ProtoDUNE-SP Cryogenics Instrumentation review
26/04/2017

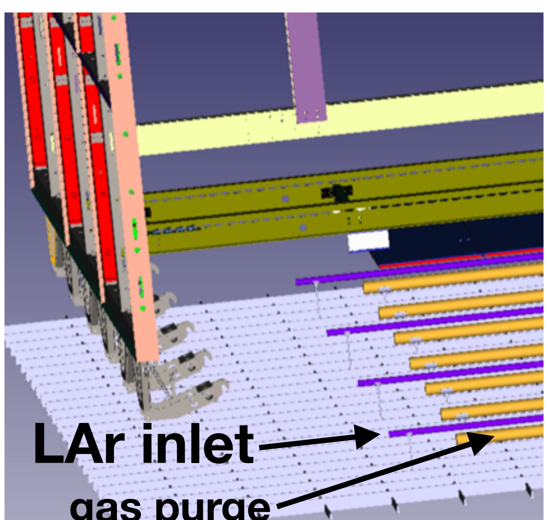
# T-gradient monitor

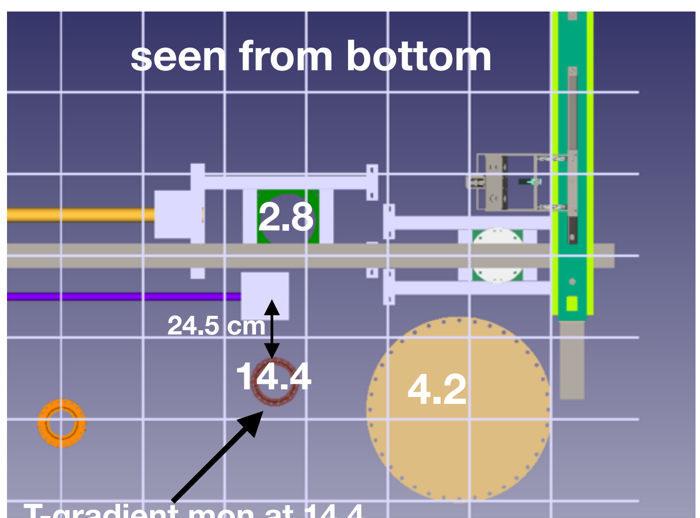
A. Cervera, A. Izmaylov, M. Sorel, P. Novella,
P. Bernabeu, J.V. Civera, P. Leon

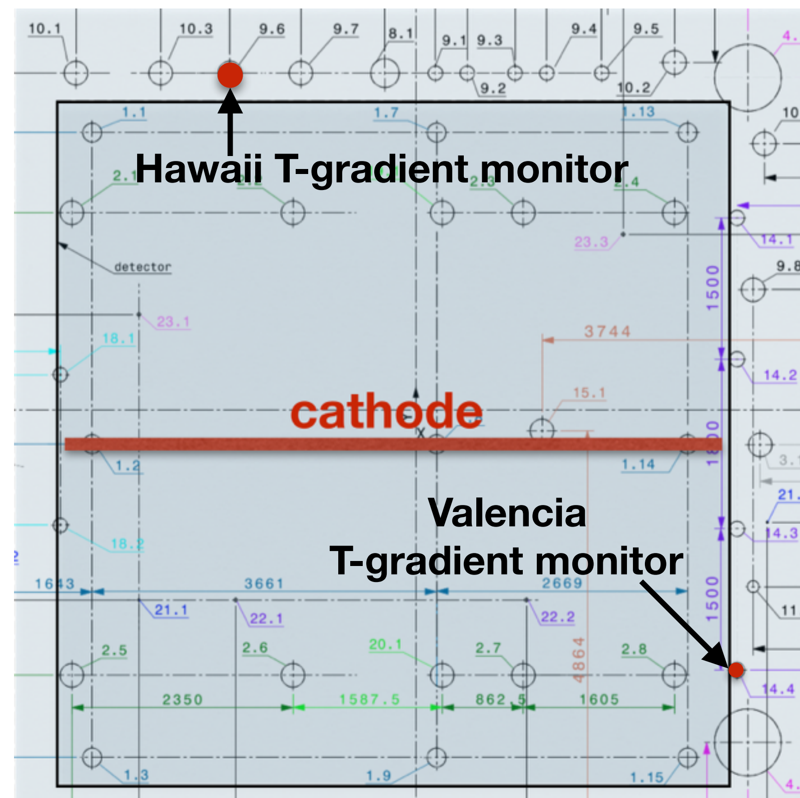
IFIC - (CSIC & Univ. Valencia)

# Motivation

- Contribute to the **3D temperature map** to validate fluid dynamic simulations and ensure a good understanding of the cryogenics system
- Cover a **different XY** position than the Hawaii T-gradient monitor, at the **other side of the cathode** in the **region of the LAr inlets**
- Provide **redundancy** and use a **complimentary technology** (static) such that **systematics** can be better understood by combining the two systems

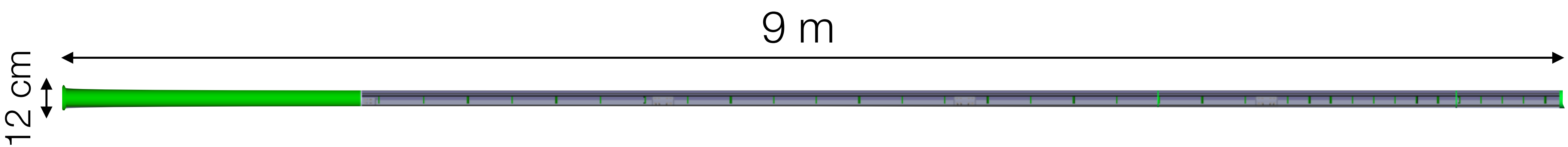


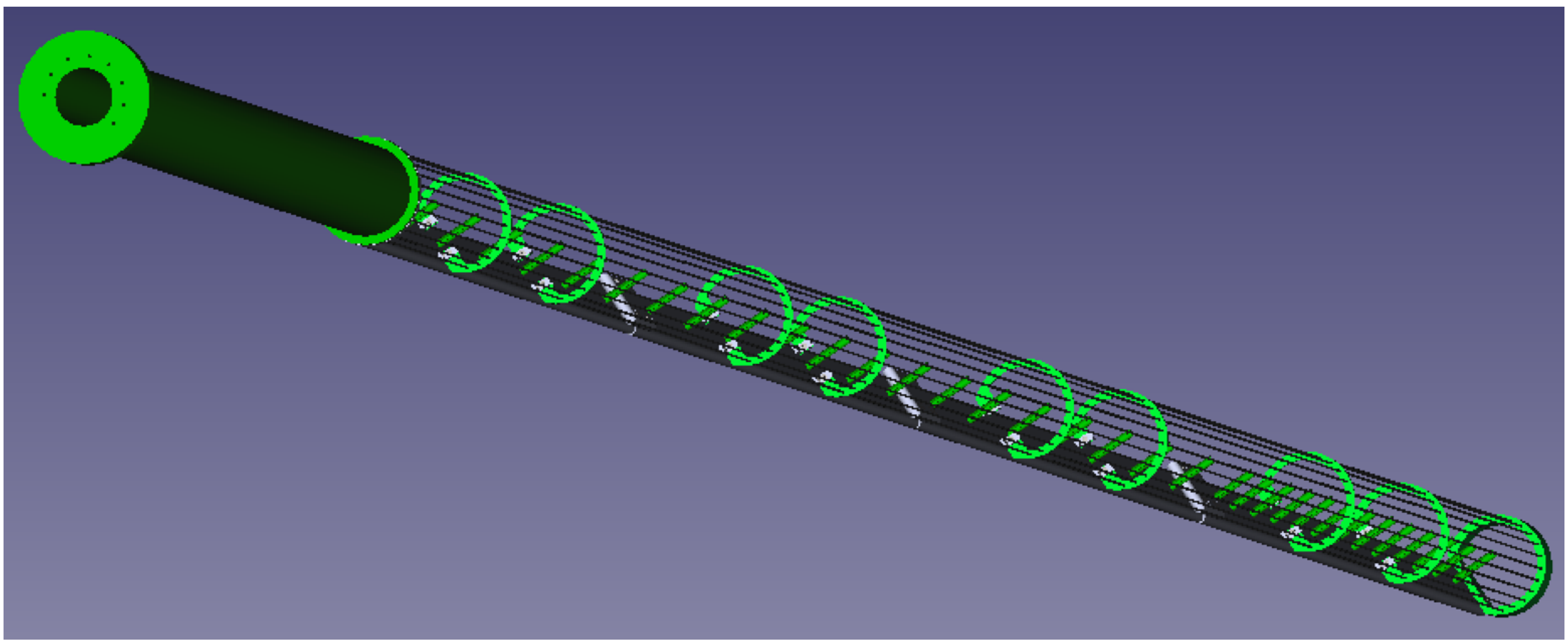



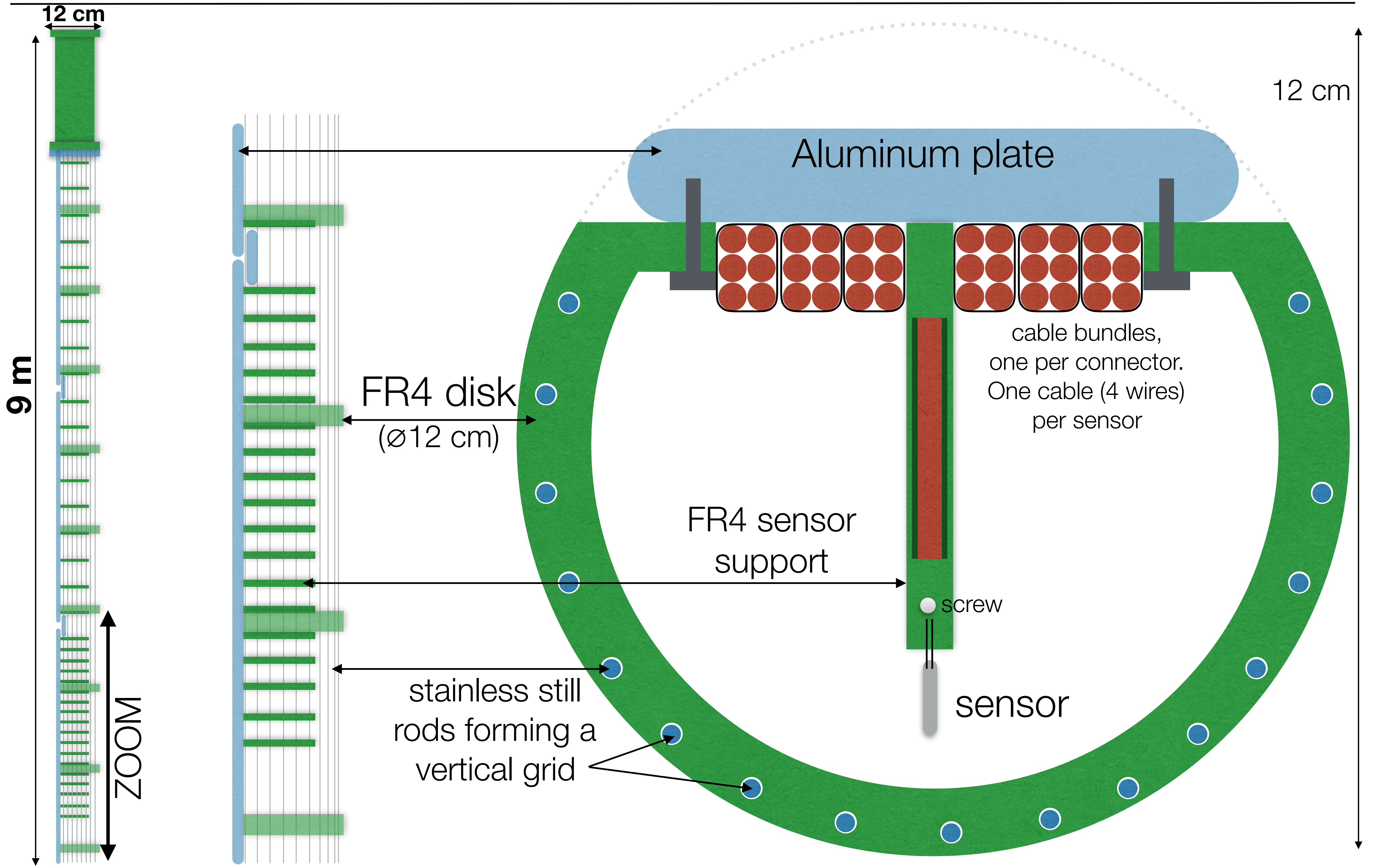
# preliminary 3D cad model

- 9 meters long and 12 cm diameter cylinder hanging from port 14.4 (14 cm diameter)



