

# **Long Baseline Neutrino Committee**

*FERMILAB, March 2023*

**CLOSEOUT Report**

**March 25th, 2023**

# Acknowledgements

*The LBNC continues to enjoy examining the advances being made the LBNF project and by the DUNE Collaboration.*

*We appreciate interactions with DUNE over the course of the previous several months and the efforts made to prepare the presentations in both Plenary and Breakout sessions. They represent an impressive body of work.*

*The committee thanks Fermilab, its Directorate, and its staff, for their continuing support.*

# Charge Letter: LBNC March 2023 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 March 2023 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, the LBNC should also receive updates on activities towards DUNE computing, and ProtoDUNE-II. Along with technical progress, 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.

# Charge Letter: LBNC March 2023 Review

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) Overall status and progress of FDR and TDR for FD1 and FD2, respectively, in view of endorsement before the FDC subproject CD2/3 Director's Review anticipated in Summer 2023.
- 2) Overall computing status including interfaces for online and offline, plans and needed R&D for analyzing low energy signals
- 3) Status of simulation and reconstruction and plans for updated sensitivities.

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

# LBNC Meeting Assignments 24-25/3/2023

LBNE Status

**Gottberg, Aleksa, Ball, Champion**

DUNE Status

**Vachon, Kopp, Bortoletto, Gouvea,**

FD1 Horizontal Drift

**Parsons, Ball, Rumerio, Wallny**

FD2 Vertical Drift

**Wood, Aleksa, Forti, Kajfasz, Para, Resigno**

Computing

**Campana, Delmastro, Rusu**

Status of simulation, reconstruction & plans for updated sensitivities

**Kopp, Bortoletto, Delmastro, Gouvea, Para**

# LBNC Meeting Assignments 24-25/3/2023

## Breakouts

Beamline Status & Progress

**Gottberg, Champion**

FD2- Vertical Drift Progress including  
ProtoDUNE-VD

**Wood, Aleksa, Forti, Kajfasz, Para, Resignco**

FD1- Horizontal Drift Progress including  
ProtoDUNE-HD2

**Parsons, Ball, Rumerio, Wallny**

Computing Progress

**Campana, Delmastro, Rusu**

# LBNF Status (Progress, Plans and Organization)

## Findings:

- CD-1RR has been approved by DOE in February 2023.
- Early procurement authority (CD-3a) for FDC was approved in February 2023.
- Energy Systems Acquisition Advisory Board (ESAAB) taking place for Far Site Conventional Facilities-Building and Site Infrastructure (FSCF-BSI) and Near Site Conventional Facilities + Beamline (NSCF-B).
- Yates Shaft has been set out of operation and is only available for emergency egress. The capacity and installation sequence through the Ross Shaft only has been studied and the impact to schedule, costs, and scope is found to be minimal.
- DOE Office of Enterprise Assessment Review at Far Site with focus on Work Management successfully completed with minor recommendations.
- DOE Office of Inspector General Review Audit conducted in November 2022, follow-up ongoing.
- System engineering team focussing on technical interfaces, NSCF and ND integrated 3D model helps managing technical interfaces.
- Technical progress on Far Site structural and interface analysis between CRP, Field Cage, cryogenic piping, wall mounted photon detectors.
- Preparing to host the international DUNE Collaboration at FNAL, FNAL will provide critical support being established through the DUNE Host Lab Task Force.
- The LN2 cryogenics system contract for FDC has been awarded, preparing acquisition plan for LAr.
- FDC cryostat fabrication has started.
- APA material flow tests successfully completed.
- NSCF+B will be completed by contractors and is on track.

# LBNF Status (Progress, Plans and Organization)

## Comments (1/2):

- The CD-1RR approval in February 2023 marks a huge milestone that manifests the commitment by DOE to the project and the trust in the stakeholders to execute it.
- The unavailability of the Yates Shaft presents a major risk to the project with large fractions of the excavation and most of the installation still ahead. The risk of a future review resulting in the complete closure of the shaft, also for emergency egress, should be very carefully monitored and the confidence of underground workers in the availability and reliability of emergency egress managed. The use of the Ross Shaft by SDSTA poses an additional potential point of friction.
- The LBNC commends the careful approach to the management of technical interfaces by the Systems Engineering team.
- The team is working hard to achieve FDC CD-2/3 readiness with major preparation work still being ahead. The schedule until FDC CD-2/3 is complex and compressed and also requires contributions from the host lab, as well as DUNE. The setup of the DUNE Host Lab Task Force is a valuable step towards preparing for the upcoming FDC CD-2/3.
- Excavation is progressing with small delays and FDC has been making substantial technical progress with cryostat installation and the award of the major LN2 Cryogenics Contract.
- NSCF+B is on track, however the contract actions are complex and will require labour-intensive careful monitoring.



