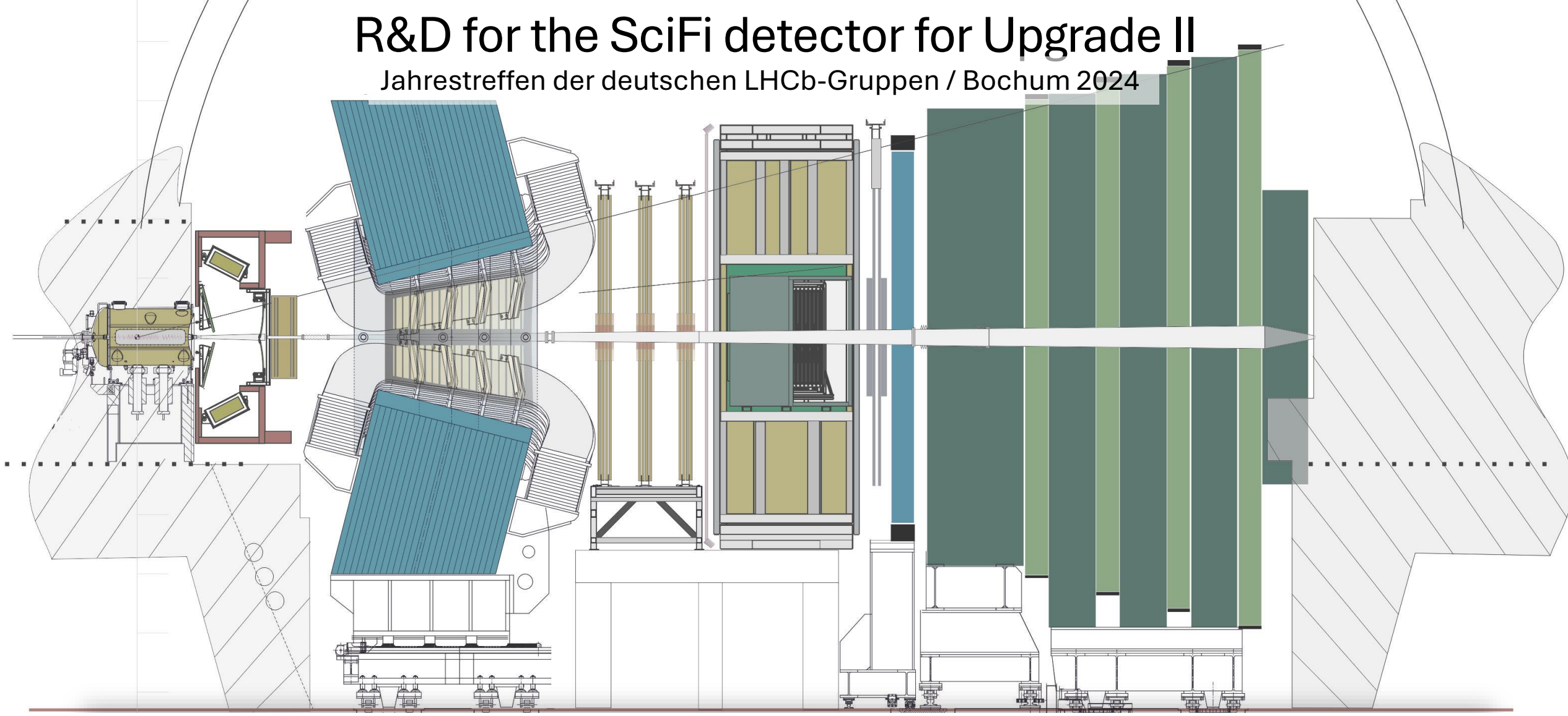
R&D for the SciFi detector for Upgrade II

