Validation of the crab-cavities internal monitoring strategy

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On behalf of MTI section

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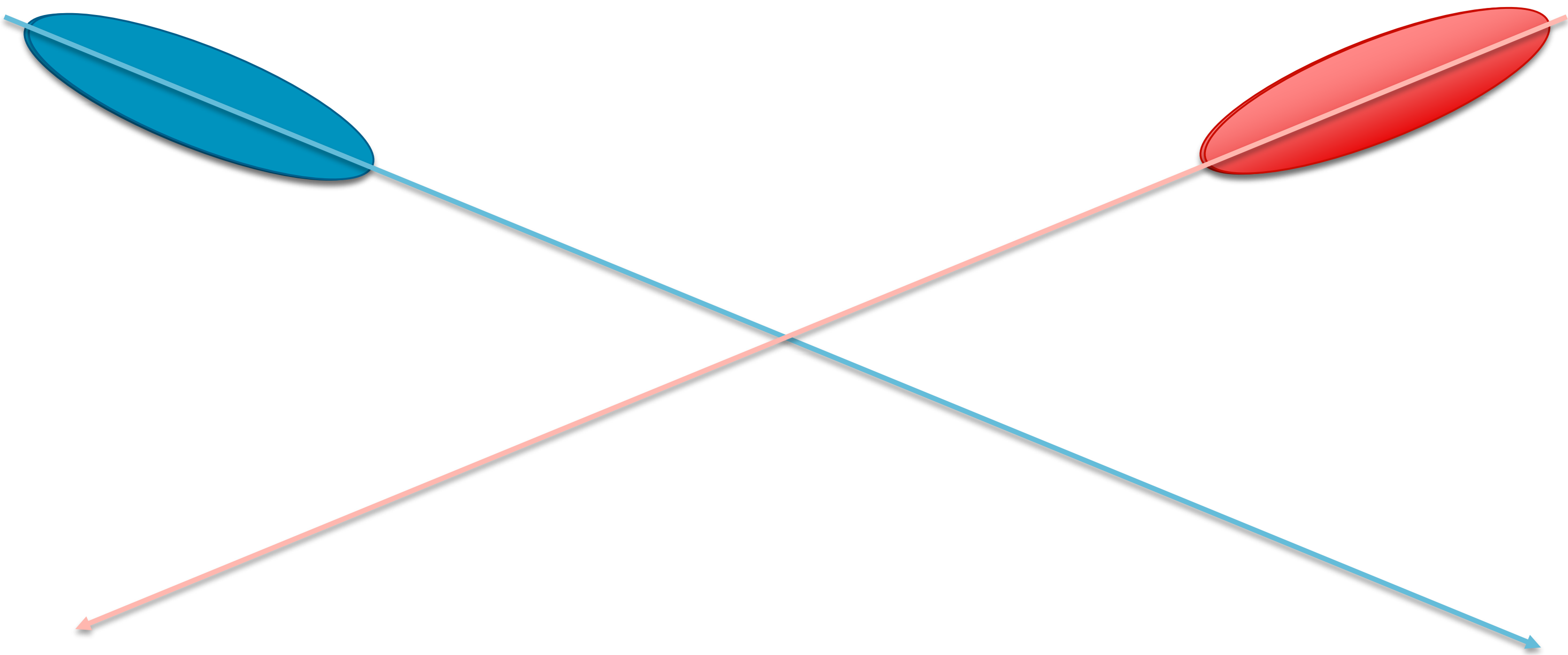
Outline

- HL-LHC project
- HL-LHC crab-cavities and alignment requirements
- Alignment monitoring systems
- Test setup (under standard conditions)
- Test campaign results
- Conclusion

LHC upgrade : HL-LHC

From LHC to HL-LHC, luminosity will be multiplied by a factor 10.

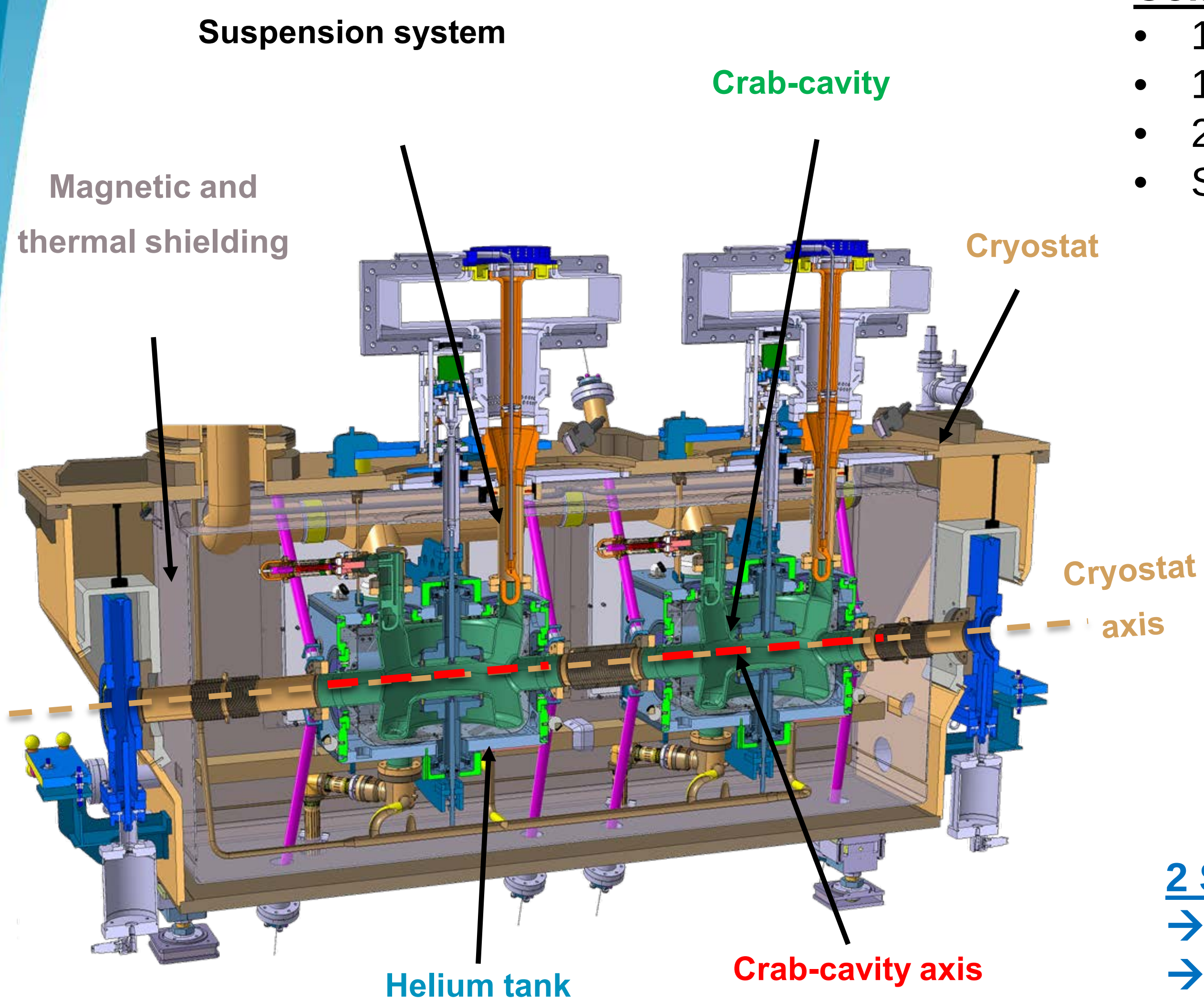
HL-LHC : Crab-cavities



Crab cavities are proposed to provide bunch rotation to give a geometric overlap with the required crossing angle at HL-LHC

