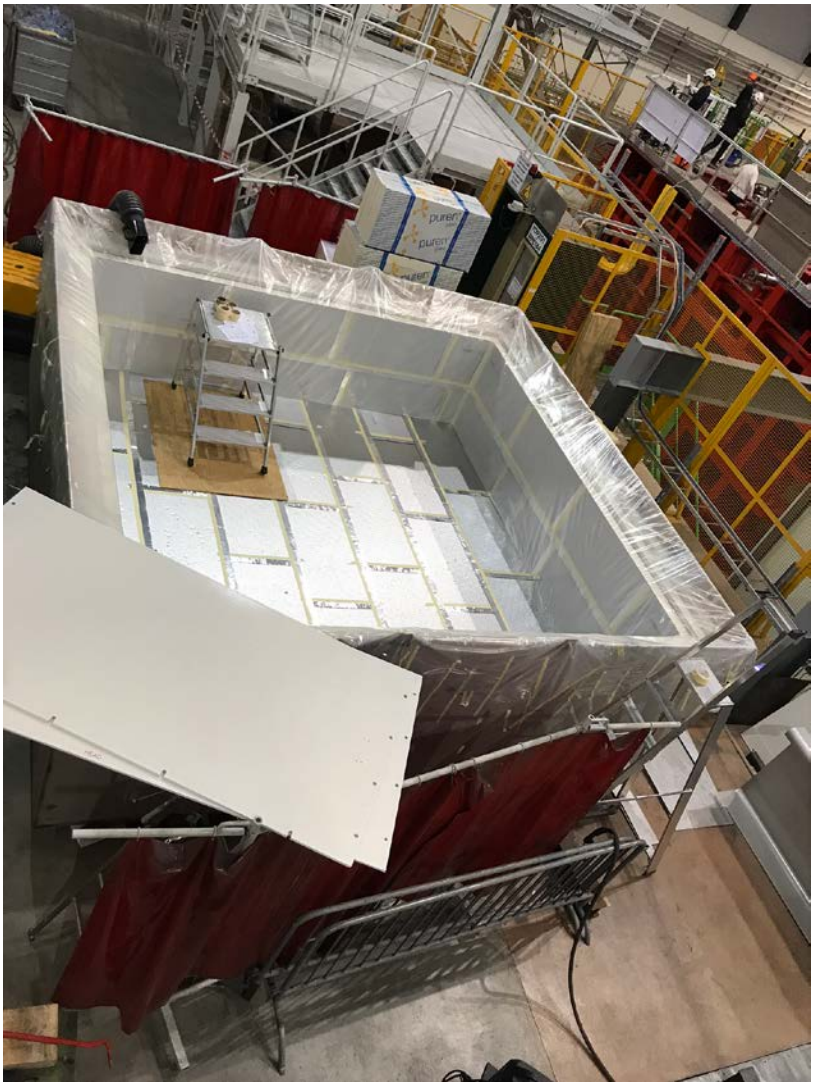
DUNE Project
Monthly Status Report
February 2018



ProtoDUNE-DP CRP cold box under construction

Version 5a: March 27, 2018

APA#3 (UK APA#1) was installed in the ProtoDUNE-SP cryostat. APA#4 (US APA#3) arrived 20 February and was installed in the cold box at the end of February. More than half of the ProtoDUNE-SP detector is now in the cryostat: APA#1–3, along with all three CPAs and the two beam-right side endwalls have been installed in the cryostat.

The ProtoDUNE-DP technical coordination group continues and a ProtoDUNE-DP/WA105 collaboration meeting was held on 26 February. Inspection of the 3×1×1 revealed some sharp solder connections, some material deposited on the cryostat floor, some rust and some loose connections, but no broken wires. The direct cause of the extraction grid HV limitation has not yet been conclusively identified, but it is likely due to the incompletely tensioned grid wires. Work on the 3×1×1 paper continues. CRP parts are in hand at CERN and a cold box test is planned for April.

The DUNE far detector consortia have focused on interfaces and key design issues, including those associated with the final conventional facilities design. Major effort is focused on the Technical Proposal.