# LBNF Status (Progress, Plans and Organization)

## Comments (2/2):

- Potential cost escalations are carefully monitored and mitigated through a funding profile that is based on increments of \$75M and \$50M in FY2024 and FY2025, respectively. This is challenging to maintain and everything needs to be done to mitigate any impact of this incremental funding strategy.
- Like for many organizations world-wide, turn-over of technical staff presents one of the largest schedule risks, especially for the large workforce at the far site.
- The dust mitigations at the far site have been successful with no dust incidents in the last year. The local community appears to be satisfied with actions taken by the project.
- A substantial labor ramp-up at the far site is needed in the the 2024-2027 time frame. This will present challenges, as recognized by the project, and additional human resource personnel have been added to support this ramp-up.

## Recommendations :

1. Assess and mitigate the risk of a full lockdown of the Yates Shaft, also as emergency egress.
2. Setup an access priority protocol to the underground work site between internal and external stakeholders.

# DUNE Status (1/3)

## Findings:

- LAr procurement issues continue to impede the ProtoDUNE effort. Stakeholders are aware that these could become critical and are prioritizing efforts to address them in a timely manner.
- There has been progress and recent activity towards defining the scope of FD3 and FD4, for example, through the hosting of a “Module of Opportunity” workshop in November 2022.
- LBNC sees recent developments of the Accelerator Complex Evolution (ACE) as very positive for the DUNE project.
- Development of TMS and SAND is progressing well.

## Comments:

- LBNC welcomes Mary Bishai in her new role as DUNE co-spokesperson
- LBNC commends DUNE for :
  - the production of an impressive Technical Design Report draft for FD2-VD.
  - reaching the important milestone of having draft MoU Annexes for FD1 and FD2 being reviewed by RRB funding agencies.
  - good progress towards the development and approval of the DUNE Community Agreement.
  - good progress in the establishment of a working group to organize the US DUNE operation funds.
  - steady progress on the computing front.
  - good progress in the simulation/analysis planning.
  - the rapid progress towards data-taking with the 2x2 ND-LAr prototype which is seen as a welcome development.
  - their excellent and exciting presentations at the P5 Town Hall Meeting.

## DUNE Status (2/3)

### Comments (continued):

- LBNC views activities toward defining the scope of FD3 and FD4, such as the recent “Module Of Opportunity” workshop, as an opportunity to attract new groups to the DUNE collaboration.
- LBNC acknowledges that Phase-2 is an integral part of LBNF/DUNE to accomplish its full project mission as defined in the 2014 P5 report.
- DUNE has established a Phase-2 Group charged with planning for Phase-2 of the experiment. LBNC welcomes the establishment of this group and views it as timely and important.
- Interesting improvements and R&D activities are being worked on for Phase-2. At the same time, the LBNC urges DUNE to treat with highest priority the securing and execution of the scope of Phase-1 of the project.
- LBNC supports the ongoing efforts to hire a Project Manager for the ND subproject.
- LBNC appreciates the sensitivity projections that were presented with FD3 / FD4 / MCND/ Booster Upgrade. It would be useful to also include in the same plot projections *without* these improvements in order to clearly illustrate the impact of FD3, FD4, MCND and the Booster Upgrade.

# DUNE Status (3/3)

## Recommendations :

- Present at a future LBNC meeting, the process and potential timeline for coming to a decision on FD3 / FD4 technology and scope.
- Present at the next LBNC meeting, the overall strategy, at the project level, to assess and mitigate the risk related to supply chain issues.

