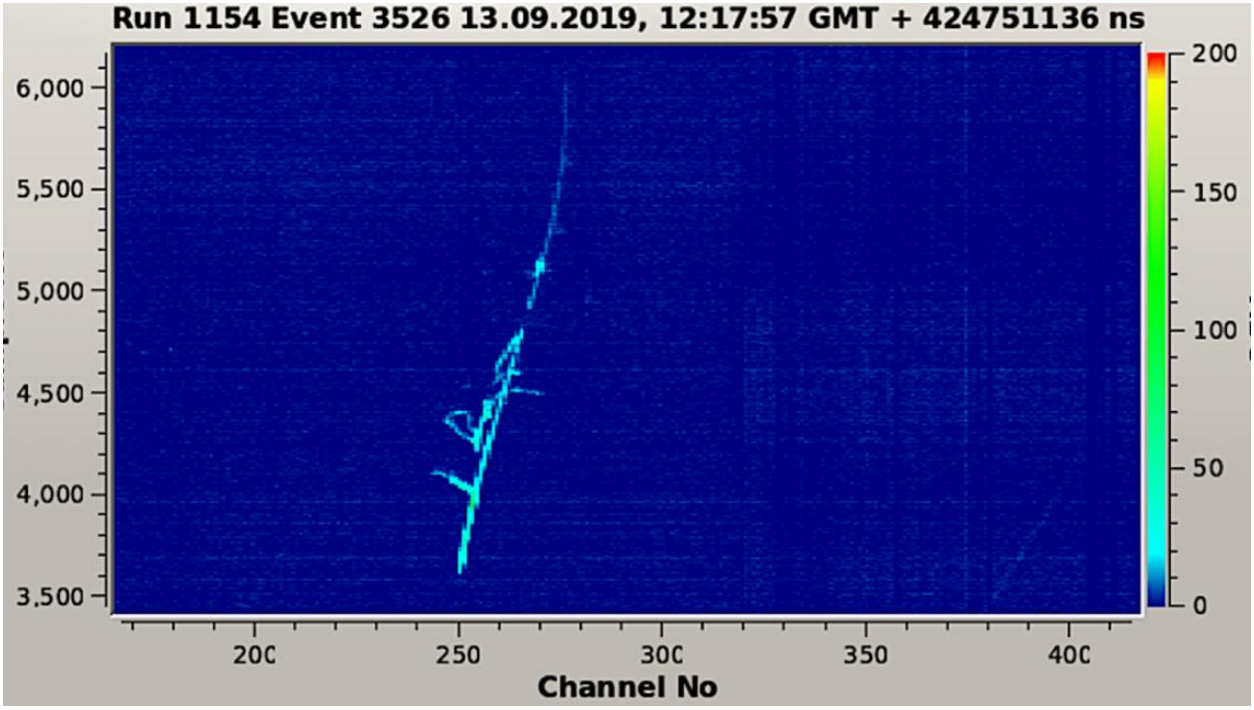
LBNC Meeting Report



December 5-7, 2019

CERN

Introduction

The LBNC met December 5-7, 2019 in CERN. This meeting was the last of three meetings held by the LBNC this year. The previous meeting was at Fermilab in April, and the second in July/August, both at FNAL.

The attendees at the meeting, shown in Appendix I, included LBNC members and consultants, DUNE collaboration spokespeople, Ed Blucher, and Stefan Soldner-Rembold, and members, the Fermilab Director, Nigel Lockyer. Representatives of the US Department of Energy, including Pepin Carolan, and Bill Wisniewski connected remotely.

The interactions between LBNC are used to monitor the technical progress of the International DUNE collaboration and those aspects of the LBNF Project which have direct impact on the DUNE experiment. The latter is usually accomplished with a single presentation at the beginning of the meeting: in this meeting there was also a breakout session devoted to the progress of the beamline. The Fermilab Director requests assistance in this process from a number of experts, who supplement the expertise of the LBNC members in the scrutiny.

During the past year, both the DUNE collaboration and the LBNC have given emphasis to the preparation and review of a suite of Technical Design Reports. The DUNE collaboration was encouraged to submit early drafts of the material and the LBNC read those drafts and in several cases convened dedicated reviews, both in person and by teleconference. For four of the Technical Design Report volumes, the LBNC recently sent a letter to the Laboratory Director which recommended approval.

The charge for this meeting, prepared with concurrence from the Director 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.

At each meeting the LBNC makes a Closeout Report open to all, and subsequently prepares this LBNC Meeting Report. The agenda and presentations used during the meeting and the Closeout Report can be found at https://indico.cern.ch/event/857610/timetable/#20191205.

The LBNC appreciates the effort put into the preparation of the presentations and material, in particular the draft volumes of the Technical Design Report, by the DUNE Collaboration, and the frank responses to questions and queries. The committee is also grateful to Angela Fava who as Scientific Secretary to the LBNC was instrumental in the compilation of the reports as well as actively participating in the discussions. The administrative arrangements made by the CERN and Fermilab staffs were excellent.

Finally, the committee thanks both labs for their support and hospitality.

Executive Summary

The committee congratulates DUNE and LBNF on its achievements over the past 5 months, since the summer meeting of this committee

The progress with LBNF is very visible at SURF and is exciting. Additionally, the committee recognizes the challenges involved in maintaining the momentum in excavation in the context of a changing DOE view of CD approval strategy.

