



Alignment experience of SPS-DQW & HL-LHC (Crab-cavities)



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On behalf of :

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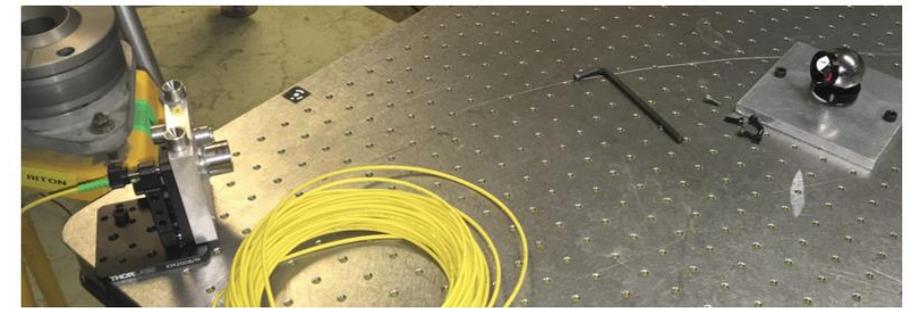
Outline

- FSI Monitoring System used for the Crab-cavities
- Configuration of the Crab cavities FSI monitoring system
- Results at Ambient condition
- Cool down (293K \rightarrow 4 K)
- Results at cold condition
- Thermal contraction (Comparison with simulation)
- Repeatability of several heat-up and cool down sequences
- Conclusion

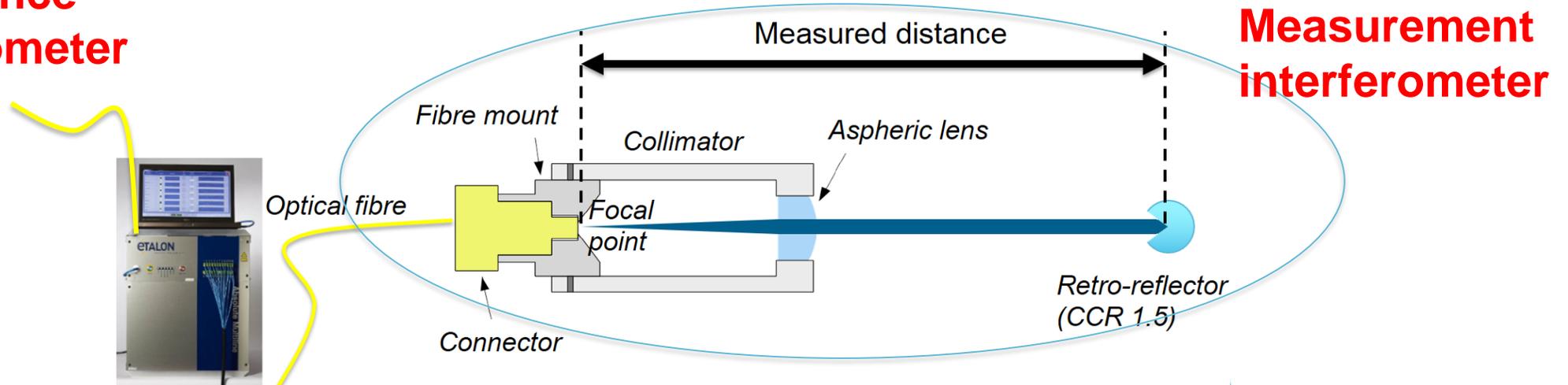


FSI : Frequency Scanning interferometry

FSI : Absolute distance measuring interferometric technique



**Reference
interferometer**



**Measurement
interferometer**

Absolute distance deduced from the ratio of the phase change between the 2 interferometers by frequency scanning

