LBNC Meeting Report

December 7-9, 2018

CERN

Introduction

The Long Baseline Neutrino Committee met at CERN December 7-9, 2018. The attendees at the meeting, shown in Appendix I, included a substantial fraction of the LBNC members, DUNE collaboration spokespeople, Ed Blucher, and Stefan Soldner-Rembold, and members, the Fermilab Director, Nigel Lockyer, and Bill Wisneuski, representing the US. Department of Energy. The Charge to the committee is shown in Appendix II. In order to address the charge, and based on the intended agenda, the LBNC committee members took responsibility for following closely different components of the presentation, they also prepared the initial drafts of the closeout reports and the full written report. These assignments are shown in Appendix III. In developing their report, the whole committee participated in the lively discussions.

The full agenda, including visits to the Neutrino Platform in the extension of the large North Area Hall EHN1 at CERN, is shown in Appendix IV.
The presentations used during the meeting can be found at https://indico.fnal.gov/event/19266/.

The LBNC recognizes the effort put into the preparation of the presentations and material by the DUNE Collaboration, and the frank responses to questions and queries. The committee also appreciated the visit to the impressive CERN Neutrino Platform with its leader Marzio Nessi, and his team who were very generous with their time. Finally, the administrative arrangements, meeting rooms by the Fermilab and staff and the host-lab, CERN were impeccable.

Exec Summary

DUNE and LBNF have made good, in some cases enormous progress on a number of fronts. The collaboration continues to grow in all three regions, Americas, Asia and Europe. There are funding initiatives active in several countries. Internally, the collaboration has been consolidating its organization; it has stood up two Consortia, for calibration and computing, and a task force to concentrate on background issues, in particular geo-physical backgrounds.

DUNE should be complimented on the Computing Consortium developments. At the basic level, processing of the three weeks of ProtoDUNE-SP data was successful, and reconstruction software appears to be functional. Importantly, the resources used were provided by numerous countries on two continents. This presages a cooperative approach necessary within the consortium. An organigram for the consortium exists, and is being populated. Requests for funding for computing resources are active in some countries. A Technical Lead has been identified and Fermilab has moved to make that assignment happen. This is important. The broad international approach being taken is entirely appropriate, and the active participation of centers which have been active in the broader particle physics computing, such as LHC will enhance that approach.

The importance of the Executive Board (EB) has already been demonstrated; it has been active in a number of strategic areas. Actions and decisions initiated at the level of the Technical Board (TB) are taken to the EB for ratification or resolution. The LBNC anticipates that there will be numerous decisions to be taken, perhaps more broadly within the collaboration, on a regular basis. The EB should maintain an awareness of these issues and ensure that it weighs in appropriately on the most important. An example we saw, which came up during the meeting, involves the plans for 2019 operations of ProtoDUNE SP, where strategic choices will likely need to be made.

While 2018 was the year of the IDR, DUNE has been working with the LBNC and the Laboratory to make 2019, the year of the TDR. Agreement has been reached to release TDR elements, in draft form, to the LBNC. The LBNC will then review the material while recognizing that they are drafts. They will read and make written comment, hear presentations and conduct teleconferences. This will inform the completion of the TDRs for final presentation in the July/August meeting of the LBNC. The LBNC will then recommend to the Director and the RRB. The Neutrino Cost Group will operate in parallel with participation from some of the LBNC reviewers.

The DUNE approach to detector requirements was discussed at several levels. A document discussing the flow-down from physics to detector was presented. An example of a tabular articulation to be used in the individual TDRs was also displayed. The former left some readers feeling that the connection from physics to detector specification was still difficult to make. In the table also, the columns indicate detector performance at a moderately low level and did not indicate the physics driver nor the higher level performance parameter. Some further, likely “offline”, interaction between LBNC and DUNE will be needed to ensure that the TDRs deliver what is needed. The section on the APA TDR preparation reminds us of the recommendations made in the August review of the IDR document.

The CERN Neutrino Platform has been an enormous success, and in particular the ProtoDUNE SP enjoyed a stellar achievement. Not without difficulties, installation was successfully completed in time for operations with beam in the Fall of 2018. Over a 3 week period, millions of triggers were taken with beam. Data are still being analyzed, but it is already clear that a substantial fraction of the key performance parameters of the detector will have been demonstrated. Crucial behavior such as High Voltage stability and noise levels appear to be excellent. The excitement within the collaboration, which the committee shares, is palpable. CERN has assured operation of the Neutrino Platform during 2019. Based on the 2018 success, a plan should be developed to exploit this opportunity.

