LBNC Meeting Report

October 5-7, 2022

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Introduction

The LBNC met October 5-7, 2022, the second meeting of 2022.

The attendees at the meeting, shown in Appendix I, included LBNC members and consultants, DUNE Collaboration spokespeople, Gina Rameika and Sergio Bertolucci, and LBNF/DUNE members, Fermilab Director, Lia Merminga, and Fermilab Deputy Director for Science and Technology and CRO, Bonnie Fleming, Chair of the FNAL Physics Advisory Committee, and representatives of the US DOE.

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 accomplished with a single presentation at the beginning of the meeting: at this meeting the discussion of progress with the beamline is also included in the LBNF report.

The project continues matches its organization to be synergistic with that of the LBNF/DUNE-US DOE project. An important goal is to reach an agreed and sustainable path towards a baseline for each and all of the LBNF/DUNE Sub-projects.

The charge for this meeting, prepared by the Deputy Director for Science and Technology, is shown in Appendix II. For this meeting there was emphasis on the plan for the Near Detector and on the Conceptual Design Report for computing.

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 reaches a consensus for both the Closeout Report and the Meeting Report.

We hold up to three full meetings a year. In practice with progress in the several sub-projects and consortia, it is a rare trimester during which we do not have multi-hour interactions between the LBNC and DUNE teams. We appreciate the excellent tenor of those interactions. During the past couple of months, in order to follow closely the progress of R&D and design of the Far Detector Vertical Drift module, a supplementary meeting between the LBNC and the Vertical Drift team took place on September 6, 2022 to consider, in particular, progress of the plans for the photon detector. The results of that review have been integrated into both the Closeout Report and the Meeting Report for this meeting. Over the past few months, the LBNC has also conducted a 2 step review of the Conceptual Design Report of DUNE computing the conclusion of which was discussed at this meeting.

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/

Again, for this meeting, the presentations have been excellent. We are pleased that DUNE places some emphasis on the physics that can extracted from the ProtoDUNE operations in the Neutrino Platform at CERN. The LBNC expresses its appreciation for the work of the DUNE and LBNF participants in preparation and presentation of all the material for this review. Finally, the committee thanks Fermilab, its freshly minted Directorate, and its support staff, for their assistance and support in making this meeting possible and productive.

The LBNC would like to congratulate Gina Rameika on her appointment as Associate Director for High Energy Physics of the Department of Energy, Office of Science. During the past several years, in several leadership roles, Gina has been a key member of DUNE and has enormously facilitated the interactions between DUNE and the LBNC.

Executive Summary

The LBNC is very impressed by the progress with LBNF which includes but is not limited to the excavation of the Far Detector caverns at SURF.

The LBNC congratulates the LBNF/DUNE project on its successful completion of the CD1RR review and the anticipated ESAAB approval. This is an enormously important step forward.

The LBNC notes that the sequence of reviews, involving CD2, CD2/3 and CD3 or international equivalents, for the various DUNE sub-detectors, will increasingly involve work scope, which is closely related to, or is even shared by the international partners. The partners, US and others, all have independent approval processes. The LBNC considers it important that all these independent review processes develop an awareness of and a sensitivity to their mutual requirements and contributions of the others.

The LBNC has explored, with the various levels of DUNE leadership, how the extant supply chain problems are being addressed. We found considerable awareness of the issues. For example, a sensitive electronics procurement was already facilitated by bridging funds, and a plan for DOE advanced procurement requests, is being developed. DUNE is to be congratulated on these efforts. However, the LBNC cannot avoid urging that a systematic exploration of the availability for all upcoming purchases be examined well in advance of procurement.

It is recognized that the most advanced DUNE component is the Far Detector 1 - Horizontal Drift module. It is close to completing its NP04 re-configuration in preparation for Module 0 operations. APA production at Daresbury has started. Overall, this detector continues to make excellent progress.

The sister Vertical Drift module has enjoyed remarkable advances in its R&D. As an example, the operation of the photon detectors on the cathode using power over fibers is functioning and the CRP fabrication process is under control. Definition and preparation of the NP02 setup for the Vertical Drift Module 0 operation is underway. Importantly, while somewhat delayed, the Technical Design Report should be completed by Spring 2023.

Technical progress with the multiple components of the Near Detector is good. It is important that DUNE has succeeded in creating a viable consortium of institutions capable of delivering the TMS detector.