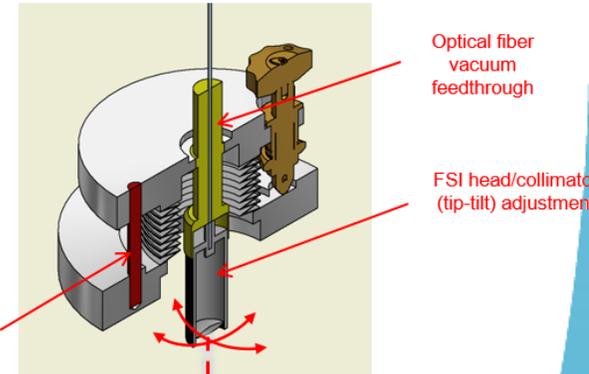
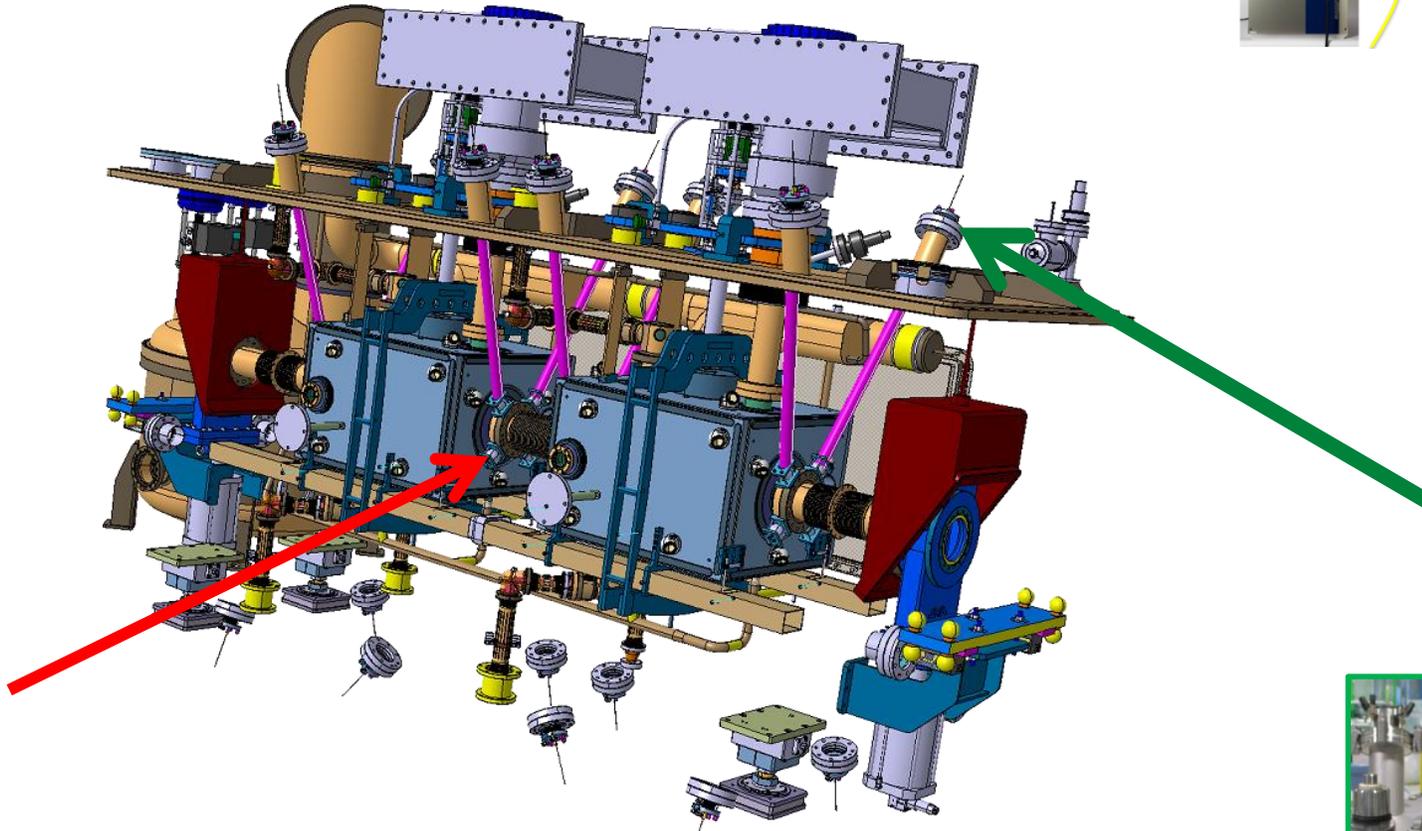
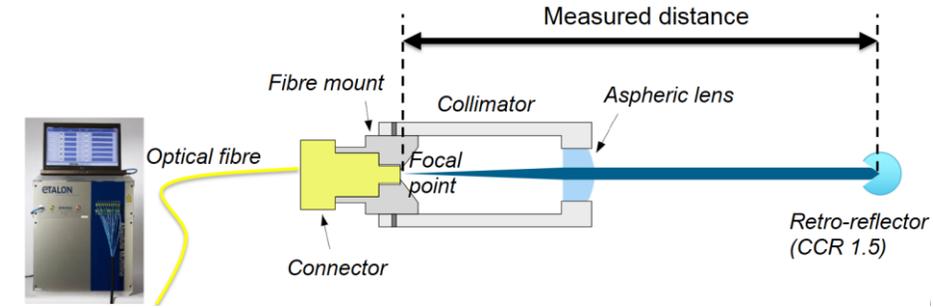
- $\Delta Phase (meas.) = \frac{2\pi}{c} * L_M * \Delta \nu$
- $\Delta Phase (ref.) = \frac{2\pi}{c} * L_R * \Delta \nu$

