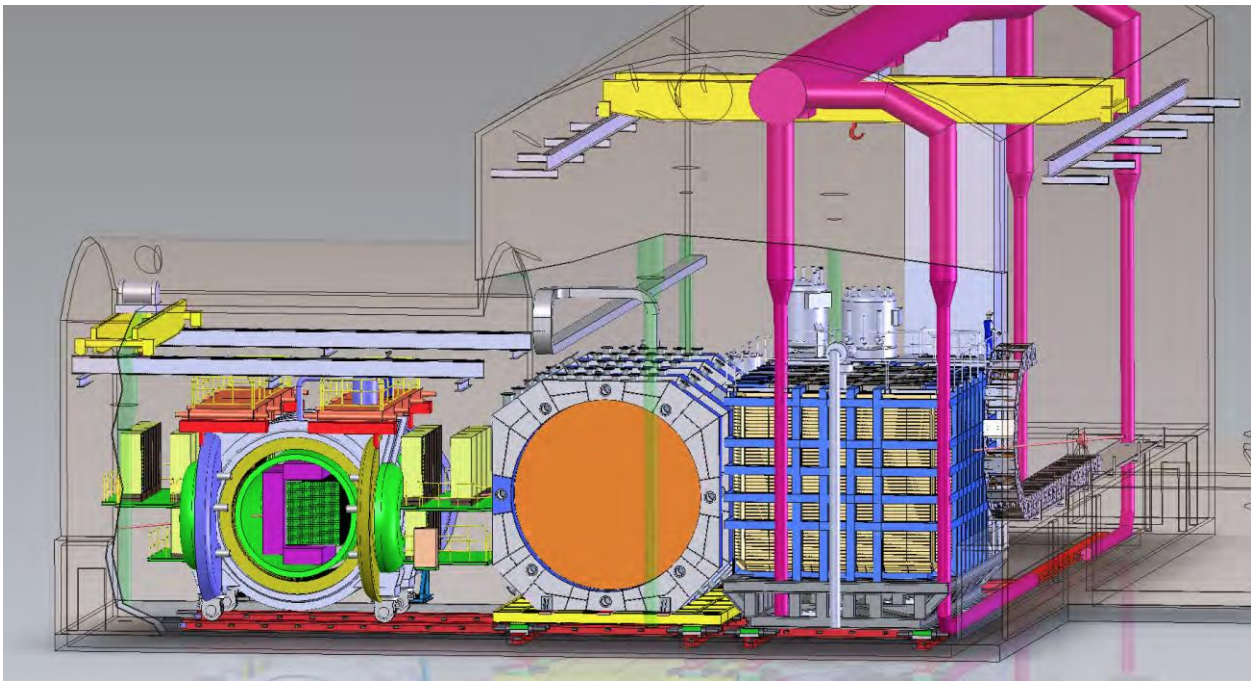
LBNC Meeting Report



September 14-16, 2020

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Introduction

The LBNC met September 14-16, 2020. This meeting, following that in March 2020, continues the pattern of three meetings per year. It is anticipated that the third meeting this year will take place December 2-4, 2020. This meeting was held entirely by video-conference.

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, Fermilab Director, Nigel Lockyer, Fermilab CRO and Deputy, Luciano Ristori and Greg Bock. DOE did not respond to the invitation to attend.

The activities of the LBNC are used to monitor the technical progress of the International DUNE collaboration and those aspects of the LBNF Project which have direct impact on the DUNE experiment. The latter is usually accomplished with a single presentation at the beginning of the meeting: at this meeting a supplementary presentation was made to discuss the anticipated power performance of the accelerator complex during the first years of operation. The Fermilab Director requests assistance in this process from a number of experts, who supplement the expertise of the LBNC members in the scrutiny.

The Dual Phase R&D using NP02 at CERN, was completed in September and the results are being examined. The Near Detector Conceptual Design Report has been submitted, was reviewed by the LBNC and is under revision.

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. The committee as a whole discusses and concurs with both the Closeout Report and the Meeting Report.

At each meeting the LBNC makes the Closeout Report open to all, and subsequently prepares this LBNC Meeting Report. The agenda and presentations used for the meeting, and the Closeout Report can be found at https://lbnc.fnal.gov/ .

The LBNC has enjoyed hearing about the substantial progress made during the past half year despite the impact of the Covid-19 pandemic. As has become habitual, the presentations from LBNF and DUNE were to the point and fully addressed the charge. Progress across the full spectrum of activities LBNF, DUNE, Single Phase, Dual Phase, Near Detector, and Computing, was described in the Plenary sessions. In order to maximize the utility of the Covid-19 constrained agenda time, five substantial breakout sessions covering Beamline, Single Phase, Dual Phase, Near Detector and Computing were held.

Finally, the committee thanks the DUNE and LBNF participants, Fermilab, its Directorate and support staff, for their assistance and support.

Executive Summary

The LBNC enjoyed hearing about the impressive progress of the **LBNF Project** especially of the pre-excavation**.** Considerable progress has been made along the path towards both placing the excavation contracts and baselining of the overall **LBNF-US DUNE Project**.

We also heard in some detail about the **Beamline sub-project.** We are pleased that this part of the project is emphasizing the exploration of ways to accelerate the schedule.

DUNE **Technical Coordination** has an expanding scope with the concurrent preparation for installation at DUNE, the preparation for ProtoDUNE II campaigns in NP02 and NP04, the continued FD R&D, and the incorporation of a multi-facetted Near Detector. It will be important for the collaboration to ensure that the organization continues to be well defined, and adequately staffed to maintain the schedule. Consequently we are requesting some standardised presentation of schedule data in future presentations.

