

T-sensors update

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Outline of the presentation

Several things evolved since last CALCI meeting at IFIC...

1. LAr T-Gradient recalibration.
2. Foreseen installation activities at CERN.
3. Status of the T-sensors kits deliveries for DUNE FD-I module.
4. Fibre-Based TMS (FTMS) for FD-II module: TB meeting (29/06/2023).
5. Plans for PD-VD: replica of DUNE-VD TMS installation.
6. Status of FTMS R&D activities at IFIC

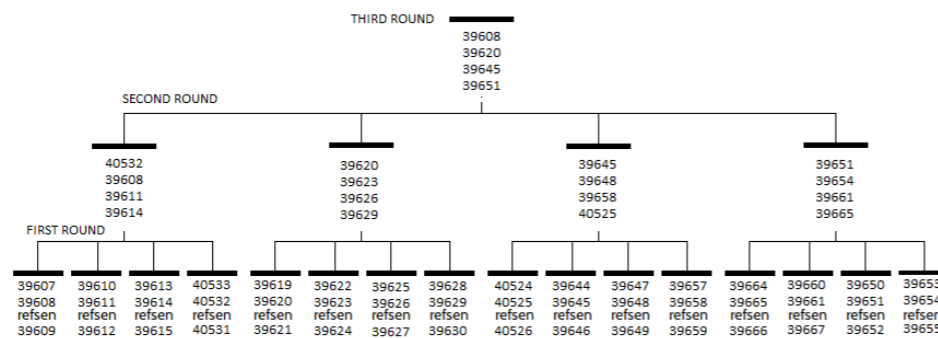
LAr T-Gradient recalibration

- Since the decommissioning of the PD-SP detector on 2019, T-Gradient T-sensors have been at IFIC.
- **T-Gradient will be operating again** in the upcoming **PD-HD** run, in 2023-2024.
- Since 2019, **three independent calibrations** have been performed in order to check the performance of the RTDs:
 - *(2022) LN2 calibration*
 - *(2023) LN2 calibration*
 - *(2023) LAr calibration*
- A calibration was obtained in **2018** by *M. A. García* using **LAr** as cryogenic media, prior to **PD-SP** operation.

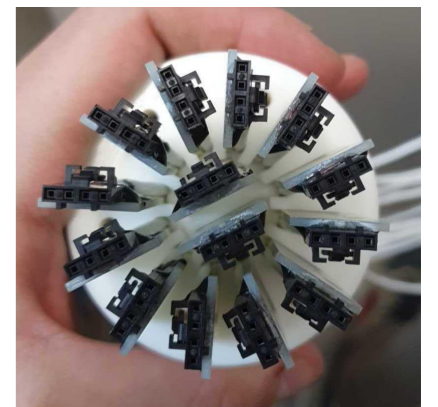
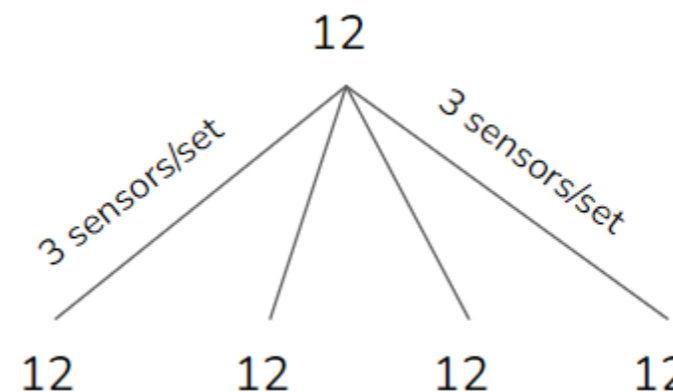
Calibrations Comparison

- The comparison between the results of the 3+1 different calibrations performed allow an estimation of the **systematic uncertainty** of a full calibration.

