

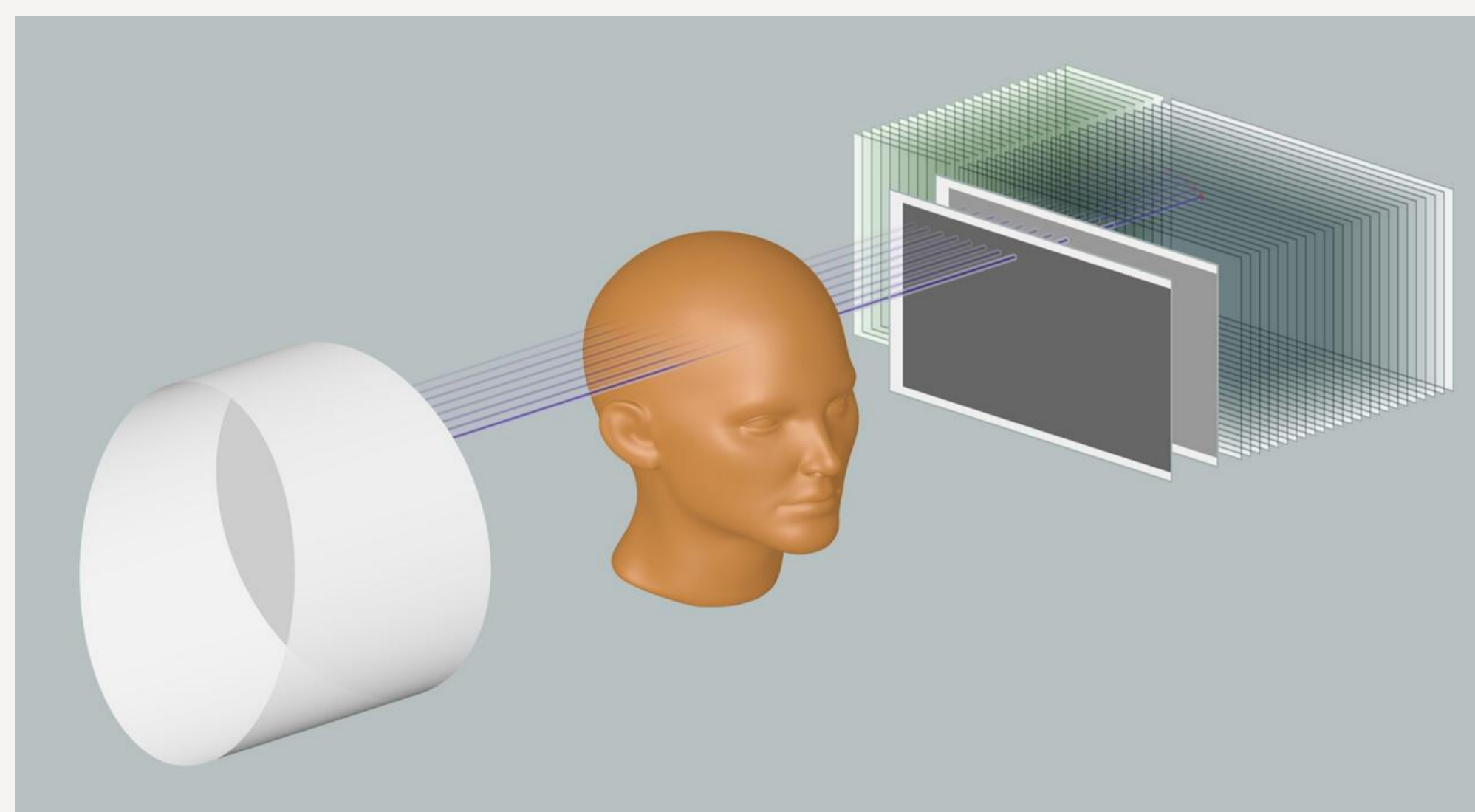
Design and integration of CMOS tracker layers in digital tracking calorimeter for pCT application

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Introduction

Proton Computed Tomography (pCT) is an emerging imaging modality in particle therapy as it enables direct reconstruction of 3D map of relative stopping power (RSP) of the target.



