# DUNE Single Phase Detector APA Panel Assembly Preliminary Design Review (60% design review)

March 27−28, 2018

## Contents

# 1 Executive Summary

This document is the report of the Preliminary Design Review (60% Readiness Review) of the Single-Phase Anode Plane Assembly (APA). The review was held at the University of Wisconsin Physical Sciences Laboratory (PSL) on March 27-28, 2019 to determine if the existing design meets the requirements of the mechanical and electrical design as outlined in the DUNE Far Detector Design Review Plan (DocDB-9564). Material was made available to the Committee on the days immediately leading up to the review. The electrical design of the APA system was not documented and was not discussed in this review. A further review should be planned, prior to the start of the construction of the first complete prototype of a DUNE APA. During the first day of the review, the Consortium presented an overview of the APA mechanical design and the specifications based on DUNE physics requirements and experience from protoDUNE. The updated design of the APA structure, APA boards, and relevant interfaces was also presented with corresponding engineering analysis and QA/QC procedures was also presented. Finally, a plan for schedule and cost estimate including future prototyping was given with the plan for the production of 300 APAs by the end of 2026 was presented. The Consortium answered additional questions on from the reviewers and presented these answers on the second day. The early findings of the review were presented to the attendees during the closeout session.

In addition to this, an independent APA structural analysis was completed to verify that all engineering analyses are sufficient to ensure the design is safe during all phases, and have applicable design codes and standards have been satisfied. Result of APA structural analysis review are here: https://edms.cern.ch/project/CERN-0000196133 As stated in:

https://edms.cern.ch/file/2142671/1/DUNE_APA_Structural_Design_Safety_Analysis_Result_Validation.docx structural analysis results are accepted at the 60% design review level. Therefore, final design and prototyping may proceed. As also stated, there are a number of outstanding issues (appendix 3) that need to be addressed before the analysis results are validated.

The committee would like to congratulate the APA team for their impressive progress and maturity of design. The APA consortium has demonstrated the ability to design, manufacture and deliver fully functioning APA's well within the design specifications, as is evidenced by the success of the protoDUNE data taking campaign. The committee found the documentation and presentations quite robust and commends the consortium on their effort to document their design utilizing tools such as EDMS. The committee believes the APA design does meet the mechanical requirements as outlined in the DUNE far detector design review plan. As noted above, a future review should be planned for the electrical design.

**Report Terminology**

**Findings** are statements of fact that summarize noteworthy information presented during the review.

**Comments** are judgment statements about the facts presented during the review. The reviewers' comments are based on their experiences and expertise. The comments are to be evaluated by the project team and actions taken as deemed appropriate.

**Recommendations** are statements of actions that should be addressed by the project team. A response to the recommendation is expected and that the actions taken would be reported on during future reviews.

The committee's findings, comments and recommendations are detailed in Section 2. with recommendations specifically outlined in Section 4. The committee's answers to the charge questions are presented in Section 3.

# 2 Findings, Comments, and Recommendations

## 2.1 Design and Specifications

### Findings

- The design of the DUNE APA which must carry the charge collection (wires), photon detector system (PDS) and cold electronics (CE) was presented
- The design of the APA is based heavily on the successful performance of the protoDUNE APAs recently built, installed, and operated at the CERN neutrino platform test beam
- The design specifications for the DUNE APA are based on the necessary physics performance to achieve identification and reconstruction of both minimum ionizing and more heavily ionizing particles over a broad energy range and the necessary vertex resolution to identify neutrino interactions in the DUNE Far Detector
    - 1.5 cm vertex resolution
    - Reconstruction of 25 MeV energy deposits (expected from supernova neutrinos) with 3-5 cm track extent