Overall, DUNE as a collaboration continues to grow adding countries, institutions, and individuals between each of our meetings. As the scope of the work of the collaboration is better understood, DUNE gains experience with the Consortium based structure and adjusts its organization. In the next several months it is intended to create new consortia to cover the Near Detector scope. This change should be done carefully to ensure that fragmentation does not lead to a lack of coherence.

Given the perceptions of good progress with the Proto-DUNE single phase analysis, the topic was given relatively limited Plenary Session time. In general, the progress overall continues to be impressive.There is some concern that the photon detection system appears to enjoy little margin. In a breakout session, particular attention was paid to the fine tuning of the design, and installation trials of the Anode Plane Assemblies. Also in the breakout, discussions were held with the electronics development group, which continues to work multiple options for the readout solution. In both cases, the LBNC team felt that good progress is being made.

An important part of the charge to this meeting concerned the progress with ProtoDUNE Dual Phase, and the derivative research and development plans and strategy going forward. In fact ProtoDUNE DP is operational and DUNE is congratulated for achieving this status. Although significant progress has been made, several issues have appeared during these initial months of operation. At a breakout devoted to the Dual Phase technology, we heard that, despite the constraints on stable operations, a CRP gain slightly in excess of the minimum requirement has been achieved, and improvements in the noise performance indicate that the noise specification can likely be met.

- DUNE is encouraged to put in place a plan to systematically address these issues during the anticipated months of operation during 2020. To maximize the productivity, they are encouraged to strengthen the technical and run coordination.

- A plan should also be developed, with realistic schedule for the needed R&D and changes to incorporate in a future ProtoDUNE DP operation.

It may take some time, however, the LBNC committee would like to see the development and articulation of an overall plan for the anticipated four Far Detector modules.

The progress with the Near Detector towards a Conceptual Design Report was presented with specific implementations of the three primary components. This approach is consistent with the recommendations of the positive LBNC review of the Near Detector, which was conducted in mid-2019. The LBNC looks forward to the opportunity to review this report.

The progress of the Computing Consortium is very positive. A report was heard from the ProtoDUNE DP analysis team, which is well integrated into the broader organization. In looking at the scope of the plans, the LBNC sees opportunities for enhanced interaction and participation by the algorithm and analysis efforts in the provision of core software frameworks.

In summary, the LBNC sees DUNE making considerable progress. In the past year DUNE:

- Has completed four technical design reports which cover an important baseline technology, planned to be used for two of the installed modules.
- Has made great progress on exploring the dual phase technology in ProtoDUNE DP, the primary candidate for another of the planned modules.
- Has made strides toward the completion of the Near Detector Conceptual Design.
- Has established the DUNE Computing Consortium as a significant player in the world of HEP computing while provisioning the extant ProtoDUNE (both SP and DP) data handing and analysis program.
- Is exploring options for a fourth module, perhaps with a new technology, as well as for innovative enhancements to baseline detector configurations. The consideration of such demands a certain level of prudence.

LBNF Status:

Management

A key finding over the last several months was the report from the DOE review in Oct. 2019. The review report did not support project baselining until the Total Project Cost (TPC) was better defined including definitive far site excavation costs, closing of international contribution gaps, and maturing of LBNF/DUNE-US near site cost estimates. The review also urged more attention to the procurement organization and a clearer leadership accountability for LBNF/DUNE-US with more dedicated responsibility for both the DOE scope and DUNE.

Notwithstanding these concerns, the review also encouraged maintaining the aggressive schedule with the far site excavation work. The goal is still to have excavation work under contract with the CM/GC in July 2020. Based on the review the project is reworking the CD-2 date from early in 2020 to July 2020 for the far site and Dec. 2020 for the near site. LBNF notes that there is still ~100M$ in unassigned scope.

The addition of a LBNF Deputy Project Director for Enterprise Coordination at 50% helps to address DOE's management concern coming from the Oct. 2019 review. The position should facilitate manpower mobilization throughout the project and should bolster the search for international contributions. Along these lines, it would be good to establish a metric for the top management positions to monitor if the 50% level is sufficient. Other notable positions added are the Associate General Counsel for Construction, 4 far site construction coordinators and one EH&S position.

Kudos to LBNF for presenting a backward-looking resource actuals vs scheduled and a forward looking projected resources. The presented data shows the deployment of ~50FTEs each month over the last 6 months with an expected increase of 10% in the next 6 months. The ~10% step jump in forward looking projections vs past typically means that some work is being pushed out and may keep being pushed out until more resources are found. The information should be broken down into skill set to inform, for example, potential shortfalls in technical or engineering skills.

SURF and FNAL are updating the MOU for far site management.

Far site

LBNF is to be congratulated for continuing to make steady progress at the far site. Nine reliability projects totaling 36M$ were reported to be on track for completion before the start of excavation scheduled for July 2020. Three reliability projects have been completed: the replacement of the Oro Hondo fan VFD, an upgrade to the refuge chamber and completion of rock transport skips. The Ross shaft construction continues with 305 new steel sets installed and is scheduled to complete in the first quarter 2020. All 31 work packages totaling 92M$ for pre-excavation have been awarded to KAJV. The contractor has 90 people on site and completion is expected in Dec. 2020 a slippage of 1 month since the last meeting. The report that KAJV contract billing is low (28%) with respect to contract duration (41%) needs careful scrutiny as it hints at further delay. Also, the reported contract disputes are concerning as they can impact schedule milestones plus the effort required to settle those disputes can be non-negligible. The Far Site teams and LBNF should be congratulated for the excellent safety record to date, certainly an encouraging sign. A far site ES&H coordinator has been added to the organization to bolster the important safety initiatives.

