EUROPEAN UNION

Structural Instruments 2014-2020

Competitiveness Operational Programme (COP)

Extreme Light Infrastructure - Nuclear Physics (ELI-NP) – Phase II

YOUNG RESEARCH AND ENGINEERING DAYS

Laser Beam Pointing Stability Analysis in HPLS

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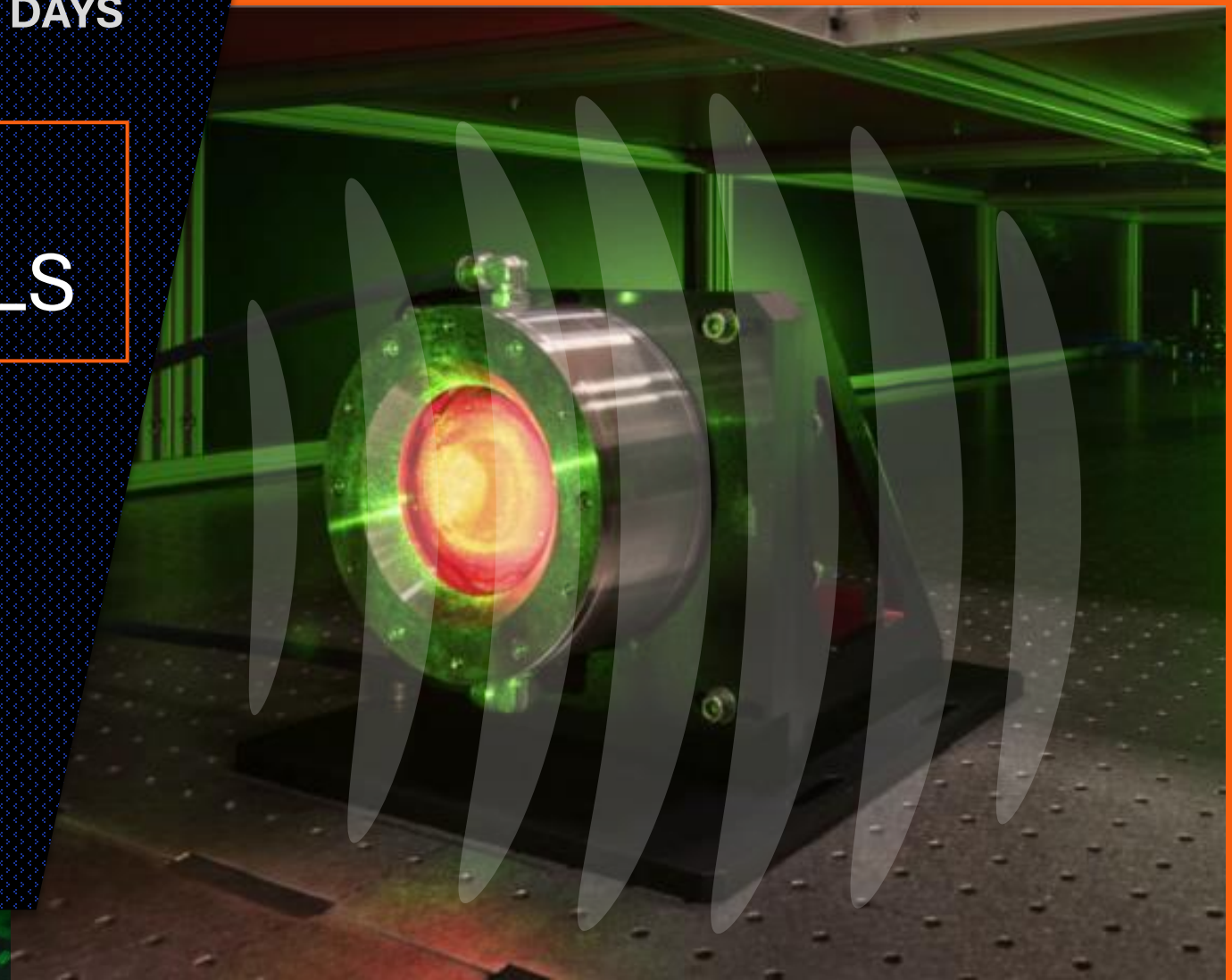
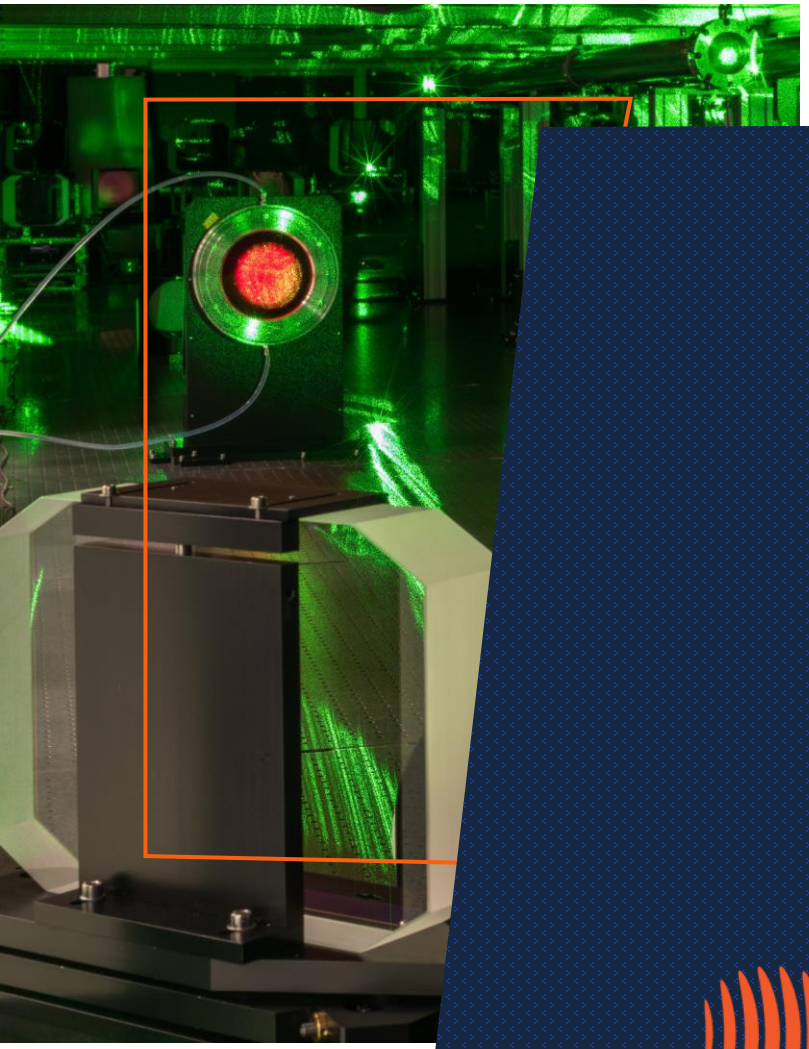
eli nuclear physics

IFIN-HH





nuclear physics

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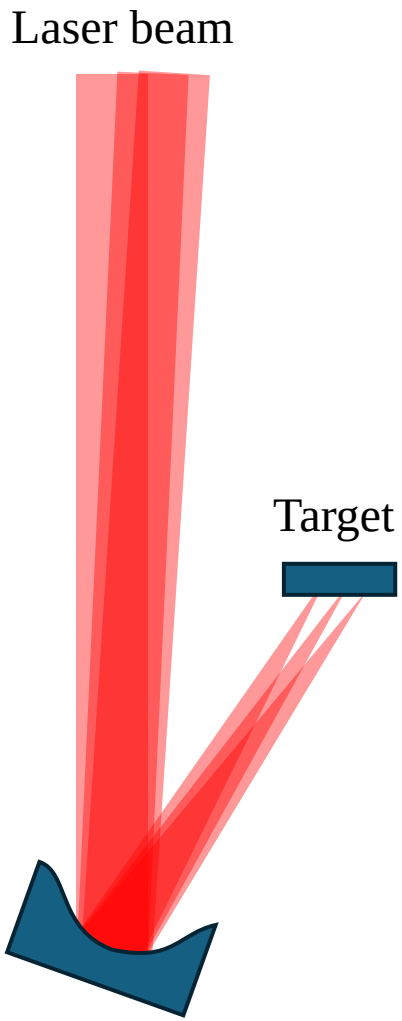
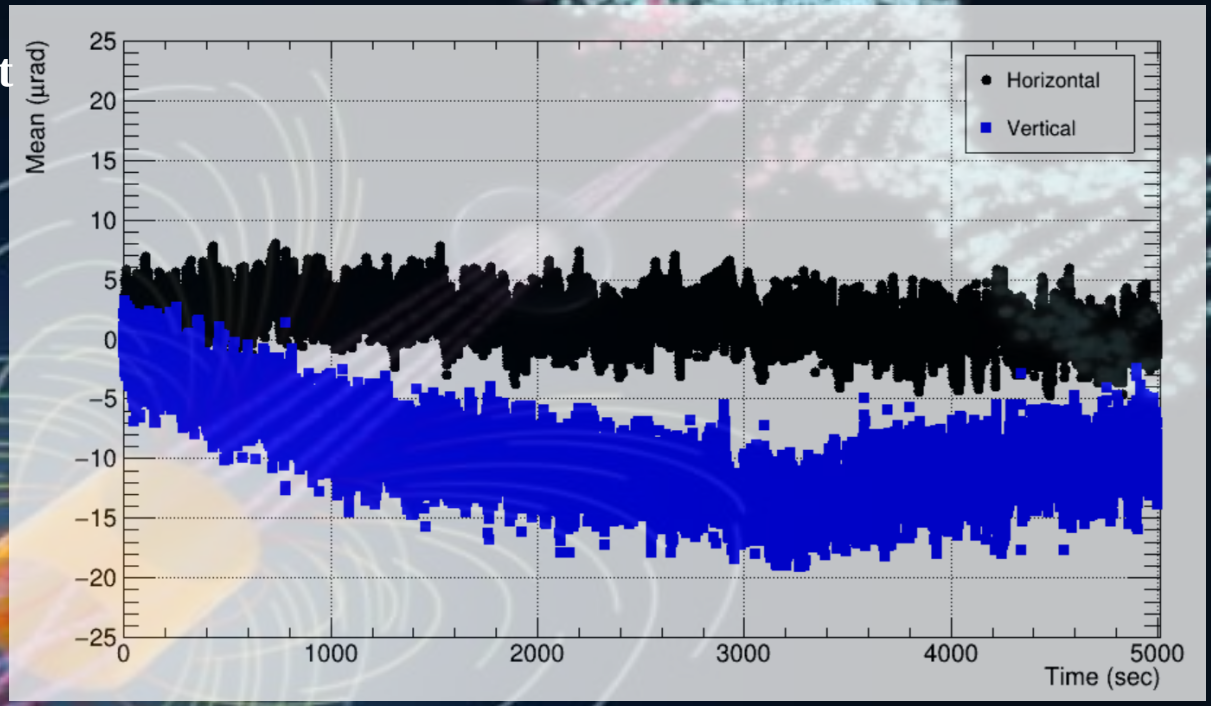
MOTIVATION AND GOALS



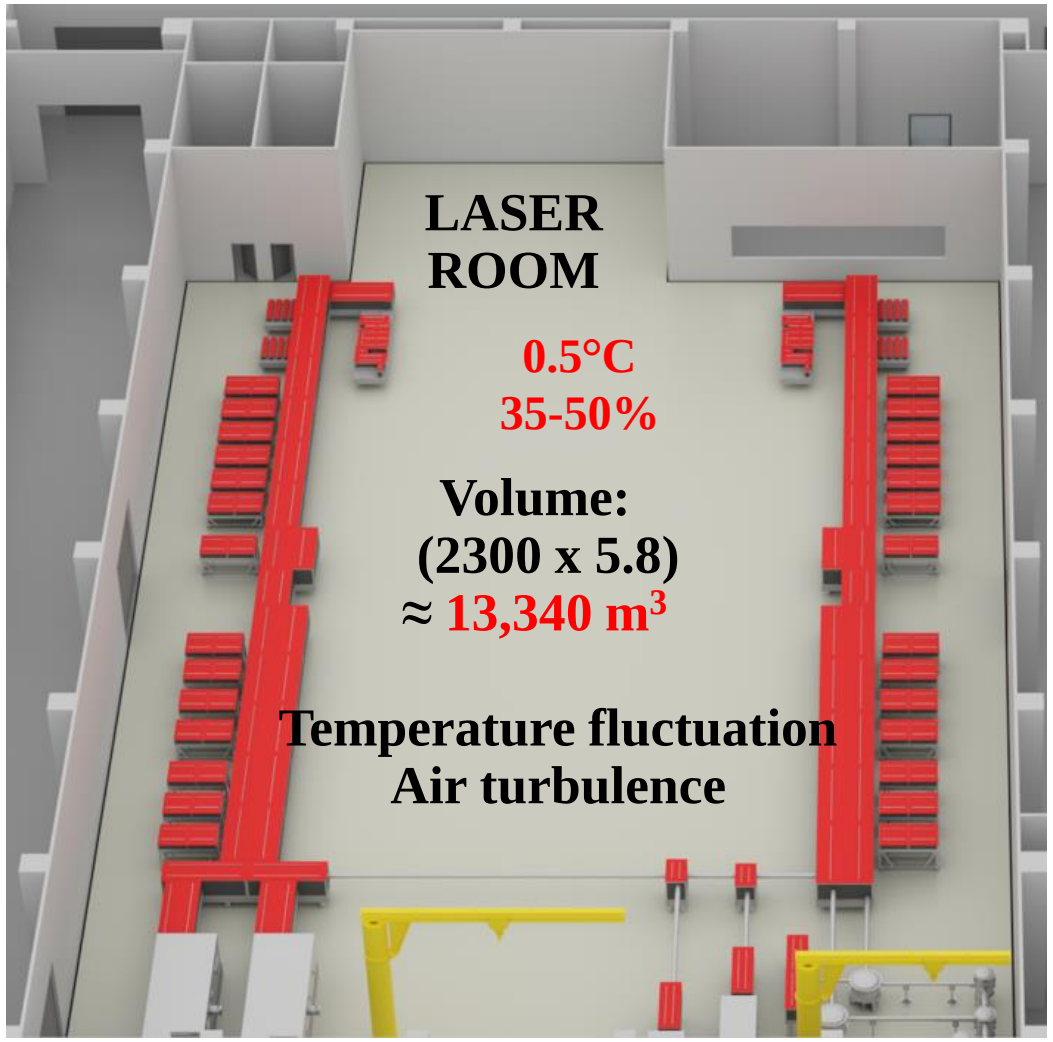
Pointing Fluctuation of the Laser in E1 on 10 PW line B - 2023 [Dominico Doria, Laser Experiment Department (LED), ELI-NP/IFIN-HH]

