Answers to Reviewer Questions

1. Given that pDUNE will be warm around Spring 2020, can you consider/make a plan to try monitoring mechanical deformations, and evaluate their impact -if any- on the new mechanical changes that are proposed for DUNE?

Yes. We will develop a plan to form a “forensic” team that consists of subsystem experts. This team will enter the cryostat first, before any disassembly crew and the scaffold crew, to assess any changes in the TPC, such as deformation or shift of components, record and taking samples of dust accumulation on the TPC, and cryostat floor. Many of the points of interests are near the top of the TPC. The experts must inspect those POI before any disassembly taking place. On HV side, we’ll need to have a thorough visual inspection of the upper middle portion of the up stream EWFC for any unusual features, location the broken PD flasher fiber, check the connection of the problematic FC termination.

2. Have you already evaluated all the tolerances relevant to the installation process?

pDune and FD tolerances were determined from AR testing. pDune assembly went well and we believe the tolerances specified were adequate

3. HV feedthrough: the lessons learnt from pDUNE operation have been incorporated in the proposed design for DUNE. This includes the room-T design. How long it will take to move from the conceptual to the final design and what are the tests foreseen before releasing production? Is there a specific document listing all the requirements for this item with all the design changes that have been presented?

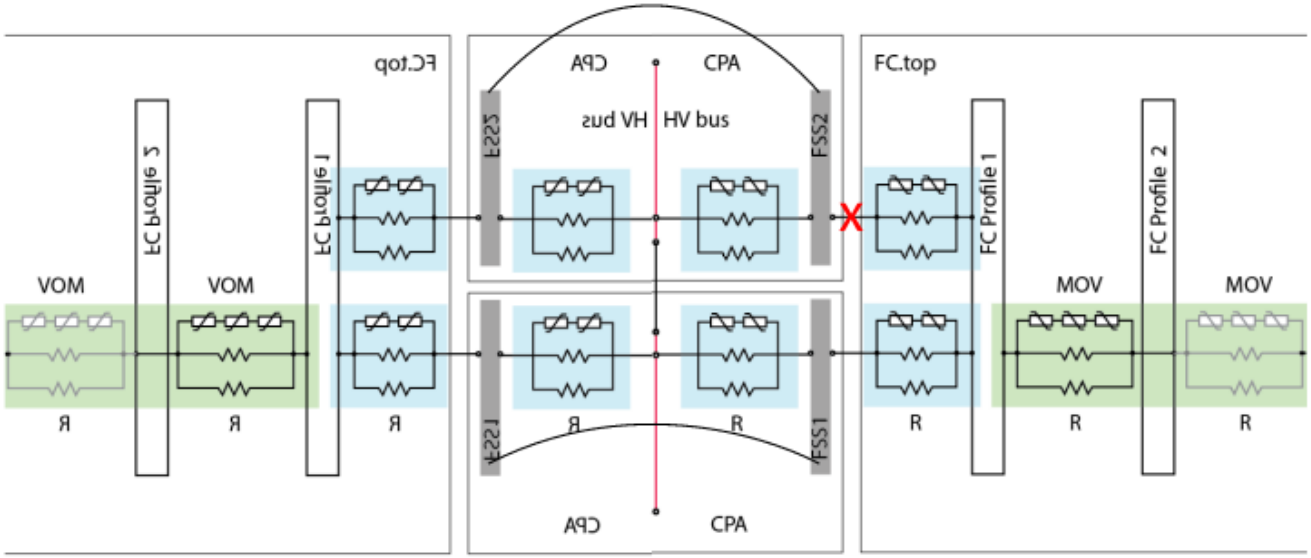
- Only the availability of a longer PE rods need to be verified for the RT design. As soon as the vendor is identified, the time required to realize a Prototype is estimated in ~ three months: the manufacturer is able to construct a FT with the required length.
- Test can be performed at CERN B182 in Pure LAr as for the previous FT. The length is not affecting the possibility to perform the test.
- We have not formulated an official requirement document for the HVFT. However, the following requirements has been implicitly applied in the design of the ProtoDUNE HVFT:
  - Hold 200 kV in Ultrapure LAr without any discharges;
  - The minimum length of the FT must be compatible with the DUNE cryostat insulation thickness and ullage depth: > 2.5m from tip to bottom of main flange;
  - The bottom edge of the outer ground shield must be immersed in LAr by at least 10 cm;
  - Spring loaded tip with minimum travel of 2cm to compensate any residual thermal shrinkage and alignment error;
  - Max flange size: CF250;
  - Corona discharge monitor integrated on the FT.
  - New: Cable termination point must be at room temperature to avoid water condensation in case of cable removal;

4. The engineering safety review of the engineering design document has just taken place, and the Board has provided a number of questions to the team. When the HV Consortium will respond to the engineering safety questions?

