ProtoDUNE Single Phase Electrical Connections and Grounding 25–26 September 2017

Review Team

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Review Home Page

https://indico.fnal.gov/conferenceDisplay.py?confId=15134

Agenda

https://indico.fnal.gov/conferenceOtherViews.py?view=standard&confId=15134

Charge

The Committee is requested to review the ProtoDUNE-SP detector plan for electrical connections and grounding and determine if it is sound and that the plan for testing the connections is sufficiently robust and complete. The committee is asked to review the TPC and Photon signal connections, the APA bias connections and the HV connections from the HV power supply, through the filters, feedthru, CPA, FC and APA (and beam plug) to detector ground.

Charge Questions

In particular, the review team is asked to address the following questions:

1. **Is the electrical connection plan for the complete "DRIFT" HV system well understood, documented and robust? Is the plan for assuring near term and long term stability of the connections sufficient?**

Yes - The HV electrical connection plan is complete. We only had one comment related to the two screws which attach the HV cup. See page 6 of https://indico.fnal.gov/getFile.py/access?sessionId=2&resId=0&materialId=0&confId=15134 This point should be made more robust.

2. **Is the plan for assuring connections on the HV subsystems (filters, feedthrus, HV cup, CPA bus, CPA, Top/Bottom FC, End Wall FC, beam plug and APA) sufficiently well developed? Is the plan for assuring connections between subsystems (CPA-T/B FC, CPA-EW FC, T/B FC-APA, EW FC-APA, EW FC-beam plug, beam plug-ground) sufficiently well developed? Do written procedures exist to insure these connections are all properly made and tested during installation?**

   Yes, there is a connection plan for these subsystems. However, a written procedure for the installation and a checklist for all connections should be generated by all the subsystems. The CPA system presented such procedures and can be taken as an example.

3. **Are all system and subsystem ground connections sufficiently well understood and documented? Are there any critical single point failures?**

   No - Line drawings showing the interconnections do not exist for some subsystems. There are schematics for the Field Cage and CPA connections, although it was indicated that they needed some updates. Schematics for the Cold Electronics and the Photon Detector system were presented; however, an overall line drawing should be produced. Cryo Instrumentation must produce line drawings for the Purity Monitor and the Hawaii Temperature Profile Gradient system.

   Some critical points of failure do exist like the connection to profile #5 of the beamplug. Redundancy is sometimes difficult to achieve due to mechanical space limitations. The field cage and CPA seem to have a sufficient level of redundancy.

4. **Is the electrical connection plan from the bias voltage supplies through the feedthrus and to the APA, FC terminations, and Electron Diverters well defined, documented and robust? Is the plan for assuring near term and long term stability of the connections sufficient? Do written procedures exist to insure these connections are all properly made and tested during installation?**

   The electrical connections are well defined. For each plane there is one bias line. Long-term stability was not presented during this review. Written procedures for verifying the installation were not presented during the review.

5. **Is the electrical connection plan for the cold electronics readout from CR board to WIB and the QC to verify signal connectivity sufficiently well developed? Do written procedures exist to insure these connections are all properly made and tested during installation? Is the channel mapping well documented and understood by the DAQ?**

   The electrical connections plan was provided at the schematic level and is well developed. The QC plan to verify the connections is in progress. A plan should be developed which allows the team to trace the connection from the wires all the way through the FE readout.

Written procedures for verifying the connections after installation was not presented and were stated to be in development. These procedures should be written prior to the Cold Box testing which will start in a few weeks.

The channel mapping in the hardware and software was presented and seems to be well understood.

6. **Is the electrical connection plan for the photon detector readout from SiPM to SSP and the QC to verify signal connectivity sufficiently well developed? Do written procedures exist to insure these connections are all properly made and tested during installation? Is the channel mapping well documented and understood by the DAQ?**

   A clear cabling scheme was presented and the connection plan looks to be well developed. A QC plan to verify the connections was not presented during the review.

   A testing plan to verify the signal integrity was not presented during the review and should be developed prior to Cold Box tests which begin in a few weeks.

   The channel mapping is well documented but no integration mapping with the DAQ was presented.

7. **Is the electrical connection plan for the cryogenic instrumentation and more general slow control readout to verify signal connectivity sufficiently well developed? Do written procedures exist to insure these connections are all properly made and tested during installation? Is the channel mapping well documented and understood? Is the grounding understood and documented?**

   This review focused on cryostat internal connections so the connections to slow control were not focused on in detail. The Valencia temperature readout did, however, present a developed plan. The Purity Monitor system and the Hawaii Temperature Gradient system must more fully develop the “warm” connections to slow controls.

   Written procedures to insure proper connections during installation were not presented during the review.

   Channel mapping schemes were not presented during the review. A schematic for the Valencia Temperature Gradient system, however, was shown.

   In general, the grounding was well understood. However, the Hawaii Temperature Gradient system grounding, especially related to the motor connection, was not clear. This needs to go to the grounding and shielding committee. In general, the documentation should be improved.

