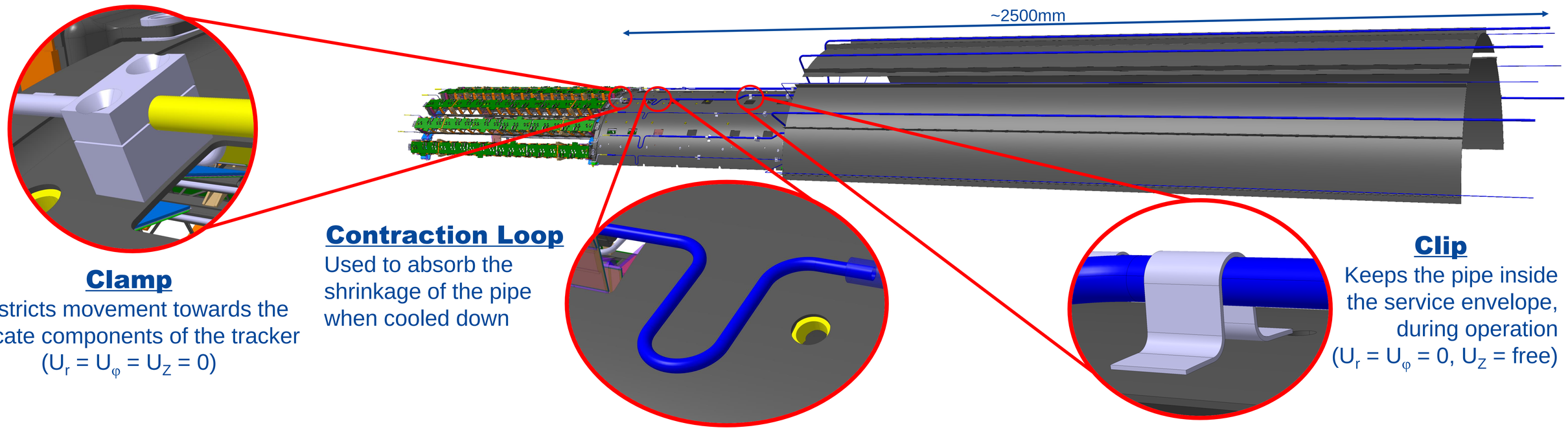
Validation of the cooling pipe design used in ATLAS ITk Pixel Outer Barrel

Szymon Wlodarczyk, Christophe Bault, Ricardo Rego, Andrea Catinaccio, Diego Alvarez

The Problem

The cold operation of silicon tracking detectors requires specific design solutions to accommodate the thermal contraction of the pipes used in the cooling circuit. In the ATLAS ITk Pixel Outer Barrel, titanium tubes are used to cool the pixel modules with two-phase CO2. Long inlet capillaries and exhaust pipes have the potential to thermally contract a large amount and introduce unwanted stresses (and deformations) to the thin evaporators used in the local supports. Custom-made clamps, clips and contraction loops have been designed to mitigate these effects.



