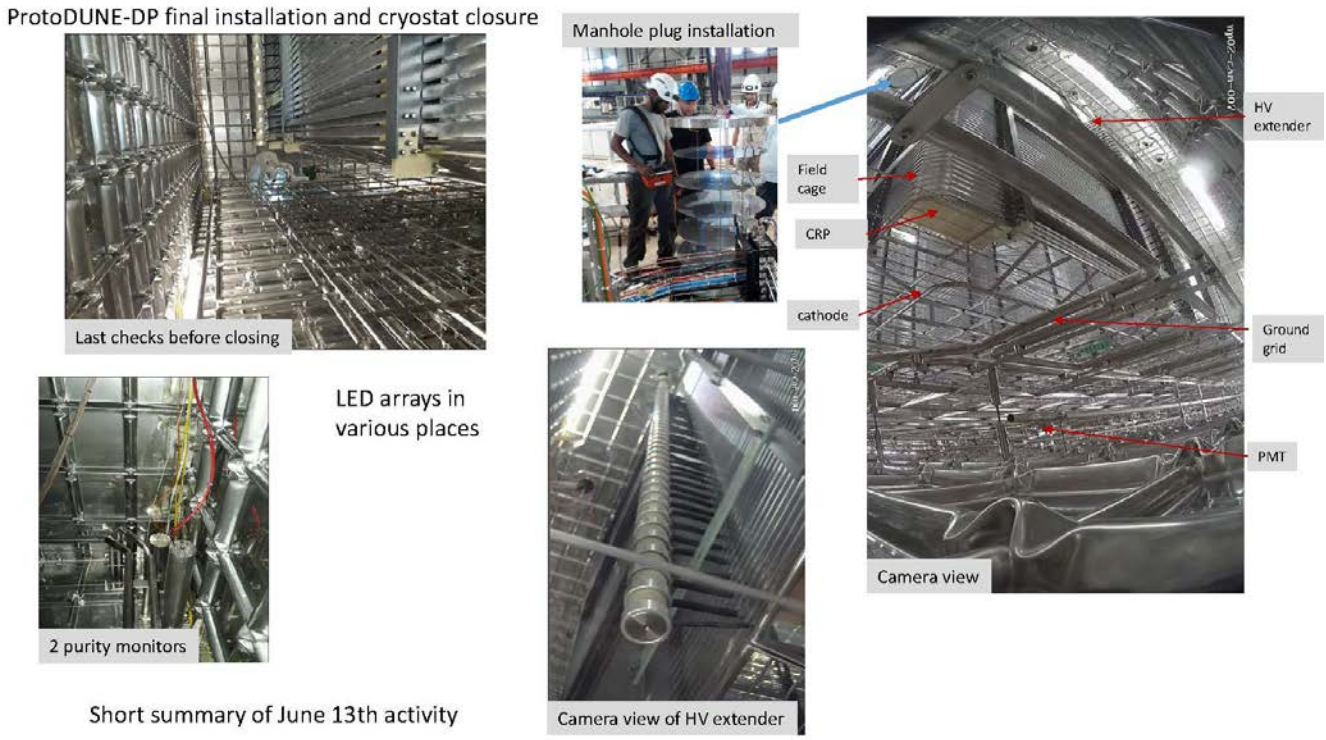
DUNE Project
Monthly Status Report
June 2019



ProtoDUNE-DP final assembly (after TCO closure)

Version 4c: July 16, 2019

Technical Coordination continues to focus on the TDR, with emphasis on updating interface documents. Further development of requirements, risks, schedule and cost continue.

Operations of the single phase ProtoDUNE prototype (ProtoDUNE-SP) continue smoothly with studies of photon system, DAQ, HV and purity. Analysis of beam data continues to make progress. The assembly of the dual phase ProtoDUNE prototype (ProtoDUNE-DP) was completed after the temporary construction opening (TCO) closing in May.

A Technical Board meeting on 13 June focused on interface documents. A Technical Integration meeting on 6 June focused on the SP TPC electronics and anode plane assembly (APA) interface. Engineering safety review of the Ash River test assembly equipment is ongoing.