OLD calibration strategy



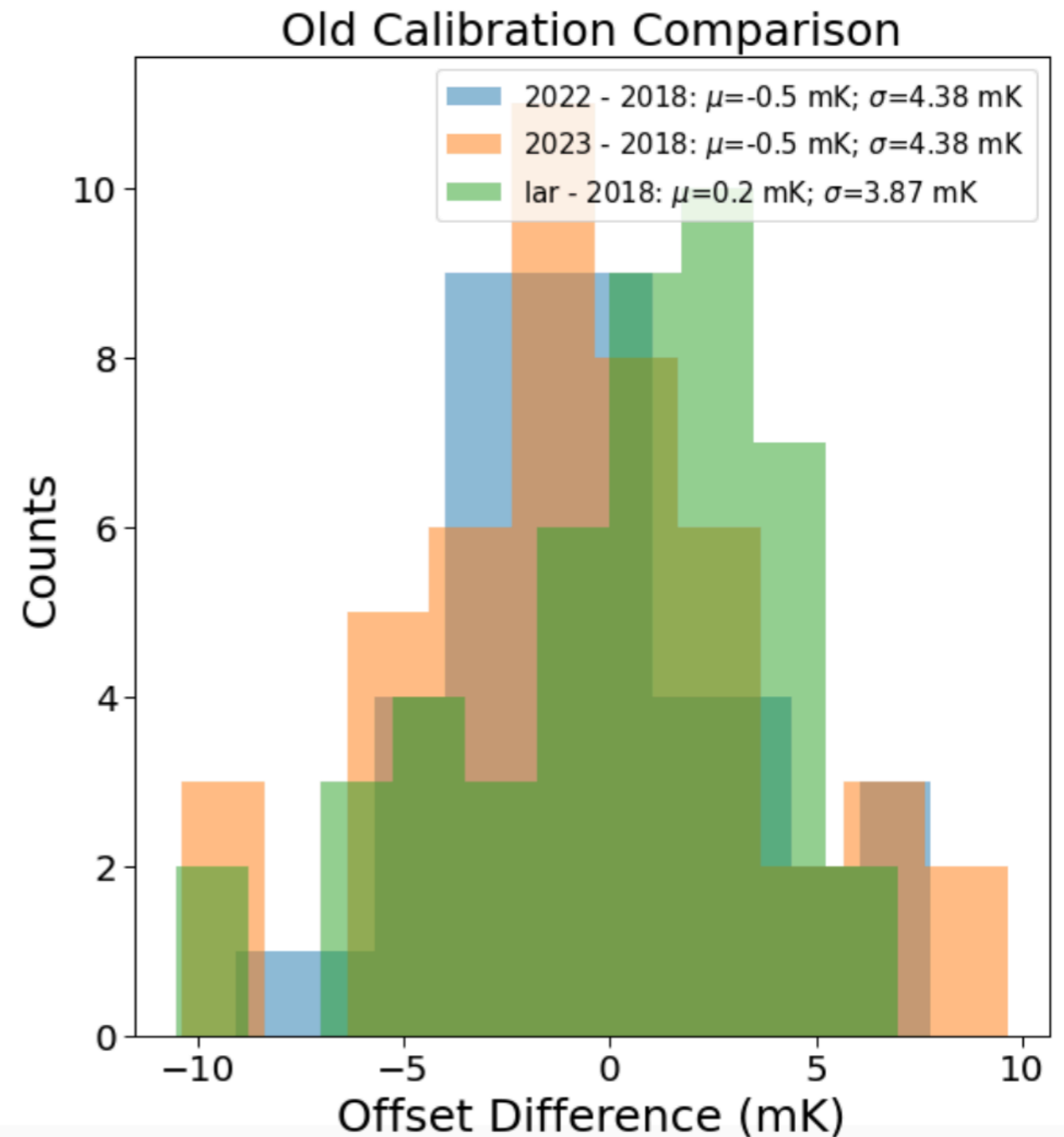
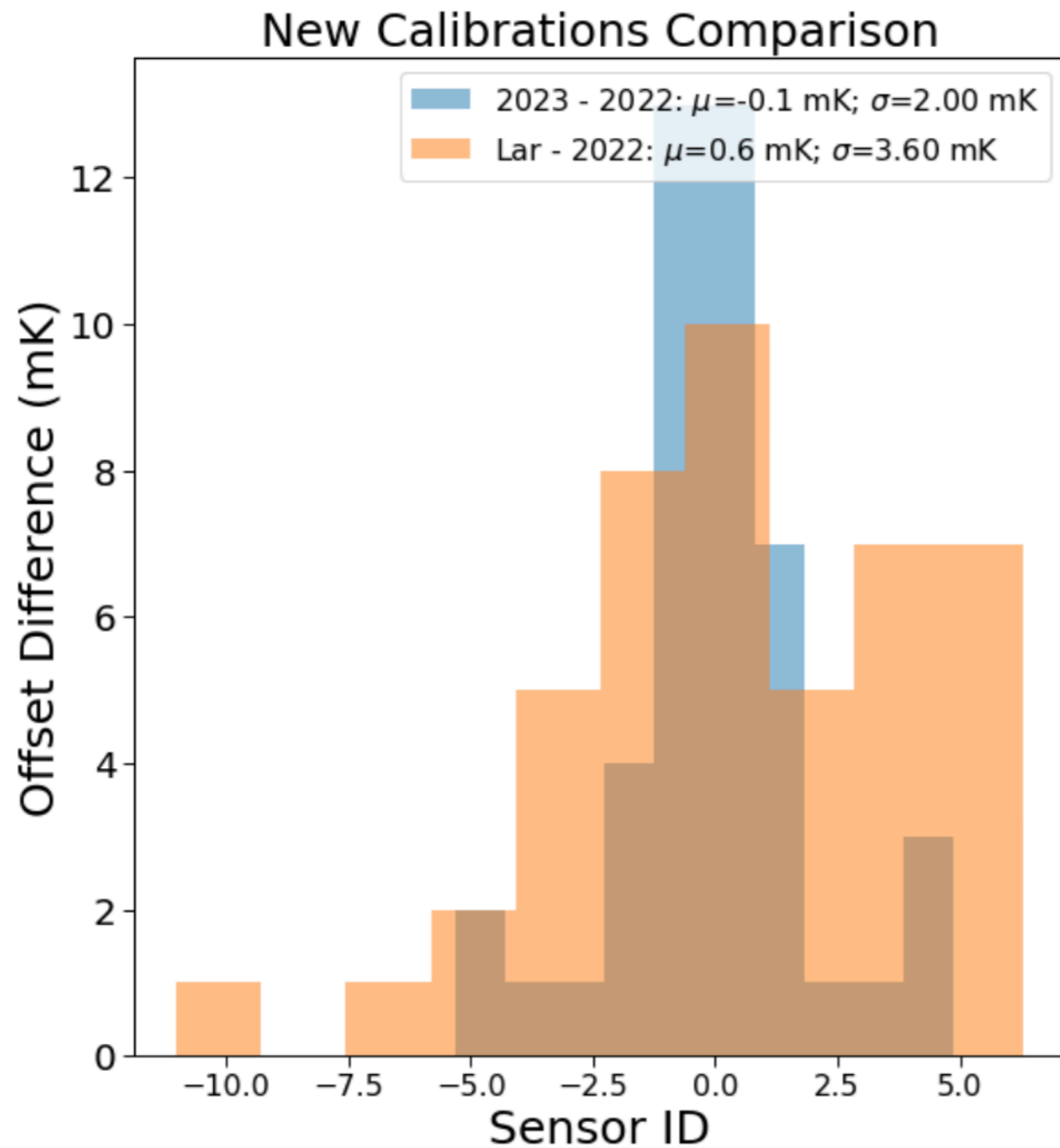
NEW calibration strategy



- Calibration strategies differ because **setups** used for the old (2018) calibration and the new (2022, 2023, LAr) one **are different**.
- Calibration constants (offsets)** are computed for each calibration and compared between themselves.

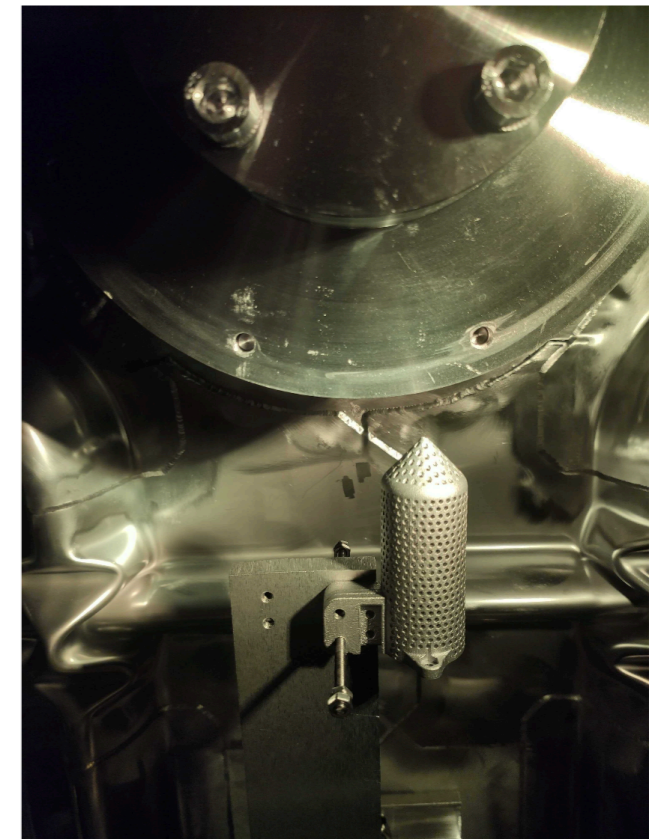
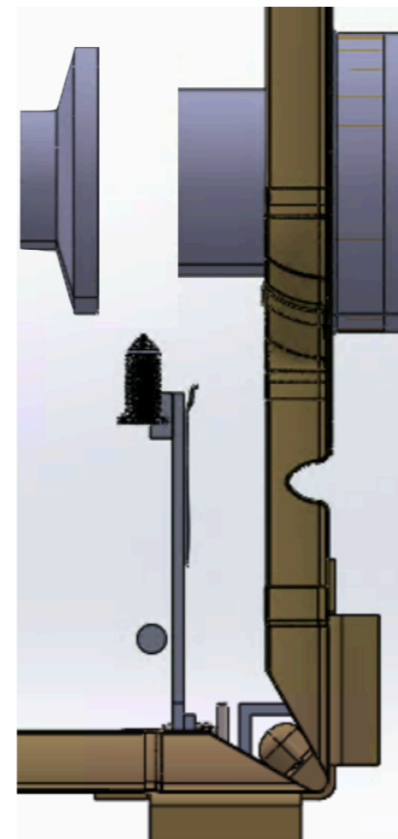
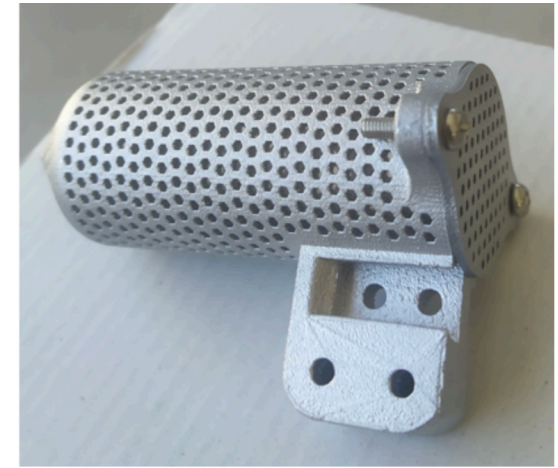
Calibrations Comparison

