



# Alignment for Crab-cavities as a part of HL-LHC Full Remote Alignment System

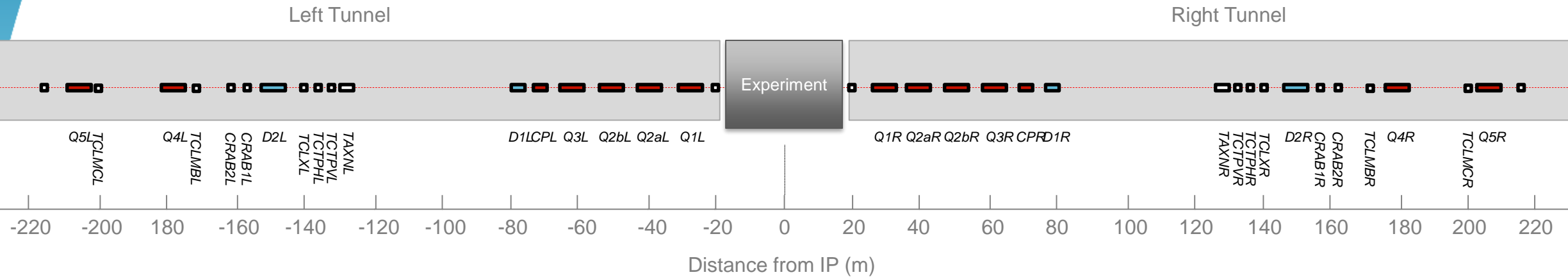
Vivien RUDE  
Mateusz SOSIN  
2022-09-21

On behalf :

Andreas HERTY  
Hélène MAINAUD DURAND

# Outline

- Alignment requirement for HL-LHC project
  - TDR objectives
  - FRAS : Full Remote Alignment System
  - External monitoring
  - Internal monitoring
- DQW prototype (installed in SPS since 2018)
  - Configuration
  - Precision and Results
- From DQW Prototype to series : main modifications
  - Main modifications
  - Integration
- RFD Prototype : Status



## ■ CERN-ACC-2015 and TDR

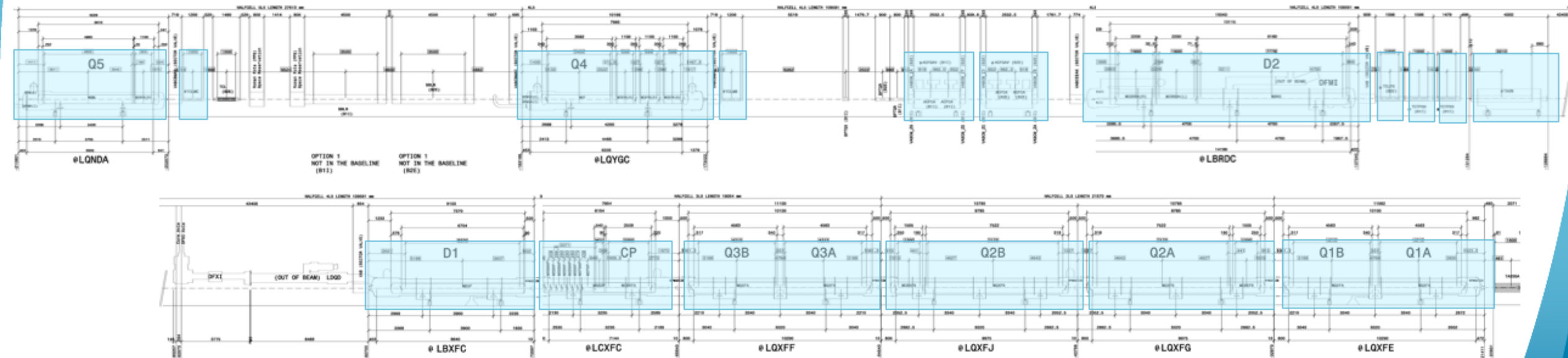
- Position of the components along one side of the tunnel : +/- 0.1 mm \*
- Position of the components along one side of the tunnel w.r.t the other side : +/- 0.15 mm \*

\* On main component



# Full Remote Alignment System

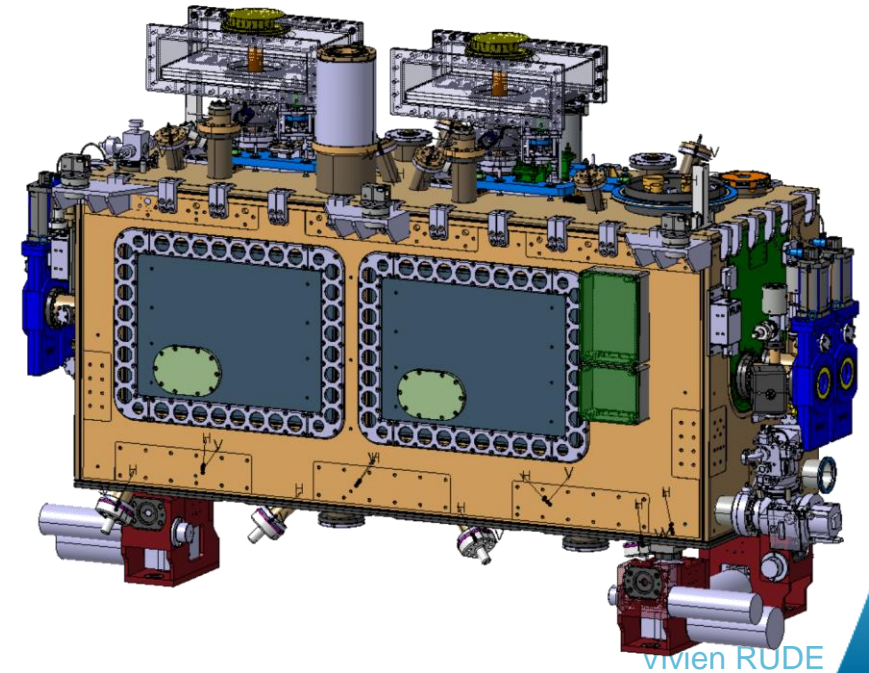
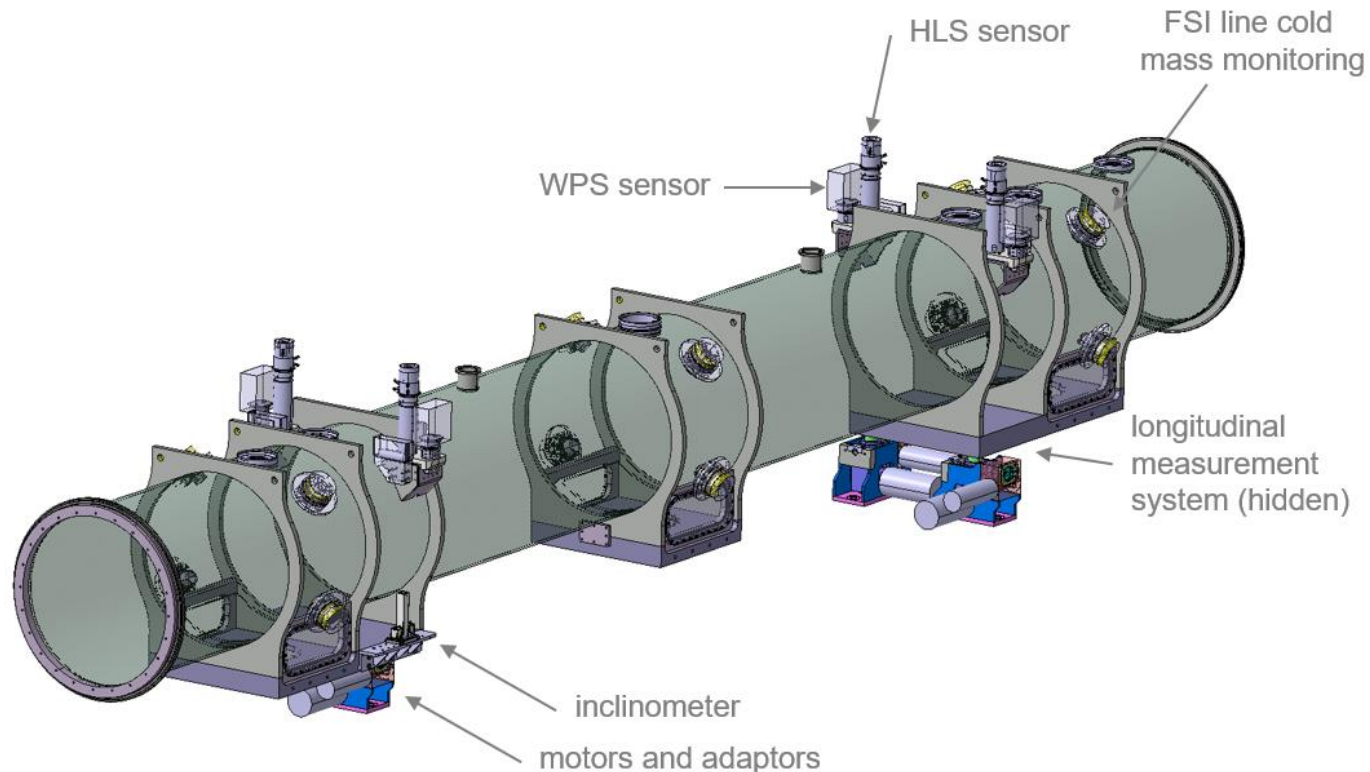
- Continuous monitoring and remote alignment system
- in P1 and P5, LEFT and RIGHT, from Q1 to Q5
- **16 components per IP side**
- Alignment (at 1 sigma): Q1-Q5  $\pm 0.100$  mm, Q5L-Q5R:  $\pm 0.150$  mm
- Minimize the radiation exposure to survey personnel
- Minimize the need for orbit corrector strength
- Aperture optimization