    - Reconstruct 50 MeV proton emanating from a neutrino vertex (~2cm in length)
    - Provide electron/photon identification using energy deposit per unit length (dE/dX)
- Tolerances on the design of the APA frame are derived from the necessary tolerances on the wire spacing, wire tension, and wire plane spacing
    - 5 mm wire plane spacing +/- 0.5 mm tolerance
        - Seems achievable based on protoDUNE experience
        - The few points which were beyond this tolerance show no evidence of a degradation in performance
    - 6 Newton +/- 10% wire tension is the default value which will be used for the construction of the DUNE APAs
        - 5 N +/- 1 N nominal wire tension for protoDUNE was the nominal value targeted.
            - Range of tensions beyond this tolerance were allowed in protoDUNE due to difficulty in controlling this was allowed (up to 7N tension)
            - No correlation has been established using protoDUNE data between tension and performance (Signal to noise, dE/dX vs Range, energy resolution) across various APA's with varying tension
                - Studies will continue into the near future to fully examine this
        - Driven by the expected protoDUNE analysis, the tolerance may be relaxed
- A comprehensive set of assembly drawings and procedural documents was presented and uploaded to EDMS for the APA frame, boards, and mounting fixtures
    - A short list of documents which don't yet exist in EDMS was also provided by the review team and a timeline to have them posted was given in the follow-up section
- Specifications for the interfaces with the cold electronics, photon system, and field cage were also identified and documented
- Design specifications for the APA frame also take into account the different aspects of the frame stresses which may be encountered and under the considered loads all pass the safety specifications

- Updates to the wire winder to include a mechanism which will maintain and monitor tension during wire winding was also presented as well as timescale for testing

# Comments

- The drawings of the APA frame side tube show a length tolerance of +/- 0.1mm. Is the tolerance necessary? Additionally, is the tolerance achievable on a tube of this length (~5.8m)?

- Mixing of both metric and imperial fasteners can create unnecessary challenges. If the practice is continued a justification for this should be understood.

- Fastener identification practices demonstrated in assembly drawings make use of one supplier's nomenclature. An alternate method should be considered which does not rely on one source.

- Torque specifications are generally included in the assembly procedure documents, but not uniformly applied everywhere. A review of all the drawings and procedures should be carried out to apply this uniformly such that the specification can be carried out at all APA construction sites

- Risk mitigation is facilitated by the design maturity that was demonstrated during the review. During the follow up response section of the review open items that will receive task force attention (e.g. electron diverters, protoDUNE analysis and CE cable conduit) were documented along with a realistic schedule to close these items.

- The design and corresponding specifications are quite mature for a 60% review from a mechanical perspective, however there was little to no information presented on the grounding and electrical connections

    - The committee appreciates that this aspect of the charge was added very late in the preparation phase and may require more time and an additional review

    - Interface drawings should either:

        - show both mechanical and electrical details

        - show mechanical and electrical as two separate drawings

    - Guidance from project technical coordination should be pursued in the absence of clarity.

- An evaluation of the inclusion of bolt retention specification in order to maintain the prescribed torque on all components should be completed in parallel to the specification of the torque requirements and a final decision made on a short time scale.

## Recommendations

- The proposed task force to evaluate the use of electron diverters using protoDUNE data should be pursued and supported in order to fully understand the impact these devices incorporation as well as their possible failure modes would have on the detector performance

# 2.2 Engineering Analysis, Cost Estimates, and Schedule

## Findings (Engineering Analysis):

- The applicable codes (ANSI/AISC 360-10, Design Guide 27, and the JRC Science for Policy Report "Prospect for New Guidance in Design of FRP") have been properly applied to the engineering analysis
- The engineering analysis examines 20 loading conditions, covering the critical phases of APA handling. Where details are not yet known (e.g., handling in the underground ITF facility) conservative assumptions have been made in the interim.
- Weld integrity is critical in the APA frame. Welding will be done by certified welders and appropriately inspected.
- Buckling analyses were appropriately performed on the frame and yoke and demonstrate substantial margins against instability
- The transient thermal analysis shows that the temperature difference between the wires and the frame cannot exceed 75K if cooldown is slower than 3 hours
- The analysis is more comprehensive than was done for ProtoDUNE. More load cases, including transportation and thermal cases were studied. The calculation of maximum acceleration load is a good way to derive requirements for shipping containers and methods.

