LCWS14 – Belgrade, Serbia

Cooling and vibration studies of a CLIC vertex detector

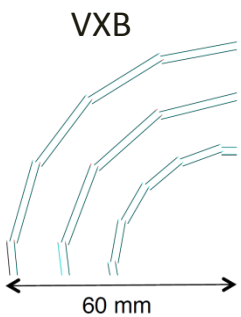
F. Duarte Ramos, on behalf of the CLICdp collaboration

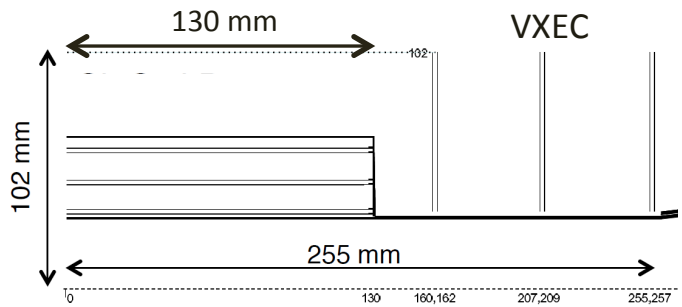
October 9, 2014

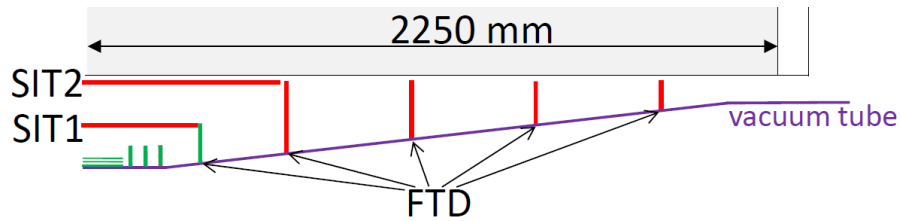
Outline

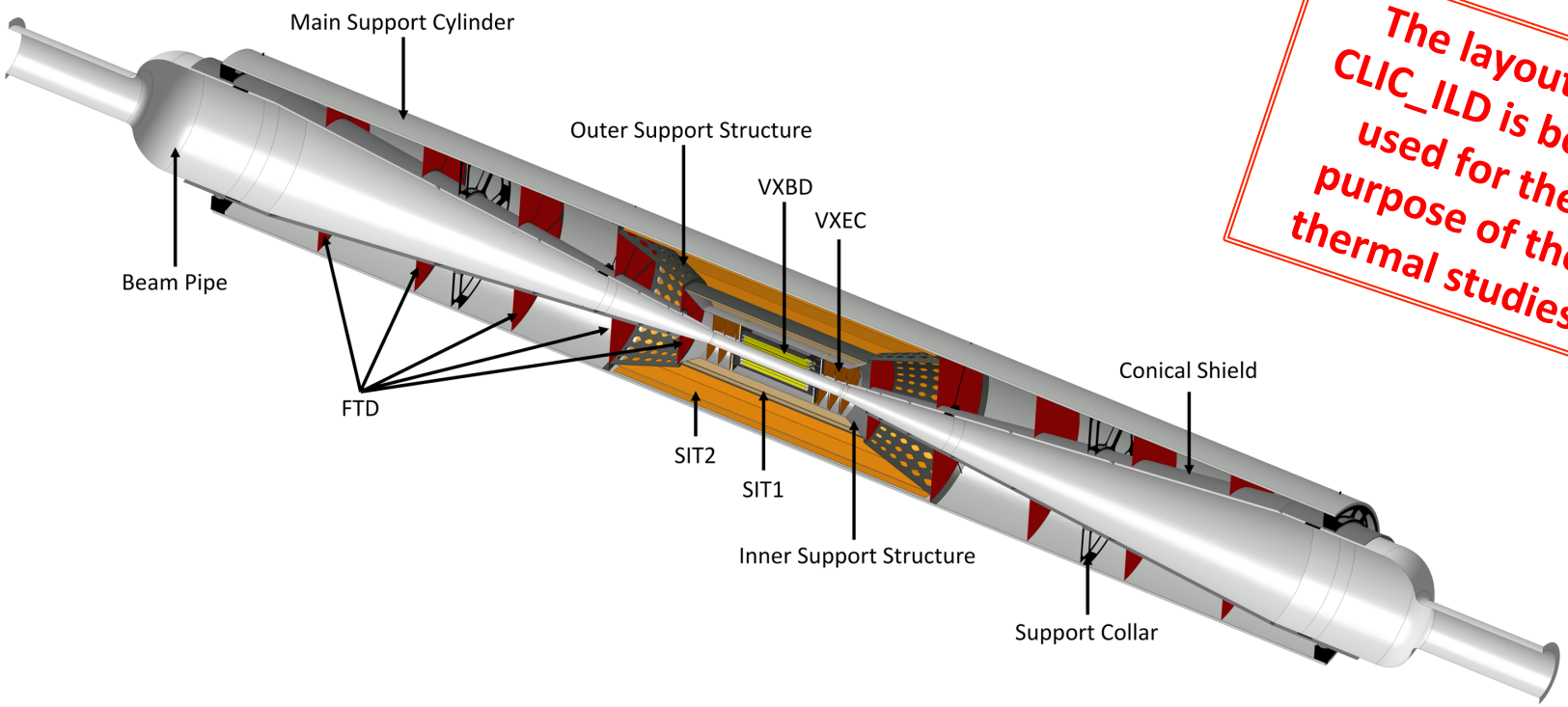
- Introduction
- Cooling strategy
- Phase I thermal test bench
- Development of light-weight support structures
- Vibration measurements
- Phase II thermal test bench (1:1 scale VTX)
- Summary

Detector inner region (VTX & Tracking)







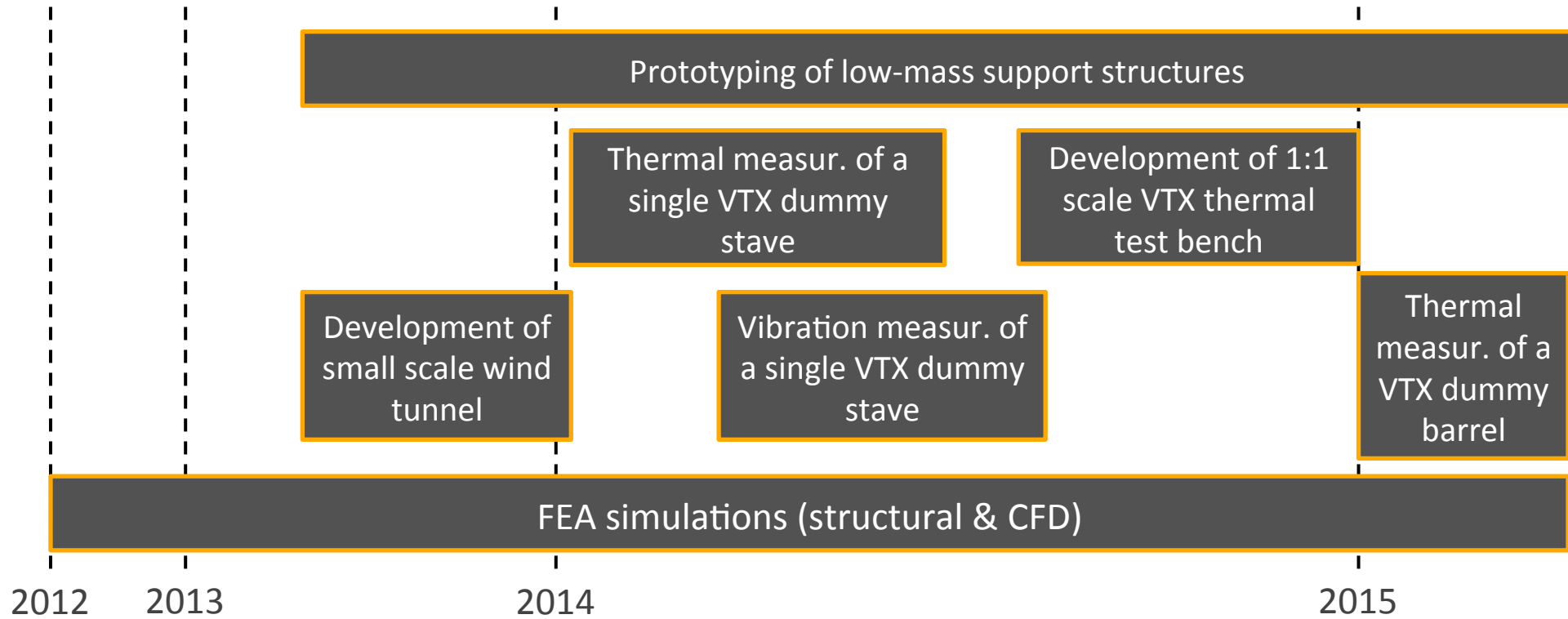


The layout of CLIC_ILD is being used for the purpose of the thermal studies

Requirements and timeline

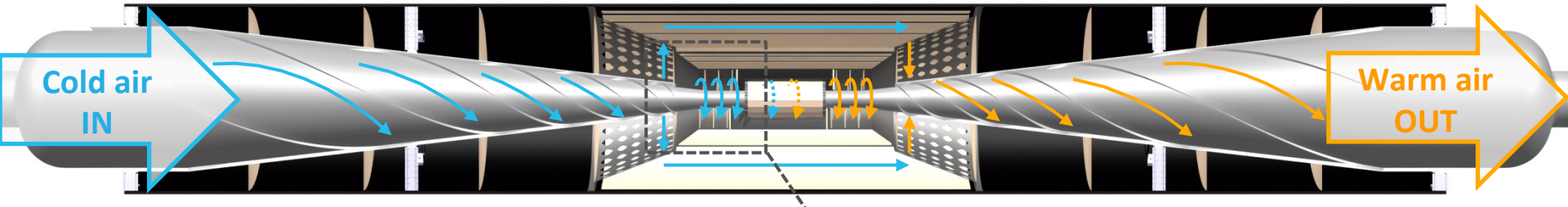
Low material budget – 0.2% X_0 per layer in the VTX barrel (including 0.11% for silicon):

- Low-mass support structures (~0.05% X_0);
- Air (dry) cooling strategy (500W; $T_{operation}$<40°C).