The LBNC review 19–21 February was successful, with all consortia presenting current status. The LBNF/DUNE interface workshop 21 February was very productive and discussed several key interface issues in advance of the final conventional facilities design: removal of the rock septum, extension of the mezzanine, concrete loading under the cryostat, ventilation around and in the cryostat during construction, crane and hoist options, loading/unloading at the Ross shaft, rock resistivity measurements, surface sealing and Alimak/stairs from 4850 to 4910. A calibration workshop is scheduled for 14–16 March. A near detector workshop has been scheduled for 22–24 March. The next collaboration meeting is scheduled for 15–18 May.

ProtoDUNE

EHN1 **F. Resnati**

NP02 (ProtoDUNE-DP)

Cold Box

- Floor and walls of the warm structure completed
- Insulation installed on floor and walls
- Cold membrane welded, leak tested with helium and load tested with water

Figure 1: *CRP cold box construction.*

Cryogenics

- Completion of the Protego valve protection

Detector Installation

- Production of field cage modules continues
- Production, installation and test of the lifting equipment for field cage Installation

NP04 (ProtoDUNE-SP)

Cold box

- Operation of the cold box with APA #3 successful

Cryogenics

- Warm piping installation on the roof completed

Slow control

- Installation of the cable trays on top of the NP04 roof completed

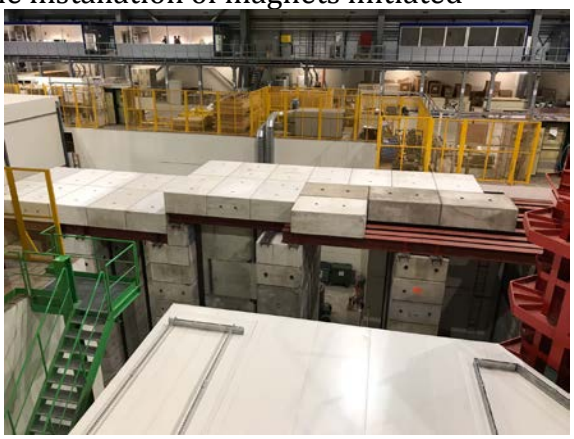
Figure 2: *ProtoDUNE-SP roof cable trays installed*

Detector Installation Support

- Design of the CRT hanging structures initiated
- Arrival of APA #4, unpacking and insertion in the clean room

Beam

- Progress with concrete block installation for the H4 beam line extension continues
- survey campaign for the installation of magnets initiated