A productive DUNE collaboration meeting was held 20–24 May at the Fermi National Accelerator Laboratory (FNAL). A successful Preliminary Design Review (PDR) of the High Voltage system for the single phase far detector (DUNE-SP) was held 3–4 June at the European Laboratory for Nuclear Research (CERN) and the committee report has been received. The Long Baseline Neutrino Committee (LBNC) review of the near detector was held on 4 June at FNAL. Workshops on Backgrounds, Calibration, Cryogenic Instrumentation and long drift were held 17–20 June at CERN. The next LBNC meeting will be 31 July – 2 August at FNAL. A DUNE Data Model workshop is scheduled 14–16 August at Brookhaven National Laboratory (BNL) and a DUNE Computing Model Workshop is scheduled 9–11 September at FNAL. An installation workshop is scheduled 19–21 August at Sanford Underground Research Facility (SURF). A workshop on the "DUNE module of Opportunity" on advanced technologies for future detectors is scheduled 12–13 November at BNL.

ProtoDUNE

EHN1 F. Resnati

NP02 (ProtoDUNE-DP)

- Cabling on the NP02 roof completed.
- Installation of the PMT light calibration system and PMT power and readout racks in progress.
- Test of the charge readout plane (CRP) position adjustment and distance meter calibration completed.
- Modification of the signal feedthrough (SGFT) warm flanges completed.
- Installation of 4 of the 10 warm flanges and final connection of the electronics.
- Installation of the cryo-instrumentation inside the NP02 cryostat: 11 cryo cameras, 11 LED lights, 3 purity monitors, 4 level meters, temperature and pressure sensors and relative connections to the feedthroughs. (see Figure 1)
- Cryogenic tests of the adherence of the Tetraphenyl butadiene (TPB) evaporated on the PMT continue.
- Installation of polyethylene naphthalate (PEN) foils as wavelength-shifter instead of the TPB on a fraction of the PMTs inside of the cryostat.
- Completion of extensive cleaning of accessible detector components, walls and floor of the cryostat.

- Removal of the false floor and scaffoldings inside of NP02 and installation of the ground grid was completed.
- Helium leak tests of the roof penetration, flanges and feedthroughs completed.
- Closure of the man hole on 13 June.
- Successful 200mbar pressure test of the cryostat.
- Installation of two cold traps to suppress moisture.
- Start purging with warm gas argon.
- Measurement of the natural vibration modes of the cryostat for seismic analysis
- Continuous test of the very high voltage (VHV) system in air and in argon gas.
- Functionality test of two purity monitor completed.
- Noise tests and grounding improvements ongoing.
- HV tests of the large electron multiplier (LEM) and LEM connections ongoing.
- Functionality test of the light detector system ongoing.
- Regeneration of the purification cartridges and start of the warm gas argon closed loop filtration.
- Start operation of the moisture cold traps.