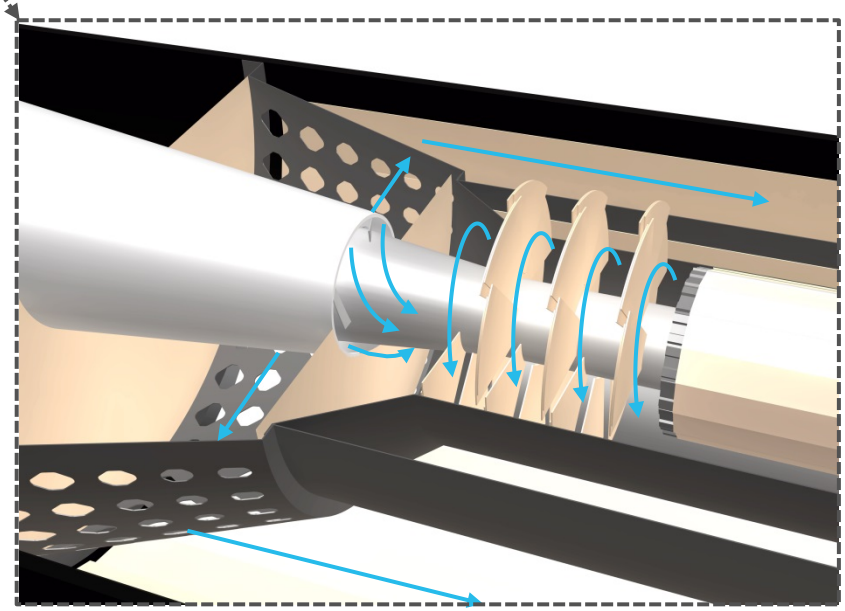


Cooling distribution

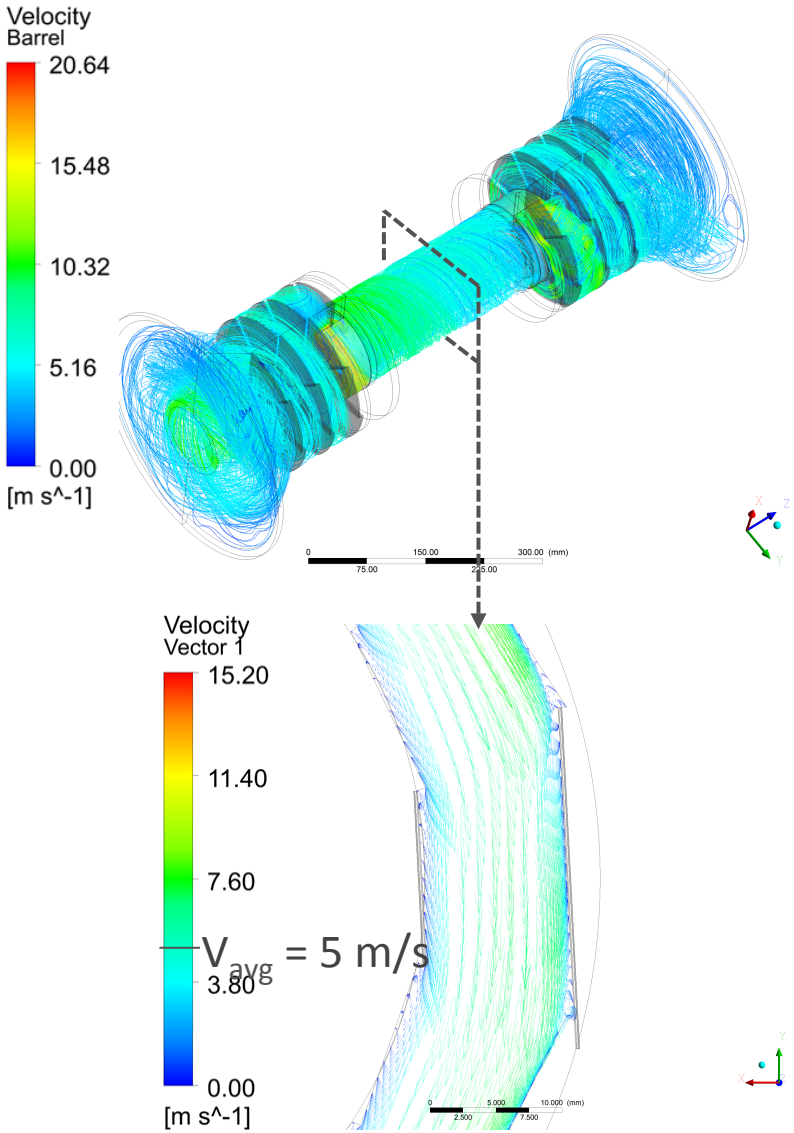
Dry air flow

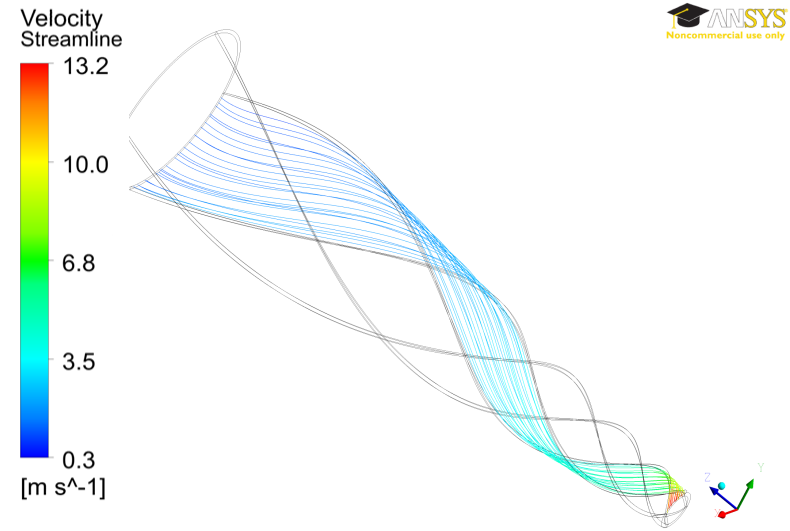


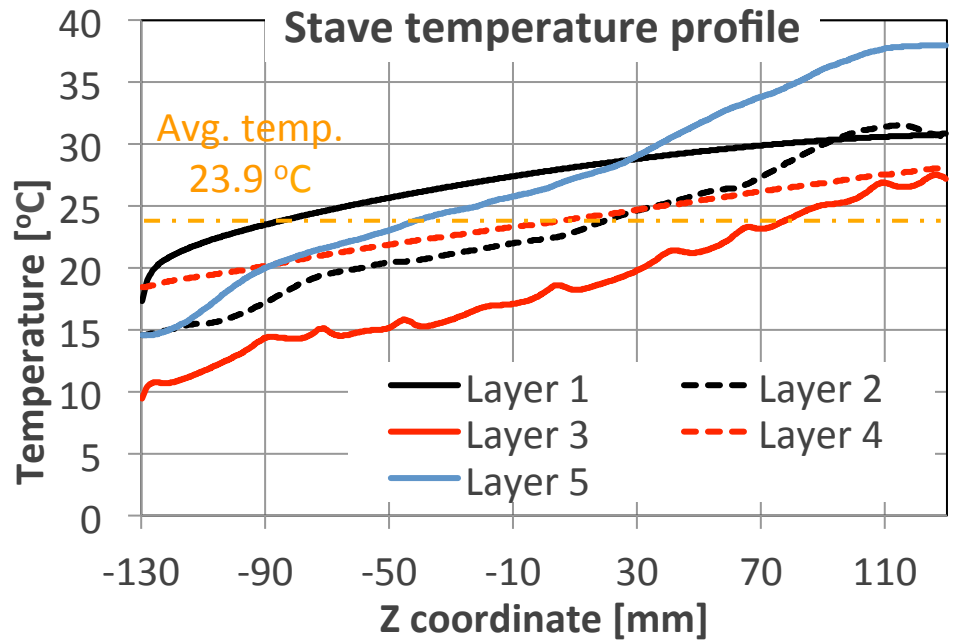
- Cooling of VTX and SIT;
- High heat load (silicon pixel + micro-strips);
- Moderate velocity forced convection;
- Dry air delivered/extracted through channel between beam pipe and conical shield;



