LBNC Closeout Report: June Review (October 25-28, 2017)

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Executive Summary

The LBNC met at SURF, October 25-28, 2017, in part to get a chance for all LBNC members to gain first-hand impressions of the underground site and future location of the far site facilities for DUNE through a visit to the 4850L. SURF provided superb support for the LBNC meeting, including arrangements for an extended underground tour. 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.

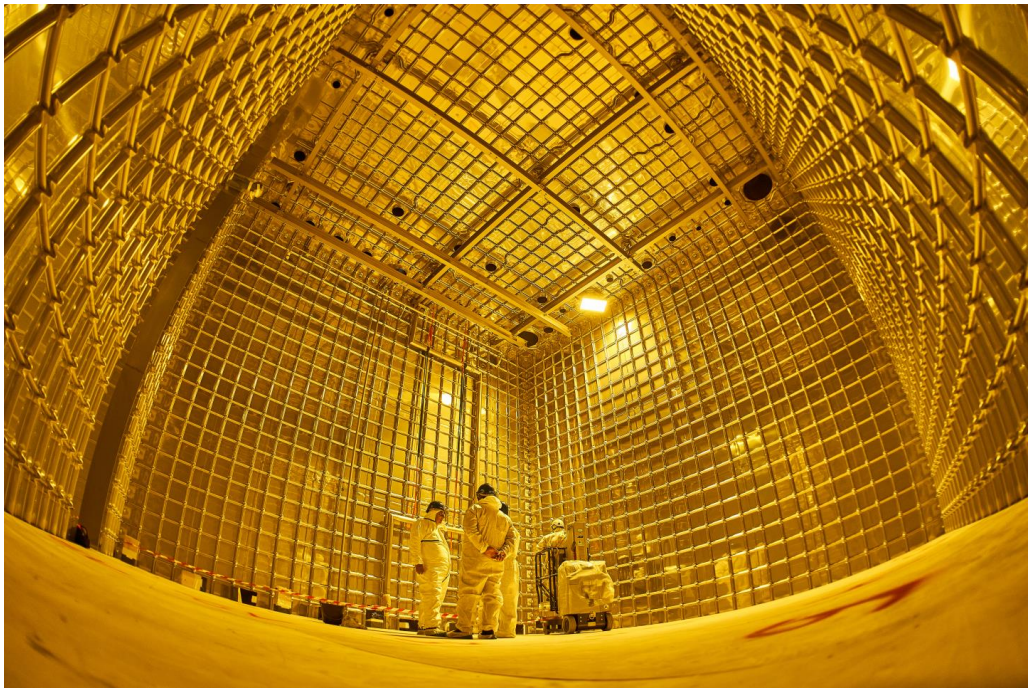
Overall, the Committee was very impressed by the significant progress achieved by both LBNF and DUNE since the last LBNC review. Of particular note for LBNF was the conclusion of the Ross shaft steel set refurbishment, letting of the CM/GC contract and the imminent start of the final design phase. Equally impressive was the successful completion of the two protoDUNE cryostats at the Neutrino Platform at CERN, as well as the delivery of the protoDUNE-SP APA plane #1 (PSL#1) at CERN, installation of photon detectors, testing of the DAQ system with the full assembly installed in the cold box. All 40 photon-detector channels are functional. Testing of APA1 at room temperature has shown noise consistent with expectations and testing at cryogenic temperatures is planned to begin the week of Oct 30. The LBNC also found the progress of the ProtoDune-SP DAQ group to be very impressive, having now reached the point where the DAQ system is ready for integration testing with the Cold Box. This early availability is very important, given that there will be not much time for debugging the DAQ *in situ* with beam.

There are a number of new and unusual procurement, liability, real estate, and tax issues that have been and will continue to be worked by LBNF, FSO, and DOE HQ. These problems are well recognized and continue to be worked, but the resulting accumulated delays in resolving paths forward (some 6 months between June 2016 and Sept 2017) are worrisome. The LBNC therefore recommends:

> *[Recommendation] The host lab and DOE efforts to resolve numerous legal and procurement challenges at the far site need to further evolve in order to allow timely resolution and achievement of the defined International Project Milestones.*

The DUNE Collaboration has continued to grow by attracting new Institutions (totaling now 1038 collaborators from 176 Institutions in 31 Nations) with about 300 FTE working on the project, including a healthy fraction of PhD students. There is significant progress in negotiations with new prospective partners in Europe, South America and Asia, with particular interest for the Near Detector from Italy, Germany and JINR/Russia. The UK has made recently an important commitment of 88 MUSD to the project. The new organizational structure based on Far Detector consortia has been established in a timely

manner for 8 out of the total 9 planned subsystems, including the appointment of leadership for them. These groups have now been operational since several weeks, initially focusing on development of a suitable WBS structure and initial institutional construction interest. The establishment of the DP CRP needs to await further internal clarification. Consortia for the Near Detector will be defined at a future stage when appropriate. The LBNC was pleased to see that there is a clear path for the evolution of the Executive Committee by May 2018 into a management and decision-making body bringing together the consortia leaders with DUNE top management. The LBNC recognizes that such an extended transition period may be needed, but would not want to see this completion date slip in the light of many forthcoming important decisions.



Interior view of the completed and cleaned protoDUNE-SP cryostat at CERN.

Other areas of progress by DUNE were also noted by the committee:

- Overall progress in detector simulation (TPC and photon detectors), low-level reconstruction (hits and tracks) as well as high-level reconstruction (PID and energy) continues to be impressive;
- DUNE Computing has been able to meet milestones and address operational issues in a timely manner. Examples include the area of databases and the successful recruitment of additional contributors to Computing and Software. We welcome the appointment of Heidi Schellman as co-convener to C & S and we thank Tom Junk for his co-leadership up until now.

