The Hyper-K Underwater Electronics Assembly project
Addendum to the Letter of Intent
CERN-SPSC-2023-021 ; SPSC-I-260

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January 24, 2024

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1 Executive Summary

In August 2023 the Letter of Intent titled "The Hyper-K Underwater Electronics Assembly project" (CERN-SPSC-2023-021, SPSC-I-260) was submitted.

The Hyper-K long-baseline neutrino oscillation experiment in Japan will start its operation in 2027 with the goals of measuring the leptonic CP phase, with a resolution better than 20° and with a 5σ sensitivity to the discovery of CP violation. It will also determine the neutrino mass ordering by combining accelerator and atmospheric neutrino data. Hyper-K has entered the mass production phase of the water-cherenkov far detector, that will be equipped with about 23,600 photomultipliers (PMT). Hence, Hyper-K is currently organizing the assembly of the 900 front-end electronics underwater units that will digitise the PMT analogue signal and send it to the on-surface DAQ system. In the Letter of Intent, the project consisting of the assembly, test and calibration and shipment to the experimental site in Japan of the 900 underwater units was proposed to be done at CERN. Such project is a common effort led by the European institutes involved in Hyper-K, that would have easy access to the facilities at CERN. Starting in 2025, the project duration will be about 1.5 years. The Letter of Intent was fully supported by the Neutrino Platform.

In this addendum, we provide additional details about the space for the storage, the assembly and the shipment of the 900 underwater units. The space satisfying the project requirements has been identified and agreed with the management of the Neutrino Platform. Additional information is given about the technical personnel required for the project and fully funded by the Hyper-K collaboration, as well as the service requested to the CERN EN-NP (Neutrino Platform), the CERN SCE-SSC-LS (Logistics), the CERN EN-HE-HH (Heavy Handling), the CERN EN-EL (Electrical Engineering) and the CERN HSE (Safety). The requests have been discussed and clarified with the Neutrino Platform.

2 Project status update

The ongoing activities at CERN, i.e. the vertical slice test (VST) and the 10-unit tests, have been described in the Letter of Intent (LoI) and have advanced over the last months. With the VST, the full front-end electronic system, comprising the PMT signal digitiser board, the Data Processing Board (DPB), the High-Voltage (HV) and the Low-Voltage (LV) modules, has been integrated and the functioning of the interface communication has been successfully tested. The 10-unit in-water test in Bldg. 182 in the WA105 cryostat tank, has been equipped with six "dummy" units, i.e. with the high-voltage and low-voltage module prototypes and dummy loads to fake the digitiser board and the DPB, as described in the LoI. The test gave positive responses and is now (February 2024) moving to the next step, i.e. the installation in-water of a fully-integrated unit, including the real digitiser board and DPB, and the start of the longevity test.

Meanwhile, HV and LV ageing tests have been successfully performed with prototypes and the pre-series production has started.

The advances in the last months have consolidated the schedule of the Hyper-K FD electronics, whose simplified version is shown in Fig. 1.

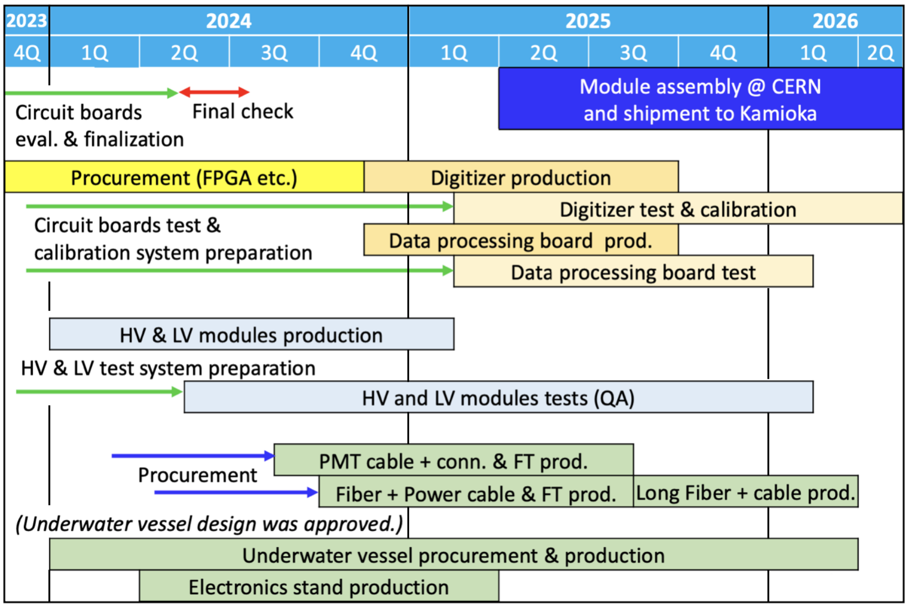

Figure 1: Hyper-K FD electronics schedule.

