# The ESRF nano-precision engineering platform:

# Overview and first results

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# OUTLINE:

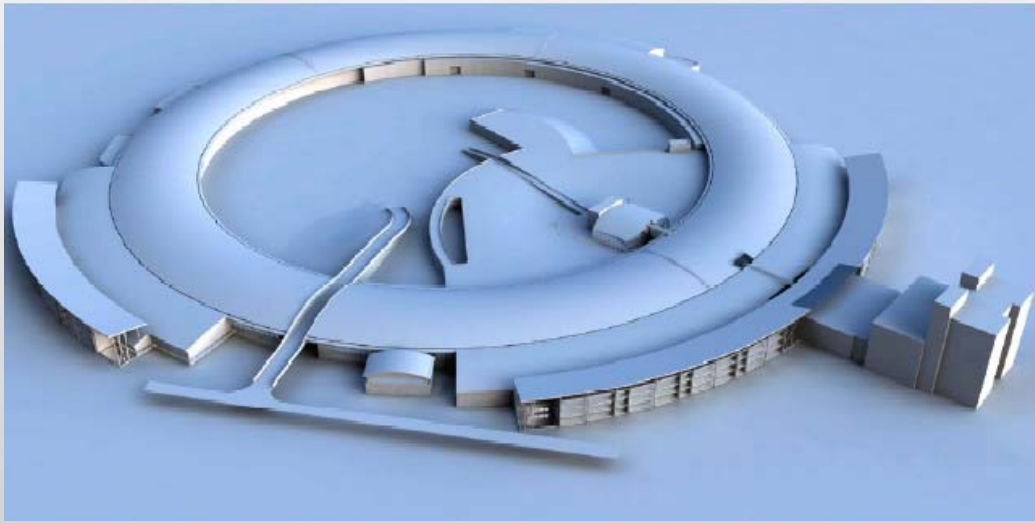
- The ESRF nano-technology platform: Motivation - Goal - Organisation
- Thermal stability
- High precision linear stages
- High precision rotation stages
- Conclusion

# The ESRF nano-technology platform: Motivation

The ESRF is preparing an upgrade programme, which is now (hopefully) in the final phase of approval

**Key features:**

- **Upgrade of the source:** increased brightness, stability, reliability
- **Extension of the buildings**, to enable the construction of new long Beamlines (nano-focussing capabilities)
- **New Beamlines** (8 in phase I): improved performance and routine nano-focus beams