- Using LRFD method, instead of ASD method that was done for ProtoDUNE is more advantageous as it conforms to latest revision of AISC and Eurocodes.
- Rigorous analysis of all welded joint was done using AISC code. Welds were also represented correctly in the FEA model and stress results were used as reference for weld calculations.
- The analysis per AISC codes shows that the frames meet the code requirements while not overly designed. This is advantageous from a performance point of view by minimizing mass of the frame.
- Detail analysis of the regions with slots for PDs and PD cables was done using sub-models. This is an improvement over ProtoDUNE analysis.
- The analysis was verified independently by Bob Wands using the model and load cases but employing different FEA software. This method of verification is very robust and should be followed in other parts of the detector.

# Findings (Cost and Schedule):

A schedule for final design validation and pre-production planning was presented.

- ProtoDUNE analysis to validate design underway, expected to complete in May (see responses to reviewer questions for details). Particular emphasis on results validating wire tension requirements, operational stability (detector aging). A detailed task-based summary of the ProtoDUNE APA experience and assembly times was presented, and it supported later production APA estimates.
- All (major) open design questions (see responses to committee questions) are scheduled to be completed by the end of summer, and selected options will be tested in the first "Pre-production" module to by built at PSL in late 2019.
- Engineering, designer and technician requirements (and available personnel) for specific tasks were identified for the US sites, and available resources for the UK. these look reasonable for the required tasks.
- No schedule for 90% design review and/or pre-production reviews was presented.

A schedule for APA fabrication which meets current project schedule requirements was presented. This included:

- A detailed plan for for APA construction and QA testing, including a bottoms-up task list buttressed by extensive procedure documents and development testing. These estimates lead to a projected fabrication time of 40 eight-hour shifts per APA module. The lion's

share of this work occurs on the winding machine, and involves fixed-duration tasks (such as the setting of epoxy) which make it difficult to accelerate the assembly rate without increasing the number of winding statins.

- A plan for pre-production work in the US and UK was presented.
    - UK: Two (possibly four) APAs built at Daresbury, starting in Summer 2020, for inclusion in the second run of ProtoDUNE (Possibly also to be used in DUNE)
    - US: One APA built at PSL (Beginning fall 2019), followed by one additional module to be built at Chicago or Yale. The second US APA will also be shipped to CERN for testing (and possible inclusion in ProtoDUNE?)
- Production plans for the first 10kt module, with ramping up in late 2020 (UK) and early 2021(US), and expected completion of the first module in late 2023.
- Projected assembly of the second 10kt module immediately following (Mid 2023 through mid-late 2026).
- No schedule for the assembly of frames and other ancillary components was presented. It was stated that they were not expected to drive assembly.

A high-level cost and labor budget for fabrication of 150 APAs (a single 10kt module) was presented.

- A detailed summary of APA fabrication cost and labor for component fabrication.
- No detailed summary of production setup was presented, but a clearly separated summary was presented allowing for a clear understanding of costs for a second 10 kT module.
- Costs and labor requirements looked reasonable given the production plans

# Comments (Engineering Analysis):

- The thermal analysis uses very conservative assumptions for temperature distribution in the frame. While the stresses are still within code requirements with such conservative assumptions, work should continue to improve the models including a more realistic temperature distribution
- The PD slots were removed from the frame to reduce analysis time. Load case 9 with the 4g load was rerun with slots. Worst load case presenting high stresses at other areas is not necessarily the worst load case where slots and holes see high stresses. Justification is needed to explain the load case 9 is the worst load case for slots and holes.
- The resistance factor (0.55, taken from Design Guide 27) applied in the base metal available strength calculation is likely incorrect. The 0.55 should apply only to the weld metal. The standard steel resistance factors should apply to the base metal. However, these factors are higher, and using 0.55 is actually conservative.

- The differential thermal contraction analysis of the G10 links might better be approached from the standpoint of a tip-guided cantilever beam, and bending stresses in the net section at the pin hole might be a better measure of adequacy. However, the links are far from marginal in this regard, given their length, low modulus, and relatively small displacement. No conclusions would be changed.
- The report is overlong, and somewhat tedious to follow. It also lacks some detail. For example, the description of FE model loading for load case 20 is vague, and doesn't mention that this is a transient analysis. The presentation, to the contrary, was crisp and accessible, and made clear some details that weren't clear in the report.