We have endorsed the NDLAr-TMS-PRISM-SAND Near Detector configuration in the past and reaffirm that endorsement here.

As discussed in several sections of this report, the LBNC is concerned that a clear path to

convergence of the resources needed for the DUNE Near Detector is not yet defined. There appears to be a funding mismatch, which is significant on the scale of the near detector, but relatively modest overall. During the discussions and presentations at this meeting, several possible options were advanced. These ranged from adjustment of DOE directives to re-partitioning of partner scope and contributions. The discussions also included the possibility of new participation. We suspect that the ultimate solution will involve a combination of all these ideas but feel that over the next several months, but well before the relevant CD2 review, resolution should be possible. A resolution is imperative.

The LBNC was very impressed by the quality of the Computing Conceptual Design Report. The review of the document which involved two passes was characterized by prompt response to recommendations. It clearly demonstrates that DUNE has taken an appropriate stance and position vis-à-vis the larger particle physics computing community. The LBNC is recommending that the Director approve the CDR.

DUNE presented analyses which are exploiting multiple sources, Single Phase, Dual Phase, and Cold Box, of data from the Neutrino Platform. As hoped it is proving to be a source of interesting original physics and detector knowledge, and is providing significant numbers of students with interesting projects.

The goal for LBNF DUNE is excellent results in neutrino physics generally but especially in oscillation measurements. We heard a report on advances on the oscillation analysis front. The presentation generated considerable interest and discussion, lots of it positive. However, the committee is concerned about whether DUNE-PRISM, which the committee feels is a key component of the DUNE strategy, is receiving sufficient explicit attention. To achieve the goals of well-developed analysis approaches at the time of data taking, it is also important that management encourages the appropriate level of collaboration effort.

LBNF Status

Findings:

- The CD-1RR review was passed in July 2022, with each subcommittee recommending approval of the CD-1RR milestone.
- The CD-1RR Funding Profile had been announced shortly before the last LBNC meeting. This funding profile has now been fully integrated into the schedule, resulting in accelerating the start of beamline operation by nearly 2 years and the near detector installation by 7 month.
- LBNF/DUNE-US has received $125M from the US Inflation Reduction Act (IRA) for 2023, this will not increase to total funding DOE envelope but will allow the project schedule to be maintained by offsetting near-term inflation impacts. However, this will not allow significant acceleration of near-site work.
- Preparations are made to issue a contract for the Far Detector and Cryogenics subproject nitrogen contract.
- The far-site excavation subproject has been baselined and baselining of the far-site building and site infrastructure subproject is ongoing.
- 18.5 days of downtime in excavation work have been encountered due to a power outage at the Ross substation. The resulting costs will be absorbed by the contingency.
- A task force, led by the CRO and the COO, has been put in place to finalize the planning of host lab support to the project and experiment.
- NSCF+B schedule is funding limited but the team is looking at early procurement authority for long-lead time items.
- The ND DOE cost cap remains at $200M.

Comments:

- Congratulations for successfully passing CD-1RR. This reaffirmed selected alternatives, re-established the project point estimate and cost range, implemented subproject execution strategies, all important steps for setting the project on track.
- A key challenge for the project is how to respond to the rapidly changing external conditions. The LBNC is relieved to see that significant immediate risks posed by supply chain issues and inflation are being mitigated using the funding advancement available through the IRA. It is an important accomplishment that the excavation project was successfully baselined and that the previous top-level project timeline could be confirmed. The Committee is pleased to note that a full risk-based re-evaluation, taking current geopolitical constraints into account, is being prepared for ESAAB. The advanced funds through the IRA are certainly mitigating the immediate effects of inflation, however, in the long term an increase of the total project costs due to inflation is very likely, should be evaluated and needs to be discussed in due time with DOE.
- Considering the growing lead times for some items, the LBNC endorses initiatives to gain

early procurement authority, especially for those subprojects that are operating on a funding-limited schedule, like the NSCF+B.

