Long Baseline Neutrino Committee

FERMILAB, September 2021

CLOSEOUT Report

September 17, 2021

Acknowledgements

The LBNC continues to enjoy examining the advances being made the LBNF project and by the DUNE Collaboration.

We appreciate interactions with DUNE over the course of the previous several months and the efforts made to prepare the presentations in both Plenary and Breakout sessions. They represent an impressive body of work.

The committee also thanks Fermilab, its Directorate and support staff, for their support.

LBNC Meeting Charge Letter 8/18/2021

- As usual, the LBNC should construct a report in which it acknowledges, comments on, and where appropriate, makes recommendations following the presentations and discussions during the meeting.

- The LBNC should hear about the general status of LBNF and DUNE. Of continuing interest is the planning for a tailored approach to baselining following the recent DOE-IPR and the schedule for future DOE-IPRs. In addition, significant changes to the baseline funding profile has considerably modified the timeline for some aspects of the project. These modifications affect the US project, international partners, overall scope and the timeline to physics. The LBNC should hear about these issues and provide input and feedback.

- The LBNC has regularly heard about the safety performance associated with the work at the Sanford lab. It would be interesting to understand how DUNE has more broadly addressed ES&H issues and integrated Lessons Learned from experience with the NP02 and NP04 experiments and other neutrino detector fabrication such as the SBND detectors,

LBNC Meeting Charge Letter 8/18/2021

- As the definition of the technical plans for the major pieces of the DUNE detector progress, it is important for DUNE to ensure that all aspects of the endeavor enjoy an appropriate organizational structure and management coverage. DUNE is expected to discuss its management structures in the DUNE overview talk, in the Technical Coordination and to a greater or lesser extent in the main Sub-detector sections. These structures should allow convenient mapping to the US-DUNE DOE project. In its reports from this meeting, the LBNC should include commentary on the current management implementation within DUNE including how well the major sub-systems Far Detector Modules, and Near Detectors are integrated.
- Prior to, and as part of, this meeting, the LBNC will undertake a "mini-review" of Far Detector 1 (FD-1, horizontal drift). The first part of the review will happen on September 8, in advance of the LBNC meeting, while the final portion of the review will occur during the LBNC meeting. The charge for the FD-1 mini-review is provided separately, closeout will be combined with the LBNC closeout.
- The LBNC should hear about the progress with the FD-2 that utilizes Vertical Drift SP technology. Focus should be upon progress achieved since the dedicated vertical drift review in April/May 2021. The presentation(s) should cover:
- a) Progress towards ProtoDUNE II VD (NP02).
- b) Technical progress on the Vertical Drift Detector, HV, CRPs, photon detection, etc.
- c) Progress on integration, documentation, including the ongoing review of the Vertical Drift CDR

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- The LBNC should hear about status and plans for the Near Detector. This should include the "Phase 1" ("Day 1") Near Detector as well as planned evolution toward the ultimate DUNE ND. In light of the funding profile issues outlined above, the LBNC should hear about priorities, options and actions planned with the Near Detector.
- The LBNC should also hear an update on safety issues related to LBNF and DUNE.
- The LBNC should hear an update from the Computing consortium, including an update on the DUNE Computing CDR. This segment should also address progress with physics analyses and publications deriving from the ProtoDUNE operations and other R&D activities.
- The LBNC should develop a Closeout Report which it should deliver at 12:15 EST September 17, 2021. Subsequently this should be refined into a LBNC Meeting report.

LBNC Meeting Assignments 3/4/2021

LBNF Status Fuerst, Peterson	**Gottberg,** Charlton,
DUNE Status Kopp	**Saoulidou**, Gray, Charlton,
DUNE Organization Peterson, Spalding	**Charlton**, Fuerst, Gottberg,
APA Single Phase Majumder, Pla-Dalmau	**Parsons**, Behnke, Fava,
Vertical Drift Kajfasz, Para, Wood	**Spalding,** Galbiati,
Near Detector Status Saoulidou	**Oser**, Behnke, Kopp,
Computing	**Campana**, Charlton,

LBNC Meeting Assignments 3/4/2021

Breakouts

Vertical Drift	**Spalding**, Galbiati, Kajfasz, Para, Wood,
APA Single Phase	**Parsons**, Fava, Majumder, Pla-Dalmau
Near Detector	**Oser**, Kopp, Saoulidou
ProtoDUNE Analysis	**Gray**, Campana, Charlton
Computing	**Campana**, Charlton, Gray,