Schematic of pCT system. Image courtesy[1]

A typical pCT detector records tracks of every single particle before and after crossing the target and residual energy after crossing the target. Hence the device is made of extra-thin tracking detectors and an energy/range detector.

Prototype Digital Tracking Calorimeter (DTC)

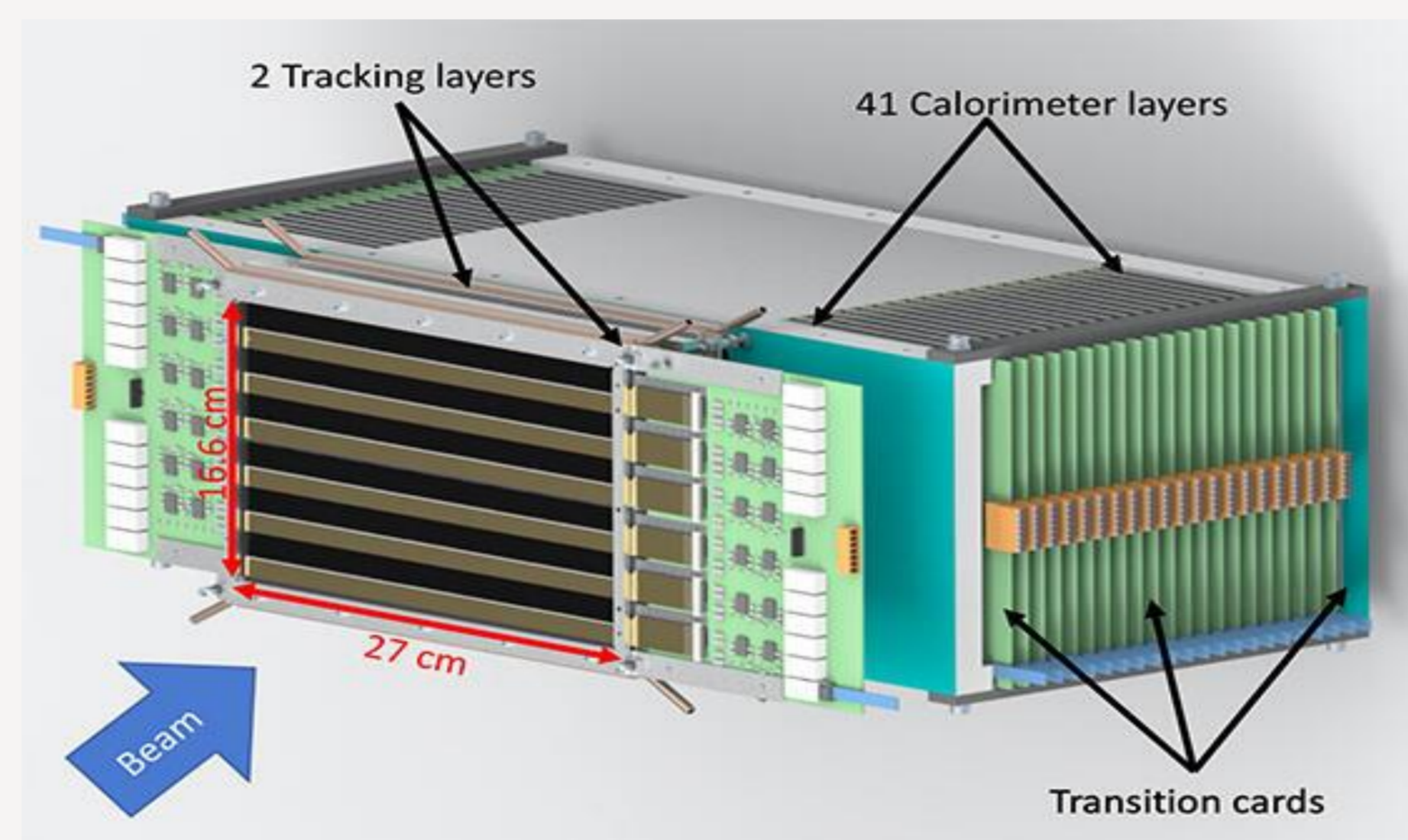
- 43 sensitive layers of pixelated silicon radiation detectors.
- Tracking layers: First two layers for tracking position of the protons.
- Calorimeter layers: next 41 layers, separated by absorber (Al plates)
- Each layer covers 27 cm × 16.6 cm, 108 CMOS sensors
- Each sensor (ALPIDE chip): 500k pixels of the size of 29.24 x 26.88 μm².