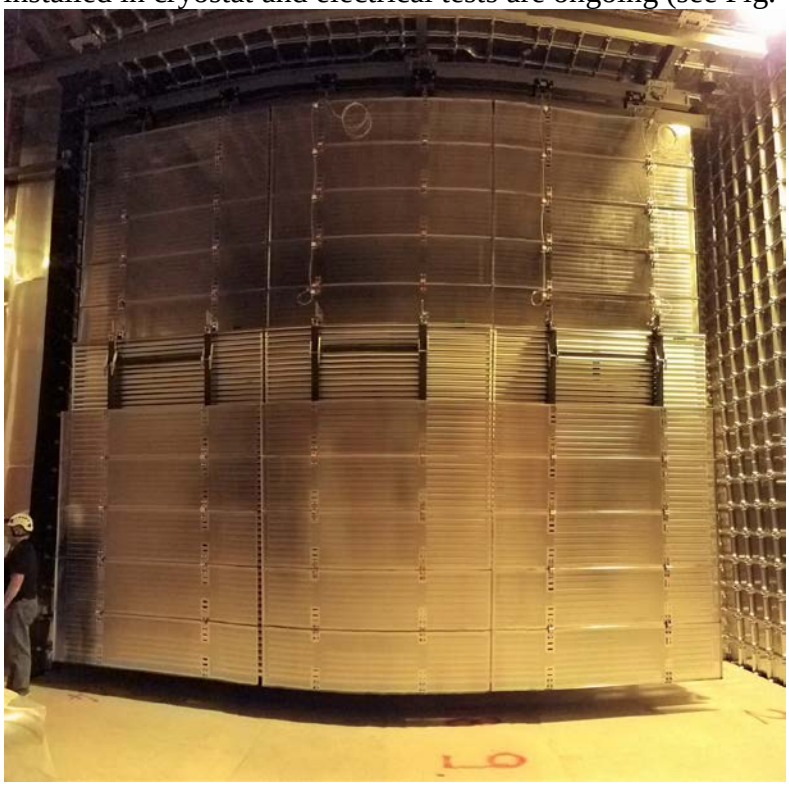


- ***Figure 3:*** *H4 (NP04) Beamline magnet support blocks*

Single-Phase ProtoDUNE — F. Cavanna

Significant progress was made on ProtoDUNE-SP installation in February:

- APA#3 completed cold tests and was installed in the cryostat
- APA#1–3 cryostat T-pipes installed and APAs cabled
- Firmware for WIB readout updated
- APA#4 arrived and photon detectors installed
- Beam plug assembled at CERN, test and final installation on endwall and survey completed
- Both endwalls were assembled and installed in the cryostat
- All 3 CPAs installed in cryostat and electrical tests are ongoing (see Fig. 4)



- ***Figure 4:*** *All 3 CPA installed in ProtoDUNE-SP.*

Dual Phase ProtoDUNE — D. Autiero

No report available.

DUNE

Far Detector Consortia

Single Phase Anode Plane Assembly

An APA Consortium workshop was held on 5 February at Daresbury Lab (UK). The workshop, with ~30 participants from both the UK and US, including representatives from potential

factory sites, focused on APA design, production planning and installation. A visit to Daresbury Lab took place and included the present ProtoDUNE APA production site and a planned larger site for FD APA production, which could host up to four APA winders.

Cable routing for Cold Electronics (CE) and Photon Detectors (PD) inside the APA frames was discussed at the workshop. One of the proposed solutions is to have pre-installed PD cables through the center tubes, while reserving the side tube for the CE and voltage bias cables.

Status and plans for the APA Consortium were presented at the LBNC review on 19-21 February. The consortium continued its preparation for the Technical Proposal. The first draft was submitted on 23 February.

While construction of the ProtoDUNE APAs is not directly part of the consortium, it has very large overlap. The 3rd US APA from the University of Wisconsin was delivered to CERN on 20 February, while winding started on the 4th US APA. Winding has been proceeding for the 2nd UK APA. Cold-box test results on the first three APAs at CERN were summarized at the APA consortium meeting, resulting in 15 abnormal wires out of 7,680 wires (0.2%).

Single Phase TPC Cold Electronics

Modifications to the front-end ASIC (LArASIC) were finished and the design was reviewed during a meeting of the cold ADC design team. The modified LArASIC will be submitted for fabrication in March. This version is intended to make the baseline used for collection wires insensitive to strain caused by coefficient of thermal expansion mismatch between the silicon chip and the plastic surface mount package in which it is mounted.

The first draft of the single phase TPC electronics section of the DUNE technical proposal was completed. Work on the technical proposal will continue in March.

Single Phase Photon Detector

The Consortium went back to full operation with all Working Groups restarting weekly or bi-weekly meetings. Many activities focused on preparation of the first draft of the Technical Proposal, which was due by 23 February. Substantial effort was dedicated to the LBNC review in the middle of the month. The Consortium has continued developing a plan for a consistent R&D strategy leading to the TDR, with the intention of balancing and optimizing international resources.

Dual Phase Charge Readout Plane

Much of February was spent preparing for assembly of the first ProtoDUNE-DP CRP at CERN which should start in April. This will bring an important step in the developing CRP construction and assembly for DUNE.

Dual Phase TPC Cold Electronics

No report available.

Dual Phase Photon Detector

The Dual Phase Photon Detection System Consortium (DPPD) focused on preparation for the February LBNC review and the Technical Proposal. Initial tables containing possible risks and system requirements were presented. Interfaces with other detector systems were reviewed and an initial schedule of activities towards the TDR completion in April 2019 was established. The first draft of the DPPD Technical Proposal was sent to the DUNE TP editors on time. The DPPD Consortium will continue improving the TP for the next version in March.

