
LBNC Meeting Report



June 5-7, 2024

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Introduction

The LBNC met remotely on June 5-7th, 2024.

The attendees at the meeting, shown in Appendix I, included LBNC members and consultants, DUNE Collaboration spokespeople, Mary Bishai and Sergio Bertolucci, the interim LBNF/DUNE-US Project Director, Ron Ray, and several LBNF/DUNE members, the Fermilab Deputy Director for Science and Technology and CRO, Bonnie Fleming, the Head of the Fermilab DUNE Coordination Office, Steve Brice, the Chair of the Neutrino Scope Group, Dmitri Denisov, and representatives of the US DOE.

The LBNC is a review and advisory committee charged by and reporting to the Fermilab Director. The charge includes making recommendations concerning the Conceptual and Technical Design Reports for DUNE to the Director. The LBNC reviews DUNE from a scientific, technical, schedule, risk and management perspective while the Neutrino Scope Group reviews the scope and schedule associated with DUNE construction. Specifically, the purpose of the LBNC is to review the scientific, technical, schedule, risk and management plans and decisions of the DUNE experiment, and to provide reports and recommendations to the Fermilab Director; the reports are made available to the DUNE Collaboration, LBNF/DUNE-US Project and the DUNE RRB. The LBNC scope does not include a review of LBNF or PIP-II beyond the relevant interfaces impacting DUNE, as these projects are reviewed through the U.S. project management process. The status and progress of LBNF and PIP-II relevant to the LBNC charges are summarized in 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 charge for this meeting, prepared by the Deputy Director for Science and Technology, is shown in Appendix II.

For each meeting the LBNC is organized into small groups which concentrate on particular components of the presentations and the discussions. 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 general meetings a year and intermediate shorter and targeted reviews as the need arises. 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. 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. LBNC thanks Fermilab, its Directorate, and its support staff, for their assistance and support in making this meeting possible and productive.

Executive Summary

LBNC commends LBNF/DUNE for significant progress made on : i) the completion of the caverns, ii) the advancements on the nitrogen system, iii) the arrival of cryostat steel and the plans for assembly underground in 2025, iv) the planning for detector component arrivals at 2026, v) the planning of Near Site construction beginning on 2025, vi) the significant efforts made towards attracting the needed and appropriate workforce for the FD installations, and vii) NSCF and Beamline with an anticipated DOE CD2/3 review in October 2024 for NSCF and in 2025 for the Beamline.

At the next LBNC meeting, the committee would like to better understand the required level of beam monitoring needed for a) proper operations and programmatic issues related with target and horn replacements, and b) keeping systematics at the desired level needed for the oscillation analysis and for achieving the main DUNE physics goals. Related to this, LBNC would like to also understand the interplay, complementarity and redundancy of the beam monitoring capabilities of beamline devices, SAND and ND-LAr+TMS.

LBNC notes that there are several uncertainties related with the finalization of major contributions from international partners, the FDC contingency and the increase of total project cost. LBNC is looking forward to mitigation strategies and assessment of their impact by all involved parties. LBNC understands the reasoning for the separation of NSCF and Beamline projects, and hopes this does not introduce further delays.

LBNC is pleased to see significant progress made on the APA production, with the formation of a dedicated FDC-EB, including expertise from lead scientists and engineers. LBNC is looking forward to the advancement and formalization of detailed QA-QC procedures, at production, before installation, and during installation and cool down that would hopefully mitigate several of the issues encountered. LBNC is also anticipating understanding and resolution of issues seen with ProtoDUNE-HD II operations.

LBNC commends DUNE for progress made on FD-VD and is eagerly awaiting ProtoDUNE-VD operations with and without beam. LBNC notes that time is short and therefore would like to see a plan of how lessons learned from ProtoDUNE-VD operations will be incorporated in the final design. LBNC expects a similar level of attention and effort on development, documentation and formalization of QA-QC procedures as is now being planned for FD-HD.

