September 1, 2019

Comments on **DUNE-FD-TDR-vol4-DP.pdf** dated July 26, 2019

The document contains two new chapters not previously seen by the review committee, the Executive Summary and Cathode Readout Plane chapters, along with four chapters that are very similar to the versions previously released, and on which the committee has already sent detailed comments on July 6 and June 10.

These comments will focus on the two new chapters, but also include further comments on the previous 4 while referring to the page numbers in the present document.

We suggest that DUNE respond comment-by-comment to what is now 3 sets of comments/questions sent by the committee. It is important that the committee understands which comments/questions are or will be addressed in updates to the text and which are not, with a brief reason given.

EXECUTIVE SUMMARY

P1-3, 1st para

“potential for charge parity (CP) in the neutrino sector” -> “potential for charge parity (CP) violation in the neutrino sector”?

P1-3, end 1st paragraph

There should be a specific reference to the physics requirements and a summary of the feed down from physics to engineering specifications for DP.

The DP specifications are separated in each chapter, with some overlap (eg. the E-field is specified in the CRP and HV chapters). It would be useful to have the full list of specifications in this first chapter.

P1-7, Table 1.1

Why is “Active width” not specified?

P1-9, para 1

“The tunable high S/N…” requires more explanation and discussion, following from the comment above.

P1-10, para 3

What sets the minimum CRP gain to x6? This is related to comments above on feed-down from physics requirements.

P1-11, para 1

Under what conditions has a gain of x20 been “typically achieved” - was this in WA105? Needs more discussion. Is it really “typically”?

P1-14/15, section 1.4.3

Very little is said about the field cage other than similarity with SP. Yet the HV chapter indicates that larger stand-offs are needed towards the bottom for 600kV. This section needs to include a summary of the changes for between protoDUNE and the FD and the developments for 600kV.

P1-15, last para

Odd wording: “Assuming a similar channel density”. Is this still to be decided? If so should explain, if not should justify the design channel density and say same for protoDUNE as FD.

The WLS material is yet to be decided? Only TPB is discussed in the TDR, yet PEN is under test at protoDUNE.

P1-17, para 1

“We assume” that the backend DAQ will be the same as for SP. Why is this not the design rather than an assumption. There should be a reference to the appropriate section in the TDR.

P1-19, Table 1.3

This section needs a table of key DP milestones leading to installation, not only these VERY high level milestones.

Surely the first four milestones are not for DP?

CHARGE READOUT PLANES

P2-20, para 2

How many separately controlled voltages are supplied? Do all LEMs in the same CRP share voltages? This needs more description

P2-22, Table 2.1

The precision on LEM-Top-bottom electrode is given as 0.010mm (10um), maybe I missed it but I couldn’t see any material in the TDR to show why this is needed and how it is controlled (QA/QC)

P2-23, Table 2.2

DP-FD-1: This specific comment may belong as much in the HV chapter. What does a minimum spec of >250V/cm and a goal of >500V/cm really mean? Will the design be for 500, so 250 is an operational fall-back. This is what the HV chapter implies. If so, what is the QA/QC requirement? What voltage will the feedthroughs, stand-offs etc be designed to? What are the design and testing margins?

This is an example of the need to describe the “specs” and “goals” in terms of design, margin and operational minimum.

DP-FD-3: Is this requirement on min PE for the entire detector volume?

DP-FD-4: What is the assumed drift velocity?

DP-FD-8: It is probably stated somewhere but what is “effective gain” (on P1-11 it is just “gain”)

P2-26

The discussion of the invar frame and differential thermal expansion/contraction needs to be stated more quantitatively.

P2-27

“At the construction level, the fiber directions are matched between the different subframes to ensure homogeneity in thermal shrinkage.”, is this supported by FEA calculations?

P2-27/28

“Dedicated decoupling systems are installed at each corner of the Invar frame (50 systems by 3Å~3m2 module). One decoupling system that allows the G10 and LEM-anode elements to slide”, are these guaranteed to slide and what happens if one doesn’t?

P2-31

Typo: “steps” 🡪 the stepper motors

P2-31

“To exploit the information from the encoders, the anchor points on the CRP must be surveyed during construction, and the absolute positions of the suspensions must be surveyed from the roof of the cryostat while the feedthroughs are installed”, what survey precision is required and how time-consuming is this surveying likely to be?

P2-32

“These devices do not require any contact with CRPs and are accurate to within approximately 0.1mm on the inter-CRP distance., I thought that the gap was required to be set within 0.1mm which seems a challenge if you can only measure to within 0.1mm. Please clarify.

P2-34, additional section to 2.2

There should be a section describing the HV distribution in the CRP, including a diagram and an explanation of separate control via what power supply and what slow controls system. Is there any risk of damage if some voltages trip and others not? Interlocks?

P2-35, last para

Need more description on changes to anode design needed - a couple of sentences would suffice.

P2-36, para 1

Seems odd to say “for CEA/Irfu”. This is for DUNE, right?

P2-36, Table 2.3

Reconcile the numbers with the statement on P2-22.

