Vertex detector cooling and mechanical supports

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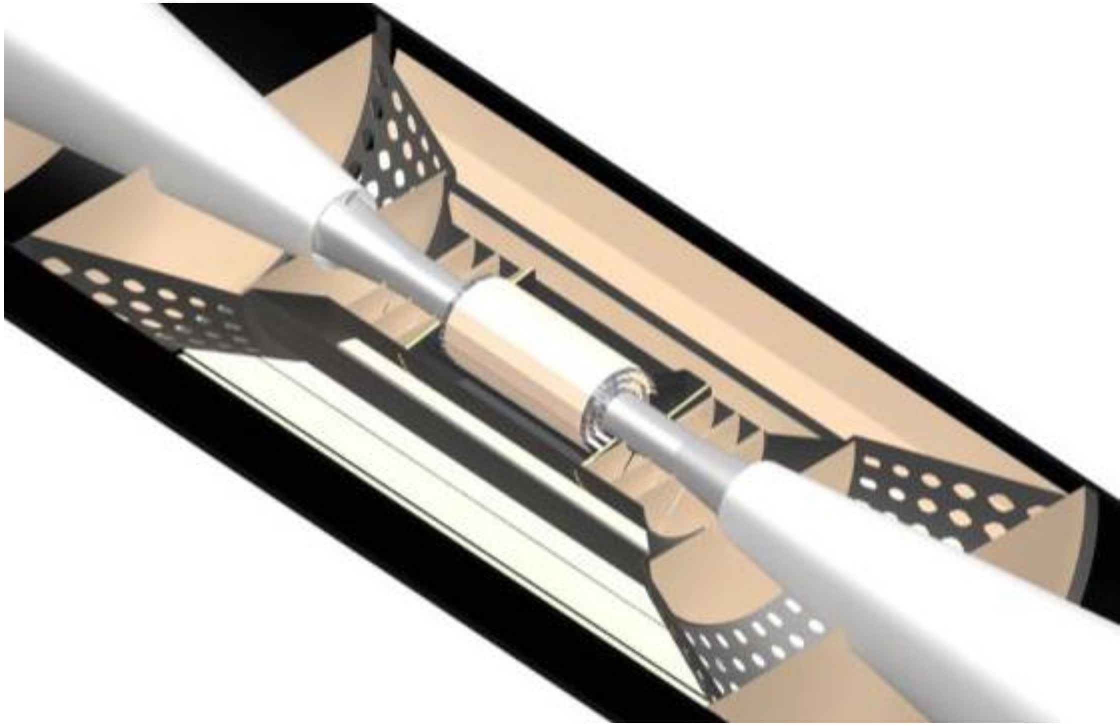


Objectives of the study

CLIC VERTEX CHALLENGES

→ Low material budget:
(0.18% X/X0 per layer in VXB of which 0.11% is silicon)
→ Air cooling:
- Room temperature operation;
- ~470 W Heat load to extract;

→ High dimensional stability
→ Assembly and cabling integration

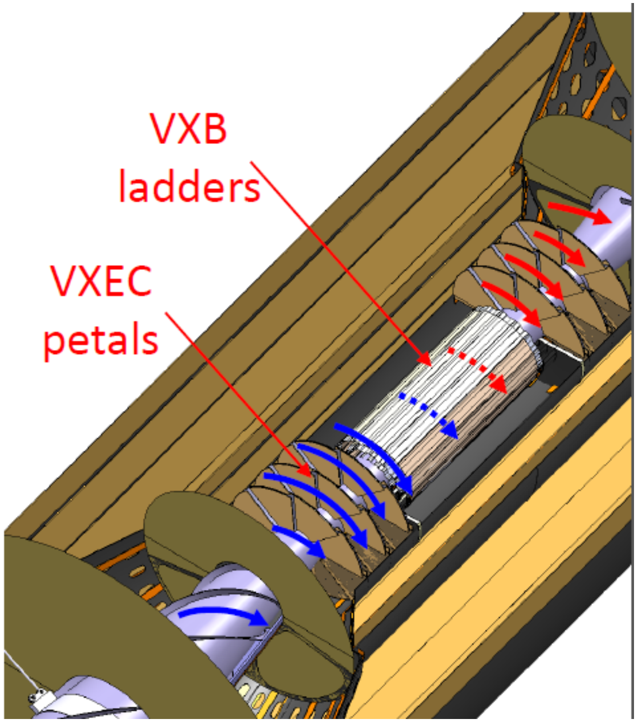
SHORT TERM OBJECTIVES:

→ Develop and characterize low-mass structures (STAVES): ~0.05% X/X0

→ Evaluate forced convection air cooling of the structure
Nominal heat dissipation: 50mW/cm^2, ΔT measurements

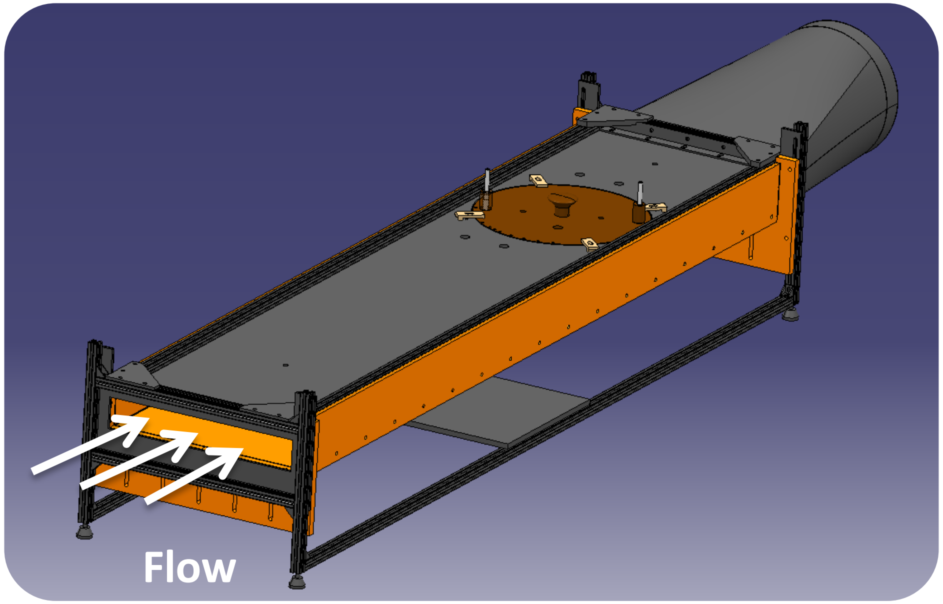
→ Measure air-flow induced vibrations on the structure

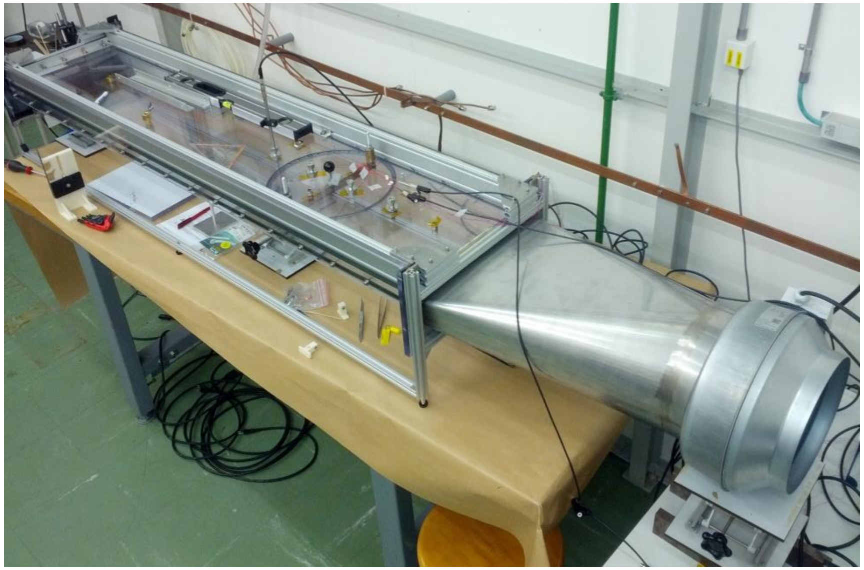
→ Validation of simulations (thermal and mechanical)



Set up Description

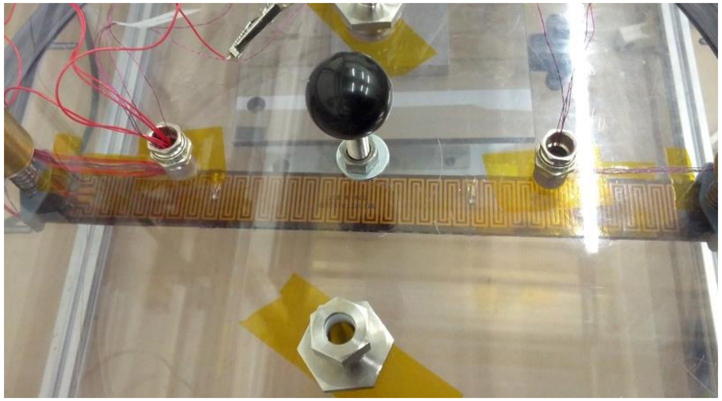
→Construction of thermo-mechanical test bench for Vertex staves





→System adaptable for the 3 Barrel layers:

- -Movable walls
- -Air flow tuning
- -Several stave orientations
- -Suitable for various stave geometries

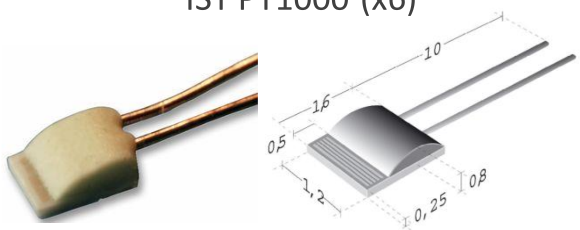


Set up Description – Read out

→ Read out system and equipment

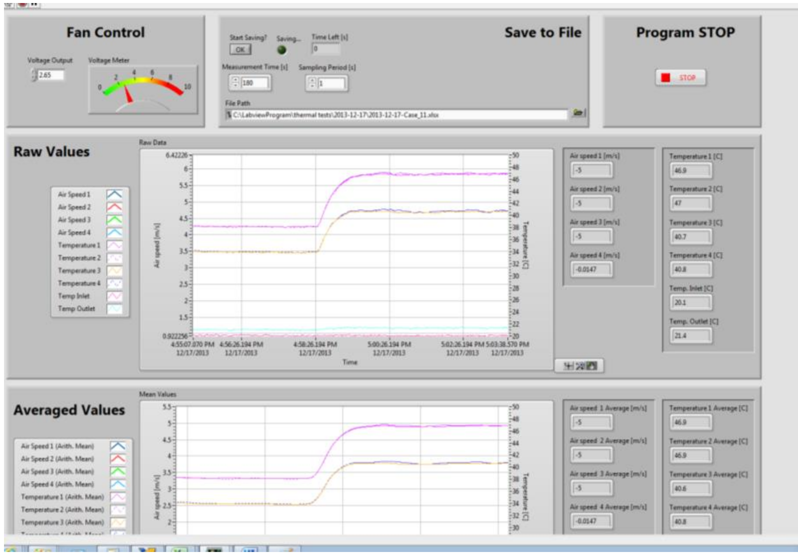
Schmidt SS 20.400 anemometer (x4)