# The ESRF nano-technology platform: Motivation

**Within the 11 candidate beamline projects for the Phase I of the ESRF Upgrade Programme**

**=> 6 projects with target focus size = 20 - 100 nm**

# To fully exploit 20 – 100 nm beams: a technical challenge involving several engineering development topics

Temperature stability

Vibration stability

**Nano-probes**

Nano-precision linear motions

Nano-precision rotation motions

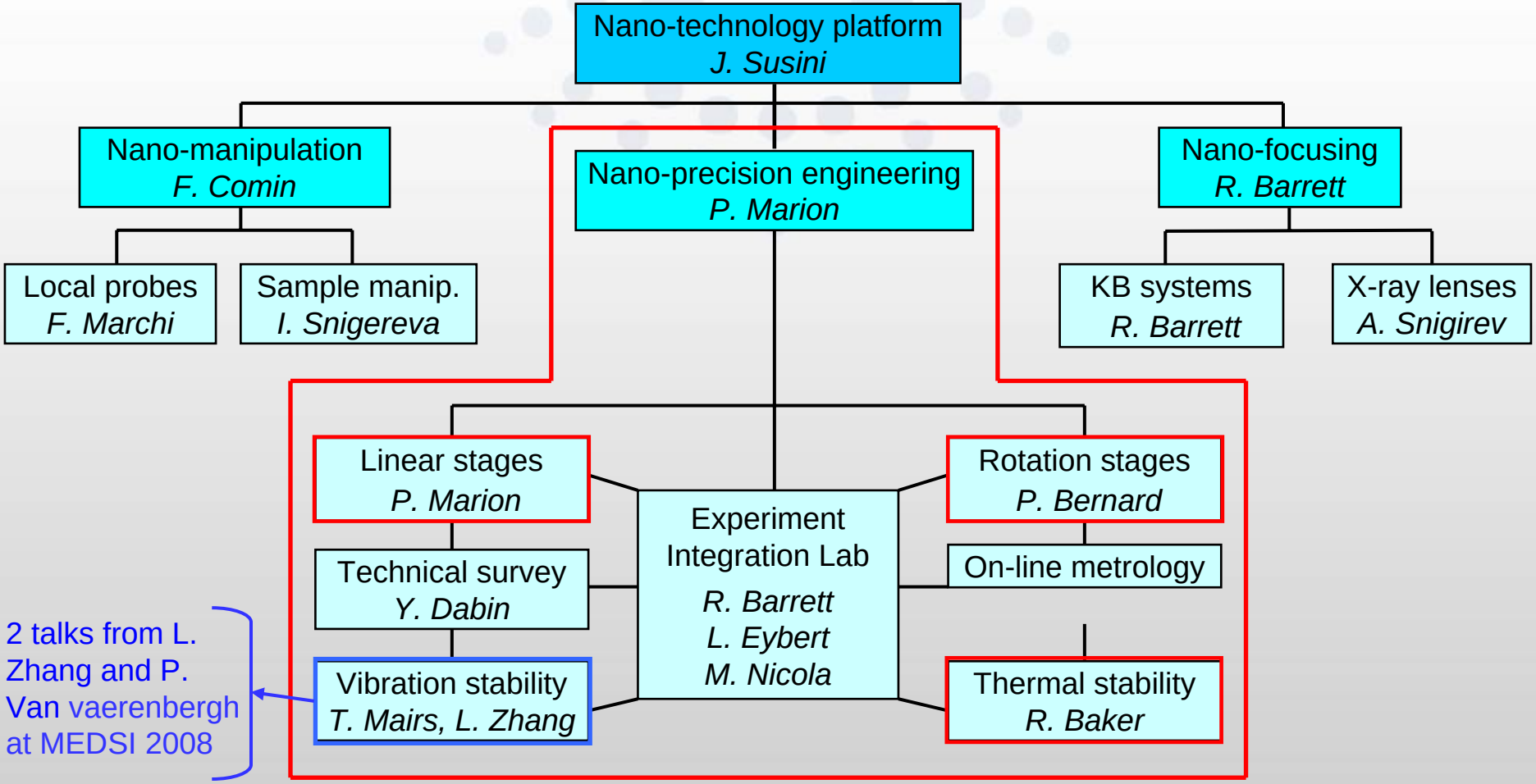
Real time position metrology

**2006:** Creation of the **nano-technology platform** at the ESRF

## Objective:

**Identify / develop / validate technical solutions for the construction of the nano-probes beamlines: > Current pilot projects ID13, ID22 NI, ID11**
**> Future projects of the upgrade**

# The ESRF nano-technology platform: Organisation




For each technical field, a working group of 3 to 6 engineers (10-30% of their time) has the mission to identify suitable technologies for the nano-probes.

# The ESRF nano-engineering platform: THERMAL STABILITY

***WG members: R. Baker,*** *L. Zhang, T. Marchial, P. Van der Linden, P. Marion.*

## A/ Environment: Reduce air temperature variations in hutches

**New air conditioning system for hutches**

**Objective: +/- 0.1 $^0$C over 24 h**

**Key features:**

- Located outside the hutch
- High flowrate: 3200 m3/h (20 volumes/hour)
- Reduced vibrations from air flow – distribution by porous textile ducts
- Overpressure: 5 Pa (limit disturbances from outside, and from door opening)
- Humidity rate control: 50% +/-10%
- Cost: 70k€

