LBNC Meeting Report

July 31- August 2, 2019

Fermilab

Introduction

The LBNC met on July 31-August 2 at Fermilab. This meeting was one of the four meetings which the LBNC holds each year. The previous meeting was at Fermilab in April, 2019, and the one prior to that in December 2018 in CERN.

The attendees at the meeting, shown in Appendix I, included LBNC members and consultants, 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 interactions between LBNC are used to monitor the technical progress of the International DUNE collaboration and those aspects of the LBNF Project which have direct impact on the DUNE experiment. The latter is usually accomplished with a single presentation at the beginning of the meeting.

The charge for the meeting, prepared with concurrence from the Director is shown in Appendix II.

For each meeting the LBNC is organized into small groups which concentrate on particular components of the presentations and the discussions. During the past nine months, both the DUNE collaboration and the LBNC have given emphasis to the preparation and review of a suite of Technical Design Reports. The DUNE collaboration was encouraged to submit early drafts of the material and the LBNC has read those early drafts and in several cases convened dedicated reviews, both in person and in teleconferences. The Fermilab Director requested assistance in this process from a number of experts, not currently members of the LBNC who participated in the scrutiny and in one case led one of the subgroups. The makeup of the teams is shown in an Appendix III.

At each meeting the LBNC makes a Closeout Report open to all, and subsequently prepares this LBNC Meeting Report. The agenda and presentations used during the meeting and the Closeout Report can be found at https://web.fnal.gov/organization/LBNC/LBNC%20Meeting%20-%20July%2031-Aug%202/SitePages/Full%20Agenda.aspx

The LBNC appreciates the effort put into the preparation of the presentations and material, in particular the draft volumes of the Technical Design Report, by the DUNE Collaboration, and the frank responses to questions and queries. The committee is also grateful to Angela Fava who as Scientific Secretary to the LBNC was instrumental in the compilation of the reports as well as actively participating in the discussions. The administrative arrangements made by the Fermilab staff, Kayla Decker and Hema Ramamoorthi, were excellent.

Finally, the committee thanks Fermilab for their support and hospitality.

Executive Summary

The LBNF/DUNE project may be the largest within the US DOE Office of Science. It enjoys all the associated challenges and the added complication of underground construction. The overall project is proceeding towards a CD2 DOE Baseline approval in 2020. With that baseline established, DUNE should define and submit the proposed milestones against which the LBNC will monitor progress.

DUNE receives oversight from the DUNE Resource Review Board which receives reports from the LBNC and from The Neutrino Cost Group (NCG). A key component of the DUNE preparation for the NCG and RRB is the resource/responsibility matrix. The development of this matrix for two Far Detector Single Phase modules is progressing well. For the Dual Phase Module, a start has been made.

In the two most recent meetings, we have seen the importance of the ProtoDUNE SP experience and results. In this respect, the ProtoDUNE Dual Phase is making enormous progress and will be operational within weeks. Consideration of the Far Detector Dual Phase Volume is delayed partially due to an appropriate emphasis on the technical work with ProtoDUNE-DP.

In all presentations so far the need for a capable Near Detector to achieve the desired CP Violation precision has been asserted. Consequently, written material was prepared and a thorough one-day review conducted. The LBNC is convinced that the Near Detector as described and discussed within the Executive Summary Volume, would enable the DUNE goals for the CP Violation measurements. It looks forward to receipt of a Conceptual Design Report.

The DUNE planning and description of the work of the Computing Consortium laid out in the Executive Summary volume represents an enterprise which has made great progress during its inaugural year. In due time, the LBNC will expect to see a Conceptual Design report as a precursor to a Technical Design Report.

Based on the reading of the several preliminary drafts and the drafts submitted on July 26, supplemented by presentations including those made during this LBNC meeting:

- The LBNC anticipates recommending for approval the Executive Summary TDR Volume, The Physics Volume, the Far Detector Single Phase Volume and the Technical Coordination Volume.
- The LBNC Review teams will make one further round of comments before September 15, 2019, and will expect subsequent responses by the Dune Collaboration teams
- This would lead to recommendations by the review teams to the Full LBNC which would hold a teleconference before submitting its recommendation to the Fermilab Director.

