"Conceptual ideas of ultra-ligthweight self-supported mechanics and cold gas cooling for ITS 3, recent prototyping and thermomechanical tests, perspectives for application in ALICE 3 design"

G. Feofilov, V. Zherebchevsky, V.Samsonov
Saint-Petersburg State University
Reported by G.Feofilov

ITS-upgrade WP5 meeting, 11 June 2024,
4:00 PM → 5:00 PM Europe/Zurich

https://indico.cern.ch/event/1425295/

Layout

LUHEP SPb SU —32 years with ALICE

YEARS of SPbU

Introduction - motivation

1) Ultra lightweight self-supported mechanics
2) Experimental setup
3) Thermomechanical tests of CTE compatibility for Si and CF
4) Vibrational tests
5) Conclusions: perspectives for application in ALICE 3 design

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Introduction - motivation

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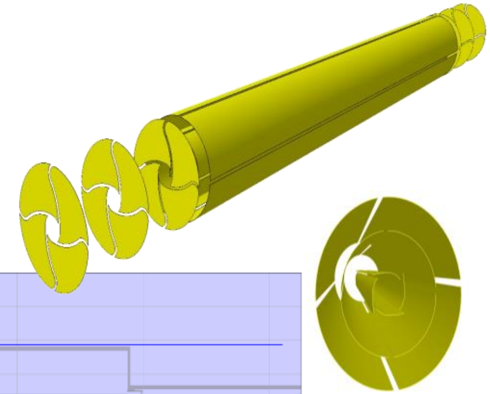
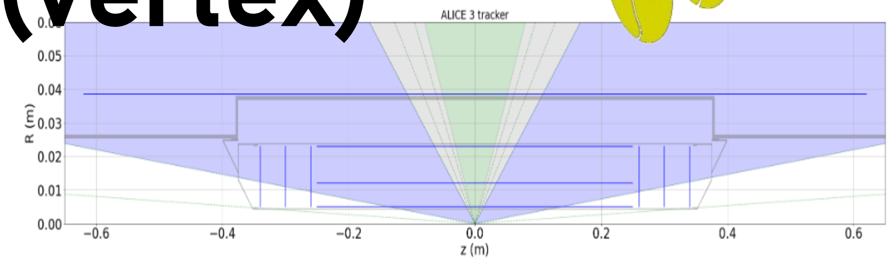
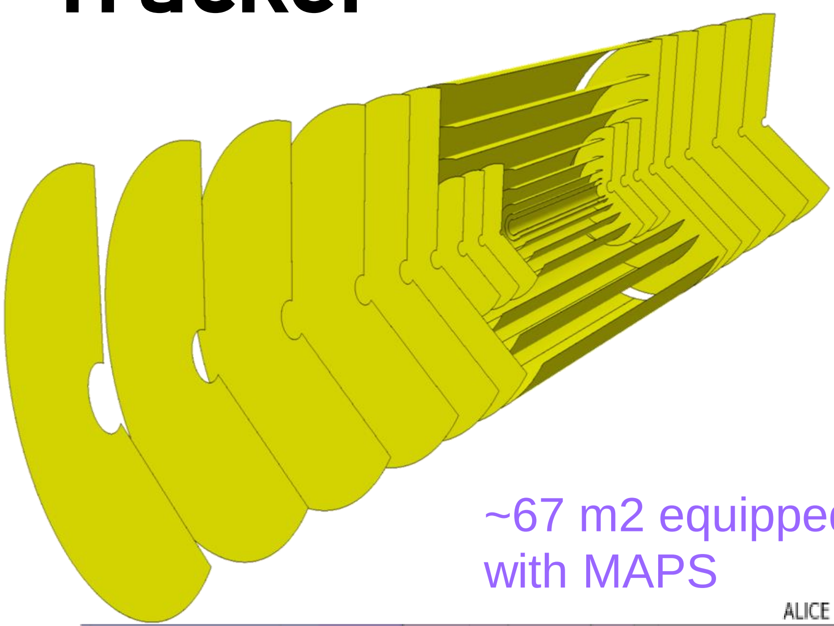
IRIS (vertex)



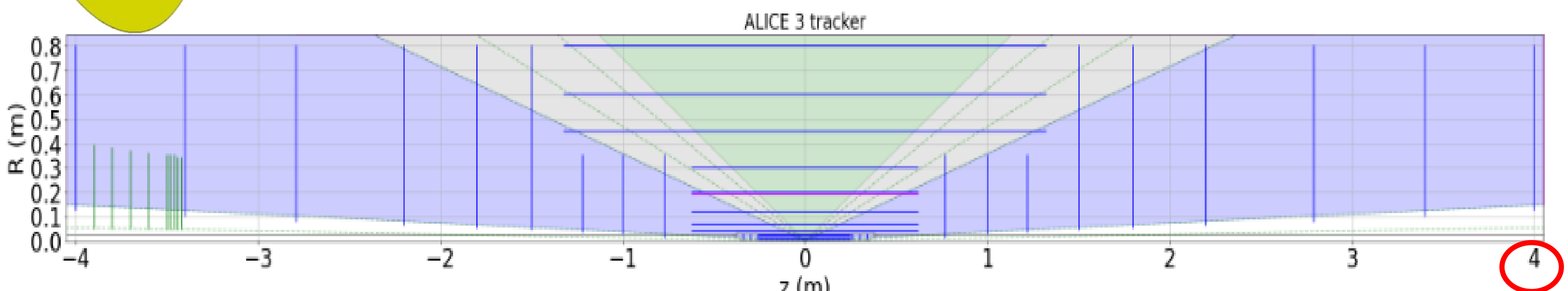


Layer	Material thickness ($\%X_0$)	Intrinsic resolution (µm)	Barrel layers Length ($\pm z$) (cm)	Barrel layers Radius (r) (cm)	Forward discs Position ($\|z\|$) (cm)	Forward discs R_{in} (cm)	Forward discs R_{out} (cm)
0	0.1	2.5	50	0.50	26	0.005	3
1	0.1	2.5	50	1.20	30	0.005	3
2	0.1	2.5	50	2.50	34	0.005	3
3	1	10	124	3.75	77	0.05	35
4	1	10	124	7	100	0.05	35
5	1	10	124	12	122	0.05	35
6	1	10	124	20	150	0.05	80
7	1	10	124	30	180	0.05	80
8	1	10	264	45	220	0.05	80
9	1	10	264	60	279	0.05	80
10	1	10	264	80	340	0.05	80
11	1				400	0.05	80

Tracker



~67 m2 equipped with MAPS



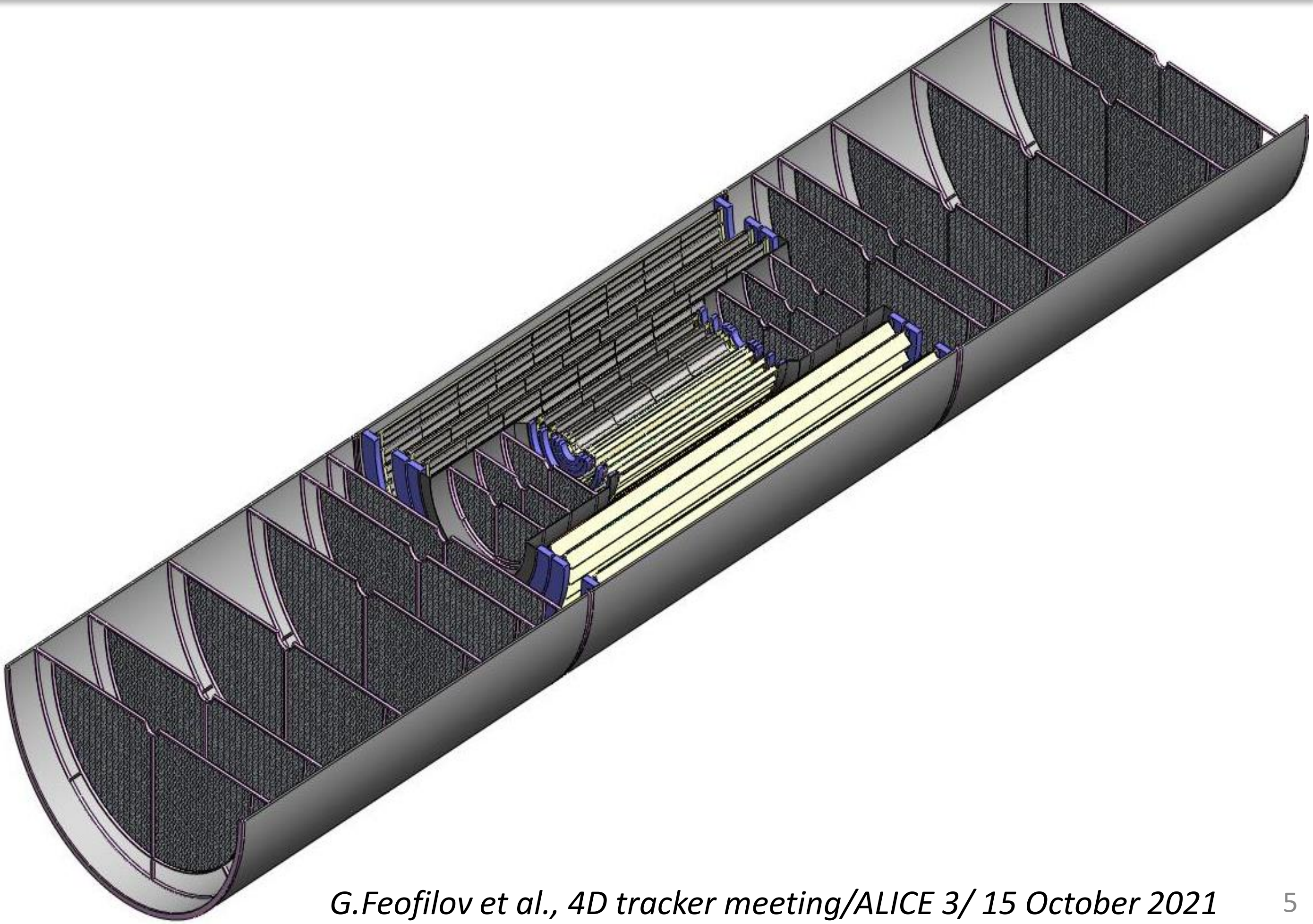
Corrado Gargiulo, ALICE Upgrade Week, 03/05/2022

