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1.0 Technical Proposal

Executive summary

Given the timing of the release of the technical proposal (May 18), just a few days in advance of the LBNC meeting, the committee's preliminary assessment is based almost exclusively on the presentations in the plenary and breakout sessions, and interactions with the proponents. The TP 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 TP charge questions on the basis of our deliberations during the May meeting. In the case of the Dual Phase Far Detector in particular, we were unable to respond even in a preliminary way at this time, since there were no breakout sessions dedicated to this topic at the May meeting. The LBNC will be reading the TP between now and the end of June and will compile a set of follow-up questions thereafter for responses at the time of the August LBNC meeting. At the end of the August review, it is our intention to provide a complete assessment of the TP for consideration by DUNE. 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 TP.

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 Technical Proposal 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.

Based on its preliminary assessment of the TP, 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 TP 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:

During the course of the May meeting the LBNC 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. In this regard, the apparent disconnect between physics efforts with the protoDUNEs and the main physics groups seem particularly unfortunate. Some examples are:

- The organizational connections between the physics activity and the data collection and processing coming imminently from ProtoDUNE should be stronger. The current separation of these activities does not appear to be optimal.
- 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 specification and/or significant design changes need to be developed, especially changes which may impact overall performance and physics capabilities. Such mechanisms will be needed to prepare decision-making by the Executive Board. Fairness, transparency, and consistency of approach should be goals. Changes to the Photon Detector System may provide an early test case for this.
- 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 ($\sim 3.5X$ 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.

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. 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 $^{214}\text{Bi}/^{214}\text{Po}$ 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 the most 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.

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, 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 that the bulk of the organization will not be in place until after the TDR and it is not clear to us that the team is 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. We expect that a strong technical coordination team will be needed during the preparation of the TDR itself. This 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 plenary speakers who summarized the technical systems described in the TP could not provide a crisply articulated argument about physics drivers and were generally unable to identify such drivers during questioning. The Collaboration is advised that at this point of development of the project it 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, where slide 11 is a particularly good example. 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 and that the “Motivation/Consideration” field contain summary arguments leading to the planned performance requirement, which routinely makes reference to documentation from a more complete study with requirements derived from MC studies.

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, 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.

4. protoDUNE experience and implications for engineering design

A detailed presentation on the ProtoDUNE-SP commissioning, operation and data analysis plan was made by Flavio Cavanna. 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. Finally, we are concerned by the establishment of a whole new organization (the Data Reconstruction and Analysis (DRA) group) with uncertain connections to the existing physics and computing organizations or the hardware consortia, which does not appear to be optimal

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 did not include any particular tests to verify the CFD model. 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 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.

Recommendation: Develop a resource loaded schedule spanning from now to CD-2 in fall 2019, which captures the work needed to complete appropriate preparations at a CD-2 level for all unassigned scope and present the schedule in Aug LBNC review

Example 2: Validation of TPC engineering design and TPC performance

As noted earlier, we are urging the Collaboration to establish a simple, centralized, official set of requirements, whose content is owned by the EB. Such a table should 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. However, we believe there should be a tight connection established between design validation for the TDR and measurements with protoDUNE and it is not clear to us that all such tests have been thought about carefully by the consortia and 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 $S/N \approx 10$ 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 μ s	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 μ s 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

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 TP 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 TP.

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 TP 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 rather generic, such as scalability, zero dead-time, full detector trigger as well as self-triggering, and synchronization. A table of event type vs data volume was shown. It is unclear what the projected evolution of the data rates might be as a function of time. Verbally, it was said that the 'cosmics' would only be 10 PB in the first year.

In particular, it is not clear whether 'zero deadtime' for SN events can be achieved given the stress these events will place on the readout overall.

For the TDR, the technical requirements will need to tie to physics, and perhaps more importantly calibration, requirements and the proposed DAQ architecture.

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 μ s 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 atmospheric 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. 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.