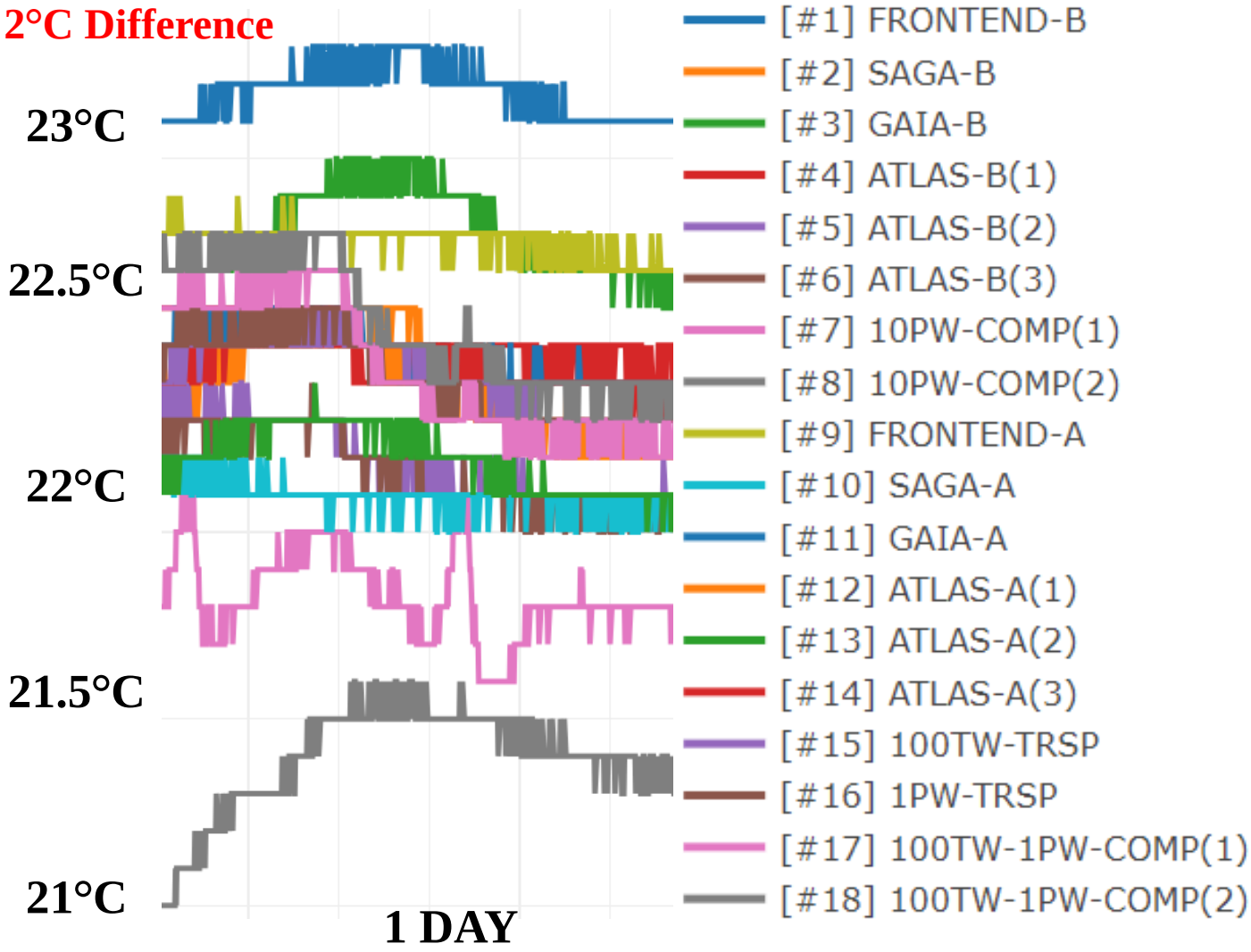


Pointing Drift of Ti:Sa Laser in E4 on Octombrie 2021 [Yoshihide Nakamiya, Laser Gamma Experiment Department (LGED), ELI-NP/IFIN-HH]

Improve the laser beam stability in HPLS

SOURCE OF BEAM POINTING DRIFT

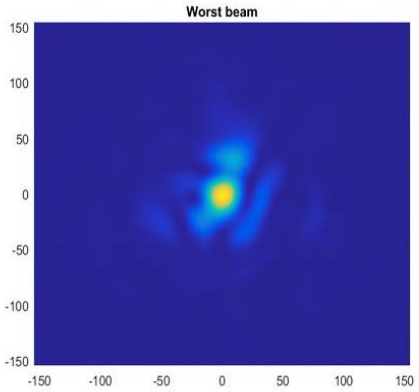


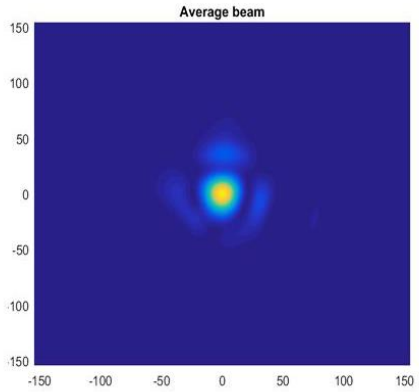


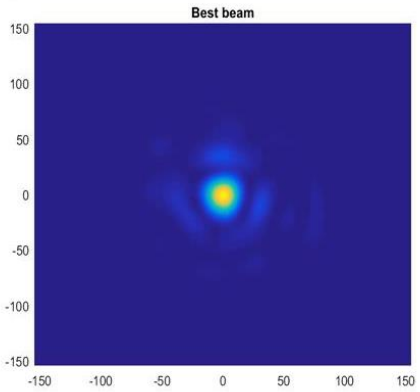
SAME PROBLEM FOR OTHER HPLS

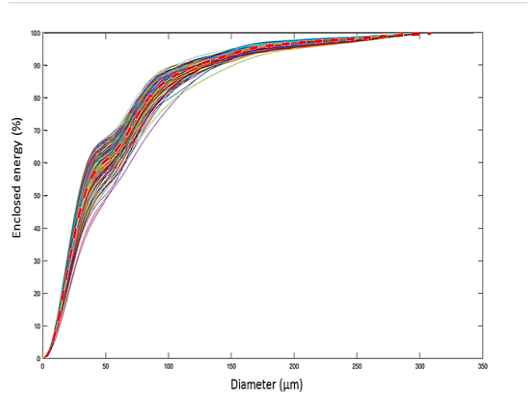
Apollon

Laser performances: Focal spot quality stability







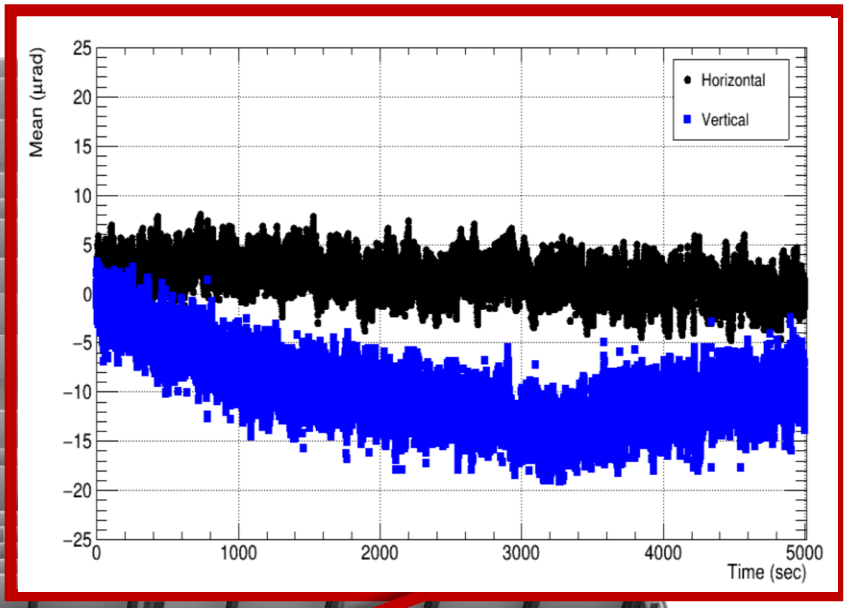


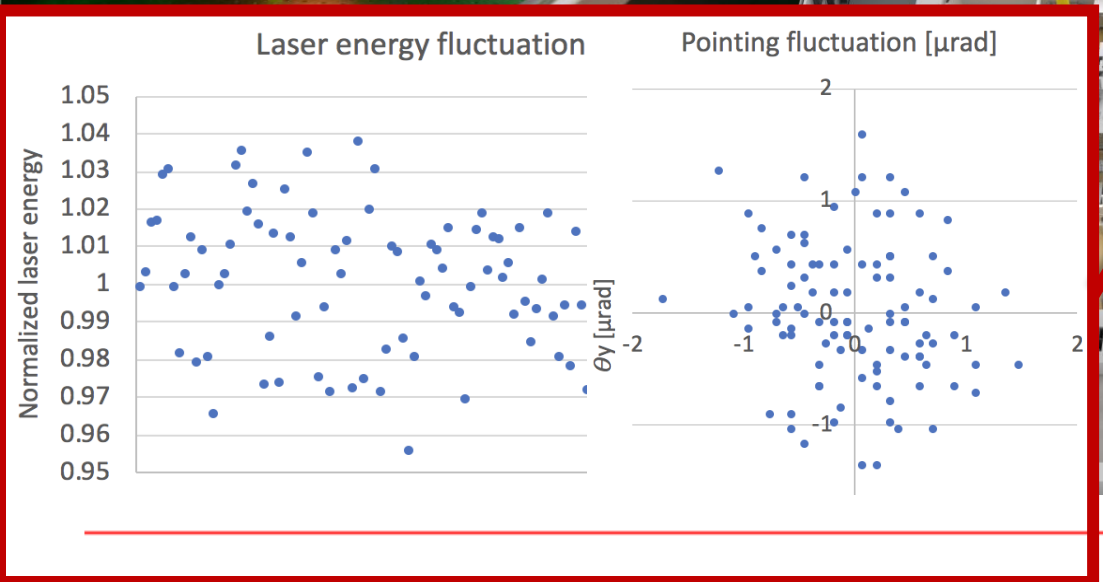
- **Air turbulence** is responsible for shot-to-shot focal spot quality variations: Most of the impact concerns the intermediate spatial frequencies
- In this 100 shots acquisition (100 min) we observed ~30% variation of the enclosed energy and a **Strehl~0.2 to 0.6**
- Measures have been taken since: covering of the amplification and separation area ➔ **Strehl~0.35 to 0.65**
  Further measures are to be taken (…2021)

Apollon laser has problems with the stability of focusing. They are doubting the Air turbulence. This situation is the same with Korean laser and maybe for our laser, too.

