LBNC Meeting Report

April 1-3, 2019

Fermilab

Introduction

The Long Baseline Neutrino Committee met at Fermilab on April 1-3, 2019. The attendees at the meeting, shown in Appendix I, included LBNC members, DUNE collaboration spokespeople, Ed Blucher, and Stefan Soldner-Rembold, and members, the Fermilab Director, Nigel Lockyer, and Pepin Carolan, David Lissauer, and Bill Wisniewski representing the US Department of Energy. The Charge to the committee is shown in Appendix II. As part of the initial Executive Session, the Chair discussed with the LBNC the overall goals of the committee to familiarize the new members. The presentation included a discussion of the participation of non-LBNC members in the TDR review process. This move has been made to make the volume of work involved tractable and to supplement the expertise of the LBNC members. Several references to the activities of the combined TDR review teams are included in this report. The transparencies used are posted along with the other talks in the agenda, see below. In order to address the charge, and based on the intended agenda, the attending LBNC committee members took primary responsibility for following different components of the presentations, and they prepared the initial drafts of the closeout reports and the full written report for those components. The assignments are shown in Appendix III. In developing their report, the whole committee participated in the lively discussions. The reports are to be understood as coming from the committee as a whole.

The full agenda is shown in Appendix IV. The presentations used during the meeting and the Closeout Report can be found at https://web.fnal.gov/organization/LBNC/April%201-3,%202019/SitePages/Full%20Agenda.aspx .

The LBNC appreciates 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 is also grateful to Alex Himmel, who stood in for Angela Fava as Scientific Secretary to the LBNC. Finally, the administrative arrangements made by the Fermilab staff, Kayla Decker and Hema Ramamoorthi, were excellent.

Executive Summary

DUNE and LBNF have made important advances on a number of fronts. For LBNF it is important that the Ross Shaft work has fully restarted. The binding of DUNE and LBNF in their common habitat in the Sanford Lab in South Dakota has been strengthened by the creation of the Joint Project Office and the appointment of an Integration Project Director. For DUNE major progress has been catalyzed by the CERN Neutrino Platform where the ProtoDUNE SP is producing impressive results from the 2018 running with beam, and ProtoDUNE DP is progressing towards completion of installation with filling to follow.

The LBNC noted that issues associated with working underground, especially safety were evident in both the planning work for LBNF, but also for the installation and commissioning of DUNE. The LBNC considers that the integration of a strong safety culture and sense of responsibility in the line management is essential for DUNE. Narratives and charts should explicitly place SAFETY “up front and central”. Inculcating the culture in DOE national lab staff took a couple of decades: for DUNE it must happen much quicker.

DUNE provided an extensive presentation of the analysis progress with ProtoDUNE-SP data. This process continues to impress as we see more and more analysis demonstrations of the

excellent performance. Overall, we feel it provides a strong basis for a successful DUNE experiment. There remain performance issues associated with, for example, the maintenance of the argon purity and understanding the scaling of this and other performance parameters from ProtoDUNE to DUNE scales. It is anticipated that some long term stability questions should be addressed with the 2019 operations.

A review of the design and expected performance of the Near Detector is planned. While this precedes the completion of a complete Conceptual Design Report, which will be ready around the end of calendar year 2019, the Near Detector is expected to strongly influence the overall DUNE performance. The Technical Design Report is anticipated to be ready in 2020. Nevertheless, the plan is to seek DOE-CD2 for LBNF Far Site Sub-Project by the end of the year with CD2 for the Near Site Sub-Project to follow in 2020. In this context, the impact on the systematic uncertainties in the primary measurements of DUNE need to be clearly articulated with an eye to potential resource constraints.

DUNE presented material covering the progress of the Dual Phase program. Enormous strides have been made and the collaboration has demonstrated a responsive approach to the December recommendations. Installation in ProtoDUNE-DP of the anticipated complement of detector elements is close to complete. The module will be closed within the next few weeks, and based on the current schedule for filling with liquid Argon we look forward to the start of operations in late summer. We were also shown dramatic improvements in both the Large Electron Multiplier (LEM) breakdown frequency and in the LEM understanding.

There is significant progress in establishing the DUNE Computing Consortium, the management team at the highest level is now complete. The consortium has embarked on a broader collaboration stance with prominence at meetings of the HEP Software Foundation, Open Science Grid, the Worldwide LHC Computing Grid. With broad participation across the collaboration, the short term resource needs have been met. However, the path to support for sufficient dedicated professional effort is not yet established. This lack appears to lead to critical gaps in core capability. Further, it may lead to an unadventurous approach to a rich menu of modern computing challenges.