3 Project schedule and first component delivery

Beyond the already ongoing VST and 10-unit tests, the project activities will start in March 2025 with the calibration of the first digitiser boards and in May 2025 with the assembly of the first underwater units, as shown in Fig. 2. The delivery to CERN of the first underwater unit components will start a few months before the start of the assembly project activities.

By the start of the assembly in May 2025 we expect to have already received at CERN:

- about 30% of the vessels. Moreover, the first production batch will arrive around October 2024 and about 100 vessels are expected to be at CERN by the end of 2024;
- almost all the electronics stands, whose production starts in 2025 and is expected to be completed rather quickly;
- all the HV and LV modules, whose production is expected to be completed by around March 2025;
- the first batch of the ID PMT digitiser boards (about 30% of the components), whose production will start at the beginning of 2025;
- the outer-detector (OD) PMT digitiser boards (in total only 320 units and rather small) before March 2025, that will take negligible space;
- the first two batches of the DPB (200 boards) before March 2025;
- 50% of the PMT feedthroughs in March 2025;
- all the communication (COM) feedthroughs in March 2025, which are small and will take a negligible space.

The production of these components will start earlier, given constraints related to either the longer production time or to ensure the proper contingency in the mass production schedule and avoid affecting the assembly line. **We need the storage space in Fall 2024 (or earlier if possible) in the form of 12 standard ISO 40-ft containers located nearby EHN1.** Each container is approximately 12 meters long and 2.44 meters wide for an area of about 30 m^2. See Sec. 4.2 for details. The production and delivery rate described above is the current baseline that can undergo some tuning depending on the outcome of the different tender processes.

In Fig. 3 the estimated number of accumulated components and assembled units that will have to be stored every month at CERN from the start of the assembly activity is shown. The assembly of the 900 underwater units will be done 5 days a week for about 1 year. With 4 units assembled and fully tested every day, about 75 units per month will be shipped to Japan. **The maximum of the storage space will be reached right before the start of the assembly and will decrease constantly until all the underwater units have been assembled.**

The assembly project is expected to be completed around middle 2026.