IST PT1000 (x6)



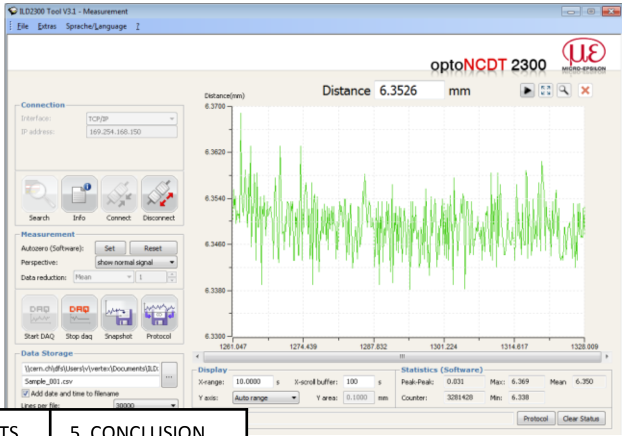
NI cDAQ-9188

LabVIEW interface



Micro-Epsilon optoNCDTLL 2300

Resolution:
→0.15μm @ 15kHz
Measuring frequency
→up to 49 kHz



Set up Description – Read out

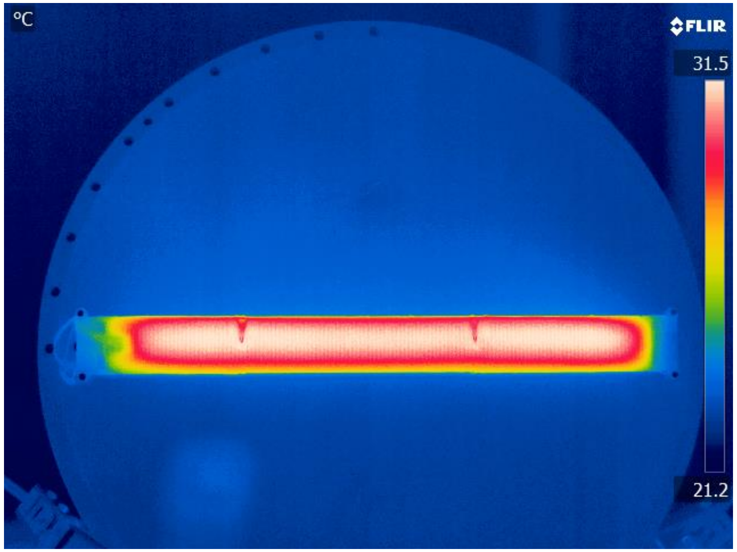
→ Read out system and equipment (From PH/DT)

PH-DT
Detector Technologies

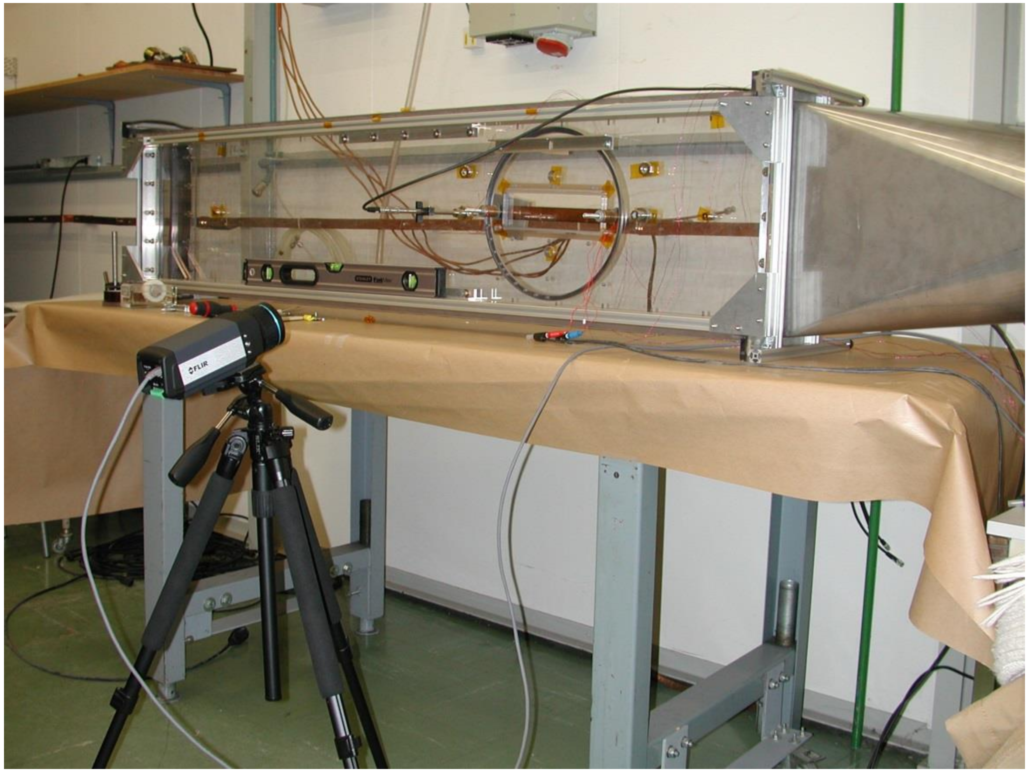
Thermal camera **FLIR A655 sc**

-Resolution:	640*480 pixels
-Images frequency:	50Hz
-Sensibility:	< 50mK
-External trigger	

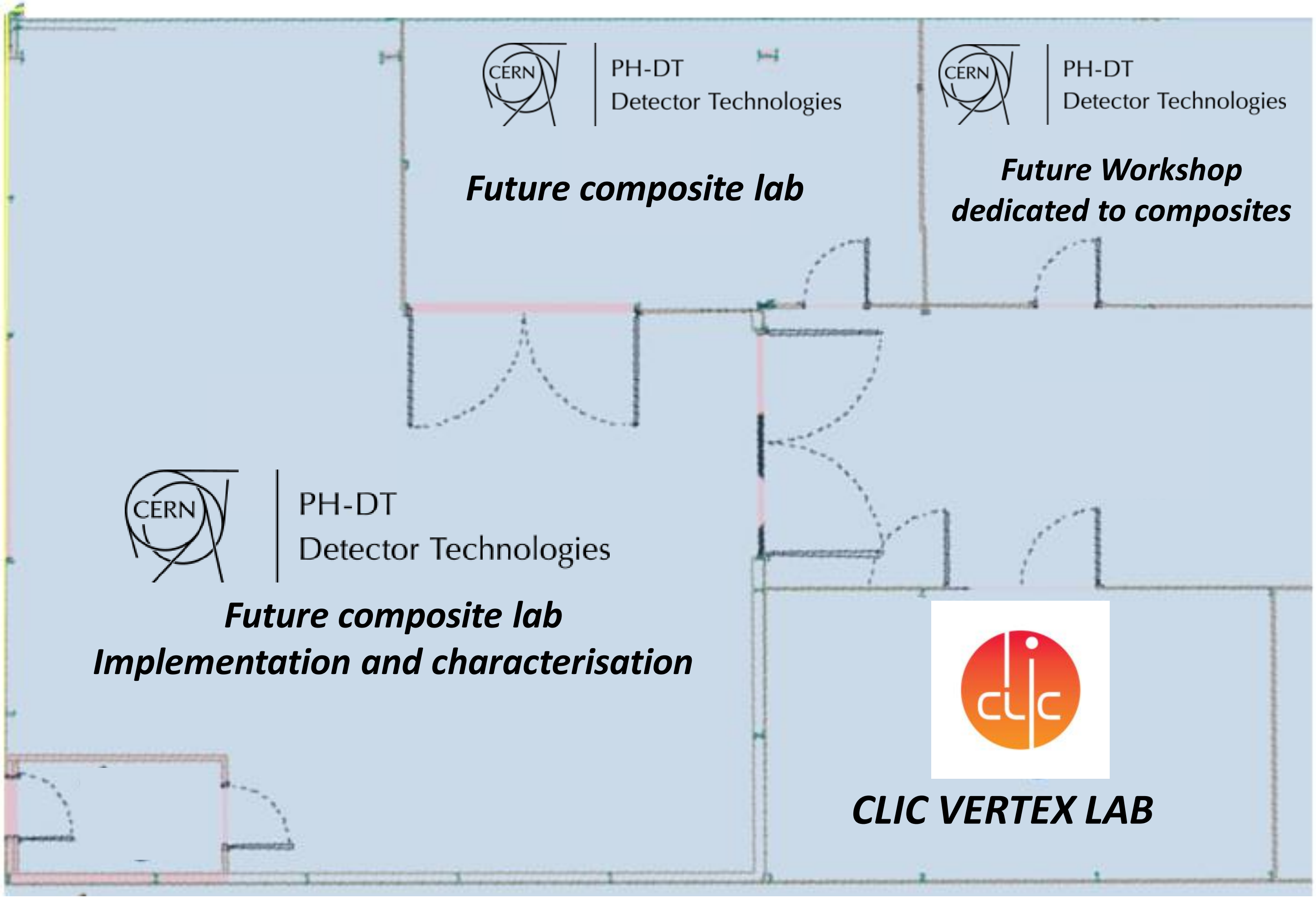
Interface



Set up



Laboratory

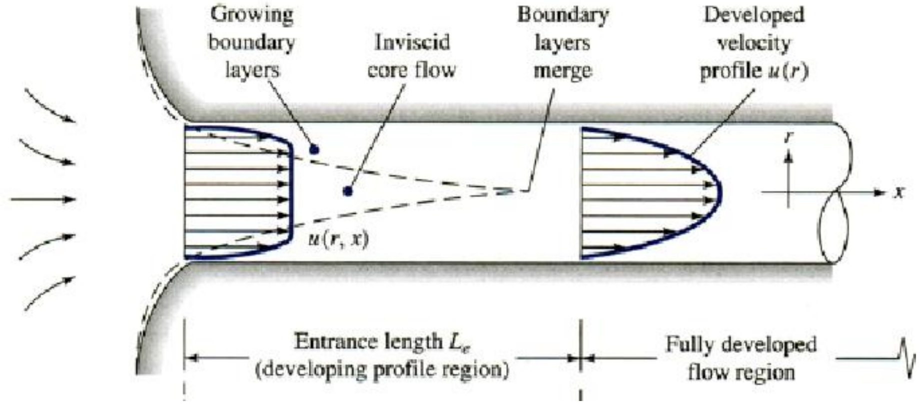


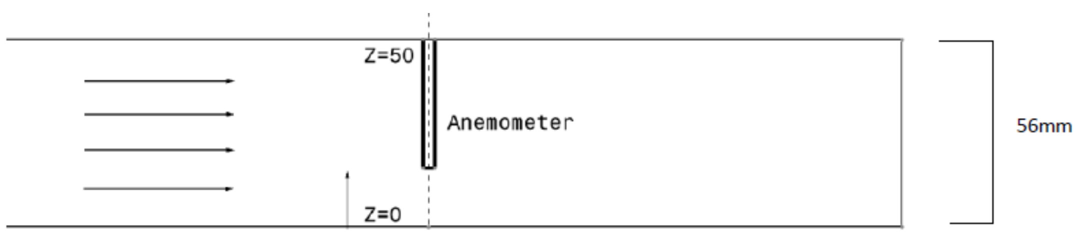
Your are welcome in 153-R-040 !

