Hi Bo, Francesco,

Here are the rest of the homework questions we have. Most should have simple answers, we hope, not requiring too much extra work from your side.

Thanks,

Jen, on behalf of the committee

**General:**

Charge Question 5: From the notes I took during the presentations today, it seems that open design choices still exist for the following items: Top Adjusting Device, Length-Adjusting Device, Carabiner, Tools/devices for CRP module installation. What else still has open design choices?

This is discussed in Bo’s talk today.

(Comment: The following systems have very advanced designs, but are not yet finalized: cathode frame design, suspension system, box beam design. HVDBs, HV delivery)

**Overview Talk-Francesco**

Charge Question 3:

· Teams include: Cathode Plane, Field Cage, Electronics, High Voltage Delivery, Mechanical? Each group is focused on specific tasks, outlined in presentations. During the presentations, it was noted the groups routinely meet, sometimes as many as 3 times a week. Is there a representative from each subgroup in attendance at all meetings? Not sure I have the right group names---there are so many, Overview slide 30.

The HVS consortium has regular 2-hours weekly meetings, where both the HD and VD tasks are discussed and updates are given. Depending on the priorities, on special occasions, more time is spent on specific issues. The participation is always high with one or more representatives of each institution present most of the time.

The group that meets as frequently as 3 times a week is the Cathode-PDS workgroup which focuses on the integration of the X-Arapucas on the Cathode and the routing of the Optical fibers. Updates on these activities are reported at the HVS meetings.

· Overview slide 32 indicates HV extender a possible issue but R&D has been implemented. I worry about the ‘rope’ mechanism. Has a thorough vendor survey been completed to see if a commercial device is available? Perhaps so but the cost is prohibitive?

We believe that the commercial lifting mechanism we plan to use for the extender (a rope from a winch mounted on a tripod) is well understood, safe and already tested several times with other heavier objects in NP04/NP02). It is included into the Structural Analysis Plan and, as such, it will be subject to detailed review by the Compliance Office.

**Cathode Design-Fabien**

Charge Question 2:

· Some testing has been done on the rope supports that produced some valuable information. Would you consider this testing to be complete or are there more tests or simulations that need to be done?

Tests on a stainless steel prototype are needed and global model analysis has to be done for all the elements connected to the rope. For the moment, we only performed analysis for critical elements such as the pulley

· Are the rope materials both compatible with LAr? I think you said yes but I wanted to confirm this.

They are some publications about Dyneema ropes working in cryogenic temperatures (Journal of Material Science 27 (1992) 4515-4522) for example. In the interaction we add with DSM (Dyneema producer), they confirm that the Dyneema can be used is LAr.

· Is there any more FEA work to do on deflection or is this considered to be completed?

Analysis note is complete on deflection

· What needs to be done to complete Comsol simulation of the drift field?

We only simulated “simple” defects (misalignments and tilts). We need to perform simulation with realistic deformation (bending in particular)

Charge Question 6:

· I don’t think this was specifically addressed in the talk. Can you briefly address this?

As stated during the presentation, the main source of changes for the cathode design can come from the PD design. We changed our design to be able to handle (weight and fiber routing) any choice of positions for the PD and thus, mitigate the impact of possible changes. In any case, there is a very good interaction with PD team which are aware of our constraints and possible margins

For the CRP system, the interface is clear (support of the hanging point) and fully integrated in their design.

Charge Question 8:

· What are the plans for prototyping the cable elongation system that pre stretches the ropes. How much design work is left to do on this?

The system shown on slide 12 allows to suspend up to 200 kg on 4 different wires (up to 6,5-meter long) and measure the elongation at cold and warm with a precision below 1 mm. It can be used for the preloading if needed. The most critical part was the overall mechanical structure able to support the constraints and the design is ended and orders for material will be placed next week (the welding will be done at IJCLab by our staff). The operation of the device is quite simple and do not require significant effort for being operative.

· What is the validation plan for the next length adjusting device prototype? When will the real parts be prototyped? What is the testing and validation plan for this device? Is there instrumentation required?

The first real version of the LAD (in stainless steel) will be produced in June. After 3 prototype versions in 3D printing, we are quite confident that the v1 will work properly. There is no dedicated instrumentation to be developed to validate it. We will check the range and the step of the rope motion. It is also important to check that the structure is supporting the 150 kg effort (with safety margin) without deformation or rope extraction.