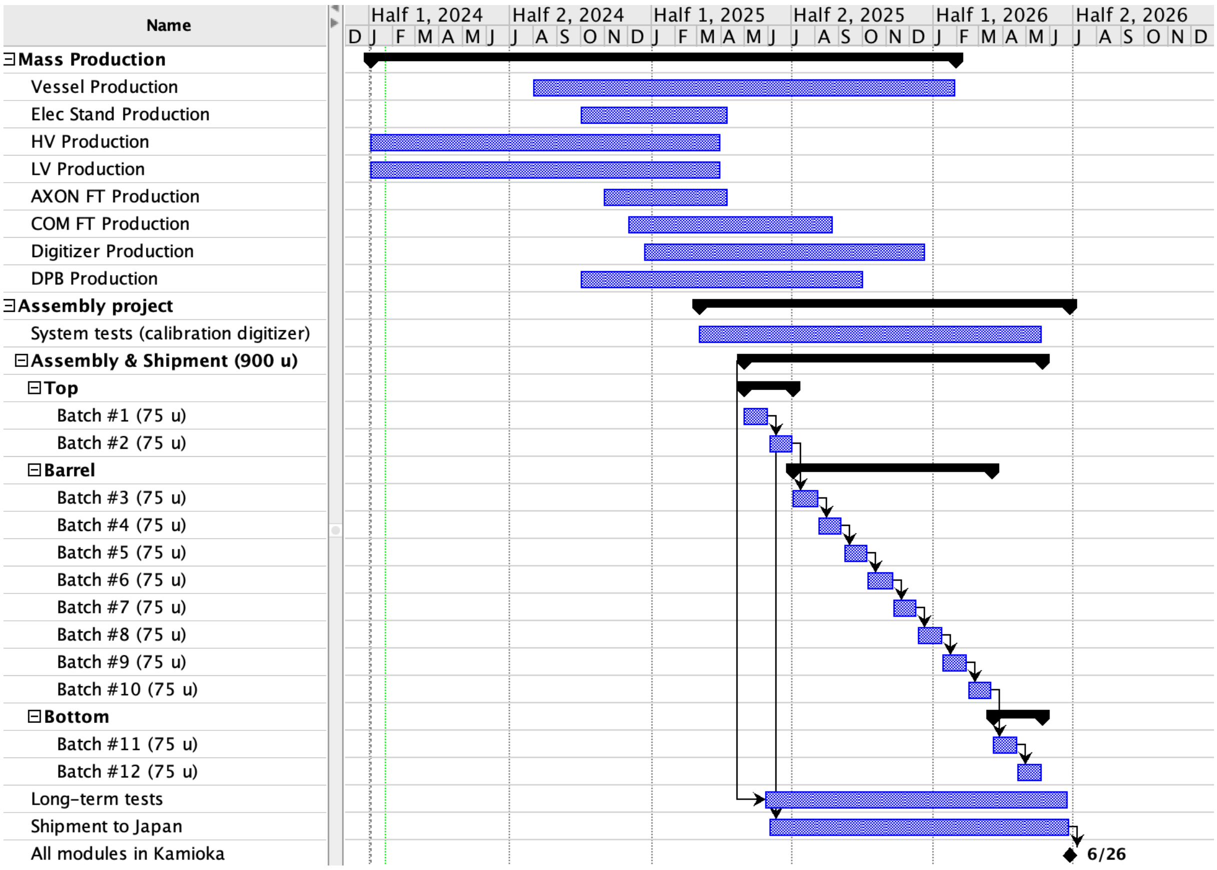

Figure 2: Assembly project schedule. The mass production period (since the start of the procurement) and the underwater unit assembly rate are shown. The shipment of each underwater unit batch (on average 75 units) will be done at the end of the "Batch # i-th" block.

4 Space requirements

The requirements related to the space necessary for the storage of the components, the assembly and test activities and the shipment to Japan have been described in the LoI. A preliminary estimate of about 850 m^2 in total was provided. Approximately 300 m^2 would be devoted to the test and the assembly of the underwater units; the rest to the storage of the components before the assembly and the storage of the assembled units before the shipment to Japan. As explicitly mentioned in the LoI, that first estimate was under study and further optimisations were planned. **Different space options have been considered and the solution that satisfies the project requirements has been found and agreed with the management of the Neutrino Platform.** The agreed solution is described in the next sections.

4.1 Assembly and test space

The assembly and test activities comprise: the calibration of the digitiser boards with a dedicated test bench, the assembly of four underwater units per day with the simultaneous electronic functioning tests, the underwater tests under pressure. As highlighted in Fig. 4, **an area inside EHN1 will be used for the**

daily underwater unit assembly and the electronics tests out of water. The room environment will be kept under control with climatization and dehumidification. There are no special cleanliness or radiopurity requirements for the inner components. Right outside the room, the pressurized tank will be placed in the open area, dedicated to the final under-pressure in-water tests. The area highlighted by the red circle already covers on its own approximately 200 m^2. In addition, since the storage space will be outside of EHN1 (see Sec. 4.2), at the beginning of each week all the components needed for the weekly assembly will be moved to the temporary storage area, part of the assembly space and highlighted by the blue circle.

The assembly and test space requirements described in the LoI are met.

4.2 Storage space

The space dedicated to the storage of the different components prior the assembly of the corresponding underwater unit was estimated in the LoI to be around 250 m^2. Since then, the definition of the storage rate of each component has been improved together with the mass production schedule as well as with a better defined assembly plan. Details are provided in Sec. 3.

The proposed solution consists of storing the components in 12 standard ISO 40-feet containers (including contingency), that will be placed next to EHN1, as shown in Fig. 5. The underwater unit components will not be exposed to weathering. The proximity to EHN1 will allow to easily move the components to the assembly space with minimal efforts.

The vessels and the electronics stand will take a large fraction of the area but will not require particular environment (temperature, humidity, etc.) conditions. Instead, the containers hosting the electronic boards and the feedthroughs will be climatized and dehumidified to keep the temperature and the humidity within an acceptable range. The proximity to EHN1 would facilitate the supply of the electricity via cables that can be equipped with proper protective covers.