BEAM-POINTING FEEDBACK FROM THE EXPERIMENTAL SIDE

HUNDREDS OF METER PROPAGATION





100 TW @ 10 Hz

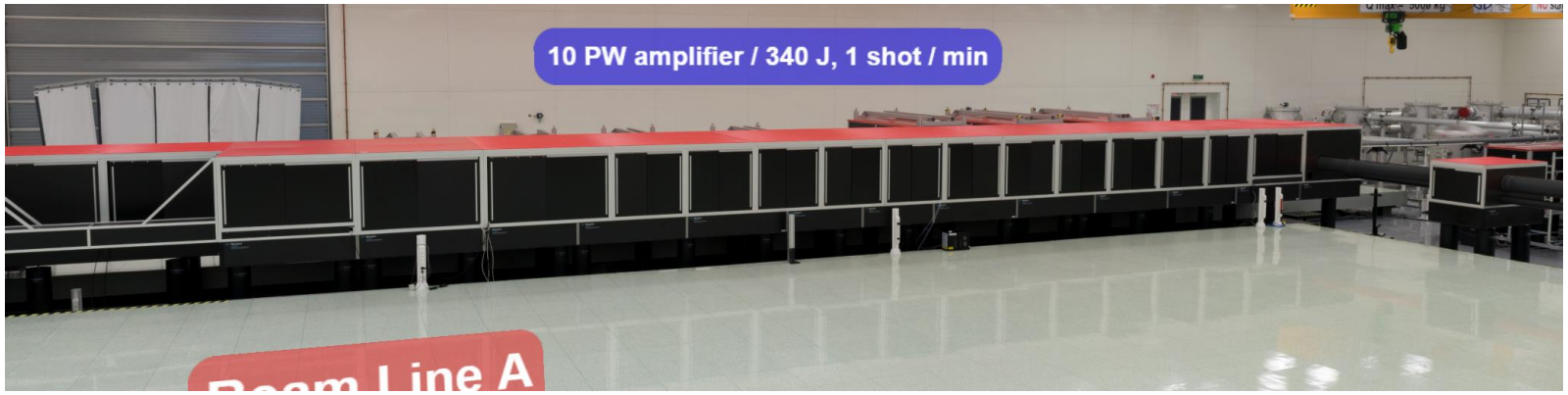
1 PW @ 1 Hz

10 PW @ 1 shot/min

WHY THE BEAM IS FLUCTUEITING AND DRIFTING?

Angle of deflexion θ :

$$\theta = \frac{L}{n}\frac{dn}{dy}$$

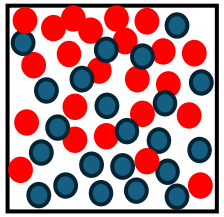


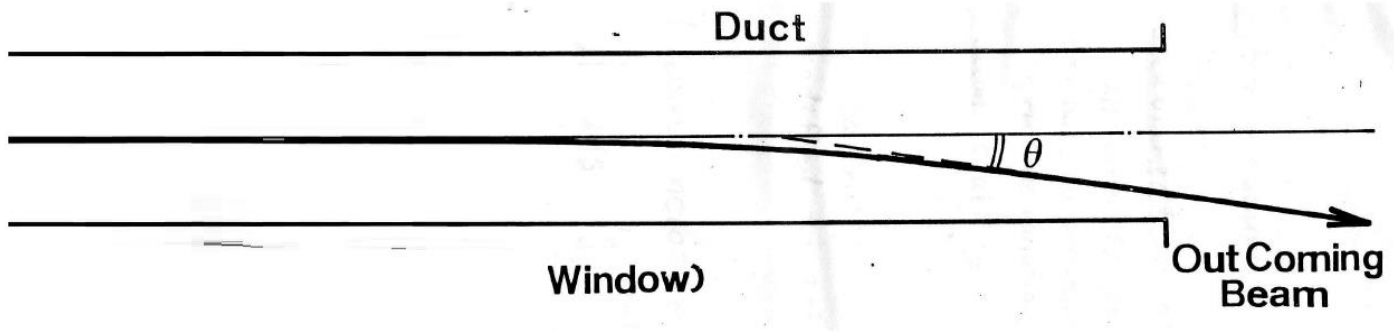
Where: n – refractive index,

L – length of propagation.

$$n = 1 + \beta\frac{\rho}{\rho_0}$$

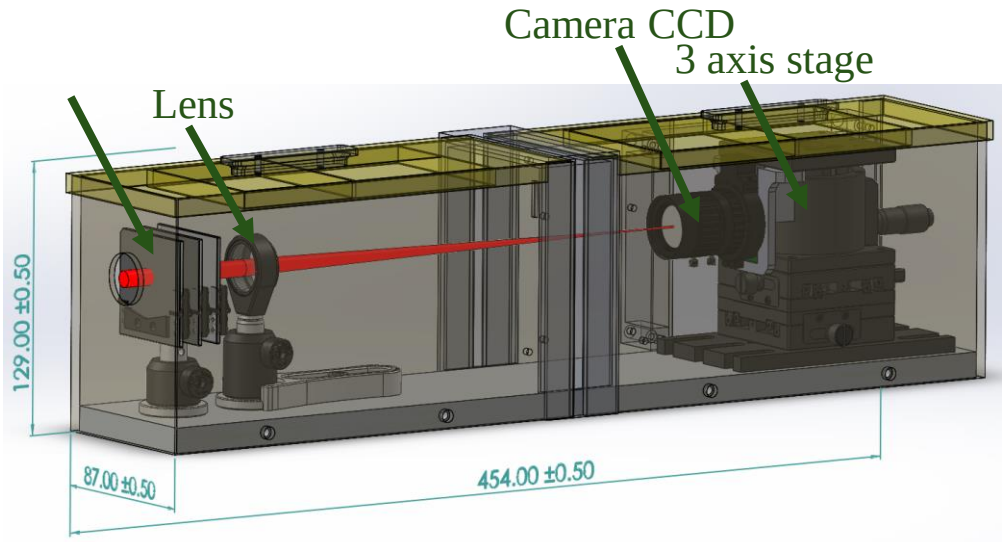
$$\frac{\rho}{\rho_0} = \frac{T_0}{T}$$



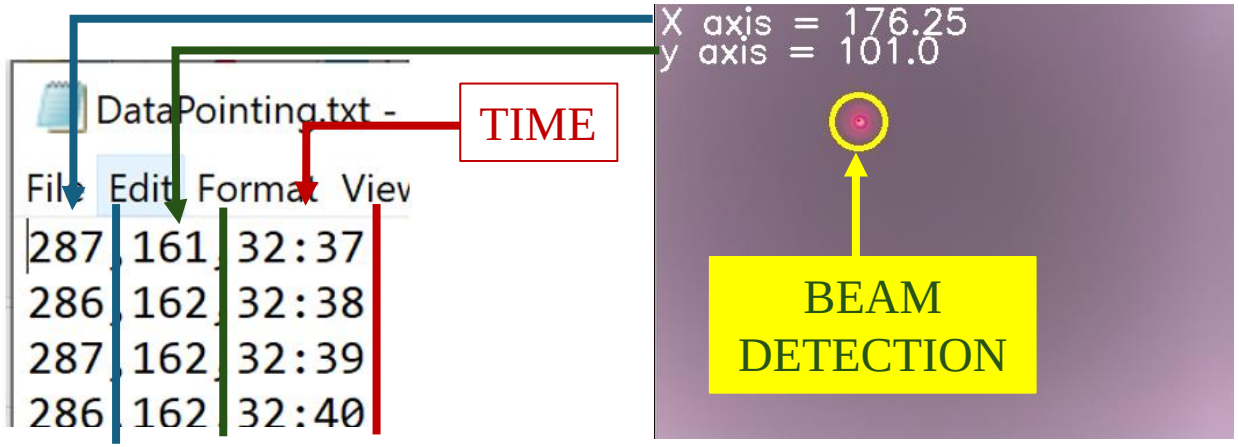


- Could air particle
- Hot air particle

BEAM POINTING DEVICE DEVELOPMENT (THEORETICAL)

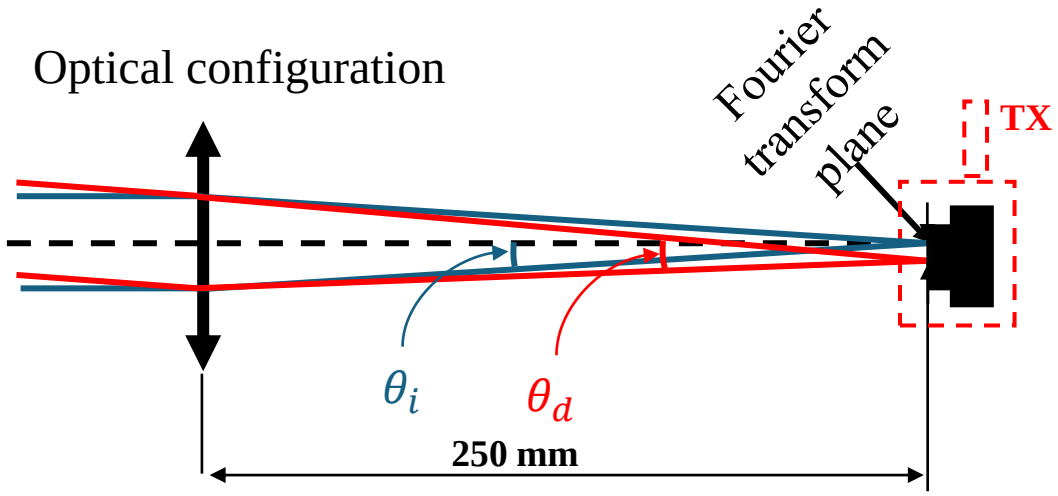


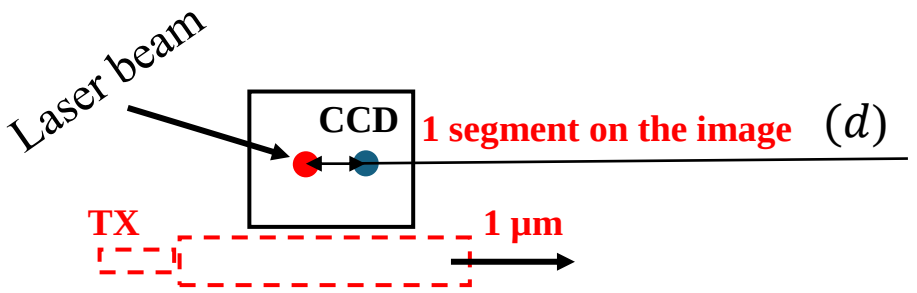
Design of the pointing monitoring system