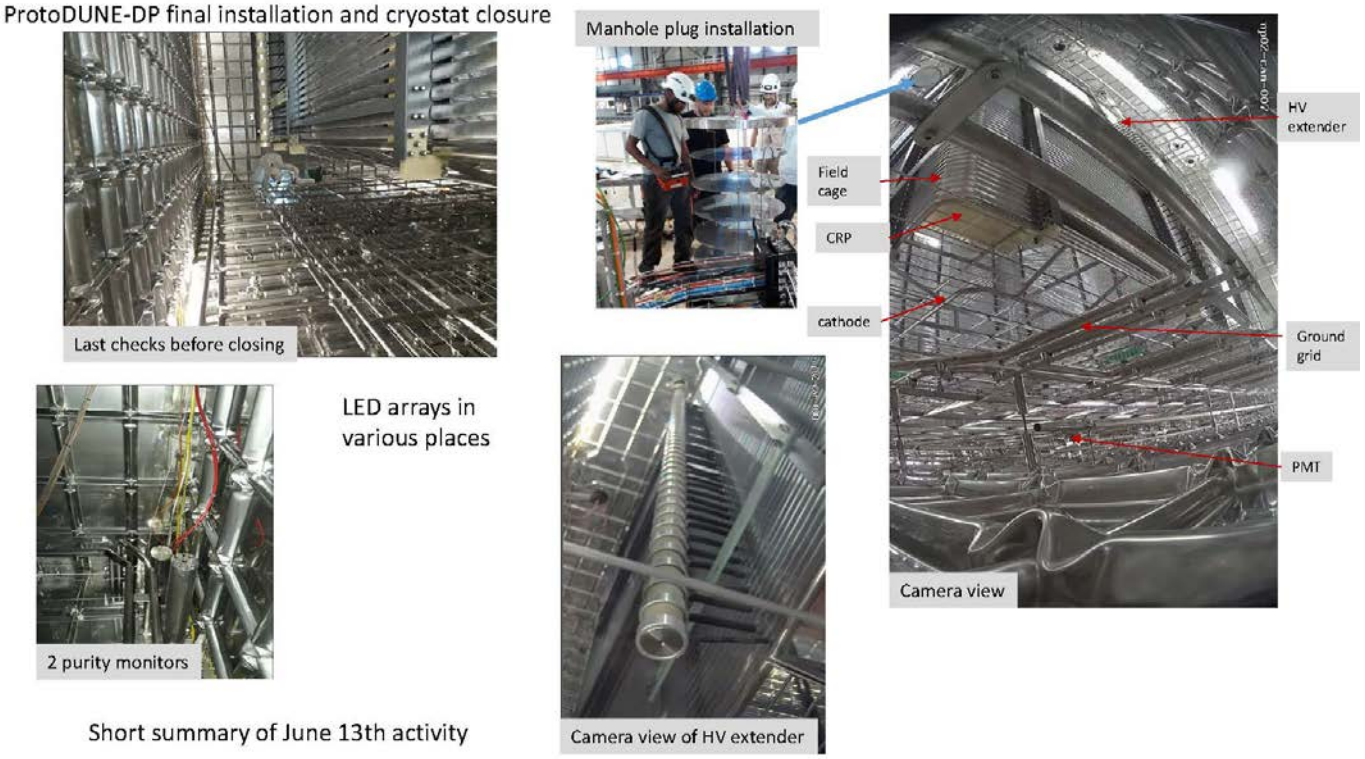


Figure 1: *Final assembly of ProtoDUNE-DP after TCO closing.*

ProtoDUNE-SP Operations

R. Acciarri, T. Yang, G. Christodoulou

ProtoDUNE-SP Operations: The first week was dedicated to photon detector (SPPD) system testing, with calibration, stability and telescope runs. The rest of the month was devoted to DAQ and HV tests.

DAQ weeks have concentrated on extension of FELIX readout (preparing APA#4 and hence half detector for FELIX readout), progress on software triggering, improvement of Run Control

with addition of new features and debugging of old issues and improvement of both system administration and backend DAQ.

The HV streamer auto-recovery system was reactivated on 10 June. We had several weeks during without intervention on HV streamers, in which the streamers would last for 10–12 hours before stopping themselves. Thereafter the HV system would be quiet for 7–10 days before another 10–12-hour streamer. Once the auto-recovery system (quenching streamers after a few minutes) was been turned back on, the frequency of streamers (each of them quenched after few minutes) immediately jumped to 3–4 per day, decreasing to the current value of ~1 streamer/day.

Two minor readout problems appeared and where fixed this month:

- 18 FEMB have been missing from the data for about a week. The problem was identified with a few board-readers which were moved to a different host without artDAQ being aware of it, hence not being able to read data out. Once identified the problem was quickly fixed.
- Around the same time, APA#1 WIB#3 was found to be not responding. The problem was the transceiver installed on the WIB not sending data to the DAQ. Replacement of the transceiver restored communication with WIB#3.

Regular cosmic (and some pulser) runs have been taken with the full detector operational to monitor gain stability and functionality of all channels. LAr electron lifetime has been stable at ~8ms.

ProtoDUNE Data Reconstruction and Analysis (DRA): The ProtoDUNE-SP DRA group is focusing on preparation for the second major analysis production run and the ProtoDUNE-SP performance paper. The new production will include many improvements and developments since the first production, such as 2D deconvolution, updated noise filtration, updated photon detector reconstruction, space charge calibration using data-driven maps and the first version of CRT reconstruction. Figure 2 shows the calibrated dE/dx vs residual range for 1 GeV/c proton data, which is in a good agreement with expectation.