Findings, Comments, and Recommendations

Global

Findings:

All teams did a significant amount of work to prepare for this review. The committee thanks those who participated.

Comments:

- Electrical connections using 'fork' type lugs should be of a hook-type design for a secure connection.
- Redundant wires should be used wherever possible to eliminate single points of failure.
- All wire connections must provide a slack in jumper cable connections for thermal contraction.
- Sub-detector groups should provide termination connectors for noise abatement studies. This is sometimes referred to as a "shorting plug" and is basically a connector which allows the grounding of all wires not required for testing a specific subsystem feature.

Recommendations:

- Line drawings of the power distribution and related ground connections are required for understanding the grounding and must be generated for each sub-system. Information on the physical connections and routing is needed to evaluate whether ground loops exist.
- The ground symbols (Detector and Building) used by the various groups should conform to the convention recommended by the grounding and shielding committee DuneDocDB#879. Circuit Common symbols (inverted triangle) should be used to indicate individual card ground plane references. The location of the circuit common connection to detector ground should be indicated.
- Written installation checkout procedures must be generated and placed into the DUNE DocDB.

Beam Plug

Findings:

A brief overview of the system was presented which highlighted the Beam Plug resistor network, current monitoring circuit, and N2 Gas System. The resistor mechanical mount testing procedure has been developed and will be used for the production build. Electrical connection procedures for the Beam Plug were presented. Electrical connections for the Profile and Metal Endcap were described. A description of the final electrical connection continuity check list was provided. The external N2 Gas System and current monitor interface to DCS is in progress.

Comments:

- The beam plug electrical and grounding connections have been presented in a clear and complete way. Even if documentation is not in place yet, a plan for testing both the single components and the whole system during and after installation is clear and appears adequate. Being the first time such a system is used in a LArTPC, previous tests done in Blanche and current test performed with the 35 ton at Fermilab will be of extreme importance to validate the system and guarantee the near term stability of the mechanical and electrical connections.

Results from the 35T test should be carefully looked at, to address, in time, potential hidden flaws in the system (like single-wire connections).

- A Teflon coated stainless steel braid covers the N2 gas hose. The cut edge of the braid should be covered with heat shrink to cover exposed braid strands. The jumper wire between the current monitor board and the SHV flange pin is a bit taught. Rotating the lug such that the wire direction out of the lug is directly toward the destination pin would allow for thermal contraction without putting stress on the termination.
- The N2 Gas System uses a 0-100mV Pressure Transducer. Consider a transducer with a larger maximum voltage, perhaps 0-5V, similar to the Gas Flow Monitor. Low signal devices can be noise sensitive. Be mindful of the Gas System enclosure mounting structure.
- Include the current monitor connector part number. The use of a male SHV connector on the warm side and pin on the cold side wasn't clearly identifiable. A Bill of Materials, including all part numbers of the system, would be useful.
- The Slow Controls interface has been started but the power supply reference and cable shield treatments have not yet been well defined.
- Consider a redundant connection to Profile #5.

Recommendations:

- Continue working on the Slow Controls interface and mapping.
- Schedule a review of the grounding of the Warm frame elements and warm cabling with the Grounding and Shielding Committee (contact - tshaw@fnal.gov).

Ground Planes

Findings:

The HV current path in present 35T is not well understood. Current spikes are seen at the power supply and the supplied current does not equal that at the anode. Thus; there has been a recent decision to implement a soft ground to the ground planes in order to monitor "streamer" currents. Twelve channels of readout will be implemented; six from the top and six from the bottom ground plane segments. Note that the six top and six bottom ground planes segments are all interconnected, so that the readout channels will be in parallel.

This has been demonstrated at the 35T.

Comments:

- Group is negotiating with cryo controls to share cable try to bring signals out.
- Group is negotiating for studs on membrane floor for bottom ground connections.
- It was noted that "signal" wire could also provide a direct ground connection is needed.

Recommendations:

None

CPA

Findings:

A complete plan was presented with many references to additional information in Dune DocDB. Because of the size of the CPA, the cold tests performed so far have only been on portions of the CPA. Resistivity tests show that cold cycling does not appear to loosen any electrical connections. Mechanical connection hardware makes extensive use of Belleville or lock washers.

Comments:

- Think about way to test the uniformity of the field. It was suggested to try injecting a fast pulse and then to look at the electronics response.

Recommendations:

- Review the two screw connection of the HV cup to the steel tube/brass plate combo; insure that this is a sufficient mechanical and HV connection.

Field Cage

Findings:

The plan for the construction of the field cage and mounting of the resistor divider boards was presented in some detail. The QC plan for the resistor divider boards was presented along with links to additional information in DUNE DocDB.