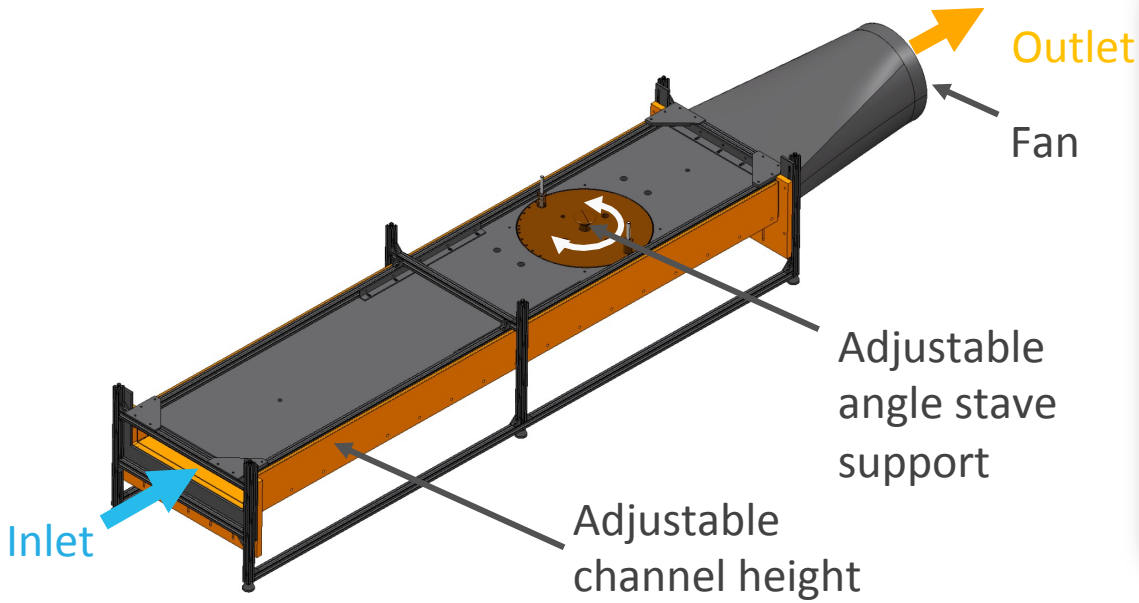
VTX cooling simulations

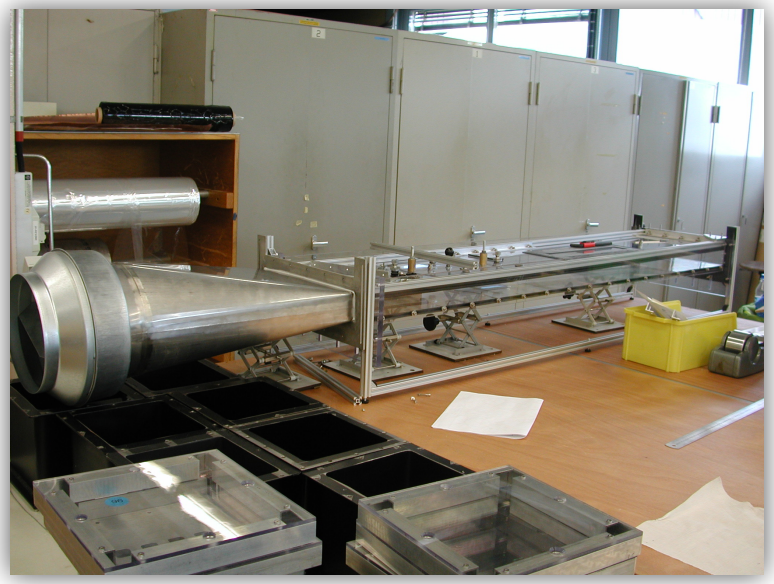




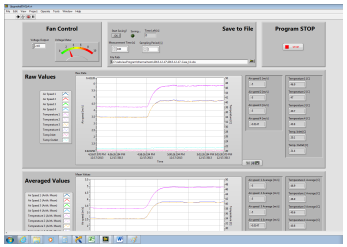


Thermo-mechanical test bench



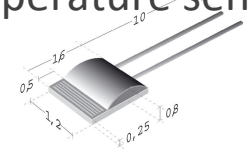


LabVIEW interface



Schmidt anemometer

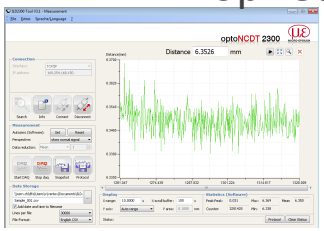
Temperature sensors

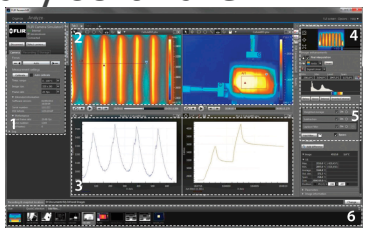


Micro-Epsilon vibration sensor

FLIR thermal camera

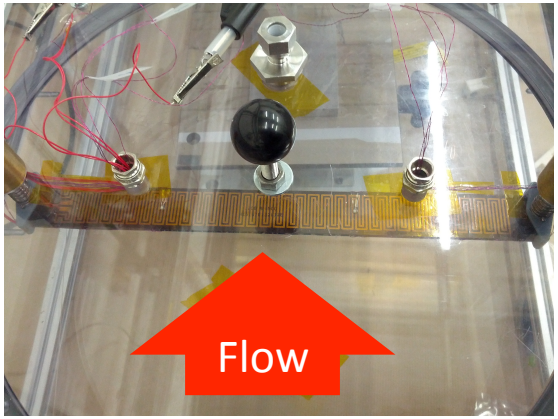
Proprietary software



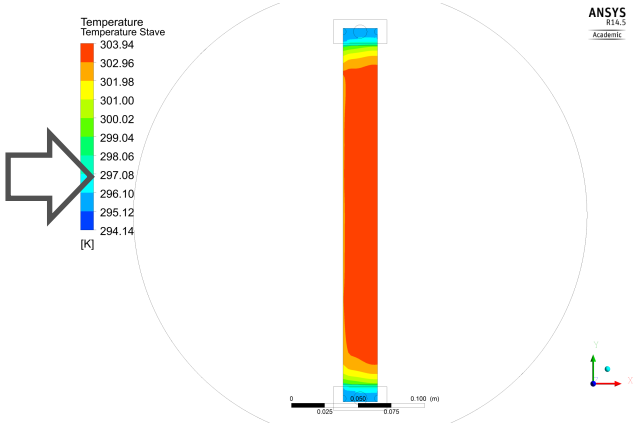


Thermal studies on dummy staves

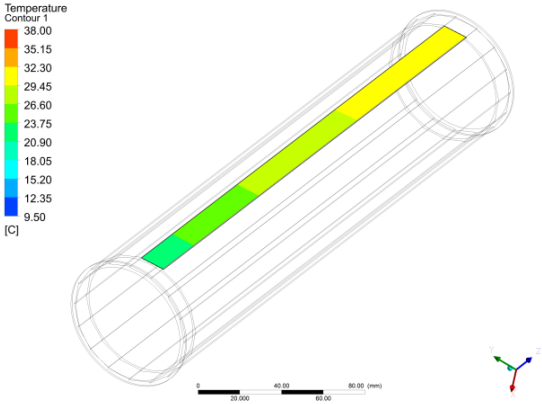
Stave temperature measurements

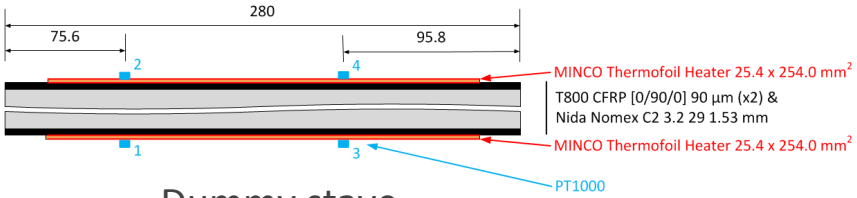


Dedicated simulations

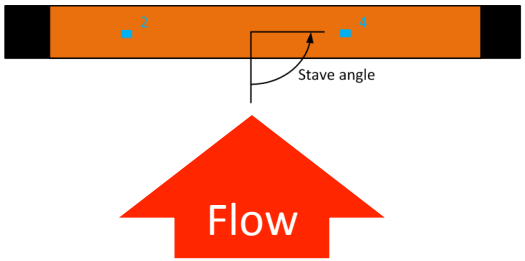


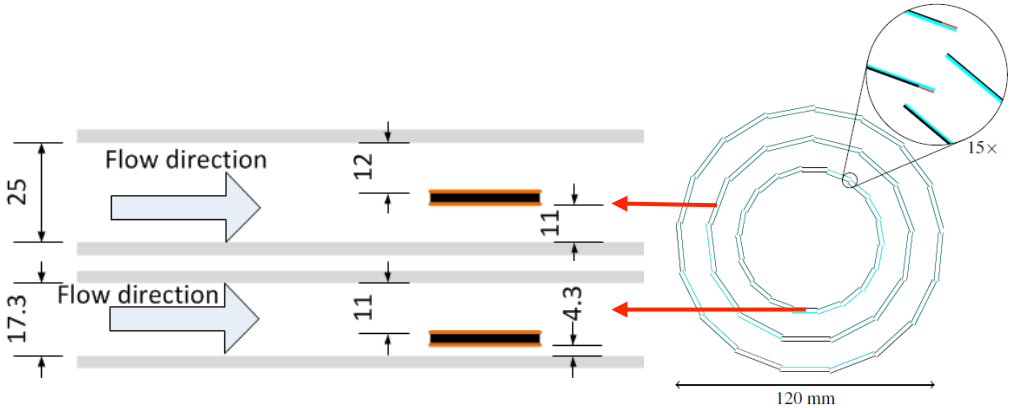
Preliminary validation





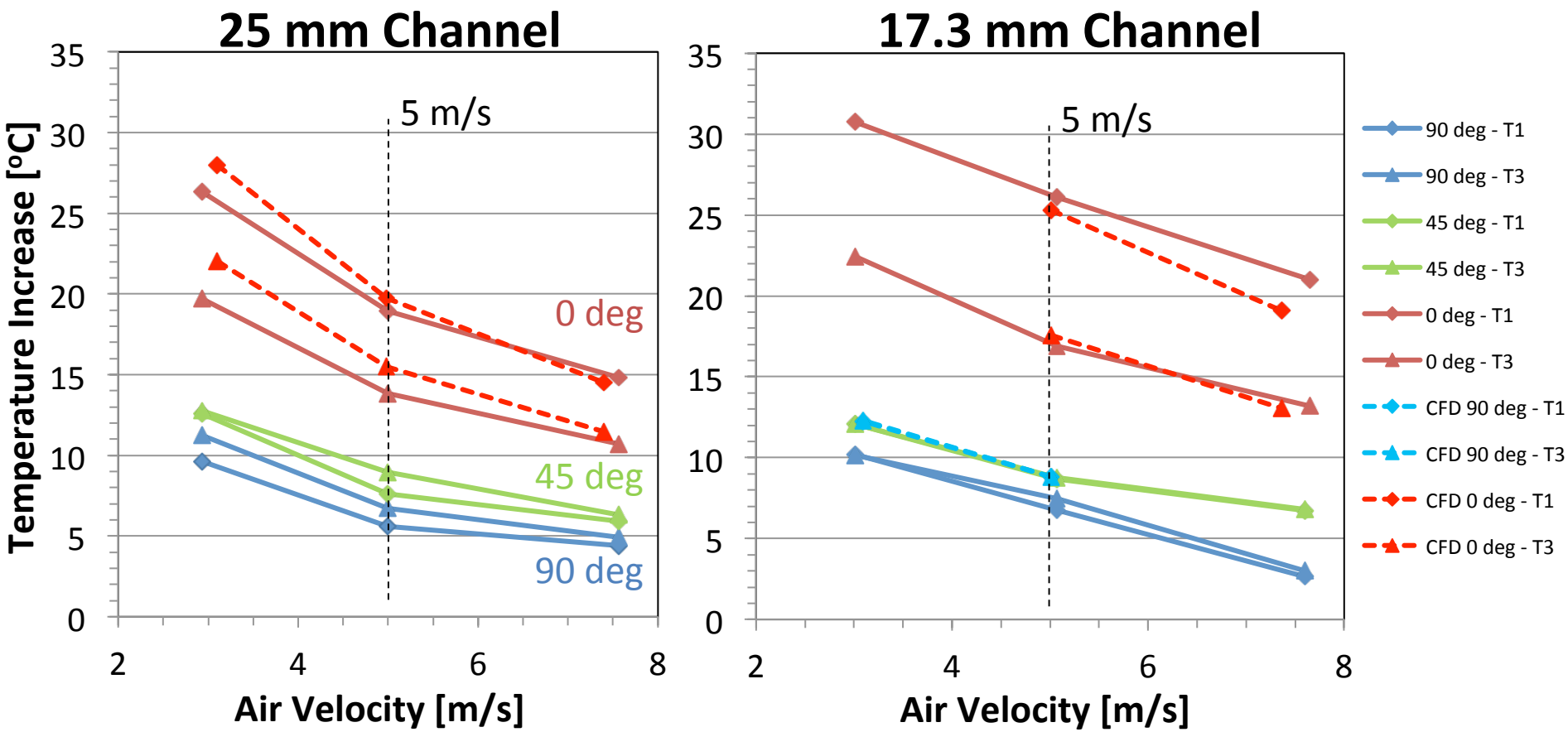
Dummy stave





Stave thermal tests

Constant heat dissipation (50 mW/cm^2)