T-Gradient Calibrations Comparison



Installation @ CERN: 17th-21st July week

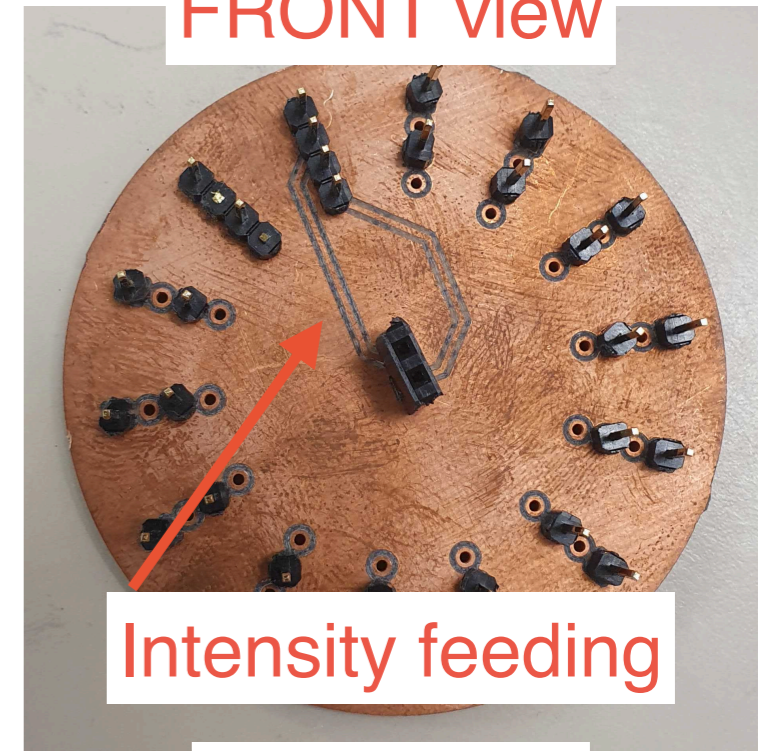
- After the successful calibration in LAr, we think we are ready to install again the T-sensors on the Valencia **T-Gradient** monitor, for **PD-HD operation**.
- Also, we will take some time to install the **pump sensors** (close to the LAr extraction pump), hosted by the 3D-printed aluminum capsules.
- Anselmo and myself are travelling on Monday to Geneva and will stay there the whole week.
- **T-Gradient operations are expected to happen on Wednesday 19th.** Need to contact *Daniela* from NP in order to book a time slot to use the main crane.



Complementary Activities @ CERN

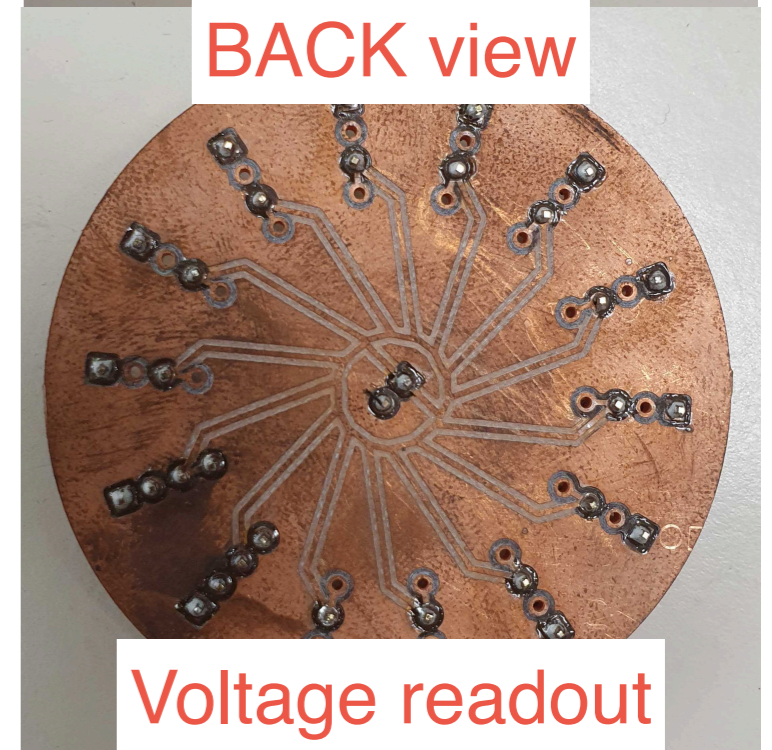
- A system to measure a possible **intrinsic offset between readout channels** has been designed by Carlos Benítez (engineer at IFIC).
- It uses a **single high-precision low-thermal-dependence resistor** to be read-out at all channels simultaneously.
 - *Current is fed by a single channel (all other current channels are short-circuited).*
 - *All voltage channels measure voltage drop between the same two terminals.*
 - *Design is so that all voltage read-out wires are equally long, within some tolerance much smaller than $\sim 0.1\text{mK}$ equivalent.*
- Another (*more tedious*) method may be used to cross-check results:
 - *Connect R1 to Ch1 & R2 to Ch2 -> OFF_12*
 - *Connect R2 to Ch1 & R1 to Ch2 -> OFF_21*
 - *OFF_12 - OFF_21 $\sim 0\text{ mK}$ -> If not, there is an intrinsic offset between channels.*
- These intrinsic offsets will be **compared** with the ones obtained from the **MUX used at IFIC** to perform the calibrations.