The **Single Phase Far Detector** work has enjoyed a stellar campaign in NP04 and the physics and technical validation is impressive. At this meeting, the LBNC has concentrated on understanding the considerable progress with the final stages of design and development, in particular of the electronics. While this continues to require close attention and management, the progress corresponds to the schedule needed.

The **Far Detector Dual Phase** work has continued to concentrate on completing the ProtoDUNE DP work in NP02. High voltage repair work was executed and the run continued until September. However, while much has been learned, the viability of the technology at scale has not been demonstrated. Planning for future work, R&D, design modifications and preparation for future ProtoDUNE work in NP02 and eventual use in DUNE must therefore be made with care.

The **Near Detector** consortia have drafted a Conceptual Design Report (CDR) which the LBNC has reviewed and provided considerable feedback. A further draft is expected before the end of the calendar year with approval expected to follow. In addition to the documentation, considerable advances in the technical issues are seen. New to this meeting was the concept of a **Day-1 Near Detector**. This features a simplified muon spectrometer constrained by initial resources. The LBNC expects to receive material enabling it to review the capability of this Day-1 Detector configuration.

The coherence and completeness of the discussion of **DUNE Computing** and its presentation showed a marked stride forward since the previous Meeting. The LBNC can now see the path for DUNE towards documentation of the computing plans in a CDR, and eventually a TDR. We continue to encourage explicit connection between the Algorithm teams and the Computing Consortium.

For the **DUNE Collaboration**, establishing a CD2 Baseline for the LBNF/US-DUNE Project is of prime importance. The successes with ProtoDUNE SP have provided a solid basis for the initial Far Detector configuration. Establishing the corresponding confidence in the Near Detector involves a clear understanding of the Near Detector Conceptual design and excellent progress has been made in this direction. In the short term, articulation and scrutiny of, a Day-1 Near Detector, which, for the LBNC, started at this meeting, will require dedicated effort from both DUNE and the LBNC.

For the longer term there are many challenges, strategic, technical, fiscal and sociological, associated with creating a clear plan for all Far Detector Modules. The LBNC looks forward to hearing, in the near future, about the technologies under discussion, and the process for making a selection.

LBNF Status

The committee commends the project for its recent accomplishments. Reliability projects are all on schedule, with 36M$ in work on-going. All projects report as on track for completion April 2021 (delayed from Dec 2020 due to Covid-19).

Pre-excavation construction work is fully underway, with a revised expected completion date of April 2021 (from DEC2020). 75% of work has been completed. Delays are due to Covid-19 and additional unforeseen work required to rebuild rock wall reinforcement in the rock removal system. Early excavation drill and blast work is ongoing since June 2020.

A reputable contractor for the far site excavation has been selected. A consent package to award was forwarded to DOE on Aug 10 2020. A DOE IPR for excavation is planned for Sep 22-24, 2020 to assess the project CD-3A revision request. The North cavern completion was reported last Dec. as stretching beyond Oct 2022. Now both caverns are shown as complete April 2024. Support for the FSCF redesign to integrate the N2 system underground and relocation of DUNE DAQ to detector is ongoing. The far site integrated model is now at V6, and the site safety record indicates 899 days without incident and one DART case.

The near site preparation design is complete and work is underway. The main scope preliminary design was 100% completed at the end of March 2020. Final design began Aug 3 2020 and is due at the end of Aug. 2021. Site preparation is reported to be on schedule and includes moving cooling ponds, rerouting power and access roads, and a new cooling tower. Work is due for completion Dec. 2020. Analysis of ND-hall crane upgrade from 15 ton to 60 ton is underway. A preliminary design review of the ND cryogenics was held in July 2020.

The Acquisition Plan for the liquid nitrogen system and auxiliaries (Nitrogen Refrigeration Equipment) is in DOE review now and the RFP is in development. The system will be procured based on vendor design, fabricate and install. Contract award is required before Sept 2022. Procurement is planned in two phases, with an initial competition based on established criteria to select three most qualified vendors. The second phase then involves a competition across Phase 1 vendors based on evaluation of a completed study. Then a subcontract is awarded to the best-value offeror for the remainder of the engineering work, the manufacture, the installation, and the commissioning of the equipment. FRA selected the phased acquisition strategy as a result of feedback received during an extensive market research and benchmarking effort.

Award of the excavation removes the largest risk to the project baseline plan and provides cost certainty. All previously unassigned scope for FS and NS has now been assigned in preparation for CD-2. The project plans to initiate excavation construction work after receiving DOE approval of a revised CD-3a, hopefully after the Sept 22-24, 2020 DOE IPR that will examine the project's plan. Completion of the CD-3a scope is expected by Sept 2022, with a planned request for DOE CD-2/3b IPR for baselining in summer 2021. Completion is expected by Sept

2022, with a planned request for DOE CD-2/3b IPR for baselining in summer 2021. Items left to complete ahead of this review include resolution of the path to a second detector module, completion of the PDR for US-ND scope, and completion of a cost reduction effort to provide 40% contingency at baselining (presently at 36%). Budgeted and earned hours for the past six months are approximately equal. Actual hours are approximately 10% below earned hours and the next few months will require a ramp up of 20% in effort as agreed with FNAL management.