The progress with the DP has been slower than planned. Some, but perhaps not all, of the delay may be attributable to the several technical challenges, which have been encountered. At the level of the Large Electron Multiplication (LEM) devices, breakdowns had mandated an increase in guard-ring width and a consequent reduction in sensitive area. However, it would seem that some enhanced understanding of the observed breakdowns, and their long-term consequences is needed. A plan for such R&D was mentioned and should be pursued. A large Cold Box, in addition to the NP02 and NP04 cryostats has been added to the suite of Neutrino Platform Facilities. For DP this has proved essential to get to the point where four Charge Readout Planes

(CRPs), two active, can be installed in NP02. This offers operation with cosmic rays, but not until the second half of 2019. The LBNC supports the two-pronged approach with R&D at the LEM level and testing of the CRP operations in NP02. The committee is concerned by the large-scale systems implications of the LEM sparking rate. A clear physics justification is needed to allow appropriate optimization of key parameters: LEM gain, LEM geometric efficiency (and therefore allowances for HV clearances) and LEM sparking rate. Such an analysis may change the emphasis for the R&D program and planning for the TDR.

Following the report of the Near Detector Task Force, and its acceptance, the collaboration has established a near Detector Development group to explore the implementation of the Task Force Report. The nascent concept includes a Liquid Argon Cube, coupled with an Argon Gas TPC, and also a multi particle detector. The plan, with which the LBNC concurs, would be to provide an abbreviated description, but with sufficient detail to be reviewed, in mid-2019. This would be followed, late in the year, by a complete Conceptual Design Report. The LBNC would like to hear an intermediate presentation at its April meeting. It will be important to clearly articulate the physics impact of the different components. This would inform a rational decision, should resources be constrained.

DUNE discussed the strategic goals it had defined for the period 2017-2019. The importance of the large scale prototype program and the testing in the ProtoDUNE modules at the CERN Neutrino Platform has enabled manifest progress toward the eventual DUNE detector construction. The formal work to develop the TDRs is informed by the substantial body of work represented by the Intermediate Design Reports (IDR). A plan exists to deliver the TDRs for review during the next 6 months.

The LBNC looks forward to the successful execution of the work needed and planned for 2019.

Recommendations: None

LBNF Status

LBNF is making sustained progress with noteworthy achievements particularly in the far site preparations. The planning towards the main excavation of the far site has achieved the 60% completion milestone with a goal of 100% by May 2019. There is ~100M$ earmarked for pre-excavation work with no road blocks foreseen. The work stoppage due to the Ross shaft safety incident has now been removed. Pre-excavation construction is advancing with 17/17 critical bid packages awarded to date. The far detector nitrogen system RFP is on target for an award in May 2019.

Nevertheless, some milestones have moved since August - some by 3months and some by 6 months. These changes look to have low impact and in the case of the far site are due to feedback from vendors updating previous in-house time estimates but are examples that the project must maintain schedule contingency such situations involving transitions to vendor planning and execution.

The limitations on the near site funding and uncertainties on the Near Detector (ND) size impacts the Near Site Conventional Facility (NSCF) definition and the NSCF timeline. The project wants to define the upper limit of ND Complex cost for the Jan 2019 IPR and the goal is to fix ND shaft and size by July 2019. This seems a tall order given the many proposals on the table from the ND task force. A lack of definition could conclude towards a costly one size fits all ND cavern and shaft. A clear science case for each of the various ND configurations needs to be made with some urgency. The upper bound on costs that will be developed in 2019 will be refined in 2020 for CD-2B. The strategy to baseline costs in 2020 while scheduling contracts in 2022 represents a project cost and schedule vulnerability and appropriate contingencies need to be developed.

The Beamline work continues to evolve with a new horn design since the last meeting. The biggest vulnerability is that a significant portion of the scope still needs to be assigned. The project reports that they have a handle on the costs with sufficient resources to develop the conceptual design and efforts are in progress to identify partners for the undefined scope.

There seems to be a healthy awareness of the importance of interfaces between DUNE and LBNF. The groups are getting together regularly – a good thing – and the importance of a central document server was mentioned (EDMS) though there were conditional statements made concerning the reality. The importance of a centralized document server and document approval protocol cannot be overstated.

Recruitment is ramping up, e.g., for the crucial FS logistics manager, but for easier tracking it would be better for future meetings if the resource actuals were charted against planning in the resource loaded schedule to get a better sense project health.