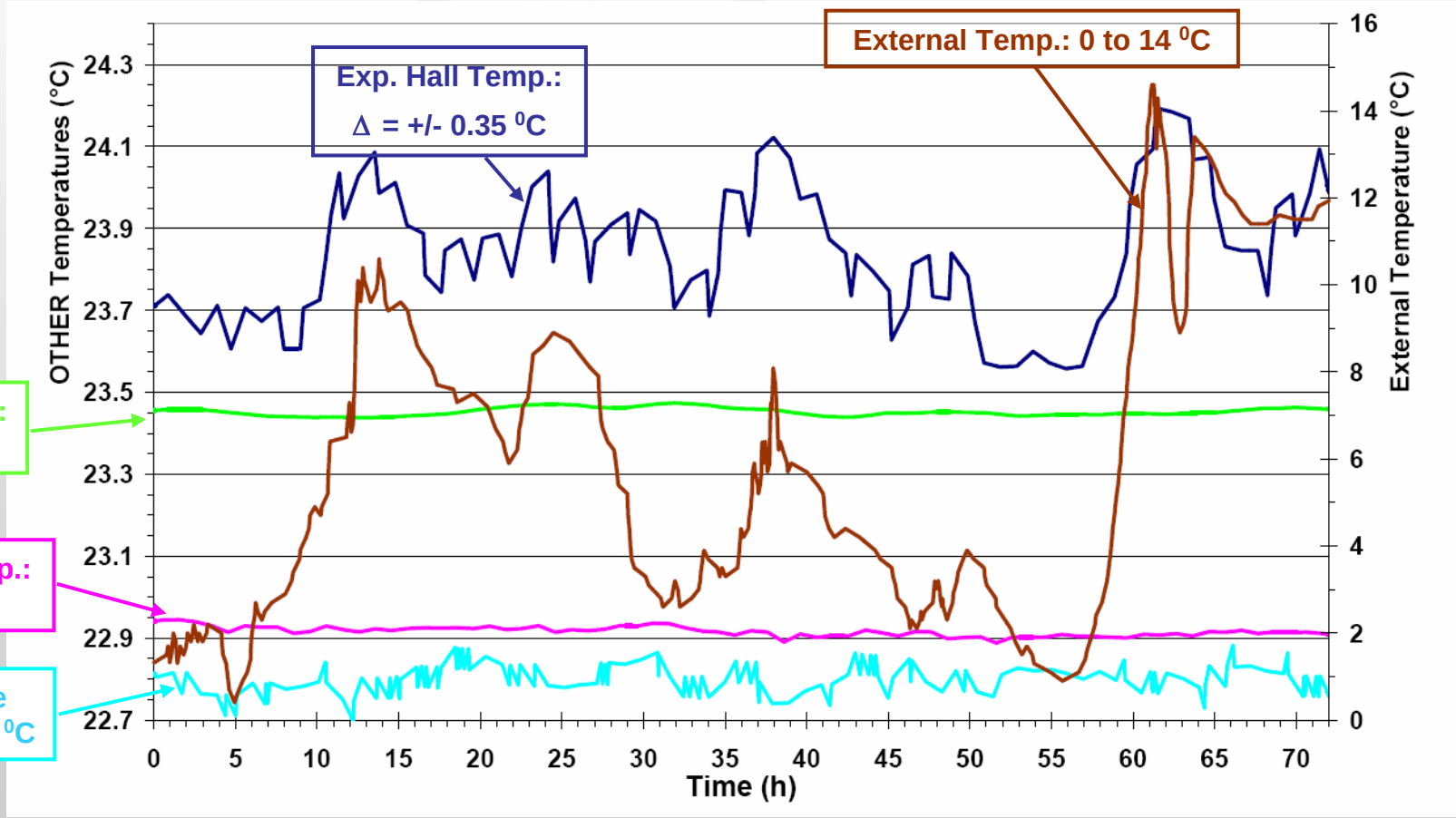
+ **entry porch** to reduce disturbances from door opening