Comments

- LBNF continues to make significant and impressive progress at the far site with, among other deliverables, significant progress on rock conveyance infrastructure.
- The slippage in completion of pre-excavation work from Dec 2020 to April 2021 is partly due to COV-19 and was expected – the additional delays concerning required refurbishing to Rock wall is a reminder that the excavation schedule needs contingency for such unforeseen events.
- The presented slides show that the caverns are now scheduled for completion April 2024 (was Oct 2022 for north cavern) – this underscores the importance of launching the excavation contract in April 2021 to prevent any further slippage.
- Resource allocations for LBNF seem to be tracking requirements except for slip in March 2020 (due to COV-19) but the next months will be challenging as 20% ramp is expected with an additional 10 engineers to join the effort as agreed by FNAL management.
- Previous concerns expressed by LBNC, regarding unassigned scope, have now been dealt with by absorbing those elements in the project – this will de-risk cost and schedule moving forward towards CD-2.
- The LBNF management and CMGC should be congratulated on the excellent safety record.
- The liquid nitrogen system will be unique and challenging as a nitrogen refrigeration system condensing Argon in a deep underground location. The Project has developed an acquisition plan for the Nitrogen Refrigeration System which recognizes that challenge and should, following DOE approval and any subsequent modifications, provide a strong framework for managing the procurement.

Recommendations

- None

Beamline

The beamline/target team continues to make impressive gains with steady and systematic progress and with evidence of good support from FNAL management. Design is presently at a 55% level. Final design is completed in beam optics and preliminary designs are completed in

key areas (primary vacuum, Horn A, Hadron absorber, hatch covers, Modules, Target hall shielding) with five more to go. Prototyping of key components is in progress. IHEP has completed the corrector magnets and other international partners include BARC (dipole and quads), RAL (target systems), and KEK (strip-line/hatch covers). Regular meetings with RAL and BARC are in progress.

The project has a well-conceived plan for nailing down loose ends before CD-2 in mid-2021. This includes updated cost and schedule estimates augmented by vendor quotes, establishing resource agreements within FNAL, completing interface definition and many planned technical and project reviews. An IPR is scheduled for January 2021, a Director's review in Spring 2021 and CD2 in the August 2021 timeframe. Previous concerns expressed by LBNC, with unassigned scope, have now been dealt with. The integrated unallocated international scope is absorbed by the project as of April 2020. This will de-risk cost and schedule moving forward towards CD-2.

The baseline schedule shows the beamline/target at early CD-4 by Q4 CY2029 with the critical path in Conventional Facilities. LBNC thanks the team for exploring how the time to `target ready' can be reduced by optimizing the cash flow. Analysis reveals that if cash-flow was not a constraint the project could advance the target area readiness by ~1 year (to Q4 2028) with no change in total project cost and the potential to reduce escalation and standing army costs. There is a ~1 year plateau after CD-3 where there is technical and conventional facilities design readiness to move ahead but insufficient cash to match. Not only will the addition of cash in the 2023-25 time frame reduce the timeline to first science but will maintain project momentum with some gain in over-all efficiency. Such a strategy will move the critical path from conventional facilities to the technical. A pulsed power engineer has been identified as a critical resource for developing the horn PS and resource sharing with other FNAL projects (PIP-II) needs careful planning but is assessed as solvable.

Recommendations

- Continue to pursue a modified cash flow to advance the beamline/target schedule

DUNE Status

The LBNC congratulates DUNE for the progress made across many areas of activity. The committee is also pleased to see continued growth of the collaboration, and appreciates the information presented on the contributions expected from the new groups. We encourage DUNE to continue and intensify the efforts on this front.

The committee is very pleased to see progress being made towards ProtoDUNE II Single-Phase acknowledging its central role on the characterization of all detector components and sub-systems in the close-to-final "Module 0" form. The committee strongly suggests that the collaboration continues to develop and closely monitor i) a realistic timeline for all ProtoDUNE-II-SP components ii) a clear plan for the installation, commissioning and operations, and iii) a clear plan and timeline on how possible feedback from ProtoDUNE-II-SP will be incorporated successfully in the schedule and the plan for the construction of the first far detector module.

The committee commends DUNE for the extensive ongoing work on the Dual-Phase technology. The LBNC urges DUNE to revise and update the plan and timeline for resolving remaining issues. Related to this, the LBNC would like to better understand how and when decisions on the detector technology that will be used for far detector modules, beyond the first, will be made. The planned workshop in November could be a good starting point in this direction.

The committee commends DUNE for making progress on defining the Day-1 near detector. The LBNC would like to see further studies for the Temporary Muon Spectrometer, and its ability to achieve the main physics goals of the experiment. The LBNC would also like to see the SAND design and optimization finalized. In particular, the LBNC would like to see studies of how the SAND detector will help PRISM achieve its goals, and how different designs have an impact on the final oscillation measurements. The committee would like to emphasize how critical is the timely finalization of the design of the Day-1 near detector for the entire project. In addition, the committee would like to urge DUNE to provide a clear timeline for the further development of the Day-1 near detector, and to determine the latest date at which it must commit to building the TMS in place of ND-GAr.

The committee commends DUNE for the significant progress made towards establishing further funding from international partners, and urges the Collaboration to continue and intensify efforts on this front especially related to securing funding for the second far detector module (detector and cryostat).

The committee notes that progress has been made on the formation of the near detector consortia, and would like to continue to be informed as the consortium structure evolves.