- The LBNC commends the massive progress that has been made on excavation while maintaining an above average safety performance. Excavation is now >40% complete bringing the overall subproject to >65% complete. LBNF/DUNE-US is providing a large fraction of cryogenic infrastructure and preparations are on track to issue a major contract in January, and an agreement has been signed with CERN to supply the second cryostat.
- The Project Executive Leadership Team structure had been presented at the previous LBNC meeting and is now fully established. The LBNC notes that this organization structure works well for all major stakeholders.
- Access to the 4850L via the Ross shaft has been a continuing issue of the far-site excavation subproject. An investigation of the recent power outage has been conducted and actions are being integrated. The LBNC wonders if an in-depth evaluation of this old shaft and its infrastructure is warranted to reduce further issues.
- The Target Station Integration Building (TSIB) is critical to support the NSCF+B subproject, as well as the LBNF operation and power ramp-up. The commitment of the host lab has recently been demonstrated by the internal funding of TSIB to maintain the construction schedule
- The $200M cap on the Near Detector Subproject continues to be a concern in that it may limit the ultimate capabilities of the DUNE experiment unless cost mitigations can be developed.
- The planned Independent Project Reviews across the five subprojects is somewhat daunting, especially for the remainder of calendar year 2022. In addition, the project is being reviewed by the DOE Office of Inspector General and Office of Enterprise Assessment. There is a risk that the project office - and project team - will not be able to adequately support so many near-concurrent reviews.
- It's unclear if the potential impacts of inflation and supply chain disruption are fully appreciated. For example, electronics components are in short supply and have long lead times. It's quite uncertain when this situation will improve.
- It will be important to proactively prepare for procurements in advance of CD-3x approvals so that the procurements can be issued without delay when ESAAB approval is obtained.

No recommendations

Beamline Status and Progress

Findings

- A CD-3a review for the NSCF+B subproject will be conducted in December 2022. Beamline kicker and horn components will be procured with the resulting budget authorization.
- The CD-2/3 review for the NSCF+B subproject is planned in the fall of 2023.
- The magnet work at BARC is on hold.
- UKRI is conducting prototyping work that will lead to final design of a full-scale prototype target.
- The accelerator ramp-up schedule indicates beam to LBNF in Q1 FY 2032.
- There are approximately 45 FTEs supporting this subproject in FY 2022. This will drop off somewhat over the next couple years before ramping up for construction and installation.

Comments

- The NSCF+B presentation from the July 2022 CD-1RR review was shared with the subcommittee following the breakout session. The subcommittee would appreciate receiving this level of detail in future LBNC meetings.
- It would be appreciated if other members of the NSCF+B team attend the breakout session and present a few relevant and timely presentations along with the Deputy Project Director's overview presentation at future LBNC meetings.
- The subcommittee looks forward to the resumption of magnet work at BARC. Final designs for the magnets are needed in order to complete the designs for related components.
- The LBNC will continue to follow the interfaces between NSCF+B and other parts of the project, especially ND and DUNE and requests that the status of all major interfaces will be presented at the next meeting.

No recommendations

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DUNE Status

LBNC congratulates DUNE for significant, critical and in occasions impressive progress made on several fronts since the last LBNC meeting. Specifically, LBNC commends DUNE for:

- Successfully completing the DOE IPR and CD1RR reviews, which signals the transition of the DUNE experiment into a new era.
- Articulating a clear and strong physics message at Snowmass on both i) DUNE's unique, complementary and synergistic capabilities in the global context and in comparison to HYPER-K and other neutrino oscillation experiments, and ii) a well thought out phased approach for achieving its main physics goals.
- Having successfully completed the Computing CDR which LBNC reviewed and proposes for approval.
- Having improved the DUNE organization and management structure, as well as the interfaces with the DUNE-US project.
- Continuing to make excellent progress on all FD1 fronts: i) the APA production ii) the photon detection system iii) the Module-0 installation iv) preparations for the CD2/3 review in June 2023.
- Continuing to make excellent progress on all FD2 fronts: i) R&D and prototyping ii) ProtoDUNE-VD installation ii) advancement and finalization of the design with a goal to deliver a first TDR draft to LBNC by mid-November 2022.
- Having FD1 and FD2 scope clearly defined in multi-institutional MOUs.
- Continuing to make very good progress on physics analysis with the ProtoDUNE-SP and ProtoDUNE-DP data-sets, and advancing on preparations for ProtoDUNE-HD and ProtoDUNE-VD.
- Making significant progress on DUNE-ND concerning the ArgonCube 2X2, all ND Phase-I sub-detector systems, and the DUNE-PRISM movement system.
- The initiation of a new effort on a more integrated and comprehensive oscillation analysis, with realistic simulations and algorithmic reconstruction of all ND sub-detector systems, and improved statistical and systematics models for obtaining the final oscillation results.