Software development for pointing monitor system

Optical configuration



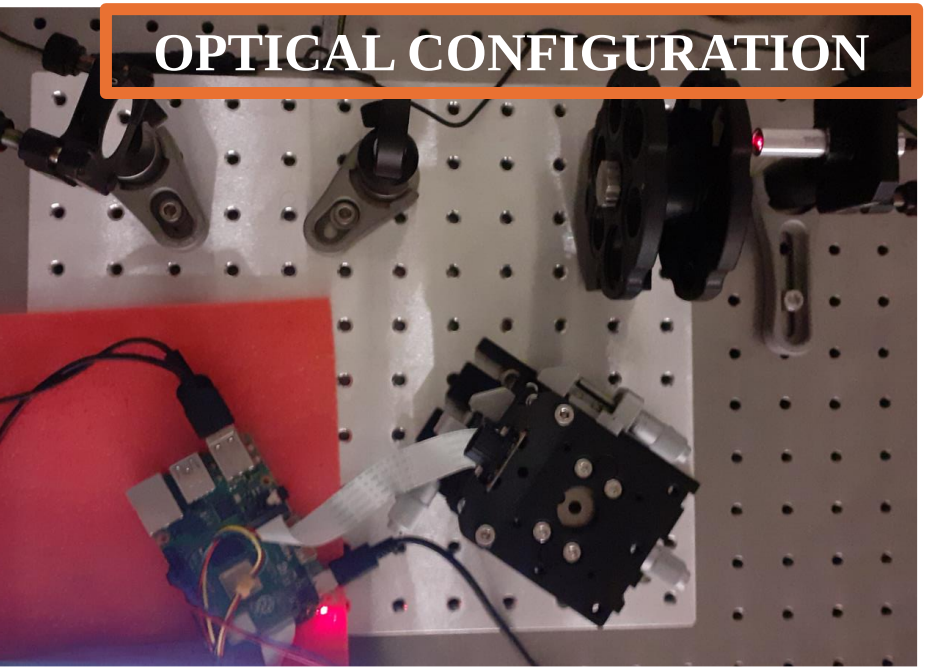


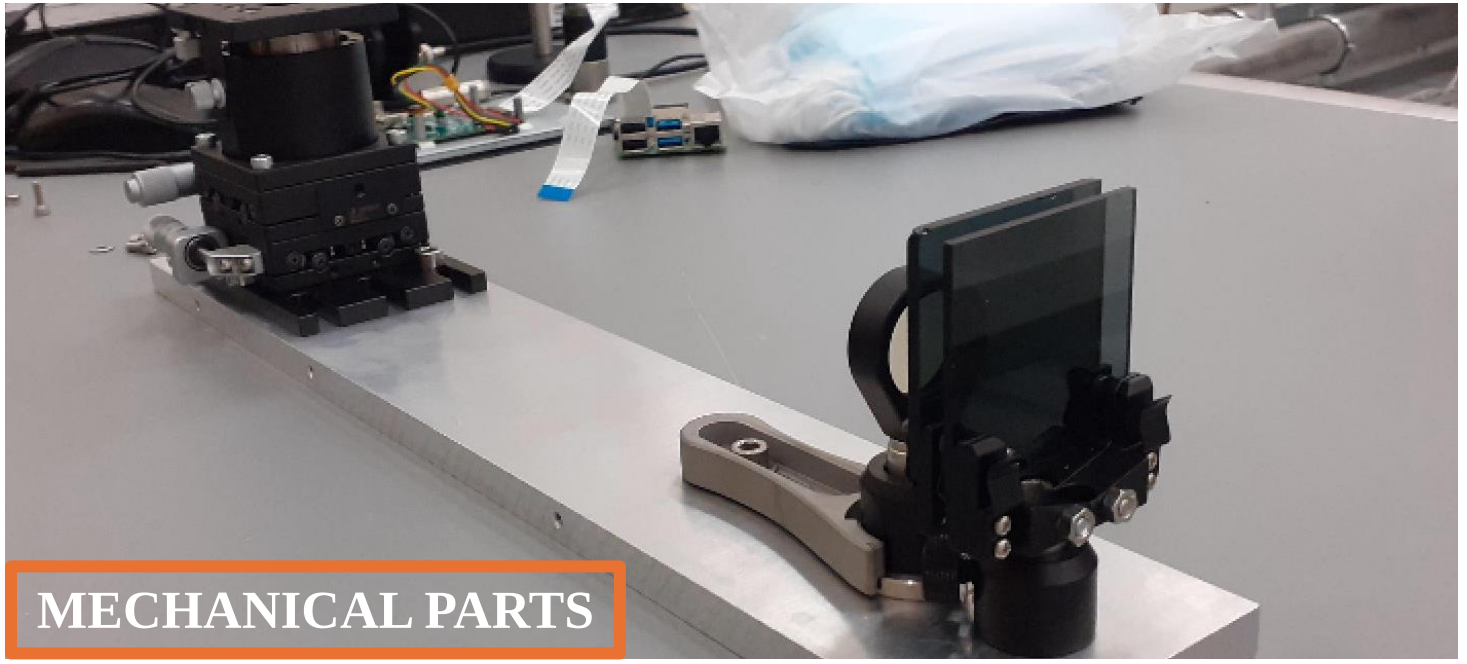
$$\theta_i - \theta_d = \frac{d}{f} = \frac{1}{0.25\ 10^{-6}} = 4\ \mu rad$$

For 1 μm displacement of translation stage correspond to ≈ 4 μrad beam pointing

BEAM POINTING DEVICE DEVELOPMENT (PHYSCAL)