# FD1 Horizontal Drift (1/6)

## Findings:

- The recommendations from the previous review have been addressed or answered
- The status of the procurements for APA production items (frames, boards, wire, ground mesh panels) has been given, and no issues are currently foreseen.
- APA production has started at Daresbury with issues and delays comprehensively reported to the LBNC (see comments and recommendations).
- A V-wire on an APA in ProtoDUNE II broke after the cold box tests. Post mortem analysis has been carried out and is informing remediation plans, as well as revised production strategy and procedures (see Comments and Recommendations later)
- The plan for the number of winders existing and planned at Daresbury (4 operational, 1 received, 1 being requested) and Chicago (1 being completed) has been updated to support an updated APA production schedule.
- Challenges in staffing and managing the UK production site have been experienced and a strategy to address them is under development.
- A benchmarking exercise to validate the APA production schedule is being planned.
- The APA transport has been demonstrated with the first DUNE instrument underground at SURF

# FD1 Horizontal Drift (2/6)

## Comments (1/4):

- The LBNC commends the DUNE collaboration on the further very good progress on FD1 HD. For example, all sub-detector FDRs have been performed (with the Installation FDR to be held in April 2023), the installation of the “Module 0” in ProtoDUNE II has been completed, and a test shipment of APAs from the UK to the Far Site was done.
- The LBNC commends DUNE on the significant progress of the TDAQ system design. The move to a COTS-based system instead of a FELIX-based FPGA system provides some advantages. Should FPGA-based acceleration prove to be needed or advantageous, it is believed this capability could be added without major perturbations to the existing TDAQ system design.
- The project is in the process of updating the FD1 TDR to reflect the detailed changes since the original document from several years ago. On a schedule still being finalized, the LBNC will review the updated TDR version, as part of the formal DOE requirements to be completed before the CD 2/3 review in September 2023. To aid in the review, an Executive Summary, a draft of which has been provided, has been included that highlights the major changes for each chapter.
- The LBNC appreciates the open and frank presentations and discussions with the project, which are of course critical to the committee being able to do its job.

# FD1 Horizontal Drift (3/6)

## Comments (2/4):

- Due to the Liquid Argon supply shortages in Europe, the ProtoDUNE II cold run will be further postponed and results will not be available before the DOE CD 2/3 review for the FDC sub-project, currently scheduled for September 2023. As noted during the previous LBNC meeting, while these risks will likely have to be accepted, the project is encouraged to critically evaluate and attempt to minimise any risks associated with continuing the APA production despite delayed feedback from the ProtoDUNE II cold run.
- A key issue on availability of Cu-Be wire for the APA production has been resolved, with identification of a second source. Given the new source uses a different raw material with slightly lower (but within requirements) wire strength, it will be important to gain experience with APA production with this new wire to ensure its suitability.
- A broken wire was discovered in the v-layer of APA #3 at CERN. Tests show that this wire was functional earlier in the testing, and seems to have broken during warm-up. Investigations have found that wires could have been over-stressed during winding, potentially weakening them and risking future failures. This is clearly a serious concern for FD1, and steps are being taken to improve the APA production procedures (see more on next slide).

# FD1 Horizontal Drift (4/6)

## Comments (3/4):

- While the APA PRR was passed in July 2022, problems have been experienced in getting to full APA production. Solving these issues will require considerable changes in both the procedures used and the organization and supervision of the effort (see Recommendation).
- Some of the APA production issues are typical of those encountered when transitioning from a prototype-phase relying on experts to a production-phase that requires increased capacity, hiring and training of additional personnel, etc.; the personpower issues in particular have been exacerbated by the current economic situation in the UK, and will require continued attention and effort.
- Other APA production issues are traceable to planning that did not include sufficient oversight by, and presence at the factory of, experienced experts. The project has recognized the deficiency of these aspects of the original plans, and has taken steps to resolve them, including hiring an experienced production engineer as a consultant, appointing a team of experts who will provide continuous oversight at the factory, and seeking additional resources to hire additional scientific personnel. The LBNC agrees that these steps will be critical to establishing APA production with the required rate and quality, and fully supports the request for the new resources that will be needed to implement these changes.