The solution found for the storage space ensures enough margin to avoid to pile up components without an assigned space and allows the storage to be close to the assembly area, minimizing the internal shipment and the need for logistic resources. **The procurement and payment of the containers and all the necessary equipment will be done by the Hyper-K collaboration.**

4.3 Shipment space

A total area of approximately 300 m^2 was considered in the LoI, also to provide the needed access to trucks for loading the assembled underwater units, ready to be shipped. The plan is to ship to Japan 75 underwater units per month on average (see Sec. 3). **The assembled underwater units will be stored in a standard ISO 20-ft container that will be used for the shipment to Japan. The container will be placed inside EHN1.** Such option ensures the proximity between the assembly and the shipment areas. It also provides an easy solution for the loading of the container onto the truck, that will have easy access to the facility and to the crane inside EHN1. The container will be climatised and dehumidified, to ensure the underwater units will be in a safe environment conditions also during the shipment. Moreover, each unit will be safely placed in its own protective box.

4.4 Long-term underwater test area and facility

As described in the LoI, long-term tests will be performed during the assembly, starting from May 2025 when the first underwater unit will have been assembled. It will accommodate 10 underwater units from different batches and will last until the end of the assembly project. It will utilize the same facility already in use for the ongoing 10-unit test: the WA105 cryostat, which has been converted into a water tank located in Bldg. 182 at CERN (see Fig. 6). To better reproduce the conditions of the Hyper-K FD, the water is cooled to 16 degrees using the existing cooling system. To perform the operations mentioned above, the space in front of the cryostat is necessary. **All the preparatory work for the ongoing 10-unit tests has been done with the approval and help of the Neutrino Platform, that agreed to continue to provide this same support during the long-term tests in 2025 and 2026.**

5 Technical Personnel and Support

In the LoI, a preliminary description of the required technical personnel was given. In this section we provide additional information to clarify the technical work and service that we would like to request to CERN.

In the LoI, the need for technicians from the CERN Field Support Unit (FSU) was highlighted. Contrary to what was mentioned, after more careful studies, **we are going to hire the technicians externally through the Hyper-K collaboration. A maximum of 8 technicians will be employed (8 technicians, each 8 hours per day, 5 days per week for 45 weeks).** They will work full time on the assembly of the underwater units for about 12 months, ensuring an average assembly rate of 4 units per day. **The cost will be covered with funding from the Hyper-K collaboration institutes.**

We would like to request the following support by:

- **CERN EN-NP (Neutrino Platform)**: to provide guidance for the preparation of the areas, before the start of the assembly, and for the decommissioning at the end of the project; to interface with the various services provided by CERN.
- **CERN SCE-SSC-LS (Logistics)**: to provide optimal logistics services associated to goods/material inbound and outbound flows, such as shipping (external transport management, import/export documentation, customs and fiscal advisory), goods reception and internal distribution. The different

components of the underwater units will be received at CERN and moved to the storage area. On average, one 20-ft container will be shipped to Japan per month. Every beginning of the week, pallets containing the components for one-week assembly work will be moved to the weekly storage space inside EHN1. Simple routine operations, such as moving single units or components between, for example, the assembly and shipment areas, will not require support from CERN.

- **CERN EN-HE-HH (Heavy Handling)**: to operate the crane for the installation and the removal of the storage containers, respectively at the beginning and at the end of project.
- **CERN EN-EL (Electrical Engineering)**: to organize the power distribution to the storage containers that will have to be thermalised and dehumidified.
- **CERN HSE (Safety)**: we will be constantly in contact with HSE to ensure that all the operations are performed according to the CERN safety regulations.

6 IRFU CEA Antenna at CERN

As an update with respect to the LoI, the IRFU CEA antenna at CERN Meyrin site in Bldg. 182, that supports the IRFU CEA experiments, will also support the Assembly project. The IRFU-antenna team at CERN will provide technical support participating to the implementation and maintenance of the project, thanks to the versatile engineering team on site. In particular, it will be involved in the electronics test and calibration related activities: it will help setting up the test bench setup, debugging and providing diagnostic of potentially faulty modules, making quick diagnosis and applying minor fixes of boards during the ongoing assembly. A new electronics workshop is being setup by the IRFU-antenna which will be able to provide further equipment and practical support. The IRFU-antenna team will also support the project with its on-site mechanical workshop and technician, that will be useful to apply quick fixes to the mechanical components. The on-site IRFU-antenna engagement will play an important role in the risk mitigation in case sudden issues occur and will allow to minimize any potential delay in the assembly line.

