Contents

1.0 Interim Design Report

Executive summary

Given the timing of the release of the Interim Design Report (May 18), just a few days in advance of the May LBNC meeting, the committee at that time made a preliminary assessment based almost exclusively on the presentations in the plenary and breakout sessions, and interactions with the proponents. The IDR itself represents a lengthy, comprehensive and impressive accomplishment by the DUNE Collaboration and it is an important milestone on the path towards the Technical Design Report in a year's time. Given the shortness of review and reading time, the LBNC can only respond in a preliminary way to some of the IDR charge questions on the basis of our deliberations during the May meeting. Subsequently, LBNC members were able to read the IDR in advance of the August meeting, with some follow-up questions provided in advance of the August LBNC meeting and others brought up in the breakout sessions and plenary talks. On this basis we are able to provide a now complete assessment of the IDR for consideration by DUNE. This final report builds on the preliminary assessment, with changes since the May report indicated in green font. The comments and recommendations are meant to guide the collaboration in producing the TDR and there is no expectation that they will be incorporated in an updated version of the IDR. Note that, in the case of the Dual Phase Far Detector part of the IDR, we were unable to respond even in a preliminary way at this time, since there were no breakout sessions dedicated to this topic either at the May or August meetings.

Overall the LBNC is impressed by the progress being made by the DUNE Collaboration, both in mounting an ambitious project to construct protoDUNE-SP and (soon to come) protoDUNE-DP and in assembling an ambitious Interim Design Report for the DUNE far detectors, as the first major deliverable from the recently formed detector consortia. The protoDUNEs represent critical engineering tests at 1/25th scale of the designs for DUNE far detectors, as well as invaluable opportunities to calibrate the response of the far detector TPCs with particle beams. CERN has continued to provide enormous support for these projects, particularly the cryostat technology development and the cryogenics systems for these devices, and the larger development of the Neutrino platform. The LBNC also notes the important progress reported from the Near Detector task force towards defining basic design requirements for an eventual conceptual near detector design and the Calibration task force, which has identified a suite of target systems to be considered for the Far Detector design.

Overall, the committee notes that the TDR is meant to be a reference design for both reviewers and the collaboration itself. In this regard, the ease of access to consolidated information and clarity of the arguments made to justify design choices, describe the intended detector and detector subsystems, and the related construction process, is paramount, rather than overall length. Given the level of investment required to realize the DUNE physics program, we are confident that the international agencies will want to see a rigorous justification of the projected scientific capabilities of DUNE and a demonstration of an optimal investment in terms of achieving these goals. We are therefore pleased to hear about the recently reported progress with full simulation of the main CP-violation analysis, where signal efficiencies and backgrounds suppressions factors have been extracted from Monte Carlo with automatic reconstruction. The performance of the automated reconstruction study confirms the levels stated in the CDR and the goals for the long-baseline program. At the time of the TDR, we expect that the conceptual design for the Near Detector will be sufficiently mature to be also incorporated in this full simulation, to validate the overall experimental design. Based on its review of the IDR, the LBNC is recommending that a schedule for completion of the TDR and two CDR volumes be developed and discussed with the LBNC, and a plan to make drafts available in confidence to the committee to allow reviewing to start as early as possible.

Based on assessment of the IDR, the LBNC has identified a number of overarching issues and recommendations for the next step of preparing a full Technical Design Report. Our comments and recommendations primarily relate to four aspects of the IDR phase for the experiment:

1) Unclear mechanisms for identifying, studying and resolving cross-cutting topics that transcend individual consortia, or which lie at the interface between hardware design and physics requirements;
2) Concern about the strength of the central integration and technical coordination team and its ability to develop and implement standards across a relatively new collaboration with diverse international experience and little in the way of established standards;
3) The lack of a comprehensive and well-documented connection between physics requirements and their connection to technical system requirements, an obvious example of an area requiring strong coordination between detector and physics teams; and
4) Concern that obtaining maximal benefit from the protoDUNE exercise requires a clear and tight focus on planning for and obtaining key engineering and scientific validation of the designs, while operating in what is essentially a full time commissioning mode, where operational conditions may be constantly changing without the benefit of significant prior experience.

We provide brief examples in each of these four areas here in the executive summary, but do not intend to be comprehensive in our survey. Other examples can be found in the main body of the report.

1. Cross-cutting topics:

In May, the LBNC has noted a number of cross-cutting topics where progress was perhaps being limited by the relatively narrow focus of the consortia and the difficulty of bringing together a wide set of interests (physics, hardware, computing) in a large international collaboration. Often a greater degree of innovation, leadership, experience, and cross fertilization of ideas is needed to galvanize efforts on these topics. Some examples have been recognized by the Collaboration already and specialized efforts established (calibration systems). In other cases, such as SuperNova physics opportunities and corresponding hardware requirements for light detection systems, the efforts are relying on a more grass roots approach, which may be missing a scientific opportunity for what is, admittedly, a hard technical problem. Close attention from DUNE leadership is particularly relevant to cross-consortium activities where the complementarity of the roles of Technical Board and Executive Board needs to be established. The Executive Board brings together leadership across the collaboration, both technical and physics, but its large size may offer challenges in terms of making sure decisions are set up in an effective and well-documented manner and that everyone at the table understands they are wearing a collaboration wide responsibility. Activities and issues connecting different areas, including the detector consortia, physics and computing, will be particularly challenging and may need to develop further. Some examples are:

- The organizational connections between the physics activity and the data collection and processing coming imminently from ProtoDUNE should continue to be monitored. The recent change in organizational structure within Physics is a good step forward in addressing concerns in this area.
- Tighter coupling between physics and software activity and the detector consortia would facilitate a broader understanding of the connections between key detector performance parameters and physics goals.
- Mechanisms to review specifications at the Executive Board level and, in the future, significant design changes are being developed, especially changes which may impact overall performance and physics capabilities, and continue to be encouraged. Such mechanisms may need careful preparation of decision-making by the Executive Board. Fairness, transparency, and consistency of approach should be goals. Changes to the Photon Detector System, involving Physics, and multiple consortia, as well as potential design risk balanced by physics payoff, may provide an early test case for this challenge.
- DUNE management is encouraged to develop further the organization of cross-cutting horizontal activities such as performance, software, computing, calibration, alignment, eventual data quality monitoring and so on, bringing together expertise from across the consortia and collaboration. Linkages are not as developed as they need to be, and a different organization may facilitate this.

Example 1: light collection system design and supernova physics impact.

One of the exciting physics opportunities for DUNE is the possibility of detecting a neutrino burst from a nearby core collapse supernova. The case was made that achieving sub-10% energy resolution would open up possible insight into the nuclear physics governing the neutrino energy spectrum. Given the cross disciplinary nature of SNB physics, the broader DUNE Collaboration may not be aware of some of these important opportunities. The path to defining clear photon detector technical requirements may very well benefit from establishing photon calorimetry goals motivated by both the presently known low-energy physics program (SNB neutrinos in particular) and the reach afforded by current state-of-the-art photon detection technologies. The integration of several candidate photon detection technologies into ProtoDUNE-SP in advance of running with beam is a remarkable achievement by the Collaboration. ProtoDUNE-SP will provide a definitive test-bed for analyzing the performance of candidate photon detection technologies and allow a baseline technology choice for the TDR. On the other hand, there was limited opportunity to explore a wider set of design options before protoDUNE-SP was constructed, so we suggest continued exploration of additional options for even further improved performance. One possibility is to consider xenon doping of the bulk liquid argon to shift the scintillation light from 127 to 174 nm. The resultant decrease in Rayleigh scattering (~ 3.5X increase in scattering length) is potentially significant. Adding reflectors to the cathode planes may improve uniformity of light collection. We note that this would be a significant perturbation on the existing protoDUNE design, but that SBND is already exploring a technical implementation of such a system, and so design options may benefit from close cooperation with the SBN program. It may be that design options will still need to be considered in the

TDR, since the risks associated with adopting some of these options may not be retired by ProtoDUNE or other R&D testing by that time.