Progress in the simulations/physics WG occurred on three fronts during February 2018. First, work is ongoing to obtain a more realistic model of the photon detector timing distributions using LArSoft fast optical simulations. This is done by considering the photon propagation times

within the detector which have been neglected thus far. Second, light from a number of event topologies of interest for DUNE physics has been simulated for the first time in a dual-phase detector geometry, including beam neutrino, supernova neutrino and nucleon decay events. This is based on LArSoft fast optical simulations, for the moment possible only in the ProtoDUNE-DP geometry. These simulations represent a starting point toward the high-level performance studies needed for the photon detector. Third, work to refine the analytical framework for light simulation is ongoing. Unlike in the LArSoft studies, the current analytical approach does not simulate the important effect of light absorption by the cathode pipes, its supporting structure and by the ground grid. Work to improve this aspect of the analytical model is underway.

HV

Single Phase:

- R&D: the third phase of the HV test in the 35 ton at FNAL was concluded in February. Results are very similar to that of the second run with HV instability occurring above 115 kV; this indicates that the beam plug is NOT the cause of the instability. Detailed data analysis is underway to try understanding the true origin of the instability. A report has been submitted at the DUNE Technical Board which gave the green light for the beam plug installation in ProtoDUNE SP (NP04) At CERN, a mini field cage was prepared and installed in the 50 liter LAr-TPC cryostat. The goal is to test in ultrapure LAr, the HV stability (possibly up to 150 kV) in a 10 cm gap defined by the ground planes and the aluminum profiles. An FRP I-beam is also inserted in-between to study the effect of possible chugging up of its insulation surface. For same reason the aluminum profiles are equipped with plastic end caps. The detector is equipped with a camera in gas phase looking downward into the detector. The Ground planed are equipped with current pick off circuits; a single wire (acting as an antenna), protected in a gridded cage, is located close to the field cage and is read-out with a charge sensitive preamplifier. Filling with LAr and HV tests have started early in March.
- ProtoDUNE-SP assembly: during February the two “beam right" End Walls modules have been successfully assembled in the NP04 Clean Room. A 3D-printed mockup of the beam plug was used to test successfully the installation procedures onto the upstream End Wall module as well as the insertion of the EW in the cryostat and the correct positioning of the plug with respect to the membrane walls. The real beam plug was then mounted on the upstream End Wall module and the EW paced in the final position in the cryostat. The beam plug nitrogen gas system was assembled, leak checked and installed on top of the NP04 cryostat.
- The first draft of technical Proposal section (for the SP detector) was completed within the due deadline;
- The presentation of the “Status and Plans of the HVS consortium” at the LBNC meeting of February 19th was discussed and prepared. It included the last developments on the consortium Strategy toward the final design of the far detector field cage, the foreseen schedule and the major milestones in view of the TDR preparation;

Dual Phase:

- Activity focused on installation of the ProtoDUNE-DP Field cage. This is progressing smoothly: about 20 modules have been assembled with minimal profiles rejection (few %). Most of the winches for the mounting of the field cage modules in the cryostat were installed and load tested. The full installation for the 6m drift field cage is foreseen to be completed by the end of March, followed by an electrical test and possibly an HV test in air.

- Cathode design review is underway in cooperation with the ETH group as well as the HV distribution.
- Preliminary concepts for 600kV HV distribution are under development.

DAQ

The consortium focused on finalization of the Technical Proposal for both single and dual-phase detectors and on definition of the R&D program for the coming year.

The Technical Proposal elaborates an example design for the far detector DAQ that is based largely on technologies already demonstrated in ProtoDUNE. Although we do not expect the basic architecture of the DAQ to change fundamentally, there are several options available to the experiment for the implementation of key parts of the system. The most promising ideas will be pursued and refined further over the next year in preparation for the Technical Design Report.

The TP example design encompasses key architectural aspects of the final design that represent the basic 'design principles' for the DAQ. The most important of these are: a single system architecture for all detector modules; an emphasis on robustness and scalability in the face of all possible experimental conditions; and a highly flexible data selection strategy, capable of preserving arbitrary space-time samples of either the full or reduced data in response to a range of trigger conditions. We anticipate that the experiment will produce a data set of up to 30PB in the first year of operation.

