Advances in low speed gas cooling and extra ligthweght self-supported mechanics for ALICE ITS-3 modules

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Reported by G.Feofilov

ITS-upgrade WP5 meeting, 10 May 2022, 16300 → 17:00 Europe/Zurich

https://indico.cern.ch/event/1158834/

Layout

Introduction

Part-I: Low-speed gas cooling of large area thin pixel sensors

- Space blanket instead of thermally isolated barrel
- Space blanket and 3 cylinder layers with heaters

Part-II: Ultraligthweight self-supported mechanics for ALICE ITS-3 modules

Geometrical parameters of the ITS-3[1]

Beampipe inner/outer radius (mm)	16.0/16.5		
IB Layer parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length (sensitive area) (mm)	270	270	270
Pseudo-rapidity coverage[a]	±2.5	±2.3	±2.0
Active area (cm^2)	305	408	508
Pixel sensors dimensions (mm^2)	280×56.5	280×75.5	280×94
Number of pixel sensors / layer	2		
Pixel size (μm^2)	$O(15 \times 15)$[b]		

[a] The pseudorapidity coverage of the detector layers refers to tracks originating from a collision at the nominal interaction point ($z = 0$).

[b] For the fallback solution the pixel size is about a factor two larger ($O(30 \times 30)\ \mu m^2$).

- Please, note rather compact dimensions!
- State-of-the-art solutions are required!

[1] ALICE-PUBLIC-2018-013

ITS-3 pixel sensor

power density below **140mWcm^{-2}**

power density below **20mWcm^{-2}**

Diagram of stitched sensor in one direction (horizontal and vertical dimensions not to scale). Stitching in the vertical direction is also possible.[1]

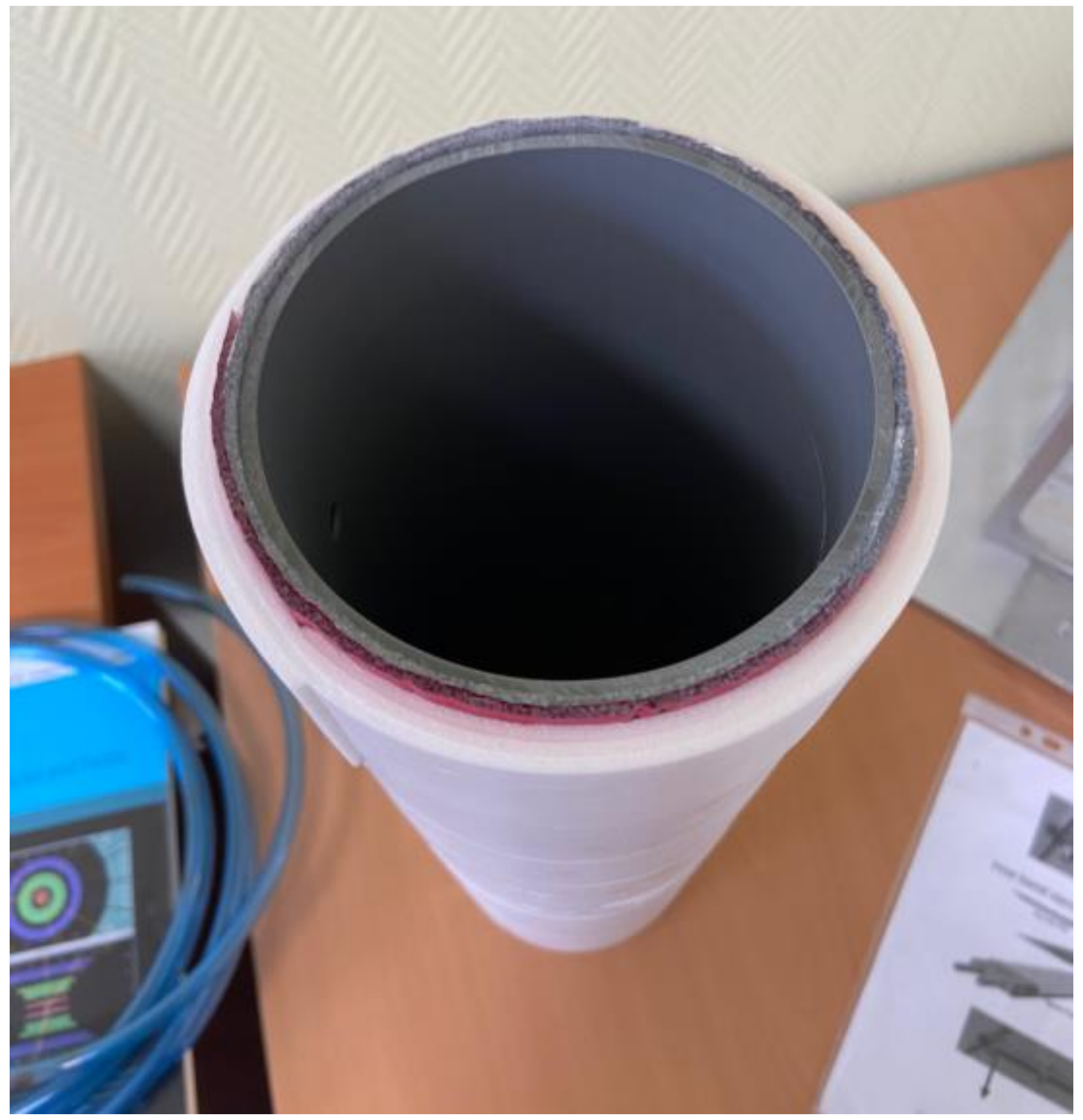
[1] ALICE-PUBLIC-2018-013

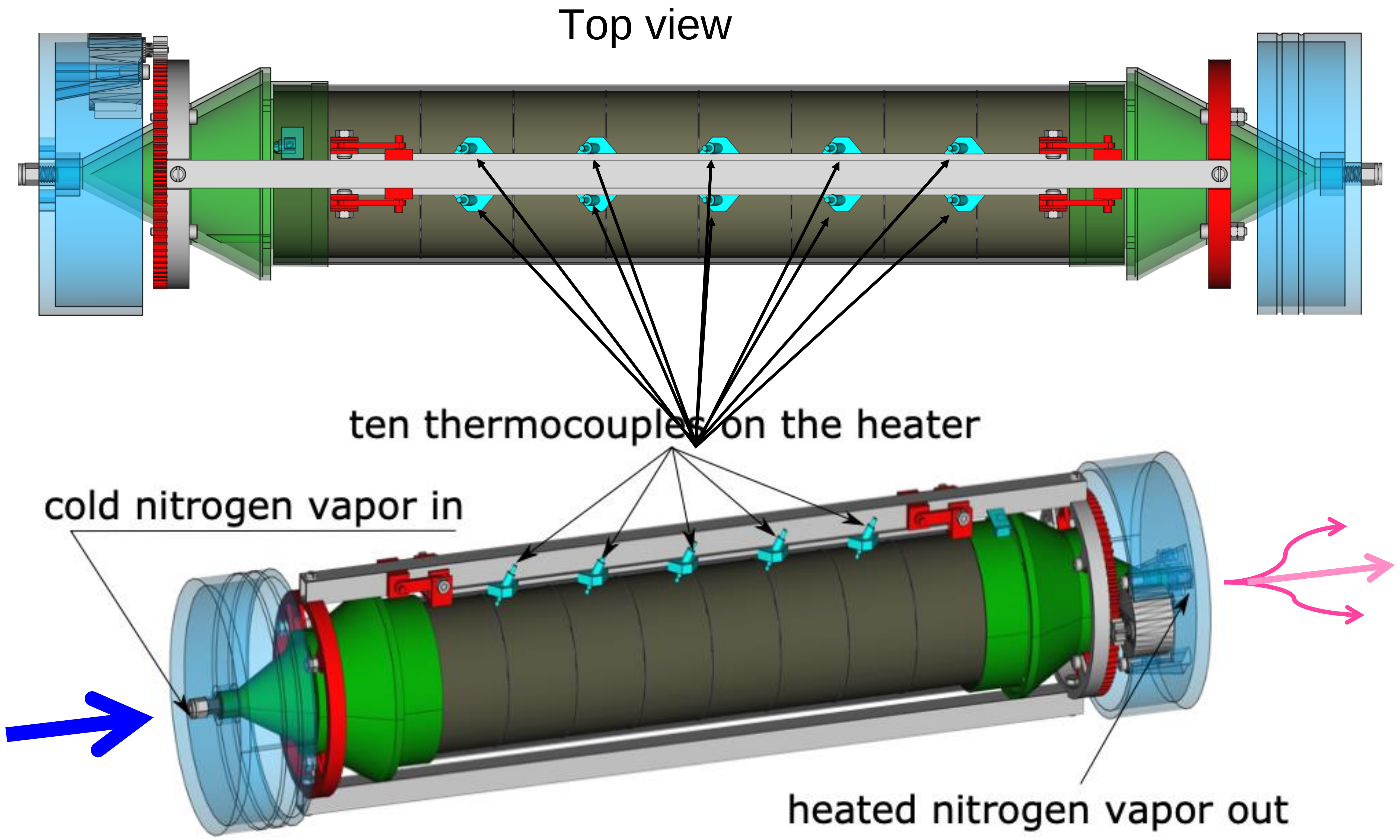
- We consider the underpressure liquid cooling as the feasible solution for power density **140mWcm^{-2}**
- **Low-speed cold gas is proposed to cool large are thin pixel sensors in order to minimize vibrations**

Low-speed gas cooling of large area thin pixel sensors

one layer

Cooling system with thermally well isolated barrel
Cylinder Layer 2 mock-up



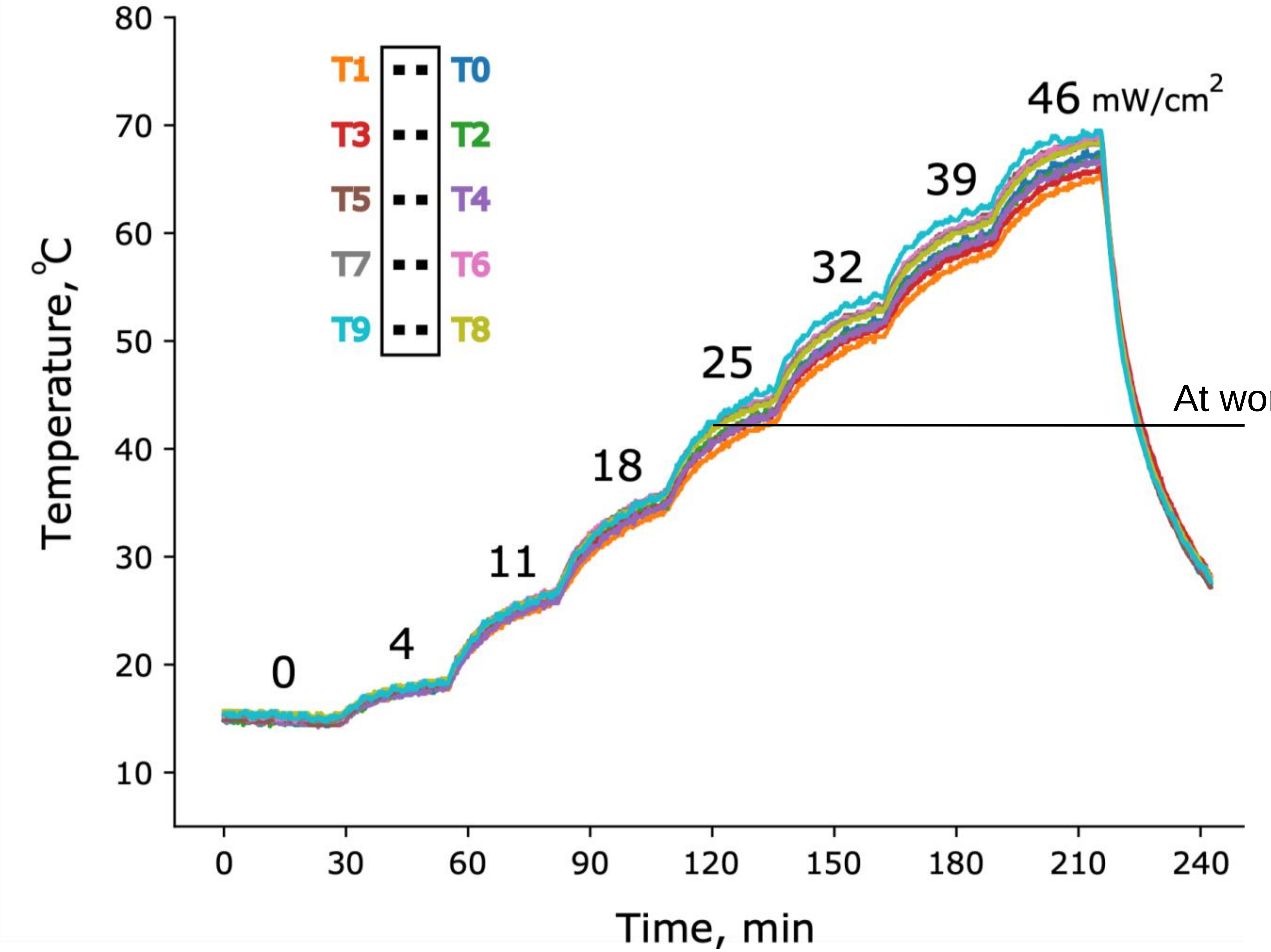


G.A. Feofilov, V.I. Zherebchevsky, et al.
G.Feofilov
ITS3 -WP5 (25 January 2022) · Indico (cern.ch)

Left: Photo of thermally isolated barrel.
Right: a scheme of cylinder Layer 2 mock-up with heater and nitrogen cooling system.

one layer

Temperature distributions measured at different heat loads with blowing from one side

