# 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.

# General comments

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.

Missing measurements of the pressure and a direct measurement of liquid argon level.  
Suggestion is to add at least one absolute pressure sensor and at least denser RTDs at around the liquid level. Capacitive meter is an option too.  
Cable derogation, mechanical safety approval, etc... move in advance  
Interlock matrix is missing and must be defined soon.

# Temperature monitors

## 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.

Comments

1. The design of the movable profile device seems very complicated and makes use of motors to be mounted on top of the detector.
2. Consider just one temperature profile design.
3. No simulation showing that the supporting/shielding structures are not perturbation the measurement of the temperature gradient.
4. Choice of instrumentation, the design, procurement and production schedules seem adequate to the detector general requirements.
5. 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.
6. The choice of 100Ohm is not yet definitive. There are advantages in increasing the resistance at least to 1k. Check this option.
7. Bellows may be a source of potential leak. Lacking any details. Need a plan for risk mitigation.
8. Sensor PCB are long because the probe must sense the temperature of liquid argon, and not being biassed 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.
9. Details of the mechanisms how to fix the bottom of the pillars are not defined.
10. This is critical (for instance for the safety of the wires). Design, fixation and tests must be done soon.

## Recommendations

1. When preliminary design information is available, please schedule a review with the ProtoDUNE Grounding and Shielding Committee by contacting [tshaw@fnal.gov](mailto:tshaw@fnal.gov).
2. Mechanical space requests must be submitted to the project team soon so that proper planning can be done.
3. Perform thermal simulation to verify that the design is appropriate.
4. The Collaboration is encouraged to revisit the decision to avoid temperature probes on the detector structures.
5. A full thermal analysis of the Temperature Gradient Monitors should be performed by end of this summer and the results discussed within the Collaboration.
6. A static solution for both Temperature Gradient Monitors is recommended unless major motivations from thermal simulations are found.
7. Procedures for installation have to be defined not later than end of July 2017.
8. 3D computation of the field in the structure is required to be sure that no point exceeds the maximum allowed value.
9. 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).
10. Cable supports is not defined and must be discussed with GTT and co.
11. Integration in the general installation planning should be done not later than end of July 2017.
12. The definition of the integration in the slow control system has to be finalized by end of 2017.

# Gas Analyzers

## Findings:

1. Gas analyzers are commercially available devices in the appropriate sensitivity range.
2. 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.
3. Procurement is compatible with the general detector schedule.
4. Installation has no impact on the detector assembly schedule.
5. Possible interferences with detector operation have still to be verified.
6. Grounding schemes have to be discussed and consequently defined.
7. No monitor for particulates is foreseen. This function is indirectly performed by measuring the pressure drop on the argon filters.

## Comments

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

## Recommendations

1. Integration with the cryogenics system slow control is recommended.
2. Alarms and control points need to be discussed and defined in collaboration with the persons responsible for the cryogenics and purification systems operation.
3. 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
4. Make sure to get approval for the fabrication drawing and the Interface Control Documents. This issue also applies to the FC design.

# Purity Monitors

## 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 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. Installation of an external purity monitor is foreseen but not fully implemented in the present cryogenics layout.
7. Procurement is already partially done and compatible with detector installation.
8. The path towards DUNE is also clear and adequate.
9. Integration in the slow control system has still to be defined.
10. Grounding scheme has still to be discussed and defined.
11. Interference with detector operation has to be verified.

## 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. The use and need of internal purity monitors during detector commissioning is quite clear while their use during detector operation is still to be defined.
4. Not clear how to understand how it is monitored if the purification cartridge is exhausted.

## Recommendations

1. When preliminary design information is available, please schedule a review with the ProtoDUNE Grounding and Shielding Committee by contacting [tshaw@fnal.gov](mailto:tshaw@fnal.gov).
2. Consider the possibility to invest in the external purity monitor which would provide essential information during filling in case of unexpected LAr purity in the ProtoDUNE cryostat.
3. 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 adequate external device at any moment.
4. Integration with the Gas analyzer response and with the cryogenics and purification control system is also recommended.
5. Procedures for installation have to be defined not later than end of September 2017.
6. Integration in the general installation planning should be done not later than end of September 2017.
7. The definition of the integration in the slow control system has to be finalized by end of 2017.

# Cameras

## Findings:

1. Design is mutuated by that of the 3x1x1 double Phase detector.
2. Adaptation to the ProtoDUNE 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.

## 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. Explore options to work with ProtoDUNE-DP.
3. Many details missing e.g. about hanging system and lighting system too.

## Recommendations

1. When preliminary design information is available, please schedule a review with the ProtoDUNE Grounding and Shielding Committee by contacting [tshaw@fnal.gov](mailto:tshaw@fnal.gov).
2. Engineering resources should be allocated to produce a camera system which will work well at ProtoDUNE.
3. Devoted 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.

# Answers to charge questions

Does the Cryogenic Instrumentation design meet the requirements? Are the requirements/justifications sufficiently complete and clear?

Does the design represent a good development path towards DUNE?

Does the design lead to a reasonable production schedule, including QA/QC, transport, installation and commissioning?

Is the installation plan sufficiently far advanced to assure that the detector can be installed as designed?

Are all internal interfaces between components (cryostat, cryogenics, TPC) documented, clearly identified and complete?

Are the interfaces with the slow control system well defined and understood?

Is the grounding and shielding of the Cryogenics Instrumentation understood and adequate?

Are operation conditions (when will/can instrumentation be turned on) listed, understood and comprehensive?

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

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?