Example 2: TPC calibration systems and feasibility of implementation

The LBNC was very pleased to hear a presentation from the calibration task force. This group has made commendable progress on defining candidate systems for the far detector TPCs. Collaboration management has stated that the next step is to move the task force into a consortium (nature to be decided shortly) before moving to a stage of evaluating more closely the efficacy and technical feasibility of proposed systems. The committee believes that the different suggested sources are not on an equal technical footing, although they were discussed as though they were. This was confusing, and a potential distraction. The committee has the impression that a real plan will be dominated by the laser ionization track calibration – regardless, the primary calibration source or sources should be emphasized so that it is clear which ones are reliable and which ones are more speculative. A specific, comprehensive calibration plan was not presented, and the committee has no way at present of assessing whether calibrating a detector the size of DUNE is actually feasible. Any calibration of a DUNE-sized device will necessarily rely on detector models to fill in the gaps (spatial and temporal) in calibration data. The robustness of these models is important in determining the volume of calibration data needed.

Similar to other systems, the physics origin of some requirements was not clear, nor was the capability of delivering on these requirements with the proposed calibration system. It would be useful to define more clearly what exactly knowing the energy scale to 1% means. Is that a 1% bias? Global or local? At a particular energy? Similarly for position accuracy – does this refer to bias on dQ/dx? Are there separate requirements for relative/absolute position?

While 39-Ar "comes for free" it is not an optimal internal source for the goals stated. The liquid-noble dark matter community makes extensive use of injected radioactive sources for this style of calibration, which have the additional advantage of mapping fluid flow in the TPC. At first glance, few-MBq flow-through 222-Rn sources are readily available and give a unique signature in the desired energy range with 214-Bi/214-Po coincidence. These sources may also be useful for understanding fluid flows in the cryostat. Other injection sources may also be appropriate.

The LBNC views the question of calibration systems as perhaps one of the more difficult of the cross cutting topics the Collaboration must face. The task force has made great progress in narrowing the choices and starting to define the goals of such a program. However, the next step is hard: establishing well understood physics requirements, understanding technical implementations and determining the practical capabilities of a real system (including data acquisition limitations, offline computing and analysis needs). This will require ongoing significant attention across physics groups and many detector consortia and therefore will be a challenging example of cross cutting topics for Collaboration leadership.

Recommendations:

- Demonstrate at a nominal level the performance and viability of the calibration scheme as part of the TDR.

- The Collaboration should resolve the long-term organizational structure of calibration efforts as soon as possible to enable groups to begin contributing in a tangible way.

2. Technical Coordination

DUNE technical coordination is responsible for project engineering, installation planning and execution, operation of the far detector integration test facility, and common infrastructure. Post TDR, the organization includes project support, integration, infrastructure, the integration and test facility, and installation groups. Overall the LBNC is concerned that the path to resourcing and filling out the technical coordination team is lengthy and uncertain. We note the important positive development that DOE is willing to support the early development of an initial Technical Coordination team prior to the TDR. The bulk of the organization will not be needed and will not be in place until after the TDR. The LBNC did not review at this time whether the ultimate buildout was sized appropriately, e.g. on the basis of benchmarking from other large-scale international detector projects. The plan is for the Technical Coordination team to be resourced from a combination of host lab and common collaboration resources. The common collaboration resource component may take some time to realize, since it will require RRB approval.

We expect that a strong technical coordination team will be needed during the preparation of the TDR itself, which underlines the importance of initial DOE funding for this effort. The Technical Coordination team will help establish collaboration-wide standards for everything from CAD drawings to interface definitions, risk registry development and WBS and costing consistency. On a positive note, hiring the DUNE Mechanical Project Engineer to complement the DUNE Electrical Project Engineer in the TC/SE team is a major step forward. The addition of designer effort to the team is also an important step forward to supporting the suite of 2d envelope drawings. Systems engineering has placed an emphasis on fostering communication across project elements. The committee applauds this effort and encourages the project to continue along this path, even as this places a further premium on ramping up the integration effort earlier and more quickly. The committee supports development of a high-level integration/interface management strategy and commends the project for this effort

3. Connecting physics and technical requirements

The LBNC continues to strongly encourage the Collaboration to develop a clear connection between the physics goals of the experiment and the technical design requirements. Many of the May plenary speakers who summarized the technical systems described in the IDR could not provide a crisply articulated argument about physics drivers and were generally unable to identify such drivers during questioning. The LBNC welcomes the first steps taken in recent months to adopt its earlier recommendation that the Collaboration develop and maintain a single, centralized, official set of requirements, whose content is owned by the EB. The format being developed is a compact summary that will be particularly useful with the planned additional columns capturing (1) the expected impact on the project of validation tests of the specific requirements using ProtoDUNE and (2) a “Motivation/Consideration” field with summary arguments leading to the planned performance requirement, which also make reference to documentation from a more complete study with requirements derived from MC studies. It may also be worth considering whether a more hierarchical style of presentation would have some benefit in clarifying flow down connections.

There are a variety of arguments in favor of developing such a clear and simple explanation of technical requirements as a best practice: (1) requirements very often become schedule and cost drivers, with implications for curtailing the overall cost of the experiment and demonstrated maximal effectiveness of limited funding on scientific output; (2) guiding value engineering, which will only come into play once the project passes from the present conceptual phase to a fully engineered design; and (3) allowing sound technical priorities and plans when confronted by decisions during the design and development phase, or later in the project when project execution encounters difficult budget, schedule or technical problems. The LBNC will expect clear statements of the flow down from physics sensitivity to technical requirements at the time of the TDR and sensitivity analysis for key parameters, identified with some judgement by the Technical Coordination team.

Recommendation: Report to the next LBNC meeting a summary of the main performance drivers with explicit couplings to the primary DUNE physics goals. Summarize which of these performance indicators will be established or explored by ProtoDUNE, and which will remain untested. Prepare a succinct document (around 20 pages or less) summarizing this, which should be made public.

> Response: Tables, prepared by Technical Coordination, summarizing the linkage of detector design parameters with required performance, were presented in draft form. While these draft tables are important parts of the documentation of the flow-down from physics goals to detector design, higher-level connections need still to be documented, starting from the physics goals. The Collaboration is urged to ensure these are clear in the TDR, and to make a standalone, maintained, public document which describes them.

4. protoDUNE experience and implications for engineering design

A detailed presentation on the ProtoDUNE-SP commissioning, operation and data analysis plan was made in May by Flavio Cavanna, with a further update provided in August. A detailed plan for beam exposure and data taking was included in this presentation. An internal ProtoDUNE-SP Data Exploitation Readiness Review was also conducted by DUNE and Fermilab SCD on May 10-11. The report from the review panel was made available to the LBNC in draft form. We concur with recommendations made there concerning establishing a schedule for remaining work on the DAQ system, which is considerable. We also concur with the comment that there is a long list of measurements and results expected from protoDUNE-SP, not all of which have been incorporated in planning to date (see below on cryo testing and item (3) above on systematically addressing physics requirements), and so the project would benefit from establishing priorities based on high-level strategic goals for protoDUNE-SP. We also note that protoDUNE-SP operations will probably be closer to a full time commissioning mode without the benefit of routine operational experience. This will make it challenging to address the full list of measurements and studies, since some may be quite exploratory in nature and therefore uncertain in duration. In this regard, the recent change to establish the Data Reconstruction and Analysis (DRA) group within the Physics organization is a positive development.

Example 1: Validation of CFD calculations in the light of protoDUNE cryostat measurements

The committee is impressed with the plan for first cooldown of the protoDUNE cryostats – this plan should be used to cross-check preparations for equipment required to monitor the cooldown. Also the plan should be clearly communicated to the DUNE teams with any requirements on platform or equipment access during the various steps of the cooldown clearly articulated and blended into the DUNE commissioning plans. Especially important is the identification of the tasks that can be done in parallel vs those that must be done serially.