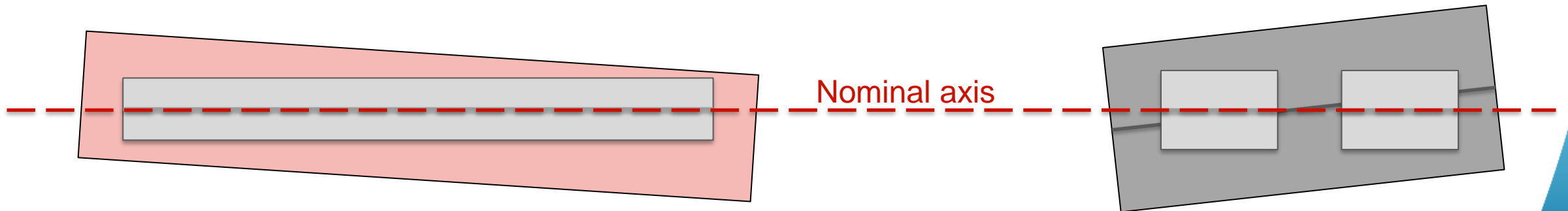
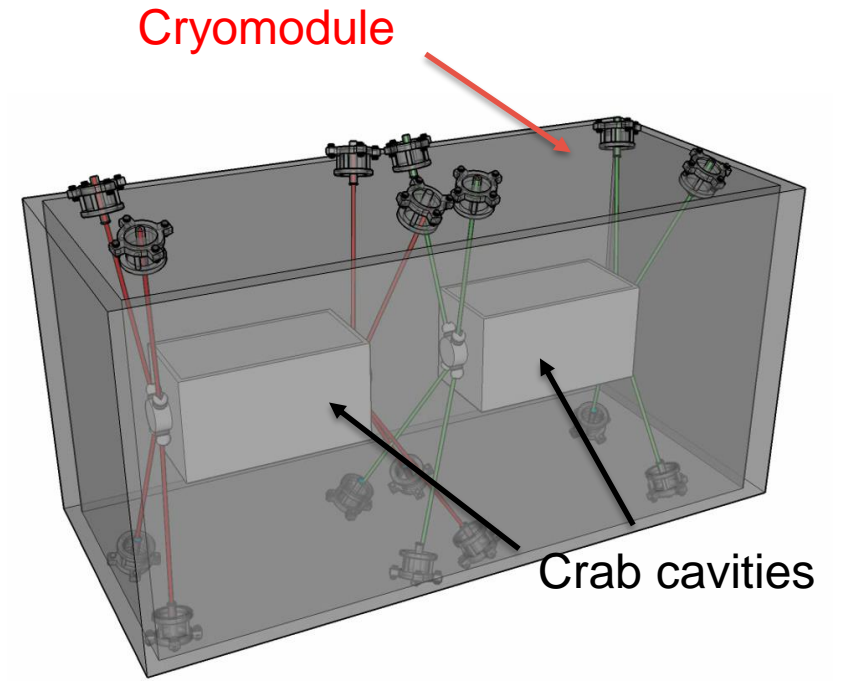
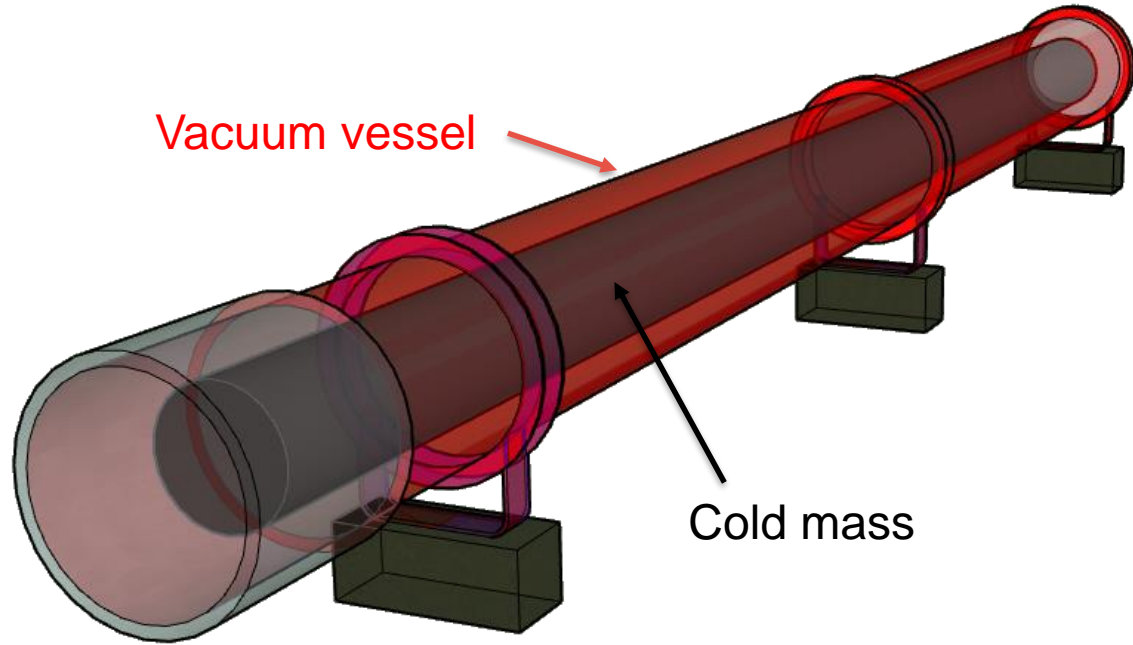
# External monitoring

Remote alignment thanks to alignment sensors and actuators:

- FRAS LSS components equipped with reference sensors
  - WPS – Wire Position Sensor (Radial, Vertical position w.r.t. Wire) – capacitive sensors technology based
  - HLS – Hydrostatic Reference Sensor (Vertical Leveling, roll – magnets) - Frequency Scanning Interferometry (FSI) based
  - Inclinometers – (Roll – IT, TAXN, collimators, TCLMB) – capacitive / FSI based
  - Longitudinal and UPS gallery long range monitoring - FSI
- Each component equipped in motorized adapters – for the remote adjustment of its position