Excavation and Building and Site Infrastructure 100% final design is now complete with 25% of the contracts out for tender. The goal is to get bids returned Feb. 2020 and contracts awarded July 2020. DOE concerns after the Oct. 2019 review have put pressure on this timeline. LBNC supports LBNF in their push towards a July 2020 contract award date for far site excavation. The efforts to address DOE concerns are encouraged to avoid delays in excavation that would further delay the availability of the North cavern and increase project costs. The awarding of 5 early excavation contracts to help pull back the delay in North cavern completion by 6 months, and save 21M$, is very positive news. Though attempts are being made to compress the schedule (e.g. Consideration of parallel activities and 24x7 excavation) it was reported that the North Hall completion milestone date of Oct. 2022 is expected to be delayed by at least 6 months. Given this almost certain delay LBNC cautions that the decision not to re-baseline before CD-2 may negatively impact or misinform other deliverables that have schedule dependencies. The impact should be analyzed.

The plan for early handover of the North Cavern while excavation continues on the South needs careful scrutiny for hidden coactivity issues. The extent to which the logistic pathways for the

cryostat installation and continued excavation works can be separated will be a key indicator of how easily this coactivity can be controlled.

The project has shown good progress in the area of systems engineering. The Far Site integrated model has matured (V5 to be released this month) and will be a useful tool for coordinating and communicating installation schedules, interfaces and potential interferences. Such models will be essential to better define the resources that will be required underground during the staging and installation phase.

With respect to cryogenics installations the warm structure and membrane design for Detector #1 are complete. The nitrogen system procurement is still in progress as vendor negotiations are progressing. The contract calls for a `turn key' system. The LBNC notes that the LN2 contract is taking a significant time to converge. While LBNF stated that the contract does not need to be signed until 2022 the project should note the issues and methodology used to date as `lessons learned' that can help guide future large procurements and avoid potential bottlenecks. There is concern that given the complexity demanded by both scale and environment, `turn key' cryogenic solutions may be too great a challenge for private companies. We also note that the LAr cryogenics package is still unallocated scope.

Near site

The A/E design phase and pre-excavation work are moving towards meaningful milestones. The LBNF strategy regarding establishing costs and effort associated with the near detector is receiving appropriate attention with the goal to help refine Total Project Cost as requested in the Oct. 2019 DOE review.

A/E design services contracts have been awarded totalling >25M$. The PDR goal is March 2020 with cost and schedule data based on the PDR expected in May 2020. There has been excellent progress in the near detector cavern definition with the facility requirements finalized and the near detector size bounded. A site preparation contract of $15M has been awarded and work has started. The project team is developing 3D models of systems similar to what has been done in the far site.

Beamlines

The beamlines report presented in the break-out session gave good confidence that the effort and planning towards the LBNF beamline and target complex are in reasonable shape for this stage of the project. The present integrated design maturity was reported at the 50% level. The successful conceptual design review of the target with RAL is a major milestone of the last period. LBNF has a good experienced partner in RAL. Other notable progress includes the continuing progress on 3D CAD integration models and the advancement of the Horn A design. Also of note are the completion of high level interface specifications between beamlines and conventional facilities and the expectation that the interface specifications within beamlines will be at the 90% level within 2019. Besides RAL, with target and target systems, other international collaborations include corrector magnets (IHEP), main dipole and quadrupoles (BARC) and high current feedthrough and hatch covers (KEK).

Prototype development and testing are underway for several subsystems: Target Shield Pile Cooling Panel prototype, Target Shield Pile Hatch Cover prototype (now being vacuum and pressure tested) and Horn high current feedthrough (strip-line) prototype being pressure tested at J-PARC. Three other prototypes are planned for the next three years – Target, Horn A and striplines for Horn B and C.

Preparations toward CD-2, planned for Oct. 2020, are advancing well with a credible plan. The project is working with a professional estimator to update BOEs for all procurements. The ES&H and QA plan look to be receiving appropriate attention. An on-going concern is that international partners for non-DOE scope are still to be defined.

The project staffing and organizational structure look reasonable. Beamline management has been consolidated with a new lead and project organizational structure with five L3 systems (CAMs) and 21 L4 systems (Technical Managers). New mechanical engineering resources have been added. The present pull on engineering resources from PIP-II and mu2e were noted but were reported as manageable with mitigation, for example, through the development of good lines of communication and a soon to be drafted MOU with the Accelerator Division. A forward look at technical resources indicated an approximately flat engineering need of ~8FTEs over the project life. A potential concern are the significant technical resources required for the build portion of the project with technical resource needs growing from 5FTEs to >20FTEs in a time frame where PIP-II may also be installing.

The presented schedule calls for first beam on target in April 2029 with CD-4 early completion Aug. 2031. This is several years after the first Dune detector would be ready for neutrinos. There seems like a real science opportunity available if the LBNF near site schedule could be pulled forward by a few years. The bottlenecks in cash flow, resources, and logistics should be analyzed now to determine whether such a schedule adjustment is feasible since long lead technical items will make this less possible as time goes on.