The LBNC was very pleased to see the progress in developing a common cryostat design for the single and dual phase TPCs, as recommended at our last meeting. The positive resolution of the recommendation regarding a common SP and DP cryostats warm structure design is a major development. The committee recognizes and appreciates the effort directed towards these issues. The penetration issues between top of the cryostat, detector and cryogenic connections, which were driving towards two separate designs,

have been resolved and are awaiting DUNE approval. The present plan is that the DP-DUNE and SP-DUNE cryostats will have common walls and floor. The roof structural steel is nearly identical between the SP and DP, with the only difference being that the central beam has been replaced by two smaller beams on the sides (of the hypothetical central beam) in the SP configuration. Much progress has also been made on the mezzanine design, including a 4.8M longitudinal shift to accommodate DUNE access to detector feedthroughs.

The LBNC discussed proposed plans for the Technical Proposals and the Technical Design Reports as presented by the DUNE management. While the committee views these plans very ambitious, it also agrees that this will allow the Collaboration to maintain full momentum for developing the project in a focused and timely fashion, including the detailed construction strategies and schedules for the various components. High level risks and mitigation strategies should also be incorporated in these documents. As part of these efforts, the LBNC recommends maintenance of a clear line of sight between physics and technical requirements:

> *[Recommendation] At our next meeting, the LBNC would like to hear a proposed mechanism for documenting the flow down from physics to technical requirements in DUNE, as well as how this will be addressed in the TDR and demonstrated with the protoDUNE test plan.*

Likewise, demonstration of the physics capability of the proposed DUNE detector will depend on consistent simulations with documented and understood performance capabilities. Therefore, the LBNC also recommends:

> *[Recommendation] There are various algorithms and tools that are being developed for SP and DP. A freeze date for a reference algorithm should be established for producing various physics plots as input for the TDR.*

One area of ongoing concern for the LBNC is the planning for the computing model to support data reduction and analysis at DUNE. We note that the collaboration decided not to set up a computing consortium at this time as part of its recent re-organization for construction of the far detector. However, at the time of the TP and certainly by the TDR, there are several aspects of the computing model with significant cost implications, which will require definition.

> *[Recommendation] By February, 2018, develop a list of questions and factors that will influence the computing model, with prioritization of those factors in terms of likely cost and schedule impact.*

Progress on the protoDUNE-SP project is proceeding well, including construction of major components such as the anode pane assemblies (APAs), cathode plane (CP) panels, field cage modules, photon detectors, electronics modules and initial testing of assembled APAs at CERN. However the assembly schedule remains very tight for completion with a full complement of six APAs. As a result, the LBNC notes that there are decisions to be made concerning the number of instrumented APAs to be installed, the installation of the beam plug and the timing of the closing of the TCO which could have a major impact on the physics program. A detailed APA construction schedule has been produced allowing maximal flexibility

in construction of APAs in the US and UK. APA2 construction took significantly less time than for APA1, however despite some optimization it seems unlikely that a substantial speed up beyond this will be possible.

The LBNC has been concerned for some time about the design and technical status of the cold electronics system for DUNE, which is first deployed as a prototype system in protoDUNE-SP. The protoDUNE-SP implementation utilizes an ADC ASIC in the LAr at cold temperatures that has known flaws and does not meet requirements. The LBNC has therefore requested that the DUNE Collaboration develop a long-term robust strategy (potentially multi-pronged) for developing and testing at scale a system that meets requirements. DUNE has been working over the last few months to put in place such a strategy and a plan was presented at this meeting. The plan includes development of a new standalone ADC ASIC in 65 nm CMOS through a multilab collaboration (BNL, FNAL and LBNL) as a part of the present three chip design approach, as well as pursuit of a second system-on-chip pathway building on development for the future nEXO experiment to produce a single combined function ADC (incorporating front-end (FE) amplification, ADC, digitization and serialization of the output data stream (COLDATA), and optical line drivers with a design team at SLAC). In the case of the 3-chip development, the Design Group has delineated responsibilities across laboratories along with a plan to carry out internal "deep reviews" of the design. The baseline design is the three ASIC approach with separate FE, ADC, and COLDATA chips, but it is expected that the alternative combined function approach will also be presented in the Technical Proposal. A third approach based on commercial off-the-shelf (COTS) ADC solutions are being evaluated for SBND and are considered only as a backup plan for DUNE. While the LBNC is pleased with the overall direction of this multiprong approach, the committee would like to see further definition of the two pathways:

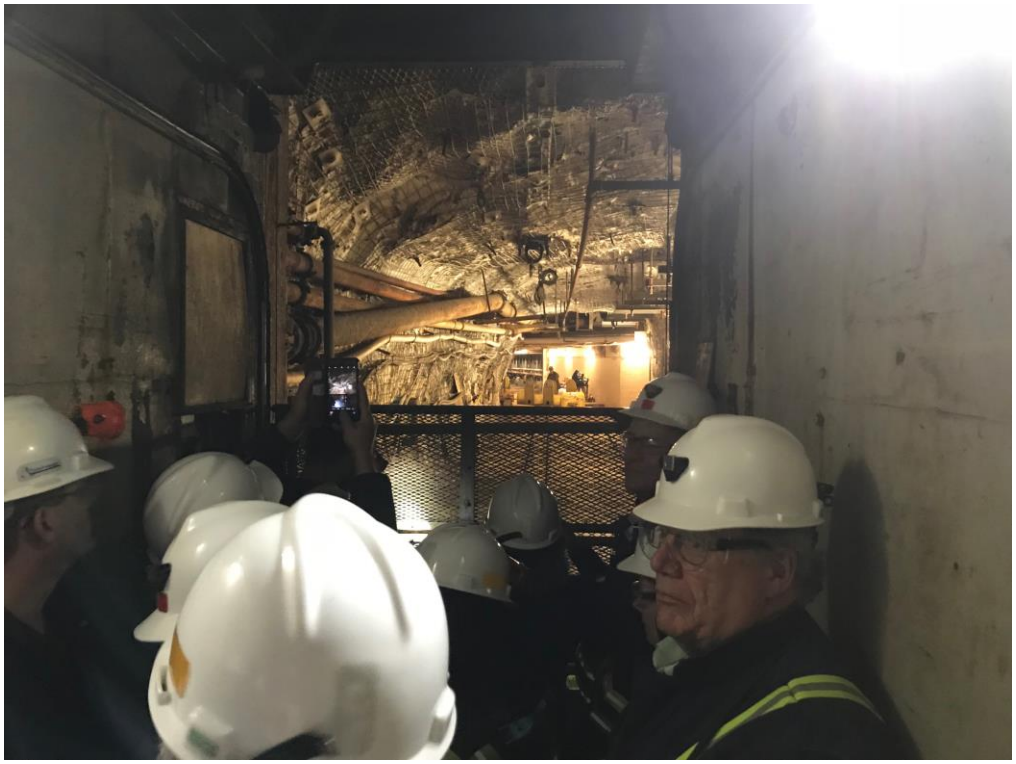
[Recommendation] By the end of November 2017, present a detailed plan for DUNE ADC development as well as testing and evaluation. This should include:

- *intermediate technical milestones over the next 9 months for the ADC development effort, and*
- *a plan and metrics by which various options might be evaluated.*

The long-term far-detector staging strategy for DUNE continues to plan with four identical 10 kT cryostats but with four similar but not identical LAr technologies. The baseline plan assumes the first far detector module will be single phase, the second will be dual phase, and the subsequent two as notionally designated as single phase and uncovered. In this context, the LBNC has followed closely the technical development of the dual phase technology and in particular the experience to date with the WA105 1x1x3m prototype at CERN. This prototype took first cosmic ray events just prior to our last meeting in June, but has experienced a variety of high-voltage and operational issues subsequently. A review of experience to-date with the 1x1x3 dual phase prototype occurred at CERN just prior to the LBNC meeting on September 25, 2017. The review was charged with answering a number of key questions about HV issues and test plans going forward. An action list for further tests was produced as an output to the review, along with a timeline for execution of these tests now being executed. A follow-up meeting to review the results of these tests will be held on November 17, 2017. The LBNC commends CERN and WA105 collaboration for these efforts and views the proposed tests as an important and complete approach to understanding the existing HV problems and informing future design modifications for the 6x6x6 protoDUNE-DP implementation, as long as they are conducted on the agreed timescale.

Donning all the proper PPE for going underground

Group ready to descend the Yates shaft to the 4850L



On our way down the Yates shaft

Witnessing the important milestone: completion of the Ross shaft refurbishment to the 4850L

Inner workings of the Yates hoist in action

Underground test blast location on the 4850L and future home of the DUNE detector and central utility caverns.

View towards the Ross hoist through the beautiful Black Hills countryside

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

Findings:

- Ross shaft refurb complete to 4850L
- Groundbreaking held
- Full funds for FY2017 received, expectation under appropriations bill is $80M for FY2018. Cash flow is being managed.
- Tax issue re FRA as prime contractor is resolved, additional issues under review
- CM/GC contract has been let (Kiewit/Albicini Joint Venture), with a plan to launch the final design process with a kickoff meeting in early November, contingent upon resolving remaining issues for moving the ARUP contract from SDSTA to FRA.
- Developing business continuity plans with SURF, defining who holds jurisdiction for various systems and sub-systems at SURF and LBNF. Operations contract with SURF based on historical costs, does not include infrastructure replacement, which is being done under individual contracts.
- Overall Business Model for SURF operations is being evaluated to determine cost-sharing model.
- Several major procurement actions are underway. Recruitment underway for two additional procurement staff, to bring team back to full strength. Additional avenues being explored, senior management engaged.
- New logistics manager taken on at far site, developing plans for hosting a surface integration facility locally. Industry day held at far site to engage liquid argon providers.
- Emergency response deep-dive conducted, identified some inconsistencies, training and qualification gaps.
- Support services for underground refuge being enhanced to allow increased capacity for 150 people.
- Planning on reliability projects continue – ventilation shaft (shaft 5) refurbishment accelerated by SDSTA, Ross cage replacement priority increased.
- International Project Milestones have been defined, are being frozen in P6 and will be aligned with P6 working milestones at baselining. 95 risks tracked actively, additional risks around beam added.
- Cooling for the decay pipe switched to nitrogen, rather than air; target chase atmosphere changed to nitrogen instead of air
- Conceptual design for optimized target completed, optimized cost for Beamline and NSCF $609M compared with currnet (CD-1) design cost of $575M. International partners undertaking work on target design, construction of corrector magnets and (potentially) seals. Additional international partners for beamline work being sought.