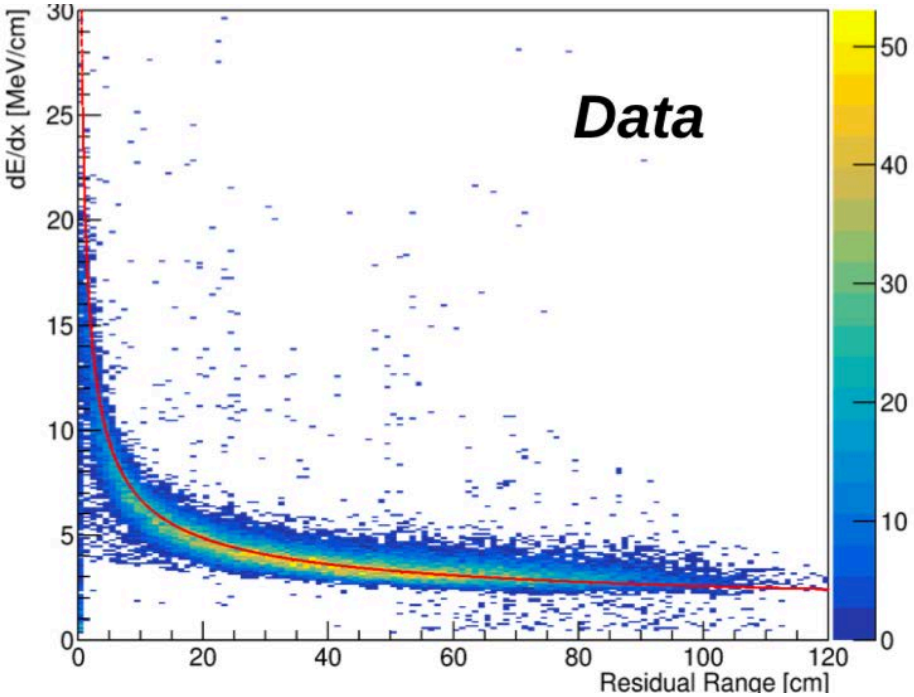


Figure 2: *dE/dx vs residual range for 1 GeV/c stopping protons after space charge correction. The red curve is the expectation.*

The ProtoDUNE-SP performance paper is progressing well. The paper will consist of a brief description of the detector and cryogenics system as well as the first performance results from both TPC and photon detectors.

DUNE

Far Detector Consortia

Single Phase Anode Plane Assembly (APA) — C. Touramanis

No report available.

Single Phase TPC Electronics (SP-ELE) — D. Christian

The ICEBERG TPC field cage was modified to eliminate HV discharges at the nominal operating voltage. Minor improvements in cryogenic instrumentation were made and the TPC suspension was modified to move the TPC three inches lower in the cryostat. A second commissioning run of ICEBERG was started during the last week of June. The TPC is operating stably with the cathode biased at -15kV and the electronic noise with ProtoDUNE-SP electronics is low. The internal argon filter has not yet been completed and one valve required for the LN_2 condenser has not yet been delivered, so the electron drift lifetime is very short and the pressure in the cryostat while the TPC is on is being controlled manually.

Bench testing of COLDADC and CRYO prototypes continued in May and June. By the end of June, bench tests of unpackaged COLDADC prototypes were completed. All the design issues in the COLDADC prototype have now been understood and most have been corrected. The remaining required design modifications have been identified. Tests of packaged COLDADC prototypes will begin in July and Front-End Mother Boards with LArASIC v8 and COLDADC will be fabricated so that system tests can begin early this fall.

Single Phase Photon Detector (SPPD) — E. Segreto

The June activity of the SPPD Consortium has focused on planning for the procurement of SiPMs for ProtoDUNE Run-2 and the far detector. Representatives of the Consortium (E. Segreto, F. Terranova, L. Patrizi, V. Zhutsi, A. Montanari, A. Machado) visited the FBK Company (Fondazione Bruno Kessler) in Italy. FBK has developed SiPM for cryogenic applications for other experiments and has been identified as a potential supplier of the photosensors for the far detector together with Hamamatsu photonics. The visit was very productive and a preliminary plan and schedule for production of optimized SiPM has been laid out.

Dual Phase Charge Readout Plane (CRP) — D. Duchesneau

The CRP consortium provided the first draft of the TDR chapter on 16 May and has been updating the chapter to provide missing elements. The major consortium focus has been activity for ProtoDUNE-DP.

Dual Phase TPC Electronics (DP-ELE) — D. Autiero

No report available.

Dual Phase Photon Detector (DPPD) — I. Gil-Botella

The Dual Phase Photon Detection Consortium (DPPD) continued preparation of the final version of the Dual Phase TDR chapter. Initial comments received by internal reviewers are being addressed together with updates on risks, institutional responsibilities and milestones. Discussions with other consortia about Supernova Burst detection requirements are ongoing with the goal to agree on the final text to be incorporated in the TDR.