IDEA 1-- general assembly issues:

Integration of **barrel layers and end cap disks of the** the Outer Tracker with the beam-pipe of ALICE 3

Conceptual layout by Sergey IGOLKIN

Using the ITS - MPD/NICA design



IDEA 1-- general assembly issues:

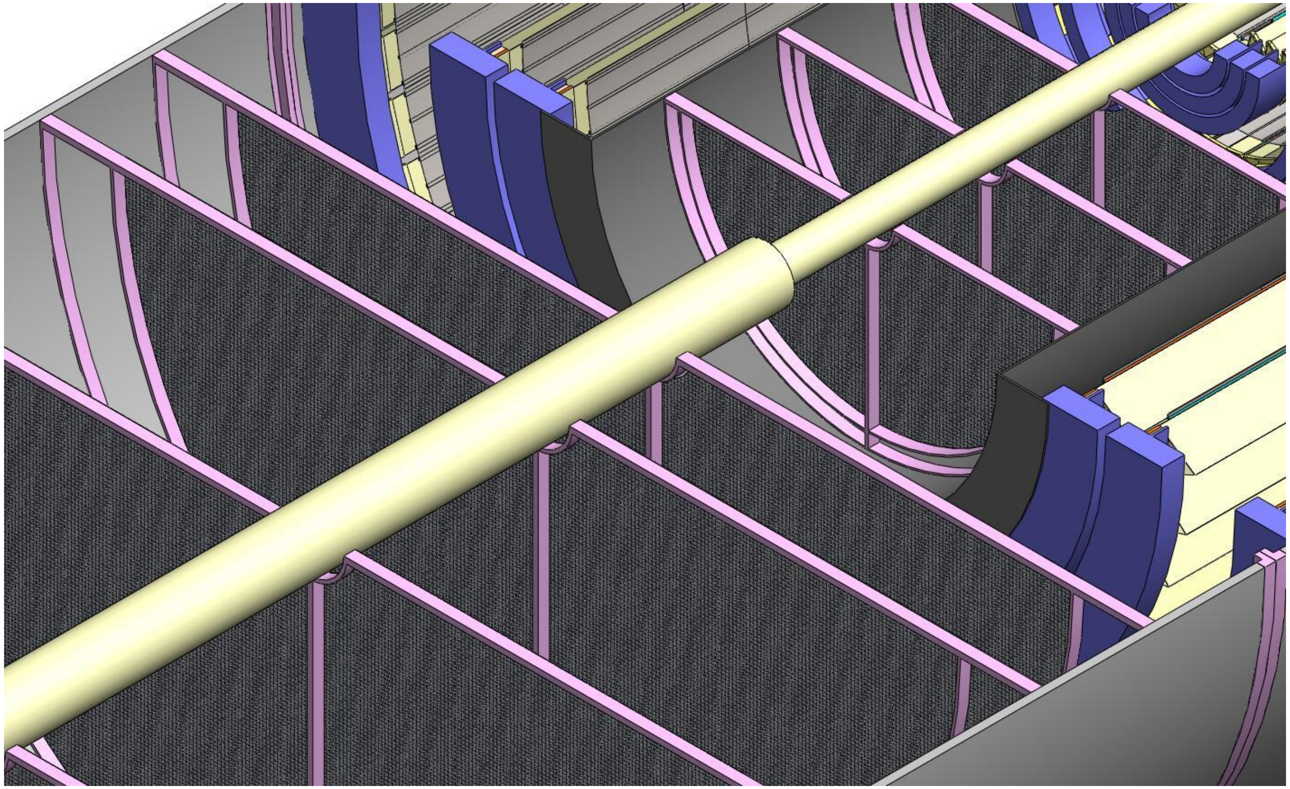
Integration of **barrel layers and end cap disks of the** the Outer Tracker with the beam-pipe of ALICE 3

Conceptual layout
by Sergey IGOLKIN

- Clam shell
- Rigid CF+honecomb
- Integration with the beam-pipe and IRIS

Questions:

1. How to cool and to drain heat?
2. CTE compatibility of large area thin Si-pixel sensors and CF?

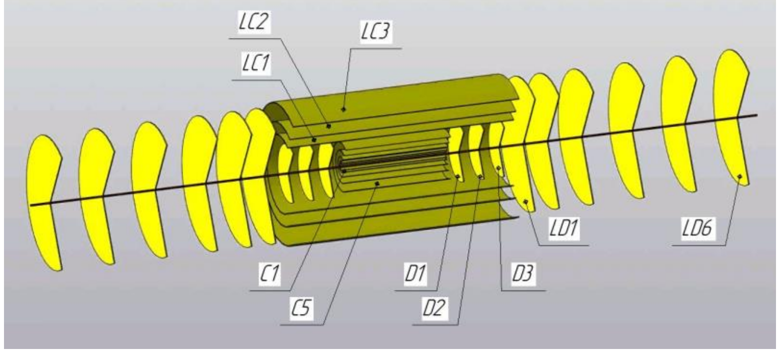


Calculations (by A.Marova) of loads and flows of cold dry air cooling for ALICE 3

	Radius, cm	Length, m	Weight, g (for 20 μm silicon layer thickness)	Weight, g (for 50 μm silicon layer thickness)	Full area, m^2	Heat flux (for q=20 mW/cm^2), kW	Heat flux (for q=140 mW/cm^2), kW
Cylinders							
C1	4,2		15,3	38,2	0,63	0,06	0,02
C2	6,6		30,5	76,3	1,00	0,09	0,03
C3	12	1,2	45,8	114,5	1,81	0,17	0,05
C4	19		61,1	152,7	2,87	0,28	0,07
C5	28		91,6	229,0	4,22	0,41	0,1
LC1	45		340,6	851,4	14,70	1,42	0,37
LC2	59	2,6	442,7	1106,8	19,28	1,86	0,48
LC3	80		613,0	1532,5	26,14	2,52	0,66
Discs							
D1-D6	33	-	16,4 (for all of discs: 98,4)	41,1 (for all of discs: 246,6)	0,68 (for all of discs: 4,08)	0,07 (for all of discs: 0,4)	0,02 (for all of discs: 0,1)
LD1-LD12	75	-	82,2 (for all of discs: 986,4)	205,5 (for all of discs: 2466,0)	3,54 (for all of discs: 42,48)	0,34 (for all of discs: 4,1)	0,09 (for all of discs: 1,1)
		Sum	2725,4	6814,0	117,2	11,3	3

Main results

Block	Weight, kg (for 20 μm silicon layer thickness)	Weight, kg (for 50 μm silicon layer thickness)	Heat flux (for heat flux density q=20 mW/cm^2), kW	Heat flux (for heat flux density q=140 mW/cm^2), kW
C	0,244	0,611	1,0	0,3
LC	1,396	3,491	5,8	1,5
D	0,098	0,247	0,4	0,1
LD	0,986	2,467	4,1	1,1
Sum	2,724	6,816	11,3	3,0