LHC -2016 : exploit only 30% of luminosity

HL-LHC : Crab-cavities



Composition :
- 1 cryostat
- 1 magnetic and thermal shielding
- 2 helium tanks with 2 cavities
- Suspension system

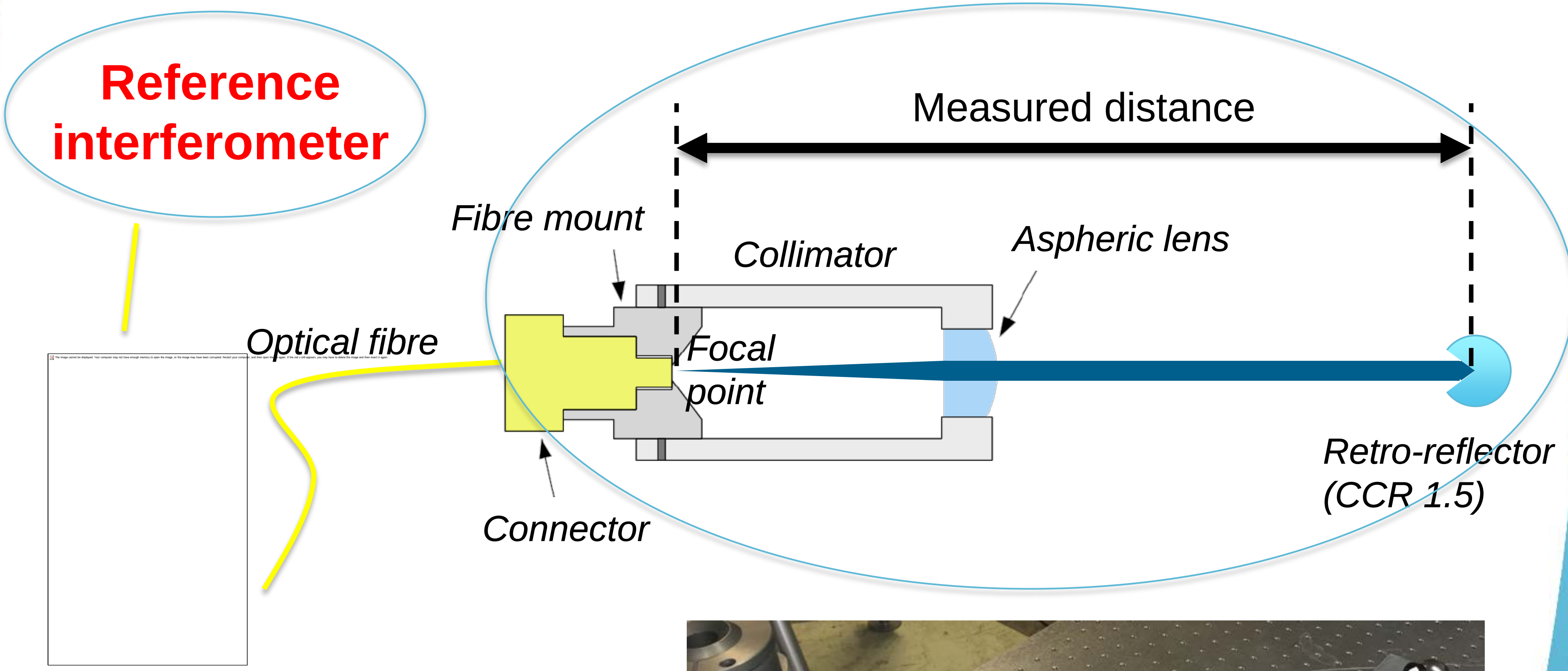
Operating conditions :
- Radiation : 1 MGy / year
- Vacuum : 10^{-6} mbar
- Temperature : 4 K

Cryostat and cavities axes
→ Alignment requirements :
+/-0.25 mm at 3σ

2 Solutions based on:
→Distance measurements
→Angle measurements

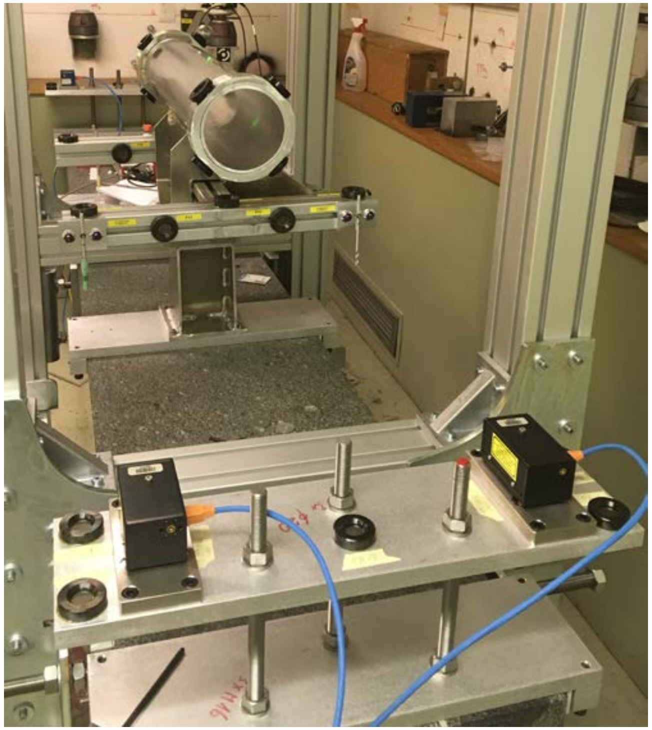
FSI : Frequency Scanning Interferometry (Absolute Distance)