Jahrestreffen der deutschen LHCb-Gruppen / Bochum 2024



Thomas Oeser

for the Aachen Cryo-SciFi group

24.09.2024

FSP LHCb
Erforschung von Universum und Materie

I. Physikalisches Institut

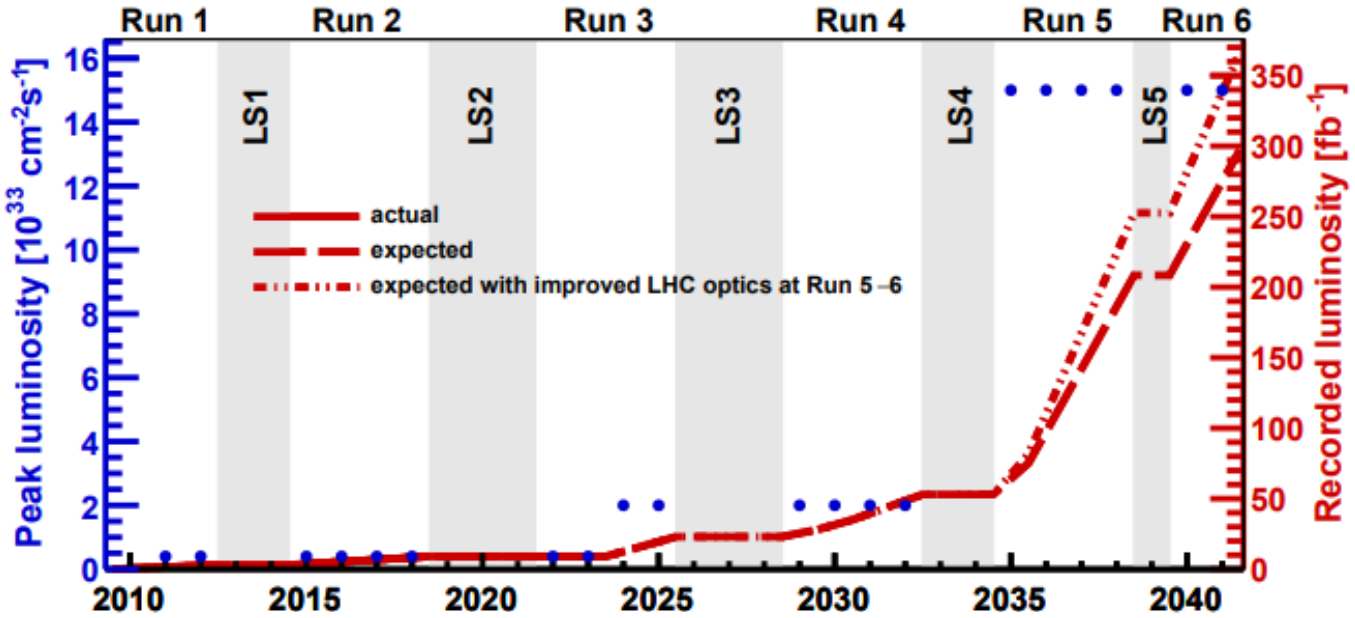
RWTH AACHEN UNIVERSITY

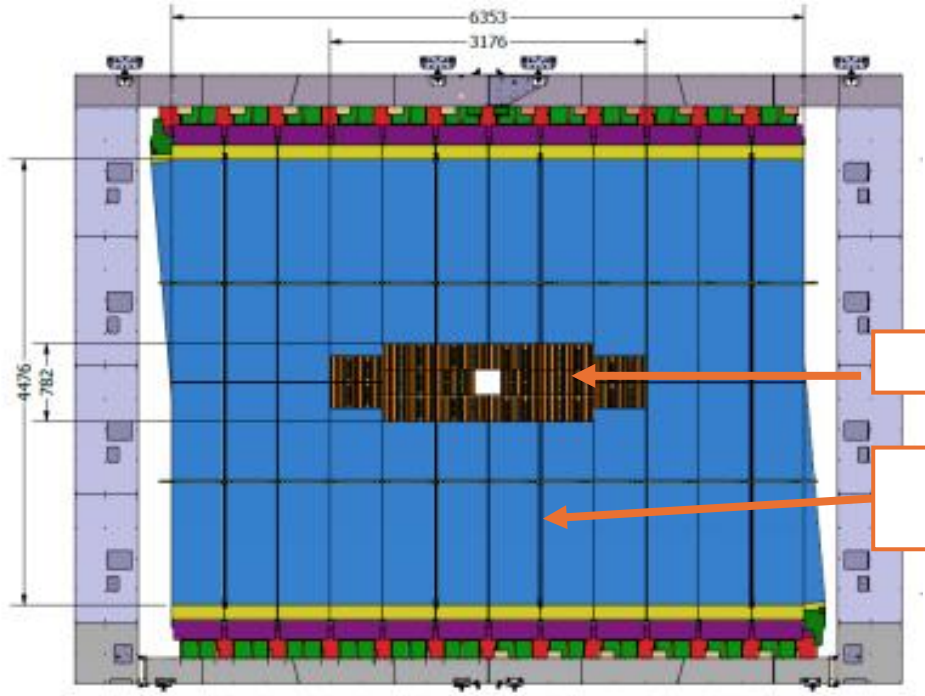
LHCb

Bundesministerium für Bildung und Forschung

Tracking in Upgrade II

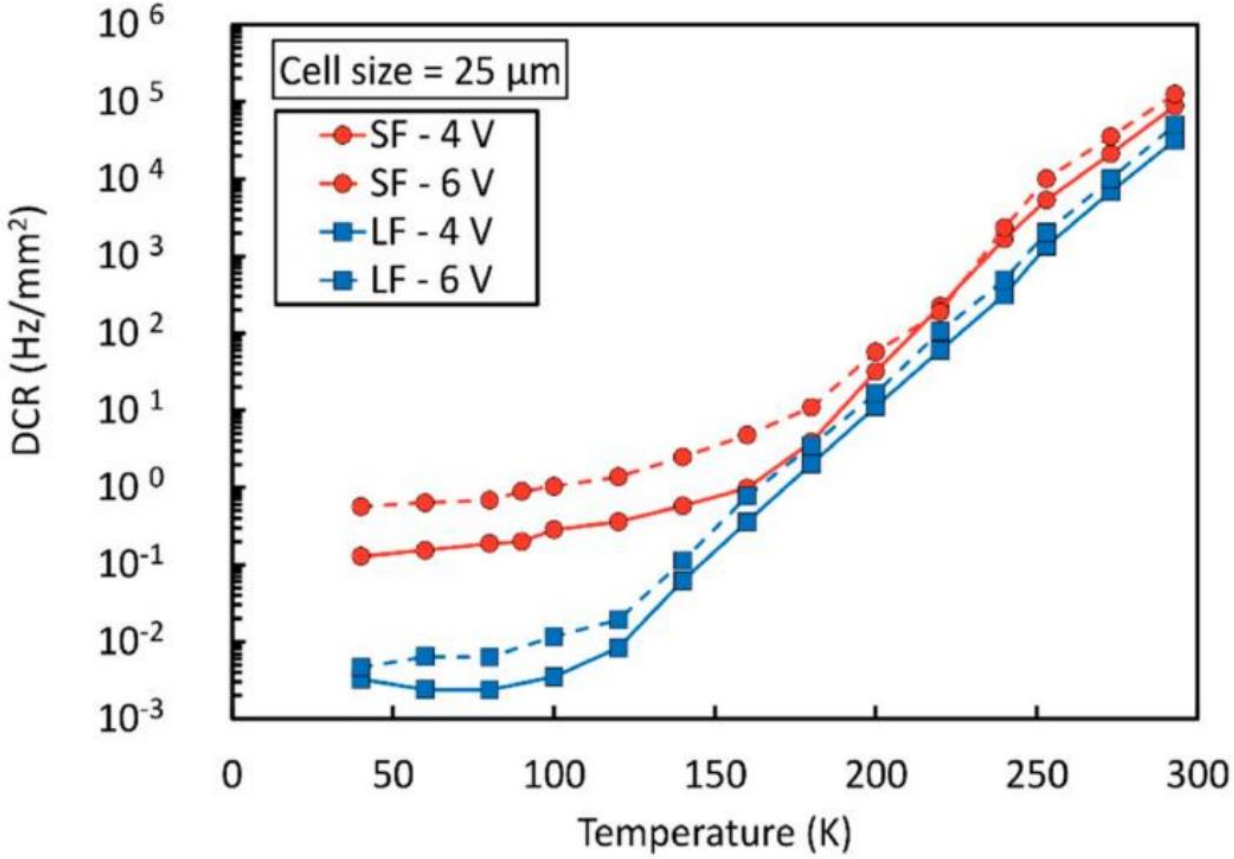
- Upgrade II to be **installed in LS4**
- Prepare detector for **harsh environment of HL-LHC** in Run 5 and beyond
- **Replace** current SciFi tracker with refined version: **Mighty Tracker** (see talk by Blake yesterday)
- Combination of **silicon pixel detector** (MightyPix) and **cryogenic SciFi detector**
- Aachen group focusses on **R&D of cryogenic SciFi**





Why cryogenic SciFi?

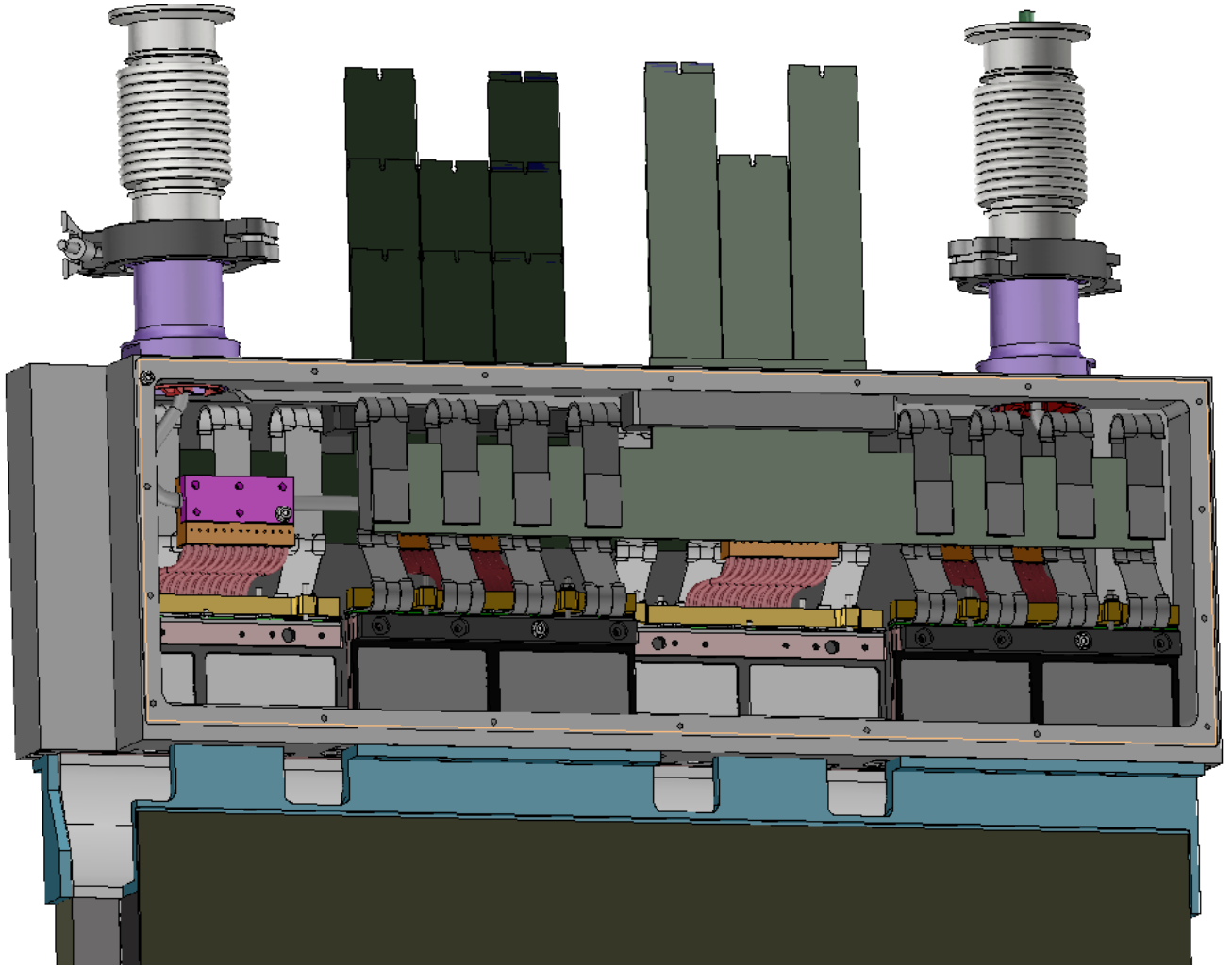
- Target luminosity of 300 fb^{-1} leads to **higher dark count rate** at current operating temperature and **lower hit efficiency** due to necessary adjustments of SNR requirement
- Only viable solution: **Cooling SiPMs to cryogenic temperatures**, greatly reducing DCR and allowing for threshold adjustments to maintain tracking performance



G. Haefeli, EPFL

Status of the cryogenic SciFi design

- Design a **full-module cold box** housing four fibre mats
- SiPMs connected to LN_2 line via **copper heat straps**
- Kapton flex cables connected to PCB **inside cold box**
- Fibre mats can be produced as for Upgrade I, afterwards slightly **bent along z-axis** close to cold box



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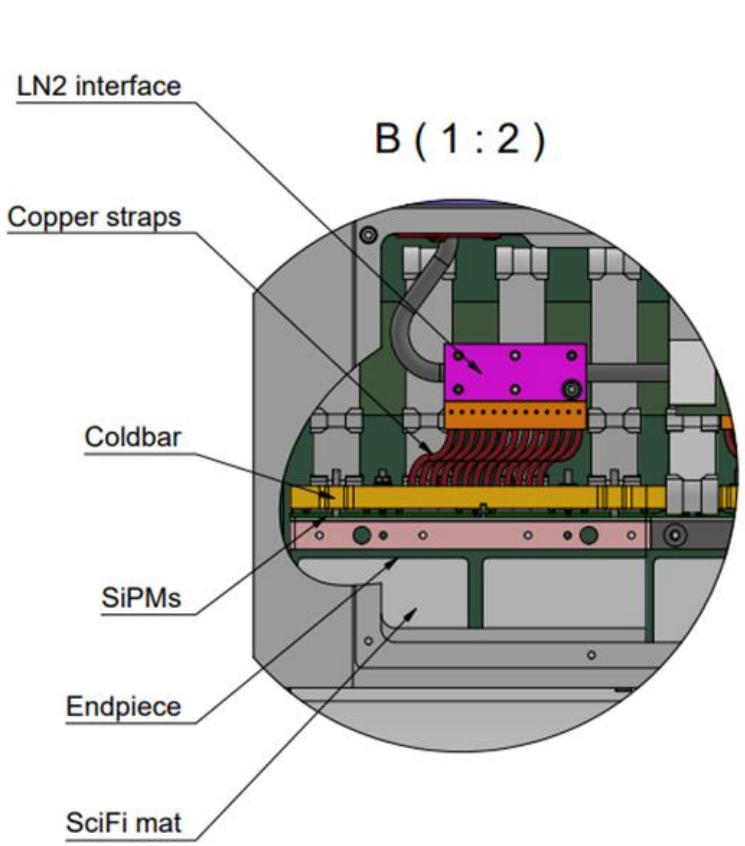