Recommendations:

- Explore the bottlenecks preventing pulling ahead LBNF first beam milestones by 2-3 years in order to realize a significant science opportunity

DUNE Overall Status

Since the last meeting, four volumes of DUNE Technical Design Reports have been recommended for approval by the LBNC, namely the Introduction, Physics, Far Detector Single-Phase and Far Detector Technical Coordination volumes. The committee extends its warm congratulations to the collaboration on this major step forward, and thanks those involved in preparing and finalizing the TDRs for their responsiveness when engaging with the committee.

Four new university groups have joined the collaboration since the last LBNC meeting, three from the US (Wellesley College, UC Santa Barbara and Rutgers University) and one from Canada (U of Toronto). The committee appreciated the short outline of each group presented on request, and would like to see similar brief summaries included for new groups in future LBNC meetings, within the Spokespersons' introduction. The LBNC notes the progression of funding applications in various countries, most notably with NSF, and in France, Switzerland and Brazil. The committee appreciated seeing a short synthesis of the funding-approval status of expected construction responsibility commitments for the single-phase far detector, and requests that such also be included in the Spokespersons' report to the LBNC in future, if it has evolved significantly from the previous meeting.

With regard to the change in consortium structure which is now underway, we agree that it makes sense to include cryogenic instrumentation relevant to detector status and operation with other detector instrumentation. However, the committee comments that cryogenic process

controls, particularly for the liquid nitrogen refrigeration system, might best be based on standard industrial process control software, and one would not want to complicate that by merging it with other more specialized controls. The collaboration is urged to proceed cautiously and to ensure that all aspects of work in the re-arranged consortia receive sufficiently strong attention.

The committee is impressed by the strong progress across many areas of single-phase far detector and near detector preparations. The collaboration, with the essential support of the CERN Neutrino Platform, is commended on the filling and startup of Dual Phase ProtoDUNE operation. As discussed through much of this meeting, progress has been very substantial, and various challenges encountered are being addressed.

The committee further notes the outcomes of the recent "Module of Opportunity" detector workshop. The apparent multiplicity of options will need to be broadly and carefully discussed within the collaboration before paths are chosen. Work towards, and on, far detector module and near detector construction should continue to be prioritized. The DUNE Collaboration management is recommended to start establishing realistic timelines which would include all detector modules, taking into account reasonable funding scenarios and technology maturity. The development and articulation of such a plan, perhaps with conditional branches, is highly desirable as a basis for distribution of resources.

Recommendations:

- Develop and articulate a plan which covers all the four Far Detector modules.

ProtoDUNE SP Status

Flavio Cavanna presented the status of ProtoDUNE-SP. This included operational experience and analysis updates. We congratulate the Collaboration on the success of ProtoDUNE as a demonstrator, providing a number of lessons learned for DUNE construction and operation.

Findings

- Results and "lessons learned" from a year of ProtoDUNE-SP running were presented.
- HV system uptime is now >99%, the streamer rate has been reduced after periods of running with auto-recovery off.
- Using tracks, a very high (40msec) electron lifetime is measured. This result varies significantly from the lifetime inferred via purity monitoring.
- A post-mortem on the pump failure was presented and corrective action has been identified. The system recovered quickly.
- Xe doping was observed to compensate for light yield loss from residual N_2 contamination.
- Calorimetric reconstruction of multiple particles was presented for the first time, from which the resolution is better than expectation. It is hypothesized that the diffusion and/or flow model is incomplete or inaccurate in simulation.
- Initial results on the characterization of the performance of the photon detection systems were presented, confirming the expectations on Arapuca performing better than the alternatives.

Comments

- We congratulate the Collaboration on successful construction, assembly, commissioning and operation of ProtoDUNE-SP.

- Considerable lessons have been learned from the HV system. Uptime is high, and the streamer rate is reduced.
- We appreciate the progress made on analyzing ProtoDUNE-SP data and understanding performance. The Collaboration should continue this work, including the items previously recommended.
- It is important to publish paper(s) sooner rather than later on the detector, performance and results.
- It would help to present an "apples to apples" comparison of the ProtoDUNE-SP Arapuca results compared to TDR projections.
- We agree and support plans for the conclusion of ProtoDUNE-SP phase 1 (including ending with testing at higher voltage) and agree with the importance of phase 2 to verify preproduction modifications, including field cages, APA and cold electronics.

Recommendations:

- None.

ProtoDUNE SP Breakout, APA

Multiple speakers presented information on APAs, including experience from ProtoDUNE, design, fabrication and shipping consideration for DUNE, and installation testing at Ash River. Progress overall is impressive.

Findings

- Based upon ProtoDUNE and extensive installation/assembly prototyping, the detailed APA frame design is in its final stages
- Cold electronics cable routing testing successfully completed. Work continues on photon detector mounting and cable routing, but sufficiently complete to finalize frame design.
- Dual APA frame mounting and assembly, including cable routing has been successfully tested several times.
- Progress has been made on shipping frames, winding apparatus and production sites. Reviews scheduled for early 2020.
- On schedule to produce pre-production modules for phase 2 of ProtoDUNE-SP and production schedule compatible with first two modules being single phase.

Comments

- We congratulate the Collaboration on considerable progress in prototyping and evaluating APA production, quality control, transport and installation.
- It is important to continue to work closely with industry so that the APA boards can be produced with the proper thickness and tolerance.