Comments:

- Committee congratulates the collaboration for progress on LBNF development, especially the conclusion of the Ross shaft steel set refurbishment, letting of the CM/GC contract and the start of the final design phase.
- Cash flow being managed for this year, knowledge of FY2018 and FY2019 becoming critical for planning purposes. Pleased to see progress on SD tax issues.
- Ability to conclude procurement actions is clearly sub-optimal and impacting schedule, encourage FNAL to work with site office and DOE to resolve. Between Dec 2016 and September 2017 there has been a roughly 6 month slippage in the LBNF schedule, largely driven by delays letting contracts rather than funding availability.
- Property considerations continue to be a challenge in setting up contracts between FRA and SDSTA.
- Pleased to see the development of business continuity plans, but concerned that the higher level Business Model for SURF may be a distraction when the bulk of SURF operations relate to HEP program.
- Conclusion of the development of the EHS program is clearly a high priority.
- Welcome the addition of the new logistics manager for far site integration.
- Not clear how lessons learnt are incorporated from progenitors.
- Support the development of International Project Milestones as a strong signal for the international community.
- The prioritization of far site work over near site work is understood, and supported by the committee
- Although near site work is being managed in close connection with DOE, international partners and the collaboration, care should be taken to ensure no impact on project delivery schedule.
- A clear strategy for resolving numerous challenges presented by an international construction project executed at a non-Federal site need resolution and a coherent approach (including responsibilities) will be needed.

Recommendations:

- The host lab and DOE efforts to resolve numerous legal and procurement challenges at the far site need to further evolve in order to allow timely resolution and achievement of the defined International Project Milestones.

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

Findings:

1x1x3 WA105

- Cryogenic performance of the 1x1x3 cryostat is good; achieved LAr purity is excellent (>7 ms lifetime); liquid surface stability and heat load appear to be acceptable.
- The upcoming schedule of testing activities for WA105 (1x1x3) is uncertain. Issues with high voltage breakdown and Large Electron Multipliers (LEM) are being investigated.
- Detailed inspection plan is being prepared.
- A collaborative decision how to proceed forward will be made during PIs meeting that is currently planned for November 17, 2017.

Proto-DUNE

- The complete cryostats (warm structures, insulation and membranes) have been assembled, tested, and cleaned.
- Insulation space testing included visual inspection by Gaztransport & Technigaz Co., Ltd (GTT) - the cryostat membrane contractor
- GTT quality inspection was followed by leak checks by both CERN and an independent company contracted by CERN.
- A comprehensive leak test of the warm structure and membranes using helium mass spectrometry has been completed.
- An independent contractor will install strain gages to monitor cryostat under load.
- GTT had four times as many staff as usual conducting installation Quality Control. The final Quality Assurance and Control report from GTT is expected shortly.
- The Neutrino Platform is developing a cryogenic performance testing plan.
- Test results will be input in the Computation Fluid Dynamic (CFD) model. The testing program will be adjusted as need to align the CFD model with actual cryostat performance.
- Proximity and External Cryogenic systems are being constructed and are planned for installation in February 2018.

LBNF

- The warm structure design review was completed in August 2017.
- The penetration issues between top of the cryostat, detector and cryogenic connections, which were driving towards two separate designs, have been resolved and are awaiting DUNE approval. The present plan is that the DP-DUNE and SP-DUNE cryostats will have common walls and floor. The roof structural steel is nearly identical between the SP and DP, with the only difference being that the central beam has been replaced by two smaller beams on the sides (of the hypothetical central beam) in the SP configuration.

- CERN has given approval to issue cryostats design contract to GTT. The contract schedule is consistent with the installation at SURF in 2021.
- Work on the installation sequence is advancing.
- Divergence in approach to the pressure safety testing exist between the Neutrino platform and Fermilab. CERN proposes to do a load test with the cryostat full of LAr and add GAr at 115% of the cryostat's Maximum Allowable Working Pressure (MAWP). Fermilab approach requires pneumatic pressure test at 115% of the cryostat's MAWP. LBNF is waiting for the risk assessment from the safety panels to state its position.

Comments:

1x1x3 WA105

- A formal detailed plan to warm-up and inspect the cryostat is a sound approach and should continue to be developed.
- Lessons learned and design improvements need to be formally captured to ensure that subsequent work benefits.

Proto-DUNE

- LBNC congratulates CERN-NP and the collaboration on the tremendous progress on the PD-SP & PD-DP cryostats.
- The demonstration of effective helium mass-spec leak detecting techniques represents a substantial step in cryostat QA. Furthermore, the project believes the technique is scalable to DUNE which would reduce project risk.
- Development of a cryogenic performance testing plan is vital. The plan should include the defined location of instrumentation, tests parameters, etc. The "dead" time during the Ar purification cycles may provide a test window.
- GTT has shown themselves an active and committed partner and is providing strong installation and QA support for the PD-SP and PD-DP cryostats.

LBNF

- The positive resolution of the recommendation regarding a common SP and DP cryostats warm structure design is a major development. The committee recognizes and appreciates the effort directed towards these issues.
- As an alternative to a room temperature pneumatic pressure test, the CERN-NP counterproposal, rigorous engineering assessment and QC measures may provide sufficient means to achieve equivalent level of safety.

Recommendations:

- Ensure that the cryogenics performance testing is given priority on Proto-DUNE and sufficient attention to collect data, baseline simulations, and iterate as needed.

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

Findings:

- Mezzanine load calculations have been done and communicated to CF and Cryostat design for static loads, totaling 183 tons, with a 50 ton deck.
- Chamber envelope drawings are being developed for the first two chambers. They will include conveyance, mezzanine, cryogenic, egress, ancillary and installation space.
- Computational Fluid Dynamics (CFD) calculations are being done to optimize the cryogenics layout inside the cryostat. The model will be informed by the protoDUNE results and used to develop internal envelope drawings.
- The CUC envelope drawings have begun, using the existing CUC plans
- The roof design for the SP and DP cryostats has been adapted, and are now different, to accommodate different detector configuration while maintaining identical cryostat sides and floor for both.
- The SP and DP cryogenic feedthroughs are now common
- ProtoDUNE feedthrough procurement experience is guiding standardization of DUNE feed through pipes and flanges
- The Ross cage design has been finalized after discussion and agreement between all stakeholders.