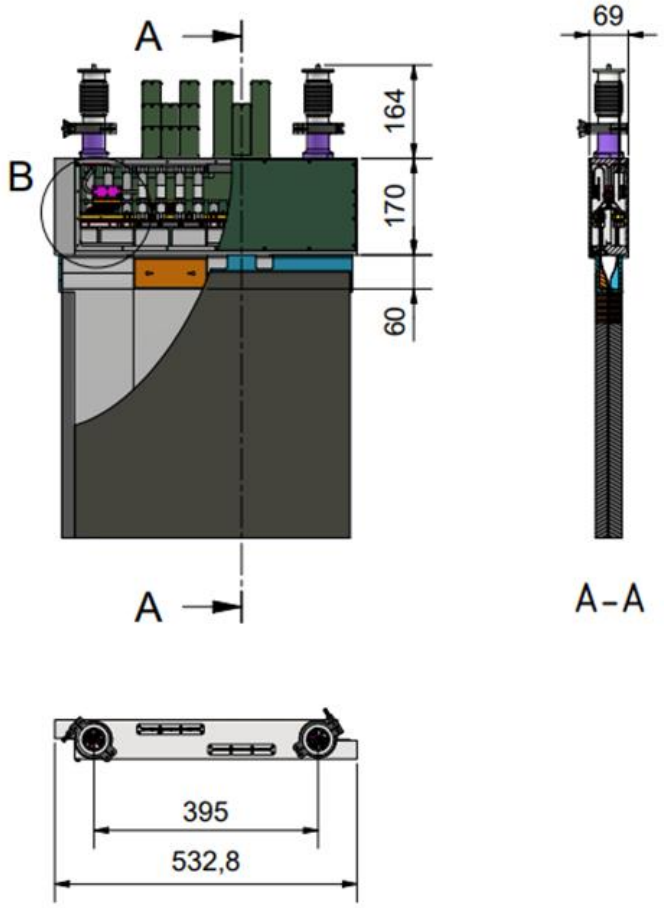

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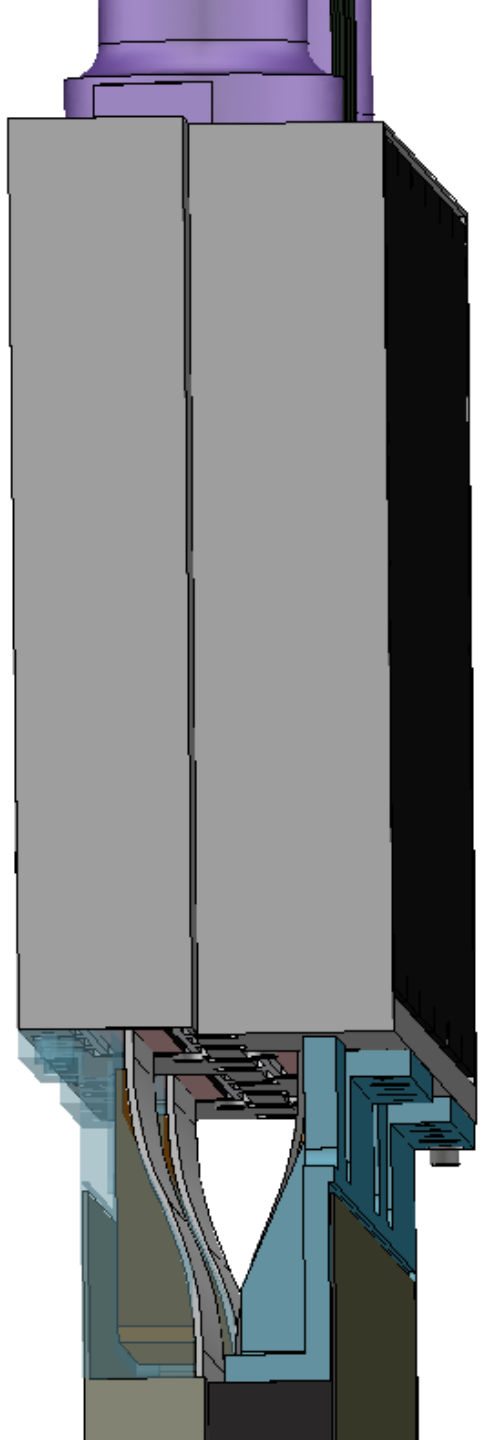
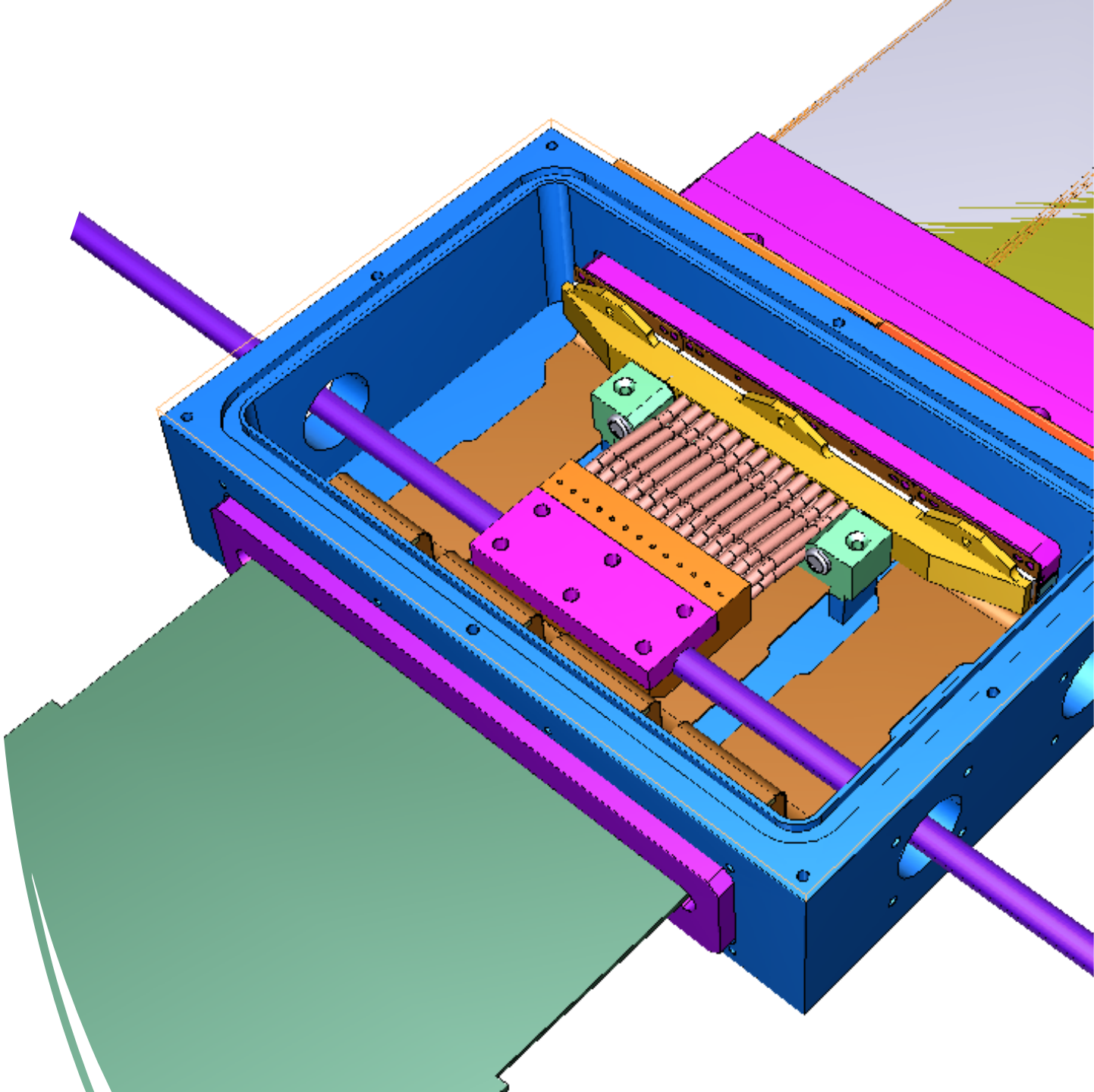


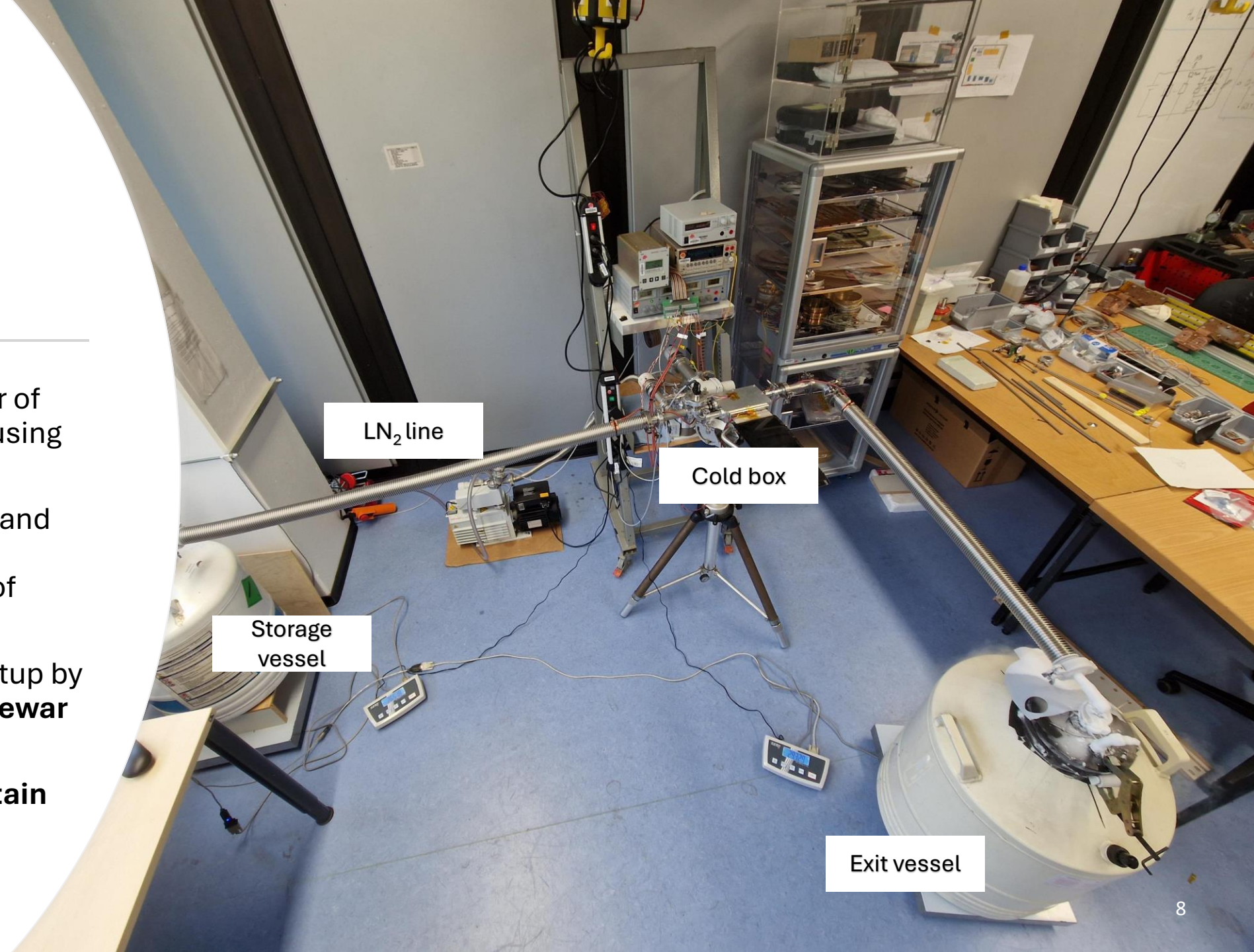
Cold box demonstrator with single fibre mat