# Comments (Cost and Schedule):

- Components and designs required from other consortia (eg CE, PD,HV) must be resolved prior to pre-production reviews. These interfaces were not specifically addressed in the presentation on schedule. Interface documents and schedules need to be updated to include these requirements
- Interface documents with other consortia must be updated to ensure they represent the most recent design/interface data. These documents should include agreed-upon schedules for delivery of designs and/or final components required for APA fabrication.
- The required review process allowing for production APA fabrication in 2020 is challenging, and not clearly specified.
- Very little time exists in the schedule to implement design changes suggested by the final development tests (e.g. Ash River, CERN tests)
- Scheduling of APA frame assembly (and other ancillary components) are critical to the schedule, and should be included.
- Include in the summary tables and future reviews schedules including APA frame manufacturing and components required from outside the APA consortium to begin fabrication.

# Recommendations (Cost and schedule)

- Develop a mitigation plan for issues which arise from prototype tests.

- Develop a review schedule commensurate with beginning fabrication of APAs at the UK site in July 2020.

## 2.3 Lessons learned, QA, and prototyping

### Findings

- ProtoDUNE, which includes 6 APAs and two drift volumes, shows that the baseline design can achieve the physics goals: 6 ms electron lifetime and noise at the 550-650 e-/channel level (requirement < 1000 e-/channel).
- ProtoDUNE APAs used 3”x4” stainless steel tubes, and DUNE APAs will use 4”x4” stainless steel tubes to accommodate cable runs.
- 4 ProtoDUNE APAs were produced at PSL, and 2 ProtoDUNE APAs were produced at Daresbury. A 7th ProtoDUNE APA was produced at Daresbury and will be used at ProtoDUNE for cold electronics testing.
- During the construction of the APAs for ProtoDUNE a record of lessons learned was made, both at PSL and at Daresbury. A similar record of lessons learned was accumulated during the integration and installation of the APAs at CERN. These records are available in DUNE DocDB-8255 [certificate link].
- The main lesson learned from ProtoDUNE is that APAs with a small number of non-functioning channels can be built with approximately 55 shifts of work on a winder.
- 0.2% of ProtoDUNE channels (38 out of 15,360 channels) are non-functioning in LAr, most in the first APA (APA1). The requirement for DUNE is <1.0% dead channels. Roughly half of the disconnected channels were observed during warm testing, while the remaining half was noticed first during cold testing of the APAs.
- There is no significant change in the wire tension measurements before and after the cold box tests at CERN. A decrease of up to 1 N is observed from the initial wire tension measurements performed at the factories and the measurements performed after transport at CERN.
- The bias voltage to the G-layer of APA 3 is disconnected, which was first noticed after the detector was completely powered down. The reason for the disconnection is not known. The G-layer charges up in approximately 18 hours.

- The APA consortium has followed the example of the CE consortium and started a new "lessons learned" document (this document is available from EDMS). In addition to including new lessons learned since the construction and the installation of the first six ProtoDUNE APAs, this document contains a description of the plans for addressing the lessons learned.
- The G-Layer bias voltage may decrease in the presence of very large showers. shows poor performance for some large charges. The capacitance connected to the wires of the G-Layer is being increased to prevent these voltage fluctuations.
- Some of the issues observed during the construction of the six original ProtoDUNE APAs have already been addressed, resulting in improvements of the construction methods, changes to the winder, proposed changes to the design of the APAs for DUNE. In some cases the improvements in the construction methods have already been implemented for the construction of the 7th ProtoDUNE APA.
- The time required for construction is dominated by the curing of epoxy, followed by wire winding and tensioning.
- A new method for installing the grounding mesh has been proposed and tested during the construction of the 7th ProtoDUNE APA, resulting in a decrease of the time required for this step from a few shifts to hours.
- The tension task force is looking at ways of speeding this step with electrical measurements, in addition to using the new winding head that provides automatic measurements for each wire.
- The new wire winding head will be tested on test frames and then later in 2019 an 8th APA.
- One of the electron diverters drew current, so all electron diverters ran at ground resulting in a modification of the drift field in that region and distortion of the tracks.
- Following these issues with one of the electron diverters, a task force to understand the needs and the risks presented by electron diverters has been formed. This task force is expected to complete its work and issue recommendations by mid-May.
- Further analysis of ProtoDUNE data could yield additional information that is relevant for the final design of the APAs.
- The APA consortium plans on regular meetings between the different factories, in addition to site reviews, to ensure that identical production procedures are followed at all sites.
- The methods for building the APA have been developed over the course of several years starting with microBoone and going through the 35t prototype, ProtoDUNE, and SBND. This has resulted in a robust construction process that has been thoroughly tested.