Comments:

- Extensive documentation for single part tests, assembly procedures, installation and pre- and post- installation procedures exists. Both within the field cage element, and in the field cage connection to APA and CPA, the presence of multiple components in parallel and fail-safe elements minimize the risk of single-point failures. Care has been taken in avoiding ground loops.
- One part that seems not to have received the same high level of care as the rest of the system is the stress test of the mechanical and electrical connections to the CPA. That has been reduced to a single-time cold cycle. Given the extensive use of wire connections in the full system, both for grounding and high voltage delivery, it could be worth it to plan a test involving several cold cycles of wires and wire connections to test their effective mechanical and electrical stability.

Recommendations:

None

APA CR and FE Adapter

Findings:

The cold electronics and APA ground point is at the electronics flange. The APA frame is grounded through the cold electronics power return.

The wire bias voltage is referenced to the APA frame with two bolt connections.

The ground connection to the APA is well established with multiple connections through the electronics.

Comments:

- In general, there are a large number of interconnections and the information is distributed in many files. If there is any way to make a document that covers all connections in one place it would be helpful. Possibly taking a single/few wire(s) and tracing it/them through the connector chain may provide a cross check that all of the interconnects are correct. Such a document will help future reviews.
- The APA bias lines are single points of failure for the APA. One could look at a means to add redundancy here. This may be difficult to implement now.

Recommendations:

- As the presentation did not take place at this review, the Grounding and Shielding Committee should request that the presentation be given to them for review.

Cold Electronics

Findings:

The cold electronics system has recently been installed on APA-1 and read out successfully. The noise levels cannot be evaluated as the system has only been operated outside a faraday cage, but plans exist to begin testing in a low noise environment soon.

The data format and communication with the DAQ has been tested successfully in a vertical slice test at CERN.

Several channels of one FEMB were damaged during installation and the group is modifying the procedures to reduce the ESD risk.

Comments:

- An independent means of verifying the cable map should be developed and tested as part of the electronics installation. The measurement of the noise pattern looks reasonable but it does not verify the exact map.
- The DAQ integration test should be repeated with the final WIB and electronics operational to confirm the DAQ integration is complete.
- The CE group should continue to monitor the electronics for damage and adapt the procedures if needed to eliminate any damage from ESD.
- The LV filtering on the PTC should be studied and optimized.

Recommendations:

- A plan for studying the ground/Bias connections and optimizing the system noise in the faraday cage (cold box) should be made.
- The grid wires should be grounded during all operations when the wires are exposed.
- The BIAS connectors should normally be grounded during installation to insure the wire potential is kept at ground.
- A plan for studying the system noise and optimizing the system inside the detector should be made. (switching systems on one by one, disconnecting cables …)

Photon Detector

Findings:

All connections between the photon readout and the DAQ are via fiber optic cable and are therefore isolated.

A cable-labeling scheme was presented to uniquely identify the SiPM cables.

The SSP has been redesigned to reduce noise generated from the DC-DC converters, which coupled to the preamplifiers.

Comments:

- The SSP has several options for optimizing the ground connections to reduce noise. A plan for testing the system should be developed and agreed upon with the ProtoDUNE-SP installation group.
- A plan for testing the photon detector after the APA are installed in the detector should be developed.

Recommendations:

- During the Cold Box tests, it is required that the system be checked for any signal induction between the SiPMs and the charge readout of the TPC.

Purity Monitor

Findings:

Modifications to the design based upon the suggestions of the Grounding and Shielding Committee review were presented. All internal electrical connections were described. A preliminary checkout procedure was described.

Comments:

- A clear plan for testing all the connections and grounding during and after installation exists. However, it should be formally documented and placed into DUNE DocDB. Grounding of the system inside the cryostat appears to be correct. The grounding scheme outside the cryostat should be fully developed and documented. Cold tests of the planned configuration should be performed or documented to validate the electrical and mechanical stability of cathode, anode and anode grid connections.
- Quartz fibers are extremely fragile. Not clear which precautions, if any, have been adopted to prevent damaging them during installation, faraday cage insertion and PM deployment inside the cryostat.
- The braid jumpers between the coax and the flange should be more robust. A floating power supply has been adopted to bias the purity monitor. A complete DC distribution schematic should be drawn, explicitly indicating the ground connections of the bias, if any, within the Purity Monitor Electronics Type 2 unit.

Recommendations:

- Insure cold tests are completed to verify robustness of all electrical connections.

Temperature (Valencia)

Findings:

The plan for temperature sensors is well developed and documented.

Comments:

- Current switch may reverse polarity every 10 seconds; require verification that this does not contribute to system noise.
- It would be useful to have shorting caps for d-dub connectors at the flanges. This will allow one to do a "quiet" test with no noise contribution from RTD readout.
- Establish a readiness procedure for sign-off after installation in the cryostat.

Recommendations:

None

Temperature (Hawaii)

Findings:

This system seems to be in the initial design phase. It would be useful to have a presentation of this system to the Grounding and Shielding Committee before much more work is done.

Comments:

- See above

Recommendations:

- Design needs be further developed and to be submitted to the Grounding and Shielding Committee