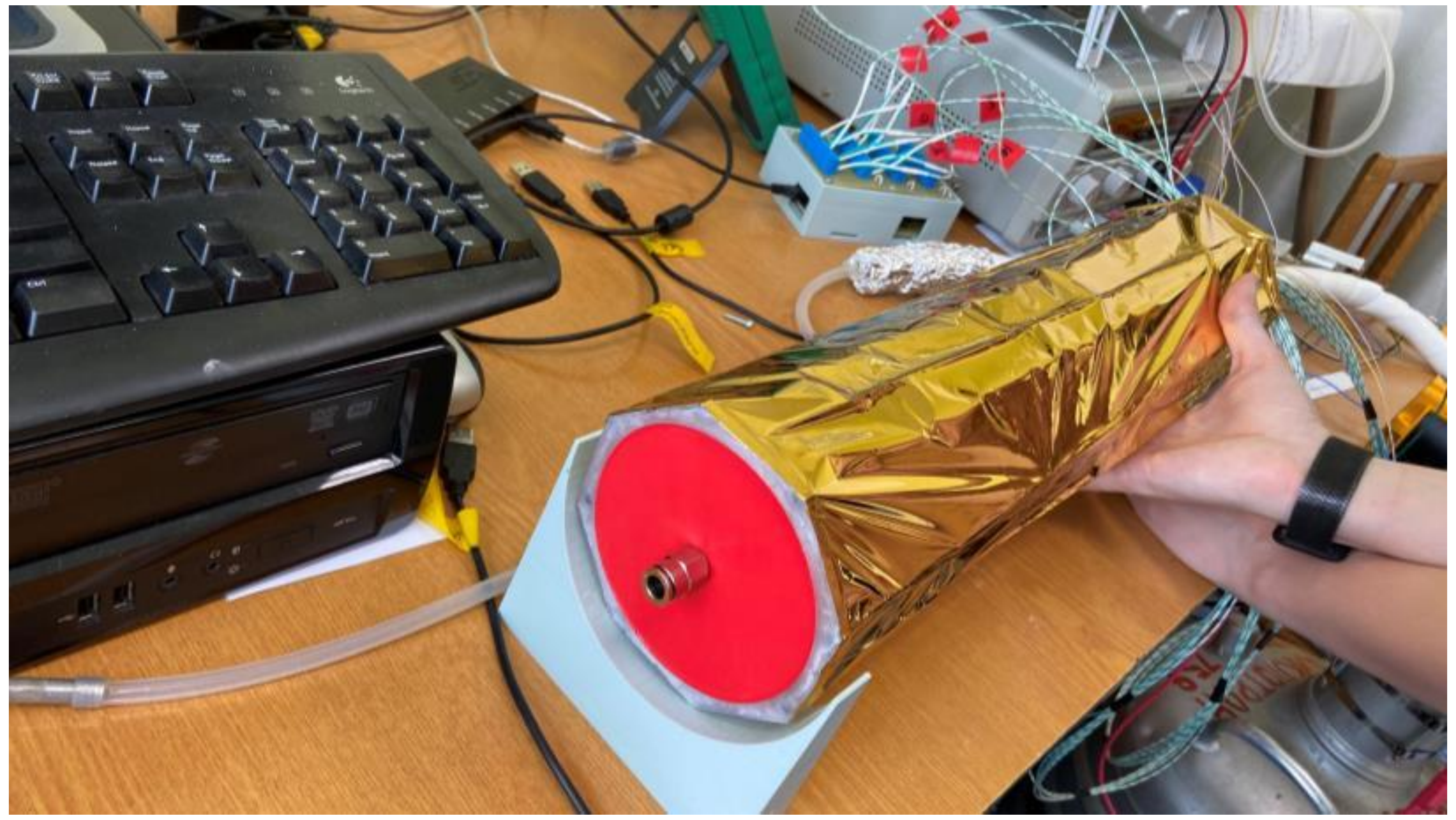


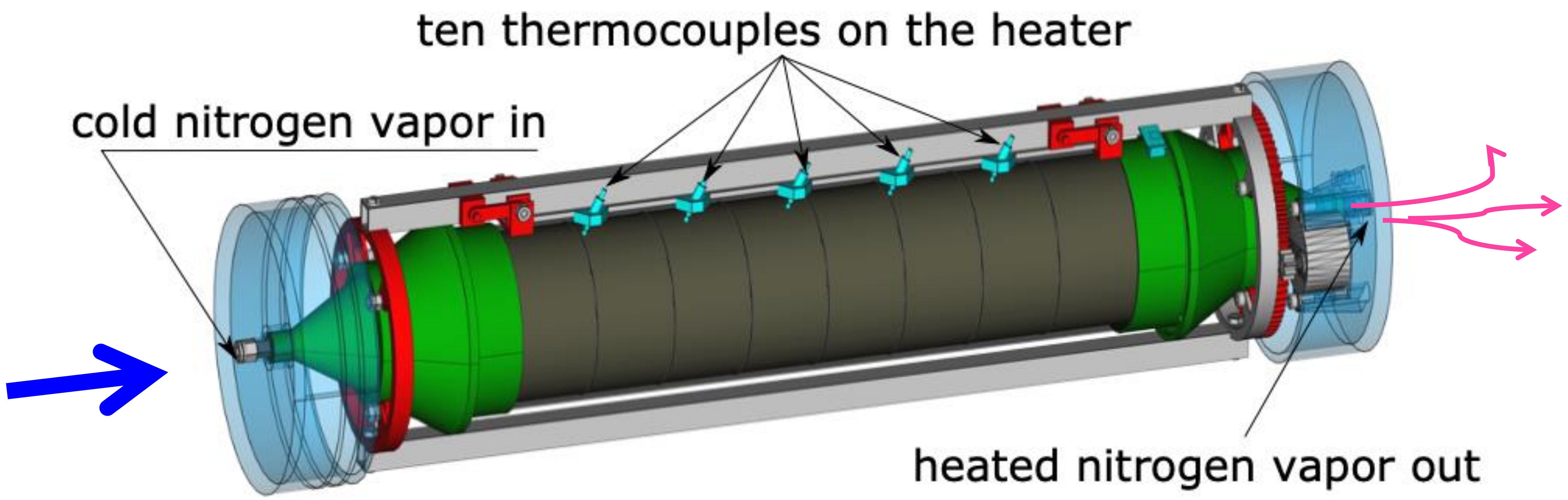
blowing from one side

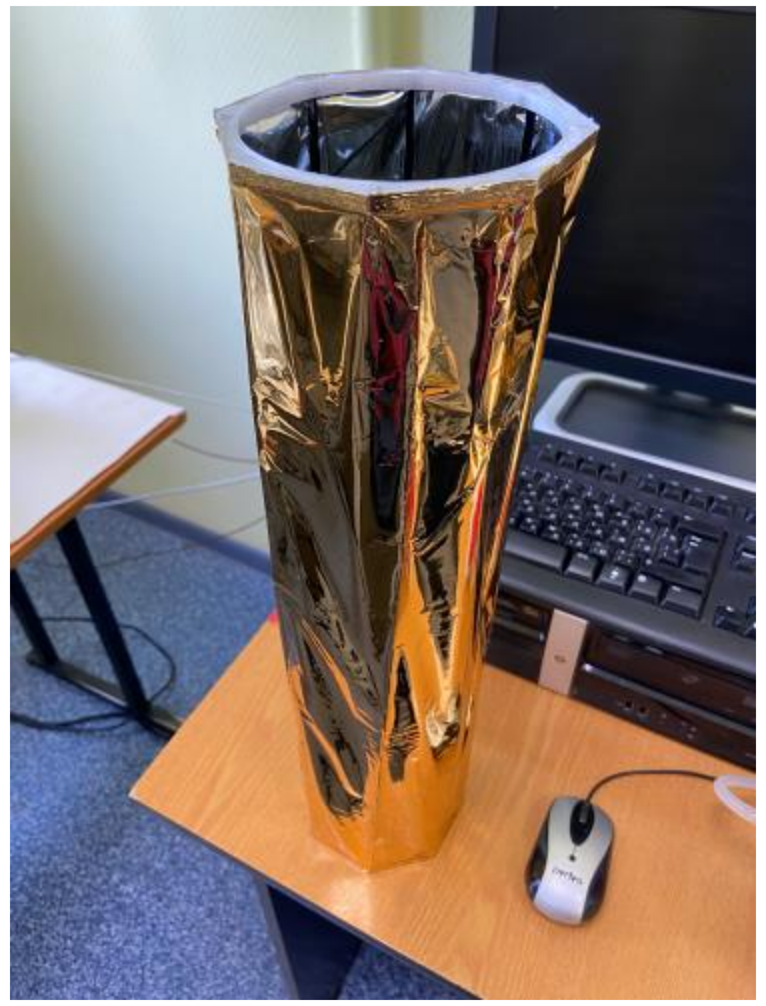
At working power density about 20 mW/cm^2 the temperature is +40 C.

Inlet temperature of nitrogen is +10 C. Blowing of nitrogen from one side.

Space blanket instead of thermally well isolated barrel.
Cylinder Layer 2 mock-up







Left: photo of self-supported outer shell with space blanket.
It consists of low-weight rigid CF bars, space blanket and plastic support ring.

Right: a scheme of cylinder Layer 2 mock-up with heater and nitrogen cooling system

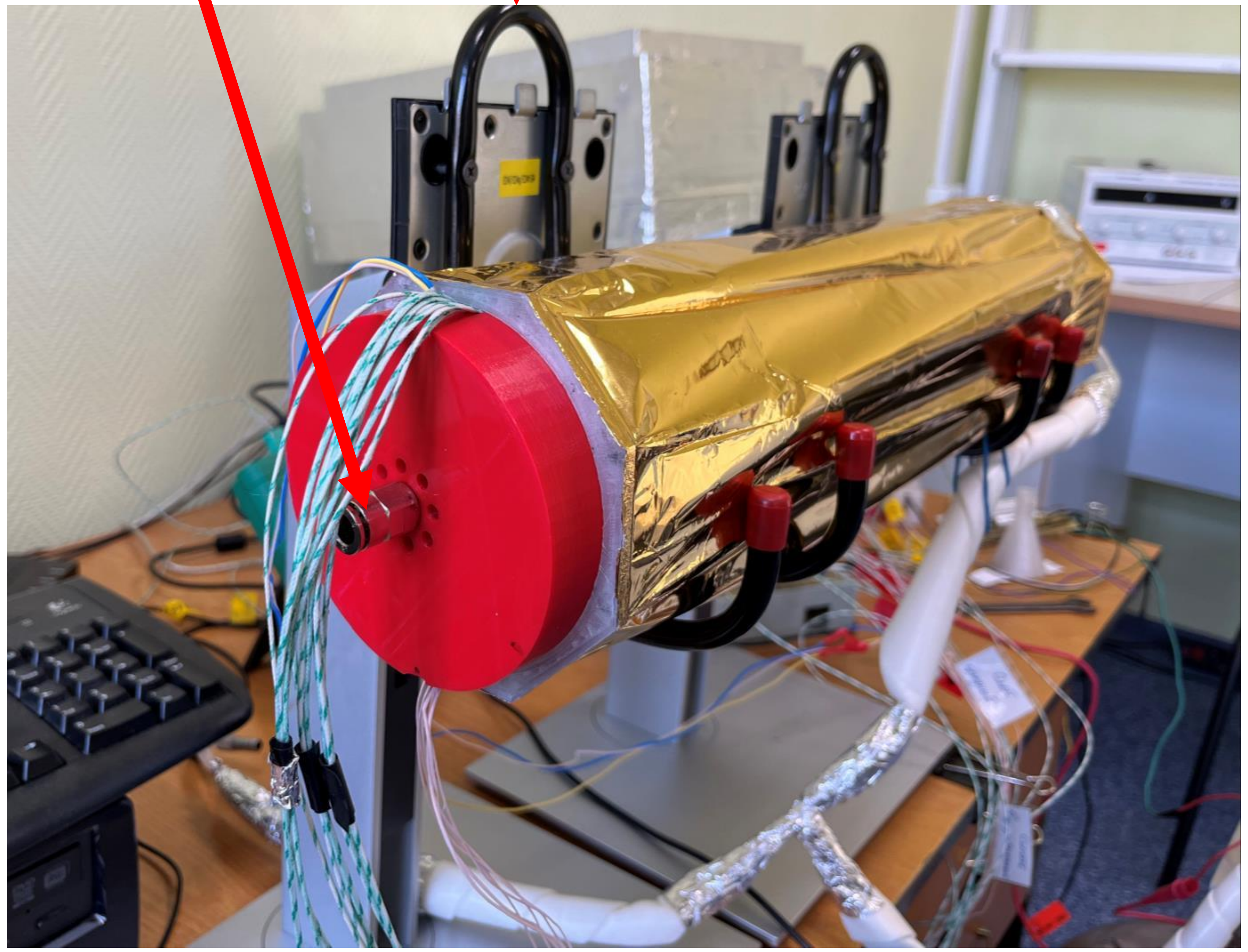
V.I. Zherebchevsky, G.A. Feofilov et al.
ITS3 Upgrade WP5 (Mechanics and Cooling) meeting 06.07.2021