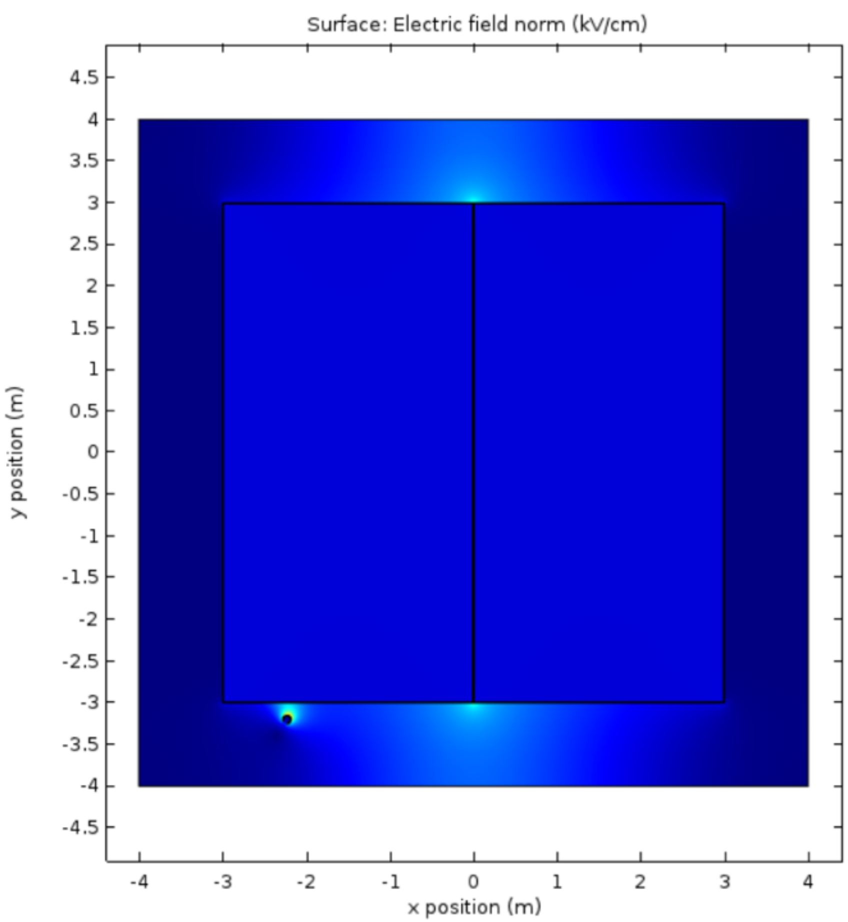



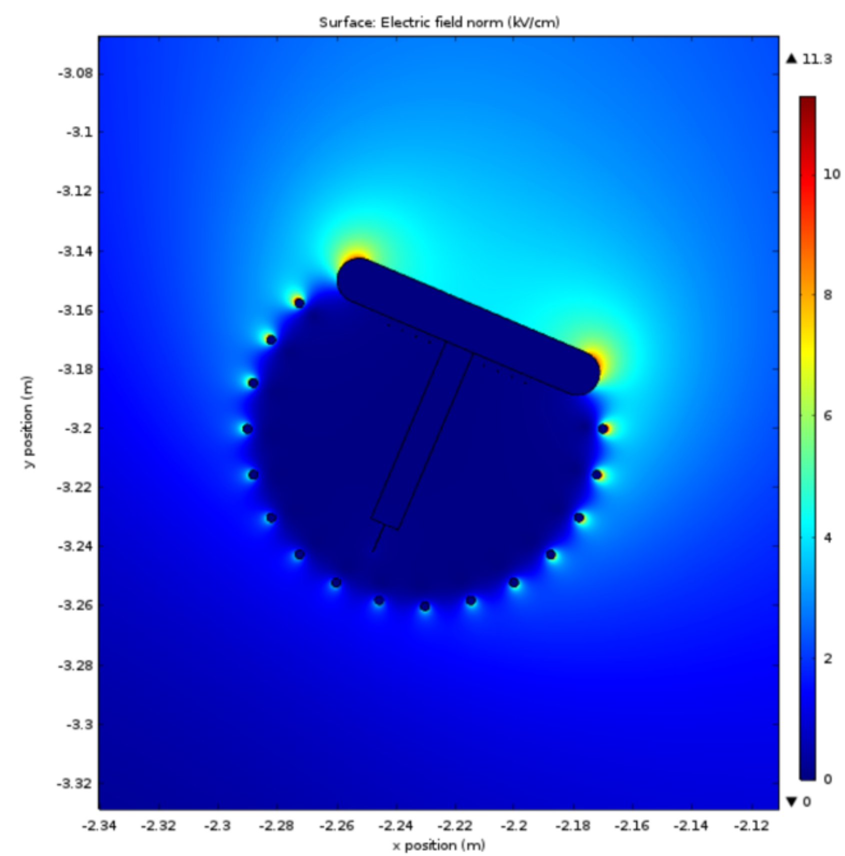
# Conceptual design



# Electrostatics simulations

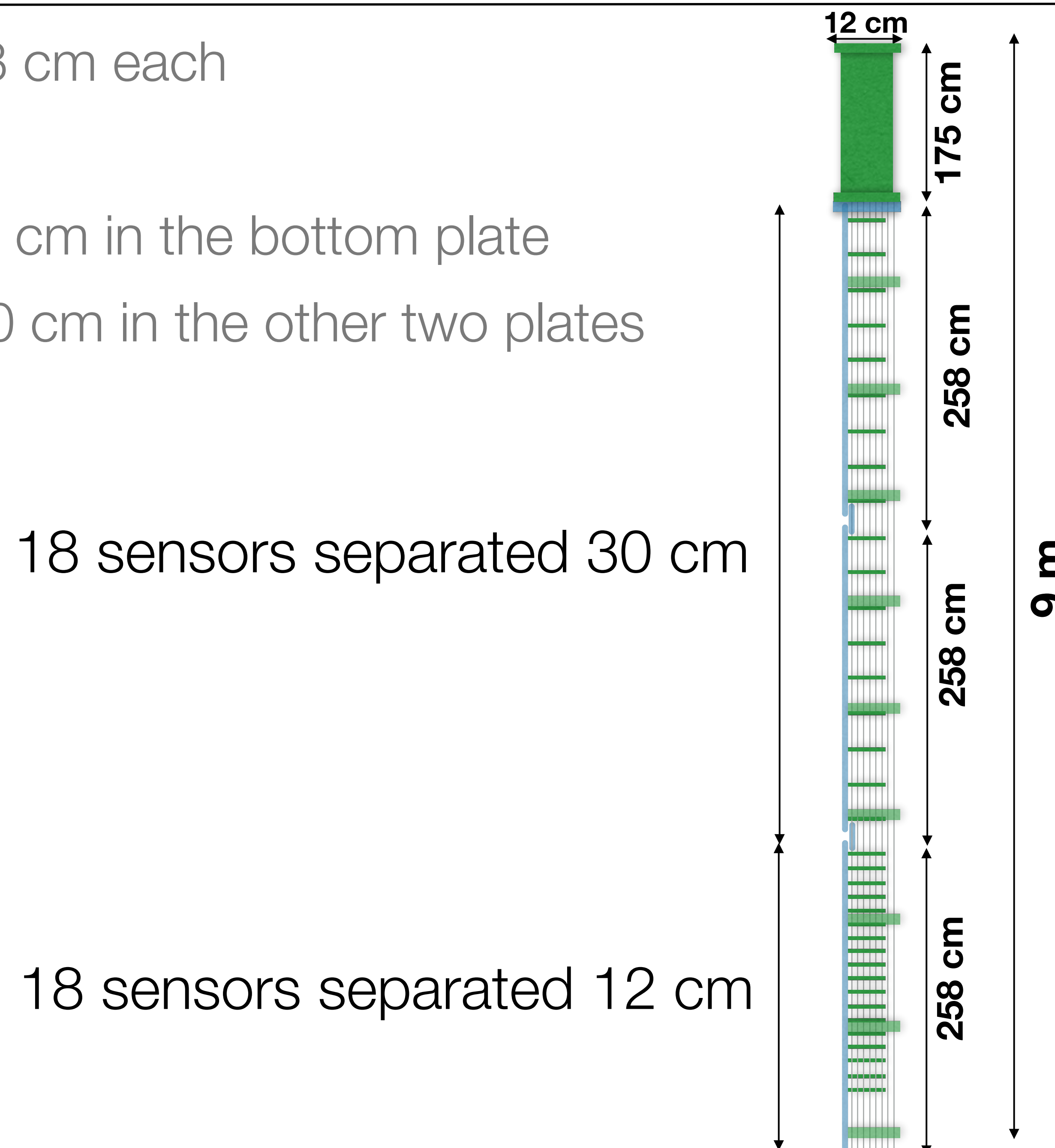
- Use Comsol v5.2a
- Several configurations tested. Maximum field for this one is 11.3 kV/cm
- Still some room for improvement



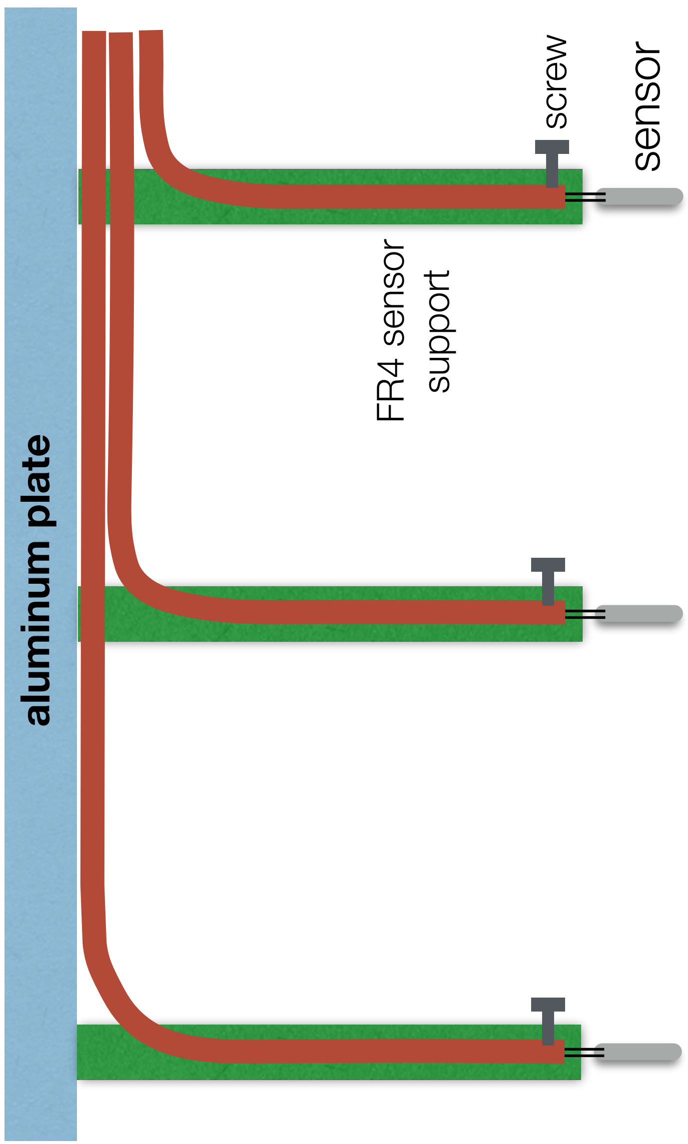
# Baseline configuration

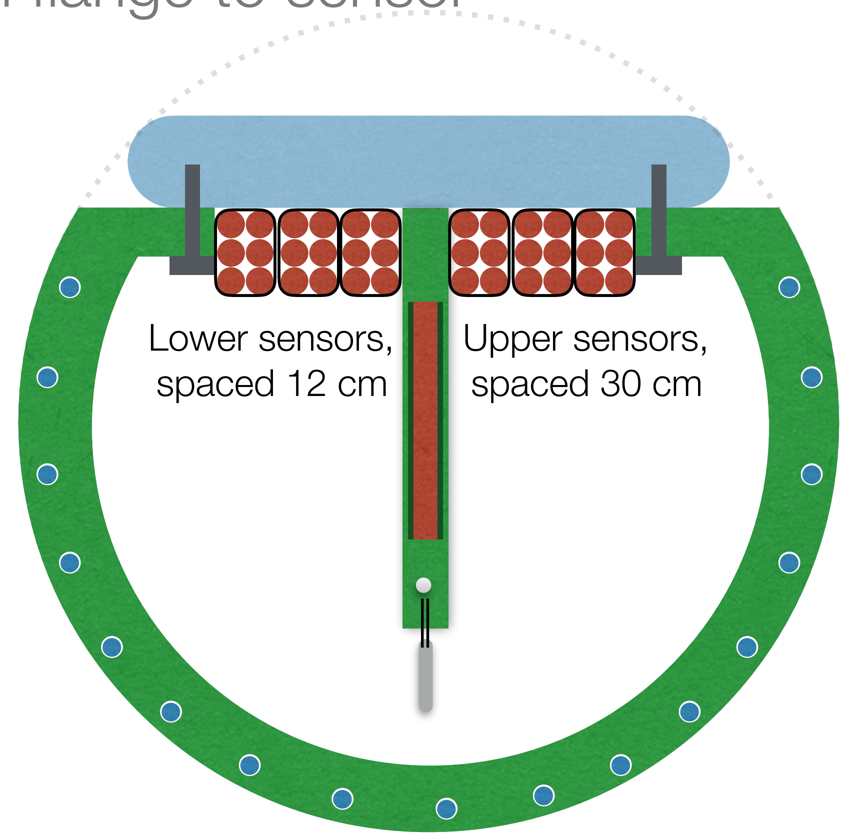
- 3 aluminum plates of 258 cm each
- 3 FR4 disks per plate
- 18 sensors separated 12 cm in the bottom plate
- 18 sensors, separated 30 cm in the other two plates



