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SAMPLE STABILIZATION FOR TOMOGRAPHY EXPERIMENTS IN PRESENCE OF LARGE PLANT UNCERTAINTY

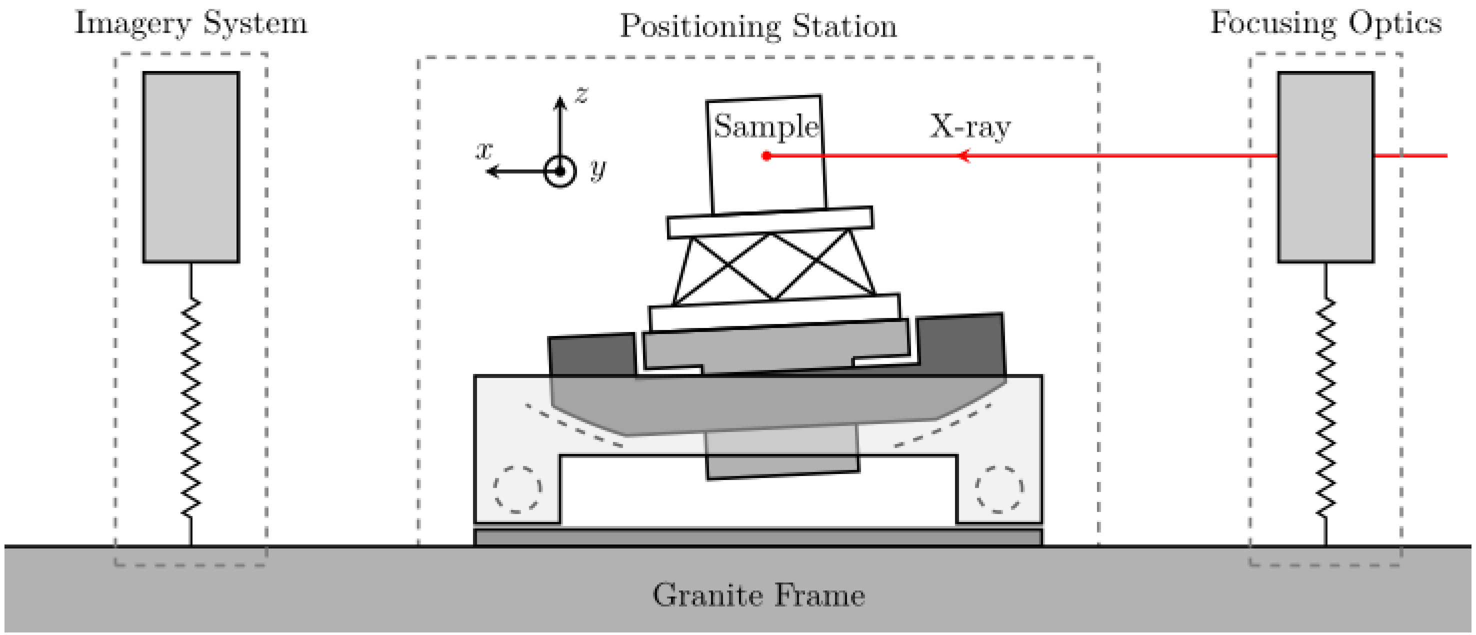
T. Dehaeze
M. Magnin-Mattenet
C. Collette

ESRF
The European Synchrotron

Precision Mechatronics Laboratory

MEDSI
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION
PARIS 2018

INTRODUCTION – ID31 END STATION



Scientist in Charge
Veijo Honkimakï

Goal
Complex Trajectories
$\approx 10nm$ - Translations
$\approx 2\mu rad$ - Rotations
Long time stability

Hard X-rays:
21 – 150keV
Beam size:
down to $200nm$ using nano focusing optics

Many experiments:
X-ray diffraction tomography, reflectivity, Truncation Rod, etc.

Many applications:
Materials science, chemistry, physics, etc.