For more information refer to: [2,3]

Tracking layers: First two layers of device

Design and integration is based on:

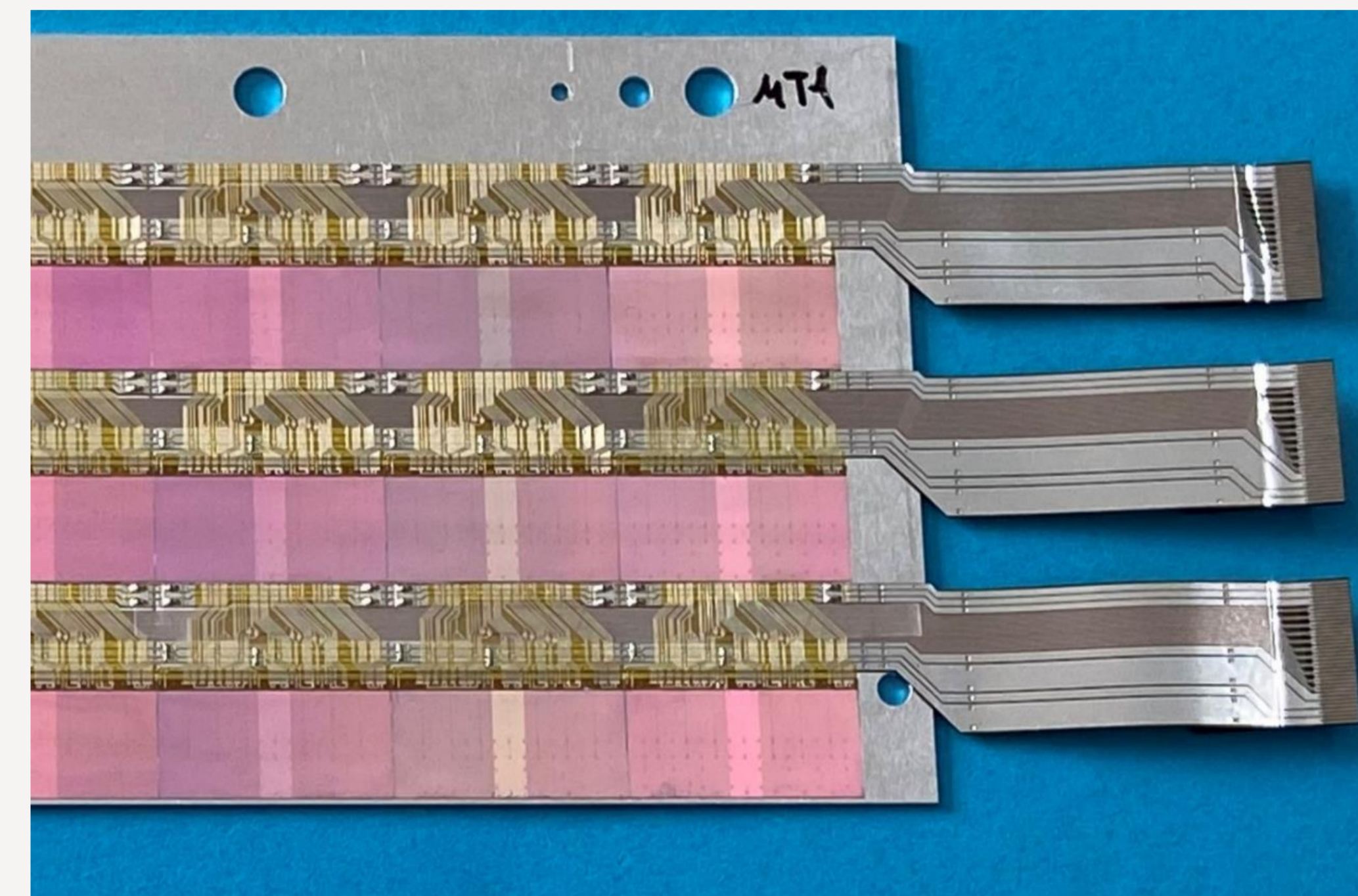
1. Connecting CMOS sensors to multilayer flex cables
2. Material between the sensor layer: CMOS sensors connected to flex cables will be glued onto a material as a support to make the layer
3. Mechanical support structure and cooling