P2-36, para 2

The rate at which LEMs can be produced seems to be an important concern.  The TDR states that “it is likely that ELTOS and ELVIA can produce 18 LEM modules per week…”  What rate was achieved for prototype production?

P2-36, last para

“One of several” sites. This is actually better described on P2-38: 4 are needed. Are they identified? Is CERN one (or two)?

A better description of the parts flow is needed early in the section. What is the timeline (full production in 2 years), what throughput (1 CRP’s worth of components per week - so 36 LEMs per week) and how many vendors, how many QC centers for each of the QC and assembly steps.

Where are the CRP assembly sites? Is CERN one?

For each QC/assembly step, the sites need to be qualified ahead of time. This should be discussed. The plan described should include making the four CRPs for protoDUNE-II plus a limited number of other preproduction assemblies. (“preproduction” meaning with final components but intended for developing the production process/throughput and systems testing, not for installation in FD)

P2-37

“For the magnitude of production required for a DP module, developing a fully automated survey system is mandatory.”, if it is mandatory then I would expect to see a conceptual design in the TDR for how to do this.

P2-37

what is a laminar flux?

P2-37

“and HV up to 4.5 kV is applied across the LEM to burn possible residual dust.”, is this the only mitigation plan for dust?

P2-37

“with a discharge probability smaller than 3 per hour.” You mean discharge rate. Also, why is 3/hr acceptable – I would have thought a lower discharge rate would have been required.

P2-39, Table 2.4

This only gives part of the tolerance story. However, position accuracy is key in this design and there should be a full discussion of tolerance specifications so support the alignment precision with component tolerances. Ideally this would be in an engineering drawing. Does such a drawing exist? If not, it would be an important addition to the TDR.

P2-40

Typo: “in at least”

P2-41

Typo: “the time needed”

P2-42, end para 1

Is this a typo? “1.5 N to 1.5 N”. If not, it is not understandable.

P2-43, section 2.4.2

Nothing was said earlier about testing each CRP at the assembly center. Since CRPs may be many months from assembly-shipping-storing-cold box testing, it is important that there be a full (as possible) characterization prior to shipping so that problems can be fed back immediately into the assembly process. Since a complete cold-box test cycle takes 8 days (2-44 para 2), a limited set of tests may have to suffice ahead of shipping?

P2-43

Are the transportation boxes air-tight?  If so, are they filled with dry air when the CRPs are loaded inside, or just ambient air?

P2-43

Concerning packaging, has any consideration been given to static charge buildup and associated dust accretion? If not, then perhaps consider this and for example also wrapping in an anti-static sheet.

P2-43

Increased high voltage is used to burn off dust – this may well be the only dust mitigation possible but then you want to track the level of dust that is being burnt off in some way to perhaps feed back into the production and packaging. You might also consider comparing to other similar activities.

P2-44

“The discharge probability under these DLAr conditions should be less than one per hour for the entire CRP, corresponding to an average discharge rate of one every 36 hours for a single LEM.”, why is this rate acceptable. The statement here should be reconciled with that on P2-37 where you have a discharge rate of 3/hr.

P2-45

“Assuming that approximately 1.2 weeks is needed for a team to prepare, survey, tune, and cable a CRP in the cryostat,”, this is a very precise statement – what is the basis?

P2-46

What is an SPFT translation mechanism?

P2-46, section 2.6

Where are the interface documents referenced?

P2-48, section 2.7

There should be some discussion on transferring the design improvements that are developed in-house to the production vendors. Is there a plan to produce some prototypes at the vendor rather than CERN?

P2-49, send of section 2.7

Presumably the plan is to build some number of prototypes, to do extensive testing in the cold box, and to fabricate 4 new CRPs for protoDUNE-II. The full development plan should be described.

P2-52, section 2.10.2

Changes in the design “may improve HV stability” and ...should also simplify” - these should be worded with more confidence. The planned design changes will improve and simplify.

P2-53, Table 2.7

* Additional milestones should be added for validating the design changes in cold-box, installing new CRPs in protoDUNE-II.
* The PRR date seems too early to benefit from protoDUNE-II experience
* CRP assembly sites are “available” - the milestone should be “are qualified”. Available has no real meaning.
* There should be the same for LEM QC sites and for LEM production as well as CRP

HIGH VOLTAGE

P3-58

300kV over 6m would have to change to 150kV to prove the DUNE minimum performance specification of 250V/cm

P3-60

In addition, because the operational voltage difference will not exceed 3 kV between the two adjacent profiles, the number of varistors will be reduced from four to two, significantly simplifying the design of the board and potentially eliminating the exposed solder balls”, presumably you still need 4 varistor in DUNE-FD?

P3-65

“This result leads to the hypothesis Thus, the current flows through a layer of water on the surface of the FRP beams due to the ambient humidity.”, followed by a statement “This result leads to the hypothesis Thus, the current flows through a layer of water on the surface of the FRP beams due to the ambient humidity.

“, rather than MAY be necessary to study this further, it should be WILL be necessary (with associated additional text in the TDR)

P3-65

I presume that all of the suggestions for future R&D will be tested in DP-II following smaller tests?

P3-82

Is laser engraving shown/known to be benign?