Measurement interferometer

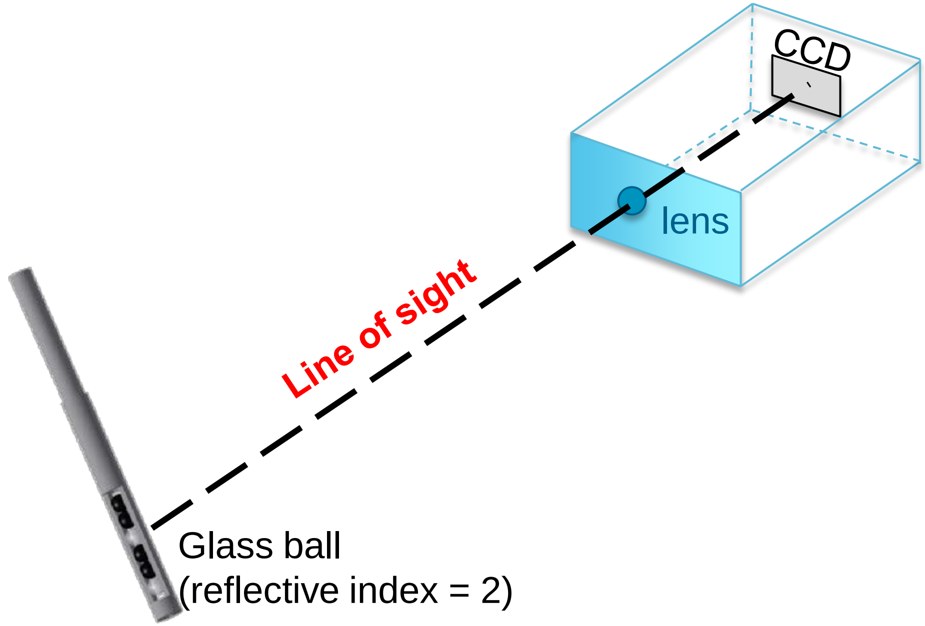


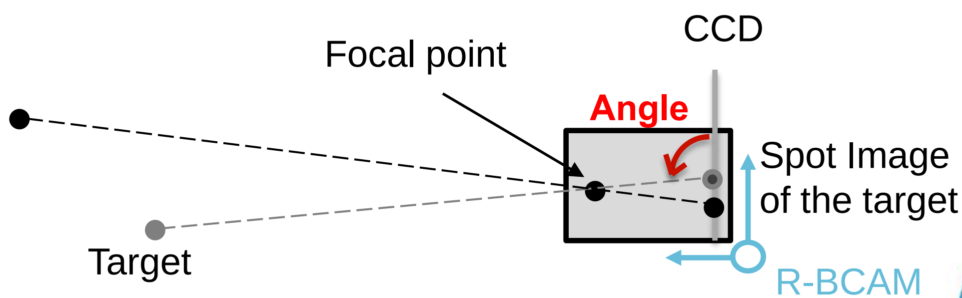
Ratio of measurement interferometer to reference interferometer fringes → Absolute Distance

BCAM : Brandeis Camera Angle Monitor (Angle measurement)