# The ESRF Nano-engineering platform: THERMAL STABILITY

## A/ Environment:

New air conditioning system for hutches…
Stability recorded over 72 hours

Temperature variations inside hutch



# The ESRF nano-engineering platform: THERMAL STABILITY

## B/ Athermal design: Reduce the thermal sensitivity of instruments

Chose low expansion materials for critical parts

Symetry is important

Local shielding

Reduce internal heat sources

Cool them at source

Thermal insulation or air gap

High thermal inertia:
High thermal mass,
High volume/area ratio

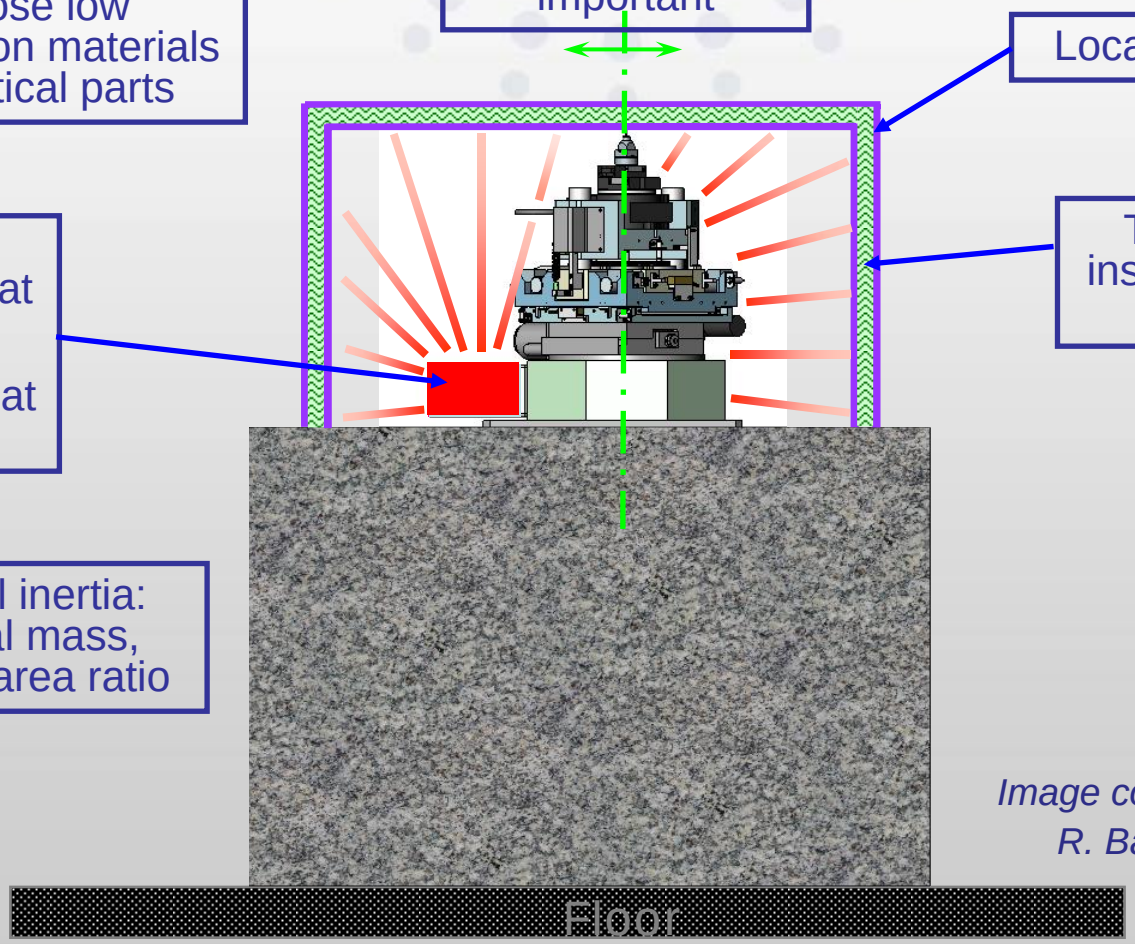



*Image courtesy:*
*R. Baker*

# The ESRF nano-engineering platform: LINEAR STAGES

***WG members: P. Marion,*** *J.M. Clement,Y. Dabin, L. Ducotte, L. Eybert, E. Gagliardini, M. Nicola.*

## Requirements:

- **High resolution Actuators** capable of 1-10nm resolution:

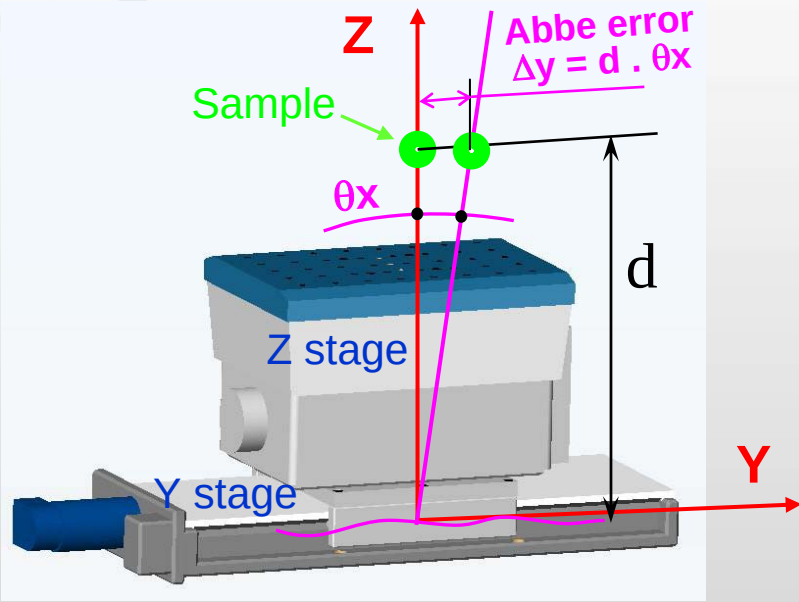
  Piezos, Linear motors, …

- **Guiding technologies** with ultra-low angular errors **θx, θy ,** and **θz** (pitch, roll and yaw) along the travel, to reduce the Abbe errors:

  20 - 50 μrad for Ball guides

  2 - 5 μrad for Air bearings

- **High stiffness, compact, low sensitivity to thermal drifts,** etc…



# LINEAR STAGES: The High stability gantry + air bearing stage project

**Goal:**

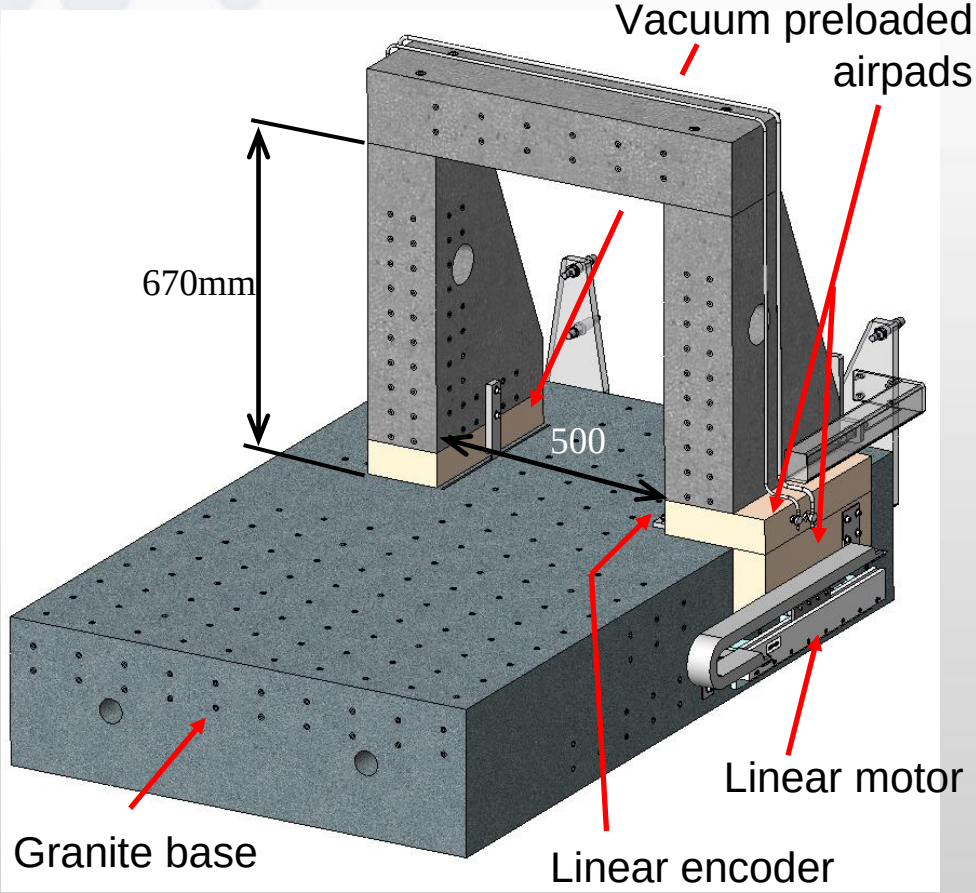
Validate techniques for a high stability gantry + High accuracy linear stage