Implementation and commissioning of a thermo-mechanical set up

→ Aeraulic tests:

Study of the air velocity profile

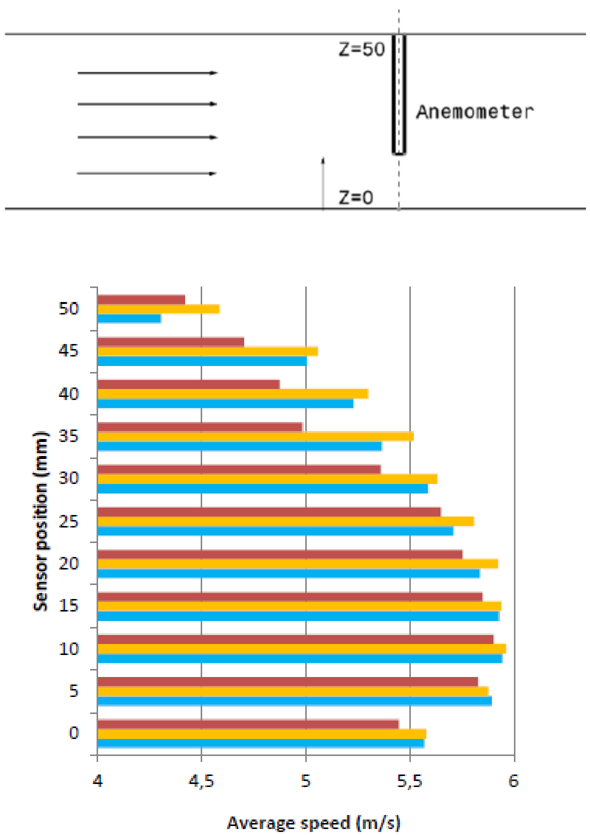


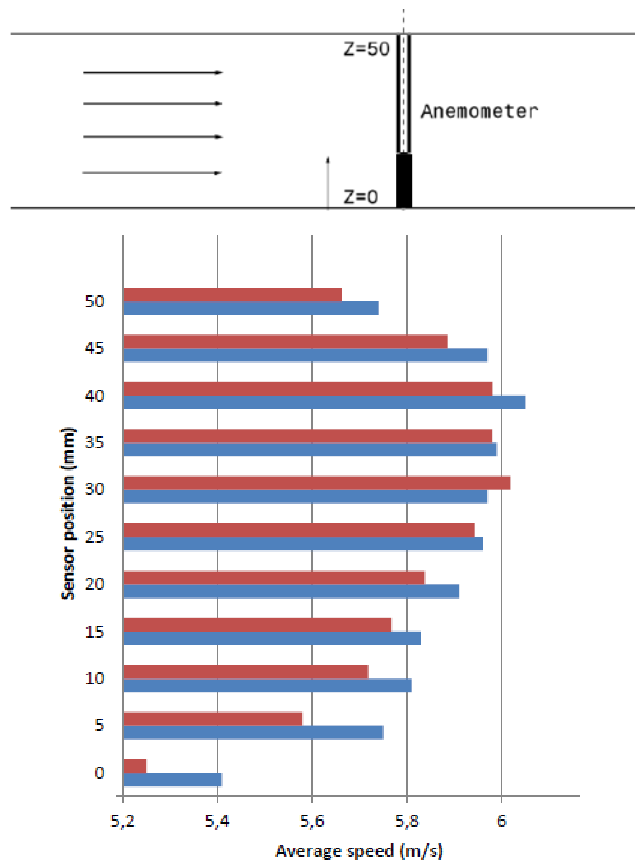


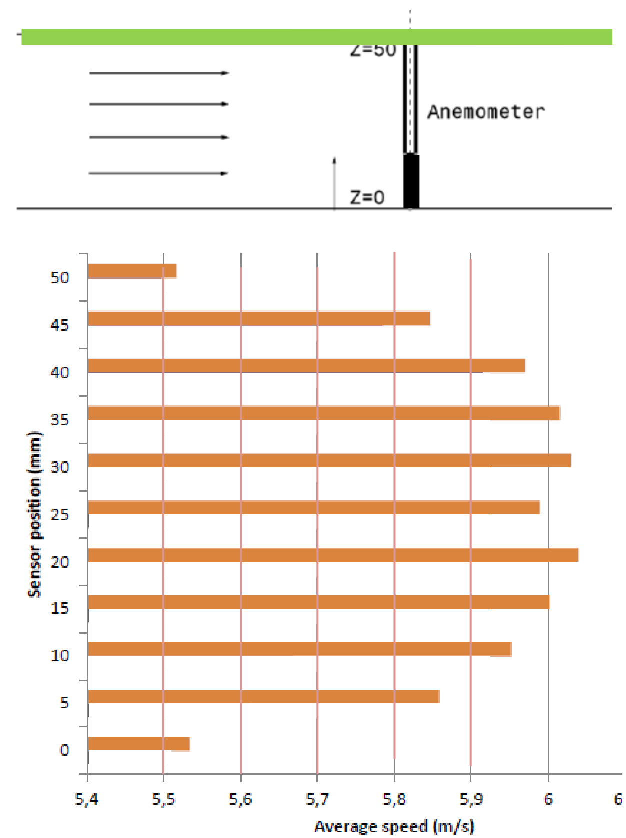
Implementation and commissioning of a thermo-mechanical set up

→ Aeraulic tests:

Study of the air velocity profile







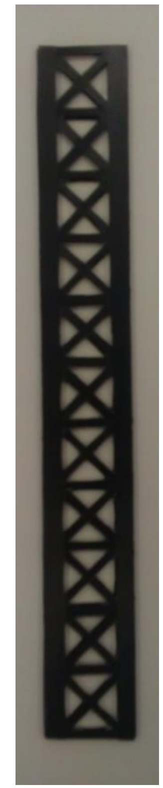
Vertex Detector Structure: Stave

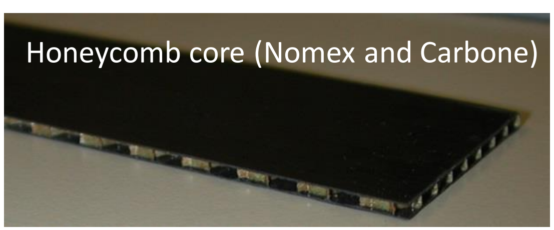
→ Several stave designs have been mechanically tested (1.8mm*26mm*280mm)

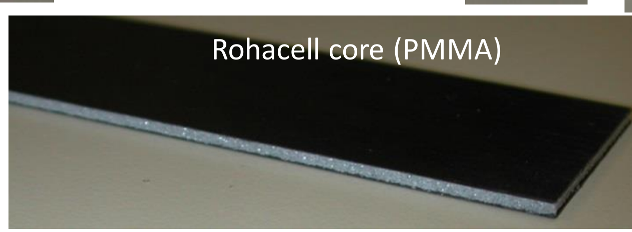
Skin Staves

Full sandwich Staves

Cross bracing Staves







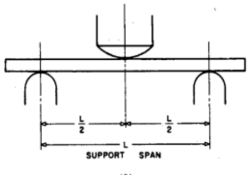
Prepreg used:
M55J 140g/m^2
T800 30g/m^2

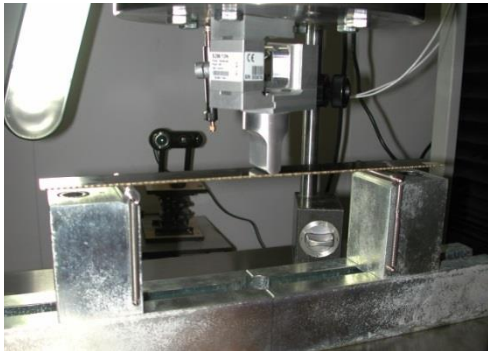
Vertex Detector Structure: Stave

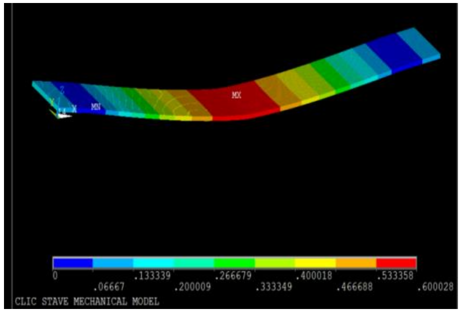
→ Study and development of manufacturing

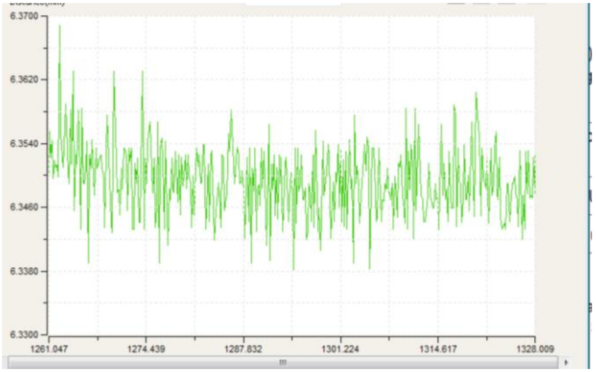
- -Mass optimisation
- -Production regularity
- -Materials and assembly process R&D (Core, skin…)