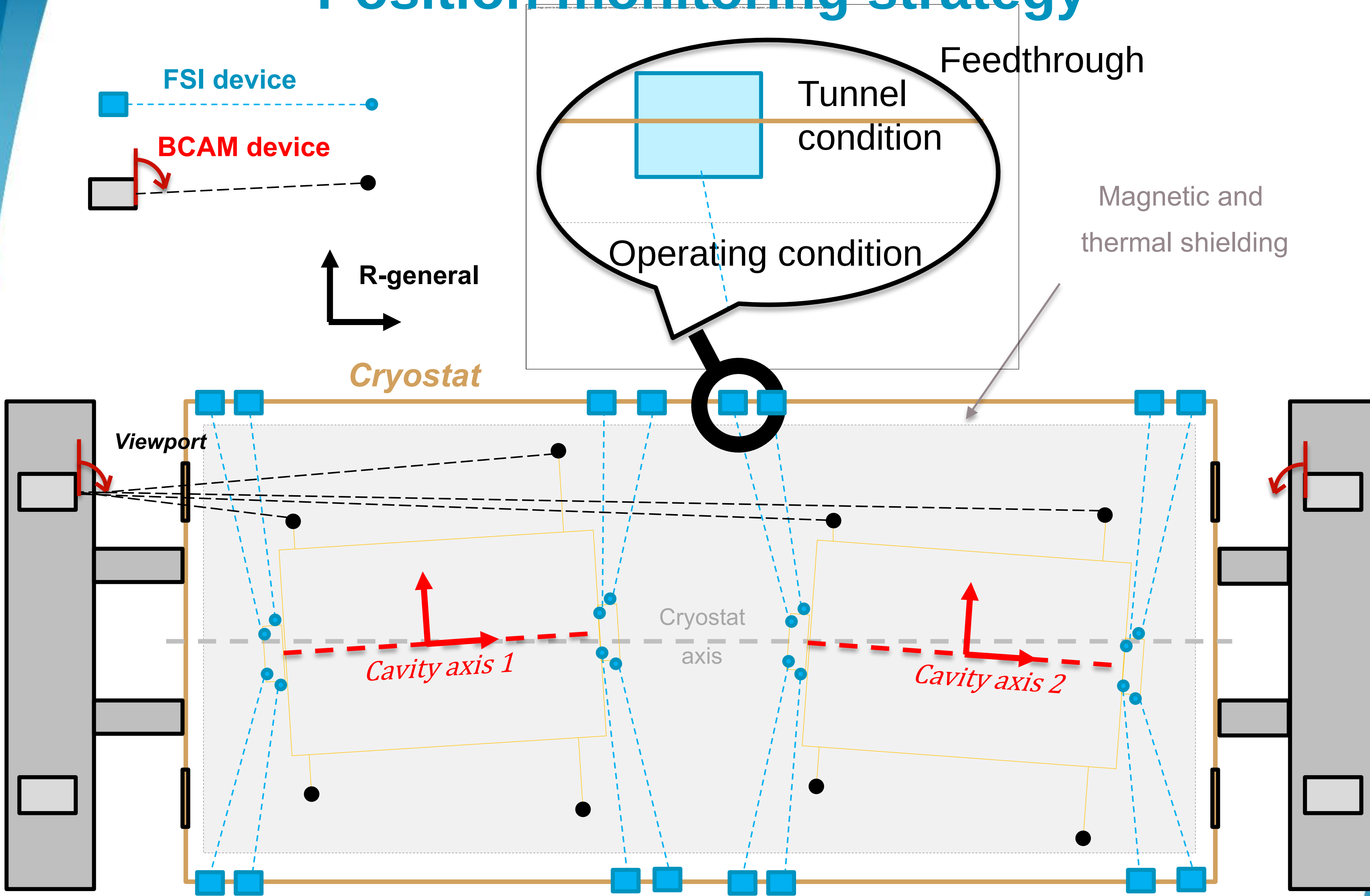


Based on image acquisition of reflective targets



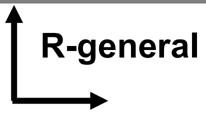


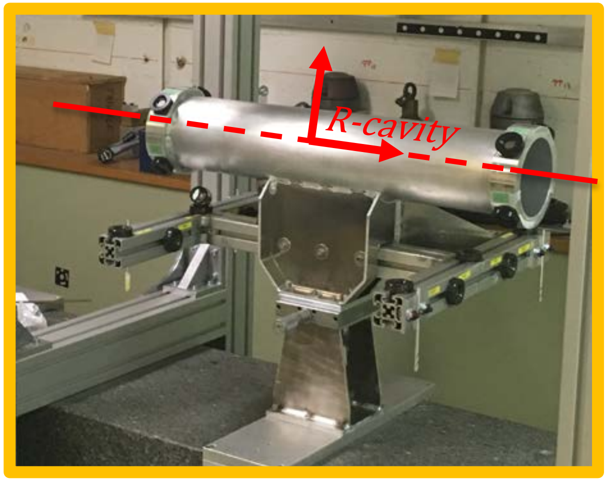
Position monitoring strategy



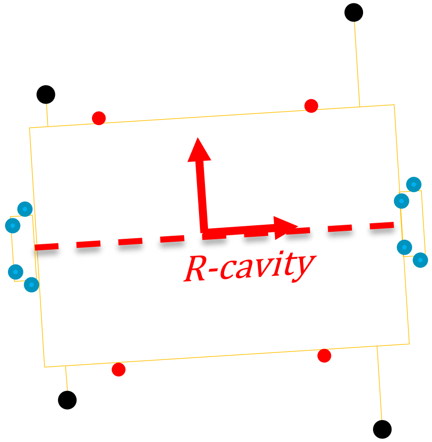
Test campaign

Test setup





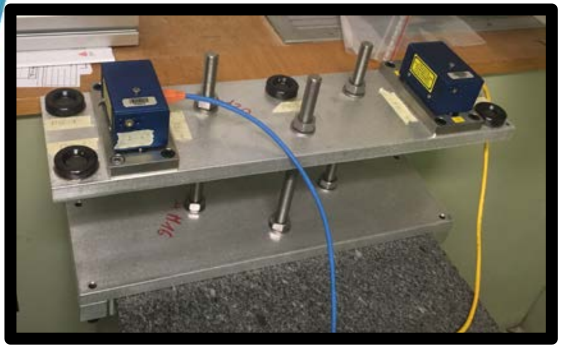
Helium tank mock up (CMM measurement : micrometric uncertainty)

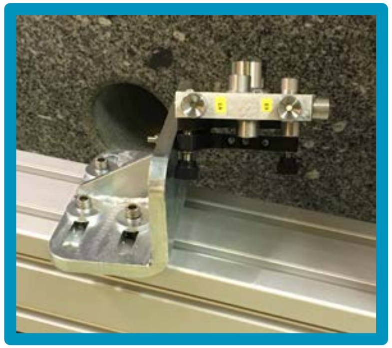


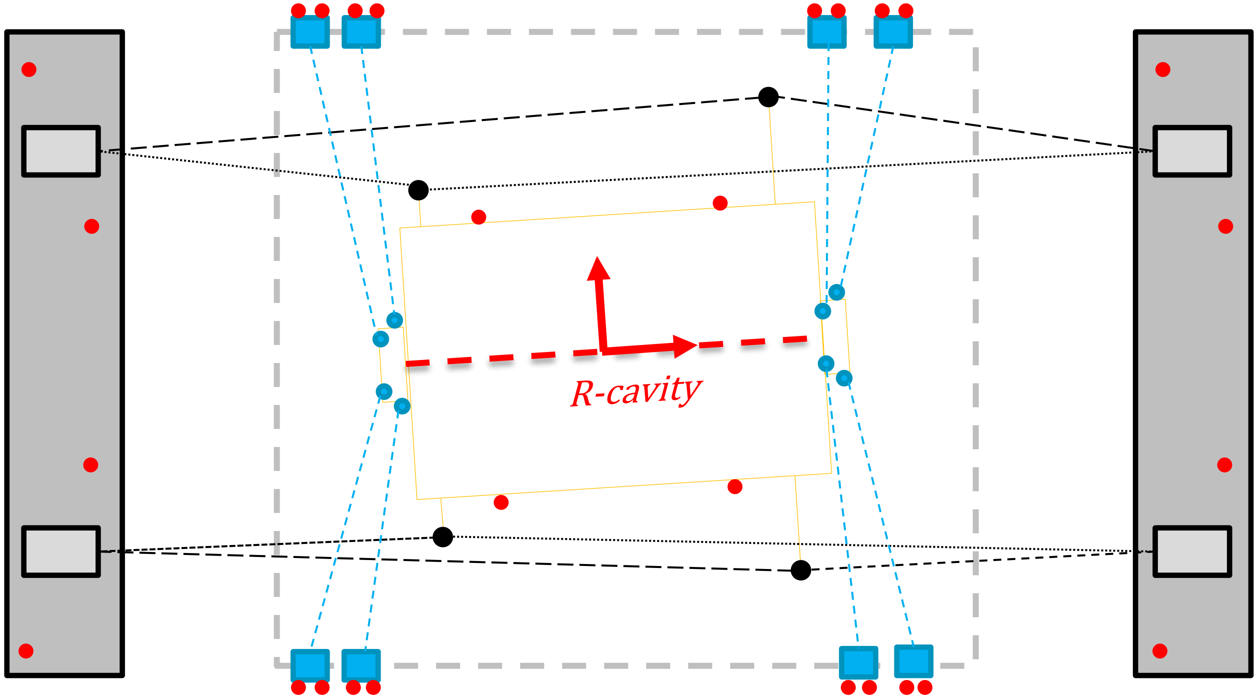
Goal : Compare both alignment monitoring systems (accuracy) under standard conditions:

- Room temperature (~20°C)
- Atmospheric pressure
- No radiation

Test campaign

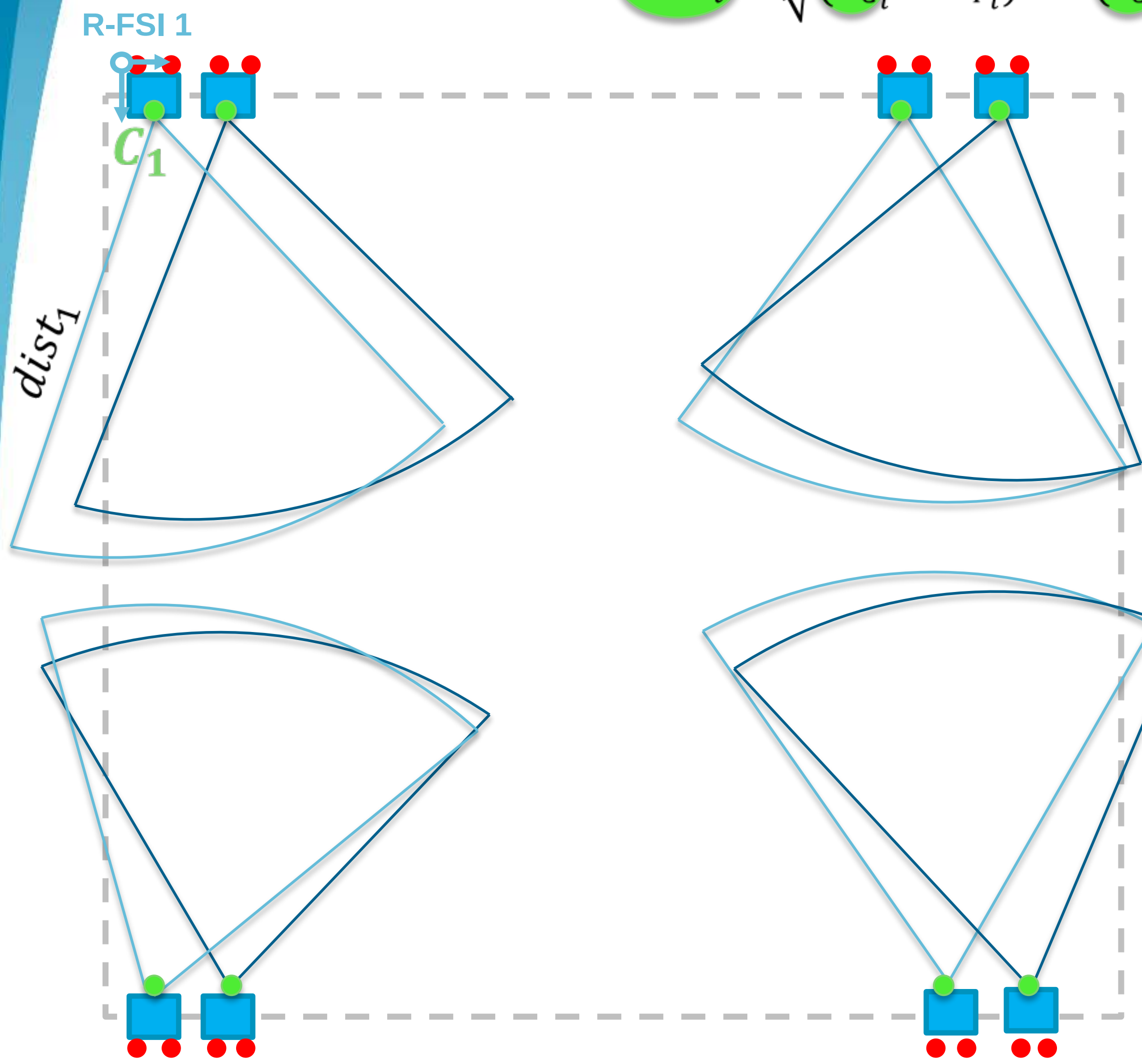






FSI alignment strategy and results

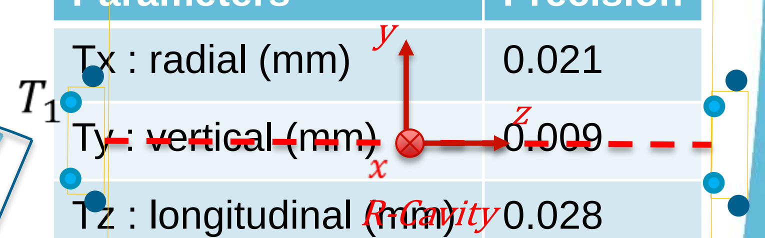
$$Dist_i = \sqrt{(X_{C_i} - X_{T_i})^2 + (Y_{C_i} - Y_{T_i})^2 + (Z_{C_i} - Z_{T_i})^2}$$



$$\begin{pmatrix} X_{Ti} \\ Y_{Ti} \\ Z_{Ti} \end{pmatrix} = \begin{pmatrix} T_X \\ T_Y \\ T_Z \end{pmatrix} + [R]^* \begin{pmatrix} x_{Ti} \\ y_{Ti} \\ z_{Ti} \end{pmatrix}$$

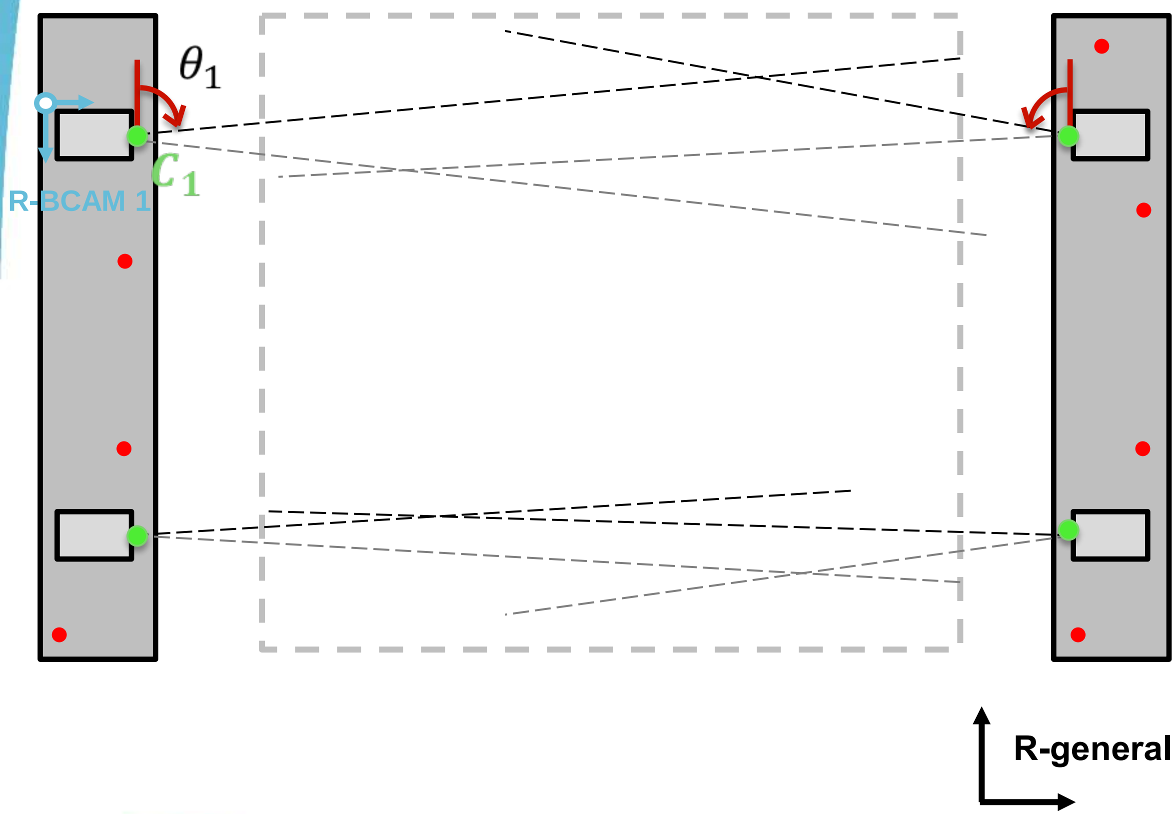
R-general *R-cavity*

Parameters	Precision
Tx : radial (mm)	0.021
Ty : vertical (mm)	0.009
Tz : longitudinal (mm)	0.028
Rx : pitch (mrad)	0.030
Ry : yaw (mrad)	0.072
Rz : roll (mrad)	0.187



BCAM alignment strategy and results

$$\theta_i = \tan^{-1}\frac{\left(X_{C_i} - X_{T_i}\right)}{\left(Z_{C_i} - Z_{T_i}\right)} \qquad \varphi_i = \tan^{-1}\frac{\left(Y_{C_i} - Y_{T_i}\right)}{\sqrt{\left(Z_{C_i} - Z_{T_i}\right)^2 + \left(X_{C_i} - X_{T_i}\right)^2}}$$