# Internal monitoring for “special” components



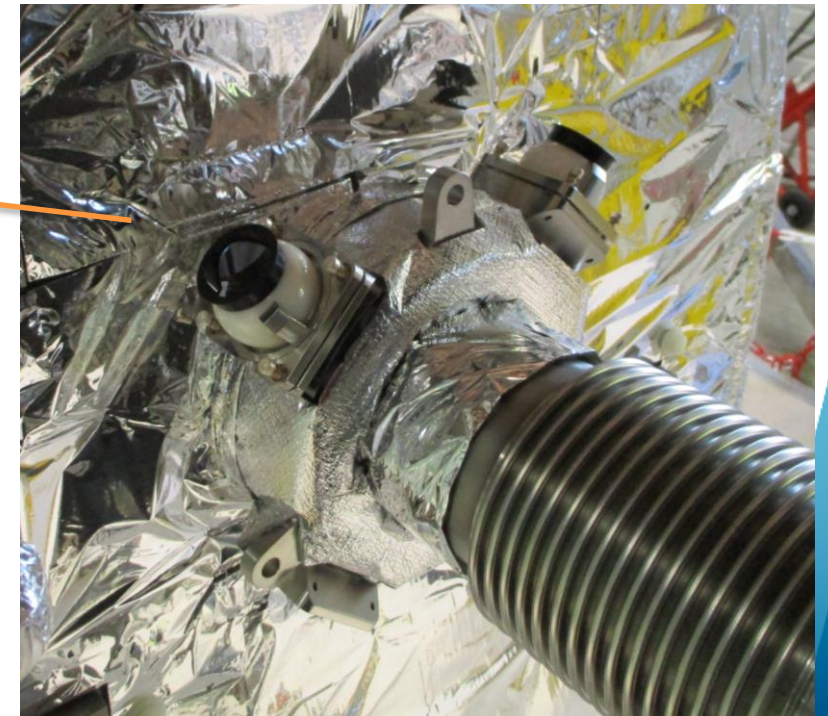
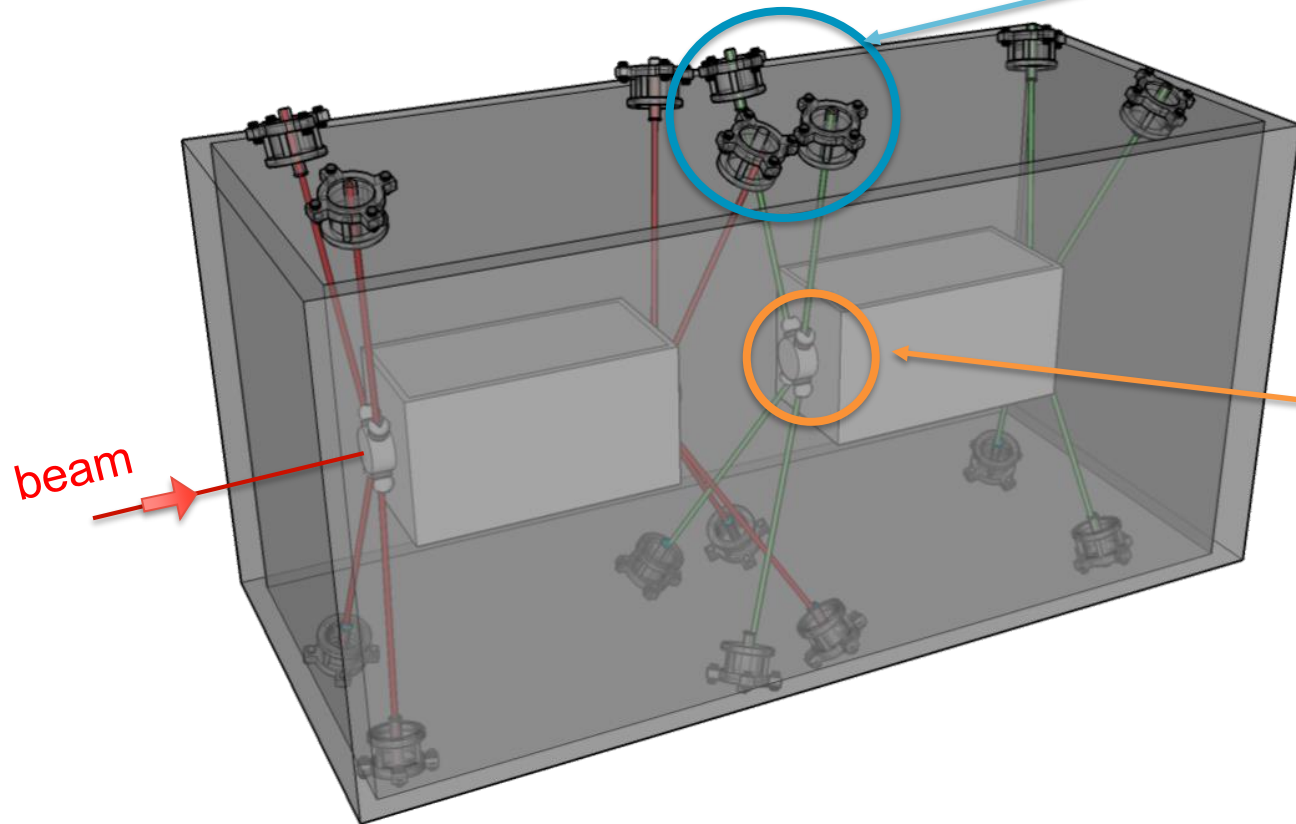
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# Internal monitoring : Configuration

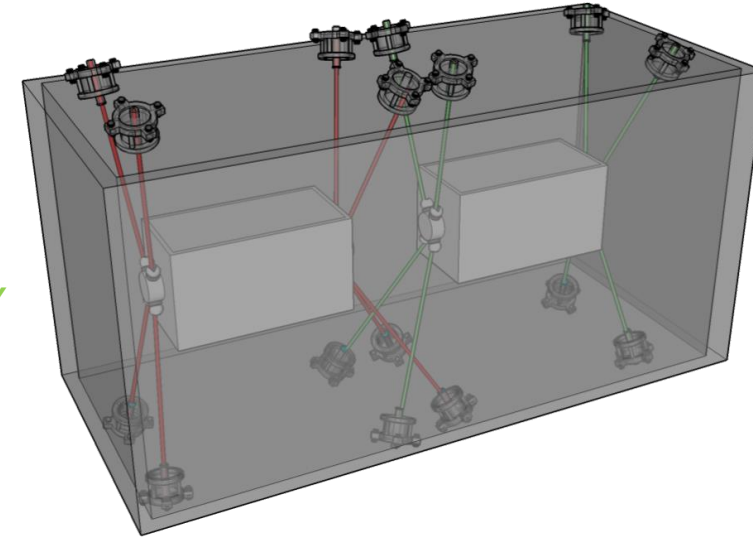
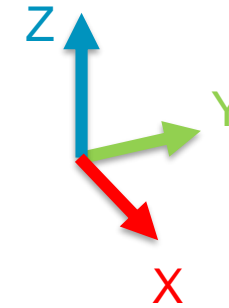
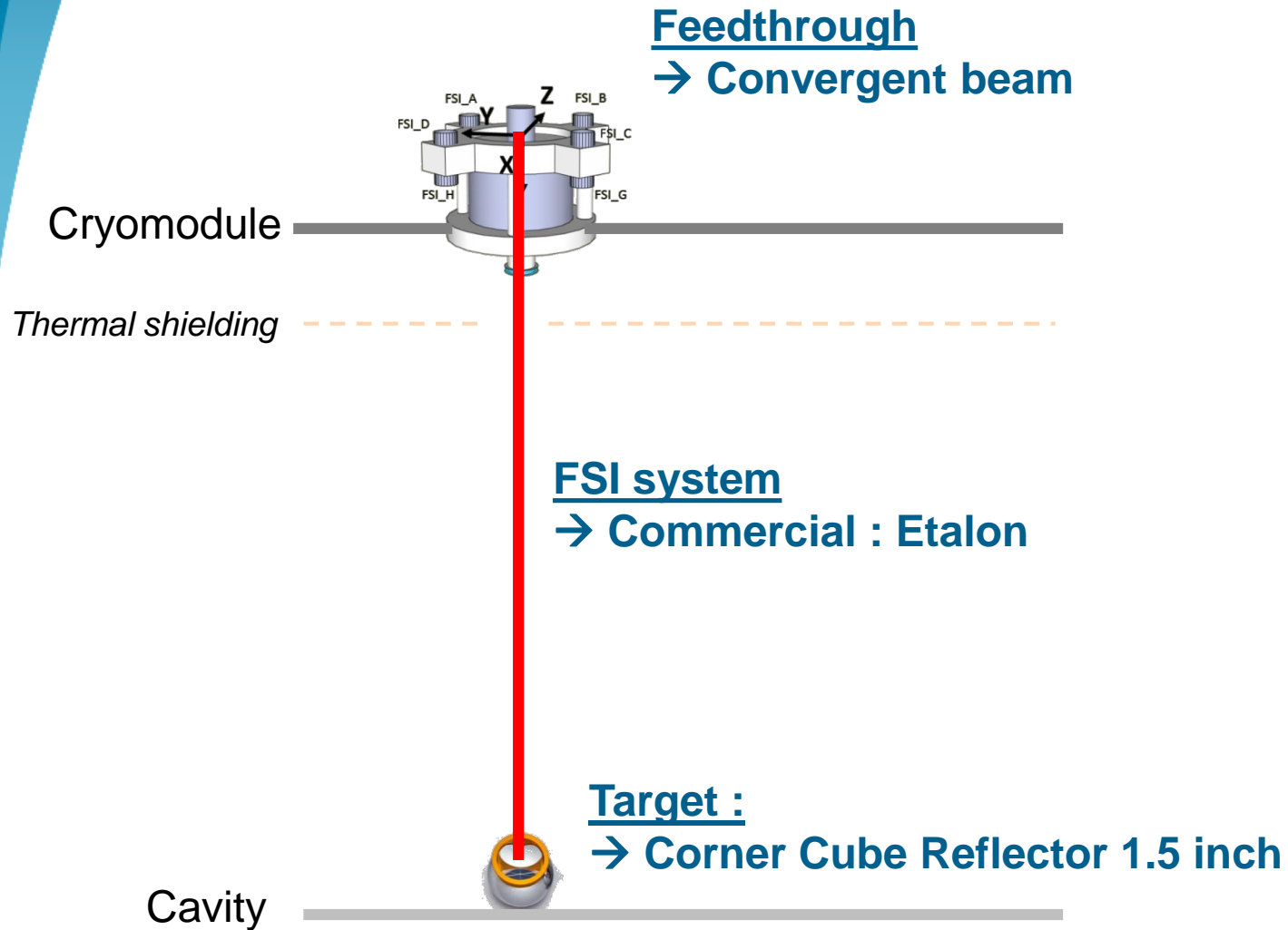
- **FSI : Frequency Scanning interferometry**