LBNC fully endorses the DUNE overall phased approach in achieving its primary physics goals. As a key element of this phased approach, LBNC acknowledges the need and importance of a highly capable Near Detector Complex, for both Phase I and Phase II, as has been described and articulated by the Collaboration thus far, i.e. as a functionally "identical" smaller replica of the FD, with ND-LAr being a key and necessary component. This approach is well established, utilized by all previous long baseline neutrino oscillation experiments, and targets both the cancellation of systematic uncertainties with DUNE-PRISM, and minimizing their impact by

providing strong constraints.
LBNC acknowledges the extensive ND Phase-I optimization studies that have been performed by DUNE, involving both ND-LAr and TMS. These clearly show that the current configuration of these two sub-detector systems is optimal, and cannot be descoped without seriously harming the physics performance.

LBNC welcomes and acknowledges the significant international partner contributions to the ND Complex from Bern (ND-LAr) and INFN (SAND), and strongly encourages the Collaboration to continue to develop a plan to best leverage these contributions given the overall cost constraints.

LBNC urges DUNE to continue to improve and advance the overall ND plan, in terms of identifying the needed human and financial resources and securing international contributions, such that Phase I, and later Phase II, detector configurations can be built.

LBNC urges DUNE to continue to systematically monitor and assess the impact of supply chain issues, and develop plans, as needed and when possible, to mitigate those.

FD1 Horizontal Drift

Findings and Comments:

- The LBNC commends the DUNE collaboration on the further excellent progress on FD1-HD.
- The Production Readiness Review for the 150 APAs was successfully signed off in July, and the UK production has started (3 APAs are currently under construction), in line with the goal of starting FD1-HD installation in 2026.
- The project has maintained four months of float in the APA production schedule.
- To further optimize the APA production plan, a fifth winder will be added at the Daresbury factory, and a production site in Chicago, equipped with a sixth winder, is being prepared with the goal of producing approximately 10% of APAs. Explanations have been provided to motivate the investment in this second site even if the production capability is limited. The extra capacity at the Chicago site could account for a relatively limited gain in schedule.
- A key issue on availability of Cu-Be wire has arisen for the APA production, due to Beryllium shortage. The amount of wire currently at hand is sufficient for only a very limited number of APAs. The project is actively consulting vendors in several countries to better understand the situation, and even started discussing possible alternative options and the many associated challenges that a change of plan would involve.
- Following the Production Readiness Review of the LArASIC chips in March, bridge funding was used to order enough LArASIC wafers for both FD1 and FD2, hence addressing the risk of losing access to the 180-nm CMOS process on which they are based. The first 50 of 250 wafers have been received.
- The project will seek DOE CD3A approval to start production of ColdADC and COLDATA ASICs in 2023, as well as to procure FPGAs and all components for FEMB, WIB, and PTC boards. This is in line with the start of module production in 2024, taking into account the currently foreseen long lead times. We commend the project for being proactive in taking preemptive measures to ensure that supply chain challenges will not negatively affect the electronics production schedule. We encourage all areas of the project to adopt or continue with this approach.
- Progress continues on the integration of ProtoDUNE-HD-Module-0 (ProtoDUNE II), where three Module-0 APAs have been outfitted with electronics and photon detectors, and have been tested in the CERN cold box, with the fourth APA currently being operated in the cold box. The detector performance has been demonstrated to be better or equivalent to ProtoDUNE-SP.
- Liquid Argon suppliers cannot currently provide the amounts needed to fill the ProtoDUNE cryostats, due to reduced oxygen production in Europe. Therefore, it is possible that the cold run will be further postponed, even beyond the DOE CD 2/3 review for the FDC sub-project, currently scheduled for June 2023. The project is encouraged to critically evaluate and attempt to minimise any risks associated with continuing the APA production despite a delayed feedback from the ProtoDUNE II cold run. These risks will likely have to be accepted.
- We thank the project for expanding the milestone list to encompass all activities through the installation of the detector.