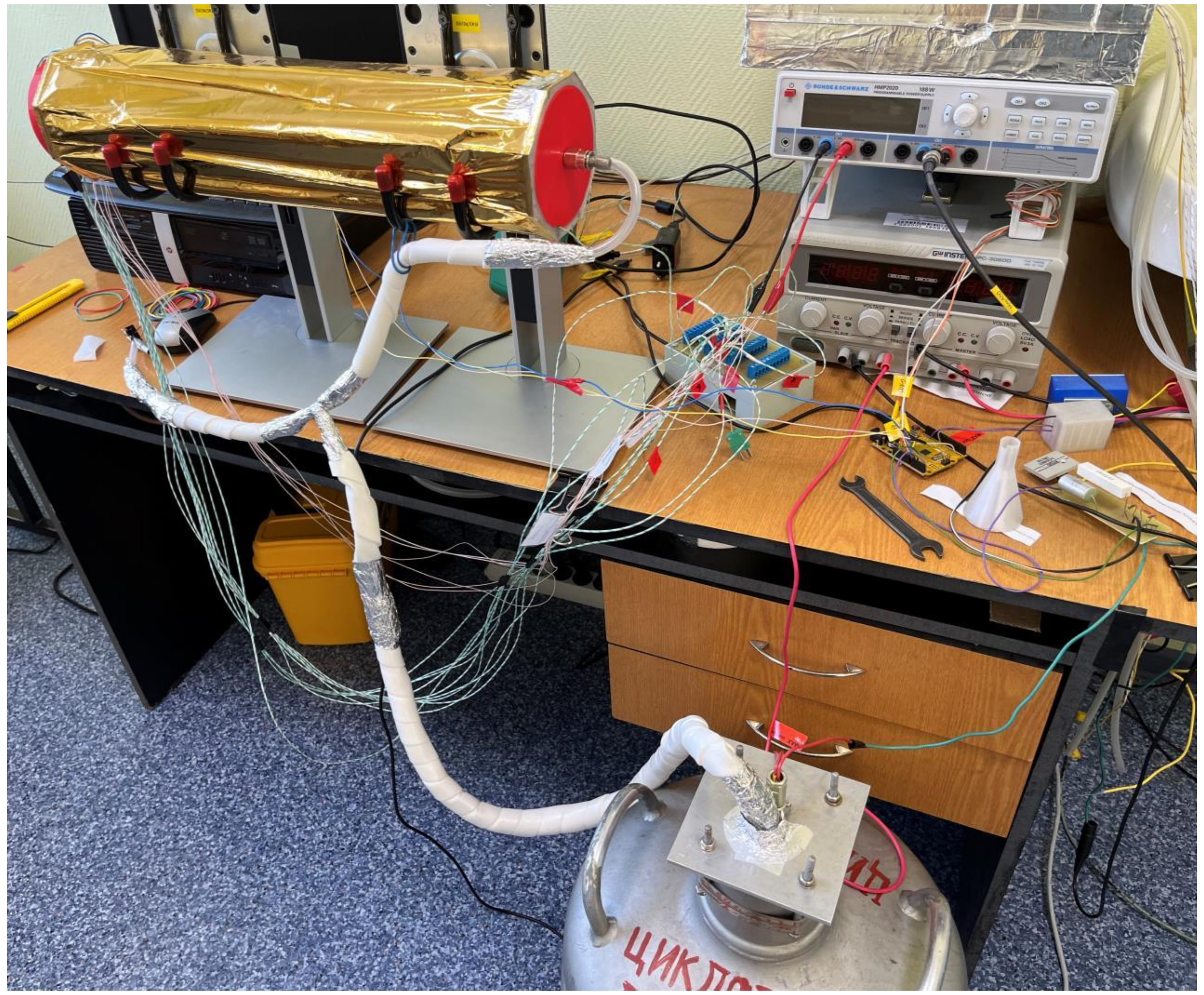
3 layers

Space blanket and
3 cylinder layers with heaters

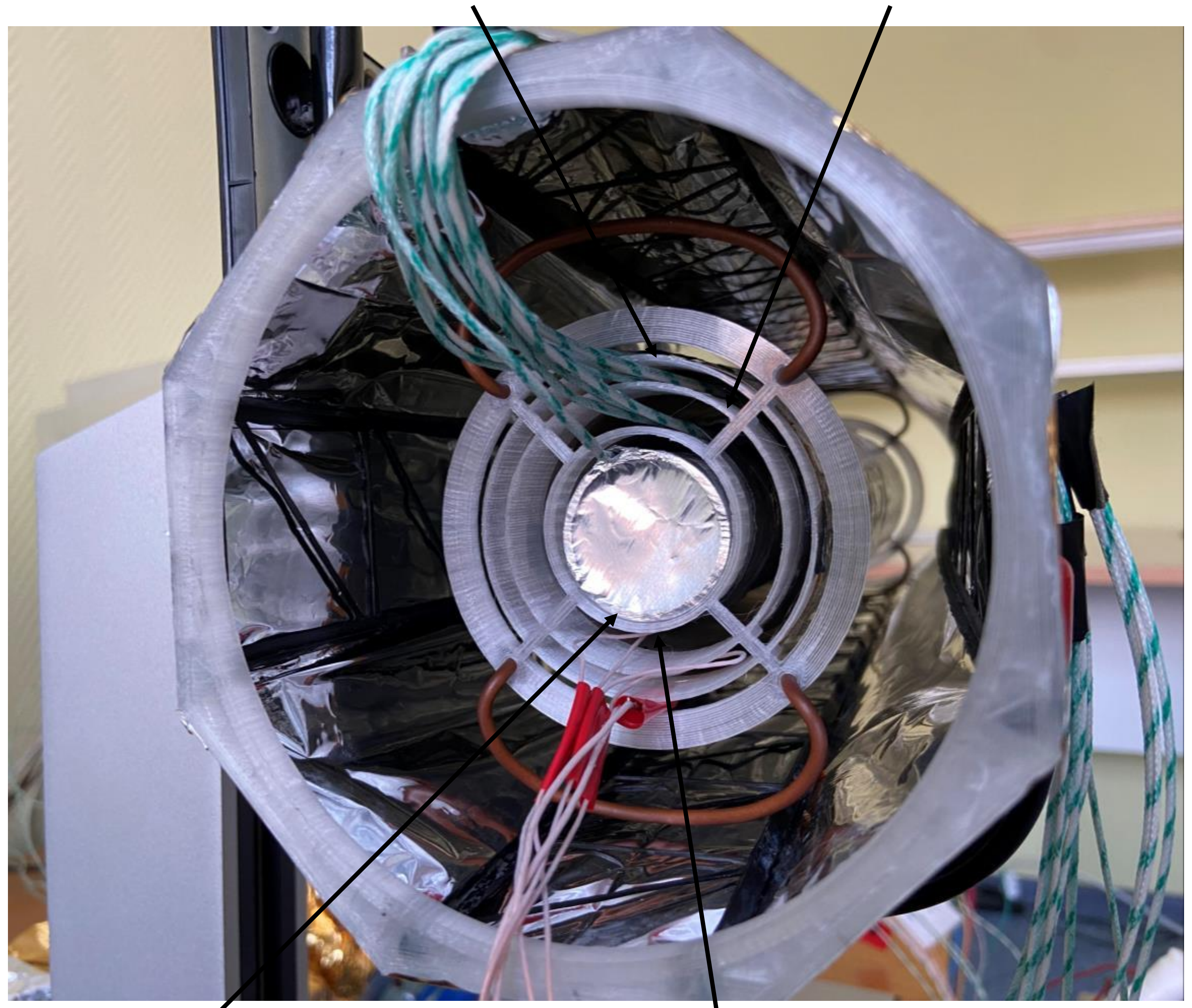
New cold nitrogen supply system

The experimental set-up was modernized





3d layer 2nd layer



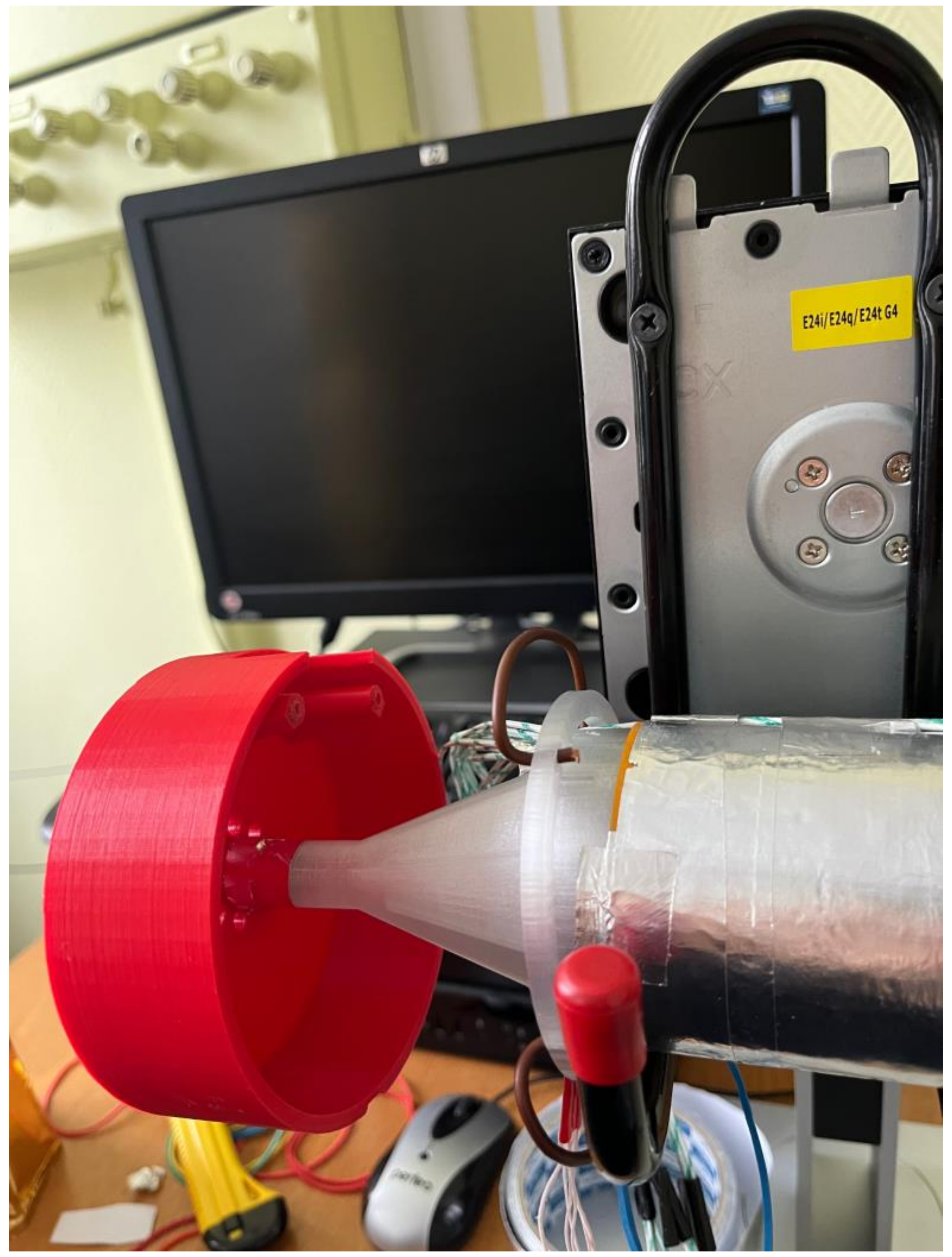
beam pipe 1st layer

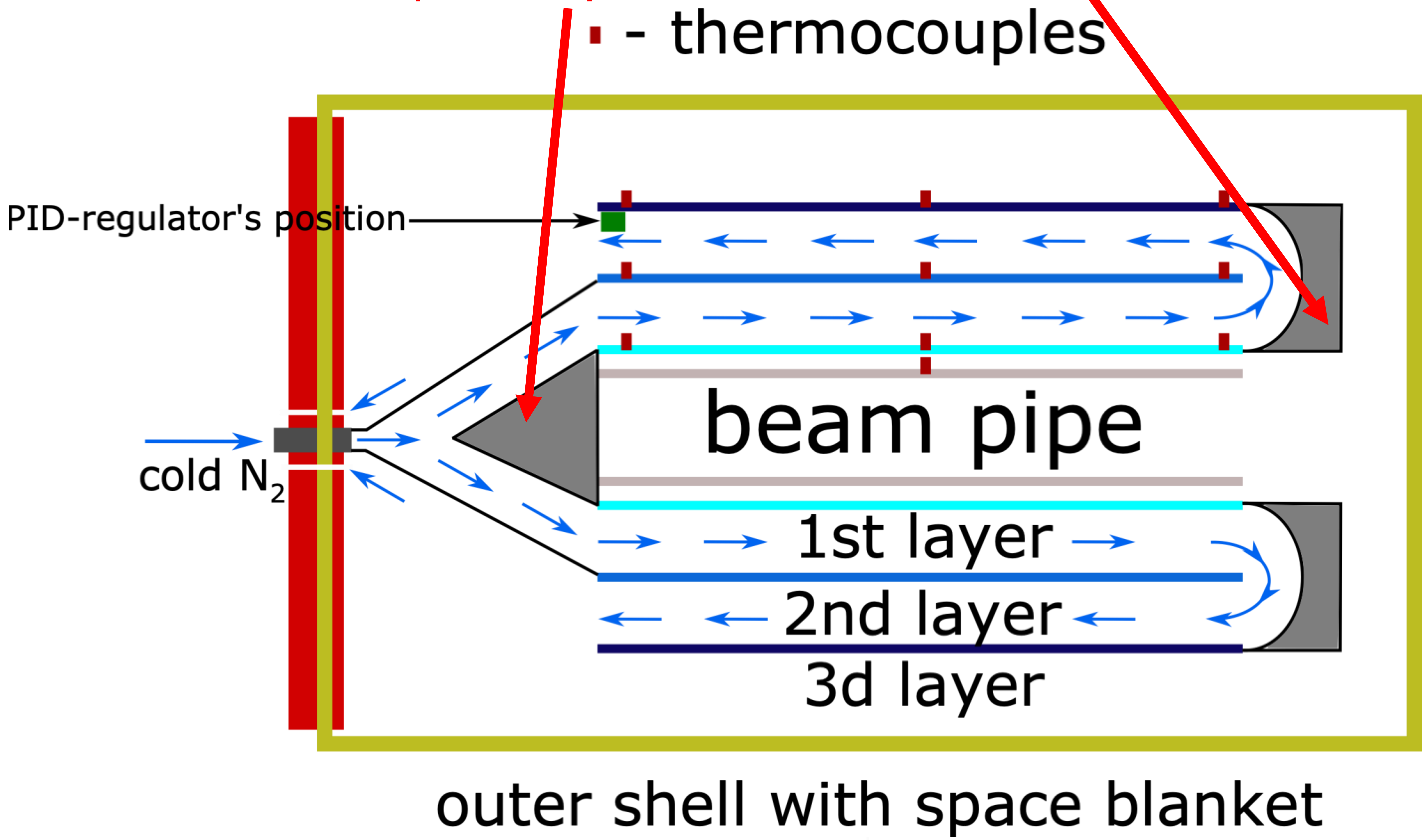
Left: a general view
Right: view of the interior of the space blanket shell

3 layers

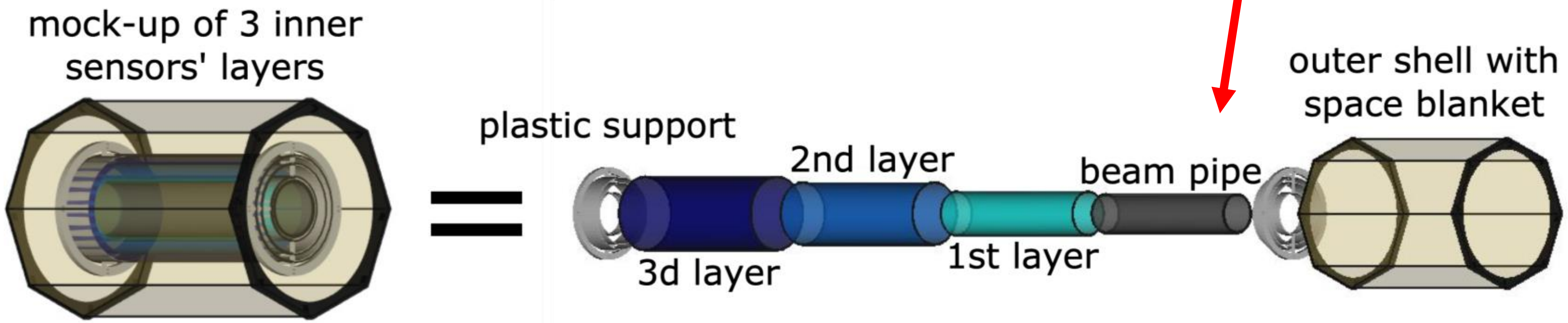
Try to avoid the temperature gradient between layers with blowing from one side.

the special spreaders were added

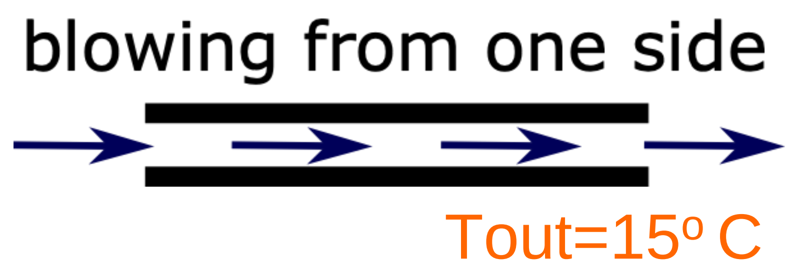




Scheme of cooling system with mock-up of 3 silicon cylinder layers and outer shell with space blanket



3 layers



Results of temperature distributions measured at different heat loads with nitrogen cooling from one side with special spreaders