→ Absolute distance measuring interferometric technique





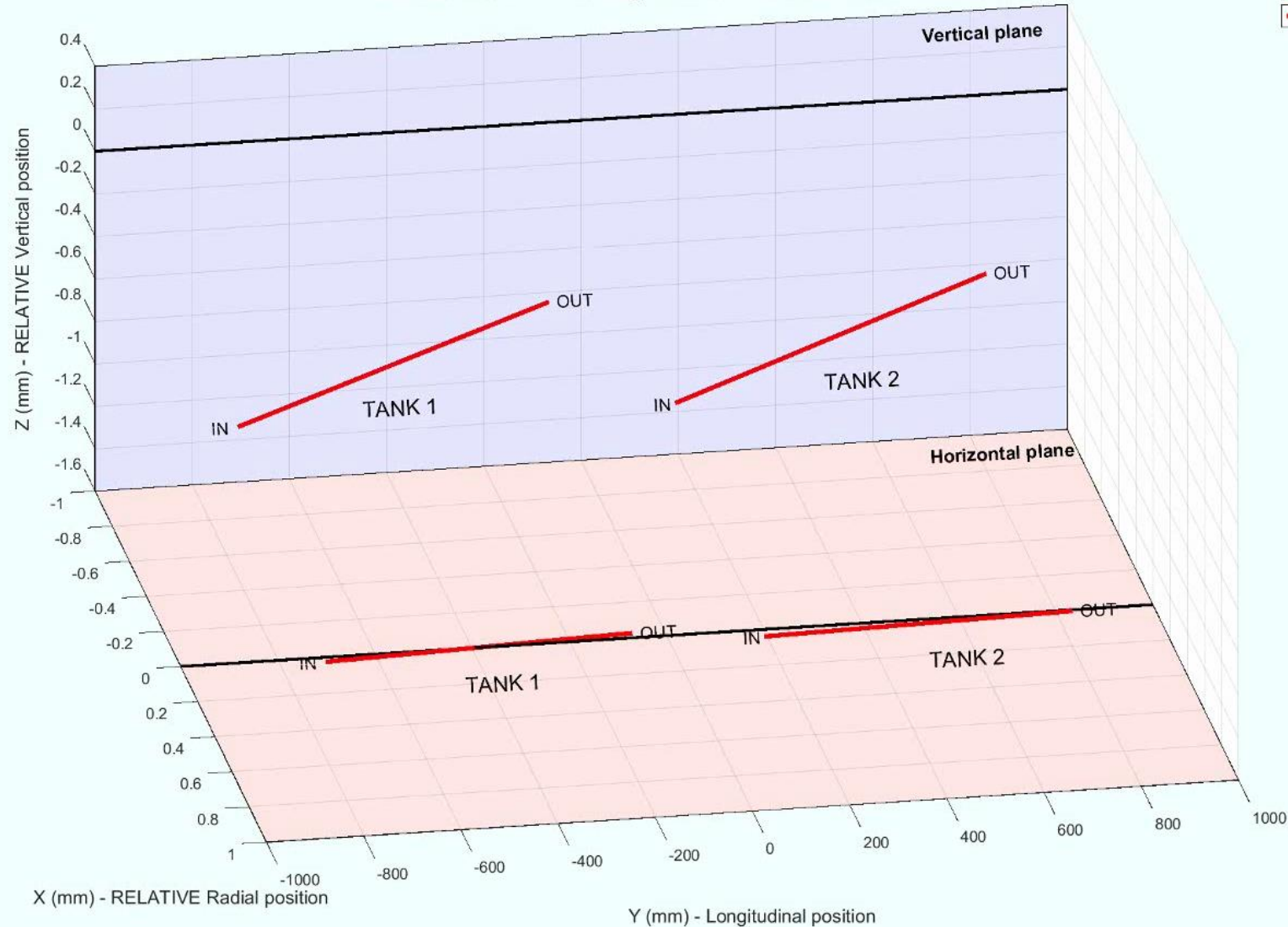
# Configuration (2018) : Uncertainty



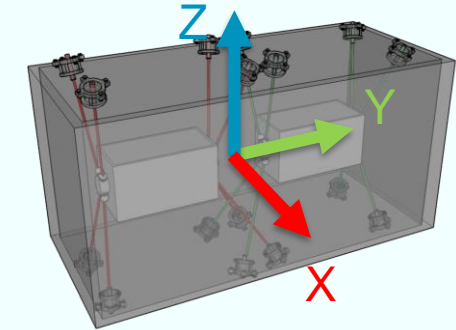
Parameter	Uncertainty ( $1\sigma$ )
Tx (radial)	+/- 25 $\mu\text{m}$
Ty (longitudinal)	+/- 45 $\mu\text{m}$
Tz (vertical)	+/- 10 $\mu\text{m}$
Rx (pitch)	+/- 30 $\mu\text{rad}$
Ry (roll)	+/- 150 $\mu\text{rad}$
Rz (yaw)	+/- 70 $\mu\text{rad}$
Scale	+/- 60 ppm

# Configuration (2021) : Cooling down

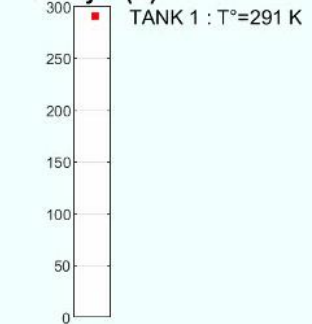
Cavities axis : Cooling down : 10-Oct-2020 00:00



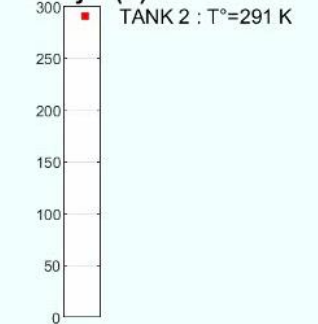
— determined with FSI measurements : RELATIVE (.K)



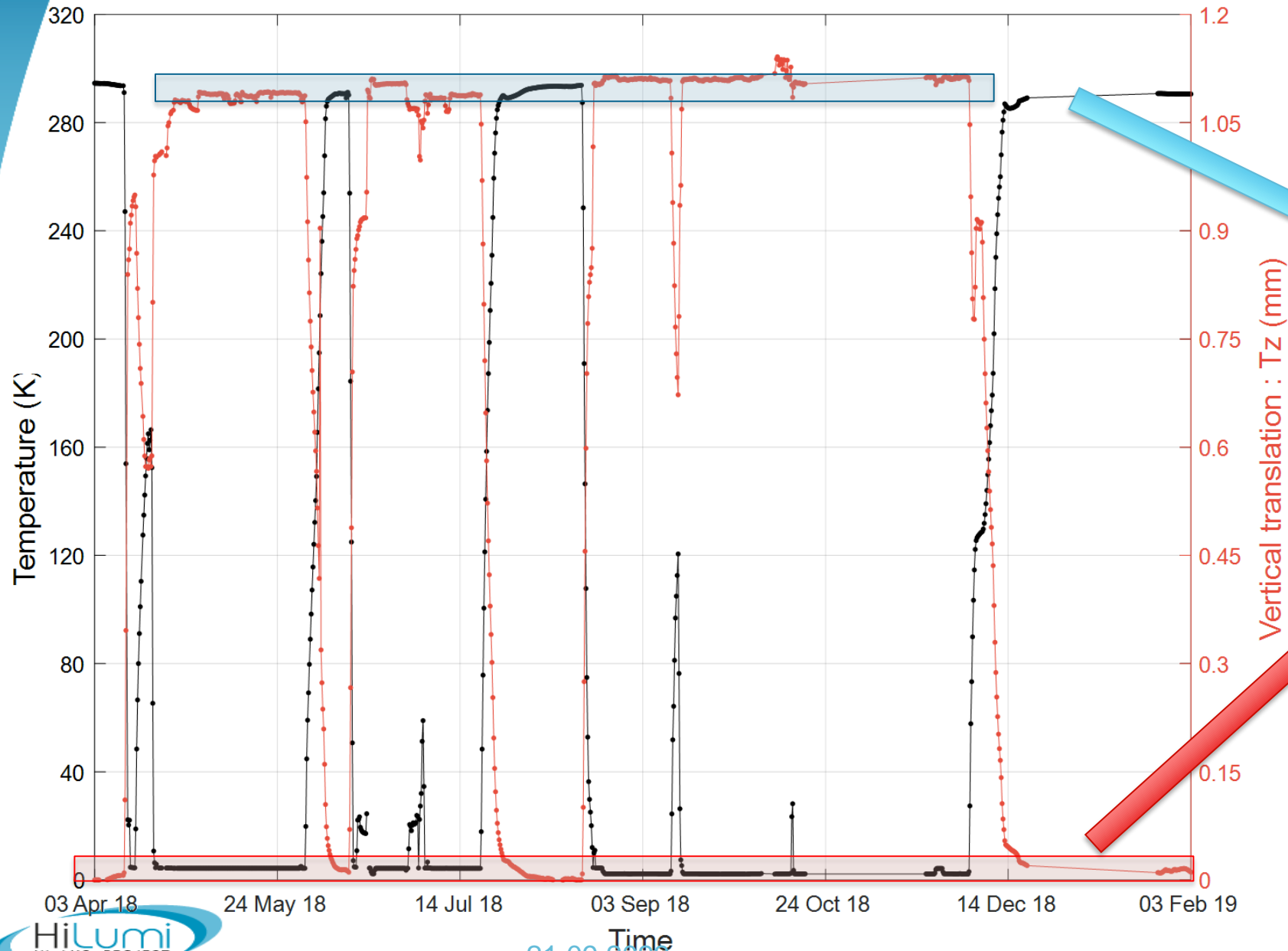
Cavity 1 (K)



