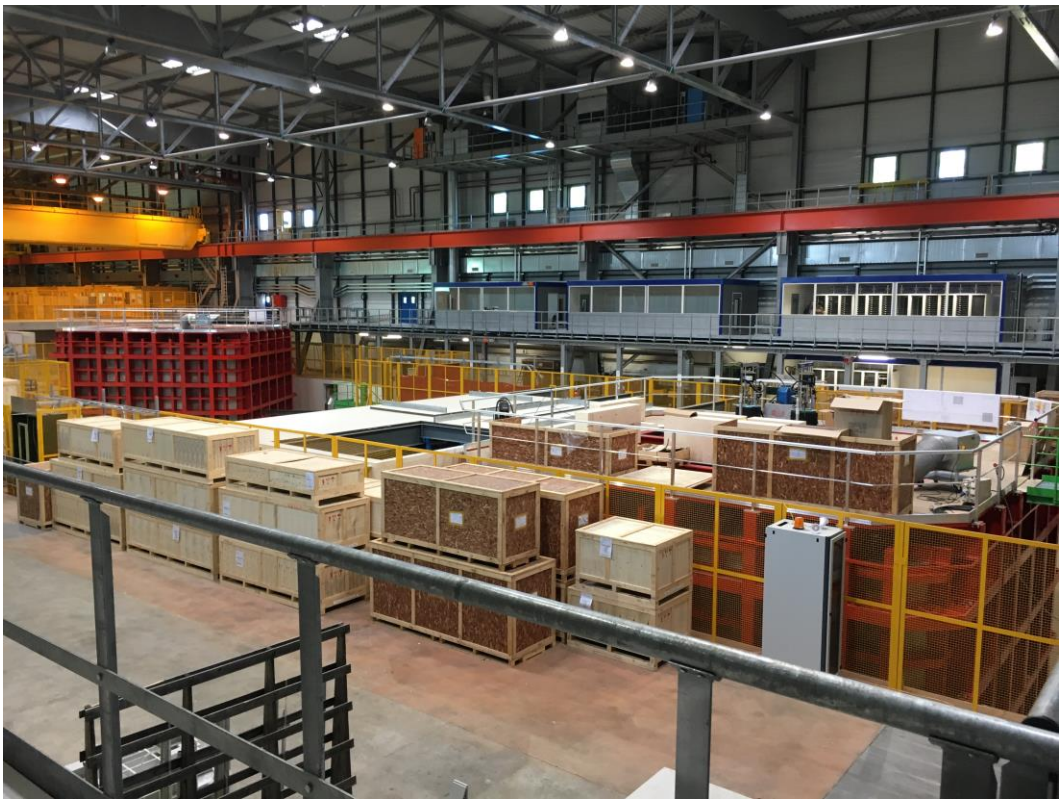
LBNC Closeout Report: June Review (June 22-24, 2017)

Contents

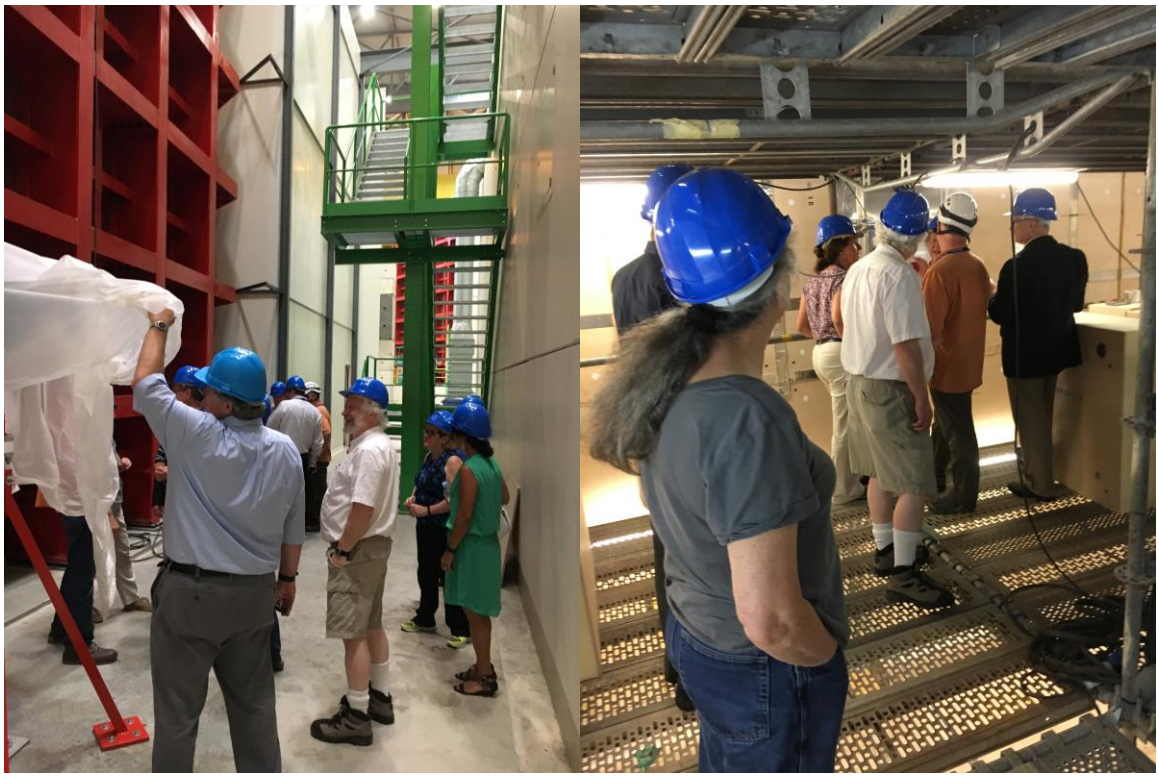
Executive Summary

The LBNC met at CERN, June 22-24, 2017. In addition to plenary presentations and discussion, the meeting included "referee subgroup" breakout sessions to focus in more detail on the following areas: (1) LBNF Management, Schedule and Planning, (2) LBNF/DUNE Planning for Cryogenics, (3) LBNF/DUNE Interfaces, (4) DUNE Management, Schedule and Planning, (5) DUNE Physics and Reconstruction, (6) DUNE Computing, (7) ProtoDUNE-SP Schedule and Plan, (8) ProtoDUNE-SP CE and TPC, (9) ProtoDUNE-SP DAQ, (10) ProtoDUNE-DP Technical, Schedule and Planning.