→ Stave Mechanical Characterisation → Simulations → **Vibration analysis**

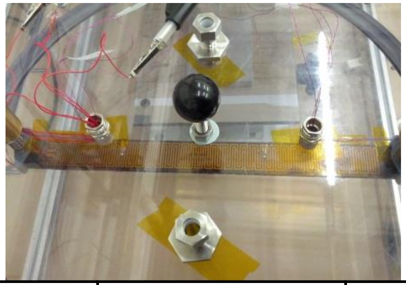


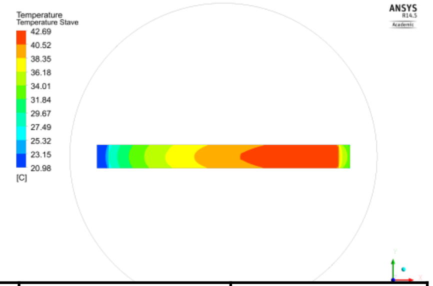


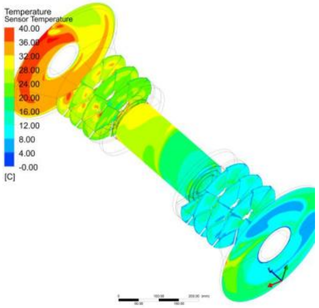




→ Stave thermal measurements → Simulations → **Cooling validation**

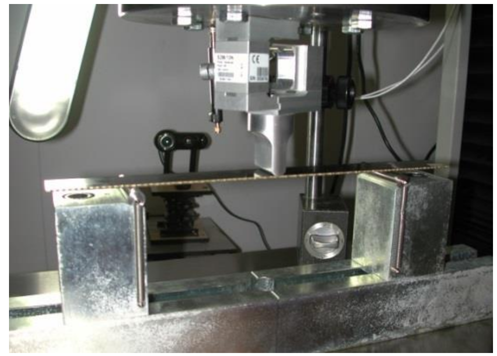


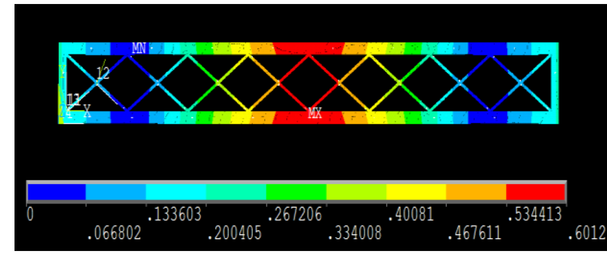


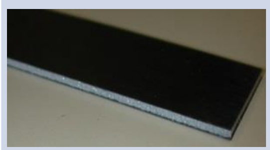


Vertex Detector Structure: Stave

→ Stave Mechanical Characterisation.
Measure of the **Flexural stiffness.**
Span: 180mm.



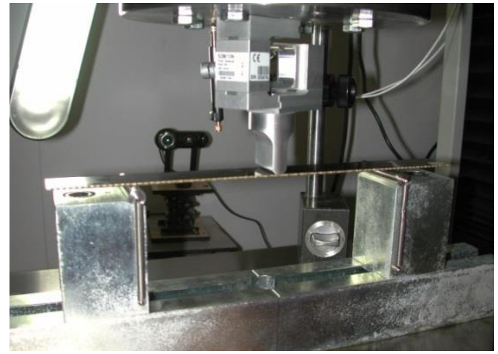


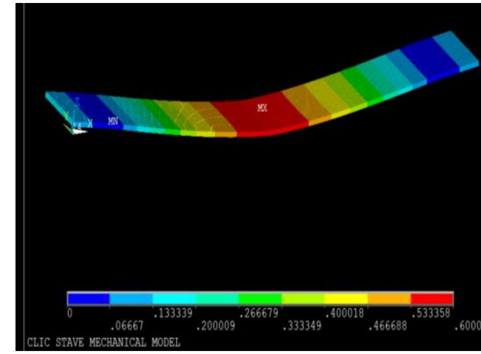
Stave label #	#1	#2	#3	#5
Material	M55J + Rohacell 51 	M55J + Rohacell 51 	M55J + Rohacell 51 	M55J + Rohacell 51 
Flexural stiffness (N/mm) Measurements	6.95 N/mm	3.3 N/mm	2.96 N/mm	2.23 N/mm
Flexural stiffness (N/mm) FEM Model	6.95 N/mm	-	-	2.30 N/mm
Mass (g) 280mm long	3.74 g	3.08 g	2.74 g	1.76 g
X/X0 %	0.121 %	*(0.118 %)*	0.068 %	0.051 %

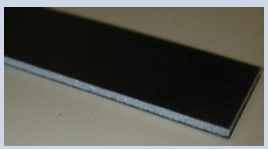
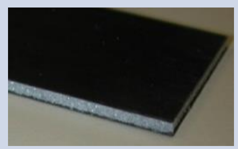
→ Full sandwich stave is stiff but out of Radiation length specs.
→ Cross bracing staves (60°) fulfil the Radiation length goal. (0.05%).
→ No clear stiffness minima are defined yet, vibration tests should be done soon.

Vertex Detector Structure: Stave

→ Stave Mechanical Characterisation. Measure of the **Flexural stiffness. Span: 180mm.**





Stave label #	#1	#7	#8	#9
Material	M55J + Rohacell 51 	T800, [0°; 90°; 0°], 	T800, [0°; 90°; 0°], 	T800, [0°; 90°; 0°], 
Flexural stiffness (N/mm) Measurements	6.95 N/mm	*2.12 N/mm*	*2.17 N/mm*	*2.24 N/mm*
Flexural stiffness (N/mm) FEM Model	6.95 N/mm	*2.15 N/mm*	*2.26 N/mm*	*2.35 N/mm*
Mass (g) 280mm long	3.74 g	3.17 g	3.45 g	3.50 g
X/X0 %	0.121 %	0.104 %	0.112 %	0.113 %

Should be easily improved!

Some reaserch are currently done reduce such values!

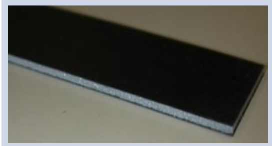
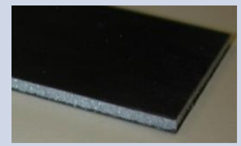
→ With a very standard process, the use of thin prepreg reduces by 18% the stave mass.
→ *Reduction by 70% of the stiffness (Layup not optimised).*
→ The thin prepreg used for stave 7, 8 and 9 implies the addition of a glue layer.
→ Thin Prepreg staves could be lighter with new assembly processes (thin glue layer – co-curing): Under study.
→ Stiff and lighter honeycomb will be also prototyped.

Vertex Detector Structure: Stave

→ Stave Mechanical Characterisation. Evaluation of the **Bending stiffness.**

$$f = \frac{F * l^3}{48 * E_s * I} + \frac{F * l}{4 * G * b * h} \qquad 1 = \frac{m * l^3}{48 * E * I} + \frac{m * l}{4 * G * b * h}$$

$$E * I = \frac{m * l^3}{48 * (1 - \frac{m * l}{4 * G * b * h})}$$

Stave label #	#5	#1	#7	#8	#9
Material	M55J + Rohacell 51 	M55J + Rohacell 51 	T800, [0°; 90°; 0°], 	T800, [0°; 90°; 0°], 	T800, [0°; 90°; 0°], 
Flexural stiffness (N/mm) Measurements	2.23 N/mm	6.95 N/mm	*2.12 N/mm*	*2.17 N/mm*	*2.24 N/mm*
Bending stiffness $N.mm^2$	$3.210*10^5$ $N.mm^2$	$1.769*10^6 N.mm^2$	$3.605*10^5 N.mm^2$	$3.132*10^5 N.mm^2$	$3.238*10^5 N.mm^2$
Natural frequency estimate (Hz) (280mm long stave clamped on both sides)	157 Hz	314 Hz	152 Hz	140 Hz	142 Hz

→ Vibration tests should tell us soon if such natural frequencies are close to exciting vibration of air.

→ The thin prepreg staves are not optimised. We should theoretically get the stiffness of #1 with the radiation length close to stave #5!

→ **Studied scenarios:**

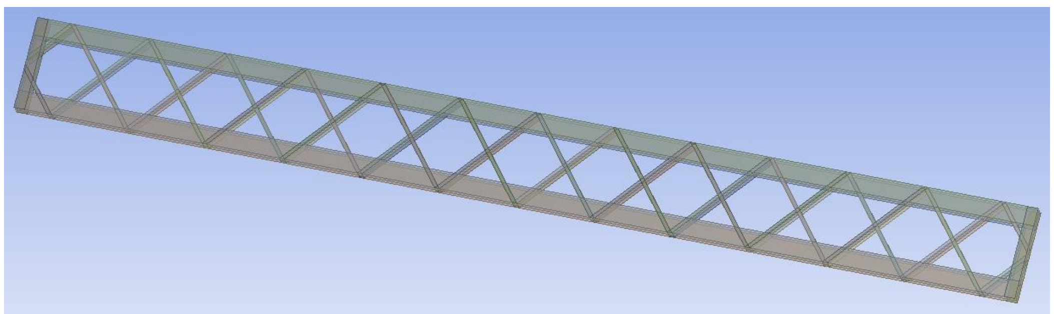
Two layers of XN80 thin prepreg (45g/m2) with honeycomb should give:
X/X0 ~ 0.08% EI=$1.54*10^6 N.mm^2$

Two layers of M55J thin prepreg (30g/m2) with honeycomb should give:
X/X0 ~ 0.058% EI=$7.7*10^5 N.mm^2$

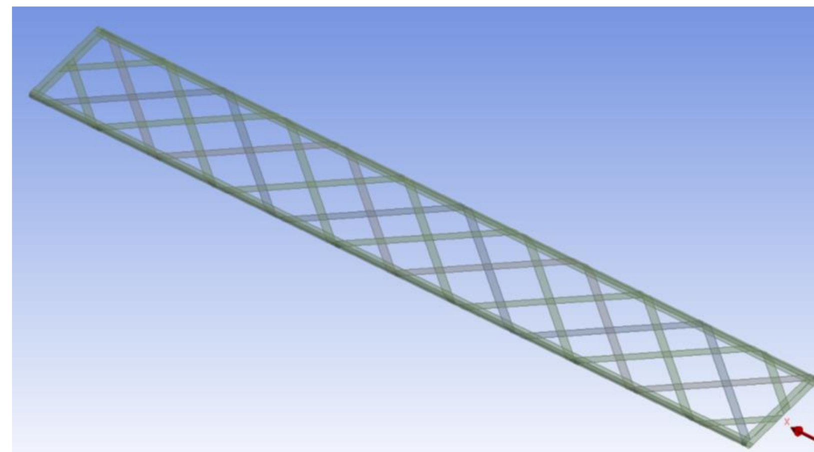
Vertex Detector Structure: Stave
Future prototypes

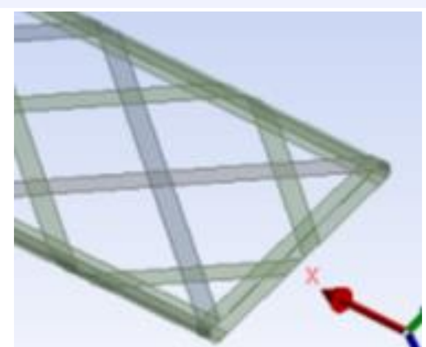
Design and simulation work…then prototyping

→Simulation of *lattice* staves done with a new technique (pre-moulded skins)