FRONT view



Intensity feeding

BACK view



Voltage readout

T-sensor kits on APA: DUNE FD-I status

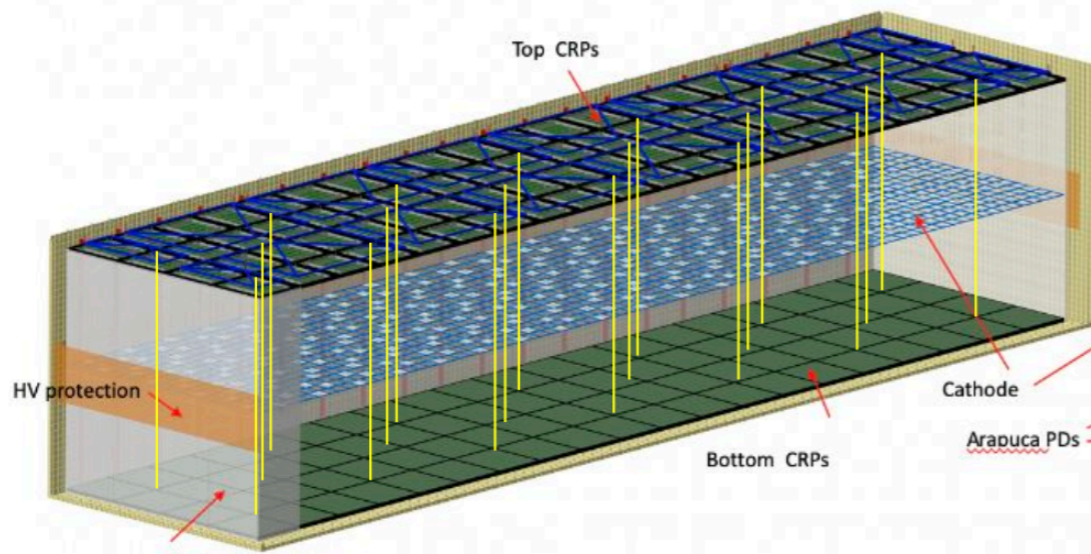
- Currently we are delivering T-sensor kits to **two different locations**: APA factory at Daresbury (UK) and University of Chicago (USA).
- Instructions were updated and sent to the new APA production site (*U. Chicago*). **First kit was received there on 20th June.**
- *Janet E. Bishop* tracks the deliveries monthly by asking myself the number of sensors mounted, calibrated and delivered to the different sites.
- We are well ahead APA production, and plan to push production forward by the incorporation of a new technician after summer.

Technical Board proposal for FD-II Fibre-Based TMS (FTMS)

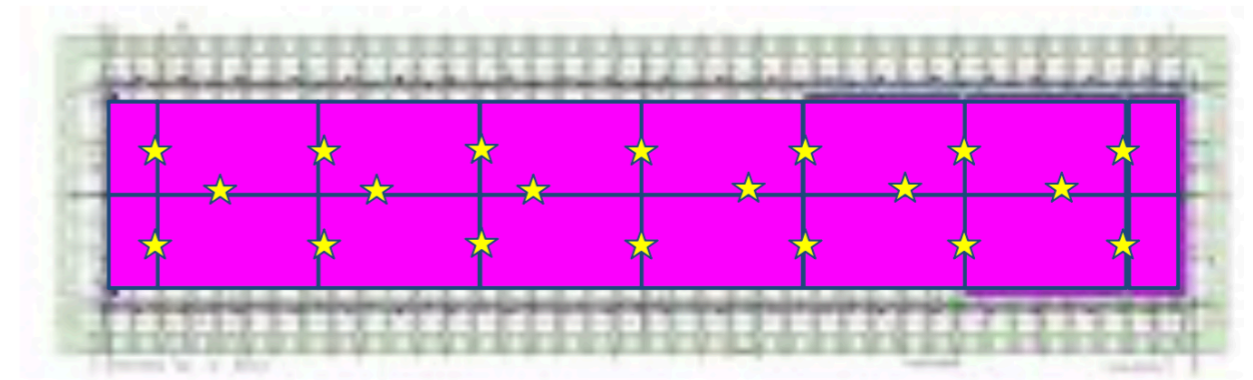
- The IFIC group has been working on a new technology to create a novel TMS based on Fibre Bragg Grating (FBG) sensors for the **FD-II module**.
- A **proposal** containing sensors' location, number of sensors, installation plan, interfaces with other subsystems and routing over the cryostat was presented on the **29th June Technical Board (TB)**.
- The proposal was received with **very good eyes** by the collaboration, and some days after it we scheduled a meeting with *Rosier Philippe & Fabien Cavallier* (Cathode WG) to keep advancing in the FTMS design.
- From the point of view of the top & bottom CRP consortia, *we have been advised to not interfere much* with any of their systems.

Overview of the Proposal

- The FTMS consists on **20 vertically aligned optical fibres** containing **~30 FBG sensors** each, a total of **600 sensors**.
- The readout is performed by a **single interrogator**, outside the cryostat.