Cavity 2 (K)



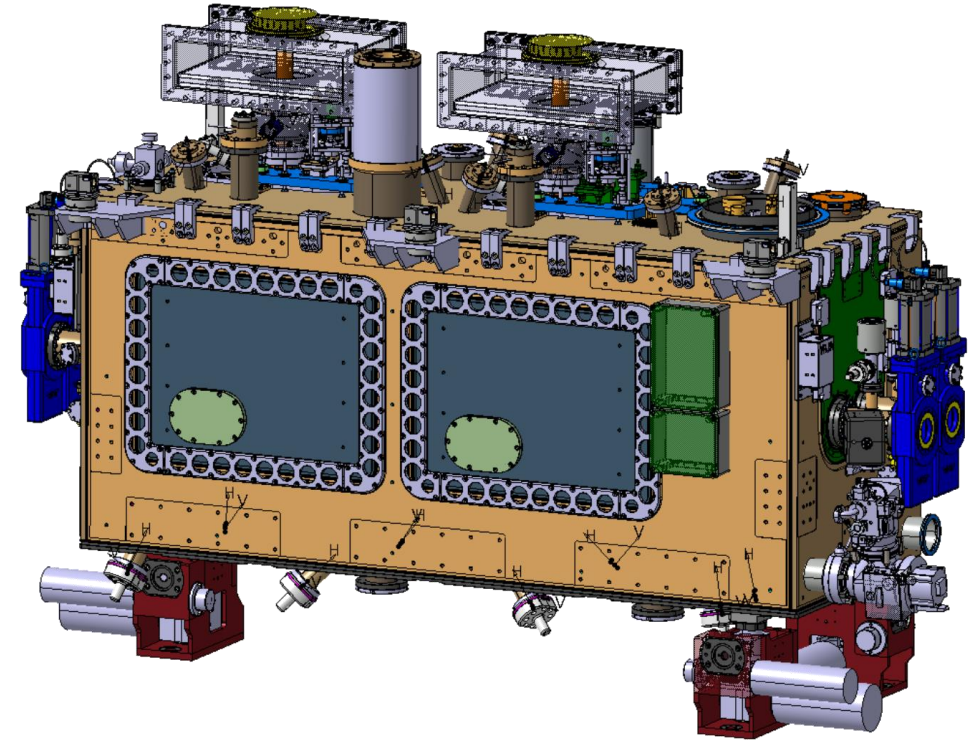
# Configuration (2018) : Repeatability



**Repeatability of several heat-up and cool down sequences :**  
→ Below 20  $\mu\text{m}$

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# Main modification w.r.t. SPS prototype (2018) : FSI system

SPS  
Prototype



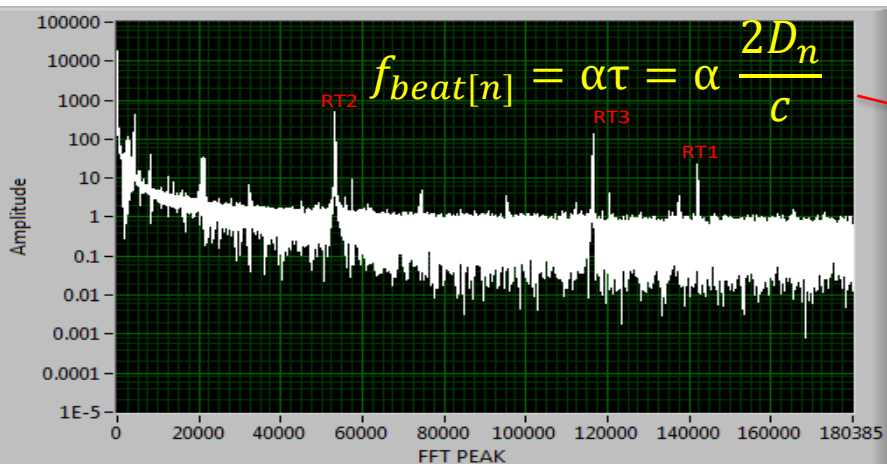
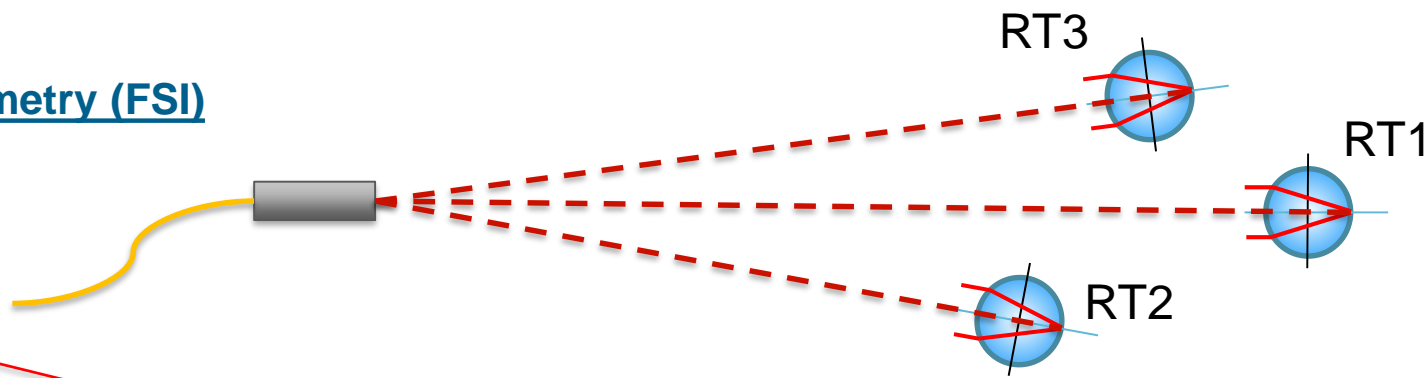
HL-LHC