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?

The LBNC has not read the TP proposal draft yet and cannot provide a full answer to these questions.

From the presentation, the most important thing missing is the connection between technical requirements to physics. Two variations of system design are shown, but no explanation nor

comments on the pros and cons for each and how and why these two are selected for consideration.

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the TP 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?

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” 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

We requested a protoDUNE talk on “DAQ lessons learned for DUNE”, but it was not scheduled.

For 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 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; to be reported at the next meeting.
- Continue during the commissioning and operations to document 'Lessons Learned' from protoDUNE and 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 TP states clearly that an ENC of 1000 e⁻ would allow calibrations of the detector via analysis of the ³⁹Ar signals. How this will proceed is unclear to the Committee since there was no coherent presentation of the strategy for calibration via ³⁹Ar.
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 TP 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

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 TP 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. 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 ^{39}Ar 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 three proposed options are described in great detail.
4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?
Yes, 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 TP, 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.
6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high-level schedule—described well enough in the TP 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?

All proposed PDs will be tested by the time of the TDR.

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 definitive test-bed for analyzing the performance of candidate photon detection technologies and allow 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 requirements.

Recommendations

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

Charge Questions

1. Are the technical requirements for system clearly stated?

Yes. Cryogenic and similarly slow (like Ar purity) instrumentation requirements are shown in slide 7 (for Single Phase) of the “Cryogenic Instrumentation and Slow Controls (CISC) Joint Consortium Update.”

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 TP 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 primarily from the PPT presentation and the introductory parts of Chapter 7 of the Single Phase TP 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 TP (response could change upon further review).

6. Are project related activities—management structure, facilities, interfaces, safety, quality assurance, integration/installation, and high level schedule—described well enough in the TP 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 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. Key risks and concerns are tabulated with mitigation strategies in slide #26 and in the file, CISC_Risk_v9_Final.xlsx.

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. A general feeling is that protoDUNE cryogenic studies are not getting sufficient attention. The protoDUNE experiment is the right place to test the CFD model in advance of the final installation and the project seems to be underselling the importance or the possibility of meaningful tests.

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.
- Requirements and flow-down from physics goals could be more clearly presented in the TP. 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.

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

Charge Questions

1. Are the technical requirements for system clearly stated?
Yes, although the TP may not yet reflect the recently produced report from the calibration task force.
2. Do the technical requirements connect well to the physics requirements of DUNE?
Yes, the TP refers to specific studies in the CDR, where 1% changes lead to significant consequences for the physics reach.
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?
Not yet. A list of calibration components was clearly presented, but there was not enough information to understand how those components work together to achieve the requirements.
4. Has the system been demonstrated to meet its technical requirements, and if not, what are the deficiencies?
No. The information presented so far is mostly a list of possible sources, without specifics on how any given source will address the requirements.
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 TP 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?
The task force has made a good start in defining possible 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?
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, but there is not enough detail presented to fully assess this question.

Comments

- 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?
- A specific, comprehensive calibration plan was not presented, and the committee has no way 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.
- The committee believes that the different sources listed 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.
- 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 $^{214}\text{Bi}/^{214}\text{Po}$ coincidence. These sources may also be useful for understanding fluid flows in the cryostat. Other injection sources may also be appropriate.

Recommendations

- Evaluate the utility of internal source injection (*e.g.* ^{222}Rn injection, for $^{214}\text{Bi}/^{214}\text{Po}$ 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 that the calibration plan achieves the 1% targets, taking into account what is currently known about each calibration source.

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 APAs, 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.