The DUNE commissioning plan as presented in May did not include any particular tests to verify the CFD model. We note that recently there has been an effort started to define a set of post-beam operations testing that may address these concerns. As protoDUNE represents a scaled version of the final DUNE detector it is the last chance to verify and refine the models on anything close to DUNE scale. During the May meeting there was a feeling that the collaboration was distancing themselves or underselling the importance or possibility of such measurements. The committee believes that this would be a significant missed opportunity. We also note that performance targets mentioned in the cryogenic commissioning plan (cryostat strain levels, LAr purity levels) are not specified.

Recommendation: Develop a detailed cryogenic data collection plan in protoDUNE with the goal to help verify or inform the CFD modeling studies. Add specific steps to the protoDUNE commissioning plan. In process.

Example 2: Validation of TPC engineering design and TPC performance

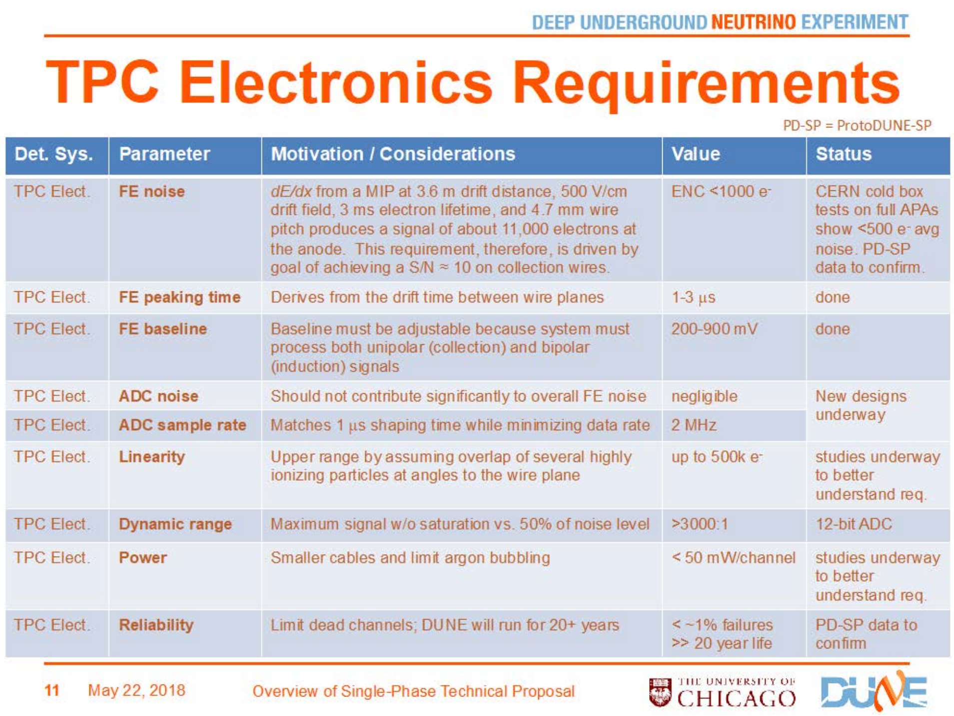
As noted earlier, we are pleased to see the Collaboration respond to earlier recommendations by moving to establish a simple, centralized, official set of requirements, whose content is owned by the EB. Such a table will also capture the expected impact on the project from validation tests of the specific requirements using ProtoDUNE-SP, which may lead to a more systematic development of a list of proposed measurements. This is an important first step in establishing a tighter connection between design validation for the TDR and measurements with protoDUNE which will also inform priorities for tests incorporated into protoDUNE-SP operational planning. While there is an effort after the fact to gather lessons learned from protoDUNE construction, a better approach would be to establish a continuous record of lessons learned log before such valuable information is lost to tribal knowledge.

1.1 Single-Phase Far Detector

Charge Questions

1. Are the technical requirements for system clearly stated? [Not consistently, see below]

   The Collaboration is advised that at this point of development the project should maintain a single, centralized, official set of requirements, whose content is owned by the EB. The desired format would be very similar to that presented by Dave Schmitz, with particular reference to slide 11 of his talk, which is reproduced below for ease of discussion. We also suggest that the table be augmented with one additional column which captures the expected impact on the project of validation tests of the specific requirements using ProtoDUNE. We also suggest that the "Motivation/Consideration" field contain summary arguments leading to the planned performance requirement, which normally also makes reference to documentation on a more complete study with requirements derived from MC studies.



DEEP UNDERGROUND NEUTRINO EXPERIMENT

TPC Electronics Requirements

PD-SP = ProtoDUNE-SP

Det. Sys.	Parameter	Motivation / Considerations	Value	Status
TPC Elect.	FE noise	*dE/dx* from a MIP at 3.6 m drift distance, 500 V/cm drift field, 3 ms electron lifetime, and 4.7 mm wire pitch produces a signal of about 11,000 electrons at the anode. This requirement, therefore, is driven by goal of achieving a S/N ≈ 10 on collection wires.	ENC <1000 e⁻	CERN cold box tests on full APAs show <500 e⁻ avg noise. PD-SP data to confirm.
TPC Elect.	FE peaking time	Derives from the drift time between wire planes	1-3 μs	done
TPC Elect.	FE baseline	Baseline must be adjustable because system must process both unipolar (collection) and bipolar (induction) signals	200-900 mV	done
TPC Elect.	ADC noise	Should not contribute significantly to overall FE noise	negligible	New designs underway
TPC Elect.	ADC sample rate	Matches 1 μs shaping time while minimizing data rate	2 MHz	
TPC Elect.	Linearity	Upper range by assuming overlap of several highly ionizing particles at angles to the wire plane	up to 500k e⁻	studies underway to better understand req.
TPC Elect.	Dynamic range	Maximum signal w/o saturation vs. 50% of noise level	>3000:1	12-bit ADC
TPC Elect.	Power	Smaller cables and limit argon bubbling	< 50 mW/channel	studies underway to better understand req.
TPC Elect.	Reliability	Limit dead channels; DUNE will run for 20+ years	< ~1% failures >> 20 year life	PD-SP data to confirm

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2. Do the technical requirements connect well to the physics requirements of DUNE?
3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?
4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?
5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?
7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?
8. Are risks to the subsystem project identified and are mitigation strategies plausible?
9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?

Comments

Recommendations

1.1.1 APAs [Tom Shutt, Eric Dahl]

Charge Questions

1. Are the technical requirements for system clearly stated?

   Partly. A high level set of requirements were presented in a systematic way, though they are not as clearly presented in the IDR.

2. Do the technical requirements connect well to the physics requirements of DUNE?

   Partly. The requirements are connected to the physics requirements, but in most cases, only at a conceptual level (e.g., wire plane spacing tolerance is important for "reconstruction precision on dE/dX").

3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?

   Yes

4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?

   Yes, following demonstration of performance in ProtoDUNE

5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?

   Yes

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?

7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?

8. Are risks to the subsystem project identified and are mitigation strategies plausible?

   Yes

9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?

Comments

Recommendations

- The requirements that connect the physics drivers to the technical specifications of the APAs should be updated and made quantitative. This is important because the cost of the APAs will be very sensitive to tolerances on the dimensions. Absent a clear understanding of how various tolerances relate to the physics performance it will be difficult to produce the APAs in the most effective manner for both cost and schedule while assuring that the physics requirements are met.

1.1.2 DAQ System [Ted Liu, Amber Boehnlein, Kevin Pitts]

Charge Questions

1. Are the technical requirements for system clearly stated?

   The high level system requirements presented are common to all DAQ systems. A table of event type vs data volume was shown, although it is not clear who 'owns' that table.

   In response to questions related to the IDR, it was stated that the full questions will be addressed in the TDR. For the TDR, the technical requirements must tie to physics, and perhaps more importantly calibration, requirements and the proposed DAQ architecture. It is essential to understand which requirements are specific drivers for the DUNE DAQ system.