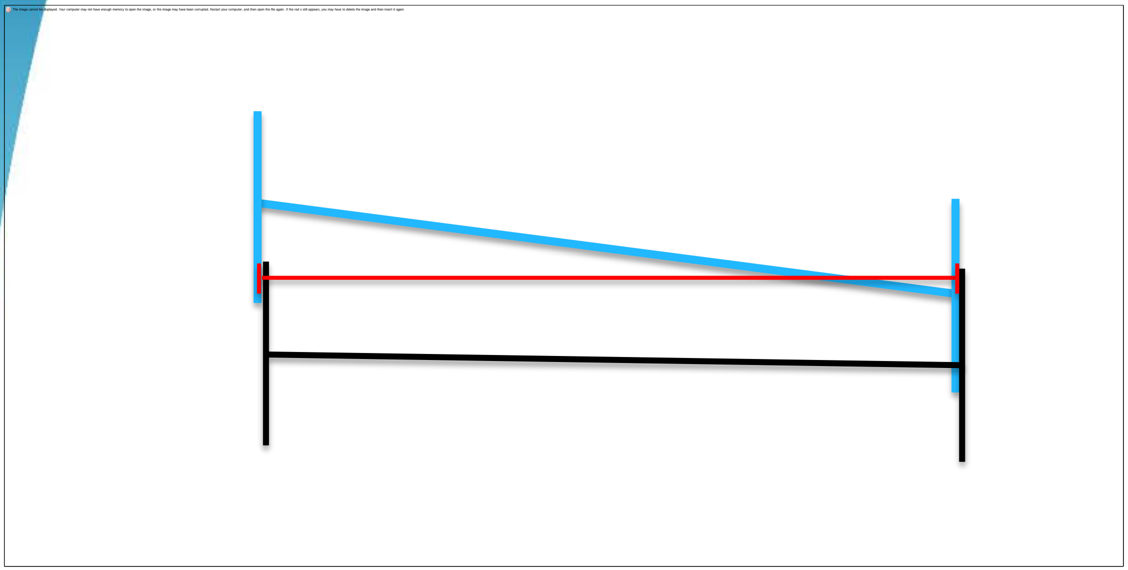


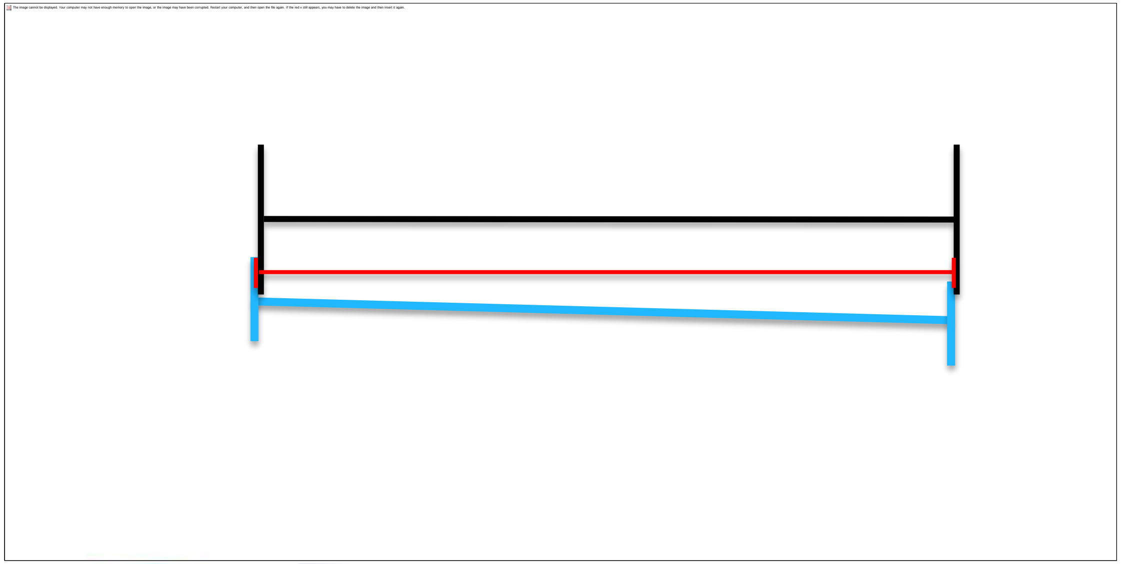
$$\begin{pmatrix} X_{Ti} \\ Y_{Ti} \\ Z_{Ti} \end{pmatrix} = \begin{pmatrix} T_X \\ T_Y \\ T_Z \end{pmatrix} + [R]^* \begin{pmatrix} x_{Ti} \\ y_{Ti} \\ z_{Ti} \end{pmatrix}$$

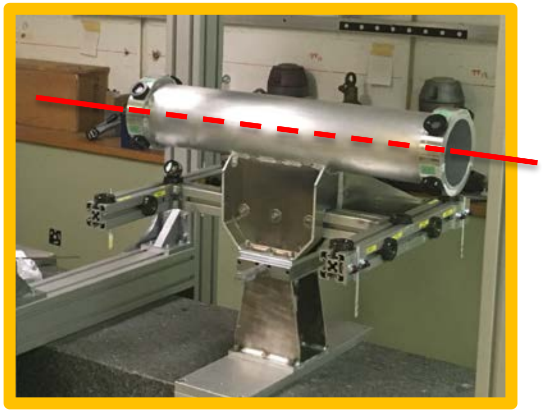
R-general   *R-cavity*

Parameters	Precision
Tx : radial (mm)	0.026
Ty : vertical (mm)	0.016
Tz : longitudinal (mm)	0.622
Rx : pitch (mrad)	0.057
Ry : yaw (mrad)	0.057
Rz : roll (mrad)	0.083

Comparison with AT401







Conclusion

- **Both systems have been tested under standard conditions and their accuracy meet the alignment requirements.**
- **Their results were compared to laser tracker measurements and their differences were acceptable.**
- **Cryogenic and radiation tests are in progress in order to validate the FSI strategy.**
- **BCAM solution will only be used during the cooling process (cross-checking measurements).**

Thank you for your attention

Acknowledgement:

Thibault Dijoud, Mateusz Sosin, Hélène Mainaud Durand, Mathieu Duquenne, Andreas Herty, Bruno Perret, Michel Rousseau, Antonio Marin, Michael Udzik

SPARE

Results: Leica BRR 1.5''