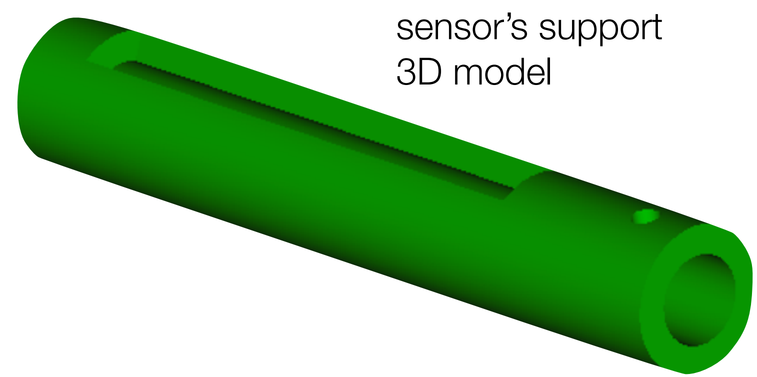
# Cables and sensors

- Single 4-wires cables from flange to sensor



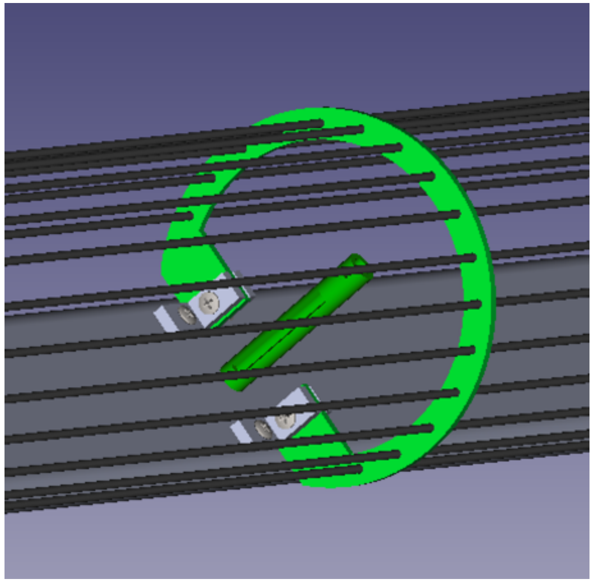

One SUBD-25 connector for each cable bundle

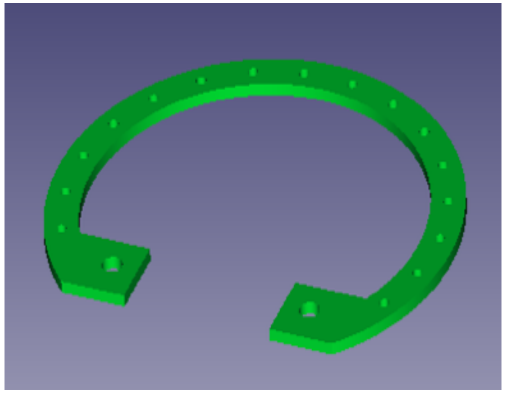


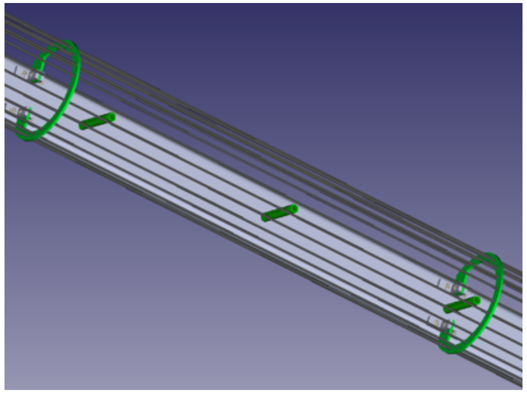
sensor's support 3D model

# Shielding grid

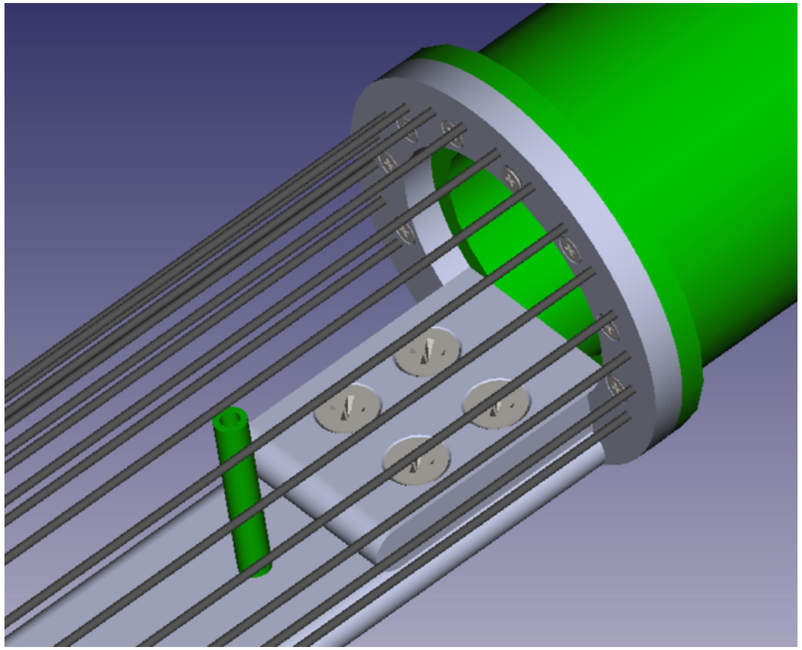
- FR4 disks keep the 3 mm diameter stainless still rods vertical and at a fix distance





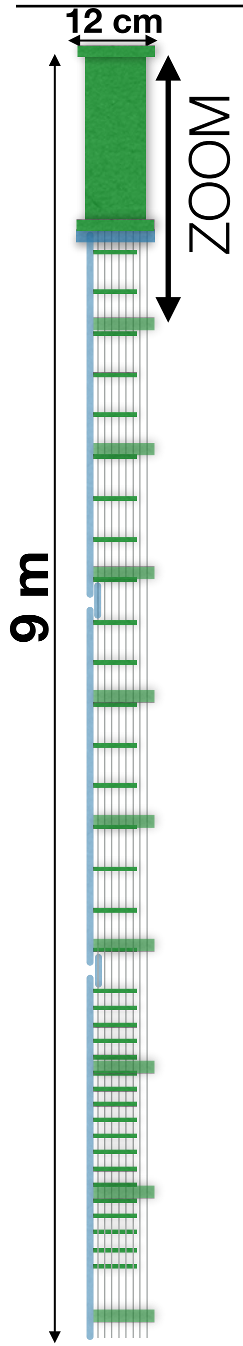


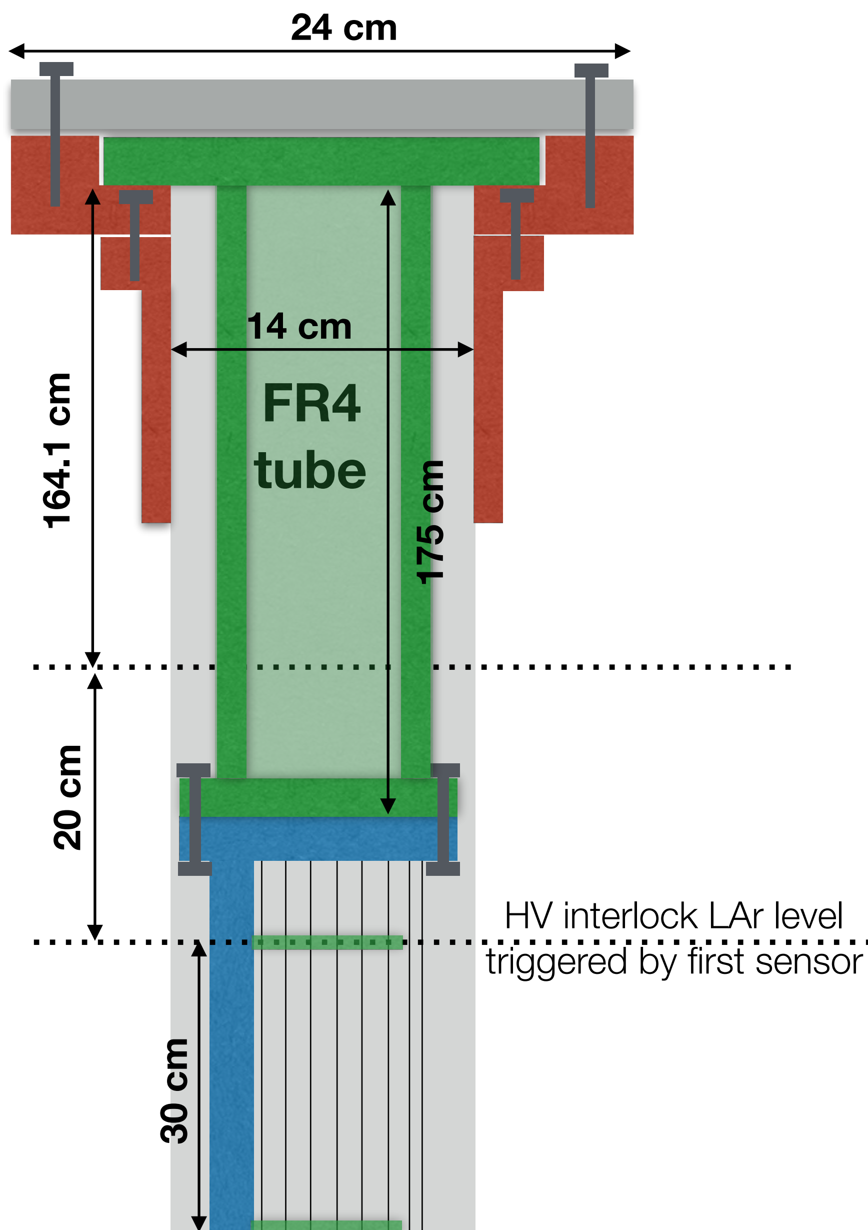
- Stainless still rods are screwed onto the aluminum disk, which is screwed to the FR4 tube and the aluminum plate