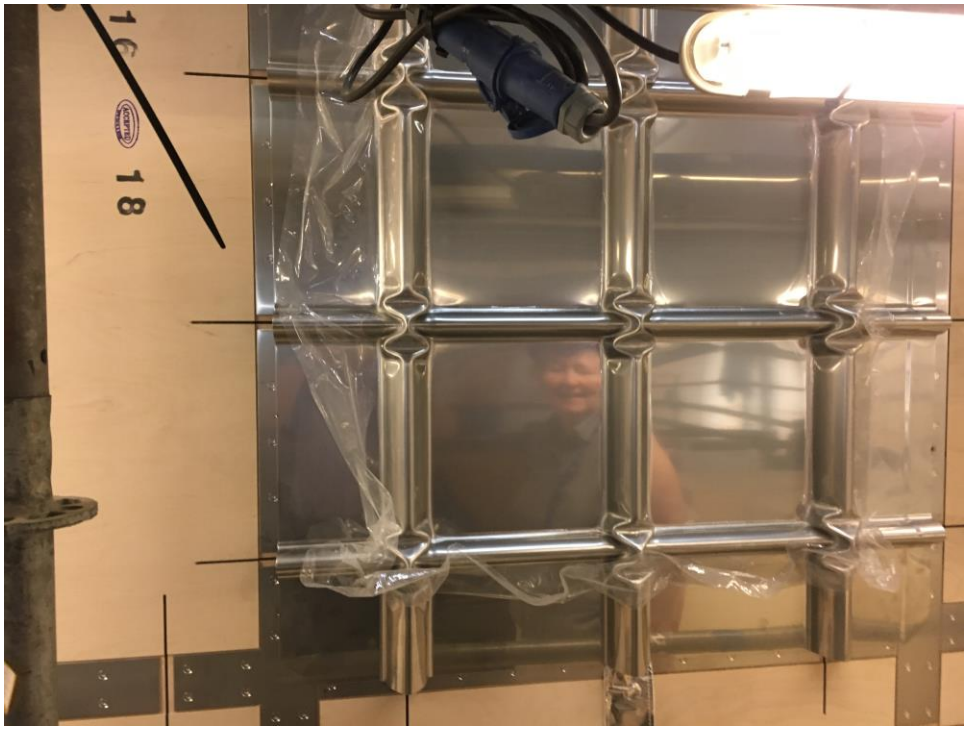
Overall, the Committee was very impressed by the significant progress achieved by both LBNF and DUNE since the last LBNC review. Of particular note are the steps taken by LBNF towards awarding the critical CM/GC and related contracts. Funding limitations and short-term limitations on delivery of funding are the primary constraint at the moment for moving forward. Equally impressive is the successful start of cryogenic operations with the WA105 1x1x3 prototype, and the progress in constructing the two protoDUNE cryostats by CERN and GTT. The LBNC site visit to CERN was particularly useful for the committee to get a firsthand impression of these impressive efforts.



View of the CERN North Hall extension with the two ProtoDUNE cryostats now under construction. Some of the many boxes containing insulation and membrane cryostat parts are also visible.



View of the exterior of the ProtoDUNE-SP cryostat looking back towards the ProtoDUNE-DP cryostat in the distance (left); view of scaffolding and insulation installation in the ProtoDUNE-SP cryostat (right).



Membrane section installed on top of foam insulation inside the ProtoDUNE-SP cryostat.

The following summary contains a selection of high-level comments and recommendations from the review. The overarching impression is that LBNF and DUNE are both making excellent progress, but that DUNE, as a recently formed major new scientific collaboration, still shows signs of its constituent parts and would benefit from efforts to establish mechanisms to ensure stronger collaboration-wide consensus and clearer lines of authority for management and decision making. Our recommendations primarily address the need to better understand the overall strategy for the first two far detector modules, to enhance coordination between protoDUNE-SP and protoDUNE-DP, to launch the DUNE consortia with an eye to the long-term need to maximize efficiency in overlapping areas of detector design, and to enhance the role of the Executive Committee and Collaboration leadership. We also note that, while it is still early, the demonstration of a working dual phase prototype with WA105, potentially warrants revisiting some aspects of the overall strategy for the DUNE far detector. CERN and GTT continue to make progress with demonstrating the membrane cryostat design for DUNE, but experience from the WA105 cryostat points to the protoDUNE cryostats as the critical next engineering step. Likewise the electronics system design for the single-phase DUNE design, including the cold electronics components, remains a significant overall concern.

i) LBNF Management, Schedule and Planning

Recognizing that the DUNE-single phase cryostat design is well advanced at this stage, the LBNC strongly encourages DUNE working with LBNF to re-evaluate whether a common cryostat structure design is possible for both SP and DP detectors, to provide greater understanding of the design and construction risks, deployment options, sequencing and construction efficiency. If this is not possible, LBNF and DUNE should assess implications on cost and schedule of any change in detector sequencing strategy, and whether a separate DP Cryostat design should be started in order to mitigate any associated risk.

ii) LBNF/DUNE Planning for Cryogenics

The tour clearly showed the impressive level of effort that is on-going to prepare the ProtoDUNE cryostats. The CERN/GTT teams were engaged with significant personnel in and around both cryostats.

There is a need to guard against the schedule pressure impacting key ProtoDUNE technical and quality steps and tests. Though there are important goals for demonstrating performance, reliability, and scientific calibration, the ProtoDUNEs should be primarily viewed as engineering prototypes. The time pressure from meeting the LS2 schedule remains an important constraint, but overall achieving this goal should not compromise the need to realize engineering prototypes, particularly for the critical membrane cryostat demonstration. The negative experience of the 1x1x3 cryostat membrane is being mitigated in ProtoDUNE by choosing a different membrane and insulating foam design and defining tighter quality control on installation. Although the revised design looks like a substantial improvement on the 1x1x3 and is the standard design employed by GTT in LNG ships, it is the first time this type of design will be used for a cryogenic LAr detector. It should be stressed that ProtoDUNE is a $1/20^{th}$-scale prototype for the DUNE cryostat. Without a working cryostat DUNE would be severely compromised, so it is critical to demonstrate at scale a working engineering design. Sufficient time must be kept in the schedule for adequate testing and confirmation of the cryogenic performance and modeling.

Recommendation: The LBNC recommends the documentation of a cryogenic testing plan for ProtoDUNE cryogenics including required diagnostics, testing steps and required schedule.

iii) DUNE Management, Schedule and Planning

The LBNC appreciates the plans towards a more global and integrated project organization with the planned evolution of the Executive Committee (EC) becoming more explicitly the decision body steering the project. The EC must bring together the leadership of the consortia being formed, the main activity coordinators, and the DUNE management to take the major decisions carried and supported by the full collaboration.