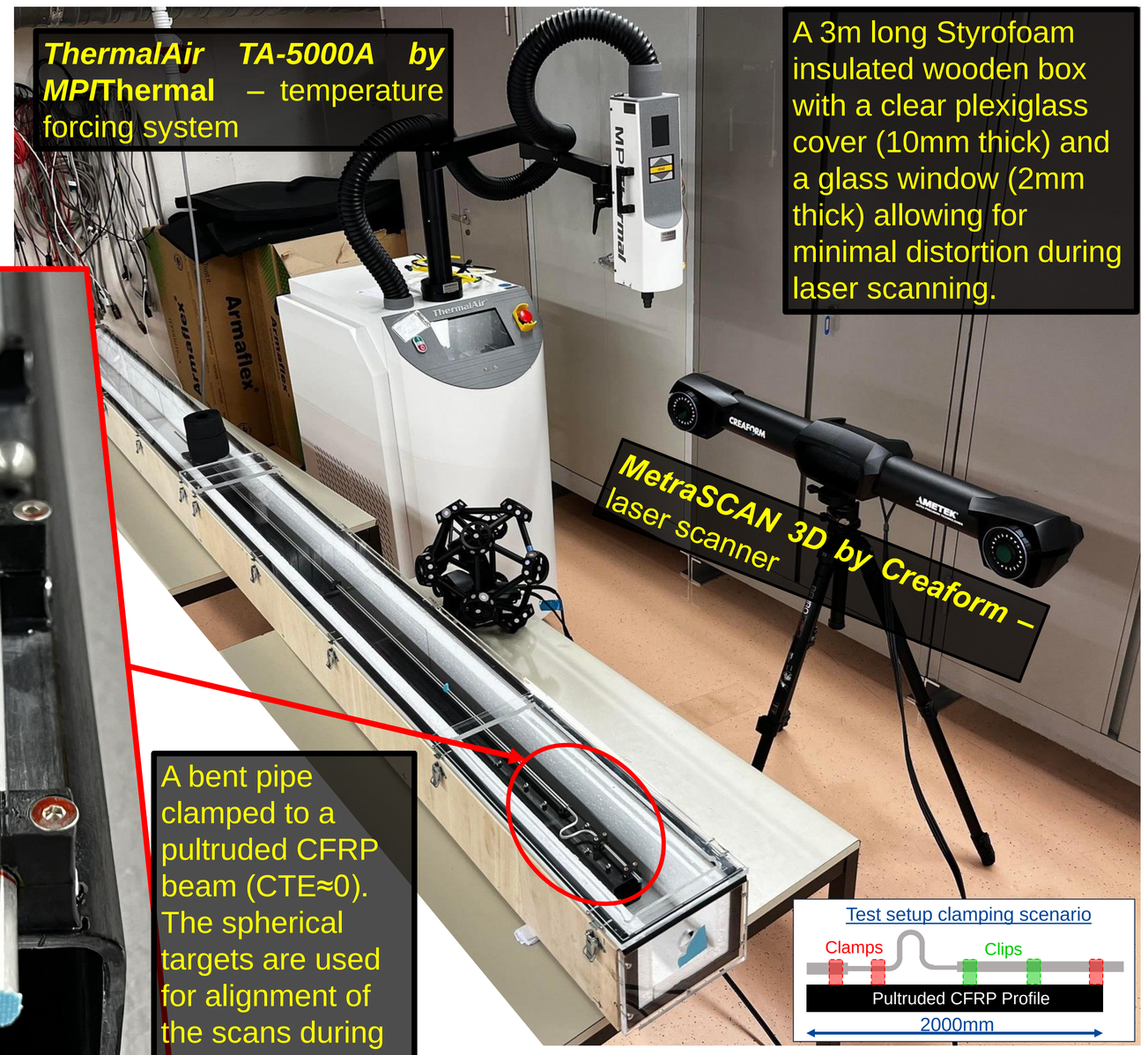
Clamp
Restricts movement towards the delicate components of the tracker ($U_r = U_\varphi = U_Z = 0$)

Contraction Loop
Used to absorb the shrinkage of the pipe when cooled down

Clip
Keeps the pipe inside the service envelope, during operation ($U_r = U_\varphi = 0$, U_Z = free)

The Method

The design validation process relies on thermo-mechanical simulations (FEA) and experimental data. The latter was collected on a test bench combining a custom-built environmental box, a temperature forcing system, and a laser scanner which allows for pipe prototype deformation measurements at different temperatures and under realistic boundary conditions.