P3-83

Typo: “is tested first at room temperature”

P3-84

“The aluminum profiles are visually inspected and felt by hand for severe scratches and sharp points.”. What happens if these are found? What is the expected fraction of such profiles?

P3-85

The feedthrough must hold target voltage… at least 24 hrs.  This seems and extremely loose requirement and justification and motivation for this test requirement should be added.

P3-99

“using UV laser beams is highly desirable to calibrate the charge signal based on the measured field distortions throughout the TPC volume.”, desirable yes but do you really mean required?

TPC ELECTRONICS

P4-101

“Please note that the DUNE Executive Board has not yet formally ratified the set of specifications and requirements for DP module. This should occur in spring 2019;”. Has this happened? If not, when will it happen (and also why, though that isn’t needed in the TDR)?

P4-103

with custom hardware and firmware development (rather than ad hoc)

P4-104

“assuming the 3 ms (minimally required) electron lifetime”, earlier this was given as 5ms. The two statements should be reconciled.

P4-105

“The LRO system must detect signals from a minimum of one photoelectron on one PMT” - what drives this requirement which seems extreme?

P4-106

“The CRO FE analog electronics use a cryogenic ASIC chip with a large dynamic range (up to 1200 fC) to accommodate the charge amplification in the CRP” - is this programmable and so can accommodate different CRP gains (and is this effective gain or just gain)?

P4-109

“the expected noise is approximately 2000 e− at 110 K.”, I though the noise had to be less than 1000 e- (DP-FD-2)?

PHOTON DETECTION SYSTEM

P5-137

Typo: gives gives -> gives

P5-140

“For non-beam events, the only possible way of correcting for the electron attachment is through PD system-based event timing”- this is a very strong statement and the footnote is too cryptic.

P5-149

“A TPB surface density of 0.2 mg/cm2, the value for which the PMT efficiency is stable as a function of the surface density”- what is the working range (as opposed to the specification), e.g. will this work for any value between 0.1 and 0.3 mg/cm2?

P5-155

“The HTC 50-3-2 has a similar attenuation as the RG-303/U (used inside the cryostat), but costs 8 to 10 times less”. There must be some difference to cause this significant difference in cost – what are they?

P5-157

“… Therefore, the higher the sampling frequency, the better for detector performance but at the cost of increased data rate and storage requirements.” - this is an interesting discussion but for the TDR what is the plan?

P5-157

“The PMTs are oriented with the first dynode perpendicular to the Earth magnetic field and the fiber parallel to the first dynode to have a similar gain to the one obtained with diffuse light”, I am not familiar with the geometry of the chosen field but doesn’t the photocathode roughly point up and how does that then make the first dynode perpendicular to the earth’s magnetic field?

P5-159

Gain vs HV .. “This measurement will be taken every time the operating conditions change. It requires more time for data taking and can be performed approximately once a week when stable operating conditions are reached.” Why is this needed – I would have thought that the gain would be extremely stable. Unless you have a very precise measurement system using these time-dependent gain constants may introduce more variability than using a single set.

P5-161

“For the PD system prototypes, no foil geometries have been simulated.”- if this is for protoDUNE-I then perhaps state this explicitly otherwise this is a very peculiar statement.

P5-161

The footnote has “This is the sampling frequency used in the WA105 DP demonstrator readout, but slower frequencies of 65MHz or 2.5MHz are being considered for the DP PD system.”, referring to the 250Mhz sampling in WA105. What is the baseline for DUNE-FD and what performance metric is used to pick this?

P5-163

Figure 5.17 seems to show that without the foils the PDS is ineffective in half of the detector volume. Therefore, the no-foil option is ruled out? Is this correct?

P5-175

“In this case, the efficiency (purity) remains > 90% only for distances up to 10m (7 m) from the cathode.” I am not sure what figure to look at to see “this”, Fig 5.17 has light yield versus distance or transverse position not purity or efficiency.

P5-181

Typo: to verify they

P5-185

Typo: an acrylic protective plates -> acrylic protective plates

P5-188

Fig 5.38 may be clear to an expert but it is not clear to me what is being shown (orientation, components etc.)

P5-190

Typo: experinece-> experience

P5-199

“Major advantages of Xe doping are triggering the long-lived triplet argon excimer to produce a faster signal reducing the fraction of late light; shifting the scintillation signal to longer wavelengths”. I had to read this several times to understand the use of the word “triggering”. Maybe use a different verb and split into two sentences to make the process and motivation clearer.

CISC

P6-206

“For example, the electron lifetime measurement precision must be 1.4% to keep the bias on the charge readout in the TPC below 0.5% at 3 ms lifetime.”- the requirement is now a 5ms lifetime and this statement should be updated (presumably lower precision on the lifetime measurement is sufficient)

P6-207

“The goal for the alarm rate is less than 50 alarms/day.”- this represents 2 per hour. Are these real alarms or ”fake”? How long will it take a shifter to service an alarm?

P6-210, Table 6.3

Something is wrong in the 2nd column of the second row. If I am correct in inferring that greater fractional precision is being specified for longer lifetimes, could you explain this as I would have thought it would go the other way?