It might sound obvious but LBNF needs to milk as much as possible from the ProtoDUNE experience. An operating model derived from this experience would be useful to help clarify LBNF and DUNE start-up and operation: what is the expectation of the operation of the DUNE detectors - what is the expectation of start-up time and operating overhead – what kind of staging is foreseen. An operational model is useful to set the requirements of the installed equipment and may be useful to better define the tests that can be done at ProtoDUNE. For example, does the realization in ProtoDune-SP of water content leaching from the detector components change the required infrastructure in DUNE. The cryogenic test plan needs implementation in SP and DP ProtoDUNEs in 2019.

The environmental plan still needs to be formalized (from previous recommendation).

Recommendations: None

ProtoDUNE SP Status

The LBNC warmly congratulates ProtoDUNE, the collaboration, and the CERN Neutrino Platform, on the successful construction, filling, operation, and data-taking, of the ProtoDUNE single-phase systems. This is a major milestone in the DUNE prototyping program and it has been met on schedule before the end of beams at CERN at the end of 2018. The rapid attainment of the 500 V/cm drift field, electron drift times of 6 ms and above, and ENC noise levels at the 500-600 e- level, are highly impressive – all beyond the minimum specification – and bode well for future DUNE operation, provided long-term stability is also demonstrated. It is evident that much is being learnt about the cryogenic and LAr-purity systems and HV operation and stability at full field.

The committee is impressed by the work program underway on the TPC drift data. The LBNC looks forward to seeing more results from analysis of the beam and cosmic-ray data – many studies were reported just to be starting at the time of this meeting, but will be crucial to support the TDR. The committee would like to see more rapid progress made on understanding the photon detector data and performance.

Prompt documentation of lessons learnt is important throughout commissioning, operations and data analysis, including root-cause analyses of problems encountered. This is vital to ensure that knowledge is carried over to the full-scale DUNE.

The LBNC believes operation of ProtoDUNE-SP during 2019 should be a high priority, and is pleased to see that this is planned. Wish lists of studies are being assembled, and will need detailed prioritization and scheduling, especially where studies are needed for the DUNE TDR. The organization of this needs to be developed, and the responsibility clarified – a close day-to-day interaction between DUNE and the CERN Neutrino Platform remains essential. The LBNC emphasizes the importance of establishing and studying the operational baseline and its long-term stability, for the TDR. The addition of Xe at the end of the running period will be of interest if the performance of the photon detector system is satisfactorily established by then.

Recommendations: None

DUAL Phase Status

Results from the 1x1x3 m^3 Demonstrator

The 1x1x3 Demonstrator took 400K cosmic events in the period July-November2017. The results have been analyzed and the Demonstrator has established many key technical and performance measures for a Liquid Argon Dual Phase TPC. For example, the demonstrator has achieved a 500v/cm drift field, an electron lifetime of ~4msec, and has shown equal charge sharing between anode collection planes, stable liquid argon level during recirculation, and correlation between scintillation light and collected charge. Stable operating conditions required a compromise between the voltages across the induction plane, the LEM, and the absolute grid HV; LEMs were operated with electric fields in the range from 23 and 31 kV/cm, with most data taken at 28 kV/cm corresponding to an effective gain in the range of ~3. Global trips occurred after operating the LEMs for ~1hr and it was not possible to bring the LEMs to high fields – prompting a change in the LEM design to incorporate a larger guard ring. A number of additional design changes were implemented based on the results of the demonstrator testing. These results have recently been published in JINST.

Recommendations: None

LEM Production & Testing

Results were presented for the 74 LEMs produced by ELTOS (Italy) and tested for installation in CRP1 & CRP2. The design to be used has a larger guard ring gap which reduces the possibility of breakdown at the cost of reduced acceptance. LEMs were tested up to 3.5 kV (35kV/cm) in Ar gas at 3.3 bar. The LEMs show a spark rate <1 spark/20 minutes. About half of these sparks occur near edges or corners, however it was noted that there was no power supply trip for these spark events. A number of HV configurations of the extraction grid, voltage across the LEM and anode potential were studied in the cold box tests. For an optimum induction voltage of 1 kV, stable operation in the cold box was not achieved for HV configurations which give an effective gain ~20; the source of instability is not fully understood. Stable configurations can be achieved by decreasing the induction field between the anode and the top of the LEM and can achieve an effective gain from 24-31. Dark spots were seen in the corner of LEMs in CRP1 following removal from cold box; this was attributed to uncontrolled sparking due to a lack of protection in the power supply. Following rework, two CRPs are operational though with the limitation above on the induction field and corresponding LEM HV (bottom HV on the LEM). Further understanding/improvement of the LEM design is being addressed; the committee is concerned about the impact of sparking on LEM performance and the viability for DUNE-DP.

