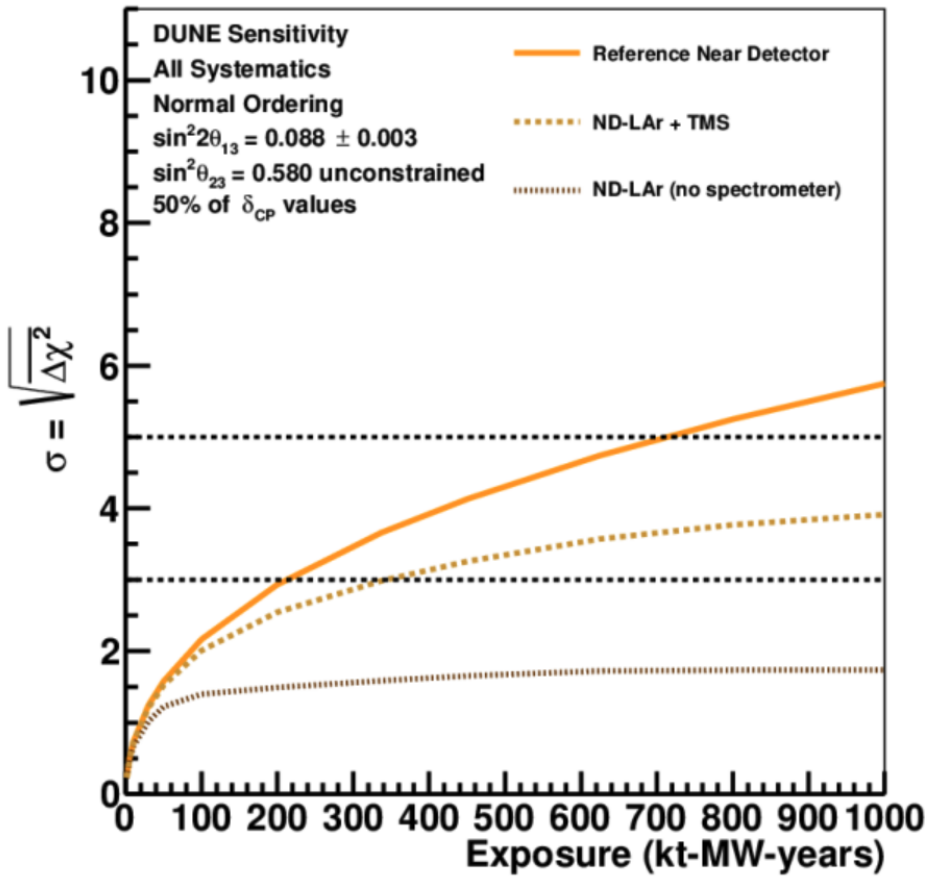
LBNC Meeting Report



March 28-30, 2022

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Introduction

The LBNC met March 28-30, 2022 the first meeting of 2022.

The attendees at the meeting, shown in Appendix I, included LBNC members and consultants, DUNE Collaboration spokespeople, Gina Rameika and Stefan Soldner-Rembold, and LBNF/DUNE members, Fermilab Director, Nigel Lockyer, and Fermilab CRO Kevin Pitts, Chair of the FNAL Physics Advisory Committee, Chair of the DUNE Resource Review Board, 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 to make adjustments to align its activities to the LBNF/DUNE-US DOE project needs. The path advances towards a separate baseline for each of the LBNF/DUNE Sub-projects.

The charge for this meeting, prepared with guidance and approval from the Director is shown in Appendix II. For this meeting there was emphasis on understanding the current staffing and schedule progress.

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.

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 clear and well focussed. As for the previous meeting, we introduced several new topics such as a report from the Neutrino Cost Group and an explicit discussion of how the detector program relates to a progression in the physics precision supported by the statistics. For these discussions, the LBNC thanks the DUNE and LBNF participants. Finally, the committee thanks Fermilab, its Directorate and support staff, for their assistance and support in making these meetings possible and productive in an unfriendly covid environment.

Executive Summary

The ongoing war in Ukraine has created global uncertainties, which will surely impact progress in physics projects, as in other human enterprises. Further the extant economic uncertainties, originating in the pandemic, lead to worries about material supplies. While LBNF/DUNE report relatively minor impacts at this stage, the LBNC urges continued attention to developments in both arenas.

The LBNF/DUNE-US project has completed the build out of its staffing to include four Deputy Project Directors and a new Project Manager. All have considerable relevant experience. The LBNF/DUNE-US Project also recently received revised funding profile guidance from the Department of Energy. A preliminary analysis indicates that this profile will advance the start date for beam-based physics to December 2030. This is extremely welcome. If it were possible to match the profile spoken of in the Authorization Bill, that would be even better.