The LBNC will expects to make a presentation to the Resource Review Board based on the above material in September 2019 and will continue to work with the NCG

LBNF Status

LBNF is making sustained progress. Ross shaft construction continues and is scheduled to complete in the first quarter 2020. Other reliability projects underway include replacement of the Oro Hondo fan VFD, rehab of the hoist motor, replacement of the hoist brakes and clutches, and an update to the refuge chamber. All 31 work packages for pre-excavation are awarded to KAJV. The contractor has 80 people on site and completion is expected in Nov. 2020 though the start has been slow in a few areas with, for example, the headframe behind by 6 weeks. To date KAJV has an excellent safety record, certainly an encouraging sign. A far site ES&H coordinator is being added to the organization to bolster the important safety initiatives.

Excavation, Building and Site Infrastructure tasks are underway with 100% final design now complete. The project has shown good progress in the area of systems engineering. The Far Site integrated model has matured (v4 now released and under configuration control) and will be a useful tool for coordinating and communicating interfaces and potential interferences. The presented efforts to understand the detailed logistics regarding delivery of equipment and people to north cavity cryostat and assembly and installation are credible and strongly encouraged. Such planning will give confidence that the infrastructure is sufficient to avoid possible bottlenecks during the site preparation and installation phase of the project.

It is concerning that a relook at the planning with KAJV has added 14 months to the schedule and 68M$ to the baseline cost. Due to their high quoted cost (more than 10% above the ICE), KAJV will NOT be the excavation contractor but will sub-contract the work. KAJV is preparing the RFP documents. The project views the higher estimate as being “just very conservative”. KAJV agrees with the project that excavation may be subcontracted for a lower cost, while continuing to be the contract manager following an already established process. The critical path for the far site runs through getting excavation work under contract and moving forward in a timely way. North cave completion reported delayed to Oct 2022 at the last meeting are now reporting further delays. Understanding the sources of delays and risk of further delay is important and the reported effort to include value engineering to gain back time is an excellent initiative.

Regarding installed cryogenics infrastructure the Detector #1 interface control documents and engineering design specifications are nearing completion. The nitrogen system procurement is on hold pending DOE approval and the GTT membrane cryostat design is complete.

Regarding the progress on the Near site, procurement of A/E design services is awaiting DOE approval. The site preparation construction contract is out for bids. The requirements document for excavation is not yet complete with the Near Site CD-2 scheduled for Oct 2020. Meanwhile DOE is looking for the costing of the whole project for the IPR review towards the end of 2019. The goal is to have work under contract with the CM/GC in August 2020 (a 8 month slip relative to the original DEC2019 date.)

The Far Site Conventional Facilities are now under configuration control. Baselining of the far site is anticipated to be pushed out by 3 months from Dec 2019. All high-level interface requirements and specifications between beamline and NSCF are now completed. The goal is to complete >90% interfaces by 2019 calendar year end.

The LBNF Beamline Project continues to make progress with design advancements and risks retired in a number of key areas. External partners are engaged including BARC (dipole and

quadrupole magnets), KEK (fabrication of prototypes for the horn strip-line feedthrough), RAL (prototype and production targets plus associated systems and IHEP (corrector magnets). Recent advances include progress on Horn A and target design with RAL and further definition of the Hall morgue design. While these are noteworthy advancements, it was not easy to tell where the project is on the completion of defining key engineering design questions. For example, there was little presented on remote handling – RH 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.

The biggest vulnerability in the beamline project is the undefined scope. 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. The new hires into lead positions are encouraging to enable progress to continue.

The transitioning of EFIG to a high level steering group is a positive step as the project moves towards the construction phase.

It is encouraging to see that LBNF labor hour actuals are reasonably close to project need for June – a backward looking plot of resource actuals vs project need and forward looking for project need (+-6 months) would be more informative.

Recommendations:

- For the next LBNC meeting report resource actuals against the resource loaded schedule over previous 6 months and project resource needs over next 6 months

DUNE Overall Status

The delivery of draft chapters and volumes of the Technical Design Report to the LBNC for review has been impressive for most of the content, with little slippage in schedules. The DUNE TDR preparation team and the Collaboration as a whole are congratulated on this excellent progress. All of the Physics, Single Phase Far Detector, Near Detector and Computing parts are in good shape and converging.