OUTLINE

SAMPLE STABILIZATION FOR TOMOGRAPHY EXPERIMENTS

1. ID31 Positioning End Station

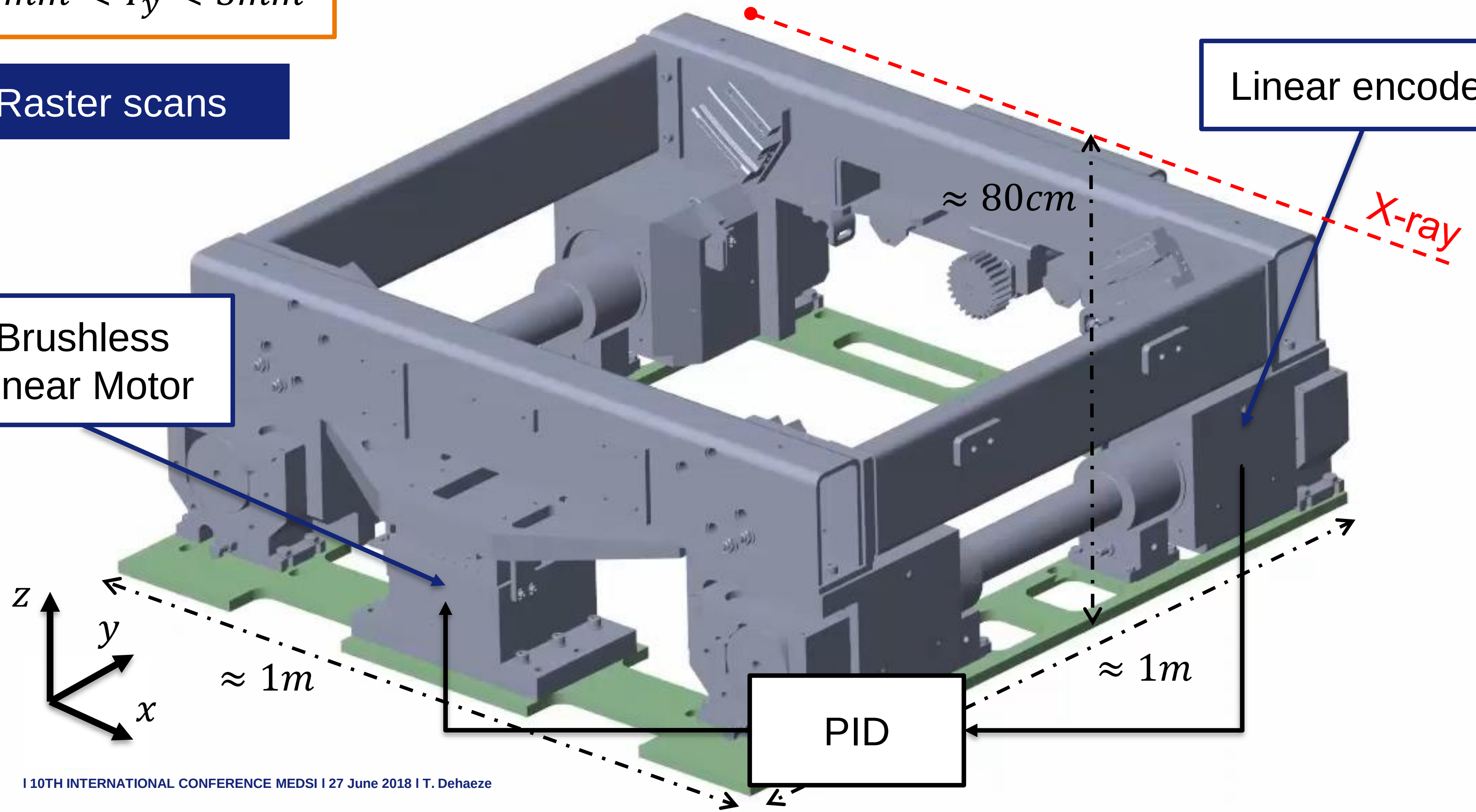
2. Multibody Model of the End Station

3. Nano Active Stabilization System (NASS)

I. TRANSLATION STAGE

$-5mm < T_y < 5mm$

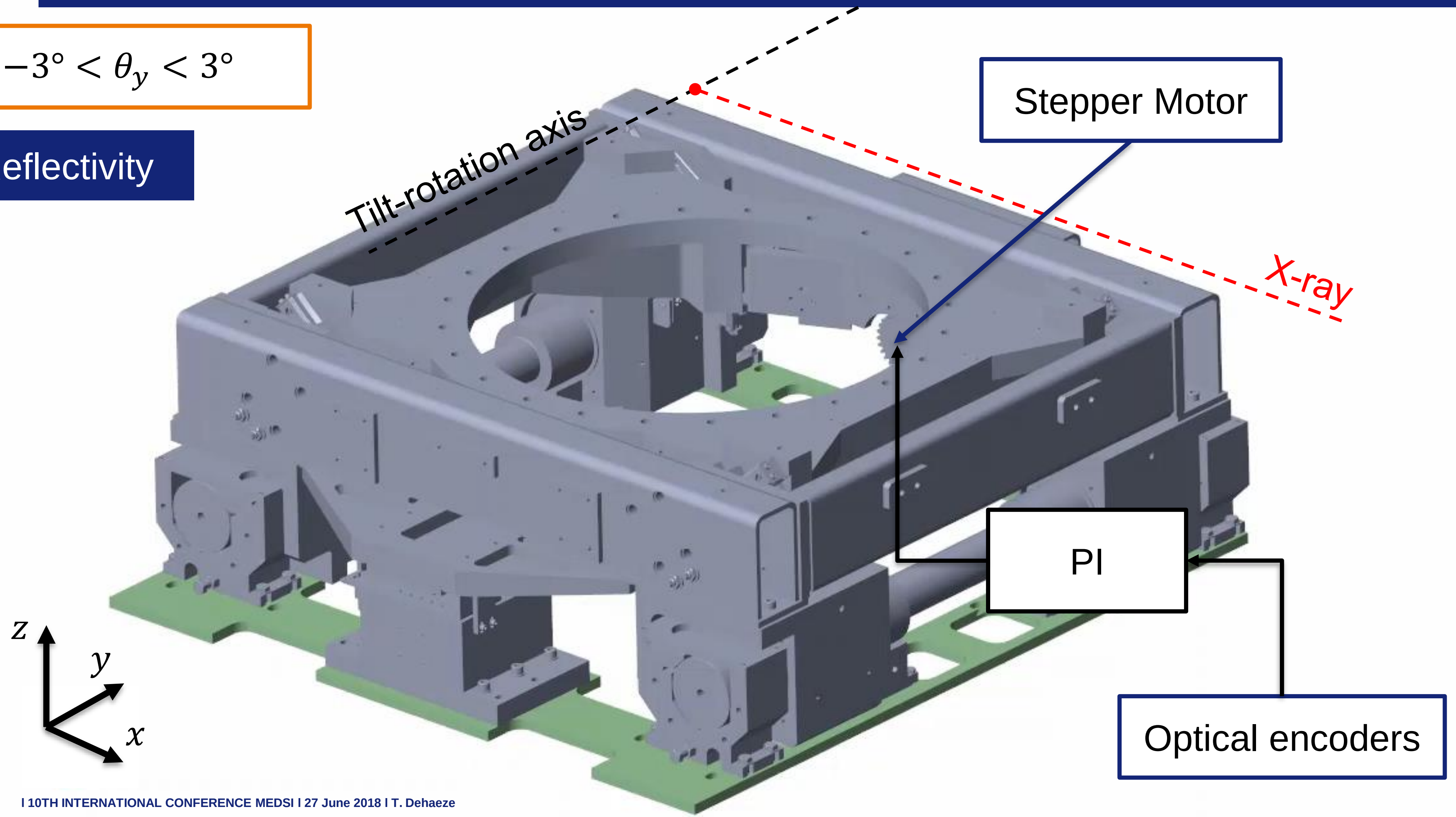
Raster scans



I. TILT STAGE

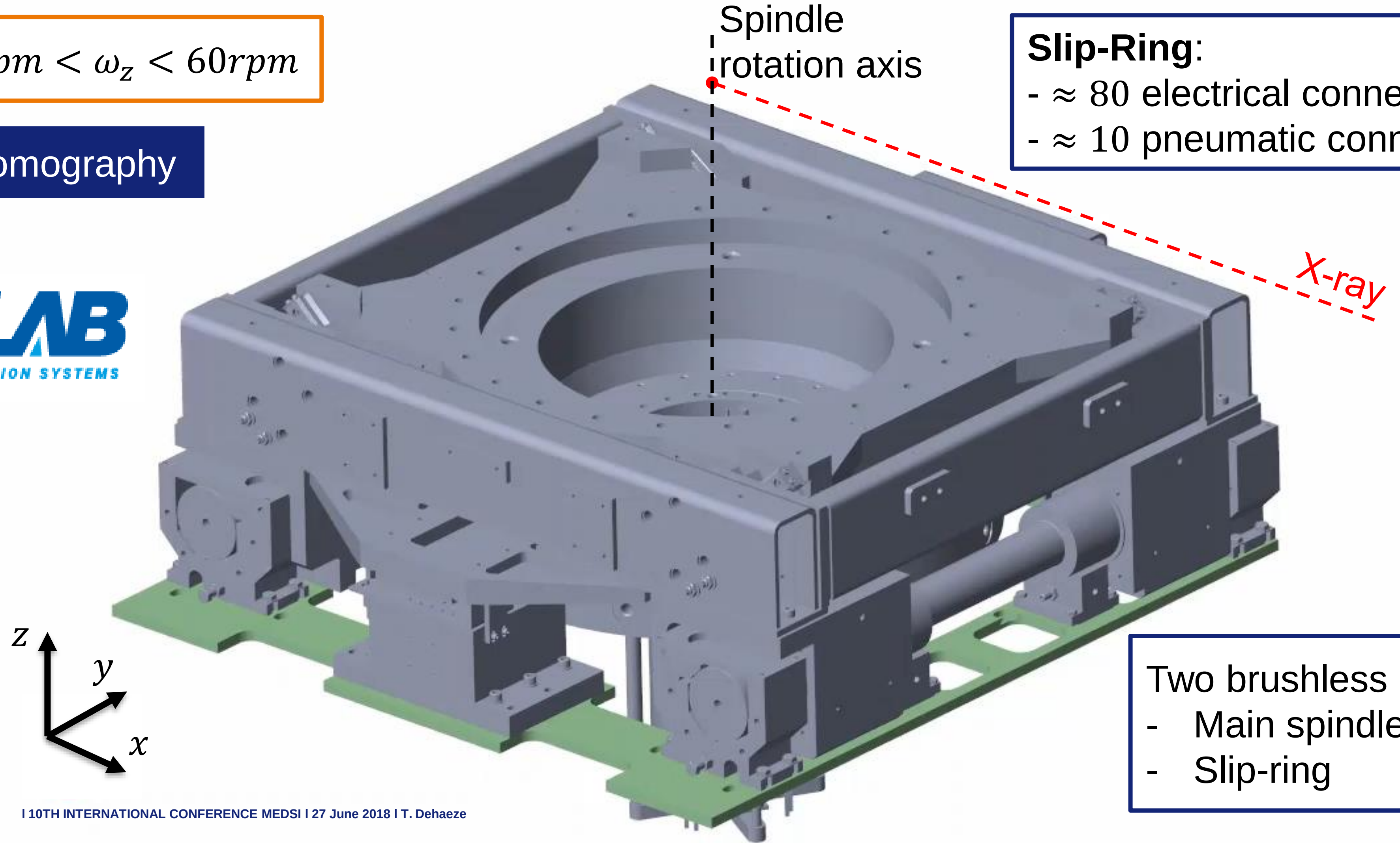
$$-3° < \theta_y < 3°$$