The LBNC sees an urgency (before the Technical Proposal) in taking these steps as a way to foster a true "collaborative working spirit" within DUNE, that will enable the collaboration to make reasoned decisions for cost-efficient common solutions and unique technology choices wherever applicable. Such decisions should take into account considerations about efficient operation and maintenance in the future.

With the recent demonstration from the WA105 prototype, the LBNC sees an opportunity to attract funding to the dual phase design and to aim for deployment of both single-phase and dual-phase detector technologies, rather than just one. However, in this scenario, there is a need to better understand the real risks, schedule implications, and practical engineering implications of deploying both technologies.

Recommendation: The LBNC looks forward to a report at its next meeting on steps taken towards forming a global collaboration.

iv) ProtoDUNE-SP Schedule and Plan

The LBNC is concerned that the cold and warm electronics will not be available on the necessary timescale for protoDUNE-SP, as many elements are late and are to be delivered "just in time".

Recommendation: The LBNC recommends that the ProtoDUNE-SP CE System Manager should communicate with the Construction Coordinator on a weekly basis through this critical period (4-16 weeks).

v) ProtoDUNE-SP CE and TPC

A long-term strategy for the overall future cold electronics development for DUNE should be developed. This should include a system design for redundancy study to improve the overall system reliability, and a large scale cold electronics testing facility for component and board level testing, evaluation and burn-in.

The LBNC is concerned that the lack of direction on the final electronics system design, including the ADC, threatens the viability of the single phase detector as a TPC option for the far detector.

Recommendation: The LBNC expects a plan for the cold electronics system design to be presented at the next LBNC review meeting.

vi) ProtoDUNE-DP Technical, Schedule and Planning

The achievement of WA105 in observing cosmic ray tracks within 6 days of commencing cryogenic operations is outstanding. We congratulate the collaboration!

Finally, the LBNC would like to thank the speakers at the meeting for the careful preparation of the presentations, and would also like to thank CERN for hosting the meeting.

Section 1: LBNF Management, Schedule and Planning [Smith, Robinson, MacFarlane]

Findings:

- Although the FY2017 US Federal Budget was approved at $50M, $5M above the LBNF/DUNE plan, LBNF continues to receive funding on a monthly basis at 1/12th of the total annual budget.
- The LBNF/DUNE FY2018 President's Budget Request (PBR) is $55M ($5M more than FY2017 approved budget), which is $40M less than the LBNF/DUNE Plan
- As a result of anticipated budget restrictions, the Far Site work has been given priority over Near Site work (cf. LBNC Charge 7.i).
- The CM/GC contract for the Far Site Excavation has been submitted to DOE for approval. It is anticipated that the contract may be placed before the end of June 2017, stated to be more likely July 2017 at this point due to two issues: cash flow and DOE contract approval.
- From a management standpoint, LBNF is transferring the final design contract with Arup from SDSTA to Fermilab. Monthly allocation of budget and the desire to time the start to the CM/GC contract start has delayed placement of this contract (anticipated by project in July 2017). A revised contracting approach will be adopted for other SURF rehabilitation projects, due to an identified potential conflict of interest in the current approach of contracting through SDSTA.
- Near Site CD-3 approval has been pushed to the end of FY2021 (from end of FY2020)
- Early completion of CD-4 has slipped by from Apr-2017 to Sep-2018 as a result of budget planning. CD-4 float from early completion to CD-4 has decreased 6 months to 24 months. A new Monte Carlo analysis of schedule risk due to duration estimate uncertainty has demonstrated an 18 month potential uncertainty in program delivery, in addition to the schedule risk already calculated from the risk register.
- The Far Site Logistics Manager position remains vacant on the current LBNF organization chart which was placed on hold based on funding constraints. This position is under active recruitment now, and is expected to be filled by the end of summer 2017.
- A key systems engineer has moved from DUNE to LBNF/DUNE.
- Several discussions have been held between LBNF and science teams on conventional facility interfaces. Interface development between the Far Detector cryostats and Far Site conventional facilities are main focus (cf. LBNC Charge 7.ii)
- The Ross shaft rehabilitation work has continued, although was deferred during April due to lack of available funding. Nonetheless, there are only twenty-six steel sets that remain to be replaced.
- The Ross shaft rehabilitation work has identified non-conformances in the wood guides used for the emergency cage arrest mechanism (dogs).
- The Addendum to the Neutrino Protocol between CERN and DOE defines reciprocity of safety standards between US and EU systems, which is being incorporated into a new FESHM Chapter. In parallel, code equivalency related to structural design has been reviewed and will be submitted to DOE in July.

- Following meetings with the South Dakota revenue agency, LBNF/DUNE is carrying a pending change request of $8M related to an unanticipated State tax burden.
- The DOE site office is leading development of a blanket DOE real property exemption related to investment of federal funds on non-federal property to remove the need for individual exemptions on each non-DOE property project.

Comments:

- LBNF is making good progress on development of all aspects of the Far Site infrastructure, has a robust risk identification and management process, and is taking appropriate actions to manage and mitigate the risks associated with SURF infrastructure.
- The current funding flow with late receipt of monthly tranches is creating substantial planning and contracting challenges, especially with the letting of large contracts such as the CM/GC contract.
- The project is focusing on Far Site work by deprioritizing Near Site work in response to the FY2018 PBR. This appears the most prudent and least undesirable option, and is being undertaken in close communication with FNAL management.
- There is a requirement for continued development of appropriate processes and protocols to manage international contributions and support personnel, which will be required to allow international contractors to operate at SURF.
- The transition of contract management away from SDSTA to FRA will streamline procurement actions, although continued engagement of SDSTA in design work is obviously critical and must be formally maintained.
- The project stated that it is going to require an all-stakeholders sign-off approval of the final Far Site pre-excavation design. While, in principle, this should reduce risk and force stakeholders to a least consider impacts and interfaces with the conventional facilities, the LBNC encourages the LBNF to closely monitor both the process and its outcomes to ensure this approach does reduce risk in practice.
- While the physical interface between the Far Site conventional construction is progressing well with detailed models, there remain logistical and implementation interfaces that have only been addressed cursorily, and engagement of all stakeholders is essential. For example, a request was reported for all of the shipping boxes associated with the insulated foam to be taken underground before assembly of the cryostat. This is extremely cumbersome from a logistical perspective, it may very likely create significant fire/safety issues and doesn't represent a reasoned approach for such an installation with a major limitation such as the shaft cage limitations and trip time.
- LBNF is progressing based on the current formal statement of DUNE sequencing, with the first detector envisaged as single phase, and the second detector as single or double phase. Insufficient resources are available to develop cryostat designs for both technologies in parallel. The planning strategy discussed by DUNE at this meeting is to assume the first module is single phase, with the second now just being assumed to be dual phase. However, this is dependent on ProtoDUNE results, with the final decision on the first detector technology being made by end 2018.