2. Do the technical requirements connect well to the physics requirements of DUNE?

   Not really. For example, it's unclear how the 10 ns synchronization within a module and 1 μs between different modules is connected to physics requirements. The requirement of 45 /day random trigger is motivated by the Ar-39 calibration scheme, although the efficacy of the technique was not yet fully worked out. The cosmics and atmospherics event type is listed as highest data volume (10PB/year/module), but it is unclear how the data set will be used for physics. The cosmic trigger is divided into beam-coincident and anti-coincident components to allow for separate thresholds. 1 M laser pulses is listed for laser calibration with lossy readout while radiological calibration readout is lossless [in IDR Table 6.3 on page 179]. It is not clear what motivates the difference, in the absence of a calibration implementation study. There are some high level discussions about special SN trigger challenges, but requirements for beam interactions and cosmics was not presented. (Note: the lossy readout is for a calibration system)

3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?

   The system description is rather conceptual. There is not enough detail to enable the reviewers to understand the design clearly.

4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?

   The system, as presented, is conceptual and has not been demonstrated.

5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?

   For the TDR, the plan is to develop a reference architecture for costing purposes while continuing to pursue R&D options to maintain flexibility. This is a reasonable strategy provided that the TDR outlines timelines and a set of criteria for finalizing the design.

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?

   Not well enough.

7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?

A timeline to TDR was presented, with first DUNE prototype HW/FW/SW available in Oct 2018, a slice demonstration completed by Jan 2019 (using one full APA of ProtoDUNE-SP), followed by full external review by Feb 2019. This is an extremely aggressive schedule, no details provided about the decision pathway and criteria needed to address the two major architectural options between now and Jan 2019. The timeline includes development of a complete functional specification document.

8. Are risks to the subsystem project identified and are mitigation strategies plausible?

A table of risks and mitigation strategies was presented.

9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?

The lack of "standard candle" at DUNE for online monitoring of detector and trigger performance, and data quality may present a new challenge. Maintaining high detector efficiency over the full fiducial volume will be challenging (high live time system requirement would require extreme reliability for each unit).

Comments

Towards the TDR

- Physics motivations for technical requirements should be clearly stated. Data volumes based on assumptions is not the only aspect to consider for the specifications on the DAQ system.
- The unique/new challenges for DUNE DAQ should be clearly identified, including all physics processes, calibrations and monitoring.
- The reference architecture of the DAQ design should be clearly described, including how such design can meet the technical requirements and address the unique/new challenges
- The options of implementation should be clearly described with pros and cons.
- Outline the strategy of how to maintain high detector efficiency over the full fiducial volume (system up time) with a large system with so many units (e.g. 150 units for SP).
- How the DAQ supports the strategy of online monitoring for detector and trigger performance, and data quality.
- The special requirements/demands for SN trigger and its impact on the overall DAQ design should be clearly explained. Include cost impacts and risks.

Recommendations

- Develop a clear and realistic R&D plan towards TDR, and how decisions on options will be made; a meeting should be scheduled in October with the LBNC DAQ sub-group to check on status.
- Continue during the commissioning and operations to document 'Lessons Learned' from protoDUNE. It is essential to incorporate these lessons into the DUNE DAQ design for the TDR.

1.1.3 ElectronicsSP System [Kevin Pitts, Ted Liu, Jimmy Proudfoot, Cristiano Galbiati]

Charge Questions

1. Are the technical requirements for system clearly stated?
   The LBNC struggled with identifying a clear and consistent statement on the electronics noise requirements in particular, in part because they may derive from multiple processes (SN neutrinos, and Ar-39 calibration), which are not documented in a self-contained MC study.

2. Do the technical requirements connect well to the physics requirements of DUNE?
   Conceptually, yes, but physics studies could make the connections stronger. For the parameter "FE Noise", which is crucial for the success of the experiment, we believe it is necessary that the requirement parameter be derived from MC simulations and be supported by a dedicated study, cited in its "Motivation/Considerations" system. Also, the SP IDR states clearly that an ENC of 1000 e- would allow calibrations of the detector via analysis of the ^{39}Ar signals. How this will proceed is unclear to the Committee since there was no coherent presentation of the strategy for calibration via ^{39}Ar.

3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?

4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?

5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?

7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?
   Considerable thought and effort has gone into the development and testing plan over the next year. Schedules are aggressive, and it is clear that multiple solutions will be carried through the TDR.

8. Are risks to the subsystem project identified and are mitigation strategies plausible?
   Technical risks have been considered and the multiple paths are meant to address these risks. Schedule risks are also a concern.

9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?
   The current development and testing cycle, taking place now and through the next 9 months, will be absolutely crucial to the effort.

Comments

- The demonstration of a commercial ADC 3-ASIC FEMB solution for SBND is a positive development.
- Since longevity criteria for DUNE will be more stringent than SBND, system-level longevity testing will be crucial to fully establish this approach for DUNE. For example, the 3-ASIC approach involves daughter cards and additional commercial components, making system-level longevity testing more important. The newly formed Reliability Committee can be a valuable asset to guide this effort.
- Given the most recent schedule for ASIC development, it is virtually assured that the DUNE Collaboration will go into the TDR with multiple options for cold electronics. This is not a problem per se, as many experiments have carried forward options for specific detector components. The current schedule and strategy is aimed at moving forward judiciously while aiming at success beyond the TDR.
- We support the plan presented which includes testing of all three options (commercial ADC, custom ADC, SLAC CRYO) on APA7 in the cold box at CERN, the 40% APA at BNL, and the small TPC currently under construction at Fermilab.
- Given the limited number of submission cycles available for the custom solutions, we support DUNE-commissioned design reviews prior to each submission.

Recommendations

- None

Findings:

- Three ADC technology alternatives are being pursued: Cold ADC, SLAC Cryo and a commercial off-the-shelf chip (in parallel with SBND).
- A multi-day workshop was held at BNL in July.
- Progress has been made on the BNL/FNAL/LBNL collaborative Cold ADC effort, with considerable effort going into integrating design components.
- The SLAC Cryo design shows promising simulation results.
- Both the Cold ADC and SLAC Cryo efforts are targeting September 2018 for chip submission.
- The timeline has submission of the Colddata chip about 2 months after the Cold ADC submission.
- LArASIC (front end for the 3-chip solution) is expected back at BNL soon. One more submission is anticipated to include differential outputs.
- SBND has continued testing the off-the-shelf ADC with good results.
- In collaboration with the APA Consortium, progress has been made on cable routing for the lower APA. Mock up work is underway at PSL. Once the Consortia agree that a workable

solution has been developed, two frames will be built and tested in a vertical configuration at Ash River.

Comments:

- The Collaboration is virtually assured to take three Cold Electronics alternatives into the TDR. These three alternatives can be described in the TDR along with plans going forward for testing, evaluation and eventual down-select. This path has submission implications for resources over a significant period.
- With the TDR no longer a target for front-end technology choice, we encourage the consortium to continue to plan for the longer term, including evaluation of individual components, board and system-level testing, and longevity testing. This planning should also include criteria for the ultimate technology selection, as well as a plan and timeline for additional chip submissions.
- Considerable progress has been made in establishing multiple cold test stands, including the BNL 40% APA, the Cold Box at CERN and the small TPC at Fermilab. These will all need to be fully utilized to fully test and evaluate the multiple solutions. We strongly encourage the Collaboration to provide sufficient staffing to fully utilize all of these facilities.
- Given the timeline and importance of the activities on Cold Electronics, it is very likely that the electronics development effort will benefit from a second ProtoDUNE run with candidate DUNE electronics. We suggest the Collaboration begin considering and planning for that eventuality now.
- We support the integration effort to finalize the cable routing for DUNE-SP and encourage the development of a decision strategy in collaboration with the APA consortium.
- We encourage the Collaboration to pull together a broad group of scientists and engineers to review and consider interfaces with the front end electronics system. We also encourage the Collaboration to take a comprehensive approach to detector safety, and identify the personnel that will take the responsibility inside DUNE for interlock systems, both hardware and software.