Comments:

- Interface communications on the SP design are advancing as needed, and have much improved over the past year.
- Much progress has been made on the mezzanine design, including a 4.8M longitudinal shift to accommodate DUNE access to detector feedthroughs
- The schedule for the additional design finalization of the 10 racks under the mezzanine to ensure access and clearances should be understood and communicated soon.
- The next steps on mezzanine, cryo, and detector interface design work are well thought out, and work should continue on them, including additional schedule and milestone development.
- Development of a chamber coordinate system is a good idea and should be pursued
- The plan to continue the envelope drawing development inside the detector is a good one, and should include lessons learned from protoDUNE
- The ongoing CFD analysis and interaction/optimization with the detector design should continue, as the current model has only 119 mm of LAr above the detector and 800 mm of ullage. This is an important exercise, and informing the detector model in substantive ways.
- The ullage space discussion, and discussion of cable outgassing and cryogenic issues associated with it was still at a qualitative stage. Development of written requirements and specifications is a necessary next step if the internal cryostat layout is to successfully converge.
- Feedthrough design inputs are advancing, and being properly communicated to the design team in a well-coordinated manner. The gate valve study for feedthroughs should be continued.
- At the June LBNC, the SP and DP cryostat designs differed from each other not only in terms of the roof, but also the spacing of the steel beams for the warm structure. The cryostat designs have converged in a very positive way. The roofs are still distinct, although changes were made to make many subsystem penetration locations common. The design changes to the roofs are modest, and an excellent, cost effective solution. Getting the rest of the steel the same (sides &

floor) is a big step.

- DUNE should continue the good communications with ProtoDUNE, and should carefully collect, document, and continue to apply lessons learned there to the FS design work.
- Given the finalization of the Ross cage design, continue to develop the Sharepoint database used to for all loads that need to be transported.

Recommendations:

No recommendation

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

Findings:

- The DUNE Collaboration has continued to grow by attracting new Institutions (totaling now 1038 collaborators from 176 Institutions in 31 Nations) with about 300 FTE working on the project, including a healthy fraction of PhD students. There is significant progress in negotiations with new prospective partners in Europe, South America and Asia, with particular interest for the Near Detector from Italy, Germany and JINR/Russia.
- The UK has made recently an important commitment of 88 MUSD to the project.
- The new organization with consortia has been established for the Far Detector in a timely manner for 8 out of the total 9 planned, including a smooth appointment of the leaderships for them. They are operational since several weeks. The setting up of the DP CRP needs to await further internal clarifications. Consortia for the Near Detector will be defined at a future stage when appropriate.
- Various Collaboration coordination bodies are in place, with new leadership appointments for computing coordination, speakers committee, and authorship and publications board.
- A schedule for the Far Detector Technical Proposals (May 2018) and Technical Design Reports (April 2019) has been proposed.
- The decision process for the Near Detector has been documented and a decision milestone newly set to May 2018, with the CDR planned for April 2019.
- A strategy has been defined for the full 4 module DUNE to be presented to the RRB, comprising two SP, one DP and one uncovered module.

Comments:

- The LBNC acknowledges the successful efforts of DUNE to attract new collaboration partners worldwide, with a notable Collaboration growth since the last LNBC meeting, and with advanced-stage negotiations with several potential major contributors that would increase non-DOE resources.
- Particularly welcome news is the firm financial commitment of the UK.
- The LBNC commends DUNE for having implemented efficiently a new structure with consortia for the Far Detector and appointed the top leadership for them, with a healthy distribution of these positions over the full collaboration. It considers this as a demonstration of a major step in building up a collaborative spirit. The LBNC also notes that this is an important step in order to facilitate newcomers to join the project.
- In setting up these consortia DUNE has indeed taken into account communalities between SP and DP matters where appropriate, as suggested by the LBNC at its last meeting. The committee questions why this logic was not carried forward fully into the TDR volume planning.

- The LBNC appreciates that the formation of the DP CRP consortium needs some more time at the present stage for internal discussions within DUNE.
- The LBNC considers the plans for the Technical Proposals and the Technical Design Reports very ambitious, but agrees that this will allow the Collaboration to maintain its full momentum for developing the project in a focused and timely fashion, including the detailed construction strategies and schedules for the various components. High level risks and mitigation strategies should also be presented.
- There is a clear path for the evolution, leading to May 2018, of the Executive Committee into the management body bringing together the consortia leaders with the DUNE top management. The LBNC acknowledges that such a transition period may be needed, but this should not slip as important decisions are forthcoming.
- The presented development plan and milestones for the Near Detector appear to be well-reasoned to the committee. The LBNC expects to see full simulation studies to validate and document design decisions for each of these milestones and the timeline may need adjustment if this requirement is not met.
- Although a calibration task force has been established, the LBNC remains to be fully convinced that this crucial issue will be efficiently handled.
- The proposed mechanism for 6 month look-ahead is appropriate. This might be even more useful to the LBNC if it included information about the issues that need to be resolved for each activity and any documentation anticipated as part of the activity.
- Following the November near-detector (ND) workshop, the LBNC would like to hear a report on progress and status of the ND conceptual design development.

Recommendations:

- A report on the calibration issues, including implications for the cryostat, should be presented at the next LBNC meeting.
- Lessons learned: A formal process to aggregate the lessons learned from previous detector prototypes, commissioning and operation of relevant LAr TPCs into the DUNE/LBNF design should be developed. The LBNC would like to hear a presentation at its next meeting on any cross-cutting system design issues that emerge from lessons learned, over and above the existing calibration task force.
- At our next meeting, the LBNC would like to hear a proposed mechanism for documenting the flow down from physics to technical requirements in DUNE, as well as how this will be addressed in the TDR and demonstrated with the protoDUNE test plan.