- Differences between the current design of SP and DP cryostats include steel structure spacing (1.5m vs 1.6m) and location and number of roof penetrations. Close communication between LBNF and DUNE is required to ensure the appropriate Cryostat and Far Site conventional facilities are developed on the required timescale.

Recommendations:

- **Recommendation 1.1:** Recognizing that the SP cryostat design is well advanced at this stage, the LBNC strongly encourages DUNE to work with LBNF to re-evaluate whether a common cryostat structure design is possible for both SP and DP detectors, to provide greater understanding of the design and construction risks, deployment options, sequencing and construction efficiency. If this is not possible, LBNF and DUNE should assess implications on cost and schedule of any change in detector sequencing strategy, and whether a separate DP cryostat design should be started in order to mitigate any associated risk.

Section 2: LBNF/DUNE Planning for Cryogenics [Klebaner, Fuerst, Robinson, Monroe, Laxdal]

Findings:

- 1x1x3 WA105
    - The static load on 1x1x3 was initially measured at 4.5kW – this was higher than anticipated. Installation issues caused the formation of cold spots (ice) on the cryostat exterior and investigations and mitigation steps delayed the 1x1x3 program by three months.
    - The static load has been reduced by injecting foam at different location. The static load is now 1.2kW (400W from the walls – 300W radiation and 300W from the feedthroughs).
    - Other delays were due to a major leak in LAr pump tower due to a broken bellow and the formation of gas pockets on the LN_2 line that required the addition of a purge valve
    - The 1x1x3 group proceeded since May with detector filling and purification. Initial instabilities (up to several mm) in the LAr level were observed but now the surface ripple is reported to be <0.5mm. The LAr Purification was reduced to the specification after 7 volume exchanges.

- ProtoDUNE
    - The 6x6x6 SP and DP Cryostats are using a different cryostat insulation design (a staggered foam layer insulation that is the standard design employed by GTT in all LNG ships). The interaction with the company GTT is reported as “proactive and engaged”. GTT has added three QA people to the installation team. The ProtoDUNE-DP cryostat has >70 penetrations on the lid.
    - Design goals
        - The quoted static load design goal is 3.6kW (not including distribution system heat load) for each cryostat – the installed cryogenic capacity is 16kW
        - The acceptable ripple in the LAr surface is 1mm in ProtoDUNE -DP
        - The required purity is 100 parts per trillion O_2
        - The required maximum acceptable temperature gradient was not reported
    - Schedule
        - The single phase (SP) Cryostat + clean room buffer should become available in July (had been planned for April) to start the detector installation activities – the dual phase (DP) is about 1.5 months staggered with respect to this schedule
        - It is considered to separate the clean room into two zones to mitigate delays in protoDUNE cryostat and the APA modules
        - The project team proposes to compensate for the delay in the SP P-Dune cryostat by slipping the clean room and cold box activities by only 1 month

and shortening system testing to only 1½ months while maintaining the original completion date depending on the arrival of the second APA.

- LBNF
    - The cryostat group is focusing on ProtoDUNE and applying present knowledge to the DUNE design
    - A 3-D model of the DUNE-SP cryostat has been created. The outer support structure has been designed and an external final design review of the DUNE-SP cryostat steel support structure is scheduled for Aug 21-22 in order to launch the GTT design.
    - The design of DUNE will be launched before there are results from ProtoDUNE with the proviso that the design can be tweaked in 2019 based on lessons learned from ProtoDUNE testing.
    - The present plan is that the DP-DUNE and SP-DUNE cryostats will have different exo-skeleton designs due to the different detector periodicities.

Comments:

- 1x1x3
    - Important experience has been gained with the 1x1x3 cryostat. These include cryostat membrane installation issues, cryostat diagnostics, gas purge and purity measurements. The cryogenics team should be complimented on their diligence in tracking down and largely mitigating the heat leaks to allow detector testing.
    - The project needs to document and communicate the remaining run plan for the 1x1x3 cryostat so that the resource/schedule impact to ProtoDUNE activities can be evaluated.
    - The project should formalize and document the lessons learned during the 1x1x3 cryostat start-up experience. It is important that the project incorporates fully all of the design implications the 1x1x3 can provide to ProtoDUNE.

- ProtoDUNE

    - The tour clearly showed the impressive level of effort that is on-going to prepare the ProtoDUNE cryostats. The CERN/GTT teams were engaged with significant personnel in and around both cryostats.
    - There is a need to guard against the schedule pressure impacting key technical and quality steps and tests. The negative experience of the 1x1x3 cryostat membrane is being mitigated in ProtoDUNE by choosing a different membrane and insulating foam design and defining tighter quality control on installation. Although the design looks like a substantial improvement on the 1x1x3, and is standard for GTT in all LNG ships, it is the first time this type of design will be used for a cryogenic LAr detector. It should be stressed that ProtoDUNE is the prototype for the DUNE cryostat. Without a working cryostat DUNE would be severely compromised. Sufficient time must be kept

in the schedule for adequate testing and confirmation of the cryogenic performance and modeling.

- The plan to recover from ProtoDUNE-SP cryostat delays by compressing system integration & test seems aggressive given the importance of the integration/test activities. All design and/or implementation changes or shortcuts that are incorporated in the installation and commissioning of the ProtoDUNE cryostats should be clearly and completely captured to ensure traceability to the DUNE cryostat design.
- The consideration to separate the clean room into two working zones needs careful pre-planning in order to identify potential bottlenecks in the process sequence.
- In order to support ProtoDUNE operations in 2018, the project should start now to develop purification/cooldown/fill/commissioning strategies and a schedule that includes adequate time for cryogenic system testing and performance evaluation. It is essential that sufficient tests are scheduled to fully characterize the cryogenics performance of SP and DP ProtoDUNE in time to modify the design of DUNE if required.
- The project should make an effort to improve communication across subsystem activities. For example there was evidence for an inconsistent understanding of the 1x1x3 cryostat test plan and path towards the ProtoDUNE beam tests.
- The presentation showing the results of modeling of the fluid dynamics was welcome. The initial results are highly informative and important. Diagnostics and tests should be planned in ProtoDUNE to confirm the fluid dynamics model.
- The cryogenics team on 1x1x3, 6x6x6 and LBNF/DUNE are doing great work but it appears that they would benefit from extra resources.