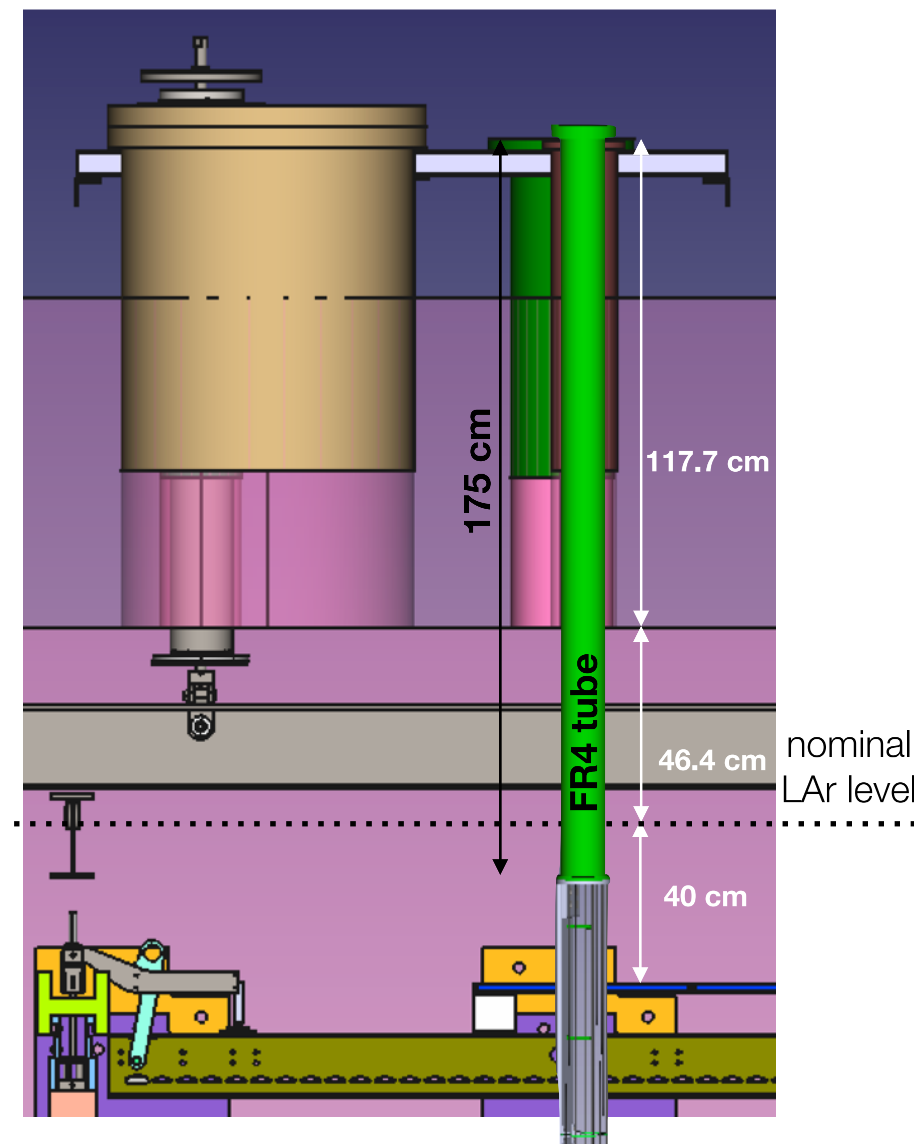


# Top section

- A FR4 tube with only cables inside, to insulate aluminum structure from flange



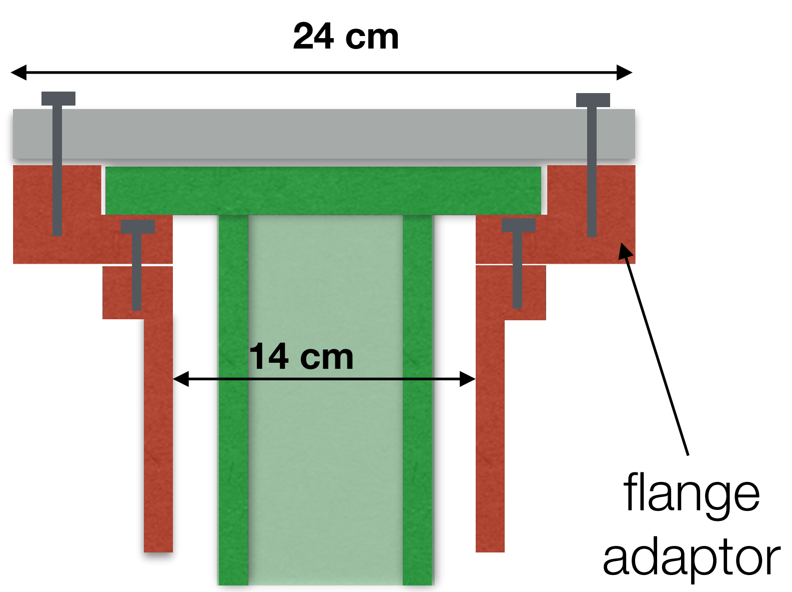



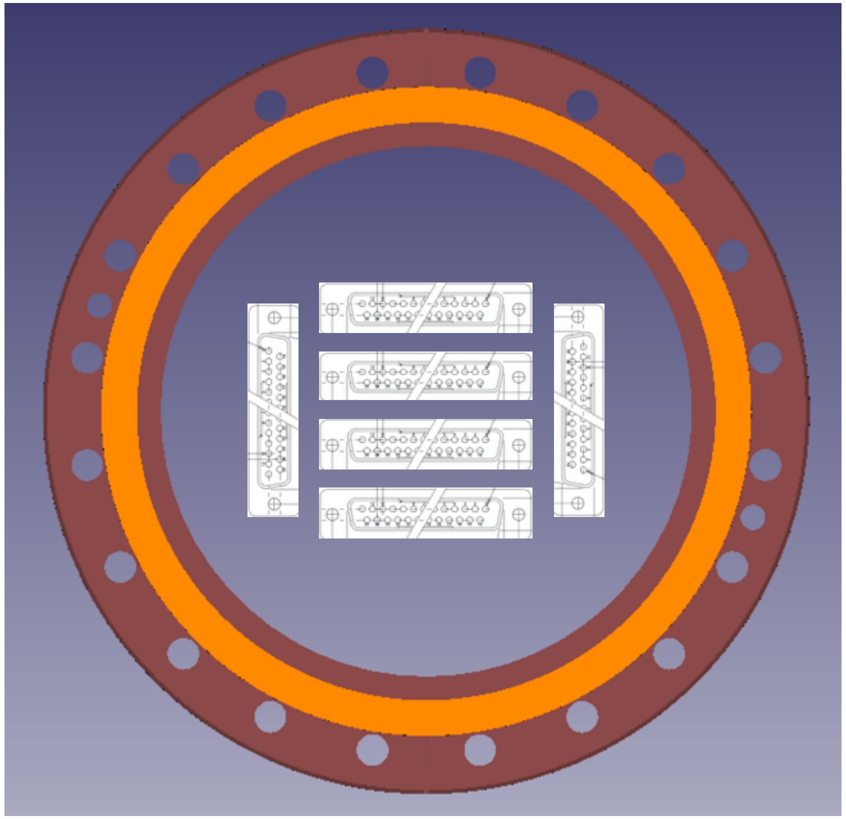



# Flange area

- The FR4 tube rests on top of the chimney (use a flange adaptor) in this way the T-gradient monitor and the flange are independent
  - We could for example open the flange to check the connections

6 SUB-D 25 pin
36 sensors
144 wires



# Getting the required precision

- How can we make sure we get the required precision ?
  - Make sure **mechanical design** do not bias the measurements
  - Use high quality **sensors** (Lakeshore PT102)
  - Use low noise **cables** and **4-wires readout**
  - Use high quality **readout system**: very precise current source and very precise voltage meter
  - Cross **calibrate** all sensors in the temperature range of interest: find curve of voltage versus temperature for each sensor
  - Investigate the effect of **connectors** and cables and find alternative solutions when needed
  - Perform all kind of **reproducibility tests**

# Cables

- In order to maximize the precision of the temperature measurements and at the same time to guarantee **good behaviour in cold and low outgassing** the following requirements have been identified:
  - 4 wires per sensor
  - Teflon jacketed (FEP, PTFE) cables
  - Twisted pair wires
  - EMC shielding every two pairs
- Three models under consideration:
  - Alpha Wire
  - Belden
  - Axon-cable
- We will chose next week and ask for the derogation

**ALPHA WIRE**

**Multipair Screened Cable, Communication, Slate, 2 Pair, 24 AWG, 1000 ft, 304.8 m**

Technical Data Sheet (130.99KB) EN

RoHS compliant

| | |
|---|---|
| Jacket Colour | Slate |
| No. of Pairs | 2 Pair |
| Wire Gauge | 24AWG |
| Conductor Area CSA | - |
| Reel Length (Imperial) | 1000ft |
| Reel Length (Metric) | 304.8m |
| No. of Max Strands x Strand Size | 7 x 0.2mm |
| Voltage Rating | 150V |
| Jacket Material | FEP |
| Conductor Material | Tinned Copper |
| External Diameter | 4.318mm |
| Product Range | - |

**BELDEN**

**SHIELDED CABLE MULTIPAIR, 2PAIR, 1000FT, 22AWG, 300V, RED**

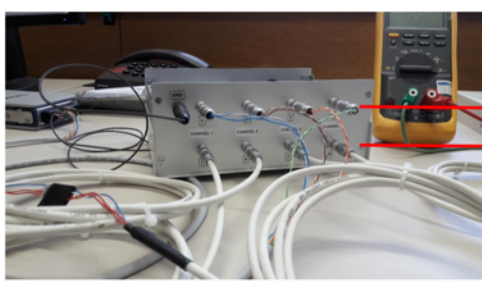
Technical Data Sheet (94.39KB) EN

RoHS compliant

| | |
|---|---|
| Jacket Colour | Red |
| No. of Pairs | 2 Pair |
| Wire Gauge | 22AWG |
| Conductor Area CSA | - |
| Reel Length (Imperial) | 1000ft |
| Reel Length (Metric) | 304.8m |
| No. of Max Strands x Strand Size | 7 x 30AWG |
| Voltage Rating | 300V |
| Jacket Material | FEP |
| Conductor Material | Tinned Copper |
| External Diameter | 3.759mm |
| Product Range | - |

# Readout and slow controls

- Developed by CERN EP-DT department (Xavier Pons). Three parts:
  - An accurate current source for PT100 excitation, implemented by a compact electronic circuit using high a precision voltage reference from Texas Instruments.
  - A multiplexing circuit based on an ADG707 Analog Device multiplexer electronic device;
  - A high resolution and accuracy voltage signal readout module based on National Instruments NI9238, which has 24 bits resolution over 1 Volt range. This module is inserted in a National Instruments Ethernet DAQ backplane, which will distribute the temperature values to the main Slow Control Software through the standard protocol, OPC UA. The Ethernet DAQ will include also the multiplexing logic



Up to 4 PT100 channels

PT100 signal to National Instruments module

4 wires connections to PT100

220 Vac or 115 Vac to ±15VDC power supply

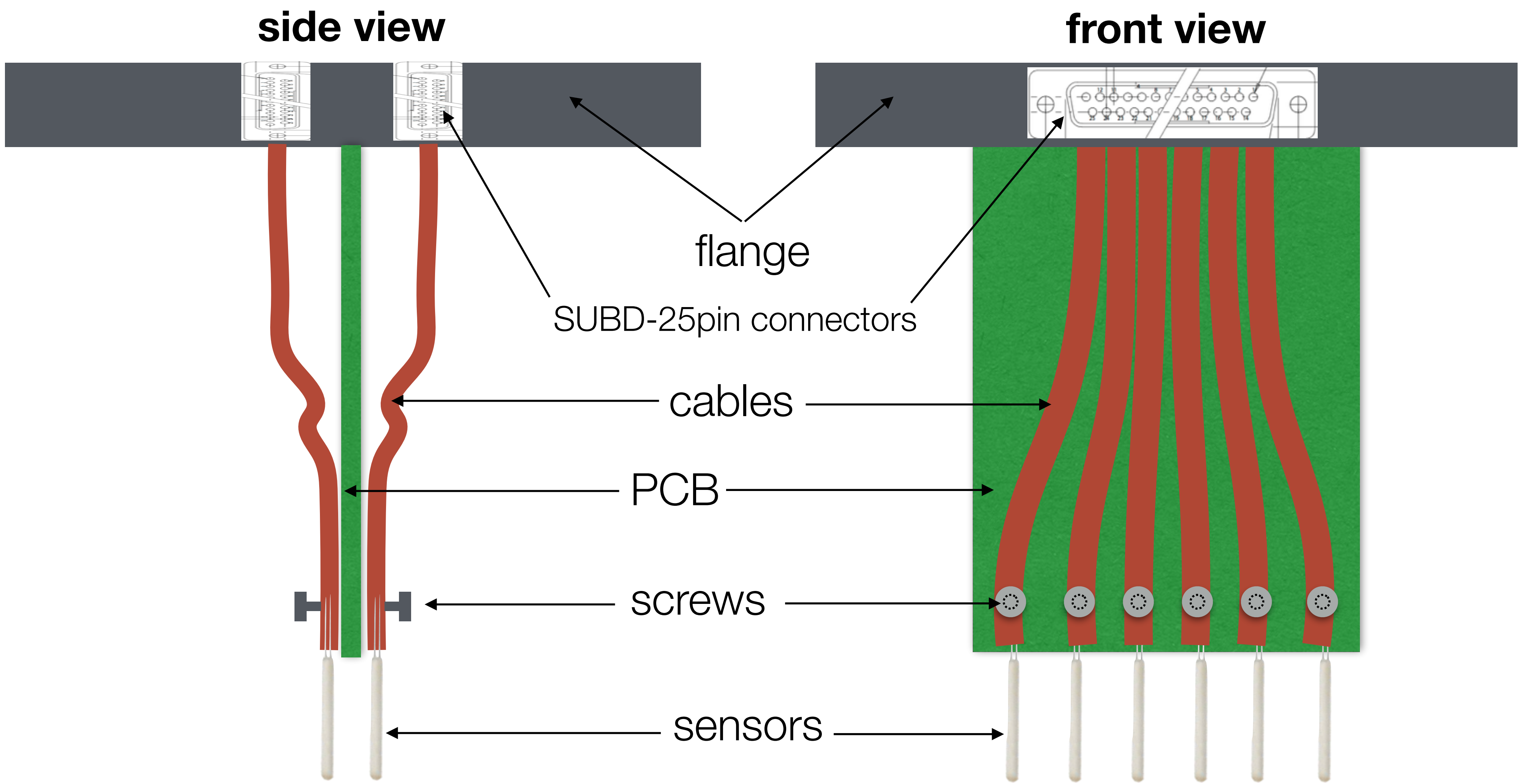
PT100 current source circuit x 4
Calibrated to 1000 μA with FLUKE 87