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

Findings:

- First Physics week scheduled in Nov 2017 with a hack-day style workshop for all physics working groups and associated activities.
- A new task force on calibration has been set up specifically to make recommendations on detector/cryostat design for TDR and to analyze expected/needed calibrations for physics TDR.
- Physics TDR timeline established. Final version expected to be ready by April 2019
- Several important milestones including initial simulation and reconstruction chain, preliminary nue, numu selection based on reconstruction and neutrino energy reconstruction achieved.
- New approaches of 3D reconstruction (instead of 2D) and event selection using Deep Learning approaches appears very promising.
- Improved photon detector simulation and reconstruction are in progress.

Comments:

- LBNC commends the overall progress made in detector simulation (TPC and photon detectors), low-level reconstruction (hits and tracks) as well as high-level reconstruction (PID and energy).
- Physics TDR must make the physics case for both SP and DP detector designs. However at present DP is less integrated into the DUNE simulation, reconstruction and physics studies environment. While this scenario is changing, LBNC is concerned with the comment that DP effort may not fully catch up in time for TDR.
- Reference algorithms required for Physics TDR need to be frozen before embarking on producing various physics sensitivity plots required for physics TDR.
- Close interaction and consultation with theorists is recommended in all areas, including neutrino interactions, prior to the TDR.
- The usage of deep learning or other advanced reconstruction techniques is very welcome, in particular in collaboration with computer scientists or statisticians, and some efforts are already ongoing towards this direction.

Recommendations:

- The Physics group and Reconstruction groups need close communication with the Computing group. This is essential in order to complete various physics studies required for the Physics TDR in a timely manner and to ensure that necessary computing resources are available. In particular, different reconstruction techniques may require resources that are currently not in any plan.
- DUNE DP simulation and reconstruction under LArSoft framework should be brought at par with that of DUNE SP in order to make the physics cases for both the detectors on equal footing.

- The effect of detector imperfections such as design parameters, as well as imperfections such wire breakage, LAr impurity, dead electronics, nonlinearities, calibrations, operational degradation as realized in operations, and any related detector conditions on key physics performance parameters should be discussed initially in the TP and in full detail in the TDR using either simulation, or experience from other closely related and relevant experiments, or both.
- There are various algorithms and tools that are being developed for SP and DP. A freeze date for a reference algorithm should be established for producing various physics plots as input for the TDR.

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

Findings:

- DUNE Computing has successfully recruited effort from the DUNE collaboration, with Oregon, Florida, Colorado State, Cincinnati, Drexel, and UMinn Duluth joining the computing effort. With this, the leadership and membership of the sub-groups have been established.
- Most major milestones through Q417 directly under the control of Dune Computing have been met, with Q317 milestones completed or largely on track. The missed or delayed milestones are being addressed, and are often related to the known integration delays with ProtoDUNE-SP electronics.
- Tutorials have proven to be successful. They attract a broad audience and more have been scheduled.
- Progress has been made in addressing computing for the ProtoDUNEs. The offline beam instrumentation database is in development and is slated for large scale testing in early November, 2017. Calibration and Hardware databases are also now in development. The data for the 3x1x1 test has been used to demonstrate bi-directional data transfer between CERN and FNAL.
- Computing hardware resources for the ProtoDUNEs at CERN are in production, and consist of 3000 Cores in addition to the already existing 1500 Cores.
- The DUNE Collaboration is launching an effort to complete Technical Proposals in 2018, and Technical Design Reports in 2019. Computing and Software volumes are included as part of this process.
- Planning for computing resources to support the Physics TDR and the ProtoDUNE reconstruction is in process. Based on estimates, adequate resources for steady state processing are in hand, although it seems likely the peak requirements for both activities are likely to significantly overlap in time. The LBNC recommendation from 6/17 for combined milestones was only partially addressed.

Comments:

- The LBNC would like to compliment DUNE Computing on continued progress in the timely meeting of milestones and addressing operational issues. We note progress in the area of databases and on the successful recruitment of additional contributors to S&C.
- We welcome the appointment of Heidi Schellman as co-convenor to Computing and Software and we thank Tom Junk for his co-leadership until now.
- The LBNC would like to see even tighter integration between Physics and Computing as a critical component during the upcoming period of supporting the ProtoDUNEs data analysis and the development of Physics TDR.

- It is not clear to the LBNC that replicating the current LHC style computing model is optimal for DUNE, particularly given all the changes in the computational landscape that are occurring and will reach maturity by the time DUNE data collection begins. This should be regarded as an opportunity.
- There are quite a few open questions and technical decisions related to the detector readout that impact the computing model including data collection strategy, triggering and zero suppression. There are also other collaboration-level decisions to make that will impact the computing model such as the degree to which computing will be an in-kind contribution. A list of these open issues should be compiled by February 2018 and presented to the LBNC.
- Cost constraints are a genuine consideration for the computing model as well. It is not likely that a brute force solution based solely on data volumes and conventional compute resources will be affordable.
- We note positively that DUNE reconstruction developers are exploring machine learning algorithms, including deep learning techniques. A collaboration strategy must be developed in this area, in particular it needs to be ensured that the necessary hardware architectures (such as GPUs) and tools are available as a collaboration resource.
- Given the number of open issues, it seems prudent to extend the development time of the Computing "Technical Proposal" (TP) to August 2019. We encourage DUNE to seize the opportunity to build a computing model, designed to support the physics needs, suitable for 2025-2037, that explores the anticipated possibilities that the developing computing landscape offers. A range of cost estimates should be developed as part of the TP for RRB planning purposes. A computing TDR should be published 1-2 years later.