Recommendations:

- Critically look at and evaluate any modifications made to the APA design of those used in ProtoDUNE-I to attain the production APA design, in order to determine if any potential weakness could have been introduced that would only manifest itself during a cold run. Perform cold tests as soon as they become feasible while production is going on.
- Consider the possibility of securing enough parts for a second winder at Chicago, which could further boost production and augment schedule contingency, that could be commissioned at the same time as the first winder. The motivation and rationale for the second site at Chicago should be better articulated.
- Continue to proactively consult known and potentially new vendors that could help solve the current shortage of Cu-Be wire for full production. If the prospects of solving this issue are found to be limited, the project should ramp up the investigation and evaluation of possible alternative wire materials and plan for qualification campaigns.

FD2 Vertical Drift

Findings:

The committee continues to be impressed with the rapid and thoughtful progress on R&D for the Vertical Drift detector, and we note a few of the highlights here.

For the Photon Detection System (PDS), the subcommittee had an extra meeting with the FD2-VD team in September to inform the committee about the rapid progress in the design and testing. Significant advances included exercising xARAPUCAs in the cold box with Power over Fiber (PoF) and Signal of Fiber (SoF). A 50% power delivery efficiency was achieved with GaAS PoF in cold. Noise issues in the PDS were also studied, including light contamination from the PoF. Mitigation strategies are being implemented.

In the High Voltage system, the field cage design was updated to extend the 70% transparent region around the ends of the module volume; same configuration to be used in Module 0. This geometry permits installation of xARAPUCAs on the end membrane, which gives more uniform light coverage. The design of the HV feedthrough was also updated, informed by previous NP02 experience.

A significant campaign of simulation and reconstruction for FD2-VD was carried out and yielded many results that will appear in the Technical Design Report (TDR). The FD2-VD simulation is running with updated CRP strip orientation (+ 30°, - 30°, 90°) and a realistic field cage, not yet with the final PDS detector locations. Technical advances made production much faster. The simulation was used to study low-energy physics efficiencies and SNB triggering, and results were compared to HD.

The CRP Anode design is nearly finalized and the same design has been used to produce the 4 CRPs (2 Top and 2 Bottom) for Module 0. New lighter framework for top modules is under test at CERN. First bottom half-module was assembled in the US (Yale) and sent to BNL for testing. Technical problems with silver printing and edge connectors observed in earlier cold box tests have been addressed with updated designs and techniques.

Comments:

- The final VD Module 0 tests may be delayed considerably by lack of argon availability. The project identified useful activities to carry out in advance of filling NP02 with LAr, including assembly exercises and testing electronics systems at warm temperatures. Given the expected delays and the relative maturity of the two FD designs, the optimal order of filling NP04 and NP02 is not obvious to the committee.
- The project team has been proactive in securing the components needed for Module 0. A few items, such as cold cables, have been identified as potential sources of delay, and these are being pursued actively.
- The simulation and reconstruction have had much less time for detailed study for VD than for HD, but it is showing comparable performance. There are outstanding items requiring deeper understanding, including the lack of expected improvement in PDS resolution with higher visible energy, and lower CVN efficiency than HD, especially for low-energy muon neutrino CC events.
- The committee was satisfied with the answers provided to the follow-up questions from the September meeting on PDS. The optical component of the PDS noise from PoF IR photons leakage has been quantified in a dedicated setup. The electronics will be optically

separated with an enclosure to mitigate the leakage. Undershoot of the PDS electrical signal is about 2% of the peak with a long duration. It is not expected to be a source of bias from pile-up.

- The committee looks forward to receiving the Technical Design Report for review in November.

Recommendations

- Formulate plans for optimal use of time for Module 0 studies in the case of significant delays waiting for liquid argon
- Finalize the PDS electronics choices for fibers, optical connectors and leakage mitigation

Near Detector

In a plenary talk and dedicated breakout session, DUNE updated the LBNC on the status of its plans for a staged near detector. The Department of Energy has capped the US project contribution to the near detector at US$200M. In response DUNE has carried out a round of cost scrubbing, which found some cost savings but still came up with a cost estimate for the US scope of $249M. DUNE has done numerous studies to consider whether further descoping is an option. We see no descoping options that would save significant costs to the US project without dramatically impacting the physics performance of DUNE as a whole even during the early stages of running. The LBNC reaffirms its support for DUNE's phased approach for its near detector. We emphasize that in order to do oscillation analyses DUNE requires all of the components of ND-LAr, TMS, DUNE-PRISM, and SAND, all of which are required for the initial phase of DUNE. Given the impossibility of further descoping, it is imperative that DUNE finds additional resources or cost savings for the near detector.