HV F. Pietropaolo

In May and June, HVS consortium activities focused on the following items:

1) SP-HVS Preliminary Design Review: May was devoted to finalizing the engineering documents describing the baseline SP design (DocDB-10452). The collaboration meeting held at Fermilab in May was used to prepare and consolidate the documents to be presented at the PDR:
    a. FC/EW/CPA Drawings
    b. Assembly procedures
    c. QC/QA documents
    d. Prototyping, construction and assembly schedules
    e. Engineering design paper with FEA analysis
    f. Further evolution and optimization of the SP-HVS design

    The review took place at CERN in June, with a generally positive outcome and the recommendation to pursue with the proposed design optimization.
2) SP-HVS design optimization: In June, the consortium started working actively on the SP-HVS design evolution with the short-term goal of preparing mechanical prototypes to test the new construction, assembly and deployment procedures at the construction factories and Ash River.
3) ProtoDUNE-SP NP04: Investigation of long tern HV stability is progressing. The detector was operated continuously at the nominal field of 500 V/cm since April with extremely stable cryogenic conditions and very high LAr purity. The automatic recovery procedure after HV glitches was kept off until the middle of June. In this period, the “streamers” of ground plane #6 (GP#6) were occurring with a rate of one every 1–2 weeks, lasting 6–12 hours. After the middle of June auto-recovery was switched on again: the streamer rate went back to 1 every 8 hours, but the trend is slowing down, now about 1 every 18 hours. No effect due to the streamers has yet been found on CE and photon detectors: a dedicated trigger is in place and is being tuned to try to identify any degradation in the detector performance due to the HV instability. After nearly 10 months of operation the HV system is not showing any reduction in performance, on the contrary the up time is steadily improving (now >99.5%) and the residual instability is always localized on a single restricted region of the detector (GP#6).
4) ProtoDUNE-DP NP02: The consortium participated in final assembly of the Dual Phase detector with deployment of the ground grid and the check of the HV system electrical continuity. During the piston purge and cool-down phases a moderate HV (up to 20 kV) was applied to the cathode and the current continuously monitored. The excess current, present with the detector exposed to humidity, immediately disappeared and the system is now behaving very stably.
5) TDR: Both DUNE-SP and DUNE-DP chapters are being revised to include answers to the questions and comments of the internal and LBNC reviewers.
6) R&D: The Lamina company in the UK has successfully produced a prototype 4m long, 12mm diameter G10 bar laminated with resistive Kapton for the DUNE-DP cathode. The bar has been tested at CERN in LAr, demonstrating that it is fully compatible with cryogenic conditions (no de-lamination, no deformations). Residual bending due to own weight is within specifications.

7) Tests on the reflective + wave shifting foils on the cathode and field cage are continuing with the 50l LAr-TPC (FLIC) at CERN. Focus is on data analysis with and without Xenon doping. Preliminary results were reported at the DUNE collaboration meeting in May.

DAQ — G. Lehmann

In June DAQ work progressed on three fronts:

1. First, effort has been dedicated to completing the TDR DAQ chapter after reception of internal and LBNC reviewer comments.
2. Second, binary discussions with the other consortia, facility and installation groups have continued to prepare interface documents. Emphasis was put on defining DAQ requirements for the facility and exploring possible ways of implementing those.
3. Last, but not least, during the two weeks dedicated to DAQ testing in ProtoDUNE-SP (NP04), the DAQ team implemented and validated the TPC trigger chain: in practice, while data are continuously readout from the TPC, the DAQ identifies hits in the raw data stream, forms trigger candidate objects and decides when to trigger the event building and data storage actions. This pattern is very similar to the one that DUNE will use and thus serves as an important proof of concept. These studies will continue throughout the summer, possibly looking also into photon detector data to form the trigger.

Cryogenic Instrumentation and Slow Controls (CISC) — S. Gollapinni

The primary focus in June was the CISC scope review workshop 19 June at CERN. In preparation for the scope review a lot of progress was made in validating fluid flow simulations with ProtoDUNE-SP data. Various parameters in the simulation are being varied to test agreement e.g. incoming LAr temperature. Two example plots with the latest simulations are shown below in Figure 3. We are seeing improved agreement between data and simulation. Additionally, there is progress in understanding the bottom and top temperature measurements.