Recommendations:

- None

ProtoDUNE SP Breakout, Cold Electronics

The DUNE team presented an update of the DUNE Cold Electronics development status and timeline. This included information on design, testing, teststands, and plans. Considerable progress has been made on many fronts, and a timeline that includes system testing in ProtoDUNE Phase 2 has been developed.

Findings

- Progress has been made on understanding the LArASIC ledge effect. Further investigation and mitigation strategy in progress.
- Noise in ColdADC is very good. Kickback effect from pipeline to sample-and-hold identified as a reason that linearity is worse-than-expected.
- COLDATA is working well, with only minor modifications foreseen.
- Most recent CRYO submission (Nov 2019) optimized for nEXO, will be used in ICEBERG test chamber. A new test board is being made to mitigate noise sources.
- Next iterations of all 4 ASICs will be submitted in spring/summer 2020.
- Considerable test stand work continues, including APA7 coldbox and a high pressure setup at BNL.
- A discharge in ICEBERG killed the front-end ASICs on all boards.
- The COTS ADC solution will undergo a coldbox test but is no longer considered as an option for DUNE.
- Timeline calls for a downselect in early 2021, a preproduction submission in spring 2021, mount boards on APAs Fall 2021, ProtoDUNE-SP phase 2 run in early 2022.

Comments

- We congratulate the Collaboration on considerable progress in multiple dimensions. Progress continues on multiple approaches, problems are being identified and studied.
- The timeline is aggressive to downselect the ASICs in January 2021.
- Results from the BNL high pressure test chamber indicate that possible bubble production at the bottom of the DUNE cryostat may not be a concern. Measurements will be repeated with actual FEMB prototypes when these are available, which is important.
- The ICEBERG "event" that killed the FE ASICs needs to be fully understood to prevent any such occurrences in the future. Although likely an anomaly with a new setup, a series of even unlikely events can pose a risk to long term success of DUNE.

<u>Recommendations:</u>

- A full postmortem on the ICEBERG "event" should be completed and lessons learned be incorporated into procedures associated with cold electronics and chambers.

Dual Phase: ProtoDUNE DP Progress and R&D Plans

The LBNC congratulates the cryogenic and DP teams on the hard work and significant progress made in commissioning ProtoDUNE-DP. The NP02 cryostat filling was completed in early August and since then extensive progress has been made commissioning the various systems (CRP alignment and tracking, LEMs and grids, PMTs, electronics and DAQ). However, several technical issues have allowed only limited periods of stable operation.

Two CRPs are fully instrumented with active LEMs (72 LEMs total), and 67 of the LEMs are fully operational. Following alignment of the CRPs and initial high voltage commissioning, and with partial mitigation of a source of common mode noise from the slow controls cables, the TPC readout noise is measured to be approximately 1,300e. It is expected that <900e will be achieved with full noise mitigation and filtering (compare to noise specification <1000e).

Studies of the CRP gain and S/N versus LEM voltage are ongoing. Progress has been limited by insufficient periods of stable operation. To date a CRP gain of 7.6 has been achieved at 3.2kV (compare to minimum specification for gain >6). Plans are in place for further measurements, extending to higher voltages.

The Photodetector System consists of 36 PMTs, 6 coated with TPB wavelength shifter (WLS), 30 with PEN WLS panels. The system has been commissioned and calibrated.

Several technical issues result in operational limitations:

- A short in a HV extender connection limits the HV to <150kV, allowing a uniform drift field over only ~1.5 m (1/4 of full depth). Within this region, track reconstruction performs well. Plans are under development for an intervention to sever the shorted connection to allow a deeper drift region. The committee considers this intervention to be high risk – even with development of special tooling and practice mockups. It needs strong justification, and if carried out, should be deferred until after high priority studies are concluded.
- Purity: several gas filter regeneration cycles have been needed due to dust clogging recirculation filters. The LAr purity, as measured by e-lifetime, has increased steadily, but is still only approximately 1.5 msec (compared to the minimum spec >5 ms).
- LAr surface bubbles (seen at two particular locations: the HV feedthrough and at clips on the field cage) and surface waves (~1mm peak to trough) limit stable CRP operation. A work-around involving pressure cycles has been developed to provide limited periods of more stable operation.
- The stable operating margin with respect to these surface conditions is compounded by reduced planarity of the CRP at LAr temperature.
- The effects of ion trapping at the liquid surface needs further study, although this is expected to be greatly reduced in operation below ground at SURF where there is essentially no flux of cosmic rays.

It is essential that these issues are either solved, or addressed with updates to the design, with validation in a future run at protoDUNE using near-final components. In particular, the LAr purity has to be understood and solved. For the waves and bubbles, it is likely that modifications to the CRP design will be needed to provide operating margin for such surface disturbances. DP should develop and provide specifications for the surface quality necessary for stable CRP/LEM operation with margin. We note that these specifications can be developed using the cold box setup.

The mapping of CRP performance, and completion of the study of the technical issues, will require several more months of protoDUNE operation. While the studies of purity, bubbles and waves will involve extended operation with unstable conditions, CRP commissioning requires stable conditions. A comprehensive run plan and strong run coordination team are needed to ensure efficient operation. The LBNC strongly endorses continuing to run for several months to complete this program.