LBNC is pleased to see advancements on all fronts related with the ND. LBNC commends DUNE for a significantly improved, in terms of clarity and focus, ND physics requirements and goals document. LBNC is very happy to see progress on 2x2 and the full scale prototypes, and is eagerly awaiting analysis of the first neutrino data.

LBNC is happy to see progress made on the ND TMS and SAND, despite difficulties related with the current ND cost cap, but would very much welcome more clear and concrete steps towards finalizing the design, prototyping and a tentative timeline for construction.

LBNC acknowledges the advancements on the simulation, reconstruction and analysis software,

but would like to stress that additional personpower that would allow for parallelizing rather than serializing efforts and progress on the various tasks is essential, and would like to urge DUNE to make every effort towards this direction. LBNC is eagerly awaiting for a complete oscillation analysis with ND and FD reconstructed data, with perhaps more than one complementary approach. LBNC commends DUNE on progress made on the atmospheric and low energy neutrino analysis and is very happy to see continuous production of impactful physics papers.

LBNC commends DUNE for the advancement of the structure of DUNE computing and the addition of new members. LBNC is looking forward to seeing the performance of the computing system on the upcoming data-taking campaigns. LBNC notes that the efforts on Core Software Framework need to be secured and strengthened.

LBNC is very positively surprised with the significant progress made towards defining a baseline of Phase II FD and ND, with concepts being developed, R&D goals identified and evolving plans for prototyping. LBNC is looking forward to the DUNE Phase II White Paper.

LBNC notes that significant progress has been made towards addressing previous recommendations and would like to see the recommendation planning document updated to reflect this.

LBNC acknowledges all the effort and time DUNE and LBNF/DUNE invest in producing and delivering complete and clear presentations but would like to emphasize that these need to be made available at least six days in advance in order for the committee to be able to better fulfill its charge.

LBNF Status

Findings: Jim Kerby, who has been leading the APS-U project at Argonne, has accepted the position of project director for LBNF/DUNE.

DOE has requested that Near Site Conventional Facilities and Beamline (NSCF+B) be split into two subprojects, thereby bringing the total number of subprojects to six.

The Far Detectors and Cryogenic Infrastructure (FDC) subproject is scheduled for a CD-2/3 IPR in October 2024. The Beamline subproject CD-2/3 IPR is not yet scheduled but is projected to be conducted in calendar year 2025.

Excavation at the far site is complete, and some unused contingency will be returned to the project. Safety performance at the far site is better than industry standards. The crane rails installed in the far site caverns were incorrectly specified and will be retrofitted with additional rails. It is a matter of tolerancing, not load capacity. The far site nitrogen liquefaction unit trains require more power than expected. If a 4th train is required, utility upgrades will be needed. The FD1 cryostat steel is enroute to the far site from Europe. Employment outreach is being conducted to attract needed staff to the far site.

A delegation from Fermilab and DOE visited Brazil and received verbal assurance that Brazil will support its in-kind cryogenic contribution. Written commitments are expected by the end of June 2024.

Full funding of \$255M was received for FY2024. The funding profile calls for \$305M for FY2025, but the president's budget requested only \$280M. Contingency for the far site Building and Site Infrastructure (BSI) subproject was reported to be too low. The FDC subproject costs have escalated, and its Total Project Cost will have to increase.

The long shutdown schedule will likely be changed with no impact on the schedule for first beam to DUNE.

Comments: The committee appreciates the presentations and discussion and congratulates the project on progress since the previous meeting. The selection of a project director is a welcome development.

Splitting NSCF+B into two subprojects is workable, but a CD-3x approach could have been used to get started on the NSCF scope instead. The subproject approach introduces project management overhead and may raise issues regarding project execution plans, reporting, contingency management, key performance parameters, and review preparation and scheduling.

The crane rail situation at the far site is unfortunate, and mitigation will be costly. All efforts should be made to prevent future mismatches in code requirements. For example, a rigorous approach to applying additional engineering review on procurements and subcontracts may be beneficial.