- LBNF
  - Unassigned scope still is an issue. It appears that CERN and FNAL cryogenics teams have sufficiently established conceptual designs of the unassigned scope to ensure that the interfaces can be adequately designed. The project plan to identify required work during the ramp up to DUNE given the lack of available resources is reasonable. The push for identifying ownership of non-DOE scope should continue with high priority.
  - The designs of the SP and DP cryostats are significantly different in terms of exo-skeleton footprint due to the detector length periodicity such that two unique designs are required. Designing two cryostat designs represents a large overhead for the project. The DUNE team needs to engage in detailed investigations to attempt to converge to a single base design with the understanding that lid penetrations in the DP be supported by the common design.

Recommendations:

- **Recommendation 2.1:** Document a detailed campaign plan for the next months of W105 (1x1x3) electronics and cryogenic testing.
- **Recommendation 2.2:** Document a cryogenic testing plan for ProtoDUNE cryogenics including required diagnostics, testing steps and required schedule
- **Recommendation 2.3:** Ensure that the installed diagnostics give important verification of the fluid model.
- **Recommendation 2.4:** Identify ways to test the ProtoDUNE cryostat thermal performance early in the event that an opportunity arises.
- **Recommendation 2.5:** Conduct a study of the DUNE-SP and -DP cryostat designs with the goal to converge to a common design and report findings at the next LBNC meeting

Section 3: LBNF/DUNE Interfaces [Lindgren, Smith, Klebaner, Fuerst]

Findings:

- Presentations were made on the state of interfaces between DUNE and the Conventional facilities
- The integration team has been strengthened and integration focus has increased
- Primary interfaces to CF are defined
- The Cryostat/Mezzanine/DP Interface was discussed at the May Far site integration meeting, and the DP feedthrough will be integrated into the cryostat model.
- Installation envelopes for both SP and DP have been developed
- There is a new 3.6M high cage design
- Will satisfy all DP transport needs
- SP will have to use slung loads for many parts
- CERN will advance the mezzanine design by August 2017
- The detector envelope is defined from ProtoDUNE components
- Integrated envelope drawings of the cryostat, proximity cryogenics and TPC have been produced
- Work on clearances and envelopes was shown
- The status of detector support work for the SP was shown
- The detector power and cooling requirements are unchanged

Comments:

- The continued progress on interfaces is commendable
- Information from ProtoDUNE is being appropriately incorporated as it is developed
- It is unfortunate the Ross cage design height cannot be increased slightly, as that would eliminate the need to transport the SP FC components as a slung load
- DUNE needs to update the list of needed loads for CF logistics.
- The largest SP object is the APA, and CF and DUNE have done a good job to ensure there are no obvious issues in moving them underground. The current plan has the APA's as freely suspended slung loads for descent, and the committee feels some additional validation of that transport method would be a good idea, especially given the time implications if more robust transport systems are needed.
- The use of the north drift area as an unpacking area, and the work required to use it should continue
- A small bridge crane over the TCO is not part of the current plan, but the need for something like that seems likely, and the DUNE team should continue to work with the CF personnel to refine the requirements and potential solutions.
- A non-interface issue was raised about the desire to transport 5000 boxes of cryostat parts underground. Logistics of box moving and fire safety issues should be carefully considered.

- The DUNE spaces in the Central Utility Cavern are said to be well understood for this stage, but some additional details on those plans should be presented at the next LNBC meeting, with attention to the DAQ/computing needs, when they are more clearly defined.
- The ongoing work to understand the interfaces with the cryo mezzanine, racks, feedthroughs, and installation sequences should continue.
- Continued attention to the layout and workflow in the TCO area is needed, and lessons learned from ProtoDUNE will be quite helpful if captured in an accurate and timely way
- They have done an analysis that modeled/identified non-uniform LAr purity, and following through with plans to sufficiently instrument the ProtoDUNE cryostats to validate the analysis is important.
- Understanding the cryostat internal LAr feed and return piping impact on Detector performance is important, and the focus on further understanding there is good.
- Given the cryostat lid penetration layout may change somewhat to accommodate the GTT final design, timely communication of any changes to DUNE is important
- The limited surface area above ground makes integration planning important, even at this stage.
- The grounding and shielding plan appears to be in good shape at this point
- Adoption of the ProtoDUNE Detector Support Structure would be a good way to leverage the experience there, if it can be made to work.
- Continued work is needed (and underway) on the SP cabling and its impact on the feedthrough design.
- The team has been responsive to previous comments and recommendations, and is making good progress.

Recommendations:

- None

Section 4: DUNE Management, Schedule and Planning [Jenni, MacFarlane, Proudfoot]

Findings:

- The DUNE Collaboration is growing, particularly also reaching out to the international community. It counts now 970 collaborators from 164 institutions in 30 nations (60% non-US institutions).
- The DUNE top-level management team is in place, since the last LBNC Edward Blucher was elected as co-spokesperson.
- DUNE is in the process of developing detector consortia and will move towards a process of identifying consortia leadership in the next month or so.
- The baseline strategy is to assume common cryostat designs for the far detector modules, with a decision on TPC technology through a process still to be defined. For planning purposes, the first detector is assumed to be single phase and the second dual phase.
- Collaboration leadership is considering encouraging common consortia between the single- and dual-phase TPC detectors.
- DUNE is moving towards a modified organizational structure with forming construction consortia, on a time scale of August 2017. In the longer term, the collaboration plans to reorganize further with the consortia project leaders becoming part of the Executive Committee (EC).
- The status and progress along the open LBNC management recommendations has been presented, including the move towards systematic tracking of high level milestones and the six-month look ahead.

Comments:

- The LBNC acknowledges the efforts made by DUNE to enlarge the collaboration with a particular emphasis on involving new teams from all over the globe that are also expected to increase non-DOE resources.
- The LBNC appreciates the plans towards a more global and integrated project organization with the planned evolution of the Executive Committee (EC) becoming more explicitly the decision body steering the project. The EC must bring together the leadership of the consortia and main activity coordinators with the DUNE management to take the major decisions carried and supported by the full collaboration.
- The LBNC sees an urgency (before the Technical Proposal) in these steps to foster a true “collaborative working spirit” within DUNE, that will enable the collaboration to reasoned decisions for cost-efficient common solutions and unique technology choices wherever applicable. Such decision should take into account considerations about efficient operation and maintenance in the future.
- There appear to be opportunities with the ProtoDUNEs to encourage wider engagement in the success of these critical efforts, while establishing a more coordinated approach to resource

management including interactions with the Neutrino Platform. The Collaboration should consider launching common consortia between the far detector systems as early as possible.