# FD1 Horizontal Drift (5/6)

## Comments (4/4):

- The delays reaching full APA production, and the lack of demonstration of the projected production rate, raise concerns about the overall APA delivery schedule. The project plans to produce a “Golden APA” with the goal of demonstrating the proposed production time of 45 days per APA. This is an important step to produce a defensible “evidence-based” schedule in time for the CD 2/3 review in September.
- Given the schedule concerns, providing additional APA production capacity is prudent. The LBNC is pleased to note that an additional (6th) winding machine is being prepared at Daresbury. In addition, the planning includes a second APA production site at the University of Chicago, with the goal of producing about 10% of the APAs, as this site will be equipped with a single winder. It will be important that the experience gained and the measures to be taken at the Daresbury site are ported to this site as well.
- While the “Golden APA” will focus on demonstrating the production rate, it is important to finalize and demonstrate the changes to the production and QC processes that will be necessary to produce robust APAs that meet all specifications. The availability of several winding machines should be leveraged to plan these multiple efforts in an optimal way, minimizing the interference between them.

# FD1 Horizontal Drift (6/6)

## Recommendations :

1. We recommend that the project perform a new formal review once the modified APA production plan has been finalized, to ensure that all parties involved are on-board with the new plan and to empower those responsible to lead and carry out the plan through to its successful conclusion.
2. The LBNC supports the introduction of an experienced production engineer as a consultant to perform a detailed review of the work planning and flow at the APA factory. While the initial consultant contract is for 3 months, we recommend seeking to secure the resources that would allow consideration of extension of this contract should it prove to be useful and warranted.

# FD2 Vertical Drift (1/3)

## Findings:

- The FD2VD subcommittee received a first draft of the FD2 TDR on 16-Dec-2022. The committee read the draft in January and sent ~500 questions and comments. An updated draft was received on 16-Mar-2023 along with responses to all comments.
- Substantial progress has been made toward the completion of FD2 Module 0 in the NP02 cryostat at CERN. All four CRPs are complete and tested. Two top CRPs and two cathode planes have been installed in the cryostat along with most of the PDS.
- The temporary construction opening of NP02 is expected to be closed in October, after which LAr filling can begin if argon is available.
- Important progress has been made in understanding the photon simulation. The propagation of Xe light is now treated more properly, and the reflectivity of some materials was corrected.
- Simulation results for charge reconstruction in the TDR were improved with higher statistics and improved fits
- New simulation campaign for both FD1-HD and FD2-VD is beginning that should allow proper comparison. Time scale is ~6 months (not for TDR)

## FD2 Vertical Drift (2/3)

### Findings (cont.)

- Updates to design were implemented to mitigate risk of damage to PDS electronics from potential HV discharges: positioning, shielding
- Signal over fiber: laser performance found to degrade in deep LAr if the focusing system is flooded with argon, thus changing the optical properties of the environment. Solution developed by redesign of the focusing to work in the liquid environment.
- Significant further progress was accomplished in demonstration of the reliable PoF and SoF systems, in particular on the light leakage suppression

### Comments:

- The LBNC commends the DUNE collaboration on the production of an impressive Technical Design Report draft for FD2VD. The subcommittee is still reviewing the 2nd draft of the TDR, but our initial impressions are that it is in good shape and that our questions have been addressed thoughtfully. The presentation of the chapters have been made more uniform and many improvements were made to the clarity.

## FD2 Vertical Drift (3/3)

### Comments (cont.)

- Some recent improvements in the scintillation photon simulation might justify updating some of the plots in the FD2 TDR, which are probably overly pessimistic.
- The LBNC commends the DUNE collaboration on the strong progress for preparing NP02 for Vertical Drift Module 0 testing.
- Some problems were found on CRP 5 which required repairs and re-testing in the cold box. The lessons learned in identifying such problems are informing the QA/QC process that will be used for production.
- If availability of LAr continues to be a limiting factor for the schedule, it may be advantageous to fill ProtoDUNE-VD (NP02) first, since this will be the first at-scale test for some features of the VD design. The committee made a similar comment at the last LBNC

### Recommendations :

- DUNE should develop a clear process for deciding the order of filling NP02 and NP04 for the VD and HD Module 0 tests.

# Computing (1/2)

- The DUNE computing consortium continues progressing with the development and commissioning of the distributed computing system. Several new components were brought into production in the last year and validated during the 2022 data challenge. More tests are planned in preparation for protoDUNE-II. We congratulate this progress and expect an update at the next LBNC meeting.
- We learned about the plans to start testing the DUNE data taking workflow (with FNAL as the Tier-0) as part of the 2024 data challenges. We support this preliminary plan as we believe it will allow DUNE to start preparing well in advance for the physics program.
- The flexible DUNE computing model and the challenging memory needs of the software offer opportunities to investigate a different use of services at the computing facilities. In particular we suggest looking into the use of caching and latency hiding services for data access. We also suggest looking into optimizing the job scheduling to leverage memory available in nodes shared with other experiments.