Excavation at SURF continues broadly on schedule, the pilot excavation for the three detector caverns and the utilities cavern are essentially complete. The beam line design work continues to make excellent progress despite the challenges imposed by the non-optimal pause anticipated between design completion and execution to match the funding profile. We also heard a presentation of how the initial turn-on of the beam to SURF is planned.

The case for the complete Near Detector complement of detectors has been previously made to the satisfaction of the LBNC. The case for a Phase 1 detector complex has also been well articulated. At this meeting we were presented with a coherent plan for addressing the determination of the systematic uncertainties associated with the primary neutrino oscillation measurements for the nominal detector. DUNE understands the issues and has a clear plan to address those issues, which is well matched in time with the requirements. Each component of the Near Detector complex, which includes the detectors themselves and the DUNE Prism capability, is essential.

Overall, DUNE is making enormous technical progress with both of the Far Detector Modules and the detector components of the Near Detector. This is confirmation that the international collaboration model is working well.

With the key electronics design work complete, the Horizontal Drift team is starting the installation of components of the Module 0 configuration in NP04. This is going well and use of the beam this calendar year is possible but certain for calendar year 2023. This includes the first production examples of APAs from the UK. The R&D program for the Vertical Drift Far Detector continues to make impressive progress. Three major demonstrations, 300kV operation of the high voltage, recording of particle tracks with a 6 m drift, and operation of the photon

detector with power over fiber at 10 kV cathode plane voltage were key elements for the viability of the configuration. All have been achieved.

The design and R&D program for the near detector has made considerable progress. DUNE is forming a viable international consortium to build The Muon Spectrometer. SAND is reviewing the motivation for an integrated Liquid Argon target with goals which are complementary to those of the LArTPC detector.

The DUNE Computing Consortium has successfully competed for DOE-OHEP support for its work. The presence of this increase in effort to complement that from its International partners has promoted a surge. The advanced status of the Computing Conceptual Design Report, which the LBNC expects to receive during this quarter, is reflected in the articulation of the goals and progress of the work. DUNE continues to make progress with the analyses of the ProtoDUNE (HD) data. These data expand the knowledge of relevant hadronic cross-sections. They have published two papers and several analyses are in progress. That they concentrate on this publication-end-game is important.

The Neutrino Cost Group is a committee, which in many aspects, is complementary to the LBNC. The NCG concentrates on risk, cost, and schedule, and the LBNC on the technical issues. Of course there is overlap. We heard of the prospects, plans and relevance of the NCG and have taken the liberty to comment. Further interactions between the two committees could prove useful.

Over the past months, the LBNC has had a significant change of personnel. The work we do is not trivial, time is spent outside the days of the reviews examining material, commenting on design reports, milestone progress, planning and executing ancillary reviews. Our reward is to see the tangible progress made by the whole LBNF DUNE enterprise. Again, we have been pleased with the evident progress, and again, we congratulate DUNE.

This meeting marks a transition for DUNE. Stefan Soldner-Rembold has completed 4 years as Co-spokesperson of DUNE. Stefan has been tireless as an advocate for DUNE and indeed as an advocate for the International collaboration that is LBNF/DUNE International today. The LBNC now looks forward to working with the new spokesperson team of Sergio Bertolucci and Gina Rameika.

Finally we conclude by thanking Nigel Lockyer for the encouragement he has shown the LBNC during his tenure. We would also like to thank Nigel for his service to the field in general and for the creation and support of this world leading project in particle physics PIP II, LBNF, and DUNE. Nigel's legacy will be **A Best-in Class Experiment.**

LBNF Status

Great progress is being made in far-site excavation, detector design and necessary project reviews. The team is absorbing yet another re-profiling of funding and taking steps towards identifying required scope contingency in preparation for DOE CD-1RR IPR in July 2022.
The CD-2/3 IPR for the far-side excavation has been passed successfully and installation work is progressing well with only 24 days accumulated delay, despite the challenges from the pandemic and resolving issues with the Yates Shaft. This impressive performance includes maintaining a well-above average safety record. Recent issues with dust release from the open cut do not pose additional environmental or health hazards. However, LBNF/DUNE requires broad public approval. Potential cost and reputation impacts and its mitigation should be monitored and mitigated carefully.

The LBNC greatly appreciates the new CD-1RR reference funding profile and any other initiatives to bring project execution closer to the technically limited schedule. With the present profile, project completion can be accomplished 1-2 years earlier as compared to the previous reference profile.