- We have not formally received the questions but did receive a printout of them on Monday. The responses to all of the questions are available in a document, and will be forwarded to Olga.
- We were also informed by Olga that this safety review process will involve back and forth communications for up to a month to complete.

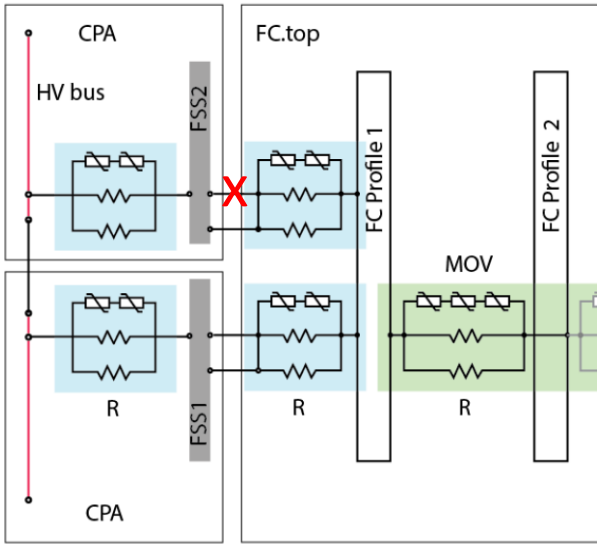
5. Can you comment on the QC of the connection between FC and CPA, and explain the consequences of losing that connection versus adding redundancy.

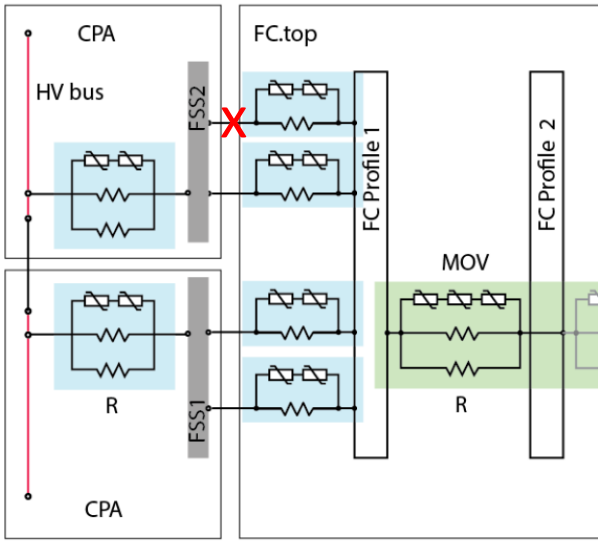
- After the top FC is mechanically tied to the two CPA panels, the long jumper wire from the FSS-FC board under the first profile of the top FC is connected to the screw terminal on the FSS. Resistance between profile 1 and the FSS terminal is verified, and so is the resistance between FSS terminal and the HV bus terminal.
- If this long jumper wire is broken (X), the bias on profile 1 will be roughly Vc+6kV. FSS1 will be at Vc+2kV, bias on the FSS2 will be around Vc+1kV, determined by the resistivity of the FSS2 loop down to the bottom of the CPA where the divider boards from the bottom FC is helping to correct the shift in voltage.



5. continued

- A redundant jumper connection shown in the lower left figure will be immune to a lost of connection on one of the jumpers.
- A redundant board connection such as the lower right figure will have a less severe distortion but not immune to such a lost of jumper connection.





6. Can you explain the plans for qualification/validation of the engineering drawings from now till the FDR? Who is responsible for the final approval? are external experts included in the approval process?

- ANL internal process will be used and the HV consortium has periodic reviews of the model/dwgs and has had a final review for pDune dwgs as well as one for the FD. In addition, whatever process defined by TC for review/approval by consortium will be followed.

