of the project to include installation of acoustic sensors on the 60kg chamber prior to installation in MINOS. This would result in a second test run in D0 prior to installation. The committee is asked to evaluate this proposal.

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

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

2. The Committee

Kurt Biery
Fritz DeJongh
Debbie Harris
Kurt Krempetz
Ron Ray – Chair

3. Agenda

8:45 Executive Session (15)
9:00 Introduction - Sonneschein (10)
9:10 Mechanical Systems, fluid handling, safety -Rucinski (20+10)
9:40 Camera and Illumination - Sonnenschein (15+5)
10:00 DAQ Overview - Cooper (20+5)
10:25 DAQ Software- Dahl (15+5)
10:45 Veto - Hall (10+5)
11:00 Schedule, including acoustic sensor testing issue- Sonnenschein (20+10)
11:30 General Discussion (20)
11:50 Executive Session
12:15 Adjourn

4. Mechanical Systems

Findings

- The mechanical systems for the 60 Kg chamber are in good shape. The re-compression system works well, the chamber itself is operating nicely. The water tank and veto system is operating as designed.

- The mechanical fluid-handling cart has been designed but fabrication has been slowed down and delayed due to the need for welding.

Comments

- The mechanical systems have taken longer than planned to design, fabricate and operate but now these tasks are basically completed and further efforts are only needed to disassemble, move, reassemble and operate the systems.

- The availability of welders at the lab has been and continues to be a serious problem.

Most of the welding for the fluid-handling cart is best done with an orbital welder, something that once setup up can be run by individuals with little welding skills.

Recommendations

- The COUPP project should request that PPD management work with TD management to resolve the welding issue as quickly as possible.

5. Illumination System

Findings

- The illumination system for the 60 Kg chamber produced less contrast for bubbles than previous chambers. In addition, corrosion in the LED array led to a progressive loss of brightness to the point that the system can no longer be used to test the trigger and DAQ systems.

- A new design uses Scotchlite retro-reflective materials, with a commercial fiber-optic illuminator to introduce light at the camera viewport. A test with the 4 Kg chamber has demonstrated superior bubble contrast with this design. A test in a 50-gallon drum has demonstrated that the brightness and depth-of-field meets the needs of the 60 Kg chamber. The new design is simple to retrofit into the chamber.

- Testing the trigger and DAQ with the new illumination system is the main motivation for the 2nd D0 run other than investigating acoustic sensors. This will also test new camera lenses.

- Installing the new illumination system is part of an assembly process estimated to take about 15 person-days. Testing the system will take about a month of running time.

Comments

- The failure of the illumination system prevented a full test of the trigger and DAQ system in the D0 assembly area. A new design for the illumination system is in hand, and is simple to retrofit into the chamber. Given the tests in the 4 Kg chamber and 50-gallon drum, the new design is likely to work.

Recommendations

- Given the likelihood that the new illumination design will resolve the illumination issues combined with the limited resources in the Field Work Proposal, the COUPP collaboration should consider whether a 2nd D0 run is warranted. The risk that the illumination system will need further replacement, along with the extra difficulty of commissioning the DAQ system in the NUMI location, should be weighed against the risk that the FWP resources might not allow for both the 2nd D0 test and the NUMI test.

6. DAQ

Findings

The DAQ system consists of a number of different hardware devices communicating with each other and a central LabView application using a number of different protocols. Considerable work has been done recently on the DAQ software to fix outstanding issues and integrate the components into the central LabView application. There is additional work that needs to be done, but the collaboration expects that the full DAQ will be ready for another run at D0 in January should such a run take place. Long-term stability testing of the DAQ has not yet been possible, but this testing is planned to be part of future running in the D0 assembly area.
Some details of note:

- The CTIC module (COUPP Trigger Interface Controller) is a custom component built by Fermilab electrical engineers. The experiment currently has two modules in hand, one for production running and one spare. Firmware changes to the modules need to be implemented by one of the engineers, and such changes can take several days to several weeks depending on engineer availability.

- Recent stability tests of the DAQ have failed with communication problems between the central application and the CTIC. This problem is expected to be fixed soon. The short-term testing goal is to reliably run the DAQ for 24 hours before any changes are made to the experimental apparatus. The longer-term goal is to reliably run the run the system for two weeks and successfully analyze the data that is collected.