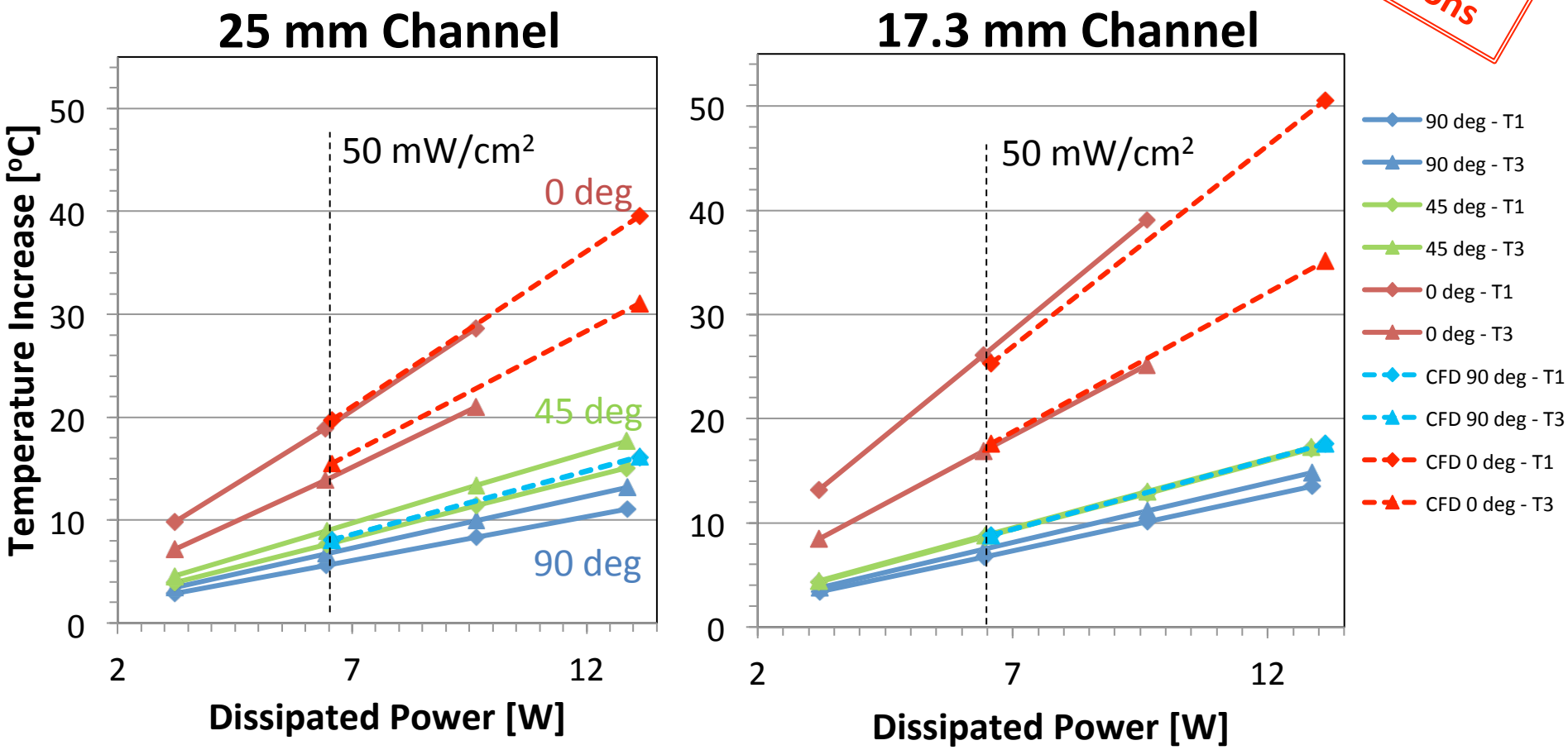


Simulated Measured

Stave thermal tests

Constant air velocity (5 m/s)

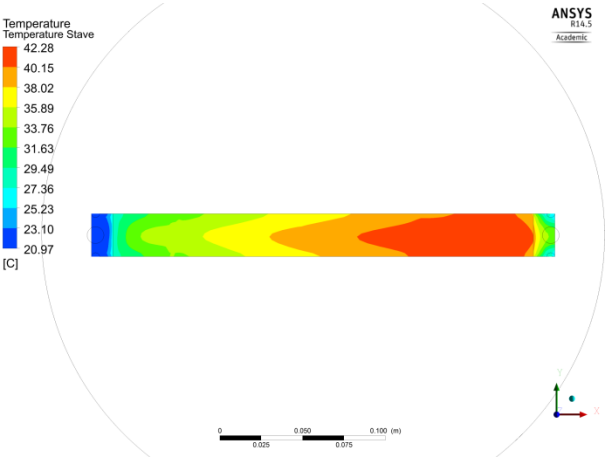
Good agreement w/ simulations

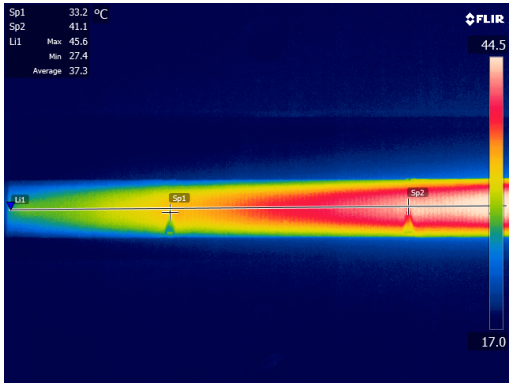


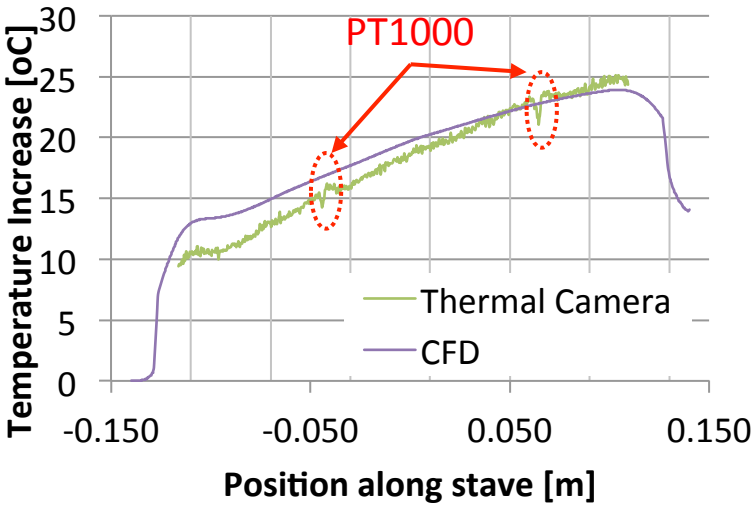
Simulated Measured

Measurements vs simulations

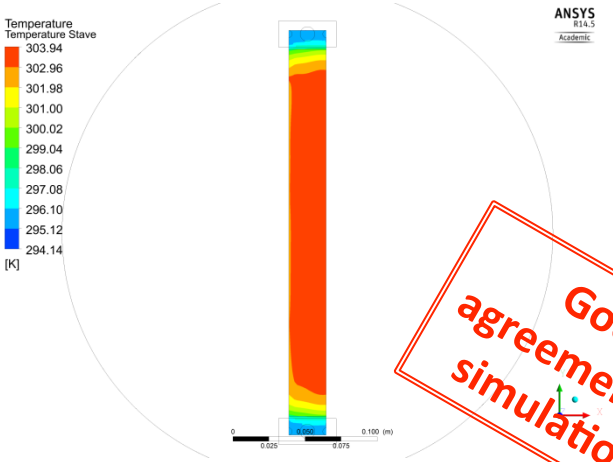
0 deg

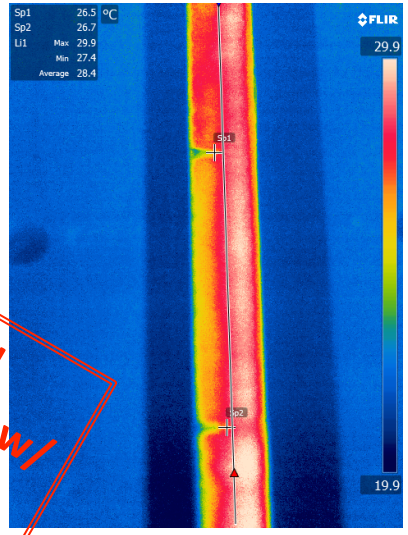




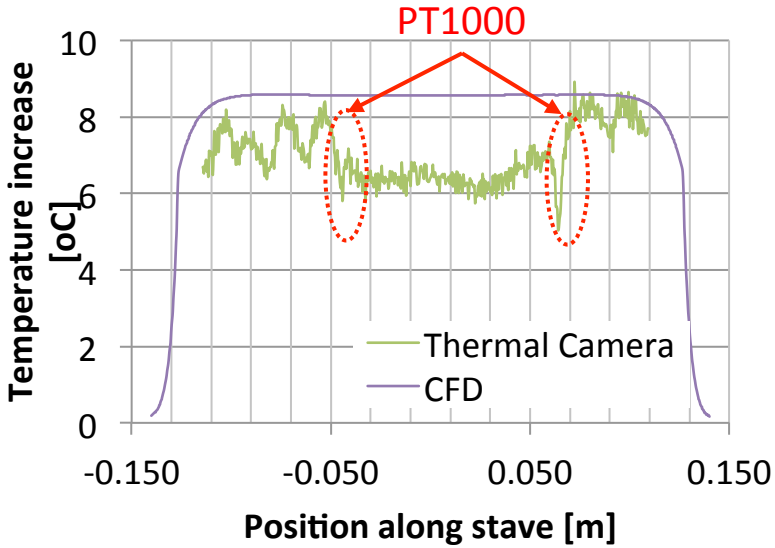


90 deg



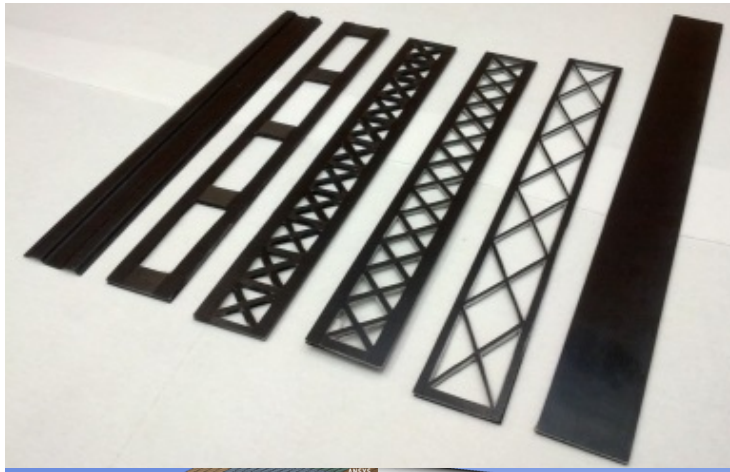


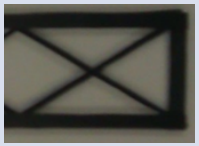
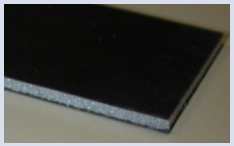
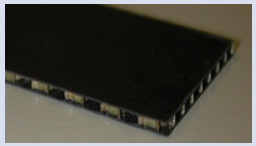
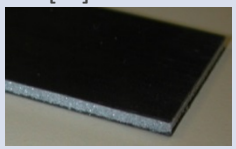
Good agreement w/ simulations



Stave support structures

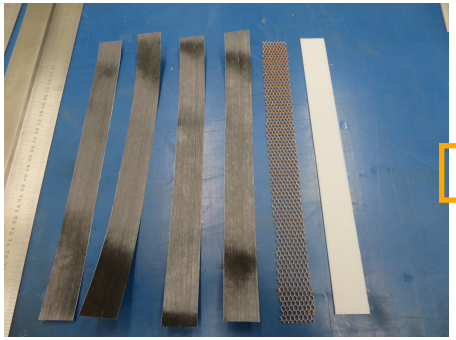
- Development of support structures that fulfil the 0.05% X_0 of radiation length ($1.8 \times 26 \times 280 mm^3$);
- 2 designs currently being pursued (full sandwich & cross bracing);
- Other ideas being investigated (Omega shape, filament winding,...).