## Computing (2/2)

- The organization of the different database instances was briefly discussed. We suggest a deeper discussion about the status and plans of the online and offline databases at the next LBNC meeting.
- The current informal pledging model continues serving well the purpose of securing the right amount of computing hardware resources to DUNE. We suggest that DUNE starts considering the process to make the model more formal.
- The evolution of the offline software presents major challenges in preparation for data taking. The software framework and the algorithms need to evolve coherently to support the DUNE novel requirements and adapt to modern architectures. This work will need specialized expertise in software development and an adequate level of coordination.

### Recommendations

- We recommend DUNE to identify the proper mechanisms to coordinate the offline software evolution, in a coherent way across the consortia in the collaboration.

# Simulation, reconstruction & updated sensitivities (1/2)

- The LBNC commends DUNE on the excellent progress towards improved simulation, reconstruction, and physics sensitivity studies. Activities in these areas have significantly accelerated since the last LBNC meeting, which is a very welcome development.
- The collaboration has divided this effort into 10 physics working groups, commensurate with the complexity and breadth of DUNE physics.
- Among the ongoing efforts, DUNE is prioritizing those targeting the long-baseline oscillation analysis as well as low-energy neutrino physics (solar and supernova neutrinos).
- The long-baseline oscillation analysis will benefit from full and improved ND and FD (both HD and VD) simulations and reconstruction, together with an improved interaction uncertainty model. As a first step, the analysis from the TDR will be augmented with a full ND simulation and with additional event samples. Afterwards, the improved FD simulation as well as DUNE-PRISM will be incorporated. In the future, also a combined sensitivity study between beam and atmospheric neutrinos is foreseen. We welcome these efforts and view them as crucial in the context of P5 and of the upcoming reviews.



# Simulation, reconstruction & updated sensitivities (2/2)

- We equally welcome the emphasis on low-energy neutrino physics at the far detector, given that the far detectors will likely be taking data without beam for some time.
- The LBNC commends the fact that the collaboration has started to concentrate some of their resources on the atmospheric neutrino sample. This is very important given that the detectors will be commissioned with atmospheric neutrinos and will be operational a few years before the beam.
- A new working group has been formed focusing on simulation, reconstruction, and analysis for the 2x2 ND prototype. This new effort is receiving a lot of interest in the collaboration, given the imminent availability of data.
- It is important that the development of algorithms and other software tools for the analysis of the 2x2 prototype data is carried out in such a way that these can be usefully transferred to the common DUNE software.
- The LBNC highlights the importance of concentrating some simulation, reconstruction and analysis resources to understanding DUNE's abilities to study the  $\nu_\tau$ -appearance channel, both for beam and atmospheric neutrinos.
- The LBNC highlights the importance of updating and communicating the sensitivity estimates for proton decay and other baryon-number-violating searches, including the charged-kaon final state and, perhaps, more exotic scenarios.

# Beamlines and NSCF (Progress, Plans and Organization)

## Findings:

- ESAAB approval of CD-3A for NCSF+B is expected this week and supports acquisition of blue blocks, wetlands permit work, kicker magnet ferrites and capacitors, and horn conductor forgings and machining
- The project anticipates conducting the IPR for CD-2/3 in July 2024
- A proposal for additional long lead procurements under CD-3B is planned and would include components for magnets, horns, and the shield pile
- BARC/India has decided not to construct the quadrupole and dipole magnets needed for the primary beamline. This scope has been added to the US project. It is anticipated that the magnet components will be fabricated by industry with final assembly and measurement at Fermilab
- Capacitors for the kickers are undergoing high voltage pulse testing with the units from one vendor having achieved ~70,000 pulses of 100,000 planned pulses
- Modelling of horn vibrations has been performed with good results. Hammer testing is planned, and further testing will be performed on a horn test stand in the future
- Construction of the Horn A prototype is progressing
- Construction of a horn power supply single cell test unit is nearly complete
- Final design has been completed on three of eleven radioactive water cooling systems
- Simulation work has been performed on the absorber to minimize dose rates to workers
- Absorber robustness studies are proceeding. A worst case of a full intensity pulse striking a water channel has been shown to be acceptable
- Installation planning for the absorber is progressing
- The design of the near site conventional facilities requires revisions by the A/E firm prior to being ready to send out for bids

