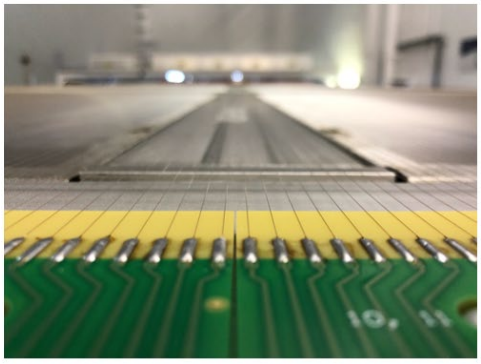
# LBNC Meeting Report



March 3-5, 2021

FNAL (Remote)

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## Introduction

The LBNC met March 3-5, 2021 remotely in FNAL. This is the first meeting of three planned for 2021.

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, Fermilab Director, Nigel Lockyer, newly appointed Fermilab CRO Kevin Pitts, and outgoing Fermilab CRO, Luciano Ristori.

The activities of the 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: at this meeting a breakout presentation was made to continue to discuss the progress with the beamline. The Fermilab Director requests assistance in this process from a number of experts, who supplement the expertise of the LBNC members in the scrutiny.

This meeting reflected the strong pivot to the use of the vertical drift technology variant for the second Far Detector and the intent to include that in the US-DOE DUNE Project. The Near Detector has completed its Conceptual Design Report and has undergone a review of the DUNE plan for a Day-1 Near Detector. The Computing consortium is preparing a Conceptual Design Report, which it expects to submit for review during the summer of 2021.

The charge for this meeting, prepared with guidance and approval from the Director is shown in Appendix II. For this meeting there was considerable emphasis on understanding the organization and management of the international DUNE collaboration and project. The breakout on Technical Coordination paid particular attention to this aspect of DUNE.

For each meeting the LBNC is organized into small groups which concentrate on particular components of the presentations and the discussions. The makeup of the teams for this meeting is shown in an Appendix III. The committee as a whole discusses and concurs with both the Closeout Report and the Meeting Report.

At each meeting the LBNC makes the Closeout Report open to all, and subsequently prepares this LBNC Meeting Report. The agenda and presentations used for the meeting, the Closeout Report, and this report can be accessed at**:** https://lbnc.fnal.gov/

The LBNC has enjoyed hearing about the substantial progress made during the past several months. Impressively, the impact of the Covid-19 pandemic has been mitigated and delays incurred are important but constrained. The presentations from LBNF and DUNE were appropriately informative and fully addressed the charge. Progress across the full spectrum of activities LBNF, DUNE, Single Phase, Dual Phase, Near Detector, and Computing, was briefly and succinctly described in the Plenary sessions. The available time for remote meetings across many time zones is limited. This puts emphasis on the multiple substantial breakout sessions which allowed coverage of Beamline and Technical Coordination, Horizontal Drift, Vertical Drift, Near Detector, and Computing and Analysis.

The committee thanks the DUNE and LBNF participants, Fermilab, its Directorate and support staff, for their assistance and support.

**Executive Summary**

The LBNF component of the project is the furthest advanced and continues to forge a strong path forward. Progress is meeting the schedule and, amazingly, the delays attributable to the impact of Covid-19 are minimal. Mining tends to be a risky endeavor and the project responded promptly to recent safety events.

The LBNC continues to be impressed by the progress of the Beamline subproject and its extension of planning into the installation phase. Its approach to several opportunities to benefit from value engineering has been proactive. In many ways this sub-project is the active interface with the PIP II project which will deliver the accelerator, and it appears to function well.

For the first time since the TDR reviews, LBNC scrutinized in some detail the workings of the Technical Coordination function. The committee was pleased to note the recent expansion to upper management with the introduction of three deputy Technical Coordinator positions, two of which have already been filled. The LBNC feels that matching the TC organization to the evolving needs is mandatory. DUNE has responded appropriately to recent commentaries from the LBNC, which feels that TC is now well structured to handle the increasing workload as the DUNE activities expand.

The single phase horizontal drift, is the most mature of the two Far Detector variants. The pre-series production of APAs, which will undergo final testing in ProtoDUNE phase II, is under way at Daresbury Laboratory in the UK. The consortium is preparing for the important TPC electronics downselect, which is scheduled for the summer. DUNE should be congratulated on all this progress, which is essential to meet the schedule for ProtoDUNE phase II.

Since the December 2020 LBNC Meeting, the DUNE collaboration has formally adopted single phase Vertical Drift for the second Far Detector. The collaboration has responded enthusiastically, broadly, and aggressively to this opportunity. For this, it should be congratulated. R&D addressing key aspects of the design is planned for the next twelve months. DUNE will need to ensure that the strategy, involved in articulating the design and physics capabilities in a CDR, is matched to the major aspects of the design. For example the photon detector design should be aligned to the physics goals and vice versa. DUNE is therefore encouraged to keep the multiple aspects of this rapid development aligned and in step.