Recommendations

- None

Technical Coordination

The LBNC was updated by the Technical Coordinator on the status of various activities in Technical Coordination. In particular, the steps towards ProtoDUNE-II-SP containing "module-0" components were outlined, on the road to the Far Detector first module. The committee noted the progress across the Far Detector Single Phase consortia, and the good functioning of the Review Office. The strategy of using ProtoDUNE-II-SP also to progress work on installation and integration, and to test the laser calibration system, were endorsed by the LBNC.

The committee noted that experience from ProtoDUNE-I-SP has informed design updates to ProtoDUNE-II-SP. Similar lessons can be expected from ProtoDUNE-II-SP, which may require re-engineering for the first Far Detector module. The LBNC believes that estimated re-engineering time, after completion of ProtoDUNE-II-SP, needs to be included explicitly in the Far Detector first module schedule.

Further information was provided about the interaction of Technical Coordination with LBNF and different subsystems of DUNE. The LBNC looks forward to seeing the description in the Near Detector CDR of how Technical Coordination interfaces to, and manages where appropriate, Near Detector design, planning, construction, and installation and integration.

The LBNC is pleased to hear that the staffing levels of TC are in line with current requirements. The committee would like to see summaries of effort available-vs-required in TC and the consortia on a regular basis in future meetings. In addition the committee requests regular updates on schedules and milestones in future meetings.

Recommendations

- Provide updates on the overall schedules for the different parts of the project (FD SP, ProtoDUNE-II, ND …) regularly at future meetings.

Dual Phase

The committee congratulates DUNE on significant progress in the DP ProtoDUNE run since the March LBNC meeting. In particular, on completion of the voltage scans for CRP operation, carefully executing the surgical intervention on the HV extender, and the extensive studies on the new issues since then.

The ProtoDUNE-DP run is now completed, and the cryostat is being emptied. This marks a major juncture for the DP project. The committee encourages the DP team to publish the measurements and experience from the run as the analyses mature.

While the intervention to disconnect the short to the field cage from the HV extender was itself successful, as summarized below it led to unforeseen consequences that made operation of the CRPs problematic and less stable for the last month of the run. As a result, much of the available time was devoted to investigating the new issues and only a short time to steady CRP operation with cosmic ray track reconstruction. Much was learned in these studies, with important additional information on the most vexing issues from the earlier running (the Grid sparking and the LAr surface conditions), and on the noise contribution from microphonic vibrations.

We strongly support the plans by DUNE to organise a workshop in November to carry out a lessons-learned analysis and to review the path forward.

Findings – protoDUNE operation

- NP02 (ProtoDUNE-DP) operation ended on September 7, and the removal of the LAr has started. This will take approximately one month, and it is expected that access to the DP detector will be possible by mid-November.
- On June 17 an intervention to repair a short between the HV extender and the field cage was carried out using specially developed tooling and procedures. This required draining ⅓ of the LAr which was then replenished using the liquid from NP04 (ProtoDUNE-SP). The NP04 LAr had been doped with Xe and N_2 for studies in the SP detector. After refilling the concentrations in NP02 were ~1.7 ppm Xe and ~1.5 ppm N_2. Towards the end of the run the N_2 concentration was increased in two steps to ~4.5 ppm to study quenching and the effect on the photon signal.
- After refilling, a de-clogging of the recirculation filter was required in early July. Good purity was then achieved, with the e-drift lifetime increasing to >15ms by the end of operation.
- In the HV intervention, the connections between the HV extender and the first three filed cage rings were cut. When recommissioning the HV system, a flashover between the surgically disconnected field cage rings and adjacent 4^{th} ring resulted in sparking at a rate of ~3 sparks per minute. In addition, a filtering resistor between the bottom of the HV extender and the field cage failed, and an unstable high resistive current path developed. As a result, HV operation was limited to approximately 120 kV with unstable sparking and field. The flashover sparks were observed visually in the cameras and their electrical characteristics measured.
- The upper ⅓ of the cryostat was exposed to air during the HV surgery, and after filling, bubbling and surface ripples were significantly worse. The use of an additional camera has identified specific locations on the field cage rings and the cryostat walls where bubbles appear. It is believed that the bubbles arise from heat leaks in the walls with bubble trapping in the rings. These studies will continue as the cryostat is emptied.

- While the LEM spark rate was unchanged after the HV intervention, the Grid spark rate increased very significantly. The rate was reduced via a "burn-off" procedure with the CRPs raised above the LAr surface, but nevertheless it remained high. This provides circumstantial evidence for a filament-like contamination on the Grid planes, although there is also evidence that wire tension has been lost in at least one location. It is not known whether such contamination would have originated from the HV intervention itself or from the partial draining and refilling moving already existing material.
- Extensive studies on the sparking and stability of operation, mapping out the CRP voltages, resulted in a minimal working point that allowed limited operating periods in which cosmic tracks were reconstructed, but no performance measurements could be made.
- The "microphonic" effect previously observed in the pedestal-RMS was studied using sound injected by a subwoofer. The technique was very successful; resonances in the region 240-286 Hz where observed. This technique would allow appropriate damping to be developed in the next CRP design.
- The photon detection system continued to operate throughout these studies, with the expected effects of the Xe and N2 in the LAr clearly seen. Detailed analysis is ongoing. The wavelength shifting efficiency of the two candidate materials, PEN and TPB, were measured. Together these measurements will inform a simulation study to assess the need for reflectors in the full design, which are under consideration for the cryostat walls in the upper half of a DP Far Detector.

