HV System for the DUNE Single Phase LAr-TPC Far detector

Preliminary Design Review

CloseOut

CERN 5/6/19

Review Commitee

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- The Committee is very impressed by the enormous amount of work that was presented, and the well reflected lessons learnt from protoDUNE construction and operation, which results in very mature designs for the Dune HV system.
- Noted that ProtoDUNE is only one of the very few projects where the HV performance has reached the design value. These could not be done without the extensive experience and long track record of the personal involved.

  Streamer issues are discovered thanks to the careful monitoring system implemented. The possible causes are identified and a detailed plan is being carefully worked out to improve the hardware installation design, test and full scale mockup in ProtoDUNE II.

Review Charge

- The Review Committee was requested to review the DUNE high voltage system design and determine if it meets the requirements of the preliminary mechanical and electrical design as outlined in the DUNE Far Detector Design Review Plan (DocDB-9564) and in the forthcoming TDR.
  - Specifically, the Committee was asked to address 11-item Charge questions and provide recommendations on the 3 HV sub-systems: CPA, FC and HV feedthrough and interconnects.

CPA

- No major design changes wrt to pDune. Construction of CPA at full length already done. Design details well explained.

- FRP design relies mostly on test, with official guidelines, so need to make sure that all tests, with proper safety factors, and all possible scenarios are considered to validate CPA design (E.g. Cold and dry)

- CPA Assembly plan (alignments and pinning) seems effective to control flatness and straightness.

- **Recommendations**
- Issue on resistivity (MOhm range) but investigating high resistivity, to be done carefully considering impact on the redundancy issues.
- Design same as PDune but assembly different (in vertical) – carefully check this design and fully define the movement of the 12m objects.

FC

- Design proposed in the TDR is good.
  - The design changes are an improvement from the HV point of view. The hints from PDune indicate that the instabilities are linked to surfaces. The proposed approach (reducing insulators, surfaces exposed) is reasonable. We encourage to continue these approach and optimize them further.
  - The new FC is mechanically cleaner than in the baseline design. It has some simplifications… but some aspects have not been tried in PDune and therefore need careful and urgent care, eg. independently supported ground plane. Any change has to be tested in PDuneII.
  - New set of drawings and FEM analysis to be remade and available well in advance the FDR.
- Scratches are an issue as damage the coating. Attention to logistics/storage/manipulation at all phases. Define a clear pass/no pass criteria and at which steps and define protection for exposed region during assembly.
- The FC profile caps are insulating, do work, but they charge up. Encourage them to go in this direction.
- Washers being used: document, properly select and apply tork is important. Add details in the manufacturing specs.
- System of alignment and pining the CPAs. can it be applied to the FC? Method of straightening seems difficult and time consuming.
- For the reflectors PDS (plastic foil) will charge up and distort the E-field. This again results in a some solutions that need to be simulated, tested, validated in ‘quasi-real’ conditions. Complete the R&D in due time.
- The studies for the calibration laser penetrations in the top FC are ongoing. Path to decision has to be clear and timely.

HV FT et al

- Load on the donut to be understood. Tip: 2 cm spring loaded should be expanded. All to make sure that contact is guaranteed.
- Power Supply – needs test well in advance!
- HV ripple noise filters shown problems but this is well understood: leaking filters. Discarded for Dune. Working on developing dry filters, custom design, prototype tested and being optimized for the resistance value. Propose reliability tests and test at ProtoDuneII. Considered not critical though.
- HV feedthrough (increase length of feedthrough) – nice to change the design to avoid it's in cold and then can be removed without the icing issues. Go on and complete design.
- Replacing wire ring terminals by forks not a good idea...
- Review redundancy needs of all interconnections. For critical contacts, use multiple redundant connections.

System Aspects

- Drawing validation to be included in the QA/QC strategy. For FDR, focus on QC/QA of sub-assembly and assembly levels, drawings with tolerances, etc
- From the presentation and the referenced files, extensive discussion of work, experiences and tests are done. The successfully installation and testing of the ProtoDUNE-SP indicate that high quality work are performed. However the documentations are spread over mostly on DocDB and not much on the EDMS SP folders. Suggest to created dedicated folder to host all QC/QA related procedures, checklist, specs and past/fail requirement definitions.
- Think on adapting feedthroughs in case of needed. Making connections to measure HV on the ground plane can be done easily. Insist with TC on any other needs.
- Redundancy of all connections, consider very carefully.
- Exploit at max PDune to get info on streamers.
- Any design change to be tested on PDuneII. Make sure that PDuneII scope can validate all design changes, and check is additional diagnostics is needed.