In order to progress towards a full costed system design for the TDR, the consortium will carry out a prioritized R&D program over the next year, with two stages of internal review. R&D will focus on preparation of realistic hardware and software components of the final DAQ, with the aim of building a demonstrator slice that can read out the ProtoDUNE detectors at CERN in self-triggered mode. This will be a challenging project, that will also serve to build and consolidate the teams of institutes that will be building the components of the final DAQ. The demonstrator slice will represent the convergence at a practical level of the ProtoDUNE and Far Detector DAQ projects. As always, we welcome new participation and collaboration in the DAQ program, especially as we enter the next crucial phase of the project.

Cryogenic Instrumentation and Slow Controls

The CISC Consortium focus in February has largely been preparing for the LBNC review and the Technical Proposal. The consortium prepared a well revised risks and requirements document for the LBNC review and is currently focusing on developing a first full draft of the facility interface document. The consortium prepared a first full draft of the Single and Dual Phase CISC chapters for the Technical Proposal (TP) in February which was well received by the main editors. The CISC section writers and especially co-editors Glenn Horton-Smith and Carmen Palomares made a dedicated effort to get the first draft out by the deadline.

Near Detector — K.-B. Luk

The Concept Study team continued to advance studies for understanding the performance of various proposals on the table. Results and progress were presented in the DUNE collaboration meeting at CERN. Although the working groups had made impressive progress, Concept Study could not make a recommendation on the choice of magnet for the Multi-Purpose Tracker downstream of the non-magnetized liquid-argon TPC (LAr TPC) due to insufficient information to resolve the degeneracy between the KLOE superconducting solenoid and a new-build dipole. The litmus test appeared to be the acceptance of the muons originated from neutrino interactions in the LAr TPC that was not addressed at the meeting.

Chris Marshall carried out a series of study on the muon acceptance for the KLOE solenoid with its active volume filled with a straw-tube tracker (STT) *a la* the Fine-Grained Tracker documented in the DUNE CDR and for a dipole coupled with a high-pressure gaseous-argon TPC (HPGAr TPC) in February. He concluded that the muon acceptance of the KLOE+STT is generally smaller than that of the dipole+HPGAr TPC, as shown in Fig. 5. The drop in acceptance is due to muons stopping in the yoke for the KLOE+STT option and muons stopping in the coil for the dipole+HPGAr TPC configuration respectively.

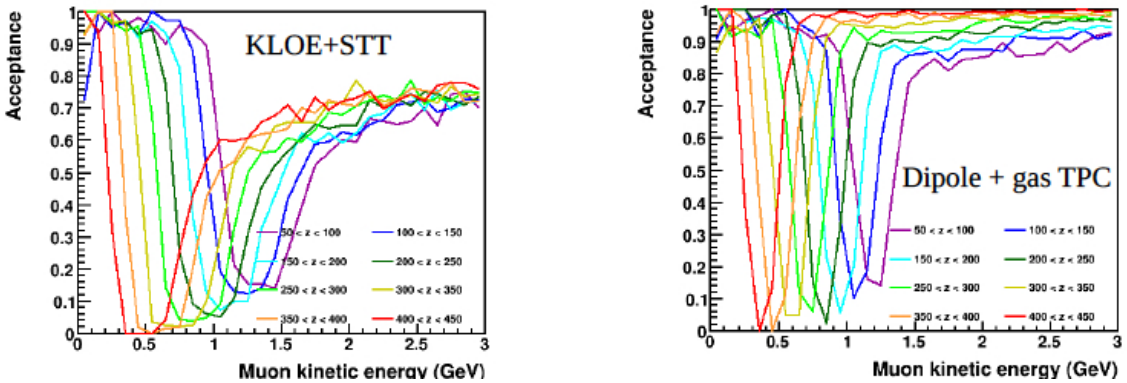


Figure 5: *Acceptance of forward-going muons (with angles less than 20 degrees) produced in charged-current neutrino interactions in the LArTPC.*