The LBNC recommends approval of the complete Near Detector CDR; this design is appropriate and indeed necessary for the full DUNE physics program. The LBNC has also reviewed very positively the design of a resource limited Day-1 Detector intended to be capable of supporting the CP violation physics of the first years of DUNE. This represents a clear definition of the scope necessary at the time of baselining and, as the name implies, on Day 1 of operations. The LBNC is very pleased with this outcome and congratulates DUNE on its work. Since the full Near Detector, including ND-GAr, will be needed to support its ultimate physics goals, DUNE should continue to support its development at an appropriate level.

The DUNE computing consortium is making good progress on a number of aspects of the computing model and their implementation while supporting the ongoing analysis efforts.

Projections of computing resource needs are being developed, and the DUNE RRB has invited a presentation from DUNE at its next meeting. The LBNC expects to receive and start to review the DUNE Computing CDR within the next few months. In this case the LBNC and DUNE would be able to discuss progress towards approval at the September 2021 LBNC Meeting.

DUNE presented an extremely detailed discussion of some interesting aspects of the ProtoDUNE analyses. The results were very impressive. The extent of the activities is sufficient that the LBNC would like to see a description of how the many efforts are organized and integrated.

Once again the LBNC has been impressed by the progress made on the multiple fronts which represent DUNE activities. The sub-projects, horizontal drift Far Detector, Near Detector, vertical drift Far Detector, and Computing, are all in different states of development but have all made substantial progress. The management structure, in particular that of Technical Coordination, to support these activities has also been strengthened. The LBNC is looking forward to interactions between several DUNE subgroups and the corresponding LBNC teams over the course of the next several months before the next LBNC meeting.

In closing, the LBNC would like to thank outgoing DUNE Spokesperson, Ed Blucher for his sterling efforts during a successful term in office. We hope that this does not signal the end of our interactions. The LBNC has expressed its admiration in the past for the work of Regina Rameika in several important roles for DUNE, most recently as Resource Coordinator. We congratulate Gina on her new appointment as Co-Spokesperson.

**LBNF Status**

The project has provided information and responses consistent with the LBNC charge: *The LBNC should hear about the general status of LBNF. Of continuing interest is the planning for a tailored approach to baselining following the recent DOE-IPR and the schedule for future DOE-IPRs.*

The committee was impressed with the status of LBNF. The sub-project tailoring strategy will expedite progress on more mature elements of the project. Far Site conventional facilities, for example, are ready for CD-2 baseline review now.

A second reaffirmation of CD-1R is necessary following restoration of the second detector. The project plans to present in May/June of this year a revised CD-1RR upper and lower cost range together with a description of the project-tailoring strategy, leading to a combined DOE CD-1RR and baseline far site construction (CD-2 for that subproject) in October 2021.

Progress continues at the Far Site. Reliability and pre-excavation activities are complete and initial preparation activities for the excavation work are complete. Review of the cryostat design by the FNAL cryo safety review panel has started. RFPs for the Nitrogen System are in the final stage of review and a draft SOW has been released to industry, with plans to release the solicitation for Phase I work next month.

Development of the LAr systems continues. The receiving facilities have been updated and optimized and an RFI for the LAr procurement is being prepared in order to freshen the cost estimate and get input on the procurement strategy.

Near site conventional facilities design work should reach 60% completion by the end of this month, with stakeholder review scheduled through early-mid April ahead of the delivery of the Final Design in September. Beamline systems design continues to make progress according to plan, with a horn prototype FDR held on 25 January. LAr and LHe cryogenics designs, for ArgonCube and SAND respectively, are underway and updates to the cost and schedule are being developed ahead of the CD-1RR review.

The project critical path is through the Near Site. The project has worked to optimize the schedule with PIP-II, resulting in some push out. This has not impacted the overall timeline but there are impacts to escalation and schedule float.

Recent safety incidents include one reportable incident (finger laceration while using a porta-band) and two closely spaced near misses. All were experienced by the same contractor and the near misses were both related to material handling and occurred roughly two weeks apart. The project provided summary reports of the TapRooT investigations and has implemented corrective measures.

- **No Recommendations.**

**Beamline**

The beamlines team continues to be on a credible path towards CD-2 baselining with impressive design progress in all major areas. Kudos for maintaining a firm grasp on a mature schedule until project completion, resource requirements are understood and well managed within a matrixed labor model with AD and other divisions. Cost estimates are up to date and stable since the last review.

The critical path to completion continues to include horns power supply design, prototyping, fabrication, installation and full system in-situ testing. Previous risks due to unavailability of pulsed high-power power supply experts have been mostly mitigated through strategic partnership with SLAC. The committee supports the request for early procurement of components for primary beam kickers and horns to reduce technical and schedule risks.

Coordination of the numerous interfaces and activities of internal and international stakeholders is complex but appears to be managed well. Proactive schedule and milestone progress tracking with international contributors will help identify potential delays at an early stage.

The beamline project works closely with PIP-II to optimize the accelerator tie-in schedule within the constraints of recent changes to the PIP-II shutdown planning. Investigations of opportunities for early tie-in should be carried on.

The team is commended for taking on continuous improvement efforts, such as developing the installation schedule and optimizing costs of the target shielding assembly in collaboration with vendors.