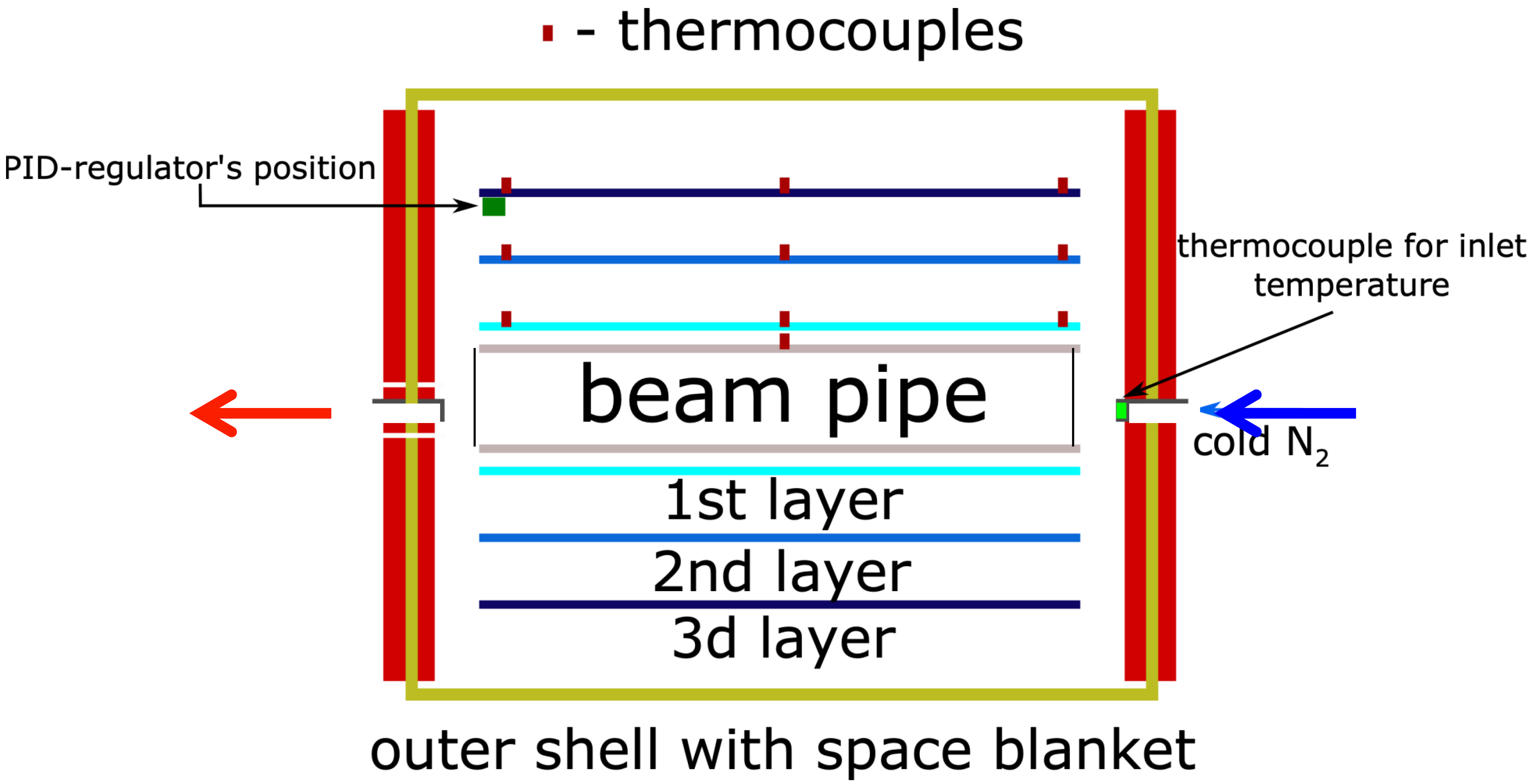
– at this moment are not quite conclusive due to the position of the PID-regulator: it was found to be sensitive both to the input and outlet temperatures position to the exit.

Work is in progerss

3 layers

blowing from one side

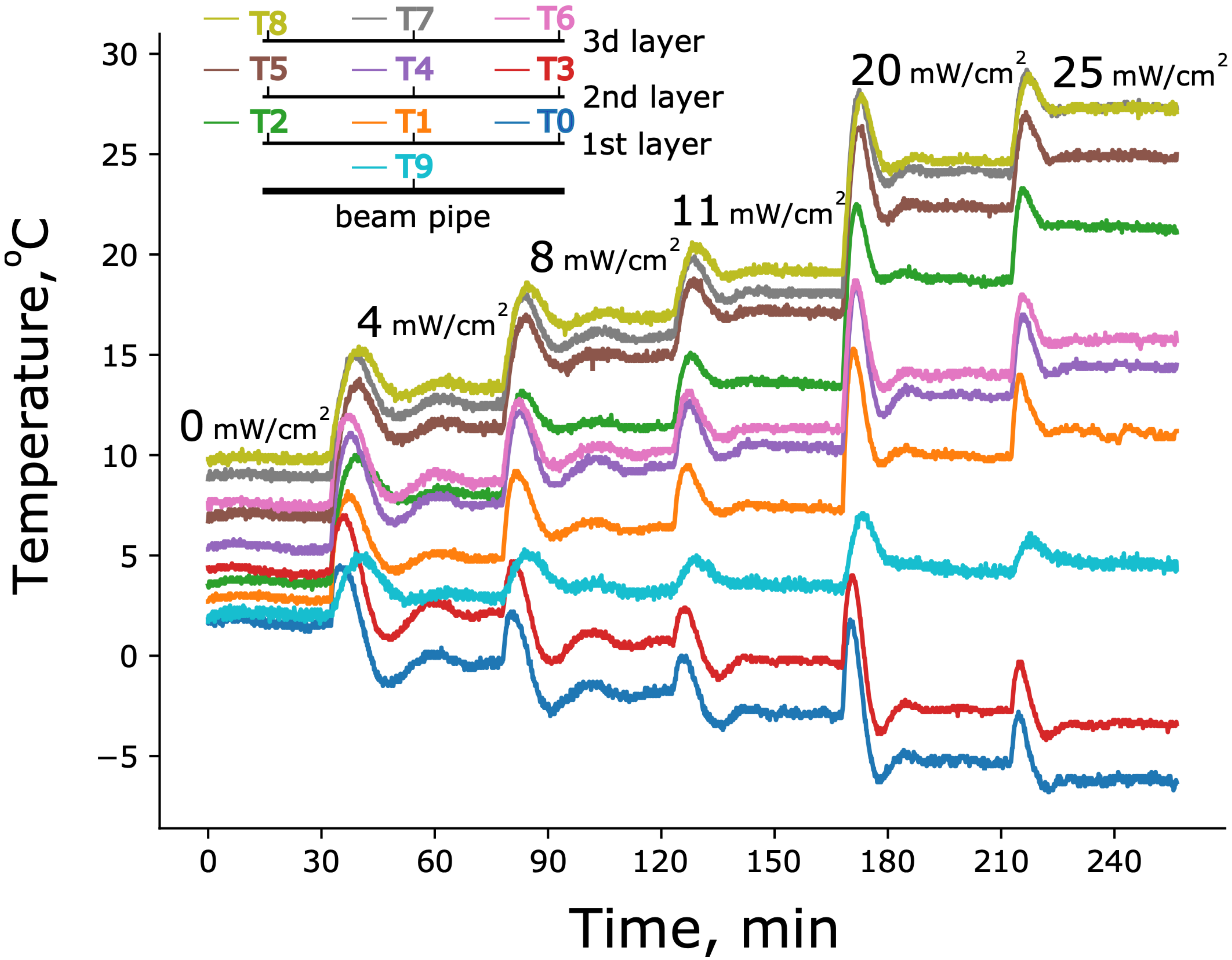
Return to previous configuration without special spreaders.
PID-regulator **on the exit**, so we control the nitrogen temperature at the outlet



3 layers

blowing from one side

Results of temperature distributions measured at different heat loads with nitrogen cooling from one side and control of the outlet temperature

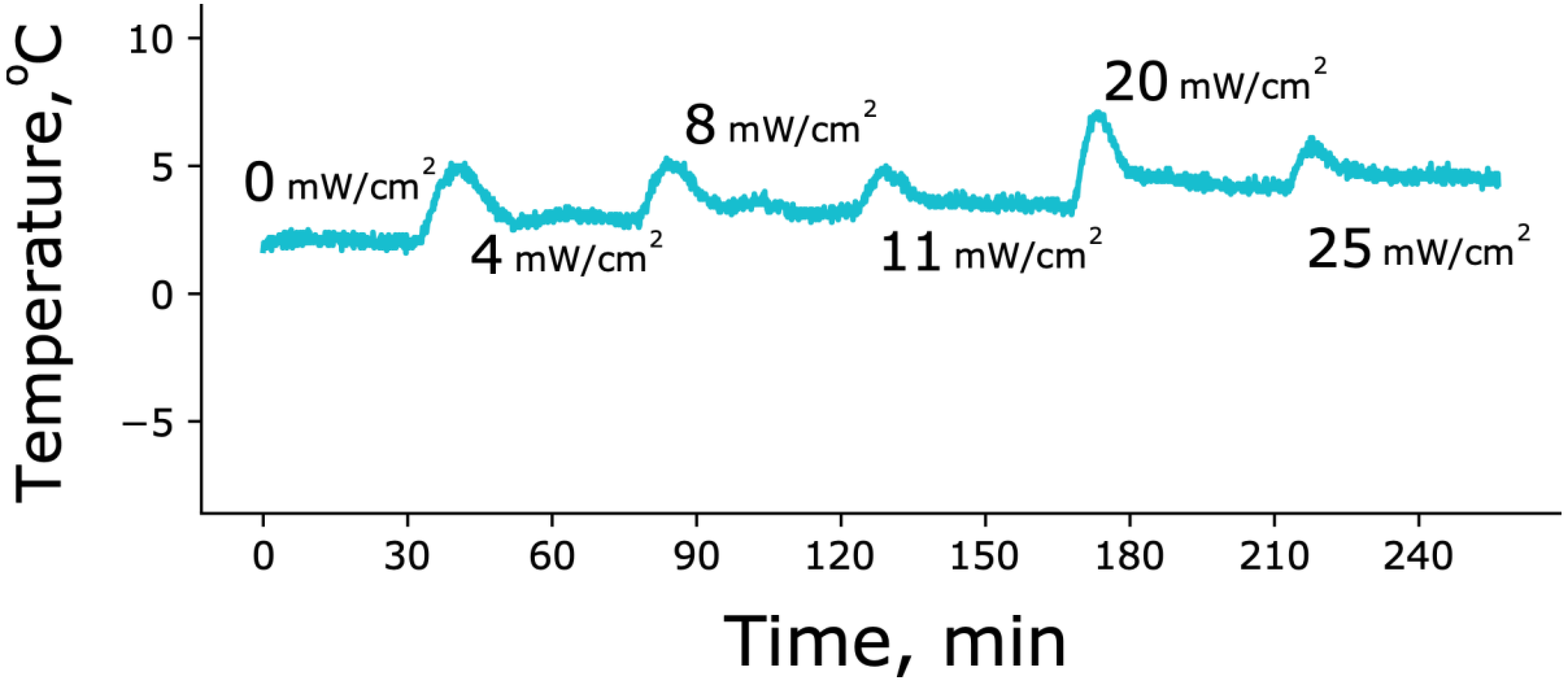


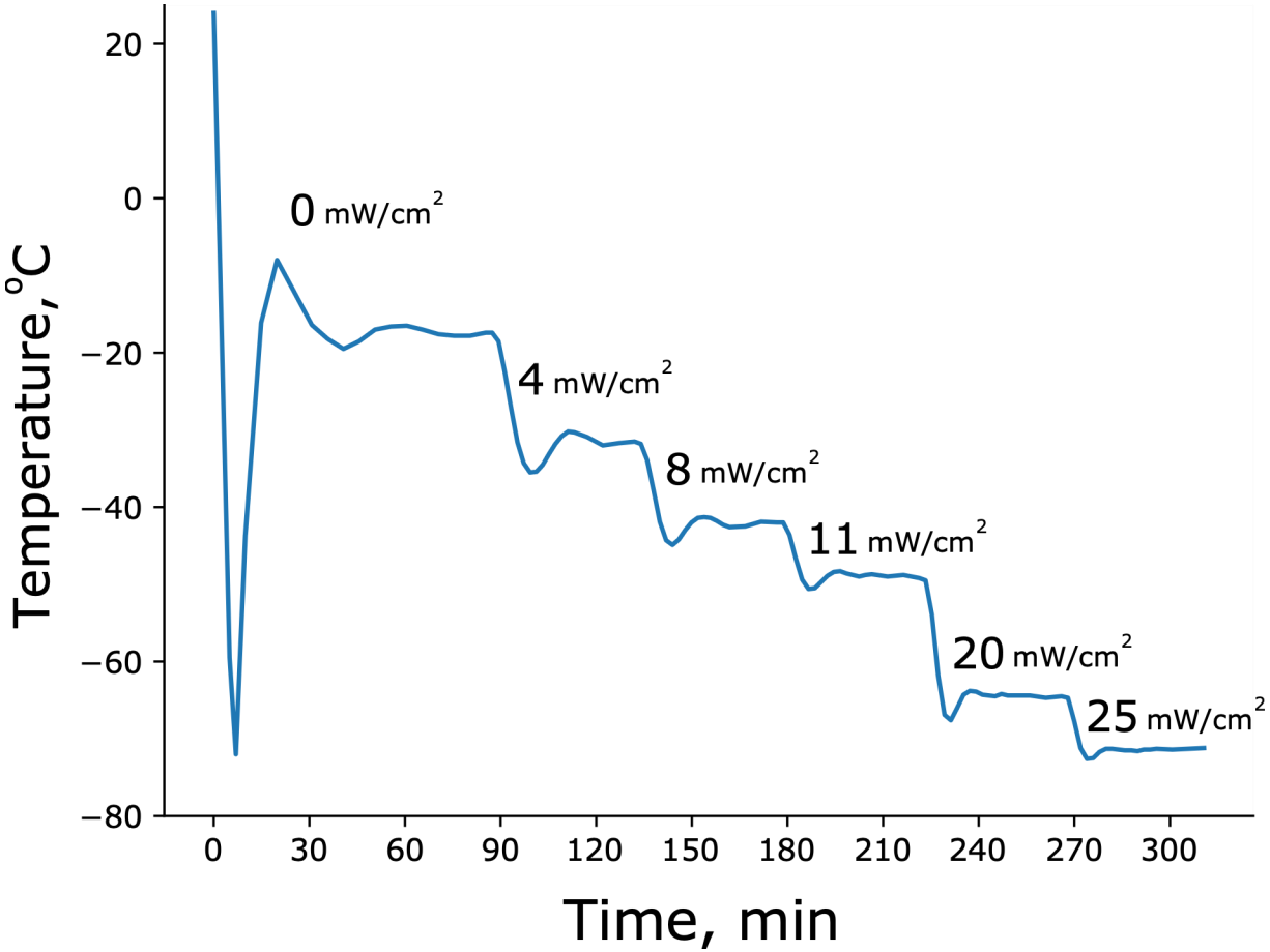
Outlet temperature of nitrogen is 15 °C
Blowing of nitrogen from one side.
Density of power is the same for each layer.