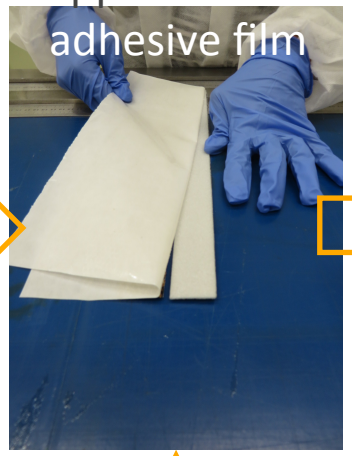
Stave label #	CERN #5	CD #7	CD #8	NTPT #5
Material	M55J + Rohacell 51 	T800 [0°; 90°; 0°] + Rohacell 51 	T800 [0°; 90°; 0°] + Nomex HC 	M55JB [0°] + Rohacell 51 
Flexural stiffness (Span=180mm)	2.23 N/mm	*2.12 N/mm*	*2.17 N/mm*	-
Flexural stiffness (Span=260mm)	-	*0.781 N/mm*	*0.776 N/mm*	*1.22 N/mm*
Mass (280mm long)	1.76g	3.17 g	3.45 g	2.07 g
X/X0	0.051%	0.104 %	0.112 %	0.064 %
Manufacturing difficulty	☹	☺	☺	😐

Stave support manufacturing at CERN

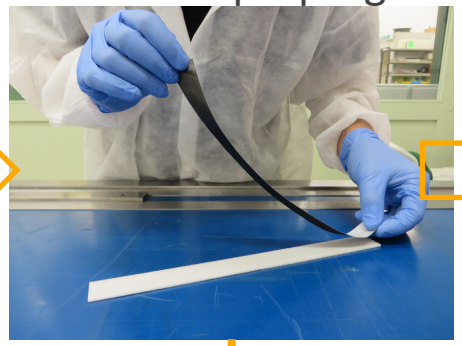
Raw CF prepreg & core



Application of adhesive film

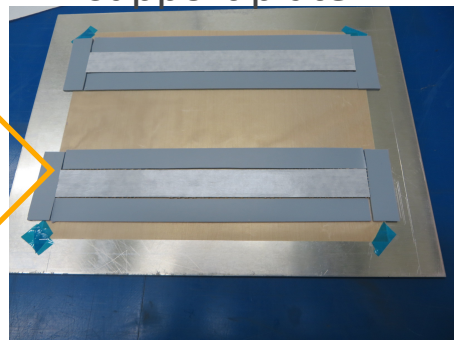


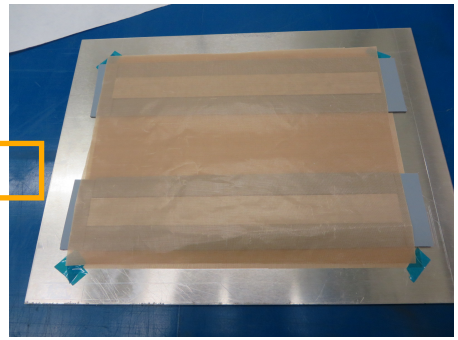
Application of raw CF prepreg



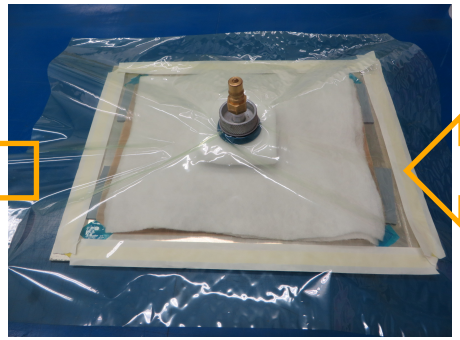
x1

Aluminium support plate

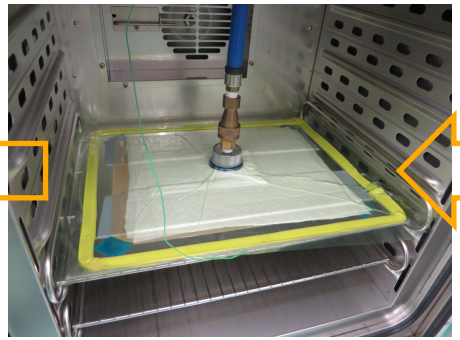




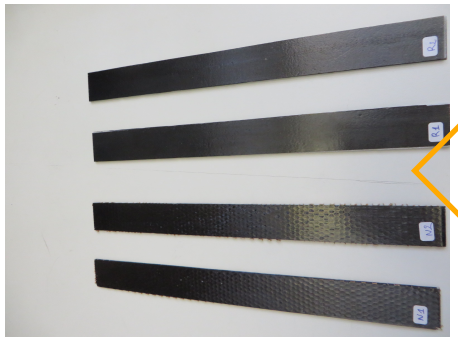
Non-stick film



Vacuum bagging



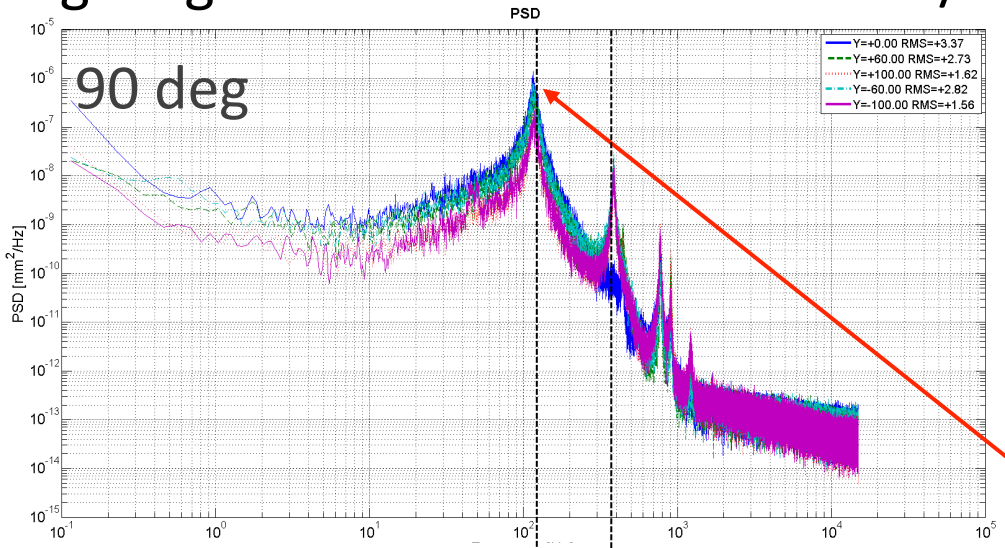
Oven

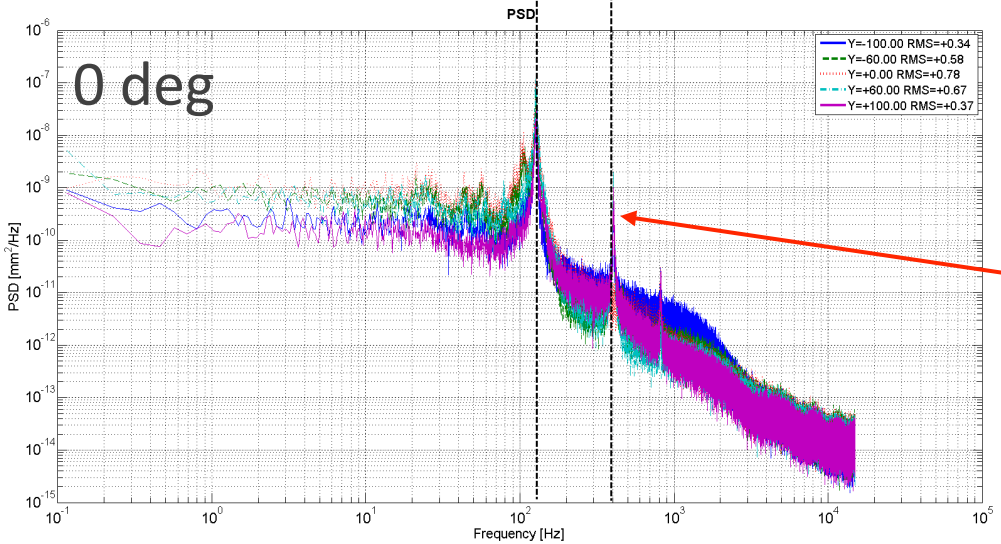


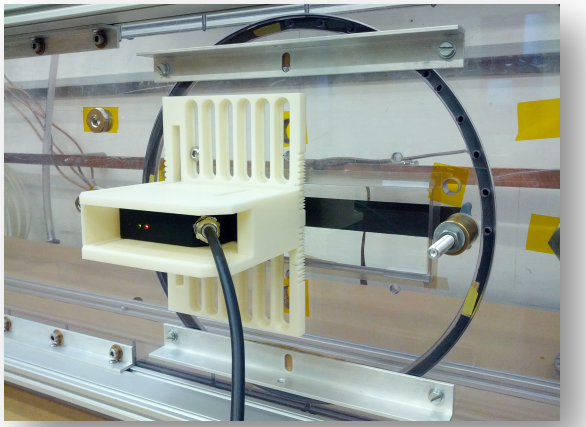
Finished staves

Vibration measurements (P.S.D.)

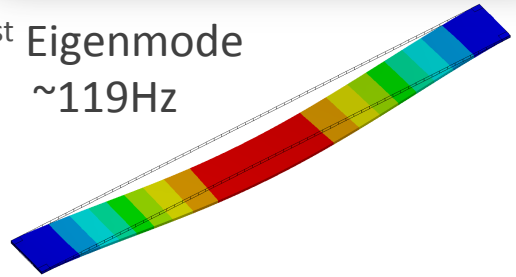
Sweep along length – 25 mm channel – 7.5 m/s – Nomex HC stave CD#8