Schematic drawing of Bergen pCT detector [3]

1. Chipcables and Single-point Tape-Automated Bonding (SpTAB):

- SpTAB: ultrasonic welding of aluminum leads to flexes, chip cables leading to a bond i.e.:
 - monometallic, non-corrosive
 - uniform, mechanically stable joint
- Every ALPIDE sensor mounted on Chip cables with SpTAB is tested
- Only good ALPIDE+ chip cable is connected to multilayered flex
- Increased reliability and production yield [5]



ALPIDE chips connected chip cables, then to flexes and further glued to aluminum support at LTU, Ukraine. All Images courtesy [5]

2. Material between the sensor layers:

- Low Z: reduce Multi. Columb Scatt.(MCS)
- As thin as possible (< 0.45 mm for two layers): reduce error in positioning
- Good thermal conductivity to handle the heat produced by sensors

Sandwiched Carbon Fiber (CF) sheets



Sandwiched Carbon Fiber sheet 200 mm x 290 mm x 0.3 mm fabricated at St Petersburg State University [6] Image Courtesy [5]

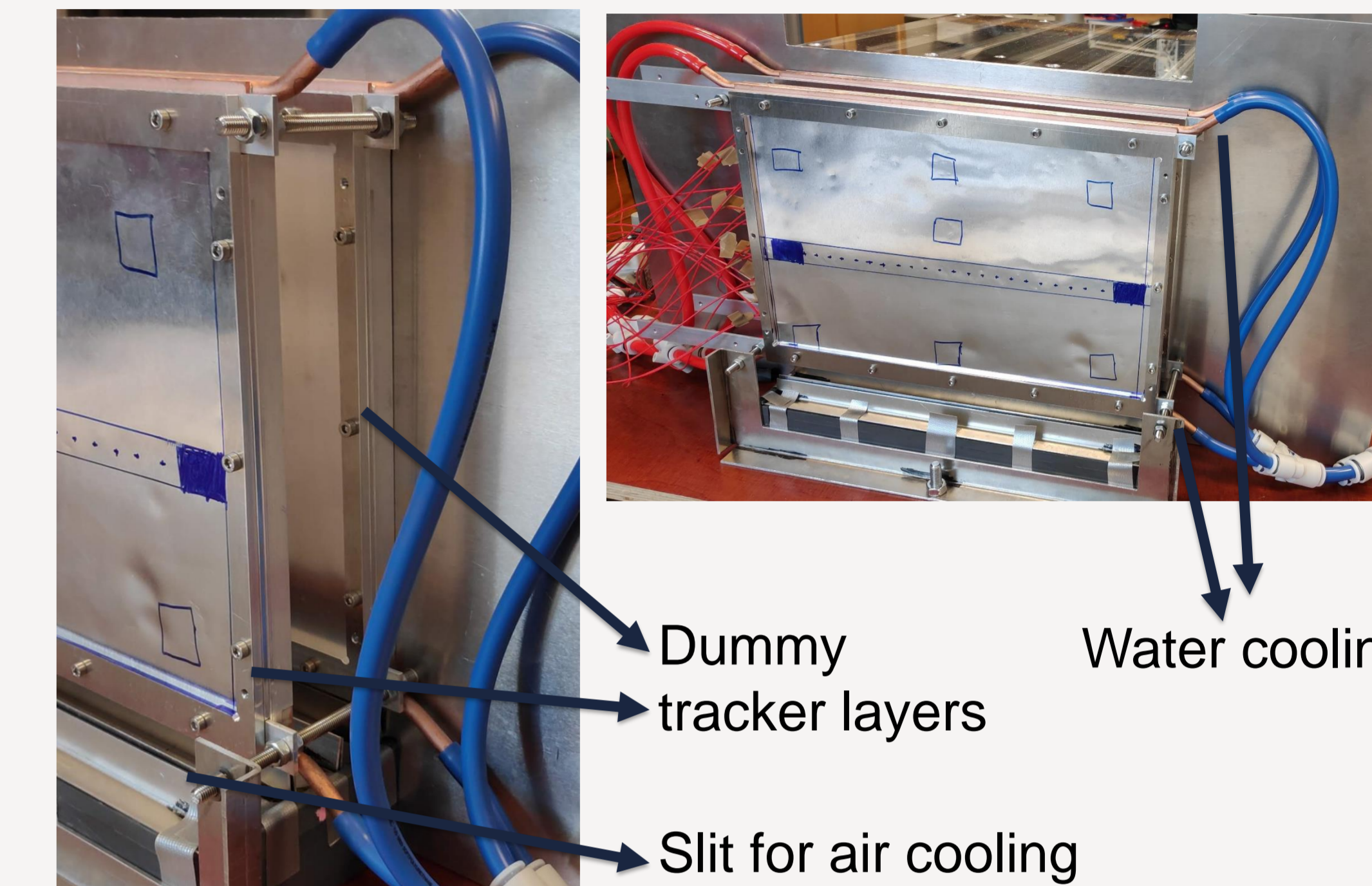
Materials used:

- Pyrolytic graphite paper: thickness 50 μm
- Carbon fleece: 8 g/m², thickness 60 μm
- Epoxy Resin 2.3 g/m², thickness 25 μm

Main Contribution to this work :

- G. Feofilov, S. Igolkin, Saint Petersburg State University, Russia
- A. Van den Brink, Utrecht University, Netherlands
- I Tymchuk, LTU, Kharkiv, Ukraine
- S Mehendale, University of Bergen, Norway