→Simulation of filament winding staves





→Very light full sandwich prototypes are also planned to be manufactured

Vertex Detector Structure: Stave

→ Manufacturing at CERN & partnership with companies

Specialists in composite prototyping

Specialists in very thin prepreg production

→ Future prototypes done at CERN

Vertex Detector Structure: Stave Summary

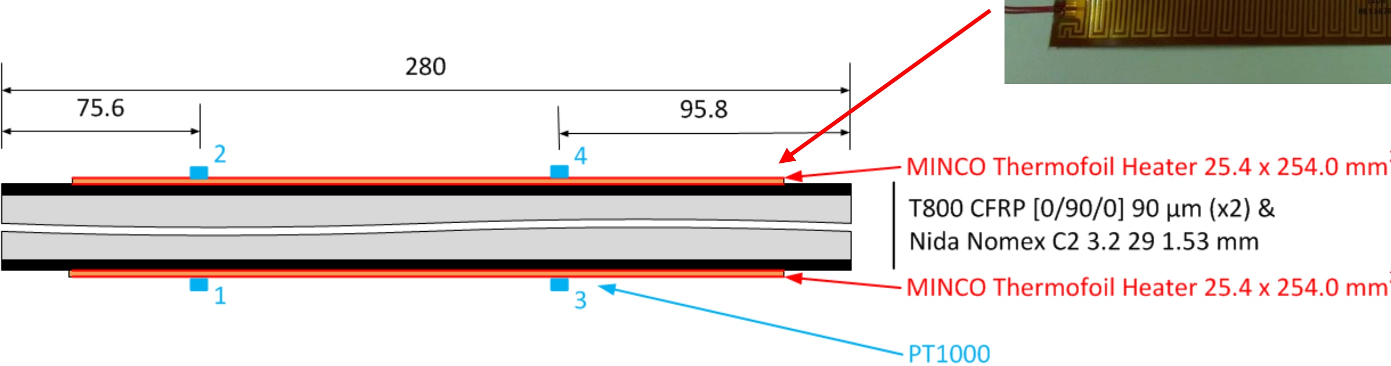
→ Simulations are now matching rather well with tests. It implies some tunings

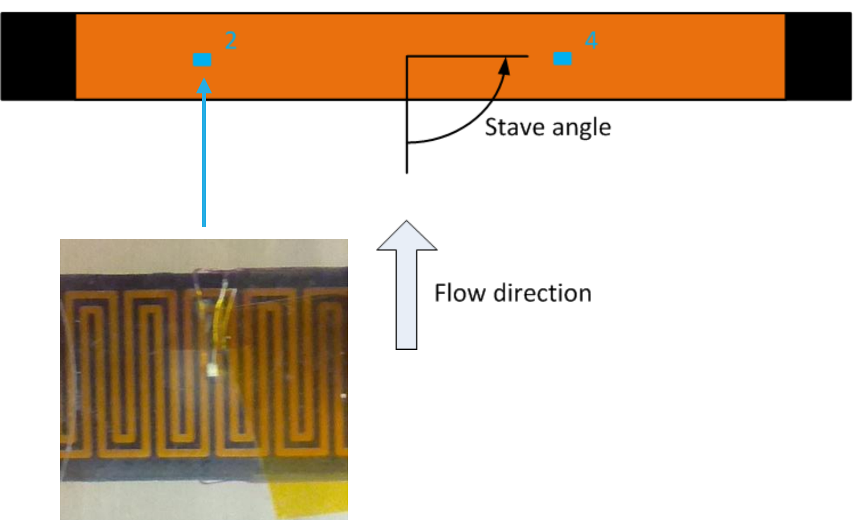
→ Full sandwich staves are **the stiffest** prototypes
-But they are still too “heavy” (X/X0~0.110%)
-These structures are still studied as they present a good design for material comparison
-Thin prepregs have not yet shown their full potential

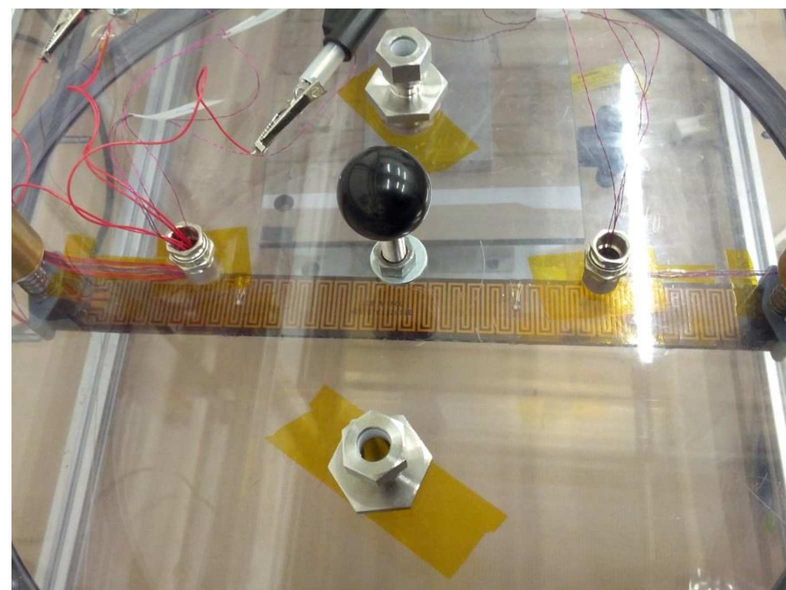
→ Cross bracing staves present **very low radiation length** (0.05%)
-The manufacturing accuracy of such staves could be improved
-Their stiffness still needs to be validated through realistic tests

→ Future staves should be considered as superlight structures
-All new potential materials could be studied
-New manufacturing techniques are proposed

Stave cooling tests
Stave Equipment

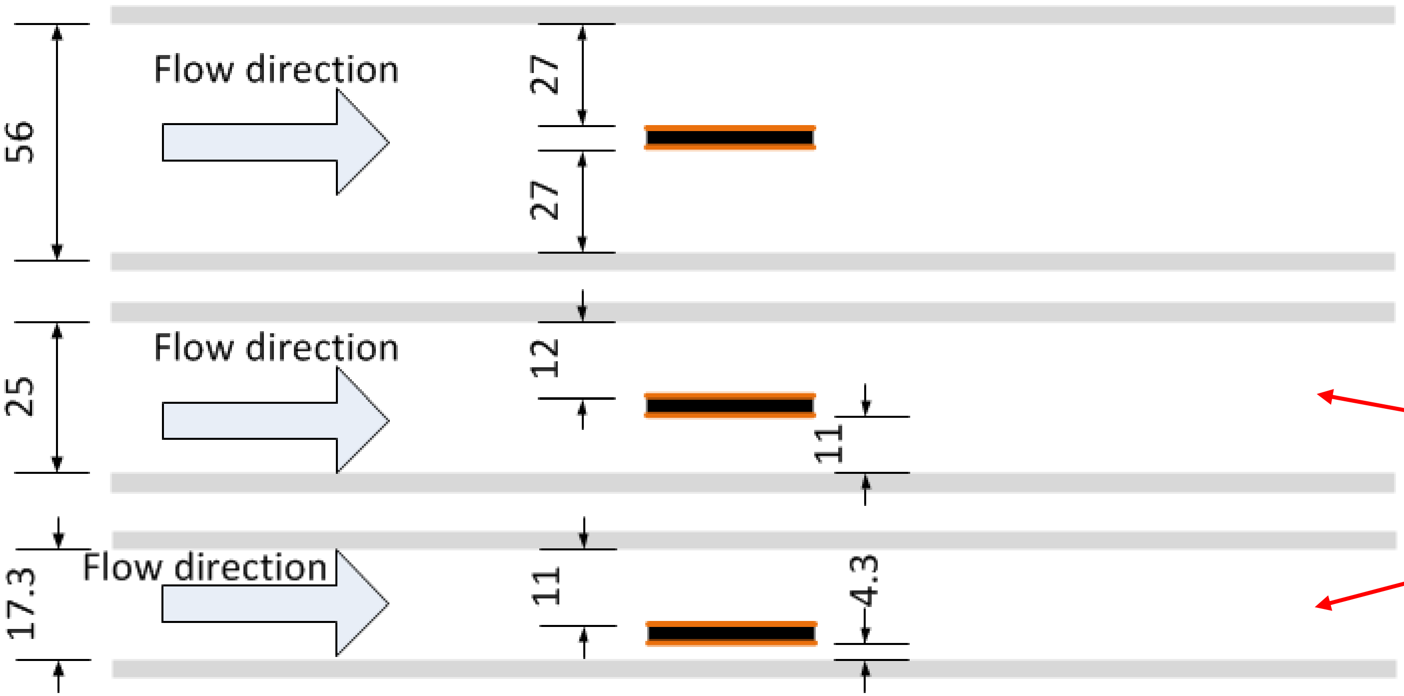


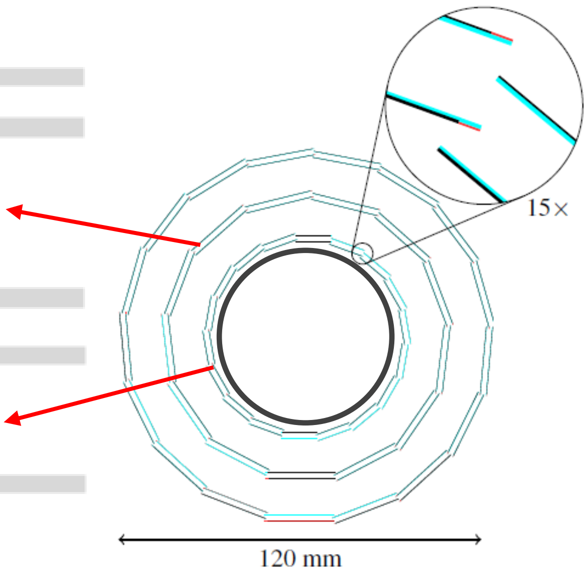




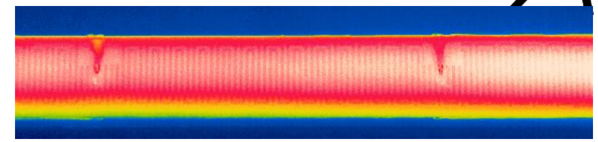
Stave cooling tests
Scenarios

Channel height [mm]	Stave angle [deg]	Air velocity [m/s]	Power dissipation [mW/cm²]
17.3	0	3	25
25	45	5	50
56	90	7.5	75
			100