The US-DOE ND subproject TPC has been capped at $200M (including $20M already spent). This budget is deemed to include 50% scope contingency. While the exact impact of this cap and contingency on the physics performance of the project is under study, it is existential to maintain critical ND functionality as a core ingredient to success for LBNF/DUNE. The practicalities of how to release unused contingency on the threshold scope into delivery of the objective scope needs careful discussion, as does the optimum way to use the DUNE international consortium resources.

The need for a mandated contingency on yearly obligations poses the risk that progress is slowed down “artificially” if risks don’t materialize. Once the project is in full swing, this contingency will hopefully develop into a sliding buffer using appropriate contingency release mechanisms. The Build to Cost strategy is a good step towards controlling costs, but automatically implies the need to define viable and substantial scope contingency and a contingency release mechanism.

The impact of supply chain, commodity costs and Russian contribution issues are on everybody's minds but have not been assessed systematically for all parts of the project.

The LBNF/DUNE organization has been refined. The new structure is considered an improvement and is a pragmatic recognition of the way the experiment and facility projects are structured and financed. The individual responsibilities and interfaces of each block in the

organization chart need to be clearly defined and delineated. However, deficiencies in the hostlab and project interfaces to the international project remain. The LBNF/DUNE project and the International DUNE Collaboration are encouraged to consider and propose further pragmatic ways to improve the situation.

The project has appointed a new project manager, Kurt Vetter. This answers the recommendation from the December 2021 LBNC meeting to “prioritize the search for a new project manager.”

Recommendation:

1. Conduct a systematic analysis of budget and schedule risks arising from the current geopolitical and geoeconomic situation. Develop mitigation actions where available and present the result at the next LBNC meeting.

Beamline Status and Progress

The LBNC congratulates the team for the recent progress. Horn and target prototyping is ongoing, the UK has successfully secured funding for the full scope of commitment to the LBNF beamline, the Hadron Absorber has passed a Director's Review, designs are progressing, planning appears reasonable, and a CD-2 IPR is planned for late 2023.
The near site conventional facilities design is complete, but construction will not begin for several years. The long idle time prior to the start of construction may be problematic with respect to potentially needed changes as technical systems designs mature, cost escalation, and staff turnover. (The people who presided over the design may no longer be on the project when construction begins.)

An independent cost estimate in February supported the accuracy of the near site conventional facilities cost estimate. However, it has been observed at other laboratories that actual construction contract costs are coming in significantly higher than estimated, especially within the current international boundary conditions.

Several workforce challenges were presented where lead engineers have departed (horns, target shield pile, power supplies, and beam windows). This will likely be an ongoing challenge, in part due to the protracted schedule of the project and idle periods. Retirements will also present challenges over the life of the project. Several risk registry entries to the effect of budget and schedule risks caused by personnel turnover have been communicated to the committee after the meeting.

Recommendations: none

Beam Delivery Planning

The LBNC heard a report which laid out the plans for ramp up from zero, once PIP-II and the Beamline are operational

Two timelines have been presented, one for the technically limited schedule and a second one for the previous reference funding profile. In discussions after the presentation, credible arguments have been presented to the LBNC that the new CD-1RR reference funding profile can be accommodated. The accelerator power ramp-up to 1.2 MW appears reasonable and fits with PIP-II plans.

Recommendations:

1. Within 3 months, develop the details of the accelerator power ramp-up and tie-in plans following the newest funding boundary conditions.

DUNE Status

The LBNC commends DUNE for the very good progress on several fronts, outlined below:

- ProtoDUNE analysis and publication status and planning.
- ProtoDUNE-II planning and early installation activities, which are already taking place at CERN.
- FD2-VD regarding R&D, prototyping, simulation, and on refining and advancing the ProtoDUNE-VD plan.
- the Snowmass effort, which yielded several interesting white papers, and a clear and strong physics message to the community regarding the updated DUNE physics capabilities and phased approach to achieve them. To that end LBNC suggests that DUNE refines the phased approach, working out details on the timeline of the various elements that will be upgraded [beam, ND, FD].
- the ND-TMS Consortium formation, as well as on software and analysis.
- the ND-LAr design, with the use of data collected and analyzed with the first module for the 2x2 demonstrator, simulation and reconstruction, as well as plans to start taking data with 2x2 @NUMI at the end of 2022
- the SAND consortium organization, as well as advancements in identifying the needed financial and human resources

The LBNC commends DUNE for continuing to improve the organization and overall management structure. LBNC encourages DUNE to ensure that the responsibilities of the DUNE Collaboration Management and the DUNE-US project are clearly and unambiguously defined, and are communicated clearly and promptly to all stakeholders. The LBNC also urges the Collaboration and the US project to act synergistically.