Commercial  
ETALON



CERN development  
MT-FSI

## Multi-target Frequency Scanning Interferometry (FSI)

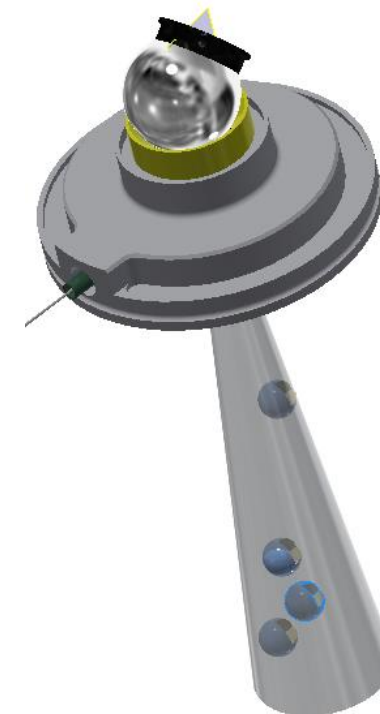
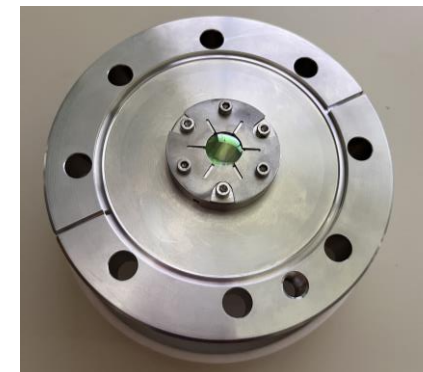
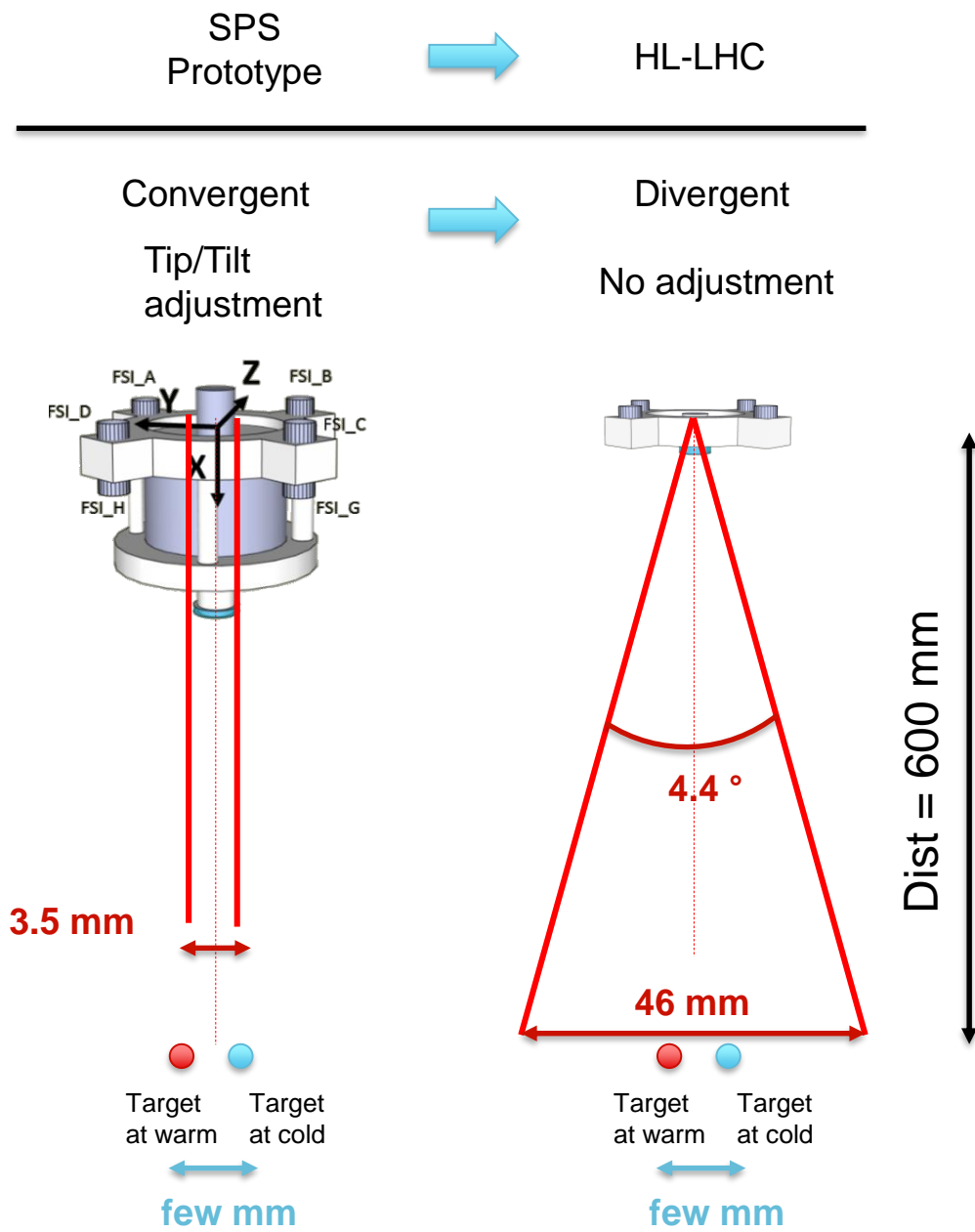


$$D_n = c \frac{f_{beat[m]}}{2 \frac{dv}{dt} n}$$

- $\alpha$  – is a sweep rate of the laser ( $\alpha = \frac{dv}{dt}$  - laser frequency change in time);
- $c$  – speed of light;
- $n$  – refractive index of light transmission medium;
- $\tau$  – time of flight of laser to the target

from Mateusz Sosin

# Main modification w.r.t. SPS prototype (2018) : Feedthrough



# Main modification w.r.t. SPS prototype (2018) : Target

SPS  
Prototype



HL-LHC



Corner Cube  
Reflector

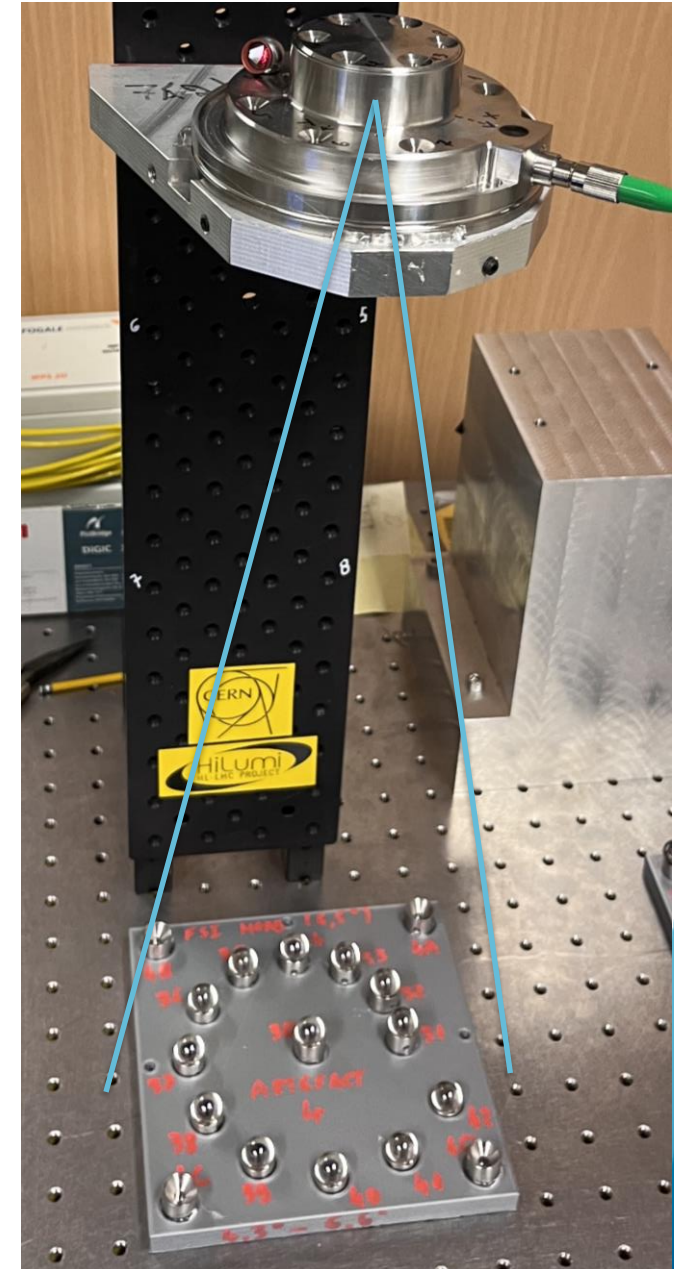
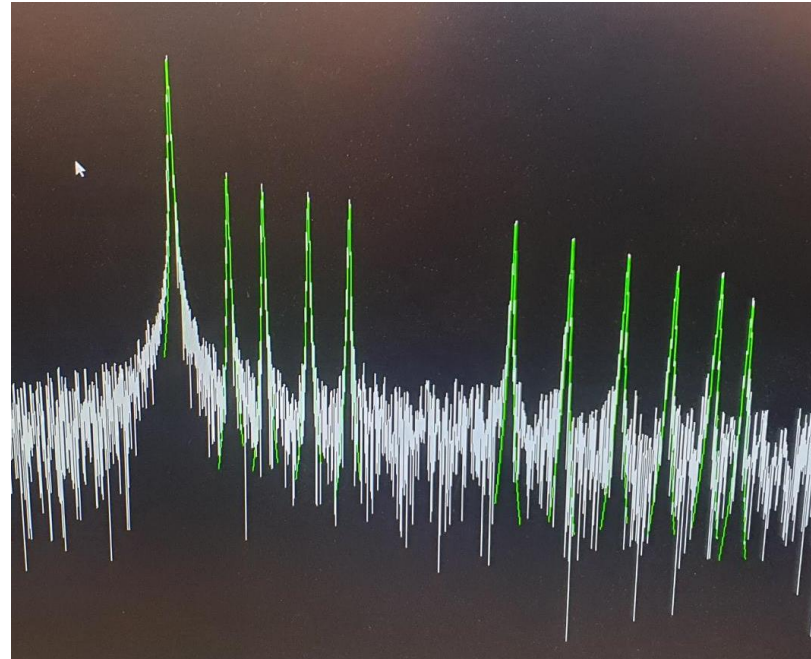
1.5 inch = 38.1 mm