The TDR review program/plan has demonstrated qualified success. Chapters of the FD-SP have been delivered on time, but the time pressures have led to a product that would have benefited from a stronger participation from non-authors. The quality of the chapters was uneven. The Technical Coordination (TC) documentation was inhibited by a complete reorganization of the TC aspects of DUNE. This resulted in a complete rewrite of the document, but with the goal to strengthen the management. The Physics TDR has had intensive interaction with the review team and progress is both evident and convergent. LBNC and DUNE understand that there are challenges involved in this process. The timescales involved generate “less than ideal” situations. Nevertheless progress is real and the goal of a thorough assessment of the DUNE technical status for the Fall 2019 RRB is achievable.

DUNE should be congratulated on the progress it has made in several directions, even in the short time since the previous meeting in December 2018. This demonstrable progress augurs well for the establishment of technical baselines, which would support a strong DUNE physics program during the upcoming decades. Careful articulation of the critical performance requirements is necessary as the collaboration stakeholders, including the Resource Review Board seek to commit resources.

LBNF Status: General

LBNF is making sustained progress with noteworthy achievements particularly in the far site preparations. The planning towards the main excavation and building and site infrastructure at the far site has achieved the 90% design completion milestone in Feb 2019 and the project is on track for 100% design completion in May 2019. All 31 work packages for pre-excavation are awarded and work is underway. The contractor currently has 50 people on site and is continuing to ramp up. Completion of pre-excavation work is expected in Nov. 2020. The goal is to have all far site main excavation and building and site infrastructure contracts awarded in 2020 with a milestone to turn over the north cavern in Oct. 2022 and the south cavern in July 2023. The far detector nitrogen system RFP is on target for an award in May 2019.

Nevertheless, a delay of 10 months has been incurred. The delays are due to three root causes: the complexity of the work compared to initial estimates, the delay in the Ross shaft renovation, and the delay in getting large contracts secured. All three causes provide opportunities for `lessons learned'. (1) Future proposed work should be planned to include sufficient contingencies to reduce schedule risks. (2) Safety is a concern, particularly since the work site is not typical for a DOE project. It may be that safety is being given adequate attention but there was little demonstration of that in the presentation. The Ross shaft incident is a sobering example of the kind of risks that are inherent in the work at the Far Site. Serious safety incidents or `near misses' would have considerable impact to the schedule. Given the uniqueness of the far site facility, LBNF should continue to welcome particular expertise in large underground excavation and installation in its review teams. (3) Given the extent of the upcoming contracts, the efficiency of procurements should be analyzed thoroughly in order to characterize potential bottlenecks. Mitigations should be implemented with appropriate tracking metrics to monitor performance. Procurements is a non-technical area where steps to improve processing time can provide a significant boost to a project.

Attempts are being made to compress the schedule (eg. with parallel activities) such that the cavern turn-over phase can achieve the October 2022 and July 2023 goals. The duration of the civil construction should be understood this summer.

There seems to be a healthy awareness of the importance of interfaces between DUNE and LBNF. System engineering has evolved with the generation of 3-D models that will be useful to assist in interface and integration discussions and reduce conflict/errors during installation. LBNF is appropriately transitioning to EDMS for document storage. Moving to EDMS across the project is strongly supported. The importance of a centralized document server and document approval protocol cannot be overstated. Cross training on various CAD platforms is useful, while efforts to move towards a common CAD platform are encouraged.

Efforts to understand the detailed logistics regarding delivery of equipment and people to the detector halls and assembly and installation are strongly encouraged. Evidence of such planning was reported in the DUNE presentation. Given the scope of the endeavor, a fully-formed, detailed plan should be developed and refined to simulate the flow of goods to the site and into the underground vaults, with adequate contingencies. Such planning will give confidence that the infrastructure and staging areas are sufficient to avoid possible bottlenecks during the site preparation and installation phase of the project in the movement of goods and people.

The transitioning of the EFIG to a high-level steering group is a positive step as the project moves towards the construction phase – the authority of EFIG is not clear from the org chart but it is too early to judge whether this will present any issues moving forward.

An important result of such an analysis would be for LBNF to review the staging areas and support infrastructure to avoid possible bottlenecks in the installation phase of the project in the movement of goods and people.