The LBNC encourages DUNE to assess the impact of the unfortunate, significant conflict in Europe and develop clear mitigation plans where necessary, including identifying possible supply chain issues with a plan to address them.

The LBNC welcomes the improved DUNE timeline for the start of physics runs, which is important for retaining DUNE's role as a world-class neutrino oscillation experiment. To that end LBNC commends all parties that contributed in achieving this, but notes that further advancement of the funding profile would be highly desirable since it would further improve the competitiveness of DUNE.

The LBNC would like to reemphasize the importance of controlling and reducing the main systematic uncertainties for the success of the DUNE neutrino oscillation physics program in

both Phase I and Phase II. These systematics are related with the knowledge of neutrino cross sections in argon, the knowledge of the un-oscillated neutrino flux, and the estimation of possibly different detector effects between the ND and the FD.

The LBNC restates that the synergistic and complementary approach the DUNE experiment has developed for the ND complex during the past years should be pursued in order for DUNE to be able to achieve its main physics goals. This two-detector approach is well established, utilized by all previous long baseline neutrino oscillation experiments, and targets both the cancellation of systematic uncertainties with DUNE-PRISM using two functionally identical Near and Far detectors with ND-LAr, and their minimization providing strong constraints.

Given the above, the LBNC notes that attempts to descope the DUNE ND could potentially seriously harm the physics capabilities of the experiment. The LBNC urges DUNE to continue to seek and secure international contributions for the ND detector complex for both Phase I and Phase II.

Recommendations: none

Physics and Systematic Uncertainties

DUNE gave a presentation reviewing its approach to systematics and how the near detector is essential to minimizing them. We were very interested to see a clear articulation of how the sensitivity of the oscillation measurement is affected by systematics and how the near detector constrains them.

The neutrino flux and detector response systematics are well defined, but cross section systematics are more complex. Multiple interaction channels with complicated kinematics impact the measured neutrino energy, and cross section uncertainties can alter the shape of the energy spectrum. Multibody nuclear effects force reliance on empirical models, tuned to data, that commonly disagree with new data. The models themselves are uncertain, even in how to parametrize them. All of these considerations require a multi-faceted and flexible near detector. It is worth emphasizing that DUNE must control systematics to a more stringent requirement than previous neutrino oscillation experiments.

DUNE's near detector design was chosen to minimize the effects of potentially large cross-system uncertainties such as cross section differences between iron and argon, which are potentially large but don't need to be evaluated if DUNE has a LAr TPC for its ND. The PRISM technique is designed to reduce sensitivity to the choice of the neutrino interaction model by taking advantage of the variation of the neutrino energy spectrum with off-axis angle in a way that breaks degeneracies between flux and cross section uncertainties. The LBNC repeats its endorsement of DUNE's near detector concept for Day 1, consisting of ND-LAr, TMS, PRISM, and the SAND on-axis beam monitor. We believe that the case for this is compelling.

Significant effort has already been spent optimizing the existing design. At this stage we do not feel that there is much to be learned by considering radically different options or descopes, nor do we think that a significantly less capable near detector would allow DUNE to produce oscillation results even in its earliest phase.

Comments:

In terms of explaining the importance of the near detector to non-experts, emphasizing how DUNE's ND concept relies on the use of LAr TPCs (similar to the FD) and the PRISM approach to minimize sensitivity to unknown systematics may be more effective than stressing how hard it is to provide a full, detailed evaluation of systematics on a short timescale.

It would be helpful to show some illustrative examples of how different ND detector technologies could yield cross section and reconstruction systematics that are not constrained and/or canceled between ND and FD, and hence have a large impact in the final sensitivities. Such an illustrative example is the one already presented where TMS is the only ND element, and sensitivity was thus limited by iron to argon scaling uncertainties.

The LBNC remains convinced that ND-LAr and PRISM are essential parts of the ND detector suite and any potential reduction in scope may seriously jeopardize the physics potential of the experiment, even in its initial stage.

The Near Detector plenary talk included a nice, easily understood table showing various alternative configurations for the ND-LAr. Such a table may be a good way to present things for CD1RR.

Recommendations: none

FD Horizontal Drift

The LBNC commends the collaboration on the continued excellent progress on Far Detector 1 - Horizontal Drift (FD1-HD).

Preparations are continuing well for ProtoDune-II (PD-II). Supply chain issues are causing some concerns, and the PD-II critical path is now set by delayed deliveries of cold cables. The current schedule is dense, including working on 3 APAs in the clean room at the same time, and has PD-II cooled down in early November. However, there exists some flexibility, since much of the "Module 0" demonstration can be achieved without beam, plus beam operations can be extended into 2023.