**Recommendation:**

- Support requests for early procurements of components for primary beam kickers and horns where possible in order to maintain the current schedule and to remove risk from the complicated procurement and installation schedule.

**DUNE Status**

We are pleased to see continuing progress towards securing international contributions. The expectation that CERN will provide the second cryostat is most welcome.

We commend DUNE for completing the Near Detector CDR, and for making significant progress towards finalizing the design of the "Day 1 ND", as a viable detector option that will achieve the physics goals of the initial running period. We advise that DUNE continue to develop a full working plan and timeline for the ND-GAr detector baselining, in the context of the new sub-project strategy.

We note that delays due to Covid have been modest so far, but that ProtoDUNE-II may be delayed by several months. It is important that the new schedule is established as soon as possible. We also note the tight schedule related with the cold electronics readiness for ProtoDUNE-II.

We welcome the new sub-project strategy because the different sub-projects naturally follow different timescales during design and construction. DUNE needs to manage the availability of the resources for the sub-projects that will be baselined later. We urge DUNE to develop and provide a baselining schedule and timeline for all sub-projects. We commend DUNE for the important steps taken towards strengthening technical coordination with the actual and planned appointments of three key deputy TCs for the ND, FD-1 and FD-2 detectors.

In addition, we commend DUNE for making rapid progress in several areas concerning the Vertical Drift detector. At the same time, we urge DUNE to i) advance the physics studies needed to assess the VD physics performance and to inform the final design choices, and ii) provide a clear plan and timeline, and to identify the needed resources. This should be both for the ongoing R&D in 2021 and for what is needed to prove the VD technology at scale (Module 0) and accompanied with expert technical reviews when necessary. In addition, we encourage DUNE to complete the coordination/management structure that will oversee the realization and proper execution of this plan. Finally, and related to the above, we note that DUNE should retain the horizontal drift detector technology as a fallback solution for FD-2.

# Technical Coordination

The LBNC thanks the collaboration for the very informative presentations both in the plenary session and the Technical Coordination (TC) breakout session at this meeting, focussing on the organisation and practical operation of TC. The committee is pleased to see that Deputy Technical Coordinators are in place with responsibility for the Near Detector (ND), and for the Vertical Drift Far Detector (VDFD), with a search underway to find a Deputy TC for the Horizontal Drift Far Detector (HDFD). No other staff shortages were reported in TC at this time.

TC coordinates the work of the consortia, and their mutual and external interactions, once the subproject (ND, HDFD or VDFD) has passed the CDR stage in DUNE. Prior to that, in the initial R&D phase before the CDR, TC follows the progress of work and provides support for activity as needed, but the R&D work is organized by the relevant detector technology team. The VD FD project is currently in this initial R&D phase. The assignment of a Deputy Technical Coordinator dedicated to the VD FD project will help ensure clear communication is maintained between VD FD R&D and TC, close coordination being essential for success.

The global installation plan is the responsibility of the Integration Office (IO) installation team. Weekly meetings take place between IO and consortia installation responsibles, with occasional workshops. This determines the installation plans and agrees the resources that will be available. This works well, has been exercised in ProtoDUNE-I Single Phase, will be used again for ProtoDUNE-II Horizontal Drift, and the main focus is now on the first DUNE far detector (HDFD) installation.

One aspect of TC responsibility discussed in some detail, with examples, was how design changes are handled. This is by a well-developed process, according to the significance of the changes:

- Small design changes, for example resulting from Proto-DUNE experience, are discussed between TC, the Integration Office (IO), and the consortia technical leads on a weekly basis. Decisions are recorded in minutes. An informal sign-off chain is defined, including consortia leads, TC and IO engineers. A summary of the decision chain and actions is recorded in EDMS. This was reported to be working well.
- More significant design changes are discussed in the Technical Board (TB). Typically the change originates in a consortium which will analyse data relating to a change and present the analysis to the TB with written documentation. The TB discusses risks, cost impacts, and interfaces with other consortia and with LBNF where relevant. If consensus is reached in the TB and there is no impact on external interfaces, the TB recommends the decision to the Executive Board (EB).
- Wider-ranging decisions, or ones where a consensus is not reached, require additional review, which would be organized by the SPs and TC, potentially involving non-conflicted referees who look in detail at the arguments. There is a procedure described in the DUNE constitution how deadlocks will be resolved, but this has not yet been exercised.
- Decisions affecting LBNF also go to EFIG, as the LBNF/DUNE-US Project Manager will need to approve any change to the project baseline.

The LBNC sees that these processes are largely now exercised, and working well. The responsibility for deciding which path is followed was not clear, but the committee believes this should lie with the Technical Coordinator, in consultation with the Spokespersons where needed.

Another substantial item for discussion was the handling of project schedules, ensuring consistency between different actors. The schedules and milestones for the work for ProtoDUNE-II Horizontal Drift, for Far Detector #1 and for parts of the Near Detector, are now largely entered into P6, which will be used as the primary TC schedule system, in common with LBNF and DUNE-US. Substantial work has been going on to understand linkages and milestones and make sure they are encapsulated into P6.