Findings – post run investigation plan

- A detailed forensic investigation is planned once the cryostat environment is safe for access. This will entail both in situ analysis and the removal of components for bench studies. It will include inspection of recirculating filter with analysis of any material found, inspection of the CRPs and other surfaces for indication of contamination and spark damage, determination of the grid wire tension, inspection of the damage in the HV extender, and investigation of the known locations for bubble formation.
- These studies are expected to extend well into Q1 2021, and will likely contribute significant information in understanding the issues encountered during the run.

Findings – R&D towards a new CRP design

- The R&D program for an improved CRP design that was presented at the March LBNC is ongoing.
- New etching techniques have been shown to be effective in reducing sparking in the LEMs, and a new guard ring design in the anodes should reduce the risk to the electronics from grid sparking.
- The new design adds mechanical stiffness in the CRP to improve planarity at LAr temperature and help with sensitivity to liquid surface instabilities.
- Now, with the new measurements made, appropriate mechanical damping can be studied to mitigate the microphonic effect observed in the run.
- The plan for the next phase is to build and extensively test new CRPs for a second protoDUNE run in NP02. The availability of a new cold box, fully capable of supporting the extensive testing program is critical for this effort and is likely to drive the schedule.

Findings – post run workshop

- DUNE will hold a workshop in November to develop the lessons learned from the run and to plan the path forward.
- R&D towards an alternative design that is under consideration, that builds on the experience with the vertical drift but using a new TPC readout, will be included in the scope of the workshop.
- This will lead to planning for the future operation of NP02 in protoDUNE-II.

Comments

- LBNC congratulates the team for the careful execution of the HV surgery, and for the extensive studies completed during the run.
- There were several problems in operating the detector throughout the run. The committee commends the DP team for battling through these problems and making very good progress in understanding the underlying issues. Much has been learned that will feed improvements to the design.
- The forensic studies planned to pinpoint the failure in the HV extender and filtering resistor, and to identify the origin of the increased Grid sparking are critical and will likely take several weeks after access is available. The sequencing and execution of these studies must be planned and completed carefully. Again, the results will be important for future designs.
- The schedule for validating a new design, including extensive system testing, is likely to take longer than anticipated. The new cold box and testing capabilities are critical. A plan for sufficient resources is needed to ensure that the schedule can be maintained.
- The LBNC strongly endorses the proposal of the DUNE management for the workshop in November. The scope of the workshop is necessarily quite broad, and a follow-up workshop/review process may be needed in developing the plan for future running in NP02.
- Plans to develop and test the 600 kV HV system for 12-meter drift should be evaluated in this process. This is undoubtedly very challenging, requiring not only the development of a 600 kV power supply itself, but a test stand able to test the complete HV design.
- In planning the R&D program and the next NP02 run, the LBNC strongly encourages narrowing the scope as early as possible, avoiding major alternative designs competing in NP02. The LBNC is concerned about a broad technology front that may be incompatible with the tight timeline for the second FD module.
- The LBNC would welcome a debriefing from the November workshop at the next meeting, and to hear more about any alternative designs under consideration.
- While much was learned from this run, DP remains in the R&D phase with significant development remaining.

Recommendations

- At the next LBNC meeting, DUNE should provide a debriefing from the November workshop on the lessons learned and plans going forward, including a description of the status of R&D and conceptual designs for alternatives.
- During the workshop/review process, DUNE should update the LBNC on the strategy for developing and deploying technologies beyond SP.

Single Phase

Findings

- Detector physics as well as LAr-hadron, shower and cosmic physics.
- First ProtoDUNE paper submitted.
- Track based and purity both show lifetimes above 20ms.
- Rayleigh scattering length consistent with L_R = 90 cm.
- Over 2020, doped LAr with Xe for photon detector studies.
- Light yield seen to grow with Xe doping, saturation at about 11ppm.
- Physics investigations/studies/measurements presented include: proton/pion-LAr cross section, transverse kinematic imbalance.

Comments

- We congratulate the ProtoDUNE-SP team and analyzers on their excellent work.
- ProtoDUNE-I photon detector light yield stability results are encouraging. Longer term studies continue.
- In order to understand secondary interactions, DUNE will require good measurements of exclusive pion scattering on Argon. We encourage the collaboration to exploit ProtoDUNE data as much as possible in this respect.
- The Xe-doping results are encouraging. What is the longer range collaboration plan regarding a decision/strategy?

Recommendations

- None

Single Phase (Breakout)

Findings

- Cheng-Ju Lin (LBNL) has been appointed Deputy Technical Lead.
- Development/prototype/submission cycle for ASICs continues:
    - ColdADC 2nd prototype received early September
    - LArASIC expected mid-October
    - COLDDATA to be submitted late September
    - CRYO expected to be submitted later this fall
- Progress has been made on FEMBs for both solutions
- Warm Interface Board is compatible with both options, considerable firmware development
- ICEBERG running slowed by Covid-19, progress made on improving operations.
- Improvements made based upon analysis of ICEBERG incident that damaged FEMB channels.
- CERN Cold Box operations affected by Covid-19.
- Progress made on top of cryostat components/services and installation studies.