LBNF Status

- Substantial progress has been made in the previous months. Design development has advanced as per plan in most areas and some detailed designs have been completed fully. The far side construction project has been split successfully into two subprojects, which provides focus and manageable scope to the teams.
- A credible plan towards CD-1RR in Q2 2022 has been presented. Preparations are well underway with a focus on finalizing the project scope, firming the international commitments and settling the funding profile. However, the level of uncertainties in the funding make planning challenging. Physics, staff profile, cash-flow constraints, and collaboration considerations went into a new top-level project sequencing to respond to the new “reference funding profile”. The uncertainties in cash and schedule projections place strain on all stakeholders and can potentially compromise ultimate LBNF excellence.
- As before, the project team is technically very strong and capable. We were pleased to see progress being made in the gender balance at the management level and are interested in seeing, in the future, how diversity is progressing more broadly across the project, including at the technical level. Also, no concrete plan has been presented as to how to manage staff turnover, which is to be expected due to length and nature of the project.

LBNF Status

Recommendations:

1. Help improve communication and decision-making processes between DOE, FNAL, LBNF/US DUNE, and the DUNE, Collaboration.

2. Clarification of the sequencing, including at intermediate level, in response to the funding profile guidance is required as soon as possible.

3. For the LBNF/DUNE project, provide a management plan document, which will be maintained to reflect any further changes in the organization.

DUNE Status

- The LBNC commends DUNE for substantial progress made on several fronts : i) The finalization of the ND design with the selection of the STT inner tracker option for SAND ii) The advancement and continuing refinement of the plan for ProtoDUNE-II construction and operation in 2023 iii) The rapid progress on the FD2 R&D and prototyping, and the completion of the FD2 CDR.

- The LBNC is concerned about the new funding schedule resulting in rather significant delays in the starting date for oscillation physics, especially given the international competition. The LBNC strongly appreciates the uniqueness of the DUNE experiment, being capable of measuring both the neutrino mass hierarchy and the CP violating phase, which is retained despite the induced delays.

- The LBNC would like to see an updated plan and timeline for CD2/CD3 for the ND, FD1 and FD2, with clear requirements and appropriate contingency. The plan should include pragmatic and realistic timelines for the construction and operation of the ProtoDUNE detectors.

DUNE Organization

The LBNC

- Notes the substantial reorganization of the LBNF/DUNE DOE project. Some simplifications in the new organization appear attractive. The LBNC is pleased to hear that two management plan documents, covering the DUNE Collaboration and the LBNF/DUNE DOE project, are being written, and would like to see them.
- Is concerned that the interactions of the international DUNE Collaboration leadership with the LBNF/DUNE project and its subprojects are too indirect in the organigrams provided. The crucial role of the international DUNE Collaboration should be evident, as it is the DUNE Collaboration that will deliver the science. Interactions between the DUNE Collaboration and the LBNF/DUNE-project need to be transparent and frequent at all levels, and lead to a shared vision of the strategy.
- Notes that more consortia now span multiple detector modules. The LBNC would like to understand how this will be managed within the different consortia.
- Notes that the readiness of the two far detector modules for CD2 review is quite different, and forcing a combination of the two into a single review is likely to result in a delay of the FD1 CD2 approval.

Recommendations

- Provide an updated DUNE management plan document, which will be maintained to reflect any further changes in the organization.

FD1 Horizontal Drift

- The LBNC has been conducting a mini-review of the FD1 HD subproject, with sessions on Sept. 8 as well as Sept. 16. The mini-review closeout is combined in these slides with the closeout of the regular LBNC Sept. meeting.
- The LBNC commends the FD1 project on the excellent technical progress on all fronts, since the last LBNC meeting in March 2021.
- The completion of the ASIC down-select completes a major milestone in the development of the cold electronics (CE). The fabrication runs needed for PD-II have been submitted for all 3 ASICs.
- The team has prepared as well as they can against possible delays due to the global ASIC shortage. Such delays, however, remain a concern, particularly given that the CE lie on the critical path for PD-II and that the CE schedule to complete PD-II by end March 2022 is tight.
- The launch of final ASIC production requires PD-II results. Given the tight CE schedule for PD-II, it was reassuring to hear that the PD-II schedule has several months of float before it would delay the ASIC production submission, and eventually the FD1 installation schedule.