The LBNC was also pleased to see the continuing gradual growth of the Collaboration, anticipating that, in due course, this will be reflected in increased resource availability, as needed to successfully deliver the best detector and physics. The LBNC requests that future institutional membership changes are presented by explicitly listing institutions (and countries) which have joined (or left) the Collaboration since the previous LBNC, rather than showing only aggregate numerical counts.

The committee welcomed the progress reported in advancing funding applications and/or approvals. Progress was noted with some agencies, including US/NSF where an application was

being submitted at the time of the meeting, and Italy/INFN where significant progress was reported.

As mentioned elsewhere in this document, important progress has been made in closing and filling the ProtoDUNE Dual Phase cryostat at CERN. The LBNC looks forward to seeing the successful operation and performance of, and eventual results from, this second ProtoDUNE detector. The committee welcomes the CERN SPSC's support for the later running of ProtoDUNE-II. The committee notes that APA series production will start before that run will be completed, and that this could incur some risk during ramp-up of production.

The committee noted the substantial progress on the Near Detector design, which includes a LAr detector, a multipurpose detector (including a GAr-TPC), and a beam monitor, with the ability to move the first two off-axis. The physics requirements for these subsystems has been demonstrated, and further performance/cost optimization is planned leading to a future Conceptual Design Review. This is further discussed later on.

The LBNC furthermore commends the Collaboration for its institution of a Code of Conduct Committee.

Recommendations:

- None

DUNE Project Schedule

The work underway to establish a new schedule for the combined LBNF/DUNE installation was presented to the committee by the Project Integration Director (PID). The LBNC endorses the pragmatism of this planning process, in particular regarding the following:

- Rather than putting full consortia schedules into the master schedules, component (i.e. consortia) planning is being incorporated into the eventual P6 master schedule through detailed shipping and delivery milestones.
- The schedule will not be formally revised until studies are complete of mitigation measures to bring earlier the first time when control of an underground area is given to Fermilab ("T_0" in the following). This will result in the baseline schedule being agreed next year.

The committee notes that maintaining the previous schedule does, to some extent, keep pressure on component delivery dates. The DUNE Collaboration is urged to ensure that this does not increase risks in component projects (e.g. if more time is needed for electronics submissions). Furthermore the LBNC notes that a detailed installation plan developed with an unspecified T_0 carries risks, if the T_0 delay is mitigated by accepting major services installation post-T_0: for example co-activity with detector installation increasing the requirement for underground staff, or double-booking SDSD resources.

The LBNC expects to receive updated milestones following the LBNF/DUNE project baselining in 2020.

Recommendations

- None

DUNE Resource Management

The LBNC thanks the collaboration for the enlightening presentation by the DUNE Resource Coordinator, explaining the process to establish the resource/responsibility matrix for two Single Phase Far Detectors, and its current status. The LBNC judges that this process is well-organized, rigorous and effective. The current resource/responsibility matrix for two Single-Phase Far Detectors is in a reasonably good shape, with clearly identified opportunities for new money and new collaborators where resources are not yet identified and/or secured. Completion of this matrix looks credible, although not assured at this time – further commitments are yet needed.

The LBNC further notes that this process is in a less advanced state for the Dual-Phase Far Detector, and is not yet started for the Near Detector – both of these will follow in due course, as the process is now well-established. The DUNE management continues to work to try to identify additional collaborators and resources to help cover these. The LBNC looks forward to hearing of future updates on the status of the DUNE resource/responsibility matrices.

Recommendations

- None

Technical Coordination Status and TDR

The review of draft chapters of the Technical Coordination (TCN) TDR had been proceeding before the meeting, with substantial progress being made. Productive detailed discussions were also held between the TCN team and a subset of reviewers on the day preceding the full LBNC meeting. The LBNC commends DUNE on the latest draft, and the excellent written responses to comments on the previous draft, both of which had been received in the days preceding the meeting: the latest version addresses many of the recommendations made on previous drafts. The committee expects to send remaining feedback in the following weeks, noting that some parts of the TDR are still being updated in parallel (e.g. an expanded executive summary chapter, Role & Responsibility definitions, the SDSD role, and risk table clarifications).

Topics that would benefit from further clarification in the TDR include:

- Description of the internal structures of (existing and functional) Technical Coordination organization within DUNE.