$$\frac{\Delta Phase (meas.)}{\Delta Phase (ref.)} = \frac{L_M}{L_R}$$

Accuracy : 0.5 μm per meter

Configuration

- Collimator → Feedthrough → Cryomodule
- Retroreflector → Crab-cavities



Configuration

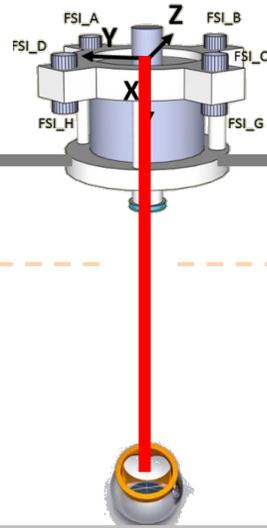
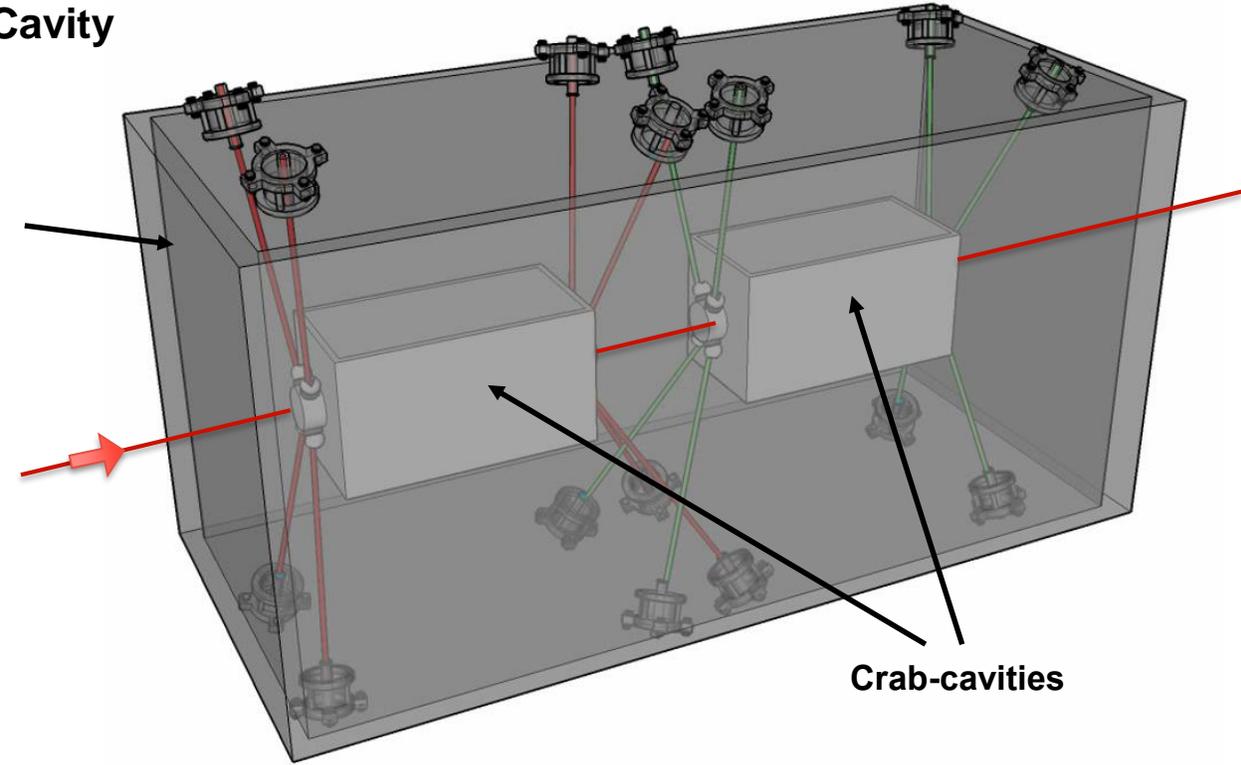
8 FSI distances by Cavity

- **Alignment requirements :**
+/-0.25 mm at 3σ
- **Environmental conditions:**
Radiation : 10 Mgy (beam pipe),
1 Mgy (cryostat surface)
Vacuum : 10^{-6} mbar
Temperature : 2 K