Not all consortia use P6 as their definitive schedule, if they are primarily or entirely non-US projects. The HV, TPC Electronics, Photon Detection, ND-LAr, TMS, and ND-PRISM master schedules are in P6; CALCI is there, but so far only for ProtoDUNE-II. The appropriate DUNE-US project level-2 managers are responsible for ensuring that the schedule is up-to-date in P6 for these, and at a less detailed level for the APA consortium. Where there is no US engagement in the consortium this is done by TC. The latter is the case currently for the DAQ and SAND consortia.

No schedules are yet in P6 for the VD FD, although outline schedules are being drawn up.

Schedule summaries and critical paths can be extracted from P6: this is currently being strengthened so that summaries can be presented to every LBNC meeting, for example. Milestone tracking is done on a monthly basis.

The LBNC looks forward to consistent regular schedule updates, and milestone reporting, at each future LBNC meeting. Schedule updates at the level of the overall project, and per consortium, should be presented with an analysis of any delay(s). The LBNC encourages more frequent milestone analysis so that delays arising can be spotted earlier and escalated as needed.

Overall, the LBNC considers that the organisation and functioning of Technical Coordination are appropriate for the post-CDR phase, and that the processes for design changes, and schedule/milestone tracking, are adequate, or soon will be.

The absence of TC oversight of the pre-CDR R&D is a concern. The committee notes that DUNE organization does not designate this as a TC responsibility, but is instead handled by a dedicated working group. The LBNC believes that TC must have an excellent vision into the work of the Vertical Drift R&D, and sees that the key role of the Deputy Technical Coordinator in this working group is crucial to ensure this.

**Recommendations**

Given the good status of the schedule integration, DUNE should report schedules and high-level milestones to the LBNC at each meeting from now on, with analysis of any delay(s).

## Far Detector (APA Single Phase)

The LBNC would like to commend the FD HD detector consortia for continued progress across all areas. The LBNC recognizes the intense period ahead to build ProtoDUNE-II as a Module 0 demonstration and also to transition to full production. The LBNC supports the appointment of a Deputy TC for the FD HD detector.

### HV

The ProtoDUNE-I run provided a successful demonstration of the HV system, with an excellent (~99.5%) uptime over the ~2-year period. Lessons learned have been incorporated into modifications to the design. Good progress is being made on the final HV system design, as well as being ready for the implementation in ProtoDUNE-II.

### PDS

Tests of SiPMs from 2 vendors have been performed at multiple labs with good results, and the ganging of 48 SiPM with S/N> 4 has been demonstrated. The SiPM down-select is scheduled for later this month. The LBNC would like to hear more technical details about the PDS at a future meeting, including long-term tests of the coating stability and solubility in LAr.

### APAs

The APA tasks are making sound progress, including demonstration of wiring tension stability and gains in production time, and redesign of the transport box to address vibrations during shipping and to be able to ship 4 APAs at once. The plan calls for production of 130 APAs in UK and 20 APAs in US, plus 4 APAs for ProtoDUNE-II. The Daresbury factory has started producing APA #1, and the PSL facility is on track to be ready in the summer. The schedule to have 4 APAs ready for ProtoDUNE-II seems reasonable.

We note that the current plan to produce only 2 spare production APAs seems minimal, though the APA team felt producing a few more if needed would not pose a big problem.

Changes to production sites/schedule due to VD planning do not seem to be a concern. Cold Box tests originally planned for February were postponed to August, which will delay retiring some risks associated with the various components.

### Electronics

A new version (p5) of LArASIC is being submitted now via an MPW run, with expected delivery of chips in late May. The latest version (p2) of ColdADC meets the DUNE specifications.

A new version (p4) of COLDATA is needed, to fix 2 errors introduced in p3. Lessons learned

should be implemented in the design validation process. A new MPW submission will be needed, once testing of p3 is completed. The international ASIC shortage means the earliest submission is in June. Luckily, it is believed that p3 can be used in the summer cold tests needed to validate the APA, etc. for ProtoDUNE-II and for their PRRs.

A new version of CRYO is being submitted soon via an MPW. Since no evidence was presented that the source of large coherent noise in the previous version has been understood and fixed, there is substantial risk that it will be seen again in the next version. If so, use of CRYO in DUNE would require evaluation of the potential impact of this coherent noise on the full physics program.

The entire readout chain from FEMB to DAQ backend (FELIX) with entirely new components was tested for the first time in ICEBERG. Despite some readout issues, first tracks were observed. Plans for future runs are still unclear, depending on the status of WIB firmware for CRYO.

The schedule for the ASICs continues to be very tight and challenging, and the impact of the international ASIC shortage poses additional schedule risks. With the current schedule, the ASIC down-select is needed in summer 2021.

Validation of APA Module 0 in (late) summer at CERN could be performed using FEMBs with COLDATA p3. FEMBs with new CRYO version could also be available then, though the schedule to accomplish this is more aggressive.

Equipping full ProtoDUNE-II requires ASICs from engineering runs, which cannot be launched before mid-August (based on COLDATA p3 tests only) or late October (if wait for p4 tests).