The PRISM concept could offer a handle for reducing systematic issues related to the neutrino beam and interaction cross section in the oscillation measurements. This requires sampling the neutrino beam with the near detector placed at different off-axis positions in the near site. Preliminary findings on the event rates at various locations and required run time, how well the linear combination of energy spectra at different position in reproducing the one observed at the far site and progress of obtaining the sensitivity in CP-violation with a fitting package were reported in the collaboration meeting. The Concept Study agreed that the PRISM working group should continue with their studies. Decision on whether the PRISM concept will be adopted as an official option will be made in the March workshop.

Other noticeable progress presented in February is from LArPix, R&D of pixelated readout for LAr TPC. Dan Dwyer reported results from the bench test of the first version of 32-channel chip at LBNL. Figure 6 shows the chip bonded to the PCB.

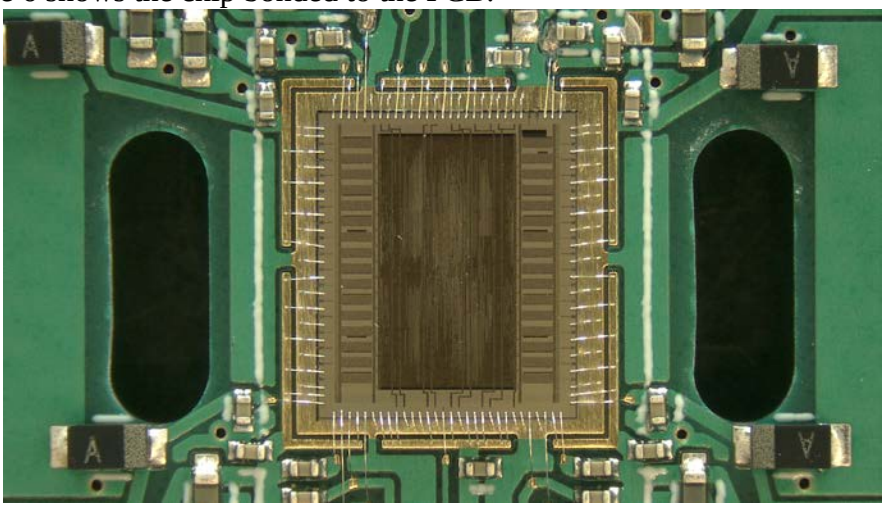


Figure 6: *32-channel custom-designed IC at LBNL for reading out pixels of LArTPC.*

The measured gain of 1mV/250 electrons was consistent with the design. The noise at LN_2 temperature was determined to be ~250 ENC which is significantly better than the design value of <~1600 ENC. The measured power consumption matches the design of 24μW/channel. When a 128-pad sensor was deployed into a 10-cm LAr TPC, charge signals were observed. Figure 7 shows an observed pulse consistent with a ~25k-electron signal.