**Key technologies:** Preloaded air pads (Microplan company), Linear motor

**Target Specifications:**

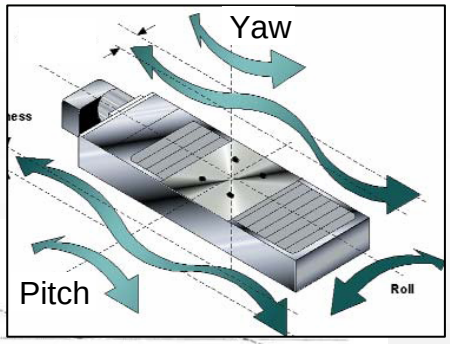
- Travel range: 300mm
- High stability, High natural frq ( > 80Hz). Air pads can be vacuum-clamped when stopped
- Resolution: 50nm / Repeatability: 100nm
- Yaw/Pitch/Roll: 10µrad (5 times less than ball stages)

**Status:**
Tests in progress

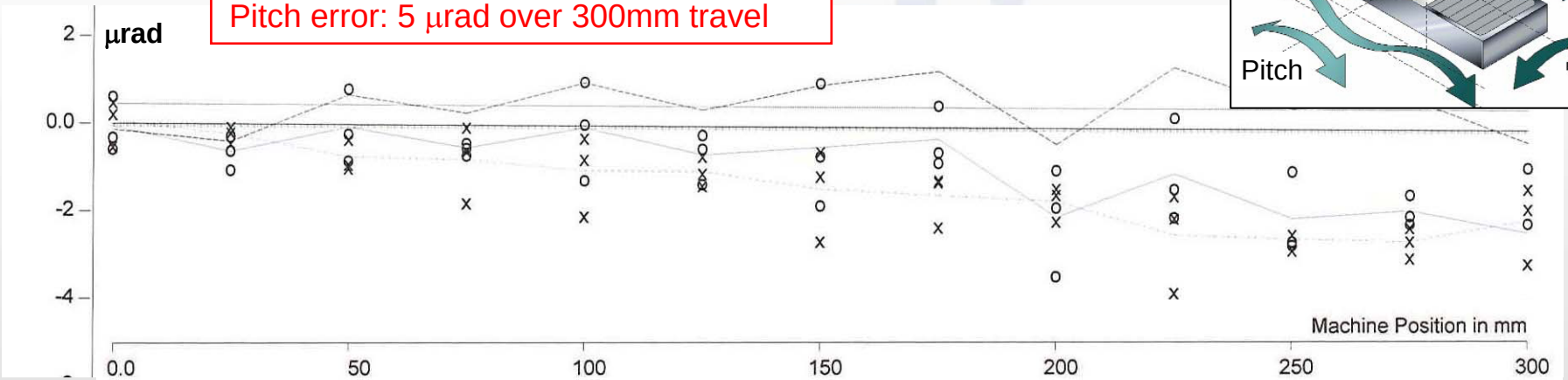


# The High stability gantry + air bearing stage project

## First measurements results: Guiding angular errors Yaw & Pitch

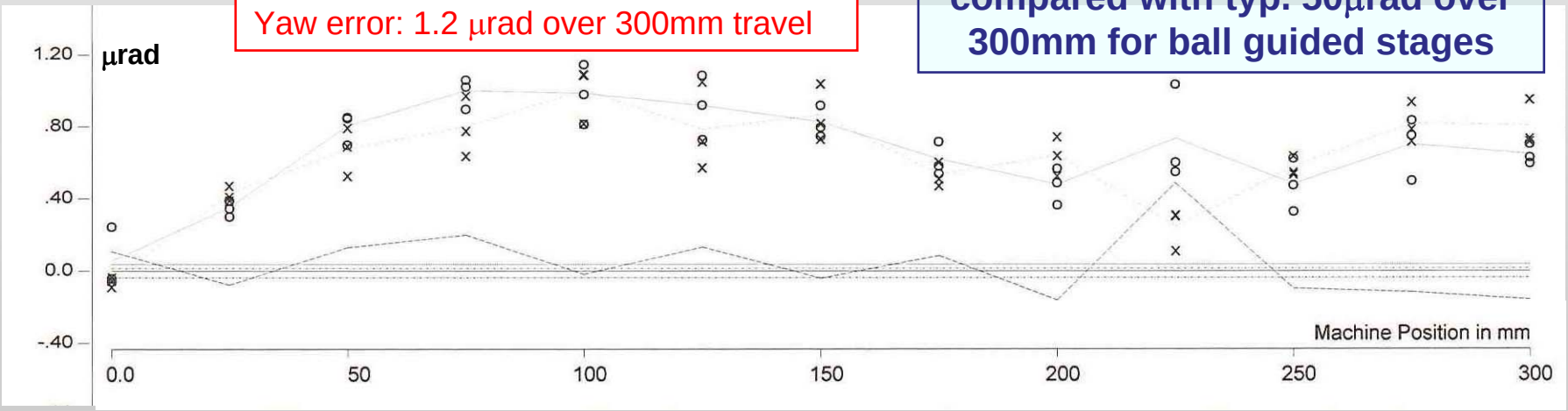



Pitch error: 5 µrad over 300mm travel




**Extremely low errors, to be compared with typ. 50µrad over 300mm for ball guided stages**

Yaw error: 1.2 µrad over 300mm travel

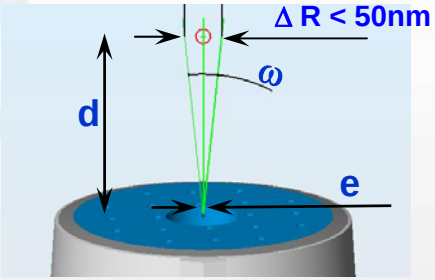


# The ESRF nano-engineering platform: HIGH ACCURACY SPINDLES

*WG members: **P. Bernard,** Y. Dabin, M. Nicola, T. Mairs, M. Renier.*