Recommendations:

1. Consider the use of financial incentives for on-time completion of conventional facilities work for the BSI and NSCF subprojects. This may also be helpful in attracting additional bidders.

DUNE Status

Findings: LBNC is happy to see that US panels, HEPAP and P5, fully endorse DUNE Phase I and Phase II as an absolutely central experiment and facility, with Phase I components (detector and beam related) characterized as ready to initiate construction, i.e. beyond the basic R&D stage. This is a significant accomplishment primarily of the DUNE Collaboration and the LBNF/DUNE project.

LBNC commends DUNE for the ongoing efforts to organize and implement a common fund and an in-kind contribution approach. LBNC welcomes the updates on the DUNE management structure, with the notable addition of an FDC Executive Board and two deputy FD and VD technical coordinators.

LBNC is happy to see significant progress made on the APA production factories with the formation of a management board to oversee production in the two sites, including expertise from lead scientists and engineers. LBNC is happy to see progress made on FD-VD on several fronts, and in preparation for ProtoDUNE-VD operations. LBNC acknowledges the usefulness and importance of the full scale test of the FD-VD installation at CERN.

LBNC is happy to see data coming out of ProtoDUNE-HD II, and commends DUNE for

adopting a more detailed approach on examining and documenting detector performance. LBNC commends DUNE for the great progress made towards updating the requirements and goals of the DUNE-ND for Phase I, and welcomes a notional timeline with AUP of the ND hall in the second half of 2028.

LBNC is pleased to see that the 2X2 ND Prototype is geared towards taking first neutrino data with the NUMI beam in a few days from now, and the progress made on the Full Scale Demonstrate, the two key elements for the final design of ND-LAr. LBNC welcomes progress made towards advancing the DUNE simulation, reconstruction and analysis software for the various different detectors. LBNC is also happy to see progress made towards a full oscillation analysis using both ND and FD data.

Comments: LBNC finds the continuous, smaller or bigger, problems on APA construction and operation in ProtoDUNE-II somewhat worrisome and would like to see detailed mitigation strategies.

LBNC is somewhat worried about the lack of the needed personpower in simulation, reconstruction and analysis software, that would allow various important projects to be pursued in parallel, rather than serially.

LBNC would like to see advancements towards a final design for ND TMS and SAND, on the level of maturity shown for ND-LAr.

We were given the impression that the MCND is on a similar trajectory, timewise, as FD4. This is somewhat surprising and worrisome given the perceived potential of the MCND to expand the DUNE scope and sensitivity to new phenomena.

Recommendations:

1. LBNC would like to see an update, for information only, on the common fund and in-kind contribution evolution from the DUNE collaboration in the next LBNC meeting. LBNC would also like to hear advancements on major contributions from all partners.
2. LBNC would like to see a detailed report from the newly formed FDC-EB and the VD and HD technical coordinators on the APA construction progress and status, and on the resolution and understanding of ProtoDUNE-HD II issues.
3. LBNC would welcome a detailed report in the next meeting of the validation of the APA assembly line that will take place this Summer. LBNC would also like to see a detailed description of the QA&QC procedures followed for both the HD and the VD components, and their installation and operations in ProtoDUNES.
4. LBNC would like to receive progress and status updates on a full oscillation analysis including DUNE-ND for Phase I, which is a critical component for evaluating its performance in terms of achieving the Phase I (and later Phase II) physics goals.

FD2 Vertical Drift

Findings: The collaboration continues making rapid progress in preparation for the Protodune II and development of plans for the full scale production and subsequent installation of the FD2.

A full scale Installation Test Platform is being constructed at CERN to rehearse the FD2 installation process. LBNC commends this development.

Several technical developments have been reported with the CRP 6: new anode production process tested in coldbox in April 2024, further tests planned in June and September.