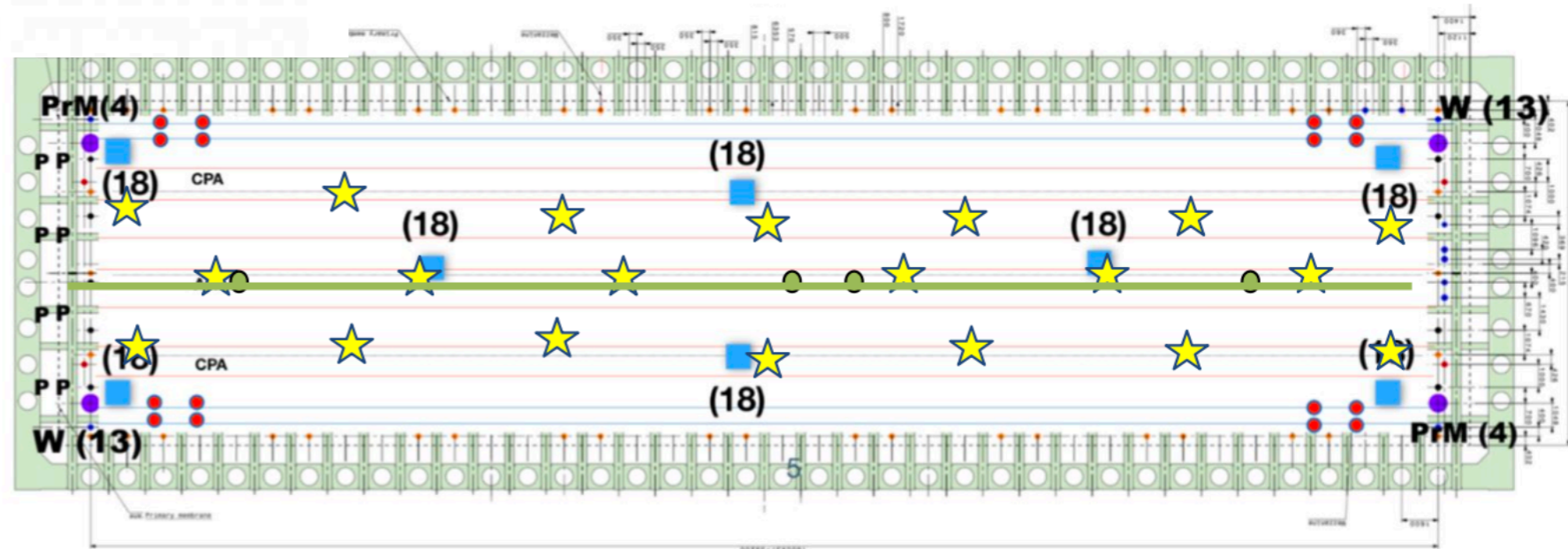


Top view of the FBG fiber positions



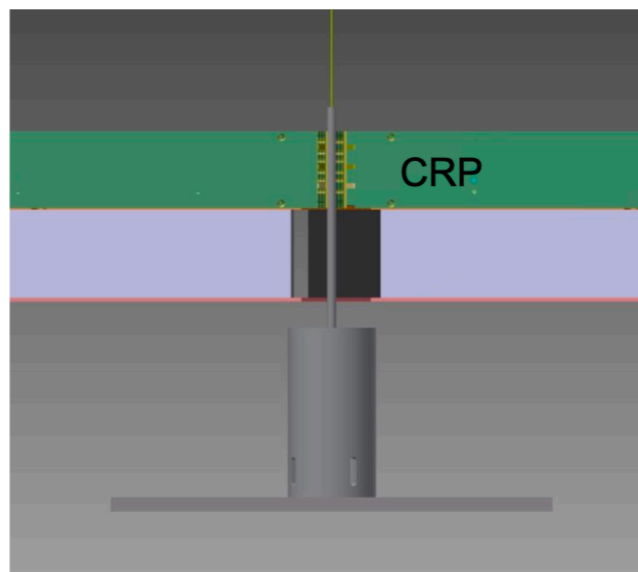
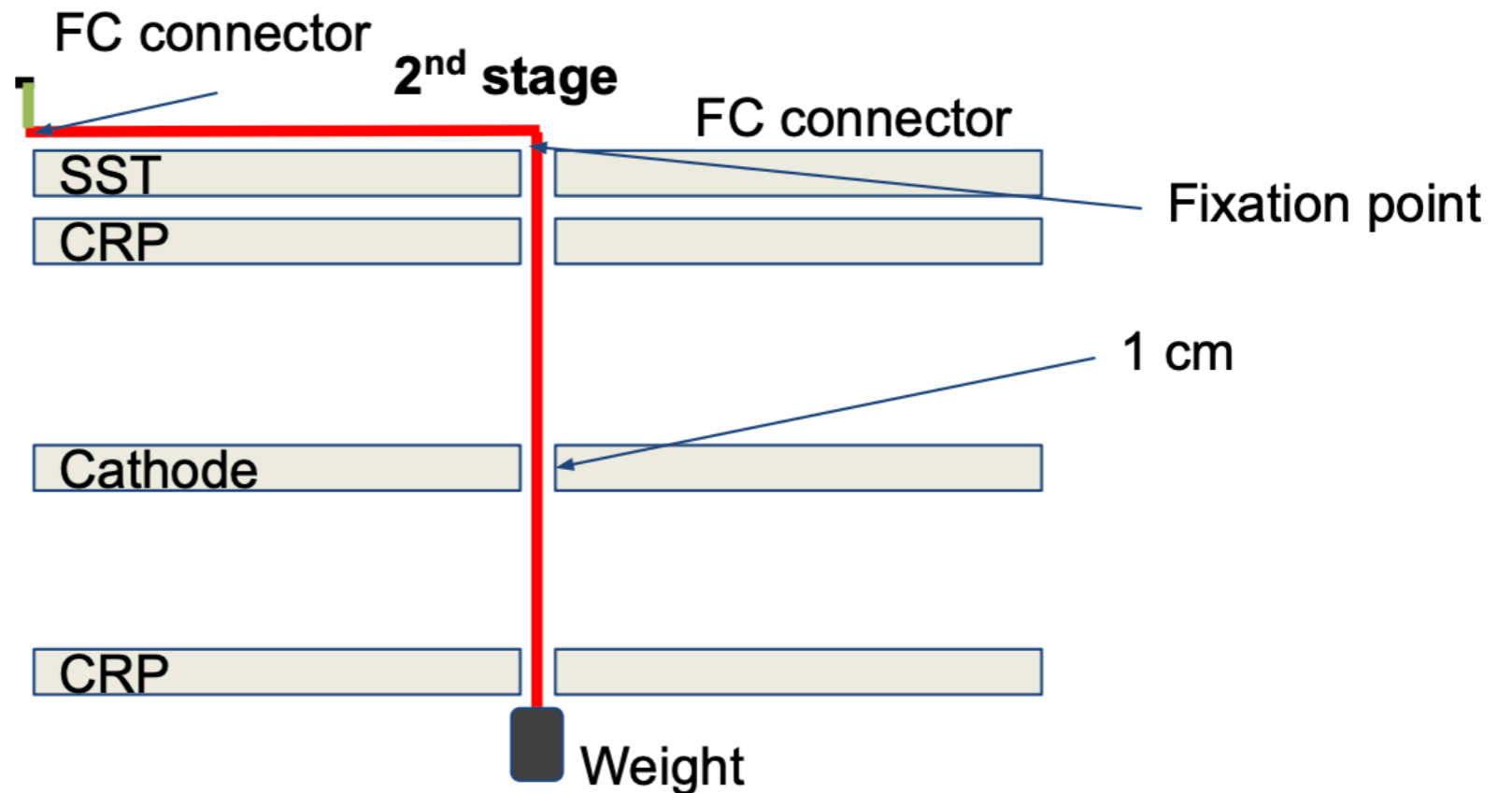
Fiber are placed between CRP superstructures.

- ★ FGB fibers
- CALCI ports
- Inlet sensor
- Gas array (18 sensors in each array)
- P pump sensor
- W Wall sensors (13 sensors in each array)
- PrM PrM sensors (4 units in each array)



Vertical routing: CRP & Cathode interfaces

- A *routing fibre* is routed prior to CRP installation starting, on the proposed cable tray to each of the measuring positions.
- The *sensing fibre* is routed on the SST that holds the top CRP and connected to the routing fibre via FC connector.
- The **FTMS installation has to follow the modularity** of the top CRP, Cathode and bottom CRP installation, so *installation plan has contemplated this* and can deal with it.



- A **weight** will be attached at the end of the fibre in order to apply a **constant tension**.
- The weight is **contained** in a piston-like cylinder so it **can not bend** due to LAr flow or other kinds of movements. It can just move in the vertical direction.