Cryomodule

beam

Crab-cavities



- Vacuum : Ambient
- Temperature : Ambient

- Vacuum : 10^{-6} mbar
- Temperature : 2 K

Cryomodule

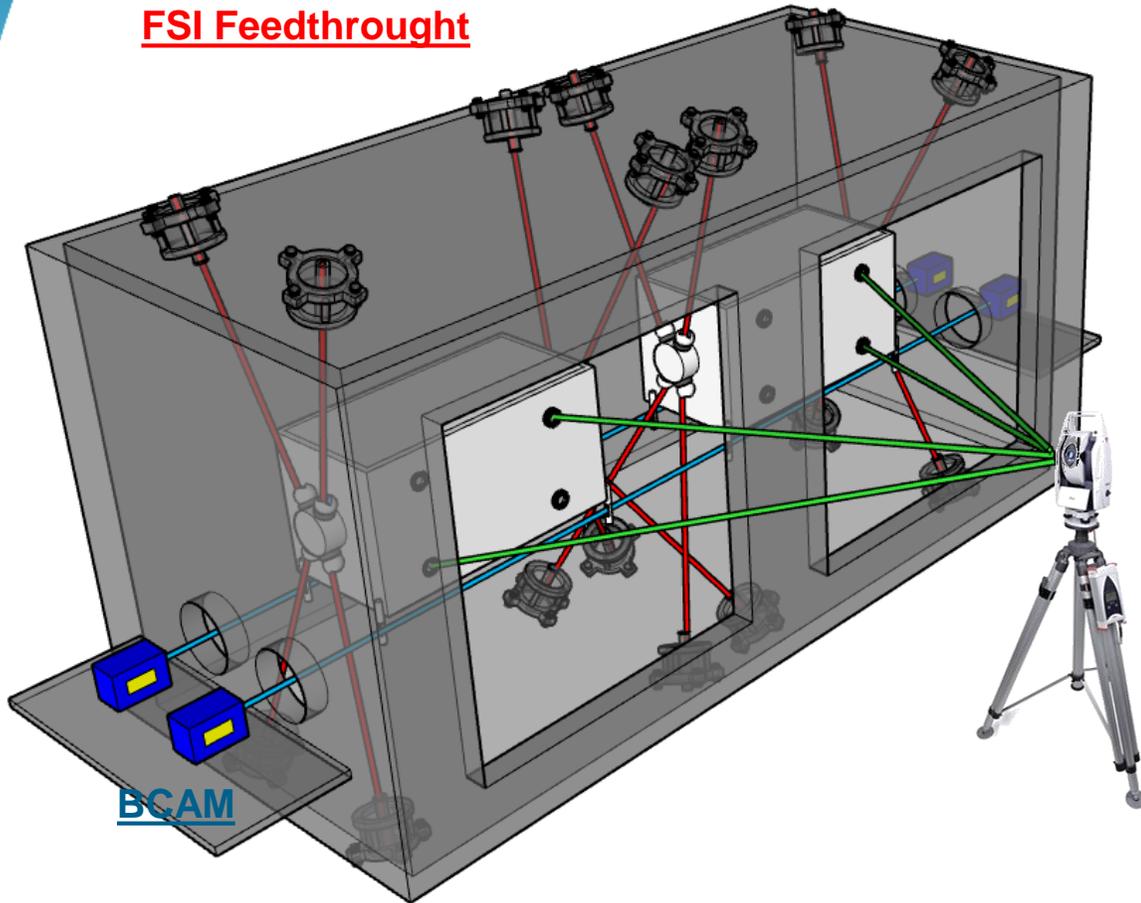
Thermal shielding

Cavity



Intercomparison between FSI / BCAM / Laser Tracker (Before to close the cryomodule)

FSI Feedthrough



FSI (absolute distances)



BCAM (Angle measurements)

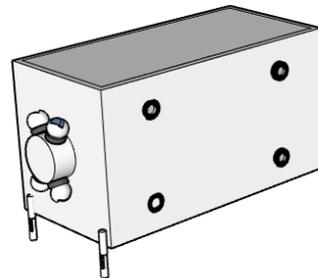


Laser Tracker

Laser Tracker (Angles and distances measurements)