PDS Long Module-1 has been tested in coldbox and revalidated in April to certify the final version of cathode electronics to be used in ProtoDUNE-VD.

As an important milestone the delivery of 300 kV 6m below the liquid level demonstrated.

Several pre-production elements have been tested in coldbox and installed in ND02: 2 top CRPs, 2 bottom CRPs, 2 cathodes, 8 x-Arapuca and 70% field cage.

Upgrades of cathode PDS electronics are ongoing.

Significant progress is being made with CRP6 value engineering: the ground plane has been , as well as the edge cards.

DAPHNE DAQ system is being prepared for the readout of the PDS.

Longevity testing of optoelectronic components has been started. LBNS considers this a very important development.

Major progress has been demonstrated in the preparation for the accelerated production for the FD2:

- resources have been identified for the filter coating and SiPM testing
- resources of the Brazilian site are considered to be redirected towards the construction of FD2,
- many French deliverables have been executed and
- 2nd CRP factory site in US has been identified

Significant progress has been reported on development and validation of a calibration procedure using a pulsed neutron source

Comments: LBNC commends the team for the progress in the installation of the TPC and the PDS in the NP02. The operation of the ProtoDUNE VD detector in early 2025 remains to be on the critical path for the timely construction of the FD2 at the Sanford Lab with no room for any significant mishaps.

The progress towards the production and installation readiness is rapid and very impressive. The

Installation Test Platform should be a very valuable tool to establish, validate, and refine installation tools and procedures.

The VD detector is pioneering the use of optical electronics components in cryogenic environments, therefore the longevity test of the components is of critical importance. LBNC looks forward to the reports of the initial results at the next LBNC meeting.

Recommendations:

None.

FD1 Horizontal Drift

Findings: Commissioning and operation of ProtoDUNE-II in Neutrino Platform 04 has continued (detector filling completed on April 30) and good performance in terms of electronics noise, HV stability (but also see below), electron lifetime.

However, a number of issues have been found or experienced: a bad bias voltage connection to the collection plane of APA#1, scattered occurrences of few transient electrical shorts between APA wires or between a wire and ground, and a few cathode HV PS current surges (spikes and longer lasting events).

Eight weeks of beam time are scheduled this summer, before the transferring of the liquid argon from NP04 to NP02, currently foreseen to occur in October.

At the UK APA production site, engineering resources have been added in support of the lead engineer, and the technical staff has been more than doubled. All winders have been commissioned, albeit with still some reliability issues. Six APAs have been produced in the last 6 months, against four in the previous 18 months.

An updated UK production schedule has been produced utilizing two parallel lines, with a APA production completion date of November 2027. The internal UK review of the production plan has been postponed from May to August.

Investigation of the 3 broken wires reported at the last LBNC have led the team to conclude that they were most likely the result of operator error. Visual inspection of all wire connections on the next APA under construction is ongoing to further support this conclusion. No additional broken wires have been found so far.

Progress continues in the commissioning of the Chicago APA production site.

The recently formed APA Project Management Board to coordinate the work of the 2 production sites has been working and meeting weekly since February.

Several early procurement reviews have been held in the past 6 months to start the acquisition of long-lead items.

Comments: We commend the collaboration for the continued progress at the UK APA

production site toward the goal of reaching the necessary production quality and rate, as well as for the progress made at the US site.

We note that the investigation of the 3 broken wires did not find technical problems with the equipment, and we see this as good news.

We concur that improving procedures, quality control and training of the further augmented APA production team are of utmost importance for the delivery of APAs of production quality.

We take note of the updated production schedule based on use of two parallel assembly lines with a completion date of November 2027, and look forward to the outcome of its review, which was moved from May to August.

We are pleased to see the good performance of the ProtoDUNE-II detector in NP04, and the crucial experience and information this effort is providing.

We share the concerns regarding the various types of issues observed during commissioning and operations (bad bias voltage connection, transient electrical shorts, HV PS current surges).