FD1 Horizontal Drift

- APA progress is very good, with APA 1 for PD-II having been produced and soon to be shipped to CERN for Coldbox testing and eventual installation in PD-II. The decision to use PD-I electronics for the Coldbox test needed to launch the APA procurement orders is wise, given the CE development schedule.
- The 5-year APA production schedule defines the critical path for FD1, the completion of which marks the beginning of physics for the overall project. The schedule shown ends with 4 months negative schedule float. While it was stated that some time savings are anticipated (for example due to a newer method of wire tension measurements that would be less time-consuming), and that such savings would provide some schedule float to cover the inevitable delays that arise during a 5-year production schedule, a baseline schedule with an appropriate schedule contingency will be needed to successfully navigate the CD baselining process.
- The PDS is considering 2 different WLS materials. The current plan is to test both in PD-II and reach a decision based on the results. This approach seems reasonable. However, to ensure a timely transition to PDS production, caution should be exercised to avoid a situation where the R&D phase drags on.

FD1 Horizontal Drift

- For value engineering and other reasons, it is being considered to change from Dupont kapton laminated G10 sheets to carbon-doped resistive G10 sheets for the CPAs. The plan is to test both options (ie. 1 CPA each) in PD-II. Apart from the limited statistics, a concern is raised by the requirement of stable operation of the DUNE detector in cryogenic conditions over multiple decades. While there are many years of experience of cryogenic operation with the Dupont kapton in multiple HEP experiments, a testing program would be needed to gain confidence in the longterm stability of the carbon-doped option.

- Plans for detector calibration systems are rather preliminary, and tests of various options will be done with PD-II. It was stated that these systems will be outside the scope of the US construction project, but related elements of the project (such as the cryostat design) will be performed to allow their eventual implementation. While this approach has obvious advantages in terms of cost and the schedule for decision making, it is rather unorthodox and the approach to identifying the needed resources should be agreed upon by all stakeholders.

- Very good progress is being made on the installation and integration planning. The experience gained at Ash River with various mockups continues to be very valuable.

FD1 Horizontal Drift

Recommendations

- Before the next steps in the CD process, determine and implement a schedule for FD1 that includes an appropriate level of schedule contingency.

- Develop and implement a plan for validation of stable longterm cryogenic performance of the various key elements going into the cryostat (eg. the possible use of carbon-doped G10 for the CPAs).

- Continue to develop the plan for detector calibration systems, allowing DUNE to progress on identifying the resources needed for their eventual implementation, and ensuring that the calibration systems are not limited unnecessarily by design decisions made in the scope of the US construction project.

FD2 Vertical Drift

Technical Review Apr-May

- The committee commended the project on the rapid technical progress and in building an effective organization to support FD2.
- The R&D and design validation is planned in two major phases:
  - coldbox demonstration of the CRP design and PDS/Arapuca operation, and demonstration of a new field cage design and HV extender in NP02
  - protoDUNE run in NP02 in 2023 which will include “module-0”, meaning final design assemblies
- While all three developments (CRP, PDS and HV) require new designs, R&D and demonstration, the electrical isolation of the Arapuca modules mounted on the cathode structure is considered the most challenging.
- The simulation and physics performance studies planned will take 6-12 months to complete. These will support design decisions ahead of module-0 construction.
- DUNE provided the LBNC with a set of 38 milestones covering the first phase of the R&D and the simulation studies for monitoring progress.
- DUNE has done an excellent job keeping the committee abreast of progress in meeting these milestones by providing interim updates.

FD2 Vertical Drift

Technical Progress (this meeting)

- DUNE continues to make excellent progress, with only minor slippage in the milestones. The project is on-track with the plan presented at the Technical Review.
- A full-scale CRP and initial PDS components are being prepared for the first coldbox test with installation planned for October. Four development cycles are planned for the coldbox, through 2022.
- Individual component tests for the new HV extender and feed-through led to design modifications incorporated in the NP02 system test. The NP02 cryostat was recently filled and the voltage ramped up to 300kV (just two days ago). This marks major progress and bodes well for this critical test of the full drift field.
- The PD module design is progressing and parallel developments are pursued for fiber powering and readout of the modules mounted on the cathode.
- The committee would appreciate a walk-through of the plans to demonstrate PDS operation at 300kV through the series of cold-box tests. See recommendation
- The configuration proposed for protoDUNE will allow full demonstration of the top and bottom anode planes and the PDS on the walls and cathode, but limits the drift depth to ~3m. The full 6m drift field will have been demonstrated in the NP02 HV test at the end of 2021. The committee endorses this approach.
- While the R&D timeline remains challenging, with the goal of demonstrating the CRP, PDS and HV solutions by late 2022, the rate of progress continues to be impressive.

FD2 Vertical Drift

Review of the Conceptual Design Report

- DUNE provided the committee with the draft CDR on Aug 10. The committee completed a thorough review and sent an extensive set of comments and questions, including 10 high level comments of a general nature and more than 300 comments of a technical, editorial and typographical nature.
- At this meeting DUNE has provided the committee with initial responses to the 10 high level comments as well as several of the others.
- DUNE will address each point and prepare a second version of the document. It is anticipated that, likely with a dedicated meeting to close loose ends, the committee will be able to conclude the review with a recommendation for CDR approval by the time of the next LBNC meeting in early December.