current source calibrated to 3 nA

# Sensor calibration

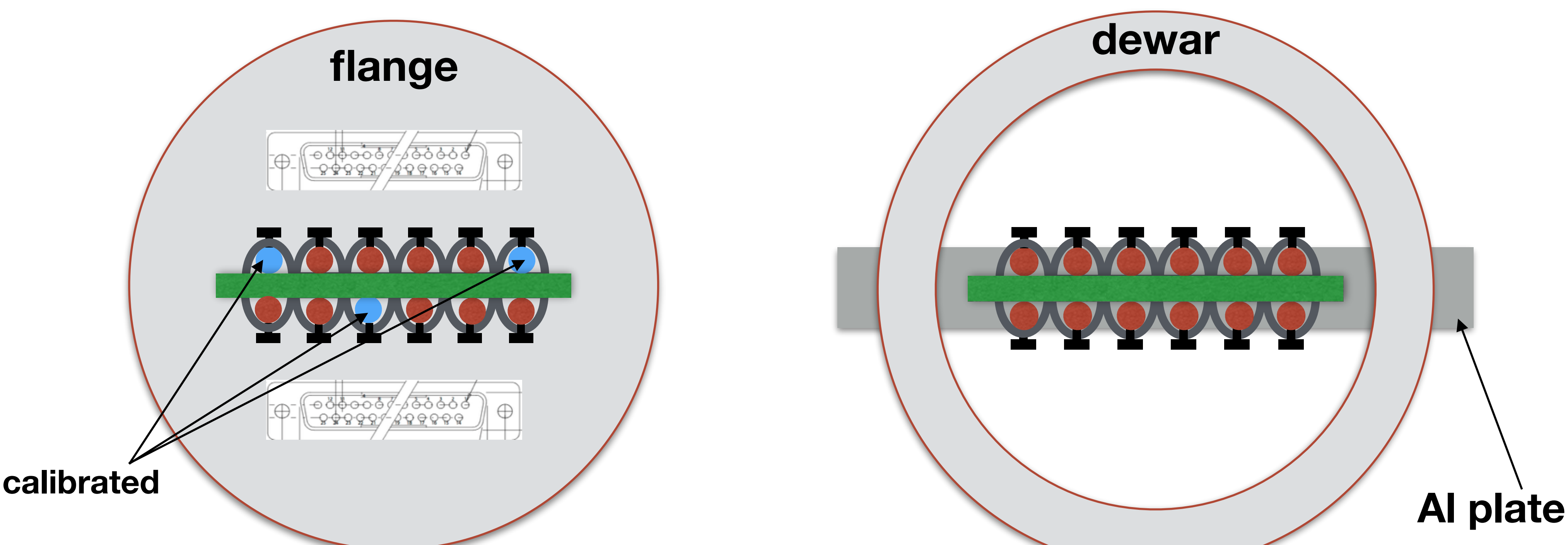
- Lakeshore calibrated sensors are 5 times more expensive ( >500 €)
- A small dewar (16 cm opening) available in Valencia (up to 15 atm)
- The idea is to use LAr as bulk
- Use LN2 and a heater to vary slightly the temperature (±5 K)
- The flange and the system to hold the sensors needs to be designed
- Initial tests with no flange will begin next week

# Conceptual design



# Conceptual design

- **9 sensors** can be **calibrated at once** using as **reference 3 sensors calibrated by Lakeshore**. Perform several combinations of locations to disentangle possible spacial variations of temperature
- The flange will arrive later, so we need some temporary solution
  - We should be able to screw the PCB holding the sensors either to the flange or to an Aluminum plate at the top of the dewar




**bottom view**

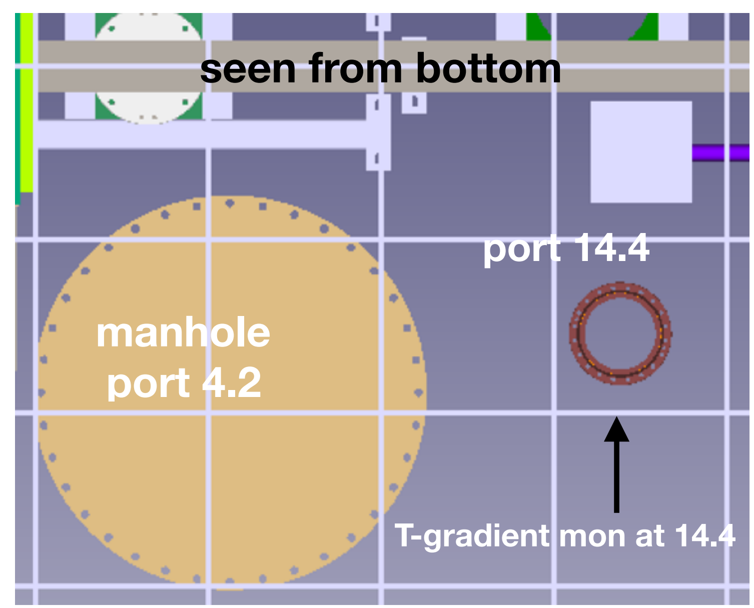
# Calibration strategy & schedule

- Calibrate all sensors inside the dewar
  - Perform reproducibility tests with different kind of connections, including different soldering, different cables, etc
- Solder sensors to their final cables (up to 9 meters long) and calibrate them again, to test the effect of the cable (all cable submerged in LAr)
  - Perform reproducibility tests, comparing with the previous calibration, connecting and disconnecting, etc
- If possible bring the calibration system to CERN and do a definitive calibration with the final readout system mounted on the rack
- **Schedule**:
  - We will get the readout system from CERN EP-DT today
  - We already have four sensors (one of them calibrated). Order the rest ASAP
  - We will build a small support for the sensors next week
  - We can start playing with the system next week

# Installation procedure

- The system will be mounted in horizontal position outside the cryostat

- Then it will be put in vertical position and introduced in the cryostat through port 14.4
- An operator inside the cryostat will put the bottom cup in place and make sure the system enters into the cup
- In principle the whole process should not interfere with any other action
- Working out the details with experts



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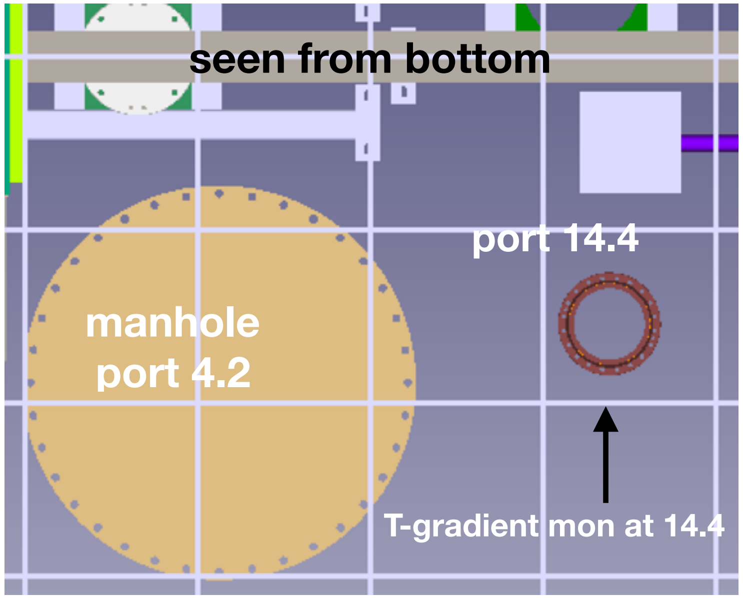

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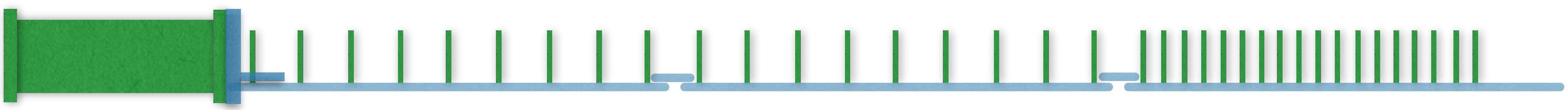

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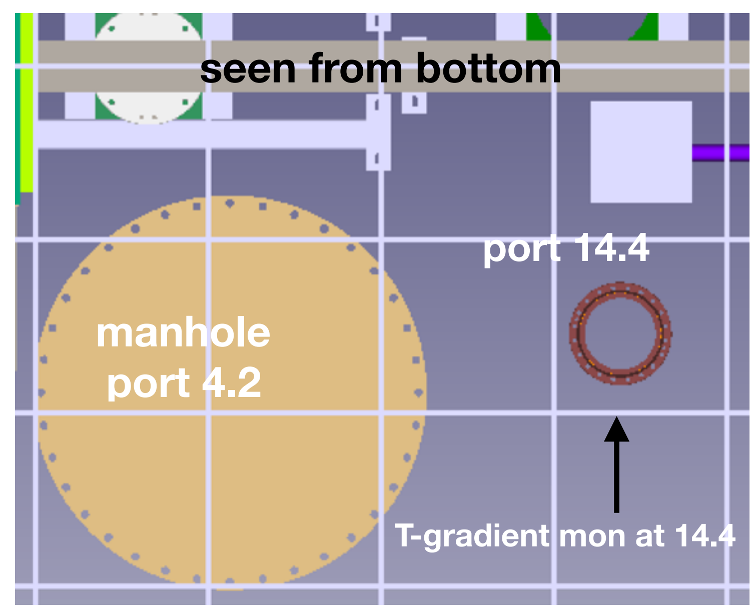

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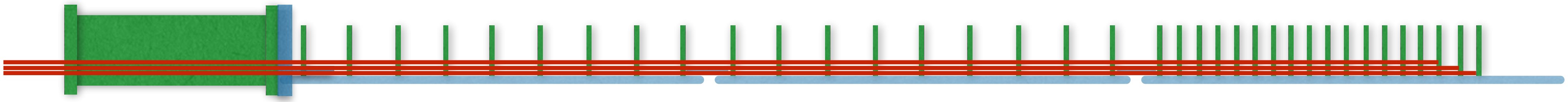

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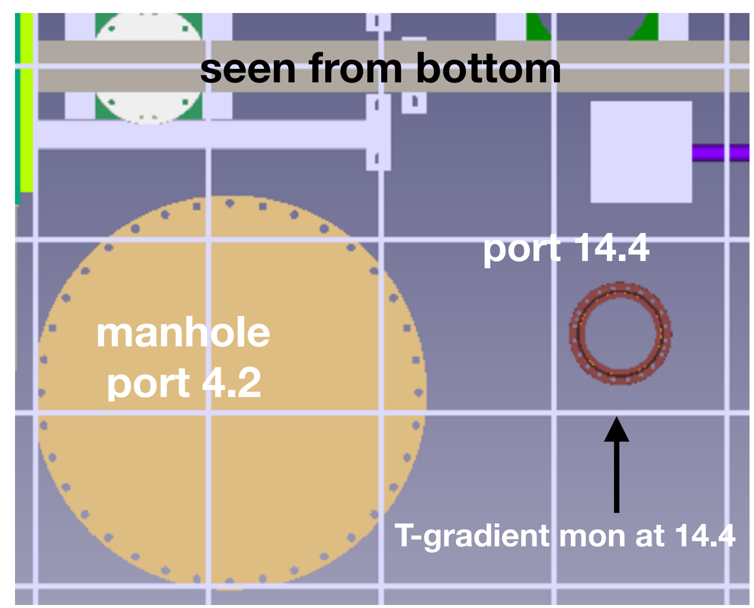

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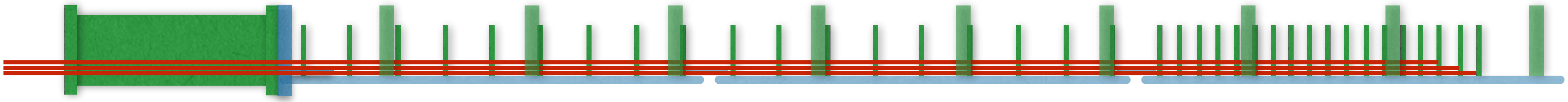