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. Nevertheless, procurements for architecture and engineering of conventional facilities are on track for preliminary facilities design this summer. The goal is to have a site preparation package ready in mid-June for construction to start in FY2020 should funds be available. LBNF appears to be appropriately dialoguing with DUNE to provide the required timeline 'drop dead dates' for the down select process so as not to delay site preparation with the goal to fix ND shaft and size by July 2019. The upper bound on costs will be finalized in 2019. Convergence on the point cost will occur in 2020 for the Near Site Sub-Project at CD-2. 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 cryogenic tests with ProtoDUNE SP are providing useful feedback on detector outgassing, LAr purity, and purification rates. The data should be used to extrapolate to requirements for the cryogenic services in DUNE.

The environmental plan recommendation is now closed with the appropriate mitigation.

Recommendations:

- Highlight efforts towards far site safety in the LBNF reporting to future LBNC meetings.

LBNF Status: Beamline

The Beamline work continues to evolve. The present schedule plans to complete the preliminary design in 2020 and hold the Near Site Sub-Project CD-2 review in July 2020. Beamline and NSCF integration meetings are being held weekly to complete interface requirements and specifications with the goal to complete >90% interfaces by 2019 calendar year end. There have been a number of notable highlights. Prototype development and testing are underway for several subsystems such as the target shield pile (TSP) cooling panel and TSP horn strip-line feedthrough plus the thermal modeling of TSP at 2.4MW. There have been advances on the design of the upstream decay pipe window replacement system and the downstream decay pipe N2 return system. In addition, Horn A and strip-line designs have also advanced. Finally, the project retired a significant risk for the Magnetic Field Uniformity at Horn Drain Ports. While these are noteworthy advancements, it was not easy to tell where the project is with respect to the completion of defining key engineering design questions. For example, there was little presented on remote handling: this technology is an aspect of the beamlines program that can drive cost, complexity and schedule. It would be good to hear more about this at the next meeting and the overall readiness of the engineering with respect to the total.

External partners are engaged with assigned scope. BARC will be producing dipole and quadrupole magnets. KEK is fabricating prototypes for the horn strip-line feedthrough. RAL is providing prototype and production targets plus associated systems. IHEP is providing corrector magnets with four delivered to date. However, the biggest vulnerability in the project is that a significant portion of the scope still needs to be assigned. While efforts are in progress to identify

collaborators, the undefined scope certainly complicates plans to move the project to CD-2. The project reports that they have a handle on the costs with sufficient resources to develop the conceptual design. However, 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.

Recruitment is ramping up but for tracking it would be better for future meetings if the resource actuals were charted against the resource loaded schedule to get a better sense of project health. The departure of Rob Roser will be a blow to the beamline progress at least in the short term. The project appears to have gained significant progress under Rob's tenure and it is obviously important that a suitable candidate be identified soon.

Recommendations:

- Report resource actuals against the resource loaded schedule across the LBNF project and report a summary at the next LBNC meeting

DUNE Update: General

The LBNC congratulates the Collaboration on the timely delivery of the TDR chapter drafts, produced while substantial progress is being made across all areas of work. The LBNC further appreciates the willingness of the collaboration to provide a large number of revised TDR chapter drafts on 3rd May and looks forward to reviewing them. The LBNC may need to stage recommendations for approval of different TDR volumes, for efficiency and so that the approval of more advanced volumes is not delayed by others.

The Committee is pleased to see the continuing gradual growth of the Collaboration, and to see some initial funding from a new nation. The survey being conducted across the collaboration of academic, post-doc and student effort working on the experiment is noted. The big cohort of graduate students and early-career scientists is impressive. The Collaboration is encouraged to complete this survey including all institutes, in order to present a comprehensive picture; partial numbers can be misleading.

The continuing operation of ProtoDUNE SP, and the progress towards ProtoDUNE DP operation in the late summer were noted. The Committee considers continued running of ProtoDUNE until 2022, once more with beam after the long shutdown, to be a high priority. The LBNC is pleased to see the positive encouragement of the CERN SPSC for the collaboration to request such continued running.

The Committee notes the initiation of a task-force to study a longer (7 m) drift distance in the single-phase detector, following the good electron lifetimes observed in ProtoDUNE. The Committee cautions, however, that the current 3.5 m-drift single-phase detector design is well studied: significant changes to this design for the first module would require strong incentives.

Recommendations:

- None

DUNE Update: Technical Coordination

The new organizational structure at SURF directed towards installation, with an increased role for EFIG, and the introduction of an Integration Project Director (IPD) with a Joint Project Office (JPO), has been developed and initiated since the last LBNC meeting. This organization differs substantially from that foreseen in the Interim Design Report, and demands a close collaborative working model between IPD/JPO and DUNE Management and Technical Coordination (TCN). The LBNC welcomes and encourages the ongoing effort to refine the roles and responsibilities of the LBNF/DUNE Joint Project Office (JPO) with respect to TCN. A clear definition of the boundary between TCN and JPO is important, and needs further development and clarification. The transition from the old to new structure is in progress, and also needs active and careful management.