Comments

- We congratulate the team on considerable progress on many fronts.
- Demonstrable progress has been made with each successive ASIC fabrication cycle. The solutions developed appear to be on a track to success.
- The next submission for COLDATA is planned for next week. However, simulations with full parasitics are still underway and have recently identified issues with the modified PLL design. This means very little time will be available for the critical step of full-chip simulation, with parasitics. The team will need to carefully weigh the technical risk of proceeding with the submission versus the loss of 1-2 months of float. Arrangements should be made now to allow for submission in October if next week's submission cannot be safely met.
- Submission of the COLDATA chip, which is on the critical path for the 3 ASIC solution, is currently limited by Fermilab engineering availability (due to conflicts with other projects) and challenges moving the orders through the Fermilab purchasing process. Given the tight schedule, these near-term resources should not be the limiting factor.
- Testing of the v2 (nEXO) version of the CRYO chip has found a sizable correlated noise contribution, which needs to be addressed before submission of the next version. The time available for understanding and fixing this issue is short, given the overall cold electronics schedule.
- To meet the ProtoDUNE-II schedule, the final ASIC choice needs to be made by June 2021, and orders must be placed for ASICs by summer 2021. Although potentially achievable, this will be challenging and leaves little room for unexpected issues. Pushing to make the schedule might affect decisions, so it is important that the collaboration have a realistic timeline for all ProtoDUNE-II components.
- Investigations of the ICEBERG incident that damaged a number of FE chips revealed several potential issues with the setup, and a likely culprit as the cause identified but not definitively proven. Subsequent changes, including in hardware interlocks, have been made and there has been no recurrence so far. The issue stresses the importance of installation reviews and operational procedures, which should be documented and fully implemented and enforced via Technical Coordination.
- Tests in the Cold Box at CERN will be an important aspect of the system testing. We encourage DUNE to work with the Neutrino Platform at CERN to develop a detailed plan for tests of the TPC electronics in the ProtoDUNE Cold Box. This will ensure that ASIC/FEMB testing can be carried out as planned ahead of final design reviews.
- The collaboration needs to consider the timing for the procurement of the components of the 2nd far detector module, in particular for the ASICs, including an analysis of the risks related to a delay in these procurements.

Recommendations

- DUNE should finalize a plan of what validation of the final ASICs is required using data collected during the warm and cold ProtoDUNE-II operation before submitting the production ASIC orders, carefully balancing technical risk versus schedule float.
- The possibility of delaying by several years the purchase of sufficient ASICs for a second FD module introduces a number of very significant risks. We encourage the collaboration to work toward procuring in a timely manner sufficient ASICs to meet its total potential needs.

Near Detector

The LBNC congratulates DUNE on the major accomplishment of completing the first draft of the DUNE Near Detector Conceptual Design Report (CDR). This CDR was delivered to the LBNC in July, and the LBNC has provided extensive feedback on all aspects of the document. DUNE has held several internal meetings to formulate its responses, and held a meeting in late August with a subset of the LBNC to discuss the CDR. The LBNC is overall quite satisfied by the preliminary responses it has received from DUNE, and looks forward to receiving a revised version of the CDR later in 2020.

DUNE presented its plans for a Day-1 suite of detectors, which would provide the minimum functionality needed for DUNE's initial physics program, and which could be implemented if resource limitations delay the deployment of the full envisioned suite of detectors. This Day 1 plan closely follows previous LBNC recommendations, which were that the Day 1 detectors must include the liquid argon TPC (ND-LAr), an on-axis beam monitor (SAND), some kind of magnetic spectrometer downstream of ND-LAr in order to measure the momenta and charges of particles that exit the liquid argon, and the capacity to move ND-LAr and the magnetic spectrometer off-axis (the DUNE-PRISM capability). The LBNC repeats its previous recommendation that this is the minimum configuration needed for initial DUNE operations.

The preferred option for the magnetic spectrometer is the high pressure gaseous argon TPC, ND-GAr. The LBNC is excited by and strongly recommends this option. However, since resource commitments have not yet been obtained for ND-GAr, DUNE has proposed that the Day-1 detector configuration may replace this with a Temporary Magnetic Spectrometer (TMS), constructed from magnetized iron with scintillator strip tracking. This TMS would be included in the DOE scope as a contingency in case resources are not initially available for ND-GAr, but would not be built if resources can be found in time to build ND-GAr for Day 1. The LBNC endorses this general strategy, but has not yet received the technical details of the proposed TMS or studies of its performance. DUNE should provide these details to the LBNC for review by the end of 2020. Information on the TMS as a Day-1 alternative to ND-GAr would be included as part of the planned Preliminary Design Report to come in 2021. We were also very interested to hear about an alternative Day 1 solution, using the magnet of ND-GAr with a temporary simple tracker, and encourage DUNE to explore this alternative. The LBNC emphasizes that even if the TMS proves adequate as a temporary measure, it is not a long-term solution and is unlikely to permit DUNE to reach its full physics sensitivity. The ND-GAr detector is vastly superior and should be built as soon as possible, and DUNE should place high priority on recruiting resources for its realization.

DUNE is considering two technology choices for the inner tracking of the SAND beam monitor: a three-dimensional scintillation tracker (3DST) with surrounding TPC or straw tube tracking, and a tracker based on layers of straw tubes and thin layers of target mass. The LBNC believes that either option is viable and will allow SAND to fulfill its critical mission as a beam monitor. The SAND group is also considering adding an active liquid argon target inside SAND, but no technical details of this or articulated physics case for it have been shown to the LBNC. We were surprised to see this described as part of the reference design, since we believe the case for this component has not been made. Cross-section measurements, which in SAND do not benefit from the DUNE-PRISM approach for breaking degeneracies between flux and cross section, should not be design

drivers for SAND. Accommodating multiple nuclear targets, including a Liquid Argon target, leads to additional complexity. Neither the physics case nor the technical feasibility for a LAr target have been justified. DUNE should expeditiously choose between the two options for the inner tracker.