Arrangement of cylindrical and disc detectors for ALICE 3

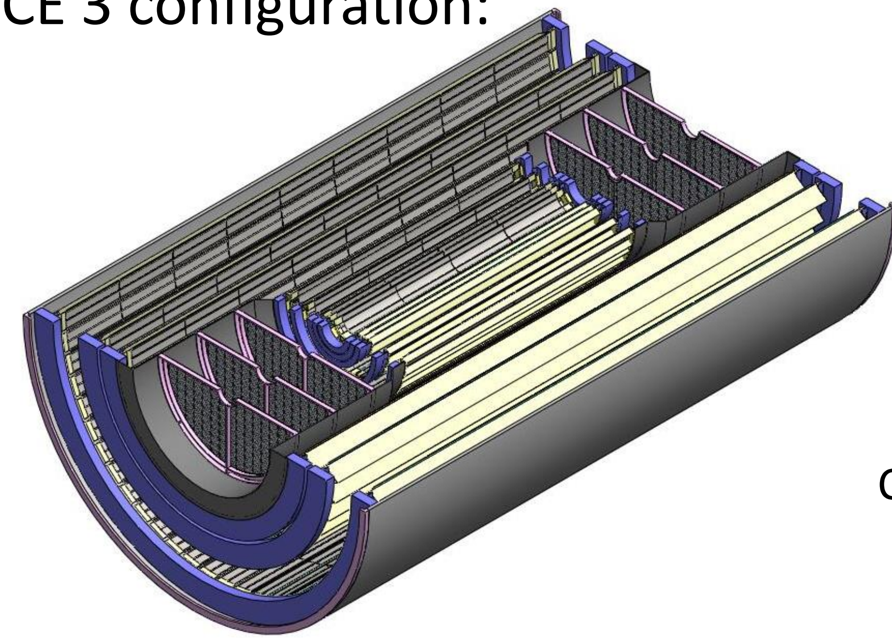
Beolé S.M. Present and future upgrades of ALICE

https://indico.cern.ch/event/1012633/contributions/4512627/

Heat flux density of 20 mW/cm^2 (or 140 mW/cm^2) is dissipated in both directions: from the inner surface of the detector and from the outer surface of the detector.

Flows of cold dry air cooling for ALICE central barrel (calculations by A.Marova)

ALICE 3 configuration:



To begin with, we will restrict ourselves to a cylinder with a radius of 80 cm and a length of 2,6 meters:

Heat flux carried away by the coolant, kW	Coolant	Flow velocity, cm/s	Input temperature, °C	Output temperature, °C
7 (cylindrical detectors only, heat flux density is 20 mW/cm²)	dry air	7,9	0	30
	nitrogen	9,0	0	30

Comparison with experimental data for ITS-3:

Heat flux carried away by the coolant, kW	Coolant	Flow velocity, cm/s	Input temperature, °C	Output temperature, °C
0,02	nitrogen	2,0	10	45

There are two main problems:

- it is necessary to provide laminar flow of the coolant;
- the temperature of the coolant should not be too low (but must provide the required temperature regime)

Possible solutions:

- To separate heat flows to provide cooling separately by modules;
- To carry out experiments to select the optimal coolant flow velocity and layout

G.Feofilov et al., 4D tracker meeting/ALICE 3/ 15 October 2021

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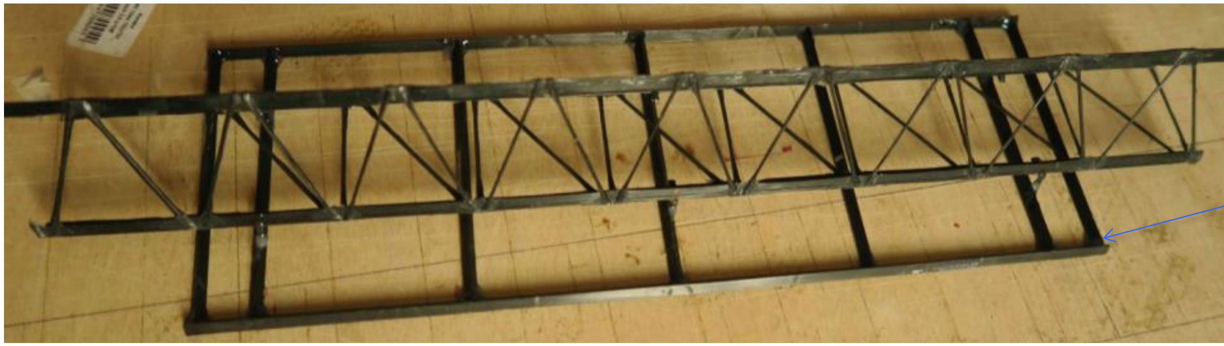
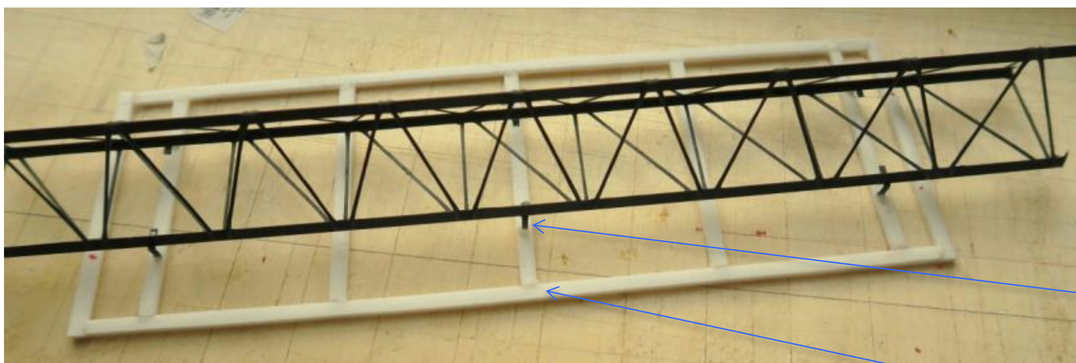
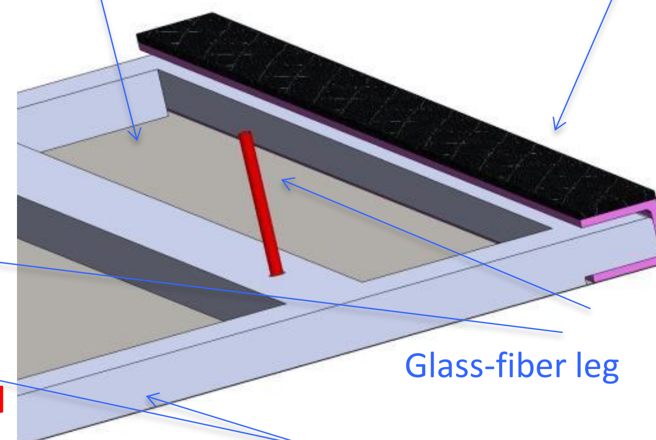
Individual 2800 mm length modules







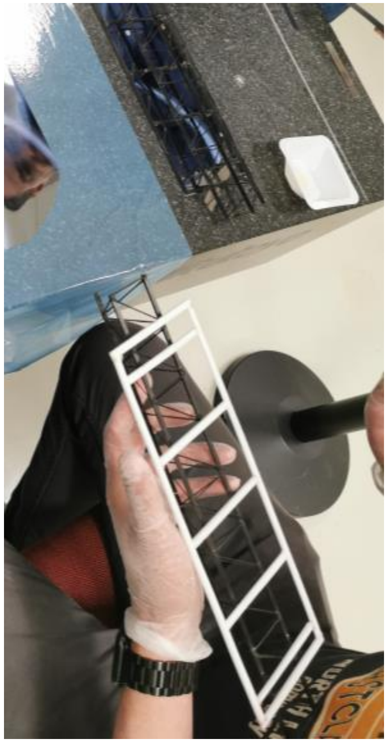
- 2 structures were prepared in St.Petersburg to be tested at CERN in April together with Si-plates glued
- Thermomechanical stability limits?
- Vibrational (hopefully)

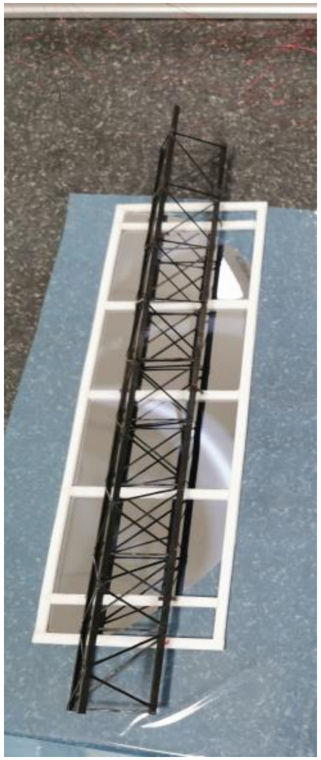
https://www.3accorematerials.com/en/markets-and-products/airex-foam

NB! Airex T92.80 alone CTE = (135 ± 10) 10-6 /K (!?)

New!