3 layers

blowing from one side

Temperatures vs. different heat loads: on a **beam pipe**(left) and **inlet nitrogen**(right)



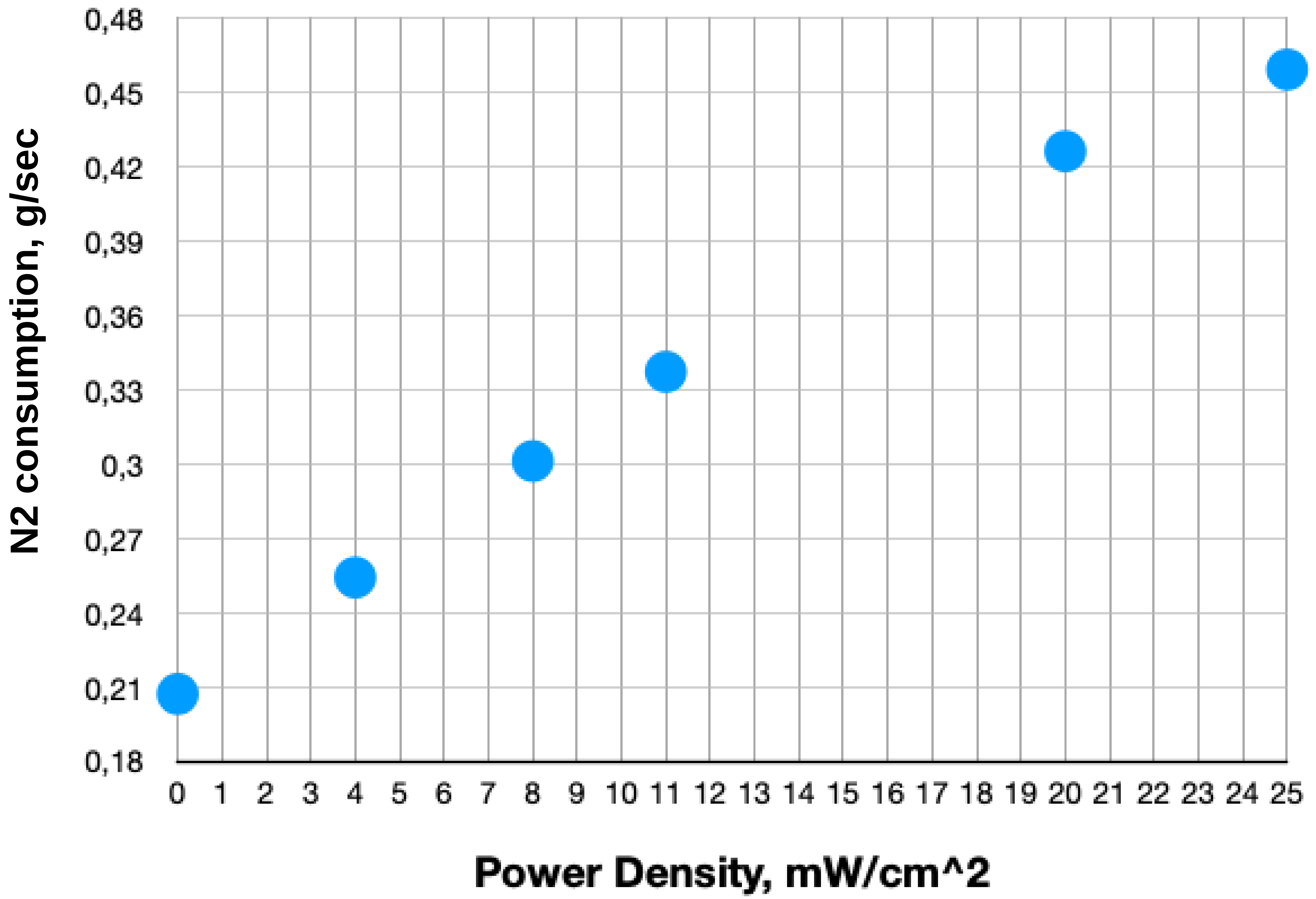


3 layers

Nitrogen consumption

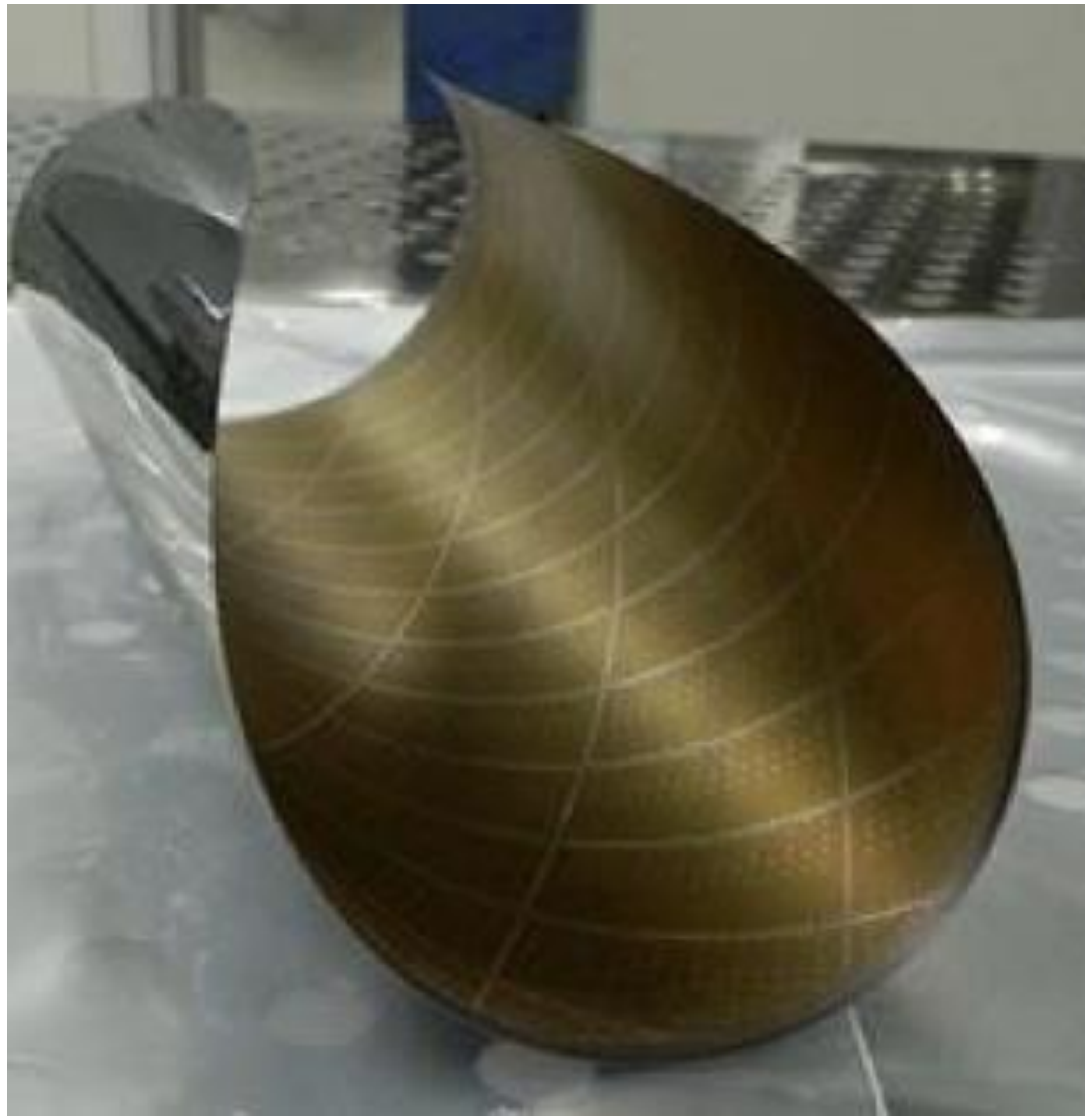
dependence of nitrogen consumption on density of power on mock-up of 3 silicon cylinder layers

- Nitrogen consumption on 25 mW/cm^2 is ~1.6r kg in hour.



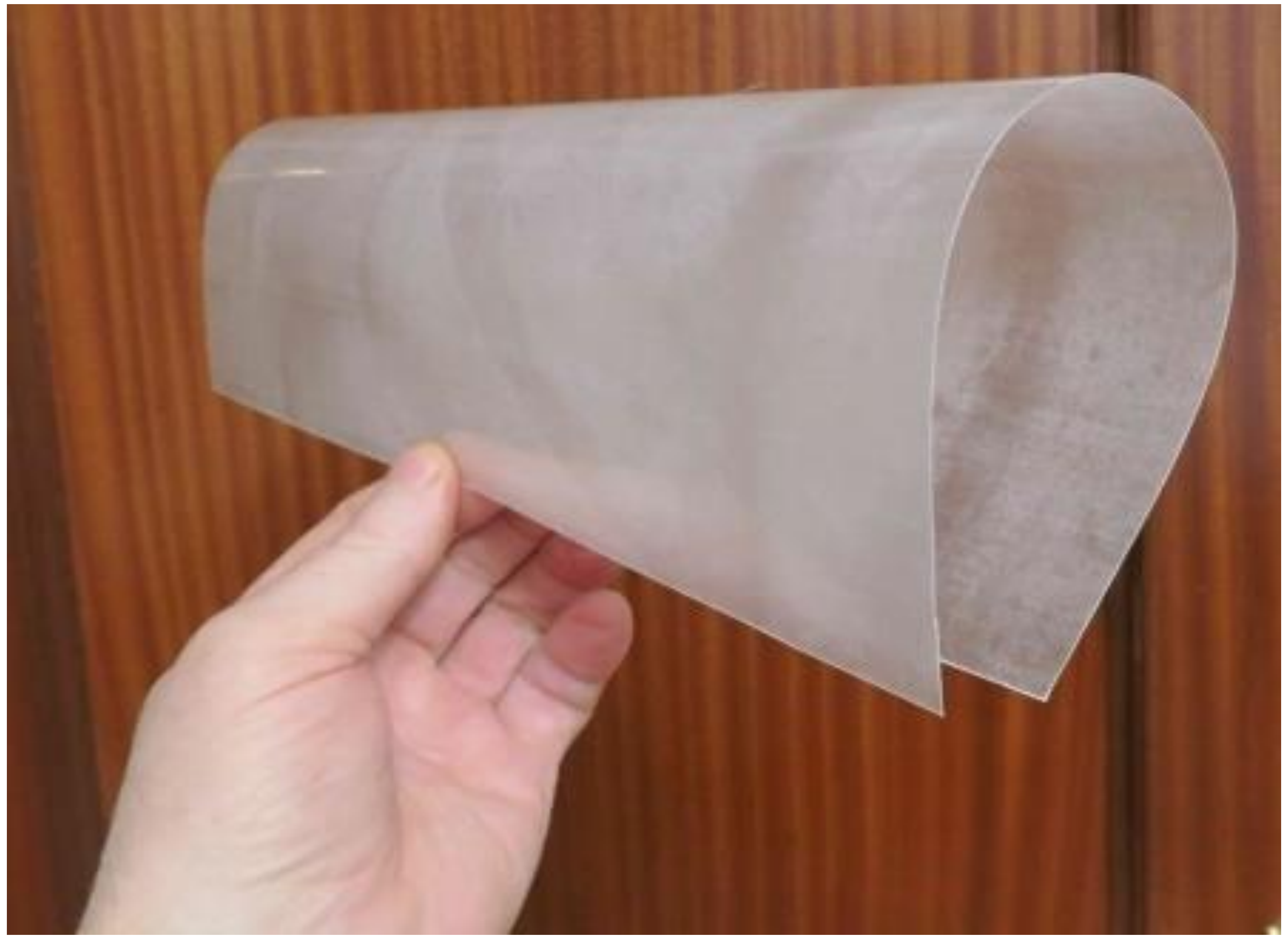
Ultraligthweight self-supported mechanics for ALICE ITS-3 modules