- Encouraging the far detector consortia to be as much in common (HV cage, photon detection, DAQ, etc) from the beginning is an important part of establishing early an expectation that optimal and cost-efficient solutions will be realized to secure funding support from the international agencies.
- The recent success of WA105 in observing cosmic ray tracks is a very encouraging step in establishing the dual-phase design as a sound approach to the far detector TPC design and points to the possibility of adopting this technology earlier as a baseline choice.
- The LBNC sees an opportunity to attract funding specifically to the dual phase design and perhaps aiming for deployment of two detector modules earlier than in the baseline strategy.
- There is a need to better understand the real risks, schedule implications, and practical engineering implications of deploying both technologies.

Recommendations:

- **Recommendation 4.1:** The LBNC looks forward to a report at its next meeting on steps taken towards forming a global collaboration.

Section 5: DUNE Physics and Reconstruction [Mondal, Boehnlein, Bhadra, Huber, Heinemann]

Findings:

- Good progress in Detector simulation (TPC and photon detectors), Low-level reconstruction (hits and tracks) as well as high-level reconstruction (PID and energy).
- Reconstruction algorithms using four different techniques (PMA, Pandora, CNN, Wire cell) developed for track and shower reconstruction.
- Pandora reconstruction can now handle multiple drift regions with unified coordinate system.
- CNN technique can separate track-like and shower-like hits in simulation as well as in data however computing time is two orders of magnitude higher than other technique such as PMA.
- Performance evaluation of different reconstruction algorithms are in progress.
- Current energy resolutions for reconstructed objects are 10-15% for ne and 20% for nm
- Integration of the DP detector simulation and reconstruction using LArSoft framework are in progress.
- Started joint biweekly LBL/ND meeting to discuss and share updates, plans and tools.
- LBL working group has now the responsibility for LBL fitting code for TDR sensitivity studies as well as for the development of Near Detector concept studies.
- CAFAna used by NOVA has now been ported into DUNE for cross section and flux sensitivity studies. Unlike VALOR it has large existing user base, good documentation and open source code.
- Convolutional Visual Network (CVN) techniques used in event classification/identification by NOnA being ported into DUNE. Gives better efficiency at low energy region important for CP analysis.
- Timeline and milestones for DUNE Physics TDR including both physics performance and software/technical readiness have been established.
- The near detector task force has been transitioned into the ND working group and where appropriate into other WGs, like reconstruction.
- Studies of missing energy due to neutron have begun.

Comments:

- Joint biweekly LBL/ND meeting is the right way to address various common issues.
- Along with optimizing various reconstruction algorithms, a relative comparison of their performances as well as time budget should be evaluated.
- DUNE DP simulation and reconstruction under LArSoft framework should be brought at par with that of DUNE SP.
- Since the baseline strategy for DUNE involves pursuit of both TPC technologies, key physics plots should be produced for both SP as well as DP detectors.

- The effect of detector imperfections such as wire breakage, LAr impurity, dead electronics etc. on key physics performance parameters should be discussed in the physics TDR using either simulation, or experience from other closely related and relevant experiments, or both.
- Engaging the broader physics community, in particular theorists, in the physics TDR preparation remains an important goal.
- The near detector effort appears vigorous and is progressing faster than previously. It still is somewhat unclear how detector requirements are derived.
- Milestones for the TDR preparation should be coordinated with Dune Computing.

Recommendations:

- None.

Section 6: DUNE Computing [Boehnlein, Bhadra, Mondal, Huber, Heinemann]

Findings:

- All major milestones through Q217 directly under the control of Dune Computing have been met, with most Q317 milestones completed or largely on track. The missed milestones are typically related to a lack of effort.
- Dune Computing has developed prioritized task and is actively recruiting effort from the DUNE collaboration. One challenge is the experience profile of the collaboration members, which favors senior faculty and beginning graduate students. Design and development of experiment databases is the most critical need currently identified and corresponds to one of the missed milestones.
- A number of technical issues have been identified, most of which have reasonably tractable solutions. For example, linkages between experiment and Core LArSoft in the continuous integration environment impacts the time it takes to rebuild the DUNE software after relatively simple changes to the DUNE code base. Other examples include physics/reconstruction algorithms or approaches that have work well for traditional neutrino experiments but do not scale up to DUNE.
- Tests for computing to support ProtoDUNE-SP have been conducted and basic services for data transfers and integrated batch systems have been deployed. Rates for ProtoDUNEs are understood in detail. Computing hardware resources for the ProtoDUNEs at CERN have been secured.
- The FNAL SCD will be assessing their effort contributions to DUNE as part of the annual budgeting process.

Comments:

- The LBNC would like to compliment Dune Computing on excellent progress in the timely meeting of milestones. The identification of key technical issues and solutions is highly commendable.
- There has been excellent progress in the CERN/FNAL interface on computing issues.
- We acknowledge that the SCD is taking steps towards assessing their contributions to DUNE and await the outcome of the planning process.
- Dune Computing is a critical component during this period of supporting the ProtoDUNEs data analysis and the development of TDR. The computing effort remains understaffed to simultaneously support multiple efforts. For this reason, we strongly suggest to increase the recruitment of graduate students, and consider streamlining the production tasks. Younger students often have a forward-looking mindset when it comes to software and computing technologies. While they might initially require more supervision and training, over the longer term, they might prove to be critical in bringing a fresh approach.

- The approach of assuming that ProtoDUNE-DP data will be handled identically to ProtoDUNE-SP from an offline computing point of view is coherent and well-motivated towards common reconstruction and analysis. We strongly encourage ProtoDUNE-DP DAQ to work closely with DUNE computing.

Recommendations:

- **Recommendation 6.1:** A combined set of milestones that include computing and reconstruction for the TDR should be developed such that appropriate Monte Carlo samples can be generated and that validated production releases are available that are appropriate for the TDR and for ProtoDUNE reconstruction.

Section 7: ProtoDUNE-SP Schedule and Planning [Proudfoot, Jenni, Heinemann, Huber, Lindgren]

Findings:

- Finding 1 The schedule for ProtoDUNE-SP has slipped since the last LBNC Review in March 2017:
  Approximately 6 weeks for the readiness of the cryostat for installation of the DS
  Approximately 6 weeks for delivery of APA1 to CERN
  Approximately 4 weeks for APA1 (UK)
  Approximately 9 weeks for delivery of the cold electronics for APA1
  The management team is mitigating the impact of these delays by shortening the time assigned to APA integration and testing. A temporary clean area is being prepared to allow integration and testing of APA1 while the completion of the cryostat is ongoing. In addition, the management team have developed an installation plan that would allow installation of any number of APAs from 3 to 6 at the cost of procuring additional frames.