Recommendations:

1. Develop or improve comprehensive and detailed QC procedures not only for the production of the detector components, but also for the integration, installation and commissioning. These should incorporate the feedback from the ongoing experience at NP04 and aim to fully validate each integration or installation step as it is completed, so that possible issues are identified before moving the subsequent step.
2. At the next LBNC, please report on the outcome of the investigations on the transient electrical shorts and HV PS current surges observed during NP04 ProtoDUNE-II operations, as well as on an assessment of the impact on performance and operations in case these effects could not be eliminated.

Near Detector for Phase I

Findings: The committee welcomes the delivery of the Physics Requirements document, which represents the first step towards the ND TDR.

Despite an elevator failure preventing work for about 2 months, assembly and warm checkout of the ND-LAr 2x2 prototype @ NUMI beam was completed. Cool down is underway and cold commissioning is expected in the next weeks, in time for collecting beam data until summer shutdown.

For ND-LAr 2x2 data challenge a robust analysis infrastructure is now operational, built essentially from scratch, taking precedence over completing ND-LAr, albeit most development will be easily portable.

The Full Scale Demonstrator will be the next main element on path to Final Design for ND-LAr

with many of the needed procurements already secured. Scheduled first reviews in late 2024 extend into 2025, breaking subsystems into technically related chunks and according to readiness.

TMS presented new coils concept based on MINOS Plank Design, with elements that can be fabricated and pre-tested by vendors, thus streamlining installation. Physics simulation enjoys a team largely rebuilt with the goal of answering design questions for the FDR.

SAND is now out of the DUNE-US project. A bilateral DOE-INFN MoU was signed on April 9, 2024, defining the respective contributions and responsibilities to SAND's construction, verification and installation. A FNAL engineering team has been established to support the consortium in developing designs and procedures in accordance with standards and regulations in use at Fermilab.

Substantial progresses have been reported on KLOE-to-SAND, inner tracker, GRAIN cryostat test in Legnaro, electronics, and optical detectors.

Recent PRISM progresses achieved also through regular dedicated integrated design meetings, have been shown. Ongoing communication with NSCF regarding rail specifications and tolerances. First Hilman roller extensively tested, with a prototype construction foreseen for this summer.

Comments: The Physics Requirements document improves over the previous one in the CDR as the critical detector measurement requirements are clearly divided between those needed for the the core DUNE neutrino oscillation physics and those that would enable other goals including new physics search, SM physics or would improve the oscillation program beyond what is strictly needed. Additional feedback from LBNC will be eventually delivered within weeks.

The requirements of SAND and ND-LAr+TMS as on-axis neutrino beam monitors are well specified, but LBNC stresses that efforts to maximize the capabilities of the LBNF beam monitors and understand their ultimate limitations in detecting even subtle changes of the beam should not be neglected.

The finalization of TMS design will require further substantial work to complete coils and fields CAD models, assembly details, study implications of flatness tolerances for steel plates, go beyond conceptual design for many items, and develop costs. The schedule for meeting the design review goal of Jan 25 looks challenging.

The finalization of the DOE-INFN MoU related to SAND is a welcome development to clarify responsibilities and resources for SAND deployment in the near detector complex in time for the foreseen September 2028 area availability.

A comprehensive and thorough scrutiny of the on-going SAND tracker risk analysis is essential to allow a timely choice among the STT and DCH options, and then clarify the remaining financial and schedule issues.

The schedule for completing all final design reviews, including further prototyping, and obtaining CD2 in late 2025 is tight and partly undetermined or not detailed to the committee.

LBNC shares the concern that the existing Near Detector budget cap may be harming the swift finalization of the overall ND complex design.