Recommendations

- None

1.1.4 HV System [Cristiano Galbiati, Tom Shutt, Eric Dahl]

Charge Questions

1. Are the technical requirements for system clearly stated?
   Yes

2. Do the technical requirements connect well to the physics requirements of DUNE?
   Yes, qualitatively. The physics origins of specific values for requirements (e.g. 250 V/cm drift field) are not always clearly presented.

3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?
   Yes

4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?
   Not yet, but there is potential for successful demonstration in PD-SP. Alternatively, protoDUNE-SP experience and current R&D will drive FD-SP design.

5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?

7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?
   Yes, in that the decision pathway hinges on protoDUNE-SP performance. The specific tests to be performed on this system in protoDUNE-SP and their possible consequences going forward are less clear, but ongoing R&D is targeting likely issues.

8. Are risks to the subsystem project identified and are mitigation strategies plausible?
   Yes, see above

9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?
   No

Comments

- The general considerations going into the field requirement were described, but the specific driver for the 250 V/cm minimum is not clear, and from the discussion it appears this value has wandered. It is not clear what the consequences of coming up short, perhaps 150 V/cm, on this requirement would be.

Recommendations

- Tie the value of the electric field requirement to physics requirements.
- Consider a requirement on light generated by the HV system (and its impact on the photo detectors).

1.1.5 PhotonSP System [Bob Tschirhart, Cristiano Galbiati, Alan Bross, Adam Para, Anna Pla]

Charge Questions

1. Are the technical requirements for system clearly stated?

   Not yet. There is for example presently a proposal to increase the light yield from the nominal 1 p.e./MeV to 10 p.e./MeV, motivated by low-energy physics opportunities such enhanced Super Nova neutrino sensitivity. In the latest version of the requirement table the number was changed to 0.5 p.e./MeV (possibly for a different location in the TPC). The proponents should determine the required photon calorimetry energy resolution needed to pursue the low-energy program. This will then set the requirement for the light yield at the center of the drift field. The requirements should include a clear statement of allowed light yield spatial variation.

2. Do the technical requirements connect well to the physics requirements of DUNE?

   Not yet, since the corresponding requirements motivated by an enhanced low-energy program are presently in flux. The committee would appreciate continued discussion on the benefit of a photon-based 10% energy resolution measurement of 10 MeV energy deposits in concert with a charge-based measurement. Enhanced resolution of low energy deposits is also motivated by the concept of intrinsic 39Ar decays as a calibration tool. The committee invites the collaboration to present this plan at the next LBNC meeting.

3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?

   The bar detectors and one-sided ARAPUCA options are described in great detail.

4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?

   Not yet. Simulations show promise at a basic level for Super Nova neutrino Bursts (SNBs). Details on system performance for nucleon decay and oscillation physics are not detailed in the IDR, but not likely to be issues given the simulation data shown for SNBs. Data from protoDUNE-SP will inform to a much larger degree.

5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?

   The level of detail will be valuable for generating the TDR. The technical description of the potential options is too detailed, especially as the baseline is not yet selected.

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high-level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?

   Yes.

7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?

   There is an aggressive path presented to demonstrate that the ARAPUCA design will give the 5-10X increase in light detection efficiency. Details on the required studies, test vehicles, etc are not given. It is also mentioned that resources are not yet in place for this effort.

8. Are risks to the subsystem project identified and are mitigation strategies plausible?

   Yes, to a large degree. ARAPUCA is the baseline with light guides the backup. One issue that was not discussed in detail is the potential problem with vapor deposited TPB, which could have an impact on the ARAPUCA. Mitigation of this risk (coatings as in the light guide) is not discussed.

9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?

   The bar detectors and one-sided ARAPUCA will be tested in protoDUNE by the time of the TDR. Plans for testing the double-sided ARAPUCA were not presented.

Comments

The integration of several candidate photon detection technologies into protoDUNE-SP in advance of running with beam is a remarkable achievement that the collaboration should be rightly proud of.

protoDUNE-SP will provide a valuable test-bed for analyzing the performance of candidate photon detection technologies that will inform a baseline technology choice for the TDR.

The possibility of longer-term running with protoDUNE-SP provides an opportunity to study the stability and reliability of photon detection systems with time.

We suggest the collaboration consider xenon doping of the bulk liquid argon to shift the scintillation light from 127 nm to 174 nm. The resultant decrease in Rayleigh scattering (~ 3.5X increase in scattering length) is potentially significant.

The path to establishing clear photon detector technical requirements would benefit from establishing photon calorimetry goals motivated by both the presently known low-energy physics program (SNB neutrinos in particular) and the reach afforded by current state of the art photon detection technologies.

- It would be valuable to have as common as possible SP and DP photon detection physics requirements.

- Proponents have stated that the SN science program does not rely on PDS performance. This is not obviously consistent with the stated physics goals of the experiment. See page 39 & figure 2.3 of the physics volume which notes sub-millisecond timing is required for measurement of SN neutrinos. Proponents should clarify the role of the PDS for SN neutrino science.

- A physics analysis that analyzes the benefit of a photon detection system optimally designed for Super Nova (SN) science (and PDK and beam physics by extension) would be a valuable guide toward an R&D plan to enhance the detector performance. Towards this end develop Figures of Merit (FOMs) which can be used to illustrate and motivate tradeoffs in light yield, coverage, timing etc.

Recommendations

- Use Proto-DUNE data to demonstrate capability of the light detection systems and compliance with TDR requirements.
- Clearly define the baseline design and associated components for the TDR, and consider presenting one optional design, e.g. with reflector foils.

1.1.6 Slow Controls and Cryo Instrumentation [Joel Fuerst, Tom Peterson, Bob Laxdal, Kem Robinson]

Charge Questions

1. Are the technical requirements for system clearly stated?
   Yes. Cryogenic and similarly slow (like Ar purity) instrumentation requirements are described in section 7.1.3 Scope and Table 7.1.
2. Do the technical requirements connect well to the physics requirements of DUNE?
   Yes. Presently the link between physics and technical requirements is loosely drawn in the narrative of the IDR section. A more sharply drawn link would be advantageous when comparing actual performance vs detection efficiency that can help to inform when performance is good enough.

3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?
   Yes, judging from the introductory parts of Chapter 7 of the Single Phase IDR section.

4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?
   No. This has still to be demonstrated with protoDUNE.

5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?
   Yes. The level of detail seems appropriate given the narrative nature of the IDR.

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?
   Yes. Sections 7.5 (Installation, Integration & Commissioning), 7.6 (Quality Control), 7.7 (Safety) and 7.8 (Organization & Mgmt) provide an adequate description.

7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?
   Yes for this stage of the project. Results from PD-SP operation may provide additional input to the TDR.

8. Are risks to the subsystem project identified and are mitigation strategies plausible?
   Yes, but not within the IDR. Risks and concerns were tabulated in the material presented in Sowjanya's CISC Update talk at the May meeting, and in DocDB #7192 but could have been better presented in the IDR. For the TDR we suggest collecting key risks and concerns in tabular format.

9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?
   Yes. The size scale-up means that liquid argon circulation patterns will be new. CFD simulations will inform the design, and protoDUNE will provide CFD model verification, but the scale-up is still new. Discussion at this meeting demonstrated commitment to the cryo studies.

Comments

- The CISC timeline would benefit from added milestones in the 2019-2022 timeframe.
- Insufficient instrumentation due to limited installation time in PD-SP could reduce the value of CISC systems, for example in terms of CFD analysis benchmarking. This would represent a missed opportunity.
- The PD-SP commissioning and test plan is aggressive and may not provide sufficient time to collect data crucial for CFD analysis benchmarking. It may be possible to take additional data parasitic to detector commissioning or following the beam time. Comments at this meeting suggest this is more likely (note S. Pordes request to extend CERN stay into CY2019).
- Requirements and flow-down from physics goals could be more clearly presented in the IDR. The TDR will benefit from tabular summaries where appropriate.
- The requirements are not as specific as they could be. For example: The design requirements table includes a column called "motivation" which includes physics requirements at least in general terms: "Max. archiving rate per channel" is 1 Hz (burst) and 1/minute (avg). Motivation is "Based on expected rapidity of interesting changes; impacts the base software choice; depends on data storage capabilities." We feel that these could be improved with more specific rationales.