- Extensive documentation of the construction process and of the quality control steps performed for ProtoDUNE is available in EDMS.
- Paper travelers have been used for the construction of the ProtoDUNE APAs. Plans were discussed to transition to electronic travelers.
- The construction of the APAs for ProtoDUNE represents a significant fraction of the QA work for DUNE.
- Flatness and wire spacing requirements were presented: the tolerance on both is +/-0.5 mm, which translates on requirements on the mechanical positioning of the wire boards and on the flatness of the APA frame.
- The wire tension requirements was originally 5+/-1 N, but this has been recently changed to 6+/-1 N to decrease the risk due to tension relaxation.
- Further studies are ongoing to determine the final APA frame planarity and wire tension requirements, and possibly loosen the constraints on both.
- Studies are ongoing to correlate noise measurements in the Cold Electronics with the wire tension.
- The yield of the quality control step for the wire boards is around 90%, arising mostly from problems with the dimensions of the boards.
- Visual inspections of all the wire boards are time consuming. Possible alternative methods involving automatic visual inspections will be investigated.
- Cleaning procedures for the detector parts are documented in EDMS,
- Procedures for the measurements of the dimension of all the APA parts are also documented in EDMS.
- After the construction of 7th ProtoDUNE APA future prototypes include the construction in the US of two APA frames without wires that will be used at Ash River for integration and assembly tests  This will be followed by prototypes of the DUNE APA, based on the most recent design as of Fall 2019, in the US and later in the UK in 2020. Smaller mechanical prototypes will be used to test the new winding head.
- The Ash River test will inform the final design of the conduit for the Cold Electronics cables and will represent the first test of the hardware link between the upper and the lower APA.
- In parallel three complete sets of pre-production wire boards will be fabricate to test design changes investigate new vendors. Dedicated tests of new pins and sockets for the wire boards will be performed at PSL in Summer 2019.
- The US and UK prototype APAs will be shipped to CERN for tests in the cold box and for use in Run 2 of ProtoDUNE.

# Comments

- Possible reasons for the dead channels are broken solder pads or bad connections to the electronics.
- The absence of bias voltage on the G-layer is most probably due to a poor connection on the SHV board. Further tests should be performed to ensure the integrity of the bias voltage connections.
- The committee commends the APA consortium for the progress in adapting the construction methods and the design to reflect the lessons learned from ProtoDUNE.
- The committee also commends the APA consortium for developing a "living" document, stored and tracked in EDMS, that records the progress in addressing the lessons learned so far. Technical coordination should encourage other consortia to follow this approach, monitor on a regular basis the progress of each consortium on the resolution of issues found during construction and operation of detector components, and help develop a unified solution for issues tracking.
- The distributed nature of the APA construction requires that updates to the lessons learned document (that may result in changes to the construction procedures) are relayed to all the APA factories in a timely fashion. Formal procedures should be developed to ensure that this is indeed the case.
- Quality control of incoming materials is not shown in the pie chart. A summary of incoming parts QA along with time estimate should be provided.
- Some hardware became loose during ProtoDUNE shipping. Fastener hardware with proper locking mechanism should be considered to be used to prevent them from loosening.
- Electronic measurements of the wire tension can be performed prior to the installation of the CE boxes. The board for the electronic wire tension measurement uses the same connector as the adapter card for the CE box.
- The possibility and accuracy of measuring the wire tension using the noise observed in the Cold Electronics should be demonstrated prior to the end of Summer 2019.
- Future presentations should provide more details on how the required precision of the wire positioning is obtained from the accuracy of the fabrication of the printed circuit boards and their location on the APA frames.
- The review committee endorses the prototyping strategy presented by the APA consortium, and encourages further coordination with other consortia. Tests of the DUNE prototype APAs at CERN should be coordinated with the CE and PDS consortia.
- The schedule presented by the APA consortium may be too optimistic. The test of the first DUNE prototype APA may only be possible if this is fully compatible (from