Option 2: individual 280 mm length module

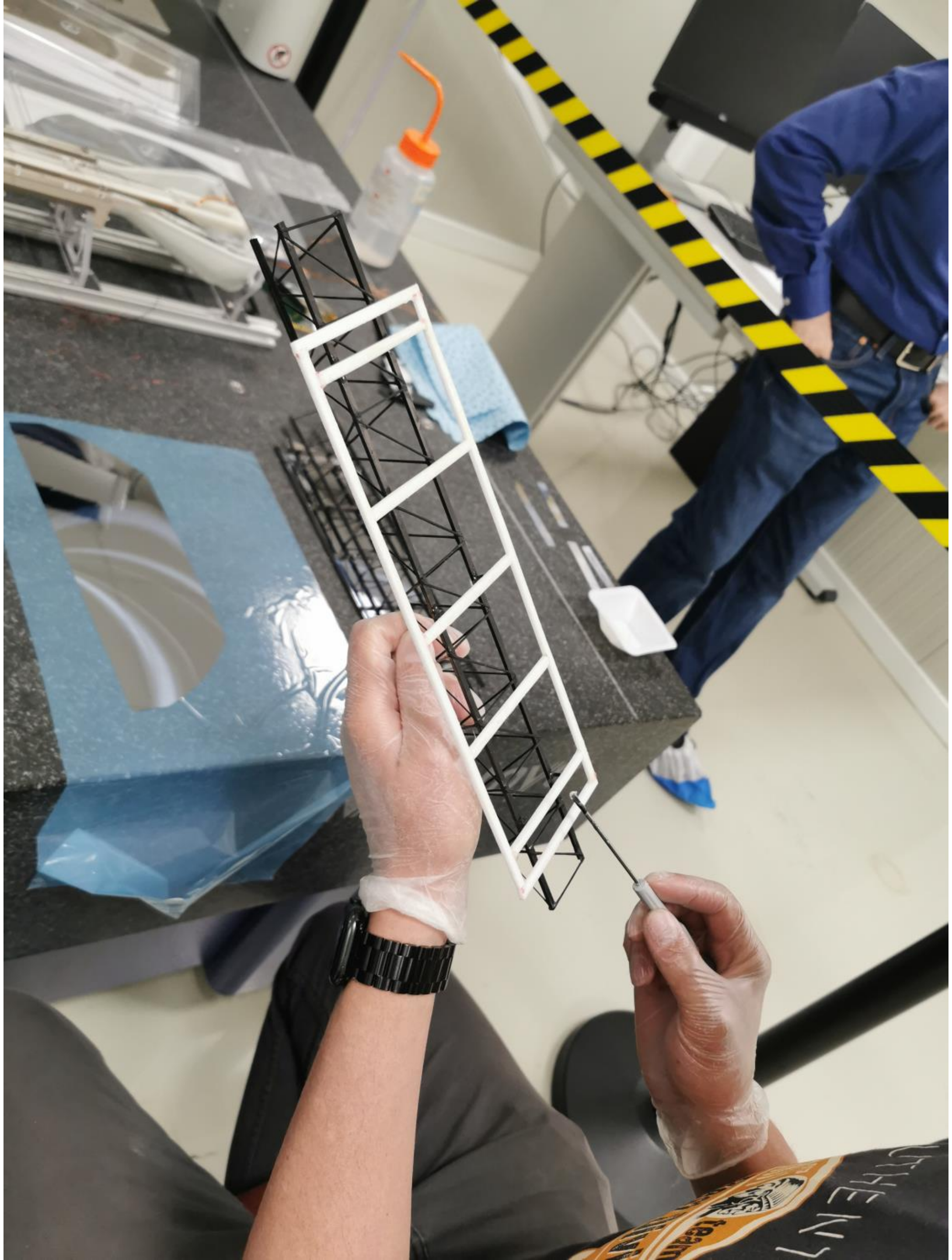




1) Thin large area 280x94 mm^2 Si-plate is glued (Araldite) to the CF frame. In several dots of glue.

2) Thin large area 280x94 mm^2 Si-plate is being glued (Araldite) to the AIREX® foam frame. Thin layer of glue.

3) AIREX® foam frame with large area Si-plate 15.04.2024



- Two different schemes for gluing of Si and frame :