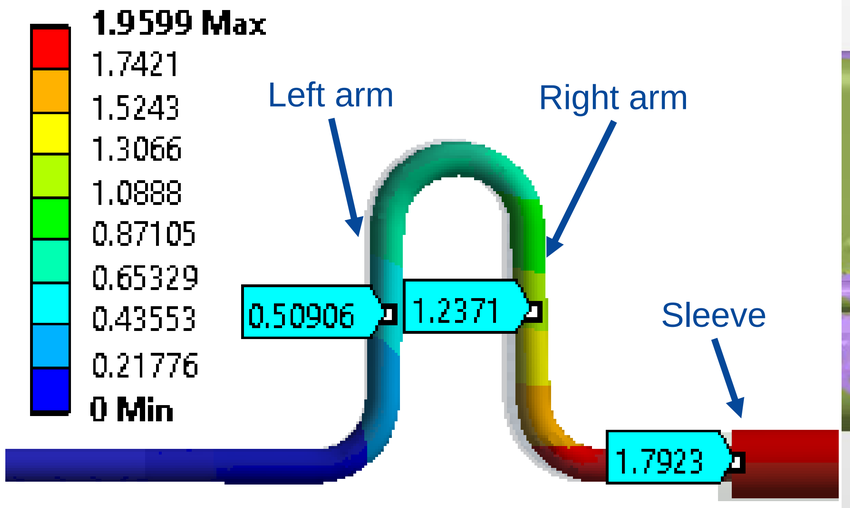


The Results

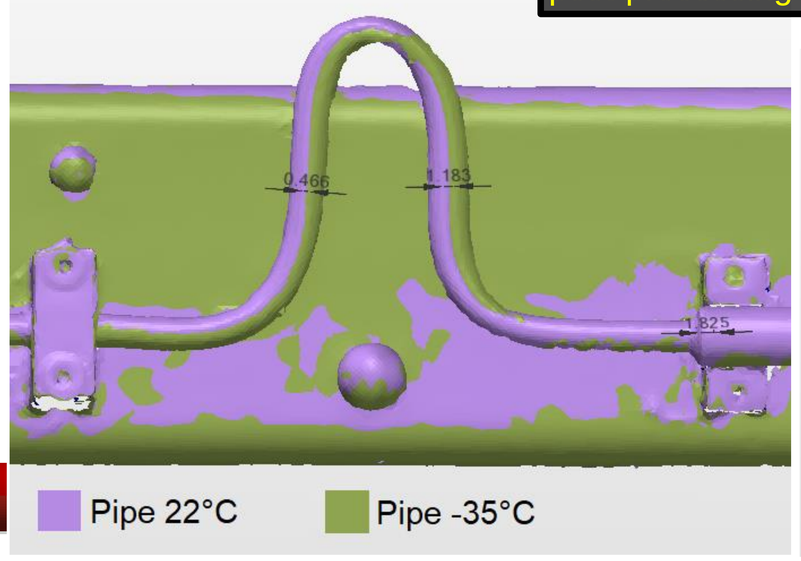
The proposed approach has been qualified using a stainless steel (316L) prototype, which has been tested at various temperatures ranging from -35°C to 77°C. The relative displacements of the pipe measured with the laser scanning system during temperature excursions agree well with the finite element results obtained in the simulations performed with ANSYS.

Contraction Loop Displacement between 22°C and -35°C

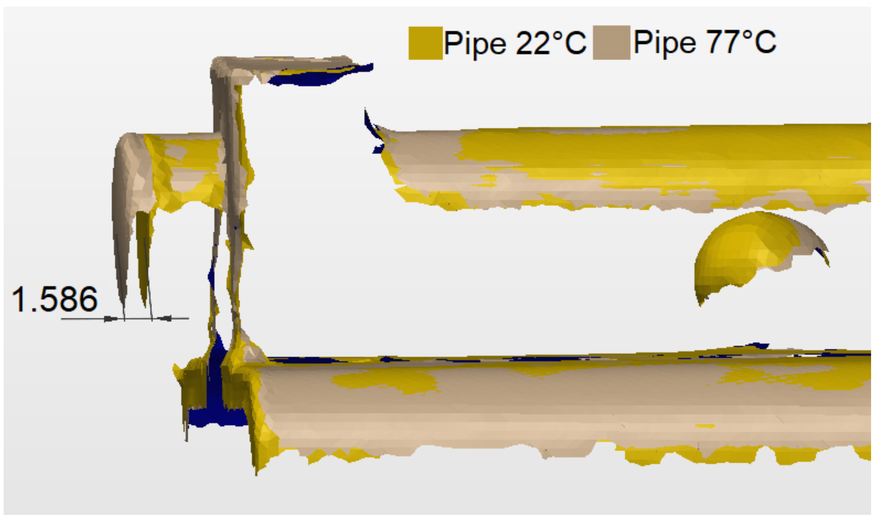
Test Point	Simulation [mm]	Experiment [mm]
Left Arm	0.51	0.47
Right Arm	1.24	1.18
Sleeve	1.79	1.83



Solid-shell ANSYS simulation of the relative total deformation (in [mm]) of a stainless steel pipe with a contraction loop. Three measurement points are used to compare the simulation with the scans.



Comparison of the scanned results for a stainless steel pipe with a contraction loop at 22°C and -35°C. The contraction measured matches the ANSYS simulation.



Comparison of the scanned results for a 2m long straight steel pipe (one end clamped) at 22°C and at 77°C. The expansion measured matches the analytical estimate: CTE=$15 \cdot 10^{-6} °C^{-1}$ $\Delta L_{analytical}$=1.5mm

The Conclusions

The preliminary results obtained with our new setup to evaluate the thermo-elastic response of cooling pipes are very encouraging. Next, it will be used in the final design validation of the titanium pipes and clamps/clips used in the ATLAS ITk Pixel Outer Barrel. Furthermore, we believe this approach has great potential to assess the response of other detector components at cold temperatures.

EP-DT
Experimental Physics
Detector Technology

Szymon.Wlodarczyk@cern.ch