Recommendations

- Create a cryogenics test plan, including confirming the CFD model, as part of the PD-SP detector commissioning and operations plan before the end of June. The PD-SP cooldown is underway and procedure "*NP04: general overview of the cryogenic process and the cryostat quality control checks taking place during the different steps of this process*" (CERN EDMS ID 1925105).

1.1.7 Calibration (Task Force) and Monitoring (CISC) [Sampa Bhadra, Naba Mondal, Eric Dahl, Hugh Lippincott]

Charge Questions

1. Are the technical requirements for system clearly stated?
   Yes, to the level that is possible at this time.

2. Do the technical requirements connect well to the physics requirements of DUNE?
   Yes, to the level that is possible.

3. Is the system accurately and clearly described, keeping in mind the criteria that a science agency specialist should understand the introductory section and a professional member of the HEP community should be able to follow the body of the text?
   Yes – the response to the questions from the May review contained a clear and concise summary of the planned timing and duration of the main categories of sources that was easier for the review committee to follow.

4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?
   The Calibrations task force (CTF) has ensured that all currently envisioned sources can be physically accommodated in the DUNE SP design, with as much flexibility as possible, although details of exactly how some sources will be used are still to be worked out.

5. Is the level of detail appropriate? Are any key elements missing? Are any components described in too much detail for this phase of the experiment?

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the IDR to show that the complete delineation of these activities needed for the TDR is on-track?
   Not directly – although the Calibrations Task Force is working on these activities, there is no formal collaboration or project structure at present from within which to track them.

7. Is there a clear decision pathway laid out to address options and unknowns between now and the TDR? Are decision criteria understood and can the required information or process realistically be executed on the proposed timeline?
   The task force has made a good start in defining calibration systems. The work will continue in the near term to define feasibility and performance requirements.

8. Are risks to the subsystem project identified and are mitigation strategies plausible?
   Yes, risks are discussed within the IDR with regard to each subsystem, although they are not formally captured.

9. Are there aspects of the subsystem design that will not be informed by previous experience or prototypes and therefore present risks to the project design and/or execution?
   We believe that most of the calibration systems proposed can be informed by previous experience or prototypes.

Findings

- The Calibrations Task Force has provided a report to the collaboration on calibration needs of the experiment.
- Design changes to accommodate all currently envisioned calibrations with as much flexibility as possible have been incorporated in the detector designs.

Comments

- Calibrations are vital to the success of the DUNE physics program.
- The CTF has done well to complete their study of calibrations and included accommodations for the envisioned sources in the DUNE SP designs. However, the CTF is a temporary body, and for the longer term work of planning out calibrations in more detail and verifying that the planned calibrations can meet the physics requirements, a more permanent organizational body is necessary.
- There is some uncertainty as to whether responsibility for various calibration sources resides with the Calibrations Task Force or its more permanent successor or with other the Consortia where the calibration system is "hosted". A similar situation will pertain to the near detector, which was beyond the scope of the CTF. These interfaces will require careful management going forward.
- While 39-Ar "comes for free" it is not an optimal internal source for the goals stated. The liquid-noble dark matter community makes extensive use of injected radioactive sources for this style of calibration, which have the additional advantage of mapping fluid flow in the TPC. At first glance, few-MBq flow-through 222-Rn sources are readily available and give a unique signature in the desired energy range with 214-Bi/214-Po coincidence. These sources may also be useful for understanding fluid flows in the cryostat. Other injection sources may also be appropriate.
- The committee believes that the different sources listed in the IDR are not on an equal technical footing, although they were discussed as though they were. This was confusing, and a potential distraction. The primary calibration source or sources should be emphasized so that it is clear which ones are reliable and which ones are more speculative
- The numbered list of sources with durations and data rate estimates provided in response to the previous recommendations was extremely useful.

- The IDR makes the following statement: "At the TDR stage, a clear and complete calibration strategy with necessary studies will be provided to demonstrate how the existing and proposed systems meet the physics requirements." This outcome is highly desirable but will also be very challenging.

Recommendations

- Evaluate the utility of internal source injection (*e.g.* 222-Rn injection, for 214-Bi/214-Po calibration) for mapping electron lifetime and fluid flow in the TPC.
- Develop a top level, nominal calibration plan, including the duration and frequency of each calibration type to be performed.
- Demonstrate at a nominal level the performance and viability of the calibration scheme as part of the TDR.
- The Collaboration should resolve the long term organizational structure of calibration efforts as soon as possible to enable groups to begin contributing in a tangible way.

1.1.9 protoDUNE-SP TPC systems, schedule & planning [Jimmy Proudfoot, Dave Charlton, Bob Tschirhart]

Findings

- The protoDUNE team has successfully installed 6 Anode Plane Assemblies (APA's) in the cryostat, delivering the last on schedule on April 6 and completing installation of all inner detector components by April 30. 5 of the 6 APAs were tested in the cold box using the DAQ and show good noise performance. The Temporary Cryostat Opening is being closed.
- A plan for detector commissioning has been prepared, milestones set, and manpower identified to staff the teams to commission detector systems.
- Test beam run and analysis plans have been written.
- The protoDUNE team has conducted a protoDUNE Single Phase Data Exploitation Readiness Review.

Comments

- The protoDUNE team is to be congratulated on the successful installation of 6 APSs, meeting the schedule set in summer 2017.
- The commissioning and test beam run plans are well defined. A few details such as setting priorities on key performance characteristics to be presented in the TDR would be a useful addition to the plan.
- The protoDUNE team is to be complimented on holding an exploitation readiness review for protoDUNE Single Phase. The findings from this review should be considered carefully in the commissioning and run plan, especially those pertaining to the readiness of the DAQ and the prioritization of work to be carried out.
- The LAriAT, microBOONE and 35-ton experiments offer a wealth of experience in signal processing and event reconstruction for surface Liquid Argon TPCs and testbeam data analysis. At the next LBNC meeting, it would be helpful to have a presentation on the signal processing and event reconstruction for protoDUNE, and plans for how this will inform the DUNE TDR.

Recommendations

- None.

1.3 DUNE physics, simulation & reconstruction [Amber Boehnlein, Naba Mondal, Sampa Bhadra, Patrick Huber, Beate Heinemann]

Findings

- Detailed top level chapter outline of the Physics TDR is in place.
- Unlike in the CDR where parametrized methods were used, DUNE physics capabilities to be presented in the TDR will be, in the main, based on a realistic and complete FD simulation and reconstruction chain.
- Reached nu-e cc selection efficiency & background rejection goals using full simulation, reconstruction and PID which is a major milestone for DUNE oscillation physics.
- CNN-based particle identification and event selection has now moved from CAFFE (Berkeley) to TensorFlow (Google) framework which has now been fully integrated in LArSoft framework. This has resulted in faster training and inferences as well as in improved selection efficiencies.
- Main challenges and worries associated with various physics working groups were presented.
- A list for detector studies for key parameters (e.g. higher noise, dead channels, lower operating voltage…) that are being considered from the flow down from physics to technical requirements to be included for Physics TDR was presented.
- For the main CP-violation analysis, signal efficiencies and backgrounds suppressions factors have been extracted from Monte Carlo and automatic reconstruction which allow to attain the stated science goal. The performance of the automated reconstruction study confirms the levels stated in the CDR and the goals for the long-baseline program.
- A new priority was stated of demonstrating that goals for systematic errors can be achieved in conjunction with the concept for the near detector.
- An outline of a plan towards the physics TDR was presented.