We note that DOE has imposed restrictive directives about the cost division between threshold scope vs. objective scope for the near detector. These constraints present difficulties for DUNE and preclude the threshold scope being sufficient to enable oscillation analyses. DUNE and DOE should revisit these constraints and ideally remove them.

We furthermore endorse the ND-GAr concept as a future upgrade for DUNE which will be necessary for DUNE to achieve its ultimate physics reach.

ND-LAr consists of a segmented array of liquid argon time projection chambers. The preliminary design for ND-LAr is now complete. A preliminary design review was held in late June, resulting in a positive report. As part of the prototyping effort for ND-LAr, DUNE is preparing to operate the 2x2 Argon Cube demonstrator in the NuMI beam in 2023. While two modules have been built and tested, the last two modules have been delayed due to supply chain issues with the charge readout electronics and cryosystems, as well as issues with delivery of light readout systems from Russia due to the war in Ukraine. In spite of these delays, DUNE still thinks it will be ready to begin operation in the NuMI beam by spring. The LBNC looks forward to operation of the 2x2 demonstrator in 2023. DUNE is also putting significant effort towards developing analysis tools (simulation, reconstruction, integrated analyses with MINERvA). Many of these tools are becoming quite advanced.

The LBNC welcomes the evident maturation of the TMS Consortium, which is responsible for delivering the magnetic spectrometer that sits downstream of ND-LAr. A suitable number of groups with relevant experience have joined this effort and are taking on defined responsibilities. The TMS group continues to refine the design for TMS. A new "short stack" design for the steel plates could introduce some modest cost savings and simplify coil installation, and is under consideration. In addition, a new ASIC developed for CALICE is being considered for use in TMS's analog front-end electronics.

An essential aspect of DUNE's near detector is that ND-LAr and TMS must be movable over a range of off-axis angles. This technique, known as DUNE-PRISM, uses the variation of the neutrino flux with off-axis angle to break degeneracies in the beam and neutrino interaction model.

DUNE presented a few advances in the analysis framework for including off-axis data in the oscillation analysis, although not in detail. It was reported that comparisons of oscillation contours from PRISM to those from traditional methods are underway. Some differences are seen and efforts are underway to understand these. DUNE hopes to be ready to show such comparisons at the January 2023 LBNC meeting. The LBNC eagerly anticipates seeing this work. The movable platforms that support TMS and ND-LAr on the PRISM system are at preliminary design stage, and we were shown many details of the design for the movement system and cabling. Plans for a 4-roller prototype were descoped to a simpler Engineering Test Unit, with one powered and one non-powered roller.

The SAND beam monitor will re-use the KLOE magnet, contributed by INFN, and monitor the beam on-axis. While much of SAND is an international in-kind contribution, it will require significant supporting infrastructure. The LBNC was shown proposed divisions and interfaces between the US project and the SAND consortium. Because the cost of the US scope for SAND is large ($26.5M), these costs should be carefully scrubbed and scope swaps considered to reduce the cost to the US project. Refurbishment and repurposing work on the KLOE magnet is ongoing, and shipment to FNAL is expected by the end of 2024. SAND is planning to build three prototypes for the Straw Tube Tracker inside SAND. A preliminary design review for the Straw Tube Tracker is planned for November 2023. It is clear that there are significant uncertainties in this work due to the pandemic, supply chain issues, and the war in Ukraine. The LBNC would like to hear details about the expected impact and mitigation strategies for these issues. The SAND group plans to include a liquid argon target, called GRAIN, inside the magnet in addition to the tracker. A prototype of GRAIN's internal vessel is planned for next year, while the outer vessel is still in preliminary design. A simulation for GRAIN is now being developed. A Preliminary Design Review for GRAIN is planned for Apr 2024. The physics case for GRAIN still seems weak to the LBNC, but we have been informed that its removal would result in little reduction of the US project cost.

Recommendations:

- All stakeholders should continue to work to ensure that sufficient resources are available to build ND-LAr, SAND, TMS, and PRISM in time for initial physics running.