Recommendations:

- The DUNE-DP consortium should develop an R&D plan to improve the LEM design to the specification needed for DUNE-DP. Performance characteristics to be studied should include LEM stability, gain, reliability, spark rate, and operational lifetime and should have a clear physics motivation.

CRP Assembly & Cold-Box

The committee notes that the cold-box developed by the CERN Neutrino Platform Team has proven to be an effective tool for CRP testing and substantially enhances the capabilities of the CERN NP infrastructure; the planarity of CRP distance to liquid level in the CB is stable to within 1.75mm and the relative distance between the liquid and the CRP is stable to 0.25mm. 4 CRPs are being prepared for installation in ProtoDUNE-DP, two of these will be dummies (i.e. with no LEMs or anodes). The CRP construction time was approximately 1 CRP/month. CRP4 will be delivered to CERN at the end of January for installation into the ProtoDUNE-DP cryostat. A number of issues were identified during the cold box testing of CRP1 and CRP2. These included HV instability and observation of a high rate of trips. Following initial testing in the cold box, corrective action has been take: modifications were made to tension of the extraction grid wires, changes to the HV connection and HV distribution were implemented. 4 LEMs were removed from CRP1 and 1 LEM was removed from CRP2 due to sparking as a result of a faulty power supply. For CRP1, these LEMs were cleaned and re-installed. For CRP2 the LEM was replaced to maintain the construction schedule.

Recommendations:

- The DUNE-DP consortium should feed back the lessons learned from assembly defects observed in the tests of LEMs and CRPs which required rework into the plan for CRP construction and QA/QC plan for DUNE (e.g. residual flux on wires, grid wire tension at cold , HV shorts on grid).

ProtoDUNE-DP

The committee congratulates the Neutrino Platform team for completion of the protoDUNE-DP cryostat and the DUNE-DP consortium for beginning instrumentation of DP readout in ProtoDUNE-DP. The tour was stunning. We look forward to seeing a successful cool-down and operations followed by first data in the fall of 2019.

The external cryogenic system has been completed following the conclusion of PD-SP operation with beam; the proximity cryogenic systems were installed in SEP2018.

The installation of 4 CRPs in the DP cryostat is in progress, two of these CRPs will be dummies. A problem appeared during the insertion of CRP3 in the cryostat where 3 wires broke in the process and 7 more broke in the following days, this has resulted in changes being made to the lifting and handling procedures. The installation schedule presently shows closing of the TCO by week 14 of 2019, with filling and purification completing by week 28, 2019 (22nd July). No cosmic data-taking plan was presented. The committee notes that the lessons learned from ProtoDUNE-SP operations will be of use in ProtoDUNE-DP operations

Recommendations:

- Develop a plan whereby performance data from operation of cold box and ProtoDUNE-DP/SP tests can be incorporated into the DUNE-DP TDR

- Quantify the tradeoff between LEM gain and physics performance and scope

- Develop a combined simulation and performance measurement plan to demonstrate the validity of the extrapolation of ProtoDUNE-DP performance to a 12m drift distance

- A number of optimizations are planned to the design of the field cage, cathode and ground in extending the ProtoDUNE-DP designs to the full 12 m detector required for DUNE-DP. The DUNE-DP TDR should present the plan by which these changes to the design are qualified.

DUNE-DP IDR & TDR

In view of the lessons learned thus far from the cold box testing of the LEMs, the DUNE-DP consortium is strongly encouraged to carefully consider their approach to definition of a baseline. The DUNE-DP consortium should establish a detailed set of requirements for DUNE-DP, clearly specifying the gain in physics sensitivity as a function of detector performance metrics, e.g. a gain of 10 vs. 20. The committee's view is that establishing a S/N ratio exceeding the range of 50-60 demonstrated by ProtoDUNE-SP is not the only motivation to continue with the development of DUNE-DP. Other appealing features of DUNE-DP are the simplicity of the detector and consequent potential reduction in costs, as well as its potential of operating as a 3D TPC. The significant benefits possible drawn from these features could render acceptable a performance on S/N ratio for DUNE-DP simply in line with that achieved by ProtoDUNE-SP. We encourage the Collaboration to explore this possibility. The committee also notes that schemes for direct readout of the charge on pads (as the two championed at the CERN Neutrino Platform and independently by the LArPIX proponents) has potential to reach a comparable S/N ratio. The DUNE-DP consortium is strongly encouraged to analyze the detector technology performance goals with respect to trade-offs between achieving a mature far detector readout design with high reliability vs. potential physics benefits of more aggressive requirements.