The Committee notes, and is concerned, that underground person-occupancy is estimated to increase from the LBNF construction steady-state of 95(day)/75(night) to a peak of 140/105 in the second quarter of 2023, ramping back down to the equivalent of the previous LBNF construction level in third-quarter 2024. The Committee remains concerned about several aspects of underground safety – even one non-trivial accident could be highly damaging to FNAL, LBNF, and DUNE. Some associated concerns are:

- In the high-level organizational charts, safety committees enter well below the level of the spokespersons. It might be appropriate that the top safety person(s) have direct access to the spokespersons.
- The planning of underground work that requires physicist skills seems over-simple to the point of naiveté. Physicists will need underground training as well as task-specific training, and probably cannot work safely (or effectively) for more than 6 days in succession.
- The assumptions of multiple years of steady work without significant contingency for interruptions due to work stoppages from "incidents" do not seem reasonable.
- In addition to high-level safety staff and rules, it may be worth considering embedding safety professionals in work groups.

DUNE has established an internal working schedule of August 2024 for the onset of installing detector #1, and August 2025 for onset of installing detector #2.

Recommendations:

- Write Roles and Responsibilities documents for both TC/TCN and the DUNE-facing part of the IPD/JPO. Incorporate these in the DUNE Collaboration governance documents.
- Specify formally the mechanism for Collaboration management oversight of the use of Collaboration resources by the JPO, considering that the IPD/JPO depends heavily upon the DUNE Collaboration for explicit resources; and that the responsibility for international DUNE Collaboration resource management, especially financial, lies with the Collaboration.

Technical Coordination TDR

The LBNC thanks the Collaboration for the first draft of the TDR, and for the presentations at the February 28th review meeting. The major organizational change, introducing Integration Project Director (IPD) and Joint Project Office (JPO) to manage installation and integration at SURF, was made just as the TDR draft was being finalized. Detailed presentations provided at the February 28th meeting by the DUNE Technical Coordinator and by the IPD were very instructive to clarify the thinking behind the reorganization, and the expectations from both sides on the working model, and initial thoughts on the division of responsibilities.

The TDR review team consists of several external experts in addition to some LBNC members, and is chaired by Austin Ball (CERN), who is also Technical Coordinator of CMS. There was an extensive discussion at the TDR review meeting of the new organizational structure at SURF, and also of the significant safety concerns of the reviewers. In addition to the full discussion at the review meeting, written remarks and recommendations were addressed to the TCN TDR team on 14th March.

The major change of organizational structure needs to be reflected in a largely new TDR draft, which the LBNC was pleased, at this meeting, to hear is being constructed. The new draft is scheduled to be made available to the LBNC and TCN-volume review team on 3rd May. Organization charts with names, even if they evolve, will be very helpful as part of the new draft.

Recommendations:

- No recommendations additional to those given by the TDR review team in the 14 March feedback document, and those reported earlier in this report under "DUNE Update (Technical Coordination)".

Near Detector

The need for a capable Near Detector to control systematic uncertainties for oscillation analyses and in particular to reach its CPV sensitivities was presented.

DUNE's design strategy envisages a Near Detector capable of handling higher event rates. It must provide model-independent flux measurements, cover phase space not visible to previous experiments, and precisely measure neutrino flavor components. The strategy includes off-axis measurements with an additional on-axis beam monitoring system.

To achieve these goals, DUNE proposes a detector system consisting of a movable pixelated LAr detector with 50 ton fiducial mass followed by a High Pressure Ar gas TPC in a 0.5T field, with an additional ECAL & muon tagger. A 3D Scintillator tracker in a magnetic spectrometer will act as the on-axis beam monitor.

While the proposed detector system adheres to the ND design strategy, we are still missing fully articulated arguments, and numbers/plots indicating the power of each component of the detector suite to improve the systematic uncertainties for CP violation measurements.

LBNC urges the DUNE collaboration to establish the requirements of the Near Detector suite from a physics performance point of view and is looking for fully articulated arguments, and numbers/plots indicating the improvement of the CPV uncertainties from the envisioned movable ND and 3DST over that achievable by a Far Detector alone.

Based upon such arguments, DUNE should specify the basic ND configuration including the size of the near detector hall required to observe CP violation.