OPTICAL CONFIGURATION



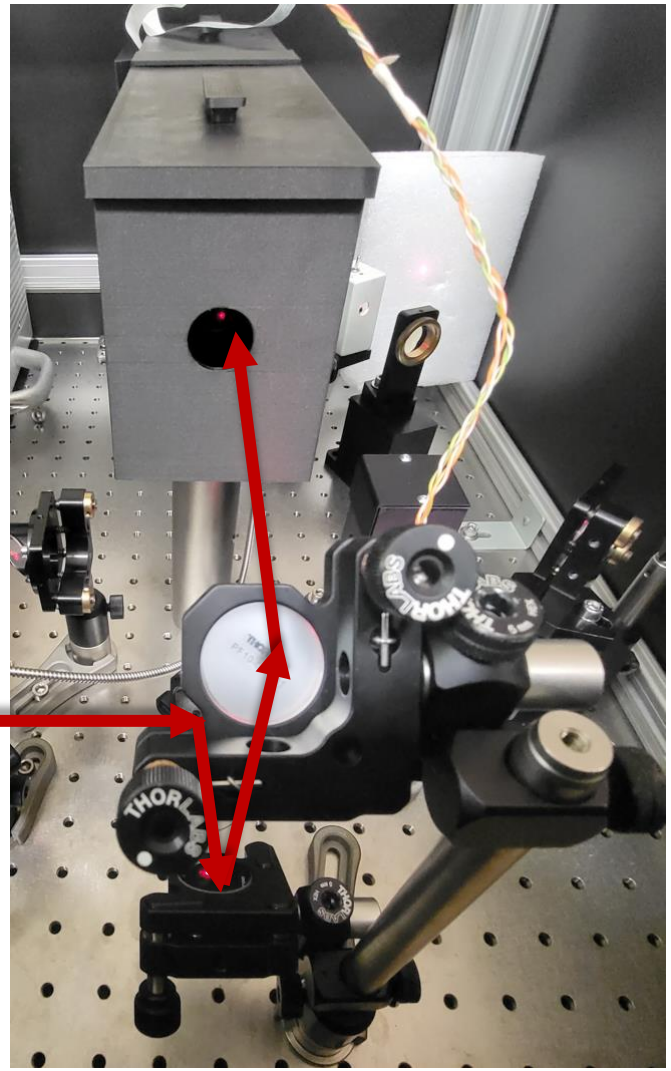


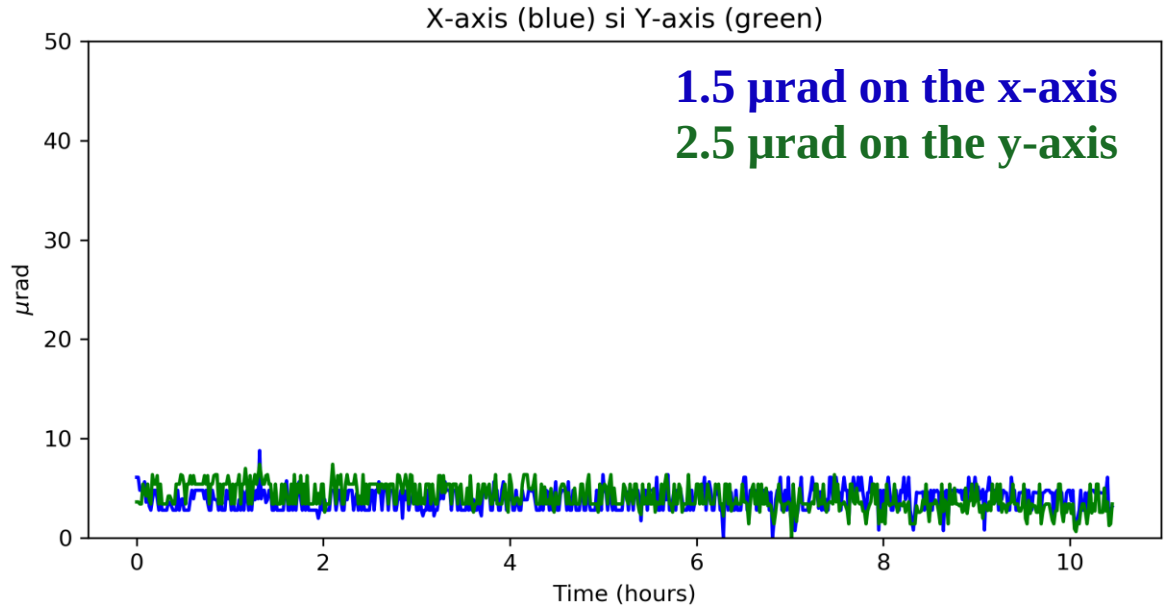
MECHANICAL PARTS

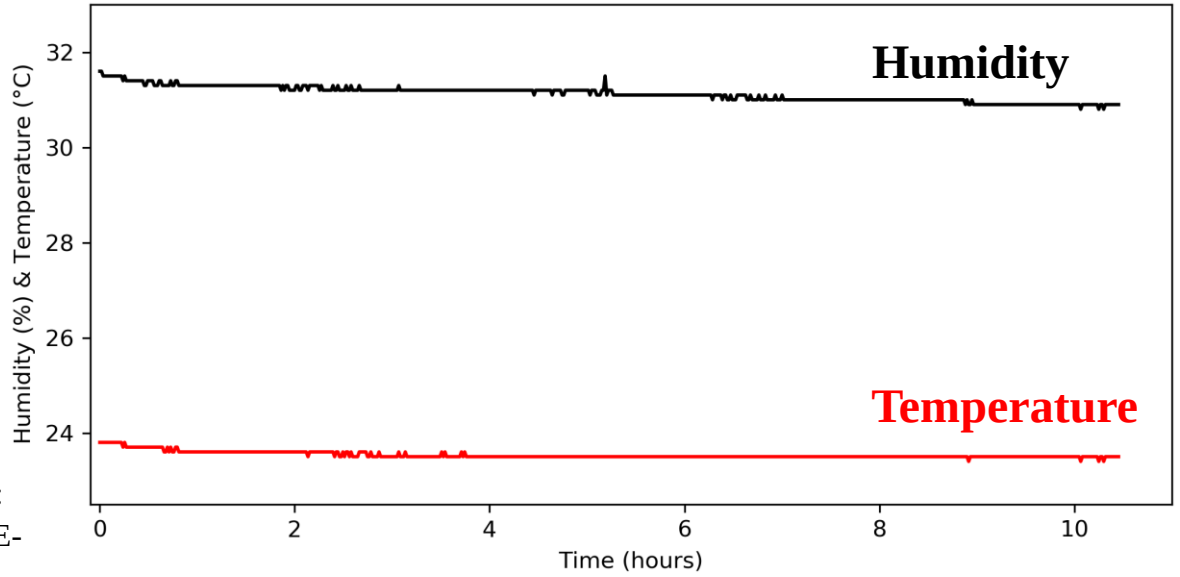
3D PRINTING

SYSTEM ASSEMBLY

STABILITY OF THE SYSTEM INCLUDING DIODE LASER

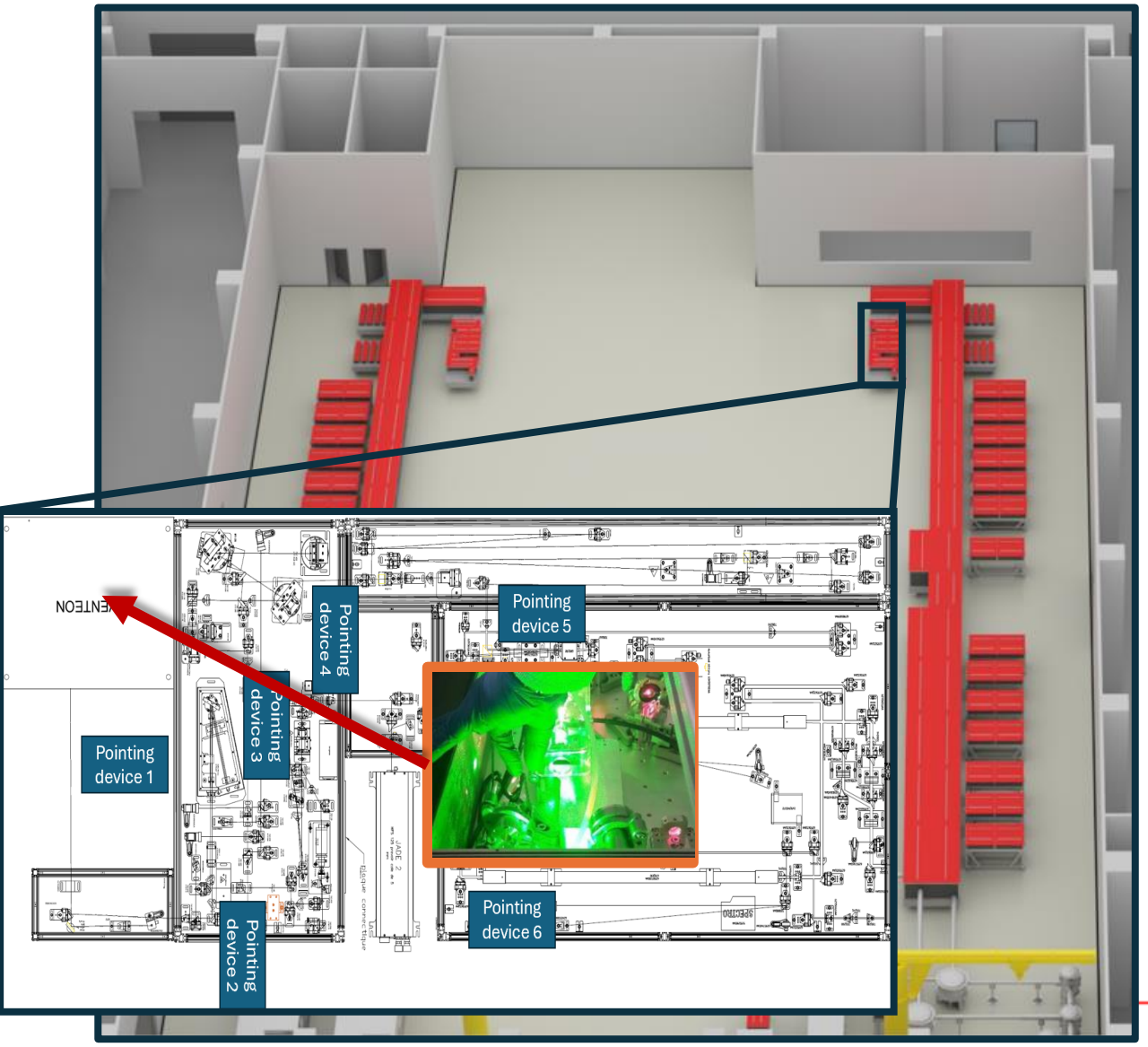


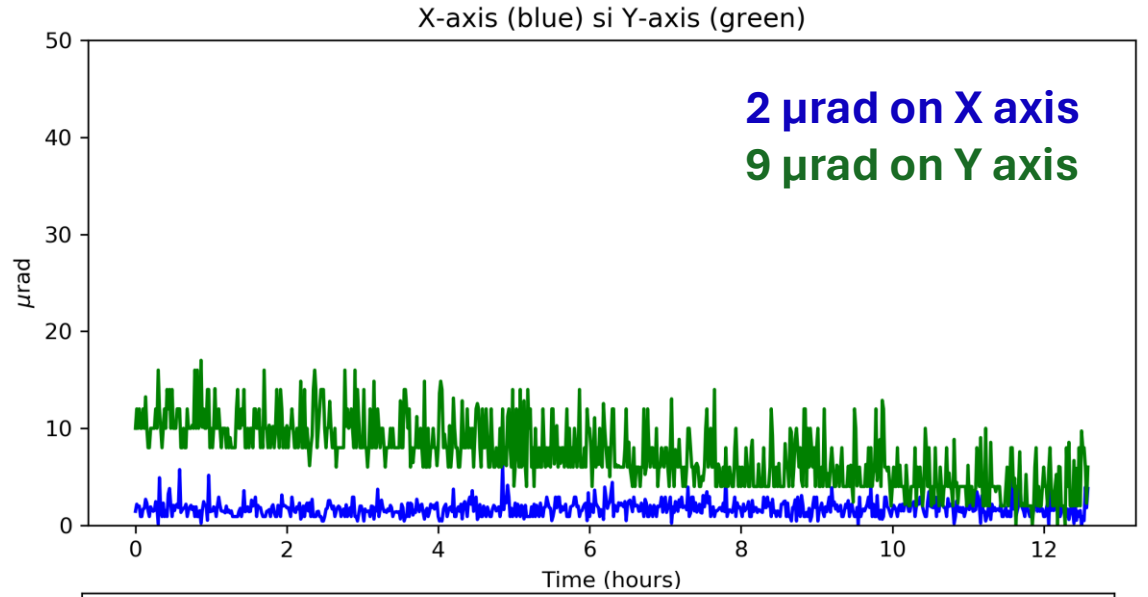


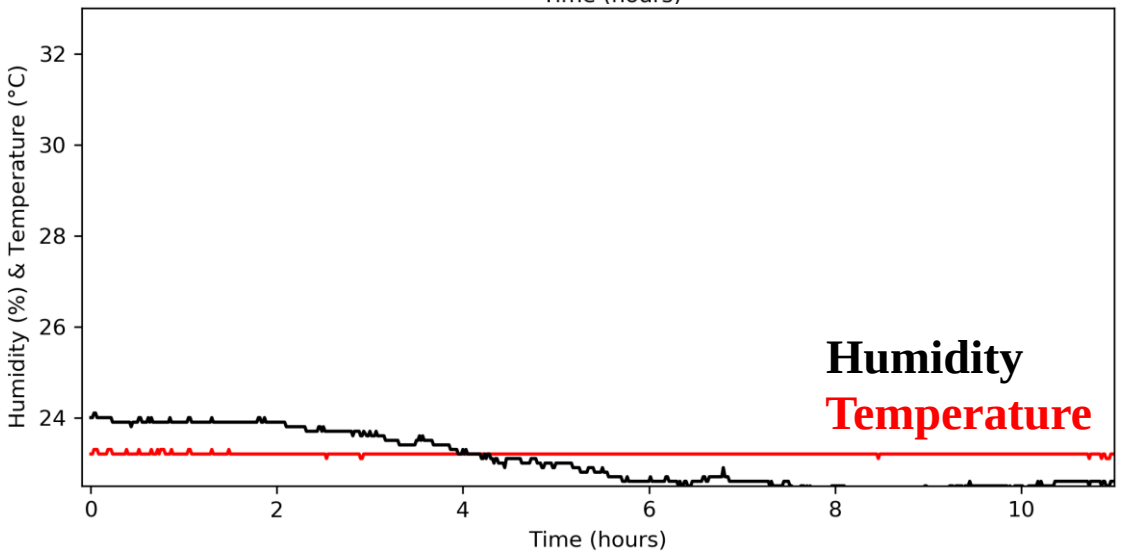


[1]. ThorLabs, Collimated Slim Laser Module 635 nm, 4.5 mW, Elliptical Beam: https://www.thorlabs.com/drawings/d8719352777d1a8b-A982ED7B-C119-CE6E-DBDFC9AED9C49261/CPS635S-SpecSheet.pdf

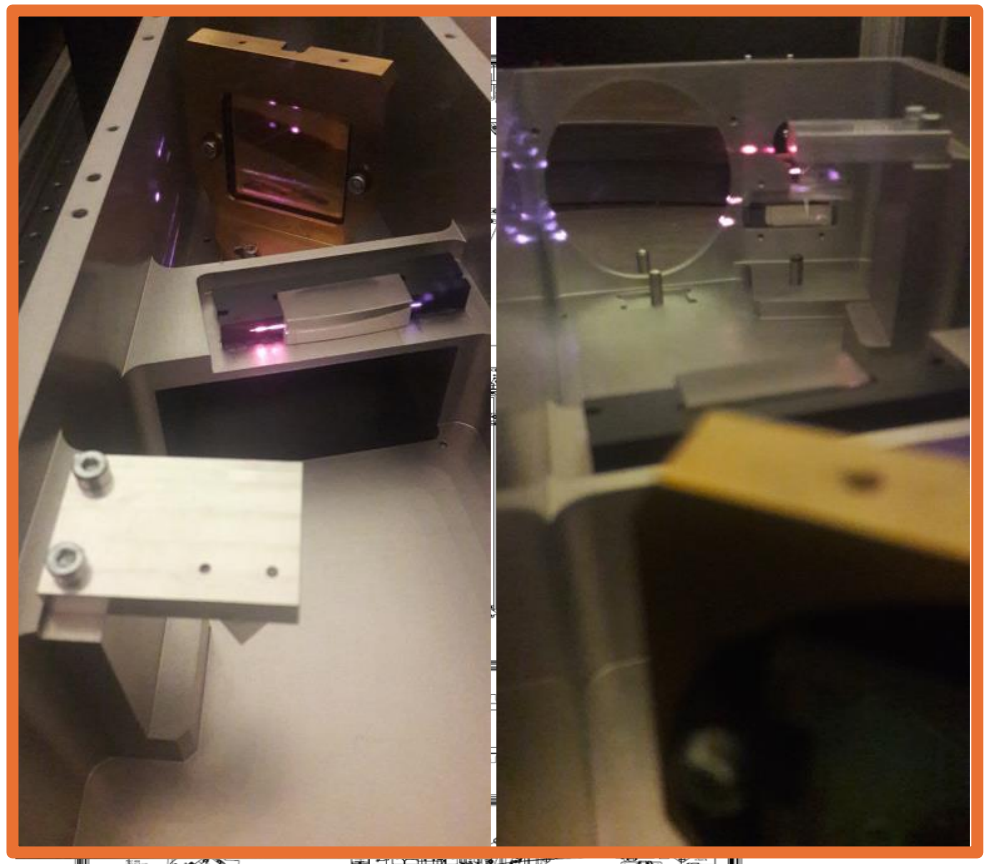
BEAM POINTING MEASUREMENTS IN HPLS FRONTEND A – VENTEON OSCILATOR