The ProtoDUNE design is used as the basis for the TDR, and is described in detail in the IDR. The committee noted a number of concerns. The last chapter of the DUNE-DP TDR, DP-CRP, is to be submitted 28/6/19 and therefore it seems unlikely that data from the ProtoDUNE-DP test with cosmic rays will be available for the CRP section of the DUNE-DP TDR. In addition to providing data on DP performance this is an important test of the integration of the DUNE-DP readout electronics with the DUNE DAQ system. The plan for development of the LEMs to bring them to a level of acceptable performance and mitigate the risk of burnout over a two-decades run is a very severe, additional concern. The plan for the design for the 600kV supply and the plan for its qualification is a third area of concern. While the use of electronics which have been developed a number of years ago presents a low risk to a detector today, there is the possibility of obsolescence of components for a detector to be constructed a number of years in the future.

A number of optimizations are planned to the design of the field cage, cathode and ground in extending the ProtoDUNE-DP designs to the full 12 m detector required for DUNE-DP. The DUNE-DP TDR should present the plan by which these changes to the design are qualified for use in DUNE. Included in this plan should be the combination of simulation and performance measurements from ProtoDUNE-DP (and SP) to demonstrate the validity of the extrapolation of ProtoDUNE-DP performance to a 12m drift distance.

Recommendations:

- The DUNE-DP consortium should prepare a TDR which addresses the concerns articulated above.

TDR/CDR Preparation Status

TDR Overall Status:

The detailed planning for the different TDR volumes was reported to the committee. Five TDR sections are being written, covering the overall DUNE design, the physics case, the single and double-phase detectors, and technical coordination. The proposal to provide “2nd drafts” of individual chapters of the different TDRs, in mixed batches, so that the committee can start reviewing is agreed by the LBNC, and the proposed schedule considered very tight but acceptable. The committee notes that multiple iterations should be foreseen for each such chapter with face-to-face and/or teleconference meetings to discuss detailed comments: approval of each TDR will only be possible once these reviews are satisfactorily completed for the subject of that volume. The collaboration is asked to ensure that overviews of each volume are made available in time for the review of the first parts of each volume. These overviews should contain big picture designs and justification of key performance parameters in terms of the physics goals, top-down, not simply be summaries of the content of the subsequent chapters. They could be in the form of slides at the start of the review process.

The length of the individual TDRs, where specified, is at the maximum acceptable. The collaboration is urged to be succinct, and to use appendices creatively for supplementary details.

Recommendation:

- The LBNC appreciates the production of the “DUNE Far Detector (Single Phase) Design Choices and Physics Connections” document, but asks to see the physics connections further developed in the TDRs.

Physics TDR Status

The physics TDR status was presented. It is planned to contain 10 chapters of about 25 pages each, so that the total volume should be about 250 pages. It was emphasized that the editors are committed to ensure that they will not exceed this length.

A first internal draft exists which contains all major physics chapters except for that on near detector physics. A very important chapter is that on “tools and methods” which explains the techniques used for the simulation and reconstructions, and for the calibration. We expect that this chapter provides much of the information how a given physics performance is linked to the underlying capabilities and calibrations of the detector. If possible the use of a different event generator to stress test the systematics assumptions would be desirable. Advanced drafts also exist for the chapters on Supernovae/low energy neutrinos, beyond the Standard Model (BSM) physics, neutrinos oscillation physics and nucleon decay. For the Supernovae and BSM chapters the studies rely to a large degree on parametric simulation, aided by dedicated reconstruction studies where appropriate. For the oscillation and nucleon decay, the estimates will be based on full reconstruction.

This strategy is fully supported by the committee. The committee notes that the danger of using full reconstruction with the analysis tools of today may underestimate the sensitivity as it is very likely that in the future more powerful tools will be developed. Therefore, a discussion of the physics limitations of the current tools and algorithms is encouraged in those areas where these matter most.