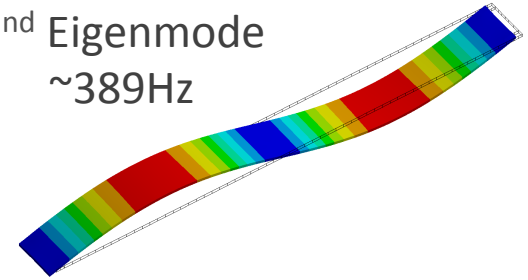




1st Eigenmode
~119Hz

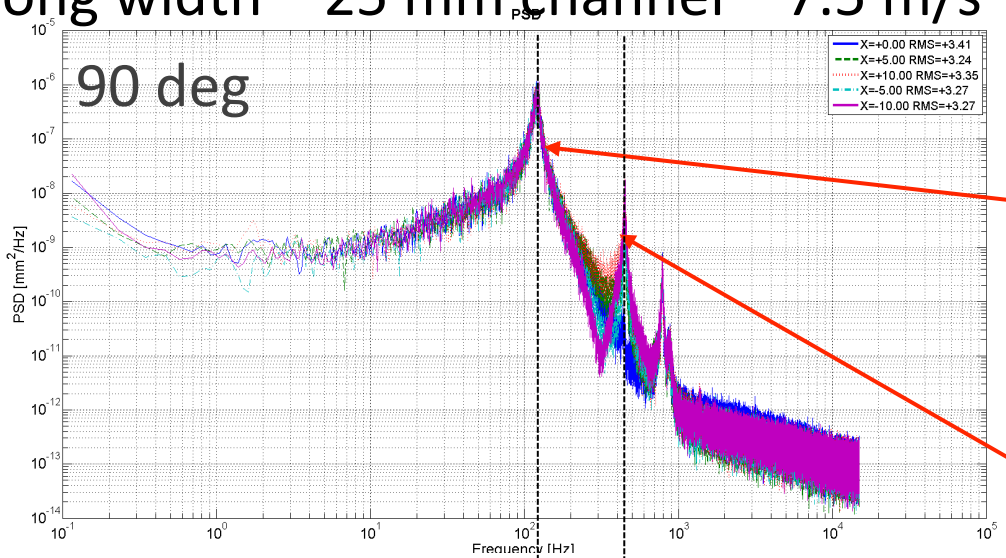


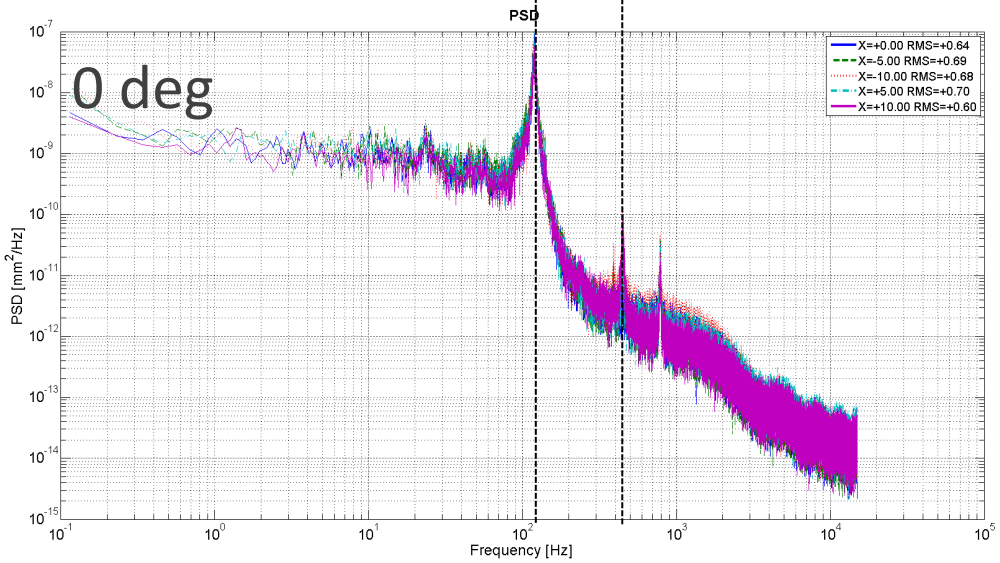
2nd Eigenmode
~389Hz



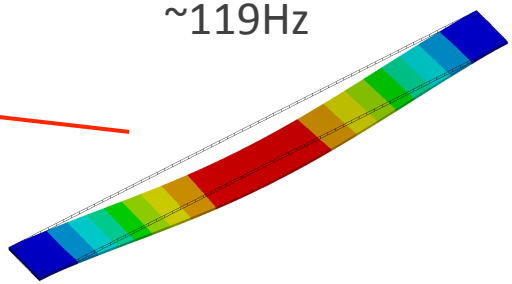
Vibration measurements (P.S.D.)

Sweep along width – 25 mm channel – 7.5 m/s – Nomex HC stave CD#8

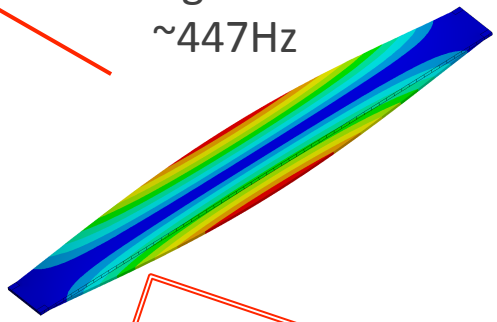




1st Eigenmode
~119Hz

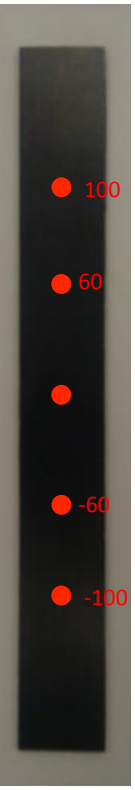


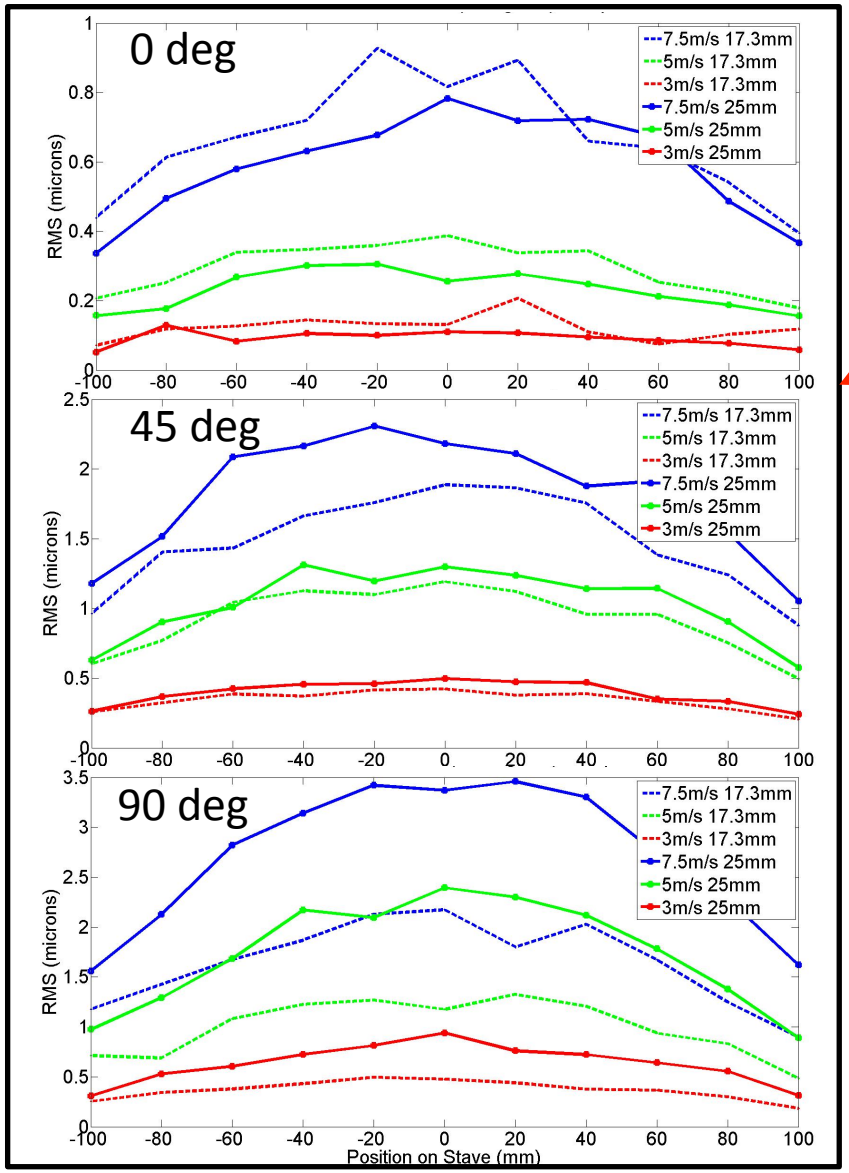
3rd Eigenmode
~447Hz

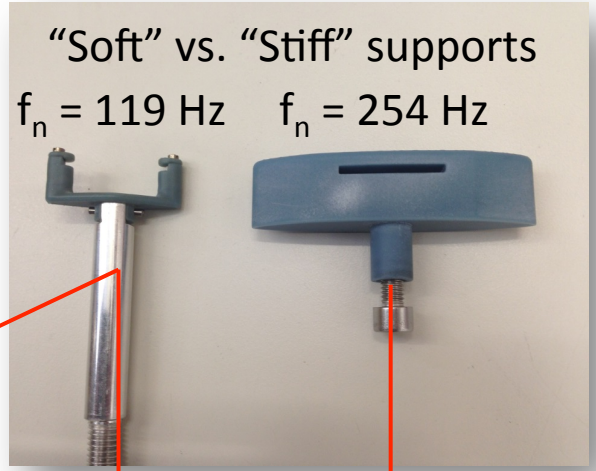


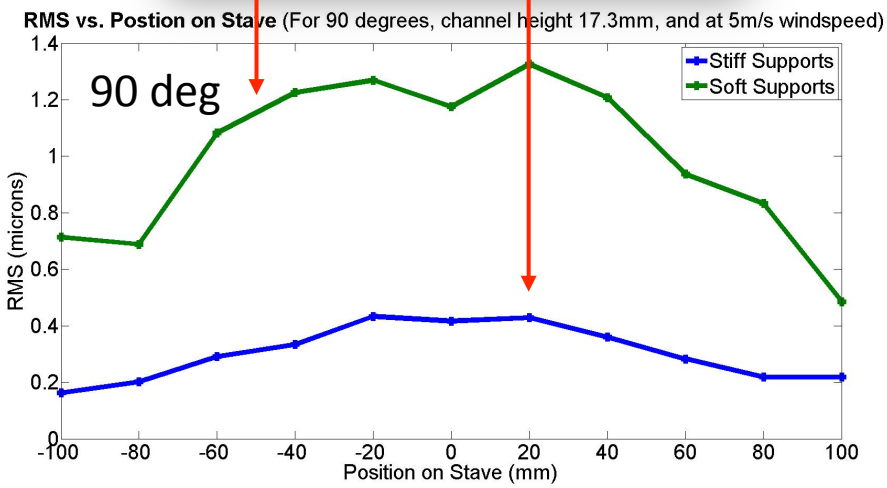
The first three eigenmodes seem to be the most excited ones

