**APA Preliminary Design Review QA and QC Plan**

Purpose and Scope:

Key requirements of this plan incorporate what we have learned from protoDUNE. This provides for confidence in our Quality Assurance plan for DUNE.

APA requirements consist of:

* Flatness of APA suport frame
* Laser survey performed on bare frame to show amount of bow, twist and fold
* Confirm electrical contact between the mesh sub-panels and APA support frame
* Component inspection and QC checks
* Wire tension measurements
* APA visual inspection
* Cold cycling

This QA/QC plan outlines the critical components that require inspection and test.

Inspection and test are performed in accordance with approved procedures. Procedures include acceptance criteria and are utilized throughout all production sites so that there is consistency in the APA assemblies.

1. **What component is being inspected or tested?**
2. Pins and sockets
3. Printed circuit boards
4. Frame planarity
5. Flatness and wire spacing
6. Wire tension
7. Channels
8. APA assembly
9. **Describe the inspection or test.**
10. Pins and sockets – Tests of pins and sockets will be conducted using representative boards and stacked structures.

1. Insertion forces and withstand forces will be measured with sample sizes of 100 pins and 100 sockets to gather adequate statistics. Total number of devices tested: 200

2. Pin and socket mating forces will be measured with sample sizes of 100 for each of two possible combinations: pin-to-pin and pin-to-socket. Total number of devices tested: 200

3. Electrical tests will be performed with groups of 100 mated pin-and-socket combinations configured in representative board structures. Tests will involve cycling boards to LN2 temperatures and measuring the combined resistance of series-connected pin and socket combinations. Temperature cycling will be repeated five times for five different board-stack structures to demonstrate the repeatability of the tests and gather sufficient statistics. Total number of devices tested: 500

1. Printed circuit boards
2. All boards will be inspected when received to assure conformance to specification
3. Complex mechanical features are to inspected to insure they are within specification
4. Manual inspection of printed circuit boards is now required
5. Vision systems are being evaluated as automated board inspection to replace manual inspection
6. Frame planarity
7. Detailed mechanical studies of frame distortions will be performed for different bending modes (twist, bow, fold)
8. Frame planarity (twist limit) < 5 mm
9. Flatness and wire spacing requirements - Wire plane spacing is very important to ensure transparency of the different layers.

* Flatness and wire spacing requirements are required: the tolerance of both is +/-0.5 mm, which translates to requirements on the mechanical positioning of the wire boards and on the flatness of the APA frame.

1. Wire tension - The wire tension requirements has been recently changed to 6+/-1 N to decrease the risk due to tension relaxation
2. Small sample of wires are to be measured before and after cold test

(F) Channels are to be checked for missing/unreadable channels

1. Number of working channel requirement is > 99% (continuity, isolation, tension)

2. Requirement is <1%, with a goal of <0.5%

(G) APA assembly inspection and test

1. Unpack the APA and visually inspect
2. Survey APA flatness and measure plane spacing
3. Measure wire tension and wire continuity/isolation

A. Current plan with laser method: 10% wires have tension measurement

B. Alternative plan with electrical method: 100% of wires are measured (preferred and currently under investigation)

4. After integration with cold electronics and photon detectors, the APA is inserted in a cold box

5. Once the cold electronics and cables have been installed, we cannot really assess the quality of the wires alone anymore (e.g. cannot measure tension with the electrical method)

6. Cold tests of the electronics inform the state of wires

7. Noise measurement in cold could inform on wire tension. Studies are currently undergoing about using cold electronics output to correlate to tension.

1. **Where is the location of the inspection or test?**
2. Component site
3. Assembly site
4. Warehouse site
5. Cavern clean room
6. Cryostat final position
7. Assembly site
8. Assembly site
9. Assembly site
10. Assembly site
11. Assembly site
12. Assembly site
13. Cavern clean room
14. **What is the technical justification of the inspection or test?**

(A) Inspect mechanical and electrical quality of all pins and sockets

(B) Inspect mechanical and electrical quality of printed circuit boards

(C) APA transparency. Ensures wire plane spacing change of <0.5 mm

(D) Enables 100% efficient MIP detection, 1.5 cm yz vertex resolution

Interplane electron transparency; dE/dx, range, and MCS calibration

(E) Assure quality of measurement by wire tension requirements

(F) Reconstruction efficiency to ensure > 99% working channels

(G) Assure quality of completed APA assembly after shipment