It is very important to learn from the current ProtoDUNE run, and to develop a detailed plan for the subsequent R&D/design program towards protoDUNE-II. Plans to improve the LEM and CRP designs are in place: reducing discharges (with improved etching in LEM fabrication and guard rings), and improving planarity (CRP thermal stiffness). For the WLS on the PMTs and on the reflector panels that are required for the final design (and to be tested in the future protoDUNE run), the selection of WLS material (TPB or PEN) and the method of application should be finalized. A plan should be developed to demonstrate long term stability in LAr. The R&D and design changes should be validated in stand-alone tests prior to assembly for protoDUNE-II.

The plans to develop the 600 kV HV system and dedicated test stand for 12m drift should proceed in parallel, but must not divert the focus on the work towards protoDUNE-II.

Recommendations:

- Provide a specification for the surface quality necessary for stable CRP/LEM operation.
- Develop a coherent prioritized run plan and stronger run coordination to support competing needs of mapping the CRP performance and the critical work to understand and mitigate the purity and surface issues.
- Develop planning for R&D and design changes with interim test steps to support successful protoDUNE-II validation of close-to-final design.

Near Detector Conceptual Design

The first volume of the Technical Design Report, that the LBNC recently approved, contains a clearly developed plan for the near detector complex, including in the reference design liquid argon TPCs (ArgonCube) and an accompanying high-pressure gas TPC+ECAL (MPD), both of which can move off-axis, along with an on-axis beam monitor based on a 3D scintillator tracker inside the KLOE magnet and ECAL (recently named the SAND detector). Important decisions needed for facility planning, such as the size of the near detector hall, have been settled and communicated to the LBNF group.

It is conceivable that a staging approach for the near detector elements may be required. The LBNC has previously recommended that any minimal configuration should include liquid argon TPCs, a simple magnetized muon spectrometer (in place of a more complex and capable MPD), the ability to move these detectors off-axis, and a simple on-axis beam monitor. DUNE reported that they are considering as temporary options both a simple magnetized spectrometer (similar to

what MINOS used) as well as running the KLOE magnet and ECAL without any inner detectors as a beam monitor. This latter idea is intriguing, but no details were presented.

Although the ability to move ArgonCube and the MPD off-axis is a core requirement for the near detector, DUNE's presentations did not address the engineering needed to enable this movement. Although many large particle detectors have been movable, the engineering is not trivial, especially for cryogenic services. Therefore, the LBNC would like to hear more details about the engineering of the detector movement systems at the next LBNC meeting. The movement systems should also be documented in the CDR.

We welcome the plan to run the ArgonCube 2x2 prototype at NuMI where MINERvA is now, starting September of 2020. This should be given high priority as a critical step for developing the ND TDR. DUNE plans to use the LARPix ASIC for ArgonCube, of which version 2 is currently being developed and will be tested soon. We note that ASICs frequently require multiple iterations and would like to request an update on the ASIC testing at the next LBNC meeting. A sharp increase in the cost of the Kapton for the resistive field cage shell for ArgonCube is also a concern. We note that alternate materials are being investigated, including the possibility of using strips of it to reduce the fill factor and hence the cost.

Design work on the MPD is continuing, and there was recently a successful near detector workshop at DESY that focused on several aspects of this detector. We note that DUNE now proposes to add a muon catcher in the downstream iron return yoke of the MPD's magnet. The CALICE ECAL design is an attractive model for the MPD's ECAL, but DUNE notes that "Fast timing [on ECAL] will need more work". We did not hear any details about this. We would like to see not only a technical demonstration or study of the timing resolution, but also a clear statement on the role and the requirements for fast timing which need to be met. These should be documented in the upcoming CDR.

The reference magnet design for the MPD has 5 superconducting coils, with two alternate designs being considered. DUNE plans a downselect at end of January 2020. This struck the LBNC as being a very aggressive schedule, and urge DUNE to consider whether a downselect in January 2020 would be premature. Requirements on the stray magnetic field and the field uniformity do not yet seem to be determined.

As noted at the last LBNC meeting, the Italian groups/INFN have agreed to contribute the KLOE magnet and ECAL for use in the on-axis beam monitor. The LBNC welcomes this development. The DUNE collaboration plans to place a 3D scintillating tracker inside this magnet, with some kind of gas tracking (TPCs or straw tubes) surrounding it. DUNE needs to flesh out the details of these plans for the CDR, especially for the gas tracking element, which has not been fully specified.

Alternate designs for the SAND detector's inner elements using thin target layers with multiple nuclear targets have been studied. We note that these designs are not part of the reference design for DUNE's CDR, and that they would require significant work in order to be fully justified from the construction & costing but also from the physics point of view.

DUNE presented a schedule calling for developing a CDR in early 2020, with a draft ready to send to the LBNC in March 2020. Much material exists already in the appendices of the DUNE TDR Volume 1, and hence we consider this timescale realistic. DUNE proposed to present an IDR by the end of 2020, informed by ArgonCube 2x2 prototype results, and a final TDR a year

later. We note that DOE may require a TDR for CD-2, and that DUNE may need to consider skipping the IDR stage for this reason.

As the CDR is prepared, various design elements must be optimized, such as the MPD magnet design, the MPD ECAL's granularity, and the gas tracking for the SAND detector. The optimization criteria for these elements need to be stated. In addition, while DUNE has made a compelling case that they require a near detector including both on-axis and off-axis beam measurements (the so-called DUNE-PRISM technique), DUNE has not explicitly shown how the combination of these elements will reduce the neutrino flux, cross section, and energy estimation systematic uncertainties for the CP violation measurement to the desired level of accuracy.