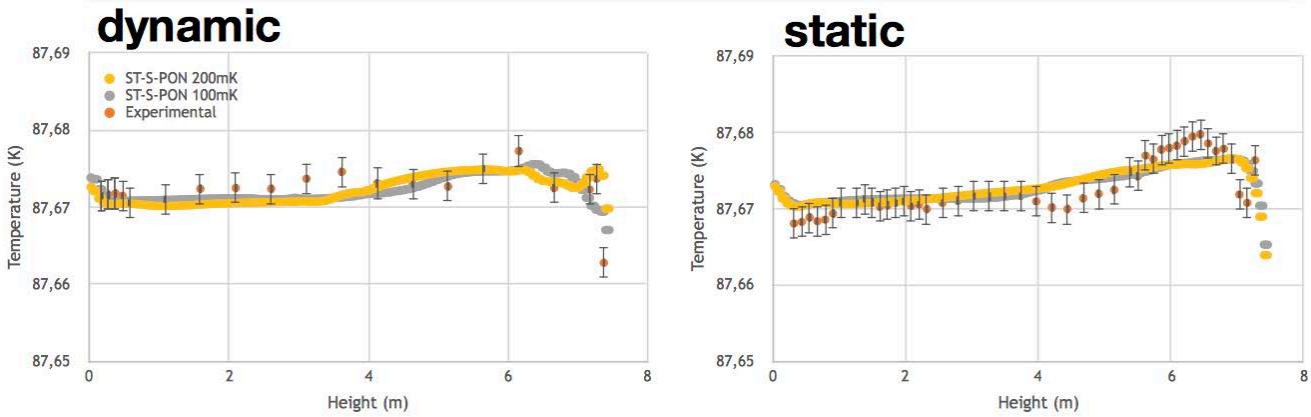


Figure 3: *Left plot corresponds to data from movable T-gradient thermometers and right plot to data from the static T-gradient thermometer. Red dots represent data and lines correspond to fluid flow simulations for different values of incoming LAr temperature. The blue (orange) line corresponds to an inlet temperature that is 200mK(100mK) higher than the LAr surface.*

Following the scope review, the consortium turned its focus to the TDR and responding to LBNC comments on SP and DP CISC chapters. We received comments from internal reviewers and those are being addressed. The consortium will focus on finalizing interface documents along with continuing discussions on interface and integration issues.

Calibration — J. Maneira, S. Gollapini, K. Mahn

Scope review: The main focus was preparation for the scope review, with dedicated meetings of the consortium and task force. Detailed responses to the scope charge questions were

prepared. 3D calculations were done for the voxel coverage of the laser beams shooting from outside the field cage. The calibration teams received many useful comments. It also became clear that further work is needed to clarify the justification for the presented scope, but we await the detailed report.

Integration issues: Discussions with the integration group are ongoing, in order to address various issues related to footprint on cryostat, grounding, power and network requirements for the calibration systems.

TDR progress: Discussion on the Executive Board meeting clarified that the outcome of the scope review should not change the main goal of the TDR and the plans for ProtoDUNE, since any system that conceivably should go into DUNE FD needs testing in PD. Work resumed in addressing the several comments received from both internal and LBNC reviewers.

Computing — H. Schellman

Continued integration of new sites into production with significant new resources from the Netherlands. Set up for a major data challenge for the dual-phase run later this year and for a second pass run of single-phase reconstruction with improved algorithms and calibration.

Near Detector — A. Bross

Near Detector Design Group (NDDG): On 4 June the reference design for the near detector complex (see Figure 4) was presented to the LBNC. We presented detector requirements for the long-baseline analysis, status of δ_{CP} sensitivity incorporating data from the near detectors, capabilities derived from off-axis running (DUME-PRISM) of LAr +MPD and technical status of the detector components.