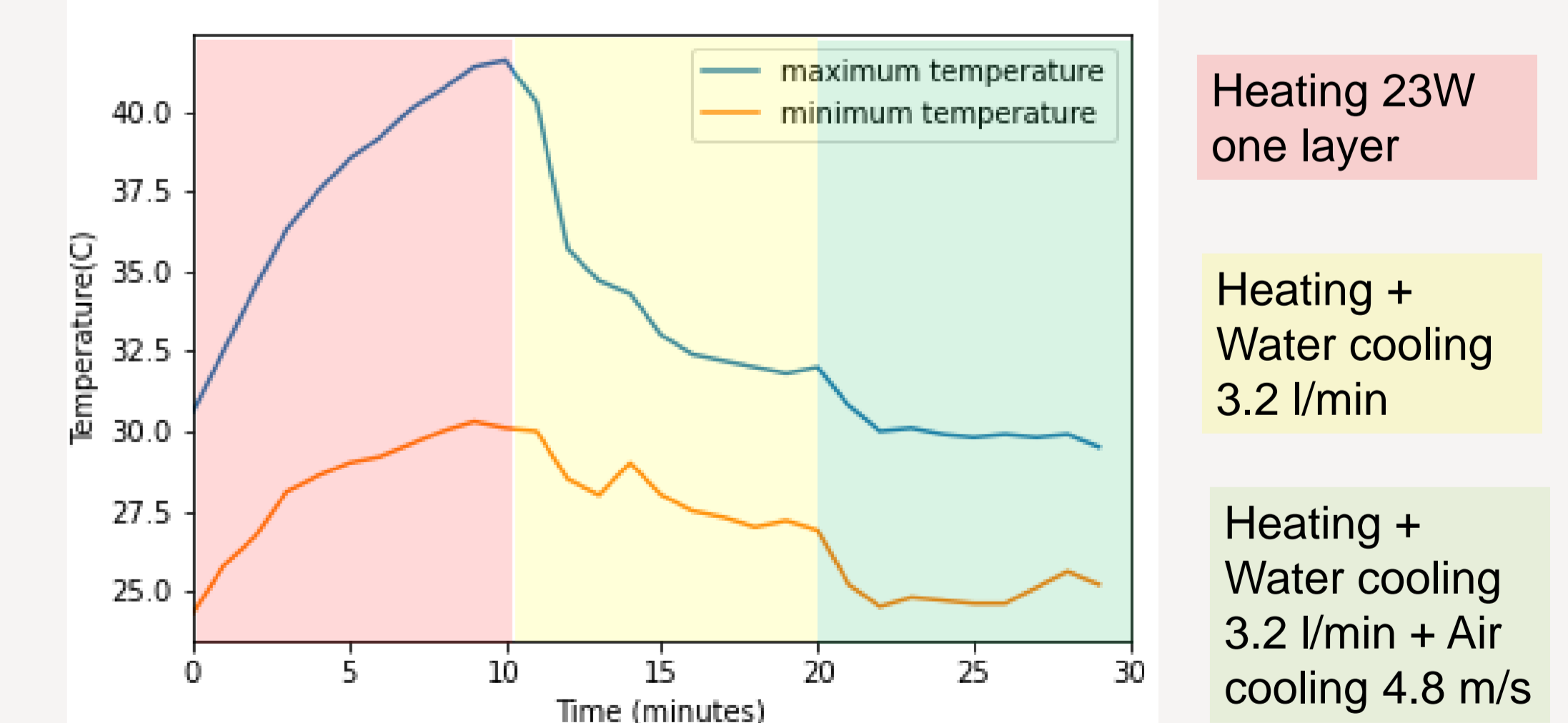
3. Mechanical support structure and cooling



Prototype tracking layers designed fabricated by Utrecht University, tested at University of Bergen

- Two CF sheets with CMOS sensors only on one side, when assembled so as the side with sensors face each other (with spacer between): one tracking layer.
- Layers are water-cooled from top and bottom in parallel
- Forced air flow on the side of CF sheet without sensors

Effect of cooling on temperature distribution of tracker layer



Next Steps:

- Mass production of CF sheets.
- Optimization of cooling parameters.
- Final production of tracker layers and assembly.

REFERENCES

- [1] <https://www.uib.no/en/ift/142356/medical-physics-bergen-pct-project>
- [2] V. Eikelinad et al, poster, PSD12, Birmingham 2021
- [3] A High-Granularity Digital Tracking Calorimeter Optimized for Proton CT, Front. Phys., 22 October 2020
- [4] H.Pettersen, PhD thesis, 'A Digital Tracking Calorimeter for Proton Computed, Tomography', University of Bergen, 2018
- [5] Dr. Ihor Tymchuk, LTU, Kharkiv, Ukraine, Personal communications
- [6] Dr Grigory Feofilov, St. Petersburg University, Russia, Personal communications
- [7] A.van der Brink, Utrecht University, Personal communications

Bergen pCT collaboration :

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