  1. Dots of araldite in the corners on the carbon or Airex frame
  2. Continuous gluing over the ribs

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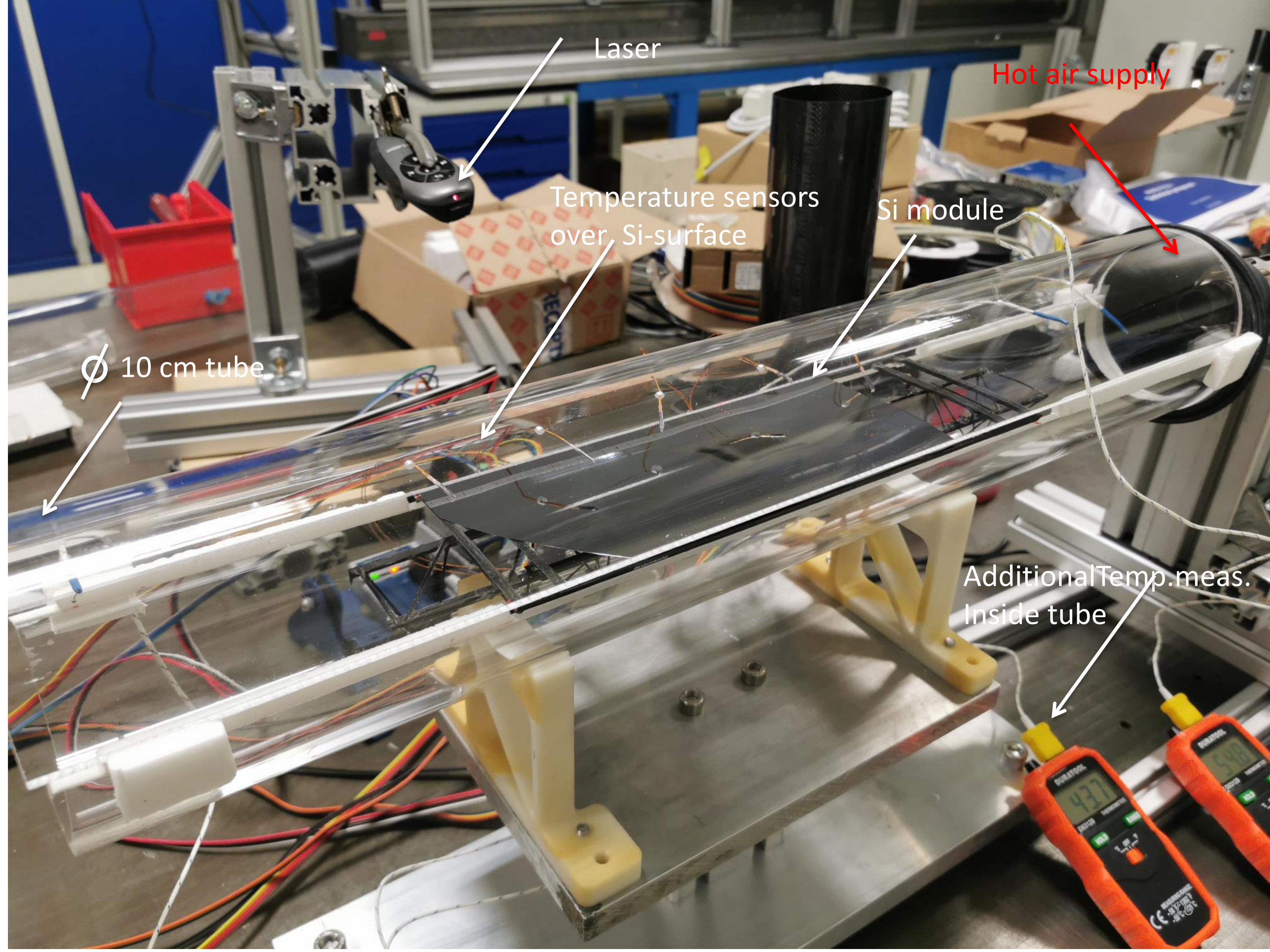
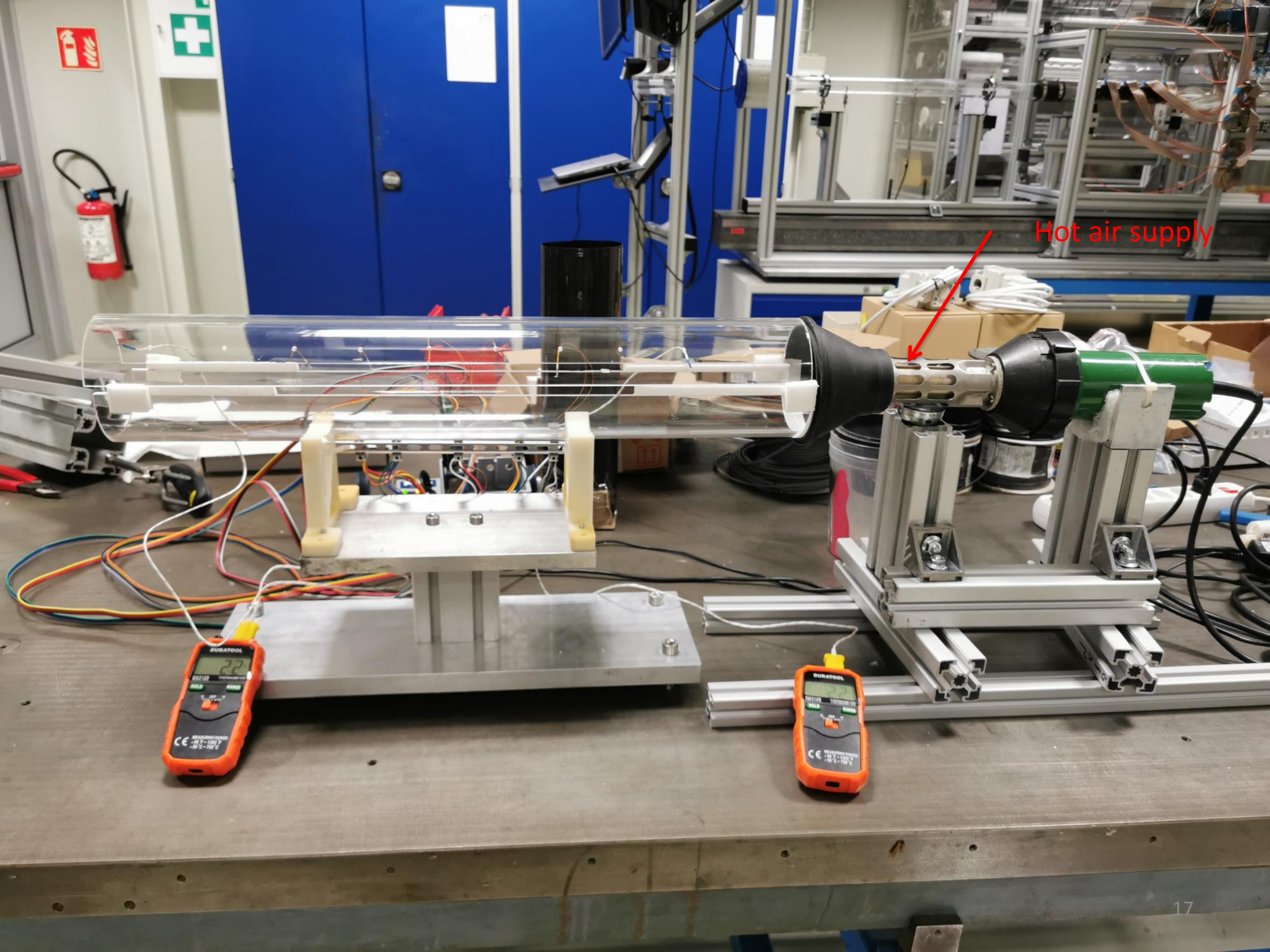
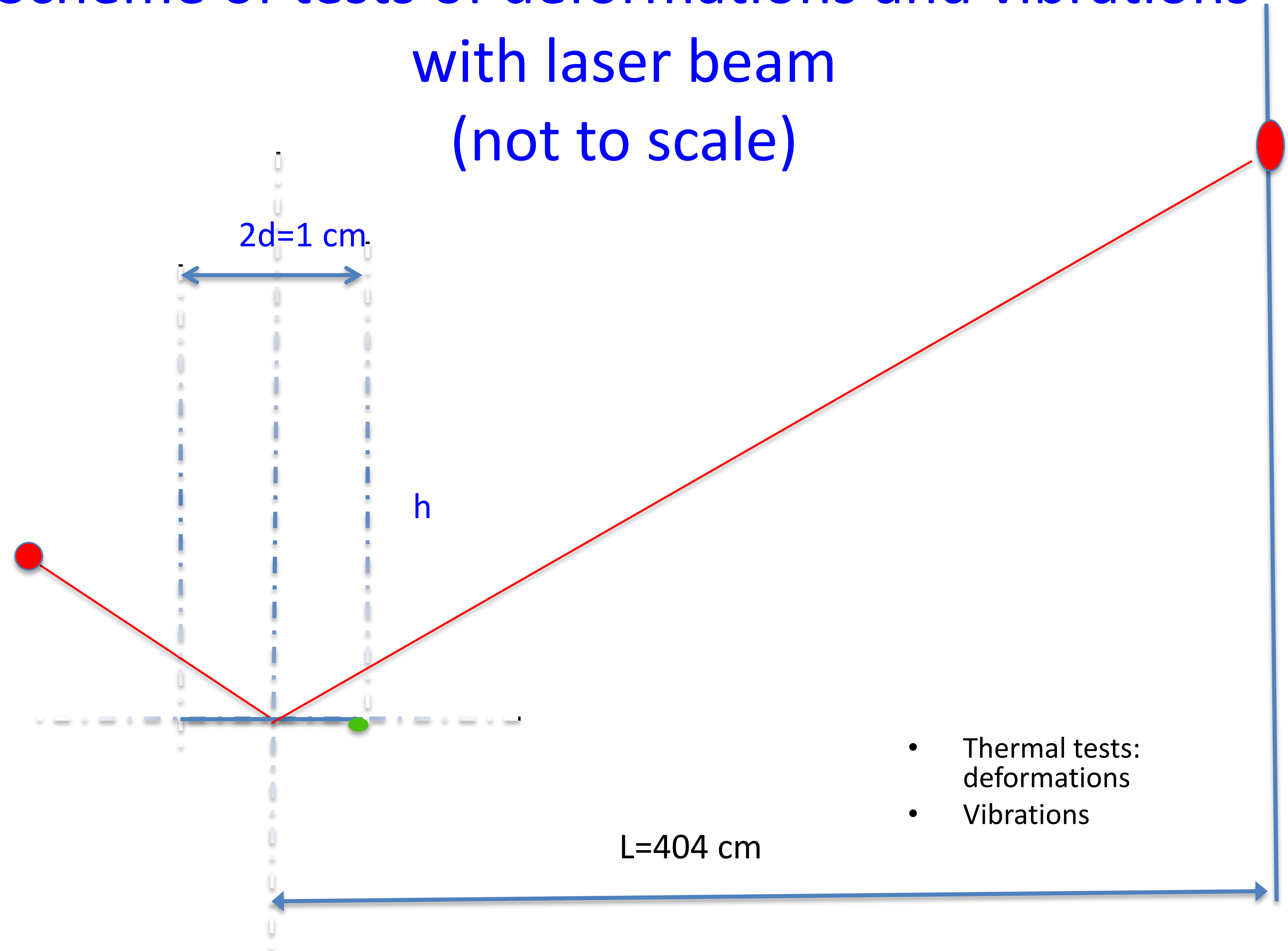

Laser
Hot air supply
Temperature sensors
over Si-surface
Si module
∅ 10 cm tube
AdditionalTemp.meas.
Inside tube