# Beamline and NSCF (Progress, Plans and Organization)

## Comments:

- The beamline and NSCF team continues to make progress towards baselining, including the horn stripline design development, target vibration studies, horn power supply test unit construction, kicker component vendor qualifications, and NSCF final design finalization.
- The inability of BARC/India to meet the schedule for the primary beamline magnets is disappointing and will incur non-trivial additional scope and cost on the DOE project.
- The committee supports the proposal to request CD-3B long lead procurement approval given the schedule for the CD-2/3 IPR
- Given the technical challenges inherent in the design and fabrication of the horn and target, the project should continue to push the related developments, prototyping, and testing as soon as possible to ensure readiness for CD-2/3.
- Most comments from the 2021 Hadron Absorber Directors Review have been addressed.
- It is important to finalize the design of the neutrino beam instrumentation to inform ongoing discussions on the Near Detector scope.

## Recommendations :

1. The long break between design completion and procurement for this subproject presents cost risks and perhaps cost opportunities. Systematically monitor exposure to supply chain issues.

# Executive Summary (1/3)

- LBNC congratulates LBNF/DUNE on the CD1RR approval which is a major accomplishment.
- LBNC continues to be very impressed with the progress made by LBNF/DUNE on all five sub-projects, both in the Far and the Near Site. LBNC is concerned with the restricted availability of the Yates shaft and the impact and associated risk this might have during the project construction phase.
- LBNC congratulates DUNE on progress made on several fronts: for completing the FD2-VD TDR and addressing the first set of comments from the committee, the advancement of ProtoDUNEs, the progress on the ND sub-detector systems, and the global simulation, reconstruction and analysis efforts.
- LBNC commends DUNE for signing the MOU Annexes for FD1 and FD2, and for initiating the formation of a “common fund” mechanism for Commissioning and Integration, and later for experimental Operations.
- LBNC welcomes the formation of a dedicated group that will look into the strategy for achieving the Phase II physics goals with the appropriate FD3, FD4, and Near Detector Complex. The committee would welcome advances of this plan and a refined strategy on how decisions on FD and ND detector technologies will be made. Related to this, LBNC notes that the success of Phase I should remain DUNE’s highest priority, along with securing all resources needed for this effort.

## Executive Summary (2/3)

- LBNC commends DUNE on progress made on ProtoDUNE-HD-Module 0. LBNC strongly suggests that DUNE continues to study and try to better understand the APA broken wire issues, with a plan to develop a viable mitigation strategy, that would be sustainable in the longer term. LBNC is concerned about the APA production issues and urges DUNE to continue to develop short and long term mitigation plans, evaluate their performance and associated risks, and assess possible impacts on the overall project schedule and cost.
- The committee congratulates DUNE for continuing to make impressive progress on FD-VD prototyping, on advancing the FD-VD design, and improving project planning. The committee notes that given the positive developments on LAr supply issues in Europe DUNE should develop a timely plan for the order of filling of ProtoDUNE-VD and ProtoDUNE-HD.

## Executive Summary (3/3)

- The committee commends DUNE for having completed the computing CDR, for having designs for most computing components and working implementations for many, and for having successfully completed data challenges for ProtoDUNE-II. Given that FD and ND offline software will need major infrastructure work to operate at scale, LBNC suggests that DUNE starts to identify and put in place the needed resources.
- LBNC commends DUNE for making substantial and continuing progress on reconstruction and analysis on several fronts: oscillation, low energy physics and BSM searches. LBNC notes that DUNE should continue to prioritize the full oscillation analysis that includes ND on axis and off axis measurements, and make sure the appropriate resources are identified and put in place for this. LBNC urges DUNE to update and communicate the experiment's capabilities on contributing to proton decay searches.
- LBNC reiterates the request that LBNF/DUNE conducts a systematic exploration of the availability for all upcoming purchases well in advance of procurement to identify supply chain issues.
- Finally, LBNC requests that presentations be provided to the committee at least 48 hours in advance.