April 30, 2017

Report of the Review on Cryogenic Instrumentation for ProtoDUNE Single Phase

April 26, 2017

CERN

1 Introduction

The committee was requested to meet to evaluate the design, status and schedule of the cryogenic equipment for the ProtoDUNE single-phase detector, planned for the operation at the CERN Neutrino Platform in 2018.
Four groups of equipment have been presented: temperature monitors, gas-analyzers, purity monitors, cameras to monitor the internal detector.
The committee was asked to address 10-item Charge questions and provide recommendations on each of the presented cryogenic equipment.
The large number of recommendations that have been put forward reflects the importance that, in the opinion of the committee, these cryogenic instrumentations have for the successful operation of the detector. They are also the outcome of the detailed discussions during the review meeting.

2 General comments and recommendations

The concepts for all of the cryogenic monitoring subsystems were presented. All of the systems still require significant work to complete the details of the design. As these designs progress, there has to be significant effort and coordination to integrate both mechanically and electrically with the overall TPC and cryostat systems. This needs to be completed as soon as possible as many of the TPC components are beginning construction. If any modifications and changes to accommodate the cryogenic monitoring equipment are required, these must be know at the latest by the end of June before shipment to CERN begins. Many of these subsystems require equipment on the roof of the cryostat. This space is currently being designed and is quite limited. Installation of items on the cryostat will begin in May or June. There is also an issue with the number of remaining available feed thru ports. All of the subsystem designs will need to pass through a design/safety review with CERN HSE before they are allowed to be installed in EHN1.

Measurements of the pressure and liquid argon level, fundamental for the correct operation of the detector, are not among the reviewed equipment, because these will be provided by third parties. The committee did not receive any information about the requirements and their fulfillment. Suggestion is ensure that the pressure and level measurements have the sufficient redundancy for a safe detector operation: (e.g.: possibility to add one absolute pressure sensor and denser RTDs at around the liquid level; capacitive-meter is an option too).

No monitor for particulates in Liquid Argon is foreseen. This function is indirectly performed by measuring the pressure drop on the argon filters.

For all the four groups of equipment, when the Grounding and Shielding information is clarified, a review with the ProtoDUNE Grounding and Shielding Committee need to be scheduled by contacting tshaw@fnal.gov.

3 Temperature monitors

3.1 Findings:

1) Three types of temperature monitoring systems are to be implemented – two types of profile measurements and one to measure various points on the cryostat. All aiming at few mK accuracy.

2) The requirements are clear and, in principle, met by the chosen instrumentation.
3) Proofs of the experimental method is achieved.
4) A thermal simulation of the Temperature Gradient Monitors, both Hawaii and Valencia types, have still to be done (including LAr convection).
5) No temperature sensors are presently foreseen on the detector structure.
6) Compatibility with grounding and noise requirements is still to be verified.
7) Details of installation procedures are still to be developed.
8) Integration in the slow control system is still largely undefined.
9) In general the choice represent a good solution towards DUNE.

3.2 Comments:

1) The design of the movable profile device seems very complicated and makes use of motor to be mounted on top of the detector.
2) No simulation showing that the supporting/shielding structures are not perturbation the measurement of the temperature gradient.
3) Choice of instrumentation, the design, procurement and production schedules seem adequate to the detector general requirements.
4) Integration with the detector, especially for cabling and grounding needs to be prioritized in view of the early installation of the sensors laying on the bottom of the cryostat.
5) The choice of 100 Ohm is not yet definitive. There are advantages in increasing the resistance at least to 1k. Check this option.
6) Bellows may be a source of potential leak. Lacking any details. Need a plan for risk mitigation.
7) Sensor PCBs are long because the probe must sense the temperature of liquid argon, and not being biased by the temperature of the surrounding material. Where the field is high, reducing this dimension may be critical. Evaluate the minimum distance with CFD computations.
8) Details of the mechanisms how to fix the bottom of the pillars are not defined.
9) This is critical (for instance for the safety of the wires). Design, fixation and tests must be done soon.

3.3 Recommendations

1) Mechanical space requests must be submitted to the project team soon so that proper planning can be done.
2) Perform thermal simulation to verify that the design is appropriate.
3) The Collaboration is encouraged to revisit the decision to avoid temperature probes on the detector structures.
4) A full thermal analysis of the Temperature Gradient Monitors should be performed by end of this summer and the results discussed within the Collaboration.
5) A demonstration that the movable solution works as expectation is required for Hawaii Temperature Gradient Monitors and alternatives to

the bellow should be considered. Alternatively, the static solution for both Temperature Gradient Monitors should be considered.

6) 3D computation of the field in the structure is required to be sure that no point exceeds the maximum allowed value.
7) Define the installation procedure so that it is viable with all the constraints form the other detector components and the facility (for instance the crane height).
8) Cable support is not defined and must be discussed with GTT and co.

4 Gas Analyzers

4.1 Findings:

1) No budget is presently allocated for the Gas analyzers system.
2) Gas analyzers are commercially available devices in the appropriate sensitivity range.
3) The design of the system is evolved from the previous experience with MicroBooNE and the 35T prototype. As such the system, largely based on commercial devices is well understood and suited to the requirements.
4) Procurement is compatible with the general detector schedule.
5) Installation has no impact on the detector assembly schedule.
6) Possible interferences with detector operation have still to be verified.
7) Grounding schemes have to be discussed and consequently defined.