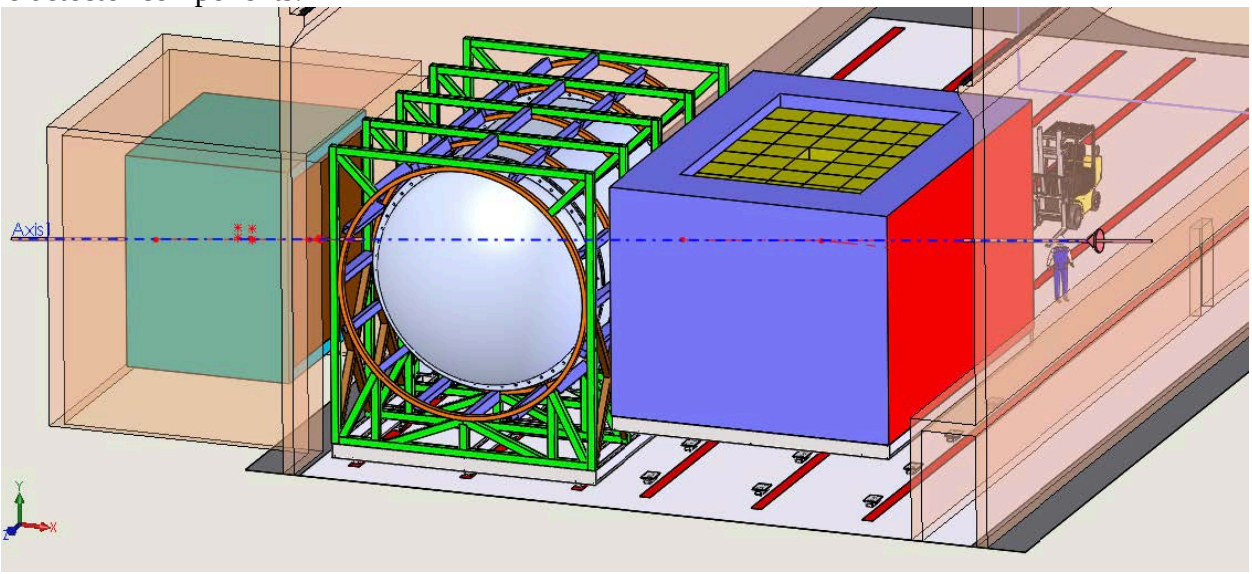


Figure 4: Near detectors: From right to left -- LAr, Multi-purpose detector (MPD), 3DST-S

The LBNC expressed strong support for the reference design with a few concerns. They considered the following components essential and required from the beginning of beam running:

1. DUNE should have an array of LAr detectors in its ND complex.
2. The off-axis concept on an argon target (DUNE-PRISM) is needed from Day-1.
3. There must be a magnetized spectrometer downstream of LAr ND that moves off-axis.
4. An on-axis beam monitor is required that is capable of accurately measuring beam center, profile and rates on a few days' timescale.

The MPD was deemed highly desirable, but more studies on its stand-alone capabilities were requested. The concerns that the committee expressed are listed below.

1. Consider options for more robust t_0 determination in gaseous TPC or show that current design is good enough.
2. The Carbon target (3DST) seems to have weak motivation in terms of the oscillation measurements on Ar, although it's fine as target mass for beam stability monitoring.
3. Is a fixed on-axis spectrometer really needed when you can move the LAr+MPD on-axis?
4. We worry whether the beam profile measurement is being done over a wide enough distance.

The NDDG is now working to address all these concerns and will update an update for the LBNC in the near future.

Technical Coordination — E. James

Technical Coordination continues to focus on the TDR, with emphasis on updating the interface documents. Further development of requirements, risks, schedule and cost continue. Weekly installation meetings with consortia continue.

Some feedback was received from the collaboration on the Technical Coordination volume of the TDR, but no written comments have been received from the LBNC. Feedback on the DUNE-SP TDR and DUNE-DP TDR volumes was received from some LBNC members.

A Technical Board meeting on 13 June focused on interface documents. Guidance was provided for both inter-consortia documents and for consortia-TCN documents. A Technical Integration meeting on 6 June focused on the SP TPC electronics and APA interface. Drawings defining the mechanical part of the interface were shown, along with proposed updates to the descriptions of both electrical and mechanical interfaces. Updated guidance on integration of the 3-D model was discussed. Engineering safety review of the Ash River test assembly equipment is ongoing.

A successful PDR of the HV for DUNE-SP was held 3–4 June at CERN and the committee report has been received. The committee endorsed the baseline TDR design and encouraged further work on proposed improvements for the final design in a year or so.

The LBNC review of the near detector on 4 June was successful. Workshops on Calibration, Cryogenic Instrumentation, Backgrounds and long drift were held 17–20 June at CERN. Spokespersons appointed 4–5-person review committees to produce reports addressing specific charge questions. The workshops were well-attended and resulted in lots of valuable discussion. Chairs shared initial feedback at the 27 June Executive Board meeting The first workshop reviewed the current state of knowledge of sources of radioactivity that may influence low energy physics of DUNE. Further studies and measurements have been identified. The second reviewed possible plans for calibration of the detector, including natural sources and beam-related, laser, neutron and gamma sources. Measurements of neutron scattering length in LAr are expected in 2019. Good progress has been seen recently in MicroBooNE e-field calibration using lasers. The second reviewed the state of the art in measurement of purity and temperature in ProtoDUNE-SP and the state of the art in CFD calculations of ProtoDUNE-SP and projections to DUNE. The appropriate level of instrumentation for DUNE-SP was discussed, along with plans for ProtoDUNE-DP and ProtoDUNE-2. The fourth featured reports from the double-drift task force and focused on risks and possible cost savings for increasing the single-phase drift length in ProtoDUNE-SP and DUNE-SP. Reports from all four workshops should be available in July.