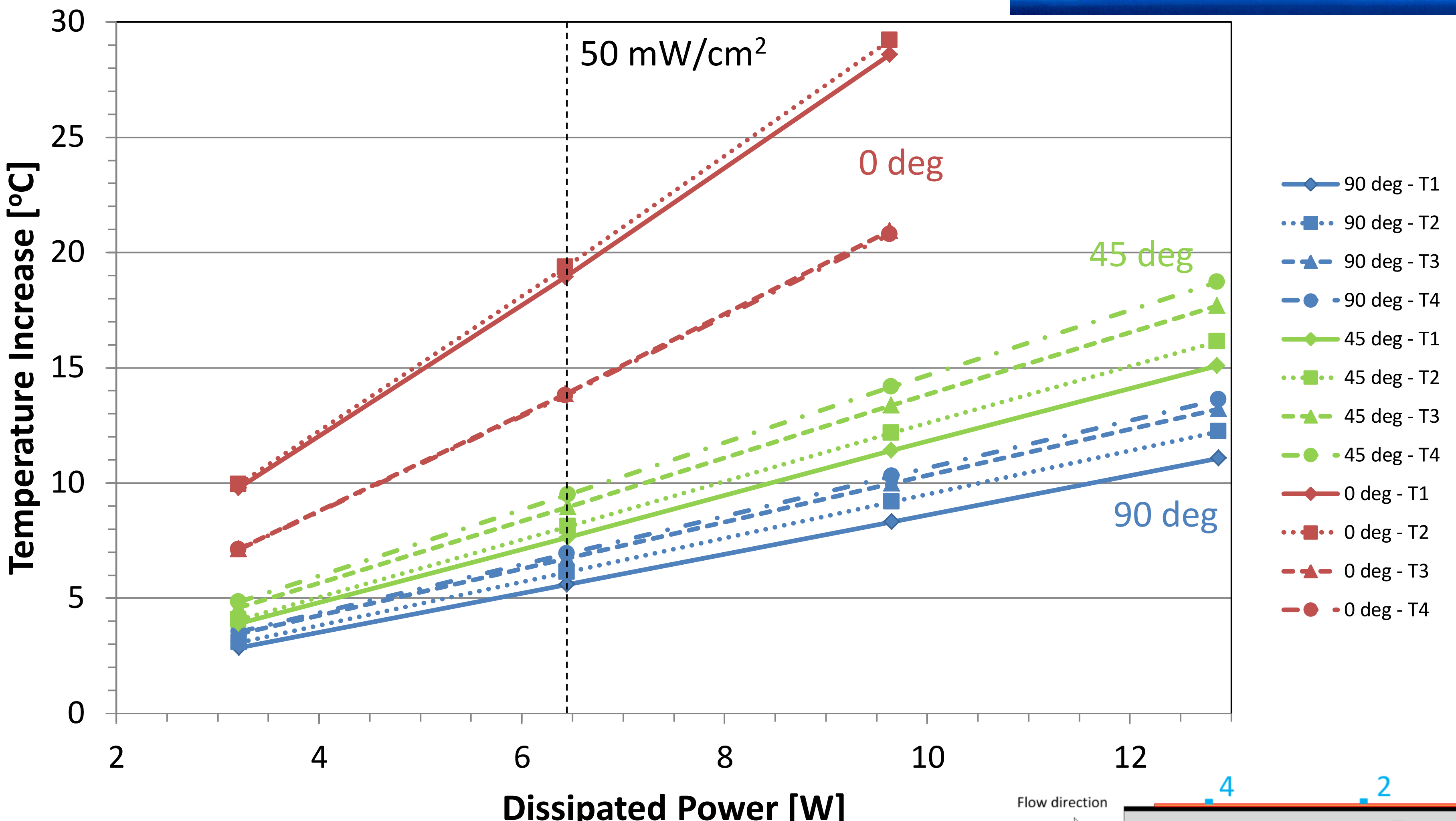


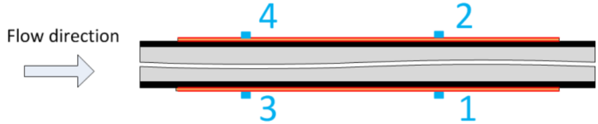


Stave cooling tests
Results for 25mm channel

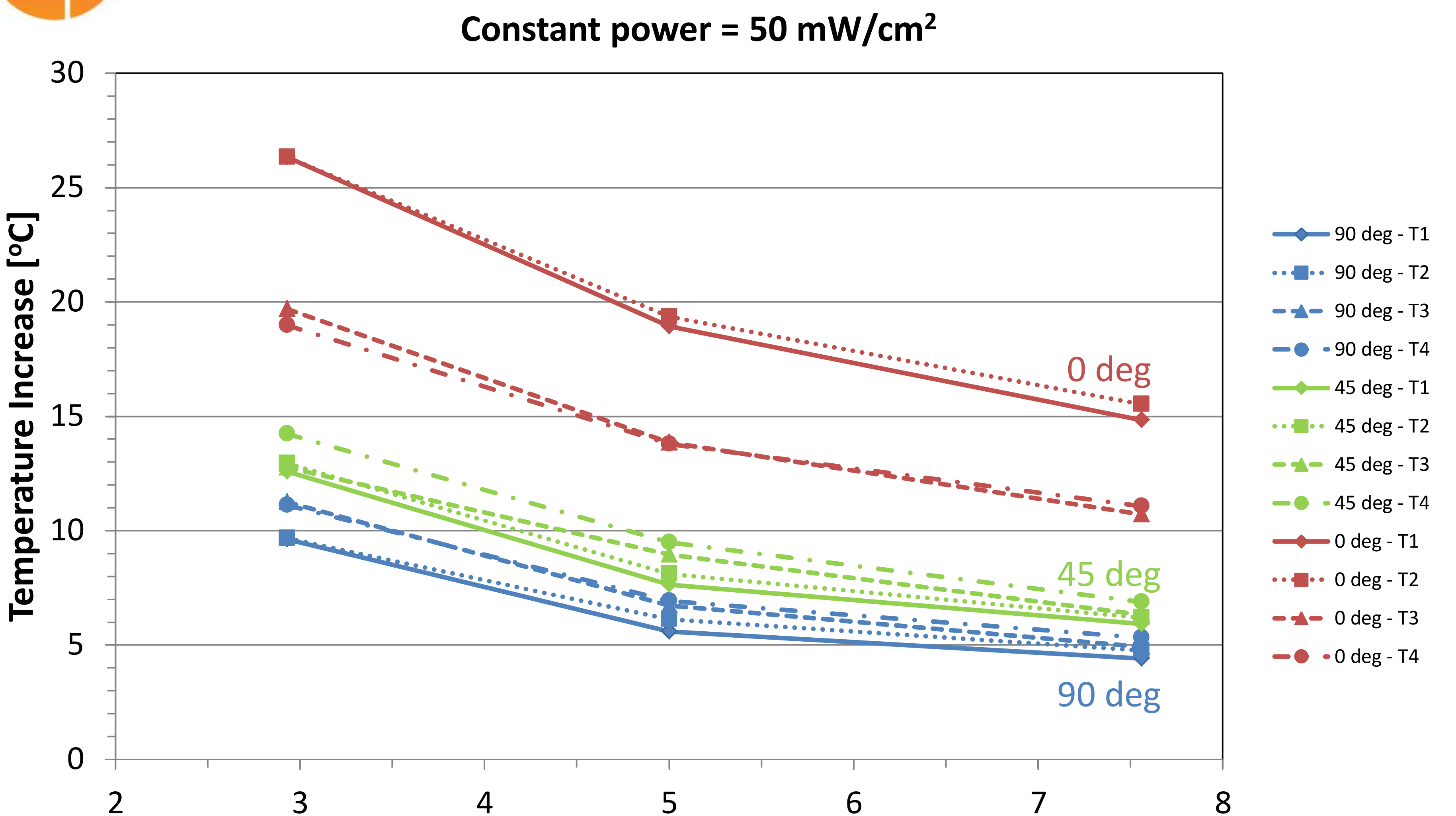


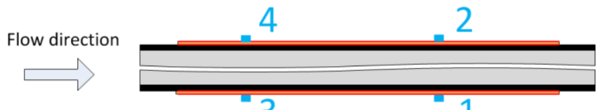
Constant velocity = 5 m/s



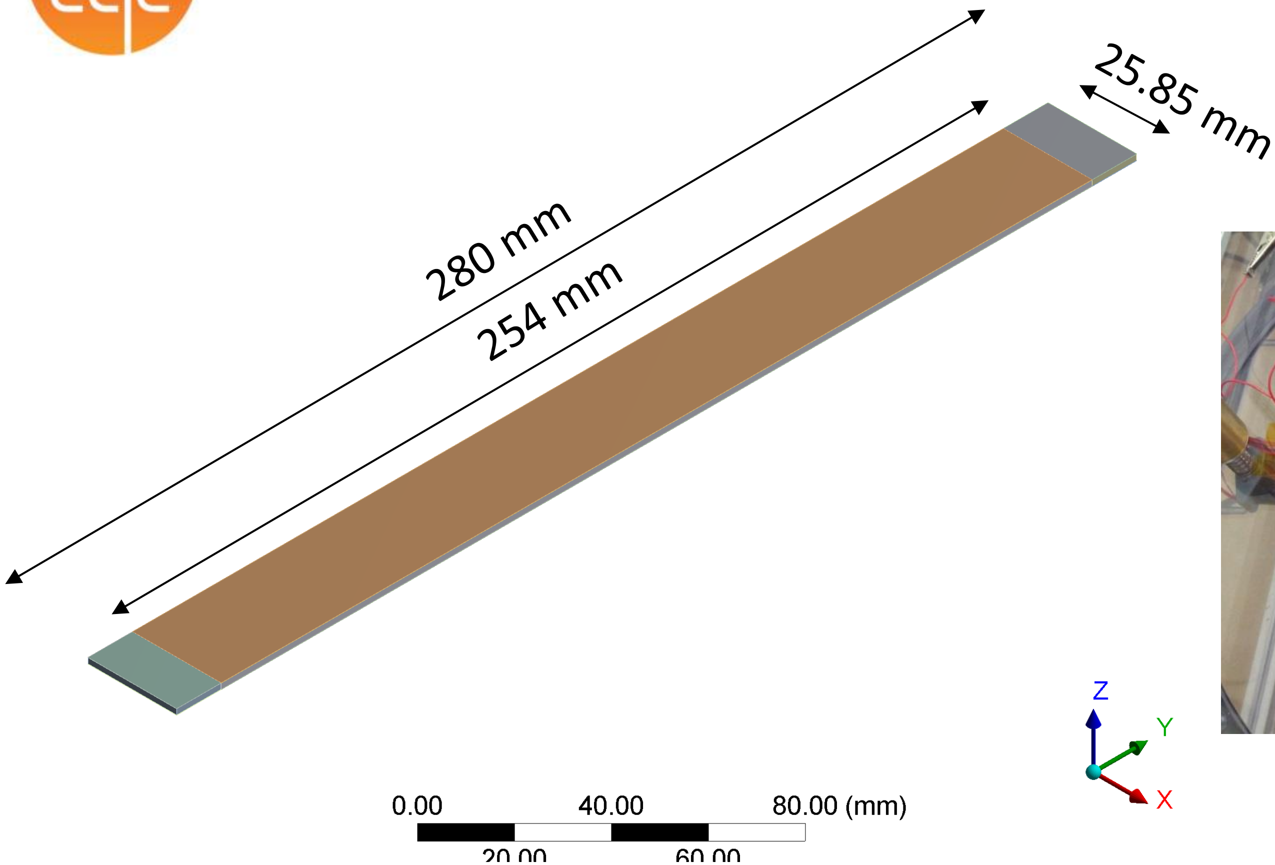


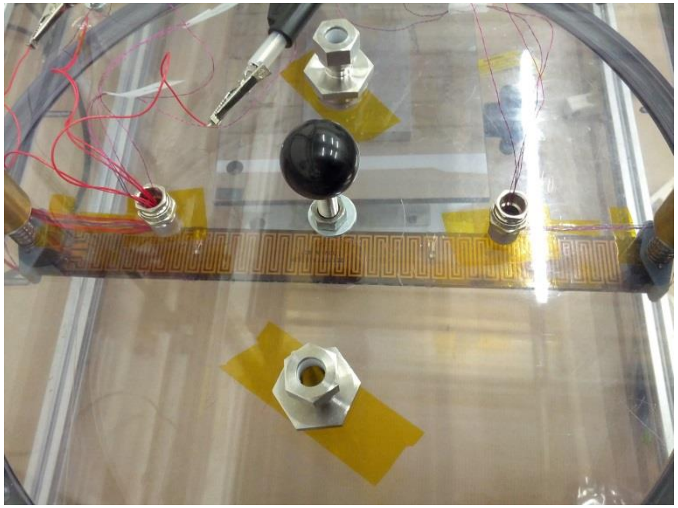
Stave cooling tests
Results for 25mm channel