LBNC recognizes that "unknown unknowns" may affect these conclusions, and requests a more complete narrative of how the ND will protect against issues due to inadequacies in the neutrino interaction model. What parts of the flux/cross-section model have the biggest impact, and which detector components are required to address those?

LBNC looks forward to a preliminary review of the ND design and its capabilities over this summer, following delivery of the ND executive summary in May.

Recommendations:

- None

ProtoDUNE-SP: Data Analysis

The presentation to the committee on the ProtoDUNE-SP Analysis demonstrated significant progress since the December 2018 LBNC meeting.

The focus of ProtoDUNE analysis is to understand and reduce the systematics for DUNE in the areas of

(i) calibration;
(ii) noise mitigation; and,
(iii) signal-to-noise ratio.

Low-level analysis of the data is in good shape: offline mitigation strategies for low-level data quality issues such as sticky code bits, and coherent noise from low voltage regulators are in place. ADC gain variations are measured to be uniform to within 5%. An empirical analysis to calibrate out field non-uniformities and attenuation was presented, correcting for variation at the 10% level across the TPC. A plan was outlined for a space- and time-domain deconvolution analysis to correct for non-uniformity.

Higher-level analysis is progressing well: a highlight is track reconstruction using PANDORA. The committee was impressed to see that within only a few months of acquiring beam data the automated track reconstruction software can distinguish between beam particles and cosmic rays. A linear energy scale calibration has been measured comparing cosmic ray muon data with simulation; applying this calibration results in good agreement for both 1 GeV protons and positrons. Time-of-flight spectra for protons and muons were presented, showing nice separation, in preparation for the cross section physics program.

For a future LBNC meeting, the committee would find it helpful to see

(i) a study masking 1-2 ADC bits to understand the operational safety margin;
(ii) lower-level details on the analysis to calibrate field non-uniformities/attenuation;
(iii) data/MC comparisons before vs. after the calibration corrections, to understand the degree of tuning; and,
(iv) a quantitative comparison of efficiencies of the various photon detection system technologies.

Recommendation:

- The LBNC recommends that a table be prepared in the TDR format, that compares the ProtoDUNE-SP performance requirement with the achieved specifications.

ProtoDUNE-SP: 2019 Operations

The presentation to the committee on the ProtoDUNE-SP Operations outlined the objectives for 2019 as

(i) understanding and validating basic detector performance;
(ii) demonstrating the long-term operational stability of the detector; and,
(iii) fine-tuning and exploring the current technological limits.

Three areas were identified for (iii); these are investigating the limiting factors towards higher LAr purity level, investigating the origin/mitigation of high voltage and current instabilities, and collecting data for the fluid dynamics simulation. Dedicated consortia tests are planned to study cryogenics parameters, APA wire plane transparency, CE noise, photon detection system efficiency, and DAQ systems development.

The committee urges the collaboration to strongly prioritize demonstrating the long-term operational stability of the detector. The run plan should prioritize the stability demonstration needs for the TDR specifications this summer, with focus on studying the operational margin.

The initial cryogenics studies presented suggest that the performance of the filter may be sub-optimal, and that the purity may be improved by identifying the particularly hot spots above the ullage. More study is needed here to understand how ProtoDUNE-SP results scale to DUNE, and to quantify the operational safety margin for DUNE.

The origin and mechanisms of the HV current blips and streamers are not clear yet. More study is needed here to understand how this scales to DUNE, and what level of mitigation/what mitigation strategies are required in DUNE, particularly with respect to detector aging.

With respect to the dedicated consortia tests, the committee suggests that the collaboration consider running a copy of DAQ/trigger in parasitic mode for development tests, in order to decouple and minimize the impact of the rest of system data taking, while maximizing the DAQ development time.

For the run after 2019 operations, a list of objectives was presented, including

(i) testing 3 final-design APAs with final charge electronics;
(ii) equipping these with the baseline photodetector system;
(iii) studying light enhancement strategies;
(iv) and DAQ development.

The committee again urges the collaboration to strongly prioritize retiring technical risks for the TDR with the tests of the final APAs + CE over R&D.

Recommendations:

- None

FD-SP TDR Status

The LBNC has received 6 draft FD-SP TDR chapters to date. The TDR draft chapters are arriving on the agreed schedule, for which we thank the collaboration.

