APA 60% design review

Responses to committee questions

1) **Please supply a summary of open design questions and schedule to address them (APA Diverter, Conduit, Mechanical interfaces to CE boxes, support of the cable strain relief, etc….).**

A. Electron diverters: A draft charge for a Task Force has been agreed with input also from Physics Coordination for a small group of analysis and hardware experts to summarise what is known and what has been found on protoDUNE data with EDs fitted / not fitted / at nominal voltage / at other voltages / not powered, and also the resource / schedule / risk aspects of having EDs in the FD or not. It should be noted that these would be different designs from protoDUNE owing to the larger gaps and having two gap sizes in the FD. We expect to have a report around mid-May and then we as a consortium will make a proposal and submit it to the TB.

B. CE cables conduit, its exact design and features and its installation procedure (at the factories or during integration, with APA horizontal or vertical). This is now open again following the recent change in integration plan with no surface ITF facility. Extensive testing at Ash River will be done to qualify the final solution, starting with the two available side tubes. Ash River tests with the two frames will start in June so the time scale for closure on this matter is around mid-summer.

C. CE boxes brackets/clamps, installation tools, fixings etc. Our existing design will be tested in the BNL setup, both for the top head tube and the bottom one, and that may lead to some modifications. The SHV board location, and the possible interference with the PD cables, will be tested in the BNL setup. We will probably be able to close this by the end of summer.

D. CE cable strain relief and its support. We intend to have a final solution designed by mid-June and test it at Ash River in the summer.

2) Please provide a justification for the dimension of the gap between the wire planes.

Ever since the LBNE LArTPC design, the APA wire pitch has hovered between 4.5mm and 5mm to balance position resolution, SNR, channel count, ease of fabrication. Following the design of ICARUS/MicroBooNE, where the wire pitch and wire plane spacing are equal (3mm), we chose 3/16” (4.76mm) as the wire plane spacing as it is a common PCB thickness for the head wire boards.

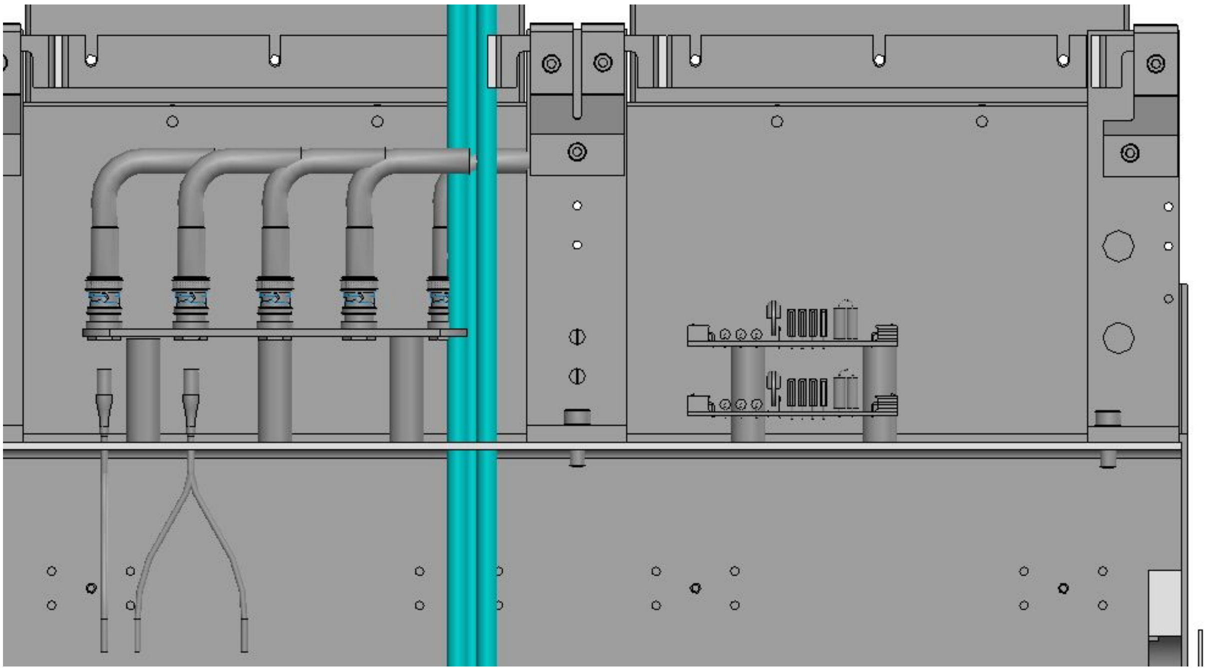
There is probably not a clear cut optimum for having a square wire cell in a LArTPC. But having a much smaller wire plane spacing with such a large APA frame would demand a tighter frame flatness tolerance which may not be practical/economical. MicroBooNE had issues with wire planes shorting out. SBND has a very elaborate frame design to ensure flatness is maintained. With a smaller wire plane spacing, each wire plane provides less of a shielding effect to the wire layer below, resulting in less induction signal, and long leading edge current waveforms. On the other hand, having a larger wire plane spacing will necessitate increased wire bias voltages to maintain electron transparency, leading to larger and more expensive capacitors, and more crowded circuit boards. Increase in wire plane spacing will also make the wrapping boards cantilever out even further, increases their deflection under wire tension.