Recommendations:

1. Completion of the software reconstruction package for ND-LAr+TMS is critical for informing the TDR with the expected physics performance of the ND complex, and should receive highest priority. Updates shall be reported at the next LBNC meeting together with an analysis of the performances from the 2x2 beam data reconstruction.
2. LBNC recommends for the next meeting a more detailed discussion of the major steps the collaboration is planning in order to meet the foreseen CD3 planned for mid 2026.
3. A tentative schedule for construction and installation of major components in the near detector complex shall be presented at a future LBNC meeting assuming CD2/CD3 and beneficial occupancy as planned.

Beamline Status

Findings: The Beamline scope is being moved to its own subproject, separate from the Near Site Conventional Facilities (NSCF). The Beamline subproject is planning for a CD-3b review later this calendar year, and the CD-2/3 review is projected for calendar year 2025. CD-3b scope includes primary beam magnets production and horn production. The Bulk Shielding scope has moved to the NSCF subproject. The magnet scope is being executed by Fermilab.

The outer conductors for horns B & C are being redesigned as three flanged sections due to manufacturability reasons. A replica target is being shipped to CERN for testing with beam.

Most of the people supporting the Beamline subproject are matrixed and have other non-LBNF/DUNE responsibilities.

Completion of Beamline installation and start of commissioning remains early calendar year 2031 even with the delay of the long shutdown.

Comments: The committee appreciates the increased project participation in the LBNF Beamline breakout session and is pleased to see that final designs are progressing.

The committee supports the plan for a CD-3b review later this year for primary beam magnets and horn production and looks forward to seeing the details of the CD-3b scope, costs and plans at the next meeting.

The impact of a one year delay of the long shutdown without changing the targeted project completion date may be significant, and the detailed installation plans after the change should be well prepared.

The current design parameters seem to be consistent with the proposed ACE-MIRT plans. Because the beamline equipment that cannot be modified later determines the ultimate beam

power, it would be good to better understand the safety margin with respect to the design beam power. This margin may be usable for potential further beam power increases after the ACE-MIRT upgrade.

An additional Technical Design Review (TDR) chapter on the “Path for Future Upgrades” was made available during the meeting. Our first impression is that it is a good addition to the TDR. The committee plans to complete the TDR review by the end of June.

Recommendations:

1. For the next meeting, we would like to have a few detailed breakout presentations on progress with target, horn and other beamline scope as appropriate. Essentially, we'd like to have a deeper look at a few of the technical highlights presented in the beamline plenary presentation.
2. Additionally, we would like to hear more about beam monitoring and instrumentation and plans for improvements at the next LBNC meeting.

Computing

Findings: the DUNE computing consortium has been reorganized and a new lead has been recently appointed. The organization of US-DUNE SW&C is also being finalized. The progress on the Core Software Framework development was presented. The requirement document was updated in Jan 2024 and will be signed off in summer. The specifications for the implementation are expected for Fall 2024 and the implementation should start quickly after. The first prototype is expected in summer 2025. The DUNE Computing consortium continues supporting the activities of the collaboration while upgrading and evolving the existing services. Examples of upcoming tasks were presented. Several areas of database development were completed and the remaining ones are work in progress. DUNE Computing operations commissioned the JustIN workflow management systems. The system was stress-tested in a data challenge in early 2024 and is now used in production. The generated events are organized in the DUNE data management system, integrated with JustIN. DUNE Computing is getting ready for the upcoming data taking campaign, both at CERN (NP04) and FNAL (ND-2x2). A plan for data placement is in place together with the needed monitoring system. The ND simulation requires the use of GPUs today available at US HPC facilities, noticeably NERSC and Argonne.