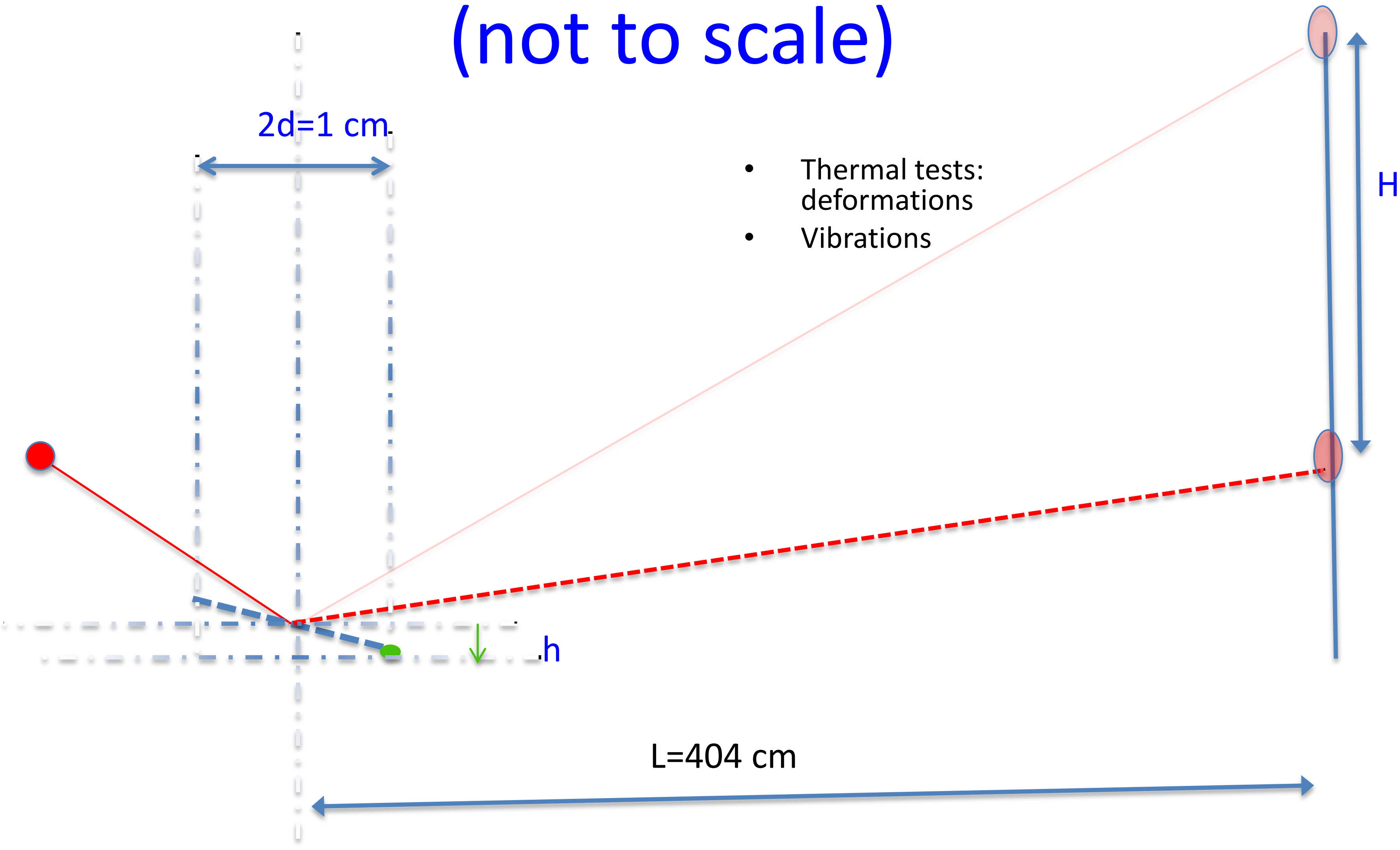

Hot air supply
DURATOOL
DURATOOL

Scheme of tests of deformations and vibrations with laser beam (not to scale)



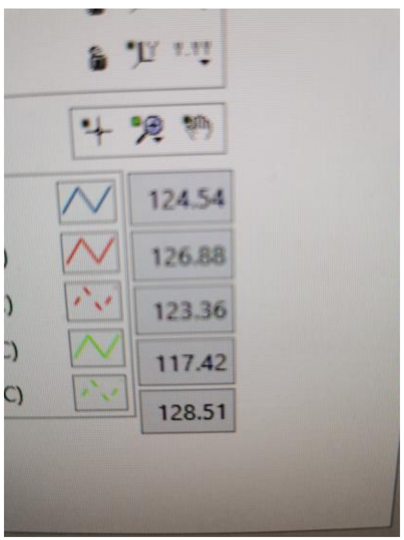
- Thermal tests: deformations
- Vibrations