Reflectivity



$1rpm < \omega_z < 60rpm$

Tomography



Slip-Ring:
- ≈ 80 electrical connections
- ≈ 10 pneumatic connections

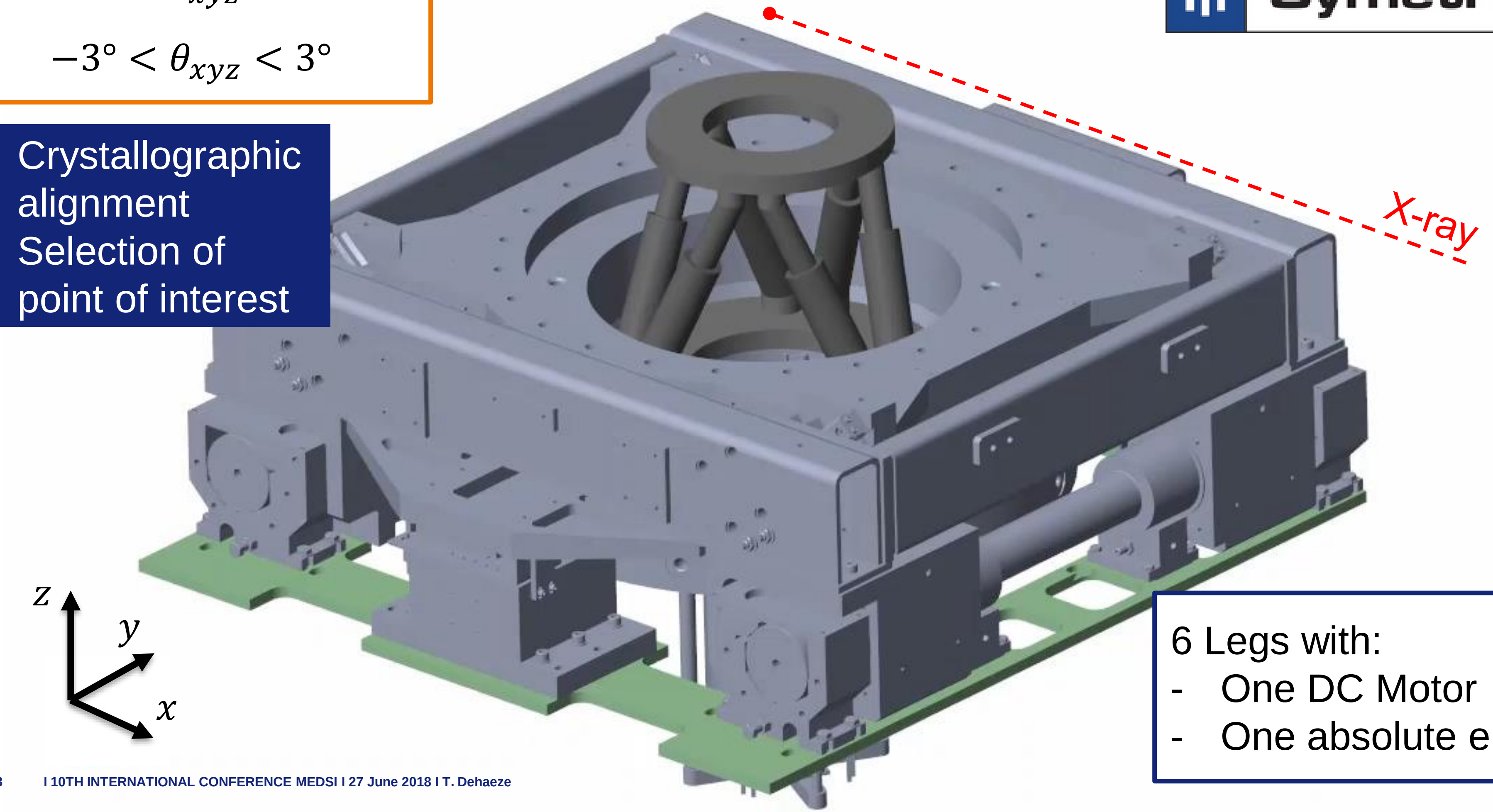
Two brushless motors:
- Main spindle
- Slip-ring

I. LONG STROKE HEXAPOD

$$-10mm < T_{xyz} < 10mm$$

$$-3° < \theta_{xyz} < 3°$$

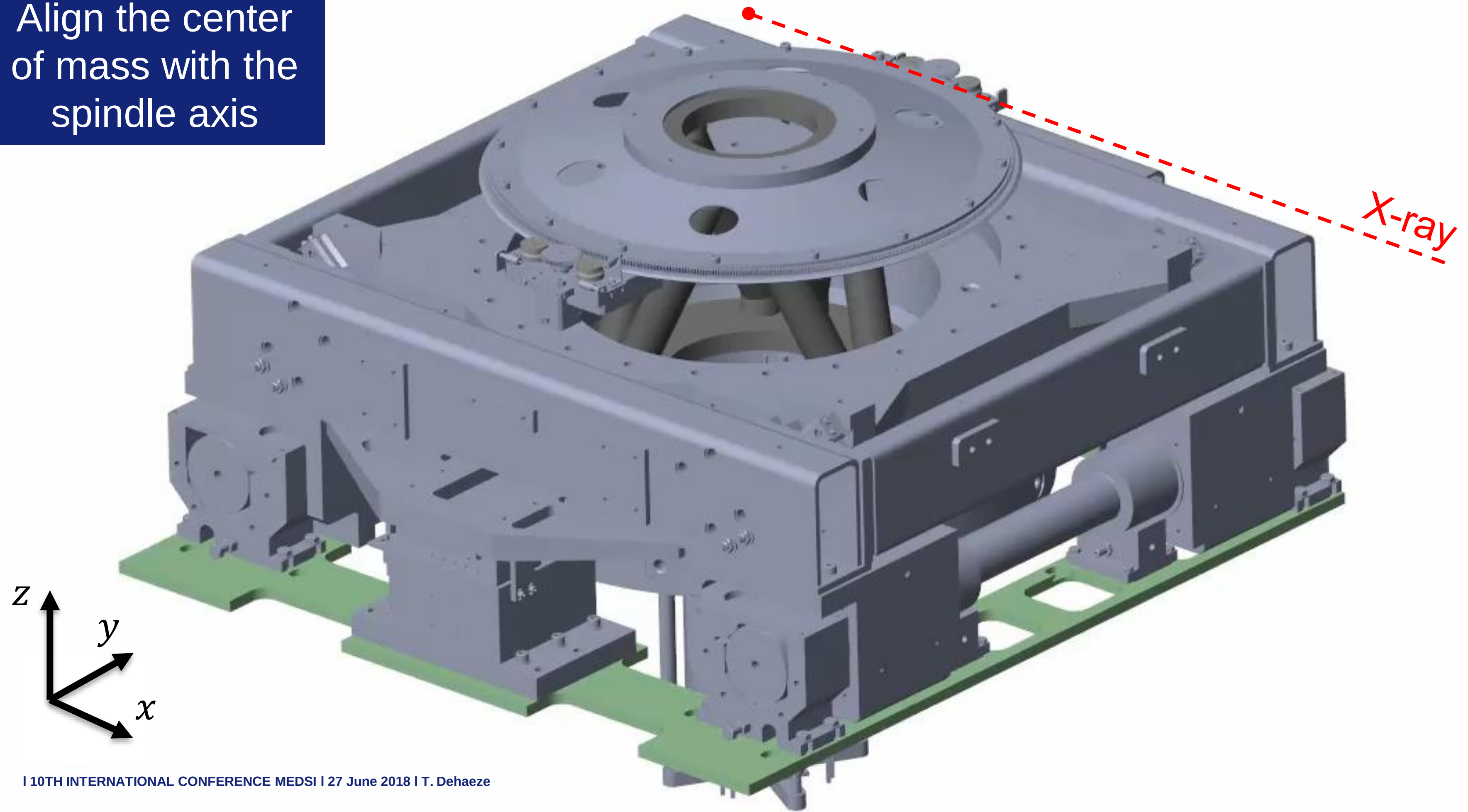
- Crystallographic alignment
- Selection of point of interest