Recommendations

- Complete the CDR review process and document release by December
- Work with the committee to organize a half-day meeting to appraise us of R&D progress and to walk through the plans for the cold-box tests in 2022
- Report on progress in the simulation work at the next LBNC meeting in December

Near Detector Status

- We note the plan for staging between beam and ND, with the ND being the last element of DUNE to be installed. We caution that data taken without ND is unlikely to be useful for oscillation analyses. While we understand the resource restrictions that necessitate this staging, all efforts must be made to minimize this period. The likelihood that beam power will be small on Day 1 will mitigate the loss of usable data in the period between beam turn-on and ND readiness.
- DUNE has chosen the straw tube tracker technology for the inner tracking of the SAND beam monitor. The LBNC welcomes this conclusive decision on the inner tracker, which will allow the consortium to move forward, and agrees that STT can satisfy SAND's critical role as a beam monitor. The possibility of using the passive C/CH_2 layers to study ν interactions on free protons is a particularly interesting capability enabled by STT.
- DUNE is considering the installation of a liquid argon target, called GRAIN, inside SAND and will organize an internal review of this component. The LBNC has not yet been presented with design details or a compelling physics case for this component.
- The ND-LAr 2x2 cryostat has been delivered to FNAL, and is being prepared for operations in CY2022. Module 1 is in production. A preliminary design review of ND-LAr is planned for early 2022.
- An updated cost estimate for the ND-GAr magnet is expected by end of September. DUNE has made progress on optimizing the ND-GAr-lite in a tracking design.

Near Detector Status

- The TMS consortium has adopted a plan to build a prototype module, known as Module One. We see steady progress in magnet design, which has settled on air cooling. TMS has switched to single channel SiPMs due to the vendor discontinuing the favored multichannel device. This will simplify the mechanical design. Mechanical prototyping effort is ongoing. The simulation effort is progressing nicely. There are concerns that TMS is short on scientific technical effort with detector design expertise. The TMS consortium leader is also in the process of retiring.
- DUNE must go into CD-1RR with a clear, crisp statement of its plan for the Day 1 ND. This plan, which we endorse, includes the TMS, SAND, ND-LAr, and the PRISM movement system. Longer term, replacement of TMS by ND-GAr will be required for DUNE to reach its ultimate sensitivity. LBNC would like to see a clear strategy of how DUNE will ultimately transition from the Day 1 configuration to ND-GAr for Phase Two, and notes that ND-GAr-lite would provide an attractive path for this transition.
- CD-1RR is planned in April, with 3 pre-reviews in January-March period. A tailored version of the ND CDR with a focus on US scope will be required for this, and DUNE would appreciate some endorsement from the LBNC of its contents. Some small scope gaps in ND will need to be resolved before CD-1RR. CD-2 is likely pushed to 2023-2024, due to new US funding profile.

Near Detector Status

Recommendations:

- DUNE should find additional technical effort for TMS with the skill set to develop the detailed design.
- At the first LBNC meeting in 2022, present technical design details and elaborate the physics case for the LAr target in SAND.

Computing

- The DUNE computing consortium continues operating a distributed data processing and storage system that serves well the activities of the collaboration. Convincing progress was made understanding the impact of data access latency. The workload management system scales effectively to absorb bursts of processing activity.
- DUNE continues engaging with ESNET to ensure its network requirements are met. At the next LBNC we would like to hear the plans about the DUNEONE overlay network and an update about the planning of the the SURF-FNAL network link.
- DUNE made progress defining the needs of the future software framework and undertook a comprehensive review from the HEP Software Foundation. We appreciate that a conclusive decision about the architecture and implementation of the framework can not be defined in time for the CDR. We note that the DUNE requirements will imply considerable development work and time, regardless of the chosen implementation. We request DUNE defines the process leading to this decision and presents it at the next meeting, with a timescale.
- DUNE plans to produce the Computing CDR by the end of 2021, in time for a March 2022 LBNC discussion. We support this plan.