Recommendations:

- DUNE should study how well "temporary minimal detectors" that are being considered if staging is required would actually work—for example, using the KLOE magnet+ECAL without inner detectors as a beam monitor, or using a magnetized muon spectrometer instead of an MPD. For this latter option, DUNE should quantify the design requirements for the muon spectrometer. If staging is required, the LBNC recommends that the capabilities of the SAND detector be descoped first, while preserving as much functionality of the MPD and liquid argon as possible, recognizing that all three detectors are required for DUNE to achieve its physics goals.
- The optimization for both the MPD's ECAL and its magnet design should be driven primarily by physics requirements. Hence, LBNC would like to see these clarified and incorporated in the process of the design optimizations. LBNC would also like to hear of possible design challenges related to the movability of the detector.
- DUNE should flesh out how the DUNE-PRISM method together with constraints on cross section and flux model uncertainties can be used in tandem to achieve the needed precision for CP violation, as well as how well these (reduction of systematics) will be achieved by the DUNE ND complex. LBNC suggest doing this by incorporating DUNE-PRISM data samples into the final oscillation fit. DUNE should aim for having this ready and included in the CDR.

DUNE Computing

We congratulate DUNE for the impressive progress of its computing since the last meeting. In particular, we recognize the key role of the Computing Consortium organizing the daily activities and planning the future evolution. We support the strategy of the Consortium organizing thematic workshops to progress in the area of Data Model, Computing Model and databases and we welcome the initiative of the newly created Frameworks task force. We note that reconstruction algorithms and simulation are today not in the scope of computing in terms of organization. We believe a stronger link should be established. We encourage the DUNE Collaboration to develop an organization which ensures synergy, and provides recognition of long-term responsibilities in this area.

ProtoDUNE Single and Dual Phase computing activities are well integrated into the DUNE computing efforts. Between the two experiments, more than 1PB of data have been produced in 2019. The processing chain was demonstrated end-to-end, from the online acquisition to analysis.

Specificaly for ProtoDUNE-DP, we congratulate the team for the very successful data taking campaign in 2019 consisting of 157 TB of uncompressed RAW data collected by the online system, archived in tape storage at CERN and Fermilab, processed in a distributed environment. We find that the online and offline computing services demonstrated the necessary capabilities and reliability to acquire, organize and process the data. The separation of responsibilities between online and offline components seems to be adequate as well as the choice of standard tools and services supported by CERN IT and Fermilab. The practice of running data challenges validating service upgrades contributed to this success and we encourage to continue such practice in the future. We understand that offline data reconstruction just started and is pending some validation step. The LBNC looks forward to seeing a report on this activity at the next meeting, and especially results from analysis of reconstructed data.

We strongly support the DUNE Computing Consortium in its strategy of leveraging synergies in many areas. At the level of services and infrastructure the collaboration with WLCG and OSG allowed to rapidly integrate data centers into the data distribution and processing chain. The collaboration with the HEP Software Foundation and other neutrino projects in the area of software allows a considerable level of code reuse. We are pleased to see a fruitful collaboration between ProtoDUNE and the DUNE Computing Consortium, CERN IT and Fermilab as we consider it essential for the success of the ProtoDUNE computing activities. The link with CERN IT through a liaison person and dedicated meetings, and the relationship with Fermilab DUNE computing operations team, were mentioned as being of particular importance by ProtoDUNE-DP.

DUNE made good progress in defining a computing model and resource needs up to 2022. The hardware resource needs based on the computing model seem achievable, and we encourage frequent discussion with the funding agencies. Worries were expressed with respect of hardware technologies, both for compute and storage. We encourage DUNE to keep up to date with the current and future trends, following the hardware technology tracking working groups organized in the context of HEPIX and WLCG. We also suggest investing from the beginning in software portability to heterogeneous architectures to take maximum benefits of the most modern systems. We invite DUNE to start the process of understanding the user analysis needs as they might have a large impact for future computing requests. The reconstruction and simulation CPU needs for the Near Detector are currently not known and might end up being considerable due to the more complex layout with respect to the Far Detectors. We would be pleased to see some preliminary evaluation at the next meeting. Long-term personnel needs seem not to match the available effort at this point in time.

We welcome the creation of the Contributions Computing board, we share its pragmatic and flexible approach in defining in the short term the expected contribution of the different countries, and support its attempt of securing more effort from key institutes. We are pleased to see

computing being an international effort in the DUNE Collaboration. We recognize the successful effort of Fermilab in setting a context for DUNE computing and we support DUNE in strengthening its international links of collaboration. We are worried about the unclear situation concerning the provisioning of the network service between SURF and FNAL. We expect that FNAL and SURF will discuss this so that a statement can be provided at the next LBNC meeting.

Recommendations:

Provide a statement clarifying the provisioning of the network link between SURF and FNAL.