Charge Question 10

· What will determine which manufacturing process you use for the resistive mesh? Can the vendor test resistivity and provide data sheets with each panel?

For the moment, only one provider is matching the resistivity requirements. So, the choice will be easy.

If both are OK, as one of the providers (Rochling-Permalli) is the frame producer, the main argument will be the overall (frame+resistive mesh) cost including mounting on the frame.

The vendors can perform this kind of measurement and provide data sheets.

· QA on the ropes pre stretching seems like it could be complicated. Who will be doing this work? Can the vendor do the pre stretching?

Our current experience shows that an initial loading with a mass (typically 200 kg for a few hours) higher than the working load eliminates the plastic deformation and that the wire is used in the elastic domain when loaded at the working point. We started the discussion with the provider to see if this preload can be done at the vendor site. If not, it will be part of the qualification and test process we will perform in any case to measure the elongations at warm and cold.

· How confident are you that you can hire qualified people as the design transitions into manufacturing, testing and procurement?

The responsible for AIVT is identified and is a permanent member of IJClab. He is already involved in DUNE performing the prototyping tests. It will ensure a natural continuity between activities. It has been also accepted by the lab that the design engineers will remain in the project anyway (with a lower involvement). The hired people (if needed) will be technicians under the supervision of the AIVT. We are expecting to have part of the technicians coming from the permanent staff of the lab.

**Field Cage Design-Jaehoon**

Charge Question 6:

· I don’t think this was specifically addressed in the talk. Can you briefly address this?

The systems that could directly impact the FC design changes are Top and Bottom CRP’s, Cathode and the calibration systems. Since the dimensions of these elements are constrained by the overall size of the detector, thus the active volume, and the designs of their structures, including the support on the ceiling and the floor are relatively well developed, the potential for their changes to significantly impact the FC design is minimal. The FC frame design change from 5cm (W)x10cm (H) to box beam frames of 5cm (W)x5cm (H) provides additional room for maneuver. The calibration system whose design is in its infant stage is not expected to cause any significant FC design change thanks to the 70% transparent FC design which already was impacted by the PDS physics requirements and provides ample optical transparency for laser light illumination. Any mirror implementations can be easily integrated into the existing FC profiles, taking advantage of the profile structure.

Charge Question 8:

· Is prototyping complete for the Cathode to FC bus connection?

While tabletop prototyping is ongoing as part of the development, the prototyping with actual connections between Cathode and the FC as well as the inter FC module connections are expected to happen during the Module-0 campaign. We will test the resistive FC bus in the cryogenic temperature prior to the installation into the NP02 for Module-0 campaign.

· Is there a plan in place to test the FC module assembly procedure?

We plan on building four modules for the Module-0 campaign and will test the assembly and installation procedures at that time. We plan to produce prototypes of the assembly stand, the storage cart and the installation cart and will refine them based on the experience in the Module-0 campaign.

Charge Question 10:

· What QC is required for the aluminum profiles? Dimensional checks? Coating QA?

The Al profiles and the surface coating are visually (also with cameras) inspected upon arrival for scratches and mechanical damages. The coating specifications for QA has been clearly given to the vendor who has been keeping up with the guides. The same vendor has been providing the profiles for the other FC modules and has been performing well. The dimensions and the hole locations for the UWHMPE caps are provided in the engineering drawings to the vendor and verified through the random sampling measurements of the profiles.

· Is there an assembly procedure written for the FC module units at volume (instead of a single prototype)?

I apologize for not being clear during my presentation yesterday but the assembly procedure I presented yesterday is for the volume production.

**HVDB Boards-Jeff**

Charge Question 6:

· I don’t think this was specifically addressed in the talk. Can you briefly address this?

If the pitch of the FC profiles were to change there would need to be a modest change in the layout of the boards. As noted in the changes document, a final internal integration review WRT to the FC design is planned.

Charge Question 8:

· The board design seemed pretty mature. Is there any prototyping or validation work left to do?

This summer we will produce two twelve-board strings for the VD-SP protodune as part of a broader HVS system test. As part of that process we will exercise (manual) component testing/QC, vendor production, and the mounting hardware design.