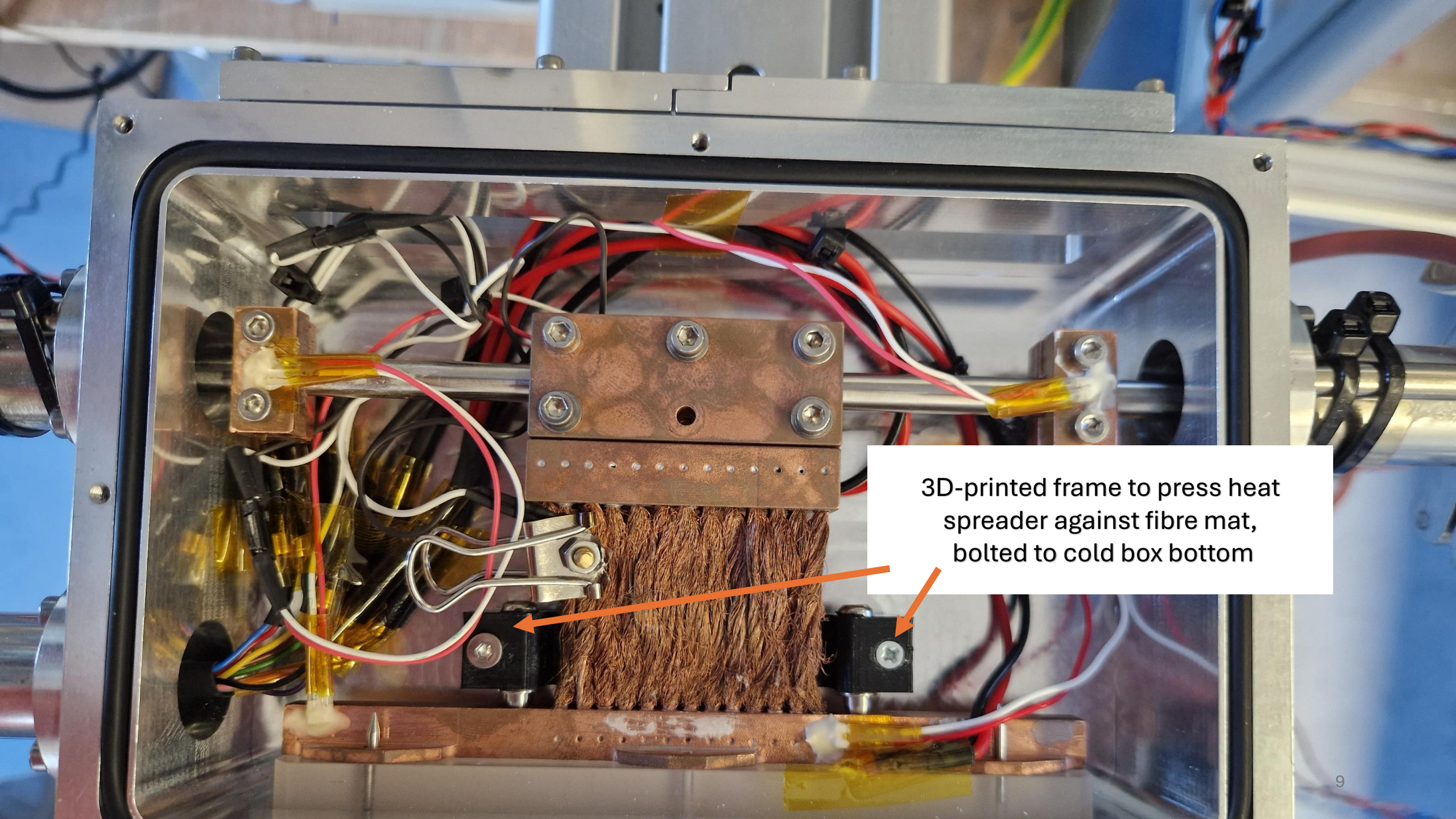
- Construct scaled-down cold box with single fibre mat for **tests on vacuum tightness & thermal properties**
- Compare results to expectation from thermal model
- After validation of performance, introduce SiPMs and readout and **perform test measurements** at room temperature and LN_2 temperature