- Resources for TC, PID and JPO, their management and reporting on their use, given that integration and installation (I&I) is a major activity spanning LBNF and DUNE.
- The consistency of figures, organization charts etc. within the TCN TDR volume, and between this volume and the *Introduction to DUNE* volume.
- That the JPO's role in supporting EFIG to ensure experiment-facility coherence is already functioning (e.g. the reviews team is organizing a review for LBNF; the integrated installation schedule is being developed).
- How the division of responsibility, and the continuity of purpose and expertise between construction (coordinated by TCN), I&I (coordinated by PID), and the transition into commissioning and operation (coordinated by DUNE), will be managed smoothly.
- The safety organization from the highest level of oversight down to safety patrols in the field.
- Explicit mechanisms about how changes in the consortia deliverables that could affect integration at SURF are propagated through DUNE to EFIG.
- Expanded risk discussion to include I&I risks – e.g. the availability of up to 144 people to work underground; facility equipment failure.
- Inclusion of a list of external organizations (e.g. city of Lead, SD) involved in oversight of installation activity, and their respective roles, to avoid schedule impact from unanticipated requirements. The LBNC recognizes that the far site ES&H coordinators will help address and manage the issues arising from multiple authorities at SURF.

Recommendations:

- None

Executive Summary Technical Design Report Volume

This volume, titled "*Introduction to DUNE*", contains an overall Executive Summary, chapters summarizing the individual volumes, and two chapters summarizing respectively the status of the Near Detector design, and the Computing and Software Consortium area. The LBNC notes the importance of this volume, in that it is likely to have a wider external readership than the other more detailed volumes, so that the narrative should be relatively non-specialist, accessible to funding agency representatives and so on.

The LBNC had received a first full view of the volume only a couple of days before the meeting, although chapters on the Near Detector and Computing, which do not appear elsewhere in the TDR, have been reviewed previously, and are in good shape. The chapter on the Single Phase Far Detector has likewise been reviewed and is close to final. Other chapters are either anticipating updates from the collaboration (Physics, Technical Coordination), or review by LBNC members is just starting (Executive Summary, Dual Phase Far Detector).

Recommendations:

- None

Near Detector Design

DUNE has convincingly demonstrated the need for a highly capable near detector (ND) in order for DUNE to achieve its physics goals. DUNE proposes three detector elements and one capability: a liquid argon TPC (ArgoCube), a magnetic spectrometer with ECAL (MPD), an on-axis beam monitor (3DST-S), and the capability of moving the liquid argon TPC and spectrometer off-axis by up to ~30m (the DUNE-PRISM concept).

LBNC considers the minimal elements for a ND to include a liquid argon TPC and magnetic spectrometer, which together can move off-axis, and some sort of fixed on-axis beam monitor. Each of these elements in our estimation is needed from the start of data-taking, including the ability to move the LAr TPC and spectrometer off-axis, as it will be very difficult to use data taken without them in oscillation analyses.

The ArgonCube detector shares many commonalities with the far detector, and we see no technical showstoppers. We welcome the testing of a scaled-down prototype next summer.

A magnetic spectrometer is necessary to determine the charge and momenta of charged particles that are not contained within ArgonCube. DUNE proposes a high-pressure gaseous argon TPC inside a low-mass superconducting coil magnet for this purpose, with a surrounding ECAL. The review committee found this concept, called the MPD, to be compelling. While a simpler magnetic spectrometer might suffice, the extra physics capacity offered by the gaseous argon target makes this the preferred option. DUNE should consider the extent to which the MPD's ECAL might be optimized to reduce cost and complexity.

DUNE's proposed on-axis beam monitor is a 3D projection plastic scintillator tracker surrounded by gas TPCs, placed inside the KLOE magnet and ECAL. This design seems capable of meeting DUNE's requirements, although it is possible that simpler designs may also suffice.

Simulation studies based upon parametrized detector responses have been presented and incorporated in the oscillation analysis framework. Further work will increase the sophistication of these studies and incorporate ND samples, especially off-axis data, more completely into the oscillation framework.

The LBNC believes that the proposed suite of ND elements will allow DUNE to achieve its physics goals for CP violation sensitivity. We look forward to receiving a CDR by the end of CY2019.

Recommendations:

- DUNE should continue to develop more complete physics simulation studies for the ND using more realistic event reconstruction, and more fully incorporating ND samples into the physics analysis.