Comments: the structure of DUNE computing seems adequate to face the future challenges. Further commitments would be beneficial, particularly from the international partners. We welcome the engagement of new members. We thank Heidi Schellman for the very constructive interactions with the LBNC in the last many years. The LBNC continues being worried by the tight schedule for having in place a new Core Software Framework (CSF), early enough for first data in 2028. For example, the time between specifications and completion of the pilot implementation is less than one year. The success of the CSF implementation plan is bound to the available effort in FY2025 that is currently below the needs. For example, a Core SW coordinator and SW release managers are still to be appointed. The LBNC was happy to hear the news about database evolution and welcomes the substantial progress. The LBNC was impressed

by the rapid process for development, commissioning and deployment of the new JustIN system, integrated with Rucio. The LBNC congratulates DUNE for this important achievement. The new system provides noticeable improvements in terms of automation and implementation of FAIR data policies. The upcoming data taking campaign will be an important activity also for evaluating the progress of the DUNE computing system. We believe that DUNE Software and Computing has done the necessary preparation. Ensuring the availability of GPUs for ND would be an extra reassurance. The LBNC expects a report at the next meeting.

Recommendations:

1. The LBNC requests an update about the Core Software Framework at the next meeting. The LBNC recommends that the update presents the specifications and milestones for the pilot implementation plan.

DUNE and ProtoDUNE Physics Program

Findings: The DUNE Physics organization has a broad scope, including both ND, FD, ProtoDUNE and ND prototype needs, and interfaces with multiple DUNE detector and analysis groups. The neutrino interaction model has seen many updates in the last 18 months: a new model tune is available, and a reweighting scheme has been implemented, allowing changes to be made at analysis level. The production of 24M FD events is complete and initial performance studies show expected results for HD/VD variants. The ND simulation for ND-LAr 2x2 is complete and will be exercised in the next few months with beam data.

The ND simulation for ND-LAr and TMS is making progress but is not yet complete. The main missing piece (calibration and reconstruction steps) will only proceed after satisfying the needs of ND-LAr 2x2, and is expected to be ready by October. The timeline for providing an updated oscillation analysis is estimated to be 1 year after the main inputs are available. This remains in time for CD2, which has moved back to Q2 2026. The production of 1M atmospheric neutrino events is complete, initial results with preliminary systematics have already been obtained and the full analysis is expected to be finished in 1 year from now.

The impact of beam systematics on the NuPRISM analysis were shown - several of the beam focusing systematics induce distortions on the off-axis flux, whereas the on-axis spectrum remains largely unchanged. The impact of these systematics on the sensitivity to the relevant oscillation parameters, ΔCP , Δm^2_{32} and the octant of θ_{23} were shown, with minimal impact on ΔCP and a more significant impact on θ_{23} .

Comments: The LBNC commends the collaboration for its efforts to develop an updated neutrino interaction model, particularly implementing a flexible reweighting scheme that will save both time and computing resources when studying the impact of cross-section systematics. We also commend the sharing of tools with the SBN program. We encourage the collaboration to make detector systematics reweightable wherever possible, for the same reasons.

We note the completion of the sim-reco developments for ND-LAr 2x2 and look forward to the first data/simulation comparisons from the imminent prototype run, which will constitute an important test of both simulation and framework performance. The collaboration should ensure that sufficient computing resources are available to satisfy the needs of ND-LAr 2x2.

The progress with the full ND simulation is delayed, and it was stated that further development would need to wait for the needs of ND-LAr 2x2 to be satisfied. We are concerned that this implies that there is insufficient personpower in the collaboration for concurrent developments. Although the delay does not impact the ability to complete the analysis prior to CD2, it is required for ND optimisation studies which should start as soon as reasonably possible.

We encourage the collaboration to further study the impact of beamline systematics on the NuPRISM analysis. The approach is very promising and we believe that the degradation in sensitivity, which is very modest for Phase 1 physics goals, could be further mitigated via an iterative approach. We take note of the imminent publication of three interesting papers and look forward to the publication of the first ProtoDUNE cross-section paper.

While we are not unduly concerned with the timeline for the atmospheric neutrino analysis, we want to (re)emphasize that, given the timeline of the DUNE project, atmospheric neutrinos should remain a very high priority for the next few years. The same applies to low energy neutrinos (supernova and solar). We look forward to learning about the findings of the internal committee on low-energy radiogenic backgrounds.