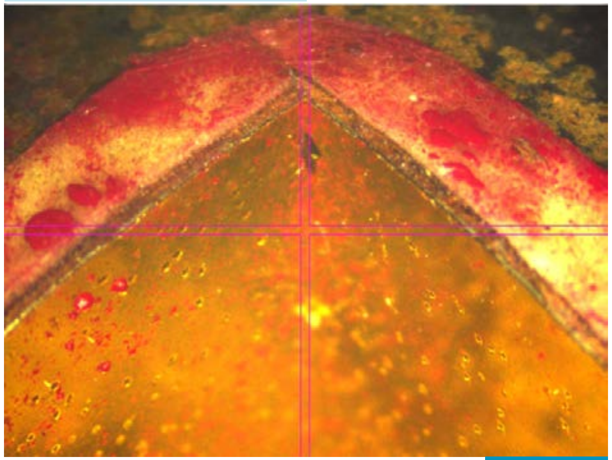
500kGy

4MGy

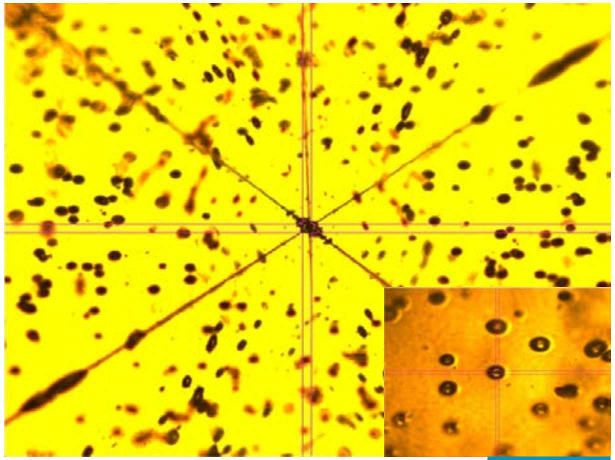
7MGy

10MGy

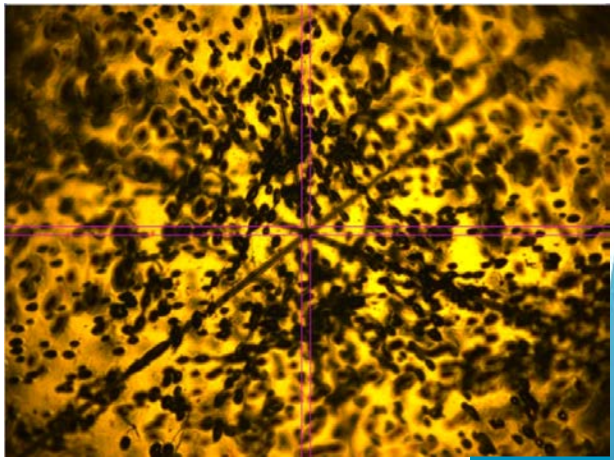
Microscope views



7MGy



7MGy



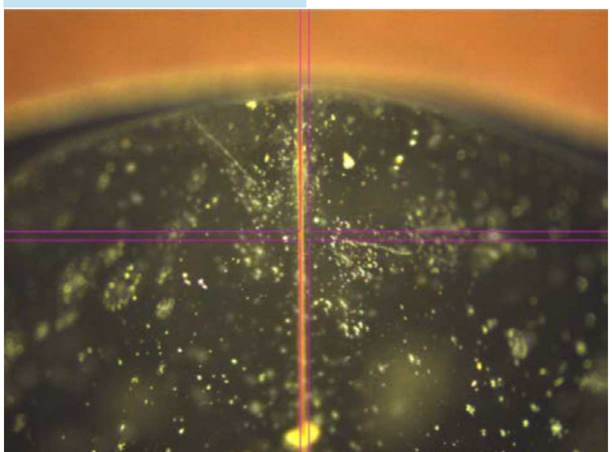
10MGy

Results: PLX Ceramic BMR 1.5’’