Appendix I: Attendees

Committee: Ties Behnke, Simone Campana, Dave Charlton, Cristiano Galbiati, Joachim Kopp, Bob Laxdal, Tiehui Liu, Naba Mondal, Hugh Montgomery, Scott Oser, John Parsons, Tom Peterson, Kevin Pitts, James Proudfoot, Niki Saoulidou, Jeffrey Spalding, Eric Kajfasz, Adam Para, Austin Ball, Darien Wood;

Scientific Secretary: Angela Fava

Fermilab PAC Chair: Apology Received

DUNE/LBNF: Dario Autiero, Sergio Bertolucci, Edward Blucher, Tim Bolton, Stefania Bordoni, Johan Bremer, Alan David Bross, David Christian, Clara Cuesta, Dominique Duchesneau, Vyacheslav Galymov, Inés Gil-Botella, Takuya Hasegawa, Ara Ioannisian, Eric James, Jonathan Lewis, Steve Manly, Edoardo Mazzucato, Elaine McCluskey, Chris Mossey, Laura Patrizii, Elisabetta Pennacchio, Francesco Pietropaolo, Stephen Pordes, Regina Rameika, Filippo Resnati, Paola Sala, Heidi M Schellman, Davide Sgalaberna, James Sinclair, Jaydip Singh, Stefan Soldner-Rembold, Luca Stanco, Matteo Tenti, Christos Touramanis, Serhan Tufanli, Marco Verzocchi, Alfons Weber

FNAL Directorate/Management: N. Lockyer, H. Ramamoorthi.

DOE: P. Carolan, W. Wisniewski

Appendix II: Charge

The LBNC would like to hear about the general status of LBNF and the principle outcomes of the recent IPR meeting. Time is devoted on the second afternoon to a report on the progress with the beamline in a parallel session. (The time is chosen such that it could be remote.)

The LBNC would like to hear from DUNE its overall status and progress from a high level, providing a within which to consider the details which follow.

The LBNC would like to hear about the progress with ProtoDUNE SP, addressing both the analyses, including results from the photo-detection and progress towards defining the operating parameters, which was seen as a primary goal for 2019. Time has been reserved on the second afternoon for breakout discussions which we suggest could be used for discussion of progress with installation and tests thereof (eg at Ash River)

The primary goal of this meeting is to understand the progress made with the Dual Phase technology. We have therefore devoted the whole of the first afternoon. Our hope would be to hear in detail of the installation and the operations thus far of ProtoDUNE DP. This should describe both the successes and the difficulties, for example the ion build-up, the bubbling, and the purity. This can be divided among several speakers. The LBNC imagines that each of the issues is likely to require significant future R&D and would like to hear about those plans including their schedules. Of particular interest may be the 600kV Power Supply design issues. Finally, we expect that this discussion leads to an understanding of a path forward towards a Dual Phase detector. The LBNC would like to hear how this path would lead to a future verification program likely including a second phase of ProtoDUNE DP operation, and to a TDR at an appropriate time.

Considerable progress was made in the first half of 2019 with understanding the needs and concepts for the Near Detector. We would like now to hear about progress towards a Conceptual Design and a CDR. In addition to a report on the recent DESY workshop, we could imagine several talks addressing key components. These should address: (ND time allocation 2 hrs)

- the current concept overall,
- the Argon Cube,
- the MPD including magnet designs for the Helmholtz or double dipole coils, and the reuse of ALICE TPC components,
- the Beam Monitor, including use of KLOE magnet, simulations, infrastructure and logistics,
- any plans for fall back systems and staging including the rationales and the way they support the goals for systematic uncertainties.

The LBNC is aware of substantial ongoing progress made by the Computing Consortium and would like to hear an update. It would be interested in any progress to co-involve those seeking and organizing the resources and those concentrating thus far, primarily on algorithm development and analysis.

The LBNC will develop a Closeout Report which it will deliver on Saturday morning at 11:00 am. Subsequently this will be refined into a LBNC Meeting report.

Appendix III: Assignments

Consultants shown in Italics

Executive Summary: **Hugh Montgomery**, all

LBNF Status General Status, IPR Report, Beamline
LBNF Review/writing Team: Bob Laxdal, Austin Ball, Angela Fava, Hugh Montgomery, Tom Peterson

DUNE Overall Status + Exec Summary (Blucher)
DUNE Review/writing Team: **Dave Charlton**, Austin Ball, Simone Campana, Hugh Montgomery

ProtoDUNE SP Status, Analysis and Ops parameter
Single Phase Review/writing Team: **Kevin Pitts**, Angela Fava, Tiehui Liu, John Parsons

DP Computing and Analysis Status:

Computing Review/writing Team: **Simone Campana**, Dave Charlton

ProtoDUNE DP detailed Progress; Installation, Operation Results.

Dual Phase R&D Plans

Dual Phase Review/writing Team: **Jeff Spalding**, Cristiano Galbiati, Eric Kajfasz, , Adam Para, Jim Proudfoot, Darien Wood

Near Detector Conceptual Design
Near Detector Review/writing Team: **Scott Oser**, Ties Behnke, Joachim Kopp, Naba Mondal, Niki Saoulidou

DUNE Software & Computing
Computing Review/writing Team: **Simone Campana**, Dave Charlton, Hugh Montgomery

Technical Breakouts
LBNF Beamline Breakout "LBNF Review/writing Team: **Bob Laxdal**, Dave Charlton, Hugh Montgomery, Tom Peterson

Single Phase Breakout: Single Phase Review/writing Team: **Kevin Pitts**, Angela Fava, Tiehui Liu, John Parsons.

Dual Phase Breakout: Dual Phase Review/writing Team: **Jeff Spalding**, Cristiano Galbiati, Eric Kajfasz, , Adam Para, Jim Proudfoot, Darien Wood