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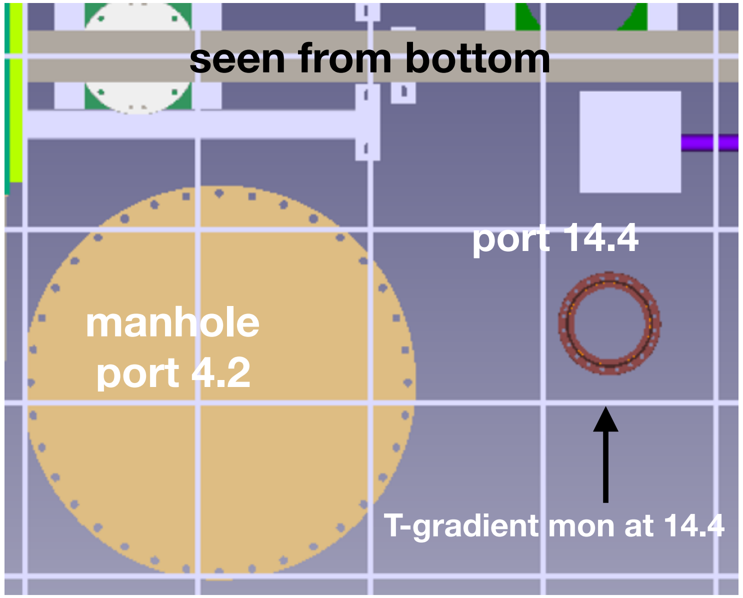

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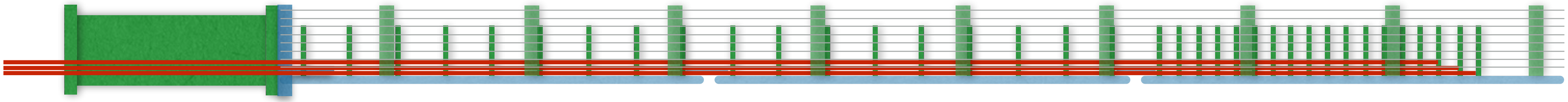

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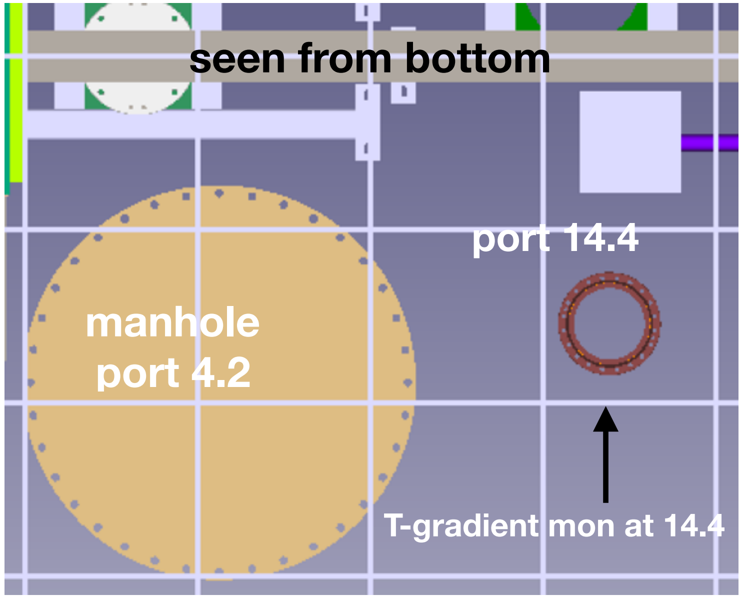

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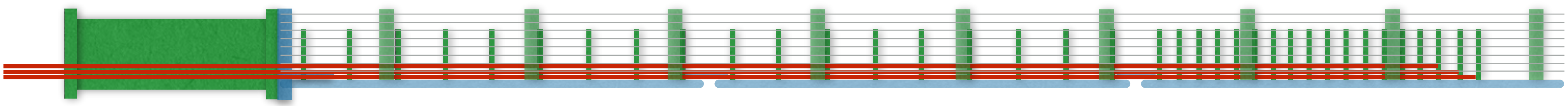

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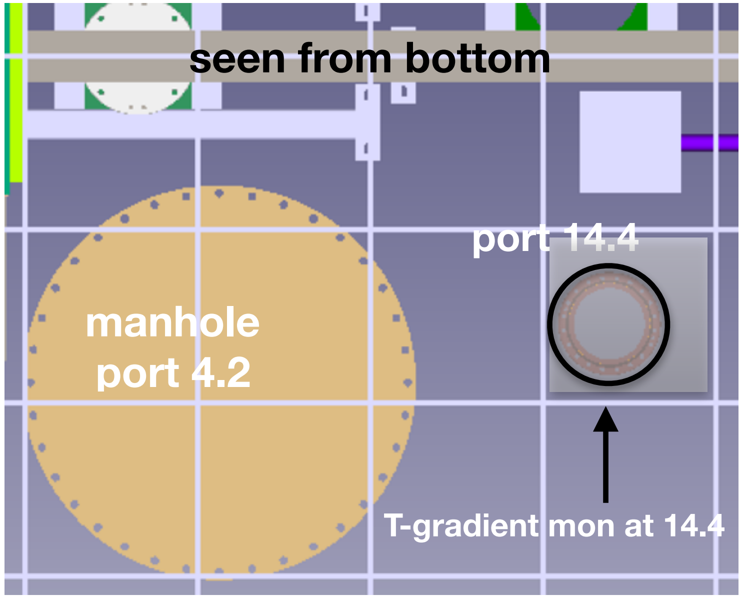


# quality control/assurance

- **All sensors will be calibrated in Valencia** both at room and cryogenic temperatures to better than 5 mK with a readout system very similar to the final one
- **If possible** we would like to repeat the **calibration at CERN** with the final readout system mounted on its rack, the final warm cables and flange
- A **test assembly** of the entire system will be done **in Valencia**

# Extrapolation to DUNE

- DUNE has a different configuration, with all anode planes facing the lateral walls: **No need for E-field shielding.** Everything can be reused except the shielding grid, which can be just removed
- The system will be twice as long
  - The mass is not doubled since the shielding grid is removed

| | SS shielding grid mass (Kg) | Aluminum plates mass (Kg) | Total mass (Kg) |
|---|---|---|---|
| ProtoDUNE | 29,0 | 24,7 | 53,6 |
| DUNE | 0 | 49,4 | 49,4 |

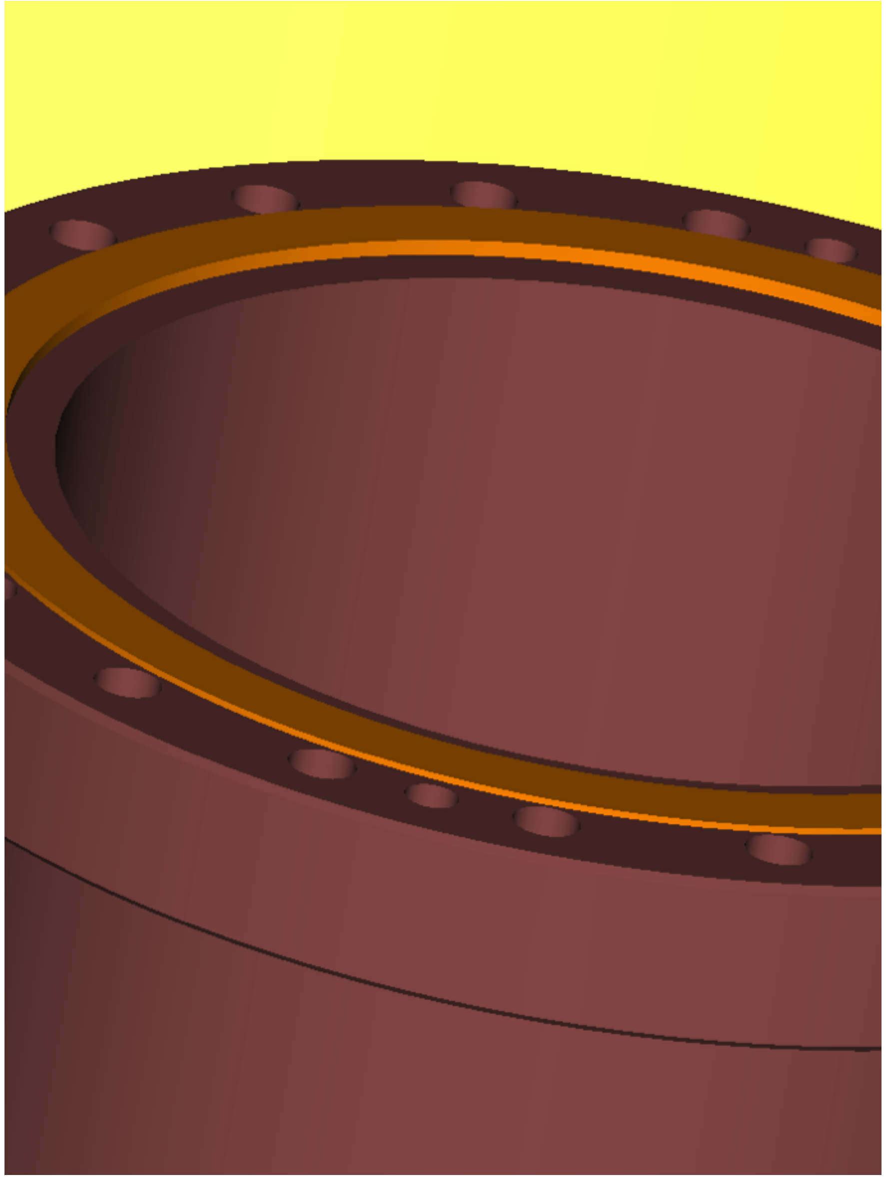
  - We will have to **test the rigidity of the system** for the new length. In any case, the aluminum structure could be thicker if necessary
- In DUNE the system will be **assembled inside the cryostat**, starting from the flange and going down. Individual pieces are lighter than 8 kg
- Sensors and cables could be the same, although better options could be investigated
- Readout and calibration system will be further improved

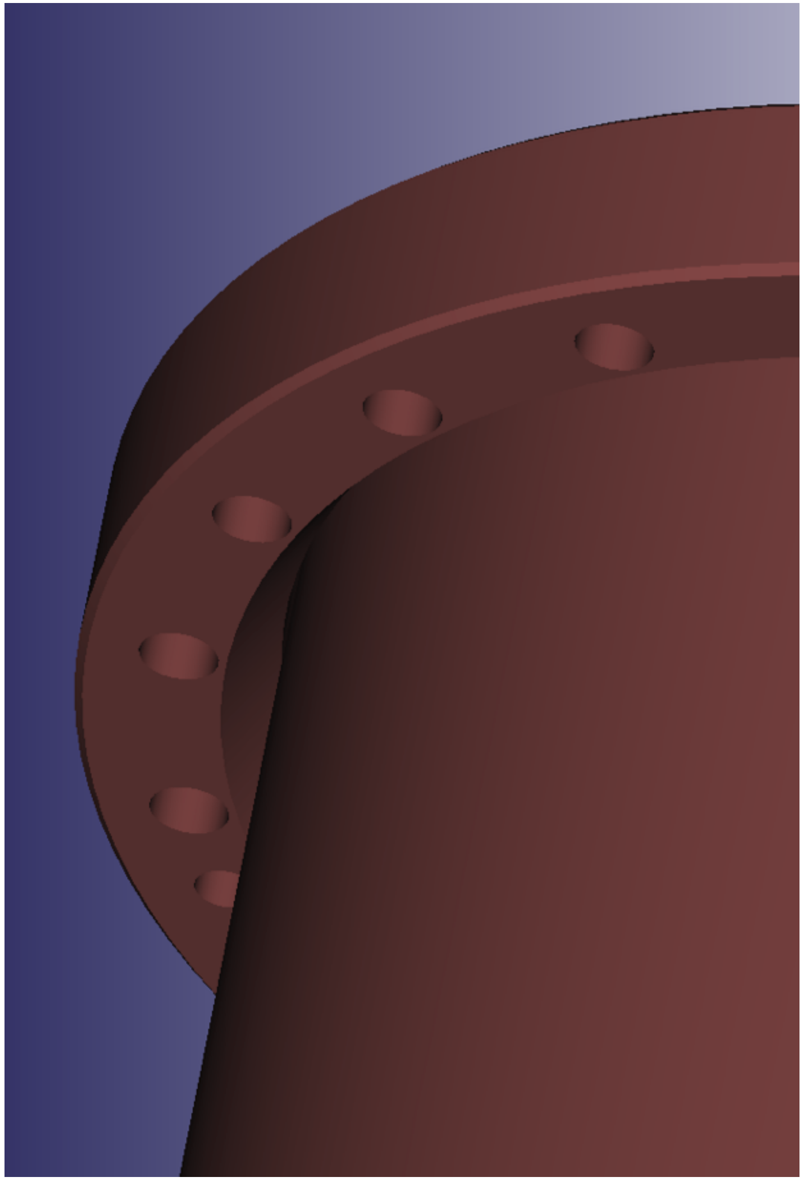
# Schedule

- Schedule is quite relaxed
- No critical aspects have been identified

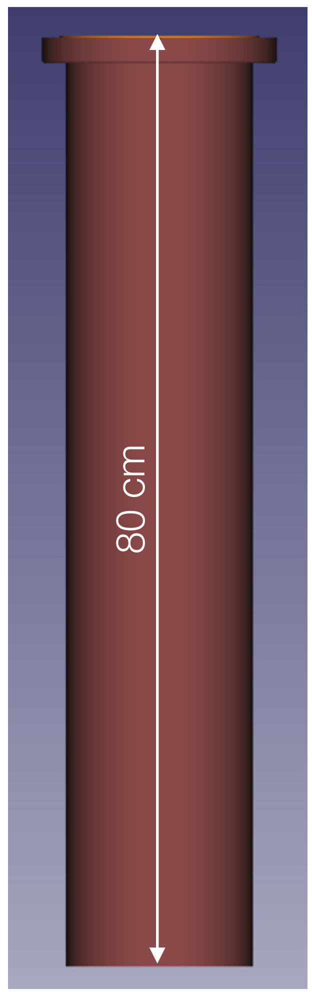
| | 2017 | | | | | | | | | 2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr | May | Jun | Jul | Aug | Set | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| Conceptual design | x | | | | | | | | | | | | | |
| Engineering design | x | x | | | | | | | | | | | | |
| Prototiping | | | x | x | x | | | | | | | | | |
| Design calibration system | x | | | | | | | | | | | | | |
| calibration comissioning | | x | | | | | | | | | | | | |
| Sensor calibration | | | calibrate “other” sensors | | | x | x | x | | | | | | |
| Fabricate mechanical structure | | | | | | x | x | x | x | | | | | |
| cable preparation and sensor-cable calibration | | | | | | | | | x | | | | | |
| sensor-cable assembly into mechanical structure | | | | | | | | | | x | | | | |
| tests in Valencia | | | | | | | | | | x | x | | | |
| test at CERN | | | | | | | | | | | | x | x | |
| installation | | | | | | | | | | | | | | x |