- Centralized reporting of error or alarm conditions is not currently part of the system. The monitoring of the status of the various components consists of experiment personnel proactively checking on the health of the system.

- The muon veto, slow digitizer, and fast digitizer DAQ components have not yet been integrated into the central LabView application.

Comments

There is a wide range in readiness of the various components. Some only need minor fixes and tuning to be made ready for a long-term stability test, others do not run reliably at the current time, and some have not yet been integrated into the LabView central application. There appears to have been significant progress on DAQ hardware and software in the weeks leading up to the review, but we were not able to judge if the goal of being ready for a January run is achievable. The system currently requires a considerable amount of operator intervention to take data, both in the realms of setting up the system and monitoring its status. This is not an unreasonable state

of affairs during construction and commissioning, but it may not be a good model for production running at an underground location.

Recommendations

- The current intensive effort on the DAQ hardware and software should be continued until the system is shown to run reliably for extended periods of time.

- As much as possible within budget and schedule constraints, reliability and automation improvements should be made to prepare for extended running at underground sites.

7. Veto Detector

Findings

- The Coup Veto Detector is a water Cherenkov system read out with photomultiplier tubes and smart PMT bases.

- The veto doubles as a 1-meter water equivalent neutron shield and provides some thermal control for the detector.

- The water is chlorinated to avoid unwanted growth of microbes.

- The detector has been immersed underwater in the veto shield for 1.5 months.

- Some rust issues were identified at the outset of veto operations that resulted in a short delay while changes were made to mitigate the problems.

- 8 PMTs are currently installed. Another 8 remain to be installed after their bases are constructed. All of the required parts are in hand and labor has been identified.

- The veto will not be used in an eventual Snowlab run because it is too large to get down the Snowlab shaft. Snowlab is contributing a new veto for that future run.

Comments

- No significant issues were identified with the veto. Because it can only be used for the run in the NuMI tunnel, resources devoted to the veto should be limited to the minimum required for adequate operation at NuMI.

Recommendations

- None

8. Acoustic Sensors

Findings

- Acoustics sensors on the 4 Kg chamber are operating very well and yielding excellent information on the acoustic signal accompanying bubble formation. While interpretation of the results is still in progress, there's a good chance that the acoustic information will provide more than an order of magnitude rejection of alpha decays and help COUPP become a leading experiment for spin-independent as well as spin-dependent WIMP detection.

- The COUPP collaboration would like to obtain the same quality of acoustic information with the 60 Kg chamber. Once sensors are attached to a chamber, they cannot be removed, so the Collaboration would like to optimize the configuration before they are permanently attached to the synthetic quartz vessel. Issues include:

    1. Optimizing the number and placement of sensors while minimizing interference with camera views.
    2. Optimizing the gain of the sensors for the best dynamic range. The gain of a sensor cannot be adjusted.
    3. Eliminating sources of acoustic noise, such as leaky valves.

- The COUPP collaboration would like to test the sensors on the prototype vessel in a 2nd D0 run before attaching them to the high-quality synthetic quartz vessel for the NUMI run. While this work is a potential game-changer for the bubble-chamber approach, it is also an increase in scope over the Field Work Proposal.

Comments

- The larger size and different shape of the 60 Kg chamber will have an effect on the acoustic signals. A test on the prototype chamber will allow an extra step in the optimization of the sensor configuration, but at additional time and cost.

- A second run in D0 would add about 3 months to the schedule. About one month of this is specifically required for the acoustic sensor tests.

- The acoustic sensors can be attached in about a week. The collaboration could take their best shot at placing the sensors and test them once the device is in the NuMI tunnel.

Recommendations

- Develop a plan to quantify the alpha rejection efficiency.
- Develop an initial plan for the acoustic sensor configuration on the 60 Kg chamber.
- Evaluate the risk that this configuration will not function optimally, and could not be fixed by adding additional sensors (possibly leaving others without read-out).
- The risk of proceeding directly to the NUMI test, with sensors attached to the synthetic quartz vessel, should then be weighed against the risk that the FWP resources might not allow for both the 2nd D0 test and the NUMI test.