A one-day review meeting was held in February 2019. Written feedback from the LBNC was provided (both high level and detailed) in March 2019. The LBNC expects that the TDR will form the basis of a cost estimate for each subsystem. For the APA chapter we can see a direct line from the TDR to a cost and schedule estimate. For the DAQ chapter we cannot. The other 4 chapter drafts are in between these two levels of readiness. Brief summaries from the February meeting of the draft chapters received thus far are:

(i) APA: chapter is in good shape, requirements should be compared with demonstrated performance in ProtoDUNE-SP.
(ii) CE: many options are described, the process for defining baseline design that will be tested as 'module-0' in ProtoDUNE-SP post-2021 is not clear. The schedule is not clear.
(iii) DAQ: does not describe a baseline design. Needs rewrite, as discussed.
(iv) HV: the discharges and streamers are potential high-threat risks. This chapter should be informed by what is learned in ProtoDUNE-SP studies.
(v) CISC: should be informed by ProtoDUNE-SP flow measurements.
(vi) Photodetectors: production plans, aging test, defining baseline versus alternatives (e.g., SiPM manufacture) are important aspects of this system that need clarification.

After discussion with the collaboration, the LBNC is expecting to see the installation chapter in the FD-SP volume.

Overall, the TDR team would benefit from expert reviewer engagement from a small number of DUNE collaborators, e.g. consortium leaders, prior to delivering draft 3 ("v3") to the LBNC. The v3 draft is scheduled to be delivered to the LBNC on May 3, 2019. The collaboration review will be launched in parallel. We welcome the intention of the collaboration for v3 provided to the LBNC to be an internally well-reviewed document.

Recommendations:

- None

Dual Phase

The committee appreciated the detailed talks and accompanying documents that were provided, including the response to the recommendations from the December 2018 LBNC meeting, the draft document on DUNE Dual Phase requirements, and the detailed report on technical progress on large electron multipliers (LEM) development. Collectively, these documents show very significant progress since the December 2018 meeting.

The committee commends the Collaboration for its thorough response to the set of recommendations issued at closure of the December 2018 meeting. One of the December 2018 recommendations, *"Quantify the tradeoff between LEM gain and physics performance and*

scope", should be re-evaluated in view of our further comments on DUNE Dual Phase requirements below.

The committee examined the draft document on requirements for the DUNE Dual Phase Module design. The combination of requirements on drift (12 m), electron mean life (3 ms), drift field (250 V/cm, corresponding to a velocity of 1 μs/mm and leading to a drift time of 12 ms), system noise (2500 electrons), charge-readout plane gain (×6), pitch (4.7 mm) leads to a signal to noise ratio on signals from near the cathode of the detector of 1.3. Several of the parameters are correlated. The committee considers it important to take this into account so that the requirements can be together interpreted as providing the minimal guaranteed performance.

The committee looks forward to the demonstration of a design *"leading to a robust and tunable S/N and a lower detection threshold" ["The DUNE Far Detector Interim Design Report, Volume 3: Dual-Phase Module"*, arxiv:1807:10340].

The committee noted the significant effort on the preparation of ProtoDUNE-Dual Phase. The progress achieved since the December 2018 Committee meeting is commendable. Four charge-readout planes have been installed: two fully live, one dummy and one with four anode-only panels. Thirty six cryogenic photomultiplier tubes have been installed to complete the photon detection system. Also, installation of the field cage, high-voltage feedthroughs, signal feedthroughs, and electronics have been completed. The current schedule foresees the closure of the cryostat temporary construction opening on April 23, 2019. The schedule (without contingency) has filling completed at end of July 2019 and purification completed by mid-August 2019. We look forward to first results and operating experience later this year. This will be a major achievement for the project.

Stable and efficient operation of LEM is the most critical element to be demonstrated for the Dual Phase approach. We note the major progress achieved in the last few months, with a factor twenty reduction in the spark rate since the report at the December meeting. The ongoing effort on identification of the source of the sparking is essential for the containment of the problem. We commend the involvement of the CERN gas micro-pattern detector group, whose actions directed to the improvement of LEMs micro-etching may lead to improved reliability.

LEMs are the critical element in the DUNE Dual Phase design. The committee feels that persistency of sparking is not only a concern for dead time, but potentially for the long-term reliability of operation. Consideration of a LEM-based TDR for a DUNE module will require demonstration of stability and a positive record of successful operations.

The Dual Phase Consortium is preparing drafts for each chapter of the TDR. The first chapter on electronics was delivered to the LBNC for comments. We look forward to reviewing drafts for the other chapters in due time. We understand that any material submitted to the LBNC before operation of ProtoDUNE-DP will necessarily lack information from this important work. Nevertheless, it is expected that a TDR which the LBNC could support as such would include results and experience from the operation of ProtoDUNE-DP and would make reference to the established positive record of successful operations mentioned above.