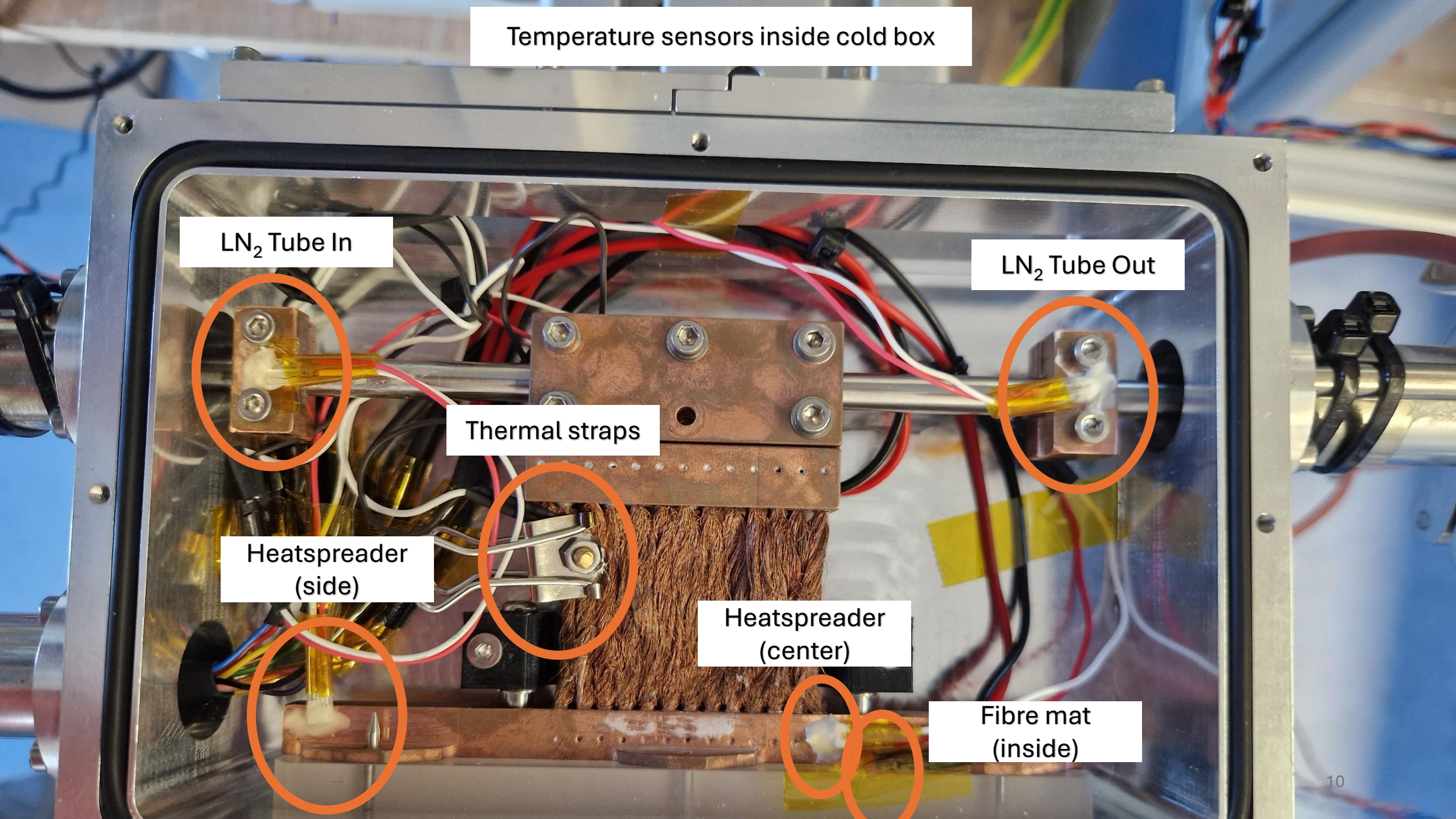


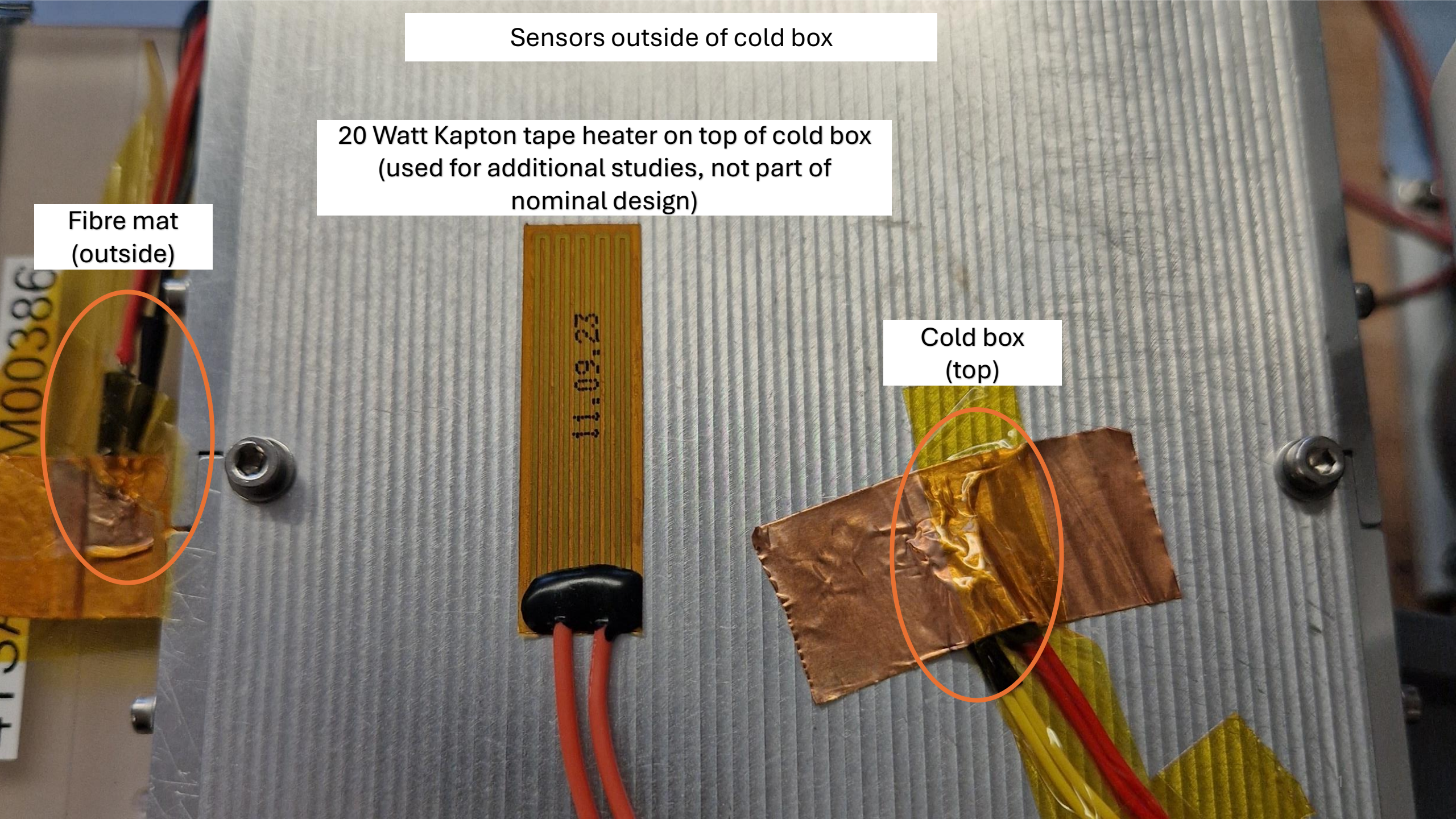
Test setup for demonstrator cold box

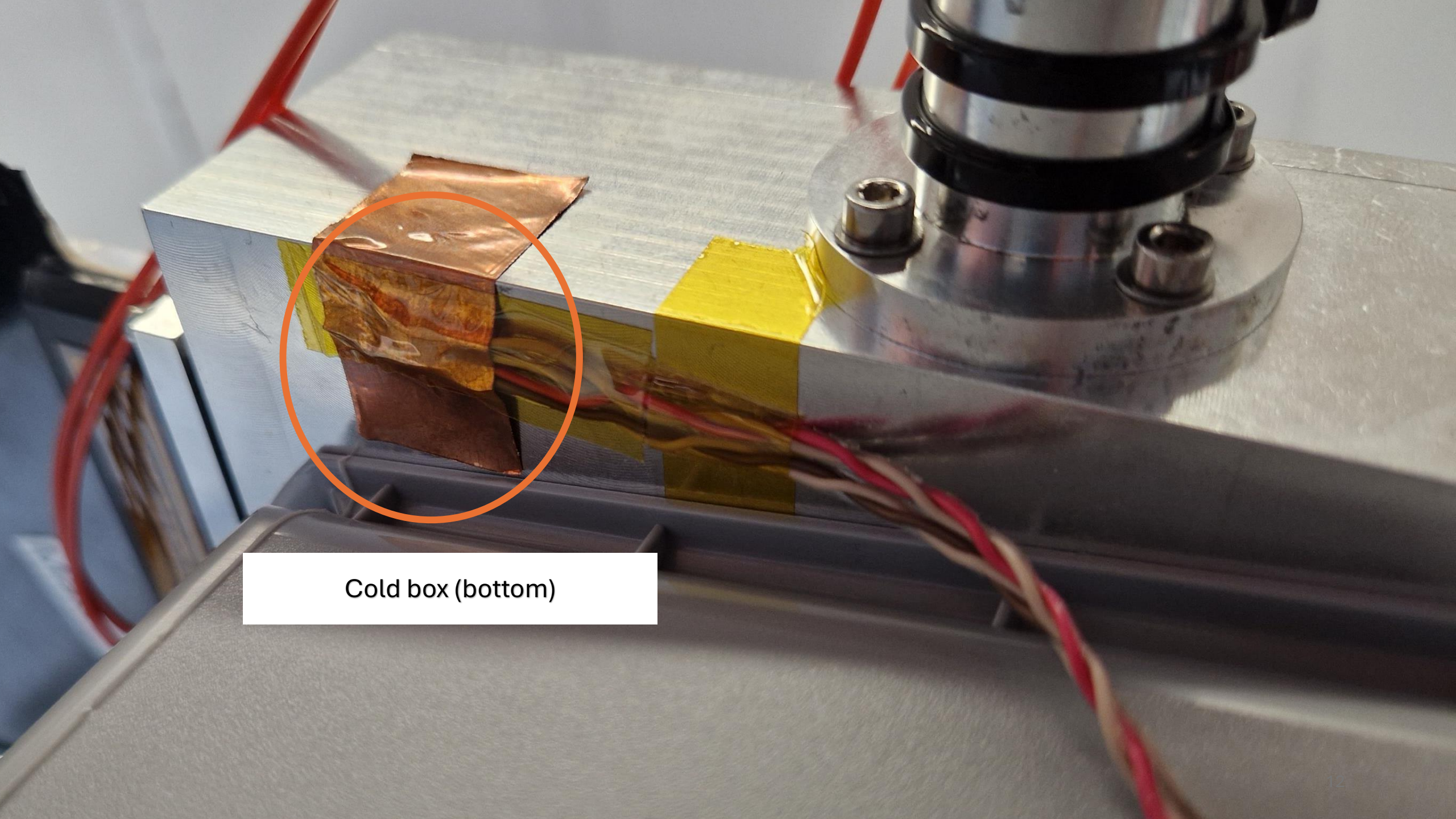
- Evaluate thermal behaviour of **scaled-down cold box** housing single 30 cm fibre mat
- Liquid nitrogen (LN_2) led to and from cold box via ¼“ tube, **vacuum-insulated** inside of 40mm corrugated tube
- LN_2 pushed through test setup by **overpressure in storage Dewar vessel**, no pumps
- Cold box does **not yet contain readout electronics**




3D-printed frame to press heat spreader against fibre mat, bolted to cold box bottom


Temperature sensors inside cold box
LN_2 Tube In
LN_2 Tube Out
Thermal straps
Heatspreader (side)
Heatspreader (center)
Fibre mat (inside)


Sensors outside of cold box
20 Watt Kapton tape heater on top of cold box (used for additional studies, not part of nominal design)
Fibre mat (outside)
Cold box (top)


Cold box (bottom)

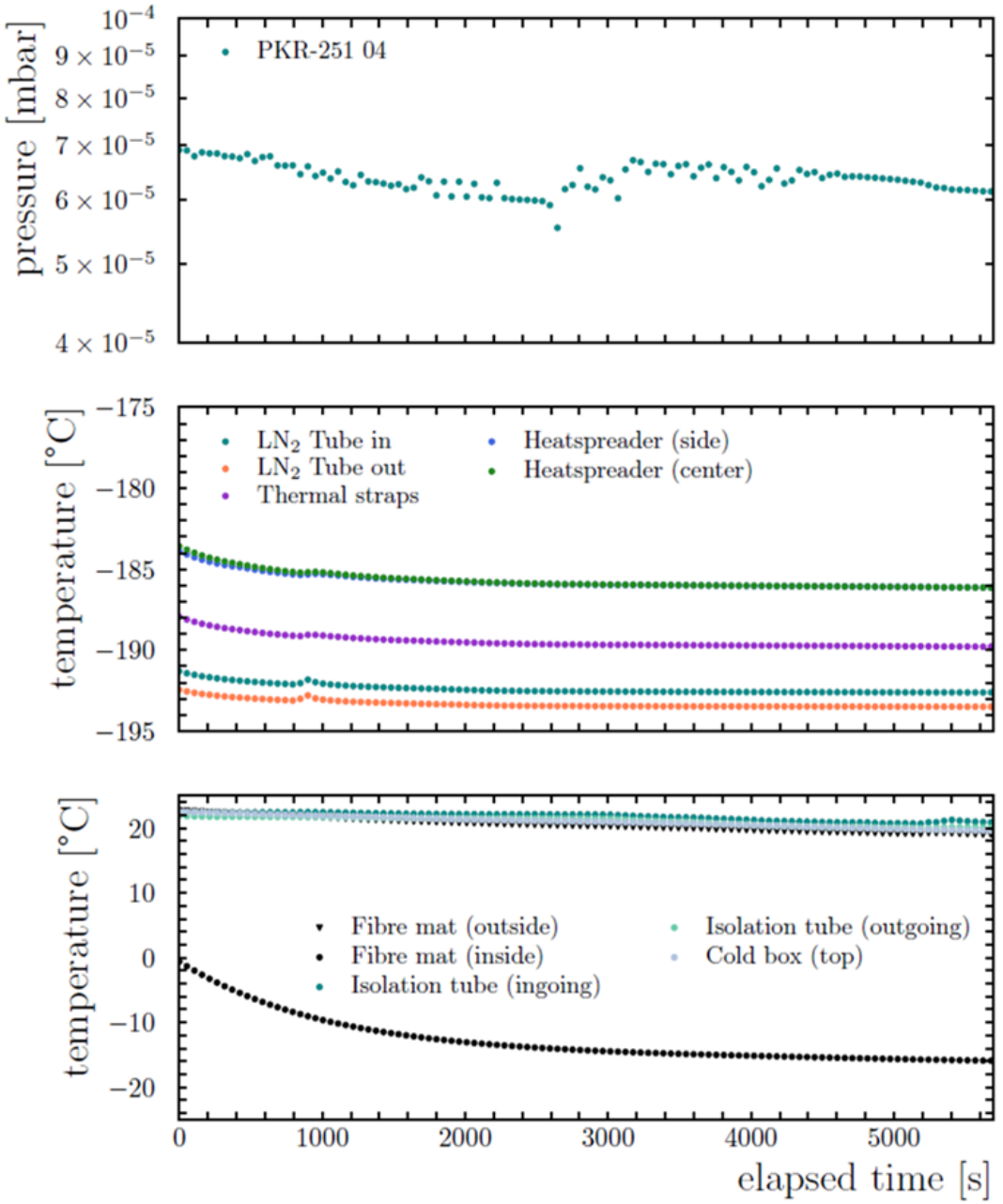
Nominal measurement

- **Stable temperatures** and pressure **for >1.5h of measuring time**
- **Gradient of temperatures** as expected (with the exception of Tube in vs Tube out)
- Isolation temperatures **above dew point**

Stable temperatures:

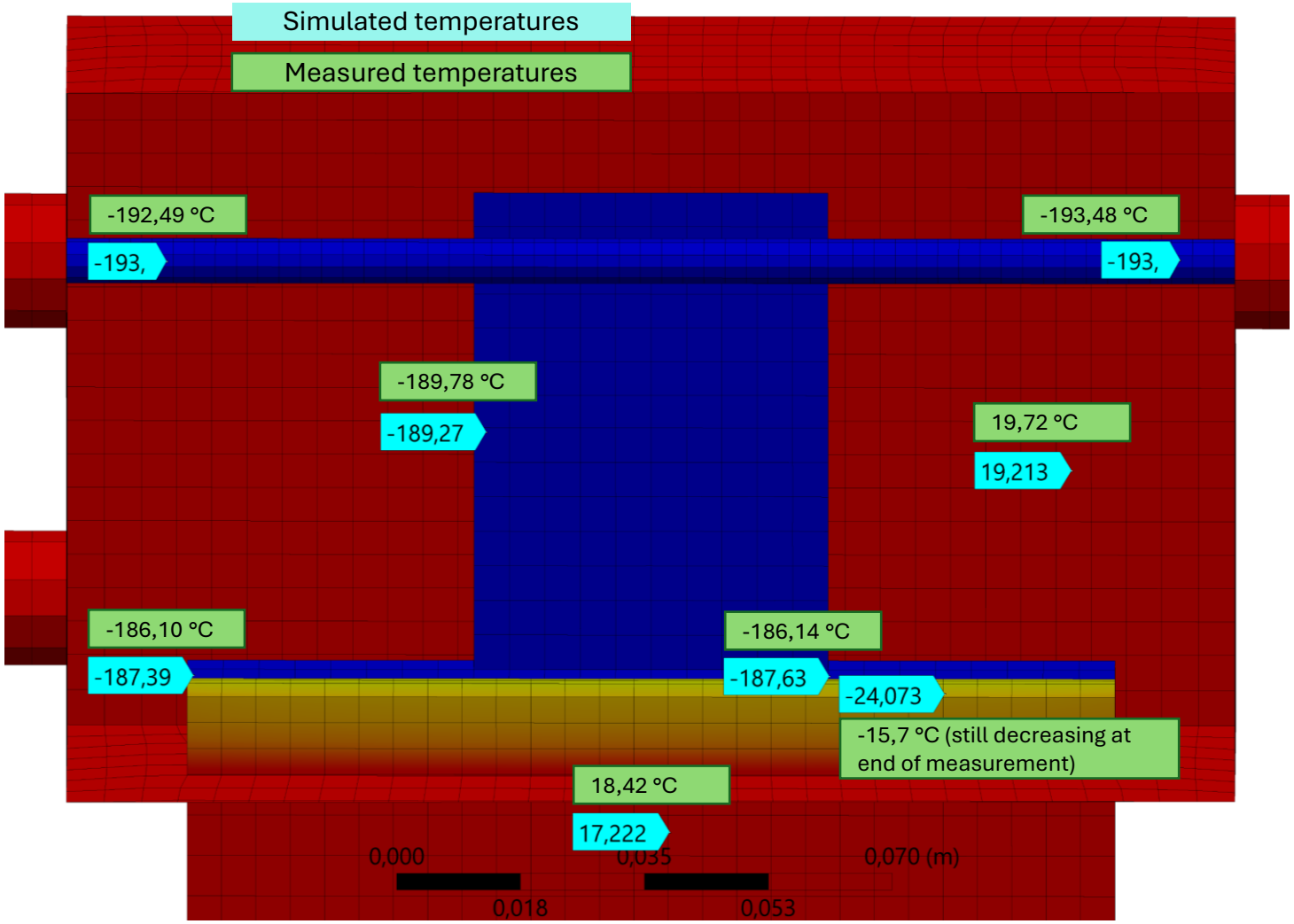
Tube in: -192.49 °C
Tube out: -193.48 °C
Straps: -189.78 °C
HS (center): -186.14 °C
HS (side): -186.10 °C

Cold box (top): 19.72 °C
Fibre mat (inside): -15.7 °C



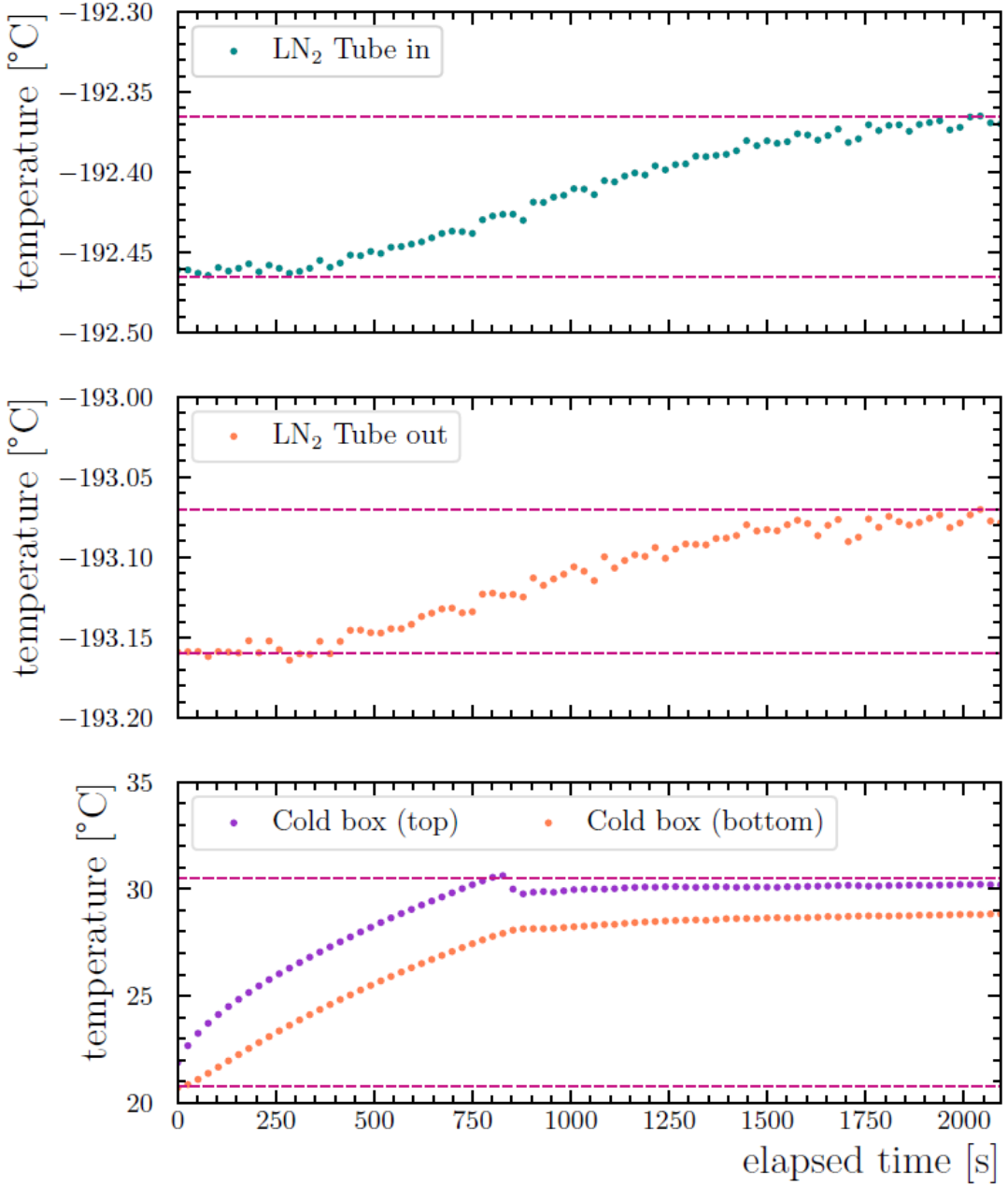
Thermal model of cold box with single fibre mat

- Temperatures obtained from thermal model **in good agreement** with measurements
- **Lowest end piece temperature** expected inside box at ~ -24 °C
- Cold box stays approx. **at room temperature**
- **Mat temperature** outside cold box drops to ~ 17 °C
- Simulated **heat load from fibre mat ~ 2W,** validated on measured temperature data



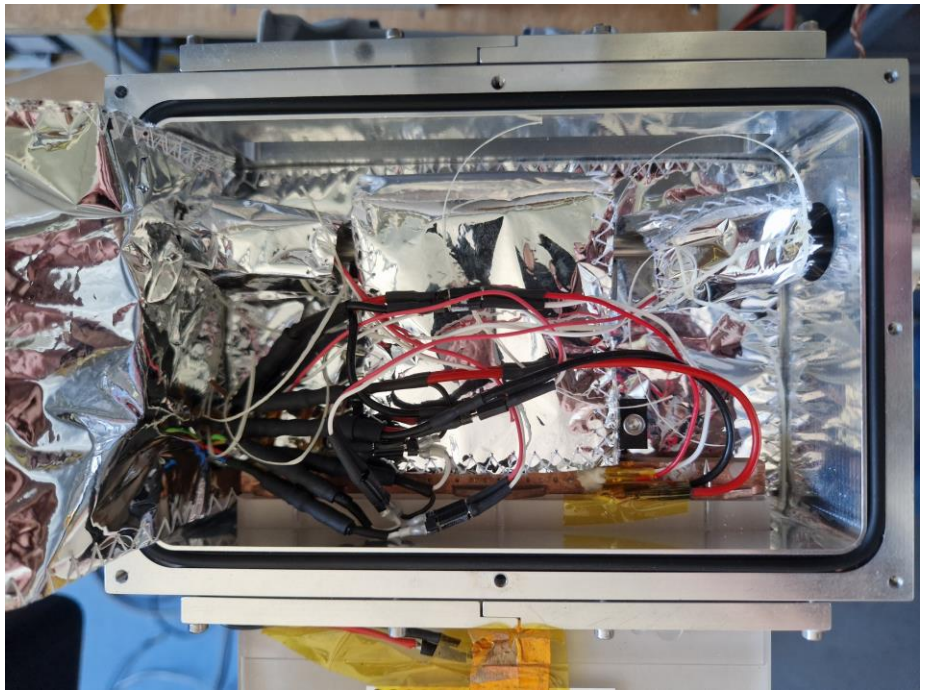
Effects of thermal radiation inside cold box

- Thermal radiation inside cold box **non-negligible**
- Sensor readings of sensors on LN_2 line show **clear response** when box surface is heated