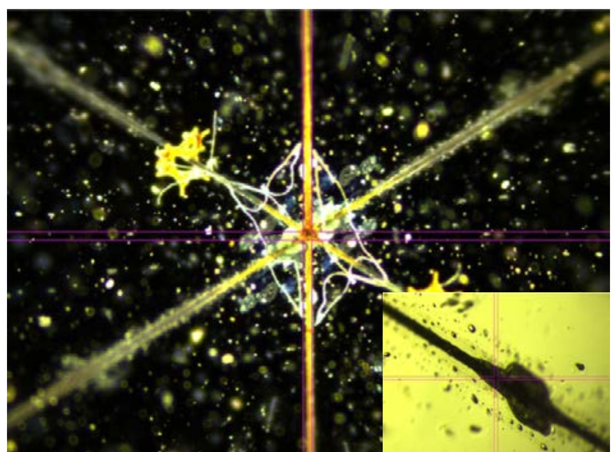
100kGy

10MGy

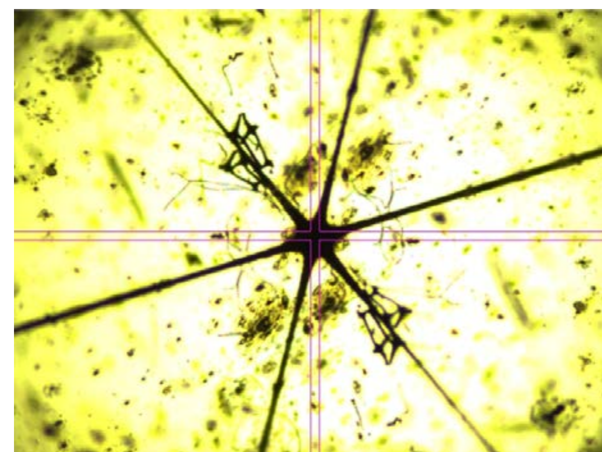
Microscope views



7MGy

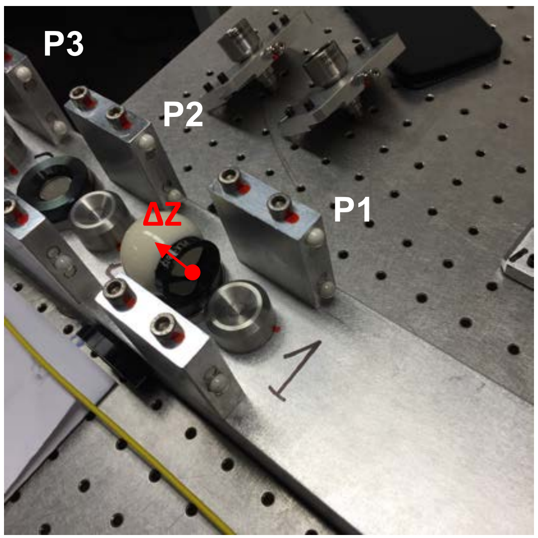


7MGy

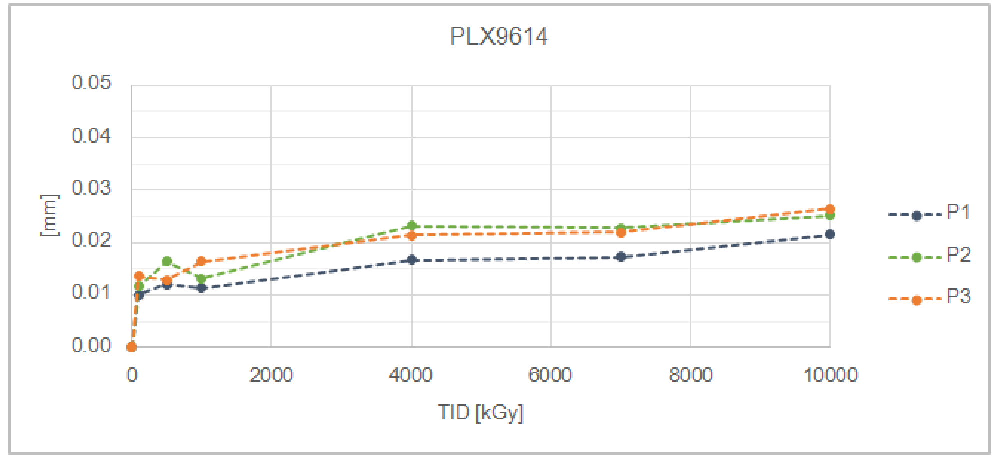


10MGy

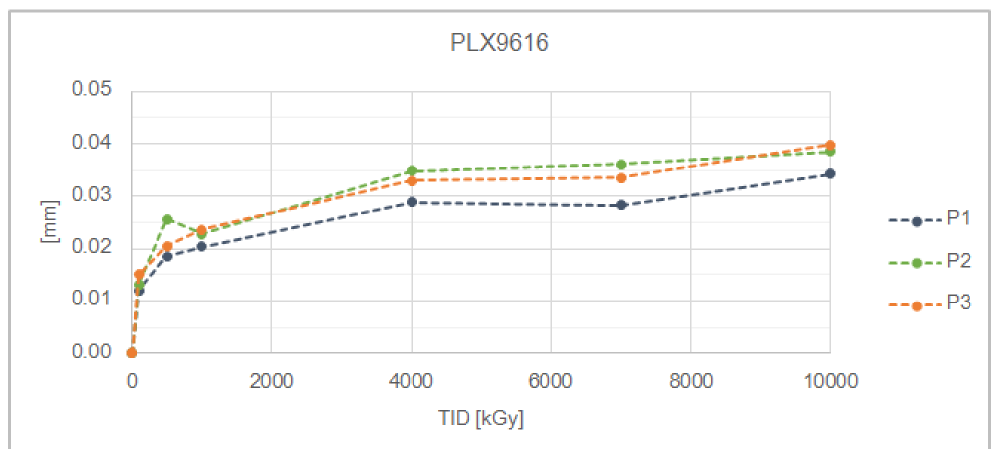
Results: PLX Ceramic BMR 1.5’’



Distance variations (ΔZ) after thermal correction

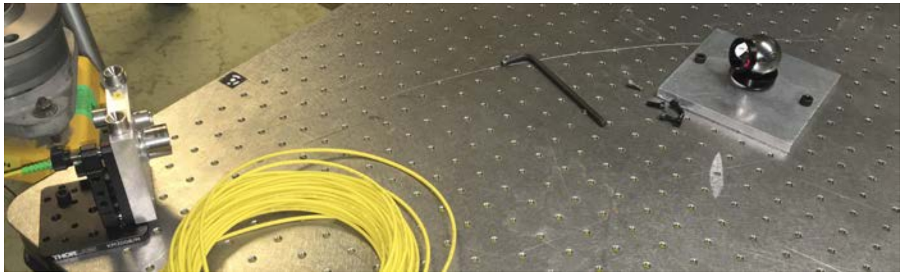


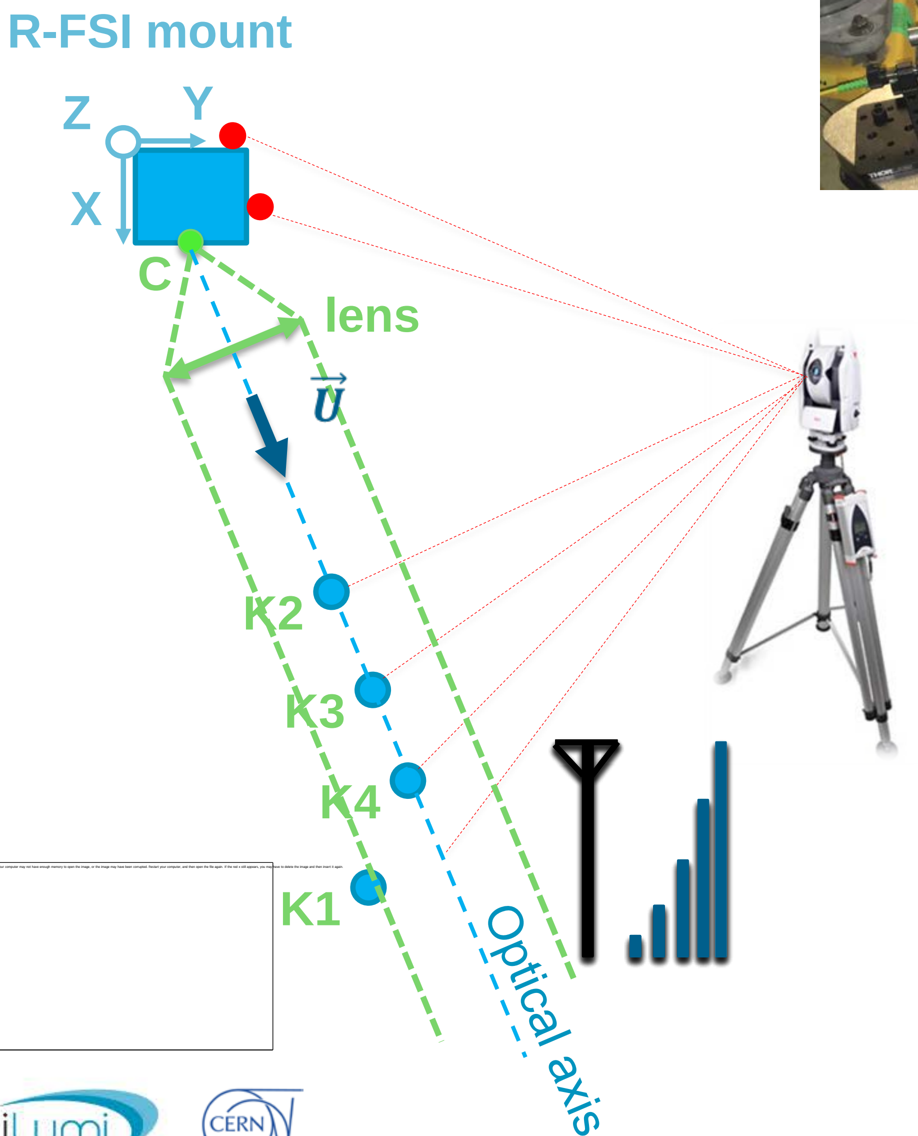
Shift measured at 10MGy with AT401: 22µm (centring of optics < 5µm)



Shift measured at 10MGy with AT401: 28µm (centring of optics < 10µm)

FSI absolute calibration





$$\begin{bmatrix} X_{K_1} \\ Y_{K_1} \\ Z_{K_1} \end{bmatrix} = \begin{bmatrix} X_C \\ Y_C \\ Z_C \end{bmatrix} + \mathbf{Dist\ 1} * \begin{bmatrix} U_X \\ U_Y \\ U_Z \end{bmatrix}$$

$$\begin{bmatrix} X_{K_2} \\ Y_{K_2} \\ Z_{K_2} \end{bmatrix} = \begin{bmatrix} X_C \\ Y_C \\ Z_C \end{bmatrix} + \mathbf{Dist\ 2} * \begin{bmatrix} U_X \\ U_Y \\ U_Z \end{bmatrix}$$

$$\begin{bmatrix} X_{K_3} \\ Y_{K_3} \\ Z_{K_3} \end{bmatrix} = \begin{bmatrix} X_C \\ Y_C \\ Z_C \end{bmatrix} + \mathbf{Dist\ 3} * \begin{bmatrix} U_X \\ U_Y \\ U_Z \end{bmatrix}$$

$$\begin{bmatrix} X_{K_4} \\ Y_{K_4} \\ Z_{K_4} \end{bmatrix} = \begin{bmatrix} X_C \\ Y_C \\ Z_C \end{bmatrix} + \mathbf{Dist\ 4} * \begin{bmatrix} U_X \\ U_Y \\ U_Z \end{bmatrix}$$

→ Xc (1σ) : 10 μm