Glass-fiber plate



Bent Si-plate

CTE Si = 5.1×10^{-6}



Glass-fiber plate 310 x 240 mm^2

CTE Glass-fiber = 5.1×10^{-6}

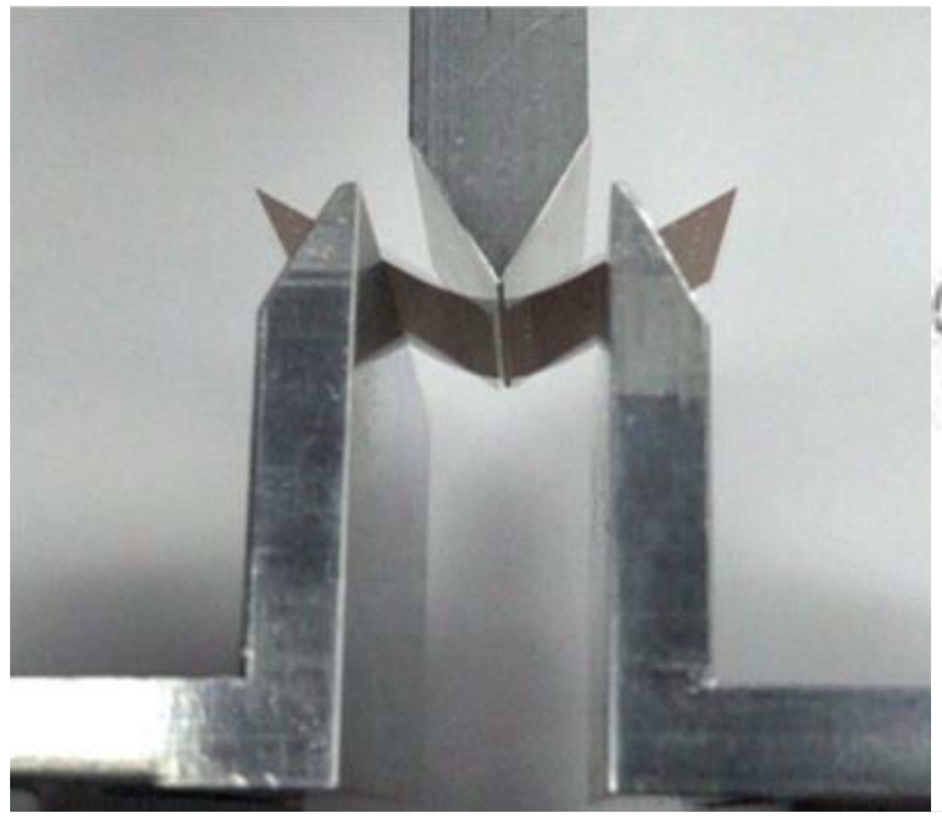
Fiber type: А-1-ТД СТТ

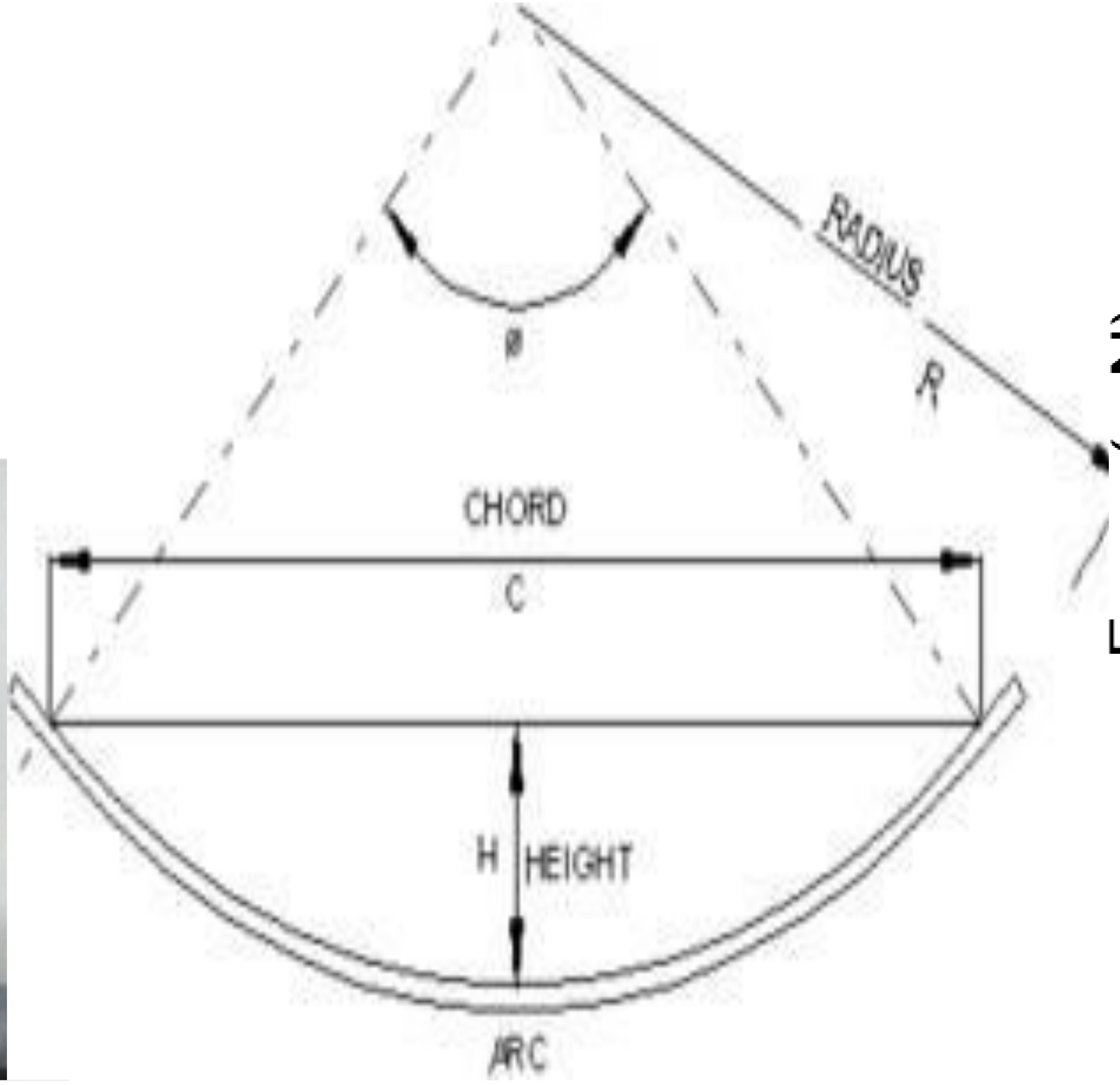
Thickness of fiber = $0,1^{+0.01}$мм

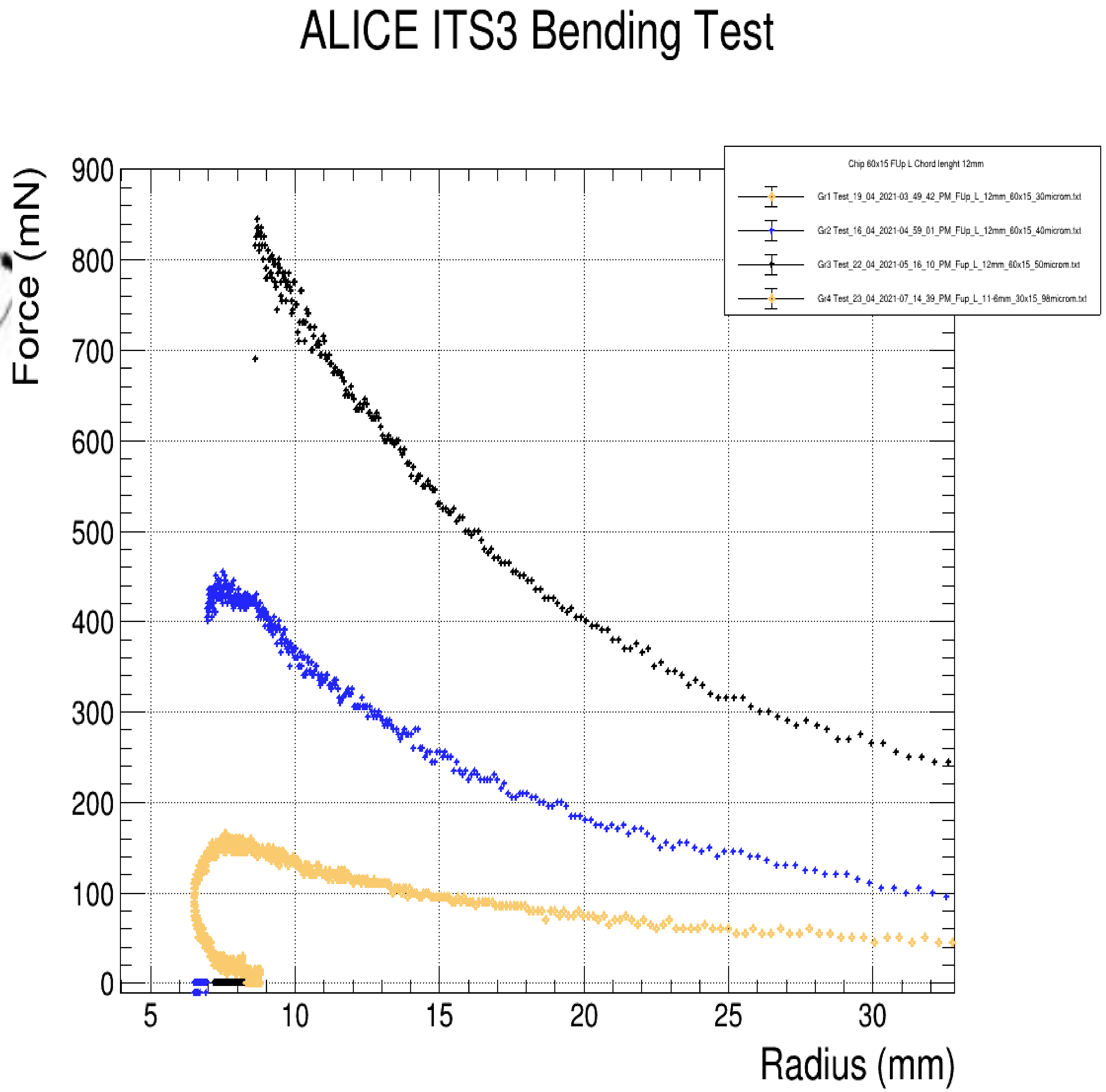
Density of fiber = 110g/m^2

Density of glass-fiber material= 0,0183г/$см^2$.