FSI Target



Laser Tracker Target

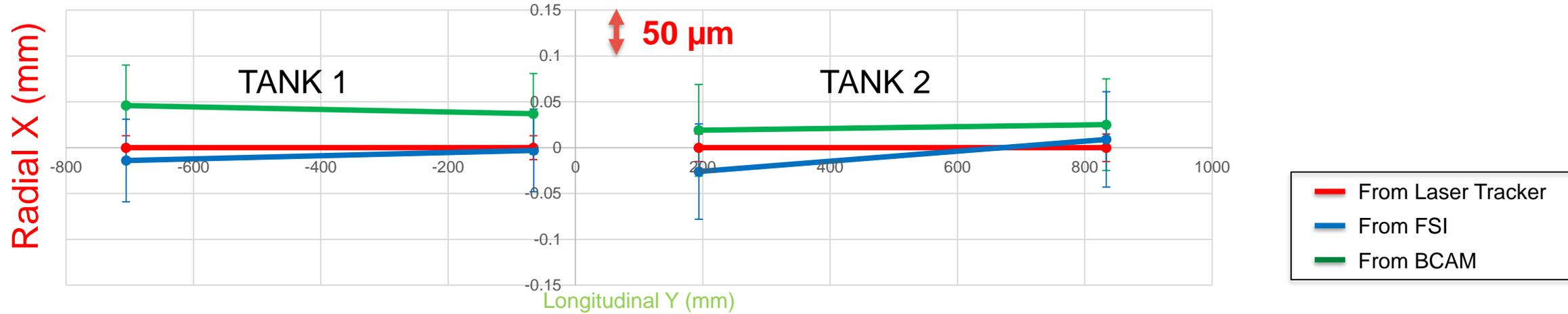
Measured by CMM

BCAM Target

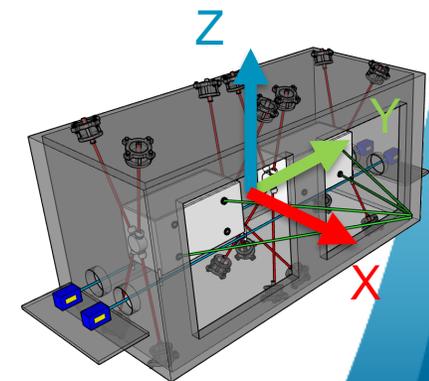
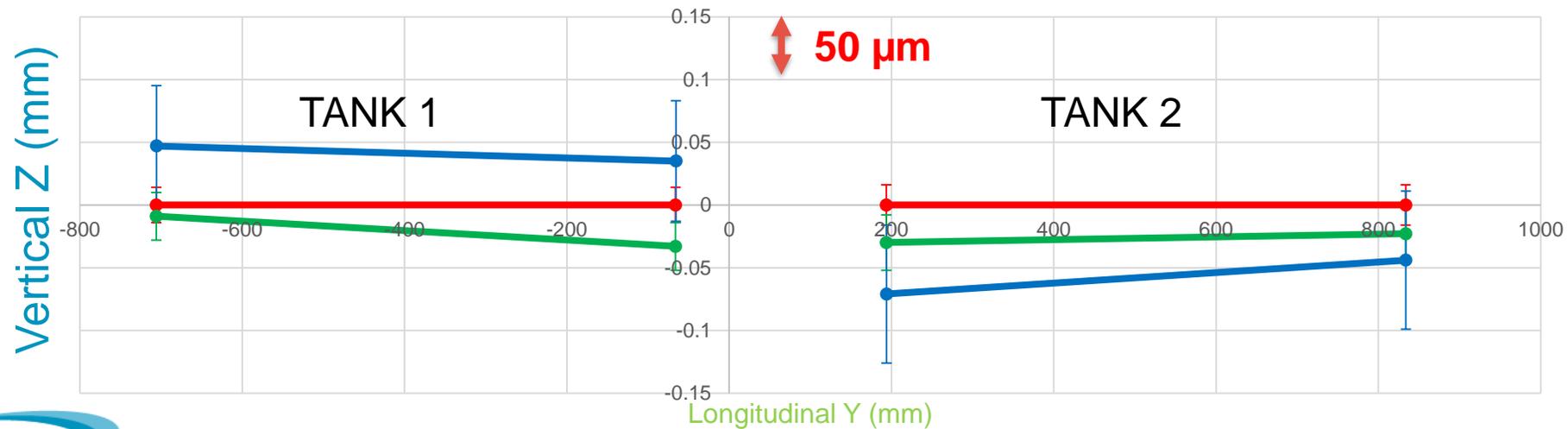
Intercomparison between FSI / BCAM / Laser Tracker (Before cooling down)

FSI, BCAM systems precision better than 50 μm (1σ), crosschecked with AT401 laser tracker measurements

Radial position (relatif with respected to AT401 measurement)



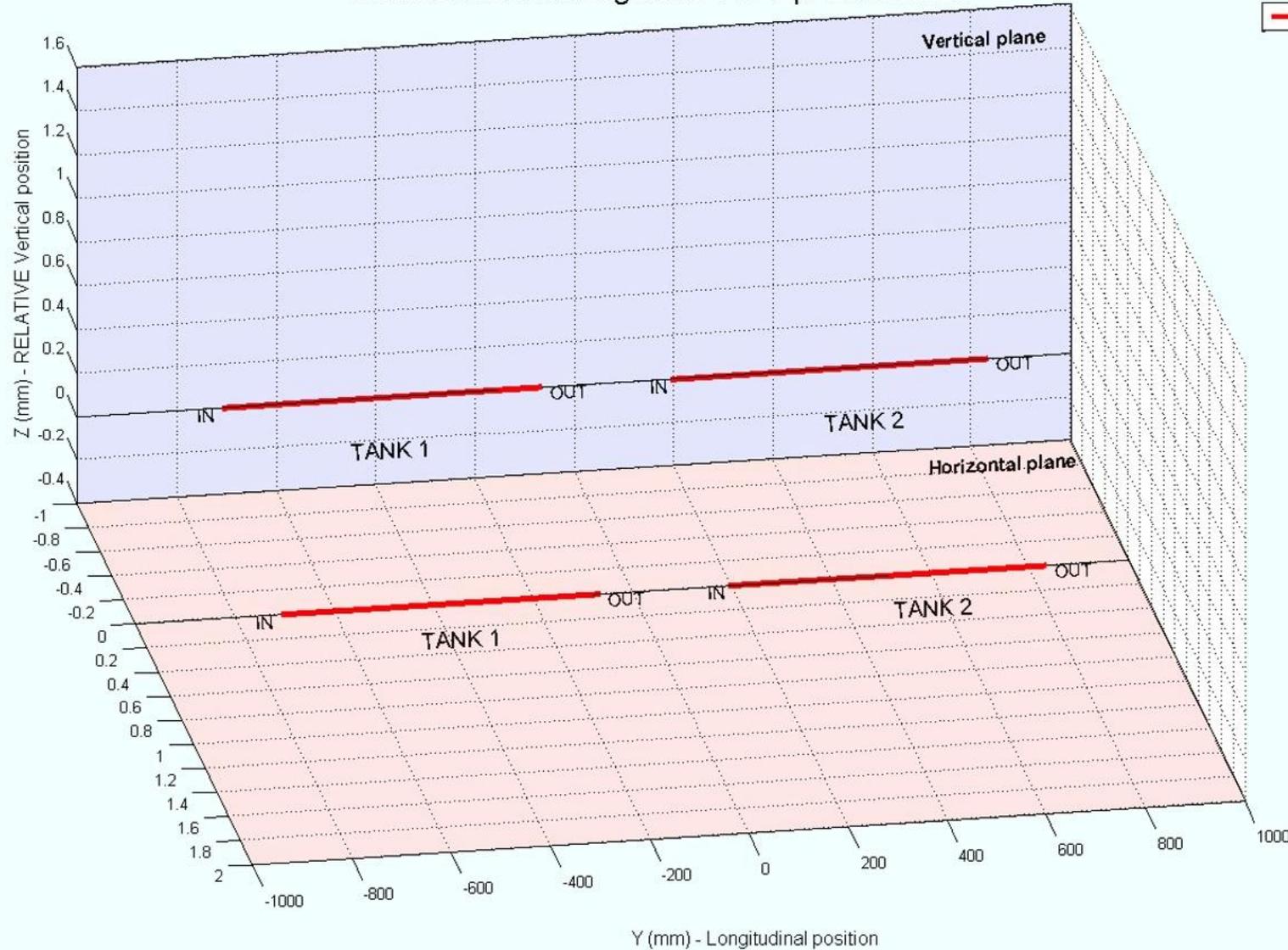
Vertical position (relatif with respected to AT401 measurement)