Recommendations:

- *A combined set of milestones that includes 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.*
- *By February, 2018, develop a list of questions and factors that will influence the computing model, prioritization of those factors in terms of likely cost and schedule impact.*

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

Findings:

- APA1 (PSL#1) has been delivered at CERN, the Photon Detector has been installed and tested with the DAQ and the full assembly installed in the cold box. All 40 photon-detector channels are functional
- Testing of APA1 in the warm has shown noise consistent with expectations, testing in the cold is planned to begin the week of Oct 30.
- APA2 (PSL#2) is close to completion at PSL and will be shipped to CERN in early November
- Winding of the first APA3 (UK#1) in the UK has begun
- All CPAs and Top and Bottom Field cages are ready for assembly to start November, endwall construction is underway
- A 4th APA is planned to be constructed at PSL
- Good progress has been made on the cold electronics: all electronics has been installed on APA1 and electronics for APA2 and APA3 are being assembled
- The cryostat for ProtoDUNE-SP is complete, leak-checked and cleaned
- Successfully took data in DAQ barrack with WIBs, SSPs, RCEs simultaneously

Comments:

- APA construction remains as the critical path. A major issue is how many APAs (#4 – 6) can be installed before the closing of the TCO. The decision on this number should be made considering the importance of protoDUNE for informing on all aspects of DUNE-SP from construction to physics.
- Work has been carried out to test the production ADC and FE ASICs and select the best performing ones for installation in protoDUNE. The delivery plan for cold and warm electronics meets the requirements for APA installation.
- The 35-ton test has shown an unexpected high voltage behaviour. It is not known whether this is associated with the beam plug and its support structure or with the changes to the field shaping geometry.
- There are decisions to be made concerning the number of instrumented APAs to be installed, the installation of the beam plug and the timing of the closing of the TCO which could have a major impact on the physics program. A detailed APA construction schedule has been produced allowing maximal flexibility in construction of APAs in the US and UK. APA2 construction took significantly less time than for APA1, however despite some optimization it seems unlikely that a substantial speed up beyond this will be possible.

- The decision on whether or not to install the beam plug is required prior to beginning installation of APA1-3 in the cryostat, presently scheduled for February 2018. Definitive results on the high voltage behavior observed in the 35ton test are unlikely to be available.
- Independent of the number of APAs installed into the protoDUNE-SP cryostat, the plan calls for one APA to remain in the cold box for longer term testing and evaluation of the APA and electronics. This is an important feature in all scenarios and should be maintained.
- The scheduling of the TCO closing is a critical date. It is good that discussions between ProtoDUNE, DUNE management and the cryostat team are ongoing to insure sufficient margin for this operation.
- A fully instrumented cryostat is preferred, however the LBNC judges that the most essential knowledge for DUNE-SP can be gained from beam running with 4 or 5 APAs.

Recommendations:

- The ProtoDUNE management should engage the DUNE collaboration and Executive Committee in a timely way, informing them of the key issues concerning the number of APAs to be installed and the concerns surrounding the beam plug and the high voltage behavior observed in the 35ton test. The consequences should be discussed with the collaboration: what they give up by not installing the beam plug and the potential risk to protoDUNE should they decide to install the beam plug

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

Findings:

- Considerable progress has been made since June on many aspects of the protoDUNE-SP TPC and CE.
- Three APAs are expected to be at EHN1 in January (2 from PSL, 1 from UK.) APA production will continue with the 6 anticipated in May (PSL) or June (UK).
- Progress has been made on field cages and cathode planes. They are at EHN1 ready for installation.
- The Detector Support Structure is completed and installed in the cryostat.
- Electronics production and testing has moved forward significantly over the last several months.
- The cold box is operational and currently holds APA 1. It is instrumented and under test at room temperature, with cooldown anticipated to happen very shortly.
- Approximately 1000 ADC chips have been tested to date (out of 5000 produced) and the best chips are being selected for protoDUNE. Based upon the Q-value metric, the quality of the chips selected for APA 1 is lower than those anticipated for other APAs.
- The 40% APA test stand at BNL shows good noise performance, consistent with expectations as a function of input capacitance.
- Consortia have been formed, including single-phase APA, CE and photon detection systems.
- Efforts are underway to capture M&S costs and labor for proto-DUNE construction that will inform DUNE cost estimates.
- There has been considerable activity toward planning for DUNE single phase TPC electronics, both prior to and since the formation of the consortium.
- The plan continues to be based upon a 3 chip design (amplifier/shaper, ADC, COLDATA) with members of the ADC Design Group from BNL/FNAL/LBNL collaborating on a new ADC chip that will be done in 65nm CMOS. The Design Group has delineated responsibilities across laboratories along with a plan to carry out internal “deep reviews” of the design.
- In parallel, work will continue on the SLAC system-on-chip design that was originally developed for nEXO.
- Commercial off-the-shelf (COTS) ADC solutions are under evaluation for SBND and are considered only as a backup plan for DUNE.

Comments:

- We congratulate the protoDUNE-SP team on the significant progress that has been made on many fronts since the June LBNC meeting.
- The timeline continues to be tight, with APA delivery driving the schedule. Although the APA schedule has slipped somewhat since June, ongoing progress and lessons learned provide a better understanding of the schedule for the remaining APAs.
- Testing of the electronics with APA 1 in the cold box while cold will happen very soon and is a high priority. Assuming that test goes well, we encourage the protoDUNE electronics

construction and testing effort to move forward as quickly as possible. This will alleviate additional "just-in-time" pressure on BNL and also maximize schedule and testing flexibility.