ALICE bending tests of Si-plates 30,40, 50 μ





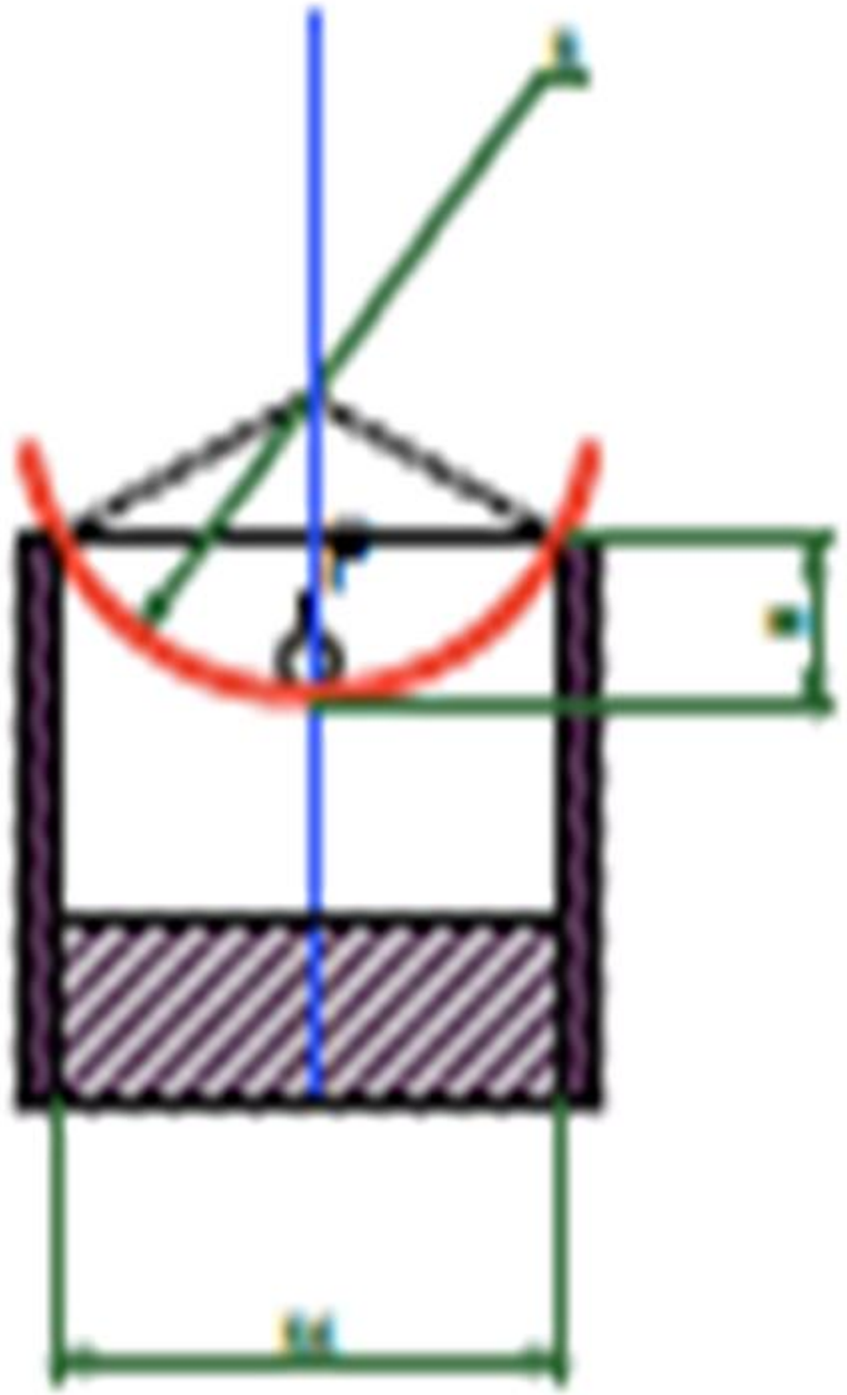


$$Rx^2=(C/2)^2 + (R-H)^2$$

Report (INFN Trieste) ITS3 WP4 R&D Status report от 28/05/2021

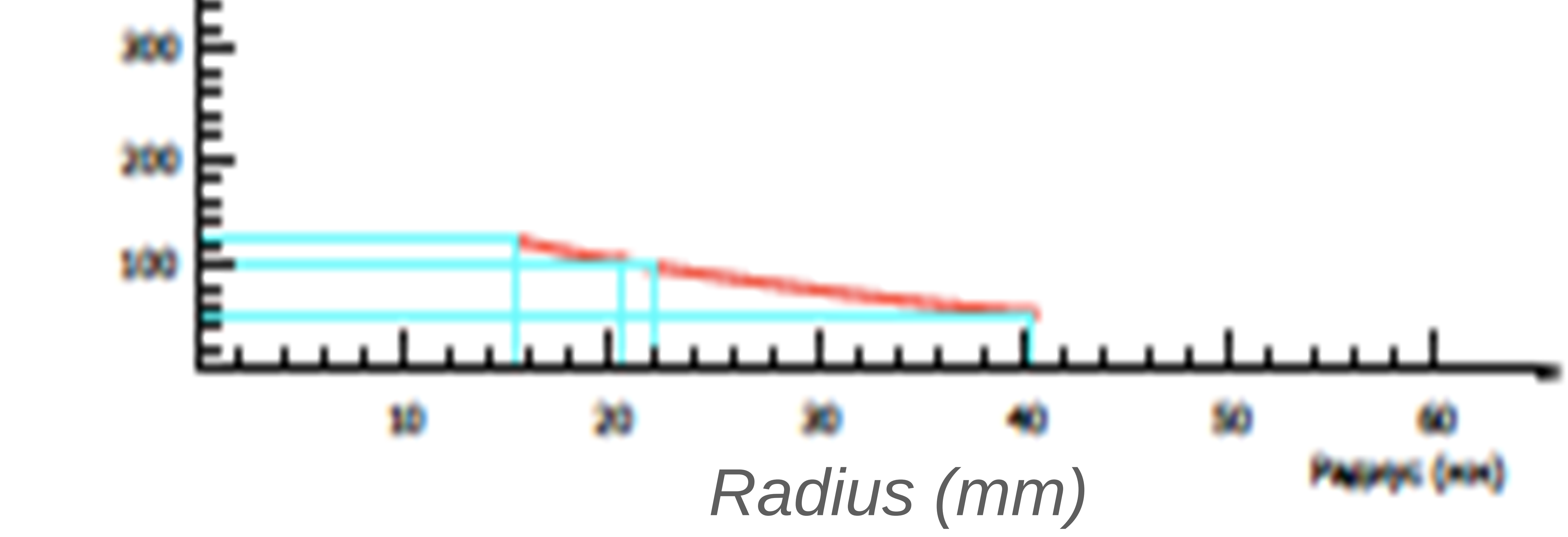
Bending tests of fiber-glass plate 100μ

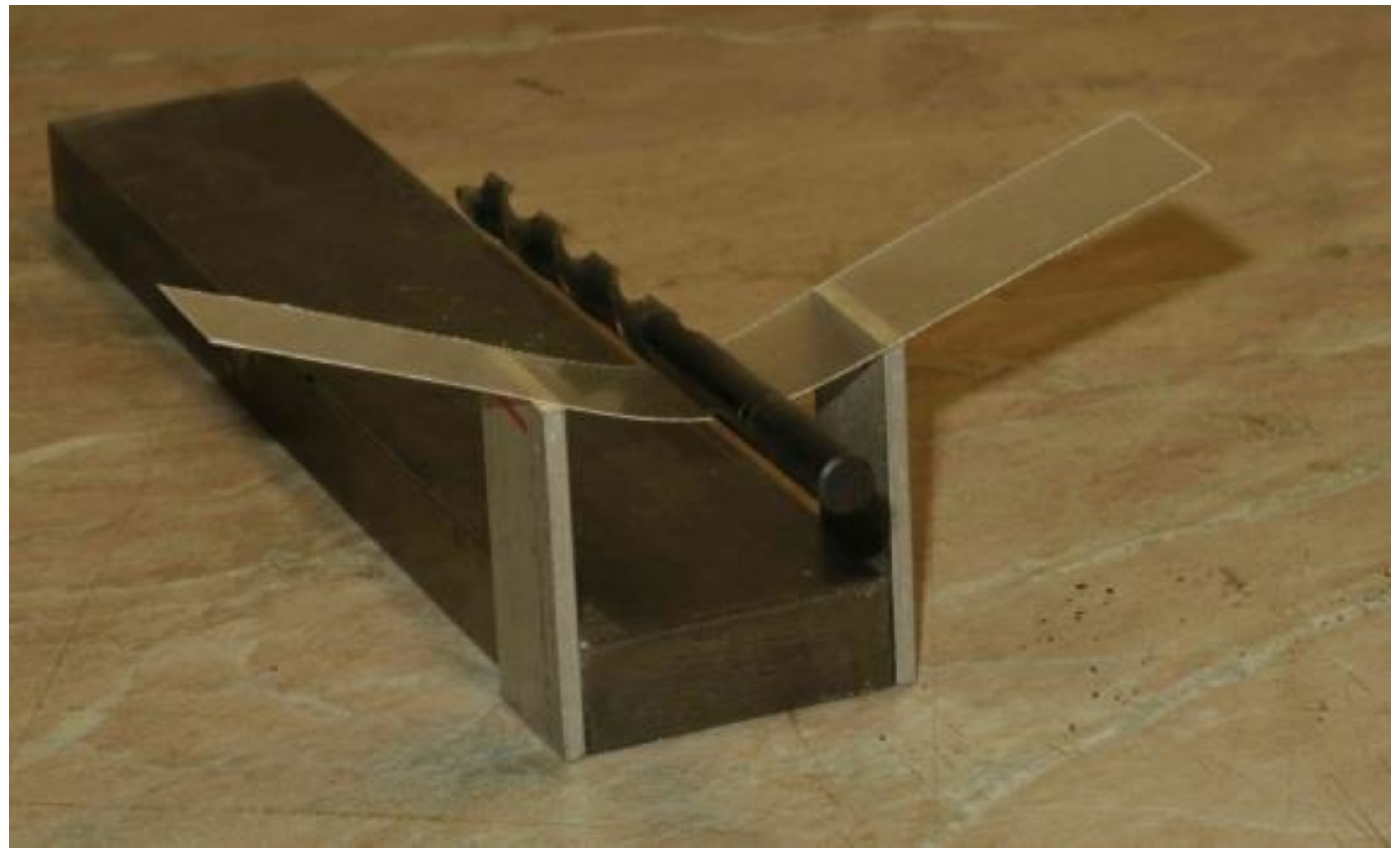
$Rx^2=(C/2)^2 + (R-H)^2$



C=28mm

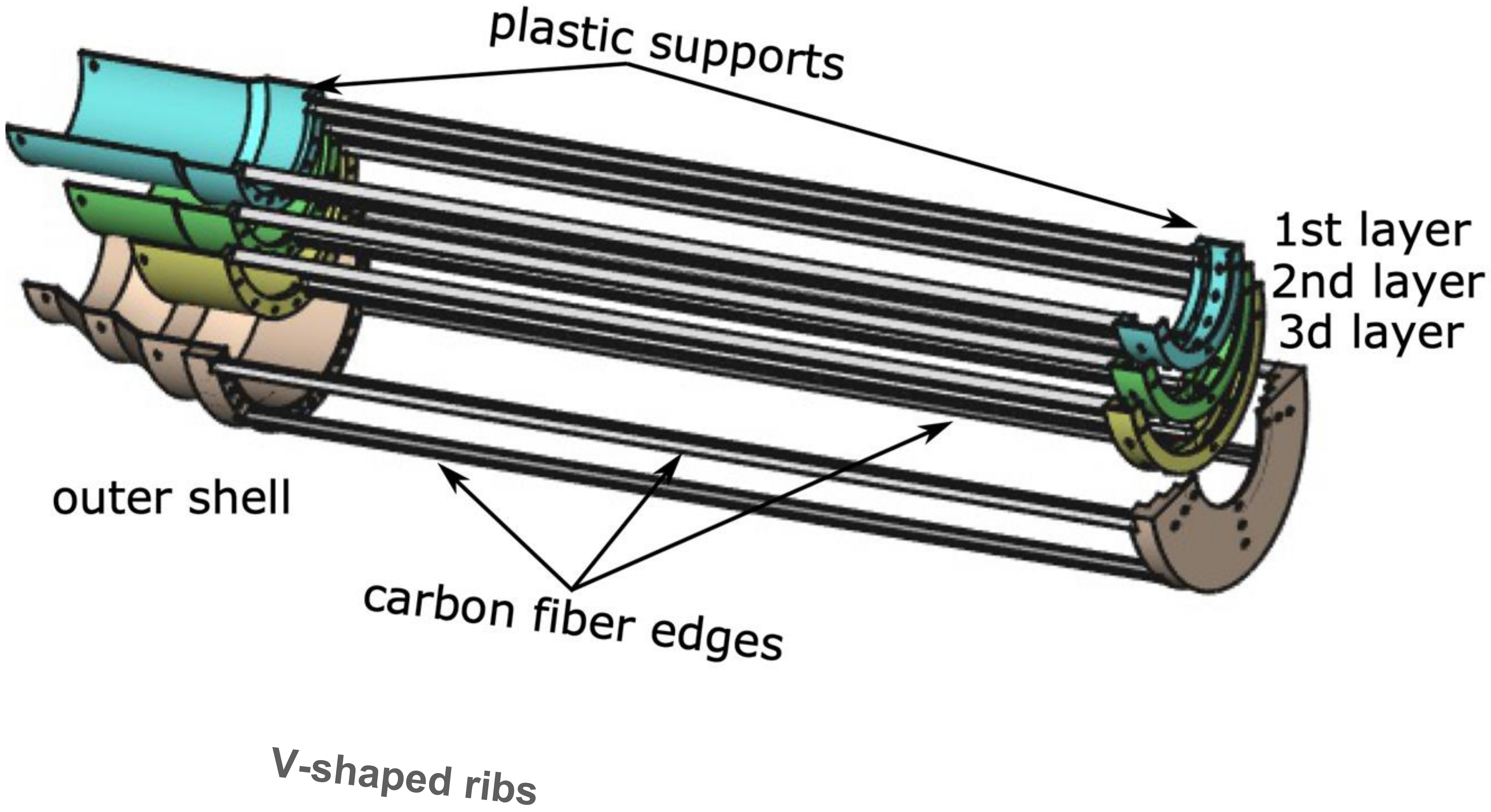
Load, g.	Sage, mm	R мм (plotted)
12,25	9	15,4
10,25	5,5	20,5
9,8	5	22,1
5,4	2,5	40,5





- The stifness is estimated to be similar to ~30μ Si

Scheme of carbon fiber support structure for inner tracking system



Part of support Structure	Weight, g
carbon fiber edge	2
plastic supports for 1st layer	9,5
plastic supports for 2nd layer	10
plastic supports for 3d layer	9,5
plastic supports for outer shell	24,9

Length of carbon fiber **V-shaped ribs** for layers: 284mm

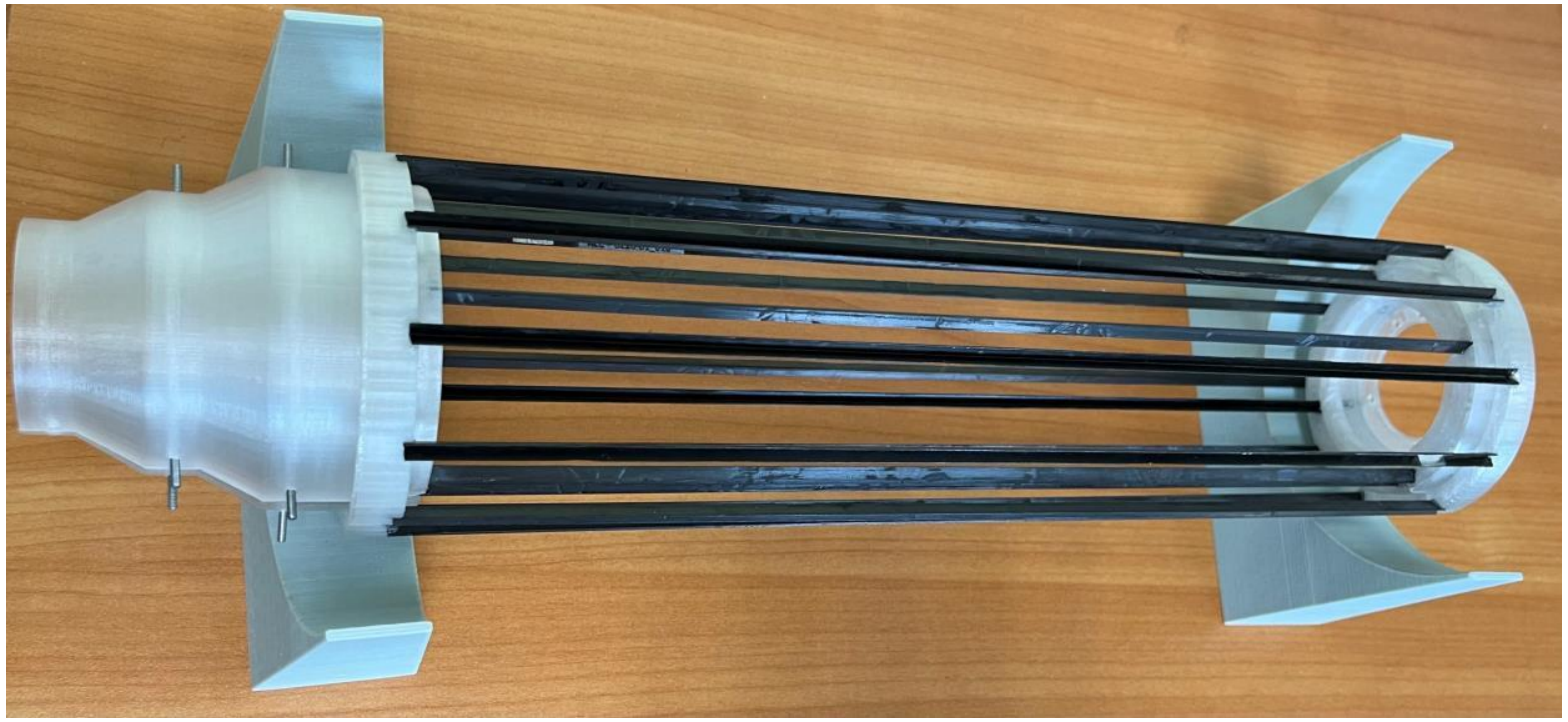
Length of carbon fiber **V-shaped ribs** for outer shell: 297mm