Computing Summary

The LBNC commends the DUNE Computing Consortium on delivering the Vol.1 penultimate computing draft which included coordination with the DAQ group on physics motivated data volume estimates. The establishment of the Computing Consortium (CSC) and the appointment of the two experienced technical leads to work with the Consortium Leader has had a positive impact over the past 9 months. This structure has led to the ability to establish cross-consortium working groups and workshops, an example of which is the upcoming Event Data Model Workshop. The CSC also making progress in outlining requirements such as drawing essential distinctions between the computing and software needs of different parts of the DUNE physics program. As part of this process the LBNC suggests that consideration should be given to relationship between computing and software tasks in DUNE, and consider expanding the consortium to be responsible for some software tasks. Another positive step the formal establishment of a resource board to track international computing contributions. Establishing a baseline of responsibilities for DUNE specific computing using LHC-B as a model is productive and appropriate. The DUNE CSC is looking for areas where 'community' codes can be leveraged—they are also establishing the areas in which DUNE can collaborate on 'community' computing projects. With the establishment of the CSC, broad contributions from DUNE collaborators, relationships to other consortia (DAQ, calibration and near detector) and workshops planned, the DUNE CSC should give some consideration to what work needs to be undertaken in order to draft the Computing CDR.

The CSC is also contributing through on-going activities, such as completing a data challenge for ProtoDune-DP and using NERSC resources to expeditiously improve the DUNE sensitivity curves for the Physics TDR.

Of some concern to the LNBC is planning for the network connectivity from SURF to the ESnet backbone. It was reported that SDSD is working with FNAL CD on a plan to address the WAN from SURF to FNAL.

Recommendations:

- None

DP: Progress on ProtoDUNE and TDR

The LBNC congratulates DUNE on very significant progress on ProtoDUNE-DP since the last LBNC meeting in April. Four CRPs are installed, two of which have fully active LEMs (72 LEMs

total), and 36 PMTs are installed, 6 with TMP wave length shifting (WLS) coating and 30 with PEN WLS sheets.

Filling is expected to be complete soon (only a little behind the plan at the April meeting - due to the present pause to regenerate filters). DUNE has made significant progress in installing/testing and starting to commission CISC monitoring, HV, photon detection and the LEMs. The DAQ is being commissioned in parallel with filling and event reconstruction will capitalize on the earlier work for SP.

The committee looks forward to first results from ProtoDUNE-DP in the next two to three months and considers it the highest priority for DP to demonstrate stable ProtoDUNE operation and to start to map out the performance parameter space.

The DUNE collaboration has gained extensive experience from the operation and data analysis of ProtoDUNE-SP. This expertise should be brought to bear for ProtoDUNE-DP to the maximum extent possible to ensure rapid progress.

To date the committee has received six draft chapters for the DP TDR volume, two of these only recently, and has commented on four of them.

Several changes to the design beyond ProtoDUNE are alluded to in the text. Plans for the development and validation for these changes should be fully described in the TDR, including the role of ProtoDUNE-II.

It is important that operating experience and performance results from ProtoDUNE-DP be described in the TDR, and that they be folded into the complete project planning for the Dual Phase module in DUNE.

Given limited resources, the rapid progress of the ProtoDUNE program should therefore take precedence in the near term. This may impact the timeline to complete the TDR.

Recommendations:

DUNE should maximize the benefit of ProtoDUNE-SP experience in ProtoDUNE-DP operation and data analysis to ensure rapid results.

ProtoDUNE SP Progress

The LBNC received an update on ProtoDUNE-SP analysis. Recent analysis progress was presented on cosmic ray muon tagger reconstruction, and first application of MicroBooNE particle ID algorithms. The Particle ID studies are in progress and promise good performance.

The LBNC was informed of a recent issue in cryogenic operations of ProtoDUNE-SP resulting in a loss of argon purity.