a mechanical point of view) with the currently available ProtoDUNE Cold Electronics.

- The construction of the first prototype DUNE APA requires that all mechanical interfaces with the CE and PDS consortia are finalized before the end of Summer 2019, and that meaningful tests are performed by that date. The APA consortium should consider the possibility of producing modified parts and of installing them on the first prototype APA, in the case that initial tests at CERN reveal the presence of problems.

- The APA consortium should consider further tests that can be performed in the cold box at CERN, like hanging an APA upside down.
- The APA consortium should work with the analysis group(s) to ensure that the analyses that can yield information relevant for the final design of the APAs are completed in a timely fashion (before the end of Summer 2019).
- The APA consortium should monitor the evolution of the number of disconnected wires during the multiple cool-down and warm-up cycles planned for the 7th ProtoDUNE APA at CERN.
- The APA consortium should finalize the studies for electronics measurements of the wire tensioning by the end of Summer 2019, such that these can be incorporated in the plans for integration and installation.

# Recommendations

- The APA consortium should continue the maintenance of the lessons learned document and identify a person responsible for its maintenance.
- The APA consortium should finalize the studies used to define the requirements on the planarity of the APA and on the wire tension before the end of Summer 2019.
- The APA consortium should consider an additional cleaning step after the completion of the assembly of the APA, prior to the wire winding, to ensure the removal of any metal chips freed up after screws are inserted in the APA frame.
- The APA consortium should update the standard operating procedures to reflect the changes in the APA assembly that have been recently developed.
- The APA consortium should work together with the CE and PDS consortia to ensure that all interfaces are fully defined prior to constructing the corresponding parts of

the first DUNE prototype APA such that tests performed at CERN or at Ash River can validate the chosen design.

- In the QA procedure ensure that overall width and length of completed APAs are measured at predefined positions, Also define and measure dimensions that ensure when top and bottom are assembled, they are within envelope dimensions. These measurements are needed to ensure correct installation and alignment.

# 3 Answers to Review Charge Questions

1. Have design choices been fully identified and do they meet detector requirements?
**Yes, the design choices for the APA have been identified along with the interfaces to the other systems and they have been made to meet the stated detector requirements. Moreover, based on protoDUNE experience, the demonstration of this design is quite mature and robust.**

2. Are the specifications and drawings for standard and custom components substantially complete and available in EDMS? Are they of sufficient maturity to proceed to final design?

**Yes, the specifications and drawings are nearly complete and available in EDMS with a few components identified which need to be added and/or updated. A timeline for completing this process was presented. The drawings and specifications are of sufficient maturity to proceed to a final design**

3. Have interfaces with other detector components been addressed and documented? Do risks of design changes in other systems have appropriate mitigation strategies?

**Yes, the interfaces with other detector components have been identified and documented to the level of maturity of the project at this time. The risks introduced by design changes from interfacing components can be mitigated in the existing design of the APA by modification of parts which are not fundamental to the design.**

4. Are engineering analyses sufficient to ensure the design is safe during all phases, and have applicable design codes and standards been satisfied?