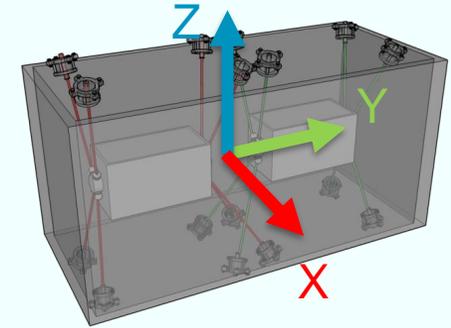
Cool down in SPS : From 293 K to 4 K

Accuracy : $< 50 \mu\text{m}$ (1σ)

Cavities axis : Cooling down : 11-Apr-2018 06:28

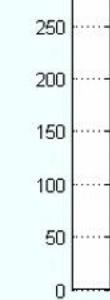


— determined with FSI measurements : RELATIVE (.K)



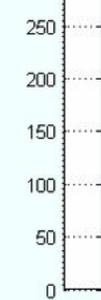
Cavity 1 (K)

TANK 1 : $T^\circ=294$ K

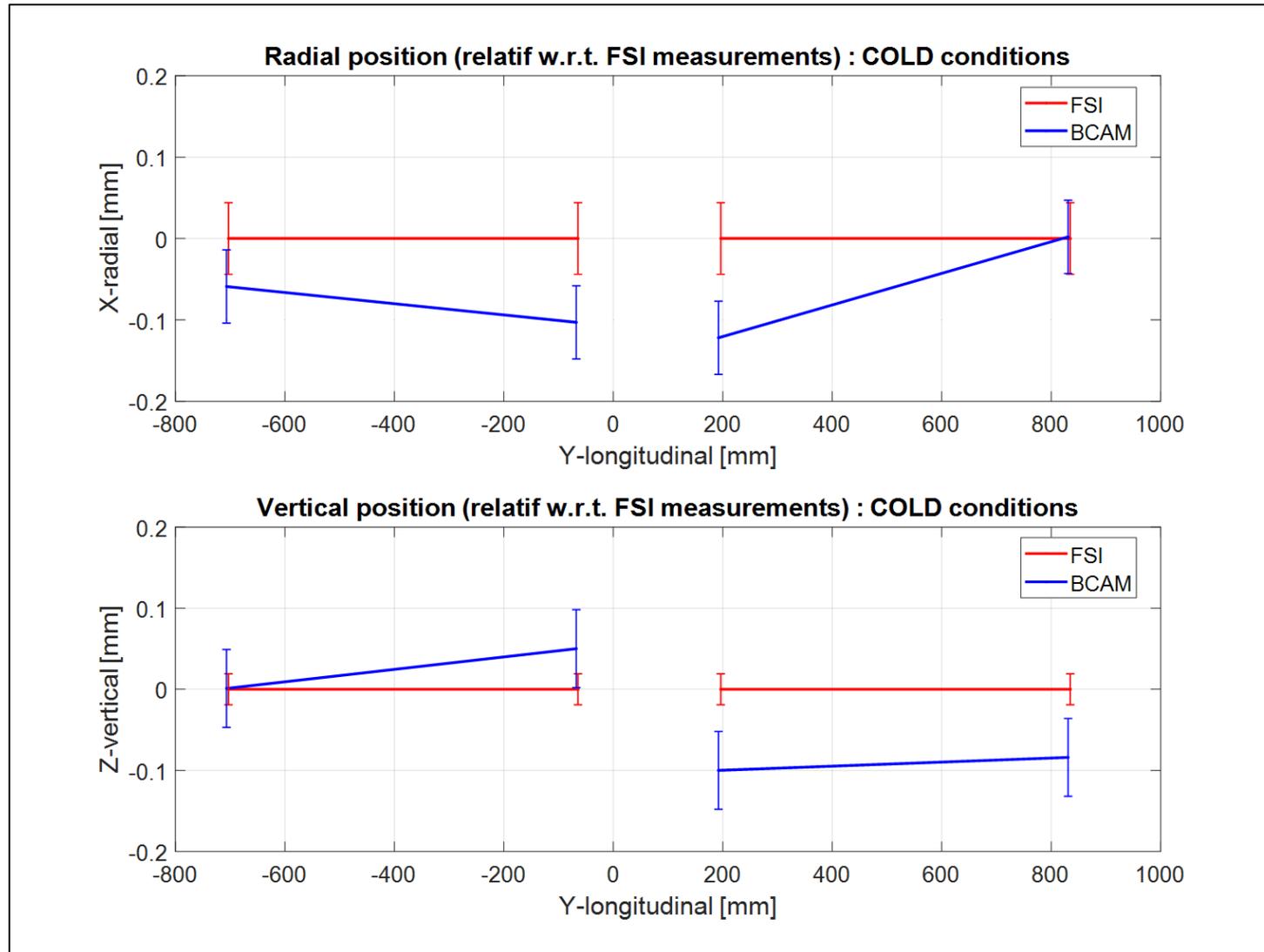


Cavity 2 (K)