9. ES&H

Findings

- COUPP did not list any ES&H Liaison, either in PPD or in the ES&H section.
- An ODH analysis of CF3I was done for running in D0.

Comments

- The ES&H requirements for underground are likely to be more stringent than those at D0 and having an ES&H liaison assigned to COUPP could help them navigate the process for getting approval to run underground.
- The air handling in NuMI Underground may be very different from that in D0.

Recommendations

- PPD should appoint an ES&H Liaison to COUPP who makes sure that the reviews that are needed get done in a timely fashion. This liaison would attend regular technical meetings to help identify potential ES&H issues as early as possible.
- COUPP should start the ODH analysis for running underground in NuMI, to be prepared for any surprises due to the different air handling.
- COUPP should also work with the ES&H Liaison to make sure that the detector and all auxiliary components adhere to the restrictions on flammable materials (pipe insulation must have fire retardant, etc.) underground. These restrictions may be much tighter underground than at D0.

10. Schedule

Findings

- The schedule for bringing the COUPP 60kg detector underground has slipped since the May 11 review for several reasons. Some are technical (illumination problems, DAQ software, muon veto PMT electronics, etc.) and some have to do with scheduling resources appropriately (in particular, Russ Rucinski 's time and the availability of welders during the summer accelerator shutdown).

- Acoustic sensor testing was presented as an important new development that could be added to the 60kg program. The schedule impacts of adding those sensors were not clearly spelled out in the review.

- The overall goal of the Collaboration is to be underground in SNOlab in early FY11.

- The schedule that was presented shows the 60kg vessel going underground in April 2010.

Comments

- It is very hard to predict when various tasks in the schedule will be complete if the schedule has not been resource loaded, and then resource leveled.

- Schedule impacts of trying to integrate the acoustic sensors could be large.

- It is very difficult to evaluate if the detector will be ready for SNOlab by FY11. For example: does the detector have to perform at a certain level at NuMI with sensors before going to SNOlab? Or can it perform without the sensors below ground at NuMI but still have sensors added to it before going to SNOLab without testing?

- Forecasting future events is difficult with a schedule that is not an accurate reflection of what has happened so far.

- Two important tasks (acoustic sensor install and Illumination system install) are scheduled to occur simultaneously and require the same people. It seems unlikely that these tasks can really proceed in parallel.

Recommendations

- The COUPP project should load resources into the schedule, look at the resource needs versus time, and level those resources as best as possible.

- COUPP needs to keep PPD regularly informed of the upcoming resource requirements, and if necessary, adjust the schedule to match the resource availability as reported by

PPD management. This includes not only engineer and technician needs but also welding needs.

- COUPP should put appropriate constraints in its schedule that are due to external factors: for example, any future accelerator shutdowns will make welders and many technicians unavailable to COUPP.

- COUPP should come up with a clear game plan concerning tests of the acoustic sensors, with appropriate branch points based on test results. The following are examples of issues that should be thought as part of a branch point analysis:

    - What should the collaboration do if the acoustic sensors don't work the first time above ground on the 60kg prototype--should they try more sensors above ground with the prototype, but put the ultra pure vessel below ground without the acoustic sensors?

    - Should they delay putting the ultra pure vessel below ground until a configuration of sensors is found on the prototype vessel above ground?

    - At what point might the collaboration consider installing acoustic sensors on a detector that was already below ground?

- The schedule for COUPP should be updated to reflect the current status of the Project.

11. Management

Findings

- The COUPP Project is currently operating without funding. A Field Work Proposal (FWP) to install and operate the 60 kg detector in the NuMI tunnel has been received by DOE but has yet to be acted upon. The funding request for the FWP was $420k. Those funds are intended to cover the work that has already been done to this point as well as the remaining work of moving and operating the 60 kg device in the NuMI tunnel.

- There are many tasks that remain to be completed including preparations of the fluid handling cart, installation of the new illumination system and moving the apparatus underground. It was also proposed to attach a set of acoustic sensors to the vessel. The Project stated that the senior mechanical Engineer currently assigned to COUPP is required to accomplish all of these tasks.