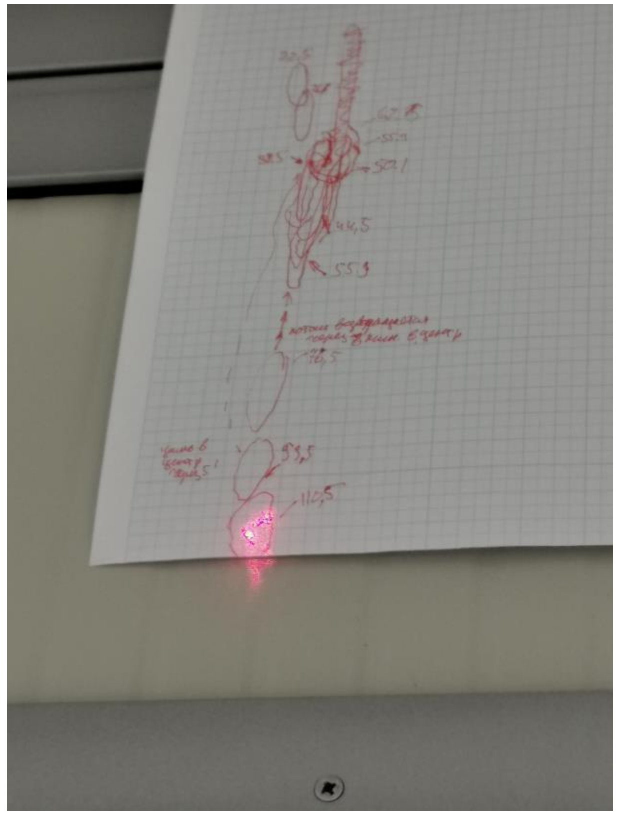
Scheme of tests with laser beam

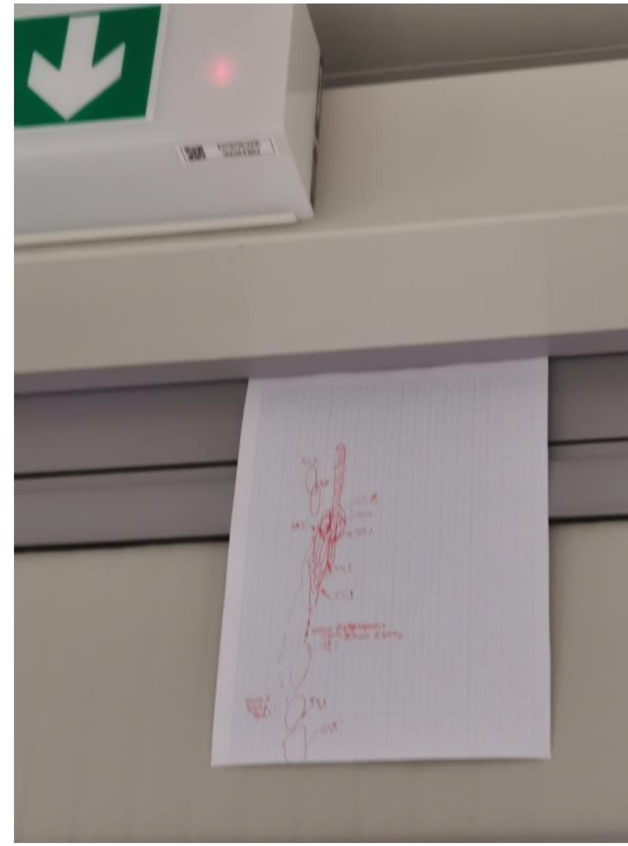


- Thermal tests: deformations
- Vibrations

Different temperature regimes





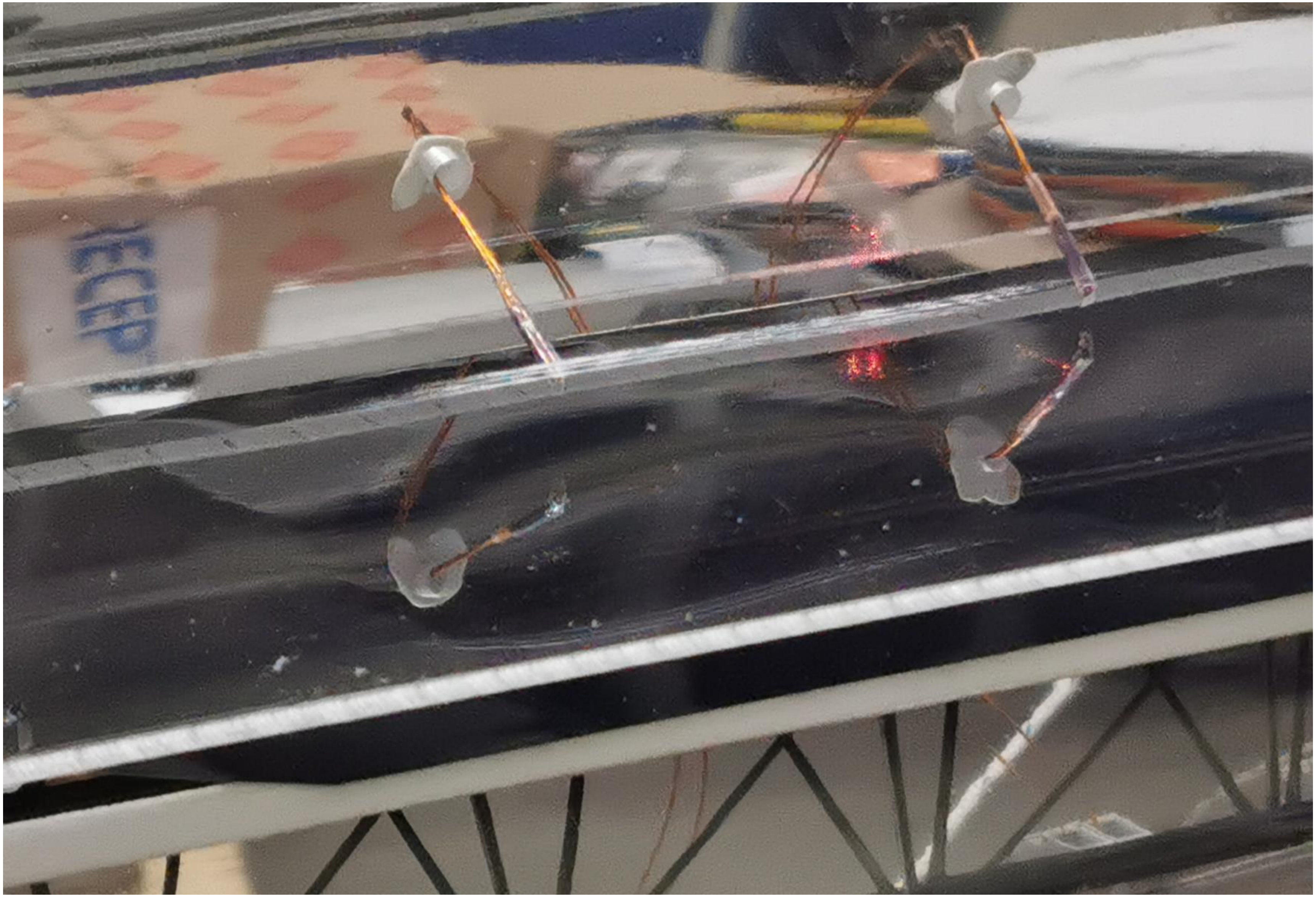


Temperature of air was measured by several sensors inside the tube

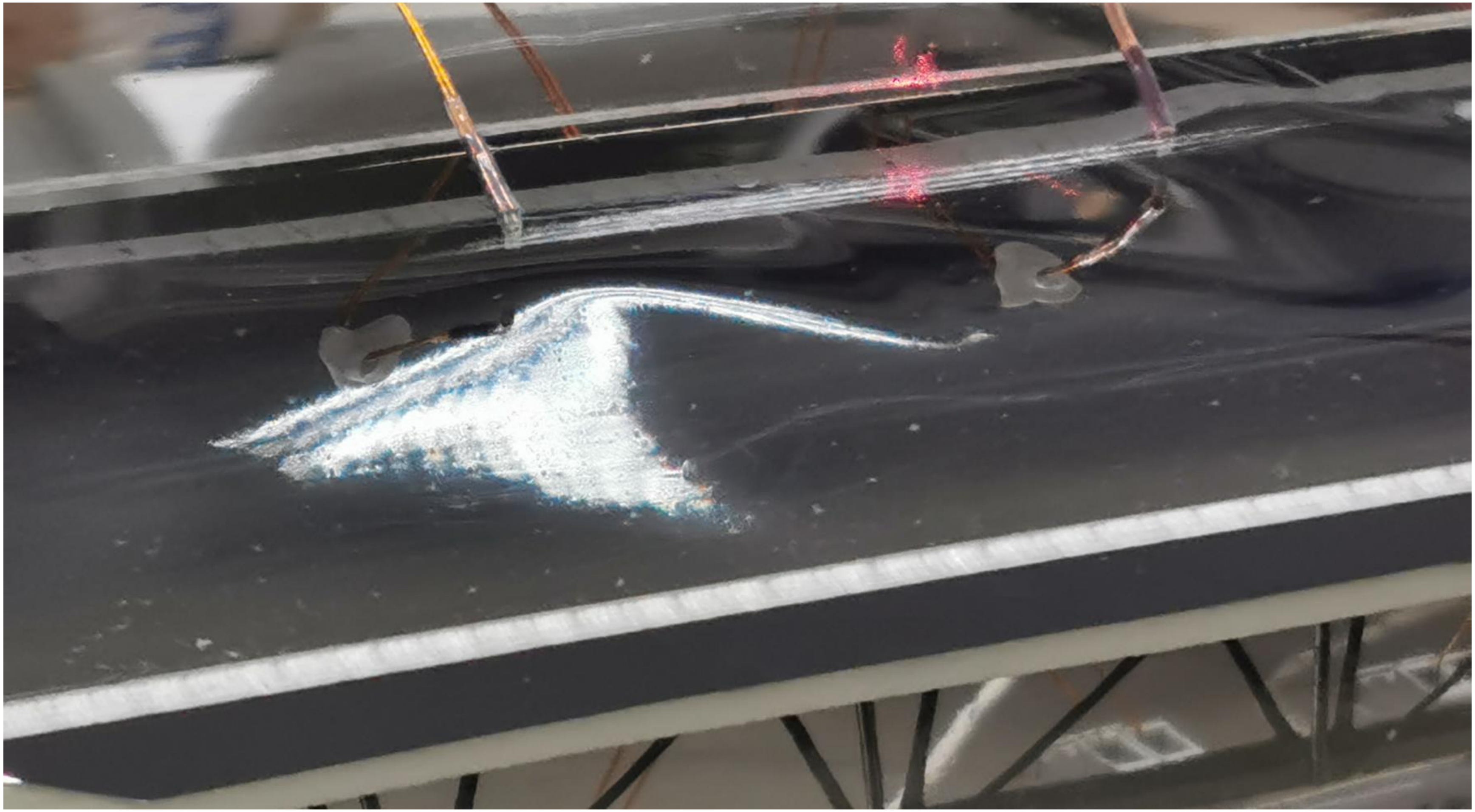
Air-speed measurements:
100 L in about 17 s --> ~ 1m/s (+-10%)

Layout

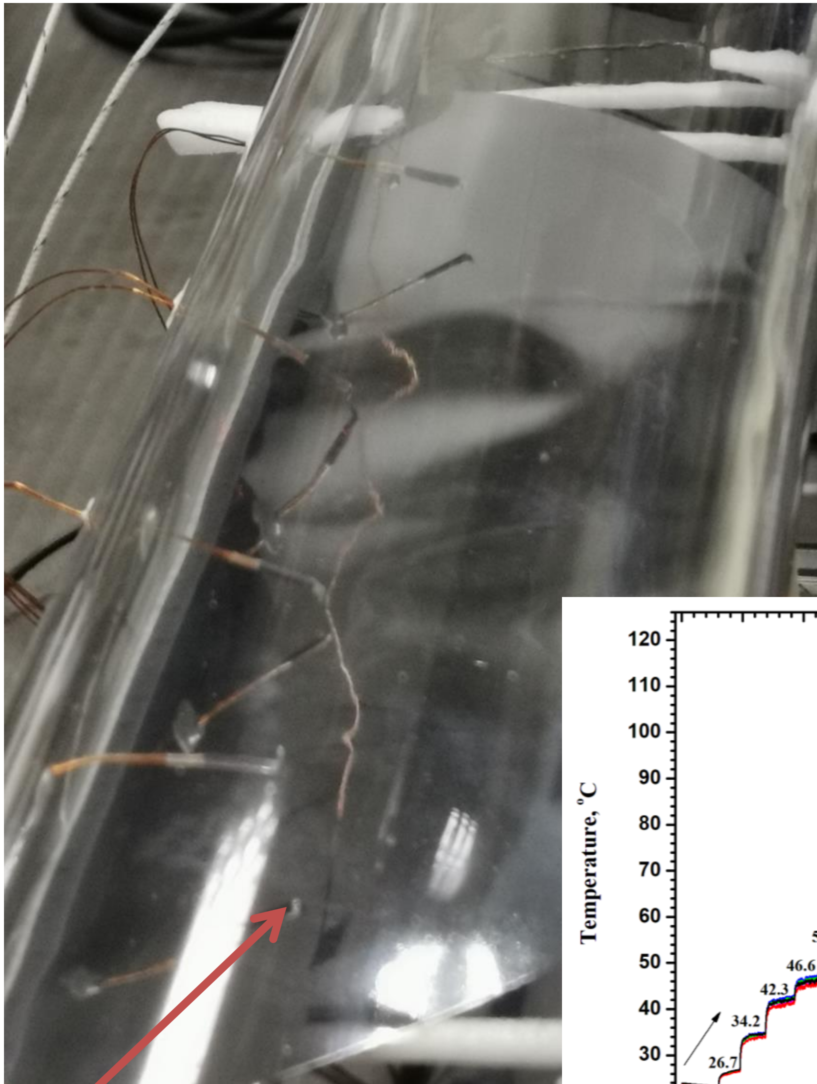
AIREX frame + Si:
deformations at different temperatures