Computing

The DUNE Computing Consortium continues progressing in the development, integration and testing of distributed computing systems to support the current protoDUNE and the future DUNE scientific program. The priority of the Computing Consortium for the next two years should be the support of ProtoDUNE phase-2 activities. There are many synergies between the computing and DAQ activities and the development of some components requires regular discussions between the two communities. The new database for conditions data, currently under development is an example. We would like to hear an update from the DAQ team at the next meeting, also covering the interfaces with offline computing.

DUNE presented the first results of the data challenge campaign. The data distribution of the protoDUNE newly collected data from CERN to FNAL and other DUNE data centers met the target metrics. We would find it useful to complement the tests with a similar campaign where FNAL is the data source, as this will be the running scenario when DUNE will operate. The offline reconstruction of the data at the DUNE sites was also part of the challenge. It allowed exercising newly developed or improved components such as the WorkFlow Management system (WFM) and the Job Dispatcher (JD). We understand that more tests will be carried on in the next phase of the data challenges and we expect to hear about the outcome at the next meeting. We also appreciate the overlaps and complementarity of the WFM and JD tools, and we would like to hear more in depth about their future role in the DUNE Computing Model in the future at the next LBNC meeting. Generally, the LBNC supports the DUNE data challenges plan as a program to commission new services and workflows. The DUNE computing model builds on the existing HEP infrastructure and contributes to evolving it according to the needs of the collaboration. The LBNC strongly supports this strategy. We suggest DUNE to discuss common data challenges with other HEP experiments, to exercise the effective use of shared resources and services. The network connectivity is a clear example where a discussion between HEP experiments and the resource providers will be needed soon, to understand how to share the service and properly support the scientific needs of the scientific communities.

DUNE produced an extensive Conceptual Design Report (CDR) that covers all the important areas of Computing. The CDR was reviewed and the LBNC is very satisfied with the reactions to the comments and the final outcome. The LBNC thanks DUNE for the constructive process and recommends to endorse the CDR. The CDR highlights some major challenges, driven by novel requirements of the DUNE experiment. The offline software framework and its need to deal with large event sizes is a clear example and the work on software parallelisation will require dedicated skills. We suggest DUNE plans the R&D activities around this and other major tasks early enough, finding the right balance with respect to supporting the ongoing operations. We expect to follow the progress in this area in the next meetings.

ProtoDUNE Physics Analysis

DUNE has a strong physics program based on ProtoDUNE data, both from SP and DP runs. Many analyses are making excellent progress on several fronts with papers being published in a timely manner. We note that a ProtoDUNE-DP performance paper is in preparation. So far there have been 4 papers published, 1 paper recently submitted to a journal and 22 analyses are ongoing. Out of those, 4 are in the advanced stage, either under active review or in paper draft.

The protoDUNE data has clearly been shown to be a fertile ground for students doing physics analyses. There are currently 20 students analyzing various protoDUNE data sets and additional 8 have already graduated.

LBNC is pleased to see that the measurements obtained from these analyses are being implemented as parameters in DUNE simulation.

The efforts for data taking, simulations and processing in anticipation of data coming out of the HD and VD modules planned for the phase-2 running are ramping up. We encourage timely completion of the current round of analyses such that additional effort can move to ProtoDUNE phase-2.

Oscillation Analysis Update

DUNE continues to work on improved simulation and analysis tools as well as their application to sensitivity studies. We commend the collaboration on the progress towards detailed simulations of all detector components. Important progress has been made in particular in the simulation of the Near Detector and in the modeling of systematic uncertainties.

DUNE has presented a coherent plan for future development of the oscillation analysis, aiming for a combined analysis of simulated data from the far detector and on-axis near detectors, generated with mature detector simulations currently under development. Separately, the DUNE-PRISM analysis has been developed further. The establishment of a new Neutrino Interaction Uncertainties Physics Working Group is a welcome development.

The committee is pleased to see that, besides the main analysis pipeline, DUNE is mindful of the need for modularity of the simulation+analysis effort, allowing for comparison of event generators, cross-section models, statistical procedures, etc.

We are nevertheless concerned that the people-power devoted to the analysis effort is limited, which will slow down the development of key aspects of the analysis.

Another concern is that, given how essential PRISM is going to be for controlling systematic uncertainties, analyses fully exploiting DUNE-PRISM appear not to have high priority. Exploration of how detector systematics will impact this method is also critical. Notably, current plans do not foresee full integration of DUNE-PRISM even for the update planned for 2024.