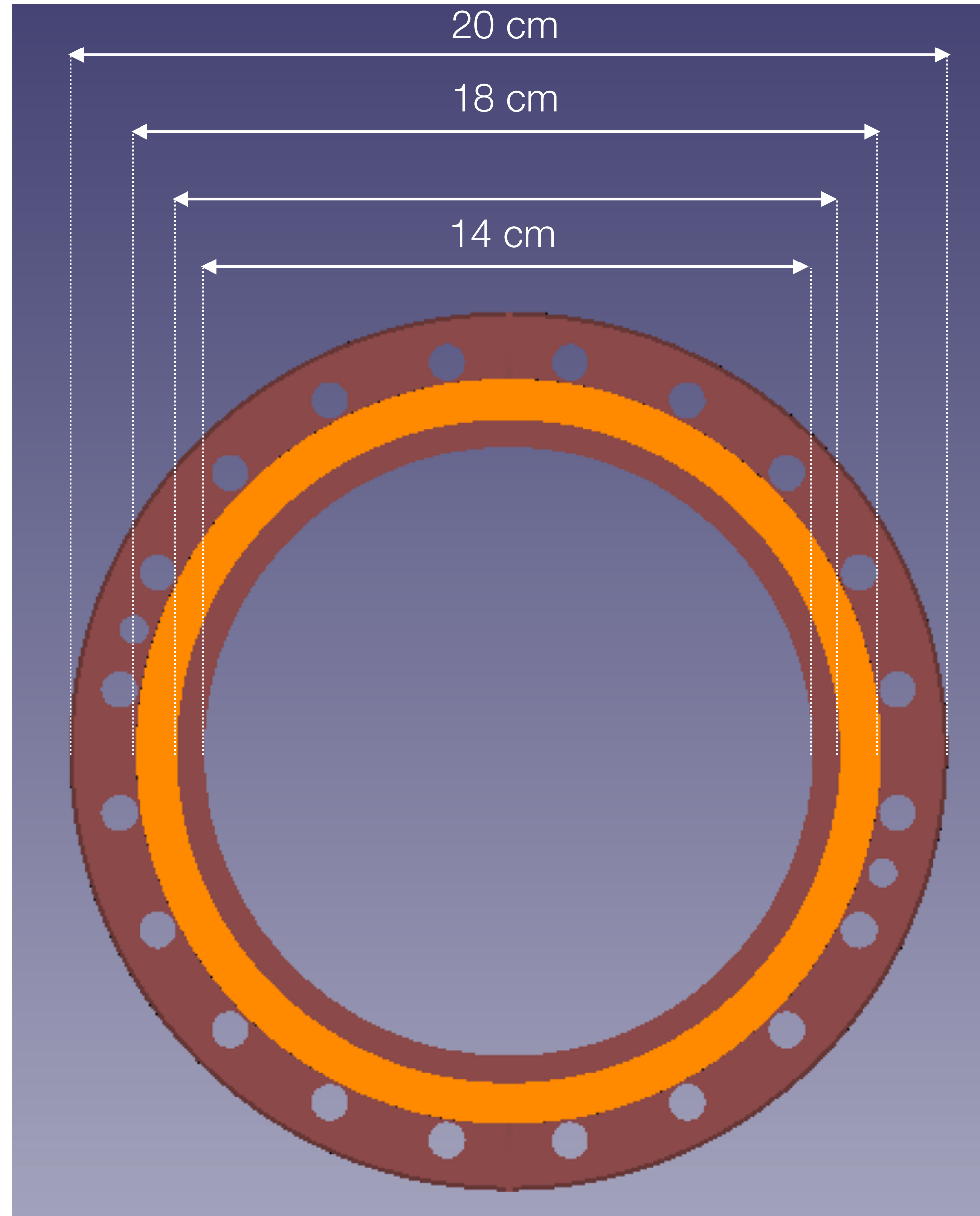
# backup





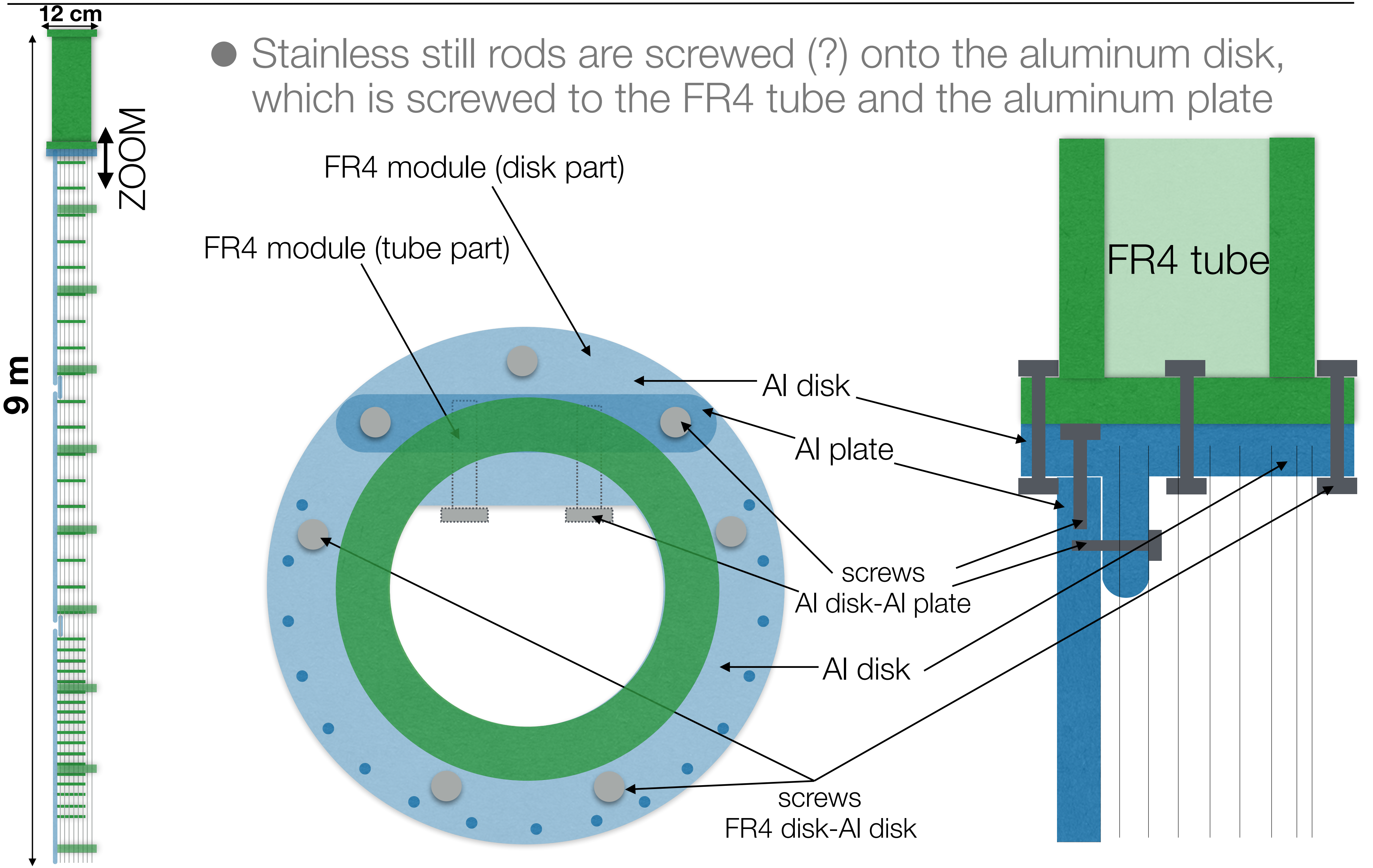

2 cm


80 cm

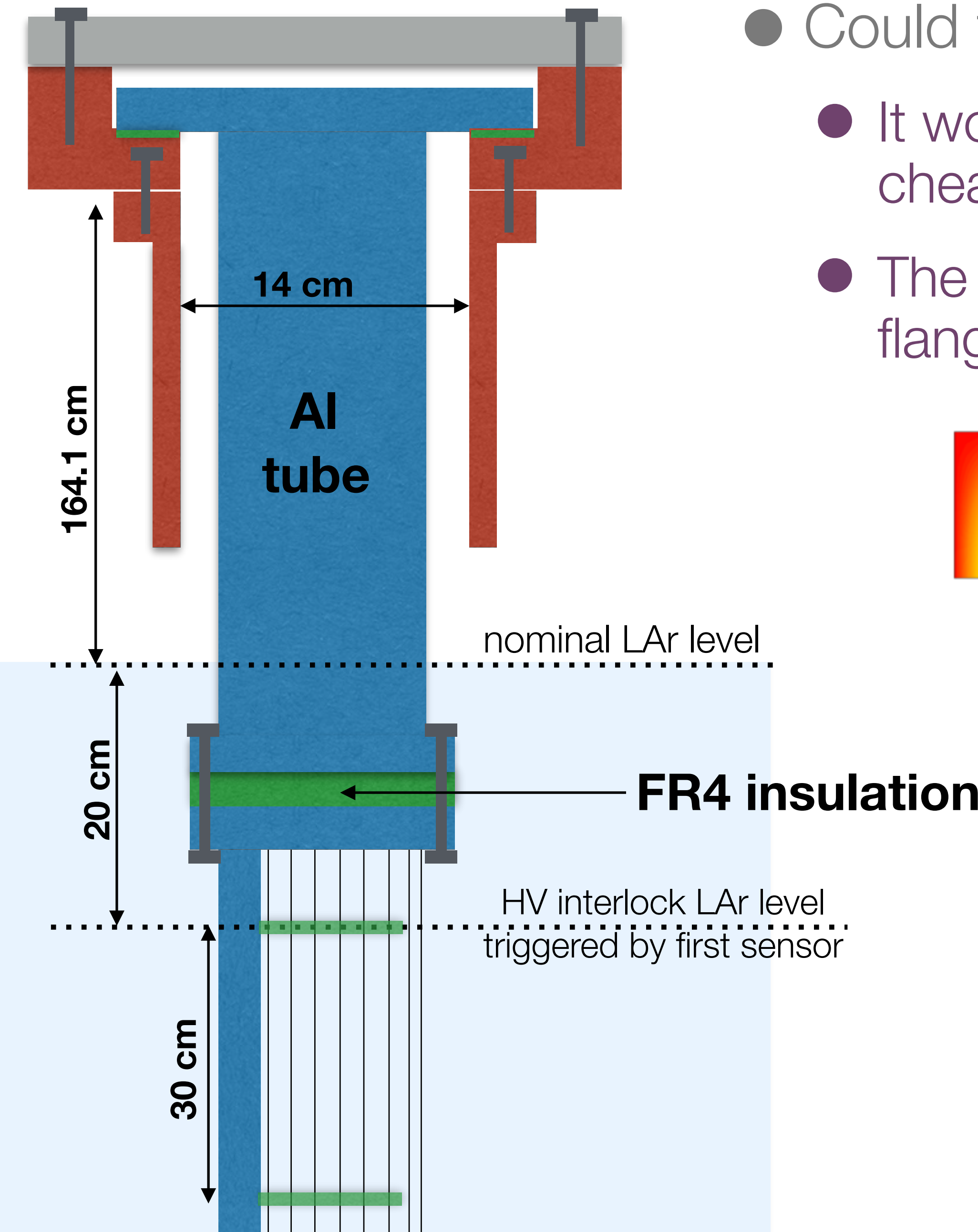

20 cm
18 cm
14 cm

# FR4-Aluminum interface

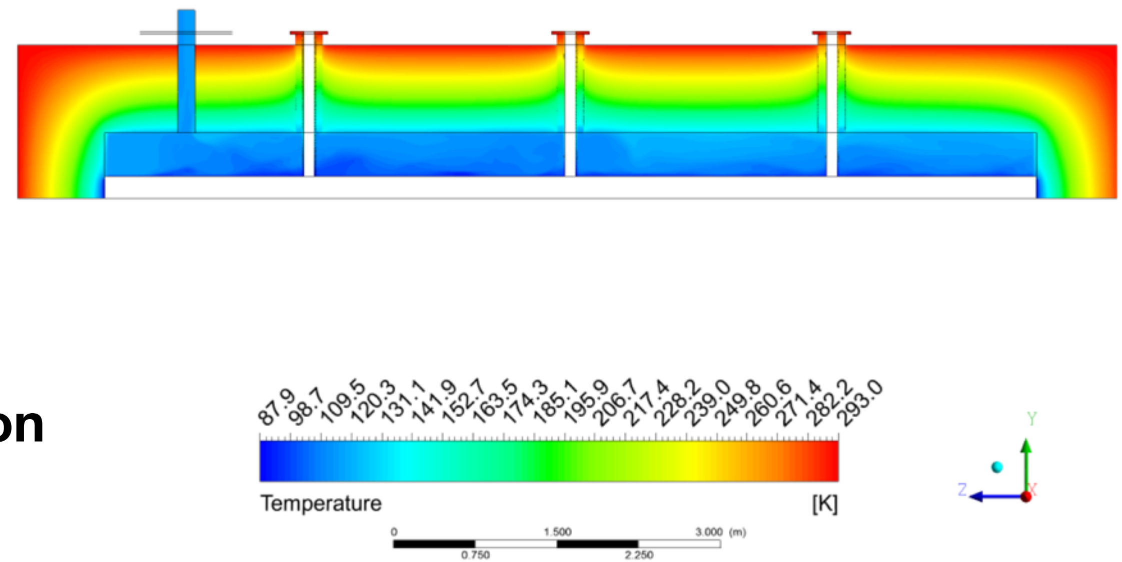
- Stainless still rods are screwed (?) onto the aluminum disk, which is screwed to the FR4 tube and the aluminum plate



# Question ?




- Could the top tube be made of aluminum ?
  - It would be much easier to machine and cheaper
  - The issue could be the heat flux from the flange (at room temperature) to the LAr




waiting for answer