- protoDUNE will offer an excellent opportunity to empirically study long-term behavior and chip performance at cold temperature.
- In addition to having protoDUNE as a basis for cost, labor and schedule estimates, it is also important to document "lessons learned" from the protoDUNE experience, e.g., in winding APAs so that every production site does not have to re-learn the lessons that have already been learned. This "lessons learned" documentation needs to happen in "almost real time" so items are not forgotten.
- A 12-bit ADC with noise and linearity performance that meets the requirements defined by the DUNE physics program – and works reliably at cold temperature – is of the utmost importance to experiment. The current plan has a single primary option (new, three-lab ADC design) with an aggressive timeline. We are encouraged to see the labs collaborating on a path toward a strong solution. However, the LBNC is not yet convinced this plan is on a path for success by the time of the TDR.
- The deep review will allow detailed investigation into the design. As planned, the deep review is limited to members of the existing study group. External evaluators – even from within the Collaboration – could provide valuable feedback on the process if engaged early and regularly.
- In addition to the multiple testing platforms outlined, we encourage the establishment of a larger scale, longer term testing facility that could be utilized to measure longevity and evaluate various designs. It is important that the DUNE collaboration be involved early in the development of test facilities and planning.
- Interesting results have been seen from SBND on a COTS ADC. This knowledge should be carried over to DUNE and could include engagement directly with vendors (e.g., Texas Instruments.) A DUNE test board with COTS ADCs might be of value to help establish criteria for evaluation of the primary solution as well as others. As the Design Group is heavily engaged in designing a new ADC solution, perhaps other collaborators could be identified to pursue this option.

Recommendations:

- By the end of November 2017, present a detailed plan for DUNE ADC development as well as testing and evaluation. This should include:
    - intermediate technical milestones over the next 9 months for the ADC development effort,
    - a plan and metrics by which various options might be evaluated.
- At the next LBNC meeting, provide updates on the progress of all ADC options as well as an overall plan and timeline to work towards the TDR.

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

Findings:

- DAQ group is continuing to make progress towards system integration with the Cold Box. The SSPs and WIBs have been moved to top of Cold Box. Able to exercise the system standalone with SSPs (integrated with detector) @24 Hz using external trigger. Standalone testing also done with RCEs and FELIX;
- To date, 4 WIBs (V2) are available and are recently connected with the cold box. However, the integration with DAQ requires new WIB firmware, which arrived on Oct 27 (at the time of review). DAQ testing with WIBs/Cold Box is imminent;
- Run Control is working, still being improved to be more user friendly;
- Basic online monitoring is in place and available from Run Control, more plots/pages are being added;

Comments:

- We find the progress of the Proto-Dune SP DAQ group to be very impressive. The DAQ system is ready for integration testing with the Cold Box.
- However, we see this state as the first stage, where components are connected but much detailed testing is still to be done in order to be ready for beam.
- *With a limited window for data taking with beam, there will be not much time for debugging the DAQ in situ with beam.* It is very important to have the system commissioned as much as possible before beam data taking.
- Before the detector components are fully operational, it would be highly desirable if simulated data (such as cosmics) can be used to test all aspects of the DAQ chain and this should also further improve the monitoring capabilities.
- We are unable to assess in details the to-do task list beyond Cold Box testing. However we agree that there is clearly still a lot of work ahead beyond Cold Box testing, including trigger, timing, and continual improvements to artDAQ, which is necessary to bring a working system ready for beam.
- Strong support with appropriate number of personnel is crucial to the success of the DAQ system development, from commission to operation. We encourage the DAQ group to update the to-do list in a timely manner so that the collaboration can better assess and deploy appropriate personnel.
- There is an understandable concern by the group that particular key people with expertise may leave to work on DUNE DAQ and we urge management to monitor this issue and step in if necessary.

Recommendations:

- DUNE management should work with the DAQ group to identify any additional need in the effort, tasks and expertise leading up to data-taking to make sure that adequate person power can be directed to the ProtoDUNE-SP DAQ group.

- Lessons learned from commissioning and operation of protoDUNE should be formally documented in real time for incorporation in DUNE DAQ design and future reference.

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

Findings:

- The experience to date with the 1x1x3 shows an overall effective gain of 1.1, taking into account the LEM gain, the extraction efficiency, the collection efficiency and charge sharing between the two views:
    - The extraction grid is limited 5kV (nominal 6.5 kV with a loss of 10% in extraction efficiency)
    - The LEM electric field was limited during running by the grid HV issues to 28-29 kV/cm (running at gain of 5 vs nominal 20)
- No standalone LEM tests at higher voltages were conducted during summer operation, independent of the grid HV issues. Tests conducted at Saclay on the LEM production for ProtoDUNE-DP seem to indicate HV issues above 30kV/cm.
- Some of the tests conducted so far suggest that there may be loose or broken wire in the grid and/or connector problems. A program of in situ visual inspection is planned.
- 150K cosmic ray events have been recorded so far with the 1x1x3

Comments:

- A review of experience to-date with the 1x1x3 dual phase prototype occurred at CERN on September 25, 2017. The review was charged with answering a number of key questions about HV issues and test plans going forward. An action list for further tests have been identified with a timelime produced from the review. These tests are now being executed. A follow-up meeting to review the results of these tests will be held on November 17, 2017.
- The LBNC commends CERN and WA105 collaboration for these efforts and views the proposed tests as an important and complete approach to understanding the existing HV problems and informing future design modifications for the 6x6x6 protoDUNE-DP implementation, if they are conducted in a timely manner.
- The procurement of the electronics chimneys for protoDUNE-DP have not yet been placed and, given their 6 month lead time for delivery, may limit completion of protoDUNE-DP by next July. The LBNC is concerned about the potential schedule impact of further delays.

Recommendations:

- None