Searches for baryon number violation were mentioned in the context of Phase II. The LBNC would like to hear more about those for Phase I. This is important in order to gauge the impact of Phase II given Phase I and potential results from HyperKamiokande.

Recommendations:

1. The collaboration should assess and implement measures - including injecting additional personpower - to allow critical path developments (such as ND-LAr 2x2 analysis support and full ND sim-reco development) to proceed in parallel.

Appendix I: Attendees

Committee: Campana, Carlin, Champion, Delmastro, Forti (partly), Friend (partly), Gouvea, Nakadaira, Para, Petyt, Resignco, Rumerio, Rusu, Saoulidou

Apologies: Bortoletto, Gottberg, Kopp, Vachon, Wallny

Scientific Secretary: Joseph Zennamo

Fermilab NSG Chair: Dmitri Denisov

DUNE/LBNF (please see registrants at <https://indico.fnal.gov/event/63290/>)

FNAL Directorate/Management: Bonnie Fleming , Steve Brice

Appendix II:

Charge Letter: LBNC June 2024 Review

The LBNC is charged by the Fermilab Director to provide external scientific peer review and to monitor the technical progress of the International DUNE collaboration, and those aspects of the facility construction that have direct impact on the DUNE experiment.

For the June 2024 meeting, the LBNC will meet to review the 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.

There is one major topic for this LBNC meeting: the LBNF beamline. Secondary focus areas will be DUNE Computing and the DUNE near detector. In addition, the LBNC should receive updates on the DUNE collaboration, far detector progress, activities on ProtoDUNE-II, and DUNE Phase II.

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. We would like to continue our work toward uniform and regular reporting and tracking of major DUNE technical milestones. The Director requests that every effort be made by the speakers to have their talks uploaded to indico at least six days before the June meeting and that responses to existing recommendations be addressed in the recommendation tracker also at least six days before the June meeting.

For the LBNF beamline topic the committee is asked to use the June meeting to advance their review of the beamline TDR as much as possible with the aim of having the review completed in time for it to be input to the Near Site CF and Beamline Director's review on 30 July 2024. The LBNC's review of the beamline TDR has its own charge.

Regarding DUNE Computing, the committee is asked to track progress on the advancement of the overall organizational structure, and the formation and execution of the plan for the computing framework development.

Regarding the ND and given that the Near Detector Requirements Taskforce is expected to have completed their work, the committee is asked to scrutinize the resulting updated ND requirements.

The LBNC should present a Closeout Report to deliver at the end of the meeting. Subsequently this should be refined into a LBNC Meeting report.

Appendix III: Assignments (Colleagues in Italics were not present)

Plenaries

LBNF Status : **Champion**, *Friend, Gottberg, Nakadaira*

DUNE Status : **Saoulidou**, *Gouvea, Vachon, Bortoletto*

LBNF Beamline : **Nakadaira**, *Friend, Champion, Gottberg*

FD-VD: Overall status, progress and plans : **Para**, *Forti, Petyt, Rescigno*

FD-HD: Overall status, progress and plans : **Rumerio**, *Delmastro, Para, Wallny*

Phase II: Status and plans : **FD-VD, FD-HD, ND sub-groups**

Near Detector for Phase I, overall status, progress and plans : **Rescigno**, *Forti, Kopp, Saoulidou, Wallny*

Computing: Status and plans : **Campana**, *Delmastro, Rusu*

Status and Plans of ProtoDUNEs: **FD-VD, FD-HD, ND sub-groups**

DUNE-ProtoDUNE Physics Program [Overview, progress and plans] :
Petyt, *Bortoletto, Gouvea, Kopp, Vachon*

Breakouts

Beamline Status & Progress : **Champion**, *Nakadaira, Friend, Gottberg*

Near Detector Status, Progress and Plans including ND-LAr 2x2 Demonstrator: **Rescigno**,
Para, Saoulidou, Forti, Kopp, Wallny

Computing Status, Progress and Plans : **Campana**, *Delmastro, Rusu*