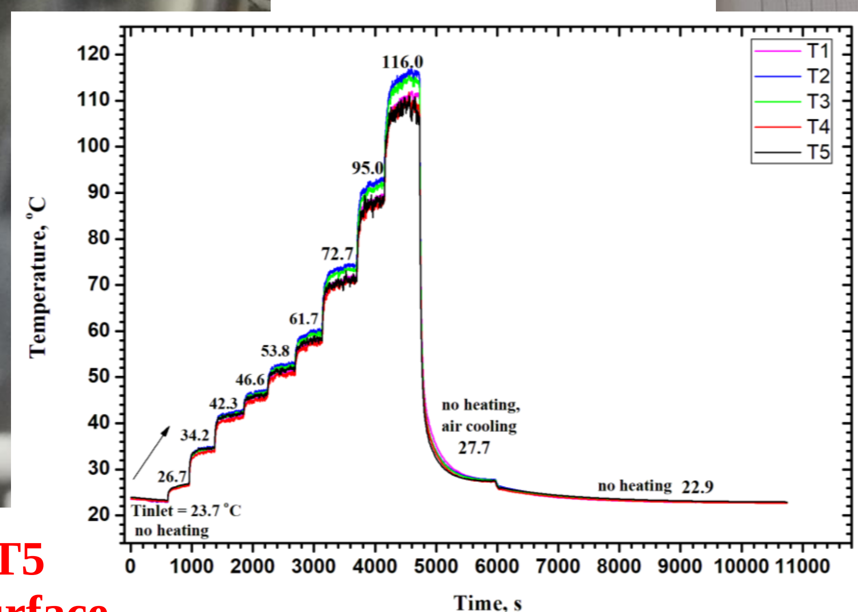


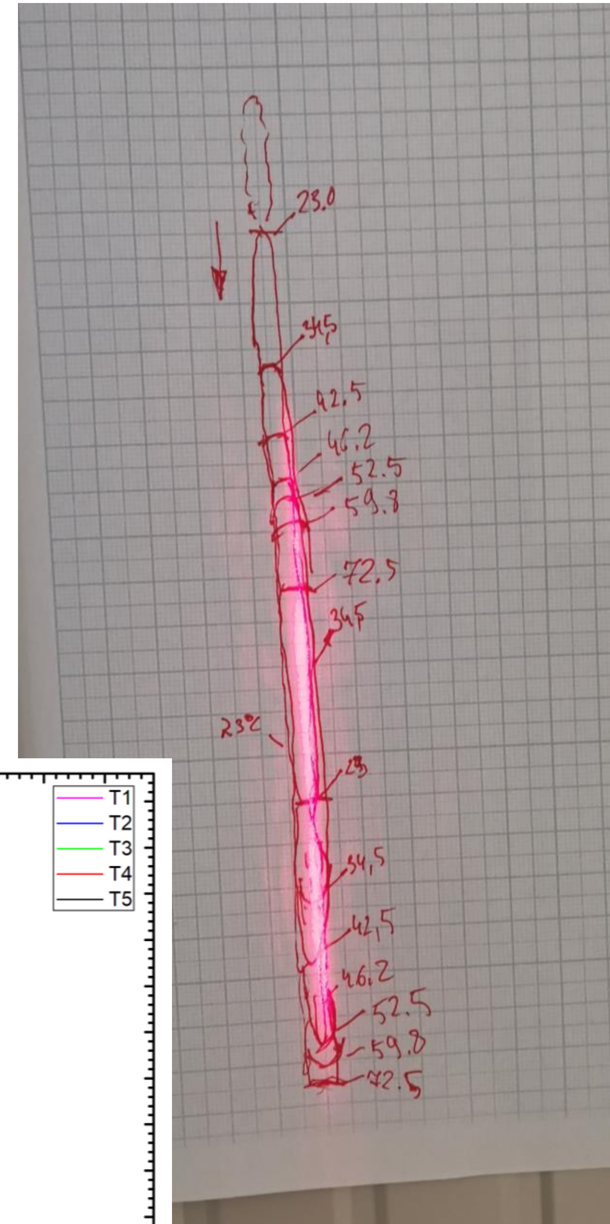
AIREX frame + Si:
deformations at different temperatures



Airex frame + Si:
deformations at different temperatures







Five thermo-sensors: T1-T5
Temperature on Si surface

Results of thermomechanical tests

- Important: Si plates fixed to the lighweight frames do not break in these temperature variations 20-120 ^{o}C!
- Temperature variations from +20 to +120 degrees C
- Deformations – value *h*, see slide 19:

for the large area thin Si-pixel sensors and AIREX (dots of glue in the corners of the AIREX frame)

– noticable deformations, at the level of ~ 250 μ -?? at the

-- large mismatch between CTEs

NB! Airex T92.80 alone CTE = (135 ± 10) 10-6 /K

-- residual deformation after coolling back to 22 degrees

- Deformations – value *h*, see slide 19:

for the large area thin Si-pixel sensors and CF frame

-- at the level of ~ 120 μ--??

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Results of vibrational tests at ~ 1m/s air flow

- Temperature variations from +20 to +120 degrees C
- Amplitude of vibrations – value *h*, see slide 19:

  for the large area thin Si-pixel sensors and AIREX (dots of glue in the corners of the AIREX frame)

  – vibration sat the level of ~ 120 μ at the

  -
- Amplitude of vibrations – value *h*, see slide 19:

  for the large area thin Si-pixel sensors and CF frame – glue is spread uniformley over ribs

  -- vibrations at the level of ~ 10 μ

  -- better performance then for Si+AIREX

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Conclusions:
perspectives for application in ALICE 3 design

IDEA 1-- general assembly issues:

- Outer supporting CF+honecomb structure in the clam-shell design housing the Outer Tracker and the FCT disks
- Integration of barrel layers of the Outer Tracker and FCT disks inside this Outer supporting CF+honecomb structure .
- two types of assembly modules:

1. ladders with arrays of thin large-area MAPS
2. half-disks of CF frames with thin large-area MAPS

- Possible integration with the beam-pipe of ALICE 3 and IRIS

IDEA 2-- extra-lightweight mechanics

IDEA 3-- laminar flows of cold dry air cooling

Conclusions:
perspectives for application in ALICE 3 design

Ideas of extra-lightweight CF support structures and cooling scheme are proposed for the future ALICE 3 that are capable to ensure:

- the high level of thermo- and mechanical- stability of large area arrays of thin (~20-40 μ) sensors in MAPS technology
- reliable assembly procedure of the ALICE-3
- low speed, low temperature, efficient gas cooling system to provide the functionality without vibrations of the large area arrays of ultra-thin 20-40 μ silicon sensors
- **ALICE Internal Technical Note is being prepared.**

BACK-UP SLIDES

Our reports at ITS-PW5

- “Conceptual ideas of ultra-ligthweight self-supported mechanics and cold gas cooling for ITS 3, recent prototyping and thermomechanical tests, perspectives for application in ALICE 3 design."

Tuesday 16 Apr 2024,

https://indico.cern.ch/event/1405488/

- **“St Peterburg updates on studies of thermomechanical compatibility of CF and Si plates with different CTEs”**, Tuesday 10 Oct 2023

https://indico.cern.ch/event/1334873/

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- **Self-supported ITS 3 modules with bent thin sensors and cold gas cooling , ITS3 Upgrade WP5 (Mechanics and Cooling) meeting 14.02.2023,** https://indico.cern.ch/event/1253461/

- **Conceptual ideas for the ITS-3 mechanics and cooling: ultra-lightweight carbon fiber support**

Structures, **ITS3 Upgrade WP5 (Mechanics and Cooling) meeting 14.02.2023**
https://indico.cern.ch/event/1253461/

- **Recent results with the mechanical mockup of the ITS 3 layers based on self-supported CF longerons,** ITS3 - WP5 Tuesday 28 Jun 2022

https://indico.cern.ch/event/1176198/

- Advances in low speed gas cooling and extra ligthweght self-supported mechanics for **ALICE ITS-3 modules,** ITS-upgrade WP5 meeting, 10 May 2022**,** https://indico.cern.ch/event/1158834/

Our reports at ITS-PW5, cntd

- Recent results on nitrogen cooling for three layers of the upgraded ITS3 mockup with space blanket, ITS3 -WP5 (25_January 2022) · Indico (cern.ch),

https://indico.cern.ch/event/1118907/

- 3 Ideas for ALICE 3: radiation transparent Cooling/Mechanics/Assembly system for MAPS based OT and FCT, 4D tracker meeting/ALICE 3/ 15 October 2021, https://indico.cern.ch/event/1087515/

- --"Conceptual ideas for the ITS-3 mechanics and cooling: Nitrogen cooling of the ITS-3, part III." **ITS3 Upgrade WP5 (Mechanics and Cooling) meeting 06.07.2021**

https://indico.cern.ch/event/1056410/

- ---On prototyping in Saint-Petersburg for ITS3, **ITS3-WP5 15.06.2021,**

https://indico.cern.ch/event/1049413/

- **---Upgrade of the extra-lightweight mechanics design for ITS3.** ITS-upgrade WP5 meeting 09 March 2021

https://indico.cern.ch/event/1015925/

----Conceptual ideas for the ITS-3 mechanics and cooling: Nitrogen cooling of the ITS-3, part II, ITS-upgrade WP5 meeting 09 March 2021 https://indico.cern.ch/event/1015925/

- **Proposals for further optimization of ALICE ITS-3 cooling/mechanics/assembly,** ITS-upgrade WP5 meeting,30 June 2020