- Finding 2 Winding of APA2 at PSL has been delayed due to a need to rework the APA frame (for APA2 and APA3). This delay is accommodated in the planned schedule by assuming a faster assembly than APA1 in addition to a shorter period for integration and testing.
- Finding 3 Cathode plane assembly, field cage construction, and the APA shipping container are proceeding within the delayed schedule and not incurring any additional delays.
- Finding 4 A full scale trial assembly at Ash River has been carried out to prepare the procedures and team for installation at CERN

- Finding 5 The ProtoDUNE-SP team addressed all charge questions.

  i) APA assembly: Lessons learned from APA1 are being analyzed to establish new assembly procedures which will speed up APA construction. There is good exchange of information between the PSL and UK APA assembly sites. The schedule for assembly of APA2-3 (US) and APA1-3 (UK) are updated in the project plan based on reasonable assumptions for improved assembly procedures to speed up construction.

  ii) DSS design and fabrication status: ProtoDUNE-SP management are to be congratulated on the outstanding progress made in the completion of the DSS design. All engineering documents required for safety review at CERN have been delivered, and key parts of the system have already been procured and delivered to CERN. All components needed for installation are expected at CERN in the next 4 weeks such that the DSS can be installed while the scaffolding used for installation of the cryostat insulation is still in place.

iii) PD status; milestones in the project plan.: Two principals designs of PDS are being developed and are in production. A common electronics readout will be used and first components of the readout have been integrated into the ProtoDUNE Vertical Slice DAQ in May.

iv) Enumeration and status of Interface documents: There has been excellent progress in this area since the last LBNC meeting. A risk register is maintained in DocDB#2814, internal reviews are reported in DocDB#1584, except for the PDS, production readiness reviews have been completed and any resulting action items resolved, Structural Safety Analyses and Assembly and Installation Procedures have been documented (DocDB #3980, DocDB #3956, DocDB #3339), a procedure for procedures has been written (DocDB #3986)

v) Watch list. The ProtoDUNE-SP management team use an informal (smiley face), but effective, approach to characterize the status of each high level activity and use this to identify activities in need of close monitoring or additional resources.

Comments:

- The LBNC is concerned that the cold and warm electronics will not be available on the necessary timescale for ProtoDUNE-SP, as many elements are late and are to be delivered “just in time”.
- We support the schedule mitigation plan presented by the ProtoDUNE-SP management, which allows for a reduced number of APAs to be installed in the cryostat while still achieving all installation and testing goals for ProtoDUNE-SP. We concur that a good approach to construction of the additional frames would be via a procurement using the UK company fabricating the frames for the UK APAs.
- The committee noted that a single institution, BNL, has responsibility for a large number of components for the CE as well as for the warm electronics and that many of these were on a very challenging delivery schedule. A particular concern was noted with the WIB: there are 6 v1 boards and that v2 is in layout. The planned delivery date of the WIB is an integral part of the preparation of the DAQ and testing.
- The committee noted a possible lack of clear communication between ProtoDUNE-SP management and the BNL team responsible for delivering elements of the cold and warm electronics. At this critical point in the project this may impact consistent setting of priorities and goals.
- There is a possibility that SP, DP, and SBND may converge on using a common, extruded aluminum profile. If possible that would benefit all systems. The LBNC would like to follow up on this possibility at the next LBNC meeting
- APA flatness is seen as an area in which improved flatness in assembly may aid in the installation process and in the long term have a major impact on DUNE installation. The LBNC would like to follow up on this at the next LBNC meeting.

Recommendations:

- **Recommendation 7.1:** The ProtoDUNE-SP management team should prepare a table with the list of the CE components to be delivered by the BNL team, their status (e.g. “Prototype”, “procurement in progress”, “all components on hand”), expected or estimated delivery dates for APA1, 2,3,4,5,6). This table should also include details of any staged delivery plan. A prioritized plan for assignment of resources to these components should be prepared.
- **Recommendation 7.2:** The WIB is in a second iteration. 5 are needed for use in the cold box test of APA1 at CERN and only 1 board is available. The ProtoDUNE-SP management should work with the BNL team to identify sufficient WIBs to allow efficient operation of the cold box testing for APA1, presently scheduled for the first week in August, and to provide boards as needed to DAQ developers for system integration.
- **Recommendation 7.3:** The ProtoDUNE-SP CE System Manager should communicate with the Construction Coordinator on a weekly basis through this critical period (4-16 weeks).
- **Recommendation 7.4:** The LBNC points of contact for CE, Planning and Schedule should follow up with ProtoDUNE-SP management and the BNL team responsible for the cold and warm electronics deliverables in the next POC interaction, which should take place in approximately one month.

Section 8: ProtoDUNE-SP CE and TPC [Pitts, Liu, Monroe, Proudfoot, Mondal]

Findings:

- Design of the Detector Support Structure is complete, engineering documentation has been provided, parts are being ordered and assembly will begin in late July.
- Winding of APA 1 is complete. Problems with the CR boards understood. New CR boards will be installed and APA 1 will be shipped on July 11, 2017.
- Start of winding of APAs 2 and 3 has been delayed by issues with the frames.
- Options for descoping ProtoDUNE-SP have been considered in case fewer than 6 APAs are available. These options require additional APA frames, unloaded, at a small cost and accommodate the photon detectors.
- Considerable progress has been made on the CPA, Field Cage, and HV system.
- Considerable progress has been made on the Photon Detection System. Three different technologies will be deployed in ProtoDUNE-SP. Issues with SiPM packaging have been identified and sufficient quantities exist for ProtoDUNE-SP.
- Trial assembly work at Ash River has been completed and documented.
- A new process has been implemented ("procedure on procedures") to ensure that procedures are well-documented.
- ASICs have been received at BNL and are currently under testing. Delivery of the ADC chips was 2 months later than the original scheduled date. Other front-end components are in various stages of prototype, testing and production.
- Phase 1 of HV testing in the 35 ton detector at Fermilab took place in April and May. Good lifetime was achieved, HV was applied and maintained for several days at a time. Spikes in current were seen that are inconsistent with discharge at a frequency of 1-2/hr. These spikes were not large enough to cause HV trips, but did lead to a reduced voltage applied.
- The Christian Committee completed their work and report on future directions for ADC technology. Three specific ADC architectures have been identified as alternatives to replace the Domino architecture.

Comments:

- The schedule for ProtoDUNE-SP to be constructed and ready for beam prior to CERN long shutdown 2 was aggressive from the beginning. The Collaboration has made significant progress on a number of fronts since the March meeting.
- The schedule remains aggressive but achievable.
- Progress on the Detector Support Structure since March has been extremely impressive. A strong design is in place along with a good plan to complete assembly very soon.