Comments

- In spite of its small size, this is a difficult Project to manage because of the history and culture of the group and because of the transition from R&D to a Project. The Project

requires a full-time Project Manager who recognizes the challenges, is clearly in charge and wields his/her authority appropriately to accomplish agreed upon goals.

- Remaining in the D0 assembly area for an extended period of time raises the concern that COUPP may exhaust the funding that is expected to arrive for the Field Work Proposal without accomplishing the main goal of the FWP; to operate underground in the NuMI tunnel.

- Failure to accomplish the goals of the Field Work Proposal in a timely manner and on budget will have ramifications for future bubble chamber work as well as for the Lab's future R&D funding. Lab management is very sensitive to this. COUPP needs to take this issue seriously as well.

- PPD mechanical engineers are currently in high demand. Limiting the scope of their involvement to essential activities that require their engineering expertise is extremely desirable from the perspective of the laboratory management. It appeared that many of the tasks that the Senior Mechanical Engineer was involved with dealt with leadership, scheduling, operation, communication and supervision.

Recommendations

- The Project Manager should focus all of his efforts on this Project for the immediate future. COUPP is at a critical juncture where full-time, effective leadership is required.

- COUPP should do everything possible to expedite their core program to accomplish the scope of the Field Work Proposal. The acoustic sensors are an exciting extension of the detector's capabilities but they should not delay the move to the NUMI tunnel.

- The Project Manager should lead the effort to account for all resources used to date and to produce a resource loaded and leveled schedule that meets the Field Work Proposal objectives with the remaining funds.

- The COUPP project should try to get others involved and off-load many of the non-engineering tasks from the current Senior Mechanical Engineer's task list. This not only addresses the Lab's engineering shortage, but could also relieve some pressure on COUPP's budget if some of this work is shifted to off-project scientists.

12. Charge Questions

Base proposal

The reviewers should evaluate the technical progress of the baseline project and each of its systems. The systems include bubble chamber and mechanical systems, camera and illumination, DAQ hardware and software, and the veto. The evaluation should cover:

1. *Has the implementation plan presented at the prior reviews been completed?*

   No. The unexpected failure of the illumination system prevented a full test of the trigger and DAQ system. In addition, the high purity quartz vessel and the fluid handling system are not ready for integration with the hardware.

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

   No. A new illumination system must be installed and a second run in D0 is being planned to test the DAQ. In addition, the schedule includes a task to install acoustic sensors, not included in the baseline, in parallel with the illumination system. If these two tasks cannot really be accomplished in parallel then the current schedule, which does not have NuMI operations beginning until May, will be further delayed. Because the current schedule has not been resource loaded and leveled, there is a high probability that it is optimistic.

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?*

   The new illumination system is critical, but given the tests in the 4 Kg chamber and 50-gallon drum, the new design is likely to be successful. The fluid-handling cart is also critical. It must be completed and commissioned. The technical risk seems low but there is a schedule risk because of the welding issue. Finally, the DAQ system must operate for long time periods. There do not appear to be any technical issues that cannot be resolved but there is a significant schedule risk if the next round of testing is not successful.

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

   The critical path is determined by the replacement and testing of the illumination system followed by the high purity fluid cart. However, the schedule contains very little float, so any unexpected problem with any system could land it on the critical path.

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

   A welder is needed to complete the fluid cart. 1 Engineer week and 1 technician week are required to complete the veto system, though it was not clear why engineering resources were required for this task. A list of tasks required to complete the DAQ were presented but without a manpower breakdown. It is believed that a post doc will do most of the remaining work. 0.75 FTE of an engineer and 2 FTE of technicians will be required for several months for the mechanical work associated with installation of the illumination system, completion and commissioning of the fluid handling cart and installation of the high purity quartz vessel.

Additional Scope

The proponents have expressed interest increasing the scope of the project to include installation of acoustic sensors on the 60kg chamber prior to installation in MINOS. This would result in a second test run in D0 prior to installation. The committee is asked to evaluate this proposal.

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 larger size and different shape of the 60 Kg chamber will have an effect on the acoustic signals. The test on the prototype chamber will allow an extra step in the optimization of the sensor configuration.

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

   One week of technician labor, and one month of running time.

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

   The proposed work at D0 would take three months, of which one month is specifically for the acoustic sensor tests.

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?*

The extra work would 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.