DUNE presented a new reference design for ND-GAr's magnet, called SPY, that features a partial return yoke and is and is similar to the design of a magnet that ASG Superconductor has recently completed for JINR's MPD experiment. The LBNC welcomes this new reference design. DUNE presented a rough outline of an R&D plan for ND-GAr, which we encourage them to flesh out and develop into a schedule. Funding for ND-GAr is still a work in progress. DUNE is also exploring an alternative Day 1 configuration using the SPY magnet with scintillator planes, as a step towards ND-GAr and as an alternative to the TMS. This approach has some advantages over TMS, in that it could simultaneously provide a Day 1 detector using the same magnet that ND-GAr will need. However, this option may cost more than the TMS, and is not currently the reference design for Day 1. We encourage DUNE to continue to explore the possibility of basing a Day 1 detector on the SPY magnet as an alternate to the TMS reference design.

The design of the full-sized LAr-TPC modules has advanced significantly. In July DUNE successfully demonstrated a scalable pixel anode, which is a notable achievement. The 2x2 ArgoCube prototype has unfortunately incurred 6 months of COVID delays. The team has put together a prototyping and R&D plan for ND-LAr, but significant work remains before CD2. Additional effort is needed in simulations and reconstruction.

DUNE-PRISM: Previous studies of the PRISM technique showed that while the method did a good job of predicting the energy spectrum at the far site over most of the energy range, it had difficulties with the high energy tail of the spectrum. New studies have shown that collecting limited amounts of data with alternate horn currents significantly improves the ability to model the high energy part of the spectrum with the PRISM technique. DUNE presented arguments that if changes in beam conditions are seen in the SAND beam monitor and can be diagnosed and modelled using the SAND data, then data taken off-axis can be corrected for the change in conditions and used in the oscillation analysis. At present a full analysis that directly includes SAND data as part of the near-to-far extrapolation is not ready.

Recommendations:

1. Deliver a revised ND CDR by the end of November 2020
2. Provide detailed technical information and physics studies for the TMS to LBNC, so we can review its suitability as a Day 1 detector. This should take the form of a document in the spirit of a CDR chapter describing the TMS and how it would meet the Day 1 requirements.
3. Determine as soon as possible the latest date at which DUNE must commit to building the TMS in place of ND-GAr for Day 1
4. Prioritize finding additional resource commitments for ND-GAr

5. Choose expeditiously between the two options for SAND's inner tracker, without letting cross-section measurements in SAND be a design driver

Computing

The LBNC congratulates the DUNE Computing Consortium for its continuous work of developing a computing system for the start of DUNE data taking, while providing a usable system for protoDUNE and simulation activities. The LBNC sees the need to start paving the road toward a computing TDR, supports the presented plans and particularly the idea of a CDR being produced by the end of 2020, to be reviewed in early 2021. We expect that the CDR, and in future the TDR, will cover aspects related to both Near and Far Detectors in a comprehensive manner.

Projections of the DUNE computing and storage resource needs were presented. The LBNC finds such projections a good starting point for the CDR which should elaborate on the assumptions used for those estimates. We expect those projections to be reviewed regularly. We note that the hardware resource needs are considerable already in 2021/2022, in order to support protoDUNE activities. We encourage the DUNE collaboration to establish the right channels to secure resources for those needs, which might require visibility at the RRB level.

We learned that DUNE is participating in the network requirements gathering process initiated by ESNET. We consider such a process as an important step in defining future network needs and we encourage DUNE to go through a similar exercise with other Research and Education Network providers.

The DUNE distributed computing system leverages many tools and services developed in the context of other HEP experiments and WLCG. The LBNC supports this approach as it seems the best way to optimise effort and guarantee long term sustainability. We encourage DUNE to consider the potential risks and mitigations of this approach, by identifying the most critical components, the dependencies from external providers and the level of effort inside the collaboration to customise and integrate such components. We expect that such high-level analysis will be part of the CDR.

The LBNC was pleased to learn about the outcome of the Frameworks Task Force. We support the approach taken by the task force, of defining the requirements of the future framework starting from the physics needs of the DUNE experiment. We also support the ultimate goal of identifying a unique framework that can cover the needs of all DUNE communities. We understand that in the next step different technical options will be considered, including leveraging existing frameworks, adapting them to the DUNE needs. We are eager to learn the outcome of this work in the next meetings.

Hardware databases are an area where coordination with many consortia is critical. Initial steps have been taken to form connections but this will require significant effort from both the computing consortium and the individual hardware efforts to identify use cases, agree on requirements and create a unified system.

The ND community clarified several aspects brought up in the context of the ND CDR. In particular it is now clear that the large uncertainties concerning resource needs relate mostly to the amount of simulation for systematic studies. DUNE is progressively acquiring a better understanding of those needs and we expect those uncertainties to reduce in the next few years. The ND is also working on its data model and we consider it essential to define a common model with the FD.

Recommendations

We note that the algorithmic aspects of software are not part of the computing consortium and we believe that the proper channels of communication should be established between the communities. We recommend that DUNE identify those channels, and reports back at one of the next LBNC meetings.