Comments

- LBNC congratulates the group for making steady progress in the area of simulation and reconstruction.
- While the collaboration is proceeding for preparing the TDR, lack of sharp definitions of technical requirements are worrisome. Need a clear connection among the physics performance goals and detector requirements to achieve those goals.
- Physics working groups involved in the developments of various reconstruction and selection algorithms and in estimating the physics reach for the DUNE far detector are not well connected with the planned efforts for protoDUNE data analysis. This lack of interface is worrisome as it is expected that the true potential of the DUNE Physics reconstruction and analysis algorithms/codes be tested using the protoDUNE beam/cosmic data. This should then be used for estimating the true potential of the DUNE Far Detector for achieving its physics goals. This should also be an important input for the TDR.
- In addition to providing t0 information, the importance of Photon Detector data in improving the energy resolution, especially for the low energy SN neutrinos in the 10-20 MeV region, needs to be studied in greater detail through simulations as well as demonstrated performance of these detectors during protoDUNE operation.
- We commend the physics working group and collaboration for showing that signal efficiencies and background suppressions factors can be attained with automatic reconstruction.

- Shifting the focus to systematics and the incorporation of the near detector concept into a ND/FD analysis is appropriate. Embedding near detector experts into the physics analysis group is appropriate.
- The plan outlined towards developing the TDR is reasonable. We propose to have a phone meeting with the physics group conveners and the physics TDR editors in about a month to follow up to hear details of the plan in order to provide feedback. The LBNC physics subgroup has agreed to submit a list of questions and specifics to be discussed well in advance.
- ProtoDUNE analysis is now considered part of the DUNE physics activity, since a few weeks. However, the TDR timescale will make it difficult to include lessons from proto-DUNE beyond a low-level proof-of-concept.

Recommendations

- Include variations in detector performances for main detector parameters and study their effects on key physics processes. Keep LBNC informed periodically on the progress made on these studies.

  Above recommendation is still open.

2.0 Other DUNE activities

Executive summary

This section of the report is intended to capture findings, comments and recommendations that relate to ongoing review of technical systems, interfaces, and activities outside the scope of the IDR.

2.1 DUNE computing [Amber Boehnlein, Sampa Bhadra, Beate Heinnemann, Patrick Huber, Nobu Mondal]

Findings

- DUNE computing submitted a chapter to the Interim Design Reportl, Volume 1 and submitted responses to questions.
- Liz Sexton-Kennedy joined the breakout session and briefly described FNAL CD plans.
- Computing Conceptual Design report is scheduled to be submitted to the LBNC in April, 2019.

Comments

- The structure of the August meeting focused on IDR and did not include an update on operational issues for protoDUNE computing. An update on international contributions also was not on the agenda. The LBNC computing sub-group will schedule a meeting in September with the DUNE computing coordinators to get updates on these issues.
- A request that DUNE Software and Computing outline of the factors that will impact the computing model, to outline the lessons learned from the experience of other LAr TPC experiments with respect to software and computing and to state the plans to use protoDUNE data to influence the computing model remained unaddressed for 9 months. The FNAL PAC has made a similar request. It is essential that a physics-driven computing model at an *appropriate level of detail* be developed for the Computing Conceptual Design Report.
- Maintaining focus on a strategic vision for globalized DUNE computing is of vital importance, especially in the face of sustained operational responsibility. The globalization of DUNE Computing provides a golden opportunity to rethink the architecture and deployment of computing services and resources. The contributions from international collaborators also require the establishment of governing bodies, similar to those in operation at CERN for LHC computing. The LBNC appreciates the experience and attention that the newly appointed FNAL CIO Liz Sexton-Kennedy will bring to this important topic.
- The LBNC Computing subgroup would like to schedule a meeting in October to discuss the outline and preparations for the CDR with the DUNE computing coordinators and the computing CDR editors.

Recommendations

Response to previous recommendations

On the timescale of the IDR, S&C must develop a list of questions and factors that will influence the computing model

This recommendation remains unaddressed for three meetings.

2.2 LBNF/DUNE cryogenics [Joel Fuerst, Tom Peterson, Bob Laxdal, Cristiano Galbiati]

Findings

- The LN2 system acquisition plan is currently in the DOE approval process and the project is developing an RFP for a design/fabrication/installation contract.
- The project continues to support design work on LAr systems (presently unassigned) in order to maintain proper integration with other scope elements. The expectation is that this effort will reach the level of preliminary design prior to the CD-2 review. Additional effort (2 FTE) has been assigned to enable this work.
- LAr vendor interactions are ongoing including cost estimate refreshes.
- CERN-NP is ready to start membrane cryostat design for the first FD cryostat.
- There is currently a high schedule risk associated with procurement's ability to process cryo-related contracts. To mitigate this risk, a new procurement manager and administrator have been added and the LN2 procurement has been re-assigned. Additional ramp-up in effort is expected through July 2018
- The cryogenic instrumentation for protoDUNE-SP will be installed in early June. The TCO is being closed now and cooldown is scheduled for early July.
- Computational fluid dynamics (CFD) simulations of both protoDUNE and Far Detector (FD) cryostats are ongoing. This work is partially carried out by CISC and partly by LBNF. Simulations will be benchmarked against data collected by CISC systems during protoDUNE commissioning. No specific tests were listed in the commissioning plan.
- The WA105 demonstrator has been at room temperature since February 2018. Cryogenic performance during the test run was excellent, with liquid level stability below the +/- 0.1 mm sensitivity of the capacitance liquid level sensor *(PD-SP IDR, p.227).*
- A PD-SP commissioning and test plan has been prepared and was presented.
- The PD-SP commissioning and test plan *(Cavanna, slide 6)* provides about six weeks from initial GAr purge to final LAr recirculation and purification. There are three weeks of contingency built into the schedule.
- A draft cryogenic commissioning plan for protoDUNE-SP was presented. It is still in development. The plan addresses initial purification, cooldown, fill, recirculation/final purification and normal operation.
- It is possible that additional cryogenic system studies will be possible after beam tests conclude.
- Previous recommendations have been adequately addressed.
- Cryogenics has added new staff resources as various fractions of people including help from Fermilab Technical Division. They will add a designer part-time (to be shared with technical coordination for interface drawings). Totaling 1.6FTE now, plus will get ½ designer. This staff enhancement is in response to the need to cover previously unassigned scope.
- LN2 cooling operates at 2.5 bar to avoid freezing Argon.
- David Montanari's presentation includes a draft of the pressure test, startup, and initial operations in full (as it exists) detail. These procedures were jointly developed with CERN, which is responsible for protoDUNE operational approval.

- The procedures for Proto-DUNE from initial pressure test through purification and liquid argon filling will be discussed with Fermilab's DUNE cryogenic safety subcommittee and will provide a basis for eventually an approved set of procedures for DUNE. It is expected that they will receive it positively, since it contains all the steps that had been discussed in the past. In particular, discussions will include the initial 200 mBarg step to certify pressure safety and compliance with Fermilab ES&H Manual rules.
- The PD-SP assembly is complete. The cryostat was successfully pressure tested on 09 July and the LAr volume was successfully purified (piston purge) over 23-27 July.
- Cryo-commissioning is underway and cooldown has begun.

Comments

- The committee commends the project for their continued support of unassigned LAr systems scope. The committee notes that the cryogenics team has opted to bring ahead all unassigned scope before CD-2 as opposed to prioritizing the work as all scope is required. The question remains whether the added manpower of 2 FTE is sufficient to complete all of the open questions sufficiently before CD-2. This still represents a schedule risk.
- The improvements in procurement effectiveness are recognized.
- The committee is impressed with the plan for first cooldown – this plan should be used to cross-check preparations for equipment required to monitor the cooldown. Also the plan should be clearly communicated to the DUNE teams with any requirements on platform or equipment access during the various steps of the cooldown clearly articulated and blended into the DUNE commissioning plans. Especially important is the identification of the tasks that can be done in parallel vs those that must be done serially.
- The DUNE commissioning plan did not include any particular tests to verify the CFD model. As p-protoDUNE represents a scaled version of the final DUNE detector it is the last chance to verify and refine the models on anything close to DUNE scale. During the meeting there was a feeling that the collaboration was distancing themselves or underselling the importance or possibility of such measurements. The committee believes that this would be a significant missed opportunity.
- Performance targets mentioned in the cryogenic commissioning plan (cryostat strain levels, LAr purity levels) are not specified.
- The committee endorses the discussion of procedures for protoDUNE from initial pressure test through purification and liquid argon filling as an excellent way to continue the process of satisfying Fermilab ES&H requirements.
- The committee congratulates the PD-SP team for reaching the cooldown phase and looks forward to a successful LAr fill followed by LAr purification and the collection of cryogenic performance data.
- There appears to be increased support for making extended cryogenic measurements in CY2019 after beam tests conclude. The committee supports this effort.