## Objective:

For nano-tomography and nano-diffraction experiments,
Axial / radial motion errors < 50 nm

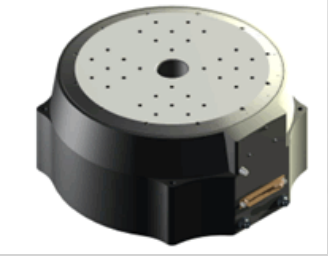



## Facts: Commercially available "Large size" spindles:

-***2005:*** **Newport PM500-360**
Measured radial error: 2700 nm @ d=91mm
Ball guiding – Gears + Stepper motor

Dimensions:
224 x 145 x 70 mm

-***2008:*** **Micos UPR 270**
Measured radial error: 103 nm @ d=145mm
Air bearing – Direct drive torque motor
M. Nicola, L. Eybert



Dimensions:
Ø 270, h 135 mm

-***2008:*** **Professional Instruments ISO 3R**
Specified radial error: 35 nm @ d=100mm
Air bearing – Direct drive torque motor
Not yet delivered / measured

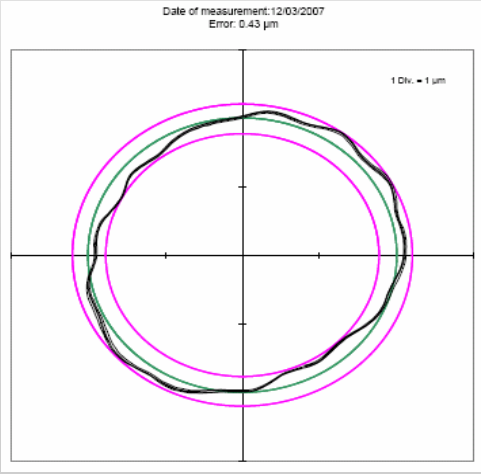
Dimensions:
Ø 126, h 180 mm

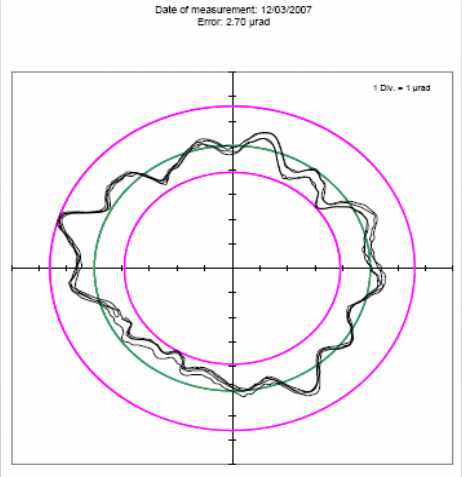
# The ESRF nano-engineering platform: HIGH ACCURACY SPINDLES