6 Legs with:
- One DC Motor
- One absolute encoder

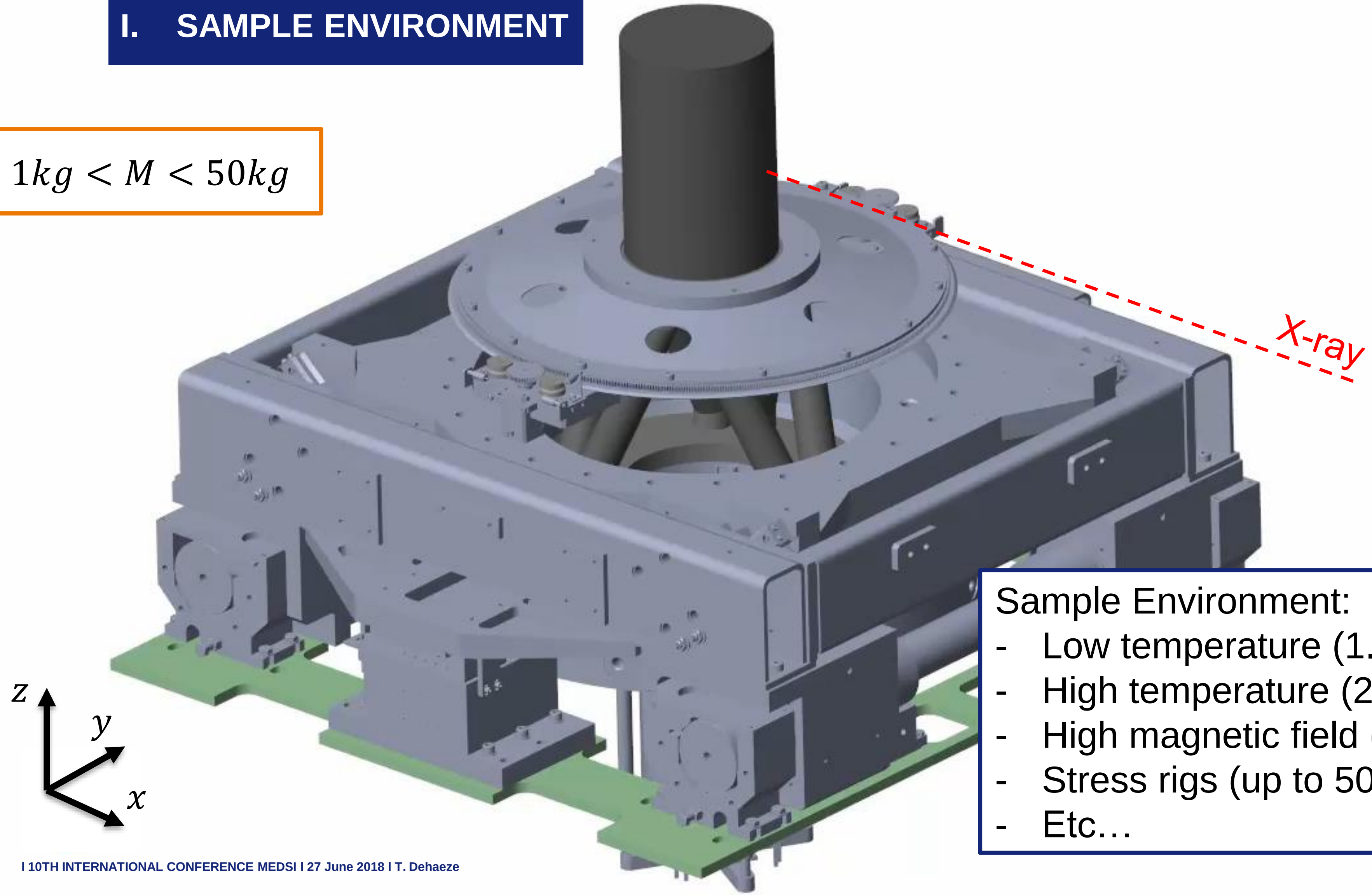
I. GRAVITY COMPENSATOR SYSTEM

Align the center of mass with the spindle axis



I. SAMPLE ENVIRONMENT

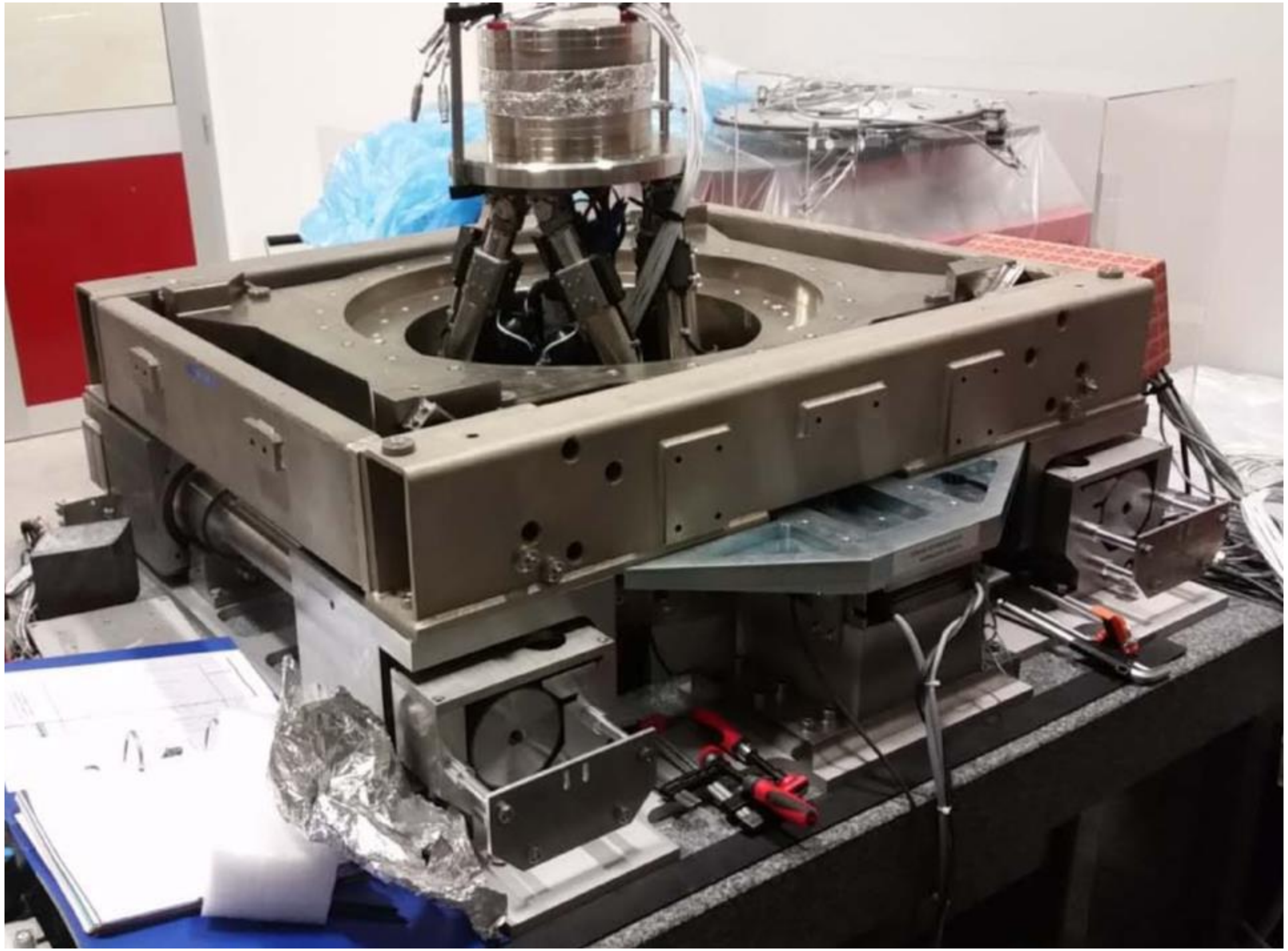
$$1kg < M < 50kg$$



Sample Environment:

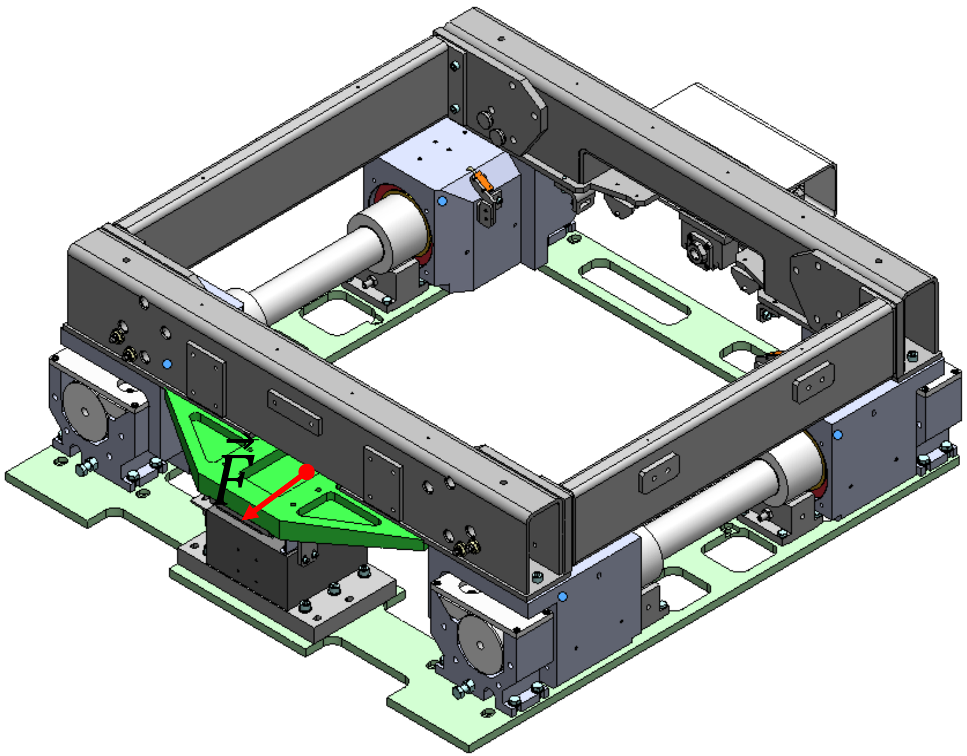
- Low temperature (1.2K)
- High temperature (2000K)
- High magnetic field (8T)
- Stress rigs (up to 50kN)
- Etc…

I. THE ID31 MICRO-STATION



Courtesy C. Clavel

II. SIMSCAPE MODEL – MULTIBODY MODEL



We need measurements to tune the model parameters

Why develop such model?

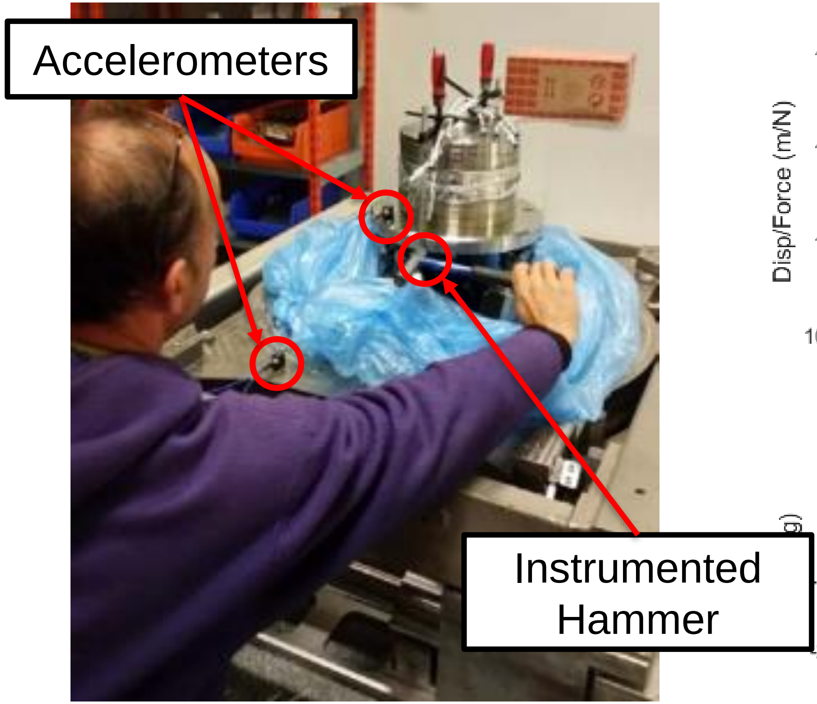
- Study the effect of perturbations
- Influence of M on the dynamics
- **Study the NASS concept**
- **Validation**: simulations of experiments

Need a model that:

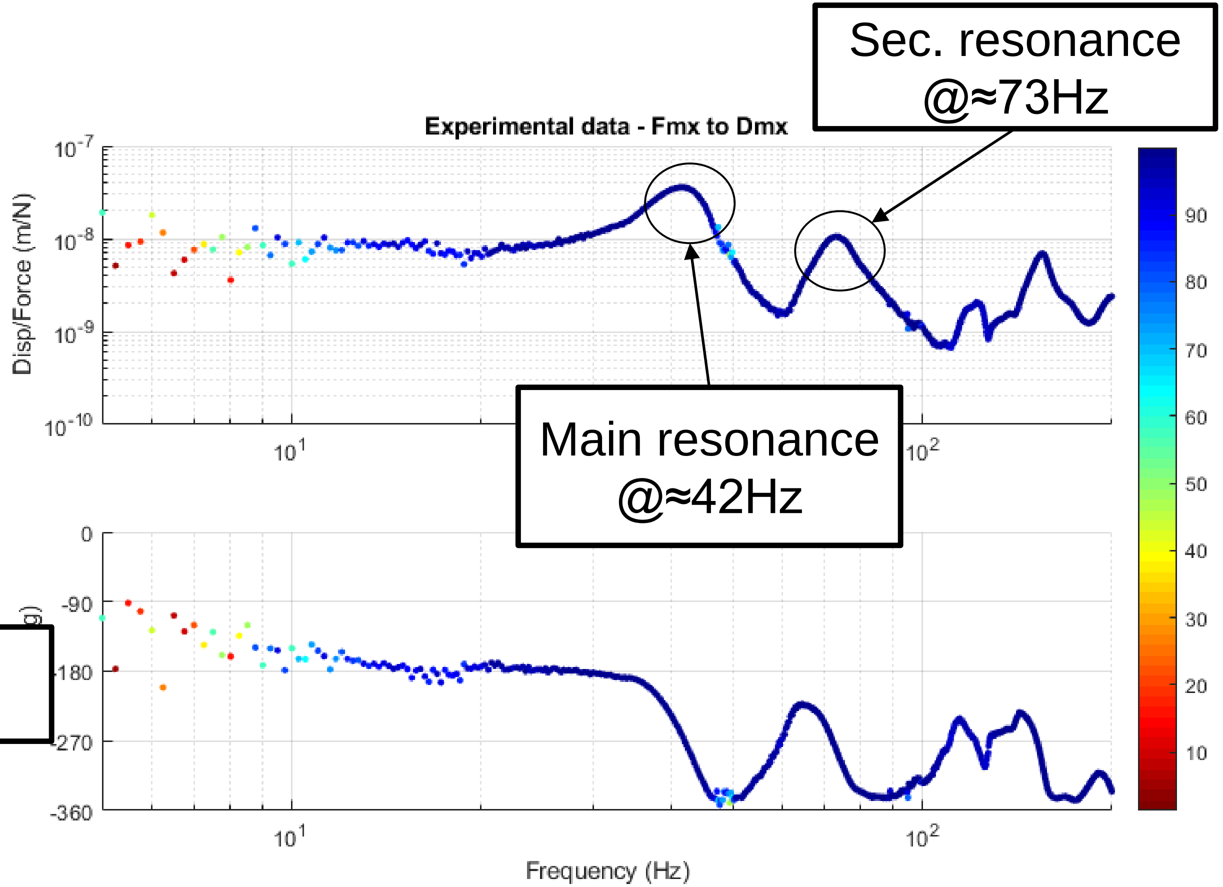
- Represent the dynamics of the system
- Include sources of perturbations and noise

Simscape multibody model:

- Solid bodies connected by spring and dampers
- Includes actuator and sensor
- Ground motion, sensor noise, control noise, etc.