1.2 Dual-Phase Far Detector

As noted in the executive summary, the completion of the TP just a few days in advance of the LBNC meeting did not allow the committee time to read the report. To compensate, the review agenda included TP summary talks in plenary as well as extensive breakout sessions. In the case of the dual phase portion of the TP, it was not possible to arrange such a breakout session at the May meeting. Therefore, the committee did not have sufficient material to address the charge questions in this preliminary report. Instead, the LBNC will expect to make a more in depth assessment at the time of the August meeting, on the basis of having read the TP by then, and following a breakout session with the dual phase consortia. The LBNC remains strongly interested in progress both with protoDUNE-DP and the technical proposal plans for a full sized dual phase detector at the far site. We fully expect to treat the dual phase sections of the TP in the same manner as the single phase, but cannot comment at this time before we have a chance to understand the detector plans in more depth.

Charge Questions

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

- There were no breakout sessions for the Dual Phase FD at this meeting, so the committee is not yet in a position to respond to the charge questions.

Recommendations

1.2.1 CRP & TPC Systems [Cristiano Galbiati, Tom Shutt, Eric Dahl]

Charge Questions

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

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

Charge Questions

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

1.2.3 ElectronicsDP System [Kevin Pitts, Ted Liu, Jimmy Proudfoot]

Charge Questions

1. Are the technical requirements for system clearly stated?
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 TP to show that the complete delineation of these activities needed for the TDR is on-track?
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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

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

Charge Questions

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

1.2.5 PhotonDP System [Bob Tschirhart, Cristiano, Alan Bross, Adam Para, Anna Pla]

Charge Questions

1. Are the technical requirements for system clearly stated?
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 TP to show that the complete delineation of these activities needed for the TDR is on-track?
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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

1.2.6 Slow Controls and Cryo Instrumentation [Joel Fuerst, Tom Peterson, Bob Laxdal]

Charge Questions

1. Are the technical requirements for system clearly stated?
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 TP to show that the complete delineation of these activities needed for the TDR is on-track?
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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

- There are some differences in requirements between Single Phase and Dual Phase systems regarding liquid level stability requirement and operating pressure, with Dual Phase providing some new challenges:
 - Single phase will utilize standard level sensors and measure liquid level to +/- 14 mm. Dual Phase requires additional precision (<1 mm) level meters.
 - Dual Phase requires precision thermometer/pressure monitoring in gas phase
 - For Dual Phase, other requirements/scope are being understood — discussions are underway

Recommendations

See Single Phase

1.2.7 Calibration and Monitoring [Eric Dahl, Hugh Lippincott]

Charge Questions

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

1.2.8 protoDUNE-DP technical, schedule and planning [Bob Tschirhart, David MacFarlane

Findings

Comments

Recommendations

1.3 DUNE physics, simulation & reconstruction [Amber Boehnlein, Naba Mondal]

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.

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 at the 10-20 MeV region needs to be studied in greater detail through simulations as well as performances of these detectors during protoDUNE operation.

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.

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 TP.

2.1 DUNE computing [Amber Boehnlein]

Findings

- DUNE computing submitted a chapter to the Technical Proposal, Volume 1
- Data volumes for far detector operations have been documented in the Technical Proposal.
- A joint Data Challenge for protoDUNE-SP was conducted April 9-13 that tested the system from the DAQ through reconstruction, including the Data Quality Monitoring. The Data Challenge proved useful in validating goals for data movement and identifying and solving some bottlenecks. Tape drive rate and contention at FNAL is expected to be solved by the on-going installation of new robot and the next generation drives.
- A readiness review for protoDUNE-SP was held on May 10-11. The review report was positive, with some constructive recommendations to address personnel gaps and resource contention.
- Significant contributions to the computing effort are being pledged by the UK and by the Czech Republic.
- The globalization of DUNE computing will have a number of implications, including standardizing on common tools that are used by the LHC community.
- DUNE computing is entering a very challenging phase between supporting operations for protoDUNE reconstruction, MC production for the TDR, integrating global resources, and developing the computing TDR.