Comments

- It is important that lessons learned from the pump seal failure inform monitoring, instrumentation and inhibit systems for DUNE-SP. The LBNC encourages the collaboration to continue developing a full fault analysis to estimate situations such as the pump membrane failure rate in the FD-SP system based on the observations in ProtoDUNE-SP.
- The committee encourages the Collaboration to continue to update the ProtoDUNE-SP lessons learned document.
- At the next meeting the LBNC would like to hear an update on what has been learned from the ProtoDUNE-SP running thus far in 2019, with emphasis on studies to establish the operational safety margin and long-term stability of the system.
- The LBNC would like to see the comparison in the measured number of photons/MeV from the ARAPUCA photo-sensor system vs. the other two Photon Detector designs in the array of deployed PDS units in ProtoDUNE-SP.
- At the April 2019 meeting, the LBNC encouraged the collaboration to pursue the following studies:
  - *Noise mitigation, S/N, ADC calibration, etc.*
  - *Suggest to study resolution impact by masking off few ADC bits.*
  - *dE/dx of beam protons and electrons data vs. MC (after all corrections).*
  - *Would be more useful to see lower level data/MC comparison before the corrections.*
  - *Fine tune and explore current technological limits, with three main objectives:*
    - *Investigate limiting factors toward higher LAr purity level*
    - *Collect data to study fluid and space charge dynamics*
    - *LAr Purity + Cryogenics (Fluid Dynamics)*
  - *Investigate how different cryogenic conditions affects the electron lifetime*.

  The LBNC reiterates the value of these studies for establishing the technical baseline for the FD-SP TDR, and would like to see these presented in future meetings.

Recommendations

- While recovering from contamination, take cosmic ray data with 3ms electron lifetime to validate existing DUNE specification, explore operational parameter space.

DUNE FD SP Status & TDR

This section reports on three specific items:

1. Cold Electronics Breakout Session
2. TPC Breakout Session
3. Status of the FD SP TDR.

Cold Electronics

Findings

- The Collaboration continues to carry 3 potential cold electronics solutions forward.
- Prototype LArASIC, ColdADC and Cryo chips have been received and are under test.
- The LArASIC "ledge effect" reproduced in simulation.
- Several issues identified in ColdADC and Cryo, many lessons learned.
- Heat load from the ASICs will be studied in test setup at BNL to test for bubble formation under pressure.

Comments

- Considerable progress has been made on the 3 ASIC and SLAC Cryo implementations. Preliminary tests have indicated a number of issues with the current ASIC iterations, but the issues do not prevent a number of important measurements from being made.
- Some of the design issues have been understood and fixes already determined. Others still require further study and testing.
- ASIC Power density specification should be developed, from the heat load study.
- Plans exist for continued testing and further review prior to the next submission. The lessons learned, including the need for stringent internal design reviews, will be important to be implemented in preparation of the next iterations.
- The long term strategy calls for 60 fully populated FEMB on 3 APAs in ProtoDUNE-II.
- ProtoDUNE-II planning should give careful consideration to the cold electronics schedule.
- It is appropriate to integrate the third submission cycle into current project plan as a high risk in the risk register.
- Demonstration of long term system level reliability is important.
- Collaboration should ensure that the cold electronics timeline is consistent with LBNF/DUNE.

Recommendations

- None

TPC

Findings

- The Collaboration has clearly set out the evolution in the design for DUNE with respect to the ProtoDUNE-SP instrumentation.
- APA production in the UK will launch before the ProtoDUNE-II run, resulting in ~10% of the UK APAs being built when ProtoDUNE-II turns on.
- The field cage re-design to address the likely streamer source is in an advanced state.
- Two SiPM types will be carried forward in the PDS to ProtoDUNE-II.
- The collaboration plans to validate changes in the instrumentation relative to ProtoDUNE-SP in ProtoDUNE-II running.

Comments

- The plan for the testing of design evolution post-ProtoDUNE-I is credible and builds confidence that the DUNE FD-SP APAs will be fully validated through the 'Module-0' prototypes in ProtoDUNE-II.
- The LBNC fully endorses the plan discussed to initiate the ProtoDUNE-II run when the 'Module-0' prototype electronics are available.
- Given the planned ex-situ testing, the risk of launching APA production in the UK prior to ProtoDUNE-II running seems acceptable.

Recommendations

- None

Single Phase Far Detector TDR Status

Findings

- Initial chapters were delivered early in calendar year 2019.
- LBNC+consultants provided multiple rounds of feedback.
- All "v3" chapters were delivered earlier this summer. Feedback has been provided on those chapters.
- The latest draft was delivered on July 26.

Comments

- We appreciate the considerable effort the Collaboration has put into the TDR, as well as the coordination efforts of the editors and collaboration leadership.
- The majority of chapters were in good shape prior to the July 26 version. We anticipate that further improvements in the most recent submission should finalize the overall FD SP volume.
- Although ProtoDUNE-SP results are included in each of the detector chapters, the collaboration might consider a segment dedicated to summarize ProtoDUNE construction, operation and results. This would provide outsiders a clear understanding of the strong proof of concept that ProtoDUNE-SP has served.