System aspects

- Built on ‘start of HVS components installation date’, works backward to produce production schedule, forward for installation, with procurement experience for pDune folded in. The schedule should be reworked to add more confortable float and accommodate unknowns (storage, shipping).

- Goals of DUNE-HV Trial Assembly at Ash River are clear: full scale mockup to test all engineering steps, draft docs, safety doc, test of access equipment, labour estimates….

- Keep a lessons learnt doc / fault tracking system / etc alive to document all issues documented, given the long lifetime of this project.

- Have a list of TODO things….

- PDune lifetime not same as Dune (decades). How is this taken into account in the qualification of the design? Example: resistive layers lifetime, coatings…..

Important

- Streamers investigation: NEED TO DEVELOP the pDUNE OPENING PROCEDURE to make sure all possibly related parts suspected to couse the streamers are collected and inspected properly should any trails left on this parts. The value engineering laid out in the presentation might have very positive impact on the improvement of the HV system and possibly eliminate the streamers. Recommend to proceed with the planned R&D and complete the detailed value engineering.
- Can DUNE design go ahead knowing that the cause of streamers is not fully understood and results in down time and it's not obvious to extrapolate the 1y PDUNE experience to a more than a decade? The Comm thinks that the team has the HV expertise to minimize this impact and proposed design changes go in the right direction.

Charge Question 1

Have design choices been fully identified and do they meet detector requirements?

- Most of the requirements for the DUNE HV system are clear, complete and documented, and have been cleverly translated in a sound design. The design relies mostly on the pDune design choices and the lessons learnt during the construction and operation of the prototype.
- A small number but challenging optimizations and few options are being explored. The most important is the revised Field Cage Design, aiming at improving the HV stability. The instability issues encountered in NP04 indicate a connection with charging up of insulator surfaces outside the field cage. The impact of this design change on any other system/interfaces was well explained.
- The ProtoDuneII effort will be key for the validation of any of the proposed changes, thus a full understanding and decisions on all options presented should be taken in Spring 2020 at the latest. ENDORSED!

Charge Question 2

Are the specifications and drawings for standard and custom components substantially complete and available in EDMS? Are they of sufficient maturity to proceed to final design?

- The experience that the team has gives us confidence that the drawings and the specifications will be available for the Final Design Review.
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- It was explained this morning that the drawings will be submitted to a 3 steps control process 1) ANL reviews and controls 2)HV team review 3) TC review, which should ensure a good level of control. We encourage the team to define this 3 step control approach to in the QA/QC document and define the criteria/charge/responsibility for each control step.
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- We also believe that the transition from DUNE db to EDMS is not yet fully complete, so this may justify the missing drawings in EDMS (picture 1).
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- The cross references between drawings should be looked at carefully, because we could identify some weaknesses on this aspects. This aspects are extremely important considering the amount of design changes foreseen with respect to protoDune (e.g. new FC configuration, GP plane modification, …)

Charge Question 3

Have interfaces with other detector components been addressed and documented? Do risks of design changes in other systems have appropriate mitigation strategies?

- Yes. All required interfaces have been identified. Many thorough documents have been written. A detailed detector/cryostat integration drawing specifies critical dimensions to the facility. A detailed drawing with key dimensions for the APA/CPA/FC/EW assembly provides dimensions relative to the design parameters from physics. More work and collaboration between HV and APA is needed to complete the APA and HV interface. Interface drawings for PD and CE are needed.
- The system is tolerant of changes in other systems that result in "local" changes to the interface, but time is limited to make such changes. The system is not so tolerant of changes on larger scales such as changing the pitch between detector elements. Their level of flexibility is very reasonable for a preliminary design review.

Charge Question 4

Are engineering analyses sufficient to ensure the design is safe during all phases. Which applicable design codes and standards have been used?

“It is difficult to answer yes. There is no evidence now that the design is unsafe, but we need more information.” >>> Waiting for the work of the ENG BOARD.

- It was explained that there is a good communication established between Eng. Safety Committee and the design team and that the different load cases are defined by the Eng. Safety Committee, and that the validation is given by the Eng Safety Committee.

- As a recommendation we would suggest to keep the test document separate from the calculations document and use it as reference because you will probable keep performing tests, but the calculations should be validated before the FDR.