**Yes. Additional input from the structural safety working group forthcoming validation report will support this conclusion.**

5. Is the design in accordance with procurement strategy and manufacturing plans?

**Yes, the strategy to build the APA's at various production sites using procurement from diversified vendors is supported by the design and validation plans.**

6. Have lessons learned from ProtoDUNE been implemented?

**Yes, at least in part. Most of the lessons learned from ProtoDUNE have already been reflected in changes in the APA design and of the APA assembly procedures. Further analysis of the ProtoDUNE data is planned and this may result in small additional design changes or in relaxing the specifications for wire tensioning and for frame planarity.**

7. Are quality assurance and testing plans sufficiently developed to proceed to final design?

**Yes. For the current stage of the project the quality assurance and testing plans are well advanced. The committee notes that some of the assembly procedures need to be updated to reflect the most recent changes.**

8. Are plans for additional prototyping reasonable and sufficient?

**Yes. although we note that there is not a lot of room for modifications of the design and further prototyping in case problems are observed during the tests planned at Ash River and the cold box testing at CERN. The construction of the first DUNE prototype APA in the Fall of 2019 depends on the timely completion of the study of the interfaces with the PDS and CE detector components.**

9. Have appropriate cost estimates and schedule been determined? Are plans for required technical resources consistent with scope of remaining work?

**Yes, although time is not currently allocated into the schedule for final and pre-production reviews**

10. Are system grounding details documented and in EDMS? Are electrical connections specified and do schematics exists in EDMS? Are all wires, cables and connections documented?

**No. The electrical aspects of the APA review were not discussed in this review, as noted in the executive summary.**

# Recommendations

## Design and Specifications

- The proposed task force to evaluate the use of electron diverters using protoDUNE data should be pursued and supported in order to fully understand the impact these devices incorporation as well as their possible failure modes would have on the detector performance

## Engineering Analysis, Cost Estimate, and Schedule

- Develop a mitigation plan for issues which arise from prototype tests.
- Develop a review schedule commensurate with beginning fabrication of APAs at the UK site in July 2020.

## Lessons Learned, QA/QC, and Prototyping

- The APA consortium should continue the maintenance of the lessons learned document and identify a person responsible for its maintenance.
- The APA consortium should finalize the studies used to define the requirements on the planarity of the APA and on the wire tension before the end of Summer 2019.
- The APA consortium should consider an additional cleaning step after the completion of the assembly of the APA, prior to the wire winding, to ensure the removal of any metal chips freed up after screws are inserted in the APA frame.
- The APA consortium should update the standard operating procedures to reflect the changes in the APA assembly that have been recently developed.
- The APA consortium should work together with the CE and PDS consortia to ensure that all interfaces are fully defined prior to constructing the corresponding parts of the first DUNE prototype APA such that tests performed at CERN or at Ash River can validate the chosen design.
- In the QA procedure ensure that overall width and length of completed APAs are measured at predefined positions, Also define and measure dimensions that ensure when top and bottom are assembled, they are within envelope dimensions. These measurements are needed to ensure correct installation and alignment.

# 4 Appendices

## 4.1 Review Website and Agenda

Website: https://indico.fnal.gov/event/18815/

Agenda:

**Wednesday, March 27, 2019**

| | |
|---|---|
| 08:15 - 08:30 | Executive Session *15'*<br>Speaker: Steve Kettell (BNL) |
| 08:30 - 08:45 | Welcome to PSL *15'*<br>Speaker: Mr. Bob Paulos (University of Wisconsin) |
| 08:45 - 09:05 | APA Design and their relationship to detector requirements *20'*<br>Speakers: Christos Touramanis, Prof. Christos Touramanis (University of Liverpool)<br>Material: Slides |
| 09:05 - 09:15 | Questions *10'* |
| 09:15 - 09:35 | Lessons from protoDUNE *20'*<br>Speaker: Dr. Justin Evans (University of Manchester)<br>Material: Paper Slides |
| 09:35 - 09:50 | Questions *15'* |
| 09:50 - 10:30 | APA Design and Interfaces *40'*<br>Speakers: Lee Greenler (University of Wisconsin - Madison), Lee Greenler (University of Wisconsin)<br>Material: Slides |
| 10:30 - 10:45 | Questions *15'* |
| 10:45 - 11:15 | Coffee Break / APA Tour |
| 11:15 - 11:45 | APA Boards *30'*<br>Speaker: Andrew Laundrie (UW Physical Sciences Lab)<br>Material: Slides |
| 11:45 - 12:00 | Questions *15'* |
| 12:00 - 12:50 | Engineering Analysis *50'*<br>Speaker: Daniel Wenman (University of Wisconsin - Madison)<br>Material: Slides |
| 12:50 - 13:10 | Questions *20'* |
| 13:10 - 14:15 | Lunch |
| 14:15 - 14:35 | Prototypes (Ash River and future protoDUNE running) *20'*<br>Speaker: Mr. Bob Paulos (University of Wisconsin)<br>Material: Slides |
| 14:35 - 14:45 | Questions *10'* |
| 14:45 - 15:15 | APA manufacturing procedure including safety and procurement *30'*<br>Speaker: Mr. Alan Grant (STFC Daresbury Laboratory)<br>Material: Slides |
| 15:15 - 15:35 | Questions *20'* |