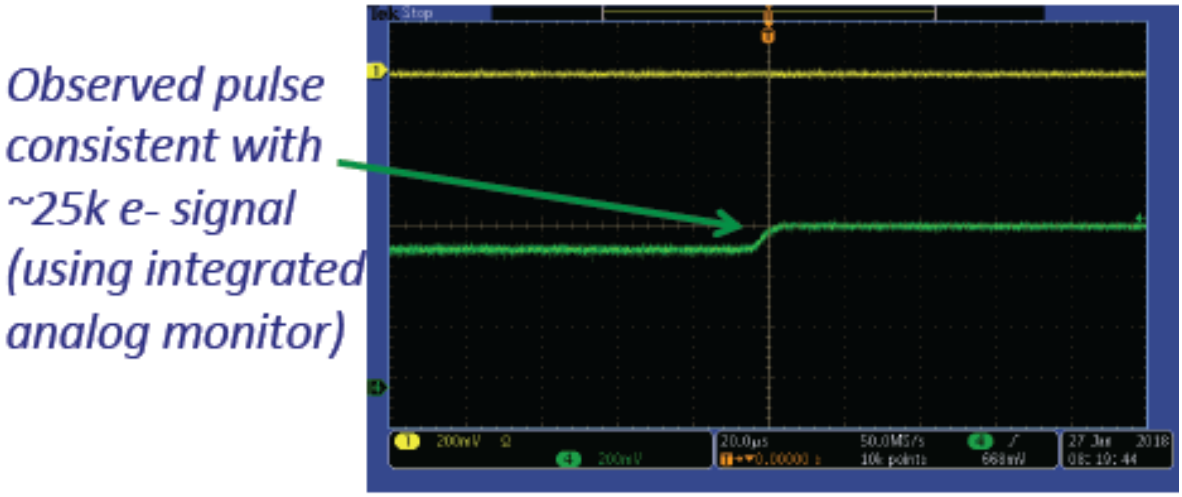


Figure 7: *Detected 25k-electron signal with LArPix.*

Technical Coordination — E. James

ProtoDUNE-SP APA#3 completed its cold box testing and was moved into the cryostat. The photon detectors were installed in APA#4 which will be inserted into the cold box in early March. APAs are still on the critical path, but cold electronics, photon detectors and installation work are all close to or on the critical path as well. Gabadi has been contracted to close the TCO starting April 30: many critical path activities to reach this milestone.

TC held meetings with consortium in preparation for the LBNC review 19–21 February. Progress continues to define interfaces, risks and requirements. WBS is being improved. Initial work on schedules is starting.

ProtoDUNE Milestones

Table #1 shows important ProtoDUNE milestones and current estimates.

Milestone	Original Date	New Date	Impact on Close SP TCO
ProtoDUNE SP Detector Production Complete	21-Feb-18	23-Mar-18	31-Aug-2018
ProtoDUNE UK APA #2 Ready to Ship to CERN	09-Jan-18	25-Apr-18	31-Aug-2018
ProtoDUNE UK APA #3 Start Winding	15-Nov-17	02-Apr-18	31-Aug-2018

Table 1: *ProtoDUNE-SP key milestone watch for February*

Installation

At the February 2nd LBNF/DUNE interface meeting the installation team presented studies of how removing the rock septum will impact the installation process (see Fig. 8).