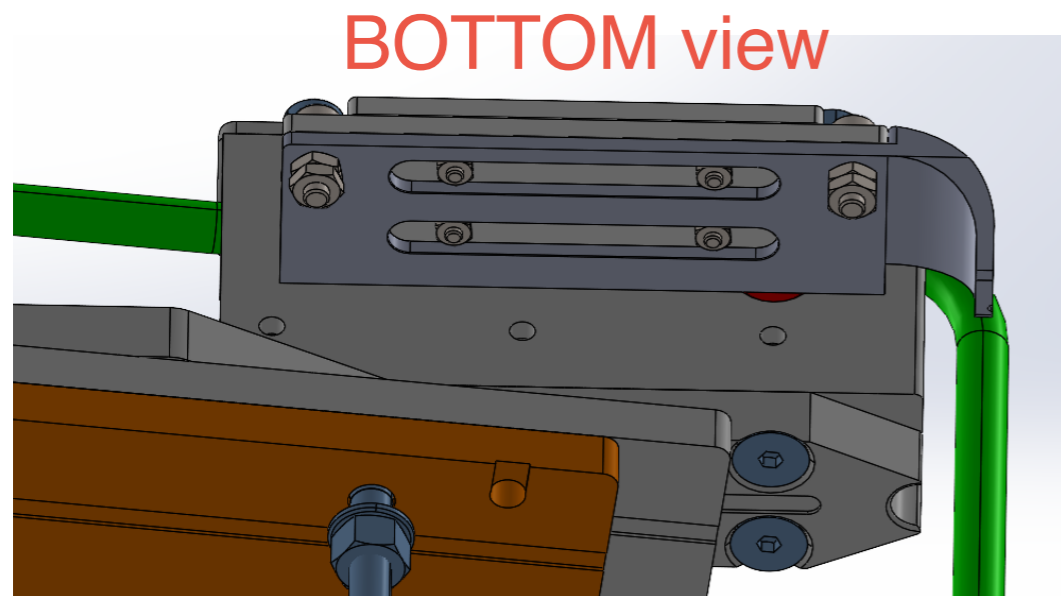
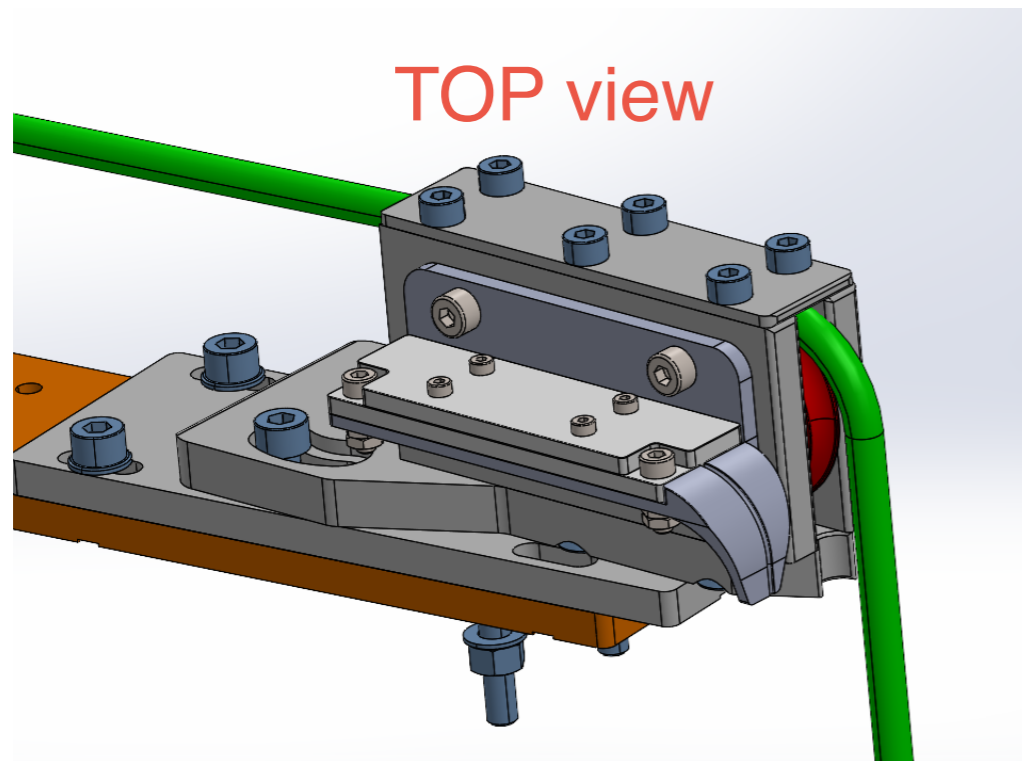
Major concerns translated during the TB meeting

The **major concerns** translated during the TB can be classified in two major categories: ***fibre integrity*** and performance during installation and operation, and ***fibre routing*** along the cryostat.