Glass Sphere

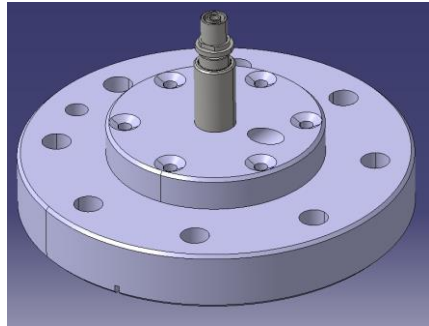


0.5 inch = 12.7 mm

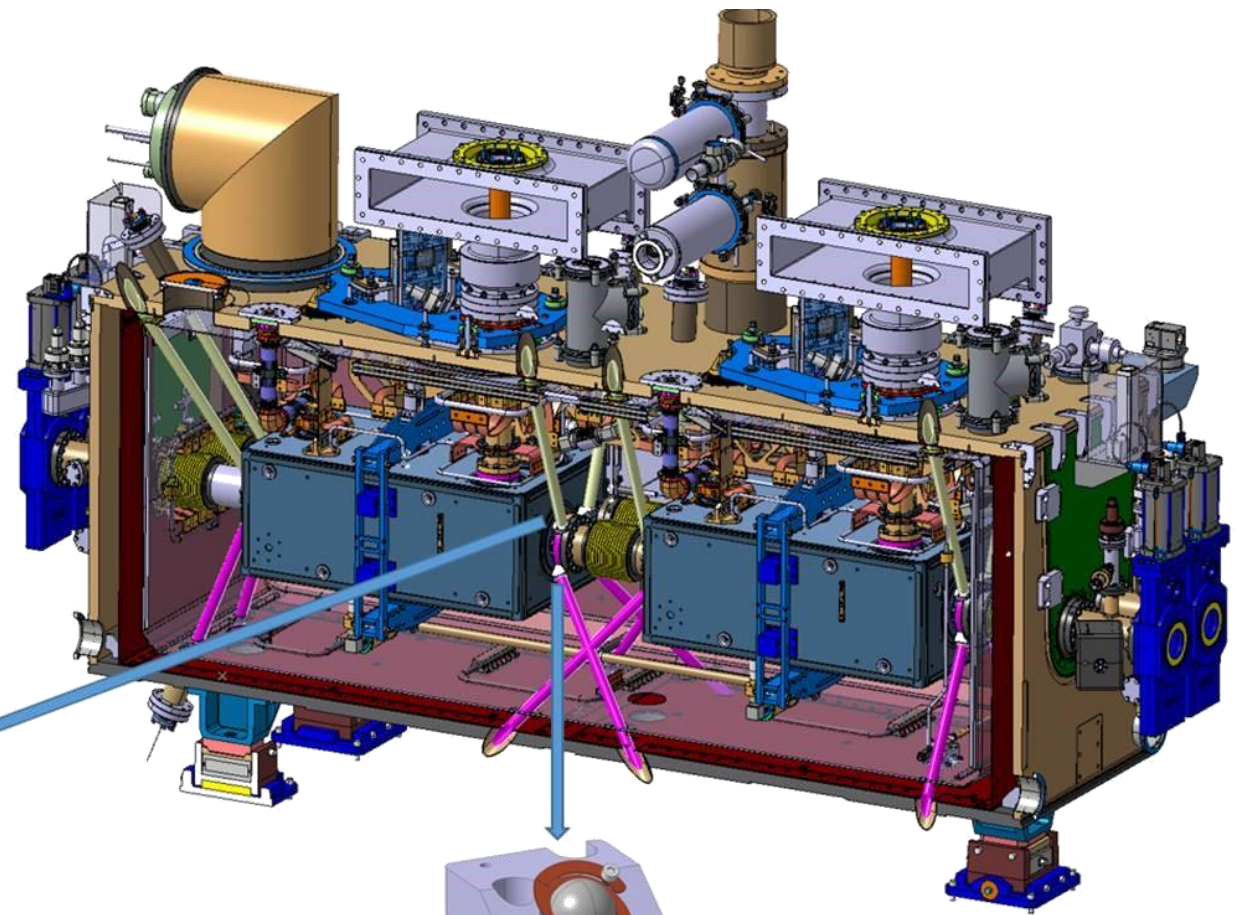
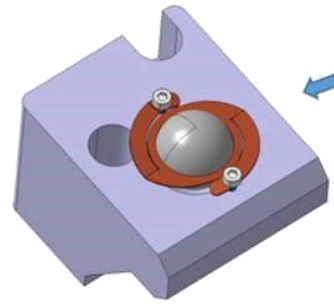


# Integration / design status (Internal monitoring)

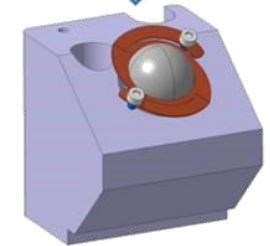
FSI targets assembly  
ST1408969\_01



ST1407441\_01



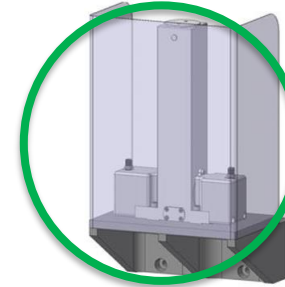
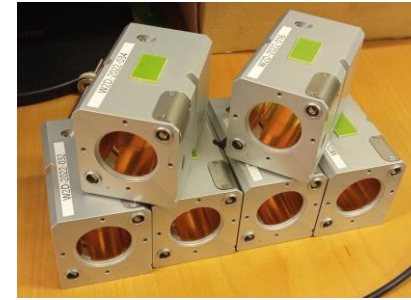
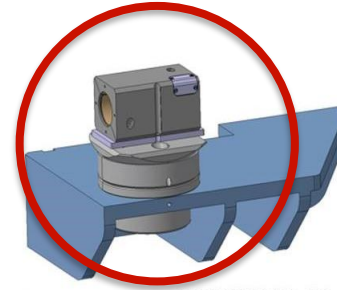
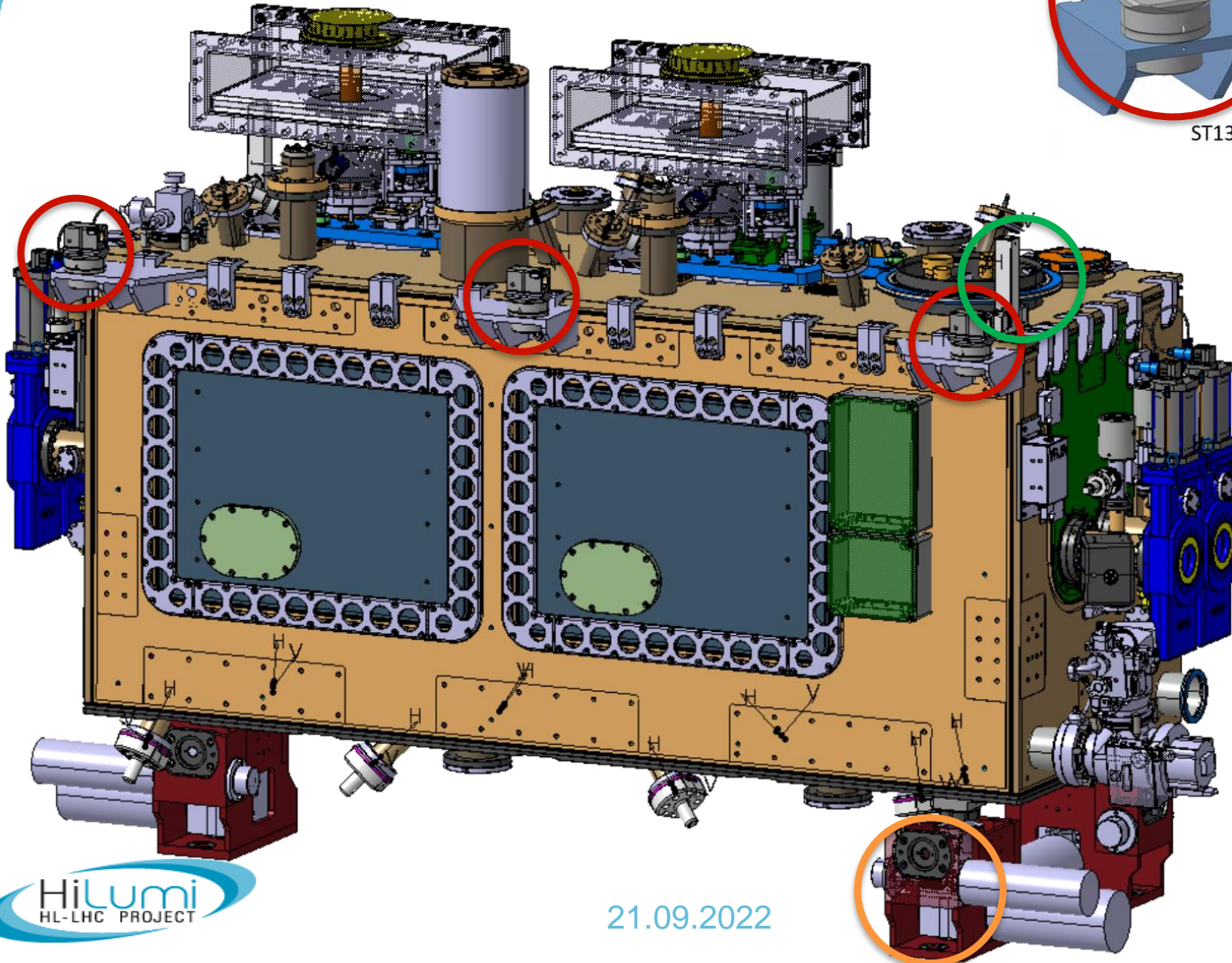
ST1408926\_01