After a successful test in the CERN ColdBox of the first production APA, which was equipped for this test with the previous cold electronics, the PRR for the APAs was held in the UK on Mar. 1-2. It is anticipated that the signoff to launch full APA production will come in April, which is important since the APAs are on the critical path for FD1.

The APA production schedule has only 3-4 months of float. While it was stated that the APA production in the US provides some contingency to recover from delays if needed, the small float remains a concern for a schedule that stretches over about 5 years.

Demonstration of the APA transportation frame continues to progress, with encouraging measurements during recent shipments from CERN to Liverpool, and plans to ship soon to the US. The final decision of shipping by sea or air remains under consideration; this is an important issue that should be decided soon.

During the ColdBox APA test, some cold electronics channels were damaged. This has been understood to have occured during some operations with non-standard conditions applied. While we were pleased to hear that the lessons learned have been incorporated into updated written procedures, to prevent any such incidents in the future, we note with concern that this is not the first incident in the project to lead to damage to cold electronics.

After successfully holding the FDR for the cold ASICs in July, engineering runs were launched for all 3 ASICs. This was a key step to have sufficient chips for use in PD-II.

The LArASIC FE chip is produced in 180 nm CMOS from TSMC, a rather mature process. A recent notice from IMEC stated they will soon cease access to this process. While LArASIC is ordered via MOSIS, which has not made a similar statement, this issue is clearly a concern. The collaboration held the PRR for LArASIC on Mar. 7-8, and is working with DOE to find a

process to submit the full production (for both FD1 and also the bottom of FD2) soon, in advance of the CD-3A approval.

The ongoing geopolitical global supply chain issues will require continued close attention and proactive efforts to try minimize and mitigate resultant delays and/or cost increases.

We were pleased to receive a draft list of FD1 milestones. Some LBNC feedback was already received and incorporated. We look forward to seeing a complete list including milestones linked into the installation schedule, that can be useful to track future FD1 progress.

The PD-II plan incorporates tests of both laser and pulsed neutron calibration systems, which should help inform finalization of the calibration plans for FD1. We heard briefly that the production of the PDS needed for PD-II is also proceeding. The LBNC requests an update on these systems at a future meeting.

Recommendations:

Continue to work toward achieving an early submission of the order for the full LArASIC production (for both FD1 and FD2), to avoid any potential loss of access to this critical technology.

Continue to work on trying to increase the FD1 schedule float.

FD2 Vertical Drift

The LBNC continues to be impressed with the swift and successful progress on R&D for the Vertical Drift Far Detector. Parallel efforts at the NP02 cryostat, the coldbox at CERN, and the 50-liter test stands all advanced the design of the VD detector.

At the large NP02 cryostat, most of the focus was on HV tests. A detailed failure analysis was carried out of the HV feedthrough cable that failed in the Fall 2021 run. It appears to be related to mechanical stress in excess of specifications; official reports will be made available shortly. A second run followed in Jan-Feb with HV extender and 6m drift depth in operating the system at 290kV-300kV. The system was quite stable with an uptime around 99.9%. The results were similar to those of Fall 2021 but with higher LAr purity (>3 ms), and recording of tracks traversing the 6m depth. More than 1M events (120 TB) were collected. Two new types of HV flashes were observed. They were not around the extender as had been observed in the previous run, nor were they near the transparent field cage. They had a short duration and little effect on HV. Some hypotheses exist, to be verified after LAr venting.

In the coldbox test, the highlight was the operation of the x-ARAPUCA photon detectors on the cathode and on the membrane with Power-over-fiber and Signal-over-fiber. The cathode was biased up to 10 kV with no ill effects on the operation of the photon detectors. Since the baseline design includes photon detectors placed on the cathode at 300 kV, this first test was critical to validating this design choice. The performance of the top drift electronics was also tested. Investigations into coherent noise and microphonic noise revealed grounding issues and a poor contact on bias connection; these problems are now believed to be understood. For the bottom drift electronics, improved grounding and filtering were implemented and the noise performance was on par with the one of the FD1 APA.

The 50-liter test stand was operated for ten days of data taking in February. A primary goal of this test was to assess the +30°,-30°,90° strip orientation for the charge readout planes. The results were generally as expected, aside from some dead strips due to problems with edge connectors particular to the 50-liter set up; the problem is now believed to be fixed for future use of the setup. This test was also used to develop a method to reduce coherent noise.