Recommendation: Produce a Computing CDR so that it can be reviewed for the March 2022 LBNC

Simulation, Reconstruction, and Analysis

- The LBNC commends the DUNE collaboration for the excellent progress on producing and publishing high quality physics analyses using the ProtoDUNE data.
- Congratulations on the publication of the ProtoDUNE-SP TPC performance in JINST and the submission of the design, construction and operation paper to JINST.
- The LBNC looks forward to the publication of the Michel electron energy resolution, Pandora performance and CNN performance.
- Good progress was shown for the hadron cross sections, seasonal variance of the cosmic ray muon rate, detector calibration, PID with dE/dx and the beam energy resolution
- We would be interested to see comparisons of the proton and neutron inelastic cross section measurements to existing results.
- In most cases, the agreement between the data and simulation is excellent.
- Studies of detector stability showed that the LAr purity is good as long as there are no issues with the Ar circulation pumps
- We were encourage to see the successful results of the Xe doping
- Recommendation
    - Report on progress in the simulation work at the next LBNC meeting in December. In particular, we wish to hear details about the photon simulation and the status and plans for the simulation for the FD2 Vertical Drift

Executive Summary

- LBNF continues to make enormous progress with its boots on and under the ground in South Dakota. Its challenges are dominated by establishing a viable and supportable project plan with a healthy funding profile and plan in order to support its continuing good performance.

- It is important that LBNF/DUNE the project and DUNE the Collaboration work well together at many levels. Without the infrastructure, there is no place to put the detectors, without the detectors there is no experiment, and without the 1500 international physicists there will be no physics. We are therefore pleased that effort is being made to clarify the organizations and their interfaces with the goal of improvement in both the organization and the decision making process.

- We continue to be concerned whether as well as talking the talk, all partners are walking the walk. Communication early and often between all partners must prevail.

- Achieving a shared vision of the strategy for project and experiment is imperative. Therefore strategic decisions must involve all stakeholders.

Executive Summary

- Over the course of the past year, we have seen DUNE show excellent progress on maturing the components of the Horizontal Drift Far Detector and make enormous strides towards establishing the Vertical Drift design. There is also a clear understanding of the eventual scope of a fully performant Near Detector. This all a pleasure to see.

- Our major concern, is predictably associated with the schedule which arises from the DOE Guidance on the possible funding profile. Managing this situation will be a challenge and the collaboration must provide guidance on the physics. We trust that the DOE understands the importance of improving the funding profile. Nevertheless, when establishing the ground rules for this initiative in the P5 process, DUNE was conceived as a “best in class” experiment. Nothing has changed that.

- We have completed a deep dive on the technical status of the Horizontal Drift module. We are finding that it is in good shape. Especially pleasing is the efficient way the downselect on the electronics was made, the completion of the APA design adjustments, and the progress in staging ProtoDUNE II.

Executive Summary

- A year ago the Vertical Drift concept was a glint in a few peoples eyes. We have observed an ambitious R&D program which is enjoying amazing success. We have reviewed the technical aspects in the Spring of the year and recently reviewed a complete Conceptual Design Report. DUNE has our comments, and we have discussed their path to what we anticipate will be a recommendation for approval of the CDR by the end of the year.

- Early in the year we reviewed and approved a Conceptual Design Report for a Near Detector which in our opinion would support the highest precision measurements of CP violation foreseen for DUNE. A key component of that suite is the SAND detector and a critical downselect of its tracker design was recently made. R&D on other elements is making progress and a Day-1 detector adequate for the first few years of operation has been clearly identified.

Executive Summary

- DUNE has established a very effective base computing capability which is ensuring accessibility to data and to analysis facilities appropriate to the current need. The challenge is now to attack some of the more difficult aspects of the needed software infrastructure and to create the team capable of doing this work, for example on the software frameworks.

- The production of the Computing CDR suffered some unavoidable setbacks and is delayed. We look forward to reviewing the CDR in early 2022.

- An established benchmark for performance of an experiment is publications. In addition to publication of its design work, DUNE has hit the mark with its publication of ProtoDUNE TPC physics data. The analysis software teams are challenged by the increased scope and demands from the multiple technology variants coming into use. An example is the vertical drift cold box and ProtoDUNE work.

Executive Summary

- Once again, DUNE has impressed us with the work it does, and the progress it is making. We look forward eagerly to the achievement of CD1RR by the LBNF/US-DUNE Project and progress to CD2 for the Far Site facilities. This would provide a solid platform from which to launch the detector sub-project CD2 considerations.

- We have continued to enjoy good interactions between the LBNC and, its sub-groups and DUNE and its sub-groups. Without this cooperation we could not have accomplished our share of the work, so it is very much appreciated.

- In conclusion, for this particular meeting, the presentations have been excellent, and responsive to need. A mild criticism, which is made by all the committees on which I have served, that we, the committee, would benefit from earlier posting of the talks.

- Finally we appreciate the support provided by the lab staff, which is responsive to our every request.