Submitting the shared engineering run for ColdADC and COLDATA before testing COLDATA p4 would pose a significant cost risk.

The estimate of 6 months from launch of engineering run to first delivery of FEMBs to CERN seems reasonable, implying fully equipping ProtoDUNE-II not before ~mid-2022. Given the number and complexity of the tasks, there exists significant risk of further delay compared to this timeline.

Progress is being made on the WIB, interface to FELIX, etc. Some issues still prevent full integration with FELIX, but they seem addressable within the available timeframe.

**Recommendations**

DUNE should prepare in detail for the upcoming ASIC down-select, documenting carefully beforehand the criteria and process that will be used to make the decision.

DUNE should plan ASIC submissions with sufficient safety margin to avoid significant delays which could be caused by the international ASIC shortage. The LBNC requests to be updated regularly on the progress and alerted to potential schedule problems.

DUNE should use the ProtoDUNE-I setup, currently being dismantled, to learn as much as possible about long term effects, including measurements of APA wire tension, inspection of HV components (particularly near the areas of localized instabilities), and analysis of coating stability in the PDS system.

**Far Detector (Vertical Drift)**

The committee strongly endorses the Vertical Drift (VD) concept for the second Forward Detector (FD) design. VD capitalizes on the modular Charge Readout Plane (CRP) concept of the earlier Dual Phase design, making the installation of the detector easier and faster than for the Horizontal Drift, and allowing the fabrication to be more readily shared across institutions. The VD Photon Detection System (PDS) offers the possibility for extended coverage that will enhance the physics capability with sensitivity to lower energy events.

The R&D program is well developed and will demonstrate the major elements of the design in the next twelve months, with a full system-level demonstration to follow in NP02. This two-stage strategy will provide confidence in the design elements in early 2022, and Module-0 demonstration ahead of production approval.

The LBNC commends DUNE on the impressive progress in developing the design, executing the R&D planned for this year, and in building an expert team and organization. However, the R&D schedule is tight, and both the work itself and the readiness of necessary infrastructure must be closely managed. We note that the recent appointment of a deputy Technical Coordinator for VD will help ensure the close integration needed with the TC organization.

Preparations for a Conceptual Design Report (CDR) are underway, including simulations and benchmark physics studies, and DUNE expects to present the CDR to the committee this summer.

Given the tight timeline for documentation needed to baseline, strong oversight and coordination will be needed. A clear strategy for structuring and presenting the project should be developed and documented, so review committees and eventually funding agencies understand the motivation of all aspects of the design and project plans. DUNE should identify the set of internal reviews that will benefit this process along the way, including in the near term the completion of the CDR.

Significant progress is being made in addressing two outstanding design choices: 2-view versus 3-view readout in the anode design of the CRP, and the extent and location of the PDS. Both issues are now well integrated into the studies and R&D.

Since the last LBNC meeting, the design of the CRPs has been improved to enhance discharge protection for the electronics. This new design will enable direct comparison of the 2-view versus 3-view readout using one CRP structure.

The PDS is proposed to be placed on either the field cage walls, or on the cryostat membrane walls, and to be integrated into the cathode plane design. The field cage and cathode locations require electrical isolation for operation at up to 325 kV, using optical powering and readout. The cryostat wall location would require a modification to the field cage design.

R&D on optical powering of the PDS modules is progressing well. Optical readout is more challenging. Two options are proposed and will be developed in the coming months. The cryostat wall location appears feasible without needing electrical isolation.

The committee encourages DUNE to decide or to clarify the project's position on the choice of 2-view versus 3-view anode readout, and on the PDS layout as early as possible. This will allow clear articulation in the baseline documentation and a focused path forward for Module-0.

The anode planes are complex in their structure, in the distribution of heat sources in the readout electronics, and in potential limitations to liquid flow. Computational Fluid Dynamics studies are ongoing to model the liquid flow but necessarily this modeling has limitations in accounting for accurate details. The committee considers it important that DUNE hold an engineering review to assess the results of these studies and to address any flow concerns.

The committee requests that DUNE provide a detailed roadmap and timeline for the R&D, the simulation studies, and the CDR preparation, including planned internal reviews, decision points, component tests and physics studies.

The LBNC requests that DUNE keeps the committee abreast of decisions and action items arising from the internal reviews, and requests that DUNE work with us to schedule an LBNC review in the near term that covers both technical progress and the plans and progress towards the CDR.

**Recommendation**

DUNE should work with the LBNC to schedule a review of technical progress and the plans and progress towards the CDR.

**Near Detector**

Since the last LBNC meeting, the final iterations of the near detector (ND) conceptual design report have finished. The LBNC has received replies from DUNE to our final set of comments, and we recommend approval of the CDR to the FNAL director. We congratulate DUNE on completion of this step.

In February 2021 the LBNC conducted a successful review of DUNE's plans and strategy for its Day 1 Near Detector suite. We found that DUNE has a coherent and workable near detector concept suitable for Day 1 operations. The LBNC's report from the review with recommendations has been sent to the FNAL director and the DUNE collaboration.