16:30 - 17:00 Cost & Schedule *30'*
Speaker: Dr. Alberto Marchionni (Fermilab)
Material: Slides

17:00 - 17:15 Questions *15'*

17:15 - 18:15 Review Committee Closed Door Session *1h0'*

18:15 - 18:30 Questions to the Review Team *15'*

18:30 - 20:30 Dinner
*Location TBD*

**Thursday, March 28, 2019**

09:00 - 10:00 Responses and follow-up from review team *1h0'*
Speakers: Dr. Alberto Marchionni (Fermilab), Christos Touramanis, Prof. Christos Touramanis (University of Liverpool)
Material: Slides

10:00 - 12:00 Closed door committee session: (Report Writing and Findings)

12:00 - 12:30 Committee presentation to review team on findings *30'*
Speaker: Dr. Jonathan Asaadi (University of Texas Arlington)

12:30 - 13:30 Lunch

## 4.2 Committee Members

| | | |
|---|---|---|
| Jonathan Asaadi | jonathan.asaadi@uta.edu | Chair / Design and Specifications |
| Marco Verzocchi | mverzocc@fnal.gov | Lessons Learned, QA, Prototyping |
| Dave Warner | warner@lamar.colostate.edu | Engineering Analysis, Cost Estimate, Schedule |
| Bob Wands | wands@fnal.gov | Engineering Analysis, Cost Estimate, Schedule |
| Kyle Zeug | kzeug@psl.wisc.edu | Design and Specifications |
| Manhong Zhao | mzhao@bnl.gov | Lessons Learned, QA, Prototyping |

## 4.3 Applicable Documents

### Charge letter

DEEP UNDERGROUND NEUTRINO EXPERIMENT

# DUNE Preliminary Design Review (60% Design Review)

## Charge

### Single Phase Detector Anode Panel Assembly

**27–28 March 2019**

The committee is requested to review the DUNE anode panel assembly (APA) design and determine if it meets the requirements of the preliminary mechanical and electrical design as outlined in the DUNE Far Detector Design Review Plan (DocDB-9564). As reference, the final design review report for ProtoDUNE-SP APA is available in DocDB-4565.

Specifically:

1. Have design choices been fully identified and do they meet detector requirements?
2. Are the specifications and drawings for standard and custom components substantially complete and available in EDMS? Are they of sufficient maturity to proceed to final design?
3. Have interfaces with other detector components been addressed and documented? Do risks of design changes in other systems have appropriate mitigation strategies?
4. Are engineering analyses sufficient to ensure the design is safe during all phases, and have applicable design codes and standards been satisfied?
5. Is the design in accordance with procurement strategy and manufacturing plans?
6. Are quality assurance and testing plans sufficiently developed to proceed to final design?
7. Have lessons learned from ProtoDUNE been implemented?
8. Are plans for additional prototyping reasonable and sufficient?
9. Have appropriate cost estimates and schedule been determined? Are plans for required technical resources consistent with scope of remaining work?
10. Are system grounding details documented and in EDMS? Are electrical connections specified and do schematics exists in EDMS? Are all wires, cables and connections documented? (added 3/25/2019)

**Review Findings:**
The committee should present its findings, comments and recommendations in a closeout meeting with DUNE Technical Coordination on February 8. The committee should provide a final written report by April 5.