4.2 Comments

1) The system is adequate and well understood and the system appears to be an adequate evolution towards DUNE.

4.3 Recommendations

1) The in-line gas analysis system appears to be mandatory at least during detector purging, filling and commissioning to guarantee that the Argon quality is at any time within specifications. Investigate a way to procure at least a system, which ensures the minimal set of measurements.
2) Integration with the cryogenics system slow control is recommended.
3) Alarms and control points need to be discussed and defined in collaboration with the persons responsible for the cryogenics and purification systems operation.
4) An impact study of Gas analysis system operation at the conditions foreseen for DUNE should be done as part of the experience of operation on ProtoDUNE.

5 Purity Monitors

5.1 Findings:

1) Solid design relies proven on devices successfully working on previous experiments.
2) A purity monitor in line with the main purification system was foreseen but not in the present layout due to cost of cryogenic vessel and equipment.
3) The technology is well established.

4) Requirements are well defined and met.
5) The design is complete and the operation of these devices well understood.
6) Procurement is already partially done and compatible with detector installation.
7) The path towards DUNE is also clear and adequate.
8) Integration in the slow control system has still to be defined.
9) Grounding scheme has still to be discussed and defined.
10) Interference with detector operation has to be verified.

5.2 Comments

1) The design as presented included a ground loop, which is not acceptable. The HV connections and the readout design electronics must be documented and reviewed.
2) There is a concern about the missing PM in line with the purification system, as this would be possibly the way to monitor the efficiency of the Purification system.
3) Not clear how to understand how it is monitored if the purification cartridge is exhausted.

5.3 Recommendations

1) Consider the possibility to invest in the external purity monitor, which would provide useful information during filling/ commissioning and to monitor filter purification efficiency.
2) Installation of valves on the ports already foreseen for the installation of an external purity monitor is warmly recommended. This would allow the installation of external devices at any moment.
3) Integration with the Gas analyzer response and with the cryogenics and purification control system is also recommended.

6 Cameras

6.1 Findings:

1) Design is derived from that of the 3x1x1 Dual Phase detector:
2) Adaptation to the Proto-DUNE case is ongoing with the 35 ton detector at FNAL as playground.
3) The challenge to make the cameras working reliably at LAr temperature is evident and progresses are present. Schedule is tight.

6.2 Comments

1) The camera system implemented in the 35T HV test included multiple “last minute” design changes to the camera unit (heaters added) and the cabling. Engineering short cuts were taken to make the system work just prior to installation at 35T HV test. “Spare” grounds were re-purposed perhaps to the detriment of the system design. Two out of six cameras have failed at 35T. If a camera is required, engineering resources should be allocated to produce a camera system likely to work well at ProtoDUNE.
2) Many details missing e.g. about hanging system and lighting system too.

6.3 Recommendations

1) Engineering resources should be allocated to produce a camera system, which will work well at ProtoDUNE.
2) Devote a lot of effort to complete the design, working in close contact with the DP groups. An additional internal review is possibly needed before the end of the summer, for a final decision on the use if cameras in the SP cryostat.

7 Answers to charge questions

1) Does the Cryogenic Instrumentation design meet the requirements? Are the requirements/justifications sufficiently complete and clear?
   Partly:
   Temperature monitor – Yes;
   Gas analyzer – Yes if at least one system will be made available;
   Internal purity monitor – Yes;
   External purity monitor – Yes, but currently not in the project plan;
   Cameras: – No, need to prioritize and develop a plan.
2) Does the design represent a good development path towards DUNE?
   Yes, most of the elements can be scaled up or the quantity increased to satisfy DUNE.
3) Does the design lead to a reasonable production schedule, including QA/QC, transport, installation and commissioning?
   Yes, for everything except for the camera system.
4) Is the installation plan sufficiently far advanced to assure that the detector can be installed as designed?
   Most of the designs have NOT been completed. Once these are complete they must be electrically and mechanically integrated in the overall experiment and EHN1 infrastructure.
5) Are all internal interfaces between components (cryostat, cryogenics, TPC) documented, clearly identified and complete?
   The integration of the components with the TPC, cryogenic piping and facility has NOT been defined.
6) Are the interfaces with the slow control system well defined and understood?
   No, not yet defined.
7) Is the grounding and shielding of the Cryogenics Instrumentation understood and adequate?
   No, all of the items need to be electrically integrated and must be reviewed by the grounding and shielding committee.
8) Are operation conditions (when will/can instrumentation be turned on) listed, understood and comprehensive?
   Partly, this is known for commissioning but not for the operation level.

9) Are the analyses of the Cryogenics Instrumentation components sufficiently comprehensive for safe handling, installation and operation at the CERN Neutrino Platform?

   Not yet. All of these designs must be completed and integrated with the experiment and EHN1 facility. Then they must be evaluated by CERN design and HSE before being approved for installation.

10) Is the Cryogenics Instrumentation quality assurance, quality control and test plan adequate? Have applicable lessons-learned from previous LArTPC devices been implemented into the device testing and into the system design?

   Yes, for everything except for the camera system. The camera design and engineering are not complete. If a camera system is to be installed, a prioritized list of locations in the cryostat must be created soon, so that the mounting and cabling can be developed.

DEEP UNDERGROUND NEUTRINO EXPERIMENT

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B. Indico sites of the Review

FNAL:
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