Radius of layers: layer 1 - 30mm, layer 2 - 24 mm, layer 3 - 18mm

From scheme to real life

Outer shell

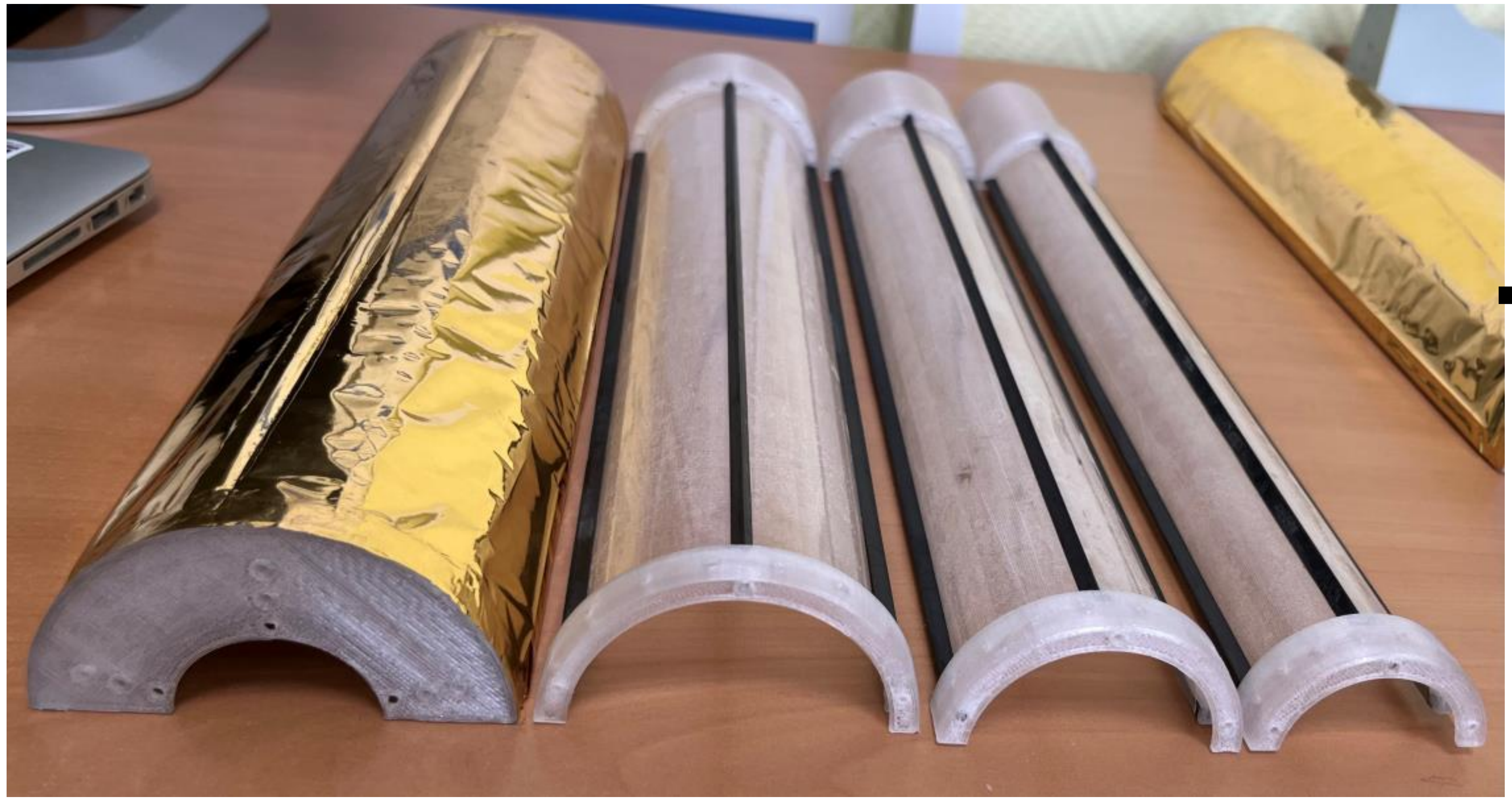
Outer shell + 3d layer



Outer shell + space blanket + 3d layer

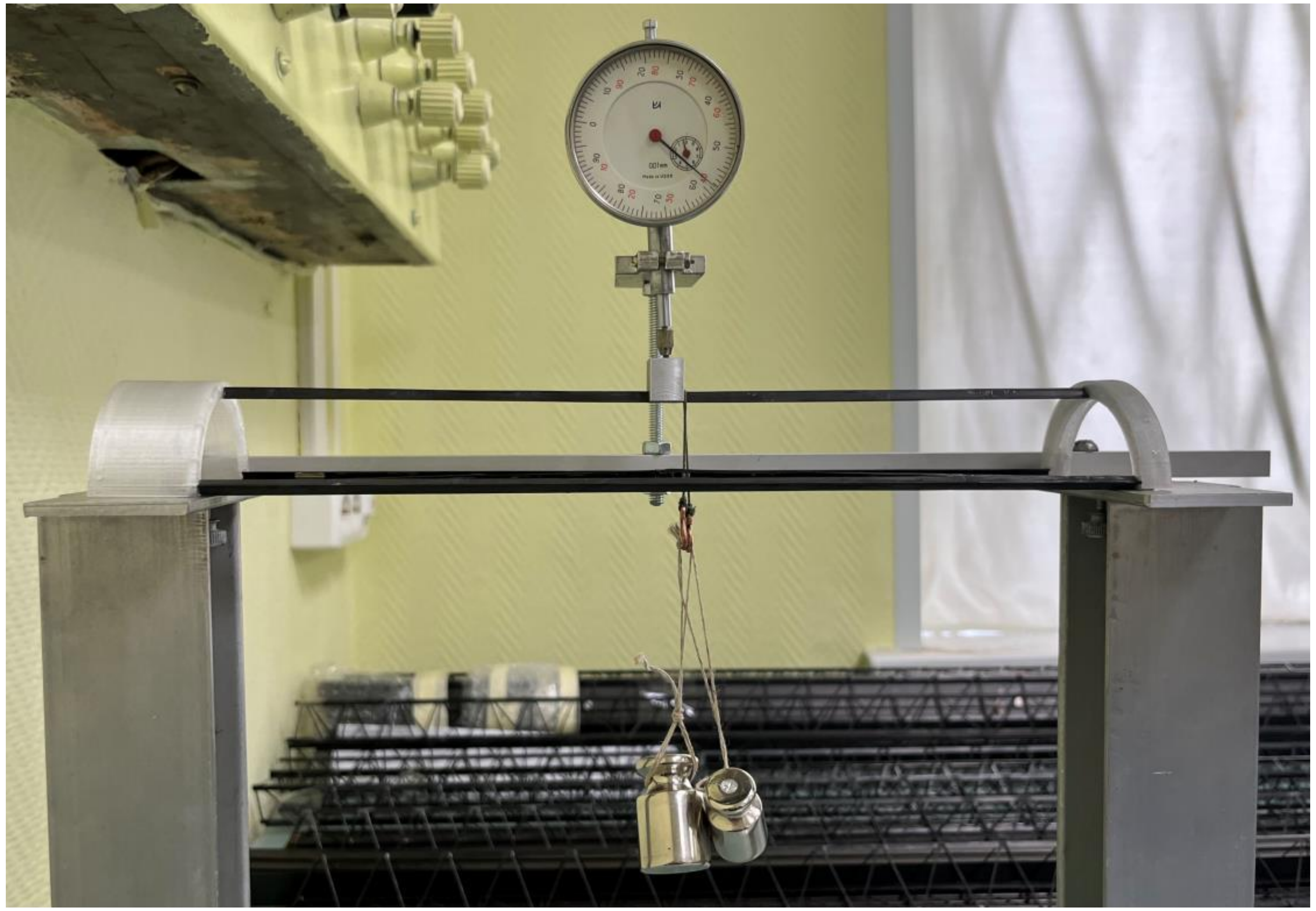
Assembling of mechanical mock-up of ITS-3

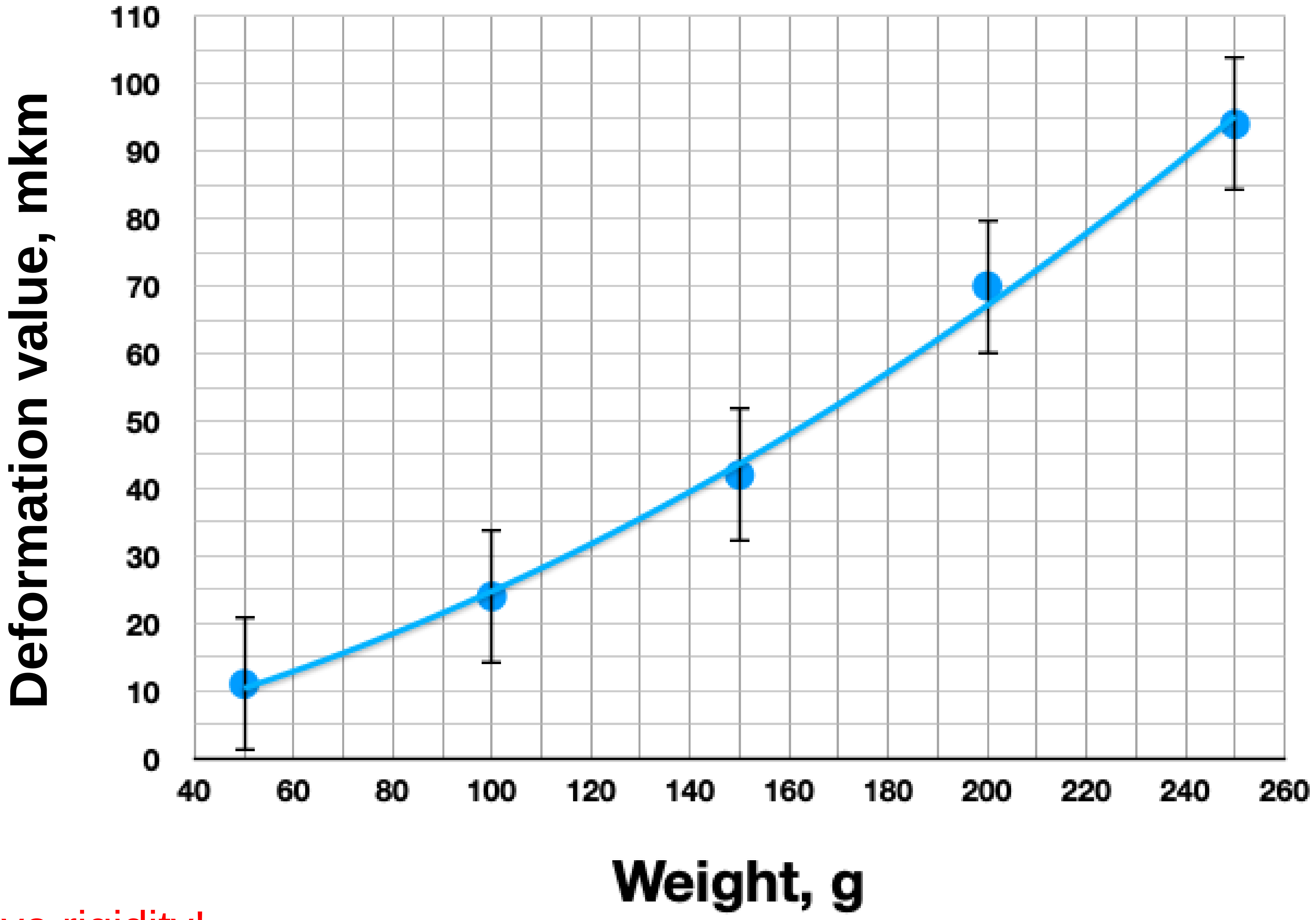
We use a fiberglass as a mock-up of silicon thin sensors



Deformation value of V-shaped CF ribs under the influence of different weights

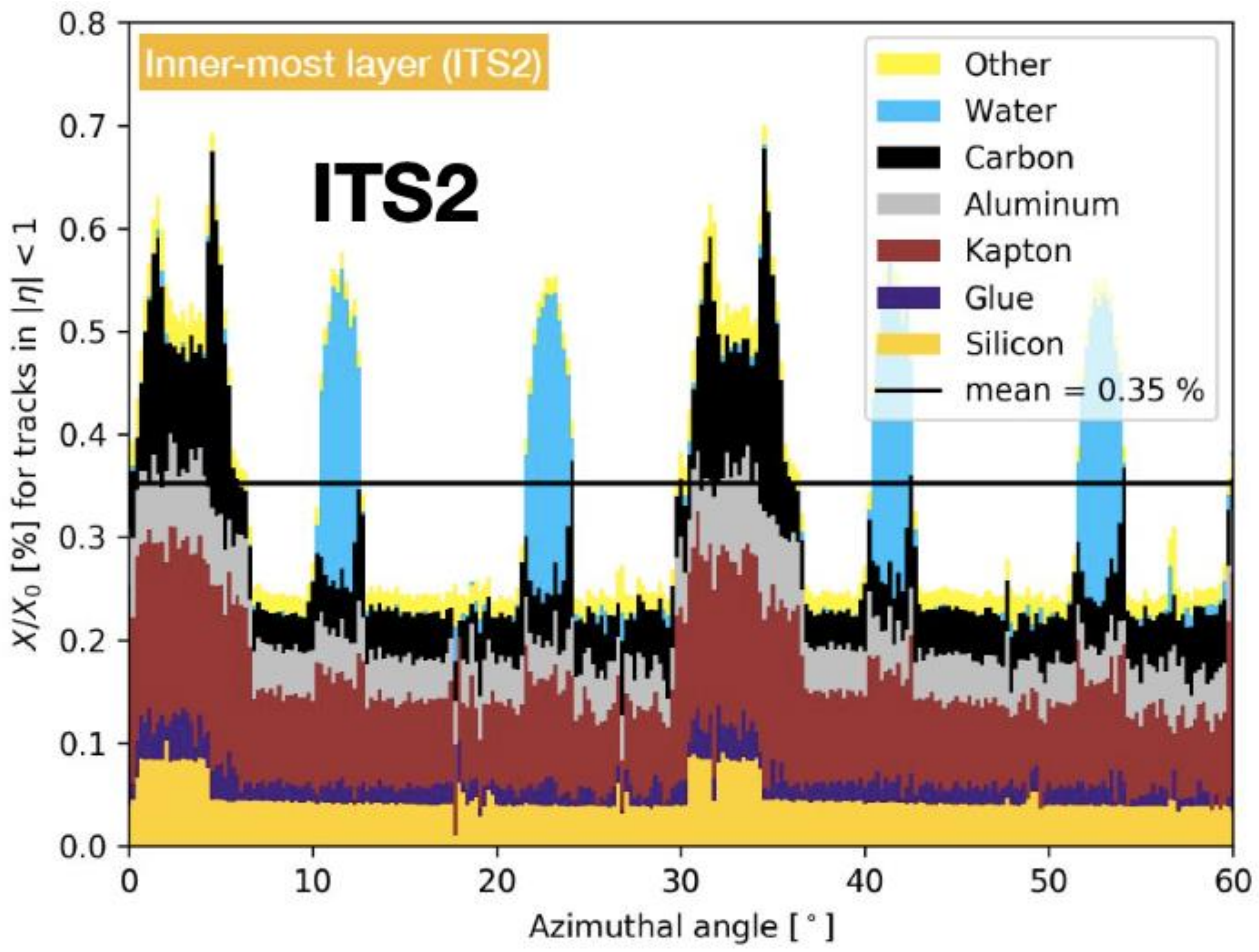
Measurements were performed by micrometer

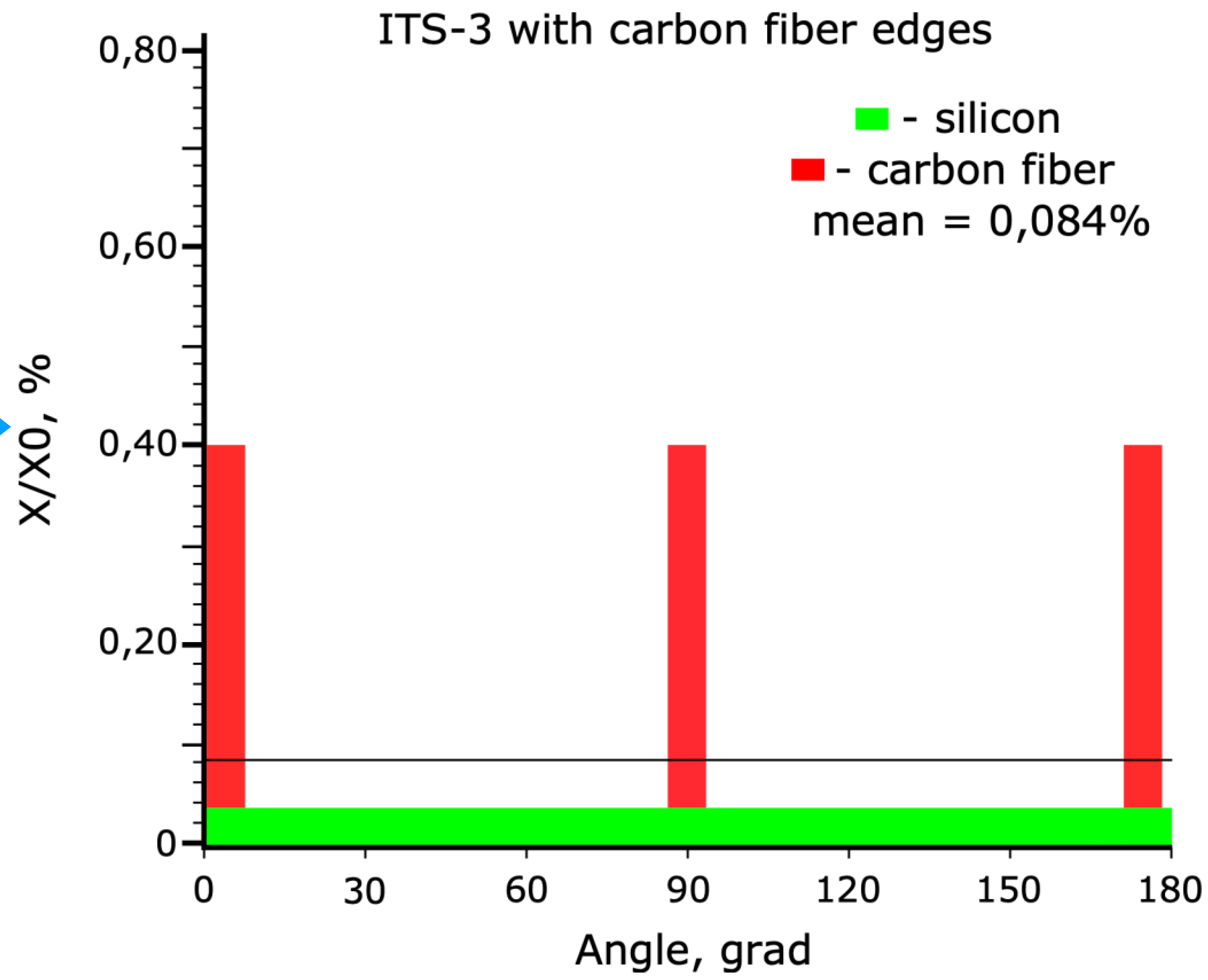




- ➢ The excessive rigidity!
- ➢ The thickness of CF V-shaped ribs might be decreased.

Radiation transparent





- The excessive rigidity!
- The thickness of CF V-shaped ribs might be decreased

Conclusions

- The performance of low-speed gas cooling of the full scale mock-up of three layers of the ITS 3 was demonstrated
- The space blanket instead of thermally well isolated barrel works perfectly well

(no any signs of water vapor condensation were noticed)

- Ultraligthweight self-supported mechanics for ALICE ITS-3 modules is based on the ITS 1 and ITS 2 carbon fiber technology
- It may allow to use the individual operations with bent modules of LO, L1 and L2
- The assembly/disasembly will not require gluing/ungluing
- All layers and the outer space blanket shell are self supported
- Thickness of CF V-shaped ribs holding the bent-Silicon and the outer shell might be further decreased

BACK-UP SLIDES