We were happy to be shown a new technical board organization chart for the near detector effort. This strikes us as a step in the right direction. We welcome the appointment of Hiro Tanaka as deputy technical coordinator for ND.

We note that the ND-GAr group (which includes the temporary muon spectrometer TMS within its remit) is not formally recognized as a consortium yet, although a proto-consortium exists. We think DUNE should consider giving it formal consortium status at this point, since ND-GAr is a necessary part of DUNE's program (even if it may not be in place on Day 1), and a conceptual design report for ND-GAr already exists. In general DUNE must be careful to avoid giving the impression that ND-GAr has lower status or importance within the ND effort, since all studies to date show that DUNE cannot achieve its ultimate physics goals without this detector component.

Because funding for ND-GAr has not yet been secured, DUNE's Day 1 detector plan includes a Temporary Muon Spectrometer (TMS) within the US scope. While this TMS is the baseline plan, if funding were available early enough for the ND-GAr magnet, DUNE would prefer to build either ND-GAr itself (including the high pressure TPC), or to build just the ND-GAr magnet and instrument its central region with scintillator tracking planes (ND-GAr Lite). This attractive scenario would avoid the necessity of building and then later scrapping the TMS and so have a lower eventual cost, but would have a higher initial cost than TMS. For these reasons DUNE's Day 1 detector plan is closely coupled to progress towards ND-GAr (both technical and in terms of funding). Desirable opportunities like having ND-GAr Lite in place of TMS on Day 1 won't just happen, but will require active effort and attention, and must be integrated into the ND management plan.

We note that ND will now be a separate subproject for the purposes of the DOE approval process. CD-2 for ND is now envisioned towards the end of 2022.

A CD1RR review for DUNE is planned for Fall 2021. The Near Detector group needs to clarify the documentation needed for this process. We note that DUNE has already produced a CDR, and will need to produce a PDR for the DOE CD2 process. Minimizing the amount of additional documentation to be written between these two steps is highly desirable.

In the breakout session we heard many details of the ND-GAr program. We heard that in the newest design, the ND-GAr magnet serves as a pressure vessel for the high pressure TPC. The magnet design itself (SPY) is very similar to one built for another experiment, at 75% scale. The

consortium is considering doing one-ended readout of the TPC (thus doubling the drift length), in order to reduce the channel count. Further study of this option is ongoing.

DUNE presented a very rough, technically limited schedule for ND-GAr. It shows that the magnet design and development drives the overall schedule. This first pass schedule suggests that DUNE would need to start construction of ND-GAr Lite in 2025 in order for it to be ready for Day 1. This in turn is a determining factor on when a decision to proceed with construction of the TMS should be taken. The ND-GAr consortium would like to carry out a preliminary design study for the magnet in the second half of 2021. Such a design study would really move the project forward and reduce uncertainty on ND-GAr's cost and schedule. The LBNC endorses the importance of this study.

DUNE presented additional details on its oscillation analysis and on how the PRISM technique will be used to reduce systematics. Impressive progress was evident on implementing PRISM analyses, especially in the treatment of detector resolution effects. We had a useful discussion of SAND's role in oscillation analyses. SAND's beam monitoring ability is critical to the ND and to DUNE's physics goals, and this should be the central focus of the SAND consortium.

DAQ is now a formal joint ND/FD consortium. The ND DAQ will share many features with the Far Detector DAQ. Some components of the ND, however, may opt to use simpler lower-throughput interfaces in preference to FELIX hardware. The LBNC would like to hear more technical/hardware details about the DAQ at a future meeting.

We suggest holding a meeting sometime over the summer between DUNE and the LBNC's ND subcommittee to bring the LBNC up to speed on progress, since the September LBNC meeting is too late to provide feedback for the planned CD1RR review. DUNE should inform the LBNC as soon as possible of the technology decision for SAND inner tracker, any significant developments in international resource availability (e.g. funding for the ND-GAr magnet), or R&D progress or setbacks.

Recommendations:

- DUNE should formally define the steps and schedule for PDR writing and CD2 approval. This includes writing down a coherent strategy for TMS and ND-GAr Lite, describing the technical and schedule interfaces between these components.
- DUNE should consider promoting ND-GAr to full consortium status, and if possible proceed with a preliminary design study for ND-GAr magnet this calendar year.

**Computing**

The Computing consortium continues to provide an efficient and reliable infrastructure for the simulation, processing and analysis activities of the DUNE collaboration. More than 4000 computing cores are, on average, used concurrently for the Pass-4 production exercise, which started in early November. Several physics analyses are already based on the Pass-4 production. The software and computing plans of the Near Detector were further elaborated and clarified since the first discussion following the ND CDR and they are now part of the Computing consortium activities. At present, the vertical drift technology does not seem to present a challenge from the software perspective as it is algorithmically very similar to the APA technology. The LBNC congratulates the Computing consortium for all these achievements.

The Computing Contributions Board made good progress in securing formal resource commitments for the next year. Disk-based storage seems to be the most constrained resource and we suggest that DUNE consider mitigation strategies in case those resources are not made available. The long term projections are constantly improved based on new information and a better understanding of the input parameters and computing model. We note there are still relatively large uncertainties in the predictions. We encourage DUNE to quantify those uncertainties and present them explicitly together with the estimates.