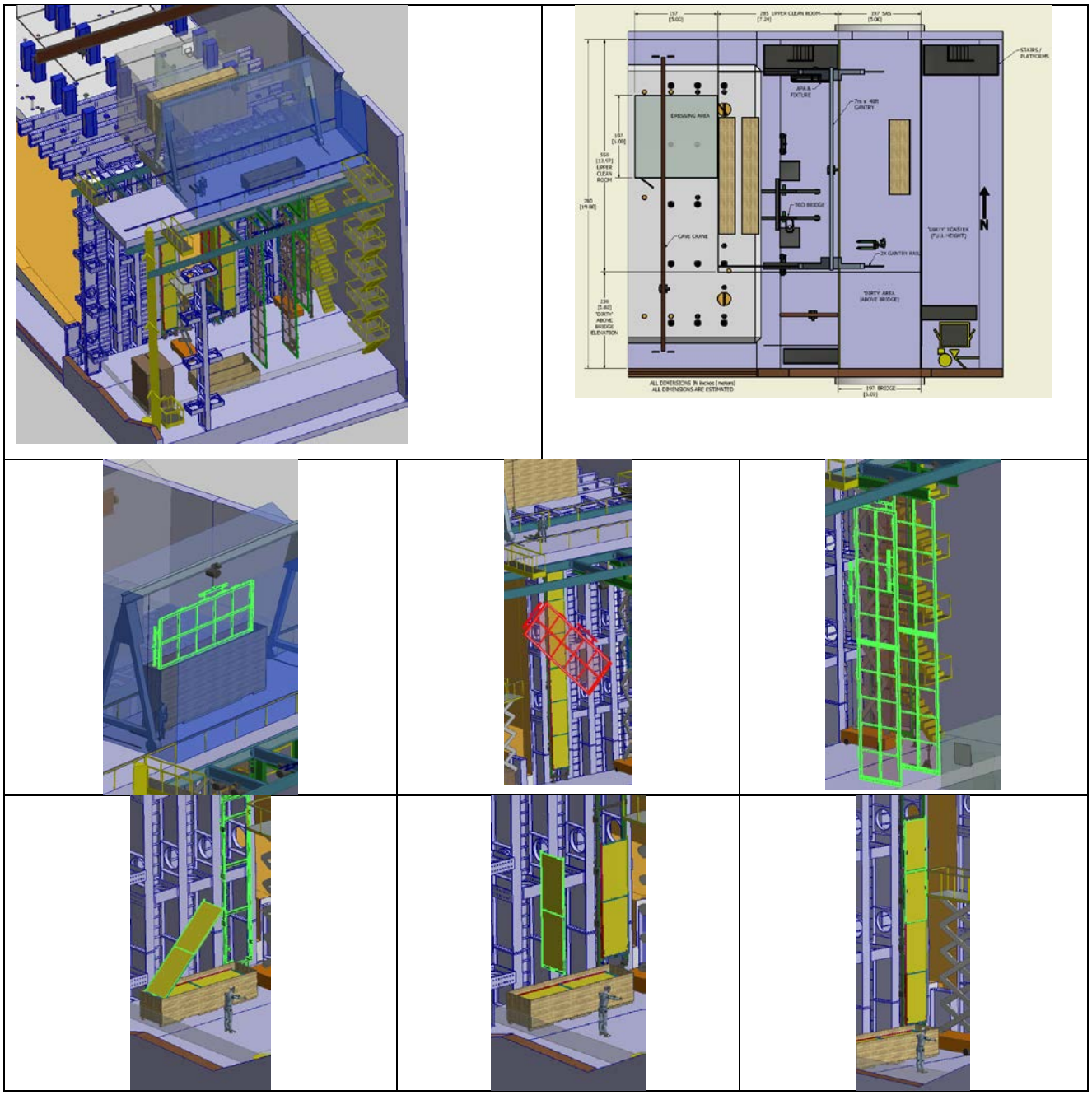


Figure 8: *Installation concept if the rock pillar is removed and the space reduced to 12m.*

It was generally accepted that removal of the septum improves the workflow substantially but the revised costs estimated for removing the septum make the option non-viable. At the meeting it was pointed out that the cost estimate for CF essentially scales the number of cubic yards of rock to be removed as this is the best estimate of the amount of time and effort needed. It was pointed out that if the rock septum is removed then one could possibly reduce the size of the total excavation by moving the cryostats closer together. This would reduce the total length of the excavation and conserve the amount of rock that must be excavated. As the space between the cryostat is more useful once the rock is removed a reduced gap between cryostats could also be sufficient for the installation. The installation plan was again reworked in February and presented again at the 21

February LBNF/DUNE interface meeting. If the original 21m gap between the cryostats is reduced to 12m then roughly the excavation costs balance. A configuration with a 5m wide bridge, which matches the North South drifts, and a 3.5m gap on both sided for installation was studied. The conclusion is that is sufficient to install the detector in an efficient manner. A layout was presented that allows parallel installation of the APA and CPA modules while also having space to test and repair any units that have defects after the last transport and cabling steps. In this layout the material SAS (cleanroom airlock) is placed on the bridge above the installation area. This allows ample space to work around the shipping crates so the equipment can easily be moved down into the cleanroom. This also allows the cleanroom at the 4850 level to be reduced in size so it does not cover any of the cryostat where racks will eventually need to be installed.

At the LBNC meeting on 20 February the interfaces between LBNF and DUNE were reviewed in a dedicated breakout session. The present status of the design was shown and the interfaces between the cryogenic systems and the detector were presented. The effort to converge on a cabling scheme for the DUNE SP detector was shown. The consortia are working on the interface control documents and the WBS dictionary to clearly define the interfaces both internally and to LBNF. The configuration management plan was presented and discussed.

QA

The update to the LBNF/DUNE QA Plan has been issued. The document can be found in DocDB-120. This latest revision is incorporating the responsibilities of the consortia under the project QA Plan. The DUNE Quality Assurance Manager can be used as a review resource when the consortia are finalizing their Technical Proposals.