Recommendation:

- DUNE should ensure that sufficient people-power is available to complete in a timely manner an oscillation analysis including DUNE-PRISM.

Appendix I: Attendees

Committee: Martin Aleksa, Austin Ball, Ties Behnke, Daniela Bortoletto, Simone Campana, Mark Champion, Francesco Forti, Alexander Gottberg, Joachim Kopp, Gobinda Majumder, Hugh Montgomery, Scott Oser, Adam Para, Marco Rescigno, Paolo Rumerio, Vadim Rusu, Niki Saoulidou, Eric Kajfasz, Rainer Wallny, Darien Wood;

Apologies: Heather Gray, John Parsons

Scientific Secretary: Joseph Zennamo

Fermilab PAC Chair: Hirohisa Tanaka

DUNE/LBNF (based mainly on registration: Regina Rameika, Sergio Bertolucci, Chris Mossey, Munerah Alrashed, Gary Barker, Mary Bishai, Janet Bishop, Dominic Brailsford, David Christian, Kevin Fahey, Jack Fowler, Ines Gil-Botella, Catherine James, Eric James, Steve Kettell, Thomas LeCompte, Cheng-Ju Lin, Jolie Macier, Chris Marshall, Marzio Nessi, Sandro Palestini, Laura Paulucci, Elisabetta Pennacchio, Francesco Pietropaolo, Veronique Puill, Peter Shanahan, Robert Svoboda, Steven Timm, Christos Touramanis, Serhan Tufanli, Sam Zeller.

FNAL Directorate/Management: Lia Merminga, Bonnie Fleming, Gregory Bock.

DOE: Adam Bihary, David Lissauer.

Appendix II:
Charge Letter: LBNC October 2022 Review, October 5-7, 2022

The LBNC is charged by the Fermilab Director to review the scientific, technical, and managerial progress, plans and decisions associated with the Fermilab Long Baseline Neutrino Facility (LBNF) and the Deep Underground Neutrino Experiment (DUNE).

For the October 2022 meeting, the LBNC will meet in hybrid mode to review status and progress of LBNF and DUNE. As with other meetings, 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. In addition to updates on major detector systems: Far Detector 1, Far Detector 2, and Near Detector, the LBNC should also receive updates on activities towards ProtoDUNE-II and LBNF Beamline. Along with technical progress, staffing and plans, presentations should report on issues and concerns related to supply chains and availability of components.

As design and construction decisions are made by partners contributing to this effort, the LBNC should comment on scope, timeline, and physics performance impacts of these decisions. Where appropriate, the LBNC should also comment on overall coherence of the international effort.

In considering the presentations and material provided for the meeting, attention should be given to prior LBNC recommendations and actions that have been undertaken to address these recommendations. For the DUNE detectors and computing, we would like to continue our work toward uniform and regular reporting and tracking of major DUNE technical milestones.

Other specific areas of review for this meeting should include:

1) Re-affirm scope and potential phasing of DUNE near detector complex. Follow up on the response to recommendations from the previous LBNC meeting.

2) Review and endorse as appropriate DUNE Computing CDR.

The LBNC should develop a Closeout Report which it should deliver at 12:15 CDT on October 7, 2022. Subsequently this should be refined into a LBNC Meeting report.

Appendix III: Assignments

LBNF Status (Progress, Plans and Organization)	**Gottberg**, Aleksa, Ball, Champion
DUNE Status	**Saoulidou**, Kopp, Bortoletto
FD1 Horizontal Drift	**Rumerio,** Ball, Majumder, Wallny
FD2 Vertical Drift Rescigno	**Wood**, Aleksa, Forti, Kajfasz, Para,
Near Detector	**Oser**, Kopp, Saoulidou, Bortoletto
Computing (inc CDR Status)	**Campana**, Rusu
ProtoDUNE Analyses	**Rusu**, Campana, Rescigno
Oscillation Analysis Update	**Kopp,** Bortoletto, Oser, Para

Breakouts

Beamline Status & Progress	**Gottberg**, Ball, Champion
FD2- Vertical Drift Progress	**Wood**, Aleksa, Forti, Kajfasz, Para, Rescigno
FD1- Horizontal Drift Progress	**Rumerio,** Ball, Majumder, Wallny
Near Detector Progress	**Oser**, Bortoletto, Kopp, Saoulidou
DUNE Computing Progress;	**Campana**, Rusu