The next LBNC meeting will be 31 July – 2 August at FNAL. A DUNE Data Model workshop is scheduled 14–16 August at Brookhaven National Laboratory (BNL) and a DUNE Computing Model Workshop is scheduled 9–11 September at FNAL. An installation and far site integration workshop is scheduled 19–21 August at Sanford Underground Research Facility (SURF). A workshop on the "DUNE module of Opportunity" on advanced technologies for future detectors is scheduled for 12–13 November at BNL.

Installation

J. Stewart

A partial delivery of the equipment for the APA test assembly was delivered to Ash River at the end of June. The equipment included two APA frames and most the parts for the APA assembly fixture. Engineering cross check and safety approval for the assembly fixture were complete early in the week. Figure 5 shows the assembly fixture being mounted to the assembly tower. Numerous small mechanical issues and missing parts prevented the completion of the work in the original one week planned. A safety review of the procedures and documentation needed to test assemble two APA take place in the week of 8 July. Assembly work will continue at the end of July.

Figure 5: *APA Assembly tower with the internal scaffolding in place. The red frame being mounted on the front of the assembly tower is the APA assembly fixture.*

One of the APA test assembly frames delivered to Ash River was equipped with a cable conduit with slots to allow photon detectors to be installed in the APA without removing the cable conduit. If the concept works then the conduit can be installed at the APA factory and does not need to be removed during installation. This will save roughly one shift of work underground per APA pair and eliminates the need to install the 6m long 2in diameter conduit after the photon detectors are in place — reducing risk. Unfortunately, the conduit was miss-installed in the new APA test frame and the slots in the conduit did not align with the slots in the APA frame. The conduit was removed from the APA frame and the mounting bracket was ground off. The bracket was then re-installed on the conduit and the conduit was inserted in the APA test side tube shone in Figure 6. A test installation of one electronics cable bundle was performed and initial indications look positive. Further tests will be done but the slotted conduit concept looks promising.

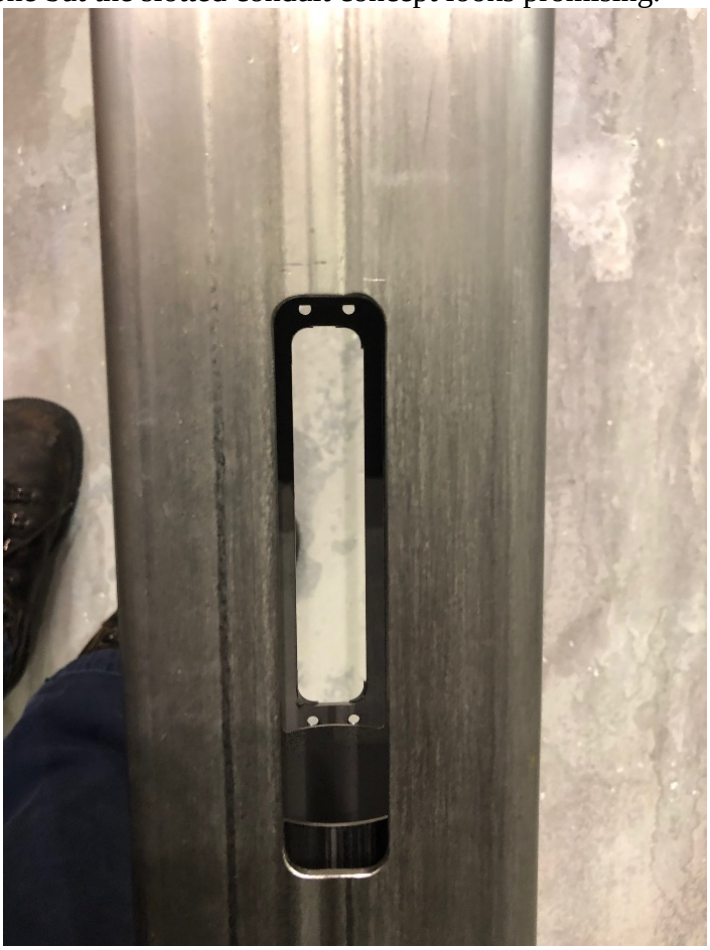


Figure 6: *APA side tube at ash River with slotted cable conduit inserted. The round cable conduit runs the length of the tube with laser cut slots lining up with APA frame slots for PD insertion.*

A detailed presentation of the installation plan was prepared.