The simulation effort showed great progress compared to the previous LBNC meeting. New people joined the effort and the VD simulation appears to have a higher priority in DUNE compared to previous reviews. A large Monte Carlo sample was generated for charge readout in the VD configuration. The analysis already shows reconstruction efficiency comparable to HD with further optimization possible. The same sample was used to train a convolutional neural net (CVN) to identify different categories of events. Again, the results are comparable to HD. The PDS signal simulation was implemented in the LArsoft framework for the VD detector with a default placement of x-ARAPUCA detectors on the cathode and the membrane. Investigations were made of the light yield map, energy calibration, dynamic range of signals, and SNB trigger efficiency. The workflow was mapped out for studies needed for the technical design report (TDR), including comparisons among different possible configurations of photon detectors and simulation of backgrounds. In general, the pace of the simulation work is going well, but there are several substantial studies to complete in the next few months to be ready for the TDR.

LBNC had asked for clarification to two questions that were raised in the CDR review in 2021, and these were satisfactorily answered. The VD management and the LBNC agreed on a schedule for review of the FD2-VD TDR. The full TDR is to be submitted to LBNC in September 2022, but drafts of chapters may be released earlier to obtain feedback from the LBNC reviewers.

In discussing supply chain issues, the FD2-VD team identified an immediate concern with SiPMs needed for upcoming tests. Issues for the production phase should be considered as well, as some mitigating action can happen well in advance.

Recommendation:

The LBNC recommends closely coordinating the simulation efforts with the design efforts to complete the studies that are needed for the TDR.

Near Detector

New funding guidance from DOE limits US scope for the near detector to $200M, of which $20M has already been spent. Of the remaining $180M, $90M is directed toward meeting threshold KPPs and $90M for objective KPPs. For comparison, the US scope for DUNE's Day 1 detector design was costed at $283M.

Proposed threshold KPPs would consist of beam monitoring only and general ND infrastructure. The objective KPP scope maps to Phase 1 physics goals, and is necessary to do any oscillation physics measurements, even with limited statistics.

In response to these severe funding constraints, DUNE has done an alternative design analysis exercise to consider other ND configurations. Alternate configurations for ND-LAr, including re-using SBND and/or its cryostat, seem not to be viable in terms of physics performance. The thickness of the SBND cryostat would degrade the momentum resolution of the ND-LAr+TMS significantly if that cryostat were used for DUNE. Keeping the current ND-LAr setup but reducing the number of TPC modules might be possible, but would compromise the physics performance of what is ultimately a systematics-limited experiment, and is not advisable.

DUNE has formed a TMS consortium, as recommended by the LBNC. Simulation studies of the TMS have advanced noticeably, and the performance looks as expected. The Threshold KPP scope of having just TMS, acting as a beam monitor, imposes new requirements on TMS. It seems that TMS can detect changes in beam conditions with just a few hours of data, but provides less information than SAND and cannot quickly determine the cause of the changes. TMS by itself without ND-LAr and PRISM would not allow DUNE to make any credible oscillation measurements.

ND-LAr plans a Preliminary Design Review in summer 2022. Analysis of data from the first module for the 2x2 demonstrator continues, with publication pending. The second module was successfully run in February. Work at FNAL to prepare for the 2x2 neutrino beam test is proceeding, with data-taking to start in late 2022. Preparations are starting for the full size demonstrator. Supply chain issues, esp. on ASICs, are occurring on the charge readout electronics, and are being monitored.

SAND is organizing subsystem working groups. STT prototyping tests are planned for mid-2022, and preparatory work has begun for refurbishing the KLOE magnet and ECAL and their relocation to FNAL.

DUNE recently held an internal review of SAND's liquid argon target (GRAIN). That review found that GRAIN cannot replace ND-LAr+TMS but perhaps could provide complementary functionality. Additional effort is needed to demonstrate the physics case for GRAIN, the impact

on the beam monitoring (esp. energy resolution) and to develop the project plan. The internal review produced many significant recommendations for further study.

Comments:

- ND-LAr is necessary for DUNE's ND to have comparable functionality to the FD, matching both the target nucleus and the detector response. This is a requirement for relating neutrino energy measurements at the ND and FD, and hence for oscillation analyses.
- All of DUNE's oscillation physics program *requires* a capable ND including LAr TPCs with a muon spectrometer, an on-axis beam monitor, and the ability to move detectors off-axis. The Threshold KPP is not sufficient to achieve DUNE's physics goals or even to do oscillation physics with limited statistics. Significant descoping of the ND is not an option, even for the initial period of running.