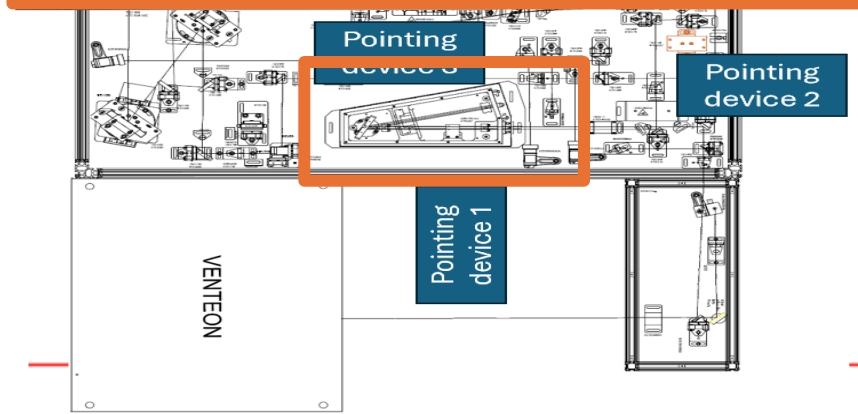


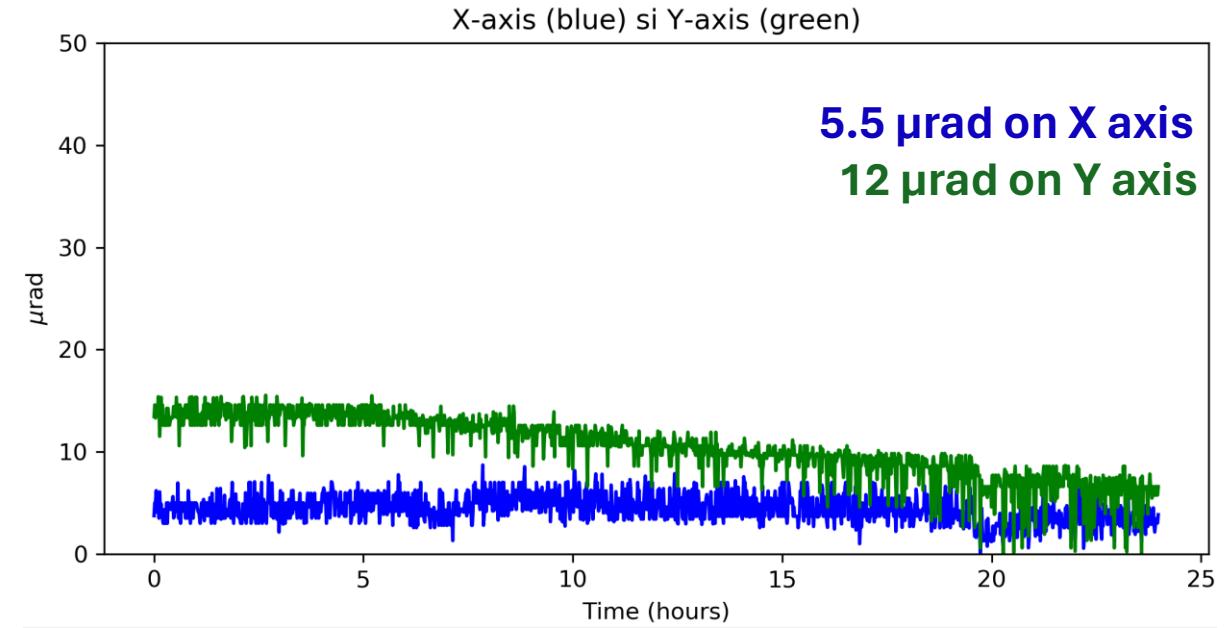


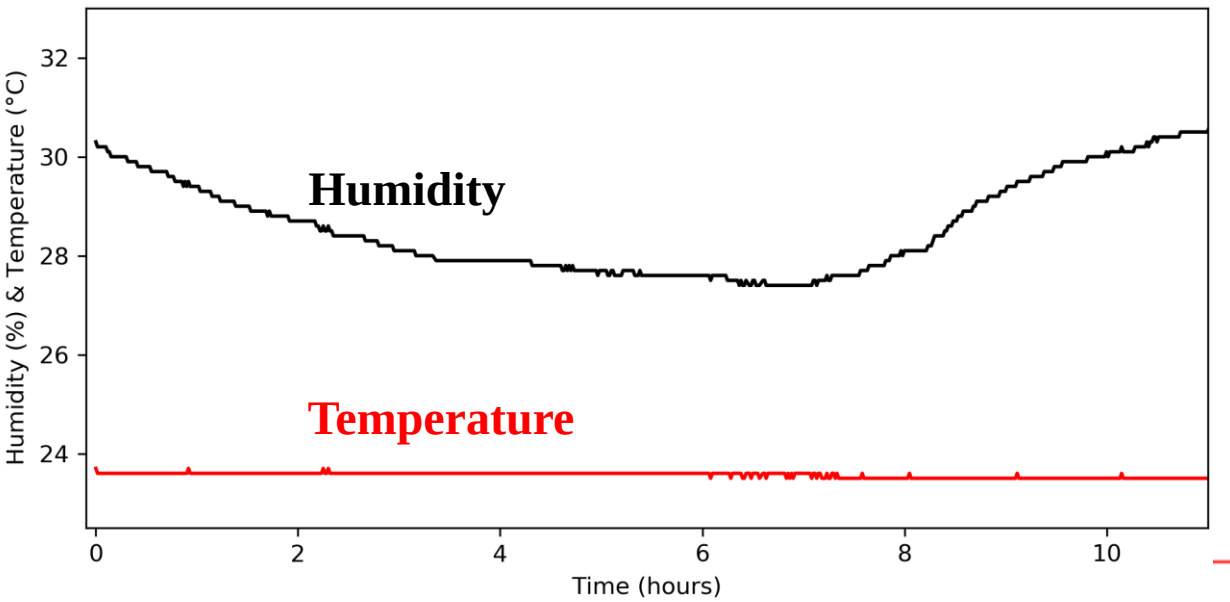


BEAM POINTING MEASUREMENTS IN HPLS FRONTEND A – STRETCHER 90 NM CEP

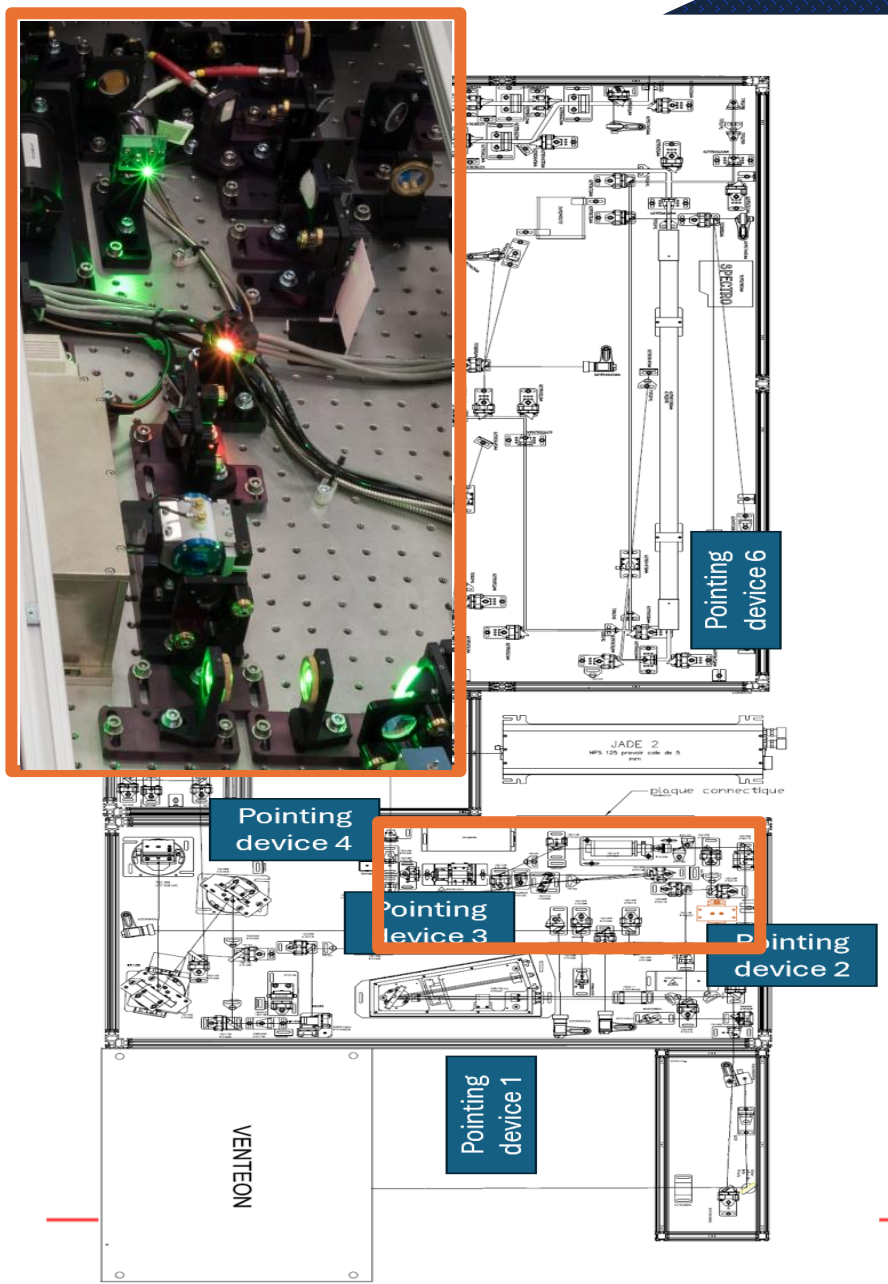


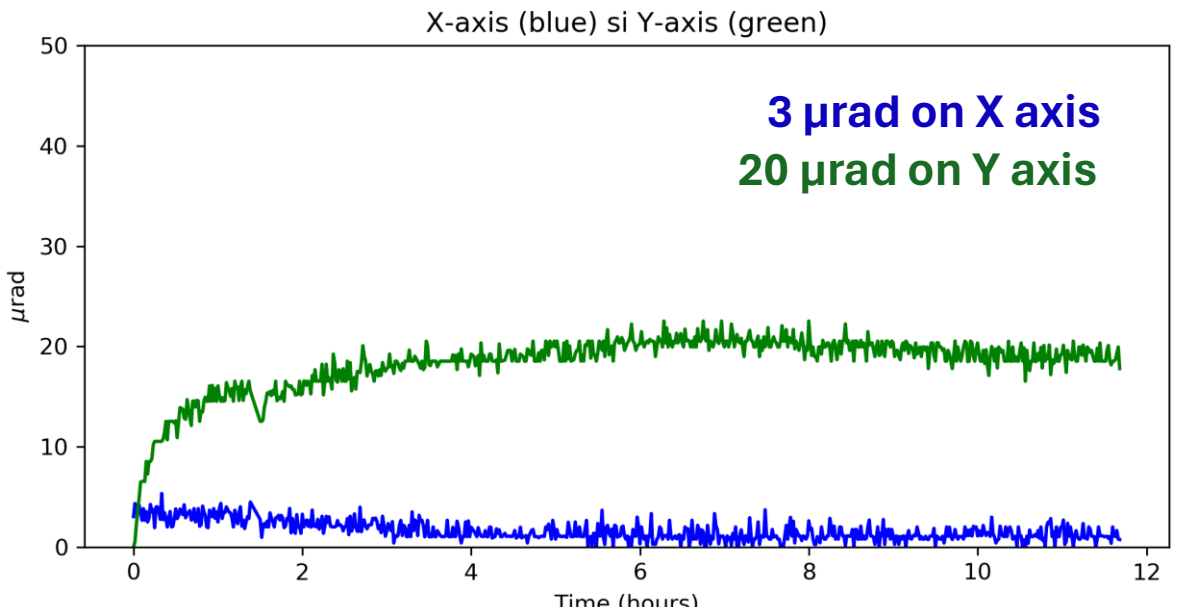


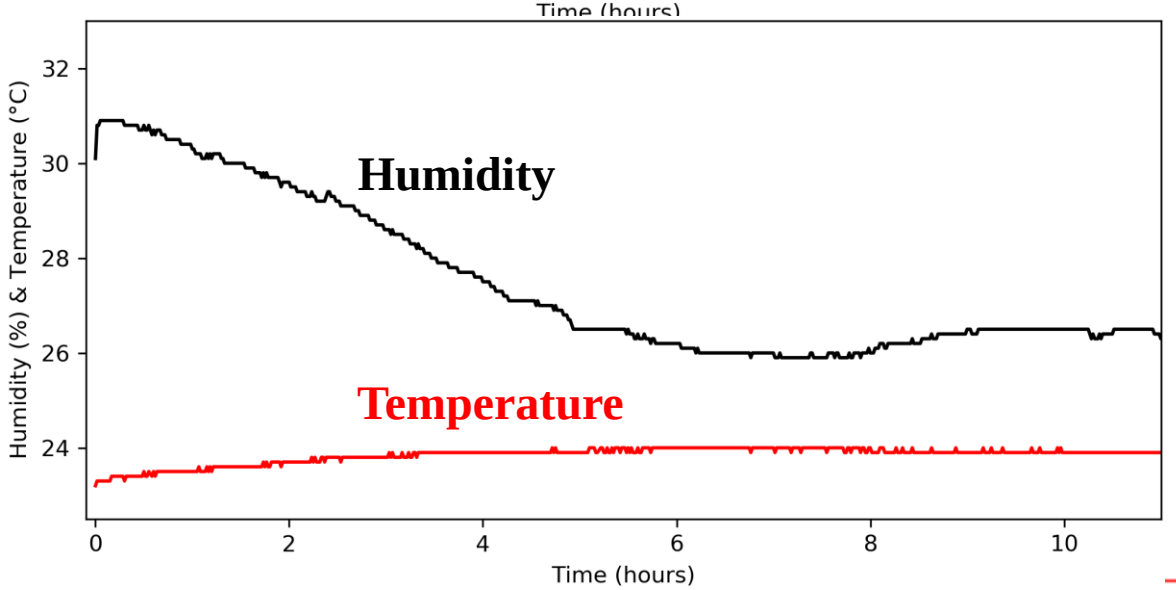