Comments

- The LBNC commends DUNE Computing on continued progress towards operational readiness including supporting protoDUNE-SP test beam, particularly for data movement and reconstruction in collaboration with CERN. The readiness review and data challenge were important accomplishments.
- The new contributions to computing from the UK and Czech Republic are very welcome news. Computing expertise and resources can be a valuable in-kind contribution.
- The globalization of Dune Computing provides a golden opportunity to rethink the architecture and deployment of computing services and resources. A unique set of services for DUNE based exclusively on the FNAL intensity frontier computing stack will not be workable in a global model. DUNE S&C recognizes this and is beginning to take steps to migrate to common solutions.
- The LBNC charge for the May 2018 meeting included 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.
- Maintaining focus on a strategic vision for globalized DUNE computing is of vital importance, especially the face of sustained operational responsibility. This strategic vision should be succinctly documented as preparation for the Computing TDR and should include plans to use input from existing neutrino experiments and protoDUNE experience. It should include the factors beyond data volume that will impact the computing model.

- The data storage and processing methodology for the protoDUNE-SP beam might be overly constrained (and constraining) relative to the goals of the run plan. There is a trade-off between production quality services and prompt feedback. In a short duration test beam, rapid feedback could be essential to success. The current plan with multiple data copies and a 24 hour turn around for data processing seems more appropriate for sustained operations. These constraints can and should be relaxed to insure prompt analysis capability on a meaningful subset of the data. The technical flexibility exists within DQM. We also urge joint meetings with the protoDUNE-SP Data Reconstruction and Analysis Group and others to make sure that the ability to do prompt analysis gets the appropriate cross organizational attention.

Recommendations

Response to previous recommendations

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

This recommendation remains unaddressed for two meetings. A mitigating factor is the preparations for the protoDUNE-SP data challenge and review.

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 TP, 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.

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.

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.
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

Response to previous recommendations

- See above.

2.3 LBNF management, schedule and planning [David MacFarlane]

Findings

- LBNC is working to identify additional resources at Fermilab that can be added to the NS beamline project in order to execute design and development efforts required before CD-2 in fall 2019

Comments

- LBNF maintains a risk registry with items of potential impact of DUNE cost, schedule or planning

Recommendations

- Working with DUNE and the LBNC, review and identify items of potential impact on DUNE cost, schedule or planning for future discussion and tracking by the LBNC

Response to previous recommendations

2.4 LBNF/DUNE interfaces [Bob Tschirhart, Tom Peterson, Joel Fuerst]

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+Electronics) 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.

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 effort

Recommendations

- None.

Response to previous recommendations

- Previous recommendations closed out.

2.5 DUNE management, schedule and planning [Dave Charlton, David MacFarlane, Jimmy Proudfoot]

Findings

- The new collaboration management structure, centered around a new Executive Board, was ratified by the Institutional Board the week prior to this LBNC meeting, and is now just beginning its operation.
- The consortium structure has now been in place for more than eight months, with the exception of the CRP(DP) consortium which is not yet set up.
- A presentation on the Near Detector Task Force recommendations was presented, as was an update on the Calibration Task Force work. Both of these will be brought to the Executive Board in the coming months.
- Changes in specification to the Photon Detector System are being considered. Changes will be brought to the Executive Board for approval in due course.

Comments

- The Executive Board structure is now in place and starts to function, but effective operation in steering the work of the collaboration will continue to need close attention from DUNE management.
- 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.
- Activities and issues connecting different areas, including the detector consortia, physics and computing, 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 be stronger. The current splitting of these activities does not appear to be optimal.
 - 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 specification and/or significant design changes need to be developed, especially changes which may impact overall performance and physics capabilities. Such mechanisms will be needed to prepare decision-making by the Executive Board. Fairness, transparency, and consistency of approach should be goals. Changes to the Photon Detector System may provide an early test case for this.
 - 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.

- The DUNE collaboration is encouraged to formalize linkages with the short-baseline (SBN) program at Fermilab – there are a range of lessons being learnt that are applicable to DUNE. These links exist at an informal level, but more formal linkages are encouraged to cement this.
- The SBN program is training technical, engineering and scientific staff in the construction, commissioning and operation of LarTPCs as a system. DUNE should endeavor to formally engage as much as possible of this expertise, to help expand an experienced central technical team.