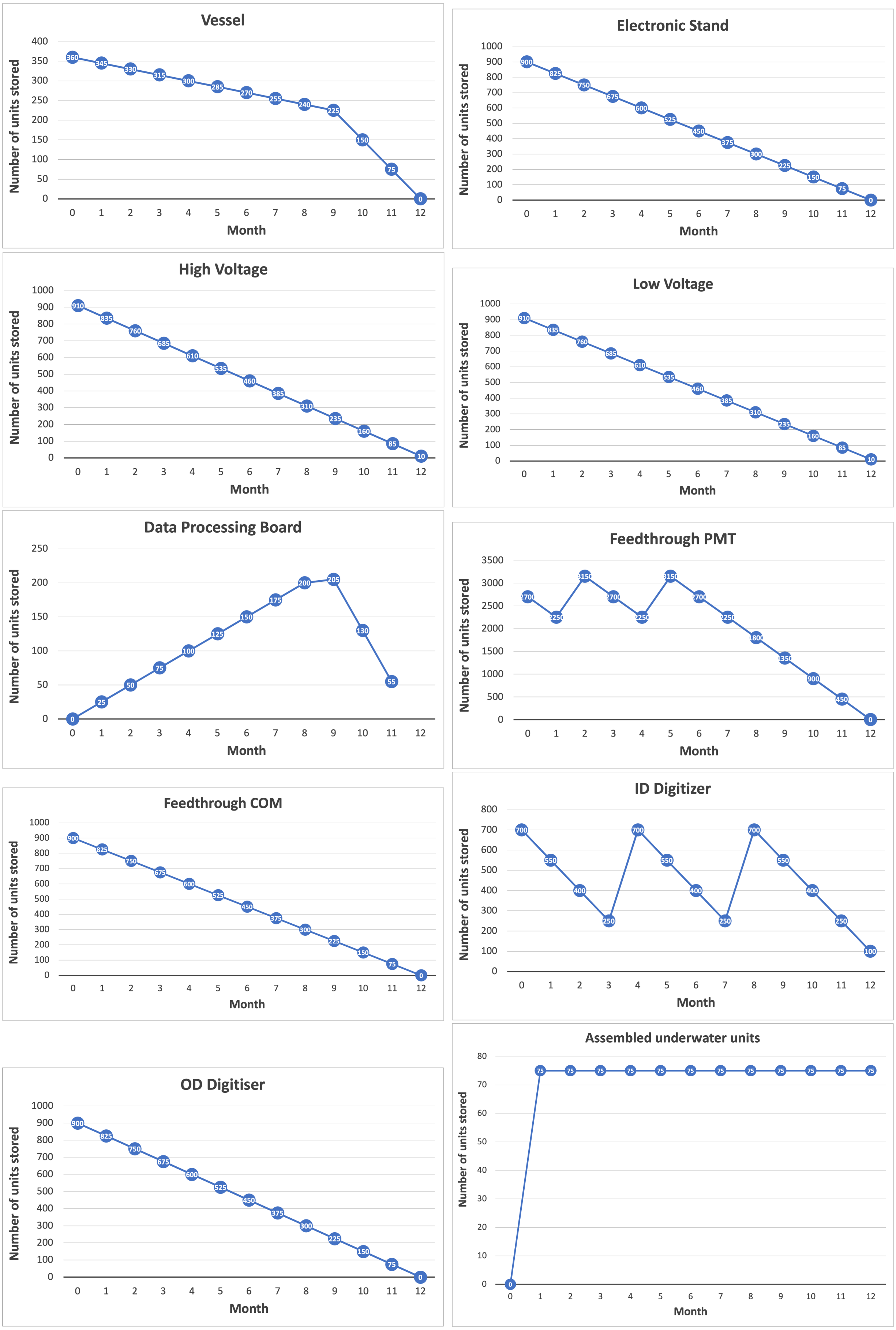

Figure 3: The expected number of accumulated elements stored every month at CERN since the start of the underwater unit assembly is shown. From top left to bottom right: vessels, electronic stands, HV modules, LV modules, DPBs, PMT feedthroughs, COM feedthroughs, ID PMT digitisers, OD PMT digitisers, assembled underwater units prior shipment to Japan. The X axis spans the assembly duration of the 900 underwater units (12 months). For some components, leftovers at the end of the assembly will be shipped to Japan as spare.