DUNE plans to adopt a flexible data processing model, with loose constraints on data locality and relying on networks to access remote data. While this flexibility brings advantages in terms of scheduling and data placement, it contains intrinsic risks in terms of job efficiency. A first study and set of measurements on the implications of this model was presented. The LBNC supports this activity and urges more studies to be performed, differentiating use cases such as analysis and production with different data ingress patterns.

The DUNE Frameworks task force concluded the process of gathering requirements for the future DUNE software framework. We commend this work and we are particularly pleased to learn that a single framework covering the needs of all DUNE subsystems is being planned. The document summarising the requirements has been brought to the attention of the HEP Software Foundation, for comments. The LBNC is eager to continue following this process and we expect to hear at one of the next meetings about the progress in identifying a suitable framework among the possible alternatives.

The current implementation of databases for condition data in DUNE is well-suited to the needs of the collaboration at the current scale. It can support ProtoDUNE data taking activities, data processing and analysis. Such implementation is based on the experience of previous neutrino experiments with a similar number of users as DUNE today. With the number of users increasing in the next few years, the conditions database service will need to be re-engineered and its scalability improved. In particular, a caching layer should be foreseen in order to avoid the congestion of the central database instance. The DUNE consortium plans to leverage technologies implemented for large scale HEP experiments. We encourage DUNE to ensure that enough effort and attention is dedicated to this topic.

The DUNE Computing Conceptual Design Report could not be delivered in time for the March LBNC meeting. The preparation of the document however appears to be progressing well, based on the material that was presented at the LBNC meeting. DUNE plans to produce the document before summer.

**Simulation, Reconstruction and Data Analysis**

The LBNC commends DUNE on the good progress that continues to be made on simulation, reconstruction and analysis

An overview of the analysis work by the recently formed electromagnetic analysis subgroup was presented. There are currently five analyses ongoing within the group: Michel electron analysis, beam electrons in the TPC, a $\pi^0$ analysis, beam electrons in the photon detector and a correlation matrix method to identify EM showers. The first two were discussed in detail and a short summary of the remaining three was presented. Excellent purity (96%) is obtained for the Michel electrons but with limited efficiency and the LBNC is happy to see that further investigations to improve the efficiency are planned. A detailed discussion about the calibration of the energy to an accuracy of 98% and the bias to the energy due to the 100 keV hit threshold was provided. The detector response to electrons from the test beam was studied. Cuts are applied to select electrons. The same method as used for the Michel electrons was used to calibrate their energy. Two different methods to integrate the charge to obtain the total hit energy were shown. Comparisons were presented between the different methods and between data and simulation. An unusual effect in the distribution for the wire method at 7 GeV was noted. The reconstructed energy is biased by 15% and further study will be made on the impact of the hit threshold. The energy resolution was extracted and found to be consistent with the energy resolution obtained from the Michel analysis. The analyses are making good progress towards publication.

The LBNC notes that, in general, the simulation is observed to well model the data thanks to the dedicated tuning efforts that has been presented previously.

The LBNC continues to be interested in seeing the performance improvements obtained in future reprocessing campaigns when they happen. We would like to see a schedule of foreseen campaigns with an explanation of what is planned for them.

The LBNC would also be interested to see a chart with the organization of the analysis activities, how they are being pursued by the different subgroups and the liaisons that exist between the different subgroups.

## Appendix I: Attendees

**Committee:** Ties Behnke, Simone Campana, Dave Charlton, Cristiano Galbiati, Alexander Gottberg, Heather Gray, Joachim Kopp, Gobinda Majumder, Hugh Montgomery, Scott Oser, *Adam Para,* John Parsons, Tom Peterson, *Anna Pla-Dalmau*, Niki Saoulidou, Jeffrey Spalding, Eric Kajfasz, Darien Wood;

**Scientific Secretary**: Angela Fava

**Fermilab PAC Chair:** Hirohisa Tanaka

**DUNE/LBNF**: Ed Blucher, Stefan Soldner-Rembold, Christopher Mossey, Marzio Nessi, Eric James, Regina Rameika; Michael Andrews, Dario Autiero, Sergio Bertolucci, Mary Bishai, Janet Bishop, Tim Bolton, Fatma Boran, Eldwan Brianne, Alan Bross, Flavio Cavanna, David Christian, Claire David, Justin Evans, Furkan Dolek, Dominique Duchesneau, Dan Dwyer, Kevin Fahey, Robert Flight, Jack Fowler, Sowjanya Gollapinni, Maxine Hronek, Chang Kee Jung, Thomas Junk, Asher Kaboth, Steve Kettell, Michael Kirby, Igor Kreslo, Andrew Lambert, Thomas LeCompte, Giovanna Lehmann, Jonathan Lewis, Cheng-Ju Lin, Sarah Lockwitz, Jose Maneira, Steven Manly, James Mateyack, Fabrice Matichard, Elaine McCluskey, Andrew McNab, Duane Newhart, Laura Patrizii, Roberto Petti, Francesco Pietropaolo, Jennifer Raaf, Aleena Rafique, Filippo Resnati, Heidi Schellman, Ettore Segreto, Theresa Shaw, James Sinclair, Luca Stanco, Francesco Terranova, Alessandro Thea, Christofas Touramanis Douramanis, Serhan Tufanli, Marco Verzocchi, David Warner, Alfons Weber, Michele Weber, Michael Wilking, Callum Wilkinson, Elizabeth Worcester, Guang Yang, Bo Yu, Jaroslav Zalesak