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 to previous recommendations

- “*Present a report on the progress and status of the ND conceptual design development at the May 2018 LBNC meeting*”
- Response: A report document has been made available to the LBNC at this meeting, and a presentation was given at the meeting, by the near-detector task force led by Alfons Weber and Kam-Biu Luk. The ND task force is in the process of concluding, with recommendations on the near-detector design concept. The Committee has not yet had chance to digest these recommendations, which should be considered at the next meeting.

2.6 Beamline design and optimization [Bob Laxdal, Eliana Gianfelice]

Findings

- The beam line scope comprises everything from proton extraction from MI up to upstream of the near detector including the proton beam line, the target hall complex and the Absorber Hall services building. The design of the proton beam line itself is well advanced.
- The horn concept has been baselined to the 'optimized' beamline configuration as of Nov. 2017
- The optimized design includes three horns of 2.3, 4.1 and 2.3 m and a 2.2m long target with Nitrogen gas for filling/cooling of the target chase and cooling of the helium filled decay pipe
- The optimized layout added \$35M of new scope outside the DOE baseline giving a total of \$70M outside the DOE scope. 66% of the Beamline BCWS cost is in the DOE scope and 34% is expected to come from International Partners.
- To date \$11-12M of the \$70M out of scope has been secured through external in kind contributions with the most significant coming from RAL/UK
- Status and maturity of design was presented as follows:
 - Primary beam - Design maturity - 64% of DOE scope
 - Neutrino beam – maturity 25%
 - System integration – maturity 36%
 - Overall – 37%- BCWS cost (without contingency)
- A risk analysis both for cost and schedule was presented. The main beamline risk cost driver is 'Tritium mitigation is found to be inadequate' at 5.4M\$. A mitigation plan was presented.
- It was stated that the preliminary design will NOT be complete for all Beamline sub-systems by the 2019 CD-2 review. Items that will or won't reach preliminary design before CD-2 are being identified through prioritization based on existing level of maturity (especially for technically challenging sub-systems, cost drivers and schedule drivers) and to help define important interfaces to DOE scope
- New funding has moved the expected work ahead by 6 months and the lab is trying to ramp up resources to meet the new expectation – In the last 8 weeks there have been the equivalent of 6FTEs working on beamlines (from 3 FTEs early in 2017 before new funding) – the beamline management identify a need to ramp-up to ~25FTEs immediately for continuous deployment over the next three years

Comments

- The new money in 2018 is clearly a good thing but the schedule can only be advanced if people get assigned to advance the design. Given discussions in the break-out the risk of not meeting the resource ramp-up proposed for the project pre-CD2 is high– new hires take ~6 months to bring on board and a ramp-up in FTEs of roughly a factor of four in the next months will be a major challenge
- The missing in kind contributions are obviously a concern and will become more so as things get more and more defined since there will be less intellectual content to attract collaborators – the risk is high that there will be a short-fall on in kind contribution

- The LBNF beamline team has done a good job at identifying and documenting project risks including risks associated with non-DOE scope. These risks have been mapped nicely to the work planning. In particular the mitigation of environmental risks including the mitigation of tritium risk has been identified for development pre-CD2.
- Due to funding the effort on beamline was ramped down leading into 2018 while the new money now allows ramping up. This inevitably has caused delays not reflected in the CD-2 date. The strategy to prepare for CD-2 seems reasonable given the late start and lack of in-kind contributors – the strategy involves prioritizing work to handle highest technical risk and less defined items and to advance non-DOE scope to define interfaces to DOE scope. One would think that the technical risk for non-DOE scope needs to be mitigated before CD-2 and schedule risk needs contingency.
- The new proposal of utilizing an in hall 'morgue' for medium term storage of rad waste seems like an excellent upgrade. The identified down side is that moving items in and out of the morgue would need to wait for shutdowns. An open question is whether there is enough room in the morgue. An operational model with expected failure rates and inventory build up was mentioned but not presented during the discussions. It would be good to see this model presented for the next review.
- By design the presentations were not particularly technical though the discussions were helpful and highlighted some open technical issues. Some of these include initial hardware alignment in the target region as well as beam based alignment protocols and diagnostics that still need resolving at the conceptual level. These should be resolved sooner than later as they may have significant ramifications on the overall design and remote handling requirements.