RMS vs. position on stave





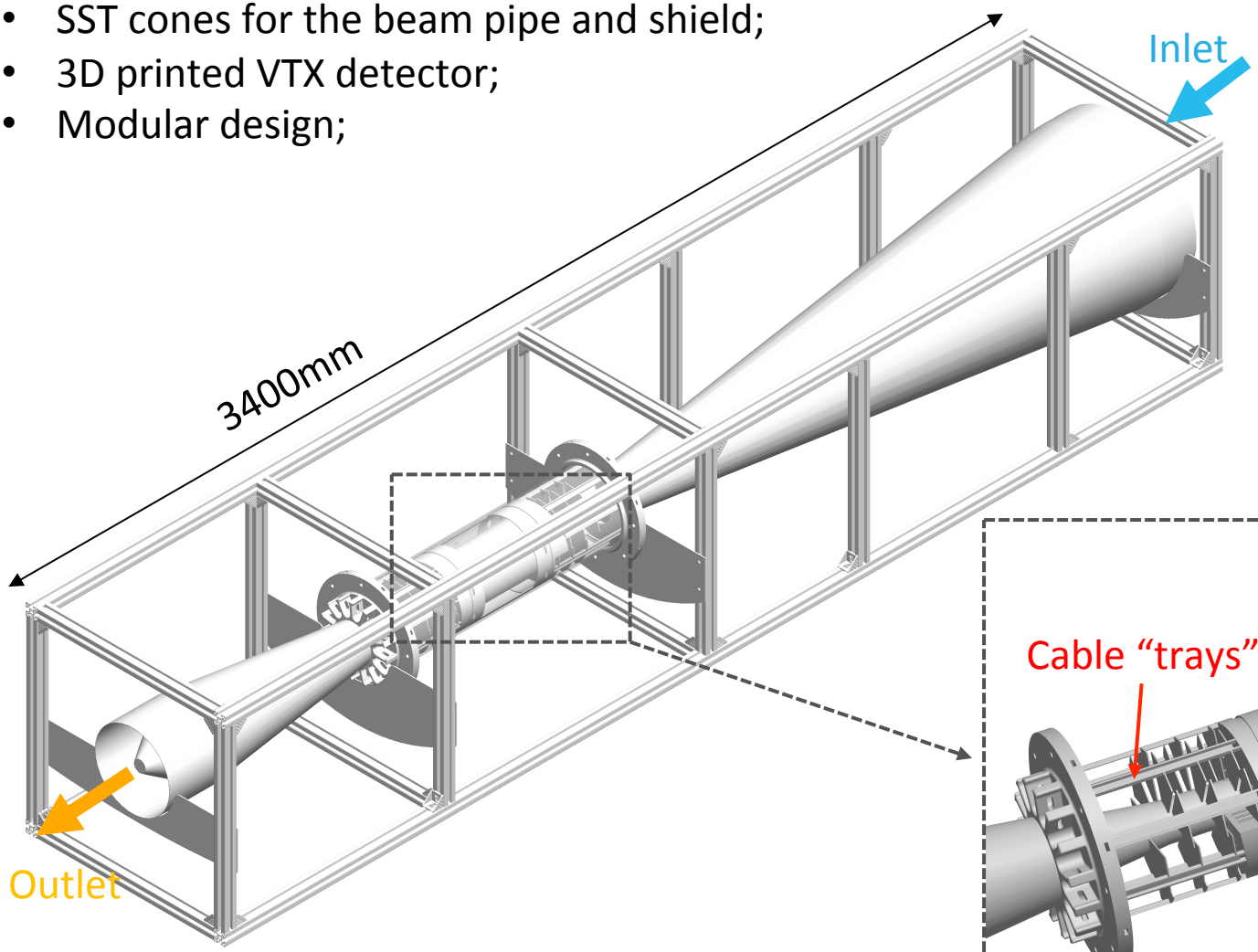




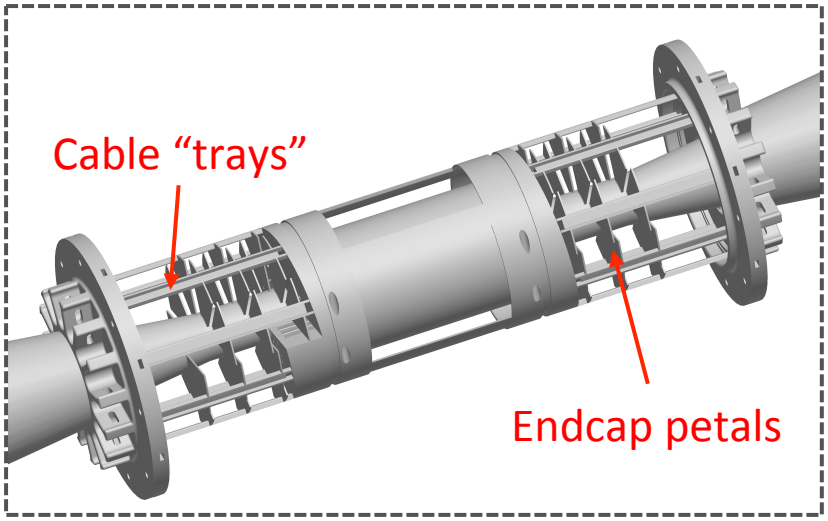
At 5m/s, vibrations are below 2.5 µm
Can be further improved with stiffer supports

1:1 scale thermal test bench

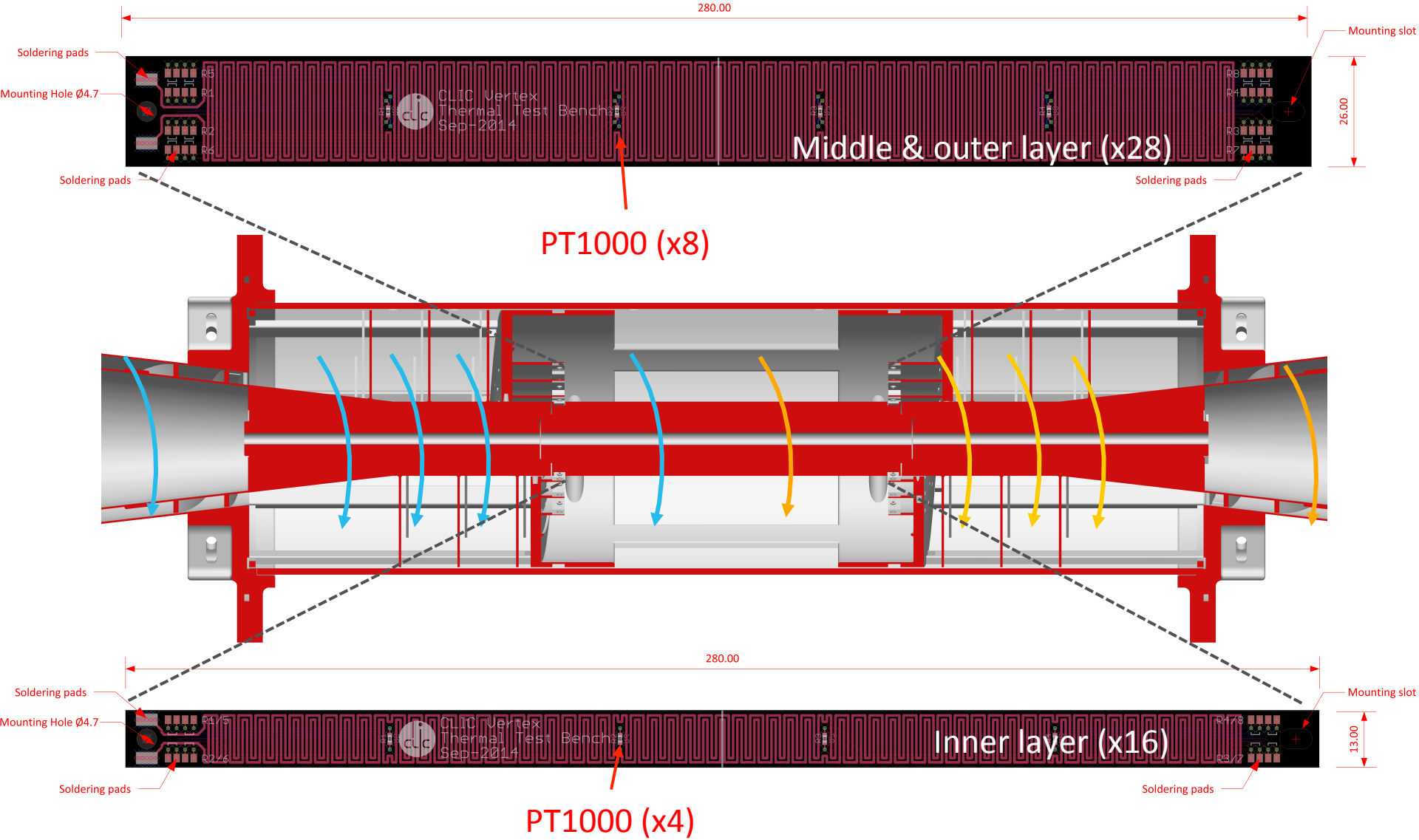
- Commissioning starts beginning of 2015 (expected);
- SST cones for the beam pipe and shield;
- 3D printed VTX detector;
- Modular design;



Objective:
Study flow conditions
&
Temperature distribution in the VTX barrel
&
Comparison with CFD simulations

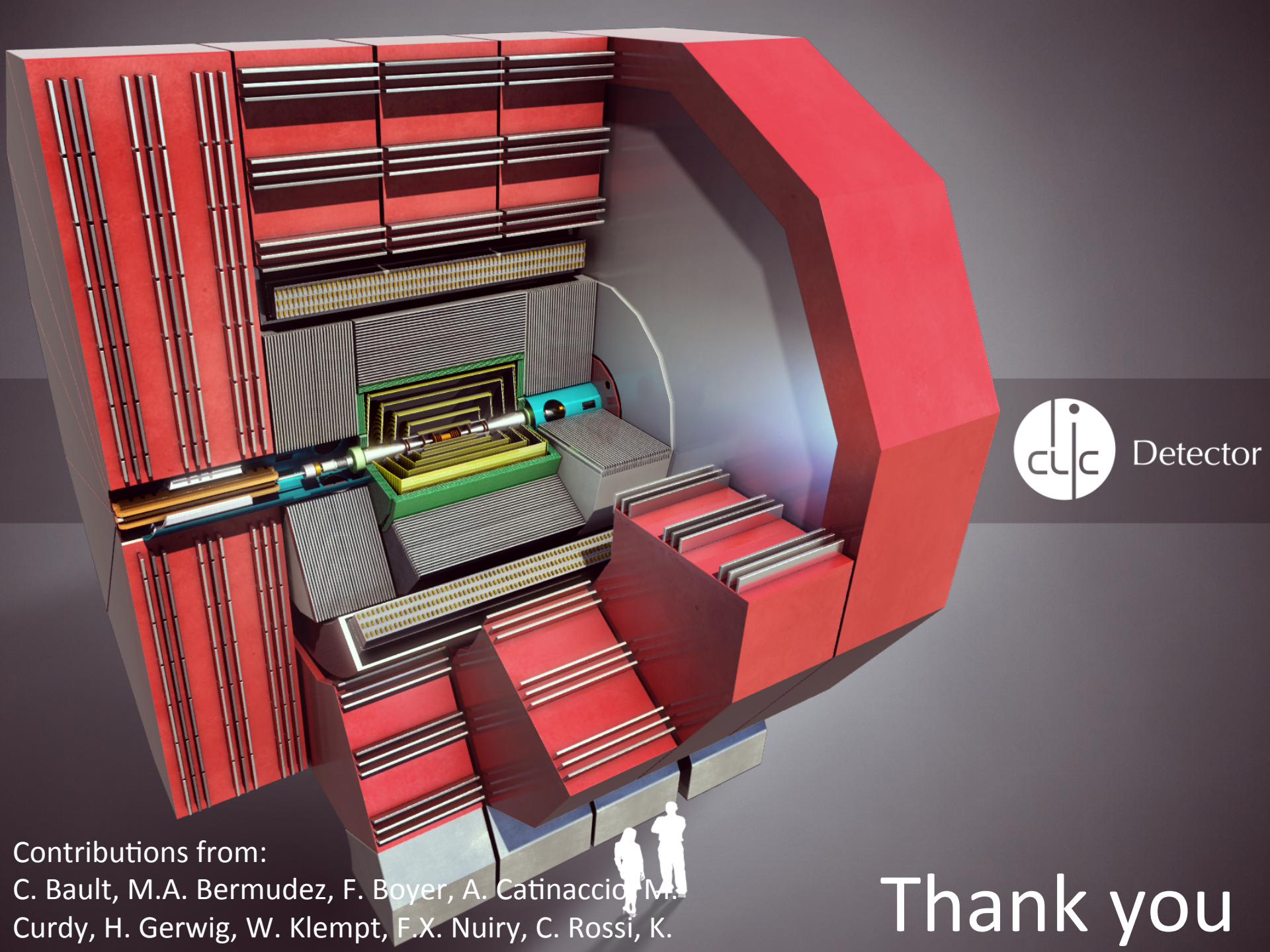


1:1 scale thermal test bench



Summary

- An air cooling strategy for the inner region of the CLIC detector is currently being investigated;
- Simulations indicate that it will be possible to maintain sensor temperatures <40 ^{o}C for a nominal heat load of 50 mW/cm^2;
- A thermo-mechanical test set-up has so far confirmed the simulations' results;
- The development of support structures shows promising results in terms of achieving the radiation length goals;
- Air flow induced vibration tests on support structure prototypes have shown that amplitudes are within the acceptable range;
- A new 1:1 scale thermal test bench of the VTX detector is being built to validate the cooling strategy.