In summary, the committee is very happy about the progress that has been made and looks forward to receiving an advanced draft (at least of the majority of the chapters) by the end of January as foreseen in the current schedule.

Recommendations: None

Computing Plans

The presentation on computing plans addressed three topics: the operational status of computing in meeting the immediate needs for ProtoDUNE-SP and producing Monte Carlo samples in support of the Physics TDR; the status of establishing a global consortium for DUNE Computing and a proposal for the TDR executive summary.

Computing operational status is extremely positive. Most notably the 7M ‘good beam data/triggers’ for ProtoDune-SP were processed within 3 calendar weeks. The reconstruction algorithms are effective for first pass analysis. 2nd generation algorithms are being developed using algorithms initially developed for other LAr TPCs, demonstrating the benefits of the LArSoft shared code base. Monte Carlo samples are continuously generated and reconstructed using distributed resources at FNAL and CERN and in the UK. The experience with Monte Carlo data challenges is the key to successful operations. Overall, the operational experience and data rates from ProtoDune-SP experience gives confidence that the scale of computing for DUNE is tractable.

A welcome development is the formation of a global computing consortium. A logical set of organizing principles is being developed to categorize types of tasks, the needed resources and the ways that institutions can contribute. It is anticipated that a WLCG-like model will be utilized and that the software stack will utilize elements that are broadly supported by HEP computing community. An early example is the use of RUCIO (being introduced for multiple LHC experiments at CERN) to replace some of the functionality of the FNAL based data management system. The next step is assembling a new management team; this is essential in order to keep the momentum. A positive development is the appointment of a new technical lead from FNAL. This will enable an articulation of the role that the FNAL Scientific Computing Division will play in the DUNE software consortium.

The presented plan for the TDR chapter was not consistent with maintaining momentum in building the consortium. The plan was to draw from ‘Lessons Learned white papers from

ProtoDune computing operations. While it is essential that the operations team produce Lessons Learned, they would be largely retrospective in nature and reflective a pre-consortium world view.

The LBNC does not see the need for a dedicated review of the computing section of the TDR.

Recommendations:

- For the computing strategy summary in the TDR we recommend a tight focus, stressing the impact of the ProtoDune experience, a short description of the consortium model, and long lead-time items, such as SURF WAN.

APA TDR Status

The requirements that connect the physics drivers to the technical specifications of the APAs should be concisely, quantitatively stated in the TDR.

As a reminder, we reproduce recommendations related to the connection between physics performance and technical requirements, from the August 2018 review of the DUNE Single Phase Far Detector IDR, include:

- The DAQ timing requirements. For example, how is the 10 ns synchronization within a module and 1 μs between different modules connected to physics requirements.
- The DAQ random trigger requirements. The requirement of 45/day random trigger is motivated by the Ar-39 calibration scheme, although the efficacy of the technique was not yet fully worked out.
- The cosmics trigger and associated data volume. Cosmics and atmospherics event types are listed as highest data volume (10PB/year/module). It is unclear how this data set will be used.
- Trigger requirements. There are some high level discussions about special S/N trigger challenges for the DAQ, but requirements for beam interactions and cosmics were not presented.
- Electronics noise. The LBNC struggled with identifying a clear and consistent statement on the electronics noise requirements, perhaps because these derive from multiple processes (SN neutrinos, and Ar-39 calibration). The requirements should be driven by dedicated MC studies, particularly for the parameter "FE Noise.".
- Interfaces between electronics noise, physics and calibration. The IDR states that an ENC of 1000 e- would allow calibrations of the detector via analysis of the ^{39}Ar signals, however there was no coherent presentation of the strategy for calibration via ^{39}Ar.
- Calibration strategies. 1 M laser pulses is listed for laser calibration with lossy readout while radiological calibration readout is lossless [in IDR Table 6.3 on page 179]. It is not clear what motivates the difference.
- HV: the specific driver for the 250 V/cm minimum is not clear. What would be the

consequences of coming up short, perhaps 150 V/cm, on this requirement? Is there a requirement on light generated by the HV system (and its impact on the photo detectors)?

- Photon detection system light yield and resolution. The required photon calorimetry energy resolution needed to pursue the low-energy program should be specified. This will then set the requirement for the light yield at the center of the drift field. Light yield requirements between 0.5 and 10 p.e./MeV have been mooted—a clear statement of the physics-driven requirement should be derived from MC, with a range of physics reach vs. light yield achieved. The requirements should also include a clear statement of allowed light yield spatial variation.