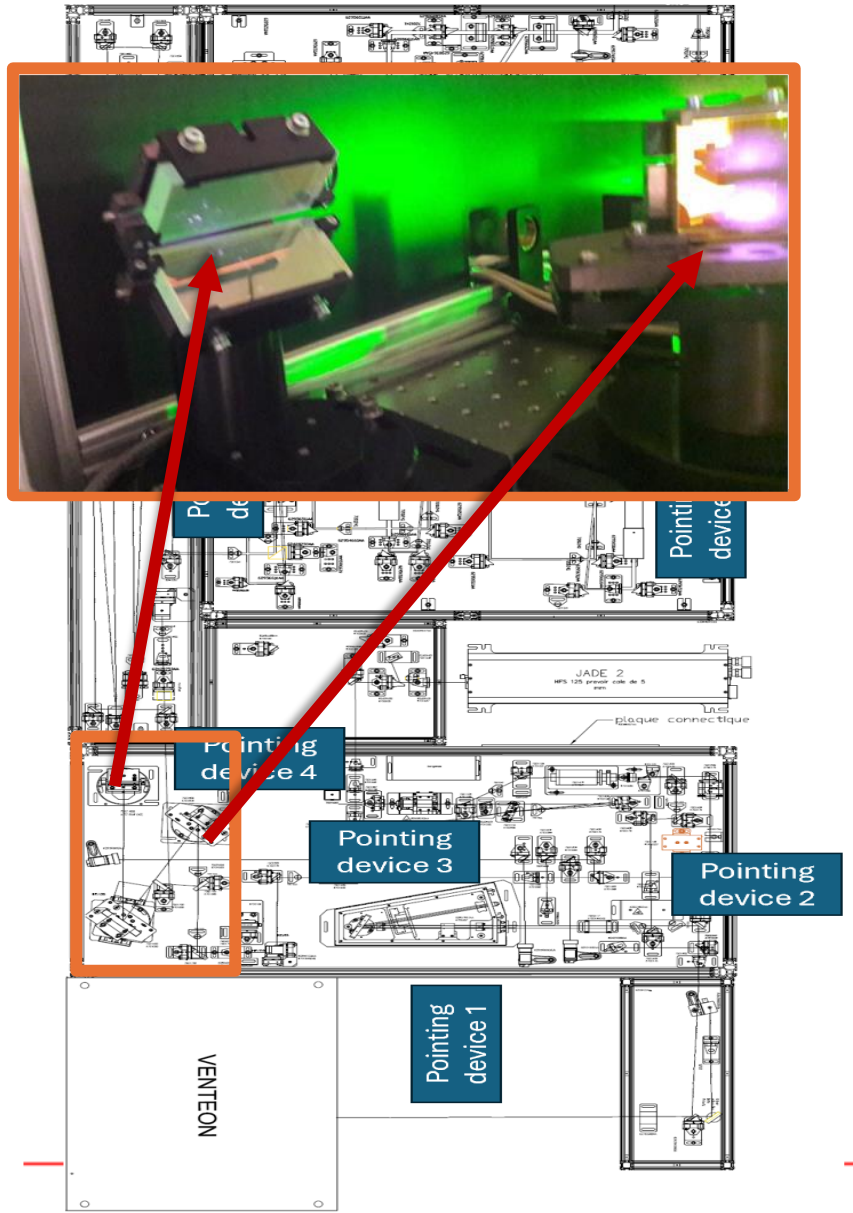
BEAM POINTING MEASUREMENTS IN HPLS FRONTEND A – REGENERATIVE AMPLIFIER

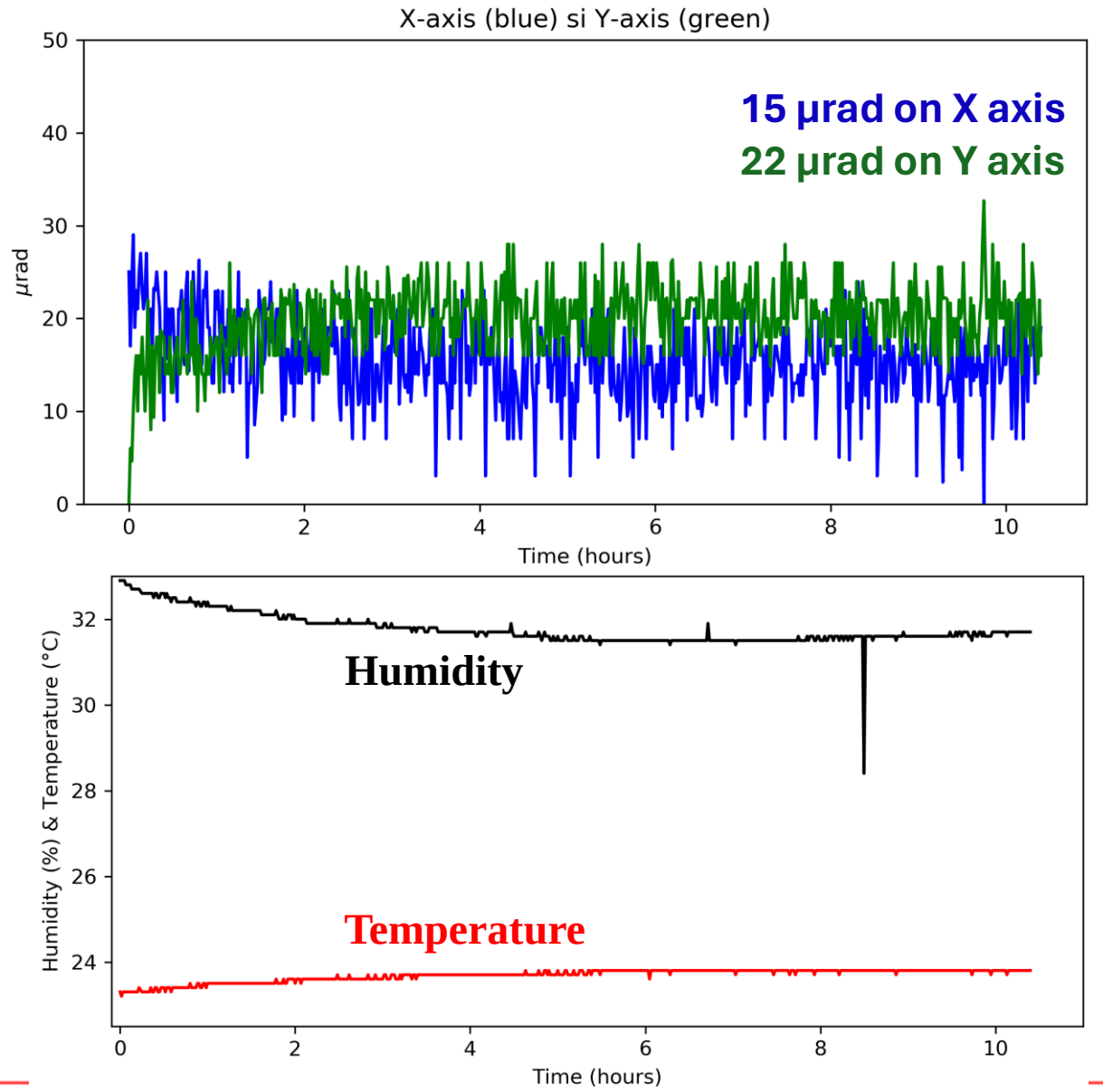




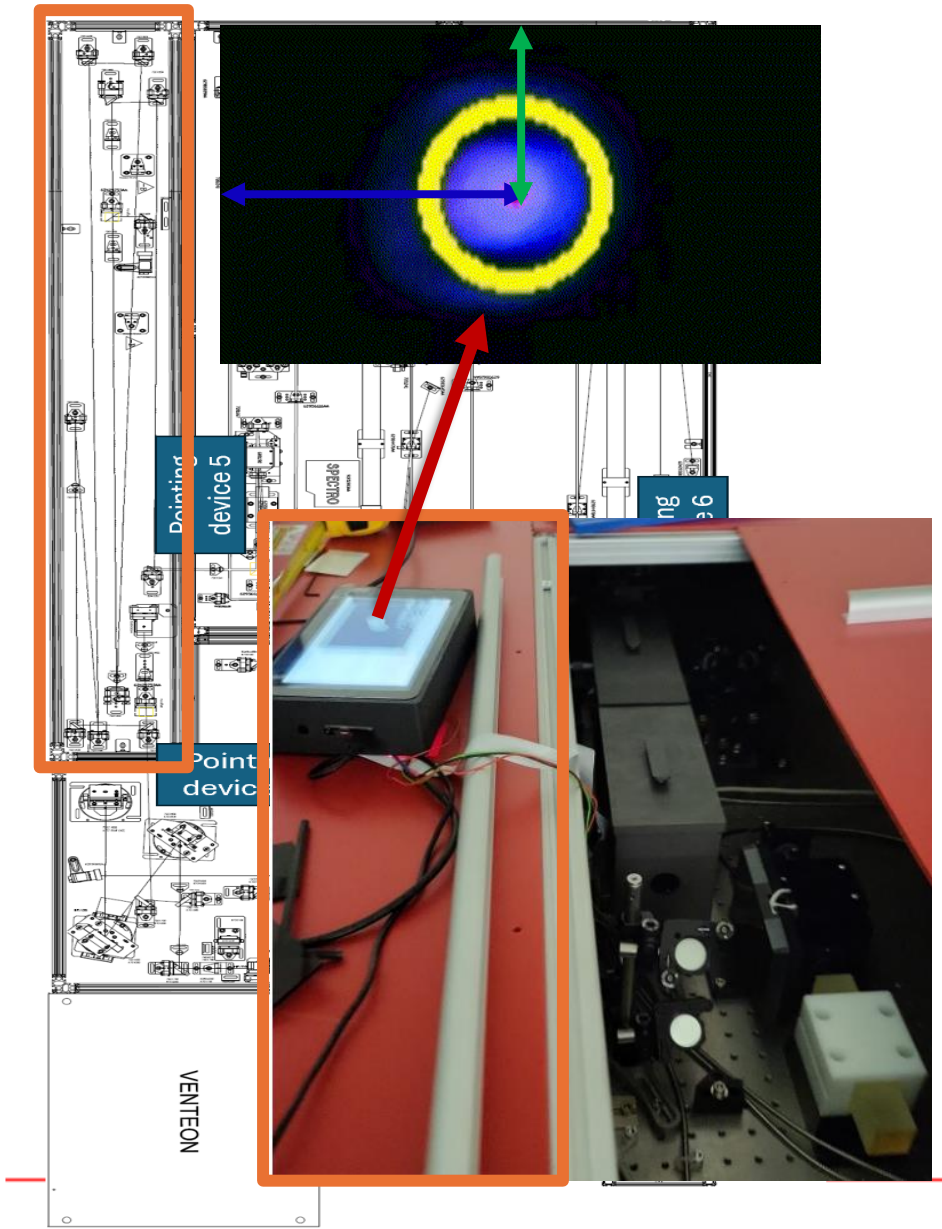


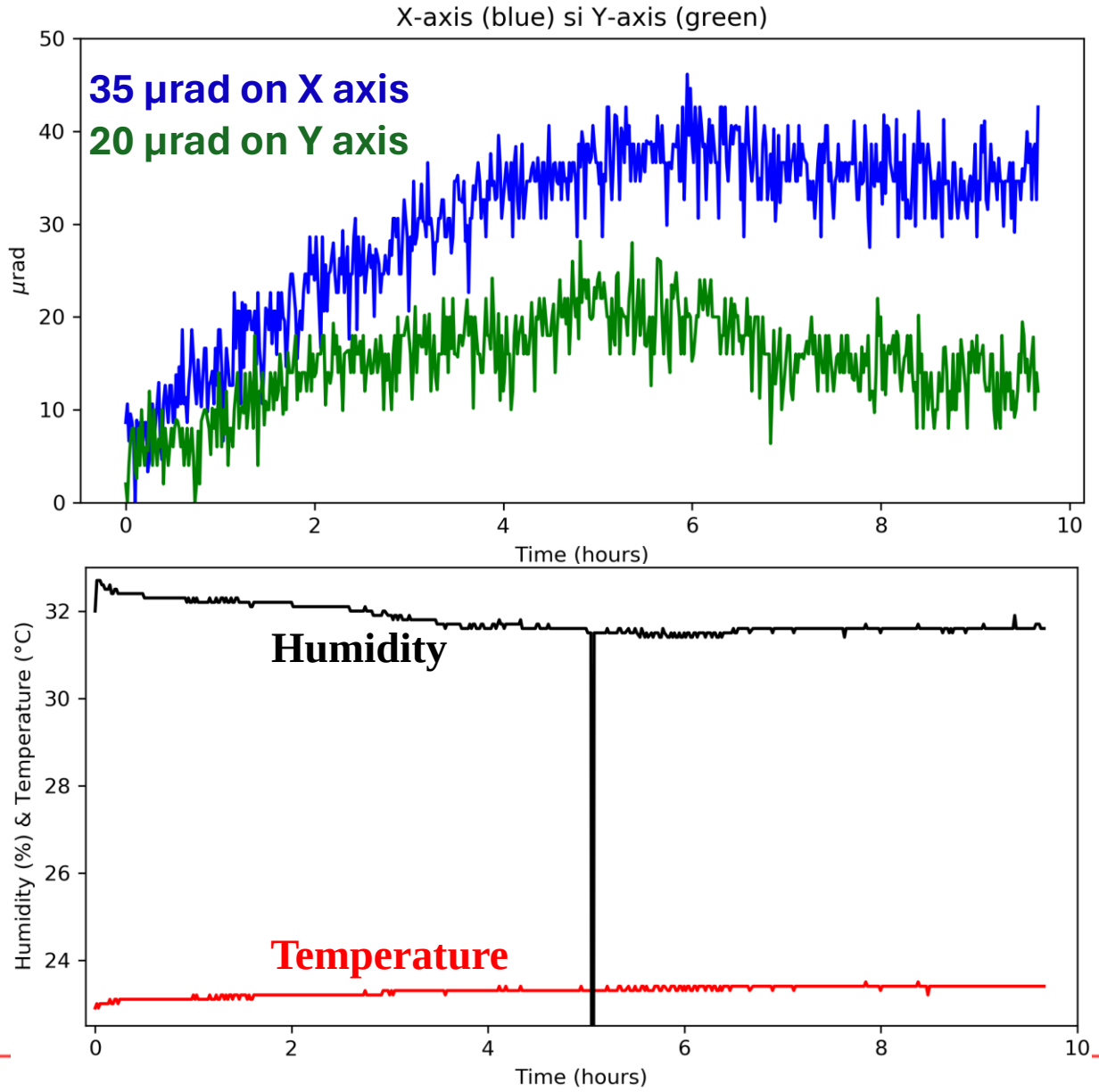
BEAM POINTING MEASUREMENTS IN HPLS
FRONTEND A – COMPRESOR KHZ