Recommendations:

- Improve the definition of requirements, taking into account correlations between different parameters (for example: gain, noise, E-field, purity) such that the requirements provide a coherent description of the minimum performance.
- Develop plans for a long-term test program to establish operating margin and build confidence in longevity/robustness of the LEM and CRP design. Such a program might include HV stress tests, power cycles, and extended operating periods.

Computing Consortium and Design

A DUNE Computing Consortium was officially formed in September 2018. Approximately 25 institutions have joined or expressed interest. Many are providing or pledging hardware resources. The leadership of the consortium has been appointed: Consortium Lead (Heidi Schellman, University of Oregon), and two technical leaders, one representing the host lab (Mike Kirby, FNAL), the other with the international portfolio (Andrew McNab, University of Manchester). The consortium is beginning to tackle global issues, such as working with the physics groups on setting policies for MC production and disk space usage. The LBNC commends the formation of the Computing Consortium and completing the management team with the appointment of Andrew McNab.

The DUNE Computing Consortium (DCC) and FNAL (as Host Lab) have begun to explore connections to a broader computing community. Connections to organizations such as the HEP Software Foundation, the Open Science Grid and Worldwide LHC Computing Grid (WLCG) are being formalized. This provides a possibility of collaborative projects, access to a marketplace of ideas, and the potential to influence development efforts in community projects. DUNE has been invited to be observers in the WLCG Collaboration Board. These are very positive developments. However, there remain DUNE specific development tasks (such as databases) and contributions to community projects that will require dedicated technical effort from DCC and from FNAL.

Based on the operational experience with ProtoDUNE, initial estimates of computing needs for an extended ProtoDUNE run and DUNE are tractable at the level of resources and projected data volumes, even without zero suppression. Through the Computing Consortium, most hardware resources have been secured for the ProtoDUNE phase. The ‘data volume based’ computing model based on these data volumes is appropriate for the ProtoDUNE phase and can serve as a baseline computing model for DUNE. A more optimal computing model would assess mechanisms for ensuring early oscillation physics and relative trade-offs between doing some data reduction in South Dakota It would also assess possible end level analysis environments, especially if High Performance Computing (HPC) resources are needed for end level analysis. Designing an optimized ‘readout to publication’ computing model requires the development of internal DUNE governance mechanisms, policies and communication channels between DAQ-offline computing-physics and reconstruction and analysis groups. The LBNC strongly encourages undertaking this. We note that securing the hardware resources for the ProtoDUNE era is a significant achievement.

Recommendations:

- The LBNC recommends that the collaboration engage more strongly in the development of computing infrastructure by securing dedicated technical effort.
- For the computing strategy summary in the TDR we strongly recommend a tight focus, stressing the impact of the ProtoDune experience, a short description of the consortium model and any long lead-time items, such as SURF WAN

Physics TDR

The LBNC received a first draft of the Physics TDR in January and sent comments. The committee very much welcomed this first draft but also noted the lack of results for the oscillation analysis. In addition to introductory and concluding chapters, the TDR contained chapters on tools and methods, the neutrino oscillation program, the physics program on GeV-scale non-accelerator neutrinos (e.g. proton decay), supernova neutrinos and low-energy neutrino physics and beyond the Standard Model physics. In addition, a chapter on precision physics with the near detector was foreseen.

End of February, the LBNC received responses to the comments and the team had a meeting with the DUNE collaborators. During this meeting the oscillation analysis results were presented for the first time, and a constructive discussion took place. The LBNC team sent comments and expect to receive answers on April 8th, and looks forward to a new draft on May 17th. On the individual chapters, the comments can be summarized as follows:

- Tools and Methods: Calibration is generally in good shape, role of different calibration systems clear. For simulation and reconstruction, the committee is impressed by the performance that has been achieved in full simulation, and considers it to be adequate for TDR.
- Oscillation analysis: the results presented in Feb. look good. The systematic uncertainties need much more explanation, in particular to understand the role of the near detector in constraining them.
- The chapters on GeV-scale neutrinos and low-energy neutrinos are both in good shape
- The chapter on BSM physics is less rigorous than other chapters but generally OK. Some sections could be relegated to an appendix
- The chapter originally foreseen on precision physics with the ND has been postponed to the ND TDR. The LBNC considers this reasonable.

The LBNC Physics TDR review team will meet about a week after the LBNC meeting to discuss remaining major questions and comments. The next draft is then expected on May 17th and further meetings will be schedule end of May and end of June to discuss this draft.