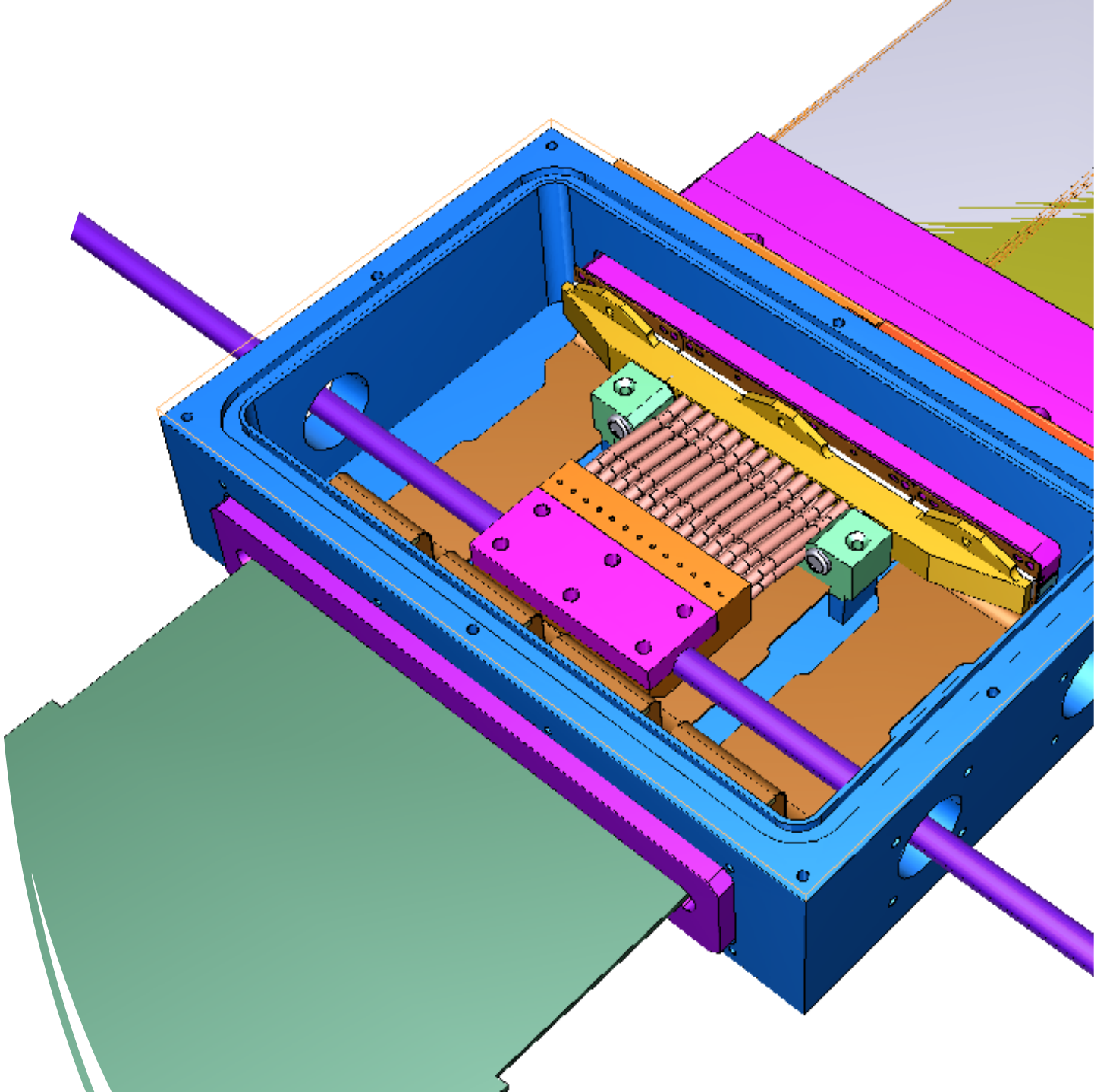
Effects of thermal radiation inside cold box

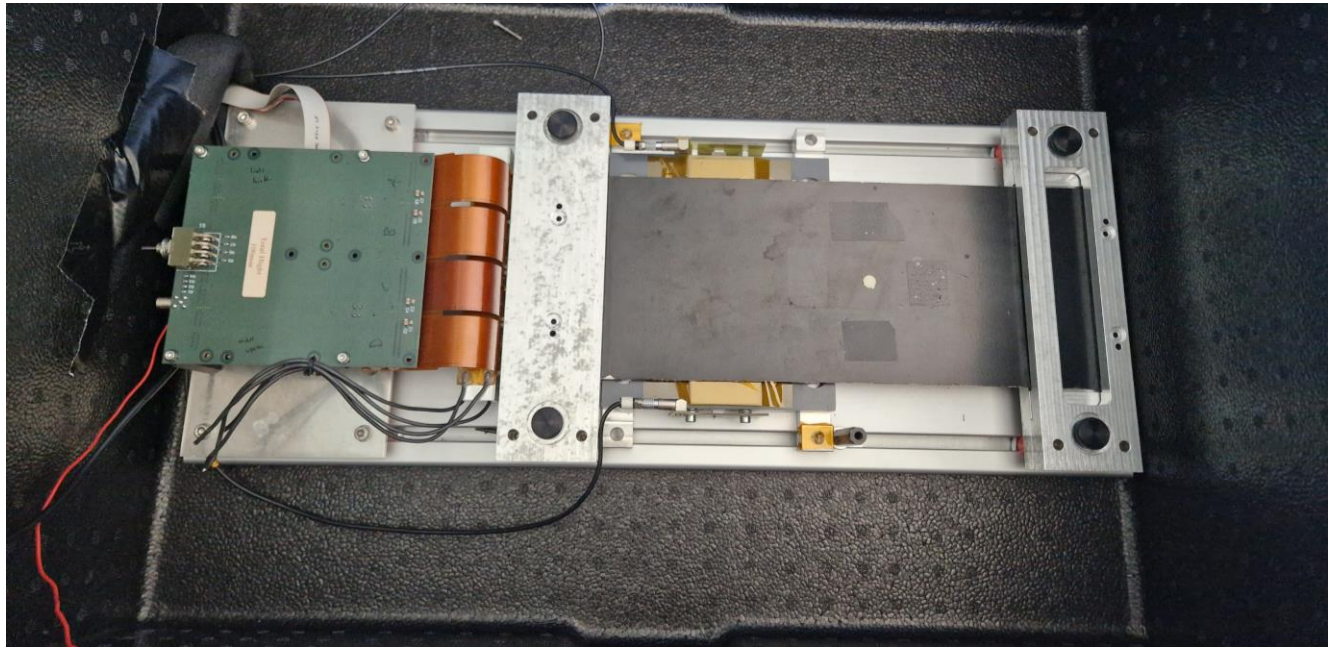
- Thermal radiation inside cold box **non-negligible**
- Sensor readings of sensors on LN_2 line show **clear response** when box surface is heated
- Introduce **MLI inside box** to decouple from thermal radiation
- After introduction of MLI, **heat load per mat reduced** from 2 W to approx. 1.6 W



Installation of the readout system

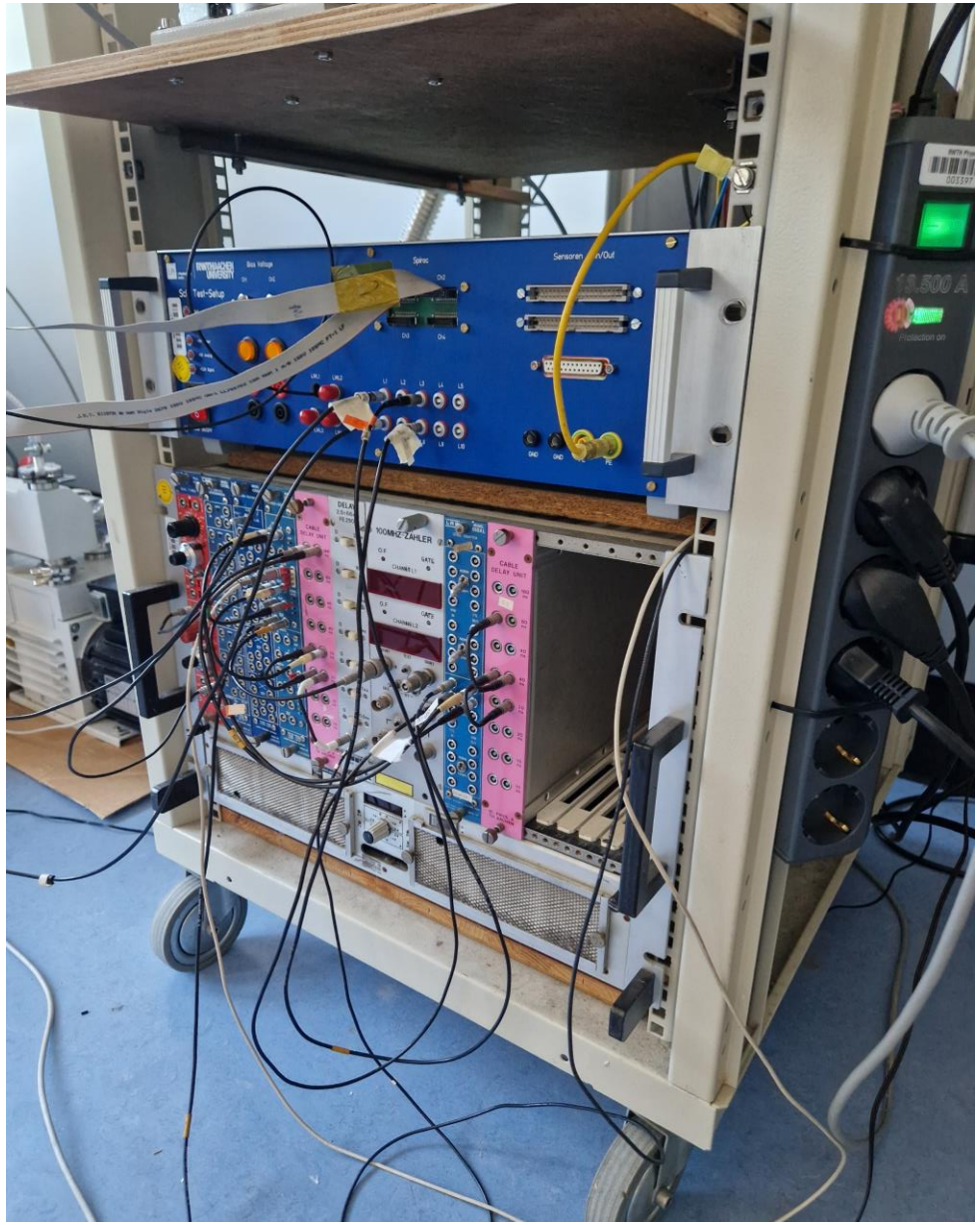
- Aim to introduce **four SiPMs** to the single-mat cold box
- Single **PCB glued into aluminium frame** as electronics feed-through into the vacuum insulation
- **Use existing readout electronics** from SciFi test stand