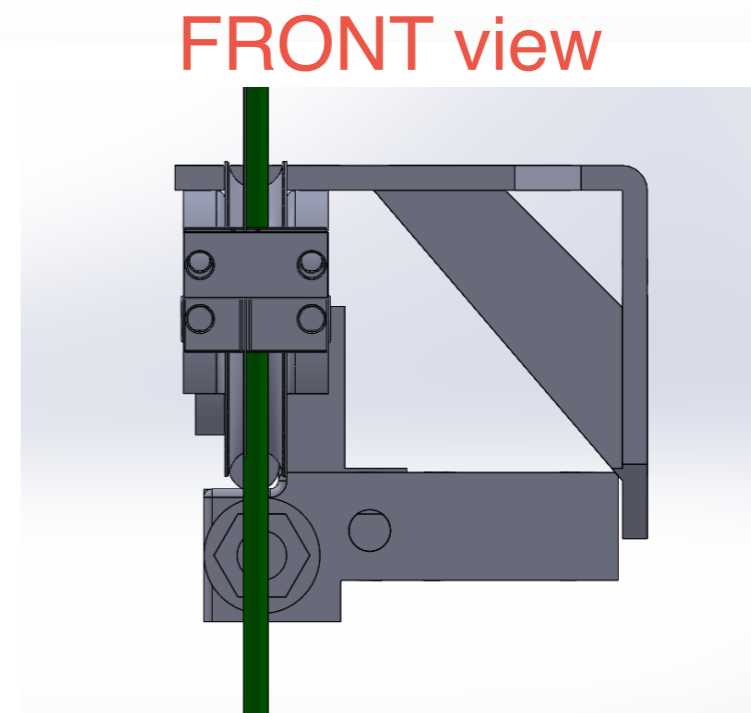
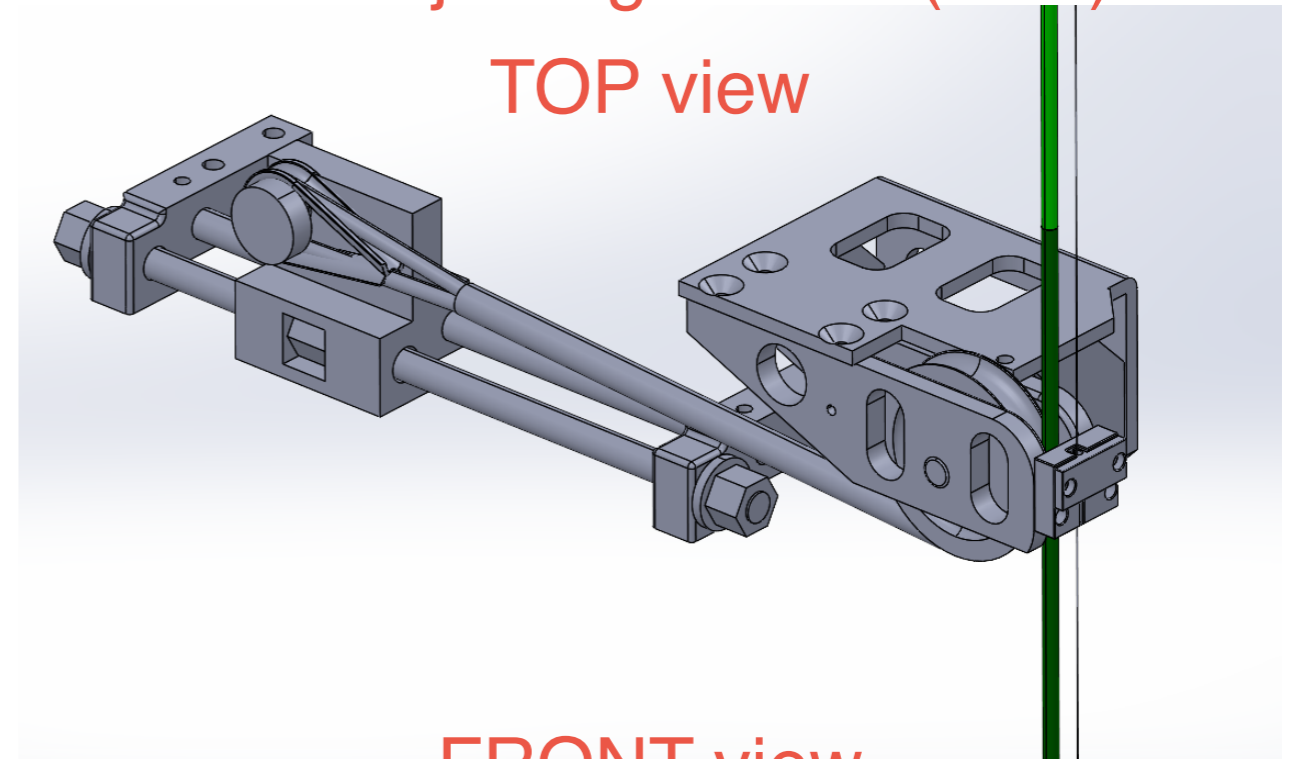
- **Light leakage out of the fibre**, especially at small bending radius points: interrogator laser works in the C-band (1530-1560 nm), so photosensors are not sensitive to it.
- **Rip of a fibre**: we need to ensure the tension applied to the fibre is far away from the breaking point, and also that mechanical properties do not vary dramatically at cryogenic temperatures and compromise the integrity of the arrays.
- **Fibre guiding**: we proposed a cable tray close to the top membrane crossing the 60m-length of the cryostat. It was seen as not possible as there are no subsection points on the top membrane at the center of the cryostat. On Friday, a meeting will be held with FD-II technical coordinators (*Steve Kettell, James Stewart, William Miller Jr*, and others) to find a solution for the cable tray.

TAD & LAD modifications to host FTMS

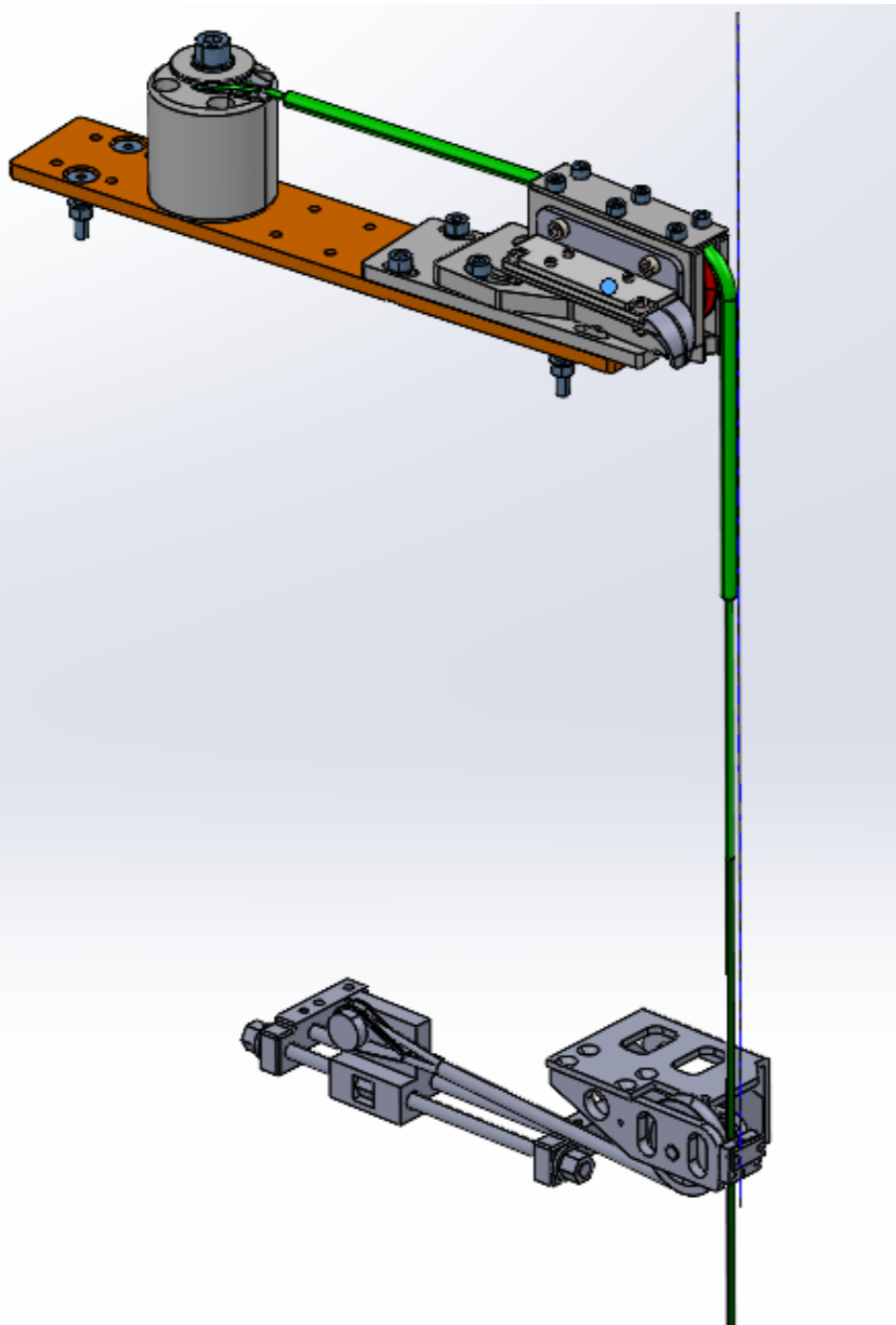
Top Adjusting Device (TAD)



Low Adjusting Device (LAD)



Vertical routing: from top CRP to Cathode



- We decided with the Cathode WG to keep an **iterative communication** about the modifications on the designs of **TAD & LAD**.
- We have just sent them today our proposed modifications and hope to hear them back soon with comments and suggestions.
- The **weight design** is still ongoing. It is **not as urgent as TAD/LAD** modifications as it does not interfere with other WGs.