BEAM POINTING MEASUREMENTS IN HPLS FRONTEND A – XPW



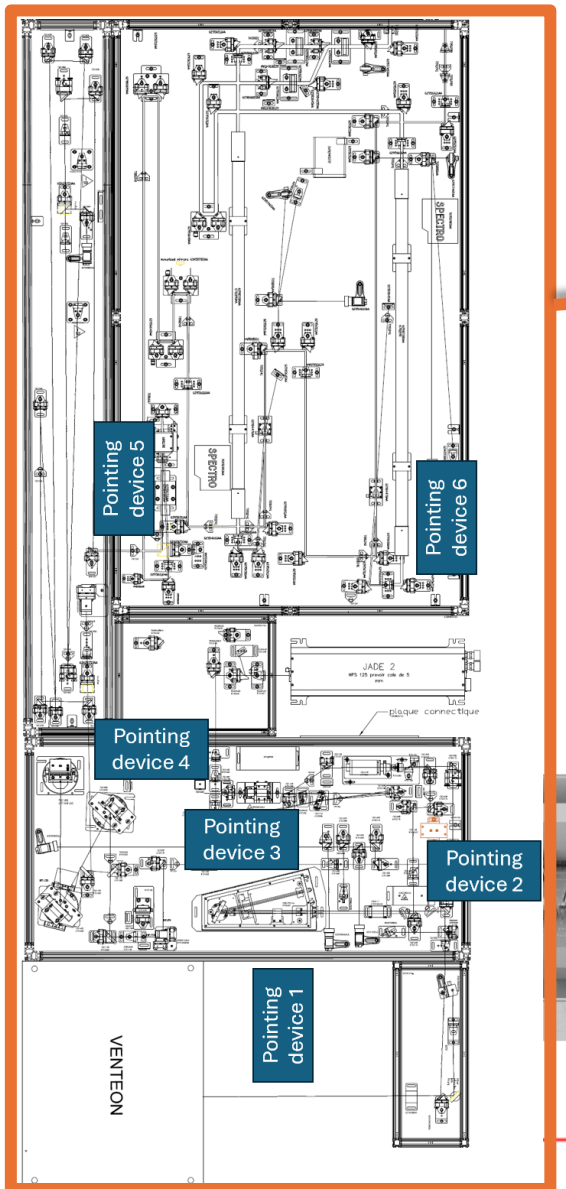


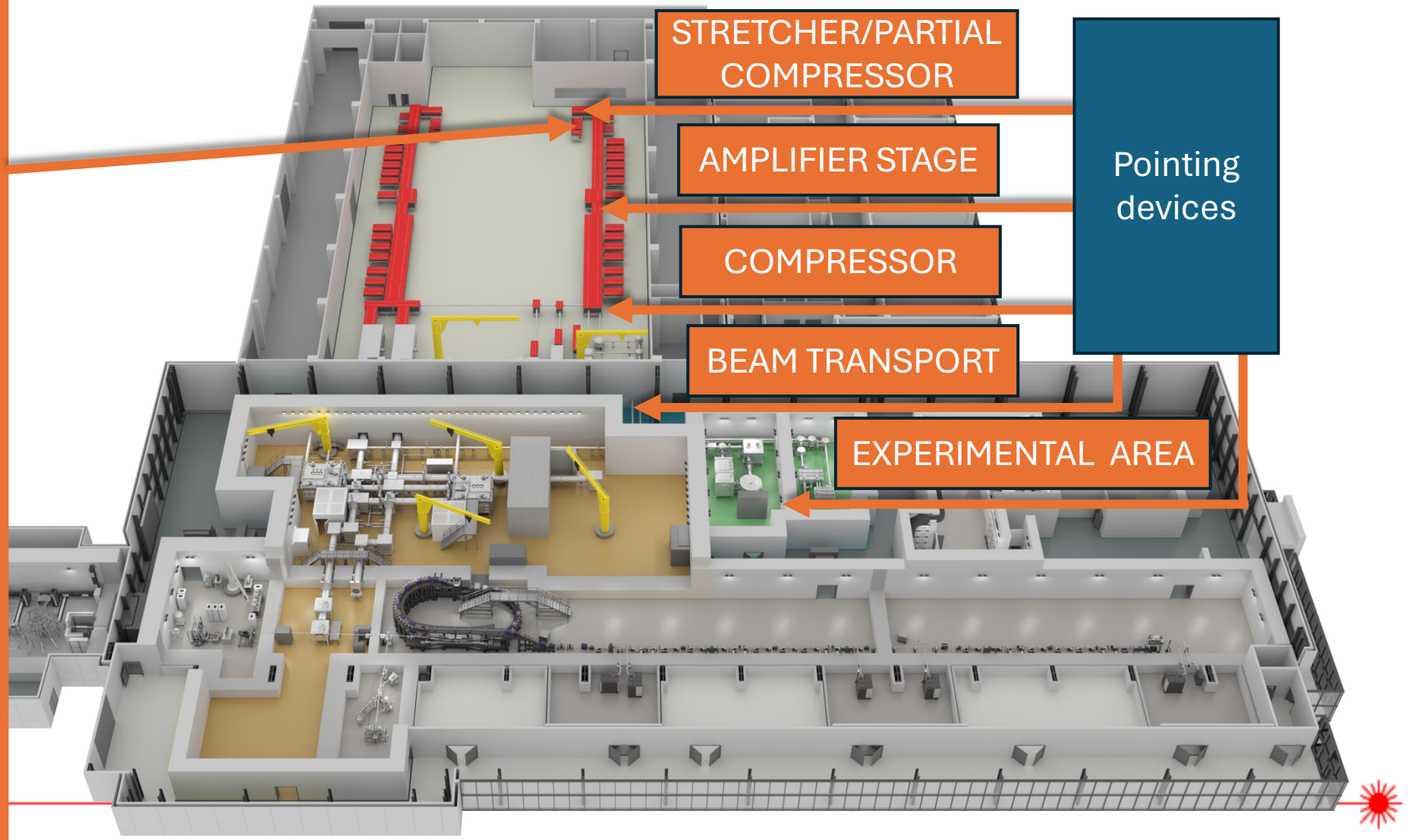
BEAM POINTING MEASUREMENTS IN HPLS FRONTEND A

FRONT END ARM A	Beam drift [µrad]		Pointing stability [µrad]		Error measurements [µrad]	Temperature Variation	Humidity Variation
MODULE	X axis	Y axis	X axis	Y axis	Both axis	[°C]	[%]
Oscilator	2	9	2	10	2 - 3	0.2	2.4
Stretcher CEP	5.5	12	4	8	2 - 3	0.2	3.5
Regen AMP	3	20	2	4	2 - 3	0.8	5
KHz CMP	15	22	15	10	2 - 3	0.6	1.5
XPW	35	20	15	10	2 - 3	0.5	1.2
OPCPA	-	-	-	-	-	-	-

FEATURE PERSPECTIVE – CORRELATION MEASUREMENTS

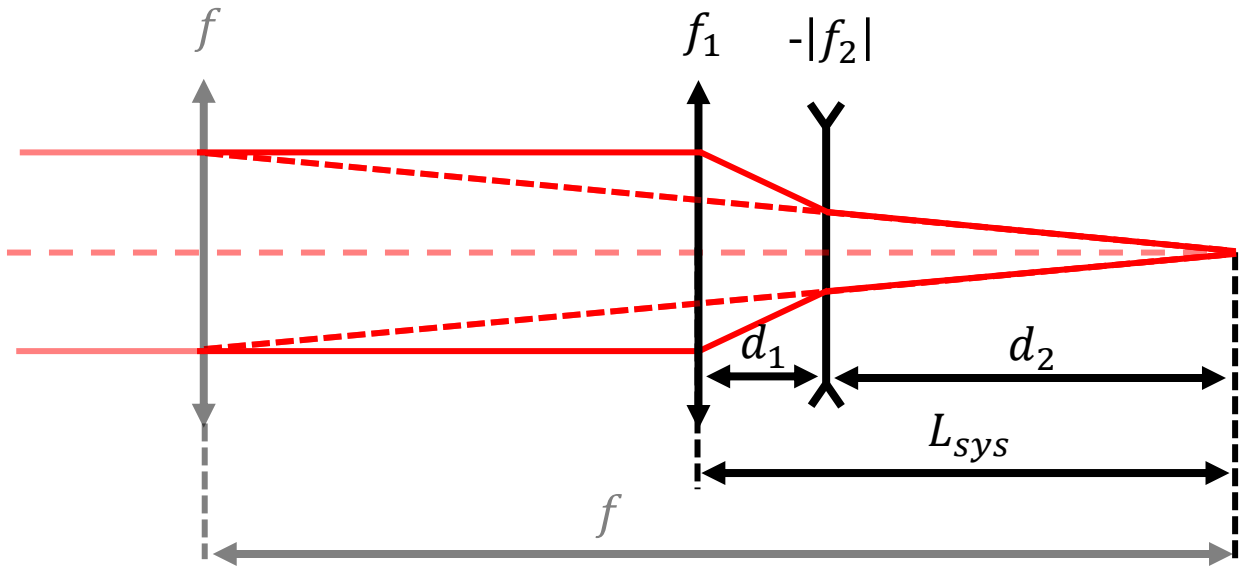
SIMULTANEOUSLY MEASUREMENTS





Decreasing the dimension size of the system and keeping the same sensitivity for pointing measurements (same focal distance)

TELE-PHOTO LENS ASSY

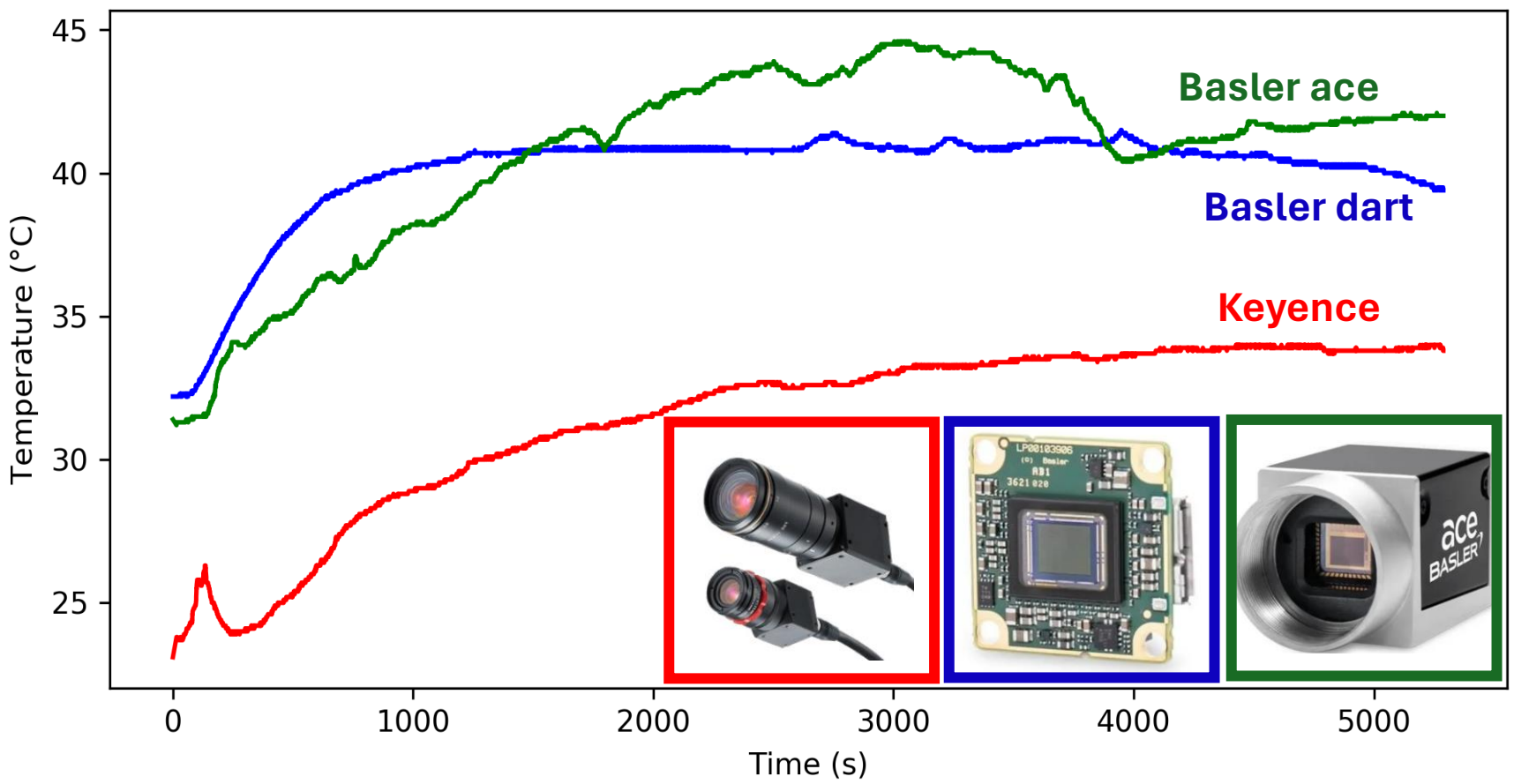


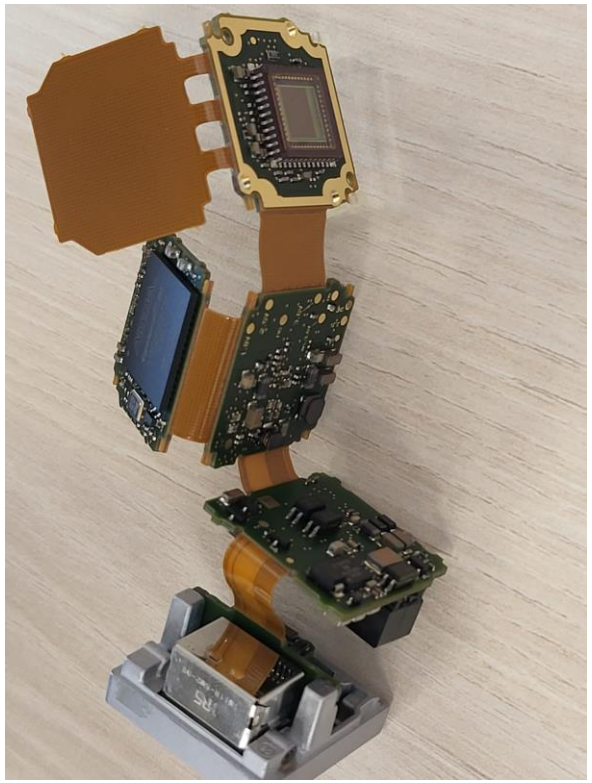
$$f_{sys} = \begin{pmatrix} 1 & 0 \\ 1/f_2 & 1 \end{pmatrix} \begin{pmatrix} 1 & d_1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ -f_1 & 1 \end{pmatrix}$$

$$f = (f_1|f_2|)/[d_1 - (f_1 - |f_2|)]$$

$$d_2 = |f_2|\,(f_1 - d_1)/[d_1 - (f_1 - |f_2|)]$$

Choosing a low-heating camera for pointing monitor device





electronic heating source

SUMMERY

IMPORTANCE

- Reproducibility of constant parameters of the laser beam
- Good data results on the experimental side

SOURCE OF POINTING INSTABILITY

- Air turbulence
- Temperature fluctuation/inhomogeneity in space
- Long distance of propagation

ACHIEVEMENTS

- Development of prototype/moveable pointing monitor system
- Software implementation for data analysis
- Beam pointing measurements on each subsystem from Frontend in HPLS

FUTURE PERSPECTIVE

- Increase the number of devices for pointing measurements
- Simultaneously measurements in HPLS and Experimental side
- Reducing the dimension of the device

EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007-2013

Sectoral Operational Programme "Increase of Economic Competitiveness"

"Investments for Your Future!"

IFIN-HH

Extreme Light Infrastructure - Nuclear Physics (ELI-NP) - Phase II

eli Nuclear Physics

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Project co-financed by the European Regional Development Fund

Thank you!