The trade-offs between the low vs. high performance range of technical specifications should be articulated clearly.

Outstanding examples of this from the IDR include the following.

- Tolerances. The cost of the APAs will be very sensitive to tolerances on the dimensions. Absent a clear understanding of how various tolerances relate to the physics performance it will be difficult to produce the APAs in the most effective manner for both cost and schedule while assuring that the physics requirements are met.

- Physics vs. cost tradeoffs, e.g. special requirements/demands for SN trigger and its impact on the overall DAQ design should be clearly explained, including cost impacts and risks.

The criteria and process for how down-selection decisions will be made should be clearly specified in the TDR, in the cases where multiple technology options go forwards in the TDR. As noted in the August 2018 recommendations, the Collaboration should be cognizant of the resource and schedule implications and should make such choices carefully and aggressively pursue resolutions.

- Cold electronics. The Collaboration is likely to take three Cold Electronics alternatives into the TDR. These alternatives should be described along with plans going forward for testing, evaluation and eventual down-select. The implications for resources of this process should be considered.

Longevity risk mitigation vs. optimization. How will decisions about demonstrating longevity in, e.g. ProtoDUNE-SP, be made, vs. further optimization of detector components? An example highlighted during the IDR review is cold electronics: the 3-ASIC approach involves daughter cards and additional commercial components, making system-level longevity testing more important.

The statement was made that the studies that feed into the TDR will be decided in Jan. 2019. This seems late given the goal of TDR delivery mid-19.

Production will be distributed across 4 sites, and QA/QC is a major factor in the time to produce each APA. We encourage the Collaboration to systematically examine the PSL vs Daresbury APAs in protoDUNE-SP for differences in production or performance. The TDR should specify how sites will be qualified to mitigate differences in production site performance.

The timescale for producing the three final-version APAs of mid-2020 is approximately 6 months after full APA production launch in the US and UK is planned. This order should be considered-- feedback from the process of producing, and cold-testing, the performance of the final APA design could inform the decision to launch full-scale production. Particularly in light of the possibility that the underground infrastructure may be ready to receive APAs 18 months after they ship.

Recommendations:

- The TDR in preparation should be responsive to the commentary above.

Near Detector Status:

The primary purpose of the DUNE Near Detector is to constrain the systematics and thereby enhance the sensitivity of the Far Detector for CP-violation measurements. The proposed Near Detector suite consists of a LArTPC, a Multi-Purpose Detector (MPD) consisting of a HPgTPC and ECAL and muon tracker. The rationale for those systems has been clearly presented: the LarTPC is similar to the far detector and will help to understand detector effects, whereas the HpgTPC will provide extremely high resolution around the interaction vertex, allowing a full reconstruction of the underlying kinematics and thus improved understanding of the energy flow in neutrino-argon interactions. In combination with the ECAL and muon tracker excellent particle ID capabilities result and thus clean tagging of NC, nu_e and nu_mu CC events is possible. The magnet adds charge ID capabilities allowing to separate neutrinos from antineutrinos, this is particularly important in the antineutrino beam. The next step is to demonstrate this capabilities in simulation and to quantify performance.

A 3D Scintillator Tracker (3DST) inside a magnet is also envisaged as an additional detector. The rationale for the 3DST is somewhat less well articulated. Overall it seems to have less spatial resolution than either of the argon detectors and it appears to fall in-between the LAr- and HpgTPC in terms of mass. Any data from the 3DST will require a microscopic nuclear physics model of neutrino nucleus interactions to extrapolate from either hydrogen or carbon to argon. The hydrogen data could serve as beam flux monitor, but so could neutrino-electron elastic events in the argon detectors.

The DUNE –PRISM concept envisages LArTPC and probably the MPD to be mobile and make measurements at several off-axis positions along with on-axis measurements. These measurements will help to simultaneously constrain neutrino flux, cross sections and energy smearing and thereby in constraining the systematics. In particular, this is so far the most direct strategy to address uncertainties in **neutrino** energy reconstruction in a wide-band neutrino beam and the whole concept of DUNE rest on the assumptions that this can be achieved with good accuracy. Early results were shown which support this concept.

For all detector systems, a detailed simulation effort is ongoing to understand the systematics reach of this detector concept. The overall concept appears to be interesting and LBNC looks forward for a full review of the design and its capabilities and cost in the summer of 2019. This review will focus on those components of the near detector system which directly and quantifiably reduce systematic errors for the long-baseline neutrino program in CP violation. For the TDR and the 2019 review it is crucial that there is a clear linkage made between the physics drivers and the technical requirements arising from those drivers for the detector performance.