Recommendations

- None

Physics Status (including ND impact) & TDR

A high-quality physics TDR has been delivered on schedule and been reviewed by the review team in several interactions. Several meetings were held between the review team and the relevant DUNE collaborators to discuss the content, in particular the more difficult aspects. At this stage, the review team is satisfied with the content of the TDR. Highlights are:

- The performance of the detector and reconstruction algorithms has been shown to be adequate for the physics program and for several aspects has been demonstrated with the data taken by ProtoDUNE.
- The neutrino oscillation analyses is now based on realistic simulations and reconstruction algorithms, and a similar sensitivity to that predicted at the time of the CDR is achieved. It has also been clarified how critical a powerful Near Detector is to constrain the flux and the neutrino interaction model as function of the neutrino energy.
- Proton decay and supernovas can be detected in ways that are complementary to approaches at other experiments. Proton decay benefits from the excellent particle ID capabilities while supernova neutrino physics benefit from the low energy thresholds and a good pointing resolution. In addition, a variety of BSM signals related to important puzzles in our understanding of particle physics can be searched for, e.g. related to sterile neutrinos, baryon number violation or Dark Matter.

The committee has received the pen-ultimate draft of the TDR just a few days before this meeting and is now in the process of reviewing it a last time. Given the reviews of earlier versions, no major changes are anticipated, with the exception of the introductory chapter which may benefit from strengthening the physics case summary and outsourcing some of requirements to make it more accessible to a broad audience.

Recommendations

- None

Appendix I: Attendees

Committee: Sampa Bhadra, Amber Boehnlein, Dave Charlton, Cristiano Galbiati(remote), Beate Heinemann, Patrick Huber, Robert Laxdal(remote), Ted Liu, Naba Mondal, Jocelyn Monroe, Hugh Montgomery, Steve Nahn(ex-officio NCG), Scott Oser, John Parsons, Tom Peterson, Kevin Pitts, Jimmy Proudfoot, Jeff Spalding.

Consultants: Austin Ball

Scientific Secretary: Angela Fava

Fermilab PAC Chair: Hiro Tanaka

DUNE/LBNF: Janet Bishop, Edward Blucher, Tim Bolton, David Christian, Kevin Fahey, Jack Fowler, Steve Kettel, Michael Kirby, Jose Maneira, Alison Markovitz, Ryan Patterson, Gina Rameika, Ettore Segreto, Theresa Shaw, Stefan Soldner-Rembold, Alessandro Thea, Christos Touramanis, Marco Verzocchi, Bo Yu, Sam Zeller

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 towards provision of material suitable to support the approval of TDRs for initial components fabrication of the DUNE experiment and to support ongoing development of components for the longer term DUNE program. The LBNC will prepare a Closeout Report followed by a Full Report. The latter will be a component of discussions between the Director and the RRB.

Appendix III: TDR Review Teams

Consultants shown in Italics

Executive Summary Volume

David Charlton (Chair)
Amber Boehnlein
Joel Fuerst
Bob Laxdal

Physics

Beate Heinemann (Chair)
Sampa Bhadra
Patrick Huber
Joachim Kopp (CERN)
Naba Mondal
Scott Oser
Vadim Rusu (FNAL)

Far Detector – Single Phase

Kevin Pitts
Philippe Farthouat (CERN)
Hugh Lippincott (FNAL)
Ted Liu
Jocelyn Monroe
John Parsons
Anna Pla-Dalmau (FNAL)
Jimmy Proudfoot

Far Detector – Dual Phase

Jeff Spalding (Chair)
Ties Behnke
Philippe Farthouat (CERN)
Cristiano Galbiati
Adam Para (FNAL)
Jimmy Proudfoot
Darien Wood (Northeastern)

Technical Coordination

Austin Ball (CERN, Chair)
David Charlton
John Osborne (CERN)
Tom Peterson
Jeff Spalding

Near Detector

Scott Oser (Chair)
Ties Behnke
Patrick Huber
Eric Kajfasz (CPPMarseille)
Dean Karlen (U. Victoria)
Naba Mondal
Beate Heinemann (ex-officio)