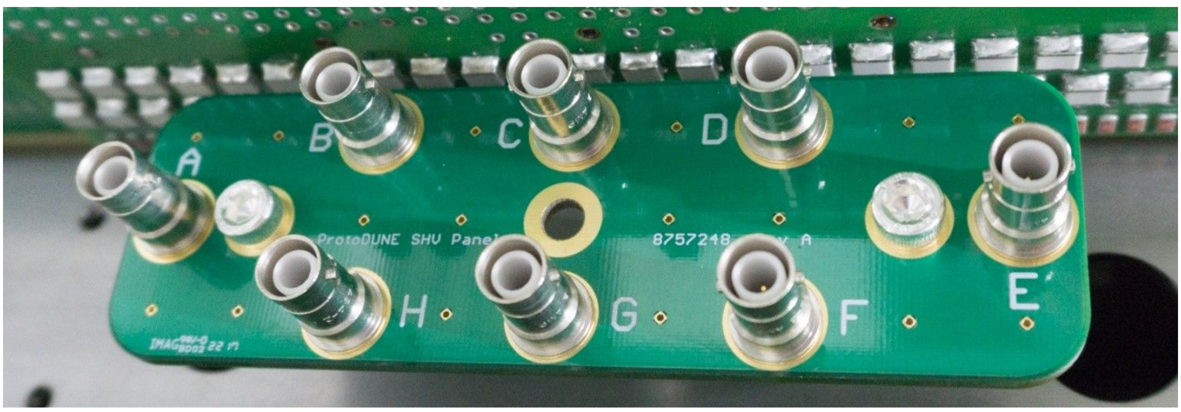
3) Can you provide a list of documents that don't yet exist in EDMS (e.g. adapter cards, G-Bias board) and what plans there are to provide them?

CE to CR adapter board - TBD
G-Bias board - TBD
Bare-board drawings - 1-wk (exist but not uploaded to EDMS)
Link attachment screw - 1-wk
Foot alignment pin - 1-wk
Field cage support assembly - 1-wk (exist but not uploaded to EDMS)
Cable guide/cable grip anchor - 3-wk

4) Could you please present a drawing of the region on top of the head tube of the upper APA where there is some interference between the SHV board and the photon detector cables from the upper APA ?

This picture was from Kyle last week showing a minor interference between the SHV panel on top of the APA head tube and the PD cables coming out of the APA head tube without bending. Obviously, the PD cables can be bent slightly to get around the SHV board, or, the SHV board can be shortened slightly by modifying the current SHV connector arrangement into a 2x4 pattern instead.





5) Can you provide torque specifications for the bolts and level of welding inspection that will be done?

Torque spec: generally torque values are called out in assembly procedures, we will review drawings and procedures for any gaps in the next two weeks and update as needed.
Welding inspection: Welds are certified to AWS D1.6/1.6M, additionally we call out lanthanated (non-thoriated) tungsten electrodes for GTAW.

6) Can you list the critical analyses of protoDUNE data for the completion of APA design and a timeline to complete them?

The main ongoing analyses whose findings will feed in the completion / confirmation of the FD APA designs are:

- Analysing dQ/dx for MIPs separately for APAs / regions of APAs with different wire tensions, and also looking at specific wires with out-of-average tensions, looking for possible performance / tension correlations.
- Same for tracking / pattern recognition efficiencies vs tension
- Same for shower / cluster average characteristics in different APAs
- Same for noise levels and stability in time
- Monitoring channel functioning in time (i.e. wires which change from normal operation to some problematic state or even the opposite, implying connection problems)
- Analysing the special data runs which are being collected at the time of writing with nominal / lower / higher wire plane bias voltages to understand the effects of that and also looking for different sensitivity of performance vs bias voltages for different wire tension areas.