Charge Question 10:

· Pre-assembly component testing and inspection is a big part of the manufacturing process for this board. There’s 62000 individual parts that all need thermal cycling and visual inspection or VI characterization. What’s the plan to be sure everything is tested properly before assembly? Are the components being tested at W&M then sent to the vendor for assembly?

W&M will buy the components and have them shipped directly to campus. We will establish a workflow within the lab rooms that ensures that only tested components proceed to the cleaning/packaging room, which will be separate from the receiving room and the QC room (both across the hall). As testing will be done in numbered batches, the app-based quality tracking/checklist tools and HWDB interface pioneered for FD1 HVS production will be fully employed for tracking the batches. A W&M postdoc and grad students will work on that development as part of the prototype assembly this summer. The components will only be shipped to the assembly vendor after they have been tested, sorted, and packaged by W&M.

· Are you confident that the APA tooth strip gluebot and the cold testing systems can be designed, built and tested on time?

I am sorry I wasn’t clear in my presentation. The APA board production is a FY21-FY22 work package (in parallel with UK production). The gluebot is operational and was used for pre-production work in spring 2022. The expected start of the HVDB production is the beginning of CY24, and the integration of the board into the FC module is in CY27.

· Will the boards components be traceable back to lot numbers?

We were not planning tracking at that level after initial QC tests and assembled board tests.

**FD2 HV Delivery-Francesco**

Charge Question 6

· I don’t think this was specifically addressed in the talk. Can you briefly address this?

We do not think that there are known possible impacts on the HV delivery design due to other system changes. None were brought up in the past, mainly because the HV delivery is a primary component for the optimal performance of the LArTPC hence it has the highest priority. As an example, the distance of the HVS extender to the cryostat walls is the minimum allowed by the HV system and no attempt to reduce it will be acceptable.

Charge Question 8

· Has the new HV FT design been tested yet?

The newest HVFT is under construction. The components will be made available at CERN before the end of July 2022. We will then perform the cryofitting at CERN and soon after we will be able to test it in pure LAr.

· How confident are you that you have determined the root cause of the HV cable and HVFT failure? Are any more prototype parts required because of the damage from the NPO2 HV test?

Up to now, we have built and extensively used 4 HV FT, designed to stand 300 kV. The first 3 had the ice formation issue but no HV problems related to the PE insulation cylinder. To be on the safe side, however, as we cannot be 100% about the origin of the failure, for the newest HVFT we decided to increase by 50% the thickness of the PE insulator. This will introduce an additional very significant safety margin for the operation at 300 kV.

We do not believe that other prototyping will be needed in addition to the planned one.

Note also that the ability to replace the HV-FT while the detector is full of LAr (as successfully demonstrated in NP02 and other LAr-TPC’s) is an important feature to ensure the continuity of teh detector operation in case of unexpected failure on the HV-FT.

Concerning the cable, we are quite sure that the failure happened due to the presence of a weak point in the insulation due to a bad manipulation of the Cable. The HV discharge on the HV-FT then triggered the sudden release of the energy stored in the cable that further cracked the cable insulation in the weakest point.

Charge Question 10

· Is there a detailed plan for QC on the HVFT PE insulation? Will every part be x rayed or do you think material sampling is adequate?

For the moment the two options are open. The CERN science material team is verifying if the X-ray technique, able to examine a 4 m long piece, has enough resolution to spot out the polluting fibers. Few days ago (before I left CERN) we got a preliminary positive answer. This will be confirmed (hopefully) in a short time. In this case, X-rays will be used on the whole PE cylinder and CT on samples.

· Are there any strain relief options to implement on the HV cable to help prevent exceeding the max bend radius? Is there any tooling to help prevent this damage from occurring?

The strain relief is actually already present on the NP02 roof: a steel frame was built to support the several HV cable turns above the HV-PS in a way that the cable is inserted into the PS vertically with practically no curvature. An arm is also connected to the frame to guide the other extreme of the cable to the HV FT. We believe that the problem arises by the fact that both the Cable and the HV PS were moved several times from EHN1 to B182 and other labs at cern for the various R&D tests. Also the cable plug was rebuilt several times and during any of this manipulation or transport the cable could have been damaged.

A protection for the cable plug termination (a rigid pipe where the cable termination is inserted into, preventing accidental sharp bending) can be designed on the basis of similar protection made for different HV cables and built.