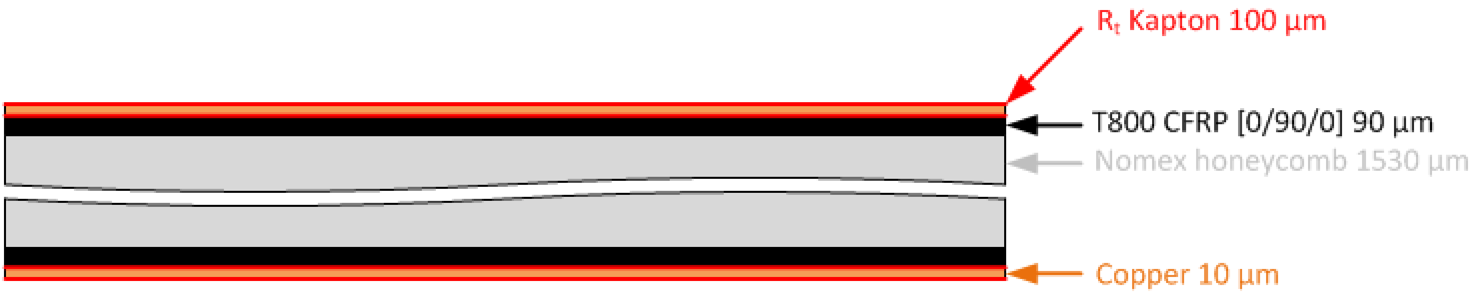




Stave cooling tests – CFD Simulations
Computational fluid dynamics



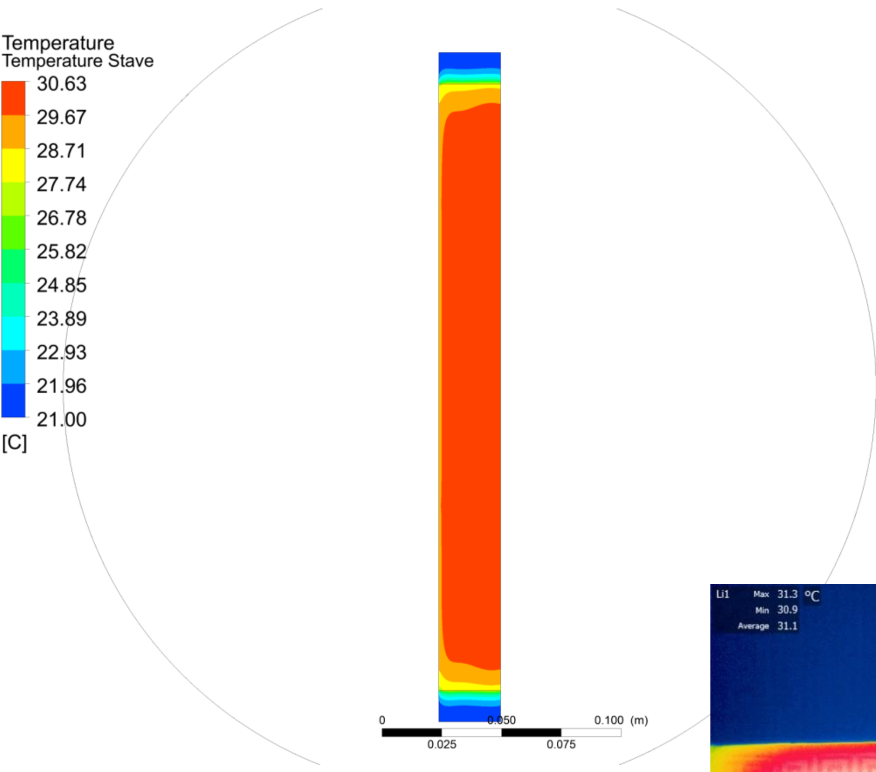




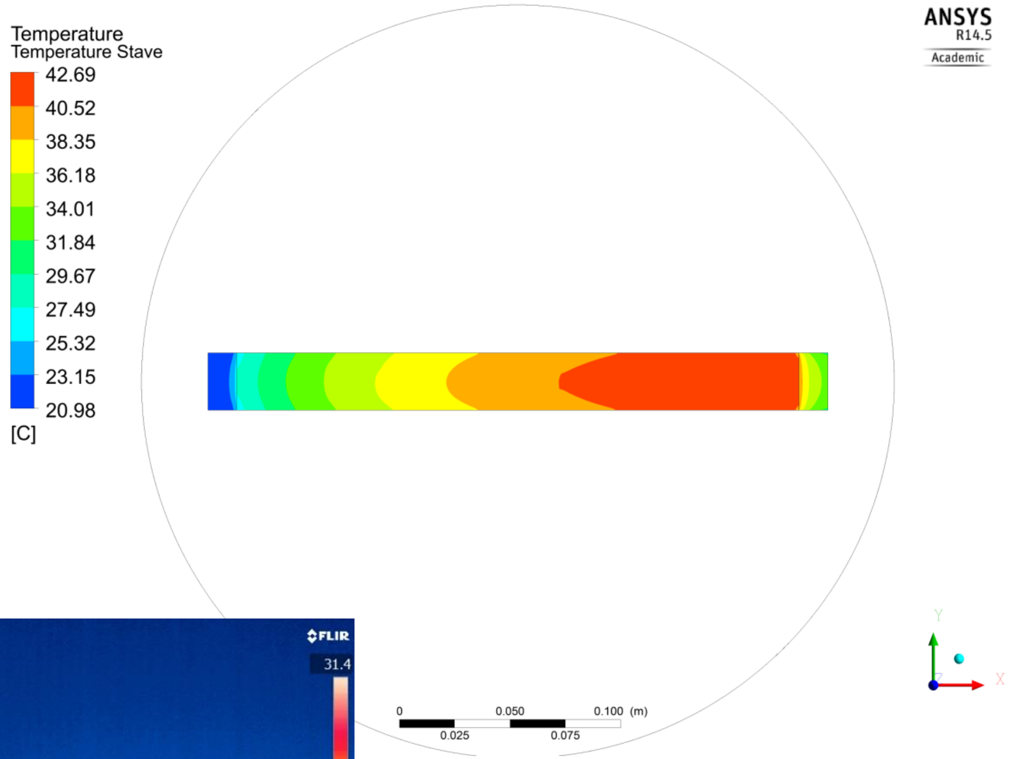
Stave cooling tests - Simulations

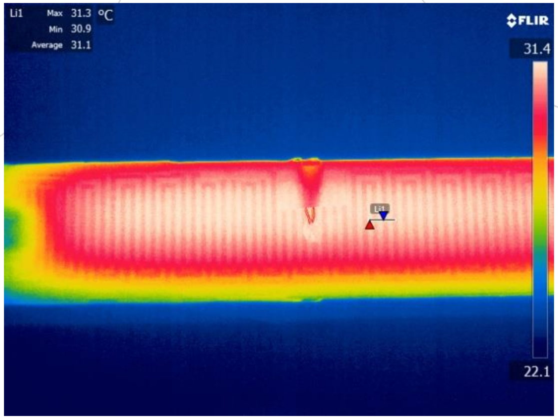
25 mm channel; 5 m/s; 50 mW/cm^2

90 deg.



0 deg.