- The ProtoDUNE-SP de-scoping options presented are valuable and well-considered. The options preserve the benefits derived from accurately mimicking DUNE assembly and also maintains the physics benefits that would be derived from test beam. These options also considerably mitigate schedule risk with little downside or cost.
- The Photon Detection System is in good shape and will allow direct evaluation of three different detectors. The de-scoping options discussed above preserve the opportunity to install and evaluate all three detector types.
- Completion of APA 1 was delayed due to the availability of auxiliary/interface pieces. These issues are better understood now. It is important to continue to consider all interfaces, mechanical and electronics.
- New CR boards will be installed on APA 1 very soon. Components have been cold-tested, but not fully loaded boards. The collaboration should consider cold testing some spare CR boards in parallel with other activities.
- Efforts are underway to ensure that lessons learned from the winding of APA 1 can be translated into an efficient and optimal procedure for future APAs. This is an important effort, and success on this front will significantly mitigate schedule risk.
- Efforts to thoroughly document procedures, interfaces and lessons learned are crucial so that they can be reviewed, improved and translated to DUNE. We commend the collaboration for these important efforts.
- Phase 1 HV testing on the 35 ton detector was successful, although some issues were encountered that are yet to be understood. Although there are elements of the 35 ton TPC that are different than protoDUNE-SP, it is important to pursue an ongoing effort to study and quantify the unexplained effects. We encourage the collaboration to identify personpower to continue this effort. We also suggest that other noble liquid HV experts be consulted informally for advice and input on these items and how to proceed.
- A number of front-end components (cold and warm) are needed relatively soon in order to perform cold-box testing of APA 1 as well as DAQ testing and evaluation. While progress has been made, several of these components present a significant schedule risk to the ProtoDUNE-SP effort, in particular, the WIB. The status and progress of the cold electronics should be closely monitored.
- The recommendations of the Christian Committee should be considered in terms of collaboration goals and priorities. A plan to evaluate options and decision points should be assembled as soon as feasible. For this effort, the collaboration must consider ADC architecture options, performance and longevity. A long term strategy for the overall future cold electronics development for DUNE should be developed. This should include system design for redundancy study to improve the overall system reliability, and large scale cold electronics testing facility for component and board level testing, evaluation and burn-in.
- The LBNC is concerned that the lack of direction on the final electronics system design, including the ADC, threatens the viability of the single phase detector as a TPC option for the far detector.

Recommendations:

- **Recommendation 8.1:** The LBNC expects a plan for the cold electronics system design to be presented at the next LBNC review meeting.

Section 9: ProtoDUNE-SP DAQ [Liu, Boehnlein, Pitts, Bhadra, Pallavicini]

Findings:

- All hardware components required for the DAQ are now available, including servers, switches, interconnections, storage solution, ATCA RCE and FLIEX PCIe solutions, timing units, central trigger board. DAQ related hardware for the cold-box is at EHN1. The power supplies for the computer racks went missing in shipping. They have been reordered and should arrive at CERN eminently.
- A complete design of the DAQ system exists, and the rates are understood.
- DAQ system integrated with SSP and initial tests successful
- The DAQ group has taken an approach of continuous integration with Milestone weeks. With this approach, all milestones under the direct control of the DAQ group have been met.
- The focus is now to get the cold-box setup running. Effort is arriving at CERN for the cold box integration tests in July and August, however
- Integration with WIB is delayed due to the availability of working WIB (hardware and firmware)
- Additional effort will be added to the monitoring tasks in July.

Comments:

- Lots of good progress has been made since last review. We commend the ProtoDUNE-SP DAQ group on the progress and the success of the continuous integration approach and for addressing the watch list items to the extent possible.
- Successful integration with SSP is a major milestone
- The main concern is the integration with the WIB due to the delay of WIB

Recommendations:

- None

Section 10: ProtoDUNE-DP Technical, Schedule and Planning [Monroe, Lindgren, MacFarlane]

Findings:

- The technology demonstrator for ProtoDUNE-DP, the 1x1x3 detector, has observed first cosmic ray tracks and demonstrated readout noise well within the design specification.
- Operation of the 1x1x3 demonstrator has retired ProtoDUNE-DP risks associated with electronics noise performance.
- ProtoDUNE-DP passed its external Design & Installation review, held at CERN April 28-29. Implementation of review recommendations is in progress.
- Electronics, LEM and tooling components for charge readout plane production are in hand for charge readout plane assembly.
- The schedule for ProtoDUNE-DP has slipped by 2 months since the March 2017 LBNC, because of delays in clean room readiness and cryostat completion.

Comments:

- The achievement of ProtoDUNE-DP in observing cosmic ray tracks within 6 days of commencing cryogenic operations is outstanding. We congratulate the collaboration!
- protoDUNE-DP should evaluate the manpower implications of constructing dual phase protoDUNE while operating the 1x1x3 prototype.
- Preparation of safety documentation, and coordination of supporting engineering resource, appears to be an area where there should be closer collaboration between ProtoDUNEs.
- We remain concerned about the extent to which ProtoDUNE-DP is integrated with the project office and the broader collaboration. We encourage the management to consider strategies to increase coordination and participation.
- A clear and formal link between cryogenics, infrastructure, and the TPC schedule would help the experimenters to plan the commissioning most efficiently.
- There does not seem to be a well-defined acceptance condition for when the cryogenics team finishes commissioning and the experiment starts.
- Neutrino Platform manpower alone may not be sufficient to accomplish the challenging installation of both ProtoDUNEs simultaneously. DUNE should carefully evaluate the combined needs for collaboration manpower to ensure successful and timely completion of both ProtoDUNE-SP and ProtoDUNE-DP.
- Defining a formal process for the DUNE experiment to interact with the EHN1 coordinator would facilitate conflict resolution between the ProtoDUNE-SP and -DP installation activities.

Recommendations:

- **Recommendation 10.1:** ProtoDUNE-DP (and -SP) should develop a resource-loaded installation schedule and make a plan jointly with the Neutrino Platform and the EHN1 Coordinator to agree the level and timing of CERN technical support
- **Recommendation 10.2:** A coordination mechanism should be defined by the collaboration for the CERN safety review process for the ProtoDUNEs. At a minimum the common systems (e.g. field cage) should have a joint safety documentation preparation process.
- **Recommendation 10.3:** An expert task force should be tasked with identifying ways to test the cryostat thermal performance as early as possible (including before closing the TCO) to mitigate schedule risk, in light of experience from the 1x1x3 commissioning.