Radial errors measured by capacitive sensors.
Precision: 1nm

(Spindle error analyser from Lion – IBS)

M. Nicola, H. P. Van der Kleij

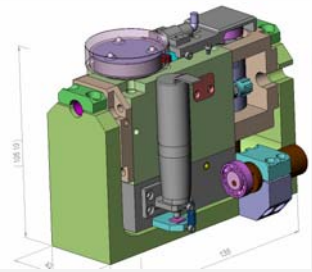


# The ESRF nano-engineering platform: HIGH ACCURACY SPINDLES

## "Low profile" spindles:

See "*Design and Commissioning of Low-Profile Tomography Spindles for the ESRF Nano-Focusing Beamlines*", Yves Dabin at MEDSI 2008



## High precision is very sensitive to parasitic forces !

**Example:**

**Micos UPR 270 alone:**

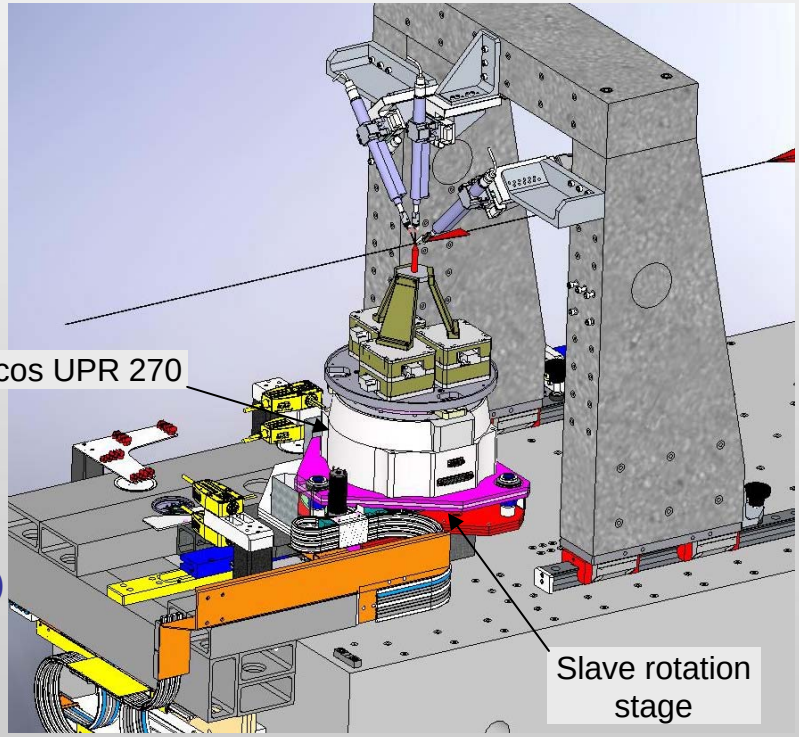
Measured radial error: 103 nm @ d=145mm

**Micos UPR 270 integrated in its end-station:**

Measured radial error: 427 nm @ d=263mm

Main cause: forces from cables

(in spite of a careful cable management by a slave rotation stage)




***ID13 endstation (C.Riekel, M. Burghammer, L. Eybert, M. Nicola)***

# CONCLUSION

- Several projects oriented towards nanometric positioning have been started at the ESRF. This jump in precision involves:
  - A careful tracking of all sources of errors: Thermal drifts, Vibrations, …
  - New technologies: Air bearings, linear / direct drive motors, position feedback by interferometers, etc…
  - Developing metrology resources for in depth characterisation: extensive use of laser interferometers and capacitive sensors, skilled staff.

- The organisation of the Nano-precision engineering platform enables a fruitful collaboration between ESRF engineers involved in high precision projects.

- We wish to collaborate with other synchrotron labs working in the same field.