- Considering that there are no standards (just guidelines) for FRP design, and as mentioned in the EDMS document FRP is a brittle material it would be important to consider all opportunities to test expansion/contraction of the different assemblies and analyse (if possible) the possible stress concentrations.

Charge Question 5

Are system grounding details documented and in EDMS? Are electrical connections specified and do schematics exists in EDMS? Are all wires, cables and connections documented?

Yes. The committee commends the HV consortium for storing all the drawings in EDMS. These include documentation of all the grounding connections,of the connections between different detector components, as well as schematics for all the printed circuit boards. In some cases part of the information is not available directly from the drawings in EDMS, and is instead available in the engineering note that documents the design and the construction and testing procedures. Further checks on the documentation will take place during the electrical safety review.

Charge Question 6

Is the design in accordance with possible procurement strategy scenari?

PDR, no procurement plan reviewed in detail, but suppliers as PDune + active search of alternative suppliers.

Attention to small orders, sometimes more difficult to control.

Need to decide how the procurement an acceptance procedures are managed (centralized vs distributed)

Charge Question 7

Are quality assurance and testing plans sufficiently developed to proceed to final design?

The successful operation of protoDUNE demonstrated that he works are in very high quality. The QA/QC documentation may not be in the perfect form or well organized in a dedicated EDMS location. The level of work and detailed knowledge is definitely advanced enough that the team should proceed with the R&D plan correctly identified to eliminate the streamers. The final design should be proceeded with lab R&D tests back up so the full scale mock up can be tested in the ProtoDUNE II run.

Charge Question 8

Have lessons learned from ProtoDUNE been implemented?

Yes. ProtoDUNE-SP demonstrated that the high voltage system concept works well and its requirements are met.

The lessons learned from building and operating ProtoDUNE are implemented on all the levels, from the design, construction and installation to the operation.
The HV consortium implemented improvements, often only details, on most of their sub system that will smoothen the assembly and operation of the detector.
There are still open questions that are urged to be answered, for instance, the exact cause of the streamers observed at ProtoDUNE during the past months.

The presented design copes with this unknowns in conservative fashion, trying minimise all the dielectric surfaces in the high field regions, that are believed to be the sources of instabilities in ProtoDUNE.

In addition, these lessons learned suggested for further developments that, if successful, would make the DUNE-SP HV system simpler to assemble and more robust.

Charge Question 9

Are plans for additional prototyping reasonable and sufficient?

Yes. There are a couple of minor changes being considered to accommodate other consortia. If adopted they will be implemented in protoDUNE II. Assembly and installation tests planned for Ash River also allow enough time to make minor changes for protoDUNE. Changes being considered for the supporting the FC and Ground planes have potential technical and cost advantages, but require a timely completion of study and design. The design portion must include the completion of the corresponding revisions to the structural analysis.

Charge Question 10

Are plans for the next post TDR design being sufficiently justified and presented?

To be answered….

Charge Question 11

Have appropriate cost estimates and schedule been determined? Are plans for required technical resources consistent with scope of remaining work?

- Yes. The schedule and cost estimate are informed by the construction, testing, and commissioning of the corresponding detector elements in ProtoDUNE. The schedule has been built under the assumption that the detector components need to be delivered in South Dakota a few weeks ahead of installation, without any buffer at the production sites. This assumption should be revisited, in coordination with the DUNE and LBNF management, and the schedule should be designed with the goal of having a significant float for the availability of the detector components prior to installation. The goal is to ensure that any issues that could arise during the production do not result in a delay of the detector installation. The HV consortium should inform LBNF of their storage needs in South Dakota, under the assumption that the a significant fraction of the detector components (>50%) are delivered there prior to the beginning of the detector installation. If needed the use of temporary storage in one of the national laboratories in the US should be considered.

  The consortium appears to have the resources and the expertise required to investigate further design changes in the detector over the next 12-18 months and build new prototypes to be used for the second run of ProtoDUNE. The dates for the 2nd run of ProtoDUNE have been set arbitrarily and if the HV consortium needs more time to complete the design and construction, they should inform the DUNE management and Technical Coordination. The committee stresses the importance of having final prototypes of all detector components for the second run of ProtoDUNE, and at the same time pursuing the integration tests at Ash River.

  A significant ramp-up of personnel is needed at the beginning of the production phase, and the consortium did not discuss whether the corresponding resources have already been identified. Distributing the procurements and the production over a longer time period could help in this respect. More detailed plans should be presented at the Final Design Review.