Recommendations

1. Develop a detailed cryogenic data collection plan in protoDUNE with the goal to help verify or inform the CFD modeling studies. Add specific steps to the protoDUNE commissioning plan. In process.
2. Complete a resource loaded schedule spanning from now to CD-2 to complete all unassigned scope to CD-2 compliance and present the schedule in August LBNC review.

Closed. The project has agreed to support unassigned cryogenic scope through CD-2 and has added the required labor to the project plan under BCR-0261 (Mossey slide 16)

Response to previous recommendations

2.4 LBNF/DUNE interfaces [Bob Tschirhart, Tom Peterson (absent), Joel Fuerst, Kem Robinson (contributions)]

Findings

- Systems engineering holds regular (weekly) interface meetings with detector, cryostat, and cryogenics teams as well as bi-weekly meetings with appropriate stakeholders to validate requirements, refine interfaces, and review change requests.
- Cross-project interface workshops are held throughout the year to address specific interfaces, incorporate protoDUNE lessons learned, and draw on CERN-Neutrino Platform (NP) experience.
- The change request to remove the detector cavern rock septum was presented as a case study.
- The interface (2d) envelope concept was presented as a tool to manage interface/integration issues.
- A configuration management plan (CMP, DUNE-DOC-82) was presented, including a baseline change request tool.
- An interface matrix is being developed to identify interfaces between consortia and track relevant documents.
- The concept of "Integration Nodes" as an interface management tool was presented. For example, four top-level nodes (Detector, Detector Support, Detector Electronics, and DAQ) that group project elements into higher-level subsystems would assist with interface identification and control. It is envisioned that the Integration Nodes will be captured into lightweight, high-level 3D CAD assemblies.
- During the period between the end of the FSCF preliminary design and the beginning of the FSCF final design, the total (4) detector power requirement increased from 2000 kVA to 2500 kVA and the overall DUNE requirement has increased 16% to 4000 kVA. The leading factor to the detector power increase is the decision to deploy DAQ hardware in the central utility cavern (CUC).
- Systems Engineering and the host lab working group project sub-team (including SDSD, LBNF and DUNE-US) are evaluating how best to document and execute the post CF outfitting scope to optimize the phased installation of the cryostat, cryogenics and detector.

Comments

- Hiring the DUNE Mechanical Project Engineer to complement the DUNE Electrical Project Engineer in the TC/SE team is a major step forward. The addition of designer effort to the team is also an important step forward to supporting the suite of 2d envelope drawings.
- Systems engineering has placed an emphasis on fostering communication across project elements. The committee applauds this effort and encourages the project to continue along this path.
- The committee supports development of a high-level integration/interface management strategy and commends the project for this ongoing effort.
- The committee is glad to see planning and execution to grow Technical Coordination (TC) staff.
- The increased power load represents a challenge to underground services, specifically cooling. TC has developed a power budget for the operation and data processing of the 4 detectors underground including contingency for detector/computing improvements and upgrades. Systems Engineering and LBNF CF with input from DUNE, are working with ARUP to accommodate all the requirements. LBNF and DUNE need to develop a sustainable operations plan that includes maintenance downtime and the associated headroom requirements for operations.

- It is unclear to the committee what the process was that led to the decision to move the computing underground, whether EFIG or some other part of the experiment-facility interface process should have been involved in looking at the associated impact on cooling requirements.

Recommendations

- None.

Response to previous recommendations

- Previous recommendations closed out.

2.6 DUNE management, schedule and planning [Dave Charlton, David MacFarlane, Hugh Montgomery]

Findings

- The description of DUNE organization and management structures presented in the Initial Design Report, both in the Executive Summary volume and the Technical Coordination chapter, provide a strong basis for the Collaboration.
- Progress in understanding the requirements from Technical Coordination and the detector Consortia in the integration and installation phase was presented, and has made good progress in recent months.
- ProtoDUNE analysis is now considered part of the DUNE physics activity, since a few weeks.

Comments

- Work aiming to increase involvement in the experiment from a broader international community was presented, and is strongly encouraged. The committee notes that the Near Detector may provide interesting opportunities for new collaborators.
- The LBNC expects that an appropriate description of the external review framework surrounding DUNE will be described in a document owned by the Fermilab Directorate, and therefore this need not be repeated in the TDR.
- While the role of the Consortia in encouraging engagement in their work is important, the Committee believes that negotiations with funding agencies should always involve the Collaboration management when they concern new funding, or funding priorities which go wider than a single Consortium.
- The LBNC notes the progress of the Near Detector Task Force, and that its recommendations are being considered in the Executive Board. The committee looks forward to receiving a Conceptual Design Report in 2019 which focuses on the physics case, the physics requirements and their flow-down to the ND performance requirements, backed up with a conceptual design that could deliver these. The case requiring a near detector, and the need for off-axis measurements, should both be addressed.
- Looking forward to the Technical Design Report volumes which the Collaboration is preparing for 2019, the Committee makes several observations:
  - The quantity of documentation which is proposed is very large, and the collaboration is urged to be succinct and to stick to reasonable size limits, while still taking the space necessary to describe the Technical Design. The overall IDR structure and length seemed reasonable and perhaps could be retained by the TDR as well.
  - The subdivision of the Report into multiple volumes, corresponding to the physics case plus requirements drivers, and typically a volume per Consortium, is recognized to be a good one.
  - The Collaboration is encouraged to submit TDR volumes to the LBNC when they are ready, not necessarily – or even desirably – all at the same time. In particular, some volumes could

be ready before the nominal April date, others may come on time, others may come later if they are not needed to be fully reviewed by the date of the US DOE CD-2/3b review.
    - The Collaboration is requested to be ready to make a draft of each TDR volume available in confidence to the Committee before the final submission, to allow the Committee to get started on the review. Reviews will only be completed based on the final volumes.
- The LBNC strongly supports the work of the Collaboration to obtain additional funding support for the work of Technical Coordination. A properly-provisioned Technical Coordination is essential for the success of the experiment.
- The committee notes that there are several situations where multiple options will be carried with the TDR. The Collaboration should be cognizant of the resource and schedule implications and should make such choices carefully and aggressively pursue resolutions.

Recommendations

- (Carried over and updated:) Report to the next LBNC meeting a summary of the main performance drivers with explicit couplings to the primary DUNE physics goals. Summarize which of these performance indicators will be established or explored by ProtoDUNE, and which will remain untested. Prepare a succinct document (around 20 pages or less) summarizing this, which should be made public.
- Propose a schedule for completion of the TDR and two CDR volumes, and a plan to make drafts available in confidence to the committee to allow reviewing to start.
- All talks presented to the LBNC should be discussed and rehearsed within the Collaboration before presentation to the committee. Likewise, identifying and supplying key supporting documents in advance of the LBNC meeting would be very helpful.

Response to previous recommendations

- "*Report to the next LBNC meeting a summary of the main performance drivers, as for example listed in this meeting in the talk "DUNE-SP Overview, Schedule & Planning", with explicit couplings to the primary DUNE physics goals. Summarize which of these performance indicators will be established or explored by ProtoDUNE, and which will remain untested.*"

    Response: Tables, prepared by Technical Coordination, summarizing the linkage of detector design parameters with required performance, were presented in draft form. While these draft tables are an important part of the documentation of the flow-down from physics goals to detector design, higher-level connections need still to be documented, starting from the physics goals. The Collaboration is urged to ensure these are clear in the TDR, and to make a standalone, maintained, public document which describes them.

    Recommendation stands and is updated, above.