Some initial findings have already been presented at the January 2019 collaboration meeting, our aim has been to freeze things in/around May.

7) Is there a document describing the cleaning of the assembled APA structure?

Our procedure is to clean all the stock before welding and then re-cleaned after machining. Then the assembly is kept clean going forward and not cleaned after frame assembly.
The basic procedure is below. PSL will provide an official cleaning document in one week.

DUNE Tube Cleaning

The stainless steel tubes for APA frames are first cleaned during incoming inspection. They are wiped with ethyl alcohol or a degreaser like Graffiti Remover if they are really dirty.

After machining, the tubes are cleaned thoroughly.

1. Check the machined features for burrs and remove any that remain with a file.
2. Use compressed air to blow out chips from the machining process.
3. Set up the PVC half-pipe near the washing station and place the tube into the PVC trough.
4. Sprinkle Alconox powder detergent on top of the tube and then add hot DI water until the tubes are over half submerged.
5. Use Scotchbrite pads to scrub the outside of the tube, turning to clean all sides. Pay particular attention to the hole and slot edges.
6. Use a nylon brush to go through the holes.
7. To clean the centers of the long tubes, use a block of foam cut to fit the inside of the tube that attaches to a long poles. Clamp a piece of Scotchbrite to the front of the foam and push that through the tube. Scrub back and forth as you go and repeat several times. The shorter tubes can be done with long handled brushes instead and just scrubbed vigorously.
8. Drain the water from the trough and rinse the tube with DI water.
9. Re-fill with hot DI and wipe the tube with a clean cloth everywhere.

10. Replace the Scotchbrite for the inside tube cleaning with a cleanroom wipe to wipe the inside. Repeat a few times until the cloth comes out clean. For the short tubes, put the wipe on the brush and wipe the inside.
11. Drain the water again and use Kimwipes to wipe off the tube.
12. Do a final rinse with hot DI and remove to air dry.

After welding, the tubes will need to be rinsed again. Follow the same steps as above, but due to the pads being welded on, cleaning the inside will be limited to what can be reached with brushes as the foam blocks will no longer go through.

8) Could you elaborate more completely on the tests that will be done on the complete board stack with the new pins?

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

9) Could you explain where the 10% boards out of tolerance come from? The committee feels this is quite high.

The percentage of defective boards varied by production lot. The most common defects involved machined mechanical features such as counter-bores and channels (controlled-depth milling). The dimensions of these features were often out of spec, probably resulting from inadequate tool maintenance or machine alignment. Less common defects included missing mechanical features, scratches, inadequate flatness, inadequate thickness control, and inadequate solder mask adhesion.

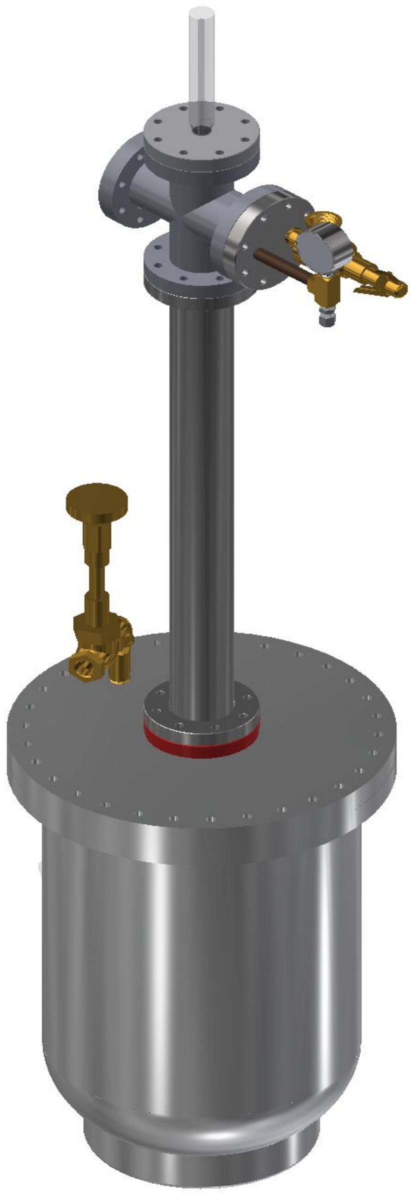
Some of our mechanical tolerances either matched or surpassed the stated capabilities of the manufacturer. We agreed to accept boards that met their stated capabilities, knowing that in most cases the results would be acceptable. As a result we expect to continue receiving some boards that do not meet spec, with past performance guiding our expectations.