Recommendations:

- All stakeholders should 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 to improve the efficiency in running distributed computing operations. The production activities leverage computing and storage resources worldwide effectively. The development of new monitoring tools to support those activities was very welcome news. In particular we are happy to see that DUNE now monitors the efficiency of processing jobs with respect to data locality, which addresses a previous LBNC concern. We congratulate DUNE for this success. The impact of the war in Ukraine on computing seems low at the moment. We encourage the collaboration to continue monitoring the situation closely.

We are pleased to see the injection of new person-power in key areas of DUNE Computing. Particularly, more effort is now available for the new software framework R&D work. We understand from the discussion that a decision with respect to the framework to adopt or develop has not been taken yet. We also understand that the R&D work in progress is general and can be integrated easily in any framework, making that choice not urgent. We note that taking a decision relatively late has the advantage of enabling the use of more modern technologies but at the same time puts pressure on the community integrating the algorithms. Communication with the algorithms developers will be essential to ensure the convergence of this work in a usable system. We expect that the Software Liaison will play a key role ensuring it.

DUNE made a lot of progress in the area of data management services. We learned about the new developments replacing the monolithic SAM system with a modular set of services. The adoption of well established technologies in HEP such as Rucio, integrated with newly developed solutions for the specific needs of DUNE seems a balanced strategy. At the same time we learned that DUNE developed a lightweight Workload Management system, tailored to its needs. The use of a custom system might present future challenges in terms of maintainability and we suggest DUNE considers them carefully.

We support the protoDUNE Run-II computing commissioning program through a series of data challenges. The first phase of the data challenges will be important to test the newly developed and integrated set of data management services, commented on in the previous paragraph. The second phase will challenge the distributed processing capabilities of DUNE and again the newly developed tools. We suggest clear targets be defined and documented early in the process and that all aspects of data processing be tested. We also invite DUNE to ensure that the challenge is a realistic test for future data taking and we understand this will need some early preparation with the DAQ community. We expect to hear the findings of the data challenges at the next meeting.

The database team presented a credible roadmap towards protoDUNE Run II. Most of the databases are in place, with the one for the SlowControl information requiring more attention. The challenges for this later one are not just technical, but also in terms of engagement of the user community in need of Slow Control information. The system for DUNE will look different because of technology and scale: enough planning in defining the interactions and enough effort should be foreseen early on for this transition.

We expect the CDR to be delivered by early Spring 2022 as planned.

Recommendations: none

ProtoDUNE Analysis and Publications

DUNE has an active physics analysis program and has made good progress on the analysis of the protoDUNE data. Thus far, two papers have been published, three analyses are under paper review and twenty analyses are under development and mostly at a similar stage of development. It is important to maintain momentum on all these efforts and ensure timely completion of all these analyses.

We are pleased to see that a number of the results are in the process of being used to tune the simulation. The recombination and diffusion results are found to be consistent with previous measurements. We note the change in the measurement of the cosmic ray muon rate compared to the results shown at the LBNC meeting in December.

We are happy to see that seven students have graduated based on the ProtoDUNE data. However, it is important that the analysis work be consolidated by publication. Unpublished results effectively don't exist, therefore, we encourage DUNE to complete the publication of the ongoing analyses soon. This will ensure adequate time for preparation of the data analyses based on the ProtoDUNE run II data.

Recommendations: none

Neutrino Cost Group

The Neutrino Cost Group was established to review the management, cost, schedule and risks of the DUNE experiment. This is a separate review from the DOE project review, focusing on the overall international project. It is largely complementary to the scientific-technical review carried out by LBNC.

The review of the FD1 was initiated in November 2021 and is ongoing. This is an asynchronous process with some iterations with the collaboration to obtain all the relevant material. The NCG has found it challenging to ensure uniformity across consortia and access all the required material, which has led to some delays with respect to the initially planned report schedule.

To ensure uniformity across different accounting systems of contributors, the NCG evaluates separately and in combination the CORE costs, the person-power effort, and the schedule.

Although the NCG review is mostly uncoupled from the DOE reviews of the US project, it is expected to provide useful input especially in terms of risks associated with international contributions.

FD2 and ND reviews are planned next, hoping for a smoother process, although a specific schedule for these reviews has not been set.

Comments

It is the first time that the LBNC hears a report from the NCG. It will be useful to hear regular updates on the process.

The methodology was adapted from other international contexts such as CERN and seems sound and effective to examine the entirety of the DUNE project.

The asynchronous organization and the relatively small committee membership may be limiting factors in the review process and prevent the timely delivery of the reports.

A more traditional, synchronous, approach to the review and availability of material could be considered to improve efficiency and avoid the dilution of the work. Direct and intense contact with experts while the committee digs into cost books and basis of estimates can provide invaluable insight in the reliability of the estimates.