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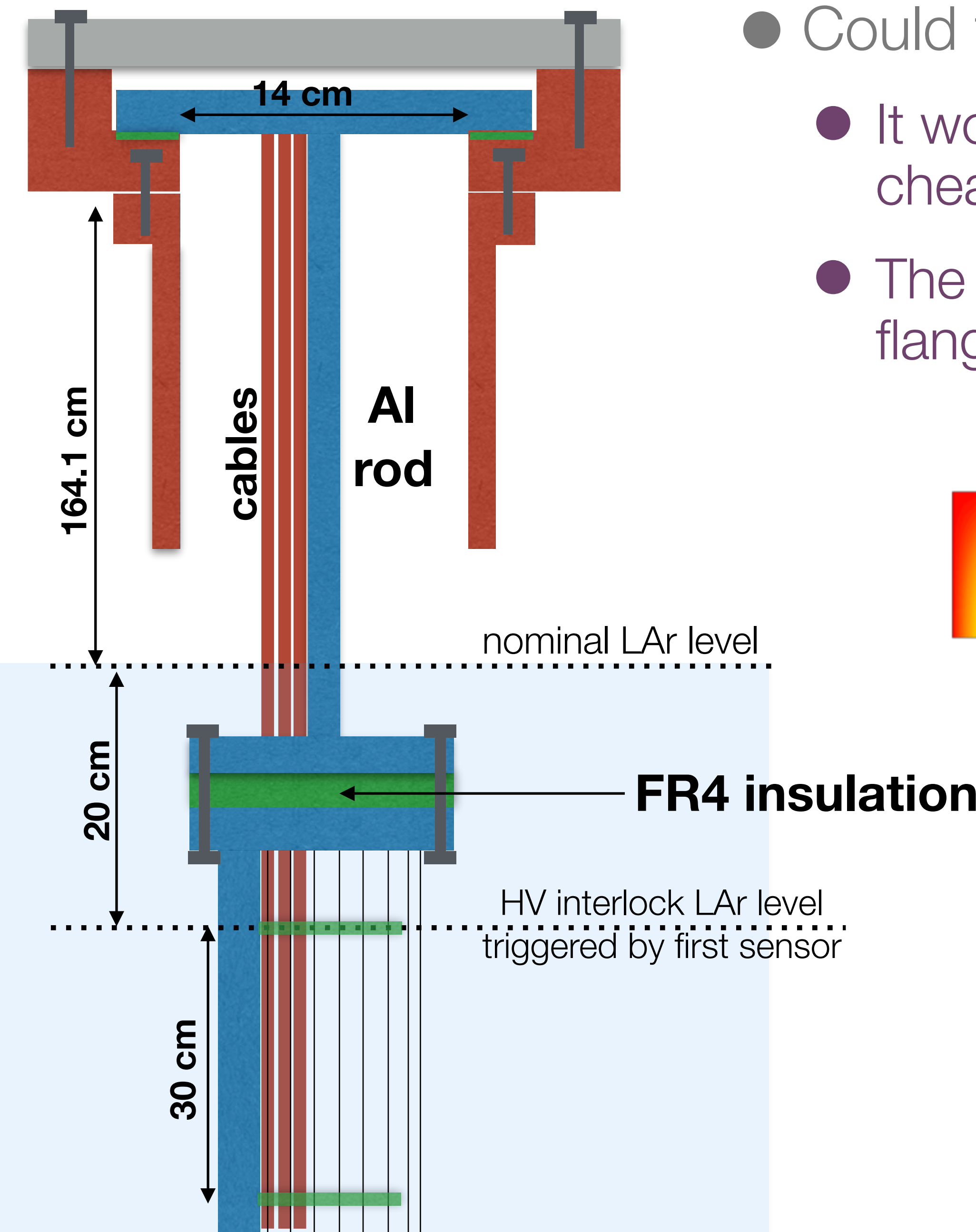


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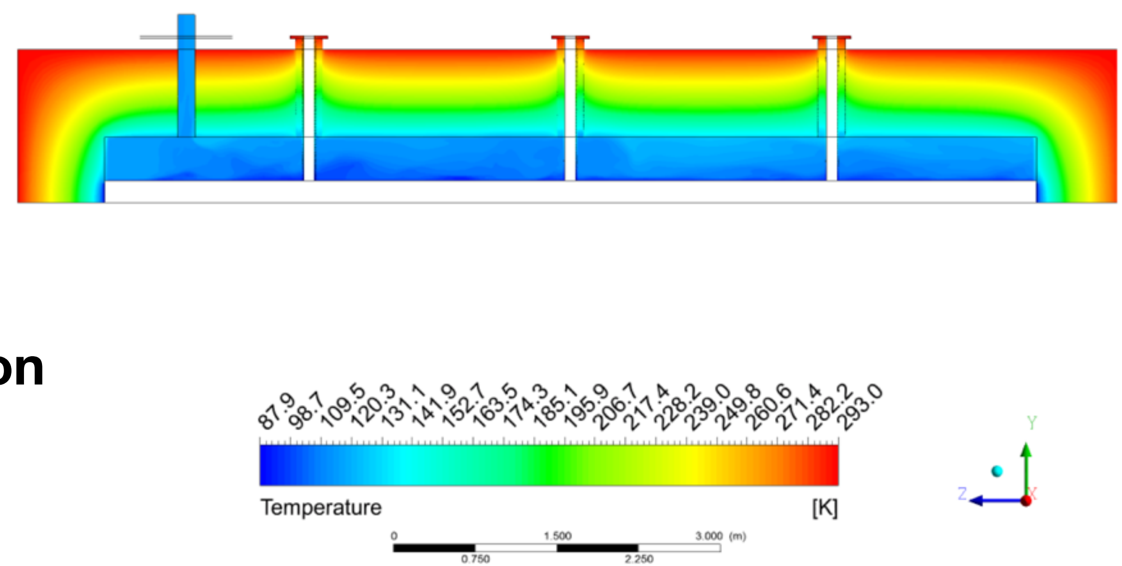
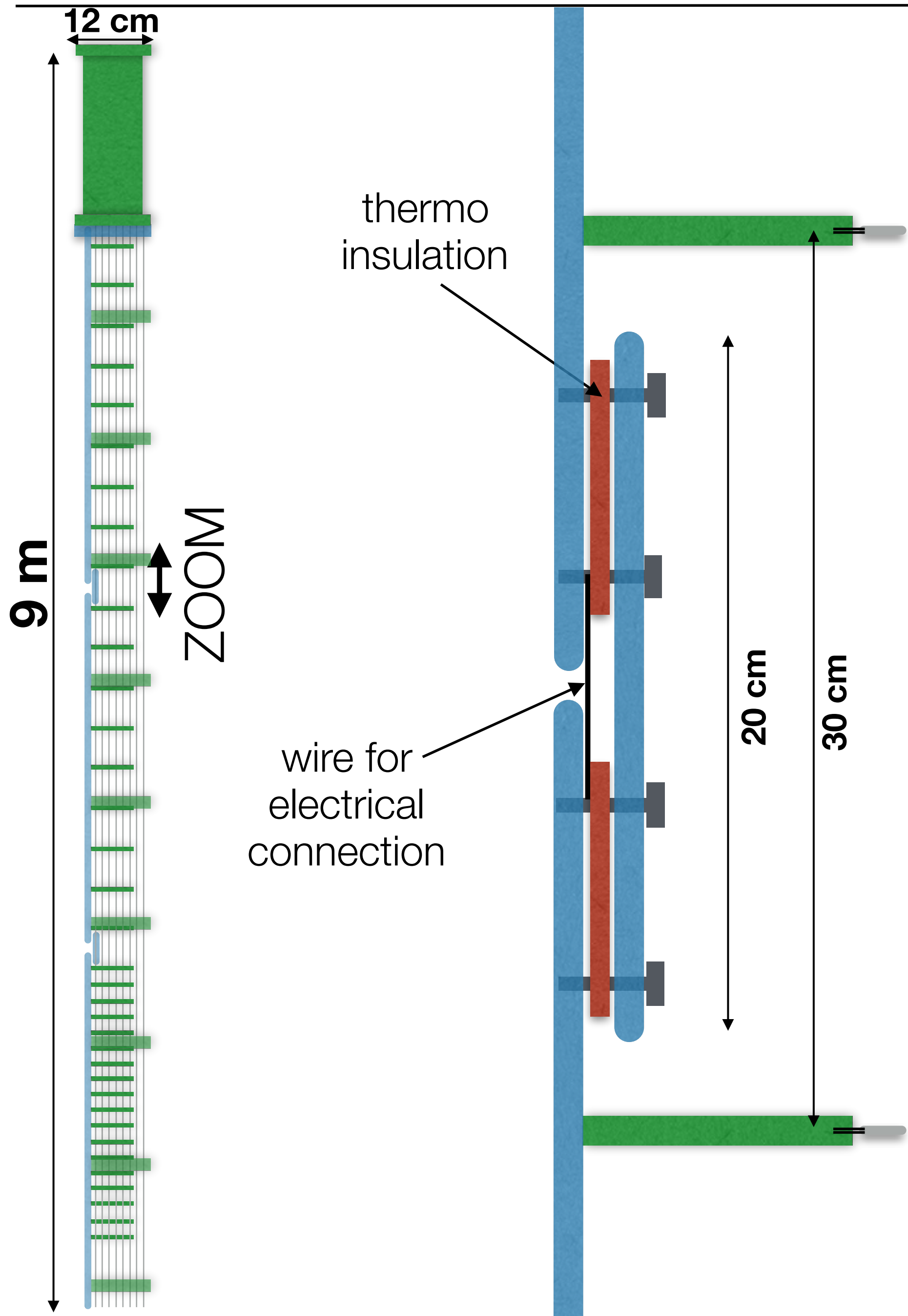


# Connection between sections




- We probably need **insulation** between plates to avoid thermal coupling, or a FR4 connection instead of aluminum
- If **two screws** are used vertically in each side we have to be **careful with shrinking**
- An **electrical connection** to guaranty all plates are at **ground**
- We need a proper design with rigidity studies

front view