**FNAL Directorate/Management**: Nigel Lockyer, Kevin Pitts, Luciano Ristori

**DUNE RRB:** Alison Markovitz

**DOE**: David Lissauer

## Appendix II: Charge March 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 progress of LBNF-DUNE towards a baseline for the DOE project continues to critically dependent on achieving a high degree of clarity with respect to the scope of the project and its components. In the presentations, LBNF and DUNE should pay attention to this aspect of its progress. In its report, the LBNC should explicitly address this issue with respect to both the Far Detectors' scope and convergence, and for the Near Detector scope and convergence.

The LBNC should hear about the general status of LBNF. Of continuing interest is the planning for a tailored approach to baselining following the recent DOE-IPR and the schedule for future DOE-IPRs. An understanding of the current schedule, and any options for early delivery of beam is important. The discussion of the beamline progress should be addressed in a breakout session shared with Technical Coordination.

The LBNC should hear from DUNE about its overall status and progress at a high level, which should provide a basis for the details which follow. The situation with respect to the IPR process and the approach to a Baseline review should be updated and clarified. The overview should include discussion of the strategic approach to the two technology variants foreseen for the first two Far Detector Modules. The development path for the second variant of the Far Detector technology should be discussed. Progress towards the Day-1 Near Detector baseline should be discussed. The LBNC should comment extensively on all these issues.

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.

In its previous reports, the LBNC has expressed concern with the breadth of the Technical Coordination activities both in terms of the scope and the available staffing. Based on the DUNE presentations, the LBNC should consider how well Technical Coordination is working and fulfilling its role as a major component of the DUNE management framework.

The LBNC should hear about the progress with the Far Detector Horizontal Drift SP technology. The presentation(s) should cover:

a) Progress towards ProtoDUNE II SP (NP04).

b) Technical progress on the SP Far Detector, APAs, assembly etc

c) Progress on the TPC electronics development and the progress towards a choice.

d) Physics analysis of the PD-SP data.

Time is reserved in the Computing Breakout for a presentation on the physics analysis and results.

Since the December LBNC Meeting, the Vertical Drift concept has been presented to the DUNE collaboration and adopted, has undergone a Director's Review, and has been presented to the January 2021 IPR. The LBNC should hear about and comment on the current plans for this technology variant, the plan for near term R&D and the progress towards testing at scale in NP02. The LBNC should comment on the plans presented for development and delivery of documentation (CDR, PDR etc).

We understand that the LBNC is comfortable with the progress of the Near Detector CDR, has made its final comments and only awaits delivery of the final version before making a formal recommendation to approve to the Director. The LBNC has also recently held a review of the Day-1 Near Detector plan and progress. The LBNC should therefore hear and discuss the issues arising from each of the CDR and Day-1 Detector reviews and should comment thereon.

The LBNC has been pleased with the progress of the DUNE Computing consortium including the development of an international infrastructure to support its resource needs. The recent IPR report indicated some interest in defining the scope of the US contributions to those resources. A Computing CDR is under development, but apparently not ready yet for submission. The work to develop this document will be discussed at this meeting; the LBNC should provide a critique and commentary as appropriate.

The LBNC should develop a Closeout Report which it should deliver at 12:15 EST March 5, 2021. Subsequently this should be refined into a LBNC Meeting report.

## Appendix III: Assignments

*Consultants shown in Italics*

| | |
|---|---|
| LBNF Status | **Fuerst**, Charlton, Gottberg, Peterson |
| DUNE Status | **Saoulidou,** Gray, Charlton, Kopp |
| Technical Coordination | **Charlton**, Fuerst, Gottberg, Peterson |
| Far Detector(Single Phase, APA) | **Parsons**, Behnke, Fava, Majumder, Pla-Dalmau |
| Dual Phase | **Spalding**, Galbiati, Kajfasz, *Para,* Wood |
| Near Detector | **Oser,** (Behnke), Kopp, Saoulidou |
| Computing | **Campana**, Charlton, Gray |
| APA Single Phase (Breakout) | **Parsons**, Behnke, Fava, Liu, Majumder, Pla-Dalmau |
| Vertical Drift (Breakout) | **Spalding**, Galbiati, Kajfasz, *Para,* Wood |
| Near Detector (Breakout) | **Oser,** (Behnke), Kopp, Saoulidou |
| Beamline | **Gottberg**, Fuerst, Peterson |
| ProtoDUNE Analysis | **Gray**, Campana, (Charlton), Montgomery |
| Computing (Breakout) | **Campana**, Gray, Montgomery |