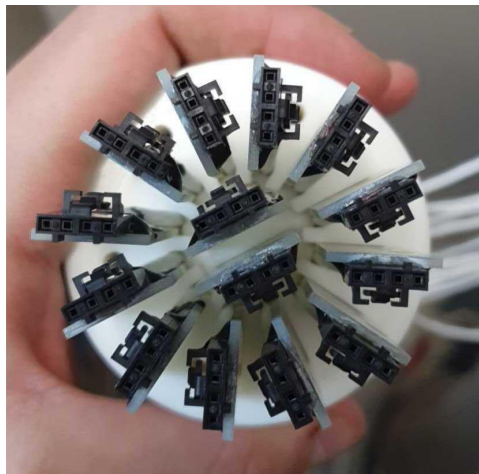
PD-VD installation plan

While waiting for the acceptance of the DUNE-VD FTMS design, we are **elaborating a plan for the PD-VD installation**:

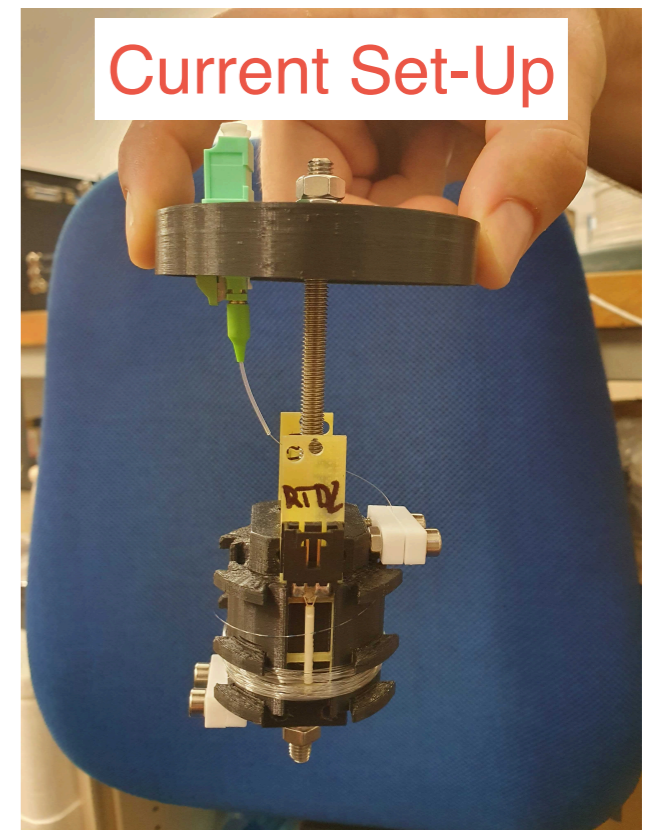
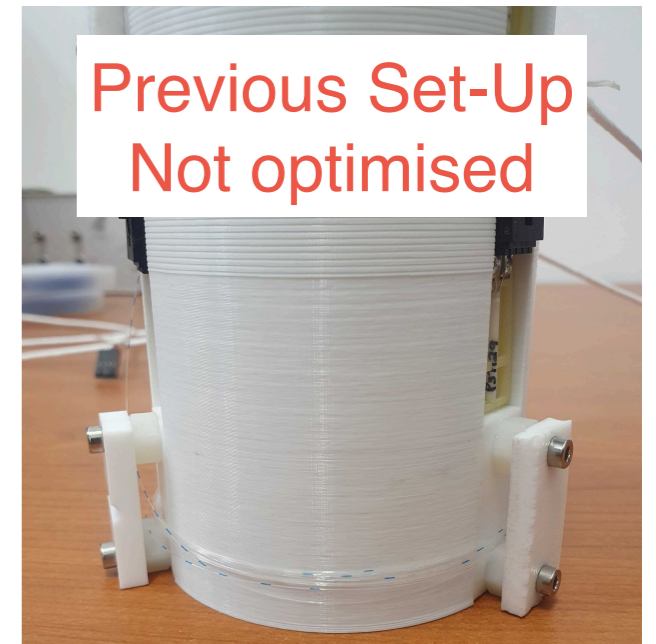
- The PD-HD FTMS will be installed **outside the field cage**.
- The idea is to **replicate** the top subjection, fibre guiding and weight suspension as proposed for the **FD-II** module.
- Different properties of the fibres will be tested there:
 - **Mechanical properties**: fibres with different weights to study elongation and vibrations.
 - **Cryogenic properties**: effects of cryogenic temperature on different coating types and coating aging.
 - **Light leakage properties**: check if more photons are detected by PMTs when interrogator is ON.
- **Physical studies**: obtention of *sensitivity curves*, *temperature gradient resolution*, performance depending on the *coating type*, sensitivity enlargers ...

FTMS R&D activities at IFIC

Reproduce the Concentrical volumes Structure as for the RTD-based calibration



- R&D activities in order to achieve maximum temperature resolution using FBG technology at IFIC are advancing well.
- After initial LN2 tests using a **non-optimised setup**, we designed a new sample holder that replicates the idea of the RTD-based calibration setup.
- Improvement in the understanding of the humidity on the FBG sensors are planned to be achieved by means of a new humidity sensor.
- Data taking with the new setup will start after CERN installation activities and after summer vacations.



Summary and Next Steps

- Valencia T-Gradient Monitor sensors' performance has been checked three times using LN2 and LAr temperatures.
- **Agreement between old and new calibrations is excellent**, showing very tiny aging effects even after years of no operation.
- Installation of Valencia T-Gradient monitor and Pump sensors will be performed **next week at CERN**, completing the TMS for PD-HD.
- DUNE FD-I module APA T-sensor kits are being delivered in a regular way to both APA production sites and tracked accordingly.
- **Fibre-based TMS for DUNE FD-II module has been proposed** and the collaboration has **not shown major concerns about it**. Designs are advancing well in collaboration with other WGs.
- FTMS mechanical installation for PD-VD will be decided when designs for the FD-II are closed in order to replicate the installation.
- **R&D activities concerning FTMS are advancing well** and solutions closer to those successful for the already well-known RTD-based TMS are being found.

There is a lot ongoing at IFIC!
Thank you!