Recommendations

1. Develop a resource loaded plan spanning the period from now until CD-2 for all scope (DOE and non-DOE). For each item the plan should itemize the required detail for CD-2 and the effort required for each.
2. Develop an operational model with expected failure rates, inventory buildup and required 'shelf time' for the Morgue and present for the next review.
3. Advance the plan for environmental risks (required for CD-2) and present the plan at the next LBNC meeting.

Response to previous recommendations

2.7 DUNE Near Detector [Naba Mondal, Sampa Bhadra]

Findings

- A report ([DUNE-docdb-8184-v1](#)) from this group was distributed in draft form to LBNC members and contains the findings, comments, and recommendations of the charges.
- The Near Detector needs to measure fluxes, total and differential cross sections on Argon, and provide a matrix to map true to reconstruction energies.
- The flux measurements can be done on any target assuming cross section is known. The methods include neutrino-electron scattering, low nu tagging, coherent scattering and neutrino interaction measurements on hydrogen.
- The approach has been to have a multi-purpose tracker to constrain the flux, measure as many differential cross-sections as possible, and a LAr TPC to measure reactions on argon and constrain detector effects.
- The DUNE Near Detector Concept Study ND subgroup was charged to provide recommendations based on scientific arguments on the choice of magnet (SC or normal) for the ND, tracker (STT or HPTPC), whether to incorporate a 3DST, and whether to implement the DUNE-PRISM concept.
- The LArTPC at the near site should be optically segmented, with a short drift space and 2-dimensional pixelated readout, similar to the concept being studied by the ArgonCube collaboration.
- The recommended concept is a near detector suite consisting of a LArTPC and a HPgTPC + 3DST combination in a dipole magnet.
- A newly built dipole is the preferred magnet for the downstream spectrometer of the DUNE near-detector complex.

Comments

- The Committee has not yet had chance to digest these recommendations, which should be considered at the next meeting.
- Additional study of the DUNE-PRISM for technical feasibility and cost should be made.

Recommendations

- None.

2.8 SBN Issues [Kevin Pitts, Dave Charlton]

Findings

- A common software framework, LArSoft, is used by the three SBN experiments, SBND, MicroBooNE and ICARUS, facilitating code and algorithm sharing.
- Frequent and regular joint reconstruction and analysis meetings, and longer workshops, are held between all three SBN experiments.
- Common meetings are also held regularly between experiments on various common hardware and operations aspects, such as DAQ, slow controls, and so on.
- The SBN program is providing hands-on training to technicians, engineers and physicists in the realities of LArTPC commissioning, operations and software.
- MicroBooNE, as the experiment currently with data, has made most progress on reconstruction and analysis tools – these are being made available to the other experiments in the LArSoft framework.

Comments

- The linkages and interactions between the SBN experiments, as presented, are impressive and well exercised so far.
- The committee believes such strong connections should continue also through the operation and analysis phases of all the experiments.
- The natural exchange – indeed overlap - of individuals between experiments is also a strongly positive feature that the panel supports. This also is important between the SBN experiments and DUNE.
- The engagement of SBN experiment experts in reviewing the protoDUNE program is a very positive step.
- The LBNC encourages the SBN experiments also to flag areas of concern, as well as successes, in future interactions with the committee.

Recommendations

- None at this time