Appendix I: Attendees

Committee: Ties Behnke, Simone Campana, Dave Charlton, Joel Fuerst, Cristiano Galbiati, Heather Gray, Joachim Kopp, Bob Laxdal, Tiehui Liu, Naba Mondal, Hugh Montgomery, Scott Oser, Marco Pallavicini, *Adam Para*, John Parsons, Tom Peterson, *Anna Pla-Dalmau*, Kevin Pitts, Niki Saoulidou, Jeffrey Spalding, Eric Kajfasz, Darien Wood;

Scientific Secretary: Angela Fava

Fermilab PAC Chair: Hirohisa Tanaka

DUNE/LBNF: Dario Auterio, Ed Blucher, Tim Bolton, Ines Gil Botella, Alan Bross, Flavio Cavanna, Dave Christian, Linda Cremonesi, Dominique Duchesneau, Daniel Dwyer, Laura Fields, Vivek Jain, Eric James, Tom Junk, Mike Kordosky, Tom LeCompte, Jonathan Lewis, Bill Louis, Steve Manly, Chris Marshall, Elaine McCluskey, Chris Mossey, Mathew Muether, Vittorio Paolone, Laura Patrizii, Zarko Pavlovic, Elizabetta Pennacchio, Roberto Petti, Gina Rameika, Heidi Schellman, Luca Stanco, Stefan Soldner-Rembold, Thomas Strauss, Guang Yang, Jae Yu, Michele Weber, Mike Wilking, Bob Zwaska.

FNAL Directorate/Management: Nigel Lockyer, Greg Bock, Luciano Ristori

DOE:

Appendix II: Charge

The LBNC would like to hear about the general status of LBNF. The LBNC understands that there may be progress with the excavation contracts. Of continuing interest are the planning for DOE-IPRs, the current schedule, and any options for early delivery of beam.

The LBNC would like to hear from DUNE its overall status and progress from a high level, providing a basis for the details which follow. The situation with respect to the IPR process and the approach to a Baseline review appears to be fluid. The LBNC would like to hear how DUNE is approaching this. This should include mention of the ND Day-1 detector.

Time has been allotted for discussions of the advances in the Technical Coordination of DUNE. At the previous meeting there was concern about how TC was handling its multiple responsibilities for construction and R&D. At this stage the incorporation of the Near Detector in the TC should be addressed.

The LBNC would like to hear about the progress with the Far Detector SP technology. The presentation(s) should cover:

a) A summary of the ProtoDUNE SP photon detection situation including results of the Xenon tests should be described.

b) Physics analysis of the PD-SP data (briefly)

c) SP technical progress including the TPC electronics development and the progress towards a choice.

d) Progress in understanding of, and tests, of installation plans and procedures for DUNE.

Substantial time has been reserved for breakout discussions which we suggest could be used for some of these discussions.

ProtoDUNE DP (NP02) has undergone HV surgery and further operations since the previous meeting. These operations are set to end early September, so a discussion of what has been learned is of particular interest. Understanding the ongoing R&D on, for example the LEM construction, continues to be important. This leads towards a plan for a second phase of NP02 operation. In this context the LBNC would like to understand the planning for configuration of NP02 for future tests. We note that in the plenary session in-depth discussion is not possible but that there is substantial breakout time.

Since the previous meeting DUNE submitted their Conceptual Design Report for the Near Detector complex for review. The LBNC provided, in writing, an extensive critique. After digestion the LBNC ND team met with the DUNE ND team to discuss development of responses and to discuss clarifications. At this stage, the full LBNC would like to hear brief comments on this, on the technical progress, and on the Day-1 Detector. There will then be extensive breakout time which should be shared between these three aspects of the Near Detector planning.

The LBNC continues to be interested in the development of the Computing Consortium. We continue to be interested in a (more) coherent view of the computing and software project. We would like to see a path toward a TDR, starting maybe with a CDR highlighting where all the pieces fit together.

For example, it would be important to understand what are the steps that the DUNE computing consortium is taking toward the definition of the computing system to be used for production, which will eventually be described in the TDR.

We are also interested in understanding how this coherent vision covers the needs of the various communities FD SP, DP, ProtoDUNE, Near Detector.

Finally a short update of progress during the past 6 months is desirable.

This is a considerable ask, so we have tentatively suggested a substantial breakout. Failing that the presentation at this meeting should be a precursor to follow-up at subsequent LBNC meetings.

The LBNC will develop a Closeout Report which it will deliver at 12:15 CDT September 16. Subsequently this will be refined into a LBNC Meeting report.

Appendix III: Assignments

Consultants shown in Italics

LBNF Status	**Fuerst,** Laxdal, Peterson
DUNE Status	**Saoulidou,** Gray, Charlton, Kopp
Technical Coordination	**Charlton**, Fuerst, Laxdal, Peterson
Single Phase	**Pitts**, Fava, Liu, Parsons,Pla-Dalmau
Dual Phase	**Spalding**, Behnke, Galbiati, Kajfasz, *Para*, Wood
Near Detector	**Oser,** Behnke, Mondal, Kopp, Saoulidou
Computing	**Campana**, Charlton, Gray
Dual Phase (Breakout)	**Spalding**, Galbiati, Kajfasz, *Para*, Wood
Single Phase (Breakout)	**Pitts**, Fava, Liu, Parsons, *Pla-Dalmau*
Near Detector (Breakout)	**Oser,** Behnke, Mondal, Kopp, Saoulidou
Beamline	**Laxdal**, Fuerst, Peterson
Computing (Breakout)	**Campana**, Charlton, Gray