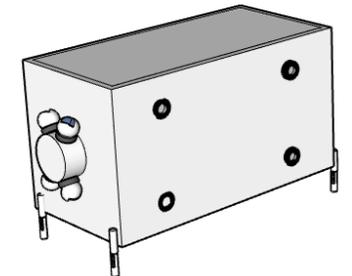
TANK 2 : $T^\circ=294$ K



Intercomparison between FSI / BCAM (Cold condition)

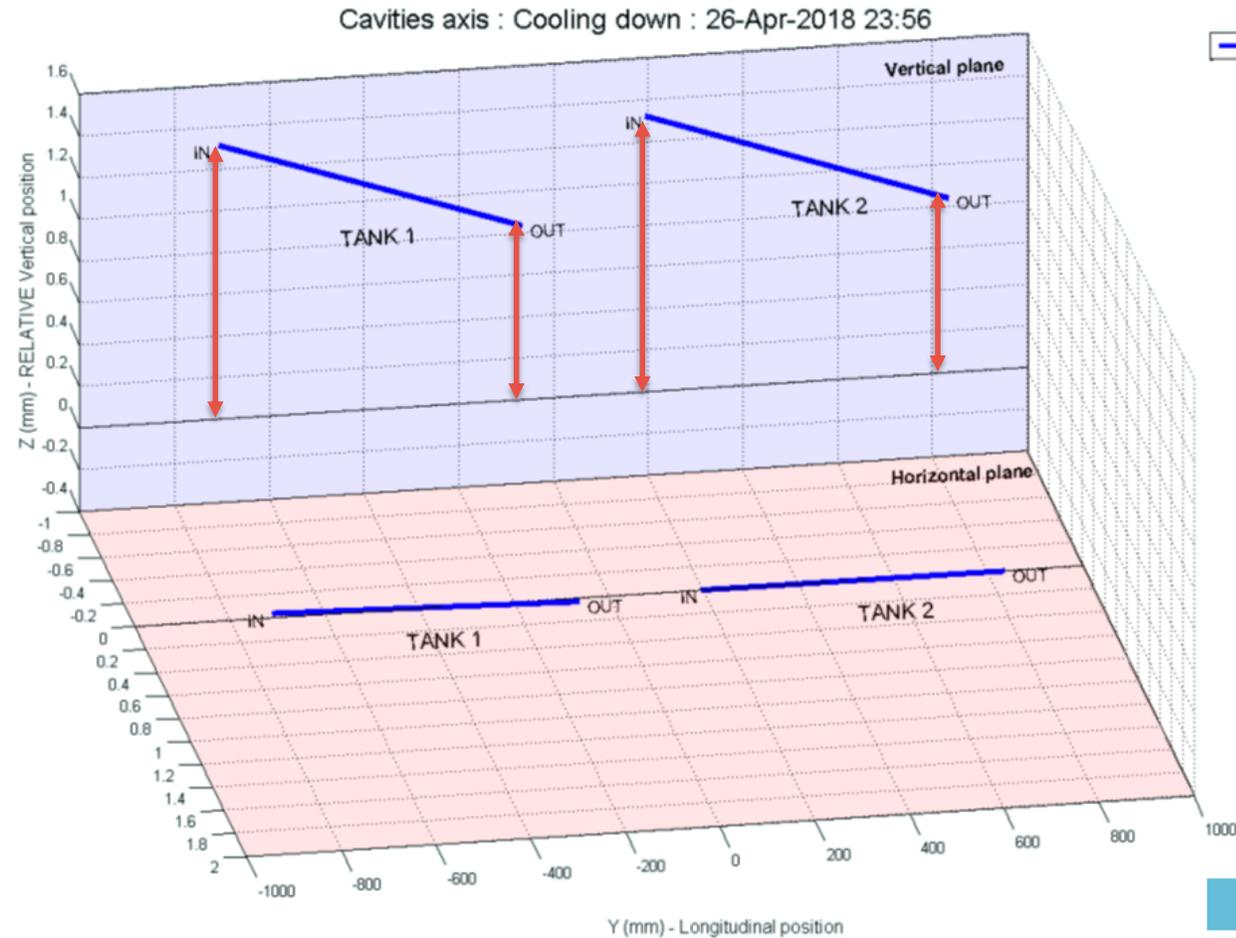


FSI Target

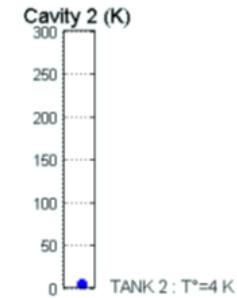
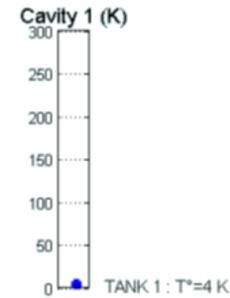