7. FRP design relies mostly on tests and consultation of official guidelines. This calls for a careful analysis of all tests that need to be done for final qualification, agreed proper safety factors, and that all possible scenarios are considered in the calculations. Which mechanism (body) has been put in place to decide on the final qualification values?

- It is our understanding that TC/Eng Safety Committee decides on the load cases and qualifications. An Analysis Plan that defined all of the load cases was submitted and approved by TC/Eng Safety committee.

8. Could you please show in detail the interface between endwalls and CPA field shaping strips: pDune had a small gap. How this is addressed and controlled?

We devised a simple scheme for NP04 to prevent the EWFC from swing away from the CPAs. The design details of this feature have not been implemented in the current baseline design, mostly because the impending change of the FC design.

During the final design phase, we'll add mechanical constraints between the CPA and the EWFC to ensure co-planarity of the modules.

9. Are the needs for instrumentation for the high voltage system fully defined and agreed with other consortia ? Please discuss them.

- No. Most of the interface documents are still at early stages. TC is has started to push for the advances of the agreements and technical specifications.
- The interfaces with the APAs are well defined based on the ProtoDUNE design. Specific detailed interface drawing are still to be generated.
- The interface details with the CEs are still to be documented. Current agreement is at the similar scope as that of the ProtoDUNE. Drawings and diagrams are to be generated.
- The current draft interface document with CISC has specified the readout of all FC termination channels and up to 100 GP monitoring channels.
- To fully instrument the diagnostic and monitoring features that we'd like, we need to secure a relatively large number of signal feedthroughs. They are not available in the current cryostat penetration plan. Since the cryostat design is already frozen, adding feedthrough ports that are parasitic with existing penetrations is the only option now. This is an import issue that we have to work with TC to resolve.

10. The HV consortium did not discuss hardware/(software) interlocks. Are these fully defined ? Could you please provide a list of the interlocks on the HV system that are currently in use in ProtoDUNE.

- The interlock / alarm are part of the interface document with the Facilities/TC. The first draft we sent to Terri/Vic has these alarm conditions:
  - Liquid argon level dropping within 2 cm of the top rim of the ground planes, while the HVPS are on.
  - Opening of the pressure relief valves, while the HVPS are on.
  - Any other conditions that could cause LAr boiling at shallow depth of the liquid, while HVPS are on
- In NP04 we have these interlocks:
  - HVPS output vs liquid level,
  - Communication failure between WINCC and cRIO slow controller,
  - Emergency Stop.
  - In addition:
    - Dynamic current limit: during the HV ramping up and normal operations, current limit on the system is defined as a function of resistance times the voltage plus an offset from the calibration of the PS (Current limit(μA) = Resistance(system) x Voltage + C (Offset)). Whenever that dynamic limit is exceeded, PS automatically adjusts the Voltage until the current is below the limit.
    - Current trip: A current threshold is defined for the specific high voltage. Whenever that threshold is exceeded for a defined time interval, PS automatically trips to 0kV.

11. When do you expect to be able to present the result of the studies of the discharges in the field cage ? Are these likely to result in any design change ? Which elements of the detector design are going to be affected ?

- We are planning to present the results to the HVS consortium in July, and to CE and APA at a later time. The preliminary results are coming out. We have to double check on some of the assumptions used in study. At this moment, it does not demand any design changes. It may impact the grid plane removal proposal.

12. Could you please discuss the redundancy in the electrical connections between the various elements of the HV detector ? Are there any connections where you think that it is necessary to build redundancy in the system ? (particularly worried by the HV bus on the CPA)

We have two rather length answers to this question. They are posted to the review site.

13. Can the monitoring capability of ProtoDune be revised, and a plan for pDUNEII be made

- Yes, we could implement more current monitoring electrodes to increase coverage and/or granularity. We could also add some optical/UV sensors in pD2. We have to coordinate with other consortia on the available signal feedthroughs: some of the currently vacant ports are expected to be occupied (calibration lasers, for example).

14. Can you show the function (electrical/mechanical/grounding…) and design details of all the important connections between items, on boards, etc..

- Most of our electrical connections are important in that a failure would introduce some form of performance degradation.
- Glenn's talk covered most of the electrical connections on the CPA.
- It would take us a while to compile the details of all the connections. And we'd like to know to what level of details we need to prepare.
- We are expecting an electrical safety review soon. We'll try our best to supply the information as part of that review process.