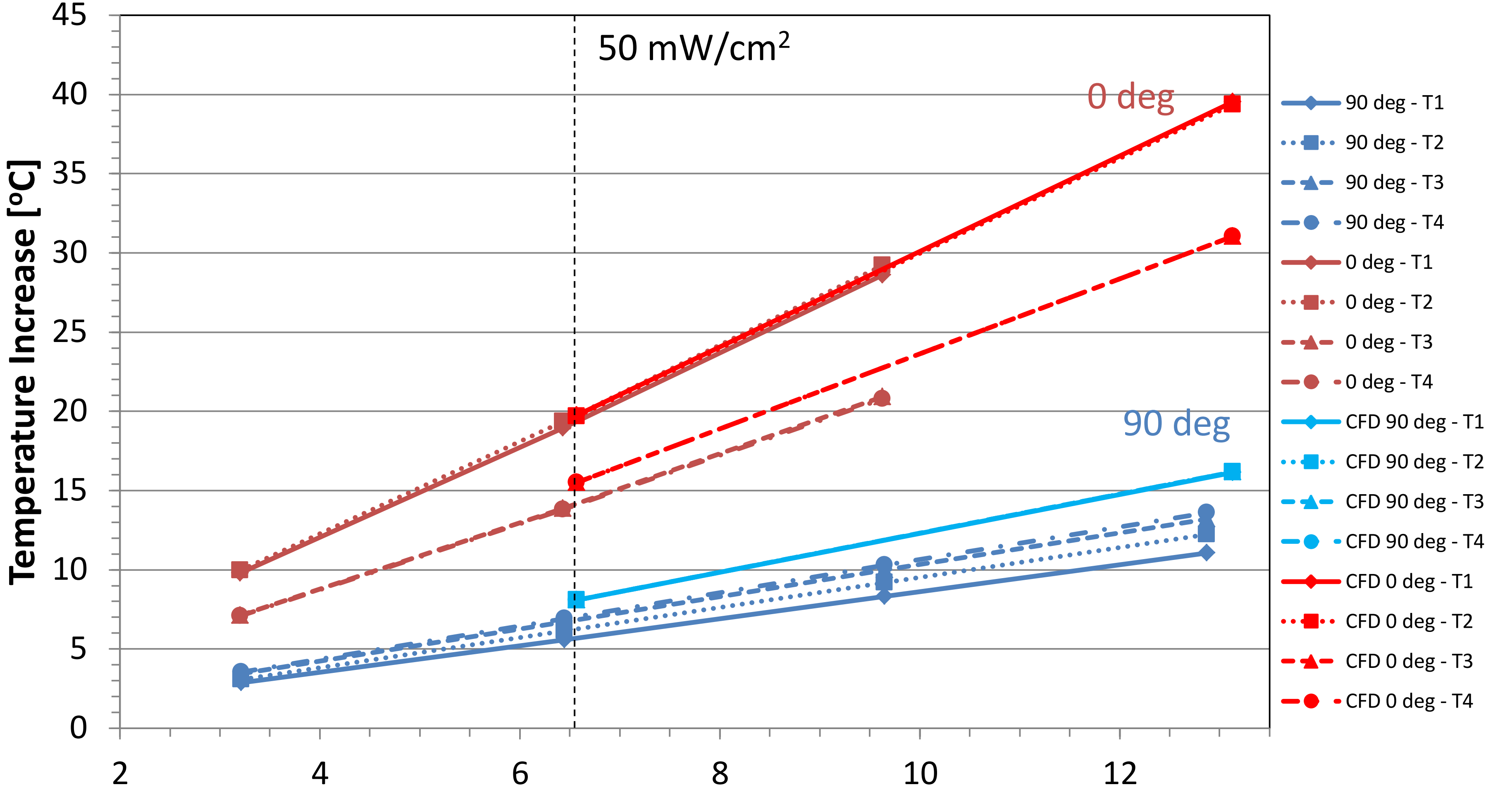


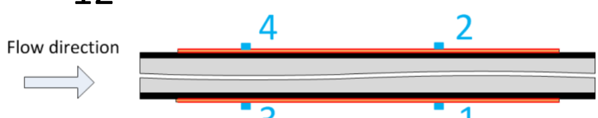


1. OBJECTIVES	2. SET UP DESCRIPTION	3. STAVE STRUCTURES	**4. THERMAL TESTS**	5. CONCLUSION
			Simulations	

Stave cooling tests – Simulations 25mm channel
Measurements versus CFD simulations

Constant velocity = 5 m/s

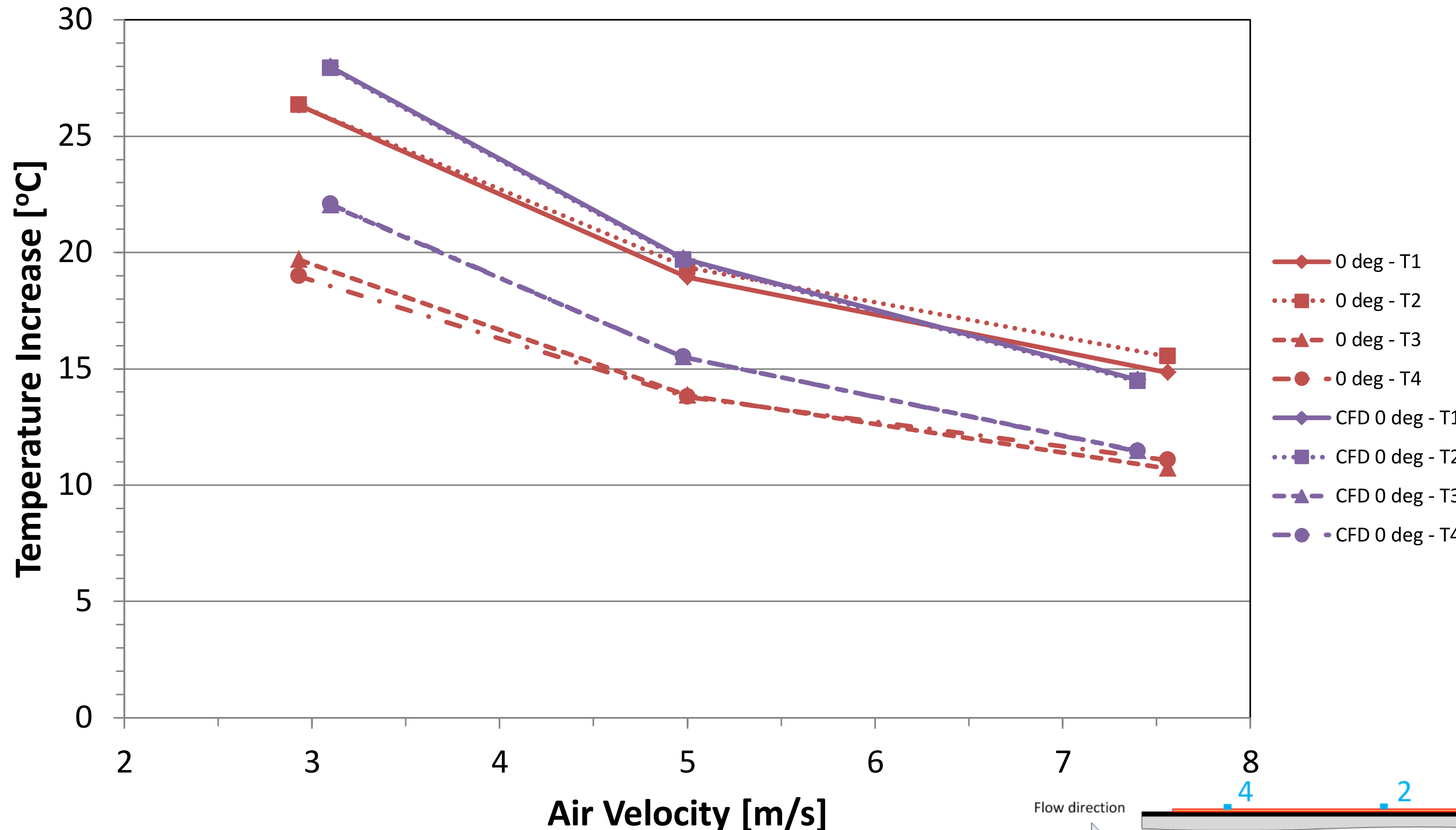


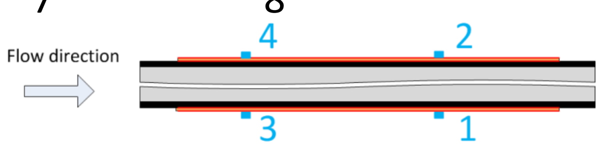


Stave cooling tests – Simulations 25mm channel

Measurements versus CFD simulations

Constant power = 50 mW/cm²





Stave cooling tests
Summary I

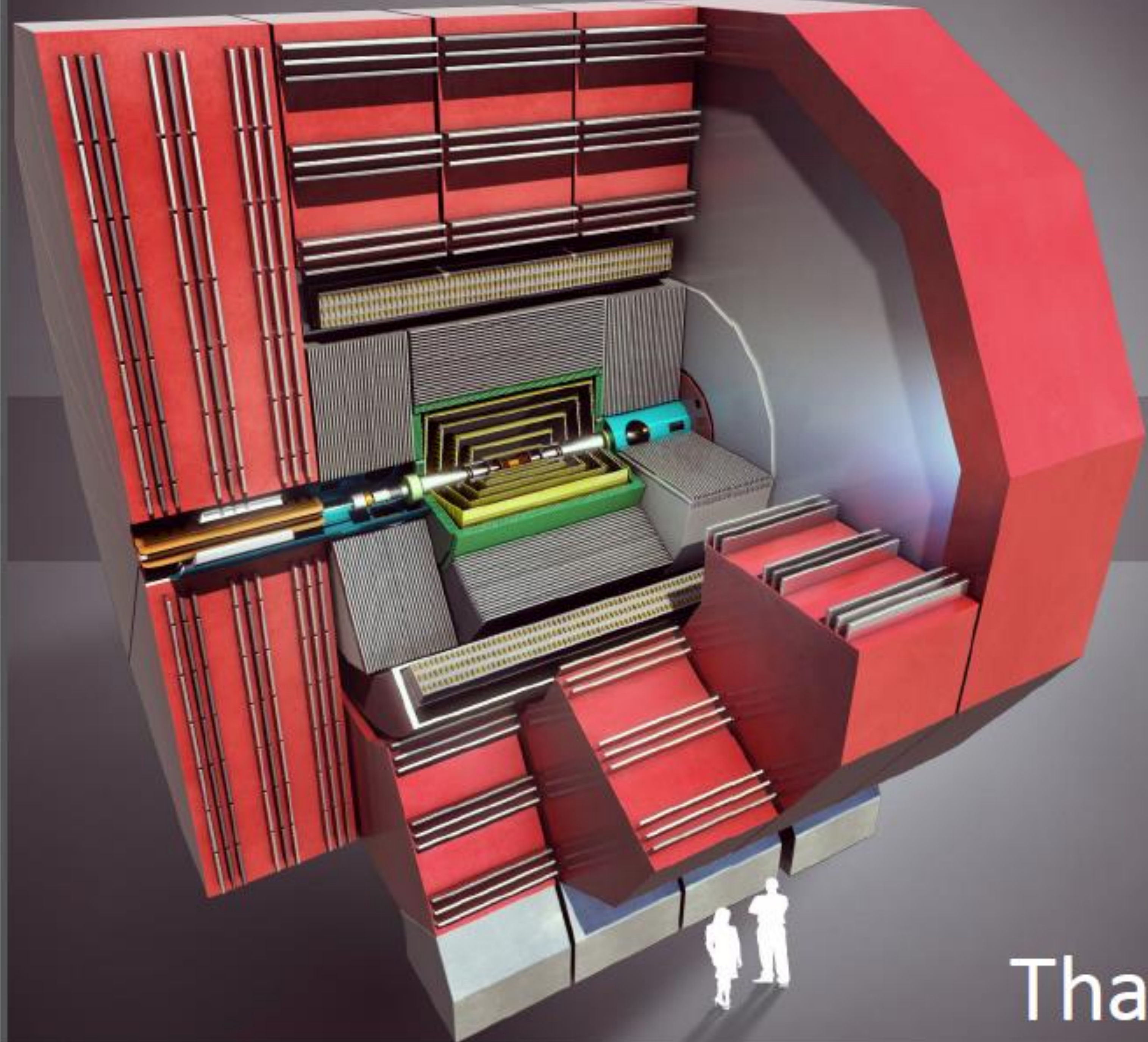
- Test set-up is assembled and producing results
- Thermal measurements have shown so far:
  - Stave angle with respect to flow influences the measured temperatures (lowest values at 90 degrees)
  - Stave angle with respect to flow influences the temperature distribution (more homogeneous at 90 degrees)
  - Temperatures decrease asymptotically for increased air velocities
  - Channel height has a relatively low influence on measured temperatures

- New dummy stave with a Rohacell core will be assembled and tested

Stave cooling tests
Summary II

- A parametric CFD model of the set-up was created
- For the cases analysed so far, the model shows the same behaviour as the set-up;
- Simulated temperatures are very close to the measured ones;
- The small differences may be partially explained by a non uniform temperature distribution in the heater and a cold spot at the PT1000 locations;

- **Thermographic** measurements are foreseen to check this assumption;
- The next step will be to measure the **vibrations induced** by the air flow.



CLIC Detector

Thank you