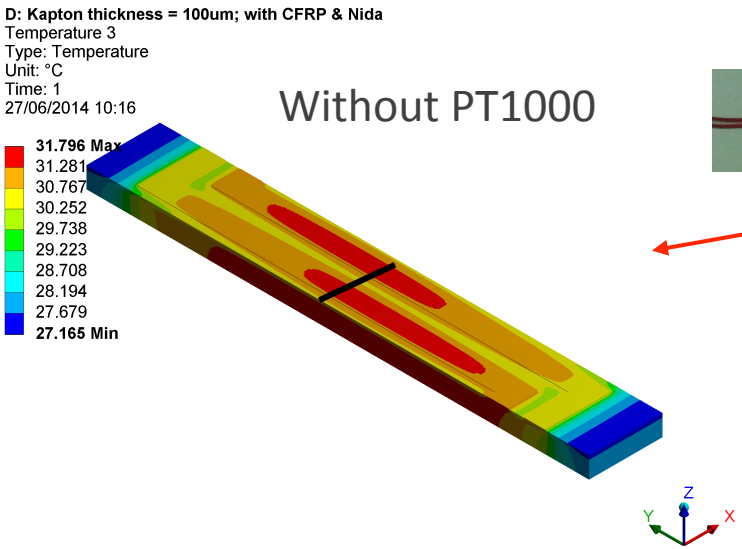


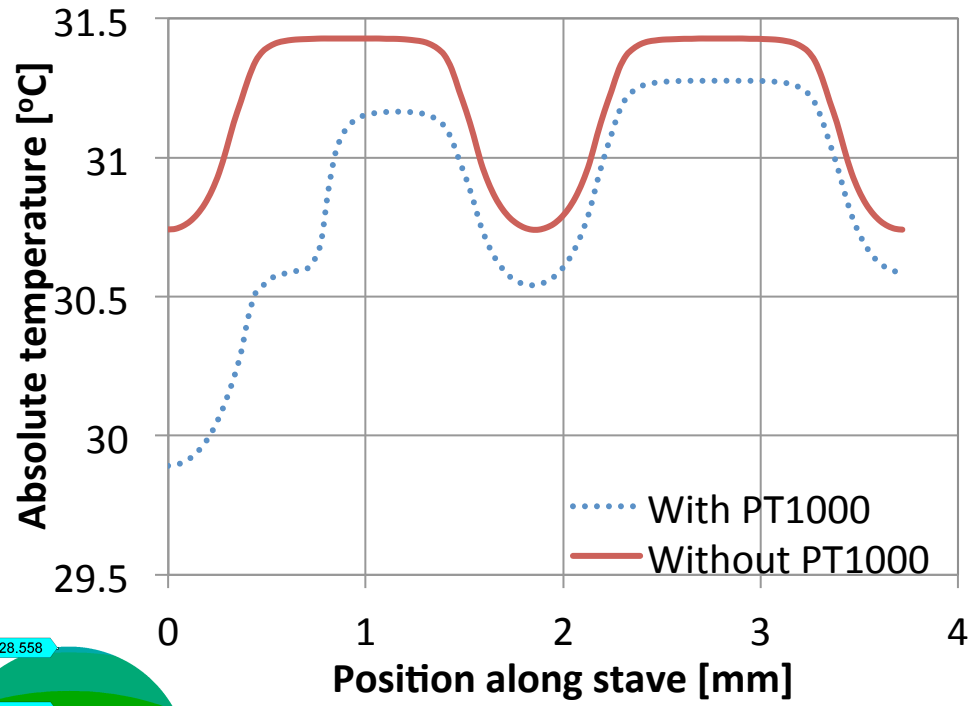
Contributions from:
C. Bault, M.A. Bermudez, F. Boyer, A. Catinaccio, M. Curdy, H. Gerwig, W. Klempt, F.X. Nuiry, C. Rossi, K.

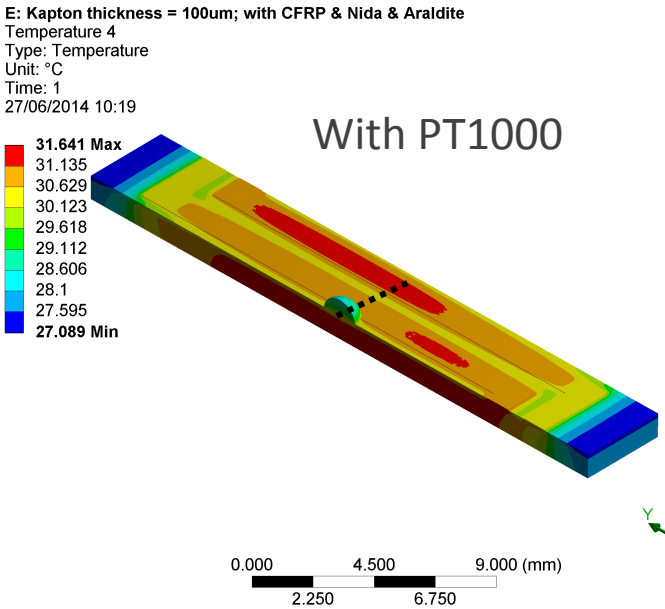
Thank you

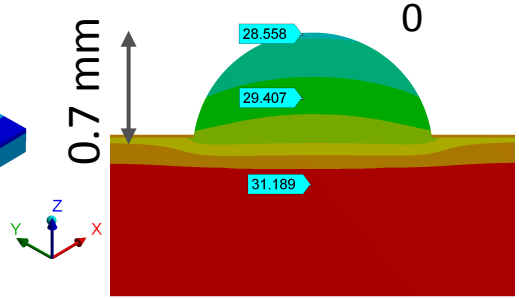
Spare slides

Detailed dummy stave simulation



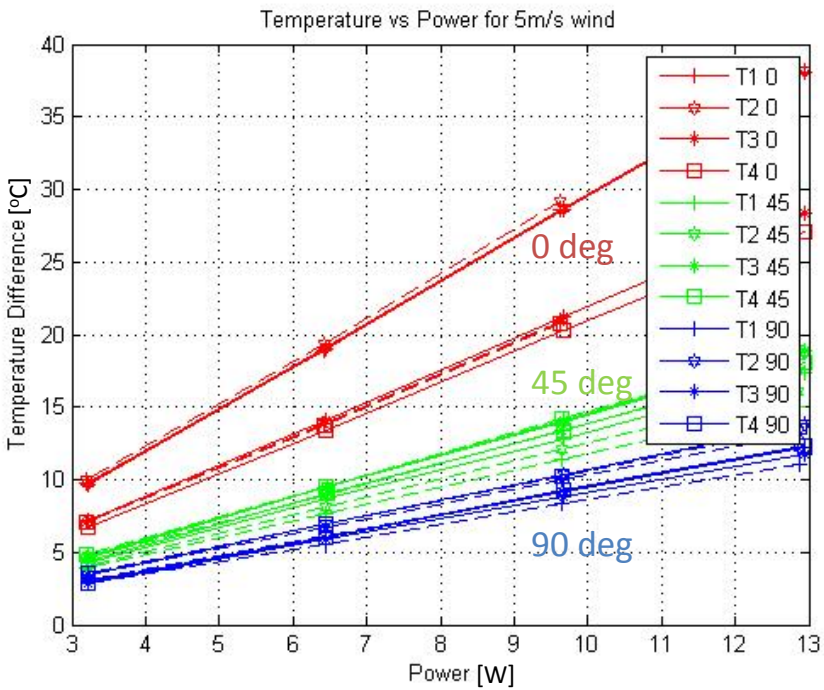


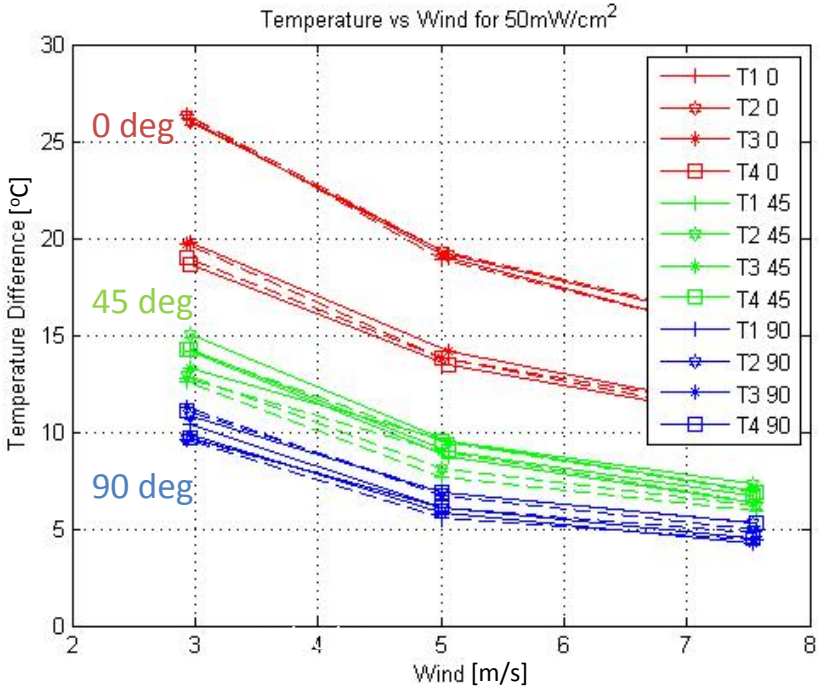


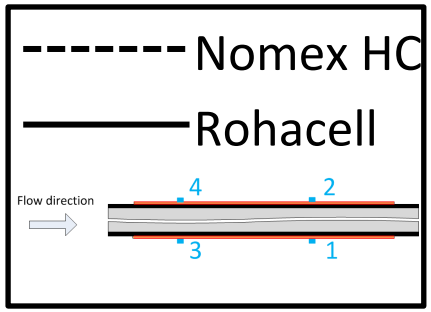


Influence of stave core material

25 mm channel







$K_{rohacell}$ = 0.029 W/mK

$K_{nomex\ HC}$ = 0.058 W/mK

Negligible influence of core material