BCAM Target

Thermal contraction : From 293 K to 4 K



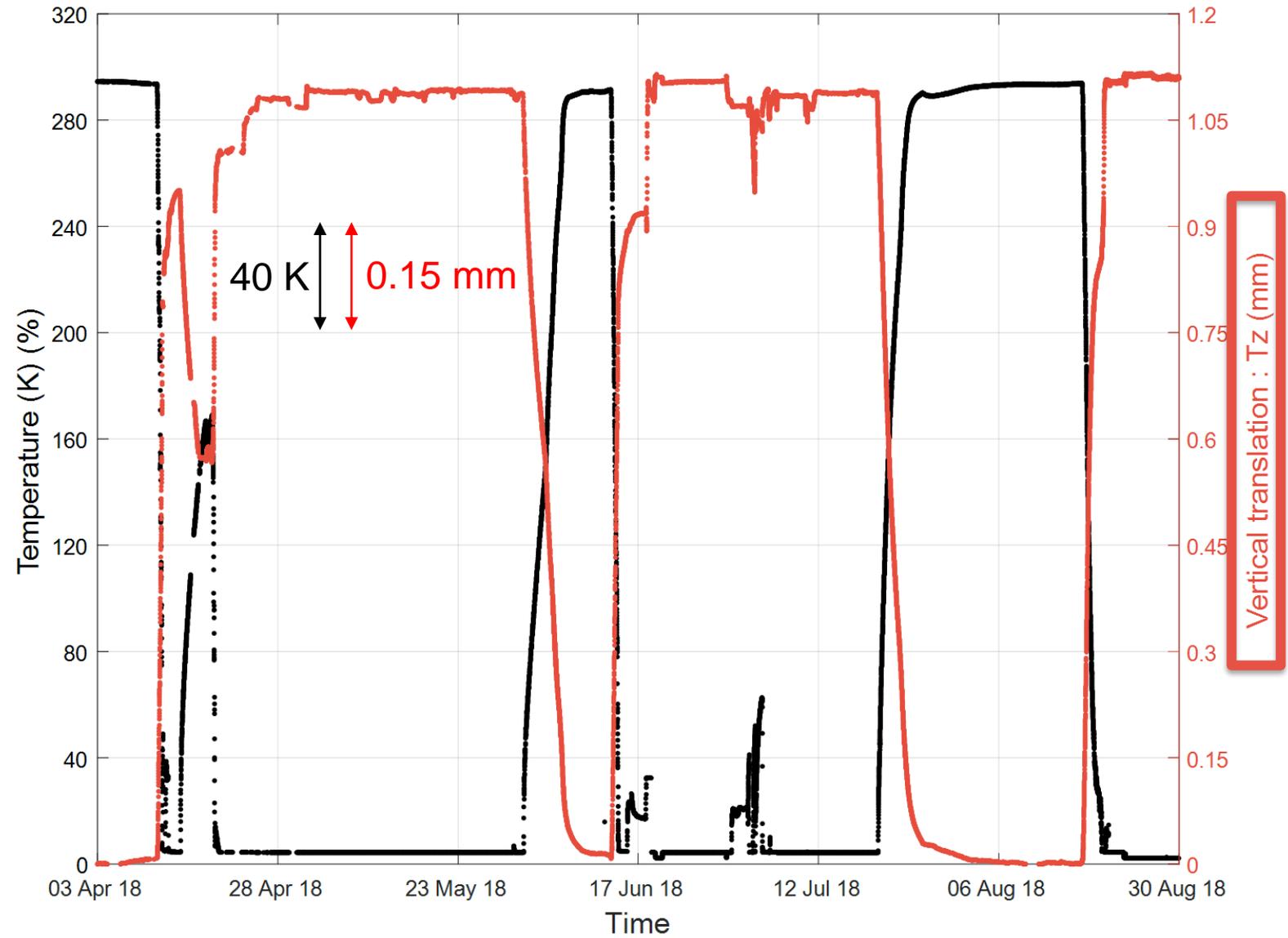
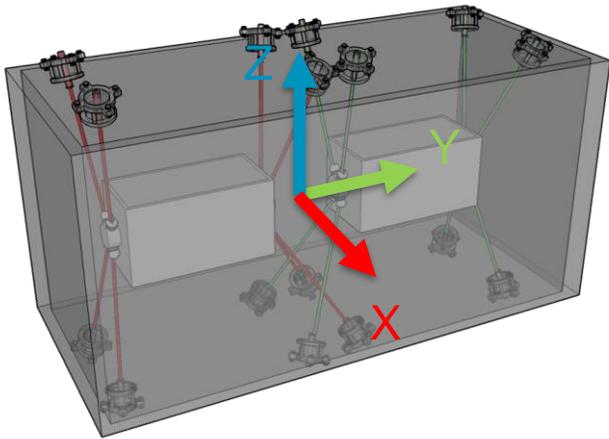
— determined with FSI measurements : RELATIVE (K)



CONTRACTION	Cav 1		Cav 2	
	IN	OUT	IN	OUT
SM18	1.321	0.843	1.295	0.832
SPS	1.310	0.834	1.320	0.835
Simulation	1.097	0.678	1.097	0.678

Long term measurement

Vertical translation of TANK 1



Conclusion

- Successful cross comparison at warm and cold condition
- Accuracy of absolute position of Crab-cavities inside cryomodule : +/- 50 μm
- Relative precision : Few microns
- Repeatability of several heat-up and cool down sequences : Below 10 μm

Thank you
for your
attention