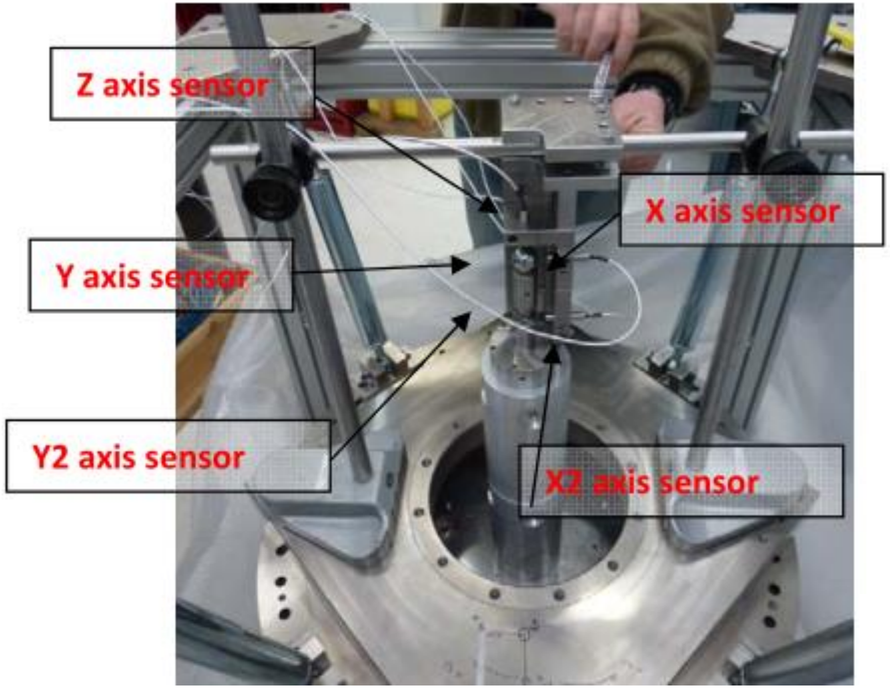


Courtesy M. Lesourd



II. CHARACTERIZATION OF EACH STAGE

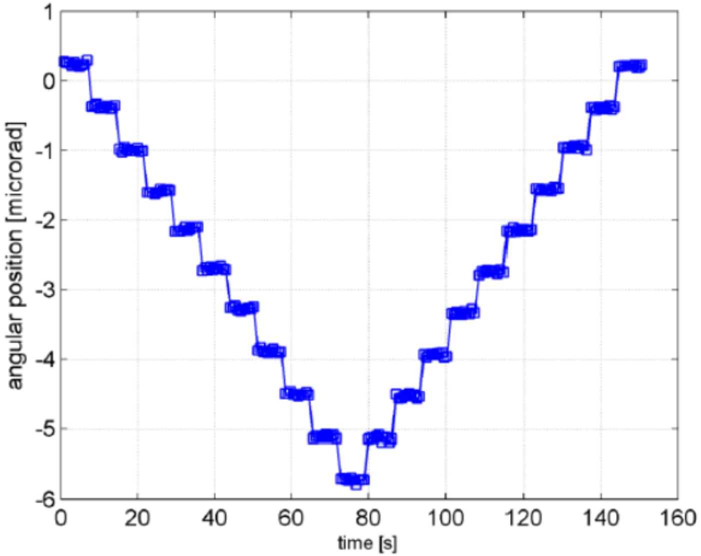
Measurements on the Spindle



Courtesy HP Van Der Kleij

Precision Engineering Laboratory (PEL)

MIM of the Spindle



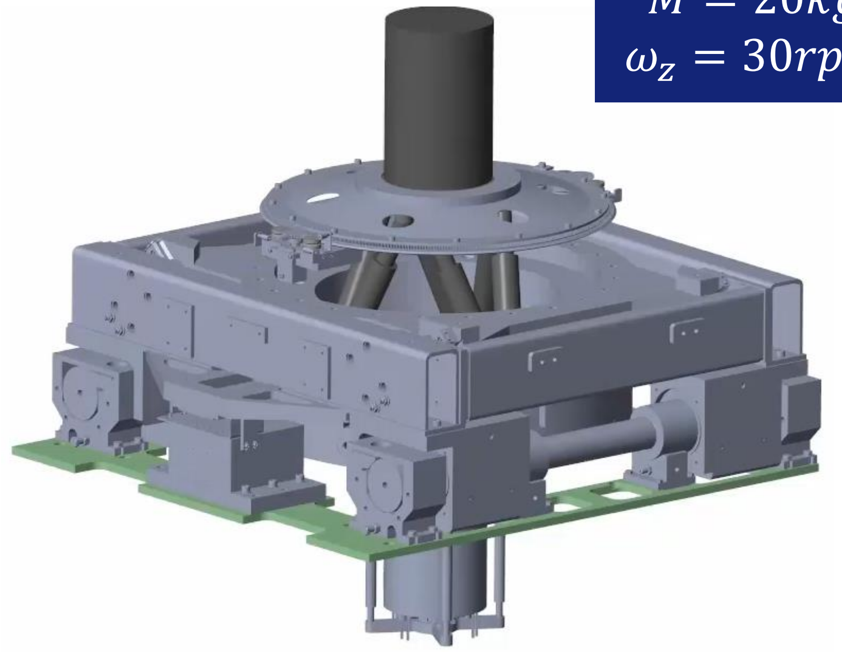
Characterization:

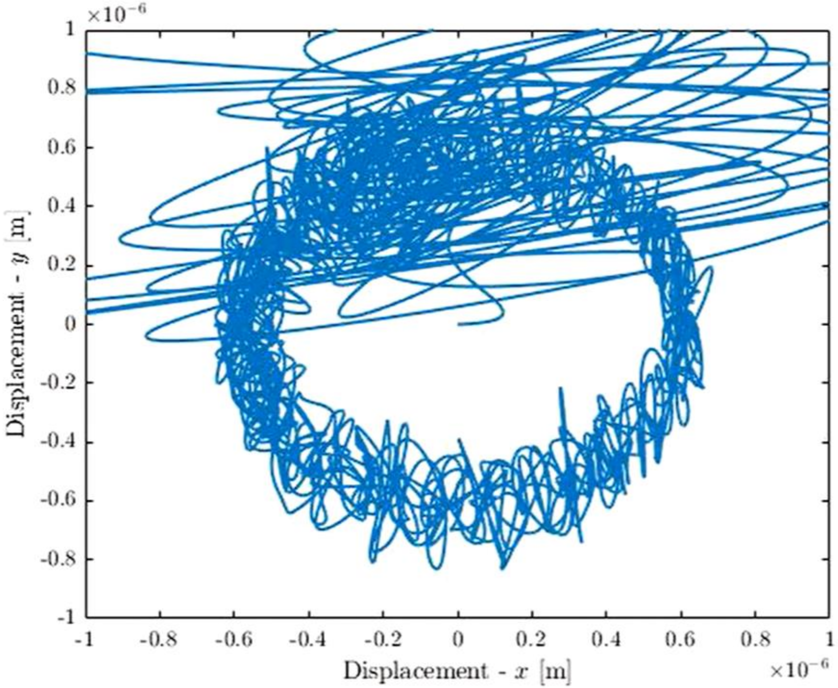
- Straightness / Flatness / …
- Stiffness
- Resolution / MIM