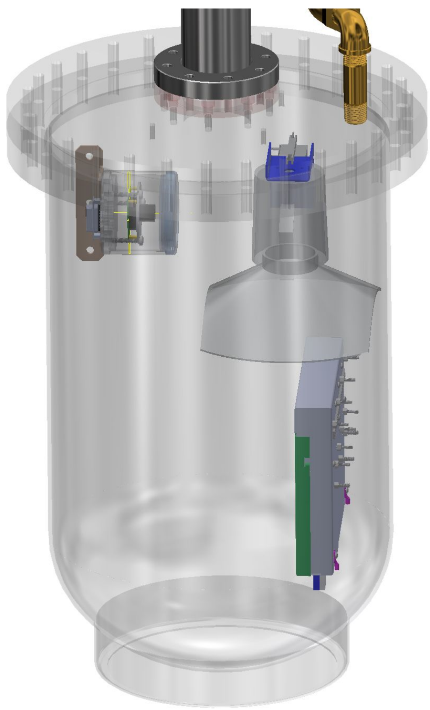
10) Could you provide further clarification on the bubble management strategy for the APAs?

At ~13m below the liquid argon surface, the bottom bank of CE is nearly at 3 bar absolute pressure. At this pressure, the liquid argon boiling point is about 10K higher than the actual liquid temperature of 87K. Boiling of LAr at this depth is much more difficult than that at the surface. It is very likely that we will not have a boiling problem for these electronics. To verify this, we are conducting a test using a specially constructed aluminum vessel with the current CE box, and a few reference heating elements inside, filled with LAr up to 30psig, submerged in an open LAr Dewar. A cold camera inside the vessel will record the amount of CE / heater's boiling as a function of the pressure, and power density. If no boiling is confirmed (with a comfortable margin) at expected power density of the new CE ASICs, we don't have to do anything to the current CE box / APA designs.

If boiling cannot be ruled out with this test, or cannot be mitigated by adding simple heat spreaders on the heating components, we'll have to proceed to implement features in the CE boxes, and the APA frame to direct the bubbles through the APA frames to the top of the cryostat. The current CE boxes already have a leak tight containment end to collect the boil-off gas. A small tube will be added to this end of the box to funnel the gas into the head tube of the bottom APA (Manhong has shown a design at the CE PDR). Andy has also increased the gap between CR boards to allow the passage of these tubes. The remaining tasks are to add features into the bottom APA's head tube to trap and redirect the gas into venting tubes embedded inside the center APA frame tube (both APAs).

PSL has build most of the pressure vessel. It has been welded by BNL. We are hoping to complete the remaining features in about a month and pass a pressure test required by BNL's pressure safety committee.





11) Has the team considered cold testing an APA in the inverted position in the cold box at CERN?

We will test the full procedure at CERN with a pre-production APA (transport frame and box rotation, Cold Box, and probably fitting one head down in the TPC). This will happen in Q1/Q2 2020.

We have also considered this already for APA 7 We may chose to do this or not depending on schedule and resources considerations:

We need to complete the design of APA cable trays and other head fittings for the inverted position, manufacture them, certify them according to CERN standards and then fit them. This would be done in any case for the FD.

We also need to design, manufacture and certify special attachment tools for attaching the APA in the transport box in such a way that it can be rotated by 90 degrees with the head down (we have the same for heads up that was used for protoDUNE, or to allow to rotate by 180 degrees starting from the APA hanging head up to head down. This will be a new procedure and all tools and devices specific for it.

The same applies to the accessories for hanging upside down inside the Cold Box.
One important thing TBC with the NP engineers is that the current box and the APA head down fixtures do fit in terms if dimensions, which we believe will not be a problem.

The latest plans from the CE consortium and the CERN NP team is that APA 7, already at CERN, will be removed from its transport box and hung in the Clean Room in June, so this test will be planned for some time in summer, giving us time to schedule the necessary design and construction work mentioned.