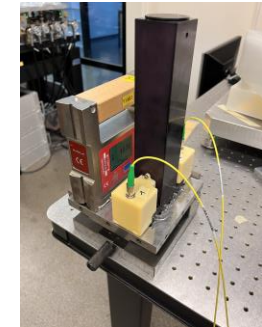


# Integration / design status (External monitoring and motorization)

3 WPS (Wire Positioning Sensors)  
2 Inclinometers



ST1385376\_01

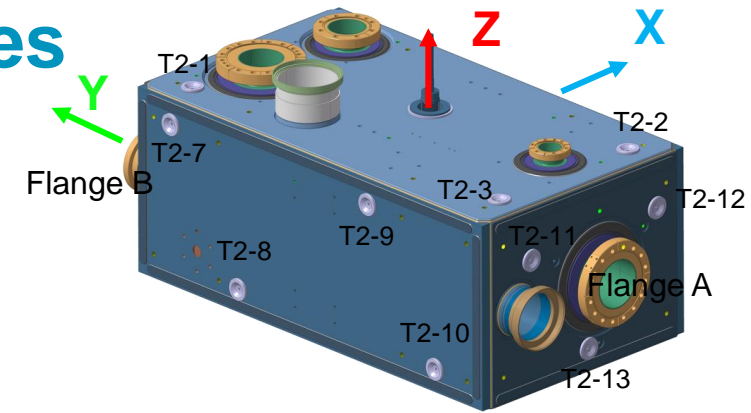


# Outline

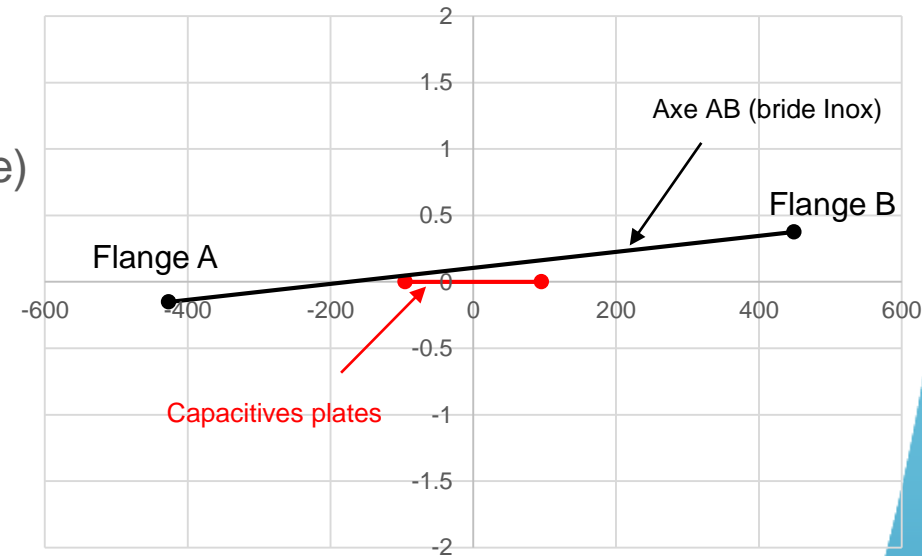
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# RFD prototype (2022-2023) : Survey milestones

- Bare cavity + tank (at CERN)
  - Determination of the position of the Capacitive plate of the cavities  
→ DONE (EDMS : 2693987, 2693991)
- Assembly (at UK) → on going
  - String line assembly in clean room → Done
  - Installation of the other components on the string line
  - Final alignment of the string line
  - Installation of the top plate (supporting plate of the string line)
  - Insertion of string line in the cryomodule
- Installation of FSI system
  - Vacuum test
  - Cold test
- Test in M7 bunker (at CERN)
  - Validation at cold



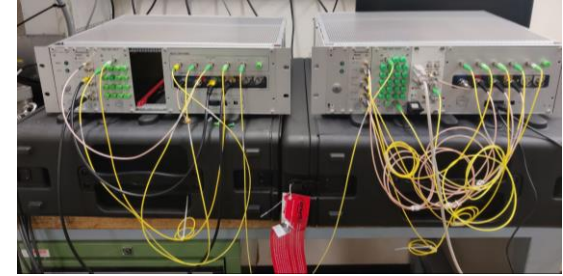
Cavity #2 : Radial X (mm)



# Summary

## ■ FSI Systems

- Chassis : 16/24 channels
  - 3 operational units (16/24 channels)
  - 3 units assembled (waiting lasers delivery) : SPS RFD, TRIUMPF and STFC
- Racks : 1000 channels
  - Intensive development works and tests (4\*256 channels) : collaboration of BE-CEM and BE-GM groups are ongoing



## ■ FSI Heads

- RFD prototype (for UK) : 20 Heads ready to send
- First Q1 (for US) : 14 Heads at Fermilab for the first Q1 → installation soon
- First Q2 (for CERN) : on going

## ■ FSI Targets

- RFD prototype (for UK) : 20 targets at STFC
- First Q1 (for US) : 12 targets already installed on first Q1 at Fermilab
- First Q2 (for CERN) : Ready

## ■ WPS / HLS / Inclinator

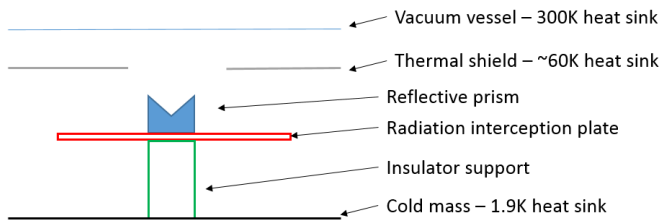
- String test : on going



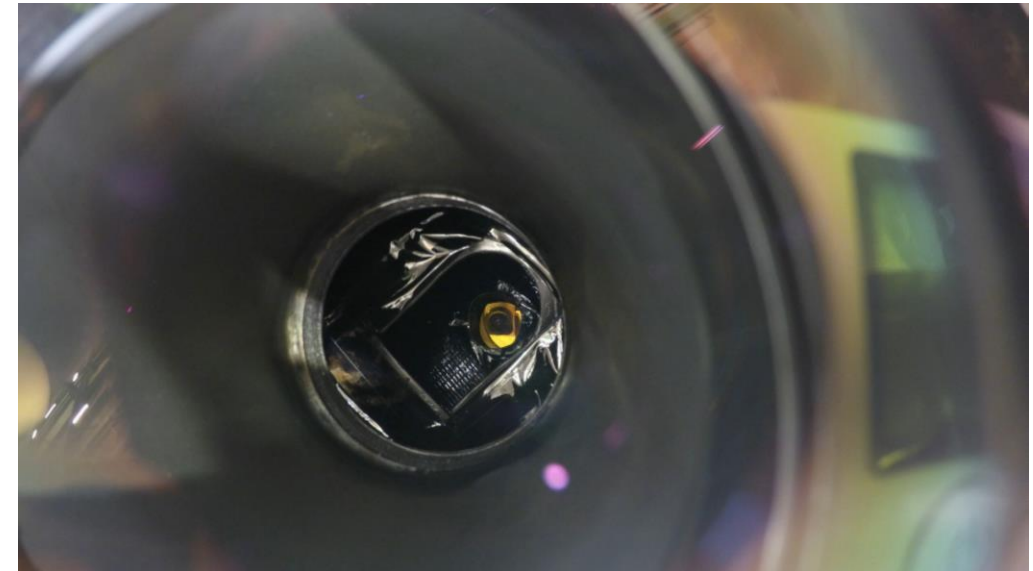
**Thank you**  
**for your attention**

# Internal monitoring – intensive tests & development to adopt FSI instrumentation for harsh accelerator environment

- Temperature → cryocondensation issues → theromo-opto-mechanical IT targets development



F. Micolon



- Radiation → validation of optical components

Figure 28: B10, 10 MGy

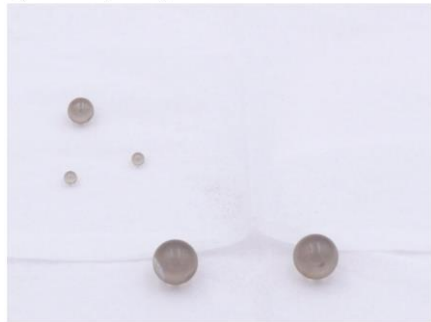


Figure 10: M5, 5 MGy



100kGy



10MGy

- Vacuum → optimizing of optical heads design (and cost)