Use to tune the model parameters

II. PRECISION - SIMULATION OF TOMOGRAPHY EXPERIMENT

$$M = 20kg$$
$$\omega_z = 30rpm$$

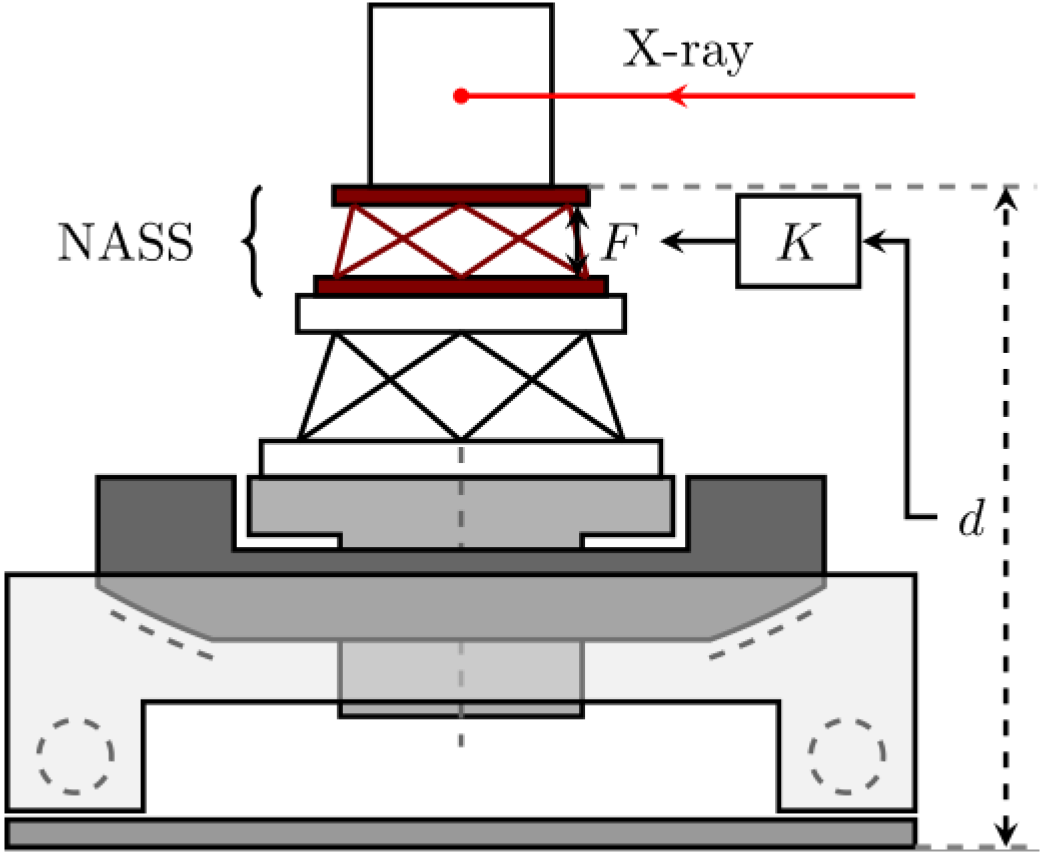




X-Y Position of the sample

$\approx \mu m$ precision → NASS → $\approx nm$ precision

III. THE NANO ACTIVE STABILIZATION SYSTEM (NASS)



6DoF Short Stroke Hexapod

- Voice coil or piezo-stack actuators
- Rough specifications:

Motion	Stroke	Repetability
T_{xyz}	$\pm 10\,\mu m$	$10\,nm$
θ_{xyz}	$\pm 10\,\mu rad$	$1.7\,\mu rad$

6DoF Metrology System (Under Study)

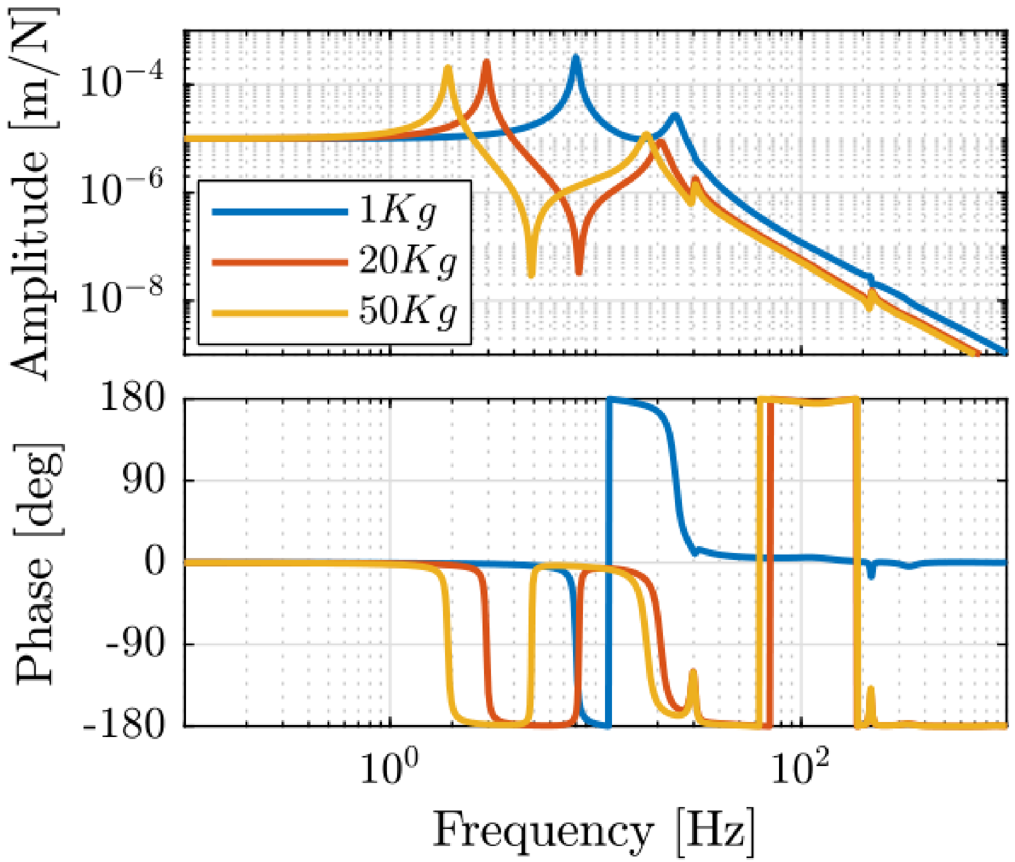
- Interferometric measurement
- Long term stability ($\approx 10nm$ for 8 hours)