The upper bound on costs that will be developed in 2019 will be refined in 2020 for CD-2B. The strategy to baseline costs in 2020 while scheduling contracts in 2022 represents a project cost and schedule vulnerability and appropriate contingencies need to be developed.

Recommendations:

Include in the TDR and the 2019 review a clear linkage between the physics drivers and the technical requirements arising from those drivers for the detector performance. This should support scope decisions should resource limitations need to be applied.

Appendix I - LBNC Attendees

Committee: Dave Charlton, Angela Fava, Joel Fuerst, Cristiano Galbiati, Beate Heinemann, Patrick Huber, Bob Laxdal, David MacFarlane, Naba Mondal, Jocelyn Monroe, Hugh Montgomery, Jimmy Proudfoot, Regina Rameika (NCG)

LBNC/LBNF: Dario Autiero, Edward Blucher, Alan Bross, Ami Dave, Dominique Duchesneau, Eric James, Kevin Fahey, Jack Fowler, Inés Gil-Botella, Takuya Hasegawa, Steve Kettell, Jolie Macier, José Maneira, Edoardo Mazzucato Chris Mossey, Sebastien Murphy Marzio Nessi, Regina Rameika, Filippo Resnati, Heidi Schellman, Stefan Soldner-Rembold, Christos Touramanis, Jon Urheim, Alfons Weber.

FNAL Directorate: N. Lockyer, H. Ramamoorthi

DOE: W. Wisneuski

Appendix II - Charge

The LBNC will hear about the progress in a number of areas including the general progress of each of DUNE, LBNF, and ProtoDUNE. There will be in depth presentations covering the development of the Dual Phase option, including a look forward to 2019 with ProtoDUNE DP, and preparations for a TDR. We will also hear about TDR and CDR preparations in a few key areas.

The LBNC will prepare a written report, which will include descriptions of the status of each of these items. Inter alia, this report will inform a presentation of the overall preparations of DUNE, which may be requested for the DOE LBNF-DUNE IPR in early January, 2019. Our goal will be to leave CERN with an advanced draft of the report in hand.

In order to facilitate achieving this, we have made tentative assignments for the attending LBNC members. Note that both Angela Fava, our Scientific Secretary and David MacFarlane, our outgoing chair are expected to be active participants. The assignments are shown below; the name in Bold Face is requested to take the lead in writing. We are looking for approximately 0.5 – 0.75 pages per item except for the Dual Phase which has several sub sections, so should be longer.

Appendix III - Assignments

DUNE Overall Status 50 mins (35+15) Stefan Soldner Rembold --
Exec Summary: **Montgomery**

LBNF Status 45 mins (30+10) Chris Mossey
LBNF Status: **Laxdal,** MacFarlane

ProtoDUNE-SP Report (and lessons-learned) 45 min (35+10) Gina Rameika

PD SP Status: **Charlton,** Fava, Montgomery

Dual-Phase

Results from the 1x1x3 m^3 Demonstrator 30 mins (20+10) Sebastien Murphy
LEM Production & Testing 30 mins (20+10) Edoardo Mazzucato
CRP Assembly & Cold-Box Testing 30 mins (20+10) Dominique Duchesneau
ProtoDUNE-DP Installation 30 mins (20+10) Filippo Resnati
DUNE-DP IDR & TDR Status 30 mins (20+10) Dario Autiero

DUAL Phase Status: **Proudfoot**, Fuerst, Galbiati, Mondal

TDR/CDR Preparation Status

Overall View/Plan/Status 35 mins (25+10) Tim Bolton (Remote)

TDR Overall Status: **Charlton,** Montgomery

Physics TDR Status/Preview 35 mins (25+10) Jon Urheim

Physics TDR Status: **Heinemann,** Huber

Computing Organization Status 35 mins (25+10) Heidi Schellman

Computing Plans: **Boehnlein,** Heinemann

APA TDR Status/Preview 35 mins (25+10) Christos Touramanis

APA TDR Status: **Monroe**, MacFarlane,

Near Detector CDR Status/Preview 35 mins (25+10) Alan Bross

Near Detector Status **Mondal**, Huber, Fava

Appendix IV – Agenda

See: https://indico.fnal.gov/event/19266/ . In this version, the talks are also posted.