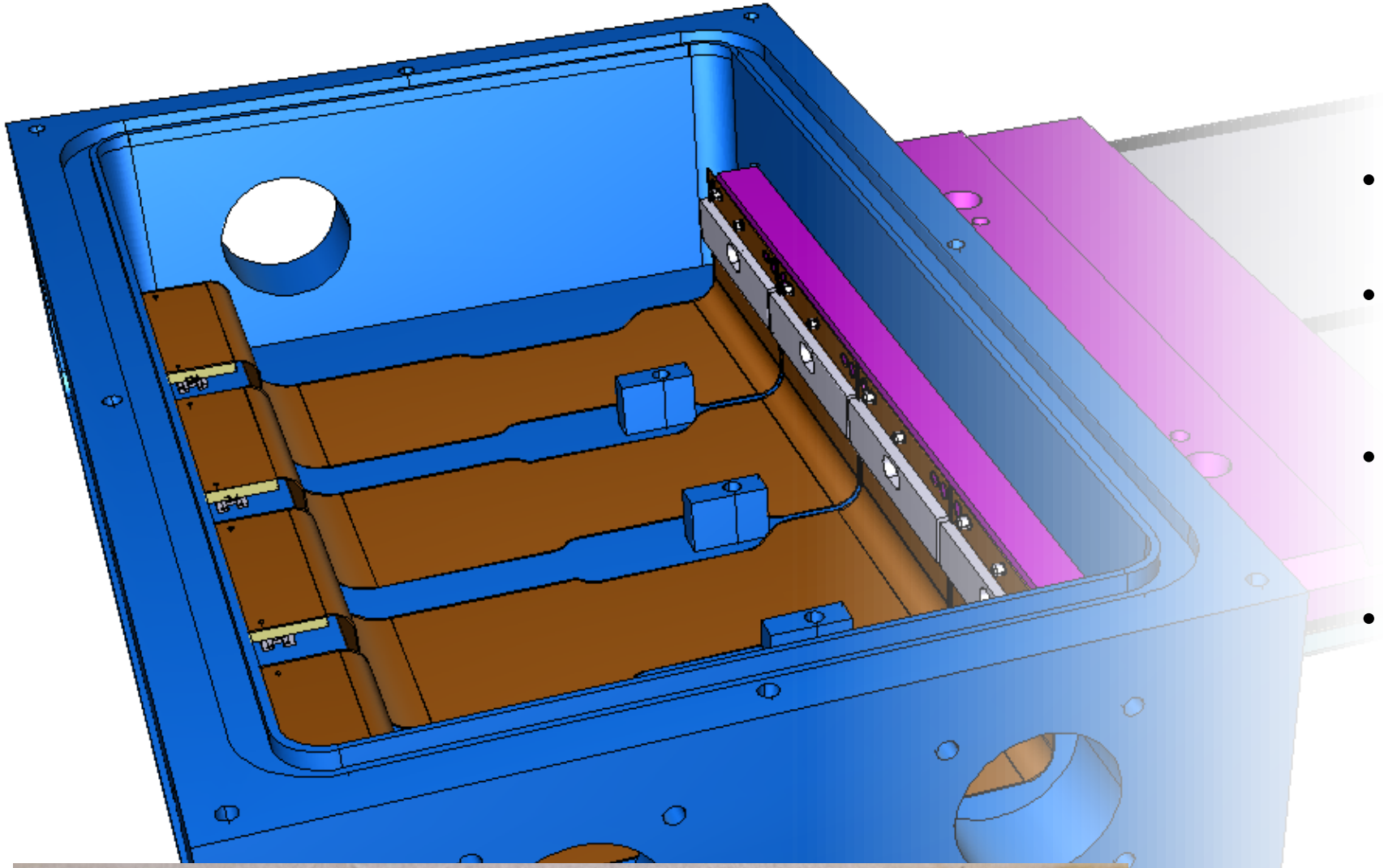




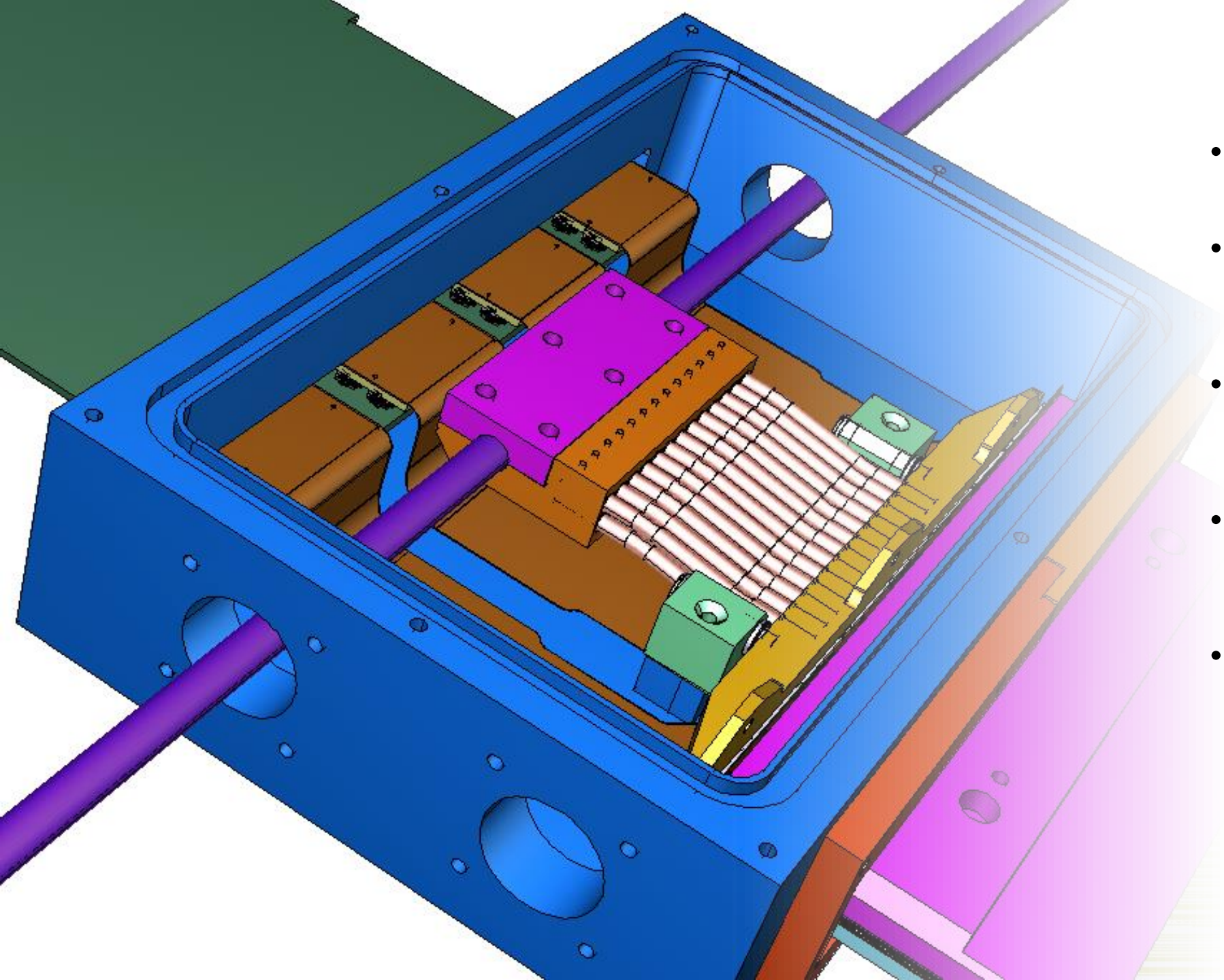
Testing the readout electronics

- Bachelor student worked **on installation and tests of the readout electronics**
- Tests at room temperature completed, use the **same electronics** in the Cryo-SciFi test stand in upcoming weeks





- **Alignment pins** in fibre mat end piece
- **SiPMs aligned with fibres** using alignment holes in flex cable
- Kapton flex cables led along bottom of the cold box **without direct contact**
- In this demonstrator box, use FBK2022 SiPMs (provided by G. Haefeli / EPFL)



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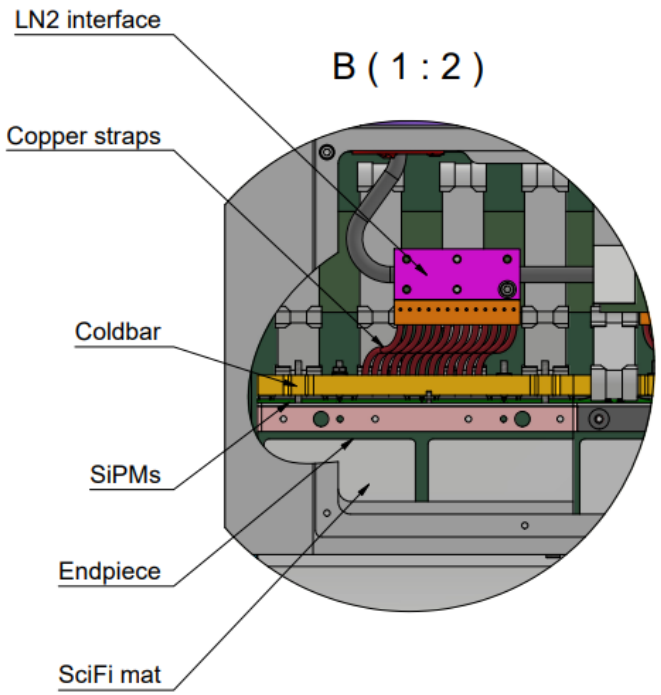
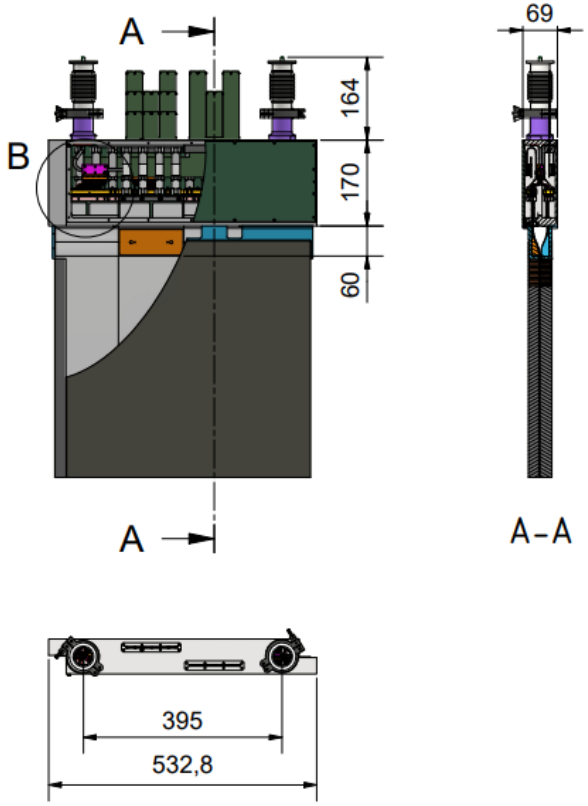
- **Custom PCB** allows for connection of the SiPM cables to existing SciFi test stand readout electronics **outside of the cold box**

Summary and Outlook

- **Development of a fully equipped read out box** for a full module already advanced
- Tests of a **single-mat cold box** without readout electronics show promising results
- Measurements are in **good agreement with thermal simulation**
- Integration of a **working readout system** using 4 SiPMs inside the cold box ongoing, expect first results within upcoming weeks





Thank you for your attention!