It may be useful to foresee a follow-up process after the first review so that the same evaluation methodology can be used by the NCG to track the project progress during the execution phase. Although full EVM is not amenable to be applied to such international projects, milestone tracking over time has been proven to be effective in detecting issues and delays.

Recommendations: none

Appendix I: Attendees

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

Scientific Secretary: Angela Fava, Joseph Zenamo

Fermilab PAC Chair: Hirohisa Tanaka

DUNE/LBNF (based mainly on registration: Sergio Bertolucci, Regina Rameika, Stefan Soldner-Rembold, Chris Mossey, Rizwan Ahmed, Benjamin Aimard, Dario Autiero, Chris Backhouse, Giorgio Bellettini, Doug Benjamin, Paolo Bernardini, Mary Bishai, Janet Bishop, Ed Blucher, Tim Bolton, Alan Bross, Norm Buchanan, Fabien Cavalier, Flavio Cavanna, David Christian, Stefano Di Falco, Lea Di Noto, Dominique Duchesneau, Kevin Fahey, Jack Fowler, Vyacheslav Galymov, Ines Gil-Botella, Takuya Hasegawa, Maxine Hronek, Eric James, Thomas Junk, Steve Kettell, Michael Kirby, Paul Laycock, Thomas LeCompte, Jonathan Lewis, Cheng-Ju Lin, Jolie Macier, Daniela Macina, Andrew McNab, Alberto Marchionni, Camillo Mariani, Franciole Marinho, Chris Marshall, Andrew Mastbaum, James Mateyack, William Miller, Tanaz Mohayai, Claudio Silverio Montanari, Giovanna Lehmann Miotto, Marzio Nessi, Sandro Palestini, Saba Parsa, Laura Patrizii, Laura Paulucci, Elisabetta Pennacchio, Roberto Petti, Luke Pickering, Francesco Pietropaolo, Michele Pozzato, Véronique Puill, Jennifer Raaf, Ron Ray, Filippo Resnati, Ryan Rivera, Paola Sala, Heidi Schellman, Ettore Segreto, Theresa Shaw, Vladimir Tishchenko, Gabriele Sirri, Luca Stanco, Matteo Tenti, Steven Timm, Christos Touramanis, Serhan Tufanli, Marco Verzocchi, David Warner, Alfons Weber, Michele Weber, Callum Wilkinson, Tingjun Yang, Bo Yu, Jaehoon Yu, Sam Zeller

FNAL Directorate/Management:Nigel Lockyer, Joseph Lykken, Kevin Pitts, Gregory Bock

DUNE RRB: Alison Markovitz

DOE: Adam Bihary, David Lissauer, Simona Rolli

Appendix II:

Charge Letter: LBNC March 2022 Review, March 28-30, 2022

10-Mar-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 Spring 2022 meeting, the LBNC will again meet virtually 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. Detector and beamline construction sequencing implies a particular approach to addressing the systematic uncertainties in the neutrino oscillation measurements. DUNE is asked to articulate their current strategy. The LBNC should comment on this approach.

As design and construction decisions are made by partners contributing to this effort, the LBNC should comment on scope, timeline, and physics performance of these changes. 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 a) planned accelerator commissioning and beam intensity profile and b) a presentation on ProtoDUNE analysis and progress toward publications. And following its recent review of Far Detector 1, the Neutrino Cost Group should provide a brief report.

The LBNC should also review progress on computing and the Computing CDR, as well as other relevant documents that are under development.

The LBNC should develop a Closeout Report which it should deliver at 12:15 CST on March 30, 2022. Subsequently this should be refined into a LBNC Meeting report.

Appendix III: Assignments

LBNF Status (Progress, Plans and Org)	**Gottberg**, Aleksa, Ball, Champion
Beam Delivery	**Gotberg,** Champion, Saoulidou
DUNE Status	**Saoulidou**, Gray, Kopp, Bortoletto
Physics and Systematic Uncertainties	**Oser**, Gray, Kopp, Para, Saoulidou
FD1 Horizontal Drift	**Parsons,** Ball, Behnke, Majumder, Rumerio
FD2 Vertical Drift	**Wood**, Aleksa, Forti, Kajfasz, Para, Rescigno
Near Detector	**Oser**, Kopp, Saoulidou, Bortoletto
Computing (inc CDR Status)	**Campana**, Gray**,** Rusu
ProtoDUNE Analyses	**Gray**, Campana, Rescigno, Rusu
Neutrino Cost Group	**Forti**, Behnke, Bortoletto, Kajfasz

Breakouts

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