MI PARTNERS — PARTNERS IN MECHATRONIC INNOVATION

Study this concept with the multibody model

III. PLANT IDENTIFICATION

Force applied along x to a displacement along x

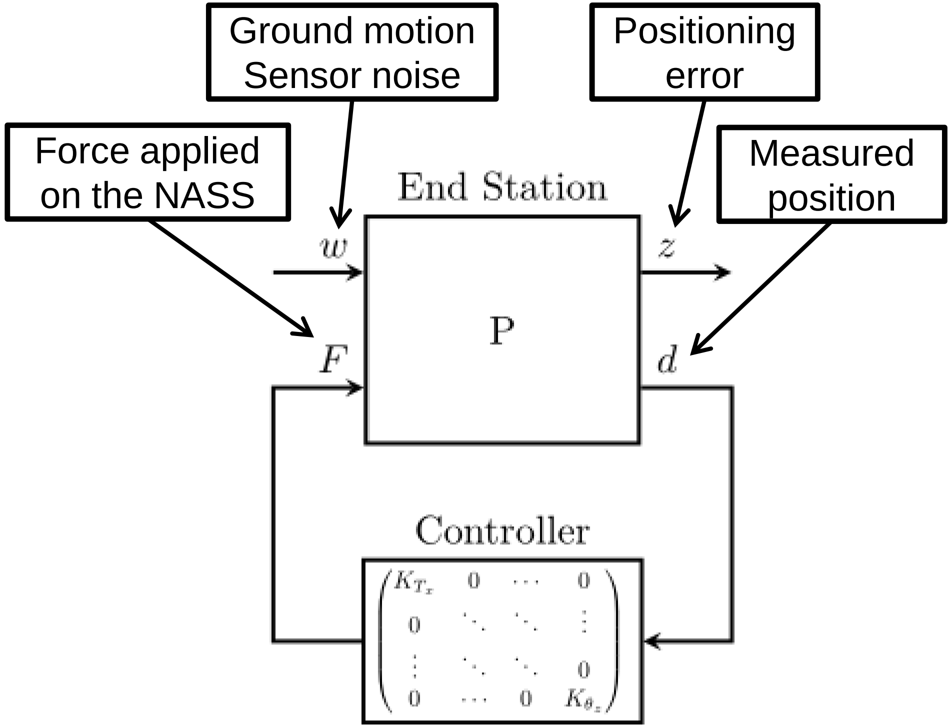


Need Robust control techniques

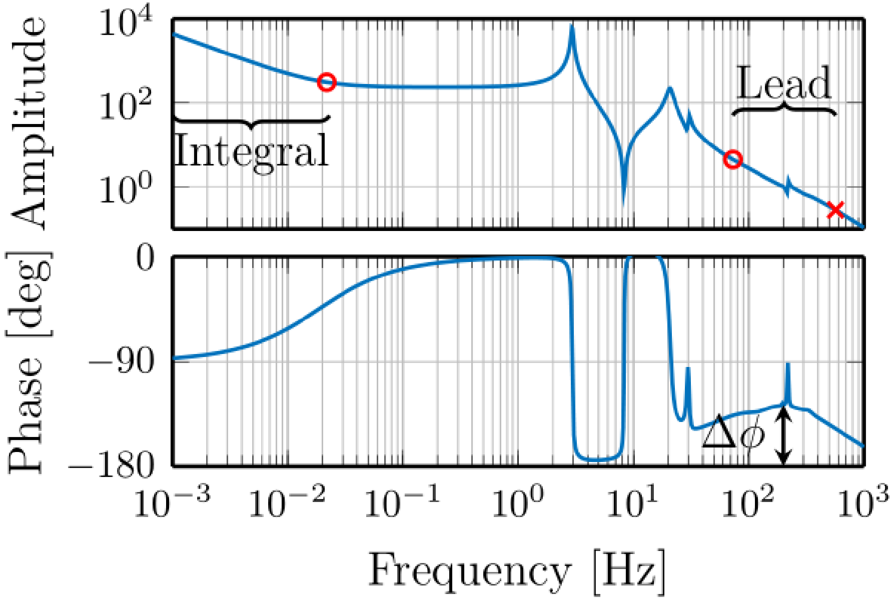
To determine the performances that we can obtain:

- $M = 20kg$
- $\omega_z = 30rpm$

III. CONTROL STRATEGY

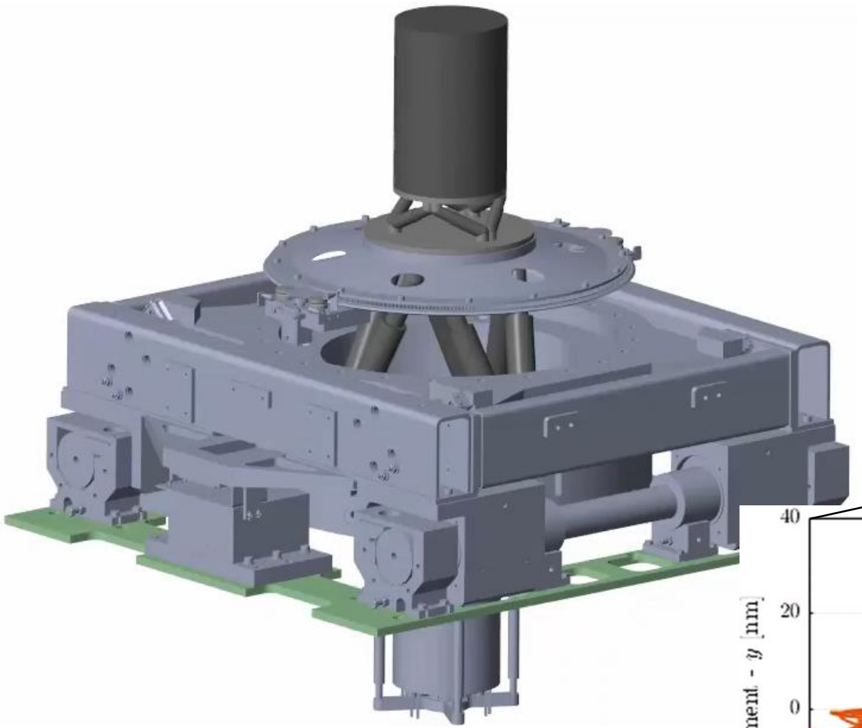


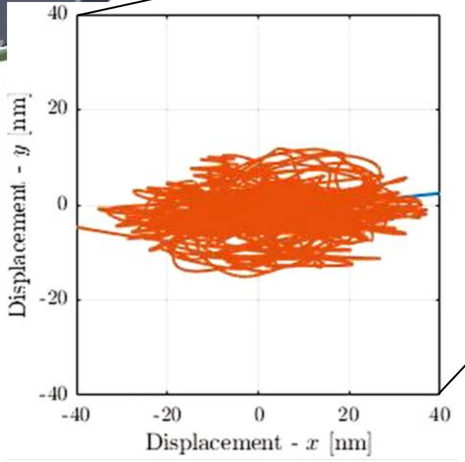
Start with diagonal controller

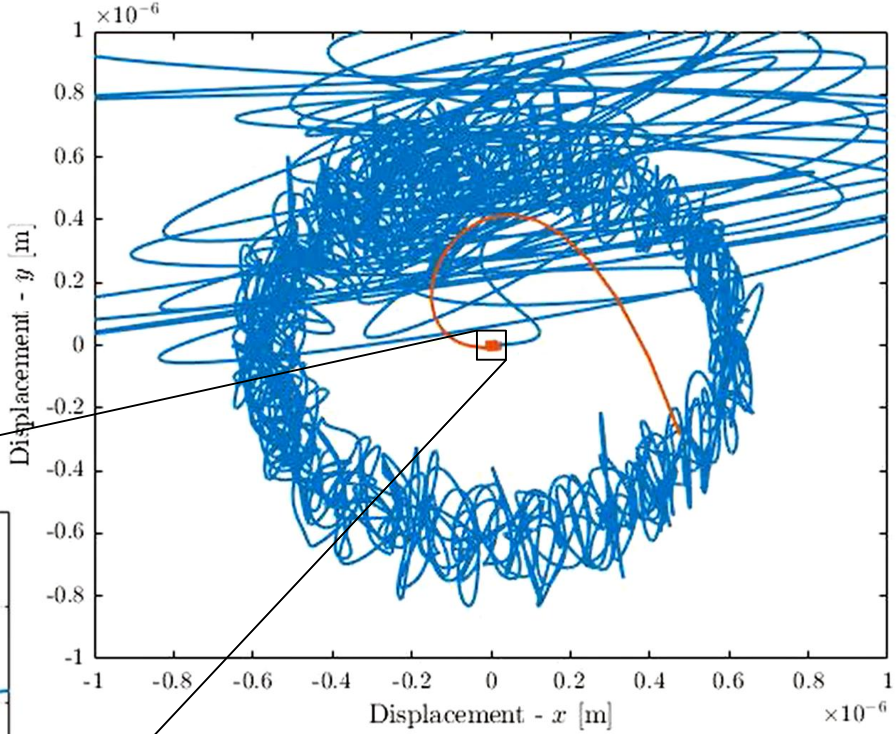


Loop gain for the x direction using a lead/lad compensator

III. SIMULATION OF TOMOGRAPHY EXPERIMENT







X-Y Position of the sample

From $\approx \mu m$ to $\approx nm$ precision

CONCLUSION & PERSPECTIVE

ID31 End-station:
- Versatile: various experiments/sample environment
- In order to obtain a nm precision, a **6DoF active stabilization stage** is proposed
- Even with a simple control architecture, the parasitic motions of the sample can be reduced down to $50nm$

The NASS could be applied for other positioning stages

To further improve the system:
- Advance control architectures: hybrid feedback/feedforward, HAC/LAC feedback control
- Robust control techniques: H_∞ control, μ-synthesis, etc.

Thank you for your attention!

Any Questions?

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T. Dehaeze
thomas.dehaeze@esrf.fr

M. Magnin-Mattenet
magnin-mattenet@esrf.fr

C. Collette
ccollett@ulb.ac.be

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