Figure 4: Top: area inside EHN1 in the North Area dedicated to the assembly and test activities (red circle) and the weekly storage (blue circle). Bottom: area (light blue line) in EHN1 identified for the assembly and test activities.

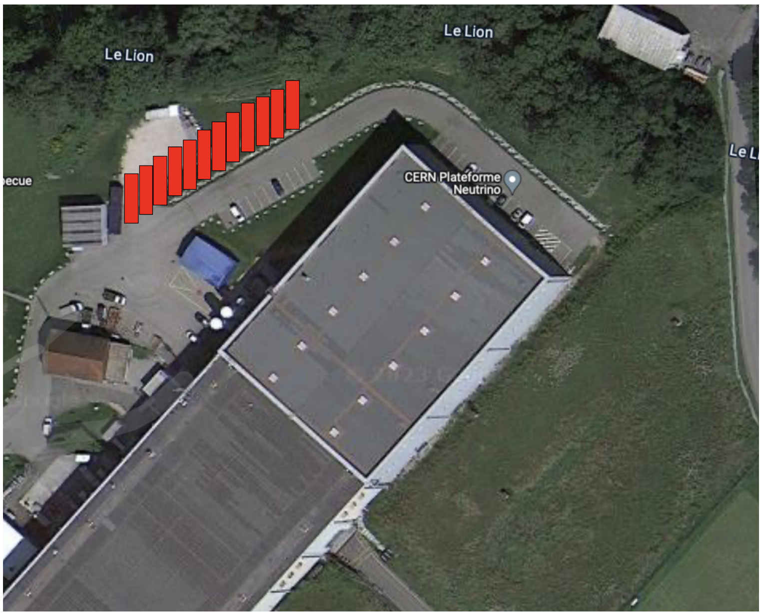

Figure 5: The storage area next to EHN1 in the North Area is highlighted by 12 red boxes, each one of the same size of a 40-ft container.

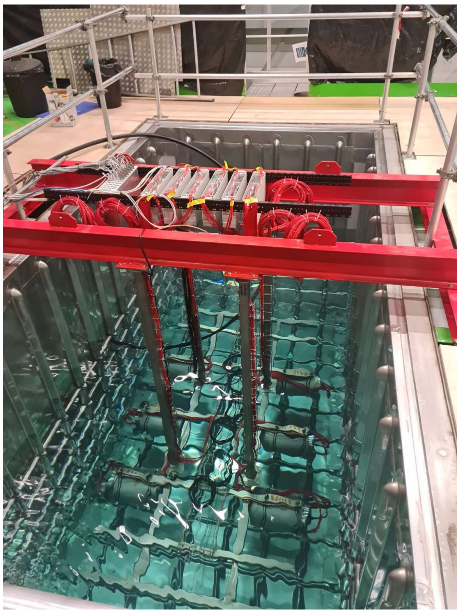

Figure 6: Underwater units installed on the support framework in the WA105 cryostat filled with water during the ongoing tests.

7 Conclusions and Outlook

The Hyper-K collaboration has entered the mass production phase of the water-cherenkov far detector, and is organizing the assembly of about 900 front-end electronics underwater units. A Letter of Intent titled "The Hyper-K Underwater Electronics Assembly project" (CERN-SPSC-2023-021, SPSC-I-260) was submitted to propose to assemble and test the 900 underwater units at CERN in the framework of the Neutrino Platform. The presentation of the assembly project, supported by the Neutrino Platform, was provided.

With this addendum, the solution on the space at CERN necessary for the storage, the assembly and test activities and the shipment, endorsed by the Neutrino Platform, is described. Additional information is provided about the technical personnel that will be externally hired and fully funded by the Hyper-K collaboration, as well as the service requested to the CERN EN-NP (Neutrino Platform), the CERN SCE-SSC-LS (Logistics), the CERN EN-HE-HH (Heavy Handling), CERN EN-EL (Electrical Engineering) and the CERN HSE (Safety). These requests have been discussed and clarified with the Neutrino Platform.

8 Acknowledgements

We thank Francesco Lanni and Filippo Resnati, respectively the head and the technical coordinator of the CERN Neutrino Platform, for the very fruitful discussions and their support to the project.