Recommendations:

- It is important that the role of the ND for the oscillation analysis systematics is clarified further (not only for the ultimate sensitivity but also for the early analyses assuming e.g. 2 detectors and max CPV)

Appendix I: LBNC Attendees

Committee: Ties Behnke, Amber Boehnlein, Marty Breidenbach, Dave Charlton, Joel Fuerst (remote), Cristiano Galbiati, Beate Heinemann, Patrick Huber, Robert Laxdal, Naba Mondal, Jocelyn Monroe, Hugh Montgomery, Steve Nahn(NCG), Scott Oser(remote), Marco Pallavicini (remote), Jeff Spalding.

Scientific Secretary: A. Himmel

DUNE/LBNF: D. Auterio (remote), E. Blucher, T. Bolton, A. Bross, F. Cavanna, E. James, S. Kettel, C. Mossey, R. Rameika, F. Resnati (remote), H. Schellman (remote), S. Soldner-Rembold, J. Urheim, E. Worcester (remote), T. Yang.

FNAL Directorate/Management: N. Lockyer, K. Decker, H. Ramamoorthi.

DOE: P. Carolan, D. Lissauer, W. Wisniewski

Appendix II - Charge

The LBNC will hear about the progress in a number of areas including the general progress of each of LBNF including the beamline, and DUNE in general and changes in the organization of the Technical Coordination functions. For ProtoDUNE SP, there will be presentations covering both the analysis of 2018 data and the 2019 operations. For the Dual Phase option, we will hear about the progress of ProtoDUNE DP, ongoing development, and preparations for the TDR. Two other foci will be the progress of the design and simulation of the Near Detector, as a precursor of its planned mid-2019 review. We will also hear more about the development of the Computing Consortium and plans. Finally, we have been active reviewing the Technical Design Report volumes for Physics, Far Detector – Single Phase, and Technical Coordination: we will hear a status report from DUNE and then, in Executive Session, from our review teams.

The LBNC will prepare a written report, which will include descriptions of the status of each of these items. Following the December 2018 meeting, a report to the DOE LBNF-DUNE IPR in early January 2019, was requested. We might expect similar during the summer of 2019. Our goal will be to leave FNAL with an advanced draft of the report in hand.

In order to facilitate achieving this, we will make tentative assignments for the attending LBNC members including one who will be requested to take the lead in writing. We are looking for approximately 0.5 – 1.0 pages of text per item, plus individual powerpoint pages for inclusion and presentation at the closeout. We will discuss the expectations in the executive session at the beginning of the meeting.

Appendix III - Assignments

LBNC Meeting April 1-3 -Fermilab – Agenda – Draft 2

LBNC Members assigned in dark Red

April 1

08:00 Executive Session Committee + Director

Role of LBNC and Status

Hugh Montgomery

09:00 LBNF Status

General Status

Joel Fuerst, Bob Laxdal

Beamline Status & Progress

Bob Laxdal, Joel Fuerst

10:00 Break

10:15 DUNE Overall Status (Spokes)

Dave Charlton, Marco Pallavicini, Bob Tschirhart

11:15 DUNE TC Evolution and Status

Marty Breidenbach, Dave Charlton, Bob Tschirhart

12:15 Lunch/ Executive Session

13:30 Near Detector

Naba Mondal, Patrick Huber

15:00 Break

15:15 ProtoDUNE Single Phase

Analysis Status

2019 Operations

Jocelyn Monroe, Ted Liu

16:45 Executive Session

18:00 Adjourn

April 2

08:30 Executive Session

09:00 Dual Phase

ProtoDUNE Dual Phase

Development Program

TDR Preparation Status

Jeff Spalding, Ties Behnke, Cristiano Galbiati

10:30 Break

10:45 Computing Consortium and Design Document

Amber Boehnlein

12:00 Lunch/Executive Session

13:30 TDR Status Reports – Dune

FD-SP

Technical Coordination

Physics

15:30 Break

15:45 Executive Session

TDR Status Reports – LBNC TDR Teams

FD-SP

Jocelyn Monroe, Ted Liu

Tech Coordination

Dave Charlton, Marty Breidenbach

Physics

Beate Heinemann, Patrick Huber

General Discussion/ Report Preparation

18:00 Adjourn

April 3

08:30 Executive Session

Report and Closeout Preparation

Closeout Dry Run

12:00 Closeout

Appendix IV – Agenda

See:

https://web.fnal.gov/organization/LBNC/April%201-3,%202019/SitePages/Full%20Agenda.aspx

In this version, the talks are also posted.